MT 26
International Conference
on Magnet Technology
Vancouver, Canada | 2019

Summary of the 26th Magnet Technology Conference

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STEAM

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(**) The Gentner program of the German Federal Ministry of Education and Research (grant no. 05E12CHA).

Overview

Presentations available at https://indico.cern.ch/event/763185/

- 22-27 September 2019, Vancouver, Canada
- ~ 1000 attendants
- ~ 1000 contributions (presentations + posters)

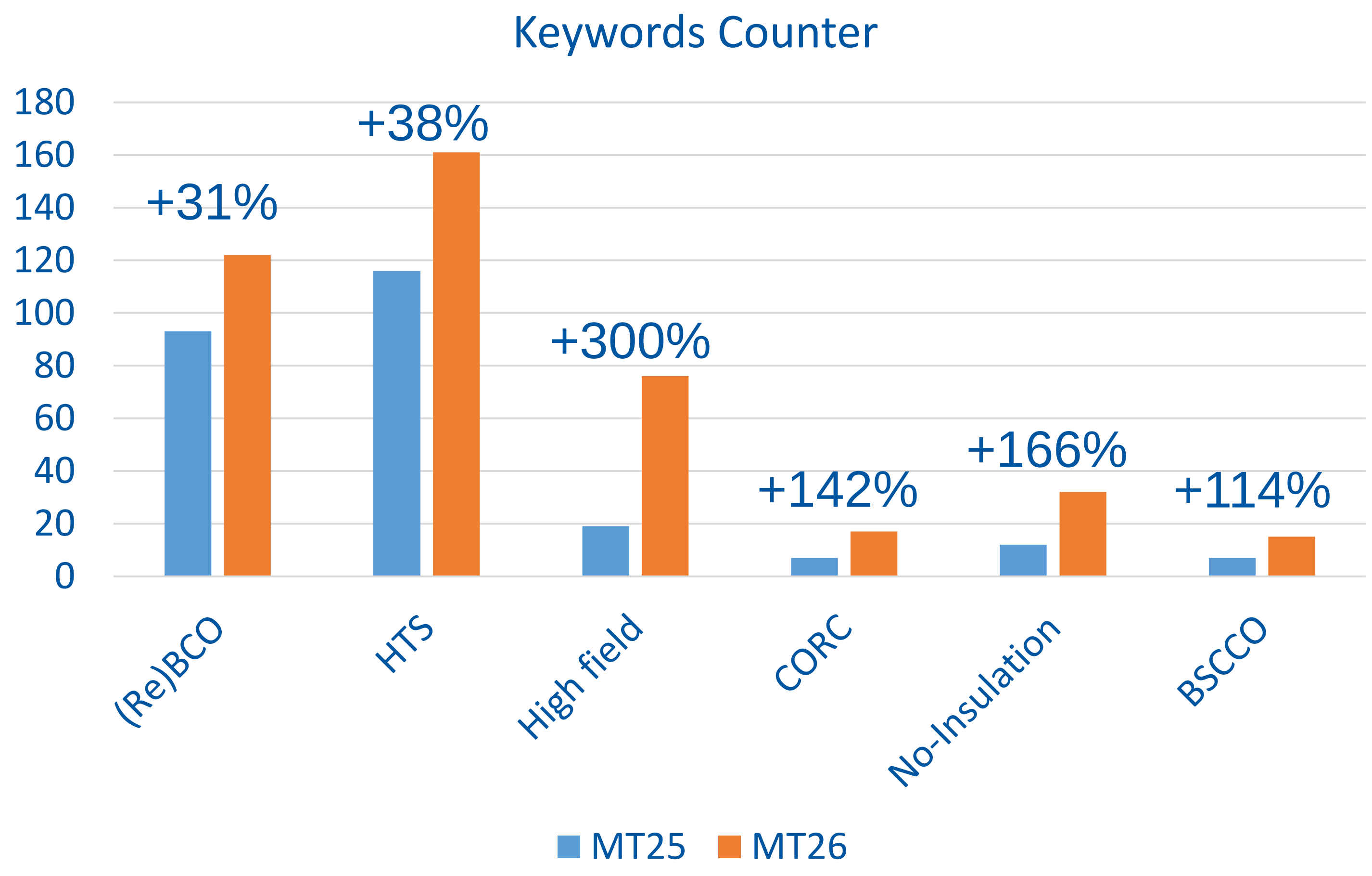
Broad coverage on magnet technology:

- Wires, cables, coils, magnets
- Design, simulation, manufacturing, test, protection
- Superconducting and normal conducting

Magnets for Accelerators, Detectors, Fusion, Motors, MRI, NMR
…and the list is not exhaustive!

Remark:
Many interesting contributions are not available / locked out

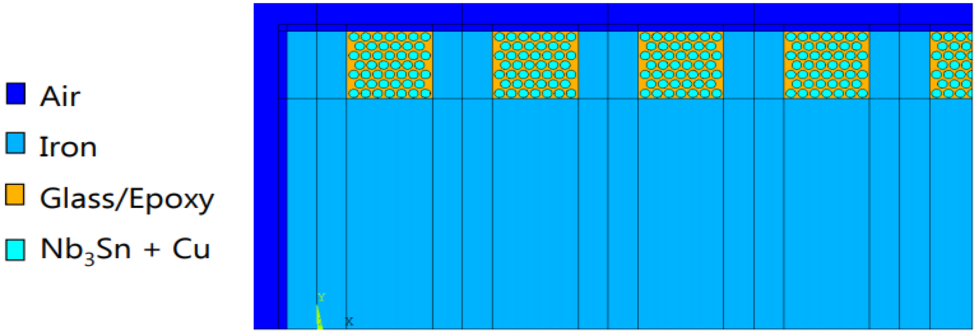
HTS: The Force Awakens (hopefully)



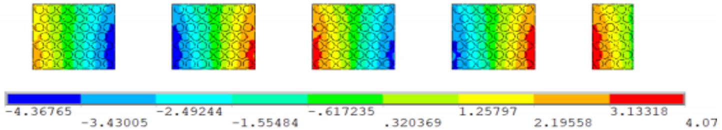
User Defined ANSYS Elements for 3D Multiphysics Modeling of Superconducting Magnets

Kathleen Edwards et. Al.

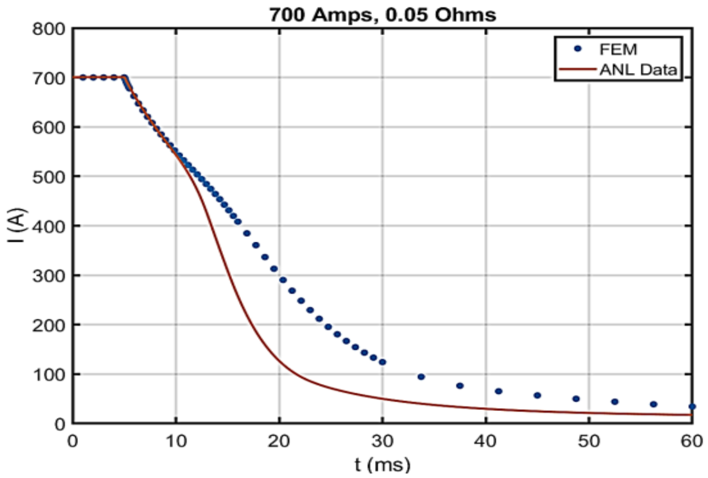
ANL Short Undulator Model



Initial field in y-direction

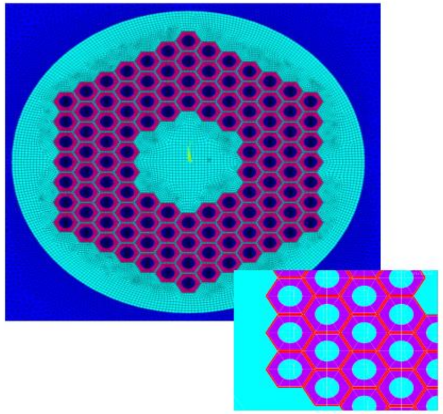


Original Model
The initial element model did not match data from ANL at currents above 500 A



