Themes of Magnet Division Work

Superconductors: Nb_3Sn, HTS
Direct Wind
Accelerator Integration
Rapid Cycling Magnets

P. Wanderer

S&T Committee Program Review of Magnet Division

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Work with Superconducting Materials

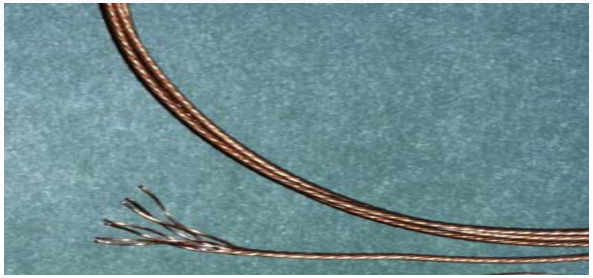
- Fundamental building blocks for magnets.
- Assure conductor properties taken into account in magnet design
  - Also cost, schedule
- Push vendor R&D toward needs of accelerator magnets
- Test strand (wire), cables, feedback to vendor

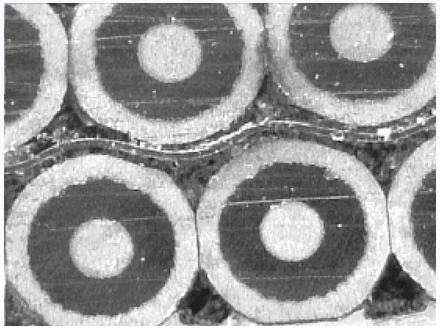
Superconductors for Accelerators

	Critical Field Bc2 (4.2 K)	Critical Temp Tc	Ductile	Accelerator Use
NbTi	10 T	9 K	Yes	RHIC, LHC, Tevatron, HERA-p
Nb_3Sn	25 T	18 K	No	LHC Upgrade (LARP)
HTS	> 40 T	80 - 100 K	No	RIA, NSLS VUV dipole

NbTi – the old reliable

- All existing accelerator magnets – NbTi
  - LHC (1.8 K) has pushed NbTi to the limit
- Work at BNL:
  - Rutherford Cables: Most LHC cables acceptance-tested at BNL; work now complete
  - 6-around-1 cable, 1 mm diameter: Flexibility essential for "direct wind" coils
  - Rutherford Cables with core: To reduce cyclic energy loss, for fast-pulsed magnets in GSI's design for its new facility, FAIR.





Nb_3Sn – the step beyond NbTi

- Nb_3Sn potential compared to NbTi
  - Higher Bc2 $\Rightarrow$ higher accelerator energy or luminosity
  - Higher Tc $\Rightarrow$ more radiation tolerance
  - Brittle after reaction at 700C
    - Options for magnet coils: wind & react (W&R), react & wind (R&W)
  - Issues: conductor stability, filament diameter (cf. Ghosh's talk)
  - Available from industry
- BNL work is part of LHC Accelerator Research Program (LARP)
  - Collaboration with Fermilab and Berkeley magnet groups
  - R&D toward upgrade of final focus quads in LHC interaction region (IR)
  - CERN will decide path for LHC upgrade in 2009 $\Rightarrow$ R&D has started
  - BNL has leadership of LARP conductor program
    - Material evaluation – meets specifications for LARP magnets
    - Material procurement – a year in advance
  - (BNL also building LARP magnets)

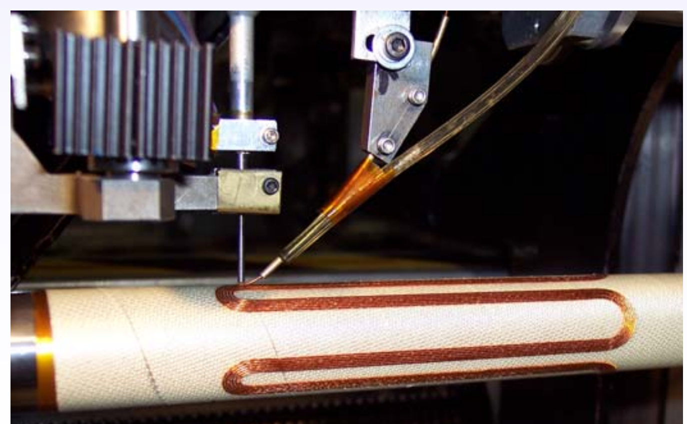
High Temperature Superconductors (HTS)

