

Magnet R&D at BNL for Future High Energy Colliders



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Thrust Areas of BNL Program

- High field HTS and high field HTS/LTS hybrid R&D magnet program
- High temperature (4K - 70K) testing (maximum field reachable at various temps, quench protection, field quality)

UNFAIR COMPETITIVE ADVANTAGE:

(remembering Bruce Strauss)

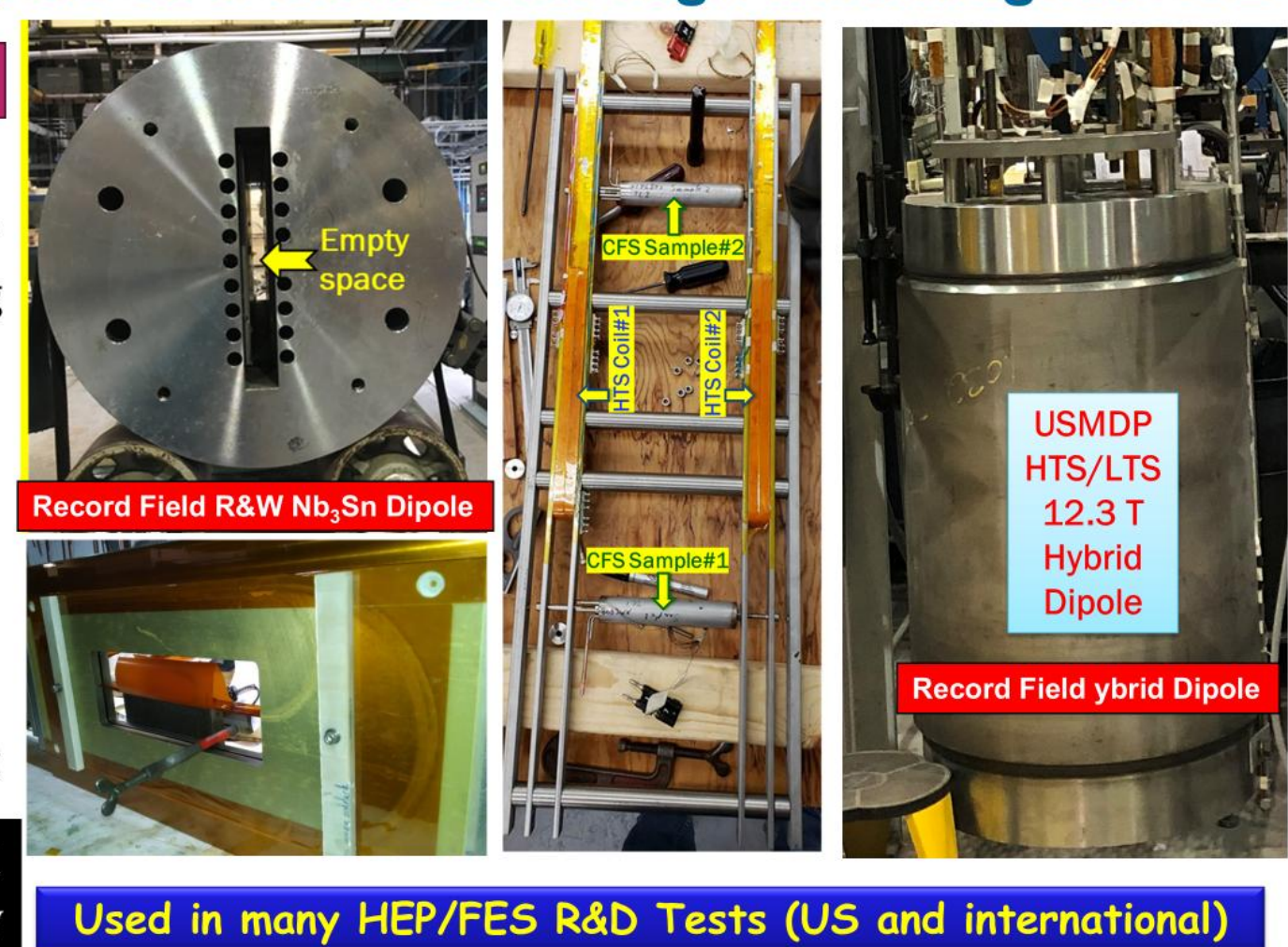
- Unique Common Coil Test Facility (CCTF) for lower-cost, rapid-turn-around high field insert coil testing
- Advance quench protection system
- Large collection of HTS coils (in variety of shapes and sizes) available for R&D