Custom element for bulk SC

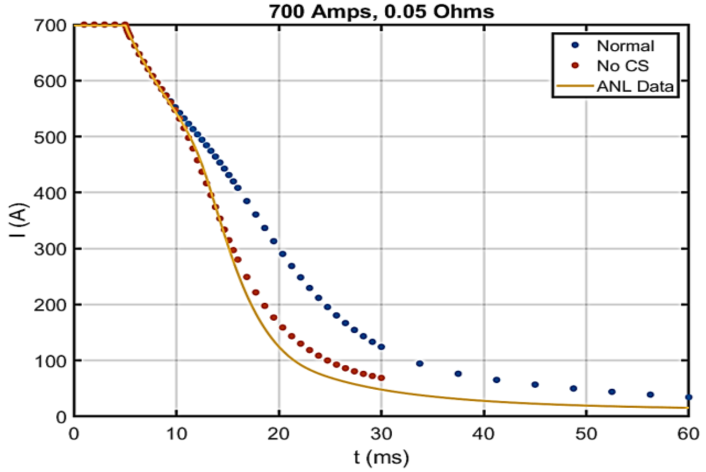
- Conductive paths defined in geometry/mesh
- Uses A-V formulation to model bulk superconductor
- Uses E-J power-law formulation
  - As $n \rightarrow \infty$, the model approaches critical state behavior



- The addition of transport current loss [2], had the most effect on the result.

$$Q_{new} = (1 + i^2) Q_{tot}$$

$$i = \frac{I}{I_c}$$



A Conceptual Study on "Magnetic Dam" to Absorb Electric Quench Energy in NI HTS Magnet

Soobin An et. Al.

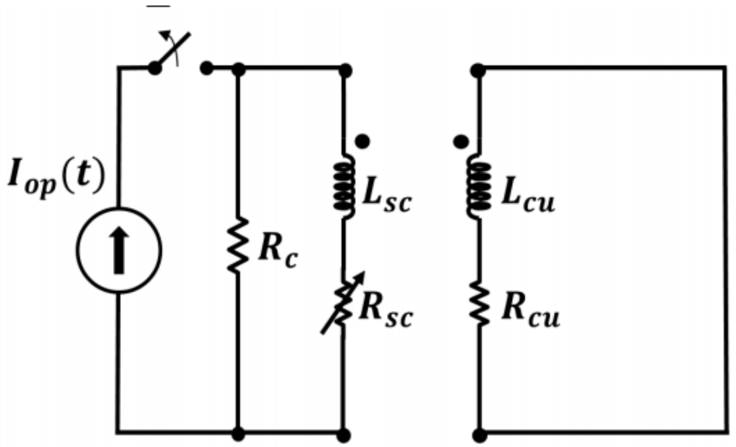


Figure 1. Equivalent circuit of a copper coil electromagnetically coupled with an NI HTS DP coil using lumped parameter circuit model.

the following conditions to absorb at least half of the stored energy in the NI coil

$k \cong 1$ ··· (1) (k : magnetic coupling coefficient)

$\frac{L_{sc}}{R_{sc}} \leq \frac{L_{cu}}{R_{cu}}$ ··· (2)

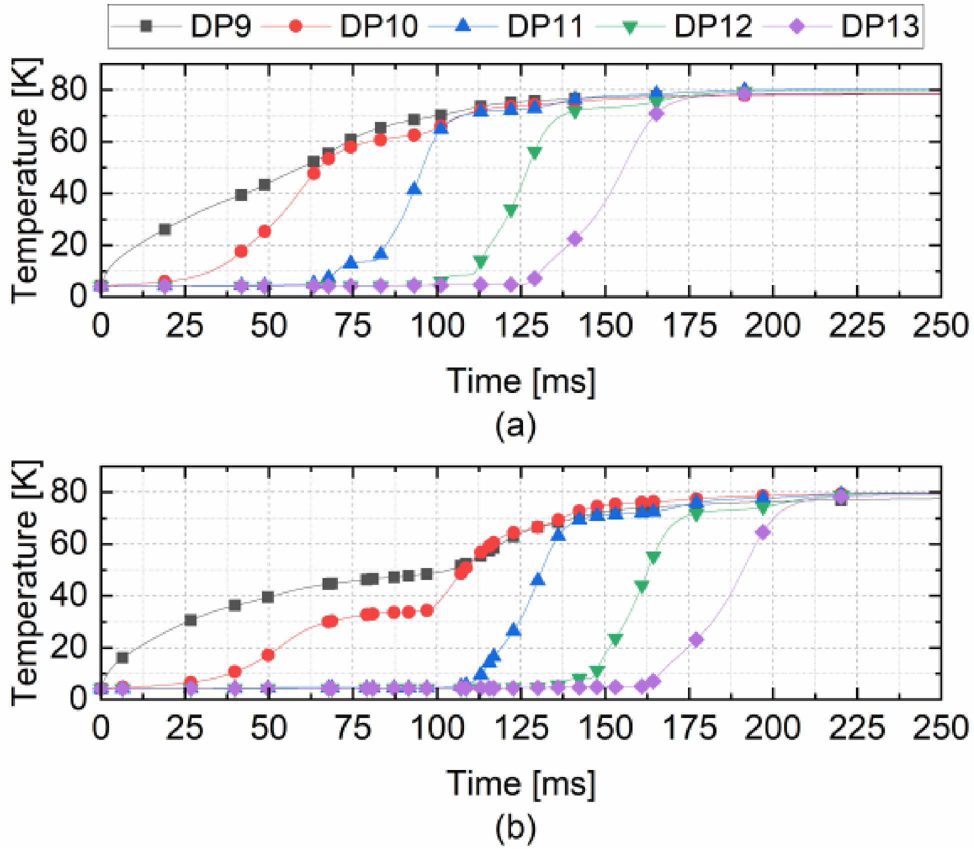
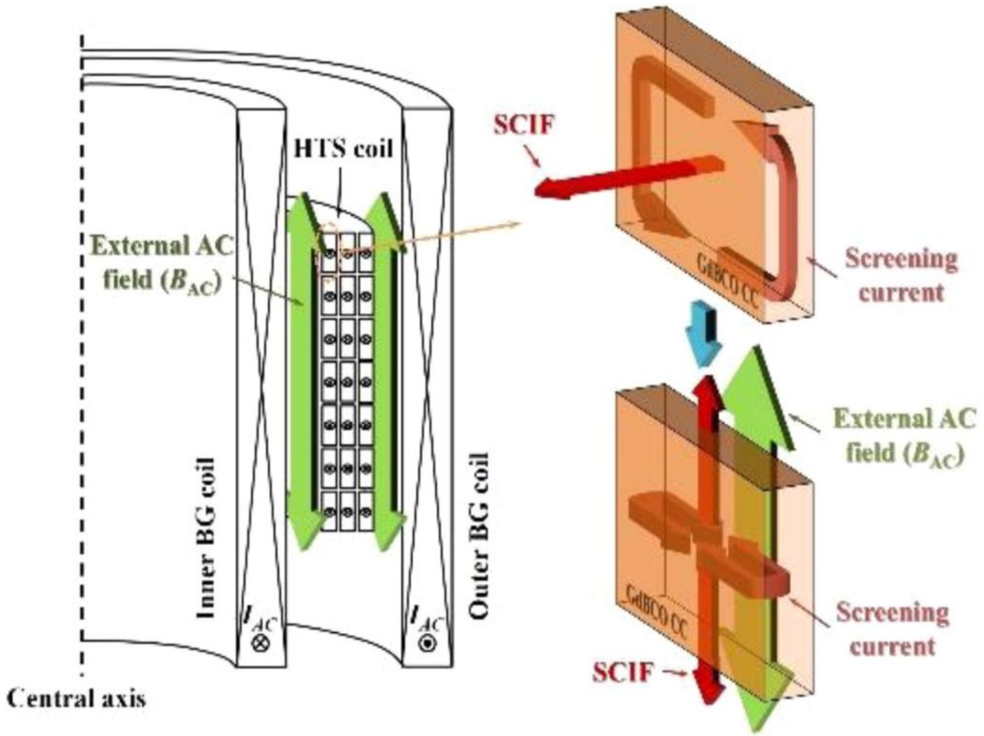
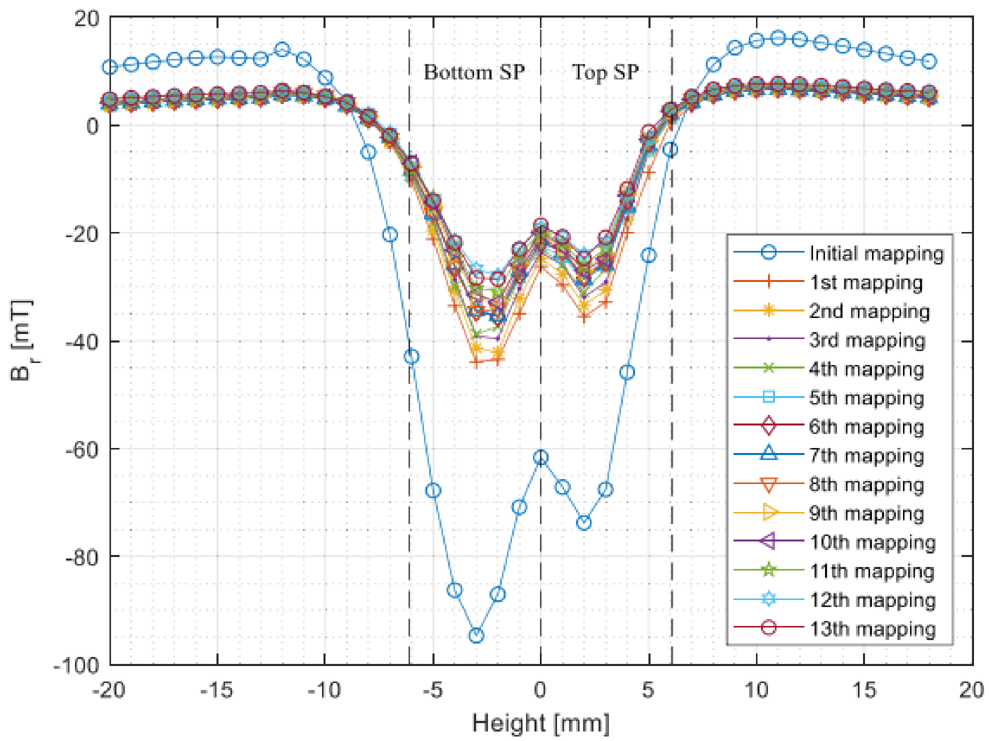


