

Brookhaven Magnet Division - Nuclear Physics Program Support Activities

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RHIC Operations Support
Magnetic Measurements
Spin Program support(AGS)
E-Cooling R&D
RIA
Funding

RHIC Magnet Systems Scope

A large superconducting inventory of magnets:

- ~ 300 8cm dipoles
- ~ 400 8cm quadrupole/sextupole/corrector units
- 96 13cm IR quadrupoles
- 24 10cm IR dipoles
- 12 18cm IR dipoles
- 12 siberian snakes/spin rotators (48 helical dipole units)

Helical Dipole Spare Units

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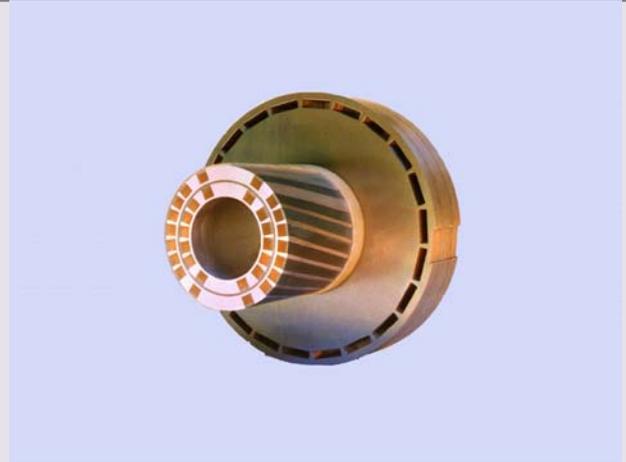


- Spare RHIC helical dipole modules
 - RIKEN funding for some materials.
 - 3 modules complete in FY03

RHIC Helical Dipoles

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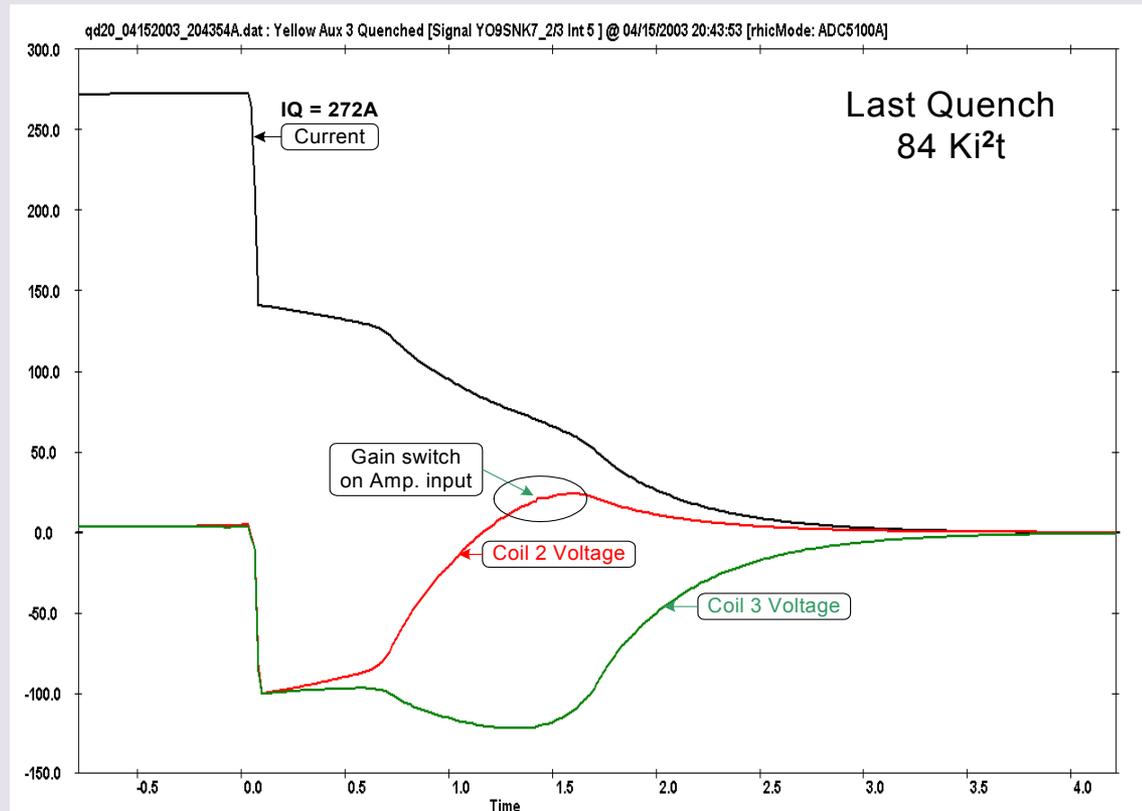
- First real indication of systematic magnet problems during the spin operation with the helical dipoles
 - HRD102 Snake (yellow sector 9) - short to ground in second module. Magnet removed from tunnel for repair.
 - HRD101 Snake (blue sector 9) - short to ground in all modules; feedthru problem. Repair in situ.
 - HRD 302 Spin Rotator (blue sector 6) - high leakage current; lead failure. Repair in situ
- Diagnosis:
 - Wire layers in slots not flat
 - Feedthru incorrectly installed
 - Leads inherently difficult



RHIC Operations - Quench Analysis

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- ~160 beam induced quenches caused a significant amount of downtime from recovery
 - Data base established to track individual magnet history
 - Ongoing quench analysis
- Many changes to both the quench detection/protection systems to make improvements in diagnostics



