Superconducting Magnet R&D

Magnet Division Activities

R&D Strategy

HTS performance

R&D Results

The Big Issue

Magnet Division activities and plans

- On-going work
  - LHC
  - Spin rotator magnet production (RHIC, FY02 completion)
  - DESY IR quad production (April/May completion)
  - RHIC shutdown support (electrical, tech)
  - SNS magnet assembly/magnetic measurements (FY03 completion)
  - Magnet R&D (ongoing)

Quad being installed into Zeus

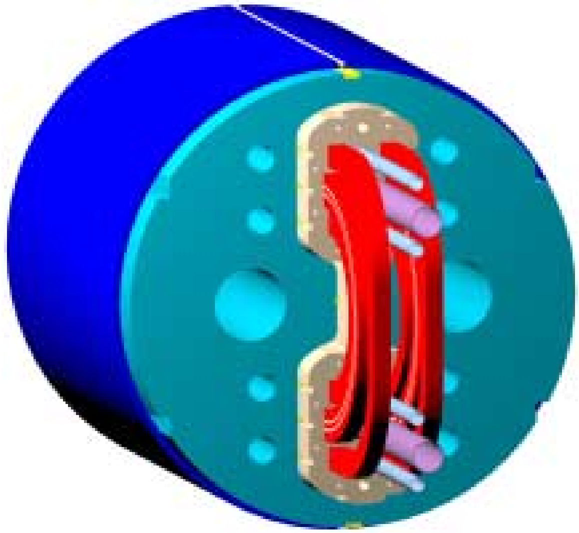
Magnet Division activities and plans

- Near future/recent starts
  - electron cooling solenoid R&D (RHIC upgrade)
  - spare magnets (RHIC)
  - GSI rapid cycling magnet R&D (3-year LDRD + collaborative support for materials/techs)
  - neutrino factory storage ring magnet R&D (2 year LDRD)
  - high field NMR (2 year LDRD, HTS materials)

Magnet Division activities and plans

- Potential future projects
  - BEPC II luminosity upgrade IR quads (based on DESY technology)
  - PEP II luminosity upgrade quads (based on DESY technology)
  - AHF (Advanced Hydrodynamic Facility - LANL proton tomography project). Final lens magnet development and production (-> FY07)
  - medical imaging ?
  - e-RHIC, muon colliders, VLHC, SC linacs etc..

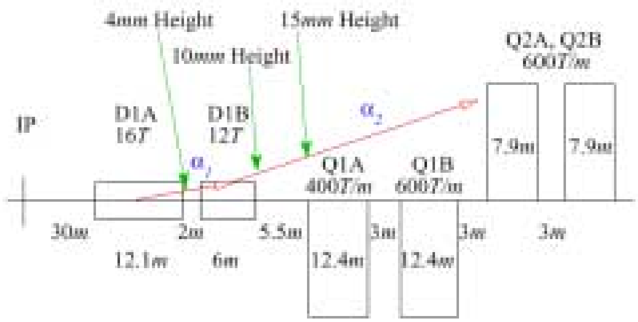
Magnet R&D strategy



- Primarily focussed on next generation materials: HTS compounds + a little Nb_3Sn
- Magnet designs based on the use of 'conductor friendly' flat coils (tapes & cable)
- Focussing on specialized applications (VLHC IR's, muon storage rings) where performance requirements dominate cost issues

R&D program is highly leveraged by the use of existing equipment and infrastructure

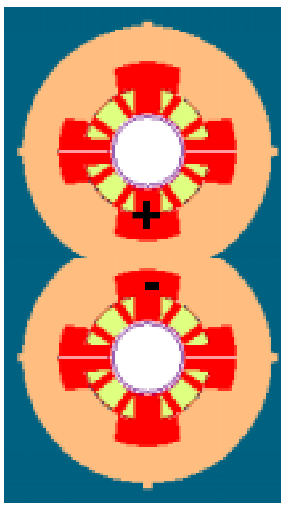
New Magnet Design For Efficient VLHC-2 Interaction Region