Figure 7. Temperature profiles :
(a) without; and (b) with magnetic dam

Experimental and Numerical Studies on a Method to Mitigate Screening Current-Induced Field for No-Insulation REBCO Coils

Jiho Lee et. Al.

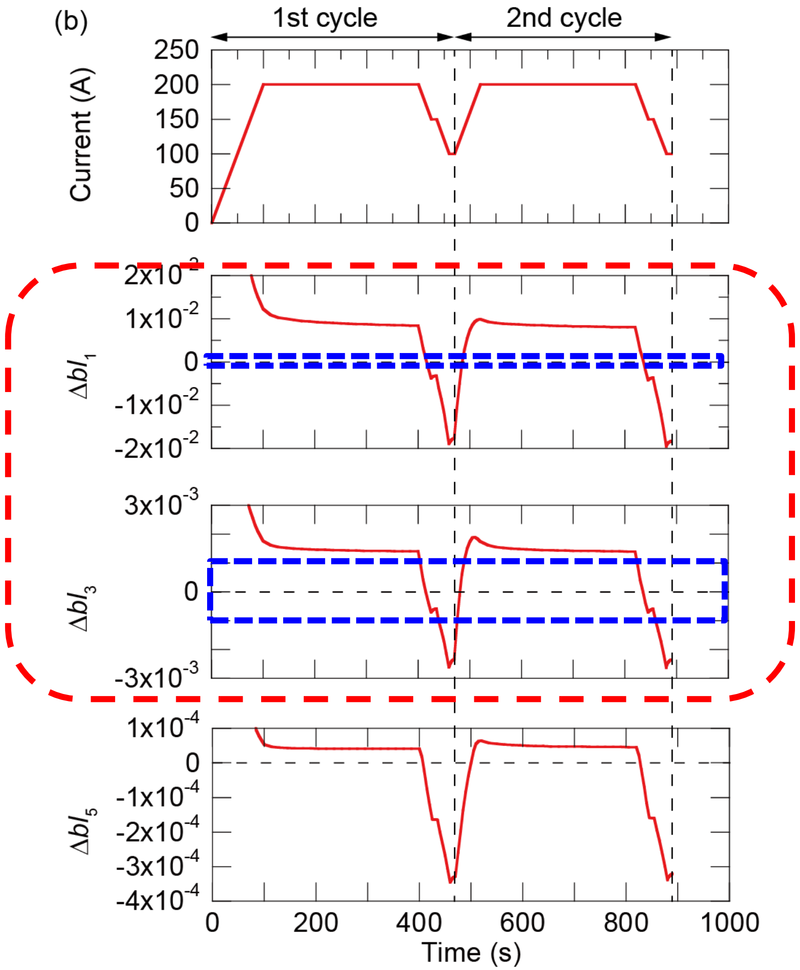


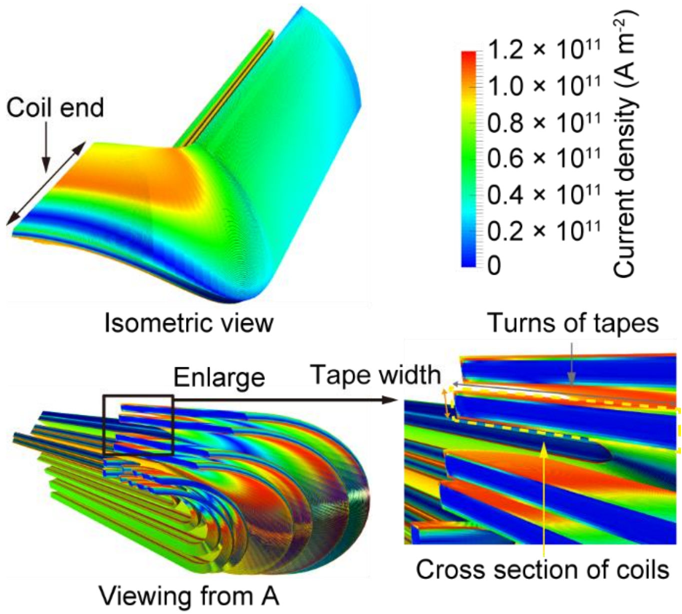


Mitigation of Shielding-current induced Field in a Magnet Wound with Coated Conductors for Accelerator Systems

Yusuke Sogabe

HOW does SCIF deteriorate field quality of accelerator magnets?





