BNL High Field and HTS Magnet Program

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BROOKHAVEN NATIONAL LABORATORY

a passion for discovery

Office of Science
U.S. DEPARTMENT OF ENERGY

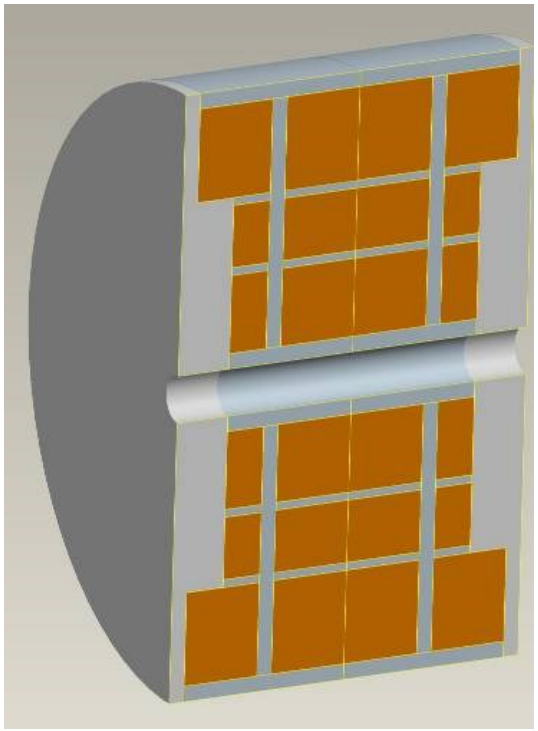
HTS Magnet Program at BNL

- **HTS magnet R&D over a wide range:**
  - **High field, Medium field and low field (high temperature)**
  - **Many geometries – racetrack, cosine theta, solenoid**
- **Number of HTS coils/magnets designed built & tested:**
  - **Well over 100 HTS coils and well over 10 HTS magnets**
- **Type of HTS used:**
  - **Bi2223, Bi2212, ReBCO, MgB_2 – wire, cable, tape**
- **Amount of HTS acquired:**
  - **~50 km (4 mm tape equivalent)**
- **Our recent activities have been largely on magnets with ReBCO**
  - **(yet one Bi2223 and one MgB_2 magnet is ready for testing)**

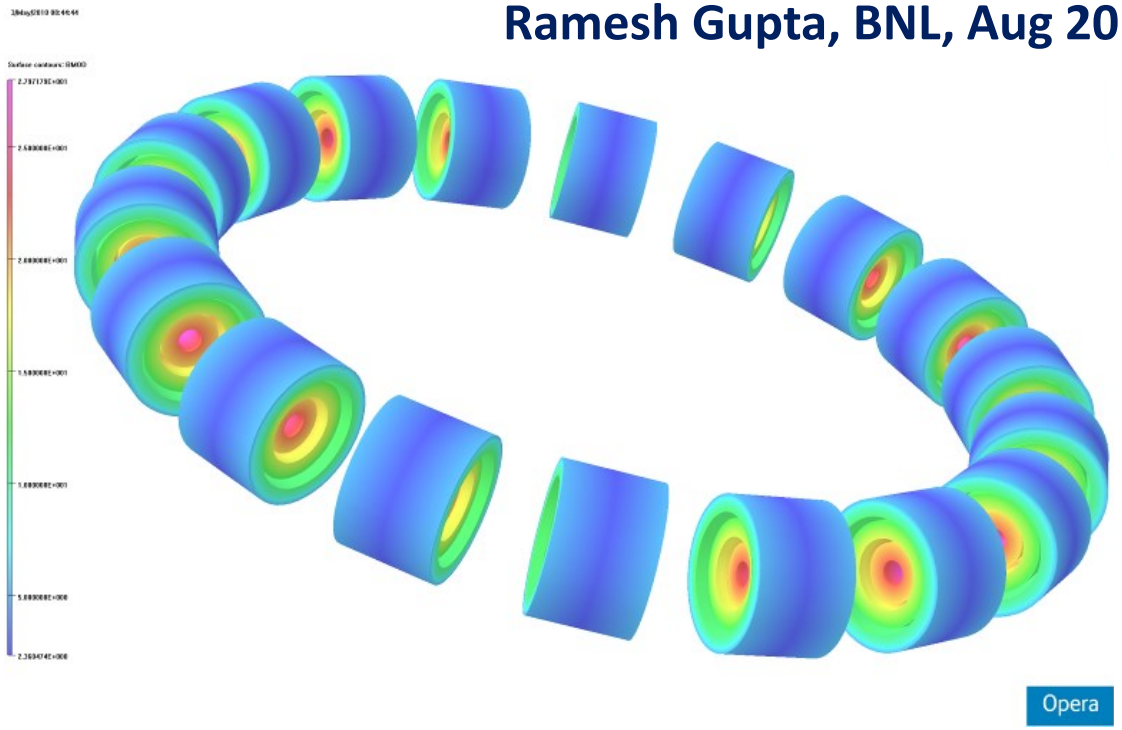
Superconducting Magnetic Energy Storage (SMES)

