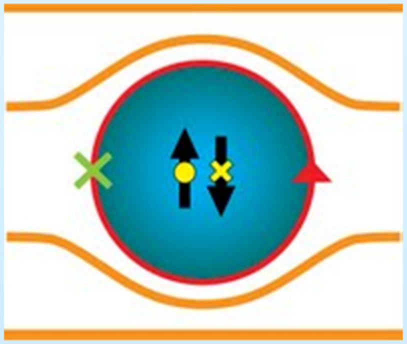
HTS Magnet Program at BNL

Ramesh Gupta



Overview

- **Active HTS Magnet Programs**
  - **Over 100 HTS coils and over 15 HTS magnets built and tested. This is a reasonable size R&D with ~25 km of 4 mm HTS tape (or equivalent) obtained so far and another ~25 km to be obtained in next two years**
- **Future HTS magnet programs**

A QUICK TOUR OF WIDE RANGE OF POSSIBILITIES

Most of our programs have collaborators/partners – more welcome

Active HTS Programs at BNL

Unique opportunity with several programs with significant activities on floor:

1. **10 T HTS Outsert Solenoid (PBL/BNL SBIR) – start of MAP R&D@BNL**
2. **10+ T HTS Insert Solenoid => 20+T all HTS when combined with above => pathway to 35+ T solenoid, if another PBL/BNL Phase 2 SBIR gets funded**
3. **24-30 T HTS Solenoid for SMES (BNL/SuperPower/ABB)**
4. **Medium Field (~3T, 40-50 K) Radiation Resistance HTS Quad for FRIB**

First three programs are for developing technology for very high field (>20 T) magnet technology that is relevant to many HEP accelerators (MAP, LHC).

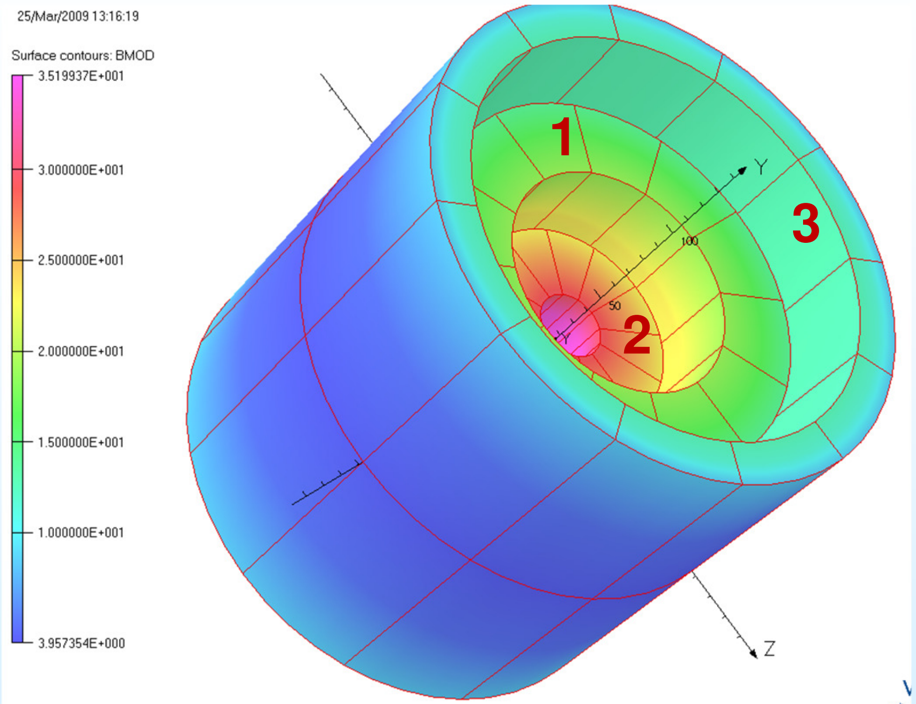
Most come to end this fiscal year or a year after that.

To preserve this R&D, we try to get funding from whatever source possible.

We do not have any base program funding to provide any level of stability.

