An overall personal reflection (design to demo – existing or new)

- **On RHIC project, I worked closely with accelerator physicists and magnet engineers to use conventional cosine theta designs in many magnets. During this period worked with the team to take features of these designs to a new level, supervised to see that those features got successfully implemented (many of them are now used worldwide). Similarly on SSC magnets, I worked with other labs (e.g., Fermilab) and industry (e.g., GA) on SSC dipoles.**
- **Invented many new designs (some very different from conventional), got them funded (convinced community and wrote successful proposals), developed and managed programs to see them demonstrated at low cost.**
- **Above required a wide-ranging skills. My working style is based on clarity and open communication. I developed relations and trust with many collaborators – within magnet division and worldwide. It also required environment within the division and in the lab (confidence and support from colleagues, freedom and support from the management).**

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RHIC Magnet Program – Leading development of specific techniques

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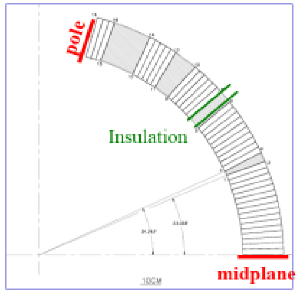
A Flexible Design from the Beginning

Design Philosophy:

- Start out with a design that allows significant adjustability for field harmonics and mechanical parameters (cable thickness, wedges, etc.).
- A flexible design is generally economical, efficient and produces magnets with better performance. I think it's a prudent approach.



Geometric: Start with a larger than required shim and midplane cap. Then adjust it, as required without changing the cross-section of the cured coil. One can also adjust the layers of wedge/cable insulation, if needed. These three parameters can adjust the first two allowed harmonics and pre-stress or cable insulation. This approach was used extensively in various RHIC magnets.

Saturation: Start out with holes in the yoke and fill them with magnetic iron rods later. Or, punch holes in yoke laminations later.

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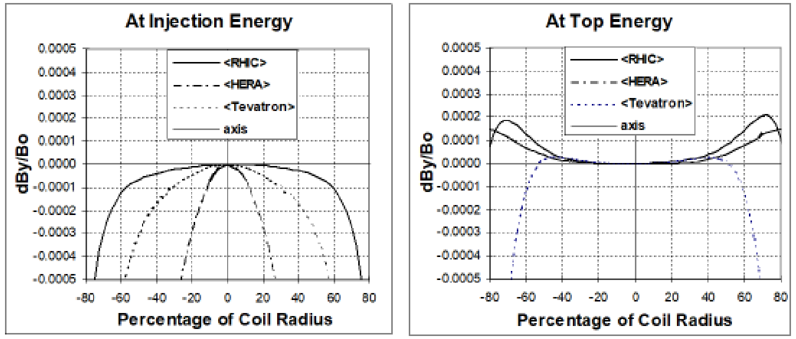
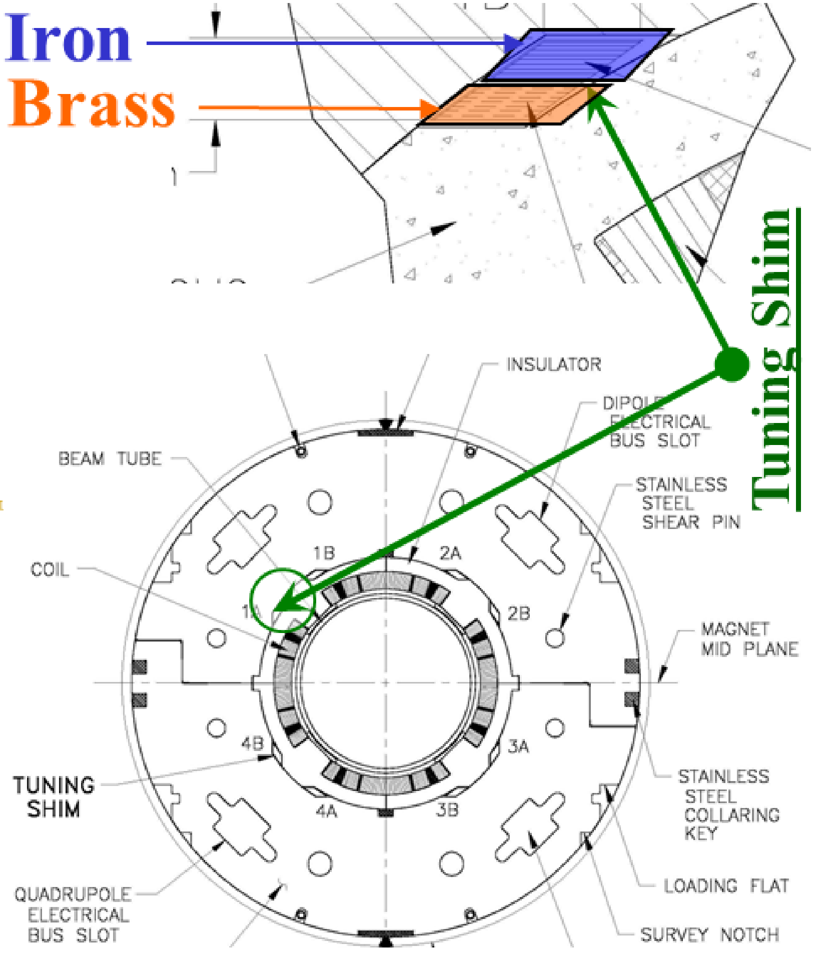
Average Field Errors on X-axis