RHIC Magnet System Operations

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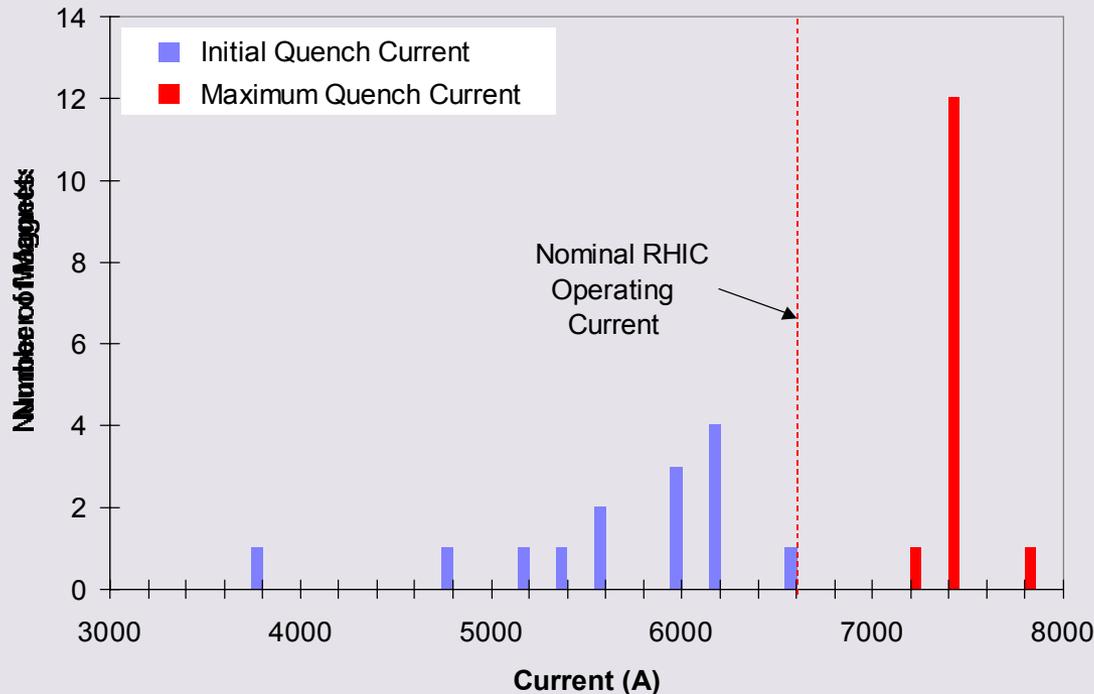
In areas of high tunnel humidity then ice balls have proved an operational issue for quench detection (leakage currents)

- Modifications include: insulation, higher temperature thermostats, lead flow adjustment, temperature monitoring (with C-AD)

RHIC DX Magnet Replacement

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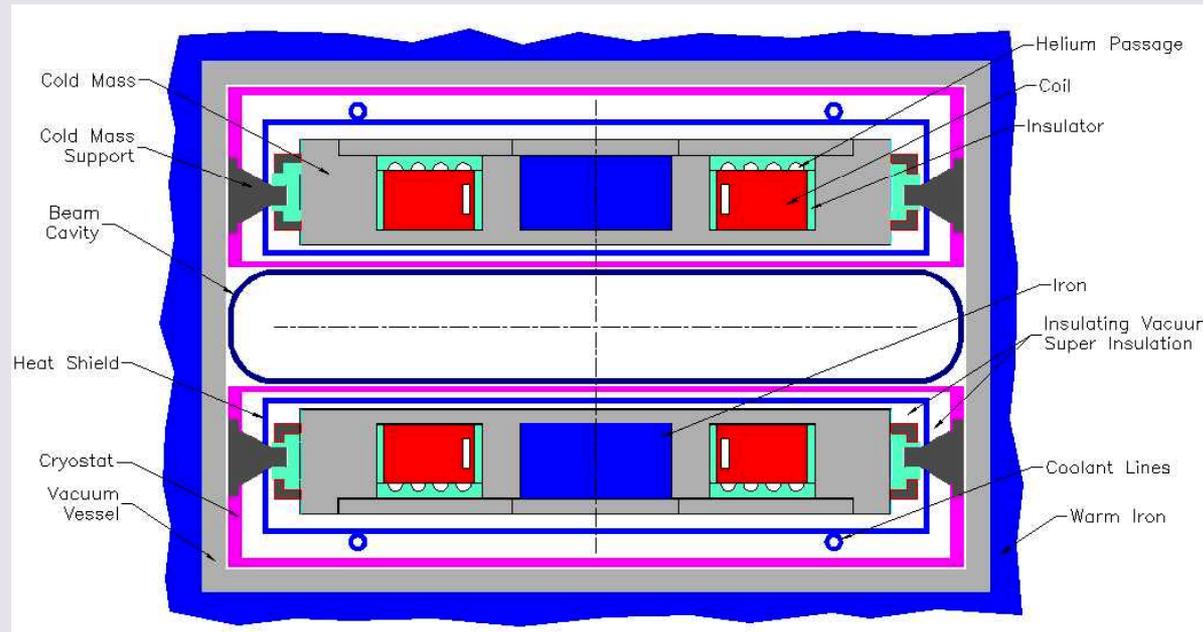
- Increased number of training quenches from the last run
- Higher energy operation



Given the ring temperature profile there is essentially no operating margin. The magnets also do not train so they need re-conditioning after a thermal cycle

RHIC DX Magnet Replacement

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Look at a 8 x 20 cm aperture element based on a possible flat coil approach (stolen from the muon collider work)
We would like to achieve > 6T nominal field based on Nb-Ti if possible. Will need to be 'slot compatible'.