Key Target Parameters: 25T, 100mm, 1.7MJ, 12mm ReBCO

High field large aperture HTS solenoid with huge stresses



Ramesh Gupta, BNL, Aug 2014



➢ Funded by arpa-e as a "high risk, high reward" project

arpa·e CHANGING WHAT'S POSSIBLE

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ABB

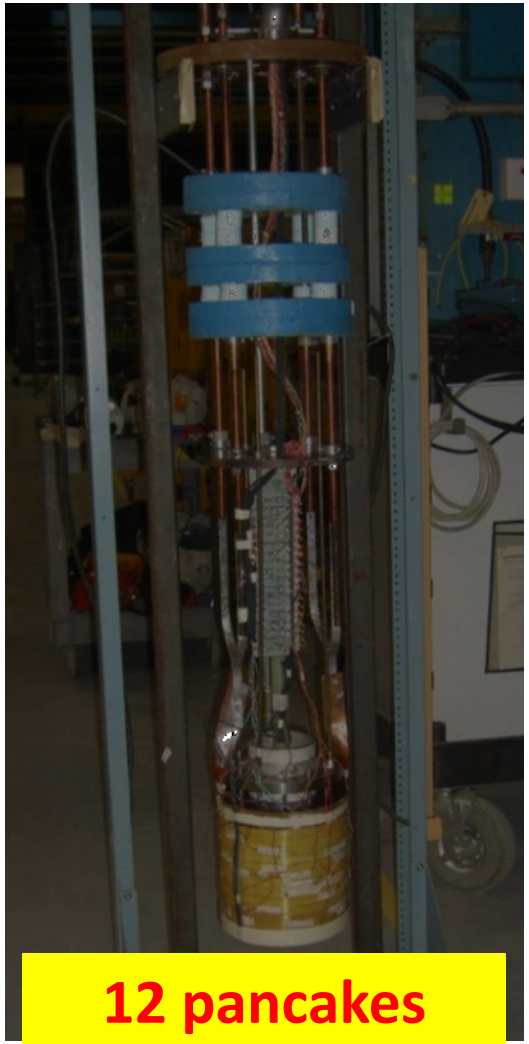
SuperPower Inc.

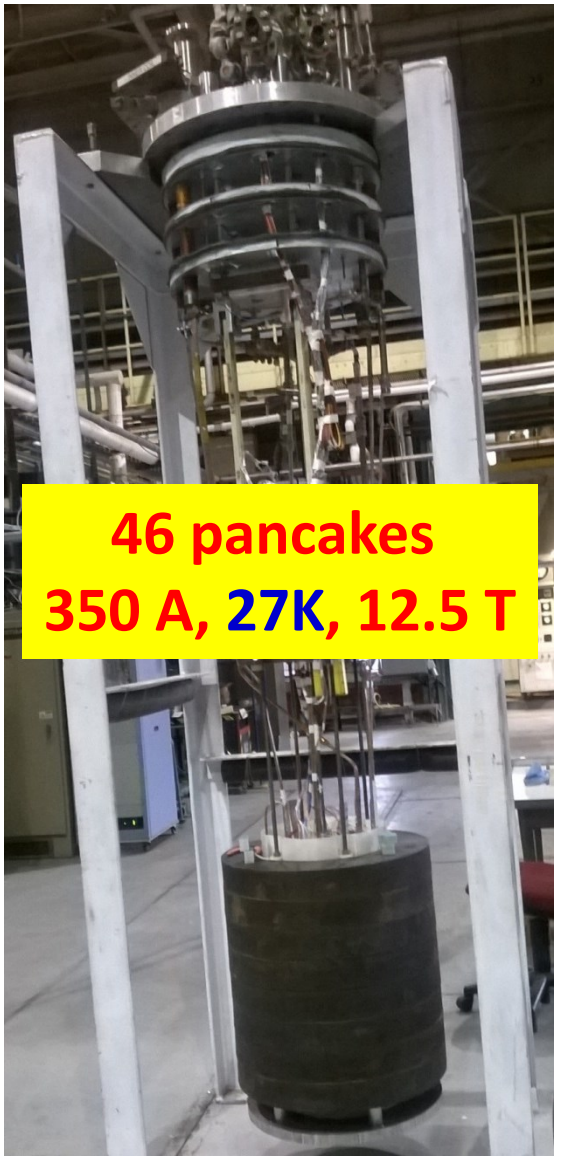
UNIVERSITY of HOUSTON

HTS Magnet Test Results (BNL/ABB/SuperPower/Houston)