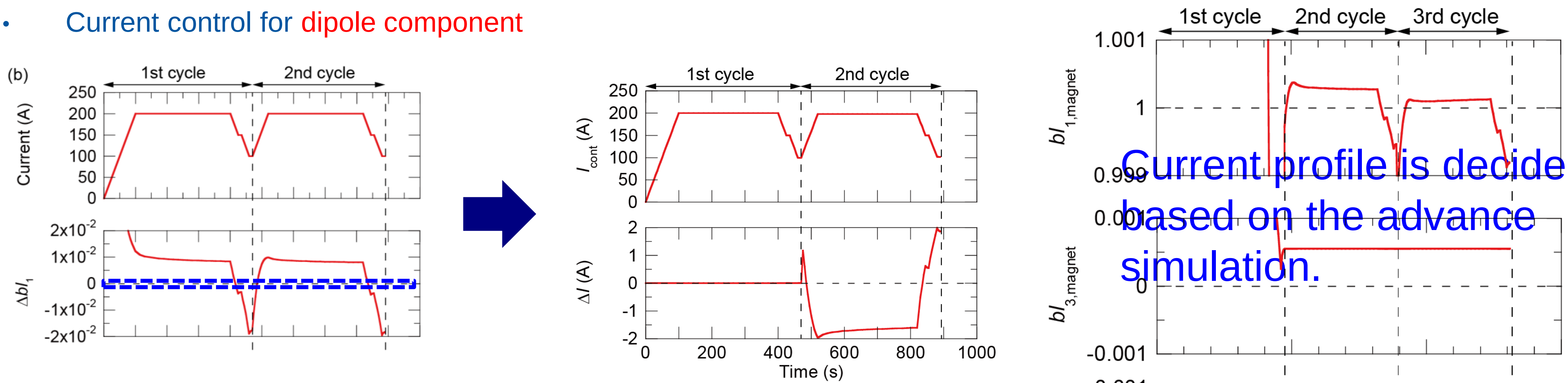
N. Tominaga, et. al., IEEE TAS, 28, 4900305

Dipole and sextupole components of SCIF have to be mitigated!!

- Dependence of SCIF on current

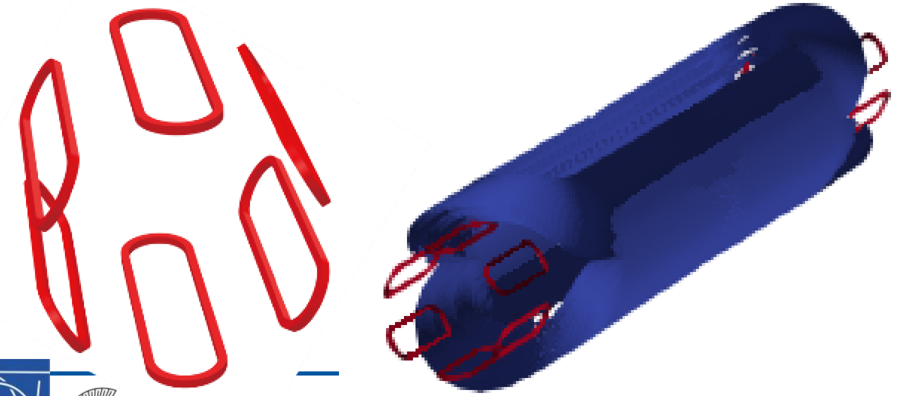
HOW can influence of SCIF be mitigated?

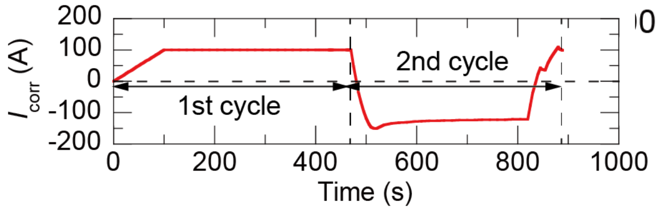
- Current control for dipole component



Current profile is decided based on the advance simulation.

- Correction coils for sextupole component





Operation pattern of the correction coil is decided based on the advance simulation.

Error field by SCIF was less than 1×10^{-3} of $BL_{1,d}$.

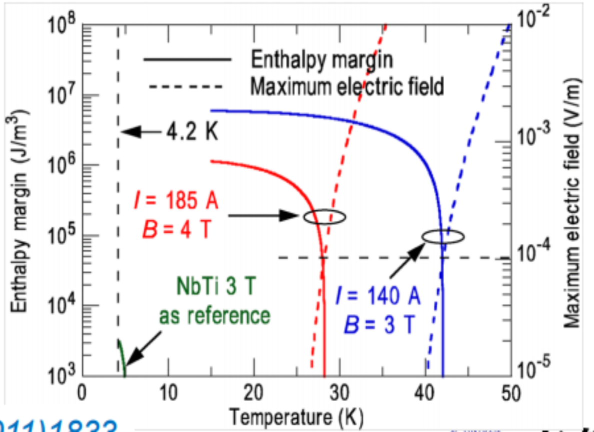
Key Issues in HTS Magnet and Conductor Technology Toward Various Applications

Naoyuki Amemiya

Stability against thermal disturbance (HTS)

- Superior stability against thermal disturbance
- If degradation is overcome, what makes quench?
  - Failure of cryocooler? Beam loss?
  - Lack of common clear answer

Enthalpy margin of HTS magnets is several order of magnitude larger than that of LTS magnets



Takahashi et al. IEEE-TAS21(2011)1833

N. Amemiya, MT-26

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京都大学 KYOTO UNIVERSITY

Magnet protection (HTS)

There might be choices …

1. Since the cause of quench is very rare …
   - Operate magnet with enough margin
   - Reduce the cause as much as possible
     - eg. beam collimator and shield in particle accelerator
   - Monitor magnet, and if something wrong is monitored, shut down magnet = magnet protection before quench
2. Implement "quench protection" (after quench), because we cannot predict what happens.

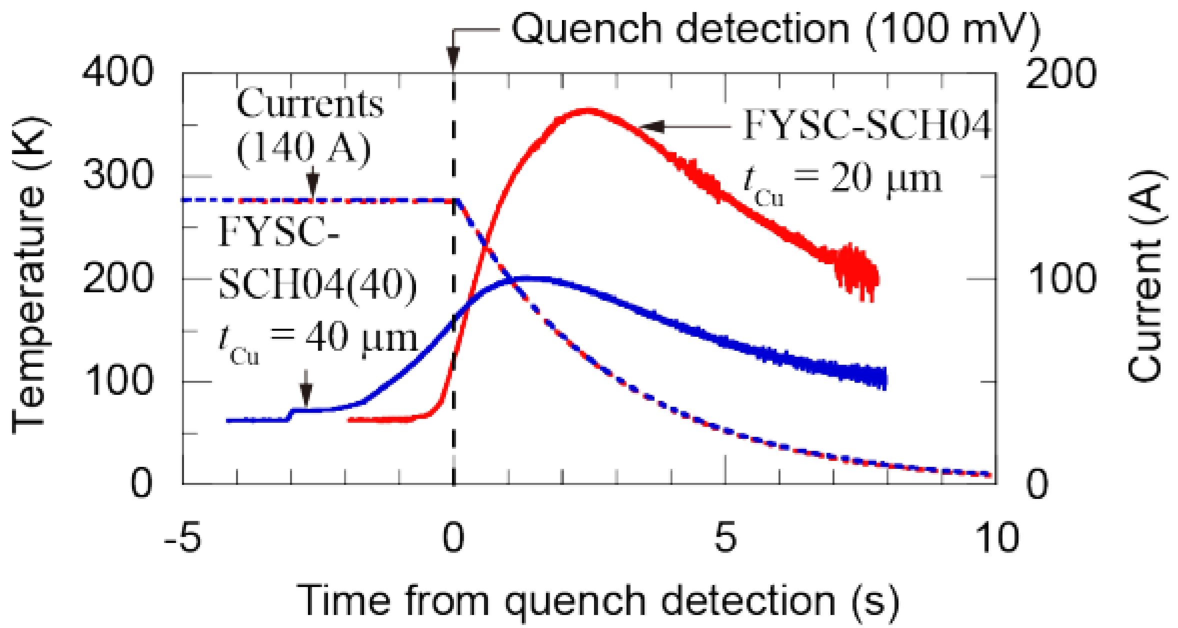
20 μm plated copper 40 μm plated copper

- Increasing critical current is improve stability (increasing MQE)
- But, it is meaningless for protection.

