BNL Capabilities for Supporting Fusion R&D

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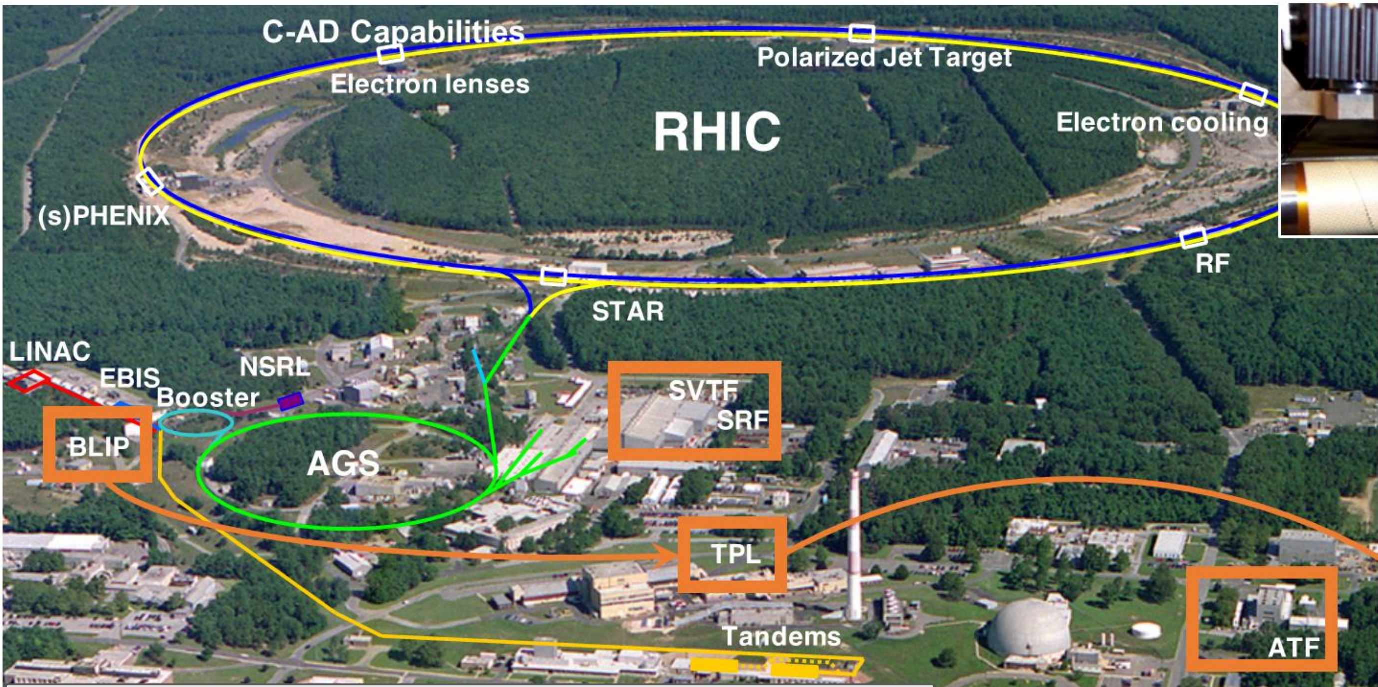
BROOKHAVEN NATIONAL LABORATORY

a passion for discovery

Office of Science
U.S. DEPARTMENT OF ENERGY

Unique BNL Capabilities for Fusion R&D



The breadth of expertise and capabilities available at BNL offer unique opportunities

Unique Superconducting Magnet Experience

Tech transfer to industry for building magnets for superconducting collider (~3.8 km) and leader in developing HTS magnet technology

Unique Materials Irradiation & Analysis Capabilities

Utilizes a unique combination of facilities: BLIP ⇨ TPL ⇨ NSLS-II
Capabilities that benefit HEP, BES, NP, FES, NE

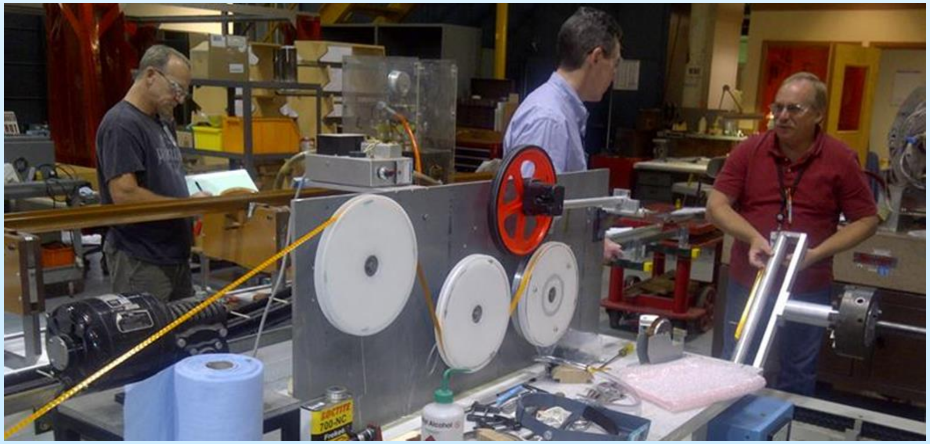
Working with Industrial Partners

- Superconducting magnets were developed at the laboratory and built in the industry with a successful tech transfer
- Magnets are working reliably with no failure in two decades
- Core team of engineers, technicians and scientists still available

