Possible BNL Contributions to High Field HTS Magnet Program

Ramesh Gupta

Overview

In addition to wire and cable tests (Ghosh), BNL can contribute to the high field magnet program with the following:

- Mechanical (stress) test on existing 2212 coils at 77 K
- Test of short HTS coils in the background field of a 10+T "Open Dipole"
- Alternate react & wind approach
- Magnet design

A significant part of above takes advantage of the hardware we have.

Some of above could be done in a short time scale and at a low cost.

- **Also some synergy with RIA work in certain type of coil R&D**

Stress/Strain Studies on Bi2212 (1)

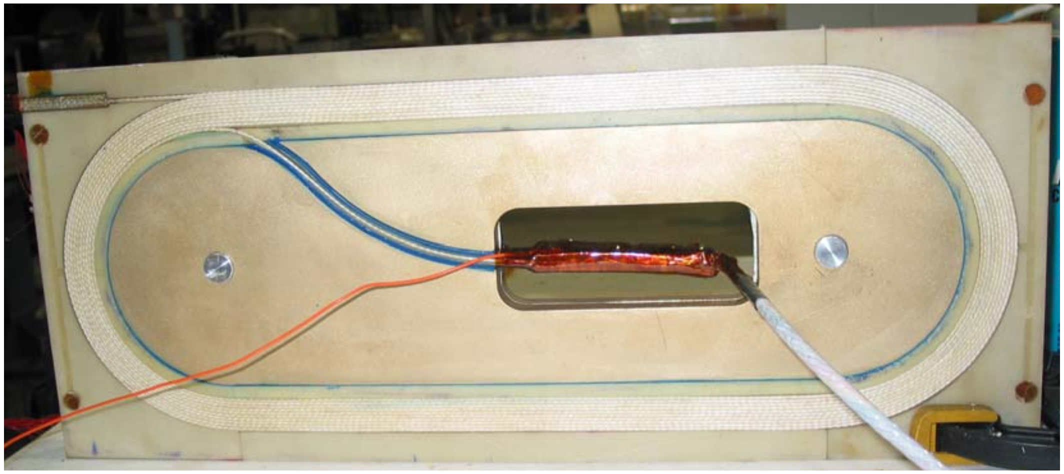
There are some questions on how the cable composite (impregnated cable with insulation) performs under the stress generated by Lorentz forces. Here is one approach:

- Take advantage of the fact that HTS is superconducting at 77 K
- Take advantage of the fact that tests and apparatus can be designed and operate much easier and cheaper at 77 K
- Take advantage of the fact that we already have many Bi2212 coils

BNL has many coils from years of magnet R&D with Bi2212 Rutherford cable.

Stress/Strain Studies on Bi2212 (2)

- Design a mechanical clamp (device to produce load) with strain gauges that provide controlled compression on the broad and narrow sides of the cable.
- This clamp could be either mechanical or use the differential thermal expansion of Stainless and Aluminum to provide desired loads.
- One could put everything (coil + clamp) in liquid nitrogen and measure I_c as a function of loads at 77K.
- Later one can find a correlation between 77K tests and 4 K tests in a simpler sample. In the past we found good correlation. One can also reduce the temperature to ~60 K by pumping to observe the change in degradation as a function of temperature.



77 K tests are relatively simple tests and we can use these coils to show good technical progress and development of an inexpensive technique.