Optics and magnet requirements (field & aperture) depends crucially on the minimum spacing in the first 2-in-1 IR Quad (doublet optics)

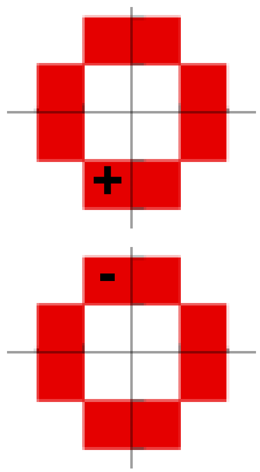
23KW of beam power radiated from the IP makes this a natural for HTS

Conventional 2-in-1 cosine theta design

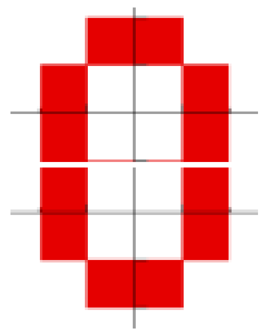


Spacing depends on the conductor and support structure requirements

Panofsky 2-in-1 quad design

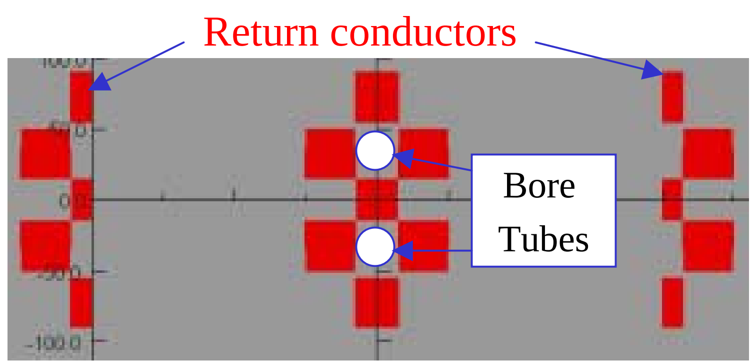


Modified Panofsky Quad



(Bo not zero)

Conductor friendly and better field quality design



Support structure and middle conductor is removed/reduced. This reduces spacing between two apertures significantly.

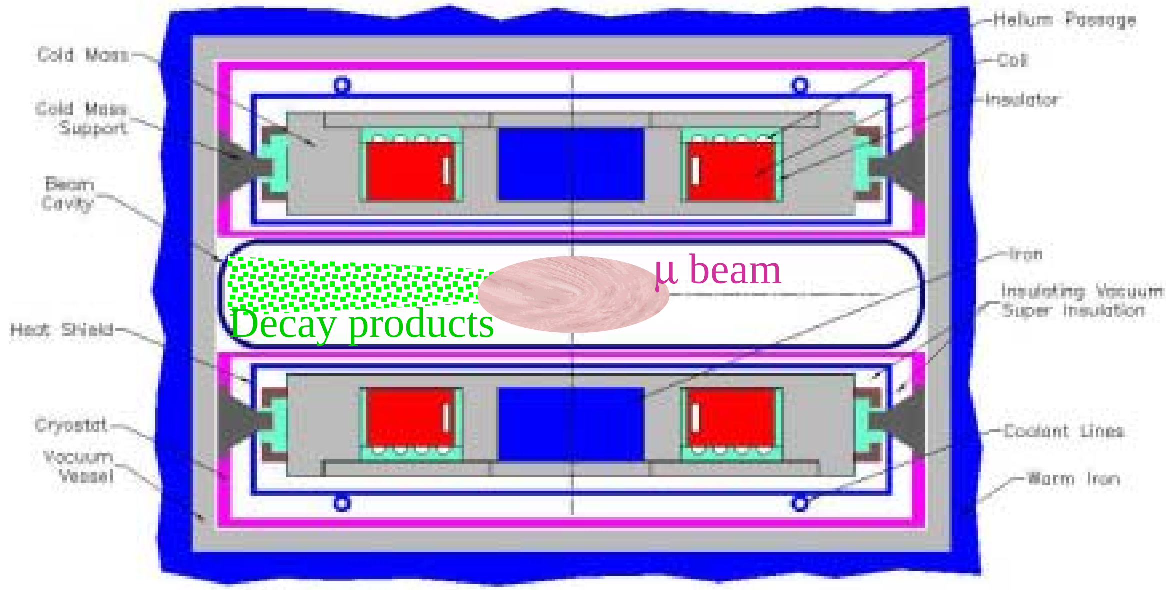
Magnet Design for ν Factory Storage Ring