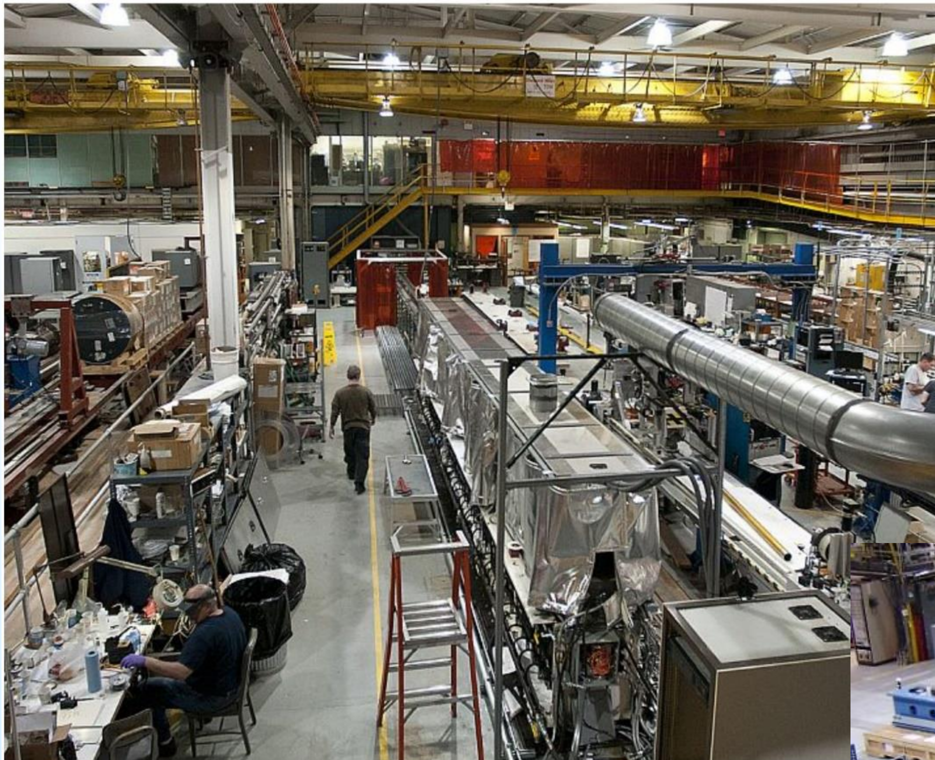
A Pictorial Tour of Superconducting Magnet Division

Coil Winding Machines

Semiautomatic coil winding with 10 m coil. The spool of cable used in the coil winding is in the foreground.



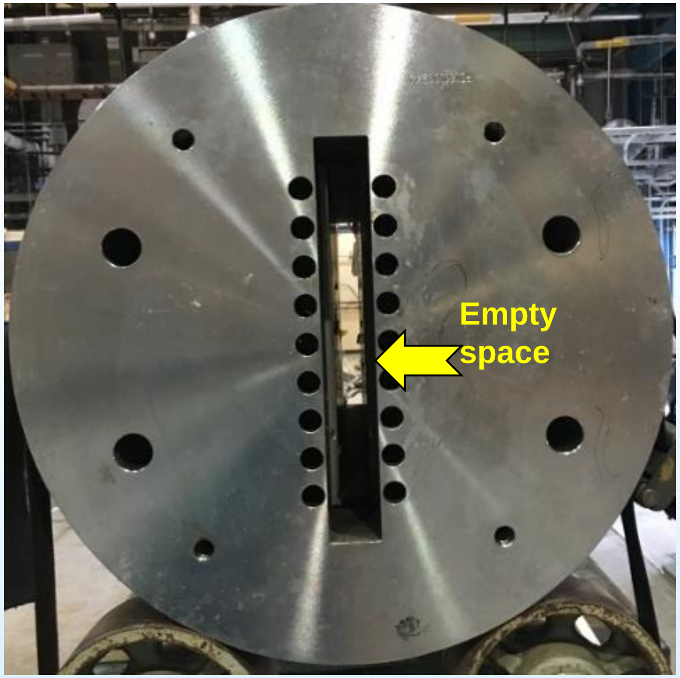
Coil Curing and Coil Reaction Furnace

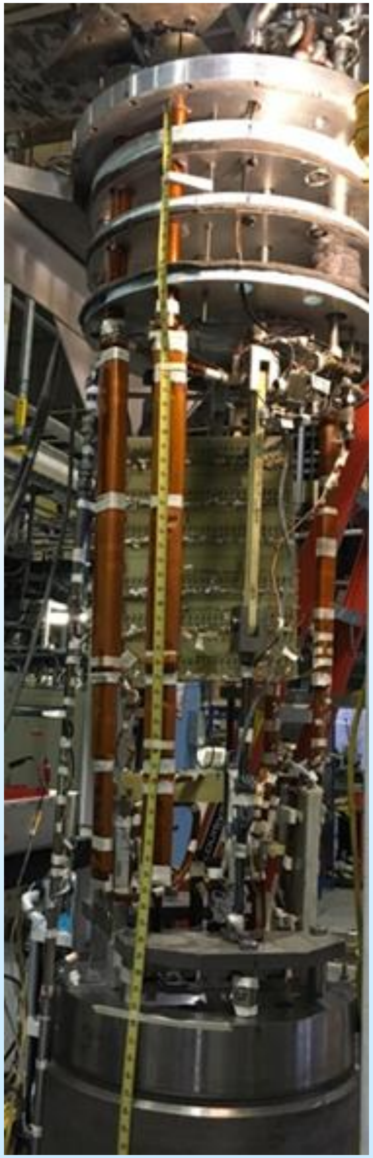


The coil, inserted in the form block, is heated electrically to set the epoxy that fixes the coil size. Heating is done inside an array of heavy cu
(foreground) that minimizes heat loss.

