MT29 Abstracts and Technical Program

Report of Contributions

Contribution ID: **7** Type: **Invited Oral**

Sat-Mo-Or2-01: [Invited] The Gauss Fusion (GFG) GIGA magnet system

Saturday, July 5, 2025 8:00 AM (30 minutes)

The GFG Fusion Power Plant is based on a stellarator with a four period quasi isodynamic plasma which, supported by results from Wendelstein 7X and advances in plasma modelling and stellarator optimisation, is expected to achieve the required confinement levels. It is sized to provide output electrical power comparable to a conventional large power plant, with realistic assumptions about power generation, auxiliary heating system efficiencies and nuclear component lifetimes: 1GW electrical from 3GW thermal, with a neutron wall load on the first wall of under 1MW/m2. This provides a major radius of 18m and a minor plasma radius of 1.7m, with a field on axis of 6T and a maximum field on the coils of 12-13T.
The stellarator configuration is particularly suitable for a fusion power reactor. It is steady state, the high aspect ratio provides easy access all round the plasma and the lack of a net plasma current (and the associated vertical stability and disruption issues acting as design drivers in tokamaks) greatly simplify the magnet and vacuum vessel designs. The steady-state nature reduces cyclic stresses on all components, including the magnets. Stellarators are well known as requiring many non-planar magnets which are often seen as design and manufacturing problems as well as generally obstructing access to the plasma. GFG is focused on a baseline design and developing magnet technology that enhance the operability of the plant and solves these disadvantages.
The medium field levels of GIGA allow both LTS and HTS superconductors to be potentially applicable and GFG is developing both with a common cross-section (circular with a diameter of about 55mm) and current (100kA) but different operating temperatures that can be used interchangeably in a common magnet design. The magnet technical development is directed on structural optimisation, protection in the event of quench, magnet repairability and improved access to the internal nuclear power producing components.
The GIGA magnet system consists of 40 coils, with 5 different shapes each replicated 8 times due to the symmetries. Each coil is non-planar with an approximate perimeter of 30-35m (a major diameter of 10m). The coils are therefore similar in size, field and capacity to those of the ITER TF system and will also weigh about 300t. So apart from the 3D shape, manufacture of the GFG coil system is roughly equivalent to two sets of ITER TF magnets. Such a set of magnets is large but would be well within the capacity of the production lines established for ITER, and can be transported from manufacturing site to power plant site in similar ways.
The magnets use a conductor-in-plate concept and curvature constraints are imposed on the shapes of the magnets so they can be bult up from cylindrical shells or flat plates curved in circular arcs. This enables the plates to be stacked to form a coil, with the distributed structure avoiding the use of a case and all the associated fitting problems. The use of plates also supports the GFG demountable coil concept which is a key technology to offer improved options for manufacturing, assembly, repair and regular operational maintenance. The coils can be mounted and demounted in handleable units (less than 20t) and an in-line joint system (mechanical and electrical) is compatible with remote handling and is space efficient. A single coil needs to include some 250 joints so a low resistance target of about 1nOhm has been set which is regularly achieved with LTS joints and would be acceptable as a cryogenic heat load. Continuing to exploit features of the conductor in plate concept, GFG is developing a low voltage quench protection system which is seen as critical to avoid the inherent high voltage incompatibility with cryogenic vacuum problems that are familiar from superconducting tokamaks that rely on external resistors to extract the magnetic

energy.
The paper will describe the GFG conceptual design of the magnet system and status of associated development programs.

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Presenter: Dr MITCHELL, Neil (Gauss Fusion)

Session Classification: Sat-Mo-Or2 - Fusion Devices: Stellarators and Levitated Dipoles

Contribution ID: **9** Type: **Poster**

Thu-Af-Po.10-01: Preliminary study of a cryogen-free cryostat for a low-temperature superconducting magnet

Thursday, July 3, 2025 2:00 PM (2 hours)

This report details the mechanism design and heat load budget for a cryostat that replace liquid helium and liquid nitrogen with commercially available cold heads (cryocoolers). However, to ensure the proper functioning of cryogenic superconducting magnets with the limited cooling capacity of cryocoolers, careful management of heat transfer, insulation, cooling, electrical power, and vacuum components is essential. This paper provides an in-depth analysis of the thermal loads of a prototype superconducting wiggler magnet within a three-layer cavity, suspension system, current system, and electron beam chamber, utilizing two cryocoolers.

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Session Classification: Thu-Af-Po.10 - Cryostats and Cryogenics I

Contribution ID: **10** Type: **Poster**

Sat-Mo-Po.04-06: Gas-cooling Structure and Cryo-stability Analysis of Gourd-shape HTS Stacked Magnets

Saturday, July 5, 2025 9:30 AM (1h 45m)

Gourd-shape high temperature superconducting (HTS) magnet is stacked by gourd-shape HTS plates and excited by field cooling method. It can operate in persistent current mode (PCM), and has the functions of magnetic flux density amplification and magnetic flux accumulation. In this paper, the cooling structure and cryo-stability of the gourd-shape HTS magnet under gas cooling are numerically analyzed. Two types of gas-cooling structure with copper plates, alternating stack and back-to-back, are proposed. Cooling holes are cut on the copper plates to improve the cooling efficiency. Thermal models of two cooling structures and simple stacked structure are established, and cryo-stability is analyzed by the finite element method. The influence of the outer edge extension length and thickness of copper plates, the number, arrangement and radii of cooling holes on the cryo-stability of the two cooling structures is studied. Results show that the two cooling structures have better thermal stability than the simple stacked structures under gas-helium cooling, and the heat transferring efficiency can be improved by changing copper plates and cooling holes. The research results provide a new perspective to the operation of HTS stacked magnets under gas cooling.

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Presenter: ZHU, Lingfeng

Session Classification: Sat-Mo-Po.04 - Protection and Stability

Contribution ID: **11** Type: **Poster**

Wed-Mo-Po.09-07: Development of a 6-slot twisted stacked-tape cable in conduit conductor for D-shaped coil

Wednesday, July 2, 2025 9:15 AM (2 hours)

Twisted stacked-tape cable in conduit conductor (TSTC-CICC) structure constitute a very promising technology due to their easy fabrication process, flexibility, and high current density. This paper introduces a 6-slot TSTC-CICC structure and a 20-meter-long cable is fabricated. To verify its performance, the cable was wound into a D-shaped coil and successfully tested at liquid nitrogen environment. The cable has six twisted slots, and 50 superconducting tapes are embedded in one slot, while copper tapes are used instead to achieve specific electrical and mechanical properties for other slots. After manufacturing the 20-meter-long cable, a pipe bending device was used to form the D-shaped coil, which is crucial for validating the manufacturing process for future tokamak (TF) magnets. To ensure the stable operation of the coil under high magnetic fields and large currents, solder is filled in the cable through vacuum pressure impregnation (VPI) technology to eliminate internal voids in the cable. This study also measured the critical current of the coil, and analyzed the critical current and n-value at the large radius and small radius of different turns of the D-shaped coil. By comparing with the test results of the straight cable, it was shown that the 20-meter-long 6-slot TSTC-CICC exhibits excellent uniformity in critical performance.

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Session Classification: Wed-Mo-Po.09 - Development and Test of Conductors for Fusion Magnets I

Contribution ID: **13** Type: **Poster**

Thu-Af-Po.02-01: Numerical and experimental study of high current-carrying CICC with 24-layer CORC strands

Thursday, July 3, 2025 2:00 PM (2 hours)

Cable-In-Conduit-Conductor (CICC) is particularly suitable for applications requiring both high magnetic fields and efficient current transmission, such as in particle accelerators, magnetic resonance imaging (MRI) systems, and high-field magnets. To further enhance the current-carrying capability of CICC, we developed a CICC conductor in which the CORC strands are made up of 24 layers, with a total of 66 YBCO tapes. A CICC sample consists of two CORC strands and four copper strands is fabricated and then tested at 77K and self-field in straight form. Subsequently, numerical studies of current-carrying capability and magnetic behavior of the CICC sample are carried out by employing a H-formulation model in COMSOL. The measured critical currents are close to the simulation results, reaching about 12 kA. This study demonstrates that increasing the number of YBCO tapes in the CORC strands effectively enhances the current-carrying performance of the CICC.

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Presenter: LI, Yifeng (Beijing Jiaotong University)

Session Classification: Thu-Af-Po.02 - HTS Cable

Contribution ID: **14** Type: **Poster**

Fri-Af-Po.04-05: Research on the Design Method of Flexible Connection of High Current Bipolar Busbar for Superconducting Magnet Power Supply of Fusion Device

Friday, July 4, 2025 2:00 PM (2 hours)

In the design of DC busbar flexible connection in Power Supply System of CRAFT (Comprehensive Research Facility for Fusion Technology, China), water-cooled aluminum busbars interconnections are connected through aluminum flexible connectors to compensate for thermal expansion and Installation deviation. As the contact surface between the DC busbar and the flexible connection is very small, the current flowing through is as high as 30 kA, and the power consumed in the contact surface is about 900W. During long-term high current operation, the flexible connection will cause contact overheating. This paper firstly introduces the different designs of high current bolted busbar, then presents the calculation method of busbar contact resistance, simulates the heat transfer at the flexible connection of busbar through ANSYS software, and calculates the temperature distribution of flexible connection. Finally, the temperature rise experiment is carried out and compared with the simulation results. Confirmed the design scheme for busbar connection. The effectiveness of the design is verified.

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Session Classification: Fri-Af-Po.04 - Supporting Technologies for Fusion Magnets II

Contribution ID: **15** Type: **Poster**

Thu-Mo-Po.06-07: Fatigue behavior of Cu-Zr alloys

Thursday, July 3, 2025 8:45 AM (2 hours)

Age-hardened Cu-Zr sheets are used in resistive magnetic field application. In this work, we studied the fatigue properties of Cu-Zr and Cu sheets. Three categories of Cu-Zr sheets with different strength were investigated and compared. Our investigation showed that their fatigue life was related to their ultimate tensile strength (UTS). Materials with higher UTS demonstrated longer fatigue life. At same UTS level, Cu-Zr sheets endured more fatigue cycles than cold deformed Cu (C101). We observed cyclic softening at the later stage of fatigue tests in both Cu-Zr and C101. The presence of Zr in Cu-Zr delayed the occurring of cyclic softening, comparing to C101.

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Session Classification: Thu-Mo-Po.06 - Mechanical Behavior and Stress II

Contribution ID: **16** Type: **Poster**

Fri-Mo-Po.08-09: REBCO multi-filamentary tape electromagnetic characteristics and insert magnets design and development

Friday, July 4, 2025 9:30 AM (1h 45m)

REBCO high-temperature superconductor has been widely used in high magnetic field applications, because of the excellent critical current properties and high critical temperature. However, REBCO tape has a huge width-to-thickness ratio (typically in the range of 1000-10000) to cause too high power dissipation in the applications. One of the effective ways to reduce AC loss is to divide the superconducting layer in the REBCO tape into filaments. The current-carrying properties degradation behavior of the prepared multi-filamentary tape is the focus of attention. In this study, REBCO multi-filamentary tapes with different numbers of filaments (2-filament, 6-filament, and 10-filament) by cutting the copper-stabilizing layers and superconducting layers through a self-developed reel-to-reel ultraviolet picosecond laser cutting device. The findings indicate that the cut groove has a depth of approximately 30 μm and the width of the groove on the superconducting layer measures around 15 μm. The authors then systematically characterized the cut multi-core materials and found that ultraviolet picosecond laser cutting does not cause substantial degradation in the IC. The authors found that cutting multi-core material resulted in a significant reduction in AC loss. The high-field interpolated superconducting coil has good high-field current-carrying and low-temperature characteristics after copper plating post-processing and is verified. This study solves the preparation process problem of ReBCO high-temperature superconducting multi-core materials and researches the materials' low-temperature and high-field performance characterization. The research results show that the preparation process of multi-core belts has practical potential.

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Session Classification: Fri-Mo-Po.08 - HTS Characterization II

Contribution ID: **17** Type: **Poster**

Wed-Mo-Po.06-03: Torque Improvement of a Partitioned Stator Flux Switching Permanent Magnet Machine With Flux Reversal Effect

Wednesday, July 2, 2025 9:15 AM (2 hours)

The regular partitioned stator flux-switching permanent magnet (PS-FSPM) machine integrates both permanent magnets (PMs) and armature windings within a single stator, providing significant space utilization for both the inner and outer stators. However, the PMs on the inner stator limits torque enhancement to adjustments in the pole arc coefficient. To overcome this limitation, a PS-FSPM machine embedded with radially magnetized PMs (NN-SS-NN alternating arrangement) on the outer stator is proposed. Under the same winding configuration and rotor tooth count, the PMs on both the inner and outer stator exhibit flux switching and flux reversal effects, respectively. By exploiting the flux coupling between these two effects in the air gap, the amplitude of the air gap flux density is increased, thereby improving the torque performance.
Based on the analytical model of permeability-magnetomotive force, the effects of flux switching effect and flux reversal effect are studied in this paper. Although the amplitude of the air gap flux density harmonics generated by these two effects are different, the harmonic orders remain consistent. Notably, the flux switching effect has a larger amplitude on the low-order harmonics, whereas the flux reversal effect has a higher high-order harmonic amplitude. Then, the equivalent magnetic circuit method is used to reveal the contribution of air gap flux density to the no-load flux linkage, and the effective coupling mechanism of the two effects in the total no-load flux linkage is verified. Under the load condition, the flux reversal effect generated by the tangentially magnetized PMs not only significantly enhances the amplitude of the 4th, 10th and 15th effective working harmonics, but also contributes to the amplitude of the 21st, 27th, 28th and 33rd high-order working harmonics. This phenomenon is consistent with the analysis of the magnetic flux density distribution at no-load condition, resulting in an improvement in output torque. Subsequently, global optimization is performed using the Non-dominated Sorting Genetic Algorithm II (NSGA-II) to determine the optimal parameter values for both the regular and proposed machines. During the optimization process, the number of PMs is constrained to be identical for both two configurations.
Through finite element analysis, the magnetic flux distribution above the embedded PMs in the outer stator teeth is concentrated, which can lead to local saturation. To mitigate this phenomenon, a chamfered stator tooth structure is employed to alleviate saturation. Under the condition of 2 times overload, the PMs of proposed machine exhibits negligible demagnetization. Additionally, in comparison to the regular PS-FSPM machine, the proposed machine demonstrates enhancements in both power factor and efficiency. Specifically, the output torque is improved by 20.55%, while the torque ripple is reduced to 2.67%.

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Presenter: MIN, Zeyu (China three gorges university)

Session Classification: Wed-Mo-Po.06 - Rotating Machinery I

Contribution ID: **18** Type: **Contributed Oral**

Thu-Mo-Or2-03: SPEEDY_HTS –An HTS rotor for an uprated mid-speed wind power generator

Thursday, July 3, 2025 11:15 AM (15 minutes)

Most conventional wind power generators need a high amount of rare-earth permanent magnet material (RE-PM).
Gearless low-speed solutions (≈10 rpm) require ≈0.5 ton/MW of RE-PMs. Most work on High-Temperature Superconductors (HTS) in wind power generators has been focused on this type so far and requires high amounts of HTS tapes.
Geared mid-speed solutions (400⋯600 rpm) need only ≈50 kg/MW RE-PMs.
Using HTS in a mid-speed generator (with typically 2 or 3 planetary gear stages and without a spur gear stage) indicates a potentially improved business case by restricting the HTS tape need to less than 3 km for a 13 MW generator.
In this work, we report on the design and first experimental results on the development of an HTS rotor. The goal of the project "SPEEDY_HTS"is to replace the conventional rotor of an existing 6 MW, 24-pole generator at 602 rpm and a 3-phase voltage of 750 Vac by a rotor with coils based on HTS. According to the simulations, this extends the power of the generator up to 13 MW in the same machine housing. Thus, the power density is far beyond the limits of conventional generator technology.
However, introducing the HTS rotor into the existing generator faces several major challenges:
1) balancing the different heat loads and the cooling capacity (at the target operating temperature of 30 K),
2) providing the very high excitation ampere-turns required for the larger air gap and the respective magnetic field,
3) meeting the dynamic excitation requirements for grid stability,
4) inclusion of a central, warm pitch-control shaft/ tube with a rotational speed differing from that of the rotor,
5) using a rotating feedthrough for the cooling system.
We report on these five challenges and describe the developed solutions.
The 24 poles of the HTS rotor are designed as double-window-frame coils using 12-mm wide HTS tape and being connected in series. The HTS rotor coil design is weakly-non-insulated characterized by a considerable, but low, turn-to-turn resistance.
First results on coil properties are given, too.
This work is funded by the German Ministry of Economy and Climate, FKZ03EE3094E, and by the Program Oriented Funding by the German Ministry of Research, Program MTET, High-Temperature Superconductivity, 38.05.03.

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Presenter: Prof. ARNDT, Tabea (KIT)

Session Classification: Thu-Mo-Or2 - Rotating Machinery II

Contribution ID: **19** Type: **Poster**

Fri-Af-Po.05-02: Concept Design of a 19T 100mm Outsert Magnet for 24T Compact Research Magnet

Friday, July 4, 2025 2:00 PM (2 hours)

20 Tesla is the nominal field limit for practical low temperature superconducting (LTS) magnet operating at 4.2 Kelvin. To achieve field above 20 Tesla, methods such as LTS magnet operating at sub-atmospheric pressure or LTS/HTS hybrid magnets, are normally adopted. Magnets working at sub-atmospheric pressure have high cryogen operating cost and high ice-blockage risk due to air leakage into system. In this paper, concept design of a 19 Tesla 100 mm cold bore LTS magnet, as an outsert for a 24 Tesla compact research magnet, aimed at 1 Tesla/min ramp rate for condensed matter physics research application is presented. The magnet has two Nb3Sn coils and two NbTi coils. It operates at about 240 A current, generates 19 Tesla vertical central field, and has a 0.1% homogeneity in 10 mm DSV in its 100 mm cold bore. In this paper, the challenges which have to be met to provide such magnets will be discussed.

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Session Classification: Fri-Af-Po.05 - High Field Solenoids Resistive and LTS

Contribution ID: **20** Type: **Poster**

Thu-Af-Po.08-01: Development of a Glass-Carbon-Glass Reinforced Pulsed High-field Magnet at the WHMFC

Thursday, July 3, 2025 2:00 PM (2 hours)

Pulsed high-field magnets are commonly reinforced with Zylon fiber to counterbalance the inter-radial Lorentz forces. However, these magnets usually undergo unintended axial disruptions. Previous studies have shown that Zylon fiber-reinforced polymers (ZFRPs) exhibit limited transverse and in-plane shear strength. This limitation results in substantial transverse damage at the ends of the magnets, where both radial and axial forces are significant.
To address this issue, a glass-carbon-glass reinforcing scheme was developed, and a double-coil prototype was constructed. The carbon fiber component serves as the "sandwich layer", which is responsible for bearing external loads, while the glass fiber component fully wraps the carbon fiber composites to provide electrical insulation. HS6 glass fiber and T600 carbon fiber were selected as inter-reinforcing materials due to their exceptional strength and elastic modulus. Both fibers exhibit favorable impregnation characteristic with epoxy, and the transverse strength of their composites were about twice that of ZFRPs. Additionally, the wet-winding technique was employed to minimize carbon fiber splashing during winding. The glass fiber was cross-wound at ±60° relative to the hoop direction (90°), while the carbon fiber was cross-wound at ±5°. This reinforcing strategy aimed to enhance the axial strength and stiffness of the reinforcement while maintaining its radial reinforcement capacity. The interlayer dielectric strength of the structure was confirmed above 18kV through high-voltage insulation testing.
The prototype was originally designed to operate at a maximum magnetic field of 96 T. The inner and outer coils were discharged by 1.6-MJ and 24-MJ capacitor banks, respectively. Unfortunately, the prototype failed at 70 T. Disassembly revealed that a localized defect in the CuNb wire may have been the cause of the failure. Despite this, the project provided valuable engineering insights for us. Future work will focus on refining the layup design of the reinforcement, and a new pulsed high-field magnet will be constructed.

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Presenter: Dr CHEN, Siyuan

Session Classification: Thu-Af-Po.08 - Materials for Pulsed Magnets

Contribution ID: **21** Type: **Poster**

Fri-Mo-Po.01-05: The study on local voltage division behavior of NI coil during charging process

Friday, July 4, 2025 9:30 AM (1h 45m)

High Temperature Superconducting (HTS) No-Insulation (NI) coil has broad applications in high field magnets due to its excellent stability. The turn-to-turn resistance, which is related to winding stress, is an essential parameter for NI coil. However, the turn-to-turn resistance is non-uniform in radial direction for present winding method. Thus, the voltage response is also non-uniform. In this study, the coil is charged by DC current at 77 K with different ramping rate and different ramping time. We use a high-speed data acquisition system based on NI PXIe board to measure the local voltage for different turns of coil from inner to outer turns. Then, a full resolution numerical model based on H-formulation is built to find out the actual turn-to-turn resistance. The local loss and radial current are calculated and analyzed. This study will help us understanding the ramping loss distribution of NI coil during charging process. After that, we can optimize the NI coil winding method, charging current waveform or cryogenic system to lower the ramping loss and improve coil performance.

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Presenter: Dr WANG, Xueliang (Shanghai Jiao Tong University)

Session Classification: Fri-Mo-Po.01 - No-Insulation Coils IV

Contribution ID: **22** Type: **Poster**

Fri-Mo-Po.09-09: Dynamic characteristics of a fully HTS magnetic bearing under pulsed excitation

Friday, July 4, 2025 9:30 AM (1h 45m)

The so-called fully superconducting magnetic bearing (SMB) is composed of a rotor of high temperature superconducting (HTS) bulk of YBaCuO and a stator wind wounded by HTS coated conductor tapes. The fully SMB has been developed a prototype and is in operation in Japan. The dynamics of fully SMB under long term operation is crucial to engineering applications, however, the experimental and theoretical studies on dynamic behaviors of fully SMB were less reported in recent years. In our previous work, the levitation properties of HTS bulk exposed to the high magnetic field, which is larger than 2 T and generated by HTS coils wounded by HTS coated conductor tapes, were numerically investigated and discussed with the fish-tail effect in levitation force prediction. In this work, a 2-dimensional(2-D) model of the fully SMB is introduced and coupled with the 2-D motion 2nd-order equations with respect to time, to simulate the dynamic behaviors in the vertical directions. The dynamic responses of a fully HTS SMB under pulsed excitation will be investigated, such as the displacements in time and frequency domains, phase trajectories, and motion trajectories. It turns out that the 2-D model with ease of implementation can provide a beneficial tool for analyzing the dynamics of linear SMB, and the numerical results, inaccessible through simplified analytical models, offer better quantitative dynamic characteristics and principles for applications of linear SMB. This work will provide an initial promotion of quantitative discussion in dynamic characteristics and principles for applications of fully SMB.

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Presenter: Dr YE, Changqing (Hohai University)

Session Classification: Fri-Mo-Po.09 - Novel and Other Applications II

Contribution ID: **23** Type: **Poster**

Wed-Mo-Po.10-08: Numerical studies on the dynamic responses of multiple levitated High-Temperature superconductors by a vector potential method

Wednesday, July 2, 2025 9:15 AM (2 hours)

In this paper, we present a 2-D numerical model based on a vector potential method and nonlinear E-J relationship to study the dynamic responses of multiple bulks of high-temperature superconductor(HTSC) levitated above different typical permanent magnetic guideway (PMG). Different from the existing related models and results of this subject, the coupling effects of different bulks are taken into account. The levitation forces are calculated by a finite element program of home-made and then the vertical motion of the levitated HTS subject to external disturbance is characterized by a second-order dynamic equation which couples the electromagnetic model via the levitation force. We study the coupling effects on the vertical dynamic characteristics of the HTSC levitated above typical Halbach-derived PMG. These comparative results would better reveal the dynamic response of the superconducting Maglev system.

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Presenter: Dr YE, Changqing (Hohai University)

Session Classification: Wed-Mo-Po.10 - Transformers and Fault Current Limiters

Contribution ID: **24** Type: **Poster**

Thu-Af-Po.09-02: Damage characteristics of single-turn coil with different conductor thicknesses

Thursday, July 3, 2025 2:00 PM (2 hours)

Single-turn coil (STC) is a destructive pulsed magnet aiming at high magnetic field beyond 100 T. To increase the peak magnetic field, delay the destruction of conductor, and avoid the damage of samples, it is important to select the thickness of STC appropriately. If the conductor is too thin, the temperature rise and deformation of the coil during discharge can be so drastic that the coil can be destroyed before the peak magnetic field is generated. However, if the conductor is too thick, the inhibition of conductor radial expansion by the thickness is too strong, which can cause the metal vapor from the vaporized inner surface of the coil to expand inward, and cause premature damage to the experimental samples or magnetic field measurement probes. In this study, the characteristics of conductor destruction at small thickness and samples damage at large thickness, respectively, are investigated. In addition, the theoretical support for the optimal experimental thickness is provided.

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Presenter: GE, Aoming (Huazhong University of Science and Technology)

Session Classification: Thu-Af-Po.09 - Single-turn Pulsed Magnets

Contribution ID: **25** Type: **Contributed Oral**

Wed-Mo-Or1-02: Overview and Assembly Strategy of the VNS Magnet System: Innovations and Challenges

Wednesday, July 2, 2025 11:30 AM (15 minutes)

The Volumetric Neutron Source (VNS) is a steady-state tokamak designed to bridge the technological gap between ITER and DEMO by enabling full-scale testing of tritium breeding blankets and other fusion reactor components under DEMO-relevant conditions. The VNS magnet system features an innovative magnetic cage architecture, where the superconducting poloidal field (PF) coils are positioned inside the toroidal field (TF) coils. This novel configuration significantly improves plasma equilibrium and controllability, reducing the required PF currents and stored energy while enhancing machine compactness and plasma shaping efficiency.
This work provides an overview of the entire VNS magnet system, including the toroidal field (TF), poloidal field (PF), and central solenoid (CS) systems. These systems utilize dry conductors with High-Temperature Superconductors (HTS), while the CS and PF systems are optimized for enhanced performance and reduced energy requirements. Emphasis is placed on the unique assembly strategy, which involves in-situ TF coil winding around pre-installed PF coils and vacuum vessel components. Although this assembly approach introduces notable mechanical challenges compared to conventional methods, it leverages HTS technology to provide a feasible solution for constructing compact tokamak systems.
The paper concludes with a comparison of VNS assembly approaches, highlighting the trade-offs between mechanical complexity, superconducting performance, and manufacturability. The magnetic cage and in-situ winding concepts represent promising strategies for achieving VNS objectives within a compact, robust, and efficient fusion device.

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Presenter: GIANNINI, Lorenzo (EUROfusion)

Session Classification: Wed-Mo-Or1 - Future Fusion Devices: Tokamaks

Contribution ID: **27** Type: **Poster**

Thu-Mo-Po.06-04: Investigation about the fatigue properties of REBCO coated conductor tapes with applied transport current under background magnetic field

Thursday, July 3, 2025 8:45 AM (2 hours)

The REBCO coated conductor (CC) tapes used in high-field magnets are subjected to a variety of mechanical and thermal loads, including stress during the manufacturing process, Lorentz forces during operation, as well as repeated electromagnetic and thermal cycles. It is crucial for the magnet designers to know the fatigue properties of CC tapes to ascertain their service life under operating conditions.

The studies of the fatigue properties of CC tapes have been done with various temperatures, with or without a background magnetic field, with axial tension, through-thickness tensile stress and U-shaped bending. In this work, the fatigue properties of CC tapes with applied transport current under a background magnetic field is studied so that the effects of transverse Lorentz force on the tensile stress fatigue can be evaluated. Special approach of current feeding and/or voltage pick-up was taken to prevent the burning of samples during the tests.

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Presenter: QIAN, Jinyang (Shanghai Jiao Tong University)

Session Classification: Thu-Mo-Po.06 - Mechanical Behavior and Stress II

Contribution ID: **28** Type: **Invited Oral**

Sat-Af-Spe1-07: [Invited] Plans and progresses on HTS CICC for fusion in China

Saturday, July 5, 2025 3:30 PM (15 minutes)

As the high critical current at high field, the representative second-generation high-temperature superconductor (2G HTS) ReBCO serves as a good candidate for future fusion devices, i.e. the Chinese fusion engineering test reactor (CFETR), the Demonstration Power Station (DEMO) with magnet field higher than 15T. The main goal of CFETR is to build a fusion engineering tokamak reactor with a fusion power of 50–200 MW, and test the breeding tritium during the fusion reaction. This requires the central solenoid and toroidal field coils with a maximum magnetic field exceeding 15T.

A 80 kA class Cable-in-Conduit-Conductor (CICC) under 15 T is targeted in the CFTER project. ReBCO is considered as a potential and promising superconductor. R&D activities are ongoing at the Institute of Plasma Physics, Chinese Academy of Sciences for demonstrating of a CICC based on ReBCO tape manufactured by Shanghai Superconductor. One sub-size conductor cabled with more than 45 tapes and then a coil wound with this conductor reaching peak field of 20T under background field were designed, manufactured and tested. In this paper, the transport properties, dependence on the strain of the ReBCO tape, as well as the performance of the sub-size conductor and the insert coil are investigated and reported. The results exhibit the feasibility of ReBCO CICC for Fusion magnet delivering high field.

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Presenter: Prof. ZHOU, Chao (Institute of Plasma Physics Chinese Academy of Sciences)

Session Classification: Sat-Af-Spe1 - [Special Session] High Current HTS Cables for Fusion and Beyond

Contribution ID: **29** Type: **Poster**

Wed-Af-Po.10-06: Mechanical characterization and critical current irreversibility limits of different ReBCO tapes

Wednesday, July 2, 2025 2:30 PM (2 hours)

High magnetic fields of up to 20 T in tokamak-type fusion devices, such as in Central Solenoids of European DEMO and the Chinese BEST fusion reactors, require High-Temperature Superconductors (HTS) and a promising candidate is ReBCO tape. The large Lorentz forces occurring under these operating conditions may locally generate very high values of mechanical stress, which can irreversibly degrade the critical current of the superconductor. For the design of these cables, detailed structural finite element analysis (FEA) based on accurate material electromagnetic and mechanical properties under relevant electromagnetic load levels is needed for reliable and optimal operation. Knowledge of the axial tensile and compressive strain irreversibility limits for the critical current of ReBCO tapes is there for essential.
For this purpose, axial tensile stress–strain measurements have been performed on ReBCO tapes from several manufacturers in the upgraded TARSIS2 facility and compressive strain imposed by bending on different core diameters. The evolution of the critical current and n-value were measured at 77 K in self field for stepwise increasing tensile load and also cyclic loading conditions were studied. The tensile stress strain characteristics were also tested at room temperature.
Full-scale 3D FE models of the tapes have been developed and validated using electrical and mechanical material properties of the used superconducting tapes and simplified stress-strain relations are proposed. The model predictions are well in agreement with experimental results and will be used to predict quantitively the impact of Lorentz load on CORC-CICC design optimisation.

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Presenter: Dr NIJHUIS, Arend (University of Twente)

Session Classification: Wed-Af-Po.10 - Development and Test of Conductors for Fusion Magnets II

Contribution ID: **30** Type: **Contributed Oral**

Fri-Mo-Or2-01: Critical current and inter-tape contact resistances under cyclic transverse loading of ReBCO round cables for fusion in the Twente Press

Friday, July 4, 2025 8:00 AM (15 minutes)

High magnetic fields of up to 20 T in tokamak-type fusion devices require High-Temperature Superconductors (HTS) and 50 kA/20 T class, full-size ReBCO Cable In Conduit Conductors (CICC). Conductors based on Conductor On Round Core (CORC®/HFRC) cables, are among others, proposed for the Central Solenoids of the European DEMO and the Chinese BEST fusion reactors. The large Lorentz forces occurring under these operating conditions may locally generate high mechanical stress, which can irreversibly degrade the critical current of the superconductor and may impact the contact resistance between tape layers in direct contact. For this reason, CORC® and HFRC cable samples, manufactured by Advanced Conductor Technologies and ASIPP (Hefei, China), have been tested under cyclic loading in the Twente Press. The samples have been loaded within geometric configurations resembling as close as possible the loading conditions of their respective CICC designs, recently tested in the Sultan facility. The critical currents, n-values and contact resistances of tapes selected from different layers have been measured at 77 K and in self field, at different loads and load cycling, beyond observed irreversible degradation.
In addition, detailed structural finite element analysis (FEA) of the conductors, based on measured material electromagnetic and mechanical properties, are compared with Twente Press experimental results and Lorentz loading conditions. An important input is the ReBCO mechanical properties and their tensile and compressive irreversibility limits, also measured at the University of Twente. The model predictions agree with experimental results and are being used to predict quantitively which configurations can best withstand Lorentz load and what the impact is of proposed geometric and material design optimisations.

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Presenter: Dr NIJHUIS, Arend (University of Twente)

Session Classification: Fri-Mo-Or2 - Mechanical Behavior and Stress III

Contribution ID: **31** Type: **Poster**

Fri-Mo-Po.09-05: Development of a New-type HTS Linear Synchronous Motor for Long-distance Acceleration Applications

Friday, July 4, 2025 9:30 AM (1h 45m)

For long-distance acceleration applications such as electromagnetic catapults and high-speed maglev trains, usually, multiple short linear motors are joined together into longer linear motors as needed. In this paper, a new type high temperature superconducting-linear motor (HTS-LM) for long-distance acceleration applications is designed. The stator winding of the HTS-LM is a ring winding structure, and the moving winding is wound with HTS tapes. The HTS winding achieve an approximately constant DC current flowing through its interior through pre-excitation. The HTS-LM was tested, and the results indicate that the motor has the characteristics of low thrust harmonic content, stable electromagnetic thrust, and slow current attenuation in the HTS winding. The research in this paper can provide reference for future high-efficiency and high-power-density linear motor development.

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Presenter: Mr LI, Chengxian (Naval University of Engineering)

Session Classification: Fri-Mo-Po.09 - Novel and Other Applications II

Contribution ID: **32** Type: **Poster**

Fri-Af-Po.03-01: Design and analysis of high-temperature superconducting tokamak magnet with liquid hydrogen cooling system

Friday, July 4, 2025 2:00 PM (2 hours)

High-temperature superconducting (HTS) magnets could be a revolutionary technique to achieve commercial fusion energy. The optimal operating temperature for the HTS tokamak magnet system is approximately 20 K, at which the HTS tape has a balanced current capacity and thermal stability. A conduction cooling system with helium gas has been developed and applied on fusion magnets operating at 20 K. Liquid hydrogen with a temperature of 13-21 K, shows a great potential on higher cooling efficiency and cost reduction compared to helium gas, making it a promising cooling option for large-scale HTS magnets. This study presents a conceptually design on HTS tokamak magnet system with liquid hydrogen cooling system. The feasibility of conducting cooling system with hydrogen is studied by comparing with its traditional counterpart with helium gas. The results show that the conduction cooling method with liquid hydrogen has comprehensive advantages on efficiency, cooling performance and cost reduction. It is a promising technique for future HTS fusion magnets.

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Presenter: PENG, Pai

Session Classification: Fri-Af-Po.03 - Supporting Technologies for Fusion Magnets I

Contribution ID: **33** Type: **Poster**

Thu-Af-Po.09-05: Electric field distribution properties and breakdown analysis of single-turn coil

Thursday, July 3, 2025 2:00 PM (2 hours)

Single-turn coil (STC) is a type of destructive pulsed magnet used to generate ultra-high magnetic fields ranging from 100 T to 300 T. In this study, a three-dimensional finite element simulation model of the STC is established, and the electric field distribution properties with different coil sizes and power excitations are investigated to assess the possibility of radial electric breakdown inside the coil and then derive the theoretical lower limit of the STC inner diameter to avoid breakdown. The results provide valuable guidance for the design of STC geometry.

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Presenter: WANG, Ning (Huazhong University of Science and Technology)

Session Classification: Thu-Af-Po.09 - Single-turn Pulsed Magnets

Contribution ID: **34** Type: **Poster**

Thu-Af-Po.09-04: Three-dimensional finite element analysis of damage and destruction of single-turn coil

Thursday, July 3, 2025 2:00 PM (2 hours)

Single-turn coil (STC) is a mainstream destructive pulsed magnet used to generate ultra-high magnetic field beyond 100 T. During the discharge process, STC is in extreme physical states with extremely high pressure and high strain rate deformation, leading to fracture and explosion of the coil. This study investigates the damage and destruction process of STC using three-dimensional finite element analysis. Simulation results shows that the damage always starts near the inner surface of STC due to high electromagnetic force and great tension pressure. By comparison, the simulation results are consistent with the measured experimental data. Based on the principle that the peak magnetic field needs to be generated before the coil explosion, this study provides theoretical guidance for the design of STC systems.

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Presenter: YANG, Wenbo (Huazhong University of Science and Technology)

Session Classification: Thu-Af-Po.09 - Single-turn Pulsed Magnets

Contribution ID: **35** Type: **Poster**

Thu-Af-Po.09-03: The theoretical modeling for the jitter time of gas switches in single-turn coil discharge system

Thursday, July 3, 2025 2:00 PM (2 hours)

Single-turn coil (STC) is a kind of destructive pulsed magnet with the peak magnetic field higher than 100 T. Due to the extremely high current rising rate and peak discharge current, gas switches are often used to control the parallel discharge of multiple capacitors. However, gas switches generally have long jitter times and their triggering is difficult to maintain a high degree of synchronization. For STCs with a current rising time of only several microseconds, the jitter time of the gas switches can affect the discharge current waveform and magnetic field of STC. In this study, the theoretical modeling for the jitter time of gas switches is carried out aiming at the discharge circuit.

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Session Classification: Thu-Af-Po.09 - Single-turn Pulsed Magnets

Contribution ID: **36** Type: **Contributed Oral**

Sat-Af-Or5-02: AC loss characteristics of the twisted multi-filamented YBCO tape under alternating magnetic fields

Saturday, July 5, 2025 4:45 PM (15 minutes)

Narrowed high-temperature superconducting (HTS) tapes have much smaller hysteresis loss and eddy current loss per unit tape width according to analytical and experimental data. Multi-filamentary technology is widely recognized as an effectively way of reducing the AC loss of HTS tapes by cutting each tape into multiple narrower filaments while maintaining the whole structure. But the magnetic coupling loss due to the background magnetic field between filaments will become the new obstacle of AC loss reduction when these filaments are fully coupled. In this work, a twisted filamentary HTS tape is simulated by COMSOL to study its AC loss characteristics, comparing to the non-twisted non-filamentary tape, the twisted non-filamentary tape and the non-twisted filamentary tape. 3D multi-layer electromagnetic models of these tapes are simulated to calculate the loss components, such as transporting loss, magnetization loss, magnetic coupling loss, and eddy current loss, in different layers. Varying alternating transporting currents and background fields are applied to discuss the characteristics of these loss components under different working conditions. The influences of the twisting pitch, the number of filaments, and the radius of the twisting axis are also considered. Through simulation results, the mechanism of AC loss reduction of HTS tapes due to the twisting and the filamentary structure are comprehensively studied, which can provide useful references for designing new filamented HTS tapes, cables and magnets.

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Presenter: ZHANG, Zhixuan (University of Bristol)

Session Classification: Sat-Af-Or5 - AC Loss and Magnetization II

Contribution ID: **37** Type: **Poster**

Thu-Af-Po.05-07: Dynamic resistance characteristics of multi-filamentary HTS tapes under perpendicular alternating magnetic fields

Thursday, July 3, 2025 2:00 PM (2 hours)

The development of multi-filamentary high-temperature superconducting (HTS) tape represents a significant research direction for the advancement of future applications, largely due to its lower AC loss. The AC loss characteristics of the multi-filamentary structure have been the subject of extensive experimental and finite element simulation studies. Nevertheless, there remains a research gap in the dynamic resistance effect and flux flow effect of multi-filamentary HTS tapes carrying DC current under perpendicular alternating magnetic fields. This paper presents the influence of different transporting currents and magnetic field with different amplitudes and frequencies on the dynamic resistance of multi-filamentary HTS tape. The results will help researchers to gain a deeper understanding of the dynamic resistance mechanism of multi-filamentary HTS tapes, which will provide new ideas for the design of flux pumps and persistent current switches.

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Presenter: FENG, Bin (university of bristol)

Session Classification: Thu-Af-Po.05 - Conductor and Coil Measurement/Test Techniques and Facilities III

Contribution ID: **38** Type: **Poster**

Wed-Af-Po.07-04: Novel modelling and simulation of Superconducting Electric Machines based on J-Φ Coupled Models

Wednesday, July 2, 2025 2:30 PM (2 hours)

Compared to the commonly used H and T-A methods for superconducting simulations, the J model offers a computational speed improvement of one to two orders of magnitude. However, due to inherent limitations, the J model is currently unable to simulate superconducting electrical devices containing ferromagnetic materials, such as superconducting motors. In this work, the existing J model is enhanced by coupling it with a magnetic network model, resulting in a J-Φ coupled model. This model is applied for the first time to the simulation of superconducting motors, which has the potential of achieving a 2-3 times speed improvement compared to the conventional T-A method. The fast computational model developed in this study provides an efficient platform for optimizing and controlling superconducting motors in future applications. This study will systematically describe the process of J-Φ coupled model and the accuracy in the calculation such as AC loss and magnetic field distribution, as well as possible future application scenarios.

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Presenter: ZHU, Hanlin

Session Classification: Wed-Af-Po.07 - Modelling and Analysis

Contribution ID: **39** Type: **Poster**

Fri-Af-Po.09-07: AC loss analysis of HTS REBCO windings in superconducting synchronous electrical machine for electric aircraft

Friday, July 4, 2025 2:00 PM (2 hours)

To meet the requirements of the high power-to-weight ratio and high efficiency for future electric aircraft, high temperature superconducting (HTS) electrical machines are expected to be the effective solutions. However, the HTS armature windings produce AC loss when operating in HTS electrical machines, leading to a reduction in the efficiency of the HTS electrical machines. This paper will establish a 3D double racetrack coil model based on T-A formulation, and the parameters of this model are based on a 10 kW superconducting synchronous electrical machine design. Then the AC loss of the HTS armature windings will be analyzed under various AC currents and AC magnetic fields. Finally, the multifilamentary design of the HTS windings will be investigated to reduce the AC loss. This study will analyze the AC loss of the HTS windings in the superconducting synchronous electrical machines, which can provide guidance for the designing and optimizing of the HTS windings.

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Presenter: MA, Jun (University of Bristol)

Session Classification: Fri-Af-Po.09 - Rotating Machinery IV

Contribution ID: **40** Type: **Contributed Oral**

Wed-Af-Or2-06: Self-protection Mechanism of Parallel-wound No-insulation, Metal-insulation, and Insulated Coils

Wednesday, July 2, 2025 5:45 PM (15 minutes)

Parallel-wound no-insulation (PWNI) high-temperature superconducting (HTS) coil is a kind of pancake-shaped coil wound with parallel-stacked tapes, which is a promising technique with reduced ramping delay and enhanced thermal stability compared to conventional no-insulation coils wound with single tape (single-wound no-insulation (SWNI) coil). The turn-to-turn current redistribution significantly enhances the thermal stability of SWNI coils, while the situation becomes much more complicated for PWNI coils. The current redistribution between parallel-stacked tapes couples with conventional turn-to-turn current redistribution, significantly changes the self-protection mechanism under thermal disturbance, which is still unknown. This study is to illustrate self-protection mechanisms of parallel-wound HTS coils based on turn-to-turn no-insulation, metal-insulation (MI), and insulation (INS) techniques, to identify underlying causes for enhanced thermal stability of PWNI coils. Results show that the current redistribution between parallel-stacked tapes plays the most important role in improving the self-protection mechanism of PWNI coils, while the turn-to-turn current redistribution affect the thermal stability. Therefore, parallel-wound coil featuring no-insulation between parallel-stacked tapes and turn-to-turn insulation would be a promising coil technique with enhanced thermal stability. Specifically, enhancing the turn-to-turn resistivity can effectively suppress the induced coupling current, reducing the extra overcurrent risk in PWNI coils. Moreover, parallel-wound turn-to-turn INS technique can deal with one of the most threatens for no-insulation coils, quench avalanche under fluctuated background field, preventing a rapid inductive quench propagation among pancakes by minimizing the magnetic field degradation during quench. A turn-to-turn insulation framework is applied on a 20 T@20 K DEMO PWNI magnet, validating its effectiveness on further improving the self-protection stability and accelerating the ramping process. These results would provide practical guidelines for the design of high-stability HTS magnets.

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Presenter: FU, Yutong (Shanghai Jiao Tong University)

Session Classification: Wed-Af-Or2 - No-Insulation Coils II

Contribution ID: **42** Type: **Poster**

Sat-Mo-Po.02-03: A multi-parameter overlapping coil with a ring-shaped shielding for improving the deep brain transcranial magnetic stimulation

Saturday, July 5, 2025 9:30 AM (1h 45m)

As a non-invasive and painless treatment method for neurological diseases, transcranial magnetic stimulation has shown great potential in the diagnosis and treatment of central nervous system diseases and mental disorders. To improve the accuracy of stimulation in specific brain areas and reduce side effects during the treatment, the geometric structural design of the stimulation coil has become a hot topic in the TMS field. To solve the problem of unsatisfied stimulation focalization when traditional TMS is applied to deep brain regions, a new design of the multi-parameter overlapping coil (the MPO coil) is proposed in this paper. The MPO coil consists of two vertically placed stimulation coils and the crossing angle between two coils is adjustable. To further improve the stimulation performance of the MPO coil, a ring-shaped shielding plate which is made up of laminated sheet silicon steel material was placed around the MPO coil. The ring-shaped shielding plate can effectively reduce eddy current losses within the coil and decrease magnetic energy loss, thereby enhancing the stimulation focalization of the MPO coil. The finite element analysis method is adopted to obtain the stimulation characteristics of the MPO coil. Results show that compared with the conventional FOE coil, the MPO coil with the shielding plate can effectively increase the stimulation depth, and narrow down the focusing area while ensuring the stimulation intensity. The optimized MPO coil can achieve a stimulation depth of 3 cm below the scalp, which is more advantageous in deep brain stimulation compared to traditional stimulation coils with a depth of 1.5cm to 2cm. Under the same constraints, the MPO coil can improve the stimulation focalization by 10.4% and stimulation depth by 28.3% when compared to the FOE coil. A real human head model is used in this paper to verify our method.
Keywords: Coil; shielding plate; transcranial magnetic stimulation; multi-parametric; eddy current losses

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Session Classification: Sat-Mo-Po.02 - Magnets for Other Medical Application III

Contribution ID: **43** Type: **Invited Poster**

Thu-Mo-Po.08-05: [Invited] IntelliMIK: A Novel Intelligent Quench Detection Method for HTS in Fusion Devices

Thursday, July 3, 2025 8:45 AM (2 hours)

High-temperature superconducting (HTS) magnets are designated for use as Central Solenoid (CS) magnets in China's next-generation fusion device. However, their temperature rises rapidly when quenching happens, which may lead to performance degradation. So the voltage detection threshold of HTS is much lower than LTS magnets. The currently employed Co-wound Wire (CWW) + Inductive Noise Realtime Calculation (MIK) voltage detection method on the EAST device can not reduce voltage noise below the detection threshold required for HTS magnets. To solve this problem, we proposed a voltage detection method called IntelliMIK, which is based on the combination of CWW technology and deep learning. It was tested on the EAST device, and the experimental results demonstrate that the detection accuracy is improved by 90%, and the quench detection time is advanced by 500 ms. Simulation analysis and experimental verification further confirm that this method can accurately identify quenches at the early stage, thereby ensuring the safe and stable operation of HTS magnets in China's next-generation fusion device. IntelliMIK provides an innovative solution for quench detection of HTS magnets. It not only draws on the mature experience of traditional voltage detection methods but also achieves faster response speed through technical improvements. It has important application value and provides new ideas for the monitoring and maintenance of superconducting magnets in the future.

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Presenter: Dr YAN, Qing (Institute of Plasma Physics Chinese Academy of Scieneces)

Session Classification: Thu-Mo-Po.08 - Quench Modelling and Detection

Contribution ID: **46** Type: **Poster**

Wed-Mo-Po.11-02: Design of a 60 T-100 ms Flat-Top Magnet with a Large Bore at the WHMFC

Wednesday, July 2, 2025 9:15 AM (2 hours)

The flat-top pulsed magnetic field can meet the requirements of many cutting-edge basic scientific researches on higher magnetic field, longer duration, and higher stability. In this study, a magnet is developed to generate 60 T pulsed magnetic field with 100 ms flat-top. Compared to conventional pulsed magnets, it has a larger internal hole diameter of 38 mm. In the design, a power-magnet collaborative design scheme is proposed. It is a multi-objective optimization model that comprehensively considers the power supply capacity, the parameters of the flat-top pulsed magnetic field producing circuit, and the thermodynamic performance of the pulsed magnet. It can reduce the demand for power supply energy while ensuring the flat-top pulsed magnetic field system to reach the parameter indicator. Fast-cooling technique is used for better cooling performance. The stainless steel screws are installed in the cooling channel. This can reduce the axial deformation caused by the circumferential pressure during the winding process of the coil, and optimize the position of the coil. The power supply of the magnet uses a sequence fire pulse forming network (SFPFN). By optimizing initial voltage and trigger time of each capacitor module in the circuit, a flat-top pulsed magnetic field with a magnetic field of 60 T, a duration of 100 ms, and a flatness of 1% can be obtained.

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Presenter: PAN, Ziying

Session Classification: Wed-Mo-Po.11 - High Field Pulsed Magnets I

Contribution ID: **47** Type: **Contributed Oral**

Sat-Af-Or4-05: Magneto-thermal stability of Nb3Sn wires: a laser-induced quench approach

Saturday, July 5, 2025 5:30 PM (15 minutes)

Proposed 14 T Nb3Sn magnet designs for a future energy-frontier circular collider often call for wires with higher Jc, larger diameter and lower copper to non-copper (Cu:nonCu) ratio. As well as pushing Nb3Sn superconducting wire technology to its performance limits, these characteristics all prove challenging for magneto-thermal stability.
This study investigates the stability of Nb3Sn wires using an unconventional approach to measure the Minimum Quench Energy (MQE), employing an ultra-violet (UV) laser to initiate quenches. The use of a pulsed laser offers an advantage over traditionally used resistive heaters, depositing the energy within nanoseconds –much faster than the characteristic time of temperature diffusion in the samples tested.
Stability has been experimentally studied for a range of internal tin and powder-in-tube Nb3Sn wire designs, comparing samples differing in copper residual resistance ratio (RRR), Cu:nonCu ratios, wire layouts, states (virgin wire compared to strands extracted from cables), and heat treatments. In each case, the MQE has been determined in external applied fields in the range of 6 T – 15 T and at both 1.9 K and 4.2 K. The stability of the tested wires is benchmarked against the well-established Restacked Rod Process (RRP®) wire with 108/127 layout employed in the quadrupole (MQXF) magnets for the High Luminosity upgrade of the Large Hadron Collider (HL-LHC project).

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Session Classification: Sat-Af-Or4 - Advances in Nb3Sn and MgB2 Conductors II

Contribution ID: **48** Type: **Poster**

Fri-Af-Po.05-03: Parameter analysis of the cooling water system for the 42.02 Tesla resistive magnet at the CHMFL

Friday, July 4, 2025 2:00 PM (2 hours)

Chinese High Magnetic Field Laboratory (CHMFL) is one of the five major labs of steady high magnetic field around the world. In Sep. 2024, its new built resistive magnet produced a steady field of 42.02 Tesla(T) with the power supply of 32.3 MW, which was the highest magnetic field of the resistive magnet in the world. In order to meet the operation requirements of the new magnet that the cooling water system has been completed the upgrading. The cooling water system has undergone comprehensive upgrades and renovations in terms of refrigeration, cooling supply, heat exchange, and purification. At present, the magnet has been open to users for experiments. By running six high-pressure pumps in parallel, the circulating cooling water flow rate of the 42.02 T resistive magnet is nearly 1700 m3/h under the pressure difference of 24.5 bar. The max flow rate of the chilled water supply is nearly 2000 m3/h through three newly replaced 132 kW chilled water pumps are running in parallel. The heat transfer capability of the system has also been upgraded. The purification flow rate of deionized water increased from 65 m3/h to 90 m3/h. In addition, the upgraded cooling water system also includes a cooling circuit for the newly added 14 MW power system. The operating parameters and energy efficiency of the cooling water system under high magnetic field experiments will be analyzed in detail.

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Session Classification: Fri-Af-Po.05 - High Field Solenoids Resistive and LTS

Contribution ID: **50** Type: **Invited Oral**

Sun-Mo-Spe1-04: [Invited] Development of the Wuhan National High Magnetic Field Center and the new Design Principles for High Field Pulsed Magnet

Sunday, July 6, 2025 9:10 AM (25 minutes)

The Wuhan National High Magnetic Field Center at Huazhong University of Science and Technology China is one of the premier facilities worldwide for conducting experiments at pulsed high magnetic fields. The Center has been operational for 13 years. Currently, a 28 MJ capacitor bank consisting of 22 modules of 1.2 MJ each and 2 modules of 800 kJ each as well as a 100 MJ/100 MVA flywheel-generator power supply have been developed to generate peak magnetic fields in the range from 50 T to 94.8 T with pulse duration from 8 ms to 2000 ms. In 2023, a $300M budget is approved to upgrade the facilities that will include new buildings, new magnets, and new energy sources. Three buildings with a total area of 47,000 m2 will be built, providing more experimental stations to meet the demands from users. The pulsed magnet aiming at a peak value up to 110 T in a 10 mm diameter and 70 T with 10 ms flat-top in 14 mm diameter, a 9.5 T magnetic resonance imaging (MRI) superconducting magnet with bore of 800 mm will be built. The energy of the capacitor bank power supply will increase to 167 MJ from 28 MJ for generating higher magnetic field. In addition to the existing experimental stations for electrical transport, magnetic properties, magneto optics, and electron spin resonance studies, more than a dozen new stations will be constructed to host new research capabilities in ultra-high magnetic fields, including magnetic heat measurements, scanning tunneling microscopy (STM), solid nuclear magnetic resonance (NMR) spectroscopy, biological MRI, and high-power terahertz spectroscopy.
Regarding the new pulsed magnets, new design principles will be implemented. High field pulsed magnets have traditionally been constructed in the form of cylindrical solenoids, with each conductor winding reinforced by interlayer composite materials in the hoop direction. For high magnetic fields, the pulsed magnet normally consists of multiple concentric coils, which can result in significant challenges from both electromagnetic and structural perspectives. The highest field magnets use multiple power sources to energize different coils, typically with longer pulses in the outer coils. From an electromagnetic perspective, when the inner coil is quickly pulsed in a background field of a larger coil, the fast rise of the field in the inner coil induces a magnetic field drop in the outer coil. Thus, at peak field, the magnetic field contributions of most coils fall below their maximum potential, limiting the overall performance of the magnet. From a structural mechanics perspective, the reinforcement efficiency of the fiber-wound solenoids decreases with increasing winding radius and thickness of the fiber layers, which in turn reduces the conductor filling factor. To address these challenges, we propose an innovative structure for a multi-coil pulsed magnet featuring radial and circumferential reinforcement with axially stacked stages. The axial stacking reduces the electromagnetic coupling between the coils, allowing each coil to achieve its full potential. Compared to traditional circumferential winding, the radial and circumferential bi-directional winding approach significantly enhances the reinforcement efficiency and conductor filling factor of the magnet. This paper.
The presentation will discuss the status of the present magnets, the plans for the new facilities, and the new magnet technology being developed including demonstrating the advanced nature and effectiveness of this innovation through both theoretical analysis and experimental validation.

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Session Classification: Sun-Mo-Spe1 - [Special Session] Towards Exceptionally High Magnetic Fields

Contribution ID: **51** Type: **Poster**

Thu-Af-Po.11-01: Status of the cryogenic helium distribution system for the RAON SCL2-IF separator

Thursday, July 3, 2025 2:00 PM (2 hours)

Rare Isotope Accelerator Complex for ON-line experiments (RAON) is the first heavy ion accelerator facility in South Korea. RAON consists of two main superconducting linear accelerators: SCL2 and SCL3. SCL3 cryogenic system was successfully completed the cryogenic commissioning in 2022 and maintained the stable cryogenic environment for the first beam commissioning in 2023. However, SCL2-IF cryogenic system has been installed without superconducting cryomodules and is awaiting cryogenic commissioning. The SCL2 cryogenic system is designed to cool not only the superconducting cryomodules but also the low temperature superconducting (LTS) magnets that are already installed in the In-Flight(IF) fragment separator. This paper will provide an overview and design of the SCL2-IF cryogenic helium distribution system, one of the main part of the SCL2-IF cryogenic system, and discuss the structure and methods used to cool the superconducting cryomodules and the LTS magnets.

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Session Classification: Thu-Af-Po.11 - Cryostats and Cryogenics II

Contribution ID: **52** Type: **Invited Oral**

Sun-Mo-Spe1-02: [Invited] Developing hybrid magnets at CHMFL

Sunday, July 6, 2025 8:20 AM (25 minutes)

The High Magnetic Field Laboratory of Chinese Academy of Sciences (CHMFL) aims to develop steady high magnetic field magnets and promote fundamental sciences on the magnets. To develop hybrid magnets is one of its main goals. A hybrid magnet is usually composed of a superconducting magnet and a resistive magnet. The first hybrid magnet in CHMFL was established in 2017, with a resistive magnet insert (Bitter type, bore diameter of 32mm) nested in superconducting coils made of superconducting cable in conduit conductors (CICC). In August of 2022, the hybrid magnet successfully created 45.22T. Since then, many experiments on various research topics have been conducted on the magnet.

A new hybrid magnet is just under design and preliminary technological tests have been undertaken at CHMFL. The magnet is designed to consist of a resistive magnet (28T/Φ32), a high temperature (HT) superconducting CICC coil (14T/Φ800), and a Nb3Sn superconducting CICC coil (13T/Φ1600).

The technology of the 45T hybrid magnet and the preliminary design of the 55T hybrid magnet will be introduced.

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Session Classification: Sun-Mo-Spe1 - [Special Session] Towards Exceptionally High Magnetic Fields

Contribution ID: **53** Type: **Poster**

Fri-Af-Po.06-08: Experimental Study on Innovative Methods to Improve Electromechanical Performance in Insert HTS Coil

Friday, July 4, 2025 2:00 PM (2 hours)

The central magnetic field of current all-superconducting hybrid magnets used in engineering applications is limited to below 40 T, primarily due to challenges such as screening-current-induced stress (SCIS)and high background magnetic field. SCIS significantly impacts the electromechanical performance of insert high-temperature superconducting (HTS) coils, particularly under high background fields. To address this limitation, effective mitigation strategies are critical for designing HTS coils capable of operating above 40 T.In this study, we conducted a comprehensive experimental investigation into innovative methods for enhancing the electromechanical performance of insert HTS coils. The research began with a theoretical analysis to elucidate the mechanisms underlying SCIS generation. Building on this foundation, two novel approaches were proposed to mitigate SCIS. These methods were subjected to experimental validation under high-field conditions. The results demonstrated substantial improvements in the mechanical robustness of the coils and confirmed the feasibility of the proposed strategies. Furthermore, the advantages and limitations of each method were systematically analyzed in the context of engineering applications. This work presents a significant step toward optimizing the electromagnetic and mechanical design of HTS coils for high-field applications exceeding 40 T, providing valuable insights for the development of next-generation superconducting magnet systems.

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Session Classification: Fri-Af-Po.06 - High Field HTS Solenoids

Contribution ID: **54** Type: **Poster**

Fri-Af-Po.06-07: Optimization design and mechanical analysis of a 5 T iron-based superconducting insert coil for high field application

Friday, July 4, 2025 2:00 PM (2 hours)

Iron-based superconductor, owing to their exceptionally high upper critical fields and relatively simple fabrication processes, exhibit significant application potential for high-field superconducting magnets. This research designed a 5 T iron-based superconducting high-field insert coil operating in the 28 T background magnetic field. An optimization strategy was applied to refine the electromagnetic structural parameters and minimize overall superconducting tape cost, while a robust support structure was developed to ensure mechanical integrity. Simulation comparing different co-wound materials, epoxy impregnation schemes, and binding strategies were conducted to ensure the stress-strain levels of the iron-based superconducting tape remain within acceptable limits. This study primarily addresses mechanical challenges encountered by iron-based superconducting high-field insert coils and aims to promote the practical application of iron-based superconductor in high magnetic field area.

Key word: iron-based superconductor, high-filed insert coil, mechanical analysis, optimization design

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Session Classification: Fri-Af-Po.06 - High Field HTS Solenoids

Contribution ID: **55** Type: **Poster**

Thu-Af-Po.10-02: Status on the design and manufacturing progress of the Cryostat for Magnet Cold Test Bench at ITER

Thursday, July 3, 2025 2:00 PM (2 hours)

Magnet Cold Test Bench (MCTB) is a test facility under development to test the superconducting Toroidal Field (TF) and Poloidal Field (PF-1) magnets at ITER. The testing of the magnets will be performed at 4K cryogenic temperature. The cryostat is required for housing the TF and PF-1 magnets in the vacuum environment for test at cryogenic temperature.

The material of construction for the cryostat is stainless steel type 304L/ 304. The cryostat shall be designed for operating conditions with vacuum level 10-4 mbar or better. The design of cryostat has to be performed in consideration of the major constraints like maximum dimensions and weight for road transport from Marseille port to ITER site, crane lifting capacity and lifting height in the ITER site building 55 where the test will be performed. This restricts the overall weight of cryostat to be under 330 tonnes with weight of top cover to be limited to maximum 90 tonnes. The maximum width of the cryostat is constrained to be under 10.5 m. The challenging schedule of the overall test program puts restriction on cryostat to be fully manufactured in factory and avoid any welding and construction activity on ITER site.

This paper will focus on the final design of the cryostat shell and associated components like the 4 K active cooled magnet supports, pressure release device, multi layer insulation. The cryostat structural analysis will be performed for the load cases like Electromagnetic (EM) loads, vacuum, magnet fast discharge, seismic. The challenges encountered during the design process will be presented in this paper. The paper also presents the update on the manufacturing process of the cryostat.

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Session Classification: Thu-Af-Po.10 - Cryostats and Cryogenics I

Contribution ID: **56** Type: **Poster**

Thu-Af-Po.02-05: Anisotropy analysis and AC loss characteristics of Twisted Stacked-Tape Cables with stepped groove

Thursday, July 3, 2025 2:00 PM (2 hours)

In order to satisfy the magnetic requirements of high current, high-field and excellent mechanical properties of magnet systems in future fusion devices, a compact high-current-carrying conductor structure inspired by quasi-isotropic strand (QIS) and twisted stacked tape cable (TSTC) structures is proposed in this paper. By placing three groups of equal volume but different direction HTS stacked tapes in each stepped groove on the skeleton, the conductor current density is significantly increased, while the anisotropy can be better solved. The conductor was numerically modeled and the anisotropy of critical currents was studied. The stacking direction and the slot arrangement of the tapes affects the force distribution and electromagnetic distribution of conductors. From the calculated results, the critical currents of the QIS-CICC were better than those of the proposed for the self-field condition. Nevertheless, the horizontal stacked superconducting tape at the top of the long section and two other vertical stacked superconducting tape in the remaining slots exhibits superior mechanical stability and good anisotropy under the external field. Furthermore, the self-field and background field AC losses of different arranged stack slotted-core cables are studied numerically. The results indicate the feasibility of the TSTC conductor with stepped arrangement in high background field.

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Session Classification: Thu-Af-Po.02 - HTS Cable

Contribution ID: **57** Type: **Invited Oral**

Sat-Mo-Or4-02: [Invited] Demountable Coil Technology for Improved Access and Cost Efficiency in Fusion Power Plant

Saturday, July 5, 2025 11:45 AM (30 minutes)

The installation and maintenance of components within the vacuum vessel (VV) of fusion power plants (FPPs) are heavily constrained by access limitations. In current magnetic confinement fusion experiments, access is typically restricted to the space between magnetic coils, significantly limiting the size of components that can be installed or maintained. These constraints are even more pronounced in stellarator designs, which, while offering key advantages in terms of steady state operation and absence of disruptions, suffer from complex coil geometries that complicate the integration of the VV and its internal components. To address this challenge, Gauss Fusion GmbH (GFG) is developing a novel demountable coil technology. This approach features superconducting coils with separable connecting elements, enabling the opening of the coil structure and facilitating the use of large ports for better access to the VV. This innovation holds the potential to transform installation and maintenance strategies for FPPs by overcoming the inherent access limitations imposed by conventional coil construction.

In addition to enhancing accessibility, the demountable coil technology can offer several advantages for FPP development. The coil production can be drastically simplified by limiting the conductor's length to a few tens of meters rather than hundreds, facilitating the production process and reducing the costs. The coil would not require continuous winding, being instead laid out in sections, redefining the manufacturing process and facilitating the movement and transport of the coils. Moreover, effective conductor grading becomes feasible, reducing the amount of superconducting material in the low-field regions and reducing the material costs while optimizing the conductors.

This paper presents the development of this demountable coil technology, focusing on a 1:1 scale mock-up currently in the final design stages, to be manufactured during 2025. The mock-up is equivalent to a sub-section of a GFG coil, featuring full-size superconducting Cable-in-Conduit Conductors (CICCs) and joints. Designed specifically to replicate the coil structure, the mock-up is constructed with multiple stainless steel (316LN) plates to encase and mechanically support the cables and joints. The mock-up measures approximately 3.0 x 0.65 x 0.55 meters and can house up to 16 conductors, each featuring two joints, for a total of 32.

The key enabling technology for this demountable coil concept is the development of robust connections between superconducting cables. GFG is exploring multiple joint configurations tailored to both low-temperature superconductors (LTS) and high-temperature superconductors (HTS). The target for joint resistance is in the 1 nΩ range under operating conditions, a key metric for ensuring the effectiveness and reliability of the demountable coil. The mock-up will serve as a versatile test platform for a range of different experiments. Both LTS and HTS joints will be assembled and tested to develop and study the assembly process. Room-temperature (RT) tests include repeated opening and closing of joints to evaluate durability and mechanical stability under dynamic loading using a hydraulic table. At cryogenic temperatures, the platform will enable joint resistance measurements for HTS conductors at 77 K, leak tests before and after thermal cycling, and assessments of joint degradation over multiple warm-up and cool-down cycles. In addition, the mock-up will be used to explore remote handling options, an essential feature for future FPP operations. Finally, the mock-up is designed to include 2 SULTAN samples, which will be extracted and tested in relevant conditions (high-current and high background field) after the loading cycles at RT.

This comprehensive development effort marks a significant step toward overcoming the engineering challenges of magnetic confinement fusion and advancing the practicality of fusion energy.

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Presenter: Dr BAGNI, Tommaso (Gauss Fusion)

Session Classification: Sat-Mo-Or4 - Technology for Fusion Reactors I

Contribution ID: **58** Type: **Poster**

Wed-Af-Po.12-04: Development of 100kW Cryogenic Inverter for Zero Emission Sustainable Transportation

Wednesday, July 2, 2025 2:30 PM (2 hours)

The aviation industry has committed to a long-term global goal of net-zero carbon emissions by 2050. Zero Emission Sustainable Transportation 1 (ZEST1), which was funded by UK's Aerospace Technology Institute and consorted by 10 partners led by Airbus, aims to accelerate technology breakthroughs to enable zero emission commercial aircraft by 2030. Within the consortium, the University of Strathclyde is responsible for the delivery of a high-temperature superconducting (HTS) machine and its motor drive (two identical 100kW inverters in parallel connection). The inverters will be operated in a cryogenic environment for reasons of not only the reduced heat leak-in to cryostat, but the minimized energy loss of power electronics, which will eventually enhance the power density and the efficiency of the powertrain. In general, the design and the assembly phase has been completed. The cryogenic inverters use three-level neutral-point-clamped topology. Various electronic components including power semiconductor devices, magnetic cores, capacitors, resistors, operational amplifiers, digital isolators and differential transceivers are characterized at cryogenic temperature for optimal screening. Cryogenic conditioning circuits and isolated gate drivers are custom designed to enable high-voltage high-side gate drive in cryogenic temperature environments. A cryostat is designed as well for immersing the inverters in liquid nitrogen. The input DC voltage has a nominal value of 735V. The cryogenic inverters supply three-phase ac line voltage with RMS value of 520 V and frequency ranges between 0 Hz and 100 Hz. One phase of the inverter, i.e., a three-level neutral-point-clamped switching stage, has been successfully tested under input voltage up to 700V. The three-phase inverter will be tested in room and cryogenic temperature by the mid of 2025.

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Presenter: YUAN, Weijia (Strathclyde University)

Session Classification: Wed-Af-Po.12 - Power Supplies

Contribution ID: **59** Type: **Poster**

Sat-Mo-Po.09-06: Numerical study on HTS magnet with the impact from the power grid side for energy storage

Saturday, July 5, 2025 9:30 AM (1h 45m)

Superconducting magnets have become a popular choice in energy storage systems due to their high efficiency and rapid response speed. The various electromagnetic environments within power grid have different impacts on the behavior of superconducting magnets. To enhance the understanding of this relationship, we first construct a superconducting magnetic energy storage (SMES) model . On the power gird side, we incorporate power conditioning systems and control blocks to simulate the dynamic behavior of the power grid under various operating conditions. On the load side, we introduce a magnet with superconducting characteristics for the first time, enabling the grid-connected operation of superconducting magnet through the adaptive extended J model (AE J model). Superconducting magnets carry current from the power grid side to store electromagnetic energy. Next, we adjust both the control strategy of power grid and the parameters of electrical equipment within power grid to simulate various grid disturbance conditions, for example, voltage sags and swells. The response state of the superconducting magnet under these conditions is computed by AE J model. Specifically, we focus on the current density, magnetic flux density distribution and AC loss. This work will provide effective support for the reliable operation of superconducting magnets under flexible grid-connected conditions.

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Presenter: CHEN, Haolan

Session Classification: Sat-Mo-Po.09 - Energy Storage/SMES, Levitation and Magnetic Bearings

Contribution ID: **60** Type: **Poster**

Fri-Mo-Po.09-08: Design of the evaluation system for materials testing using HTS coils at cryogenic temperature

Friday, July 4, 2025 9:30 AM (1h 45m)

The International Maritime Organization has set a 'Net Zero' target for the maritime industry to reduce greenhouse gas emissions to zero by 2050 in response to climate change. To achieve this goal, the shipbuilding industry is focusing on the design and research of cryogenic equipment for the transportation of liquid hydrogen and carbon capture in cryogenic states. Liquid hydrogen must be stored and transported at cryogenic temperatures. Therefore, testing of specimens is crucial to accurately assess the performance and stability of materials used in such equipment. Currently, most specimen tests are conducted at relatively high temperatures, which do not reflect the actual operating environments, complicating the accurate prediction of material performance. In cryogenic conditions, the mechanical properties of materials can change significantly, and conventional specimen tests may not ensure material reliability at operational temperatures.
This paper deals with an evaluation system for materials testing at cryogenic temperatures using HTS coils. The evaluation system is configured to evaluate the mechanical properties of specimens by utilizing the repulsive force generated when current flows in the same direction through each HTS coil. A pair of HTS coils was designed to generate a high magnetic field and force. Within the evaluation system, the HTS coils are positioned at an appropriate distance considering the test specimen. A specimen was positioned between two HTS coils for the mechanical test. The evaluation system was designed for the capability to test the tensile strengths exceeding 520 N/mm^2, similar to those used in liquid hydrogen tanks like SUS316L.
The HTS coils were designed with YBCO wire and metal insulation to enhance cooling performance and ensure mechanical stability under significant electromagnetic forces. The operating temperature of the HTS coils was set at 20 K, the same as the test temperature of the specimen. A tensile testing fixture conforming to the standard of ISO 6892-3 was located on the side of the HTS coil bobbin, and the specimen was positioned between the fixtures. The HTS coils were cooled down by the conduction cooling method using a cryocooler, and the specimen positioned between the HTS coils was also cooled to 20 K through conduction cooling. The HTS coils are connected to the cryostat through G10 supports, and the G10 supports and cryostat are linked by a rod to allow for swinging like a pendulum when repulsive forces occur between the HTS coils. The margin of the HTS coils in the evaluation system was set at 75%, with the maximum operating current and central magnetic field measured at 462 A and 4.82 T, respectively.
As a result of ramping a pair of HTS coils at a rate of 0.1 A/s, the repulsive force increased by 22 N with each increment, culminating in a maximum repulsive force of 100 kN. The simulation results confirmed that tensile testing of materials using the electromagnetic force between the HTS coils is feasible in a cryogenic environment. The evaluation system for materials testing is expected to be widely utilized in the fields of cryogenic properties and material testing.

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Presenters: Dr KIM, Changhyun (Research Institute of the Medium & Small shipbuilding); CHOI, Jeong Ho (EDF Renewables)

Session Classification: Fri-Mo-Po.09 - Novel and Other Applications II

Contribution ID: **61** Type: **Poster**

Wed-Mo-Po.08-04: Damage detection procedure and damage source analysis on the REBCO high temperature superconductor

Wednesday, July 2, 2025 9:15 AM (2 hours)

In this work, we developed an entire damage detection procedure, including the four-probe method, 2D-Hall scan method, magneto-optic method, and nano-CT method. The procedure can help us find the exact damaged area with a special resolution of 0.5 μm and non-destructively investigate the microstructure in three dimensions. Combined with destructive characterization methods such as SEM, we can get enough information on the damaged area and the speculation on the damage source.
We used a real damage REBCO current lead for the LTS magnet as an example to show the feasibility of our damage detection procedure. The damaged area and microstructure can be fully detected. According to the damaged microstructure, we successfully speculated the possible damage source on the REBCO current lead. Finally, we initially proved and partially reproduced the entire damage process in our finite element simulation model.

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Session Classification: Wed-Mo-Po.08 - Novel Applications and Characterizations

Contribution ID: **62** Type: **Poster**

Fri-Mo-Po.02-05: Proposal for a new pulsed-field magnetization with the addition of first applying a very small magnetic field (FAVS method)

Friday, July 4, 2025 9:30 AM (1h 45m)

A superconducting bulk magnet can generate a strong magnetic field in a compact and lightweight device. Among magnetization methods for bulk magnets, pulsed-field magnetization (PFM) is effective for industrial applications because a bulk can be excited on-site in a short time. In terms of the generated magnetic field, it is reported that almost 100% of the sample's field trapping performance can be achieved at 77 K. However, when using at temperatures as low as 30 K, it is only about 50%. Then, to improve the trapped field, advanced PFM methods such as changing the magnetizing device to extend the pulse width, changing the pulse waveform, and applying a pulsed field multiple times with varying the temperature and the amplitude of the applied field have been reported.

In this paper, we propose a new PFM technique with the addition of First Applying a Very Small magnetic field immediately before the application of a pulse magnetic field of the desired magnitude (hereinafter called "FAVS" method). Applying a low magnetic field causes a small amount of heat to be generated in areas with low properties, which reduces the superconducting properties of those areas and weakens the magnetic shield, resulting in those areas becoming a path for the magnetic flux. By subsequently applying a magnetic field of the desired magnitude, the magnetic flux can be expected to efficiently penetrate through the pathway and be trapped inside the sample. The proposed method has the advantage of great versatility because it takes advantage of slight differences in the properties of any sample.

To confirm the effectiveness of the proposed method, PFM experiments were conducted using a φ60 mm × 20 mm GdBCO bulk. The temperature was set to 20 and 30 K, and a magnetic field of 5.0 or 5.4 T was applied immediately after the first application of 0.8-3.0 T. The trapped field distribution on the pole surface was measured after magnetization, and the total magnetic flux was calculated from the measured data. As a result, it was confirmed that applying a magnetic field of about 0.8 to 1.5 T for the first time improves the total magnetic flux compared to applying a single pulsed field of 5.0 and 5.4 T, demonstrating the effectiveness of the proposed FAVS method.

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Session Classification: Fri-Mo-Po.02 - Bulk and Permanent Magnets

Contribution ID: **63** Type: **Poster**

Fri-Mo-Po.05-11: Detector magnet design and R&D for CEPC

Friday, July 4, 2025 9:30 AM (1h 45m)

The Circle Electron Positron Collider(CEPC) is a large international scientific project initiated by and to be hosted in China. It will produce large samples of Higgs, W and Z bosons to allow precision measurements of their properties as well as searches for BSM physics.The magnet system uses a solenoid that is supported by an aluminum alloy cylinder and cooled indirectly by liquid helium to an operating temperature of 4.5K. A room temperature bore is required with 7.07m in diameter and 9.05 m in length. The magnet locates outside the hadronic calorimeter detector. The low temperature superconducting (LTS) solenoid is the baseline, which will use aluminum stabilized NbTi/Cu Rutherford cable. High temperature superconducting(HTS) plan is the backup option, which will use the Aluminum stabilized Stacked REBCO Tape Cable(ASTC).

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Session Classification: Fri-Mo-Po.05 - Electron-Ion Collider

Contribution ID: **64** Type: **Poster**

Fri-Mo-Po.09-01: Effect of stress along the high temperature superconducting tape conductor induced by vertical electromagnetic forces in a ship deperming racetrack coil carrying 200 kA electric current

Friday, July 4, 2025 9:30 AM (1h 45m)

Steel-hull ships generate a magnetic field making them vulnerable to weapons equipped with magnetic sensors. To mitigate this threat, navies use ship deperming treatments to reduce the ship's magnetization. We design a flat seabed coil with a racetrack shape to deperm a ship that remains stationary above the coil for quick operation. The required magnetic field generated by the coil is calculated from the magnetic property of ship's steel and demagnetization factor caused by the shape of the ship. The mathematical model of a ship was a spheroidal shell, which consists of high-tensile steel, commonly used in civil ships. We calculated a required magnetic field of 2,370 A/m.

To generate this magnetic field including demagnetization factor, onto a target ship, three racetrack coils with a common center, each up to 1,200 m in length, are designed to carry 200 kA of electric current. This high current is transmitted via high-temperature-superconducting (HTS) cables, which reduce cable volume and power consumption due to their zero resistivity. We base the design on commonly available HTS material—Rare Earth Barium Copper Oxide (REBCO) tape conductor—considering the superconducting properties related to temperature, magnetic field and electric current.

The racetrack coil design incorporates parallel and series connections of the tape conductors to reduce the required current from the power supply. To minimize the cost of specialized winding machines, a cable–on–round–core (CORC) assembly is used, with multiple CORC cables bundled to form a racetrack coil conductor.

The magnetic field on the conductor is a key design parameter, along with the electromagnetic forces arising from high current. The electromagnetic force exerted on a tape conductor due to the magnetic fields generated by other tape conductors within a designed CORC bundle was analyzed. In this calculation, the electric current within the tape conductor is assumed to flow along the center of the tape. The magnetic field generated by neighboring tapes within the CORC is oriented circumferentially and induces a compressive force along the thickness of the tape, directed toward the center of the CORC. This compressive force is counteracted by the stiffness of the core material.

Next, we considered the electromagnetic forces between racetrack coil cables. The CORC bundles, as cable conductors, are placed inside a cryogenic pipe for refrigerant flow. The electromagnetic forces push the conductor toward the outer shell of the cable, and the pipe, supported by a plastic structure, resists this force. The stiffness of the support and thermal input from the outer shell satisfy the design requirements.

Additionally, parallel stress is induced along the length of the tape conductor due to the vertical electromagnetic force on its surface as described previously. This stress is critical in coils with uniform hollow shells, such as solenoids, where the electromagnetic force uniformly distributed across all elements. In the CORC bundle, the magnetic field acting on each tape conductor varies, leading to different stresses and strains across the cross-section. Considering the stiffness and stretch of the tape conductor and support materials, we discuss the structural integrity of the seabed racetrack coil under electromagnetic forces.

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Session Classification: Fri-Mo-Po.09 - Novel and Other Applications II

Contribution ID: **65** Type: **Poster**

Wed-Mo-Po.01-01: Design and magnetic measurement of the longitudinal gradient dipole magnet for WALS

Wednesday, July 2, 2025 9:15 AM (2 hours)

Six longitudinal gradient dipole magnets (DLGs) are used in every standard arc of the storage ring at Wuhan Advanced Light Source to reduce the beam emittance. Each DLG is made of 5 permanent magnetic units, providing the transverse filed gradient by tilting the polar faces and the longitudinal gradients simultaneously The field designs, assembly, and detailed magnetic measurement of the DLG1 prototype are presented. By optimizing the shapes of the pole faces in OPERA3D, the field integrals uniformity is optimized to lower than 5.0E-4. The magnetic field can be controlled accurately by adjusting the transverse position of each magnet-unit, and the temperature stability is better than 10ppm/℃ by filling several iron nickel alloy sheets between the poles and returning yokes. Magnetic measurement results indicates that the field integrals uniformity is below 5.0E-4 within the good field region.

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Presenter: XIANG, Pai (Wuhan University)

Session Classification: Wed-Mo-Po.01 - Accelerator Magnets I

Contribution ID: **66** Type: **Poster**

Fri-Mo-Po.07-02: Single Sided Anti-Bending Magnet For The WALS Ring

Friday, July 4, 2025 9:30 AM (1h 45m)

In order to reduce the beam emittance, four single sided anti-bending magnets(ABM) are employed in each standard arc of the storage ring at Wuhan Advanced Light Sourc(WALS). Each ABM is made of one half of a quadrupole and a pair of slim auxiliary poles, providing the transversal gradients and a dipole field simultaneously. Based on the NSGA2 Genetic Algorithm and chamfers at the ends of the ABM, the field harmonics normalized to the main dipole field are optimized to lower than 5.0E-4. Measurement results indicate that the field integrals uniformity is also below 5.0E-4 within the good field region. The field designs, assembly, and detailed magnetic measurement of the ABM prototype are presented.

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Session Classification: Fri-Mo-Po.07 - Accelerator Magnets III

Contribution ID: **67** Type: **Poster**

Wed-Mo-Po.11-07: A 35 T high field pulsed magnet cooled by a cryogenic refrigerator at WHMFC

Wednesday, July 2, 2025 9:15 AM (2 hours)

A high field pulsed magnet up to 35 T, cooled by a cryogenic refrigerator, has been developed for ultrafast spectroscopy at Wuhan national high magnetic field center (WHMFC). To cool the magnet fast, two thin beryllium copper sheets are chosen as end plates and reinforced with epoxy. The beryllium copper sheets are linked with a cryogenic refrigerator to ensure the magnet can be cooled down to 77 K. In this article, a three-dimensional finite element model is built to analyze the eddy current, magnetic field, heat dissipation capability and mechanical properties of these beryllium copper sheets of magnet. The experiments have been done and show that the pulsed magnet can generate a magnetic field up to 35 T and can be cooled down to below 77 K in one hour.

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Session Classification: Wed-Mo-Po.11 - High Field Pulsed Magnets I

Contribution ID: **68** Type: **Poster**

Thu-Af-Po.02-13: Critical Current Characteristics of the Novel Cable Woven with Transpositional HTS tapes under the Magnetic Field

Thursday, July 3, 2025 2:00 PM (2 hours)

This paper proposes a novel approach to enhance both the engineering current density and the uniform distribution of the magnetic field in a high-temperature superconducting (HTS) strand. This is achieved by weaving the strand using transpositional REBCO tapes. The H formula is utilized to establish a three-dimensional (3D) Finite Element Model (FEM) in the proposed approach. In the proposed investigation, both numerical and experimental methods are employed to analyze the distribution of magnetic field and critical current at a temperature of 77 K under the magnetic field. Based on the obtained results, it has been observed that the novel high-temperature superconducting (HTS) strand exhibits several favorable characteristics when compared to the strand stacked by three REBCO tapes. These characteristics include larger critical current under the magnetic field.

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Session Classification: Thu-Af-Po.02 - HTS Cable

Contribution ID: **69** Type: **Poster**

Wed-Mo-Po.04-07: Empowering the 2G-HTS Tape Industry: SuperMag's Progress on Production and Research

Wednesday, July 2, 2025 9:15 AM (2 hours)

Due to the rapid development of compact nuclear fusion devices, the industrialization of second-generation high-temperature superconducting tapes (2G-HTS) have entered a new historical phase. SuperMag Technology (Shanghai) Ltd, a spin-off from Shanghai Jiao Tong University, has swiftly established at the end of 2022 as an manufacturer dedicated to cost-effective 2G-HTS tapes. After two years of development, SuperMag has demonstrated serval remarkable progress in R&D and manufacturing capabilities. Firstly, for the Hastelloy substrate, we successfully integrate an industrializable, low-cost mechanical polishing process, which significantly enhance the fault tolerance of electro-polishing and reduces multi-scale defects. As a result, Ic homogeneity is significantly enhanced and Ic drops are also remarkably reduced. Secondly, by improving deposition process and film composition, we achieved a milestone of an Ic value exceeding 200 A-4 mm (77 K, self-field), with an annual production capacity of over 1800 km/year. Last but not least, we have developed a highly customized post-treatment process tailored to our customers' specific application scenarios. We have applied diverse post-treatment processes to provide customized HTS-tape solutions for our clients.

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Session Classification: Wed-Mo-Po.04 - HTS Conductors I

Contribution ID: **70** Type: **Poster**

Fri-Mo-Po.01-04: Reduced screening-current-induced stress in NI-REBCO coils by actively degrading the critical current of REBCO tape through heat treatment

Friday, July 4, 2025 9:30 AM (1h 45m)

No-insulation REBCO (NI-REBCO) coils, with self-protecting capabilities during quench, have attracted significant interest and shown considerable potential for high-field applications. As research advances, it has become increasingly evident that uneven stress/strain induced by screening currents is a critical factor affecting the performance of NI-REBCO coils. Therefore, reducing screening-current-induced stress/strain is vital for the effective mechanical design and stable operation of NI-REBCO coils and magnets. Our numerical simulations indicate that the critical current of coils located at the two ends of the NI-REBCO magnet is lower than that of the coils at the center, primarily due to the influence of the perpendicular magnetic field. Since the coils are connected in series, the transport current is limited by the lowest critical current, resulting in the critical current of the central coils being significantly higher than required. Our results also reveal that screening-current-induced stress is strongly correlated with the critical current of the REBCO tape. Consequently, for coils where the critical current significantly exceeds the demand, reducing the critical current to mitigate screening-current-induced stress is an effective strategy. Building on these numerical findings, we conducted experimental investigations by fabricating a set of coils with 10 turns REBCO tape and applying heat treatment to reduce their critical current. These coils were then tested in a 20 T, 200 mm bore, water-cooled magnet to observe the variation in hoop strain as the background magnetic field was varied. The experimental results confirmed that reducing the critical current of the REBCO coils effectively mitigates screening-current-induced stress. However, certain heat treatment parameters (temperature and duration) were found to adversely affect the mechanical properties of the tape. This underscores the importance of balancing stress reduction with the preservation of the tape's mechanical integrity. Future research should focus on optimizing heat treatment conditions or exploring alternative methods to reduce the critical current without compromising the material's mechanical properties.

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Session Classification: Fri-Mo-Po.01 - No-Insulation Coils IV

Contribution ID: **71** Type: **Poster**

Fri-Af-Po.11-04: Development of a Novel High Temperature Superconducting Compact D-shaped magnet for Tokamak

Friday, July 4, 2025 2:00 PM (2 hours)

High-temperature superconducting (HTS) magnets are emerging as key R&D components for compact and economical future fusion devices. Institute for Plasma Research (IPR), India, has undertaken an R&D initiative focused on the design and development of fusion-relevant HTS magnets. This initiative covers the development of compact solenoids and D-shaped magnets and dedicated test facilities. As a part of this effort, the design, fabrication, and testing of a D-shaped HTS magnet with dimensions of 1.1 m in height and 0.7 m in width have been completed. This magnet comprises a vacuum-jacketed liquid nitrogen chamber housing the HTS winding pack. The winding pack terminations of this coil are electrically connected with a pair of liquid nitrogen-cooled copper current leads for interfacing with the power supply. The winding pack is composed of a double pancake with 12 turns of stacked-type REBCO HTS cable in a layered configuration. The fabrication of the winding pack of magnet is carried out using dry FRP tape insulated HTS cable with in-house setup using LN2 casing bottom section as a mandrel to achieve the required D shape profile. The voltage taps and PT-100 temperature sensors are installed on the winding pack at critical locations. The winding pack is then encapsulated by welding the remaining section of the LN2 casing which is further inserted and encased in a D-shaped vacuum chamber of volume 0.05 m3. This D-shaped magnet has been successfully tested at 77 K, up to 1.2 kA. The design parameters, fabrication processes, test results, and the technical difficulties faced during the development of this magnet will be discussed in this paper.

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Session Classification: Fri-Af-Po.11 - Experiments and Test for Fusion Magnets

Contribution ID: **72** Type: **Contributed Oral**

Sat-Af-Or5-03: AC loss characteristics of SCSC cables under various practical operating conditions

Saturday, July 5, 2025 5:00 PM (15 minutes)

The Spiral Copper-plated Striated Coated-conductor cable (SCSC cable) is our novel concept of high current cable with low ac loss, in which copper-plated multifilament (striated) coated conductors are wound spirally on a metal core in multiple layers. Whereas copper-plating allows current sharing among filaments against local defects in a filament, filaments are decoupled electromagnetically against transverse ac magnetic field thanks to its spiral geometry. Note that ac loss cannot be reduced effectively in a flat copper-plated multifilament coated conductor because of electromagnetic coupling among filaments. The structure of an SCSC cable, in which copper-plated filaments are spiraled, is like the structure of a conventional LTS wire, in which filaments embedded in copper matrix are twisted.

In their practical applications, SCSC cables will be subjected to magnetic fields with various amplitudes and various frequencies and will be used at various temperatures. In the stator windings of rotating machines such as propulsion motors of aircrafts, the cables will be used in magnetic fields with moderate amplitudes (from one to a couple of Tesla) and high frequencies (50 –200 Hz). In the CS coils of tokamaks and the beam bending magnets of accelerators, they will be used in magnetic fields with high amplitudes (10 –20 T) and relatively low ramp-up rate. Therefore, the quantitative evaluation of ac losses under such various operating conditions is very important.

We propose a method of quantitative evaluation of ac losses in SCSC cables under various conditions based on experimental results: we evaluate hysteresis losses and coupling losses separately. We measured the magnetization losses of SCSC cables with various configurations at various frequencies in liquid nitrogen and extracted hysteresis-loss components. Even though we could apply magnetic field up to 100 mT, this field amplitude was higher than the penetration fields of sample cables, considering small critical currents at 77 K. The plots of normalized hysteresis loss vs. normalized field amplitude of various sample cables showed us that hysteresis losses above the penetration field reasonably agree with Brandt and Indenbom's analytical values for each filament with a correction factor for field orientation. Therefore, by using the critical current at an arbitrary operating temperature measured elsewhere, we can calculate hysteresis loss above the penetration field at this temperature using the Brandt and Indenbom's formula. Meanwhile, we measured the coupling losses of SCSC cables with various configurations in a wide range of frequency up to 20 kHz at various temperatures. Using a plot of measured coupling loss vs. frequency of a sample cable at a temperature, we can determine the coupling time constant and geometry factor of coupling loss of the cable at this temperature. Note that the temperature dependence of a copper plating of multifilament coated conductor, which influences its transverse resistance, causes the temperature dependence of the coupling time constant of the SCSC cable consisting of the multifilament coated conductor. Using the determined coupling time constants and geometry factors of coupling losses, we can calculate the coupling losses of various SCSC cables at arbitrary frequency and arbitrary temperature.

This work was supported in part by JST-ALCA-Next Program Grant Number JPMJAN24G1 and in part by JSPS KAKENHI Grant Number JP24H00316, Japan.

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Session Classification: Sat-Af-Or5 - AC Loss and Magnetization II

Contribution ID: **73** Type: **Poster**

Thu-Mo-Po.01-01: Numerical study on Transport AC loss in REBCO-coated conductors with magnetic substrates carrying non-sinusoidal currents

Thursday, July 3, 2025 8:45 AM (2 hours)

In practical high-temperature superconducting (HTS) applications, various harmonics are present, causing the transport current to become non-sinusoidal, which may pose new challenges for controlling AC losses. However, the transport AC loss characteristics of REBCO coated conductor (CC) with magnetic substrates under non-sinusoidal currents are still unclear. In this study, we performed a numerical study of the AC loss of a 4.8 mm wide RABiTS REBCO CC carrying both sinusoidal and non-sinusoidal currents. The current amplitude, frequency, and n-value were varied. The non-sinusoidal current waveforms studied included square waves, trapezoidal waves, and triangular waves. The results show that at low frequencies, the AC loss is predominantly due to the superconducting layer and the magnetic substrate, with the AC loss being highest for the square wave current waveform and lowest for the triangular waveform, as determined by the flux penetration depth. At high frequencies, the eddy current loss in the metal layer dominates, but the AC loss remains highest for the square wave and lowest for the triangular wave, driven by the induced eddy currents. Furthermore, the REBCO CC with a magnetic substrate still follows the critical state model, meaning that for an infinitely large n-value, the differences in AC loss values for all waveforms would disappear.

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Session Classification: Thu-Mo-Po.01 - AC Loss and Magnetization I

Contribution ID: **74** Type: **Poster**

Sat-Mo-Po.07-06: Double Aperture HTS Dipole Magnet Model for the Persistent Current Operation

Saturday, July 5, 2025 9:30 AM (1h 45m)

Magnet systems of particle accelerators consist of many various types of magnets. There is an interest in replacing rather low-field conventional resistive magnets with high-temperature superconducting (HTS) magnets. The main goal is to reduce operational expenses which is critical during the continuously increasing cost of electricity. At Fermilab were built and successfully tested several HTS accelerator magnets. The paper described the variant of double aperture dipole magnet which could be suitable for future Lepton Colliders. A single short-circuited HTS coil of 3.8 kA generates a homogeneous magnetic field of 57 mT in both magnet gaps of 84 mm. The peak field in Lepton Colliders is limited by synchrotron radiation. The short model magnet was designed, built, and successfully tested at liquid nitrogen temperature. This magnet works in a persistent current mode, providing additional cost savings when used in particle storage rings operated at a stable magnetic field, presented and discussed results of design, fabrication, and tests. The magnet demonstrated a high magnetic field stability in both apertures, efficiency of correction coils, and primary powering circuit.

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Presenters: TURRIONI, Daniele; KASHIKHIN, Vladimir

Session Classification: Sat-Mo-Po.07 - HTS Magnets

Contribution ID: **75** Type: **Poster**

Fri-Mo-Po.08-08: Defect detection in REBCO layers using machine learning

Friday, July 4, 2025 9:30 AM (1h 45m)

REBCO conductors are emerging as a prominent choice among high-temperature superconductors due to their superior superconducting properties at high magnetic fields. However, depending on the fabrication route, there can be microstructural heterogeneities such as porosity, CuO precipitates, and a-axis grains. Such defects at a larger scale can disrupt current transport and limit the critical current density. This study focuses on the investigation and characterization of defects in commercial REBCO conductors of varying characteristics. Top-view images of the REBCO layer are captured post-etching using scanning electron microscopy (SEM). Traditional image analysis and segmentation are limited and inadequate for quantifying such defects in SEM images, while manual identification is labor-intensive and time-consuming. To address this, the application of machine learning (ML) techniques is explored for rapid, automated and accurate defect detection. Specifically, different open-source foundational computer vision models are fine-tuned to analyze the SEM images. The results from the ML models are compared and utilized for statistical analysis with the hope of establishing correlations between these microscale defects and measured in-field transport critical current.

This work was supported in part by the U.S. Department of Energy, Office of Science, Office of High Energy Physics, through the Magnet Development Program, under Contract DE-AC02 05CH11231, which is performed at Lawrence Berkeley National Laboratory.

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Session Classification: Fri-Mo-Po.08 - HTS Characterization II

Contribution ID: **76** Type: **Poster**

Fri-Af-Po.06-02: Review on the technology and application of all-superconducting high-field magnet

Friday, July 4, 2025 2:00 PM (2 hours)

All-superconducting high-field magnets are in high demand across various scientific disciplines, including large-scale science devices, materials science, and biology. They play a crucial role in researching material properties, the origin of life, and disease prevention and treatment. These magnets offer significant advantages, such as compact size, low power consumption, flexibility, and convenience.
With the continuous advancement in superconducting materials and magnet technology, a key focus is placed on developing the essential technology for large aperture all-superconducting high-field magnets with independent intellectual property rights. This effort, driven by the national "13th Five-Year" major science and technology infrastructure project known as "Fusion reactor Key System Comprehensive Research Facility (CRAFT)," aims to develop the homemade high-field superconducting magnet. The ultimate goal is to achieve the domestic commercialization of all-superconducting high-field magnets with apertures exceeding 15T.
After over two years of accumulating experience and conducting extensive technical research, the project team successfully realized the commercial value of a 15T&77mm aperture all-superconducting hybrid magnet. The magnet's dimensions are Ø306mm×340mm, with a central magnetic field reaching 15.12T at an operating current of 118.6A. The axial magnetic field uniformity is ≤1%@Ø60mm×42.6mm cylindrical area, and the central magnetic field reaches the target value after two excitation exercises.
Building on the key technology of designing and preparing full superconducting high-field magnets, the project team plans to develop a larger aperture (≥150mm) high-field (˜15T) all-superconducting hybrid magnet. This will be achieved by combining it with high-temperature superconducting interpolation magnets, aiming to create a central magnetic field strength of ˜35T&80mm aperture for a high and low-temperature all-superconducting hybrid magnet. The overarching goal is to provide technical reserves and core component support for high-field material scientific research in fusion reactor development and contribute to the national strategic layout for high magnetic field development.

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Session Classification: Fri-Af-Po.06 - High Field HTS Solenoids

Contribution ID: **77** Type: **Contributed Oral**

Sat-Af-Or2-07: Review on the development progress of the high-field all-superconducting magnets with a large bore for superconducting material characteristics evaluation and future research plan

Saturday, July 5, 2025 3:30 PM (15 minutes)

Research on high-field all-superconducting magnets has garnered significant global attention in recent years due to their reduced size, lower cost, and enhanced convenience compared to hybrid magnet systems. These magnets play a pivotal role in various research fields, including material science, biological studies, and quantum computing. However, the fabrication of high-field superconducting magnets, particularly those using Nb3Sn superconducting wires, presents considerable challenges and requires meticulous care.
Since 2019, our team has embarked on designing and producing a 19T all-superconducting magnet with a bore diameter exceeding 70 mm. This magnet aims to serve as the background field system for investigating superconducting material properties for future fusion reactor. The project is a sub-component of the Comprehensive Research Facility for Fusion Technology (CRAFT) initiative, which seeks to establish a comprehensive laboratory equipped with capabilities related to superconducting materials, AC loss measurement, structural materials evaluation, thermal-hydraulic studies, non-destructive testing, and high-voltage research.
To ensure safety and feasibility, a stepwise research approach was adopted:
Initial Phase: Design and construct a 15 T low-temperature superconducting (LTS) magnet using Nb3Sn and NbTi wires, featuring a bore size larger than 70 mm.
Intermediate Phase: Attempt to increase the bore size to 150 mm. Concurrently, develop an insert magnet utilizing high-temperature superconducting (HTS) double-pancake coils with a 70 mm aperture.
Final Phase: Achieve the target by integrating the 15 T & 150 mm LTS outer magnet with a 5 T & 70 mm HTS insert magnet.
After nearly five years of dedicated research, we have successfully developed China's first 15 T & 77 mm LTS magnet, along with a compact version of the same specifications, and a custom-built 15 T & 150 mm LTS magnet. By combining these with a 5 T & 70 mm HTS insert magnet, the project objective was met in 2024. The resultant LTS + HTS all-superconducting magnet achieves a stable central magnetic field of 19.13 T, with an available measuring bore of 70.1 mm.
This paper reviews the development progress of high-field all-superconducting magnets within the CRAFT project. Although the target has been achieved, numerous challenges remain to be addressed for the stable operation of the home-made all-superconducting magnets. Specifically, improving the success rate in manufacturing all-superconducting magnets using brittle Nb3Sn superconducting wires is a critical issue that needs resolution. Addressing this challenge will significantly advance the development of high-field magnet technologies.

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Session Classification: Sat-Af-Or2 - Progress in Ultra High Field Solenoids

Contribution ID: **78** Type: **Poster**

Thu-Af-Po.11-02: Impact of cryogenic system on RF phase stability in RAON SCL3

Thursday, July 3, 2025 2:00 PM (2 hours)

The cryogenic system for accelerator complex for ON-line experiments (RAON), is designed to maintain extremely low temperatures to support superconducting equipment, such as superconducting linear accelerators and low-temperature superconducting magnets. Superconducting RF (SRF) cavities are integral to particle accelerators, where phase stability ensures precise particle acceleration. The cryogenic system, responsible for maintaining ultralow temperatures for superconductivity, can inadvertently introduce instabilities due to thermal or mechanical perturbations. This study investigates how cryogenic systems affect the RF phase stability in superconducting linear accelerators (SCLs). We measured the changes in RF stability caused by the movement of cryogenic valves and variations in external heat input through experiments. By analyzing the interaction between thermal fluctuations, mechanical vibrations, and electromagnetic properties of RF cavities, we aim to provide insights into optimizing cryogenic operations to enhance phase stability.

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Session Classification: Thu-Af-Po.11 - Cryostats and Cryogenics II

Contribution ID: **79** Type: **Poster**

Fri-Mo-Po.02-04: Investigation on Magnetization Characteristics of YBCO Bulk Superconductors in Post-Assembly Magnetization Application

Friday, July 4, 2025 9:30 AM (1h 45m)

High-temperature superconducting (HTS) bulks can exhibit superconducting properties at liquid nitrogen temperature. As a type-II superconductor, these materials demonstrate flux pinning effects, wherein magnetic flux is pinned inside the superconductor when the external magnetic field exceeds its lower critical field. This phenomenon imparts permanent magnet characteristics to the material, with remanent magnetization surpassing that of conventional rare-earth permanent magnets.For existing permanent magnet motors, magnetized HTS bulks can replace traditional permanent magnets as the magnetic source. Most current studies on the flux-trapping characteristics of HTS bulks employ the field-cooling (FC) method, wherein a steady magnetic field is applied before cooling the material below its critical temperature. While this approach enables maximum flux capture, it is impractical for HTS bulks mounted on motor rotors in real-world applications.To address this limitation, the pulse field magnetization (PFM) method emerges as a portable and flexible alternative. However, challenges such as non-uniform magnetizing fields during the pulsing process need to be overcome. Limited research exists on the magnetization characteristics of HTS bulks under varying angles and pulse widths of magnetic fields.This study investigates the anisotropic PFM characteristics of YBCO bulk superconductors. An experimental platform was designed to examine the magnetization performance of HTS bulks under magnetic fields with different angles and pulse widths. Magnetization curves of YBCO bulks were measured under various magnetic field intensities, pulse durations, and angles. Finite element numerical simulations were also conducted to validate the experimental results. These findings provide guidance for the application of HTS bulks in high-temperature superconducting permanent magnet motors.

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Session Classification: Fri-Mo-Po.02 - Bulk and Permanent Magnets

Contribution ID: **80** Type: **Poster**

Thu-Mo-Po.05-02: Research on Axial Tensile Characteristics of High Current CORC Cable

Thursday, July 3, 2025 8:45 AM (2 hours)

The high temperature superconducting (HTS) CORC cable has the advantage of high flexibility, making it one of the best candidate cables for producing compact fusion magnets. The intense background magnetic field strength and high current in the fusion device will cause the CORC cable to be subjected to a huge axial tensile electromagnetic force. Excessive axial tensile load can cause irreversible degradation in the current carrying capacity of CORC cables. To achieve better control of plasma configuration in fusion devices, high current carrying CORC cables are necessary. At present, most of the research on the axial tensile performance is focused on CORC cables with critical currents less than 5000 A. Therefore, this article conducts axial tensile experiments on CORC cables with 24 layers of superconducting tapes and critical currents greater than 5000 A (77 K, self field). In addition, a CORC cable axial tensile simulation model is established to theoretically analyze the strain distribution of the cable under axial tensile load. The research results provide theoretical support for the application of CORC cables in compact fusion projects.

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Session Classification: Thu-Mo-Po.05 - Mechanical Behavior and Stress I

Contribution ID: **81** Type: **Poster**

Fri-Af-Po.10-04: R&D of cryogen-free 2G-HTS wiggler in NSRRC

Friday, July 4, 2025 2:00 PM (2 hours)

This paper presents the development of a cryogen-free 2G High-Temperature Superconducting (HTS) wiggler for use at the National Synchrotron Radiation Research Center (NSRRC). The proposed design leverages the advanced properties of 2G-HTS materials to provide magnetic fields around 2.7 T. The wiggler utilizes modified double pancake winding techniques for the HTS coils. This method doesn't need soldering connection between each poles. The choose of cryogen-free design eliminates the need for liquid helium, simplifying maintenance. The paper details the mechanical design, magnetic field simulation, tape winding methodology, and integration of the HTS wiggler into the NSRRC's advanced synchrotron systems.

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Session Classification: Fri-Af-Po.10 - Undulators

Contribution ID: **82** Type: **Poster**

Fri-Af-Po.02-03: Quench simulation and validation for EIC direct wind magnets

Friday, July 4, 2025 2:00 PM (2 hours)

The Electron-Ion Collider (EIC), a new facility to be built in the United States at the U.S. Department of Energy's Brookhaven National Laboratory in collaboration with Thomas Jefferson National Accelerator Facility. The EIC project will provide us answers to the mysteries of the origin of mass and building blocks of our universe.
There are many different types of superconducting magnets near the interaction region (IR) of EIC: traditional collared dipole and quadrupole magnets and tapered canted-cosine theta (CCT) and serpentine magnets. The direct wind technology, pioneered by BNL, will be used to build those CCT and serpentine magnets.
A 6-around-1 NbTi cable will be used for CCT and serpentine magnets. Given the relatively smaller conductor used for those direct wind magnets, the overall engineering current density will be 2-3 times higher in comparison to traditional collared magnets in EIC. This is technically challenging and potentially represents high risks for quench protection.
In this paper we use different tools and methods for quench simulation for several EIC direct wind magnets. We also present results of a sensitivity study, exploring different material properties and Jc curves. This paper also discusses and validates the quench simulation results with measurement results from a small-scale serpentine magnet tested at BNL in October 2024.

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Session Classification: Fri-Af-Po.02 - Quench Detection and Protection III

Contribution ID: **83** Type: **Poster**

Sat-Mo-Po.08-01: Plasma-driven film deposition method to enhance surface hydrophobicity of multi-filamentary REBCO tape

Saturday, July 5, 2025 9:30 AM (1h 45m)

With the widespread application of high-temperature superconducting (HTS) REBCO tapes in fields such as energy, healthcare, and transportation, their operating environments have become increasingly complex, placing higher demands on their operational stability. Although the multi-filamentary REBCO tapes can improve the electromagnetic performance, specific metals and compounds in REBCO tapes somehow react with water after exposing without stabilization layers, leading to HTS material degradation and performance failure. This study proposes a plasma-driven film deposition method based on atmospheric pressure low-temperature plasma jet (APPJ) with hexamethyldisiloxane (HMDSO) precursor to enhance the hydrophobicity of REBCO tapes. Results show that after the plasma film deposition, the water contact angle (WCA) on the tape surface increases from the original 94°±7° to 137.5°±1.5°. Moreover, scanning electron microscopy (SEM) with X-ray spectroscopy (EDS) indicates that there is a typical spherical cluster-like film covering the tape surface, which mainly consists of silicon (Si) and oxygen (O) elements rather than copper (Cu), yttrium (Y), or barium (Ba) elements. Furthermore, the immersion test in liquid nitrogen was also carried out, and it shows that the film maintains considerable stability in hydrophobicity performance and chemical composition after 30 minutes of liquid nitrogen bathing, demonstrating the feasibility of the plasma film fabrication for hydrophobicity improvement of superconducting tapes. This study provides an effective method for enhancing the weather resistance and long-term stability performance of REBCO tapes, offering potential technical support for high-performance design of multi-filamentary REBCO tapes.

Keywords: multi-filamentary REBCO tapes, multi filaments, plasma treatment, surface modification, hydrophobicity

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Session Classification: Sat-Mo-Po.08 - Structural and Insulation Materials

Contribution ID: **85** Type: **Poster**

Wed-Af-Po.03-02: Modular retaining structures for the REBCO racetrack coil development at CERN

Wednesday, July 2, 2025 2:30 PM (2 hours)

A R&D program for the development of HTS magnets is ongoing at CERN. Double pancake coils are manufactured using a polyimide insulated cable made of an assembly of REBCO and copper tapes. The coils are then assembled in groups inside a structure optimized to contain the electromagnetic forces and limit the cable deformations (and consequent stresses).
It is foreseen to have a step-by-step approach. The program begins with the fabrication of short windings, approximately 250-mm in length, using 4-mm wide HTS tapes. In a first phase, the aim is to reach fields between 5 T and 9 T at 4.2 K by using groups of coils arranged in a common coil configuration or piled up in stacks. Then, in a second phase, the coil size and the field level will increase profiting of the acquired experience and know how. The final goal of the program is to reach fields of the order of 20 T in double aperture, 50-mm bore dipoles, with coils approximately one meter long.
In this note, we describe the configuration of the coils and the containment structures that are used in the first phase. The approach is modular; meaning that the transition from the first phase to the second, at higher fields, will be realized by a gradual increase of the key geometrical dimensions without changing the validated functional principles.

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Presenter: PERINI, Diego (CERN)

Session Classification: Wed-Af-Po.03 - High Luminosity LHC and FCC

Contribution ID: **86** Type: **Poster**

Thu-Mo-Po.02-03: Design of low field dipole for FCC-ee booster ring

Thursday, July 3, 2025 8:45 AM (2 hours)

This paper presents the design of the FCC-ee booster dipole magnets. The booster dipoles are low-field iron-dominated cycled H-type magnets. They consist of an 11 meter long laminated steel yoke with anodized aluminum busbars instead of coils. The magnet is designed to mitigate parasitic effects, namely the Earth's magnetic field and yoke hysteresis, that become significant at the 6.5 mT field required for 20 GeV injection. The analytical design is validated by Finite Element Analysis. The hysteretic effect is modeled, and the cross-section of the magnet is optimized to obtain the required field quality across the full cycle from 6.5 mT to 59 mT. The predictive power of the hysteresis model is validated by the test of a similar magnet from CERN stock. Finally, experience from a short prototype magnet, built and tested, is reported. The test results confirm that the proposed magnet meets the design requirements, demonstrating the feasibility of dipoles for 20 GeV injection energy.

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Session Classification: Thu-Mo-Po.02 - Design and Development of Accelerator Magnets I

Track Classification: A: Magnets for Particle and Nuclear Physics: A02: Resistive Accelerator Magnets

Contribution ID: **87** Type: **Poster**

Wed-Af-Po.03-01: Assembly of the Nb3Sn MQXFB Quadrupole for HL-LHC

Wednesday, July 2, 2025 2:30 PM (2 hours)

The High-Luminosity LHC (HL-LHC) project aims at upgrading the existing LHC machine to increase its integrated luminosity by a factor of ten. A key aspect of this upgrade are the inner triplet (or low-β) quadrupole magnets, the MQXF, which utilize Nb3Sn superconducting magnet technology and reach a conductor peak field of 11.3 T. The MQXFB version, manufactured at CERN, is characterized by a magnetic length of 7.2 m, making it the longest Nb3Sn accelerator magnet ever realized. A total of ten MQXFB series magnets are needed for HL-LHC (eight to be installed and two spares). These magnets rely on a system of water pressurized bladders and keys to pre-tension the aluminium shrinking cylinder at room temperature and to apply pre-stress to the coil-pack. The coil pre-load increases after cool-down to 1.9 K thanks to the larger thermal contraction of the aluminium shrinking cylinder with respect to the rest of the magnet components. Since this structural design is used for first time in an accelerator magnet, the accumulated experience of assembling 80% of the magnets provides valuable insights for the potential application of Nb3Sn technology in future colliders. This paper analyses the main measurables for the mechanical assembly of the MQXFB series magnets and assesses the reproducibility of the production. The main lessons learned during the fabrications process are also described.

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Session Classification: Wed-Af-Po.03 - High Luminosity LHC and FCC

Contribution ID: **88** Type: **Poster**

Thu-Mo-Po.03-03: Magnet system of the new electron cooler for the CERN antiproton decelerator (AD) ring

Thursday, July 3, 2025 8:45 AM (2 hours)

A new electron cooler for the antiproton decelerator (AD) ring at CERN is under construction and will be installed in the next long shutdown (2026-2028) to replace the existing 40-year-old device. This paper presents the design of the new electron cooler magnet system, justifies key design choices, and details the performance. Compared to the existing electron cooler magnet system, the new magnet system gives a factor five improvement of drift region field quality and includes provision for electron beam expansion. The upgrade has the potential to reduce the length of the electron cooling plateaus in the AD cycle and thereby increase the number of antiprotons available to CERN's rich antimatter physics program.

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Session Classification: Thu-Mo-Po.03 - Design and Development of Accelerator Magnets II

Contribution ID: **89** Type: **Poster**

Wed-Mo-Po.08-03: Development of an experimental test stand and machine learning surrogate models for capturing complex responses in pulsed septa

Wednesday, July 2, 2025 9:15 AM (2 hours)

The complex electromagnetic and structural response of pulsed septum electromagnets is currently being studied, aiming to reveal insights in the prediction of their life cycles. The fault prediction remains a key challenge, requiring efforts in modelling and onsite instrumentation. Recently, a high-fidelity numerical model was developed, which allowed us to deepen our understanding of the system's behavior. The insight on critical stress/strain conditions are now allowing to better understand early fatigue observations in the coil conductor and required peripheric equipment. As a next step, a numerical parametric study has been conducted, enabling prediction of the mechanical and electromagnetic dynamic response under different operation conditions. A stringent experimental campaign has been carried out to validate these results. These tests required developing the test-setup including careful selection of non-contact and on-device instrumentation, as well as the data acquisition system. The setup has demonstrated the feasibility of potential implementation in the CERN accelerator complex. In parallel, significant efforts have been made to study the possibility of using Machine Learning (ML) models to reduce the time-consuming simulation process based on analytical solvers. Several custom loss functions reflecting physical constraints, as well as augmentation techniques, have been implemented to overcome the challenge of a strongly limited dataset size. The created ML pipelines and dedicated Graphical User Interface (GUI) are now enabling instantaneous response of the device's model. The paper will summarize the efforts and project status with the long-term vision to develop a digital twin for septum magnets.

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Session Classification: Wed-Mo-Po.08 - Novel Applications and Characterizations

Contribution ID: **90** Type: **Poster**

Wed-Af-Po.02-01: Conceptual design of the hidden sector spectrometer magnet made with MgB_2 cable for the SHiP experiment and qualification of the technology demonstrator.

Wednesday, July 2, 2025 2:30 PM (2 hours)

The SHiP experiment, located at CERN in the ECN3 North Area cavern, aims to detect feebly interacting particles, potentially shedding light on neutrino mass and dark matter. A key component of the detector is the Hidden Sector Spectrometer, potentially the first large-scale, energy-efficient experimental magnet using superconducting MgB_2 cables. This technology, initially developed for the High Luminosity upgrade of the Large Hadron Collider (HL-LHC) at CERN, has now been adapted for electromagnets, cooled to about 20 K.
We present the current status of the proof-of-principle demonstrator, which features a coil wound from MgB_2 cable on radial plates and mounted inside an iron yoke. The demonstrator has been successfully tested in gaseous helium at 20 K. In the upcoming phase, the demonstrator will be upgraded to test indirect cooling of the MgB_2 cables, while the yoke will remain at ambient temperature.
This work is a validation step toward the design of the spectrometer magnet for SHiP, focusing on achieving high homogeneity with a magnetic field strength of 0.6 Tm over a large aperture of 4 m x 6 m. The main features of the conceptual magnet design are outlined. Challenges for the production are also presented.

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Session Classification: Wed-Af-Po.02 - Detector and Spectrometer Magnets

Contribution ID: **91** Type: **Poster**

Wed-Af-Po.12-03: HTS Power Supplies for DC Fusion Magnets

Wednesday, July 2, 2025 2:30 PM (2 hours)

OpenStar is building a levitating dipole reactor (LDR), following in the footsteps of LDX and RT-1. In our quest to achieve fusion we are building Junior; an assembly of non-insulated (NI) high temperature superconducting (HTS) pancake coils weighing 500 kg operating at 1.44 kA and a peak field of 5.6 T.
An enabling step for the LDR is developing an integrated power supply system which has the ability to maintain the current in the magnet while it is levitating and confining plasma. Recent developments in HTS superconducting power supplies have shown that they are a viable solution to keeping an HTS magnet charged with minimal heat leak to the magnet (operating at 30-50 K). We will detail the challenges of building and operating a power supply which needs to interface with two drastically different temperature regimes (50 K and 300 K) in addition to another intermediate regime (65 K).
While levitated, we need the power supply system to operate without supervision, maintaining the current and watching for crucial events; like over temperature, which can be communicated via simple IR communications. A traditional suite of semi-conducting power supplies and control electronics were developed and integrated which is housed in an internal cavity on-board Junior.
In this presentation we will present the performance specifications of the developed HTS power supply system, such as charge time, energy efficiency, and thermal performance of our dipole system during our first plasma experiment.

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Session Classification: Wed-Af-Po.12 - Power Supplies

Contribution ID: **93** Type: **Poster**

Thu-Mo-Po.11-01: Fabrication and Test of a Curved-Canted-Cosine-Theta (CCCT) Dipole at CERN

Thursday, July 3, 2025 8:45 AM (2 hours)

Canted Cosine Theta (CCT) magnet is a very interesting design for compact accelerators or gantry systems for hadron-therapy. Indeed, it offers great flexibility in generating complex field harmonics in straight and curved configurations for which compactness is even higher. The Fusillo project at CERN aims to design, build, and test a Nb-Ti curved CCT dipole demonstrator generating 3 T at 4.5 K in a large aperture of 236 mm, bent over 90° with a small bending radius of 1 m, and multi-harmonic field features to correct for the curvature. In this paper we describe the fabrication process, the winding and the assembly of a Fusillo demonstrator. We report on the test results in liquid helium, including quench performance and magnetic field measurements.

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Session Classification: Thu-Mo-Po.11 - Magnets for Other Medical Application I

Contribution ID: **94** Type: **Poster**

Thu-Af-Po.07-01: 3D Simulation of STEP Test Coil Single-Tape Double-Pancake HTS Coil using the SIMULIA Opera Quench Thermal Solver

Thursday, July 3, 2025 2:00 PM (2 hours)

The Spherical Tokamak for Energy Production (STEP) Small Test Coil Programme aims to provide relevant real-world experimental data to validate models and designs that can then be extended to larger scale coils with increased confidence. SIMULIA Opera TM is being used to validate simulation models for these initial designs. Simulation of the coupled electric and thermal 3d effects is required in order to fully capture the complete behaviour of these type of coils.
The initial design is an insulated single-tape double-pancake. The initial tests included heating the test coil to initiate quench of the tapes and monitoring subsequent temperature and current behaviour. A second set of experiments involved measuring AC loss due to an offset sinusoidal transport current, with different frequencies and temperatures tested.
Both of these experiments have been simulated in a 3D environment using SIMULIA Opera, and the simulation approach and results are reported and summarised in this paper. Simulation results are compared to measured data to ensure an accurate representation of the coil models.

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Presenter: PINE, Ben

Session Classification: Thu-Af-Po.07 - Quench in Fusion Magnets I

Contribution ID: **95** Type: **Poster**

Thu-Af-Po.01-07: The Design and Measurement of Direct-drive Pulsed Septum Magnet for CSNS-II RCS Injection

Thursday, July 3, 2025 2:00 PM (2 hours)

In the CSNS-II, the energy of the H^- ion beam from the linear accelerator will be increased from the current 80 MeV to over 300 MeV. Consequently, the integrated magnetic field strength of all magnets in the RCS injection system will be raised by 2 to 2.5 times compared to the requirements during the CSNS phase. To achieve the complex functions of the injection system within a constrained space, various types of special magnets have been introduced. Due to the change of the injection point location, the angle at which the waste beam is drawn out is very small. To minimize the influence of the leakage field from the septum magnet on the circulating beam and to reduce the local peak power and temperature on the target of the injection dump station, a horizontal pulsed septum magnet is employed for the extraction of the waste beam. This magnet utilizes six types of metallic materials, with the core made of 0.15 mm thick silicon steel sheets, end plates made of stainless steel, coils made of oxygen-free copper plates, leakage field shielding material made of Permalloy, vacuum box material within the magnet gap made of Inconel 625, and auxiliary shielding material outside the circulating beam pipe made of 0.5 mm thick silicon steel sheets. The pulse duration is 1.5 ms, and the maximum current is 5000 A. This paper will first provide an overview of previous research on pulsed septum magnets, followed by a presentation of the design analysis and magnetic field measurement results of the out-of-vacuum Direct-drive pulsed septum magnet in the CSNS-II RCS injection system, including simulations of the eddy current effects of various materials and methods of pulse magnetic field measurement and data analysis.

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Session Classification: Thu-Af-Po.01 - Accelerator Magnets II

Contribution ID: **96** Type: **Poster**

Wed-Mo-Po.08-01: A theoretical study on the design of a compact fingerprint-shaped vector magnet

Wednesday, July 2, 2025 9:15 AM (2 hours)

Vector magnet technology is being developed at the Wuhan National High Magnetic Field Center (WHMFC). Vector magnets can generate magnetic fields at arbitrary angles to meet user-specific requirements, offering significant potential in fields such as topological states and electron spin manipulation. This paper presents a mathematical model for designing compact vector magnet coils. The model employs the stream function theory for the optimal design and discretization of coil current density distribution and applies Tikhonov regularization theory to impose diverse constraints and optimize magnet performance. A custom code was developed to implement this design theory, leading to the creation of a compact vector magnet. The magnet consists of three sets of coils that generate magnetic fields along the X, Y, and Z directions. Among these, the Z-direction coil adopts a multi-turn cylindrical design, while the X- and Y-direction coils feature a fingerprint-shaped design.

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Presenter: LI, Jianglan (Wuhan National High Magnetic Field Center)

Session Classification: Wed-Mo-Po.08 - Novel Applications and Characterizations

Contribution ID: **97** Type: **Poster**

Fri-Af-Po.08-10: Diffusion behavior and Investigation of the Properties of High Jc Nb3Sn Wires with SnCuTi Alloy Application

Friday, July 4, 2025 2:00 PM (2 hours)

In the development of high-Jc superconducting wires, the formation of Nb3Sn is critical, and KAT utilizes Nb filaments combined with SnTi alloy to facilitate Nb3Sn formation. In this study, a ternary alloy was fabricated by incorporating 5 wt% Cu into SnTi alloy via powder metallurgy, resulting in micro-sized SnCuTi alloy particles. These particles were then incorporated into high-Jc wires, followed by a series of heat treatments to examine phase changes and their effects on the wire properties. The addition of 5 wt% Cu is expected to reduce the Sn content, potentially leading to a decrease in the formation of Nb3Sn and, consequently, a deterioration in the critical current (Ic) characteristics. However, it is anticipated that during the Sn diffusion process, the presence of Cu within the SnCuTi alloy will promote a more stable solid-state diffusion compared to SnTi, thus mitigating the negative effects of Sn reduction. This paper thoroughly investigates the resulting phase transformations and their impact on the material's properties, providing insights into whether the observed changes align with the expected degradation or contribute to performance enhancement.

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Session Classification: Fri-Af-Po.08 - Advances in Nb3Sn and MgB2 Conductors I

Contribution ID: **98** Type: **Poster**

Fri-Af-Po.10-02: Construct a Closed-gap Undulator with Permanent Magnets and Electromagnets

Friday, July 4, 2025 2:00 PM (2 hours)

In order to meet the requirement for rapid switching between left- and right-handed circularly polarized light, we have designed and constructed an undulator incorporating a combination of permanent magnets and electromagnets. The 0.5-meter-long prototype undulator generates a horizontal magnetic field through four rows of permanent magnets, each with adjustable horizontal gaps, while the vertical magnetic field is provided by electromagnets. By switching the polarity of the current, the magnetic field is capable of alternately switching between left- and right-handed circular polarization of light. The paper shows the design considerations, fabrication process, and presents the current measurement results.

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Presenter: CHUNG, TingYi (NSRRC)

Session Classification: Fri-Af-Po.10 - Undulators

Contribution ID: **100** Type: **Poster**

Wed-Mo-Po.06-04: A Study on the design of industrial servo motor using anisotropic bonded magnets

Wednesday, July 2, 2025 9:15 AM (2 hours)

Permanent magnet motors use rare earth permanent magnets that are sintered light rare earth elements (Nd, etc.), heavy rare earth elements (Dy, Tb, etc.), and iron. Currently, since heavy rare earth element imports depend entirely on specific countries, high-performance permanent magnets that exclude heavy rare earth elements have been developed in order to stabilize the domestic supply chain. However, although they can be applied to large-sized drive motors such as electric vehicles, they are difficult to apply to small and low-capacity motors such as servo motors. High-performance and high-durability servo motor technology that applies anisotropic bonded magnets that exclude heavy rare earth elements and can be manufactured and applied to medium and small motors such as servo motors is required. Existing motors use magnets that are sintered by mixing light rare earth elements (Nd, etc.) and heavy rare earth elements (Dy, Tb, etc.) and have high magnetic flux density characteristics of approximately 1.2 T or more. In the case of the rare earth-excluded anisotropic bonded magnet, the magnetic flux density is about 20% lower than that of the existing sintered magnet at a maximum of 0.95T, so the size increases when applied to the existing servo motor. It is possible to develop a low-cost motor with the same or higher output density characteristics as the existing motor using the existing sintered magnet through the design technology for high-output servo motors using the rare earth-excluded anisotropic bonded magnet.

In the case of the existing rare earth-based isotropic permanent magnet, a thin film coating is required, and the gap expansion due to the thin film coating thickness is reflected as a phenomenon of reduced output. In the case of the rare earth-reduced anisotropic permanent magnet, the thin film coating can be excluded, so the electromagnetic gap reduction effect can be obtained. In order to verify the application and validity of the rare earth-reduced anisotropic permanent magnet developed through this study, the developed material was applied to servo motors of various capacities, and suitability analysis was conducted through series development.

We plan to confirm and establish the irreversible demagnetization characteristics of the development material according to the environmental temperature through electromagnetic analysis and test evaluation, and through this, we aim to confirm the optimal driving environment of the motor to which the material is applied.

We propose the development process and results of low-cost permanent magnets, and analytically elucidate the design characteristics and input/output characteristics of the motor to which the permanent magnet is applied. In addition, we finally elucidated the validity of the material and the development product through production and test evaluation.

Acknowledgements
This study was supported by the Ministry of Trade, Industry, and Energy (MOTIE) and Korea Evaluation Institute of Industrial Technology (KEIT) of the Republic of Korea under Grant 20023875

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Session Classification: Wed-Mo-Po.06 - Rotating Machinery I

Contribution ID: **101** Type: **Poster**

Sat-Mo-Po.07-07: Study of Shielding Current Characteristics in High-Temperature Superconducting Dipole Magnets

Saturday, July 5, 2025 9:30 AM (1h 45m)

High-temperature superconducting (HTS) magnets, with their superior current-carrying capacity and high operating temperatures, have shown considerable potential for applications in medical imaging, particle accelerators, power transmission, and scientific instrumentation. However, HTS coated conductors (CCS) are susceptible to significant shielding current effects due to their high aspect ratio, which considerably affects the magnetic field distribution and becomes a major limitation in the performance of HTS magnets. The shielding current effect causes central magnetic field attenuation, magnetic field drift, and degradation of field uniformity, presenting substantial challenges to the field stability required for high-precision applications, such as particle accelerators. The characteristics of shielding currents are closely related to the E-J relationship of the superconductor, with the n-value serving as a critical parameter that influences the distribution and behavior of shielding currents.

This study focuses on high-temperature superconducting dipole magnets and employs the T-A homogenization model to develop a numerical simulation framework in COMSOL Multiphysics. The distribution characteristics of shielding currents and their induced field (SCIF) effects on the magnetic field were systematically analyzed. The variations in shielding current-induced fields and magnetic field drift under different n-value conditions were analyzed, and the effectiveness of current reversal scanning techniques in reducing magnetic field drift was further explored. The results reveal that the distribution of shielding currents and their induced fields significantly affect magnetic field performance. As the n-value increases, the shielding current-induced field diminishes, while the influence of the n-value on magnetic field drift follows an opposite trend. Moreover, current reversal scanning effectively reduces magnetic field drift, thereby enhancing the operational stability of the magnet.

This study provides a comprehensive analysis of the shielding current effects in high-temperature superconducting dipole magnets and their influence on magnetic field performance. The findings offer valuable theoretical insights and engineering guidance for optimizing the design of superconducting magnets in high-precision applications such as particle accelerators.

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Presenter: Prof. YANG, Wenjie (Institute of modern physics)

Session Classification: Sat-Mo-Po.07 - HTS Magnets

Contribution ID: **102** Type: **Poster**

Sat-Mo-Po.01-10: Development of a closed helium circuit cooled (CHiC) demonstrator magnet for carbon ion therapy

Saturday, July 5, 2025 9:30 AM (1h 45m)

Closed-circuit cooling of superconducting magnets unlocks new possibilities for advanced accelerator designs and applications. In hadron therapy, it has clear potential for compact rotating gantries, while for future accelerator cryogenic systems it could significantly reduce helium inventories. For this reason, a 1 m long Closed Helium Circuit Cooled (CHiC) straight demonstrator magnet is being constructed as the first stage in developing a curved cos-theta dipole for carbon ion therapy. A Stress-Managed-Like (SML) design is adopted, employing additively manufactured stainless steel formers as the primary supports for Nb-Ti coils. Integrated cooling channels supply supercritical helium at 3 bara and 4.5 K. To meet clinical requirements, the CHiC demonstrator aims to achieve a maximum bore field of 4 T, with continuous ramping up to ±0.4 T/s. A central objective is to develop and verify accurate multiphysics numerical models for simulating the extraction of transient losses. Ultimately, these tools will be validated experimentally through magnet testing. This paper details the magnetic, thermal, and mechanical design optimisation of the CHiC demonstrator.

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Presenter: GEIGER, Kieran (CERN)

Session Classification: Sat-Mo-Po.01 - Magnets for Other Medical Application II

Contribution ID: **103** Type: **Poster**

Thu-Mo-Po.01-02: A fast frequency-domain finite element model for simulating high temperature superconductors in AC regime

Thursday, July 3, 2025 8:45 AM (2 hours)

The need to find computationally efficient numerical models to simulate High Temperature Superconductors (HTS) has led to the development of finite element models (FEM) relying on different formulations of the Maxwell equations. Still, due to the time dependence and the highly nonlinear behavior of the superconductor, these transient FEM are computationally slow and, in general, demanding in terms of resources. To alleviate this computational burden, FEM using the up-to-date T-A and J-A formulations mixed with the scalar potential φ (H = -grad(φ)) have been built. This proposal is perfectly suited to estimate the electromagnetic and thermal steady-state variables of the HTS operated at rated values in AC, but it also provides initial conditions for a subsequent transient analysis if required. In this phasor modelling approach, the Root Mean Square resistivity of the superconductor is introduced, which is subsequently approximated by an exponential decreasing function depending on the transition index, thus, introducing a factor to ease its implementation in the commercial software COMSOL Multiphysics. This work builds on a previous reported research by extending the case study with a REBCO insulated coil for which experimental measurements, in particularly AC losses, were acquired at 77 K in liquid nitrogen. The results of the time- and frequency-domain FEM simulations are cross-checked and compared against those experimental data. A fair agreement was found.

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Presenter: TRILLAUD, Frederic

Session Classification: Thu-Mo-Po.01 - AC Loss and Magnetization I

Contribution ID: **104** Type: **Contributed Oral**

Sun-Mo-Or1-04: Smart-insulation studies for the TF coils of the EU DEMO reactor

Sunday, July 6, 2025 9:00 AM (15 minutes)

The new type of insulation where metals, varistors on more in general media with a change in resistivity are called "smart insulation". Among the latter, metal-to-insulator transition (MIT) materials have lately collected interest, since one could get both the advantage of a full insulation during charge/operation (low T) and hot-spot redistribution during a quench (high T).
In this respect, VxOy (Vandium Oxide) compounds were experimentally investigated. This study reports on their new off-stoichiometric chemical preparation, application process, resistivity ρ, effects of background field and thermal behavior between 4.2 K and 77 K.

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Session Classification: Sun-Mo-Or1 - Technology for Fusion Reactors II

Contribution ID: **105** Type: **Poster**

Sat-Mo-Po.08-07: Progress on NI-coil design for the EU DEMO Toroidal Field magnet

Saturday, July 5, 2025 9:30 AM (1h 45m)

Progress on NI-coil design for EU DEMO

M.Ortino, N. Bykovskiy

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This study presents the latest results of a 3D original Matlab code, developed for simulating in a fast fashion the charge/discharge of a EUROfusion DEMO toroidal field (TF) coil, by especially coupling both the electrical and thermal evolution e.g. in case of a quench propagation. We now report results with a higher accuracy (increment of nodes by a factor 2-10) reached also by means of high performance computing (HPC) at EPFL.
We show maximum temperature reached in the coil in case of several current extraction systems, different amount and distribution of bridging elements over the conductor length as well as their electric behavior (monotonic or two-fold resistivity regime).

Acknowledgment:
This work has been carried out within the framework of the EUROfusion Consortium, via the Euratom Research and Training Programme (Grant Agreement No 101052200 —EUROfusion) and funded by the Swiss State Secretariat for Education, Research and Innovation (SERI). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union, the European Commission, or SERI. Neither the European Union nor the European Commission nor SERI can be held responsible for them.

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Session Classification: Sat-Mo-Po.08 - Structural and Insulation Materials

Contribution ID: **106** Type: **Poster**

Wed-Mo-Po.08-02: Effects of partial coupling on the trapped field of HTS stacked gourd-shaped REBCO loops under field-cooling magnetization

Wednesday, July 2, 2025 9:15 AM (2 hours)

High-temperature superconducting (HTS) closed-loop magnet composed of gourd-shaped RE-Ba-Cu-O (REBCO, RE is rare earth) plates is potential for persistent current mode (PCM) with magnetic flux amplification and accumulation under field-cooling magnetization. Preliminary experiments and simulations confirm that the configuration can trap substantial magnetic fields, potentially exceeding 20 T in PCM. However, partially coupled self- and mutual inductances between adjacent superconducting loops may affect overall flux amplification by altering the induced current distribution and final magnetic flux density, highlighting the need for further exploration to achieve higher fields. In this study, experimental measurements and numerical modeling were employed to elucidate the mechanism of partial inductive coupling and to quantify its impact on trapped magnetic fields and the stability. Furthermore, an extended structural arrangement was proposed and validated using finite element methods, confirming its capacity in trapping higher magnetic fields. This work lays a foundation for optimizing excitation approaches and stacking configurations in HTS REBCO magnets, thereby advancing more robust and scalable high-field superconducting magnet designs for high-field applications in PCM.

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Presenter: Ms MENG, Ziqing (North China Electric Power University)

Session Classification: Wed-Mo-Po.08 - Novel Applications and Characterizations

Contribution ID: **107** Type: **Poster**

Thu-Mo-Po.01-06: Evaluation of screening and coupling currents in stacks of HTS tapes for large-scale magnets.

Thursday, July 3, 2025 8:45 AM (2 hours)

SupraFusion is a French research program aiming to boost HTS (High-Temperature Superconductors) technologies towards large scale societal applications and particularly compact fusion machines. In the framework of this program, a large-scale demonstrator magnet will be designed, manufactured and tested. This ambitious goal requires incremental steps, including the fabrication of smaller prototypes and the development of key technological components. Among these, the development of a suitable conductor for the demonstrator using HTS poses significant challenges. Our research focuses on stacked REBCO (Rare-Earth Barium Copper Oxide) tapes as conductors, which face critical difficulties in the development of high-performance magnets. These tapes are susceptible to screening currents induced by magnetic fields orthogonal to the tapes, which can reduce the stability and field homogeneity. During current transients, individual tapes experience AC losses. Furthermore, stacked tapes exhibit coupling currents, which are current loops between tapes that generate opposing magnetic fields and losses, potentially compromising magnet performance and stability. These issues are particularly pronounced in stacked configurations due to the enhanced electromagnetic interactions between individual tapes. This work aims at advancing the understanding and modeling of these phenomena using an A-V formulation implemented via finite difference methods. The A-V approach provides a robust framework for capturing time-dependent electromagnetic behavior and offers some computational advantages over traditional finite element methods.
In this study, we will present the screening current analysis for potential conductor design for the final demonstrator. This analysis includes a detailed evaluation of the impact of screening and coupling currents on the magnetic field distribution, transport current capacity, and the impact of the AC losses. These insights will guide the optimization of conductor configurations, bringing us closer to achieving the performance required for the large-scale demonstrator.

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Session Classification: Thu-Mo-Po.01 - AC Loss and Magnetization I

Contribution ID: **109** Type: **Poster**

Fri-Af-Po.03-07: Status of the top plate and anticryostat for high field cable test facility at Fermilab

Friday, July 4, 2025 2:00 PM (2 hours)

Fermi National Accelerator Laboratory (Fermilab) is currently constructing a new High Field Vertical Magnet Test Facility (HFVMTF) designed for testing High Temperature Superconducting (HTS) cables in high magnetic background field. This facility is expected to offer capabilities similar to those of EDIPO at PSI and FRESCA2 at CERN. The background magnetic field of 15 T will be generated by a magnet supplied by Lawrence Berkeley National Laboratory. The primary function of HFVMTF will be to serve as a superconducting cable test facility, facilitating tests under high magnetic fields and a broad spectrum of cryogenic temperatures. Additionally, the facility will be utilized for testing high-field superconducting magnet models and demonstrators, including hybrid magnets, developed by the US Magnet Development Program (MDP). This paper provides a comprehensive description of the current status of two pivotal components of the facility: the Top/Lambda Plates Assembly, which is in the final design and fabrication stage, and the Anticryostat for the Test Sample Holder, currently in the conceptual design phase. These components will serve as principal interface elements connecting cable test samples with the facility's cryostat, ensuring effective integration and functionality.

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Presenter: NIKOLIC, Vlad (FERMILAB)

Session Classification: Fri-Af-Po.03 - Supporting Technologies for Fusion Magnets I

Contribution ID: **110** Type: **Poster**

Fri-Mo-Po.09-06: Design and Operating Characteristics of Wireless Current Charging Controller for Superconducting Magnet Using Current Divider Unit Combined with Supercapacitors in the Hyperloop Train

Friday, July 4, 2025 9:30 AM (1h 45m)

The various wireless power charging (WPC) units for high speed hyperloop train should be practically required to supply electric power without overhead wire power lines of pantographs, since such a unit can reduce the construction cost for pantographs in the transportations. Generally, in order to charge superconducting levitation magnet for hyperloop train combined by WPC unit, the high power RF generators combined with high power converter should be required since the high field magnet keeps the high value of electric time constant. From these reasons, Wireless high Current Charging unit combined with Supercapacitors (WCCS) can be expected as one of reliable next generation WPC systems because the supercapacitors (SCs), which benefit from unique features including high power density (20A˜200A), long cycle life, wide temperature operation range (-40oC˜60oC), durability in harsh environments, efficient cycling, and low maintenance cost. As the SCs can discharge with high power density quickly, in order to charge the superconducting magnet with high stability, the smart current divider (SCD)unit, which can control the duration of discharging for the SC to avoid quench in the superconducting magnet, should be required to charge the superconducting magnet with high stability. Especially, as the WCCS module combined with SCD and SC can sable charge the superconducting magnet under the operating current mode, the proposed wireless current charging unit has been promisingly utilized as one of current compensators in the superconducting magnet system. From these reasons, the WCCS technology combined with SCD and SC system has been promisingly studied as one of reasonable energy charging units in the superconducting magnet. As the temperature operation range of the supercapacitor is affected by LN2, which cools the superconducting levitation magnet, the design of shield cooling system for supercapacitors should be considered in the Hyperloop. In this paper, authors present the operating characteristics of WCCS combined with SCD and SC system for high speed superconducting Hyperloop train. The 600W, 100kHz RF generator is adopted as a wireless power.

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Session Classification: Fri-Mo-Po.09 - Novel and Other Applications II

Contribution ID: **111** Type: **Poster**

Thu-Af-Po.02-03: A Fast and Accurate Method for electromagnetic analysis of a CS Magnet Wound with Multilayer Cables

Thursday, July 3, 2025 2:00 PM (2 hours)

High-temperature superconducting Conductor on Round Core（CORC）cable, with advantages of strong current-carrying capacity, low loss, light weight, and good bending performance, has become an excellent choice for winding high-field magnets and meeting the requirements of magnetic field shaping. In particular, CORC cable has great potential in manufacturing the Central Solenoid magnet (CS magnet) in nuclear fusion devices. The CS magnet is a crucial component of the nuclear fusion device and is generally located at the center of the device.
For electromagnetic design of a CS magnet, especially for a magnet wound by CORC cables with multilayer, due to the complex helical structure of the cables and the uneven current distribution on the superconducting tapes, the modeling process is complicated, and the calculation process consumes excessive resources and time. Currently, the main methods mostly use the finite element method, which models through three-dimensional or two-dimensional models with H-Formula or T-A method to obtain the magnetic field distribution and inductance of the CS magnet with alternating current.
Based on the Biot-Savart law and the Neumann Formula, this paper established an analytical calculation model for the inductance and magnetic field of the CS magnet considering the complex helical winding structure of the CS magnet and the current distribution in the width direction of the superconducting tape, proposing a fast and accurate method for calculating the magnetic field distribution on the CS magnet wound by CORC cables with multilayer at a transit alternating current and inductance of it. Compared with the existing methods, this method features a simpler modeling method and process, a faster calculation speed, and more accurate calculation results.

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Presenter: PENG, Shuhao

Session Classification: Thu-Af-Po.02 - HTS Cable

Contribution ID: **112** Type: **Poster**

Sat-Mo-Po.02-09: Design and structural analysis of Conical-Canted-Cosine-Theta scanning magnet for heavy ion therapy

Saturday, July 5, 2025 9:30 AM (1h 45m)

In heavy ion therapy, reducing not only the radius of the rotating gantry but also the size of the power supplies for the gantry's magnets is crucial to miniaturizing the facility. The rotating gantry primarily consists of several bending magnets and a downstream scanning system. The use of combined-function superconducting magnets and cosine-theta-type combined X-Y scanning magnets has already significantly reduced the gantry's rotating radius.
However, shortening the length of the beam delivery system by introducing cosine-theta-type scanning magnets significantly increases the nominal capacity of the power supplies. To address this issue while maintaining the same length of the beam delivery system, a canted-cosine-theta (CCT) scanning magnet is proposed. A typical CCT magnet consists of two layers of solenoids with opposite tilt angles. This configuration cancels the axial components of the magnetic field while adding the dipole components, thereby generating pure dipole fields over a wide bore region. Its magnetic field strength is independent of the bore size, making it particularly suitable for scanning magnets that require a large bore at the outlet.
In this study, a combined X-Y scanning magnet was designed by overlaying two CCT coil layers in orthogonal directions. The magnet has a conical shape and maintains consistent magnetic field strength from the small bore inlet to the large bore outlet, achieving high BL integration. In numerical analysis, this scanning system meets the requirements for a 200×200 mm irradiation field, a scanning speed of 40 mm/ms, and a length of the beam delivery system of 3.5 m, with a nominal current and voltage of 600 A and 600 V, or less, for 430 MeV/u carbon ions.
The results of structural analysis simulations for the CCT scanning magnet will be presented.

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Session Classification: Sat-Mo-Po.02 - Magnets for Other Medical Application III

Contribution ID: **113** Type: **Poster**

Thu-Af-Po.02-04: AC Loss Analysis of a CICC consisting of CORC cables by finite element modeling

Thursday, July 3, 2025 2:00 PM (2 hours)

Assembling high-temperature superconducting conductor on round core (CORC) cables into Cable-in-Conduit Conductor (CICC) have the advantages of high current-carrying capacity and excellent mechanical properties, which makes it exhibit significant superiority in high magnetic field applications. However, its complex structure greatly increases the modeling difficulty and computational complexity to the simulation. Therefore, the evaluation of its AC losses inevitably faces challenges. In this paper, a simulation model is proposed by setting appropriate boundary conditions and geometric equivalent. The accuracy of the model is verified by comparison with the experiment. Then, the magnetic field, current density distribution and AC loss distribution are presented and discussed. The AC loss characteristics of the during dynamic operations are emphatically investigated. The model and conclusions will provide references to design and stability analysis of the magnet wound by CICC.

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Presenter: YANG, Zhixing

Session Classification: Thu-Af-Po.02 - HTS Cable

Contribution ID: **114** Type: **Poster**

Thu-Mo-Po.11-02: Cryogenic Test of First Prototype and first batch of Superconducting Gantry Magnets for Miniaturized Heavy-Ion Facility

Thursday, July 3, 2025 8:45 AM (2 hours)

Lanzhou Ion Therapy Company, Ltd. (LANITH) began the research and development of miniaturized heavy ion therapy devices since 2022. The Gantry superconducting magnet, which composed of a curved dipole magnet and two quadrupole magnets at both ends of the dipole coil, is the core component of the whole device. At present, this project has completed manufacturing process for a prototype and a batch of gantry magnets, and started a series of cryogenic tests.
In order to test magnet winding and impregnation process, a gantry prototype magnet without iron core was processed and tested at first. After excitation test result of prototype reached the target parameters, the cryogenic tests of a batch of gantry magnets with iron core were conducted. In this paper, the cryogenic test process and analysis of test results are introduced emphatically. Some specific test contents were tested detailly, like quench protection process, magnetic field distribution and uniformity measurement results, dipole-quadrupole joint excitation and fast ramping operation results. After completed cryogenic test in liquid helium, the Gantry magnets are planned to be loaded into a conduction cooling cryostat for extra testing of cooling process, AC loss and magnetic field uniformity.

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Presenter: Dr YANG, Yanbing (Guoke Ion (hangzhou) Medical Technology CO.,LTD)

Session Classification: Thu-Mo-Po.11 - Magnets for Other Medical Application I

Contribution ID: **115** Type: **Poster**

Fri-Mo-Po.09-07: Research on filament HTS tapes used in large capacity HTS shunt reactors

Friday, July 4, 2025 9:30 AM (1h 45m)

The large current density of superconducting tape makes it have obvious advantages in improving the quality of power grid, reducing the transmission losses and reducing the floor space of electrical equipment. Large capacity superconducting shunt reactors have the advantages of small size, light weight, low noise and no fire risk. However, the AC loss of superconducting tapes is an important reason to limit the application of large capacity electrical equipment. As for the superconducting shunt reactors, because of the combined action of AC current and the synchronous AC background field on the tape, its AC loss is large, which will significantly improve the operation energy consumption of the reactor, decreases the reliability of long-term operation, and concurrently increases the cooling costs. Therefore, an effective AC loss suppression strategy is needed to optimize the energy consumption of the reactor.
In this paper, based on the filament tapes made by laser cutting technology, simulation and experimental research are carried out to study the HTS tapes and shunt reactor. The sections of the filament tapes are observed by electron microscope to determine the appropriate laser cutting parameters, including laser type, power and speed. The critical current of different filament tapes is tested to ensure the stability of the filament tapes. And the magnetization loss of HTS tapes with different number of filaments is analyzed based on simulation and experimental research. What's more, a double-cake coil is wound made of filament tapes, which is use as a HTS reactor module coil. Compared with the original reactor coil, the feasibility of tape filamentation in the AC loss optimization is demonstrated. which lays a theoretical foundation for the further cost optimization of the subsequent superconducting toroidal air-core reactor.

Author: ZHAO, Ruimin

Presenter: ZHAO, Ruimin

Session Classification: Fri-Mo-Po.09 - Novel and Other Applications II

Contribution ID: **116** Type: **Poster**

Thu-Mo-Po.03-05: Tilted Solenoids Magnet Using Superconducting Stacked Tapes

Thursday, July 3, 2025 8:45 AM (2 hours)

As a recently developed type of dipole field magnets, the tilted solenoids technology has great potential in various fields such as proton therapy, particle accelerators, and high-field applications. High-temperature superconducting materials can further enhance the magnetic field strength, reduce the bending radius, and lower the device cost. This research is based on differential geometry theory and proposes design methodology along with optimization principle for tilted solenoids magnet utilizing stacked high-temperature superconducting tapes. The engineering implementation strategies for tilted solenoid technology employing superconducting tapes are explored. Both single-turn and multi-turn coils are designed and fabricated respectively, and the critical currents are tested. Additionally, a double-layer tilted solenoids magnet was modeled; magnetic field simulation as well as higher-order analyses were conducted to validate the effectiveness of this methodology.

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Presenter: Dr DU, Junjie (East China University of Technology)

Session Classification: Thu-Mo-Po.03 - Design and Development of Accelerator Magnets II

Contribution ID: **117** Type: **Poster**

Wed-Mo-Po.10-02: Scheme Design and Performance Analysis of Flux-Coupling-Type SFCL for Inhibiting Cascading Fault of AC/DC Hybrid Power Grids

Wednesday, July 2, 2025 9:15 AM (2 hours)

This paper centers around the scheme design and performance analysis of flux-coupling-type superconducting fault current limiters (SFCL) for inhibiting the cascading fault of AC/DC hybrid power grids. Firstly, it introduces the background and significance of researching the flux-coupling-type SFCL in the context of AC/DC hybrid power grids. The complex power flow characteristics and potential cascading fault risks in such grids necessitate practical fault current limiting measures. Subsequently, the design scheme of the flux-coupling-type SFCL, consisting of the superconducting coil and coupling transformer is elaborated. Regarding the superconducting coil design, the critical current density, magnetic field tolerance level, and temperature stability are carefully considered, and the structural style, tape length, and quenching resistance are optimized to improve the techno-economics. In addition, the winding type, core selection, and inductance values of the coupling transformer are determined. The flux-coupling-type SFCL's performance under different operating conditions is evaluated through the electromagnetic transient simulation models. Results indicate that it demonstrates outstanding current limiting capabilities, capable of rapidly suppressing fault currents during cascading faults, thereby safeguarding the stability and reliability of the power grids. Moreover, the electromagnetic properties and AC loss of the flux-coupling-type SFCL are acceptable. Finally, the paper also points out the existing challenges and potential improvement directions in the practical application of the flux-coupling-type SFCL.

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Presenter: Prof. CHEN, Lei

Session Classification: Wed-Mo-Po.10 - Transformers and Fault Current Limiters

Contribution ID: **118** Type: **Poster**

Sat-Mo-Po.09-08: Conceptual Design and Evaluation of an HTS Magnet for an SMES Used in Decreasing Subsynchronous Oscillation of Virtual Synchronous Generator

Saturday, July 5, 2025 9:30 AM (1h 45m)

This paper focuses on the conceptual design and evaluation of an HTS magnet for superconducting magnetic energy storage (SMES) aimed at mitigating subsynchronous oscillation (SSO) caused by a virtual synchronous generator (VSG). Considering the frequency characteristics of the 150 kW class VSG and its requirements for decreasing the fluctuations, the stored energy of the SMES magnet is set as 450 kJ, and the YBCO tapes are adopted to make a solenoid SMES magnet. Utilizing an enhanced version of the genetic algorithm, we focus on optimizing various magnet parameters. This includes critical current, which is essential for assessing the performance of superconducting materials, tape length, which affects the physical dimensions and application of the magnet, as well as the optimization of parallel and perpendicular magnetic fields. By adjusting these parameters, it is aimed to achieve improved efficiency and effectiveness in magnet design. Finally, to assess the performance of the designed HTS magnet for the SMES, we conduct the simulation analysis and incorporate the detailed electromagnetic behavior of the magnet into the power system dynamics model. By simulating diverse operating scenarios, including sudden load changes and grid faults, we quantified the damping effect of the SMES on SSOs. The simulation results demonstrated that the proposed HTS magnet-based SMES could substantially reduce the subsynchronous oscillations, and meanwhile, the maximum stress, mechanical strength, and heat accumulation of the SMES magnet are satisfied.

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Presenter: Prof. CHEN, Lei

Session Classification: Sat-Mo-Po.09 - Energy Storage/SMES, Levitation and Magnetic Bearings

Contribution ID: **119** Type: **Poster**

Fri-Mo-Po.06-01: JT-60SA Central solenoid conductor hotspot risk analysis for high voltage protection

Friday, July 4, 2025 9:30 AM (1h 45m)

The upgrade to JT-60SA tokamak (R=3m, a=1.2m) was conducted within a Europe-Japan collaboration agreement featuring the implementation of superconducting magnets. In 2021, an arcing issue on EF1 coil led to an overall insulation reinforcement against high voltage on the magnet system. Because the Central Solenoid (CS) is less accessible for repair it deserves specific attention related to its voltage exposure. Risk mitigation was initiated by decreasing the power supply voltage during plasma scenario current transients, but in order to further minimize risk, it was decided to also address the case of fast discharge events, less frequent but likely to be the risk-driver case as it induces the highest voltage on the magnet. The voltage value during discharge being proportional to the external dump resistance, it is envisaged to decrease this resistance of 30%. The consequence is a slower current decrease after a quench event, inducing a higher Joule energy absorbed by the conductor and therefore a higher temperature rise in the conductor, increasing the risk of thermo-mechanical degradation due to hotspot occurrence.
It is therefore needed to conduct a risk analysis associated to this mitigation action and the present paper exposes the different steps passed in this aim. The first step includes the development and cross-check of two thermo-hydraulic models of CS winding pack that independently evaluate the maximum temperature of CS conductor components using THEA and GANDALF tools. Then, several standard reference cases of quench events and associated CS discharges are investigated for different quench detection conditions. The overall results are presented and discussed regarding the influence of detection settings. Further to the reference cases in question, several parametric studies are conducted considering variants on parameters bearing uncertainties in their definition. This encompasses e.g. the quench location, the quench zone length, the current variation pattern or the copper RRR value. This step aims to establish a more accurate estimation of the impact derived from those intrinsic uncertainties on quench event features. In addition some potential investigations on the use of possible margins are shown.
For this risk evaluation studies, a particular emphasis is given to the methodology followed for definition of hotspot risk criteria, and the rationale and references having contributed to the establishment of those methodologic elements. After application of those rules to the above mentioned modelling results, the evaluation outcomes are discussed with the aim of issuing a consolidated assessment on the absolute risk faced by the CS magnet in case of quench event. Finally, recommendations are made regarding the possibility to validate and implement the decision to decrease the CS magnet dump resistance by the JT-60SA project team in order to better protect the CS from applying high voltage.

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Presenter: ZANI, Louis

Session Classification: Fri-Mo-Po.06 - Quench in Fusion Magnets II

Contribution ID: **120** Type: **Poster**

Sat-Mo-Po.04-05: Research on key technologies of quench detection for CFETR TF prototype coil

Saturday, July 5, 2025 9:30 AM (1h 45m)

The design and development of quench detection for the CFETR TF prototype coil is in progress, which is expected to be completed in the fourth quarter of 2025. According to the quench simulation analysis, the voltage detection with a threshold of 200 mV and a delay of 2 s satisfies the quench detection design criteria, that is, the hotspot temperature is less than 150 K. The foundation of a successful quench detection system, of course, is the reliable measurement of the original high voltage signals, high precision suppression of inductive voltage noises, and accurate execution of quench discrimination. Key technologies include many different things such as optimal design of installation schemes for co-wound tape (CWT) and co-wound wire (CWW), automatic wrapping of CWT, welding and extraction of high voltage taps, transfer of high voltage wires and cables, high resolution data acquisition and sensitive quench discrimination mechanism. The optimization design scheme for compensation circuit and the key processes for high voltage measurement have been developed successfully to manufacture the low field sub-coils of CFETR TF prototype coil, and the test results meet the design requirements. In addition, a quench discrimination mechanism based on the varying trend of voltage has been also developed to avoid delays caused by timer reset and improve the sensitivity of quench detection. These technologies can not only further improve the reliability of CFETR TF prototype coil quench detection, but also provide robust assurance for the secure and stable operation of ITER and future full superconducting fusion reactors.

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Presenter: Dr WANG, Teng (Institute of Plasma Physics, Chinese Academy of Sciences)

Session Classification: Sat-Mo-Po.04 - Protection and Stability

Contribution ID: **121** Type: **Invited Poster**

Thu-Af-Po.10-03: [Invited] Towards a reduced Helium content cryogenic cooling scheme at 4.5 K for CERN's FCC-hh accelerator

Thursday, July 3, 2025 2:00 PM (2 hours)

In the framework of the Future Circular Collider (FCC) study at CERN, a conceptual design of a cooling scheme for Nb_3Sn-based accelerator magnets operating at 4.5nbsp;K is proposed for the FCC-hh (hadron) configuration. This alternative, at a higher operating temperature than the baseline at 1.9nbsp;K using Heliumnbsp;II, is motivated by a strong commitment to a more energetically sustainable machine, while ensuring compatibility with the tunnel structure envisaged for the FCC-ee (lepton) configuration, and providing a technically viable solution for the required superconducting magnets.
In the proposed cryogenic scheme, cooling is achieved by a forced flow of supercritical helium at 3nbsp;bar, 4nbsp;K, through channels embedded into the cold mass structure. The same stream runs along the entire magnet cooling sector, warming up as it absorbs heat generated by or deposited on the magnets. To mitigate the intrinsic temperature increase, the supercritical stream is periodically re-cooled by heat exchange with two-phase helium reservoirs at a lower saturation pressure than the supercritical stream, at intervals coherent with the cell lattice. This creates a saw-tooth temperature profile along the sector, and a quasi-identical cryogenic environment for each of the cells. On the return line back to the cryoplant, small portions of the returning mass flow are expanded into the two-phase area to fill the re-cooling stations. The characteristics of the helium gas recovery line of the re-cooling stations determine their saturation temperature, and as a result, of the supercritical helium stream. The temperature rise in the fluid is limited to 4.5nbsp;K to allow for sufficient temperature margin for magnet operation.

The study is carried out for the latest configuration of the FCC-hh machine, considering Nb_3Sn superconducting magnets with an operational magnetic field of 14nbsp;T, for a center-of-mass energy of 90nbsp;TeV with a magnetic filling scheme of 87%. The updated heat loads are presented, and the system parameters, along with longitudinal and expected radial temperature gradients in the magnet structure, are evaluated. The move from 1.9nbsp;K operation, making extensive use of Heliumnbsp;II, towards 4.5nbsp;K using single-phase helium significantly reduces the overall cryogenic power consumption by at least 30%, and the machine's helium inventory by 50% with respect to the baseline scenario at 1.9nbsp;K. Other advantages, such as a simplification of the cold mass structure and the relaxation of access exclusion zones due do the more manageable helium content in case of release are analyzed and compiled. The challenges associated with this cryogenic cooling scheme, which has so far not been implemented in such a large-scale accelerator, are addressed.

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Presenter: Dr TAVARES COUTINHO BORGES DE SOUSA, Patricia (CERN)

Session Classification: Thu-Af-Po.10 - Cryostats and Cryogenics I

Contribution ID: **122** Type: **Poster**

Wed-Mo-Po.04-02: Design, Fabrication and Preliminary Test of the Bi2212 CICC Sample for High-field Applications

Wednesday, July 2, 2025 9:15 AM (2 hours)

The Cable-in-Conduit Conductor (CICC) is one of the core components in large-scale superconducting (SC) magnet systems, characterized by its multidisciplinary and technically complex nature. This paper investigated and developed a rectangular Bi2212 CICC to withstand high magnetic pressures in the CHMFL. Detailed analyses of its mechanical, stability, fabrication, and preliminary tests are presented. The Bi2212 CICC short-sample with 60 SC wires achieves nearly 40 kA at self-field. Test results demonstrate that the rectangular conductor, with low porosity (≤30%) and long twist pitch (stage-Ⅲ>145mm), still retains excellent performance even under large deformation with optimized aspect ratio. These findings highlight its promising potential for applications in high magnetic fields.
Index Terms—Design, Fabrication, Preliminary test, Bi2212, CICC.

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Session Classification: Wed-Mo-Po.04 - HTS Conductors I

Contribution ID: **123** Type: **Invited Oral**

Fri-Mo-Or3-01: [Invited] Progress on a 100-kW superconducting propulsion unit for zero emission aviation

Friday, July 4, 2025 8:00 AM (30 minutes)

This presentation summarizes the development and testing progress of a 100 kW superconducting propulsion unit designed for zero-emission aviation. The findings draw from two major UK-funded projects, in collaboration with Airbus Upnext. The propulsion unit features an axial-flux fully superconducting motor and an integrated cryogenic drive system. The motor, comprising two HTS stators and one HTS rotor, is designed to achieve a power density target of 15 kW/kg.

The HTS stator utilizes double-stacked HTS windings to increase current loading while maintaining relatively low AC losses. The HTS rotor incorporates a novel charging system that enables persistent-current operation with low-resistance soldered joints. Complementing the motor, the cryogenic drive system features three-phase IGBT switches with customized cryogenic gate drives.

The presentation will detail the latest advancements in motor and drive design, along with testing results for the customized cooling system, HTS stators, HTS rotor, and the cryogenic motor drive. These developments represent significant progress toward achieving sustainable propulsion systems for future aviation.

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Presenter: ZHANG, Min (University of Strathclyde)

Session Classification: Fri-Mo-Or3 - Coils for Power, Energy, Transport and Other Applications

Contribution ID: **124** Type: **Poster**

Wed-Mo-Po.03-06: Effect of Bending Before Over Pressure Heat Treatment on Current Carrying Capacity of Bi2212 Round Wires

Wednesday, July 2, 2025 9:15 AM (2 hours)

Bi2Sr2CaCu2O8+x (Bi-2212) material, the only high-temperature superconducting material capable of being fabricated into isotropic round wires, holds significant potential for the future manufacturing of high-field magnets. In coil design and fabrication, the selection of coil radius is crucial, as an excessively small radius can substantially reduce the coil's current-carrying capacity. This study systematically investigates the impact of bending on the critical current performance of Bi2212 round wires. The wires were bent into arcs with varying radii before over pressure heat treatment. Following heat treatment, the wires were carefully transferred to a test board, where their critical current performance was evaluated at 4.2 K under background magnetic fields ranging from 10 to 20 T. The relationship between the bending radius and critical current performance was examined. Furthermore, the magnitude and distribution of stress within the wire during the bending process were simulated and compared. Lastly, the microscopic structure of the wires was analyzed using microscopy to explore the underlying mechanisms by which bending influences current-carrying capacity. These findings offer valuable insights for designing coil radii in practical applications.
Index Terms—Bi2212,bending,cracks,stress,current current

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Session Classification: Wed-Mo-Po.03 - HTS Characterization I

Contribution ID: **125** Type: **Poster**

Fri-Mo-Po.07-01: Design and Simulation Analysis of a 5T Conduction-Cooled Magnet for the Quantum Materials Resonant Scattering Experimental Station

Friday, July 4, 2025 9:30 AM (1h 45m)

The Quantum Materials Resonant Scattering Experimental Station (QMRSES) is a key component of the Hefei Advanced Light Facility (HALF) to investigate the quantum materials through the Resonant Elastic X-ray Scattering (REXS). The station assists researchers in investigating the electronic, spin, and orbital properties. The cryostat with the system is designed to provide various magnetic fields that operate at cryogenic chambers with 4.2 K and ultra-high vacuum of 2×10^{-8} Pa. To realize the incident angle of the specific sites and the atoms, the cryostat must incorporate experimental room-bores along the x, y, and z axes. Specifically, the x-axis requires a conical aperture with a ±35° angle, the y-axis requires a conical aperture with a ±10° angle, and the z-axis provides a cylindrical bore with a 65 mm diameter. The magnet in the cryostat presents a superconducting (SC) split type and generates a 5.0 T field to meet the QMRSES specified requirements. This paper presented the magnet device in detail, including the SC magnet design, the cryostat optimization, and the electromagnetic and force-thermal interactions through the finite element method (FEM) are provided to verify its applicability.

Key words: Quantum materials, HALF, Superconducting magnet, Conduction cooling, Finite element analysis

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Session Classification: Fri-Mo-Po.07 - Accelerator Magnets III

Contribution ID: **126** Type: **Poster**

Thu-Mo-Po.10-04: Optimization of coupling loss in HTS sector-shaped conductors

Thursday, July 3, 2025 8:45 AM (2 hours)

High-temperature superconductors (HTS) coil systems are currently being considered within the context of magnetic confinement fusion for enabling higher operating temperatures, increased transport currents, and stronger magnetic fields. For the DEMO Central Solenoid coil, a novel HTS sector cable-in-conduit conductor (CICC), targeting 60 kA at 4.5 K and 18 T, has been proposed recently. In HTS cables, AC losses constitute a major performance limitation and must be carefully considered throughout the design and thermal assessment of the magnet. Beside the hysteresis losses, also coupling and Eddie current losses both play a significant role in the sector-shaped twisted-stacked tape conductor. This work leverages on a FEM model based on the 2D electrostatic formulation of the coupling loss in twisted HTS cables. The model was implemented based on a previously developed and validated model for LTS strands. The aim is to optimize the cable design by exploring variations in the aspect ratio and tape arrangements within the cable's internal structure.