Design Principles and Requirements:

Decay products clear superconducting coils, magnets can tolerate large beam power

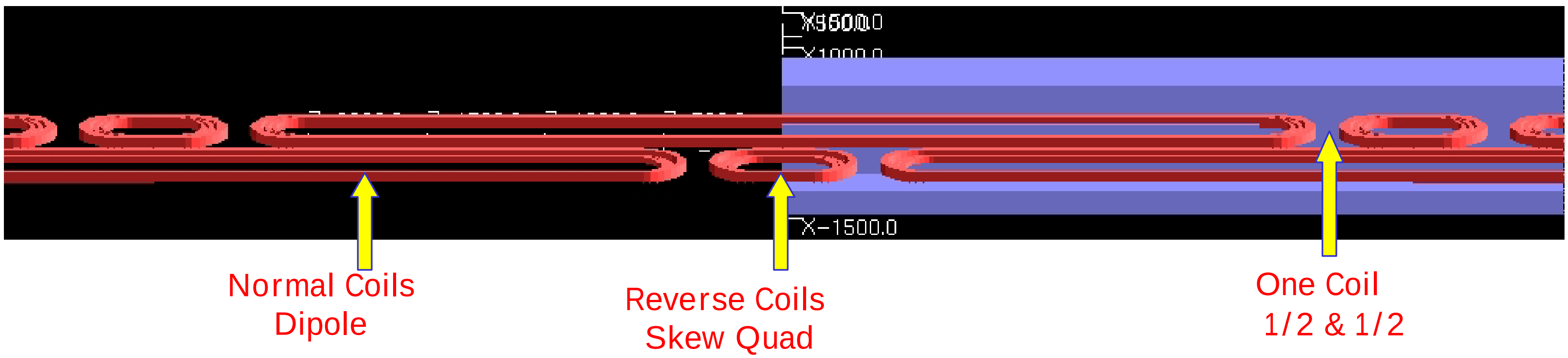
Highly compact arc structure desirable to maximize 'useful' decays

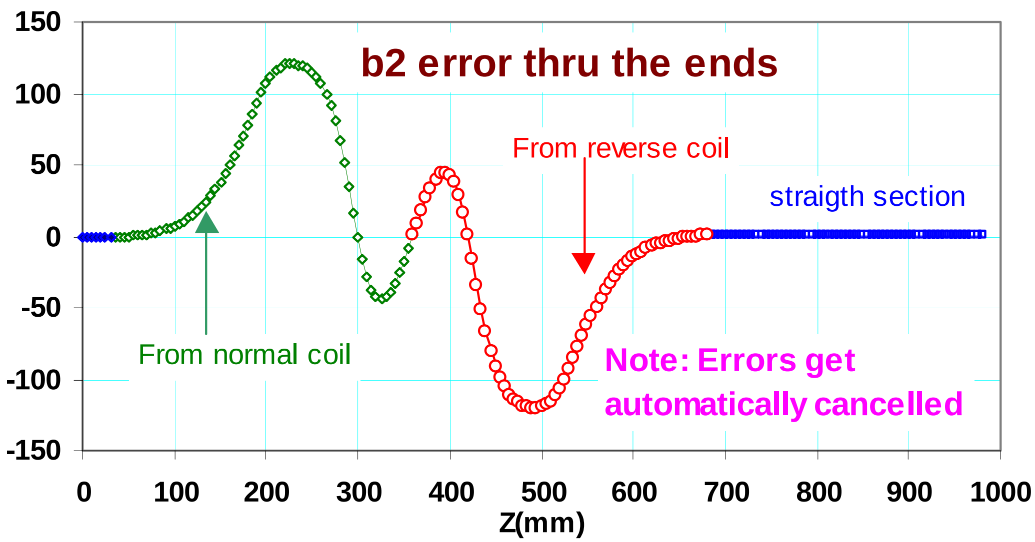
⇨ Need high field magnets and efficient machine design