Luo et al. IEEE-TAS under review

N. Amemiya, Abb. Conf. Name 20XX

9



Luo et al. Tue-Mo-Po2.10-03

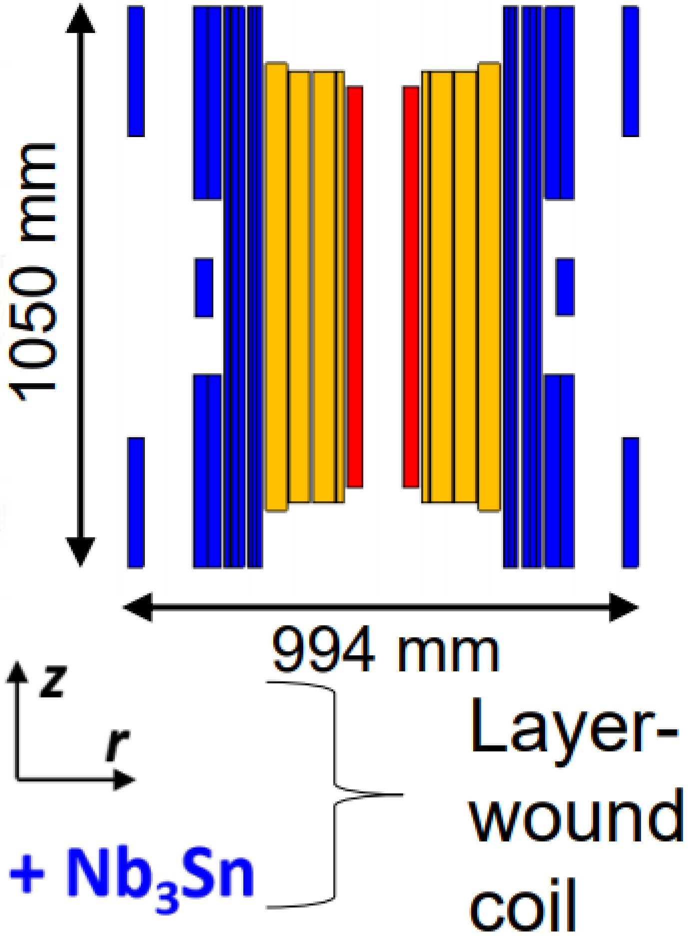
Key points as summary

- ✓ Copper current density is much more important than critical current density for quench protection.
- ✓ Ac loss in HTS is large, but its larger temperature margin is attractive in magnets generating time-dependent magnetic field.
- ✓ Mitigation of SCIF in magnets generating time-dependent magnetic field is a challenge.

30 T generation using an intra-layer no-insulation (LNI) REBCO coil in a 17 T LTS magnet

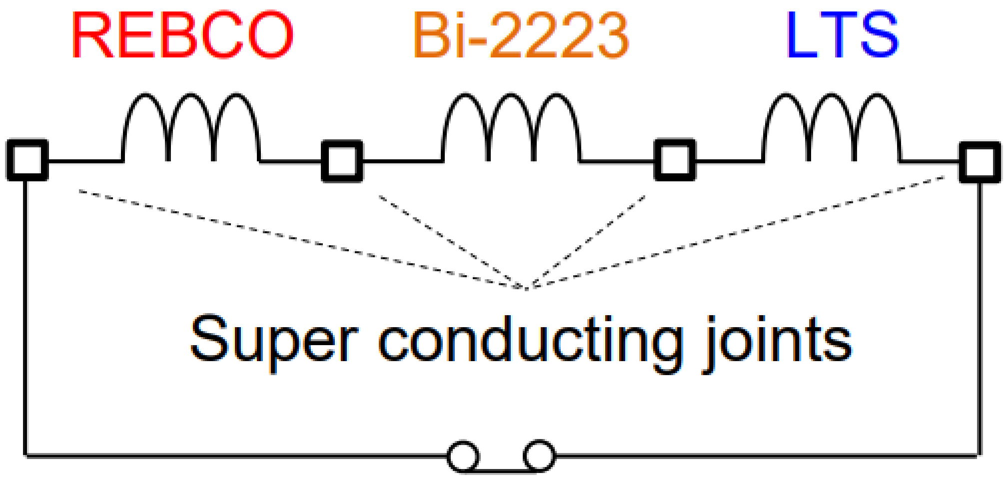
Y. Suetomi et al.