COIL ID : RHIC 80 mm, HERA 75 mm, Tevatron 76.2 mm



- Warm-Cold correlation have been used in estimating cold harmonics in RHIC dipoles (~20% measured cold and rest warm).
- Harmonics b_1-b_{10} have been used in computing above curves.
- In Tevatron higher order harmonics dominate, in HERA persistent currents at injection. RHIC dipoles have small errors over entire range.

Tuning Shims for Very High Field Quality IR Quad



Led from the invention to the demonstration

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Saturation in RHIC Arc Dipoles

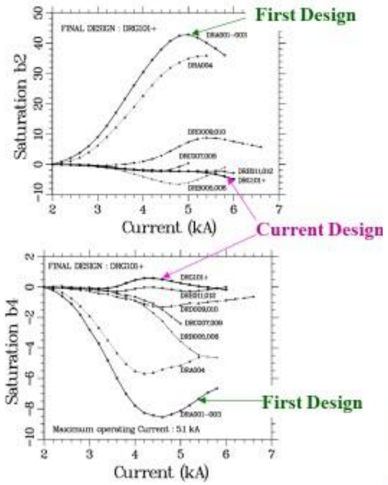
In RHIC dipoles, iron is closer to coil and contributes ~ 50% of the coil field:

3.45 T (Total) ~ 2.3 T (Coil) + 1.15 (Iron)

That's good.

But the initial designs had bad saturation, as conventionally expected when iron yoke is so close to the coils and contributes such a large fraction of coil field.

This course will teach you several techniques to reduce the current-dependence of field harmonics.



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Lecture VIII

Field Quality as a Tool to Monitor Magnet Production

Ramesh Gupta
Superconducting Magnet Division
Brookhaven National Laboratory

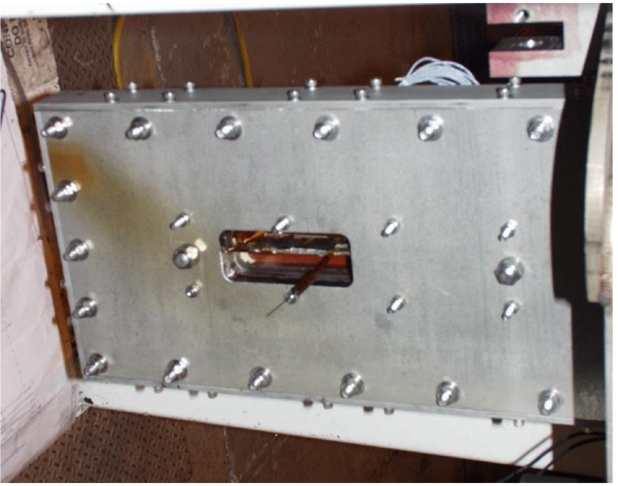
US Particle Accelerator School
Arizona State University
Phoenix, Arizona
January 16-20, 2006

