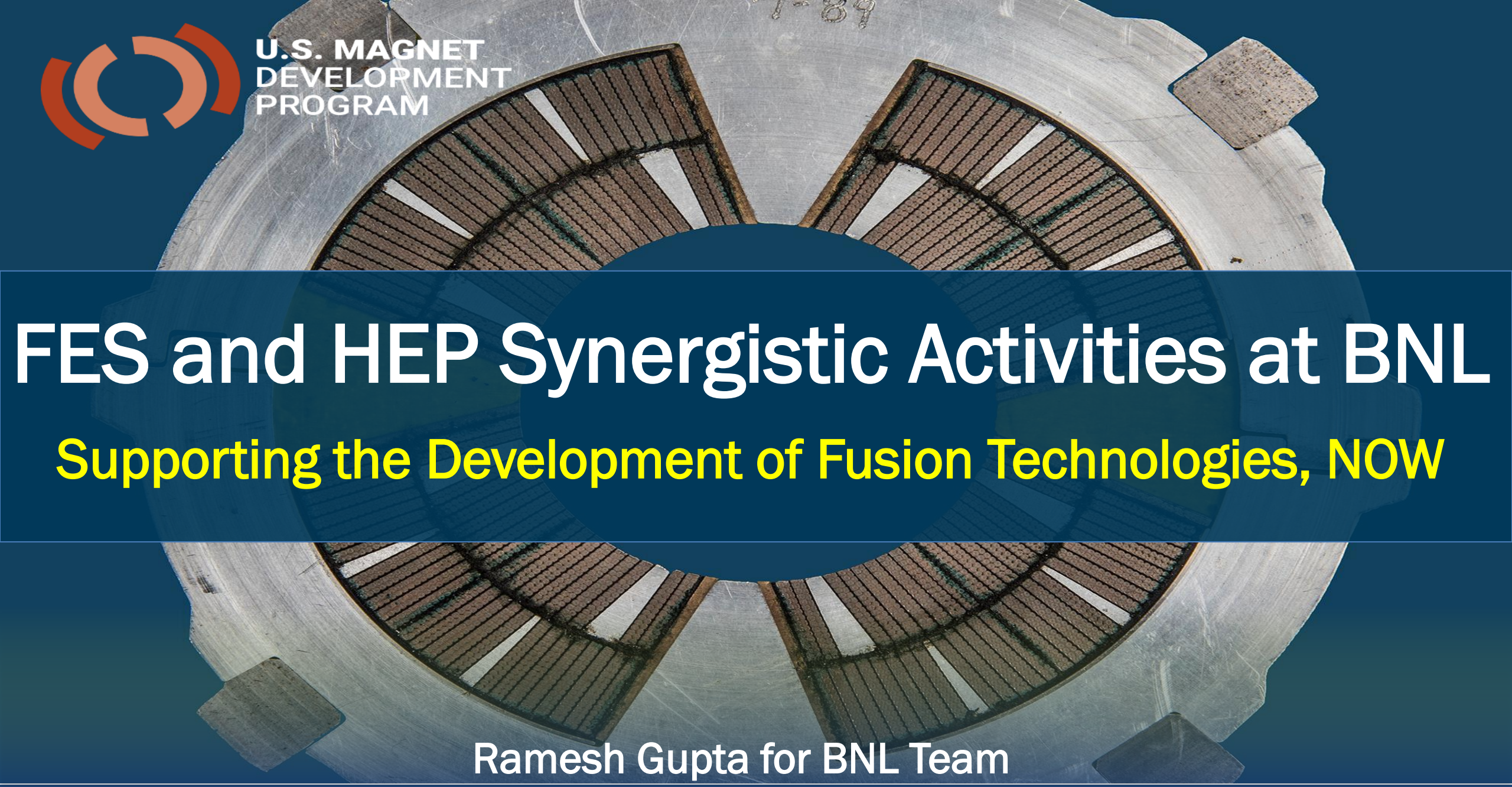

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FES and HEP Synergistic Activities at BNL

Supporting the Development of Fusion Technologies, NOW

Ramesh Gupta for BNL Team

Nb_3Sn Common Coil Dipole for High Current HTS Cable Testing (FES)