PBL/BNL SBIR for High Field Solenoid for MAP with 2G HTS Tape

BROOKHAVEN NATIONAL LABORATORY
Superconducting Magnet Division



20⁺ T All HTS Solenoid (1 & 2):

addresses challenges with high field HTS solenoids (funded)

35⁺ T All Superconducting Solenoid (1, 2 and 3):

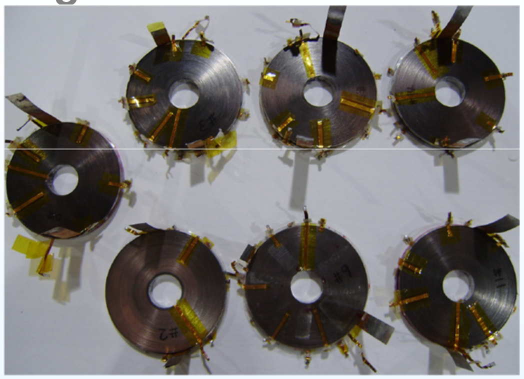
addresses challenges with high field superconducting solenoids

1. ~10 T HTS solenoid (middle): All coils built. All coils tested at 77K and some at 4K. ½ solenoid assembled and tested at 77K
2. 10+ T HTS (inner): All coils built and tested at 77K (some at 4K)
3. 12-15T Nb_3Sn (outer): Phase II to be applied -important for MAP