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Presenter: TOMASSETTI, Giordano

Session Classification: Thu-Mo-Po.10 - Modelling of Fusion Conductors and Coils II

Contribution ID: **127** Type: **Contributed Oral**

Fri-Mo-Or5-03: Artificial Neural Networks predictions of Conductor-on-Round-Core cables performance

Friday, July 4, 2025 11:45 AM (15 minutes)

High-Temperature Superconductors (HTS), particularly Rare-earth Barium Copper Oxide (ReBCO) tapes, offer the most promising path towards developing high-field magnets for fusion machines, meeting stringent requirements for high operating currents, current densities, and compact coil geometries. The high tolerance of ReBCO to the tensile strength and compressive strain lead to the development of the Conductor-On-Round-Core (CORC®) cable where tapes are wounded around a central copper core. The CORC® represents a strong contender due to its round cross-section and inherent electrical and mechanical isotropy in the perspective of achieving 20 T field levels. However, the development of reliable numerical models for the design and the optimization of magnets using CORC® cables requires consistent experimental data for model calibration and validation. The critical current Ic and the entire V-I curve are some of the key parameters to estimate cable performances. The strong non-linearities of superconducting materials and the complex geometry of CORC® cables, especially with increasing numbers of layers, render conventional numerical simulations computationally expensive. To address this challenge, this work proposes the use of Artificial Neural Networks (ANNs) as surrogate models to efficiently compute and predict the V-I curves of CORC® cables with diverse configurations. Based on experimental data available in literature and/or a 2D T-A model, previously verified and validated, which aims at the reproduction and prediction of the Ic and the whole V-I curve for the HTS tapes and CORC® -like cables, ANNs were trained and exploited to surrogate intensive computations or complex experimental campaigns.

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Presenter: TOMASSETTI, Giordano

Session Classification: Fri-Mo-Or5 - HTS Conductors and Cable

Contribution ID: **128** Type: **Poster**

Fri-Af-Po.10-10: Thermal and Magnetic Modeling of 14-mm-Period Nb_3Sn Undulator Magnets

Friday, July 4, 2025 2:00 PM (2 hours)

Undulators are magnetic devices vital for synchrotron light sources. Installed on storage rings or FELs, they generate highly brilliant photon beams for a wide range of scientific applications. Among them, superconducting undulators (SCUs) offer the greatest benefits in spectral performance due to higher fields and smaller undulator periods. At the Advanced Photon Source (APS), a novel 18-mm-period SCU was successfully deployed, yielding at least a 20% increase in magnetic field compared to its NbTi predecessor. Encouraged by this achievement, a new project was initiated to develop a cryogen-free 14-mm-period SCU designed to test the performance limits of Nb_3Sn technology. To guide the conceptual design, detailed thermal and magnetic models were performed with a particular focus on mitigating coil-to-ground insulation challenges. This presentation will highlight the design strategy, modeling approaches, and short prototyping efforts.

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Presenter: KESGIN, Ibrahim

Session Classification: Fri-Af-Po.10 - Undulators

Contribution ID: **129** Type: **Poster**

Thu-Af-Po.10-04: Progress on the cryogenic system of the EDIPO2 magnet

Thursday, July 3, 2025 2:00 PM (2 hours)

The Swiss Plasma Center is proposing an upgrade to the EDIPO test facility (EDIPO 2), which will generate a 15 T background field within a 144×144 mm^2 aperture. This upgrade will enable variable-temperature, high-current testing of superconductor samples, enhancing the facility's capabilities for advanced material research and development. This work presents an overview of the progress on the cryogenic system for EDIPO2.

The magnet will be cooled using a 4.2 K liquid helium bath, supplied by the facility's existing cryoplant, which delivers supercritical helium at 4.5 K, 10 bar. The magnet mass kept at liquid helium temperature is around 20 tons and the electromagnetic stored energy is 21 MJ. The magnet will make use of the existing EDIPO vacuum vessel, and a new helium vessel has been manufactured for EDIPO 2. Detailed calculations are performed in order to assess the thermal losses through conduction, radiation, and heat exchange with surrounding components.

Acknowledgment:
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Presenter: NES, Thomas (EPFL-SPC)

Session Classification: Thu-Af-Po.10 - Cryostats and Cryogenics I

Contribution ID: **130** Type: **Poster**

Fri-Af-Po.02-04: Progress on the quench analysis of the EDIPO2 magnet

Friday, July 4, 2025 2:00 PM (2 hours)

The Swiss Plasma Center is proposing an upgrade to the EDIPO test facility (EDIPO 2), which will generate a 15 T background field within a 144×144 mm^2 aperture. This upgrade will enable variable-temperature, high-current testing of superconductor samples, enhancing the facility's capabilities for advanced material research and development. This work presents an overview of the progress on the quench protection system for EDIPO2.

To model the quench behavior, a simulation of heat propagation within various locations of the coil winding of the magnet is made. The magnet is protected against overheating during a quench by an external energy dump through a 0.1 Ω resistor. Thermal properties, including heat capacity and conductivity, are determined using the rule of mixtures for Nb3Sn, copper, epoxy impregnation, and fiberglass insulation. Electrical resistivity is modeled based on current sharing between Nb3Sn and copper, considering the longitudinal electric field. Cooling terms are applied at the boundary nodes to account for wet contact with the liquid helium bath, assuming a 0.2 mm thermal interface of glass-epoxy.

Acknowledgment:
This work has been carried out within the framework of the EUROfusion Consortium, via the Euratom Research and Training Programme (Grant Agreement No 101052200 —EUROfusion) and funded by the Swiss State Secretariat for Education, Research and Innovation (SERI). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union, the European Commission, or SERI. Neither the European Union nor the European Commission nor SERI can be held responsible for them.

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Presenter: NES, Thomas

Session Classification: Fri-Af-Po.02 - Quench Detection and Protection III

Contribution ID: **131** Type: **Contributed Oral**

Sat-Af-Or5-06: AC loss measurement for parallel-wound HTS coils

Saturday, July 5, 2025 5:45 PM (15 minutes)

This presentation reports AC loss study for parallel-wound HTS coils used for AC applications, e.g. fusion PF coil and rotational machines. The reason for parallel winding is to increase the current rating of winding without increasing too much the winding inductance. We made several four-conductor parallelly wound HTS coils and measured both the current distribution and AC loss. Our measurement unveils that the transport current AC loss of this type of HTS coil is frequency-dependent. Due to the impedance mismatch of the four parallelly wound HTS tapes, the measurement shows a frequency-dependent current sharing among the HTS tapes: the higher the frequency, the bigger the current sharing. For the same coil, current sharing is different with different frequency, leading to a frequency-dependent transport loss. Our study also leads to a useful conclusion that achieving inductance matching for the parallel-wound HTS coils is important for reducing AC losses.

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Presenter: ZHANG, Min (University of Strathclyde)

Session Classification: Sat-Af-Or5 - AC Loss and Magnetization II

Contribution ID: **132** Type: **Poster**

Thu-Af-Po.05-05: Inductive energization of one-turn secondary coil with single high-temperature superconducting wire by exciting primary coil with alternating current

Thursday, July 3, 2025 2:00 PM (2 hours)

High-temperature superconducting (HTS) generators cooled by liquid hydrogen are being researched and developed, with a 6kA-class assembled conductor required to superconduct the field winding of a 600 MW-class generator. The development target was a conductor consisting of 9 HTS wires in a thiree-layer structure with a 5 mm diameter former. To verify the current capacity of the assembled conductor, it is necessary to perform a 6 kA-class energization test under liquid hydrogen immersion cooling. However, the current capacity of the liquid hydrogen cryostat installed at the Noshiro Rocket Test Center of the Japan Aerospace Exploration Agency (JAXA) is 500 A. There are significant challenges in upgrading it for a 6 kA-class energization test apparatus.
The induction method has traditionally been used for energization testing on high-current low-temperature superconducting (LTS) conductors. It involves shortening both ends of the conductor to form a low-inductance secondary coil. A high current is induced in the secondary coil by the sweep excitation of a magnetically coupled high-inductance primary coil. The same method is supposed to be used for energization tests of the HTS assembled conductor. However, the measurement accuracy of the induced current using Rogowski coils, extremely low-resistance joint technique of the assembled conductors, and zero-reset method of the induced current are challenges that need to be addressed.
Therefore, a new inductive excitation method was investigated by applying an alternating current (AC) to the primary coil, and the configuration of the 6 kA-class inductive excitation test was discussed. The primary REBCO coil consisted of four double pancake coils wound with 4 mm-wide REBCO wires divided into upper and lower sections by a central space (24 mm). The inner diameter, outer diameter, coil height, and average number of turns were 130 mm, 206 mm, 9.5 mm, and 444, respectively. A short-circuit coil with an assembled conductor was used as the secondary coil, and the secondary coil was placed in the center space of the primary coil. Applying an AC to the primary coil induced an AC in the magnetically coupled secondary coil. When the frequency was approximately 1 Hz, and the joint resistance was 100 nΩ or less, the effect of the joint resistance on the induction factor of the secondary current was almost negligible. Considering the stability of the primary coil carrying AC, a higher induction factor was desirable, and the number of turns was chosen to be one. A radius of approximately 75 mm was found to be appropriate, with the position of the conductor having a minimal effect on the induction factor.
To verify the high-current inductive excitation test configuration, one-turn 144 mm-outer diameter short-circuit secondary coils were fabricated using a single REBCO or BSCCO wire, respectively, and installed in the center of the primary coil. A Rogowski coil was attached to measure the induced current in the secondary coil. The inductive excitation tests were performed under liquid nitrogen cooling. The primary current frequencies were 0.5 Hz and 1 Hz. The phase difference between the primary current and the Rogowski coil voltage decreased sharply when the secondary peak current was above the critical current (Ic) of the HTS wire. These results indicate the possibility of determining the Ic of the secondary coil using the phase difference of the Rogowski coil as an indicator. In addition, a transient electric circuit simulation was performed using an n-valued model targeting the region where the peak current exceeds the wire's Ic. The measured

and simulated Rogowski coil waveforms will be discussed in the presentation.

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Session Classification: Thu-Af-Po.05 - Conductor and Coil Measurement/Test Techniques and Facilities III

Contribution ID: **133** Type: **Poster**

Wed-Mo-Po.12-03: An automatic HTS flux pump driven from a 24V NiMH battery

Wednesday, July 2, 2025 9:15 AM (2 hours)

Flux pumps are gaining traction as alternatives to traditional power supplies for HTS magnets due to their reduced heat-leak and compactness. Automatic flux pumps are the simplest embodiment and rely on a section of superconductor parallel to the load magnet, known as the bridge, being driven outside its critical surface by an induced voltage on the secondary of a transformer. Most previously reported automatic HTS flux pumps have been experimental prototypes, using programmable laboratory power supplies to drive the transformer primary. Here we report on an automatic HTS flux pump driven from a compact 24 V Nickel Metal Hydride (NiMH) battery pack, by a custom half-bridge inverter through a 1000:1 transformer. This configuration achieved DC load current above 120 A in a small inductive HTS load when operating at 1 Hz. We replicate several previously reported results, including the benefits of using copper in the transformer secondary loop and having a non-inductive bifilar bridge section made from REBCO tape. We also introduce several simplifications, including driving the transformer primary with a rectangular voltage pulse waveform and replacing the primary-side power supply with a battery and discrete power semiconductors. Further, we develop a clear model of the automatic flux pump, which demonstrates the relationships between the secondary-side fixed resistance, leakage inductance, operating frequency, charging rate and maximum current. Our results show that automatic HTS flux pumps are simple, well-understood and are ready for application as HTS magnet power supplies in demonstration systems.

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Session Classification: Wed-Mo-Po.12 - Diodes, Flux Pumps, and Switches

Contribution ID: **134** Type: **Contributed Oral**

Fri-Mo-Or1-02: High Field Cos Theta Dipole Magnet Falcon D development at CERN

Friday, July 4, 2025 8:15 AM (15 minutes)

The Falcon D (Future Accelerator post- LHC Cos-theta Optimised Nb3Sn dipole) dipole is part of the High Field Magnet (HFM) program. CERN in collaboration with the Italian Institute for Nuclear Physics (INFN Genova and LASA Milano), is developing the design of cos theta dipole magnet beyond 11T based on proven Nb3Sn technology in the MQXF quadrupoles used in the high-luminosity upgrade of the LHC. The magnet, with aperture diameter of 50 mm and a bore field of 12 T, can give a 73 TeV center of mass energy for the Future Circular Collider FCC-hh. The collaboration has specific objectives to design and investigate a cos theta coil design based on a two-layer coil with the largest possible cable. Moreover, the study of mechanical structures based on Al rings and bladder and keys technology developed in High Lumi MQXF quadrupole will be presented as a baseline for a cos⊠ dipole coil. The baseline of the structure preloading and a collared assembly variant shall be tested on mechanical mock ups at 77 K prior to build two single then a 2-in-1 accelerator magnet models using 1.5 m long Nb3Sn two-layers coils. In this paper, we provide an overview of the CERN Falcon D magnet project plan, the status of various preliminary turns winding trials outcomes, and the detail design of the magnet model structure proposal. Based on the given cable winding behavior and mechanical measured properties features, some alternative magnetic optimized coil cross section with ends and mechanical design for the Nb3Sn 1-in-1 dipole model is reported.

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Session Classification: Fri-Mo-Or1 - Development and Testing Towards High Field Accelerator Magnets

Contribution ID: **135** Type: **Poster**

Fri-Mo-Po.05-04: Optimum Integral Design for EIC Dipole B1ApF

Friday, July 4, 2025 9:30 AM (1h 45m)

The Optimum Integral Design (OID) with Direct Wind (DW) technology offers a unique value engineering opportunity for the Interaction Region (IR) dipole B1ApF of the Electron Ion Collider (EIC). The current design of the B1ApF magnet is based on the conventional cosine theta configuration using Rutherford cable. As compared to most accelerator magnets, B1ApF has a small coil length (1500 mm) to coil aperture (370 mm) ratio. The relative benefit of the Optimum Integral Design is significant in such short magnets since it minimizes the loss in effective magnetic length due to ends. In the Optimum Integral Design, the midplane turns extend over the full length of the coil, making the effective magnetic length closer to the full coil length. Further benefits of the design come from the elimination of end plates, which in the current cable magnet design, take a significant portion of the slot length available in the lattice. Calculations show that for the required integral field of 4.05 Tesla-meters, the increase in magnetic length in the Optimum Integral Design is so much that the field at the center of the magnet can be relaxed from 3.92 T to 2.55 T. As a result, the Lorentz forces/stresses, and hence the technical challenges and risk to the program, get significantly reduced. Since the Direct Wind Technology doesn't need coil winding, coil curing and coil collaring tooling, the cost and time required to build such a magnet gets significantly reduced as well. Hence, the proposed OID option provides significant savings, making it a value engineering alternate to the baseline design of B1ApF. The required field integral can be achieved with only two layers of windings with the 6-around-1 cable that is being purchased for the EIC program. As a part of the complete study, we will also present several other design options. The paper will also provide a summary and benefits of the Optimum Integral Design.

*This work was supported by DOE Grant No. DE-SC0021578 and by Brookhaven Science Associates, LLC under contract No. DE-SC0012704, with the U.S. Department of Energy.

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Session Classification: Fri-Mo-Po.05 - Electron-Ion Collider

Contribution ID: **136** Type: **Contributed Oral**

Thu-Mo-Or1-01: Design, construction, and test of a superconducting dipole based on the Optimum Integral Design

Thursday, July 3, 2025 10:45 AM (15 minutes)

Design, construction, and test of a ~3.8 T, 114 mm aperture dipole based on the Optimum Integral Design using the Direct Wind technology will be presented. This work is being carried by Particle Beam Lasers, Inc. (PBL) and the Brookhaven National Laboratory as a part of the Small Business Technology Transfer (STTR) program. The design significantly reduces the loss of effective length due to the end and is, therefore, particularly attractive for short magnets, such as some needed in the Electron Ion Collder (EIC). The parameters are chosen to meet the design requirements of the full length EIC interaction region dipole B0ApF. In the Optimum Integral Design, the midplane turns extend essentially the full length of the coil, and the fields in the body and ends are combined for optimizing the integral field harmonics. The Optimum Integral Design creates a higher integral field for a given coil length. A proof-of-principle 1.7 T, 114 mm aperture, 600 mm long, 2-layer superconducting dipole was successfully designed, built and tested earlier as a part of a Phase I grant. A six-layer, ~3 T coil was constructed and tested (including the warm field harmonics measurements) during the first year of the Phase II program. All twelve layers of the coil have been wound. The final construction and assembly of the magnet is underway to prepare it for cold testing.

*This work was supported by DOE Grant No. DE-SC0021578 and by Brookhaven Science Associates, LLC under contract No. DE-SC0012704, with the U.S. Department of Energy.

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Presenter: Dr GUPTA, Ramesh (Brookhaven National Laboratory)

Session Classification: Thu-Mo-Or1 - LTS Magnet Advanced Concepts

Contribution ID: **137** Type: **Poster**

Wed-Af-Po.04-01: Study on the universality of copper bonding joints on different REBCO copper-plated tapes

Wednesday, July 2, 2025 2:30 PM (2 hours)

Joint technology is one of the key technologies for the application of second-generation high-temperature superconducting (2G HTS) tapes. The simplicity of the joint fabrication method and the excellence of the electrical and mechanical properties of the joints significantly impact the performance of REBCO in large-scale applications. Copper bonding joint technology, a new type of solder-free, low-resistance joint created using warm welding method, is suitable for REBCO copper-plated tapes. In this paper, we further investigate the performance of copper bonding joints in bonding various copper-plated tapes. In this research, tapes produced by SST, SuperOx, and Theva were used to make copper bonding joints, validating the strong universality of the copper bonding joint technique. The joints were made under various bonding temperatures, pressures, and bonding time, and their electrical and mechanical properties were tested. The results indicate that factors such as the copper plating process, the thickness of the copper stabilizer, and the thickness of the tape substrate all influence the difficulty of producing well-bonded copper bonding joints.

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Session Classification: Wed-Af-Po.04 - HTS Joints

Contribution ID: **138** Type: **Contributed Oral**

Sat-Mo-Or5-04: Fast Quench Detection in Superconducting Devices Using REBCO Tape as a Microwave Transmission Line

Saturday, July 5, 2025 12:00 PM (15 minutes)

We have developed a new fast quench detection method for superconducting devices utilizing the REBCO superconductor tape itself as a microwave transmission line. Unlike voltage detection where the signal is proportional to the length of the normal zone, a 100-m-long transmission line will effectively become two 50-m transmission lines if quench occurs midway along the tape, joined by a resistive transmission segment. The standing waves formed in the transmission line are immediately disturbed, which can be readily sensed by a frequency analyzer in sweep mode that acts as a source of excitation and a sensing circuit. We have experimentally verified that the resonance peaks in both reflection (s11) and transmission modes (s12) change immediately and drastically on quench, and the resonance peaks are sensitive to size of quenched region. Quench detection has been demonstrated with simultaneous transport current through bare tape (13% critical current (Ic)), tape with silver overlayer (39% Ic), and with copper stabilizer (58% Ic). Quench triggered by a heat pulse was quickly detected in all cases by a shift in the amplitude and frequency of s11 reflection. The efficacy of the quench detection method in the presence of transport current has been confirmed in multi-turn coils constructed with epoxy and paper insulation. This quench detection method is a potent approach for HTS magnets, without a need to co-wind extrinsic sensors.
This work was supported by Office of Naval Research award N00014-21-1-2429.

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Session Classification: Sat-Mo-Or5 - Quench Detection Modelling

Contribution ID: **139** Type: **Contributed Oral**

Wed-Af-Or2-01: Lessons learned from ultra-high-field, high-stress REBCO coil tests

Wednesday, July 2, 2025 4:30 PM (15 minutes)

The 'Little Big Coil (LBC)' magnet test bed investigates key coated conductor characteristics in a high field and high stress environment by testing a REBCO coil in the bore of the NHMFL 31.1 T Bitter magnet. Indeed, LBC3 first demonstrated excessive screening current stress (SCS) resulting in wavy plastic conductor damage, while obtaining the record-high DC magnetic field of 45.5 T by generating 14.4 T in its 31.1 T background field. The important result of LBC3 was that single slit tapes with slit edges pointing towards the coil center were barely damaged while those with opposite orientation showed large damage. To explore this apparent paradox, LBC4 was wound completely from single-slit tapes whose slit edges were all pointed towards the coil center. Indeed, almost no damage was seen on LBC4 attaining 44.0 T. Our *post mortem* showed that the key reason was a specific peculiarity of the MOCVD tapes used in our LBC coils. The edges of the tapes have a markedly higher density of current-blocking CuO and *a*-axis grains that markedly lower the edge J_c below that of the more central slit edge even with its cracked edge. Measurement of the transverse J_c variability and implementation of the local edge J_c into the SCS model yielded stresses consistent with the transition from large SCS-initiated damage in LBC2 (42.5 T) and 3 (45.5 T) to much lower SCS damage in LBC4. We are now investigating new Little Big Coils using recent laser-slit, thicker REBCO, and PLD conductors made for compact superconducting fusion magnets to obtain a direct comparison with mechanically slit MOCVD conductors that we have used until now.

Acknowledgment: A portion of this work was performed at the National High Magnetic Field Laboratory, which is supported by the National Science Foundation Cooperative Agreement No. DMR-2128556 and the State of Florida. This work is primarily supported by the DOE Office of Fusion Energy Sciences Grant DE-SC0022011. Many aspects of this work have been done in collaboration with the groups of Professor Seungyong Hahn at Seoul National University and Professor So Noguchi at Hokkaido University.

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Session Classification: Wed-Af-Or2 - No-Insulation Coils II

Contribution ID: **140** Type: **Poster**

Wed-Mo-Po.10-01: Current-Limiting and Fast Interrupting Characteristics of a New Superconducting Fuse

Wednesday, July 2, 2025 9:15 AM (2 hours)

With the development of superconducting technology, high temperature superconducting (HTS) tapes can be mass-produced. With the advantages of high current density, zero resistance in superconducting state and high resistance in normal state, HTS tapes can be used to limit and interrupt fault current as a fuse. However, with the superconducting layer to load normal current, the critical current of HTS tape with half circle or trapezoid restricted zone is lower than HTS tape without restricted zone. The critical current of HTS tape with restricted zone is also unstable, which causes difficulty in the application of superconducting fuse. In this paper, we proposed a new types superconducting fuse with restricted zone manufactured on the stainless-steel layer, which can maintain the critical current of HTS tape and promote the interrupting process with lower heat capacity and higher resistance. An experimental model is established with impact source and HTS tapes with single restricted zone, and the current limiting and interrupting characteristics of the superconducting fuse are tested. Experimental results show that the current limiting ratio of the new superconducting fuse is 20% higher than superconducting tape without restricted zone, and the interrupting time of the new superconducting fuse is 30% shorter than superconducting tape without restricted zone. At the same time, the fusing area of the new superconducting fuse is almost in the restricted zone. With high and stable critical current and excellent interrupting ability, the new superconducting fuse can help to protect high load current grid from short-circuit and improve the stability.

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Session Classification: Wed-Mo-Po.10 - Transformers and Fault Current Limiters

Contribution ID: **141** Type: **Poster**

Wed-Mo-Po.04-06: Research on transport AC loss characteristics in tenon-mortise modularized conductor (TMMC) with double-layer copper formers

Wednesday, July 2, 2025 9:15 AM (2 hours)

Evaluation of AC loss is a key issue for high temperature superconducting (HTS) conductor design and optimization, which is critical for the efficient operation of large HTS devices. our research group previously presented a novel HTS conductor named Tenon-Mortise Modularized Conductor (TMMC), composed of multi-layer concentric round sub-conductors arranged in a fully-misaligned configuration. These concentric round sub-conductors are composed of slotted copper formers, which are used for installing stacked REBCO tapes. This research objective is to investigate the transport AC loss characteristics in TMMC, caused by the different amplitudes and frequencies of triangular wave current. Both numerical simulations and experimental methods were employed at 77 K for a comprehensive analysis. A 1-meter-long double-layer TMMC specimen, fabricated from double-layer copper formers, was subjected to electrical testing to measure transport AC loss. It was observed that the transport AC loss of tapes increased with the amplitude of the triangular current, while the frequency of the current had a relatively small impact on the AC loss. Specifically, At current amplitudes of 6 kA and 8 kA, the reduction in current frequency from 1000 kA/s to 500 kA/s corresponded to differences in mean AC loss of 6.5% and 15.5%, respectively, suggesting a low dependence of transport AC loss in TMMC on current frequency. In addition, a 2D double-layer TMMC model was constructed using finite element method (FEM), and the simulation results were compared with experimental results. There was good agreement between the measured and simulated results, with discrepancies likely due to experimental noise. This study investigates the transport AC loss characteristics of the latest proposed TMMC through experimental methods, providing a solid foundation for the development of high-current, low-loss HTS cables for future fusion applications. However, further research is essential to fully understand the factors influencing AC loss and to develop effective strategies for minimizing it.

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Session Classification: Wed-Mo-Po.04 - HTS Conductors I

Contribution ID: **142** Type: **Contributed Oral**

Fri-Mo-Or5-01: High-performance REBCO conductors and cables for high magnetic field applications

Friday, July 4, 2025 11:15 AM (15 minutes)

REBCO conductors with high critical currents and high engineering current densities (Je) in magnetic fields of 20 T and above are needed for several applications such as particle accelerators and fusion reactors. We have demonstrated round, 2.5 mm diameter REBCO STAR® wires with a Je of about 600 A/mmˆ2 at 4.2 K, 30 T at a bend radius of just 15 mm, using high critical current REBCO tapes. These tapes are produced in lengths of 50 meters with critical currents at 4.2 K, 20 T that are 3x that of typical commercial tapes. Defect-tolerant features have been incorporated in our REBCO tapes that enable better current sharing and quench stability. REBCO tapes with a higher delamination strength are also being developed to withstand the high transverse stresses experienced in high-field magnets. Prototypes of insert coils for high-field magnets are being demonstrated with our REBCO STAR® wires and cables. The recent progress in the development of our high-performance REBCO conductors and cables will be presented.

This work was supported by Small Business Innovative Research (SBIR) awards DE-SC0021689, DE-SC0022900, DE-SC0024855 from the U.S. Department of Energy Office of High Energy Physics and N68335-23-C-0228 from the U.S. Naval Sea Systems Command.

The work at LBNL was also supported by the U.S. Magnet Development Program through Director, Office of Science, Office of High Energy Physics of the US Department of Energy under Contract No. DEAC02-05CH11231.

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Session Classification: Fri-Mo-Or5 - HTS Conductors and Cable

Contribution ID: **143** Type: **Contributed Oral**

Sun-Mo-Or1-06: Lessons learnt from the HTS Quench Experiment campaign for the EU-DEMO CS design and operation

Sunday, July 6, 2025 9:30 AM (15 minutes)

An extensive experimental campaign to study the evolution of the quench in REBCO conductors has been carried out within the EU-DEMO programme, motivated by the use of High Temperature Superconducting (HTS) conductors in the Central Solenoid (CS). The aim was to explore the quench initiation and propagation in different conditions in HTS conductors based on stacked tapes layout. Seven 15kA-class samples have been successfully tested in SULTAN facility and the results are presented and compared in the present work.
A series of quench events have been triggered on each sample and measurements show that a temperature peak beyond 150 K on the stack of REBCO tapes may lead to the degradation of the DC performance of the conductor, mainly due to thermal gradients. This provides a first reference value the conductor designers may refer to, impacting both the magnet quench detection and protection strategy, as well as the definition of the conductor layout. In fact, the EUROfusion quench experiments suggest that it could be necessary to revise the criterion for the maximum quench temperature, reducing it from 250 K to only 150 K on the tapes. If this new value is confirmed it may be necessary to increase the amount of stabilizer and/or improve the heat transfer from tapes to metals (stabilizer and steel).
In addition, the projection to the expected performance in the EU-DEMO CS is carried out, focusing on the maximum hotspot temperature reached, depending on the layout. Results show that it is more convenient -from the quench protection point of view- having a conductor with a large effective heat capacity.

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Session Classification: Sun-Mo-Or1 - Technology for Fusion Reactors II

Contribution ID: **144** Type: **Contributed Oral**

Wed-Mo-Or3-03: Progress in production scale-up and enhancement of in-field properties with PLD at SuNAM

Wednesday, July 2, 2025 11:45 AM (15 minutes)

SuNAM has long been at the forefront of coated conductor (CC) technology, leveraging its proprietary Reactive Co-evaporation-Deposition and Reaction (RCE-DR) process to meet diverse industry needs, particularly in grid applications. However, the emergence of compact fusion reactors has presented unprecedented challenges, demanding in-field critical current performance that surpasses the capabilities of our enhanced RCE-DR process, even with integrated pinning centers.

To overcome these limitations, we have strategically pivoted to Pulsed Laser Deposition (PLD) technology. Our team is in the final stages of optimizing this system for mass production of fusion-grade CCs. This presentation will provide insights into our comprehensive optimization process, detailing our analysis of electrical characteristics, microstructural properties, and the intricate interplay of various deposition parameters.

Furthermore, we will showcase our parallel efforts in cost reduction strategies, including the development of wider-web processing techniques and the implementation of machine learning algorithms for process automation. These advancements aim to ensure that our high-performance CCs remain economically viable for large-scale fusion projects.

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Presenter: LEE, Hunju (SuNAM Co., Ltd.)

Session Classification: Wed-Mo-Or3 - REBCO Manufacturing

Contribution ID: **146** Type: **Poster**

Wed-Af-Po.07-01: Modeling method of transformer under strong steady magnetic field based on equivalent magnetic circuit network method.

Wednesday, July 2, 2025 2:30 PM (2 hours)

The transformer in the power supply is naturally sensitive to the external magnetic field, and its operating characteristics are easily changed under the influence of the strong external stray magnetic field, resulting in the change of the operating characteristics of the power supply and even failure. Therefore, the establishment of an accurate transformer model under the external magnetic field is an important requirement for realizing the design of power supply immunity. Because the external magnetic field will cause the transformer core saturation and the uneven distribution of magnetic flux in the core, the traditional modelling method based on magnetic circuit is no longer suitable, and the modelling method based on electromagnetic field finite element analysis is difficult to take into account the calculation accuracy and efficiency. In this paper, a transformer modelling method considering the effect of external magnetic field is proposed based on the equivalent magnetic circuit network method. The transformer core and the external air domain are divided into several magnetic circuit units to form a magnetic circuit network. The field distribution in the model is obtained by iteratively solving the magnetic circuit network equation. The proposed method is used to model an EE transformer and calculate the field distribution and the excitation inductance value of the transformer under a uniform steady strong magnetic field. By comparing the calculated results with the finite element simulation results and the real experimental results, the accuracy and efficiency of the proposed scheme are verified.

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Session Classification: Wed-Af-Po.07 - Modelling and Analysis

Contribution ID: **147** Type: **Poster**

Wed-Mo-Po.01-03: Design and optimization a Dipole DCT Superconducting Magnet for Compact Heavy-Ion Synchrotron

Wednesday, July 2, 2025 9:15 AM (2 hours)

A compact synchrotron based on superconducting magnets is under development in China. The compact synchrotron, with a circumference not exceeding 35 meters, is equipped with eight superconducting dipole magnets. It is designed to accelerate multiple types of heavy-ion beams from 7 MeV/u to 430 MeV/u. The Discrete-Cosine-Theta (DCT) coil structure is used to reduce the magnet size. The central magnetic field ranges from 0.19 T to 3.32 T, with ramp rate of 1 T/s, and the region of good field is no less than 100 mm. This article focuses on the structure and optimization of magnets. To enhance excitation efficiency and improve the operational stability of the superconducting magnets, an iron yoke is placed around the coil. Optimization of the yoke has been carried out to achieve a uniform magnetic field distribution under both low and high field conditions. In order to solve the problem of the temperature rise caused by the rapid ramping rate, a hybrid approach, combining forced-flow and conductive cooling, has been used. The retention of liquid helium flow channels within the iron yoke has brought more challenges to the optimization of the magnetic field quality. The first prototype magnet is currently under fabrication.

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Session Classification: Wed-Mo-Po.01 - Accelerator Magnets I

Contribution ID: **148** Type: **Poster**

Fri-Af-Po.09-06: Shielding for trapped field stacks against cross field demagnetisation in a superconducting machine

Friday, July 4, 2025 2:00 PM (2 hours)

High-Temperature Superconducting (HTS) Coated Conductors (CCs) can be sliced and stacked together and utilised as Trapped Field Stacks (TFSs) for electric motors and generators after magnetisation. However, TFSs are vulnerable to higher-order harmonic waves within the air gap of electric machines, which stem from the stator's alternating arrangement of slots and teeth, leading to a phenomenon of magnetic moment collapse and decay in the trapped magnetic field within the TFSs, when the TFSs face a transverse field applied orthogonally to their initial magnetisation direction. This is known as cross-field demagnetisation.

To mitigate the demagnetisation issues, the diamagnetism of superconductors has been employed as a potential preventive method. To investigate their ability to shield TFSs against external alternating current (AC) field, superconductors has been added as side tapes around a TFS in a 2D electromagnetic-thermal coupled numerical model, which has been built for a Fractional Slot Concentrated Winding (FSCW) machine, with its traditional Permanent Magnets substituted by stacks of HTS tapes on the rotor surface. This model was developed using the Finite Element Method (FEM) and validated against experimental data. The HTS stacks were magnetised through Pulsed Field Magnetization (PFM), and once magnetised, they function as TFSs to produce rotor fields. The trapped magnetic field, current distribution within the TFSs, and temperature dynamics of the TFSs as well as the current distribution in the side tapes have been examined to demonstrate the shielding effect. The shielding effect has been demonstrated to be stronger with a higher number of layer number of side tapes. This study will contribute to understanding the shielding capabilities of HTS CCs in practical superconducting machines and aid in designing HTS TFS rotors.

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Presenter: WANG, Qi (University of Cambridge)

Session Classification: Fri-Af-Po.09 - Rotating Machinery IV

Contribution ID: **149** Type: **Contributed Oral**

Fri-Mo-Or5-04: Tensile Strain Dependence of E-I Characteristics for Striated REBCO Coated Conductors for SCSC Cables

Friday, July 4, 2025 12:00 PM (15 minutes)

A Spiral Copper-plated Striated Coated-conductor (SCSC) cable is a round cable composed of striated REBCO coated-conductors (CCs) wrapped around a metal core wire. A REBCO film in each CC is divided into multifilaments by laser-striation, while Cu-plating surrounds the whole cross-section. Thanks to this structure, SCSC cables are promising for application to accelerator magnets since the impact of the screening current on the field quality can be reduced while keeping electrical and thermal robustness against local defects. A REBCO film in a CC is subjected to various stresses and strains during cabling, coil winding, resin impregnation of a coil, magnet assembly, cooling, and excitation. To ensure the reliable operation of a magnet, the electro-mechanical properties of SCSC cables must be understood.
As a first step, we evaluated the uniaxial tensile strain dependence of critical current (Ic) for REBCO CCs with a usual single filament or 10 filaments. In a striated CC, it has been reported that an electric field (E) –current (I) curve is strongly influenced by current-sharing among the filaments and the position of voltage taps. Indeed, we found that more complicated Ic-strain characteristics were observed in the striated CCs than in the CCs with a monofilament due to a change in E-I curved at the electric field level below or comparable to the Ic criterion. Controlling the position of voltage taps is essentially important for the striated CCs to determine a strain at which an irreversible degradation of Ic starts. Therefore, we tried to attach the voltage taps to a specific single filament. Then, the Ic-strain characteristics for the filaments at different locations in a width direction were evaluated. Based on these results, we will discuss the filament position dependence of the irreversible strain of Ic.

This work is supported in part by JST-ALCA-Next Program Grant Number JPMJAN24G1 and in part by Japan-U.S. Science and Technology Cooperation Program in High Energy Physics.

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Session Classification: Fri-Mo-Or5 - HTS Conductors and Cable

Contribution ID: **150** Type: **Poster**

Thu-Af-Po.04-03: Proof-of-Concept of a Reinforcement-Learning- Based RT shimming technique for HTS magnets

Thursday, July 3, 2025 2:00 PM (2 hours)

We report a newly developed room-temperature (RT) shimming method for high-temperature superconducting (HTS) magnets employing a deep Q-network (DQN), a type of reinforcement learning theory. With only one training session, the shimming control system (agent) learns how to improve the spatial field homogeneity of an HTS magnet and quickly implements the actual shimming process even under various magnetic field distribution conditions based on the experience gained during the training. Various RT shimming simulations with the MATLAB reinforcement learning toolbox were conducted to verify the feasibility of the method. An agent was trained in a 5 T HTS magnet of which the initial homogeneity was 25.79 ppm at a diameter of 10 mm of the spherical volume (DSV) and enhanced the homogeneity of the magnet under identical field condition. The trained agent was then subjected to various deteriorated field conditions of 32.97 and 35.48 ppm and successfully improved the homogeneity to the target value within a very short time. Shimming results demonstrate that the homogeneity of the HTS magnets, for which the field conditions fluctuate with time due to the screening-current-induced field (SCF) or instability of the power supply, can be improved quickly and frequently by using the proposed method whenever necessary.

Author: HAN, Jaehyeok

Co-authors: SEO, Boun; JANG, Jaeyoung

Presenter: HAN, Jaehyeok

Session Classification: Thu-Af-Po.04 - Screening Currents and Shimming

Contribution ID: **151** Type: **Poster**

Thu-Af-Po.04-01: A Study on Determining Charging Current Waveform to Reduce Screening Current Induced Field in HTS NMR Magnets

Thursday, July 3, 2025 2:00 PM (2 hours)

In this paper, we present a method for determining the appropriate charging current waveform to mitigate the screening current-induced field (SCF) in an NMR class high temperature superconducting (HTS) magnet. Screening currents have been observed to cause magnetic field drift in NMR class HTS magnets, leading to a degradation in performance. To address this performance degradation, various techniques were considered, and the Current Sweep Reversal (CSR) method, which mitigates SCF by adjusting the charging current waveform, was selected for this study. A simulation program was developed to predict the effects of specific charging current waveforms on the screening current and the resulting magnetic field variations in HTS magnets. By comparing the magnetic field changes induced by several preselected current waveforms, the most suitable waveform for a given HTS magnet was determined. To validate the accuracy of the program, the same current waveforms were applied to the actual HTS magnet, and the central magnetic field was measured. We compared the experimental results with the simulations and confirmed that they were nearly identical. This technique is expected to allow us to determine the most suitable charging current waveform for reducing screening currents before conducting time-consuming and resource-intensive charging experiments.

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Session Classification: Thu-Af-Po.04 - Screening Currents and Shimming

Contribution ID: **152** Type: **Poster**

Fri-Af-Po.02-05: Long-term reliability evaluation of high voltage signal conditioners for ITER superconducting magnets during plasma operation in the KSTAR Tokamak

Friday, July 4, 2025 2:00 PM (2 hours)

Quench detection is critical to protect superconducting coils, especially in fusion superconducting magnets, due to enormous energy. A quench event can result in significant damage to fusion superconducting magnets. A High Voltage Signal Conditioner (HVSC) designed for quench voltage detection in the ITER superconducting magnet system has been developed collaboratively by the Korea Institute of Fusion Energy (KFE) and JH Engineering. Various types of HVSCs for ITER magnets and feeder systems were successfully designed, fabricated, and tested under high-voltage conditions and external magnetic fields simulating the fusion tokamak operational environment. However, long-term tests under actual tokamak plasma operation is essential to validate their reliability prior to deployment in ITER. Four types of HVSCs were installed and integrated with quench detection voltage taps of the Korea Superconducting Tokamak Advanced Research (KSTAR) superconducting magnets and bus lines. The long-term reliability tests of HVSCs were conducted during the 2024-2025 KSTAR campaign. The performance and reliability of the HVSCs were evaluated by comparing the recorded data with that of the KSTAR quench detection system

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Presenter: KIM, Jinsub (Korea Institute of Fusion Energy)

Session Classification: Fri-Af-Po.02 - Quench Detection and Protection III

Contribution ID: **153** Type: **Poster**

Wed-Af-Po.12-01: Conduction Cooled Cryogenic Current Drive with HTS Filter

Wednesday, July 2, 2025 2:30 PM (2 hours)

Supplying high current to a superconducting magnet incurs significant conduction losses through current leads. Due to the limitations imposed by the Wiedemann-Franz Law, the minimum loss is independent of the lead material and is ⍰ 45 W per 1,000 A of DC current.
Here we propose and demonstrate a synchronous rectifying DC current drive with no thermal linkage between room temperature and cryogenic environments. The high-voltage signal is stepped down by an in-vacuum transformer and converted to DC by a cryogenic synchronous rectifier circuit operating at 18 K and a maximum current of 1,000 A. The key component of the current drive is a HTS filter, which ensures < 10 mV voltage ripple on the coil. We discuss the design of the filter inductance and identify off-shelf capacitors that can operate below 20 K.
We analyze the source of both conduction and switching losses. The switching losses originate from the discharge of leakage inductance of the secondary winding. Proper management of the gating sequence significantly reduces the switching loss, thus making it possible to design a cryocooled magnet system rated for 1,000 - 4,000 A capacity that is cooled with a single cryocooler.
The source operation is demonstrated on a 2 Tesla second-generation HTS magnet operating at 18 K.

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Session Classification: Wed-Af-Po.12 - Power Supplies

Contribution ID: **154** Type: **Poster**

Wed-Af-Po.06-05: An improved method for detecting turn-to-turn resistivity without destruction and predicting all operating conditions in full-scale REBCO coils

Wednesday, July 2, 2025 2:30 PM (2 hours)

An improved non-destructive detection method for detecting the turn-to-turn resistivity(TTRD) of large non-insulated REBCO coils is proposed. In previous studies, a method based on ODE and GA algorithm is proposed but tested only in a circular experimental coil. This study improves the method by modifying the optimization algorithm and detecting process to raise robustness, and tests in a large-scale racetrack-shaped double-pancake(DP) coil in various operating conditions, applied in the high speed maglev project. By detecting TTRD of the DP coil and predicting various operating conditions, a more reliable detecting method for practical large-scale coils is proposed.

The voltages of each unit in the coil and the magnetic field at center point are measured during magnetization and demagnetization process to evaluate the TTRD. We first solve the ordinary differential equations derived from the MODERATE equivalent circuit model using the voltage data. This provides an initial range of the TTRD. Then, an improved genetic algorithm(GA) is adopted to fit the voltage curves. This algorithm is well-known for handling complex optimization problems, and by adding the deviation of the central point magnetic field as a penalty function, the algorithm can optimize more precisely.

By combining the heuristic genetic algorithm with an optimization algorithm that has a descent direction, the convergence speed is much faster, cutting down the computing time and resources needed, and the chance of the algorithm getting stuck in local optimal solutions is reduced, making sure we search more widely and thoroughly for the truly best TTTR.

We carry out experiments on full-size REBCO coils used in high-speed maglev. Voltage and magnetic field data under different operating conditions are collected, covering magnetization, demagnetization, quench, and external AC field conditions, to detect the TTTR. Moreover, the detected values we got are used to predict the electromagnetic characteristics under other conditions, in order to evaluates its robustness. In-depth studies have been conducted to evaluate how different operating conditions affect the robustness of the detection results. This full evaluation process helps us understand the method's reliability and adaptability better.

Finally, a highly reliable detection method for the TTTR of large REBCO coils is proposed. This method can accurately predict the electromagnetic characteristics of coils under different working conditions and provide useful guidance for practical engineering. It has the potential to greatly change the design, maintenance, and performance optimization of large coil-based systems, ensuring their long-term reliable and efficient operation.

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Session Classification: Wed-Af-Po.06 - No-Insulation Coils I

Contribution ID: **155** Type: **Poster**

Fri-Mo-Po.09-02: Research on the AC Loss Characteristics of Flux Detection Coils in HTS DCCTs

Friday, July 4, 2025 9:30 AM (1h 45m)

Zero-flux DC current transformers (DCCTs) utilize a closed-loop flux detection control to generate a compensation current that cancels the magnetic flux in the magnetic core induced by the measured current. The effectiveness of cryo-DCCTs, composed of copper flux detection coils and a superconducting compensation coil, for measuring superconducting cables that carry tens of kA of current had been verified. However, the heat generated by the AC-driven flux detection coil can cause the superconducting compensation coil to quench, thus limiting the measurement range. This paper proposes high-temperature superconducting (HTS) flux detection coils to reduce resistive losses and improve DCCT measurement performance. The frequency dependence of the AC loss in the HTS flux detection coil-core system is investigated using numerical and experimental methods. AC loss distributions at different current frequencies and amplitudes were computed based on H-formulation. An electrical measurement platform for the AC loss has been established based on a lock-in amplifier. It is found that there is a critical condition where the AC loss of the system is minimized and DCCT sensitivity becomes relatively high as the current frequency reduced and amplitude increased.

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Session Classification: Fri-Mo-Po.09 - Novel and Other Applications II

Contribution ID: **156** Type: **Poster**

Thu-Af-Po.02-12: Critical Current Characteristics of Round REBCO Cables at 4.2 K and in High Magnetic Fields

Thursday, July 3, 2025 2:00 PM (2 hours)

The development of high-current cables made of rare-earth barium copper oxide (REBCO) coated conductors is a key technology for high-field accelerator magnets above 16 T. A flexible round REBCO cable has been proposed as one of the candidates for the high-current cable. This round REBCO cable consists of many coated conductors wound in multiple layers in a helical configuration on a metal core. The current transport properties of the round REBCO cable at 4.2 K and in high magnetic fields are essential for the design of high-field accelerator magnets. In this study, a solenoid-wound bobbin made of glass fiber reinforced plastic (GFRP) was developed to characterize the critical current (Ic) of the round REBCO cable at 4.2 K and 18 T. A 2-mm-wide coated conductor, manufactured by SuperPower Inc., was used to fabricate the sample cable. The Ic of the coated conductor was also measured at 4.2 K for comparison with that of the sample cable. The Ic and lift factors (Ic(4.2 K)/Ic(77 K)) of the coated conductor and the sample cable were reported, and the estimation of the cable Ic using the conductor Ic was discussed. As expected, the lift factors of the coated conductor and the sample cable were almost the same after correcting for the self-field effect.

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Session Classification: Thu-Af-Po.02 - HTS Cable

Contribution ID: **159** Type: **Poster**

Wed-Af-Po.06-04: Study on the turn-to-turn resistivity distribution for optimizing the charging characteristics of non-insulation REBCO coils

Wednesday, July 2, 2025 2:30 PM (2 hours)

Non-insulation (NI) high-temperature superconducting coils are widely utilized owing to their high current-carrying density, high thermal stability, and self-protection features. However, in engineering applications, the primary challenge associated with NI coils is charging delay, along with two additional issues. Firstly, in a closed-loop NI coil, once the Persistent Current Switch (PCS) transitions to the superconducting state, the redistribution of azimuthal current makes it difficult to ascertain the steady-state operating current. Secondly, under specific turn-to-turn resistivity distributions, a significant reverse azimuthal current will occur during charging, increasing the risk of coil damage.

Specific explanation on these two issues is as follows: 1) After the power supply current reaches stability, the different azimuthal currents in each turn result in different voltages between turns, causing the current to be redistributed along the turn-to-turn circuit and converge to the current of the source until the PCS resistance decrease. Premature decreasing of the PCS resistance will cause the process of convergence of the azimuthal currents to the current of the source to be interrupted, and instead converges to a new stable value, making it difficult to accurately control the steady-state operating current. 2) In the NI coil, the inductance of the inner turns is smaller than the outer turns, so when the coil is charging, the inner turns are quickly charged, and the current rise rate of the middle turns and the outer turns is relatively slow. Then the positive azimuthal current of the inner turns will generate positive induced voltage in the middle turns through the mutual inductance with the middle turns of the coil, thereby producing the positive turn-to-turn current. When this amplified turn-to-turn current has exceeded the coil operating current, it can only "backflow" into the azimuthal circuit, resulting in reverse currents. Reverse current will increase the risk of coil damage, for example, if the current direction of adjacent turns is opposite, it may cause one turn to be squeezed out of the coil. According to the process, the distribution of turn-to-turn resistivity has an impact on this current redistribution.

The root cause of these problems lies in the unsuitable distribution of turn-to-turn resistivity within the NI coils. To address these issues, this study proposes an ideal distribution of turn-to-turn resistivity based on an equivalent circuit model. The advantage of this distribution is that it not only improves charging speed but also ensures that the azimuthal current between different circuit elements remains consistent, facilitating the prediction of steady-state operating current while effectively preventing the occurrence of large reverse azimuthal current. This ideal distribution can be quickly obtained through the calculation of the coil's inductance matrix and is applicable to various NI coil structures.

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Session Classification: Wed-Af-Po.06 - No-Insulation Coils I

Contribution ID: **160** Type: **Poster**

Wed-Af-Po.03-05: Development and testing of REBCO racetrack model coils at CERN

Wednesday, July 2, 2025 2:30 PM (2 hours)

One of the goals of the High Field Magnet (HFM) Programme at CERN is to explore High-Temperature Superconducting (HTS) magnet technology for accelerator applications that go beyond the limits of low-temperature superconductors and offer a pathway for the development of more sustainable particle accelerators operating at temperatures above 1.9 or even 4.5 K. As a stepping stone to achieving these goals, CERN has launched the development of model coils in racetrack geometry that can be scaled up for use in common coil-type magnets. The model coils were used to validate winding tooling, newly developed cable insulation technology, instrumentation placement, conductor performance and other key design choices with a short iteration cycle that allows for rapid development.
We detail the coil electromagnetic design and several lessons learned during the progression from single-layer to double-layer coils with a layer jump that allows for a modular magnet design approach. Additionally, the results from liquid nitrogen tests and preliminary findings from liquid helium testing are discussed.

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Session Classification: Wed-Af-Po.03 - High Luminosity LHC and FCC

Contribution ID: **161** Type: **Poster**

Fri-Mo-Po.04-07: Design of a concentrically arranged joint-less HTS solenoid magnet with persistent current switch for NMR applications

Friday, July 4, 2025 9:30 AM (1h 45m)

We have been conducting the basic design, fabrication, and testing of a joint-less high-temperature superconducting (HTS) magnet operating in persistent current mode using second-generation HTS conductors. The joint-less winding method is typically used to produce double pancake coils, but for magnet applications, multiple coils must be stacked. However, the inherent characteristics of the joint-less winding method result in gaps between pancake coils, which degrade both the central magnetic field strength and the spatial homogeneity of the magnetic field. To address this issue, we proposed a coaxially arranged joint-less HTS magnet by symmetrically combining two joint-less coils in an up-down configuration. Unfortunately, small manufacturing errors led to significant induced current differences, resulting in poor magnetic field distribution. In this paper, we propose a concentrically arranged HTS joint-less magnet, consisting of an inner coil with a smaller inner diameter placed inside an outer coil with a larger inner diameter. Based on the fabrication and testing of a prototype, we evaluated the design and verified the potential of the concentrically arranged HTS joint-less magnet for applications in nuclear magnetic resonance (NMR) systems.

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Presenter: Dr YOON, Miyeon (Tech University of Korea)

Session Classification: Fri-Mo-Po.04 - Magnets for NMR

Contribution ID: **162** Type: **Poster**

Thu-Mo-Po.01-05: Non-contact Method for Critical Current Estimation of Superconducting Stacked Cable by Measured Magnetization Loss

Thursday, July 3, 2025 8:45 AM (2 hours)

A non-contact method for estimating critical current is proposed, which can be applied to both single superconducting wires and various types of cables with multiple superconducting wires. The authors have previously proposed a method for measuring magnetization loss of a superconducting wire as a means of non-contact estimation of the critical current of a single superconducting wire. Since the magnetization loss generated in a superconductor by an external magnetic field is closely related to the full penetration depth of the externally applied magnetic field and the critical current density of the superconductor, the critical current of the superconductor could be successfully estimated by measuring the change of magnetization loss with the external magnetic field. The method is completely non-contact, using only an external magnetic field and a pick-up coil to estimate the critical current, eliminating the possibility of physical damage to the superconducting sample during the measurement process. The authors propose that for superconducting stacked cables with multiple layers, the magnetic shielding effect of each layer is superposed, requiring additional calibration calculations. To validate this proposal, a test was conducted to estimate the critical current of a high-temperature superconducting stacked wire. The magnetization loss was measured by varying the number of wire layers to one, two, and four. The actual critical current magnitude was then compared to the estimated critical current of the high-temperature superconducting stack by varying the number of layers of superconducting wires from one to four.

This research was supported by National R&D Program (2022M3I9A1076800) and Basic Science Research Program (2021R1F1A1063208 and 2023R1A2C1005911) through the National Research Foundation of Korea(NRF) funded by Ministry of Science and ICT.

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Session Classification: Thu-Mo-Po.01 - AC Loss and Magnetization I

Contribution ID: **164** Type: **Poster**

Wed-Mo-Po.07-02: Investigation of thermal characteristics of CORC cables in complex flow channels

Wednesday, July 2, 2025 9:15 AM (2 hours)

With the rapid development of superconducting technology, the application scenarios for high-temperature superconducting (HTS) cables continue to expand, leading to increasingly complex configurations for cable installation. The thermal characterization of CORC cables is essential to ensure the stable and safe operation, making it an inevitable part of the design process of CORC cables. Due to the complex geometry of the CORC cables and the coupling of electromagnetic field, temperature field, flow field and others, the analysis of the thermal characteristics becomes extremely complex, especially under the complex laying configuration. Therefore, this paper proposes a feasible thermal analysis method for CORC cables in complex flow channels. First, according to the actual laying configuration of the HST cables, the complex flow channel was decomposed into a straight part and a curved part. Furthermore, a two-dimensional axisymmetric model for the straight part and a three-dimensional refinement model for the curved part of the superconducting cables were established based on COMSOL, and the thermal characteristics of the CORC cables in complex flow channels were analyzed. Finally, based on the above methods, the thermal characteristics of CORC cables under different pulsed currents were analyzed and the ability to withstand pulsed currents was determined.

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Session Classification: Wed-Mo-Po.07 - Thermal Analysis: Magnets and Conductors

Contribution ID: **165** Type: **Poster**

Fri-Af-Po.02-06: Quench Protection in HTS Insulated Conductors : Design Optimization and Detection Strategies

Friday, July 4, 2025 2:00 PM (2 hours)

SupraFusion is a French research program aiming to boost HTS (High-Temperature Superconductors) technologies towards large-scale societal applications and particularly compact fusion machines. In the framework of this program, a large-scale demonstrator magnet will be designed, manufactured and tested. This ambitious goal requires incremental steps, including the fabrication of smaller prototypes and the development of key technological components.
Ensuring a safe and robust quench protection remains one of the main technological challenges of large-scale HTS magnets. Indeed, the protection of HTS conductors in the event of a quench poses a significant risk of damage due to their inherently slow normal zone propagation velocities (NZPV), particularly for insulated designs. To address this, a first prototype called D0 was developed by CEA to experimentally study quench detection and protection (including NZPV measurements) of a copper stabilized HTS conductor capable of carrying a 10 kA current under a 9 T external field at 4.5 K.
Analytical and numerical studies were conducted to optimize the conductor design. Parametric evaluations identified the optimal copper cross-section, achieving a balance between effective protection and reliable detection. Although the chosen design should ensure safe protection, maintaining temperatures below 100 K for a detection threshold of 100 mV, further improvements were sought. As a result, a second alternative strategy involving the integration of Superconducting Quench Detectors (SQDs) was proposed. This approach aims to enhance detection sensitivity and, consequently, improve the overall safety and reliability of the protection system. This SQD strategy efficiency has been studied numerically and will be shortly tested and qualified experimentally.

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Session Classification: Fri-Af-Po.02 - Quench Detection and Protection III

Contribution ID: **166** Type: **Poster**

Fri-Af-Po.02-07: The D0 prototype HTS conductor: Advancing Quench Detection for High-Temperature Superconducting Magnets for SupraFusion

Friday, July 4, 2025 2:00 PM (2 hours)

Suprafusion is a French exploratory program focusing on the development of high-temperature superconductors (HTS) to meet tomorrow's energy and societal challenges, using fusion needs as a vector for this research. In particular, the program aims to design, manufacture and test a large-scale HTS demonstrator magnet. To meet this goal, the program will follow a stepwise development plan with smaller mockups and prototypes to qualify the main demonstrator key technological bricks.
One important risk in the demonstrator development will be ensuring its safety against quench. Indeed, due to their slow normal zone propagation velocities, quench in HTS magnets are hard to detect and can totally damage a coil by the joule power deposited. To address this challenge, the first prototype (called D0) build in the framework of the SupraFusion program will aim to study the quench detection of HTS copper stabilized insulated coil.
The D0 prototype HTS conductor will be first wound as a one-layer spiral on a stainless steel mandrel with a bending radius of 60 mm. Then, the mandrel will be assembled with large copper pieces soldered to the conductor and ensuring a good electrical connection to the busbars. To ensure a homogeneous thermal map and allow parametric studies, the whole device will be actively cooled by forced flow supercritical helium. Finally, the D0 prototype coil will be inserted in a 9 T solenoid background field magnet called OPTIMIST. The design target is to operate this prototype and perform quench studies at 10 kA, 4.5 K under a field of nearly 10 T. Once under operation, this prototype will allow us to qualify several key aspects of our technology: the propagation quench velocity, the conductor hot spot temperature, the quench protection system sensitivity, the conductor critical current, etc. This poster will present the main design aspects of this D0 prototype including: magnetic field and load line margin computations, thermoelectric studies on the electrical connections, cooling strategy and thermal map, mechanical behavior under load, integration of the prototype in the MATTRCIS cold test facility.

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Presenter: Dr GENOT, Clément (CEA SACLAY)

Session Classification: Fri-Af-Po.02 - Quench Detection and Protection III

Contribution ID: **167** Type: **Poster**

Thu-Mo-Po.05-08: Finite Element Approach for Calculating Stress Distribution in Non-Circular High-Temperature Superconducting Coils

Thursday, July 3, 2025 8:45 AM (2 hours)

Complex stress distribution arises in high-temperature superconducting (HTS) coil based on REBCO coated conductors, which is affected by the applied winding tension, thermal stress during cooling down, and electromagnetic forces when energizing the coil. The material and structure of bobbin and overband also play an important role. If the stress exceeds a certain range, it can cause delamination and damage to the tapes, resulting in a significant drop in the performance and lifetime of HTS magnets.
In this study, a finite element (FE) method model was proposed for analyzing the stress distribution of HTS coils with non-circular geometries, especially the stresses arise from winding tension and overband. Compared to traditional analytical methods, this approach is not only applicable to circular coils but also to coils of other shapes, such as racetrack coils for magnetic levitation applications and D-shaped coils in tokamak that could hardly be calculated analytically. Comparison between the traditional analytical model and the proposed FE method model was obtained, which validated the latter one according to the simulation results on the radial and hoop stresses of two circular coils. Next, the proposed approach was used to analyze the winding stress distribution of a racetrack coil and a D-shaped coil. Furthermore, a comprehensive analysis of the stress distributions in the epoxy impregnated racetrack coil and the D-shaped coil was conducted, considering winding stress, thermal stress, electromagnetic stress, and the influence of overband.

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Session Classification: Thu-Mo-Po.05 - Mechanical Behavior and Stress I

Contribution ID: **168** Type: **Poster**

Fri-Af-Po.02-02: Experimental studies on quench detection of stacked ReBCO tapes using FBGs

Friday, July 4, 2025 2:00 PM (2 hours)

High-temperature superconductors (HTS), with their appreciable current density and superior thermal stability, exhibit significant potential for high-field applications. Compared to the normal zone propagation velocity (NZPV) of low-temperature superconductors (LTS), the NZPV in HTS is typically two to three orders of magnitude slower than that in LTS. The slow quench propagation significantly complicates quench detection.The same issue will also arise in stacked superconducting tapes, which are the fundamental components of HTS cable-in-conduit-conductors (CICCs).Fiber Bragg Grating (FBG) sensors have been used widely for temperature measurement and have shown promise as cryogenic temperature sensors for quench detection of HTS tapes. This paper investigates quench detection based on Fiber Bragg Gratings (FBGs).A multiplexed fiber Bragg grating sensor with multiple gratings is adhered to a 4 mm-wide stacked superconducting tape using 2850FT. Thermocouples are arranged on the same side to synchronously measure the temperature distribution during a quench induced by a heater. On the opposite side, voltage taps are installed to compare the voltage and temperature distributions during the quench process.Experimental results demonstrate that the FBG can rapidly detect the temperature change when the quench occurs.

Acknowledge
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Session Classification: Fri-Af-Po.02 - Quench Detection and Protection III

Contribution ID: **169** Type: **Contributed Oral**

Sat-Mo-Or6-03: Warm to cold correlations and other test results of the MQXFA low-beta quadrupole magnets for the High-Luminosity Large Hadron Collider

Saturday, July 5, 2025 11:45 AM (15 minutes)

The production of the MQXFA low-beta quadrupole magnets for the High Luminosity LHC (HL-LHC) is quite advanced with about 20 magnets cold tested in a vertical cryostat. The MQXFA magnets are fabricated by the US HL-LHC Accelerator Upgrade Project (AUP) and are being used in the Q1 and Q3 Inner Triplet (IT) elements of the HL-LHC, whereas CERN is fabricating similar magnets for Q2a and Q2b IT elements.
These large-aperture, high-gradient quadrupole magnets are first-of-the-kind accelerator magnets introducing Nb_3Sn conductor to High Energy Physics colliders. At this point of MQXFA production there is sufficient data to look at warm to cold correlations for the HL-LHC and for future use of Nb_3Sn magnets in particle accelerators. Examples of warm-cold correlations discussed in this paper are field quality (including the use of magnetic shims for low-order harmonics correction), magnetic length (correlation between coil physical lengths and magnetic length at nominal current), preload, magnetic axis and magnetic field angle. A summary of main test data will also be presented and discussed.

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Session Classification: Sat-Mo-Or6 - High Luminosity LHC

Contribution ID: **170** Type: **Poster**

Wed-Mo-Po.07-03: Thermal analysis of 30MJ/5MW LIQHYSMES magnet cooled by liquid-cooling plates

Wednesday, July 2, 2025 9:15 AM (2 hours)

Liquid Hydrogen and Superconducting Magnetic Energy Storage (LIQHYSMES) system based on electric-hydrogen conversion and superconducting magnetic energy storage is one of the important development directions of composite energy storage technology. As an important electromagnetic energy storage unit of the system, the thermal stability of LIQHYSMES magnet is crucial for the safe operation of the system. Currently, there are two main cooling methods for LIQHYSMES magnets, namely immersion cooling and conduction cooling, but have the disadvantages of difficult pressure resistance design and low heat transfer efficiency, respectively. The object of this paper is a 30MJ/5MW LIQHYSMES magnet cooled by liquid-cooling plates. Thermal stability analysis is carried out considering the AC loss of superconducting magnet and eddy current loss of liquid-cooled plates.

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Session Classification: Wed-Mo-Po.07 - Thermal Analysis: Magnets and Conductors

Contribution ID: **171** Type: **Contributed Oral**

Wed-Mo-Or3-06: Mass Production and Performance of SST REBCO Tape

Wednesday, July 2, 2025 12:30 PM (15 minutes)

With the beneficial characteristics of high irreversible field, high superconducting transition temperature and high critical current density, REBCO material has reached the stage of mass commercial production. Meanwhile a large number of superconducting power transmission projects and superconducting magnets have been developed using REBCO tapes. Recently, due to the significant demand for REBCO tapes by compact fusion industry, Shanghai Superconductor Technology Co., Ltd. (SST) has kicked off a new round of production expansion. Through independent design and manufacturing, SST has swiftly built a large number of vacuum coating equipment and post-processing equipment, including MS, IBAD, PLD, slitting, copper-plating, lamination and so on. This production expansion targets to further reduce the fabrication cost and improve the performance of REBCO tapes, providing a consistent supply of high performance tapes for downstream applications. By the end of 2023, the SST's annual REBCO supply has reached 2000 km/12 mm, and will be further expanded to 4000 km/12 mm in 2025. Along with the production expansion, SST also carries out researches extensively on tape customization and problem solving for specific application scenarios, covering laser slitting, stainless steel lamination, insulation coating, low resistance joints, continuous online thickness measurement techniques, and superconducting coil winding technologies, to help customers meet their technical requirements and achieve a successful project using SST's REBCO products. This paper will focus on the industrialization and R&D progress that SST has recently achieved.

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Presenter: Dr ZHU, Jiamin (Shanghai Superconductor Technology Co., Ltd.)

Session Classification: Wed-Mo-Or3 - REBCO Manufacturing

Contribution ID: **172** Type: **Poster**

Wed-Mo-Po.02-02: Performance limits of combined function magnets for a Muon Collider

Wednesday, July 2, 2025 9:15 AM (2 hours)

An International Muon Collider Collaboration (IMCC) has been formed following the recommendation of the Updated European Strategy for Particle Physics (ESPPU) to study the feasibility of a 10 TeV muon collider within a compact 10 km ring. This machine combines the precision of lepton colliders with the energy reach and discovery potential of hadron colliders, overcoming synchrotron radiation limitations affecting electron-positron machines. However, the short muon lifetime (2.2 μs at rest) presents several challenges in the development of magnets, RF systems, targets, shielding, and cooling. One of the main concerns is the flux of neutrinos originated by muon decay in the collider, which calls for the need of minimizing straight sections. This constraint makes conventional FoDo cells unsuitable, necessitating the development of combined function magnets that integrate bending and focusing/defocusing or chromaticity correction functions. To address these challenges, magnets capable of combining a dipole field with either a quadrupole field (B1+B2) or a sextupole field (B1+B3) are currently under study. This work extends the Aperture-Field (A-B) plot methodology, previously applied to single dipoles or quadrupoles, to dipole-quadrupole combined function magnets, delineating feasible designs based on aperture, field strength, mechanical stress, quench protection, and cost. Using a Python-ANSYS tool, optimized configurations were simulated under the sector coil approximation, focusing on ReBCO coils operating at 4.5K, 10K, and 20K, providing Dipole Field –Quadrupole Gradient (B-G) plots that illustrate the design space, highlighting the technological limits and feasibility of different dipole and quadrupole combinations.

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Session Classification: Wed-Mo-Po.02 - Muon Collider

Contribution ID: **173** Type: **Poster**

Fri-Af-Po.02-01: Enhanced Quench Stability of Coils Employing Defect-Tolerant REBCO Conductors

Friday, July 4, 2025 2:00 PM (2 hours)

High-temperature superconductors (HTS) are being implemented in magnets and coils for fusion energy, aviation, wind generators, high-energy physics, and nuclear magnetic resonance. HTS coils face a critical challenge for use in these applications: their inherently slow quench propagation velocity complicates quench detection and protection, raising concerns about operational safety and reliability. Addressing these issues demands advancements in coil stability and defect tolerance.

In this work, we have investigated the quench stability of HTS coils fabricated using defect-tolerant REBCO tapes. Notably, we have developed innovative tape architectures such as double-sided tapes and Slot 'n'Fill Tapes which incorporate slots within the insulating buffer stack that are filled with a conductive material. These new architectures enable efficient current-sharing with the substrate, significantly improving quench stability margins and enhancing the coil's tolerance to localized defects.

This work was funded by U.S. Naval Sea Systems Command Small Business Technology Transfer award N68335-23-C-0228 through AMPeers LLC.

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Session Classification: Fri-Af-Po.02 - Quench Detection and Protection III

Contribution ID: **174** Type: **Poster**

Thu-Mo-Po.08-02: An Ansys APDL Quench Suite

Thursday, July 3, 2025 8:45 AM (2 hours)

The simulation of quench dynamics in superconducting magnets is crucial for understanding their thermal and electromagnetic behavior under fault conditions. From a numerical simulation point of view, this is a challenging multiphysics problem involving thermal, electrical and magnetic phenomena. This article presents an advanced application based on ANSYS APDL program developed to simulate the quench behavior of superconducting magnets, able to accommodate several geometries, including cos-theta, canted cos-theta, and solenoid configurations, providing a versatile tool for various applications.
While temperature-dependent material properties are commonly modelled in ANSYS, our simulation framework allows for the consideration of magnetic field-dependent material properties in the cable, such as magnetoresistivity and the superconducting critical temperature during the transient.
A key feature of the program is its ability to account for eddy current effects arising from AC transient phases (e.g. the current charge and discharge), allowing the simulation of quench-back phenomena in metal-insulated magnets and large detector magnets. Comparison between our tool and analytical evaluation will be made, exploiting the capability of our suite to support both adiabatic conditions and helium cooling.

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Session Classification: Thu-Mo-Po.08 - Quench Modelling and Detection

Contribution ID: **175** Type: **Poster**

Wed-Mo-Po.02-03: Update on the Preliminary Electromagnetic and Mechanical Design of the Block-Coil Dipole for the Muon Collider Ring

Wednesday, July 2, 2025 9:15 AM (2 hours)

Within the framework of the International Muon Collider Collaboration (IMCC), a feasibility study is underway to develop the proposed 10 km collider ring, aimed at achieving a center-of-mass energy of 10 TeV. The stringent requirements to maximize luminosity and shield decay products of muons - characterized by only 2.2 μs lifetime at rest - necessitate the design of compact, high-field, and large-aperture superconducting magnets. These ambitious specifications present substantial technological challenges from both physical and engineering perspectives, pointing the importance of using ReBCO high-temperature superconductors (HTS) as the primary conductor material. These operating conditions call for the development and exploration of advanced methodologies to address multiple aspects of the system's design and operation. Key considerations include cooling strategies, quench protection mechanisms, AC losses mitigation, mechanical structure integrity, and the integration of effective internal shielding. This paper presents a preliminary 2D analysis of dipoles in a block-coil configuration, featuring an innovative stacked cable orientation and a novel end-winding concept. An updated electromagnetic design with a bore field of 16 T in a 140 mm aperture diameter is introduced, accompanied by an analytical estimation of hysteretic losses, accounting for transport current effects. Additionally, a preliminary mechanical design is provided using finite element analysis (FEM) via ANSYS software, employing a stress-management strategy to address the high Lorentz forces.

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Session Classification: Wed-Mo-Po.02 - Muon Collider

Contribution ID: **176** Type: **Invited Oral**

Wed-Mo-Or1-05: [Invited] Engineering Design and Status of the LTS Magnets for Next Generation Compact Fusion Reactor in China

Wednesday, July 2, 2025 12:15 PM (30 minutes)

In the past few years, with the continuous improvement of the performance requirements for superconducting magnets in future compact fusion devices, China has been committed to the design and manufacture of superconducting magnets. At present, the comprehensive design of low temperature superconducting (LTS) magnets for next generation fusion reactors in China has been finalized, encompassing toroidal field (TF) and poloidal field (PF) components. And the coil winding and insulation VPI technology have been developed. In terms of overall design, the TF magnet system has a total of 16 coils, the high-field and low-field coils are wound with CICC conductor prepared with high-Jc-Nb3Sn and ITER Nb3Sn, respectively. Its operating current is 55 kA/turn and inductance is 7.5 H. The PF coils are wound with CICC conductor prepared with ITER Nb3Sn/NbTi, with a maximum operating current of 52.86 kA/turn and a maximum inductance of 1.2 H. According to electromagnetic analysis, the magnetic field at the center of the plasma (@R=3.6 m) is 6.15 T, the maximum magnetic field in TF coil region is about 13.5T. The overturning moment and maximum stress of the TF are 62 MN·m and 850 MPa. Under the condition of 7 MA plasma current, the highest magnetic field of PF magnets is 11.1 T and the maximum stress of PF coil jacket is 498 MPa. The thermal-hydraulic analyses based on the influence of nuclear heat, AC loss, and conduction heat under various working conditions have also been completed. The temperature margin is higher than 1.64 K under all plasma scenarios, which meets the design requirements. At present, the winding, heat treatment, jacket, insulation VPI, and internal joints of TF dummy coil have all been completed, which also met the design requirements. The PF5-7 coils are being wound and are projected to be completed in the first half of 2025. Regarding the overall assembly of superconducting magnet system, the installation scheme design of TF magnets and PF magnets has been completed. The above works will contribute to the construction of Burning Plasma Experimental Superconducting Tokamak (BEST) in China.

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Session Classification: Wed-Mo-Or1 - Future Fusion Devices: Tokamaks

Contribution ID: **177** Type: **Poster**

Wed-Mo-Po.01-04: Design of Superconducting Quadrupole Magnets for a High Rigidity Spectrometer at FRIB

Wednesday, July 2, 2025 9:15 AM (2 hours)

With an enhanced magnetic rigidity of 8Tm, the High Rigidity Spectrometer (HRS), is proposed to enhance the scientific reach at the Facility for Rare Isotope Beams (FRIB). The HRS consists of High Transmission Beam Line (HBTL) section and Spectrometer Section (SPS). Lawrence Berkeley National Laboratory (LBNL) is responsible for designing the two large aperture quadrupole magnets, QSA and QSB in the SPS section. For QSB, it provides the quadrupole field up to 5.25T/m with the radius of aperture of 0.40m; Additionally, it includes sextupole and octupole coils with the fields up to 4.73T/m^2 and 8.61T/m^3 to tune the beam. The high order non-uniformity of quadrupole is required to be less than 1%. The quadrupole and high order corrector coils are independently-powered. The interaction between the quadrupole and the other coils significantly affects the magnetic forces to cover entire operation ranges. In this paper, we describe the magnet specification and a conceptual design with 2D and 3D magnetic and mechanical analysis, conductor selection, coil fabrication and magnet cold mass assembly plan, and quench analysis.

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Presenter: YANG, Ye

Session Classification: Wed-Mo-Po.01 - Accelerator Magnets I

Contribution ID: **178** Type: **Plenary**

Sun-Mo-PL1-04: Magnetic levitation systems with HTS 2G tapes: the newest developments and future perspectives

Sunday, July 6, 2025 11:00 AM (10 minutes)

The use of high temperature superconductors (HTS) in magnetic levitation (Maglev) has been investigated for decades. Superconducting materials may be used in both the propulsion and levitation subsystems of a device. For the propulsion subsystem, their use in electric machinery potentially reduces losses and increases the power to volume or mass ratio. For the levitation subsystems, they are part of passive magnetic bearings, with both linear and rotational movement, depending on the application. One of the most successful areas of application is transportation. Several magnetic levitation vehicles have been built and fully implemented, sometimes to full scale. The preferred material of choice for these systems were HTS bulks. In the last decade, however, there has been an increased interest in HTS second generation (2G) tapes for many applications of superconductors, such as electric machinery, cables, fault current limiters, and, of course, Maglev systems. These tapes are regarded as being more uniform and of having better thermal and mechanical characteristics than bulks while also showing higher force to volume ratio when applied to levitation. In this work, the use of HTS 2G tapes in magnetic levitation, especially to those applied to transportation systems, is discussed. Advantages and disadvantages of this application, as well as the current trends and future perspectives, are presented and examined.

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Session Classification: Plenary 1: Young Scientist Plenary

Contribution ID: **179** Type: **Contributed Oral**

Sat-Af-Or4-08: Effect of the Filament Diameter Size on the Hysteresis Loss of Nb3Sn Wires

Saturday, July 5, 2025 6:15 PM (15 minutes)

Commercially available Nb_3Sn wires with high critical current density are commonly used to manufacture high-field magnets (greater than 10T). To improve their current-carrying capacity, various types of Nb_3Sn wires have been developed. However, as the critical current increases, drawing the Nb_3Sn wire becomes more difficult, leading to larger filament sizes (on the order of hundreds of microns). This can result in flux jumps and high AC losses. Therefore, it is essential to study the impact of filament size on hysteresis loss in Nb_3Sn wires for the effective production of high-field magnets. In this study, we processed various samples with different diameters to produce Nb_3Sn filaments of varying sizes after heat treatment. The hysteresis loops of the Nb_3Sn wire samples were measured at different conditions, and the effect of filament size on flux jumps was investigated to determine the critical filament dimension that avoids flux jumps. Hysteresis loss was calculated from the hysteresis loop data, showing that smaller Nb_3Sn filaments exhibit lower hysteresis losses. However, for micron-level filament samples, reducing filament size becomes increasingly difficult due to filament coupling.

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Session Classification: Sat-Af-Or4 - Advances in Nb3Sn and MgB2 Conductors II

Contribution ID: **180** Type: **Poster**

Sat-Mo-Po.08-02: Significance of corrosion phenomena for accelerator and fusion magnets

Saturday, July 5, 2025 9:30 AM (1h 45m)

Although superconducting accelerator and fusion magnets operate at cryogenic temperature and in most cryogenic applications corrosion is not an issue, it is essential to avoid corrosion phenomena that may occur during production and fabrication of parts and components of magnet systems, or during their installation, assembly or maintenance. A delayed leak or a structural failure that would arise in operation due to onset of corrosion phenomena at an earlier stage could lead to grave consequences due to many such components becoming embedded and virtually unrepairable. Therefore, corrosion prevention is of paramount importance in all the phases of a project involving superconducting magnets and their vacuum systems, including during storage of components or assemblies before their final commissioning and operation, in order to minimise the associated risks and guarantee their reliability over time.

The return from decades of experience in assessing and investigating magnet components and ancillaries, and in analysing their failures is presented, showing the relevance and variety of corrosion phenomena that may affect magnet systems of accelerators, high energy physics experiments and fusion devices and their ancillaries. Through the examples and the failure analyses provided, the paper discusses the most relevant corrosion mechanisms, their prevention and applicable remediation actions. The identification of their causes can allow restrictions to be introduced in due time to the fabrication, joining and testing procedures that can be crucial in preventing and minimising corrosion damage, either immediate or delayed, and thus contribute to the future reliable operation of the magnet and associated cryogenic and vacuum systems.

"The views and opinions expressed herein do not necessarily reflect those of the ITER Organization."

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Session Classification: Sat-Mo-Po.08 - Structural and Insulation Materials

Contribution ID: **181** Type: **Contributed Oral**

Fri-Mo-Or1-04: Quench Protection for a Four-Layer Nb3Sn Cos-Theta Dipole in the CERN High Field Magnet R&D Program

Friday, July 4, 2025 8:45 AM (15 minutes)

The High Field Magnet (HFM) R&D program at CERN aims to find technological solutions for the construction of accelerator magnets to be installed in future post-LHC colliders. The Italian Institute of Nuclear Physics (INFN) and CERN are collaborating to design and fabricate a new four-layer Nb3Sn cos-theta dipole able to achieve a bore field of 14 T with at least 20% of margin on the loadline. The magnet will be fabricated as a short model to demonstrate the feasibility of the technology, but the engineering solutions are thought to be adopted to a longer version as well, in view of the production of a full prototype ready to be installed in an accelerator. One of the main challenges of the long Nb3Sn accelerator magnets is the quench protection system. Usually, the high energy density cannot be extracted with standard solutions, therefore the quench protection system must be optimized properly considering all the fault scenarios.

In this paper, we describe different options for quench protection systems for the short model design, considering the impact of extrapolating the results for a longer version of the magnet. The efficiency of the protection systems presented will be discussed, considering the safe values for hot spot temperature and voltages chosen for this magnet.

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Session Classification: Fri-Mo-Or1 - Development and Testing Towards High Field Accelerator Magnets

Contribution ID: **182** Type: **Contributed Oral**

Wed-Mo-Or1-03: The STEP magnetic cage –latest concept development

Wednesday, July 2, 2025 11:45 AM (15 minutes)

The Spherical Tokamak for Energy Production (STEP) is the United Kingdom's next-generation publicly funded fusion power plant prototype, aiming to export 100 MW of electrical power to the grid. For all magnets, the basic requirements imposed by the plasma and the spatial constraints are provided, as well as the anticipated modes of operation where applicable. Then, the most up-to-date concept design for each system is shown. It is illustrated by presenting relevant results of electromagnetic, thermohydraulic, structural, and quench protection analysis conducted using COMSOL, Quanscient Allsolve, ANSYS, and Python-based in-house algorithms.

STEP's preferred maintenance strategy directs that the TF magnets centre column must be lifted in and out of place remotely in-situ, which heavily restricts its geometry and winding pack design. In relation to this, several of the PF coils and the CS must be manufactured around the completed TF centre column. Also, the large stored energy in the TF poses a significant challenge for quench protection especially when considering the expected voltage limitations. This work also details the endeavour to address these and other challenges so that the existing baseline design can be refined.

At the end, an overview of the future steps in concept design is given against the backdrop of the STEP delivery schedule.

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Session Classification: Wed-Mo-Or1 - Future Fusion Devices: Tokamaks

Contribution ID: **183** Type: **Poster**

Wed-Af-Po.10-03: Critical Current Test and Mechanical Behavior Analysis of Rutherford Cable Fabricated by HTS Quasi-Isotropic Strands

Wednesday, July 2, 2025 2:30 PM (2 hours)

A design of a Rutherford cable (Rfc) consisting of a copper core and 10 Quasi-isotropic Strands with symmetrical geometry has been proposed. In this paper, a preliminary sample of the Rfc is fabricated by partially-filled Q-ISs. The cable sample's self-field critical current and critical current dependence on the magnitude and orientations of the magnetic field are measured in liquid nitrogen. Then, a mathematical geometry method rapidly establishes the cable's three-dimensional (3D) model, which considers the strand number, the cable core's thickness, the cable's twist pitch, and the strand's laying angle. Based on the 3D model, to analyze the mechanical behavior of the proposed cable, the simulations of the flat Rfc under bending loads are implemented by the finite element method (FEM). The measurement results and analysis show that the proposed Rfc is a potential and prospective solution for high-current superconducting cables in power transmissions and large-scale magnets with a high magnetic field.

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Session Classification: Wed-Af-Po.10 - Development and Test of Conductors for Fusion Magnets II

Contribution ID: **184** Type: **Contributed Oral**

Sat-Mo-Or2-04: A Parametric and Multi-physics Workflow for the Design of High-Field Magnets for optimized Stellarators

Saturday, July 5, 2025 9:00 AM (15 minutes)

A candidate of fusion reactor using magnetic confinement is the stellarator, which has an inherently steady-state nature. Among the various stellarator types, the optimized stellarator represents a promising topology. One challenge is the complex coil shapes required to create the necessary magnetic field to confine the plasma. As the achievable fusion power increases with the strength of the magnetic field, it is also of importance to scale up the magnetic field for the next generation of stellarators.
This work presents a parametric approach for the magneto-static and mechanical analysis of stellarator coils, considering a 13 T peak-field, based on Nb3Sn or 18-20 T peak-field, based on HTS in the winding pack. In the mechanical simulation, the stresses and strains of coil cases and the support structure are investigated and evaluated. In addition, a thermal-hydraulic simulation for the winding pack is performed, which includes the steady state analysis and the determination of the hotspot temperature during a quench. An exemplary winding pack design for the LTS and HTS option is illustrated and analyzed with the finite element method (FEM).
The complex and non-planar 3D geometry is one of the stellarator-specific difficulties for the design. Given the existence of various stellarator configurations, the development of a parametric tool for magnetic design would significantly accelerate the overall stellarator design process and its evaluation.
The parametric tool has been benchmarked with former analysis for the HELIAS configuration, which shows a good agreement. Furthermore, its applicability to another stellarator configurations is illustrated and analyzed. We discuss and evaluate the magnet design of high field stellarators based on the HELIAS configuration and point out possible challenges/risks.

Acknowledgement
This work has been carried out within the framework of the EUROfusion Consortium, partially funded by the European Union via the Euratom Research and Training Programme (Grant Agreement No 101052200 —EUROfusion). The Swiss contribution to this work has been funded by the Swiss State Secretariat for Education, Research and Innovation (SERI). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union, the European Commission or SERI. Neither the European Union nor the European Commission nor SERI can be held responsible for them.

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Session Classification: Sat-Mo-Or2 - Fusion Devices: Stellarators and Levitated Dipoles

Contribution ID: **185** Type: **Contributed Oral**

Sat-Af-Or1-03: Progress on the EDIPO 2 test facility

Saturday, July 5, 2025 2:45 PM (15 minutes)

Over the past two decades, the SULTAN test facility at EPFL-SPC has qualified superconductors for all major superconducting fusion facilities worldwide. However, the increasing demand for higher field and higher current conductors—partly driven by the development of High Temperature Superconductors —requires testing capabilities beyond those of SULTAN (limited to a background field of ≤11 T and a sample current of ≤100 kA). In this context, the EDIPO2 test facility will significantly enhance the testing capabilities at EPFL-SPC to align with the requirements of the new generation of superconducting samples. Key improvements include a new magnet capable of generating a 15 T background field, an enlarged aperture, and a superconducting transformer designed for testing samples beyond 100 kA. In recent years, EPFL-SPC has developed the conceptual design for the EDIPO2 magnet which relies only on planar racetrack coils wound with a flat two-stage cable. Efforts in 2025 will focus on procuring the required superconducting strand, producing a prototype Nb3Sn cable, conducting technological R&D for coil manufacturing, and initiating the engineering design of the magnet and the upgraded transformer. This contribution will report on the status of these activities.

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Session Classification: Sat-Af-Or1 - Fusion Test Facilities

Contribution ID: **186** Type: **Contributed Oral**

Sun-Mo-Or1-03: The SupraFusion French Research Program: Development of HTS technologies for Fusion and wide societal applications

Sunday, July 6, 2025 8:45 AM (15 minutes)

The French government has recently launched the SupraFusion Research Program lead by CEA and CNRS with the partnership of multiple other national laboratories and universities. This national program has been granted 50 M€ in order to boost the development of HTS superconductors technology towards large societal applications, using the vector of nuclear fusion as a powerful driver for this research and innovation. In order to achieve this goal the SupraFusion Progam has been built around five technological bricks covering the whole life cycle of the technology. The first brick aims to the large characterization and modelling of REBCO tapes allowing magnet designs and qualification with confidence. The second one targets to the development of high current & high field conductors matching the main constraints and performances needed by the magnets. The third brick will deeply study HTS coils quench protection and propose new technological solutions to ensure magnets safety. The fourth aims to design, manufacture and test in nominal conditions a large-scale demonstrator achieving about 20 T and 100 MJ of stored energy to prove this technology viability for fusion and other large-scale applications. The fifth brick will propose designs for future HTS compact fusion machines towards energy production. Finally, in order to wider spread HTS technology potential into society, this large national program will also launch opens calls to support studies or projects targeting the use of HTS technology in other societal applications that could be MRI, wind generators, motors, high energy physics, etc. This paper will present the French SupraFusion scientific program, its strategic road map and the first main achievements.

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Session Classification: Sun-Mo-Or1 - Technology for Fusion Reactors II

Contribution ID: **187** Type: **Poster**

Sat-Mo-Po.03-03: Mechanical 3D Modelling of the EDIPO2 Magnet

Saturday, July 5, 2025 9:30 AM (1h 45m)

The magnet at the core of the EDIPO2 test facility aims at generating a 15 T background field within a 144×144 mm² aperture and maintaining a field homogeneity length of 900 mm (assuming a 1% drop of the field). Its design features two pairs of flat racetrack coils: one pair (vertical coils) located above and below the aperture, and another pair (side coils) located on its sides. All coils are wound using the same flat two-stage Nb_3Sn cable. The advantage of the proposed magnet layout is its simplicity compared to flared-end designs. Even though this flat-racetrack-coil design requires a larger cross-section of superconductor to generate the same magnetic field, it eliminates 3D transitions at the coil ends, simplifying both manufacturing and assembly. In the proposed design, the coils are assembled in a steel housing. The final assembly of coils and yoke is enclosed inside a 30-mm-thick stainless-steel shell. Independent axial support is provided by large end plates and three pairs of longitudinal rods. Significant lateral and axial preload is applied to the vertical coils, which generate most of the magnetic field in the aperture. However, no preload is applied to the side coils. The mechanical design of the magnet will be justified with 3D finite element models to evaluate the mechanical stress and strain in the coils and the magnet structural components.

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Session Classification: Sat-Mo-Po.03 - Mechanics of Fusion Magnets

Contribution ID: **188** Type: **Contributed Oral**

Fri-Mo-Or1-05: Coil Manufacturing and Assembly of R2D2, the Research Racetrack Dipole Demonstrator

Friday, July 4, 2025 9:00 AM (15 minutes)

CEA Paris-Saclay is developing, in collaboration with CERN, the R2D2 (Research Racetrack Dipole Demonstrator) magnet. The main goal is to demonstrate the feasibility of key technologies for future high field 16 T Nb_3Sn magnets for particle colliders. On one hand, the coil manufacturing has been finalized and four coils have been produced. First, two practice coils have been manufactured, following all the steps representative of a real coil (winding, heat treatment, impregnation, instrumentation, electrical tests and geometrical measurements). One coil used Cu dummy cables and allowed to validate the infrastructure, the tooling and the manufacturing procedures. Another coil used the Nb_3Sn nominal cables and allowed quantifying the behavior during the reaction of Nb_3Sn conductors. The dilatations and contractions observed were compared and validated with measurements on cable-stacks and subscale coils. The practice coils have been cut for analysis and to validate the quality of the manufacturing. In addition, two Nb_3Sn series coils have been manufactured, and are ready for an assembly in the mechanical structure. In parallel, the mechanical structure has been procured, and a first assembly has been performed using an Al dummy coil block. The structure followed a procedure similar to the final magnet assembly: the magnet has been pre-loaded to the final target, and then cooled-down in liquid nitrogen to simulate the cool-down in liquid helium. During these loading steps, the stresses have been monitored using strain gauges mounted on the structure and on the Al dummy coil block, and compared with the Finite-Elements models. This allowed the validation of the mechanical behavior of the structure in representative conditions. The magnet is now ready to be assembled with two Nb_3Sn coils for a first performance test in liquid helium at CERN. An overall update of the project status will be given, and the next steps will be presented.

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Session Classification: Fri-Mo-Or1 - Development and Testing Towards High Field Accelerator Magnets

Contribution ID: **189** Type: **Poster**

Wed-Af-Po.05-06: Electron microscopy investigation of cracks in REBCO tapes by bending and uniaxial tension

Wednesday, July 2, 2025 2:30 PM (2 hours)

There have been increased interests in REBCO Coated Conductor (CC) in applications such as ultra-high field user magnets as well as magnets for nuclear fusion and high energy physics. The CC tape has good tensile strength in longitudinal direction thanks to its high strength substrate Hastelloy. In ultrahigh field magnets, however, the CC tape could experience electromagnetic stress exceeds the irreversible stress limit, at which point the microcracks are formed and critical current (Ic) is significantly degraded leading to the failure of the magnets. Therefore, the irreversible stress limit of CC is one of the most important properties in applications. There had been intensive studies on Ic versus uniaxial stress of CC. However, the microstructural origin of the Ic degradation of the CC tape is still elusive.
In this work, we report the observation of the cracks resulted from either bending or uniaxial tension in the longitudinal direction by scanning electron microscopy (SEM), transmission electron microscopy (TEM), and scanning transmission electron microscopy (STEM). In particular, the location of the crack initiation will be investigated by TEM at atomic scales. The effect of substrate yielding on the crack formation will be discussed.

Acknowledgement
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Session Classification: Wed-Af-Po.05 - HTS Conductors II

Contribution ID: **190** Type: **Poster**

Sat-Mo-Po.03-04: Electromagnetic and mechanical analyses of an explorative HTS-based central solenoid for the DTT Tokamak

Saturday, July 5, 2025 9:30 AM (1h 45m)

This work investigates the potential advantages of using a High-Temperature Superconducting (HTS) Central Solenoid (CS) in the Divertor Tokamak Test (DTT), an Italian nuclear fusion project based in Frascati, Italy, aiming to complete its engineering design phase by 2025 and construction by 2031. To sustain sufficiently long plasma discharges, the project requires a high-performing CS capable of partially balancing resistive and inductive losses through the poloidal magnetic flux it induces. The objective of this study is to quantify the improvements in induced poloidal magnetic flux achievable with a ReBCO VIPER-like HTS-CS, instead of the Low-Temperature Superconducting (LTS) configuration currently proposed.

The analysis evaluates the electromagnetic and mechanical performances of a conceptual HTS-based CS. The design optimizes the cable layout and turn distribution to ensure manageable conductor currents while avoiding excessive mechanical and thermal loads. Electromagnetic simulations, based on two-dimensional axisymmetric static plasma equilibrium models, are developed achieving a gain in terms of poloidal magnetic flux, enabling longer plasma discharges.

The mechanical behaviour of the CS is assessed through a preliminary equivalent elastic model derived by homogenizing detailed conductor components, including copper/ReBCO sections, cooling channels, stainless steel jackets, and insulation. A subsequent mechanical analysis of the equivalent CS stack identifies the most stressed module under Lorentz forces and precompression, allowing an accurate evaluation of displacements and stresses by incorporating orthotropic insulation properties and contact interfaces. These results confirm compliance with ITER mechanical standards and validate the structural reliability of the HTS-CS under operational conditions.

Thermal performance of the conductors is optimized by refining the copper cross-section of the ReBCO VIPER-like conductors through a power balance model, which accounts for Joule heating and thermal dissipation. Hotspot temperature simulations for quench prediction, considering the thermal and electrical properties of the materials, demonstrate rapid stabilization and efficient heat dissipation, ensuring the system's safety and reliability during transient events.

This integrated analysis suggests that HTS technology could offer advantages in terms of electromechanical performances and thermal stability, highlighting the potential of HTS-based configurations for high-field tokamak applications, and potentially contributing to the development of more efficient and resilient fusion devices.

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Session Classification: Sat-Mo-Po.03 - Mechanics of Fusion Magnets

Contribution ID: **191** Type: **Contributed Oral**

Wed-Af-Or2-02: Pyrolytic graphite: an effective solution for optimizing turn-to-turn resistivity and thermal conductivity in high-temperature superconducting coils

Wednesday, July 2, 2025 4:45 PM (15 minutes)

The no-insulation technique in high-temperature superconducting (HTS) coils has significantly advanced HTS magnet technology by introducing an innovative approach to protection. This technique allows current redistribution between adjacent turns, enabling self-protection of the coils. However, it also introduces charging delays. To reduce the charging delay while maintaining self-protection capability, partial insulation and metal-insulation methods have been proposed. These approaches involve adding materials between coil windings to optimize the turn-to-turn electrical resistivity and the overall thermal conductivity.

In this contribution, we demonstrate that integrating pyrolytic graphite between coil windings is a promising approach to achieving turn-to-turn electrical resistivity values comparable to those obtained by competing technologies, such as the metal insulation technique. Furthermore, we show that pyrolytic graphite exhibits exceptional thermal conductivity, surpassing that of copper at temperatures higher than 30 K and exceeds it by nearly an order of magnitude above 80 K. Finally, we present results on the charging times of coils fabricated using HTS tapes co-wound with pyrolytic graphite layers of thicknesses ranging from 70 to 200 micrometers, along with measurements of their overall thermal stability.

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Session Classification: Wed-Af-Or2 - No-Insulation Coils II

Contribution ID: **192** Type: **Poster**

Wed-Mo-Po.02-08: Winding Challenges and Solutions in the INFN Falcon Dipole Project

Wednesday, July 2, 2025 9:15 AM (2 hours)

The Falcon Dipole is a project led by the Italian Institute of Nuclear Physics (INFN) which aims to fabricate a 12 T short model of a Nb3Sn cos-theta accelerator dipole as part of the High Field Magnet (HFM) R&D program at CERN. The status of the project is at the fabrication step of the first dummy coil in the industry and, in this paper, we present the results of the first campaign of winding tests in the industry.
The winding process for the Falcon Dipole is challenging because the size of the Rutherford Cable used for the coils is comparable to the bore radius. This results in high bending and torsion stresses, making the cable structure unstable. To address these challenges, the previous 3D model has been modified to improve the winding feasibility. The setup has been prepared to monitor technical parameters that will help in modeling the coil geometry and identify sources of critical issues. In this paper, we present the results of the winding campaign and discuss the proposed changes to the coil end design to address the issues that arose.

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Session Classification: Wed-Mo-Po.02 - Muon Collider

Contribution ID: **193** Type: **Contributed Oral**

Wed-Af-Or1-03: Metal as Insulation REBCO racetracks coils: development, fabrication, and cryogenics testing at CEA Paris-Saclay

Wednesday, July 2, 2025 5:00 PM (15 minutes)

High Temperature Superconductors (HTS) offer significant potential for very high field dipole. We started the development of REBCO-insulated dipole magnetsin 2010 with EUCARD and EUCARD2 programs. CEA Paris-Saclay then chose to apply the Metal-as-Insulation (MI) REBCO winding, originally developed in the 32.5 T solenoid insert project NOUGAT, the design, fabrication and tests of HTS high field dipoles. These new developments started in 2023 through the support of a CERN-CEA collaboration in the framework of High Field Magnet (HFM) CERN program. It is the first step toward a 14 T+ HTS dipole magnet for accelerator machines.
The development strategy is to start with small and simple coils to validate the numerical design models, and then increase gradually the complexity and risks. In this regard, we began by modelling and studying the racetrack coil shape. This configuration offers the advantages of planar winding and therefore does not require hardway bending. This kind of geometry is therefore easily transferable from the pancake solenoid coils. The MI approach is also well suited for testing models limits because it allows for very compact coils. Additionally, despite the higher complexity of numerical models, MI coils present lower degradation risks compared to its insulated counterpart during testing. Over the past two years, we focused on developing the tools for making MI racetrack coils. This includes numerical tools for MI racetrack coils design, as well as tooling, and winding procedures. We have also focused on the design of mechanical structures, including the cooling aspects, the stresses management, and the assembly of multi racetracks coils. Recently, we fabricated and tested the first two mockup racetracks coils in 140 mm and 600 mm straight part length versions With a 30 mm width mandrel. These tests were conducted in a self-field configuration, at liquid nitrogen temperature for both coil lengths and at liquid helium temperature only for the shortest coils.
After a brief description of the program's philosophy and strategy, this presentation will detail the design, fabrication, assembly and test of two racetracks. We will also discuss the lessons learned from measurements at current density above 1500 A/mm² and the results regarding the design and numerical evaluations. One major aspect is the high magnetization effect that can lead to a lower critical current than expected even for 4 mm-wide REBCO tape. This is due to very high local current densities and related magnetic stresses.

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Session Classification: Wed-Af-Or1 - HTS and Hybrid Magnets for Accelerators

Contribution ID: **194** Type: **Poster**

Fri-Af-Po.04-04: On-Site Progress and Challenges in ITER Feeder Joint Insulation Construction

Friday, July 4, 2025 2:00 PM (2 hours)

The ITER Feeder joints, as critical connections between the Feeders and the superconducting magnet system, play a vital role in ensuring the system's safety and stability. The on-site joint insulation process is a core task to meet design objectives and ensure operational reliability. Since the Feeder joint insulation work began in September 2022, significant progress has been made despite the challenges posed by complex working conditions and stringent quality requirements. To date, insulation and high-voltage testing for over 30 MB joints have been completed, while insulation work on 14 CB joints is ongoing. This paper focuses on the progress of Feeder joint insulation construction, the main challenges encountered, and the strategies adopted to address them. It also summarizes feedback and lessons learned, aiming to provide valuable references for similar future projects.

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Session Classification: Fri-Af-Po.04 - Supporting Technologies for Fusion Magnets II

Contribution ID: **195** Type: **Poster**

Wed-Mo-Po.11-01: Magnet-technology developments at the HLD pulsed-field facility

Wednesday, July 2, 2025 9:15 AM (2 hours)

The Dresden High Magnetic Field Laboratory (HLD) is a pulsed-field user facility, which provides external and in-house researchers with the possibility to perform a broad range of experiments in pulsed magnetic fields [1]. Being a member of the European Magnetic Field Laboratory (EMFL), HLD offers access and supports more than 100 scientific projects annually. At the HLD, a diverse set of high-resolution experimental techniques allows to measure, for example, electrical transport, magnetization, ultrasound, magnetostriction, magnetic resonance (ESR and NMR), permittivity, magnetocaloric effect, and high-field infrared spectroscopy in non-destructive pulsed magnetic fields. The Dresden High Magnetic Field Laboratory operates ten experimental cells equipped with a variety of pulsed magnets energized by two independent, modular capacitor banks with maximum stored energies of 50 and 14 MJ at 24 kV maximum operational voltage.
In addition to the pulsed-magnet designs for the needs of the HLD, we further develop pulsed magnets for other large-scale facilities, such as the European XFEL and the ESRF, with the goal of providing magnetic fields up to the 60 T range. Here, we discuss different approaches, advances, and challenges in the pulsed-magnet design for x-ray scattering experiments at large-scale facilities.
We acknowledge support provided by ISABEL, which has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 871106.

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Session Classification: Wed-Mo-Po.11 - High Field Pulsed Magnets I

Contribution ID: **197** Type: **Poster**

Sat-Mo-Po.01-03: The rake magnet: a novel configuration for a dual-plane scanning magnet for hadron therapy

Saturday, July 5, 2025 9:30 AM (1h 45m)

The EuroSIG project aims at designing a superconducting carbon ion gantry for hadron therapy that relies on the use of a scanning magnet system located downstream of the last bending dipole. This layout shifts the burden towards the scanning magnet system that must be compact enough not to impact the gantry radius and must rapidly deflect the beam over a large scanning area to fulfill the clinical requirements.
To face these challenges, we present a novel magnetic configuration for a dual-plane bending magnet called *rake*.
The basic principle of the rake magnet is a yoke with multiple slits perpendicular to the pole surface, large enough to host a series of coils surrounding the gap on the four sides. This layout avoids the increase of the gap due to the coil thickness, significantly increasing its efficiency in terms of stored energy, while maintaining the field quality within specifications.
Here we report the main features of the rake magnet, analytically exploring the differences with respect to more traditional magnetic configurations such as window-frame and cos-theta.
We present the 2D model of the magnet, highlighting the distinct behaviors in single- and double-plane. Further, we describe the algorithm that optimizes the slits' position and geometry to minimize the field deviation from the nominal value over the whole good field region.
Finally, we discuss the possibility of using tapered configurations - either acting on the yoke poles or on the geometry of the coils - and weigh the advantage of reducing the stored energy against the significant increase in complexity of the design and fabrication.

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Session Classification: Sat-Mo-Po.01 - Magnets for Other Medical Application II

Contribution ID: **198** Type: **Poster**

Wed-Af-Po.11-05: AC losses of scaled HTS TF magnets under various magnetic fields

Wednesday, July 2, 2025 2:30 PM (2 hours)

High-temperature superconductor (HTS) magnets are gaining attention for their vital position of compact, high-field tokamaks, helping speed up the path to fusion energy. In future commercial nuclear fusion plants, steady-state operations lasting several months will be required. One of the main challenges for steady-state operation is the instability of plasma confinement, which can be reduced by imposing large and stable localized magnetic fields. 2nd generation HTS have been proven to maintain over 10^3 A/mm^{2}critical current density to provide over 20 T magnetic field in TF (toroidal field) magnet. However, various factors can generate external fields which cause instability of the TF magnet, including the current ripple of the power supply, the plasma torus and the CS coil pulse. These instabilities will not only cause magnetic field fluctuation, but also lead to heat dissipation and low energy efficiency.
This research aims to fill this gap. We build 3D FEM (Finite Element Method) numerical models of the HTS TF magnet using H-formulation and T-A formulation. Parametric studies are conducted using this model in COMSOL aligned with the 'PROCESS'code developed by UKAEA. With the optimal parametric study result, we wind a double pancake D-shape magnet to measure the loss under AC (alternating currents), DC (direct current) external magnetic fields, and AC external magnetic fields respectively. This research contributes to the steady-state, continuous power generation of future commercial fusion reactors by reducing the AC losses of the HTS TF magnet, thereby increasing the stability of the reactor.

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Session Classification: Wed-Af-Po.11 - Modelling of Fusion Conductors and Coils I

Contribution ID: **199** Type: **Invited Poster**

Wed-Af-Po.08-07: [Invited] Distributed deformation monitoring of canted cosθ dipole high-temperature superconducting magnet using fiber optic

Wednesday, July 2, 2025 2:30 PM (2 hours)

High-temperature superconductors (e.g., REBCO) are key to developing high-field magnets for next-generation high-energy circular colliders and compact fusion reactors. The U.S. Magnet Development Program, in collaboration with industry, is advancing REBCO magnet technology through multi-tape CORC® wires. Conventional sensors (strain gauges and voltage taps) are becoming insufficient to provide the full strain distribution or precise localization of resistive transitions, limiting insights into the magnet performance. This work implements single-mode optical fibers for distributed fiber optic sensing (DFOS), enabling continuous strain measurements along a six-layer, 40-turn canted cosθ dipole magnet using high-temperature superconducting CORC® wires. Tests conducted at 77 K and 4.2 K, on both individual layers and the assembled coil, revealed coil deformation under mechanical and thermal loads, along with potential resistive transition locations. The optical fiber layout and installation were optimized to cover sensing distances of up to 45 m at cryogenic temperatures. The result demonstrates the feasibility of DFOS for detecting strain distributions along the coil during operation. The result also shows hysteresis behaviors and a linear correlation between Lorentz force and strain, allowing identification of resistive transition sites. This approach offers a practical method for monitoring larger magnet systems and may facilitate early detection of thermal runaway in high-temperature superconducting magnets.

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Session Classification: Wed-Af-Po.08 - Conductor and Coil Measurement/Test Techniques and Facilities I

Contribution ID: **200** Type: **Contributed Oral**

Sat-Af-Or2-03: Design of dual- and triple-coil magnets at the Dresden High Magnetic Field Laboratory

Saturday, July 5, 2025 2:30 PM (15 minutes)

The Dresden High Magnetic Field Laboratory (HLD), a member of the European Magnetic Field Laboratory (EMFL), is a pulsed-field user facility that allows external and internal researchers to perform a wide range of experiments in pulsed magnetic fields [1]. Taking advantage of two independent, modular 50 and 14 MJ capacitor banks with charging voltages up to 24 kV, we operate a large variety of non-destructive pulsed magnets with a wide range of technical specifications, such as peak field, magnet-bore diameter, pulse duration, and cooling time. All our pulsed magnets are designed and manufactured at the HLD. Some of them are specially tailored for specific, advanced experimental techniques to ensure optimal scientific outcome. Furthermore, within our magnet-technology developments, we pay special attention to magnet reliability, low noise levels, and magnet longevity.
Specifically for the magnetic field range above 90 T, which is challenging to achieve with monocoil magnets, we have developed 9 MJ dual-coil and 27 MJ triple-coil non-destructive pulsed magnets, which are now in production. We report details of the design, including challenges, upgrades, and improvements, and our operating experience with the multi-coil prototypes at the HLD.
We acknowledge support provided by ISABEL, which has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 871106.

[1] http://www.hzdr.de/hld

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Session Classification: Sat-Af-Or2 - Progress in Ultra High Field Solenoids

Contribution ID: **201** Type: **Poster**

Thu-Mo-Po.08-03: Calibration of numerical simulations of hot spot generation in regular and CFD REBCO tapes based on electrical measurements

Thursday, July 3, 2025 8:45 AM (2 hours)

Quench detection and protection of high-temperature superconductor (HTS) magnets remain a challenge. Even if the enthalpy margin of HTS conductors is two to three orders of magnitude than low-temperature superconductors (LTS) conductors, a normal zone can be induced by local critical current inhomogeneities or sudden heat load. Because of the high enthalpy and current margins of HTS magnets, the normal zone propagation velocity (NZPV) is low, making it difficult to detect a local quench. A higher NZPV is expected to facilitate quench detection.

In the last years, it has been demonstrated that the NZPV in REBCO tapes can be enhanced by at least one order of magnitude with the current flow diverter (CFD) concept. The CFD concept relies on increasing the current transfer length (CTL) between the superconducting layer and the stabilizer by inserting a patterned electrical resistance between the REBCO layer and the stabilizer or by using the buffer layers between the REBCO layer and the substrate. This increase of the CTL results directly in an increase of the NZPV.

To properly design quench detection systems, it is useful to understand the physics behind the formation of a normal zone in REBCO tapes and to develop numerical simulation models that predict accurately the quench behavior. This requires performing experiments to calibrate the models. In this work, the voltages generated by a hot spot in commercial and CFD REBCO tapes were measured. The measurements consisted in applying a constant current until a voltage threshold was reached, triggering an exponential decay of the current. Voltage thresholds were varied between 5 mV and 20 mV while the discharge time constant was set to 11 ms. The experiments were done in a bath of liquid nitrogen at ambient pressure (77 K). A NdFeB magnet was used to reduce locally the critical current by approximately a factor of 2.

The samples consisted in modified commercial REBCO tapes from SuperPower. The base samples were 10 cm long and 4 mm wide, including a 50 microns thick Hastelloy substrate and a 2.5 microns thick silver layer. From these base samples, two different architectures of REBCO tapes were fabricated. The first architecture, called "regular"tape, consisted in adding a 2.5 microns thick copper layer on both side of the sample, for a total of 5 microns of copper. The second architecture, called "CFD"tape, was first modified to include a highly resistive patterned layer (CFD layer) between the superconducting and the silver layer. Then, a 5 microns thick copper layer was deposited on the substrate side only.

In all experiments, for the same applied current, the threshold voltage was always reached faster with the CFD tape. Furthermore, in the case of the CFD tape, once current sharing between the superconducting and silver layers has started, a rapid and strong generation of voltage is observed, up to 50 times faster than in the regular tape. These results were used to calibrate the simulation models, in which an alternative to the traditional E-J power-law model for REBCO resistivity had to be implemented to obtain accurate results. Furthermore, these experiments demonstrated the need to consider magnetic diffusion effects in the calculations during the quench of CFD tapes.

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Session Classification: Thu-Mo-Po.08 - Quench Modelling and Detection

Contribution ID: **202** Type: **Poster**

Fri-Af-Po.04-03: Installation Progress and lesson learned of Feeder Joint Assembly on ITER site

Friday, July 4, 2025 2:00 PM (2 hours)

Feeders, as key components located on the upper and bottom of ITER tokomak, provide power supply, cooling and signal measurement to ITER superconductive magnets (PF, TF and CC coils). The installation of Feeder joints consists of three major stages (joint assembly, joint insulation, mechanical installation) and hundreds of precise operations, and involves thorough planning, engineering, special process, qualification, challenging welding, etc. To date, a significant progress of ITER feeder joints installation has been made, including completion of the first CFT-CTB joint assembly, closure of the CFT-CTB connection of first superconductive joint. This paper will provide a brief overview of the recent progress of Feeder joint assembly, as well as some critical process, challenges and lesson learned in construction.

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Session Classification: Fri-Af-Po.04 - Supporting Technologies for Fusion Magnets II

Contribution ID: **203** Type: **Poster**

Fri-Mo-Po.05-08: Tapered Canted Cosine Theta Magnets for the Interaction Region of EIC

Friday, July 4, 2025 9:30 AM (1h 45m)

Brookhaven National Laboratory (BNL) was chosen to host the international Electron-Ion Collider (EIC), which will collide high energy and highly polarized hadron and electron beams with a center of mass energy up to 140 GeV. The IR will be loacted at RHIC's IR6; due to the requirements of the physics community the magnet designs are very challenging.

Space constrains in transverse and longitudinal direction in combination with the required fields and gradients are pushing the limits of magnet technology. The space constraints are arising from a combination of the crossing angle and lattice requirements.

One technology which helps in this regard is so called canted-cosine theta (CCT) or double helix magnets. EIC uses this technology for several of the low-beta quadrupole magnets to mitigate space constraints. The technology may also replace several of the collared hadron forward magnets. A high field demonstrator is presently under construction at BNL. This paper gives an overview of the various CCT designs and an update on the status of the prototype magnet including test results.

[1] An Assessment of U.S.-Based Electron-Ion Collider Science. (2018). Washington, D.C.: National Academies Press. https://doi.org/10.17226/25171

Work supported by Brookhaven Science Associates, LLC under Contract No. DE-SC0012704 with the US Department of Energy.

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Session Classification: Fri-Mo-Po.05 - Electron-Ion Collider

Contribution ID: **204** Type: **Poster**

Sat-Mo-Po.04-09: Comparing 3-D electro-thermal and magneto-thermal formulations for predicting hot spot generation in regular and CFD REBCO tapes

Saturday, July 5, 2025 9:30 AM (1h 45m)

Accurate simulations of quench events in high temperature superconducting (HTS) tapes, cables and magnets often rely on complex finite element models (FEM) and the challenges for such simulations are well known. The non-linear properties and high-aspect ratio mesh of HTS tapes lead to poor convergence of the models, especially near a quench event. At the superconducting-to-normal transition, the resistivity of HTS changes rapidly, and accurate computations of quantities such as current sharing, voltage drop and the temperature rise remains an important challenge. This implies that the quality of the material data and mathematical formulations are critical for such problems. In recent years, many FEM formulations and other numerical simulation models have been suggested to predict the hot spot generation and propagation as accurately as possible. For commercial HTS tapes, a relatively simple coupled electro-thermal model is often sufficient for temperature and voltage calculations, either in 2-D or in 3-D.

In this work, 3-D FEM simulations were conducted on different HTS tape architectures, using multiple mathematical formulations and resistivity functions. It is first shown that a simple V-T formulation leads to almost identical results as a complete H-ϕ-T magneto-thermal formulation for commercial HTS tapes. However, this is not the case for current flow diverter tapes (CFD), and it is shown that the simple electro-thermal model fails to predict quench events in such architectures, especially during the pre-quench regime. The concept of the CFD architecture being that the current sharing at the hot spot location occurs unevenly along the width of the tape, the complete magneto-thermal model accurately predicts a swift expulsion of the magnetic field when a hot spot is generated. This is also reflected by a steep increase in the voltage computed between terminals, which aligns with experimental measurements.

Some benefits of the CFD architecture are now well documented. It has already been shown that the normal zone propagation velocity (NZPV) of these tapes is increased by an order of magnitude in comparison with the commercial tapes. Moreover, the simulations conducted show that the voltage across the CFD tapes can reach much higher values than with regular tapes when the current sharing occurs, meaning that threshold voltages are reached at much lower hot spot temperatures. These findings are important considering that the CFD architecture is currently being investigated for high-field magnet applications.

In parallel, these simulations were also an opportunity to assess the flaws of the standard power-law, which predict quenches prematurely as compared to experiments. For accurate pre-quench regime simulations, a novel piecewise resistivity function is suggested to capture the flux-flow regime of HTS tapes, which slightly delays the hot spot generation, in conformity with the experiments.

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Session Classification: Sat-Mo-Po.04 - Protection and Stability

Contribution ID: **205** Type: **Poster**

Fri-Af-Po.03-06: Could the parasitic heat load from the supports jeopardize the operation of the superconducting feeder of the Divertor Tokamak Test facility?

Friday, July 4, 2025 2:00 PM (2 hours)

The superconducting (SC) magnets of the Divertor Tokamak Test (DTT) facility, a fusion experiment under construction at the ENEA Research Center in Frascati, Italy, require several tens of kA, necessitating the use of SC feeders. These feeders are based on the Cable-in-Conduit Conductor (CICC) concept, where a bundle of twisted NbTi strands is encased in a stainless-steel jacket and cooled by a forced flow of supercritical helium passing through the strands. The DTT magnet system includes feeders for the Central Solenoid (CS), the Poloidal Field (PF) Coils, and the Toroidal Field (TF) Coils, along with additional "jumpers"to connect the TF coils in series. Each feeder has its own path within the machine, with specific lengths, magnetic fields, and operating current scenarios.

The design of the feeder CICCs, including their sizing and the evaluation of the required coolant mass flow rates, has been completed and is now finalized. The design ensures a minimum temperature margin for the SC strands to counteract thermal loads, including Joule heating at the joints, AC losses from current or field variations, and parasitic loads from radiation emitted by the environment, which consists of a cryostat equipped with a thermal shield at liquid nitrogen temperature. Additionally, the heating due to the nuclear flux escaping the plasma has been accounted for. However, parasitic heat loads introduced by conduction through thermal bridges, caused by the mechanical support of the feeders, were not included since the mechanical design of the component is not yet available. Such contributions may significantly reduce the temperature margin, as indicated by experiences from other tokamaks.

This paper aims to address the issue of parasitic heat loads from the supports through a parametric analysis, evaluating the maximum tolerable heat load under the nominal operating mass flow rate, assuming a reasonable spatial distribution of the supports. The study, conducted using the OPENSC2 software, is performed under steady-state conditions for all CS, PS, TS, and jumper feeders, considering a reference plasma scenario and an environment temperature of 80 K. For the most critical feeders, a transient analysis is also performed, incorporating AC losses calculated using the Ogasawara equation. The results of this analysis support the projects with guidelines and constraints for the thermal design of the feeder supports.

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Session Classification: Fri-Af-Po.03 - Supporting Technologies for Fusion Magnets I

Contribution ID: **206** Type: **Poster**

Fri-Mo-Po.05-10: An Induction Septum magnet for Hadron injection into the EIC

Friday, July 4, 2025 9:30 AM (1h 45m)

The Electron Ion Collider (EIC) is under design to be built at Brookhaven National Laboratory (BNL) to collide hadron bunches with the electron bunches. The hadron bunches will be injected and accelerated in the Hadron Storage Ring (HSR) and will be brought in collisions with the electron bunches of the Electron Storage Ring (ESR). To minimize the kicker strength of the fast strip line injection kickers of the Hadron Storage Ring (HSR), a 5 mm thin Induction-type septum magnet has been designed using the ELEKTRA module of the OPERA computer code. To minimize the Eddy current losses, the iron core of the magnet has been designed with 0.35 mm thick lamination. A complete Electromagnetic design of the Septum magnet will be presented.

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Session Classification: Fri-Mo-Po.05 - Electron-Ion Collider

Contribution ID: **207** Type: **Poster**

Wed-Mo-Po.02-07: Progress in mechanical structure development of the Nb_3Sn 12 T cosθ dipole for the High Field Magnets R&D Programme: the INFN-CERN agreement for the FalconD project

Wednesday, July 2, 2025 9:15 AM (2 hours)

Next-generation particle accelerators require the development of high-field bending dipoles to enable precise beam control and enhance operational efficiency. Nb_3Sn has emerged as a promising superconducting material, already proven in accelerator magnets like the MQXF quadrupoles for the high-luminosity upgrade of the LHC. In partnership with CERN, the INFN divisions in Genoa and Milan are leading the development of FalconD (Future Accelerator post-LHC Cosθ Optimized Nb_3Sn dipole), a 12 T, Nb_3Sn dipole model with a cosθ geometry. This project aims to push the boundaries of magnetic field strength and stability. This paper analyses the mechanical performance of the design after several modifications to the magnet's cross-section. The project's key challenge is its 'bladder & key'(B&K) mechanical structure, which must withstand intense Lorentz forces and will be implemented for the first time in a cosθ dipole. The study employs 2D and 3D finite element modelling (FEM) to evaluate the mechanical behaviour of the FalconD during each construction phase.

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Session Classification: Wed-Mo-Po.02 - Muon Collider

Contribution ID: **208** Type: **Poster**

Fri-Af-Po.08-03: Stress-Strain Behavior and Tensile Stress Tolerance of Critical Current for Jelly-Roll Processed Nb3Sn Cables Composed of Ultra-Fine Composite Wires

Friday, July 4, 2025 2:00 PM (2 hours)

NIMS is developing ultra–fine A15 composite wires with a diameter of 0.03–0.05 mm. One of the applications of such wires is a flexible Rutherford cable for accelerator magnets. The advantage of the ultra-fine wires is a reduction in bending strain proportional to the wire diameter. Taking advantage of this merit, fabrication of A15 coils by a wind-and-react (W&R) process is expected. In our previous study, basic mechanical properties such as fracture strength and Young's modulus were evaluated for single 0.05 mm-thick bronze-processed Nb3Sn wires and their 19 twisted cables. We confirmed that the fracture strength of a twisted cable can be predicted simply by a product of that of a single wire and the number of wires. A critical current (Ic) at 4.2 K under external magnetic fields measured after applying uniaxial tensile stress at room temperature exhibits that the stress tolerance of a single wire and a twisted cable is comparable. The intrinsic tensile strain at which Ic degradation starts was estimated to be 0.44%, which is comparable to the existing monolithic Nb3Sn wires. Although these results demonstrate the promising mechanical properties of ultra-fine Nb3Sn wires, the non-Cu critical current density (Jc) of these bronze-processed wires is still lower than the target values for the accelerator magnet above 12 T. For improvement in non-Cu Jc, jelly-rolled Nb3Sn wires with a diameter of 0.05 mm were newly fabricated by NIMS. In these wires, non-Cu Jc of 1.8x103 A/mm2 has been achieved at 12 T and 4.2 K. This paper will present the results of tensile stress-strain behavior and stress tolerance of Ic for ultra-fine jelly-rolled Nb3Sn single wires and their twisted cables. The influence of cyclic loading as well as static one on Ic will also be reported. Based on these results, we will compare the mechanical properties of ultra-fine Nb3Sn wires and cables fabricated by different processes.

This work is supported in part by Japan-U.S. Science and Technology Cooperation Program in High Energy Physics operated by MEXT in Japan and DOE in the U.S. (Grant No. 2023-13-3).

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Session Classification: Fri-Af-Po.08 - Advances in Nb3Sn and MgB2 Conductors I

Contribution ID: **210** Type: **Poster**

Fri-Mo-Po.03-01: Design of a DC-Coil for MRI magnet using second-generation high-temperature superconducting tapes

Friday, July 4, 2025 9:30 AM (1h 45m)

Magnetic Resonance Imaging (MRI) is a technique that generates high-resolution volumetric images of the body using a strong magnetic flux density. The image quality directly depends on the magnetic field homogeneity. Commercial superconducting magnets have a magnetic field homogeneity below two parts per million (ppm) and use Nb-Ti magnets. However, they need to be cooled at 4 K. It is costly to achieve and keep this temperature, and two cryocooler stages are necessary. The second-generation (2G) high-temperature superconducting (HTS) tapes are a possible technical-economical solution to address the abovementioned points, as they can be cooled to temperatures between 20 to 77 K. But these tapes are susceptible to the magnetic field. Therefore, to correctly design a magnet made of HTS tapes, it is necessary to simulate the device. The finite element model (FEM) is the chosen numerical method in this case. This study simulated the design of a 0.5 T MRI magnet with a patient bore of 70 cm, considering space for the gradient and radiofrequency (RF) body coils. The J-A formulation, a new and easily implementable formulation, and the power law are used to simulate the DC-coil. A commercial 12 mm wide 2G HTS tape is simulated using the data available from the Robinson Research Institute. It has considered the current density and n-value characteristics in relation to the magnetic flux density. Passive and active shims were not represented in this work. The final results obtained a magnetic field homogeneity of less than 20 ppm in a diameter spherical volume (DSV) of 10 cm, which we consider acceptable.

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Session Classification: Fri-Mo-Po.03 - Magnets for MRI

Track Classification: D: Magnets for Medical, Biological, and Analytical Applications: D02: Magnets for MRI

Contribution ID: **211** Type: **Poster**

Fri-Af-Po.08-09: Study on the Improving the uniformity of Ti distribution in new type of High Jc Nb3Sn Wire Produced by WST

Friday, July 4, 2025 2:00 PM (2 hours)

Nb3Sn wires are wildly used in high-field (> 10 T) magnets and have great potential value in the next several decades. Internal-tin Nb3Sn strand has been developed by many methods for the future fusion reactor, high energy accelerator and so on. Increasing the critical current density of Nb3Sn wire, reducing the use amount of wire in magnets and reducing the price are important ways to promote the industrialization and mass application of Nb3Sn wire. A new type of high Jc Nb3Sn wire without Nb barrier in the 61 sub-elements but with one entire Ta barrier inside the outer copper, was designed and fabricated based on the ITER Internal-tin Nb3Sn with 19 sub-elements. It can be clearly stated that doping a certain amount of Ti has a significant effect on improving the critical current density of the wire. The common three-stage heat treatment process cannot achieve homogeneous distribution of Ti in Nb3Sn phase. Adding a heat treatment platform between the medium temperature stage and high temperature stage of the three-stage heat treatment process can significantly improve the uniformity of Ti distribution in the Nb3Sn phase of the wire after final heat treatment. The Ti content is critical to improve the current density of the wire. After heat treatment, the critical current density of the wire has been significantly improved, reaching 2800A/mm2.

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Session Classification: Fri-Af-Po.08 - Advances in Nb3Sn and MgB2 Conductors I

Contribution ID: **212** Type: **Poster**

Thu-Mo-Po.06-06: Tensile and compressive fracture behavior of BSCCO filaments

Thursday, July 3, 2025 8:45 AM (2 hours)

Reinforced BSCCO wire has been considered to have a small margin of strength on the compression side because the filaments has been introduced to compressive strain. However, due to the presence of a sheath and the difficulty of observation, there were no examples of actual fracture behavior in compression. In this paper, we report on in situ microscopic observations of BSCCO filaments exposed at room temperature under tensile and compressive strains.

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Session Classification: Thu-Mo-Po.06 - Mechanical Behavior and Stress II

Contribution ID: **213** Type: **Poster**

Fri-Af-Po.09-05: Conceptual Design of an Axial Field Machine with Stacked Superconductors

Friday, July 4, 2025 2:00 PM (2 hours)

The development of high-temperature superconducting (HTS) electrical machines results in applications of various fields, as they have higher efficiency and power density. Axial field machine (AFM) is a machine topology with higher efficiency and power density, and is a novel way to achieve fully-superconducting electrical machine for various applications. Stacked HTS coated-conductors (CC) have been proven to be a feasible way as trapped field magnets on machine rotors, due to their ability to trap high magnetic fields. Modelling of AFM is more complicated than conventional radial field machines, as they have inconsistent structure axially and radially. This paper presents a design of AFM with stacked HTS CC, with its own magnetization circuit layout within the machine topology, this design is simulated with COMSOL Multiphysics with 2D and 3D simulation using H-A and T-A formulation, where the superconducting coil is simulated with a 2D infinitely long model, this model also divides the electrical machine into two parts: the superconducting parts and non-superconducting parts. This design will use both simulated results and experiment data to optimize the overall design,

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Session Classification: Fri-Af-Po.09 - Rotating Machinery IV

Contribution ID: **214** Type: **Poster**

Wed-Mo-Po.05-01: Winding Configuration of REBCO Fully Superconducting Linear Synchronous Motor for Launch System for eVTOL

Wednesday, July 2, 2025 9:15 AM (2 hours)

Electric Vertical Takeoff and Landing (eVTOL) aircraft is attracted as a new means of transportation. The vertical takeoff consumes much amount of energy, leading the limitation of range and payload. To address this problem, we proposed a new method of takeoff by using a launch system for eVTOL with fixed wings. The eVTOL is accelerated by a linear motor mounted on the system. When the eVTOL reaches takeoff speed, the fixed wings generate lift force to take off. Since the system is assumed as installed at narrow space such as rooftop of the building at downtown, it should be designed as small size and lightweight. Thus, we propose applying the fully superconducting linear synchronous motor for the system. Both the stator and mover windings consist of REBa₂Cu₃O_{<i>y</i>} (REBCO) wires.
The REBCO windings can generate high magnetic field without iron cores owing to its high critical current property, realizing lightweight design of machines. The distribution of the magnetic field generated by the air-cored windings strongly depends on the winding configuration, thus the optimization of the winding configuration is the key of designing the motor. Without the optimization, the field contains spatial harmonics and this causes some problems as follows. One of those is the thrust ripple that can lead velocity fluctuation, vibration, and noise pollution. Furthermore, the harmonics causes increasing of the AC loss is generated. To prevent these problems, we design the winding configuration for both the stator and mover windings.
The REBCO wire is tape-shaped, and its critical current deteriorates if it is curved in the edgewise direction or twisted. Thus, the REBCO windings in the motor are composed of racetrack coils to avoid deterioration of the critical current. The stator windings are used as the armature windings generating a moving magnetic field by energizing by three phase AC power supply. The mover windings are used as the field windings generating a constant magnetic field. To generate an ideal field distribution without harmonics, the currents of each winding should be distributed as an ideal sinusoidal waveform spatially. However, the spatial distribution of the current is discrete corresponding to the positions of the wires composing the racetrack coils. Hence, based on the pulse width modulation technique, we set the positions of the REBCO wires so that it imitates sinusoidal distribution. We applied this configuration both for armature and field windings. In this study, the effectiveness of such configuration for the motor properties is investigated from the viewpoint of the reduction of thrust ripple and AC loss. The motor properties are calculated by electromagnetic analysis based on finite element method.

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Session Classification: Wed-Mo-Po.05 - Novel and Other Applications I

Contribution ID: **215** Type: **Poster**

Thu-Mo-Po.09-05: Design and development of a pulsed magnetic field measurement system of CSNS

Thursday, July 3, 2025 8:45 AM (2 hours)

The BUMP magnet is an important part of a high intensity proton accelerator. In CSNS II, to achieve high injection power and improve injection efficiency, the magnetic field of the BUMP magnet would be increased to 0.55 T with a faster ramping rate of 3500T/s. Considering the limitation of the saturation magnetic field of soft ferrite, a 0.15 mm silicon steel sheet is adopted. At this time, the eddy current effect cannot be ignored, it is necessary to achieve the dynamic magnetic field measurement of the fast BUMP magnet. The paper introduce the design and development of a plused magnetic field measurement system of CSNS. In order to realize the uniformity measurement in the process of fast excitation, a PCB array scheme is adopted. Considering the rapid rate of the BUMP magnet, a novel design of an active RC integrator is introduced. Finally the measurement results of leakage field in injetion line is also discussed. The measurement results show high measurement accuracy and repeatability.

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Presenter: HAN, Wenjie

Session Classification: Thu-Mo-Po.09 - Conductor and Coil Measurement/Test Techniques and Facilities II

Contribution ID: **216** Type: **Contributed Oral**

Sat-Af-Or4-06: Optimization of critical current density at 16 Tesla in Nb3Sn superconducting wires fabricated in WST

Saturday, July 5, 2025 5:45 PM (15 minutes)

To develop superconducting wires suitable for applications demanding extremely high magnetic fields, we conducted an experimental investigation on the optimization of microstructure and heat treatment processes aimed at enhancing the critical current density (non-Cu *Jc*) at 16 T in Internal-tin type multifilamentary Nb3Sn superconducting wires fabricated in WST. Utilizing comprehensive analytical techniques, including Scanning Electron Microscopy (SEM), Energy Dispersive Spectroscopy (EDS), and the Physical Property Measurement System (PPMS), we established a correlation between Nb3Sn grain refinement and the irreversibility field (*Hirr*). Our findings revealed that, under optimal growth conditions characterized by specific time and temperature parameters, where Nb3Sn grain size increased slightly, *Hirr* demonstrated the highest value, we obtained significantly enhanced performance at 16 T in these Nb3Sn wires. Specifically, by fine-tuning the Nb3Sn growth condition to 680℃ for 80 h, we achieved an impressive *Hirr* of 27.42 T (4.2 K), and *Jc* was elevated to values exceeding 1300 A/mm² (4.2 K, 16 T), accompanied by an atomic percentage of Sn in Nb3Sn reaching 24 at.%, conditions conducive to Sn-rich Nb3Sn phases, representing one of the highest performances reported thus far for Ti-doped Nb3Sn wires. These findings pave the way for future advancements, suggesting that by optimizing the superconducting properties within such meticulously heat treatment processes, it is feasible to elevate *Jc* towards meeting 16 T or even higher magnet requirements in such Internal-tin Nb3Sn wires.

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Session Classification: Sat-Af-Or4 - Advances in Nb3Sn and MgB2 Conductors II

Contribution ID: **218** Type: **Invited Oral**

Sat-Af-Spe1-02: [Invited] Electromechanical properties of SPARC CS and PF superconductor cables under relevant transverse and axial compression.

Saturday, July 5, 2025 2:15 PM (15 minutes)

SPARC is a compact, high-field tokamak based on high temperature superconductor (HTS) magnets developed by Commonwealth Fusion Systems and the Massachusetts Institute of Technology. This research explores the mechanical and electromagnetic behavior of SPARC's cable-based magnet systems, namely the Central Solenoid (CS), the Poloidal Field Coils (PF), and the feeder (FEED) systems. Our studies focus on the CS, which will experience an average hoop compression of 350 MPa from the bucking Toroidal Field (TF) magnets. We present the design and execution of two experiments which systematically subject the superconductor to operation-relevant loads and monitor the reversible and irreversible effects on Ic at 77 K. The first experiment explores the cable's limits under static and cyclic transverse (SPARC radial) loading alone. We find that the cable unit cell is able to withstand 100s of cycles without degradation at 400 MPa of transverse compression—and that the onset of permanent degradation is not observed until >550 MPa. The second experiment explores a combined longitudinal (along cable-axis) and transverse compression, which are both present during hoop compression observed in the CS. To that end we developed a test rig which is able to cyclically load cable samples longitudinally and transversely (simultaneously), in liquid nitrogen, with loads up to 533kN (1.2 GPa) longitudinally (without buckling the cables) and 850kN (535 MPa) in transverse compression—while at the same time allowing for in-situ transport current measurements.

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Session Classification: Sat-Af-Spe1 - [Special Session] High Current HTS Cables for Fusion and Beyond

Contribution ID: **219** Type: **Contributed Oral**

Sat-Af-Or5-08: Experimental study on AC loss reduction in a REBCO coil assembly by applying superconducting shielding coils

Saturday, July 5, 2025 6:15 PM (15 minutes)

Reducing AC loss in high-temperature superconducting (HTS) coils is critical in HTS applications such as SMES (superconducting magnetic energy storage) and fast ramping magnets. One effective approach is applying magnetic flux diverters to reshape the magnetic field distribution in the vicinity of end coils/windings. However, the benefits of MFDs diminish in high magnetic fields that exceed the saturation field of the MFDs. Alternatively, superconducting shielding coils (SSC) present a promising solution due to their high-field diamagnetic properties. Nevertheless, there is no experimental benchmark on the AC loss reduction achieved by SSC.

In this work, AC loss in an HTS coil assembly with and without SSC is measured at 77 K. The coil assembly consists of three double pancake coils (120 turns in total). The coils assembly and SSC are respectively wound from 4-mm-wide SuperPower and 12-mm-wide THEVA wires. The experimental results were compared with the finite element modelling results based on the T-A formulation. The AC loss reduction at different operating currents and frequencies achieved by SSC is analysed.

Keywords: HTS coil, AC loss reduction, superconducting shielding coils, T-A formulation

Acknowledgement:

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Session Classification: Sat-Af-Or5 - AC Loss and Magnetization II

Contribution ID: **221** Type: **Contributed Oral**

Sat-Af-Or1-07: Development of the Qualification Program for the SPARC PF High-Temperature Superconducting Magnets

Saturday, July 5, 2025 3:45 PM (15 minutes)

The SPARC compact, high-field tokamak developed by Commonwealth Fusion Systems and the Massachusetts Institute of Technology is based on high temperature superconductor (HTS) magnets. This device employs 8 Poloidal Field PF magnets which are made with PIT-VIPER cable wound in pancakes, the smallest measuring 1.2 meters radius, and the largest 8 meters. There are 10-14 pancakes in each magnet, each of these pancakes with their own grading scheme. The performance of each of these pancakes must be verified in liquid nitrogen before integration into SPARC. To this end we present the development of the qualification process for the PF magnets, covering the design of the test stands as well as the evolution of the thermo-electromagetic models. The test stands are able to deliver up to 24 kA while ensuring appropriate support for the self-field, Lorentz forces, but without sacrificing the testing pace required by the SPARC schedule. The models take into consideration the twisted topography of the cable, the pancake's geometry, grading schemes as well as the HTS allocated to create a prediction of the critical current Ic at 77K, self-field. But measuring this is not an easy feat. Because the grading scheme is designed for the SPARC's 20K-20T performance, an additional thermodynamic model is necessary to design the current ramps to safely test the pancakes in liquid nitrogen.

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Session Classification: Sat-Af-Or1 - Fusion Test Facilities

Contribution ID: **222** Type: **Poster**

Wed-Mo-Po.06-09: Optimal Design of Heat Pipes and Heat Sinks for Thermal Management of Permanent Magnets in PMSM

Wednesday, July 2, 2025 9:15 AM (2 hours)

With the rapid growth of the electric vehicle (EV) market, the demand for high-efficiency and high-power motors has steadily
increased. Consequently, the use of rare-earth materials such as neodymium (Nd) permanent magnets has also risen. However, the
monopolistic supply chain and price volatility of rare-earth elements limit their wide adoption. In this study, we propose a motor structure
that eliminates the use of dysprosium (Dy)—a rare-earth element critical for maintaining coercivity in high-temperature environments—
to address concerns related to supply instability and cost escalation. While Dy plays a key role in preventing irreversible demagnetization
by preserving magnet coercivity under elevated temperatures, this research demonstrates that stable performance can still be achieved
at high temperatures without Dy by integrating a heat pipe into the motor design. The heat pipe effectively reduces the temperature of
the permanent magnets; however, poor structural design may exacerbate eddy current losses, leading to further temperature increases.
Hence, we conducted a thermal equivalent circuit analysis to verify that the heat pipe successfully controls magnet temperature rise and
prevents irreversible demagnetization. The proposed structure is expected to reduce the consumption of rare-earth materials while
enhancing both the efficiency and reliability of the motor

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Presenter: YOON, Sung Hyun

Session Classification: Wed-Mo-Po.06 - Rotating Machinery I

Contribution ID: **223** Type: **Poster**

Thu-Af-Po.01-06: Design and Measurement of a DC Septum Magnet for CSNS-II RCS Injection

Thursday, July 3, 2025 2:00 PM (2 hours)

The remould of the magnet of CSNS injection system is an important part of CSNS II magnet, which includes three septum magnet: two DC septum and one plused septum. Due to the installation limitation, the thickness of the shielding should be less than 2mm and the leakage field in the RCS is required to be less than 0.1%. This paper introduces the design and measurement of a DC Septum Magnet for CSNS-II RCS Injection, with main topic: (1) the design considerations of the central magnetic field and eddg shimming; (2) the accurate simulation of remote leakage field; (3) the optimization of filling materials in cutting plates. Finnaly the magntic field measurement results based on Hall probe is also introduced.

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Presenter: HAN, Wenjie

Session Classification: Thu-Af-Po.01 - Accelerator Magnets II

Contribution ID: **224** Type: **Poster**

Sat-Mo-Po.06-04: Magnetic field measurements of superconducting magnets in the BEPCII upgrade project

Saturday, July 5, 2025 9:30 AM (1h 45m)

The upgrade project for the Beijing Electron-Positron Collider (BEPCII) aims to enhance the colliding beam energy from 1.89 GeV to 2.35 GeV, increasing the peak colliding beam energy to 2.8 GeV. In order to meet the requirement for higher luminosity at higher energy, newly designed superconducting magnets have been developed for the interaction region. These superconducting magnets consist of three anti-solenoids and one vertically focusing quadrupole magnet, symmetrically installed on either side of the interaction point. During the winding process of the anti-solenoid coils and quadrupole coils, low-temperature magnetic field measurements were carried out in a vertical Dewar to ensure that performance meets design specifications. Following the integration of the superconducting coils into a horizontal cryostat, horizontal magnetic field measurements of the superconducting magnet were conducted. This paper presents both the vertical and horizontal measurement systems, along with the associated measurement results.

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Presenter: CHEN, Wan

Session Classification: Sat-Mo-Po.06 - Mechanical and Magnetic Measurements

Contribution ID: **225** Type: **Poster**

Wed-Af-Po.06-03: The Characteristic Changes of No-Insulated Coils After Multiple Thermal-Magnetic Cycles

Wednesday, July 2, 2025 2:30 PM (2 hours)

In the context of accelerator and fusion magnet applications, high-temperature superconducting (HTS) coils must maintain stable performance over extended periods post-installation, during which they undergo multiple thermal and magnetic cycles. This study investigates the stability of REBCO MI/NI coils under repeated thermal cycling and periodic electromagnetic loading. The degradation of Ic performance, observed after multiple thermal-magnetic cycles, can be attributed to cumulative thermal stresses and electromagnetic forces that induce deformation. Such deformations lead to significant strain and localized stress concentrations within the coils. Notably, MI and NI coils exhibited an increasing delay time with the number of test cycles during liquid nitrogen evaluations, hinting at the presence of irreversible deformations accrued through repetitive testing. This paper summarizes the performance characteristics of MI/NI coils following multiple cycles and compares these findings with coils cured in paraffin.

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Session Classification: Wed-Af-Po.06 - No-Insulation Coils I

Contribution ID: **226** Type: **Contributed Oral**

Thu-Mo-Or1-08: The High Rigidity Spectrometer at FRIB: Magnet Development Status

Thursday, July 3, 2025 12:30 PM (15 minutes)

Since commissioning in 2022, the Facility for Rare Isotope Beams (FRIB) has successfully delivered over 270 rare isotope beams, including the discovery of five new rare isotopes. To fully leverage the scientific potential of FRIB, a new High Rigidity Spectrometer (HRS) has been proposed to overcome the limitations of the existing Spectrometer of S800, the legacy from the NSCL era.
The HRS comprises two primary sections: the High-Transmission Beamline (HTBL) and the Spectrometer Section (SPS). At the ASC 2024, we introduced the key design features of the HTBL magnets and outlined the project's path forward. This talk will report an update on the progress of construction and testing for the first-article HTBL magnets: switching dipole and cold iron quadrupole triplet. Additionally, we will unveil the preliminary design of new magnets including the sweeper and sector dipoles, as well as the coil-dominated quadrupoles singlets for the SPS. This talk will discuss the challenges encountered during the dipole design process, particularly those related to the large beam space requirements. Furthermore, we will highlight the collaborative efforts with Lawrence Berkeley National Laboratory (LBNL) in developing two large-aperture coil-dominated quadrupoles that incorporate nested higher-order multipoles. We will introduce the quadrupole coil winding, force-restrain architecture, and tooling design.

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Session Classification: Thu-Mo-Or1 - LTS Magnet Advanced Concepts

Contribution ID: **227** Type: **Contributed Oral**

Sat-Mo-Or3-01: Effect of neutron irradiation on the superconducting properties of REBCO conductors

Saturday, July 5, 2025 8:00 AM (15 minutes)

The superconducting solenoid for the muon source to be installed in the future second target station of materials and life science experimental facility of J-PARC is required to be highly radiation resistant. Over a 10-year operation period, the superconducting solenoid is expected to reach an absorbed dose of 100 MGy and a neutron fluence of 7.8×10^{22} n/m^2. A research and development program have been performed radiation-resistant magnets based on REBCO conductors. Radiation resistance study of REBCO conductors is essential for realizing the radiation-resistant magnets. In this contribution, the post-irradiation examination of REBCO samples neutron irradiated in the Belgian research reactor (BR2) and the Japanese research reactor (JRR3) in the neutron flux range of 0.1-10×10^{22} n/m^2 will be presented.

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Session Classification: Sat-Mo-Or3 - HTS Characterization III

Contribution ID: **228** Type: **Poster**

Wed-Af-Po.06-02: Surface-shunt skeleton for overcurrent quench prevention in no-insulation REBCO magnets for single silicon crystal growth system

Wednesday, July 2, 2025 2:30 PM (2 hours)

No-insulation (NI) technology is widely adopted in REBCO coils due to its lower risk of electrical burnout, attributed to the turn-to-turn current-sharing feature. However, the contact resistance of NI coils is difficult to control under the influence of REBCO tape preparation process, coil winding and the cooling cycles. When contact resistance increases to a level that prevents bypass current during quench, the risk of burnout increases significantly, particularly in conduction-cooled, high-turn coils, which fails to provide stable conditions for high-quality single silicon crystal production. This study presents a method to prevent overcurrent quench in NI coils by utilizing a surface-contact shunt. A specialized coil skeleton is designed that contacts the coil bottom and functions as a parallel resistor, diverting current from the dissipative regions during overcurrent operation. It also providing a conductive cooling path, thus improving the cooling efficiency of operation process. Comparative experiments under 20 K conduction-cooled conditions are investigated to study the electromagnetic and thermal behavior of NI coils with and without the surface-shunt skeleton. The results demonstrate that the high-risk regions within the coil are effectively protected, suppressing the initiation and propagation of the quench. These findings validate the effectiveness of the proposed method and provide an effective solution for enhancing the operational safety of high-field NI REBCO coils.

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Session Classification: Wed-Af-Po.06 - No-Insulation Coils I

Contribution ID: **229** Type: **Poster**

Fri-Af-Po.02-10: Local hot-spot quench test and analysis on parallel-wound no-insulation high temperature superconductor coil for a single silicon crystal growth system

Friday, July 4, 2025 2:00 PM (2 hours)

The demand for high-quality silicon wafers with larger diameters has been heightened due to the fast growth of semiconductor integrated circuit industry. High temperature superconductor (HTS) magnet is capable of generating high static magnetic field at high operating temperature, which plays a crucial role in improving the quality of single silicon crystal during its growth process. Parallel-wound no-insulation (PWNI) HTS coil, wound with parallel-stacked HTS tapes, has the advantages of low inductance, fast ramping rate and enhanced thermal stability. These characteristics give PWNI coil broad application prospect in high-quality silicon wafers production. The simulation model demonstrates that the quench characteristics of PWNI coil differ from those of single-wound no-insulation (SWNI) coil, which is wound using a single tape, due to current redistribution among the stacked tapes. However, experimental data on this topic remains insufficient. This study aims at experimentally investigating and analyzing the local hot-spot quench characteristics of PWNI HTS coil. In this study, the voltage tap, Hall sensor and thermocouple are used to monitor the variations in voltage, magnetic field and temperature during the local hot-spot quench process of PWNI and SWNI coils. Based on the measured data, key parameters including the minimum quench energy (MQE) and normal zone propagation velocity (NZPV) are calculated. The experimental result confirms that PWNI coil exhibits superior thermal stability and lower magnetic field degradation compared to SWNI coil. This study provides data support for understanding the local hot-spot quench properties of PWNI HTS coil, offering reference for its application and design as high-field magnet in advanced technological systems.

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Presenter: PENG, Pai

Session Classification: Fri-Af-Po.02 - Quench Detection and Protection III

Contribution ID: **230** Type: **Poster**

Wed-Af-Po.07-06: A Retrospective of the Magnetic-field Calculation Methods for Accelerator Magnets and Solenoidal Detector Magnets from 1969 to 2000

Wednesday, July 2, 2025 2:30 PM (2 hours)

When this author started his career as an accelerator engineer over 60 years ago, accelerator dipoles were combined function iron dominated magnets that produced a dipole field overlaid with a quadrupole field. These were the same type of magnets that were in the Brookhaven AGS and the CERN PS machines. These magnets produced an induction of ˜1.5 T at the beam center. The largest detector magnet of that period was the 1.93 m (72 inch) 1.8 T bubble chamber at Berkeley. In 1961, an 8.8 T small Nb3Sn solenoid showed that high fields could be produced using superconductors. Accelerator physicists dreamed of dipole and quadrupole magnet that could produce peak fields of >4 T, which would allow higher energy machines to be built on less land. These machines would have dipoles, focusing and defocusing quadrupoles, and correction magnets that could be superconducting. The earliest superconducting accelerator magnet this author knows about is a Nb3Sn tape quadrupole built by W. B. Sampson at Brookhaven National Laboratory (BNL) in 1965. The six-week 1968 summer study at BNL had an objective of studying superconducting accelerator magnets, RF cavities and large detector magnets for bubble chambers. This paper discusses the concepts behind the codes that calculated the magnetic fields where the accelerated beam is located. The programs that this author and others used to design accelerator magnets and detector magnets will be described. These programs calculated both the transport current field and the fields due to circulating currents in the superconductor. These programs could also assess the effects of small errors in coil fabrication and support on an accelerator beam. For detector magnet, they had to be fabricated with the desired field uniformity and have a lot of magnetic field where the detector was located. The magnet design was dictated by the requirements of the detector.

Author: GREEN, Michael

Presenter: GREEN, Michael

Session Classification: Wed-Af-Po.07 - Modelling and Analysis

Contribution ID: **232** Type: **Poster**

Wed-Af-Po.05-05: Numerical electromagnetic field analyses of multifilament coated conductors with improved current-sharing properties

Wednesday, July 2, 2025 2:30 PM (2 hours)

When considering the application of coated conductors to ac equipment such as motors and generators, it is necessary to reduce ac losses, especially hysteresis losses caused by external ac magnetic fields, by multifilamentation. In multifilament coated conductors, the finer the filament, the better, since the overall hysteresis loss is reduced inversely proportional to the filament width. However, if the filaments are thin, there is concern that the current flowing through each filament may be blocked by local defects, resulting in deteriorated current transport characteristics of multifilament coated conductors. Therefore, when thinning the filaments, a current path that allows current-sharing among filaments to make current bypassing local defects is essential to maintain the current transport characteristics of the multifilament coated conductors.
We have performed numerical electromagnetic field analyses for straight and spiral multifilament coated conductors with improved current-sharing properties to evaluate their ac loss characteristics. These multifilament coated conductors have a structure in which the filaments are locally connected by inter-filament superconducting bridges. The longitudinal spacing of the inter-filament bridges is varied, and the ac loss characteristics of the multifilament coated conductors with inter-filament bridges are compared with them of conventional monofilament and multifilament coated conductors. For the ac loss characteristics, only an external ac magnetic field is applied, and the dependence on the amplitude and frequency of the external magnetic field is evaluated.

This work was supported by JSPS KAKENHI Grant Number JP24H00316.

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Session Classification: Wed-Af-Po.05 - HTS Conductors II

Contribution ID: **233** Type: **Poster**

Fri-Af-Po.10-05: Pulsed wire measurement system of superconducting wiggler

Friday, July 4, 2025 2:00 PM (2 hours)

The performance of synchrotron radiation or free electron lasers is not only dependent on the quality of the electron beam but also on the quality of the magnetic field of the insertion devices, making accurate magnetic field measurement critical. Conventional measurement methods typically use Hall probes for point-by-point measurements. However, the use of Hall probes becomes difficult in scenarios such as small gaps, closed gaps, or mechanical constraints (e.g., superconducting undulators). In the pulsed wire method, the metal wire is very thin and can directly measure the first and second integrals of the magnetic field in confined spaces. Over years of development, the accuracy of this method has improved significantly. The Shanghai Synchrotron Radiation Facility is currently developing a superconducting wiggler and plans to measure the magnetic field using the pulsed wire method. This paper presents the design of the pulsed wire system in the superconducting wiggler.

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Co-author: Mr HAN, Lei

Presenter: ZHOU, Shudong

Session Classification: Fri-Af-Po.10 - Undulators

Contribution ID: **234** Type: **Poster**

Wed-Af-Po.06-01: Ramping behaviour of parallel-wound no-insulation high temperature superconducting magnet for a single silicon crystal growth system.

Wednesday, July 2, 2025 2:30 PM (2 hours)

The parallel-wound No-insulation (PWNI) high temperature superconducting (HTS) coil is a novel type of pancake-shaped no-insulation coil made by parallel-staked HTS tapes, which is a promising solution for high field magnets. Previous studies have analyzed the electromagnetic characteristics of a PWNI HTS coil during the ramping process through simulations. The current distribution of these models is mainly solved from the equivalent circuit model. However, these models would lose axial fidelity and the computation cost of the equivalent circuit model is too large to calculate the multiple PWNI HTS coil. This paper is to investigate the ramping behaviour of the PWNI HTS magnet for a single silicon crystal growth system through finite-element modelling using rotated anisotropic resistivity. The results show that the turn-to-turn losses and magnetization losses show a significant non-uniform distribution among different coils during the ramping process. The middle coils of the magnets produce higher turn-to-turn losses but lower magnetization losses. The turn-to-turn losses are much higher than the magnetization losses so the total losses show higher values at the middle coils of the magnet. The non-uniform loss distribution would lead to a large temperature difference among the different coils of the magnet, which might cause a local quench to the magnet. By grading distributed the turn-to-turn resistivity, the loss can be adjusted relatively uniformly. This will provide some useful guidelines for the design of PWNI HTS magnets for single silicon crystal growth systems.

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Session Classification: Wed-Af-Po.06 - No-Insulation Coils I

Contribution ID: **235** Type: **Poster**

Wed-Af-Po.05-04: Repairing Defects in 2G High-Temperature Superconducting Tapes Using REBCO Repair Patch

Wednesday, July 2, 2025 2:30 PM (2 hours)

This study presents a method for addressing defects in 2G high-temperature superconducting tapes using the REBCO Repair Patch (RRP) and analyzes its effects on performance enhancement. The main focus of the research includes an analysis of defect cases in the tapes and an experimental evaluation of performance improvements after the installation of the patch on defective tapes. Experiments were conducted on bare tapes, defective tapes, and samples after installation of the repair solution, using 2G tapes from SuNAM. A comprehensive analysis of the primary defect factors and a detailed explanation of the installation method are provided, along with experimental results demonstrating the effectiveness of the RRP in resolving defects. This research is expected to contribute to improving the reliability of high-temperature superconducting tapes and is anticipated to be useful in addressing defects found during the winding process when applying the results obtained from tape-level experiments to coil-level applications.

This research was supported by National R&D Program through the National Research Foundation of Korea (NRF) funded by Ministry of Science an ICT (2022M319A1072464).

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Presenter: YANG, Hongmin (Korea Basic Science Institute)

Session Classification: Wed-Af-Po.05 - HTS Conductors II

Contribution ID: **236** Type: **Poster**

Wed-Af-Po.12-08: Design and Experimental Verification of High-Voltage Power Supply for Electron Irradiation Accelerators Based on Insulated Core Transformer

Wednesday, July 2, 2025 2:30 PM (2 hours)

This paper presents the design of a high-voltage power supply based on insulated core transformer, specifically tailored for electron irradiation accelerators to meet the demands of irradiation processing applications. The segmented magnetic core structure, however, inevitably leads to leakage issues, complicating the design of this high-voltage power supply. To develop a high-performance electron accelerator, a simulation model was constructed using finite element analysis software. The simulation results of the model were meticulously compared with the experimental data of the prototype to validate the model's accuracy. Utilizing ANSYS software for modeling, this paper provides an in-depth discussion on the design methodology of an insulated core transformer-type high-voltage power supply. This approach has been successfully implemented in the high-voltage power supply of a 200 kV/20 mA electron accelerator system. The study offers valuable insights and a robust foundation for designing high-voltage power supplies with high rated power. The finite element model, corroborated by experimental results, effectively demonstrates the feasibility of this method in designing insulated core transformer-type high-voltage power supplies.

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Presenter: JIANG, Can (Hubei University of Science and Technology)

Session Classification: Wed-Af-Po.12 - Power Supplies

Contribution ID: **237** Type: **Poster**

Fri-Af-Po.01-09: A Rapid Method for Prediction of the Worstest Engineering Thermal Quench situation of Large - scale REBCO Coils

Friday, July 4, 2025 2:00 PM (2 hours)

This paper presents an approach to calculate the thermal quench temperature of non-insulation(NI) REBCO coils and predict the thermal quench upper limit of large - scale engineering coils. This method serves as a guiding principle for the design of coil and magnet structures. Given a specific quench margin, it safeguards the coil from damage and ensures excellent thermal stability.

Quench remains a formidable challenge in the application of high - temperature superconducting(HTS) tapes. When the conducting current surpasses the tape's critical current, the resistance of the superconducting layer escalates rapidly, resulting in the loss of superconducting properties. In contrast to insulated coils, NI coils exhibit remarkable thermal stability and self - protection capabilities. In the event of a quench, the current at the quench site can bypass the quenched region via the inter - turn contact resistance, enabling automatic current sharing. This substantially reduces the current capacity of the quench region and the local heat generation within the coil, thereby expediting the recovery of the tape during the quench process. Nevertheless, due to the presence of inter - turn branches, the current distribution within NI coils becomes more intricate during the quench process, rendering it arduous to measure the current distribution and its variations experimentally.

To investigate and forecast the operating characteristics of NI coils, different equivalent circuit models have been proposed. The Partial Element Equivalent Circuit (PEEC) model divides each turn of the coil into multiple units along the circumferential direction, which offers high - precision calculations but demands a substantial amount of time. The Moderate equivalent circuit model aggregates several turns of the coil into a single unit. Although its calculation accuracy is marginally lower, it features a significantly faster calculation speed. In this study, equivalent circuit models are integrated with the finite - element simulation models of the magnetic field and thermal field to simulate the electro - magnetic - thermal characteristics of the coil during the quench process. Since the Moderate model is incapable of simulating point - quench, a point - quench in the PEEC model is manifested as the entire - unit quench of the corresponding unit in the Moderate model.

By comparing the simulation results of the two models, it is evident that under identical quench conditions, the maximum temperature and steady - state average temperature of the coil obtained through the Moderate model are slightly higher than those of the PEEC model, while the remaining magnetic field retention rate is marginally lower. However, the overall trends of temperature and magnetic field variations are entirely consistent. In terms of calculation speed, the Moderate model is nearly 12 times faster than the PEEC model. For large - scale engineering coils, the PEEC model is more complex and exerts extremely high demands on computing resources. Employing the Moderate model to predict the engineering thermal quench upper limit can significantly conserve computing resources and time in practical use.

Consequently, this paper advocates that the Moderate equivalent circuit model be coupled with the finite - element simulation model, and the entire - unit quench be utilized to approximate the point - quench within the unit for simulating and deriving the thermal quench upper limit of large - scale engineering coils. Based on this upper limit, the thermal and mechanical structures can be designed to ensure the thermal stability of large - scale engineering coils.

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Presenter: WANG, Qiyu (上海交通大学)

Session Classification: Fri-Af-Po.01 - Quench Detection and Protection II

Contribution ID: **238** Type: **Poster**

Fri-Af-Po.08-08: Preparation and performance research of superconducting switching wire

Friday, July 4, 2025 2:00 PM (2 hours)

Superconducting switch wire is a key component in the superconducting magnet. If the superconducting magnet quenches during operation, the superconducting switch wire will disconnect automatically to protect the magnet from being damaged. Given the characteristic of high-resistance, the copper-nickel alloy is commonly the prime material for the matrix of switch wire. However, the high hardness of the copper-nickel alloy makes the preparation of superconducting switch wire extremely difficult. In the present study, a novel 631 filament NbTi/CuNi superconducting switch wire was successfully designed and fabricated. It is characterized by a gradient change in the nickel content within the wire matrix, which effectively improves the applicability of the superconducting switch wire. The lower nickel content in the outer layer facilitates the use of the wire, while the higher nickel content in the inner layer ensures the wire resistance. The nickel content difference between the outer and inner layers can reach 45 wt%. Then, the NbTi/CuNi superconducting switch wire with the diameter of 1.041 mm, with the ratio of CuNi/SC of 1.1 was obtained. The Ic at 5 T & 4.2 K of the wire is 676.9 A and the line resistance is 448 mΩ/m. The Western Superconducting Technologies Co., Ltd (WST) has already achieved mass production of various types of NbTi/CuNi superconducting switch wire. At present, WST superconducting switch wire and cable has been successfully delivered to many different superconducting magnet manufacturers in countries all over the world, and received good reviews and feedback.

Author: YAN, Pengfei

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Presenter: YAN, Pengfei

Session Classification: Fri-Af-Po.08 - Advances in Nb3Sn and MgB2 Conductors I

Contribution ID: **239** Type: **Contributed Oral**

Wed-Af-Or3-04: Cryogenic Test and High-precision Temperature Regulation of a 50-period bulk HTS undulator

Wednesday, July 2, 2025 5:15 PM (15 minutes)

A 50-period bulk high-temperature superconducting (HTS) undulator, utilizing a staggered-array configuration of RE-Ba-Cu-O bulk superconductors and magnetized by a 7 T solenoid magnet, is currently under development at Zhangjiang Laboratory for Shanghai Soft X-ray Free Electron Laser (SXFEL) facility [1-2]. The device operates through multiple temperature control stages for the HTS insert, including heating above the critical temperature, ˜110 K, to transition out of the superconducting state, field-cooled (FC) magnetization at 10 K, flux freezing at 8 K and stable operation at 7 K. Achieving a homogeneous undulator field with minimal peak-to-peak field error necessitates the maintenance of a stable and uniform temperature distribution across the long HTS insert, imposing stringent demands on the temperature control system. The system was developed using Python, integrating Lakeshore controllers and 12 sensors for high-precision temperature monitoring, with resistive heaters mounted on the second-stage cold head of each GM cryocooler at both ends to facilitate regulated temperature control. By dynamically adjusting the PID parameters to align with the cooling power provided by the GM cryocooler, we successfully managed the temperature control sequence from 110 K to 10 K, 8 K and 7 K, achieving an accuracy better than ±0.01 K within the critical temperature range of 5 K to 15 K. The cold shrinkage of the long HTS insert along the electron beam direction was measured using high-precision displacement sensors, showing consistency with the calculated value. This study presents a detailed summary on the cryogenic test and high-precision temperature regulation of the 50-period bulk HTS undulator.

Key words: High-Temperature Superconducting Undulator, Temperature Control System, PID Control, Python-based Control System

References

[1] K. Zhang et al, 2025, IEEE Trans. Appl. Supercond., 35, 4100205
[2] D. Wei et al, 2024, IEEE Trans. Appl. Supercond., 34, 4100705

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Presenter: Ms LIU, Chan (Zhangjiang Laboratory, Shanghai)

Session Classification: Wed-Af-Or3 - Wiggler Magnets

Contribution ID: **240** Type: **Poster**

Sat-Mo-Po.06-06: Designed an in-vacuum pulsed-wire magnetic field measurement system

Saturday, July 5, 2025 9:30 AM (1h 45m)

Cryogenic permanent magnet undulators(CPMUs) and superconducting magnets are essential components of synchrotron light sources. The SAFALI system is a commonly used method for measuring magnetic field performance. However, installing and using the SAFALI system to measure the magnetic field in CPMUs with smaller gaps presents significant challenges. In previous studies, we used the PWM system to measure undulators and a small-bore permanent quadrupole magnet, and the results demonstrated its measurement reliability. Therefore, we designed a PWM system for use in vacuum environments. The in-vacuum PWM system includes the wire tension control system and wire displacement detection system. We used an in-vacuum tensiometer mounted on a stepper motor stage to control the wire tension. For the wire displacement detection system, we used an optical design different from that used in previous studies. Finally, we will evaluate the system's accuracy and repeatability in measuring magnetic fields.

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Presenter: CHUNG, TingYi (NSRRC)

Session Classification: Sat-Mo-Po.06 - Mechanical and Magnetic Measurements

Contribution ID: **241** Type: **Poster**

Fri-Mo-Po.02-03: Electromagnetic properties YBCO bulk superconductor with porous structure

Friday, July 4, 2025 9:30 AM (1h 45m)

In the melt heat treatment process for growing YBaCuO superconducting single crystals, increasing the distribution density of flux-pinning particles, Y2BaCuO5, is critical. The flux-pinning effect occurs at the interface between Y2BaCuO5 and YBa2Cu3O7, so a Y1.6Ba2.3Cu3.3O7-y bulk was fabricated to enhance Y2BaCuO5 concentration and improve oxygen diffusion during growth. However, the high viscosity of the molten material often traps gases like O2 and CO2, forming pores that degrade electrical, magnetic, and mechanical properties. Reducing pore density is thus essential for high-density superconductors. To address this, artificial holes were introduced to increase surface area and allow gas escape during oxygen annealing, significantly reducing pore density. Experimental results showed that the artificial hole structure reduced porosity during melting and annealing, enhancing gas discharge. Using a Nd-B-Fe magnet (30 mm diameter, 5.27 kG surface tension) under zero-field cooling, the repulsive force of the bulk with artificial holes reached 116.228 N, compared to 72 N for the hole-free bulk. The remanent magnetic field of the hole bulk was 481.92 mT, much higher than the 228.78 mT of the bulk without holes. These findings demonstrate that artificial holes improve oxygen diffusion and reduce porosity, enhancing the superconducting properties. This research was supported by Korea Electric Power Corporation.(Grant number : R22XO05-01)

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Session Classification: Fri-Mo-Po.02 - Bulk and Permanent Magnets

Contribution ID: **242** Type: **Poster**

Sat-Mo-Po.04-07: Design and performance evaluation of a 9.0 T frameless conduction-cooled superconducting magnet

Saturday, July 5, 2025 9:30 AM (1h 45m)

A 9.0 T frameless conduction-cooled superconducting magnet has been successfully developed in our laboratory. The electromagnetic design was accomplished using a hybrid global optimization method. The magnet features a cold clear bore of 95 mm. Leveraging the frameless design, the consumption of superconducting wire is reduced by approximately 20% compared to conventional designs with an equivalent bore size and central field. Cooling is achieved using one GM cryocooler, enabling the magnet to reach temperatures below 4 K from room temperature. The magnet comprises five coaxial NbTi superconducting coils connected in series, operating at a current of 79.73 A, with a total magnetic energy storage of 0.14 MJ. A passive quench protection system is implemented through coil subdivision, ensuring self-protection by propagating the quench to all coils in the event of an overcurrent. The frameless design eliminates sliding interfaces between the coils and structural frames, preventing friction-induced joule heating during excitation and significantly reducing the occurrence of training quenches. This novel design demonstrates improved efficiency and reliability for conduction-cooled superconducting magnet systems.