Storage ring magnet design
(cold coils - warm magnet)

Efficient Magnet System Design for Good Field Quality in Body & in Ends

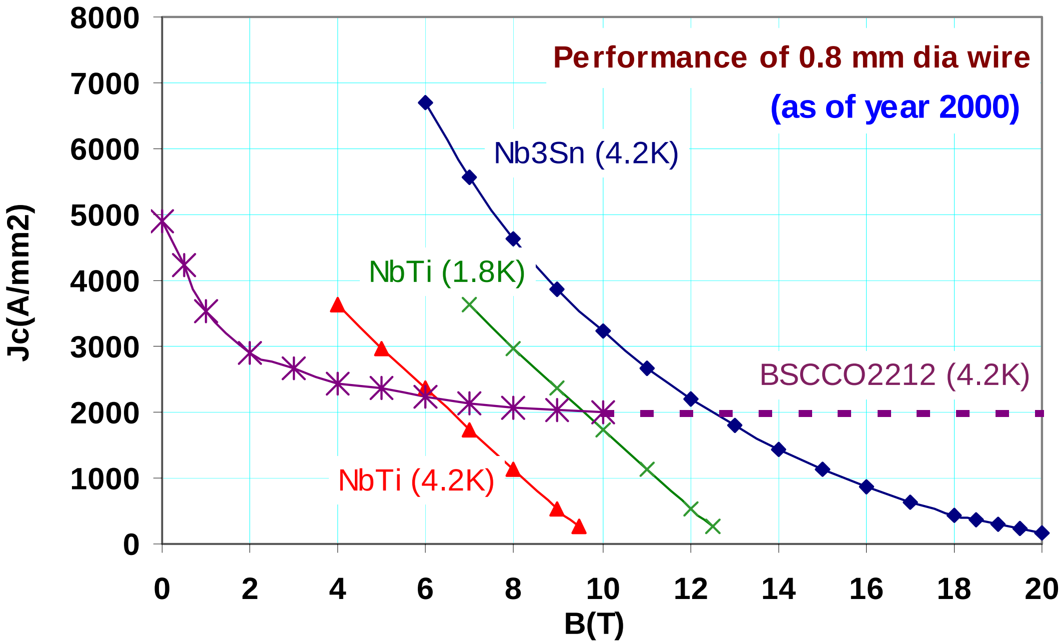




No space is wasted.

- Two normal coils makes a dipole
- Reverse field coils makes a skew quad
- Space between the two coil ends makes a combined function magnet region

Magnet R&D - Expected Performance of HTS-based Magnets



Year 2000 data for J_c at 12 T, 4.2 K

Nb_3Sn: 2200 A/mm^2

BSCCO-2212: 2000 A/mm^2

Near future assumptions for J_c at 12 T, 4.2 K

Nb_3Sn: 3000 A/mm^2 (DOE Goal)

BSCCO-2212: 4000 A/mm^2 (2X from today)

Expected performance of all Nb_3Sn or all HTS magnets at 4.2 K for the same amount of superconductor:

Year 2000 Data	
All Nb_3Sn	All HTS
12 T	5 T
15 T	13 T
18 T	19 T*

*20 T for Hybrid

Near Future	
All Nb_3Sn	All HTS
12 T	11 T
15 T	16 T
18 T	22 T

Cu(Ag)/SC Ratio

BSCCO: 3:1 (all cases)

Nb_3Sn: 1:1 or J_{cu}=1500 A/mm^2

Magnet R&D - Price of Conductor (Today)

Price of 0.8 mm diameter wire based on recent purchase orders:

- NbTi: $0.6 per meter
- Nb_3Sn: $5 per meter
- BSCCO: $20 per meter

Another cost evaluation method: price/meter/kA

⇨ Important for high field magnets

Materials - BaF_2 Process for Thick High J_c YBCO

Requirements for YBCO coated conductors:

- **Thickness: > 5 μm on both sides of a substrate**
- **J_c: > 10^4 A/mm^2 at 77K self field (and ~ 15 K, 12 T)**
- **Growth rate: > 0.5 nm/s is needed to make 1 km tape less than two weeks using a 10 m furnace (we demonstrated ~ 0.3 nm/s with high J_c and 5 μm and this is the best value so far.)**

In order to improve upon this situation, we are developing a new less expensive precursor deposition method.

- **1) Spray a nitrate H_2O solution with Y, Ba, Cu ions on a hot substrate**
- **2) Fluorinate the film by heating in a F containing gas. This makes the coating a mixture of a (Y,Ba) oxy-fluoride and CuO. (a same condition as the e-beam evaporation derived precursor.)**
- **3) Heat treat in the same way as other precursor films.**

We believe that this could provide a controlled porosity film which helps to grow YBCO at faster rates.

Materials - Magnesium DiBorate MgB_2

- **This is a metallic superconductor like Nb_3Sn.**
- **T_c ~ 39 K**
- **H_{c2} ~ 18 T at 0 K (lower than Nb_3Sn)**
- **[This is due to its large coherence length ξ. Since ξ ~ 1/resistivity, there is a possibility to increase H_{c2}.]**
- **J_c ~ 10^2 - 10^3 A/mm2 at ~ 5 K in self field.**

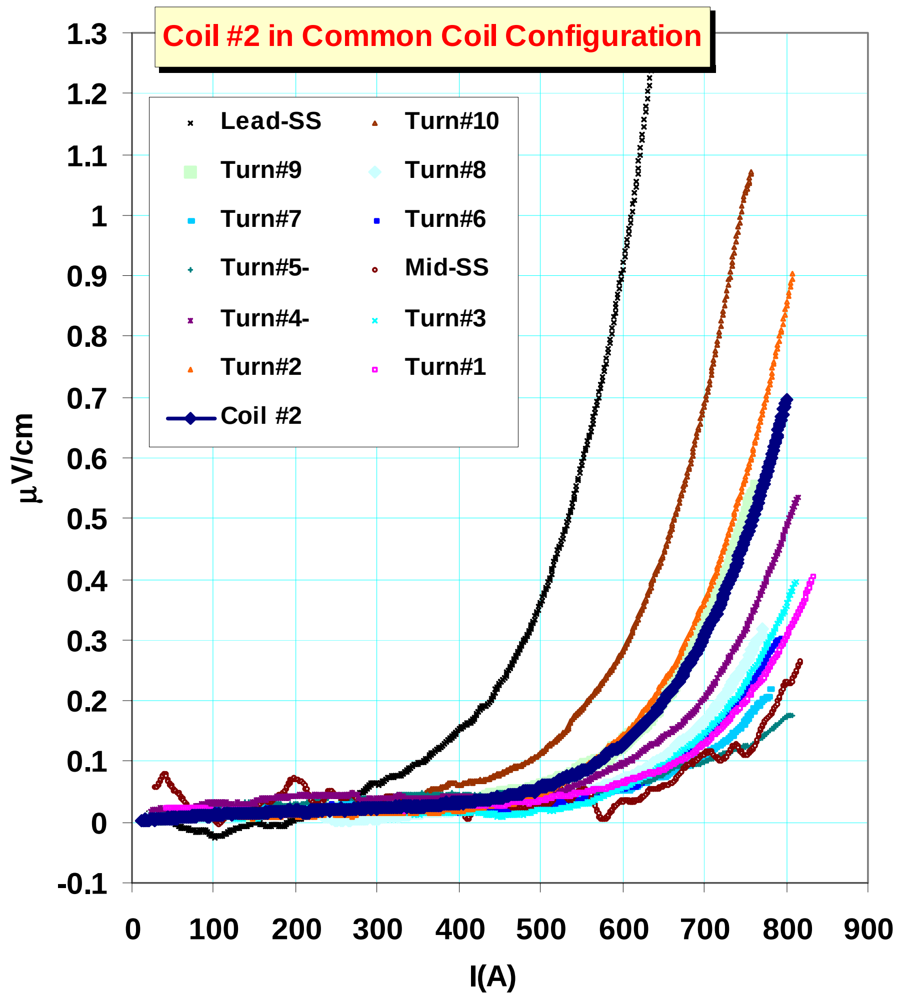
[Fabrication of MgB_2wires is difficult since it does not sinter very well, but unlike the cuprate superconductors, its grain boundaries are not weakly coupled.!!]