100 mm bore ReBCO ARPA- E SMES Coil

R. Gupta, BNL, Aug 2014

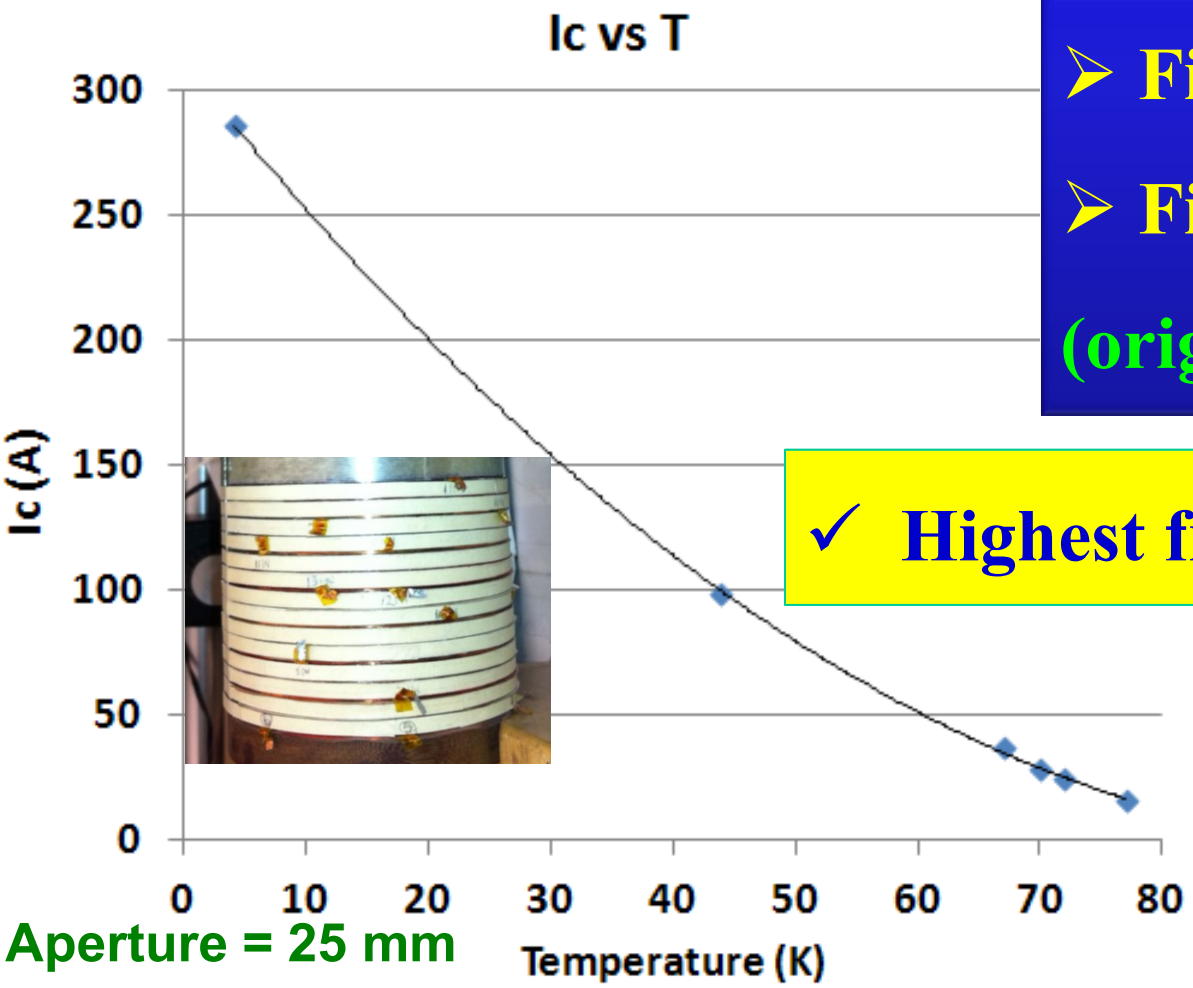




Peak fields higher

arpa·e CHANGING WHAT'S POSSIBLE | BROOKHAVEN NATIONAL LABORATORY | ABB | SuperPower Inc. | UNIVERSITY of HOUSTON

High Field HTS Magnet- PBL/BNL SBIR



Aperture = 25 mm

- Field on axis: 15.7 T
- Field on coil : 16.2 T

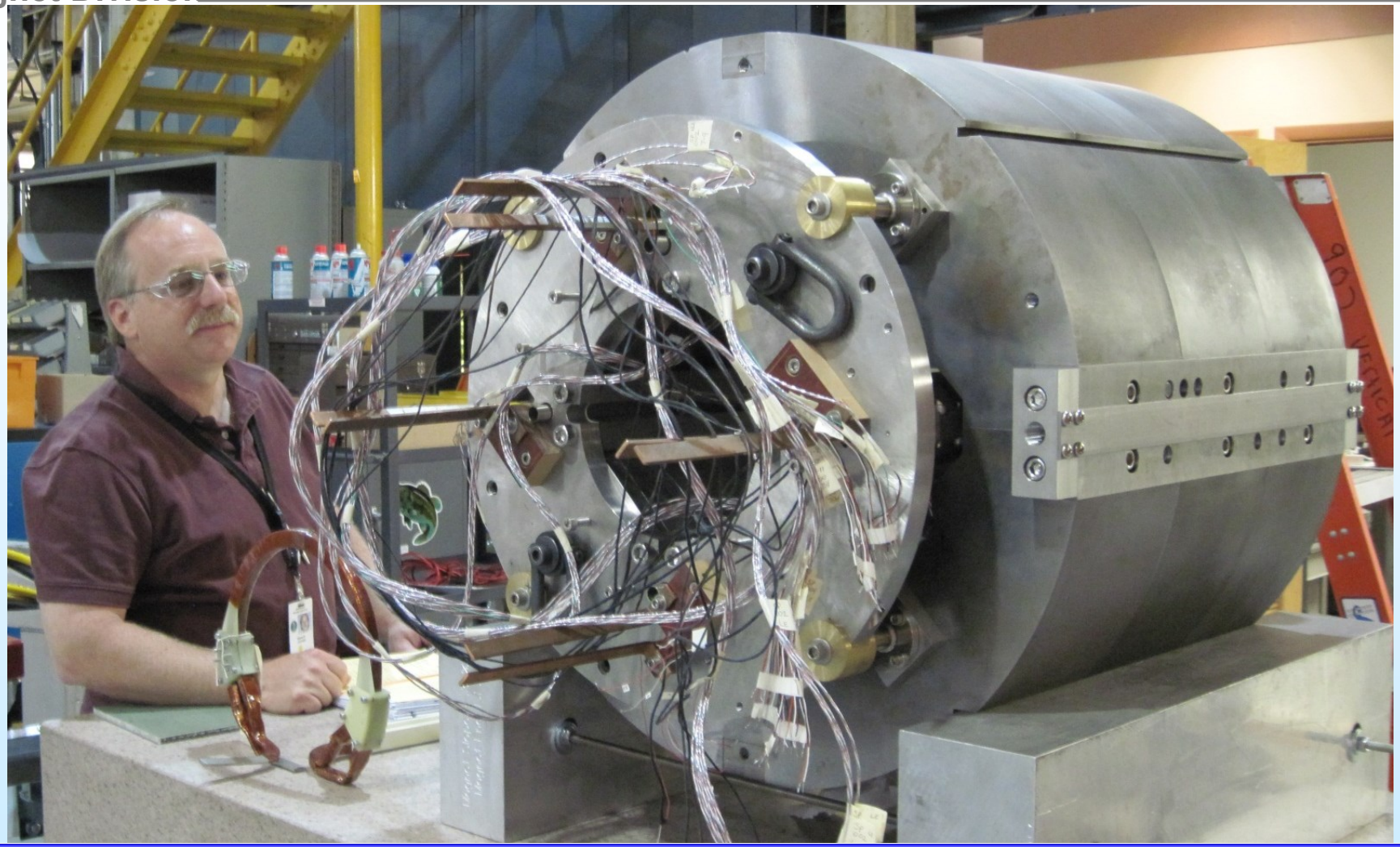
(original target: 10-12T)