Our target : Persistent mode 1.3 GHz NMR magnet



Primitive designs by Hamada, JASTEC

H. Maeda., IEEE TAS, 29, 5 (2019)

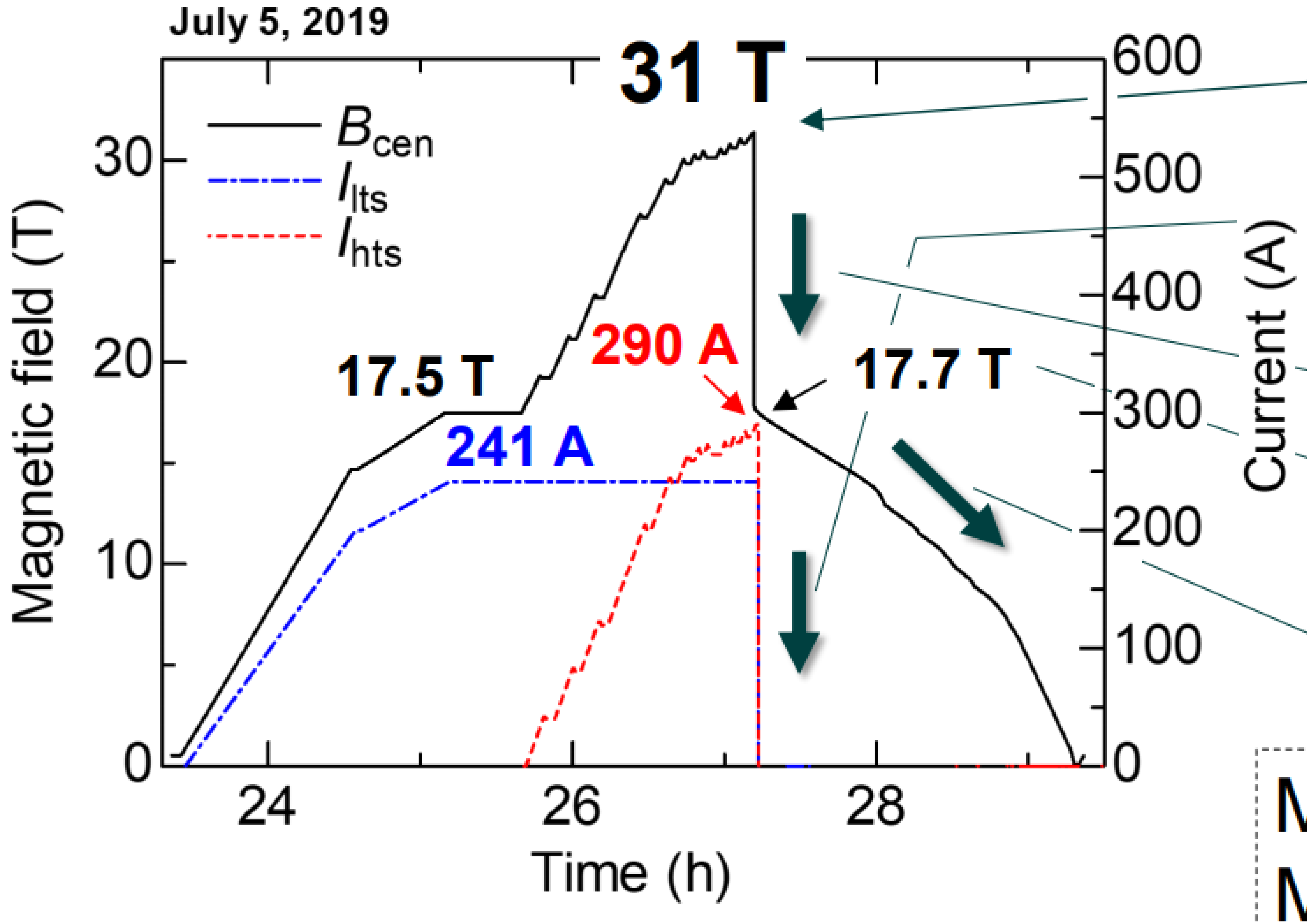


Requirements

- **30.5 T** generation by LTS / Bi-2223 / REBCO **layer-wound** coils.

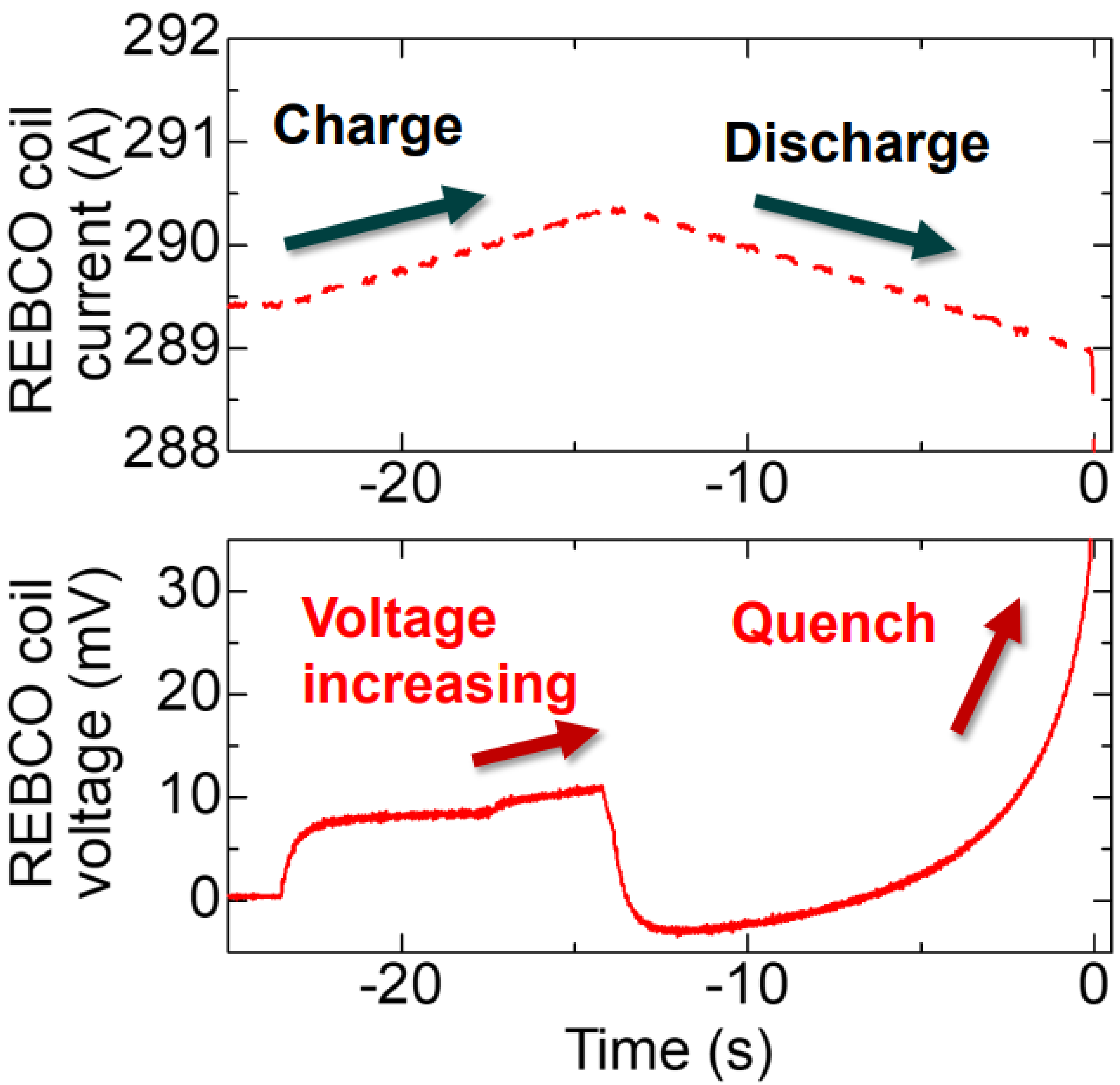
etc.

31 T generation ➡ REBCO coil Quench

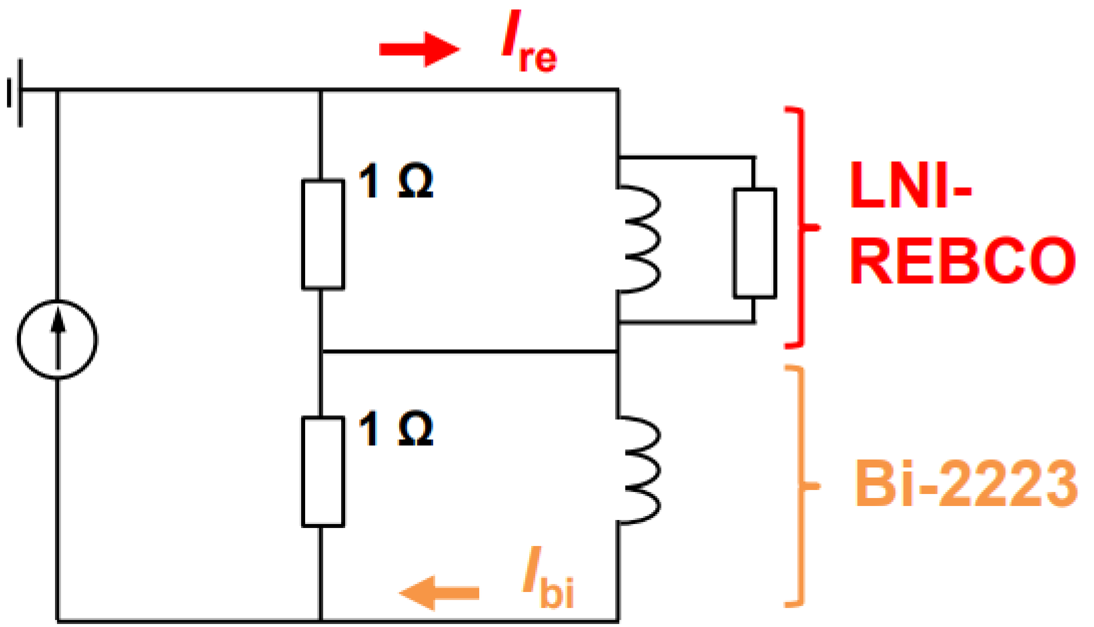


1. Quench occurred in the LNI-REBCO coil
2. Power supplies were shut down
3. HTS fields vanished
4. No quench in the LTS coil
5. Diode discharge