Authors: CHENG, Zhiwen; LI, Jianglan; SONG, Yunxing (Wuhan National High Magnetic Field Center)

Presenter: CHENG, Zhiwen

Session Classification: Sat-Mo-Po.04 - Protection and Stability

Contribution ID: **243** Type: **Poster**

Fri-Mo-Po.03-02: A theoretical study on the design of multilayer self-shielding asymmetric gradient coil

Friday, July 4, 2025 9:30 AM (1h 45m)

3.0T Head-Only Superconducting magnetic resonance imaging (MRI) is under developed at the Wuhan National High Magnetic Field Center (WHMFC). Gradient coils, which generate linear gradient magnetic fields orthogonal to each other along the X, Y, and Z directions, are critical components of MRI systems. However, existing asymmetric gradient coil designs often encounter challenges, including excessive wire density on one side, which complicates coil winding and introduces gradient magnetic field distortions near the target area's edges, resulting in increased field non-uniformity. To address these issues, this paper proposes a multilayer self-shielding gradient coil design method. This approach incorporates an additional auxiliary coil layer on the densely wound side to jointly generate the target magnetic field with the main coil. Tikhonov regularization is employed to impose constraints and optimize gradient coil performance. A custom algorithm was developed to implement this design methodology, yielding a gradient coil system that is both winding-friendly and high-performing. The Z-direction coil utilizes a cylindrical configuration, while the X- and Y-direction coils feature saddle-shaped designs.

Authors: SONG, Yunxing (Wuhan National High Magnetic Field Center); WANG, Zhenghang

Presenter: WANG, Zhenghang

Session Classification: Fri-Mo-Po.03 - Magnets for MRI

Contribution ID: **244** Type: **Poster**

Fri-Af-Po.02-08: Study on quench behavior of HTS REBCO stacked tape cable for space solar power station

Friday, July 4, 2025 2:00 PM (2 hours)

Stacked tape superconducting cables based on second-generation high-temperature superconducting REBCO tapes exhibit high current density and excellent mechanical performance under cryogenic conditions, showing significant potential for applications in power transmission systems of space solar power station. This study investigates the quench behavior of HTS REBCO stacked tape cables under various structural parameters and operational conditions through a combination of experimental and numerical analysis methods. A series of TSTC samples with different numbers of stacked layers and twisting angles were fabricated and tested experimentally in the liquid nitrogen temperature range. Key performance indicators, including the current-carrying capacity, minimum quench energy (MQE), and normal zone propagation velocity (NZPV), were analyzed in detail. Based on the experimental cable parameters, an electromagnetic-thermal coupled numerical model was developed, and its computational results were validated against experimental data. This study reveals the influence of structural parameters on the quench behavior of stacked tape cables, providing critical insights and design guidance for enhancing the operational stability and optimizing quench protection strategies of TSTC in space station and satellite applications.

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Presenter: FU, Yutong (Shanghai Jiao Tong University)

Session Classification: Fri-Af-Po.02 - Quench Detection and Protection III

Contribution ID: **245** Type: **Poster**

Thu-Af-Po.05-08: Impact of Critical Current Measurement Criteria on the Performance and Durability of HTS Coils under Conduction Cooling Conditions

Thursday, July 3, 2025 2:00 PM (2 hours)

High-temperature superconducting (HTS) coils are widely utilized in magnet applications due to their superior performance in compactness and energy efficiency. Traditionally, the critical current (Ic) of HTS coils has been measured using the 100 μV/m criterion, adopted from the international standard for second-generation HTS wires. However, as discussed in previous research, this criterion may not be suitable for determining the critical current of HTS coils due to the non-uniform magnetic field distribution within the coil.
The authors investigate the impact of applying different critical current measurement criteria on the performance degradation of HTS coils under conduction cooling conditions using a Gifford-McMahon (G-M) cryocooler and vacuum insulation. The criterion previously proposed by the authors, which addresses the limitations of the 100 μV/m standard, is employed as the minimum threshold, while the conventional 100 μV/m criterion is used as the maximum threshold. Critical current measurements are conducted under different criteria to evaluate whether repeated testing leads to irreversible performance degradation in HTS coils.
By applying conduction cooling using a cryocooler instead of conventional liquid nitrogen cooling, this research enables critical current measurements across various temperature ranges, providing a more practical assessment of HTS coil performance in real-world applications. The findings are expected to offer insights into effective criteria for critical current measurements, helping to prevent coil damage and improve the durability and operational safety of HTS coils during repeated measurements.

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Session Classification: Thu-Af-Po.05 - Conductor and Coil Measurement/Test Techniques and Facilities III

Contribution ID: **247** Type: **Poster**

Fri-Af-Po.02-09: Investigation of near-symmetrical quench current decay in NI-like coils with current path design by PEC

Friday, July 4, 2025 2:00 PM (2 hours)

No-Insulation (NI) or NI-like techniques (including metal insulation) have become essential for quench protection in high-temperature superconducting (HTS) coils. However, the turn-to-turn resistance inherent to NI techniques is an intrinsic property that cannot be fully controlled by coil designers, leading to several challenges. One critical issue is asymmetric quench behavior, where the quenching of a specific section of the magnet causes a rapid current decay in the affected and adjacent coils, potentially resulting in mechanical imbalance within the magnet system. In this study, a method using the recently developed Partial-Electrical Connector (PEC) was proposed to address this issue. By designing PECs to partially insulate sections of the magnet, this approach aims to induce near-symmetrical quench behavior. The proposed concept was tested using sample double pancake coils (DPCs). Although achieving complete control remains challenging due to the need to maintain bypass current paths, this study demonstrates a viable method to optimize quench dynamics in magnet systems and presents new insights for improving quench behavior in HTS magnets.

This research was supported by National R&D Program through the National Research Foundation of Korea (NRF) funded by Ministry of Science an ICT (2022M319A1072464).

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Presenter: Dr LEE, Wooseung (Korea Basic Science Institute)

Session Classification: Fri-Af-Po.02 - Quench Detection and Protection III

Contribution ID: **248** Type: **Poster**

Fri-Mo-Po.08-06: Design, fabrication and testing of a 5-T conduction-cooled HTS magnet

Friday, July 4, 2025 9:30 AM (1h 45m)

A 5 T high-temperature superconducting (HTS) magnet utilizing conduction cooling with REBCO tape has been designed and constructed at the Wuhan National High Magnetic Field Center (WHMFC). The magnet comprises three double pancake (DP) coils, employing a no-insulation (NI) winding technique, and is designed to operate at a current of 260 A at 4 K. During magnet operation, the turn-to-turn contact resistance and screening current effects in the NI magnets introduce additional thermal loads, overstresses, and magnetic field distortions, all of which can negatively impact the magnet's performance. To gain a deeper understanding of these phenomena, a set of multi-physics simulation models has been developed to comprehensively analyze the magnet's behavior under various physical conditions, including the cooling and charging processes. These models integrate electromagnetic, thermal, and structural simulations to capture the full-cycle operational dynamics. The accuracy and reliability of these models are validated by comparing the simulation results with experimental data.

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Session Classification: Fri-Mo-Po.08 - HTS Characterization II

Contribution ID: **249** Type: **Poster**

Thu-Af-Po.02-06: Study on electromagnetic field analysis model for coil windings composed of spiral copper-plated striated coated-conductor cables

Thursday, July 3, 2025 2:00 PM (2 hours)

Spiral copper-plated striated coated-conductor (SCSC) cables, in which copper-plated multifilament coated conductors are wound around a metal core with a circular cross-section, are characterized by both low ac losses and high robustness against thermal runaway or quench, as well as large current capacity and excellent mechanical flexibility. Taking advantage of these features, SCSC cables are expected to be applied to coil windings for rotating machines and magnets generating time-varying magnetic fields for accelerators and fusion reactors. To discuss the possibility of these applications, it is necessary to evaluate the ac losses and the accuracy of the generated magnetic fields of coils wound with SCSC cables by electromagnetic field analyses. However, there has not been sufficient study from a practical viewpoint on how to consider the influence of curved geometry and magnetization interaction of adjacent cables that should be considered in the electromagnetic field analysis for coils wound with SCSC cables.
We are working on analytical techniques for curved SCSC cables and for multiple SCSC cables in adjacent rows to develop an electromagnetic field analysis model of coil windings composed of SCSC cables. In conventional analysis models of curved spiral cables, the width of the coated conductors varies. However, considering that the ac losses and the magnetization strongly depend on the width of the coated conductors, and that the width of the coated conductors does not change when the actual spiral cable is bent, the above modeling is inappropriate, and then, we propose a new modeling method. In our analysis model of curved SCSC cables, the width of the coated conductors that consists of the SCSC cable does not change, and spacing between the coated conductors changes.
Using this analysis model, electromagnetic field analyses are performed for the case of curved SCSC cables lined up next to each other, simulating coil windings and carrying currents under external magnetic fields. We evaluate ac losses, magnetization of coated conductors, and generated magnetic fields under magnetic fields of various amplitudes and applied angles. In addition, methods for reducing the degree of freedom in the analyses of adjacent cables will be also discussed.

This work was supported by JST-ALCA-Next Program Grant Number JPMJAN24G1, Japan.

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Presenter: Dr SOGABE, Yusuke

Session Classification: Thu-Af-Po.02 - HTS Cable

Contribution ID: **250** Type: **Poster**

Fri-Mo-Po.07-08: Coil Manufacturing of R2D2, the Research Racetrack Dipole Demonstrator

Friday, July 4, 2025 9:30 AM (1h 45m)

The Research Racetrack Dipole Demonstrator (R2D2) is a short model magnet developed by CEA Paris-Saclay, in collaboration with CERN. The main goal is to demonstrate the feasibility of key technologies for future high field 16 T Nb3Sn magnets for particle colliders. Using a block-coil design, two different cable grades are wound in the same coil layer, in order to maximize the current density, therefore to minimize the size of the magnet and the use of superconductor. The choice was made of the concept of external joints, for which the cable exits are guided outside of the coil to perform the connections between the cable grades. Two Nb3Sn instrumented single-layer racetrack coils are required to manufacture the magnet. Through the manufacturing of a copper coil, followed by a Nb3Sn practice coil, all the toolings and the manufacturing procedures have been validated. Two coils are now ready to be assembled in the mechanical structure, which has been tested in parallel. An overview of the coil manufacturing experience will be given, with an analysis of the various measurements performed and a feedback on the manufacturing process.

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Presenter: Dr RONDEAUX, Francoise (CEA Paris-Saclay)

Session Classification: Fri-Mo-Po.07 - Accelerator Magnets III

Contribution ID: **251** Type: **Contributed Oral**

Wed-Af-Or3-05: Modeling and experiment result of double staggered-array helical undulator made of stacked RE-Ba-Cu-O tapes

Wednesday, July 2, 2025 5:30 PM (15 minutes)

High-temperature superconducting (HTS) materials have attracted significant interest for use in insertion devices due to their higher critical temperature, Tc and larger critical current density, Jc compared to low-temperature superconducting wires [1-3]. These properties enable the development of undulators with shorter period and larger on-axis magnetic field. Helical undulators, which suppress higher harmonic photon generation, are particularly well-suited for free electron laser (FEL) facilities that utilize photons at their fundamental wavelength. To facilitate the future upgrade of the Shanghai Soft X-ray Free Electron Laser (SXFEL) facility, we propose the development of a 12 mm-period HTS helical undulator incorporating a double staggered-array configuration based on stacked RE-Ba-Cu-O tapes. Numerical optimization for various configurations of stacked tapes indicates that an on-axis field Bx0 and By0 reaching 1.0 T (with an effective magnetic field, Beff, of 1.4 T) can be achieved using 12 mm-width stacked tapes in a trapezoid configuration, with a period length of 12 mm and a magnetic gap of 6 mm. Based on the optimized configuration, we fabricated an HTS helical undulator model with ten periods at Zhangjiang Laboratory. The short model underwent an initial testing following field-cooled magnetization from 0.3 T to 0 T at 77 K, with subsequent testing conducted using a superconducting solenoid magnet with Bs > 10 T. This study provides a detailed summary of the sample preparation process and the corresponding test results.

Key words: helical undulator, high-temperature superconductor, RE-Ba-Cu-O

References

[1] Z. Chen et al., 2024, Supercondivity, 12, 100134

[2] K. Zhang et al., 2023, Supercond. Sci. Technol., 36, 05LT01

[3] K. Zhang and M. Calvi, 2022, Supercond. Sci. Technol., 35, 093001

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Session Classification: Wed-Af-Or3 - Wiggler Magnets

Contribution ID: **252** Type: **Contributed Oral**

Wed-Mo-Or2-02: Updates on the Conceptual Design Study of the Magnets for the Muon Collider Storage Ring

Wednesday, July 2, 2025 11:30 AM (15 minutes)

The Muon Collider represents an exciting proposal for a post-LHC accelerator, capable of exploring higher-energy regions with greater power consumption efficiency compared to hadronic alternatives, while avoiding synchrotron radiation limitations inherent in electron colliders.

This contribution will focus on the magnets for the Muon Collider storage ring. These magnets pose an unprecedented technological challenge: high magnetic fields are required to ensure the compactness of the ring, maximizing the number of muon beam passes through the interaction region and thereby increasing luminosity. Additionally, large apertures are essential to accommodate an adequate shielding system that keeps the thermal and nuclear loads induced by the beam within acceptable limits. Furthermore, minimizing straight sections is critical to avoid the radioactive hazard posed by collimated neutrino beams, necessitating the use of combined-function magnets (dipole + quadrupole and dipole + sextupole). The interaction region also presents extreme conditions that demand the development of magnets beyond the current state of the art.

In this contribution, we will discuss the progress in the feasibility study of magnets for both the arc and the interaction region of the Muon Collider storage ring. Performance limits will be analyzed for dipoles, quadrupoles and combined function magnets, taking into consideration constraints on mechanical stresses, margin on the load line, ease of the protection system and cost, assuming both LTS (Nb_3Sn) and HTS (ReBCO) materials.

Finally, the most up-to-date conceptual designs of the arc dipole will be presented, comparing the strengths and challenges of the cos-theta and block coils layouts in terms of achieving of electromagnetic requirements, mechanical structure feasibility, and windability This analysis will provide valuable insights into the development of advanced magnet technologies required for the Muon Collider.

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Presenter: CAIFFI, Barbara (INFN e Universita Genova (IT))

Session Classification: Wed-Mo-Or2 - Muon Collider Magnets

Contribution ID: **253** Type: **Poster**

Wed-Af-Po.05-02: Development of Scribed Y–Gd–Ba–Cu–O Coated Conductors Fabricated by Trifluoroacetate Metal Organic Deposition Process

Wednesday, July 2, 2025 2:30 PM (2 hours)

REBa₂Cu₃O_y (REBCO, where RE is a rare-earth element) coated conductors (CCs) fabricated using the trifluoroacetate metal organic deposition (TFA–MOD) method are promising for various electric power applications, such as superconducting cables, motors, and generators. This is due to their low cost and high criticaenter code herel current (I_c) under high magnetic fields, even at liquid nitrogen temperatures. REBCO CCs offer significant advantages in direct current applications because of their negligible energy loss. However, for alternating current (AC) applications, they exhibit substantial AC loss, which necessitates effective reduction strategies. The multifilamentation technique is a proven method for reducing AC loss; however, the application of laser scribing to achieve multifilamentation in TFA–MOD-derived CCs poses challenges. The presence of pores in these CCs can lead to the delamination of the superconducting layer. Previously, we successfully fabricated long-length BaZrO₃ nanoparticle-doped Y_{0.77}Gd_{0.23}Ba₂Cu₃O<sub>
((Y,Gd)BCO+BZO) CCs by employing an intermediate heating temperature technique and an ultra-once coating method, resulting in pore-free CCs.
In this study, we applied laser scribing to create multiple filaments in (Y,Gd)BCO+BZO CCs and evaluated its impact on superconducting properties. The four-filament scribed (Y,Gd)BCO+BZO CCs demonstrated no delamination, and the I_c value was approximately 20 A per filament (with a filament width of ˜1 mm) in short CCs at 77 K under self-field conditions.
This paper details the superconducting properties and AC loss characteristics of scribed (Y,Gd)BCO+BZO CCs with varying filament numbers, offering insights into their potential for AC applications.
This study is based on findings obtained from Project, which was subsidized by the New Energy and Industrial Technology Development Organization.

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Presenter: SATO, Michio

Session Classification: Wed-Af-Po.05 - HTS Conductors II

Contribution ID: **254** Type: **Contributed Oral**

Sat-Mo-Or6-06: Field Quality of the Series of Orbit Nested Corrector Magnets for HL-LHC

Saturday, July 5, 2025 12:30 PM (15 minutes)

MCBXF magnets are orbit correctors for the High-Luminosity (HL) Large Hadron Collider (LHC) upgrade. The magnet design consists of two nested dipoles, with an aperture of 150 mm. The magnets have been designed in two physical lengths, namely of 2.5 m (MCBXFA) and 1.5 m (MCBXFB), with the same cross section. The series production of the magnets consists of 6 long and 11 short magnets and being carried out at CIEMAT and assembled at CERN. In this paper we summarize the results of training and magnetic measurements of the magnets produced so far. Warm magnetic measurements are also included.

The first magnets featured repetitive results regarding field quality. Afterwards, some of the magnets showed a shift of the main harmonics. After careful analysis of the fabrication steps, it was found out that the impregnation mould assembly strategy impacted on the coil dimensions. The shimming plan was tuned to deal with this feature, and the field quality was enhanced accordingly.

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Session Classification: Sat-Mo-Or6 - High Luminosity LHC

Contribution ID: **255** Type: **Poster**

Wed-Mo-Po.03-04: Magnetic field angle dependence of Jc-B properties for FF-MOD method Gd123 thin films with Gd214 artificial pins

Wednesday, July 2, 2025 9:15 AM (2 hours)

We have fabricated GdBa2Cu3O7-δ (Gd123) thin films doped Gd2CuO4 (Gd214) as artificial pins on LaAlO3 single crystal substrate by fluorine-free metal organic decomposition method and investigated their crystallinity and magnetic field angle dependence of JC-B properties. Recently, we have succeeded in fabricating Gd123 crystals introduced Gd214 as effective artificial pinning centers. TEM observation revealed that Gd214 crystals form plate-like 15-20 unit cells perpendicular to the c-axis of Gd123 crystals. Therefore, the pinning force densities Fp may be maximum at μ0H ⊥ c-axis by contrast of normal BaMO3 particle pins We measured the transport currents by changing the applied magnetic field angle from 0° to 120°. As a result, a significant increase in Fp was confirmed in the magnetic field perpendicular to the c-axis of Gd123 crystals. Furthermore, the amount of Gd214 introduced that maximizes Jc was clarified.

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Presenter: Mr ISHII, Ryota (Tokyo Metropolitan University)

Session Classification: Wed-Mo-Po.03 - HTS Characterization I

Contribution ID: **256** Type: **Poster**

Wed-Af-Po.12-05: Research of 0°/-180° phase-shift asymmetric firing converters for steady-state magnet power supplies

Wednesday, July 2, 2025 2:30 PM (2 hours)

Converters composed of thyristor full bridges are commonly used to feed superconducting coils and test magnets. Since magnets mostly operate in the steady state, converters under symmetric firing generate significant reactive power. In this paper, a design of the 0°/-180°phase-shift converter is proposed with asymmetric firing to reduce fundamental reactive power, and the even harmonics cancelling are further explained. Then, the sufficient voltage output capability is introduced in terms of available firing angle selections. As for operation issues, firstly, steady ripple calculations provide a reference for selecting DC reactors and firing angles. Secondly, while symmetric firing is still used during pre-excitation and demagnetization, the switch logic from symmetric to asymmetric firing is designed to avoid commutation failures and estimate the perturbation to current balance of bridges. Furhter analysis indicates that transient unbalanced volt-seconds remain constant despite firing angle changes. Thirdly, a current-sharing control method that meets both reliable commutation and the minimization of even harmonics is proposed. Finally, the converter design and characteristics are verified by simulations using the parameters of CSMC converters.

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Session Classification: Wed-Af-Po.12 - Power Supplies

Contribution ID: **257** Type: **Contributed Oral**

Wed-Mo-Or1-04: Engineering progress of the toroidal field and the central solenoid model coils for the CTRFR-1 spherical tokamak

Wednesday, July 2, 2025 12:00 PM (15 minutes)

CTRFR-1 (Compact Tokamak-based Repetitive Fusion Reactor-1, R = 1 m, a = 0.56 m, A = R/a = 1.8, B0=3.2 T, Q=1) is the next-generation high-temperature superconducting (HTS) spherical tokamak (ST) designed by Shannxi Startorus Fusion Technology Co., Ltd., a commercial fusion enterprise from China. The spherical tokamak is an economical and fast-building option for a fusion reactor, which allows to confine high-pressure plasma using a modest magnetic filed in a compact device due to its low aspect ratio. However, the limited space in the center column of the ST, also due to the low aspect ratio, necessitates higher engineering current density and reduced radiation protection for the magnet used in the ST. Attracted by the high current-carrying capacity and greater temperature margin of the HTS technology, researches on HTS toroidal field model coil (TFMC) and central solenoid model coil (CSMC) are conducted by Startorus Fusion.

The TFMC is one of sixteen REBCO toroidal field coils with 4 meter in height, achieving 6.87 T peak filed-on-coil with 4.4 kA of terminal current. The engineering current density of the winding pancake is 147 A/mm2 while the entire magnet, including the structural case, is 62 A/mm2. The TFMC consists of two double no-insulation pancakes, each with 104 turns. The winding pancake is co-wound by 9 superconducting tapes and 1 stainless steel tape, all 12 mm in width. The ground insulation of the TFMC is achieved by filling the epoxy-impregnated G-10 panels between the structural case and winding pancakes. A specially designed demountable pancake-to-pancake joint for the 9-layer stacked cable can operates in the 0.2 to 1 nΩ range at 20 K. An innovative technique involving the application of Stycast 2850 on the side of no-insulation pancake for efficient insulation and cooling has been proposed.

The CSMC is a 1/10 scaled-down REBCO central solenoid coil with 0.4 meter in height, 160 mm in inner radius and 240 mm in outer radius. It achieves 13.8 T peak filed-on-coil with 7.2 kA of terminal current. The CSMC provides a magnetic flux of 1.5 Wb and a maximum magnetic field change rate of 70 T/s, generating 8 V loop voltage for plasma breaking. The engineering current density of the winding pancake is 202 A/mm2 while the entire magnet, including the structural case, is 100 A/mm2. It consists of 26 double pancakes, each with 28 turns, using a non-twisted stacked superconducting cable. This cable is co-wound by 36 superconducting tapes with 6 mm in width. The turn-to-turn insulation of the CSMC is achieved by wrapping the cable in glass-Kapton tapes with a thickness of 0.5 mm. Additionally, the ground insulation of the CSMC is provided by epoxy-impregnation of the entire magnet.

Both the TFMC and CSMC are cooled down by a crycooler based cryogenic system provided 300 W of cooling power at 20 K with mass flow rate of supercritical helium up to 18.4 g/s at a maximum design pressure of 5 bar. The manufacturing of TFMC and CSMS is currently in progress, with the cooling, discharge, and AC loss test results of the CSMC expected by mid-2025, and the cooling and charging test results of the TFMC expected by late 2025.

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Presenter: Prof. TAN, Yi (Tsinghua University)

Session Classification: Wed-Mo-Or1 - Future Fusion Devices: Tokamaks

Contribution ID: **258** Type: **Poster**

Fri-Mo-Po.04-06: An Improved Target Field Method for Cylindrical Shim Coils Optimization in NMR Systems

Friday, July 4, 2025 9:30 AM (1h 45m)

Imaging quality is a critical metric for evaluating the performance of magnetic resonance systems, heavily influenced by the strength and homogeneity of the main magnetic field. While a high degree of homogeneity can theoretically be achieved during the design phase of the main magnet, unavoidable losses in homogeneity occur during manufacturing and assembly processes. The classical target field method for shim coil design constrains current density distribution to a cylindrical surface, expanding it via Fourier series. Magnetic field values derived from Biot-Savart's law and ideal magnetic field values are used to construct a system of equations to solve for the current density distribution. The resulting current density is subsequently discretized using the stream function method. However, discrepancies between the designed and expected outcomes are occasionally observed. This paper presents an improved shim coil design method for a 5T nuclear magnetic resonance (NMR) system, extending the traditional target field method. The proposed method incorporates considerations of wire spacing and coil turns to ensure the final design satisfies the specified requirements.

Authors: JIANG, Xunhuang; SONG, Yunxing (Wuhan National High Magnetic Field Center)

Presenter: JIANG, Xunhuang

Session Classification: Fri-Mo-Po.04 - Magnets for NMR

Contribution ID: **259** Type: **Poster**

Thu-Af-Po.03-04: Structural optimization and performance testing of a racetrack coil for a 50 Mvar superconducting synchronous condenser

Thursday, July 3, 2025 2:00 PM (2 hours)

It is urgent to address the problems of reactive power imbalance in the power grid with a high proportion of renewable energy. Compared to traditional reactive power regulation devices, a superconducting synchronous condenser is an appreciate choice due to its higher power density, faster response time for reactive power regulation, and higher operational efficiency. To minimize the mass and volume of the 50 Mvar superconducting synchronous condenser simultaneously, a multi-objective optimization approach combining Taguchi and finite element method (FEM) is proposed. After optimization, the mass is 20.232 tons and volume is 3.523 m^3. An experimental platform is built for testing current carrying performance of the racetrack coil that is wound by REBCO superconducting tapes and cooled by liquid nitrogen. According to the results, critical current of the racetrack coil is about 1.3 times the maximum operational current. It shows the racetrack coil has the excellent stability margin.

Authors: ZHU, Jiahui; Mr LIU, Yue

Presenter: ZHU, Jiahui

Session Classification: Thu-Af-Po.03 - Rotating Machinery III

Contribution ID: **260** Type: **Poster**

Fri-Af-Po.07-05: Research on the application of digital twin technology for the pulsed high magnetic field facility

Friday, July 4, 2025 2:00 PM (2 hours)

To improve visualization capability, simulation effort, and experiment efficiency for the Pulsed High Magnetic Field Facility (PHMFF) at Wuhan National High Magnetic Field Center (WHMFC), an intelligent operation and maintenance method based on digital twin technology is proposed. Reference to standard model, digital twin framework is first described including physical entity, virtual entity, service, etc., and key technologies for constructing PHMFF digital twin system are introduced. Second, possible applications are analyzed, such as facility visual monitoring, process analysis, discharge simulation, intelligent configuration, state forecasting, and fault diagnosis. Finally, the challenges and problems in the application of digital twin technology for PHMFF are discussed. PHMFF digital twin system is planned to be developed during the next years, which will be great helpful to promote the operation and maintenance capability of the facility.

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Session Classification: Fri-Af-Po.07 - High Field Pulsed Magnets II

Contribution ID: **262** Type: **Poster**

Thu-Mo-Po.02-01: Conceptual Mechanical Design and Analysis of CEPC Detector Magnet

Thursday, July 3, 2025 8:45 AM (2 hours)

A large-scale low-temperature superconducting magnet is proposed for the future detector of Circular Electron Positron Collider (CEPC) at the Institute of High Energy Physics, Chinese Academy of Sciences (IHEP,CAS). The central magnetic field of the magnet is 3 Tesla, the length, inner and outer diameter of the magnet is 9.05 m, 7.07 m and 8.47 m， respectively. The weight of the cold mass is about 185 t. This paper presents the mechanical design of the support structure of the cold mass and the cryostat of the magnet.

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Presenter: HOU, Zhilong

Session Classification: Thu-Mo-Po.02 - Design and Development of Accelerator Magnets I

Contribution ID: **263** Type: **Poster**

Thu-Mo-Po.09-06: Superconducting-compensated DCCT large current measurement technique for high-temperature superconducting cables

Thursday, July 3, 2025 8:45 AM (2 hours)

In view of the challenges such as small range, low accuracy and weak tracking ability in current measurement of high-temperature superconducting cable for ultra-high field magnets, a high precision and fast response current measurement scheme based on core coil improvement and superconducting coil compensation is proposed. A DCCT high-temperature superconducting compensation coil has been designed, extending the static current measurement range to the hundred-thousand ampere level, thus enabling the measurement of large currents at this level. Additionally, the control circuit has been optimized, incorporating Hall current sensors as a feedforward element, resulting in a high-precision, fast-response current measurement system with complementary advantages. Furthermore, DCCT magnetic shielding technology suitable for complex electromagnetic environments has been developed, and the geometric design has been optimized to avoid magnetic core saturation caused by busbar eccentricity. A preliminary laboratory-scale DCCT prototype capable of measuring current levels of 20 kA has been developed. It is designed to achieve current measurements of 20 kA under a background magnetic field of beyond 10T, with a precision of less than 200 ppm. It is promising to provide effective technical means for accurate and rapid measurement of large currents in ultra-high magnetic fields.

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Presenter: LU, Jin (Shanghai Jiao Tong University)

Session Classification: Thu-Mo-Po.09 - Conductor and Coil Measurement/Test Techniques and Facilities II

Contribution ID: **265** Type: **Poster**

Wed-Af-Po.09-01: Startup of a multi-physics simulation platform for fusion magnet design and analyses

Wednesday, July 2, 2025 2:30 PM (2 hours)

For advancing the development of fully superconducting tokamak magnets and accelerating the progress to the next step in fusion reactor DEMO design, a refined and integrated large-scale superconducting tokamak simulation platform is being developed in China. The aim is to optimize the design and performance of tokamak magnets, improve their efficiency and reliability, solve complex multi-physics R&D problems, and improve the efficiency of design workflows involving macroscopic and detailed analysis. In pursuit of the ultimate goal, the software being developed not only integrates several secondary development interfaces to commercial software but also codifies a set of codes covering macro and detailed scientific issues, such as stability analysis, quenching, etc. The platform will incorporate separate design modules for electromagnetic, thermal, mechanical, and thermo-hydraulic while allowing for multi-module coupling to meet optimization and transient multi-physics coupling demands. The developed module will be cross-checked with the corresponding experiments and the material database will be integrated at the same time. Creating an effective user interface and workflow is also under consideration, while the scalability and maintainability of the software to support future developments and updates will be discussed. It is believed that the tool will bring benefits to designers.

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Session Classification: Wed-Af-Po.09 - Magnets for Tokamaks: Design and Analysis

Contribution ID: **266** Type: **Poster**

Thu-Af-Po.08-02: A Novel Radial Reinforcing Scheme for High-field Pulsed Magnets

Thursday, July 3, 2025 2:00 PM (2 hours)

Conventional high-field pulsed magnets employ layered reinforcement techniques, where high-strength fiber composites are inserted around each conductor layer within solenoid coils to withstand the substantial Lorentz forces. For magnets exceeding 80 T, the required reinforcement layer thickness exceeds 5 mm. However, this design reduces the conductor filling factor and increases the coil inductance, resulting in higher energy requirements. Furthermore, the stress distribution within the reinforcement layers is uneven in this structure, with maximum stress concentrated on the inner layers, while the outer layers remain underutilized in terms of mechanical capacity, leading to decreased material efficiency. To address these issues, the WHMFC team has proposed a novel pancake magnet structure based on radial reinforcement. In this design, thin reinforcement layers are radially stacked around each conductor layer of the pancake coil, effectively counteracting the radial Lorentz forces. This paper presents a theoretical investigation into the mechanical advantages and efficiency of this new magnet structure and provides a comparative analysis with the traditional hoop-reinforced structure. Starting from the fundamental equations of mechanics, approximate analytical stress formulas for both the conductor and reinforcement layers under radial and hoop reinforcement are derived. The conductor filling factor and reinforcement volume efficiency of both methods are then analyzed in detail, along with the factors influencing these parameters. Subsequently, stress distribution within the magnet is analyzed by establishing mid-plane stress calculation methods for both radial and hoop reinforcement. Based on this, the optimal reinforcement layer thickness for both single pancake magnets and axially stacked pancake magnets is determined and further compared with corresponding hoop-reinforced magnets. The results demonstrate that radial reinforcement leads to a more uniform stress distribution and higher conductor filling factors, as well as improved reinforcement volume efficiency within the magnet structure. Therefore, the proposed radial reinforcement scheme exhibits significant advantages in terms of mechanical performance and reinforcement efficiency for high-field magnet systems.

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Session Classification: Thu-Af-Po.08 - Materials for Pulsed Magnets

Contribution ID: **267** Type: **Poster**

Fri-Af-Po.07-04: A Structural Calculation Method for Pulsed High-field Magnets Considering the Deviation of Axial Strain

Friday, July 4, 2025 2:00 PM (2 hours)

Solenoidal high-field pulsed magnets typically employ layered reinforcement techniques to mitigate the substantial Lorentz forces acting on the conductors. The thickness of each reinforcement layer must be optimized through stress analysis to achieve a uniform and reasonable stress distribution. Although commercial finite element analysis (FEA) software can accurately calculate the stresses within magnets, it presents challenges such as complex modeling processes, slow computation speed, and poor convergence, which require researchers to invest considerable time during the early stages of magnet design. In contrast, the specialized pulsed magnet design software PMDS offers faster computation. However, the PMDS model assumes a constant axial strain in the mid-plane of the magnet, simplifying the calculations but introducing errors. In reality, due to the non-uniform axial Lorentz forces and the characteristics of the contact interface between conductors and reinforcement layers, the axial strain in the mid-plane varies along the radial direction. In this paper, an improved mechanical model for stress analysis of solenoidal pulsed magnets is proposed, which accounts for the radial variation of axial strain and its influence on stress distribution. By introducing a parabolic distribution for the axial strain, a complete one-dimensional finite element calculation theory and method is established. Compared to the classical generalized plane strain analysis, the improved model significantly enhances the accuracy of stress predictions. The results obtained from the proposed model are validated through comparison with commercial FEA software. This improved model achieves both high efficiency and high accuracy, making it a valuable tool for optimizing high-field solenoidal pulsed magnets and exploring the potential for achieving higher magnetic fields.

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Session Classification: Fri-Af-Po.07 - High Field Pulsed Magnets II

Contribution ID: **268** Type: **Poster**

Wed-Mo-Po.10-03: Design and experimental investigations of a 35 kV/1.5 kA CORC-based superconducting fault current limiter (SFCL)

Wednesday, July 2, 2025 9:15 AM (2 hours)

The increasing demand for reliable power supply in modern grids has highlighted the need for effective fault current limiting solutions. Superconducting Fault Current Limiters (SFCLs) based on Conductor on Round Core (CORC) technology offer a promising approach to address this challenge, combining high performance with cost-effectiveness. This paper presents the design, development, and experimental investigation of a 35 kV/1.5 kA CORC-based SFCL. A comprehensive design methodology is employed, incorporating electromagnetic, thermal, and mechanical considerations to optimize the CORC conductor configuration for fault current limiting applications. Numerical simulations using finite element analysis are conducted to evaluate the electromagnetic characteristics, thermal behavior, and mechanical stability under both normal and fault conditions. A prototype SFCL is fabricated using advanced CORC conductor technology, and a specialized test setup is developed to accurately measure the performance parameters. Experimental results demonstrate the SFCL's ability to transport a steady alternate current of 1.5 kA at 35 kV, and to effectively limit a fault current of 20 kA with rapid response times and excellent recovery characteristics. The CORC-based design shows significant improvements in current density and material efficiency compared to conventional SFCL approaches. This research provides valuable insights into the development of cost-effective, high-performance SFCL solutions for medium-voltage power gird applications.

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Presenter: ZHU, Jiahui

Session Classification: Wed-Mo-Po.10 - Transformers and Fault Current Limiters

Contribution ID: **269** Type: **Poster**

Thu-Af-Po.01-05: A new eddy current septum magnet for fast extraction from CERN's Proton Synchrotron

Thursday, July 3, 2025 2:00 PM (2 hours)

A new eddy current septum for the fast extraction from CERN's Proton Synchrotron has been designed and constructed. This development aims to improve the magnet's reliability, extend its service interval, and reduce radiation exposure for maintenance personnel. The new eddy current device is set to replace the existing direct-drive magnet and its ageing power converter.
This paper summarizes the electromagnetic design calculations, the mechanical concept and the subsequent detailed design implementation. It also describes the magnet's construction process and the results from the comprehensive validation tests, including magnetic field measurements, to achieve operational readiness ahead of commissioning in the Proton Synchrotron accelerator.

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Session Classification: Thu-Af-Po.01 - Accelerator Magnets II

Contribution ID: **270** Type: **Poster**

Sat-Mo-Po.02-02: Three-degree-of-freedom control strategy for the magnetically controlled capsule endoscope under the rotating magnetic field of dual permanent magnets

Saturday, July 5, 2025 9:30 AM (1h 45m)

For a single permanent magnet to control the orientation of the magnetically controlled capsule endoscope (MCCE), it is difficult to meet the demand for a complex orientation adjustment in three-dimensional space due to the non-uniformity of the magnetic field and insufficient torque. A cooperative control strategy of dual permanent magnets based on a rotating magnetic field is proposed to improve the orientation accuracy of the MCCE in the digestive tract.The control strategy provides a stable rotating magnetic field reference by one permanent magnet. Another rotating magnetic field dynamically adjusts the angle or direction, thus realizing the orientation adjustment of the MCCE in three degrees of freedom: roll, pitch, and yaw.This paper calculates the rotating magnetic field distribution of double external permanent magnets and the magnetic moment acting on the MCCE based on the magnetic dipole model under the control strategy. Finally, the proposed control strategy is verified through experiments. The results show that the control strategy significantly improves the accuracy of the MCCE's orientation adjustment and provides a feasible method for this in the digestive tract environment.

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Session Classification: Sat-Mo-Po.02 - Magnets for Other Medical Application III

Contribution ID: **272** Type: **Poster**

Thu-Mo-Po.04-10: Experimental study on overcurrent and quench characteristics of NI HTS coil wound with thin REBCO tape

Thursday, July 3, 2025 8:45 AM (2 hours)

For non-insulated (NI) HTS coils wound with thin REBCO tapes, on the one hand, due to increasing current density, the coils can generate higher magnetic field; on the other hand, the compactness and the mechanical stability of the coils can be improved for the reason of higher proportion of Hastelloy. However, up to now, there is a lack of experimental research data on the electro-thermal stability of such NI coils. This work builds an experimental test platform for these NI coils, focusing on the coil electro-thermal stability. Our experimental coil is wound with 50μm thick REBCO tape (10μm for the single-sided copper layer and 30μm for the Hastelloy layer) using NI technology. It is worth noting that the experimental coil has more than 200 turns, more than 8 temperature sensors, and more than 10 voltage testing signals, which helps us realistically simulate the coils used for high-field superconducting magnets and fully understand its electrical and thermal characteristics during overcurrent and quench events. In addition, for the first time, we put both local heater and whole-turn heater into the coil. Using the former one to trigger quench events can obtain the circumferential normal zone propagation velocity (NZPV) of the coil, and using the latter one can obtain the radial NZPV, which helps us to decouple heat transfer at circular direction and at radial direction. In order to make the power supply produce higher heating power, we divide the whole-turn heater into 4 parts and connect them in parallel, thereby improving the matching degree between the resistance of the heater and the rated resistance of the power supply. The experiment was carried out under the conduction-cooled condition. At 77K, 65K and 20K, we firstly tested the critical current of the coil as a benchmark for subsequent experiments. We then set the coil current to 1.3Ic to test the coil ability to cope with overcurrent. Finally, we set the coil current to 0.7Ic, using local heater and whole-turn heater to trigger the quench, and evaluated the minimum quench energy (MQE) and NZPV of the coil. This work further improved the database of electro-thermal stability performance of NI coils, providing important data support for magnet design, construction, analysis and modeling.

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Session Classification: Thu-Mo-Po.04 - No-Insulation Coils III

Contribution ID: **274** Type: **Contributed Oral**

Sat-Af-Or2-02: The Grenoble hybrid magnet: From design and construction to commissioning up to 42 T as a first step

Saturday, July 5, 2025 2:15 PM (15 minutes)

A CNRS-CEA French collaboration has developed and built a new modular hybrid magnet at LNCMI-Grenoble to provide intense magnetic fields and fluxes. It was designed to reach in its main configuration at least 43 T in a 34 mm warm bore aperture with 24 MW of electrical power. This is achieved by combining resistive inserts, including Cu-alloy polyhelix (25.5 T) and Bitter coils (9 T), with a large bore superconducting coil (1100 mm) generating a nominal magnetic field of 8.5 T. The latter is made of a total length of about 9 km of a specifically developed Nb-Ti/Cu Rutherford cable-on-conduit conductor (RCOCC) with strict control of AC losses. This has been achieved from in-house soft-soldering of the Rutherford cable onto a hollow rectangular Cu-Ag stabilizer, which is cooled to 1.8 K by a pressurized superfluid helium bath at 1200 hPa. The superconducting coil consists of 37 double-pancake windings stacked and connected in series. These are housed within a helium vessel, which is connected via a cryoline to an external cryogenic satellite ensuring that all valves are positioned in a stray magnetic field lower than 10 mT. A cylindrical eddy-current shield in Cu, reinforced by austenitic steel and cooled down to 35 K, was inserted in between resistive and superconducting coils to lower the field variation seen by the RCOCC in case of resistive insert trips and therefore preventing quenches. The Grenoble hybrid magnet requires additional equipment such as a 5000 m3/h pumping unit, a dedicated He liquefaction plant of 150 l/h, power converters of 7500 A/±15 V for the superconducting coil and 12 + 18 MW for the resistive inserts delivering separately up to about 32 kA each. Two fully redundant Magnet Safety Systems (MSSs) have been specially developed for the quench detection and energy extraction of the superconducting coil, as well as dedicated control-command and acquisition systems.
Throughout the commissioning phase, the superconducting coil alone reached the nominal field of 8.5 T eleven times in total without quench. During the combined tests with Bitter coils, an unexpected quench appeared at 17.43 T very close to the nominal field of this configuration equal to 17.5 T. It was not far from a stagnant quench, difficult to detect, and also known as a "silent magnet killer"with a slow propagation velocity of about 10 cm/s. Both MSSs reacted as expected and the hot-spot temperature was limited to about 85 K validating their efficiency in one of the worth case scenarios. For the combined tests between superconducting and polyhelix coils, a magnetic field of 34 T was reached, but during the current ramp-down, the power converter of the superconducting coil overheated and lost communication with the PLC causing a fast energy discharge. No damage to the superconducting coil neither resistive inserts were detected. Investigations revealed a misfunctioning of the power converter with one of the protection crowbars that was switched on before reaching the triggering voltage threshold. A few components of the power converter were changed and mitigation actions were implemented to avoid the occurrence of such a problem, before continuing the commissioning tests. Finally, the Grenoble hybrid magnet reached 42 T, as a first step. Focus will be given to the problems encountered and solved during this successful initial commissioning phase, as well as the potential to achieve higher magnetic fields.

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Session Classification: Sat-Af-Or2 - Progress in Ultra High Field Solenoids

Contribution ID: **275** Type: **Poster**

Wed-Mo-Po.02-01: Update on the electromagnetic and mechanical design of a cos-theta dipole for the Muon Collider study

Wednesday, July 2, 2025 9:15 AM (2 hours)

Within the framework of the International Muon Collider Collaboration (IMCC), researchers are involved in a feasibility study to develop high-temperature superconducting (HTS) magnets for the proposed 10 km collider ring, designed to reach a 10 TeV center-of-mass energy. Due to the short lifetime of muons of only 2.2 µs, the machine must minimize the acceleration time of the particles allowing them to collide before they decay. To optimize the machine cost and maximize the collider luminosity, the superconducting dipoles of the collider ring must be compact and generate high steady-state magnetic field. In addition, they must feature large apertures to assure enough space for the insertion of a shielding structure needful to preserve superconducting coil from interacting with products of muons decays. These demanding specifications pose significant technological challenges for the dipole magnets design, both in terms of physics and engineering.
In this contribution we update the 2D cosϴ electromagnetic and mechanical design of the main collider dipoles. Since the coil design requires the use of REBCO tapes (whose magnetization effect in field quality and losses is not negligible), an analytical code has been written in MATLAB to evaluate the electromagnetic performances considering non-uniform current distribution inside REBCO tapes according with Brandt model. Validation study of the code - by comparing the results with finite element method (FEM) simulations - is also presented in this work. This includes a comparison of computational time between the analytical and FEM method, to better appreciate the advantages of the two calculation methods and their accuracies.

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Session Classification: Wed-Mo-Po.02 - Muon Collider

Contribution ID: **276** Type: **Poster**

Thu-Mo-Po.04-09: Numerical simulation and experimental study on real-time calculation of NI HTS coil contact resistance

Thursday, July 3, 2025 8:45 AM (2 hours)

The contact resistance of non-insulation high-temperature superconducting (NI HTS) coils is an important parameter to characterize their thermal stability. While numerous discharging experiments have demonstrated that the contact resistance of NI HTS coils is not constant, the real-time evaluation of its transient behavior remains insufficiently explored. This paper proposes a novel inverse modeling strategy for the contact resistance of NI HTS coils, based on macroscopically measured coil voltage and central magnetic field. The numerical model implemented in COMSOL, integrates equivalent circuit and finite element methods, using the measured coil voltage and magnetic field as inputs to output the real-time contact resistance during the transient process. The results demonstrate that the contact resistance exhibits nonlinear variations during these processes, significantly affecting the time constant. The inverse modeling approach proposed in this study provides valuable insights into evaluating the real-time contact resistance during the transient process of NI HTS coils.

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Session Classification: Thu-Mo-Po.04 - No-Insulation Coils III

Contribution ID: **277** Type: **Poster**

Wed-Af-Po.07-05: A semi-analytical stress analysis method for interturn separation in dry-wound electromagnetic coil

Wednesday, July 2, 2025 2:30 PM (2 hours)

The finite element analysis method is a commonly used and accurate approach for calculating the stress in electromagnetic coils. However, for dry-wound coils with nonlinear contact behavior, especially those with many turns, these methods are often time-consuming and may have convergence issues. Therefore, this study proposes a semi-analytical stress analysis method specifically designed to address the separation of turns in dry-wound electromagnetic coils. Primarily, we derive an integral expression for the electromagnetic stress within the continuous integral electromagnetic coil. Secondly, we employ the concept of average displacement to identify the separation and contact phenomena, thus determining different boundary conditions. Finally, by iteratively solving for these boundary conditions, we obtain the ultimate stress distribution. We compare these computed results with finite element methods to validate the accuracy of our approach. What sets this method apart is its ability to achieve accurate results without the need for establishing many contact pairs, resulting in significant computational resource savings. This method holds great significance for iterative design searches and optimization in dry-wound electromagnetic coil applications.

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Session Classification: Wed-Af-Po.07 - Modelling and Analysis

Contribution ID: **278** Type: **Poster**

Sat-Mo-Po.02-01: Research on magnetic driving model and control strategy of magnetic guidewire based on nonlinear magnetic field

Saturday, July 5, 2025 9:30 AM (1h 45m)

The magnetic field distribution of externally driven permanent magnets and its effects on the magnetic force and torque at the tip of a Magnetic Guidewire (MG) directly determine the precision of its deflection and movement. To enhance the control accuracy of MGs within blood vessels, this study proposes an MG magnetic driving model based on a nonlinear magnetic field. The research begins by solving the distribution of the driving magnetic field and calculating the magnetic force and torque exerted on the axially magnetized permanent magnet embedded at the MG tip. Subsequently, a kinematic model of the MG, incorporating a single axially magnetized permanent magnet at its tip, is developed based on Euler-Bernoulli beam theory and Cosserat rod theory. Finally, the proposed model is validated through experiments. The results indicate that, compared to the finite element method, the magnetic field calculation error of the model is within 0.048 T, the prediction error of the MG tip deflection angle is less than 5°, and the MG posture reconstruction error is less than 0.5 mm. These findings provide theoretical support and experimental evidence for the precise control of MGs in vascular interventional surgeries.

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Session Classification: Sat-Mo-Po.02 - Magnets for Other Medical Application III

Contribution ID: **279** Type: **Poster**

Wed-Af-Po.11-01: Development of a thermal-hydraulic simulation module for cable stability analysis

Wednesday, July 2, 2025 2:30 PM (2 hours)

In this paper, we develop a new thermal-hydraulic simulation module as part of the Tokamak magnet software under development. The module focuses on the coupling effect between thermo-hydraulics and electromagnetism to study the LTS/HTS cable-in-conduit-conductor (CICC) stability margin and quench characteristics. The algorithm of the program is based on the finite element method. We present the structure of the module, emphasizing the various codes and the methodologies employed for their integration. Then, the application of the module is evaluated, showing good consistency with physical expectations and other developed codes. Based on this module, we provide parameter analysis capabilities in CICC cable design, and this module will serve as a key part of our future software development.

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Session Classification: Wed-Af-Po.11 - Modelling of Fusion Conductors and Coils I

Contribution ID: **280** Type: **Poster**

Fri-Mo-Po.04-05: Development of Bi-2212 shim coil for extremely high field high-temperature superconducting NMR magnets: design, construction, and testing results

Friday, July 4, 2025 9:30 AM (1h 45m)

Extremely high field NMR magnets have received much attention by improved resolution and higher sensitivity. However, one of the main reasons limiting its development is the magnetic field inhomogeneities generated by high-temperature superconducting (HTS) magnets cannot be compensated by conventional superconducting and room temperature shim coils. The design, fabrication, and testing results of the world's first Bi-2212 shim coils for the inner-layer of the extremely high field NMR magnet is presented in this paper. The effects of stress on the coil at extremely high field and dimensional change after heat treatment has been considered for the electromagnetic design and the fabricated coil prototypes are tested at 77 K. The complete results will be fully applied to the already built 26T and the upcoming 35T extremely high field superconducting magnets and the peak-to-peak field homogeneities over a 30 mm length on the Z-axis of the 35T magnet can be improved from 631.47 ppm to 4.71 ppm by using Z1 and Z2 Bi-2212 shim coils. The almost negligible screening current of Bi-2212 wire compared to REBCO tape gives it a unique advantage when applied to the fabrication of shim coils at extremely high field. Meanwhile, The Bi-2212 shim coil has a much higher critical current at extremely high field than conventional NbTi shim coil, allowing for minimal space occupation, and being placed inside the HTS magnet which is unaffected from the windings'diamagnetic wall effects. These advantages are particularly attractive when applied to extremely high field nuclear magnetic resonance (NMR) magnets. The Bi-2212 shim coil brings more possibilities to the next-generation, extremely high field NMR magnets, allowing more factors to be taken into account during the magnet design phase rather than just being limited to field homogeneity.

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Session Classification: Fri-Mo-Po.04 - Magnets for NMR

Contribution ID: **281** Type: **Poster**

Fri-Mo-Po.08-02: Current Distribution and Quench Propagation Velocity of BSCCO/REBCO Composite Superconducting tape and Strand

Friday, July 4, 2025 9:30 AM (1h 45m)

As the development of new superconducting materials gradually reaches the bottleneck, it is worth exploring new method to obtain superconducting tapes with better performance through the composite method. BSCCO and REBCO high-temperature superconducting (HTS) tapes are two main commercialized tapes at present. In this paper, based on the parallel physical structure of BSCCO/REBCO composite superconductors, the E-J characteristics of superconductors and the percolation flow model, a parallel model for the current distribution of composite superconductors is established. The simulation and experiment of the current distribution in BSCCO/REBCO composite superconductor are carried out and the current density distribution of quasi-isotropic superconducting strand (QI-S) made of BSCCO/REBCO composite superconducting tapes and the quench propagation velocity (QPV) are also investigated. The results show that the current density of the composite superconductor strand is higher than that of the strand made of only REBCO tapes. The QPV of the composite superconductor strand is between that of the BSCCO strand and the REBCO strand, and much smaller than that of REBCO strand, which avoids the quench propagation too fast and the expansion of normal zone, improving the strand's stability.

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Session Classification: Fri-Mo-Po.08 - HTS Characterization II

Contribution ID: **282** Type: **Poster**

Wed-Mo-Po.06-02: Dynamic AC loss and thermal analysis of high-temperature superconducting rotors in synchronous condensers

Wednesday, July 2, 2025 9:15 AM (2 hours)

High-temperature superconducting (HTS) synchronous condensers have demonstrated exceptional potential in enhancing grid stability and providing rotational inertia, particularly in power systems with a high proportion of renewable energy. By incorporating HTS magnets into rotor systems, these devices improve dynamic support performance, reactive power regulation, and grid inertia, addressing critical challenges in modern power grids.

This study focuses on the dynamic AC loss characteristics of racetrack-shaped HTS rotor magnets under transient strong excitation conditions. Through the development of a homogenized model based on the H-formulation, spatially resolved AC losses across linear and arc segments of the rotor are evaluated. The analysis incorporates electromagnetic coupling between the stator and rotor and considers the influence of back iron on loss distribution. The excitation process, characterized by rapid current ramps (up to 3.5 times the nominal current within 0.1-0.5 seconds), is thoroughly examined to quantify hysteresis, eddy current, and coupling losses.

The findings offer critical insights into the thermal behavior of HTS magnets during high-stress operational phases, providing guidance for rotor design and cryogenic system optimization. These results lay the groundwork for further studies on the integration of rotational effects and multi-field coupling in high-capacity HTS synchronous condensers, ensuring their reliability and scalability in future grid applications

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Session Classification: Wed-Mo-Po.06 - Rotating Machinery I

Contribution ID: **283** Type: **Poster**

Fri-Mo-Po.08-03: Study on the Current Transfer Length in the Connection Between two Quasi-Isotropic Superconducting Strands

Friday, July 4, 2025 9:30 AM (1h 45m)

The second-generation high-temperature superconducting (HTS) materials (REBCO) have excellent characteristics such as high current density, high critical transition temperature, and high critical magnetic field, and have broad application potential in many fields such as power transmission, fusion applications and healthcare. However, in the actual use of REBCO tapes, it is inevitable to connect multiple superconducting tapes or groups of superconducting coils. Based on the structure of quasi-isotropic superconducting strand (QI-S), a connection between QI-S strands is developed in this paper. Firstly, the connection of two HTS tapes is modeled and the current transfer length (CTL) is also calculated. Then, based on the CTL of a single HTS tape, the electric field, current distribution, CTL and joule loss are simulated in the connection between two QI-S strands by the stepped connection. Finally, the same simulations in the connection between two QI-S strands connected by a copper ring are also carried out for comparison. The results show that the stepped connection method has better current transfer performance.

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Session Classification: Fri-Mo-Po.08 - HTS Characterization II

Contribution ID: **284** Type: **Invited Oral**

Sun-Mo-Spe1-05: [Invited] Production of multi-megagauss ultrahigh magnetic fields using destructive magnets for material science

Sunday, July 6, 2025 9:35 AM (25 minutes)

Ultrahigh magnetic fields of 100 to 1000 T (multi-megagauss fields) can be produced destructively [1-4]. In this almost unexplored field range, more interesting magnetic field-induced phenomena are expected to be discovered, in addition to as previously reported the discovery of the novel high magnetic field phase of solid oxygen [5] and the dissociation of molecular orbitals in vanadium dioxide by a magnetic field [6,7].
When one considers the application of the megagauss fields to material science, one of the most important issues in the ultrahigh field generation is the reproducibility of the magnetic fields. It is naturally anticipated that the time variation of the magnetic field (field waveform) would be different at each field production because of the destruction of the coil every time, although the experimental parameters such as the electric energy and the coil dimensions are the same.

In our institute, two destructive magnetic field generation manners have been developed for longer than half century [1, 2]. One is the electromagnetic flux compression (EMFC) and the other one is the single-turn coil (STC). The EMFC can generate 1000 T –class magnetic fields [2] which are the highest magnetic fields one can utilize for material science. The alternate manner is explosive flux compression (ExFC) using chemical explosives [3]. The advantage of the EMFC to ExFC is that the magnitude of destruction along with the field generation is much smaller, and thus the field production system can be handled more easily. The parameters of the coil and those of the energy power source can control the field waveform. Even though, obtaining high reproducibility better than a 2-3 % difference is challenging for the EMFC at present because the probe part for measuring the magnetic field and several physical quantities of the sample material is also broken due to the implosion during the field generation process.

The STC is a more compact field generator than the EMFC and provides multi-megagauss fields up to 300 T [4]. The coil explosion takes place outer direction and thus the set-ups for the experiments including measurement probes survive if the field is typically lower than 200 T. The reproducibility of the generated field waveform is as good as a 2-3 % difference [8]. This is a big advantage for application of the megagauss fields to the material science. Several measurement techniques using STC have recently been developed [8 –10].

The EMFC field generator was renewed recently [2] and several minor technical improvements on the STC were employed. In the presentation at the MT29 conference, waveforms of multi-megagauss fields taken recently with the EMFC and STC in The Institute for Solid State Physic, The University of Tokyo with several coils- and power source-parameters will be introduced, and the magnetic field properties including the field reproducibility will be discussed.

References

[1] N. Miura et al., J. Low Temp. Phys. 133, 139 (2003).
[2] D. Nakamura, et al., Rev. Sci. Instrum. 89, 095106 (2018)
[3] O. Portugall et al., Phys. D: Appl. Phys. 32, 2354 (1999).
[4] A. S. Dzurak, et al., Physica B 246-247, 40 (1998).
[5] T. Nomura et al., Phys. Rev. Lett. 112, 247201 (2014).
[6] Y. H. Matsuda, et al., Nat. Commun. 11, 3591 (2020).
[7] Y. H. Matsuda et al., J. Phys. Soc. Jpn. 91, 101008 (2022).
[8] S. Takeyama et al., J. Phys. Soc. Jpn. 81, 014702 (2012).
[9] A. Ikeda et al., Rev. Sci. Instrum. 88, 083906 (2017).

[10] T. Nomura et al., Rev. Sci. Instrum. 92, 063902 (2021).

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Presenter: MATSUDA, Yasuhiro H.

Session Classification: Sun-Mo-Spe1 - [Special Session] Towards Exceptionally High Magnetic Fields

Contribution ID: **285** Type: **Poster**

Wed-Mo-Po.04-09: ReBCO conductor R&D within the SupraFusion demonstrator project

Wednesday, July 2, 2025 9:15 AM (2 hours)

SupraFusion is a French research program aiming to boost HTS (High-Temperature Superconductors) technologies towards large-scale societal applications and particularly compact fusion machines. In the framework of this program, a large-scale demonstrator magnet reaching 20 T of peak field and 100 MJ of energy will be designed, manufactured and tested. To reach this very challenging goal, a specific high performance conductor have to be developed. The present strategy is to use a stacked ReBCO conductor stabilized with copper for quench protection and able to reach large current (˜50 kA) in high magnetic field (20 T). Such a technology would be usable by fusion and also other societal applications. The development of this conductor will be done stepwise in the next 5 years: it will start with the manufacturing and qualification of some short lengths, then with prototype coils and finally, with the large-scale demonstrator that will need kilometers of conductor.

In this paper, we will review the large number of possible configurations for an HTS conductor geometry. Then, we will study a first simple configuration made of a two tapes stack for our starting R&D. An initial specification will be presented with the first short lengths at 10 kA and 10 T. The basic principle for this R&D will be to characterize each step of fabrication: tape geometry, assembly of 2-tape and stabilizer soldering. Controls are critical currents, geometrical inspections, micrographs and electrical resistance measurements. Soldering is a delicate point of the technology: several solder temperature levels are preferable for making the junctions without disassemble the conductor. Flux will grantee a good adhesion but they leave always some residues. Depending on the soldering process, the conductor performances can be very different. For these reason, several soldering possibilities will be explored and alternative connections too. Finally, we present the instrumentation implantation on the first conductor: co-winding, Superconducting Quench Detector···

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Session Classification: Wed-Mo-Po.04 - HTS Conductors I

Contribution ID: **287** Type: **Contributed Oral**

Sat-Mo-Or5-03: Modelling of close-coupled secondaries for quench protection of stellarator magnets

Saturday, July 5, 2025 11:45 AM (15 minutes)

We present a modeling framework to evaluate the feasibility of using a close-coupled-secondary (CCS) for quench protection of stellarator magnets. Foreseen compact stellarator fusion reactors feature non-planar high-temperature-superconductor (HTS) coils with a large stored magnet energy, on the order of 100 GJ. Safely extracting this energy in case of a quench requires avoiding excessive temperature, temperature gradients, voltage, and mechanical stress.

CCS, a well-established technique in superconducting magnets [1,2,3], enhances quench detection and protection by enabling lower quench detection voltage thresholds through inductive noise reduction [4]. Additionally, the inductive transfer of current from the HTS primary coil to the metallic secondary reduces localized heating in quenching sections. Furthermore, the induced current in the secondary generates heat, which transfers thermally to the primary and triggers additional quenches (*thermal quench-back* [1]). This effect is highly dependent on the local magnetic field magnitude and orientation, which vary significantly across the stellarator coil geometry.

To assess CCS for stellarator quench protection, we employ a novel coupled model comprising: 1) an electrical network, 2) a 1D current-sharing model for the HTS primary, and 3) a 3D thermal model. By incorporating a 1D magnetic field profile along the conductor, we quantify localized heating in the secondary, heavily influenced by magnetoresistance. The model also captures the thermal quench-back effect, where thermal contact between the secondary and primary creates additional normal zones. This occurs in the high field regions, where the critical current of the primary is low and the resistive heating in the secondary is high. A limitation of the model is that it can only represent insulated cables due to the 1D current sharing assumption.

We show that incorporating a CCS can significantly help the safe extraction of the stored magnetic energy in a stellarator relative to protection methods such as solely external extraction in combination with balanced voltage taps. The CCS helps distribute energy across the primary, the secondary, and across external dump resistors, enabling better control of voltages and hotspot temperatures. We identify key design trade-offs, including allowable voltages and thermal limits, and highlight an optimal balance between the metallic stabilizer in the primary and the space allocated for the secondary.

[1] https://doi.org/10.1016/0011-2275(84)90049-3
[2] Wilson, M.N. (1983) Superconducting Magnets. Clarendon Press, United Kingdom
[3] DOI: 10.1109/TASC.2015.2510078
[4] DOI: 10.1109/TASC.2016.2529838

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Presenter: KOSSE, Jaap (PSI)

Session Classification: Sat-Mo-Or5 - Quench Detection Modelling

Contribution ID: **288** Type: **Poster**

Sat-Mo-Po.09-07: Design, fabrication and testing of a full-scale high-temperature superconducting magnet for high-acceleration electrodynamic levitation systems

Saturday, July 5, 2025 9:30 AM (1h 45m)

High-temperature superconducting (HTS) maglev has the advantages of strong suspension ability, high speed, and low operating cost, which is an important candidate technology for future high-speed rail transportation, and the on-board HTS magnet is one of its core components. In recent years, metal-insulated (MI) winding technology has brought better mechanical stability and good self-protection characteristics to the on-board magnet. In this paper, an on-board HTS magnet for a high-acceleration electrodynamic suspension (EDS) system was designed. Firstly, full-scale HTS racetrack coils were wound with second-generation (2G) HTS tapes co-wound with stainless steel tapes, and they were tested separately in a liquid nitrogen environment. These coils were then assembled and further tested, and these test data were compared and analyzed. Finally, based on these data, a persistent current switch (PCS) for this magnet was designed and fabricated. The closed-loop operation experiments of the on-board magnet were successfully completed under a liquid nitrogen environment, and the experimental results meet the application requirements. This work provides technical support for the application of closed-loop operation on-board HTS MI magnets in the future.

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Session Classification: Sat-Mo-Po.09 - Energy Storage/SMES, Levitation and Magnetic Bearings

Contribution ID: **289** Type: **Contributed Oral**

Sat-Af-Or4-02: Jelly-Roll Processed Nb3Sn Ultrafine Superconducting Wires

Saturday, July 5, 2025 4:45 PM (15 minutes)

The National Institute for Materials Science (NIMS) is ongoing the R&D on ultrafine Nb3Sn superconducting wires less than 50 microns in diameter. So far, we have successfully fabricated a kilometer-scale of Nb3Sn ultrafine wire through the bronze process. The starting billet was assembled by 19 Nb rods, a bronze alloy matrix of Cu-14%Sn-0.3%Ti. The outer diameter of the starting billet is 45.2 mm. After the hot extrusion with an extrusion ratio of 9.1, it was cold-drawn from 15.0 mm to 0.05 mm (50 microns) in diameter with intermediate annealing with a reel-to-reel process. Eventually, we obtained over 7,000 m in a piece length without wire breakages. To increase the critical current density, we have tried to fabricate the precursor wires through the Jelly-roll process. Nb and Cu thin foils are overlapped on the pure Sn rod without Ti additive, and then this laminated composite is inserted into the Cu tube with the Nb foil diffusion barrier. The rotary swaging was applied at the beginning of area reduction and then conventional die-drawing was applied. Eventually, we could fabricate the ultrafine Nb3Sn wires with 50 microns in diameter through the Jelly-roll process. According to the microstructure study in transverse cross-section of the 50 microns wire reacted at 675 oC for 48 h, Nb3Sn thick layer was synthesized like a donut ring with 32 microns in outer diameter and 22 microns inner diameter. The fine Nb3Sn grain size of sub-microns and very dense microstructure were obtained. The non-Cu critical current densities at 4.2 K were 1,800 A/mm2 at 12 T and 1,000 A/mm2 at 14 T.
A part of this work was supported in part by U.S.-Japan Science and Technology Cooperation Program in High Energy Physics operated by MEXT in Japan and DOE in the U.S. (Grant No. 2023-13-3).

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Session Classification: Sat-Af-Or4 - Advances in Nb3Sn and MgB2 Conductors II

Contribution ID: **290** Type: **Poster**

Fri-Mo-Po.05-07: Construction and Test of a Superconducting "Direct Wind"R&D Magnet for the EIC Interaction Region

Friday, July 4, 2025 9:30 AM (1h 45m)

Brookhaven National Laboratory (BNL) was chosen to host the international Electron-Ion Collider (EIC), which will collide high energy and highly polarized hadron and electron beams with a center of mass energy up to 140 GeV. The Interaction Region (IR) requires several large aperture, relatively high field superconducting dipole and quadrupole magnets, some of which are very closely spaced. A value engineering effort is underway as part of the EIC Project to construct and test a Direct Wind magnet (coil comprised of NbTi conductor deposited directly onto a support tube, in this instance tapered, and secured mechanically against Lorentz forces afterwards) to replace two Rutherford cable collared magnets. This magnet exceeds the combination of aperture, number of coil layers, and magnetic field, as compared to existing accelerator and R&D Direct Wind magnets to date. Furthermore, construction has been completed using a newly commissioned winding machine, upgraded in anticipation of upcoming EIC production coil fabrication. Construction issues, lessons learned, and results shall be discussed, including the planned and accomplished corrections to multipoles made in successive coil layers based on warm magnetic measurements of preceding layers. Cryogenic magnet cold test results including maximum gradient and final field uniformity achieved will also be reported.

Work supported by Brookhaven Science Associates, LLC under Contract No. DE-SC0012704 with the US Department of Energy.

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Session Classification: Fri-Mo-Po.05 - Electron-Ion Collider

Contribution ID: **291** Type: **Contributed Oral**

Sun-Mo-Or1-07: AC Loss Experiments at the SULTAN Facility on Aluminum Slotted-Core HTS REBCO Conductors for Fusion Applications

Sunday, July 6, 2025 9:45 AM (15 minutes)

High-Temperature Superconductors (HTS) technology offers significant advantages in reactor design, representing a key step toward commercial fusion power plants. These advancements have driven extensive R&D efforts on HTS conductors for fusion magnets based on Rare Earth-Barium-Copper-Oxide (REBCO) tapes.
The aluminum slotted-core cable concept developed by ENEA features stacks of HTS tapes embedded in slots within an extruded aluminum stabilizer, which acts as both electrical and thermal stabilizer. In this design, the HTS stacks are not soldered but compacted during the jacketing process with an external aluminum tube. This configuration enhances the cable's mechanical behavior, providing good tolerance to bending loads, as previously demonstrated. However, the AC losses in such cables with non-soldered tape stacks remain unexplored under conditions relevant to fusion applications.
This contribution presents recent AC loss experiments conducted at the SULTAN test facility on aluminum slotted-core conductors. The SULTAN samples consist of two 3.6 m long Al slotted-core conductors in a hairpin configuration, electrically connected by a joint at the bottom and linked to the facility current leads at the top. AC loss tests were performed as part of the EUROfusion Quench Experiment campaign. Cryogenic tests at 6 K employed the gas flow calorimetric method, applying sinusoidal AC external fields (ranging from ±0.1-0.4 T) with frequencies from 0.1 Hz to 5 Hz, superimposed on a 2 T DC background field and with zero operating currents.
The AC loss analysis focused on quantifying contributions from magnetization and coupling/eddy current losses. Electromagnetic analytical methods and Finite Element simulations were used to interpret experimental data. These findings provide critical insights into minimizing coupling and eddy current losses in future cable designs, with the goal of optimizing HTS conductor performance for fusion applications.

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Presenter: DE MARZI, Gianluca

Session Classification: Sun-Mo-Or1 - Technology for Fusion Reactors II

Contribution ID: **292** Type: **Poster**

Fri-Af-Po.01-02: Numerical Modeling and Protection Design for the SupraFusion Demonstrator Conductors

Friday, July 4, 2025 2:00 PM (2 hours)

SupraFusion is a French research program aiming to boost HTS (High-Temperature Superconductors) technologies towards large-scale societal applications and particularly compact fusion machines. In the framework of this program, a large-scale HTS magnet demonstrator is presently under design. This large-scale magnet aims to demonstrate our capability to reach safely a peak field of about 20 T and 100 MJ of magnetic stored energy under nominal conditions of current and temperature. One important point of this demonstrator design is that it is planned to be fully insulated. These operating conditions and performances pose significant risks for the protection of the magnet and its conductors in case of quench. Indeed, due to their slow normal zone propagation velocities, quench in HTS coils are hard to detect and can totally damage a magnet by the high joule power locally deposited. To address these challenges, several protection strategies are being explored, aiming to optimize critical parameters such as hotspot temperature, current density, and voltage.

To assist in this process, multiple numerical models have been developed simulating the REBCO-based conductor of the demonstrator. These models allow for the analysis of thermal stability, quench propagation, and hotspot behavior under transient conditions. Additionally, parametric studies have been conducted to determine the optimal design of the conductor and the electrical characteristics of the protection circuit, ensuring that the detection and protection criteria for the demonstrator are met. This paper will present the main protection strategies explored for the demonstrator and the related thermal and electrical transient computation results.

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Session Classification: Fri-Af-Po.01 - Quench Detection and Protection II

Contribution ID: **294** Type: **Contributed Oral**

Fri-Mo-Or4-02: EIC Interaction Region Magnet Design Overview

Friday, July 4, 2025 11:30 AM (15 minutes)

Brookhaven National Laboratory (BNL) was chosen to host the international Electron-Ion Collider (EIC), which will collide high energy and highly polarized hadron and electron beams with a center of mass energy up to 140 GeV. The Interaction Region (IR) requires several large aperture, relatively high field superconducting dipole and quadrupole magnets, some of which are very closely spaced. This paper describes the overall design philosophy of the fourteen one-of-a-kind, unique superconducting magnets in the "Inner Interaction Region"on both sides of the detector. A summary of the style chosen for each of the magnets with design rationalizations will be presented. The impact of the very tightly spaced, consistently off-axis layout of forward side hadron magnets, from which difficulties result will be described. The many internal interfaces (vacuum, instrumentation, cryogenics, power supplies, detector, etc.) and associated issues thereof will be discussed. Installation issues and plans to date will be shown.

Work supported by Brookhaven Science Associates, LLC under Contract No. DE-SC0012704 with the US Department of Energy.

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Presenter: ANERELLA, Michael

Session Classification: Fri-Mo-Or4 - Magnets for Electron Colliders

Contribution ID: **295** Type: **Contributed Oral**

Sat-Af-Or2-04: Status of the High-Field Nondestructive Pulsed-Magnet-Development at the Laboratoire National des Champs Magnétique Intense

Saturday, July 5, 2025 2:45 PM (15 minutes)

The Laboratoire National des Champs Magnétiques Intenses (LNCMI) is a French host facility for experiments in high magnetic fields. LNCMI is a member of the European Magnetic Field Laboratory (EMFL) with the Hochfeld-Magnetlabor in Dresden (HLD) and High Field Magnet Laboratory in Nijmegen (HFML). Based on two sites, the LNCMI offers routinely static magnetic fields up to 37 T at its Grenoble site, and pulsed magnetic fields up to 90 T using nondestructive magnets and up to 200 T using single-turn coils at its Toulouse site. Most of the instrumentation required by experiments in magnetic field, including the electromagnets that generate these high fields is developed in the laboratory. We present here some recent developments on our triple-coil-magnet aiming to generate 100 T nondestructively for our users.

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Session Classification: Sat-Af-Or2 - Progress in Ultra High Field Solenoids

Contribution ID: **296** Type: **Contributed Oral**

Fri-Mo-Or4-03: Design and Construction of a Prototype B1pF Large Aperture Rutherford Cable Superconducting Magnet for the EIC Interaction Region

Friday, July 4, 2025 11:45 AM (15 minutes)

Brookhaven National Laboratory (BNL) was chosen to host the international Electron-Ion Collider (EIC), which will collide high energy and highly polarized hadron and electron beams with a center of mass energy up to 140 GeV. The Interaction Region (IR) requires several large aperture, relatively high field superconducting dipole and quadrupole magnets, some of which are very closely spaced. B1pF is a large aperture (300mm coil ID), medium field (4.2T), 3 meter long superconducting dipole magnet. Its size is larger than the largest superconducting magnet in the RHIC accelerator (180mm DX dipole, 4.2T, 3.7m L). As such, B1pF was chosen as the representative magnet to be prototyped to demonstrate the technological choice, design and construction details. This paper describes the analyses and considerations which informed both the magnet and magnet tooling designs, and construction results so far, in particular the plan for novel coil winding tooling and the test coil winding & curing program that was carried out prior to coil and magnet construction.

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Session Classification: Fri-Mo-Or4 - Magnets for Electron Colliders

Contribution ID: **297** Type: **Poster**

Thu-Mo-Po.07-01: ALESIA: A new tool for superconducting magnet design optimization

Thursday, July 3, 2025 8:45 AM (2 hours)

Designing superconducting magnets presents a challenge due to their inherently multi-faceted nature. It requires a deep understanding of diverse physics domains and the integration of specialized tools. To streamline the design process, CEA-IRFU started developing ALESIA, a novel optimization and data management platform.

Our platform leverages advanced algorithms, including nonlinear programming techniques, evolutionary algorithms, active learning strategies, and surrogate modelling, to navigate the intricate parameter space efficiently and converge rapidly towards optimal magnet designs while minimizing computational cost. Its flexible architecture seamlessly integrates with any existing physics simulation software, currently encompassing OPERA for magnetic field calculations and CAST3M for mechanical analysis.

Crucially, its automated optimization loop aims at considering, at the same time, all the critical stages: electromagnetism, conductor properties, mechanics, and quench behavior, ensuring holistic and robust design solutions. Currently, ALESIA is already employed in the development of superconducting magnets for two projects: the SPIN ROTATORS project for the Electron-Ion Collider (EIC) and the ASTERICS magnets for the NEW GAIN ion injector at GANIL. This paper details the optimization algorithms used during all the stages and its applications.

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Presenter: MINENNA, Damien (CEA, IRFU)

Session Classification: Thu-Mo-Po.07 - Design Optimization

Contribution ID: **298** Type: **Poster**

Fri-Mo-Po.05-09: Conceptual design of a large-scale, rectangular-shaped superconducting dipole magnet for Facility for Rare Isotope Beams (FRIB) spectrometer project

Friday, July 4, 2025 9:30 AM (1h 45m)

The Spectrometer Section (SPS) is a critical part of the ongoing High Rigidity Spectrometer (HRS) project at FRIB, Michigan State University. The HRS can accept high rigidity beam up to 8 Tm from FRIB and will significantly enhance the scientific output. One of the key components in the SPS is a large-scale, rectangular-shaped iron-dominated superconducting dipole magnet DS1. The overall dimensions of this large magnet with warm iron yoke are 6.6 meters wide, 4.6 meters tall and 2.835 meters long, with a large primary steel pole gap of 0.6 m. The magnet is to be designed with the ability of steering beams of 8Tm rigidity with a central mid-plane field of ˜ 2.26 T and a field inhomogeneity of less than 0.1% within ±0.47 m around geometrical center at bisecting plane. The warm iron primarily shapes the dipole field, field clamps made of ferromagnetic steel were added onto the upstream and downstream sides of the steel to minimize the stray field effect on nearby electronic devices. Superconducting coils made of NbTi conductors were used to excite the magnet, which are located around chamfered primary poles. Large rectangular Wire-In-Channel (WIC) NbTi wire with a bare dimension of 3.25 by 2.02 mm was chosen with several considerations: 1) winding feasibility, 2) power supply requirements of the large cross section of the coil designed and 3) iterative conductor ramp loss studies. The ratio of copper to superconductor in the conductor on average is around 7. To overcome large internal voltage generation during quench at a current near 500 A as well as the limited wire conductor length issue, each of the dipole coils is subdivided into 3 sub-coil segments. The overall 6 sub-coils for this dipole magnet will be wet wound with Stycast 2850FT and cooled by liquid helium. A circuit with cold diodes for preventing the unbalanced forces on supporting links during certain quench conditions is designed and evaluated. The radial force and stress on epoxy during quench between each of the sub-coils were calculated and analyzed.

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Session Classification: Fri-Mo-Po.05 - Electron-Ion Collider

Contribution ID: **300** Type: **Poster**

Fri-Mo-Po.05-06: Initial Parametric Study of the SPIN ROTATORS Solenoids for the Electron-Ion Collider

Friday, July 4, 2025 9:30 AM (1h 45m)

The Electron-Ion Collider (EIC) requires eight solenoid magnets to polarize the spin of the electron beam. These magnets, called SPIN ROTATORS, are categorized as four LONG (6.2 m) and four SHORT (2.5 m). They operate at a peak magnetic field of about 8.5 T with a 100 mm bore diameter. The integrated magnetic field along the axis is the figure of merit for these magnets, being respectively 46.75 Tm for the LONGs and 15.3 Tm for the SHORTs.

This study focuses on multi-physics simulations for magnetism, mechanics, conductor design, and quench protection to optimize these solenoids respect to the required figure of merit. We investigated NbTi and Nb3Sn conductor based solutions for both the SHORT and LONG magnets. A multi-physics optimization platform employing metaheuristic algorithms was utilized to meet the EIC's requirements. Both solenoids underwent the same optimization routine with tailored target values to address their specifications. The study also aims at finding a design solution that would allow to use the same conductor and to operate at the same temperature for both LONG and SHORT solenoids. The optimization process begins by defining geometrical parameters as well as ranges and conductor characteristics. Then 2D axisymmetric magnetic simulations using Opera are performed to calculate the figure of merit, field values, and inductances. Subsequently, margins based on superconductor quantity, operating point, and several conductor designs are computed. Mechanical studies utilizing homogenized properties based on conductor composition are performed to extract stress values. Finally, adiabatic stability and quench studies compute enthalpy margin and hotspot temperature. Designs are then ranked based on their target values and the optimization process converges towards suitable magnets.

This systematic approach enabled us to identify diverse optimal designs for the EIC's demanding requirements. The multi-physics simulations and metaheuristic optimization strategy presented here have successfully facilitated the design of efficient and reliable solenoids for electron spin polarization at the EIC.

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Presenter: PENAVAIRE, Robin (CEA/IRFU)

Session Classification: Fri-Mo-Po.05 - Electron-Ion Collider

Contribution ID: **301** Type: **Contributed Oral**

Wed-Af-Or1-06: Exploring hybrid designs for a 14 T common coil demonstrator magnet (DAISY)

Wednesday, July 2, 2025 5:45 PM (15 minutes)

Building on the initial magnetic design of DAISY, the 14 T common coil magnet demonstrator being developed at CIEMAT under the High Field Magnet (HFM) programme, this paper investigates the feasibility of hybrid designs combining Nb_3Sn and NbTi for high- and low-field regions, respectively. The primary goal is to minimise superconductor usage while ensuring that the magnet meets the functional requirements of future collider applications, such as the Future Circular Hadron Collider (FCC-hh). The study examines the potential to achieve accelerator-grade field quality without ancillary coils and to maintain minimal multipole variation between low and nominal currents, highlighting the trade-offs in superconductor efficiency. Furthermore, the feasibility of hybrid configurations at 4.5 K compared to the baseline operation at 1.9 K is evaluated, considering the reduced temperature margin of NbTi relative to Nb_3Sn under these conditions. Comparisons are made with all Nb_3Sn designs, including magnet protection, to identify the relative advantages and limitations of hybrid layouts. The results offer valuable insights into optimising superconductor usage and refining design strategies for next-generation high-field common coil magnets, addressing the unique challenges associated with hybrid configurations.

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Session Classification: Wed-Af-Or1 - HTS and Hybrid Magnets for Accelerators

Contribution ID: **302** Type: **Poster**

Wed-Af-Po.09-09: Suprafusion demonstrator: preliminary conceptual design

Wednesday, July 2, 2025 2:30 PM (2 hours)

The "SupraFusion" program is a French initiative dedicated to advancing High-Temperature Superconductor (HTS) technology. HTS materials enable ultra-high magnetic fields (>20 T) at low temperatures (4 K - 20 K), potentially revolutionizing fields such as fusion energy, wind power, and medical imaging. The program's primary goal is to establish France as a leader in HTS research and innovation, leveraging nuclear fusion as a key driver. Divided into five research projects spanning the entire lifecycle of HTS technology, from material development to final applications like fusion reactors, SupraFusion seeks to drive progress in this field. One crucial project focuses on designing, fabricating, and testing a demonstrator magnet. This document outlines the initial approach used to define the performance specifications for the SupraFusion demonstrator magnet. It describes the overall concept, including an insulated conductor housed within a radial-plate-like mechanical structure and potential cooling methods. Based on quench detection/protection assumptions, sizing parameters are selected for the demonstrator. Subsequently, 3D electromechanical simulations are conducted using these parameters and finely analyzed taking into account stress orientation along the conductor and Tresca stress in the massive parts. The mechanical structure is then refined through a parametric investigation. The results are analyzed and discussed to provide a preliminary conceptual design for the SupraFusion demonstrator magnet.

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Presenter: LORIN, Clement

Session Classification: Wed-Af-Po.09 - Magnets for Tokamaks: Design and Analysis

Contribution ID: **303** Type: **Contributed Oral**

Fri-Mo-Or1-03: Mechanical mockup development and analysis of a 12 T Nb3Sn costheta dipole prototype for FCC-hh

Friday, July 4, 2025 8:30 AM (15 minutes)

The Future Circular Collider-hadron-hadron (FCC-hh) project is envisioned as the successor to the Large Hadron Collider (LHC) at CERN (European Organization for Nuclear Research). The proposed particle accelerator, with a center-of-mass energy up to 100 TeV, will be housed in a tunnel approximately 100 km in circumference, representing a major leap forward in the exploration of fundamental forces and particles. A key component for the success of the project is the development of high-field dipole magnets capable of steering high-energy particle beams with precision and stability. In this context, the INFN (Istituto Nazionale di Fisica Nucleare) is involved with the FalconD (Future Accelerator post-LHC Cosθ Optimized Nb_3Sn Dipole) project, which focuses on the design and construction of a 12 T Nb_3Sn single-aperture cosθ dipole magnet. The prototype will demonstrate the feasibility of achieving the required magnetic field strength and test innovative manufacturing and assembly techniques. A distinguishing feature of the FalconD magnet is the use of the bladder and key (B&K) assembly process, providing an innovative solution to the mechanical and operational challenges posed by high-field magnets in future accelerators. As a crucial step toward full-scale production, a mechanical mockup of the magnet's straight section was constructed, as described in the Technical Design Report (TDR) published in 2021. This mockup aims to provide valuable insights into the mechanical behavior, assembly process, and cooling of the magnet under realistic conditions. In this contribution, we present the results of the mockup assembly and the corresponding experimental analysis of stress, measured using strain gauge technology. These experimental data will be compared with the results from the Finite Element Method (FEM) model to validate the theoretical predictions and optimize the magnet design for future applications.

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Session Classification: Fri-Mo-Or1 - Development and Testing Towards High Field Accelerator Magnets

Contribution ID: **304** Type: **Poster**

Sat-Mo-Po.09-02: Investigation of modular superconducting magnetic energy storage system in power system

Saturday, July 5, 2025 9:30 AM (1h 45m)

As the proportion of intermittent energy sources such as wind and solar power increases in the power grid, the importance of energy storage technology in the power system becomes increasingly evident. Among various technologies, Superconducting Magnetic Energy Storage (SMES) is unique for its fast response, dynamic power compensation, high charge-discharge cycles, and long lifespan, offering promising applications. Due to the inherent properties of superconducting materials and the limitations of power conversion and refrigeration systems, it is still challenging to realize a superconducting magnetic energy storage system with tens of megajoule capacity in a single device. To address this issue, this paper proposes a modular superconducting magnetic energy storage system (M-SMES: Modular SMES), which aims to achieve modular integration and distributed deployment of SMES through advanced control techniques, thereby improving the stability and performance of the power system. This paper starts with the modeling of a single SMES, and extends to the aspects of magnets and power electronics. It proposes the topology structure of a modular SMES and its control design method. Finally, based on the distinct characteristics and operating conditions of SMES magnets, the coordinated operation mode of modular SMES and the corresponding power allocation strategy are discussed from three perspectives: synchronous operation, distributed operation, and dispersed operation.

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Session Classification: Sat-Mo-Po.09 - Energy Storage/SMES, Levitation and Magnetic Bearings

Contribution ID: **305** Type: **Poster**

Wed-Mo-Po.01-06: Development of the CCT superconducting magnets for the STCF interaction region

Wednesday, July 2, 2025 9:15 AM (2 hours)

In older to explore charm physics and tau physics in next decades, a third-generation circular electron-positron collider Super Tau-Charm Facility (STCF) with the energy range of 2-7 GeV is being developed and pre-studied in University of Science and Technology of China. As the last correction of the particles before the collision, the superconducting magnets in the interaction region (IR) play an important role in the whole device. The distance between the interaction point (IP) and first IR magnet (called QD0) is 900mm and the collision angle of IR magnet is only 60 mrad. The effective thickness of the QD0 magnet is very limited. The QD0 magnet need 50 T/m at the reference radius of 10 mm. The pre-design of the CCT QD0 magnets will be proposed in this study.This high order harmonics and cross-talk of the of the twin aperture CCT magnet will be studied and analyzed. The optimization method of the twin aperture CCT magnet will be proposed. Some ideas of CCT magnet and its analysis will be also introduced in this study.

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Session Classification: Wed-Mo-Po.01 - Accelerator Magnets I

Contribution ID: **306** Type: **Poster**

Wed-Mo-Po.04-05: Structural Optimization of TMMC Conductor for Enhanced Current -Carrying Capability in Engineering Applications

Wednesday, July 2, 2025 9:15 AM (2 hours)

In fusion devices, superconducting magnets are subjected to the combined effects of magnetic fields, temperature gradients, and mechanical stresses during operation, resulting in significant stress on the conductors. These conductors require high critical currents, low AC losses, and high mechanical strength. We have designed a novel tenon-mortise modularized conductor (TMMC) and studied the effects of tape configuration and bending radius on evolution of critical current and AC losses. For enhanced current-carrying capability, we further optimized the structure of the TMMC conductor. The optimized conductor consists of two layers of sub-conductors. The first layer has a copper framework with four square grooves, used for installing superconducting tapes. The second layer's copper framework is made into a semi-circular shape through extrusion and drawing, which are then merged into one after the first layer's tapes are installed, with the layer fixed using tenons. To fill the gap between the first layer's conductor tapes and the second layer's framework, we designed a metal filling and tubing method. Copper blocks are placed above the tape within the square grooves, and the conductor is then enclosed in an aluminum tube, which is compressed to ensure reliable mechanical support for the tape. We conducted experiments to evaluate the critical current and quenching characteristics of the optimized TMMC conductor, and the results show that, under self-field conditions with liquid nitrogen immersion, the conductor's critical current is 10.7 kA, and the engineering current density is 69.5 A/mm^2. When the conductor carries 9.5 kA, the quenching starts with a heating wire input of 0.4335 W after 46 seconds. And the calculated minimum quenching energy is 15.606 J, with a maximum quenching propagation speed of 1.98 m/s. With structural optimization, the engineering critical current density of the TMMC conductor has been enhanced, showing promising potential for future applications in compact fusion magnets.

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Session Classification: Wed-Mo-Po.04 - HTS Conductors I

Contribution ID: **307** Type: **Contributed Oral**

Sat-Mo-Or1-04: Recovery of terminations in ITER CS Module 3

Saturday, July 5, 2025 9:15 AM (15 minutes)

The ITER Central Solenoid (CS) is under fabrication by the US ITER organization and its subcontractors. US ITER will supply seven modules to ITER IO, six of which will be assembled in a stack that forms the ITER Central Solenoid. All CS modules (CSM) were or will be tested at 40 kA in the Final Test facility at General Atomics.
CSM 3 testing campaign took place in 2021, and a breakdown occurred that damaged the terminations of the module.
To recover, new terminations needed to be designed, qualified and built to make the CSM3 fit for service. This effort had several challenges that were not addressed in the previous projects with large Nb3Sn magnets with cable-in-conduit conductors.
This paper describes a design, fabrication and qualification of the terminations, and the successful test results of the CSM3 with the recovered terminations.

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Session Classification: Sat-Mo-Or1 - Assembly and Commissioning Fusion Tokamaks

Contribution ID: **308** Type: **Poster**

Wed-Af-Po.05-03: Enhanced Critical Current Densities via Co-doped RE214 Artificial Pinning Centers in FF-MOD Gd123 Films

Wednesday, July 2, 2025 2:30 PM (2 hours)

We have fabricated Gd123 thin films co-doped with several kinds of RE_2CuO_4 (*RE*214: *RE* = Gd, Nd, Sm, Eu) by the FF-MOD method and investigated their superconducting properties. We have already reported that the introduction of the superconductor *RE*214 (Tc = 18.5 K) as an artificial pinning center (APC) into *RE*123 thin films which improved the $\mathcal{J}$c-B properties for the first time [1]. In this study, we introduced multiple types of *RE*214 with different lattice constants into the base Gd123 material for finer *RE*214 crystals and attempted to further improve the $\mathcal{J}$c-B properties. As a result, with the same volume fraction of *RE*214 introduced, the $\mathcal{J}$c-B properties improved as the number of different types of *RE*214 co-doped increased, and all films showed better $\mathcal{J}$c-B performance compared to non-doped films. At 4.2 K and 6.9 T parallel to the c-axis of Gd123 thin films, the $\mathcal{J}$c was 0.782 MA/cm^2 with the addition of Sm214 and 0.877 MA/cm^2 with the addition of three types (Gd214, Nd214, Sm214), representing increases of 1.07 times and 1.19 times, respectively, compared to the non-doped film. TEM images also confirmed that the *RE*214 pins were oriented along the c-axis, and it is inferred that they are introduced in a plate-like manner within the ab-plane. Therefore, it is expected that applying a magnetic field perpendicular to the c-axis during magnetization measurements could result in even higher calculated $\mathcal{J}$c values.
Moving forward, further improvements in superconducting properties are expected by altering the combinations of *RE* in *RE*214, their doping ratios, and the sintering conditions.

References

[1] R.Ishii, O.Miura,"Achievement of high critical current densities by co-doping Ba*M*O3 (*M*= Zr, Ce, Sn) and Gd2CuO4 for FF-MOD GdBa2Cu3O7-σ thin films", The Applied Superconductivity Conference2024, Utah(U.S.A), September 2024.

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Session Classification: Wed-Af-Po.05 - HTS Conductors II

Contribution ID: **309** Type: **Invited Oral**

Sun-Mo-Spe1-01: [Invited] The hybrid superconducting resistive magnet in Grenoble

Sunday, July 6, 2025 8:00 AM (20 minutes)

The hybrid superconducting resistive magnet (M8) in Grenoble has reached an important milestone in 2024 : 42T was reached in a cold bore of 34mm. The first experiments are planned in 2025. The experimental setup which had allowed to reach this important milestone will be described, as well as the tests which were done in the commissioning phase. This hybrid magnet is planned to be integrated in future in the use of EMFL (European Magnetic Field Laboratory) possibly in 2026. In 2024, the maximum electric power was also increased from 24MW to 30MW, with the implementation of a new electric line with a new dedicated 225kV transformer which will allow to reach new opportunities of high magnetic field in Grenoble. With these two new realizations in Grenoble, new scientific opportunities in high magnetic field science will be possible in a near future.
In parallel, a very important activity concerns the increase of efficiency in term of the use of energy, as well as the investments, translated into greenhouse gas emission, with the objective to be one of the best place in the world in term of greenhouse gas efficiency for the use and the construction for resistive magnets.

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Session Classification: Sun-Mo-Spe1 - [Special Session] Towards Exceptionally High Magnetic Fields

Contribution ID: **310** Type: **Poster**

Fri-Af-Po.10-12: Preliminary thermal analysis of conduction-cooled HTSCU cores

Friday, July 4, 2025 2:00 PM (2 hours)

Currently Rare-Earth Barium-Copper-Oxide (REBCO)-based superconducting undulator (SCU) prototypes have been developed. Magnetic and mechanical designs of these prototypes using 4-mm- and 2-mm-wide tapes are in progress. The magneto-static and force calculation using Maxwell 3D confirms the OPERA calculation. Thus, conduction-cooled short prototypes of a High-Temperature Superconducting Undulator (HTSCU) have been designed. In this paper, a preliminary thermal analysis of the conduction-cooled HTSCU is presented.

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Session Classification: Fri-Af-Po.10 - Undulators

Contribution ID: **311** Type: **Poster**

Wed-Af-Po.10-07: Study on electromechanical properties of HTS twisted stack slotted-core cable for fusion magnets

Wednesday, July 2, 2025 2:30 PM (2 hours)

REBCO coated conductor, the second-generation high-temperature superconducting (HTS) material, is one of the most promising materials for application in future fusion reactor high-field magnets due to its high critical current density and excellent mechanical properties. The Institute of Plasma Physics, Chinese Academy of Sciences (ASIPP) is conducting the research and development activities on REBCO Twisted Stack Slotted-core Cables (TSSC) to validate the feasibility of CICC. In the manufacture and operation of high-field superconducting magnets, twisting, bending and transverse compression of cables are inevitable. Therefore, it is crucial to investigate the effect of mechanical properties on the electrical performance of TSSC cables. In this paper, an HTS TSSC cable based on vacuum soldering process has been developed and several measurements have been carried out at 77K and self-field. The effect of mechanical properties on the critical current (Ic) of TSSC cables was analyzed by means of experimental study and numerical simulation. Numerical simulations were able to calculate the Ic at different twist pitches and bending radii, and to predict the possible range in which the degradation of Ic occurred. The bending radii corresponding to the no-slip and perfect-slip models are approximately 1100 mm and 300 mm, respectively, when the criterion is taken to be 95% Ic retention. In the bending experimental tests, the samples to be tested were bent to a specified radius at room temperature, and then Ic measurements were taken at 77 K and self-field. A comparison of the performance changes of the cables under bending stress, both before and after vacuum soldering, was conducted to evaluate the effect of the soldering process on the bending performance. Furthermore, the compression experiments were performed by continuously applying progressively larger transverse loads to the samples in liquid nitrogen. In the monotonic transverse loading test, compression performance was better at 0° than at 45°, with Ic degradation to 95%, corresponding to a minimum load of 104 MPa. For cyclic transverse loading, there was no degradation in performance for 1000 cycles at 100 kN load, whereas at 120 kN load there was no degradation in performance for the first 10 cycles, with degradation to 91% and 73% after 50 and 900 cycles respectively. These results lay the foundation for large-scale applications of the REBCO CICC. The full-size CICCs with TSSC cables as sub-cables are being prepared for testing in the SULTAN facility to verify their operation stability under high electromagnetic loads for fusion applications.

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Session Classification: Wed-Af-Po.10 - Development and Test of Conductors for Fusion

Magnets II

Contribution ID: **313** Type: **Poster**

Wed-Af-Po.10-04: towards enabling HTS fusion using PSALM

Wednesday, July 2, 2025 2:30 PM (2 hours)

The dream of a world with clean and infinite energy has driven human beings to devote effort to the R&D of nuclear fusion for decades. Now, thanks to the rapid development of high-temperature superconducting (HTS) wires, we have never been closer to commercial fusion power reactors and ultimate clean energy. Producers all over the world are now supplying over 10,000 km superconducting wires to commercial companies to build fusion reactors. Even though the current performance of HTS wires is roughly sufficient for compact fusion magnets and the manufacturing technology is still fast-progressing, there are scientific and technical obstacles to overcome. The AC loss is the most crucial one.
This paper will address the AC loss problem of HTS wires used for fusion magnets and a possible solution as provided by PSALM (Patterned Superconductor for AC Loss minimisation). a novel structure of HTS coated conductors which aims to replicate a roebel type structure in a single tape without the need for cutting or assembly The project is part of a UK Engineering and Physical Sciences Research Council (EPSRC) funded project, The talk will describe our progress so far with the fabrication of PSALM tapes and detail their application.

Author: COOMBS, Tim

Presenter: COOMBS, Tim

Session Classification: Wed-Af-Po.10 - Development and Test of Conductors for Fusion Magnets II

Contribution ID: **314** Type: **Poster**

Fri-Mo-Po.04-04: 400 MHz all REBCO NMR magnet: design, optimization, and construction

Friday, July 4, 2025 9:30 AM (1h 45m)

Building upon the successful development of 26.86 T @ 30 mm and 16.6 T @ 100 mm fully REBCO high temperature superconducting (HTS) magnets, we have initiated the research and development of an 800 MHz NMR magnet with a 54 mm room-temperature bore. High-field HTS magnets face significant challenges during operation, such as pronounced screening current effects, which lead to poor magnetic field stability and localized stress concentration. As a preliminary step to address these issues, we have designed and constructed a 400 MHz small-scale NMR magnet based on REBCO conductors. The magnet consists of 26 double pancake coils, designed to operate at a current of 247 A, generating a central magnetic field of 9.4 T. The coils are wound with a standard inner diameter of 38 mm, with those near the center employing a notch structure to enhance field homogeneity, achieving a uniformity of 4.1 ppm over a 10 mm DSV. To mitigate magnetic field drift, a metal-co-wound no-insulation winding technique was adopted, and a localized adhesive impregnation method is planned to secure the coils, further improving the long-term stability of the magnetic field. This paper comprehensively presents the magnet design, magnetic field optimization, coil fabrication and assembly, as well as performance testing at 4.2 K. It also provides an in-depth analysis of operational characteristics, offering essential theoretical and practical insights for the development of 800 MHz HTS NMR magnet.

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Session Classification: Fri-Mo-Po.04 - Magnets for NMR

Contribution ID: **315** Type: **Poster**

Fri-Mo-Po.01-07: Design of Non-insulated HTS Coils for a stellarator demonstration experiment

Friday, July 4, 2025 9:30 AM (1h 45m)

Due to the increasing interest in nuclear fusion, basic plasma experiments/small scale devices are good to illustrate plasma physics properties like magnetic surfaces and/or the importance of it. The construction of a table-top stellarator experiment, referred to as Polaris, is envisaged for the Swiss Plasma Center of EPFL. Polaris (major radius ˜40cm and minor radius ˜15cm) consists exclusively of six circular planar coils arranged in an optimal way to generate a large volume of magnetic surfaces and rotational transform in vacuum. The configuration has been optimized following a procedure described in [1]. The main objective is to provide a demonstration of steady-state toroidal plasma confinement without toroidal current, to assess the quality of the magnetic field by experimentally tracing magnetic field lines, and to measure some basic plasma parameters.
There are two sets of coils for Polaris: water-cooled copper coils and non-insulated (NI) HTS coils. With the copper coils, the magnetic field on the plasma axis is around 0.04T. With NI HTS coils a higher magnetic field can be achieved and therefore the confinement is improved.
This works presents the design of the NI HTS coils for Polaris, which have an inner diameter of 21.8cm and are cooled with circulating liquid nitrogen. The operating temperature will be in the range of 65K to 77K. The peak field in the winding pack reaches 0.5T depending on the operating temperature. The design process includes electromagnetic and force calculation of the setup and the layout of the winding pack. In addition, the cryogenic design of the device is illustrated and explained. The current distribution within the NI HTS winding pack is analyzed, considering its impact on the generated magnetic surfaces.

[1] Phys. Plasmas 31, 112501 (2024) https://doi.org/10.1063/5.0226688

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Presenter: BIEK, Daniel Louis Arthur (EPFL, Swiss Plasma Center)

Session Classification: Fri-Mo-Po.01 - No-Insulation Coils IV

Contribution ID: **317** Type: **Contributed Oral**

Fri-Mo-Or6-05: A pulse forming network for quench protection of superconducting magnets

Friday, July 4, 2025 12:15 PM (15 minutes)

The design and simulation of a modified Rayleigh Line Pulse Forming Network (PFN) is presented for active quench protection of superconducting magnets. In this context, the PFN is a network of capacitors and inductors designed to deliver energy to quench heaters over a significantly longer period than a single capacitor or capacitor bank. The PFN is advantageous for protection of coils constructed with REBCO tape, which have a slow normal zone propagation speed and a high critical temperature. PFN's also have an inherent safety advantage over battery bank energy sources. The rise time of a typical Rayleigh network for this purpose can be on the order of 10-100 ms which is unacceptably slow compared to the timescale for thermal runaway during the onset of a quench. This is exacerbated by the time required for quench detection and the time it takes for energy to percolate from the heaters, through layers of electrical insulation, and into the superconductor. Thus, as a modification to the Rayleigh Line PFN, an extra stage consisting of a discharging capacitor with no accompanying inductor is added to achieve a nearly instant rise time. The advantages of this strategy are discussed, and the flexibility of the system is investigated when varying resistive loads, charge voltages, and component design.

This work was performed at Florida State University's National High Magnetic Field Laboratory, which is supported by National Science Foundation Cooperative Agreement Numbers DMR-1644779 and DMR-1839796 and the State of Florida.

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Presenter: ROGERS, John

Session Classification: Fri-Mo-Or6 - Quench Detection and Protection I

Contribution ID: **318** Type: **Poster**

Wed-Mo-Po.03-03: Critical current and magnetic flux transport in 2G HTS wires with an artificial pinning landscape caused by a fractal percolation structure

Wednesday, July 2, 2025 9:15 AM (2 hours)

The effect of pinning landscape on critical current in percolative HTS composites is studied. The superconductor contains percolative superconducting cluster carrying a transport current, and artificial pinning centers created by normal-phase fractal clusters. Such a structure provides for effective pinning and thereby raises the critical current because the magnetic flux is locked in finite clusters of a normal phase, and so the vortices cannot leave them without crossing the surrounding superconducting space. The normal-phase clusters have fractal boundaries and this feature exerts an appreciable effect on vortex dynamics. Any movement of magnetic flux causes energy dissipation in superconductors therefore the method of suppressing such movement is of great practical importance. The influence of vortex percolation in the course of flux flow and flux creep on the critical current for different values of fractal dimension of normal-phase clusters is analyzed. Various modes of creep are considered. The resistive characteristics of percolative superconductors in the presence of the pinning landscape with fractal pinning centers are obtained. Electric field induced by vortex motion is analyzed and the critical current value is estimated. It is found that the existence of fractal boundaries between normal and superconducting phases intensifies pinning and suppresses the electric field. The use of normal-phase fractal clusters as pinning centers provides an additional opportunity to increase the critical current, since the structural irregularities of such objects with fractional dimensions span a wide range of geometric sizes, up to the vortex core diameter, which ensures effective pinning. The current-carrying capability can be increased by creating such a pinning landscape that could simultaneously provide creep suppression both in Anderson-Kim and collective creep modes. Correlated defects, such as clusters of columnar defects, can be used to suppress Anderson-Kim creep, while collective creep can be suppressed by randomly distributed point defects. In order to create such a combined pinning landscape, PLD (Pulsed Laser Deposition) technology in combination with ion irradiation, can be used. Results apply to YBCO coated conductors for use in superconducting magnet windings.

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Session Classification: Wed-Mo-Po.03 - HTS Characterization I

Contribution ID: **319** Type: **Poster**

Wed-Af-Po.08-06: deBOX: effect of transverse stress on the training of Nb3Sn Rutherford cable

Wednesday, July 2, 2025 2:30 PM (2 hours)

Within the framework of the study of future high-energy particle colliders, high-field (15-16 T) Nb3Sn magnets are being developed. These magnets are usually impregnated using epoxy resin with glass fiber to provide electrical insulation and mechanical support to the conductor.
However, several phenomena are often observed: first, the high-stress conditions applied during pre-load, cool-down, and powering of magnets lead to cracks in the resin. Then, during powering, high Lorentz forces may break the epoxy bond at the interface between cables and metallic components, and provoke a detachment of the coils and conductor motions. Later, friction phenomena may appear. This irreversible behaviors are likely to release enough energy to trigger quenches of the conductor. Understanding and reducing the causes of these phenomena can help to significantly reduce the number of quenches and increase the maximum quench current during the training phase of magnets and therefore improve the performances of future high field magnets.
A campaign has been carried out at the University of Twente. The goal is to characterize the training behavior of Nb3Sn Rutherford cables in representative conditions, and to reproduce the detachment phenomena under low contact pressures. To do so, an existing experimental setup has been redesigned to allow an accurate measurement of the compressive force up to 10 MPa of compressive stress. This experiment was named the deBonding eXperiment (deBOX).
Four deBOX samples were tested, changing the interface between metallic sample holder and epoxy CTD-101K impregnation resin. Training at 10 MPa of compression were made for each sample. Then, the Nb3Sn Rutherford cables have been subjected to a gradual release of the transverse compressive force at cryogenic temperature with at constant current in the sample. It was observed for the first time that the release of the compression force triggered quenches of the cable. Finally, after the full training of the samples, another training at lower compression force was made. In this case, a detraining was observed, with difficulties to reach the critical current. The behavior of the different samples is analyzed and the effect of the various contact conditions are compared.

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Session Classification: Wed-Af-Po.08 - Conductor and Coil Measurement/Test Techniques and Facilities I

Contribution ID: **320** Type: **Contributed Oral**

Thu-Mo-Or1-07: Challenges and Field Tuning Strategies for the Magnetic Qualification of Triplet Magnets for the SLS 2.0 Upgrade

Thursday, July 3, 2025 12:15 PM (15 minutes)

This paper presents the measurement results of the Triplet magnets assemblies for the Swiss Light Source (SLS) 2.0 upgrade. Emphasises is given to the measurement challenges related to the tuning process of those magnets guarantying the production quality. The complete renewal of the SLS storage ring (SLS 2.0) relies on the longitudinal gradient bend (LGB) function, implemented by a Triplet, that results in a critical component of its seven-bend achromatic structure. The precise tuning of the integral LGB function, with a relative uncertainty of 0.2 % from the nominal design value, sets demanding requirements in terms of measurement precision.

The Triplet assembly comprises three magnets, namely, a central dipole flanked by two combined-function magnets that integrate quadrupole and dipole components. Each magnet is constructed with NdFeB permanent magnet blocks, ensuring a compact and high-performance design. This paper provides an overview of the Triplet magnets characteristics, highlighting design choices and the meticulous assembly process required to meet the stringent beam dynamics specifications. Finite Element (FE) simulations play a pivotal role in deriving measurement requirements, authors show from there how to tailor measurements procedures for individual magnets and fully assembled Triplets according to the chosen measurement technique. The series measurement results provide valuable insights into the production quality and performance consistency. Key lessons from that process are thereafter discussed. The findings highlight the critical importance of rigorous measurement frameworks in achieving the ambitious performance goals of SLS 2.0.

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Presenter: MONTENERO, Giuseppe (PSI)

Session Classification: Thu-Mo-Or1 - LTS Magnet Advanced Concepts

Contribution ID: **321** Type: **Contributed Oral**

Sat-Mo-Or3-04: High-field and angular dependence study of the critical current surface in modern REBCO coated conductors

Saturday, July 5, 2025 8:45 AM (15 minutes)

Understanding the dependence of the critical current, I_c, on magnetic field intensity and orientation, as well as on temperature is essential for developing reliable models for REBCO tape-based magnet design. This knowledge is particularly critical for advancing ultra-high-field magnets (20–40 T) required for applications ranging from fusion and particle accelerators to high-field science. To address the rapid evolution of commercial REBCO tape properties, we investigated the I_c(B,θ,T) surface of tapes from leading manufacturers.
At the University of Geneva, transport critical current measurements up to 2 kA were conducted on full-width tapes at 4.2 K, 20 K, and 40 K in fields up to 19 T and at fixed orientations (θ=0°, 7.5°, 15°, 80°, 90°) relative to the tape surface. Complementary experiments at Tohoku University's High Field Laboratory employed laser-fabricated microbridges from the same tape batches, covering the 5–77 K range, with fields up to 24 T and continuous angular dependence data (−20° to 115°) using an in-field rotating stage. The comparison of full-width and microbridge measurements reveals consistent trends. The non-copper critical current density, calculated as the critical current divided by the tape cross-section area minus the Cu area, routinely exceeds 2 kA/mm^2 at 4.2 K and 19 T, and approaches 1 kA/mm^2 at 20 K and 19 T in perpendicular fields. However, significant variations in the angular dependence of I_c among different manufacturers reflect differences in processing methods, REBCO layer composition, and pinning center designs (e.g., 3D nanoparticles vs. 1D nanorods).
These results provide a robust foundation for achieving high-fidelity descriptions of the critical current surface over a wide range of fields and temperatures, leveraging a complementary approach that combines a limited number of experiments on full-width tapes with detailed angular scans on microbridges.

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Presenter: Prof. SENATORE, Carmine

Session Classification: Sat-Mo-Or3 - HTS Characterization III

Contribution ID: **322** Type: **Poster**

Sat-Mo-Po.03-07: Updated mechanical beam model for magnet system analysis of fusion machines

Saturday, July 5, 2025 9:30 AM (1h 45m)

Fusion magnets for so-called compact high-field machines present a new challenge for designers. Tools for fast assessment of magnet pre-designs are needed, and a new mechanical toolbox called CIRCE has been developed.

New updates to the analysis tool will be presented, including improved winding pack and casing contact, a detailed inner leg interface between adjacent tf coils and additional support strategies. The new code structure makes joint use of Matlab and Cast3M finite element software, facilitating parametric studies that highlight trends associated with certain mechanical parameters. Advanced post-treatment has been added with first estimates of component stresses and thorough analysis of load distribution in the vault and inter-coil structures.

Emphasis will be placed on the study of out-of-plane effects. The torsional stiffness of the toroidal system is characterized in several configurations, including the bucked and wedged option. Finally, an application of CIRCE to a Stellarator design demonstrates the tool's great flexibility, paving the way for future studies.

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Presenter: BOUDES, Baptiste (CEA Cadarache)

Session Classification: Sat-Mo-Po.03 - Mechanics of Fusion Magnets

Contribution ID: **323** Type: **Contributed Oral**

Sat-Mo-Or5-02: A novel approach to quench protection and detection of superconducting detector magnets

Saturday, July 5, 2025 11:30 AM (15 minutes)

Quenches are a major issue for superconducting magnets because of their high current density which translates to high stored magnetic energy and eventually heat dissipation that may cause irreversible damage if left unadressed. Designing a well-protected magnet against quenches is one of the key considerations in the design. The objective of this paper is to describe the experimental demonstation of a novel quench detection and protection principle, combining a superconducting coil with a co-wound normal-conducting secondary coil. Similar to a co-wound voltage tap, the presence of the secondar coil allows for inductive noise suppression, thus facilitating low-noise quench detection. After quench detection, discharging the superconducting coil over an energy extractor featuring diodes and resistors gives rise to a very quick initial discharge of the superconducting coil. Following the quench-back principle, the induced currents in the secondary coil quickly heat up the cold mass and trigger a homogeneous quench. A major benefit of this quench protection principle is that, compared to quench protection configuration featuring energy extraction without quench-back, the needed voltage over the energy extractor is reduced by more than one order of magnitude.

To experimentally demonstrate the principle, a demonstrator magnet consisting of co-wound NbTi and Cu coils with an open warm bore size of 400 mm was assembled and tested. During testing the magnet was ramped to nominal current of 200 A without training quenches while producing a B-field of 1 T at center bore. The operational parameters were measured and found to agree with simulations and calculated results. The detection threshold voltage of quenches is verified at common electromagnetic noise-inducing frequencies by an inductively coupled pick-up coil paired with a signal generator.

The quench detection and protection method is expected to not just be beneficial for low-temperature superconductors, but also high-temperature superconductors, where quench detection at low threshold voltages is an important attribute to have. This paper describes how these principles can be scaled to higher field low- temperature superconducting or future high-temperature superconducting (HTS) detector magnets.

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Session Classification: Sat-Mo-Or5 - Quench Detection Modelling

Contribution ID: **324** Type: **Poster**

Wed-Mo-Po.01-07: Impact of winding geometry on AC loss in superferric magnet with REBCO racetrack coils

Wednesday, July 2, 2025 9:15 AM (2 hours)

Electromagnets used in the beam lines at GSI Darmstadt have been wound using metallic Cu wires. As a result, ohmic losses signify a non-negligible contribution to the energy consumption during machine operation. We performed a theoretical study aimed at one-to-one replacement –keeping the same number of turns and waveform of electrical current –of the Cu winding in one of the bending magnets with a coil wound with a coated REBCO conductor.
In the first step, a simplified semi-analytical approach was utilized to identify the suitable range of operating temperatures and preliminary estimation of dissipation in AC regime. Then, for a limited set of designs, time-dependent electromagnetic finite-element computation modeling the magnetic flux penetration in superconducting material during the unipolar cycle was performed. We found that the simplified analytical approach provided correct guidance towards optimization of the coil winding arrangement.

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Presenter: GÖMÖRY, Fedor

Session Classification: Wed-Mo-Po.01 - Accelerator Magnets I

Contribution ID: **325** Type: **Plenary**

Thu-Mo-PL1-01: Challenges in REBCO Magnet Technology toward Industrial Level of Technology Readiness

Thursday, July 3, 2025 8:00 AM (45 minutes)

Nearly four decades have passed since the first discovery of high temperature superconductor (HTS). To date multiple HTS wires have been developed and some of them are now readily available in a commercial market. REBCO has been regarded as one of the most advanced HTS wire options with the benefit of large in-field current carrying capacity and strong substrate mechanical toughness. The recent high expectation of REBCO for "compact fusion"accelerates global competition of mass production of REBCO wire, which naturally leads to the wire cost reduction for the first time in the history of HTS. Nowadays, over hundreds of REBCO coils are being built annually ranging laboratory use to various industrial applications. Yet, we are still facing fundamental challenges to ensure our REBCO technology for our industrial partners. For example, precise estimation of critical current of an REBCO magnet is still challenging. And REBCO magnets are designed without clear understanding of temporal and spatial distribution of currents—transport, screening, and radial leak (in case of no-insulation)—even in steady-state not to mention under quench. Magnet designers are still struggling with in-consistent Ic(B,T) behaviors and weak delamination force of REBCO wire. As a result, high field REBCO magnets are designed and constructed without precise estimation of their electrical and mechanical limits. To date, REBCO magnets that reach over 30 T twice or more are rare; none are under routine service. This paper summarizes lessons learned from the recent milestone REBCO magnets and categorized key technical challenges in both conductor and magnet perspectives. Then, suggestions on collaborative R&D directions to our REBCO community toward enhancing industrial level of technology readiness for REBCO magnet technology are followed.

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Presenter: Dr HAHN, Seungyong (Seoul National University)

Session Classification: Plenary: Seungyong Hahn [Challenges in REBCO Magnet Technology toward Industrial Level of Technology Readiness] - sponsored by Lihan Cryogenics

Contribution ID: **326** Type: **Poster**

Thu-Mo-Po.02-04: Magnet Design and Magnetic Measurements at Laboratori Nazionali di Frascati

Thursday, July 3, 2025 8:45 AM (2 hours)

The Frascati National Laboratories (LNF) of National Institute for Nuclear Physics (INFN) have extensive experience in the design and measurement of electromagnets and permanent magnets for particle accelerators. A large amount of design and tests, including detailed magnetic characterization for various projects such as the DAΦNE collider [1] , CNAO [2], and other experiments have been carried out consolidating the expertise in this field.
In the last decades, the activities of the Laboratories moved towards high-brightness electron sources with the SPARC [3] linac test facility where the current activities are focused on plasma-based acceleration techniques. This facility is the baseline for the future EuPRAXIA@SPARC_LAB accelerator [4]. Additionally, a Beam Test Facility (BTF) [5] is present at LNF. This facility is a beam transfer line designed for the optimized, stochastic production of single electrons/positrons for detector calibration, offering high beam versatility in terms of spot size, divergence, multiplicity (number of particles/spill) and energy.
According to the requirements of the LNF facilities, several designs of magnets have been carried out in recent years, primarily for linac accelerators. These designs cover a wide range of magnets typologies, including electromagnetic solenoids, dipoles, quadrupoles and steerers, as well as permanent magnets dipoles and quadrupoles.
A Magnetic Measurement Laboratory is present at LNF; it is devoted to deep magnets characterization thanks to a wide range of equipment for integrated magnetic measurement and for 3D field mapping. In the last years, an instrumentation revamping phase was necessary to maintain measurement capabilities and preserve expertise. This upgrade [6] has been started thanks to several co-funding projects, such as LATINO [7], IRIS [8] and internal INFN support. The revamping was oriented both towards the update of the existing instrumentation, such as the Hall probe measurement bench, and towards the purchase of new equipment, including a rotating coil [9], a Single Stretched Wire Bench [10], a Pulsed Wire bench, a probe calibration system, and 3D Hall probe mole system.
Thanks to these instruments, many magnets have been measured both for LNF facilities and for external projects involving INFN, such as FOOT [11] and STAR [12].
In this paper, several magnets design and magnetic measurement tests performed at LNF are presented covering a wide range of magnet typologies and measurement methods. Moreover, an overview of the magnetic laboratory equipment upgrade is given, highlighting the current and future instruments that will be hosted in the renewed facility. These improvements are aimed at guaranteeing high flexibility in meeting measurement requirements covering a wide range of magnets type for external user and for the future projects at LNF, such as EuPRAXIA.

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Presenter: Dr VANNOZZI, Alessandro

Session Classification: Thu-Mo-Po.02 - Design and Development of Accelerator Magnets I

Contribution ID: **327** Type: **Poster**

Fri-Mo-Po.02-02: φ-H-ϕ and φ-J-A-ϕ mixed formulations for the fast 3D finite element simulation of porosity in REBCO bulks

Friday, July 4, 2025 9:30 AM (1h 45m)

The increasing use of Rare-earth barium copper oxide (REBCO) bulks in electromechanical applications, particularly for acting as "pseudo"permanent magnets, is driving the development of more sophisticated numerical models. The focus has been on modeling electromagnetic phenomena with greater accuracy and efficiency, taking into account the non-linear and heterogeneous characteristics of high temperature superconductor (HTS) bulks. The issue of dealing with HTS bulks is their non-isotropic nature and the inhomogeneity inherent to the fabrication process, which leads to the formation of pores, grain boundaries and defects such as cracks that can affect their magnetization. In the present work, two incremental modified mixed formulations, φ-$\mathbf{H}$-ϕ and φ-$\mathbf{J}$-$\mathbf{A}$-ϕ, are proposed in conjunction with the finite element method (FEM) to reduce the computational burden in 3D thermo-electromagnetic transient simulations of pulsed field magnetization of porous HTS bulks. The idea is to find the formulation of the Maxwell equations that leads to the fastest computational time in order to generate enough numerical results for statistical analysis in the future. In the proposed scheme, the heat balance equation is coupled to the electromagnetic physics in the COMSOL Multiphysics® software. The trapped field results for both the φ-$\mathbf{H}$-ϕ and φ-$\mathbf{J}$-$\mathbf{A}$-ϕ 3D FEM models are cross-checked with the respective results obtained with using the more classical $\mathbf{H}$, $\mathbf{H}$-ϕ and $\mathbf{J}$-$\mathbf{A}$ FEMs. A validation is provided using experimental data from the literature. The φ-$\mathbf{H}$-ϕ formulation showed the fastest computation times with reasonable accuracy, making it more favorable for understanding the impact of defects in REBCO bulk on their performance.

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Session Classification: Fri-Mo-Po.02 - Bulk and Permanent Magnets

Contribution ID: **328** Type: **Contributed Oral**

Sat-Af-Or4-04: Numerical analysis of Nb3Sn wires under compression

Saturday, July 5, 2025 5:15 PM (15 minutes)

Superconducting magnets in particle accelerators currently use mostly a Nb-Ti alloy, which has a critical temperature (⊠⊠) of 9.2 K and a critical field (⊠⊠2) of 14.5 T. However, future particle accelerators, such as those beyond the LHC, will require dipole magnets capable of generating fields of 16 T or higher. This necessitates a shift to high-performance superconductors, with the intermetallic compound Nb3Sn being the most commonly chosen material.
High-field Nb3Sn magnets are created by winding Rutherford cables made from wires containing Nb3Sn precursors. During the cabling and winding processes, the wires undergo deformation, increasing the risk of deterioration and loss of transport properties. The heat treatment, which takes place after the winding process, results in the formation of Nb3Sn. A primary challenge is that Nb3Sn is brittle, and stresses from cooling, assembly, and Lorentz forces during magnet energization significantly affect its transport properties. As a result, the operating range of high-performance, high-field magnets is limited by these stresses.
Understanding the behavior of wires under stress, both before and after heat treatment, is critical for investigating the effects of deformation on Nb3Sn wires. To this end, a collaboration between the Genoa section of INFN and CERN is developing a finite element (FE) analysis to simulate wire behavior under deformation. This paper will focus on two key aspects: the effect of cabling-induced deformation on unreacted wires, and the influence of deformation from magnet operation on reacted wires. The paper will present a set of two-dimensional models of the cross-sectional area of an internal tin Nb3Sn wire, some idealized and symmetrical, while others based on SEM images of MQXF quadrupole wires. The differences among these models will be explored, and the simulation results will be compared to the actual wires.

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Presenter: BRACCO, Michela

Session Classification: Sat-Af-Or4 - Advances in Nb3Sn and MgB2 Conductors II

Contribution ID: **329** Type: **Poster**

Sat-Mo-Po.05-10: Gas Properties Studies using Reflectometry: First Steps Toward Real Time Cooling Gas Temperature Monitoring in Superconducting Magnets

Saturday, July 5, 2025 9:30 AM (1h 45m)

The results of numerical and experimental studies of fundamentals of the quench monitoring technique based on frequency and time domain reflectometry (FTDR) are discussed. To carry out fast (real time) monitoring of the coolant gas temperature and thus to observe evolution and prevent the quenching in superconducting (SC) magnets the techniques of detection and analysis of microwave electromagnetic signals propagating in coolant gas channels have been recently proposed. The techniques should also allow monitoring other anomalies including the gas pressure and flow variations. Through the studies, we show that variations of external conditions (affecting gas temperature and pressure) induce change in the gas permittivity, which can be measured fast and accurately. We demonstrate that: (a) monitoring and analysing the spectral lines shifts (in a range of a frequencies) allow the average changes of the gas properties observation within the whole system; (b) measuring variations of a single frequency signal amplitude and phase, propagating in the cooling pipes, allowing evaluation of the gas local temperature fluctuations i.e. hotspots appearance.
The methodology presented is based on the established correlations between thermodynamic gas variables such as temperature and pressure with its electromagnetic properties i.e. refractive index. Through the numerical studies it was found that a localised hotspot can be detected with minimal time delay, which is crucial consideration for the systems necessitating rapid response for quench prevention and magnet "health"monitoring i.e. cooling pipe integrity, fast temperature fluctuations of the gas and etc. The experimental data observed agree well with the theoretical understandings, and the findings demonstrate the validity of the proposed technique. While the technique holds significant potential for monitoring HTS magnets it also offers a possibility to develop new monitors in the areas encompassing many devices using SC magnets including fusion reactors, MRI systems and others.

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Presenter: Mr FERNÁNDEZ SERRACANTA, Oriol (University of Strathclyde)

Session Classification: Sat-Mo-Po.05 - Quench Detection and Protection IV

Contribution ID: **330** Type: **Contributed Oral**

Thu-Mo-Or1-06: Test of an Alumina-filled wax large-aperture Nb3Sn canted cos-theta dipole.

Thursday, July 3, 2025 12:00 PM (15 minutes)

As part of the US Magnet Development Program, Lawrence Berkeley National Laboratory (LBNL) is developing high field stress-managed Nb3Sn dipole magnets using canted-cosine-theta (CCT) technology. A series of epoxy two-layer magnets, CCT3/4/5, with short sample bore field of approximately 10 T and a 90 mm diameter open aperture have been designed, fabricated, and tested. The third and final magnet of this series, CCT5, reached 88% of the short sample current.
Alumina-filled wax was used as impregnation material in a subscale CCT magnet with the same design (4.5 T and 50 mm bore aperture). The magnet was fabricated and tested. It exhibited minimal training with only one quench observed before reaching short sample limit current.
A filled wax impregnated magnet, CCT5-W, that is otherwise identical to CCT5 has been recently fabricated. This paper summarizes the quench performance of the CCT5 wax filled magnet. The effect of the wax impregnation on the stress managed structure and on the conductor performances is also being discussed.

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Presenter: BALDINI, Maria

Session Classification: Thu-Mo-Or1 - LTS Magnet Advanced Concepts

Contribution ID: **331** Type: **Contributed Oral**

Sun-Mo-Or2-02: Fabrication and testing of a prototype sextupole coil for a Nb3Sn ECR ion source magnet

Sunday, July 6, 2025 8:15 AM (15 minutes)

Several superconducting electron cyclotron resonance (ECR) ion sources for heavy ion accelerators are in operation around the world. These rely primarily on magnets wound using Nb-Ti conductors. Development toward the use of Nb_3Sn conductor as an alternative conductor is advancing, with higher magnetic field limits resulting in higher intensity high charge beams being a primary motivation. In this context, Lawrence Berkeley National Laboratory (LBNL) is building a sextupole-in-solenoid magnet for a previously reported proof-of-concept 28 GHz superconducting ECR ion source for the Facility for Rare Isotope Beams (FRIB). A prototype Nb_3Sn sextupole coil identical to the planned series of coils has been fabricated. It is tested using a mirror magnet structure. Earlier on we reported the tooling and process we developed to manage challenges arising from using Nb_3Sn for ECR ion source magnet. Here we report details of the prototype coil fabrication, mirror structure, and test results.

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Presenter: MALLON, Philip (Lawrence Berkeley National Laboratory)

Session Classification: Sun-Mo-Or2 - Fabrication and Testing of Magnets for Facilities

Contribution ID: **332** Type: **Poster**

Fri-Af-Po.01-01: Quench Detection and Protection of the Excitation Coils of a 2G HTS Superconducting Wind Generator Based on Multi -Turn Co - wound Coil Technology

Friday, July 4, 2025 2:00 PM (2 hours)

For offshore superconducting wind generators, the complex operating conditions inside the machine—including thermal losses, stress, vibration, and transient load variations—pose significant challenges to the stable operation of the magnet. These factors can trigger coil quenching, potentially leading to the burnout of excitation coils and further generator fault condition. This study is a preliminary study for the 25 MW wind generator development plan, investigates the quench overload capability and inter-turn current sharing of no-insulation (NI) coils, metal-as-insulation (MI) coils, and insulated coils under the defects situation with the application of multi-turn co-wound technology. Experimental validation was conducted on scaled-down coils at 77 K, demonstrating that multi-turn co-wound technology significantly enhances the overload tolerance of superconducting excitation coils. Additionally, it amplifies quench voltage signals under fault conditions, enabling earlier fault detection and response.

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Session Classification: Fri-Af-Po.01 - Quench Detection and Protection II

Contribution ID: **334** Type: **Contributed Oral**

Wed-Mo-Or3-02: Recent status of RE-based High Temperatures Superconductors at Fujikura

Wednesday, July 2, 2025 11:30 AM (15 minutes)

RE-based High Temperatures Superconductors (HTS) are expected to be applied in various fields due to their high in-field critical current (Ic) and mechanical properties.
Fujikura Ltd. has developed high-performance RE-based HTS using Ion Beam Assisted Deposition (IBAD) and Pulsed Laser Deposition (PLD) techniques, and has supplied to various customers for many years.
Fujikura mainly has two types of 2G HTS tapes. One is an artificial pinning (AP) type with HTS layer of EuBCO+BHO and the other is a Non-AP type with GdBCO.
Users can select RE-based HTS suitable for their operation temperature and magnetic field.
Our RE-based HTS has uniform and high Ic characteristics with small lot-to-lot variation. Recently, we have shipped uniform HTS for developing compact fusion energy reactors as a mass-production. Since we have applied a laser slitting technology to fabricate 2-4 mm-width tapes over ten years, our HTS with a crack-free HTS layer perform good mechanical properties. Recently, we also have shipped uniform 1km unit length HTS with 4mm width as a mass-production.
Then, we have expanded HTS production capacity with reliable and excellent quality. In this presentation, recent status and activities of RE-based HTS at Fujikura Ltd. are presented.

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Session Classification: Wed-Mo-Or3 - REBCO Manufacturing

Contribution ID: **335** Type: **Poster**

Wed-Mo-Po.01-08: Hybrid Nb3Sn/Bi-2212 SMCT Magnet Analyzed with Heterogeneous Rutherford Cable Model

Wednesday, July 2, 2025 9:15 AM (2 hours)

It is known that Bi-2212 strands withstand higher external magnetic fields than LTS superconductors, allowing higher current density when allocated in the innermost layers of a high-field magnet. For this reason, the first stress-managed cosine-theta insert based on Bi-2212 Rutherford cable was designed at Fermilab within the U.S. MDP and is currently in the realization process. The HTS insert has a 16 mm aperture and will be positioned within the 120 mm aperture of the LTS SMCT outer coil made of 2 layers of Nb3Sn Rutherford cables. This article first introduces the hybrid magnet structure's design and main parameters obtained from the axial and transversal cross-section optimization performed on ROXIE. It then reports the magnetic and mechanical FEM analysis of the hybrid magnet assembly. Magnet simulation requires multi-physics analysis where geometrical, electromagnetic, and thermal aspects deeply interact to describe the system behavior. For this reason, in this paper, the entire 4-layer hybrid magnet was modeled using a more detailed geometry description of the Rutherford cable in Ansys APDL. This heterogeneous cable model allows a higher resolution to investigate the stress and strain state in each LTS/HTS superconductor component better and to obtain more accurate information on mechanical solicitation and displacements within the Stress Management structural elements. All results are collected and reported for the entire hybrid magnet structure after current powering at 4.2 K.

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Presenter: D'AGLIANO, Alessio

Session Classification: Wed-Mo-Po.01 - Accelerator Magnets I

Contribution ID: **336** Type: **Contributed Oral**

Fri-Mo-Or2-03: A Numerical Comparison of the 3D Mechanics of REBCO CORC® Dipole Designs

Friday, July 4, 2025 8:30 AM (15 minutes)

Conductor on Round Core (CORC®) cables, consisting of REBCO coated tapes helically wound around a metal former, are a promising conductor option for future high-field dipole magnets in particle accelerators. Crucial to the success of this application is the conductor resilience to mechanical loads. The promising electrical performance of the CORC® wires may be compromised by damage and degradation resulting from forces experienced during magnet fabrication, assembly, cooldown, and energization. This paper compares the mechanical performance of the primary CORC® dipole designs proposed to date: Canted Cosine-theta (CCT), Uni-Layer (UL), and Stress-Managed Cosine-theta (SMCT). These designs all employ a “conductor-in-groove” approach, utilizing rigid metal components to separate the cables and mitigate electromagnetic forces. A 3D electro-magneto-mechanical modeling framework was developed to automatically calculate mechanical stresses in the conductor and mandrel based on the winding configuration. This framework incorporates multi-scale modeling strategies, enabling evaluation of both overall cable loads and localized stresses at the tape level. Using this tool, we explore the performance of each design at different magnetic field levels and investigate the influence of cable constraint conditions provided by different impregnation strategies. These results provide important insights for optimal magnet and cable design choices, highlighting the mechanical challenges and potential failure risks associated with high-field CORC® cable applications, and pointing to possible mitigation strategies to enable such applications.

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Session Classification: Fri-Mo-Or2 - Mechanical Behavior and Stress III

Contribution ID: **337** Type: **Poster**

Wed-Mo-Po.02-04: Rapid-cycling HTS magnet for muon acceleration

Wednesday, July 2, 2025 9:15 AM (2 hours)

Based on the measured [1] very low power loss of the HTS-based magnet of 0.4 T field in 10 mm beam gap and ramp rate of 300 T/s we outline the HTS-based accelerator magnet conceptual design for 2.0 T field in the 30 mm (V) x 150 mm (H) beam gap for the muon acceleration with ramp rates up to 1000 T/s. The arrangements of the magnetic core and the 72 kA HTS power cable are presented. The placement of HTS cable within the magnet core is optimized for the minimum magnetic field crossing its space. The supercritical helium of 5.5 K and 0.28 MPa is chosen for the HTS conductor coolant due to its high specific heat that allows for a strong minimization of cryogenic power loss. The numerical calculation of HTS cable hysteresis loss at 15 K (minimal available temperature of YBCO critical current vs external B-field) is scaled to the magnet operations at (5 - 10) K using the dependence of the YBCO critical current vs temperature [2]. The projected in this way HTS cable hysteresis power loss is 3.5 J/m for the 1000 T/s ramp rate within the +/- 1.7 T field linear response to the energizing current. With the helium coolant flow of 2.5 g/s, the projected cryogenic electric power is 4.6 kW/m at 5 Hz, indicating the power-wise economic feasibility of this HTS magnet for the muon acceleration.

[1] H. Piekarz et al., IEEE Trans. on Appl. Superconductivity, 32 (2022) 6, 4100404
[2] C. Senatore et al., Superconductivity. Sci. Technol. 29 (2016) 014002

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Session Classification: Wed-Mo-Po.02 - Muon Collider

Contribution ID: **338** Type: **Poster**

Thu-Af-Po.01-04: Mechanical Design and Vacuum Pressure Impregnation of Combined Function Electromagnets

Thursday, July 3, 2025 2:00 PM (2 hours)

There are 96 combined function magnets (48 focusing and 48 defocusing) that have been in operation in the Fermi National Laboratory's Booster without a critical failure requiring replacement for over 50 years. The Proton Improvement Plan-II (PIP-II) poses risk to these magnets and Fermilab does not currently have the tooling or knowledge of process to fabricate spares. A longer straight section is required by PIP-II to make room for new Orbital Bump magnets at the injection region. This will be accomplished by replacing one defocusing magnet on either side of the injection region with new shorter magnets (Booster Gradient Defocusing Short, or BGDS). Also, to reduce beam loss due to scraping at the extraction region, a defocusing magnet will be replaced with a similar magnet with greater vertical aperture (Booster Gradient Defocusing Wide, or BGDW) upstream of the septum magnet used for extraction. These gradient magnets are void-free monolithic structures accomplished by vacuum impregnating the core and all coils at the same time. They do not have a beam tube for the purpose of maximizing aperture while reducing physical dimensions, peak stored energy, and power consumption. Risk of failure, as well as need for spares, will increase dramatically with implementation of PIP-II due to the Booster frequency increasing from 15 Hz to 20 Hz and a consequent increase in peak to ground voltage. The BGDS and BGDW magnets will be fabricated in the same way as the current booster magnets so that future combined function magnet spares can be produced. BGDS and BGDW mechanical design and vacuum pressure impregnation technique will be discussed in this paper.

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Presenter: Mr SZABO, Benjamin (FNAL)

Session Classification: Thu-Af-Po.01 - Accelerator Magnets II

Contribution ID: **339** Type: **Poster**

Wed-Mo-Po.01-02: Design of a superconducting sector dipole magnet for the High Rigidity Spectrometer at Facility for Rare Isotope Beams

Wednesday, July 2, 2025 9:15 AM (2 hours)

The High Rigidity Spectrometer (HRS) at the Facility for Rare Isotope Beams at Michigan State University is designed to study exotic neutron-rich isotopes at high beam energies. With a maximum magnetic rigidity of 8 Tm, the HRS is optimized for the rigidities at which rare-isotope beams are produced at FRIB. It consists of two main sections: the High-Transmission Beamline and the Spectrometer Section (SPS). A key magnet component of the SPS is the DS2 superconducting dipole magnet, which provides a 60° beam bending capability. This magnet, currently under design, features NbTi conductor embedded in a copper channel to support a passive quench diode protection scheme and generates 2 T dipole peak field to achieve the 8 Tm rigidity. The magnet includes a warm iron yoke with dimension is 5.9 m x 4.2 m x 2.2 m and a pole gap of 0.2 m. To achieve horizontal focusing without additional quadrupole magnets, a 20° pole-face angle is applied to both sides of the magnet poles. This paper presents a detailed design of the DS2 magnet, covering its magnetic properties, coil forces, conductor stability, quench analysis, and mechanical structure.

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Presenter: KIM, Junseong (MIT)

Session Classification: Wed-Mo-Po.01 - Accelerator Magnets I

Contribution ID: **340** Type: **Poster**

Thu-Af-Po.01-03: Development of Design for the STS Extraction Magnet System

Thursday, July 3, 2025 2:00 PM (2 hours)

The Oak Ridge National Laboratory STS Project will enhance the Spallation Neutron Source by adding a new neutron source. The upgrade includes a 30% increase in beam energy and a 50% boost in beam current, doubling the accelerator's power capability to 2.8 MW. The Ring-to-Second-Target Beam Transport (RTST) system is vital in directing high-energy proton beams to the target. A key element of the RTST system is the extraction magnets, which are tasked with precise beam extraction and transport. Within the framework of this work, Fermilab is responsible for carrying out the development of 3 types of magnets: Pulsed Dipole, Large Aperture Quadrupole and Narrow Quadrupole. The Pulsed Dipole with a gap of 25 cm and a yoke length of 50 cm is designed to generate an integrated field of ≥ 0.1839 T-m for a duration of at least 2 ms, operating at a frequency of 15 Hz. The Large Aperture Quadrupole with 40 cm aperture diameter and 70cm core length is engineered to deliver an integrated field of ≥ 3.0872 T, ensuring precise beam focusing and alignment. The Narrow Quadrupole integrated field strength is set at 2.9650 T ± 1% and the aperture size is ≥ 20.9 cm. The compact design of the magnet assembly should provide compatibility with the RTBT system's spatial limitations with dimensions not exceeding 70 cm in width. Working on these three types of magnets is a challenge for Fermilab engineers because, in addition to the high requirements on the quality of magnetic fields, they are subject to major restrictions related to their dimensions. Magnetic, mechanical, and thermal calculations were carried out for all three types of magnets, confirming the functionality of the designs.

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Session Classification: Thu-Af-Po.01 - Accelerator Magnets II

Contribution ID: **341** Type: **Poster**

Thu-Af-Po.01-02: Refurbishment status update of the IQ-type Quadrupoles at the Fermilab Main Injector

Thursday, July 3, 2025 2:00 PM (2 hours)

The Fermilab Main Injector Complex operates with 208 quadrupoles magnets of the IQ type, nominally 84"(IQB) 128 each, 100"(IQC) 32 each, and 116"(IQD) 48 each. The 84"quads were originally all reused Main Ring quads, longer quads are new construction. In constructing the Main Ring quadrupoles a layer of pre-impregnated glass tape was applied to the bare coils and cured, coils were wrapped with an additional layer of dry glass tape and were assembled into the cores. The whole magnet was then vacuum impregnated with epoxy. This resulted in a robust mechanical structure. The IQB have failed over the last 50+ years at a manageable rate, where failure is defined as developing a ground fault sufficiently severe to require replacement in the tunnel. When a magnet fails, it can be rebuilt.
The new magnets used the same basic construction approach, attempting to improve reliability for the Main Injector, more of the manifolding was encapsulated by epoxy loaded with glass beads and a thin layer of G 10 was added between the coils and the core as additional ground insulation. Both changes have proved detrimental. Burying the braze joints makes them much more time-consuming to repair, requiring a magnet change rather than the in-situ repair often possible when the joints are exposed. Even worse, the Imperfect vacuum impregnation of both sides of the impervious G 10 sheets turned them into slip planes that concentrated the stresses from differential thermal expansion of coils and cores and caused cracks in the epoxy insulation at the ends that became ground faults. With a high failure rate of the newly constructed magnets in the first two years of operation, an improvement project was launched, relying on vacuum impregnating insulated coils and installing them in existing cores secured only in the middle to allow differential expansion without a build-up of shear stress. The first spares were not tested exhaustively until January 2022, when an IQC failed in the tunnel. Two of the new spares were installed and failed within days as the coils were inadequately secured against the lateral magnetic forces under power and the ends moved up to a millimeter and more at full excitation, concentrated in a few thin spots in the copper tubing where it joined the ceramic insulators leading to work-hardening. A new scheme was devised to secure the coils against lateral motion while maintaining the core geometry during assembly and allowing removal of coils without damaging the insulation. As of December 2024, a few IQC magnets have been rebuilt with this approach. Measurement of coil position as a function of excitation has shown that the end motion has been controlled. One magnet has been subjected to test runs at repetition rate of 32 cycles per minute, consisting of a ramp up at approximately the 120/0.3 GeV rate considered for ACE¬¬ MIRT but a slower ramp down due to power supply constraints. The longest test ran 72 hours. No failures appeared and when the coil position was monitored during a slow cycle after all the fast ramps, no motion was evident. From this we conclude that the new configuration is sound, but the custom fit-up of each magnet will limit the rebuilding rate unless improvements are made.

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Presenter: STRAUSS, Thomas

Session Classification: Thu-Af-Po.01 - Accelerator Magnets II

Contribution ID: **342** Type: **Poster**

Thu-Af-Po.01-01: Oakridge PPU Magnets –Results and Measurements

Thursday, July 3, 2025 2:00 PM (2 hours)

The Spallation Neutron Source (SNS) at ORNL was being upgraded from 1.0 GeV to 1.3 GeV (or 1.4 to 2.8 MW). Several water-cooled magnets got upgraded to transport 30% higher beam energy. Fermilab contributed the magnet design for the new chicane magnets and injection/extraction septum. Designing the magnets was a challenging task because the new magnets required good combined integrated field quality and needed to occupy the old magnets space but with about 20% greater integrated magnetic field. Additional strong requirements applied to the magnets fringe field do not disturb the circulating beam. After fabrication of the magnets, an extensive measurement campaign was setup and performed at Fermilab's Magnet Test Facility. Magnetic measurements are performed at Fermilab for both projects internal to the lab and as well as work for other laboratories. The measurements needed to assess the performance and compare to magnet design calculations include verification of field strength and harmonics along an 8 m length and 200 mm good field diameter, including end-field Hall probe mapping, for the chicane dipoles, and measurements along two differently curved trajectories within the ˜3 m septum gradient magnet. Details of the measurements and system are presented along with results and comparison to field models.

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Presenter: DIMARCO, Joseph

Session Classification: Thu-Af-Po.01 - Accelerator Magnets II

Contribution ID: **343** Type: **Poster**

Fri-Af-Po.03-03: Development of a 36 kA LN2 Test Stand for Magnet Terminations

Friday, July 4, 2025 2:00 PM (2 hours)

The magnets of the SPARC tokamak as developed by Commonwealth Fusion Systems and the Massachusetts Institute of Technology include superconducting magnet termination cables that supply power to the winding pack. It is important to qualify these superconducting cables because they are epoxied into the cable magnets, making their removal extremely difficult, possibly scrapping a magnet. We present a test stand developed to determine the critical current of these terminating cables at 77 K. The test stand is capable of supplying up to 36kA to fully map the superconducting-normal transition of both poloidal field (PF) and central solenoid (CS) magnet terminations, as well as CS coils. A unique challenge is the complex shape of some of these cables, featuring 3D bends in some required to fit in a compact tokamak. In addition the design must account for manufacturing tolerances, so several features were developed to accommodate the wide variety of test article geometries: a gantry to support moveable busbars, flexible braided conductors, and continuously adjustable clamping mechanisms. A method for determining stresses induced by Lorentz forces on the irregularly-shaped test articles was developed taking into account the HTS tape allocated for each cable as well as sample geometry. Finite element analysis was also used to determine thermal loads induced by joule heating, allowing for the test stand to be tuned for pulsed operation and reduced costs. Finally, a boiler system is included to allow for quick test turn-around. The result is a test stand that ensures the magnet terminations perform up to specification before their permanent incorporation into the winding pack, derisking downstream integration.

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Session Classification: Fri-Af-Po.03 - Supporting Technologies for Fusion Magnets I

Contribution ID: **344** Type: **Poster**

Fri-Mo-Po.07-05: Mechanical Design of the PIP-II ORBUMP Pulsed Dipole Magnet

Friday, July 4, 2025 9:30 AM (1h 45m)

The Proton Improvement Plan-II (PIP-II) is a vital upgrade to Fermilab's accelerator complex. The upgrade is designed to power the world's most intense high-energy neutrino beam in future experiments. The magnet pulse repetition rate of the PIP-II injection system is being upgraded from 15 Hz to 20 Hz and requires a roughly 30% increase in the magnetic field of the new Orbital Bump (ORBUMP) magnets in the Booster. The magnet is secured in a vacuum box and the core is made up of 0.127 mm thick, low carbon steel laminations with a C-5 inorganic coating. The core is clamped using external tie bars welded to the core end plates. ANSYS Finite Element Analysis (FEA) was used to evaluate the clamping design to minimize the deflection of the core post welding of the tie bars. The water-cooled single turn coil is electrically isolated from the core using virgin PEEK insulating material in the gap. An investigation into the high voltage performance of the virgin PEEK insulator was conducted. The design of the coil which shapes the magnetic field by acting as the pole tips is critical for the integrated field homogeneity. The coil manufacturing tolerances and fabrication techniques were evaluated to ensure the magnetic properties of the magnet could be obtained. The ORBUMP magnet mechanical design is presented in this paper.

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Presenter: KARAS, Dino

Session Classification: Fri-Mo-Po.07 - Accelerator Magnets III

Contribution ID: **345** Type: **Poster**

Sat-Mo-Po.08-08: Exploring novel mechanical reinforcement techniques using high-strength ceramic fiber for Bi-2212 magnets

Saturday, July 5, 2025 9:30 AM (1h 45m)

Bi-2212 multi-filament round wire is a high-field capable, isotropic conductor that does not experience the large screening-current stresses suffered by ReBCO. Together with its high current carrying capabilities, Bi-2212 is a very promising candidate for compact high-field/high-homogeneity magnets. Superconducting coils tend to experience large mechanical stresses under operating conditions. These stresses are mainly caused both by the Lorentz forces during energization and by thermal contraction of the winding pack during cool down. Unlike ReBCO, which contains a strong substrate, Bi-2212 wire is sheathed in a ductile matrix made from Ag-Mg, making it susceptible to large stresses
and, therefore, it requires reinforcement. We have devised a series of experiments to help us investigate several methods for reinforcing a Bi-2212 winding pack. Bi-2212 coils are made in a wind-and-react process, which requires heat-resistant and chemically stable materials for electrical insulation as well as reinforcement. Recently, we have found several strong candidate materials, mostly composed of alumina, that can be used for electrical insulation as well as reinforcement. Several winding composite samples, as well as coils, have been made to study their properties. The gathered data established values for Young's modulus and Poisson's Ratio at cryogenic temperatures. The experiments also allowed us to compare the feasibility and ease of fabrication using different reinforcement techniques. Results and progress on these ongoing investigations will be presented and discussed.

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Session Classification: Sat-Mo-Po.08 - Structural and Insulation Materials

Contribution ID: **346** Type: **Poster**

Sat-Mo-Po.08-06: Development of a cryogenic, vacuum, friction machine to test SPARC insulation

Saturday, July 5, 2025 9:30 AM (1h 45m)

Commonwealth Fusion Systems (CFS) is currently developing and building a commercially relevant fusion energy machine that will produce more energy than is put into it (SPARC). In this research, an insulation that electrically isolates the toroidal field (TF) magnets from each other is being tested to determine its behavior, evolution, and failure rate during the shear displacement and high contact pressures that are expected to occur in SPARC. SPARC is a bucked tokamak and very compact making the insulation a challenge for our approach.
In this poster, we will discuss the test stand designed for the insulation with a newly developed custom vacuum chamber capable of applying up to 1GPa of contact pressure between insulation layers and reaching temperatures of 80K with pressures below 1e-4 torr. The test can be run over a total of 13,000 cycles at a rate of 0.1Hz. Contact pressures, coefficient of friction, and more can be measured in real time while testing.

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Presenter: JOSEPH, Laurin (Commonwealth Fusion Systems)

Session Classification: Sat-Mo-Po.08 - Structural and Insulation Materials

Contribution ID: **347** Type: **Poster**

Wed-Af-Po.02-04: Magnetic Field Mapping of MOLLER Spectrometer Magnets at Jefferson Lab

Wednesday, July 2, 2025 2:30 PM (2 hours)

The Thomas Jefferson National Accelerator Facility (JLab) has developed a unique spectrometer system to study the weak interaction between electrons. The "Measurement of Lepton-Lepton Electroweak Reaction" (MOLLER) experiment, utilizing JLab's recent 12 GeV electron beam upgrade, is scheduled to operate for three years. Central to the MOLLER experiment are five water-cooled toroidal magnets, each with a unique geometry and seven-fold symmetry, designed to focus the particles. These magnets generate the magnetic field needed to separate incident beam electrons scattered from target electrons (Møller scattering) and protons (elastic e-p scattering) within a target. This paper details the magnet field measuring technique developed to map all five MOLLER toroidal magnets at multiple locations within the open sector and along the bore. It covers the design, mounting, and operation of the probe, along with the calibration procedure to determine the field and to prepare field map for GEANT4 analysis. Additionally, the paper addresses the challenges of accurately measuring low magnetic fields.

Index Terms –magnets, spectrometer, toroid, field mapping, calibration

Acknowledgement –This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics under contract DE-AC05-06OR23177.

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Presenter: Mr ENG, Brian (JLab)

Session Classification: Wed-Af-Po.02 - Detector and Spectrometer Magnets

Contribution ID: **348** Type: **Poster**

Thu-Mo-Po.10-07: Study of CORC@ conductors with respect to individual tapes properties

Thursday, July 3, 2025 8:45 AM (2 hours)

CEA has been studying the advantages of a conductor based on an assembly of CORC-like cables (CORC®: Conductor on Round Core) in the high field zone of a hybrid Central Solenoid (CS) magnet for EU-DEMO. To this end, the detailed study of geometrical and electrical parameters of a CORC-like structure are studied in order to evaluate the cable's electrical performance as well as to determine a number of important parameters (crossing points, contact surface etc…) as function of the cable structure. The paper first presents these geometrical and performance analyses. It will then introduce smeared models in order to reduce the cable's performance to 1D tape scaling law using effective parameters. That reduction is of importance for use in thermal-hydraulic models.
Finally, the paper will present the case study of a particular CORC@ conductor that is being procured and is foreseen to be tested in the SULTAN superconducting conductors test facility in 2025. The paper will try to give some predictive estimate of the cable performance and identify some of the unknowns related to current redistribution and joint resistance.

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Presenter: TORRE, Alexandre

Session Classification: Thu-Mo-Po.10 - Modelling of Fusion Conductors and Coils II

Contribution ID: **349** Type: **Poster**

Thu-Af-Po.01-08: Progress in the Design and Fabrication of the Large-Aperture Nb3Sn Dipole Magnet CCT6

Thursday, July 3, 2025 2:00 PM (2 hours)

We present progress in the design and fabrication of CCT6, a Canted Cosine Theta (CCT) Nb3Sn magnet considered as part of the general R&D program for high field superconducting magnets supported by the US Magnet Development Program (US-MDP). Future testing with HTS inserts in a hybrid configuration motivates the design's large clear aperture of 120 mm and target operating dipole field of 12-14 T. We present updates to the magnetic and mechanical design which leverage an existing cable design from the HiLumi project. We share layer fabrication studies, with machining, winding, and reaction tests motivating the change to the MQXF cable for the inner layers. A 3D magnetic design is then presented, where a grading is used in the outer layers for conductor efficiency and reducing the magnet OD. Finally, we show a 3D mechanical design coupling the layers to an external structure which meets stress criteria up to the 15 T short sample at 4.2 K.

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Presenter: BROUWER, Lucas

Session Classification: Thu-Af-Po.01 - Accelerator Magnets II

Contribution ID: **350** Type: **Poster**

Wed-Af-Po.09-04: Magnet design activities at CEA for EU-DEMO new baseline

Wednesday, July 2, 2025 2:30 PM (2 hours)

In 2024, a new EU-DEMO baseline was released which changed substantially the constraints on the magnets systems. In particular, the stored energy of the TF system is about half of the former baseline value, which is bound to impact the magnetic loads as well as the coils protection.
After summarizing the main changes in the design inputs, this paper will present the changes implemented in the MADMACS design toolbox, in particular to include the fatigue analysis in the pulsed CS magnet. Fatigue hypotheses will be briefly discussed, including some sensitivity analysis with respect to the parameters and safety factors used.
We will then present the magnets internal structure (winding pack, cable etc…) obtained using this toolbox, and the preliminary detailed studies made to confirm these designs. In particular, we will focus on the benefit of adding layers of HTS conductor in a hybrid CS design.
We will conclude with some proposals regarding the developments still needed to interface HTS conductors with pulsed fusion magnets.

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Presenter: TORRE, Alexandre

Session Classification: Wed-Af-Po.09 - Magnets for Tokamaks: Design and Analysis

Contribution ID: **351** Type: **Contributed Oral**

Wed-Mo-Or2-06: Assembly of the MOLLER Toroidal Magnets at Jefferson Lab

Wednesday, July 2, 2025 12:30 PM (15 minutes)

The MOLLER experiment at the Thomas Jefferson National Accelerator Facility (JLab) aims to precisely measure the weak interaction between electrons. This experiment leverages the 12 GeV electron beam and will run for three years. A crucial component of MOLLER is a system of five uniquely shaped water-cooled toroidal magnets. These magnets, possessing seven-fold symmetry, are designed to focus particles by separating electrons scattered off hydrogen in a liquid hydrogen target. The five magnets separate electrons scattered off electrons (Møller scattering) and protons (elastic e-p scattering) within target into approximately circular rings at the detector. This paper presents the assembly process for these five toroidal magnets, detailing critical steps including epoxy application, pin insertion, soldering and brazing, coil assembly, and alignment, all performed to meet stringent magnet specifications. Additionally, it discusses challenges encountered during construction and highlights lessons learned, offering insights for future magnet development projects.

Index Terms –magnets, spectrometer, toroid, assembly, epoxy, soldering, brazing

Acknowledgement –This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics under contract DE-AC05-06OR23177.

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Presenter: Mr LAMONT, Joe (JLab)

Session Classification: Wed-Mo-Or2 - Muon Collider Magnets

Contribution ID: **352** Type: **Poster**

Thu-Af-Po.01-09: Direct Wind corrector magnets for the FCC-ee interaction region

Thursday, July 3, 2025 2:00 PM (2 hours)

The Interaction Regions (IR) for the FCC-ee collider as envisioned by the CERN FCC Feasibility Study requires a variety of superconducting correction coils that must be integrated with the main IR focusing quadrupoles. The present technological basis for these main quadrupoles is to wind superconductor supported in side-by-side slotted tubes, located deep inside the experimental detector solenoid as consistent with the FCC-ee IR crossing angle. Thus, the corrector coils, which are located radially outside these quadrupole coils, must be accommodated in very limited space and fabricating them also via a conductor in slots configuration would take up too much radial space. Our solution takes advantage of BNL's Direct Wind coil technology to essentially print multiple nested corrector layers, with small diameter superconductor wire, on a common support tube. As with the main quadrupole coils, because there is no magnetic yoke material between the side-by-side coils, these corrector coils must include a deliberate, longitudinally varying, admixture of field harmonics to self-consistently compensate for field crosstalk between neighboring coils. Here we present the design considerations for the two FCC-ee IR optics schemes currently being evaluated, along with the corrector coil design optimization procedure and our plans for fabricating a coil test prototype to validate the corrector design software.

Work supported by Brookhaven Science Associates, LLC under Contract No. DE-SC0012704 with the US Department of Energy.

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Co-author: TEOTIA, Vikas (Brookhaven National Laboratory)

Presenter: PARKER, Brett (Brookhaven National Laboratory (US))

Session Classification: Thu-Af-Po.01 - Accelerator Magnets II

Contribution ID: **353** Type: **Contributed Oral**

Fri-Mo-Or3-03: Radiation shielding and energy storage, dual use of high temperature superconducting magnets in space

Friday, July 4, 2025 8:45 AM (15 minutes)

With current propulsion capabilities, the trip to Mars takes around 6 to 8 months during which astronauts, plants, seeds, and electronics are exposed to energetic cosmic rays and solar flares that exceed acceptable radiation limits. This presents a critical challenge for future human interplanetary missions. In this work, we present a conceptual design for an innovative dual-purpose system utilizing High Temperature Superconductors (HTS) Coated Conductors (CC) coils. These coils are configured in a toroidal shield-craft attached to the exterior of a vessel providing magnetic shielding against radiation during transit. A similar system on planetary surfaces serves the alternative function of Superconducting Magnetic Energy Storage (SMES).
The system can also supply emergency energy to the ship during the journey, or function as a radiation shield for habitats on celestial bodies with no magnetosphere and a thin or non-existent atmosphere (e.g., the Moon). Recent improvements in HTS-CC performance driven by the interest in magnetically confined fusion energy, have enabled the routine construction of magnets operating at T⊠20K and B⊠20T using commercial CCs.
A key advantage of our proposed system is the modular design. The identical coils can be independently mounted, energized, and replaced, allowing for reconfiguration to accommodate various ship geometries, shielding needs, and energy storage requirements. Furthermore, the system enables operation of the shield and the SMES at different magnetic field strengths. The shielding figure of merit is characterized by the fraction of incident particles deflected, which scales as B × toroid radius. For the SMES, it is the stored energy, ˜ Bˆ2 × volume. While he SMES can operate at 20T-20K, the shield requires only B ˜ 3T, allowing for higher operating T and reduced structural support to sustain the magnetic pressure.

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Presenter: CIVALE, Leonardo (Department of Physics, University of Connecticut, Storrs, CT)

Session Classification: Fri-Mo-Or3 - Coils for Power, Energy, Transport and Other Applications

Contribution ID: **354** Type: **Poster**

Wed-Af-Po.11-08: Calculating the expected critical current for 3D coils of arbitrary shape made with VIPER-like HTS cable

Wednesday, July 2, 2025 2:30 PM (2 hours)

Superconducting coils utilizing VIPER-like HTS cable for tokamaks and
stellarators are being designed, built, and tested. In order to assess a coil's ability to operate at the desired current, and/or to evaluate
possible degradation of a coil's performance due to manufacturing
processes, it is necessary to calculate the expected critical current, Ic, of the coil. This is actually a difficult task, since the Ic of HTS tape varies non-linearly with B-field magnitude, B-field angle to the tape plane, and temperature. VIPER-like cables consist of stacks of HTS tape, and even though the cross-sectional area of a stack is typically only a few mm^2, the near-field generated by the current in the stack is high enough to drastically reduce the Ic of the tapes within the stack. Therefore an accurate calculation of the expected Ic at any location along the coil requires modeling each stack of HTS tape as a dense array of current filaments, and the geometry of these filaments must reflect the geometry of the tape stacks, which wind helically around the cable axis with a twist pitch of order 100-200 mm. At high currents the far-field generated by the non-local parts of a coil can also reduce Ic at the location of interest, and therefore must also be modeled as a set of current filaments, which can be of lower spatial resolution, but which must reflect the geometry of the full coil. For irregular coil shapes, this entails using specialized 3D coordinate systems, such as Frenet-Serret or related frames of reference.

A code to calculate the expected Ic for arbitrarily shaped 3D coils using VIPER-like HTS cable has been developed at MIT PSFC. The code is
specifically for coils operating in steady-state (such as for optimized
stellarators). The basic physics assumption is that at any location along the coil, the E-field is uniform across the cable cross-section and equal to 1 μV/cm (10^{-4} V/m), which is the definition for HTS being at critical current. The code reads in a .csv file containing the xyz-coordinates of the cable centerline, and generates a dense array of current filaments representing the HTS tape stacks at the desired location of interest along the coil, and a low-resolution array of filaments representing the balance of the coil. The filaments reflect the actual geometry of the coil, and include the twisting geometry of the HTS tape stack in VIPER-like cables. The code iterates the current in each of the many current filaments at the location of interest, until each filament is at its Ic, which depends on the B-field magnitude at each filament, and the B-field angle to each filament. Due to the non-linearity of the problem, the calculation must be iterative, since changing the filament currents changes |B| and its angle, which changes the Ic of each filament, and so on. In addition to requiring the coil geometry as input, the code also requires the HTS tape characterization, Ic(B, angle, T) where T is the operating temperature of the coil.

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Presenter: GRANETZ, Robert S (MIT Plasma Science and Fusion Center)

Session Classification: Wed-Af-Po.11 - Modelling of Fusion Conductors and Coils I

Contribution ID: **355** Type: **Contributed Oral**

Sat-Mo-Or5-01: A study of mechanical and thermal transients associated with magnet quenching due to impregnation material failure

Saturday, July 5, 2025 11:15 AM (15 minutes)

Eliminating quench training in superconducting accelerator magnets requires understanding the underlying mechanical transients, which include cracking of the impregnation material, interfacial debonding between the impregnation material and conductor, and slip-stick conductor motion; these events can release heat and lead to premature quenching and training. Earlier, we developed a system consisting of a cryogenic probe and tensile tester in order to apply mechanical stress to samples of copper wire embedded in commonly used impregnation materials [1]. The samples were monitored by a shear-piezo transducer and miniature temperature sensor to record acoustic emissions (AE) and local temperature variations. We have now also integrated a capacitive displacement sensor and pulsed spot heater to more accurately measure the sample displacement and thermally calibrate the system. We have tested a range of impregnation materials and reported the AE and temperature change of each to assess each material's suitability for high-field magnet fabrication. A finite element thermomechanical model was developed to estimate the heat released during transient mechanical events based on the observed rise in temperature. We have calculated material-specific ratios of released AE energy to thermal energy to inform future AE-based diagnostics for different event types.

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Presenter: SARAVANAN, Anjana

Session Classification: Sat-Mo-Or5 - Quench Detection Modelling

Contribution ID: **356** Type: **Poster**

Wed-Af-Po.08-05: Test and commissioning of a 15 kA Superconducting Current Transformer

Wednesday, July 2, 2025 2:30 PM (2 hours)

The manufacturing of superconducting magnets for High Energy Physics (HEP) and Fusion Energy Sciences (FES) applications requires high-current conductors to generate stronger magnetic fields without increasing the inductance of the magnet. Increased inductance is undesirable due to the associated AC losses, which reduce the temperature margin; and the quench protection also becomes complicated. Testing high-current superconductors with a direct current room temperature power supply is unfeasible for two primary reasons: 1) the limited capacity to supply large currents, and 2) the significant heat load losses at the current leads. A superconducting current transformer offers a solution to both of these challenges. A 50kA superconducting current transformer is planned for manufacturing and commissioning at Brookhaven National Laboratory as part of its user facility upgrade. This current transformer will facilitate the testing of superconducting cables, conductors, joints, and insert coils under high magnetic field conditions (10 T) and with currents up to 50 kA. To evaluate the manufacturing process and validate the theoretical models, the magnet division has developed and tested a 15kA prototype transformer. This prototype can deliver 15 kA to the test sample for up to 13 minutes, assuming a secondary resistance of 10nΩ and an inductance of 1μH. A closed loop digital control system has been implemented to ensure precise current delivery to the sample. This paper presents the experimental results from these tests.
Keywords: superconducting transformer, fusion, accelerator, test facility, high field testing.