BNL common coil dipole as a test bed for high field magnet R&D

Unique Test Facility @BNL

- 10 T, Nb₃Sn R&W 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

Lower cost, fast-turn-around demo of high field technology

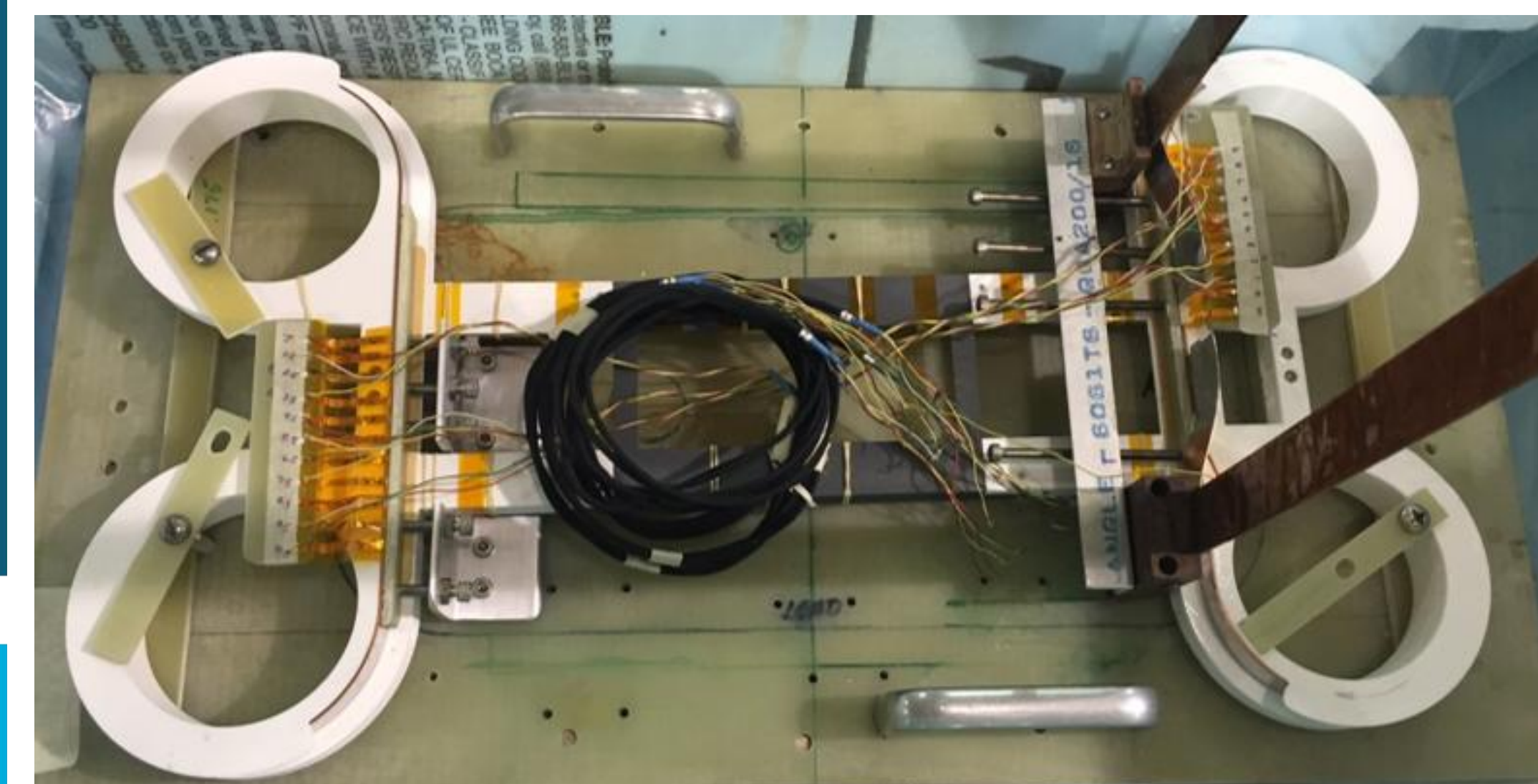


Quench studies with a large number of expensive HTS coils leftover from the previous R&D programs

(No fear of destroying them for a "burn to learn" approach)