✓ Highest field all HTS solenoid

Overall J_o in coil: >500 A/mm^2 @16 T

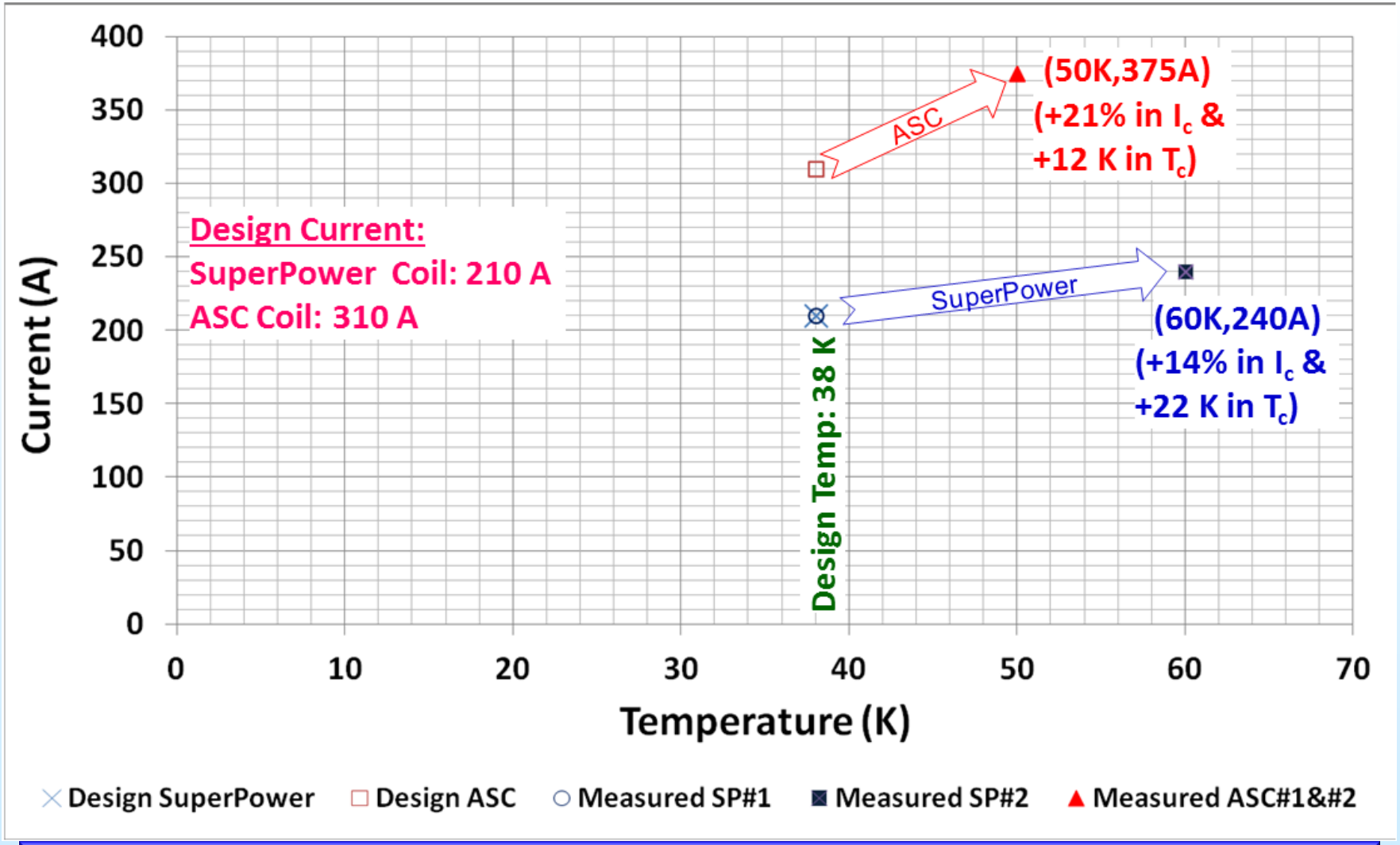
*Credit to SBIR/STTR office for this and SMES work which was the result of this