A Few Slides on Test Facilities

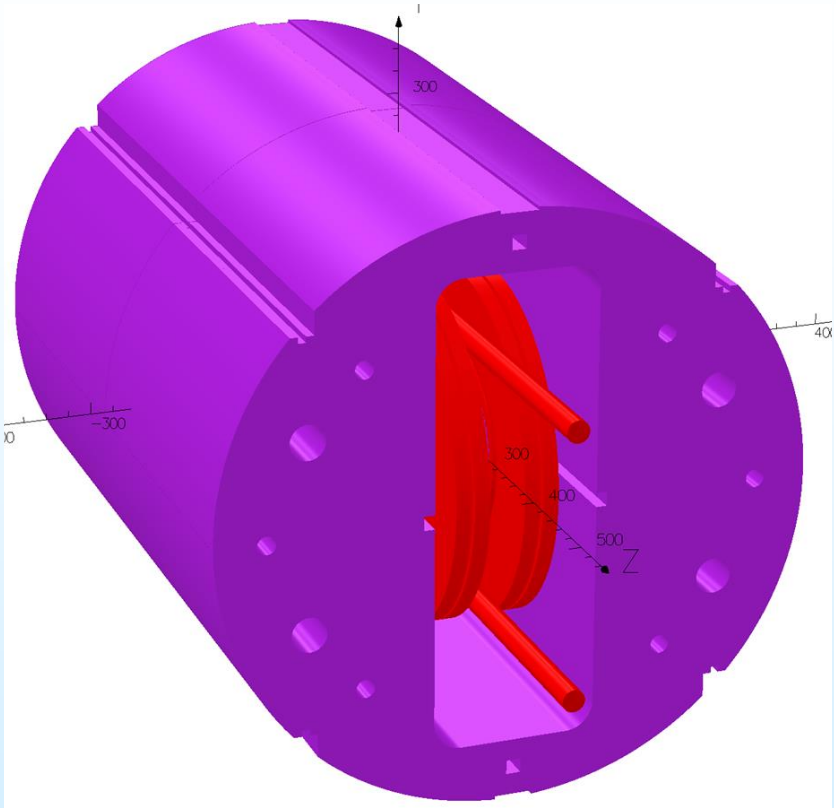
A Unique Test Facility for Fusion R&D

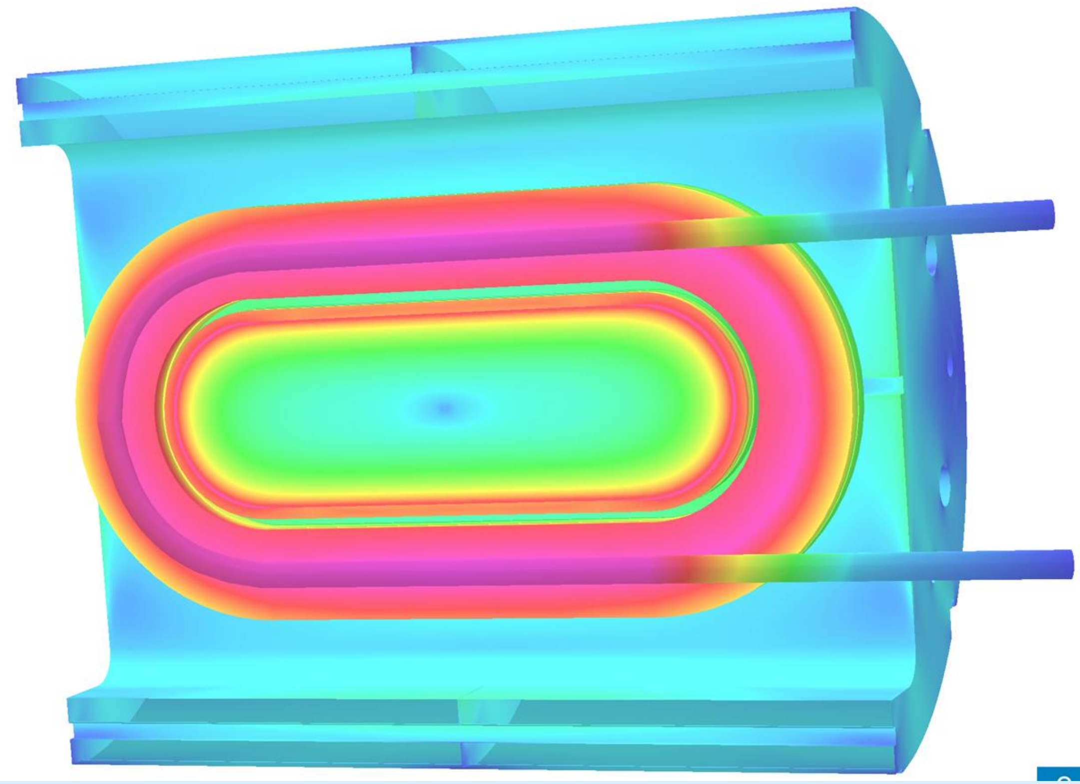




- A Nb_3Sn dipole providing a background field up to 10 T
- Large open space: 31 mm wide and 335 mm high
- Cable with large bend radius can be easily accommodated
- Cable can be looped inside the high field region for a long length in-field test
- To be used in the CFS INFUSE HTS cable quench studies

Model of Cable Test in 10 T Background Field Magnet





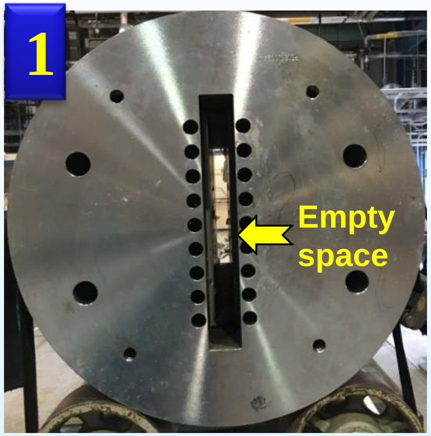
Cable can be bent in a large bending diameter

(~140 mm to ~300 mm) and stays in a high field region

Rapid turn-around, Low-cost Tests of R&D HTS Coils (total field: ~15 T)

Five Simple Steps/Components

1



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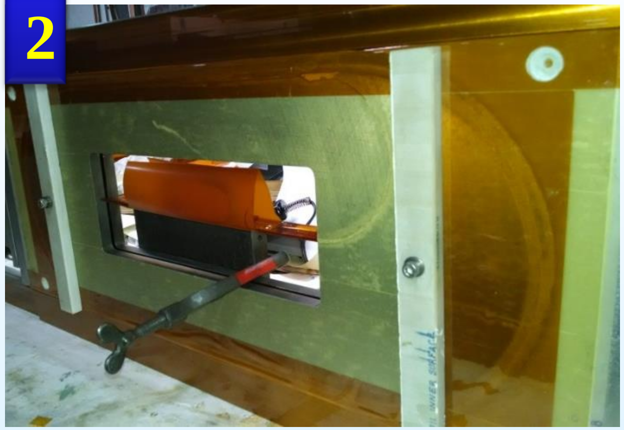
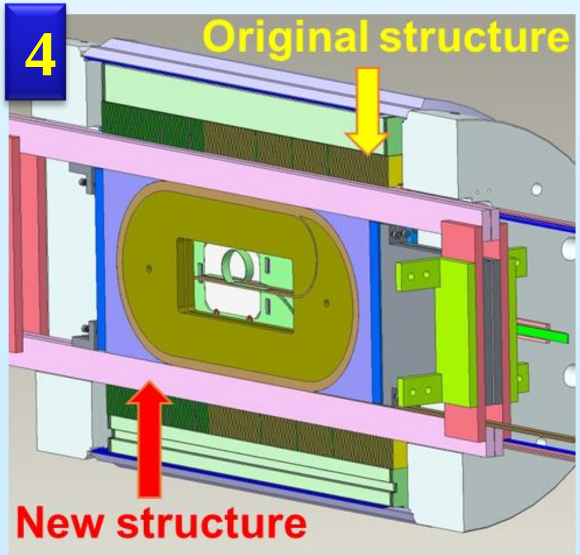