Magnetic Measurements

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- FY03
 - Polarised Gas jet
 - Sextupoles, helmholtz coils
 - Data base support
 - Persistent currents v's I_{max} in the main dipoles
 - Develop ramp flexibility
 - Down ramp characteristics
 - Sextupole hysteresis at low currents (1A→20A), field reproducibility for 20mA changes
 - Better chromatic control



FY04

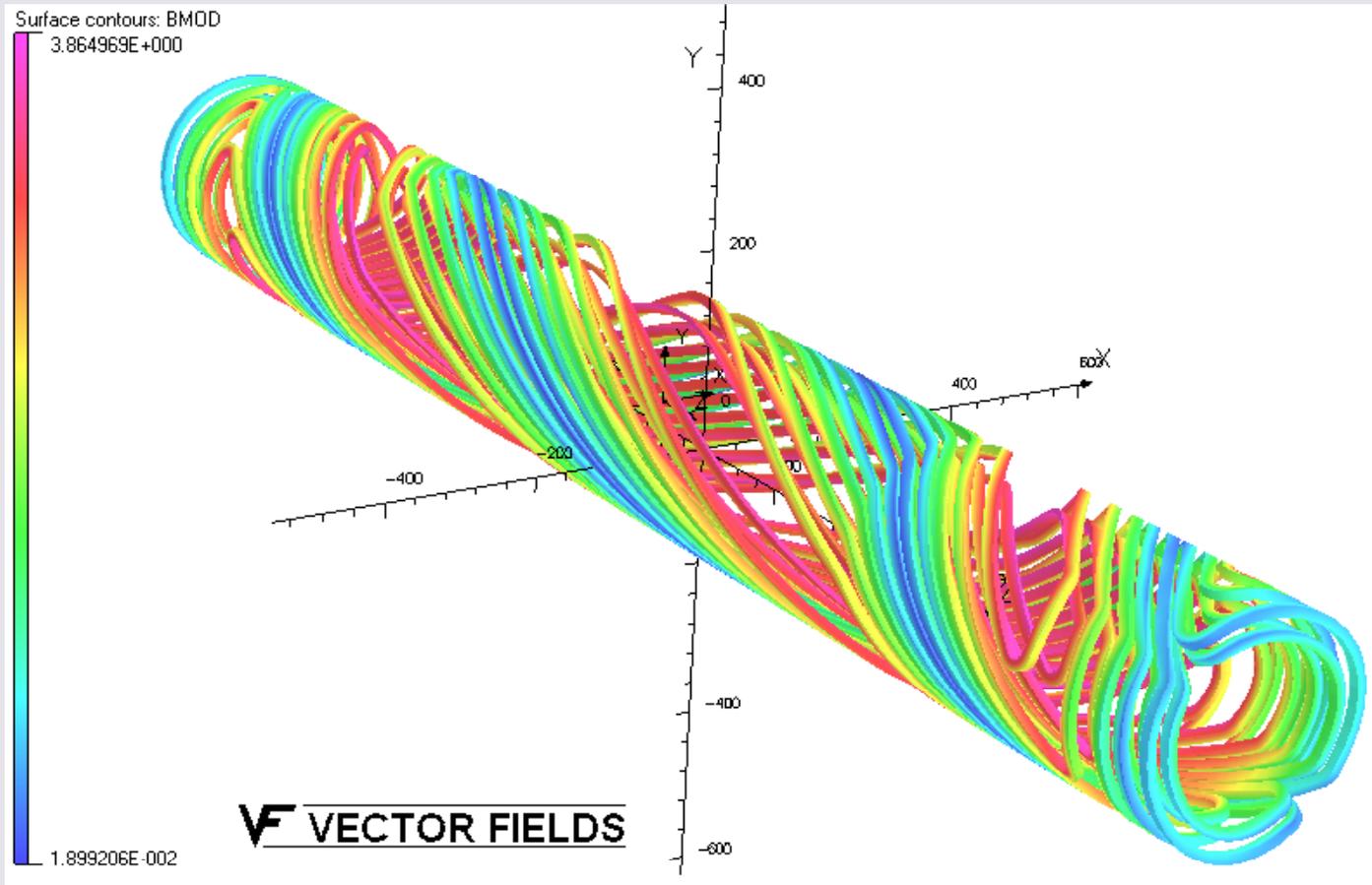
- beta-star 1/2m
 - Trim quadrupoles at higher excitation
- AGS Snake
 - Warm snake (RIKEN)

AGS Siberian Snake

- AGS Snake
 - Replace the existing 5% partial snake with a more powerful 30% one. Polarisation 45% -> 70%
 - Issues
 - Large aperture, high field (20cm, 3T)
 - No cryogenic infrastructure (cooldown, heat leak, cryo-coolers)
 - AGS beam loss induced quenching (energy removal)
 - Complex geometry (variable pitch helix)

AGS Snake - Coil Geometry

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AGS Snake - An Integrated Approach to Complex Magnetic Elements

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The philosophy behind the present approach is that

- (a) the physics calculations (3-D fields)
 - (b) design room drawings (Pro-Engineer)
 - (c) cutting of the metal (C&C Milling machines)
- will be driven by the same master file; the design room drawings.

Pros

- Expected better agreement between calculations and measurements
- Possibly detect errors in constructions before the metal is cut

Cons

- Complicated

AGS Snake Status

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Cold mass design complete. Cryostat
in progress (stand alone
cryogenics !)