BROOKHAVEN NATIONAL LABORATORY

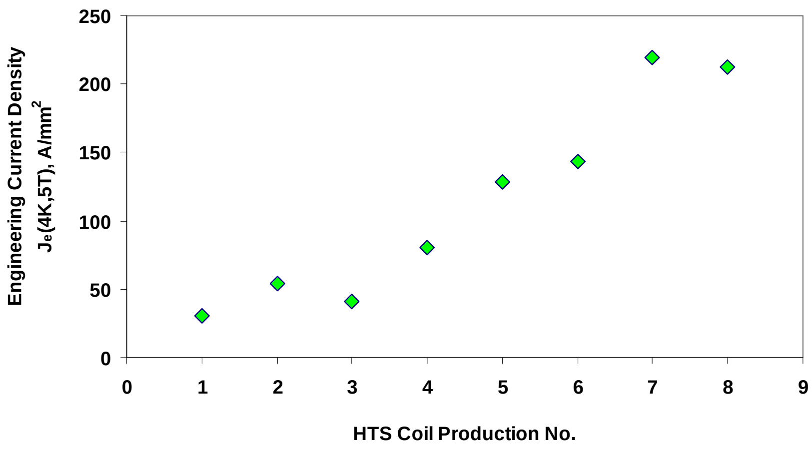
Superconducting Magnet Division

Coils for Statistics

Coils and Magnets built with Rutherford Bi2212 Cable

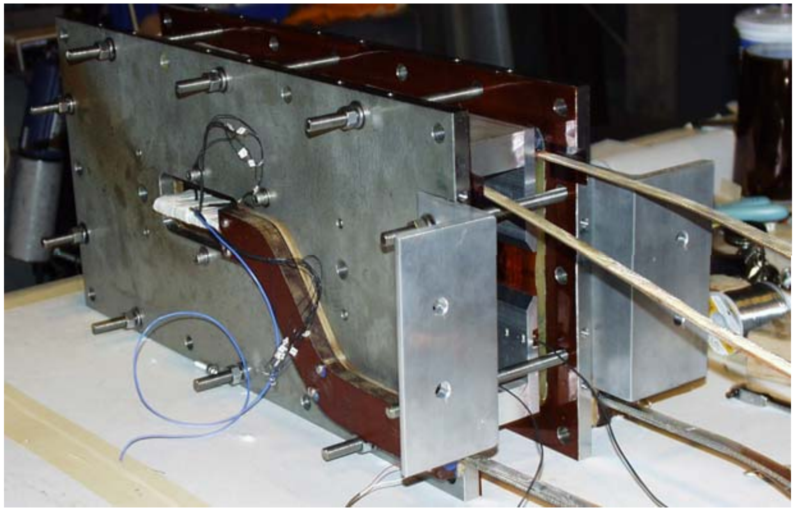
Coil / Magnet	Cable Description	Magnet Description	I_c (A)	J_e(sf)[J_e(5T)] (A/mm^2)	Self-field, T
CC006 DCC004	0.81 mm wire, 18 strands	2 HTS coils, 2 mm spacing	560	60 [31]	0.27
CC007 DCC004	0.81 mm wire, 18 strands	Common coil configuration	900	97 [54]	0.43
CC010 DCC006	0.81 mm wire, 2 HTS, 16 Ag	2 HTS coils (mixed strand)	94	91 [41]	0.023
CC011 DCC006	0.81 mm wire, 2 HTS, 16 Ag	74 mm spacing Common coil	182	177 [80]	0.045
CC012 DCC008	0.81 mm wire, 18 strands	Hybrid Design 1 HTS, 2 Nb_3Sn	1970	212 [129]	0.66
CC023 DCC012	1 mm wire, 20 strands	Hybrid Design 1 HTS, 4 Nb_3Sn	3370	215 [143]	0.95
CC026 DCC014	0.81 mm wire, 30 strands	Hybrid Common Coil Design	4300	278 [219]	1.89
CC027 DCC014	0.81 mm wire, 30 strands	2 HTS, 4 Nb_3Sn coils (total 6 coils)	4200	272 [212]	1.84

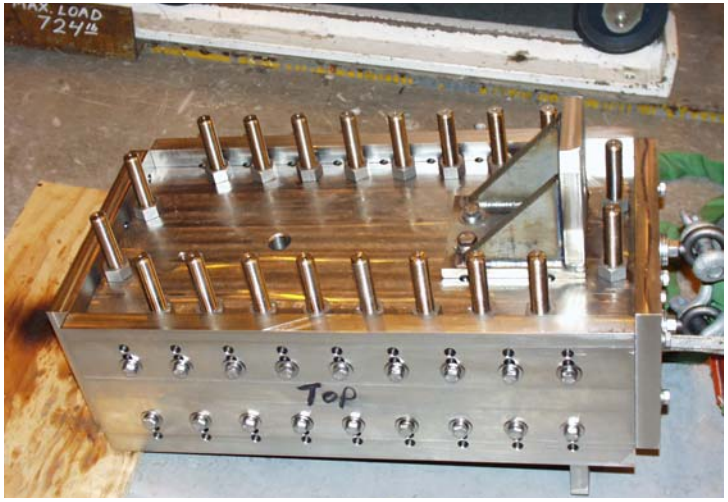
We have a number of coils to examine if they show different degradation under stress (would be good to test one from Oxford conductor, as well)