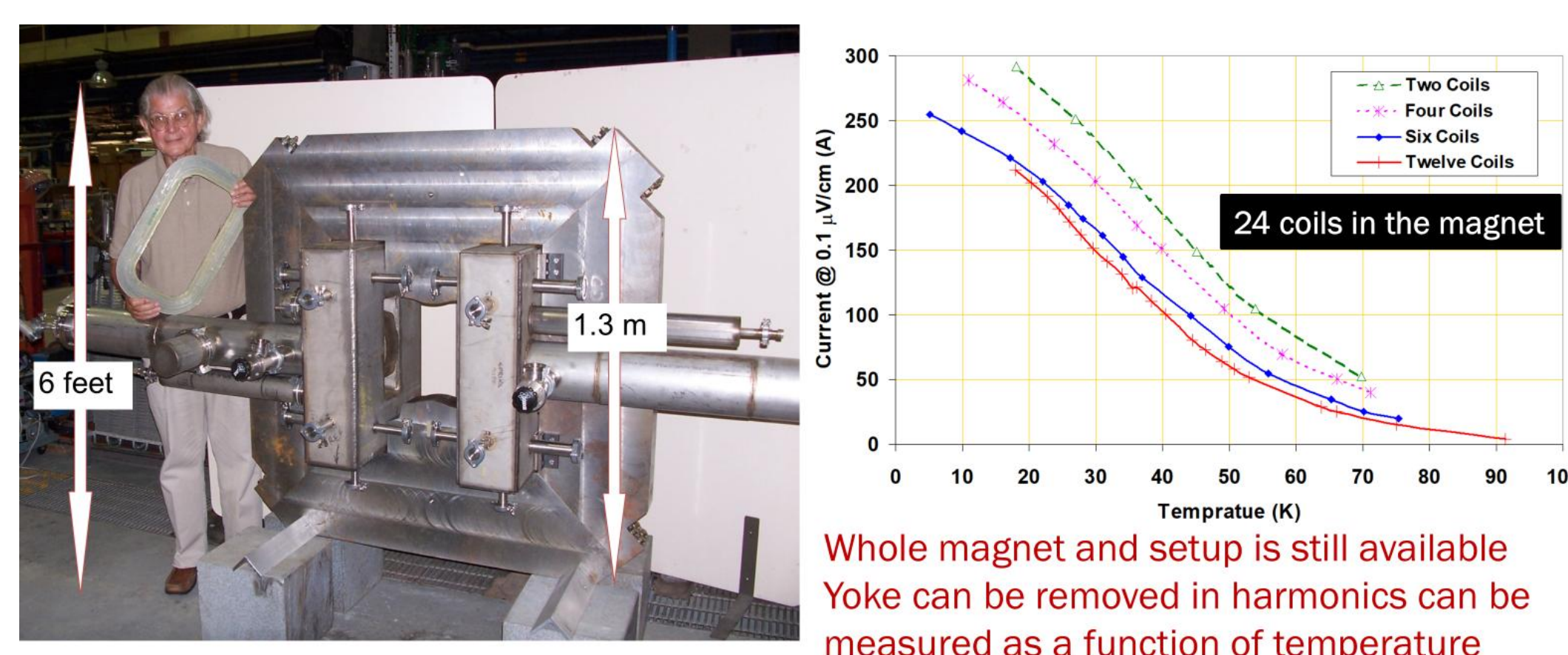


Inventory of HTS coils in a variety of shapes



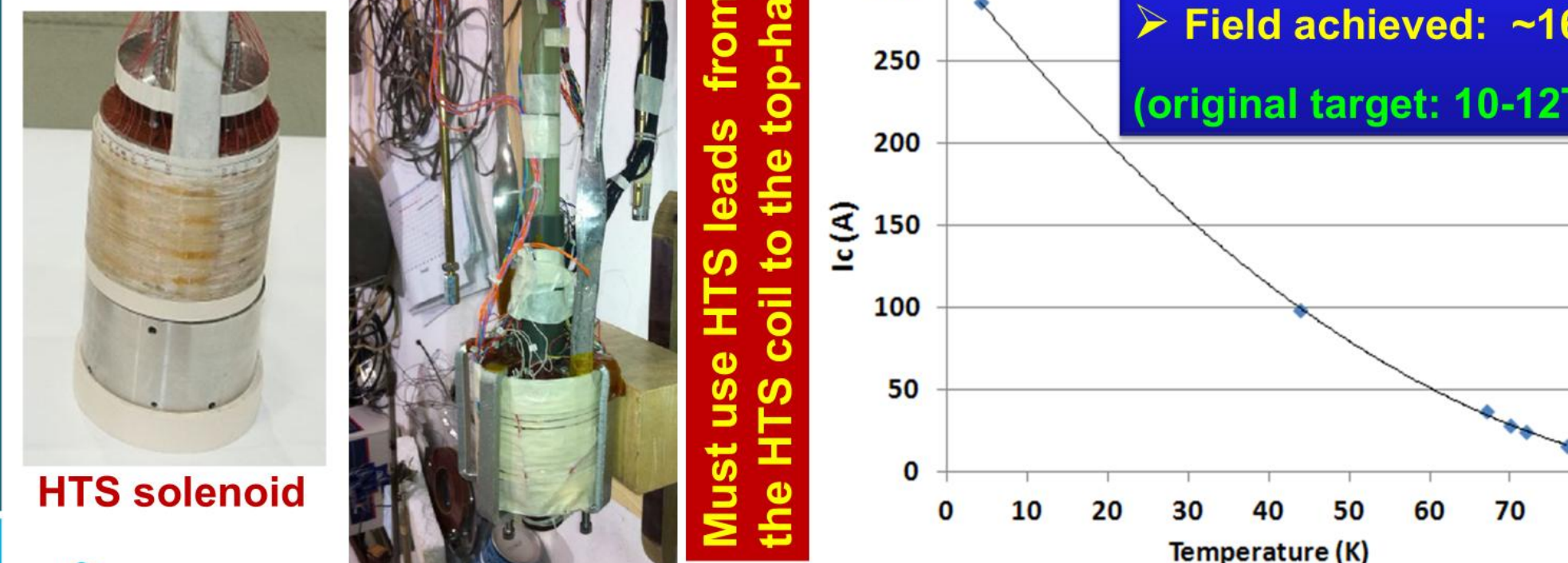
High Operating Temperature R&D for HTS Magnets

- Interest in Fusion and HEP community in operating HTS magnets at high temperature to save on cryogenics
- BNL has a significant experience in this area and opportunity to add more
- Just upgraded leads for testing large coils at high temperature. Feed-back based temperature control planned.