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Presenter: JOSHI, Piyush

Session Classification: Wed-Af-Po.08 - Conductor and Coil Measurement/Test Techniques and Facilities I

Contribution ID: **357** Type: **Poster**

Thu-Mo-Po.04-08: Performance Evaluation of Electrically-condctive Epoxy Composite in Racetrack HTS Coil Applications

Thursday, July 3, 2025 8:45 AM (2 hours)

The no-insulation (NI) winding method is widely known for its ability to improve the stability of high-temperature superconductor (HTS) coils by bypassing the hot spot during a local quench. However, one major drawback of this method is the occurrence of charge and discharge delays due to current leakage between winding turns. To address this limitation, we recently proposed an impregnation technique using an electrically-conductive epoxy composite. This approach has shown the potential to reduce the charge/discharge delay while maintaining the inherent quench protection of NI HTS coils. Following this study, this paper aims to evaluate the proposed impregnation technique in a racetrack HTS coil, which is widely used in applications such as superconducting motors and generators. This study involves the fabrication and performance testing of racetrack HTS coils impregnated with an electrically-conductive epoxy composite, focusing on key aspects such as charge/discharge behavior and over-current characteristics. The results validate the feasibility of this method for larger and more practical HTS coil geometries, as well as its applicability in HTS electrical machines and other industrial systems.

This work was supported by the National R&D Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science and ICT under Grant 2022M3I9A1073187, and the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (No. RS-2024-00391886).

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Session Classification: Thu-Mo-Po.04 - No-Insulation Coils III

Contribution ID: **358** Type: **Poster**

Fri-Af-Po.08-07: Reinforcement of magneto-thermal stability in High Jc Nb3Sn strands through wire design optimization

Friday, July 4, 2025 2:00 PM (2 hours)

The superconducting strands, essential components for the future energy industry and fundamental scientific research, demand higher specifications to fulfill the requirements of increased energy production and advanced research. The manufacturer of superconducting strands has been performing continuous research to satisfy these requirements. However, upcoming facilities slated for construction now necessitate materials with even higher specifications, inevitably giving rise to challenges related to the stability. In response to the increasing specifications of superconducting strands, Kiswire Advanced Technology Co., Ltd.(KAT) has developed wires by incorporating locally modified sub-elements in both single barrier and distributed barrier designs to reinforce magneto-thermal stability. We confirmed a 30% reduction in effective diameter compared to conventional designs. In this study, we focused on the design improvement of High Jc Nb3Sn, with a specific emphasis on analyzing reinforcements in magneto-thermal stability.

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Presenter: Mr KIM, Young-Kyoung (Kiswire Advanced Technology Co., Ltd.)

Session Classification: Fri-Af-Po.08 - Advances in Nb3Sn and MgB2 Conductors I

Contribution ID: **359** Type: **Poster**

Thu-Mo-Po.03-07: Design study of superconducting septum magnets for future accelerators

Thursday, July 3, 2025 8:45 AM (2 hours)

To overcome the magnetic field strength limit of conventional iron-dominated septum magnets of about 2 T, GSI has proposed a superconducting septum magnet with a truncated cosine theta design. A high-field septum magnet, aiming at around 4 T, is required for future high-energy accelerators such as the Future Circular Collider (FCC) or a second stage synchrotron above the SIS100 heavy ion accelerator for FAIR at GSI. So far, several magnet design studies have been carried out at GSI with a truncated cosine theta coil and a half-cylindrical iron yoke including the coil ends. A brief summary of the design studies and the latest design study including the application of HTS conductors will be presented.

Author: SUGITA, Kei

Co-author: ROUX, Christian-Eric

Presenter: SUGITA, Kei

Session Classification: Thu-Mo-Po.03 - Design and Development of Accelerator Magnets II

Contribution ID: **360** Type: **Poster**

Thu-Af-Po.04-02: Electromagnetic Investigation of Shielding Effect of NI REBCO Windings for Screening Current Reduction

Thursday, July 3, 2025 2:00 PM (2 hours)

The no-insulation (NI) technology is a powerful technique toward very high field generation over 40 T. The National High Magnetic Field Laboratory (NHMFL), in 2017, successfully generated a field of 45.5 T, which is the world record for the DC field [1]. The success is attributed to the use of rare-earth barium copper oxide (REBCO) and the NI technology. REBCO conductors can withstand a very high magnetic field and mechanical stress, while the NI technology grants the REBCO coil very high thermal stability. The combination of REBCO conductors and NI technology is promising and adopted in many high-field magnets [2], [3], [4]. One of the major drawbacks of the NI REBCO coils is the screening current effect. Screening currents are induced when a field perpendicular to the REBCO tape changes; i.e., during magnet energization and de-energization. The screening current causes the unbalanced current distribution in the REBCO conductors and consequent unbalanced forces, which may lead to excessive electromagnetic forces and possible conductor degradations in such a high field [5]. The temporal field instability due to the screening current is an undesired characteristic as well. Reducing or suppressing the screening currents can open the way for the higher field generation.
In this presentation, we propose the use of NI REBCO windings as shielding coils from the screening current fields. The NI REBCO windings, which are not energized, are placed close to the edge sides of the main NI REBCO coil, and the non-energized NI REBCO coil prevents the radial field change and reduces the screening current. The electromagnetic simulation is performed using the partial element equivalent circuit (PEEC), and the electromagnetic behaviors of the shielding coil, as well as the suitable configuration of the NI REBCO windings, are investigated.

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Presenter: MATO, Takanobu

Session Classification: Thu-Af-Po.04 - Screening Currents and Shimming

Contribution ID: **361** Type: **Invited Poster**

Thu-Mo-Po.05-01: [Invited] Nb3Sn React-and-Wind Racetrack Coil as a Demonstration of Strain Management

Thursday, July 3, 2025 8:45 AM (2 hours)

In the manufacture of Nb3Sn coils, the react-and-wind (R&W) method, which uses heat-treated wire to manufacture coils, has advantages, such as no need for heat treatment of the coil. In the R&W method, it is necessary to consider the degradation of the critical current due to Nb3Sn strain, including strain due to winding. Recently, we demonstrated the fabrication of R&W coils with a small bending radius of 55 mm minimum using a polyvinyl formal-coated CuNb-reinforced Nb3Sn wire. Although small bending radius increases the bending strain, we have shown that it is possible to fabricate coils without degradation by the strain control. Strain management includes windings that do not exceed irreversible strains and taking into account the effects of strain distribution within the wire, such as bending strains. As a next step, we have demonstrated the fabrication of a racetrack coil using the R&W method as a demonstration of strain management. The racetrack coil has straight sections and has both the same and opposite bends in the same coil relative to the heat treatment bend. In this presentation, the fabricated racetrack coil and test results will be reported.

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Presenter: EBARA, Yuta (Sumitomo Heavy Industries, Ltd.)

Session Classification: Thu-Mo-Po.05 - Mechanical Behavior and Stress I

Contribution ID: **362** Type: **Poster**

Sat-Mo-Po.07-05: Thermal properties of Block-type dipole superconducting magnets wound using REBCO cables with defects and specified thermal and electrical interface properties

Saturday, July 5, 2025 9:30 AM (1h 45m)

Quench and protection in superconducting magnets wound using REBCO cables is important for high energy particle accelerators. Quite large minimum quench energy (MQE) and quite low normal zone propagation (NZP) velocity has led to an interest in electrically non-insulation coils. We analyzed numerically, using a Finite Element Method (FEM), the performance of REBCO cable containing various structural defects. We focused on effects of the defects on heating and thermal runaway of the magnets. Defects are possible in any HTS cable, originating from the tape manufacture, or during cabling, or in service. The influence of electrical and thermal contact resistances was included. The impact of thermal boundary conditions was also quite important, and these block dipoles were assumed to be epoxy impregnated, such that helium cooling (pool boiling) was only present on the magnet surface. This led to more rapid thermal runaway as compared to systems with more direct cooling contact. To model the REBCO superconducting material we used its measured power law E-J curve. Heat disturbances of different size, intensity and duration have been analyzed from the viewpoint of the magnet quench and stability.

Authors: Prof. COLLINGS, Edward (The Ohio State University); SUMPTION, Michael; MAJOROS, Milan

Presenter: MAJOROS, Milan

Session Classification: Sat-Mo-Po.07 - HTS Magnets

Contribution ID: **363** Type: **Poster**

Thu-Mo-Po.03-06: Design of a structure for assembly and cooling the magnet of the next-generation 45 GHz ECR ion source MARS-D

Thursday, July 3, 2025 8:45 AM (2 hours)

The current 28 GHz Electron Cyclotron Resonance Ion Sources (ECRISs), constructed with Nb-Ti wires and conventional sextupole-in-solenoid or unconventional solenoid-in-sextupole structure, have utilized about 90% of the critical limits of the Nb-Ti wires to achieve maximum operating frequencies of up to 28 GHz. To produce an ECRIS capable of operating at fields required for frequencies of about 45 GHz while maintaining the Nb-Ti wires operating within conductor limits, a Mixed Axial and Radial field System Demonstrator (MARS-D) is being constructed at Lawrence Berkeley National Laboratory (LBNL). This system, which consists of an innovative hexagonal Closed-Loop Coil (CLC) and a set of solenoids, can generate up to 50% higher magnetic fields than the conventional magnet structure while using only about 50% superconducting wire, enabling Nb-Ti wires to be used in the next generation 45 GHz ECRIS. However, the assembly and cooling of such efficient and compact magnets are particularly challenging due to the small radial gap between CLC and solenoids and the small operating temperature margin. To address these challenges, a structure combining a three-section radially split solenoid mandrel with a series of interference-fit reinforcement rings and cooling channels was developed. This paper presents the detailed structure, manufacturing method, assembly procedure, impregnation method, mechanical and thermal Finite Element Analysis (FEA), and cryogenic test plan.

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Session Classification: Thu-Mo-Po.03 - Design and Development of Accelerator Magnets II

Contribution ID: **364** Type: **Poster**

Thu-Af-Po.03-07: Design and Analysis of a 10 kW-Class Axial-Flux Permanent Magnet Motor for Electric Propulsion Systems

Thursday, July 3, 2025 2:00 PM (2 hours)

Axial-flux permanent magnet (AFPM) motors have gained significant attention in industries such as electric vehicles and ships due to their compact size, high torque density, and superior efficiency. While various AFPM designs have been proposed, this study focuses on the yokeless and concentrated armature structure, which offers unique advantages by eliminating the stator yoke. This reduces motor weight, thereby enhancing torque density, and decreases iron losses to improve overall efficiency. In this research, an AFPM motor was designed and optimized to achieve an output of 10 kW or more. The motor employs a single-stator dual-rotor configuration with permanent magnets mounted on both rotor surfaces, reducing magnetic flux leakage. To further enhance performance, the stator was designed with a soft magnetic composite (SMC) core, while the rotor utilized solid magnetic materials to achieve a balance between weight and magnetic properties. An optimization approach using 3D finite element analysis (FEA) was applied to refine the motor design. The optimized motor demonstrated higher efficiency and lower losses compared to the initial design, all while maintaining the target output of 10 kW. This study shows the potential of AFPM motors not only in compact electric vehicles but also as a scalable solution for high-efficiency propulsion systems.

This paper was supported by Korea Institute for Advancement of Technology (KIAT) grant funded by the Korea Government (MOTIE)(RS-2024-00424595 / Regional Residency Program for Cultivating Advanced Research Talent in Next-Generation Marine Mobility Industry Innovation), and the National Research Foundation of Korea (NRF) grant funded by the Korea government(MSIT) (No. RS-2024-00391886).

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Session Classification: Thu-Af-Po.03 - Rotating Machinery III

Contribution ID: **365** Type: **Poster**

Thu-Mo-Po.09-07: Design, Construction and Operation of a Conduction Cooling-Type HTS Module Testing System

Thursday, July 3, 2025 8:45 AM (2 hours)

Currently, The National High Magnetic Field Laboratory (NHMFL) is in the process of developing a 40 T High Temperature Superconducting (HTS) user magnet, and for the magnet development, it is essential to evaluate the performance of a large number of HTS modules in the future. Typically, each HTS module requires performance evaluation after winding and before being assembled into a magnet. While testing under Liquid Helium (LHe) conditions, where the final product will operate, is ideal, due to cost and time constraints, inspection under LN2 conditions is known to be a more efficient approach. However, since the final operation of HTS magnets is conducted in LHe and the performance of HTS tape, which plays a critical role in the module's performance, does not exhibit linear behavior between Liquid Nitrogen (LN2) and LHe temperatures, discrepancies arise between the performance of the HTS module verified under LN2 conditions and its performance under LHe conditions. To address the above issue, a performance evaluation system for HTS modules based on the conduction cooling method was developed. This paper describes the design, construction, and test results of the system. The constructed conduction cooling-type HTS module testing system uses two two-stage GM cryo-coolers as the primary cooling source. The 1st stage cold head of the cryo-cooler is responsible for cooling the metal current leads and radiation shields, and the bottom side of the HTS leads. The 2nd stage temperature section is responsible for cooling the Oxygen Free Copper (OFCu) cooling plate and top-side of the HTS leads. The HTS test module is cooled through the OFCu cooling plate. The HTS module testing system controls the temperature of the HTS module under testing from 4 K to 30 K and can supply an operating current of up to 800 A. All operating parameters of the HTS module test system are controlled and recorded using a Data Acquisition (DAQ) system based on LabVIEW.

ACKNOWLEDGMENTS
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Session Classification: Thu-Mo-Po.09 - Conductor and Coil Measurement/Test Techniques and Facilities II

Contribution ID: **366** Type: **Poster**

Fri-Mo-Po.07-04: Development of a 270-degree achromatic bending magnet suitable for proton beamline

Friday, July 4, 2025 9:30 AM (1h 45m)

State Power Investment Corporation (SPIC) is leading a project that uses cyclotron for proton irradiate power chips. Compared to electrostatic accelerator, cyclotron have the advantage of lower cost and higher beam intensity. However, a disadvantage of cyclotron is that the extracted beam has relatively large energy dispersion. For horizontally placed power chips, the beam must be injected vertically. Therefore, the cyclotron beam extracted along the horizontal direction must undergo a 90-degree deflection to reach the irradiation terminal. Traditional 90-degree bending magnets, when handled with the large energy dispersion of the cyclotron beam, can cause significant beam loss, especially at low energies.
This report presents the progress in the development of a 270-degree achromatic bending magnet suitable for this application. In the past, this type of magnet has typically been used in electron beamline and when attempting to apply it to proton beamline, corresponding optimizations to its theoretical design are needed to make it more economically efficient in terms of weight and power consumption. This report introduces the theoretical design of this type of magnet prototype, compares its beam transport with that of a 90-degree bending magnet, presents manufacturing and magnetic measurement results, and discusses the actual beam test results.

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Session Classification: Fri-Mo-Po.07 - Accelerator Magnets III

Contribution ID: **367** Type: **Poster**

Fri-Mo-Po.05-05: Structural Analysis of a Serpentine Superconducting Magnet for the Interaction Region of Electron Ion Collider

Friday, July 4, 2025 9:30 AM (1h 45m)

The Electron Ion Collider (EIC) will collide high energy and highly polarized hadron and electron beams with luminosities up to 10ˆ34/cmˆ2/s. The magnet designs at the interaction region (IR) are challenging due to the close proximity of the hadron and electron beams. Several serpentine types of superconducting magnets have been designed due to the space restrictions at the IR. To validate the designs in terms of the mechanical strength and the allowed deformations, a detailed structural mechanical analysis for a 12-layer superconducting quadrupole serpentine magnet (Q1BpR) has been carried out using the finite element method (FEM) considering the prestress, shrinking due to cool down, and the electromagnetic force on the conductors in both 2D and 3D geometry. The 3D electro-magnetic (EM) simulations were performed using RAT, the structural mechanical analysis were performed using COMSOL by considering the contact elements.

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Session Classification: Fri-Mo-Po.05 - Electron-Ion Collider

Contribution ID: **368** Type: **Contributed Oral**

Sat-Mo-Or3-02: Effect of transverse compressive loads applied at room temperature on the electromagnetic performance of superconducting STAR® wires

Saturday, July 5, 2025 8:15 AM (15 minutes)

The US Magnet Development Program is considering REBCO symmetric tape round (STAR®) wires as candidates for the next generation of high-field hybrid magnets for high-energy particle colliders. In high-field dipole magnets, the conductors experience strong mechanical loads transverse to their longitudinal axis. The current-carrying capability of the superconductor may decrease under these transverse loads and eventually degrade due to cracks caused by excessive loading. Therefore, understanding the response of superconducting wires to transverse loading is a crucial factor in the design of high-field accelerator magnets. The mechanical performance of STAR® wires under transverse compressive loads has not yet been fully investigated, and the results of the test campaign will help clarify the load limits of these wires and prepare the ground for possible fabrication improvements. STAR® wires with a diameter of 1.35 mm have been fabricated by AMPeers with four REBCO tapes, where the width of the first three tapes is to 2 mm and the final one is 2.6 mm. The diameter of the copper former is 0.8 mm. To estimate the forces representative of the room temperature prestress that could cause irreversible degradation, STAR® wires are mounted on a dedicated impregnation mold that recreates the conditions experienced by the wires in the grooves of the magnet support structure. For this test campaign, paraffin wax filled with aluminum oxide has been selected as the impregnation material to protect the REBCO tapes from delamination, which could compromise the magnet performance. As a soft impregnation medium, filled wax does not apply a strong pulling force on the tapes. The design of the impregnation mold ensures that the wire is surrounded by a square matrix of filled wax. The critical current of STAR® wire is measured before and after the impregnation procedure at 77 K to establish the baseline performance and asses any potential degradation. Then, after each transverse compressive load is applied to the sample at room temperature, the wire is cooled-down to 77 K, and the critical current is measured to identify the irreversible load limit. The machine used to apply the compressive loads during the test campaign is the Instron 6800 Series. A 3D finite element model is also under development to estimate the stress on the REBCO tapes, and to analyze and compare the experimental data.

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Session Classification: Sat-Mo-Or3 - HTS Characterization III

Contribution ID: **369** Type: **Contributed Oral**

Wed-Mo-Or3-01: Manufacturing and development of high performance REBCO wires at SuperPower for various magnet applications

Wednesday, July 2, 2025 11:15 AM (15 minutes)

The increasing demand for REBCO wires from various magnet applications such as that for the HTS-based compact fusion, accelerators, transportation, medical and analytical systems is driving the increase in our production capacity and the further improvements in wire performance and qualities. In the last several years, SuperPower was focusing on advancing the wire manufacturing technologies. Great efforts have been made in upgrading the production systems and optimizing the processing techniques. These efforts were made aiming at the development of the next generation manufacturing technologies that are needed to make a transition from small-scale production to large-scale production. Highly stabilized processes with high throughput and high yield in all the processing steps, particularly in REBCO deposition, are the key to realize such transition. For this purpose, the critical components in the manufacturing systems are being redesigned or modified and new components are being added.

Continuous efforts are also being made at SuperPower in the further development of REBCO wires, aiming at achieving improved performance and required additional functionalities. Following the widely adopted HM tapes, which have an average Ic of 450 A/4mm at 4.2K-17T//c and an average Ic of 160 A/4mm at 20K-20T//c, we are working on the development of a new REBCO formula that will have a further increase in the in-field performance, especially at high fields around 20K. Seeing an increasing demand, we are establishing the manufacturing capability in-house for manufacturing filamentized tapes, which is based on laser striation. We have built a system in-house for making insulated tapes with polyimide coating. We are developing an advanced slitting technique for the improvement of the slit edge quality. In this talk, we will present an overview on these development work and the progresses in wire manufacturing.

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Session Classification: Wed-Mo-Or3 - REBCO Manufacturing

Contribution ID: **370** Type: **Contributed Oral**

Sat-Mo-Or6-07: Performance Evaluation of Series Magnets of Beam Separation Dipole for HL-LHC

Saturday, July 5, 2025 12:45 PM (15 minutes)

KEK have so far tested four series beam separation dipoles, a.k.a. D1 (MBXF) magnets, for the High Luminosity LHC upgrade (HL-LHC). The magnet is wound on Nb-Ti Rutherford cables and designed to operate at 1.9 K generating a central field of 5.6 T with a magnetic length of 6.3 m, which corresponds to a field integral of 35 Tm. All the series magnets were subjected to a quench training campaign in the KEK-owned vertical cryostat, and were energized successfully up to an ultimate current of 13.23 kA. The magnetic field error of these magnets was also evaluated with a rotating coil system developed in-house, and was confirmed to meet the acceptance criteria.
Statistics of the test results have been accumulated so far with four series magnets. We have observed that each magnet showed various training trends. Particularly MBXF2 and MBXF3, which are the 3rd and 4th series magnet respectively, showed a slow training rate; more than 10 quenches were required to reach the ultimate current. We have also confirmed that there is a correlation between the individual coil size and unallowed multipoles, which were investigated through finite element (FEM) analyses. In this paper we first report the recent result of the MBXF3 test obtained during the period of Dec. 2024-Jan. 2025. Then we introduce the training trend and magnetic field quality of the MBXF series obtained so far. We also give our insight on the field quality using the FEM analysis and the mechanical data obtained during fabrication process.

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Session Classification: Sat-Mo-Or6 - High Luminosity LHC

Contribution ID: **371** Type: **Poster**

Wed-Mo-Po.12-05: Development of Inductive Wireless Charging Systems for HTS Magnet Applications

Wednesday, July 2, 2025 9:15 AM (2 hours)

High-temperature superconductor (HTS) magnets have demonstrated significant potential for generating high magnetic fields and transporting DC current with minimal power loss, making them essential components in advanced applications such as NMR, MRI, and superconducting motors. Despite the advantages, the high joint resistance of HTS magnets has limited the adoption of persistent current mode (PCM), necessitating the use of power-driven modes, which introduce thermal loads and reduce operational stability. To address these challenges, our previous study proposed an inductive coupling-based contactless current charging system designed for a HTS coil operating in cryogenic environments. This system effectively demonstrated feasibility through finite element analysis, electrical circuit simulations, and prototype experiments. In this study, we aim to extend the application of this technology to larger-scale HTS magnets. The research will focus on the design and fabrication of a system capable of charging HTS magnets efficiently while addressing challenges such as optimizing coupling coefficients and ensuring robust performance under cryogenic conditions. This result is expected to provide a practical and scalable approach to contactless current charging for HTS magnets, enabling broader adoption in advanced superconducting applications.

This research was supported by National R&D Program through the National Research Foundation of Korea (NRF) funded by Ministry of Science and ICT (2022M319A1072464), and the National Research Foundation of Korea (NRF) grant funded by the Korea government(MSIT) (No. RS-2024-00391886).

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Session Classification: Wed-Mo-Po.12 - Diodes, Flux Pumps, and Switches

Contribution ID: **372** Type: **Poster**

Sat-Mo-Po.08-03: Feasibility Study of Epoxy-Based Soft Magnetic Powder Cores for Electric Motor Applications

Saturday, July 5, 2025 9:30 AM (1h 45m)

This paper examines the potential of epoxy-based soft magnetic powder cores (SMPC) for electric motor applications. SMPC, created by uniformly dispersing iron-based ferromagnetic powder into epoxy resin, effectively reduces eddy current losses and decreases magnetic anisotropy, resulting in more uniform magnetic properties. Although SMPCs exhibit lower permeability compared to conventional laminated steel cores, they are particularly advantageous for complex geometries, such as those in axial-flux motors. This study examines the feasibility of epoxy-based SMPCs by analyzing their magnetic properties and mechanical strength. Key factors, including powder particle size and the powder-to-epoxy ratio, are investigated to optimize both magnetic performance and structural integrity. Additionally, fabrication methods for achieving homogeneity in SMPCs are investigated to ensure consistent performance in electric motors. These results are expected to advance the development of SMPC materials for future motor applications.

This paper was supported by Korea Institute for Advancement of Technology (KIAT) grant funded by the Korea Government (MOTIE) (RS-2024-00424595 / Regional Residency Program for Cultivating Advanced Research Talent in Next-Generation Marine Mobility Industry Innovation), and the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (No. RS-2024-00391886).

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Session Classification: Sat-Mo-Po.08 - Structural and Insulation Materials

Contribution ID: **373** Type: **Poster**

Wed-Mo-Po.03-02: Real-Time Thickness Monitoring of HTS Coated Conductors in Reel-to-Reel Processing

Wednesday, July 2, 2025 9:15 AM (2 hours)

High-temperature superconducting coated conductors (HTS CCs) are essential components in advanced technologies such as high-field magnet, fusion, power transmission, and medical imaging. However, non-uniform thickness along their length and width can severely affect the performance of HTS magnets. Despite the importance of maintaining thickness uniformity, no system currently exists to continuously measure the thickness of HTS CCs during reel-to-reel (R2R) processing. This limitation poses significant challenges for quality control and efficient large-scale manufacturing. To address this issue, we developed a continuous R2R thickness measurement system that employs a high-precision confocal laser sensor. The system provides real-time thickness measurements with an accuracy of ±1 μm while generating detailed 3D thickness profiles. Although it is currently optimized for moderate processing speeds, ongoing upgrades, including the implementation of a damping mechanism, will enable high-speed operation of up to 600 meters per hour, making the system suitable for industrial-scale production.

This innovative system overcomes key challenges in HTS CC manufacturing by enabling continuous, real-time thickness monitoring and significantly improving quality control. Its integration into automated production lines ensures high-quality fabrication of high-performance HTS magnets, paving the way for broader adoption of HTS technologies in critical applications.

Keywords: HTS CCs, Thickness measurement system, Reel-to-reel, Confocal laser sensor

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Session Classification: Wed-Mo-Po.03 - HTS Characterization I

Contribution ID: **374** Type: **Poster**

Fri-Mo-Po.07-03: Design of the main magnet of a 300MeV separated sector cyclotron

Friday, July 4, 2025 9:30 AM (1h 45m)

High intensity cyclotrons play a significant role in radionuclide production. Our institute has formulated a plan to design and build a 300 MeV proton cyclotron and has already initiated preliminary research. Among all the subsystems, the main magnet stands out as one of the most critical and challenging components.When compared with low beam current cyclotrons, the main magnet system of a high beam current cyclotron has a more demanding requirement. It must generate a substantially strong vertical focusing force. This is essential for preventing beam expansion, which can be triggered by perilous resonances and space charge effects.Within the scope of this paper, the three dimensional modeling and optimization efforts dedicated to this large scale magnet system are presented in comprehensive detail.

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Session Classification: Fri-Mo-Po.07 - Accelerator Magnets III

Contribution ID: **375** Type: **Poster**

Wed-Mo-Po.05-02: Design and cost analysis of an HTS magnet array for ship magnetic signature replication in naval minesweeping

Wednesday, July 2, 2025 9:15 AM (2 hours)

Naval minesweeping is a crucial initial operation in naval warfare, ensuring safe passage for friendly forces by clearing sea lanes of mines deployed by adversaries. Current minesweeping methods utilize permanent magnets or copper cables to trigger magnetic mines. Generating stronger magnetic fields enables the clearance of deeply laid mines and the replication of larger vessels' signatures. However, permanent magnets are limited by their remanent flux density, while copper cables require significant volume due to their low current density. To address these limitations, the application of superconducting technology has been explored to develop lighter, higher-flux minesweeping magnets. In particular, No-Insulation (NI) High-Temperature Superconducting (HTS) magnets offer the potential for generating significantly stronger magnetic fields, providing substantial advantages in minesweeping operations. This study focuses on calculating ship magnetic signatures and designing an NI HTS magnet array to replicate these signatures. Furthermore, we calculate the required HTS conductor length for replicating signatures of various vessel sizes and conduct a cost analysis of NI HTS minesweeping magnet based on these calculations.

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Session Classification: Wed-Mo-Po.05 - Novel and Other Applications I

Contribution ID: **377** Type: **Contributed Oral**

Sat-Af-Or1-05: High Field Compact Machine Approach to Fusion and Relevant Superconducting Technologies

Saturday, July 5, 2025 3:15 PM (15 minutes)

High Field Compact Machine Approach to Fusion and Relevant Superconducting Technologies*
B. Coppi1, L. Sugiyama1 and C. Mazzotta2
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Given the limitations of relevant theory and available experimental results at the current stage of fusion research, reaching regimes close to ignition conditions is necessary in order to investigate the physics of meaningful fusion burning plasmas Among various options considered at present, the line of high magnetic field compact machines remains the most promising for this objective, given its demonstrated ability to produce well confined and pure plasmas with record high pressures.
The Ignitor machine, the first experimental machine to be proposed and fully designed [1] for this goal, has adopted proven high temperature and superconducting magnets (MgB2) for its largest poloidal field coils [2]. An effort is underway to adopt different types of superconducting magnets which are capable of reaching higher fields for the remaining "external"(to the machine core) poloidal field coils of the Ignitor machine. Considerations of reliability related to the need to approach ignition conditions have led to the decision to maintain the copper solution [2] for the toroidal magnet and the central solenoid. In fact, particularly serious issues have to be faced when considering the adoption of superconducting materials for the toroidal magnet and central solenoid. One of the main concerns that have been identified is that of protection against quench events. In fact, it is necessary to maximize both the plasma current and the associated poloidal field in machines designed to produce meaningful fusion burning plasmas. To achieve this, minimization of the aspect ratio of the plasma column and optimization of its major radius are required while ensuring that these high field, "large volume"magnets remain feasible. As a result, the space left to incorporate a reliable quench protection system becomes limited. A significant effort, considering the attractive properties of high temperature superconducting materials (HTS) [3], is being devoted to dealing with this issue in the context of the Ignitor program and existing international collaborations. In fact, a second version of the Ignitor machine can be envisioned where all magnets capable of producing the needed high fields are superconducting.

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[1] B. Coppi, Comments Plasma Phys. Cont. Fusion, 3, 47 (1977).
[2] B. Coppi, A. Airoldi, R. Albanese et al. Nucl. Fusion 53, 104013 (2013).
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Session Classification: Sat-Af-Or1 - Fusion Test Facilities

Contribution ID: **378** Type: **Poster**

Sat-Mo-Po.03-05: Mechanical Behavior of the KSTAR Magnets for Long-Pulse Discharges

Saturday, July 5, 2025 9:30 AM (1h 45m)

The KSTAR superconducting magnet system is designed to confine and control the high-temperature plasma necessary for nuclear fusion reactions. It comprises Toroidal Field (TF) coils, Poloidal Field (PF) coils, and Central Solenoid (CS). The TF coils generate a strong toroidal magnetic field to confine the plasma, the PF coils control the plasma's vertical position and shape, and the CS induces and sustains the plasma current. To improve the capability for sustained plasma operation, KSTAR has conducted long-pulse discharge experiments in each campaign.
During plasma operation, high current in the TF coils generates a primary electromagnetic field, while varying currents in the CS and PF coils produce additional electromagnetic fields. The interaction of these fields, along with the electromagnetic forces generated by the currents in each coil, exerts significant mechanical forces on the magnets and their supporting structures, resulting in complex mechanical behavior. This behavior is monitored using strain gauges and displacement gauges installed on the magnet system. By analyzing the measured physical quantities, the safety and stability of the system can be assessed and effectively managed. Furthermore, the development of accurate analytical methods for predicting these measurements under given operating conditions is critical for designing and advancing new devices.
Over the past three years, mechanical behavior during major long-pulse discharge experiments was systematically compared, and the reliability of the measurement devices was verified. Specifically, the vertical displacement of the stacked CS coils and the strain in high-stress regions of the TF magnet structures were analyzed by comparing measured values with those predicted by analytical models. These results confirmed that the mathematical analysis techniques and finite element analysis (FEA) models are suitable for accurately predicting mechanical behavior.

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Session Classification: Sat-Mo-Po.03 - Mechanics of Fusion Magnets

Contribution ID: **380** Type: **Poster**

Fri-Mo-Po.09-03: Comparison of low temperature superconductor (LTS) and high temperature superconductor (HTS) for fast ramping magnet of adiabatic demagnetization refrigerator (ADR)

Friday, July 4, 2025 9:30 AM (1h 45m)

Adiabatic demagnetization refrigerator (ADR) is a cooling method that utilizes the cooling effect from the magnetic material under a changing magnetic field. Commonly, the field variation is generated by a superconducting magnet. If a 4 K cryocooler is implemented as a heat sink of the magnet, both low temperature superconductors (LTS) and high temperature superconductors (HTS) can be used for the magnet winding. Due to the distinct characteristics of these conductors, their stability energy margins during the ramping operation differ. This study analyzes the suitability of each superconductor type for ramping magnets in ADR systems. The ratio between the hysteresis loss and the stability energy margin (the maximum energy that can be absorbed while maintaining the superconducting state) is proposed as a critical factor for stable magnet operation. This ratio of different superconductors is analyzed, leading to a recommendation for the optimal conductor for the ADR applications. Additionally, a conduction-cooled magnet utilizing HTS conductors is developed, incorporating a thermal drain structure to efficiently dissipate hysteresis losses during the ramping operation. The fabricated magnet achieves the ramping rate of 0.1 T/s with the maximum central magnetic field of 4 T. Using gadolinium gallium garnet as the magnetic material for ADR, the system reaches the minimum temperature of 0.3 K from 4 K. The detailed analytical and experimental results are discussed in the paper.

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Presenter: Mr KWON, Dohoon (KAIST)

Session Classification: Fri-Mo-Po.09 - Novel and Other Applications II

Contribution ID: **381** Type: **Poster**

Fri-Af-Po.10-07: Enhancing Hall Probe Measurement Accuracy for Magnetic Field Characterization in Undulators

Friday, July 4, 2025 2:00 PM (2 hours)

Precise magnetic field measurement of undulators is a cornerstone in optimizing synchrotron radiation facilities. This study introduces a position-sensitive Detector (PSD)-based system aimed at enhancing the accuracy of point measurements using Hall probes. By focusing on the challenges of positional deviation and misalignment, the system improves the precision of magnetic field data critical for undulator performance.

The system utilizes PSD technology to achieve high-resolution detection of the transverse coordinates of Hall probes. Real-time feedback mechanisms are integrated to correct the guide rail straightness and mitigate angular deviations during scanning, thereby reducing systematic errors in magnetic measurements. The approach emphasizes robustness and adaptability to standard undulator configurations, ensuring consistency across diverse measurement setups.

The innovations address common challenges in conventional Hall probe methods, such as mechanical instability and positional drift. These advancements contribute significantly to achieving tighter tolerances in undulator magnetic field characterization, enabling higher brilliance and more precise control in synchrotron radiation applications.

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Presenter: WANG, Jun (Shanghai Advanced Research Institute, Chinese Academy of Sciences)

Session Classification: Fri-Af-Po.10 - Undulators

Contribution ID: **382** Type: **Poster**

Sat-Mo-Po.04-04: Effect of the type of solder flux on high-temperature superconductor tape under time-varying conditions

Saturday, July 5, 2025 9:30 AM (1h 45m)

The fabrication of superconducting coils using high-temperature superconductor (HTS) tape necessitates the use of soldering processes to join sections of tape or to connect the tape to the current lead. During this process, flux is commonly used to remove the oxide layer from the copper stabilizer to improve the soldering quality. However, residual flux remaining on the surface or permeating between the turn-to-turn layers after soldering can lead to corrosion and contamination over time, which significantly degrades the properties of the tape and current lead. These issues are one of the primary causes of reduced long-term reliability in superconducting applications. In this study, two types of solder flux with different compositions were used to fabricate superconducting coils, after which the surface of the coils and the electrical characteristics of the coils were monitored and compared over time. We systematically investigated the effects of the type of flux and the temporal progression of residual flux on the material degradation and the performance and stability of superconducting coils.

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Co-authors: NOH, Hyun Sung (Korea University); Mr SUN, Min Kyu (Korea University); Prof. MUSSA, Mtangi Mohamed (University of Dar es Salaam); Mr HYUNSOO, Park (Seoul National University); HAHN, Seungyong (Seoul National University)

Presenter: KIM, Younghoon (Korea University)

Session Classification: Sat-Mo-Po.04 - Protection and Stability

Contribution ID: **383** Type: **Poster**

Thu-Mo-Po.06-03: Optimization of partial surface friction in GdBCO tapes for mitigating Lorentz force-induced stress in high-field magnets

Thursday, July 3, 2025 8:45 AM (2 hours)

When designing magnets with strong magnetic fields, it is imperative to consider the mechanical stress induced by the Lorentz force. However, conventional stress-strain calculation methodologies, or force balance equations that utilize the BJR formula, often neglect the frictional force between superconductor tapes. This motivated our previous study on the relationship between the frictional force on the surface of the superconducting tape and the deformation of the coil. These results confirmed that the friction coefficient on the surface of the superconducting tape is related to the stress-strain experienced by the coil. In the present study, the effect of the friction area on the coil was investigated by optimizing the frictional force by fabricating GdBCO tape of which part of the surface has a deliberately designed friction coefficient. The mechanical stress on the magnet wound with the intentionally roughened GdBCO tape was examined by simulating the occurrence of the Lorentz force. The experimental results will be discussed in detail, with particular reference to the deformation of the coil and the optimization of the friction area.

< Acknowledgment>
This work was supported by the National R&D Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science and ICT (2022M3I9A1073924) and in part by a National Research Foundation of Korea (NRF) grant funded by the Korean government (MSIT) (No. 2021R1A2C209312212).

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Presenter: NOH, Hyun Sung (Korea University)

Session Classification: Thu-Mo-Po.06 - Mechanical Behavior and Stress II

Contribution ID: **384** Type: **Poster**

Sat-Mo-Po.04-03: Thermal/electrical characteristics of ice-impregnated coils enhanced with ethanol and Zylon filler

Saturday, July 5, 2025 9:30 AM (1h 45m)

During the operation of rotating motors based on superconducting coils, impregnation is used to enhance the mechanical integrity against rotational vibration and to protect the superconducting coils from mechanical disturbances in strong magnetic fields. Generally, epoxy resin is primarily used for high-temperature superconducting (HTS) coil impregnation because of its low cost, excellent mechanical strength, and superior adhesion. However, its low thermal conductivity can cause thermal gradients, and the significant difference in thermal contraction between the epoxy resin and HTS coils degrades the superconducting properties. Attempting to overcome these problems, we previously proposed an ice impregnation method that exploits the expansion of water during its phase transition to ice; however, this method has limitations because of the low mechanical strength of ice. In this study, we investigated a novel ice impregnation method using ethanol and Zylon filler. This method involves mixing ethanol, a hydrophilic substance that prevents the formation of voids and cracks during the phase transition to ice, with Zylon fiber, a high-strength material with a negative thermal expansion coefficient, as a filler to provide enhanced support for HTS coils. The effect of ice impregnation with ethanol and the Zylon filler on the thermal and electrical properties of HTS coils was examined by performing cool-down tests, repetitive cooling tests, compressive tests, and charge-discharge tests.

< Acknowledgment>
This work was supported by the National R&D Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Science and ICT (2022M3I9A1073924) and in part by a National Research Foundation of Korea (NRF) grant funded by the Korean government (MSIT) (No. 2021R1A2C209312212).

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Presenter: KIM, Ki Hong (Korea University)

Session Classification: Sat-Mo-Po.04 - Protection and Stability

Contribution ID: **385** Type: **Poster**

Fri-Mo-Po.08-04: Critical current measurement by torque magnetometry for the 40 T superconducting magnet project

Friday, July 4, 2025 9:30 AM (1h 45m)

NHMFL is designing a 40 T superconducting user magnet [1]. In this magnet, significant quantity of REBCO coated conductor will be used for the insert coils. Fully characterizing critical current (Ic) of REBCO tapes at temperatures of its operation (4.2 K) and during a potential magnet quench (> 4.2 K) is critical to the success of the project. Due to the strong anisotropy of REBCO coated conductor, critical current is much higher when sample's ab plane is nearly parallel to the magnetic field, which is the case in most parts of our magnet. However, the conventional transport Ic measurement suffers from sample burn-out due to the high current. The newly developed Ic measurement method by torque magnetometry [2],[3] overcomes this difficulty and provides a more efficient measurement solution.
In this work, we measured Ic vs field angle for samples obtained from over 70 spools. Ic was measured in magnetic field up to 15 T with angles from -60 degrees to + 60 degrees from ab plane at 4.2 K. In addition, several samples were measured at 10 −50 K in magnetic field up to 30 T. We compared the results with transport Ic measured at 4.2 K in magnetic field at 18 and 8 degrees off the ab plane of REBCO. We studied the reproducibility of the measurement. The factors influence the measurement accuracy are discussed.

Reference
[1] H. Bai, M.D. Bird, L. Cooley, I.R. Dixon, K.L. Kim, D.C. Larbalestier, W.S. Marshall, U.P. Trociewitz, H.W. Weijers, D.V. Abraimov, G.S. Boebinger, "The 40 T Superconducting Magnet Project at the National High Magnetic Field Laboratory,"IEEE Transactions on Applied Superconductivity, vol. 30, no. 4, pp. 1-5, 2020.
[2] J. Jaroszynski, A-M. Constantinescu, G. Miller, A. Xu, A. Francis, T. Murphy and D. C. Larbalestier„ 'Rapid assessment of REBCO CC angular critical current density Jc(B, T = 4.2 K, θ) using torque magnetometry up to at least 30 tesla', 2022 Supercond. Sci. Technol. 35 095009.
[3] J. J. Jaroszynski, G. Miller, D.C. Larbalestier, A-M. Constantinescu, 'Magnetometer for large magnetic moments with strong magnetic anisotropy', US Patent No. 12,181,540.

Acknowledgement
This work was performed at the National High Magnetic Field Laboratory, which is supported by National Science Foundation Cooperative Agreement No. DMR- 2128556, DMR- 2131790, and the State of Florida, and by DMR-1644779 through User Collaborations Grants Program Project #5206.

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Session Classification: Fri-Mo-Po.08 - HTS Characterization II

Contribution ID: **386** Type: **Poster**

Sat-Mo-Po.02-05: Design of an eccentric curved symmetrical coil for improving the intensity and focalization of transcranial magnetic stimulation

Saturday, July 5, 2025 9:30 AM (1h 45m)

Non-invasive transcranial magnetic stimulation (TMS) is a promising technology for treating many neurological disorders, such as Alzheimer's disease and depression. Since different diseases correspond to different target areas, in order to avoid stimulation of non-target tissues, the stimulation coil generates a focusing induced electrical field in the intracranial target area to achieve neuromodulation. This paper introduces an eccentric curved symmetrical coil (the ECS coil), which is based on a multi-layer, multi-turn circular coil with different-sized circular coils nested within each other to form a left-right symmetric structure. The inner nested coils fit the center end and maintain consistent bending angles for both the inner and outer coils. The ECS coil is placed horizontally above the human head, with a distance of 1 to 3 cm between the coil and the head, taking into account the encapsulation of the coil, the bending of the coil, and the obstruction of the hair. By changing the bending angle of the ECS coil, the stimulation intensity can be improved and the stimulation focalization can be reduced. The internally nested curved coils can move flexibly, further improving the focalization of stimulation on the target area when biased toward the central end. In this paper, a uniformly isotropic real human head model is established, and the stimulation characteristics of the proposed coil are analyzed by using the finite element numerical simulation method, and the spatial distribution characteristics of the intracranial induced electric field such as the stimulation intensity, focalization and attenuation rate of the ECS coil are calculated in detail. Under the same stimulation conditions, using the conventional FOE coil as the reference coil, the stimulation intensity of the ECS coil is 1.9 times that of the conventional FOE coil, and the stimulation focalization is improved by 12.5% compared to the FOE coil. For the optimized geometric parameters of the ECS coil, the coil skeleton was designed by 3D printing, and the ECS coil was wound and processed by using the litz wires composed of multiple strands of fine wires. The experimental test was carried out by using a saline tank mimic, and the spatial distribution of the induced electric field generated by the ECS coil in the tank was obtained by placing the small detector coil at different sampling points in the tank, and the obtained distribution curves of the induced electric field in the X and Y directions matched well with the theoretical values, which verified the feasibility of the present design. The novel coil design scheme proposed in this paper provides more possibilities for balancing the stimulation intensity and the stimulation focalization.

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Session Classification: Sat-Mo-Po.02 - Magnets for Other Medical Application III

Contribution ID: **387** Type: **Poster**

Fri-Af-Po.10-11: Numerical Simulation and Experimental Investigation on a MgB2 Bulk Superconducting Undulator

Friday, July 4, 2025 2:00 PM (2 hours)

The bulk high-temperature superconducting (HTS) undulator constructed from RE-Ba-Cu-O (REBCO) bulks demonstrates the capability to generate an undulator field up to 2.1 T of 10 mm period [1]. This performance exceeds that of the current state-of-the-art permanent magnet and low-temperature superconducting undulators [2]. Compared to REBCO bulks, the alternative MgB2 bulk superconductors exhibit a relatively lower critical current density, Jc but possess superior mechanical properties and machinability. Moreover, the field-trapping capability of individual MgB2 bulks shows reduced variability, which is advantageous for minimizing peak-to-peak undulator field errors. This study presents a numerical and experimental investigation of a short HTS undulator constructed using a staggered-array configuration of MgB2 bulk superconductors with enhanced critical current density. The highly dense MgB2 bulks were fabricated at CRISMAT using the unconventional Spark Plasma Sintering technique [3]. To improve the on-axis magnetic field performance, the MgB2 undualtor was designed with a period length of 15 mm and a magnetic gap of 4 mm. This study provides a detailed summary of the sample preparation processes conducted at Zhangjiang Laboratory, the experimental setup at the University of Cambridge and PSI and the associated test results.

Key words: HTS undulator, MgB2 bulk, Numerical Simulation.

REFERENCES

[1] Kai Zhang et al., "Record field in a 10 mm-period bulk high-temperature superconducting undulator,"Supercond. Sci. Technol., vol. 36, 05LT01, 2023
[2] Dabin. Wei, et al., "Electromagnetic Design Study of a 12-mm-Period Bulk High-Temperature Superconducting Undulator," IEEE Trans. on Appl. Supercond., vol. 34, no. 5, pp. 1-5, Aug. 2024, Art no. 4100705.
[3] Xing, Yiteng, et al. "High critical current density of nanostructured MgB2 bulk superconductor densified by spark plasma sintering." Nanomaterials 12.15 (2022): 2583.

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Session Classification: Fri-Af-Po.10 - Undulators

Contribution ID: **388** Type: **Poster**

Wed-Mo-Po.11-03: Electromagnetic Characteristics of Axial-Stacked Pulsed High-field Magnets

Wednesday, July 2, 2025 9:15 AM (2 hours)

Pulsed high-field magnets serve as a crucial tool for the frontiers of fundamental researches. With the development of internal reinforcing techniques, magnetic fields up to approximately 65 T can now be generated with a simple coil. However, as the target magnetic field increases, the use of multiple coils becomes necessary to manage internal stress. Magnetic systems exceeding 80 T typically employ a radial-nested coil configuration, where the energy required by each coil increases exponentially from the outermost to the innermost coil. Due to energy limitations, the innermost coil is typically constrained to an outer diameter of around 180 mm, restricting its field generation capacity to approximately 50-60 T. This limitation significantly restricts the design flexibility and becomes one of the major barriers to promote scientific experiments under magnetic field over 80 T.

Upon this, the axial-stacked topology might be more suitable for pulsed high-field magnets. In this configuration, the primary coil is positioned at the center of the magnet system, providing the strongest magnetic field in the central region. Two (or more) identical secondary coils are placed at the ends of the primary coil to generate the background magnetic field. The axial-stacked topology geometrically decouples the primary coil from the secondary coils, removing the constraints imposed by energy limitations.

This paper explores the electromagnetic characteristics of axial-stacked pulsed magnets in detail. First, an analytical calculation method is proposed, combining the unconditionally stable FDTD method with the magnetic penetration method for axial-stacked pulsed magnets. Second, the validity of the proposed method is verified using ANSYS 19.0. Finally, the effect of coil geometric configuration on magnet performance is analyzed using the proposed method. The calculations demonstrate that the axial-stacked magnet can achieve the same magnetic field strength with approximately 70% of the energy required by a radial-nested configuration.

Authors: CHEN, Siyuan; LI, Liang; LI, Wenzhe

Presenter: CHEN, Siyuan

Session Classification: Wed-Mo-Po.11 - High Field Pulsed Magnets I

Contribution ID: **389** Type: **Contributed Oral**

Wed-Af-Or3-06: Characterization and Magnetic Field Optimization of an HTS Undulator Short Model Composed of RE-Ba-Cu-O Bulk Superconductors at 77 K

Wednesday, July 2, 2025 5:45 PM (15 minutes)

A 12 mm-period, 0.6 m-long HTS undulator, employing staggered-array Gd-Ba-Cu-O (GdBCO) bulks and magnetized by a 7 T superconducting solenoid, is currently being fabricated at Zhangjiang Laboratory for deployment at the Shanghai Soft X-ray Free Electron Laser (SXFEL) facility [1-2]. Realizing an undulator field with an RMS phase error of only a few degrees requires approximately 100 half-moon-shaped GdBCO disks with highly uniform field trapping capabilities in the temperature range of 7 to 10 K. Preliminary magnetic assessments at 77 K are essential to expedite the selection of qualified GdBCO disks. A 2D magnetic field scanning system was developed to identify GdBCO disks with internal cracks, magnetized at 0.3 T at 77 K, while a magnetic levitation force measurement system screens disks with extreme superconducting performance. Twenty presorted GdBCO disks, selected based on their measured levitation forces, were assembled with ferromagnetic poles in a staggered-array configuration to construct a ten-period undulator model with a period length of 12 mm. The short undulator model was field-cooled at 77 K using an 0.3 Tesla electromagnet, with its magnetic properties characterized using a four-dimensional magnetic field measurement system. Based on the measured undulator field profile, the superconducting performance of each GdBCO disk was extrapolated, enabling their re-sorting and height adjustments of those ferromagnetic poles to achieve a more uniform undulator field. This study presents a comprehensive overview of the sample preparation process, magnetic characterization of individual GdBCO disks, and magnetic field optimization for the short-period HTS undulator model.
Key words: HTS undulator, RE-Ba-Cu-O bulk, Magnetic Field Optimization.
REFERENCES

[1] K. Zhang et al, 2025, IEEE Trans. Appl. Supercond., 35, 4100205
[2] D. Wei et al, 2024, IEEE Trans. Appl. Supercond., 34, 4100705

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Session Classification: Wed-Af-Or3 - Wiggler Magnets

Contribution ID: **390** Type: **Poster**

Fri-Mo-Po.05-03: Electromagnetic Design of B1pF: Superconducting Magnet for EIC Interaction Region

Friday, July 4, 2025 9:30 AM (1h 45m)

The Electron-Ion Collider (EIC) plans to have a number of unique superconducting magnets in its interaction region (IR) to satisfy challenging requirements. As a test bed for addressing several R&D challenges in the development of Rutherford cable magnets with very large apertures, B1pF is currently being built as a full-length prototype at the Superconducting Magnet Division at Brookhaven National Laboratory (BNL). Designed as a single layer coil of NbTi Rutherford cable, B1pF has a coil inner aperture diameter of 300 mm and a total length of 3 m. To address the construction challenges at the same time to meet the stringent field quality and cross-talk requirements in the heavily space limited interaction region, the design is aimed to include maximum flexibility to compensate for any construction tolerances. This contribution discusses 2D and 3D design choices with a focus on magnetic shimming and 3D coil end optimizations based on trial winding iterations and feeding back of these results into the electromagnetic design.

Author: KURIAN, Febin

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Presenter: KURIAN, Febin

Session Classification: Fri-Mo-Po.05 - Electron-Ion Collider

Contribution ID: **391** Type: **Poster**

Wed-Mo-Po.05-03: Study on Aluminum Melting by Superconducting DC Induction Heating

Wednesday, July 2, 2025 9:15 AM (2 hours)

Aluminum die-casting requires an efficient melting technology to conserve energy, because aluminum die-casting process produces a large amount of aluminum casts and consumes huge quantity of energy. We have suggested the possibility of supplying molten aluminum to the die-cast process in a short time by DC induction heating using a superconducting magnet. In our DC induction heating equipment, the aluminum samples in sample holders were rotated around the rotating shaft which is perpendicular to the magnetic field. The mechanical energy to rotate the aluminum samples in a magnetic field was converted into heat and it could melt the samples. We presented the preparation of the conduction-cooled superconducting split coil pair comprised of eight rectangle shaped double pancake coils, using REBCO coated conductors. The superconducting split coil pair was cooled and generated a magnetic field of about 1 T at the outermost circumference of the rotating aluminum specimens. This time, we examined some ways to hold the aluminum specimens to reduce the uneven distribution of aluminum melt. Then aluminum samples with a total weight of more than 2 kg were observed to melt in a short period and that is better for energy saving. The details of the aluminum melting tests will be discussed.

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Presenter: Dr WATANABE, Tomonori (Chubu Electric Power Co., Inc.)

Session Classification: Wed-Mo-Po.05 - Novel and Other Applications I

Contribution ID: **392** Type: **Poster**

Wed-Af-Po.04-02: Predictability of the change in solder resistance under thermal cycling conditions

Wednesday, July 2, 2025 2:30 PM (2 hours)

The solder layer in electronic systems has been the subject of a vast number of studies in the field of reliability assessment due to the weakness of this layer and the large difference between its mechanical characteristics and those of the rest of the system. Among these characteristics, the difference in the coefficient of thermal expansion drives the generation of thermal stress, which can result in performance degradation and the possibility of failure during long-term operation. This issue becomes more significant in the case of a superconducting system, because the system is exposed to a wide range of temperatures. The results relating to the reliability of the solder layer revealed an interesting phenomenon. The resistance of the solder layer started to rise after a certain number of cycles of thermal stress application, whereas it remained almost consistent before the threshold. Based on our previous study on the long-term operation of a current lead, which showed a similar change in the terminal resistance, we planned and conducted a study to test the consistency of the threshold point for the rise in resistance, to use it as a means to predict the long-term performance of a system containing a layer of solder. Toward this purpose, we prepared multiple samples consisting of superconducting tape and copper blocks that are connected to each other with a layer of solder. To compare their change in resistance quantitatively, the soldering conditions were controlled by an electronic system, and the samples were exposed to the same thermal cycles. Finally, the samples were compared in terms of the change in their terminal resistance to evaluate whether the controlled conditions result in a similar threshold of resistance.

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Presenter: Mr SUN, Minkyu (Korea University)

Session Classification: Wed-Af-Po.04 - HTS Joints

Contribution ID: **393** Type: **Poster**

Thu-Mo-Po.05-07: The effect of cool down and external magnetic field induced mechanical damage in epoxy-impregnated REBCO magnet

Thursday, July 3, 2025 8:45 AM (2 hours)

This work provides an overview of the experimental and numerical simulation studies on the effects of cool down and external magnetic field-induced mechanical damage in epoxy-impregnated REBCO magnets. Firstly, a circumferential stress numerical model for an epoxy-impregnated REBCO no-insulation (NI) insert magnet was established. The simulation encompasses the cooling process, the influence of the external magnetic field, and the coil charging up to the operating current. Secondly, we fabricated and tested an epoxy-impregnated REBCO NI insert magnet, comparing the numerical model results with the experimental data. The magnet consists of six stacked double pancake (DP) coils, with a winding inner diameter of 17 mm and an outer diameter of 23 mm. The epoxy-impregnated REBCO NI insert magnet was tested under conditions of 4.2 K and an external magnetic field intensity of 12 T. Finally, when the operating current reached 217 A, the central magnetic field strength reached 15 T, allowing stable operation. Epoxy resin impregnation effectively enhances the mechanical environment of superconducting coils. The effects of structural parameters of interpolated magnet, epoxy impregnation, low temperature cooling and external field strength on the mechanical damage of the coil were further studied. This work can serve as a reference for the design and analysis of high-field epoxy-impregnated HTS insert magnets.

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Presenter: WANG, Zhaoran

Session Classification: Thu-Mo-Po.05 - Mechanical Behavior and Stress I

Contribution ID: **394** Type: **Poster**

Wed-Mo-Po.12-04: Optimizing Operating Frequency for Charging No-Insulated HTS Magnets Using Transformer-Rectifier Flux Pumps

Wednesday, July 2, 2025 9:15 AM (2 hours)

No-insulated (NI) high-temperature superconducting (HTS) magnets exhibit several advantages over conventional insulated (INS) magnets. The inherent turn-to-turn resistance of NI magnets facilitates the dissipation of localized hotspots, significantly reducing the risk of quenching and improving thermal management. These characteristics make NI magnets especially attractive for high-field applications.

Flux pumping offers an efficient method for inductively magnetizing superconducting coils while providing thermal, electrical, and mechanical isolation between the cryogenic environment and the power supply. This approach reduces cryogenic loading and allows for more flexible arrangements in superconducting magnet systems.

However, charging NI magnets using a transformer-rectifier flux pump presents challenges, particularly related to the operating frequency of the transformer. This paper examines the charging characteristics of NI HTS magnets with a transformer-rectifier flux pump, emphasizing the identification of an optimal operating frequency to balance efficiency and system stability. Experimental studies explore the relationships among frequency, inductive impedance, and charging performance. Key parameters, including charging efficiency, thermal behavior, and magnet performance under various operating conditions, are analyzed to provide insights into achieving reliable and efficient operation of NI magnets.

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Presenter: HUANG, Zhipeng (University of Cambridge)

Session Classification: Wed-Mo-Po.12 - Diodes, Flux Pumps, and Switches

Contribution ID: **395** Type: **Poster**

Sat-Mo-Po.06-07: Roll angle measurement of dipole and quadrupole magnets based on a stretched wire measurement system

Saturday, July 5, 2025 9:30 AM (1h 45m)

The stretched wire method is one of the magnet alignment techniques and also the field measurement techniques, especially for long and narrow magnets. A stretched wire measurement system has been developed at IHEP to measure the roll angles of the longitudinal gradient dipole and quadrupole magnets, as well as two superconducting combined quadrupole magnets in the horizontal test. The wire position is detected by an absolute scanner AS1 with a Leica AT960 laser tracker or a coordinate measuring machine. Some experiments are performed with a CMM for verification. The linear motion and the circular trajectory are compared. The roll angle is obtained by linear fitting of linear motion or Fourier analysis of the circular trajectory. The roll angle measurement accuracy obtained is better than 30 urad.

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Presenter: YANG, Mei

Session Classification: Sat-Mo-Po.06 - Mechanical and Magnetic Measurements

Contribution ID: **396** Type: **Poster**

Sat-Mo-Po.04-08: Stability and quench development in HTS windings: challenges and possible solutions

Saturday, July 5, 2025 9:30 AM (1h 45m)

To achieve magnetic fields above 20 T in modern magnets for fusion devices and high-energy physics accelerators, the use of high-temperature superconductors (HTS) at low temperatures below 20 K is proposed. In recent years, there has been active development of increasingly larger HTS coil systems. However, as the size of the magnets increases, the issues of stability and protection for these systems become more pronounced. One of the key challenges is the slow propagation speed of the normal zone in HTS coils. This leads to difficulties in detecting the normal zone/quench start and timely activating protection systems for the coils. As a result, there is a risk of damage to the magnets, which can lead to significant costs and delays in research projects.
In this work, we analyze the stability issues and quench development in large HTS magnets at temperatures close to liquid hydrogen/helium temperatures, compared to coils based on low-temperature superconductors (LTS). Qualitative approaches to analyzing transition development, previously developed for LTS, are employed [1]. We also consider the applicability of methods that were previously developed for liquid nitrogen temperatures to the analysis of stability and quench development at near-helium temperatures [2]. Thus, this study aims to identify key problems and seek effective solutions to enhance the reliability and safety of HTS coils under magnetic fields exceeding 20 T and temperatures close to liquid hydrogen/helium levels. The results of this work may be beneficial for further research and practical applications in the fields of thermonuclear fusion and high-energy physics.
1. Rusinov A.I. et al, IEEE Trans. Mag., v.25. N2, 1989, 1541-1542
2. . A.L. Rakhmanov, et al, Cryogenics, 2000, v.40, N1, pp.19-27

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Session Classification: Sat-Mo-Po.04 - Protection and Stability

Contribution ID: **397** Type: **Poster**

Wed-Mo-Po.05-04: Demonstration of a MgB2 DC-DC boost converter for ultra-fast battery charge up to 200 A - 200 V output power.

Wednesday, July 2, 2025 9:15 AM (2 hours)

An increase in the ratio of Electric Vehicles (EV) to conventional petrol cars will be one of the most effective ways to reduce CO2 emissions throughout their life cycle, and make the goal of 2050 carbon neutrality more realistic. The boost converter, which is the most essential for photovoltaic plants to maximize its output power for providing electricity to the utility grid was chosen as a prototype of DC-to-DC converter whose inductor is made of MgB2 superconducting material that is to be suitable for liquid hydrogen cooling. Since fast battery chargers introduce DC-to-DC converter topologies, the conversion by the proposed system from the DC output of renewable sources to batteries introduced to EV and/or other storage stations makes the system extremely effective even in very short-time charge. A double-boost converter operating up to 15kW, 100A output current has already been provided to a 3-ohms constant load demonstrated with 95 percent efficiency in the previous phase of our project, this time, higher current operation with up to 200A, which imposes the inductor current up to 400 A will be demonstrated. Besides, another circuit topology with higher step up voltage type has been designed and tested, which helps the system strengthen their design flexibility for practical use.

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Presenter: YAGAI, Tsuyoshi

Session Classification: Wed-Mo-Po.05 - Novel and Other Applications I

Contribution ID: **398** Type: **Poster**

Fri-Af-Po.08-06: Study on High Jc, Fine filament, Ultra low loss NbTi/Cu5Ni/Cu Superconducting Wires for Accelerator Magnet in WST

Friday, July 4, 2025 2:00 PM (2 hours)

With the innovation of accelerator magnet technology, the design of superconducting magnets is also changing and put forward high requirements on the performance of NbTi superconducting wire, which requires high critical current density and ultra low loss. A new type of superconducting wire with high critical current density, fine filament, ultra low loss NbTi/Cu5Ni/Cu has been developed in this paper. The wire uses high purity Cu5Ni alloy instead of conventional high purity oxygen-free copper as the matrix, which prevents the coupling between every filament at low temperature and reduces the AC loss effectively. Meanwhile, the Cu5Ni matrix and NbTi filament are separated by high purity Nb. Nb as a barrier layer could isolate the diffusion reaction between Cu and Ti in the process of high temperature and long time aging heat treatment, and reduce the number of wire breakage effectively. In order to reduce the hysteresis loss of the wire, the filament of the wire is increased to 75276, the filament diameter is reduced to 1.9μm, and the Cu/Sc ratio is 1.3. The filament diameter of Φ1.2mm wire is 2.9μm, Jc(4.2K, 5T) is 2710A/mm2, and the 'n'value is 35. When the filament diameter further decreases, the filament diameter of Φ0.82mm wire is 1.9μm, Jc(4.2K, 5T) is 2410A/mm2, and 'n'value is only 18. The Jc and 'n'value of the wire are all reduced. The reason may be due to the breakage of some filaments. Finally, the wire with Φ0.82mm, 75276 filaments and Cu/Sc ratio of 1.3 was prepared. The hysteresis loss (4.2K,±3T) was 20.1mJ/cm3, which reached a new low in history.

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Session Classification: Fri-Af-Po.08 - Advances in Nb3Sn and MgB2 Conductors I

Contribution ID: **399** Type: **Poster**

Thu-Af-Po.03-05: Design, fabrication, and operation of a nested cryogenic high purity aluminum winding armature for a partially superconducting motor

Thursday, July 3, 2025 2:00 PM (2 hours)

High-purity aluminum armatures present a viable alternative to traditional superconducting armatures, which can face quench issues during AC operation despite their high-power density. Leveraging the low electrical resistance and lightweight properties of high-purity aluminum at cryogenic temperatures, this study presents the development of an armature for a 500 kW partially superconducting motor operating in liquid nitrogen. To maximize the cooling performance of the high-purity aluminum winding and enhance armature performance, careful consideration of the contact area between the winding and liquid nitrogen is crucial. In this study, a nested winding structure is adopted, and the ratio between the conductor and cooling channels is optimized. Through multi-physics analysis, the optimal current density and geometry, which maintain a temperature below the insulation breakdown limit while considering cooling performance, are determined. Furthermore, a mechanically robust bobbin structure that maximizes the cooling area is designed. Subsequently, nested windings are implemented using high-purity aluminum wire. The armature is then operated at the target current density to measure losses and analyze the performance of the final 500 kW motor. Based on the experimental results obtained with liquid nitrogen, the performance under other cryogenic conditions, such as using liquid hydrogen (LH2) and liquefied natural gas (LNG), will also be analyzed.

Acknowledgements
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Session Classification: Thu-Af-Po.03 - Rotating Machinery III

Contribution ID: **400** Type: **Poster**

Fri-Mo-Po.03-04: Development and measurement of a 7T cryogen-free animal MRI superconducting magnet

Friday, July 4, 2025 9:30 AM (1h 45m)

The pursuit of ultrahigh magnetic fields is a key research direction in MRI, offering high signal-to-noise ratio (SNR), high resolution, and advanced imaging methodologies. However, ultrahigh-field MRI systems, such as 7T human MRI, are extremely costly, often around 10 million US dollars, making them unaffordable for many researchers. Therefore, there is a high demand for developing ultrahigh-field MRI systems that are lower in cost while retaining basic functionality. This work presents a 7T MRI superconducting magnet with a clear bore size 54mm that is aimed at micro-imaging, which is affordable, lightweight, and easily maintained using cryogen-free technology. The magnet weight is only 304 kg, with dimensions of 58 cm in length and 65 cm in height, allowing for flexible installation in the lab. The 5Gauss line is tightly surrounded around the magnet with ±0.7m at the axial direction and ±0.5m at the radial direction, and the decay rate of the magnetic field is only 0.01ppm/h. The initial magnetic field homogeneity over a 30mm diameter of spherical volume (DSV) is 107.42ppm, and it is highly improved to 11.12ppm after superconducting shimming with the shim coils integrated into the cryogenic system. Initial imaging generates high-quality images with a resolution of 48μm, which demonstrated the strong potential of the magnet scheme on details imaging. The ultrahigh-field, cryogen-free, portable, high-resolution MRI system will be an economical tool for researchers engaged in ultrahigh-field related studies.

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Session Classification: Fri-Mo-Po.03 - Magnets for MRI

Contribution ID: **401** Type: **Poster**

Wed-Mo-Po.02-06: Mechanical Tests and Analysis of the Bladders and Keys Magnet Support Structure for R2D2, the Research Racetrack Dipole Demonstrator

Wednesday, July 2, 2025 9:15 AM (2 hours)

In the framework of the CERN-CEA collaboration and as part of the HFM program, CEA is developing the R2D2 magnet. This magnet is a key milestone in the development of Nb3Sn high field block coil magnets with grading for future circular colliders. R2D2 is a 1.6-m long dipole made of two Nb3Sn racetrack coils, each one made of two different conductors wounded together in order to explore the grading concept. The R2D2 magnet support structure is based on three shell segments and bladders-and-keys technology for the transverse preload, as well as four tie rods and end-plates for the longitudinal preload. The shell segments, the rods, and the coils are instrumented with strain gages to monitor the mechanical loading. To validate the structure and characterize its behavior, an instrumented aluminum dummy coil was used to replace the Nb3Sn coils inside the coil pack. This assembly was first loaded transversely and then axially, before being cooled-down at 77 K in liquid nitrogen. This paper summarizes the various steps of R2D2 support structure practice preload and cooldown, with a major focus on the analysis of the structure mechanical behavior extracted from strain gages measurement along with the correlation with FEM models.

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Session Classification: Wed-Mo-Po.02 - Muon Collider

Contribution ID: **402** Type: **Poster**

Thu-Mo-Po.10-05: Preliminary Quench Analysis on HTS Stacks-In-Conduit Conductors for Fusion Toroidal Field Coils

Thursday, July 3, 2025 8:45 AM (2 hours)

Strong magnetic fields might be crucial for enhancing the performance of nuclear fusion devices. High-temperature superconducting (HTS) tapes have emerged as promising materials due to their capability of carrying high current densities in high-magnetic field environments. Alongside with various types of HTS conductors for fusion proposed by numerous research institutions, in our previous studies, we proposed novel non-twisted HTS stacks-in-conduit conductors (SICC). As an extension, a preliminary quench study has been carried out by using a thermal-hydraulic modeling analysis on KSTAR size toroidal field (TF) coils to establish an effective protection scheme. We evaluate the thermal runaway temperature and minimum runaway energy through coupled thermal-hydraulic simulations. As compared with cable-in-conduit conductors (CICC), where cryogen forced-flows due to porous nature of cables, SICC can be characterized by their fast cryogen flow, which enables relatively fast ramping rate for TF charging. Thermal disturbance both during ramping and normal operation conditions are studied. Characteristic difference as compared with CICC will be further discussed.

Acknowledgement
This research was supported by R&D Program of "Fusion HTS Magnet Fabrication Process Development (code No. CN2504)" through the Korea Institute of Fusion Energy(KFE) funded by the Government funds, Republic of Korea.

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Session Classification: Thu-Mo-Po.10 - Modelling of Fusion Conductors and Coils II

Contribution ID: **403** Type: **Poster**

Wed-Mo-Po.09-06: Trial Fabrication Report on HTS Stacks-In-Conduit Conductors for Fusion Applications

Wednesday, July 2, 2025 9:15 AM (2 hours)

As compared with low-temperature superconducting (LTS) conductors where wires are typically fully transposed, simply stacked high-temperature superconducting (HTS) conductors may be argued as easier to be fabricated. However, brittleness of HTS tapes presents significant challenges for efficiently assembling them into HTS conductors. Once winding finished, it is preferable stacks are tightly bound together to reduce possible damage on coated layer. Here, we report on trial HTS conductor fabrication results, fabricated based on our previous design work. Basically, our HTS conductor designs consist of three parts, 1) bundle part, 2) stabilizer part with a spiral shape, and 3) stainless steel jacket. First, 30-layer stacks were co-wound on a 1.5 m diameter bobbin, where stacks can be wrapped by a 70 m thick copper tape if needed. Then the stacks are accumulated into 4x4 bundle and copper wrapped bundle was put into square cross-section thick copper spiral then into a jacket and squeezed. Non-wrapped bundle was covered with a copper sheet, pressed, capped with grooved copper formers, put into a jacket and compacted. Automated machines were developed for processes such as stacking, wrapping, cabling, capping, spring insertion, and jacketing. Detailed fabrication process, step-by-step fabrication results, and final conductor shape, cross-sectional views and especially manufacturing issues related to spring-back effect during roll forming process will be further discussed.

Acknowledgement
This research was supported by R&D Program of "Fusion HTS Magnet Fabrication Process Development (code No. CN2504)" through the Korea Institute of Fusion Energy(KFE) funded by the Government funds, Republic of Korea.

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Session Classification: Wed-Mo-Po.09 - Development and Test of Conductors for Fusion Magnets I

Contribution ID: **404** Type: **Poster**

Thu-Mo-Po.02-05: PRISMAC: A R&D program and a new dedicated laboratory for very high field superconducting magnets

Thursday, July 3, 2025 8:45 AM (2 hours)

For the development at CERN (European Center for Nuclear Research) of the post-LHC accelerator infrastructures, HL-LHC (High Luminosity Large Hadron Collider) and FCC (Future Circular Collider), a new generation of magnets with extreme mechanical constraints, capable of generating high-quality magnetic fields of the order of 14T (operational) and energy efficient will be required. These magnets will be based on technological knowledge currently under development and new superconducting materials. To foster the Spanish efforts to contribute to these strategic goals, CIEMAT (Research Center for Energy, Environment and Technology), CDTI (Center for the Technology Development and Innovation), and CERN signed three collaboration agreements in 2019 within the framework of the PRISMAC program (Very High Field Superconducting Magnets Program).

This paper depicts the progress of the PRISMAC program activities and the tasks foreseen to achieve its goals. PRISMAC is based on three work packages: i) the delivery of a small series of the nested orbit correctors MCBXF, non-conventional superconducting magnets, for the HL-LHC, ii) the construction of a dedicated laboratory at CIEMAT for prototyping and testing of high-field superconducting magnets up to 2m in length (SMART-Lab, Superconducting MAgnet Research and Technology Laboratory), and iii) the development and assembly of Nb3Sn demonstrator magnets for the FCC study. An extension of the program is under consideration for the design and development of high-temperature superconducting (HTS) magnets for future needs in accelerator facilities and their applications in other fields, in particular Energy. The PRISMAC program is outlined, focusing on the commissioning of the new laboratory.

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Session Classification: Thu-Mo-Po.02 - Design and Development of Accelerator Magnets I

Contribution ID: **405** Type: **Poster**

Thu-Mo-Po.02-06: An Improved High Strength and High RRR Conductor for CEPC Detector Magnet

Thursday, July 3, 2025 8:45 AM (2 hours)

The Circular Electron Positron Collider (CEPC), to be hosted in China in a circular underground tunnel of approximately 100 km in circumference. A 4-layer superconducting solenoid with cold bore of 7.07m serves as a key component of the large electron collider, providing a uniform and stable magnetic field for the detector. Due to the high magnetic force at 3 Tesla field inside the winding, the conductor itself serves as a main stress bearing structure. So the Rutherford type superconductor, stabilized by Al-Ni-Be alloy, is reinforced by aluminum alloy through a second extrusion process. This paper describes the optimization of the fabrication process and characteristics the developed conductor.

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Session Classification: Thu-Mo-Po.02 - Design and Development of Accelerator Magnets I

Contribution ID: **406** Type: **Poster**

Thu-Af-Po.05-03: Real-time temperature distribution prediction for superconducting magnet cooling process based on improved physical information neural network

Thursday, July 3, 2025 2:00 PM (2 hours)

The background magnets of the superconducting conductor test facility (Super-X) are composed of CICC-wound superconducting coils, weighing approximately 100 tons, and are actively cooled using supercritical helium. During the cooling process, fluctuations in the chiller's power and the complexity of heat transfer may cause deviations from the designed cooling process. These factors hinder the efficient cooling of the superconducting magnets to their operating temperature. In this paper, we propose a deep learning model that integrates physical laws with neural networks to enable real-time monitoring of the temperature distribution across the entire magnet during the cooling process, as well as to make cooling predictions. We simplify the magnet heat transfer model and incorporate it into a multi-scale Convolutional Neural Network (CNN)-Long Short-Term Memory (LSTM) network. The multi-scale CNN performs feature extraction at various scales, capturing both local and global information from the input parameters. The LSTM network incorporates an attention mechanism to effectively process information from longer time series. The boundary conditions and heat balance equations are incorporated into the loss function, thereby enhancing the interpretability, robustness, and generalization of the model. The results show that the model predicts the magnet temperature distribution with an error of less than 1K and requires less than 500 ms, demonstrating its ability to accurately predict the magnet's temperature distribution. This work can guide the operation of the magnet cooling process and provide valuable insights for optimizing future magnet cooling designs.

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Session Classification: Thu-Af-Po.05 - Conductor and Coil Measurement/Test Techniques and Facilities III

Contribution ID: **407** Type: **Contributed Oral**

Fri-Mo-Or6-03: Design and implementation of an acoustic waveguide quench detection and localization sensor for the HTS Uni-layer magnet prototype

Friday, July 4, 2025 11:45 AM (15 minutes)

Proper detection and localization of quench events is essential to protect superconducting magnets for particle accelerators. Voltage taps are widely adopted for low-temperature superconductors (LTS), but they do not ensure reliable quench detection for high temperature superconducting (HTS) magnets. Indeed, the propagation velocity of the normal conducting zone is in the order of m s−1 for LTS, compared to cm s-1 for HTS, leading to a higher risk of irreversible conductor degradation before any voltage can be detected. As an alternative solution, non-leaky ultrasonic waveguides have been proposed [1] as a diagnostic option to monitor hot spots by tracking thermally induced sound velocity variations. A first practical implementation of this concept has been developed and tested for a Uni-layer [2] magnet at Lawrence Berkeley National Laboratory (LBNL). In this work, we present the practical design of a non-leaky acoustic waveguide tailored for this magnet. We also show the results of an experimental campaign conducted to assess hot-spot detection and localization for the ultrasonic waveguide sensor both in a straight and a geometric configuration representing the magnet working condition. Finally, the application of this technique is presented over a Uni-Layer magnet copper mock-up. The results of the tests at room temperature and liquid nitrogen temperature are discussed.

References

[1] Marchevsky, M., and S. Prestemon. "Distributed thermometry for superconducting magnets using non-leaky acoustic waveguides." Superconductor Science and Technology 36.4 (2023): 045005.
[2] Fernández, José Luis Rudeiros, and Paolo Ferracin. "Uni-layer magnets: a new concept for LTS and HTS based superconducting magnets." Superconductor Science and Technology 36.5 (2023): 055003.

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Session Classification: Fri-Mo-Or6 - Quench Detection and Protection I

Contribution ID: **408** Type: **Contributed Oral**

Wed-Af-Or3-01: Design and Preliminary Tests of a Short, High-Temperature Superconducting Wiggler for Synchrotron Light Source

Wednesday, July 2, 2025 4:30 PM (15 minutes)

The European Synchrotron Radiation Facility (ESRF) is currently working on the development of a new synchrotron light source for its beamline BM18. The proposed source is a short wiggler composed by three pairs of magnetic poles, delivering a peak magnetic field of 1.58 tesla. A crucial requirement is the possibility of performing scans of the magnetic field intensity, while keeping the overall installation footprint as small as possible, due to space constraints in the storage ring.

Second-generation, high-temperature superconducting (HTS) tapes based on rare-earth barium copper oxide compounds (ReBCO) offer an unprecedented current density which makes them suitable for high-field, compact applications. Moreover, the control of the source current offers a suitable alternative to bulky mechanical devices typically used in traditional permanent-magnet based phase-shifters for varying the magnetic field intensity.

This work presents the design, numerical optimization, and preliminary testing of a novel short superconducting wiggler. The magnet is composed by a set of racetrack coils and an iron yoke which optimizes the magnetic field shape and allows to meet field requirements while operating the HTS tapes at 65 K, in liquid nitrogen. Due to the simplified cooling system and cryostat, the footprint of the application is minimized. A no-insulation technique is applied to the coil winding for enhancing the robustness of the magnet against the consequences of quench events.

The electromagnetic design is carried out using COMSOL and RADIA, aiming for a magnet load line of 80% at nominal current. Subsequently, a numerical optimization approach is employed to refine the design parameters, in particular the shape of the iron yoke. Particular attention is given to minimizing the first and second integrals of the magnetic field along the particle beam path for the overall supply current range, ensuring stable operations in the synchrotron storage ring.

Preliminary tests are conducted on a prototype winding at 77K. The magnetic field characterized is compared with simulations, and the layer contact-resistance of the winding is determined, providing crucial information for the further coil winding, assembly and operation.

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Session Classification: Wed-Af-Or3 - Wiggler Magnets

Contribution ID: **409** Type: **Poster**

Wed-Af-Po.09-06: A novel method to design the shape of high-temperature superconducting toroidal field coils for spherical tokamaks

Wednesday, July 2, 2025 2:30 PM (2 hours)

The spherical tokamak (ST), characterized by its low aspect ratio and compact geometry, necessitates a toroidal filed (TF) coil design that typically adopts a sharper D-shape profile. This design is distinguished by its slender and tall configuration with a reduced radius of curvature, which can result in localized magnetic field and stress concentration on coils. Furthermore, the incorporation of a straight segment in the Princeton-D shape presents challenges in applying winding tension, particularly for high-temperature superconducting (HTS) TF coils fabricated from HTS tapes. To address these issues, a novel method for optimizing the TF coil shape in the ST is proposed. First, a semi-analytical code for calculating the magnetic field and the ratio of input current to the critical current on TF coils is developed. Next, a simplified analytical expression is derived to quantify the stress induced by both winding tension and electromagnetic forces. Finally, a genetic algorithm is employed to iteratively refine the coil shape, aiming to minimize the stress and the ratio of input current to the critical current, while ensuring the magnetic field and facilitating the winding process. This method is implemented in the design of the TF coil for the CTRFR-1 spherical tokamak, and its validity is rigorously assessed through comparative analysis with finite element simulations.

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Session Classification: Wed-Af-Po.09 - Magnets for Tokamaks: Design and Analysis

Contribution ID: **411** Type: **Poster**

Thu-Mo-Po.07-03: Topology optimization approach for superconducting magnet design using dot sensitivity analysis

Thursday, July 3, 2025 8:45 AM (2 hours)

Superconducting magnets have been extensively studied for their applications in advanced magnetic technologies, taking advantage of their capability to generate high current densities and strong magnetic fields. In the design of superconducting magnets for high field density, a key consideration is the characteristic critical current density, beyond which superconductivity is lost. A previous study introduced a method for analyzing the topological derivative, referred to as dot sensitivity, for superconducting systems. This approach models the variation in electromagnetic performance with respect to the distribution of the operating current, which is governed by the critical current as a function of the applied magnetic field. This paper proposes a topology optimization method for the design of superconducting magnets using dot sensitivity analysis. A significant advantage of the proposed method is its efficiency during the optimization iteration process. Unlike conventional methods that require computationally intensive numerical analysis at every iteration, the proposed approach performs the numerical analysis for dot sensitivity only once at the initial stage of the optimization. As a result, despite the high-dimensional design space explored in topology optimization, the proposed method enables sophisticated and complex designs with low computational cost and rapid solution convergence. Moreover, the dot sensitivity analysis provides relevant information for determining coil topology while considering the critical current as a function of the applied magnetic field. Consequently, the proposed method is well-suited for designing superconducting magnets that achieve high magnetic field density and precise field uniformity. The effectiveness of the proposed method is demonstrated through the design of superconducting magnets for practical applications.

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Co-authors: Ms JUNG, Eunchae (Sungkyunkwan University); Prof. PARK, Il Han (Sungkyunkwan University)

Presenter: Dr SEO, Kyungsik (Sungkyunkwan University)

Session Classification: Thu-Mo-Po.07 - Design Optimization

Contribution ID: **412** Type: **Poster**

Sat-Mo-Po.02-06: Deformation and mechanical stability of no-insulation REBCO coils in 1/2-scale coil system of Skeleton Cyclotron

Saturday, July 5, 2025 9:30 AM (1h 45m)

Compact cyclotrons are required to produce radiopharmaceuticals used in targeted alpha-particle therapy, which is a promising treatment for patients with intractable cancers. To realize a compact cyclotron, we have proposed the Skeleton Cyclotron—an air-core compact cyclotron using high-temperature superconducting (HTS) technology. This cyclotron consists of circular and non-circular coils, all wound with REBCO tape using a no-insulation (NI) winding technique. We have fabricated a 1/2-scale REBCO coil system of the Skeleton Cyclotron called the Ultra-Baby Cyclotron, which has a diameter of about 0.7 m (the full-scale Skeleton Cyclotron has a diameter of about 1.6 m). In this experiment, the degradation of the REBCO coil was observed before charging to the target current. The mechanical deformation was confirmed in the degraded REBCO coil. We attribute this to thermal contraction and additional stress due to the screening current. REBCO coils in Ultra Baby Cyclotron are non-impregnated and non-insulated, they are considered susceptible to deformation, such as the formation of gaps between the winding and the external reinforcement after cooling. And numerical calculations show that the screening current circulates in the REBCO windings in excess of the energizing current. In this study, the coil degradation observed in the experiment is verified in terms of stresses due to thermal shrink and electromagnetic force including screening currents.
The part of this work was supported by JSPS Grant-in-Aid for Scientific Research (S) Grant Number 18H05244.

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Presenter: Prof. UEDA, Hiroshi (Okayama University)

Session Classification: Sat-Mo-Po.02 - Magnets for Other Medical Application III

Contribution ID: **415** Type: **Poster**

Wed-Mo-Po.09-05: Electromechanical Behavior of Double Casing Conductors under Torsion and Bending for High-Current Fusion Devices

Wednesday, July 2, 2025 9:15 AM (2 hours)

In fusion applications, cables made from high-temperature superconducting tapes are required to transport high currents in strong magnetic fields. Cable-in-conduit conductors (CICC) using multiple high-temperature superconducting (HTS) strands, such as the HTS conductor, meet these demanding requirements. This study presents experiments on a double casing conductor (DCC), a round HTS strand developed with the HTS twisted stacked-tape cable (TSTC) approach. The soldering quality was enhanced through vacuum pressure impregnation. The inner casing offers extra support for the tapes, minimizing mechanical issues caused by weak solder, while the outer casing ensures proper solder flow and prevents the inner casing from cracking under direct stress. To achieve the required high currents, multiple DCC strands must be assembled into cables. The triplet-CICC structure is considered a crucial step toward full-size fusion conductors. Initial tests include a twisted triplet sample, where the relationship between current-carrying performance and twisting pitch will be evaluated. Subsequently, tests on the winding radius will determine the minimum radius that the conductor can tolerate when wound into large coils. In the experimental tests, samples were bent to specified radii at room temperature, followed by critical current measurements at 77 K under self-field conditions. Each sample was characterized at various bending radii in decreasing order, and cross-sectional images were taken to assess any macroscopic damage.

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Session Classification: Wed-Mo-Po.09 - Development and Test of Conductors for Fusion Magnets I

Contribution ID: **416** Type: **Poster**

Sat-Mo-Po.01-02: Advancements in Superconducting Magnet Design for Hadron Therapy: Design, Construction Readiness, and Assembly Challenges of a Curved CCT Magnet in the HITRIplus project

Saturday, July 5, 2025 9:30 AM (1h 45m)

A detailed overview of the ultimate magnet design developed within Work Package 8 of the collaborative European project HITRIplus is presented. Focused on the development of superconducting magnets for ion therapy synchrotron and gantry systems, the study introduces an innovative approach utilizing a curved Canted Cosine Theta layout magnet based on NbTi superconductor. The design targets a central magnetic field strength of 4 T, an 80 mm aperture, and a maximum ramp rate of 0.4 T/s, while addressing the challenge of a tight 1.65 m bending radius. This paper highlights the latest advancements in magnetic and mechanical designs, as well as the construction and assembly procedures for the curved former. The rope cable conductor utilizes a 2×7 layout, optimizing current density distribution with a 1.5 kA current per rope. Key advancements include magnetic and mechanical design improvements, construction readiness, and a detailed comparison of assembly procedures with and without an iron yoke. The vertically split iron yoke design manages thermal contraction through innovative approaches, including tapered iron laminations and aluminium clamps. Aluminium bronze is selected for the curved former, with machining and validation tests highlighting its suitability. Additionally, the paper explores field quality analysis before and after magnet energization, addressing geometric yoke optimization to enhance field uniformity. Progress in conductor development, winding and wax impregnation tests, and assembly trials are presented, with a focus on ensuring robustness and field accuracy in both yoke-inclusive and yoke-free configurations.

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Session Classification: Sat-Mo-Po.01 - Magnets for Other Medical Application II

Contribution ID: **417** Type: **Poster**

Thu-Mo-Po.04-03: Measurement of Contact Resistance in No-Insulation HTS Coils under Varying Winding Tensions and Thermal Cycles

Thursday, July 3, 2025 8:45 AM (2 hours)

No-insulation (NI) high-temperature superconducting (HTS) coils have gained attention for their high overall current density, thermal stability, and mechanical integrity. However, the time constant and the characteristic resistance in NI HTS coils, which are dominantly governed by radial turn-to-turn contact resistances, still require further investigation to examine coil specifications. Although the sudden discharge test has traditionally served as an effective method to measure the time constant, it can impose mechanical and electrical stress on the magnet. In this study, we conduct a comparative analysis of characteristic resistances using a curve-fitting method under linear charging and discharging—based on a parallel RL equivalent circuit model. To investigate how various factors affect characteristic resistance, we systematically varied the winding tension, the number of thermal cycles, and the ramping iteration. By comparing the data obtained from these experiments, we identify the conditions that enable accurate measurement of contact resistance in NI HTS coils.

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Session Classification: Thu-Mo-Po.04 - No-Insulation Coils III

Contribution ID: **418** Type: **Poster**

Wed-Af-Po.09-05: Design and Analysis of BEST PF coils

Wednesday, July 2, 2025 2:30 PM (2 hours)

The BEST (Burning Plasma Experimental Superconducting Tokamak) is a compact tokamak device under design. The parameters of the device include major radius is 3.6m, minor radius is 1.1m, plasma current is 7MA, and central field strength is 6.15T. The magnet system of the device consists of 12 central solenoid coils (6 high-temperature superconducting coils and 6 low-temperature superconducting coils), 16 TF coils, and 7 PF coils. The PF coils mainly contribute to the shaping and equilibrium of plasma. The design of BEST PF coils is based on three operating mode (steady state operation mode, hybrid operation mode and induction operation mode). Based on the magnetic field distribution of each PF coil, the superconducting material of PF coil is determined, namely Nb3Sn superconducting material is used for PF1/6/7 , while NbTi superconducting material is used for PF2 to PF4. This paper analyzes the mechanical properties of PF coils from the aspect of electromagnetic-structure, evaluates the structural strength of PF magnet components, including jacket, insulation, helium inlet/outlet, joints, et al. and determines their structural safety. In terms of thermal hydraulic, the heat loads of the magnet are analyzed first, and then the thermal hydraulic safety of the magnet under the normal operation and the quench condition is analyzed based on the GANDALF program. In terms of electrical safety, the operating voltage and failure voltage due to power supply or ground fault are analyzed. The results of structure, thermal and electrical evaluation can determine that the design of PF coils are safe and reliable.

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Presenter: LIU, Xufeng

Session Classification: Wed-Af-Po.09 - Magnets for Tokamaks: Design and Analysis

Contribution ID: **419** Type: **Poster**

Fri-Af-Po.08-12: Study on Nb APC NbTi superconductor made by powder metallurgy

Friday, July 4, 2025 2:00 PM (2 hours)

Scientists have incorporated other metal as pinning centers into Niobium-titanium alloys in order to increase the critical current density of Niobium-titanium superconductors. This type of superconductor is known as an artificial pinning center niobium-titanium superconductor. Methods for fabricating artificially pinned superconductors include Rod-based, Gun-drill, Diffused-layer, Jelly-roll, Powder-metallurgy, and so on. In this study, APC Niobium-titanium wires, fabricated by the Powder-Metallurgy technique, involve niobium-titanium powder and niobium powder, that particle sizes range from 53 to 150 microns and Niobium powder ratio range from 10% vol to 30% vol . We explored the influence of niobium powder doping ratio on the microstructure and superconducting properties of artificially pinned Niobium-titanium wires. And the highest Critical Current Density of the wire, which niobium powder ratio is 30%, was obtained at lower magnetic fields. The Critical Current Density of 30%Nb-APC wire is 8180A/mm2 at 2T and 4.22K.

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Presenter: ZHANG, Kailin (Western Superconducting Technologies Co.,Ltd.)

Session Classification: Fri-Af-Po.08 - Advances in Nb3Sn and MgB2 Conductors I

Contribution ID: **421** Type: **Poster**

Thu-Af-Po.02-14: Analysis on Fault Current Characteristics of Self-shielding HTS DC Cable

Thursday, July 3, 2025 2:00 PM (2 hours)

Self-shielding high-temperature superconducting (HTS) DC cables made of REBCO tapes can almost eliminate the magnetic field within the cable layers, greatly improving the uniformity of current and magnetic-field distributions. In this paper, based on the H-equation and the circuit model of the cable, the current evolutions in two self-shielding HTS DC cables made of REBCO tapes with different current directions are simulated under fault currents and their abilities to limit fault currents are also compared. Results show the HTS DC cable with the current direction of "+—+"has a larger quench resistance, and can effectively limit the rise and peak of the fault current, showing better performance in limiting the fault current.

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Presenter: Prof. PI, Wei (North China Eletric Power University)

Session Classification: Thu-Af-Po.02 - HTS Cable

Contribution ID: **422** Type: **Poster**

Fri-Af-Po.04-02: Manufacture and testing of production proof samples for ITER CS coaxial joint

Friday, July 4, 2025 2:00 PM (2 hours)

The Central Solenoid (CS) coaxial joint is an electrical connection designed to link the terminals of the CS module to their busbar extensions. This paper outlines the manufacture and testing of the CS coaxial joint Production Proof Samples (PPS), during the CS module stacking process. Once the PPS was completed, it was sent by the ITER Organization (IO) to the CEA. Detailed and increasingly representative electrical resistance tests were conducted at the SELFIE station (CEA-Cadarache, France). The measured electrical resistance of the PPS coaxial joint was less than 4.1 nΩ at 4.2 K under a self-field transport current of 70 kA. The successful testing of the PPS validated the joint concept, confirmed the effectiveness of its assembly procedure, and certified the operators to proceed with the assembly of the actual coaxial joints.

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Session Classification: Fri-Af-Po.04 - Supporting Technologies for Fusion Magnets II

Contribution ID: **423** Type: **Poster**

Fri-Af-Po.11-03: Development of 15T DC magnet for SUPER-X test facility

Friday, July 4, 2025 2:00 PM (2 hours)

The superconducting conductor performance test facility SUPER-X, as an integral part of the superconducting magnet system for the key fusion reactor core system, is currently being developed by the Institute of Plasma Physics, Chinese Academy of Sciences. The 15T DC magnet in SUPER-X test facility serves as the core component, consisting of LF (low field) pancake coils and MF & HF (medium field & high field) layer coils. During the manufacturing of the coils, the processes of winding and forming, insulation wrapping, terminal fabrication, heat treatment, and VPI (vacuum pressure impregnation) are critical to the final quality of the coils. This paper provides a detailed description of the manufacturing processes for both the pancake and layer coils of the 15T DC magnet, and presents measurements of their dimensions and electrical insulation performance. The measurement results demonstrate that the dimensional accuracy and electrical insulation properties of the pancake and layer coils meet the technical requirements, thus providing essential support for the successful fabrication of the SUPER-X device.

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Presenter: HAN, Houxiang (ASIPP)

Session Classification: Fri-Af-Po.11 - Experiments and Test for Fusion Magnets

Contribution ID: **424** Type: **Poster**

Thu-Af-Po.09-01: Mechanical and microstructural changes in Cu single-turn coils revealing the effect of high-speed pressurization, deformation and heating during megagauss field generation

Thursday, July 3, 2025 2:00 PM (2 hours)

MegaGauss facilities provide a unique environment to study materials under extreme conditions. This not only concerns samples exposed to the magnetic field in the center of a coil, but also the coil itself. The present study focuses on the deformation of copper single-turn coils (STC), specifically analyzing the impact on the material microstructure. While generating the field, STC undergo magnetic pressure giving rise to their radial expansion and axial compression. These deformations occur on a timescale of a few microseconds, leading to exceptionally high deformation speeds. The primary objective of this research is to quantify the changes in copper microstructure resulting from these rapid and intense deformations.
Three types of STC were selected, each representing a different level of magnetic field exposure. "Raw coils"did not generate any magnetic fields and thus served as reference material. "Intermediate field coils"successfully generated a magnetic field without being destroyed. These were used to study the effects of non-destructive deformations induced by the magnetic field. "Maximum field coils"were destroyed during the process of generating a high magnetic field and thus represented extreme deformation conditions in our study.
To quantify the impact of deformation on copper microstructure, Vickers microhardness measurements were locally performed across relevant conductor cross sections, revealing both softening and work-hardening (135HV0.1) effects depending on position. Experimental results where then compared with finite element simulations taking into account local current distributions, heating, magnetic pressure and deformation experienced by the conductor while generating the magnetic field
Our preliminary study demonstrates that substantial local changes in microhardness can be measured as a result of the deformation of STC during magnetic field generation in the MegaGauss facility. Observations are in good agreement with numeric calculations of the pressure and temperature distribution in STC indicating a competition between annealing, driven by high local temperature (~2500 K) on the one hand, and work hardening caused by the magnetic pressures (~10 GPa) and deformations with microsecond duration on the other hand.

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Session Classification: Thu-Af-Po.09 - Single-turn Pulsed Magnets

Contribution ID: **425** Type: **Plenary**

Sun-Mo-PL1-06: High temperature superconducting technology for fast ramping hadron therapy magnets: an efficient and sustainable solution for future tumor treatment?

Sunday, July 6, 2025 11:20 AM (10 minutes)

Hadron-therapy is a very promising treatment addressing a critical public health issue such as tumors irradiation with a millimetric precision to spare the neighboring healthy tissues. The main advantage of this technology compared to X-rays is having a very localized treatment avoiding a large energy deposition into healthy tissues. However, despite the great advantages, the main drawbacks of this technology, such as weight, cost and size, prevent the diffusion on a large scale. High-temperature superconductors (HTS) might provide an effective solution for more efficient and compact devices that do not require to build bigger rooms and dedicated infrastructures. The use of superconductivity would reduce the footprint of the device, while increasing the treated area and avoiding patching and the HTS would decrease the power consumption related to the cooling costs. However, superconductivity has always raised several concerns related to their thermal stability and expensive cost. Moreover, depending on the implemented operating strategy with higher momentum acceptance or fast ramping, more concerns are related to the AC losses and the field quality. Although the use of copper is still a safer choice for several facilities, this is no longer valid when using heavier particles. So the use of HTS can be the game-changer for making hadron-therapy, depending on our capacity to solve the aforementioned drawbacks. This talk is aiming at providing an overview of the status of the superconductivity for hadron-therapy and the benefits and drawbacks of fast ramping compact HTS magnets. It will then focus on the research direction together with the different strategies that can be implemented using HTS technology.

Author: RICCIOLI, Rebecca

Presenter: RICCIOLI, Rebecca

Session Classification: Plenary 1: Young Scientist Plenary

Contribution ID: **427** Type: **Contributed Oral**

Thu-Mo-Or2-01: Design of a 2MW REBCO Fully Superconducting Synchronous Generator with Saddle-Shaped Field coils and Distributed Armature Windings

Thursday, July 3, 2025 10:45 AM (15 minutes)

We are developing an advanced electric propulsion system as a promising solution to achieve carbon-neutral growth in the aviation sector. In a previous study, we successfully developed and tested a 400 kW-class fully superconducting synchronous machine using REBCO racetrack-shaped coils for both the field and armature. The cooling system utilized sub-cooled liquid nitrogen for the armature coil and helium gas for the field coil. The machine operated stably at 2,500 rpm, with a maximum line voltage and short-circuit current of 590 V and 490 A, respectively, thereby resulting in an estimated generator output of 250 kW. Building on these results, we have initiated a new project supported by the New Energy and Industrial Development Organization (NEDO) to scale up to a 2 MW-class fully superconducting synchronous generator. For the field coil, a saddle-shaped coil wound on a through-shaft was adopted to withstand high-speed rotation at 3,600 rpm. To prevent critical current degradation of the coil from bending strains during three-dimensional winding, a Face-to-Face Double Stacked REBCO tape (FFDS) was employed. For the armature coil, distributed winding using REBCO tapes was proposed to reduce AC losses and improve output performance. The armature coil wounds with 40 stacked transposed REBCO tapes to handle a large AC current of 881 Arms at 65 K. Furthermore, each REBCO tape was divided into four strands via a laser ablation technique to reduce AC loss. This presentation will provide an overview of the project and the electromagnetic design of the 2 MW superconducting synchronous generator.

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Presenter: MIYAZAKI, Hiroshi (Kyushu University)

Session Classification: Thu-Mo-Or2 - Rotating Machinery II

Contribution ID: **428** Type: **Poster**

Wed-Mo-Po.06-07: An Eccentric Pole Coaxial Magnetic Gear With Spoke Structure and Asymmetric Halbach Array

Wednesday, July 2, 2025 9:15 AM (2 hours)

Magnetic gears have the advantages of overload protection, no lubrication, fixed transmission ratio, and have broad application prospects in the field of low-speed and high-torque transmission. They can be used for motors, hydro-wind power generation, space gravity-free transmission, etc. Magnetic gears not only have research value for electrical disciplines, but also open up new ideas in various fields such as motors, machinery, and power plants. Therefore, the magnetic gear has more and more research value and significance. Due to the principle of magnetic field modulation, the harmonic content of the air gap magnetic field of the magnetic gear is rich, which will lead to large torque ripple in the transmission process. In order to solve this problem, the structure of the magnetic gear is improved to increase the effective working harmonic of the air gap magnetic field and reduce the harmonic of the pulsation.

In this paper, an eccentric pole coaxial magnetic gear with Spoke structure and Halbach array is proposed. The inner rotor permanent magnet is an eccentric pole Halbach array, and the inner rotor permanent magnet is unevenly distributed. The distribution ratio is 1 : 3 : 1, and the outer rotor permanent magnet is a combination of Spoke structure and Halbach array. In addition, with high output torque and low torque ripple as the optimization objectives, based on sensitivity analysis, response surface method (RSM) and multi-objective genetic algorithm (MOGA) are used to optimize, and the optimization parameters of the improved magnetic gear are determined. A finite element simulation model with the upper pole pairs of inner and outer rotors of 4 and 17 is established.

By comparing with the traditional magnetic gear, it is found that the improved CMG can change the amplitude of the air gap magnetic density. The internal torque fluctuation range is 72.56N·m˜74.42N·m, and the external torque fluctuation range is 306.18N·m˜313.64N·m. By reducing the magnetic flux leakage, the torque of the CMG can be improved. The output torque of the improved model is 29.35 % higher than that of the traditional model. Reducing the magnetic flux leakage is beneficial to improve the utilization rate of the permanent magnet. At the same time, the torque ripple of CMG is analyzed. The torque ripple of the improved model is 27.48 % smaller than that of the traditional model. Reducing the ripple can make the torque output more stable.

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Presenter: YIN, Mingji (China Three Gorges University)

Session Classification: Wed-Mo-Po.06 - Rotating Machinery I

Contribution ID: **429** Type: **Poster**

Thu-Mo-Po.11-03: Design and Development of a High-Temperature Superconductor CCT Magnet for Research and Hadron Therapy Applications

Thursday, July 3, 2025 8:45 AM (2 hours)

The European I.FAST project's WP8 initiative focuses on advancing Canted Cosine Theta (CCT) magnet technology using High-Temperature Superconductors (HTS). These magnets aim to revolutionize synchrotron and gantry designs by reducing their size and cost, offering transformative potential for research and hadron therapy. HTS materials enable higher magnetic fields and smaller cryogenic systems compared to Low-Temperature Superconductors (LTS). However, challenges such as cable production, magnet design, and cost-efficiency must be addressed. This work presents the design of a straight HTS CCT magnet capable of achieving a central dipole field of 4 T at an operating temperature of 20 K, using a cable configuration composed of two HTS tapes. A ramp rate of 0.4 T/s is targeted, with a lower initial ramp rate of 0.15–0.2 T/s deemed acceptable for early-stage development. The magnetic design was optimized to ensure high field quality, both at initial energization and under operational conditions, accounting for the impact of electromagnetic forces. A preliminary mechanical design is proposed, identifying and addressing potential criticalities in the structure. Heat extraction is managed through a dual-channel cooling system, with helium gas flowing at 20 K through inner and outer channels. Thermal simulations demonstrate the effectiveness of this cooling approach, ensuring operational stability. Protection aspects have been evaluated based on experimental cold tests of the cabling and splicing, ensuring reliable operation under quench scenarios. Additionally, the paper highlights key assembly procedures and experimental tests conducted for qualifying critical fabrication steps, including cabling and winding. Results from these tests confirm the reliability and robustness of the developed methods, flooring the way for future HTS CCT magnet advancements. The progress presented here represents a significant step toward compact and efficient superconducting magnets, aligning with the project's goal of fostering innovative solutions for next-generation synchrotrons and gantries.

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Presenter: DE MATTEIS, Ernesto (INFN Milano - LASA)

Session Classification: Thu-Mo-Po.11 - Magnets for Other Medical Application I

Contribution ID: **430** Type: **Poster**

Thu-Mo-Po.06-05: Compressive stress-strain analysis of stacked REBCO tapes for HTS magnet applications

Thursday, July 3, 2025 8:45 AM (2 hours)

High-temperature superconducting (HTS) magnets, fabricated by winding HTS tapes, are widely utilized in various advanced applications. During operation, these HTS magnets and their wound HTS tapes are subjected to compressive loads caused by external factors such as winding tension, thermal contraction during cooling, and electromagnetic forces, leading to mechanical deformation. Previously, the mechanical properties of HTS tapes have been predicted based on the material properties and composition ratios of their constituent materials. However, this approach is only valid for single HTS tape and fails to accurately represent the mechanical behavior of tapes in wound or stacked configurations due to interfacial effects. Therefore, it is necessary to study the mechanical properties of stacked HTS tapes to account for the actual behavior of HTS magnets during the design stage.
In this study, stacked HTS tapes specimens were fabricated using rare-earth barium copper oxide (REBCO) tapes, and compression tests were conducted under both room and cryogenic temperatures. A displacement-controlled load was applied up to 100 MPa, and to analyze the plastic deformation region, loading-unloading repeated test were performed 3 cycles on the same specimens. To minimize the effect of the cut edges of the specimens, a specially designed cutting method was developed and applied. The reproducibility of the experimental results was verified through replicated tests on identical specimens.
Based on the experimental results, the stress-strain behavior of the specimens was analyzed, and their surface conditions were examined. In particular, a fitting equation was derived to predict the Modulus based on the strain of the specimens. The findings of this study are expected to provide critical data for the structural design and optimization of HTS magnets during the fabrication process.

Acknowledgments
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Presenter: Mr JANG, Bohyun (Changwon national university)

Session Classification: Thu-Mo-Po.06 - Mechanical Behavior and Stress II

Contribution ID: **432** Type: **Poster**

Thu-Af-Po.02-02: Study on Quench Behavior in Aluminum stabilized Stacked REBCO Tapes Cable

Thursday, July 3, 2025 2:00 PM (2 hours)

Study on Quench Behavior in Aluminum stabilized Stacked REBCO Tapes Cable

The Circular Electron Positron Collider (CEPC) is a significant international scientific facility proposed by the Chinese particle physics community in 2012. Its main objective is to conduct detailed measurements of the properties of the Higgs boson. The latest conceptual design of the CEPC detector magnet has introduced a novel Aluminum-stabilized Stacked HTS Tape Cable (ASTC). To ensure the long-term stable and safe operation of CEPC detector magnets, it is essential to study the quench behavior of ASTC used in these magnets. This paper establishes a three-dimensional quench simulation model of ASTC, which integrates the electric field, magnetic field, and temperature field. The quench behavior of ASTC is simulated under different operating currents and various thermal interference conditions, including liquid nitrogen immersion cooling mode and conduction cooling mode. The model solves for the distributions of temperature, current density, and magnetic field of ASTC, and calculates the minimum quench energy (MQE) and quench propagation velocity (QPV) of ASTC. This research provides a solid foundation for studying the quench behavior of coils wound with ASTC.

ACKNOWLEDGMENT
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Session Classification: Thu-Af-Po.02 - HTS Cable

Contribution ID: **433** Type: **Poster**

Fri-Af-Po.06-01: 40 Tesla All-HTS Miniature Magnets

Friday, July 4, 2025 2:00 PM (2 hours)

The generation of ultra-high magnetic fields is critical for advancing a wide range of scientific and technological research areas, including condensed matter physics, materials science, and biomedical imaging. Conventionally, achieving magnetic fields exceeding 40 T requires the combined use of superconducting and resistive magnet technologies, which are characterized by their substantial size, weight, and power consumption often reaching the megawatt range. In this study, we present the development and characterization of two compact all high-temperature superconducting (HTS) magnets. These magnets, small enough to be held in one hand, are capable of continuously generating magnetic fields of 38 T and 42 T, respectively, while operating at currents exceeding 1000 A. In particular, they achieve this high field strength with an ultra-low power consumption of less than a few hundred watts, significantly lower than the conventional systems.

The high magnetic fields reached by these HTS magnets is facilitated by the application of the no-insulation (NI) winding technique and a soldered coil structure, both of which contribute to enhanced mechanical strength and operational stability under strong forces and magnetic fields. To validate the field strength and reliability of these coils, nuclear magnetic resonance (NMR) measurements were conducted within the narrow 3 mm bore of the magnet. These NMR experiments also served as a precise calibration method for Hall effect sensors.

The compact size, high field strength, and energy efficiency of these HTS magnets hold significant promise for a broad spectrum of scientific and industrial applications, such as high-field NMR spectroscopy, enabling more widespread use in chemical analysis, structural biology, and materials research. Beyond NMR, these magnets could also support advancements in fundamental physics experiments, fusion research, and medical diagnostics, offering a transformative step toward more versatile and energy-efficient high-field magnetic systems.

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Session Classification: Fri-Af-Po.06 - High Field HTS Solenoids

Contribution ID: **434** Type: **Poster**

Wed-Mo-Po.06-06: A study on Performance Improvement of Axial Flux Motor Through Halbach Array and Same Direction Skew

Wednesday, July 2, 2025 9:15 AM (2 hours)

In this paper, methods to reduce iron loss through same direction skew and halbach array by utilizing the shape freedom of 3D printing are proposed. Axial flux motors have a higher power density than radial flux motors and are advantageous in a multi-pole structure. However, in the case of an axial flux motor, it is difficult to manufacture through electrical steel sheet lamination for iron loss reduction. As a method for reducing iron loss in existing axial flux motors, manufacturing through core-loss type, armor force steel plate, and powder material rolling is mainly used. However, in the case of the armor force steel plate, there is a disadvantage in that it is difficult to manufacture, and in the case of manufacturing through rolling, high-cost mold manufacturing is essential. It is possible to overcome the disadvantages of the existing manufacturing method when manufacturing a motor by utilizing the shape freedom, which is an advantage of 3D printing technology. However, cores manufactured using 3D printing currently have high iron loss characteristics, which is a fatal disadvantage to motor output. To reduce iron loss, a combination of pole numbers and slots with a small number of poles can be selected, but a combination with a small number of poles opposes the characteristics of an axial flux motor. Through the same direction skew and Halbach array, the performance of an axial flux motor can be increased even in a combination with a small number of poles. The validity of the proposed model was reviewed through finite element analysis.

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Presenter: HONG, Min-Ki

Session Classification: Wed-Mo-Po.06 - Rotating Machinery I

Contribution ID: **435** Type: **Poster**

Sat-Mo-Po.02-10: Improvement of bending magnet iron yoke design for a compact heavy-ion therapy synchrotron

Saturday, July 5, 2025 9:30 AM (1h 45m)

A project to develop a compact heavy-ion therapy system has been initiated at the National Institutes for Quantum Science and Technology in Japan. This therapy system uses a 430-MeV/u synchrotron with four 90-degree bending superconducting magnets. The bending magnets have been designed to generate central dipole fields from 0.3 T to 3.5 T at the ramping rate of 0.64 T/s, and each magnet is operated by a conduction-cooling system with GM cryocoolers. The magnets are required to provide field homogeneity in the order of 10-4. In the previous study, the NbTi wire alignment and the iron yoke shape were conceptually designed for the required field quality. To realize stable operation of the conduction-cooled superconducting magnets, it is preferable to lower a maximum energization current and a load line ratio. The iron yoke design has been reviewed to reduce the operation current while keeping the field strength and quality. By optimizing the holes in the cross section of the iron yoke, the maximum energization current could be reduced by 5%. In addition, the eddy current generated in the iron yoke was analyzed, and the slits at the top and bottom of the iron yoke have been introduced to reduce the ac loss due to the eddy current. The improved iron yoke design will be reported as well as the results of the field quality assessment.

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Session Classification: Sat-Mo-Po.02 - Magnets for Other Medical Application III

Contribution ID: **436** Type: **Poster**

Wed-Mo-Po.06-05: Study on the offset force reduction structure of integral magnetic bearing

Wednesday, July 2, 2025 9:15 AM (2 hours)

The motor with magnetic bearings has a structure in which the shaft is magnetically levitated outside the rotor, which can reduce friction loss, but increases the size of the motor system. Since the size of the motor system increases, it is not appropriate because it goes against the industrial demand for weight reduction and miniaturization. In order to reduce the overall size of the motor structure with magnetic bearings applied, an integrated magnetic bearing motor structure can be proposed that utilizes the space of the back yoke as an insertion space for the magnetic bearing by using the Halbach arrangement for the SPM type.

At this time, gravity is applied to the rotor, and an offset force is required to offset the gravity applied to the rotor to prevent collision with the stator due to this.

As an offset force to offset the gravity applied to the rotor, an offset current sufficient to magnetically levitate the weight of the rotor must be continuously applied to the magnetic bearing winding on the ground side to generate magnetic force, and copper loss occurs due to this. An offset magnet can be inserted between both ends of the bearing core to generate a magnetic force in the direction of offsetting the gravity of the rotor that occurs in the direction of the ground. This is possible because the rotor back yoke in the integral structure acts as a magnet. In this paper, we analyzed the bearing force according to the insertion of the permanent magnet. After inserting the offset magnet, we confirmed that an additional magnetic levitation force of about 45 N was generated, and we proceeded with the design to increase this. The proposed content verified the validity of the integral magnetic bearing structure using the finite element method.

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Session Classification: Wed-Mo-Po.06 - Rotating Machinery I

Contribution ID: **437** Type: **Poster**

Thu-Af-Po.04-04: Active shimming method for a 7T MRI superconducting magnet

Thursday, July 3, 2025 2:00 PM (2 hours)

In the design of ultrahigh field magnetic resonance imaging (MRI) superconducting magnets, it typically requires a high homogeneous magnetic field in the diameter of spherical volume (DSV) to obtain high quality image. Spherical harmonic based B0 shimming relies significantly on the fitting process, which can be computationally demanding, especially when handling a large number of shim coils. This study introduces an active shimming method that optimizes magnetic field homogeneity by acquiring the FID signal at each layer. It uses the full width at half maximum (FWHM) of the spectrum for each layer as a metric and iteratively adjusts the shim coil current. By minimizing the FWHM, this approach efficiently identifies the optimal shimming coil current, significantly enhancing spatial field homogeneity. The experimental validation conducted on a 7 T MRI superconducting magnet confirmed the efficacy of the suggested approach. Specifically, employing gradient coils and active shim coils, the active shimming approach increased the field homogeneity of a 130 mm DSV, resulting in a much better magnetic field environment for subsequent MRI. Furthermore, this method enables rapid shimming before imaging, substantially reducing the time required for imaging preparation.

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Session Classification: Thu-Af-Po.04 - Screening Currents and Shimming

Contribution ID: **438** Type: **Poster**

Wed-Af-Po.04-03: Aging effects in (RE)B2C3O7-d tapes solder joints made with indium-tin

Wednesday, July 2, 2025 2:30 PM (2 hours)

Rare-Earth Barium Copper Oxide (REBCO)-based High-Temperature Superconductor (HTS) tapes are used for large-scale applications, which typically require spools longer than those currently produced. Therefore, several joints are often needed for a single project, emphasizing the importance of low-resistivity, mechanically strong, and repeatable joints. Currently, soldering is one of the most common method used, however, aging effects such as diffusion and oxidation are known to occur with the solders typically used. No studies have yet been conducted on this phenomenon to our knowledge for REBCO tape solder joints.
This study examines the changes in the properties of REBCO tape solder joints made with eutectic indium-tin solder over time. One suspected aging effect is the intermetallic compound (IMC) growth at the copper layer and solder interface. Since IMC growth is relatively slow at room temperature, heat treatment at 100℃ is used to accelerate the process and observe its consequences. The IMC growth is expected to have an impact on the joints resistivity, and in extreme cases where the solder diffuses up to the REBCO layer, an impact on the critical current.
Finally, storage at room temperature in a desiccator is a common practice, especially for test coils; therefore, the changes in joint properties over time due to oxidation in the desiccator are also studied. All resistivity and critical current measurements are conducted in a liquid nitrogen bath using the four-probe method.

Acknowledgement:
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Session Classification: Wed-Af-Po.04 - HTS Joints

Contribution ID: **439** Type: **Poster**

Fri-Af-Po.08-04: Study on Superconducting Performance of Ultra-fine strand Nb3Al Cable fabricated by React & Wind method in Solenoid Coil

Friday, July 4, 2025 2:00 PM (2 hours)

SuperKEKB accelerator is considering the introduction of superconducting sextupole magnets to improve collision performance. In addition to the main sextupole coil, three types of correction coils will be incorporated in this superconducting magnet. We are developing the correction coils using ultra-fine strand Nb3Al superconducting cables with strand diameters less than 50 um fabricated by the React & Wind method. In this paper, we report the measurement results of the superconducting performance of Nb3Al cables of 0.6 to 0.8 m in length in the solenoid coils with radius of curvature from 15 mm to 25 mm.

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Session Classification: Fri-Af-Po.08 - Advances in Nb3Sn and MgB2 Conductors I

Contribution ID: **440** Type: **Poster**

Sat-Mo-Po.02-11: Development of a Rotating Coil System for Superconducting Magnets in a Compact Synchrotron for Heavy-Ion Therapy.

Saturday, July 5, 2025 9:30 AM (1h 45m)

A compact superconducting synchrotron for heavy-ion therapy is under construction at National Institutes for Quantum Science and Technology. This synchrotron is being downsized for widespread applicability in medical facilities using combined-function superconducting magnets for 90-degree main dipoles. The magnetic field of the dipole reaches 3.5 T with a field gradient of 1.5 T/m by quadrupole. The dipole field strength must be measured within accuracy of less than 250 ppm over the field region of ±30 mm in horizontal and ±19 mm in vertical.
Such accuracy is generally achieved with rotating coils, however, no such measurement system have been made with an long magnet with a small bending radius as in this case, necessitating a careful study (about 3m in length and 1.89m bending radius).
At present, we are developing a compact measurement system to be attached to the end of an industrial robotic arm, allowing the measurement of the local magnetic field distribution at arbitrary positions along the beam trajectory. The system includes a coil with a length of 75 mm and a radius of 15 mm approximately, as well as encoders, piezo motors, accelerometers for field direction measurements and other parts. Consequently, the overall length and diameter of the system are expected to be around 250 mm and 35 mm.
In this presentation, we report the design and current status of this system.

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Session Classification: Sat-Mo-Po.02 - Magnets for Other Medical Application III

Contribution ID: **441** Type: **Poster**

Fri-Mo-Po.06-05: Time and Frequency Domain Reflectometry for Quench Monitoring in Superconducting Magnets

Friday, July 4, 2025 9:30 AM (1h 45m)

High-temperature superconductors (HTS) are increasingly being used to build electromagnets to generate strong magnetic fields for a wide range of applications, from medical devices and electric motors to future fusion reactors. These superconductors are subject to quenching, a phenomenon that manifests itself as a rapid rise in the temperature of the HTS material, leading to a loss of the superconducting state and interruption of magnet operation. The timely and rapid detection of the quenching is currently one of the most active areas of development.
A technique based on frequency and time domain reflectometry (FTDR) is suggested in this presentation for the quench monitoring. We use the detection and analysis of microwave electromagnetic signals propagating in the coolant gas channels to monitor the temperature of the coolant enabling the quench monitoring. The techniques suggested should allow both a real-time quench detection capability, as well as, facilitating the acquisition of valuable information regarding the health of the whole magnet system throughout its operation time.
The methodology presented here is based on the established correlations between thermodynamic gas variables such as temperature and pressure with its electromagnetic properties i.e. refractive index. The technique has been recently subjected to both numerical and experimental validations. Numerical simulations were conducted using CST Microwave studio and it was found that a localised hotspot can be detected with minimal time delay, a crucial consideration for systems necessitating rapid response monitoring for safety purposes. The experimental data observed agree well with the theoretical understandings and it will be presented. While the technique holds significant potentials for quench monitoring it also offers valuable opportunities to develop new monitors in areas encompassing many devices which are applying complex gas cooling, such as fusion reactors, MRI systems and others.

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Session Classification: Fri-Mo-Po.06 - Quench in Fusion Magnets II

Contribution ID: **442** Type: **Contributed Oral**

Fri-Mo-Or3-02: Possible use of MgB2 cryomagnets for Maglev vehicles

Friday, July 4, 2025 8:30 AM (15 minutes)

Investigations carried out up to now on superconducting Maglev trains have always planned to use YBCO or REBCO oxides as superconducting materials [1, 2]. While MgB2 enters more and more applications [3], bulk MgB2 has not yet been seriously considered for Maglev projects. Its main drawback is its Tc that is low as compared to that of HTS oxides. As a consequence, the cooling costs are assumed to be much higher, although cryo-coolers able to provide a high cooling power at 20K are now available [4]. Bulk MgB2 presents, however, advantages that could offset this inconvenient. Magnesium and Boron are abundant and available worldwide and MgB2 is a light, low cost and high hardness material. The fabrication process of MgB2 bulks by Spark Plasma Sintering-SPS [5] is simpler, takes much less time and is much less expensive than the techniques used for the growth of YBCO or REBCO bulks [6]. In addition, MgB2 bulks can be made with a priori no limitation on their dimensions and shape.
The non-conventional SPS process is based on the combination of a high current and a mechanical high pressure applied directly to the powder material. This technique presents the advantage to provide dense materials in a few minutes while mastering their microstructure. A lot of works have been reported since the introduction of SPS in research laboratories, and many groups have tried to understand the densification mechanisms involved. After a brief history of the SPS technique, the characteristics of this process will be detailed and compared to those of the other sintering techniques.
The densification, and the functionnal properties of superconducting MgB2 cryo-magnets sintered by SPS will be discussed. Levitation forces up to 700 N at 20 K measured on a 120 mm diameter MgB2 disc will be reported. The effect of the thickness and the diameter of cylindrical superconductors on the levitation force and the condition for stability in superconducting magnetic levitation will be also analysed.

References

[1] G. G. Sotelo, D. H. N. Dias, E.S. Motta, F.Sass, et al., Physics Procedia 36 (2012) 943 –947

[2] F N Werfel, U Floegel-Delor, R Rothfeld, T Riedel, et al., Supercond. Sci. Technol. 25 (2012) 014007

[3] Yukikazu Iwasa, Physica C 445–448 (2006) 1088–1094

[4] https://www.cryomech.com/products/

[5] J. G. Noudem, M. Aburras, P. Bernstein, X. Chaud, M. Muralidhar and M. Murakami, J. Appl. Phys. 116, 163916 (2014).

[6] X. Chaud, S. Meslin, J-G. Noudem, C. Harnois, et al., Journal of Crystal Growth 275 (2005) 855-860.

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Session Classification: Fri-Mo-Or3 - Coils for Power, Energy, Transport and Other Applications

Contribution ID: **443** Type: **Poster**

Wed-Af-Po.11-06: A Study on Voltage Distribution Characteristics Considering Stray Capacitance for Fusion Magnets

Wednesday, July 2, 2025 2:30 PM (2 hours)

Predicting the voltage distribution of a superconducting coil has an important diagnostic purpose in relation to the maintenance of the coil. Under high-frequency conditions, the voltage distribution within a superconducting coil can become non-uniform, leading to localized high voltages may compromise the insulation between coil turns. This issue is particularly significant in systems requiring pulsed current flow conditions in superconducting coils such as plasma control and surge protection fault conditions during fast discharge. The non-uniform voltage distribution primarily arises from stray capacitance within the superconducting system.
This paper investigates the voltage distribution characteristics of superconducting coils across varying frequency levels. Circuit modeling was carried out considering the KSTAR PF coils, followed by circuit analysis that accounted for stray capacitance. The results are expected to contribute to a better understanding of voltage distribution in superconducting coils and enhance the magnet's operational stability and maintenance.

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Session Classification: Wed-Af-Po.11 - Modelling of Fusion Conductors and Coils I

Contribution ID: **444** Type: **Poster**

Wed-Af-Po.11-04: Modelling Current Distribution and Transport Losses in High-Temperature Superconducting Toroidal Field Coils for Fusion Applications

Wednesday, July 2, 2025 2:30 PM (2 hours)

The transition from low-temperature superconductors (LTS) to high-temperature superconductors (HTS) has opened new possibilities for toroidal field coil design in fusion applications. These next-generation HTS coils represent a significant departure from traditional D-shaped LTS coils, introducing unique operational dynamics and challenges. A key innovation is the adoption of HTS stacks, where hundreds of stacked HTS tapes are soldered together to form robust, high-current coils. While these coils offer resilience to small heat loads or quenches, they introduce complications during rapid charging, as currents may redistribute unevenly among the tapes due to current-sharing effects.

This study explores the behaviour of these HTS toroidal field coils under various operational scenarios, with a focus on understanding the interplay between charging rates, current sharing, and loss mechanisms. A hybrid modelling approach is employed, combining circuit modelling with finite element method (FEM) simulations using the T-A formulation. This methodology captures the critical influence of ramp rates, joint resistance, turn-to-turn resistance, and superconductor saturation on coil performance and energy efficiency.

A particular emphasis is placed on understanding current-sharing phenomena in large-scale stacked coils containing up to several hundreds of HTS tapes. The simulations and models demonstrate how rapid charging can induce significant current redistribution, potentially leading to increased losses and non-uniform heating. Addressing these challenges is essential for ensuring the reliability and scalability of HTS toroidal field coils in fusion devices.

Additionally, the work includes a comparative analysis of square and D-shaped coil geometries, examining their relative advantages and drawbacks under fixed constraints such as central magnetic field or transport current. This analysis provides valuable insights into optimizing the coil design for specific operational requirements, considering both geometric and electromagnetic factors.

This study highlights the distinct characteristics of HTS-based toroidal field coils, particularly the critical role of current-sharing dynamics in stacked coils. By integrating advanced modelling techniques and exploring innovative geometries, the findings contribute to the development of more efficient, stable, and scalable superconducting coil systems for next-generation fusion technologies.

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Session Classification: Wed-Af-Po.11 - Modelling of Fusion Conductors and Coils I

Contribution ID: **445** Type: **Poster**

Thu-Mo-Po.03-02: Model-based development of pulsed electromagnets for accelerators by simulation

Thursday, July 3, 2025 8:45 AM (2 hours)

Compared to DC magnets with constant current, pulsed magnets with instantaneous current flow are superior in terms of energy conservation because the time required to generate Joule heat due to the electrical resistance of the coil is limited. However, the magnetic field distribution that affects beam orbit control cannot be known accurately until the pulse power supply is excited, because the current path through the coil and the load resistance change with time due to the current skin effect, respectively. Therefore, it is difficult to confirm before excitement whether the design is as expected. If a mistake is found, the design must be redone. For this reason, we have introduced model-based development (MBD), which integrates electromagnets and power supplies, whereas previous simulation analysis was performed separately for electromagnets and power supplies. For the simulation, we combined OPERA-3D transient analysis, which has a proven track record in the development of pulsed magnets for the J-PARC accelerator, and MATLAB/Simulink for circuit simulation. The introduction of MBD is expected to reduce the number of actual prototypes and development costs and shorten the development period because highly accurate results can be obtained in a short period of time. In addition, simulation of trouble cases that cannot be covered by verification of actual machines alone is possible, which is expected to improve safety. In this presentation, we will report the evaluation results compared to the actual machine.

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Session Classification: Thu-Mo-Po.03 - Design and Development of Accelerator Magnets II

Contribution ID: **446** Type: **Poster**

Wed-Mo-Po.06-01: Evaluation of Current Distributions in Superconducting Armature Coils with Transposed Three Parallel Conductors under Rotating Magnetic Field

Wednesday, July 2, 2025 9:15 AM (2 hours)

Fully superconducting synchronous motors have great potential to achieve a high-power density (kW/kg), which is very attractive technology for future electric propulsion systems for aircraft applications. This system is expected to be operated with low voltage (several kV) and large current (several hundred A or more). Hence, the armature coil is required to have a large current capacity. In order to realize this, our research group focused on the transposed parallel conductors to enhance the current capacity on the armature coils. In this method, the armature coil is composed of the parallel conductors stacked with multiple superconducting wires. However, differences in the interlinkage magnetic flux between the stacked wires disrupt the inductance balance of this coil, leading to non-uniform current distribution between each strand. To address this problem, the transposing technique into the armature coil has been developed to achieve uniform current flow. While we have studied the transposition methods which have been applied to the armature coil under the single-phase coil condition in previous study, an actual motor consists of the three-phase armature coils and the rotating field coil or magnet.
In this research, in order to evaluate the effectiveness of the transposition method that is developed in an actual motor situation, the effect of the magnetic field of the field magnet on the current distribution rate of the armature coil will be investigated. For this evaluation, we prepared racetrack-shaped double pancake coils consisting of the three-strand parallel conductors applying the optimal transposition. The sample coils with 18 turns were made of REBCO tapes provided by Fujikura Ltd. The stational armature coils consists of three phases and each phase is composed of two armature coils which are facing each coil with a distance of 150 mm. The rotating field magnet consists of a cylindrical iron core and permanent neodymium magnets. The neodymium magnets with a surface magnetic flux density of approximately 0.6 T were arranged to cover the iron core. In Addition, the magnetic field generated by the permanent magnet at the coil surface, located 75 mm from the magnet, was approximately 0.14 T. In this test system, an AC current was supplied to the three-phase armature coils in liquid nitrogen. The current distributions in the parallel conductors were measured using a Rogowski coil when the rotating magnet was rotating synchronously with the rotating magnetic field of the three-phase armature coils. When a current of 40 Hz and approximately 50 A applied to the armature coil and the field magnet rotated at 2400 rpm, the current distribution rates among the three-strand parallel conductors were 34.5%, 31.3%, and 34.2%, which is almost perfect uniform. The measurements also conducted with only the single-phase armature coil without the field magnets, showed distribution rates of 35.1%, 31.8%, and 33.1%. In addition, only the three-phase armature coils resulted in rates of 36.7%, 30.5%, and 32.8%. Here, when a current of 50 A was applied to the coil, the magnetic field at the coil surface was calculated by analysis to be approximately 0.013 T. These results indicate that the transposition method developed using a single-phase coil in nearly uniform current distribution even when the rotating magnetic field due to the field is larger than the magnetic field of the armature coil.
The effect of current distribution due to the magnetic field of the magnet will be clarified through analysis. The experimental results and details will be discussed in MT29.

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Session Classification: Wed-Mo-Po.06 - Rotating Machinery I

Contribution ID: **447** Type: **Poster**

Thu-Af-Po.08-07: Development of a Copper-Tungsten Composite wires Using Cold Spray and Wire-drawing for High Magnetic Field Applications

Thursday, July 3, 2025 2:00 PM (2 hours)

Copper-based conductive wires with both a high strength and a high electrical conductivity could find applications in aerospace and power engineering as well as in niche scientific applications such as materials for the production of high-field pulsed magnets. Indeed, in order to produce non-destructive fields, the coils must be wound of wires with a very high mechanical strength to resist Lorentz forces. LNCMI-Toulouse produces some of the most intense non-destructive pulsed magnetic fields in the world with a European record of 98.8 T and aims at reaching more than 100 T.
This study explores the potential of the cold spray (CS) technique to produce dense composite cylinders of copper (Cu) and tungsten (W), which act as precursors for wire-drawing processes. The cold spray technique, a solid-state deposition process, consolidates powders into dense structures without melting the feedstock material. This method is particularly advantageous for preserving the microstructural integrity of materials while achieving high-density composites. Additionally, the high velocity of the deposited particles during cold spraying results in significant plastic deformation, leading to enhanced mechanical properties, such as elevated ultimate tensile strength (UTS), and unique microstructural characteristics.
The composite powder used in this study comprises Cu particles (15–45 µm) coated with an ultra-thin W layer (1 vol% W; ˜100 nm) created via Fluidized Bed Chemical Vapor Deposition (FBCVD). The choice of feedstock material played a pivotal role in determining the final properties of the composite wires. The W coating provided a homogeneous dispersion of the second phase, ensuring a nanoscale distribution critical to achieving the desired combination of electrical and mechanical performance.
W-Cu cylinders (diameter 8 mm or 14 mm, length 80 mm) prepared by CS serve as precursors to wire-drawing. The diameter of the cylinders is reduced by wire-drawing at room temperature, in several passes, thus producing progressively finer wires (diameter in the range 1-0.2 mm).
The electrical resistivity and tensile strength were measured at 293 K and 77 K. The composite wires containing 1 vol.% W achieved a tensile strength of 757 MPa and a low electrical resistivity of 0.33 µΩ·cm.
The results of this study underscore the effectiveness of the cold spray technique in fabricating advanced composite materials with tailored properties, paving the way for their implementation in cutting-edge scientific and industrial applications.

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Session Classification: Thu-Af-Po.08 - Materials for Pulsed Magnets

Contribution ID: **448** Type: **Poster**

Sat-Mo-Po.03-02: Preliminary design of a supporting structure for the full current test of ITER TF Magnet

Saturday, July 5, 2025 9:30 AM (1h 45m)

IO (ITER Organization) planned cold tests for Toroidal Field (TF) and Poloidal Field (PF1) coils, and a test facility is under development for this specific purpose. The TF coil test campaign foresees a series of tests at half operational current and a final one at full current, 68kA. The latter requires a further development of the facility, due to the severity of the test together with a series of design constraints. Firstly, a stand-alone TF coil is subjected to a stress condition different from the operational one, since it is not part of the entire magnetic system, where centripetal actions are shared and reacted by wedging. This condition results in significant bending of the inboard leg and a strain state potentially affecting the superconductor performance. Secondly, the required supporting structures to mitigate this bending, apart from being effective in increasing the stiffness and structurally sound, must withstand strict requirements in terms of dimension, interface with other components, handling and weight. In this investigation the preliminary design of the necessary auxiliary structure is discussed. The results of the FEM mechanical and thermal analyses show how the design meets the requirements in terms of stresses in the TF coil and strain in the WP, as well as the structural compliance of both coil and supporting structure, also in compliance with the requirements of assembly and handling in the facility.

The views and opinions expressed herein do not necessarily reflect those of the ITER Organization.

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Session Classification: Sat-Mo-Po.03 - Mechanics of Fusion Magnets

Contribution ID: **450** Type: **Poster**

Sat-Mo-Po.08-04: Gamma-Ray Irradiation Characteristics of an Organic Olefin-based Thermosetting Dicyclopentadiene Resin under Vacuum Atmosphere

Saturday, July 5, 2025 9:30 AM (1h 45m)

An organic olefin-based thermosetting dicyclopentadiene (DCP) resin is commercially available in Japan as TELENE® from RIMTEC Corporation, and its viscosity is less than one-tenth that of the CTD-101K® epoxy resin. In previous studies, the TELENE® can withstand greater strain than CTD-101K® and can achieve higher heat capacity when mixed with ceramic powders from a previous study. The use of TELENE® as an impregnation resin is expected to reduce the number of quench training for Nb3Sn magnets. In this study, the TELENE® resin was subjected to gamma-ray irradiation experiments exceeding 15 MGy under vacuum atmosphere. The gamma-ray irradiation experiment was carried out at room temperature using a Cobalt-60 source at the Takasaki Advanced Radiation Research Institute, Japan. The flexural properties of the TELENE® were measured by three-point bending tests and compared to those of the CTD-101K®.

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Session Classification: Sat-Mo-Po.08 - Structural and Insulation Materials

Track Classification: F: Conductors and Materials for Magnets: F05: Structural and Insulation Materials for Magnets, Other Magnet Components

Contribution ID: **452** Type: **Contributed Oral**

Sat-Mo-Or6-05: Status of series production and cold test results of the first series Hi Luminosity LHC Main Bending Recombination Dipole magnets

Saturday, July 5, 2025 12:15 PM (15 minutes)

The High-Luminosity LHC (HL-LHC) upgrade aims to increase the colliders integrated luminosity by an order of magnitude through significant modifications to the interaction region layout. One of the key hardware components involved in this upgrade is the MBRD combination-recombination dipole, a double-aperture magnet with magnetic fields aligned in both bores. For this magnet, a magnetic field of 4.5 T in a 105 mm aperture is required, both values increased by 30% compared to the magnets currently installed in the LHC. A completely new design to address challenges such as magnetic cross-talk between the two apertures and the increased Lorentz forces.
The experimental program included the development of a short model (1.5 m in length), which was successfully cold-tested at CERN in 2020, followed by the construction of a full-length prototype, also successfully tested in 2022-2023. The series production plan comprises six magnets, four of which are intended for installation in the tunnel and two reserved as spares. As of now, the series production is halfway complete, with three out of six magnets constructed and one undergoing cold testing at CERN in the spring of 2025. This contribution will provide an overview of the current status of the series production and discuss the results of the cold tests conducted on the first of series magnet so far.

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Session Classification: Sat-Mo-Or6 - High Luminosity LHC

Contribution ID: **453** Type: **Contributed Oral**

Sat-Mo-Or6-01: Performance and reliability evaluation of Nb_3Sn MQXFB quadrupoles for the HL-LHC at midpoint production

Saturday, July 5, 2025 11:15 AM (15 minutes)

At the heart of the High-Luminosity project (HL-LHC) of the CERN Large Hadron Collider (LHC), new low-beta* Nb_3Sn superconducting quadrupole magnets will be installed on each side of the ATLAS and CMS experiments. Half of these magnets are built by CERN and are called MQXFB. A total of 12 MQXFB magnets are being constructed: two to be installed in the IT String facility, for systems qualification; four to be installed in the LHC near ATLAS; four to be installed in the LHC near CMS, and two spare magnets. In the last two years, the first six MQXFB magnets have been tested and qualified up to nominal current in nominal operation conditions. In this paper we present the tests and analyze the magnets'performance, with emphasis on qualification, non-conformity detection, and reliability evaluation.

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Session Classification: Sat-Mo-Or6 - High Luminosity LHC

Contribution ID: **456** Type: **Poster**

Fri-Af-Po.01-03: Quench protection of direct wind magnets

Friday, July 4, 2025 2:00 PM (2 hours)

Direct wind technology is capable of manufacturing complex multi-functional multi-layer coil structures without the need for creating custom production tooling and fixturing for each new project. The prestressing and field quality corrections is integrated in the manufacturing steps, and
the final coil does not require curing. The direct wind coil has several unique features. The conductor layout is characterized by thin single conductors wound over long lengths and separated
from the other turns with thick layer of insulation. Moreover, there are several layers of winding. The strong non-uniformity in the magnetic field distribution results in different current and thermal
margins for quenching in different regions. The quench protection modeling involves multiphysics coupling between electrical, thermal and magnetic transient. The material properties vary with time. This coupled with the complexity in the geometry adds to long computation times. We propose a theoretical framework to simulate the quench propagation in the direct wind magnets. Thereafter, we study the performance of different quench protection strategies. The objective of this study is to understand the quench propagation in the EIC high inductance direct wind magnet and to design appropriate quench protection strategy to protect the magnet. The theoretical model has been validated with controlled spot heater induced quenches in a real 4T class direct wind magnet.

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Presenter: KUMAR, Mithlesh

Session Classification: Fri-Af-Po.01 - Quench Detection and Protection II

Contribution ID: **457** Type: **Contributed Oral**

Fri-Mo-Or4-04: Test results for the High Field Direct Wind magnet

Friday, July 4, 2025 12:00 PM (15 minutes)

Brookhaven National Laboratory (BNL) has a unique Direct Wind (DW) technology which is used to fabricate complex multi-functional superconducting magnets. Some of these magnets have been integrated in currently operational accelerator complexes, such as, HERA, BEPC, JPARC, and RHIC. These multi-layer magnets do not require custom production tooling necessary for cabled magnets. The Electron Ion Collider (EIC) project is planning to use DW technology for most of the magnets at the Interaction Point IP6. To study the performance of a direct wind magnet at high
magnetic field (and high Lorentz force), a High Field Direct Wind (HFDW) magnet was manufactured. It consists of three double layer coil-sets wound with a six-around-one 1.575 mm diameter conductor on a 38 mm radius mandrel. This magnet was tested up to Bpeak,conductor ≈ 4T.
This paper discusses 1) the magnet training behavior under repeated spontaneous quenches, and 2) quench behavior with spot heater induced quenches.

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Presenter: KUMAR, Mithlesh

Session Classification: Fri-Mo-Or4 - Magnets for Electron Colliders

Contribution ID: **458** Type: **Poster**

Thu-Af-Po.10-05: Study on the optimization of MLI stacking density in the limited gap of superconducting rotating machinery

Thursday, July 3, 2025 2:00 PM (2 hours)

Multi-Layer Insulation (MLI) is widely used in cryogenic systems to effectively suppress radiation due to temperature differences. In particular, MLI plays a crucial role in reducing cooling energy consumption and maintaining the thermal stability of superconducting coils in superconducting magnet systems. High-field superconducting magnets require cryogenic environments to sustain high current densities and magnetic fields, and minimizing external heat intrusion is a key challenge in ensuring the performance and efficiency of superconducting systems.
MLI is commonly used by stacking multiple layers to reduce radiation. However, when considering narrow gaps, such as between superconducting field coils and cryostats, various factors need to be considered in optimizing the stacking density of MLI. Excessive stacking density in narrow gaps can increase conduction heat transfer, potentially degrading the overall insulation performance. This suggests that the interaction between stacking density and heat transfer performance greatly influences MLI effectiveness.
In this study, we experimentally analyzed the effect of stacking density on thermal insulation performance, considering the narrow gap between the superconducting field coils and cryostats. A thermal conductivity measurement device equipped with a two-stage GM cryocooler was used to simulate the cryogenic environment, and the relationship between stacking density and heat transfer was quantitatively measured. The measured heat transfer was converted into effective emissivity for analysis, and the optimal stacking density for maximizing insulation performance in narrow gaps was experimentally determined.
This research provides crucial data for designing the optimal stacking density in narrow gaps between superconducting field coils and cryostats and accurately predicting radiation heat load. These findings can contribute to improving system stability and energy efficiency in high-field superconducting magnets and superconducting power systems.

Acknowledgement
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Session Classification: Thu-Af-Po.10 - Cryostats and Cryogenics I

Contribution ID: **459** Type: **Poster**

Wed-Mo-Po.05-05: Design of field shaper-based magnets for electromagnetic forming

Wednesday, July 2, 2025 9:15 AM (2 hours)

Electromagnetic forming (EMF) is a significant application direction of pulsed high magnetic fields. As a high-speed forming technique, EMF offers typical advantages associated with high forming rates, such as enhancing the material forming limit, suppressing wrinkling and springback. Additionally, the driving force in EMF is a non-contact force, eliminating the need for a force transmission medium and enabling high-quality forming surfaces. The magnet responsible for generating the magnetic field is one of the most critical components in EMF. The design of magnets based on the structure of the field shaper involves optimizing the shape of an additional metal block within the magnet. Compared to magnets that rely solely on coil windings for field generation, such designs provide a richer force field and enhance the mechanical strength and lifespan of the magnet.However, current field shaper designs for metal sheet forming are primarily based on axisymmetric structures, optimizing the force field only in the radial direction. This one-dimensional optimization limits improvements in the uniformity of the force field of the field shaper.
This paper presents a multi-stage optimization method for field shapers, decoupling the field shaper's structural parameters into basic structural parameters and bottom structural parameters . Based on the structural characteristics of the field shaper and leveraging software advantages, different simulation models are established to ensure computational accuracy while improving computational efficiency. First, a two-dimensional COMSOL model is developed based on a cylindrical field shaper to determine the basic structural parameters of the field shaper. A more accurate three-dimensional COMSOL model is then created, with the bottom surface structure parameterized. The effects of the bottom surface height distribution of field shaper in the radial and circumferential directions on the electromagnetic force distribution are analyzed, and the design range for the bottom structural parameters is determined. Finally, an electromagnetic-structural field coupling simulation model is developed using LS-DYNA, the bottom structural parameters are finalized, and the electromagnetic force distribution and forming capabilities of the field shaper are validated. Simulation results show that the field shaper designed using this method achieves precise control over the radial and circumferential distribution of the electromagnetic force and allows flexible control of the workpiece deformation behavior.Based on the simulations, a large-scale aluminum alloy sheet metal forming experimental platform is established. The field shaper is used to form a 1000 mm radius, 4 mm thick A1060 aluminum sheet. Experimental results demonstrate improved workpiece forming uniformity and thinning, thereby validating the feasibility of the proposed field shaper design method.

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Session Classification: Wed-Mo-Po.05 - Novel and Other Applications I

Contribution ID: **461** Type: **Poster**

Thu-Af-Po.12-02: Development of Gas Blow Thermal Coupling for High-speed HTS Rotating Machinery

Thursday, July 3, 2025 2:00 PM (2 hours)

High-temperature superconducting (HTS) motors and generators utilizing HTS magnets exhibit exceptional energy efficiency and output performance due to their high current density. In these systems, maintaining the rotating HTS magnets at cryogenic operating temperatures is crucial. Specifically, the rotor requires a thermal coupling structure to enable cryogenic cooling between the stationary and rotating components. Conventional coupling methods face significant challenges, such as excessive weight and low cooling efficiency when cryocoolers are applied to the rotor. Additionally, integrating heat exchange channels into the rotor presents issues related to limited space, structural complexity, and leakage. Therefore, a more stable and reliable thermal coupling method is essential to overcome these limitations. This study introduces an thermal coupling design, termed the Gas-Blow Thermal Coupling. This system incorporates an impeller-shaped, non-contact flow path within the rotating cooling channel. The impeller actively circulates a sealed gas refrigerant, enabling efficient cooling through forced convection heat exchange with the stationary heat sink. Designed for semi-permanent operation with a sealed refrigerant system, the Gas-Blow Thermal Coupling also allows for easy assembly and disassembly. Moreover, the cooling mechanism of the stationary heat sink is adaptable to various conditions, providing flexibility in the selection of cryocoolers and refrigerants.This research verifies the operational principles of the Gas-Blow Thermal Coupling and examines its feasibility as a cooling channel that meets the specified operating conditions through structural optimization and finite element method (FEM) analysis. Based on this design, a test apparatus was fabricated to simulate the thermal load of HTS rotating machinery, and its performance was experimentally evaluated and analyzed.

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Presenter: KIM, Ki Hwan

Session Classification: Thu-Af-Po.12 - Novel Devices

Contribution ID: **462** Type: **Plenary**

Sun-Mo-PL1-07: Design and Analysis of a Modular Pipe Cryogenic Cooling System for a 20 MW LTS Wind Generator

Sunday, July 6, 2025 11:30 AM (10 minutes)

Superconducting wind generators provide significant advantages in terms of power density over conventional wind generators, resulting in reduced weights and volumes, which contribute to significant cost reduction in the installation and maintenance of offshore wind turbines. An efficient cryogenic cooling system is crucial to ensure the safe and stable operation of low-temperature superconducting (LTS) excitation coils. To enhance the maintainability and economic efficiency of the superconducting wind generator, especially given the significant cost of liquid helium, the cryogenic cooling system of the 20 MW LTS excitation wind generator adopts a modular cryostat structure and utilizes a helium pipe cooling technology. The generator design includes a stationary armature and rotating LTS excitation windings supplied by rotary transformers, thereby eliminating the use of brushes and slip rings and reducing operational fault rates. Additionally, the wind generator experiences frequent start-ups and shutdowns throughout its operation. Achieving efficient and stable cryogenic cooling for both rotating LTS coils and those stationary at any angle using pipe cooling technology presents a novel and challenging task.

This paper presents the detailed structural design of the modular cryostats and the pipe cooling system for a 20 MW LTS wind generator, along with an analysis of the effectiveness and heat transfer performance of the cryogenic system. The structure of helium pipes has been optimized with the aim of enhancing the thermal efficiency between the LTS coils and the cryocooler cold head. Considering the influence of gravity, the analysis investigates the flow characteristics of helium gas and liquid helium, as well as the overall heat transfer efficiency, in pipes under both rotating conditions and stationary conditions at various angles. By incorporating the calculated thermal loads on the LTS coils, such as conductive heat leakage, radiative heat leakage, and current lead heat leakage, the analysis determines the temperature differences between the coils and the cold head during both rotating and stationary conditions. This analysis validates the effectiveness of the pipe cooling system.

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Session Classification: Plenary 1: Young Scientist Plenary

Contribution ID: **463** Type: **Contributed Oral**

Sat-Mo-Or4-03: STEP TF cable and remountable joint prototype testing

Saturday, July 5, 2025 12:15 PM (15 minutes)

The Spherical Tokamak for Energy Production (STEP) is a prototype fusion power plant, planned to be operational in the 2040s. STEP TF coils consist of cables operating at 90kA of current with a peak-field on coil of 16T. These cables are jointed together through a remountable interface at multiple locations in the coil pack which allow for remote maintenance. The joints are intended to operate at 1 nΩ with a background field of 5T on average. Over the course of the last year, the STEP program has worked with Advanced Conductor Technologies (ACT) to develop the STEP TF cable by developing a vacuum pressure impregnation (VPI) manufacturing process for the cable. Two sub-scale cable legs with a re-mountable joint have been tested at SULTAN.

Mechanical and electrical model verification was conducted using shorter cables of length 0.5m –1m with an assortment of tape level tests. Tape critical current degradation under axial strain, transverse compression and transverse tension were measured, feeding into a mechanical model that was used to predict cable level behaviour. Several 0.5m length cables were manufactured using VPI and attested to failure in a 5-point bend test. Critical current degradation of the cable was captured using an ANSYS model, which was used to design the SULTAN legs. A series of electrical tests have been conducted to understand the performance of the joint and Multiphysics models have been built to enable model verification that is fed back into the concept design.

This paper outlines the advances made in manufacturing process, quality inspection of solder impregnation through CT, microscopy, inter-tape resistance at various cable lengths (0.5m, 1m, 3.5m) and the results of the test campaign at SULTAN. The SULTAN campaign consists of measurements of the critical current, temperature and joint resistance. Mechanical cycling has been conducted to check for the robustness of the cable. A series of temperature, voltage and hall measurements have been compared to multiphysics models of the test article developed in H4C, Ansys CFX and ANSYS mechanical to predict cable and joint performance. This activity is a major de-risking exercise with learnings fed back into the design of the jointed TF coils.

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Session Classification: Sat-Mo-Or4 - Technology for Fusion Reactors I

Contribution ID: **464** Type: **Poster**

Sat-Mo-Po.07-02: Thermo-mechanical design of a ReBCO upgrade for normal conducting beam line magnets

Saturday, July 5, 2025 9:30 AM (1h 45m)

The high-energy beam line infrastructure at GSI, Darmstadt, connecting accelerators and experimental areas, is commonly realized using normalconducting electromagnets. Depending on the duty cycle, each magnet consumes up to 43 kW of DC electric power.
This work presents a study on a future modular upgrade path for the beam line magnets with respect to energy consumption. The concept aims to reuse all parts of the magnet while replacing the coil package.
The study presents the thermo-mechanical design for a drop-in replacement of a normalconducting winding package with a ReBCO racetrack winding package. Taking the results of the AC loss modeling as input parameters for the selection of a cryocooler, the thermal design was built around a dry cooling concept.

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Presenter: Dr WINKLER, Tiemo

Session Classification: Sat-Mo-Po.07 - HTS Magnets

Contribution ID: **465** Type: **Poster**

Wed-Af-Po.11-02: Multiphysics verification and validation of STEP toroidal field cable and remountable joints

Wednesday, July 2, 2025 2:30 PM (2 hours)

The Spherical Tokamak for Energy Production (STEP) is a prototype fusion power plant, planned to be operational in the 2040s. The STEP concept depends for its continuous operation on a system of high-temperature superconducting (HTS) magnets. The Toroidal Field (TF) magnets are required to be re-mountable, allowing for the vertical maintenance strategy adopted by the STEP programme. Verified and validated multiphysics analysis is essential for design and performance prediction of the STEP TF cable, re-mountable joints, and coils.

Electrical, Electromagnetic (EM) and structural-thermoelectric analysis of joint resistance has been performed in FEMM, ANSYS, APDL and COMSOL, using different formulations and degrees of complexity. The results are compared to test results, and a strategy is proposed for future analysis, which must consider the global EM forces acting on the joints. Transient thermal-EM analysis of cables to be tested at the SULTAN facility has been performed in ANSYS CFX and ANSYS APDL and verified against the H4C code developed by Politecnico di Torino for HTS cables. This analysis includes thermal hydraulics for the coolant channel, and in the case of ANSYS CFX a 3D CFD region. The fluid-thermo-electric model is used to determine the critical current and temperature behaviour of short cables along with voltage and temperature measurements. This is a multi-pronged approach to verify the critical current of cables. Structural analysis has been performed on ANSYS mechanical and verified against short cable tests. This has been used to size the TF cable tested at SULTAN with remountable joint.

This work leads to a structural-thermo-electric model capable of capturing the current distribution, joint resistance, joint pressure distribution, structural loads, stresses, strains and impact on critical current for a remountable TF coil at scale.

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Presenter: TIPPETTS, Sam (UKAEA)

Session Classification: Wed-Af-Po.11 - Modelling of Fusion Conductors and Coils I

Contribution ID: **466** Type: **Poster**

Sat-Mo-Po.02-07: 3D Mechanical Design of a Superconducting Dipole for Next-Generation Ion Gantries

Saturday, July 5, 2025 9:30 AM (1h 45m)

The Superconducting Ion Gantry (SIG) project is part of a collaborative effort between INFN, CERN, CNAO, and MedAustron to improve cancer treatment through the development of lightweight, compact ion gantries. These systems aim to enhance patient care by enabling precise, non-coplanar irradiation with reduced damage to surrounding healthy tissues. Central to this effort is the design of a 4 T curved superconducting dipole magnet, based on Nb-Ti Rutherford cables, with a curvature radius of 1.65 m and an 80 mm aperture, tailored for a 430 MeV/u carbon ion gantry.
This work focuses on the mechanical challenges posed by the magnet's high curvature, maintained by two curved steel clamps, and the use of indirect cooling systems. A 30° demonstrator is under development as a proof of concept for the final 45° dipole, validating both the magnet's design and the proposed assembly technique.
Building on previous studies, this work presents a complete 3D FEM analysis of the SIG dipole magnet's support structure. The vertical tie-rod system is dimensioned to provide preload, compensating for differential thermal contractions and maximizing contact between the coil, collars, and yoke, while respecting structural limits. Additionally, the horizontal preload system is designed.

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Session Classification: Sat-Mo-Po.02 - Magnets for Other Medical Application III

Contribution ID: **467** Type: **Poster**

Thu-Mo-Po.07-04: Design optimization method of permanent magnet for open MRI using dot sensitivity analysis

Thursday, July 3, 2025 8:45 AM (2 hours)

The demand for magnetic resonance imaging (MRI) devices with low cost and reasonable weight continues to increase as applications keep requiring diverse fields of view (FOV). In response to this demand, research on open MRI employing permanent magnets has been actively pursued.
The use of permanent magnets eliminates the need for power consumption and cooling systems, making the setup environment for MRI devices significantly more cost-effective. Moreover, as long as the operational temperature remains below the Curie point, deviations in magnetism by external effects do not need to be considered.
To maintain a portable size and low weight while ensuring the homogeneity of the static magnetic field within the FOV, researchers develop numerous design methods of permanent magnets.
There are several methods to optimize the shape and topology of magnets or magnetic materials in various applications. These include gradient-free approaches such as genetic algorithms and gradient-based approaches that use sensitivity analysis. Previous studies proposed design optimization methods that utilize continuum sensitivity analysis to optimize the orientation and position of magnets or the shape of magnetic materials.
Optimization based on continuum sensitivity offers advantages compared to gradient-free methods, such as flexibility in defining design variables and independence from discrete models. However, gradient-based methods have limitations, including dependency on the initial shape and a tendency to converge to local optimum solutions.
In addition, earlier design approaches use finite element methods (FEM) to numerically analyze the system with high accuracy. During the optimization process, iterative finite element analyses result in long computation times and costs.

In this paper, we propose a design method for permanent magnets in the open MRI device by applying the advantages of the aforementioned approaches. We introduce a simplified algorithm based on dot sensitivity, a concept that falls within the continuum topology sensitivity.
The permanent magnet dot sensitivity is defined as the change in the objective function when a permanent magnet dot is introduced into a vacant region. This derivation uses an analytical solution for the magnetic field within the dot created under a uniform external field. The magnitude and direction of the permanent magnetization are assumed to be uniform and fixed, respectively.
The dot sensitivity distribution over the design domain is computed in a numerically modeled system using FEM. This distribution is then used to derive the permanent magnet configuration that satisfies the desired field distribution.
The process begins by discretizing the design domain into □×□ grid of cells. Cells are randomly selected to integrate dot sensitivity within each selected region. This integrated value is referred to as cell sensitivity. Among all cell configurations, the permanent magnet distribution yielding a cell sensitivity most close to the integral value of the objective function in the initial model is identified. The configuration with the fewest number of selected cells is the optimized solution.
To demonstrate the applicability of the proposed method for open MRI magnet design, the C-shaped and H-shaped magnets were designed. The derived results showed that the method achieved field homogeneity using a low quantity of magnets. The designed geometries, assumptions, and specifications will be detailed in the full paper.
In this paper, permanent magnet dot sensitivity formulations are derived for a restricted application with fixed magnetization direction, and the optimization process is established. In the future

work, the method may be extended to systems with variable magnetization directions, such as the Halbach cylinder, which offers advantages in weight reduction.

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Session Classification: Thu-Mo-Po.07 - Design Optimization

Contribution ID: **468** Type: **Contributed Oral**

Wed-Mo-Or3-04: THEVA - High-Performance REBCO HTS tapes for high-field applications: advancements in medical imaging and fusion energy.

Wednesday, July 2, 2025 12:00 PM (15 minutes)

High-temperature superconducting (HTS) REBCO tapes are being developed for practical use in high-field applications such as medical imaging and nuclear fusion. These tapes achieve current densities exceeding 800 A/mm² at 20 K and 20 T, made possible by incorporating artificial pinning (AP) particles that enhance their magnetic field resilience and overall performance. Mechanical stability is also a crucial focus in our development, as the tapes must withstand the strong forces encountered in high-field magnets, ensuring that they maintain performance and reliability.

In the Filaments4Fusion project, the focus was on developing REBCO tapes with reduced AC losses, enhancing their performance for fusion magnets. Within the new HTS4Fusion project THEVA is developing JANUS wire, i.e. assembled HTS-wires with broad, angular symmetric critical current distribution offering a wide tolerance margin for use in fusion magnets.

The REBCO tapes are being integrated into advanced medical imaging systems to meet the increasing demand for high-field magnets in healthcare. Ongoing collaborations with medical technology partners demonstrate their potential in next-generation MRI systems, including a 14T full-body scanner.

Key findings from the SuperEMFL project, aimed at achieving 40+ T all-superconducting user magnets, include successful testing of the tapes under extreme conditions. The tapes were tested in stacked coil configurations, demonstrating excellent winding ability and mechanical stability under high magnetic fields

Acknowledgments

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Session Classification: Wed-Mo-Or3 - REBCO Manufacturing

Contribution ID: **469** Type: **Poster**

Sat-Mo-Po.05-09: Quench behavior of graded REBCO tapes after heat treatment

Saturday, July 5, 2025 9:30 AM (1h 45m)

REBCO tapes are promising material for the
construction of high field magnets because of large engineering
critical current densities at high field, however, the slow normal zone propagation velocity (NZPV) makes the protection against
quenches a critical issue. Stability margin of REBCO cables is
two or three orders of magnitude greater than that of lowtemperature superconducting cables, which leads to a much
slower quench propagation in REBCO cables. On the other hand, heat treatment is a key process to ensure stability of the high
temperature superconductor (HTS) cable. Thus, the main aim of
this article is to analyse the quench behaviors of graded REBCO
tapes with different critical current after heat treatment. To
control the critical current of graded REBCO tapes precisely, heat treatment is taken for 4-mm-wide REBCO conductors under different temperature gradients while maintaining the
same heating time in a vacuum tubular furnace and tested them
to get the relation between heating time and critical current in 77
K. Besides, NZPV of these tapes with various critical current was
investigated at the same current margin (80% Ic) the finding is
that it was more affected by the transport current than the margin. When heated for 60 minutes, the NZPV of the tapes was 1.2 times larger than that of without heat treatment, independent of the temperature. Afterwards heating time has changed, realizing the velocity was positively related to heating time. A
conclusion is drawn that the reason of this tendency is the change of the interlayer resistance of the tape by heating.

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Session Classification: Sat-Mo-Po.05 - Quench Detection and Protection IV

Contribution ID: **470** Type: **Poster**

Fri-Mo-Po.03-03: Passive shimming of a 7T cryogen-free MRI superconducting magnet by iron strip arrangement

Friday, July 4, 2025 9:30 AM (1h 45m)

The conventional iron matrix shimming method is sensitive to positional variations, which significantly impacts the magnetic field homogeneity of small-aperture 7T/54mm cryogen-free MRI superconducting magnets. This study aims to develop a robust, adjustable shimming method to improve magnetic field uniformity and precisely cancel low-order harmonics in these sensitive systems. A set of circumferential thin iron strips is attached to the surface of the gradient coil, with their positions and dimensions optimized using a genetic algorithm. The optimization adjusts the position of the strips in both the radial and axial directions to minimize interactions of iron strips and improve overall field homogeneity. The results show that the peak field homogeneity improved from 11.12 ppm to 6.66 ppm after shimming, a 40.11% improvement. The method successfully reduces first-order harmonics, although the cancellation of second-order harmonics requires further refinement. Additionally, the magnetic field drift after shimming is reduced to less than 0.1 ppm, demonstrating the method's robustness. This approach is more flexible and easier to implement than traditional methods, offering a reliable solution for small-aperture MRI superconducting magnets. Future work will focus on further reducing field homogeneity to 2-3 ppm for even higher precision.

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Session Classification: Fri-Mo-Po.03 - Magnets for MRI

Contribution ID: **471** Type: **Poster**

Fri-Af-Po.06-09: Progress report and future plans for a 20 T, 50 mm room temperature bore high-homogeneity all-HTS magnet with conduction-cooled system

Friday, July 4, 2025 2:00 PM (2 hours)

High-temperature superconductors (HTS) are indispensable for producing magnetic fields exceeding 20 T, a subject that has attracted substantial research efforts in recent years. This study aims to develop a conduction-cooled all-HTS magnet capable of generating a 20 T magnetic field with a 50 mm room temperature bore. The magnet has been designed to operate at a maximum temperature of 20 K using hybrid HTS tapes. To address mechanical and electrical challenges, the design incorporates a stainless steel co-winding approach to mitigate high stress while maintaining optimal turn-to-turn contact resistance. Additionally, a solderless joint method has been employed for connecting double pancake coils (DPCs), effectively eliminating corrosion issues caused by flux. So far, 8 out of the 18 DPCs required for the full magnet have been partially fabricated and tested, achieving a magnetic field of approximately 5.4 T. Moving forward, the remaining components will be integrated to complete the 20 T magnet.

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Session Classification: Fri-Af-Po.06 - High Field HTS Solenoids

Contribution ID: **472** Type: **Poster**

Wed-Af-Po.04-04: Thermal and soldering effects on REBCO HTS tapes: optimizing joint reliability for high-field magnets

Wednesday, July 2, 2025 2:30 PM (2 hours)

High-Temperature Superconducting (HTS) magnets, composed of multiple pancake coils made from Second Generation (2G) HTS tapes, offer significant advantages due to their superior performance in elevated magnetic fields and temperatures compared to traditional low-temperature superconductors. A critical aspect of manufacturing these magnets is creating reliable joints, which transfer current between pancake coils and connect short tape lengths. The quality of these joints directly influences the magnet's overall performance and operational stability. Among the various joint techniques, non-superconducting soldered joints are considered the most cost-effective and practical. However, thorough testing is essential to ensure these joints do not compromise the superconducting properties of the tapes due to heat and solder application.

This study introduces a comprehensive approach to test and characterize HTS tapes for better joint reliability in magnet applications. The samples were subjected to controlled heating at temperatures ranging from 170 ℃ to 250 ℃ for varying durations. This step aimed to simulate the thermal exposure typically encountered during soldering processes and magnet operations. Another set of samples underwent pre-tinning with Sn60Pb40 solder at selected temperatures. This process involved applying melted solder to the tape to evaluate its impact on the tape's surface and overall superconducting quality. After each treatment (heating or pre-tinning), critical current measurements were conducted at 77 K (self-field). This approach allowed us to isolate the effects of direct heat exposure from the impact of melted solder on the tape surface, offering a deeper understanding of how different thermal processes influence the tape's integrity. Notably, critical current degradation following pre-tinning could be attributed to the delamination of the tape's top layer, driven by thermal-induced contraction.

Practical challenges in joint preparation, such as repetitive heating during soldering, were simulated to assess potential damage under realistic conditions. Statistical reliability was ensured by testing a large number of samples under identical conditions, allowing us to identify consistent trends across multiple datasets.

The Rare-Earth Barium Copper Oxide (REBCO) tapes tested were sourced from world-leading manufacturers. Variations between tapes from different manufacturers and batches are currently being analyzed. These outcomes are expected to provide insights into acceptable thermal limits for soldering without compromising superconducting integrity. The obtained parameters will be crucial into optimizing HTS magnet coil design for tapes from different manufacturers, ensuring enhanced reliability and performance.

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Session Classification: Wed-Af-Po.04 - HTS Joints

Contribution ID: **473** Type: **Poster**

Thu-Af-Po.01-10: Turning points in the application of superconductivity to magnets

Thursday, July 3, 2025 2:00 PM (2 hours)

The report will explore the societal context of the major turning points in the application of superconductivity that have been crucial for the development of magnet technology. This is relevant in that we are now at a point where a further breakthrough is necessary to enable the development of affordable high field magnets (16 to 20 tesla dipoles), appropriate for series production and economical use in particle accelerators. Analysis of the historical context associated with previous watershed moments may indicate ways to create an environment conducive to bringing forth the next such turning point.