2G HTS Quad for FRIB Fragment Separator Region



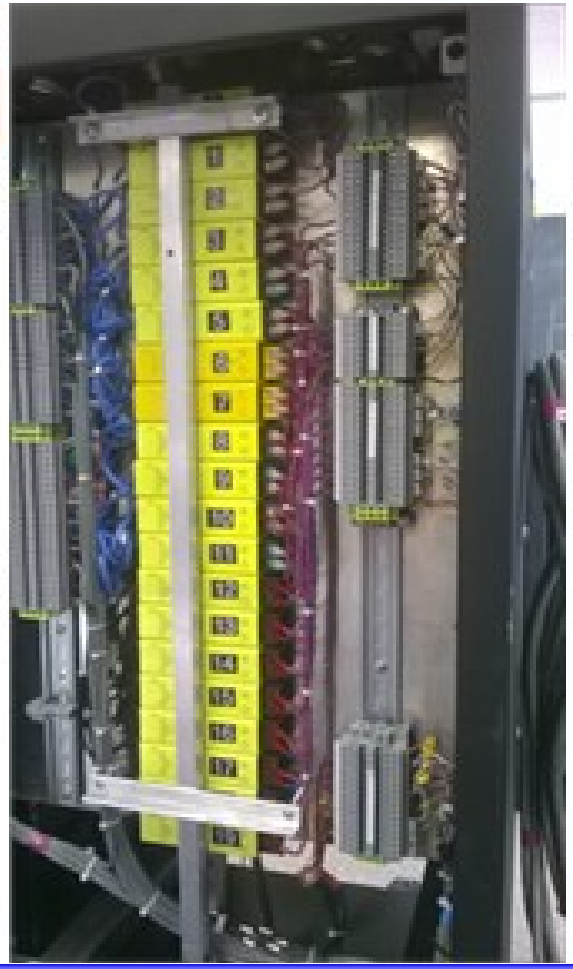
Important: Magnet for a real machine- baseline design of FRIB

Large Temperature Margins (only possible with HTS)



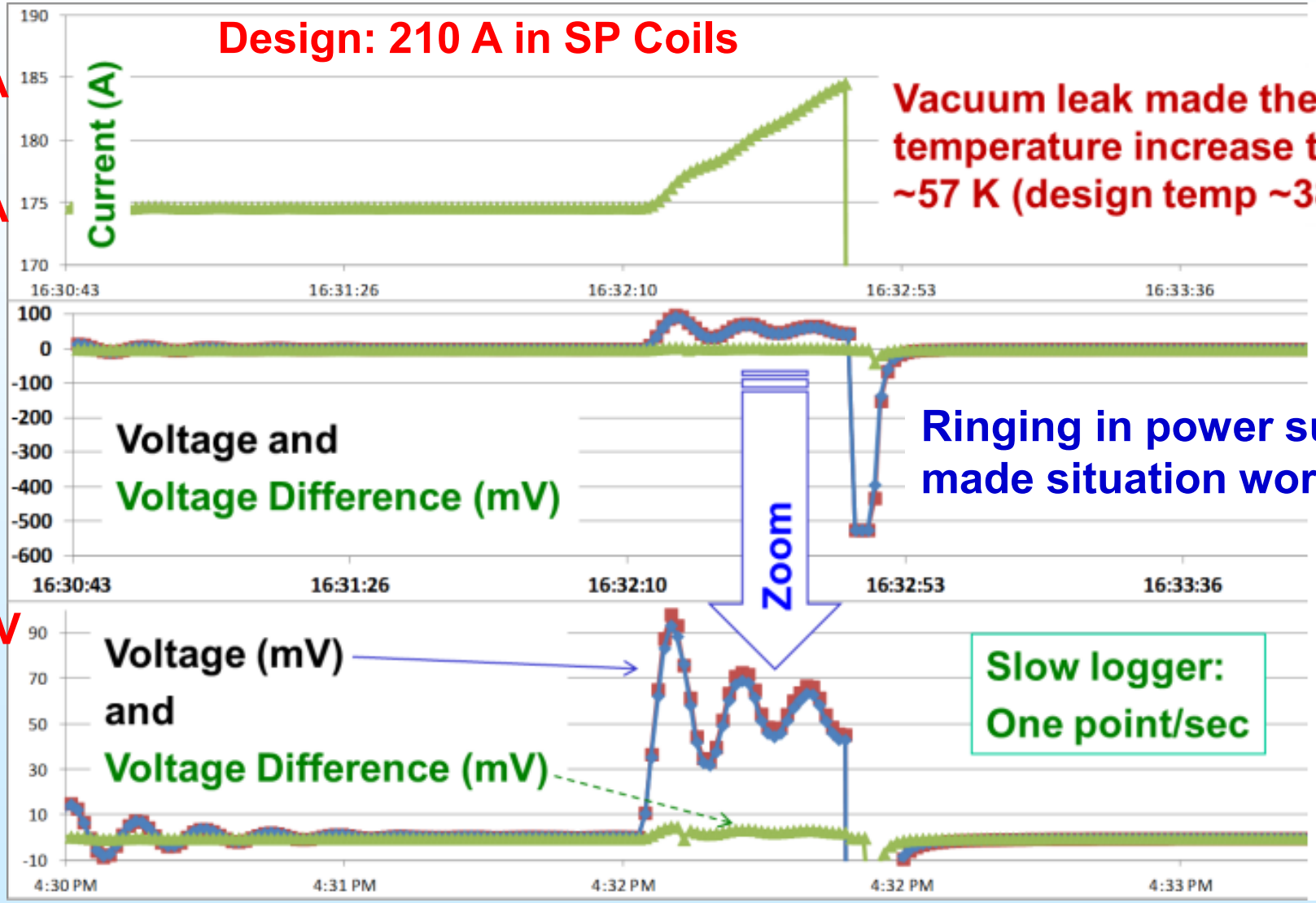
Provides robust operation against local and global heat loads

Advanced Quench Protection Electronics



Detects onset of pre-quench voltage at < 1mV and with isolation voltage > 1kV allows fast energy extraction