Max. BJR : **513 MPa**
Max. σ_z : **12.9 MPa**



During the quench

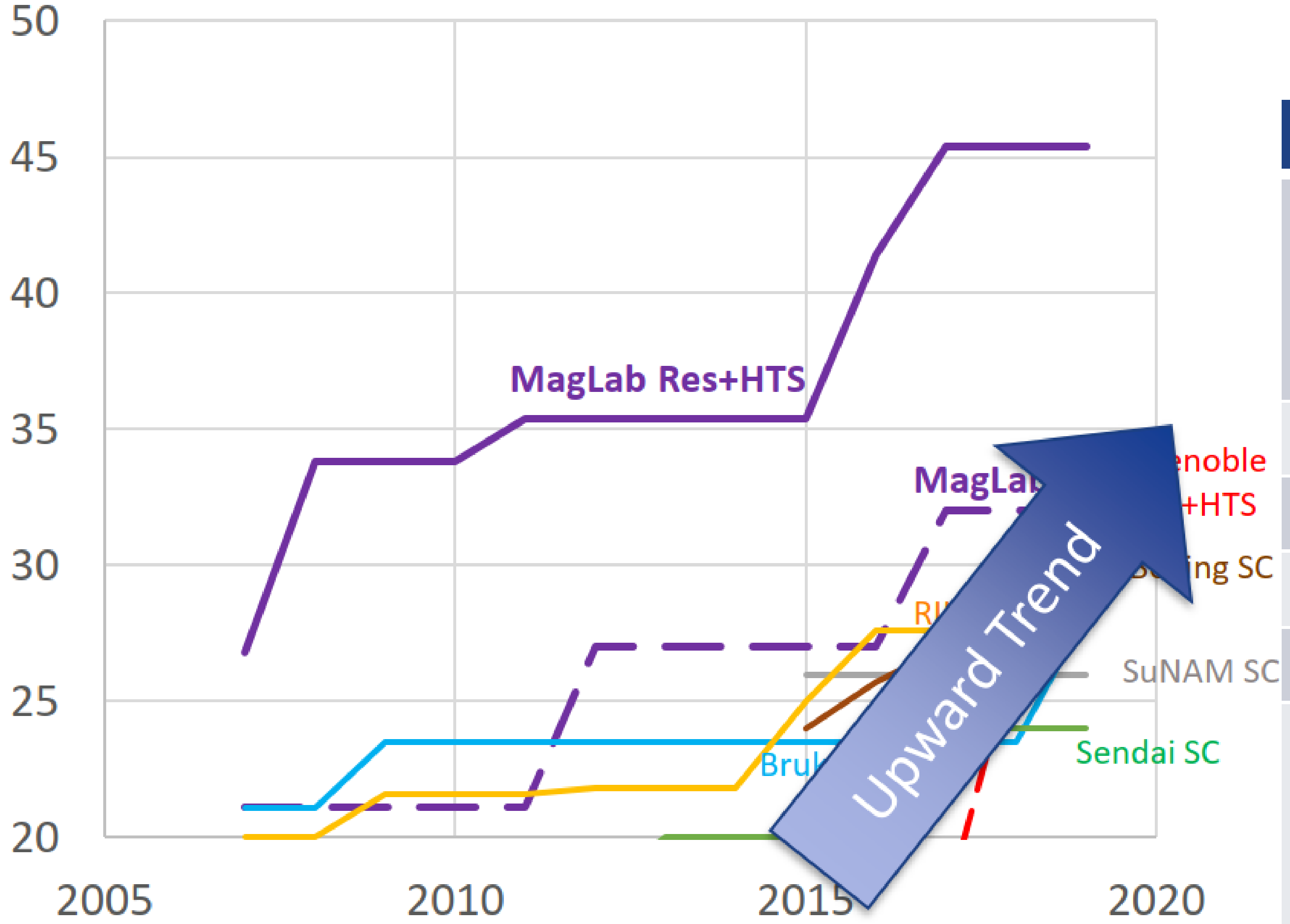


- ✓ The DC power supply was shut down with **0.2 V** of V_d.
- ✓ The Bi-2223 coil did not quench.

Advances in Ultra-High Field Magnet Technology

Mark D. Bird

Present Status > 23.5T SC



There are now at least 8 organizations worldwide developing HTS coils for service at Ultra-High Fields.

NMR = Nuclear Magnetic Resonance. MRI = Magnetic Resonance Imaging.

Publicly Stated Goals

Magnets are for Condensed Matter Physics unless stated otherwise.
Bold = Magnet in Service.

Organization	Present	Goal	Date
Sendai, Japan	**24 T**	30 T	2021
		33 T	funded
		40 T	
Tallahassee, Fl, USA	32 T	40 T	1st yr
Grenoble, France	32.5 T Res+	40 T	Study
Hefei, China		40 T	1st yr
KBSI, Korea	26 T	35 T	
Beijing, China	27 T test	30 T test	2019
		30 T	2021
		27 T ssNMR	2021
		28 T MRI	
Bruker	**25.8 T NMR**	**28.2 T NMR**	2019
RIKEN, Japan	27.6 T test	30.5 T NMR	2024

I-REBCO Quench Protection Concept

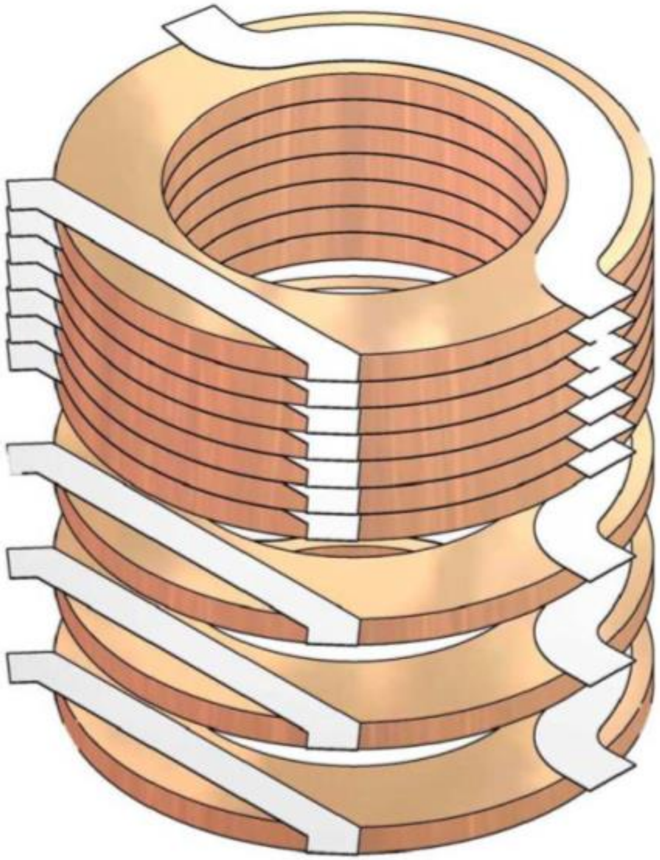


Fig. 2. Exploded view of pancake coil windings, showing concept of distributed heaters as heater strips on each pancake, with different heater configurations and degree of coverage of the pancake area.