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Session Classification: Thu-Af-Po.01 - Accelerator Magnets II

Contribution ID: **474** Type: **Poster**

Sat-Mo-Po.01-05: Fabrication of a straight canted cosine-theta prototype magnet for hadron therapy

Saturday, July 5, 2025 9:30 AM (1h 45m)

Canted Cosine Theta magnets are a very promising layout for applications in small accelerator systems, for example for the gantries needed at hadron therapy facilities. A 1-meter-long, straight and combined function magnet demonstrator with 80 mm aperture diameter, 4 T central field and 5 T/m quadrupole component is under development in the framework of the European-funded project IFAST. The main purpose of this demonstrator is to develop competencies and expertise about the CCT layout and explore the possibility of implementing a combined function CCT magnet. The design has been reported elsewhere. This paper includes details about the fabrication of this demonstrator, describing the techniques and tooling used in each step: machining, winding, wax impregnation and assembly. Special attention is paid to the splices since the cable is a twisted rope of six NbTi wires around a central copper wire.

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Session Classification: Sat-Mo-Po.01 - Magnets for Other Medical Application II

Contribution ID: **475** Type: **Poster**

Wed-Mo-Po.11-05: Development of multi-stage compensation coil preserving the magnetic distribution for FTPMF

Wednesday, July 2, 2025 9:15 AM (2 hours)

The flat-top pulsed magnet field (FTPMF) can achieve the fields above 40 T with long duration, which enables the development of the terahertz gyrotron of 1THz with the operation width longer than 1 ms. The performance of the gyrotron is significantly influenced by the stability of FTPMF. Using a small compensation coil built into the bore of the magnet is a practical method to achieve the stability of FTPMF better than 100 ppm. However, the fields generated by the compensation coil can lead to the distortion of the magnetic fields distribution, which will cause the gyrotron to be unable to operate. Therefore, in this paper, we proposed a multi-stage coil to compensate the pulsed magnetic field in order to achieve high stability of FTPMF without affecting the magnetic distribution on the axis of the gyrotron. Firstly, in order not to change the magnetic distribution, the multi-stage coil need to generate the field with the same distribution on the axis as that generated by the magnet. An optimization model based on particle swarm optimization algorithm (PSO) is established to design the number of turns, dimensions, and current proportion of each coil in the multi-stage coil. Secondly, the coupling between each coil and the magnet will influence the currents in each coil. To eliminate the coupling, the external series coupling transformers is utilized to overcome the mutual inductance. Finally, a 40 T flat-top pulsed magnetic field with the stability better than 100 ppm and without changing the magnetic distribution on the axis is achieved.

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Session Classification: Wed-Mo-Po.11 - High Field Pulsed Magnets I

Contribution ID: **476** Type: **Poster**

Wed-Af-Po.12-06: Design and Operation of a 42-MW Highly Stabilized Power Supply at the CHMFL

Wednesday, July 2, 2025 2:30 PM (2 hours)

The 42-MW highly stabilized power supply, developed by the High Magnetic Field Laboratory, Chinese Academy of Sciences (CHMFL), successfully energized a newly designed water-cooled resistive magnet, achieving a world-record magnetic field of 42.02 T in September 2024. This power supply system is composed of a newly developed 14-MW power supply in parallel with a pre-existing 28-MW unit. The 14-MW power supply integrates high-voltage Static Var Generator (SVG) technology, which replaces the conventional power factor correction method used fixed-capacitor banks, enabling dynamic reactive power compensation and stabilization of the grid voltage. Additionally, a novel series-connected active filter has been developed to further reduce current ripple. The active filter features lower losses, compact size, and easier control. This paper provides a detailed description of the design, testing processes, and operational data analysis of the 42-MW power supply system under the 42.02-T resistive magnet. Furthermore, future optimization strategies for the power supply system are discussed.

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Session Classification: Wed-Af-Po.12 - Power Supplies

Contribution ID: **477** Type: **Plenary**

Sun-Mo-PL1-03: Quench Dynamics of REBCO High Temperature Superconductors

Sunday, July 6, 2025 10:50 AM (10 minutes)

Magnet technologies employing REBCO high temperature superconductors (HTS) have bloomed over the last decade. Many flagship projects are pushing HTS technologies to the boundaries of achieving reliable high magnetic field. Nevertheless, quench protection of an HTS magnet remains a challenge for designers, which must be addressed to enable more practical applications of HTS magnets. That is, there is yet no definitive strategy to make a quench protection scheme for an HTS magnet, no matter the turn to turn is insulated or not. Despite the remarkable high field achieved with the no-insulation coils, its passive quench protection has not been fully quantitatively described, making it difficult to design a magnet that can rely solely on this method to survive any quench event. For insulated HTS coils, there is still no strong evidence to suggest if quench detection by resistive voltage is reliable or not. Meanwhile, other novel quench detection approaches have yet to fully demonstrate their efficiency and reliability. Another challenge regarding quench protection of an HTS magnet is what active quench protection method is available. The dump resistor is only useful for insulated coils, and one must carefully balance the magnet inductance and the operating current. Other methods to heat up the whole coil like quench heater and CLIQ could be extremely inefficient for HTS due to its high critical temperature and correspondingly high enthalpy. Beyond these technical issues, a more fundamental problem is, what could be the reason that really quenches a HTS magnet? In view of these, this talk will review the extensive experimental and numerical research conducted around these issues in the past decade to enhance our understanding of HTS quench dynamics that specially focusing on the thermal and electrical processes. The insights gained from such research would bring us one step closer to developing a mature and reliable quench protection scheme for HTS magnets.

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Session Classification: Plenary 1: Young Scientist Plenary

Contribution ID: **478** Type: **Poster**

Wed-Mo-Po.06-08: A New Rotor Permanent Magnet Flux-Switching Motor With V-shaped Magnetic Poles

Wednesday, July 2, 2025 9:15 AM (2 hours)

The rotors of conventional rotor flux switching permanent magnet (R-FSPM) motor are all fractured and require non-magnetic materials for support to avoid the permanent magnetic field being closed in the rotor, which will reduce the mechanical robustness of the rotor. In order to overcome the above limitations, a V-shaped combination of magnetic poles rotor permanent magnet flux-switching motor is proposed in this paper. The key innovation of the proposed motor is its new rotor topology with the unique arrangement of the auxiliary PMs based on combined magnetic poles to ensure that the flux produced is not short-circuited via the rotor core but rather contributes to the air-gap flux to maximize the output torque production. The PMs materials of proposed motor is composed of NdFeB and ferrite. It reduces the use of NdFeB materials and has the characteristics of high performance and low cost. Compared with the separated rotor parts, the proposed motor of embedded V-shaped can enhance the rotor-side flux linkage coupling, thereby increasing the amplitude of the air gap magnetic field density by adjusting the ratio to increase the air gap flux density.

This paper first introduces the detailed working principle of the proposed motor, and analyzes the winding, feasible stator slot and rotor pole combination of the motor. The stator-slot filling factor analysis of the proposed motor is also presented. And then based on the analytical model of permeability-magnetomotive force, the air gap flux density of the 20/11 the proposed motor is calculated, and the dominant working harmonic order is analyzed. Under no load conditions, the proposed motor significantly increases the amplitude of the 9th and 11th effective working harmonics, and increases the amplitude of the 21st, 28th and 33rd higher-order working harmonics, thereby increasing the output torque.

Subsequently, Based on the multi-objective optimization, the sensitivity analysis of the structural parameters of the motor is carried out, and the response surface model is established. The optimization value of the structural parameters of the motor is obtained by the multi-objective genetic algorithm. Finally, a two-dimensional finite element model is established. In the optimization process, the number of PMs in the two configurations is limited to the same. Finally, compared with the conventional type , the proposed motor has improved power factor and efficiency. Specifically, the output torque is increased by 20.15 %, while the torque ripple is reduced by 2.57 %.

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Session Classification: Wed-Mo-Po.06 - Rotating Machinery I

Contribution ID: **480** Type: **Contributed Oral**

Sun-Mo-Or1-05: DC and AC characterization of DTT superconducting cabled-in-conduit-conductor (CIC) samples

Sunday, July 6, 2025 9:15 AM (15 minutes)

The DTT magnetic system is mainly constituted by the following superconducting coil sets: 18 Toroidal Field (TF) magnets, 6 external Poloidal Field (PF) coils and a stack of 6 independently fed Central Solenoid (CS) modules. The PF coils system, characterized by a full top-down symmetry, is realized in Nb3Sn (PF1 and PF6) and NbTi (PF2, PF3, PF4 and PF5). This work is focused on the SULTAN tests of the Nb3Sn PF conductors, and of the TF production samples conductors. These tests are carried on to confirm the design choices and to deal with a crucial aspect concerning Nb3Sn Cable-In-Conduit Conductors (CICCs), that is to manage the risk of the possible performance degradation with cyclic Electro-Magnetic (EM) and thermal loads.
The DTT PF16 SULTAN sample was made of two distinct Nb3Sn CIC sections, namely 'PF16-A' and 'PF16-B', differing for the cabling twist pitch sequence and joined at the bottom. Both sections were made with ITER like strand wires produced by OST and were designed to work in DTT at 28.3 kA at 9.2 T peak field. The PF16 characterization comprised 6000 electro-magnetic (EM) cycles and two warm-up-cool-down (WUCD) steps, and in detail it included: pressure drop measurements as a function of the mass flow rate, AC measurements with and without background magnetic field and transport current on the virgin conductors, on cyclic loaded conductors and after WUCDs; DC tests at 8T/28.3 kA with intermediate EM cycles at 8 T/28.3 kA before and after WUCDs; DC tests at different Lorentz force loads to investigate the conductors'strain state, Trapezoidal pulsing and Minimum Quench Energy tests at 8 T/28.3 kA after cycles and WUCDs.
Concerning the TF production samples tests, the measurements aimed at confirming the excellent results of the qualification sample, including one WUCD cycle and 1000 EM cycles. Tests comprised pressure drop measurements as a function of the mass flow rate, AC measurements with and without background magnetic field and transport current on the virgin conductors, on cyclic loaded conductors and after WUCD, DC tests at 10.85T/42.5 kA with intermediate EM cycles at 10.85 T/45kA before and after WUCD; DC tests at different Lorentz force loads to investigate the conductors'strain state
In this work the results of the analysis of AC and DC tests both concerning PF16 and TF conductors will be presented and explored in depth.

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Presenter: FIAMOZZI ZIGNANI, Chiarasole (ENEA)

Session Classification: Sun-Mo-Or1 - Technology for Fusion Reactors II

Contribution ID: **481** Type: **Poster**

Wed-Af-Po.04-05: Development of 600 A-class current leads for cryocooler-cooled devices using copper and REBCO wires

Wednesday, July 2, 2025 2:30 PM (2 hours)

To achieve a controllable operating temperature for superconducting magnet devices, the development of cryocooler-cooled superconducting magnets has garnered significant attention. Typically, the excitation current of commercially available cryocooler-cooled superconducting magnets ranges from approximately 100 to 200 A. However, increasing the excitation current of superconducting magnets is desirable for applications such as superconducting magnetic energy storage (SMES) systems in electric power systems. Achieving a high-current coil winding requires careful design and development of current leads that connect the room-temperature and low-temperature sections.

To address the challenges and design considerations associated with achieving high current flow through cryocooler-cooled current leads, the authors developed and tested 600 A-class current leads for cryocooler-cooled devices. In this research, the authors utilized a two-stage GM cryocooler, with a cooling capacity of approximately 60 W at 70 K in the first stage and about 15 W at 20 K in the second stage.

The current leads are composed of copper and high-temperature superconducting (HTS) components to minimize heat transfer to the low-temperature section. Initially, the copper parts were placed between the first stage of the cryocooler and the room temperature section. The optimal length-to-cross-sectional area ratio is typically determined through numerical analysis, using the average resistivity and thermal conductivity values over the temperature range to reduce conductive and Joule heating of the copper current leads. However, experimental results revealed that such designs might lead to localized overheating of the current leads. To address this issue, the authors substituted the physical property values at each temperature into a differential equation to obtain the temperature distribution through numerical analysis, thereby optimizing the shape ratio. With this new design approach, the optimal length-to-cross-sectional area ratio was $6.32 \times 10^3\ \mathrm{m}^{-1}$ at the operating current of 600 A, between 300 K and 60 K. To prevent overheating caused by Joule heating, the length of the copper parts should be designed to be 90 % of the optimal length. The authors demonstrated that a flat braided copper current lead with an effective cross-sectional area of $60\ \mathrm{mm}^2$ and an effective length of 341 mm could prevent localized overheating, as confirmed through experimental testing.

The authors conducted a short-circuit current test on the copper parts assembly of the current leads. The test results showed that the temperature at the low-temperature end, connected to the first stage of the cryocooler, remained below 70 K even when a current of 600 A was applied for 300 seconds. These findings demonstrate the feasibility of a 600 A-class cryocooler-cooled current lead and suggest that the research outcomes could serve as a model for cooling current leads in high-current applications.

On the other hand, for the HTS current leads connecting the first and second stages of the cryocooler, it is essential to limit conductive heat to 15 W at 20 K. This requirement is met using two strands of 12 mm-wide REBCO tape wires manufactured by Fujikura Ltd. The critical current of the REBCO wires is 719 A at 77 K in a self-magnetic field. This paper summarizes the design conditions and the test results of the 600 A-class cryocooler-cooled current leads using copper and REBCO wires.

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Presenter: YAJIMA, Kenta (Meiji Univ.)

Session Classification: Wed-Af-Po.04 - HTS Joints

Contribution ID: **482** Type: **Poster**

Sat-Mo-Po.09-01: Energy Cycle Efficiency of Superconducting Magnetic Energy Storage

Saturday, July 5, 2025 9:30 AM (1h 45m)

Superconducting magnetic energy storage (SMES) is a promising candidate for electric power compensation. The target applications of SMES are widely covered with voltage sag, instant shortage, power stabilization, frequency control, load fluctuation, and load leveling. High-temperature superconductors are expected to reduce refrigeration energy requirements for superconducting coils. Particularly, REBCO tapes are strong candidates for high-field magnets because they keep a higher critical current density in a high magnetic field range. In addition, the Hastelloy substrate of the REBCO tapes can be used as support structures for electromagnetic forces. Reversible stress with a 99% critical current recovery is from 610 to 1410 MPa. However, the winding configuration of superconducting coils should be optimized to enhance the stress limit caused by electromagnetic forces.
Based on the virial theorem, the force-balanced coils (FBCs) can balance the electromagnetic forces through a helically wound configuration and minimize the required mass of support structures for energy storage. When the allowable stress and the mass density of the support structure are 400 MPa and 8000 kg/m3, SMES with a conventional coil configuration, such as a solenoid and toroidal field coils, stores the magnetic energy up to 25 to 50 kJ/kg. The FBCs can enhance the theoretical limit of the stored energy up to 50 to 100 kJ/kg. For reference, the theoretical limits of capacitors and flywheels are 25 kJ/kg and 42 kJ/kg. Therefore, SMES with the FBCs'configuration can realize the weight saving of the energy storage system.
This work discusses the theoretical energy cycle efficiency of SMES with the FBCs'configuration. The energy cycle efficiency is defined as the ratio of the output energy to the input energy. In SMES, the input energy should include the energy consumption of cooling systems. The radiative heat loss, the thermal conduction loss from a pair of current leads, and the AC loss in the superconducting coils mainly determine the cooling power.
On the other hand, the ampere-meters of superconductors and the coil surface are a function of the stored energy and the maximum magnetic field. The radiation heat loss is calculated from the coil surface. The AC loss is evaluated by the ampere-meters of superconductors and the operating current density due to the stress limit based on the virial theorem.
Based on the scaling law, the authors show the theoretical energy cycle efficiency determined by the stored energy, the maximum magnetic field, the mass of structures, the ampere-meters of superconductors, the cooling temperature, and cooling power and explore the potentiality of the FBCs as SMES coils. From the energy cycle efficiency viewpoint, the authors examine the feasible target application of SMES depending on the cooling temperature and the type of superconductors, such as NbTi, MgB2, and REBCO, compared to other energy storage systems.

Author: Prof. NOMURA, Shinichi (Meiji University)

Co-author: Dr XU, Hang (Meiji University)

Presenter: Prof. NOMURA, Shinichi (Meiji University)

Session Classification: Sat-Mo-Po.09 - Energy Storage/SMES, Levitation and Magnetic Bearings

Contribution ID: **483** Type: **Poster**

Fri-Af-Po.09-04: Investigating the electromagnetic characteristic and AC loss performance of superconducting excitation magnet in homopolar inductor generator under different speed of output response

Friday, July 4, 2025 2:00 PM (2 hours)

Aviation electric propulsion is characterized by distributed propulsion, flexible maneuverability, and high efficiency with low pollution. The aviation superconducting electric propulsion system based on the concept of direct-drive power generation from turbines, which is one of the most promising solutions for meeting the power demands of high-power aviation electric propulsion aircraft. This system uses an aviation turbine engine to directly drive a superconducting generator for efficient power generation, which is then supplied to a superconducting motor via superconducting cables to drive the fan and produce flight thrust. By decoupling the turbine from the fan and connecting a high-speed turbine to a high-speed superconducting generator, the core machine power density is enhanced. A high-efficiency superconducting motor drives the fan for large bypass ratio propulsion, which together significantly reduces fuel consumption and promotes the development of green and low-carbon aviation.
The superconducting homopolar generator(SHG) capable of operating at extremely high speed shows the potential for application in the aviation turbo-electric system. Compared to the conventional superconducting generators, SHG has the following merits: i) solid rotor allows it to operate at high-speeds. ii) HTS winding is stationary mounted on the stator, which simplifies the cooling structure and improves the reliability. The stationary superconducting excitation coil is directly exposed to a complex external vertical alternating field. The superconducting coil carrying direct current will generate AC losses, including dynamic losses and magnetization losses, which are detrimental to the operation of the superconducting excitation magnet. Especially under high-speed and high-frequency operating conditions, the alternating losses of the superconducting excitation magnet are more significant.
To meet the load requirements of electric aircraft at multiple voltage levels, the generator is connected to an AC/DC rectifier. The air-gap flux density of a permanent magnet generator cannot be adjusted, and active power switches must be used, which brings issues of reliability and additional losses. In contrast, the air-gap flux density of a superconducting homopolar generator based on electrical excitation is fully controllable. Therefore, AC/DC rectifiers can be constructed using uncontrolled diodes in the power generation system of a superconducting homopolar generator. Compared with active power switches, the use of uncontrolled diodes can improve efficiency, reliability, cost-effectiveness, and power density. In this case, the response of the output voltage is achieved by controlling the excitation current. However, to quickly establish a steady-state output voltage, the excitation current needs to reach the target value in a short period of time (usually in milliseconds). The rapid change of the excitation current poses higher AC losses for the superconducting excitation winding and increases the risk of quenching in the superconducting excitation winding.
So this paper will investigate the electromagnetic characteristics and AC loss conditions of the superconducting excitation magnet in the superconducting homopolar generator under rapid excitation rates. The models of the superconducting homopolar generator and the superconducting excitation magnet have been established. The critical current of the superconducting excitation

magnet and various alternating current (AC) loss conditions are analyzed under different output voltage response speeds. The temperature distribution and temperature rise due to AC losses are also studied. Finally, the fastest excitation rate of the superconducting homopolar generator after suppressing AC losses is explored. This research provides meaningful reference value for the safe and reliable application of superconducting homopolar generators in aviation turbine direct-drive power generation units.

Author: Dr YAN, Juzhuang (Beihang University)

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Presenter: Dr YAN, Juzhuang (Beihang University)

Session Classification: Fri-Af-Po.09 - Rotating Machinery IV

Contribution ID: **484** Type: **Poster**

Fri-Mo-Po.07-06: A two-dimensional non-linear magnetic equivalent circuit model to facilitate the preliminary design of a normal conducting quadrupole

Friday, July 4, 2025 9:30 AM (1h 45m)

Normal conducting quadrupoles have been used to focus charged particle beams in synchrotrons, beam transfer lines, medical linacs, etc. for a long time. Optimization techniques based on analytical expressions combined with the use of a numerical field analysis tool exist in the literature for the design of an optimal pole tip shape. However, the initial shape and dimensions of the remaining yoke (including the pole itself and yoke base that act as the return path) are usually less well-defined. This article discusses a design methodology for a normal conducting quadrupole based on a two-dimensional magnetic equivalent circuit. This approach considers the geometry of the entire magnet and the non-linear behavior of the yoke material, thereby eliminating the initial iterations. The design outcome of this exercise serves as a competent starting point and can then be used to refine the pole tip, pole taper, yoke size and add other geometrical features to achieve the required field quality, gradient, coil considerations, etc. by employing a finite element analysis tool. An example design study to demonstrate the proposed methodology is presented.

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Presenter: SINGH, Harshita

Session Classification: Fri-Mo-Po.07 - Accelerator Magnets III

Contribution ID: **485** Type: **Poster**

Wed-Mo-Po.12-02: Charging HTS magnet by REBCO superconducting diode bridge : Small-scale proof of concept

Wednesday, July 2, 2025 9:15 AM (2 hours)

A superconducting diode is a device whose critical current is different depending on the direction of the current. It can be obtained using REBCO tapes,in which rectified motion of flux quantum is observed [1]. In this study, we develop a concept of wireless HTS magnet charging utilizing such HTS REBCO diodes. This concept was first we introduced at the last Applied Superconductivity Conference, with a non optimized device charging only 1 A in a mini coil.
We present here a detailed study of this wireless charging structure using coupled thermo-electrical modeling, in order to estimate its potential to provide low-loss DC power supply in cryogenic environment.
The requirement for optimizing REBCO conductor for this novel application will also be discussed based on this modelling effort.
It will be shown that this concept can enable quasi-persistent mode operation in REBCO coils by compensating the eventual joint losses.
We will also present a more meaningful proof of concept featuring tens of meter of tape, enabling the charge of a lab-scale magnet.

Authors: BADEL, Arnaud (CNRS - Université Grenoble Alpes); TIXADOR, Pascal (Grenoble-INP); Prof. AWAJI, Satoshi (Tohoku University); Mr SOURICE, Hugo (CNRS - Université Grenoble Alpes); TSUCHIYA, Yuji (Tohoku University)

Presenter: BADEL, Arnaud (CNRS - Université Grenoble Alpes)

Session Classification: Wed-Mo-Po.12 - Diodes, Flux Pumps, and Switches

Contribution ID: **486** Type: **Poster**

Wed-Af-Po.05-01: Investigation of In-Field Critical Current Properties of Trifluoroacetate Metal Organic Deposition-Based Nanoparticle-Doped Y-Gd-Ba-Cu-O Coated Conductors

Wednesday, July 2, 2025 2:30 PM (2 hours)

$REBa_2Cu_3Oy$ (REBCO, where RE is a rare-earth element) coated conductors (CCs) fabricated using the trifluoroacetate metal organic deposition (TFA–MOD) method are among the most promising candidates for superconducting applications due to their low cost and excellent performance. High critical current (Ic) under magnetic fields is crucial for applications such as generators, nuclear magnetic resonance, magnetic resonance imaging, and nuclear fusion reactors. In a previous study, we successfully fabricated BaZrO3 (BZO) nanoparticle-doped Y0.77Gd0.23Ba2Cu3Oy (YGdBCO+BZO) CCs using a newly developed reel-to-reel system furnace [M. Sato et al., IEEE Trans. Appl. Supercond., 34, (2024) 3]. These 100-m-class YGdBCO+BZO CCs exhibited a highly uniform Ic distribution in the self-field at 77 K, with a minimum Ic of 102 A/cm-width at 70 K and 2.5 T. However, TFA-MOD YGdBCO+BZO CCs often contain significant amounts of second phases, such as CuO, Y2O3, and $Y_2Cu_2O_5$, which are detrimental to achieving high Ic. Thus, controlling the Ba/RE ratio in the starting solution is a key factor in reducing second-phase formation and improving in-field Ic.
In this study, we fabricated YGdBCO+BZO CCs with various Ba/RE ratios in the starting solution to suppress the second phase and enhance in-field Ic properties. The CCs with a Ba/RE ratio of 1.8 achieved a self-field Ic of 471 A/cm-width at 77 K, which is 1.25 times higher than that of CCs with a standard Ba/RE ratio of 1.5. This is attributable to the significant reduction in the second phases. This paper focuses on the in-field Ic properties of YGdBCO+BZO CCs, including their performance at low temperatures and under high magnetic fields, offering insights into further optimizing their superconducting properties for advanced applications.
This study is based on findings obtained from Project, which was subsidized by the New Energy and Industrial Technology Development Organization.

Author: SHIOHARA, Kei

Co-authors: Mr OYAMADA, Takuma (SWCC); Dr SATO, Michio (SWCC); Dr ADACHI, Kazuhisa (SWCC); Prof. INOUE, Masayoshi (Fukuoka Institute of Technology); Dr NAKAOKA, Kouichi (National Institute of Advanced Industrial Science and Technology); Dr IZUMI, Teruo (National Institute of Advanced Industrial Science and Technology)

Presenter: SHIOHARA, Kei

Session Classification: Wed-Af-Po.05 - HTS Conductors II

Contribution ID: **487** Type: **Poster**

Fri-Mo-Po.04-08: Design and Testing of Bi-2212 High-Temperature Superconducting Shim Coils for Extremely High Field NMR

Friday, July 4, 2025 9:30 AM (1h 45m)

The extremely high magnetic fields offer significant advantages in improving imaging quality and analyzing the fine structures of materials. However, these benefits critically depend on achieving high levels of B0 magnetic field homogeneity. This necessitates the development of advanced shimming technologies, which can be effectively realized using superconducting shim coils. This paper presents the design and testing of a high-temperature superconducting shim coil system for a 27 T ultra-high-field superconducting magnet with a 30 mm DSV. The design includes four sets of shim coils—Z1, Z2, X, and Y—developed using the boundary element method. To ensure smooth and reliable connections, the independent conductor paths generated by the stream function method were linked using Bézier curves. The four shim coils were subsequently mounted onto alumina ceramic carriers, which were integrated into a shimming rod for placement and testing within the magnet. Bi-2212, the only high-temperature superconductor available as isotropic round-wire conductors, is uniquely suited for extremely high-field applications. Its use supports advanced superconducting homogenization and enables the development of next-generation NMR systems operating at 1.3 GHz and beyond.

Authors: MIAO, Haotian (School of Electrical and Electronic Engineering, Huazhong University of Science and Technology); Dr WANG, Yaohui (Institute of Electrical Engineering, Chinese Academy of Sciences); Prof. SONG, Xiaowei (School of Electrical and Electronic Engineering, Huazhong University of Science and Technology)

Presenter: MIAO, Haotian (School of Electrical and Electronic Engineering, Huazhong University of Science and Technology)

Session Classification: Fri-Mo-Po.04 - Magnets for NMR

Contribution ID: **488** Type: **Contributed Oral**

Wed-Af-Or1-07: Development of a hybrid superconducting dipole magnet with the magnetic field towards 16 T

Wednesday, July 2, 2025 6:00 PM (15 minutes)

Several high-field dipole magnets have been developed at the Institute of High Energy Physics, Chinese Academy of Sciences (IHEP, CAS) for preliminary research on next-generation high-energy colliders such as the Super Proton-Proton Collider (SPPC), Future Circular Collider (FCC), and others. Following the achievement of a 12.47-T main field at 4.2 K by the LPF1 magnet in 2021, IHEP is currently involved in the production of a hybrid magnet, LPF3, with a magnetic field strength reaching 16 T. LPF3 consists of six racetrack Nb3Sn coils on the exterior, designed to generate a 13-T main field within two 55-mm apertures, with additional HTS coils inserted to boost the field strength to 16 T. Graded common-coil configuration was implemented during the fabrication of the six Nb3Sn coils. Additionally, internal-joint soldering technology was explored to manufacture the innermost two 2-in-1 Nb3Sn coils, effectively enhancing the magnet's efficiency. A shell-based support structure with dedicated hydraulic pistons was employed to replace traditional bladders for applying pre-stress during assembly. Resistive strain gauges, along with fiber optic sensors, were utilized to monitor stress distribution during the three loading steps from assembly to energization. The magnet was subjected to testing at 4.2 K, successfully achieving a main field strength of 11.47 T through two 55-mm apertures during the initial training tests. In order to maximize its higher current-carrying capacity, the inserted ReBCO coils were configured in a Block-type design, aligning the wide surfaces of the tapes with the magnetic flux. The HTS insert coil has been energized to the design current with a field delay. Details about the development of Nb3Sn coils and HTS coils will be presented.

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Presenter: Dr WANG, Chengtao (Institute of High Energy Physics, University of Chinese Academy of Sciences)

Session Classification: Wed-Af-Or1 - HTS and Hybrid Magnets for Accelerators

Contribution ID: **489** Type: **Poster**

Wed-Af-Po.08-03: Multiphysics Model for Analysis and Real-Time Operations of HTS Magnets

Wednesday, July 2, 2025 2:30 PM (2 hours)

Advanced automation tools are promising wide-range solutions for the various problems still affecting High-Temperature Superconducting (HTS) magnets, including Non-Insulated (NI) ones. State-of-the-art techniques have the potential to enable online monitoring and control of these devices, significantly enhancing their operational robustness to the extent of entirely preventing quench events, shifting the paradigm of magnet protection.
Previously, we proposed an electromagnetic model reduced using Proper Orthogonal Decomposition (POD), demonstrating its ability to preserve the accuracy of the full model while requiring only a fraction of the computational effort. We now integrate a finite-element thermal model with nonlinear material properties and introduce a novel approach to describe the hysteresis of cryogenic bath cooling. Experimental campaigns conducted on small coils in liquid nitrogen are used to validate this model.
The thermal model is then coupled with the electromagnetic model, and the coupled model is processed with model order reduction techniques. We discuss how the reduced model can effectively run with a computation time not exceeding the simulated time, i.e. in real-time. We conclude discussing some of the most relevant automation applications for the model.

Authors: Dr SANTINI, Carlo (INFN Milan, LASA laboratory); Dr NELLI, Emanuele (Politecnico di Milano and INFN Milan, LASA laboratory); Dr BALCONI, Lorenzo (University of Milan and INFN Milan, LASA laboratory); Prof. ROSSI, Lucio (University of Milan and INFN Milan, LASA laboratory); Dr STATERA, Marco (INFN Milan, LASA laboratory); SORTI, Stefano (University of Milan and INFN Milan, LASA laboratory)

Presenter: SORTI, Stefano (University of Milan and INFN Milan, LASA laboratory)

Session Classification: Wed-Af-Po.08 - Conductor and Coil Measurement/Test Techniques and Facilities I

Contribution ID: **490** Type: **Poster**

Fri-Af-Po.08-01: Experimental study on critical current degradation of MgB2 superconducting strands and developed with low-bending strain cable for force-balanced helical windings

Friday, July 4, 2025 2:00 PM (2 hours)

The authors have designed a 1-MJ-class mobile superconducting magnetic energy storage (SMES) system. The SMES coil features a force-balanced helical coil (FBC) to reduce weight, as the FBC minimizes the mass required to support the induced electromagnetic forces.

In this study, the authors propose using 0.67-mm diameter MgB2 strands, manufactured by Hitachi, Ltd., for winding the FBC. Initially, the FBC was designed with an MgB2 Rutherford cable to enhance the current capacity of the winding. However, the bending strains experienced by MgB2 strands during the fabrication of Rutherford cables can degrade the critical current of the superconducting wire. To address this issue, the authors suggest an alternative approach: winding the FBC with a stranded cable that induces smaller bending strains of MgB2 strands.

The proposed stranded cable consists of 12 MgB2 strands twisted around a central copper strand with a diameter of 1.92 mm. Unlike Rutherford cables, this design eliminates the need for significant deformation of the MgB2 strands at the edges, thereby reducing bending strains. As a result, the impact of deformation on critical current degradation is minimized, enhancing the overall current capacity of the cable.

Numerical analysis indicates that the bending strains of the MgB2 strands in a stranded cable with a twist pitch of 80 mm are less than 0.5%. This suggests that the allowable current for the stranded cable will be higher than 1200 A at 20 K.

In this presentation, the authors will report on the critical current experiments conducted on MgB2 strands that were bent prior to heat treatment and will discuss the critical current characteristics of MgB2 strands under bending strains before heat treatment at first. During these experiments, the MgB2 strand samples were cooled using a two-stage GM refrigerator, maintaining the temperature at 20 K. The critical current was measured using the four-terminal method.

Additionally, the authors will present experimental results on the critical current of MgB2 stranded cables with varying twist pitches and bending conditions. Based on these experimental findings, the study aims to evaluate the allowable bending strain for MgB2 wires and discuss design considerations for MgB2 cables and the force-balanced helical windings.

Authors: Dr XU, Hang (Meiji University); Prof. NOMURA, Shinichi (Meiji University)

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Presenter: Dr XU, Hang (Meiji University)

Session Classification: Fri-Af-Po.08 - Advances in Nb3Sn and MgB2 Conductors I

Contribution ID: **491** Type: **Poster**

Wed-Af-Po.09-07: DTT Poloidal Field Magnet System

Wednesday, July 2, 2025 2:30 PM (2 hours)

DTT (Divertor Tokamak Test) is a fusion reactor facility which is being built in the Research Centre of ENEA Frascati, to cope with the technological challenges related to the divertor system in DEMO. The magnetic system includes 18 toroidal field (TF), a central solenoid (CS) composed by 6 modules and 6 poloidal field (PF) coils. These last are solenoids based on Nb3Sn for the 2 more performing polar magnets, PF1 and PF6 (Bmax 9T, Imax=28.3kA), and on NbTi for the other 4 larger PF2 to PF5 coils (Bmax 5.3T, Imax=28.6kA). In this paper, the requirements for the operation of these coils in DTT leading to the final design and the main qualification tests are summarized. The procurement phase of the PF magnet system is also illustrated in the present work, along with the definition of possible experimental assessment of the insulation performances in relevant condition by ad-hoc manufactured mock-ups of the PFs winding pack.

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Presenter: TURTU, Simonetta

Session Classification: Wed-Af-Po.09 - Magnets for Tokamaks: Design and Analysis

Contribution ID: **492** Type: **Poster**

Thu-Mo-Po.09-01: Development and Performance Assessment of a High-Field Superconducting Conductor Testing System

Thursday, July 3, 2025 8:45 AM (2 hours)

Superconducting conductors and coils are critical components in high-field applications, requiring rigorous performance evaluation to ensure reliability and efficiency. This paper introduces the design and construction of a superconducting conductor testing apparatus, developed to assess the performance of superconducting conductors and coils under high magnetic fields. The apparatus consists of four key systems: a background magnet, a cryogenic system, a power supply system, and a measurement and control system. These systems collaboratively provide a 20 T background magnetic field, the necessary temperature range, testing currents, and data acquisition.

Finite element method (FEM) electromagnetic analysis shows that the influence of the background magnetic field and the self-field generated during current flow on the current-carrying capacity is negligible. Mechanical analysis validates that the structural design meets the anticipated performance requirements, and all components effectively fulfill their designated functions. The system demonstrates stable and safe operation.

Thermal stability analysis indicates that the cryogenic system, utilizing forced-flow helium, effectively maintains temperatures within the desired range, ensuring the apparatus meets the thermal requirements during testing. These results confirm that the testing apparatus is well-suited for reliable evaluation of superconducting conductors and coils, contributing to advancements in high-field applications.

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Presenters: Dr JIANG, Donghui (The High Magnetic Field Laboratory, Chinese Academy of Sciences); YANG, Shige

Session Classification: Thu-Mo-Po.09 - Conductor and Coil Measurement/Test Techniques and Facilities II

Contribution ID: **493** Type: **Poster**

Thu-Af-Po.05-02: Optimized design of frequency characteristics of high-sensitivity inductive coil for magnetization measurements

Thursday, July 3, 2025 2:00 PM (2 hours)

A high-sensitivity inductive coil for detecting the Haas-van Alphen oscillations of magnetic materials or calibrating magnetic field was fabricated. The coil contains part A and part B which are well compensated in applied external fields with opposite winding directions. Fabrication of a high density (>1000 turns) pick-up coil within a small sample space (diameter˜3mm) is challenging. Therefore, A higher degree of compensation, suitable sensitivity, and excellent high-frequency characteristics are key factors in the design of magnetization detection coils. However, the greater number of turns in the coil results greater inductance. When measuring high-frequency signals, the large inductance of the coil will resonate with the distributed capacitance of the measurement system, resulting in oscillations and phase lag in the measured magnetization signal.
In this study, the magnetization signal was superimposed by dividing the detection coil into different parts and collecting each part separately. Coil segmentation reduce the total inductance of each line, enabling optimization of coil frequency characteristics. A sensitivity and inductance values of coil with different structures were analyzed by finite element simulation, to find optimal structure of coil with the smallest inductance at the same precision. Combined simulation and experiment, the coil design was changed several times. Finally, we made a high frequency characteristics and high sensitivity magnetization detection coil, which is used for magnetization measurements in pulsed fields up to 60 T.

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Session Classification: Thu-Af-Po.05 - Conductor and Coil Measurement/Test Techniques and Facilities III

Contribution ID: **494** Type: **Contributed Oral**

Sat-Af-Mem1-07: Design of a REBCO large bore 10 T split-magnet and validation on prototype pancakes

Saturday, July 5, 2025 6:00 PM (15 minutes)

REBCO HTS material makes it possible to consider very high engineering current densities in coil windings even above 10 T with operation temperatures up to 30 K. In this work, we present the design of a 500 mm bore split-coil magnet made of two stacks of REBCO double-pancakes. It is developed as a platform offering eihter 10 T in a mid-plane room temperature bore for magneto-science, or up to 14 T when removing the midplane spacer, thus exceeding the state of the art for LTS background magnets. The electro-magnetic and mechanical design are presented with a focus on stress management and quench protection. The tests results of several prototype pancakes will be presented to validate key aspects of the design, from mechanical performance to dielectric strength.

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Session Classification: Sat-Af-Mem1 - Huub Weijers Memorial: High Field Magnets

Contribution ID: **495** Type: **Poster**

Fri-Mo-Po.04-02: Adaptive ferromagnetic shim design technique using recursive linear programming to reduce the manufacturing complexities

Friday, July 4, 2025 9:30 AM (1h 45m)

Accurate magnetic field correction is essential in MR applications to achieve high field homogeneity and reduce manufacturing complexities. This study proposes an adaptive shim design method that leverages recursive linear programming for efficient optimization of shim configurations. Conventional nonlinear optimization approaches, such as Sequential Quadratic Programming (SQP), often result in prolonged computational times and increased design complexity. In contrast, the proposed method uses linear programming for initial shim placement, followed by iterative refinement to enhance field homogeneity while simultaneously addressing manufacturing challenges. By incorporating a perimeter length evaluation metric to minimize the manufacturing complexities, this approach enables rapid convergence, precise field corrections, and practical applicability in the magnet shimming. The results demonstrate significant improvements in computational efficiency and overall design performance for NMR HTS magnets. The effectiveness of the new design approach will be verified through a shimming experiment conducted on an all-ReBCO NMR magnet.

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Session Classification: Fri-Mo-Po.04 - Magnets for NMR

Contribution ID: **496** Type: **Contributed Oral**

Sat-Af-Mem1-08: Experimental studies on performance of YBCO magnet in self-field and high field

Saturday, July 5, 2025 6:15 PM (15 minutes)

YBCO is one of the best choices for high field superconducting magnets due to its high current carrying capacity. We present a highly compact no-insulation (NI) magnet wound with 45-micrometer-thick YBCO high temperature superconducting (HTS) tape. A YBCO magnet with one double pancake (DP) coil generated a direct-current magnetic field of 28.20-tesla (the current is 740.4 A), the highest magnetic field generated solely by YBCO coil, at 4.2 K in self-field. Another YBCO coil with two DP coils was tested in a 34-tesla resistive magnet, and reached a 41.65-tesla central magnetic field (the current is 143.3 A). The structure of YBCO magnet, experimental test in self-field and high field were presented in this paper. The experimental results provide abundant evidence that YBCO magnets have great potential for high field application.

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Session Classification: Sat-Af-Mem1 - Huub Weijers Memorial: High Field Magnets

Contribution ID: **497** Type: **Contributed Oral**

Fri-Mo-Or5-05: PSALM for Compact Fusion Magnets

Friday, July 4, 2025 12:15 PM (15 minutes)

PSALM (Patterned Superconductors for AC Loss Minimisation) is a latest developed concept of high-current and low-loss HTS cables for high-power AC applications. In this work, samples of PSALMs with single superconducting layer are manufactured, tested, modelled, and analysed. In the experiments, the critical current degradation and the transport AC losses are measured. In the simulation, with the 3D finite element method (FEM) models based on the T-A formulation, the transport AC losses are calculated and compared with the experimental data, and the current distribution is analysed in detail. This model is then used to simulate long PSALMs which could be used in practice and calculate the transport AC losses. The losses are found over 30% lower than that of the normal HTS ReBCO tapes, which verifies the loss-reduction performance of the HTS Roebel tapes. This work provides both experimental and simulation proof of the advantage of the HTS Roebel tape as a high-current and low-loss HTS cable. It could potentially become the key to the compact fusion magnets which require high power density and suppressed losses.

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Session Classification: Fri-Mo-Or5 - HTS Conductors and Cable

Contribution ID: **498** Type: **Poster**

Wed-Af-Po.10-02: High Temperature Supra-conductor sub-scale conductor development for DEMO central solenoid magnets

Wednesday, July 2, 2025 2:30 PM (2 hours)

High temperature superconductors incarnates the future of magnet technologies. Their ability to transport higher current within higher magnetic field compared to LTS make them the perfect contender toward compact high field magnets for TOKAMAKS. This possibility would increase drastically their performances and therefore possibly clearing a path to clean and sustainable energy. Modern TOKAMAKS project such as EUROFUSION DEMO explore design using HTS or Hybrid magnets. CEA proposed a hybrid CS magnet design featuring a high field HTS conductor and a low field LTS conductor. This article will focus on the HTS conductor by introducing its subscale conductor. It is composed by a single CORC conductor featuring 120 tapes of 4 mm width. Its intended performances are a current of 20 t o25 kA at 18 T and 20 K. A sample is actually being design to qualify this sub-scale conductor in the SULTAN facility in Switzerland, which is used to qualify conductors design with a background field of 11 Tesla at nominal current. Cooling will be done by supercritical helium circulation within the sample. Sample's particularity is to use pre-tined tapes, objective is to assess the performance impact of such design before and after heat treatment. The sample will be composed by a heat treated leg a non-heat treated one. By doing so, CEA intends to demonstrate a possible mechanical stability increase under magnetic load.
Thermal hydraulics performances and AC losses will also be evaluated and presented in this paper.

This work has been carried out within the framework of the EUROfusion Consortium, funded by the European Union via the Euratom Research and Training Programme. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Commission. Neither the European Union nor the European Commission can be held responsible for them.

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Session Classification: Wed-Af-Po.10 - Development and Test of Conductors for Fusion Magnets II

Contribution ID: **499** Type: **Poster**

Wed-Af-Po.07-07: Transient finite element simulation of superconducting accelerator magnets using thermal thin shell approximation

Wednesday, July 2, 2025 2:30 PM (2 hours)

The design and operation of superconducting accelerator magnets necessitate accurate knowledge of thermal conditions to ensure their stability and performance. During the operation of these magnets, quench events can lead to complex thermal transients. Their analysis is commonly supported by detailed simulations, for which the finite element (FE) method can be used. The FE method offers robust capabilities for modelling the intricate geometries and material properties of superconducting magnets. However, accelerator magnet geometries can consist of superconducting cables with a high ratio of bare conductor thickness to electric insulation thickness. The thermal gradients across these thin insulation layers must be resolved accurately to ensure the overall validity of the simulation, for which high-quality meshes are required. This leads to many degrees of freedom (DoFs) in a classical FE discretization, resulting in significant computational time requirements, particularly since non-linear material properties are involved.

In this work, we propose to use a thermal thin-shell approximation (TSA) to improve the computational efficiency when solving the heat diffusion equation in two dimensions. The TSA collapses thin electrical insulation surfaces into lines while accurately representing the thermal gradient across the insulation thickness, thereby removing the need for a surface mesh of the insulation. Consequently, this approach significantly reduces the number of required DoFs and the computational time. The TSA method enables the implementation of arbitrary multi-layered insulation regions, including internal heat sources, such as quench heaters (QHs). Furthermore, the TSA allows boundary conditions to approximate cryogenic helium cooling via a temperature-dependent heat transfer coefficient.

In this contribution, we apply the TSA method to compute the thermal transient response of superconducting Large Hadron Collider (LHC) and High-Luminosity LHC (HL-LHC) accelerator magnets. First, the method is verified by comparison with classical FE simulations with meshed surface insulation regions for detailed models of the Nb_3Sn HL-LHC MBH and the Short Model Coil (SMC) dipole magnets. The results show that the TSA approach preserves the solution's accuracy while significantly reducing the computational time, thereby rendering it viable for full-size magnet simulation.

Second, the QH delay computed with the TSA method is compared to measurements. To this end, the thermal transient simulation is coupled to a magnetostatic solution to account for magneto-resistive effects. Third, the full capabilities of the TSA are then showcased in non-linear magneto-thermal simulations of several LHC and HL-LHC superconducting magnets.

The TSA is implemented in the multipole module of the free and open-source Finite Element Quench Simulator (FiQuS). FiQuS provides the superconducting magnet community with access to simulations of superconducting magnets, regardless of their level of expertise in modelling and simulation. The software design of FiQuS provides a user interface that separates the coil design, material composition and powering details from the numerical computing aspect. All presented multipole magnet models are generated programmatically from human-readable input text files, which aids in the reproducibility, traceability and parametrization of the simulations. The input files and source code to recreate the results are shared.

Acknowledgment. The work of E. Schnaubelt has been supported by the Wolfgang Gentner Programme of the German Federal Ministry of Education and Research (grant no. 13E18CHA) and the Graduate School CE within the Centre for Computational Engineering at TU Darmstadt.

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Session Classification: Wed-Af-Po.07 - Modelling and Analysis

Contribution ID: **500** Type: **Poster**

Fri-Af-Po.03-05: Optimizing cooling strategies for CORC-like conductors in high-field fusion applications

Friday, July 4, 2025 2:00 PM (2 hours)

Magnets remain the cornerstone technology in the development of high field fusion machines such as tokamaks. In this context, high-temperature superconductors (HTS) and the conductors derived from them are considered enabling technologies . HTS materials enable higher magnetic fields, paving the way for more compact and potentially higher-performance machines. However, the integration of these advanced materials necessitates a reevaluation of cable designs. Among these, CORC-like (Conductor On Round Core) cables stand out for their flexibility and use in pulsed field environments. Under the conductor section of the French State-funded SupraFusion PEPR project, these structures are being explored to adapt these next-generation conductors to the extreme environments of compact high-field fusion tokamaks.

This work focuses on two closely related aspects: numerical simulations of various conductor designs and experimental campaign to support and refine the models. Using THEA, a commercial 1D software from CryoSoft, we evaluate different cooling strategies for jacketed CORC-like conductors. Parametric studies on the fluid dynamics for these strategies are presented and their impact on quench dynamics studied.

To enhance the accuracy of the numerical models, an experimental campaign is being conducted at the CEA Cadarache Othello facility. This campaign investigates pressure drops within the tape bundle for different configurations, including various CORC-like cables, which are in-house fabricated with different sizes (ranging from a few to several layers) and crimping pressures. Additionally, measurements are performed on a 20 kA-class CORC® provided by Advanced Conductor Technologies LLC (ACT), the same sample that is going to be tested in the Sultan facility at PSI, Switzerland.

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Session Classification: Fri-Af-Po.03 - Supporting Technologies for Fusion Magnets I

Contribution ID: **501** Type: **Poster**

Wed-Mo-Po.04-04: Finite Element Analysis of Bending Behavior in Stacked HTS CICCs for Large-Scale High-Field Magnets

Wednesday, July 2, 2025 9:15 AM (2 hours)

Large-scale superconducting magnets, characterized by their substantial diameter and high magnetic field strength, play a pivotal role in various high-field applications. To optimize the performance of these magnets, it is crucial to understand the mechanical behavior of the superconducting conductors used in their construction. This paper introduces a finite element model (FEM) developed to analyze the bending behavior of stacked high-temperature superconducting (HTS) Cable-in-Conduit Conductors (CICCs) tailored for large-scale, high-field magnets. The model simulates the bending of long conductors into the dimensions required for target coils and examines the mechanical performance of the conductors at different positions along the tape. This analysis extends beyond previous studies that focused on the bending properties of short conductors, providing a more realistic representation that aligns with the actual dimensions of large-scale magnets. Such an approach enhances the understanding of the mechanical behavior of HTS conductors in practical applications, supporting more accurate performance assessments for large-scale superconducting magnets. The results of this study contribute to more accurate performance assessments of HTS conductors, aiding in the design and development of more reliable and efficient large-scale superconducting magnets.

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Session Classification: Wed-Mo-Po.04 - HTS Conductors I

Contribution ID: **502** Type: **Invited Poster**

Wed-Af-Po.08-02: [Invited] Experimental campaign of small-scale coils at INFN for future particle accelerators

Wednesday, July 2, 2025 2:30 PM (2 hours)

REBCO tapes stand out as the most promising conductors for a large variety of applications yet being still far from being fully understood on both the theoretical and experimental sides.
For this purpose, within the PNRR-IRIS project currently at its final phase, a 10 T cryogen free dipole magnet demonstrator fully built with HTS has been designed and is being manufactured, namely ESMA (Energy Saving Magnet for Accelerators).
To keep up with the development of ESMA, as well as to enhance the understanding of the tape in real winding applications aimed at future particle accelerators, an experimental campaign is being carried out. This campaign focuses on validating the conductor behaviour and performance using a 12 mm Faraday Factory Japan (FFJ) REBCO tape through small sample measurements and small coil winding and testing in LN2.
For this aim, a series of racetrack coils have been designed, with an eye on repeatability, produced and tested in LN2. The tests include charging and discharging the coil at different rates, transition measurements to the Normal Conducting (NC) state, and overcurrent powering. All tests were performed multiple times and over several cooldown and warm up. Measurement results have been collected using various distributed sensors, including voltage taps, Hall probes, and temperature sensors.
The expected margins and central field of the windings have then been calculated and compared with experimental data. These results, along with the design and manufacturing details of the racetrack coil, are going to be described and discussed throughout the article.

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Session Classification: Wed-Af-Po.08 - Conductor and Coil Measurement/Test Techniques and Facilities I

Track Classification: G: Generic Application Technologies: Approaches and Tools: G07: Conductor and Coil Measurement/Test Techniques and Facilities

Contribution ID: **503** Type: **Poster**

Thu-Mo-Po.04-07: Thermal stability of NI HTS pancake coils for varying contact resistivities and critical current distributions

Thursday, July 3, 2025 8:45 AM (2 hours)

High-temperature superconductor (HTS) coated conductors (CC) can be wound into no-insulation (NI) pancake coils, i.e., coils without electrical insulation in-between the turns. Along the CC length, the critical current has an inherent variation due to its manufacturing process. This variation causes non-uniform heat generation when the coil is operated at a high fraction of the critical current or when large critical current degradations are present. The presence of a finite turn-to-turn (T2T) contact resistance enables the current to bypass a zone with a reduced critical current (RCCZ). Therefore, the dynamic behaviour of NI coils is directly influenced by the T2T contact resistance and RCCZ distribution. Currents bypassing the RCCZ need to flow through the T2T resistances, thereby generating Joule heating. The resulting temperature evolution is influenced by the cooling condition, namely conduction cooling via (copper) current leads or cryogenic bath cooling can be considered. The interplay between non-uniform Joule heating and cooling, in combination with non-uniform critical current distributions and magnetic fields, determines whether a thermal runaway occurs or if the critical current degradation can be tolerated. This temperature distribution is difficult to compute and requires coupled magneto-thermal three-dimensional (3D) simulations.

This contribution presents the results of simulations using the Pancake3D module of the free and open-source Finite Element Quench Simulator (FiQuS) tool developed at CERN as part of the STEAM framework. It solves the coupled 3D magnetodynamic and heat balance equations efficiently using H−ϕ thin shell approximations and a CC homogenization. The latter resolves the current sharing in the CC between HTS and normal conducting layers. FiQuS-Pancake3D is capable of handling different cooling conditions, variations in critical current along the length, and different electric and thermal T2T contact resistivities. Advanced parametric analyses are performed using the Dakota software developed by Sandia National Laboratories via the STEAM framework developed at CERN.

The usage of Dakota is enabled by FiQuS-Pancake3D, which automatically generates all models from human-readable input text files. It also aids the reproducibility and traceability of the simulations. The FiQuS user interface separates coil design parameters from numerical computing aspects, thereby providing access for all researchers to simulations of superconducting magnets, irrespective of their level of expertise in modelling and simulation, and regardless of their access to costly software licences.

The simulation results allow investigating the effect of different RCCZ along the CC length and determine whether the coil can reach and maintain its nominal operating conditions. Various RCCZ distributions of variable critical current levels and contact resistivities will be considered. The results will demonstrate the maximum allowed T2T contact resistance to ensure coil operation immunity to RCCZ under specific cooling conditions.

Acknowledgment. The work of E. Schnaubelt has been supported by the Wolfgang Gentner Programme of the German Federal Ministry of Education and Research (grant no. 13E18CHA) and the Graduate School CE within the Centre for Computational Engineering at TU Darmstadt.

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Session Classification: Thu-Mo-Po.04 - No-Insulation Coils III

Contribution ID: **504** Type: **Poster**

Fri-Af-Po.05-01: Evaluation of physical properties and electrical performances of HTS mock-up magnets wound with various REBCO tapes under external magnetic fields at 4.2 K

Friday, July 4, 2025 2:00 PM (2 hours)

We have been working on several projects to develop 32 T to 40 T class all superconducting magnet for end-users. For the first step, four REBCO tapes were estimated: 1) THEVA (TV); 2) Shanghai Superconductor Technology (SST); 3) Faraday Factory Japan (FFJ); and 4) Fujikura (FJK). From this estimation, we found that, except TV's tape, the coils of all REBCO tapes were suddenly deformed at winding tensions above 50 MPa. In addition, in the case of TV and FFJ tapes, delamination of the tapes easily occurred. In 2024, we received tapes from TV, SST, and FFJ companies that had improved these shortcomings. Therefore, three REBCO mock-up magnets wound with these tapes, each consisting of two metal-as-insulation (MI) double pancake (DP) coils, were constructed. The magnets have the same structure and geometry except for the manufacturer of the REBCO conductors. Their physical properties, the delamination strength and windability of each tape, were estimated during this winding process. Each mock-up magnet was suddenly discharged at 20 A in self-field at 4.2 K to measure its charging time constant. The magnets were charged up to 500 A under various external magnetic fields to investigate its'real current-carrying performance. In addition, the magnets were repetitively charged and discharged to confirm mechanical stability of the magnets. For estimating critical current, joining strength and our protection scheme, quench tests of the magnets were also conducted under various background magnetic field at 4.2 K.

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Session Classification: Fri-Af-Po.05 - High Field Solenoids Resistive and LTS

Contribution ID: **505** Type: **Poster**

Wed-Af-Po.03-04: Preliminary design for a solenoid magnet for the future muon collider experiment MUSIC

Wednesday, July 2, 2025 2:30 PM (2 hours)

Among the most innovative and promising next generation particle accelerators, a muon collider is at a time a viable compromise between the increase of available energy at the interaction point and the sustainability of the related infrastructure. The International Muon Collider Collaboration is pursuing the design of a complete accelerator complex, up to the detectors to be installed on the two interaction points foreseen on the collider. Here we present a preliminary design of a solenoid magnet for one of the proposed detectors, MUSIC, aiming at a compromise between the requests for the detector tracker and the beam-induced background rejection. The goal is to achieve up to 5 T at the interaction point, good field uniformity on a volume comparable with the warm bore of the solenoid (4.6 metres in diameter and 4.6 metres long), strong integration with the sub detectors and with the final focusing magnets of the collider, which are foreseen at less than 8 metres from the magnet centre. Starting from a CMS-like design, we plan to fulfil the requirements with a central solenoid coupled with additional coils embedded in the hadronic calorimeter and the end caps of the return yoke.

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Session Classification: Wed-Af-Po.03 - High Luminosity LHC and FCC

Contribution ID: **506** Type: **Contributed Oral**

Wed-Af-Or3-02: Assembly and Test results of Cryogen-free Conduction Cooled Wavelength Shifter Magnet in Final Cryostat

Wednesday, July 2, 2025 4:45 PM (15 minutes)

In 2022, a collaborative team led by Pohang Accelerator Laboratory, Seoul National University and Kangwon National University began the development of a 5 T metal-insulated high-temperature superconducting (HTS) wavelength shifter (WLS) magnet, aiming to enhance the brilliance of photons by 1,000 times at 100 keV in Pohang Light Source II. In 2023, we reported test results of the magnet in a vertical conduction cooling machine, where it successfully reached its full field of 5 T twice without any visible obstacles.
To enable installation in an actual particle accelerator, we completed the fabrication and assembly of WLS magnet in a dedicated horizontal conduction cooling machine with cryogenic beampipe. Here we report technical challenges faced during the assembly and test of the WLS magnet system. After that, we present test results of the WLS magnet in a dedicated cryostat including initial cooling results, analysis of temperature and voltage during current operation, and field integral measurements obtained using a 3D PCB search coil. The progress made since 2022 and our plan for the installation of the magnet in an actual particle accelerator will be presented.

This research was supported in part by National R&D Program through the National Research Foundation of Korea (NRF) funded by Ministry of Science and ICT (2022M3I9A1072846 and 2022M3I9A1073808), in part by the Applied Superconductivity Center, Electric Power Research Institute of Seoul National University. This research was conducted by support program for Kangwon High Magnetic Field Research Center through the Gangwon Technopark(GWTP) funded by Gangwon Province.

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Session Classification: Wed-Af-Or3 - Wiggler Magnets

Contribution ID: **507** Type: **Poster**

Sat-Mo-Po.01-06: Methodological approach for a non-linear optics in a static HTS magnet gantry system for particle therapy

Saturday, July 5, 2025 9:30 AM (1h 45m)

In particle therapy, multiple treatment angles are generally used to concentrate the absorbed dose in a tumor and to minimize the dose in healthy tissues in the vicinity of the tumor. This is typically achieved with a rotating gantry system. However, implementing a rotating gantry system presents serious challenges due to high cost and enlargement of a space for a large-scale three-dimensional mechanical frame to support a beamline. Additionally, the rotational speed needs to be limited for safety, to prevent potential collisions. In contrast, the static gantry system using a high-temperature superconducting magnet has the potential to **significantly reduce the cost and size of a facility building**, making advanced cancer treatment more accessible, particularly in developing countries with limited healthcare infrastructure. Additionally, from clinical point of view, the static gantry system may enhance treatment efficiency by reducing the duration of each session, easing the burden on patients and improving facility throughput. Importantly, the static gantry system is well-suited for the treatment of tumors in motion-prone regions, such as the thorax and abdomen. This design **enables effective motion mitigation**, allowing for precise targeting of tumors affected by respiratory or other bodily movements. This can broaden the scope of patients who can benefit from proton therapy, particularly for tumors that are otherwise difficult to treat. **To achieve compactness and rapid changes in treatment angles, enabling stereotactic irradiations to mitigate motion effect on the dose distribution, we are designing a static gantry system using HTS magnets.**

In this concept, the beam is guided to the appropriate azimuthal angle with cylindrical magnetic field excited by a huge HTS dipole magnet surrounding the patient, and treatment angles are set only by adjusting the strength of dedicated magnets, instead of rotating a gantry with magnets for beam transportation around the patient. This method is realizing a fast change of azimuthal angle in a static gantry system. The rapid change of treatment angle also provides potential possibility of FLASH radiotherapy, a promising approach that may allow for the treatment of tumors near critical organs at risk. This capability could expand treatment options for previously untreatable tumors, such as some cases in pancreas and lever.

In this work, the magnetic field distribution required for a static gantry, considering beam focusing at various treatment angles, is analyzed. The conceptual design of the HTS magnet to achieve the target magnetic field profile using OPERA-3D is also presented. In the dipole magnet for the static gantry, the proton beam is bent over 300 degrees in certain treatments, leading to significant defocusing in the bending plane due to momentum spread. Therefore, it is crucial to **develop a methodological approach for non-linear optics in the the static magnet gantry system to evaluate and optimize beam transportation**. To address this, we developed a particle tracking code capable of optionally modifying the field distribution based on OPERA-3D simulation results. This program tracks particles under specific initial conditions in both real space and phase space. The results from the self-developed particle tracking program were further validated using OPAL, a widely-used open-source particle tracking code for designing cyclotrons and beamlines. Using the optimized parameters for field distribution modification, we designed an HTS dipole magnet tailored to the target field distribution. **Simulations were conducted with OPERA-3D, and beam transportation performance for various treatment angles was evaluated using both OPAL and the self-developed particle tracking code.**

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Presenter: Mr ZHAO, Hang (Research Center for Nuclear Physics, University of Osaka)

Session Classification: Sat-Mo-Po.01 - Magnets for Other Medical Application II

Contribution ID: **508** Type: **Poster**

Sat-Mo-Po.07-04: HTS superferric combined function magnet for the FCC-ee project

Saturday, July 5, 2025 9:30 AM (1h 45m)

Energy consumption represents an increasing critical challenge for particle physics research laboratories like CERN. This issue is particularly significant in large accelerator facilities, where normal conducting magnet technology plays a fundamental role in the beamline design. In this context, research, development, and study of high-temperature superconducting (HTS) magnets offer promising solutions to improve energy efficiency. HTS materials can substantially reduce energy consumption and operational costs enabling higher operating temperatures compared to conventional superconductors. When combined to superferric magnets designed, this technology can offer simpler, cost-effective designs, exploiting the iron yoke pole shape for magnetic field quality reducing the influence of the high temperature superconductor large magnetization effect. In this paper, a combined superferric (sextupole and quadrupole) HTS magnet for the FCC-ee's main ring is described.

Rather than prioritizing energy savings for each magnet, the main goal of this proposal is to produce the same performances of the current resistive magnet configuration while reducing magnet length in the accelerator. This design increases the dipole filling factor, which offers two key advantages: a slight decrease in overall energy consumption through reduced RF cavity power requirements or, more significantly for high-energy physics, improved beam luminosity at constant RF power consumption. The electromagnetic optimization of the HTS superferric design, able to provide independent tuning of quadrupole and sextupole gradients, is discussed by comparing the provided field quality with the baseline resistive design. Independent tuning of quadrupole and sextupole gradients address specific experimental needs and the possibility to be used for different accelerator configurations. Furthermore, a preliminary thermo-mechanical study is reported to have an initial look at the power consumption of the magnets and the possible cryogenic system. This project targets high-energy, low-field particle accelerators, leveraging the use of iron yokes to minimize the required HTS material, hence the cost of the magnet, and reduce even more the manufacturing technologies needed. This approach balances cost efficiency with performance, offering significant progress in sustainable accelerator technology.

Authors: ROSSI, Lucio (University of Milan and INFN Milan, LASA laboratory); MARIOTTO, Samuele; BUSATTO, Simone

Presenter: BUSATTO, Simone

Session Classification: Sat-Mo-Po.07 - HTS Magnets

Contribution ID: **509** Type: **Plenary**

Sun-Mo-PL1-01: The role of high temperature superconductors for a 10 TeV muon collider

Sunday, July 6, 2025 10:30 AM (10 minutes)

The international particle physics community, among different options for the development of future high-energy particle colliders and fundamental interactions exploration, considers Muon Colliders (MC) as a great opportunity to achieve high discovery potential and integrated luminosity compatible with a compact and cost-effective accelerator machine. An international muon collider collaboration (IMCC) has recently been set up, following the recommendations of the European Strategy for Particle Physics (ESPP), to produce a conceptual design of a Muon Collider with a 10 TeV center-of-mass energy.
From the analysis of the collider's various magnetic components, large stored energies for the capture and cooling solenoids, very high magnetic fields up to 40 T for the final cooling solenoids, and large bore (up to 140 mm) and high field combined function magnets for the accelerator and collider rings are required. High-temperature superconductors (HTS) result the enabling technology to address these challenges and achieve the required collider performances. Given the peculiar accelerator stages of the muon collider, most superconducting magnets are required to operate in steady-state mode, with normal-conducting dipoles handling rapid acceleration and fast field variations, allowing the use of HTS coated conductors to increment magnet performances compared to low temperature superconductors (LTS) technology. This aspect is also fundamental in advancing the energy efficiency and sustainability goals of next-generation accelerator facilities for high-energy physics. By enabling magnet operation at temperatures above liquid helium, HTS offer the potential to significantly reduce the energy consumption of entire accelerator complexes. This energy-saving capability must be increasingly prioritized in magnet design strategies with different impacts on the collider performance, cost and feasibility.
In this paper we elaborate on the above aspects, discussing the technological challenges for the 10 TeV muon collider configuration and how HTS will make them viable and efficient to pave the way to new compact and high-performance particle collider machines capable to overcome the current energy frontier.

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Presenter: MARIOTTO, Samuele

Session Classification: Plenary 1: Young Scientist Plenary

Contribution ID: **510** Type: **Poster**

Fri-Af-Po.07-03: Development of Pulsed Vector Magnet at the Wuhan National High Magnetic Field Center

Friday, July 4, 2025 2:00 PM (2 hours)

The structure of the pulsed vector magnet has been optimally designed at the wuhan national high magnetic field center (WHMFC). The pulse vector magnet consists of a magnet that generates a magnetic field in the z-direction and a magnet that generates a magnetic field in the x-direction. the z-direction magnet is in the center hole of the x-direction magnet. The two magnets are held together as a single unit. The center hole of the z-direction magnet has a diameter of 28mm, which can satisfy most of the experimental research in basic science. The diameter of the center hole of the x-direction magnet is 200mm, which is determined by the outer diameter of the z-direction magnet. Both z-axis and x-axis magnets are powered by a 1-MJ capacitor banks. Calculations show that 30T-10T vector magnetic fields can be obtained.

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Presenter: WANG, Shuang (Huazhong University of Science and Technology)

Session Classification: Fri-Af-Po.07 - High Field Pulsed Magnets II

Contribution ID: **511** Type: **Poster**

Fri-Af-Po.09-08: Investigation of Key Design Parameters and No-Insulation HTS Field Coil Behaviors in High-Speed Homopolar Motors

Friday, July 4, 2025 2:00 PM (2 hours)

Growing environmental concerns have increased the demand for high-power-density electric propulsion systems. One way to achieve higher power density is through the use of superconducting technology. In particular, no-insulation (NI) high-temperature superconducting (HTS) coils offer improved power density due to their ability to carry high currents and withstand external disturbances.

Superconductors are commonly used in the field coils of electric propulsion systems to reduce AC losses. However, using superconducting field coils in rotating parts creates several challenges. First, delivering high current requires slip rings and brushes, which makes the system more complex. Second, designing a cooling system for rotating parts is difficult. These challenges make the rotor design more complicated and limit the speed of operation.

Homopolar topology can be an alternative to these problems by keeping the field coil stationary, removing the need for slip rings, brushes, and complex cooling systems. Therefore, the homopolar topology is better suited for applications that require relatively high speeds.

This study investigates the basic design of a homopolar motor using NI HTS coils to improve power density in electric propulsion systems. It identifies key design parameters and compares the power density of different designs. Additionally, since NI HTS coils have no insulation between turns, current can flow in the radial direction, and radial current may be induced by changes in the external magnetic field during motor operation. Therefore, this study analyzes the parameters (inductance, contact resistance Rc, and time constant) of the NI HTS field coil according to key design parameters, and analyzes how the NI HTS field coil behavior (leak current and heat generation) occurring during operation affects the motor's operation characteristics (average torque, torque density, and torque ripple).

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Session Classification: Fri-Af-Po.09 - Rotating Machinery IV

Contribution ID: **512** Type: **Poster**

Fri-Mo-Po.06-02: Fusion Magnet Quench Risk Increase With Radiation Damage

Friday, July 4, 2025 9:30 AM (1h 45m)

Superconducting material enables fusion reactor magnet concepts to operate with current densities that would melt materials with non-zero resistance. The application of superconducting material is considered essential for net-positive power machines. Catastrophic damage can occur when superconductivity is lost and the current generates heat. This scenario is called a quench. Stabilizer material carries the magnet current (typically copper) during a quench and is the focus of this work.

Irradiation-induced defects store energy in the Cu crystalline lattice. The presence of defects reduces thermal conductivity (thermally insulating the superconductor), electrical conductivity (increasing temperature ramp rate during a quench), and specific heat capacity (increasing thermodynamic instability). The release of stored energy in the magnet materials, in combination with the magnet material property changes, has the potential to cause extreme off-normal events in superconducting magnets that worsen with fluence.

Stored energy can be released causing local heating and increasing the risk of a quench. For example, following irradiation at 4.6K and a fluence of 0.45×10^{18} n/cm^2, an energy release of 0.023 J/g was measured from Cu when increased in temperature from 10K to 18K, which would have been enough energy to create the same temperature increase spontaneously.

Extrapolations of experimental data are used to estimate when spontaneous heating can occur due to the release of energy stored in irradiation-induced defects. Critical fluence values are estimated between 1.74×10^{18} n/cm^2 and 2.85×10^{19} n/cm^2 for neutron irradiation of Cu at a temperature of 20K.

In-situ cryogenic calorimetry experiments, operated at high-temperature-ramp rates on irradiated magnet materials, could offer certainty for fusion magnet system designers. Periodic annealing of defects through controlled temperature cycling will be essential in fusion power plants to manage the increasing risk of quench as the superconducting magnets accumulate dose. The ideal frequency and dynamics of these maintenance temperature cycles will be established with further experimental examination.

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Presenter: JOHN, Jacob (UKAEA)

Session Classification: Fri-Mo-Po.06 - Quench in Fusion Magnets II

Contribution ID: **513** Type: **Contributed Oral**

Fri-Mo-Or3-04: Conceptual Design of a 10-T Split-Pair Racetrack High-Temperature Superconducting Magnet for a Novel Concept Magnetohydrodynamic (MHD) Propulsion

Friday, July 4, 2025 9:00 AM (15 minutes)

This paper presents the conceptual design of a 10-T split-pair racetrack high-temperature superconducting (HTS) magnet, utilizing REBCO tapes for a novel concept magnetohydrodynamic (MHD) propulsion system that generates 100-N thrust, currently being developed by SRI International. A key design challenge involves creating wide access channels in both transverse directions to allow seawater and ionic current to traverse the high magnetic field region, thereby generating thrust. Conventional high-field magnet configurations, such as solenoids and saddle-type dipoles, are unsuitable for implementing SRI's new MHD concept due to the physical topology constraints inherent to these designs.

The magnet design incorporates key innovations: the application of novel Pyralux insulation, a four-in-hand winding technique, which includes two REBCO tapes to enhance defect tolerance, and the integration of intermediate rings within each single pancake coil to effectively manage mechanical stresses in large-diameter pancakes. Screening current effects in the REBCO coils were analyzed using a 3D T-A formulation, and the mechanical stresses were calculated to ensure reliable performance. The coil shape and the number of divided sections were optimized to meet the MHD system's requirements—achieving an average of 10-T over the MHD field volume of ˜28,000 cm^3 while maintaining acceptable stress level within the coil. Additionally, viable support structure designs were explored and analyzed to address the significant axial force of ˜10 MN between the split coils. Using these analytical results, we developed a conceptual design for the electromagnetic coil and the initial early-stage mechanical structure. The magnet is designed to operate at around 10 K and will be cooled by conduction through highly-thermal-conducting spacers installed between the racetrack coils and the cooling pipe containing circulating supercritical helium.

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Presenter: HU, Jintao

Session Classification: Fri-Mo-Or3 - Coils for Power, Energy, Transport and Other Applications

Contribution ID: **514** Type: **Poster**

Wed-Af-Po.03-03: Conceptual Design of a 3 T HTS solenoid for Future Circular Collider Particle Detectors

Wednesday, July 2, 2025 2:30 PM (2 hours)

Novel conceptual designs for next-generation high-energy particle detectors are currently under development by the international research community. As part of the Future Circular Collider (FCC) conceptual design study in the electron-positron collision configuration, the baseline detector proposals (CLD and IDEA project) have selected aluminum-stabilized NbTi Rutherford cables as the primary technology for their solenoidal detector magnets. For the IDEA detector design, a thin solenoid able to provide a 2 T nominal magnetic field has been considered to maximize the overall transparency and energy resolution of the detector calorimeters positioned outside of the solenoid volume. Despite the high reliability and well-known performances of the low-temperature superconductors (LTS) for particle detector magnets, this technology is at present not commercially available resulting in high costs of the magnet construction and development program. In this context, a new superconducting solenoid design able to provide a 3 T central magnetic field entirely based on aluminum stabilized High-Temperature Superconductor (HTS) cables is being developed at the Istituto Nazionale di Fisica Nucleare (INFN) Laboratorio di Acceleratori e Superconduttività Applicata (LASA). This innovative design features an increased bore radius to accommodate enhanced dual-readout crystal calorimeters with the possibility to work at an operating temperature of 20 K. The proposed configuration significantly reduces the cryogenic power consumption improving the overall accelerator sustainability while increasing the operating margin of the superconducting winding. In this paper, the electromagnetic performances and a preliminary thermo-mechanical analysis of the proposed HTS design are discussed and compared to LTS configurations. Details of the protection feasibility are provided together with transparency calculations of the coil volume showing the advantages of the proposed HTS configuration as an important step towards increased performances and enhanced energy efficiency of future particle detector magnets for lepton collider experiments.

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Presenter: MARIOTTO, Samuele

Session Classification: Wed-Af-Po.03 - High Luminosity LHC and FCC

Contribution ID: **515** Type: **Invited Oral**

Thu-Mo-Spec1-05: [Invited] Protection concepts and simulation tools for REBCO magnets

Thursday, July 3, 2025 11:55 AM (15 minutes)

This talk provides an overview of several protection concepts and simulation tools, specific to REBCO coils, that are currently under development within the TE-MPE group at CERN. Capacitive discharge and more efficient variants of the Coupling Loss Induced Quench method will be presented as promising new protection methods. While simulation tools for LTS magnets are well developed and validated, similar tools for REBCO coils, wound from a single tape or a multi-tape cable, require a completely different approach. This is primarily due to the slow quench propagation, which often necessitates three-dimensional simulations, and the highly anisotropic behavior of the tape which complicates homogenization. In the context of non-insulated (NI) or metal-insulated (MI) coil designs, the introduction of additional current paths between turns necessitates detailed modelling at microscopic scale. Furthermore, the large magnetization effects and turn-to-turn currents resulting from these designs can significantly increase the local Lorentz force during a quench, thereby necessitating the co-simulation of thermo-electro-magnetic and mechanical models.

This presentation introduces several simulation tools, developed as part of the STEAM framework, tailored for both insulated and NI/MI magnet types. It highlights methods to reduce the computational cost, such as conductor homogenization, thin-shell approximation, reduced order and multiscale modelling, and showcases the simulation outcomes that illustrate the intricate nature of quench development in REBCO coils.

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Presenter: VERWEIJ, Arjan (CERN)

Session Classification: Thu-Mo-Spec1 - [Special Session] Quench Protection for Large Stored-energy REBCO Magnets

Contribution ID: **516** Type: **Poster**

Sat-Mo-Po.01-01: Screening current effect on thermal stability of no-insulation REBCO coils in 1/2-scale coil system of Skeleton Cyclotron

Saturday, July 5, 2025 9:30 AM (1h 45m)

We have manufactured the 1/2-scale demonstration no-insulation (NI) REBCO magnet system for ‘skeleton cyclotron’with no iron core (air-core), called "Ultra Baby Skeleton Cyclotron (UBSC)."The USBC magnet consists of center coils, main coils and AVF coils generating the azimuthal varying field. The outermost size of magnet is approximately 70 cm, and the designed center magnetic field is 1.6 T at an operating current of 540 A, corresponding to 5 MeV of proton acceleration energy. All the NI REBCO coils (center, main, and AVF) are connected in series, and the operating temperature is 30 K cooled by a conduction cooling system. In this R&D project, we will investigate the quality of fields generated by the developed REBCO magnet system including the screening current-induced fields, but we have no plant to accelerate particles.
In a charging test, the operating current increased up to 250 A. The developed UBSC magnet suddenly quenched in a few tens after stopping the magnet charging. The current 250 A is much smaller than the critical current of over 700 A. We observed that a few main NI REBCO coils have damaged with losing superconductivity after quench. To investigate the cause of quench, we have simulated the current behaviors during charging. As the result, the large screening currents were observed on the top and bottom main REBCO coils. However, the Hoop stress is not so high to damage the main REBCO coils. Meanwhile, the unexpected heating on REBCO tapes is seen on the simulation result. We will keep investigating the thermal stability of the developed UBSC NI REBCO magnet.

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Presenter: NOGUCHI, So (Hokkaido University)

Session Classification: Sat-Mo-Po.01 - Magnets for Other Medical Application II

Contribution ID: **517** Type: **Poster**

Wed-Mo-Po.03-01: Implementation of a Standardized Quality Control Process for Commercial HTS Tape

Wednesday, July 2, 2025 9:15 AM (2 hours)

The large-scale design and manufacture of HTS magnets will require the production and use of thousands of kilometres of HTS tape, supplied by various manufacturers worldwide. A critical step in enabling the production of these magnets is establishing a robust quality control (QC) procedure that can be consistently applied to all received batches of HTS tape before their use in Tokamak Energy's (TE) magnet projects. While several studies have previously reported on characterizing the individual properties of HTS tape relevant to magnet design and construction, there is currently no standardized procedure for controlling the quality of these tapes.
We report here on our efforts to implement a standardized set of quality control processes developed to assess the suitability of commercially produced HTS tapes for TE's magnet development projects. These processes are part of TE's broader HTS tape quality control program. The tests are designed to screen received tapes for dimensional non-conformities and to ensure that the mechanical, thermal, and electrical properties of the tapes meet TE's specified requirements.
TE has employed a combination of commercially supplied and bespoke measurement rigs to perform reel-to-reel visual inspection, 90-degree peel tests, internal resistance measurements and measurements of the residual resistivity ratio of the copper stabiliser. These tests are routinely applied each spool received from a commercial supplier and enable TE to comprehensively evaluate the suitability of each received batch of tape for our magnet applications.

Author: Dr BEDFORD, Tom (Tokamak Energy Ltd.)

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Presenter: Dr BEDFORD, Tom (Tokamak Energy Ltd.)

Session Classification: Wed-Mo-Po.03 - HTS Characterization I

Contribution ID: **518** Type: **Contributed Oral**

Sat-Af-Or4-01: Challenges and Approaches for Introducing Internal Oxidation in Rod-in-Tube Nb3Sn wires

Saturday, July 5, 2025 4:30 PM (15 minutes)

We introduced internal oxidation in Rod-in-Tube (RIT) Nb₃Sn subelements, used in simplified restacked wire, by using SnO₂ powders as an oxygen source (OS). During Nb₃Sn synthesis, the OS decomposed, resulting in a grain size below 60 nm. This grain refinement is consistent with an increase of the critical current density (J_c) towards the performance target of 1500 A/mm² at 16 T and 4.2 K for the dipole magnets of the Future Circular Collider (FCC).
Internal oxidation relies on the combined effects of the oxygen source (OS) and a high oxygen-affinity element, such as Hf or Zr, alloyed with Nb. This process inhibits Nb₃Sn grain growth and enhances J_c through the formation of nano-oxide precipitates. While internal oxidation is typically implemented in Powder-In-Tube (PIT) wires, where incorporating an OS is less challenging, RIT wires—for example those produced via the Rod-Restacked Process (RRP)—are preferred for accelerator-magnet applications due to their superior mechanical properties and reduced I_c degradation during Rutherford cabling.
A key challenge is that the RIT process does not use powders, and it involves high-temperature treatments (e.g., hot extrusion), which risks premature OS decomposition that could harden the Nb alloy. In our approach, each Nb-alloy filament was assembled with the OS, then deformed and restacked into subelements. The filament assembly procedure was specifically conceived to prevent OS decomposition during hot extrusion.
This achievement represents a promising step toward the commercial-scale introduction of internal oxidation in RIT wires. While further optimization of wire design is needed (e.g., reducing Cu excess and increasing filament and subelement count), this work marks a progress in meeting the stringent performance requirements for next-generation high-field magnets.

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Presenter: BOVONE, Gianmarco (University of Geneva)

Session Classification: Sat-Af-Or4 - Advances in Nb3Sn and MgB2 Conductors II

Contribution ID: **519** Type: **Poster**

Thu-Mo-Po.04-06: Quench current and thermal distributions in a no-insulation REBCO pancake coil with metallic shunting on the winding surfaces

Thursday, July 3, 2025 8:45 AM (2 hours)

In this paper, we present investigation of the impact of the surface shunting on the current and thermal distributions within no-insulation (including metal-insulation) REBCO coils, particularly in relation to quench and overcharge events. The metallic surface shunt serves as an additional current bypass outside of the winding, complementing the turn-turn bypass present inside metal-insulated windings. This modification may alter both the electromagnetic and thermal characteristics of the coil. To further investigate this effect, we will fabricate a demonstration coil and evaluate the influence of various shunting materials and dimensions, including foil thickness and winding surface coverage area, through experiments. These results will be compared with corresponding simulations for quench and overcharge scenarios. We expect that the insights gained from this investigation will be valuable for the design of very high-field magnets for various applications, including physics experiments, materials science, and nuclear magnetic resonance (NMR).

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Presenter: DONG, Fangliang

Session Classification: Thu-Mo-Po.04 - No-Insulation Coils III

Contribution ID: **520** Type: **Poster**

Thu-Mo-Po.09-04: Design and Construction of the Frascati Coil Cold Test Facility for Big Size Superconducting Magnets

Thursday, July 3, 2025 8:45 AM (2 hours)

The large facility under construction at the ENEA Frascati Research Center, named Frascati Coil Cold Test Facility (FCCTF), has been designed with the original purpose of testing the superconducting magnets of the DTT (Divertor Tokamak Test facility) experimental reactor in cold conditions (4.5 K inlet temperature) and high current up to 43 kA. In a 600 m2 large hall, FCCTF will host a large cryostat, a supercritical Helium refrigerator, a High-Current/Low Voltage power supply and an associated safety discharge system for protection in case of quench, thus allowing a safe investigation of the coil behavior in close-to-operative conditions.
The large cryostat is a vessel, with a removable top lid, capable of housing magnets up to 7 meters long, 3 meters wide, and 1.7 meters high, with a maximum weight of 17 tons. It is equipped with a pair of BiSCCO current leads capable of handling up to 43 kA. The Linde Helium refrigerator cooling system for the FCCTF provides helium at a maximum inlet pressure of 12 bar and a mass flow rate of 73 g/s. It offers a refrigeration thermal capacity of 500 W at 4.5 K plus 450 W at 16 K, ensuring the necessary cooling power for effective superconducting coil testing.
In this contribution, the design of the main components and features of the facility will be described together with the time schedule leading to the final commissioning fixed for mid-2027. Finally, the current status of the FCCTF implementation will be reported.

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Session Classification: Thu-Mo-Po.09 - Conductor and Coil Measurement/Test Techniques and Facilities II

Contribution ID: **521** Type: **Contributed Oral**

Fri-Mo-Or6-02: A fully 3D thermal-hydraulic and electric model for the simulation of quench propagation in HTS conductors for fusion

Friday, July 4, 2025 11:30 AM (15 minutes)

Conductors and magnets for fusion applications based on High Temperature Superconducting (HTS) materials are currently being designed and tested. Quench propagation in such conductors is an open issue due to the small normal zone propagation velocity when compared to Low Temperature Superconductors. This, in turn, makes the quench detection and the protection of HTS magnets more challenging. Numerical modelling may help in developing alternative quench detection strategy as well as improving the conductor design itself.

Currently, the numerical models used to model quench propagation are based on those developed for LTS conductors, i.e., they are based on a 1-dimensioinal approximation of the conductor along its axis. This strategy proved to be reliable and accurate for LTS conductors. However, most HTS conductor designed so far are characterized by bulky solid parts, thus making the approximation of uniform current and temperature on their cross-section -which is at the basis of the 1D approximation- less accurate.

For this reason, in this work, a fully 3D model able to follow the entire evolution of the quench propagation is presented. The model solves the heat diffusion equation in the solids, from which their temperature is computed; the Navier-Stokes equations, from which the pressure, velocity and temperature of the coolant is retrieved; the electric potential equation, from which the current is derived.

The case study presented in this work focuses on an HTS conductor designed and manufactured by ENEA which was recently tested in SULTAN. The conductor is based on the slotted-core concept, i.e., a core made of aluminum featuring 6 slots where non-soldered tapes are stacked. The cable is then jacketed to provide coolant containment and mechanical support. The conductor was quenched in different conditions in terms of coolant mass flow rate, background magnetic field and transport current.

The 3D model free parameters, such as the thermal contact resistance between the conductor subcomponents, are first calibrated and then its results are validated in terms of voltage and temperature, which are both measured in several location along and across the conductor. Such detailed model is then used to interpret some of the collected experimental data.

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Presenter: ZAPPATORE, Andrea

Session Classification: Fri-Mo-Or6 - Quench Detection and Protection I

Contribution ID: **522** Type: **Poster**

Thu-Mo-Po.04-05: Effect of graded insulation on the performance of HTS pancake coils

Thursday, July 3, 2025 8:45 AM (2 hours)

In the development of high-temperature superconductor (HTS) pancake coils, the no-insulation (NI) is a well-known approach that enables self-protection by allowing radial current redistribution during thermal events. This method, while advantageous for mitigating damage during quench, presents significant challenges due to the low contact resistance, which causes a substantial reduction in the azimuthal current responsible for magnetic field generation. This extends the re-energization time after recovery and might also induce quench propagation in multi-coil NI magnet systems. In contrast, metal-insulated (MI) coils, which use a metallic layer as an intermediate insulator, offer higher transverse resistance. This configuration mitigates some of the drawbacks of NI coils by providing a balance between fully insulated and non-insulated designs. However, both NI and MI coils face limitations, particularly in achieving optimal performance during fast discharges and other dynamic operating conditions, where a uniform transverse resistance may not be ideal.
This work investigates the 'graded approach' to transverse resistance in HTS pancake coils. This method is designed to address the NI and MI coils limitations by varying the insulation level across different sections. Three pancake coils were realized and tested: an NI coil, an MI coil, and a graded coil with sectionally varied stainless steel (SS) tape layers to modulate transverse resistance. All coils were tested under the same conditions in liquid nitrogen, undergoing variable current ramps, fast discharges, and overcurrent-induced quenches. Multiple voltage taps and a Hall sensor were implemented in each coil to monitor their respective responses. Additionally, thermo-electrical simulations were used to model and analyze current distribution across the coil turns. The distinctive features of each coil configuration are analyzed through a comparison of the model and test results, highlighting the potential benefits of the graded approach in specific scenarios.

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Presenter: Dr MUSSO, Andrea (RSE S.p.A., Milan)

Session Classification: Thu-Mo-Po.04 - No-Insulation Coils III

Contribution ID: **523** Type: **Poster**

Sat-Mo-Po.09-03: Research on the Stability of Miniaturized High-Temperature Superconducting Magnets Under Extreme Operating Conditions

Saturday, July 5, 2025 9:30 AM (1h 45m)

To fulfill the demand for high-performance magnetic fields in extreme environments, such as those found in maglev trains, the implementation of superconducting magnets with high cur-rent-carrying density offers a lightweight alternative to traditional copper or permanent magnets. This is particularly significant for enhancing the safety and cost-effectiveness of high-speed maglev trains. In this paper, we introduce a novel design for a miniaturized high-temperature superconducting magnet structure, which employs Stirling conduction cooling to provide the necessary refrigeration for the magnet. This innovative approach replaces the traditional use of liquid helium or GM refrigerators equipped with large compressors, thereby reducing the weight of the superconducting magnet from approximately 150 kg to around 50 kg. Moreover, we con-ducted stability simulation analysis and calculations for the miniaturized high-temperature su-perconducting magnet under background magnetic fields ranging from 0.5T to 2T, using the T-A numerical analysis method. These calculations took into account the thermal load working conditions of the magnet during accelerations of 5-10g and during operation. The results re-vealed that, even at a maximum operating current of 60A, the stability margin of the supercon-ducting magnet exceeded 1000 mJ/cc. Additionally, through AC loss analysis, we found that the superconducting magnet would only experience quenching when the current frequency sur-passed 250 Hz, thereby satisfying the requirements for high-frequency excitation operation of superconducting magnets. Finally, cooling and energization tests were performed to validate the low-temperature characteristics of the Stirling conduction-cooled high-temperature supercon-ducting magnet. The magnet maintained stable operation for more than 8 hours under conduc-tion cooling, with a temperature difference not exceeding 1K. This confirms the feasibility of the miniaturized conduction-cooled superconducting magnet scheme proposed in this paper, laying a solid foundation for the safe operation of superconducting magnets in extreme condi-tions of high-speed maglev trains in the future.

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Session Classification: Sat-Mo-Po.09 - Energy Storage/SMES, Levitation and Magnetic Bearings

Contribution ID: **524** Type: **Poster**

Fri-Af-Po.09-03: Magnetic field coil power supply using a flywheel generator with a planetary gear and a very small capacity inverter

Friday, July 4, 2025 2:00 PM (2 hours)

Flywheel generators are used as power sources for various plasma experiments because of their long-life span and high-power repetition. However, huge capacity inverters for energy conversion have been necessary to charge and discharge rotating energy. Furthermore, in conventional flywheel generators, the power output also decreases as the rotation speed decreases. In response to this, the authors propose a flywheel generator equipped with a type of continuously variable transmission gear called a planetary gear and an extremely small capacity motor that controls that gear. This flywheel generator can always charge and discharge rotational energy at rated output without using the huge inverter mentioned above. Here, it is assumed that the magnetic field coil is composed of a diode rectifier and a coil current-controlled chopper.

First, the mechanical shaft connection of this flywheel generator and the planetary gear is as follows. Conventionally, the flywheel shaft and the generator shaft are connected by a coupling and have the same rotation speed. However, the proposed flywheel generator is unique in the connection of both shafts. The flywheel shaft is connected to the sun gear, the generator shaft to the carrier gear, and the control motor shaft to the ring gear. By adjusting the ring gear rotation speed with the control motor, the stored energy of the flywheel generator can be discharged to the magnetic field coil.

Next, the method for adjusting the rotation speed of the control motor is explained as follows. First, the flywheel rotation speed and generator rotation speed are measured. In response to the drop in the flywheel rotation speed due to discharge, the control motor rotation speed is adjusted to keep the generator rotation speed constant. In other words, even if the flywheel rotation speed drops, the generator rotation speed is kept constant. This is because the planetary gear mechanism is a continuously variable transmission. Therefore, the generator can always achieve the rated output. This control method has been experimentally verified with a 1-kW class flywheel generator.

Finally, the specifications of a newly manufactured 10-kW class flywheel generator are as follows. The flywheel diameter and thickness are 500 mm and 135 mm respectively. The rated flywheel speed is 3000 rpm, the maximum and minimum speeds are 125% and 75% respectively, and the available energy is 150 kJ at 10 kW for 15 seconds. The generator is a 6-pole capacitor self-excited induction generator, the speed increase ratio of the planetary gear mechanism when the rotation of the control motor is locked is 3, and the inverter capacity for the control motor is 1 kW, 1/10 of the generator. In other words, the inverter capacity that adjusts the rotation speed of the control motor is also 1 kW.

In the future, we plan to experimentally verify this 10-kW class flywheel generator as a power source for magnetic field coils that can significantly reduce the inverter capacity.

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Session Classification: Fri-Af-Po.09 - Rotating Machinery IV

Contribution ID: **525** Type: **Contributed Oral**

Sun-Mo-Or2-01: Electromagnetic Design of Ioffe Magnet for Project 8

Sunday, July 6, 2025 8:00 AM (15 minutes)

Project 8 aims at measurement of the absolute neutrino mass using tritium, by precisely measuring the energies of the beta-decay electrons in the high-energy tail of the spectrum. A trap for atomic tritium is envisaged using a Ioffe magnet, which is discussed in this paper. The fundamental requirement is to trap atomic tritium within a large microwave cavity for cyclotron radiation emission spectroscopy. The cavity also acts as the bobbin of the Ioffe magnet. The Ioffe magnet is a high-multipolarity magnet constructed with precision to ensure its insignificant contribution to the field inside the cavity except near the walls. The central field is an electron trap produced by a normal conducting solenoid magnet. This paper discusses the electromagnetic design, optimization, and parametric studies of the Ioffe magnet, and it explores the feasibility of constructing and testing this magnet using BNL's direct-wind magnet technology.

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Presenter: TEOTIA, Vikas (Brookhaven National Laboratory)

Session Classification: Sun-Mo-Or2 - Fabrication and Testing of Magnets for Facilities

Contribution ID: **526** Type: **Poster**

Sat-Mo-Po.03-09: Mechanical stresses induced by high screening currents in fusion magnets

Saturday, July 5, 2025 9:30 AM (1h 45m)

The high field superconducting coils in fusion reactors will require HTS conductor designs that reduce the impact of high screening currents. These screening currents may induce high mechanical stresses, particularly in conductors carrying non-uniform currents under high magnetic fields. This work aims at investigating the current distribution in HTS conductors and mechanical stresses in winding packs using 2-D multi-physics models and the E-J power law. Magnetic field distribution and its orientation to the HTS tape are taken into account to calculate critical currents and local electric fields.

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Presenter: Mr ZAGHLOUL, Aziz (UKAEA)

Session Classification: Sat-Mo-Po.03 - Mechanics of Fusion Magnets

Contribution ID: **527** Type: **Contributed Oral**

Fri-Mo-Or2-05: Experimental study on delamination induced by electromagnetic forces in REBCO tapes.

Friday, July 4, 2025 9:00 AM (15 minutes)

This study investigates the delamination behavior of REBCO coated conductors (CCs) using the electromagnetic delamination strength (EDS) method. Unlike the mechanical delamination strength (MDS), which relates stress to structural failure, EDS focuses on the irreversible threshold at which critical current degradation occurs. This distinction is particularly important for high-field magnet applications, such as fusion magnets and particle accelerators, where REBCO CCs are increasingly utilized for their exceptional superconducting properties. However, conductors in these applications are subjected to substantial Lorentz forces, driven in part by the interaction between screening currents and the magnetic field.

The inherent weakness of REBCO coated conductors (CCs) lies in their multilayer structure, particularly the adhesion between the superconducting layer and the buffer layers. To investigate the degradation of the critical current (Ic), a custom-designed sample holder was developed, aided by numerical analyses to minimize hoop stress components and isolate the radial stresses responsible for delamination. Experiments were performed on 4 mm-wide commercial samples from various manufacturers, using magnetic fields up to 19 T and currents up to 2 kA. The relative orientation of the magnetic field and current generated an average transverse tension of up to 10 MPa. Measurements conducted at 77 K and 4.2 K were complemented by inductive mapping of the local critical current density (Jc) before and after testing, as well as SEM/EDX analyses, providing detailed insights into damage distribution and underlying mechanisms. Forensic analyses revealed compositional changes in specific regions, highlighting simultaneous quench events and localized delamination, which predominantly occurred at the tape edges. To investigate the influence of the current density profile within the superconducting layer, experiments were conducted under varying magnetic fields and temperatures. Furthermore, as 4 mm-wide tapes are fabricated by mechanical or laser slitting from 12 mm-wide tapes, the effect of the slitting process on delamination was also analyzed.

These findings offer critical insights for magnet design, identifying the conditions that cause irreversible degradation of superconducting properties and informing strategies to mitigate such effects.

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Session Classification: Fri-Mo-Or2 - Mechanical Behavior and Stress III

Contribution ID: **528** Type: **Contributed Oral**

Sat-Mo-Or6-04: Qualification and test analysis of HL-LHC magnets and cryo-assemblies

Saturday, July 5, 2025 12:00 PM (15 minutes)

The High-Luminosity upgrade of the LHC at CERN requires 32 new cryo-assemblies to be installed around the interaction points 1 and 5. They incorporate 90 magnets of various types, and in addition several prototypes and spares are built. The magnets are produced within the HL-LHC project, and a large part is tested at CERN. Most of the magnets are tested first in standalone configuration in a vertical test bench, before being assembled in a cold mass and tested in its final cryo-assembly. The test of about half of the cryo-assemblies, including the prototype magnets, have been completed at CERN, while in the vertical configuration about 70 % of the magnets have been tested.
In this paper we show the progress in testing, and we report on the most important findings of magnet performance and test results of the magnets tested at CERN in stand-alone and in cold mass configuration.

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Presenter: WILLERING, Gerard (CERN)

Session Classification: Sat-Mo-Or6 - High Luminosity LHC

Contribution ID: **530** Type: **Contributed Oral**

Sat-Af-Mem1-05: Towards a feasible 40 T solenoid magnet for high-energy physics experiments: conceptual design and screening-current reduction for the Extreme-NI coils

Saturday, July 5, 2025 5:30 PM (15 minutes)

Ultra-high field magnets are being developed for various applications in fundamental-physics experiments, materials sciences, and nuclear magnetic resonance (NMR). Here we report our recent R&D work focused on conceptual design and enabling technologies for a 40 T all-superconducting solenoid magnet with a 20-mm warn bore, intended for potential high-energy partial physics experiments. Adopting commercial REBCO conductors, we propose the Extreme-no-insulation (NI) winding technique to enhance the mechanical integrity and thermal self-protecting ability through an extra low-resistance shunting layer on the winding surfaces of the REBCO coils, along with copper cooling sheets attached to them. A small-scale Extreme-NI magnet will be wound and tested in a conduction-cooling cryostat to demonstrate high mechanical integrity and improved over-current/quench stability. To mitigate the screening-current effect, we have investigated two practical methods: the temperature-controlled charging sequence (TCCS) and the vertical-field-first charging sequence (VFCS), both of which will be tested to reduce the locally concentrated magnetic stress during charging. Based on these results, we present a conceptual design for the Extreme-NI HTS magnet for the 40 T user solenoid magnet. By employing the TCCS and/or VFCS methods, we expect the maximum hoop strain in the REBCO winding to remain below 0.5%, achieving an anticipated ˜20% reduction in peak strain compared to conventional charging sequences.

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Session Classification: Sat-Af-Mem1 - Huub Weijers Memorial: High Field Magnets

Contribution ID: **532** Type: **Contributed Oral**

Sat-Af-Or1-06: Demo4 - Presentation of the assembly and commissioning of a representational set of high filed HTS magnets in a reactor relevant configuration

Saturday, July 5, 2025 3:30 PM (15 minutes)

• Tokamak Energy is pursuing commercial fusion energy based on the development of spherical tokamaks with high temperature superconducting (HTS) magnets.
• The Demo4 project is an ambitious high field HTS magnet build that has delivered a full spherical tokamak magnet system. This will provide a world first demonstration of the operation of a representative array of coils in a toroidal and poloidal configuration, operating at fusion-relevant magnetic fields and temperatures.
• This presentation will provide a system-level overview of the magnet system and its key components, including HTS coils, vacuum vessel, bespoke cryogenic cooling system, mechanical structure, instrumentation and other systems.
• 2024 saw the accelerated build of Demo4, taking 28 Toroidal field coils, and 16 Poloidal field coils and building them into a cold mass assembly with over 600 sensors. Phase testing of sub-assemblies down to 18K was completed, testing both the power supplies and TF current leads up to full energisation current. Early 2025 saw the full HTS cold mass suspended below the cryostat top plate and enter into the commissioning phase.
• The assembly sequence will be shown from coil winding to commissioning at 20K
• The sequence of initial cool down and commissioning, leading to the energisation of the TF and PF HTS coils will be presented.

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Presenter: DUNBAR, Graham (Tokamak Energy Limited)

Session Classification: Sat-Af-Or1 - Fusion Test Facilities

Contribution ID: **533** Type: **Poster**

Wed-Mo-Po.09-04: Development and Testing of High Temperature Superconducting Vertically Stacked Cable for Fusion Applications

Wednesday, July 2, 2025 9:15 AM (2 hours)

High-temperature superconductors (HTS) are promising candidates for use in the high-field magnets required for compact fusion reactors, such as the Spherical Tokamak for Energy Production (STEP). United Kingdom Industrial Fusion Solutions (UKIFS), in collaboration with Seoul National University and PowerNix, is developing vertically stacked tape (VST) HTS cables using $ReBa_2Cu_3O_{7-x}$ coated tapes for high-field magnet applications.

For larger fusion magnets, such as toroidal field coils operating at currents around 100 kA, cable-in-conduit conductor (CICC) configurations and low-loss joints are necessary. In the VST cable, hundreds of individual tapes are soldered together into a monolithic conductor block, ensuring efficient current sharing within the tapes and with the stabilizer (the copper former). The copper former, equipped with a cooling channel, is designed to optimize the arrangement and quantity of HTS tapes to achieve the desired operating current at 20 K while minimizing stresses in the cable. These stresses arise from transverse loads caused by electromagnetic forces during operation at 20 T and 100 kA.

Preliminary tests were performed on multiple short samples (1.0 meter) to characterize the thermal, electrical, and mechanical performance of the solders, individual tapes, and the cable as a whole. A longer-length cable (3.5 meters) currently in development is planned to be tested at the SULTAN facility at 100 kA in background fields of up to 11 T and at various temperatures ranging from 5 to 50 K. These tests will provide valuable performance data and demonstrate the feasibility of producing HTS coils and CICC for future fusion reactor applications.

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Presenter: Dr CHOUHAN, Shailendra Singh (United Kingdom Industrial Fusion Solutions Ltd.)

Session Classification: Wed-Mo-Po.09 - Development and Test of Conductors for Fusion Magnets I

Contribution ID: **534** Type: **Poster**

Wed-Mo-Po.05-11: Dynamic Characteristics Analysis of HTS Maglev Systems Using Neumann Boundary Conditions

Wednesday, July 2, 2025 9:15 AM (2 hours)

High-temperature superconducting (HTS) Maglev trains are gaining attention as a next-generation transportation technology due to their high efficiency and ultra-high-speed capabilities. However, losses occurring during operation significantly impact system stability and the maintenance of the target magnetic field. In particular, in PCS (Persistent Current Switch)-based HTS Maglev trains, variations in the load factor (the ratio of operating current to critical current) induce nonlinear changes in dynamic resistance and heat losses, presenting substantial challenges for design and operation. To address these issues, this study aims to utilize the homogeneous T-A formulation to calculate current density and magnetic field distribution within the HTS magnet and applies Neumann boundary conditions to precisely analyze energy interactions at the boundaries.
This research will simulate operating scenarios, including initial current charging, acceleration, steady-state operation, and deceleration, to analyze the nonlinear characteristics of current decay and dynamic resistance. The study will specifically evaluate the nonlinear relationship between dynamic resistance and current decay under varying load factors and aims to derive design criteria for PCS to maintain the target magnetic field during operation.
This analysis will clarify the effects of load factor on dynamic resistance and heat losses, providing a systematic understanding of the correlation between thermal stability and magnetic performance. The findings will propose an extensible methodological framework to enhance the design and operational efficiency of not only HTS Maglev trains but also various superconducting systems.

This research was supported by the National R&D Program through the National Research Foundation of Korea (NRF), funded by the Ministry of Science and ICT (2022M3I9A1073187), (No.2019R1A5A8083201).

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Session Classification: Wed-Mo-Po.05 - Novel and Other Applications I

Track Classification: G: Generic Application Technologies: Approaches and Tools: G03: Losses in Conductors and Coils, Thermal Analysis

Contribution ID: **535** Type: **Poster**

Wed-Mo-Po.12-01: A HTS-based Diode for powering superconducting magnets

Wednesday, July 2, 2025 9:15 AM (2 hours)

The development of superconducting diodes has significant interest for their potential to revolutionize advanced magnetic systems such as magnetic systems powered by a flux-pump. A novel method for producing a passively controlled superconducting diode has been developed. The design is based on high-temperature-superconducting (HTS) conductor technology with the use of a ferro-magnetic yoke. A demonstrator has been built and tested to validate the concept.
In this design we will utilise the relatively low critical field properties of BSCCO-2223 as a switching element. The switching element interact with a magnetic field induced by a ReBCO bias coil wound around a ferromagnetic core. In series of the switching element there is second ReBCO coil wound around the Bias coil called the "primary coil". The primary coil will increase or decrease the field induced by the bias coil and therefore switch the switching element. The diode allows high current (>100 A) to pass for one voltage polarity and prevents the current flow in reversed polarity. This is done with minimal losses, no heating elements, and no active controls.
In this presentation, the design, the associated simulations, and the experimental results obtained with the demonstrator are presented. HTS-based diodes have a variety of potential applications, for example for the powering of superconducting magnets such as when using a flux pump and subsequent persistent operation.
Research part of Experimental Physics R&D CERN.

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Session Classification: Wed-Mo-Po.12 - Diodes, Flux Pumps, and Switches

Contribution ID: **536** Type: **Poster**

Sat-Mo-Po.05-08: Optimization of distributed fiber optic sensors for quench detection in HTS cables

Saturday, July 5, 2025 9:30 AM (1h 45m)

HTS coils will be an essential component of future accelerator magnets. Among the existing challenges, there is the lack of a robust quench detection system for HTS magnet technology. In this work, we explore the use of distributed fiber optics for local real-time monitoring of temperature variations. Fiber optic sensors based on Rayleigh backscattering were used on a series of test performed in liquid He during quench of REBCO tape and Nb3Sn extracted wire. A spot heater is used to initialize an actual quench at several current levels and find the minimum quench power. We also explore the use of distributed fiber optics for quench detection in STAR® REBCO cables. Those experiments are providing feedback on fiber sensitivity and to test different coating materials to improve the sensitivity at low temperatures.

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Presenter: BALDINI, Maria

Session Classification: Sat-Mo-Po.05 - Quench Detection and Protection IV

Contribution ID: **538** Type: **Poster**

Fri-Mo-Po.07-07: The design of an analytical magnet

Friday, July 4, 2025 9:30 AM (1h 45m)

An analytical magnet has been designed for the SV project at the Shanghai Advanced Research Institute, Chinese Academy of Sciences. According to the design parameters proposed by the Physics Department, we have confirmed the dimensions of the magnet and optimized the field quality. The simulation of the electronmagnetic field has been finished in OPERA 3D. In the paper, we give the optimization solution of the pole, study the spatial distribution of the field and errors in the good field region, and also verify that the integrated field meets the design specifications. The magnet will be manufactured in the next two months. When the magnet is produced, we will perform the magnetic field measurement.

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Session Classification: Fri-Mo-Po.07 - Accelerator Magnets III

Contribution ID: **539** Type: **Poster**

Wed-Mo-Po.04-03: Numerical simulations of a thermal runaway in Bi-2212 conductors and comparison with REBCO conductors

Wednesday, July 2, 2025 9:15 AM (2 hours)

Understanding quench dynamics in high-temperature superconducting (HTS) conductors is pivotal for their reliable integration into next-generation superconducting magnets. In this work, we present electrical and thermal simulations of Bi-2212 conductors during a current ramp to thermal runaway quench and compare them with test results. Bi-2212 conductors analyzed include a single round-strand and a Rutherford cable. We then compare the results obtained from Bi-2212 to those of single-tape REBCO tapes and two-ply REBCO conductors. We use our analysis to address quench detection thresholds and time scales during which thermal runaway can be contained to prevent conductor degradation. Furthermore, we investigate the impact of varying factors such as cooling conditions, the n-value, and the long-length critical current distribution on quench development and detection. Our work provides useful insights into the complex quench processes in HTS conductors and offers practical guidelines for detecting, managing, and mitigating quench events in advanced superconducting magnet systems.

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Session Classification: Wed-Mo-Po.04 - HTS Conductors I

Contribution ID: **540** Type: **Invited Oral**

Sat-Mo-Or1-02: [Invited] ITER Central Solenoid manufacturing and assembly progress

Saturday, July 5, 2025 8:30 AM (30 minutes)

ITER Central Solenoid (CS) at the heart of tokamak progresses its assembly on a platform in the ITER Assembly Hall where the six coil modules are vertically stacked and connected individually to their corresponding bus bar leads, and finally to be installed with all structural components that apply a vertical pre-compression on the completed stack. The status of manufacturing and assembly of CS components are reported here. All CS structural components have been successfully delivered on site whereas the remaining three CS modules are waiting for the Factory Acceptance Test (FAT) to complete. As previously reported, the third in manufacturing, CSM3, has had an incident during FAT and has been designated as a spare module to be tested after repair and to be shipped last. The sixth module, CSM6, had an insulation failure during FAT at a location of complex geometry. A collaborative effort at IO and at GA/USIPO have successfully developed and qualified an insulation repair method that is applied to CSM6. The seventh module, CSM7, successfully completed FAT and is ready to be shipped.

The assembly at ITER has completed the stacking of all lower modules in positions CS3L, CS2L and CS1L. The assembly required negotiations of mm order clearance over several meters long bus bar leads while lifting 110-ton CS module mass to the final position within ±1 mm accuracy. The fourth in stack, CS1U (CSM5), is the first of upper modules which have the terminals pointing upwards. A dedicated alignment tooling is used for the assembly of the coaxial joint between the bus bar leads and the module terminals.

The hydraulics cylinder system for the CS pre-compression, which concept was previously reported as an alternative to the multi-jackbolt system, retrofit the threaded inserts in the Upper Key Blocks. During manufacturing, a weakness was found that lead to design and manufacturing changes. After successful completion of FAT, the hydraulic system and cylinders have all been delivered.

Disclaimer: The views and opinions expressed herein do not necessarily reflect those of the ITER Organization.

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Presenter: MIYOSHI, Yasuyuki (ITER Organization)

Session Classification: Sat-Mo-Or1 - Assembly and Commissioning Fusion Tokamaks

Contribution ID: **541** Type: **Contributed Oral**

Wed-Af-Or2-07: Development of compact, fast ramping, high field HTS coils for fusion and other applications.

Wednesday, July 2, 2025 6:00 PM (15 minutes)

Fast-ramping REBCO HTS magnets are required for the central solenoid and poloidal field coils of spherical tokamaks. Beyond fusion, this class of magnets has broad relevance to a range of emerging applications including motors and generators, space propulsion, manufacturing and other sectors. These magnets cannot adopt no-insulation (NI), which offer the most compact route to high fields using HTS coils, due to well-established charging-delay limitations. Various technical challenges are therefore faced associated with quench protection, stress management and thermal management, all of which traditionally result in significantly reduced engineering current density compared to NI coils.

This presentation will describe the development of compact, fast-ramping, conduction-cooled HTS coils based on "ultra-compact insulation"technology developed recently by TE Magnetics. The work has been conducted by rapid prototyping, involving the manufacture and test of some tens of HTS coils throughout 2024 and 2025, at 100 –300 mm diameter scale. The presentation will include the results of cryogenic testing at 20-50 K at multi-kilo-amp currents. This explores aspects such as transient field stability, linearity of field vs current response, field homogeneity, and the resilience of the coils against thermal cycling, electromagnetic cycling, and intentionally induced quenches. These experimental test results will be presented alongside the predictions of our modelling software. The talk will also cover the coil development approach and choices made to optimise the design for volume manufacturability within live commercial projects. The readiness of this technology to meet the needs of various emerging commercial applications will be highlighted.

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Presenter: BRITTLES, Greg (Tokamak Energy Ltd)

Session Classification: Wed-Af-Or2 - No-Insulation Coils II

Contribution ID: **542** Type: **Poster**

Fri-Mo-Po.04-03: Design and Optimize of Gradient and Shim Coils for 1T Halbach Magnets

Friday, July 4, 2025 9:30 AM (1h 45m)

The Halbach magnets are assembled from multiple magnetic pole modules according to certain rules. Due to its small size, it can be made into desktop magnetic resonance equipment and have wide applications in food composition testing and chemical composition detection areas. Because of the use of permanent magnetic materials and assembly processes, the magnetic field uniformity of Halbach is relatively low. After manual field shimming, the uniformity within a 1 cm sphere radius is about 300 ppm. After room-temperature field auto shimming, it can reach within 10 ppm. This paper will introduce the design and analysis of the shim coil and gradient coil based on the separated conductor method and target field optimization method. The magnetic field uniformity after field uniformization is better than 10 ppm, and the gradient field intensity reaches 25 Gs/cm. By introducing a current density penalty factor to optimize the power consumption of the gradient coil, this paper will introduce the design and optimization process of the gradient and field uniformization coils and the subsequent test results.

Authors: TONG, Li (High Magnetic Field Laboratory, Chinese Academy of Sciences); Dr MINHUI, Song (High Magnetic Field Laboratory, Chinese Academy of Sciences)

Presenter: TONG, Li (High Magnetic Field Laboratory, Chinese Academy of Sciences)

Session Classification: Fri-Mo-Po.04 - Magnets for NMR

Contribution ID: **543** Type: **Poster**

Thu-Mo-Po.11-04: Compact and affordable particle therapy with high temperature superconductors

Thursday, July 3, 2025 8:45 AM (2 hours)

The treatment of cancers with particles is a superior modality compared to a treatment with X-rays. Particles are more effective and treatment is more localized, thereby sparing healthy tissues and reducing the risk of secondary tumors, resulting in an improved quality of life, as well as being the only radiation option for children and infants. Despite the clear advantages of particle therapy (PT) over X-rays, only around 10% of the patients that would benefit from PT has access to a treatment facility. The root cause of the limited availability of PT compared to X-rays is system-size and -cost. The single-room PT-system installation cost, including building, is 35 to 50 MUSD, compared to below 10 MUSD for an X-ray facility, while the cost of multi-room PT treatment facilities quickly becomes exorbitant.

The Compact Particle Therapy Development Initiative (Compact PT) was founded to address the size- and cost-issues of PT, by utilizing state-of-the-art high temperature superconductors (HTS) and unprecedented cryogen-free magnet designs. These technologies are used to create PT treatment-configurations that are size- and cost-competitive to X-ray machines, while retaining the same clinical treatment quality and options, as are available in the current, costly, and large, state-of-the-art PT treatment solutions.

In this presentation, we will provide an update on our current status and progress, and demonstrate how 360-degree rotating gantries can be achieved with radii below 2 meters for protons, and below 3 meters for carbon ions.

Author: Dr GODEKE, Arno (Compact PT)

Co-authors: Mr HARMANT, Aymeric (Compact PT); Dr SCHILLO, Michael (Compact PT)

Presenter: Dr GODEKE, Arno (Compact PT)

Session Classification: Thu-Mo-Po.11 - Magnets for Other Medical Application I

Contribution ID: **544** Type: **Contributed Oral**

Fri-Mo-Or6-01: First demonstration of the ESC quench protection concept on a common-coil magnet

Friday, July 4, 2025 11:15 AM (15 minutes)

A new quench protection technique, Energy Shift with Coupling (ESC), has recently been proposed, which is very promising for the protection of high-field magnets. The ESC system includes normal-conducting coils that are highly magnetically coupled to, but galvanically insulated from, the magnet coils. When the system is activated, rapid shift of energy from the magnet to the ESC coils is achieved, which quickly results in a substantial reduction of ohmic loss in the magnet hot spot and a transition of the superconducting coils to the normal state due to transient losses. Furthermore, during the magnet current discharge part of the magnet's stored energy is transferred to the ESC coils. ESC was successfully demonstrated at CERN on a 400 mm long flat racetrack in a structure without aperture.

In this contribution, we present the application of the ESC method to a subscale common-coil magnet named SMCC2, which was designed and manufactured by the Magnet Development (MagDev) laboratory at the Paul Scherrer Institute (PSI). The SMCC2 is a 300 mm long magnet including four stress-managed Nb3Sn common-coils and designed to reach bore and coil peak fields of about 5.3 T and 6.4 T, respectively, at a short-sample current of 9.5 kA. Protecting this magnet after a quench without using energy extraction is extremely difficult due to its very high current density, which is nearly 6 kA/mm2. The proposed ESC-based quench protection scheme relies on two ESC common-coil-type coils made of rectangular copper conductor, which are located on the outer sides of the magnet coils.

Tests were carried out at the CERN magnet test facility, successfully demonstrating ESC performance under various operating conditions. These results show that ESC is an effective and high-performance technology that can protect magnets up to very high current densities.

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Presenter: Dr RAVAIOLI, Emmanuele (CERN)

Session Classification: Fri-Mo-Or6 - Quench Detection and Protection I

Contribution ID: **545** Type: **Contributed Oral**

Sun-Mo-Or2-05: The HTS4 project: Energy-efficient FCC-ee operation using HTS nested magnets

Sunday, July 6, 2025 9:00 AM (15 minutes)

We present our work on the HTS4 project, part of the CHART framework and the FCC Feasibility Study, on energy-efficient nested HTS magnets for FCC-ee. By replacing the normal conducting sextupole and quadrupole magnets in the 2900 short straight sections by HTS nested variants, significant amounts of energy can be saved. This follows from 1) avoiding ohmic dissipation in the sextupoles and quadrupoles and 2) a reduction in synchrotron radiation via increasing the dipole filling factor. We estimate that the combination of these two points will allow a reduction of the total FCC-ee energy consumption by 20%. As a bonus, the better filling factor results in a reduction of the total RF voltage needed, which results in an extra reduction of capital expense for the RF system.

The optimum operating temperature of such a nested HTS system is found by balancing the operational costs (dominated by electricity use for cooling) with capital costs (dominated by HTS conductor). As cooling options, both conduction cooling with (redundancy based) cryocoolers as well as cooling via a distribution line and centralized cooling plants are considered. We show that from a total cost point of view HTS-based FCC-ee operation is competitive to the normal-conducting baseline.

The end goal of the project, a sextupole-quadrupole nested prototype, is supported by demonstrators manufactured at CERN and PSI. Our first two demonstrators investigate the options of using a wax-impregnated canted-cosine-theta based on insulated tape, and a partial-insulation based cosine-theta configuration. We discuss winding techniques and results from tests in PSI's cryogen-free test stand and the status of the prototype.

This work was performed under the auspices of and with support from the Swiss Accelerator Research and Technology (CHART) program (www.chart.ch).

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Presenter: KOSSE, Jaap (PSI)

Session Classification: Sun-Mo-Or2 - Fabrication and Testing of Magnets for Facilities

Contribution ID: **546** Type: **Contributed Oral**

Sat-Af-Mem1-03: Progress in the Development of the MIT 1.3-GHz NMR Magnet: Separate Testing Results of HTS Insert and LTS Background Magnets

Saturday, July 5, 2025 5:00 PM (15 minutes)

We present an update on the ongoing development of the MIT 1.3-GHz nuclear magnetic resonance (NMR) magnet system (1.3G). The 1.3G consists of a 19.6-T (835-MHz) high-temperature superconducting (HTS) REBCO insert magnet (H835) and an 11.7-T (500-MHz) low-temperature superconducting (LTS) background magnet (L500). These two magnets are coaxially aligned and independently powered to generate a combined magnetic field of 30.53 T (1.3 GHz). The 835-MHz REBCO insert (H835) has been successfully constructed and charged to its target current of 230 A. During standalone testing at operating temperatures ranging from 17 K to 4 K in solid nitrogen, the measured center field strength at 230 A was 19.43 T, which is slightly below the designed value due to the screening current effect. In this paper, we will summarize the design, construction, and test results of H835, including a discussion of the challenges encountered. Additionally, we will present the assembly process and standalone test results of L500. These tests will be conducted in a newly developed solid-nitrogen-cooled cryostat equipped with a 2.5-W@4.2 K pulse-tube cryocooler for the 1.3G system and an NMR-standard 54-mm room-temperature bore. Following the discussion of these separate test results, we will propose the final design, operational parameters, and sequence for the integrated 1.3G system. The integration of H835 and L500 is expected to be completed by the end of 2025, finalizing the 1.3G system.

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Presenter: Dr PARK, Dongkeun (Massachusetts Institute of Technology)

Session Classification: Sat-Af-Mem1 - Huub Weijers Memorial: High Field Magnets

Contribution ID: **547** Type: **Poster**

Sat-Mo-Po.01-04: Magnetic Field Mapping of a 2.5 T HTS Magnet for Proton Therapy

Saturday, July 5, 2025 9:30 AM (1h 45m)

We present results from testing a high-temperature superconducting (HTS) magnet prototype for proton therapy. This magnet is specifically designed for a novel rotating gantry capable of delivering the entire proton beam energy range (70–225 MeV) while maintaining a fixed magnetic field in the superconducting magnets. The gantry's innovative layout simplifies the magnet design by enabling the use of straight, flat racetrack DI-BSCCO Bi-2223 coil technology and operation at higher temperatures (˜10–15 K).

The magnet has a non-linear field distribution for bending and focusing the proton beams. To validate this feature, we developed a system for measuring the magnetic field distribution in the magnet aperture. We present the design of this hall probe array and experimental results from two different magnet tests at 4.2 K in a liquid helium bath. These results are compared with expected results from simulation of the field distribution and discussed in the context of required field quality for the application.

This work was supported by the Director, Office of Science, Accelerator R&D and Production, and U.S. Department of Energy under contract No. DE-AC02-05CH11231.

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Presenter: MOSAT, Marek (Lawrence Berkeley National Laboratory)

Session Classification: Sat-Mo-Po.01 - Magnets for Other Medical Application II

Contribution ID: **548** Type: **Contributed Oral**

Thu-Mo-Or1-03: Protecting Nb3Sn accelerator magnets with the new ESC method

Thursday, July 3, 2025 11:15 AM (15 minutes)

Quench protection of high-field, high-energy-density magnets poses significant challenges. Maintaining the hot-spot temperature and peak voltage-to-ground within acceptable limits requires a protection system that quickly transitions most of the coil turns to the normal state.
Long established magnet protection technologies, such as quench protection heaters or the Coupling Loss Induced Quench system (CLIQ), have been successfully applied. However, they both present shortcomings since in the case of the heaters they require a thin insulation between the heaters and the magnet conductor, or in the case of CLIQ direct electrical connections to the magnet coil.
A new quench protection method, Energy Shift with Coupling (ESC), is investigated. It can achieve excellent quench protection performance without requiring any electrical connection or close physical contact with the protected coils.
ESC relies on normal-conducting auxiliary coils, which are strongly magnetically coupled with the main magnet coils. Upon quench detection, capacitive units installed across the auxiliary coils introduce a large current change in the auxiliary coils, causing a rapid shift of magnet stored energy from the main magnet coils to the auxiliary coils. This has three beneficial effects: sudden reduction of ohmic loss in the magnet conductor hot-spot, introduction of high transient losses in the magnet conductor, thus causing a quick transition to the normal state, and extraction of part of the magnet's stored energy to the auxiliary coils and their circuits.
The applicability of the ESC-based protection to various Nb3Sn accelerator magnet designs with a peak field between 12 T and 15 T is studied. The magnets are characterized by different geometries and are analyzed with electro-magnetic and thermal transient simulations performed with the STEAM-LEDET program. Simulation results show that ESC can be applied to protect full-scale magnets with reasonable requirements in terms of size and location of the auxiliary coils, and of capacitive unit parameters.

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Presenter: Dr RAVAIOLI, Emmanuele (CERN)

Session Classification: Thu-Mo-Or1 - LTS Magnet Advanced Concepts

Contribution ID: **549** Type: **Poster**

Fri-Mo-Po.07-09: Optimization of a 123-mm Aperture Nb3Sn Dipole Coil with Stress Management

Friday, July 4, 2025 9:30 AM (1h 45m)

A 123 mm aperture Nb3Sn cos-theta (CT) dipole coil with stress management (SM) was developed at Fermilab to demonstrate and test the SM concept. Additive Manufacturing technology was used to produce the coil mandrel. Several changes were made to the SMCT coil design and technology based on the analysis of post-production and two cold tests of the first SMCT coil. This article describes the differences in coil design, fabrication steps, and final parameters of the second SMCT coil and its components.

Author: NOVITSKI, Igor

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Presenter: NOVITSKI, Igor

Session Classification: Fri-Mo-Po.07 - Accelerator Magnets III

Contribution ID: **551** Type: **Poster**

Fri-Af-Po.05-04: Towards commissioning of the Nijmegen 45 T hybrid magnet system

Friday, July 4, 2025 2:00 PM (2 hours)

The High Field Magnet Laboratory of the Radboud University in Nijmegen has been building a 45 T hybrid magnet system over the last 10 years. The 12.3 T Nb3Sn CICC outsert coil has been wound and further processed by the National High Magnetic Field Laboratory in Tallahassee FL, USA. The coil is placed in a separate enclosure and will be operated at 4.5 K in an atmosphere of 1 bar of helium gas. Binary HTS/Cu-HEX current leads have been placed at some distance from the magnet, and are connected with a 4 meter long NbTi superconducting busbar to the magnet coil. The bus bar and the HTS section of the current leads are surrounded by the 1 bar helium gas atmosphere over their entire lengths as well, thus reducing the risk of high-voltage discharges that can occur in vacuum.
Significant forces may act on the superconducting outsert coil when the 32.7 T resistive insert magnet would fail, such as through partial burn-out. We have implemented novel solutions for the axial and radial support of the outsert magnet to sustain these forces comfortably.
The superconducting magnet is cooled with a forced flow of supercritical helium delivered by a helium refrigerator. The combination of the cryogenic distribution box and the refrigerator was extensively tested and shows that the cooling and guarding procedures in principle are adequate, and can be programmed into the Valve Box Control System, that will supervise the cryogenic operation of the hybrid magnet.
At present, assembly and integration of the outsert magnet system is completed, all auxiliary systems are commissioned and in place. After repair of several leaks in internal helium sub-systems, the magnet cryostat will be closed soon. The first cool-down of the outsert magnet of the Nijmegen 45 T hybrid magnet is expected in the second half of this year. In this paper, we briefly summarize the main design concepts and the system's status.

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Session Classification: Fri-Af-Po.05 - High Field Solenoids Resistive and LTS

Contribution ID: **552** Type: **Contributed Oral**

Wed-Mo-Or2-05: Techno-economical comparison of energy-efficient superconducting magnets for large accelerator facilities sustainability

Wednesday, July 2, 2025 12:15 PM (15 minutes)

Large particle accelerator facilities for medium-high proton and heavy ion beamlines extensively rely on normal conducting magnets which, while effective, suffer from significant energy losses due to resistive heating in their copper coils. One successful strategy for improving these facilities involves upgrading their existing infrastructure by replacing resistive magnets with magnesium diboride (MgB2) or high-temperature superconductor (HTS) based alternatives. By retaining the iron yoke while substituting copper coils with MgB2 or HTS windings, the operational cost and energy consumption of the magnet can be significantly reduced while maintaining the same performance.

In this framework, the Energy Saving Accelerator and Beam Line Magnets (ESABLiM) project was launched to develop and implement superconducting-based magnets specifically tailored for existing accelerator facilities, including the Paul Scherrer Institute (PSI) and the Centro Nazionale di Adroterapia Oncologica (CNAO). The project's primary objective is to lower the overall energy consumption of accelerator magnets by reducing power losses and optimizing cryogenic systems required to maintain superconducting conditions. The integration of MgB2 and HTS technologies promises to enhance magnet efficiency by decreasing the energy consumption of the cooling systems operating at cryogenic temperatures above 20 K. In this paper, superconducting models of superferric dipoles are compared with equivalent resistive configurations, through a semi-analytic script that integrates a FEM electromagnetic optimization of the magnet cross-section. Mechanical and thermal designs are optimized to minimize the power consumption of the superconducting magnet and heat load on the coils. The calculated investment and operational cost of the new superconducting configuration and its power consumption are compared by evaluating the parameter region where superconducting designs are more cost-efficient than a normal conductive one. The results of the comparison outline the benefit of MgB2 and HTS technologies as key elements of next-generation accelerator facilities, offering improved performance, reduced energy consumption, and enhanced sustainability.

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Presenter: MARIOTTO, Samuele

Session Classification: Wed-Mo-Or2 - Muon Collider Magnets

Contribution ID: **553** Type: **Poster**

Fri-Af-Po.07-02: Miniature split-pair coil for x-ray measurements at the European X-Ray Free-Electron Laser Facility

Friday, July 4, 2025 2:00 PM (2 hours)

We introduce a miniature pulsed magnetic field setup and a sample cryostat that is available at the European XFEL user facility for x-ray beamtimes. It is installed at one of the six beamlines called Materials, Imaging and Dynamics that uses femto-second x-ray pulses of extreme brilliance to study ultra-fast dynamics of magnetic materials and nano-structures [1].
We describe the experimental setup that uses an in-house built split-pair coil cooled directly by liquid nitrogen to provide a magnetic field of up to 15 T. A sample cryostat allows solid-samples to be studied in vacuum at cryogenic temperatures from 10 K to 300 K in the bore of the magnet. The magnet design allows for a wide angular diffraction of x-rays on a sample by incorporating a large horizontal slit. The unique structure of x-rays at the Eu-XFEL has a burst of duration 600 μs made up of 2700 ultra-short x-ray pulses. The magnetic field pulse has a rise-time of 500 μs which, when overlaid with the x-ray burst, allows single x-ray pulses to probe the sample over the complete magnetic field range, greatly increasing the duty cycle of the available x-ray pulses in the presence of a magnetic field.
We describe the integration of the setup at the beamline including power source, magnet cryostat, sample cryostat, sample exchange and sample alignment. Finally we report on commissioning and performance of the setup for x-ray experiments.
[1] A. Madsen et al. ”Materials Imaging and Dynamics (MID) instrument at the European X-ray Free-Electron Laser Facility”J. Synchrotron Rad. 28, 637-649 (2021)

Author: Dr MOORE, James

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Presenter: Dr MOORE, James

Session Classification: Fri-Af-Po.07 - High Field Pulsed Magnets II

Contribution ID: **554** Type: **Contributed Oral**

Sun-Mo-Or1-02: A ladder approach to investigate radiation damage in coated conductors for magnetic confinement nuclear fusion reactors magnets

Sunday, July 6, 2025 8:30 AM (15 minutes)

Strong efforts to develop magnets for compact fusion reactors using coated conductors (CC) are presently underway. To determine the operational lifetime of fusion magnets, it is necessary to know the effects of radiation damage on the critical current density J_c of the CC. According to plans, fusion magnets will operate between 10 and 30 K in a background field up to 20 T. As portions of the magnet will be exposed to lower fields, and some to slightly higher ones, and considering that CC are anisotropic, we need to investigate J_c(B,Θ,T) up to B>20T, for T≥10K, and for all field orientations (Θ). These extensive studies can only be performed in a limited number of facilities, and a complete J_c(B,Θ,T) characterization will be time consuming and expensive.
The pinning landscape in CC is complex, consisting of various types of defects, both spontaneously occurring and introduced as artificial pinning centers (APC), which act in combination, producing cooperative and competitive effects. The resulting J_c(B,Θ,T) is unique to each deposition method, to the APC nanoengineering, and to processing parameters. The radiation damage will interact with preexisting landscape and reduce the superfluid density in ways that need to be explored and understood in each case. Thus, the studies will have to be repeated for each reactor design and for each CC. Although that detailed investigation cannot be totally avoided, we have designed an approach to make that process as efficient as possible.
In the B-Θ-T space, CC exhibit several pinning regimes that can be identified by the functional dependences of J_c(B,Θ,T) and the pinning force F_p(B,Θ,T). It is extremely difficult (if not impossible) to infer the effects that adding defects will have in one regime by measuring their effects in another one, thus investigating the irradiation/annealing evolution in a regime different from those to occur in the actual magnets has limited value. However, if the functional dependencies of J_c(B,Θ,T) are known, we can apply scaling rules to infer J_c at different B-Θ-T conditions as long as the sample remains in the same pinning regime. Our approach is to map the dependences and boundaries of those regimes in the B-Θ-T space for unirradiated CCs, identify which are relevant to fusion reactor magnets, and then follow their evolution with fluence for different types of irradiations (neutron, proton) at various conditions (room or cryogenic temperature) and after thermal annealing, using a "ladder of experiments"of increasing complexity, from permanent magnets to electromagnets, SQUID up to 7T and VSM up to 14T, and pulsed fields up to 65T; each step informing the next one. Thus, the irradiation effects can be assessed by performing extensive studies using fast and easily accessible systems, complemented with a limited number of the more involved measurements at selected samples and conditions. In this talk I will describe our methodology and present initial results for unirradiated and irradiated samples.

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Presenter: CIVALE, Leonardo (Department of Physics, University of Connecticut)

Session Classification: Sun-Mo-Or1 - Technology for Fusion Reactors II

Contribution ID: **555** Type: **Poster**

Fri-Mo-Po.04-09: Experimental validation demonstrating cryogen-free technology for high resolution solid- and liquid-state NMR.

Friday, July 4, 2025 9:30 AM (1h 45m)

A 9.4 T cryogen-free system developed by Cryogenic Limited has been used for the high resolution solid-state magic angle spinning (MAS) and liquid-state NMR experiments. The temporal magnetic field distortion due to the cold head operation was 2 Hz peak-to-peak on the resonance frequency 400 MHz [1]. This distortion occurred at the frequency of 1.7 Hz in our experimental setup.

In solid-state NMR measurements, the distortion appears as additional line broadening that is too small to be visible in ordinary MAS experiment. To see the effect, the amplitude of the distortion was enhanced by a factor of 40 above its natural value. Notably, if the NMR signal only lasts a small fraction of the cold head period, for instance, 100 ms, the effect of the cold head can be fully removed by synchronizing the signal acquisition with the cold head operation. In this case the distortion amplified by 400 times remained invisible. This approach was successfully demonstrated through our experiments in recording the solid state multi-quantum 2D spectra of 87Rb in RbNO3. The spinning speed was 11 kHz.

In liquid-state NMR measurements, however, the signal acquisition time normally covers several cold head periods. In this case, the additional peaks separated by the cold head frequency appear in the NMR spectra. The sweep coil of the room-temperature (RT) shim set was used for the correction (or amplification as above) of the cold head distortion. Our experimental observations showed that the amplitude of the distortion needs to be reduced by a factor of 10 to stop being important in liquid-state NMR.

In addition, we have demonstrated that applying reference deconvolution post-acquisition software processing [2] helps remove the field instability artifacts from NMR data, in both 1D and 2D NMR. We have also developed a method to stabilize the magnetic field in a short period of time following a field ramp [3], enabling high resolution measurements at different fields every day. We have measured four double quantum (DQ) filtered COSY spectra in ethyl acetate at 50, 100, 155 and 400 MHz. These spectra were measured at different fields in four consecutive days.

Currently, we are developing a dedicated liquid-state NMR system based on a cryogen-free magnet with an improved design. This next-generation system aims to eliminate the need for field corrections or post-acquisition processing, thereby improving both measurement accuracy and operational efficiency.

References

1. E. Kryukov et al, SS NMR, 113(2021)101732
2. A. Karabanov et al, JMR, 353(2023)107494
3. E. Kryukov et al, SS NMR, 109(2020)101684

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Presenter: Dr BRACANOVIC, Darko (Cryogenic Limited)

Session Classification: Fri-Mo-Po.04 - Magnets for NMR

Contribution ID: **556** Type: **Poster**

Fri-Mo-Po.04-01: Construction and Test Results of a Cryogen-Free, Iron-Shielded 23.5-T REBCO Magnet for Benchtop 1-GHz NMR Spectroscopy

Friday, July 4, 2025 9:30 AM (1h 45m)

In this paper, we present the finalized design, construction, and test results of a cryogen-free, iron-shielded 23.5-T/28-mm room-temperature bore REBCO magnet, developed for use in benchtop 1-GHz microcoil NMR spectroscopy. This benchtop magnet is composed entirely of REBCO conductors and operates at ˜10 K in a conduction-cooled cryostat, featuring an external iron cylinder outside the vacuum chamber for fringe field shielding. The magnet employs a surface-shunting no-insulation (NI) winding technique, with copper cooling sheets attached to each winding surface to mitigate quenching risks from potential fault modes, thereby enabling self-protection. The design was modified to include 32 double pancake coils using 4-mm-wide REBCO tape. This change was implemented to align with the manufacturer's standard dimensions, addressing the conductor thickness uniformity issues encountered during winding. The coils are co-wound with Hastelloy tapes to reduce overall current density, lower stress, and enhance structural strength within the winding pack. Additionally, the top and bottom winding surfaces are shunted with low-temperature solder to improve thermal and electrical performance. We detail the construction process, including winding, surface-shunting, jointing, and assembly into a custom-developed, vibration-isolated, iron-shielded, conduction-cooled cryostat. The paper concludes with the initial test results and performance evaluation of the magnet.

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Session Classification: Fri-Mo-Po.04 - Magnets for NMR

Contribution ID: **557** Type: **Poster**

Fri-Mo-Po.08-01: HTS tapes for very High Field Magnets: Performance specification, Characterisation and Uses

Friday, July 4, 2025 9:30 AM (1h 45m)

As the principal components and conductors of the new generation of very high field superconducting magnets, High Temperature Superconducting Tapes (HTS tapes) are getting a particular attention on their selection, characterisation and uses.
In this context, Tokamak Energy has multiple specification covering the needed performance, tolerance and characteristics of HTS tapes. The most important parameters will be discussed in this poster alongside our tape selection and qualification process in order to guaranty the best performance for our magnet systems.

In addition, we will exhibit the extensive characterisation platform developed on both short samples and coils to determine the electromagnetic performances of HTS tapes over various temperature and fields, including in fusion-relevant conditions (<30 K, >15 T). This characterisation platform is both used for quality control and quality assurance as it supports the relevancy on the tape specifications and evaluate the position of each available product in the market in a regular basis.

Lastly, a discussion toward the relevancy of the highlighted tape specifications on magnet development will be presented with the help of concrete examples based on our recent HTS coils and magnet development held at TOKAMAK Energy.

In conclusion, we will highlight the important characteristics to work on to improve our coil quality and production capability.

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Session Classification: Fri-Mo-Po.08 - HTS Characterization II

Contribution ID: **558** Type: **Poster**

Sat-Mo-Po.06-01: Active shimming magnet for dipole accelerator magnet to compensate sextupole harmonic field

Saturday, July 5, 2025 9:30 AM (1h 45m)

High temperature superconducting (HTS) accelerator magnets can achieve higher magnetic field with higher current capacity. However, with the shielding current effect of the HTS materials, the current distribution inside REBCO tape will deviate from uniform current assumption, which results in a higher sextupole field harmonics. To compensate sextupole harmonic field in the accelerator magnet due to the shielding current effect, an active shimming coil was designed and tested. The shimming magnet had three racetrack coils wounded with 2 mm wide REBCO tapes. The top and bottom coils were normal racetrack coils with 300 mm long straight sections,
and the middle racetrack coil had hard-bending sections at the coil end with a radius of 800 mm. According to simulation, the shimming magnet could generate a sextupole field under self-field ramping. As for the situation when the shimming magnet was inserted into a dipole magnet, the shimming magnet could compensate the sextupole error harmonic field with small effects on other higher harmonics. Under 77 K self-field test, the active shimming magnet could ramp up to 20 A without significant voltage rise. Then the active shimming magnet was inserted into a dipole accelerator magnet and tested under 4.2 K with a dipole magnetic field of 1 T and 3 T. The field quality was measured with a rotating PCB pick-up coil with a reference radius of 4 mm. The test result showed that the sextupole harmonic field decreased with the ramping of the shimming magnet linearly, and the sextupole field quality reached below 1 unit with a shimming current of 35 A under 1 T and 40 A under 3 T, which proved the feasibility of the active shimming magnet. This work proved the possibility of reaching good field quality below 1 unit using active shimming technology with HTS magnet, and will contribute to the development of HTS accelerator magnets.

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Session Classification: Sat-Mo-Po.06 - Mechanical and Magnetic Measurements

Contribution ID: **559** Type: **Poster**

Thu-Mo-Po.09-10: E(J) characterization of REBCO tapes using pulsed current method

Thursday, July 3, 2025 8:45 AM (2 hours)

Characterization of superconducting Rare-Earth Barium Copper oxide (REBCO) tapes is a prerequisite to produce electrotechnical devices such as electromagnets, superconducting fault current limiters or superconducting magnetic energy storage.
The Grenoble applied superconductivity group is developing a high field large bore cryocooled magnet and knowing the critical current Ic everywhere in the device is essential for the realization and operation of the magnet. Therefore, a transport current characterization activity for commercial tape is under development. The chosen approach is the pulsed current method coupled with the use of microbridges. The greatest advantage of the pulsed current method over the ramp method is that, for sufficiently short pulses in the order of the millisecond, the temperature drift of the sample can be neglected [1], and the behavior at high dissipation levels can be observed safely. On the other hand, other phenomena such as magnetic relaxation and the noise of a high-speed acquisition system must be considered to obtain consistent results. The use of microbridge is chosen to reduce the amount of current to be injected through the characterization probe.
A characterization probe was designed and assembled to fit into a 19T superconducting magnet available at the high field facility LNCMI with a variable temperature insert. This probe can carry upward of 200 A between 4.2 K and 77 K, supports a rotating sample holder for Ic-θ measurements and has superconducting current leads to reduce heat dissipation in the cryogenic environment.
Measurement of the V-I characteristic of REBCO tape samples using both pulsed current and ramp method combined with the use of current sharing algorithms, enables us to estimate not only the critical current Ic but the E(J) relationship over a wide range of Electrical field.

Reference

[1] Y. Tsuchiya et al., IEEE Trans. Appl. Supercond. 34, 9500207 (2024).

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Session Classification: Thu-Mo-Po.09 - Conductor and Coil Measurement/Test Techniques and Facilities II

Contribution ID: **560** Type: **Contributed Oral**

Sat-Mo-Or5-05: Analysis of Quench Protection and Detection in a Bifilar REBCO Racetrack Coil

Saturday, July 5, 2025 12:15 PM (15 minutes)

The development of high-field magnets using high-temperature superconductors (HTS) presents significant challenges, particularly in quench detection and protection. Due to the inherently slow quench propagation in HTS, conventional detection and protection methods may be ineffective. To address these challenges, novel approaches are being explored by the magnet community. A possible method involves winding superconducting coils in a bifilar configuration, where two adjacent conductors are wound side by side, enable operation in series mode during normal conditions and in anti-parallel mode during a quench event. In this configuration, the coil differential inductance is close to zero during a quench, allowing extremely rapid current oscillations through capacitor discharge. This process induces fast heat dissipation, effectively quenching the entire coil on the microsecond timescale. Additionally, the strong intrinsic coupling between the two halves of the bifilar coil effectively cancels electrical noise in voltage taps, enabling accurate measurement of voltage growth due to a spontaneous quench. In this paper, we demonstrate the feasibility of this concept using a REBCO bifilar racetrack coil. We describe the design and construction of the magnet and present experimental results obtained from testing in liquid nitrogen. These results confirm the ability to quench the entire coil within microseconds and detect resistive voltage growth before a spontaneous quench poses a danger. Furthermore, we validate a simulation model capable of reproducing the coil behavior under rapid current oscillations, showing good agreement with experimental results.

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Session Classification: Sat-Mo-Or5 - Quench Detection Modelling

Contribution ID: **561** Type: **Contributed Oral**

Sat-Mo-Or2-05: Renaissance fusion's magnet program for simplified high-field stellarator magnets based on laser patterned wide HTS conductors

Saturday, July 5, 2025 9:15 AM (15 minutes)

Stellarators have traditionally been constructed using complex 3D magnets to produce the helical-shaped magnetic field configuration needed to confine the plasma. The complexity of manufacturing stellarator magnets has prevented their large-scale development, despite their advantageous steady-state operations and current-free plasmas compared to other magnetic confinement devices such as tokamaks [1].

Renaissance Fusion has been developing manufacturing processes, electromagnetic design optimization tools, high-temperature superconductors (HTS) and copper electromagnets to simplify the construction of stellarator magnets. Our aim is to deliver high-field simplified stellarator magnets based on laser-engraved, meter-wide, HTS sheets wound over cylindrical structures. The present work describes the company's program for fusion magnets and our recent experimental results, with a focus on three technological pillars; (1) a newly developed roll to roll HTS engraving laser machine with experimental tests showing the ability to engrave HTS tape and the processing of 500mm wide conductor sheets over hundreds of meters in length. (2) A 0.65m major radius toroidal device, based on piece-wise cylindrical coils made from laser engraved wide copper sheets optimized to replicate within 10^{-4} field accuracy, a scaled-down Wendelstein 7X (W7X, stellarator fusion machine currently under operation in Germany) magnetic configuration with 0.1T on its axis. (3) A 6T peak Helmholtz-type, no-insulation, HTS magnet of 1.2m in diameter, cooled at 20K, developed to provide a background field 0.9T for a liquid metal experimental loop operating at temperatures up to 900℃.

The experimental results from these three demonstrators validate and de-risk our simplified stellarator magnet program. They provide a steppingstone towards integrating laser engraving coil technology with Renaissance Fusion's wide HTS sheets, delivering high-field, laser-engraved HTS magnets wound over cylindrical structures generating accurate stellarator magnetic configurations.

[1] Bosch, H. S., Wolf, R. C., Andreeva, T., Baldzuhn, J., Birus, D., Bluhm, T., … & Jenzsch, H. (2013). Technical challenges in the construction of the steady-state stellarator Wendelstein 7-X. Nuclear Fusion, 53(12), 126001.

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Session Classification: Sat-Mo-Or2 - Fusion Devices: Stellarators and Levitated Dipoles

Contribution ID: **563** Type: **Poster**

Thu-Mo-Po.10-03: J-A-φ formulation with homogenizing technique used to efficiently model HTS cable-in-conduit.

Thursday, July 3, 2025 8:45 AM (2 hours)

The integration of high-temperature superconductors (HTS) into fusion coil systems is a key advancement for magnetic confinement fusion technology. HTS conductors provide significant benefits, including higher operational thresholds for temperature, transport current, and magnetic fields, which are pivotal for future fusion applications. A previous study introduced an innovative HTS sector cable-in-conduit conductor optimized for low losses and developed an analytical model to estimate magnetization losses during varying magnetic fields. Building on this background, the present work introduces a novel computational approach using the 2D J-A-φ formulation, significantly enhancing simulation efficiency, by reducing computational time of one order of magnitude. This improved framework, based on Finite Elements Analysis (FEA), enables practical assessment of magnetization losses under complex field conditions. The results exhibit excellent agreement with the prior analytical model and the T-A formulation, affirming both accuracy and efficiency. This approach opens new possibilities for optimizing HTS cable designs, particularly for high-performance applications like the DEMO Central Solenoid coil, where precise thermal and magnetic behavior predictions are critical during demanding plasma initiation and operation scenarios.

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Session Classification: Thu-Mo-Po.10 - Modelling of Fusion Conductors and Coils II

Contribution ID: **564** Type: **Poster**

Thu-Af-Po.07-04: Validation of the 4C code against data from the cooldown of the EAST TF magnets

Thursday, July 3, 2025 2:00 PM (2 hours)

After the first plasma in 2006, the Experimental Advanced Superconducting Tokamak (EAST) is approaching now 20 years of operation. It has been the first tokamak featuring both toroidal and poloidal superconducting coils. In particular, its toroidal field (TF) magnet system is composed by 16 coils with an height of about 4 m.
The superconducting coils are operated at a temperature of 4.5 K, being cooled by supercritical He (SHe) at 3.76 bar. To reach the nominal operating conditions, the magnet system undergoes a transient (the cooldown) during which its temperature is slowly reduced from room temperature to the operating (cryogenic) one.
The Cryogenic Circuit, Conductor and Coil ("4C") code is a numerical tool developed more than 15 years ago at Politecnico di Torino to perform the thermal-hydraulic analysis of superconducting magnets for fusion applications. It has been validated against several transients (from the fast quench to the slow cooldown) and is now being applied to simulate the same transients to support the design of the magnet systems of future tokamaks.
In this work, the 4C code is used to model the cooldown of the EAST TF coils, aiming at its first validation in the case of a magnet cooldown in a tokamak. The measured boundary conditions (inlet temperature and inlet and outlet pressures) will be applied to the 4C magnet model, and the evolution of the computed outlet temperature will be compared with the experimental data to quantify the accuracy of the model.
As the actual cooldown process of the EAST TF coil is controlled by the temperature difference between the SHe outlet and inlet, but the maximum temperature difference inside the coil cannot be measured because it location is not known a priori, the 4C simulation will also support the optimization of the cooldown: the possibility to accelerate the cooldown without exceeding the maximum allowed temperature difference will be investigated.
This validation exercise will move a step forward in the qualification of the 4C code in perspective of its application to future machines, also in view of the licensing requirements, as (to the best of our knowledge) currently there is not any tool qualified for this. In particular, the 4C code is already being applied to the CFETR TF coil cooldown simulation.

Aknowledgements
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Session Classification: Thu-Af-Po.07 - Quench in Fusion Magnets I

Contribution ID: **565** Type: **Poster**

Fri-Af-Po.11-07: Development of Paschen-tight Insulation Repair for Complex Geometries for the ITER CS Modules

Friday, July 4, 2025 2:00 PM (2 hours)

General Atomics (GA) is fabricating seven ITER Central Solenoid Modules (CSM) for the ITER Organization (IO). As part of the fabrication process, all CSMs undergo factory acceptance testing (FAT) prior to shipment to the IO. The FAT includes Paschen testing the CSMs up to 15kV between 1e-3 and 100 mbar. During post-cooldown Paschen testing of CSM6, there was a fault on one of the terminal breakout locations which would require a repair. This location of the fault consisted of complex geometry that required development of advanced insulation repair methods to return the module to Paschen-tight condition.

Successful insulation repairs require sufficient compression to achieve a Paschen-tight seal of the applied insulation to the underlying surfaces. Typically for circumferential shapes, compression is achieved utilizing shrink tape or silicone tape wrapped around the perimeter. The complex geometry of CSM6 required research into other compression methods including vacuum bagging, expanding foam, and externally pressurized bladders of complex shapes. Multiple test articles were created to replicate the shape of the fault area and repair methods were developed and Paschen tested to 30kV from 1e-3 to 100 mbar.

This paper will discuss the development of the qualified repair process for the complex fault location of CSM6, and present to the magnet community the lessons learned from that development.

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Session Classification: Fri-Af-Po.11 - Experiments and Test for Fusion Magnets

Contribution ID: **566** Type: **Invited Oral**

Sat-Af-Spe1-05: [Invited] REBCO Rutherford-Type Cables (FReTC) for high-current and high-field applications

Saturday, July 5, 2025 3:00 PM (15 minutes)

Rare Earth-Barium-Copper-Oxide (REBCO) High-Temperature superconductor (HTS) exhibits high-current performance in high magnetic fields. Various cabling methods for REBCO tapes have been developed, including Roebel Assembled Coated Conductor (RACC), Stacked Tapes Assembled in Rigid Structure (STARS), Conductor-On-Round Core (CORC®), Twisted Stacked-Tape Cable (TSTC), and a few other alternatives.
We recently developed a Rutherford-type cable for flat REBCO tapes [1]-[3]. Rutherford-type cables have previously been used for low-temperature superconducting and BSCCO-2212 round wires. In addition, high-current Rutherford-type cables based on RACC and TSTC cabling have been fabricated for flat REBCO tapes. However, these REBCO Rutherford-type cables were fabricated by sub-cables composed of Roebel RACC or round-sheathed stacked tape conductors. Therefore, they result in low engineering current density and require extra fabrication steps.
Our Rutherford-type cable, called FReTC, can be directly fabricated onto a thin, flat, round-edge former by winding REBCO tapes from the manufacturer's tape spools. This cabling method allows the fabrication of a full-size conductor, such as a 40 kA-level cable, in a single process.
FReTC has various advantages over other HTS cabling methods, resulting from the Rutherford-type structure of the flat tape superconductors. It has a robust cable structure with a flat core former. FReTC provides better characteristics against transverse electromagnetic forces than other REBCO cables, especially for high electromechanical load applications.
The superconducting tapes in a FReTC are symmetrically wound in parallel. Therefore, the tape inductances are nearly uniformly distributed among the tapes better than other cabling options. Consequently, a uniform current distribution is anticipated. FReTC especially provides an excellent cabling method for narrow-width tapes, which is suitable for AC ramp-field and pulse-field applications. Other advantages are cable design flexibility, excellent tape usage, and cost-effective fabrication.
Therefore, FReTC will be suitable for various applications, especially for high electromechanical load applications, AC pulsed field magnets such as fusion CS magnets, and also industrial motors and generators, accelerator machines, and power transmission cables.
We will present electromechanical characteristics of REBCO FReTC conductors for high-current and high-field applications, including single-process full-size cable fabrication methods, which we are building at MIT PSFC.

Acknowledgment: This work was supported in part by the U. S. Department of Energy under Grants: DOE STTR DE-SC0024864 and DE-SC0023458.

References:

1. M. Takayasu, "Width-bending characteristic of REBCO HTS tape and flat-tape Rutherford-type cabling," Supercond. Sci. Technol., 34, 125020 (13pp), 2021, https://doi.org/10.1088/1361-6668/ac30eb.
2. M. Takayasu, "Rutherford-Type Cabling for REBCO Fine-Filament Tapes,"IEEE Trans. Appl. Superconduct., 34, no. 5, pp. 1-5, 6601505, August 2024, https://doi.org/10.1109/TASC.2024.3364138.
3. M. Takayasu, L. Chiesa, C. Bird, P. Moore, and V. Solovyov, "Bending characteristics of REBCO Rutherford-type cable (FReTC),"ASC 2024, IEEE Trans. Appl. Superconduct, 2025, https://doi.org /10.1109/TASC.2025.3527943.

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Session Classification: Sat-Af-Spe1 - [Special Session] High Current HTS Cables for Fusion and Beyond

Contribution ID: **568** Type: **Contributed Oral**

Sun-Mo-Or2-06: Final design and production of a 10 T HTS energy saving dipole magnet for the Italian facility IRIS

Sunday, July 6, 2025 9:15 AM (15 minutes)

The Innovative Research Infrastructure on Applied Superconductivity (IRIS) is a project funded by the Italian Minister for University and Research, with leadership assigned to INFN, and LASA laboratory serving as its coordinator. This project, currently in its final phase, involves the design and construction of an Energy Saving, fully high-temperature superconducting dipole Magnet for Accelerators (ESMA). ESMA is intended to be both a technological demonstrator for sustainable, cryogen-free accelerator magnets, and a user magnet for the IRIS cable test facility at Genoa (Italy). This article describes the final design of the dipole and its fabrication process in ASG Superconductors S.p.A. The electromagnetic design consists of 12 flat racetracks, assembled in a 6+6 configuration. The coil pack is about 0.6 meter long and with a coil-to-coil aperture of 104 mm. The target central field at operation is of 10 T.
To withstand Lorentz forces in operation, a mechanical structure made by high-strength alloys has been designed and produced. The design of the cryogen-free cooling system is also discussed.
Finally, the protection scheme is discussed, together with an introduction to the incoming tests and operations.

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Session Classification: Sun-Mo-Or2 - Fabrication and Testing of Magnets for Facilities

Contribution ID: **569** Type: **Invited Poster**

Wed-Af-Po.08-01: [Invited] Development of a Continuous Characterization System for High-Temperature Superconductors: Advancing In-Field Quality Assurance for High-Field Applications

Wednesday, July 2, 2025 2:30 PM (2 hours)

High-temperature superconductors (HTS), particularly rare-earth barium copper oxide (REBCO), are critical for ultra-high-field magnets in next-generation accelerators and compact fusion reactors due to their superior performance under high magnetic fields. However, existing characterization techniques cannot continuously evaluate long HTS conductors under simultaneous low-temperature and high-field conditions, which are essential for real-world operation. This limitation, coupled with the sensitivity of HTS magnets to low-critical current density (Jc) defects that can trigger quenches, underscores the need for advanced inspection methods. This study introduces a novel continuous characterization system developed at Princeton Plasma Physics Laboratory, designed for rapid and contactless evaluations of HTS conductors under applied magnetic fields. The initial prototype integrates a 0.5 T superconducting magnet with a liquid nitrogen saturation cooling system and achieves measurement speeds exceeding 100 mm/s at temperatures between 65-77 K. Preliminary results demonstrate the system's capability to detect Jc variations caused by inhomogeneous artificial pinning centers and defects in REBCO conductors at 65 K. While currently optimized for REBCO and bismuth strontium calcium copper oxide conductors at 65 K, a separate system operating at 20 K is under development to extend testing capabilities to higher background magnetic fields and other superconductors with lower critical temperatures. Building on this proof of concept, we are advancing toward higher-field cryogen-free systems: a 7.5 T system nearing completion, a 12 T system under design, and a planned 20 T reel-to-reel inspection system—all operating at 20 K. These developments aim to enable conductor characterization under conditions closely replicating high-field magnet applications, providing robust quality assurance protocols for superconducting magnets in fusion energy and other high-field technologies.

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Presenter: Dr CHEN, Siwei (Princeton Plasma Physics Laboratory)

Session Classification: Wed-Af-Po.08 - Conductor and Coil Measurement/Test Techniques and Facilities I

Contribution ID: **570** Type: **Poster**

Thu-Af-Po.07-03: Quench simulations of a 3×3 field shaping NI HTS coil array for a planar coil stellarator

Thursday, July 3, 2025 2:00 PM (2 hours)

Stellarators confine plasma in a stable toroidal configuration using twisted external magnetic fields. However, this requires complex 3D coil shapes that can pose a significant design, manufacturing, and maintenance challenge. To address this challenge, Thea Energy, Inc. is developing the planar coil stellarator. This approach utilizes multiple smaller, individually energized coils that collectively produce the requisite 3D magnetic field necessary for sustaining continuous fusion reactions.

We introduce the "Canis"3x3 array of high-temperature superconductor (HTS) planar coils, and present a transient coupled thermal, electromagnetic and mechanical finite element model to analyze quench behavior. In particular, we focus on turn-to-turn resistance requirements for the non-insulated (NI) coils with respect to quench tolerance and quench resistance. Further details on the evaluation of the array's performance under realistic and hypothetical scenarios, such as induced currents due to electromagnetic coupling, and operation in a strong background field generated by encircling coils, are shared. These results offer key insights for the design of simplified stellarators, paving the way for a simpler approach to commercial fusion energy.

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Session Classification: Thu-Af-Po.07 - Quench in Fusion Magnets I

Contribution ID: **571** Type: **Poster**

Fri-Af-Po.11-05: Quality control and cryogenic testing of complete HTS coil set for Demo4 magnet

Friday, July 4, 2025 2:00 PM (2 hours)

Demo4 is a unique, high-field device comprised of a total forty-four high-temperature superconducting (HTS) coils made from stacked rare-earth barium copper oxide (REBCO) tapes in a compact, spherical tokamak (ST) configuration. The complete magnet set consists of twenty-eight toroidal field (TF) coils manufactured into fourteen TF limbs, and sixteen poloidal field (PF) coils in two PF stacks. This magnet system is designed to operate in a relatively low current regime, compared to other fusion machines, of up to several kiloamperes steady state at a base temperature of 20 K. Demo4 allows us to cost-effectively demonstrate background magnetic fields and compressive loads representative of a full-scale ST fusion pilot plant and gain hands-on experience in both normal and fault condition system operations.
To derisk system assembly and operations, the complete set of HTS coils needed for Demo4, including several spare coils, have been rigorously tested both mechanically and electrically throughout their manufacturing processes. Here, I present our performed quality control checks, including nominal, electrical measurements of all HTS coils at 77 K in liquid nitrogen. This talk summarises the challenges faced during coil characterisation, the data acquisition and analysis, and how we have subsequently used these results to inform our decision for optimal TF coil allocation in final system assembly.

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Session Classification: Fri-Af-Po.11 - Experiments and Test for Fusion Magnets

Contribution ID: **572** Type: **Contributed Oral**

Sat-Mo-Or4-04: Can no-insulation/partial insulation be used to protect large ReBCO high stored energy coils during a quench?

Saturday, July 5, 2025 12:30 PM (15 minutes)

There are many applications, companies and institutes pursuing and building large and high field REBCO magnets for a variety of applications, for example the toroidal field coils of a tokamak. Using a classical external dump for discharge and quench protection presents several problems, such as very high voltages. Whether or not these magnets can be protected using internal non-insulation or partial insulation technology is an ongoing debate in the HTS and magnet communities. Tokamak Energy have pioneered partial insulation for high stored energy density fusion magnets. In this talk we will discuss the physical and engineering parameters that are necessary to successfully control a discharge in the event of a quench of a large scale and high stored energy REBCO magnet. These includes critical current margin, normal state conductivity, thermal conductivity, heat capacity, protection voltage, mechanical properties and many others. To explore this, we present the results of several electromagnetic-thermal and stress simulations, highlighting the failure modes and where the window for success can be found. We will present on how balancing the necessary parameters against one another, and selecting appropriate materials and technologies, can result in a safe discharge, successfully extracting the stored magnetic energy from a large coil. Having identified a technology path on protecting coils of this scale and stored energy, we present the first experimental results on validating this approach in real magnets. We will show how experimentally validated simulation tools predict that ReBCO coils of the scale necessary for a fusion power plant are protectable with partial insulation technology.

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Presenter: BRITSOW, Matt (Tokamak Energy Ltd)

Session Classification: Sat-Mo-Or4 - Technology for Fusion Reactors I

Contribution ID: **573** Type: **Poster**

Thu-Af-Po.05-01: High-rate production and validation of Canis magnets

Thursday, July 3, 2025 2:00 PM (2 hours)

"Eos", Thea Energy, Inc.'s first integrated fusion system, will utilize arrays of small, optimized planar coils that help to mitigate manufacturing complexity found in prior generations of the stellarator. To properly shape the magnetic fields necessary for plasma confinement, Eos will require hundreds of these planar coils; Thea Energy's ability to reliably and quickly produce them will be critical for future development.

Through the manufacturing, testing, and integration of the "Canis"3x3 array of high-temperature superconducting (HTS) planar coils, Thea Energy successfully demonstrated the ability to rapidly scale magnet production while maintaining performance. With development focused equally on the critical and complex winding and stacking processes, in-house tools, fixtures, and software, we produced resilient and consistent magnets across differing input materials and piece part quality levels. Several design iterations and manufacturing process automations for tape preparation further enabled Thea Energy's magnet manufacturing to grow from one magnet per week to two magnets per day across a six-month period.

In parallel, Thea Energy developed and deployed all the instrumentation and testing infrastructure necessary to reliably perform acceptance testing of each of the Canis 3x3 magnet array's planar coils. Acceptance tests were conducted in a bath of liquid nitrogen at 77K, where each test consisted of current ramps, and voltages across various parts of the magnet coil were measured. Field measurements were obtained using Hall sensors, and magnet parameters such as equivalent series resistance (ESR), radial resistance, field scaling, etc. were extracted from the data acquired from each test. While an acceptance criterion based on Joule heating was used to qualify a magnet coil, other factors such as relative variance of field scaling and radial resistances were also considered. Winding, stacking, and testing operations together ensured that build and performance variance was within acceptable limits and that Thea Energy could reproduce this effort.

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Session Classification: Thu-Af-Po.05 - Conductor and Coil Measurement/Test Techniques and Facilities III

Contribution ID: **574** Type: **Poster**

Thu-Mo-Po.08-04: Building Datasets and Training Methods for ML Based Magnet Quench Detection

Thursday, July 3, 2025 8:45 AM (2 hours)

Detecting quenches in superconducting (SC) magnets during training is a challenging process that involves capturing physical events that occur at different frequencies and appear as various signal features. These events may be correlated across instrumentation type, thermal cycle, and ramp. These events together build a more complete picture of continuous processes occurring in the magnet, and may allow us to flag potential precursors for quench detection. We present our work on building an automatic machine learning (ML) based quench detection system.
We build upon our existing work on unsupervised auto-encoders for acoustic sensors and quench antenna (QA) by first establishing a supervised ML training pipeline. We show the results of an event tagging, analysis, and simulation framework on our QA and acoustic data which are used concurrently to build a training dataset for a supervised implementation. We then show how this supervised training can be used as a prior in a semi-supervised framework and compare this to the unsupervised neural network auto-encoder performance.This allows us to have a more concrete understanding of the performance of our algorithms relative to physical events occurring in the magnet, and also provides a baseline software tool to generically evaluate our quench prediction autoencoders under completely unsupervised, supervised, and semi-supervised training conditions.

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Session Classification: Thu-Mo-Po.08 - Quench Modelling and Detection

Contribution ID: **576** Type: **Poster**

Fri-Mo-Po.03-08: Conduction-cooled test rig for superconducting joints for cryogen-free MRI magnet

Friday, July 4, 2025 9:30 AM (1h 45m)

Superconducting joints play a very important role in the superconducting magnet of any Magnetic Resonance Imaging (MRI) scanner. The multi-coil superconducting magnet is the heart of any MRI machine. The superconducting magnet in MRI needs to generate a highly homogenous magnetic field (± 5ppm) and high field stability (<0.1 ppm/hr) in its imaging volume to ensure a consistent and clear image. The superconducting joints between the coils and the superconducting switch enable the persistent mode operation allowing the MRI machines to maintain high temporal field stability. Presently, the whole-body MRI magnets are made of NbTi having a critical temperature of 9.2K thereby need to be cooled to 4.2 K using liquid helium. Due to the depleting resources of helium, the technology for the whole-body conduction-cooled MRI magnet needs to be developed to meet future needs. Hence, it is necessary to characterize the behaviour of the NbTi joints in the conduction-cooled environment.