1. Magnet (dipole) with a large open space
2. Coil for high field testing
3. Slide coil in the magnet
4. Coils become an integral part of the magnet
5. Magnet with new coil(s) ready for testing

3

4



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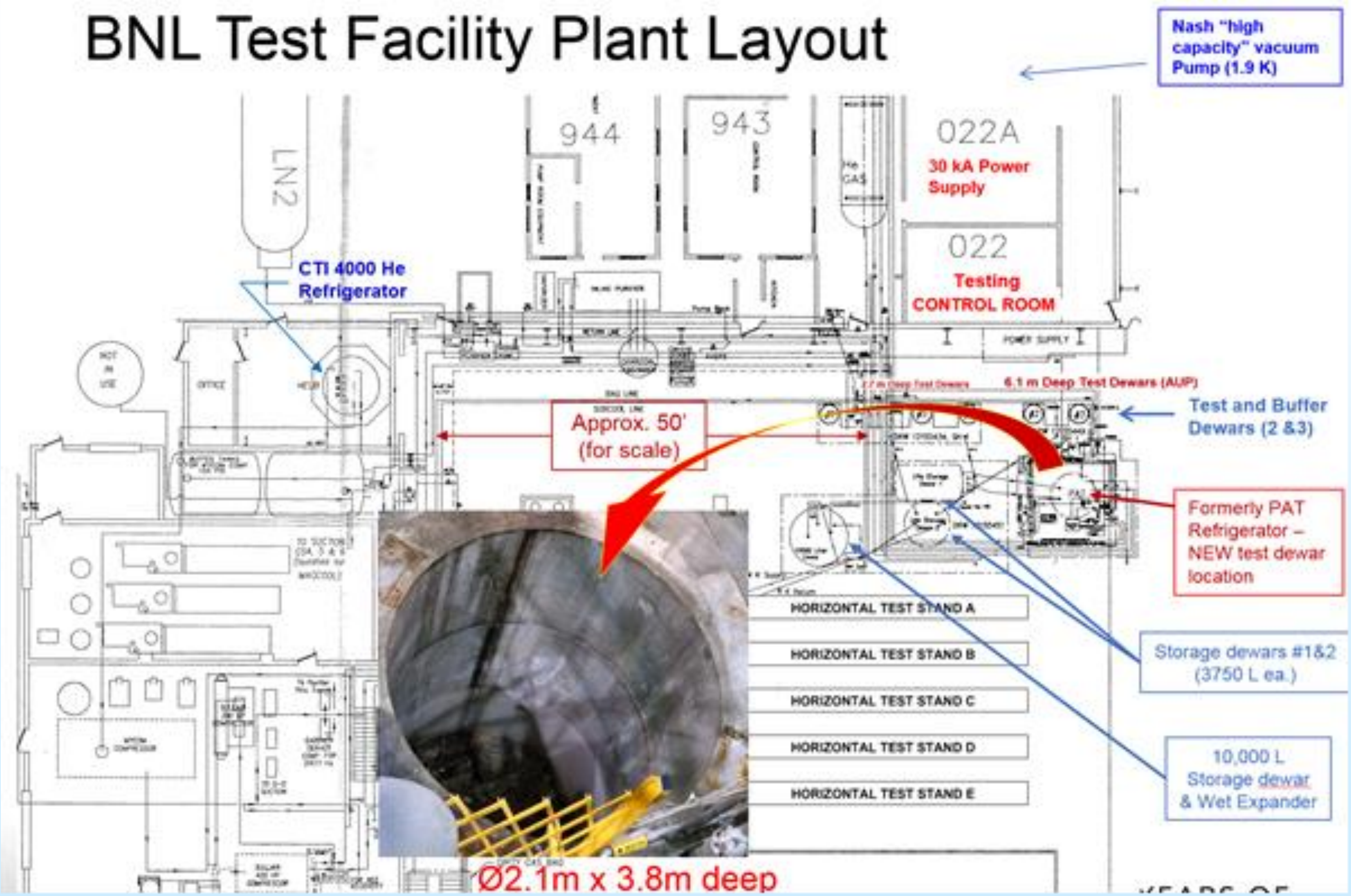
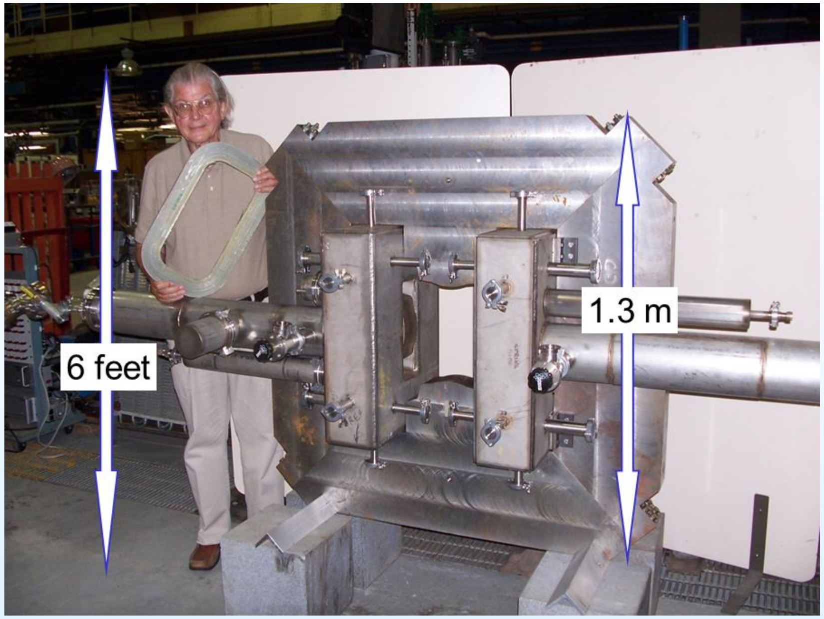
Six Dewar at Vertical Test Facility (up to 4.5 m, 1.9 K)