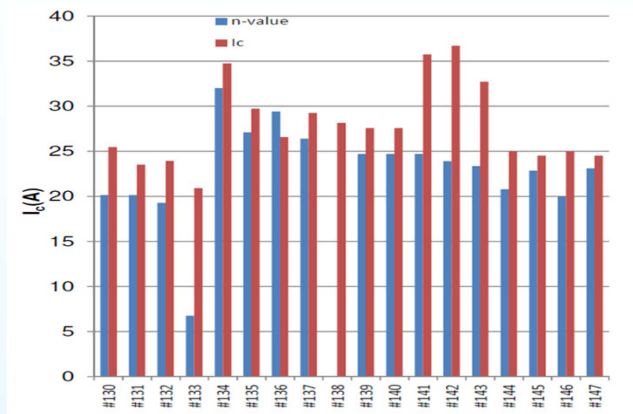
BROOKHAVEN NATIONAL LABORATORY

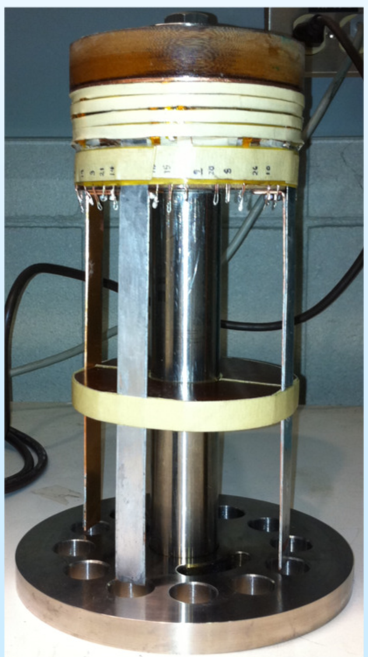
Superconducting Magnet Division

Status of PBL/BNL HTS Solenoids

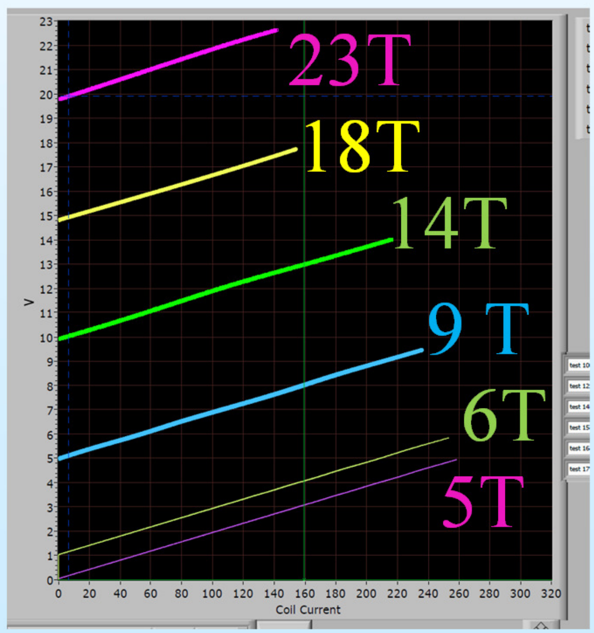


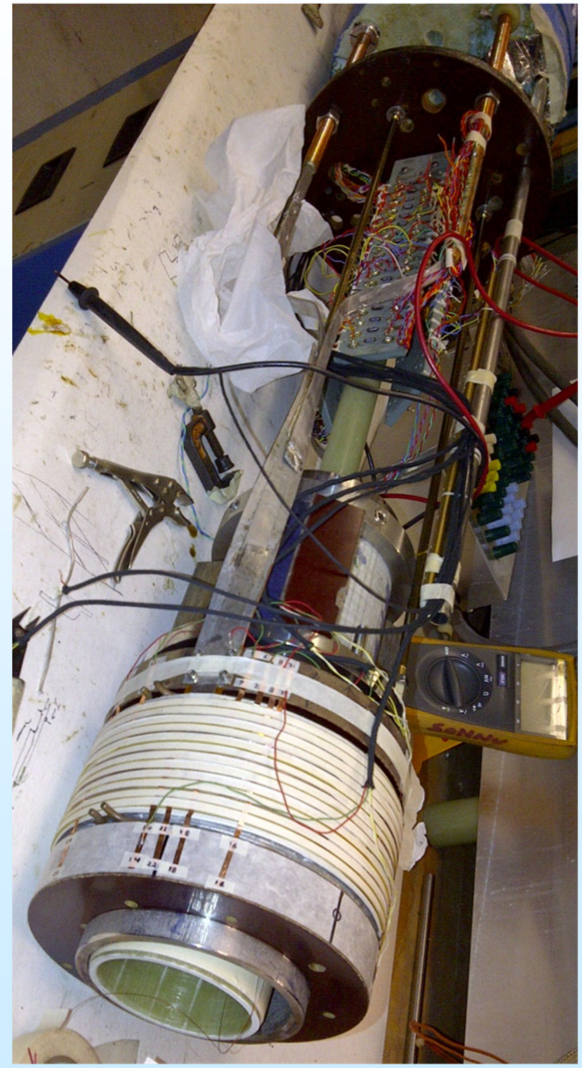
Inner ~25 mm, 10+ T





Posters by Y. Shiroyanagi





Outer ~100 mm, 10 T

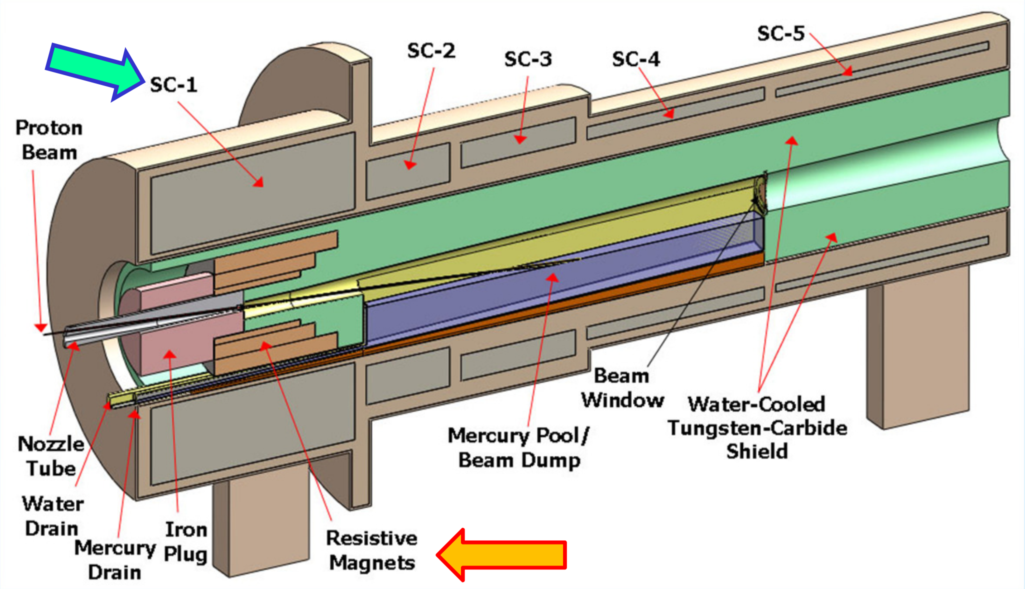
Insert coil test @NHMFL with SS insulation