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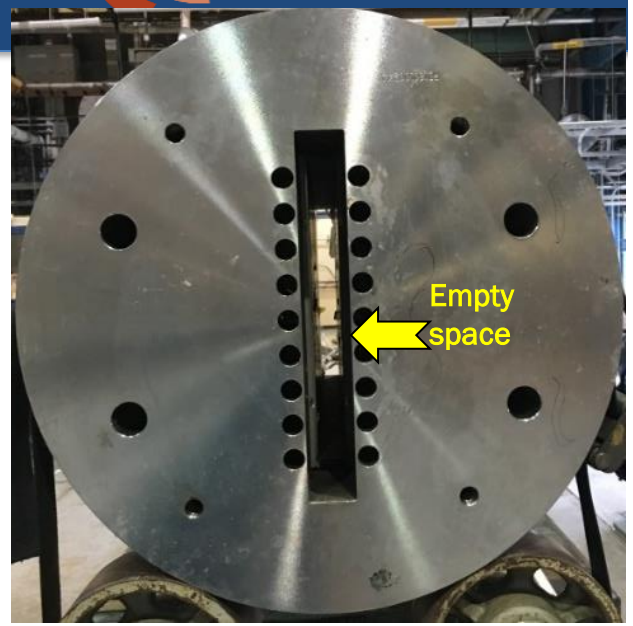
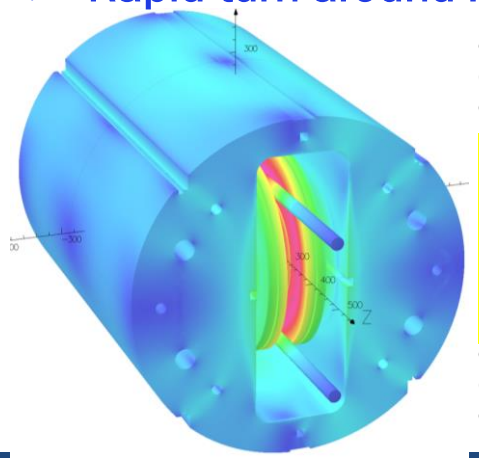
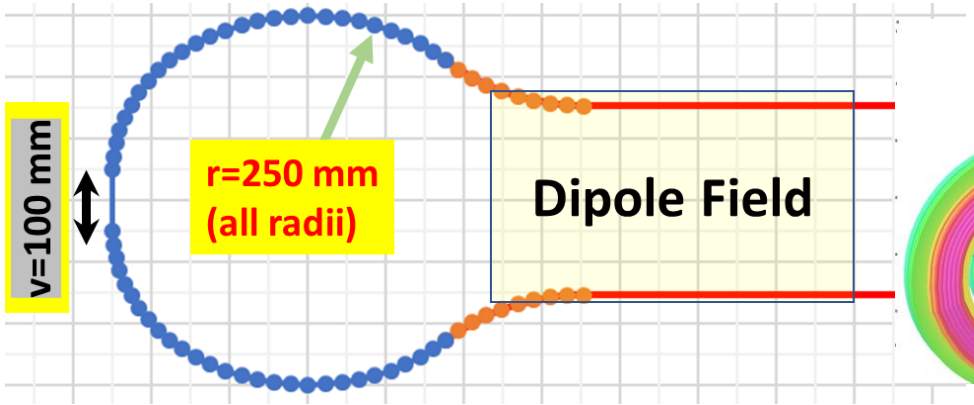
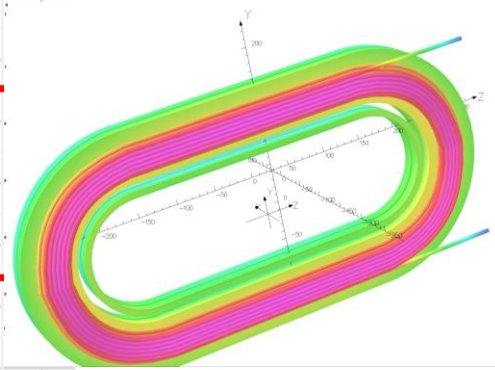


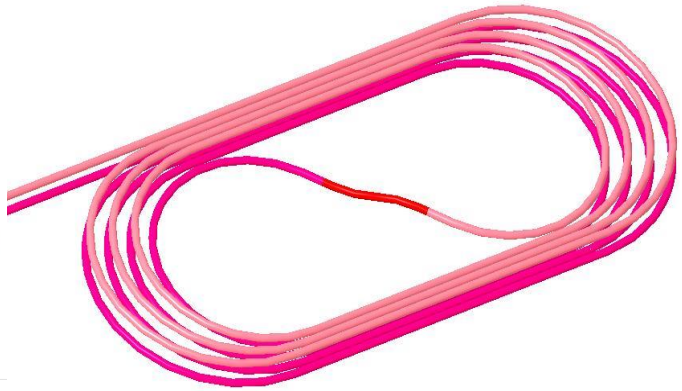
- A Nb_3Sn dipole with a large opening (335 mm) providing a field of 10.2 T
- Unique Features: High current, long length, HTS cables with large bend radius can be tested in applied dipole field (important for Fusion cables)
- Even larger radii, longer length cable/joints can be looped in the high field region
- HTS cables can be tested at high temperatures (4K – 50^+ K) with small upgrades
- Advanced instrumentation (quench protection); capability to accommodate more
- Innovative HEP R&D facility offers unique opportunities to FES. Researchers can do new type of R&D that typically can't be imagined. Need community dialogue
- Available now while even a higher field facility becomes available in US in future

➢ Rapid-turn-around HTS/LTS Hybrid Dipoles (see backup slide - presented for HEP this Tuesday – is it synergy or not?)