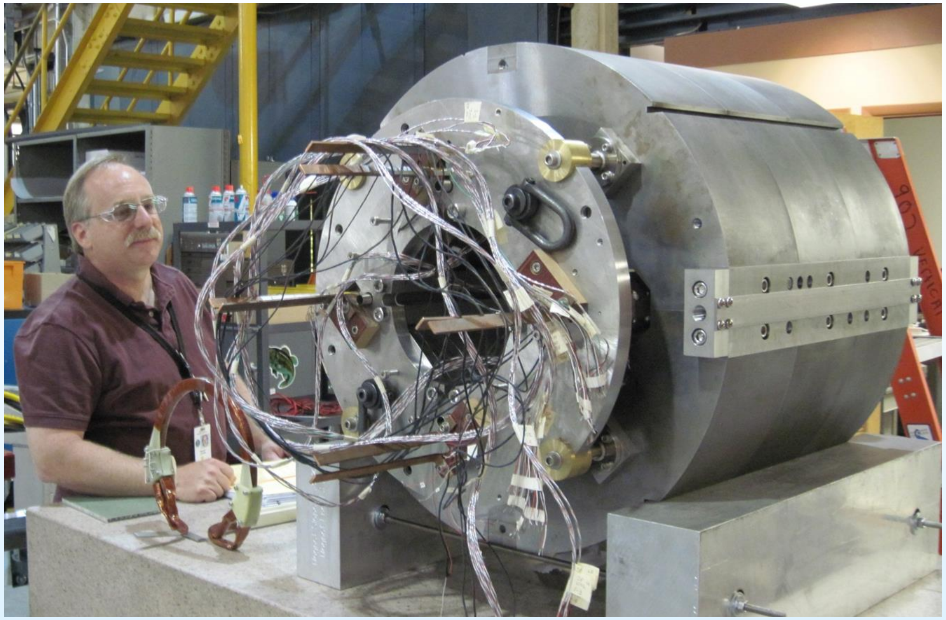
A 2.1m diameter x 3.8m deep pit (a future test-stand to share)

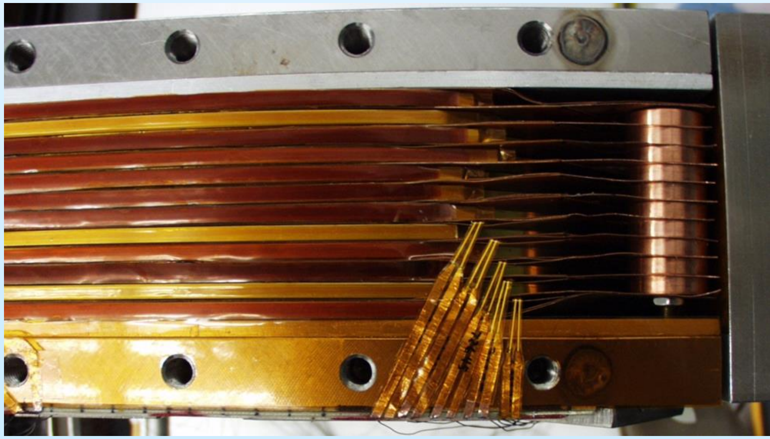


Unique Experience and Capabilities with the HTS Magnet Technology

HTS Magnet Technology for High Radiation and Large Heat Loads



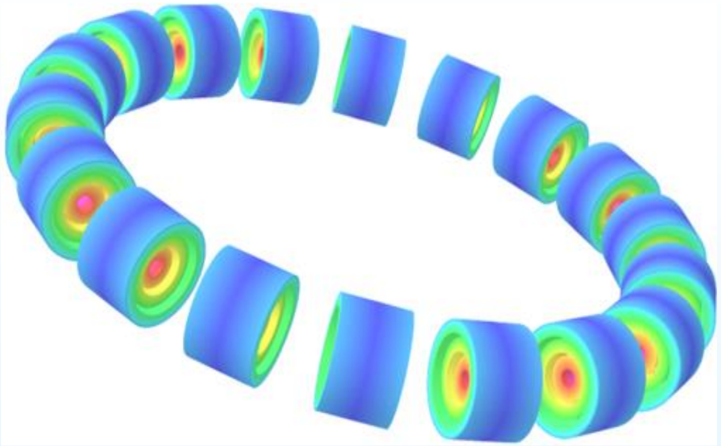




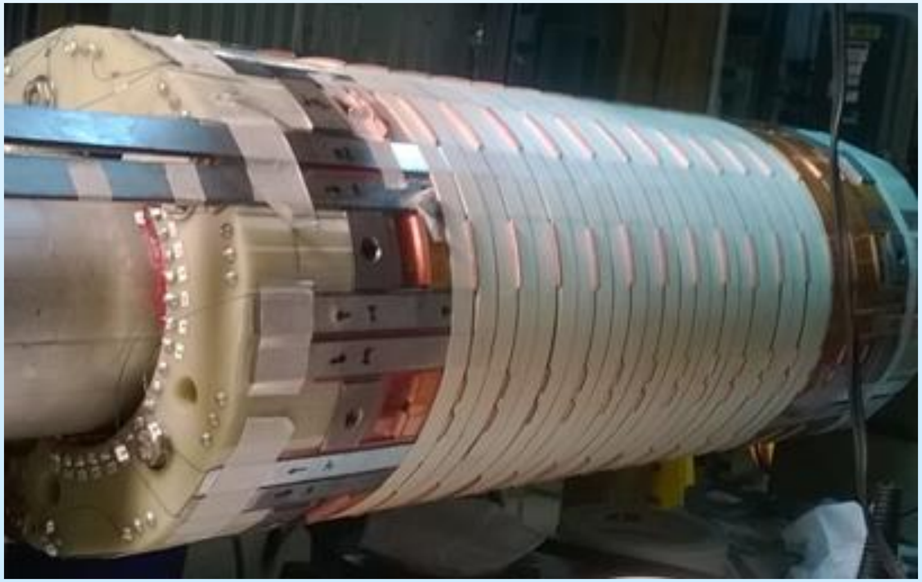
Radiation : ~10 MGy/year

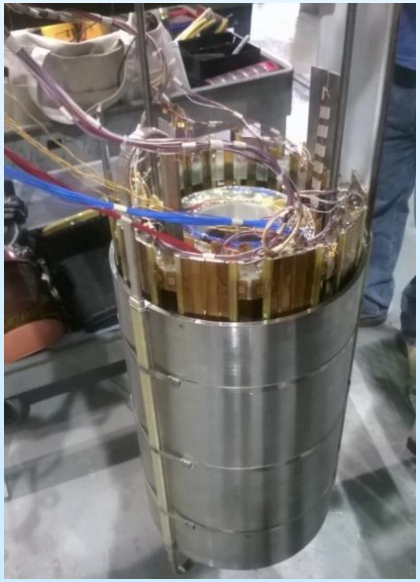
Large heat load environment. Stable operation with 5kW/m^3 at ~30 K

