Brookhaven Magnet Division - Nuclear Physics Program Support Activities

RHIC Operations Support

Magnetic Measurements

Spin Program support(AGS)

E-Cooling R&D

RIA

Funding

RHIC Magnet Systems Scope

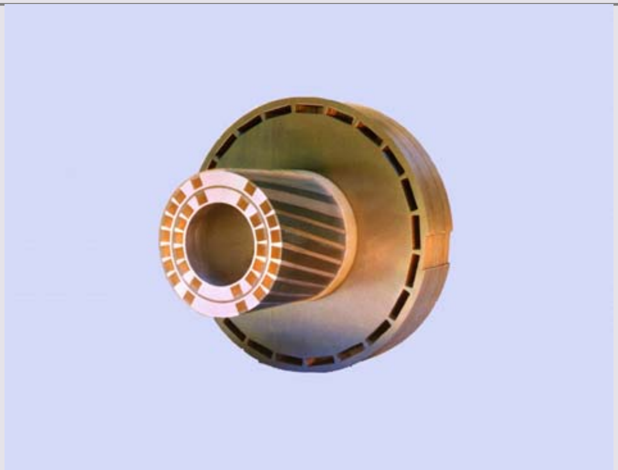
A large superconducting inventory of magnets:

- ~ 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

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

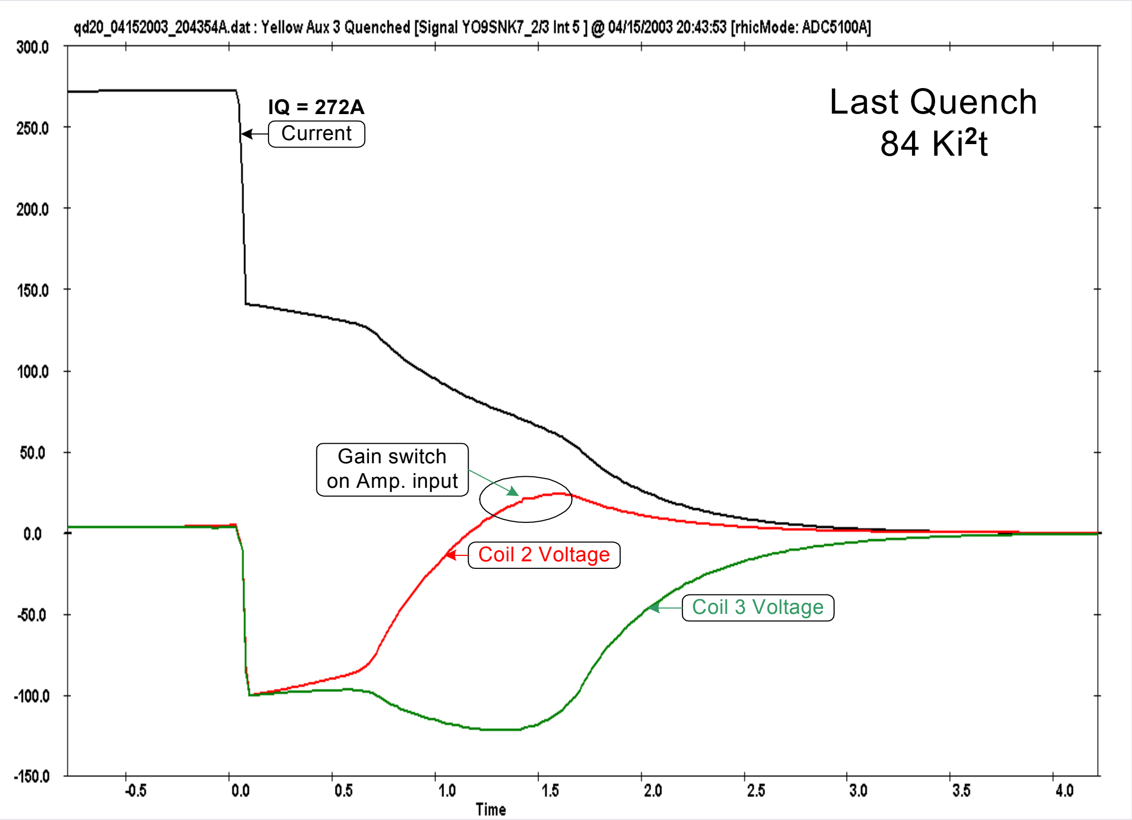
RHIC Helical Dipoles



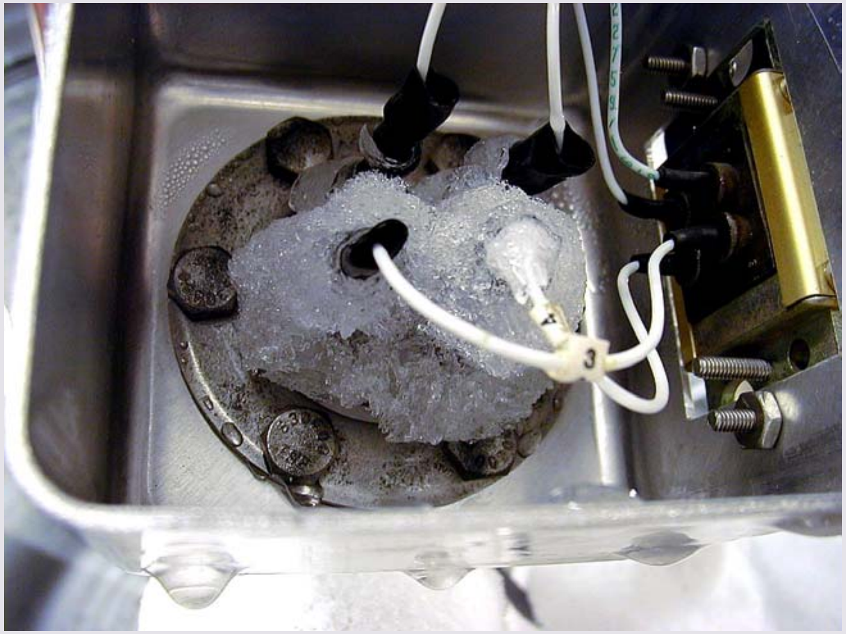
