HFM

High Field Magnets Programme

Update on High Field Magnets Programme

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LDG, 20th September 2024

Contents

- Summary of actions in first half of 2024 and plan for the next 12 months

- News since last LDG (June 2024)
  https://indico.cern.ch/event/1413617/

Summary of actions

- Steering board March 2024 https://indico.cern.ch/event/1383912/
  - Mandate: setting HFM as a direct R&D
  - Target for Nb_3Sn of 14 T operational field and 90 TeV energy
  - Roadmap for Nb_3Sn FCC-hh option for operation in 2050/55 (and not in 2070)
  - Activation of a unique HFM forum https://hfm.web.cern.ch/hfm-forum
- Steering board June 2024 https://indico.cern.ch/event/1425470/
  - Activation of working groups https://hfm.web.cern.ch/hfm-working-groups
  - Activation of common forum with the US-MDP
  - Order of Nb_3Sn conductor
  - Streamlining of 12 T INFN and CERN activities on Nb_3Sn dipoles: focusing on the same coil geometry and joining the efforts
    - Two different conductors and cables used in the previous baseline

Summary of actions

- HFM-TE day to review the CERN program, share information and have a internal discussion https://indico.cern.ch/event/1425262/
- Steering board 4th October 2024 (to come)
  - Cost estimate for Nb_3Sn dipoles, and difference between 12 and 14 T
  - Update of deliverable and costs for CERN activities
  - Preparation of ESPP
  - Analysis of the 4.5 K option, focus on sustainability
- First targets for 2025
  - Simplification of structure to allow the activation of PSM (program steering meeting)
  - More detailed roadmap for proving that HTS can be used for accelerator magnets

Contents

- Summary of actions in first half of 2024 and plan for the next 12 months

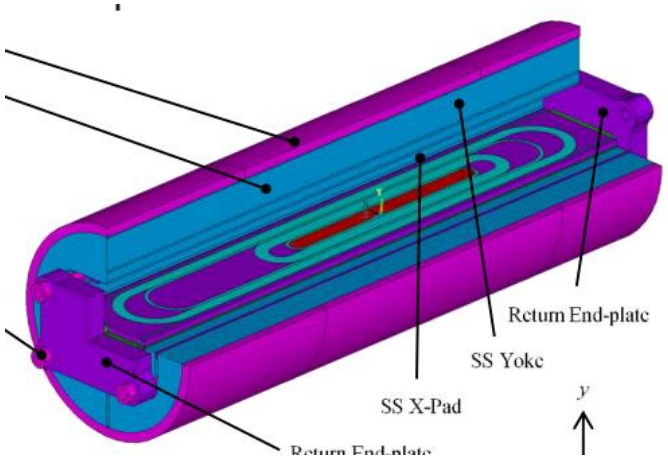
- News since last LDG (June 2024)
  - Focus on sustainability/cost and activities on integration: cooling
  - Nb_3Sn magnets activities:
    - PSI small scale common coil test at CERN: 7 T
    - First windings in CEA for R2D2
    - Winding the second set of coils for RMM
  - Nb_3Sn order of conductor
  - HTS racetracks wound and tested at 77 K at CERN

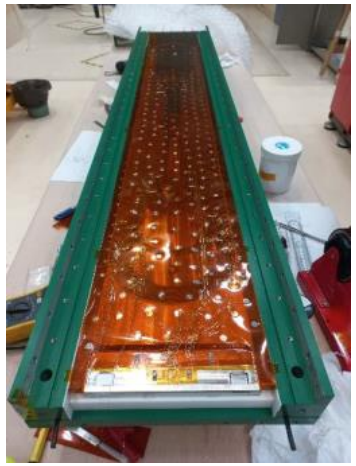
Focus on sustainability and cost

- As it was shown in previous meeting, the change of targets allows to imagine a 14 T magnet, at 80% of loadline at 1.9 K, but operating at 4.5 K
  - This is what HL-LHC triplet magnet are proving today
  - This option would allow a considerable savings in the cryogenics (order of a factor 3)
- The option of a cooling at 4.5 K is being studied from several points of view
  - Cryogenics: what one can expect as variation of temperature along the string of magnets
  - Magnet: how to measure the temperature margin of a magnet operating at 4.5 K ? Is it possible to test at 5.5-6 K to prove a 1-1.5 K margin ?
- Ways to reduce the He inventory are also being considered
  - From "fully floating" magnets to semidry magnets (from 20 l/m of He as in the LHC, to 5 l/m) [P. Borges de Sousa will report in October]