Record HTS SMES Performance (12.5 T at 27 K in 100 mm aperture)



- High risk, high reward - funded by arpa-e
- HTS: >6 km, 12 mm wide from SuperPower
- Design field : 25 T at 4 K (12.5 T at 27 K)
- Design Hoop Stresses: 400 MPa
- Run terminated after 27 K test because of the arcing in the leads (HTS coils ok)
- ✓ These results (12.5 T at 27 K) may be relevant to HTS magnet R&D for fusion





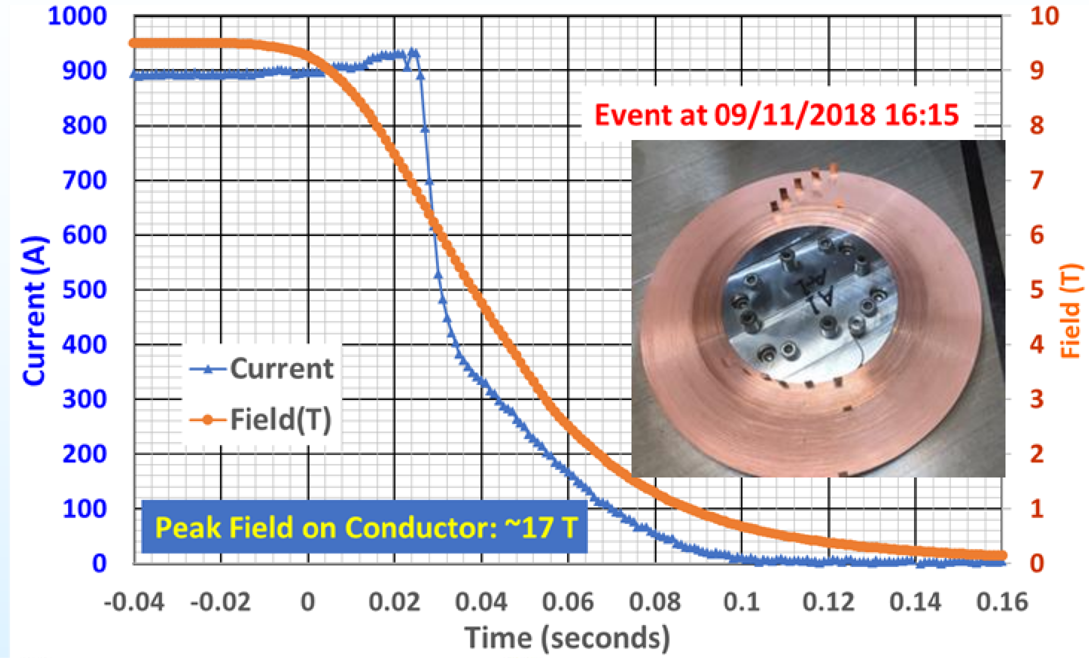
No-Insulation Coil Technology @4K for High Field and Large Aperture

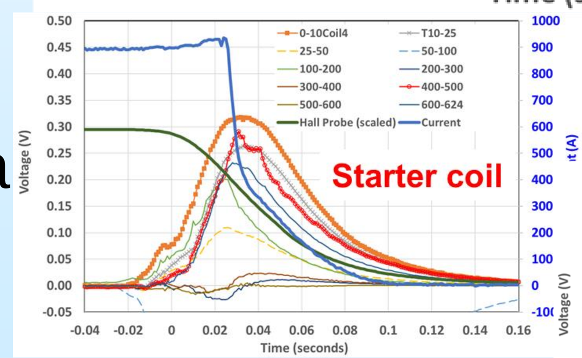
Magnet Design

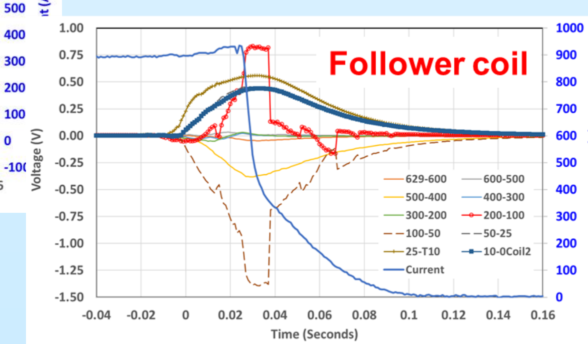
- 105 mm, 25 T design
- Hoop stresses ~480 MPa
- Conductor: SuperPower ~6 km, 12 mm

Quench Test @4 K

- Peak field: 17 T, double pancake
- Hoop stresses ~400 MPa
- Several quenches
- Accident scenarios tested







Advanced Quench Protection Electronics



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

Materials Irradiation & Analysis Capabilities

Utilizes a unique combination of facilities: BLIP ⇨ TPL ⇨ NSLS-II

BLIP: Brookhaven Linac Isotope Producer
TPL: Target Processing Laboratory
NSLS II: National Synchrotron Light Source II