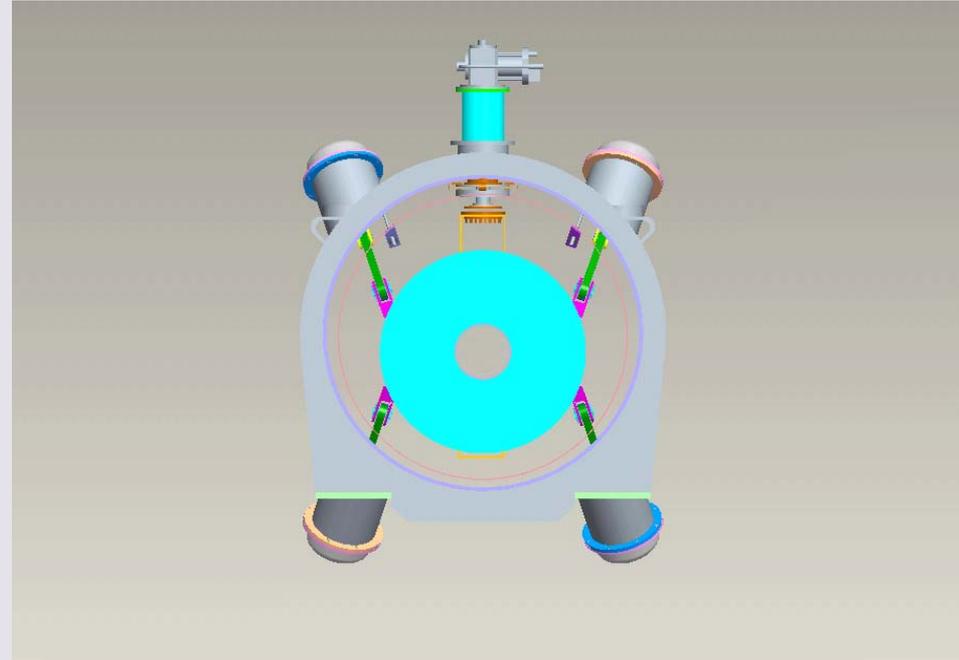
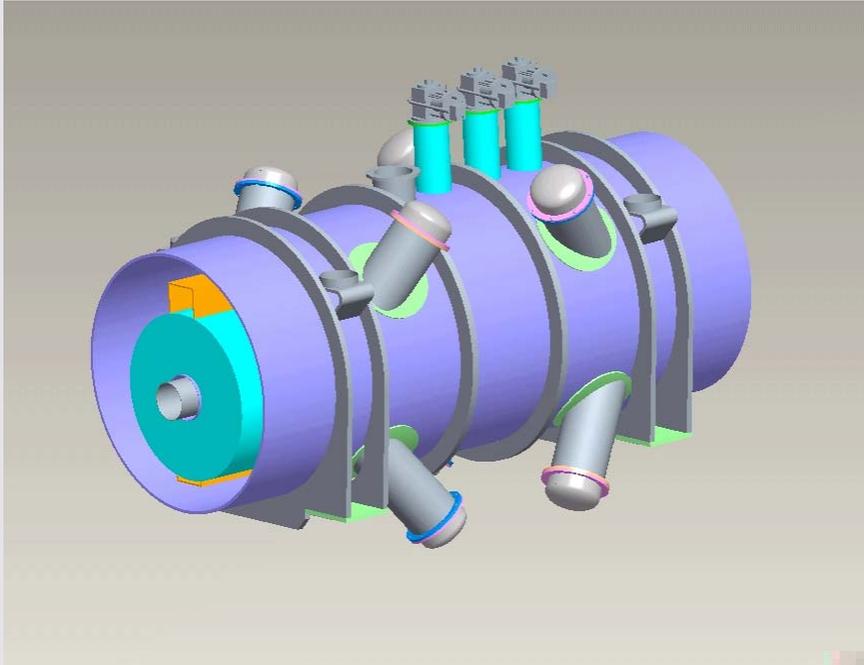
Slot insulation complete on the inner
shell. Winding starts today

Trying to decide on measuring-
correction strategy



AGS Snake Status

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Scheduled for end of construction - ready for final cold testing - on 7/28/04. This schedule has no contingency which given the complexity of the device is probably somewhat optimistic.