We have designed and developed a 4.2K GM cryocooler-based versatile test rig to characterize the electrical performance of the superconducting joints at 600A of current at 4.2K. The current is induced in the superconducting test loop using a superconducting micro-transformer which is cooled by conduction using the limited refrigeration capacity of the cryocooler. The turns ratio between the primary and the secondary coil i.e. the test loop is ˜ 11 :1. The ratio of the cross-sectional areas between the primary and the secondary coil is 3.5 :1. Hence the secondary coil will experience 65 % of the flux of the primary coil. The secondary coil needs to be changed every time for the new test sample. This versatile test rig can accommodate the straight single joint between two ends of a single superconducting wire (conductor -1) or two straight joints between each pair of ends of two different superconducting wires (conductor -1 and 2) or the spiral joint between two ends of a single superconducting wire (conductor -1). The thermal contact between the 4K cold plate and the secondary coil plays a crucial role in determining the thermal stability of the joint sample. The resistance is measured from the decay of the current in the sample coil induced by the primary superconducting coil using the flux-conservation principle. It can measure the resistance up to 10E-15 Ohm. Two pairs of high-temperature superconducting (HTS) current leads have been used for the primary superconducting coil and the 1.5T NbTi magnet. The primary coil, made- up of 80 m of NbTi wires, generates ˜2.1 T field at 150A of current. The electrical joint of the secondary coil is placed at the centre of the 1.5T solenoid magnet to test its electrical behaviour in the presence of the background magnetic field. Several temperature sensors have been used at various locations of the test rigs to analyze the thermal performance.

This paper describes the design of the conduction-cooled test rigs for superconducting joints for cryogen-free whole-body MRI magnets. The paper also discusses the thermal design and simulation of the conduction-cooled test rigs and its performance. The thermal stability of the system has also been analyzed. The performance of the superconducting joints at cryogen -free environment is extensively discussed in this paper.

Acknowledgement

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Session Classification: Fri-Mo-Po.03 - Magnets for MRI

Contribution ID: **577** Type: **Contributed Oral**

Sat-Mo-Or6-02: Test results of the LQXFA/B02 and LQXFA/B03 cryo-assemblies for the High Luminosity LHC upgrade

Saturday, July 5, 2025 11:30 AM (15 minutes)

The US High-Luminosity LHC Accelerator Upgrade Project (AUP) is responsible for delivering cryo-assemblies for the Q1/Q3 quadrupole optical components of the High Luminosity LHC upgrade at CERN. Total of 10 cryo-assemblies containing two Nb3Sn quadrupole magnets per cold mass will be delivered within this program. After the successful test of the first pre-series cryo-assembly in 2023, two more cryo-assemblies were tested at Fermilab's horizontal test facility.
Production overview and the test results of the LQXFA/B02 and LQXFA/B03 cryo-assemblies are summarized in this paper. After the first test, to increase the capability of the horizontal test facility, various improvements have been made. These improvements are also described in this paper.

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Session Classification: Sat-Mo-Or6 - High Luminosity LHC

Contribution ID: **578** Type: **Poster**

Fri-Af-Po.09-01: Transient behavior during faults in superconducting coils for direct-drive wind generators

Friday, July 4, 2025 2:00 PM (2 hours)

Offshore wind energy offers substantial potential to drive the decarbonization of the energy sector through the generation of large amounts of renewable power. Recent trends in the offshore wind industry favor increasing turbine size and rated power to reduce the levelized cost of energy (LCOE). However, scaling up brings challenges in terms of structural integrity, thermal management, electromagnetic performance, manufacturing, and supply chain logistics. Partially superconducting generators (SCGs) (superconducting field, normally conducting armature) emerge as promising candidates for large direct-drive generators due to their capability to achieve high torque density and efficiency, while minimizing the use of critical materials, such as rare earth magnets. Despite their advantages, the industry has limited experience with SCGs, particularly concerning their behavior during electromechanical transients, which can differ significantly from conventional generators. Low temperature SCGs with airgap windings to reduce the cold mass AC losses have a very low inductance, which in turn causes large fault currents and forces in the superconducting field coils. This paper introduces a semi-analytical model to examine the transient behavior of SC generators under three-phase and phase-to-phase short circuit conditions. A comprehensive analysis of the forces encountered during faults is conducted using an equivalent circuit in conjunction with a finite element model. The findings from this study are crucial for the mechanical design of the generator's support structure and provide valuable insights into improving the design of SC machines.

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Session Classification: Fri-Af-Po.09 - Rotating Machinery IV

Contribution ID: **579** Type: **Poster**

Fri-Af-Po.09-02: Electromagnetic shielding and AC losses of Superconducting coils for direct-drive wind generators

Friday, July 4, 2025 2:00 PM (2 hours)

Superconducting (SC) coils used in rotating machinery necessitate effective electromagnetic shielding to mitigate AC losses caused by asynchronous field harmonics created by the armature windings. Coils employing low-temperature superconductors, such as niobium-titanium, are characterized by a narrow thermal margin and limited cooling capacity within the cold mass. Conventional "rule of thumb" methods for determining the electromagnetic shield thickness prove inadequate for direct-drive wind generators due to the low fundamental frequency of their armature, which results in large skin depths. This paper offers a comprehensive analysis of shielding effectiveness and the losses incurred from asynchronous harmonics of various temporal and spatial orders. A case study is presented, demonstrating the impact of different armature configurations on cold mass losses within the generator, thereby highlighting the significance of armature winding layouts for the viability of such generators. The insights gained from this study are critical for the practical design of SC generators operating at low fundamental frequencies, like those found in direct-drive wind generators.

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Session Classification: Fri-Af-Po.09 - Rotating Machinery IV

Contribution ID: **580** Type: **Poster**

Wed-Mo-Po.03-05: A study of the effects of CO2 and H2O on Bi-2212 properties

Wednesday, July 2, 2025 9:15 AM (2 hours)

High J_c in Bi-2212 wires is crucial for their use in high-field magnets. CO_2 and H_2O, which can inadvertently be incorporated into Bi-2212 wire, negatively impacts J_c. At room temperature before the heat treatment, CO_2 and H_2O are present in the wires as carbonates, hydrates, or surface adsorbates, but during the overpressure heat treatment they become gases. The overpressure heat treatment compresses the CO_2 and H_2O gases preventing these gases from forming bubbles during the heat treatment. On cooling, they can form carbonates and hydrates in the fully processed Bi-2212 ceramic that degrade J_c. This study investigates the J_c performance of Bi-2212 wires with different CO_2 and H_2O contents.

This work was supported by the U.S. DOE Office of High Energy Physics under Grant DE-SC0010421, by the NSF NHMFL under Award DMR- 2128556, and by the State of Florida, and was performed under the purview of the U.S. Magnet Development Program (MDP).

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Session Classification: Wed-Mo-Po.03 - HTS Characterization I

Contribution ID: **582** Type: **Contributed Oral**

Sat-Af-Mem1-06: Development of high-field dipole and solenoid magnets using the latest generation of CORC® cables and wires

Saturday, July 5, 2025 5:45 PM (15 minutes)

Dipole magnets that approach or surpass magnetic fields of 20 T for use in future particle circular accelerators, and high-field solenoids that operate at 20 K, such as envisioned in a multi-TeV muon collider, require the use of high-temperature superconductors (HTS). Several prototype magnets based on high-current HTS CORC® cables and wires, wound from REBCO coated conductors, have been demonstrated in recent years. Although considered one of the most flexible HTS cables, previous-generation CORC® wires degraded by 20 –30 % when bent to a 30 mm radius. The limited bending flexibility required rather conservative magnet designs, limiting the magnetic field generated by these early prototype magnets.
Advanced Conductor Technologies (ACT) has recently developed CORC® wires with improved bending flexibility that now allow bending to a 20 mm radius without significant degradation. Very-high current CORC® cables were also developed that have an expected critical current (Ic) of over 30 kA at 10 T at a temperature of 20 K, or at 20 T at 4.2 K. Although the cable contains 96 REBCO tapes of 4 mm width, it allows bending to a 125 mm radius.
The much higher bending flexibility of CORC® conductors allows for more efficient CORC®-based dipole magnets that would ultimately generate 20 T, such as canted-cosine-theta (CCT) magnets under development at Lawrence Berkeley National Laboratory (LBNL) and Conductor on Molded Barrel (COMB) magnets under development at Fermilab. An overview will be provided of the dipole magnet development at both laboratories in support of which ACT will deliver a total length of 225 meters of CORC® wire in the coming months.
The improved bending flexibility and in-field performance of CORC® conductors also allows for the development of low-inductance, high-field solenoids. An overview is presented of the initial designs of 35 –40 T solenoids in which several series-connected CORC®-based inserts are operated within a low-temperature superconducting (LTS) outsert, or as a stand-alone HTS solenoid. An overview of the initial design of a 1.2 meter bore 20 T target solenoid for the muon collider, wound from very-high current CORC® cables, will also be provided.

This work is supported by the U.S. Department of Energy, Office of Science, under Award Numbers DE-SC0014009, DE-SC0024159 and DE-SC0024760. The work at LBNL was also supported by the U.S. Magnet Development Program through Director, Office of Science, Office of High Energy Physics of the US Department of Energy under Contract No. DEAC02-05CH11231.

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Presenter: VAN DER LAAN, Danko

Session Classification: Sat-Af-Mem1 - Huub Weijers Memorial: High Field Magnets

Contribution ID: **583** Type: **Poster**

Wed-Af-Po.09-02: ENABLING the build of large scale HTS magnets for Spherical Tokamaks.

Wednesday, July 2, 2025 2:30 PM (2 hours)

At Tokamak Energy (TE) we have been working on a range of technology blocks and magnet demonstrators to raise the Technical Readiness Level (TRL) of REBCO HTS based magnets for spherical tokamaks (ST). This is a broad programme addressing technologies including coil manufacturing, quench protection, modelling and simulation, HTS irradiation, and other aspects. This talk will demonstrate how our current active development programmes are derisking our journey to delivery of the HTS coil systems for fusion pilot plants, with particular focus on coil manufacturing.

The Demo4 demonstrator, consisting of 44 HTS coils in 14 Toroidal Field (TF) limbs and 2 Poloidal Field (PF) stacks, will demonstrate the function of the coils at temperatures and in background field environments that closely replicates how larger scale coils would function in a commercial scale ST. Operation of Demo4 will give detailed validation of the predicted operational margins of the 44 coils in steady state, transient scenarios and system fault conditions. It will also provide evidence on the optimal deployment of HTS in larger magnet systems, potentially saving millions of dollars in coil costs. For example, how much grading can be applied to large scale TF coil return limbs?

To optimise the use of REBCO in the coils and provide the engineering current density the ST requires, the TF coil designs are based on stacked tape cables. Instead of forming tapes into steel clad cables and using large scale machines to bend these stiff cables into coils, we are developing tooling to wind coils directly into copper structures to form compact coil packs with high thermal conductivity and enough thermal mass to absorb the magnetic energy in a fault condition without inducing damaging thermal stresses in the structures. The winding machine is coil size and shape agnostic. These coil packs can then be mounted in a steel support structures to contain the stresses associated with magnet operation.

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Presenter: BATEMAN, Rod

Session Classification: Wed-Af-Po.09 - Magnets for Tokamaks: Design and Analysis

Contribution ID: **584** Type: **Poster**

Wed-Af-Po.09-08: Toward design finalization for the Central Solenoid coil system of the DTT tokamak

Wednesday, July 2, 2025 2:30 PM (2 hours)

The design of the Central Solenoid (CS) for the "Divertor Tokamak Test"(DTT) facility has evolved through different options, investigated with the aim to satisfy the demanding magnetic flux performance required by the DTT scientific program, while providing a robust solution from the manufacturing and operational point of view.
In the present paper we illustrate the current design choice, based on a stack of six identical Nb3Sn modules, and the required pre-compression structure, and the engineering activities carried out so far.
A crucial aspect supporting the design choice, has been the test outcomes under relevant electro-mechanical conditions at 77 K, of a 5 x 5 turns winding pack mock-up, in particular to probe the inter-turn electrical insulation limits under the effect of the foreseen 2x25000 electromagnetic loading cycles.
Particular care has been devoted to the definition of the quench detection technique, as in the specific current design of the DTT CS, a quench detection tape co-wound around the conductor is considered risky for the integrity of the highly loaded winding pack insulation. In this work, different layouts of quench detection sensors have been studied, also considering the expected noise levels that have been computed by numerical codes, so to evaluate different possibilities, such as: using just the voltages measured across the different coil layers; using a steel wire co-wound at the corner of each CICC turn for inductive noise cancellation; or adopting an internal quench wire placed inside the superconducting cable. Since the coil is made of Nb3Sn strands, any of these sensors must be resistant to the superconductor reaction heat treatment temperatures. The minimum temperature margin has been computed during all relevant operation scenarios of the magnet, including the effects of the very rapidly varying current and field at plasma breakdown, where the computation of AC losses has to be carried out under the assumption of cable saturation, with specific models. The main results of the thermo-hydraulic analyses performed with the "4C"code will be reported, along with the main outcomes of the 3D FEM structural analyses.

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Presenter: Dr MUZZI, Luigi

Session Classification: Wed-Af-Po.09 - Magnets for Tokamaks: Design and Analysis

Contribution ID: **585** Type: **Poster**

Wed-Af-Po.10-01: Electromechanical Characterization of Flat Round-Edge Former Tape Cable for Fusion Devices

Wednesday, July 2, 2025 2:30 PM (2 hours)

Future fusion devices must leverage the advantages of high temperature superconductors. To meet this challenge, a novel Rutherford-type cable winding of superconducting (REBCO) tape stacks has been proposed. This cable, known as the Flat Round-Edge Former Tape Cable (FReTC) is comprised of several multi-tape subcables wrapped around a flat, round-edge former. As part of enabling the use of FReTC, thorough investigations of cable electrical and mechanical properties are required.

Previous work established simplified quarter-twist-pitch, single-tape models of the FReTC geometry in ANSYS Mechanical APDL software. Building on this work, hard bending and easy bending models will be developed for the analysis of strains and stresses in the cable. From these results, the critical current degradation of the cable will be deduced. Finally, experiments measuring the critical current carrying capacity as a function of the load will be used for model validation.

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Presenter: NAVARRO, Claudia (Tufts University)

Session Classification: Wed-Af-Po.10 - Development and Test of Conductors for Fusion Magnets II

Contribution ID: **586** Type: **Contributed Oral**

Thu-Mo-Or1-05: BigBOX2: Assessment of Training Performance and Robustness of Filled Paraffin-Wax Impregnated Nb3Sn Demonstrator Under High Magnetic Field

Thursday, July 3, 2025 11:45 AM (15 minutes)

The BigBOX experiment aims to assess the training performance and robustness of paraffin-wax impregnated Nb3Sn coils under high Lorentz forces. The results of the experiment are the product of a collaborative effort between the Swiss Accelerator Research and Technology initiative (CHART) at the Paul Scherrer Institute (PSI) and Brookhaven National Laboratory (BNL). The experiment involves the integration of the Nb3Sn coil, manufactured at PSI, with the common coil magnet DCC17, developed and operated by BNL. Using two independent powering systems, the coil is tested in a range of background magnetic fields from 0 to 9 T at various current levels. Following the first BigBOX, which reached a peak field of 12.3 T and a stress level of 170 MPa on the coil, a second coil—BigBOX2—was manufactured. This coil was impregnated with paraffin-wax containing particles to increase overall stiffness and reduce the risk of conductor degradation at higher forces. This work presents the test results of BigBOX2 and explores the correlation between these results and those obtained from other experiments using the same cable and impregnation system.

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Presenter: MARTINS ARAUJO, Douglas

Session Classification: Thu-Mo-Or1 - LTS Magnet Advanced Concepts

Contribution ID: **587** Type: **Poster**

Thu-Mo-Po.01-07: Magnetic field analysis and shielding of components for the Material Plasma Exposure Experiment

Thursday, July 3, 2025 8:45 AM (2 hours)

The magnet system for the Material Plasma Exposure eXperiment (MPEX) provides the necessary field profile to enable rf source and heating along the length in order to meet the desired key performance parameters (KPPs) at the target area. In addition to the magnet system, MPEX has other systems (vacuum, diagnostics, rf source and heating) that operate in close proximity and require shielding solutions that have to be optimized with respect to location and their potential impact on magnet operation. Several magnetic or magnetically sensitive components near the magnets have been analyzed including structural steel beams used to support the high-efficiency particulate air (HEPA) filter system, motors located on the helicon and ion-cyclotron heating (ICH) plasma heating boxes, the Target Exchange Cart (TEC), external magnet mounting and alignment rails, the electron-cyclotron heating (ECH) gyrotron, and the Surface Analysis Station (SAS) which includes a field-sensitive mass spectrometer. Using finite element modeling, the impact on each component is assessed and shielding solutions presented for each component. Verification of performance in a local magnet test stand was carried out to validate modeling and confirm the ability of the component to operate in a limited number of cases.

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Presenter: BURKHARDT, Earle (Oak Ridge National Laboratory)

Session Classification: Thu-Mo-Po.01 - AC Loss and Magnetization I

Contribution ID: **588** Type: **Poster**

Wed-Af-Po.11-03: Impact of axial and bending strain on the Tcs of ITER TF conductors under MTCB working conditions

Wednesday, July 2, 2025 2:30 PM (2 hours)

The ITER Toroidal Field (TF) coils are manufactured in the double-pancake configuration with cable-in-conduit-conductors (CICC), each containing several hundreds of Nb3Sn strands. These strands are produced by eight different companies using either the bronze-route or the internal-tin manufacturing process. These differences in the manufacturing procedure result in different performances of the TF coils.

Given the intrinsic brittleness and strain-sensitive electromechanical behavior of Nb3Sn, significant efforts have been made in the past to investigate the effects of strain on Nb3Sn conductors. An extensive test campaign was conducted at the SULTAN facility (Villigen, Switzerland) on TF qualification and production samples [1, 2]. A dedicated campaign was also carried out to study the impact of electromagnetic and thermal cycling loads on TF conductors manufactured by different companies [3]. In these studies, the current-sharing temperature was estimated by assuming a single strain value in the conductor, referred to as effective strain.

The ITER TF conductors were recently tested in the SULTAN facility under the working conditions relevant to the operation of the TF coils in the standalone configuration, the same conditions foreseen in Magnet Cold Test Bench (MCTB) currently under development at ITER. The conductors have been tested in SULTAN at the nominal operating current of the TF during the tokamak operation but with half of the peak magnetic field.

The experimental results and the performances of the conductors, in terms of current sharing temperature and n-value, obtained during the tests are presented in this work. The current sharing temperature is determined based on a novel approach able to distinguish between the contributions of the axial and bending strain. The results allow to assess the Tcs of the TF conductors in the MCTB configuration and to determine the impact of both axial and bending strain on the conductor performances.

The views and opinions expressed herein do not necessarily reflect those of the ITER Organization.

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Presenter: CAVALLUCCI, Lorenzo

Session Classification: Wed-Af-Po.11 - Modelling of Fusion Conductors and Coils I

Contribution ID: **589** Type: **Invited Oral**

Sat-Af-Spe1-04: [Invited] Development status of the HTS SECAS conductor for a full-size test sample

Saturday, July 5, 2025 2:45 PM (15 minutes)

The ENEA Superconductivity Laboratory, in collaboration with the industrial partner TRATOS Cavi, is continuing the development activity of the high-current / high-field SECAS Cable-in-Conduit conductor, based on stacked REBCO tapes and a segmented, sector-shaped Cu former. The test outcome of various prototypes, carried out at 77 K and self-field in the previous years, have clarified important aspects of the manufacturing process and cable performance, and identified the key aspects of the processing steps. The industrial manufacturing process is consequently being developed, and partly applied for the manufacture of full-size samples, to be tested in the SULTAN facility. The conductor is designed to operate at 4.5 K, with a current of 60 kA and at a field of 18 T (as required by the EUROFusion DEMO development plan). Different layouts have been probed, either based on 4 mm-wide, or on 12 mm-wide tapes, but maintaining the same total superconductor cross-section, in order to verify the impact on AC losses and on tape mechanics. Two of these layouts have been assembled into a single SULTAN sample, made of two legs connected by a bottom joint. The development of the joint/termination assembly technique for this full-size sample is discussed. The sample has been also equipped with fiber optic sensors, to demonstrate the transition detection capabilities: all the steps undertaken to define an appropriate layout to include systematically these sensors during cable manufacturing are discussed here, and have been verified during tests carried out at 4.2 K and at 10 T magnetic field, on representative sub-size samples.
All results of these development activity are presented in this work, together with the foreseen test plan of the full-size conductor lengths.

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Presenter: Dr MUZZI, Luigi (ENEA)

Session Classification: Sat-Af-Spe1 - [Special Session] High Current HTS Cables for Fusion and Beyond

Contribution ID: **590** Type: **Poster**

Thu-Af-Po.03-09: Scaling Study of Superconducting Rotors with Spoke Torque Tubes

Thursday, July 3, 2025 2:00 PM (2 hours)

Introduction
A torque tube with a low heat-conduction spoke torque tube was introduced in an earlier study. This study explores the characteristics and design trade-offs of this topology using a combination of analytical models and experimental validation. Results indicate that the spoke-supported topology generally favors small diameters due to its negligible heat leakage. Additionally, a strong positive correlation is observed between specific, specific power and torque, and cryocooler lifting power.

Modeling of Rotor Electrical Properties
The electrical modeling links the machine's active region temperature to its torque production. Torque (τ) is expressed as a function of temperature (T) with the machine's power subsequently derived.
$\tau_{max} = 2A_{peak}B_{peak}R_{ag}^2 L Here,A_{peak}$ represents the electric loading, defined by the armature stator design, while on the rotor side, $B_{peak} \propto J_f$. R_{ag} is the air-gap radius, and L is the active length. The baseline machine coil design yields the relationship: J$_r = 170B_{coil} Inthisstudy, SuperPower2GHTStapewa$
$90.5e^{-0.057T} **Modelingofrotormechanicalandthermalproperties**Themechanicalmodelingdeterminestherotor$

1. The HTS holder are designed for coil's compressive and shear stress, 2. The Dewar is designed to resist buckling by ambient pressure and torsion, 3. The shaft is sized for the torque generated.

Thermal modeling constructs the full heat transfer path, incorporating:

1. The temperature delta across HTS coils and their support structure, 2. Conductive cooling paths between the cryocooler and HTS coil, 3. Conductive leakage through the spoke torque tube, and 4. Radiation heat leakage that includes the realistic performance of multi-layer insulation

Study Results The electrical and mechanical models are combined to relate machine dimensions to performance. The model iteratively computes the steady-state HTS temperature and the resulting torque generation. The machine diameter is varied while the machine's aspect ratio (diameter to active length) and rotor tip speed are held constant. Scaling the motor from the baseline design reveals the following trends:

1. Small Diameter Preference: The topology favors a smaller diameter due to negligible thermal conduction through the spoke torque tube and the dominance of radiation heat leakage. Reducing the diameter decreases radiation heat transfer proportionally with surface area, while the spoke length decreases proportionally with the diameter. Specific power and torque are maximized at the minimum diameter in the study. **2. Torque and Power Trade-Offs:** Torque and power reach their maximum near, but not at, the minimum rotor diameter. This results from the R_{ag^2} term in the expression for τ_{max}. Slightly increasing the diameter trades field coil current density for radius, improving performance. When cryocooler technology is simulated with improved performance curves, torque, and power scale proportionally with cryocooler lift capacity. In the full paper, each of the diagrams will be displayed, and their implications will be discussed in detail.

3.Significant Impact of Cryocooler Technology Improvements: When improved cryocooler performance curves are simulated, torque and power scale nearly proportionally with cryocooler lift capacity.

In the full paper, detailed diagrams will be provided, and their implications discussed in depth. This study highlights the intricate balance between mechanical, electrical, and thermal design in HTS synchronous machines, emphasizing the impact of scaling and the interdependence of key parameters.

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Presenter: Dr XIAO, Jianqiao (Hinetics Inc)

Session Classification: Thu-Af-Po.03 - Rotating Machinery III

Contribution ID: **591** Type: **Contributed Oral**

Thu-Mo-Or1-02: Manufacturing and Testing of subscale SMCC2: the second Nb3Sn subscale Stress-Managed Common Coil Dipole Magnet including Energy Shift with Coupling (ESC) Quench Protection Method

Thursday, July 3, 2025 11:00 AM (15 minutes)

The Magnet Development (MagDev) laboratory at the Paul Scherrer Institute (PSI) has designed and successfully manufactured the first subscale stress-managed common coil magnet. The magnet was tested at CERN and reached 98% of its short sample current. Following the high-field magnet roadmap of the Swiss Accelerator Research and Technology initiative (CHART), a new magnet was assembled after replacing two of the four Nb3Sn coils and manufacturing four copper-based coils. These coils are part of the Energy Shift with Coupling (ESC) quench protection method.

The ESC system uses normal-conducting auxiliary coils that are strongly magnetically coupled with the magnet's superconducting coils for protection. When a quench is detected, a current is discharged through the auxiliary coils, leading to a rapid shift of the magnet's energy from the Nb3Sn coils to the copper-based coils. This process results in high transient loss within the superconductor, which facilitates quick quench initiation and magnet current discharge.

This work presents the manufacturing of the copper-based coils, magnet assembly, and test results of the subscale SMCC2, and explores the comparison between these results and those obtained from subscale SMCC1.

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Presenter: MARTINS ARAUJO, Douglas

Session Classification: Thu-Mo-Or1 - LTS Magnet Advanced Concepts

Contribution ID: **592** Type: **Poster**

Thu-Af-Po.07-02: Quench mitigation strategies in a FNSF scale HTS magnet

Thursday, July 3, 2025 2:00 PM (2 hours)

Startup and quench behavior in a FNSF scale Toroidal Field (TF) HTS magnet were explored in a previous ASC paper. In that study a mix of superconducting and resistive materials are arrayed in a Bitter Plate like arrangement. In the studies presented here, various quench mitigation scenarios are explored. The conductor arrangement is a parallel set of HTS channels with radially conductive/resistive materials between the channels. Additionally, resistors are included in the channels near the terminals to improve start-up current uniformity. The arrangement is intended to explore the parallel circuit design, and provide some insight into partially insulated HTS coils in a large scale reactor.
Current non-uniformity is explored vs Ramp up rates . Quench is simulated by forcing a channel to locally go fully resistive. Then current distributions in neighboring channels can be quantified. The time to quench a local region is treated in parameter studies. The time to detect the quench is also treated as a variable. Use of heaters throughout the magnet are assumed to force resistive behavior, and to provide –hopefully, a uniform heat-up of the magnet which would be below the threshold of any damage to the conductors. Thermal conductance time from heater to conductor is treated as a variable as well. Initial studies showed that there had to be some resistive conducting material between the terminals for each plate, otherwise the inductance and magnet stored energy would force an arc across the terminals. The goal is to avoid large variations in the local operating currents that might cause a cascade of quenches, and local damage of the conductors. Finite element modeling and circuit simulations are presented.

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Presenter: Mr TITUS, Peter (Princeton Plasma Physics Laboratory)

Session Classification: Thu-Af-Po.07 - Quench in Fusion Magnets I

Contribution ID: **594** Type: **Poster**

Wed-Af-Po.07-02: Efficient calculation of self-magnetic field, self-force, and self-inductance for electromagnetic coils with rectangular cross-section

Wednesday, July 2, 2025 2:30 PM (2 hours)

For designing high-field electromagnets, the Lorentz force on coils must be computed to ensure a support structure is feasible, and the inductance should be computed to evaluate the stored energy and dynamics. Also, the magnetic field and its variation inside the conductor is of interest for computing stress and strain, and due to superconducting quench limits. For these force, inductance, energy, and internal field calculations, the coils cannot be naively approximated as infinitesimally thin filaments due to divergences when the source and evaluation points coincide, so more computationally demanding calculations are usually required, resolving the finite cross-section of the conductors. Here, we present a new alternative method that enables the internal magnetic field vector, self-force, and self-inductance to be computed rapidly and accurately within a 1D filament model. The method is applicable to coils for which the curve center-line can have general noncircular shape, as long as the conductor width is small compared to the radius of curvature. This work extends our previous calculation for circular-cross-section conductors [Hurwitz et al, IEEE Trans. Magnetics (2024)] to consider the case of rectangular cross-section. The reduced model is derived by rigorous analysis of the singularity, regularizing the filament integrals such that they match the true high-dimensional integrals at high coil aspect ratio. The new filament model exactly recovers analytic results for a circular coil, and is shown to accurately reproduce full finite-cross-section calculations for a non-planar coil of a stellarator magnetic fusion device. Due to the efficiency of the model here, it is well suited for use inside design optimization.

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Presenter: Dr LANDREMAN, Matt (University of Maryland)

Session Classification: Wed-Af-Po.07 - Modelling and Analysis

Contribution ID: **595** Type: **Poster**

Fri-Mo-Po.05-02: Serpentine magnet designs for the interaction region of the Electron-Ion Collider (EIC)

Friday, July 4, 2025 9:30 AM (1h 45m)

The Electron-Ion Collider (EIC), hosted by Brookhaven National Laboratory, is designed to deliver a peak luminosity of 10ˆ34 cm−2 s−1. The interaction region (IR) of the EIC imposes several constraints in terms of field quality, aperture, and spatial layout, which necessitates the development of several unique superconducting serpentine direct wind magnets. These magnets are constructed using either a single strand or a small-diameter 6-around-1 NbTi cable, presenting unique challenges for design and optimization. This paper introduces a new computational code specifically developed to streamline and integrate the design process for these magnets, enabling faster design iterations while addressing their complex requirements.

In this paper, we first introduce the code, which builds on established electromagnetic fundamentals. The code incorporates tools for optimizing winding patterns and for correcting magnetic multipoles; additionally, it interfaces with established magnet design software. We also present the design of several serpentine magnets for the EIC IR, demonstrating the code's capability to deliver precise and efficient solutions. These designs highlight the code's ability to accelerate the development cycle, ensuring the serpentine magnets meet the demanding specifications of the EIC project.

Work supported by Brookhaven Science Associates, LLC under Contract No. DE-SC0012704 with the US Department of Energy.

Authors: BEN YAHIA, Anis (Brookhaven National Laboratory); WITTE, Holger (Brookhaven National Laboratory)

Presenter: BEN YAHIA, Anis (Brookhaven National Laboratory)

Session Classification: Fri-Mo-Po.05 - Electron-Ion Collider

Contribution ID: **596** Type: **Poster**

Sat-Mo-Po.08-11: Ultra-high thermal conductivity metal-halide insulation for cryogenic electromagnets: processing and performance

Saturday, July 5, 2025 9:30 AM (1h 45m)

There remains an urgent need for higher thermal conductivity electrical insulation for high steady-state thermally loaded superconducting and cryoresistive electromagnets, such as those used for fusion, undulator light sources, particle colliders, and alternating-current operated electric machines. Polymeric materials, which are currently used, demonstrate degraded thermal conductivity at cryogenic temperatures and max out at single digit W/mK. In addition, polymeric insulations have a limited pot-life, making impregnation of thick windings more difficult.
Shown in this research is ultra-high thermal conductivity polycrystalline CsI (>100 W/mK), which may be melt impregnated during a typical Nb3Sn, MgB2, or Bi-2212 heat treatment schedule. The maximum steady-state operational peak-to-peak alternating current density of sub-scale conduction-cooled electromagnetic windings impregnated with CTD-101K following standard procedures will be compared with those impregnated with polycrystalline CsI. Challenges of metal-halide melt impregnation will be presented, and the importance of finding high thermal conductivity metal-halide ceramics and processing techniques which may be integrated for REBCO coated conductors will be discussed. Other processing routes such as high solid loading gel coatings, laser additive manufacturing, and hot pressing of metal-halide powder into bulks be presented, as these processes may prove useful to provide auxiliary electrical isolation components.

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Presenter: KOVACS, Chris (Scintillating Solutions LLC)

Session Classification: Sat-Mo-Po.08 - Structural and Insulation Materials

Contribution ID: **597** Type: **Poster**

Fri-Mo-Po.05-01: Assessment of design options for the B0pF forward spectrometer for the interaction region of the Electron-Ion Collider (EIC)

Friday, July 4, 2025 9:30 AM (1h 45m)

The Electron-Ion Collider (EIC), hosted by Brookhaven National Laboratory, is designed to deliver a peak luminosity of 10ˆ34 cm−2 s−1. The interaction region (IR) of EIC incorporates a series of superconducting magnets, each uniquely constrained by stringent requirements for field quality, aperture, and spatial integration. Among these, B0pF is a forward spectrometer magnet closest to the interaction point (IP). Due to geometric constraints both the hadron as well as the electron beam share the aperture of this magnet. The aperture is large to accommodate detectors; for the hadron beam a field of 1.3T is required, and for the electrons a quadrupole field of 14 T/m.

This paper presents and evaluates electromagnetic (EM) designs options for the B0pF magnet, exploring configurations that optimize field quality considering engineering and operational constraints. The proposed designs are assessed through EM simulations, quench protection analysis, and structural evaluations. This study provides a comparative overview of potential solutions, highlighting the trade-offs between field uniformity, construction feasibility, and the magnet's impact on the detector space.

Work supported by Brookhaven Science Associates, LLC under Contract No. DE-SC0012704 with the US Department of Energy.

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Session Classification: Fri-Mo-Po.05 - Electron-Ion Collider

Contribution ID: **598** Type: **Contributed Oral**

Fri-Mo-Or2-04: Measurements of the electromechanical delamination strength of REBCO CCs under lorentz force: the numerical modeling

Friday, July 4, 2025 8:45 AM (15 minutes)

Rare-earth barium copper oxide (REBCO) coated conductors (CCs), the leading candidates for the construction of ultra-high field magnets, are produced in the form of thin tapes, with a laminar structure consisting of different layers of functional materials. The feeble adhesion strength between layers has been long remarked, and represents a major concern for magnet design, as it imposes hard bounds on the allowable tensile stress through the materials'interfaces. Post-mortem analyses on conductors deconstructed from high-field test coils have shown signs of delaminated and fractured regions, often coinciding with burnt locations considered as the limiting damage of the coils, leading to the concept of quench concomitant to delamination (QCD).

To date, research in the literature has focused on the mechanical delamination strength (MDS) of REBCO CCs, i.e. the delamination strength measured under mechanical loads. However, the non-standardized nature of the testing methods, as well as their mere mechanical aspects, has raised uncertainty on the scalability of the measured strength on an isolated sample to what a conductor would exhibit when inserted in an operating magnet configuration.

For this reason, in the applied superconductivity laboratory of the University of Geneva, an experiment has been set up to study the electromechanical delamination strength (EDS), i.e. the delamination strength when the tape is subjected to Lorentz forces, a scenario in which the conditions of the conductor approach those of when operating in a magnet configuration.

In this contribution, we report on the numerical analyses that accompany the experimental campaign, both in the evolution of the hardware and in the interpretation of the results. After introducing the experiment, we analyze the stress state inside the REBCO layer when subjected to Lorentz forces, assessing the impact of modeling approximations and experimental uncertainties. We then highlight the limiting factors and considerations that led to a new sample holder, and we evaluate the improvements in terms of stress state in the superconductor. Finally, we present the interpretation of the experimental results through the numerical models, linking the observables of the experiment, i.e. critical current and degradation current, to the measured EDS of the REBCO CCs.

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Presenter: VERNASSA, Gianluca (CERN & Ecole des Mines de Saint-Etienne)

Session Classification: Fri-Mo-Or2 - Mechanical Behavior and Stress III

Contribution ID: **599** Type: **Poster**

Thu-Mo-Po.09-09: Comparison of mechanical properties of QXF Coils

Thursday, July 3, 2025 8:45 AM (2 hours)

During the production of Nb3Sn coils for the Hi-Lumi LHC, some differences have been observed in coil performance in coils that follow a mostly identical fabrication process. Post mortem analysis on underperforming coils has indicated conductor degradation in regions of high stress/strain gradients as a result of filament cracking. To better understand the mechanisms for this behavior, a comparative analysis of two coils was completed to see if the bonding strength in the region of interest varies by a substantial amount. Tests devised included an apparent shear strength test using a punch and die for the coil wedge interface and a bending strength test of the coil cross section which shows difference in bond behavior at the pole. This information is compared to expected behavior in operation via FEA.

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Presenter: KRAVE, Steve

Session Classification: Thu-Mo-Po.09 - Conductor and Coil Measurement/Test Techniques and Facilities II

Contribution ID: **600** Type: **Poster**

Fri-Af-Po.11-01: Characterizing Mechanical and Thermal Effects of Solder Voids in Stacked-tape HTC Coils and Cables for Fusion

Friday, July 4, 2025 2:00 PM (2 hours)

High-field magnet designs for fusion increasingly utilize stacked high-temperature superconducting (HTS) tapes embedded in a solder matrix through vacuum impregnation. The extreme mechanical loads placed upon the tapes as well as multiple sources of heating within a fusion machine make voids within the solder matrix represent a critical source of uncertainty. If not properly accounted for during design, these voids could lead to unexpected performance degradation under operational stresses and diminished thermal stability.

This study integrates experimental and simulation-based approaches to quantify the effects of solder voids on key performance parameters, including critical current, n-value, electrical resistance, and thermal flux. Through mechanical testing and finite element simulations, we identify mechanisms through which voids exacerbate damage onset under Lorentz forces. Thermal analysis reveals the influence of voids on hot spot propagation, demonstrating how localized voids can intensify thermal instability. By elucidating the impact of void size, shape, and distribution on soldered HTS stacks, this work provides actionable insights to improve the design, manufacturing, and quality control processes for solder impregnated stacked-tape conductors for use in fusion magnets.

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Presenter: MOORE, Peter S. (Tufts University)

Session Classification: Fri-Af-Po.11 - Experiments and Test for Fusion Magnets

Contribution ID: **601** Type: **Poster**

Wed-Mo-Po.02-05: Design, Prototyping, Fabrication and Test of the Mu2e AC-Dipole Magnets

Wednesday, July 2, 2025 9:15 AM (2 hours)

Fermilab Magnet Systems is building three High-frequency AC-Dipole Magnets for the Mu2e experiment at Fermilab. These magnets are composed of three single-loop one-meter-long ferrite loaded segments. The excitation consists of a copper tube, which is also used as a means for its cooling with the inherited challenges of Voltage and Frequency uncoupling. These magnets are designed to operate either at 300 kHz or 4.4 MHz via resonance tuning.
Following the completion of the design, prototyping, and analysis phases, all ferrites and other components were procured, and the magnets were fabricated to meet vacuum compatibility requirements using strict procedures. Each magnet undergoes thorough baking and testing before being installed in the experiment.
This paper discusses the magnets' role in proton background suppression as it represents a unique and essential device for the Mu2e experiment at Fermilab. We present the magnet design choices, modeling approach, and the challenges encountered during fabrication. Additionally, we outline the power supply driving mechanism, the testing that was performed, and our results.

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Presenter: ELEMENTI, Luciano

Session Classification: Wed-Mo-Po.02 - Muon Collider

Contribution ID: **602** Type: **Contributed Oral**

Wed-Mo-Or2-01: Magnet R&D Plans for the Muon Collider

Wednesday, July 2, 2025 11:15 AM (15 minutes)

The Muon Collider (MC) embodies a groundbreaking concept in circular colliders for high-energy physics, offering a unique pathway to achieve unprecedented energy and luminosity of the colliding partons while significantly reducing environmental impact compared to conventional collider technologies. A critical aspect of its feasibility lies in the development of cutting-edge superconducting magnet systems capable of meeting the demanding requirements of muon production, acceleration, and collision.

Key research and development (R&D) objectives include achieving magnetic field strengths of up to 40 T (in solenoids), managing stored energies exceeding 300 MJ in a single magnet (solenoid), mitigating heat loads from muon decay at levels of several W/m, and ensuring radiation resistance exceeding 50 MGy. Overcoming these extraordinary challenges requires the innovative integration of high-temperature superconductor (HTS) technology, optimized for efficient operation at cryogenic temperatures up to 20 K, as well as the pursuit of compact designs to reduce capital expenditure.

In recent years, the International Muon Collider Collaboration (IMCC), hosted at CERN, has made significant progress in both the conceptual and, in some cases, the engineering design of these systems. This includes advancements in materials development, small-scale coil testing, and the establishment of a comprehensive R&D roadmap. This paper outlines a detailed plan with staged milestones, focusing on the development and testing of small- and full-scale magnet prototypes, ultimately culminating in their validation under collider-relevant conditions. This systematic approach aims to advance the technological readiness of magnet systems, bringing the realization of the Muon Collider closer to reality.

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Session Classification: Wed-Mo-Or2 - Muon Collider Magnets

Contribution ID: **603** Type: **Poster**

Fri-Mo-Po.03-09: Development of an actively shielded whole-body 1.5T MRI Magnet in India

Friday, July 4, 2025 9:30 AM (1h 45m)

A significant milestone in India's scientific and technological advancement has been achieved with the successful development of India's first indigenously designed 1.5T whole-body Magnet Resonance Imaging (MRI) magnet. The cryogenics and applied superconductivity lab at the Inter-University Accelerator Centre (IUAC), New Delhi has recently developed an actively shielded whole-body 1.5T superconducting magnet for a clinical scanner. The superconducting magnet system is the heart of any MRI scanner, the performance of which directly affects the quality of imaging. The design process of the magnet was focused on achieving optimal magnetic field homogeneity, and stability and minimizing operational costs while maintaining international standards. The multi-coil MRI magnet not only poses many challenges in achieving homogeneity at unshimmed conditions but also increases the inter-coil forces, number of superconducting joints etc.

An extensive FEA simulations on electromagnetic, thermal, cryogenics, mechanical, and electrical have been done during the design of the 1.5T MRI magnet. We performed extensive prototyping, and developed various associated technologies; superconducting joints, superconducting switches, quench protection systems, and performed component characterization, endurance testing, validation etc. The superconducting MRI magnet needs the development of various complex technologies to achieve high homogeneity ((±5ppm) and high temporal stability (0.1ppm/hr or 6Hz/hr) and zero-boil-off condition of the magnet system. The whole-body MRI magnet developed at IUAC has recently been tested. The magnet was parked at 1.5T field. The unshimmed homogeneity is achieved 615 ppm in the imaging volume. The field stability is measured to be ˜ 0.02 ppm/hr. The performance of the passive quench protection system of the MRI has been tested during a quench of the MRI magnet.

This paper briefly discusses the design, optimization and development, experimental studies of various critical components of the 1.5T whole-body actively shield MRI magnet system. Such development involved overcoming challenges related to superconducting coils, quench protection systems, superconducting switches, integrating magnets and the cryostat, cryogenic cooling etc. This paper briefly discusses the challenges faced during the development of such a whole-body magnet in an R&D laboratory in India

Acknowledgement

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Presenter: KAR, Soumen

Session Classification: Fri-Mo-Po.03 - Magnets for MRI

Contribution ID: **604** Type: **Contributed Oral**

Sat-Mo-Or3-05: Are REBCO CCs good for high field magnet construction?

Saturday, July 5, 2025 9:00 AM (15 minutes)

This is a comparative study of the angular critical current (I_c) in different REBCO coated conductors (CC) at high magnetic fields ($B < 45$ T) performed with torque magnetometry (US Patent 12,187,540)
The high I_c of REBCO makes transport measurements challenging at low temperatures (T) and high B, which are crucial for magnet construction and pinning mechanism studies. On the contrary, this is a region where the torque magnetometry works the best, providing a rapid assessment of $I_c(B, T, \Theta)$, where θ is an angle between field and the normal to the ab plane. The measurements agree well with transport data, where available. The study includes data from over 200 samples and shows significant diversity in $I_c(B, T, \Theta)$ between samples, even when manufactured using the same process. Observed exponential and stretched exponential I_c decays at angles when B is in the vicinity of the ab plane and power function and simple exponential decays far from the ab plane allows to clearly distinguish between weak and strong pinning contributions to overall I_c.
The results reveal significant lengthwise I_c variations, especially in tapes cut from the sides of 12 mm-wide production tapes compared to those cut from the center.
These variations are most pronounced when the field is in the vicinity of the ab plane.
Importantly, flux jumps are observed in samples with thick REBCO layers and thin stabilizers, underscoring potential thermal instabilities. These findings provide valuable insights into REBCO tape performance under extreme magnetic fields, highlighting their relevance for high-field magnet and nuclear fusion applications. Actually, these latest results make the author more confident in REBCO CC application in high field magnets.
A. Francis, G. Bradford, A. Xu, R. Ries, D. Larbalestier contributed. NHMFL is funded by NSF DMR2128556 and the State of Florida

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Session Classification: Sat-Mo-Or3 - HTS Characterization III

Contribution ID: **605** Type: **Poster**

Wed-Af-Po.01-05: A magnet system for the magnetic-confinement direct-fusion-drive device used in space propulsion

Wednesday, July 2, 2025 2:30 PM (2 hours)

The direct-fusion-drive device is a compact nuclear fusion engine that uses magnetic-confinement to achieve fusion reactions, providing both thrust and electrical power for spacecraft. Its operating principle is based on particle-confinement using extremely high magnetic fields exceeding 20 tesla to confine plasma. Subsequently, an electric field accelerates the plasma to initiate fusion in the chamber. The generated energy is used to heat liquid hydrogen to provide thrust, and is also utilized for electricity generation by thermoelectric conversion materials. This article details the design, modeling, and fabrication processes of a 20 tesla superconducting magnet, using the second-generation high-temperature superconducting REBCO coated conductors for the magnetic-confinement fusion device. Critical issues, including the screening currents induced during charging, the magnetic and mechanical behaviors of the magnet after charging, as well as neutron radiation and magnet protection, have been fully discussed. The work aims to provide both theoretical and practical foundations for the design of ultra-high-field magnets in compact fusion reactors and magnetic-confinement fusion propulsion systems, with applications in long-term energy generation and long-distance space exploration.

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Session Classification: Wed-Af-Po.01 - Magnets for Stellerators and Other Configurations

Contribution ID: **606** Type: **Poster**

Wed-Af-Po.02-03: EIC Detector Solenoid (MARCO) Design Update and Sample Conductor Testing

Wednesday, July 2, 2025 2:30 PM (2 hours)

The MARCO magnet is a 2T superconducting solenoid magnet central to the Electron Ion collider (EIC) detector at Brookhaven National Laboratory (BNL). The magnet utilizes a Rutherford cable in channel conductor with a nominal current of approximately 4 kA at 4.5 K. The cable and the copper stabilizer design was refined to aide fabrication of a 50 m long sample conductor. The characteristic of the conductor was revised to reflect the new design and the sample conductor was further systematically tested to confirm the same. The performance and safety margin of the magnet with the new conductor configuration was re-established. The return flux layout around the magnet was updated to reflect the change to the Rapid Cycling Synchrotron (RCS) beamline. The return flux steel configuration was optimized using OPERA to reduce the stray field at specified locations. The overall weight of the detector was reduced in the process which helps with the weight restrictions at the experimental hall.

Index Terms –detector magnet, Rutherford cable, superconductor, NbTi, OPERA

Acknowledgment –This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics under contract DE-AC05-06OR23177.

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Session Classification: Wed-Af-Po.02 - Detector and Spectrometer Magnets

Contribution ID: **607** Type: **Contributed Oral**

Sat-Af-Or2-06: A comprehensive framework for the mechanical analysis of Ultra High Field REBCO Solenoids

Saturday, July 5, 2025 3:15 PM (15 minutes)

The need for strong steady state magnetic fields, of 40 T and above, raises several new challenges in the design of superconducting magnets. Rare-earth barium copper oxide (REBCO) coated conductors (CCs) are nowadays the strongest candidates for this type of applications, yet the layered structure of these materials carries along the major mechanical challenges. Recent tests of ultra-high field (UHF) REBCO magnets have demonstrated the capabilities of these conductors of operating at fields up to 45.5 T, but they also evidenced some critical multi-scale dynamic effects, where crack patterns and delaminated areas in the REBCO phase influence the electrodynamics and quench behavior of the magnet.

In this contribution, we report on an encompassing multi-scale approach for the mechanical analyses of REBCO UHF solenoids; a paradigm that has been proposed in the context of the R&D studies for a 40+ T no/partial-insulation (NI/PI) solenoid for the Muon Collider. The goal of this approach is to estimate the stress/strain state inside a superconductor when employed for UHF applications. We investigate here the mechanical challenges based on material characterization campaigns and modeling efforts developed synergistically at coherent scales.

Initially, as a steppingstone, we focus on mechanical properties of REBCO layers'materials, presenting a measurement campaign at the micro-scale which provided with reliable constitutive laws for any further mechanical studies. We then address the issue of screening currents induced stresses/strains (SCIS) in connection with measurements of the delamination strength of REBCO CCs under Lorentz force. Finally, we move to examining the mechanical loads in the case of quenches in the windings. The evolution of the force density field and consequent stress fields are treated in a statistical manner, highlighting trends and extreme case scenarios.

In conclusion, for each of the mechanical load step mentioned above, we propose a set of design criteria to be used in the design of UHF solenoids.

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Session Classification: Sat-Af-Or2 - Progress in Ultra High Field Solenoids

Contribution ID: **608** Type: **Poster**

Fri-Mo-Po.03-05: Development of a 0.4 T permanent magnet and a planar coil gradient system for an MRI prototype

Friday, July 4, 2025 9:30 AM (1h 45m)

The Brazilian Center for Research in Energy and Materials (CNPEM) has built a medium field Magnetic Resonance Image (MRI) prototype as part of an overall effort on the in-house development of fundamental MRI technology know-how. The system is comprised of a permanent-magnet-based dipole, a set of planar coils for gradient field generation and a radiofrequency system with a transmission-reception radiofrequency coil. The 0.4 T main-field system is based on NdFeB permanent-magnet disks and its magnetic structure (return yoke, poles and shimming pieces) made of low-carbon iron steel. The field homogeneity aimed at a 4 cm diameter spherical volume (DSV) was in the order of 10 ppm. To achieve these requirements, the pole surface and the magnet disks dimensions were optimized via finite elements magnetic simulations. A special procedure was devised allowing for the high magnetic force between the NdFeB disks at the assembly procedure. The magnet was characterized using a three-dimensional hall probe mapping system allowing for field shimming iterations. Two strategies were considered for the correction of homogeneity: movable ferromagnetic cylinders inside the disks, shimming the main-field direction; and lateral height shifts, adjusting angle inclination and correcting the transversal directions fields. The gradient subsystem consists of three planar coils on either side of the DSV, one pair per axis of the image. Each coil combination must generate a magnetic field linearly dependent on its corresponding axis, with high angular coefficient and low nonlinearities. This system must have small inductance and resistance, allowing for higher electrical current to pass through, thereby increasing the gradient field strength. Since there is a limit to how low these electrical properties can reach without compromising the field quality, an optimization algorithm is necessary. The open-source code pyCoilGen was used to find an optimal wire pattern and position of the coils. Parallel computing was employed to test hundreds of different configurations. Each generated coil pair had their electrical and field properties quantified to rank each individual design and choose the best suited result for fabrication and characterization. The magnetic subsystems were integrated into the final MRI prototype system allowing three-dimensional images with phantom samples to be acquired at the end of 2024.

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Session Classification: Fri-Mo-Po.03 - Magnets for MRI

Contribution ID: **609** Type: **Poster**

Wed-Af-Po.04-06: Design and Fabrication of Current Leads for Superconducting Rotor Cooled with Rotating Cryocooler

Wednesday, July 2, 2025 2:30 PM (2 hours)

The concept of a rotating cryocooler for superconducting rotating machines eliminates the need for cryogenic liquids in the cooling loop, thereby simplifying and compacting the cooling system. This approach enables the development of extremely lightweight machines with high torque density. However, at high rotational speeds (e.g., >3000 rpm), operational conditions often limit the applicability of off-the-shelf cryocoolers for rotational use. As a result, the cooling power of a rotating cryocooler may be constrained and must be carefully considered in the overall cooling system design, including provisions for current leads, radiation shields, and other thermal management components. In this study, we present the design and fabrication of current leads for a superconducting rotor cooled with a rotating cryocooler. The cryocooler utilized is a single-stage Stirling cryocooler with a symmetric structure, centrally positioned within the motor and rotating along its axis. The designed current leads are divided into two sections: (1) the connection from the feed-throughs to the cold tip of the cryocooler and (2) the connection from the cold tip to the rotor. The first section employs a non-superconducting conductor optimized to minimize the total heat load, accounting for both heat intrusion and heat generation. The second section utilizes a copper bus bar reinforced with superconducting tapes to ensure low-loss current transfer. Prototype fabrication results are provided, along with performance test data, demonstrating the feasibility, efficiency, and practicality of the proposed current lead design.

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Session Classification: Wed-Af-Po.04 - HTS Joints

Contribution ID: **610** Type: **Contributed Oral**

Fri-Mo-Or5-06: Development of Bi-2212 conductors for accelerator magnets

Friday, July 4, 2025 12:30 PM (15 minutes)

Bi-2212 conductors and accelerator magnets have been advanced in the USA through a collaboration between US national labs, university, and wire industry connected by the US Magnet Development Program (MDP) and by recently the U.S. Department of Energy's Accelerator R&D and Production (ARDAP) Office. For example, a high engineering critical current density of 1000 A/mm2 has been demonstrated at 4.2 K and 27 T. Canted-cosine-theta coils have been made from Bi-2212 Rutherford cables and tested as a dipole magnet; the fabrication scheme and an initial performance benchmark have been established. Here in this talk we will summarize key findings and results under a two years' ARDAP project, which aims to advance conductor manufacturing and various aspects of coil technologies relevant for accelerator magnets with complimentary efforts and coil development from US MDP. We will discuss results of ARDAP conductor development that fabricates eight 2 kg conductor billets, which targets for establishing key powder characteristics and wire performance relationships and improve produce consistency and yield. Among the eight billets, there are two billets produced in 0.7 mm and fabricated as a Rutherford cable; a billet was produced in usual wire architecture and 0.8 mm but encased in a thicker Ag-0.2wtMg sheath. The wires also receive various modifications to thermo-processing to improve understanding of wire production. We will also discuss new understanding of Bi-2212 Rutherford cable fabrication and causes of ceramic leakages revealed in this collaborative effort.

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Session Classification: Fri-Mo-Or5 - HTS Conductors and Cable

Contribution ID: **611** Type: **Poster**

Sat-Mo-Po.08-05: Comparison of Nb3Sn Insulation Systems with as received and de-sized glass

Saturday, July 5, 2025 9:30 AM (1h 45m)

Epoxy cracking has been the main suspected contributor to training in Nb3Sn magnets for some time, as it leads to energy release and magnet quenching. Cracking in a superconducting composite can occur from several modes, and the likelihood of these modes is not well understood. Failure has been observed between insulation systems and the superconducting cable itself rather than within the cable or insulation. Previous work has suggested that the sizing present on glass fibers may affect performance of the composites. To target the behavior at the interface, samples have been fabricated with standard S2 glass as well as the same which has been di-sized using heat cleaning. These samples tested for mode I fracture toughness in an adapted version of ASTM D5528, as well as short beam strength using ASTM D2344. This work seeks to better characterize the behavior of the conductor-insulation interface to better understand how to model and design insulation systems.

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Presenter: KRAVE, Steve

Session Classification: Sat-Mo-Po.08 - Structural and Insulation Materials

Contribution ID: **612** Type: **Poster**

Fri-Af-Po.03-04: The design and performance of the Canis 3x3 magnet array support systems

Friday, July 4, 2025 2:00 PM (2 hours)

Thea Energy, Inc has designed, developed, and tested the "Canis"3x3 array of high-temperature superconductor (HTS) planar coils, which will serve as a prototype for the development of the "Eos"planar coil stellarator. The Canis 3x3 magnet array support systems consist of a vacuum vessel, a radiation shield, first and second stage cooling systems, a magnet current distribution system, and a mechanical support structure. The support systems were designed, developed, and deployed to enable the operation and test of the Canis 3x3 magnet array. A custom vacuum vessel houses and provides an environment for the array and support systems. The radiation shield and first stage current leads are cooled to a temperature of 79 K by a liquid nitrogen (LN2) distribution system with 600 W of cooling power, supplied by LN2 dewars. The HTS magnet array and second stage current leads are further cooled to a temperature of 20 K using supercritical helium (ScHe) supplied by an external cryoplant and ScHe cryo-circulation system with 250 W of cooling power. The magnet array is supplied with 150 A of operating current by 9 pairs of hybrid current leads, made of copper and HTS. Finally, the magnet array and associated hardware is mechanically supported and thermally isolated by a custom G-10 and stainless-steel support structure. The Canis 3x3 magnet array test campaign infrastructure is housed in a dedicated test cell at Thea Energy' s headquarters in Kearny, NJ. This poster will describe the design of the Canis 3x3 magnet array support systems and report on their performance as part of the test campaign.

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Session Classification: Fri-Af-Po.03 - Supporting Technologies for Fusion Magnets I

Contribution ID: **613** Type: **Poster**

Thu-Mo-Po.07-02: Efficient calculation of and coil shape optimization for Lorentz forces

Thursday, July 3, 2025 8:45 AM (2 hours)

The Lorentz forces on electromagnetic coils play an important limiting role in the design of practical magnetic confinement fusion reactors and other high-field devices as designs must demonstrate that the forces are within prescribed limits. Unfortunately, the Lorentz force is time-consuming to numerically evaluate due to a source point singularity in the calculation of the self-force and, as a result, is typically reserved for engineering design considerations. A method to rapidly calculate the self-force is desirable as Lorentz forces could be more easily incorporated into the earlier physics design itself, though naive attempts to treat coils as infinitesimally thin in order to reduce computational time fail as the magnetic field nonphysically diverges. Instead, we present a novel method for calculating the Lorentz self-force (in addition to similar models for the self-inductance and self-field) using non-singular integral formulae of reduced dimensions that were derived rigorously by dividing the domain of integration of the magnetic vector potential into two regions and exploiting the unique assumptions of each region. We demonstrate that these formulae show good analytic and numerical agreement to high-fidelity calculations yet evaluate ˜250x faster than finite element analysis software. Taking advantage of the numerical efficiency of the reduced formulae, we optimize stellarator coils for small Lorentz forces and demonstrate reductions in the maximum force by up to ˜50% with minimal deterioration to desirable properties like fast particle losses.

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Session Classification: Thu-Mo-Po.07 - Design Optimization

Contribution ID: **614** Type: **Poster**

Sat-Mo-Po.05-07: Tests and Analyses on Quench Behavior of Conduction-cooled No-Insulation Racetrack Coils

Saturday, July 5, 2025 9:30 AM (1h 45m)

This paper presents the quench test results and analysis of no-insulation (NI) REBCO (Rare-Earth Barium Copper Oxide) double pancake racetrack coils under conduction cooling conditions. Two racetrack coils, differing in dimensions and number of turns (280 and 488 turns), were tested at a temperature of 50 K each. The current was ramped up to their critical values until quenching occurred, during which the terminal voltage, central magnetic field, and temperature distribution were monitored. To ensure the reliability and reproducibility of the results, each coil underwent quench testing at least three times. Both circuit-based and finite element method (FEM)-based simulations were conducted to analyze the coils' behavior during quench events. Additionally, inverse calculation techniques were employed to estimate peak temperature rises within the coils that could not be directly measured by the temperature sensors. The study also examined the impact of detailed coil design parameters—such as winding geometry and support structures—on quench behavior. Based on these findings, practical design recommendations are proposed to enhance the quench robustness and operational reliability of NI REBCO coils, contributing to the development of more resilient superconducting systems.

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Session Classification: Sat-Mo-Po.05 - Quench Detection and Protection IV

Contribution ID: **615** Type: **Poster**

Wed-Af-Po.01-02: Designing Robust Stellarator ReBCO Coils

Wednesday, July 2, 2025 2:30 PM (2 hours)

The APEX (A Positron Electron eXperiment) collaboration is developing a "tabletopsized" stellarator, EPOS (Electrons and Positrons in an Optimized Stellarator). In this work, we present ReBCO non-planar, non-insulated (NI) coils designed to confine pairplasmas within a quasi-axisymmetric magnetic field of 2.0 T on axis. The stellarator's small size enhances its utility by reaching higher plasma densities with relatively low amounts of available positrons. Both aspects enable long-lived matter-antimatter plasmas. HTS tape was selected for its ability to achieve high field strengths with efficient cryogenic operation. The design minimizes binormal, torsional strains on the HTS tapes while simultaneously ensuring their structural integrity, and critical current retention under operational loads. Additionally, trade-offs between field accuracy and coil shapes — e.g. exclusion of concave sections, ensuring enough coil-to-coil spacing, and robustness to manufacturing errors —were carefully managed during the conception process. This balance was achieved through iterative stochastic single stage optimization to ensure that the plasma shape/topology is compatible with buildable coils. The final configuration was chosen after an initial selection process, result of a reduced parameter scan in the coil currents and major radius. This method allowed to push further than initially expected the accuracy of the magnetic field while maintaining manufacturability and mechanical resilience.

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Session Classification: Wed-Af-Po.01 - Magnets for Stellerators and Other Configurations

Contribution ID: **616** Type: **Contributed Oral**

Sun-Mo-Or2-04: Update on the Qualification of the Superferric Magnets for the FAIR SuperFRS at CERN

Sunday, July 6, 2025 8:45 AM (15 minutes)

As part of the FAIR project and within the GSI and CERN collaboration, the superferric magnet production series —key components of the Superconducting FRagment Separator (SuperFRS) under construction at FAIR, Darmstadt, Germany—are undergoing rigorous testing at CERN in a dedicated cryogenics test facility.
The tested magnets include dipoles and various types of multiplets (composed of different numbers of quadrupoles, steering dipoles, sextupoles, and octupoles, housed inside a shared vacuum vessel), which must be qualified for cryogenics, electrical and magnetic field performances. The dipoles were designed by CEA (France) and manufactured by Elytt Energy (Spain), while the multiplets are produced by ASG (Italy).
This paper outlines the updated capabilities of the test facility for large-scale magnet testing. It provides a detailed summary of the tested magnet series and configurations, highlighting key results from powering tests. Special attention is given to the analysis of the quenches that occurred during magnet testing. The strategy proposed to mitigate magnet training, therefore optimizing the testing time, including precise voltage measurements and tailored powering ramps is presented. The paper concludes with the outlook of the future tests.

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Session Classification: Sun-Mo-Or2 - Fabrication and Testing of Magnets for Facilities

Contribution ID: **617** Type: **Poster**

Thu-Mo-Po.02-08: Observation of electromagnetic transients in a Nb3Sn 4 layer stress managed cosine theta magnet

Thursday, July 3, 2025 8:45 AM (2 hours)

During the testing of the Stress Managed Cosine-Theta magnet SMCT-01, magnet quenches were observed following large voltage spikes in the half coil voltage taps which preceded normal quench initiation. Following some recent work at CERN measuring power current convertor transients in relation to flux jumps, an additional differential current probe was added to the magnet instrumentation. Measurements of this probe, as well as the half coil voltage taps show a fast and substantial current change preceding the quench, hinting at coil motion. A simple model based on relative shift of the inner and outer layer coils was developed which suggests the magnitude of coil shift events is on the estimated relative coil shift from the magnet constraint conditions. The behavior is shown to be reversible and characteristic of stick-slip.

Author: KRAVE, Steve

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Presenter: KRAVE, Steve

Session Classification: Thu-Mo-Po.02 - Design and Development of Accelerator Magnets I

Contribution ID: **618** Type: **Poster**

Fri-Mo-Po.03-06: Low-AC-Loss Nb3Sn Validation Model Coil in Solid Nitrogen for a Fast-Switching-Field MRI Magnet Prototype

Friday, July 4, 2025 9:30 AM (1h 45m)

In this paper, we present the design and test results of a low-AC-loss Nb3Sn model coil developed to validate key enabling technologies for a fast-switching-field magnetic resonance imaging (MRI) magnet concept that can change the magnetic field very quickly in time, within 1 second, between significantly different field strengths: a high field (3 T) for relaxometry and prepolarization and a low field (0.5 T) for spectroscopy and imaging. While conventional MRI magnets require a static magnetic field, we expect that our proposed superconducting magnet with rapidly changing fields can provide opportunities for novel contrast mechanisms, which include level-crossing between spin-1/2 and quadrupolar nuclei, accelerated spin-lattice relaxation, and adiabatic demagnetization/remagnetization, by permitting differential relaxometry enabled by a large field strength difference, and ratiometric molecular/superthermal imaging. We have developed and demonstrated an innovative magnet design that uses a very low-AC-loss Nb3Sn coil and a novel cooling technology featuring highly heat-conductive thermal links between the coil and solid nitrogen surrounding the coil. These thermal links in solid nitrogen are anchored at one end to the cryocooler cold head. This design enables rapid switching between two magnetic fields in the superconducting magnet without inducing quench. The paper provides details on the construction, test results, and an in-depth analysis of AC losses and the maximum temperature rise in the coil of the small-scale fast-switching-field magnet system.

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Session Classification: Fri-Mo-Po.03 - Magnets for MRI

Contribution ID: **619** Type: **Poster**

Thu-Af-Po.03-01: Thermal and mechanical design of superconducting field coil modules for offshore wind generators

Thursday, July 3, 2025 2:00 PM (2 hours)

One of the greatest challenges in designing the superconducting field winding for a superconducting generator (SCG) is balancing mechanical loads while limiting heat that can enter via mechanical structure. This paper outlines the thermal and mechanical co-design of the field coils for a low speed, high torque, partially superconducting generator using LTS wire. Mechanical design is focused on minimizing loads in and around the field coils, thereby minimizing the amount of structure through which heat can enter. Conduction cooling is used to simplify the system. Material selection, thermal design, and performance projections for an SCG designed for offshore wind turbines are reviewed.

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Session Classification: Thu-Af-Po.03 - Rotating Machinery III

Contribution ID: **620** Type: **Poster**

Thu-Mo-Po.03-04: Design and Development of Large-Bore Conduction-Cooled Nb3Sn-Based Axion Haloscope

Thursday, July 3, 2025 8:45 AM (2 hours)

Investigations into the existence of Axions, a hypothetical Dark Matter candidate, have led to numerous experiments requiring stable magnetic fields over a large volume for an extended duration of time, a feat currently limited to low-temperature Niobium-based superconductors. While Nb-Ti is the standard at 4.2 K and <10 T, Nb_3Sn has a larger T_c, larger H_{c_2}, and most critically, can be jointed with high-field-tolerant superconducting bulk-Nb_3Sn, removing the need for low H_{c_2} PbBi superconducting joints. In this study, a conduction-cooled, 16-cm bore, 12"long, persistent-capable, quench-protected, Nb_3Sn-based solenoid with a peak-field of 5 T was designed, constructed, and tested at Princeton Plasma Physics Laboratory. Development of the magnet required extensive testing of Nb_3Sn superconducting joints, fabrication of a Nb_3Sn switch heater, integration of cold-diodes for passive protection, vacuum-pressure-impregnation (VPI) of epoxy, mechanical reinforcement to accommodate the brittle Nb_3Sn, and many other novel challenges, all while contending with cryogen-free operation. The 16-cm bore magnet developed in this work will be implemented into a microwave cavity for a prototype Axion Haloscope, in collaboration with Princeton University. Following the commissioning of this prototype and drawing upon the lessons learned thus far, a much larger solenoid (79 cm bore, 1 m long) with a similar peak field will be designed and the feasibility of construction assessed, with aspirations to ultimately construct a solenoid capable of investigating an unexplored mass-range for Axions. Princeton Plasma Physics Laboratory is developing its superconducting materials capabilities and facilities to address the growing demand for low-temperature and high-field characterizations. Nb_3Sn is a critical technology for current and future superconducting applications with many technological hurdles undisclosed in the literature, especially when considering cryogen-free operation. Overall, the development of a large-bore Nb_3Sn Axion Haloscope involves many such challenges and will establish considerable experience in superconducting solenoid fabrication at Princeton Plasma Physics Laboratory, will expand the literature regarding many of these challenges through publications, and enable a novel experiment in a previously unexplored mass-range for Axions.

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Presenter: BRADFORD, Griffin (Princeton Plasma Physics Laboratory)

Session Classification: Thu-Mo-Po.03 - Design and Development of Accelerator Magnets II

Contribution ID: **621** Type: **Poster**

Wed-Mo-Po.01-05: ESC enables quench protection of a hybrid 20 T accelerator magnet

Wednesday, July 2, 2025 9:15 AM (2 hours)

The US Magnet Development Program is leading the ambitious challenge of developing an accelerator dipole magnet targeting a bore field of 20 T. Among the explored designs is a 6-layer, cos-theta hybrid magnet, which includes low-temperature superconductor (LTS) and high-temperature superconductor (HTS) coils powered in series. The objective is to build a 1 m long demonstrator magnet with features that meet the operational requirements of a particle accelerator. This includes demonstrating effective magnet quench protection without relying on energy extraction, as well as scalability of the protection strategy up to a full-size, 15 m long magnet.
Protecting this high-field magnet after a quench is extremely challenging due to the high energy density, high current density, large margin to quench (particularly in the HTS coils), and highly non-uniform quench response of the HTS and LTS coils. A previous study showed that CLIQ-based protection relying on a 1 kV capacitive unit is effective in protecting such a magnet design only up to a magnetic length of about 5 m. While increasing the magnet coil size and the CLIQ charging voltage could extend this range, such approaches would have significant drawbacks, including higher costs and increased risk of electrical failure.
This study explores the application of the recently-developed Energy Shift with Coupling (ESC) technology to this magnet design. ESC relies on resistive coils integrated into the magnet cross-section, which are utilized to introduce high transient losses in the superconductor, hence quickly transitioning the superconductor to the normal state and transferring part of its stored energy to the ESC coils. Simulations performed with the STEAM-LEDET program show that a 15 m long, 20 T magnet can be effectively protected using six 1 kV ESC capacitive units powering six ESC coils, which can be integrated into the magnet without significantly altering its magnetic design.
The successful application of ESC to this challenging magnet design marks a significant advancement in quench protection technology, enabling the development of next-generation high-field accelerator magnets.

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Session Classification: Wed-Mo-Po.01 - Accelerator Magnets I

Contribution ID: **622** Type: **Poster**

Thu-Mo-Po.03-08: Design and fabrication of an elliptic-aperture combined-function superconducting magnet demonstrator for fixed-field acceleration

Thursday, July 3, 2025 8:45 AM (2 hours)

In this work, we present the design of a combined-function Canted-Cosine-Theta (CCT) accelerator magnet with an elliptic aperture and report progress on the fabrication of a NbTi demonstrator magnet. This unique bore shape is desired for fixed-field accelerators to accommodate horizontal orbit offset between beams of different energy. We first share the magnetic and mechanical design of a two-layer CCT magnet based on NbTi Rutherford cables, with a target field of 5 T at 4.2 K. Analytic and numerical methods are employed to optimize the coil winding path to produce the desired combination of dipole and quadrupole fields. The iron shape and coil path are further optimized using a 3D magnetic model to reduce the undesired higher-order harmonics resulting from iron saturation. Stress analysis is carried out with periodic 3D and full 3D models to ensure mechanical robustness. We then discuss the unique advantages and challenges when developing fabrication procedures using subscale prototypes. Finally, we report the status of layer fabrication and assembly of the 0.6 m long demonstrator magnet.

Author: YAN, Yufan (Lawrence Berkeley National Laboratory)

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Presenter: YAN, Yufan (Lawrence Berkeley National Laboratory)

Session Classification: Thu-Mo-Po.03 - Design and Development of Accelerator Magnets II

Contribution ID: **623** Type: **Poster**

Fri-Af-Po.06-06: Feasibility study of low-inductance high-field solenoid magnets using CORC® conductors

Friday, July 4, 2025 2:00 PM (2 hours)

In the past few years, there is a growing interest in low-inductance high-field solenoid magnets for high-energy physics experiments including future muon colliders. Advanced Conductor Technologies (ACT) has recently developed CORC® wires wound from REBCO coated conductors with improved bending flexibility that allow for bending to a 20 mm radius and CORC® cables containing up to 96 tapes with very-high current-carrying capability in high-field. This study explores the performance limit of low-inductance high-field solenoids based on start-of-art CORC® conductors. A modeling framework is developed, taking into account current margin, mechanical limits, magnet protection difficulties, and costs. This is applied to examine the feasibility of solenoids with a target field of 35-40 T and a bore size of 50 mm, as series-connected inserts operated with a low-temperature-superconducting outsert or as a stand-alone magnet, and 20-T with a 1.2-m bore envisioned for future muon colliders. We discuss the challenges and limiting factors of the respective cases and provide an overview of the initial designs.

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Session Classification: Fri-Af-Po.06 - High Field HTS Solenoids

Contribution ID: **624** Type: **Poster**

Fri-Mo-Po.03-07: Quench test of an actively shielded whole-body 1.5T MRI magnet

Friday, July 4, 2025 9:30 AM (1h 45m)

The quench protection system (QPS) plays one of the most crucial roles in the safe operation of any MRI magnet. The higher magnetic stored energy (few MJ) of the MRI magnet makes it imperative to design an efficient QPS to prevent any damage due to the localized temperature rise, insulation breakdown, or any voltage arcing during a quench [1-2]. The persistent mode of operation of the MRI magnet possesses a significant challenge in designing the QPS for any superconducting MRI magnet [3]. In the persistent mode, the stored energy needs to be dissipated safely into the cryostat during an event of a quench of the MRI magnet. Otherwise the entire stored energy would be dissipated in the limited volume of the magnet that may result in a local temperature rise which may even damage the magnet. Designing a QPS for a multi-coil MRI magnet poses an additional challenge due to the inductive coupling among the coils.
An actively shielded multi-coil 1.5 T superconducting MRI magnet system is recently designed and developed for a whole-body clinical scanner. A passive QPS of the 1.5T MRI magnet is designed using self-activated quench propagation heaters to spread the normal zone over all the coils. The coils of the 1.5 T magnet are grouped in two symmetric sub-divisions. Each symmetric sub-division has a QPS and also a quench propagation circuit. The thermal and electrical behaviour of the QPS for the coil has been simulated using OPERA-3D finite element analysis (FEA) code. The total stored energy of the magnet is about 3.7 MJ. The maximum inter-layer quench voltage generated in the symmetric sub-division is ˜ 45 V/layer with a peak voltage of ˜1.7 kV and a hot spot temperature of 180 K. During a quench, an average driving voltage of 1.3 kV and the associated current of 1.75 A is generated in both quench propagation circuits of the magnet with the symmetric sub-division. There are a number of voltage taps used across various coils and components located at the different sections of the quench propagation circuit. Each voltage tap has a cold resistor (˜10 kohm) in series to protect the induction of any high current into the lead. Each pair of voltage taps has been connected to the fast data acquisition system through a signal isolator to protect the data acquisition system from a high voltage if it appears during a quench.
This paper briefly discusses the thermal and electrical behaviour of the QPS of the 1.5T actively shield whole-body MRI magnet. The performance of the QPS has been tested during a quench in the MRI magnet. Extensive analysis has been done using the voltages of the various coils and various sections of the magnet recorded during the quench. The paper describes the details of the quenching analysis of a whole-body 1.5T MRI magnet developed at the Inter-University Accelerator Centre, New Delhi

Acknowledgement
The authors would like to thank the Ministry of Electronics and Information Technology (MeitY), Govt of India for funding this research under the IMRI project. The authors would also thank members of the cryogenic group for providing technical support in development of the test rigs.

[1] P.F. Smith, Protection of superconducting coils, Rev. Sci. Instrum. 34 (4) (1963) 368–373.
[2] A.V. Dudarev, Quench protection of very large superconducting magnets, IEEE Trans. Appl. Supercond. 5 (2) (1995) 226–229.
[3] RE Schwall, Quench protection for the inductively coupled magnet, IEEE Trans. on magnetics, 27(2), 1991, 1700-1703.

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Session Classification: Fri-Mo-Po.03 - Magnets for MRI

Contribution ID: **625** Type: **Contributed Oral**

Wed-Mo-Or2-04: Novel and Underexplored Quench Protection Strategies for High-Field Magnets

Wednesday, July 2, 2025 12:00 PM (15 minutes)

Over the past decades, the superconducting magnet community has proposed various concepts to protect magnets from the undesired consequences of a quench. While only a handful of protection methods have been implemented in large-scale production magnets, other less-known concepts have been explored only at a conceptual stage. This study presents various protection techniques that are either novel or not well established, with special attention to innovative approaches that have the potential to influence future magnet design.
The widespread availability of high computing power, coupled with recent advancements in comprehensive, validated, and fast multiphysics software tools, enables the evaluation of any protection concept more easily than before. STEAM framework tools were leveraged to analyze the applicability of existing and novel methods, highlighting their advantages and disadvantages in terms of effectiveness, robustness, simplicity, redundancy, and ease of integration.
Future areas of development including software development, R&D on the protection hardware, and experiments aimed at validation of the proposed concepts are identified.

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Session Classification: Wed-Mo-Or2 - Muon Collider Magnets

Contribution ID: **626** Type: **Poster**

Wed-Af-Po.05-07: Transverse Lorentz stress experienced by REBCO tape in ultrahigh magnetic field

Wednesday, July 2, 2025 2:30 PM (2 hours)

REBCO coated conductor has great potential to be used in ultra-high field magnets [1]. In such magnets, it is crucial to manage the high mechanical stress on REBCO due to electromagnetic force. The commercial REBCO tapes is strong in the longitudinal direction but is prone to delamination by tensile stress in the thickness direction. It had been observed that transverse tension by electromagnetic force could delaminate some commercial REBCO tapes [2].
In this work, we generated screen current in REBCO samples by either fast ramping magnetic field while sample is stationary or rotating a REBCO sample in a fixed magnetic field up to 30 T. The goal is to create high transverse tensile stress to study the possible delamination behavior. The experimental results will be presented. The implication of the results to the design of ultrahigh field REBCO magnet is discussed.

Reference
[1] S. Hahn, et al, "45.5-tesla direct-current magnetic field generated with a high-temperature superconducting magnet", Nature, vol. 570, pp. 496-99, 2019.
[2] M. Bonura, et al., "Quench concomitant to Lorentz force induced delamination in commercial REBCO coated conductors", 2OrSM-4, MT-28, Aix-en-Provence, France, Sept. 10, 2023.
Acknowledgement
This work was performed at the National High Magnetic Field Laboratory, which is supported by National Science Foundation Cooperative Agreement No. DMR- 2128556, DMR- 2131790, and the State of Florida

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Session Classification: Wed-Af-Po.05 - HTS Conductors II

Contribution ID: **627** Type: **Contributed Oral**

Sat-Af-Mem1-04: Simulated and experimental screening current induced strain in the Large Scale Coil

Saturday, July 5, 2025 5:15 PM (15 minutes)

The Large Scale Coil (LSC) is a high-temperature superconducting (HTS) coil that has been developed and tested in the research and development efforts for the 40-T All-Superconducting Magnet Project at the National High Magnetic Field Laboratory. The LSC is composed of stacked pancake disks consisting of 2-in-hand wound rare-earth barium copper oxide coated conductor (CC REBCO) tapes with stainless steel and copper co-wind. Under high magnetic fields, Lorentz forces on the REBCO tapes can impact the performance of the coil. Therefore, it is important to accurately predict strain in the pancake disks when designing these HTS magnets. Modeling of the LSC was done in COMSOL using a T-A formation coupled with structural mechanics, while accounting for screening current induced strain.

Experimental data was collected and compared to simulated results. On the LSC, strain gauges were placed on the inboard and outboard edges of three disks, along with compensation gauges to account for magnetic field effects. The LSC was operated in a background field of 11.5 T. LSC simulations were conducted using FLOSSS (Florida Screening Strain Software) [1] [2] [3]. Initial results reveal significantly higher simulated strain at both inboard and outboard gages. Therefore, further simulations were needed to investigate the discrepancy between simulated and measured strain.

Manufactured REBCO have variations along tape width including 'roughness'on the tape surfaces, whereas a flat tape surface was assumed for initial simulations. Methods to address this include a penalty method [4] and introducing a gap dependent on variation in thickness along the REBCO tape. Comparison of experimental results to simulations reveal that incorporating this aspect of REBCO tape surface structure decreases the difference between simulated and experimental results.

Strain data from the LSC tests are a valuable resource for verification of modeling methods and improving our understanding and design of large and complex HTS magnets such as the 40-T. This investigation compares measured strain data with simulated strain to assess and improve our current modeling techniques for HTS coil design. Details on comparisons of strain data from experiments and simulations during cooldown, background magnet ramping, and insert current ramping will be included. In addition, implementation of simulation methods will be detailed.

[1] D. J. Kolb-Bond et al., "Computing strains due to screening currents in REBCO magnets,"IEEE Trans. Appl. Supercond., vol. 30, no. 4, Jun. 2020)
[2] D. Kolb-Bond et al., "Screening current rotation effects: SCIF and strain in REBCO magnets," Supercond. Sci. Technol., vol. 34, no. 9, 2021
[3] Y. Suetomi et al., "Screening Current Induced Stress/Strain Analysis of High Field REBCO Coils With Co-Winding or Over-Banding Reinforcement," IEEE TAS, 34, 5, 8400206 (2024).
[4] J. Park, "A Numerical Study on Mechanical Boundary Conditions for Screening Current Induced Stress Analysis of REBCO Magnets", ASC 2024, 5Lor1C (2024)

This work was performed at the National High Magnetic Field Laboratory, which is supported by National Science Foundation Cooperative Agreement No. DMR-2131790, DMR-2128556, and the State of Florida.

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Session Classification: Sat-Af-Mem1 - Huub Weijers Memorial: High Field Magnets

Contribution ID: **628** Type: **Contributed Oral**

Sat-Af-Or1-02: Current Progress on the High-Field Cable Testing Facility at Fermilab

Saturday, July 5, 2025 2:30 PM (15 minutes)

Fermi National Accelerator Laboratory (Fermilab) is constructing a new High Field Vertical Magnet Test Facility (HFVMTF) with capabilities comparable to the European facilities EDIPO and FRESCA2. The facility, located at Fermilab, will feature a background magnetic field of 15 T, generated by a magnet provided by Lawrence Berkeley National Laboratory (LBNL). The HFVMTF will support two U.S. national programs under the DOE Office of Science: the U.S. Fusion Energy Science (FES) program and the Magnet Development Program (MDP). It will enable the testing of HTS samples in high magnetic fields across a wide range of temperatures and facilitate the development of hybrid magnets combining LTS and HTS superconductors. This paper presents an overview of the current progress in constructing the facility, including updates on the test cryostat, power supplies, and systems for quench protection and monitoring.

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Presenter: VELEV, Gueorgui

Session Classification: Sat-Af-Or1 - Fusion Test Facilities

Contribution ID: **629** Type: **Poster**

Thu-Af-Po.02-10: Study of current sharing in high-temperature superconducting CORC® cables using finite-element model coupled with electrical circuit

Thursday, July 3, 2025 2:00 PM (2 hours)

Limited by filament size, the dimensions of Rare-earth Barium Copper Oxide (ReBCO) cables are usually comparable to the width of the constitutive tape strands. Resultantly, the distribution and redistribution of currents amongst strands can have a strong impact on the behaviors of the cable, including current-voltage characteristics and in-field performance. In this study, we present a modeling framework coupling a three-dimensional periodic finite-element model based on the T-A formulation with an electrical circuit considering terminal resistances through inductive and resistive voltages and strand currents. On a 4-layer CORC® cable, we first demonstrate the dynamics of current redistribution and voltage profiles considering nonuniform strand critical currents and unequal terminal resistances. Then we examine the behaviors of the cable in a background field, which help to understand the effects of layer-to-layer shielding and in-field cable performances. Finally, we discuss the practical implications for the effective use of voltage signals for quench detection.

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Presenter: YAN, Yufan (Lawrence Berkeley National Laboratory)

Session Classification: Thu-Af-Po.02 - HTS Cable

Contribution ID: **630** Type: **Poster**

Sat-Mo-Po.07-08: Design and prototyping of CORC CCT inserts for testing in background dipole fields

Saturday, July 5, 2025 9:30 AM (1h 45m)

We present design options and initial prototyping of CORC Canted Cosine Theta (CCT) dipole inserts compatible with testing in the ˜8 T background field of the existing Nb3Sn outsert CCT5. We explore different CCT geometries and configurations, seeking to optimize the coil geometry to meet the minimum bending radii requirements of the CORC conductor with maximum coil magnetic efficiency. The result of these studies is a four-layer CORC CCT dipole design with ˜ 5 T stand-alone short-sample limit at 4.2 K that maintains compatibility with testing in the 90 mm clear aperture of the CCT5 outsert. We present the full magnetic design of this insert magnet and initial studies of the mechanical coupling between the insert and outsert in 2D. Finally, we share initial prototyping of this design where short lengths of CORC conductor are characterized before and after winding into the CCT coil geometry as a first step towards demonstrating degradation-free coil fabrication.

This work was supported by the U.S. Department of Energy, Office of Science, Office of High Energy Physics, through the US Magnet Development Program under contract No. DE-AC02-05CH11231.

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Presenter: BROUWER, Lucas

Session Classification: Sat-Mo-Po.07 - HTS Magnets

Contribution ID: **631** Type: **Contributed Oral**

Sat-Mo-Or5-06: Radio-frequency quench sensing integrated with flexible round HTS cables

Saturday, July 5, 2025 12:30 PM (15 minutes)

Quench detection is a crucial technology that enables using HTS conductors in high-field magnets for high-energy physics and fusion applications. At the same time, hot spot localization capability provides valuable insights to magnet developers and operators. Distributed temperature sensing along the conductor path can achieve both goals and is especially suitable for fast-ramping magnets or current-shared cable conductors, where voltage signals due to a slowly propagating normal zone may be ambiguous or unreliable. Various temperature sensing approaches for HTS magnets using optical fibers, radio-frequency (RF), and ultrasonic methods have recently been reported. Among those, RF sensors stand out as the most robust and less expensive than optical fibers while showing a superior thermal sensitivity. The present work discusses quench sensing enabled by the temperature-induced permittivity variations in RF transmission lines made with custom insulation materials. Two distinct measurement techniques are reported. One is an RF interferometry, which is entirely based on coherent software-defined radio (SDR), and the other is a classic time-domain reflectometry using picosecond-level pulsing and a 25 GHZ sampling oscilloscope. To demonstrate our approach in practice, we have custom-wound round flexible multi-conductor ReBCO cables and embedded distributed RF temperature sensors into them. Using the above-described measurement techniques, we validate quench detection and localization capabilities in such a cable at 77 K and cross-calibrate voltage and thermal responses. The next development steps will be discussed, including measurements of the thermal runaway margin and cable-level integration of active quench protection.

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Session Classification: Sat-Mo-Or5 - Quench Detection Modelling

Contribution ID: **632** Type: **Poster**

Fri-Af-Po.11-02: A low AC loss, fast ramp HTS solenoid prototype for compact spherical tokamaks

Friday, July 4, 2025 2:00 PM (2 hours)

Next-step US spherical tokamak test facilities and/or compact stellarators configured as fusion pilot plants (FPP) to support fusion commercialization are recommended options by multiple recent consensus studies. The goal for a FPP is to make 50-100 MW net electricity power plants with either extended long pulses or steady state options. Significant HTS conductor and coil technology efforts are underway by privately funded startups with the goal to demonstrate HTS maturity for commercial fusion. Test results, however, indicate critical issues remain to meet performance goals, and demonstrate coil operation repeatability and reliability. To this end, exploring and enabling multiple viable conductors is critical for enabling next generation fusion magnets beyond ITER with advances in conductor materials, coil manufacturing, and HTS quench sensing. To validate the low AC loss characteristics of commercial Bi-2212 conductors made in the USA, a simpler ohmic heating (OH) coil module is developed for next step compact tokamak devices.

The primary goal for this project is to build and test a Bi-2212 prototype coil designed by Princeton Plasma Physics Laboratory (PPPL) aiming for a spherical tokamak (ST) ohmic heating central solenoid (CS) fast ramp operation. For a ST pilot plant, one of the superconducting magnet challenges is the tight space constraint in a center column where the in-board toroidal field (TF) coil bundle and the OH coil are assembled inside a center cryostat and a structural casing where plasma facing components are attached. To this end, a model coil design based on high current density Rutherford cables consisting of 17 strand Bi-2212 wires previously used and tested in HEP was developed for ST fusion. Recent evaluations of Bi-2212 wires have shown that Bi-2212 conductors have orders of magnitude lower AC losses compared to REBCO coated conductors, very comparable to ITER Nb3Sn wires. This makes Bi-2212 wires suitable and potentially the only viable high field option for a fast ramp, high field solenoid for compact ST operation. This is significant because most recent studies in support of private fusion have shown promising results of net fusion gain by operating a pulsed tokamak machine.

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Presenter: ZHAI, Yuhu (Princeton Plasma Physics Laboratory)

Session Classification: Fri-Af-Po.11 - Experiments and Test for Fusion Magnets

Contribution ID: **633** Type: **Invited Poster**

Wed-Af-Po.08-08: [Invited] Overview of remountable joint test facilities at UKAEA

Wednesday, July 2, 2025 2:30 PM (2 hours)

Remountable joints for large scale superconducting magnets are of considerable interest, particularly for fusion, as they open the possibility of new advantageous maintenance regimes. Developing this low maturity technology to the point of deployment on full scale tokamak magnets requires a host of specialised hardware test campaigns that inform design choices and prove out components under operation and maintenance regimes. To fulfil this need for the Spherical Tokamak for Energy Production (STEP) and the wider fusion community, the UK Atomic Energy Authority (UKAEA) is developing and building a user facility for testing of remountable magnet joints and subsystems under representative conditions. This work explains the rationale for the test facilities before providing an overview of the development process and capabilities of the existing rigs. Planned upgrades to the rigs, as well as completely new rigs are discussed. Based on these activities, UKAEA will provide the infrastructure to develop the STEP remountable joints in line with the programme's proposed technology roadmap. In addition, the wider fusion and magnet community will benefit from the existence of an R&D hub, accessible to researchers external to UKAEA.

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Presenter: DIEUDONNE, Yannik

Session Classification: Wed-Af-Po.08 - Conductor and Coil Measurement/Test Techniques and Facilities I

Contribution ID: **634** Type: **Poster**

Wed-Af-Po.12-02: Initial Results of a 10-kA Superconducting Power Supply For Levitated Dipole Reactors

Wednesday, July 2, 2025 2:30 PM (2 hours)

OpenStar Technologies Ltd is pursuing a levitating dipole reactor (LDR) for fusion energy production. In this concept, fusion plasma is confined around a single dipole magnet. The scaling and deployment of the LDR concept and beyond relies on the development of integrated power supply systems. These devices, so-called flux pumps, have the ability to maintain the current in the magnet while it is levitating and confining plasma without any external connections that would interrupt plasma confinement.

OpenStar has recently completed integration and testing of a 1.44 kA flux pump using a full-wave transformer-rectifier topology. Future devices may require 6-10 kA of current to produce the required field strength. Volume constraints onboard the magnet may require this to come from only a single unit, which is more current output than any single HTS flux pump has achieved to date.

Here, we present initial design work towards a 10 kA flux pump for use in future LDRs. This involves the design of the HTS transformer-rectifier circuit, switches and transformer, thermal and electrical expectations, and specifications of the necessary electronic and cryogenic systems.

These designs are compared to initial experimental results of the HTS switch and superconducting transformer. Experimental results include HTS switch performance, applied field electromagnet characterization, transformer output measurements and thermal stability in a conduction-cooled setup. These results are then used to simulate the output of a 10 kA system.

Such HTS power supplies systems are also promising for efficiently supplying other DC magnet systems, both for fusion energy and other applications like NMR/MRI and electric motor-generators.

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Session Classification: Wed-Af-Po.12 - Power Supplies

Contribution ID: **635** Type: **Poster**

Sat-Mo-Po.02-04: Design and Test of Two Long Bi-2212 Coils to Address Their Axial Properties for Bi-2212 High Field Insert Coil Program

Saturday, July 5, 2025 9:30 AM (1h 45m)

The over-pressure heat-treatment (OPHT) processed Bi-2212 insert coil technology for high field (> 24 T) magnet systems is based on two critical technologies developed at the National High Magnetic Field Laboratory (NHMFL): optimized OPHT process for high in-field performance (*JE* ˜ 900 A/mm2 at 20 T) and introduction of alumina fiber reinforcement for efficient magnetic stress management. In 2022, we were able to operate a test coil withstanding over 350 MPa of *JBr* stress while producing a magnetic field of 4.9 T in 12 T background field. To understand the coils'axial properties, ASC started looking into "long"Bi-2212 test coils (up to three times longer than the test coil in 2022) as to confirm the effectiveness of the proposed stress management techniques against thermal and magnetic stresses . Two mid-scale Bi-2212 test coils are under preparation and will be tested in the 12 T background field in 2025. The two test coils will be used to compare two different coil reinforcement layouts. The test results will be compared from the perspective of their in-field performance, stress management and mechanical integrity, magnetic field uniformity, and Bi-2212 coil protection. The test results will be applied to our Bi-2212 insert coil development projects, e.g., our in-house Φ 54 mm bore / 20 T research magnet and the NIH R01 funded Φ 42 mm bore / 28 T high homogeneity NMR demonstrator magnet.

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Session Classification: Sat-Mo-Po.02 - Magnets for Other Medical Application III

Contribution ID: **636** Type: **Poster**

Thu-Af-Po.06-05: Instrumentation and Control Systems for Operation of High Field HTS Coils for WHAM Magnetic Mirror

Thursday, July 3, 2025 2:00 PM (2 hours)

Commonwealth Fusion Systems (CFS) completed the design, construction, assembly, and full field dual magnet factory acceptance testing of two identical compact (< 2 ton), high-field (20 T on tape, 17 T in warm bore) HTS REBCO magnets for a magnetic mirror in an axial fusion device. The CFS magnets now serve as the high field end coils for the ARPA-E funded project, "An HTS Axisymmetric Magnetic Mirror on a Faster Path to Lower Cost Fusion Energy."CFS is a subrecipient of the ARPA-E BETHE Fusion Grant with the University of Wisconsin-Madison. The magnets have now operated at full field for multiple test campaigns for > 110 cumulative days of full field operation (as of this writing, 1/15/2025), in the presence of numerous sources of electromagnetic interference. We will present the instrumentation systems and control schemes of the mirror system, and discuss their performance over an extended period of operation.

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Session Classification: Thu-Af-Po.06 - Magnets for Fusion Devices

Contribution ID: **637** Type: **Invited Oral**

Thu-Mo-Spec1-04: [Invited] Exploring the limits of passive quench protection in high-stored-energy non-insulated superconducting magnets

Thursday, July 3, 2025 11:45 AM (10 minutes)

Non-insulated (NI) magnets made of rare-earth barium copper oxide (REBCO) high-temperature superconducting tapes are of interest for a variety of different magnet applications, such as in the toroidal field magnets of fusion devices. One of the primary reasons for this is the potential ability for NI coils to passively protect themselves against damage during a rapid global loss of superconducting behavior, known as a quench. Some prior tests of NI coils have demonstrated robust self-protection against thermal quench damage, but this does not appear to be universal; for example, during the intentional quench test of the SPARC Toroidal Field Model Coil (TFMC), the coil incurred significant thermal damage [1]. Consequently, the specific design and operational space in which NI coils, particularly coils with large stored magnetic energy, are intrinsically self-protected against thermal quench damage is not well understood. To explore this self-protection regime, a variety of multiphysics quench models of NI coils have been developed. Chief among these is a self-consistent axisymmetric 2D model of sudden-discharge in NI coils that was built using COMSOL Multiphysics [2]. This model has been validated against, and shows good agreement with, experimental sudden-discharge tests of NI and metal-insulated (MI) coils [2]. In addition, a slab model of individual conductor turns was developed and coupled to this 2D model to study how non-uniform I_c and T_{cs} within conductor turns impact the thermal and electromagnetic evolution of quench in non-axisymmetric coils, such as tokamak toroidal field coils. This coupled 2D-Slab model has been used to model the full winding pack of the SPARC TFMC, and validation against the experimental results of the TFMC test campaign is currently underway. The developed models are currently being used to identify the primary coil design and operating conditions that enable self-protection in NI coils with large stored magnetic energies; in particular, the impacts of current density, stored magnetic energy density, and macroscopic I_c and T_{cs} non-uniformity along conductor turns have been explored as potential key drivers of thermal quench damage. This presentation will discuss the details of the developed quench models, validation of the models, including against the SPARC TFMC, and preliminary exploration of the passively-safe quench space and potential implications for the design and operation of high-stored-energy NI coils.

[1] Z. S. Hartwig et al, "The SPARC Toroidal Field Model Coil Program."IEEE Trans. Appl. Supercond., no. Special Issue on the SPARC Toroidal Field Model Coil Project, 2024.
[2] D. Korsun et al, "Simplified Multiphysics Models for Open-Circuit Quench in Non-Insulated and Metal-Insulated Superconducting Magnets."IEEE Trans. Appl. Supercond. ASC 2024, submitted Sep. 2024, revised Dec. 2024.

This work is supported by the MIT Plasma Science and Fusion Center SPARC Fellowship Fund.

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Presenter: KORSUN, Daniel (MIT Plasma Science and Fusion Center)

Session Classification: Thu-Mo-Spec1 - [Special Session] Quench Protection for Large Stored-energy REBCO Magnets

Contribution ID: **638** Type: **Contributed Oral**

Thu-Mo-Or2-02: Retrofitting Closed-Loop Rotor-Mounted Cryocooler Superconducting Rotor into an Induction Motor: Design, Analysis, Assembly Procedure, and Experimental Results

Thursday, July 3, 2025 11:00 AM (15 minutes)

The field of electrified aircraft propulsion is undergoing a transformative evolution, driven by breakthrough advancements in superconducting electrical machines. Significant interest exists in the development of closed-loop, rotor-mounted cryocooler superconducting rotors, with several projects pursuing this innovative approach. This design simplifies the cryogenic requirements of superconducting motors, making them practical for high-torque applications such as commercial electric propulsion and ship propulsion.

This paper presents the design, assembly procedures, and experimental studies conducted on a superconducting rotor retrofitted into an industrial induction motor. The motor is specifically engineered to address challenges associated with a rotor-mounted, closed-loop cryocooler superconducting rotor. Although the machine is not designed to produce substantial power or torque, it is expected to generate 10 kW of power under full load. The team is conducting an extensive experimental campaign to mitigate risks in critical subsystems and ensure the successful demonstration of this motor. The results will serve as a foundation for the design of large-scale, rotor-mounted superconducting machines.

Key advancements in the superconducting rotor employed in this study include a rotor-mounted cryocooler, a spoke suspension torque transfer system, and a novel radiation management system. Risk mitigation efforts feature a rotor-mounted Stirling-cycle cryocooler, which integrates a commercial off-the-shelf (COTS) Stirling-cycle cryocooler into a rotationally compatible configuration for closed-loop conduction cooling. Additionally, the rotor cryogenic thermal management system (TMS) incorporates a novel coil suspension system to transfer torque between the cold field winding assembly and the warm rotor shaft while minimizing conduction heat load to the cryocooler. Innovative techniques are employed to reduce radiation heat leakage to less than 10 W. Furthermore, the rotor features quench-tolerant HTS magnets, which demonstrate passive quench tolerance using conduction-cooled, no-insulation (NI), double-pancake (DP) high-temperature superconducting (HTS) magnets.

For this experiment, the existing stator of a NEMA-standard, three-phase induction motor with a 900-rpm rating was utilized. The rotor was designed with an eight-pole configuration and a 21 mm magnetic air gap to accommodate the vacuum chamber and proposed radiation management system. The vacuum shell outer diameter (OD) is designed to be 11 inches, while the rotor winding holder OD is 12 inches. A single cryocooler is used to cool the superconducting coils and intercept the current leads. The rotor coils are designed to operate at a temperature of 70 K. Since the rotor focuses on addressing challenges related to cryogenic cooling, dynamic operation, and maintaining vacuum integrity during operation, the design has not been optimized for weight reduction. The rotor shaft and vacuum chamber are constructed from stainless steel to facilitate easy welding for vacuum integrity, while the coil holder is a single aluminum shell that houses all the rotor windings.

No-insulation (NI) HTS coils offer passive quench protection by providing alternative current paths around defects and promoting uniform heat dissipation, which minimizes the risk of localized hotspots leading to thermal runaway. Test DP-NI coils were manufactured and tested in liquid nitrogen before being installed on the rotor. The operating current is set to 65 A at 70 K, maintaining a 25% critical current density margin. The coils are glued to the rotor shell using Stycast resin to ensure excellent thermal conductivity. Conduction cooling is employed for the coils, with a combination of firm and flexible thermal straps used to isolate vibrations from the rotor to the cold head.

This paper provides a comprehensive overview of the rotor design, as well as the assembly and testing efforts. The motor will be tested at the POETS test facility in Champaign, Illinois. These findings contribute to the advancement of rotor-mounted cryocooler superconducting electric motors, paving the way for cleaner and more efficient air transportation.

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Session Classification: Thu-Mo-Or2 - Rotating Machinery II

Contribution ID: **639** Type: **Contributed Oral**

Fri-Mo-Or2-02: Screening current induced stress and strain analysis considering thickness variation along the width of REBCO tape

Friday, July 4, 2025 8:15 AM (15 minutes)

Consideration of screening current induced stress (SCIS) is crucial for management of stress and strain in the design of ultra-high field REBCO magnets. We developed a numerical simulation tool that utilizes COMSOL and studied the effects of including reinforcement in REBCO coils such as co-winding or over-banding steel tapes [1]. The model employs the penalty method as a boundary condition between neighboring tapes and assumes a "hard contact", meaning the effective Young's modulus in the radial direction of the coil winding (Er,eff) is the same as that of the REBCO tape. However, it is found that this Er,eff is significantly smaller than that of the bulk REBCO tape and changes nonlinearly depending on the magnitude of radial compression [2, 3]. This is due to a reduced tape-to-tape contact area caused by microscopic roughness on the tape surface and macroscopic (μm level) thickness variation in the REBCO tape's width direction. In this case, the stress and strain distribution in the winding and effectiveness of reinforcement that was discussed in the previous study [1] changes significantly. The effects of this low and nonlinear Er,eff on structural analysis is studied further here.
In [4], modeling of a low and nonlinear Er,eff was represented by changing the penalty factor in COMSOL's penalty method. However, the relationship between actual gaps between tapes and the applied penalty factor is unclear.
In this study, the developed numerical simulation model has been improved to perform SCIS analysis that accounts for thickness distribution along the REBCO tape's width. We will present details of the simulation model, simulation results on both small and practical-scale coils, and discuss the effects of the profile of REBCO tape's thickness and the magnitude of turn-to-turn gap length on the simulated results.
[1] Y. Suetomi et al., "Screening Current Induced Stress/Strain Analysis of High Field REBCO Coils With Co-Winding or Over-Banding Reinforcement," IEEE TAS, 34, 5, 8400206 (2024).
[2] S. Xue et al., "Compressive Stress-Strain Behavior of REBCO Coated Conductors and Cables," IEEE TAS, 33, 5, 4800706 (2023).
[3] Y. Yan et al., "Measurement and analysis of winding stresses in dry-wound pancake coils considering nonlinear compressive behaviors"SuST, 36, 115019 (2023)
[4] J. Park, "A Numerical Study on Mechanical Boundary Conditions for Screening Current Induced Stress Analysis of REBCO Magnets", ASC 2024, 5Lor1C (2024)
This work was performed at the National High Magnetic Field Laboratory, which is supported by National Science Foundation Cooperative Agreement No. DMR-2131790, DMR-2128556, and the State of Florida.

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Session Classification: Fri-Mo-Or2 - Mechanical Behavior and Stress III

Contribution ID: **640** Type: **Poster**

Wed-Af-Po.11-07: Residual Inductive Voltage Calculations for the Quench Detection Loops of the ITER TF Coils during Single Coil Testing in the ITER Magnet Cold Test Bench

Wednesday, July 2, 2025 2:30 PM (2 hours)

While the ITER assembly is progressing, a Magnet Cold Test Bench (MCTB) is also under preparation to test some of the ITER superconducting coils at 4 K up to nominal current before their installation in the pit. In this context calculations were performed to estimate the residual inductive voltages in the quench detection loops of the TF coils during the test scenarios. These residual inductive voltages are defined as the difference between the turn and co-wound- tape voltages appearing during ramping operation. These residual voltages need to be known as they cannot be avoided and because they need to be smaller than the resistive voltage developing during a quench to allow its detection. In particular the case of a fast discharge is investigated, which represents the most severe transient operation expected for MCTB, generating the largest possible residual inductive voltages. Once validated against the MCTB tests, the models used to predict these residual inductive voltages in the ITER TF coils, can be applied to predict these voltages during a plasma pulse during ITER operation. This would allow the assessment by which margin quenches can be detected in the ITER TF coils during operation.

The views and opinions expressed herein do not necessarily reflect those of the ITER Organization.

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Presenter: BAUER, Pierre

Session Classification: Wed-Af-Po.11 - Modelling of Fusion Conductors and Coils I

Contribution ID: **641** Type: **Poster**

Thu-Mo-Po.10-06: 3D Electro-Thermal Modelling of Quench in Slotted Core ReBCO Cables for Fusion Tokamaks

Thursday, July 3, 2025 8:45 AM (2 hours)

The slotted core configuration is a promising candidate for the implementation of High-Temperature-Superconducting (HTS) magnets in compact fusion reactors. Quench dynamics is not yet fully understood in this type of cable and experimental and numerical investigations are still required to fully characterize their behavior in the operative conditions relevant to fusion machines.
In this work, a 3D FEM electro-thermal model, under development at the University of Bologna, (Italy) is presented. The model solves the heat balance and charge conservation equations, providing the temperature and electric potential distribution in the solid domains. The cable self-field is computed in the external domain by solving the Poisson equation for the magnetic vector potential. A homogenization procedure is employed to model the electrical and thermal properties of the stack of ReBCO tapes, allowing for considerable savings on the degrees of freedom. The model also accounts for the presence of the tape-to-tape and tape-to-core contact parameters.
The model is applied to the description of the ENEA extruded aluminum slotted core ReBCO cable in conduit conductor. Three non-twisted, non-soldered, 15-kA-class conductors were manufactured at the ENEA Frascati Research Center and tested in the SULTAN test facility (Villigen, Switzerland) to explore their quench behavior under variable conditions of temperature and background magnetic field. The operation of the 3.6-m-long conductors was monitored through voltage taps and thermometers positioned at various locations along the cable length both on the jacket and the HTS stacks.
A benchmark of the model is provided by comparing the spatial and temporal evolution of the simulated temperature and voltage distributions to the measured ones. The model is also applied to compute the current sharing temperature of the cable, the minimum quench energy, and the normal zone propagation velocity. Owing to its 3D nature, the model provides useful insights into the redistribution of heat and current occurring between the different cable components.

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Session Classification: Thu-Mo-Po.10 - Modelling of Fusion Conductors and Coils II

Contribution ID: **642** Type: **Poster**

Wed-Mo-Po.04-08: Effect of excimer laser irradiation on the Y1-xGdxBa2Cu3O7-d films

Wednesday, July 2, 2025 9:15 AM (2 hours)

Y1-xGdxBa2Cu3O7-d films were deposited by pulsed laser ablation on commercial Hastelloy tapes buffered with IBAD-MgO and LSMO layers. The films were grown with x spanning from 0 to 1 and by varying the deposition conditions.
The films were irradiated using a homogenized XeCl laser beam at varying fluence. The effect of laser irradiation on the structural properties of the films was accurately studied through standard and high-resolution X-ray diffraction and Raman spectroscopy measurements.
The evolution of the cation disorder and micro-strain has been investigated and correlated with the flux pinning properties of the films.

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Session Classification: Wed-Mo-Po.04 - HTS Conductors I

Contribution ID: **643** Type: **Contributed Oral**

Sat-Af-Or5-01: Effect of magnetic coupling on the magnetisation losses of Roebel cables of straited REBCO strands

Saturday, July 5, 2025 4:30 PM (15 minutes)

Magnetisation losses of Roebel cable samples with striated REBCO strands were measured at different temperatures between 4K and 85K in ac magnetic fields up to 0.2T. While the losses of Roebel cables with non-striated strands were shown previously in quantitative agreement with the losses of magnetically coupled two side-by-side tape stacks as thin Norris' strips, significantly differences in the loss behaviour were found in Roebel cables with striated strands. Firstly, the peak loss factor occurred at a lower field than that of the non-striated, contrary to the expectation of no change in the peal position in isolated filaments by striation. In reality, there is strong magnetic coupling among the filaments in striated strand and the present work explains how such a coupling would lead to the desired lowering of the peak position using both the analytical results of magnetisation for infinite in-line array of thin strips and numerical results for striated strands with finite filaments. Secondly, our experimental results also showed the stacking of striated strands did not exhibit the shift of the position of peak loss factor to a higher field, as expected for a higher critical current by strand stacking. Using numerical modelling, the present work demonstrates that such a desirable but unexpected behaviour is most likely due to small and random misalignments of the striated strands in the stacks. In conclusion, the present work highlights the fundamental role of magnetic coupling among straited strands in the reduction of magnetisation losses and its unique presence for REBCO strands as thin Norris' strips.

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Session Classification: Sat-Af-Or5 - AC Loss and Magnetization II

Contribution ID: **644** Type: **Poster**

Thu-Af-Po.08-03: Glading on the properties of alumina strengthen Cu

Thursday, July 3, 2025 2:00 PM (2 hours)

National High Magnetic Field Laboratory (MagLab) uses Cu matrix composites to build high field magnets. One of the composites is made from alumina- reinforced Cu. The fabrication of these composite conductors requires pure Cu cladding or container, which contains the Cu+ alumina composites, leading to a macro-composite. The cladding has lower strength and higher electrical conductivity than Cu+ alumina composites. In out pulsed magnets, we have been using macro-composite. In our tests, however, we sometimes tested only Cu+alumina core. This paper reports our work on the impact of cladding on mechanical properties of Cu+alumina composites. We will discuss the important for testing samples with and without cladding.

Acknowledgement
This work was performed at the National High Magnetic Field Laboratory, which is supported by National Science Foundation Cooperative Agreement No. DMR-1644779 and DMR-1839796, and the State of Florida.

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Presenter: HAN, Ke

Session Classification: Thu-Af-Po.08 - Materials for Pulsed Magnets

Contribution ID: **645** Type: **Poster**

Thu-Mo-Po.01-04: Insulated HTS pancake AC simulation with different numerical approaches: A-H and H-phi formulations and circuit model

Thursday, July 3, 2025 8:45 AM (2 hours)

Many experimental and theoretical research studies have been conducted in recent years at the Paul Scherrer Institute (PSI, Switzerland) on the treatment of cancer with proton therapy. The PSI approach is based on fast volumetric rescanning, a technique in which the energy of the beam changes quickly. The development of a suited electromagnetic model to study superconducting magnets for proton therapy in fast ramping regime would allow simulating their transient behavior and compare different configurations, such as the curved Canted Cosine Theta (CCT) and conventional accelerator dipoles. The availability of validated numerical tools would also make it possible to carry out studies to select the most suitable technical superconductor for fast ramping applications.
In this work, we present a comparison between three numerical approaches to simulate insulated high-temperature superconducting (HTS) pancakes in AC mode. Two of them are based on well-known and approved in many papers FEM models implemented in COMSOL Multiphysics and Quanscient (cloud computations with domain decomposition). In particular, the A-H formulation is used in the COMSOL model, while the H-phi formulation is applied in the Quantscient model. The third approach is based on a lumped parameter non-linear circuit model, called CALYPSO, developed at the University of Bologna to investigate the electrodynamic behavior of HTS cables and magnets. The main advantage of the circuit model is to avoid the use of the fine meshes usually required by FEM models, it results then in quicker computations, extremely important for large magnets. A difference between the CALYPSO code and other circuit models presented in the literature is the use of a sparse matrix of the mutual inductances instead of a full one. This is achieved by neglecting the contribution to the magnetic vector potential and the magnetic flux density at a node in a given location due to the currents flowing at a sufficient distance from the considered node.
The goal of this study is to benchmark the three aforementioned numerical methods in operating conditions relevant for the operation in the PSI proton therapy machines and to assess the most adequate approach for the analysis of more complex magnet designs.

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Presenter: RICCIOLI, Rebecca

Session Classification: Thu-Mo-Po.01 - AC Loss and Magnetization I

Contribution ID: **646** Type: **Contributed Oral**

Sun-Mo-Or2-03: Superconducting magnets for SIS100 and Super-FRS at FAIR: project progress

Sunday, July 6, 2025 8:30 AM (15 minutes)

Superconducting magnets for SIS100 and Super-FRS - project progress

The heavy ion synchrotron SIS100 and the fragment separator Super-FRS form the central elements of the novel accelerator facility FAIR at Darmstadt, Germany. In both machines, superconducting magnets are utilised for the ion-optical lattice.
Currently, the production and testing of the magnet series are ongoing involving several project partners and suppliers. The completion of both machines comprising several hundred superconducting magnets is essential to launch the experimental program of FAIR, as aimed for in 2028.
In order to serve such demanding timelines, production and testing processes are optimised and quality assurance is intensified. For SIS100, an alternative supply chain is prepared in terms of prototyping and development of further testing capacities for the need case.
This paper gives an overview on the project landscape for the production and testing of superconducting magnets for FAIR. The current status of deliveries and acceptance is summarised.
Special focus is given on the recent progress of module installation into the facility, where the processes have been developed at the successfully assembled and operated module string test setup.
This paper concludes with an outline for completion of the SIS100 and Super-FRS.

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Session Classification: Sun-Mo-Or2 - Fabrication and Testing of Magnets for Facilities

Contribution ID: **647** Type: **Poster**

Fri-Mo-Po.05-12: Status of the ESR D2 Dipole magnet for the Electron Ion Collider

Friday, July 4, 2025 9:30 AM (1h 45m)

The Electron Ion Collider (EIC) currently in development at Brookhaven National Laboratory (BNL) will collide high energy and highly polarized hadron and electron beams with luminosities up to 10ˆ34 cmˆ-2 sˆ-1. Part of the EIC is the Electron Storage Ring (ESR), which will store and maintain the electron polarity of the EIC electron beam for collision energies up to 18 GeV. There are two main dipole types used in the arc cells of the ESR. The two dipoles types, named D1/D3 and D2, have been designed to meet the performance requirements. This paper discusses the design concept, simulation results and engineering concept for the D2 magnet.

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Presenter: NOTARO, Sara

Session Classification: Fri-Mo-Po.05 - Electron-Ion Collider

Contribution ID: **648** Type: **Contributed Oral**

Fri-Mo-Or4-01: A spectrometer design that fulfills EIC interaction region machine detector interface requirements.

Friday, July 4, 2025 11:15 AM (15 minutes)

For the Electron Ion Collider (EIC) at BNL, the interaction region (IR) magnet closest to the EIC experiment on the forward (outgoing hadron and incoming electron) side, denoted B0PF-Q0EF, must satisfy many conflicting machine detector interface (MDI) requirements. First it must provide sufficient transverse field in a large warm bore to provide spectrometer functionality for outgoing particles that would otherwise be missed in a forward angular region between the inner edge of the detector acceptance and the maximum acceptance in combined angle and momentum offset that can pass the rest of the forward hadron magnets to reach Roman Pots and the Zero Degree Calorimeter. For this function the experiment places several planes of silicon tracking and a compact calorimeter immediately surrounding a warm beam pipe though which the hadron beam circulates. However, even with a crossing angle of 25 mrad the electron beam must also pass through this warm B0PF-Q0EF main aperture, and the incoming electron beam would generate unacceptable levels of synchrotron radiation in the detector if it experienced this same, 1.56 T·m, integrated field. For this reason, the hadron spectrometer field is deliberately made combined function such that the combined dipole and local quadrupole field components cancel at the electron beam axis and the electron beam only sees a linear defocusing field with very close to zero net dipole component. This combined function field is achieved by powering large concentric quadrupole and dipole superconducting coils in series inside a magnetic yoke and we use an additional small aperture dipole superconducting corrector coil, just around the electron beam aperture, to null out any residual dipole field. Unlike the other dipoles in the hadron ring this B0PF magnet is run at the same field independent of the hadron beam energy with later IR dipoles adjusted to close the orbit bump initiated by B0PF. Note the residual B0PF defocusing field at the electron beam axis is very close in strength to what is required for the first electron quadrupole element, Q0EF, at the 10 GeV e-beam operating point. In order to provide correct operating gradients at the other e-beam energies of 18 and 5 GeV, we also provide a small aperture electron gradient tuning coil to add or subtract gradient as needed for the electron IR optics. Both the large hadron and smaller electron superconducting coils will be fabricated using the BNL Direct Wind technique. Since the main hadron B0PF coils have quite large combined inductance, special care is required for their quench protection. Also, with the B0PF-Q0EF nested warm and cold structures and very limited longitudinal allocated space, the cryostat design necessitates careful optimization. These and other B0PF-Q0EF design challenges are addressed in this paper.

Work supported by Brookhaven Science Associates, LLC under Contract No. DE-SC0012704 with the US Department of Energy.

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Session Classification: Fri-Mo-Or4 - Magnets for Electron Colliders

Contribution ID: **649** Type: **Poster**

Sat-Mo-Po.04-02: Consolidation of the superconducting circuits energy extraction systems at the Large Hadron Collider

Saturday, July 5, 2025 9:30 AM (1h 45m)

At the beginning of the next long shutdown, foreseen mid 2026, the Large Hadron Collider (LHC) will have been in operation for almost 20 years. After this time lapse, the operation of the present Energy Extraction (EE) systems, that are part of the protection of the superconducting circuits of the LHC, will present significant challenges. . As many system components will have exceeded their expected lifetimes, the risks of failure, system degradation, and obsolescence increase, ultimately compromising operational performance and safety.
Although preventive maintenance is regularly performed on the EE facilities, an extensive consolidation program of these facilities has started, to improve their dependability and assure their performance till the end of operation of the LHC.
This paper illustrates the two projects of consolidation of the 600 A and 13 kA EE systems, which aim to modernize and optimize these systems, ensuring that they continue to provide reliable protection while reducing maintenance costs and integrating the latest advances in materials, control technologies, and diagnostics, together with enhanced safety.

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Session Classification: Sat-Mo-Po.04 - Protection and Stability

Contribution ID: **650** Type: **Poster**

Sat-Mo-Po.04-01: Optimization of the Angle Between the Magnetic Field and the Tape Surface for Pancake Coils

Saturday, July 5, 2025 9:30 AM (1h 45m)

High-temperature superconducting (HTS) coated conductors (CCs) have become increasingly available for high-field magnet applications, thanks to continual advancements in manufacturing. Previous studies have revealed that HTS CCs, characterized by their anisotropic lattice structures, exhibit a critical current density that strongly depends on the angle between the magnetic field and the tape surface. This angular dependency poses both challenges and opportunities for optimizing HTS-based magnet designs. In this work, using the experimental data from the literature, a conventional pancake coil is optimized by tilting the tapes to achieve a more favorable angle between the magnetic field and the tape surface, thereby improving the critical current density distribution without compromising the field quality. This enhancement can reduce the quench risk in HTS coils. A comparison between the optimized coils and traditional pancake coils is presented. How these results can inform the design of more complex coil geometries is discussed.

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Session Classification: Sat-Mo-Po.04 - Protection and Stability

Contribution ID: **651** Type: **Poster**

Fri-Af-Po.03-02: Development of a reusable case for SPARC toroidal field magnet testing

Friday, July 4, 2025 2:00 PM (2 hours)

Commonwealth Fusion Systems (CFS) is developing and building a commercially relevant fusion energy machine that will produce more energy than is put into it. In this research, a reusable structural case for testing toroidal field (TF) magnets in the Coil Test Stand Cryostat prior to integration in the SPARC Tokamak has been developed and is currently employed in this critical evaluation of TF magnets. This technology enables CFS to learn about the performance of the magnets under SPARC representative condition and make any necessary changes to the TF magnets post-test.

In this poster, we will discuss the requirements for this case and how it can handle the extreme loads applied by the magnet. Furthermore how it can perform at ambient and 20K test conditions, maintain a helium-tight pressure vessel and overall maintain its reusability. The material testing, structural analysis and calibration of the model based on strain measurements during TF testing will also be discussed. The 6 month design-build process for this case will further be discussed as an example of how to execute on tough technical challenges in the fusion industry.

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Session Classification: Fri-Af-Po.03 - Supporting Technologies for Fusion Magnets I

Contribution ID: **652** Type: **Poster**

Thu-Af-Po.08-04: Performance of fiber-reinforced conductors under cyclic loading

Thursday, July 3, 2025 2:00 PM (2 hours)

Pulsed magnets in the US National High Magnetic Field Laboratory (MagLab) use rectangular cross-section conductors that reinforced by Nb-fibers. During the manufacture of the conductors, large deformation strain was required, leading to very high internal stresses. The internal stresses affected deformation behavior of the conductors. This special deformation behavior was reflected in stress-strain curves generated in our tests. At cryonic temperatures, thermal expansion difference between the fibers and matrix added to addition internal stress in the conductors. We studied the mechanical deformation behavior of Nb-fiber-strengthened Cu under cyclic loading. We related deformation behavior of such conductors to their microstructure.

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Presenter: HAN, Ke

Session Classification: Thu-Af-Po.08 - Materials for Pulsed Magnets

Contribution ID: **653** Type: **Poster**

Fri-Mo-Po.06-06: Effects of Cryogenic Irradiation on Optical Fiber Sensors based on Brillouin Scattering and Type-II Bragg Gratings for Fusion Magnet Monitoring

Friday, July 4, 2025 9:30 AM (1h 45m)

Optical fiber sensors are gaining attention as a promising technology for magnet monitoring and quench detection in fusion reactors. These sensors enable precise measurement of strain and temperature profiles within superconducting magnets and their integration into superconducting wires and cables has been demonstrated as viable. However, when embedded into fusion magnet systems, these sensors will be subjected to ionizing radiation, potentially degrading their performance or altering the sensing signals, especially under cryogenic conditions. Understanding these effects is essential for harnessing the benefits of optical fiber sensors in such extreme environments.

This study investigates the impact of cryogenic (77 K) gamma irradiation on light transmission and several types of optical fiber sensors. Specifically, we evaluated:
• The effects of ionizing radiation at cryogenic temperatures on light transmission in optical fibers of various material compositions.
• The influence of cryogenic gamma irradiation on Brillouin scattering-based distributed sensing and a comparison with room-temperature irradiation effects.
• The response of type II fiber Bragg gratings (FBGs) to cryogenic gamma irradiation and their behavior relative to room-temperature conditions.

Overall, the results of this study indicate that under the tested conditions, cryogenic irradiation is unlikely to prevent the application of these sensors to fusion magnets. Current technical challenges that require further research are presented.

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Session Classification: Fri-Mo-Po.06 - Quench in Fusion Magnets II

Contribution ID: **654** Type: **Plenary**

Sun-Mo-PL1-02: Towards 20 T Hybrid Magnets: Perspectives and Challenges (Young Scientist Plenary)

Sunday, July 6, 2025 10:40 AM (10 minutes)

The aim of providing high collision energy for future particle accelerators relies on the capability to design and demonstrate the feasibility of 20 T dipole magnets. To reach the ambitious goal of a future proton-proton collider, a coordinated effort is required to overcome the current technological limits. The US Magnet Development Program is exploring the hybrid magnets option to reduce the overall design cost. In these magnets, High Temperature Superconductors (HTS) such as Bi-2212 and REBCO coated conductors are used in the high-field portion of the coils and Low Temperature Superconductors (LTS), like Nb3Sn, are used in the lower field region. One of the various designs under development is the cos-theta dipole configuration. The main challenges encountered so far concern the protection of this class of magnets from quench events and the stresses in the mechanical support structure and in the conductors to avoid degradation. To help address the challenge of withstanding the Lorentz forces, a shell-based support structure based on the key-and-bladder technology, which provides azimuthal prestress during room temperature assembly and cooldown to cryogenic temperatures, is being considered. To protect such a high-field magnet from quench events, different quench protection systems are being evaluated for both short prototypes and 15 m long ones. In addition to analyzing the magnetic, mechanical and thermal status of these magnets during room temperature assembly, cooldown to cryogenic temperatures, energization and quenching, the mechanical performance of HTS conductors is under investigation to clarify the load limits that cause irreversible degradation. One of the candidates for the high-field hybrid magnets generation consists of REBCO symmetric tape round (STAR®) wires. However, the mechanical response of STAR® wires has not yet been fully investigated, and studying the behavior of these superconductors is a crucial aspect for the magnet design and potential fabrication improvements. Combining the analysis from multi-physics finite element code with the results of the test campaign is fundamental for designing and building reliable 20 T hybrid magnets. As a stepping stone toward 20 T magnets, the Lawrence Berkeley National Laboratory (LBNL) is planning to test the first 9 T hybrid dipole magnet that combines Bi-2212 and Nb3Sn. The assembly of these magnets has highlighted significant mechanical challenges that need to be considered in the magnet design phase. The results of this test will set the stage for future hybrid magnets in the high-energy particle field.

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Session Classification: Plenary 1: Young Scientist Plenary

Contribution ID: **656** Type: **Poster**

Wed-Af-Po.04-07: A high power quick-connect between lightweight cryoresistive and high temperature superconducting aerospace power transmission cables

Wednesday, July 2, 2025 2:30 PM (2 hours)

In the United States, a NASA University Leadership Initiative program with The Center for Cryogenic High-Efficiency Electrical Technologies for Aircraft (CHEETA) and a separate ARPA E Connecting Aviation By Lighter Electrical Systems (CABLES) program have been developing 2 kA-rated, medium voltage, and lightweight quick connectors for aerospace. These quick connectors will also permit a transverse cryogen flow for force-flow cooling of cryoresistive cables and to rapidly recover superconducting cables in the case of thermal instability. The research presented here includes the design and results of derisking tasks associated with a high power quick-connect. The quick connector has been designed to be a junction between a multistrand aluminum cryoresistive cable and REBCO superconducting cable.

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Session Classification: Wed-Af-Po.04 - HTS Joints

Contribution ID: **657** Type: **Contributed Oral**

Thu-Mo-Or1-04: Development of a filled wax large-aperture Nb3Sn canted-cosine-theta dipole

Thursday, July 3, 2025 11:30 AM (15 minutes)

A key focus of the US Magnet Development Program (USMDP) is the development of stress-managed magnets with minimal training and operating near the short sample limit. Training free behavior was previously demonstrated in a paraffin-wax-impregnated subscale (canted-cosine-theta) CCT dipole as part of the CCT subscale magnet program at Lawrence Berkeley National Laboratory. A subsequent Alumina-filled wax impregnated subscale CCT dipole reached the predicted short-sample limit after a single quench in the magnet. The addition of the Alumina filler to the paraffin wax improves the mechanical properties, which could be critical for high field applications with large Lorentz forces. In this work, we present the technical developments for the fabrication of a 90 mm diameter aperture CCT magnet, CCT5-W, with a predicted short sample bore field of approximately 10 T at 4.5 K. The performance of the magnet is compared to a previously tested, otherwise identical, epoxy impregnated magnet, CCT5. The implications of filled-wax impregnation for future magnets operating at higher fields is discussed.

This work was supported by the U.S. Department of Energy, Office of Science, Office of High Energy Physics, through the US Magnet Development Program under contract No. DE-AC02-05CH11231.

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Presenter: ARBELAEZ, Diego

Session Classification: Thu-Mo-Or1 - LTS Magnet Advanced Concepts

Contribution ID: **659** Type: **Contributed Oral**

Wed-Af-Or1-04: Test results and performance characterization of a Nb3Sn and Bi-2212 canted-cosine-theta hybrid dipole magnet

Wednesday, July 2, 2025 5:15 PM (15 minutes)

The US Magnet Development Program (USMDP) is pursuing hybrid dipole magnet testing with low temperature superconductor (LTS) outserts and high temperature superconductor (HTS) inserts, as an efficient way to characterize HTS magnets at higher fields and stress levels. In this work, we present the test and performance characterization of the first hybrid dipole test at the recently upgraded LBNL magnet test facility. The hybrid magnet is composed of a Nb3Sn canted-cosine-theta (CCT) outsert dipole with a 90 mm aperture and a Bi-2212 CCT dipole insert with a 30.8 mm aperture. Both magnets have been previously tested in stand-alone configurations, with the Nb3Sn dipole reaching a bore field of 8.5 T and the Bi-2212 dipole reaching a bore field of 1.6 T. The results of the hybrid magnet are presented in comparison to the predicted performance based on the stand-alone tests. The coupled behavior of the insert and outsert during quench and / or energy extraction is explored. The resulting response from the instrumentation (i.e. voltage taps, strain gages, and hall probes) on the insert and the outsert is also presented.

This work was supported by the U.S. Department of Energy, Office of Science, Office of High Energy Physics, through the US Magnet Development Program under contract No. DE-AC02-05CH11231.

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Presenter: ARBELAEZ, Diego

Session Classification: Wed-Af-Or1 - HTS and Hybrid Magnets for Accelerators

Contribution ID: **660** Type: **Poster**

Sat-Mo-Po.05-06: Coherent-Phase Optical Time Domain Reflectometry for Monitoring High Temperature Superconductor Magnet Systems

Saturday, July 5, 2025 9:30 AM (1h 45m)

High temperature superconductor (HTS) magnet systems, especially those designed for fusion reactors, require effective and reliable monitoring to avoid damaging anomalies. In tokamaks, some of the magnetic coils are time dependent, which cause additional strain and electromagnetic effects within the magnet system. Ionizing radiation can also lead to non-uniform degradation of conductors. The resulting decrease in critical current uniformity across the magnet, along with manufacturing defects, failure of structural materials or cooling systems, can all potentially initiate a quench. HTS have a lower normal zone propagation velocity than low temperature superconductors, and this causes normal zones to be localized and hard to detect, increasing the risk of permanent damage. Fiber optic sensors have several qualities that are essential in fusion systems; above all they are immune to electromagnetic fields, which would overwhelm voltage-based detection systems.

In this study, the efficacy of a novel optical fiber interrogation technique to monitor superconducting magnets is tested. This solution focuses on the use of optical fibers interrogated by coherent-phase Optical Time Domain Reflectometry (cpOTDR), which is capable of long-range interrogation (tens of kilometers) at high acquisition rates (tens of kilohertz), as well as separation of strain and temperature. Although there is limited data on temperature sensitivity and cross sensitivities of this technique at cryogenic temperature, interrogation range and acquisition rates are potentially superior to conventional Rayleigh backscattering interrogation based on Optical Frequency Domain Reflectometry (OFDR), motivating research in this area. The cpOTDR interrogation method has been well demonstrated in geophysical applications at room temperature, as well as under low magnetic fields. This study characterizes its ability to detect temperature variations at temperatures as low as 4 K. Additionally, the response to highly localized heating that is smaller than a fiber gauge length was evaluated to determine the viability of this interrogation technique for detection of hot-spots within HTS magnets. Results showed that the technique holds promise for this application and highlighted the current technical challenges that have to be addressed by further research.

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Session Classification: Sat-Mo-Po.05 - Quench Detection and Protection IV

Contribution ID: **661** Type: **Poster**

Wed-Af-Po.01-04: Multi-Objective Optimization of C0 Stellarator Coils with Only Planar Segments in DESC

Wednesday, July 2, 2025 2:30 PM (2 hours)

Magnetic confinement fusion devices, such as tokamaks and stellarators, use coils to confine plasma in a toroidal shape. Tokamaks rely on D-shaped pancake coils but also require a toroidal current in the plasma to generate the desired magnetic fields. Stellarators, on the other hand, avoid the need for a plasma current by relying solely on external coils, which leads to complex 3D coil geometries. Although stellarators offer certain advantages over tokamaks, the complexity of coils and coil support structures complicate the construction of the magnets. In this work, we explore a previously unexamined coil concept that connects multiple planar coil segments to form a coil that is continuous in position but discontinuous in its derivatives (so-called C0 coils). Such coils can provide more flexibility in their design and potentially lead to more engineering-feasible coils. In this work, the stellarator optimization suite DESC, which can find and optimize coil geometries that produce the magnetic field needed for plasma confinement under specified objectives, is employed. With appropriate objectives, segmented C0 stellarator coils are designed with DESC. The results are shown and compared to traditional, continuously differentiable coil designs. The trade-offs between the two approaches are discussed.

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Presenter: ATALAY, Sina (Princeton University)

Session Classification: Wed-Af-Po.01 - Magnets for Stellerators and Other Configurations

Contribution ID: **662** Type: **Poster**

Fri-Af-Po.04-01: Shear strength evaluation of REBCO tape lap joint with indium using double bridge joint

Friday, July 4, 2025 2:00 PM (2 hours)

Bridge-type mechanical lap joint with indium insertion between REBCO tapes is planned to be utilized for joint-winding of high-temperature superconducting (HTS) helical coils in heliotron-type fusion reactors, such as FFHR-d1 [1]. Shear strength evaluation of single lap joints using tensile shear testing at 77 K, self-field has been conducted to discuss if the joints can keep their performance under large electromagnetic forces [2-5]. According to [4], the shear strength seems to depend on both contact conductivity at joint interface and applied pressure to joint section during the tensile shear testing. However, which factor strongly affect the shear strength is still not clarified due to the limitation of data. In addition, bending moment prevents pure shear strength evaluation in the tensile shear testing of the single lap joint [3,4]. Furthermore, temperature dependence of the shear strength must be also clarified to evaluate structural integrity of joints at fabrication, cooling and operation phases.

In this study, double bridge joint configuration was introduced to avoid the bending moment during tensile shear testing. In this configuration, two bridge-type mechanical lap joint with indium insertion were attached to jigs so that they were arranged symmetrically with respect to the tensile axis. Joint samples were fabricated utilizing REBCO tapes provided by two manufacturers, SuperPower and Fujikura. In addition, two groups of joint sample with different contact conductivity at the joint interface (<600 S/m² and >1500 S/m² at 77 K) were prepared utilizing different joining process. Applied pressure to joint section and temperature (room temperature in air and 77 K in liquid nitrogen) during tensile shear testing were parameters for the shear strength evaluation. During the tensile shear testing, tensile force and joint resistivity (product of joint resistance and joint area) were monitored, where current terminal and voltage taps were attached to the joint samples. The shear strength in Pa was evaluated based on the maximum tensile force and joint area. The contact conductivity was evaluated based on the joint resistivity and resistance factors of joint such as resistance of inserted indium, resistance of stabilizers and interfacial resistance inside REBCO tapes. Some samples were also used for comparison between single lap joint and double bridge joint configurations.

Shear strength evaluated with double bridge configuration was a slightly higher than that with single lap joint configuration, which could be caused by the presence or absence of bending moment. The shear strength increased with an increase in the contact conductivity at <600 S/m² and was constant at >1500 S/m², but was not influenced by applied pressure during the tensile testing. This indicated that the contact conductivity is main factor to determine the shear strength. The shear strength at >1500 S/m² was ˜5 MPa and ˜30 MPa at room temperature and 77 K, respectively for SuperPower's samples. The tensile shear testing of Fujikura' s samples is now under preparation. Temperature dependence of the shear strength was also discussed based on the experimental results of tensile shear testing and literature for temperature dependence of yield stress of indium. Detail of the remained experiments and discussion are also presented at the conference.

References
[1] N. Yanagi et al., Nucl. Fusion, Vol. 55, 2015, Art. no. 053021.
[2] S. Ito et al., IEEE Trans. Appl. Supercond., Vol. 25, 2015, Art. no. 4201205.
[3] L. Aparicio et al., Plasma Fusion Res., Vol. 11, 2016, Art. no. 2405065.
[4] L.E. Aparicio et al., Fusion Sci. Technol., Vol. 72, 2017, pp. 789-795.
[5] L.E. Aparicio et al., Fusion Eng. Des., Vol. 136, 2018, pp. 1196-1201.

Acknowledgment

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Session Classification: Fri-Af-Po.04 - Supporting Technologies for Fusion Magnets II

Contribution ID: **663** Type: **Contributed Oral**

Wed-Mo-Or2-03: A "20 T at 20 K"Model Coil for the Muon Collider Target Decay and Capture Solenoid

Wednesday, July 2, 2025 11:45 AM (15 minutes)

The Muon Collider (MC) is one of the options under study as the next step for high-energy physics beyond the Large Hadron Collider. The magnets for a MC, largely based on high-temperature superconductors (HTS), bear some of the most pressing technology challenges and will require intense development and demonstration in the next years. The "target decay and capture solenoid" , a high field solenoid hosting the muon beam production target, is one of these challenges. In the present baseline, the solenoid is 18 m long, produces a peak field of 20 T in a large bore of 1.4 m, it is designed to operate at 20 K, and has a stored energy in excess of 1 GJ. We have designed it based on a HTS, force-flow cooled, high-current conductor. Such performance is well beyond present state-of-the-art. This is why we are proposing to build and test a model coil that aims at increasing the technology readiness level, giving enough confidence that the whole system can be built and operated. Beyond its direct application to the Muon Collider, this development aligns with demands from other scientific fields, such as high-field physics, and societal applications, including fusion energy. In this paper we set the requirements on the model coil geometry and performance. We then describe the conceptual design of a 20 T model coil operated at 20 K, its initial engineering and analysis, and propose a construction and test plan.

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Session Classification: Wed-Mo-Or2 - Muon Collider Magnets

Contribution ID: **664** Type: **Contributed Oral**

Wed-Af-Or1-02: Development of a second COMB dipole magnet with STAR® wires

Wednesday, July 2, 2025 4:45 PM (15 minutes)

Rare-Earth Barium Copper Oxide (REBCO) coated conductors are an attractive option for application in high-field accelerator magnets due to their high critical field and the convenience of fabrication without heat treatment compared to some other superconductors.

Fermilab plays a vital role in superconducting accelerator magnet R&D under the framework of the U.S. Magnet Development Program. An integral part of that program is the accelerator magnet development based on REBCO conductors to demonstrate self-fields of 5 T or greater compatible with operation in hybrid configurations to generate fields beyond 16 T for future High Energy Physics (HEP) applications.

A small, two-layer REBCO dipole magnet based on the Conductor on Molded Barrel (COMB) magnet technology, developed at Fermilab with Symmetric Tape Round (STAR®) wires from AMPeers LLC was recently fabricated and tested in liquid helium, demonstrating the design feasibility.

A second dipole magnet based on the same technology is currently under development at Fermilab. The coil has a 60-mm clear bore and a 120-mm OD and consists of six layers of graded STAR® conductor, which allows to significantly increase the magnetic field compared to the previous design, and potentially probe the 5 T self-field target.

The magnet is tested standalone in liquid nitrogen and liquid helium and may also be re-assembled and tested later as an insert into a Nb3Sn magnet. This paper reports the progress in the magnet development and discusses the preliminary test results.

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Session Classification: Wed-Af-Or1 - HTS and Hybrid Magnets for Accelerators

Contribution ID: **665** Type: **Contributed Oral**

Fri-Mo-Or5-02: Magnetic Penetration Fields and AC losses of helically wound ReBCO tape stacks

Friday, July 4, 2025 11:30 AM (15 minutes)

ReBCO tapes and cables are of great interest high field magnets because of their high current carrying capability, high Tc, and high magnetic field tolerance. The magnetization and AC loss properties of ReBCO tapes are well known, however, for cables, especially the helically wound counterparts some interesting aspects remain. It is well known that for ReBCO tape the losses are strongly influenced by the ratio of the maximum applied field (Bmax) to the penetration field (Bp), and that Bp is proportional to tape thickness, rather than width, as it is for slabs or cylinders. It has also been shown that when tapes are stacked together, the penetration field tends back towards the stack width, and so the per tape loss can be suppressed if in so doing Bp increases above Bmax. In this work, we see that this effect is not directly translated for helically wrapped ReBCO tape stacks. Instead, changes in the AC loss per tape with increasing number of tapes is much more sluggish. We show measurements and analysis of the AC loss of helically wound ReBCO tapes as a function of increasing layer numbers to understand the behavior of effective penetration field. AC loss measurements were made on strips of 10 cm long ReBCO tapes helically wrapped around a non-conductive core. Measurements were made in a 0.55 T permanent magnetic test chamber up to frequencies of 120 Hz. The samples are placed in boiling nitrogen and the AC losses were measured using a calibrated nitrogen boil-off rate. We present a model for penetration field as a function of layer number and tape properties, and correlate the measured losses with the evolution of Bp with changes in layer number.
Work was performed under NASA University Learning Initiative (ULI) #80NSSC23M0063

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Presenter: Mr KWON, Jin

Session Classification: Fri-Mo-Or5 - HTS Conductors and Cable

Contribution ID: **666** Type: **Poster**

Sat-Mo-Po.08-12: Experimental study of current sharing behavior of PANI-CNT coating ReBCO cables for use in accelerator magnets.

Saturday, July 5, 2025 9:30 AM (1h 45m)

Rare-earth barium copper oxide (ReBCO) coated conductors (CCs) are considered promising materials for high-performance cables and high-field accelerator magnet design. ReBCO tape-wound magnets with no insulation between tapes were designed to protect themselves from thermal instability through a current-sharing mechanism. However, they face challenges such as insufficient mechanical support and potentially high coupling loss due to electrical conductivity between tapes. In contrast, the epoxy-potted design provides mechanical support and reduces loss and field error but is not preferable for quench protection. To address these trade-offs, a novel technique involving polyaniline (PANI) and carbon nanotube (CNT) coatings has been developed. This conductive polymer coating offers mechanical support and adjustable conductivity (modulated by doping materials) between tapes to introduce flexibility in balancing mechanical support, quench protection, and coupling loss. In this study, we used a three-layer ReBCO tape stack, with an artificial defect in the middle layer, to demonstrate the current-sharing behavior of PANI-CNT-coated tape stacks. Three tape stacks were prepared with different surface treatments between tapes: (i) no treatment but with pressing, (ii) PANI-CNT coating, and (iii) Stycast 2850 FT. We measured critical current (Ic) values for these three middle-layer-defective tape stacks at 77.2 K and demonstrated that PANI-CNT coating can share the current between tapes when there is a defect among the tapes, although the sharing ability is not as strong as non-insulation direct pressing. This study is funded by DOE.

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Presenter: Mr GUO, Yang (The Ohio State University)

Session Classification: Sat-Mo-Po.08 - Structural and Insulation Materials

Contribution ID: **667** Type: **Poster**

Wed-Mo-Po.07-01: Analytical and numerical study of thermal hydraulic instability in channel two-phase flow cooling based on liquid nitrogen flow cooling single-slot stator experiment for aircraft propulsion application.

Wednesday, July 2, 2025 9:15 AM (2 hours)

A crucial aspect of electric aircraft propulsion is the development of higher power density motors and generators. One promising approach to achieving this is using cryogenic flow cooling, which reduces the weight and losses in conductors in motors. The resistivity of aluminum decreases significantly with lower temperatures, dropping by a factor of 10 from room temperature to 77.2 K (liquid nitrogen). However, continuous cooling is required due to the joule heating. To address this, we developed a motor with liquid cryogen-cooled aluminum bar windings for the stator. An experimental single-slot fixture was designed to demonstrate thermal hydraulic instability within the stator. This fixture contains two parallel aluminum bars with cross-sectional areas of 1.6 mm × 4.6 mm and 3.2 mm × 4.6 mm, separated by a 1.6 mm gap to allow cryogen flow. The total length of the channel is 120 mm. In previous study, we demonstrated experimentally that the ampacity of the aluminum stator bars could reach 75 A/mm² with liquid nitrogen flowing. We ascribed the maximum current density was limited by thermal hydraulic instability in two-phase boiling flow cooling, but this phenomenon was not analyzed in detail. In this study, we developed analytical and numerical models to investigate thermal hydraulic instability in two-phase flow cooling. Our analysis shows that a sudden pressure increase, caused by phase change in the cooling flow, can impede the flow and lead to thermal runaway. A computational fluid dynamics (CFD) model was created to simulate and demonstrate the thermal runaway phenomenon. This study is funded by ARPA-E program.

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Session Classification: Wed-Mo-Po.07 - Thermal Analysis: Magnets and Conductors

Contribution ID: **668** Type: **Contributed Oral**

Thu-Mo-Or2-08: Transport Properties and AC loss measurements of low AC loss BSCCO 2212 racetrack Coils

Thursday, July 3, 2025 12:30 PM (15 minutes)

Bi:2212 is a well-known high current superconductor which can be made in round wire form. It has usually been of interest for DC or low ramp applications because of both filament bridging and also a high Ag content which encourages large coupling and eddy current losses. However, a new low loss Bi:2212 has been under development which both attempts to suppress the bridging as well as eddy and coupling currents. One potential application of these new conductors is in electric propulsion motors for electric aircraft. The loss limits for this application are, however, stringent, and the required testing regime is challenging –20 K, high frequency and moderate magnetic field amplitude. Here we present loss measurements performed in OSU's cryo-test facility. A coil was wound with the new conductors cabled into the form of a small, flat, Rutherford-like cable, and a racetrack coil was made, instrumented, and cooled down and measured in our device. The racetrack coil was tested in a 1.5 m ID conduction cooled cryostat where a calibrated cryocooler lift was used to measure the AC losses in the coil. Here we present various DC properties such as Ic vs T as well as self-field AC loss properties by exciting the coil up to 50 Arms and 1 kHz. The electromagnetic fields simulated in FEM are used in analyzing the AC loss behavior of the coil.
This work was performed under NASA Phase 1 SBIR

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Session Classification: Thu-Mo-Or2 - Rotating Machinery II

Contribution ID: **669** Type: **Contributed Oral**

Wed-Af-Or2-05: SMART Coil-to-Coil Insulation for Online Temperature Mapping of Non-Insulated (RE)Ba2Cu3O7-x Pancake Coils

Wednesday, July 2, 2025 5:30 PM (15 minutes)

No-insulation (NI) high-temperature superconducting (HTS) coils have been shown to have improved thermal stability properties and an improved winding pack density over traditionally wound HTS coils. These improved properties have led to new design proposals for a wide range of applications, include some of the magnets of a fusion magnet system. However, further research still needs to be conducted into the feasibility of NI coils for various applications, and the inherent design of NI coils means that sensor systems that would otherwise be easily embedded into traditional coils cannot be used. Thus, although NI coils can be more stable in certain operating conditions, they would be harder to monitor, which is a limitation to their overall suitability to applications.
Here we demonstrate a proof-of-concept for a sensing system that can be embedded into the coil-to-coil insulation of a pancake coil stack. This system is based on embedding optical fibers in a thin coil-to-coil insulation layer and can be used to map the temperature of the coils with millimeter level spatial resolution on the 2D coil surface. Unlike prior sensor integration approaches, this system is equally adaptable to both NI and insulated REBCO coils, offering a valuable tool for future development and application of NI coils into magnet systems.

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Session Classification: Wed-Af-Or2 - No-Insulation Coils II

Contribution ID: **670** Type: **Poster**

Thu-Mo-Po.05-04: Effect of transversed compressive stress on CORC in visualized Micro-CT images.

Thursday, July 3, 2025 8:45 AM (2 hours)

CORC® ReBCO cables show great potential as conductors for the next generation of high-performance cables in high-field accelerator magnets. However, due to the unavoidable mechanical stresses present in high-field magnet applications, it is important to investigate the deformation and damage these cables sustain under significant transverse compressive stresses. Our previous study demonstrated that support conditions, such as side-support plates and epoxy impregnation, can increase the threshold for elastic-plastic deformation. However, we did not evaluate these effects at cryogenic temperatures, nor did we measure the critical current (Ic) degradation due to the compression under different support conditions. In this study, we developed a cryogenic fixture compatible with our material testing system (MTS) to evaluate samples at cryogenic temperatures (liquid nitrogen) while simultaneously measuring their electrical properties. Our goal is to visualize the deformation that caused the Ic degradation. Five CORC samples with different compression levels were prepared for Ic measurement: i) as received; ii) 25% of its elastic-plastic transition load; iii) 50%; iv) 75%; v)100% of its elastic-plastic transition load. Then, Micro-CT images were taken to characterize the deformation due to the compression. Throughout, we collected compression stress data, critical current value, and Micro-CT images to comprehensively analyze the progression of deformation and Ic degradation. The results characterized the relationship between deformation and Ic degradation because of the cleavage stress between tapes.This study is funded by DOE.

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Presenter: Mr GUO, Yang (The Ohio State University)

Session Classification: Thu-Mo-Po.05 - Mechanical Behavior and Stress I

Contribution ID: **671** Type: **Contributed Oral**

Wed-Af-Or1-01: Fabrication and test results of a canted cosθ dipole magnet using high-temperature superconducting CORC® wires

Wednesday, July 2, 2025 4:30 PM (15 minutes)

High-temperature superconducting REBCO coated conductors have strong potential for high-field magnet applications. Significant technology gaps, however, need to be filled before we can fully leverage the conductor capability for future accelerator magnets. The U.S. Magnet Development Program is collaborating with conductor vendors to address this need. We report on the fabrication and test of the C3 magnet, a six-layer canted cosθ dipole magnet using high-temperature superconducting CORC® wires developed by Advanced Conductor Technologies LLC. We present the detailed test results of the C3 magnet at 77 and 4.2 K. We also discuss the addressed and open technical issues from the C3 magnet, and conductor development needs for future dipole magnets using high-temperature superconducting CORC® wires.

The work was supported by the U.S. Magnet Development Program (MDP) through Director, Office of Science, Office of High Energy Physics of the US Department of Energy under Contract No. DEAC02-05CH11231. Conductor used in this work was procured by U.S. MDP, Conductor Procurement and R&D, supported by the Office of High Energy Physics, U. S. Department of Energy.

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Presenter: WANG, Xiaorong

Session Classification: Wed-Af-Or1 - HTS and Hybrid Magnets for Accelerators

Contribution ID: **672** Type: **Contributed Oral**

Fri-Mo-Or1-01: Progress on the Development and Fabrication of the 15 T Cable Test Facility Dipole Magnet

Friday, July 4, 2025 8:00 AM (15 minutes)

The test facility dipole magnet (TFD) is being developed at the Lawrence Berkeley National Laboratory (LBNL). This is a large-bore Nb_3Sn dipole magnet to be at the center of the High Field Vertical Magnet Test Facility (HFVMTF), funded by the U.S. Department of Energy (DOE) Office of Science (SC), and designed to test advanced cables and inserts in a high transverse background field and in a wide range of temperatures. The magnet is designed as a block-type magnet, using flared end coils, a support structure based on the bladder and key concept, and an external aluminum shell. During the powering of the magnet, steel rods and endplates provide axial support to the coils. The TFD is designed to create a field of 15 T at 1.9 K in a quasi-rectangular 100 x 150 mm bore. This paper presents the progress of the development, design, and fabrication of the coils and magnet structure, including the tooling regarding winding, reaction, and impregnation of the coils, and reporting on the progress of the production of the first full-scale prototype coil, and the assembly of the magnet structure.

This work was supported by the U.S. Department of Energy, Office of Science, Office of High Energy Physics, through the US Magnet Development Program under contract No. DE-AC02-05CH11231.

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Session Classification: Fri-Mo-Or1 - Development and Testing Towards High Field Accelerator Magnets

Contribution ID: **673** Type: **Poster**

Thu-Mo-Po.10-02: Transport current loss modeling for a twisted-stacked-tape cable

Thursday, July 3, 2025 8:45 AM (2 hours)

High-temperature superconducting (HTS) Twisted-Stacked-Tape-Cable (TSTC) conductors have been developed for use in high-field magnets, particularly those needed for compact, high-field fusion tokamaks. TSTC conductors generally contain a large number of simply-stacked RE-Ba2Cu3O7-x (RE=rare earth) (REBCO) coated conductors inserted into helical channels in a round former. Multiple versions have been proposed by several labs throughout the world, for both DC and pulsed-field applications. The inductance of each tape in the TSTC depends on its position relative to the cable centerline. A large variation among the tape inductances could cause current in the cable to distribute nonuniformly when current is changed at high rates. For instance, current ramp rates of several kilo-Amperes per second occur during pulsed-field applications, such as in fusion or accelerator magnets.
In this paper, we develop an analytical model of the behavior of a TSTC conductor during transient operation, during which the current distribution in the cable is determined chiefly by inductive effects rather than by the distribution of the tape-to-terminal resistances at the cable ends. The model is principally directed towards determining the self-field transport current losses in the cable during fast ramping. The modelled results are then compared with experimental data measured at the MIT Superconducting Magnet Test Facility during the test of magnet prototypes wound using Commonwealth Fusion System's PIT-VIPER TSTC conductor.

Acknowledgement: This work was sponsored by Commonwealth Fusion Systems of Devens, MA.

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Presenter: MICHAEL, Philip C. (MIT Plasma Science and Fusion Center)

Session Classification: Thu-Mo-Po.10 - Modelling of Fusion Conductors and Coils II

Contribution ID: **674** Type: **Poster**

Fri-Mo-Po.05-13: Mechanical design of D1/D3 dipole magnets for the Electron-Ion Collider (EIC)

Friday, July 4, 2025 9:30 AM (1h 45m)

The Electron-Ion Collider (EIC) at Brookhaven National Laboratory (BNL) is designed to deliver a peak luminosity of 10ˆ34 cmˆ-2 secˆ-1. An electron storage ring (ESR) will be installed in the existing Relativistic Heavy Ion Collider (RHIC) tunnel and will store polarized electron beams from 5 to 18 GeV. The ESR will have 750 dipole magnets with varying field requirements, including 576 super-bend triplets consisting of two magnets D1/D3 and D2. This paper presents on the mechanical design of the D1/D3 dipole magnets within the arcs. The magnet includes a coil design that allows the magnet to be configured for variable ampere-turns per energy.

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Presenter: LOVELACE, Racquel

Session Classification: Fri-Mo-Po.05 - Electron-Ion Collider

Contribution ID: **675** Type: **Poster**

Thu-Mo-Po.05-03: Critical Current Reduction as a Function of Two-Dimensional Bending Radius for Two CORC® Cables

Thursday, July 3, 2025 8:45 AM (2 hours)

There is presently a lot of effort to design and build magnetic confinement fusion machines using high temperature superconductors (HTS), perhaps most notably with rare-earth barium copper oxide (ReBCO) tapes. One such multi-ReBCO tape conductor is Conductor-On-Round-Core (CORC®). Of course, any conductor will need to be bent and deformed, in order to meet a given magnet's design criteria, which thus risks a reduction in conductor performance. Therefore, we have investigated the critical current (Ic) reduction of two CORC® conductors with a high number of tapes each as a function of two-dimensional (2D) bending. The conductors were measured as-received (i.e., nominally straight) and subsequently bent around formers with ever decreasing radii. At each bending radius, the Ic was measured at 77 K in liquid nitrogen and in self-field. The conductors were then carefully restraightened and remeasured to measure their Ic recoverability. A cross-comparison of the Ic response of these conductors to bending is made and the ramifications discussed.

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Presenter: NAUS, Michael

Session Classification: Thu-Mo-Po.05 - Mechanical Behavior and Stress I

Contribution ID: **676** Type: **Poster**

Thu-Mo-Po.04-04: Zethus: a prototype HTS planar shaping coil for the Eos stellarator

Thursday, July 3, 2025 8:45 AM (2 hours)

To generate the twisted magnetic fields necessary for fusion plasma confinement, stellarators have historically required complex and precise modular coils, which are difficult to manufacture and maintain. In mitigating this challenge, Thea Energy, Inc. is actively developing "Eos", a planar coil stellarator that can shape the needed magnetic fields using arrays of hundreds of smaller, optimized planar coils. As the first step to Eos, we launched the "Zethus"program to demonstrate a prototype high-temperature superconducting (HTS) shaping coil. During the project, we rapidly iterated through design versions as well as research and development trials, leading to the manufacturing of a 3.7 T (peak field, on conductor), soldered, metal-insulated HTS shaping coil. Furthermore, we developed and commissioned a custom cryogenic test and measurement system to operate this prototype coil. We installed the coil into a cryostat, conductively cooled it to 20 K, and validated it through a test campaign. Testing consisted of a coil characterization phase, a thermal cycling phase, and finally a quench characterization phase. By the end of all test stages, this HTS shaping coil prototype maintained robust and consistent performance, thus opening the path to the "Canis" 3x3 array of HTS planar coils and to the Eos stellarator.

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Session Classification: Thu-Mo-Po.04 - No-Insulation Coils III

Contribution ID: **677** Type: **Contributed Oral**

Sat-Mo-Or2-02: Prototyping and test of the Canis 3x3 magnet array for stellarator field shaping

Saturday, July 5, 2025 8:30 AM (15 minutes)

Thea Energy, Inc. is currently developing the "Eos"planar coil stellarator, the Company's first integrated fusion system capable of forming optimized stellarator magnetic fields without complex and costly modular coils. To demonstrate the field shaping capability required to enable a planar coil stellarator, Thea Energy designed, prototyped, and tested the "Canis" 3x3 array of high-temperature superconductor (HTS) planar coils after successfully demonstrating a single HTS planar coil prototype. Thea Energy manufactured nine demountable HTS planar coils and developed the cryogenic test and measurement infrastructure necessary to validate the array. Thea Energy assembled and operated the array at 20K, generating several stellarator-relevant field shapes and demonstrating closed loop field control of the superconducting magnets within a margin of error acceptable for stellarator operations. The Canis 3x3 magnet array test campaign provides a proof of concept for HTS planar shaping coils as a viable approach to confining stellarator plasmas.

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Session Classification: Sat-Mo-Or2 - Fusion Devices: Stellarators and Levitated Dipoles

Contribution ID: **678** Type: **Poster**

Wed-Af-Po.01-03: Canis: 3x3 array of sub-scale planar coils for the Eos stellarator

Wednesday, July 2, 2025 2:30 PM (2 hours)

The "Canis"3x3 array of high-temperature superconductor (HTS) planar coils was designed, manufactured, and tested by Thea Energy, Inc to demonstrate the viability of its core technology to generate stellarator magnetic fields for "Eos", the company's first integrated fusion system. The Canis 3x3 magnet array demonstrated the ability to create complex magnetic field shapes with sufficiently small field error for stellarator operation tolerant to minor variations in individual coil performance and build. The coil set consists of nine winding packs, five double pancakes soldered in series, each with a maximum in-bore field of 1.7 T at 20 K and a minimum charge rate of 5 A/min. Details of the mounting and connection schemes will be presented. This work details the coil array design and field-shaping performance along with the cooling and electrical structures.

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Presenter: CHEN, Brian (Thea Energy, Inc.)

Session Classification: Wed-Af-Po.01 - Magnets for Stellerators and Other Configurations

Contribution ID: **680** Type: **Contributed Oral**

Wed-Af-Or1-05: Development of HTS magnets based on the Uni-Layer concept.

Wednesday, July 2, 2025 5:30 PM (15 minutes)

The novel *uni-layer* concept for superconducting magnets introduces a new geometrical approach to form a magnetic field orthogonal to an aperture. The new design allows for independent single layers, eliminating the need for internal layer jumps and favoring the use of grading, while maintaining high efficiency in the use of conductor. The unique attributes of the *uni-layer* concept are particularly advantageous for high-temperature superconductors, especially for those that are strain-sensitive and prone to winding degradation, in very high field accelerator magnet applications, that require high efficiency and compact aperture.
This paper presents an overview of the developments at the Lawrence Berkeley National Laboratory (LBNL) regarding the first demonstrators and magnets based on the uni-layer concept. The various magnet designs, based on CORC®, STAR®, and Bi-2212 conductors are conceived as insert magnets for the LBNL Nb_3Sn CCT 6 (Canted Cosine Theta) magnet, with a combined 16+ T in the hybrid configuration. The conceptual designs will be presented, including the main features of the magnet, winding geometry, bore and peak field, and main dimensions and characteristics of the support structure.

This work was supported by the U.S. Department of Energy, Office of Science, Office of High Energy Physics, through the US Magnet Development Program under contract No. DE-AC02-05CH11231.

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Presenter: RUDEIROS FERNANDEZ, Jose Luis

Session Classification: Wed-Af-Or1 - HTS and Hybrid Magnets for Accelerators

Contribution ID: **681** Type: **Poster**

Thu-Af-Po.02-11: Current sharing in defected superconducting REBCO tape stack cables: FEM modeling.

Thursday, July 3, 2025 2:00 PM (2 hours)

High energy physics magnets use superconducting cables to decrease their inductances which limit their induced voltages during magnet ramp rates and quenches. For HTS strands, the minimum quench energy (MQE) is quite large. Heating due to small defects within the cable can be mitigated by strand-to-strand current sharing. In this case of particular interest are REBCO tape stacks, Roebel and CORC cables. Small defects may arise in the original tapes, either during cabling or in service in the magnet. Then local heating can be generated in absence of current sharing. In this paper we modelled the current sharing in tape stack cables containing seven double-sided REBCO tapes with defects present in some of them. Electrical and thermal contact resistances between the tapes in the cables were considered. In the present work, we used Finite Element Method (FEM) modeling, assuming critical current densities of these tapes relevant for operation at 4.2 K (boiling liquid He).

Authors: COLLINGS, Edward (The Ohio State University); SUMPTION, Michael; MAJOROS, Milan; Mr JIANG, Minzheng

Presenter: MAJOROS, Milan

Session Classification: Thu-Af-Po.02 - HTS Cable

Contribution ID: **682** Type: **Poster**

Wed-Mo-Po.12-06: Bulk BSCCO-2223 as an HTS switch: Transport current measurements and experimental validation

Wednesday, July 2, 2025 9:15 AM (2 hours)

This presentation explores the potential for using bulk BSCCO-2223 as a material for High-Temperature Superconducting (HTS) switches. HTS switches typically utilize ReBCO wire (2G HTS). Switching is achieved using either applied AC or DC magnetic fields, an increase in temperature, or both. Such methods reliably and repeatably modulate effective resistance between a closed- and open-state.

Magnetization measurements of bulk BSCCO-2223 are characterized by a relatively high critical temperature, large self-field critical current density, and a strong reduction critical current under relatively small magnetic fields (<2 T). These qualities make it a promising alternative to 2G HTS as a switching material.

Here, novel transport critical current (I_c) measurements of bulk BSCCO-2223 under applied field are presented from the SuperCurrent system at the Paihau-Robinson Research Institute (NZ). These have been performed on a bar sample provided by CAN Superconductors (CZ). Results include temperature and magnetic field strength and angle dependence $I_c(T, B, \theta)$ across a range of experimentally relevant parameters. These transport current measurements confirm expectations of bulk BSCCO as a promising switch material in high-current settings (>100 A).

In addition, we present experimental results of bulk BSCCO-2223 as an HTS switch. Switching is achieved in liquid nitrogen using applied DC magnetic field. Results include measurement of effective resistivity at a range of applied fields and transport currents, and tests of the transient voltage response.

Author: RICE, James (OpenStar Technologies Ltd)

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Presenter: RICE, James (OpenStar Technologies Ltd)

Session Classification: Wed-Mo-Po.12 - Diodes, Flux Pumps, and Switches

Contribution ID: **683** Type: **Poster**

Fri-Af-Po.11-06: Paschenization and testing of the SPARC Central Solenoid Model Coil

Friday, July 4, 2025 2:00 PM (2 hours)

The SPARC tokamak developed by Commonwealth Fusion Systems (CFS) and the Massachusetts Institute of Technology Plasma Science and Fusion Center (MIT PSCFC) uses pulsed high temperature superconductor (HTS) magnets with composite insulation. Each of the SPARC insulated magnets is to be acceptance tested to 21 kV in Paschen minimum conditions, and any failures are to be repaired before installation of the magnet into SPARC. To qualify the insulation breakout schemes and the insulation layup proposed for SPARC, the Central Solenoid Model Coil (CSMC), which was manufactured and tested in 2024, was "Paschenized"and Paschen-tested to 21 kV in a 0.01 mbar to 1 bar pressure range. We present the process, lessons learned, and results.

Author: HUGHES, Annie (Commonwealth Fusion Systems)

Co-authors: SANABRIA, Charlie (Commonwealth Fusion Systems); MICHAEL, Philip (MIT PSFC); GOLFINOPOULOS, Theodore (MIT PSFC)

Presenter: HUGHES, Annie (Commonwealth Fusion Systems)

Session Classification: Fri-Af-Po.11 - Experiments and Test for Fusion Magnets

Contribution ID: **684** Type: **Poster**

Sat-Mo-Po.08-09: Elimination of Training in Nb3Sn and NbTi Superconducting Magnets

Saturday, July 5, 2025 9:30 AM (1h 45m)

By using TELENE® resin as superconducting magnet impregnation material, training and magnet retraining after a thermal cycle were nearly eliminated in Nb3Sn undulators. This allows reducing operation margins in light sources, and increasing the on-axis magnetic field, thereby expanding energy range and brightness intensity. TELENE is Co-60 gamma radiation resistant up to 7-8 MGy, and therefore already applicable to impregnate planar, helical and universal devices operating in lower radiation environments than high energy colliders. Radiation resistance further increases in TELENE when mixed with high-Cp and/or high-thermal conductivity powders. We herein show that when combined with the ductility and toughness properties of TELENE, these resins display superior training performance with respect to CTD-101K in a variety of Nb3Sn magnet models. In addition, TELENE was proven to eliminate training also in NbTi accelerator magnets. Therefore, TELENE can be used in the Magnetic Resonance Imaging (MRI) industry to solve the NbTi solenoids training problem. The transfer of technology in using TELENE resin to the $40B+ MRI industry will have transformative societal impact on global health.