- First real indication of systematic magnet problems during the spin operation with the helical dipoles
  - HRD102 Snake (yellow sector 9) – short to ground in second module. Magnet removed from tunnel for repair.
  - HRD101 Snake (blue sector 9) - short to ground in all modules; feedthru problem. Repair 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

- ~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

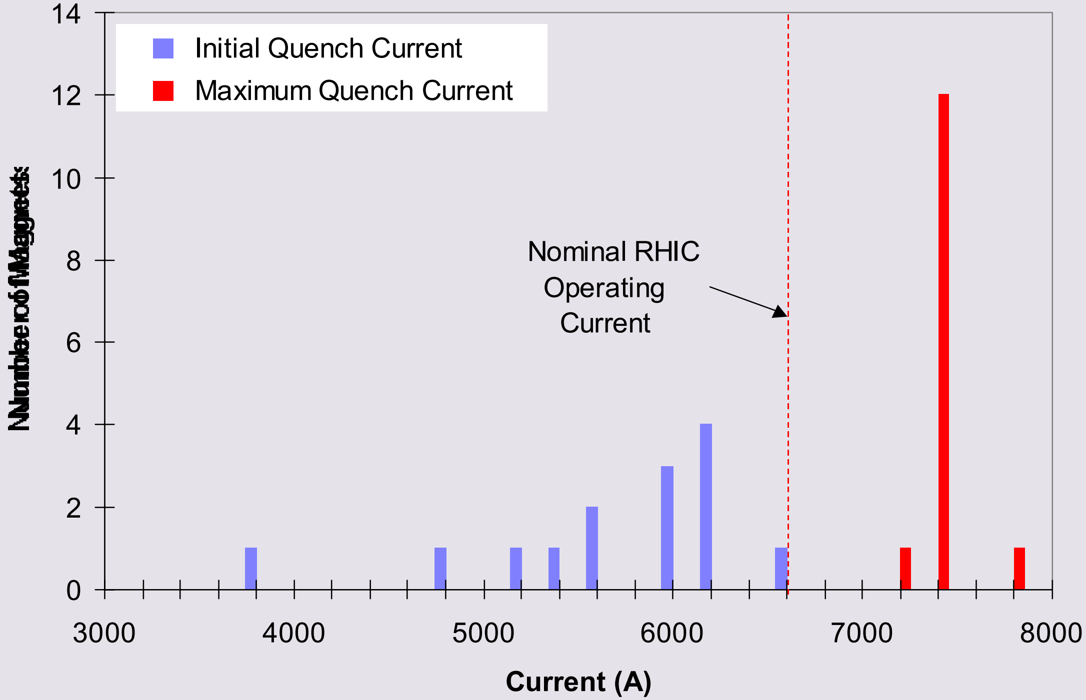


In areas of high tunnel humidity then ice balls have proved an operational issue for quench detection (leakage currents)