Protection of HTS Magnet During an Operational Accident Near Design Current

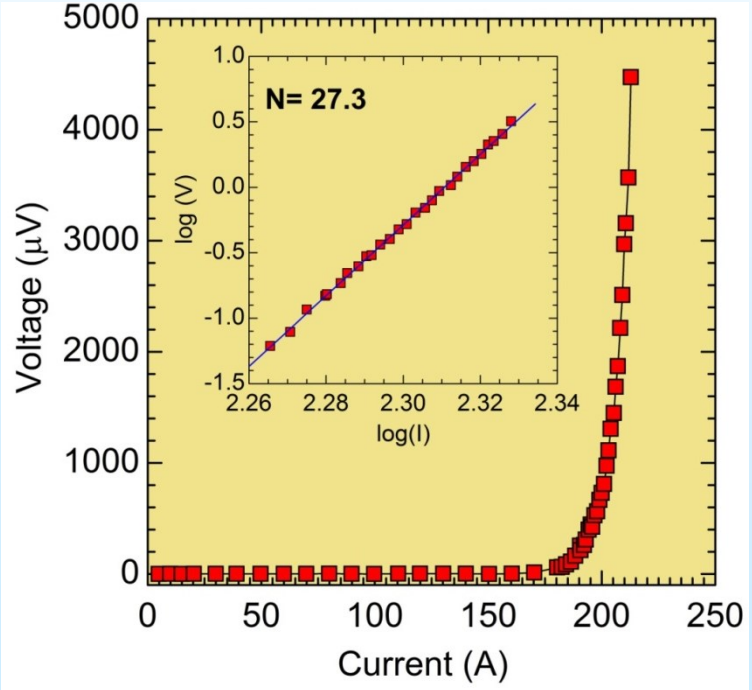


Magnet Designs for FCC

Cos (θ) Coil - PBL/BNL STTR#1 (12 mm, one block, 77 K)

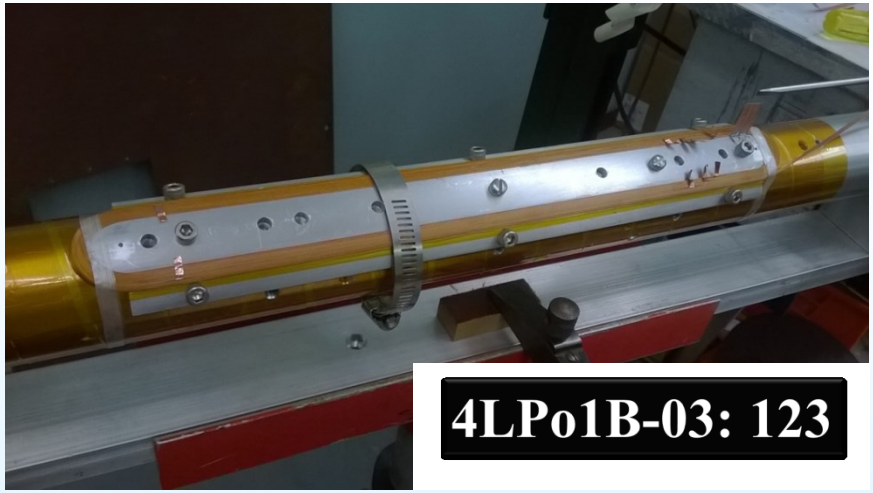
BENEFITS of Kapton-CI:

- No epoxy/adhesive to HTS tape (prone to degradation by epoxy)
- Standard insulation in magnets
- Cured coil can be handled easily
- Makes good coil (including ends)

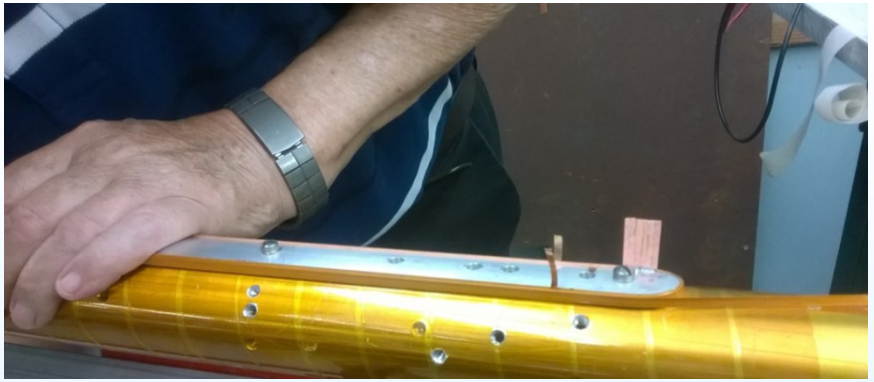


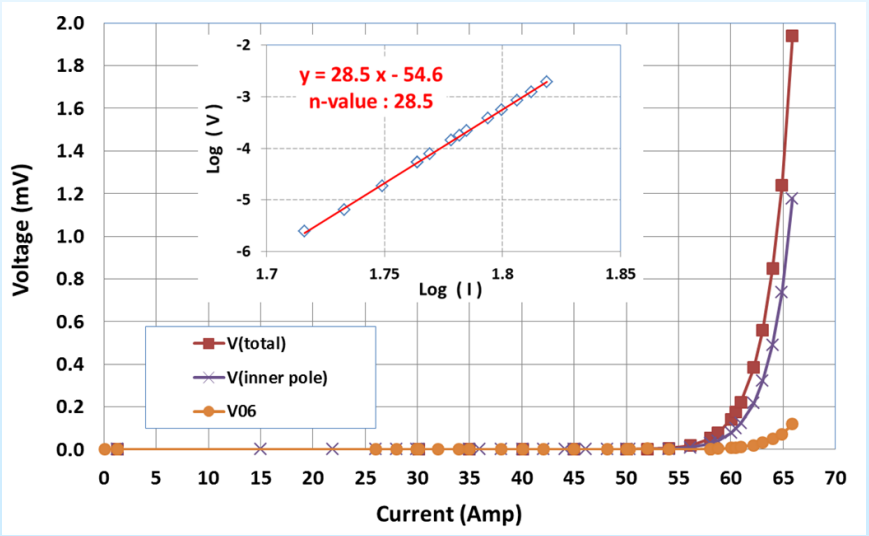
No measurable degradation@77 K

Cos (θ) Coil - PBL/BNL STTR#2 (4 mm, goal: full coil, 4 K test)