Winding coils

- In CEA the first Nb_3Sn coils for the R2D2 model have been wound
  - Electrical issues found in the layer jump – analysis ongoing





- RMM program at CERN
  - Second assembly of the 16 T magnet is ready for test (reproducibility of assembly) – test in October
  - Second set of coil is being manufactured at CERN (reproducibility of manufacturing)
- Setting agreements with MDP to have 44 strands cable manufactured in LBNL for the 14 T block dipole magnet

Test of small subscale stress managed common coil (SSSMC)

- This magnet belongs to the "stress managed family", such as CCT developed in LBNL or SMcosθ developed in FNAL
  - First subscale to test the technology with Nb_3Sn in HFM
  - Reaction and test done at CERN: 6 T reached, close to short sample at 1.9 /4.5 K
  - Next steps: a higher field magnet (with more coil) , based on available strand, aiming at 12 T

Subscale Stress-Managed Common-Coils (SubSMCC)

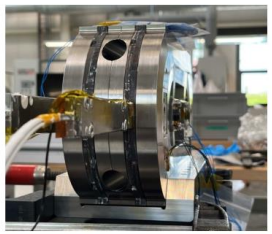
HFM High Field Magnets Programme · CHART Swiss Accelerator Research and Technology · PSI

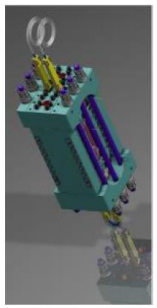
Validating manufacturing process and introducing advanced concepts: coil pre-load free, at room temperature; stress-management structure and splicing on the low-field region.

Fast turn-around platform for testing matrix systems; protection concepts and cooling options.

Possibility to test a Hybrid magnet with LTS (Nb_3Sn) Common-Coils and HTS racetracks

LTS (Nb_3Sn) conductor manufactured by LBNL (cct subscale cable)





Number of turns	Wire type	N wire x dia in mm	Cu/nCu	Bare Cable dimensions in mm	Insulation thickness in mm
18 / layer	Nb_3Sn RRP® 132/169	11 x 0.6	1.17	3.8 x 1.3	0.155

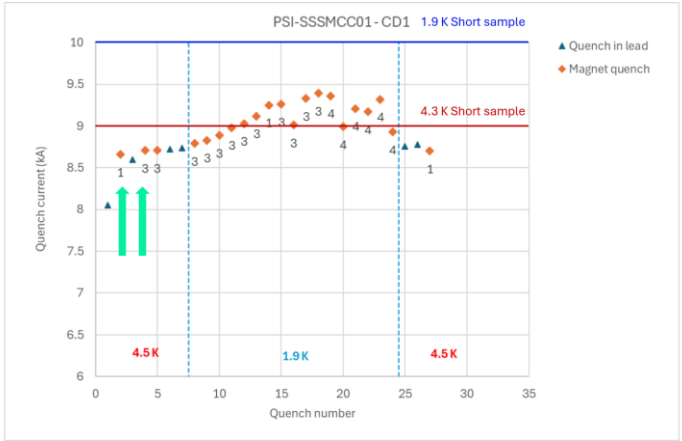
T_{op}	I_{ss}	B_{peak} in T	B_0 in T	J_{sc} in kA/mm²	J_{cu} in kA/mm²	J_{ov}** in kA/mm²
4.3 K	9.0 kA	6.1	5.0	6.5	5.6	1.4

** Including insulation area

5 Paul Scherrer Institute PSI

SSMC magnet [D. Araujo, et al.]

