BNL High Field and HTS Magnet Program

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HT Toys R Us

BNL, NY USA
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, MgB₂ – 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 MgB₂ 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

Funded by arpa-e as a “high risk, high reward” project

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

100 mm bore ReBCO ARPA- E SMES Coil

2 pancakes
1140 A, 4K

12 pancakes
760 A, 4K, 11.4 T

46 pancakes
350 A, 27K, 12.5 T

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Peak fields higher
High Field HTS Magnet - PBL/BNL SBIR

- Field on axis: 15.7 T
- Field on coil: 16.2 T
  (original target: 10-12T)

- Overall $J_o$ in coil: >500 A/mm² @16 T

Aperture = 25 mm

*Credit to SBIR/STTR office for this and SMES work which was the result of this
Important: Magnet for a real machine - baseline design of FRIB
Superconducting Magnet Division

FCC Magnet Meeting

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Slide No. 7

Charlotte, NC, USA

August 13, 2014

Large Temperature Margins
(only possible with HTS)

Design Current:
SuperPower Coil: 210 A
ASC Coil: 310 A

Design Temp: 38 K

(50K,375A)
(+21% in I_c &
+12 K in T_c)

(60K,240A)
(+14% in I_c &
+22 K in T_c)

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

Design: 210 A in SP Coils

Vacuum leak made the temperature increase to ~57 K (design temp ~38 K)

Ringing in power supply made situation worse

Slow logger: One point/sec
Magnet Designs for FCC
**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)

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**Cos (θ) Coil - PBL/BNL STTR#1**

(12 mm, one block, 77 K)

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August 13, 2014  
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**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
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?

Highest field R&W Nb₃Sn dipole

HTS tape common coil dipole

Used in Chinese Proposal
A Coil Design with Overpass/Underpass Ends
Optimized for ReBCO Tape

- 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 $J_c$
  - Lower magnetization (will depend on the thickness and not on the width)

Magnet R&D for FCC
• BNL has a unique $10^+ \text{T} \mathrm{Nb}_3\mathrm{Sn}$ 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 ($\sim 15 \text{T}$)
A Warm bore Cryo-cooled Magnet with 6 HTS coils

- 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
• 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.