- HTS Materials:
  - BSCCO-2212 (cable) – commercial R&D
  - BSCCO-2223 (tape) – commercial product
    - One US vendor, available for several years
  - YBCO tape – "coming soon" commercially
- Compare to low temperature superconductors (LTS), e.g., NbTi
  - Advantages: higher Bc2, Tc ⇨higher operating temperatures, high heat load environment
  - Disadvantages: brittle, expensive, low current density
- Example of new things to learn for accelerator magnets
  - Quench protection (avoid overheating conductor)
  - How to splice one coil to another
- Have designed and built DC magnets with HTS coils for accelerator facilities (i.e., RIA)

Direct Wind - a unique capability

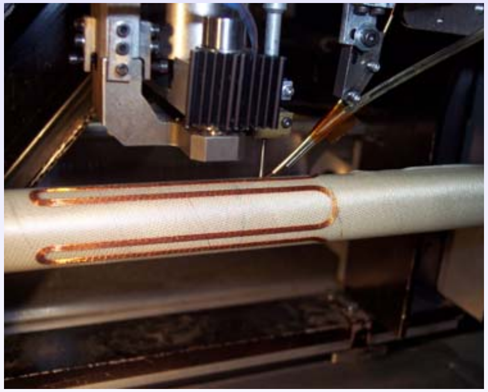
Development of Direct Wind Technology (1)

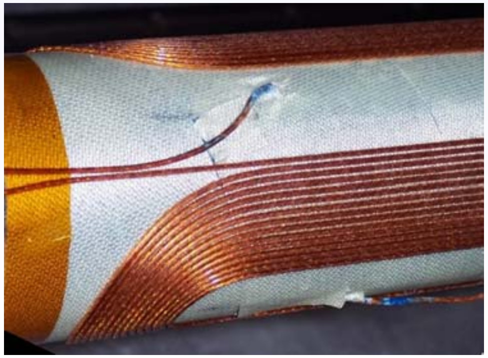
- RHIC correctors – challenge: mass production
  - Adapt technology for bonding wire to printed circuit boards
    - CAD/CAM: coil design ⇒ winding machine
  - Bond insulated superconducting wire to flat Kapton substrate
    - Ultrasound used to bond epoxy
  - Wrap substrate around cylindrical support surface
  - Overwrap with Kevlar or fiberglass
- RHIC helical dipoles
  - Build CAD/CAM machine to wire 1 mm cable on cylinders
  - (Ultimately, wound dipoles by hand.)



Development of Direct Wind Technology (2)

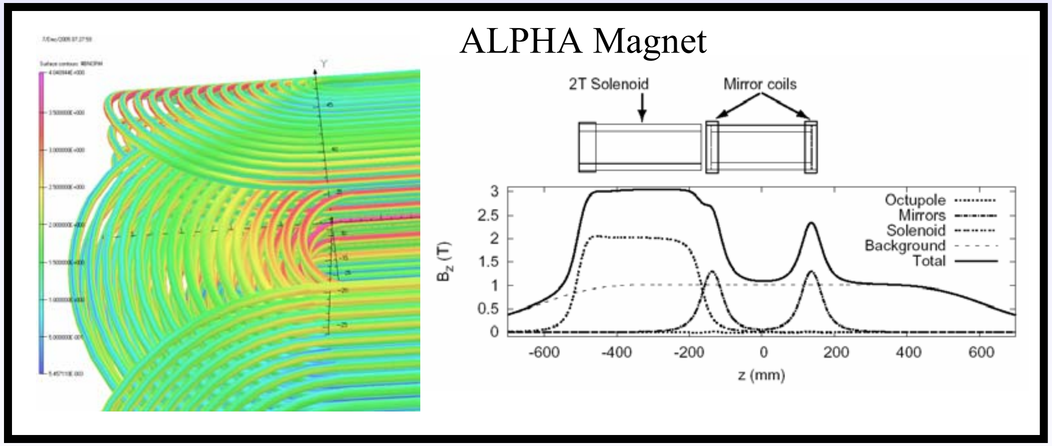
- DESY: IR magnets for HERA II:
  - Build 2nd CAD/CAM winding machine.
  - Learn to wind multiple layers of same coil type, and multiple coil types, on tapered support tube
  - Learn to improve field quality by designing layer "n" to compensate for imperfections measured in layer "n-1"
  - Magnets have operated successfully since 2002
- IHEP (Beijing): IR magnets for BEPC II
  - Implement "Serpentine winding" along with dual-layer coilset windings (cf. Gupta's talk)
    - Integral harmonics from coil ends are ~ 0 (i.e., no design effort needed here)
    - No extra radial space needed for leads
  - Add capability of winding complex (anti)solenoids
- ILC final focus quad QD0:
  - Learn to wind cable at small radius (~ 10 mm tube)
  - Implement "self canceling" quad concept