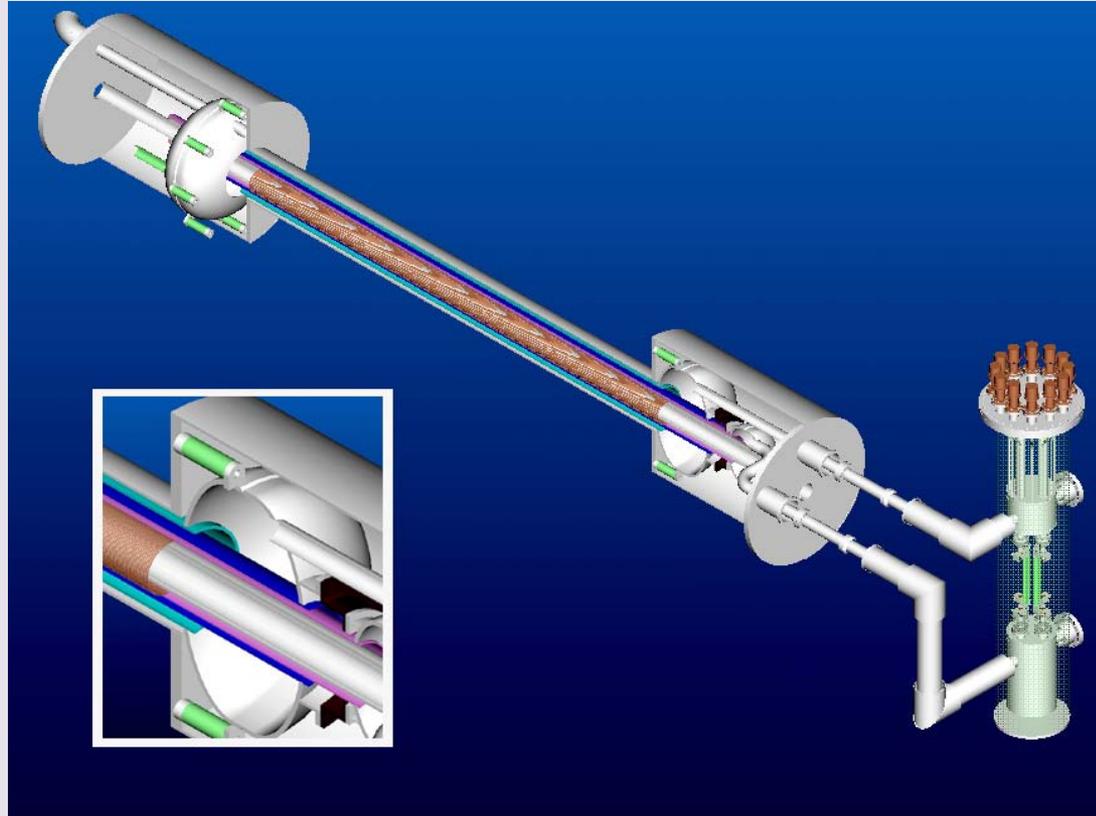
e-Cooling R&D: Solenoid development

Solenoid Requirements

- 1 Tesla axial field (> 1 T preferred)
- Up to 30-meter total length (in two or more sections)
- 100 mm coil ID (gives approx. 89 mm cold bore diameter; warm bore needed?)
- $B_{\perp}/B_{\text{axial}} < 10^{-5}$
 - on-axis \Rightarrow straightness
 - How about off-axis? At least ~5 mm radius zone is needed just to make measurements.

E-Cooling Conceptual design

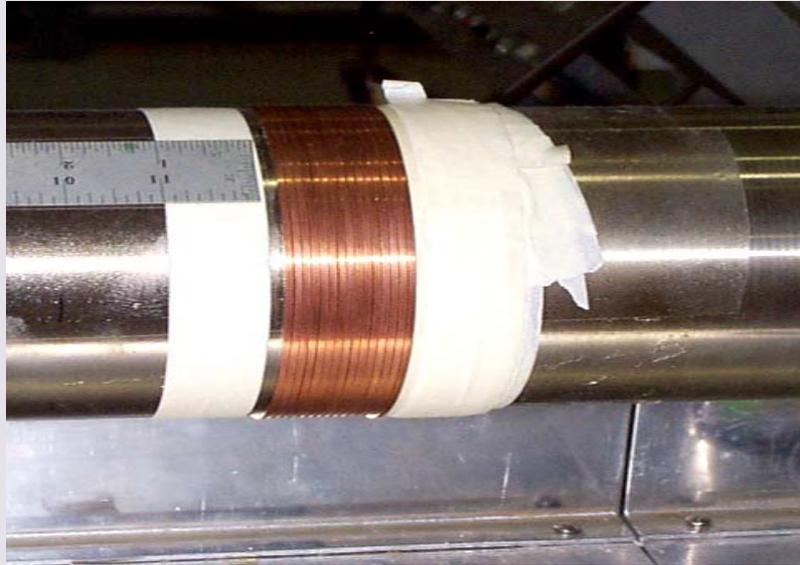
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- Working on the end configuration which would include short (phase advance) quadrupoles

e-Cooling R&D: Solenoid development

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- Smaller conductor size could produce a better field quality, but increases inductance and reduces quench margin.
- It is desirable to have sufficient copper in the conductor to handle a quench at the maximum possible field (J_{Cu} at quench ≤ 1000 A/mm².)
- Wires of rectangular cross section are preferred over circular cross section for multilayer solenoids.
- An off-the-shelf, 0.093"×0.062" wire with Cu:Sc ratio of 7:1 has been found to be appropriate (MRI material)

e-Cooling R&D: Solenoid development

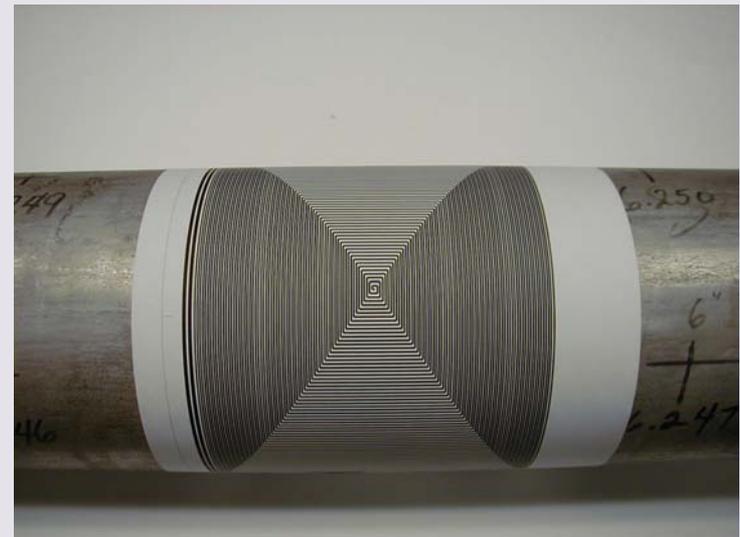
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Dipole Correction Coils