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

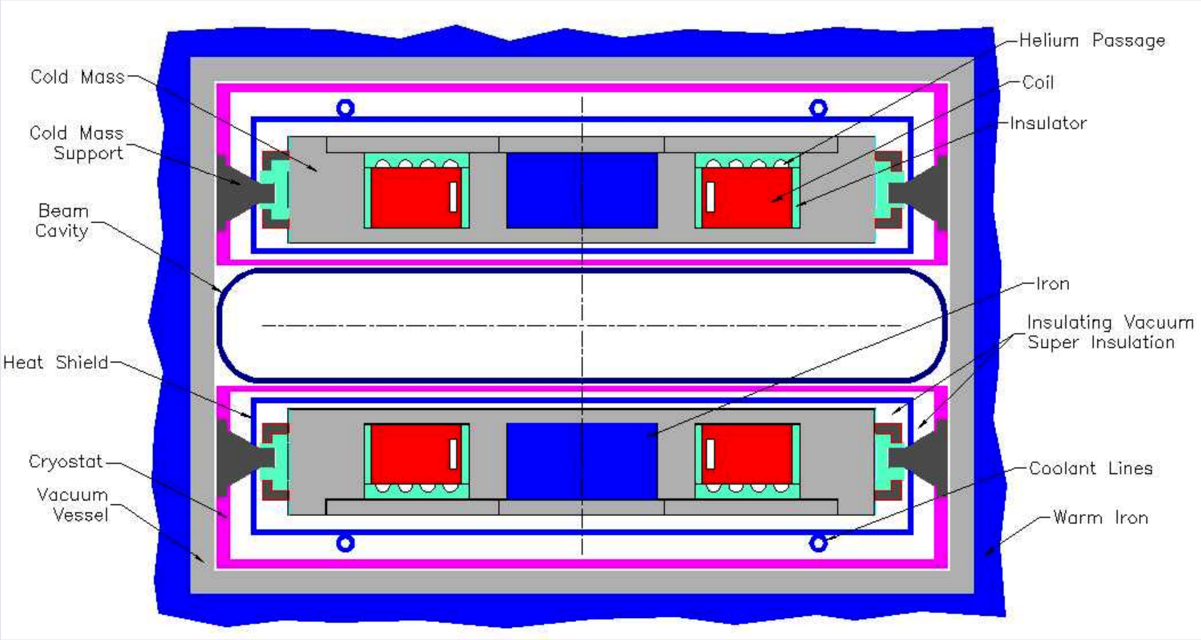
RHIC DX Magnet Replacement

- 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



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 compatable'.