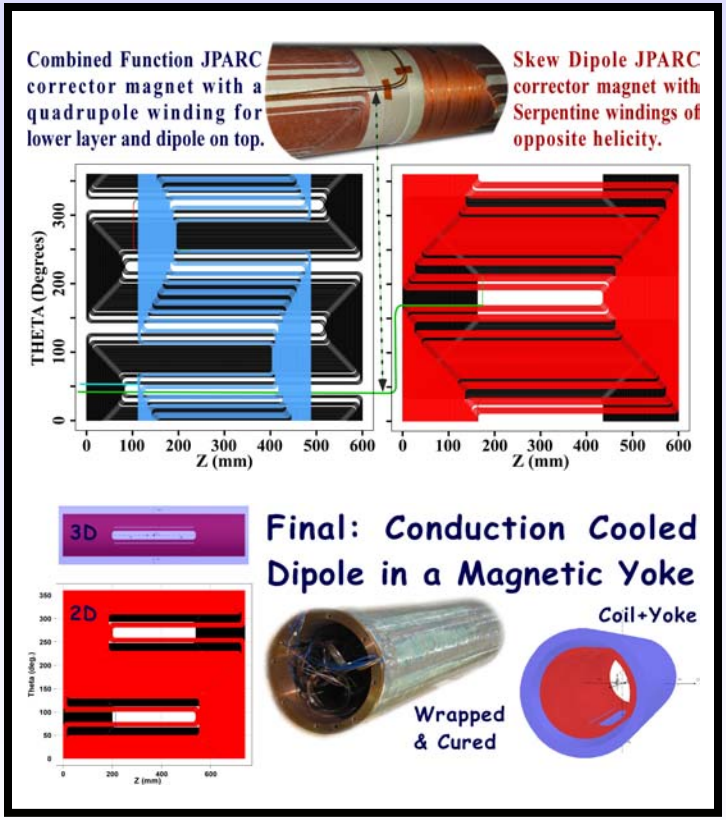




Direct Wind Scope

- Direct wind ⇒
  - o Compact, cowound coils
  - o Multiple layers
  - o Arbitrary coil patterns





Direct wind experience ⇒

Several likely new projects (some listed later in this talk)

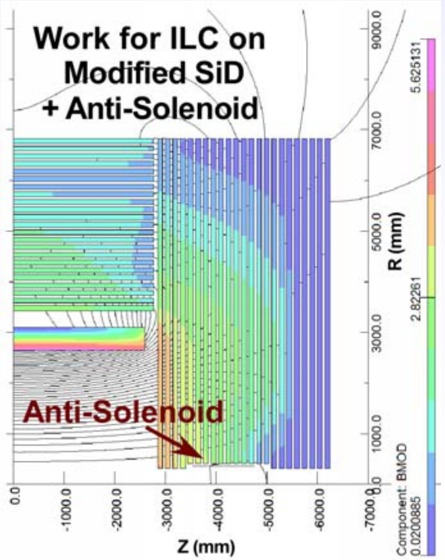
Many preconceptual discussions about magnets and accelerators