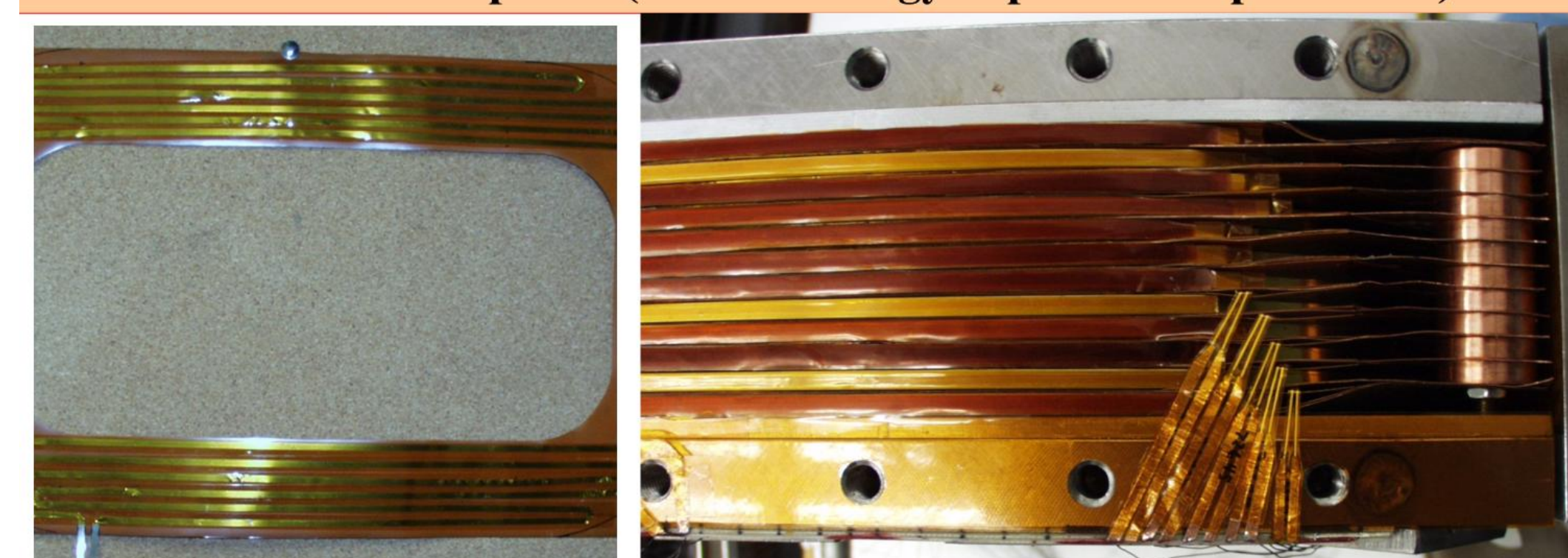


HTS 16 Tesla Solenoid (Record in 2012) and I_c Vs T

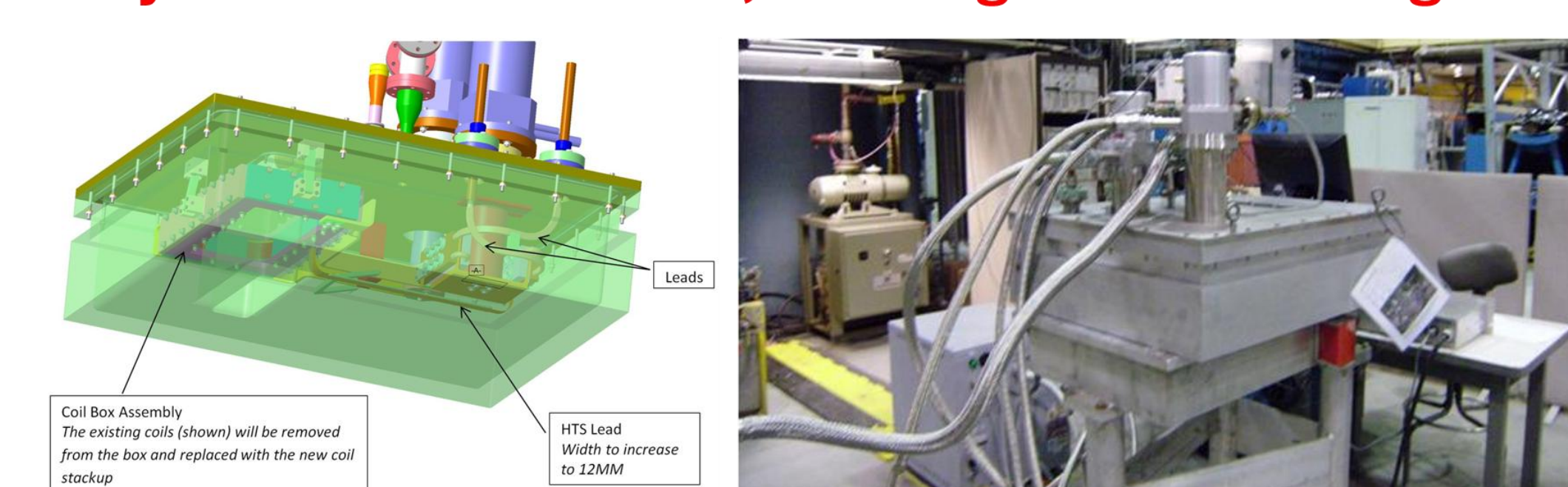
Make measurements at intermediate temperature with controlled cooling by adjusting the flow of helium (for future feedback loop on controlling valve?) or perform measurements during the warm up.