Magnetic Measurements

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

FY04

beta-star 1/2m

Trim quadrupoles at higher excitatio

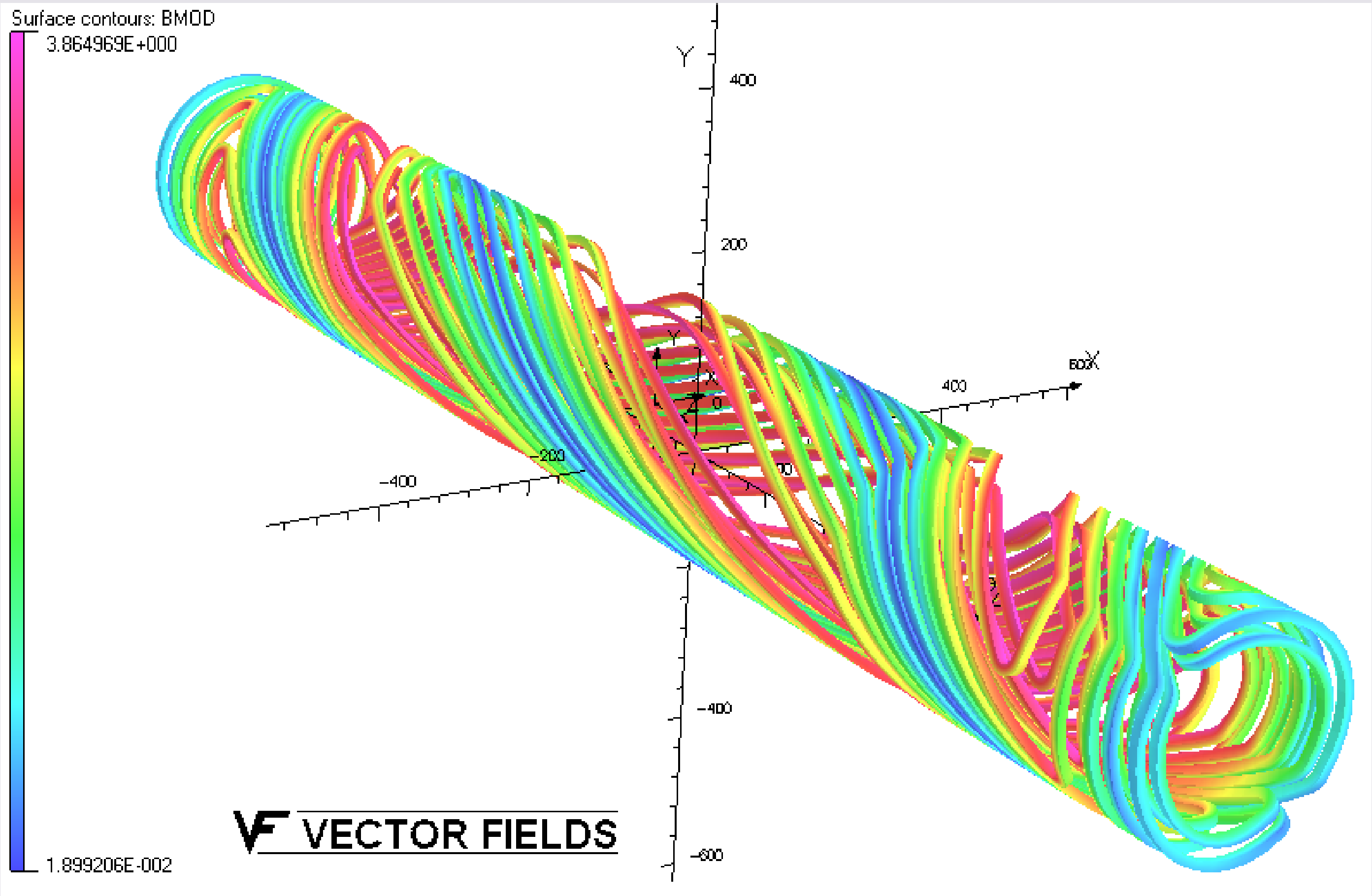
AGS Snake

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



AGS Snake-An Integrated Approach to Complex Magnetic Elements

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

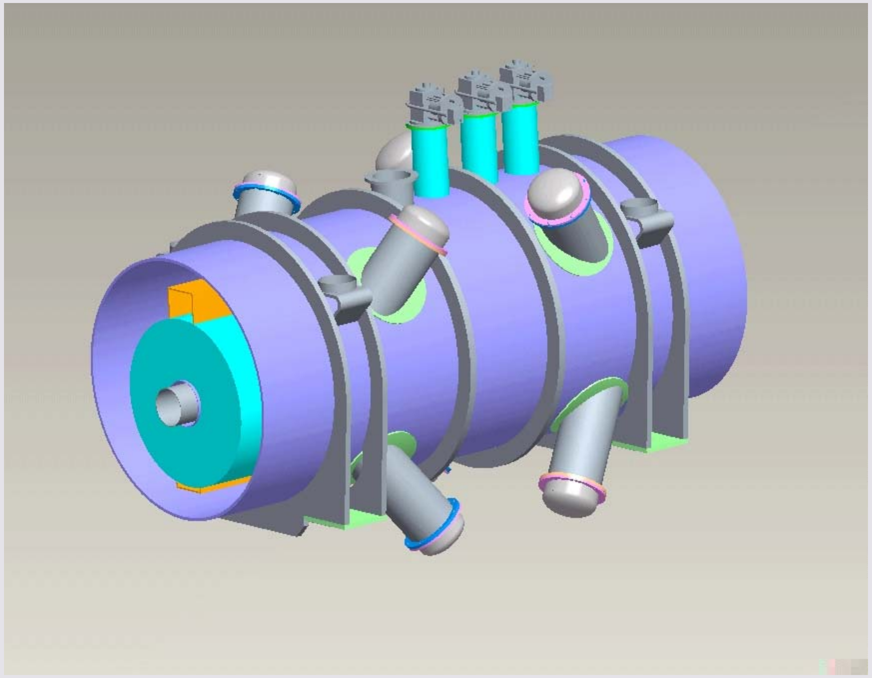
AGS Snake Status

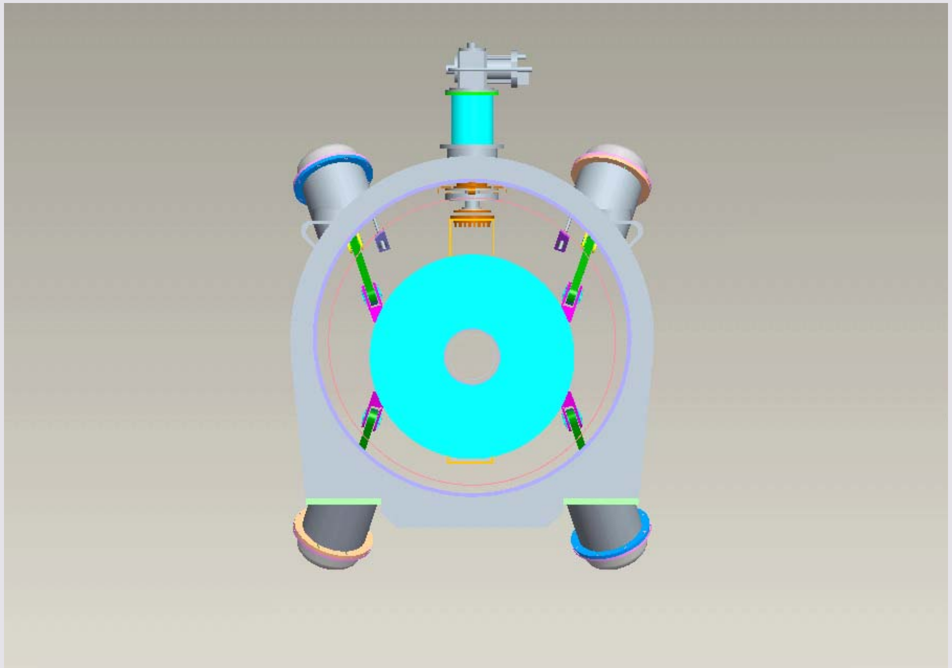
Cold mass design complete. Cryostat in progress (stand alone cryogenics !)

