

# High Field Magnet R&D with YBCO

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# Relevance of HTS R&D at BNL to LHC-HE

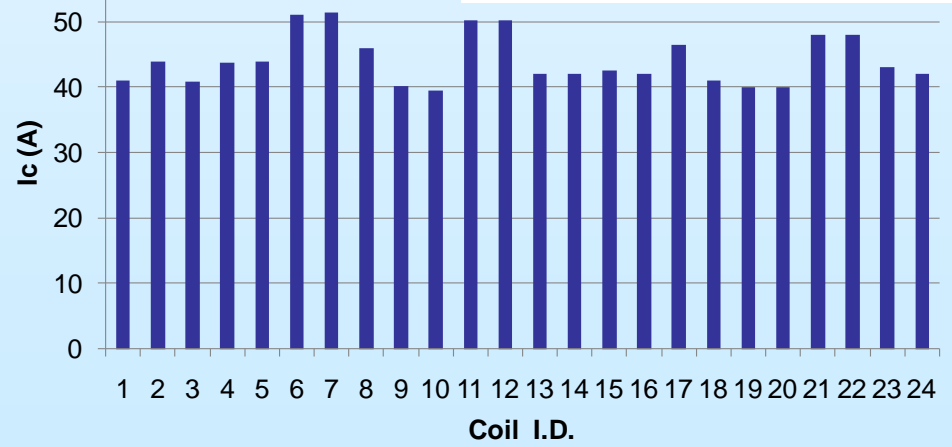
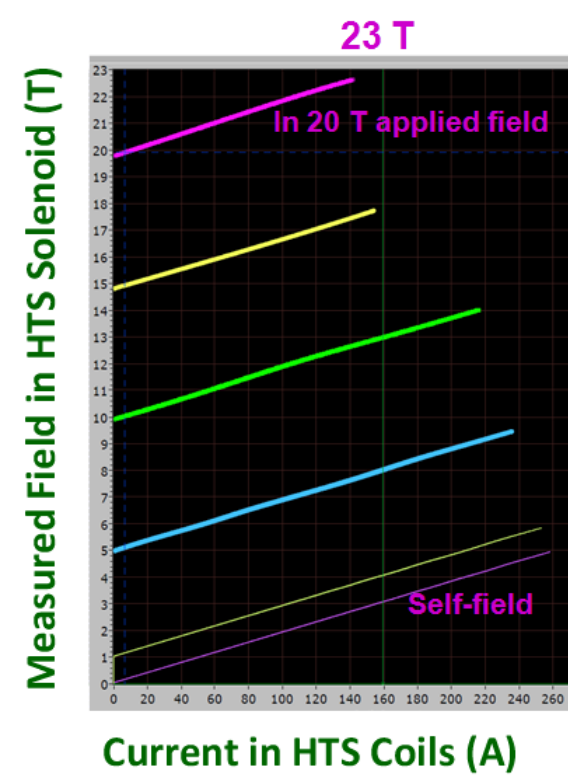
- **BNL has a significant HTS R&D program with a large portion of it directly related to high field magnets**
- **At this early stage, the question is: Can we learn to use HTS (which is very different from LTS) to make high field magnets (irrespective of the geometry)**
- **Can HTS magnets (with different quench properties) with large stored energy be protected? A million dollar question with a million dollar R&D program**
- **Currently funded programs for next 2 years with sizable YBCO coils:**
  - ❑ **20+ T HTS (then more) with number of coils using ~3 km of YBCO tape**
  - ❑ **~25 T large bore magnet using about a million dollars of YBCO**
  - ❑ **8 racetrack coils, each using ~1 km, 4 mm equivalent tape**