Status of Common Coil Magnet Phase 2 Program

- New engineering design and construction techniques developed
  - “React & Wind” HTS and Nb_3Sn coil
- Rapid turn-around demonstrated
  - 9 racetrack 10-turn coils have been built and 3 more are underway (5 HTS and 7 Nb_3Sn coils)
- Three 4.2 K and a number of LN_2 tests of common coil design performed
- HTS and Nb_3Sn cable tested as a function of field (a lot more testing on HTS)
- New top hat (for 20-25 kA current) and associated components are almost ready
- Two support structures built (9 T common coil test is expected in ~1 month)
- New thinner fiberglass insulation in collaboration with industries
  - 3 varieties with 50% less thickness (equivalent gain in conductor J_c is ~10%)
- Magnetic design of 12 T background field magnet completed; conductor ordered. The next major technical goal of this program is to test an HTS coil in a ~12T Nb_3Sn hybrid magnet.

Magnet Test Results

10-turn HTS coil. Measurements at every turn



Typical criterion for HTS to turn normal: 1µV/cm

Common coil magnet with Nb_3Sn

Ramped to 86% (power supply limit) of cable short sample limit (11kA) measured at BNL

One quench at 9.7 kA flattop

Another quench at ~6500 A at a ramp rate of 62,000 A/sec (NO TYPO)

Magnet does not quenching after ~10 ramps, tried various ramp rates.

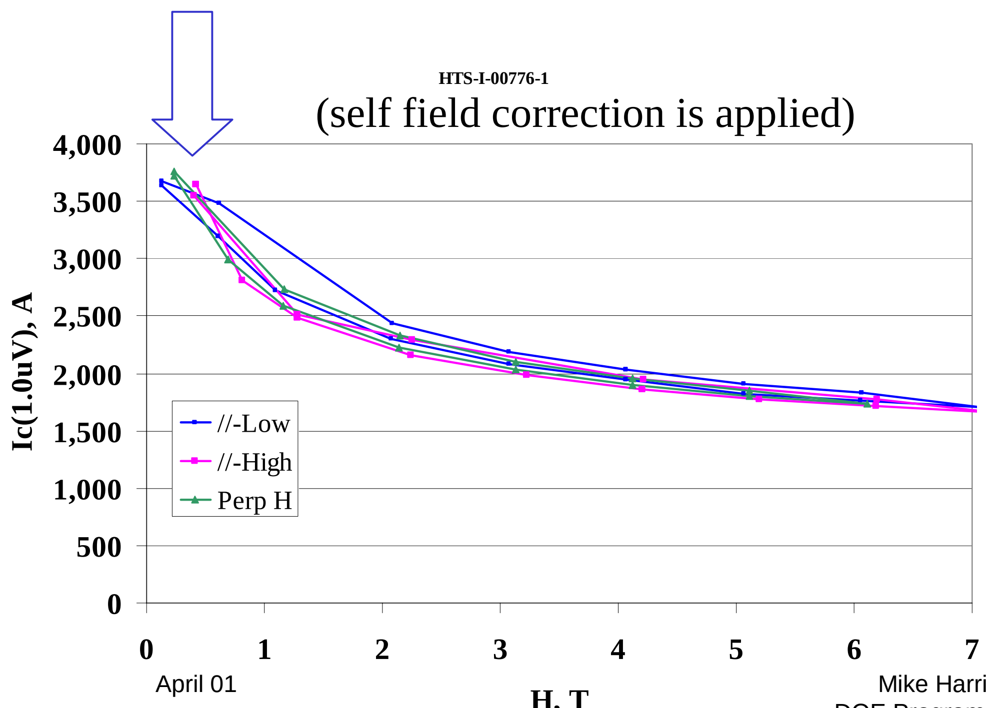
Unlike others, we do not see any large ramp rate degradation till 1500 A/sec