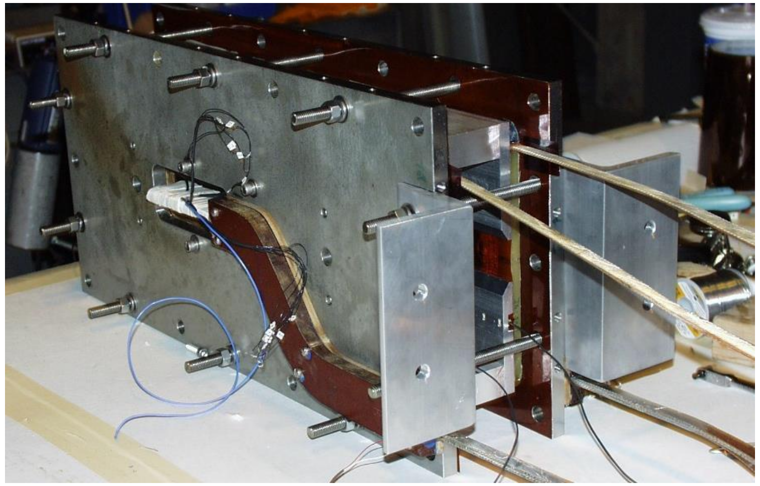
ASU Arizona State University

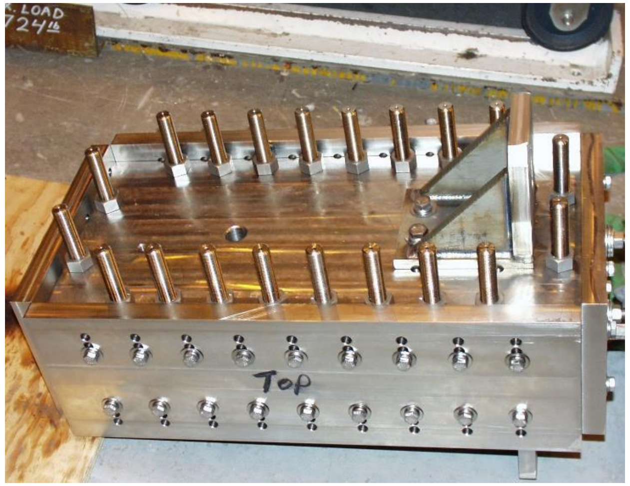
Specific R&D Program Led (example: within BNL with broader impact)

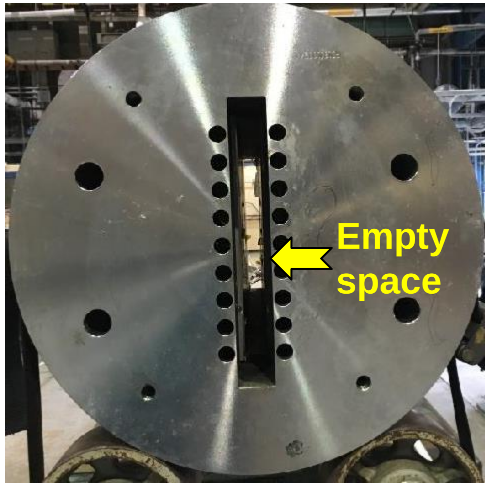
Common Coil

- Developed and supervised new design and new type of R&D program at BNL with a series of magnets (see below - DCC017 was the last magnet of that series)
- Technology developed/implemented – “React & Wind” Nb_3Sn, “React & Wind” Bi2212 (these required working and getting feedback from number of experts), demo of “HTS/LTS hybrid magnet technology”, and new rapid-turn-around R&D
- Invented and led the development of common coil design and R&D philosophy, convinced community to fund and build at many places (BNL, FNAL, IHEP, etc.)









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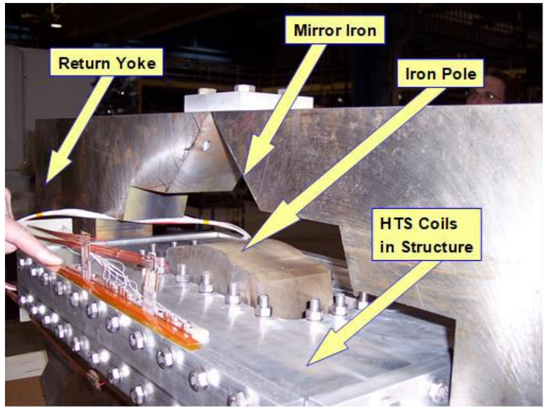
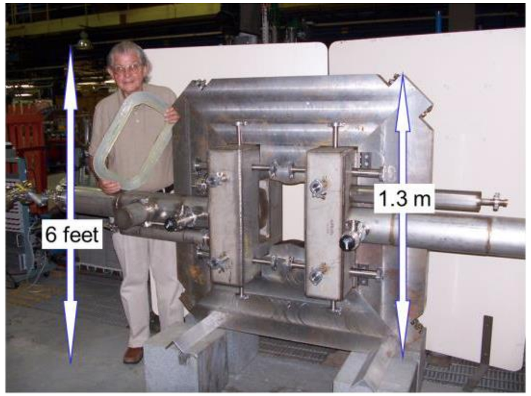
Specific Program and Design Led (with/for outside Lab)