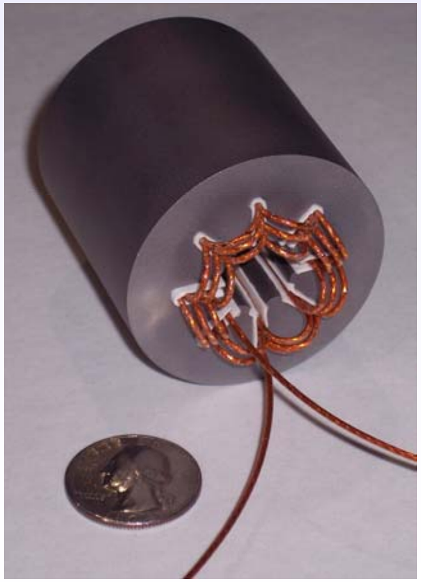
Integrated Design

Magnets + Accelerator Optics

Integration of Accelerator and Magnet Design

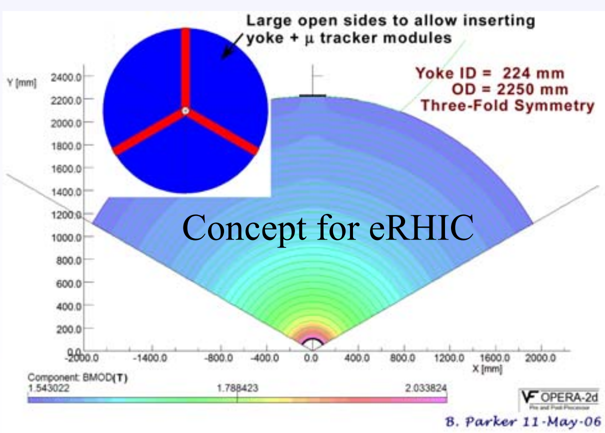
- Historically - RHIC
- Present – Direct Wind
  - Includes cryostat, warm-cold transitions and specialty magnets
- Staff members with expertise in both areas:
  - Brett Parker (direct wind CAD), Mike Harrison, Steve Peggs
- Rapid iteration of magnet design and accelerator optics design
  - Separate essential from nice-to-have features
  - Can generate new ideas

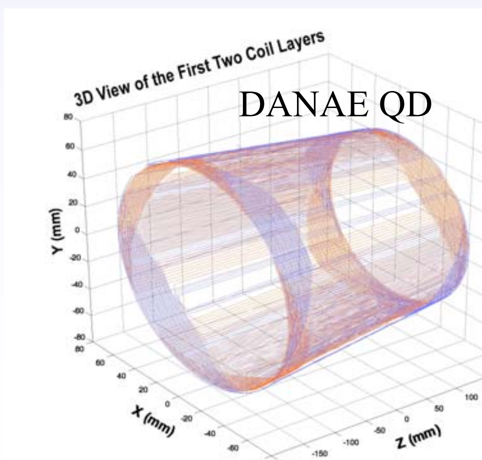


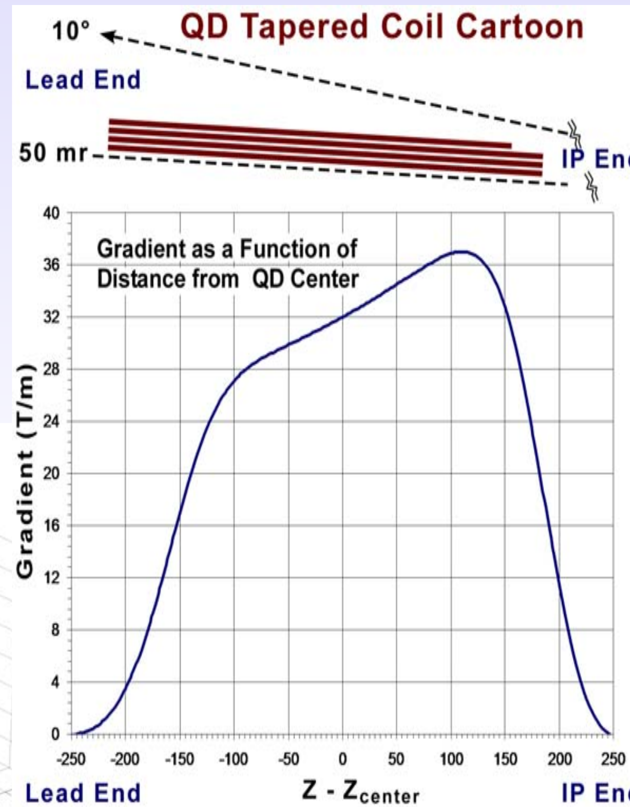


Examples of Integrated Designs

- Direct Wind originally developed for winding on cylindrical surfaces
- HERA II upgrade: magnets inside existing detectors ⇒ tapered support tube with multifunction coils
- Discussions for other interesting IR magnets:
  - eRHIC (original IR optics, the beam separation magnets and new ideas for experimental magnet)
  - Danae (upgrade of Italian e+e- collider Dafne)
  - Super-Flavor Factory (see recent preprint of J. Seeman *et.al.*, from the *Flavor Physics and CP Violation Conference*, Vancouver, 2006)