4LPo1B-03: 123



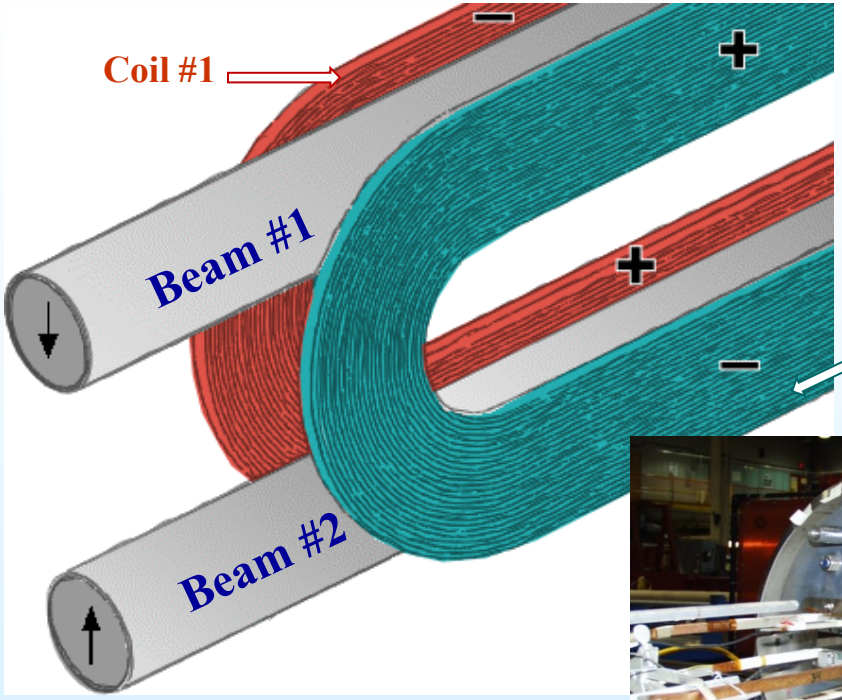


No measurable degradation@77 K

Future Plan (Phase I & Phase II)

- Construction and 4 K test of full cos (θ) coil in next few months
- R&D to develop base technology for accelerator magnets in next few years (includes measuring and finding ways to deal with magnetization)
- Use these magnets in an accelerator in next few decades

High Field 2-in-1 Common Coil Dipole Design for Colliders



Highest field R&W Nb_3Sn dipole

HTS tape common coil dipole

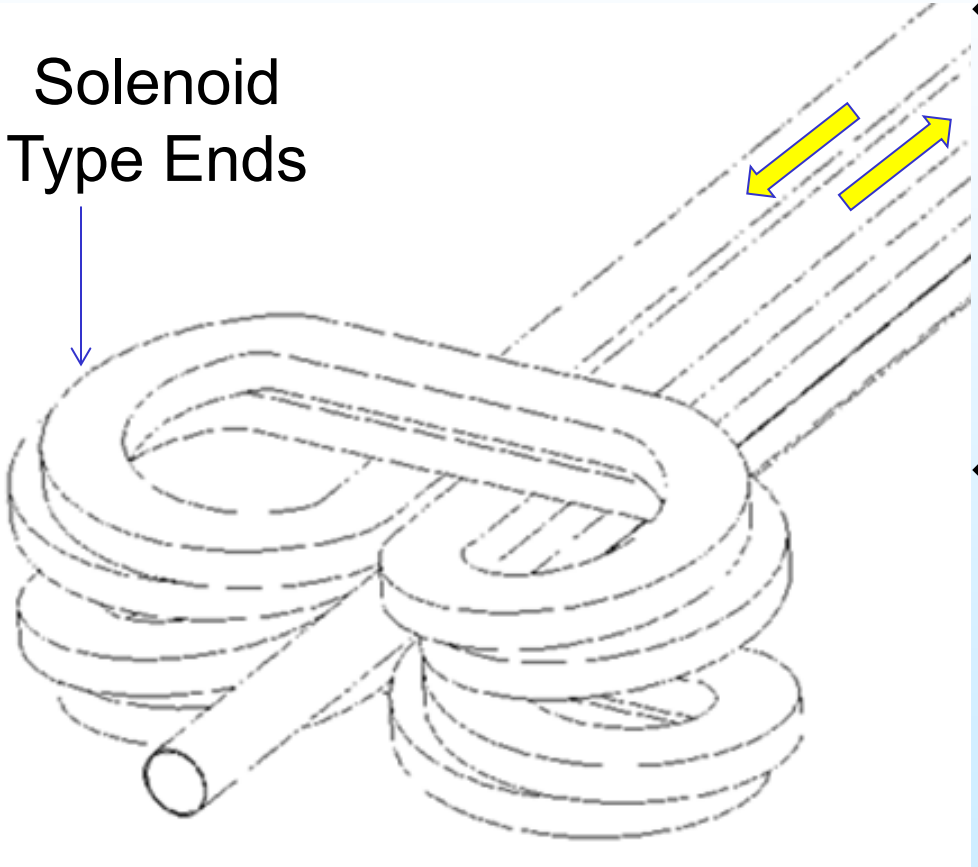
A conductor friendly design

- ✓ Suitable for HTS coils – Roebel cable
- ▪ Unfavorable orientation w.r.t. field
  - ○ However, think long term. Will Ic remain so anisotropic forever?