Authors: KIKUCHI, Akihiro; TURRIONI, Daniele; ARBELAEZ, Diego; Prof. BARZI, Emanuela (Ohio State University); KESGIN, Ibrahim; TAKEUCHI, Masaki (RIMTEC Corporation)

Presenter: Prof. BARZI, Emanuela (Ohio State University)

Session Classification: Sat-Mo-Po.08 - Structural and Insulation Materials

Contribution ID: **685** Type: **Poster**

Fri-Mo-Po.08-05: Study on the Feasibility of Using TELENE® Resin for HTS Superconducting Magnets

Friday, July 4, 2025 9:30 AM (1h 45m)

By using TELENE® resin as superconducting magnet impregnation material, training and magnet retraining after a thermal cycle were nearly eliminated in Nb3Sn undulators and NbTi accelerator magnets. We herein perform a study on how effective TELENE is in preventing quenches also in HTS magnets, without damaging the superconductor. This study encompasses measurements of transport current, minimal quench energy (MQE) and mechanical properties of wires and cable stacks at nitrogen temperature. The critical current and the MQE of REBCO tapes was measured for bare samples, and samples impregnated with different TELENE resins and epoxies, including 2850 STYCAST and CTD-101K. The critical current of REBCO cables of various geometries was measured using a superconducting transformer. The mechanical properties were measured for both REBCO and Bi-2212 cable stacks impregnated with TELENE resins.

Authors: KIKUCHI, Akihiro; TURRIONI, Daniele; BARZI, Emanuela (Ohio State University)

Presenter: TURRIONI, Daniele

Session Classification: Fri-Mo-Po.08 - HTS Characterization II

Contribution ID: **686** Type: **Poster**

Fri-Af-Po.06-05: Temperature stability of 25-T cryogen-free superconducting magnet during initial and subsequent ramping

Friday, July 4, 2025 2:00 PM (2 hours)

A 25 T cryogen-free superconducting magnet (25T-CSM) has been installed at the High Field Laboratory for Superconducting Materials, Institute for Materials Research, Tohoku University. It consists of low-temperature superconducting (LTS) outsert coils and a high-temperature superconducting (HTS) insert coil. The LTS coils are composed of three Nb₃Sn sections (L1–L3) and three NbTi sections (L4a, L4b and L5), employing high-strength CuNb/Nb₃Sn Rutherford cables and NbTi Rutherford cables for the respective sections. The HTS insert coil is constructed as a stack of double-pancake coils wound with high-strength Ni-alloy-laminated silver-sheathed Bi2223 tape. The LTS and HTS coils can generate 14.0 T and 11.1 T, respectively, resulting in a total field of 25.1 T for the 25T-CSM.
During the initial ramping of the LTS coils to their rated value, the temperature rise in the LTS coils was more pronounced compared to that observed during the subsequent simultaneous ramping. For instance, during the sweep from 812 A to 830 A, the temperature of the L2 coil increased from 4.5 K to approximately 5 K. To mitigate the pronounced temperature rise in the LTS coils, a special sequence with multiple plateaus at half the normal ramping rate is applied only at the initial ramping. Conversely, during the simultaneous sweeping in one-hour ramping mode in normal operation, the maximum temperature of the L2 coil just before reaching the rated current of 854 A from 0 A was approximately 5.2 K.
The temperature increase observed in the initial ramping is hypothesized to result from coil training. This study investigates the temperature rise mechanism through analyses that include considerations of wire movement and hysteresis losses, aiming to provide a quantitative explanation of the observed phenomena.

Author: Dr TAKAHASHI, Kohki (Tohoku University)

Co-author: Prof. AWAJI, Satoshi (Tohoku University)

Presenter: Dr TAKAHASHI, Kohki (Tohoku University)

Session Classification: Fri-Af-Po.06 - High Field HTS Solenoids

Contribution ID: **687** Type: **Poster**

Sat-Mo-Po.07-03: Thermal Performance of a Conduction-Cooled ReBCO Magnet: Cyclic Cool-Down, Conduction Cooling Design, and Thermal Gradient Studies

Saturday, July 5, 2025 9:30 AM (1h 45m)

This study presents the conduction-cooled current injection design/thermal gradient and cyclic testing for a ReBCO canted cos-theta magnet designed and Fabricated by LBNL (magnet C2). This coil has been measured at 77 K (LN2) and 4.2 K (liquid helium), as previously reported by LBNL, but in this case, we used a large conduction cooled cryostat available at OSU. Testing this coil in a conduction cooled mode has relevance for the advanced accelerator program in the US, as there are continuing incentives to move away from 100% liquid cryogen cooling, including the development of "green" accelerator technologies. The coil had four layers, each wound with ReBCO coated conductor based CORC cable. The magnet itself was 613 mm long, and the total length with current leads was 1.5 m (our size limit). The magnet mass was 75 kg, with an OD of 127 mm, and a 77 K nominal Ic of 300A. The coil was mounted on a Cu cold ring which was cooled by two Sumitomo RDK 415D cold heads with a total cooling of 3 W at 4.2 K, and with cooling of 150 W (total) at 77 K. The magnet and current leads were left on the G-10 strongback, which was laid across the Cu cooling ring, and clamped down. Conduction cooling was performed with the use of a series of Cu straps which were attached to the magnet end rings, and also a thermal radiation shield, and then to the cold ring. We then tested the base temperature, and then performed a number of cooling cycles, and measured the thermal gradient. The results of these measurements and the comparison to FEM models is discussed. HTS sister connections were made to the current injection lugs of the magnet, and low level currents (up to 10 A) were injected at 77 K to explore the development of thermal gradients with current injection, and these results are reported.

This work is supported by the United States Department of Energy, Office of Science, Division of High Energy Physics under Grant DE-SC0011721.

Author: GARG, Tushar (The Ohio State University)

Co-authors: MAJOROS, Milan (The Ohio State University); WANG, Xiaorong (Lawrence Berkeley National Laboratory); SUMPTION, Michael (The Ohio State University); COLLINGS, Edward (The Ohio State University)

Presenter: GARG, Tushar (The Ohio State University)

Session Classification: Sat-Mo-Po.07 - HTS Magnets

Contribution ID: **688** Type: **Plenary**

Qualification of the HTS Magnets for SPARC

Wednesday, July 2, 2025 8:30 AM (45 minutes)

Commonwealth Fusion Systems (CFS) is building the SPARC tokamak in Devens, MA, USA, with first plasma planned in 2026. The initial objective of SPARC will be scientific demonstration of Q>1 (net fusion energy) in a tokamak, with experiments then shifting to the goal of exploring operating regimes for ARC, the first fusion power plant. SPARC utilizes a high field, compact, pulsed tokamak design enabled by superconducting Toroidal Field (TF), Poloidal Field (PF), and Central Solenoid (CS) coils. After the underlying technology for the SPARC HTS magnet systems was de-risked with the TFMC and CSMC programs, CFS constructed a manufacturing facility to build the SPARC magnets. As a part of this operation, CFS has constructed a set of test facilities to allow for the progressive testing of all magnet subcomponents through final tests of the full magnets themselves at SPARC operating conditions. At the component scale, facilities were built and qualified to allow for the testing of the input HTS tape at low temperature and high field as well as testing the structural material of the magnets at low temperature. At the magnet sub-unit scale, facilities were built and qualified to test the superconducting performance of every pancake/layer at 77 K to uncover any potential manufacturing defects before the pancakes/layers were integrated into full coils. Finally, two large cryogenic, high current test stands were built and qualified to enable the full testing of every single TF, PF, and CS coil before being sent to SPARC for installation. In addition to achieving the required operating conditions for each step of testing, the test facilities were designed and built to match the high throughput achieved by the manufacturing line, and will ensure high confidence that every magnet delivered to SPARC will work as designed. This talk will provide an overview of these test facilities and testing progress to date.

Author: Dr SORBOM, Brandon (Commonwealth Fusion Systems)

Presenter: Dr SORBOM, Brandon (Commonwealth Fusion Systems)

Session Classification: Plenary: Brandon Sorbom [Qualification of the HTS Magnets for SPARC] - sponsored by Western Superconducting Technologies Co., Ltd.

Contribution ID: **689** Type: **Poster**

Fri-Af-Po.04-06: Performance of indium wire and indium foil joints between high-temperature superconducting PIT VIPER cables

Friday, July 4, 2025 2:00 PM (2 hours)

High-quality joints are essential for building practical assemblies of fusion-scale magnets, integrating the magnets with bus and leads, and allowing modularity in magnet design. The essential figure of merit for the quality of the joint is its electrical resistance which should be as low as possible. Due to its low bulk resistivity and high ductility, indium is often used to cold-weld the interfaces of a joint. Indium can be applied in different forms, primarily as wire or foil, with wire being preferred because of the resistive indium oxide layer that forms on indium foil. Indium wire has an oxide layer as well, however, it is compromised as the wire experiences significant plastic deformation during joining.
In this paper, we present the results of an experimental series conducted at the MIT Plasma Science and Fusion Center's Liquid Nitrogen Superconducting Magnet Test Facility, aimed at comparing the performance of joints containing either indium wire or indium foil. During a test, a joint between two superconducting PIT VIPER cables joined by a set of five saddles was submerged in liquid nitrogen and energized. In total, nine experiments were run including joint tests with acid-etched foil to remove the oxide layer. Across the experiments, different parameters were varied, such as clamping pressure within the joint, electrical contact area, wire spacing, and foil thickness. Experimental data are compared with results from a COMSOL Multiphysics simulation to develop a model for the total joint resistance. Results demonstrate that the resistance of the indium oxide layer is, in fact, negligible compared to other factors such as contact resistances due to voids and other effects –including but not limited to oxides - at interfaces between different materials and the extent to which the indium undergoes plastic deformation, which allows indium to fill voids and ensure intimate contact between joint components. Nevertheless, it is obtained that joints containing indium foil have approximately 40% higher resistances than those containing indium wire.

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Presenter: USCUPLIC, Kerim (MIT PSFC)

Session Classification: Fri-Af-Po.04 - Supporting Technologies for Fusion Magnets II

Contribution ID: **690** Type: **Invited Oral**

Sat-Af-Spe1-08: [Invited] Development of high current CORC® cables, CICC, and low resistance demountable joints for fusion magnet applications

Saturday, July 5, 2025 3:45 PM (15 minutes)

It has been widely recognized that compact fusion machines that take advantage of high-temperature superconductors (HTS), which allow magnets to operate at relatively high magnetic fields and at temperatures that won't require liquid helium cooling, have the potential to significantly reduce the timeline towards net fusion energy production. HTS also may enable demountable toroidal field (TF) coils that would allow easy access to the fusion core and thus would significantly ease maintenance of the fusion device.
Advanced Conductor Technologies (ACT) is developing HTS Conductor on Round Core (CORC®) cables, wound from RE-Ba2Cu3O7-□ (REBCO) coated conductors, Cable-in-Conduit-Conductors (CICC), formed by bundling several CORC® cables in parallel, and low-resistance demountable joints between CORC®-CICCs. An overview will be provided, outlining the status of CORC® cable, CICC and demountable joint development for fusion magnet applications.
Very-high current CORC® cables were developed specifically for the prototype Stellarator coil under development at Type One Energy Group. The single CORC® cable of 10 mm in thickness contained 96 REBCO tapes of 4 mm width from Fujikura, resulting in an expected critical current (Ic) of over 30 kA at 10 T at a temperature of 20 K, or at 20 T at 4.2 K. The CORC® cable was optimized to allow bending to a 125 mm radius without experiencing significant performance degradation, making it a highly attractive candidate for winding into the non-planar coils of Stellarator reactors.
Very-high current CORC® cables were also developed in collaboration with CEA Cadarache. A CORC® cable was developed containing 120 REBCO tapes from Shanghai Superconductor Technologies, to allow operation at 20 –25 kA at 18 T at a temperature of 20 K. The tapes contained a thin layer of SnPb solder that will be melted after winding to provide the cable with a higher mechanical strength and better current sharing capabilities between tapes compared to a CORC® cable wound from REBCO tapes that don't contain a layer of solder. The performance of the CORC® will be tested within the SULTAN test facility in the near future.
The results of the pair of CORC®-CICC samples that was developed in collaboration with the United Kingdom Atomic Energy Authority (UKAEA) and tested in the SULTAN facility will be discussed. Although the sample was operated to its expected Ic of 40 kA in a background magnetic field of 10.8 T at 20 K, the sample quenched before Ic was reached at temperatures below 20 K. Temperature gradients that may develop over the sample length, and especially between the parallel CORC® cables, could become the main driver behind the current distribution between cables within the CICC. Voltage measurements taken during the SULTAN test indicate that the thermoelectric voltages caused by the temperature gradient may cause reversal of the current in one or more CORC® cables within the CICC, significantly reducing its quench current.
The latest results of the development of remountable joints between CORC®-CICCs for fusion reactor magnets in collaboration with UKAEA will be outlined. Earlier tests performed at 4.2 K at a background magnetic field of up to 8 T demonstrated the feasibility of using CORC®-CICCs in demountable TF coils. A total loop resistance, including their terminations and joint, was about 4 nΩ at 4 K in self-field, with the contact resistance between the pressed copper joint surfaces being less than 1 nΩ at a high contact pressure of 50 MPa. Here we report on the latest results of the

performance of demountable joints having different joint interfaces that would facilitate easier mounting and demounting at a reduced contact pressure of about 10 MPa. Loop resistances of 6 –10 nΩ were measured at currents up to 5 kA at 25 K in self-field, with the contact resistance over the joint interface being as low as 0.5 nΩ, depending on the sample pair and joint surface preparation.

Authors: TORRE, Alexandre; SIDDARTH SWAMINATHAN, Aurobindo (UK Industrial Fusion Solutions); LAMB, Chris (UKIFS); NGUYEN THANH DAO, Clement; KWIATKOWSKI, Daniel (Advanced Conductor Technologies); VAN DER LAAN, Danko; SCHNEIDER, Gregg (Type One Energy Group LLC); WEISS, Jeremy (Advanced Conductor Technologies and University of Colorado, Boulder); HOLT, Julian (UKAEA); RADCLIFF, Kyle (Advanced Conductor Technologies (ACT)); MUSCAT, Peter (UKAEA); TEYBER, Reed; CHOUHAN, Shailendra Singh; DÖNGES, Sven (Advanced Conductor Technologies); DIEUDONNE, Yannik; JOHNSON, Zachary (Type One Energy Group LLC)

Presenter: VAN DER LAAN, Danko

Session Classification: Sat-Af-Spe1 - [Special Session] High Current HTS Cables for Fusion and Beyond

Contribution ID: **691** Type: **Contributed Oral**

Fri-Mo-Or6-04: A Voltage-Based Quench Detection and Fast Discharge System for High-Temperature Superconductor Devices at MIT PSFC's Superconducting Magnet Test Facility

Friday, July 4, 2025 12:00 PM (15 minutes)

A quench detection and fast discharge scheme has been deployed in the Superconducting Magnet Test Facility at MIT's Plasma Science and Fusion Center for use with high-temperature superconductor (HTS) devices. In particular, the system was developed to protect the SPARC Central Solenoid Model Coil (CSMC), an insulated HTS cable magnet constructed of 40 turns of PIT VIPER cable, as well as the facility's VIPER-cable HTS cold bus and 50 kA binary current leads. Quench detection is realized by classical techniques of voltage measurement with programmable voltage thresholds and hold times, and filters allowing for thresholds less than 10 mV. The configuration fielded for SPARC CSMC tests processed 50 voltage signals in real-time using Siemens PLC hardware. End-to-end response times of ˜300 ms, including a programmed 150 ms hold time, were demonstrated with an 8 mV threshold in quench experiments with >30 kA operating current. The fast discharge system comprises a set of four Secheron switchgear in line with the positive bus, each capable of handling 12.5 kA continuously, together with a set of Hubbel dump resistors with variable resistance between ˜2 and ˜10 mΩ, placed in parallel with the load. Data acquisition and conditioning electronics are protected by a number of Dataforth isolation amplifiers. A voltage limit of 125 V has presently been placed upon the system; this peak voltage was sufficient to safely discharge the CSMC in the event of a quench, while allowing it to reach ˜4 T/s during discharge. Desired future work on the system includes improving and testing insulation of the current leads and cold bus to increase this voltage ceiling. The system will next be deployed in service of experiments with Type One Energy's "Magnet Zero" prototype, with an expanded set of voltage tap inputs and an improved response time.

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Presenter: GOLFINOPOULOS, Theodore (Massachusetts Institute of Technology)

Session Classification: Fri-Mo-Or6 - Quench Detection and Protection I

Contribution ID: **692** Type: **Contributed Oral**

Wed-Mo-Or1-01: Rapid Iteration of HTS Magnet Technologies for Levitated Dipole Systems

Wednesday, July 2, 2025 11:15 AM (15 minutes)

OpenStar is advancing fusion energy generation through the development of a levitated dipole reactor, building on the Levitated Dipole Experiment (LDX) concept. This approach integrates high-temperature superconducting (HTS) magnets with an onboard superconducting power supply.

Having successfully demonstrated the feasibility of integrating HTS magnets into the levitated dipole concept, OpenStar now focuses on an accelerated roadmap toward practical fusion energy. The levitated dipole concept features a highly decoupled system comprising a magnet and a reaction container, enabling rapid iteration of magnet technologies without requiring significant modifications to the reactor's core components.

However, the pace of magnet technology development towards high performance, and the progress of plasma science, is inherently tied to the production timeline of innovative and gradually stronger magnets. To address this challenge, OpenStar prioritizes rapid iterations of magnets and their associated onboard technologies. Over the past two and a half years, OpenStar has successfully constructed two magnets and plans to deliver two more within the next 18 months.

These new magnets will feature improved levitation times (less than 2 hours) and/or enhanced magnetic field strengths, all leveraging coil-based technology. These magnets will be designed with modularity features and standardized interfaces for the surrounding systems to further support rapid iteration and innovation of magnet related technologies.

This presentation will highlight OpenStar's advancements in coil-based HTS magnet technologies, showcasing their role in developing a rapid technology platform. It will also explore the design and the contribution in accelerating fusion technology development of four conduction-cooled magnet designs, operating at temperatures ranging from 25K to 50K, achieving magnetic field strength from 3T to 12T, and current range from 700A to approximately 2 kA.

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Session Classification: Wed-Mo-Or1 - Future Fusion Devices: Tokamaks

Contribution ID: **693** Type: **Poster**

Sat-Mo-Po.05-05: Simulation of Thermal Diffusion and Critical Current Evolution in Large Superconducting Magnets with Active Quench Heaters

Saturday, July 5, 2025 9:30 AM (1h 45m)

Active quench protection systems in large superconducting magnets rely on the rapid and efficient delivery of heat from quench heaters to the magnet windings to initiate a controlled quench. However, thermal diffusion is significantly influenced by the multi-layered electrical insulation, thermal barriers, and contact resistance between surfaces. This work presents simulation results that elucidate the heat transfer dynamics from quench heaters through these layers and their impact on the magnet. Additionally, the evolution of the critical current with temperature changes during and after quench heater activation is explored, providing insights into the interplay between thermal and electromagnetic properties. These findings aim to enhance the design and performance of quench protection systems in large-scale superconducting applications.

This work was performed at the National High Magnetic Field Laboratory, which is supported by National Science Foundation Cooperative Agreement No. DMR-2131790, DMR-2128556, and the State of Florida.

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Session Classification: Sat-Mo-Po.05 - Quench Detection and Protection IV

Contribution ID: **694** Type: **Poster**

Fri-Af-Po.01-04: SSRF Superconducting Wiggler Control & Coil Voltage Monitoring System and Quench Monitoring Results

Friday, July 4, 2025 2:00 PM (2 hours)

The SSRF (Shanghai Synchrotron Radiation Facility) superconducting wiggler consists of three parts: a superconducting multipole magnet, a cryostat system and magnet power & control system. Superconducting multipole magnets can generate a strong magnetic field with a peak of 4.2T, and the generated magnetic field alternates positively and negatively along the direction of electron motion in the storage ring. The superconducting wiggler is installed in the BL12 unit of the SSRF Storage Ring. The voltage monitoring system can monitor the voltage of each part of the coil of the superconducting multipole magnet through the voltage sense leads, thereby obtaining the voltage trends of each part of the coil when the coil quench occurs. The voltage monitoring system collects the voltage data of each coils through a Siemens S7-1512 PLC analog input modules which is an innovative method. And the system realizes the quench detection by recording the voltage cycle by cycle and judge by a delay threshold. Based on the PLC system both the equipment monitoring function and the voltage monitoring function are achieved. The quench voltage of each coil is captured and analyzed.

Authors: Dr YI, DIng (Shanghai Advanced Research Institute, Chinese Academy of Sciences); Mr MENG, Tianya (Shanghai Advanced Research Institute, Chinese Academy of Sciences)

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Session Classification: Fri-Af-Po.01 - Quench Detection and Protection II

Contribution ID: **695** Type: **Poster**

Thu-Mo-Po.04-02: Analysis on Critical Current Measurement of No-Insulation HTS Coils and its Correction and Compensation

Thursday, July 3, 2025 8:45 AM (2 hours)

This paper presents both numerical and experimental investigations aimed at achieving accurate measurements of critical current in no-insulation (NI) high-temperature superconducting (HTS) coils. Leakage currents can flow through the turn-to-turn contact resistance in NI HTS coils. Additionally, screening current-induced voltages become dominant factors during the initial charging process. Both phenomena introduce additional errors and decrease the accuracy of critical current measurement. To address these challenges, we propose a method for correction and compensation that minimizes the impact of leakage currents and screening currents. Numerical and experimental results confirm that our approach improves the accuracy of critical current measurements in NI HTS coils.

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Presenter: CHO, Bonghyun (Pusan National University)

Session Classification: Thu-Mo-Po.04 - No-Insulation Coils III

Contribution ID: **696** Type: **Contributed Oral**

Sat-Af-Or5-04: An approach to Modelling of external field losses in CORC Conductors including hysteretic, eddy current, and coupling currents

Saturday, July 5, 2025 5:15 PM (15 minutes)

CORC, STAR, and in general, conductors consisting of a set of helically wound conductors on a round core are of substantial interest for use in High Energy Physics accelerator magnets because of their high Bc2 and excellent transport properties in high fields. Their magnetization properties as well as their AC loss are also of interest, because they can cause particle beam defocusing and excess cryogen losses, respectively. In this work we use a combination of finite element and analytical modelling to calculate three important loss components, (i) hysteretic, (ii) eddy current, and (iii) coupling current losses. We chose to treat the case of fields well above penetration for simplicity, and also we take the case of low to modest ramp rates, both because it is the regime of interest for particle accelerators, but also because it allows us to treat these three components as non-interacting, at least for fields well above penetration. The hysteretic losses of tapes is seen to agree with (2/⊠)* the straight tape in a perpendicular field if the cable pitch is large enough, and eddy currents with non-helical eddy current tape loss by (2/⊠)2. The additional losses due to coupling currents can be estimated by treating the losses as a summation of tape pairs with inter-tape coupling currents. FEM calculations are compared to analytic models for these pairs over a range of sample lengths and dB/dt values before summing to give a total coupling loss. In this way we make an estimate of total CORC Magnetization and losses using a simple and fast model.

Authors: COLLINGS, Edward (The Ohio State University); SUMPTION, Michael; MAJOROS, Milan

Presenter: SUMPTION, Michael

Session Classification: Sat-Af-Or5 - AC Loss and Magnetization II

Contribution ID: **697** Type: **Poster**

Fri-Af-Po.06-04: Detailed manufacturing design of REBCO insert and cooling performance of 33T Cryogen-Free Superconducting Magnet

Friday, July 4, 2025 2:00 PM (2 hours)

The 33T Cryogen-Free Superconducting Magnet (33T-CSM) project is progressing at Tohoku University Institute for Materials Research. The 33T-CSM consists of a 19T REBCO coil (HTS) with a 68mm bore and a 14T Nb3Sn+NbTi Rutherford coil (LTS) with a 320mm bore. The 14T-LTS coil was completed in 2024 and its stand-alone test was successfully performed. The 19T-HTS coil design, which involves winding REBCO tape conductors in a two-layer bundle and impregnating only the end faces, has been completed and is expected to enter the manufacturing phase soon. This design reduces the risk of local degradation, which can cause hotspots, and optimizes the stress distribution within the coil to minimize maximum stress. Following these concepts, detailed manufacturing design of specific stacking methods of the pancakes and connections between the pancakes is discussed. In addition, the evaluation of the cooling capacity of the GM-JT refrigerator and GM refrigerator used for gas circulation cooling of the HTS and LTS coils in the cryostat of the 33T-CSM, as well as the future scalability, will be presented.

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Presenter: NEZUKA, Hayato (Toshiba Energy Systems & Solutions Corporation)

Session Classification: Fri-Af-Po.06 - High Field HTS Solenoids

Contribution ID: **698** Type: **Invited Poster**

Thu-Mo-Po.06-01: [Invited] A study on multiscale modelling of REBCO toroid field coil

Thursday, July 3, 2025 8:45 AM (2 hours)

In tokamaks, a strong and stable toroidal magnetic field is essential for plasma confinement. Among the available materials for toroidal field coil, REBCO is a promising candidate due to its excellent stability margin and high critical magnetic field. However, the design and analysis of toroidal field coils, which consist of multiple components such as REBCO-coated conductors, solder, stabilizers, cooling channels, and insulation, pose significant challenges. Many components have very thin dimensions, making them unsuitable for direct meshing in finite element modeling. Furthermore, the significant Lorentz forces and high stress levels in the coils require the inclusion of elastoplastic nonlinear properties in the model. These factors, combined with the geometric complexity, lead to substantial computational costs.
To address these challenges, we developed a multiscale modeling framework. This approach splits the model into a large-scale model and a small-scale model, where the two interact dynamically: the small-scale model provides equivalent material properties to the large-scale model, while the large-scale model supplies boundary conditions to the small-scale model. This method captures detailed mechanical behaviors while maintaining computational efficiency.
In this study, we implemented a finite element model capable of accurately reflecting the mechanical behavior of each component in the toroidal field coil. This model enables a rigorous analysis of coil performance, contributing to the development of mechanically robust and efficient designs for tokamaks, which are critical for advancing fusion technology.

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Session Classification: Thu-Mo-Po.06 - Mechanical Behavior and Stress II

Contribution ID: **699** Type: **Poster**

Thu-Mo-Po.08-01: Current Sharing and Quench in ReBCO based superconducting cables for Accelerator Dipole Magnets: Modelling and Measurement

Thursday, July 3, 2025 8:45 AM (2 hours)

This work analyzed current sharing and quench evolution in REBCO based superconducting cables intended for use in the High Energy Physics (HEP) accelerator dipole magnets. Current sharing was explored for simple tape stack cables using FEM modelling. Summaries are given for finite element work performed on various number of stacked tape cables, in 3D configurations while varying interstrand contact thermal and electrical resistance, for fixed thermal boundary conditions, as well as several different values of defect densities. We focused on determining the point of thermal runaway, which can be considered a measure of current sharing, and found it to be dependent on interstrand and intra-strand electrical and thermal contact resistances, including, e.g., the effects of oxide surface layers on the outsides of the tapes, and buffer layers inside of the tapes, and also the number of defects per unit length in the tape and their distribution. It was seen that it is possible to develop a simple equation for current sharing which incorporates both inter- and intra-strand electrical and thermal resistances. This was compared to an analytic/lumped model approach, and developed expressions for the approach to the current for thermal runaway for liquid cooled cables with sparse defects. To do so we coupled simple thermal and electric expressions, and showed explicitly, (under simplifying assumptions) that the total current that can pass through a mildly defected superconducting cable is determined by its cooling boundary conditions, its inter-tape resistivity, the tape stacks thermal conductivity, and the distance between defects. These results were compared to a series of simple experiments using three tape cables with defects intentionally introduced. Measurements in this case were performed in self-field in LN2. We compared soldered and "as received"(untreated) stacks of tapes with different defects patterns, and with different cooling boundary conditions (access to the LN2).

Authors: COLLINGS, Edward (The Ohio State University); SUMPTION, Michael; MAJOROS, Milan; JIANG, Minzheng

Presenter: SUMPTION, Michael

Session Classification: Thu-Mo-Po.08 - Quench Modelling and Detection

Contribution ID: **700** Type: **Poster**

Thu-Mo-Po.05-06: Research on the mechanical performance of REBCO CICC sub-cable for fusion reactor

Thursday, July 3, 2025 8:45 AM (2 hours)

To fulfill the requirement of the high field (> 15 T) and high current carrying capacity (> 40 kA) superconducting magnets for the next-generation fusion reactor, the Institute of Plasma Physics, Chinese Academy of Sciences, proposed two kinds of CICC design concepts, which are both manufactured from a sub-cable. The sub-cable is formed by winding REBCO tape around a stainless steel spiral tube. The combination of high operating current and high magnetic fields results in large Lorentz forces on the sub-cable that could cause irreversible degradation. Therefore, It is important to improve the mechanical strength of sub-cables. In this report, the mechanical performance of REBCO CICC sub-cable will be reported, for example, tensile, and transverse compression. In addition, the influence mechanism of the structural parameters for sub-cable on its mechanical performance will be elucidated, the cable structural design with high mechanical strength will be proposed. These research results will promote the development of high field superconducting magnet technology, and provide important data for the design of future fusion magnets.

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Co-author: Ms JIN, Huan (ASIPP)

Presenter: XIAO, Guanyu (ASIPP)

Session Classification: Thu-Mo-Po.05 - Mechanical Behavior and Stress I

Contribution ID: **701** Type: **Contributed Oral**

Sat-Af-Or5-05: Magnetization of Helically Wound ReBCO Cables in Potted and Non-potted Configuration with Analysis of Hysteretic, Eddy Current, and Coupling Contributions

Saturday, July 5, 2025 5:30 PM (15 minutes)

This study investigates the magnetization of ReBCO cables, utilizing experimental measurements in magnetic fields up to 30 T at 4.2 K. The cable is comprised of 29 ReBCO tapes, with a cable OD of 3.63 mm and cable pitch of 7.16 mm. The tapes were 2 mm wide and had a substrate thickness of 30 µm, and a Cu plating thickness of 5 µm. The cable had an Ic of 1675 A at 77 K and self-field. The ReBCO cables were tested in various configurations, including three-stack ReBCO cables, three-stack with epoxy impregnation, three-stack with solder coating, and three-stack Ni-plated ReBCO cables. We used a susceptibility technique, with the NHMFL's Bitter (resistive) magnet acting as the primary coil. We constructed a sample holder with a pick-up coil as well as a compensation coil. The ReBCO cables were measured as a three-stack ReBCO, placed with the field perpendicular to the conductor length. Magnetization (M) versus applied magnetic field (µ0H) was measured for field sweeps with amplitudes up to ± 30 T. In the second set of measurements, we utilized a three-stack ReBCO cable with epoxy impregnation, then the third set with a three-stack ReBCO with solder coating, and the final set with Ni-plated three-stack ReBCO cables. We analyzed results breaking out hysteretic, eddy, and coupling components, comparing the performance of these different ReBCO cables. The findings of this study provide valuable insights into the design and optimization of ReBCO cables for high-field applications, such as fusion reactors, particle accelerators, and magnetic resonance imaging (MRI) systems. Understanding all the loss components for these cables could lead to the development of more efficient and reliable devices. Coupling, eddy, and hysteretic currents in ReBCO cables are significant factors that impact their performance in high-field applications.

This work is supported by the United States Department of Energy, Office of Science, Division of High Energy Physics under Grant DE-SC0011721.

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Presenter: GARG, Tushar (The Ohio State University)

Session Classification: Sat-Af-Or5 - AC Loss and Magnetization II

Contribution ID: **702** Type: **Poster**

Thu-Mo-Po.04-01: An Experimental Study on Transition of Contact Resistivity in REBCO Coated Conductor at Critical Temperature

Thursday, July 3, 2025 8:45 AM (2 hours)

For REBCO magnets, the no-insulation (NI) winding technique, which eliminates turn-to-turn insulation, is considered a key approach. The NI technique offers advantages, particularly during quench events, as the absence of turn-to-turn insulation allows current to bypass localized heat sources or defects naturally. In fact, several studies have reported that NI magnets achieved higher operating currents and demonstrated more stable operation compared to insulated magnets. However, accurately reproducing the electromagnetic behavior (especially voltage) of NI magnets during quench using existing analytical methods has shown to be highly challenging. When circuit-based methods are used to analyze the voltage and magnetic field of NI magnets, the results match well under normal operating conditions when inductance and characteristic resistance are considered. However, applying the same parameters to quench analysis yields entirely inconsistent results.
This study proposes that the cause of the above issue is the 'transition' of contact resistivity at critical point. Some previous studies have indicated the potential existence of such a phenomenon based on indirect evidence. In this research, experimental results confirmed a drastic change in contact resistivity around the critical temperature. Quantitative measurements of resistance at different temperatures between REBCO conductors in contact were performed to observe this transition. Additionally, temperature-dependent characteristic resistance measurements of NI coils were conducted to assess how this transition manifests at the magnet level, and a revised analytical model was suggested. The findings of this study will enable more accurate analysis of NI magnet behavior during quench and provide criteria for magnet protection. Furthermore, it could lead to a deeper understanding of the origin of contact resistivity.

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Presenter: KIM, Geonyoung (Seoul National University)

Session Classification: Thu-Mo-Po.04 - No-Insulation Coils III

Contribution ID: **704** Type: **Poster**

Thu-Af-Po.04-05: Prototype REBCO First and Second Order Transverse Shim Coils for High-field HTS Magnet

Thursday, July 3, 2025 2:00 PM (2 hours)

For magnets requiring high uniformity, such as those used in MRI and NMR, shimming techniques are applied to correct the magnetic field distribution. These shimming techniques can be divided into two types: shim coils that are powered with current, referred to as active shimming, and iron shims that do not require current, referred to as passive shimming. In active shimming, superconducting shim coils are capable of generating stronger magnetic fields, thereby enhancing the correction effect. Low-temperature superconducting (LTS) NbTi wires are commonly used for this purpose. However, they have the drawback of requiring cryogenic cooling under 4 K and cannot operate in high-field magnets exceeding 10 T.
This study suggests a superconducting active shim coil using REBCO conductors as an alternative to NbTi. While previous research has reported the use of REBCO active shim coils for correcting axial magnetic field harmonics, there are few cases of implementing REBCO shim coils for transverse correction. In this study, a transverse shim coil using REBCO conductors was designed, followed by numerical analysis and liquid nitrogen experiments. The screening current generated in REBCO and their impact on the magnetic field distribution were analyzed, and the magnetic field strength was quantitatively compared at different operating current levels. This research provides insights into future magnetic field correction methods for high-field magnets and identifies the key factors necessary for installing such coils in real magnets.

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Presenter: KIM, Geonyoung (Seoul National University)

Session Classification: Thu-Af-Po.04 - Screening Currents and Shimming

Contribution ID: **705** Type: **Poster**

Sat-Mo-Po.01-08: Asymmetric magnetic levitation for enhanced cell density measurement and analysis

Saturday, July 5, 2025 9:30 AM (1h 45m)

Subtle variations in cell density often serve as precursors to shifts in physiological characteristics. Consequently, the accurate detection and detailed characterization of cell density are of paramount importance for elucidating cellular functional states, pharmacological responses, and cellular heterogeneity. Contemporary mainstream methods for density-based characterization predominantly rely on density gradient centrifugation, which requires complex apparatus, intricate procedural steps, and significant processing time. In contrast, Magnetic Levitation (MagLev), grounded in the principles of negative magnetophoresis, offers a label-free, cost-effective, and highly precise alternative. This approach is particularly well-suited for the measurement and manipulation of small-volume samples. Currently, MagLev devices used for cell density measurement can be categorized into bar magnet MagLev and ring magnet MagLev. The former presents challenges in sample manipulation and offers suboptimal efficiency, while the latter is characterized by low sensitivity, failing to meet current application requirements. As a result, there is an urgent need to develop innovative MagLev devices to enhance the efficiency and precision of cell density measurement and manipulation.

In this work, we introduce the Asymmetric MagLev system, engineered by combining ring magnets with cylindrical magnets to optimize the magnetic field source. Numerical simulations and experiments using microbeads of known densities validated the system's enhanced levitation characteristics. The results show that the asymmetric design significantly enhances the working distance and system sensitivity without compromising the density measurement range. Compared to the ring magnet MagLev, the system sensitivity of this design is improved by more than 25 times, effectively addressing the long-standing trade-off between system sensitivity and measurement range in conventional MagLev. Moreover, the presence of the ring magnets ensures the system's operability and observability. The Asymmetric MagLev system is applied to cell density measurement, in conjunction with biocompatible paramagnetic solutions (gadopentetate di-glucosamine and DMEM culture medium), to quantify the density of different cell types, including NCM460 and HCT116. The results suggest that Asymmetric MagLev enables the characterization of cell density distributions without the need for labeling or intervention, providing a convenient operation with a short processing time. Additionally, capitalizing on its high sensitivity and real-time monitoring, we further extend the application of the Asymmetric MagLev to in vitro pharmacological testing. In the experiments, we perform real-time characterization of the suspension state and density of HCT116 cells under various drug concentrations. This allows us to detect the effects of drug treatment and subsequently evaluate the short-term or long-term responses of patients to therapy.

In conclusion, our findings suggest that asymmetric MagLev offers a promising solution for the measurement and characterization of cell densities, and could potentially be a powerful tool for cell analyses and manipulations based on density.

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Session Classification: Sat-Mo-Po.01 - Magnets for Other Medical Application II

Contribution ID: **706** Type: **Contributed Oral**

Wed-Af-Or2-04: Field Collapse of a No-Insulation REBCO Coil During a Quench: Numerical Study

Wednesday, July 2, 2025 5:15 PM (15 minutes)

Advancements in high-temperature superconductors (HTS), particularly REBCO coated conductors, have catalyzed breakthroughs in ultra-high field magnet technology. However, significant challenges remain, with quench protection being a critical unresolved issue. The no-insulation (NI) winding technique offers a promising approach to mitigate these challenges. By allowing turn-to-turn bypass currents, NI coils exhibit intrinsic "self-protection"against localized overheating, enabling tolerance of minor defects in the conductor and temporary current overloading. Despite these advantages, quench still happened to many NI REBCO magnets, causing unexpected severe damages.

This study investigates the quench dynamics of NI REBCO coils through numerical modeling. While NI coils are known for their long charging time constants, quench events often result in rapid field collapse, posing significant challenges for timely detection and effective protection. To understand and address these phenomena, we model the quench in a small-scale NI REBCO magnet triggered by a localized defect. Two numerical methods are employed to allow cross-checking of the results: (1) a 2D axisymmetric model using the H-formulation with rotated anisotropic resistivity, and (2) a 3D model utilizing the open-source FiQuS/Pancake3D framework. These models are used to analyze the dynamic behavior during quench events, including inter-turn current sharing and intra-turn screening currents. Based on the numerical results, we discuss the implications for protection strategies and potential methods to enhance the reliability of NI REBCO magnets in high-field applications.

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Session Classification: Wed-Af-Or2 - No-Insulation Coils II

Contribution ID: **707** Type: **Poster**

Wed-Mo-Po.05-06: Design, construction, and operation of conduction-cooled Bi-2212 magnet for solid-state spin qubit experiment

Wednesday, July 2, 2025 9:15 AM (2 hours)

Bi-2212 round wire offers advantages in low screening current due to its filament structure compared to REBCO tapes among high-temperature superconductors (HTS). Additionally, established methods for creating superconducting joints are well known for Bi-2212. These characteristics have led to extensive research into its use in nuclear magnetic resonance (NMR) magnets, which require high temporal magnetic field homogeneity, and its potential application in the central solenoid of fusion reactors, where low heat dissipation due to AC loss is critical.
A recently identified application that demands high temporal magnetic field stability is the solid-state spin qubit experiment for quantum computers. This experiment requires precise magnetic field alignment to the nitrogen-vacancy (NV) axis of a diamond sample and exceptional temporal stability.
In this study, we present the fabrication and testing of a conduction-cooled Bi-2212 solenoid test coil designed for solid-state spin qubit experiments. The electromagnetic design of the coil was optimized to minimize conductor usage while maintaining magnetic field strength. The bobbin was designed and fabricated with conduction cooling in mind. We fabricated two types of current leads: 1) copper current leads subjected to heat treatment, and 2) replaceable current leads that are replaced after heat treatment. Furthermore, because the solid-state spin qubit experiment is conducted off-center within the magnet, we measured the temporal stability of the magnetic field both at the experiment spot and at the magnet's center.

This work was supported in part by National R&D Program through the National Research Foundation of Korea(NRF) funded by Ministry of Science and ICT(2022M3I9A1073924), in part by the Applied Superconductivity Center, Electric Power Research Institute of Seoul National University, and in part by Kiswire Advanced Technology Co., Ltd.

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Presenter: JUNG, Wonju (Seoul National University)

Session Classification: Wed-Mo-Po.05 - Novel and Other Applications I

Contribution ID: **708** Type: **Poster**

Fri-Af-Po.01-05: Analysis of joint stress during quench in a REBCO magnet

Friday, July 4, 2025 2:00 PM (2 hours)

No-insulation (NI) rare-earth barium copper oxide (REBCO) magnets have demonstrated the potential to achieve high magnetic fields in compact spaces. Several REBCO magnets, whether combined with resistive outserts or operating standalone, have successfully reached fields over 20 T. However, many quench events have been reported during operation without clearly identified causes, leading to mechanical deformation and increased resistance in REBCO turns and joints.
A notable characteristic of a quench in NI REBCO magnets is the presence of radial leak current. During a quench, when the magnetic field and current change rapidly, current can flow radially within the magnet. This radial flow causes the azimuthal current in each double pancake (DP) coil to vary, resulting in different magnetic stress values for each coil. Such variations may lead to excessive stress at the joints connecting adjacent DP coils, potentially causing mechanical damage.
In this study, we analyze the joint stress of a REBCO solenoid magnet under a background field during a quench. A turn-distributed circuit model coupled with a thermal resistance circuit is used for quench simulation. The azimuthal current in each turn is obtained from the simulation, and these values are then applied in a 2D axisymmetric finite element model (FEM) to simulate joint stress. The joint stress is plotted alongside quench propagation to illustrate how stress changes as the imbalance in current between adjacent DP coils increases.

This work was supported in part by National R&D Program through the National Research Foundation of Korea(NRF) funded by Ministry of Science and ICT(2022M3I9A1072846) and in part by the Applied Superconductivity Center, Electric Power Research Institute of Seoul National University.

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Presenter: JUNG, Wonju (Seoul National University)

Session Classification: Fri-Af-Po.01 - Quench Detection and Protection II

Contribution ID: **709** Type: **Poster**

Wed-Mo-Po.09-03: A study on inter-strand resistance of Vertically Stacked Tape (VST) cable

Wednesday, July 2, 2025 9:15 AM (2 hours)

The inter-strand contact resistance in REBCO-based superconducting cables is a key parameter influencing current redistribution, AC losses, and cable stability. In this study, we measured the inter-strand resistance of short vertically stacked tape (VST) samples at liquid nitrogen temperature (77 K). The effective contact resistivities between the stabilizer and the REBCO tapes were estimated based on experimental results and validated using a finite element model.
The analysis revealed that the edge-side contact of REBCO tapes plays a significant role in determining the inter-strand resistance. This finding highlights the importance of optimizing fabrication process and material interfaces for improved cable performance. This study provides foundational insights into the inter-strand resistance of REBCO cables, offering a basis for further investigations and optimization in superconducting cable design for advanced applications.

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Session Classification: Wed-Mo-Po.09 - Development and Test of Conductors for Fusion Magnets I

Contribution ID: **710** Type: **Poster**

Fri-Mo-Po.01-10: Stochastic analysis on the factors affecting critical current and index value of multi-tape co-wound NI HTS coil

Friday, July 4, 2025 9:30 AM (1h 45m)

The estimation of critical current (I_c) and the index value for single-tape wound coils and magnets is relatively straightforward. However, for multi-tape co-wound coils, the process becomes complex due to various factors influencing current distribution within the coil. This study conducts a numerical analysis to explore these factors and their impact on the I_c and index value of multi-tape co-wound HTS coils. An equivalent circuit model, the multi-tape turn distributed circuit, is utilized to represent each tape turn in the coil. Key parameters such as the 77 K self-field I_c of REBCO (Rare Earth Barium Copper Oxide) tape, its index value, contact resistance, and lead resistance are treated as variables during the charging simulation. A stochastic approach is employed to analyze the relationship between these parameters and the coil's I_c and index value through multiple simulations using randomly generated parameter values. The results demonstrate a strong correlation between the coil I_c and the average I_c of the REBCO tapes. Furthermore, the coil index value is found to be significantly influenced by the average contact resistivity between the REBCO tapes.

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Session Classification: Fri-Mo-Po.01 - No-Insulation Coils IV

Contribution ID: **711** Type: **Poster**

Sat-Mo-Po.05-04: Precise solder shunt area control for improved quench protection in HTS magnets

Saturday, July 5, 2025 9:30 AM (1h 45m)

High-temperature superconducting (HTS) magnets are essential for advanced applications such as particle accelerators and fusion reactors, requiring effective quench management to ensure safety and performance. No-insulation (NI) coils, which allow current to move between turns during quench events, are commonly used in HTS magnet design. However, the contact conditions between turns in NI coils need further study, especially when combined with other insulation methods like metal insulation. This research presents a soldered surface shunt method that precisely controls the solder shunt height within 200 µm, enabling better tuning of contact resistance and charging delay. We fabricated two 50-turn coils with a 50 mm inner diameter using 4 mm-wide Shanghai Superconductor tape. One coil was co-wound with Kapton tape as insulation (INS), and the other was wound without insulation (NI). The soldered surface shunt was applied to different portions of the coil's top surface (12.5%, 25%, 50%, 75%, and 100% for INS; 33%, 66%, and 100% for NI) using a controlled soldering process. Experiments were conducted in liquid nitrogen at 77 K. Scanning Electron Microscopy (SEM) and Energy Dispersive Spectroscopy (EDS) were used to analyze the solder interfaces. Additionally, a localized heater structure was integrated to induce controlled quenches in specific coil areas. Results showed that increasing the soldered area reduced contact resistance by up to one order of magnitude and increased time constants by two orders of magnitude, enhancing quench stability. The critical current increased by about 9% for NI coils and 10% for INS coils with larger solder areas. The soldered shunt method remained stable over 50 thermal cycles, demonstrating its reliability. Furthermore, resistance estimation models based on SEM and EDS data confirmed the relationship between soldered area and time constant. This study could contribute to future designs of HTS magnets using the solder shunt method.
Keywords: HTS magnets, Contact resistance, Insulation techniques, Thermal stability
Funding: This work was supported in part by the National Natural Science Foundation of China (NSFC) under Grant 52277026, in part by the Strategic Priority Research Program of Chinese Academy of Sciences under Grant XDB25000000.

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Session Classification: Sat-Mo-Po.05 - Quench Detection and Protection IV

Contribution ID: **712** Type: **Poster**

Thu-Af-Po.10-06: Thermohydraulic analysis of a stainless-steel demonstrator coil conduction cooled by high pressure gas-helium

Thursday, July 3, 2025 2:00 PM (2 hours)

A comprehensive thermohydraulic analysis was conducted on a conduction cooled demonstrator coil operating at 20K. The primary objective was to assess potential cooling options for High-Temperature Superconducting (HTS) magnets intended for fusion energy applications. The entire process involved the design, manufacturing, and testing of a 0.2mx0.3m demonstrator coil in a vacuum environment. The demonstrator coil, which featured both straight and circular sections, was designed to investigate the cooling efficiency considering different geometric shapes. This approach aimed to ensure adaptability to various HTS magnet designs. To facilitate conduction cooling, 6mm/4mm (OD/ID) stainless steel pipes were incorporated into the design and high-pressure helium gas served as coolant. The coil itself followed a double pancake structure with stainless steel tape (50 turns). Experimental and simulation-based assessments were carried out to estimate a realistic heat load of 200W. Conduction cooling was achieved using gaseous helium at 20K, and the stainless-steel winding underwent a 10 A current to model operational conditions. Critical parameters such as mass flow rate, pressure, temperature distribution, and heat exchange were evaluated and compared to numerical data. Numerical results indicated that the coil maintained temperatures below 30 K, with inlet temperatures around 20 K and outlet temperatures near 25 K, demonstrating partial non-uniform cooling. This non-uniformity shows the significant influence of coil geometry and flow design on thermal performance. This methodology not only served to validate existing cooling strategies but also showcased the potential for optimizing cooling approaches in larger HTS magnets for future applications. The insights gained from this study may contribute to advancing the understanding of thermohydraulic dynamics in HTS magnet systems, offering valuable considerations for the development of efficient cooling solutions in fusion energy contexts.

Keywords: Cryogenics, thermohydraulic analysis, fusion magnets, gaseous helium
Funding: This work was supported in part by the National Natural Science Foundation of China (NSFC) under Grant 52277026, in part by the Strategic Priority Research Program of Chinese Academy of Sciences under Grant XDB25000000.

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Session Classification: Thu-Af-Po.10 - Cryostats and Cryogenics I

Contribution ID: **713** Type: **Poster**

Fri-Af-Po.08-11: Cyclic mechanical deformation of HPAL composites and its effect on RRR at low temperatures relevant to electric aircraft application

Friday, July 4, 2025 2:00 PM (2 hours)

High power-density motors are required to meet demand for increasing interest in aircraft electrification. To reach these requirements high current density and lightweight conductors are required in the motor windings. With liquid cryogen on-board, low temperatures (20 K with LH2) are achievable where very high purity normal metals benefit from resistance ratio (RR) values of up to 1000. This high RR occur not only due to high purity, but also low levels of defects (including grain boundaries and dislocations). High-purity Aluminum (HPAL) is one such material where 99.999% or higher purity allows for highly competitive ampacity. However, HPAL intrinsically possesses low yield and tensile strength and requires a strengthening matrix for use in applications. Previous efforts in developing a multifilamentary HPAL composites were successful with an Al-alloy as the metal matrix which increased composite strength without degrading HPAL purity, but faced degradation in RR values in electric windings due to an anomalous magnetoresistance contribution. We show in this work the higher resistivity matrix mitigated this anomalous magnetoresistance while maintain the ability to recover the RRR of the HPAL filaments after cold work. A second issue seen in previous HPAL composites was the presence of RR degradation with cycling. However, the new composite design utilizes a metal matrix with a higher elastic modulus in order to enable higher stress before RR degradation. In this work we measure the effect of cyclic mechanical deformation on RRR in HPAL composites at low temperatures in a new testing fixture. We further our measurements and analysis of cryogenic mechanical testing by measuring at various temperatures of interest in electric aircraft applications.
This work was performed under NASA Phase 1 SBIR

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Presenter: Mr KWON, Jin

Session Classification: Fri-Af-Po.08 - Advances in Nb3Sn and MgB2 Conductors I

Contribution ID: **714** Type: **Poster**

Fri-Mo-Po.01-01: Measurement and numerical analysis on the current distribution of parallel co-wound no-insulation REBCO coils

Friday, July 4, 2025 9:30 AM (1h 45m)

No-insulation (NI) coils are known for their high thermal stability and self-protecting features due to turn-to-turn contacts. Parallel co-winding is a promising method to reduce the charging delay of NI coils while maintaining thermal stability. This technique shows significant potential for applications in fusion and other large-scale or high-field magnets. In parallel co-wound NI coils, the potential non-uniform current distribution among parallel superconducting tapes may lead to thermal and mechanical problems. We conducted experiments on small parallel co-wound NI REBCO coils to investigate non-uniform current distribution. The parallel tapes in the input and output sections of the tested coils were separated. A series of Rogowski coils was used to measure the current in each tape. The voltage at different turns within the coils was also measured. In the tested 2-tape and 4-tape co-wound coils, the maximum currents in the parallel tapes during the charging process were 105 A and 60.6 A, respectively, while the average current was 30 A. After the current stabilized, significant non-uniform current distribution remained, with maximum currents of 40.6 A and 59.9 A, respectively. We combined an FEM model based on the T-A formulation with an equivalent circuit model to calculate the current distribution in co-wound coils. The calculated current and voltage results, using the experimental parameters, are consistent with the ramping, sudden discharging, and over-current test results. The calculations also indicated that the current distribution within the coil was also highly non-uniform, primarily influenced by the joint resistance between the superconducting tapes and the terminals. The influence of joint resistance, contact resistance, and other coil parameters on the current distribution was analyzed based on the calculation model and experimental results. Furthermore, the effect of current distribution on local strains considering the screening current effect in high-field magnets was also discussed. This study may contribute to the future development of magnets utilizing parallel co-wound NI coils.

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Session Classification: Fri-Mo-Po.01 - No-Insulation Coils IV

Contribution ID: **715** Type: **Poster**

Sat-Mo-Po.03-01: Strain and Axial Displacement Measurements in the SPARC Central Solenoid Model Coil

Saturday, July 5, 2025 9:30 AM (1h 45m)

The SPARC Central Solenoid Model Coil (CSMC) designed and built by Commonwealth Fusion Systems in collaboration with the Massachusetts Institute of Technology Plasma Science and Fusion Center (MIT PSFC) aims to de-risk design aspects of the SPARC CS. One of the main risks associated with the bucked design of the SPARC tokomak is the large loads from the Toroidal Field magnets on the Central Solenoid. Average pressures of ˜300 MPa on the CS insulation mean the solenoid must have high enough modulus to withstand the pressures without collapsing. The CS is insulated with composite layers consisting of E-glass and Kapton which provide structural support and electrical insulation. Additionally, it is important to predict the cool down axial displacement of the CS to ensure that the proper preload is maintained before operation. Here we present the methods used to measure insulation strains and winding pack displacements during the 20K CSMC test campaign at the MIT PSFC. Strains are measured using a fiber optic strain sensor bonded to the insulation of the winding pack and a low CTE linear displacement translator to measure displacement. This data in turn helps us understand the mechanical performance of the winding pack and determines future processes.

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Session Classification: Sat-Mo-Po.03 - Mechanics of Fusion Magnets

Contribution ID: **716** Type: **Poster**

Thu-Af-Po.11-04: The control system of sub-cooled liquid nitrogen cooling system for C11 CPMU at SSRF

Thursday, July 3, 2025 2:00 PM (2 hours)

Cryogenic Permanent Magnet Undulator (CPMU) is an important kind of insert device at the synchrotron radiation facilities. The magnets of CPMU have a better magnetic performance than a conventional In-vacuum Undulator. The work temperature of CPMU magnets in C11 CPMU is below 80K. The cryogenic operation of CPMU requires a sub-cooled liquid nitrogen cooling system. The operational stability of cooling system is the key factor for device operation throughout one continuous operation period. The control system design for the sub-cooled liquid nitrogen cooling system will be discussed including control system architecture, hardware and software design, control methods. The control loop parameters and performance will be introduced. The system was put into operation in August 2024 and maintains a steady state till January 2025 which has a steady control effect on controlled temperature and pressure.

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Session Classification: Thu-Af-Po.11 - Cryostats and Cryogenics II

Contribution ID: **717** Type: **Poster**

Wed-Af-Po.04-08: Design, fabrication, and experiment of roller shaped high-temperature superconducting coil joint apparatus

Wednesday, July 2, 2025 2:30 PM (2 hours)

The fabrication of high-temperature superconductor (HTS) magnets often involves manual soldering joints, which relies on operator skill and causes performance variations. To address these challenges, this study presents the design, fabrication, and experimental evaluation of a roller-shaped HTS coil joint apparatus for soldering rare-earth barium copper oxide (REBCO) tapes. The apparatus was developed to facilitate the soldering process across various coil dimensions, ensuring high performance and reliable joints between HTS coils.
First, simulations and analyses were conducted to ensure the thermal and mechanical requirements based on prior REBCO tape-to-tape joint researches. The apparatus is equipped with functionalities to control parameters such as solder type, target temperature, heating rate, holding time, cooling time, and pressure. Then, the fabricated joint apparatus was primarily utilized to validate the tape-to-tape soldering process, with a focus on maintaining consistent electro-mechanical performance. Finally, experimental evaluations of HTS coil-to-coil joints evaluations demonstrated the ability to achieve high performance and reliability joint, highlighting its potential for applications in advanced HTS REBCO magnet systems.

Acknowledgement
This research was supported in part by National R&D Program through the National Research Foundation of Korea (NRF) funded by Ministry of Science and ICT (2022M3I9A1073924), and in part by the Applied Superconductivity Center, Electric Power Research Institute of Seoul National University.

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Presenter: PARK, Hyunsoo (Seoul National University)

Session Classification: Wed-Af-Po.04 - HTS Joints

Contribution ID: **718** Type: **Contributed Oral**

Thu-Mo-Or2-06: Modular consequent pole direct-drive superconducting generator for offshore wind

Thursday, July 3, 2025 12:00 PM (15 minutes)

Offshore wind power generation is pivotal for the decarbonization of the energy sector, with projections indicating that installed capacity could exceed 200 GW by 2030. As turbine size and power ratings increase, the industry encounters challenges concerning components such as blades, structures, and generators. Partially superconducting generators (SCGs) (superconducting field, normally conducting armature) offer a promising alternative to conventional permanent magnet machines for offshore wind turbines, given their potential for high torque, efficiency, and reduced mass. However, traditional superconducting machines are often complex, involving intricate manufacturing and prolonged assembly processes that hinder series production. This paper introduces an innovative modular consequent pole SCG, designed as self-contained field coil modules to facilitate high-throughput manufacturing and assembly. The paper explores the electromagnetic characteristics, mechanical design, and cooling strategy, while also providing insights into the manufacturing process of both the modules and the overall generator. The modular segmented cold mass simplifies generator assembly and decreases the magnetic gap between field coils and the armature, enhancing performance and reducing material costs.

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Session Classification: Thu-Mo-Or2 - Rotating Machinery II

Contribution ID: **719** Type: **Contributed Oral**

Wed-Af-Or2-03: Investigation of contact resistivity dependent minimum quench energy for inductive-type quenches in no-insulation HTS coils

Wednesday, July 2, 2025 5:00 PM (15 minutes)

High temperature superconductor (HTS) coils are widely acknowledged for having greater stability margins than low temperature superconductor (LTS) counterparts. In particular, no-insulation (NI) coils are often assumed to exhibit even greater stability owing to enhanced thermal conduction between turns and inherent current bypass capabilities. However, we hypothesize that this assumption may not universally hold. Specifically, reducing the turn-to-turn contact resistivity in NI HTS coils can actually heighten their quench susceptibility, because normal zones can expand through an electromagnetic "inductive-type"mechanism rather than relying solely on the conventional "diffusive-type"thermal conduction. This fundamental difference in quench propagation necessitates distinct stability assessment methodologies for NI HTS coils.

In this study, we examine the influence of turn-to-turn contact resistivities on the stability of single pancake NI HTS coils by determining their minimum quench energy (MQE). Our findings reveal that MQEs for inductive-type quenches decrease as inter-turn contact resistivities are lowered, indicating an increased vulnerability of NI HTS coils to inductive-type quenches when inter-turn contact resistance is excessively reduced.

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Presenter: CHOI, Kibum

Session Classification: Wed-Af-Or2 - No-Insulation Coils II

Contribution ID: **720** Type: **Poster**

Fri-Af-Po.01-06: A Quench Detection Method for HTS Magnets Based on Fiber Optic Michelson Interfering Principle

Friday, July 4, 2025 2:00 PM (2 hours)

High temperature superconducting (HTS) magnet is only option for applications of high magnetic field above 20 T due to high upper critical magnetic field at low temperature. However, the quench detection is challenge for HTS magnet since its low quench propagation velocity coming from low thermal conductivity and wide operation range of temperature. In this paper, we propose a novel quench detection method based on Michelson interfering principle. There are two arm, one arm optical fiber was co-wound with HTS tapes and the other path, so called reference arm, has same length with co-wound optical fiber and locates outside of HTS magnet in bath cooling with constant temperature environment. The laser emits light which is transmitted through a fiber splitter to two arms, that is, the measuring fiber arm and the reference fiber arm. The two beams of light interfere and form interfering intensity which is detected by potoelectric conversion device. The interfering effect associates closely with optical path difference coming from two arms since the refractive index of optical fiber depends on temperature. Since the reference arm locates in constant temperature environment, the measuring arm has same temperature with HTS magnet. While the temperature in HTS magnet rises, although the refractive index of optical fiber in reference arm keeps constant since it in constant temperature so that its optical path also keeps constant, the refractive index of co-wound optical fiber changes so that the optical path difference between two arms creates and the intensity of interfering occurs. Then, the magnets temperature rise is reflected by the phase difference change of the interference light from two arms. The experiment is performed in liquid nitrogen temperature. The results show that the proposed method has the significant advantages of fast response, high accuracy and immunity from electromagnetic interference compared to conventional techniques, which is potential for bottleneck of quench detection for HTS magnet.

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Session Classification: Fri-Af-Po.01 - Quench Detection and Protection II

Contribution ID: **721** Type: **Contributed Oral**

Fri-Mo-Or2-06: Strain measurement of the no-delaminated thermosetting-epoxy-impregnated REBCO coils coated by release agent layers

Friday, July 4, 2025 9:15 AM (15 minutes)

The delamination problem of the epoxy-impregnated REBCO coils was always an obstacle for REBCO magnet application. To avoid the delamination, recently a novel method that coating release agent layers on the REBCO tapes was proposed, and it has been preliminarily verified by REBCO coils impregnated room-temperature curing epoxy (Stycast 2850). For thermosetting epoxy, like IR3 (supplied by Technical Institute of Physics and Chemistry, CAS), silicon release agent was selected as the appropriate material to be coated on the REBCO tapes. The bonding strengths of the interface between the IR-3 epoxy and REBCO tape surface were measured both at room temperature and 77 K. Then several different-radius IR3-impregnated REBCO coils wound by release agent coating REBCO tapes was tested in liquid nitrogen, compared with the controlled coils without any epoxy and release agent, to verify the effectiveness of this method. During the cooling process, the strain inside the IR3- impregnated REBCO coils was measured by Bragg grating fiber sensors or strain gauges, which was compared with the FEM simulation results. The strain during IR3 epoxy curing process was also measured, which indicated there would be intrinsic strain inside the impregnated REBCO coils after curing.

Acknowledgement

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Session Classification: Fri-Mo-Or2 - Mechanical Behavior and Stress III

Contribution ID: **722** Type: **Contributed Oral**

Sat-Af-Or2-08: 42 T Resistive Magnet Performance and 45 T Design Prospects at CHMFL

Saturday, July 5, 2025 3:45 PM (15 minutes)

In September 2024, the 42 T resistive magnet at The High Magnetic Field Laboratory of Chinese Academy of Sciences (CHMFL) was successfully commissioned, and in October, it was opened for user experiments. This paper provides a detailed account of the commissioning process and systematically investigates the evolution of critical parameters, including coil voltage and water flow rate, throughout its experimental operation. Our next major construction milestone is a 45 T resistive magnet, we therefore present a comprehensive overview of its envisioned design parameters.

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Session Classification: Sat-Af-Or2 - Progress in Ultra High Field Solenoids

Contribution ID: **723** Type: **Poster**

Thu-Af-Po.06-02: Design and integration of Top Magnet in the Levitated Dipole experiment

Thursday, July 3, 2025 2:00 PM (2 hours)

Open Star Technologies is advancing the Levitated Dipole reactor concept, utilizing high-temperature superconducting technology to maintain a toroidal magnetic field for effective plasma confinement. Inspired by Earth's magnetic field, this innovative approach offers distinct advantages over other fusion concepts. It enables rapid iteration cycles, ensures inherently stable plasma physics, and leverages groundbreaking applications with HTS technologies. Coupled with cost-effective infrastructure scaling, it guarantees swift and affordable risk retirement.

Levitated dipole concept is realized by combining two magnets, one Top Magnet which provides lifting and containment of the Core Magnet within the vacuum chamber where plasma is generated. Levitating a half a tonne magnet, in the environment specific to the dipole fusion generation technology, poses special challenges to the magnet designer. The Top Magnet provides a lifting/containing force ensuring the toroidal magnet within the experimental chamber is levitated and kept within strict positional tolerances.

The Top Magnet at Open Star is created utilizing 2G (YBCO) HTS tape, wound in a double pancake configuration (˜300 turns each, using a total of ˜2km of YBCO tape). It is designed within its own cryostat to handle significant loads induced by magnetic couplings.

The Top Magnet operates at up to 700A with an AC control component. During levitation procedure, its power supply is controlled using PID modulation ensuring stable position of the Core Magnet. This modulation produces up to ±100V across the HTS coil.

This presentation covers the Open Star Top Magnet design, construction and integration into the control network.

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Session Classification: Thu-Af-Po.06 - Magnets for Fusion Devices

Contribution ID: **724** Type: **Poster**

Thu-Af-Po.10-07: Cooling Design and Thermal Analysis for Thermal Shields of a Cryocooler-cooled Superconducting ECR Ion Source MARS-D Magnet

Thursday, July 3, 2025 2:00 PM (2 hours)

A demonstrative NbTi based Mixed Axial and Radial field System (MARS-D) is being developed for a next-Generation Electron Cyclotron Resonance Ion Source (ECRIS) at Lawrence Berkeley National Laboratory, which employs a novel closed-loop coil design scheme that more efficiently utilizes conductor fields and extend the application of NbTi for high frequency (up to 45 GHz) ECR operation. The NbTi MARS-D magnet consists of a single hexagonally shaped closed-loop coil and a set of auxiliary solenoids. Nine binary leads made of copper leads with design current ranging from 175 A to 600 A and High Temperature Superconducting leads (HTS) ranging from 250 A to 1000 A will be used for magnet energization. A cryostat for cooling the MARS-D magnet is under design at LBL. The MARS-D magnet working around 4.2 K will be bath-cooled in liquid helium using multiple two-stage cryocoolers. An intermediate temperature thermal radiation shield system is adopted to reduce the heat leakage imposed on 4.2 K coil cold mass assembly from room temperature. The thermal shield system consists of upper neck shield, main shield assembly, flexible cooling connections and its supports. The shield system is conduction-cooled by the first-stage cold heads of the two-stage cryocoolers and the cold head of an additional single-stage cryocooler shared with nine binary leads. The maximum temperature on the shields shall be no higher than 60 K, which is limited by maximum allowable working temperature of warm ends of HTS leads. The paper presents thermal analyses on the thermal radiation shield system including heat loads and effects of eddy current induced during magnet energization on its material selection, as well as optimal design of its cooling structure.

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Session Classification: Thu-Af-Po.10 - Cryostats and Cryogenics I

Contribution ID: **725** Type: **Poster**

Wed-Af-Po.01-01: EPOS: A Stellarator to use ReBCO High-Temperature Superconductors

Wednesday, July 2, 2025 2:30 PM (2 hours)

The EPOS stellarator, a compact device for confining electron-positron plasmas, will leverage high-temperature superconductors (HTS) to generate a highly optimized toroidal magnetic field. To achieve this, we will employ non-planar, non-insulated coils made from rare-earth barium copper oxide (ReBCO) tapes, which enable a 2T magnetic field on axis and a plasma volume of approximately 10L. We will use a closed-cycle helium compressor system, which provides cooling of the HTS coils to 20K and superconducting leads to supply current.

In this contribution, we present the engineering design of EPOS, including the optimized winding pack orientation to mitigate torsion and bending-induced damage to the brittle, ceramic ReBCO tape, as well as the mechanical analysis of Lorentz forces on the support structure.

Additionally, we present the thermal and electrical system design, which is critical for achieving the low power consumption required by the cryocooler. To minimize heat loads and ensure reliable operation, we have optimized the thermal and electrical interfaces to achieve very low contact resistances between the superconducting leads and the 22 coils as well as to deliver sufficient cooling power to their winding packs.

We discuss the techniques we employ for manufacturing the non-planar coils, including the development of a winding machine to ensure high-quality and reliable coil production.

Our design decisions were informed by a comprehensive hardware test campaign, which involved the successful construction and testing of a non-planar coil with optimized winding pack orientation, supported by a 3D printed aluminium structure. Notably, we achieved a peak field of 3T on the superconductor, which resembles the conditions in the EPOS experiment.

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Session Classification: Wed-Af-Po.01 - Magnets for Stellerators and Other Configurations

Contribution ID: **726** Type: **Poster**

Thu-Af-Po.03-02: Researches on Disconnectable Superconducting Magnetic Drivers

Thursday, July 3, 2025 2:00 PM (2 hours)

Magnetic drive is a technology that utilizes magnetic force to achieve non-contact driving, which has advantages such as high efficiency, reliability, and environmental protection. It can meet the needs of different working conditions and has important application prospects. Due to the lack of disconnection function in magnetic drives, we conducted researches on magnetic drivers based on superconducting bulk and superconducting magnet in this presentation. The principle and structure of superconducting magnetic drives and their disconnection devices were explained, and the simulation calculations and optimization designs were carried out for the breakable superconducting magnetic drives and their disconnection devices. The prototype of superconducting magnetic drives and breakable magnetic drives were developed, and a testing platform for superconducting magnetic drives was built. Performance tests were conducted on the developed magnetic drives and magnetic disconnectors.

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Session Classification: Thu-Af-Po.03 - Rotating Machinery III

Contribution ID: **727** Type: **Poster**

Fri-Af-Po.10-03: Development of a magnet sorting method for an elliptically polarized undulator for HALF

Friday, July 4, 2025 2:00 PM (2 hours)

The Shanghai Synchrotron Radiation Facility (SSRF) insertion device team is developing several 4.2-meter-long elliptically polarized undulators (EPU) for the Hefei Advanced Light Facility (HALF). Magnet keepers are directly installed onto the sliding girders, rather than utilizing traditional pre-assembled subassemblies, to ensure precise positioning of the magnets in the beam direction. We employed a Hall probe to measure the spatial magnetic field of individual magnets, and took into account machining errors and mechanical deformations in the sorting algorithm. In this paper, we describe the testing process for individual magnets, the measurement of mechanical errors, the sorting algorithm, and demonstrate the optimization results.

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Session Classification: Fri-Af-Po.10 - Undulators

Contribution ID: **728** Type: **Contributed Oral**

Thu-Mo-Or2-04: Development of low AC loss, high purity aluminum (HPAL) and MgB2 conductors and magnets to enable high power density motors and generators

Thursday, July 3, 2025 11:30 AM (15 minutes)

Hyper Tech Research will report on progress that has been made on developing high purity aluminum (HPAL) and magnesium diboride superconductor wires, cables and coils with significantly lower AC losses. The use of HPAL low AC loss stands will enable high power density motors and generators in the 35-45 kW/kg range, with efficiencies in the range of 99%. HPAL low AC loss coils for stators can enable rotating machines at higher frequencies than superconductors, allowing for much higher rpm machines that are lightweight. We will also show that present day MgB2 conductors are usable for AC applications such SMES, motors and generators. Electrical and mechanical properties of strands and cables will be discussed in addition to loss values and strand/cable architecture.

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Session Classification: Thu-Mo-Or2 - Rotating Machinery II

Contribution ID: **729** Type: **Contributed Oral**

Thu-Mo-Or2-07: Conduction cooling test of salient-pole no-insulation HTS field winding for synchronous motor

Thursday, July 3, 2025 12:15 PM (15 minutes)

Recently, due to the electrification of mobility systems such as aircraft and ships, the development of high power density propulsion systems has been actively researched. In conventional electric machines based on permanent magnets and copper, the power density is limited due to constraints in current density and magnetic field. As an alternative, high-temperature superconducting (HTS) motors, which enable high energy density operation, are emerging as a promising solution. In particular, HTS field windings with no-insulation (NI) winding technique enhance operational stability for motors due to their robustness against external disturbances. From a topological perspective, an iron-cored HTS field winding is a viable option due to its advantage in reducing HTS consumption. Additionally, a concept is emerging to integrate hydrogen fuel cells with liquid hydrogen to cool the superconducting field coils of motors. Therefore, it is necessary to verify the operational stability of the field coils at an operating temperature of 20–30 K, which is near the boiling point of liquid hydrogen. In this paper, we design and fabricate a four-pole NI HTS field winding with salient iron-core, and implement current charging experiments in a 20 K conduction-cooled environment before the motor operation test. We use a lumped circuit model with an inductance look-up table according to azimuthal direction coil current for analysis of coil voltage profile considering non-linear properties of iron-core. The following key characteristics of salient pole NI HTS field winding are discussed: (1) magnetic field rise rate differences due to contact resistivity variations between poles; (2) resistive values of the pole-to-pole electrical connection; (3) temperature gradient of coil structure.

Acknowledgement
This research was supported by National R&D Program through the National Research Foundation of Korea(NRF) funded by Ministry of Science and ICT(2022M3I9A1072846), in part by National R&D Program through the National Research Foundation of Korea(NRF) funded by Ministry of Science and ICT(2022M3I9A1073187), and in part by the Applied Superconductivity Center, Electric Power Research Institute of Seoul National University.

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Presenter: YOON, Jonghoon

Session Classification: Thu-Mo-Or2 - Rotating Machinery II

Contribution ID: **730** Type: **Poster**

Wed-Mo-Po.03-07: Investigation of Temperature Effects on Radiation Damage in High-Temperature Superconducting Materials Using Molecular Dynamics

Wednesday, July 2, 2025 9:15 AM (2 hours)

High-temperature superconducting (HTS) magnets are essential for advanced technological applications but are susceptible to performance degradation under extreme environmental conditions, including irradiation and thermal variations. While extensive research has focused on the effects of irradiation on HTS materials, the mechanisms by which temperature influences their irradiation response remain poorly understood. In this study, molecular dynamics (MD) simulations were employed to systematically investigate temperature-dependent radiation-induced damage in HTS materials, with particular attention to the effect of temperature on vacancy formation and restoration. The analysis focused on variations in the threshold displacement energy of oxygen atoms, a critical parameter governing defect formation. The results demonstrate a significant reduction in threshold displacement energy with increasing temperature, indicating heightened susceptibility to defect generation at elevated thermal conditions. Additionally, higher temperatures were found to enhance atomic mobility, promoting partial restoration of irradiation-induced vacancies. These findings reveal that temperature exerts a comprehensive influence on vacancy and defect number through the interplay of enhanced defect formation and partial restoration processes. The results demonstrate that the displacement threshold energy of O1 atom exhibits significant anisotropy in different directions, ranging from 2-35eV. The displacement threshold energy of the oxygen atom at the O4 position is smaller, less than 5eV. By quantitatively assessing the impact of temperature on irradiation effects, this study offers new insights into the thermal and radiation behavior of HTS materials. These insights provide a mechanistic basis for enhancing the performance and reliability of HTS magnets in extreme conditions.

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Session Classification: Wed-Mo-Po.03 - HTS Characterization I

Contribution ID: **731** Type: **Poster**

Fri-Mo-Po.01-03: Characterizing the effects of distributed time constants and screening currents on the voltage responses of no-insulation HTS coils

Friday, July 4, 2025 9:30 AM (1h 45m)

No-insulation (NI) high temperature superconductor (HTS) coils are characterized by their turn-to-turn contact resistivity, leading to circuit-based models composed primarily of resistors and inductors. In a simplified lumped circuit representation, NI HTS coils can be modeled as variations of RL circuits, yielding voltage responses governed by a single-valued time constant. However, experimental measurements tend to deviate from these simplified predictions.

To achieve improved accuracy, two key factors can be considered: (1) the distributed nature of the time constants rather than relying on a single-valued parameter, and (2) the changes in coil inductance caused by screening currents. In this study, we demonstrate how to extend the standard RL-circuit transfer function to accommodate continuously distributed time constants. In addition, we employ the Preisach model of hysteresis to incorporate inductance hysteresis effects, thereby capturing the impact of screening currents on coil voltage responses.

Although these refinements introduce additional complexity, simulations based on these enhanced models retain computational efficiency comparable to that of conventional lumped circuit approaches. Consequently, the refined models can enhance the reliability of NI HTS coil performance assessments, including more accurate estimates of turn-to-turn contact resistivity.

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Presenter: CHOI, Kibum

Session Classification: Fri-Mo-Po.01 - No-Insulation Coils IV

Contribution ID: **732** Type: **Invited Oral**

Sat-Af-Spe1-03: [Invited] Status update on the development of simple-stacking HTS conductors at NIFS and HF

Saturday, July 5, 2025 2:30 PM (15 minutes)

The High-Temperature Superconducting (HTS) magnet is being developed for the fusion reactor magnets. One of the options for the large-current HTS conductor is a simple stacking type in which REBCO tapes are stacked without twisting or transposing.
The Stacked Tapes Assembled in Rigid Structure (STARS) conductor has been developed at the National Institute for Fusion Science (NIFS) since 2007. A stack of REBCO tapes is embedded in a copper stabilizer and a stainless-steel jacket sealed with laser-beam welding. A 20-kA-class conductor sample was successfully tested in a 6-m long, 3-turn coil configuration in an 8-T magnetic field and 20-K temperature. While it is possible to wind this conductor into a three-dimensional (3-D) shape by plastically deforming the stainless-steel jacket, the "Joint-Winding"method with a prefabricated jacket and a mechanical bridge-type lap joint facilitates an on-site winding of large coils. Non-uniform current distribution in the stacked tapes is analyzed by numerical simulation, which shows good comparison with experiments. The internal electrical insulation is helpful to be used in case of a fast coil discharge.
The Wound and Impregnated Stacked Elastic tapes (WISE) conductor has been developed at Helical Fusion (HF) through a public-private partnership with NIFS. An on-site 3-D winding is easy due to its flexibility, and later the winding conductors will be mechanically fixed by impregnation using low-temperature melting metal to form a non-insulation coil. A transport current of 40 kA has been achieved at 8 T, 20 K with a hairpin-shape conductor sample tested at NIFS. A double pancake coil is planned to be fabricated and tested in 2025. Another type of low-resistive mechanical lap joint is also being developed for this conductor.

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Session Classification: Sat-Af-Spe1 - [Special Session] High Current HTS Cables for Fusion and Beyond

Contribution ID: **733** Type: **Poster**

Thu-Af-Po.03-06: Optimized design of high-temperature superconducting permanent magnet synchronous motor based on cogging torque and efficiency

Thursday, July 3, 2025 2:00 PM (2 hours)

High temperature superconducting materials are commonly used in permanent magnet motors for stator armature windings, which can increase the power density of the motor. The use of ferromagnetic materials in the stator reduces the magnetic field in the superconducting coil, which increases the current carrying capacity of the superconducting coil. The rotor uses permanent magnets for excitation. The advantage of this design is that it ensures that the superconducting coil does not incur high AC losses due to excessive current. However, high-temperature superconductivity is environmentally demanding, so additional cooling ducts are installed in the stator tank to keep the superconducting coil below a critical temperature.
The author notes that the magnetic properties of ferromagnetic materials deteriorate at very low temperatures, which leads to poorer permeability and higher iron losses. This will reduce the efficiency of the superconducting motor. In this manuscript, the magnetic properties of three types of motor core materials, namely, conventional non-oriented silicon steel, amorphous magnetic material and nanocrystalline magnetic material, are firstly tested under extremely low temperature environment. The three ferromagnetic materials were fabricated into identical circular samples to simulate the stator of the motor. Through the analysis of the test results, the changing law of low temperature magnetic properties of the three materials is found. Then amorphous magnetic material, which has lower iron loss and smaller change of magnetic properties, is used as the stator of the motor to design and study a high-temperature superconducting permanent magnet motor with a power of 200kW and a speed of 500rpm. Amorphous has a large magnetostriction, and the core laminations made from it cannot be over-compressed, which leads to serious noise and resonance problems in the motor compared with conventional non-oriented silicon steel. The effect of this situation is more pronounced for motors with low-speed operating conditions, which further affects the reliability of superconducting cooling ducts. Therefore, the author optimized the cogging torque and efficiency separately. In order to reduce the cogging torque while improving the efficiency, a multi-objective optimization method based on genetic algorithm is used. The stator structure is optimized by oblique slots, unequal width slots, introduction of auxiliary slots, etc. The number of stator slots and the number of rotor poles are reasonably selected, and the shapes of the stator and superconducting coil cooling pipes are optimized.
Finally, the effectiveness of the optimized design is proved by observing the cogging torque waveform and efficiency MAP diagrams, etc. through the finite element method. The related research in this paper can provide certain material selection basis and design ideas for superconducting motor research.

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Session Classification: Thu-Af-Po.03 - Rotating Machinery III

Contribution ID: **734** Type: **Contributed Oral**

Thu-Mo-Or2-05: Robust, high current HTS-2212 wire, cables and coils for ac and fast ramp applications

Thursday, July 3, 2025 11:45 AM (15 minutes)

Higher field, much lighter-weight and more efficient ac magnets that can operate at affordably cooled temperatures above 12 K require HTS. Stator coils for example operate in fast AC modes where HTS tapes cannot be used due to excessive induction-driven losses, requiring instead HTS as small cross-sectioned, fine-filament, axially twisted wires in transposed cable forms. An approach has been previously described that builds all required loss reducing features into small, nominally 0.16 mm diameter round Bi2212 wires, with non-merged, small-sized. to order 10 mm filaments, short twist pitch lengths in the 5 to 10 mm range, and increased inter-filament resistances. Recently, through process and material science developments, the Je levels attained in these wires now match those attained in the highest performance 2212 magnet wires that do not include loss reducing features. In parallel, wire fabrication was also successfully scaled to produce 3 km piece lengths. Building on these advances, fully transposed low loss cable design developments are under way. This paper is focused on recent wire-related advances and applying those low loss wires to develop advanced, fully transposed low loss 2212 cables, with attributes that are tailored to meet all the specific requirements of applications in next-generation rotating machines and medical systems. A long length generic cabling line has been developed, cabling processes established, and prototypes made, including a baseline 16-strand Rutherford design and a cable of cables 48-strand design. The processes and designs of these of these cables has been optimized with respect to performance to where to strand Je levels are approaching the Je levels non cabled wires. Techniques for reinforcement have also been developed and validated. Their suitability to the fabrication of advanced coil designs is now also under development and in excess of 70 prototype test coils were made to optimize coil designs and fabrication

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Session Classification: Thu-Mo-Or2 - Rotating Machinery II

Contribution ID: **735** Type: **Poster**

Thu-Mo-Po.05-05: Study on the friction effect of multi-layer spiral cable bending behavior

Thursday, July 3, 2025 8:45 AM (2 hours)

Multi-layer spiral cable based on second-generation high-temperature superconducting (HTS) tapes is a great candidate for large-scale magnet applications, due to excellent mechanical and electromagnetic performance. Research has shown that the critical current of superconducting tapes and cables is highly related to mechanical strain. The bending properties of spiral cables are widely considered in the magnet's preparation. It is acknowledged that the bending performance is affected by the friction between multiple layers of tapes, but the mechanism of friction force effects is complex and lacks research. In this paper, a model of single-layer and multi-layer spiral cables is established and a dynamic simulation is conducted on the bending process. The strain evolution in HTS tape with bending deformation is studied. The influence of friction on the slip and deformation of tapes during cable bending is revealed. Friction coefficient parameterized analysis was conducted, and the results show that the coefficient of friction significantly affects the critical current degradation. Two patterns and transitional points can be observed. The research is complementary to the analysis of mechanical and critical current damage during the bending of multi-layer spiral cables.
keywords: REBCO tape, spiral superconducting cable, bending behavior, friction effect, strain

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Presenter: ZHOU, Xuan

Session Classification: Thu-Mo-Po.05 - Mechanical Behavior and Stress I

Contribution ID: **736** Type: **Invited Oral**

Sat-Mo-Or4-01: [Invited] Harnessing Data from Large-Scale 2G-HTS Wires Production by PLD Method: Insights from Thousands of Kilometers of Fusion-Grade Wires

Saturday, July 5, 2025 11:15 AM (30 minutes)

Faraday Factory Japan (FFJ) has established itself as a leader in the second generation of high-temperature superconducting (2G-HTS) wire production through continuous advancements in manufacturing capacity, innovative technology, and research excellence. In 2024, FFJ commissioned a state-of-the-art facility in Zama (Japan), enabling the production of over 1,000 kilometers of 12 mm superconducting tape annually. These 2G-HTS tapes are vital for high magnetic field applications, particularly in fusion energy systems, where they must withstand magnetic fields of 20 T and operate 4.2 K and 20 K.
Over the past five years, FFJ's contributions to the SPARC project and other compact fusion initiatives have driven a significant expansion in 2G-HTS wires production. This unparalleled manufacturing scale, the largest in the history of HTS wire production, has provided an extensive dataset for systematic analysis. These analyses have identified key opportunities to enhance production efficiency and refine research objectives, enabling advancements in 2G-HTS wire performance for real-world applications.
Innovative breakthroughs include the optimization of PLD target compositions to fine-tune microstructures and control impurities, leading to enhanced superconducting properties. By incorporating Y_2O_3 nanoparticles into the YBCO matrix and applying oxygen overdoping techniques, FFJ has achieved engineering critical current densities (Je) nearing 1,000 A/mm^2 at 20 K and 20 T. These enhancements are essential for supporting the demanding requirements of compact fusion systems, including tokamaks, stellarators, and levitating dipoles.
In parallel, FFJ continues the development of 2G-HTS wire solutions for the aviation sector. Such wires are engineered with artificial pinning centers to perform optimally at 65–70 K and under magnetic fields of 1–3 T. The innovations include multilayered architectures with integrated 1D and 3D pinning centers to minimize anisotropy and enhance the angular dependence of critical current (Ic). Additional advancements, such as double-stacked soldered tapes and multifilament wires manufactured through precision laser scribing, address the specific operational needs of electrical aircraft applications.
These accomplishments reflect FFJ commitment to advancing 2G-HTS wires technology, paving the way for transformative applications across energy, transportation, and industry.

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Session Classification: Sat-Mo-Or4 - Technology for Fusion Reactors I

Contribution ID: **738** Type: **Poster**

Wed-Mo-Po.09-02: Experimental study of thermal contact resistance in stacked REBCO tapes for superconducting cable under dry and wet configuration

Wednesday, July 2, 2025 9:15 AM (2 hours)

As interest in and the need for advancements in high-field technology grow, the development of superconducting cables capable of stably carrying high currents in the range of tens to hundreds of kA has become increasingly important. Stacking REBCO tapes can meet the high current demands of those systems while maximizing space efficiency.
Within the temperature-dependent critical current characteristics of superconductors, it is essential to maintain stable temperatures of the stacked REBCO tapes. However, the layered structure inherently introduces thermal contact resistance in the transverse direction due to surface roughness and contact pressure between the REBCO tapes. This resistance creates temperature gradients between the stacks, which must be minimized to ensure the stable operation of REBCO stacked cables.
This paper experimentally investigates the thermal contact resistance of stacked REBCO tapes and explores the parameters to reduce the thermal contact resistance between stacks. Using the REBCO tape stack, both dry and wet configurations with In52Sn48 soldering were tested under varying conditions of former presence and applied pre-load levels. Thermal contact resistance was calculated by measuring the temperature using a conducting cryocooler, and the results were analyzed.

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Session Classification: Wed-Mo-Po.09 - Development and Test of Conductors for Fusion Magnets I

Contribution ID: **739** Type: **Poster**

Wed-Af-Po.05-10: Effects of Neutron Irradiation on the Critical Properties of High-Temperature Superconducting REBCO Tapes

Wednesday, July 2, 2025 2:30 PM (2 hours)

High-temperature superconductors (HTS) REBCO (Rare Earth Barium Copper Oxide) tapes are key candidates for applications in fusion reactors and high-energy particle accelerators due to their excellent critical current densities and high magnetic field tolerance. However, their performance in radiation-intensive environments, particularly under neutron irradiation, remains a crucial research question. This study investigates the impact of neutron irradiation on the critical properties of REBCO tapes, using a combination of macroscopic superconducting performance tests and microscopic structural characterizations. Samples with different doping levels were irradiated with neutrons at doses ranging from 1.0×10^22 to 5.0×10^22 n/m^2. Magnetic induction was employed to determine the critical transition temperature (Tc) and critical current density (Jc), analyzed under varying magnetic fields and temperatures (30 K, 50 K, and 77 K). Transmission electron microscopy (TEM) and neutron diffraction were used to examine irradiation-induced structural changes. Results indicate a dose-dependent Tc reduction and distinct trends in Jc. At 30 K, Jc decreases under low magnetic fields but improves under high fields due to enhanced flux pinning. At 50 K, Jc shows minimal changes, while at 77 K, Jc declines across all does due to dominant thermal activation effects. Notably, higher doping levels mitigate the Jc reduction, highlighting doping as a promising approach to enhance radiation tolerance. TEM analysis revealed irradiation-induced defect clusters and dislocation that contribute to enhanced pinning, while neutron diffraction confirmed lattice distortions correlating with changes in superconducting properties. These findings reveal the interplay between irradiation-induced pinning and thermal activation effects in REBCO tapes and provide guidance for designing advanced HTS materials for radiation-intensive environments, such as fusion reactors and high-energy physics facilities.

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Session Classification: Wed-Af-Po.05 - HTS Conductors II

Contribution ID: **740** Type: **Poster**

Sat-Mo-Po.06-09: Strain measurements on the coils of the MQXFA magnets during the vertical test in liquid helium

Saturday, July 5, 2025 9:30 AM (1h 45m)

The MQXFA quadrupoles of the U.S High Luminosity LHC Accelerator Upgrade Project are being assembled at the Lawrence Berkeley National Laboratory, and then tested vertically in liquid helium (LHe), at 1.9 K, at the Brookhaven National Laboratory. Three magnets initially did not pass the vertical test due to lack of coil support at the end region. These magnets were re-assembled with increased azimuthal preload, and re-tested. Their test was successful, and one of these magnets did not even train during the re-test. Given that the coils are typically thinner at the ends, a decision was made to insert tapered shims at one of the coils ends, in order to provide better support during the test. This modification was implemented in the last two tested magnets and their test was successful. In total, 16 magnets plus three rebuilds have been tested so far. This work presents a summary of the strain gauge data of the tested magnets, with a focus on the rebuilds with increased preload, and on the magnets that had tapered shims inserted.

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Session Classification: Sat-Mo-Po.06 - Mechanical and Magnetic Measurements

Contribution ID: **741** Type: **Poster**

Thu-Af-Po.03-08: Design, fabrication, and operation of proto-type miniature cylindrical YBCO bulk induction motor for cryogen pump

Thursday, July 3, 2025 2:00 PM (2 hours)

Using a superconducting bulk into the rotor enables torque generation by inducing current through an external armature, similar to the principle of an induction motor, without the need for direct current application to the rotor. This topology can reduce rotor resistance losses compared to conventional induction motors due to the low resistance of the superconducting material. Moreover, this topology has been explores for applications in pumps with flowing liquid cryogens, addressing the cooling of the superconducting rotor while simultaneously acting as the pump's motor.
In this paper, a feasibility study is presented on an induction motor with a YBCO bulk mounted on the rotor for a cryogen pump application. Based on the preliminary design, fabrication, and experimental result of a miniature cylindrical HTS bulk induction motor test in a liquid nitrogen environment, a scale-up design of a full-size YBCO bulk induction motor is presented.

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Session Classification: Thu-Af-Po.03 - Rotating Machinery III

Contribution ID: **742** Type: **Invited Poster**

Fri-Mo-Po.01-02: [Invited] 15 T in-field REBCO coil tests to discuss two intriguing, controversial issues for higher field generation: the use of higher conductors and the importance of the misorientation of the REBCO layer's c-axis to the tape plane

Friday, July 4, 2025 9:30 AM (1h 45m)

The Small Test Coil (STC) magnet testbed using a REBCO coil and a 15 T background magnet was designed to answer key issues in high-field, high-stress superconducting magnet technology. Recent STC revisited screening current stress (SCS) and subsequent conductor damage issues, and concluded the limit of the full elastic deformation assumptions for accurate SCS calculations and conductor damage evaluations of high-field, high-stress coils, thus proposing the consideration of elastic-plastic deformation regimes. We are now addressing two intriguing, controversial issues for higher field generation using the same experimental settings of the recent test. The first one is that higher critical current density (J_c) conductors are necessary to generate higher fields, but ironically, such higher J_c results in more conductor damage due to large SCS, which can greatly reduce operational stability. The next one is SCS induction depending on the REBCO layer's c-axis orientation. For instance, if the c-axis points inward towards the magnetic field center, then J_c decreases depending on the field condition, but the penetration depth (w_{pen}) of screening current increases due to the penetrating component increases. In contrast, if it points outward towards the center, then J_c increases but the depth decreases. Since the magnetic force correlates to $J_c \times w_{pen}$, we do not know what is better orientation at present yet. We designed, fabricated, and tested several coils having the same coil dimensions, coil charge scenarios, and background fields, but different J_c and the c-axis orientation. This presentation will provide experiment details, test results, and comparison results.

Acknowledgment: A portion of this work was performed at the National High Magnetic Field Laboratory, which is supported by the National Science Foundation Cooperative Agreement No. DMR-2128556 and the State of Florida. This work is primarily supported by the DOE Office of Fusion Energy Sciences Grant DE-SC0022011.

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Session Classification: Fri-Mo-Po.01 - No-Insulation Coils IV

Contribution ID: **743** Type: **Poster**

Sat-Mo-Po.09-04: Performance evaluation of forced-flow cooling HTS SMES with 6 kA-level current capacity

Saturday, July 5, 2025 9:30 AM (1h 45m)

For the situation of energy compensation that needs several kA level current capacities, we developed a high temperature superconducting magnetic energy storage system. This HTS SMES system can fill the gap in research on superconducting energy storage systems in the field of high current-carrying energy compensation. The SMES coil consists of 8 sub-solenoid coils serially connected with each other. Each sub-solenoid coil is wound with a new type of CORC cable with hollow 316L mandrel and outer 316L jacket, which can form the central and circumferential cooling channels. the 8 sub-solenoid coils are cooled with forced-flow supercritical helium cooling method. The welding technology between 316L jacket and copper block for current conducting has been studied based on a lot of experiment, which is aiming to avoid REBCO damage and realize high vacuum rate. The rated operating current is 6 kA and the maximum stored energy can reach 1 MJ. Based on the model coil with 20 m CORC cable, we finish the coil winding experiment. The CORC joint with forced-flow cooling channel is also prepared based on the model coil. The test results show that the critical current of the model coil can reach 2650 A (theoretical value is 2600 A) at liquid nitrogen temperature. The electrical resistance of the joint is about 50 nΩ. It means that the coil winding method and CORC joint can meet the operating requirements. The forced-flow cooling test of the model coil at 10 K is also undergoing. The preparation of all the CORC cables and SMES assembling has been finished. The testing at 10 K temperature zone with supercritical helium will be finish in 2025.

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Session Classification: Sat-Mo-Po.09 - Energy Storage/SMES, Levitation and Magnetic Bearings

Contribution ID: **744** Type: **Poster**

Sat-Mo-Po.05-03: Effect of Screening Current on Stability of REBCO Magnets

Saturday, July 5, 2025 9:30 AM (1h 45m)

Screening currents on REBCO magnets are well known as causes of troublesome. The screening current-induced fields cause a low quality; i.e., it deteriorates the field homogeneity or generate unexpected fields. In recent years, the local high strain effect due to screening currents has been investigated. The screening current under high magnetic fields rotate REBCO tapes. It results the REBCO tape rotation with local high strain. Finally, the REBCO tapes have damages of plastic deformation together with the critical current degradation.
Meanwhile, as far as we experienced, some REBCO magnets reached to quenches at operating currents lower than the rated currents or the critical currents. We have investigated the cause of early quenches through simulations. As well known, some REBCO magnets have large screening currents induced by the self fields. The simulation results show a possibility that the screening currents generate a high heating locally. We will clarify such curious heating phenomenon through some simulation, and we will investigate its effect on the magnet stability. In addition, we will investigate some extra heating caused by the leakage currents (radial currents) of no-insulation REBCO magnets after stopping the current increasing.

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Session Classification: Sat-Mo-Po.05 - Quench Detection and Protection IV

Contribution ID: **745** Type: **Poster**

Fri-Af-Po.10-06: Design, fabrication, and testing of a double-period undulator prototype for the SHINE project

Friday, July 4, 2025 2:00 PM (2 hours)

The FEL-II beamline of the Shanghai High Repetition Rate XFEL and Extreme Light Facility (SHINE) will utilize 14 advanced double-period undulators to cover the photon energy range from 0.4 to 3 keV. Magnetic force compensation technology has been adopted to reduce the overall size of the undulator to address the limited tunnel space. Specifically, a new magnet array is added next to the existing planar undulator magnet array, with a fixed offset in the beam direction between the two magnet arrays. When one undulator is in working, the other provides a repulsive force to reduce the magnetic load on the girder. This paper introduces the design, fabrication, and testing of a double-period undulator prototype in detail.

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Session Classification: Fri-Af-Po.10 - Undulators

Contribution ID: **746** Type: **Poster**

Sat-Mo-Po.06-08: Integration of a Nb3Sn and a Bi-2212 CCT magnet for a hybrid dipole magnet test

Saturday, July 5, 2025 9:30 AM (1h 45m)

As part of the U.S. Magnet Development Program, LBNL fabricated a hybrid magnet combining Nb3Sn and Bi-2212 canted-cosine theta (CCT) coils. This hybrid magnet integrates CCT5, a 1 m long, 90 mm bore Nb3Sn dipole magnet with BIN5c, a 39 cm long, 30.8 mm bore Bi-2212 dipole magnet. These magnets were fabricated and tested individually, and they were not originally designed to be assembled together. The integration of these two magnets posed several mechanical challenges due to their differing lengths. This work provides an overview of the different stages the integration went through, highlighting the mechanical considerations that led to the final assembly configuration. Additionally, the quench protection strategy associated with the hybrid magnet test is discussed.

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Session Classification: Sat-Mo-Po.06 - Mechanical and Magnetic Measurements

Contribution ID: **747** Type: **Poster**

Sat-Mo-Po.05-02: Quench measurements on ReBCO conductors in applied magnetic fields above 15 T

Saturday, July 5, 2025 9:30 AM (1h 45m)

The high current density of ReBCO conductors at elevated fields makes them particularly suitable for high-field applications. One of the key challenges in the design of high-field ReBCO devices is effective quench detection and protection, making it crucial to investigate the magnetic field-dependent quench behavior of ReBCO conductors. The minimum quench energy (MQE) is known to decrease with increasing background field due to the reduced critical temperature and current sharing temperature. Higher magnetic field may increase the normal zone propagation velocity (NZPV) because of the reduced temperature margin, but they may also decrease the NZPV due to the reduced critical current density. In this study, the MQE and NZPV of ReBCO conductors were measured in applied fields above 15 T using the 200 mm bore water-cooled resistive magnet developed by the High Magnetic Field Laboratory at the Chinese Academy of Sciences, with transport currents ranging from 50% to 70% of Ic. The measurement results are analyzed, discussed and compared.

Acknowledgements
This work was supported in part by the National Natural Science Foundation of China under Grant 52307036 and National Key R & D Program of China under Grant 2024YFA1613300.

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Session Classification: Sat-Mo-Po.05 - Quench Detection and Protection IV

Contribution ID: **748** Type: **Contributed Oral**

Wed-Af-Or1-08: Design and Test of a 5-T / 34-mm REBCO Dipole Magnet Insert for a 15-T Full-Service-Field Testing Facility

Wednesday, July 2, 2025 6:15 PM (15 minutes)

A new testing facility employing a 15-T transverse field to evaluate the full-service-field characteristics of superconducting materials is now under development in China. A key objective is the development of a large bore, 15-T dipole magnet to provide the transverse magnetic field load. In this study, we designed and constructed a compact high-temperature superconducting (HTS) dipole magnet insert, consisting of six block-type no-insulation double pancakes (DP) wound with REBCO tapes. The insert features a 34-mm user bore and is designed to generate a 5-T field at 4.2 K with an operating current (J_{op}) of 278 A, within a 10-T LTS background dipole magnet. Each DP coil incorporates hard bending at both ends with a bending diameter of 1 m. To suppress the electromagnetic stress under high background fields, circumferential confinement structures were installed around the REBCO coil group. Numerical simulations indicate that the maximum strain within the coils is less than 0.3%, while the maximum von-Mises stress within the supporting structure remains below 700 MPa, assuming uniform current within the coils. Considering the screening current, the maximum current operating point, defined as the maximum ratio of $J_{\mathrm{op}}/J_{\mathrm{c}}$ across the magnet, is 0.583. The magnet was tested independently at 4.2 K. Over three charging cycles, small voltage spikes were observed during current ramping, most of which disappeared in subsequent charging sequences. However, a large voltage spike above 3 mV occurred at I_{op}=232 A with the central field of 3.91 T, prompting the current to be reduced to 210 A. No damage was detected afterward. Future tests at 4.2 K within a 6-T LTS dipole magnet are planned. This work provides valuable validation of the design methodology and fabrication techniques for block-type HTS dipole magnets with hard bending.

This work was supported by the Special Fund for Basic Research on Major Scientific Instruments of National Natural Science Foundation of China under Grant No. 12327901, and the National Natural Science Foundation of China under Grant No. 52277026.

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Session Classification: Wed-Af-Or1 - HTS and Hybrid Magnets for Accelerators

Contribution ID: **749** Type: **Poster**

Thu-Mo-Po.09-08: Development and evaluation of mechanical reinforcement strategies for REBCO racetrack coils using a custom test rig

Thursday, July 3, 2025 8:45 AM (2 hours)

High-temperature superconducting (HTS) motors have emerged as a compelling alternative to conventional copper-based systems by achieving significantly higher current density and stronger magnetic fields, thereby realizing remarkable increases in torque density. These advantages have spurred intensive research into adopting HTS motors for electric propulsion in aircraft and ships. While cryogenic operation and mechanical stability both present formidable challenges, our work specifically focuses on ensuring the mechanical stability of HTS racetrack coils under high current density—an essential factor for reliable and robust operation.
To systematically address this challenge, we have developed a dedicated evaluation rig designed to investigate the mechanical behavior of racetrack coils and their reinforcement structures. Instead of reproducing Lorentz forces through high background magnetic fields, our method applies external mechanical forces directed radially outward from the coil's innermost region. This setup effectively simulates the loads experienced during actual operation, allowing for direct assessment of coil deformation and effectiveness of reinforcement structures. By centering our research on mechanical stability, we aim to identify and refine reinforcement strategies that enhance the operational reliability of HTS motors at high current densities.

<Acknowledgment>
This work was supported in part by National R&D Program through the National Research Foundation of Korea(NRF) funded by Ministry of Science and ICT(2022M3I9A1073924), and in part by the Applied Superconductivity Center, Electric Power Research Institute of Seoul National University.

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Session Classification: Thu-Mo-Po.09 - Conductor and Coil Measurement/Test Techniques and Facilities II

Contribution ID: **750** Type: **Poster**

Wed-Af-Po.02-02: Magnetic field measurement and analysis of the detector solenoid for the COMET experiment

Wednesday, July 2, 2025 2:30 PM (2 hours)

The Standard Model of particle physics is not a perfect theory. Many experiments seek to observe phenomena beyond the Standard Model to fix it.
COMET experiment (COherent Muon to Electron Transition) is planned to be conducted at J-PARC. COMET aims to find the neutrinoless transition of muon to electron, known as "μ-e conversion."To find this process, the first stage of COMET, COMET Phase-I, plans to produce approximately 10^{15} muons by a strong proton beam from J-PARC. This proton beam first enters the Pion Capture Solenoid(PCS), colliding with a carbon target to produce pions. These pions decay into muons, which are transported through a 90-degree curved Transport Solenoid to the Detector Solenoid (DS). In the DS, there is an aluminum target to capture a muon in its atomic nucleus, and the tracker detector inside the DS is designed to detect trajectories of electrons produced from a muon captured in the aluminum nucleus via μ-e conversion ($\mu^- + N(A,Z) \rightarrow e^- + N(A,Z)$). This process is extremely suppressed in the Standard Model with a predicted branching ratio of $O(10^{-54})$. Detecting this process with the sensitivity of COMET Phase-I ($\sim 10^{-15}$) would provide evidence for new physics beyond the Standard Model.
Due to the mass difference between the muon and the electron, the electron's momentum converted from the muon in the aluminum nucleus is estimated to be $105\ \mathrm{MeV}/c$. COMET has to distinguish this electron by the momentum. COMET Phase-I plans to measure this momentum using the magnetic field's value and the signal electron's track curvature.
Therefore, the magnetic field map around the detector region is required to be measured with a relative accuracy of less than $0.5\ \%$ to realize a sufficient sensitivity for the outgoing mono-energetic conversion electrons. COMET Phase-I requires the superconducting solenoid magnet as the DS, which can generate a $1\ \mathrm{T}$ magnetic field at the center of the magnet The DS was fabricated in JFY 2023 and tested in March and June 2024 without an iron yoke. The DS was cooled by conduction cooling by 3 Gifford-MacMahon cryo coolers and could be successfully cooled down to about 4 K for two weeks, including liquid nitrogen-precooling for the first week. The DS has also been successfully excited to the rated current $189\ \mathrm{A}$ without any training quenches. The magnetic field map of DS was measured using a 3-axis Hall probe, and the analysis of the result is in progress. The detailed results of the analysis will be presented at this conference.

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Session Classification: Wed-Af-Po.02 - Detector and Spectrometer Magnets

Contribution ID: **751** Type: **Poster**

Thu-Af-Po.06-04: Non-Insulated HTS Magnet Parameter Identification

Thursday, July 3, 2025 2:00 PM (2 hours)

OpenStar Technologies Ltd is pursuing a levitating dipole reactor (LDR) for fusion energy production. As part of the first LDR prototype, a 5.6 T, 1.44 kA HTS magnet, Junior, has been successfully designed, built and tested.

Junior consists of 14 non-insulated (NI), solder impregnated HTS coils connected in series. Coil parameters such as radial resistance and joint resistances are carefully designed parameters which impact magnet performance and place constraints on other systems, such as the on-board HTS Power Supply (Flux Pump). These parameters must be estimated to validate that they met design specifications. Two factors complicating the Parameter Identification process included mutual coupling between coils and joint resistances being embedded in coil voltage measurements.

Each of the 14 coils are inductively coupled, described by an inductance matrix, M, and estimated using COMSOL. Circuit models (ODE's) were derived for magnet charging and discharging cases, from which radial and joint resistances could be estimated using experimentally obtained coil and coil interface voltage measurements. Curve fitting was performed using Non-Linear Least Squares.

The results showed good agreement between estimated parameters and experimental data. It was also revealed that coil radial resistances impact the zero-field region in the magnet torus center, which is a requirement set by the on-board HTS Power Supply due to the transient response of coil currents during charging. This was a result predicted by field modelling and verified experimentally. While these results are of specific interest for dipole fusion magnets, the estimation approach can be applied to any magnet comprised of multiple NI HTS coils.

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Session Classification: Thu-Af-Po.06 - Magnets for Fusion Devices

Contribution ID: **752** Type: **Poster**

Fri-Mo-Po.02-01: Design of Maglev Rail Based on Halbach Array Topology Optimization

Friday, July 4, 2025 9:30 AM (1h 45m)

Since there's a huge travel speed gap between airplanes (900km/h) and high-speed trains (300km/h), maglev trains (400~1000km/h) now seem having an extensive development space. The performance of the maglev rail is an important factor which limits the development of maglev trains. Conventional maglev magnetic rails mainly adopt the scheme using equidistant permanent magnets(PMs), while the more advanced Halbach array scheme, which can effectively increase the single-sided magnetic density (increase the levitation force) and improve the sinusoidal distribution of magnetic field (increasing guiding force). The change of the width ratio of the PMs in different magnetization directions in the Halbach array will significantly affect the magnetic density. In this paper, by optimizing the topology and arrangement of the PMs in the maglev rail, the optimal width ratio is calculated to improve its suspension force and guiding force. Then the magnetic field distribution is subjected to finite element calculation, and five orbital models of different schemes are built and tested, and the correctness of the scheme is verified by superconducting suspension test.

Section II. Experimental Scheme.
In order to explore the influence of the structure and arrangement of PMs on the performance of the Halbach array maglev rail and the advantages of the Halbach array maglev rail over the traditional maglev rail, five models with different PM arrangements were built: (a) Equal width NSNS array; (b) Equal width Halbach array; (c) Optimized Halbach array scheme A; (d) Optimized Halbach array scheme B; (e) Triangular array).

Section III. Calculation and Analysis of Mathematical Model.
Based on the equivalent surface current method and Biot Savart Law, establishes a mathematical model of the magnetic levitation orbit and compares the numerical calculation results with the finite element calculation results.

Section IV. Finite element calculation and analysis.
A two-dimensional model is adopted, and the change of magnetic density in the direction of maglev rail is ignored. In the optimization process, the total weight of the PM in Scheme (b) and Scheme (c) is consistent, which means the total area of the magnetic rail is the same in the two-dimensional model calculation process. The optimization parameter is the width ratio of the of PM, so the height of the PM remains unchanged. In Scheme (b), the width of each PM is 19mm and the height is 23mm. In Scheme (c) and Scheme (d), the width of the transverse magnetized PM is X1, the total width of the maglev rail is 115mm, and the width of the longitudinal magnetized PM is (115-3X1)/2. By comparing the result of different scheme, it is found that when the width ratio of the transverse magnetized PM to longitudinal magnetized PM is 3.18, the performance of the maglev rail is optimal.

Section V. Physical model construction of maglev rail and comparative analysis of experiments.
Firstly, the high-grade N52 NdFeB PM was selected, and the guide assembly tooling and the magnetic rail magnetic steel holding bracket (all 316 stainless steel materials) were designed. The upper surface of the magnetic rail was protected by a 3mm thick stainless steel cover plate, and

the magnetic flux density perpendicular to the upper surface of the magnetic suspension track was measured by Tesla meter (378 test points for each scheme), and the magnetic flux density data of the five schemes at 3mm were compared. In order to ensure the accuracy of the experiment, the punctuation test was carried out at the junction of the magnetic rail surfaces of different schemes, and the measurement results were repeatedly fitted. In order to verify the above theoretical analysis and performance test, the superconducting carrier is designed and the suspension experiment is carried out. Liquid nitrogen is added to the carrier to cool the superconductor to the superconducting state. By measuring and comparing the suspension height of the superconducting carrier on the magnetic track of each scheme, the effects of the five schemes are compared.

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Session Classification: Fri-Mo-Po.02 - Bulk and Permanent Magnets

Contribution ID: **753** Type: **Invited Poster**

Wed-Af-Po.08-04: [Invited] Test facility for rapid and iterative evaluation of magnet technologies at OpenStar Technologies Ltd.

Wednesday, July 2, 2025 2:30 PM (2 hours)

OpenStar Technologies Ltd. is advancing fusion research through the development of a levitated dipole reactor inspired by the Levitated Dipole Experiment (LDX). The reactor design includes two main magnet components: a suspended, doughnut-shaped high-temperature superconducting (HTS) magnet at the chamber's center, and a top magnet above the chamber to maintain stable magnetic levitation.

All technologies behind the coil design—ranging from advanced winding techniques, superconducting materials, and joint resistance methods—were developed in-house at OpenStar. To support this work, a widely applicable testing facility has been essential during the development, validation, and quality assurance of the magnets and their components.

Key applications of this testing facility include:
- Individual ReBCO HTS Sample Testing: Testing joint resistance, current leads, and material performance.
- Coil Evaluation: Testing coils in various configurations, from small R&D coils to 1-meter-diameter production coils, both insulated and no-insulation types.
Custom Vacuum Chambers: Specialized chambers for testing different magnet designs and cooling methods.
- Liquid Nitrogen (LN2) and Cryogenic Testing: Optimized for testing the 14 ReBCO coils within the levitated dipole reactor under operational cryogenic conditions.
- In-house Electronics: Custom electronics and instrumentation for real-time monitoring and data collection during testing.

This presentation will showcase the testing facility's role in quality assurance, particularly in evaluating the performance and reliability of each ReBCO coil before integration into the levitated magnet system. It will highlight the use of our 1.2-meter vacuum chamber, which facilitates rapid, iterative conduction-cooled testing of fully assembled magnets. This capability allows for quick issue detection and resolution, significantly accelerating the overall development process.

Additionally, the presentation will cover new testing capabilities being added to meet the demands of next-generation fusion magnets. New test facilities are being designed to:

- Handle complex magnet geometries and configurations.
- Support levitation stability and control testing with a new customized vacuum chamber for suspended magnets.
- Validate quench detection and tolerance in magnet designs.
- Enable strain and stress measurement.
- Automate testing for faster, repeatable quality assurance.

By expanding our testing infrastructure, OpenStar will reduce development time and enable simultaneous, faster testing of all magnet system components.

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Session Classification: Wed-Af-Po.08 - Conductor and Coil Measurement/Test Techniques and Facilities I

Contribution ID: **754** Type: **Poster**

Fri-Af-Po.06-03: Graded parallel-wound coil technique for highly compact HTS magnet.

Friday, July 4, 2025 2:00 PM (2 hours)

This work presents a graded parallel-wound (GPW) coil technique for high temperature superconductor (HTS) magnet consisting of multiple pancake coils. The coil is wound by parallel-stacked HTS tapes, all the coils are connected in series, so that they have a same transport current. The key idea is to assign number of parallel-stacked tapes to pancake coils on different position of the magnet: the top and bottom pancakes have most parallel-stacked tapes as well as lowest overall current density, and the middle pancakes have least parallel-stacked tapes as well as highest overall current density. The GPW technique minimizes the detrimental anisotropy in current-carrying capacity of HTS tape, and enable all the HTS pancake coils on different position have similar ratio of transport current to critical current. It enables HTS magnets to be highly compact, minimum tape usage as well as magnet price. A 25T@20K HTS magnet is developed to validate the GPW technique. The magnet generates a 25 T field at the center, a record high in magnetic fields for operating temperature upon 20 K. The total tape usage is reduced more than 40% in comparison to its counterpart wound with single tapes. The results demonstrate strong potential of GPW technique for HTS high field magnets.

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Session Classification: Fri-Af-Po.06 - High Field HTS Solenoids

Contribution ID: **755** Type: **Poster**

Wed-Mo-Po.09-08: Electro-mechanical and thermal characterization of simply-stacked REBCO flat cable for fusion magnet

Wednesday, July 2, 2025 9:15 AM (2 hours)

REBCO coated conductors have emerged as a promising option for high-field fusion magnet applications, thanks to their outstanding critical current performance. However, their high aspect ratio tape-like cross-section, anisotropic properties, and susceptibility to various transverse mechanical stresses require careful consideration in cable design, particularly to prevent issues like delamination. In this study, we propose and investigate a flat-shaped REBCO cable, featuring multiple horizontally aligned REBCO substacks, each formed by stacking dozens of individual tapes. aimed at high-current TF (toroidal field) magnets operating at 20 K under a high magnetic field. By reducing the number of tapes in each substack and horizontally distributing multiple substacks close to the bending neutral axis, our design mitigates electro-mechanical strain such as cable bending while preserving high electromagnetic performance.

To validate the feasibility of this approach, we fabricated multiple cable prototypes using tapes obtained from different manufacturers and subjected them to various impregnation schemes—including a dry (non-impregnated) method and a solder-impregnated concept. We then performed comprehensive tests on the electromagnetic, mechanical, and thermal performance of these cables in a 77 K liquid nitrogen environment. Electromagnetic characterization involved measuring the critical current of representative tapes and evaluating interfacial contact resistances. Mechanical performance was assessed by examining how critical current degraded under different cable bending radii. Finally, thermal stability was investigated to analyze the cable's resilience in quench-prone operational scenarios.

<Acknowledgment>
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Session Classification: Wed-Mo-Po.09 - Development and Test of Conductors for Fusion Magnets I

Contribution ID: **756** Type: **Poster**

Thu-Mo-Po.03-09: Study of coil end of cos-theta superconducting coil with mini cable

Thursday, July 3, 2025 8:45 AM (2 hours)

The saddle-shaped coil with mini round cable is a commonly used type of superconducting magnet coils. The cables are embedded in the slots on the formers for winding. The end shape of the coil affects the winding process and the magnetic field. This article compares several types of end shapes for saddle-shaped coils, including the radical-type end, Walstrom end, circular arc transition end, and B-spline end. The main difference lies in the relationship between the axial position z and the azimuth angle φ. This article provides detailed equations describing the path of the coils for the four types of end shapes, including the path equations for the jumper section. The design and processing methods of the coil fomers and slots are introduced for different ends. Two methods for establishing finite element models of the saddle-shaped coil using the opera3d 20-node brick, are proposed in this paper. One is to establish it turn by turn with a circular cross-section, and the other is to establish it layer by layer with a fan-shaped cross-section. The calculation method of the 20-node model are described in detail, and the modeling method is suitable for any end shape. Simulation was used to assess the impact of different end shapes on the maximum field at the end and the integral field. The fomers is processed with different end shapes, and a dipole coil and a hexapole snake coils are respectively wound to preliminarily evaluate the winding process of different end-shaped coils. This paper compares different end shapes from the aspects of smoothness, winding process, wire usage, maximum field at the end, and integral field. This study provides valuable insights for selecting and designing end shapes for saddle-shaped superconducting coils.

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Session Classification: Thu-Mo-Po.03 - Design and Development of Accelerator Magnets II

Contribution ID: **757** Type: **Poster**

Sat-Mo-Po.07-01: Design of a Bi-2212 dipole insert for a high field hybrid magnet

Saturday, July 5, 2025 9:30 AM (1h 45m)

In the framework of the U.S. Magnet Development Program, LBNL is planning to fabricate a high field hybrid magnet combining Nb3Sn and Bi-2212 dipole magnets. The Nb3Sn outsert will be a four-coil canted cosine theta (CCT) dipole magnet, designed to generate 14 T in a 120 mm bore diameter. The Bi-2212 insert aims to achieve the highest field possible in a 40-45 mm diameter bore. Coil designs based on the CCT and the SMCT technologies are being considered for the Bi-2212 insert. However, winding a wide Rutherford cable in such a small radius presents significant challenges, primarily due to de-cabling issues caused by bending and twisting the cable during the winding process. To address these challenges, a tilted channel at the pole region is being considered for the CCT option in order to ease the hard-way bend of the cable. In addition, a new coil design approach, based on the uni-layer coil concept, is being explored. This work presents these modifications to the coil design, and discusses the results of winding tests conducted using these approaches.

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Session Classification: Sat-Mo-Po.07 - HTS Magnets

Contribution ID: **758** Type: **Poster**

Fri-Af-Po.10-09: A magnetic measurement system for cryogenic permanent magnet undulator (CPMU)

Friday, July 4, 2025 2:00 PM (2 hours)

Compared to the conventional temperature oscillator, CPMU enhances the peak magnetic field of the oscillator. However, due to limitations in its design structure, a visual high-precision magnetic measurement based on C# is developed for vacuum-based magnetic field testing and correction. The measurement system comprises a Hall probe, a vacuum translation motor, a laser interferometer optical lens, among others. This system enables accurate adjustment and recording of the vertical Y position of the probe, as well as the left and right tilt angles and straightness along the vertical Y direction. The probe can move up to 2.6m. After modifying and integrating the probe's position at room temperature, test data is compared with that obtained from a three-dimensional point measurement platform with excellent rigidity to ensure high test accuracy. It can be utilized for testing purposes in CPMU.

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Session Classification: Fri-Af-Po.10 - Undulators

Contribution ID: **759** Type: **Poster**

Sat-Mo-Po.06-02: Mechanical behavior of no insulation HTS insert coil for a 15 T hybrid dipole magnet

Saturday, July 5, 2025 9:30 AM (1h 45m)

A new testing facility employing a 15-T transverse field to access the full-service-field characteristics of superconducting materials is now under development in China. A primary objective involves producing a large bore 15-T dipole magnet to serve as the source of the transverse magnetic field load. The magnet consists of a Low-Temperature Superconducting (LTS) dipole magnet providing 12 T and a High-Temperature Superconducting (HTS) dipole magnet insert providing 3 T. The HTS dipole magnet insert is composed of four coils wound with REBCO tapes, and a block-type configuration with flared ends is utilized to acquire high magnetic field within a large bore. Reliable prediction of strain and stress inside the coil is paramount for designing suitable support structure. In this paper, the stress and strain under high magnetic fields were analyzed using both homogenized and detailed models, with special emphasis on the mechanical properties of the flared ends. Firstly, the mechanics in superconducting coils are modeled assuming homogenized material properties inside a coil volume. Then, a multi-scale structural analysis model suitable for no insulated HTS coil was developed, the model takes into account the contact nonlinearity of the component structure, which can simulate the contact and separation behavior between adjacent turns during the deformation process. We discussed the mechanical properties of the magnet based on the analysis results, which show that significant stresses occur at the flared ends. Furthermore, considerable differences between the behavior of modeled homogenized coil blocks and coils where turns are individually considered. This work can effectively guide the structural design of the HTS dipole magnet insert.

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Presenter: LU, Jiaqi (Tsinghua University)

Session Classification: Sat-Mo-Po.06 - Mechanical and Magnetic Measurements

Contribution ID: **761** Type: **Contributed Oral**

Wed-Mo-Or3-05: Data-Driven Approach to Maximize both Ic and n-index in PLD Processed REBCO Coated Conductors

Wednesday, July 2, 2025 12:15 PM (15 minutes)

Establishment of stable and reproducible mass-production method for high performance REBCO coated conductors (CCs) is now crucial issue to realize practical applications of REBCO CCs in industrial scale for such application as compact fusion reactor. Critical current, Ic, of the wire is one of the most important material parameters in the CCs. The steepness of the current-voltage (I-V) transition, which can be characterized by the power index of the I-V curve (so called n-index), is also relevant from both practical and fundamental point of view, however, there is very limited study on the influence of process conditions on the n-index. In this study, we demonstrate a new data-driven approach to accelerate the development of the manufacturing method of CC wires. We have had succeeded in measuring Ic and n-indices as a function of position with high-throughput in reel-to-reel manner in a long REBCO coated conductors. This measurement method is further coupled with machine learning based regression analysis by using combinatorial long length samples of REBCO CCs fabricated by pulsed laser deposition (PLD) to clarify the influence of PLD conditions on both Ic and n-index of the REBCO wire. We have succeeded in predicting Ic and n-index by the ML model from the deposition conditions. This data-driven approach allows us to understand the influence of the control parameters in the PLD process in detail and to optimize the deposition conditions efficiently in industrial scale production systems.
Acknowledgements: This work was supported by Moonshot R&D - MILLENNIA Program Grant Number JPMJMS24A2 and JSPS KAKENHI Grant Number JP24H00320.

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Presenter: KISS, Takanobu

Session Classification: Wed-Mo-Or3 - REBCO Manufacturing

Contribution ID: **762** Type: **Contributed Oral**

Sat-Af-Or4-03: Microstructure and heat treatment study of ultrafine Nb3Sn jelly roll wires

Saturday, July 5, 2025 5:00 PM (15 minutes)

Novel ultrafine jelly roll Nb3Sn ultrafine wires, i.e. ~50 µm diameter, offer the potential of building Nb3Sn magnets using the react-and-wind approach with high-Jc wires. The high flexibility of these wires due to their small diameter, the ability to assemble multiple of them in Rutherford cables, and the long unit lengths that have recently been manufactured motivates further studying the performances and behavior of these ultrafine wires.
A heat treatment study of individual ultrafine jelly roll Nb3Sn wires will be presented. A qualitative and quantitative observation of phase and microstructure evolution during the heat treatment by electron microscopy will be presented. The residual resistivity ratio (RRR) results of the wires after heat treatment to study Cu-matrix contamination from over-reaction in regions not visible in the analyzed cross-sections will also be summarized.

This work is supported by the U.S.-Japan Science and Technology Cooperation Program in High Energy Physics under DOE National Laboratory Program Announcement Number LAB 24-3200. The work performed at Lawrence Berkeley National Laboratory was also supported by the Office of High Energy, U.S. Department of Energy, under contract No. DE-AC02-05CH11231.

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Session Classification: Sat-Af-Or4 - Advances in Nb3Sn and MgB2 Conductors II

Contribution ID: **763** Type: **Poster**

Sat-Mo-Po.08-10: Experimental study of the solderless joint on solenoid magnet with radial pressure structure

Saturday, July 5, 2025 9:30 AM (1h 45m)

High-temperature superconducting (HTS) rare-earth barium copper oxide (REBCO) magnets are typically fabricated in a stacked configuration of pancake coils. Conventionally, the electrical connections between pancake coils is achieved by joining the REBCO splice with soldering process. In this process, solder flux is applied to remove oxide layer on the REBCO tape surface and to enhance solder adhesion. However, the solder flux penetrates into the inside of the coil around the joint section, leading to oxidation and corrosion of the conductors and degrading the magnet performance.
In this study, we adopted a method of connecting pancake coils solely through contact without using a soldering process, so called solderless joint, and proposed a mechanical structure applying radial pressure for this purpose. A solenoid magnet system was designed and constructed based on this proposed concept, followed by 77 K liquid-nitrogen and 20 K conduction cooling tests. Experimental results confirmed that the solderless joint could achieve resistances in the tens to hundreds of nano-Ohms range and preserve magnet performance during repetitive tests. These results demonstrated the feasibility and reliability of solderless mechanical joints as an alternative to conventional soldered joints while offering advantages in terms of ease of assembly and maintenance.

Acknowledgement
This research was supported in part by National R&D Program through the National Research Foundation of Korea (NRF) funded by Ministry of Science and ICT (2022M3I9A1072846), and in part by the Applied Superconductivity Center, Electric Power Research Institute of Seoul National University.

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Session Classification: Sat-Mo-Po.08 - Structural and Insulation Materials

Contribution ID: **764** Type: **Poster**

Wed-Af-Po.01-06: S.M.A.R.T.: A bold design to achieve aneutronic fusion energy

Wednesday, July 2, 2025 2:30 PM (2 hours)

S.M.A.R.T. promises to be the boldest design to generate aneutronic fusion energy, first as process heat, and then as electricity for the power grid. I propose to incorporate 27 novel features to enable the Toroidal-Field (TF) system–with its brittle ceramic HTS conductor–to survive the peak stresses–and strains–from the (J x B) Lorentz forces generated by a peak ambient field of more than 30 tesla. About half of these innovations will be unique: new, superior materials, improved geometries, etc. As a mechanical engineer and novel-materials advocate, I espouse the philosophy, "More progress is wrought through judicious exploitation of novel materials than is yielded through meticulous optimization of familiar materials." In particular, note that HTS is a ceramic and brittle. At a mere 0.4% strain, the current-density (CD) of HTS degrades by ˜10%; at 0.7% strain, the CD plummets by ˜50%! Thus, high tensile- and yield-strength properties are of little value; it is high modulus and/or meticulous rigid external support that are crucial. Except for brittle tungsten, no metal has adequate stiffness. Thus far, high-modulus carbon fiber, such as ". . . high tensile strength (3.76 - 5.53 GPa), high tensile ductility (8 - 13%) and high electrical conductivity (1.82 - 2.24) * 10**4 S / cm"� (https://www.nature.com/articles/ncomms4848) is one of the woefully few materials that possess adequate high modulus (˜400 GPa), tensile yield strength (>1.6 GPa), and elongation to fracture (˜10%). Someday soon, we hope that graphene, fullerenes, carbon nanotubes, and carbyne, etc. will supplant high-modulus carbon fiber. Ultra-pure aluminum, reinforced with graphene platelets, etc., may slash magneto-resistivity (>25); ice-powered "pistons"� may "torque"� the Toroidal Field (TF) coils to eliminate the vertical strain in the flimsy Inner Leg. Direct Energy Conversion (DEC) from the protons and alpha particles will be attempted; additional electricity will be extracted from the bremsstrahlung and/or synchrotron radiation. Several heating techniques will be evaluated for plasma ignition; if an Ohmic Heating (OH) system proves essential, it will be partitioned into two independent systems: the first, a high-voltage, low-eddy-current, twisted-cable, modest volt-second system to enable plasma ignition, the second, a low-voltage, high-CD, high volt-second system to greatly prolong the pulse length of the plasma current, perhaps even to steady state.

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Session Classification: Wed-Af-Po.01 - Magnets for Stellerators and Other Configurations

Contribution ID: **765** Type: **Poster**

Sat-Mo-Po.03-10: Optimisation and Stress Management of OpenStar's 20 T Tahi Core Magnet

Saturday, July 5, 2025 9:30 AM (1h 45m)

The Levitated Dipole Reactor (LDR) is a promising concept for confining fusion relevant plasmas. In an LDR, a high field dipole magnet (core) is levitated in a large vacuum chamber, mimicking the plasma confinement physics observed in planetary magnetospheres. The performance of an LDR is largely determined by the ability of the core magnet to resist the natural diamagnetic expansion of the fusion plasma, which places requirements on the magnet's strength and stored energy. One key challenge in scaling LDRs is managing the Lorentz force generated by the superconductor. Naive magnet designs that satisfy the plasma performance requirements have been shown to have large tensile stresses in the REBCO HTS windings, leading to permanent degradation of the HTS tape no matter the supporting structure.

OpenStar, a fusion startup based in New Zealand, is aiming to build LDRs for the grid. An optimisation scheme has been developed that alters the core magnet cross section to maximises the plasma pressure for a target core magnet hoop stress. Alongside this, a new magnet structure has been developed that leverages high tensile modulus materials and large precompressions to reduce conductor strain to acceptable levels. Together, these technologies enable the design of feasible core magnets with HTS strains less than 0.4% while maintaining suitable performance for a D-T fusion power plant.

This work discusses in detail how these technologies have been used in the design of OpenStar's Tahi experiment. The Tahi core magnet, which requires a 1m diameter core magnet with a peak field of at least 20T, aims to prove the viability of these technologies and pave the way for full scale LDRs.

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Session Classification: Sat-Mo-Po.03 - Mechanics of Fusion Magnets

Contribution ID: **766** Type: **Poster**

Fri-Mo-Po.09-10: Test and Analysis of Feasibility for HTS Magnet in SMES Applications Using High-frequency Switching Power Electronics Circuits

Friday, July 4, 2025 9:30 AM (1h 45m)

This research investigates the feasibility of high-temperature superconductor (HTS) magnets as pivotal components for superconducting magnetic energy storage (SMES) applications, with a focus on their integration into power grids. SMES systems store energy in the magnetic field of superconducting coils, and the large current-carrying capability of HTS has shown its potential for SMES applications utilizing HTS magnets. To evaluate the potential of SMES for power grid applications, simple power electronics circuits were employed.

In simple charging/discharging test, the constructed HTS magnet demonstrated its designed inductance value. However, under AC conditions, its inductance decreased to nearly half of its original value. For no-insulation (NI) class magnets, the conventional lumped circuit model could not fully explain the frequency response at high frequencies. Therefore, a new NI lumped circuit model has been proposed to address the observed discrepancies under AC conditions. According to the proposed model, the equivalent inductance of the NI-class HTS magnet is reduced under high-frequency conditions. To address this limitation, an insulated HTS magnet was constructed and tested in subsequent experiments. Challenges encountered during its fabrication, such as wrapping insulation around the superconducting tape and creating reliable joints between tapes and pancake layers, are discussed alongside the experimental results.

Based on the lessons learned from the prototype insulated HTS magnet, a small-scale module coil was designed and constructed for further experimentation, which includes the integration of the insulated HTS magnet and the power electronics circuits. This study details the technical difficulties and experimental findings related to the insulated HTS coil. Based on these results, this research highlights the feasibility of scaling up HTS magnets for SMES applications.

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Session Classification: Fri-Mo-Po.09 - Novel and Other Applications II

Contribution ID: **767** Type: **Poster**

Wed-Mo-Po.03-08: Quench Behaviors of High-temperature Superconductor Stacked-tape Cable

Wednesday, July 2, 2025 9:15 AM (2 hours)

High-temperature superconductor (HTS) cables have a broad prospect in power transmission applications due to their low loss and high current capacity. The stacked-tape cable is a type of HTS cables wound with parallel-stacked tapes, which shows enhanced thermal stability due to electrical and thermal contacts between tapes. During local quench, the transport current is redistributed among stacked tapes through tape-to-tape electrical contacts and terminal joint resistances. It leads to complicated quench behaviors, which have not been studied so far. This study investigates the quench behaviors of stacked-tape cables. An electro-thermal coupled model is developed, integrating a lumped-parameter equivalent circuit model of HTS stacked-tape cables with a finite-element heat transfer module. The current redistribution and heat propagation in stacked-tape cables during local quenches are analyzed. The influences of terminal joint resistances and contact resistivities on quench behaviors and thermal stability of stacked-tape cables are studied based on the minimum quench energy (MQE). Results of this study would provide valuable insights into the stable operation of HTS cables in power transmission applications.

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Session Classification: Wed-Mo-Po.03 - HTS Characterization I

Contribution ID: **768** Type: **Poster**

Fri-Af-Po.08-05: Investigation of the relationship between RRR degradation from Rutherford cabling and facet dimensions at the edge of a cable by cross-sectional metallography

Friday, July 4, 2025 2:00 PM (2 hours)

Superconducting wires undergo large plastic deformation during manufacturing of Rutherford cables, especially at the cable edges. Previous studies on Restack Rod Process (RRP) Nb_3Sn wires have shown that the position of the strands in the cable and the orientation of the subelement stack, with respect to the main rolling direction during cabling, are affecting the amount of plastic deformation to which individual subelements are subjected. Subelements with damaged niobium diffusion barriers lead to tin diffusion into the copper matrix during heat treatment and a reduction of the residual resistivity ratio (RRR). For the High-Luminosity Upgrade of the Large Hadron Collider, more than one hundred Rutherford cables were manufactured at Lawrence Berkeley National Laboratory. In-line imaging of all four sides of the cables were acquired to assess cabling deformation and more by measuring the dimensions of all facets on the minor and major edges. RRR measurements at the cable-edge kinks and the straight sections of individual extracted strands were also performed to assess cabling-induced performance degradation. This study is building on this historical data to advance our understanding of the relationship between facet size and RRR degradation in Nb_3Sn RRP wires during cabling. Cross-sectional metallography at the kink of extracted strands is used to study differences in microstructures after heat treatment for wires with different RRR values and facet sizes.

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Session Classification: Fri-Af-Po.08 - Advances in Nb3Sn and MgB2 Conductors I

Contribution ID: **769** Type: **Poster**

Wed-Af-Po.07-03: Analytic formulas for any system of coaxial, rectangular-cross-section,UCD coils

Wednesday, July 2, 2025 2:30 PM (2 hours)

Using MACSYMA—the superb computer calculus program developed at MIT in the 1970s, ‘80s, and ‘90s—I have derived, verified, and meticulously simplified the analytic formulas for all magnetic quantities generated by any system of coaxial, axisymmetric, rectangular-cross-section (RCS), uniform-current-density (UCD) coils. All formulas now have the same constant of integration —zero—verified by differentiating all formulas in every possible permutation. The more complex analytic formulas require the definition of a new function, EI, which is the integral of E, the elliptic integral of the second kind. Note that both E and EI have no singularities—in fact, E varies merely from 1 to π/2! Thus, the accuracy of these formulas is excellent. During these derivations, I derived the analytic formula for the radial component of the magnetic field of a disk, BRDISK. This new formula represents the first advance in analytic formulas of this type since Professor Snow at MIT derived the analytic formulas for any system of coaxial solenoids in1939! I also derived—or perhaps rederived—a simple identity between the elliptic integrals of the third kind of arguments n1 and n2: π (n2, k) = F (k) - π (n1, k). This identity, of course, permits an alternate expression for the formulas for solenoids, disks, and coils.

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Session Classification: Wed-Af-Po.07 - Modelling and Analysis

Contribution ID: **770** Type: **Poster**

Thu-Mo-Po.06-02: Study on mechanical movements of HTS coils due to winding and thermal effect

Thursday, July 3, 2025 8:45 AM (2 hours)

Structural issues in high-temperature superconducting (HTS) magnets under high magnetic fields have garnered significant attention in recent years. While much of the research has focused on the electromagnetic forces induced by operational and screening currents during magnet operation, the mechanical behavior of HTS magnets during fabrication and cooling stages remains underexplored.

This study investigates the mechanical characteristics of small-scale HTS coils by analyzing the displacement of linear surface markings applied during the winding and cooling processes. By drawing reference lines from the bobbin to the wound turns, we track the movement of each turn and assess the coil's structural behavior under varying conditions. Various factors during the magnet fabrication process—such as winding tension, friction between turns, the anchoring method of the first turn, and the finishing technique for the last turn—can significantly influence these displacements. These movements, combined with thermal contraction during cooling, may lead to deformations that affect the overall integrity of the magnet.

Through experiments conducted on modular coils under different fabrication and cooling conditions, we aim to uncover how these variables impact the mechanical state of HTS magnets. The resulting displacement patterns provide valuable insights into the structural responses of larger-scale HTS coils, allowing for a more comprehensive understanding of their mechanical stability during non-operational stages.

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Presenter: IM, Chaemin

Session Classification: Thu-Mo-Po.06 - Mechanical Behavior and Stress II

Contribution ID: **771** Type: **Poster**

Thu-Mo-Po.10-01: Influence of winding pitches on dynamic resistance of CICC consisting of quasi-isotropic strands

Thursday, July 3, 2025 8:45 AM (2 hours)

The large-scale superconducting magnet in controlled nuclear fusion systems and accelerators are key components for achieving high magnetic fields. As a superconducting conductor made from high-temperature superconducting (HTS) tapes, quasi-isotropic strand (Q-IS) exhibits quasi-isotropic properties such as thermal and mechanical stability as well as making it an ideal choice for application in large scale magnets with high magnetic field. Q-IS can serve as the basic unit for manufacturing cables with higher current-carrying capacity, such as cable-in-conduit conductors (CICC), to meet the demands of large-scale superconducting magnets. However, Q-IS and CICC conductors carry direct current (DC) and are simultaneously to alternating current (AC) magnetic fields due to ripple current or charging and discharging so that the dynamic resistance appears, which affects the current distribution of among tapes or Q-ISs except for creating AC losses, decreasing its stability. In this paper, three-dimensional models of Q-IS and CICC were established, and finite element software was used to calculate the critical current and dynamic resistance based on the T-A model. The results demonstrate that their winding pitches significantly impact the dynamic resistance and are useful for design references for the application of large scale superconducting magnets made from Q-ISs based CICC.

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Presenters: PI, Wei (State Key Laboratory of Alternate Electrical Power System with Renewable Energy Sources, North China Electric Power University); ZHU, Lingfeng (School of Mechanical Engineering, University of Houston)

Session Classification: Thu-Mo-Po.10 - Modelling of Fusion Conductors and Coils II

Contribution ID: **772** Type: **Poster**

Sat-Mo-Po.05-01: From Modelling to Application: Exploring Quench Tolerance in High-Field HTS Magnets.

Saturday, July 5, 2025 9:30 AM (1h 45m)

A magnet undergoing a quench is one of the most challenging scenarios for any operator, often leading to potential failure of the magnet. While quench phenomena are well understood in LTS magnets—where manufacturers deliberately induce quenches during commissioning to ensure reliability—the same cannot be said for HTS magnets. Challenges such as the slow propagation of the normal zone and a significant operating temperature margin before transitioning to the non-superconducting state make quench detection and active protection methods for HTS magnets less effective, particularly in high-field applications.

Given these limitations, designing passively quench-tolerant magnets emerges as a more practical approach. In this work, we present two modelling techniques developed at OpenStar Technologies for the levitating non-insulated DC magnet: (1) a circuit-based modelling approach and (2) a finite element method (FEM) approach. Both methods incorporate a multi-physics framework, with the circuit model offering a fast and simplified analysis, while the FEM approach provides a slower but more detailed simulation.

These models were specifically tailored to mimic OpenStar's Junior core magnet, comprising of 14 solder-impregnated, thermally coupled coils. The results from both models were consistent with each other and validated against experimental data, demonstrating their reliability.

We further leveraged these tools to explore design enhancements for the next generation of quench-tolerant magnets. Key findings include the significance of non-uniform coil time constants, optimal placement of thermal masses, and effective thermal routing. While these insights may seem intuitive, they are critical in identifying and addressing design bottlenecks without compromising structural integrity.

Currently, the models couple electro-thermal and magnetic physics. Future work aims to incorporate structural mechanics to develop fully optimized magnet designs tailored to specific application requirements.

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Presenter: SIMPSON, Tom (OpenStar Technologies)

Session Classification: Sat-Mo-Po.05 - Quench Detection and Protection IV

Contribution ID: **773** Type: **Poster**

Sat-Mo-Po.09-05: Efficient Power Conversion System for SMES-Powered Pulsed Loads

Saturday, July 5, 2025 9:30 AM (1h 45m)

Pulsed power applications, such as pulsed-field magnets, electromagnetic launchers, and fusion experiments, require high-performance, efficient, and compact energy storage systems. These applications demand large amounts of energy in short bursts, often at high rates, which traditional energy storage technologies cannot support effectively or are highly inefficient. Superconducting Magnetic Energy Storage (SMES) systems are particularly well-suited to pulsed power needs due to their exceptional characteristics, including high cycling efficiency (the ability to charge and discharge repeatedly without significant degradation), fast charge and discharge times, and high power and energy densities. These attributes make SMES systems ideal for powering pulsed loads, such as those used in pulsed-field magnets across various scientific and industrial setups.
To effectively transfer energy from an SMES system to the pulsed magnet load, a high-performance Power Conversion System (PCS) is essential. The PCS must manage the conversion and regulation of energy between the SMES storage and the load, ensuring that energy is delivered rapidly and efficiently. Recent innovations in materials, such as high-temperature superconducting (HTS) materials—particularly second-generation high-temperature superconducting (2GHTS) tapes and wires —and wide band Gap semiconductor devices, hold great promise for enhancing the efficiency and performance of SMES-based pulsed power systems. These advancements allow for higher power densities, faster switching speeds, and reduced energy losses, making them ideal for incorporation into the PCS.
This paper examines the use of an SMES system along with its associated PCS in pulsed power extraction. The system design includes key components such as the SMES, DC link capacitor, IGBT/IGCT-based converter system, and resistive pulsed magnet/load. A comprehensive analysis of different PCS configurations and their respective performance is discussed. The paper compares system efficiency, response time, and overall effectiveness of various designs studied. The insights and results support the continued development of high-performance, efficient SMES systems for pulsed power applications, showcasing their potential to advance future energy storage and delivery technologies.

Author: BHARDWAJ, Ashish (Los Alamos National Laboratory, FAMU-FSU College of Engineering, Center for Advanced Power Systems)

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Session Classification: Sat-Mo-Po.09 - Energy Storage/SMES, Levitation and Magnetic Bearings

Contribution ID: **774** Type: **Poster**

Thu-Mo-Po.11-05: Conceptual design and preliminary experimental validation of a novel bi-directional scanning magnet with ceramic support bobbin for cooling

Thursday, July 3, 2025 8:45 AM (2 hours)

Superconducting gantries are required to reduce the size and cost of proton or carbon beam delivery systems for cancer radiation treatment. To map out the whole volume of a tumor, a well-focused pencil beam is scanned over the tumor in the two transverse directions while beam penetration and energy deposition in the axial direction is achieved by adjusting the beam energy. To minimize the aperture of the superconducting gantry magnets, it is required to perform the beam scanning downstream of the gantry which requires strong normal conducting bending magnets which are pulsed at 100-200 Hz. To achieve the bending strength, large, pulsed excitation currents are needed which cause significant eddy currents and DC and AC losses in the coil windings. A novel coil configuration is presented which enables field uniformities below 0.1% despite the presence of eddy currents and the effect of the external field enhancing iron yoke. The demanding cooling requirements are met by using heat conducting ceramic bobbins as the coil support and immersing the whole winding in a fluor-inert liquid. With the novel cooling scheme, the large required current densities of about 60 A/mm2 in copper conductor can be achieved. The high cooling efficiency, possible with heat conducting ceramics, and the expected AC losses for the complete magnet has been analyzed with numerical multiphysics calculations. Total power loss has been measured for a prototype of this system at the Center for Advanced Power Systems (CAPS). These experimental results along with model predictions are presented.

Authors: RAVICHANDRAN, Adwaith (Argonne National Laboratory); MEINKE, Rainer (AML Superconductivity and Magnetics); MUSTAPHA, Brahim; NOLEN, Jerry (Argonne National Laboratory); PAMIDI, Sastry (The Florida State University)

Presenter: RAVICHANDRAN, Adwaith (Argonne National Laboratory)

Session Classification: Thu-Mo-Po.11 - Magnets for Other Medical Application I

Contribution ID: **775** Type: **Poster**

Thu-Mo-Po.07-05: System modelling and optimisation of the Openstar HTS dipole magnet with transformer rectifier flux pump using MATLAB/Simscape

Thursday, July 3, 2025 8:45 AM (2 hours)

Inspired by the Levitated Dipole Experiment (LDX), Openstar proposed replacing the LTS core magnet with an HTS magnet powered by flux pumps. Embedded flux pumps enable the HTS magnet to maintain a constant DC field similar to LTS magnets with persistent joints. However, due to the limited zero-field region within the magnet, optimizing the flux pump design is critical to achieving maximum voltage and current ratings while minimizing heat leak in the system.

Existing tools for modelling magnet characteristics span various complexity levels and multi-physics couplings, including FEM, circuit modelling, and hybrid approaches. A unique challenge lies in bridging the modelling of both the transformer rectifier flux pump and the magnet under a unified framework. MATLAB/Simscape offers an unparalleled advantage by combining multi-physics capabilities with customizable components, enabling magnet models of varied complexity alongside flux pump modelling.

Independent models of the flux pump and magnet were implemented using MATLAB/Simscape and validated against experimental results. While the circuit modelling approach limits the dynamic resistance prediction, the flux pump behaviour was captured similar to experimental findings. The magnet was modelled as 14 magnetically- coupled coils (L-R circuits), providing a robust framework for system-level optimization. This enabled iterative evaluations of flux pump parameters, including transformer sizing, switch length, field amplitude, input current waveform, and frequency.

Practically, integration revealed significant variations in flux pump characteristics based on load conditions, emphasising the importance of co-modelling the flux pump with its load. The system-level model effectively replicated experimental results, including voltage waveforms, and provided insights into issues such as long charging times, heat dissipation, and current distribution under varying operating conditions.

The model facilitated the optimization of flux pump output voltage to meet the rated operation requirements of the magnet. This optimization informed critical design parameters for flux pump iterations, enhancing overall system performance and reliability.

To further enhance the model, we aim to incorporate temperature-dependent functionality for the flux pump switches and include thermal domain modelling for the magnet. The versatility of MATLAB/Simscape enables the integration of additional physics modules, paving the way for developing comprehensive digital twin models for HTS systems.

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Presenter: VENUTURUMILLI, Sriharsha (Openstar Technologies Ltd)

Session Classification: Thu-Mo-Po.07 - Design Optimization

Contribution ID: **776** Type: **Poster**

Fri-Af-Po.10-08: Deformation Detection of SHINE Undulator Girders

Friday, July 4, 2025 2:00 PM (2 hours)

Phase error is a critical indicator of the performance of undulator magnetic fields, directly determining the quality of the radiated light. The rigidity and deformation of the upper and lower girders have a direct impact on the magnitude of phase error, and this deformation is primarily caused by the interaction forces between the magnets. These interaction forces generate mechanical stress, leading to the deformation of the girders. Currently, the permanent magnet system of the undulator for the hard X-ray free electron laser (XFEL) facility under construction has completed the testing and acceptance of two undulator prototypes. The deformation monitoring system, based on capacitive sensors and laser displacement meters, is capable of achieving a measurement precision of 1 micron in the SHINE undulator girder deformation detection, playing an active role in the development and acceptance process. This paper presents an introduction to the mechanical structure of the SHINE undulator, its deformation monitoring system, and the test results.

Authors: YU, Cheng; Ms YANG, Jie; WANG, Jun; Mr XIANG, ShengWang; Mr ZHOU, ShuDong; ZHANG, Wei; ZHU, Ya

Presenter: WANG, Jun

Session Classification: Fri-Af-Po.10 - Undulators

Contribution ID: **777** Type: **Poster**

Thu-Af-Po.06-01: Overview and updates on the Tahi Core Magnet, a 20 T cable-based dipole.

Thursday, July 3, 2025 2:00 PM (2 hours)

Openstar Technologies is advancing the Levitated Dipole fusion reactor concept. OpenStar's first experiment, 'Junior'retired engineering risk and matched performance of similar experiments elsewhere. The next experiment, Tahi, will enable new fusion science and produce a triple product greater than 1e19 [keVm-3s]. Magnetic confinement for this experiment is provided by the Tahi Core Magnet - a 20 T HTS magnet which is levitated inside a large vacuum chamber. This work introduces the experiment, details the magnet's systems and presents the latest updates on the Tahi Core Magnet.

This magnet is a similar size to the Junior magnet; however, it is designed to produce 4x higher peak magnetic field. This is achieved by adding more conductor and operating at a lower temperature. Consequently, the magnet operates close to the critical strain of the HTS tape. This magnet is designed to explore the edge of the of the strain envelope, as hoop stresses will be a limiting factor in larger devices.

The magnet consists of approximately 50km of 4mm wide Rebco tape, bundled into a simply stacked cable within a structure. The conductor is arranged in the shape of a torus, with an outside diameter of approximately 1 meter. The operating current and temperature are approximately 8 kA and 30 K respectively. A zero-field region exists in the centre of the toroid, which is required for the onboard power supplies.

The magnet, housed within a cryostat, operates between a levitated and docked position within the main vacuum chamber. Cooling is provided via a heat exchanger loop while in the docked position. The float time is dictated by the thermal mass of the magnet balanced against heat loads. Charging and maintenance is provided by an onboard power supply.

Details of cable bundling, coil winding, manufacturing and testing facilities have also been included.

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Presenter: WORDSWORTH, Theo (Openstar Technologies)

Session Classification: Thu-Af-Po.06 - Magnets for Fusion Devices

Contribution ID: **778** Type: **Poster**

Sat-Mo-Po.06-03: Evaluation of the room temperature field quality measurements of HL-LHC MQXFA magnet assemblies

Saturday, July 5, 2025 9:30 AM (1h 45m)

As a member of the multi-lab U.S. High Luminosity LHC Accelerator Upgrade Project (HL-LHC AUP), Lawrence Berkeley National Laboratory (LBNL) is assembling high-field Nb3Sn low-beta MQXFA quadrupole magnets for eventual installation at CERN as part of the HL-LHC upgrade. Each magnet undergoes room temperature magnetic measurements at two points during the assembly process: once after completion of the coil pack sub-assembly and once after the magnet is fully assembled and pre-loaded. Beyond its use to verify that each magnet assembly can meet operational requirements, the data from this two-stage measurement process allow for investigation into the impact of the pre-loading operation on field quality. Furthermore, recent measurements on magnet rebuilds as well as exploratory coil pack reconfigurations provide an opportunity to see in isolation the effects of changes to a magnet's coil selection or coil layout. In this work, we present the magnetic measurement results of MQXFA magnets assembled or currently in process, focusing particularly on magnets with data corresponding to multiple builds, and discuss trends and insights which may be beneficial for the remaining MQXFA magnet production or for future Nb3Sn accelerator magnets.

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Presenter: DOYLE, Jennifer (LBNL)

Session Classification: Sat-Mo-Po.06 - Mechanical and Magnetic Measurements

Contribution ID: **779** Type: **Poster**

Fri-Mo-Po.01-09: A study on thermal stability of No-Insulation coil with multi-bundled HTS tapes under the open circuit condition

Friday, July 4, 2025 9:30 AM (1h 45m)

No-Insulation (NI) coil utilizing HTS tape conductor has become a promising option for high-field magnets, capable of delivering both excellent thermal stability and high current density. NI coil can reduce heat generation due to a current behavior that bypasses the defect when a local hot-spot is formed in HTS tape conductor. In the high-field magnet application, a coil structure with large number of bundled HTS tape conductors without insulation between layers is utilized to achieve large current capacity. In recent years, there have been reports of burnouts during power supply shutdowns, even when NI coils were utilized. One of the courses of these burnouts can be a current concentration on particular turn-to-turn contact resistance. In this paper, the authors examined the thermal stability of NI coils with multi-bundled tape conductors under the open-circuit condition. Additionally, an effect of turn-to turn contact resistance distribution on current distribution and thermal stability of the multi-bundled NI coil is performed. This analysis can contribute to the NI coil design with high current capacity and thermal stability. When dealing with a NI coil composed of parallel HTS tapes, the current distribution within the coil becomes intricate. Therefore, the partial element equivalent circuit (PEEC) model is utilized. In this model, every turn within the coil and the corresponding loop section are subdivided and depicted as an electric circuit. This approach enables to conduct a comprehensive analysis on the current and temperature distribution of the NI coil, facilitating a detailed examination of electromagnetic phenomena. The calculation results of current behavior under the power supply shutdown revealed that the circumferential current concentrates in innermost and outermost layers, which results in heat generation in the NI coil. Also, local heat generation and maximum temperature rise due to the power supply shutdown tend to be larger when the number of bundled tape conductors increases. Therefore, the results of this paper contribute to the realization of a coil structure design that can guarantee high thermal stability of NI coil for the application of the high-field magnet.

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Presenter: KOBAYASHI, Hiroyasu (Chiba University)

Session Classification: Fri-Mo-Po.01 - No-Insulation Coils IV

Contribution ID: **780** Type: **Poster**

Thu-Af-Po.11-05: Operation results of JT-60SA cryogenic system in pulsed heat mitigation control for plasma operation

Thursday, July 3, 2025 2:00 PM (2 hours)

JT-60SA is a superconducting tokamak for plasma fusion experiment developed in Japan. This is a joint international research and development project under the Broader Approach Agreement between Japan and Europe. The mass of the superconducting magnet system for JT-60SA is 750 tons. To cool down the magnets, the Helium Refrigeration System, which has an equivalent refrigeration capacity at 4.5 K of 9 kW, has been installed in 2016, and the assembly of JT-60SA was completed in March 2020. The first commissioning phase was conducted from October 2020 to March 2021, and the second commissioning phase and first plasma operation was conducted from May to December 2023.
The refrigeration system supplies a forced flow of supercritical helium to the magnets by using 2 cold circulators. The nominal heat load coming from magnets during TF magnet operation is 3 kW, but transitional pulsed heat loads are applied on magnets and magnet structures during plasma operation or magnet discharge event. A major feature of the refrigeration system is its 7 m^3 liquid helium buffer tank to mitigate pulsed heat load to optimize system requirements. This method of using a buffer tank to conduct heat load mitigation control is also adopted in ITER. However, the control logic has not been tested yet in a large-scale refrigeration system such as JT-60SA.
In this presentation, the operational result of the JT-60SA refrigeration system and the result of the pulsed heat mitigation control will be described.
JT-60SA was jointly constructed and is jointly funded and exploited under the Broader Approach Agreement between Japan and EURATOM.

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Presenter: FUKUI, Kazuma

Session Classification: Thu-Af-Po.11 - Cryostats and Cryogenics II

Contribution ID: **781** Type: **Contributed Oral**

Sat-Mo-Or2-03: Achieving full-field magnet performance: insights from Openstar junior experimental campaigns 1 and 2.

Saturday, July 5, 2025 8:45 AM (15 minutes)

High-Temperature Superconducting (HTS) fusion magnets play a pivotal role in plasma confinement for tokamaks and stellarators. Building on insights from the LDX and RT-1 programs, Openstar Technologies has developed a novel approach utilizing ReBCO for a levitated dipole magnet, powered by HTS flux pumps. We aimed to demonstrate a 5.6 T DC magnet made of 14 solder impregnated HTS coils, mimicking the output performance of the equivalent LTS magnet used in LDX. This work highlights the outcomes of both experimental campaigns we had, highlighting the key achievements..
Achieving plasma confinement with a fully levitated magnet at full field is our ultimate goal. Given the complexity of constructing and powering the largest HTS magnet with flux pumps, we structured the development into three milestones.

Campaign 1: Demonstrated plasma confinement using a mechanically supported magnet operating at ˜40% of its rated current.
Campaign 2: Aimed at plasma confinement with a levitated magnet, operating at over 60% of its rated current.
In Campaign 1, we achieved plasma confinement for over 20 seconds using a supported magnet. However, this approach did not address the critical challenge of levitating a 500 kg magnet at ˜1 m above the chamber base. Campaign 2 is designed to tackle these risks, achieving magnet levitation while maintaining plasma confinement.

This presentation will cover experimental findings from both campaigns, including: 1. Magnet current, voltage, operating temperature, and field as functions of time. 2. The unique behaviour of non-insulated magnets with HTS flux pumps, focusing on the non-uniform time constants of the coils.
Experimental results are further compared with modelled predictions to deepen our understanding of magnet performance. These insights pave the way for delivering our pre-seed targets while achieving full-field magnet performance.

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Session Classification: Sat-Mo-Or2 - Fusion Devices: Stellarators and Levitated Dipoles

Contribution ID: **782** Type: **Poster**

Fri-Mo-Po.01-08: Study on Electrical Contact Resistance of No-Insulation Magnet by Surface Treatment of REBCO tape

Friday, July 4, 2025 9:30 AM (1h 45m)

Many studies have focused on different types of no-insulation (NI) high-temperature superconducting (HTS) magnets. In particular, REBCO-based NI magnets have been explored in various forms, including conventional no-insulation magnets with copper stabilizers, cladding methods where high-resistance metals or semiconducting materials are coated on REBCO tapes, and co-winding methods where REBCO tapes are wound together with high-resistance materials like stainless steel tapes or mesh-shaped metal tapes. Contact resistance has been identified as an important factor in some of these studies, depending on the material properties and manufacturing processes.
In this study, we investigated how the surface condition of the copper stabilizer affects contact resistance. Specifically, we analyzed the changes in contact resistance when the oxide layer on the stabilizer surface was removed using chemical or mechanical methods. Additionally, we examined how contact resistance evolves over time as the oxide layer grows during repeated winding and charge-discharge cycles. These findings can enhance the understanding of contact resistance in NI magnets.

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Presenter: NAM, An Jin (Standard Magnet Inc.)

Session Classification: Fri-Mo-Po.01 - No-Insulation Coils IV

Contribution ID: **783** Type: **Poster**

Thu-Af-Po.02-07: Current distribution measurements of two-layer spiral-coated-conductor cable

Thursday, July 3, 2025 2:00 PM (2 hours)

In a superconducting cable, in which element superconductors often called strands are assembled to increase current-carrying capacity, current distributions among strands impact its performance. Here, we focus on cables in which coated conductors are wound spirally on their cores such as CORC cables and SCSC cable. In this presentation, such a cable is called spiral-coated-conductor cable as a general noun.

We are studying current distributions in two-layer spiral-coated-conductor cables, in which each layer consists one coated conductor and two normal conductor tapes. Because the tapes in the two layers are wound in different directions, they generate longitudinal magnetic field in different directions. As the first step, we installed a small Hall sensor in the hollow core of a sample cable to measure the longitudinal magnetic field. Using measured longitudinal magnetic field as well as total current, we succeeded in determining the current distribution clearly at one longitudinal location. As the next step, we will install several Hall sensors along a sample cable to measure the current distribution along it.

This work was supported in part by JST-ALCA-Next Program Grant Number JPMJAN24G1, Japan.

Authors: Prof. AMEMIYA, Naoyuki (Kyoto University); XU, Guangwei (Kyoto University); KOYAMA, Yuya (Kyoto University); Dr SOGABE, Yusuke

Presenter: Prof. AMEMIYA, Naoyuki (Kyoto University)

Session Classification: Thu-Af-Po.02 - HTS Cable

Contribution ID: **784** Type: **Poster**

Wed-Af-Po.04-09: HTS tapes joining techniques and its I-V characterization at 77 K

Wednesday, July 2, 2025 2:30 PM (2 hours)

In this study, different types of joints (lap joint and bridge joint) using commercially available second-generation (2G) high-temperature superconductor (HTS) tapes from two manufacturers were prepared, and their I-V characteristics were studied at 77 K, liquid nitrogen temperature. Both types of joints were prepared by taking each sample of HTS tapes with effective overlapping lengths ranging from 30 mm to 100 mm using two low melting point soldered materials such as Pb63Sn37 and In52Sn48 alloys. Also, the pressure applied to the solder joint during the soldering process varied from 1 to 5 MPa. The effect of the type of solder materials, overlapping length, and applied pressure on the joint resistance and the critical current of the joint normalized to the critical current of initial HTS tape under a self-magnetic field were investigated at 77 K.

Author: CHAND, Sumit (Research Scholar)

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Presenter: CHAND, Sumit (Research Scholar)

Session Classification: Wed-Af-Po.04 - HTS Joints

Contribution ID: **785** Type: **Invited Oral**

Sun-Mo-Or1-01: [Invited] Cryogenic irradiation of REBCO tapes for fusion magnets

Sunday, July 6, 2025 8:00 AM (30 minutes)

Fusion magnets in deuterium-tritium based power plants will experience bombardment by high energy neutrons during operation. This is a particular severe problem for REBCO-based compact high-field fusion reactors. The fusion magnets in these devices will typically be operated at around 20 K and accumulate radiation damage at this very temperature.
We have commissioned a cryogenic ion irradiation setup at MIT, that utilizes MeV range ions as proxy for fusion neutrons to study the radiation response of REBCO tapes under fusion-relevant conditions. This test facility allows to irradiate samples at temperatures between 20 K and 300 K while analyzing in-situ changes of critical currents (I_c) and transition temperature (T_c). We used 1.2 MeV protons in fluences of up to 10²¹ m⁻² to study the influence irradiation temperature on the degradation behavior of REBCO tapes. We found that 20 K irradiations degrade I_c and T_c at a 40 % higher rate than irradiations at 300 K. This suggests that previously determined radiation limits for fusion magnets, which were based on room-temperature irradiation results, should be re-evaluated.
We are currently building a cryogenic neutron irradiation facility next to the MIT reactor which will closely replicate the harsh fusion environment to test the degradation behavior of magnet components like REBCO tapes, stabilizers, insulation materials and sensors. First experimental results are expected by the end of 2025.

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Co-authors: DEVITRE, Alexis (Massachusetts Institute of Technology); WOLLER, Kevin (Massachusetts Institute of Technology); CLARK, Ben (Massachusetts Institute of Technology); FISHER, Zoe (Massachusetts Institute of Technology); HARTWIG, Zachary (Massachusetts Institute of Technology)

Presenter: FISCHER, David

Session Classification: Sun-Mo-Or1 - Technology for Fusion Reactors II

Contribution ID: **786** Type: **Contributed Oral**

Sat-Mo-Or3-03: Current Sharing Experiment for YBCO cable with Defects

Saturday, July 5, 2025 8:30 AM (15 minutes)

This study investigates the impact of nickel-plated YBCO (Yttrium Barium Copper Oxide) tapes on current sharing levels and performance, as compared to traditional copper-wrapped tapes. Prior simulations demonstrated a correlation between defect density and current sharing levels, prompting an experimental evaluation. Nickel-plated tapes were utilized to enhance thermal conductivity by replacing the copper oxide layer found in traditional YBCO tapes. The tape was laser cut one to three cracks in the YBCO layers, followed by structural verification using microCT or TEM imaging (not sure yet). Experiments were conducted under 4T magnetic fields in liquid nitrogen environments. Additionally, the nickel-plated tape is made by corroding the copper layer of YBCO tapes with acid and plating the nickel in its place. The crack experiment verified the current sharing level decreases when the density of crack increases which we got from the previous simulation study. The Nikel-plated YBCO tape results showed its current sharing levels is higher than traditional YBCO tapes. This enhancement is attributed to the improved thermal conductivity provided by the nickel layer, offering a promising alternative for advanced applications of YBCO-based materials.

Author: SUMPTION, Michael

Co-author: JIANG, Minzheng

Presenter: JIANG, Minzheng

Session Classification: Sat-Mo-Or3 - HTS Characterization III

Contribution ID: **787** Type: **Poster**

Thu-Mo-Po.01-03: Sensitive measurement of AC loss characteristics of short straight HTS tapes by reducing background losses in the pickup coil method

Thursday, July 3, 2025 8:45 AM (2 hours)

For practical applications such as power cables and transformers using high temperature superconducting (HTS) tapes, it is necessary to reduce the losses of HTS tapes. We have investigated the reduction of background loss, which is the apparent loss that occurs even where there is no specimen in the pickup coil, in order to improve the sensitivity of the AC loss measurement for HTS tapes using the pickup coil method. The purpose of this study is to quantify the relationship between the parameters of the pickup coil pair and the background loss for high sensitivity measurements of the AC loss characteristics of short straight HTS tapes, and to clarify the improvement in sensitivity due to an increase in the specimen volume occupancy in the pickup coil. In this study, various pickup coil pairs symmetrically arranged in the magnet for applying the external magnetic field were fabricated according to the measurement specimen, and the effect of reducing background losses was evaluated. The high sensitivity of AC loss measurements on short straight HTS tapes due to increased specimen volume occupancy in the pickup coil was also investigated. The AC losses of Bi-2223 tape as a measurement specimen were measured with various pickup coil pairs and the background losses per unit volume of the specimen were compared. The measurement results showed that the background losses relative to the AC losses of the specimen were lowered due to the increased specimen volume occupancy in the pickup coil, and the measurement sensitivity of the AC loss improved.