- $B_{\perp} / B_z \sim 10^{-5}$ implies a straightness of 10 μm over 1 meter length. This may not be achieved with mechanical alignment alone.
- Winding imperfections are also likely to produce transverse fields on-axis.
- Goal is to achieve as close to 1×10^{-5} as possible with construction tolerances and mechanical adjustment (expect \sim a few $\times 10^{-4}$)
- Correct the remaining errors with an array of dipole correction coils.

Dipole Correction Coil Design

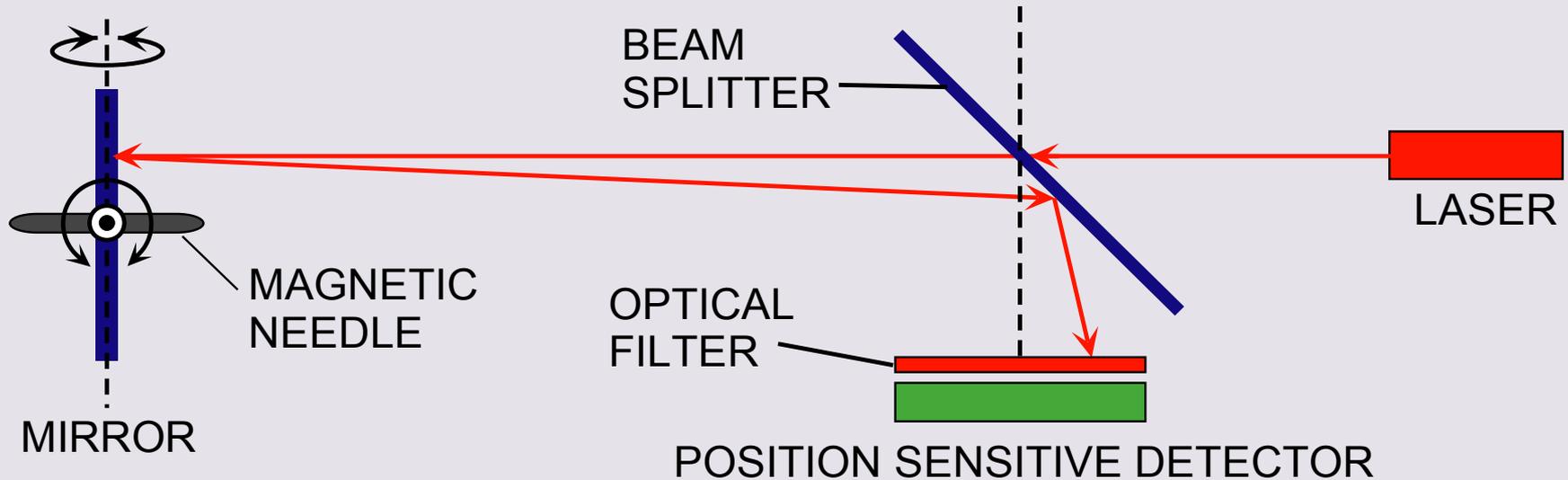
- Typical length scale for field variation \sim coil diameter = 100 mm.
- Need an array of very short dipoles (Length less than diameter, Field $\sim 10^{-3}$ T at ~ 2 A)
- Printed circuit dipoles, with purely azimuthal end turns, could provide an inexpensive way of building such correction elements



e-Cooling R&D: Solenoid development

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Magnetic Measurements

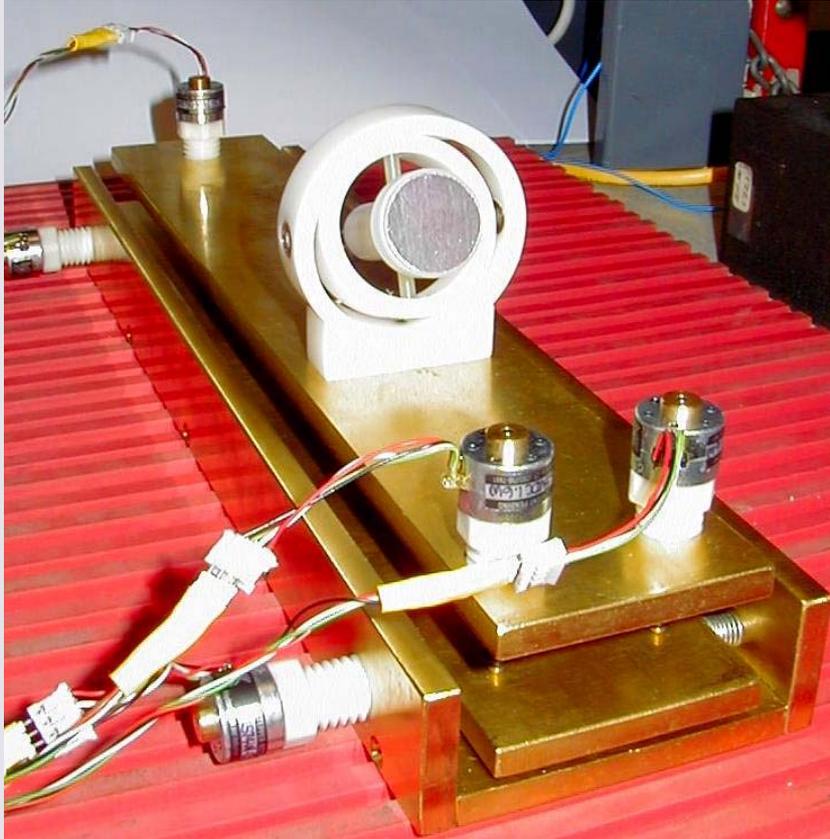


(Based on C. Crawford et al., *FNAL and BINP, Proc. PAC'99*, p. 3321-3)