Used in Chinese Proposal

A Coil Design with Overpass/Underpass Ends Optimized for ReBCO Tape

R. Gupta, et al., "Next Generation IR Magnets for Hadron Colliders," ASC2002

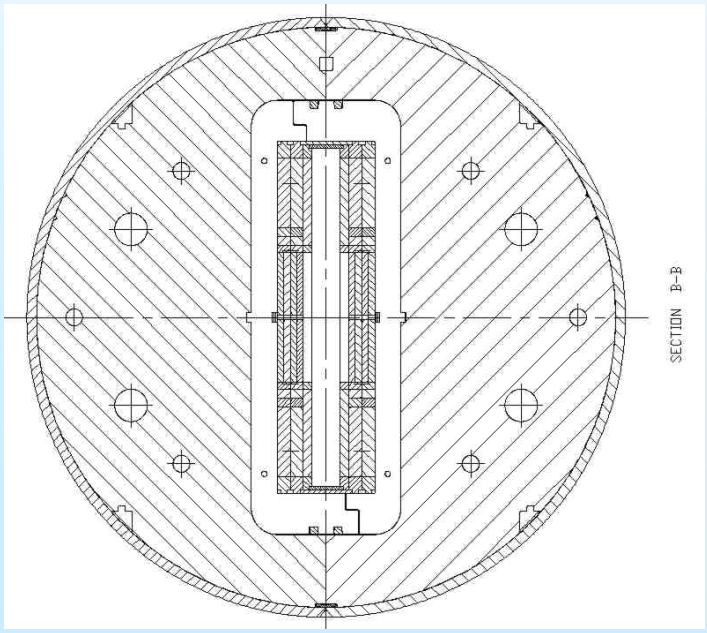


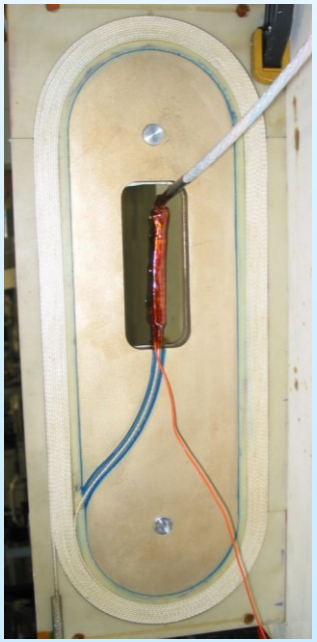
- **No need for lifting the ends and no reverse curvature**
  - **Less strain on the conductor but winding more complicated**
- **Align ReBCO tape parallel to the field for**
  - **Higher Jc**
  - **Lower magnetization (will depend on the thickness and not on the width)**

Magnet R&D for FCC

Common Coil Dipole at BNL for Testing HTS Insert Coils as in a Hybrid Magnet

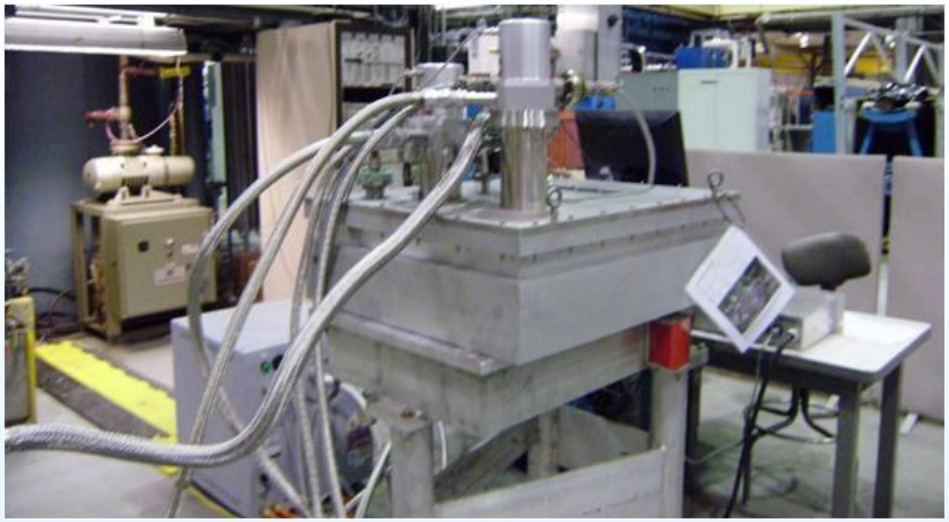
- BNL has a unique 10^+ T Nb_3Sn common coil dipole with large open space to test HTS coils in background field.
- Provides fast turn around plus economic and systematic R&D as no disassembly/assembly of the magnet is required
- HTS coil become a part of the hybrid magnet test (~15 T)





High current 2212 coil

A Warm bore Cryo-cooled Magnet with 6 HTS coils



Evening: Switch ON; Morning: COLD

Suitable for various studies

- Quench studies
- Measure magnetization induced harmonics
  - as a function of time
  - as a function of temperature
  - as a function of field

BNL has about 50 HTS coils available for various studies; about 30 with ~100 meters of HTS

- **Consider utilizing this asset**

Summary

- Yet a long way to go before HTS magnets can be used in HEP accelerators, HTS magnet technology has made a major progress over last decade. (I'm personally optimistic).
- BNL has been active on developing HTS magnet technology and has made many significant demonstrations. BNL is looking forward to offer its unique and substantial experience to future HTS magnet R&D for FCC.
- However, we are more than 

(of which I'm proud of). We also have active programs on LTS magnets (our bread-and-butter), and are the one US facility with working superconducting accelerator magnets.