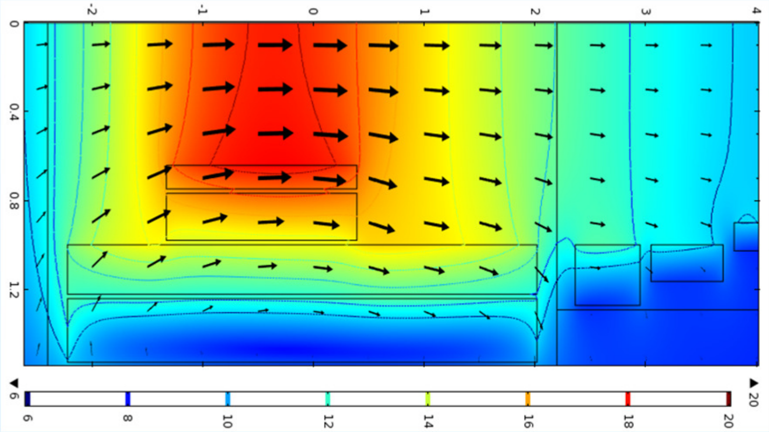
Some Future Opportunities

(one slide summary of each)

A HTS Insert for a 20 T Superconducting Pion-Capture Solenoid for a Muon Collider

- In capture solenoid system, field varies from 20 T to 1.5 T over ~15 m
- In original design, 20 T section consists of 14 T s.c. and 6 T resistive
- Resistive insert consumes ~12 MW power making operation expensive
- The solenoid system must tolerate ~4 MW dissipation of beam power
- Therefore, investigation of the use of HTS insert is highly attractive
- HTS will be compact and will reduce the size of s.c. solenoid





Stress/strain to be kept within acceptable limit

Courtesy: Weggel

Not enough resources to build or test something meaningful in Phase I

High Field Cosθ Magnet with 2G Tape

Different approaches:

1. **Develop type of conductor we are used to and love**
2. **Develop magnet designs to adapt to the conductor**
3. **Use conductors "~as is" in the designs we love but determine the level of problem & engineer a way out**
   - Ultimate goal: develop accelerator technology to do physics - not certain type of conductors or magnets
   - In addition to conductor vendors, also challenge magnet scientists and machine physicists on how to use these conductors, as specific progress in conductor is unlikely without significant funding

An early cos θ coil with Nb_3Sn tape (Sampson)

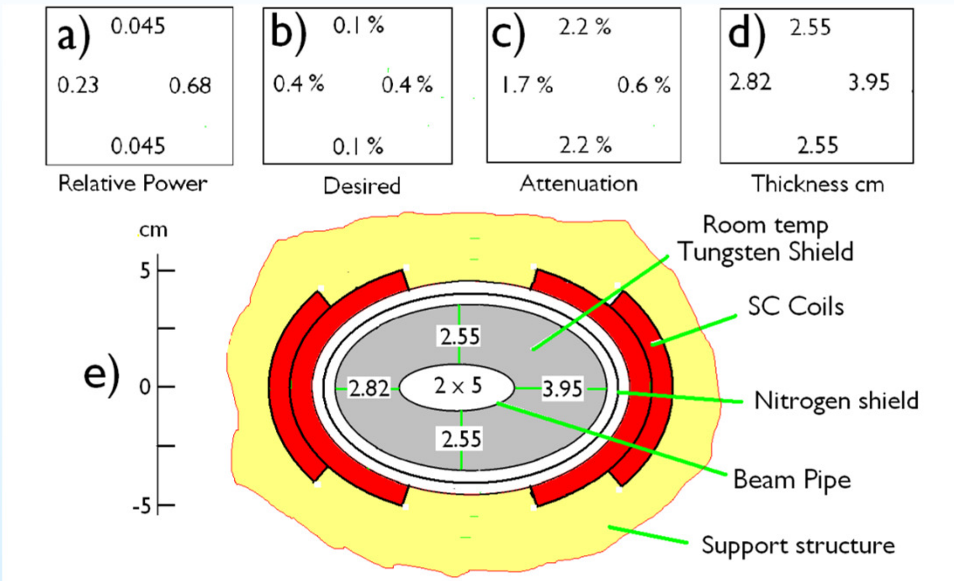
Parallel approach to 2212 Rutherford cable and 2G Roebel cable

High field cosine theta magnet for accelerators with 2G tape

- Build coil & test field performance in large aperture magnet
- Carry out measurements of field errors to better define the problem for accelerator physicists. There could be some solutions or errors may be acceptable in some cases.