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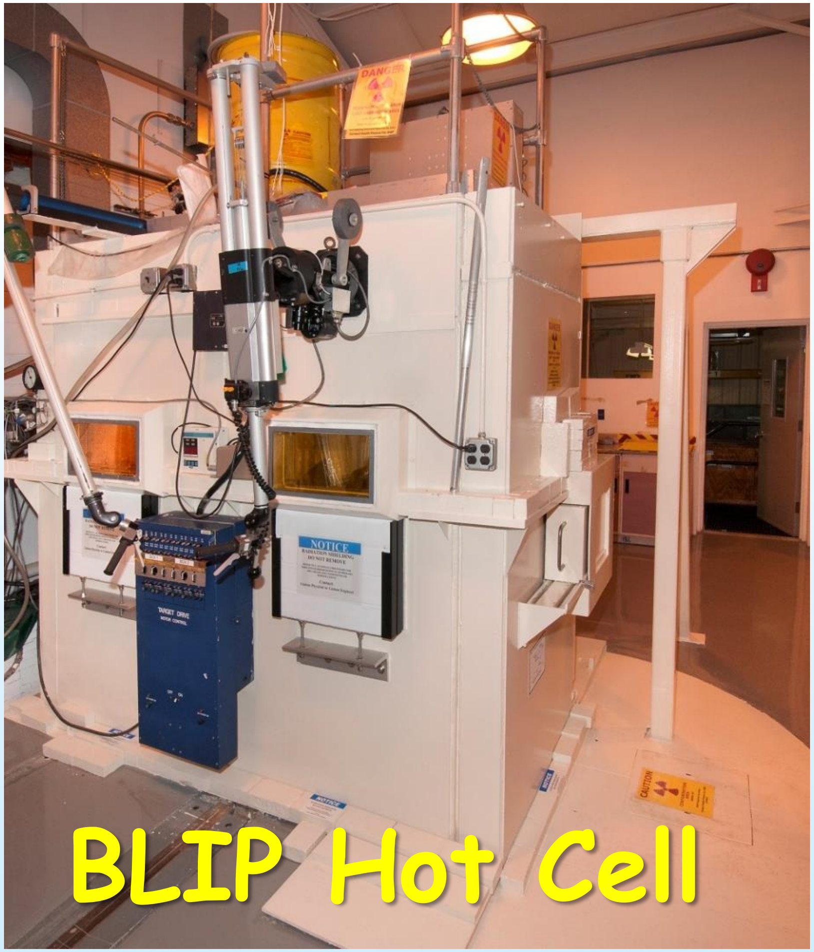
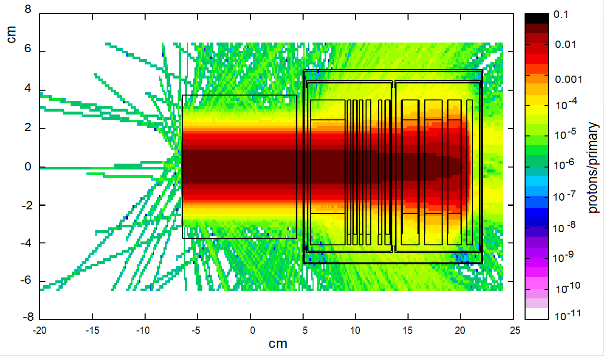
Irradiation Facilities at BNL BLIP and NSLS-II