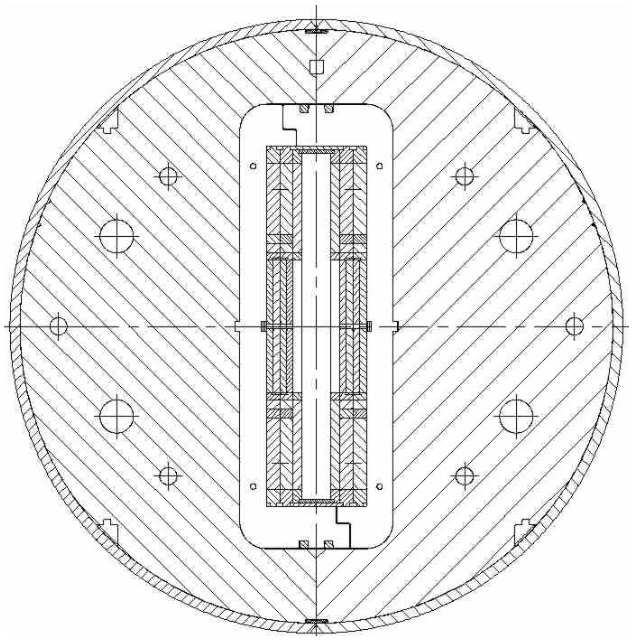
Five Accelerator Type R&D Magnets

Magnet Structures for Bi-2212





A Vehicle to Test HTS Coils in an Open Background Field Common Coil Dipole

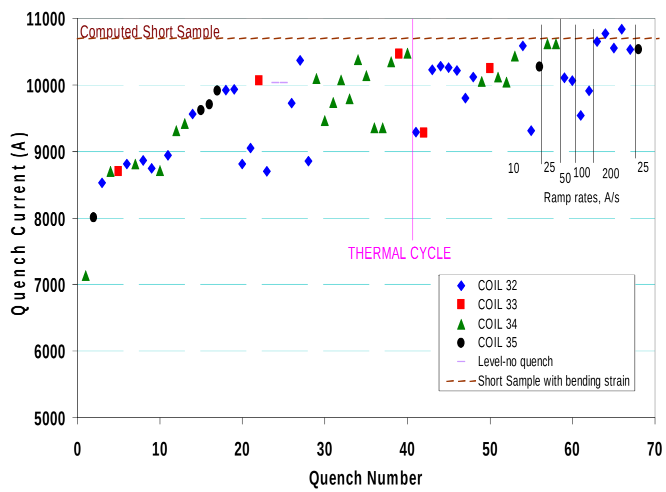


- Large tall clear space (~240 mm) for testing HTS coils in a reasonably high background field.
- In a hybrid test, HTS coils will be at ~13 T.
- Cost effective and rapid turn around as the magnet does not have to be dis-assembled for inserting HTS Coils.
- Ideal for testing various technical issues.
- Cost of putting this in service small if we limit our goal to utilizing magnet and power supplies, as is.

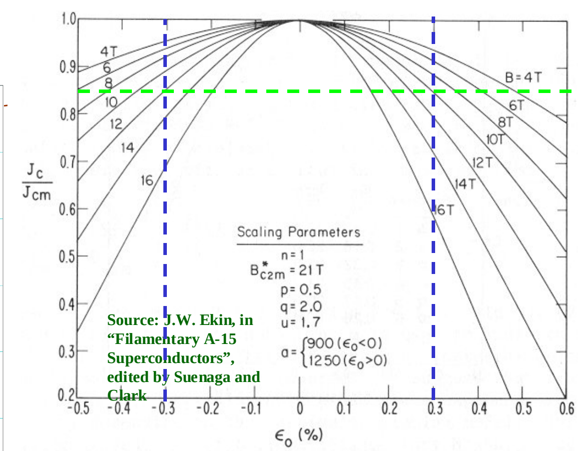
Alternate React & Wind Approach for HTS

- React & Wind is an interesting alternate for HTS magnets as it bypasses challenges associated with fine temperature control in high volume and at high temperature. Moreover, Bi2212 may not suffer the same bending strain degradation as function of field as Nb_3Sn does.
- Since we have experience in making many React & Wind coils with Bi2212 Rutherford cable, we could contribute to exploring the "React & Wind" option, in addition to "Wind & React".

Coil winding machine for brittle conductors



Quench performance of R&W Nb_3Sn dipole to the expected 10.4 T field



Relative critical-current density J_c/J_{cm} as a function of intrinsic strain $\epsilon_0(\equiv\epsilon-\epsilon_m)$ for different magnetic fields, evaluated using Eq. (3) and the typical set of scaling parameters indicated in the figure.