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Session Classification: Thu-Mo-Po.01 - AC Loss and Magnetization I

Contribution ID: **788** Type: **Poster**

Thu-Mo-Po.10-08: A simulation tool for managing geometrical requirements of tokamak toroidal magnet system

Thursday, July 3, 2025 8:45 AM (2 hours)

The complexity of tokamak machines requires virtual alignment studies from the design until the assembly phase. The component variability after manufacturing can cause deviations of the components from their nominal design with consequent installation misalignments. Proper positioning and alignment of the as-built tokamak components, such as magnets, vacuum vessel and in-vessel components, to the main reference system are primarily important for the fulfilment of the functional assembly requirements. Virtual assembly and alignment studies allow to face with these challenging issues during their lifecycle. Among the main superconducting magnet systems, the tokamak toroidal magnet system is usually composed of a certain number of D-shaped coils encased in a case which provides structural integrity and isolation for the superconductors, while ensuring proper connection to other machine components.
This work describes a simulation tool for the tolerance management of the toroidal magnet assembly. In the early design phase, when the as-built data are not available, an instance is needed per each component affected by geometrical variability for simulating and studying the virtual assembly of non-nominal geometries. In a later phase of the product development, as-built data, acquired in the metrology survey, may not include all the surfaces relevant for the analyses or the entire data set may be not available at the same time. In these cases, a non-nominal geometry can be used in combination with the real as-built model. The need to integrate the analyses, performed with Computer Aided Tolerancing (CAT) tools, with the information obtained through the component acquisition can create a smart virtual prototype. Starting from the knowledge of the manufactured systems, the other systems, whose design is similar, are characterized by predictable errors. Updating the models with the as-built data allows to study the assembly with the real shape of components. The developed assembly model evaluates the toroidal gaps of the toroidal magnet system with the aim to test the instance generation on components, whose knowledge is high enough to introduce reasonable variation sources due to manufacturing and assembly. Robustness of the assembly model is tested and tuned with single and multiresponse analyses based on the desirability function for verifying the coherence of the results. This model can integrate metrology expert knowledge about external and internal variation sources due to manufacturing and assembly processes. The instances of the components are pseudo as-built models which allows to carry out predictive assembly simulations in designed experimental conditions. A model for the generation of the pseudo as-built data is proposed for studying a set of key assembly characteristics among two toroidal field coils until closing the whole toroidal magnet system.

Acknowledgments
This publication reflects the views only of the authors, and Fusion for Energy cannot be held responsible for any use which may be made of the information contained therein.

Keywords
Superconducting Magnets, Toroidal Magnets, Tokamak, Assembly, Tolerance Management

References
N. Mitchell et al., "Status of ITER Magnets,"Fusion Engineering Design, vol. 84, Issues 2–6, June 2009, Pages 113-121.
A. Portone et al., "The Role of Advanced Modeling in the Assembly and Operation of Tokamak Magnets," in IEEE Transactions on Applied Superconductivity, vol. 34, no. 3, pp. 1-7, May 2024, Art no. 4202407.
G. D'Amico, "TF Magnet Assembly Analysis: FE Analysis simulating non constant gap between

inner legs,"Fusion for Energy, Barcelona, Spain, Fusion For Energy Tech. Rep. 3LJTEG v2.0.

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Session Classification: Thu-Mo-Po.10 - Modelling of Fusion Conductors and Coils II

Contribution ID: **789** Type: **Poster**

Thu-Mo-Po.03-01: PM magnet development status for BESSYII+

Thursday, July 3, 2025 8:45 AM (2 hours)

Permanent-Magnet (PM) magnets combine up to zero power consumption with highly stable magnet operation without magnetic field ripple from power supply instabilities and cooling fluid vibration effects resulting in a more energy-efficient and stable accelerator operation.
As part of the upgrade program BESSYII+, we will install the B2PT dipole triplet as the first PM-based accelerator magnet. It concludes the transfer line of the BESSYII synchrotron facility in Berlin, Germany, transporting the electron beam from the booster ring to the storage ring by imposing a bend in the beam trajectory which sends the beam into the injection septum of BESSYII' s storage ring.
The new B2PT is planned with three PM hybrid dipole units of 300 mm length each to substitute the present power-hungry 1-m long resistive electromagnet. The triplet produces a stable magnetic field that can be trimmed during operation by electro-correctors positioned in the outer two magnets of the triplet. The permanent magnetic field reduces injection noise into the storage ring and shrinks the total power consumption by almost 30 kW.
This paper reviews simulated beam bending optimization of the B2PT PM dipole triplet in several possible magnetic configurations as well as gives details of the magnet assembly process and associated tooling and measurement setup, opening up to permanent magnet development that is also required for the preparation of the envisaged magnetic lattice linear elements of the future 4th-gen low-emittance synchrotron light source BESSYIII.

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Presenter: ASPARUHOV, Ilia

Session Classification: Thu-Mo-Po.03 - Design and Development of Accelerator Magnets II

Contribution ID: **790** Type: **Poster**

Thu-Mo-Po.09-02: Instrumentation of the Canis 3x3 superconducting magnet array

Thursday, July 3, 2025 8:45 AM (2 hours)

Thea Energy has created the "Canis"3x3 array of high-temperature superconducting (HTS) planar coil magnets as a prototype for the "Eos"stellarator. This poster covers instrumentation of the Canis 3x3 magnet array highlighting the magnetic field control and field validation support systems. Field sensors mounted on each coil combined with individual magnet power supplies allowed the array field to be driven to stellarator relevant shapes with real-time feedback. The field shape and field error produced by the Canis 3x3 magnet array was validated with a hall effect probe mounted to a magnetic field scanning gantry placed on top of the array's vacuum vessel. The planar coil magnets were equipped with one of three separate temperature and voltage profiles based on resolution required. This instrumentation configuration allowed for a per-coil testing scheme that eased machine maintenance through promoting modular, separate-system testing.

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Session Classification: Thu-Mo-Po.09 - Conductor and Coil Measurement/Test Techniques and Facilities II

Contribution ID: **791** Type: **Poster**

Wed-Af-Po.05-08: Measurement of Transverse Resistance for Stacks of Non-insulated REBCO Tapes

Wednesday, July 2, 2025 2:30 PM (2 hours)

Transverse resistance among adjacent conductors is necessary information to calculate AC losses in stacks of non-insulated conductors. An existing transverse pressure insert (TPI) was modified at Fermilab to measure at nitrogen temperature transverse resistance of stacks made of non-insulated REBCO tapes as a function of transverse pressure. Pressure up to xyz MPa was applied with a hydraulic cylinder. A small current was flown in the stack sample through REBCO tape segments spliced above and below the stack. The latter had a bending radius larger than 6 cm to prevent damage. The voltage was measured just outside the compressed area. Stack samples included stacks of bare REBCO tapes, of REBCO tapes alternated with stainless steel ribbons of various thicknesses, and of both impregnated and soldered stacks. We herein present results of these transverse resistance measurements. Results show a stronger dependence on pressure for smaller pressure vs. larger ones. Also, of the two components of transverse resistance, i.e. contact and bulk, the latter was negligible.

Authors: ZLOBIN, Alex; TURRIONI, Daniele; TAMAGNINI, Elena; BARZI, Emanuela (Ohio State University); SAVOLDI, Laura; WANG, Xiaorong

Presenter: TAMAGNINI, Elena

Session Classification: Wed-Af-Po.05 - HTS Conductors II

Contribution ID: **792** Type: **Poster**

Wed-Mo-Po.11-04: Split pulsed magnet combining high peak central magnetic field and long rise time for pulsed field magnetization

Wednesday, July 2, 2025 9:15 AM (2 hours)

Split pulsed magnets are widely employed in high temperature superconducting (HTS) motor armature winding as magnetizing coils to implement in-situ pulsed field magnetization (PFM) for HTS field pole magnets. We have designed and developed a split pulsed magnet, that balances a peak central magnetic field of nearly 7 T and a rise time of 24 ms, making it particularly suitable for PFM of HTS materials at lower temperatures. Single and two-step PFM experiments of HTS GdBCO bulk in different temperature ranges are conducted and the maximum trapped fields (BT) are observed to be >3 T in the 40-50 K temperature range and nearly 4 T at 30 K in a 30mm diameter GdBCO bulk, with the absence of iron core. The trapped field results validate the excellent PFM ability of this designed split pulsed magnet and indicate a high trapped field (close to 4T) can also be obtained in coreless copper armature windings. Moreover, multi-physical field responses of split pulsed magnet during discharge are analyzed by a 3D field-circuit coupling model, which manifests that the split pulsed magnet is in a stable and safe operating state even under the highest charge voltage. Finally, this study may provide a novel clue for the development of coreless HTS linear motors and axial flux motors and suggest that HTS coreless motors can maintain a high air gap magnetic field while avoiding losses and thrust or torque fluctuations caused by iron core saturation under high magnetic fields.

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Presenter: Dr HU, Juntong (School of Astronautics, Beihang University)

Session Classification: Wed-Mo-Po.11 - High Field Pulsed Magnets I

Contribution ID: **793** Type: **Contributed Oral**

Sat-Af-Or5-07: AC-loss Analysis in Stacks of Non-insulated REBCO Tapes

Saturday, July 5, 2025 6:00 PM (15 minutes)

High-current HTS cables made of stacked REBCO tapes are being considered for large superconducting magnet systems for fusion and other applications. AC losses are critical when analyzing a stack of non-insulated tapes. Using finite element software such as COMSOL, it is possible to model a 3D stack of non-insulated REBCO tapes and assess how AC losses vary, depending on factors such as the stack's width, length or the number of tapes it contains. Each REBCO tape was modeled as a high-temperature superconductor (HTS) layer, surrounded by two copper layers. Stacks were formed by adding several tapes into the model. The stack sample is exposed to an external, time-varying magnetic field, applied to its outer surface. To model the superconducting behavior of the HTS layers, the well-established H-formulation (derived from Maxwell's equations) and the E-J Power law have been used. A key input parameter to the AC loss model is the transverse resistivity among the superconducting tapes. This parameter has been experimentally measured at liquid nitrogen temperature for stack samples of bare REBCO tapes, and of REBCO tapes alternated with stainless steel ribbons of various thicknesses. The measurements were performed at Fermilab's Superconducting R&D lab as a function of transverse pressure using a modified transverse pressure insert (TPI). These experimental data were used in the COMSOL model. This paper describes the COMSOL model and presents the results of the AC loss studies in various REBCO stacks.

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Presenter: TAMAGNINI, Elena

Session Classification: Sat-Af-Or5 - AC Loss and Magnetization II

Contribution ID: **794** Type: **Poster**

Thu-Af-Po.12-01: Recent Progress of a Robotic Winding Machine for Saddle-Shaped HTS Coils

Thursday, July 3, 2025 2:00 PM (2 hours)

We have developed a robotic winding machine for manufacturing saddle-shaped HTS coils applicable to accelerators, motors, and MRIs. This winding machine is designed to wind HTS saddle coils with a maximum length of 50 cm and a maximum diameter of 10 cm based on a cylindrical bobbin. A 5-axis robotic arm moves to position the spooling wire accurately. After constructing the winding machine, we measured the accuracy of the multi-joint robot's movements and analyzed the deviation from the ideal winding path. To prevent wire unwinding during the winding process, additional guides and fixing pins were devised and applied to the bobbin. The winding tests were conducted using mock HTS wires made of copper and SUS. In this presentation, we will introduce the recent development process of the robotic winding machine.

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Presenter: Dr HAHN, Garam (Pohang Accelerator Laboratory, POSTECH)

Session Classification: Thu-Af-Po.12 - Novel Devices

Contribution ID: **795** Type: **Poster**

Thu-Af-Po.10-08: A 30K/4K Closed-Cycle Cryogenic Helium Circulation System for Superconducting Magnets

Thursday, July 3, 2025 2:00 PM (2 hours)

Superconducting magnets serve as pivotal components in advanced rail transportation, next-generation power systems, Magnetic Confinement Fusion, and other critical infrastructure. They find extensive applications across various sectors including industry, energy, medicine, large scientific apparatuses, and semiconductors. Superconducting magnets are typically cooled through coolant immersion or cryocooler heat conduction methods. For low-temperature superconducting magnets made by NbTi and Nb3Sn, while direct cooling via cryocoolers reduces the consumption of liquid helium, it necessitates additional auxiliary equipment like compressors and water coolers. Consequently, for applications requiring high system integration and flexibility, liquid helium immersion remains the preferred cooling method for superconducting magnets. Nevertheless, the substantial consumption of liquid helium renders testing prohibitively expensive for both experimental and engineering applications, particularly in regions with limited helium resources. Therefore, developing a closed-cycle helium cooling cryogenic system is crucial, which is the focus of this study.

The proposed closed-cycle helium circulation system consists of two cryocoolers, a cryogenic fan, high-efficiency heat exchangers, flexible adiabatic transmission tubes, and quick-connect interfaces compatible with superconducting magnets. The cryogenic fan drives the helium flow, while a single-stage GM cryocooler and a hybrid GM/JT cryocooler serve as cold sources. Specifically, the single-stage GM cryocooler cools the cryogenic fan, cold shields, and other components, functioning as a pre-cooling source for helium gas. Meanwhile, the hybrid GM/JT cryocooler provides cooling for superconducting magnets across two temperature ranges: rapid pre-cooling at 30K and minimum operating temperature at 4K.

The heat exchanger efficiency exceeds 95%, and all connections utilize bayonet quick-connect interfaces. The inlet and return vacuum adiabatic pipes for the superconducting magnet are independent conduits, ensuring heat loss along the path remains below 1W/m, facilitating long-distance cold helium transmission. This paper details the thermodynamic parameter calculations within the circulation system and presents the overall layout design for the coupled superconducting magnet system. The system is capable of providing continuous cooling for superconducting magnets from 300K down to either 30K or 4K, making it suitable for both high-temperature and low-temperature superconducting applications. During normal operation, the superconducting magnet requires either no liquid helium or only a minimal amount, thereby reducing its costs and complexity.

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Presenter: Dr ZHANG, Tao (Xi'an Superconducting Magnet Technology Co., Ltd.)

Session Classification: Thu-Af-Po.10 - Cryostats and Cryogenics I

Contribution ID: **796** Type: **Poster**

Sat-Mo-Po.06-05: Development of a New Flip-Coil Measurement System for NSLS-II

Saturday, July 5, 2025 9:30 AM (1h 45m)

A novel flip-coil measurement system has been developed for the National Synchrotron Light Source II (NSLS-II) at Brookhaven National Laboratory (BNL). This paper describes the design, implementation, and commissioning of the new measurement bench, highlighting its key features, including improved mechanical stability, advanced data acquisition, and enhanced reproducibility. The system enables precise characterization of field integrals and multipole components, ensuring the optimal performance of IDs before installation in the NSLS-II storage ring. The flip-coil system incorporates an innovative approach to minimize mechanical and electrical errors, which significantly improves the reproducibility of measurements. In addition, the system features a state-of-the-art data acquisition system that enables real-time monitoring and analysis, further enhancing the efficiency and accuracy of the measurement process. Preliminary tests have demonstrated that the new system meets the stringent requirements for magnetic field characterization of advanced insertion devices (IDs), making it an essential tool for future ID commissioning and quality assurance at NSLS-II.

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Presenter: Dr MUSARDO, Marco

Session Classification: Sat-Mo-Po.06 - Mechanical and Magnetic Measurements

Contribution ID: **797** Type: **Poster**

Fri-Af-Po.10-01: End-Field Analysis and Phase Tuning of a Segmented Superconducting Undulator Prototype

Friday, July 4, 2025 2:00 PM (2 hours)

This paper presents the end-field analysis and phase optimization of a segmented superconducting undulator prototype (SC-AGU). This prototype consists of multiple segments, each requiring precise alignment and phase tuning to ensure optimal magnetic field performance and synchrotron radiation output. This segmented undulator design enables each segment to have distinct magnetic gaps, deflection parameters (K), and period lengths (λu), while ensuring a constant resonant fundamental photon energy across all segments, as permitted by the constraints of electron beam dynamics. This paper presents the methodology for end-field analysis, which includes detailed simulations to characterize the magnetic field distribution at the ends of each magnetic array. Special attention is given to the impact of field quality at the segment junctions and on radiation properties, maximizing on-axis spontaneous emission while retaining the electron beam's 'stay-clear' area and reducing the impedance constraints imposed by the undulator magnet structure along the entire straight section.
Furthermore, the phase tuning process is investigated by optimizing the phase shift between the superconducting segments. This optimization aims to minimize magnetic field deviations at segment junctions, ensuring smooth transitions and consistent field profiles. By preserving the desired radiation properties and enabling efficient, high-quality beam performance, this approach significantly enhances the device's overall performance.

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Presenter: Dr MUSARDO, Marco

Session Classification: Fri-Af-Po.10 - Undulators

Contribution ID: **798** Type: **Invited Poster**

Fri-Mo-Po.03-10: [Invited] Cool-down and Ramp Test of a Low-Cryogen, Lightweight, Head-Only 7T MRI Magnet

Friday, July 4, 2025 9:30 AM (1h 45m)

A low-cryogen compact 7T MRI system(C7T) dedicated for brain imaging has been developed at the GE HealthCare Technology and Innovation Center. The C7T magnet utilizes a fully sealed helium cooling system. Only 12 liters of liquid helium are condensed at 4.2 K from high pressure gaseous helium charged at room temperature. The C7T magnet is designed for a B0-field homogeneity <1.0 ppm in a 26-cm field-of-view. Both active superconducting shim coils and passive shimming are applied for shimming the C7T magnet. This C7T MRI system has a similar footprint and weight of a clinical whole-body 3T MRI scanner. C7T will greatly improve the access of ultra-high-field MRI brain imaging for a more diverse group of patients.
A Cryomech MPC600 helium circulation system is applied to firstly pre-cool the C7T magnet down to about 50 K, then three SHI RDE-412 cryocoolers cool the cold mass down to 3.4-3.5 K to its equilibrium state. The C7T magnet cool-down, energization and quench protection performance will be reported in this paper.

Acknowledgment
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Session Classification: Fri-Mo-Po.03 - Magnets for MRI

Contribution ID: **800** Type: **Poster**

Thu-Af-Po.08-05: Fast cooling pulsed magnet using high thermal conductive reinforcement layers

Thursday, July 3, 2025 2:00 PM (2 hours)

Accelerating the cooling rate of pulsed magnets has a significant impact on the efficiency of physics experiments. Inserting axial liquid nitrogen cooling channels in the magnet is a common method to accelerate the cooling rate. However, the cooling channels prevent stress from being transmitted between the layers of the magnet, which reduces the structural strength and increases the design complexity. Therefore, by adding aluminum nitride (AlN) and graphene high thermal conductive fillers to epoxy (EP) used for impregnating poly(p-phenylene-2,6-benzoxazole) (PBO) fiber reinforcement layers, we propose fast cooling magnets with high thermal conductive reinforcement layers to accelerate the cooling rate of the magnet without affecting the transmission of stress. The effects of different filler content on the mechanical properties, thermal conductivity and electrical insulation properties of the reinforced layer were tested, and the differences in cooling rate, structural strength and service life between the magnet with high thermal conductive reinforced layers and the common magnet were studied. This technology can significantly enhance the cooling speed of the magnet while minimizing structural strength loss, and can also be integrated with cooling channels to further expedite the cooling speed of the magnet. Subsequently, this technique will be applied to a 55 T pulse magnet with 300 ms pulse duration. The simulation results show that the cooling time of the magnet will be reduced from 180min to 30min.

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Session Classification: Thu-Af-Po.08 - Materials for Pulsed Magnets

Contribution ID: **801** Type: **Poster**

Wed-Mo-Po.11-06: Design of quasi-force-free magnet for terahertz gyrotrons.

Wednesday, July 2, 2025 9:15 AM (2 hours)

Quasi-force-free magnets, with their small volume and low inductance characteristics, are considered a promising option for the magnetic system in THz gyrotrons. However, the current quasi-force-free magnets suffer from complex structures that are difficult to fabricate. Moreover, due to the inherent instability of their structure, a dielectric with a sufficiently high Young's modulus needs to be filled in the gap to reduce the stress on the conductor below its ultimate strength, which further increasing the fabrication difficulty. Therefore, we propose a design for a quasi-force-free magnet using copper tubes, high-strength steel tubes, and poly(p-phenylene-2,6-benzoxazole) (PBO) fiber reinforcement layers. This design not only simplifies the magnet fabrication process but also eliminates the need for filling high Young's modulus dielectrics. The magnet structure was studied and optimized to meet the ultimate strength limit of the conductor. Firstly, the pitch of the coil was adjusted to subject the conductor to an outward radial electromagnetic force. Then, by winding a PBO fiber reinforcement layer around the magnet and filling a small amount of epoxy resin in the gap, the unbalanced electromagnetic force was counteracted. This enables the quasi-force-free magnet to be fabricated using a process similar to that of common pulse magnets. Simulation results show that this structure of quasi-force-free magnet can generate a strong magnetic field of 50T.

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Session Classification: Wed-Mo-Po.11 - High Field Pulsed Magnets I

Contribution ID: **804** Type: **Poster**

Fri-Mo-Po.06-04: A European Phased RD&D Program for Quench Protection of Large-Scale HTS Magnets

Friday, July 4, 2025 9:30 AM (1h 45m)

A European Research, Development & Demonstration (RD&D) program is being proposed by EUROfusion and partners to address key challenges and demonstrate the feasibility of safely quench-protecting large-scale High-Temperature Superconducting (HTS) magnets. This initiative is designed to pave the way for the development and deployment of HTS magnets in large tokamaks. The program is divided in three phase: Step 1 will test multiple quench detection schemes and determine their suitability and characteristics (e.g. response time, sensitivity, etc.); Step 2 will test a 10 MJ insulated coil to validate quench detection and protection strategies under realistic conditions; and Step 3 will scale up to a ˜250 MJ coil, demonstrating effective detection and protection under fusion-relevant conditions and scale (this being roughly the stored energy of the TF coils for the Volumetric Neutron Source - VNS). Each phase is based on insulated coil designs with indirect cooling. A key focus of the program is the development and testing of a high aspect ratio conductor concept. In contrast with multistage ITER cables, it is fully soldered, monolithic (without voids) and it has no cooling channel (dry conductor). The electrical insulation is placed between cable and jacket, so that it is protected by shearing stresses in large magnets. The paper provides an overview of the program objectives, its phased implementation strategy, and the innovative conductor and double pancake design to be employed in the model coil. Main parameters for the model coil and test facility are discussed, and early results in terms of hardware procurement and fabrication (first double pancake) will be presented.

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Presenter: GIANNINI, Lorenzo (EUROfusion)

Session Classification: Fri-Mo-Po.06 - Quench in Fusion Magnets II

Contribution ID: **806** Type: **Poster**

Wed-Af-Po.09-03: Detailed Margin Analysis due to Field Loading of the HTS Toroidal Field Coil of the STEP Tokamak

Wednesday, July 2, 2025 2:30 PM (2 hours)

The economic viability of fusion power plants such as UK Industrial Fusion Solutions Spherical Tokamak for Energy Production (STEP) [1] is a function of their size, toroidal field (TF) strength and availability throughout their operating lifetime [2]. This optimisation has led STEP to adopt a compact design featuring TF cables comprising a stack of rare-earth barium copper oxide (REBCO) coated conductors (CC) as the current carriers for their magnets, given its excellent current carrying capacity at low temperature and high field [3].

During operation, the magnets of the STEP tokamak will need to operate at high current density to produce the strong fields required for efficient deuterium - tritium fusion. STEP consists of several electromagnets, each of which will generate a magnetic vector that will impinge on the magnet itself and adjacent electromagnets and this will change over the course of a plasma pulse. Given that the TF coil is to use REBCO as its current carrier and that it has been reported that REBCO current carrying capacity is a function of temperature (T), field strength (B), and field angle (θ, φ) [4], [5], knowing how the magnetic vector field impinging on the REBCO in the TF coil's cable changes is required to accurately determine the margin between the operating current and the limit of the cable's current carrying capacity, defined here as the critical current per unit width of a single tape (I_{cpw}) multiplied by the number of tapes in the cable's tape stack.
In this work, the STEP magnet design was analysed to determine how the magnetic field vector impinging on each cable of the STEP TF coil varies along its length. This is compared to I_{cpw}(B,θ,φ) data acquired for a REBCO CC made by Faraday Factory using a multi-axis sample goniometer [6], [7]. The goal was thereby to determine if the operating current of the TF coil exceeds the I_{cpw} for each cable at any point along its length. Results of the magnetic field vector analysis at different moments during a STEP plasma pulse allow the cable sections with the lowest margins to be identified and resulting design recommendations to be made.

[1] Chapman et al. 2024. doi: 10.1098/rsta.2023.0416
[2] Sorbom et al. 2015. doi: 10.1016/j.fusengdes.2015.07.008
[3] Wimbush, Strickland 2017. doi: 10.1109/TASC.2016.2628700
[4] Zhou et al. 2025. doi: 10.1088/1361-6668/ad9ad6
[5] Wimbush, Strickland 2022. doi: 10.1088/1361-6668/ac4172
[6] Hopkins et al. 2012. doi: 10.1016/j.phpro.2012.06.171
[7] Wiegand 2010. PhD Thesis, Cambridge University

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Presenter: ILIFFE, William

Session Classification: Wed-Af-Po.09 - Magnets for Tokamaks: Design and Analysis

Contribution ID: **807** Type: **Poster**

Thu-Af-Po.10-09: Development of a novel high-capacity, high-efficiency and high-reliability cryogenic system for high-Tc superconducting magnets used in the controlled nuclear fusion system

Thursday, July 3, 2025 2:00 PM (2 hours)

Several new controlled nuclear fusion systems are under development in China. To achieve the higher magnetic field intensity and to minimize the final size as well, the high-Tc superconducting magnets are adopted. There are a variety of rigorous requirements on the associated cryogenic system expected to provide 600 W at around 20 K, of which high-efficiency and high-reliability are especially stressed. A novel cryogenic system based on the pulse tube cryocooler which features high-reliability and high-efficiency in the aimed operating temperature range is proposed, and how to significantly enhance the gross cooling capacity of the system becomes one of the key points. This paper presents optimization design and performance improvement approach about the cryocooler and then describes in detail the system integration of the novel cryogenic system with the high-Tc superconducting magnets. The expected cooling performance of the cryogenic system used in the developing controlled nuclear fusion system is also evaluated.

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Session Classification: Thu-Af-Po.10 - Cryostats and Cryogenics I

Contribution ID: **809** Type: **Invited Oral**

Sat-Af-Or1-01: [Invited] ITER Magnet Cold Test Facility Design and Assembly

Saturday, July 5, 2025 2:00 PM (30 minutes)

ITER project has decided mid 2023, to procure a Magnet Cold Test Facility (MCTF) to test as many as possible Toroidal Field Coils (TFC) and the Poloidal Field Coil PF1, before they will be assembled in the tokamak. An important constraint is that the coil tests shall not impact the tokamak construction. The earliest readiness of the facility is then very important factor to optimize its usage for TFC.
The main objectives will be to check the coil behavior or performances (as joint resistance, mechanical deformation, operating conditions) at 4 K at full current, 68 kA for TFC and 48 kA for PF1, with a special focus on the ground insulation in Paschen condition. In addition to the coils tests, the facility will be a training facility for ITER magnet commissioning as it is foreseen to use as far as possible ITER equipments (as the cryoplant, the current leads, the quench detection systems, the control system), but also ITER commissioning and machine protection procedures.
The Power Converter rated at 70 kA has been designed and procured for the facility, as well as a cryostat, 20 m long and 10 m width able to host as well a TFC or PF1. The Fast Discharge Unit (FDU), also procured on purpose, has the same design layout than the ITER FDU. The status of these procurements and of the facility assembly will be presented.
In order to support these different components design, interfacing and the test protocole, the project has carried out an exhaustive analysis plan that is including the cryostat evacuation, the cooling down at 4 K, the electromagnetic load in static and transient, the quench analysis. The main outcomes of these analysis will be presented.
The MCTB project is starting his commissioning phase, and the optimisation of the coil test sequence to support the tokamak assembly schedule. The commissioning plan will be presented as well as the main steps of the tests phases.

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Session Classification: Sat-Af-Or1 - Fusion Test Facilities

Contribution ID: **810** Type: **Poster**

Fri-Mo-Po.06-03: Quench simulation of partially insulated STEP TF model coil using Quanscient-Allsolve

Friday, July 4, 2025 9:30 AM (1h 45m)

The STEP (Spherical Tokamak for Energy Production) program in UKAEA aims to develop a large-scale high-temperature superconducting (HTS) toroidal field (TF) model coil over four years, with plans to scale it up to a full-size TF coil. The TF model coil (TFMC), with approximate dimensions of 1m × 2m and a terminal current reaching up to 100kA, serves as part of the risk retirement program for the TF coil development. This work focuses on the quench protection design of TFMC using partial insulation, which has the potential to prevent avalanche quench triggered by hotspots and to reduce overall voltage during the quench discharge process, thereby enhancing operational safety and stability.

Simulating 3D quench behaviour in partially insulated coils presents several challenges, such as demanding mesh quality, capturing leakage currents in the insulation and the current-sharing process governed by the E-J characteristics of HTS materials. To enable rapid iteration of the TFMC quench design, the STEP team collaborated with Quanscient from Finland to simulate the quench behaviour of TFMC using their Allsolve platform. It incorporates an in-house developed *H-Φ* formulation tailored for superconducting applications, offering several distinct advantages over conventional *H-Φ* formulations:

1. Automatic cohomology cut generation for applying net currents and solving for unknown/unconstrained ones. No additional surfaces (elsewhere called 'thin cuts'or 'cohomology cuts') required in geometry.
2. Direct access to the total voltage (dual to the net current) during the simulation, including both the inductive and the resistive voltage.

Using these unique features and the cloud computing resources with extensive and parallel processing of the Allsolve platform, we simulated various quench events in TFMC, such as sudden power-offs and critical current (Ic) drops, optimizing the design of the partially insulated material, including its optimal electrical resistivity. Then, the impact of remountable joints on the quench process of partially insulated TF coils was also investigated. Finally, we examined the influence of mesh size on quench simulation outcomes, particularly its effect on the accuracy of the temperature propagation profile. While achieving a very fine mesh is often impractical in 3D HTS simulations, it remains crucial to assess the implications of coarser meshes on the reliability of the results.

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Session Classification: Fri-Mo-Po.06 - Quench in Fusion Magnets II

Contribution ID: **811** Type: **Poster**

Thu-Af-Po.05-09: Magnetostriction Measurement with π-Phase Shifted Fiber Bragg Grating under Pulsed High Magnetic Fields

Thursday, July 3, 2025 2:00 PM (2 hours)

Under pulsed high magnetic fields, the interaction between the magnetic field and the spin of a material provides a unique opportunity to explore various magnetic properties, such as magnetization, dielectric polarization, and magnetostriction. These properties are critical for characterizing the diverse phase transitions that materials undergo. Among the measurement techniques available, magnetostriction measurement stands out for its exceptional sensitivity, allowing for the detection of intriguing phenomena that are often beyond the reach of traditional measurement methods. One of the most promising approaches in this field is the use of Fiber Bragg Grating (FBG) technology for magnetostriction measurement, particularly in environments subjected to pulsed high magnetic fields. FBGs are favored due to their remarkable insensitivity to vibrations and electromagnetic noise, making them ideal for precise measurements in challenging conditions. In this study, we present the development of an FBG-based magnetostriction measurement system tailored for use under pulsed high magnetic fields. A key innovation in our approach is the introduction of a novel type of Bragg grating sensor known as the π-phase shifted FBG. This sensor design enhances measurement resolution significantly. Unlike conventional FBGs, the π-phase shifted FBG is characterized by a distinct narrow notch at the center of its reflection peak, which results in a reduced full-width at half-maximum (FWHM). Experimental tests have demonstrated that the integration of π-phase shifted FBGs into our measurement system can improve resolution by approximately 50% compared to traditional FBGs. This substantial enhancement underscores the considerable potential of π-phase shifted FBGs for advancing magnetostriction measurements in pulsed high magnetic field applications. The findings of this research pave the way for more sensitive and accurate investigations into the magnetic properties of materials, promising to facilitate deeper insights into their phase behavior and underlying mechanisms.

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Session Classification: Thu-Af-Po.05 - Conductor and Coil Measurement/Test Techniques and Facilities III

Contribution ID: **812** Type: **Invited Oral**

Sat-Mo-Or1-01: [Invited] Magnet commissioning on the world's biggest operating tokamak JT-60SA

Saturday, July 5, 2025 8:00 AM (30 minutes)

JT-60SA is the world's biggest operating tokamak (R=3, a=1.2) having achieved a plasma volume of 160m^3 in 2023. As the first of a new generation of large fusion experimental machines, its commissioning represents a unique opportunity to gain invaluable operational experience.
The magnets form the backbone of any tokamak, and the superconducting magnet systems of JT-60SA play a critical role in allowing long pulse operation, essential for studying plasma behaviour in conditions relevant to reactor operation.
The novel design of the NbTi Toroidal Field (TF) magnet, providing the main confinement field for the plasma, allows its 18 coils (each 7.5m high) to expand radially when energized within their Outer Intercoil Structures, which in turn provide lateral support. The 100-tonne Nb_3Sn Central Solenoid is key to driving current in the plasma while the six NbTi Equilibrium Field coils, up to 12m in diameter, shape and control it.
The TF magnet was successfully operated at its full 2.25 T on-axis field in 2021, and in October 2023 all the magnets could be operated together to produce the first tokamak plasma.
While individual components - such as a coils, power supplies or cryoplants - can be thoroughly tested in isolation, many critical aspects of their interaction can only be assessed during integrated commissioning, where all systems are operated together.
This presentation provides an overview of the magnet system integrated commissioning process and highlights key lessons learned, particularly regarding insulation integrity, Paschen testing, applied voltages, power circuit design, and quench detection.

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Session Classification: Sat-Mo-Or1 - Assembly and Commissioning Fusion Tokamaks

Contribution ID: **813** Type: **Invited Poster**

Wed-Mo-Po.04-01: [Invited] Recent Advances in Bi-2212 Research at NIN

Wednesday, July 2, 2025 9:15 AM (2 hours)

Bi-2212 is a promising high-temperature superconductor (HTS) for ultra-high field magnet applications, owing to its exceptional current-carrying capacity under high magnetic fields, good mechanical stability, and unique isotropic round wire structure. The Northwest Institute for Nonferrous Metal Research (NIN) has been actively engaged in advancing the performance and industrial development of Bi-2212 superconducting wires. This paper provides a comprehensive overview of recent progress of Bi-2212 development in NIN. Significant efforts have been made to optimize the precursor powders prepared via the spray pyrolysis method, with a focus on compositional tuning and process improvements to ensure homogeneity and high purity. Advances in wire structure design, including the adjustment of filament numbers and structural configurations, have further enhanced the structural integrity of Bi-2212 wires during deformation process. The heat treatment processes have also been optimized to improve the grain connection of Bi-2212. In addition, this paper also introduces the development of Bi-2212 cables and conductors, demonstrating their structural integrity and superior performance in high-field environments. These achievements are complemented by progress in scaling up the production of Bi-2212 wires, addressing challenges in reproducibility and scalability to meet industrial demands.

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Session Classification: Wed-Mo-Po.04 - HTS Conductors I

Contribution ID: **814** Type: **Poster**

Wed-Af-Po.12-07: Design of High Voltage Power Supply Grounding Protection System for Upgrading Pulsed High Magnetic Field Facility in WHMFC

Wednesday, July 2, 2025 2:30 PM (2 hours)

The high voltage power supply system of the pulsed high magnetic field facility at Wuhan National High Magnetic Field Center (WHMFC) will be upgraded to 167 MJ capacitor banks with 73 modules for 27 magnet experimental stations in 5 years. The capacitor bank power supply system and all magnet experimental stations are located on the second and first floors of the same building (Pulsed Building), respectively, and each floor covering an area of approximately 2000 square meters. The 27 experimental stations are divided into 4 independent zones, each equipped with different capacitor power modules and independent grounding system. This ensures that operators in other zones are not affected by high-voltage and high magnetic field experiments in a certain zone and only need to evacuate from the experimental stations in the same zone. This can improve the experimental efficiency of the facility and greatly enhance its utilization.

In this paper, a grounding protection system for the Pulse Building was designed. Ionic grounding electrodes were installed in deep underground wells outside the building, and the outdoor grounding electrodes were connected to the grounding box at the junction of the 2nd floor power hall and the 1st floor magnet experimental stations of the Pulse Building through cables. There are a total of 6 independent deep well ion grounding systems with grounding resistance less than or equal to 0.5 Ω, including 4 high-voltage experimental station zones, 1 low-voltage experimental zone, and 1 backup zone. Six independent deep well ion grounding systems are also connected to the steel bars of the building through cables from the outdoor grounding electrode, forming a unified grounding body for the entire Pulse Building.

A pulse magnetic field fault testing platform and simulation model have been established, including high-voltage power supply, magnet, low-temperature and scientific experiment systems. Simulation studies have been carried out on various serious system faults, including magnet explosion damage and high-voltage power supply short circuit. The waveforms of overvoltage and overcurrent and their transmission paths within and between experimental stations have been analyzed. Isolation transformers and SPD surge protectors have been installed on the low-voltage distribution system and equipotential connections in the experimental station to isolate high voltage and discharge short-circuit currents. Preliminary test results indicate that the designed independent grounding protection system can achieve high-voltage isolation between experimental stations, ensure the safety of equipment and personnel, and meet the requirements for reliable and efficient operation of the upgraded pulsed high magnetic field facility.

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Presenter: DING, Tonghai (Huazhong University of Science and Technology)

Session Classification: Wed-Af-Po.12 - Power Supplies

Contribution ID: **815** Type: **Poster**

Wed-Mo-Po.05-07: Design and analysis of three-phase electromagnetic wiping coils for hot-dip galvanizing of steel strips

Wednesday, July 2, 2025 9:15 AM (2 hours)

Hot-dip galvanizing is a widely used method for protecting steel workpieces from corrosion, and controlling the coating thickness through wiping is crucial for ensuring both product quality and performance. Traditional gas wiping technology, though widely used, faces challenges, including air pollution, coating oxidation, uneven coating distribution, and difficulties in precise thickness control. Alternating-current electromagnetic wiping offers a non-contact and easily controllable solution. However, the single-phase electromagnetic wiping coil primarily generates large normal electromagnetic force with limited tangential force, which restricts wiping efficiency.

This study adopts three-phase coils structure to realize three-phase electromagnetic wiping (TPEW), where a traveling magnetic field is generated along the steel strip surface to increase tangential electromagnetic force and improve wiping effectiveness. The TPEW device employs three sets of plate-type coils energized by three-phase alternating current, interacting with the molten zinc layer to generate substantial tangential electromagnetic forces, which effectively remove excess liquid zinc. Adjustments to the frequency and amplitude of the TPEW coils currents enable precise modulation of the traveling magnetic field and electromagnetic forces, achieving accurate control over coating thickness and uniformity.

An analytical model is developed to identify key parameters affecting wiping performance. The model indicates that coils geometry, air gap distance, and power supply parameters significantly influence the magnitude of the electromagnetic forces. A multiphysics simulation model incorporating electromagnetic-fluid-thermal coupling and moving meshes is applied to analyze the interactions between the traveling magnetic field, the molten zinc layer, and thermal behavior. The results show that under appropriate current parameters, the zinc coating thickness is reduced to below 40 μm, with significant improvement in coating uniformity. Cooling channels integrated within the coil cores enable water circulation to reduce temperature rise. Compared to designs without cooling channels, this configuration reduces the temperature rise of the TPEW device from 120 K to less than 60 K. The simulation model also reveals the dynamic process of zinc liquid being wiped, forming distinct regions of thinning, fluctuation, and accumulation. This combined approach, incorporating analytical modeling, multiphysics simulation, and thermal management strategies, promotes the practical application of electromagnetic wiping technology in continuous galvanizing lines for steel strips.

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Session Classification: Wed-Mo-Po.05 - Novel and Other Applications I

Contribution ID: **816** Type: **Poster**

Thu-Af-Po.08-06: Study on Cu-based composites with high strength and electrical conductivity for pulsed magnets

Thursday, July 3, 2025 2:00 PM (2 hours)

Cu-based composites with high strength and electrical conductivity are core conductor materials for high-field pulsed magnets. High-performance composite wires have been well developed by Northwest Institute for Non-ferrous Metal Research (NIN), such as Cu-Nb and Cu-Ta materials. In this study, the jelly-roll + accumulative drawing and bundling (ADB) process has been inventively applied for the fabrication of these composites, which further enhanced the volume fraction of dual-phase interface and optimized comprehensive performance. The evolution of structure, strength and conductivity of composites during deformation was investigated through the combination of experiment and simulation methods. Besides, the relationship between structure and strength along with conductivity was studied and discussed. Based on these results, an effective strategy for structure design was proposed, which could substantively help with the development of ultra-high field pulsed magnets (110T).

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Session Classification: Thu-Af-Po.08 - Materials for Pulsed Magnets

Contribution ID: **817** Type: **Poster**

Wed-Af-Po.10-05: Bending characteristic of Bi-2223 three-groove CICC for fusion application

Wednesday, July 2, 2025 2:30 PM (2 hours)

Bi-2223 high temperature superconducting (HTS) tape has shown high mechanical stability and current capacity, which could be a potential material of cable-in-conduit-conductor (CICC) design and manufacture for fusion magnets. During winding process of magnet coil, bending strain is induced which cause the current capacity degradation. Thus, the bending performance of CICC cable is needed to be characterized through experiment and simulation. In this study, a 500 mm three-groove CICC sample was fabricated with Bi-2223 tapes stacked in each groove and bending test with different bending radii was performed at 77 K and self-field condition. To establish the model of Bi-2223 three-groove CICC and explain the experimental results, simulation using finite element method combined analytical model driven by bending test results of Bi-2223 HTS tape was carried out. The experimental and numerical results in this work will demonstrate the presented structure can meet the bending requirement of 15 kA-level CICC for fusion application.

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Session Classification: Wed-Af-Po.10 - Development and Test of Conductors for Fusion Magnets II

Contribution ID: **818** Type: **Poster**

Fri-Af-Po.01-08: Impact of bending on the quenching characteristics of Bi-2223/Ag stacked-tape impregnated with solder

Friday, July 4, 2025 2:00 PM (2 hours)

The Bi-2223/Ag high-temperature superconductor (HTS) tape has become one of the best candidate materials for high-performance superconducting magnets due to its high current-carrying capacity and excellent multi-filament stability. To achieve the capability of transporting thousands of amperes or even higher current levels, it is common to assemble multiple sub-cables constructed from stacked-tape impregnated with solder, into a single cable. However, during the winding process of the HTS Coil, the current-carrying performance and thermal stability (quenching) of the cable are often degraded due to the effects of mechanical strain and impregnants. In this study, the evolution of the normal zone in Bi-2223/Ag stacked sub-cables under different bending radii was characterized experimentally, including the changes in critical current before and after triggering quenching. Besides, a finite element analysis (FEA) model is constructed to investigate the quenching propagation. Using this numerical model, we completed the analysis and discussion of the experimental phenomena. Moreover, the quenching characteristics of one HTS conductor integrated with three Bi-2223/Ag sub-cables are also investigated.

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Session Classification: Fri-Af-Po.01 - Quench Detection and Protection II

Contribution ID: **819** Type: **Poster**

Fri-Af-Po.01-07: Investigation on the feasibility of quench detection methods with fiber bragg grating sensors in bending Bi-2223/Ag tapes

Friday, July 4, 2025 2:00 PM (2 hours)

Tokamak controlled nuclear fusion emerges as a promising solution to the current global energy predicament. The solenoid coil, a pivotal component, plays a crucial role in confining plasma within the Tokamak device. Bi-2223/Ag high temperature superconducting tapes, with a high critical temperature and excellent machinability, are favored material for fabricating solenoid coils. Nevertheless, during the coil winding process, the tape's performance is inhibited by bending and intense electromagnetic interference, which may even lead to quench damage. These factors also impede the operation of electrical sensors. Fiber Bragg Grating (FBG) sensors, featuring robust electromagnetic interference resistance and convenient multi-channel integration capabilities, present a novel option for measuring quench characteristics of Bi-2223/Ag.

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Session Classification: Fri-Af-Po.01 - Quench Detection and Protection II

Contribution ID: **820** Type: **Poster**

Thu-Af-Po.11-06: Cooling Experiment of High-Temperature Superconducting Magnet Components (Parts of a 20 T Magnet)

Thursday, July 3, 2025 2:00 PM (2 hours)

To generate a magnetic field exceeding 20 T, high-temperature superconductors (HTS) are essential. This study focuses on the conduction cooling experiments of high-temperature superconducting magnets capable of generating a 20 T magnetic field. This magnet is designed to operate at temperatures up to 20 K using hybrid HTS tapes, and the room temperature bore is 50 mm. To solve mechanical and electrical problems, a stainless steel co-winding method was applied, and the double pancake coils (DPC) were connected using a solderless joint method to effectively eliminate corrosion issues due to flux.
Out of the total 18 DPCs required for the 20 T, 8 DPCs have been manufactured and cooling experiments have been performed on them. Cooling was achieved using Sumitomo's RDK-415D GM cooler, with the coil cooling temperature reaching approximately 5 K and a magnetic field of 5.4 T. The remaining 10 DPCs will be manufactured and assembled to complete the 20 T magnet, with the Cryomech's PT-815 cooler to be used for conduction cooling.

Acknowledgement: This research was supported by National R&D Program through the National Research Foundation of Korea (NRF) funded by Ministry of Science and ICT (2022M3I9A1072464).

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Session Classification: Thu-Af-Po.11 - Cryostats and Cryogenics II

Contribution ID: **821** Type: **Poster**

Thu-Af-Po.02-09: Influence of various mechanical stresses during winding processes on current transport characteristics of SCSC cables

Thursday, July 3, 2025 2:00 PM (2 hours)

We have been developing the SCSC cable (Spiral Copper-Plated Striated Coated-Conductor Cable) consisting of copper-plated striated (multifilament) coated conductors wound spirally around a round core. Its spiral geometry decouples filaments electromagnetically against transverse magnetic fields like twisted low Tc superconductor wire and, then, reduces AC loss. The copper helps current sharing between filaments, making the cable more robust against local defects and normal transitions. Winding multiple copper-plated striated coated conductors allows the cables to carry a large current. One of the advantages of this cable is its ability to bend it in all directions, which enables winding three-dimensional-shape coils. During winding processes, bending stress, axial tensile stress and transverse compressive stress are applied to the cables. Consequently, each tape in the cable experiences combined stress of axial tensile, transverse compression, torsion and shear stress from the load of flatwise/edgewise bending and torsion. Firstly, we examine the influence of such various mechanical stresses on the current transport characteristics of short sample of SCSC cable. Bending stress, axial tensile stress and transverse compressive stress, which simulate those in winding processes, are applied to short samples of SCSC cables at room temperature. Hereafter, their voltage –current characteristics are examined in liquid nitrogen. Secondly, a small coil is wound under practical winding conditions. Its voltage –current characteristic is examined in liquid nitrogen, and the results are compared with the results obtained using short samples.
This work was supported by JST-ALCA-Next Program Grant Number JPMJAN24G1, Japan.

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Session Classification: Thu-Af-Po.02 - HTS Cable

Contribution ID: **822** Type: **Poster**

Thu-Mo-Po.02-02: Design and manufacturing of a 1T MgB2 magnet for the PTOLEMY experiment

Thursday, July 3, 2025 8:45 AM (2 hours)

The MgB_2 wire manufacturing process at ASG Superconductors has reached an advanced level of maturity, ensuring high reproducibility and homogeneity in long-length superconducting wires and tapes. These wires are available in various sizes and configurations, with single-unit lengths extending up to 6–7 km. The wires exhibit excellent mechanical properties, tailored through the careful selection of sheath materials and optimized heat treatment parameters. As a result, the reacted wires are well-suited for magnet winding and cable production using industrial machinery. These characteristics make MgB_2 technology ideal for a range of applications, including magnets for MRI systems, particle accelerators, and detectors, as well as cables for power transmission, distribution networks, and busbars for industrial or fusion applications.
This work highlights one of the most compelling applications of MgB_2 technology: replacing low- and intermediate-field resistive magnets by superconducting ones. The PTOLEMY project, which aims to detect cosmological relic neutrinos—the oldest particles predicted by the Standard Model—serves as a prime example. These measurements require highly stable and uniform magnetic fields to maintain precision in particle detection and energy measurements. To support this endeavor, we are developing a low-power-consumption magnet based on ASG's MgB_2 wires.
The PTOLEMY magnet is designed as a C-type dipole with extension arms on one side of the pole faces to shape the fringe field, providing a consistent and uniform 1 T field in the air gap. While a resistive version of this magnet already exists, a cryogen-free superconducting magnet is being developing to optimize performance and energy efficiency. This transition from resistive to superconducting technology will not only reduce operational costs but also minimize the environmental impact, contributing to the sustainability of the experimental infrastructure.
In this work, we present the latest updates on the PTOLEMY magnet, focusing on wire selection, magnet and cryogenic design, quench protection strategies, and field uniformity optimization. Additionally, we provide an update on the manufacturing process and initial testing results. We also discuss future plans for further refinement of the magnet design, integration with the PTOLEMY experimental setup, and the potential scalability of this technology to other scientific and industrial applications.

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Session Classification: Thu-Mo-Po.02 - Design and Development of Accelerator Magnets I

Contribution ID: **823** Type: **Poster**

Sat-Mo-Po.09-10: Design, manufacturing and test of the MgB2 coil for the Hybrid Energy Storage System in the V-Access project.

Saturday, July 5, 2025 9:30 AM (1h 45m)

The V-ACCESS (Vessel Advanced Clustered and Coordinated Energy Storage Systems) project brings together expertise on supercapacitors, superconductive magnetic energy storage systems (SMES), design and control of shipboard power systems, power electronics, lifetime cycle analysis, and ship classification to increase the technology readiness level (TRL) of hybrid storage systems, i.e. combining a battery with either supercapacitors, SMES, or both.
The proposed technologies (SMES and supercapacitor) will be analysed from the component levels, already tested and validated at TRL3, and modelled into the vessel's power system. Different use cases have been considered to evaluate pro and cons of the HESS implementation in terms of costs, weight and volume.
Business models and standardisation needs will be deeply analysed and measures to unlock existing barriers and8 will be promoted in parallel to the technical knowledge generated from the project to ensure further exploitation of the project results and the definition of the steps to upscale the design of the V-ACCESS system. This will pave the ground for a full-scale demonstrator to be developed after the end of this project and bringing the proposed technologies closer to market.
In this work, the main topics of the project and the results of the use cases analysed will be explained, together with an update of activities related to the design, manufacturing and test of the MgB2 coil. Technical specifications of the power electronics for the DEMO activities will be also discussed.

V-Access is a project funded by the European Union under the GA 101096831.

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Session Classification: Sat-Mo-Po.09 - Energy Storage/SMES, Levitation and Magnetic Bearings

Contribution ID: **824** Type: **Poster**

Thu-Mo-Po.11-06: Multi-layer halbach array optimization based on the finite halbach dipole analytical modeling

Thursday, July 3, 2025 8:45 AM (2 hours)

Halbach dipole cylindrical magnets have attracted significant attention due to their ability to generate high magnetic flux density within limited space. However, the end-effect significantly impacts the uniformity of the magnetic field, hindering the application of Halbach dipole arrays, especially in low-field MRI. Currently, most optimization methods focus on adjusting the geometric configuration of the array to minimize the inhomogeneity of the magnetic field inside the magnet. Various optimization algorithms have been applied to refine the structure, improving the influence of the end-effect to varying degrees. However, these methods often suffer from parameter adjustment issues that lead to impractical configurations, low optimization efficiency, and a lack of sufficient theoretical support for the final results. This paper starts with the analytical model of the Halbach dipole array and uses the precise theoretical expression as the fitness function for the genetic algorithm. The genetic algorithm is employed to optimize the multi-layer Halbach array. Furthermore, the method is validated through progressive model refinement, which shows that the magnetic field uniformity improves as the model becomes more refined. Ideally, this method provides the theoretical solution for achieving the minimum magnetic field uniformity within a multi-layer Halbach array, and its results can serve as a valuable reference for other optimization approaches.

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Session Classification: Thu-Mo-Po.11 - Magnets for Other Medical Application I

Contribution ID: **825** Type: **Poster**

Fri-Af-Po.08-02: Preliminary Design of a Superconducting MgB_2 Feeding System for Fusion Applications

Friday, July 4, 2025 2:00 PM (2 hours)

With the goal of generating net energy by 2040, fusion energy represents a cornerstone in the development of sustainable power generation technology, combining innovative approaches with advanced engineering solutions. Several programs aim to demonstrate the viability of fusion as a scalable energy source. However, the integration of remountable joints, the presence of large amounts of stored magnetic energy, and the spatial constraints imposed by magnetic geometries create significant technical challenges for the design and operation of magnet systems in fusion devices.

A key issue in this context is the development of a reliable and efficient current feeding system capable of meeting the demanding requirements of fusion magnets. To address this challenge, a preliminary design study has been conducted for a superconducting feeding system employing magnesium diboride (MgB_2) cables cooled by gaseous helium. MgB_2 offers a compelling balance between performance and cost-effectiveness, making it an ideal choice for high-current applications in fusion devices. The design process integrates considerations spanning electrical, thermal, magnetic, and mechanical domains to ensure compatibility with the unique operational environments of fusion systems.

From an electrical perspective, the supply current and voltage profiles, including transient behaviors during ramp-up, steady-state operation, and quench events, were analyzed. The discharge dynamics in the event of a quench were evaluated to ensure system safety, and the insulation requirements were defined based on the maximum voltage levels expected under normal and fault conditions. The configuration of the feeding system terminations, tailored to interface with magnet connections, was also optimized to facilitate efficient power transfer and minimize resistive losses.

Thermal management leverages the availability of gaseous helium as a coolant. Detailed analyses of helium flow rates, temperature gradients, and pressure drops along the feeding system were performed to ensure adequate cooling capacity and maintain the MgB_2 cables in their superconducting state.

The magnetic environment within fusion reactors imposes strict constraints on the design of the feeding system. The influence of stray fields and the maximum permissible magnetic flux density in various sections of the system were carefully evaluated to prevent flux jumps and ensure the stability of the superconducting state. The radiation environment, characterized by both intensity and type, was also considered to ensure the long-term performance and reliability of the materials and components employed.

Preliminary results from this study highlight the feasibility of a superconducting feeding system based on MgB_2 as a robust and scalable solution for delivering the high currents required by fusion magnet systems. By addressing the critical challenges associated with current delivery in fusion applications, this work represents a significant step toward realizing the goal of sustainable and commercially viable fusion energy and underscores the potential of MgB_2 as a key material in this class of applications.

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Session Classification: Fri-Af-Po.08 - Advances in Nb3Sn and MgB2 Conductors I

Contribution ID: **826** Type: **Poster**

Thu-Af-Po.05-04: DeepONet-based surrogate model for efficient magnetic field analysis and coil design optimization

Thursday, July 3, 2025 2:00 PM (2 hours)

The analysis and calculation of magnetic fields serve as the cornerstone for magnet design. In scenarios requiring intricate spatial magnetic field configuration optimization, high-throughput analytical computations are often necessary, posing significant computational cost challenges to existing finite element method (FEM)-based approaches. In recent years, surrogate model computations leveraging artificial intelligence algorithms have emerged and been applied across various domains, including fluid dynamics, materials science, and biology, offering potential breakthroughs to the aforementioned challenges. This paper introduces a magnetic field surrogate model methodology based on the deep operator network (deepONet). By leveraging low-throughput FEM model data, it establishes a precise mapping between the magnet coil design space and the spatial distribution of magnetic fields, laying the foundation for rapid coil design optimization methodologies. Specifically, the effectiveness of the proposed method is validated through two types of cases with varying complexities. The first type comprises coil structure models featuring axial symmetry, while the second type encompasses coil structures with three-dimensional asymmetric configurations. The constructed model takes the coil design space and physical three-dimensional spatial coordinates as inputs, outputting the spatial magnetic field. This paper systematically explores model accuracy across different network structures and provides guiding insights. Additionally, it presents engineering applications based on this model methodology, applying it to the analysis and calculation of electromagnetic-mechanical multi-physics coupling problems in the field of electromagnetic forming manufacturing, and quantitatively assesses its effectiveness and the enhancement in coupling analysis efficiency.

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Session Classification: Thu-Af-Po.05 - Conductor and Coil Measurement/Test Techniques and Facilities III

Contribution ID: **827** Type: **Poster**

Wed-Mo-Po.05-08: Fabrication of compact HTS coil for x-ray diffractometer with controllable magnetic field angle

Wednesday, July 2, 2025 9:15 AM (2 hours)

The no-insulation (NI) technique has been widely used in the development of high temperature superconducting (HTS) magnets. The compact 23 T NI-HTS magnet consists of pocket-sized double pancake coils was developed and reported. Therefore, it has been demonstrated that NI HTS coils are suitable not only for large-scale, high-field applications but also for small-scale, high-field applications. On the other hand, X-ray diffractometers using cryocooler are very useful instruments for identifying materials and determining crystal structures of crystalline samples. In the study of the crystal and electronic structures of materials using an X-ray diffractometer, physical properties are measured while varying external conditions such as temperature, pressure, and magnetic field. Although permanent magnets are used in X-ray diffractometers to apply magnetic fields, permanent magnets cannot change the magnetic field. While a normal electromagnet can change the magnetic field strength, the magnetic field strength is very low and generates heat due to the energizing current. In addition, a problem with current X-ray diffractometers is that the space needed to install a magnet is limited. In this study, we fabricated a compact HTS coil for X-ray diffractometer that can be installed in a narrow space (cylindrical space 50mm in diameter and 50mm in height). We proposed the NI HTS coil that can control not only the strength of the applied magnetic field but also the angle of the magnetic field. The target magnetic field strength applied to the sample crystal is 0.5 T, and the variable angle of the magnetic field is 45 degrees. Two Helmholtz-shaped HTS coils wound with REBCO wire on the top and bottom of a copper bobbin (ID and OD are 15 and 19 mm) were prepared. The number of turns in each coil is 100, and the two Helmholtz-shaped HTS coils are crossed at right angles. The direction of the magnetic flux applied to the sample crystal is changed by the magnetic field from the HTS sub coil assembled perpendicular to the HTS main coil. The magnetic field performance of the fabricated HTS coil was measured in liquid nitrogen and under conduction cooling, and the experimental results will be presented.

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Session Classification: Wed-Mo-Po.05 - Novel and Other Applications I

Contribution ID: **828** Type: **Contributed Oral**

Sat-Af-Mem1-02: Electromagnetic Behaviors and Magnetic Instability of Robust REBCO Coils with Edge-impregnation

Saturday, July 5, 2025 4:45 PM (15 minutes)

We have proposed "Robust REBCO coil"concept for high field cryogen-free superconducting magnet (CSM), which consists of two REBCO tapes co-winding and edge-impregnation. It is expected that the two tapes co-winding in direct electric contact can reduce the risk of burn-out coming from local degradations and the edge-impregnation reduce the maximum hoop stress [1-3]. From an electromagnetic point of view, the effect of coupling currents developing within the two-tape bundle, in addition to the screening currents, should be considered. In fact, the screening and the coupling currents are causing an error in the magnetic field. These two currents have an opposite effect on the magnetic field error [4, 5].
In addition, we observed magnetic field instability over a large-scale prototype of a HTS coil with the "Robust REBCO coil"concept when it operates at a temperature lower than 20 K. We assume that this instability is coming from the screening and the coupling currents. We have often observed many spikes in the coil voltage signals, usually considered coming from wire movements. However, in addition of these spikes, we observed over transient voltage, that we assumed to be of different origin related to a magnetic instability. In this contribution, the electromagnetic behaviors of the large-scaled prototype of the future HTS insert for the 33 T- CSM project will be discussed.

References

[1] S. Awaji et al., IEEE TAS, 31 (2021) 4300105.
[2] T. Abe et al., IEEE TAS, 32 (2022) 4603306.
[3] K. Takahashi et al., IEEE TAS, 32 (2022) 8400305
[4] A. Badel et al., IEEE TAS, 33 (2022) 4601505
[5] A. Zampa et al., IEEE TAS, 34 (2024) 4700205.

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Session Classification: Sat-Af-Mem1 - Huub Weijers Memorial: High Field Magnets

Contribution ID: **829** Type: **Poster**

Sat-Mo-Po.01-09: A Novel Two-Dimensional Magnetic Driving System using Maxwell Coils and a Halbach Array

Saturday, July 5, 2025 9:30 AM (1h 45m)

Microrobots are increasingly being applied in bionics and medicine, demonstrating significant potential in minimally invasive surgery and targeted drug delivery. Among them, magnetic microrobots have attracted considerable attention, driven by the interaction between external magnetic fields and built-in permanent magnets. This enables the separation of the driving system from the robot body, allowing for a smaller size, more flexible movement, and contactless control.

For magnetic microrobots moving in a two-dimensional plane, microrobot actuation requires bidirectional gradient magnetic fields and a controlled uniform magnetic field. The gradient fields generate a propulsive force, while the uniform field generates a magnetic torque to rotate the microrobot. Traditionally, electromagnetic coil systems, such as Maxwell coils or Helmholtz coils, have been used to generate these fields. In previous works, two-dimensional planar magnetic field control systems typically used two pairs of Maxwell coils and two pairs of Helmholtz coils arranged vertically. However, such an 8-coil system suffers from high energy consumption, complex configuration, and significant challenges in development and optimization.

To address these limitations, we propose a novel two-dimensional magnetic driving system that comprises only one pair of Maxwell coils alongside a hard-magnetic Halbach array. The first part, the Maxwell coils, can generate an axial gradient field as well as a radial concomitant gradient field in their central plane. Although the concomitant gradient field is generally considered detrimental, its symmetry can still be utilized to replace the two pairs of axial Maxwell coils by producing bidirectional gradient magnetic fields. This allows for the pushing of magnetic microrobot along its magnetization direction through the gradient magnetic force. The second part is the ring-shaped Halbach array, which consists of 32 small magnets and is driven by a servomotor. It serves as an effective alternative to Helmholtz coils to generate a controllable uniform magnetic field with reduced energy consumption. This uniform field aligns the magnetization direction of the microrobot with the desired orientation through magnetic torques. Then the combination of the pushing forces generated by the Maxwell coils and the torques produced by the Halbach array enables flexible movement of the microrobot in the two-dimensional plane.

To validate the performance of our proposed device, we model it using finite element simulation software to verify the theory and method outlined above. In the model, we optimize the parameters of the Maxwell coils and the Halbach array to ensure the synergistic action of the gradient and uniform fields, while minimizing mutual interference and maximizing the effective control range of the entire coupled system. We design the effective control area to have a radius equal to 9% of the Maxwell coils' radius and a height equal to 15% of the distance between the two coils. In this control area, the magnetic field generated by the Maxwell coils is approximately 10% of the size of the Halbach array, while the magnetic field gradient generated by the Halbach array is about 10% of the size of the Maxwell coils. Finally, we place a permanent magnet in the area and analyze its force and motion characteristics. The simulation results demonstrate the high efficiency, stability, and flexibility of the proposed magnetic driving system, enabling precise manipulation of microrobots in the two-dimensional plane.

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Session Classification: Sat-Mo-Po.01 - Magnets for Other Medical Application II

Contribution ID: **830** Type: **Poster**

Wed-Af-Po.05-09: Flux pinning properties of spherical irradiation defects arranged in serial in high-Tc superconducting films and tapes

Wednesday, July 2, 2025 2:30 PM (2 hours)

In-field critical current density Jc properties in high-Tc superconductors are significantly affected by the morphology of nano-sized crystalline defects acting as pinning centers (PCs): the optimization in the shape and spatial distribution of PCs is one of important issues on development of REBa2Cu3Oy (REBCO) coated conductors (CCs) for superconducting magnet applications and even on approaching the value of depairing current density Jd, at which Cooper pairs are broken up. The morphology of PCs can be tuned by the energies of ion irradiation to high-Tc superconductors. Columnar defects (CDs), which are produced by swift heavy ion irradiation, work as strong PCs in a certain magnetic field orientation where CDs is parallel to the magnetic field. By contrast, randomly distributed spherical defects (SDs), which are generally formed by proton irradiation, have morphology with no preferential orientation for flux pinning, leading to the isotropic pinning force against any orientation of magnetic field. Furthermore, spherical irradiation defects arranged in serial can be also induced by tuning the electronic stopping power of the heavy-ion beam to high-Tc superconductors. The unique irradiation defects can be expected as PCs combining both flux pinning properties of CDs and randomly distributed SDs. In this work, we systematically investigated flux pinning properties of SDs arranged in serial for REBCO films and CCs with and without Y2O3 as APCs, where the irradiation defects were prepared by 44 MeV Au-ion irradiations parallel to the c-axis. The in-field Jc was enhanced by the introduction of the SDs, the increment in Jc depends on the kind of sample. In particular, the Jc was more pushed up with the fluence for CCs with APCs, which was the same tendency as the introduction of continuous CDs in our previous work. However, the increase in Jc with the fluence was smaller than that for the continuous CDs. The morphology of SDs is more advantageous for suppressing the flux creep than continuous CDs, which provides extra pinning effect. The introduction of the SDs arranged in serial suppressed the flux creep rate for the low fluence, but the flux creep rate increased for a large amount of the fluence. This result suggests that the series SDs behaves as linear defects, promoting the hopping motion of flux lines.

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Session Classification: Wed-Af-Po.05 - HTS Conductors II

Contribution ID: **831** Type: **Poster**

Thu-Af-Po.12-03: Design and research of magnetic fluid rotary seal for high temperature superconducting motor

Thursday, July 3, 2025 2:00 PM (2 hours)

High-temperature superconducting (HTS) motors have broad application prospects in fields such as energy and transportation due to their high efficiency and energy-saving characteristics. However, the vacuum and low-temperature conditions in their operating environment impose stringent requirements on sealing technology. This study addresses the sealing demands of HTS motors by designing a rotary sealing structure based on ferrofluid sealing. The structure ensures stable helium transmission with a low leakage rate and integrates with sliding brushes to facilitate power transmission. A theoretical model of ferrofluid sealing was established to analyze the effects of magnetic field strength, sealing gap, and ferrofluid properties on sealing performance. By combining numerical simulations with experimental validation, the sealing structure's parameters were optimized, and its performance and stability under various operating conditions were evaluated. The results indicate that the ferrofluid rotary seal exhibits excellent gas-tightness and durability, effectively meeting the operational requirements of HTS motors and providing technical support for their engineering applications.

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Session Classification: Thu-Af-Po.12 - Novel Devices

Contribution ID: **832** Type: **Poster**

Thu-Af-Po.06-03: Superconductor selection assessment for magnetizing coil magnets for a FFHR based on a RFP configuration

Thursday, July 3, 2025 2:00 PM (2 hours)

The Fusion-Fission Hybrid Reactor (FFHR) concept has been envisioned since the early days of fusion research as a system in which fast neutrons produced by a high-temperature D-T plasma interact with a surrounding blanket containing fissile material and then a Li-based target. This process enables the production of plentiful tritium in quantities exceeding the requirements of the fusion core [1]. Such a surplus of tritium could also be used to fuel other fusion reactors without the need for a breeding blanket, thus streamlining their design and simplifying both their construction and operation.
For what concerns the FFHR fusion core, the Reversed Field Pinch (RFP) stands out as a compelling option. This toroidal plasma configuration relies on a self-generated toroidal magnetic field, with the plasma temperature increased, in principle, solely by ohmic heating [2]. These features make the RFP an attractive and potentially cost-effective choice for hybrid reactor designs.
Based on such a configuration, the study explores the suitability of various superconductors, among LTS (i.e. NbTi and Nb3Sn) and High-Temperature Superconductors. While HTS offer higher critical current densities and operational temperatures, their generally lower neutron irradiation resistance may limit their applicability in the high-flux environment of a quasi-continuous "double-swing"operation characteristic of a RFP configuration [3]. The investigation also considers the impact of transient stresses induced during the dwell phase and the need to maintain stable performance over extended operational periods.
This research aims to establish a comprehensive framework for superconductor selection tailored to FFHRs based on RFP configurations. The outcomes will inform material and design choices for future hybrid reactors, addressing the challenges of high neutron flux and demanding operational regimes, and advancing the feasibility of commercial fusion-fission hybrid systems.

[1] S. Murgo et al. "RFP-MSR Hybrid reactor model for actinides transmutation and tritium breeding", submitted to Nuclear Fusion, Poster presented to the 2023 IAEA FEC.
[2] L. Marrelli et al. "The Reversed Field Pinch", Nuclear Fusion, Vol. 61, n. 2, 2021.
[3] R. Piovan et al, "A continuously pulsed Reversed Field Pinch core for an ohmically heated hybrid reactor", Fusion Engineering and Design, Volume 136, Part B, 2018.

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Session Classification: Thu-Af-Po.06 - Magnets for Fusion Devices

Contribution ID: **833** Type: **Poster**

Thu-Af-Po.03-03: High-Temperature Superconducting Motors: A 2.5D Design Approach and Comparative Analysis of Axial and Radial Flux Topologies

Thursday, July 3, 2025 2:00 PM (2 hours)

With the growing prevalence of electrical propulsion technology in aerospace and new energy applications, high-temperature superconducting (HTS) motors have garnered substantial interest due to their high efficiency and power density. Among these, axial flux motors (AFMs) stand out for their compact design and superior efficiency, positioning them as a promising candidate for future electrical propulsion systems. However, traditional design methodologies for AFMs often necessitate complex three-dimensional (3D) finite element analysis (FEA), which entails significant computational costs. To mitigate this issue, this paper introduces a novel 2.5D design approach that dramatically reduces computational time. This method is further enhanced by integrating the NSGA-II algorithm to optimize the design of a 1-MW HTS axial flux motor. The optimized AFM is then compared with a 1-MW HTS radial flux motor through finite element validation. The results provide essential theoretical insights and technical support for the application of HTS motors in electrical propulsion, highlighting the potential of AFMs as a viable solution for next-generation propulsion systems.

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Session Classification: Thu-Af-Po.03 - Rotating Machinery III

Contribution ID: **834** Type: **Poster**

Sat-Mo-Po.03-08: Innovative fusion-reactor-specific fatigue design criteria: insights and advances from the DEMO central solenoid study

Saturday, July 5, 2025 9:30 AM (1h 45m)

The design of the DEMO Central Solenoid (CS) poses significant challenges due to the risk of fatigue failure and the stringent design criteria required to mitigate it. These criteria impose constraints on the allowable size of the solenoid, which, in turn, affect the configuration of the toroidal system and influence the overall performance of the fusion reactor. To address these challenges, the DEMO project focuses on developing a fatigue design criterion specifically tailored to the unique operational demands and loading conditions of a fusion device.
Building on established guidelines, such as ITER's design criteria and the RCC-MRx code, this work aims to pave the way for an optimized criterion that accounts for the combined effects of cyclic electromagnetic forces and thermal loads typical of fusion environments. The approach integrates a multidisciplinary workflow combining analytical, numerical, and experimental methodologies. Key activities include optimizing the CS's dimensions and configurations, performing finite element simulations, and conducting experimental validation to evaluate fatigue behavior under representative loading conditions.
This effort aims at establishing a robust framework for validating a fatigue design criterion for DEMO. It encompasses the development of numerical models to demonstrate compliance and the collection of experimental data to confirm the criterion's reliability. By enabling the design of a CS that meets magnetic flux requirements over multiple plasma pulses while maintaining structural integrity and long-term reliability, this initiative contributes significantly to the feasibility and efficiency of future fusion reactors.

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Presenter: Prof. BOSO, Daniela P. (University of Padova)

Session Classification: Sat-Mo-Po.03 - Mechanics of Fusion Magnets

Contribution ID: **835** Type: **Poster**

Fri-Mo-Po.09-04: Design of a Distributed Coil Array Magnet System for Electromagnetic Stress Relief in Large Aluminum Alloy Rings

Friday, July 4, 2025 9:30 AM (1h 45m)

Large aluminum alloy rings are vital components in wind turbine and high-speed train, serving as bearing rings, transition rings, and reinforcing structures. The structural stability and mechanical properties of these rings are critical to ensuring assembly precision and safety performance of these systems. However, the manufacturing process of large aluminum alloys rings inevitably introduce residual stress due to uneven thermal and mechanical loading during large-scale forming. These residual stress can adversely affects both the mechanical strength and dimensional accuracy of the components.
Common methods for eliminating residual stress include mechanical and energy-based approaches. Mechanical techniques rely on external forces exceeding the material's yield strength to induce plastic deformation and relieve residual stress. But these techniques risk surface damage and can introduce new residual stresses. Energy-based approaches reduce lattice distortions by applying external energy to restore atomic equilibrium and promote uniform dislocation distribution. However, these methods often lead to grain coarsening, compromising component strength and dimensional accuracy. In our recent research, a pulsed magnet coaxial aligned with an aluminum alloy ring was employed to generate a Pulsed High Magnetic Field (PHMF), inducing plastic deformation and significantly reducing residual stress without compromising material strength. This method offers advantages such as uniform force application and non-contact operation. However, scaling the method to larger rings introduces challenges, including increased manufacturing complexity and higher costs for single-coil magnets.
To address these limitations, this study proposes a novel magnet topology based on a distributed coil array. The system consists of 24 pancake coils uniformly arranged along the inner circumference of the ring. Each coil generates localized electromagnetic force, enabling precise and uniform deformation. By combining circumferential rotation and multiple discharge cycles, high uniformity in ring expansion is achieved. Finite element simulations using LS-DYNA, incorporating partial electromagnetic modeling and explicit-implicit coupling, were conducted to evaluate system behavior. Systematic investigations of the magnet's structural parameters and coil distribution informed the design of the electromagnetic system and discharge processes. Simulation results demonstrate that when the total energy of the 24 coils per discharge reaches 4.5 MJ, eight discharge cycles induce an average plastic strain of 1.20%, with a maximum deviation of 0.16% between the highest and lowest strain values. This level of plastic strain effectively eliminates residual stress. The findings highlight that the coil array design reduces production costs, minimizes operational risks, enhances system flexibility, and extends service life.

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Presenter: Dr LI, Xiaoxiang (Huazhong University of Science and Technology)

Session Classification: Fri-Mo-Po.09 - Novel and Other Applications II

Contribution ID: **837** Type: **Poster**

Thu-Mo-Po.02-07: Fabrication and testing of the D-magnet and Q-magnet for a magnet-based beam diagnosis system

Thursday, July 3, 2025 8:45 AM (2 hours)

The injector operating within the 3–15 MeV energy range is considered to hold significant potential for various practical applications, with broad prospects demonstrated in scientific experiments and industrial applications. For such typical injectors, the precise measurement of beam quality through a beam diagnosis system is considered crucial. The development of a universal beam diagnosis platform based on magnets has been presented in this paper, with a focus on the design, fabrication, and testing of its core magnetic components—the dipole (D) magnet in the energy spectrum measurement system and the quadrupole (Q) magnet in the emittance measurement system. Based on the system's physical design, key parameters such as magnet uniformity and multipole moments have been considered to ensure the system's precision. The validity of the design has been confirmed by comparing the measured data of the fabricated magnets with simulation results. Through the study and optimization of the D and Q magnets, accurate beam parameter analysis is enabled by the universal magnet-based beam diagnosis system, which supports the optimization of injector performance.

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Session Classification: Thu-Mo-Po.02 - Design and Development of Accelerator Magnets I

Contribution ID: **838** Type: **Poster**

Thu-Mo-Po.01-08: AC Loss Prediction in High-Temperature Superconducting Coils Using a Transformer-Enhanced Surrogate Model

Thursday, July 3, 2025 8:45 AM (2 hours)

AC losses significantly impact the design and operation of superconducting power devices, making their fast and accurate calculation essential. However, calculating AC losses in high-temperature superconducting coils often requires substantial computational resources. This paper proposes an artificial neural network (ANN) model with a Transformer architecture to calculate AC losses in high-temperature superconducting coils. The Transformer model is integrated to capture long-range dependencies and complex interactions between input features such as frequency, temperature, and current density, which significantly influence AC losses. The self-attention mechanism of the Transformer allows the model to focus on the most influential parts of the input data, thereby improving prediction accuracy. The ANN is trained using data derived from finite-element analysis (FEA) to accurately estimate AC losses. The model minimizes output error by adjusting the weights and thresholds. The response set Y at sample points X is obtained through FEA calculations, and an AC loss surrogate model is constructed using the dataset of sample points X and their corresponding responses Y. The accuracy of this surrogate model is validated by comparing its predictions with those obtained from COMSOL simulations. The results demonstrate that the Transformer-enhanced surrogate model can significantly improve computational efficiency without sacrificing accuracy.

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Session Classification: Thu-Mo-Po.01 - AC Loss and Magnetization I

Contribution ID: **839** Type: **Poster**

Sat-Mo-Po.01-07: Opportunities and challenges on magnet design for beam delivery in compact proton therapy systems

Saturday, July 5, 2025 9:30 AM (1h 45m)

Various types of magnets, including dipole, quadrupole, sextupole and combined-function type, are used for beam transportation and delivery in proton therapy systems (PTS). Toward urgent demands for lightweight PTS, we will discuss the opportunities and challenges on magnet design issues, especially for gantry beamline. Two gantry beamline design schemes will be introduced and compared: (1) a superconducting gantry using combined-function curved AG-CCT magnets, (2) a compact normal-conducting gantry with optimized layout. The former scheme also exhibits large energy momentum acceptance feature, that has potential clinical applications. Other topics, including compact scanning magnets and optimizations on normal-conducting magnets for beam delivery in PTS, will be discussed. This paper try to extract essential and common factors in this research area, based upon existing literatures and research works performed at HUST.

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Session Classification: Sat-Mo-Po.01 - Magnets for Other Medical Application II

Contribution ID: **841** Type: **Poster**

Sat-Mo-Po.03-06: Calibration Test for Preload Control with Ultrasonic Checking for Magnet Studs during ITER Machine Assembly

Saturday, July 5, 2025 9:30 AM (1h 45m)

The ITER superconducting magnet system comprises 18 Toroidal Field (TF) coils, one Central Solenoid (CS), 6 Poloidal Field (PF) coils, and 18 Correction Coils (CC). These superconducting coils are integrated using robust, flexible structures and over 2,000 high-grade large studs ranging from M56 to M110.
During assembly, these studs are preloaded from hundreds to thousands of kN with Hydraulic Tensioners or Multi-jack bolt Tensioners (Superbolts). Since preload losses are inevitable under current methods with hydraulic tensioners, and the maximum allowable loads are constrained by the material's yield strength as per ITER Magnet Structure Design Criteria, these constraints create a narrow operational window for successful assembly to the expected preload.
Precise preload control is critical to ensuring proper integration of the superconducting magnets. Ultrasonic bolt load measurement emerges as a promising solution, especially in scenarios where one end of the stud is inaccessible after installation. Calibration tests at ITER are underway to validate the use of this method for preload measurement during machine assembly.
This article presents calibration test results, including velocity, stress factor, load factor, preload loss, and field calibration measurements. It concludes with insights from the design and manufacturing of high-grade studs, highlighting their impact on achieving accurate preload control via ultrasonic inspection.

The views and opinions expressed herein do not necessarily reflect those of the ITER Organization.

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Session Classification: Sat-Mo-Po.03 - Mechanics of Fusion Magnets

Contribution ID: **842** Type: **Poster**

Fri-Af-Po.07-06: Development of magnet health monitor systems using optical fiber strain sensors

Friday, July 4, 2025 2:00 PM (2 hours)

The 100T multi-shot (100TMS) and 60T controlled-waveform (60TCW) magnets are signature pulsed magnet systems at the National High Magnetic Field Laboratory (NHMFL) –Pulsed Field Facility (PFF) in Los Alamos. Both magnets are powered by a massive 1.4 GW generator to produce unique pulsed magnetic fields for user experiments. The 100TMS magnet can generate world-record pulsed magnetic fields up to 100.75 T non-destructively, while the 60TCW magnet can deliver magnetic fields up to 60 T with a 100 ms flat-top. These systems are built with concentric coils, which are both costly and time-consuming to construct due to the need for specialized high-strength conductors and reinforcing materials. Therefore, real-time monitoring of the coils' health is crucial for making informed decisions regarding their operation and maintenance. This paper introduces a new system that uses optical fiber Bragg grating strain sensors to monitor deformation at the mid-planes of the coils. The system was tested on one of our 65T magnets, and the evolution of coil deformation during its operation will be presented.

Authors: NGUYEN, Doan; MICHEL, James; LUCERO, Jason; BETTS, Scott

Presenter: BETTS, Scott

Session Classification: Fri-Af-Po.07 - High Field Pulsed Magnets II

Contribution ID: **843** Type: **Contributed Oral**

Sat-Af-Or2-05: Recent upgrades at Pulsed Field Facility –National High Magnetic Field Laboratory

Saturday, July 5, 2025 3:00 PM (15 minutes)

The National High Magnetic Field Laboratory (NHMFL) –Pulsed Field Facility (PFF) at Los Alamos operates ten pulsed magnet stations that deliver magnetic fields up to 100 T for user experiments. In recent years, PFF has enhanced its capabilities with upgraded magnets, enabling the generation of higher magnetic fields and an increased number of pulses. This presentation will provide an overview of recent magnet upgrades at PFF, including the performance of new systems such as the 75T and 85T duplex magnets. Additionally, a novel cooling technique that significantly reduces cooling time without compromising magnet lifespan or stability will be discussed. Lastly, the presentation will cover maintenance and upgrades of our facility's signature magnet systems, including the 100T multi-shot and 60T controlled-waveform magnets.

Authors: Mr VALDEZ, Abran; BHARDWAJ, Ashish (Los Alamos National Laboratory, FAMU-FSU College of Engineering, Center for Advanced Power Systems); NGUYEN, Doan; MICHEL, James; LUCERO, Jason; BETTS, Scott

Presenter: NGUYEN, Doan

Session Classification: Sat-Af-Or2 - Progress in Ultra High Field Solenoids

Contribution ID: **844** Type: **Contributed Oral**

Sat-Mo-Or1-03: Long-Term Performance of Pultruded Fiberglass Pre-Compression Rings for ITER

Saturday, July 5, 2025 9:00 AM (15 minutes)

The ITER Pre-Compression Ring system provides radial constraint and centripetal load to the 18 TF coils. The rings are composed of six pultruded fiberglass-reinforced composite rings with an external diameter of 5.6 m, a cross-sectional area of 95,600 mm², and a weight of 3.4 tons each. These rings are designed to operate at 4.2 K during 20 years under preload given at room temperature during their assembly.

To investigate how prolonged loading affects key mechanical properties, such as ultimate tensile strength (UTS) and ultimate compressive strength (UCS), an extensive 3-year test program included tests on both small-scale specimens and 1/5-scale PCR mock-ups. Full-scale tests under operational conditions would have been prohibitively expensive and difficult to implement, so small-scale specimens were used to study the material's creep behavior under tensile and compression loads for up to 5000 hours at room temperature. This approach allowed for testing a large number of samples to provide statistical confidence in the results. The small-scale tests were performed by CERN, Switzerland.

In parallel, eight 1/5-scale PCR mock-ups with a diameter of 1 m were tested at ENEA Frascati. The test campaign included stress relaxation tests at different stress levels and durations, followed by UTS tests at room temperature. To replicate operational conditions more accurately, one mock-up was subjected to an uneven load distribution to simulate the pre-compression effects experienced by the full-size rings. Another mock-up was tested with an artificial defect to evaluate the impact of structural imperfections on mechanical performance.

Finite element method analysis was conducted to support the experimental campaign. The analysis was used to translate the preload conditions of the full-size rings to the 1/5-scale mock-ups. This approach ensured that the test conditions for the subsize rings accurately reflected the behavior expected in full-size rings.

The combined results from the tests revealed that stress relaxation does not influence the mechanical properties of the rings. These findings validate the design, material selection, and manufacturing process of the PCRs. The study concludes that the pultruded fiberglass-reinforced composite rings can maintain their mechanical performance and structural reliability throughout the entire 20-year operational life of the ITER tokamak.
The views and opinions expressed herein do not necessarily reflect those of the ITER Organization.

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Session Classification: Sat-Mo-Or1 - Assembly and Commissioning Fusion Tokamaks

Contribution ID: **845** Type: **Poster**

Thu-Af-Po.05-06: Magnetic measurements of Fermilab rapid cycling Booster gradient magnets

Thursday, July 3, 2025 2:00 PM (2 hours)

Fermilab is upgrading its Booster synchrotron to increase its ramp rate and intensity. This is part of the Proton Improvement Plan (PIP-II) that will allow the Main Injector to achieve proton beam power of 1.2 MW within the next few years. This upgrade includes running the 55 year old Booster magnets at 20 Hz instead of the usual 15 Hz, and construction of some shorter and wider aperture versions of these gradient magnets. Magnetic measurements were performed to characterize the present 15 Hz AC performance, and then again with 20 Hz ramp cycle to insure performance and compatibility in this new operating regime. A 3 m-long curved flat-coil was developed for these measurements using Printed Circuit Board (PCB) technology. The probe also has a separate 0.5 m-long body-field probe, allowing both the integral and body fields to be measured across 100 mm of the magnet aperture. The sampling rate for these measurements during the AC cycle was 200 kHz, and field resolution was better than 0.01%. Details of the probe, measurements, and results are presented in this paper.

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Presenter: DIMARCO, Joseph

Session Classification: Thu-Af-Po.05 - Conductor and Coil Measurement/Test Techniques and Facilities III

Contribution ID: **846** Type: **Poster**

Sat-Mo-Po.09-09: Advanced 3D Modeling of AC Losses in Superconducting Magnetic Energy Storage Systems for Maritime Applications

Saturday, July 5, 2025 9:30 AM (1h 45m)

The POSEIDON project, funded by the European Union, seeks to develop an HTS Superconducting Magnetic Energy Storage (SMES) systems for maritime applications. A key challenge in this endeavor is the accurate modeling of AC losses, which represent a major heat load on the cryogenic system and critically influence system optimization. This study presents a novel numerical model based on the integral form of Maxwell's equations to address this issue. The proposed method facilitates the analysis of three-dimensional geometries while significantly reducing computational demands compared to traditional finite element H-formulation approaches. The study is structured into three parts: first, the numerical methodology is introduced and validated against conventional modeling techniques, comparing accuracy and computational efficiency. Second, the experimental methodology, employing a calorimetric approach, is described in detail. Finally, the numerical results are compared with experimental data, followed by a discussion of future directions and implications for modeling superconducting electrical machines.

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Presenter: HERNANDO, Carlos (CYCLOMED)

Session Classification: Sat-Mo-Po.09 - Energy Storage/SMES, Levitation and Magnetic Bearings

Contribution ID: **848** Type: **Poster**

Thu-Af-Po.02-08: Investigation of the first full-scale Roebel structure transposed cable with in-plane bending of ReBCO tapes (X-cable)

Thursday, July 3, 2025 2:00 PM (2 hours)

The Superconducting Magnet Group of the Institute High Energy Physics, Chinese Academy of Sciences, is investigating a dipole magnet fabricated with Nb3Sn and HTS to achieve a field of 15-20 T or even more higher. A compact high current carrying compacity and low AC loss ReBCO cable (X-cable) is developed for the insert HTS coil. The structure of the cable is similar to the original Roebel cable, but is implemented by in-plane bent ReBCO stacks. The concept of X-cable has been proposed in 2016 by IHEP. The first 10 m prototype cable has been successfully fabricated in 2020. It is delightful that the experimental results of the prototype cable demonstrate the feasibility of the cable design and cabling process. Based on the test results of the prototype cable and design parameters of the insert HTS coli, the first full-scale X-cable has been successfully fabricated in 2023 on a production line. The transposition period length of the cable is more than halved compared to the prototype X-cable, which will further reduce the AC loss of the cable and make the current distribution more uniform. In this work, a 2D model is used to analyse the effect of transposition length on the current distribution of the cable. Meanwhile, a 1 m full-scale X-cable is tested in liquid nitrogen, the voltage at each ReBCO tape contained in the cable and the voltage at different position of the copper terminals are real-time monitored during the whole test. The experimental and simulation results demonstrate that the quality of the termination made in this work is relatively good, and the critical current of the cable reaches 2019.1 A.

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Session Classification: Thu-Af-Po.02 - HTS Cable

Contribution ID: **849** Type: **Poster**

Fri-Af-Po.09-09: A new radial structure of torque tube with superior performance for high-temperature superconducting motors

Friday, July 4, 2025 2:00 PM (2 hours)

The torque tube is crucial for the normal operation of high-temperature superconducting motors, serving as a mechanical support and torque transmission element. Including adiabatic performance, cold shrinkage performance and mechanical stress, the performances of torque tube are important indicators in superconducting electrical design, which need to be analyzed and studied comprehensively. The conventional structures of torque tube suffer from the problems of large contact areas and short heat transfer paths, leading to serious heat leakage from the superconducting coils. Therefore, it is necessary to design the torque tube reasonably to reduce the heat leakage without increasing the volume of the motor rotor and satisfying the rotor support capacity.
In this paper, a novel radial structure of torque tube that enables good mechanical stress and low heat leakage is proposed. By comparing the performances of different torque tube structures with the same dimensions, the proposed structure possesses the advantages of exhibit smaller thermal leakage and transmitting high torque, which meets the design requirements for high temperature superconducting motor. Moreover, this study provides a comprehensive analysis of the tradeoffs between heat leakage and mechanical stress in the torque tube, offering valuable insights for optimizing its design.

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Session Classification: Fri-Af-Po.09 - Rotating Machinery IV

Contribution ID: **850** Type: **Poster**

Fri-Mo-Po.08-10: Development of Critical Current Measurement Platform for REBCO Tapes with Micro-Bridges Based on High-Frequency Pulse Current Injection

Friday, July 4, 2025 9:30 AM (1h 45m)

The development of new high-field superconducting magnets is significantly constrained by the limiting critical properties of superconducting coated conductors (CCs). A major challenge is that REBCO tapes have high critical current densities. It is essential to create micro-bridges on REBCO tapes to test the critical current at low temperatures and high fields. However, pulsed high magnetic fields exceeding 50T generated within just milliseconds present technical challenges for the measurement of critical current. Current studies have assumed that the effect of micro-bridges on tapes is the same at 77 K self-field and at low temperatures and high fields. In this study, we develop a specialized measurement platform for determining the superconducting critical current of tapes with micro-bridges. This platform injects high-frequency, high-precision pulse currents lasting less than 100 milliseconds during the flat-top phase of pulsed high magnetic fields, enabling accurate measurement of the critical current. We compared the critical current measurements of the tapes obtained under a wide range of magnetic fields and temperatures using both DC and pulse current, thus verifying the effectiveness of the proposed platform. Our study provides a more systematic investigation of the impact of micro-bridges on critical currents and lays an important basis for more accurate measurements of critical currents at low temperatures and high fields.

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Session Classification: Fri-Mo-Po.08 - HTS Characterization II

Contribution ID: **853** Type: **Poster**

Fri-Mo-Po.08-07: Characterization of Critical Currents and Validation of REBCO Tapes with Micro-bridges Using Pulsed Current Measurements

Friday, July 4, 2025 9:30 AM (1h 45m)

High-temperature superconducting tapes, such as REBCO, are anticipated to be used in ultra-high field magnets (40 T), fusion reactors, and particle accelerators. Significant progress has been made in enhancing the critical current of REBCO tapes by introducing pinning centers. At 4.2 K, the critical current of 4 mm wide tapes can reach thousands of amperes. However, accurately measuring the critical current in these tapes is challenging due to the heating of current leads and cooling limitations. To address this, we have developed a method using pulsed currents to measure critical currents with a maximum output of 30 A. A 2 ms trapezoidal pulse was applied to the sample, and the voltage was recorded using a DMM7510 with a high sampling rate. To reduce the required current for testing, microbridges of varying widths were etched onto the samples. The critical current of the tapes with micro-bridges was measured at 77 K in a self-field configuration, with corrections based on previous studies of the microbridge structures. The critical current characteristics of REBCO tapes with micro-bridges were compared under both pulsed and steady-state current conditions, showing that they are effectively equivalent.

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Presenter: YUAN, Qi (Wuhan National High Magnetic Field Center, Huazhong University of Science and Technology)

Session Classification: Fri-Mo-Po.08 - HTS Characterization II

Contribution ID: **854** Type: **Contributed Oral**

Sat-Af-Or1-04: Large bore high field fast ramp test facility for in-field measurements of HTS cables and model coils

Saturday, July 5, 2025 3:00 PM (15 minutes)

Significant efforts to advance high temperature superconductor (HTS) and HTS coil technology are underway by privately funded startups with the goal to demonstrate HTS maturity for commercial fusion. The goal for a fusion pilot plant (FPP) is to make 50-100 MW net electricity power plants with either extended long pulses or steady state options. Although a high current, self-field test facility exists without external or background magnetic fields, there are insufficient present magnet cables and in-field coil test facilities in the U.S. There is also a vital need for bigger bore high pulsed field test facilities to de-risk FPP development to validate the AC loss characteristics, quench dynamics of high current fusion cables or insert ohmic heating coils with HTS conductors made in the USA. A large warm bore (22") fast ramp coil test facility (up to 10 T/s) is presented for next step compact tokamak and compact stellarator devices to understand plasma startup, in-field transients and ac losses of HTS cables. The background field coil can be ramped with positive and negative current up to 20+ kA. A stand-alone conduction cool cryostat assembly can easily be integrated into the 22"large warm bore fast ramp coil testbed. The dummy load coil test facility can be further upgraded from 4T to higher magnetic field (>10T) as a high field pulsed test facility to address critical test needs for the ac loss comparison of HTS cables and HTS model coils. Recent evaluations have shown that commercial Bi-2212 wires are suitable and potentially the only viable high field option for a fast ramp, high field solenoid for compact ST operation. This is significant because most recent studies in support of private fusion have shown promising results of net fusion gain by operating a pulsed tokamak machine.

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Presenter: ZHAI, Yuhu (Princeton Plasma Physics Laboratory)

Session Classification: Sat-Af-Or1 - Fusion Test Facilities

Contribution ID: **855** Type: **Poster**

Thu-Mo-Po.09-13: Investigation of a Concept for Magnetic Annealing Oven for Applications in MRAM and other GMR, TMR Effect Devices

Thursday, July 3, 2025 8:45 AM (2 hours)

A concept for a magnetic annealing oven for applications in the fabrication of MRAM and other GMR, TMR effect devices is investigated. With the oven, it is possible to anneal 20 to 50 wafers with a diameter of 200-300 mm at temperatures up to 450℃ in a magnetic field of 1 T or more. The magnetic field in this study is created by HTS coils made up of THEVA, SuperOx, Sumitomo and Shanghai Superconducting tapes in Helmholtz and Maxwell coil configurations that allow high magnetic fields at the wafer position with a high uniformity of the field in direction and magnitude. This study includes the literature research about magnetic annealing requirements for MRAMs and other GMR effect devices, known concepts for generating high and uniform magnetic fields in a large volume, and technologies to build high-temperature superconducting coils for this purpose. Later, a setup of a FEM-model to simulate the magnetic field in mentioned coil arrangements for the given purpose is proposed and then a parameter variation is carried out to optimize the coil arrangement to achieve the best field uniformity for magnetic fields of 1 T at the wafers while minimizing the total cost for the coil. Major targets are to maintain minimal wire consumption and the operation at the highest possible temperature

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Presenter: AKBAR, Muhammad (Technical University of Munich)

Session Classification: Thu-Mo-Po.09 - Conductor and Coil Measurement/Test Techniques and Facilities II

Contribution ID: **856** Type: **Contributed Oral**

Sat-Af-Or2-01: Building the 14T HTS MRI magnet for the DYNAMIC Consortium

Saturday, July 5, 2025 2:00 PM (15 minutes)

Neoscan Solutions is currently building the 14T HTS MRI magnet for whole-body MR imaging and spectroscopy, under the supervision of a magnet committee formed by the DYNAMIC consortium, i.e. seven research institutes and medical centers in the Netherlands who will be using the system. The magnet will be sited at the Radboud University in Nijmegen. It offers an 82 cm wide warm bore for MRI of human subjects [1].
Previously, a concept study had shown that such type of magnet seems feasible with respect to its critical currents in an ambient field of up to 16.2 T in the magnet coils, at up to 20 K temperature [2]. The proposed magnet is unshielded, conductively cooled, and does not use any liquid He. The core magnet is accessible by removing the lids of the cryostat. Its pancake coils are not casted and but can be unwound for repair or reconfiguration. A conductor layout yielding a highly homogeneous central field has been proposed; the stresses in the core magnet have shown to be within the limits of the conductor, and a cooling concept and methods for quench protection have been devised. An HTS magnet appears an attractive concept in ultra-high field (UHF) MRI, since it could offer resilience against heating of the magnet induced by the gradient fields used for image encoding. The magnet currently under construction will offer a temperature safety margin of about 15 K before reaching its Ic limit. In comparison, temperature safety margins are significantly lower in LTS magnets for imaging of humans at fields above 10T.
Here we present how the magnet and associated simulations have been improved compared to the original concept: (i) the rationale for choosing REBCO over BSCCO; (ii) a new mechanical model of the magnet coil inner forces, taking into account three different coil materials and coil confinement; (iii) the choice of coil co-winding material for improving passive quench protection, experimental data of shoot-out testing; (iv) electrical and mechanical properties of its joints. The finalized cryostat is shown. Furthermore, the strategy for experimental validation of the magnet design and its construction will be presented and discussed.
[1] Bates S, Dumoulin SO, Folkers PJM, Formisano E, Goebel R, Haghnejad A, Helmich RC, Klomp D, van der Kolk AG, Li Y, Nederveen A, Norris DG, Petridou N, Roell S, Scheenen TWJ, Schoonheim MM, Voogt I, Webb A. (2023). A vision of 14 T MR for fundamental and clinical science. MAGMA. 36(2):211-225. doi: 10.1007/s10334-023-01081-3. Epub 2023 Apr 10. PMID: 37036574; PMCID: PMC10088620.
[2] Li Y, Roell S (2021). Key Designs of a Short-bore and Cryogen-free High Temperature Superconducting Magnet System for 14 T Whole-Body MRI. Superconductor Science and Technology. 34. 10.1088/1361-6668/ac2ec8.

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Session Classification: Sat-Af-Or2 - Progress in Ultra High Field Solenoids

Contribution ID: **857** Type: **Poster**

Thu-Af-Po.11-03: Exploration of Liquid Mixture for Novel HTS Magnets and Devices

Thursday, July 3, 2025 2:00 PM (2 hours)

Low temperature refrigeration is one of the important factors restricting the large-scale application of HTS magnets. Helium/Neon are the scarce resource in the earth and expensive; The thermal stability of HTS magnets directly cooled by refrigerator is poor, and the electrical insulation under low vacuum is also poor. Liquid hydrogen/LNG are flammable and explosive, which may cause safety accidents; Liquid nitrogen has a high freezing point, and the electromagnetic properties of magnets at 65 K are limited; The thermal stability of HTS magnets cooled by solid nitrogen is also poor because of thermal separation of solid nitrogen and magnet, and the electromagnetic properties may also deteriorate after multiple cold and hot cycles. In order to solve above problems, a variety of binary and ternary liquid mixture are explored. The newly developed liquid nitrogen-carbon tetrafluoride mixed liquid media has a freezing point close to 60K at a molar ratio of 9:1, while the liquid nitrogen-liquid oxygen mixed liquid media has a freezing point close to 50K at a molar ratio of 2:8. It is of great significance to explore newer binary and ternary liquid mixtures in the 50K temperature zone or below. In this paper, recent progress concerning the liquid mixture-cooled HTS magnets and devices including superconducting energy pipeline (SEP), superconducting fault current limiter (SFCL) and superconducting magnets is presented with the emphasis focused on their electromagnetic characteristics and thermal stability compared with those devices cooled by other means.

Authors: QIU, Qingquan; Prof. XIAO, Liye; Prof. TENG, Yuping; Ms JING, Liwei; Prof. ZHANG, Jingye; Prof. SONG, Naihao

Presenter: QIU, Qingquan

Session Classification: Thu-Af-Po.11 - Cryostats and Cryogenics II

Contribution ID: **858** Type: **Invited Oral**

Sat-Af-Spe1-06: [Invited] Characterization of electromechanical properties of striated REBCO CC tapes for TORT cables with reduced magnetization AC losses

Saturday, July 5, 2025 3:15 PM (15 minutes)

REBCO CC (Rare-earth barium copper oxide coated conductors) are the best candidate materials for superconducting TORT (tapes on round tube) cables and high-field magnets due to their excellent mechanical strength, high current-carrying capacity, and magnetic strength. It is currently known that the AC (alternating current) loss can be decreased when TORT cables are made using REBCO multi-filamentary tapes. However, when winding such geometrically adjusted tapes into cables, their mechanical robustness is equally crucial. This mechanical robustness is important both during the winding and cable production process as well as during the electromagnetic environment loads themselves, thus raised concerns around striated tape lifetimes. This work involved the preparation of various types of 2 mm wide REBCO striated tapes through chemo-mechanical striating, followed with deposition of thermal and chemical stabilization multilayers. Subsequently, the striated tapes were bent at a lay angle of 45° over bending diameters from 13 mm to 1 mm and current-carrying performance under self-field conditions at 77 K were measured. Electrical measurements demonstrated that up to 2 mm of bending diameter, the striated tapes did not exhibit any I_c deterioration. Conversely, at 3 mm bending diameter, non-striated tapes started to deteriorate. The SEM FIB observation proved that the adhesion of additional stabilization layers in the filaments was not disrupted. The filament edges marked the key zone in terms of delamination or crack formation. The simple bending tests of striated tapes continued with high cycle fatique studies at 77 K and self-field conditions. Finally, the effect of groove geometrical irregularities on the mechanical performance of striated REBCO tapes were supported by FE (finite element) analysis and correlated with experimental results.

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Session Classification: Sat-Af-Spe1 - [Special Session] High Current HTS Cables for Fusion and Beyond

Contribution ID: **859** Type: **Invited Oral**

Thu-Mo-Spec1-01: [Invited] Quench Protection for Large Stored-energy REBCO Magnets

Thursday, July 3, 2025 10:45 AM (20 minutes)

REBCO has been regarded as one of the most promising high temperature superconductor (HTS) options mainly due to its large in-field current carrying capacity and strong substrate mechanical toughness. Thus, it may not be a surprise that the recent high expectation on compact fusion has been largely relying on REBCO conductor and magnet technologies. Despite the recent notable achievements in some milestone REBCO magnets, however, we are still struggling with even fundamental challenges such as accurate estimation of critical current and understanding of spatial and temporal distributions of currents. Thus, modern REBCO magnets have been designed and operated with lack of confidence in precise estimation of their electrical and mechanical limits. Yet, adequate quench protection for REBCO magnet is still far from success. Firstly reported in 2009, the so-called no-insulation (NI) winding technique enables "current sharing"among adjacent turns, which introduces an alternative quench protection mechanism for REBCO magnets. Despite its "self-protecting"behaviors in small NI REBCO coils, however, failures of protection have been often reported particularly in large stored energy NI REBCO magnets. This paper summarizes protection failures of selected REBCO magnets to date, analyze mechanisms of damages, and suggests alternative vision on quench protection and potential solutions to protect large stored energy REBCO magnets.

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Presenter: Prof. HAHN, Seungyong (Seoul National University)

Session Classification: Thu-Mo-Spec1 - [Special Session] Quench Protection for Large Stored-energy REBCO Magnets

Contribution ID: **860** Type: **Invited Oral**

Thu-Mo-Spec1-02: [Invited] Quench protection of large-stored-energy REBCO magnets

Thursday, July 3, 2025 11:05 AM (20 minutes)

Our experience with REBCO coils comes primarily from the development of high-field double-pancake/module wound coils for NMR magnet systems. However, many of the conclusions we have reached are quite general. We focus on insulated/insulation coils with a distributed stainless-steel co-wind as the least problematic and thus more promising for our projects, although we also have some experience with no-insulation coils, and we will also touch on that, albeit a little, too. Quench protecting large-stored-energy high-field multi-module REBCO coil magnets is incomparably more complex and difficult than quench protecting any large LTS magnets. In particular, for a number of well-known reasons, it is absolutely necessary to use numerous powerful quench-protection heaters distributed throughout the REBCO windings to quench a significant volume of the coil(s) in a very short time. The difficulty lies in the fact that the magnet design is primarily determined by the requirement not to exceed the maximum permissible value of the strain of the REBCO tapes (including that due to the screening currents), and so the magnet design is not so easy, and sometimes impossible, to change in order to increase the effectiveness of quench protection. As a result, zones appear in the winding that are difficult to quench by the heaters due to too small field angles and thus very high critical currents. This leads to the problem of too high module voltages and thus the magnet voltage-to-ground, which requires additional measures to solve. Also, predictions of the magnet quench behavior and recommendations for the quench protection system design, obtained through comprehensive quench analyses, turned out to be extremely sensitive to the accuracy of information about the parameters of the REBCO tapes used, and first of all - to the one about the value of the critical current (strongly depending on the magnetic field vector and temperature), which varies greatly along the length of the tapes: by up to 10% in a field perpendicular to the tape surface and up to 50% in the parallel field. Properly taking this circumstance into account and achieving good agreement between measurements of module voltages and current in our model coils in the event of a quench and the results of calculations/predictions is a very serious challenge that makes it very difficult, albeit possible, to benchmark the quench code used and its input. The need to take into account significant rotation of REBCO turns due to the screening currents will also be viewed. On the top of it, the magnet systems we design typically include a REBCO insert and an LTS outsert, which requires their protection systems to cooperate.

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Presenter: Dr GAVRILIN, Andrew V. (National High Magnetic Field Laboratory, Florida State University)

Session Classification: Thu-Mo-Spec1 - [Special Session] Quench Protection for Large Stored-energy REBCO Magnets

Contribution ID: **861** Type: **Invited Oral**

Sat-Af-Spe1-01: [Invited] Status, Advances and Challenges of HTS Conductors for Fusion Magnets

Saturday, July 5, 2025 2:00 PM (15 minutes)

The quest to produce energy from fusion power with magnetic confinement follows two main lines of research and development, as far as the generation of the magnetic field is concerned. On the one hand, several national and international roadmaps to fusion rely on tokamak designs obtained scaling up ITER, i.e. based on low temperature superconducting (LTS) magnets. The use of high temperature superconductors (HTS) is only considered as an option to increase the magnetic flux generated by the Central Solenoid. On the other hand, an increasing number of private companies are developing HTS magnets to achieve commercial fusion power on an earlier time horizon. HTS magnets potentially represent the enabling technology for the achievement of high-field fusion with a significant reduction in machine size, complexity and cost.
This paper will review the status, advances and open challenges in the design, qualification, and manufacturing advances of high-current / high-field conductors employing HTS materials, which are crucial for fusion as well as for so many other applications requiring high magnetic field. The main lessons learned during the development of the LTS cable in conduit conductors (CICCs) for the ITER project are recalled, with special reference to the performance degradation due to electromagnetic and thermal cyclic loading. The advances in the development of HTS conductors for fusion from the early short samples to the present model magnets are discussed, describing the different cabling configurations and the remarkable steps made to reach the present high current carrying capacity, current sharing temperatures and mechanical robustness. The characteristic time constants of these conductors, their quench behavior and losses during electrodynamic transients are discussed, also by comparison with the corresponding characteristics of LTS conductors. The paper finally points out the open challenges in this development, along with the ongoing experimental and theoretical R&D activities performed to address them.

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Session Classification: Sat-Af-Spe1 - [Special Session] High Current HTS Cables for Fusion and Beyond

Contribution ID: **862** Type: **Invited Oral**

Sun-Mo-Spe1-03: [Invited] The user facilities and high field HTS magnet program at the National High Magnetic Field Laboratory

Sunday, July 6, 2025 8:45 AM (25 minutes)

The National High Magnetic Field Laboratory (MagLab) operates high field user facilities in Tallahassee (dc, NMR, EMR, ICR) and Gainesville (MRI, HiB/T), Florida, and Los Alamos, New Mexico (pulsed). These facilities serve approximately 2,000 scientists every year. The recent arrival of ultra-high field magnets based on the high temperature superconductors (HTS) is expected to impact most of these facilities. The MagLab has been leading the way in the development of ultra-high field HTS magnets and is now developing a 40 T all-superconducting (SC) magnet for condensed matter physics. The decision-making process that was used to choose between the various HTS materials and potential coil fabrication and protection methodologies in designing the 40 T SC magnet is described.

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Presenter: BIRD, Mark (NHMFL - Florida State University)

Session Classification: Sun-Mo-Spe1 - [Special Session] Towards Exceptionally High Magnetic Fields

Contribution ID: **863** Type: **Contributed Oral**

Wed-Af-Or3-03: Horizontal winding method for undulator using high-temperature superconductor tapes

Wednesday, July 2, 2025 5:00 PM (15 minutes)

To achieve a short-period, high-field undulator using HTS tape, we propose novel winding methods specifically designed for this purpose. Given the minimum bending radius constraint of HTS tape, conventional horizontal winding has been considered unsuitable for short-period undulators, leading to a primary focus on vertical winding. However, to overcome this limitation, we introduce an innovative winding technique that allows for the successful realization of a short-period undulator using horizontal winding. In the conference, we will show the winding method, winding procedure, and the simulation results of the achievable undulator field.

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Presenter: Mr SANO, Satoshi (OIT)

Session Classification: Wed-Af-Or3 - Wiggler Magnets

Contribution ID: **864** Type: **Invited Oral**

Thu-Mo-Spec1-03: [Invited] A review of the tools for quench simulation and protection for large REBCO coils

Thursday, July 3, 2025 11:25 AM (20 minutes)

This presentation aims to provide a concise overview of the current modeling capabilities and highlight critical gaps in simulation and protection strategies for large REBCO coils. High Temperature Superconductors (HTS) are revolutionizing the design of magnetic confinement systems for nuclear fusion and beyond, offering compactness and efficiency through their ability to generate high magnetic fields at cryogenic temperatures. REBCO tapes have emerged as a leading candidate for large-scale high field magnets. However, the successful integration of REBCO into large magnets presents significant challenges, among which quench protection.
This review explores the diverse landscape of computational tools available for modeling quench dynamics and protection of REBCO coils. These range from simplified yet highly informative 0D models to intricate 3D simulations, where intuition alone often falls short. While complex models offer detailed insights into quench propagation and magnet behavior under fusion-relevant conditions—such as high magnetic fields, intense mechanical stresses, and cryogenic environments—simplified models frequently reveal the power of computational efficiency and conceptual clarity. Both approaches are essential, depending on the specific needs, from early feasibility assessments to advanced design optimization.
More than just a review, it seeks to foster discussion within the community: What tools are we using, and how do they shape our understanding? What are we missing? By exchanging perspectives, we can refine our collective approach and better steer the development of robust, scalable solutions for HTS integration into next-generation high-field systems.

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Presenter: NICOLO, Riva (Proxima Fusion)

Session Classification: Thu-Mo-Spec1 - [Special Session] Quench Protection for Large Stored-energy REBCO Magnets

Contribution ID: **865** Type: **Invited Oral**

Thu-Mo-Spec1-06: [Invited] Quench detection and localization techniques for high-temperature superconductor accelerator magnets

Thursday, July 3, 2025 12:10 PM (20 minutes)

Accelerator magnets based on high-temperature superconductors will be fundamental to producing a field in excess of 16 T for future HEP machines. One of the known challenges of practical conductors made with HTS materials is a slow normal zone propagation resulting from a large superconducting temperature margin in combination with a higher heat capacity compared to conventional low-temperature superconductors. As a result, traditional voltage-based schemes may be ineffective for detecting normal zone formation in superconducting coil windings. Non-voltage techniques designed to measure local temperature rise along the HTS conductor are therefore being developed as a viable alternative to voltage detection and redundancy. We will review non-voltage quench detection and localization techniques based on optical fibers, ultrasonic waveguides, and radio-frequency time-domain reflectometry and compare these techniques' capabilities, advantages, and drawbacks. The most recent results on strain and temperature sensing and localization will be presented using all three techniques. Directions for future improvement of these methods to fully address the HTS magnet protection challenges will be discussed.

Authors: BALDINI, Maria; MARCHEVSKY, Maxim

Presenters: BALDINI, Maria; MARCHEVSKY, Maxim

Session Classification: Thu-Mo-Spec1 - [Special Session] Quench Protection for Large Stored-energy REBCO Magnets

Contribution ID: **866** Type: **Poster**

Fri-Af-Po.07-01: Optimizing Electromagnetic Force Distribution in Tube Forming: A Novel Magnet Design for Convex Field Shaper

Friday, July 4, 2025 2:00 PM (2 hours)

Electromagnetic forming (EMF), renowned for its high forming speed and strain rate advantages, has been extensively applied in industrial manufacturing, transportation, and other sectors. The principle of EMF involves generating an electromagnetic force on the workpiece using a pulsed magnet, driving the material to undergo plastic deformation. However, traditional solenoid-based forming magnets often produce non-uniform deformation, characterized by excessive bulging at the center of tubular workpieces and insufficient deformation at the ends. This issue arises from the non-uniform distribution of electromagnetic force field generated by conventional coil structures, significantly limiting the application of EMF in tube manufacturing.

Magnetic field shaper (FS), commonly used in magnet technology to control magnetic field configurations, are typically fabricated from highly conductive metal blocks. By leveraging differences in the surface areas of their inner and outer walls, FSs regulate magnetic field distributions. These structures have been extensively applied in high-field magnets and magnetic pulse welding. In this work, a novel convex field shaper (CFS) is introduced into the design of forming magnets to address the uneven electromagnetic force distribution during tube forming. The CFS features a convex structure, where the end sections have smaller surface areas, and the middle section has a larger surface area. This design increases current density at the tube's ends while reducing it at the center. Since current density is directly proportional to electromagnetic force, this adjustment redistributes the force, achieving a uniform distribution.

The effectiveness of the CFS was validated through both COMSOL simulations and discharge experiments. Results revealed that, after integrating the CFS into the A6061-O aluminum alloy tube electromagnetic bulging system, the current and electromagnetic force distributions followed the desired pattern: higher forces at the ends and lower forces at the center. Compared to conventional systems, the CFS improved the axial deformation uniformity by approximately threefold, significantly enhancing the overall deformation uniformity. Further investigations into the effects of circuit parameters on tube displacement and axial deformation uniformity were conducted. Simulation and experimental data showed that increasing the discharge voltage led to greater tube displacement; however, an optimal voltage value was identified for maximizing axial deformation uniformity. In conclusion, the proposed CFS-based forming scheme significantly enhances the axial deformation uniformity of tubular components, optimizes the forming profile, and expands the potential applications of electromagnetic forming technology in tube manufacturing processes.

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Session Classification: Fri-Af-Po.07 - High Field Pulsed Magnets II

Contribution ID: **867** Type: **Poster**

Wed-Mo-Po.05-09: Decoupling high-speed deformation from electromagnetic effects in electromagnetic forming: A novel magnetic field shielding device design for electromagnetic expansion

Wednesday, July 2, 2025 9:15 AM (2 hours)

Electromagnetic forming (EMF), a critical application of pulsed magnetic field technology, is extensively utilized in manufacturing lightweight automotive components and high-precision aerospace structures. The process involves rapidly discharging high-energy pulsed currents from a capacitor bank into a coil, generating a transient, intense magnetic field. When a conductive workpiece is placed within this dynamic magnetic field, eddy currents are induced on its surface. The interaction between these eddy currents and the pulsed magnetic field produces electromagnetic forces, causing plastic deformation of the workpiece. Unlike conventional quasi-static forming, EMF operates at high strain rates, offering advantages such as reduced springback and enhanced material formability. However, Unlike other high-strain-rate techniques, such as explosive forming, laser shock forming, and vaporizing foil actuators, EMF introduces multifactorial effects, including thermal, electroplastic, and magnetoplastic phenomena due to the pulsed magnetic field and induced currents. These effects complicate the isolation of mechanical deformation from electromagnetic influences. Consequently, decoupling high-strain-rate deformation from electromagnetic effects is essential to elucidate their distinct impacts on macro- and microstructural material properties, advancing both the efficiency and applicability of EMF.
To achieve this decoupling, this study investigates the electromagnetic expansion of 6061 aluminum alloy rings (inner diameter: 108 mm, outer diameter: 118 mm, height: 8 mm). An electromagnetic expansion platform was established, comprising a discharge coil, coil framework, and end plates. The coil (inner diameter: 72 mm, outer diameter: 96 mm, height: 30 mm) was wound onto the framework and secured with end plates and bolts. A magnetic shielding device was designed to enable shielding-driven expansion. The shielding mechanism leverages the high conductivity of the ring material to induce eddy currents, which generate opposing magnetic fields that attenuate internal magnetic flux penetration. Simultaneously, the aluminum alloy ring expansion is driven by the electromagnetic force generated from the interaction between the induced eddy currents and the pulsed magnetic field in the shielding ring. Key design considerations included the skin effect: shielding ring thickness significantly smaller than the skin depth reduces eddy current efficacy, while excessive thickness diminishes expansion efficiency and increases costs. Through theoretical calculations and COMSOL simulations, an optimized red copper shielding ring (inner diameter: 98 mm, outer diameter: 106 mm, height: 15 mm) paired with an embedded copper plate structure was designed to balance magnetic shielding and forming efficiency. Then, conventional and shielding-driven electromagnetic expansions were experimentally compared. Plastic strain and residual stress elimination rates were analyzed. Microstructural characterization via Electron Backscatter Diffraction (EBSD) evaluated grain size, texture, and microscopic deformation. By comparing the macroscopic residual stress elimination and microstructural changes between conventional electromagnetic expansion and shielding-driven expansion, the study successfully decouples the effects of the magnetic field and its associated phenomena on the macro- and microstructural properties of aluminum alloy rings.
COMSOL simulations and experimental data validated the shielding device's efficacy, confirming

its ability to decouple electromagnetic effects and high-speed deformation. This decoupling provides critical insights into the distinct roles of electromagnetic phenomena in altering material properties, establishing a theoretical foundation for optimizing high-efficiency EMF processes.

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Session Classification: Wed-Mo-Po.05 - Novel and Other Applications I

Contribution ID: **868** Type: **Poster**

Wed-Mo-Po.05-10: Improved Array Welding Magnet Structure Design and Optimization for Enhancing Magnetic Pulse Welding Quality of Dissimilar Metal Tubular Components

Wednesday, July 2, 2025 9:15 AM (2 hours)

Welding of dissimilar metals can significantly enhance the performance of metal components by utilizing the distinct physical and chemical properties of different materials, offering substantial potential in lightweight and multifunctional manufacturing. Magnetic Pulse Welding (MPW), a solid-state process, employs pulsed electromagnetic fields to accelerate dissimilar metals to supersonic speeds within microseconds. This results in high-speed collisions, facilitating atomic diffusion and metallurgical bonding at the weld interface. However, traditional MPW for tubular components uses a single-coil coaxial structure to deliver magnetic energy, which may be inefficient for large-diameter tubes. As the coil radius increases with component size, the total discharge circuit inductance and discharge current rate rise, limiting effective deformation velocity within the short acceleration period. Additionally, conventional MPW systems are constrained by coil structure limitations. During discharge, the welding magnet undergoes significant radially outward expansion forces. Under the combined mechanical-electrical-thermal loading conditions and geometric constraints, existing MPW magnets suffer from low energy conversion efficiency, poor interfacial bonding, and limited adaptability of coil topologies.
To address these challenges, this study introduces a novel array-based welding magnet structure for tubular components. The proposed topology features two key components: circumferentially distributed modular array coils and an encircling conductive channel. The modular coils are arranged in equidistant multi-stage configurations along the component's periphery, with multiple independent power supplies to enhance discharge current rates. The conductive channel, made from high-strength chromium-zirconium copper alloy with superior conductivity, forms a closed circuit and utilizes leakage flux from the coil array to improve energy efficiency. Together, these components optimize the uniformity of collision interface pressure, enhancing weld quality while reducing equipment complexity.
A three-dimensional FEM-BEM collision model of the welding process was developed using LS-DYNA software to simulate energy transfer and collision dynamics. Key parameters, such as coil spacing, cross-sectional geometry, and axial coil stages, were optimized. The results show that the array-based magnet structure, in conjunction with multi-stage coordinated power discharge, effectively increases material acceleration in large-diameter component welding. Additionally, the conductive channel transforms the outward-expanding electromagnetic forces into inward compressive forces, greatly improving the magnet's load-bearing capacity. These findings provide crucial insights for enhancing MPW joint quality and broadening the industrial applications of this technology.

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Presenter: LI, Mengxian

Session Classification: Wed-Mo-Po.05 - Novel and Other Applications I

Contribution ID: **869** Type: **Poster**

Thu-Mo-Po.09-03: 8 Tesla high-temperature superconducting magnet for Ic(B, T) measurement system at SuNAM

Thursday, July 3, 2025 8:45 AM (2 hours)

In superconducting applications such as NMR/MRI, SMES, and fusion reactor systems, the critical current (Ic) of the wire is an essential component in determining device performance. This critical current depends on the applied magnetic field (B) and temperature (T), and particularly exhibits magnetic anisotropy in tape-shaped HTS. SuNAM, a manufacturer of HTS wire, operates a 4 Tesla Ic(B, T) measurement system to evaluate the characteristics of the developed wire and ensure product quality, while currently establishing a new 8 Tesla system. This presentation provides an overview of the design, fabrication, and testing results of the magnet utilized for applying the magnetic field in the Ic(B, T) system. The magnet, constructed with HTS coils, uses No-insulation winding techniques with wires of 4, 6, and 8 mm in width. The warm bore of the magnet has a diameter of 70 mm, and the system will be completed in combination with an insert probe under development.

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Session Classification: Thu-Mo-Po.09 - Conductor and Coil Measurement/Test Techniques and Facilities II

Contribution ID: **870** Type: **Poster**

Fri-Mo-Po.01-06: Measurement and analysis of radial stress for no-insulated High Temperature superconducting pancake coils

Friday, July 4, 2025 9:30 AM (1h 45m)

No-insulated high temperature superconducting (HTS) coils are widely favored for high engineering current density and self-protection properties. Radial stress is an important parameter for HTS coils, which is mainly the superposition of winding tension, electromagnetic load and thermal stress. Radial stress is related to the magnet transient behavior and the self-protection characteristics of HTS coils. The main reason is that the contact resistance is related to the radial stress. The greater the compressive stress, the smaller the contact resistivity. So the current at the hot spot will be more likely to shunt from the radial direction to avoid quench. In this review, we present experimental and theoretical analyses on the radial stress in a REBCO insert setup based on the contact resistance Rct. Firstly, the correspondence between the contact resistivity Rct of tapes and radial stress is tested and get in use of press machine. Then, an experimental insert coil is developed in which the voltage signal points are arranged. After that, the HTS pancake coil is excited. Referring to the current, the potential signal and the mutual inductance matrix, we can derive the experiments of the radial stress. Finally, the discrete-coupled model with turn-to-turn contacts, the discrete-sequential model and the block model are also implemented and compared against the measured radial stress.

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Presenter: Dr DAI, Tianli (Institute of Plasma Physics, Chinese Academy of Sciences)

Session Classification: Fri-Mo-Po.01 - No-Insulation Coils IV

Contribution ID: **871** Type: **Poster**

Wed-Mo-Po.10-04: Study on DC Fault Current Limiting and Protective Relay Operation of Flux-Coupled Type SFCL-CB

Wednesday, July 2, 2025 9:15 AM (2 hours)

With the growing integration of renewable energy sources such as photovoltaics, research on DC systems has been actively performed. DC systems offer superior compatibility with renewable energy sources and lower power transmission losses compared to AC systems. However, it faces critical challenges, such as rapid increase of fault currents directly after a fault occurs and the absence of natural current zero-crossing, complicating fault current interruption. To mitigate these issues, significant efforts have been devoted to develop DC superconducting fault current-limiting circuit breaker (SFCL-CB) capable of quickly reducing fault current, thereby alleviating power burden of circuit breaker.

Among the studied SFCL-CB, the flux-coupled type SFCL-CB maintains superconducting state of its superconducting element before a fault occurs, allowing the magnetic flux generated by the windings to cancel each other out. In the event of a fault, the superconducting element transitions to conducting state, inducing voltage across the windings and effectively limiting and interrupting the fault current. However, the interrupting time of flux-coupled type SFCL-CB varies significantly depending on the winding method or turns of the winding, and the interrupting time does not take into account protection coordination with adjacent protective relays, posing a limitation.

In this study, a novel protection coordination-enabled flux-coupled type SFCL-CB with parallel two windings via a iron core was proposed. Also, fault current limiting and protective relay operation of flux-coupled type SFCL-CB was studied in DC system. The protective relay part of flux-coupled type SFCL-CB measures the current flowing through the secondary winding and sends a trip signal to circuit breaker connected in series with the secondary winding. Through simulation results using PSCAD/EMTDC, it was demonstrated that the proposed flux-coupled type SFCL-CB can not only limit fault current effectively but also adjust the trip time based on the fault current magnitude, thereby mitigating the impact on protection coordination with adjacent protective relays. Additionally, the experimental results validated the appropriate winding configuration for the flux-coupled type SFCL-CB with protective relay functionality.

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Presenter: Ms KIM, Su-Hyeon (Soongsil University)

Session Classification: Wed-Mo-Po.10 - Transformers and Fault Current Limiters

Contribution ID: **872** Type: **Contributed Oral**

Sat-Af-Or4-07: Fabrication of km-class MgB2 wires by the internal magnesium diffusion method in WST

Saturday, July 5, 2025 6:00 PM (15 minutes)

MgB2 is one of the practical superconductors that has been widely studied over the past two decades. The internal magnesium diffusion (IMD) method serves as a promising method because it can enhance the grain connectivity of MgB2 phase and thereby improve the superconducting current of MgB2 wires. In this work, we successfuly fabricate the km-class 30-filament MgB2 wires using the IMD method, which is strickingly the first km-class IMD MgB2 wire in the world. This indicates great potential for the application of IMD method in the future. The finished wire is ϕ1.00mm in size and the filling factor of MgB2 is around 0.10. The superconducting current Ic(4.2 K, 3 T) of our IMD MgB2 wire reaches 650 A. The highest layer-superconducting current density Jc(4.2K, 3T) is 8.9×10ˆ5 A cm-2 and the engineering superconducting current density Je(4.2K, 3T) is 8.3×10ˆ4 A cm-2. Meanwhile, the copper ration of our IMD MgB2 wire is around 0.28 and the RRR(300K/40K) is above 50. The high copper ration can enhance the thermal stability of low-temperature application. The flux pinning mechanism, mechanical properties, and hysteresis loss of the IMD MgB2 wire have also been studied. Finally, we are sincerely looking forward to give an oral prensention about our work in the conference.

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Session Classification: Sat-Af-Or4 - Advances in Nb3Sn and MgB2 Conductors II

Contribution ID: **873** Type: **Poster**

Wed-Mo-Po.10-05: Analysis on Fault Current Limiting Operation of Flux-Coupled Type SFCL with Adjustable Reactor Tap

Wednesday, July 2, 2025 9:15 AM (2 hours)

In modern power distribution systems, ensuring stability and reliability has become increasingly important due to the continuous rise in electricity demand. Overcurrent incidents can cause severe damage to electrical equipment and widespread power outages, making the implementation of effective fault current limiting solutions essential. The flux-coupled type superconducting fault current limiter (SFCL) has attracted attention as an efficient method for mitigating overcurrent issues by utilizing flux coupling and superconducting elements. This study focuses on analyzing the fault current limiting characteristics of the flux-coupled type SFCL with an adjustable reactor tap. The adjustable reactor tap allows for fine-tuning the SFCL's operational characteristics, enhancing its adaptability to various fault conditions. Through simulations and experimental validations, this study evaluates the impact of different reactor tap settings on current-limiting performance under fault conditions. The results confirm that optimizing the reactor tap settings improves the overall performance of the SFCL and effectively reduces fault current.

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Presenter: LIM, Sung-Hun

Session Classification: Wed-Mo-Po.10 - Transformers and Fault Current Limiters

Contribution ID: **874** Type: **Poster**

Wed-Mo-Po.10-06: Analysis on the Fault Current Limiting Characteristics of DC Superconducting Fault Current Limiting Circuit Breaker with Adjustable Current Limiting Reactor

Wednesday, July 2, 2025 9:15 AM (2 hours)

In this paper, the DC superconducting fault current limiting circuit breaker (SFCL-CB) with Adjustable Current Limiting Reactor was suggested and its fault current limiting characteristics was analyzed. The proposed DC SFCL-CB consists of two mechanical switches (SW), a magnetically coupled CLR and two superconducting elements(SC). In case that DC fault current occurs, the first superconducting element quenches, which can limit DC transient fault current due to its resistance generation. Depending on the adjustable CLR coupling method, the quench occurrence of the second superconducting element makes the mechanical switch open. Through the experimental analysis, it was verified that the DC SFCL-CB, in case of the current limiting reactor designed by subtractive polarity winding, could enhance DC fault current limiting and interrupting characteristics.

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Presenter: LIM, Sung-Hun

Session Classification: Wed-Mo-Po.10 - Transformers and Fault Current Limiters

Contribution ID: **878** Type: **Poster**

Wed-Mo-Po.10-07: Study on Suppression of Voltage Fluctuation and Reduction of Induction Motor's Driving Current using Smart Inverter for SFCL Application in a Power Distribution System

Wednesday, July 2, 2025 9:15 AM (2 hours)

Induction motor starting often causes voltage fluctuations due to high inrush current, which can impact system stability and power quality. To address this, smart inverters with power control functions and superconducting fault current limiters (SFCLs) have emerged as promising solutions for reducing voltage instability. The power control of smart inverters ensures that the voltage at the point of common connection is maintained at a constant level, adapting to the system's conditions. In this paper, system voltage characteristics during induction motor starting were analyzed by applying smart inverter power control and SFCL, aiming to suppress voltage fluctuation under high inrush current conditions. Experiments were conducted with smart inverters dynamically adjusting reactive and active power while SFCLs limit high inrush currents. The results show that smart inverters effectively suppress voltage drops during motor starting. Although SFCLs reduce inrush current, they can further decrease system voltage at the point of common point. This issue can be reduced through smart inverter control, improving voltage stability.

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Presenter: CHOI, Seung-Su (Soongsil University)

Session Classification: Wed-Mo-Po.10 - Transformers and Fault Current Limiters

Contribution ID: **879** Type: **Plenary**

Sun-Mo-PL1-05: Cryogenic motors for aircraft propulsion

Sunday, July 6, 2025 11:10 AM (10 minutes)

The aviation sector's greenhouse gas emissions could be reduced by replacing jet engines with electric motor-driven propellers. However, the high power required of these motors is possible only by increasing the motor size and/or the current it carries. Larger size means more mass, which would reduce the plane's range and payload capability. Higher current means more heat generated by resistive losses. This heat cannot exceed the system's cooling capability, so the current must be limited accordingly.

Cryogenic cooling could enable higher currents by reducing the electrical resistivity of the motors' magnetic coils. At cryogenic temperatures, the motor coils could employ superconductors (SC) or non-SC materials, like aluminum, whose resistivity drops significantly with temperature. In either case, the reduced heat generation would allow higher currents, and hence higher power, without increasing motor mass or size. This could help make electric motors suitable for aircraft propulsion.

This talk presents the motivation and technology status of cryogenic motors for aircraft propulsion. Ongoing research projects are discussed, and key research needs are identified.

Author: FELDMAN, Joshua (University of Illinois)

Presenter: FELDMAN, Joshua (University of Illinois)

Session Classification: Plenary 1: Young Scientist Plenary

Contribution ID: **880** Type: **Poster**

Wed-Af-Po.11-09: Thermal hydraulic simulation of Tcs test in the ITER Magnet Cold test facility

Wednesday, July 2, 2025 2:30 PM (2 hours)

The Magnet Cold Test Bench (MCTB) will be assembled and commissioned in 2025 with existing ITER systems (Cold terminal Box, Cryogenic system,) and new components (cryostat, power supply, interconnection valve box). The objective is to test as many TF coils as possible in the MCTB without impacting the assembly schedule in the pit. ITER TF magnet system consist of 18 coils. The Current sharing temperature (Tcs) test is planned only for the spare coil TF19 to check the performance in the stand-alone configuration at half field (6 T) and nominal current 68 kA.
In order to prepare the Tcs test proposal for the TF coil in the MCTB, a dedicated TF thermal hydraulic model is developed with the Supermagnet code. The model has been developed to assess the strategy of increasing the inlet temperature with a resistive heater up to the estimated Tcs at about 11 K in the MCTB configuration. To avoid the quench occurring during the Tcs test, the test procedures will be investigated in order to achieve an accurate temperature control.

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Presenter: Mr LI, Junjun

Session Classification: Wed-Af-Po.11 - Modelling of Fusion Conductors and Coils I

Contribution ID: **881** Type: **Oral**

Test Title for Presentation Upload

Authors: CADY, Annett; CONFERENCE ORGANIZATION, CEC-ICMC 2025

Presenter: CADY, Annett

Contribution ID: **882** Type: **Poster**

Fri-Af-Po.03-08: Long-term energy projections for fusion magnets supplied by flux pumps

Friday, July 4, 2025 2:00 PM (2 hours)

Superconducting (SC) magnets are becoming the base for magnetic-confinement fusion devices. However, the energy demands of their power supply (PS) systems pose a critical challenge to their economic viability, especially in the perspective of delivering a net energy to the electrical grid. Conventional power systems introduce significant losses, from resistive busbars to current leads, which can impose substantial operational costs, potentially jeopardizing the feasibility of future reactors. Addressing this issue, flux pumps (FPs) have emerged as a promising alternative, capable of powering SC magnets with negligible operational losses.
FPs are contactless devices that induce currents in SC circuits without requiring continuous external power. By exploiting the unique properties of superconducting materials, FPs enable a lossless persistent or quasi-persistent current mode after the first ramp-up, eliminating the need for resistive components such as current leads. These devices are particularly suited for DC or low-dynamics operations, such as the toroidal field coils of tokamaks or stellarator magnets, independently of the SC technology (LTS or HTS). The advantages of FPs are enhanced by the present trends of SC coils, such as high-temperature, self-protection and jointless assembly.
This study presents a comparative analysis of energy consumption in traditional PSs versus FP-based systems over a 30-year operational period. Since different FP topologies could be adopted, the analysis moves from general aspects to specific implementation details. Using advanced modeling and simulation tools for designing and characterization, the potential energy savings achievable were quantified for fusion applications. The main investigated case study consists in the toroidal field (TF) magnets for the Divertor Tokamak Test (DTT) facility, also considering its Cold Test Facility.
The findings demonstrate that, over the considered timeline, the adoption of FP approach with proper control algorithms could drastically reduce cumulative energy consumption from tens or hundreds of GWh for conventional PS systems to less than ten MWh, offering substantial economic benefits for future commercial fusion reactors. The relationship between the energy and other FP performances, as charge time and ripple, will be also addressed.
The integration of FPs also brings additional advantages, including reduced system complexity, enhanced reliability and a smaller footprint. These benefits underscore the transformative potential of technology in overcoming the engineering challenges of magnetic confinement fusion. Therefore, this work provides forecasts and insights into the general advantages of FPs, outlining its potential disruptive impact in the field of nuclear fusion.
The presented guidelines and results can be extended to many applications where SC loads are characterized by slow current variations.

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Presenter: LAMPASI, Alessandro (ENEA & DTT)

Session Classification: Fri-Af-Po.03 - Supporting Technologies for Fusion Magnets I

Contribution ID: **883** Type: **Poster**

Thu-Mo-Po.02-09: Design strategies for beam impedance reduction of kicker magnets in particle accelerators

Thursday, July 3, 2025 8:45 AM (2 hours)

In high-energy particle accelerators, kicker magnets are essential for injecting and extracting particle beams using fast-pulsed magnetic fields. A key challenge in their design is minimizing beam coupling impedance to maintain beam stability and reduce induced power losses while preserving the fast rise and fall times of the magnetic pulse.

This paper presents innovative principles and mechanical approaches for reducing beam impedance in several kicker magnets operating under vacuum across the CERN complex. Kicker magnets use ferrite or laminated steel as a magnetic yoke, which is susceptible to beam-induced heating. The proposed techniques aim to screen the ferrite yoke, provide a low impedance path for the beam image current, and eliminate cavities that could generate resonances. Simultaneously, the screen must allow the passage of fast pulsed magnetic fields. Techniques include the insertion of ceramic chambers holding screen conductors, the serigraphy of conductive paint, and thin metallization by sputtering. Bridges eliminate cavities between adjacent magnets or vacuum vessels.

The performance of these design strategies is evaluated through a combination of high-frequency simulations, laboratory impedance measurements, magnetic field assessments, and temperature monitoring of kicker magnets after installation in accelerators. The results demonstrate significant improvements, which are discussed in detail. This work establishes a foundation for further innovations in kicker magnet design, with the potential to enhance existing systems and guide the development for future accelerators such as FCC ee with shorter bunches where the impedance is becoming even more important.

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Presenter: TRUBACOVA, Pavlina (CERN)

Session Classification: Thu-Mo-Po.02 - Design and Development of Accelerator Magnets I

Contribution ID: **884** Type: **Poster**

Wed-Mo-Po.09-01: Trial fabrication report on twisted and simply stacked HTS cable by using individual equipment

Wednesday, July 2, 2025 9:15 AM (2 hours)

As HTS(high-temperature superconducting) cables emerge as a potential alternative to drive innovation in the power sector, we are building equipment that can produce various types of cables. In particular, as research on various types of conductors using REBCO based tape-type superconductors becomes more active, we are manufacturing equipment that can produce cables with twisted and transposed structure and simply-stacked structure.
(Twisted and transposed cable) We are analyzing the technology required to manufacture cable with twisted and transposed structure, and are making manufacturing equipment that reflects the technology. First, the cable to be manufactured using the equipment is wound in a spiral shape around a circular former using HTS tape at a winding angle selected according to the cable design value. The former is selected as litz wire and wound with nomex tape for a smoothing layer so that it can be used for manufacturing long cables and for equipment(flexibility). The former wound on the Litz wire bobbin moves to the cable bobbin, with four tapes wound in the first layer (section 1, winding clockwise), and then in the second layer (section 2, winding counterclockwise). 2 layer are wound in one motion, and this motion can be repeated to manufacture cables with multiple layers. Based on various studies, we will further upgrade our manufacturing equipment.
(Simply stacked cable) Also, semi-automated multiple-layer HTS tape stacking equipment is manufactured. The pulling tension required for each tape during stacking is controlled manually by using the frictional force of a metal block on the tape's spool axle. Trench type guide rollers are installed to align each HTS tape, and the aligned tapes creates a cable bundle. With a bundle processor, stacked HTS tapes are wrapped with narrow-width metal foil, pressed and go through a series of processes(jacketing) for cable manufacturing. and then pressed.

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Presenter: YUN, Junsu (POWERNIX Co., Ltd.)

Session Classification: Wed-Mo-Po.09 - Development and Test of Conductors for Fusion Magnets I

Contribution ID: **886** Type: **Poster**

Fri-Af-Po.03-09: Development and testing of a high-voltage temperature sensor for ITER high-temperature superconducting current leads

Friday, July 4, 2025 2:00 PM (2 hours)

The high-temperature superconducting current lead (HTSCL) plays a key role in supplying large currents to the ITER superconducting magnets. To measure the temperature of the HTSCL cooled by helium gas, PT-100 sensors are installed at both the warm end of the HTS section and the room-temperature terminal. These sensors are exposed to a high-voltage environment, depending on the type of ITER magnet. For example, if a fast discharge occurs in the Toroidal Field (TF), Central Solenoid (CS), or Poloidal Field (PF) coils, the potential level along the current lead (CL) can reach up to 20 kV. Due to the high potential difference between the ITER magnets and the ground, the design of the temperature measurement interface, including the sensors installed on the HTSCL and the data conditioning into an analog output, must be carefully considered.
This paper presents the design, fabrication, and test results of a prototype temperature measurement system specialized for HTSCL, referred to as the High-Voltage Temperature Sensor (HVTS). Based on the technical specifications suggested by the ITER Organization (IO), functional test results—such as measurement accuracy and high-potential testing—of the HVTS will be discussed. Additionally, the long-term operational test, which has been conducted on the PF current leads of the KSTAR Tokamak at the Korea Institute of Fusion Energy (KFE), will be briefly introduced.

Author: Dr PARK, Young Gun (JH Engineering, Co., Ltd.)

Co-authors: NAM, Seokho; KIM, Jinsub (Korea Institute of Fusion Energy); JOURNEAUX, Jean-Yves (ITER); LEE, Seungje (ITER Organization)

Presenter: Dr PARK, Young Gun (JH Engineering, Co., Ltd.)

Session Classification: Fri-Af-Po.03 - Supporting Technologies for Fusion Magnets I

Contribution ID: **887** Type: **Plenary**

Artificial Intelligence for Superconducting Magnets: Towards Smarter Magnet Technology

Sunday, July 6, 2025 11:40 AM (20 minutes)

The field of applied superconductivity is on the brink of a transformative evolution, driven by the rapid advancements in artificial intelligence (AI). Historically rooted in physics, material engineering, and electrical engineering through experimental tests at cryogenic temperature, deterministic methods and rigorous mathematical modelling, superconductivity now face the necessity of integrating data-driven approaches to keep pace with new demands.

Superconducting magnet is one of the most advanced and commercially available applications of superconducting technology. Various types of SC magnets have been widely applied for research, MRI, NMR, accelerator and fusion magnets. These magnets are significantly contributing to healthcare, physics, materials, and energy sectors. Fusion energy is now one of the promising trends of decarbonization for curbing the existing emissions, and decelerating the global warming.

Existing analytical and finite element methods for design development and modelling of SC magnets largely focus on either their use in a general sense or their application in narrowly defined areas, leaving a critical gap in comprehensive, practical references tailored specifically to magnet technology. AI has demonstrated unprecedented capabilities in optimization, performance evaluation, predictive analytics, process automation, and real-time decision-making, all of which are becoming indispensable across magnet technology domain.

On the other hand, recent advancements in AI, such as generative models, reinforcement learning, and advanced neural networks, will enable solutions that were previously unattainable. For instance, AI-powered design optimization of superconducting magnets can drastically shortened development cycles, while machine learning will revolutionize SC magnet's, performance, manufacturing process and energy and cooling managements. Additionally, the global push toward sustainability, decarbonization, and digital transformation has created an urgent need for magnet engineers to integrate AI to address complex, and multidisciplinary challenges related to the predictive diagnostics and prognostics of such magnets especially in fusion applications.
Superconducting magnet designers, researchers, and manufacturers need guidance on adopting AI tools and methodologies to improve system efficiency, optimize designs, and address complex, interdisciplinary challenges including those related to fault, quench, deformations, sensor placement, etc. Practical examples and case studies showing real-world applications of AI in applied superconductivity are essential for translating theoretical concepts into actionable strategies. As the industry landscape evolves, the demand for SC magnet engineers proficient in AI applications has increased, but the educational infrastructure has not kept pace.

This Plenary talk provides a timely resource that bridges these gaps, offering insights into the latest AI tools, methodologies, and their potential applications in superconducting magnet technology.

The Plenary talk will provide my insights on solutions to specific problems, such as:

- AI/ML/DL/RfL introduction
- Design optimisation of SC magnets based on heuristic or meta-heuristic, or swarm-based algorithms.
- Surrogate modelling of SC magnets through machine learning and neural networks.
- Data-driven loss prediction of using machine learning techniques.
- Automating complex simulations for SC magnets.
- Quench detection using AI-enabled data-analytics.

- Mechanical defect detection using ML/DL-assisted techniques.
- AI-assisted RUL estimation for magnet cryocoolers.
- Predictive maintenance of SC magnet systems.
- Smart manufacturing of SC magnets.
- Addressing sustainability challenges through AI-enabled resource optimization, and lifecycle assessments.
- Next step: Digital twins for SC magnets.
- Future trends: GenAI for SC magnets.

Keywords: Artificial Intelligence, Digital Twins, Fault Detection, Generative AI, Machine Learning, Superconducting Magnet, Surrogate Modelling.

References:
[1] M. Yazdani-Asrami, et al. Roadmap on artificial intelligence and big data techniques for superconductivity. Superconductor Science and Technology, 36(4), 043501, 2023.
[2] M. Yazdani-Asrami, et al. Ultra-fast Surrogate Model for Magnetic Field Computation of a Superconducting Magnet Using Multi-layer Artificial Neural Networks. Journal of Superconductivity and Novel Magnetism, 36, 2023.

Author: Dr YAZDANI-ASRAMI, Mohammad (University of Glasgow)

Presenter: Dr YAZDANI-ASRAMI, Mohammad (University of Glasgow)

Session Classification: Plenary 2: Mohammad Yazdani-Asrami [Artificial Intelligence for Superconducting Magnets: Towards Smarter Magnet Technology]

Contribution ID: **888** Type: **Poster**

Fri-Mo-Po.01-11: Design and construction of a small-scale layer-wound no-insulation (LW-NI) insert magnet with REBCO coated conductors operating in a background magnetic field exceeding 15 T

Friday, July 4, 2025 9:30 AM (1h 45m)

Rare-earth-based barium copper oxide (REBCO) coated conductors have shown remarkable high in-field performance in current transport and tensile strength, and their application as a layer-wound insert magnet during the construction of a high-field superconducting magnet is reasonably expected. However, the inhomogeneous stress distribution induced by the screening current, coupled with significant vertical magnetic field exposure at the end of the magnet, poses threats to the mechanical stability of the layer-wound insert magnet. Meanwhile, the quench protection in REBCO magnets is a critical issue, adopting no-insulation winding can provide the super magnet with self-protecting capability. To verify the feasibility of the manufacturing process for the layer-wound magnet as well as accumulate technological reserves for the subsequent construction of nuclear magnetic resonance (NMR) magnets, a layer-wound no insulation (LW-NI) insert magnet was fabricated with REBCO-coated conductors. The winding has an inner diameter of 40 mm, an outer diameter of 42 mm, and a total height of 66 mm, nine layers of REBCO tapes were wound with 18 turns per layer. The layer-wound magnet successfully operated with the current of 480 A (1 μV/cm criterion) and generated 1.13 T self-field in the axial direction of the magnet in an external 14 T background magnetic field (15.13 T in total) at 4.2K.

Author: WAN, J.H.

Presenter: WAN, J.H.

Session Classification: Fri-Mo-Po.01 - No-Insulation Coils IV

Contribution ID: **890** Type: **Poster**

Thu-Af-Po.01-11: Nb3Sn/NbTi hybrid concepts in block for high field dipole magnets

Thursday, July 3, 2025 2:00 PM (2 hours)

As part of the High Field Magnet program (HFM) at CERN, the Nb3Sn block coil configuration is a candidate for the main dipole in future large hadron collider as FCC-hh. To reduce the cost, the use of material grading in the block coil is explored by using NbTi conductor instead of Nb3Sn in the external low field regions. Different designs are being investigated for dipoles with a target nominal field of 14 T and 12 T. The gain in conductor volume as well as in AC-losses are reported, together with consideration on operational temperature (1.9 K vs. 4.5 K). Finally, the preliminary design of a Nb3Sn/NbTi Short Model Coil (SMC) is presented as a first proof of such a concept of hybrid technology in block coils.

Authors: HAZIOT, Ariel (CERN); Dr TODESCO, Ezio (CERN)

Presenter: HAZIOT, Ariel (CERN)

Session Classification: Thu-Af-Po.01 - Accelerator Magnets II

Contribution ID: **891** Type: **Poster**

Wed-Mo-Po.09-09: Visible light image-based insulation condition monitoring system for CFETR CSMC

Wednesday, July 2, 2025 9:15 AM (2 hours)

During the acceptance phase of the China Fusion Engineering Testing Reactor (CFETR) Central Solenoid Model Coil (CSMC), Paschen testing was conducted to verify the reliability of the insulation structure. To locate insulation faults during magnet testing, this study developed an Insulation Condition Monitoring System (ICMS) based on visible light imaging technology. The ICMS software, developed using C++ and OpenCV, integrates camera control, image acquisition, discharge image detection, and fault area localization. To address large-scale image data processing, the system employs an improved convolutional neural network architecture with attention mechanisms and combines morphological feature analysis of discharge images to design an intelligent discharge region detection algorithm, enhancing detection efficiency. During CSMC Paschen testing, 21 cameras were deployed for real-time monitoring of insulation weak points in the superconducting magnet system. The ICMS successfully captured 4 discharge flash regions. After implementing insulation repair measures, the CSMC passed the Paschen test. The results confirm that the ICMS effectively monitors insulation conditions and locates breakdown points during CSMC testing, thus robustly ensuring the safe and stable operation of the magnet system.

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Presenter: MA, Shuliang (Institute of Plasma Physics, Hefei Institutes of Physical Science, Chinese Academy of Sciences)

Session Classification: Wed-Mo-Po.09 - Development and Test of Conductors for Fusion Magnets I

Contribution ID: **892** Type: **Poster**

Thu-Mo-Po.09-11: Effects of Residual Strain and Thermal Strain on the Electrical Performance of ReBCO Superconducting Tapes

Thursday, July 3, 2025 8:45 AM (2 hours)

High-temperature superconductors (HTS) have become fundamental materials in modern high-field magnet technology due to their excellent current-carrying capability under strong magnetic fields. The second-generation high-temperature superconductor (2G HTS) ReBCO has the potential to significantly reduce the size and cost of fusion reactors in the field of magnetic confinement fusion, making it a crucial material for the development of compact fusion reactors. In the field of high-energy physics, ReBCO is used in high-field accelerator magnets for colliders. Additionally, ReBCO coils are employed as insert magnets in combination with low-temperature superconducting coils to form hybrid magnets that generate ultra-high magnetic fields.However, ReBCO superconducting tapes are often subjected to complex stresses, strains, and environmental factors during operation. These influences include strong thermal stress and electromagnetic forces induced by high current and low-temperature conditions, additional thermal stress caused by mismatched thermal expansion coefficients due to the multilayer structure of the material, and residual stress generated during epoxy resin encapsulation and curing. Since the current-carrying capability of ReBCO tapes is strain-sensitive, these factors may lead to performance degradation or even failure.This study aims to investigate the strain monitoring of ReBCO superconducting tapes based on fiber Bragg grating (FBG) sensing technology and further explore the mechanisms of their electrical performance degradation. First, an electrical testing platform for ReBCO superconducting tapes was established, and an FBG-based strain monitoring method was proposed to analyze the impact of residual strain on electrical performance. Subsequently, combined with microscopic morphology analysis and COMSOL numerical simulations of the three-dimensional multilayer tape structure, the mechanisms of performance degradation and its expansion behavior under background fields were studied.

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Session Classification: Thu-Mo-Po.09 - Conductor and Coil Measurement/Test Techniques and Facilities II

Contribution ID: **893** Type: **Poster**

Fri-Mo-Po.03-11: Design and Development of Active Shimming Coil for 7T Whole Body MRI Superconducting Magnet

Friday, July 4, 2025 9:30 AM (1h 45m)

Abstract：High field magnetic resonance imaging (HF-MRI) systems can achieve higher image resolution and sensitivity, resulting in better image quality and more biological information, which has significant value in life science and clinical medicine applications. The key to high field magnetic resonance imaging systems is the high homogeneous superconducting magnets, and active homogenization coils can help to achieve high homogeneous superconducting magnets. This article introduces the design and development process of active shimming coils for 7T whole-body MRI superconducting magnets. Based on the initial magnetic field homogeneity of the 7T superconducting magnet, according to analytical method, the positions of three groups of solenoid shimming coils Z1, Z2, and Z3 were calculated, as well as the linear distribution of six groups of saddle shaped shimming coils X, Y, ZX, ZY, X2Y2, and X-Y. The homogeneity compensation ability, coil current, and electromagnetic stress of each group of shimming coils were calculated in this article. The maximum compensation ability of Z1/Z2/Z3 was 125ppm, the maximum current was 5A, and the maximum electromagnetic stress was 120MPa. The skeleton of the active homogenization coil was designed, made of epoxy material G10, and the stress and deformation of the skeleton were analyzed using finite element method. The results showed that the maximum stress of the skeleton was 41.3 MPa and the maximum deformation was 0.141 mm. The coil design meets the project requirements, and the active shimming coil of the 7T whole-body MRI superconducting magnet is feasible.
Index Terms：High Field MRI（HR-MRI），7T，Superconducting Magnet，Active Shimming Coil，Homogeneity， Compensation Capacity， Electromagnetic Stress

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Session Classification: Fri-Mo-Po.03 - Magnets for MRI

Contribution ID: **894** Type: **Poster**

Sat-Mo-Po.02-08: Design and Analysis of An Extremely Compact 800MHz NMR Superconducting Magnet

Saturday, July 5, 2025 9:30 AM (1h 45m)

Abstract：High field nuclear magnetic resonance spectrometer (NMR) is an important scientific instrument in the fields of biology and chemistry, mainly used for qualitative and quantitative analysis of organic and inorganic substance structures. High field NMR superconducting magnets require higher magnetic field strength, smaller magnetic field uniformity, lower magnetic field drift, and smaller stray field range. This article introduces the design and optimization process of an ultra compact 800MHz (18.79T) NMR superconducting magnet. With the design requirements of the 800MHz (18.79T) NMR superconducting magnet as the goal, a nonlinear multi-objective programming optimization algorithm is proposed. Through this method, the optimization results of multiple objective parameters are output, and the magnetic aperture, magnetic field uniformity, and stray field (5 Gauss line) are optimized. The spatial position, electromagnetic density, and electromagnetic stress of different coils are obtained, and the stability of the magnet coil design is evaluated using coil load rate and safety margin indicators. The 800MHz NMR superconducting magnet adopts a technical path combining low-temperature NbTi superconducting wire and high-temperature ReBCO superconducting tape. The coupled electromagnetic stress of the low-temperature coil and high-temperature coil is calculated, and the stress and deformation distribution of the coil skeleton is analyzed. Mechanical simulation analysis is also carried out on key components such as the low-temperature system and suspension rod of the magnet. The optimization results show that the room temperature aperture of the magnet is greater than 54mm, and the homogeneity of the magnet design (without adding a uniform field coil) is 1.15ppm@18mm DSV, magnet stray field (5Guass line) is 2.3m in the axial direction and 1.63m in the radial direction from the center of the magnetic field. The minimum safety margin of the magnet coil is 15.87%, and the maximum circumferential stress of the magnet coil is 180Mpa. The stress-strain of the magnet skeleton is less than the yield stress of the material. The magnet meets the design requirements and provides necessary reference for the engineering prototype of the 800MHz superconducting magnet.
Index Terms：High Field NMR, Superconducting Magnet, Homogeneity, Warm Bore, Stray Field, Safety Margin, Electromagnetic stress, High Temperature Superconductor

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Session Classification: Sat-Mo-Po.02 - Magnets for Other Medical Application III

Contribution ID: **897** Type: **Invited Oral**

Thu-Af-Spec1-02: [Opening Presentation] Private Sector Leadership to Successful Market Servicing

Thursday, July 3, 2025 4:20 PM (10 minutes)

The growth of superconducting magnets broadly disrupting private sector markets has been impressive over the past five years, especially in next generation MRI's and other medical applications like radiation oncology. To successfully enter and fully service all the possible superconducting magnet markets, it is crucial that the formation and support of commercial ecosystems be a main focus of both the public and private sector stakeholders. Unlike research initiatives, which are historically best managed by the public sector, serving commercial superconducting magnet markets requires strong leadership from the private sector. This approach is not new and has been demonstrated in many other existing successful commercial ecosystems. The semiconductor manufacturing industry in Florida, USA for example, has achieved tremendous success thanks to robust private sector leadership which is evident worldwide through its strong presence in the supply chain. The power of private sector led commercial ecosystems is also well demonstrated in long standing areas such as the Silicon Valley in northern California, USA and the newer and rapidly expanding areas like the Elevate Quantum ecosystem in Colorado, USA.

To ensure continued success of any commercial ecosystems, it is essential to adopt, modify as needed and/or establish new partnership models that address supply chain, business development and investment needs efficiently and effectively. These key partnership models can be unique to each specific ecosystem and the best way to ensure quick addressment of both existing and new markets for the commercial superconducting magnet ecosystem is to leverage previous proven partnership models and create new models as needed. It is critically important that any commercial ecosystem landscape include all the key partners needed for emergence, support and growth regardless of industry sector of the ecosystem. After decades of research, the time is now for formation of these partnership models within the global ecosystem to usher in the industrial era of commercial superconducting magnets.

Author: WHALEN, Jeff (MagCorp)

Presenter: WHALEN, Jeff (MagCorp)

Session Classification: Thu-Af-Spec1 - [Special Session] Commercial Superconducting Magnets for the Future

Contribution ID: **898** Type: **Invited Oral**

Thu-Af-Spec1-01: [Opening Presentation] Strategic Roadmap for Commercialization of Superconductivity Applications

Thursday, July 3, 2025 4:00 PM (20 minutes)

Over the past few years, significant advancements have been made in superconducting technologies, particularly in the performance and supply of low- and high-temperature superconductors, cryogenics, and system integration. These developments are now ready for scaling up and deployment in a wide range of applications beyond their current uses, such as MRI, NMR, and various fields in physical sciences and research.

Superconductivity has the potential to contribute to zero-emission targets by enabling extensive wind power generation, facilitating zero-emission transportation, supporting fusion power, enhancing superconducting quantum computing, improving water purification, developing new medical diagnostics and therapy tools, and achieving new scientific breakthroughs.

To fully realize the potential of superconductors, it is essential to foster new partnerships and alliances, including innovative business models for investment and funding. This approach will help accelerate the development of commercial superconducting technologies and solutions across various sectors, ultimately translating these innovations into successful commercial applications.

This presentation will review the progress of the Superconducting Global Alliance (ScGA) initiative, which aims to foster a greener, healthier, and more prosperous sustainable future. We will present proposed strategic roadmaps and provide updates on consortia membership that addresses the grand challenges facing innovative markets in diverse sectors.

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Presenter: MELHEM, Ziad (Oxford Quantum Solutions Ltd)

Session Classification: Thu-Af-Spec1 - [Special Session] Commercial Superconducting Magnets for the Future

Contribution ID: **901** Type: **Poster**

Thu-Mo-Po.09-12: A device for thickness profile measurement of REBCO tapes

Thursday, July 3, 2025 8:45 AM (2 hours)

The accurate measurement of thickness profile across the width of REBCO conductors is critical to design and fabrication of REBCO magnet windings. This is because the non-uniform thickness profile such as so-called 'dog-bone'or 'pillow'shapes compromise winding's geometrical integrity, which is especially critical for dry-wound pancake coils. Non-uniform also has significant impact on the Cu/non-Cu ratio which is critical for quench performance.
Conventionally thickness is measured by a micrometer at several locations cross the width. This convenient method, however, does not have sufficient resolution for thickness profiling. For more accurate profile determination, a polished cross-section sample needs to be prepared and subsequently measured by microscopy. This is method is accurate but labor intensive and time consuming. A laser micrometer works well for inspection of diameter of round wires, but it is not applicable in thickness measurements of flat tapes.
We have developed a thickness gauge based on digital indicator with ball contacts of small diameter. With accurate transverse positioning, it is capable of measuring thickness profile with a resolution of 50 μm (80 points along 4 mm width). The device is calibrated by a thickness standard. The profiles of a dozen samples were measured and compared well with the results by cross-sectional microscopy. The calibration and cross-checking confirm that this device is suitable for quality assurance tests for large REBCO magnet projects.

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Co-author: LU, Jun (National High Magnetic Field Laboratory, USA)

Presenter: Mr GAVIN, Noah (National High Magnetic Field Laboratory, USA)

Session Classification: Thu-Mo-Po.09 - Conductor and Coil Measurement/Test Techniques and Facilities II

Contribution ID: **903** Type: **Invited Oral**

Thu-Af-Spec1-06: [Panel 4] Superconducting Rotating Machines

Thursday, July 3, 2025 6:00 PM (30 minutes)

Superconducting magnets are the critical differentiating technology of superconducting rotating machines. High Temperature Superconducting (HTS) rotating machines will revolutionize aero-propulsion aviation, ship propulsion, power generation, industrial motors, and many other applications by providing unmatched efficiency and power density. This panel discussion will focus on the latest advancements, challenges, and prospects of superconducting magnets, particularly their application in rotating machines for energy and transport applications.
The panel will discuss the development of magnets and their integration into transport platforms and power and energy applications, highlighting their significant advantages over conventional technologies. Key topics will include the mechanical and electromagnetic performance of HTS magnets and the challenges that need to be addressed to accelerate the technology's commercial adoption.

Author: PAMIDI, Sastry (CAPS/FAMU-FSU College of Engineering)

Presenter: PAMIDI, Sastry (CAPS/FAMU-FSU College of Engineering)

Session Classification: Thu-Af-Spec1 - [Special Session] Commercial Superconducting Magnets for the Future

Contribution ID: **904** Type: **Invited Oral**

Thu-Af-Spec1-03: [Panel 1] Emergence of a new HTS Ecosystem in Florida

Thursday, July 3, 2025 4:30 PM (30 minutes)

abstract pending

Presenter: KELLY, Alex (FloridaCommerce)

Session Classification: Thu-Af-Spec1 - [Special Session] Commercial Superconducting Magnets for the Future

Contribution ID: **907** Type: **Contributed Oral**

Sat-Af-Mem1-01: Title Pending

Saturday, July 5, 2025 4:30 PM (15 minutes)

abstract pending

Presenter: SCHWARTZ, Justin (University of Colorado Boulder)

Session Classification: Sat-Af-Mem1 - Huub Weijers Memorial: High Field Magnets

Contribution ID: **908** Type: **not specified**

Discussion

Thursday, July 3, 2025 12:30 PM (15 minutes)

Session Classification: Thu-Mo-Spec1 - [Special Session] Quench Protection for Large Stored-energy REBCO Magnets

Contribution ID: **909** Type: **Invited Oral**

Thu-Af-Spec1-04: [Panel 2] HTS for the Next Generation of MRI

Thursday, July 3, 2025 5:00 PM (30 minutes)

The magnets used in Magnetic Resonance Imaging (MRI) are the largest commercial application of superconducting technology. These magnets predominantly employ niobium-titanium technology, traditionally maintained at cryogenic temperatures by immersion in a liquid helium bath. Recent advancements in sealed and cryogen-free MRI magnet technologies reduce helium dependence, marking a step towards a more sustainable future. High-temperature superconductors (HTS) provide further opportunities for increasing sustainability by operating at higher temperatures, thereby reducing refrigeration power consumption. Beyond environmental benefits, HTS technology may enhance MRI by improving imaging resolution through increased field strength and allowing more compact designs. This panel will review the progress and challenges associated with incorporating HTS in new MRI systems.

Author: HILDERBRAND, Josh

Co-authors: BOSQUE, Ernesto; WHALEN, Jeff; MARSHALL, William (Magnetics Corporation)

Presenter: HILDERBRAND, Josh

Session Classification: Thu-Af-Spec1 - [Special Session] Commercial Superconducting Magnets for the Future

Contribution ID: **911** Type: **Invited Oral**

Thu-Af-Spec1-05: [Panel 3] Superconductivity Solutions for Vanquishing Cancer

Thursday, July 3, 2025 5:30 PM (30 minutes)

Eradicating cancer and improving cancer treatment have been ongoing challenges for decades, resulting in the loss of millions of lives. However, the development of innovative cancer therapies enabled by high-temperature superconducting (HTS) materials offers renewed hope for potentially eradicating this devastating disease within our lifetime.

Current radiation oncology methods require significant irradiation of healthy tissue to administer the necessary radiation dose to target tumors, which poses life-threatening risks. Moreover, the construction of medical beamlines and patient treatment vaults demand multi-billion-dollar investments, leading to limited patient throughput and staggering capital and operational expenses.

New partnerships are emerging between dedicated medical system providers, superconductivity materials and service suppliers, and end users. An example of such collaboration is the initiative led by Empyrean Medical Systems, which includes the MagCorp, Mayo Clinic, MD Anderson Cancer Center, and Moffitt Cancer Center.

Advancements in HTS technology have created large-bore superconducting magnets capable of manipulating and conditioning charged particle beams. This progress opens new possibilities for delivering radiation to patients, minimizing damage to healthy tissues while delivering lethal doses of radiation solely to target tumors.

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Co-author: Dr WHALEN, Jeffrey (Magnetics Corporation)

Presenter: FISHMAN, Kal (Empyrean Medical Systems)

Session Classification: Thu-Af-Spec1 - [Special Session] Commercial Superconducting Magnets for the Future