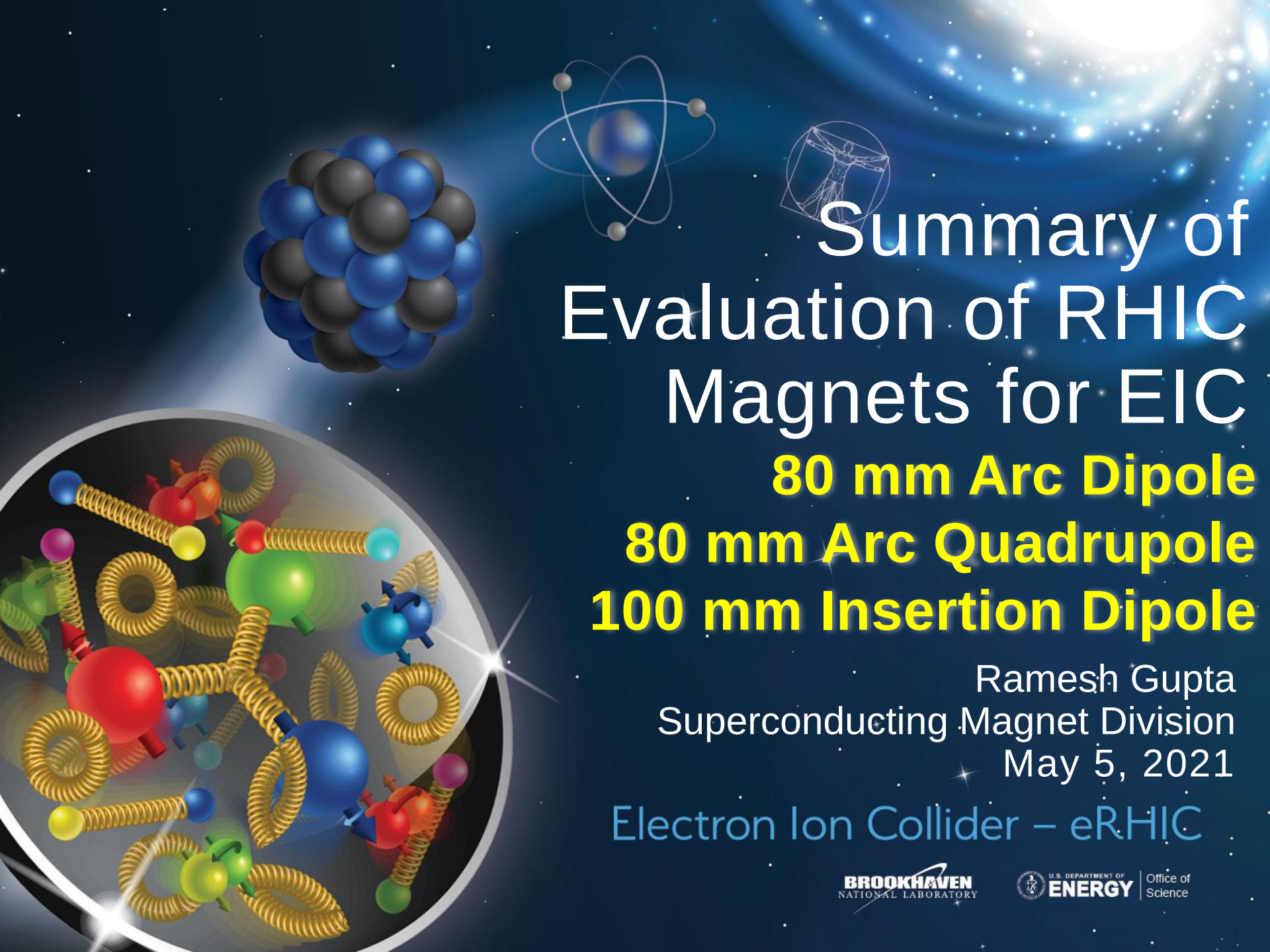

Summary of Evaluation of RHIC Magnets for EIC

80 mm Arc Dipole
80 mm Arc Quadrupole
100 mm Insertion Dipole

Ramesh Gupta
Superconducting Magnet Division
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Electron Ion Collider – eRHIC