Bending strain degradation in Nb_3Sn. HTS may not have the same high field drawback

BROOKHAVEN NATIONAL LABORATORY

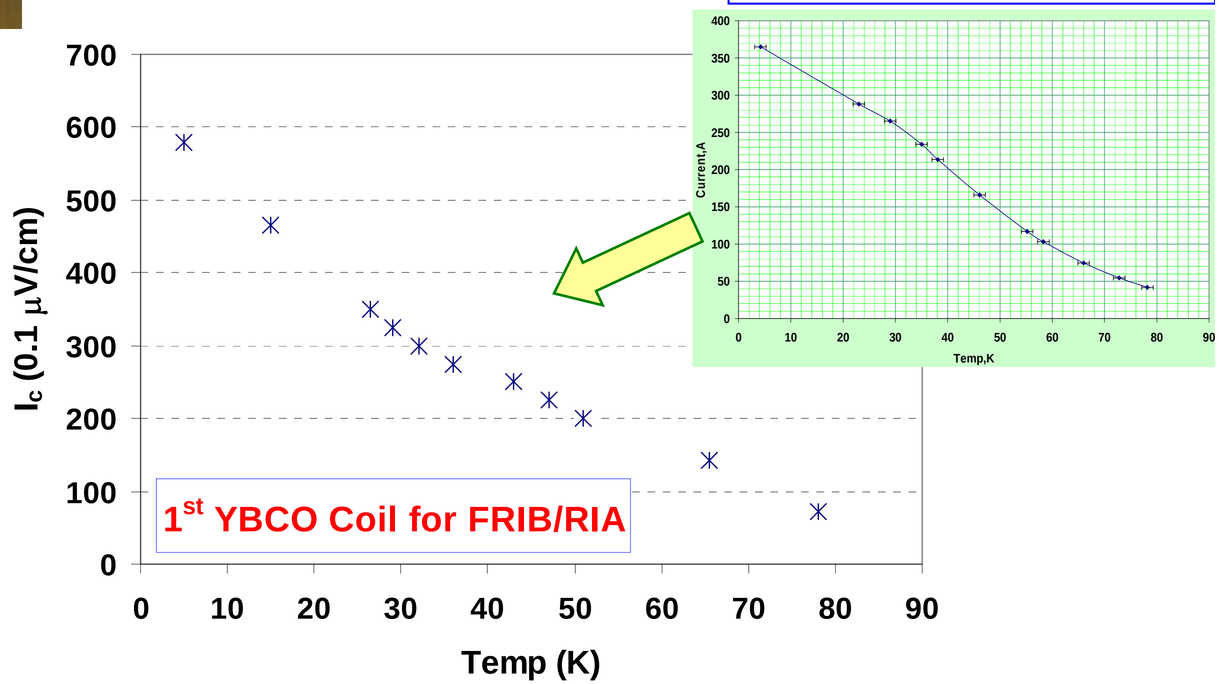
Superconducting Magnet Division

Possible Synergy with RIA/FRIB Program

After making 25 coils with 2223, RIA/FRIB program at BNL is moving towards YBCO. Even though RIA is a lower field program, there are a number of issues that are similar in the coil R&D.