- Expected resolution $\sim 10^{-5}$ radian, just enough to achieve $B_{\perp}/B_z \sim 10^{-5}$. Better techniques ?
- Field quality on the test stand Vs. field quality in the as-installed magnet ?
Alignment Stability ?

Measuring R&D

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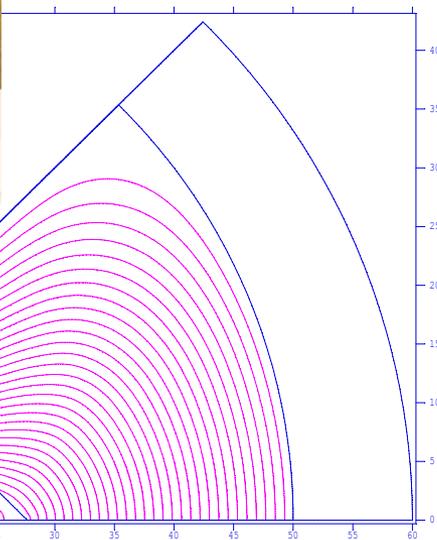
- Prototype 5-axis control. Eventually support frame and position adjustment replaced for dynamic system.

Relativistic Isotope Accelerator - Quadrupoles for the Fragment Separator

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Quadrupoles immediately downstream of the fragment separator are subjected to very large radiation dose



- This is a BNL/NSCL collaboration with BNL developing HTS technology and NSCL addressing the radiation issues.
- HTS Quads can operate at a higher temperature (20-40 K instead of 4K) and allow a large variation in temperature.
- A warm iron yoke brings a major reduction in amount of heat to be removed at lower temperature.
- The coils are moved outward to significantly reduce the radiation dose.
- We plan to use stainless steel as the radiation resistant insulation.
- It is shown that the gradient and field quality requirements can be met.

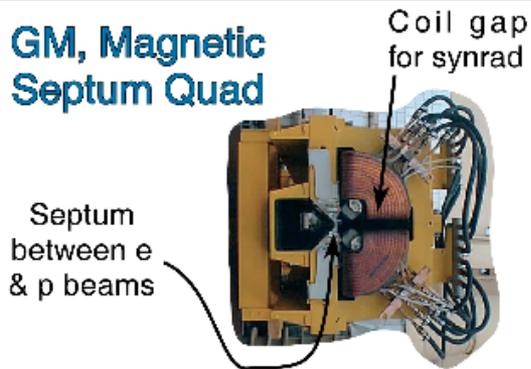
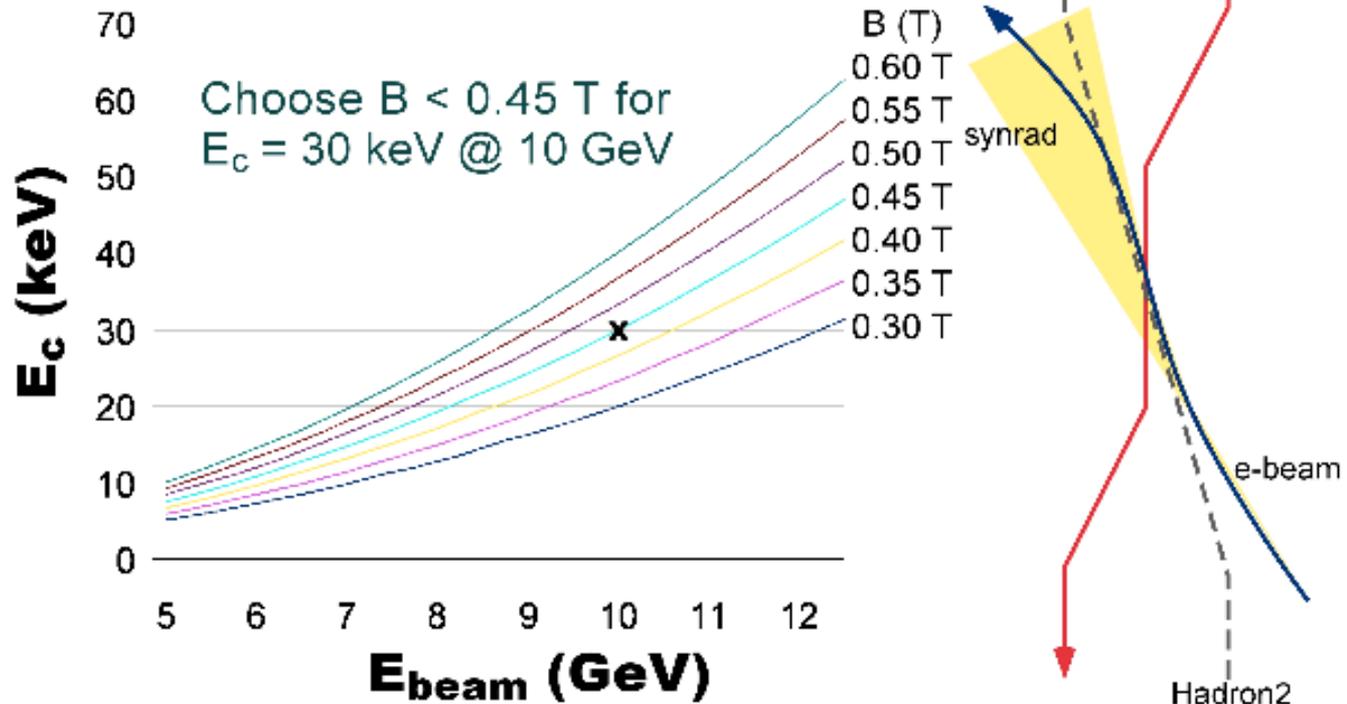
A high temperature, medium field application of High Temperature Superconductors (HTS), where the gradient requirements can be met with the conductor available today.