See ASC conference in SLC, and HFM forum in July https://indico.cern.ch/event/1432805/



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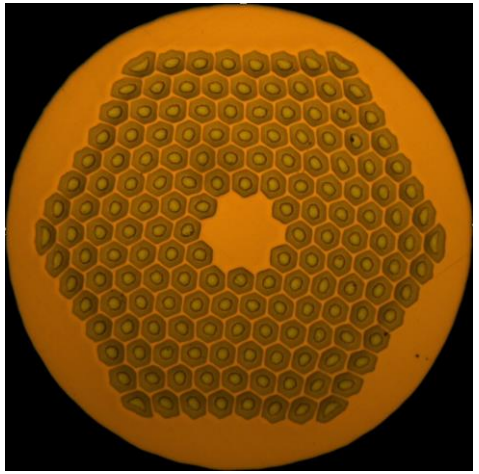
Test results [G. Willering, et al.]

Order of Nb_3Sn strand

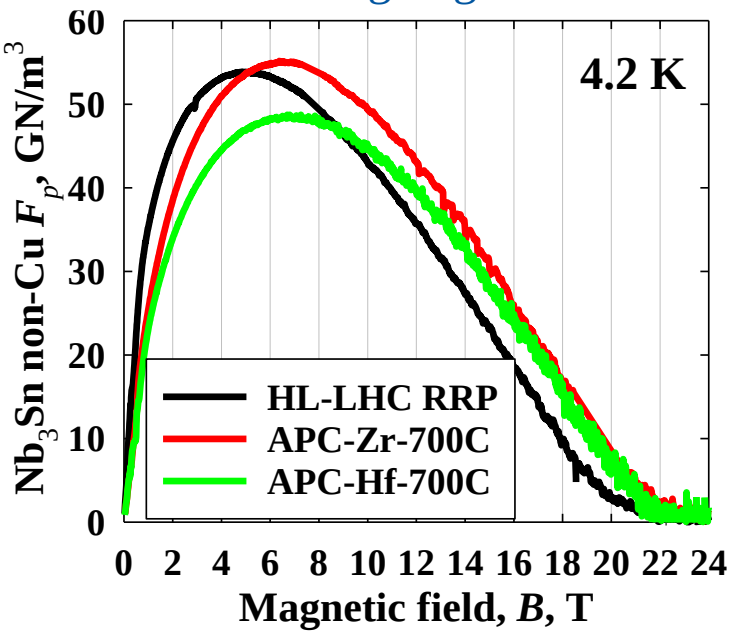
- Decision to order 1.1 mm and 0.7 mm strand (T. Boutboul et al.)
  - 162 / 169 layout for the 1.1 mm, giving the higher performance, is selected
    - Backup of 150/169 also ordered
  - Order not directly related to the needs of collaboration (strategic reserve)
  - Will arrive not before 2 years – we will probably go through a period of scarce availability of strand for the program
  - Collaborations are building magnet around the available cable (as for instance PSI)
  - Guidelines to make all efforts not to waste the available strand, and to limit the contingencies usually added
  - Program of characterization of 162/169 strand ongoing