High Field Elliptical Aperture Dipole for Muon Collider Ring

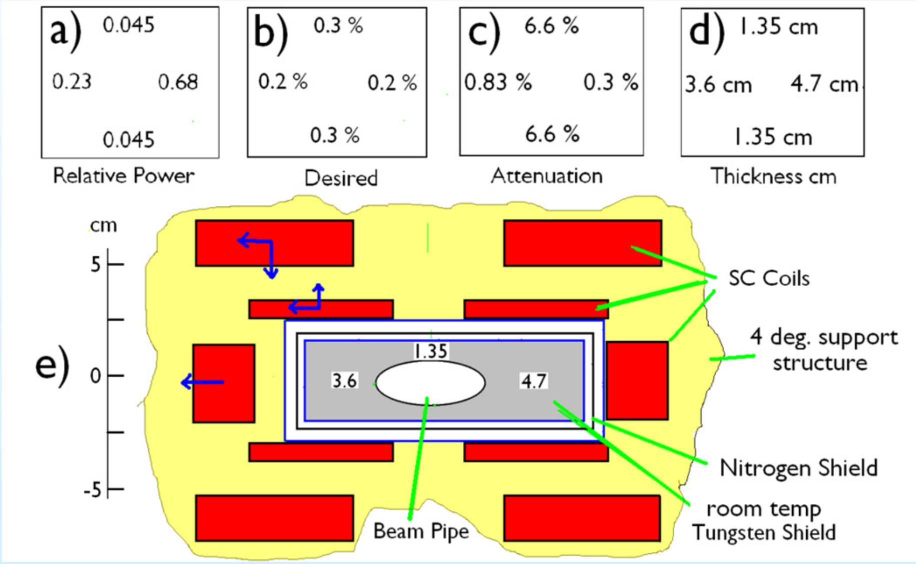
Energy deposition is anisotropic in a muon collider



Conceptual design of elliptical shield and Cos theta superconducting coils

Courtesy: Bob Palmer

Conceptual design of rectangular shield and superconducting block coils

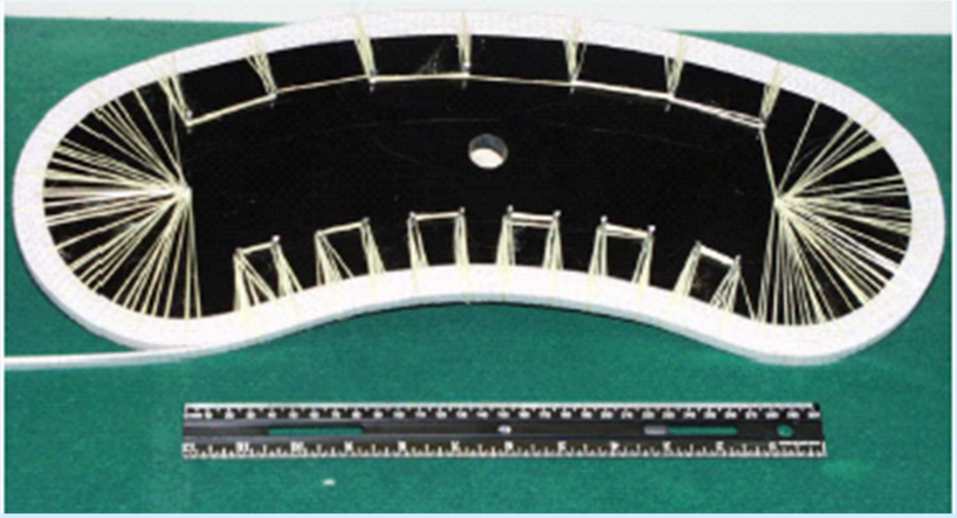


- HTS in some coils
- Force navigation as developed for open midplane dipole

FRIB SBIR with Muons, Inc. on Curved Dipole and Compact Corrector

- HTS magnets are preferred in FRIB due to very high energy deposition
- HTS quads now form the base line design of the fragment separator region
- There are number of other magnets but they depart from racetrack coil

Muons, Inc./BNL SBIR/STTR submitted under Nuclear Physics (not HEP)