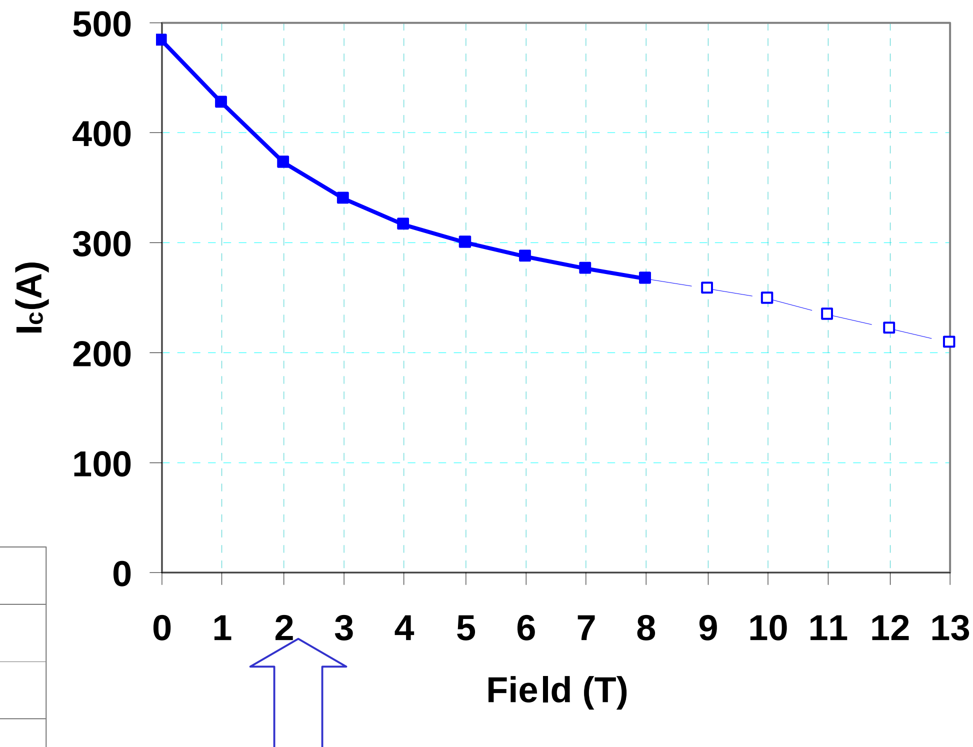
Measured Performance of HTS Cable and Tape As A Function of Field at BNL

Note: Tape and wire have about the same area. Cable has 18 wires (strands).

Measurement of "***BSCCO-2212 cable***" at BNL test facility

(Ic is better by a factor of 2 now)





Measurement of "***BSCCO 2223 tape***" wound at 57 mm diameter with applied field parallel (1μV/cm criterion)

(field perpendicular value is ~60%)

Magnet R&D

- The Big Issue
  - obviously the long term future of the BNL magnet division requires a significant magnet R&D program ($3-4M/yr.) to take shape about the FY03/04 time frame as LHC winds down. This R&D program would be (presumably) aimed at the VLHC.
  - This will depend very largely on this years HEPAP sub-panel. The sub-panel is charged with a 20-year time period.
  - If there is no long range commitment to U.S. SC magnet technology then we ponder 'wither goest' !

"Accelerator R&D is the lifeblood of our science, creating the tools that are needed to explore the physics of matter, space and time. Current funding levels for R&D toward new accelerators are endangering the near and far term future of the field and should be increased substantially" - Gilman sub-panel