Join us **NOW** to get real experience and help make above programs successful

# BNL/PBL SBIR for High Field Solenoid (Ultimate Goal ~40 T)

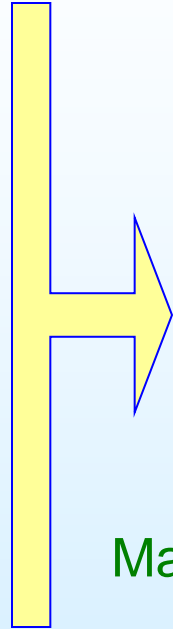
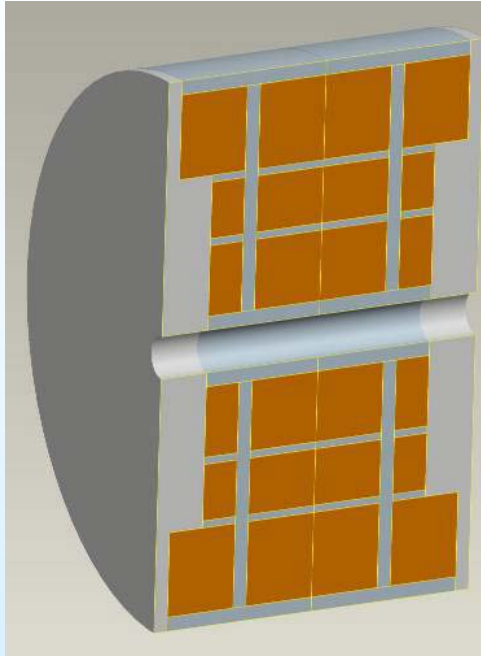
- Required coils with 2G HTS built and tested in LN<sub>2</sub>
- Technology proved for 20+T with background field@NHMFL
- Next phase:
  - Demonstrate a well protected 20+ T HTS magnet
  - Demonstrate higher fields with LTS & background field

**Join us now for remaining challenging tasks**



# High Field HTS Magnet for SMES (Partners: BNL, SuperPower & ABB)

Large bore HTS Magnet for Superconducting Magnetic Energy Storage (SMES)



- Field: ~25 T
- Inner Diameter : ~100 mm
- Conductor: ~10 km, 12 mm wide 2G tape
- Stored Energy: 2.5 MJ
- Ramp up and ramp down time : 10 minutes

Many questions are similar to accelerator magnets

- **Conductor: Develop 600 A (~500 A/mm<sup>2</sup>) at 30 T in any field direction**
- **Magnet/coil technology: Very large stress and strain on conductor**
- **Quench protection: Self stated overall risk rating to program – high**

High risk, high reward R&D with several challenges - join us now

# HTS Quench Protection R&D at BNL (development of hardware and understanding)

We recognize that quench protection in HTS poses a major challenge. Significant R&D program on hardware, software, measurements for scientific understanding, etc. is underway with funding from several sources:



- SMES
- FRIB
- PBL/BNL SBIR
- Base program
- LDRD (funding decision awaited)

A budget of ~1 M\$ shows the level of interest.

But all areas are still not covered.