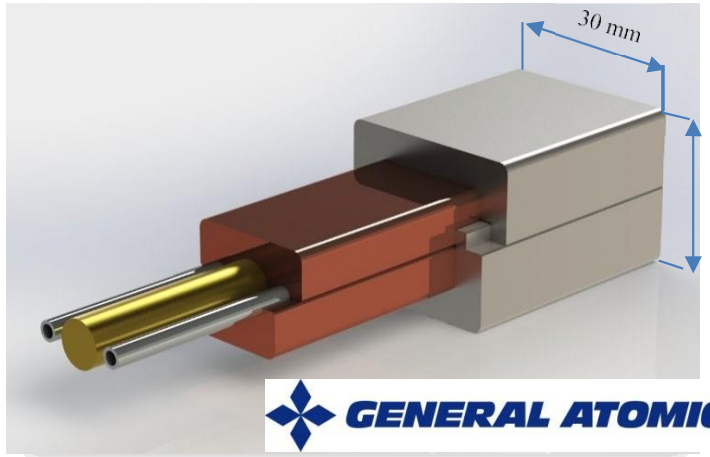


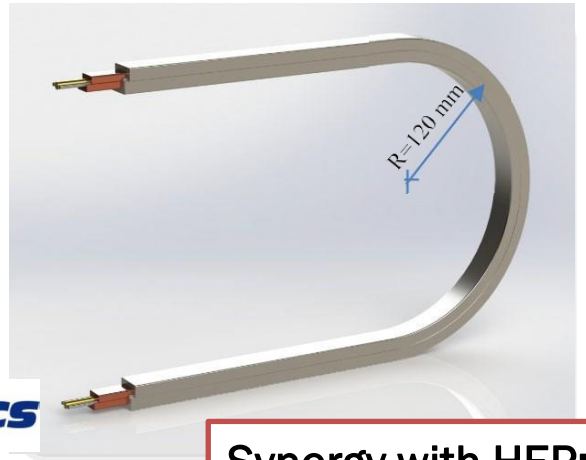


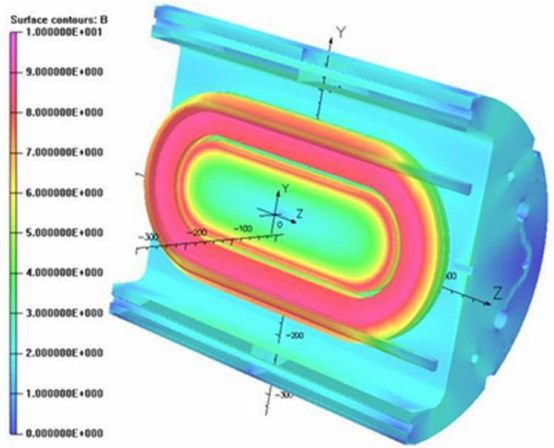


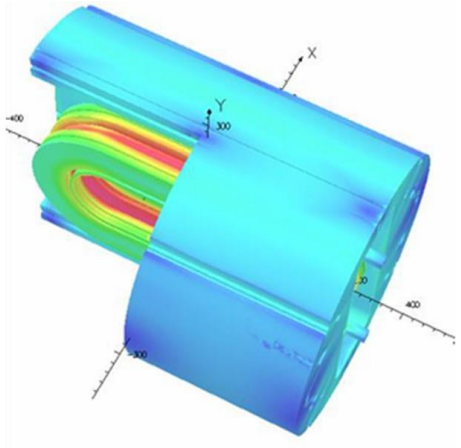
Variety of Upcoming Cable Tests

- ✓ Twisted Stacked/Viper from CFS (INFUSE) - two tests completed (one last week, 3 slides)
- ➢ Magnum NX™ from SMS (INFUSE) – Performance under field - funded
- ➢ Two tests of Viper cable from CFS (arpa-e) – funded
- ➢ CORC from ACT (MDP) – Quench and technology studies – funded (also ACT/BNL STTR)
- ➢ Cable-in-conduit for fusion magnets from BTG (SBIR) – Phase I funded
- ➢ CICC from GA (INFUSE) – applied for funding









Synergy with HEP: Certain dipole designs can take advantage of such cables

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SPARC

Courtesy: C. Sanabria, CFS

First INFUSE Test- added with MDP Coils– Feb 2020 (HEP/FES Synergy – 2 HEP Coils and 2 FES Samples)

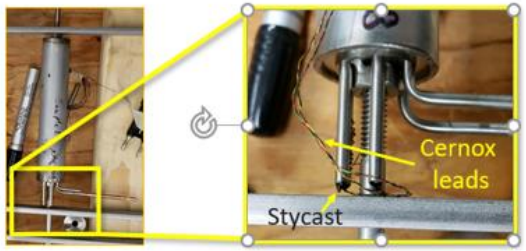
Program goals

1. Characterize PIT VIPER cable AC losses at relevant dB/dt

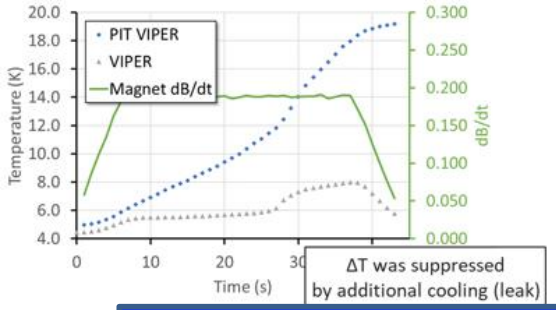
   Note: induced currents from the changing magnetic field are heating up the sample (AC losses).

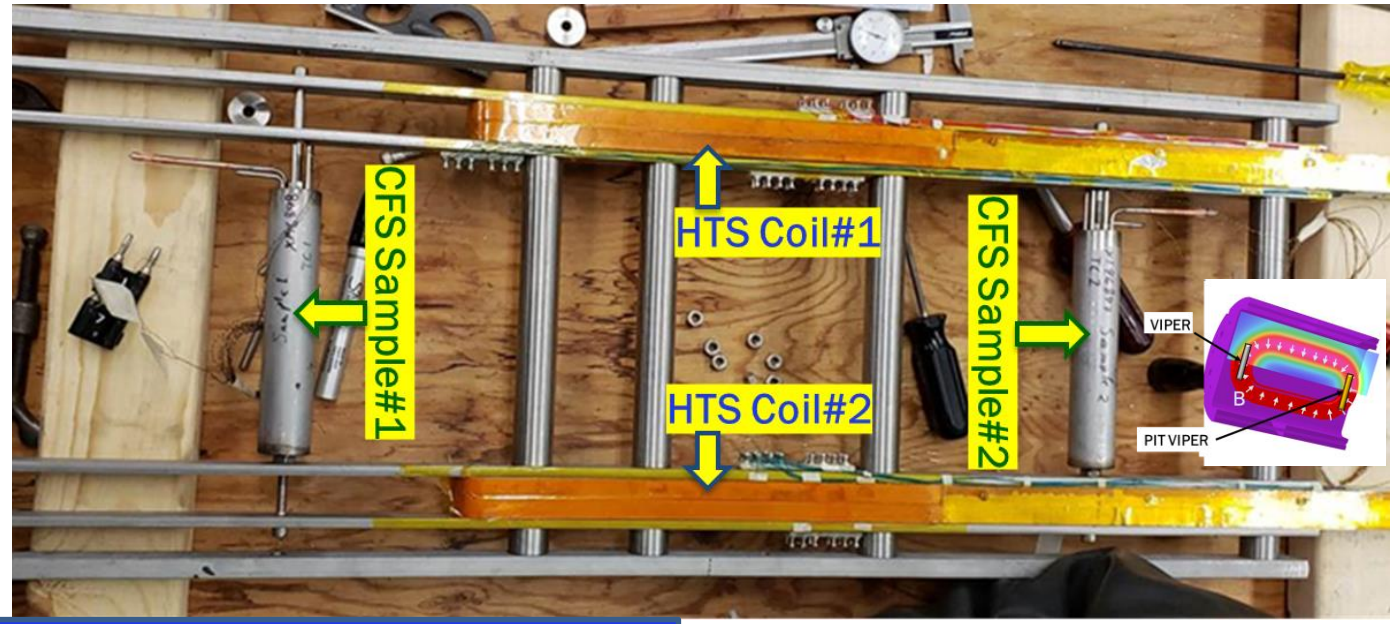
2. Characterize and qualify novel quench detection systems.