Coil made with YBCO

1st series of BSCCO Coil

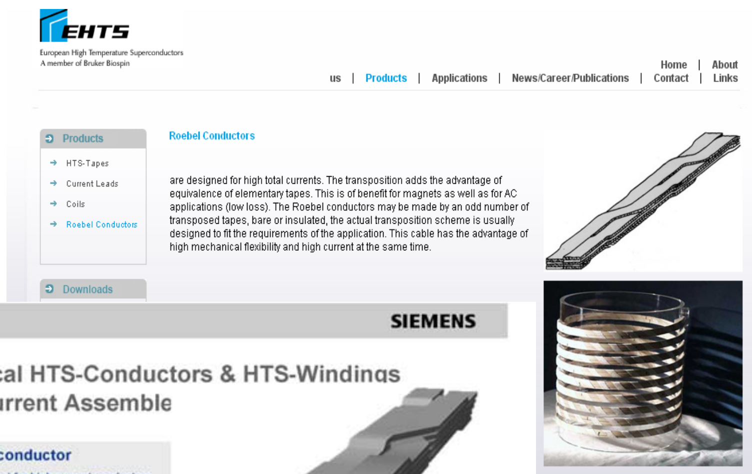


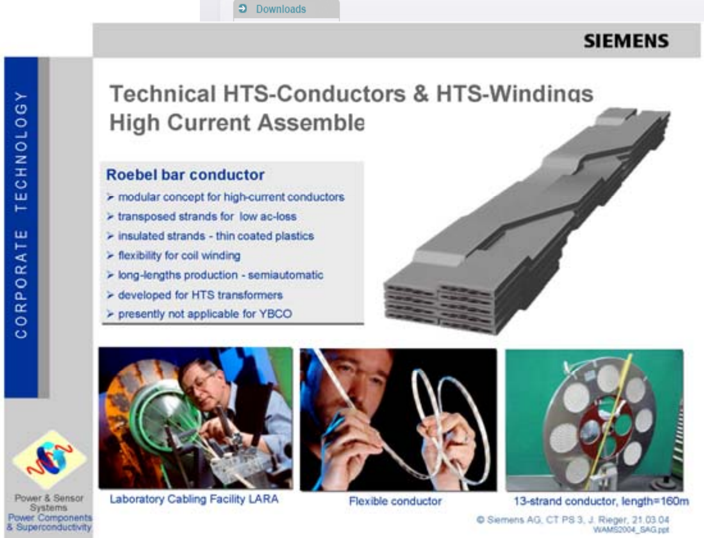
Note: YBCO is already better than BSCCO.

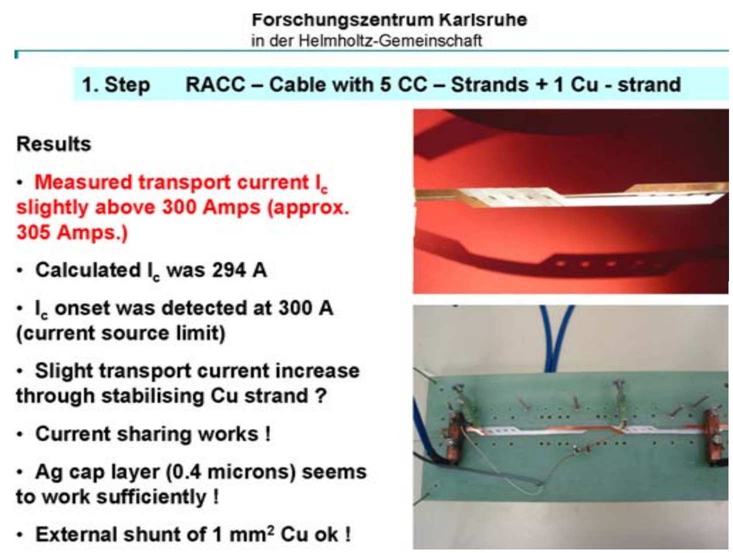
And there is still a large potential for improvements.

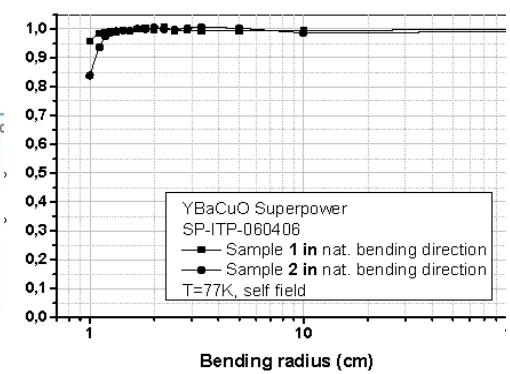
ROEBEL High Current Cable
(development of this may be useful to both programs)

- Roebel cable allows higher operating current and coupling between a number of wires (somewhat analogous to Rutherford cable with round wires)
- Roebel cable may make YBCO tape much more attractive for accelerator and other type of magnets









Summary

- We are looking forward to contribute to the national high field conductor, coil and magnet R&D program with HFS.
- We can make a number of contributions in a short time scale and with a small budget thanks to the available hardware. Examples:
  - A systematic study of the influence of the stress on the coil composite at 77K (or possibly lower temperatures) when conductor is in s.c stage.
  - Test of short Bi2212 coils in the background field of “10+T Open Dipole”.
  - Keeping alternate react & wind option open.
  - Synergy with RIA on YBCO coils.

This would allow us to show some initial technical progress towards coil and associated magnet technology, and that should be good for the future of the overall program.