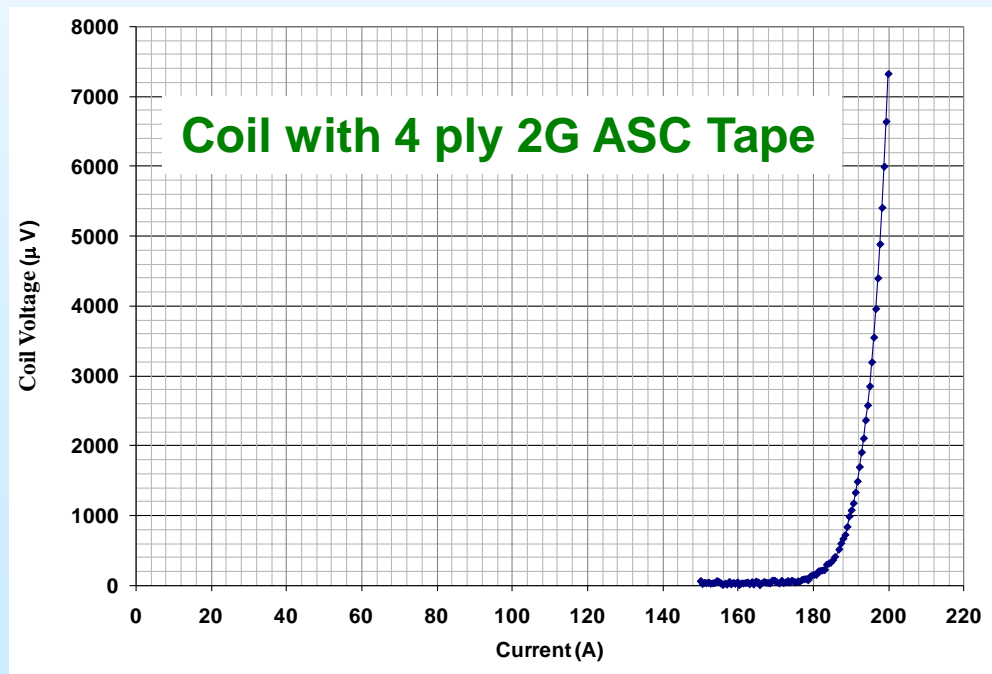
➤ **We welcome collaborations.**



# Large Racetrack Coils with YBCO



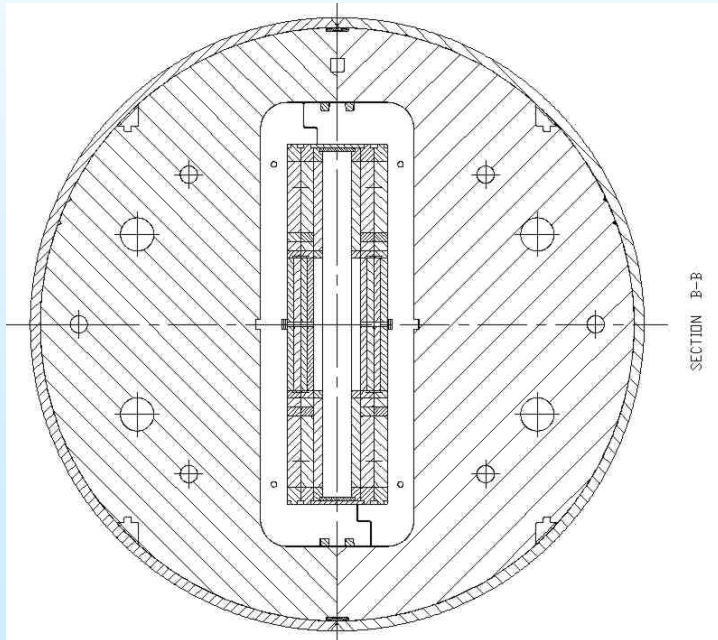
- The baseline design of Quadrupoles for the Facility for Rare Isotope Beams (FRIB) consists of significant size HTS racetrack coils
  - Each coil uses **over 1 km** equivalent of standard 4 mm 2G HTS tape
- Unique opportunity to test large 2G HTS coils made with tape from multiple US vendors
- 8 coils built (4 with SuperPower and 4 with ASC)



- Successful construction, test and demo of quench protection of large HTS coils should be useful to LHC upgrade.
- The current plan, however, is limited to medium field ~40 K testing (FRIB need).
- Additional 4K high field tests of these large size HTS racetrack coils could provide useful technical data for LHC.

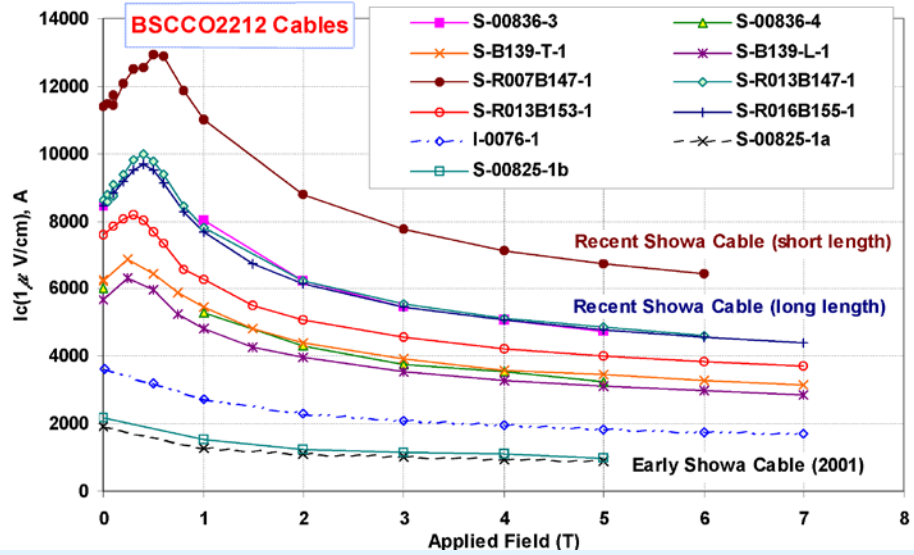
# A Magnet for Background Field Coil Testing