Stainless steel tape heaters for changing temperature of the coils by adding heat load on the outer plates (also for energy deposition experiments)

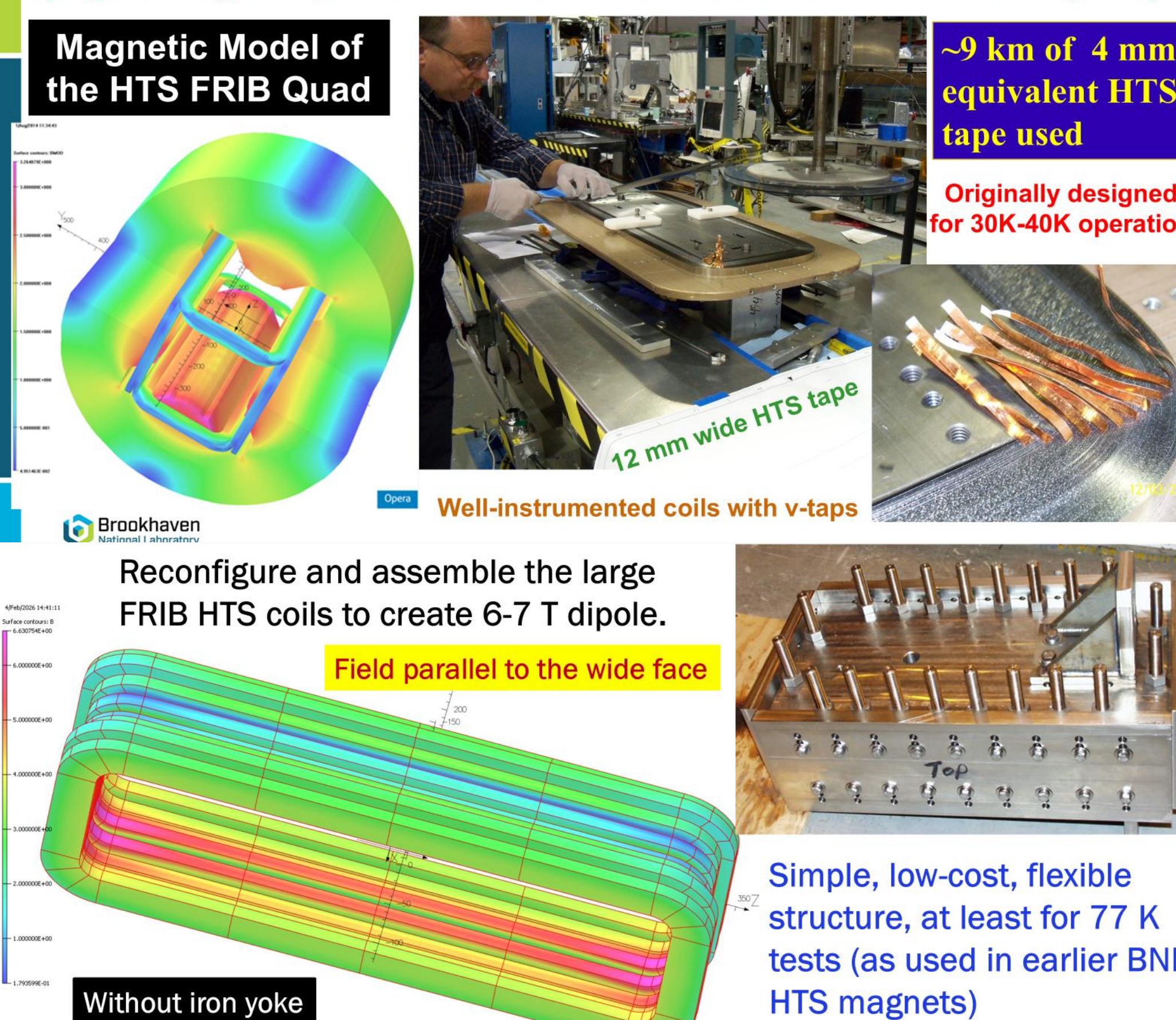


Cryo-cooler based fast-turn around bolted cryostat
Easy to install HTS coils; Evening on => Morning test