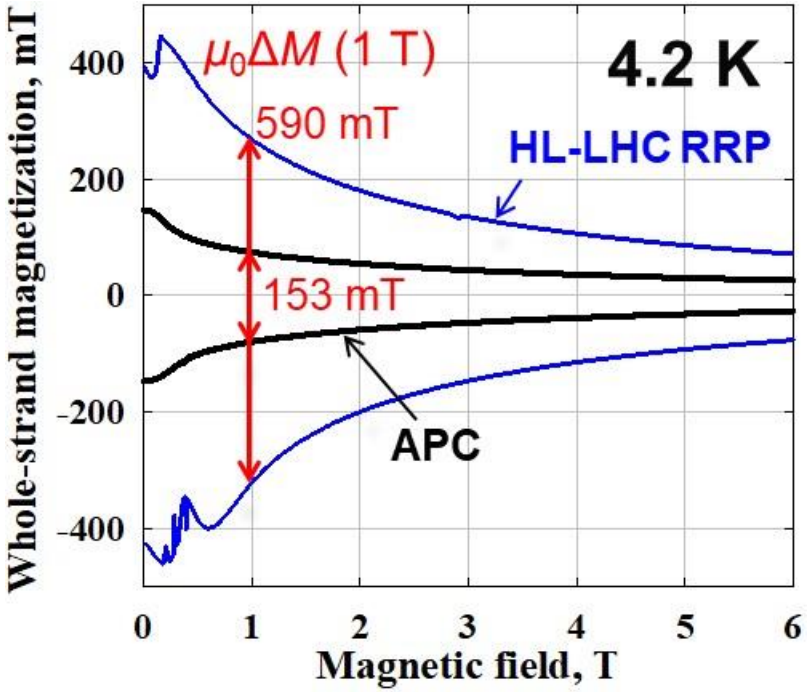


162/169 layout from OST

Nb_3Sn strand improvement

- Significant APC advancement in the US, reported at the ASC in SLC, and presented in HFM forum on Sept. 16 by X. Xu https://indico.cern.ch/event/1454133/
  - Getting rid of high current desitites at low field (hysteresis) and increasing current at low field – large reduction of hysteresis losses
  - Efforts also ongoing in HFM

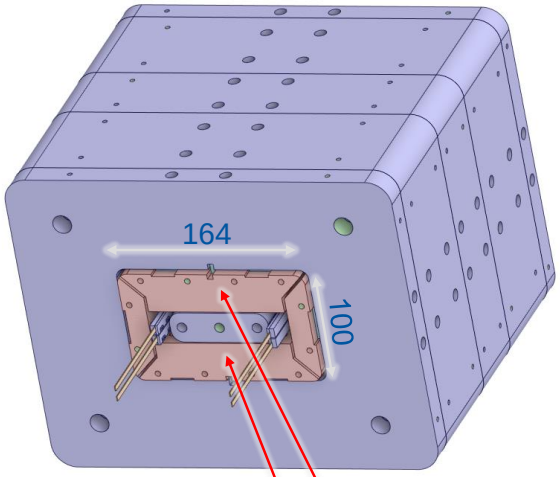


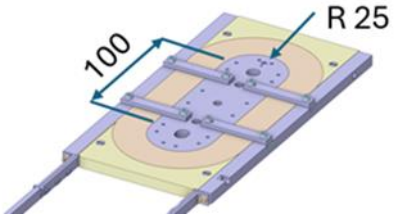


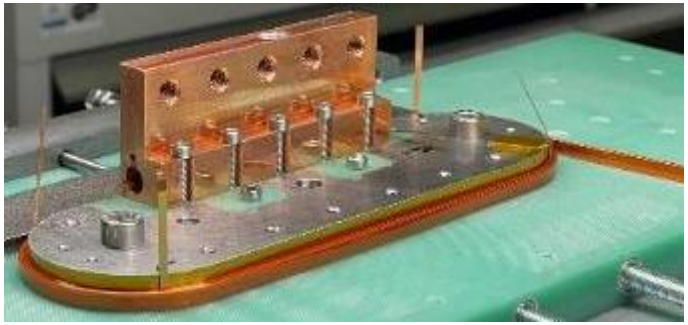
Pinning force comparision between RRP and APC (left) and magnetization (right)
[Xingchen Xu, et al., ASC conference]

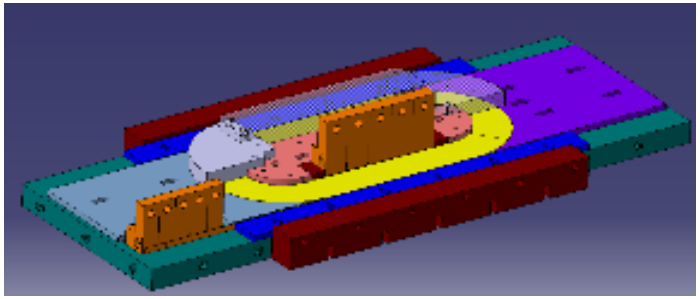
HTS news

- Production line in KIT commissioned (B. Holzapfel et al.) in March 2024 as reported previously
- At CERN, racetrack wound with dielectric insulated (DI) REBCO and went through preliminary tested at 77 K
- Then a test at 4.5 K – 20 K will be done









Optimized for number of racetracks

[A. Ballarino, et al., HFM TE day https://indico.cern.ch/event/1425262/]

HTS news

- Path towards a common coil with 50 mm free aperture with flat coils (no field quality) is being defined

[A. Ballarino, et al., HFM TE day https://indico.cern.ch/event/1425262/]