High Field Magnet R&D at BNL for Future High Energy Colliders

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Main Features of the BNL High Field Magnet R&D Program

- Common Coil Design

- Insert Coil Test Facility

This presentation focuses on why and how?
Common Coil Design
(Summary of Benefits)

- Simple 2-d coil geometry for colliders
- Fewer coils (about half) as the same coils are common between the two apertures (2-in-1 geometry for both iron and coils)
- Conductor friendly - large bend radii with simpler ends allowing many new options
- Block design with lower internal strain on the conductor under Lorentz forces
- Savings from less support structure
- Easier segmentation for hybrid designs (Nb$_3$Sn & NbTi and possible HTS?)
- Minimum requirements on big expensive tooling and labor
- Potential for producing lower cost, more reliable (less margin) high field magnets
- Efficient and rapid turn around magnet R&D due to simpler and modular design
Brief History of Common Coil

- R&D magnets built at LBL, BNL and FNAL
- Started the culture of fast turn-around R&D
- Base line design for VLHC; also for SppC

Work stopped after a few years for reasons other than the failure of the design.
Remains to be Demonstrated
Accelerator-type Field Quality

➢ Require “pole coils” which must clear the beam tubes in the ends

(a) Pole coils like midplane coils of cosine theta dipoles (easy bend)

(b) Simpler configuration of pole coils (waste some conductor)

Good field quality have been shown in computer models but not yet demonstrated in a model magnet with added (minor) complication
Proposal with PBL to Demonstrate Nb$_3$Sn Proof-of-Principle Common Coil Dipole

- Build Nb$_3$Sn pole coils and insert and test them inside the existing BNL Nb$_3$Sn common coil magnet with large open space
- Can be done within the budget of SBIR/STTR as the magnet doesn’t have to dis-assembled
- These insert coils become an integral part of the magnet and run in series with other coils

Made as a part of another PBL/BNL program
Plan to use 3-d printed parts to develop ends
HTS Coil Winding

77 K Test (PBL/BNL STTR)
Over 350 A (No degradation)

See test results of 2G coil in the poster tomorrow

Also works for Roebel cable
(large bend radii, bend in easy way, properly aligned)
Promising CORC® Cable
High Je, High Ic

- Je of >600 A/mm² at 20 T for 10 kA cable next year?
- Jo of ~1000 A/mm² at 20 T for 20 kA cable in a few years?
• High $I_c$, High $J_e$ CORC® cable requires large bend radii - Common coil design allows that
• We propose HTS CORC® cable coil powered in series with LTS Rutherford cable coil
• Easier operation, easier protection – reasonable inductance (high current)
• Partially transposed CORC® cable also helps in reducing magnetization-induced field errors associated with the high strength ReBCO tape
• Proof-of-principle dipole with HTS insert running in series with Nb$_3$Sn BNL Common coil dipole within the budget of Phase II
Single Aperture Block Coil
Phase I SBIR with e2P
Novel High Field Hybrid Dipole Magnet
• Cross-section is OK but the design gets complicated in the end region with bend of cable in hard direction – lifted ends to clear the tube, long length, reverse bend.

• The performance of such magnets often gets limited by the end region.
To understand it, imagine driving on high way

- No hard-way bend
- No reverse bend
- Less strain – conductor friendly design
- Less axial space

An Innovative design which could possibly bring a novel solution to an issue spanning over decades

Thank you SBIR
Actual Demonstrations in Phase I (e2P poster for another coil)

Superconducting Magnet Division

77 K Test Results

12 mm wide tape
No degradation

Courtesy 3d printer
Future Possibilities

- A successful demonstration of this technology will open the door for many new possibilities
- In HEP high field magnets, it can be used for Roebel (CERN) with field in right direction
- It can also be used in Nb$_3$Sn magnets
- Phase II for more automated coil winding & insert high field coil testing inside BNL dipole

Please visit e2P/BNL Posters

CERN
SUMMARY

• Racetrack coil/common coil design for Nb$_3$Sn and HTS (particularly ReBCO) offer technically attractive options for future high field magnets.

• US should continue to maintain its leadership and remain in play with this option with small investment from whatever source(s) possible.
Extra Slides
Superconducting Magnet Division

HTS Coils Test Results

A Hybrid HTS/LTS Superconductor Design for High-Field Accelerator Magnets, PBL, DOE/HEP STTR Phase II

Novel High Field Hybrid Dipole Magnet, Energy-to-Power Solutions (e2P), DOE/HEP SBIR Phase I

High Field Solenoid Development for Axion Dark Matter Search at CAPP/IBS, KIST, Korea, WFO

Baseline

Alternate

Baseline

Alternate

Test Results with ReBCO Tape (NO degradation)

Test Results with ReBCO Tape

1st 10-turn of one coil when both coils powered in series at ~48 K

77 K test to examine degradation, if any, with 12 mm wide ReBCO tape

Favorable and Unfavorable configurations

Roebel Cable with Desired Alignment in Common Coil Design

ASC2002

Dipole with Curved Coils

New Overpass/Underpass Design (Compact, NO hard-way lifting, NO reverse bend, low peak field

High Field Magnet R&D at BNL

Ramesh Gupta

BNL Collaborators (mostly SBIR/STTR):
PBL; e2P; Muons, Inc.; HyperTech; IBS

Development of MgB2, Superconducting Coils for Nuclear Physics Applications, HyperTech, DOE/NP SBIR Phase II

High Radiation Environment Nuclear Fragment Separator Magnet, Muons, Inc., DOE/NP STTR Phase II

Radiation resistant Quads and dipole

MgB2, solenoids to replace Cu solenoids

POSTER TOMORROW

High Radiation Beamdump

400 kW Production Target

High Temperature Superconducting Magnet, Single and Multipart

POSTER TOMORROW

LTSW’16
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BNL
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Superconducting Magnet Division

BNL is the only national lab in US that has a significant size operating superconducting circular collider

BNL is the most recent national laboratory in the US that has successfully built a significant quantities of superconducting magnets both with industry and in-house

- These magnets have been cost-effective, reliable and have met or exceeded all requirements (magnetic, mechanical, cryogenic, electrical, etc.)

BNL has also been taking bold steps in starting new R&D (HTS magnets, common coil design, etc.) - such steps often bring major changes in cost-performance matrix

BNL brings a unique insight and promise to the table for developing reliable and lower cost superconducting magnets. The collaboration and DOE should benefit from taking advantage of the asset it has.