Note: quench detection systems are not being qualified with transport current, only heat pulses.

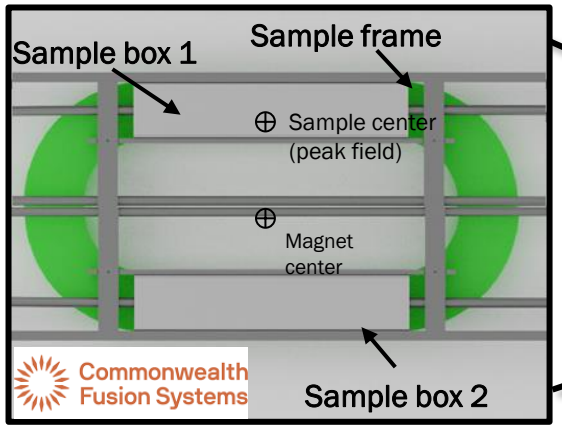


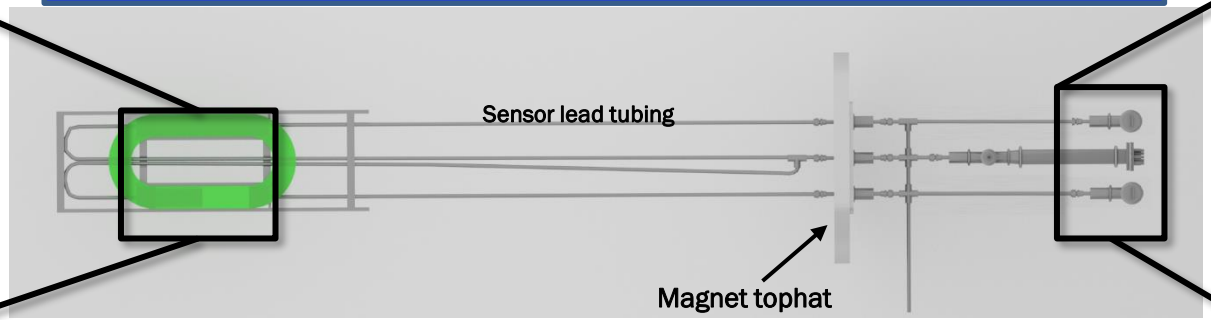
0.183 T/s to 7.49 T

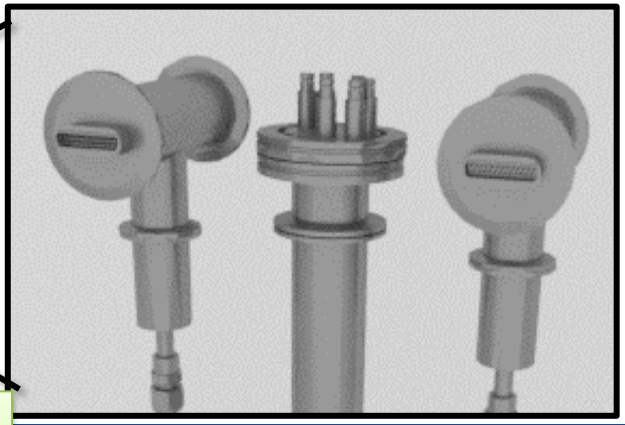




First test gave initial data but had leaks and <0.2 T/s







Goals for the second test: higher ramp rates and lower leaks

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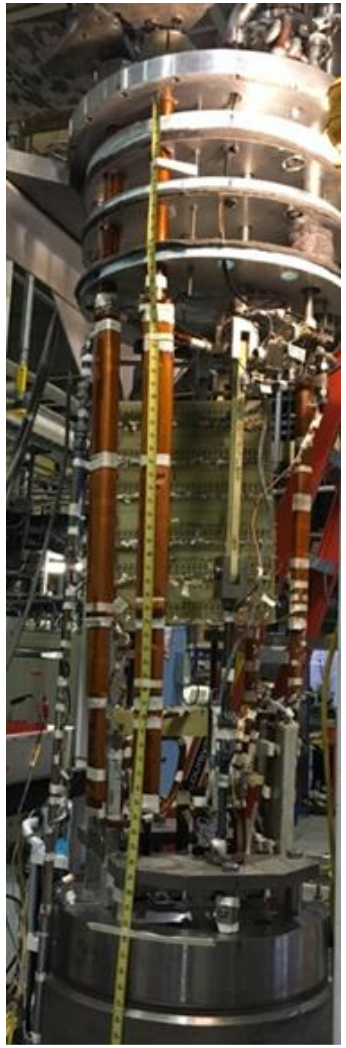
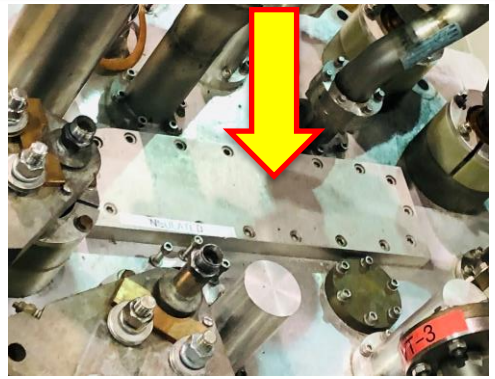
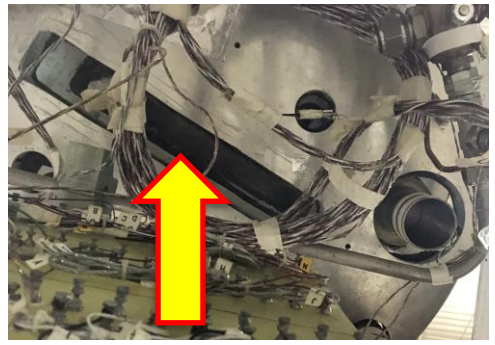
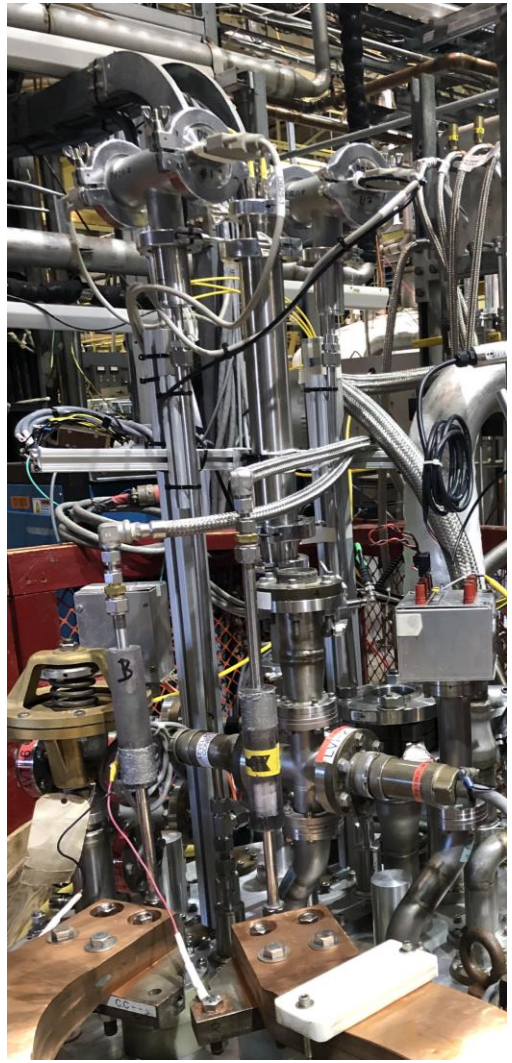
Second Dedicated CFS INFUSE Test – Feb 2021