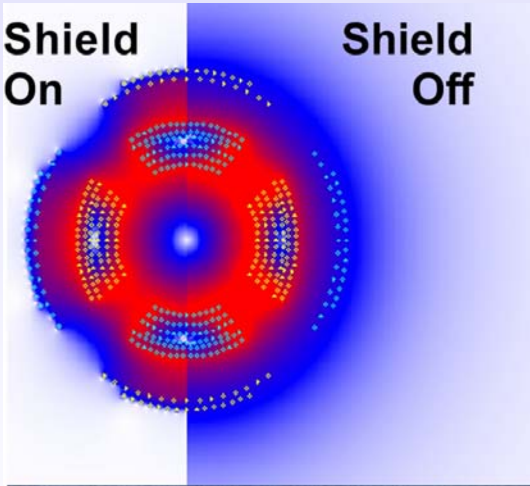


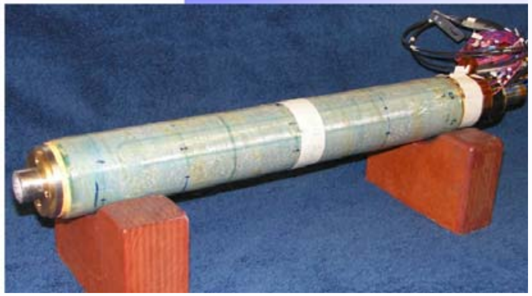




Example of Integrated Design: ILC

- ILC interaction region (IR) magnets for large crossing-angle IR.
- Need to vary ILC energy + required field strength $\Rightarrow$ superconducting magnets.
- Magnets + cryostat nearest the interaction point (IP)
  - Initial magnet designs for 20 mrad crossing angle
  - Reduce crossing angle to 14 mrad by making magnets to be self-shielding. Redesign includes "self-canceling" winding on the quadrupole nearest the IP. Our redesign also preserves the option for $\gamma\gamma$ expts.





- Several other IR magnets designed:
  - Detector Integrated Dipole (DID) to correct effect of detector field due to beam collision angle
  - "Tail-folding" octupoles focus beam halo without impacting core $\Rightarrow$ open up collimators (cf. Anerella)
  - Antisolenoid to cancel effects of detector solenoid on the beam that are independent of the crossing angle

Fast-pulsed magnets

Fast-Pulsed Magnets: GSI

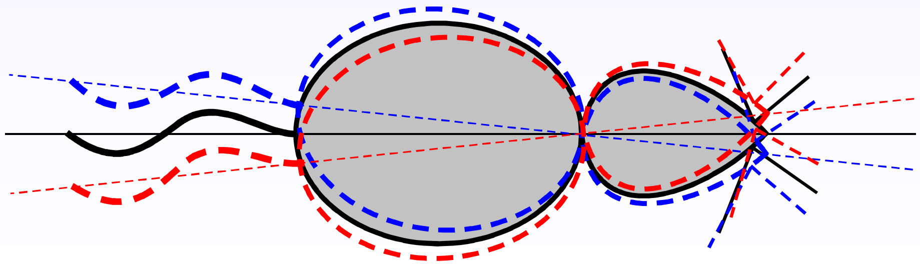
- GSI (Darmstart) is designing a new heavy ion and antiproton facility with two (!) fast-pulsed superconducting accelerators (FAIR)
- The initial design of one accelerator (SIS200) called for magnets with central field 4 T and 2 T/s ramp rate
  - Compare RHIC arc dipole: 4 T, 0.06 T/s
- For GSI, BNL designed a model SIS200 magnet by modifying RHIC arc dipole components to reduce cyclic energy loss
  - Modifications of NbTi strand, cable, cable insulation
  - Modifications of most metal parts of cold mass
  - Magnet operated well.
- BNL built systems to measure the field and energy loss of fast-pulsed magnets. Fast-pulsed field measurement unique to BNL. CERN wants our help to build a similar system. (cf. Jain's talk)

Fast-pulsed magnets for other uses

• CERN's upgrade options include fast-pulsed magnets in the injector chain (PS, SPS).

• BNL proposal to upgrade AGS to a neutrino factory included fast-pulsing of the present magnets.

• NMR for study of metabolic functions in "awake" (i.e., non-sedated) animals (i.e., rats) possible by mounting fast-pulsed dipoles inside 4T NMR solenoid, powering dipoles so that the direction of the resultant field follows the motion of the rat's head within 6 degrees (see figure). These dipoles, made by the direct wind method, worked well.



Additional Background Material

Recent Publications (and the other background material) at:

http://www.bnl.gov/magnets/ALD_Review/index.asp