Slot insulation complete on the inner shell. Winding starts today

Trying to decide on measuring-correction strategy

AGS Snake Status





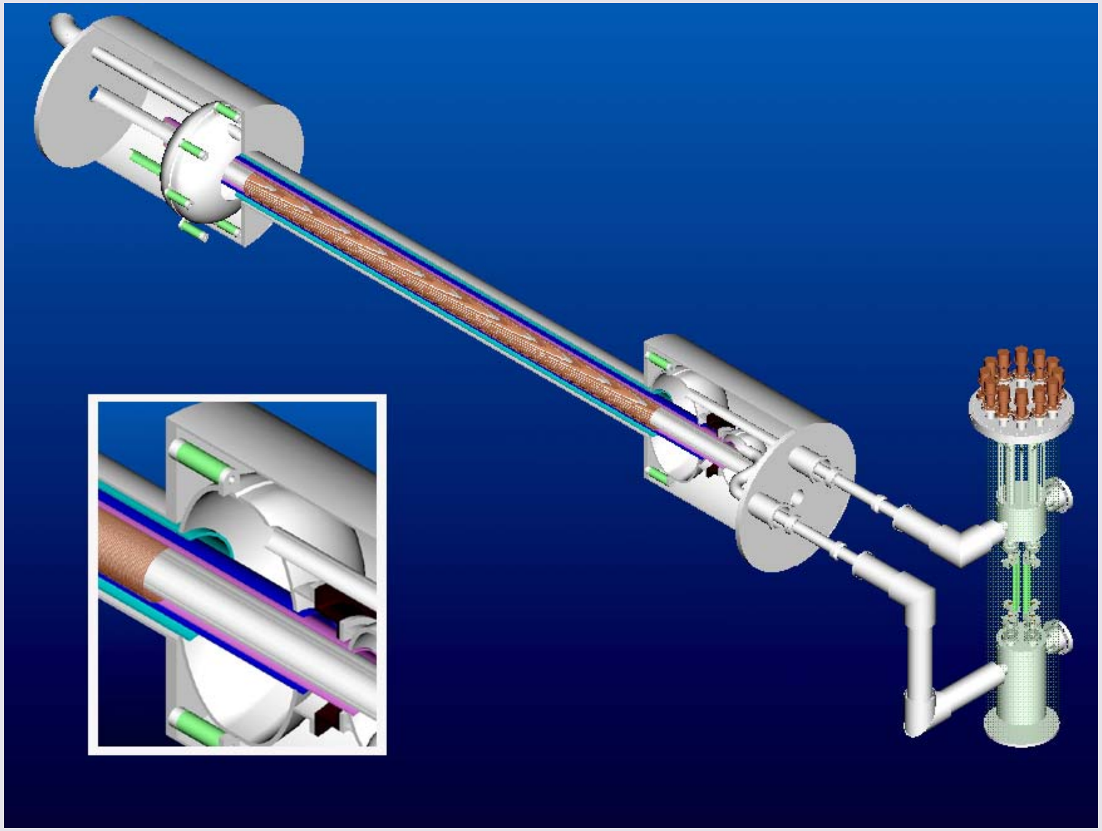
Scheduled for end of construction - ready for final cold testing - on 7/28/04. This schedule has no contingency which given the complexity of the device is probably somewhat optimistic.

e-Cooling R&D: Solenoid development

Solenoid Requirements

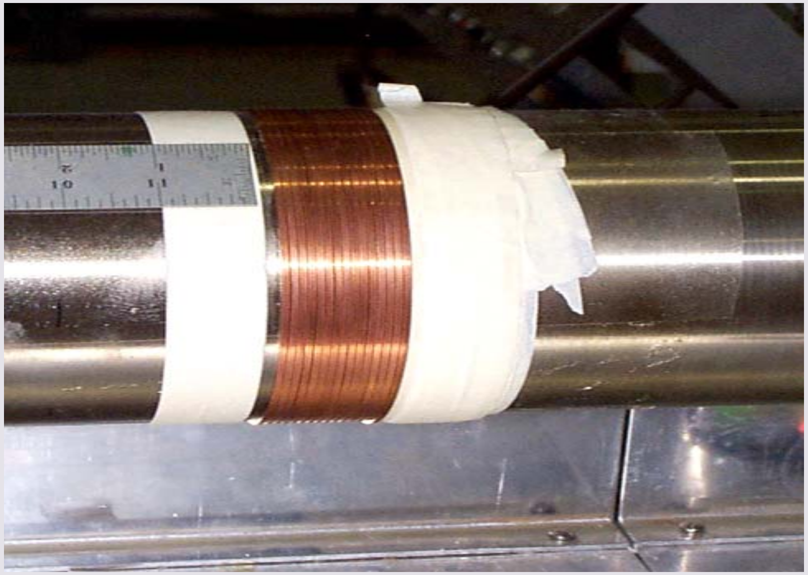
- 1 Tesla axial field (> 1 T preferred)
- Up to 30-meter total length (in two or more sections)
- 100 mm coil ID (gives approx. 89 mm cold bore diameter; warm bore needed?)
- $B_t/B_{axial} < 10^{-5}$
  - on-axis ⇒ straightness
  - How about off-axis? At least ~5 mm radius zone is needed just to make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

E-Cooling Conceptual design



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

e-Cooling R&D: Solenoid development



- 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 $\leq$ 1000 A/mm^2.)
- 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