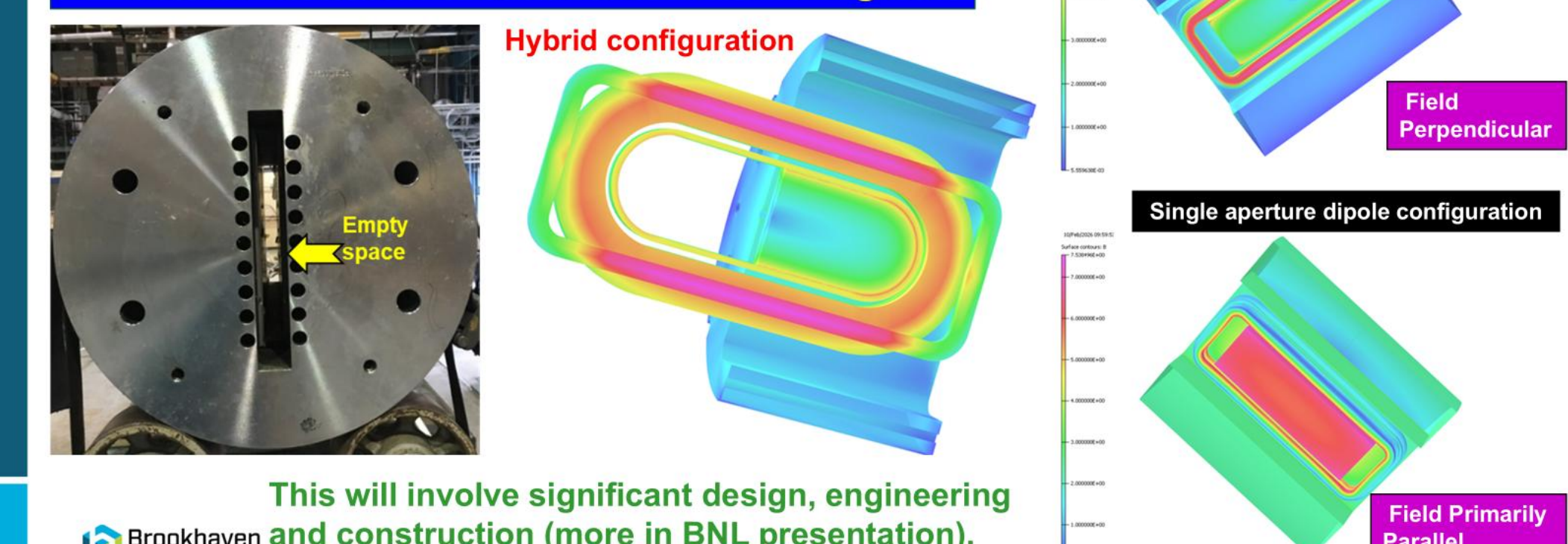
HTS Magnet with Large Coils

HTS R&D Program Leveraging Existing Hardware (eight large expensive HTS coils made for FRIB R&D quad)

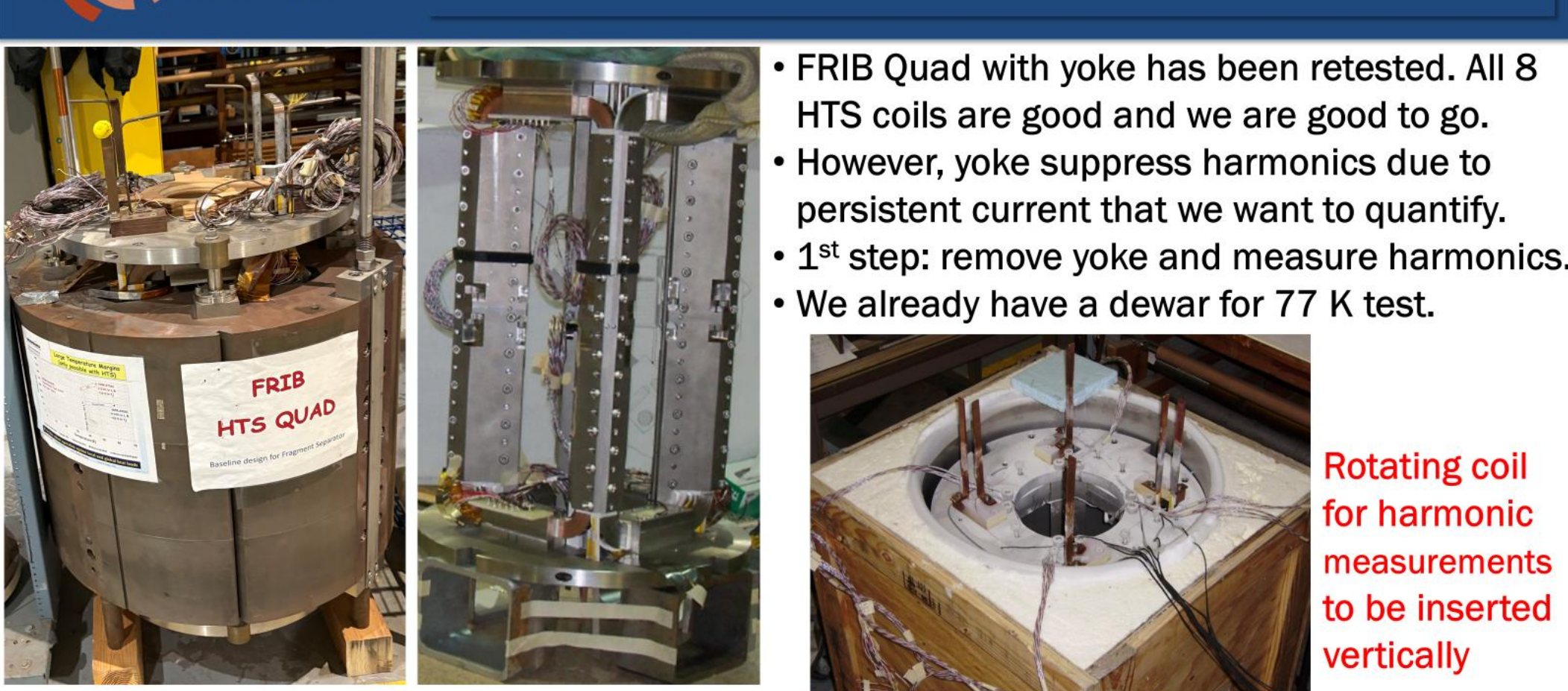


HTS/LTS Hybrid and All HTS Dipoles with Large HTS Coils (FY27-FY29)

