

Managing a Variety of Programs with Multiple Collaborators together

There was no specific program, group or funding at BNL to develop HTS magnet technology. Creating such a diverse program (listed on left), required managing multiple programs from diverse funding sources and multiple collaborators. It also required flexibility, clarity and strategies to deal with conflicts.

Since HTS itself was expensive (very expensive), managing and obtaining conductor at “no-cost” (such as significant amount of Bi2212 Rutherford cable where first wire was obtained, then cable was made, and then reacted in very specialized and control furnace) and MgB₂ or “reduced-cost” (such as from ASC, SuNAM, SuperPower) required skills and respect.



Highlights of the HTS Magnet Program at BNL

- **First US national lab to start HTS magnet R&D (over 20 yrs ago)**
 - Opted the approach of demonstrating capabilities of HTS to create new opening and create excitement, rather than waiting for the conductor to get matured before starting magnet R&D
- **A wide ranging HTS magnet R&D at BNL**
 - High field, high temperature and the middle course
 - Solenoid, racetrack, cosine theta, curve coils, clover-leaves, ...
- **Number of HTS coils and magnets designed, built and tested**
 - Well over 150 HTS coils and well over 15 HTS magnets
- **HTS used: Bi2223, Bi2212, ReBCO, MgB₂ – wire, cable, tape**
- **Amount of HTS acquired: Over 60 km (4 mm tape equivalent)**

PI/Leader of a Variety of Many HTS Projects

A List of HTS Programs at BNL (old slide)

- 25 T, 100 mm HTS solenoid for IBS, Korea (Work for Others)
- Hybrid Dipole with CORC® Cable (Phase II SBIR)
- High field solenoid for Neutron Scattering (Recent SBIR)
- Passive shielding for Electron Ion Collider (Phase I SBIR)
- Modular racetrack coil quadrupole for EIC (Phase I SBIR)
- 100 mm aperture “12.5 T @27 K” HTS SMES (arpa-e)
- High field collider dipole (Phase II STTR)
- Curved ReBCO tape dipole (Phase II SBIR)
- MgB₂ solenoid (Phase II SBIR)
- High field open HTS midplane dipole (Phase I SBIR)
- High radiation HTS Quadrupole for FRIB (Collaboration)

(older slides, not updated for recently)

Completed HTS Magnet Programs

- 25 mm aperture 16 T HTS solenoid (SBIR)
- 100 mm aperture 9 T HTS solenoid (SBIR)
- HTS quadrupole for RIA (Collaboration with MSU)
- Bi2223 HTS tape common coil dipole (funded by DOE)
- Bi2212 Rutherford cable Common Coil Collider Dipole (DOE)
- HTS solenoid for Energy Recovery Linac (BNL project)
- HTS magnet for NSLS (BNL Project)
- Cosine theta dipole with 4 mm YBCO/ReBCO tape (SBIR)
- Cosine theta dipole with 12 mm YBCO/ReBCO tape (SBIR)
- ...and a few others.

A Partial List of Collaborators

(with whom either working now or worked significantly in past)

Research Institutions

- MSU/FRIB
- CERN
- KEK, Japan
- University of Kyoto, Japan
- IBS, Korea
- RISP, Korea
- PSI, Switzerland
- IHEP, China
- University of Houston
- Texas A&M
- LBNL
- Fermilab
- SSC
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Businesses

- Particle Beam Lasers, Inc. (PBL)
- Muons, Inc.
- HyperTech
- General Atomics (GA)
- Commonwealth Fusion Systems (CFS)
- Renaissance Inc., USA
- Solid Material Systems (SMS)
- Columbus Superconductor, Italy
- Showa, Japan
- SuperPower, US
- American Superconductor Corporation
- Advanced Conductor Technology (ACT)
- ABB
- ...

... and many others with whom just had collaborative relationship, but no significant work or funds involved yet (proposals may have been written but not funded)

PBL SBIR/STTR Awards with BNL

1. A 6-D Muon Cooling System Using Achromat Bends and the Design, Fabrication and Test of a Prototype High Temperature (HTS) Solenoid for the System. DE-FG02-07ER84855	August 2008	\$850,000
2. Study of a Final Cooling Scheme for a Muon Collider Utilizing High Field Solenoids. DE-FG02-08ER85037	June 2008	\$100,000
3. Design of a Demonstration of Magnetic Insulation and Study of its Application to Ionization Cooling. DE-SC000221	July 2009	\$100,000
4. Study of a Muon Collider Dipole System to Reduce Detector Background and Heating. DE-SC0004494	June 2010	\$100,000
5. Study of a Final Cooling Scheme for a Muon Collider Utilizing High Field Solenoids: Cooling Simulations and Design, Fabrication and Testing of Coils. DE-FG02-08ER85037	August 2010	\$800,000
6. Innovative Design of a High Current Density Nb ₃ Sn Outer Coil for a Muon Cooling Experiment. DE-SC0006227	June 2011	\$139,936
7. Magnet Coil Designs Using YBCO High Temperature Superconductor (HTS). DE-SC0007738	February 2012	\$150,000
8. Dipole Magnet with Elliptical and Rectangular Shielding for a Muon Collider. DE-SC000	February 2013	\$150,000
9. A Hybrid HTS/LTS Superconductor Design for High-Field Accelerator Magnets. DE-SC0011348	February 2014	\$150,000
10. A Hybrid HTS/LTS Superconductor Design for High-Field Accelerator Magnets. DE-SC0011348	April 2016	\$999,444
11. Development of an Accelerator Quality High-Field Common Coil Dipole Magnet. DE-SC0015896	June 2016	\$150,000
12. Novel Design for High-Field, Large Aperture Quadrupoles for Electron-Ion Collider. DE-SC00186	April 2018	\$150,000
13. Field Compensation in Electron-Ion Collider Magnets with Passive Superconducting Shield. DE-SC0018614	April 2018	\$150,000
14. HTS Solenoid for Neutron Scattering. DE-SC0019722	February 2019	\$150,000
15. Quench Protection for a Neutron Scattering Magnet. DE-SC0020466	February 2020	\$200,000
16. Overpass/Underpass Coil Design for High-Field Dipoles. DE-SC002076	June 2020	\$200,000
17. A New Medium Field Superconducting Magnet for the EIC. DE-SC0021578	February 2021	\$200,000
18. A New Medium Field Superconducting Magnet for the EIC. DE-SC0021578	April 2022	\$1,150,000

Ongoing Projects with Ramesh Gupta as PI

- Very High Field Magnet R&D, US Magnet Development Program
- A collaboration framework to advance high-temperature superconducting magnets for accelerator facilities, U.S.-Japan Science and Technology Cooperation Program In High Energy Physics
- Low Temperature Testing of New Lower Cost Magnum-NXTM HTS Cable for Fusion, INFUSE Program with Solid Material Solutions, LLC (SMS)
- In-field Performance Testing of a Novel HTS CICC for Fusion Magnets, INFUSE Program with General Atomics (GA)
- Pulsed High Temperature Superconducting Central Solenoid Model Coil for Plasma Current Drive and Control in High-Field Compact Commercial Fusion Power Plants, arpa-e Grant with Commonwealth Fusion Systems (CFS)
- A new medium field superconducting magnet for the EIC, Phase II STTR with Particle Beam Lasers, Inc. (PBL)
- CORC[®] cable based high field hybrid magnets for future colliders, Phase II STTR with Advanced Conductor Technologies (ACT)