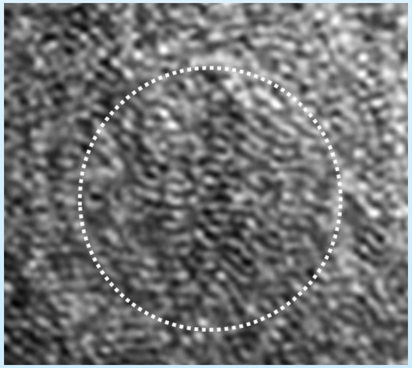


BLIP uses 145 µA proton beams of up to 200 MeV

NSLS-II is a state-of-the-art 3 GeV electron storage ring



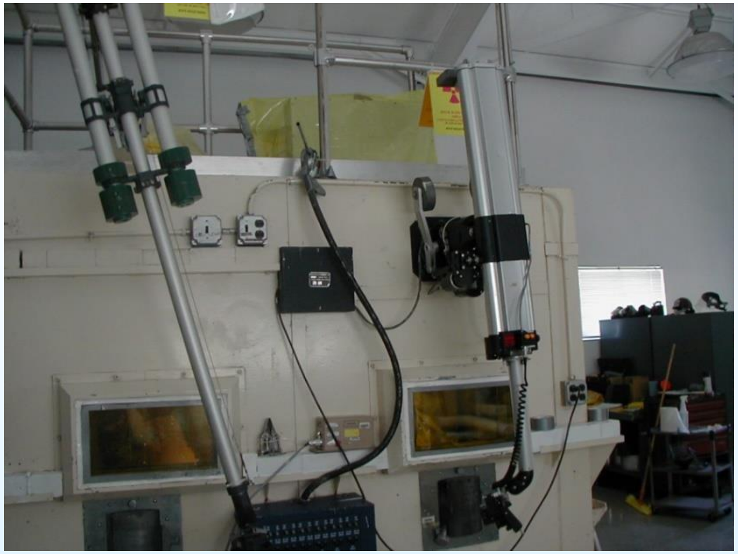
Irradiation with BNL Linac protons



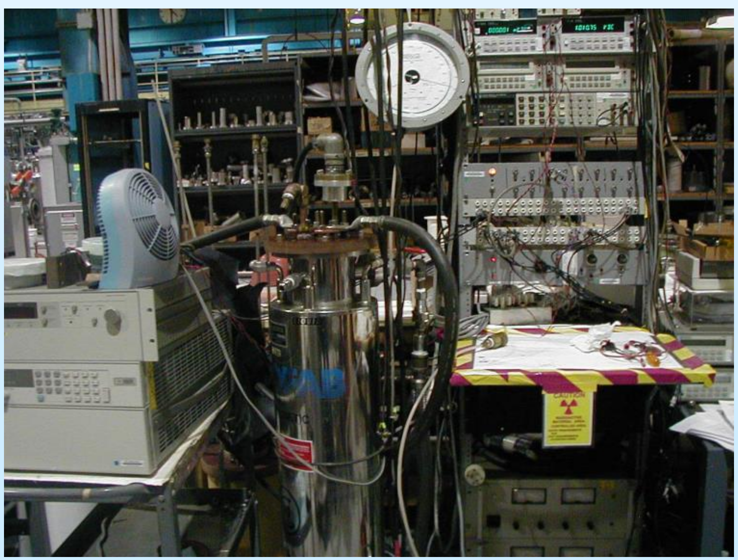
Diagnosis of Target Failure – NSLS-II

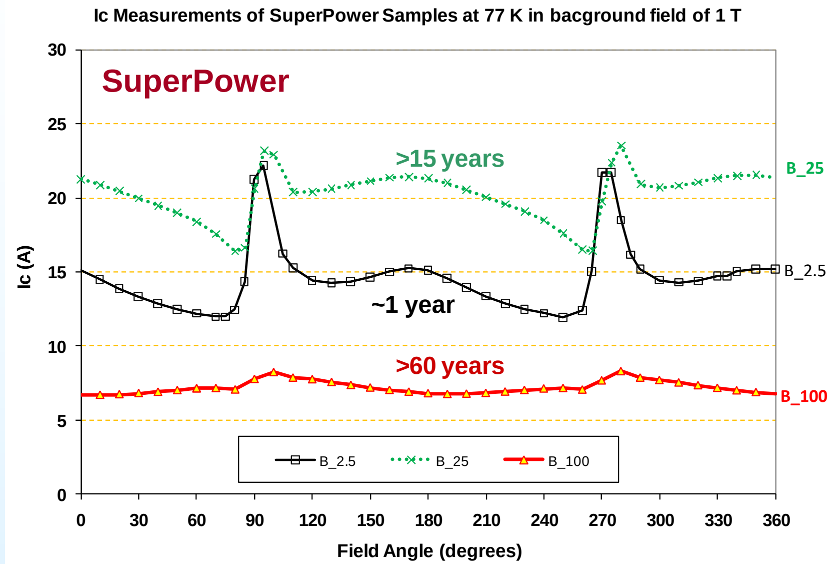
Radiation Damage Studies at BNL from 142 MeV Protons on ReBCO Tapes for FRIB

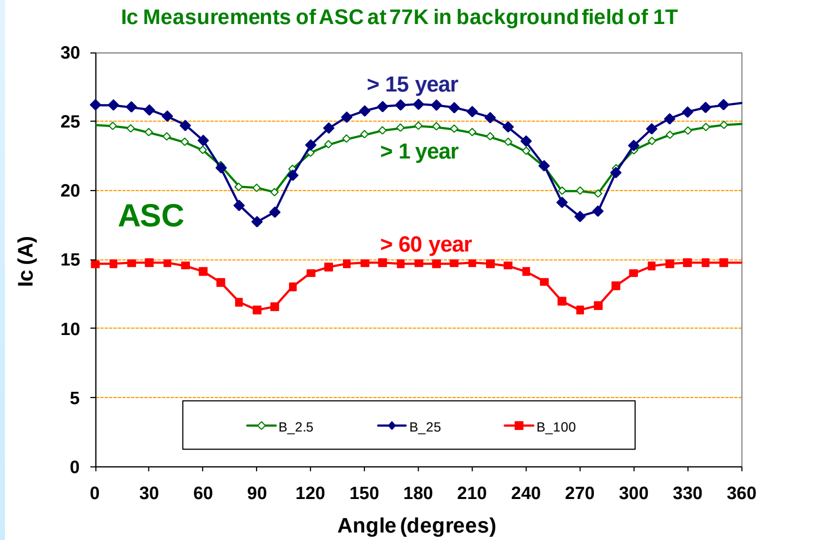
Irradiated at BLIP



(77 K, 1T) Testing at Magnet Division







BNL Capabilities in Engineering

Oak Ridge National Laboratory

Conceptual Design of MPEX Magnet System

Robert Duckworth*, Thomas Bjorholm, Robby Hicks, Dean McGinnis, Arnold Lumsdaine, Michael Anerella, Ramesh Gupta, Joseph Muratore, Piyush Joshi, John Cozzolino, Paul Kovach, Andrew Marone, & Stephen Plate

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OAK RIDGE National Laboratory | MATERIAL PLASMA EXPOSURE eXPERIMENT

MPEX Magnet Design - Partnership with Brookhaven National Laboratory utilized to address knowledge gaps in magnet design

- BNL Magnet Group worked with ORNL as strategic partner to evaluate design baseline in key areas and detailed assessment of ICH system
  - Previous experience on multiple superconducting solenoid geometries that have designed, fabricated, and commissioned.
- Areas examined for all MPEX coils
  - Axial/radial forces – all coils
  - Quench Protection – all coils
  - Current lead penetrations - ICH
  - Coil winding/mandrel construction - ICH

Goal is to have a conceptual design that identifies key issues and provide necessary information to develop effective specifications for MPEX magnet system

BNL AGS Snake Magnet (3 T max, 20 cm warm bore, LHe recondensing system)

MPEX magnets (0.2 T to 1.35 T max, 66 cm / 1.5 m warm bores, LHe recondensing system)

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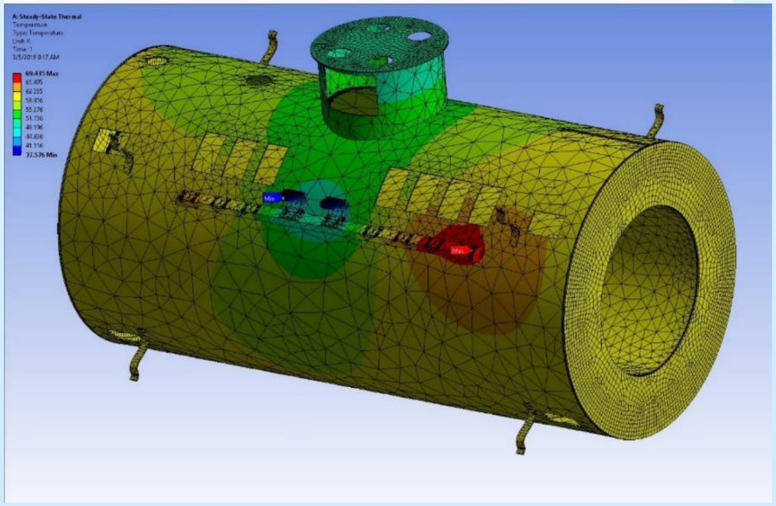
MPEX_CDR_4_Magnets_Duckworth_External

BNL Contributions



Summary

- **BNL can help the fusion program in many ways**
- **A team of people who have worked with industry**
- **Unique experience with HTS technology**
- **Irradiation Capabilities**
- **We are looking forward to working with INFUSE industrial partners**