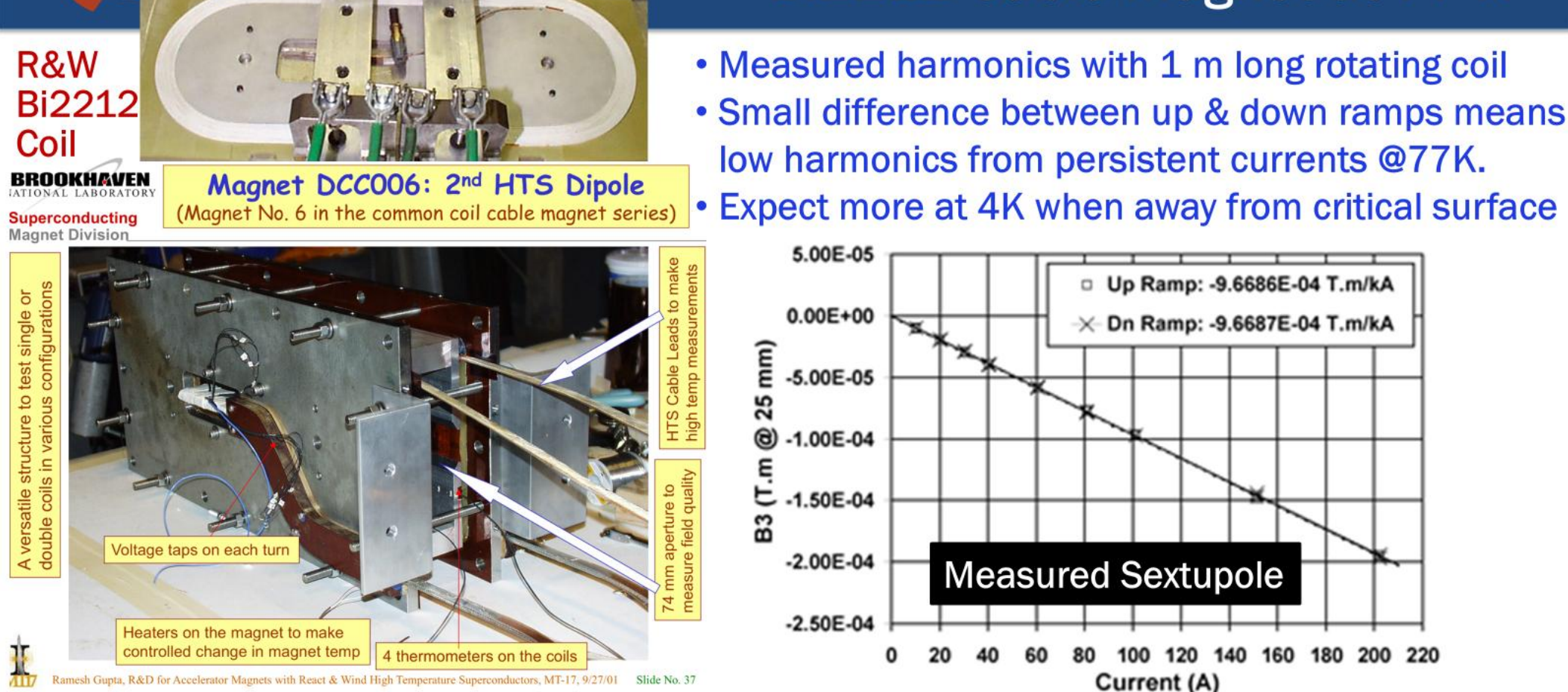
- ❖ ~14 T HTS/LTS Hybrid configuration
- ❖ ~7 T all HTS dipoles with large coils
- High temperature operation to be performed
- Cold electronics to be tested in real magnets



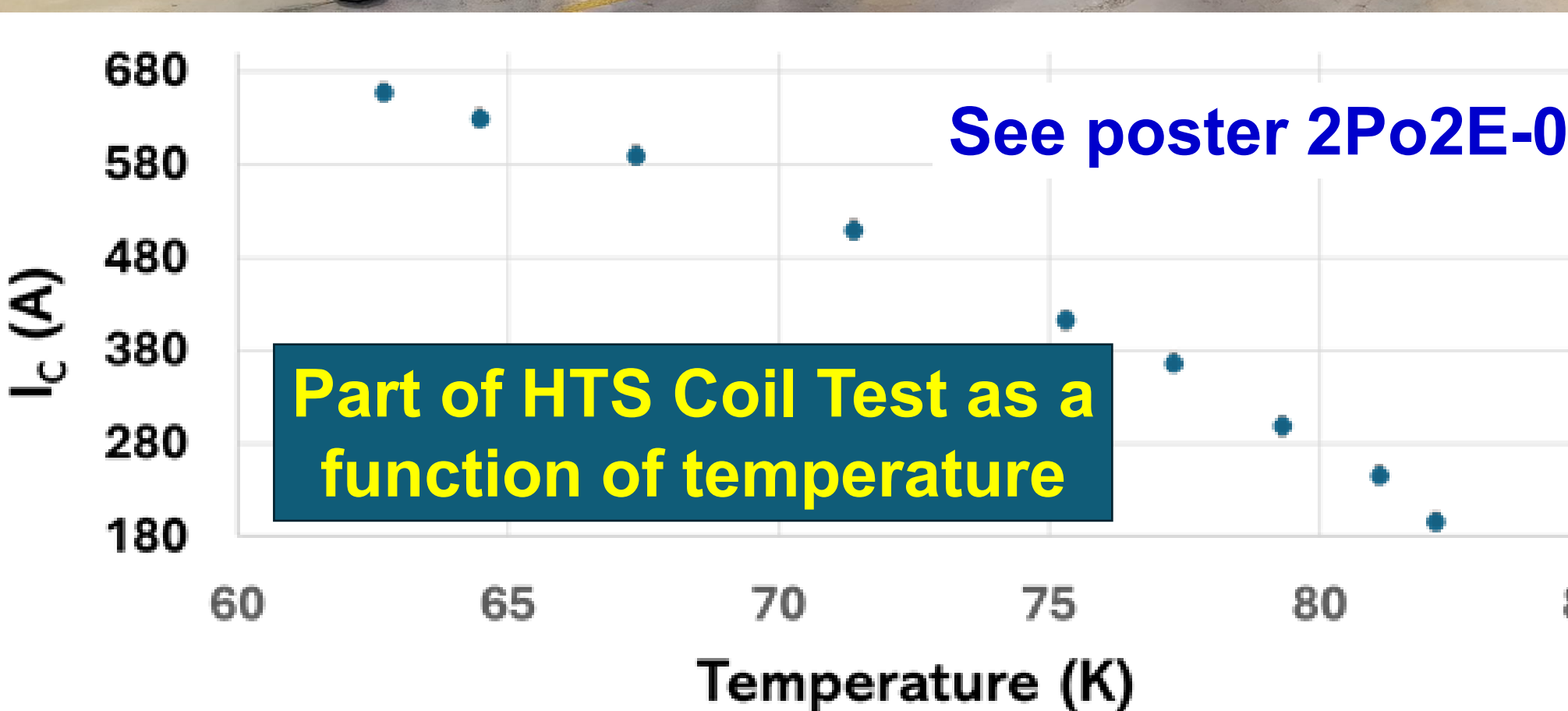
Field Harmonics Measurements in Large FRIB HTS Coils