(FES/HEP Synergy – Technology developed for FES, critical to HEP)









Fixture inserted from top hat into the magnet

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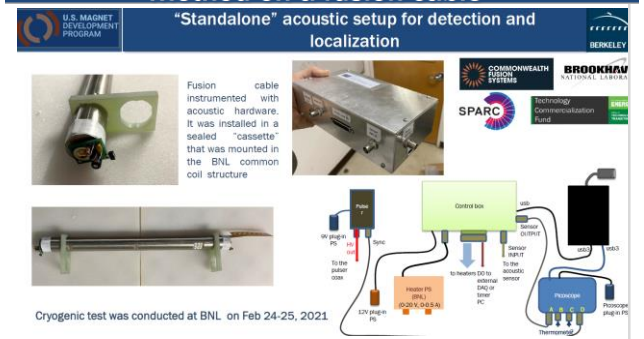
Courtesy: Charlie, CFS, Maxim, LBL

High Ramp Rates During the INFUSE Test (1kA/s or 1 T/s during ramp down in DCC017)

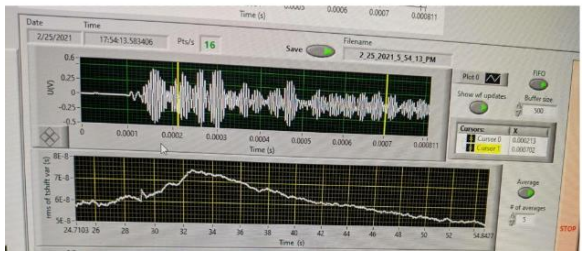
Temperature Control on HTS Sample ~4 K to ~50 K