e-RHIC concepts

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IR design - Parker

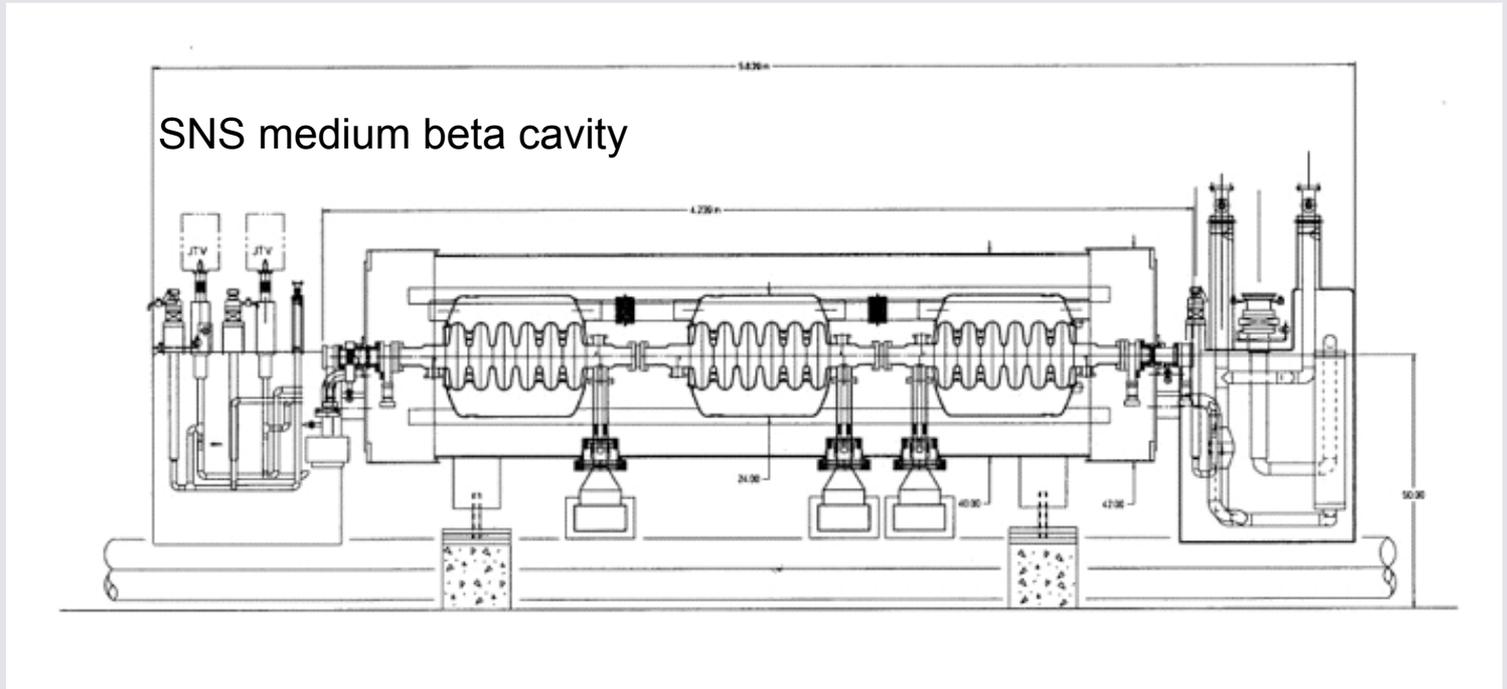
$$E_c \approx \frac{2}{3} B [T] E^2 [GeV^2]$$



HERA-II Magnet

e-RHIC concepts

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Looking at utilization of Magnet Division expertise in the cryostat portions of srf

RHIC Program Funding

Superconducting Magnet Division

<u>Nuclear Physics</u>	<u>FY 2001</u>	<u>FY 2002</u>	<u>FY 2003</u>	Request <u>FY 2004</u>
RHIC Operations	\$4,786	\$4,740	\$5,350	\$5,600
Effort - FTE	25.5	26.5	28.5	29.0

We assume that the magnet program will remain at this level of effort (~28 FTE's) for the foreseeable future.

This represents ~35% of the Magnet Division's total activity. There are benefits of having a larger program than just RHIC.

Summary

The RHIC program support requirements are maturing (as is the machine):

Magnetic measurements are becoming more subtle

Magnet technology is becoming more complex

No major production tasks anticipated in the near future. We are moving into a low volume, R&D, environment (spin, e-cooling, e-RHIC).

Some reliability issues with the helical dipoles. The other RHIC magnets appear to be very reliable.

Planning on a constant level of effort