Curved coil with negative curvature

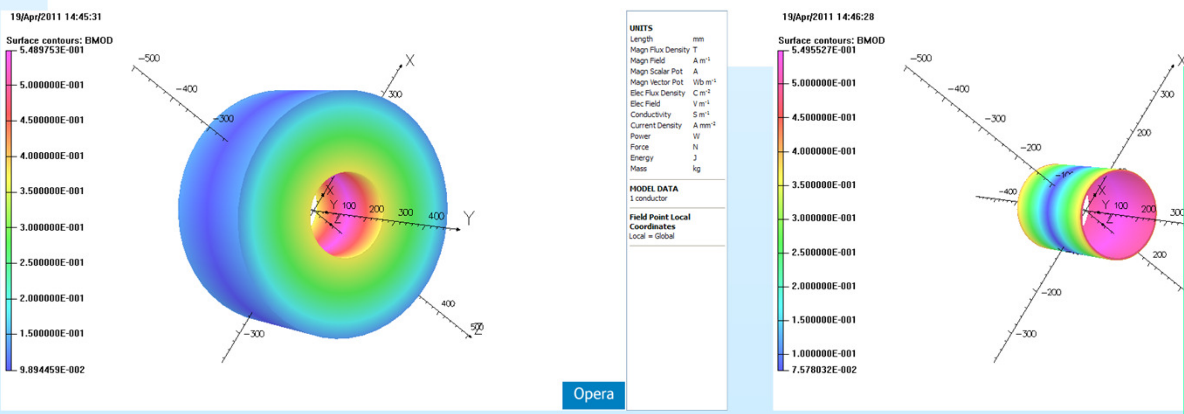
Curved ends (like cos theta)

In both cases, we propose to build and test one or more HTS coils in Phase I

Taking MgB_2 HTS Magnets from R&D Stage to Machine Application

For upgrade Cu solenoid requires over 1 MW power - not available locally

MgB_2 HTS offers a unique solution

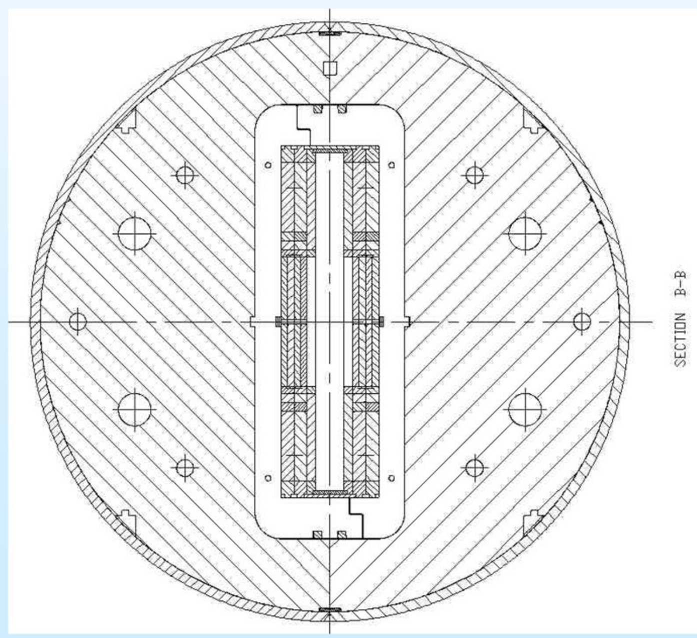


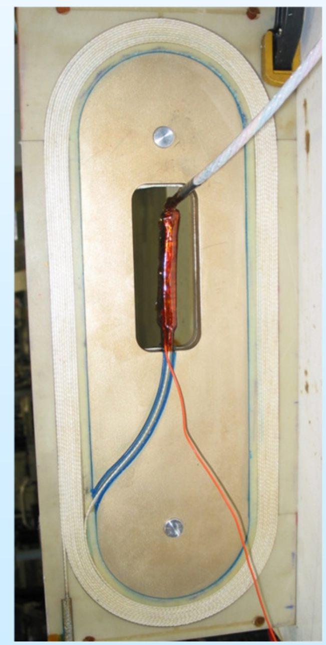
- Such situation is/could be faced in other upgrades.
- Critical lifetime tests, reliable quench protection, etc. must to be established before a real machine use.

Mike Tompsic presentation tomorrow

Make Testing of HTS Coil As Simple And As Routine As Testing of HTS Cable

- For testing experimental coils, we need a test bed where R&D coils can be easily tested in a background field (somewhat similar to testing cable).
- We have this for solenoid coils at NHMFL, but how about for dipole/quad coil?
- A magnet was successfully built and tested for 10+ T field but remain unused.
- Start a program where we can try different ideas and/or do systematic studies.





High current 2212 coil

This unique magnet is safely stored – can be brought into service with proper collaboration/funding

SUMMARY

- A variety of designs and technologies for various applications is being explored with a significant amount of conductor in use
- Progress has been made through demonstrations in R&D HTS coils and magnets which allows more acceptability of HTS
- Lab management has noted the progress and has declared the development of HTS magnet technology as one of its mission
- With funding from whatever source(s), we hope to continue to contribute to the development of high field magnets for HEP