- A magnet has been designed and built with a large clear space for efficient testing of HTS insert coils in high background field (no need to disassemble)
- Major difference from preparing a magnet every time for each insert coil test
- Large clear space: ~240 mm high, ~30 mm wide, ~500 mm long
- Successfully tested at self-field of 10.4 T (higher field with insert coils)



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

# Alternate Approach for Magnets with 2212 Rutherford Cable: React & Wind



## Two approaches:

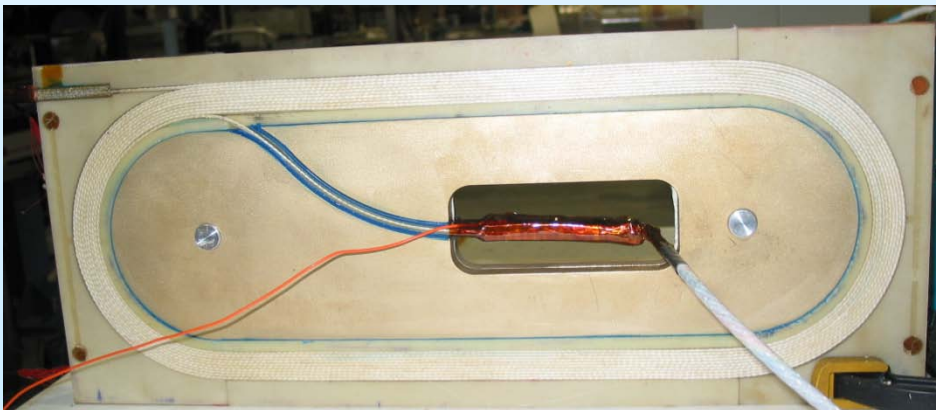
- Develop conductor to do what we are used to
- Develop magnet designs to fit the conductor

Ultimate goal is to develop accelerator technology to do physics (not certain type of conductors or magnets). We (both magnet scientists and machine physicists) have time to learn how to use these new conductors.

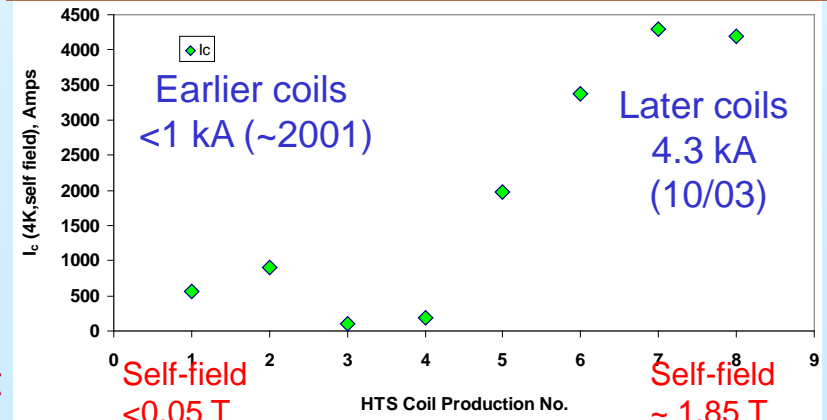
Recall history: Copper Vs. SC magnets

Wire: Showa, Cable: LBL, Reaction: Showa, Test: BNL

R&W Bi2212 cables, coils & magnets carried significant current (still record?)



Coil wound and tested @BNL in a common coil magnet





# SUMMARY

- **BNL has a significant HTS R&D program which covers a wide range. A large part of it will directly benefit LHC-HE upgrade with high field magnets.**
- **All are invited join us in this exciting R&D**
  - **Benefit to participants: real hands on experience beyond paper studies.**
  - **Benefit to us: extra support and your intellectual contribution.**
- **We don't have extra funding to provide direct support but believe at present we have several programs to provide early opportunity to understand the challenges associated with high field HTS magnets and develop technology for future.**
- **At an individual level, collaborators will find unique challenges and be able to make contributions of lifetime. Such opportunities don't come too often.**