First successful cryogenic demonstration of the method on a fusion cable

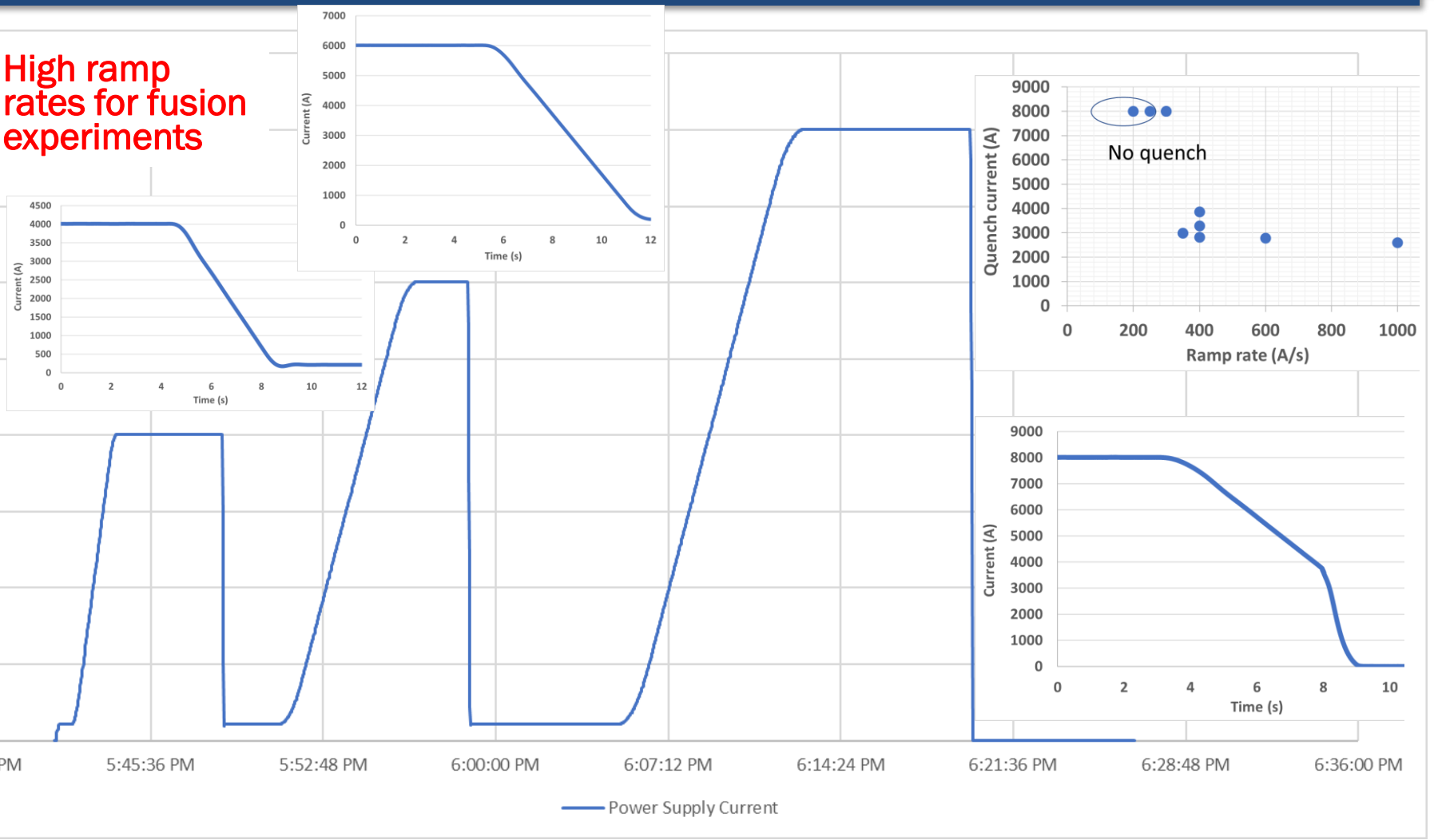


M. Marchevsky, LBNL

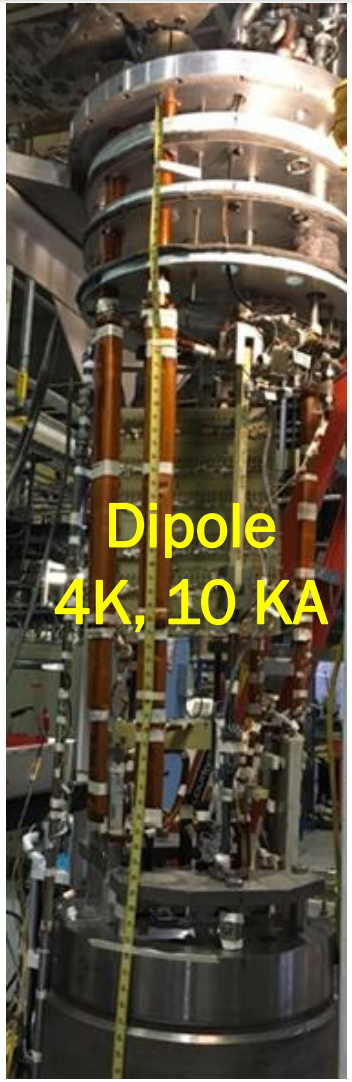
11.7 K -> 13 K



High ramp rates for fusion experiments

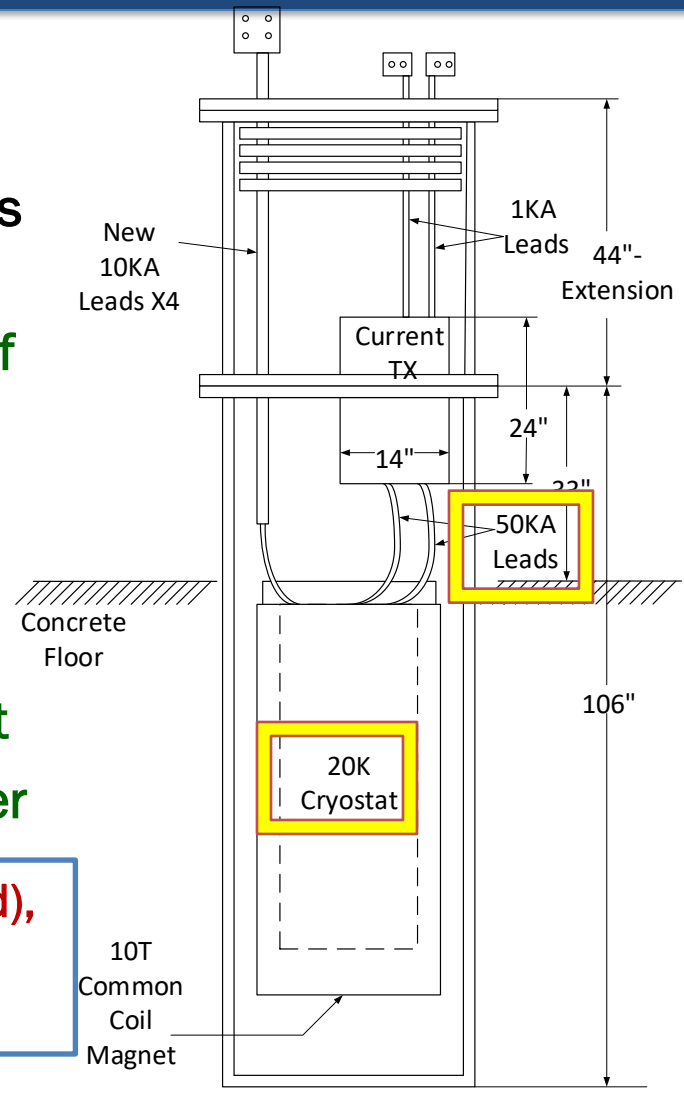


A Unique US HEP/FES Facility – Status and Proposed Upgrades



- The current facility provides a field of 0 -10 T at ~4 K and up to 10 kA in cable if connected in series with the magnet
- BNL is investing significant funds (~1.5 M$) in various upgrades to turn this unique dipole with large opening to a unique facility
- The following can be (and should be) added in a short period of 1-3 years with modest external support and/or collaboration
  - A reliable facility operating independently of other programs (some reconfiguration and maintenance required)
  - 1-50^{+} kA on cable/joints with superconducting transformer
  - 4-50^{+} K test temperature for users with a secondary cryostat
  - ~40 m long cable in dipole field, 150-500 mm bend diameter

This 10 T dipole test facility is complimentary to SULTAN (solenoid-based), and a facility available to users in US now while the higher field (15 T) dipole FNAL/LBNL facility becomes operational in 5 (?) years.