Mirror cold iron

Mirror warm iron

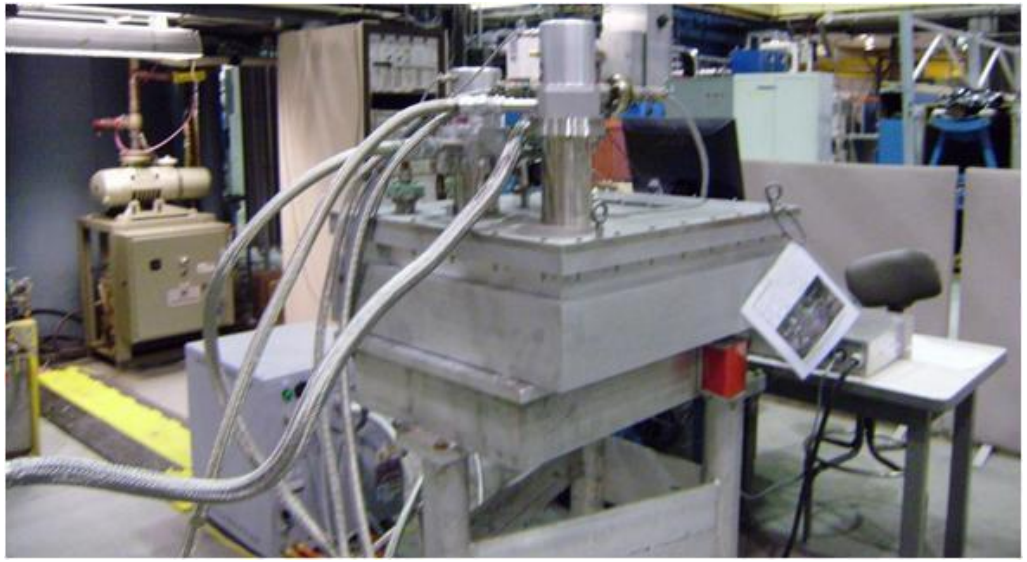


Warm Iron Design to Reduce Heat Load

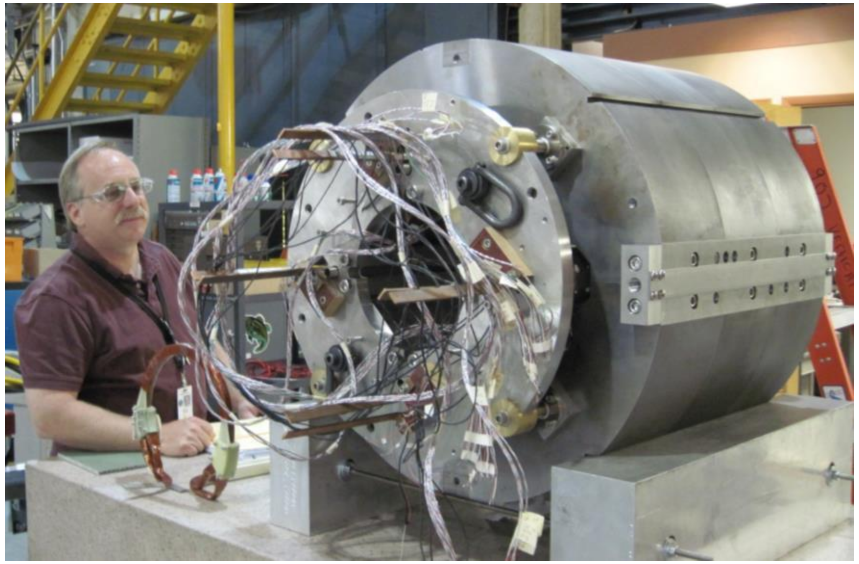
1G HTS, warm iron design

FRIB/RIA HTS quadrupole

- Three technologies, three designs (plus three variations of the first design), three shades of funding (DoE to BNL => to MSU/FRIB, transitional, DoE to FRIB => to BNL)
- Managed collaboration with MSU/FRIB and with HTS vendors when conductor was in early stages of development



Conduction-cooled design



2G HTS, cold iron design

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Magnet Projects with External Collaborators
(as an inventor and/or as a PI/leader of a new R&D project)

- **Common coil dipole**
- **Optimum integral design**
- **Overpass/Underpass magnets**
- **Open midplane dipole**
- **Modular quadrupole design**
- **HTS dipoles/quadrupoles/curved magnets**
- **High field HTS solenoids for many applications (muon collider, SMES, Axion search, neutron scattering)**
- **Superconducting shielding**
- **Recent fusion and HEP research with rapid-turn-around R&D facility with uniquely designed and built magnet DCC017**

-Ramesh Gupta, 2022