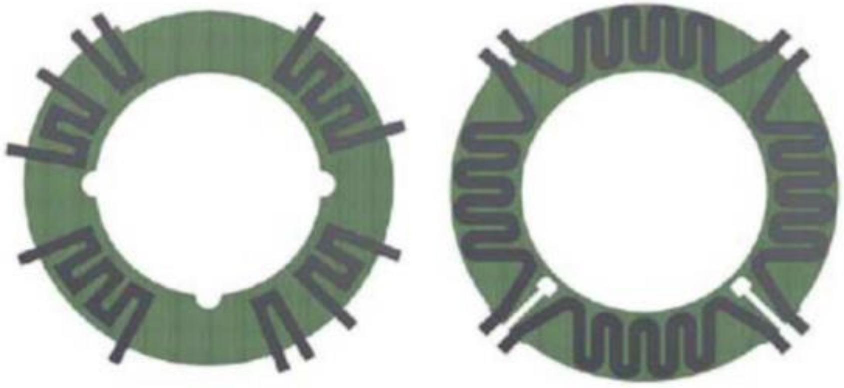
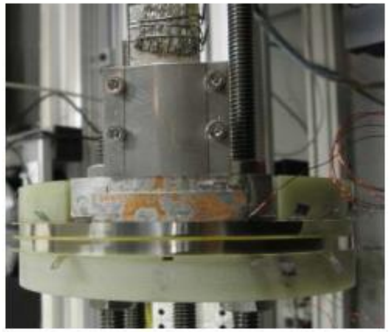
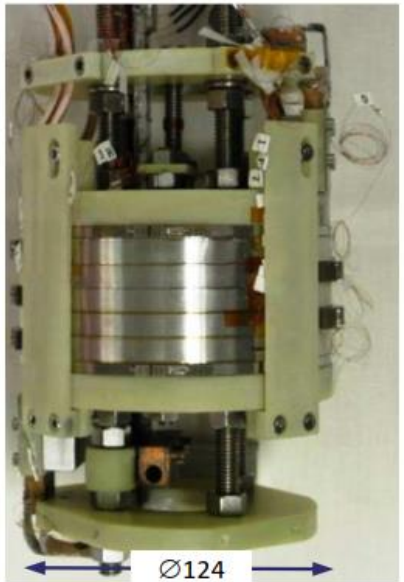


Fig. 2. One of two heater disks for Coil 1 (left). One of five heater disks for Coil 2 (right).

Quench heater





42-62 Mark 2:
2nd test coil

W. Denis Markiewicz, *IEEE TAS,* **18**, 2, June 2008, pp. 1333- 1336.

P. D. Noyes, W. D. Markiewicz, A. J. Voran, W. R. Sheppard, K. W. Pickard, J. B. Jarvis, H. W. Weijers, and A. V. Gavrilin, *IEEE TAS,* **22**, 3, (2012), 4704204.

Screening Currents: Strain

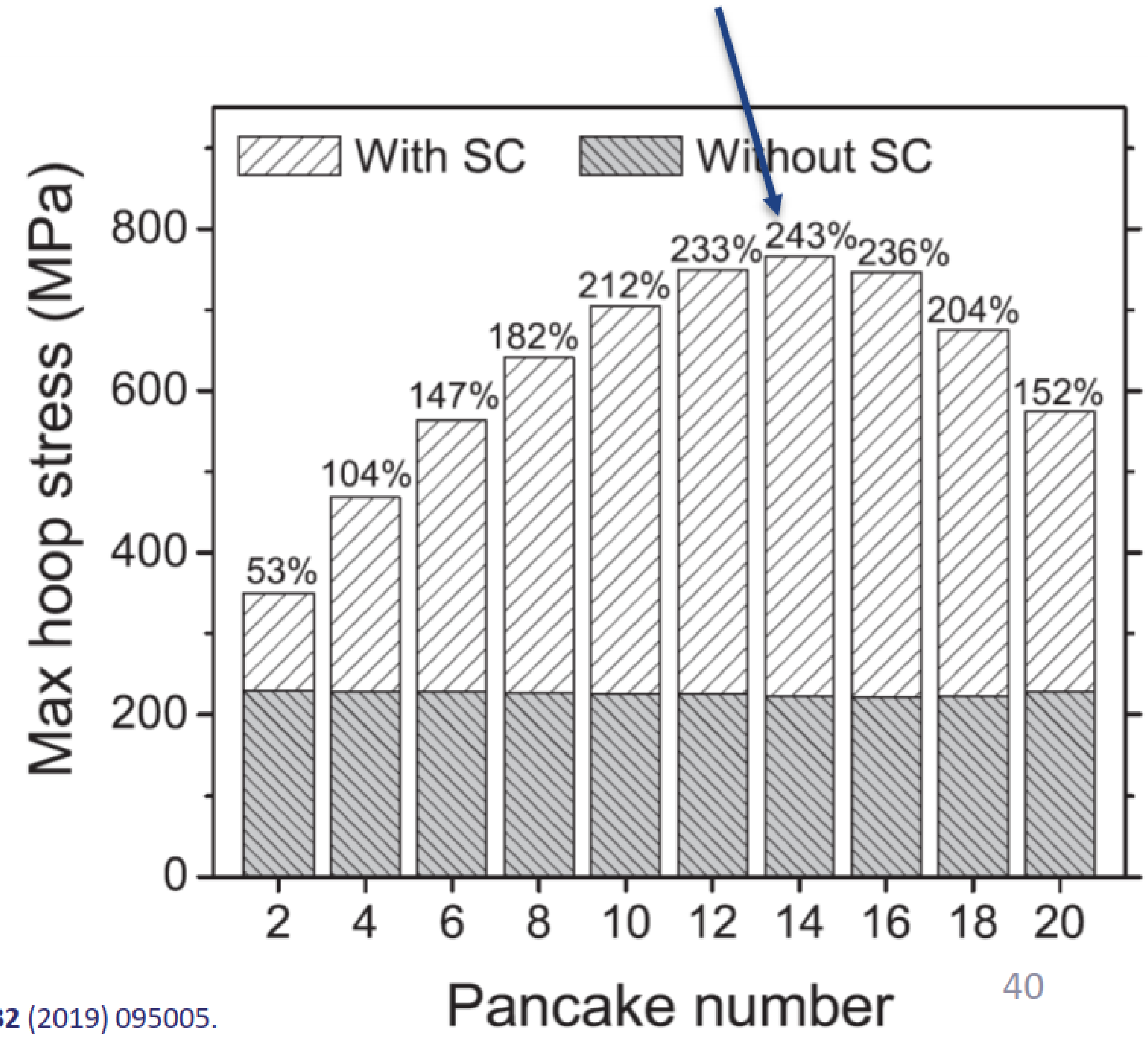
In the 1970s & 1980s, IGC built Nb_3Sn tape magnets.

Rippling of the edge of used tapes was observed.

In 2019 Jing Xia, et al., showed that if a coil was designed for uniform stress due to transport current only, actual stress including screening currents might be 2.4x higher.

Low screening currents at mid-plane due to low radial field.
High radial field at end of coil limits Jc.

Max. Torque and Strain for REBCO.



Jing Xia, Hongyu Bai, Huadong Yong, Hubertus W. Weijers, Thomas A. Painter, & Mark D. Bird, *SuST* **32** (2019) 095005.

40 T SC in Tallahassee: Considering 5 options

	Insulated REBCO	No-Insulation REBCO	Integrated Coil Form REBCO	Bi-2212	Bi-2223
Pros	Same technology as 32 T magnet: Extensive quench protection testing has been successfully completed (single coils >150 quenches).	Very compact → Lower cost. Has produced 26 T all-SC test coil & 45 T (31 + 14 HTS) test coil.	Very compact → Lower cost. Cables provide redundancy. Reinforcement system is better suited to screening currents.	Round, multi-filamentary wire facilitates coil construction and minimizes screening currents. Current density has recently surpassed I-REBCO.	Wire is produced in large quantities and length. Good quality control.
Cons	Concern about magnet life-time due to single-point failure of "single-crystal by the mile."	Quench protection not well developed.	No test coils to date.	No fatigue data. Coils built to date are very small. Reaction.	Wire has low current density, which results in larger magnets.

The goal of each test coil program is to reach a "Go/No Go" decision as soon as possible. This requires a dynamic process of weighing further risk reduction against time and cost of each test coil program.