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Acknowledgements

- INFUSE and HEP for making this connection possible – in particular, Dennis Youchison, Ahmed Diallo, Daniel Clark, Ken Marken and MDP
- BNL management
- Co-workers in magnet division - Piyush Joshi, Sonny Dimaiuta, Ray Ceruti, Daniel Sullivan, P. Galioto, P. Doutney, Bill McKeon, Bill Sampson, Shresht Joshi, Anis Ben Yahia, Rick Feltor, Glenn Jochen, Henry Hocker, Mike Anerella, M. Samms, Kathleen Amm and many others
- Collaborators: Charlie Sanabria, Dave Meichle, Michael Segal, Elle Allen, Brandon Sorbom (CFS) and Maxim Martchevsky

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Summary and Outlook

- Common coil dipole with a large opening has already started providing a unique test bed for testing fusion cables and HTS magnet technologies for FES and HEP. More on the way
- Within a period of 1-2 years, it has emerged as an informal case to show how HEP & FES can work together and how much synergy and commonality is present between the two
- With a small investment on maintenance and upgrades, this could become even more useful US facility for both FES and HEP till a more desired facility at Fermilab becomes operational based on ambitious and reliable large aperture, high field LBNL/FNAL dipole
- We are looking forward to offer even more testing of high current (0 to 50^{+} kA), long length (up to 40 m) HTS cables in a dipole field at a range of temperature (4 to 50^{+} K)
- Currently there is no such equivalent facility present in US or any where in the world
- Such a facility should start a new kind of R&D previously thought or imagined possible

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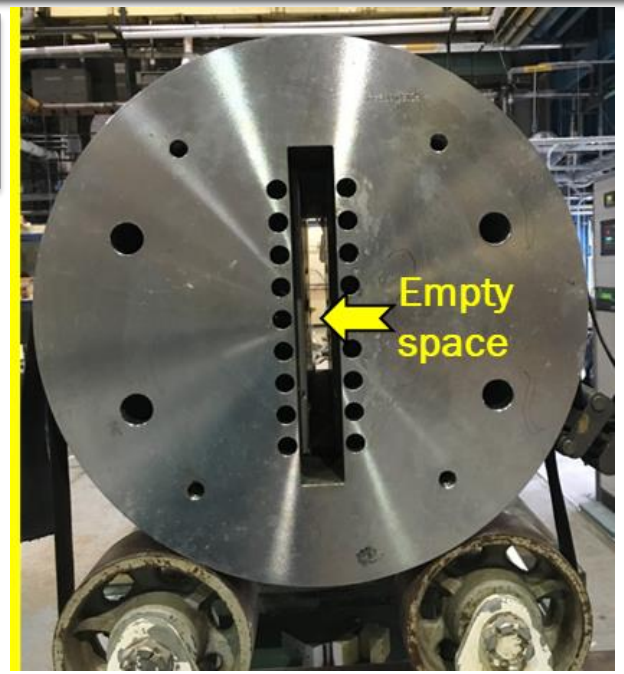
BACKUP SLIDES

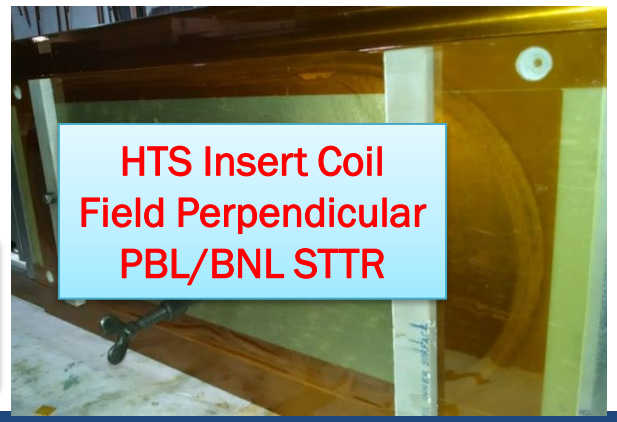
Rapid-turn-around HTS/LTS Hybrid Dipoles

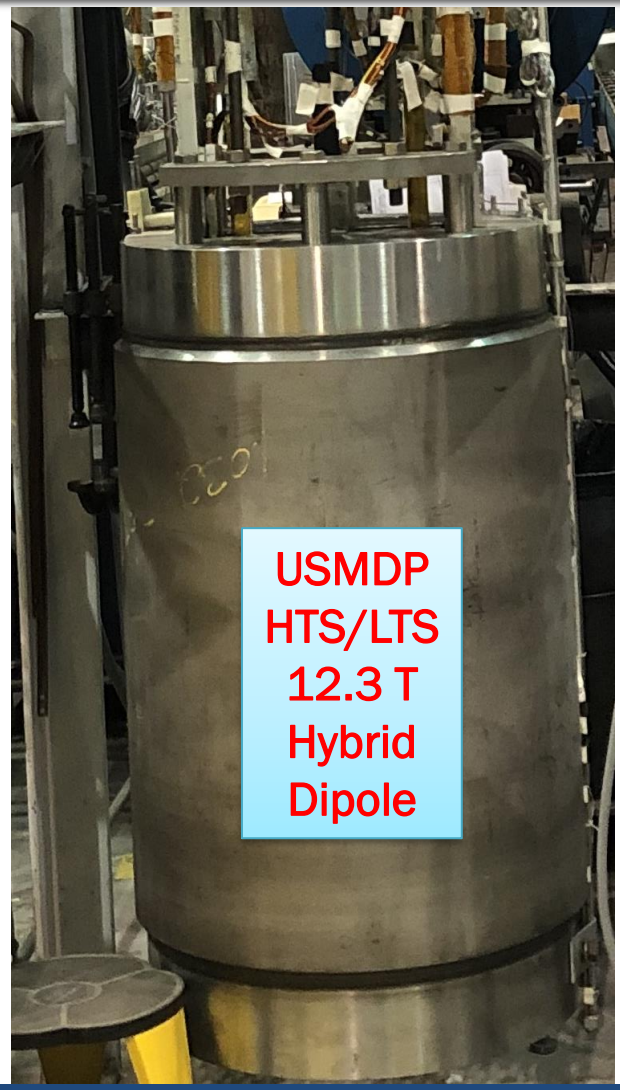
Key components/steps for Rapid-turn-around R&D