Dipole Correction Coils

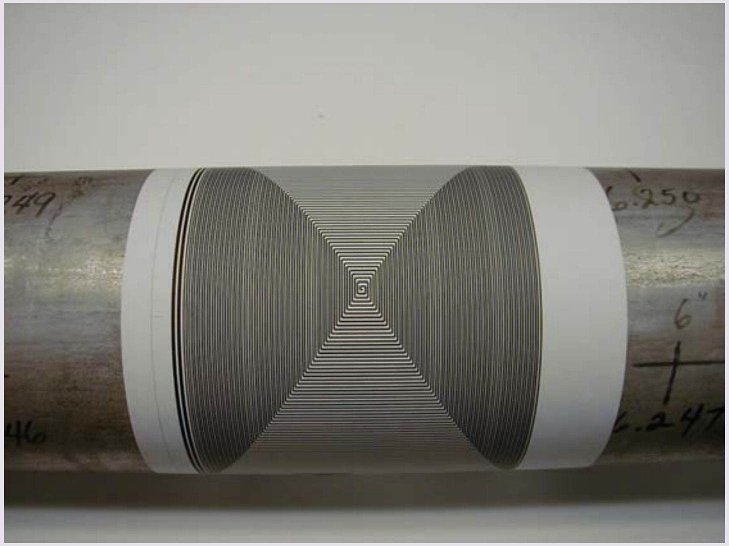
- $B_\perp / B_z \sim 10^{-5}$ implies a straightness of 10 μm over 1 meter length. This may not be achieved with mechanical alignment alone.
- Winding imperfections are also likely to produce transverse fields on-axis.
- Goal is to achieve as close to 1×10^{-5} as possible with construction tolerances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

Dipole Correction Coil Design

•Typical length scale for field variation ~ coil diameter = 100 mm.

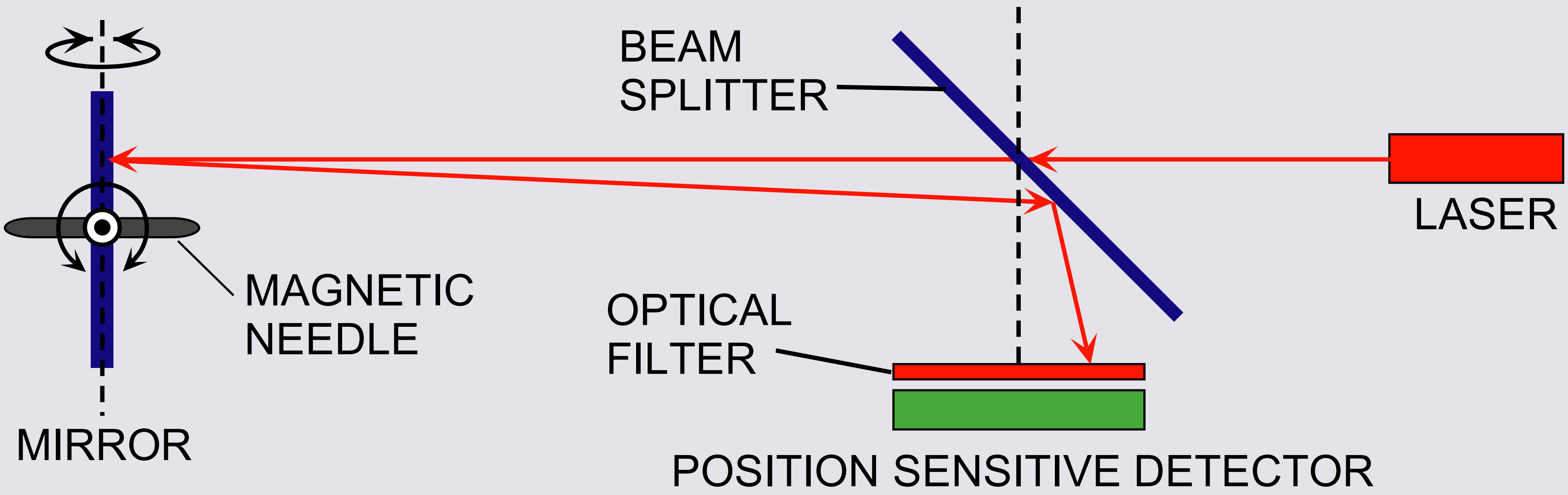
•Need an array of very short dipoles (Length less than diameter, Field ~ 10^{-3} T at ~ 2A)