Harmonic Measurements in Bi2212 Cable Magnet at 77 K



Recent and Upcoming Tests

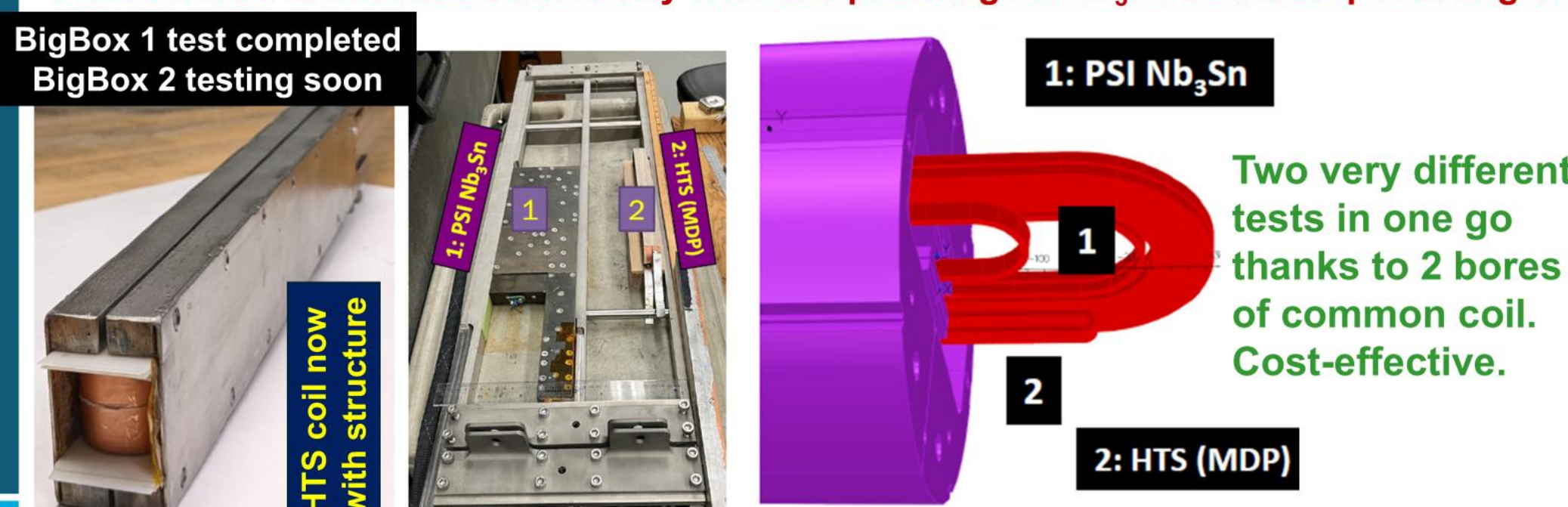


Upcoming PSI and BNL Tests at CCTF (FY27)

- PSI: Wax impregnated Nb₃Sn coil to study improvement in training performance
- BNL: HTS coil to study magnetization and to reach higher HTS/LTS hybrid field

No structure around HTS coil in the HTS/LTS hybrid test in 2020 which reached 12.3 T

Performance seems to be limited by HTS coil pinching on Nb₃Sn coil and quenching it.



Summary of the BNL R&D Program

- 7-8 T all HTS dipole with significant volume
 - Take advantage of the existing large HTS coils
- High Field HTS/LTS Magnet R&D Program
 - Unique Common Coil Test Facility for low cost, rapid-turn-around R&D for developing high field technology
- Quench protection of HTS (including cold electronics)
 - A major issue in developing HTS magnet technology
- Field quality measurements in HTS magnets
 - Important for using HTS in accelerator magnets
- Temperature dependent performance of HTS magnets
 - A platform to study the performance of HTS magnets as a function of temperature (field quality, maximum reachable field, quench protection). There is a large interest in reducing cryogenic and operational cost



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