- 10 T, Nb_3Sn dipole with a large open space for high field insert coil testing
- New coil(s) in the magnet without any disassembly
- Coils become an integral part of the dipole magnet
- A new coil test essentially becomes a new magnet test

High field technology demo possible in ~1 year and ~$200k

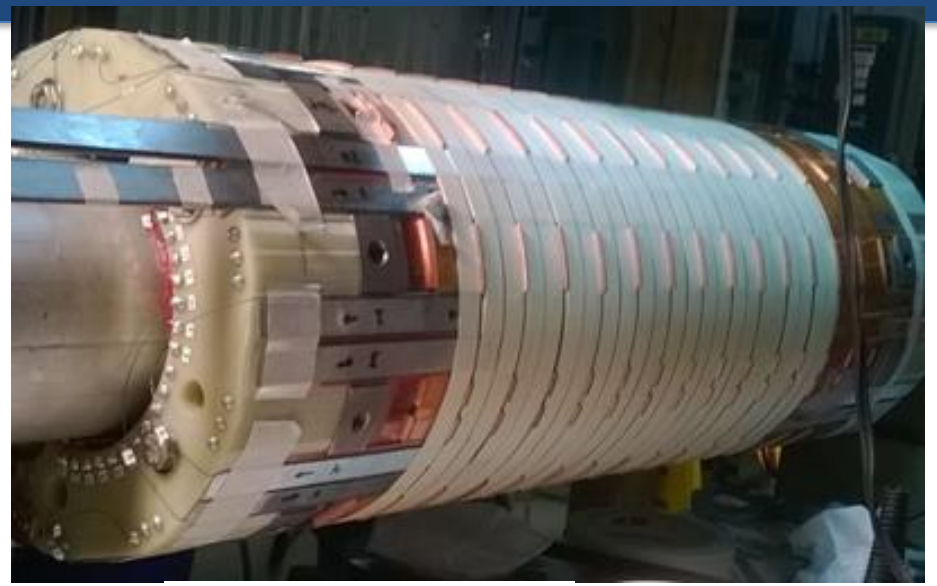


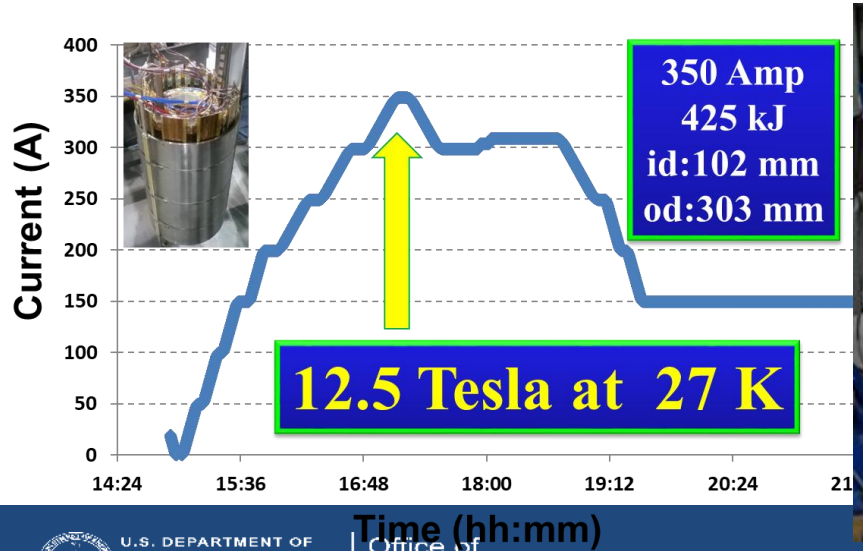


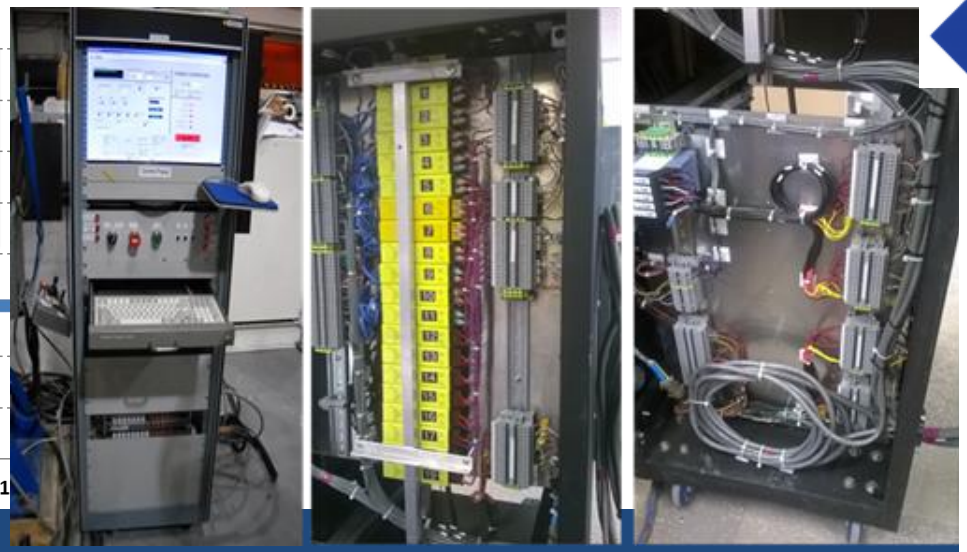


Other Facilities Under Discussion with Fusion Partners

- HTS Splices (Renaissance - INFUSE - funded)
- CICC INFUSE Cable Test Proposal from GA
  - CICC – could be a way to go for high field magnets
- HTS/HFS magnets (100 mm bore 12.5 T, 27 K SMES)
- Advanced Quench Protection for HTS magnets
- Radiation damage studies of HTS samples







RENAISSANCE FUSION

In collaboration with University of Houston