•Printed circuit dipoles, with purely azimuthal end turns, could provide an inexpensive way of building such correction elements



e-Cooling R&D: Solenoid development

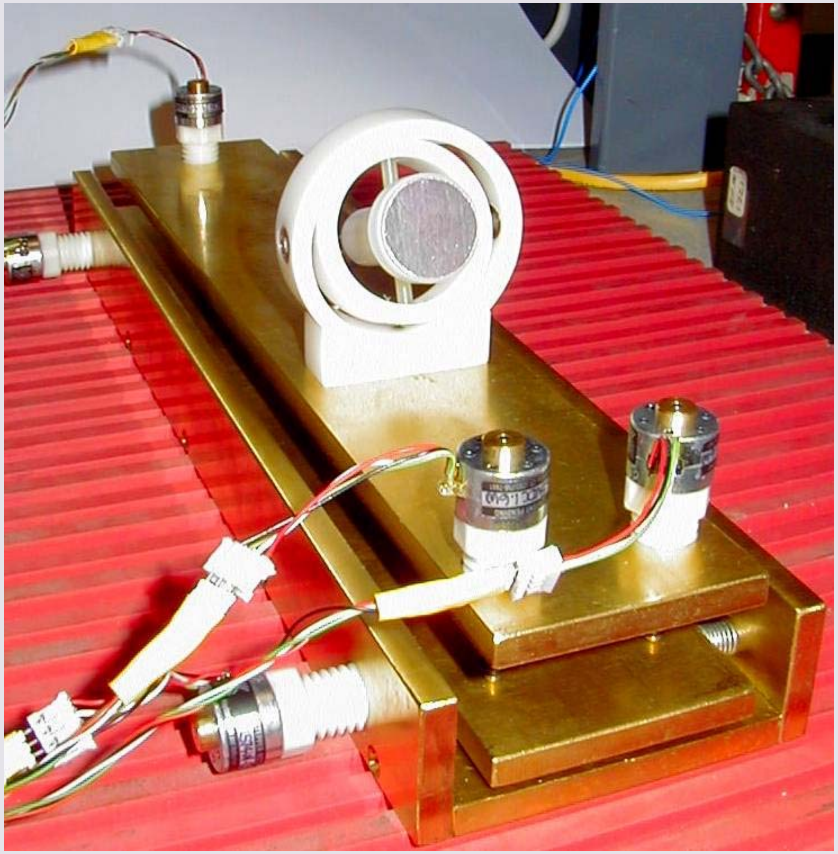
Magnetic Measurements



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

- Expected resolution ~ 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 ?

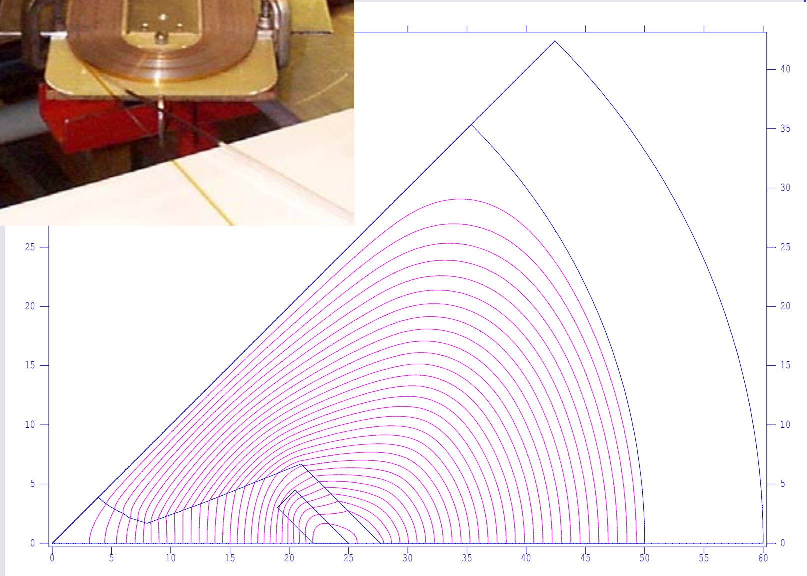
Measuring R&D



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

Relativistic Isotope Accelerator - Quadrupoles for the Fragment Separator

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



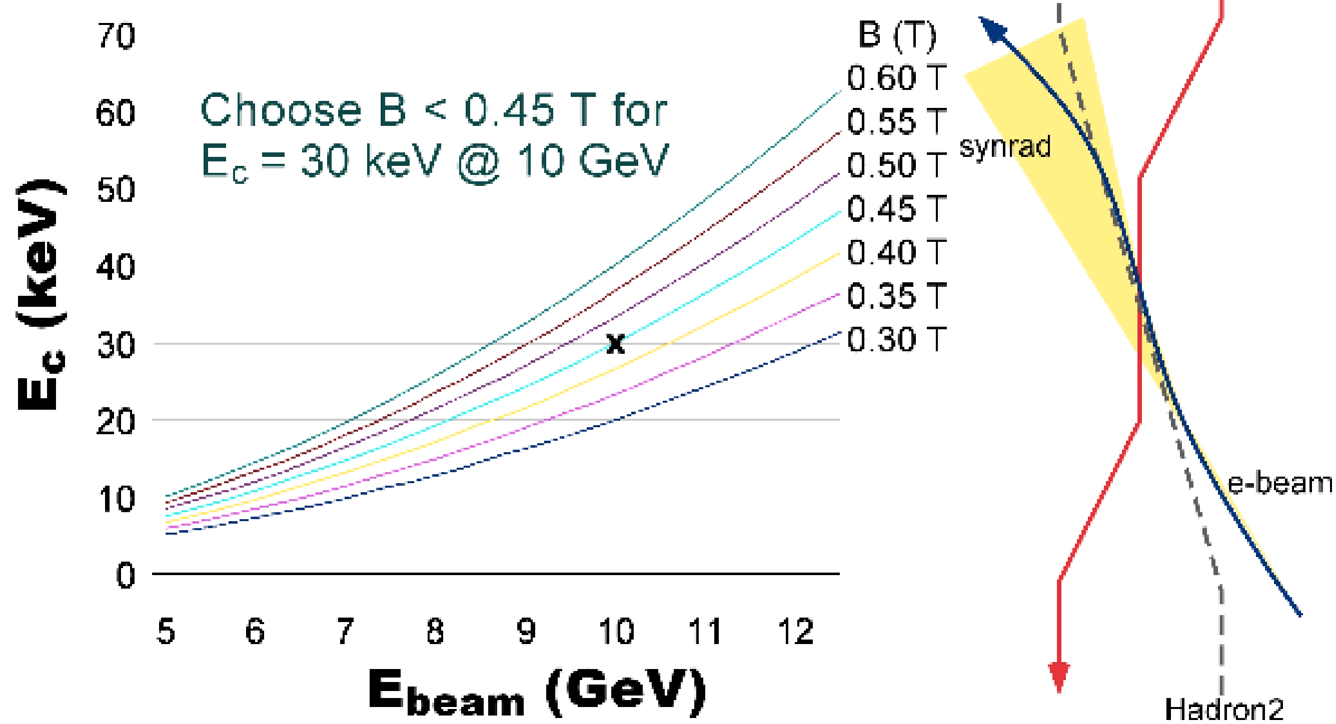
A high temperature, medium field application of High Temperature Superconductors (HTS), where the gradient requirements can be met with the conductor available today.

- 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.

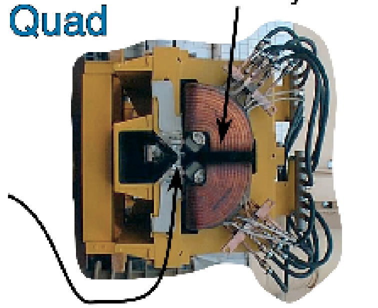
e-RHIC concepts

IR design - Parker

$$E_c \cong 2/3\, B\,[T]\, E^2\,[GeV^2]$$



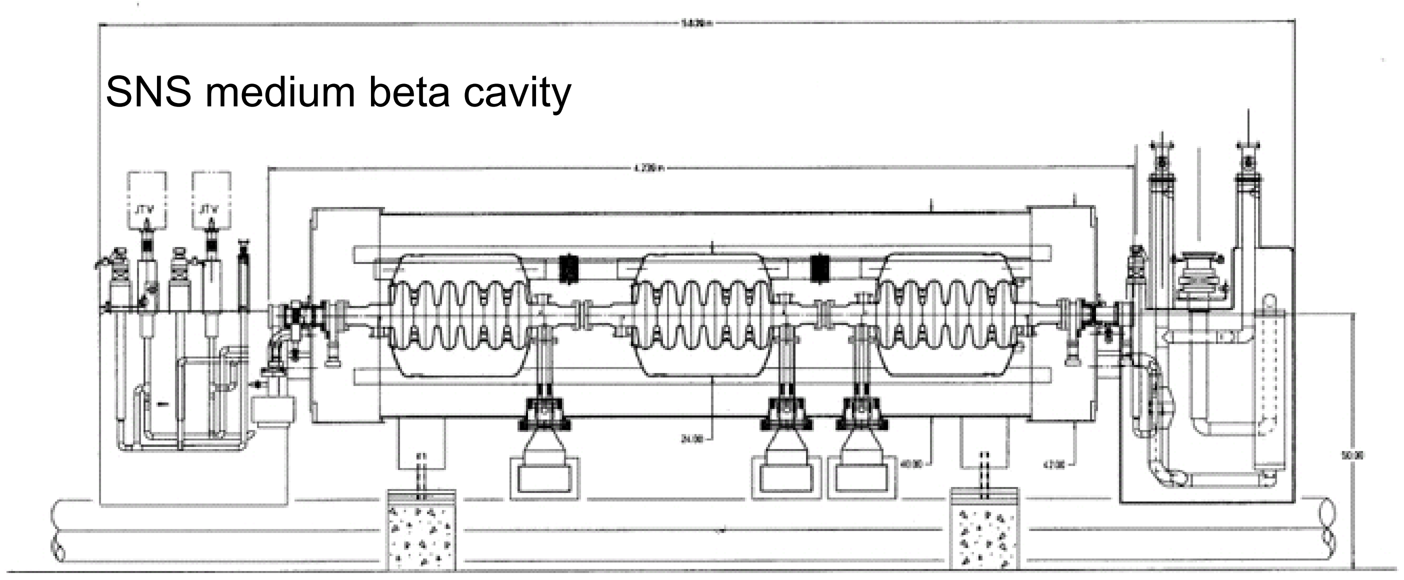
GM, Magnetic Septum Quad



HERA-II Magnet

e-RHIC concepts

SNS medium beta cavity



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

RHIC Program Funding

Nuclear Physics	FY 2001	FY 2002	FY 2003	Request FY 2004
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