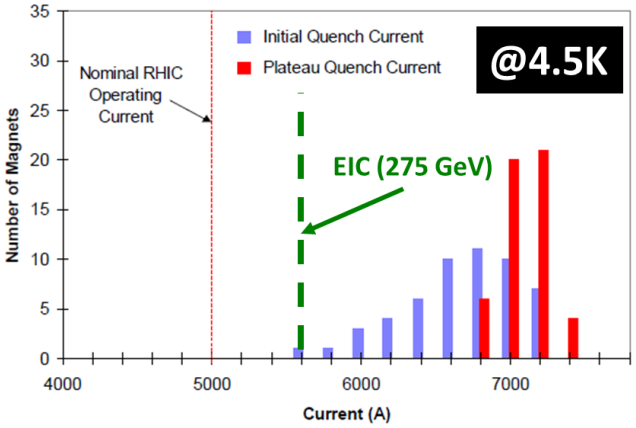
BROOKHAVEN NATIONAL LABORATORY
U.S. DEPARTMENT OF ENERGY | Office of Science

Background and Strategy

- EIC design requires RHIC magnets to operate at higher fields. The plan, furthermore, is to operate them at higher temperatures as well.
- Even though, most RHIC magnets were designed with a heathy margin, doing both (higher field & higher temperature) raises concern.
- Risk Evaluation needs to have two components
  - The best RHIC magnets can do - compute design performance at higher fields and higher operating temperatures based on the conductor properties (doesn't account for the fact that the mechanical design was made to the design field +some margin)
  - Examine the measured quench history of these magnets at ~4.5 K (superconducting magnets don't always reach the design field even after many quenches – how many quenches are acceptable)
- The question is: Will test of the magnets at higher fields and higher temperature produce useful data (like early warnings) even if the test can't be performed at the EIC design level? Cost vs. benefits?

RHIC 80 mm dipoles (in a good shape)

Measurements show that RHIC 80 mm dipoles have sufficient "*mechanical*" margin for EIC operation at 275 GeV



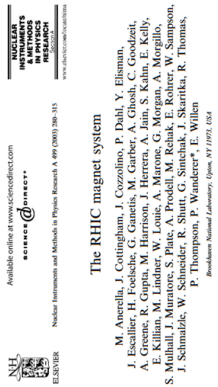
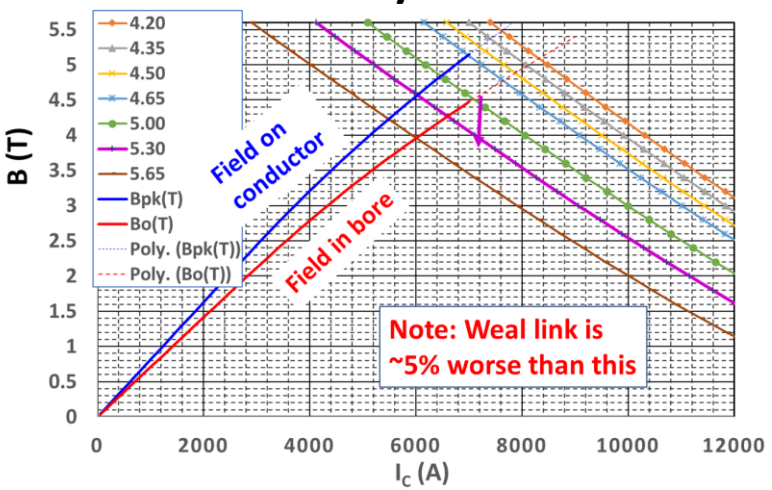
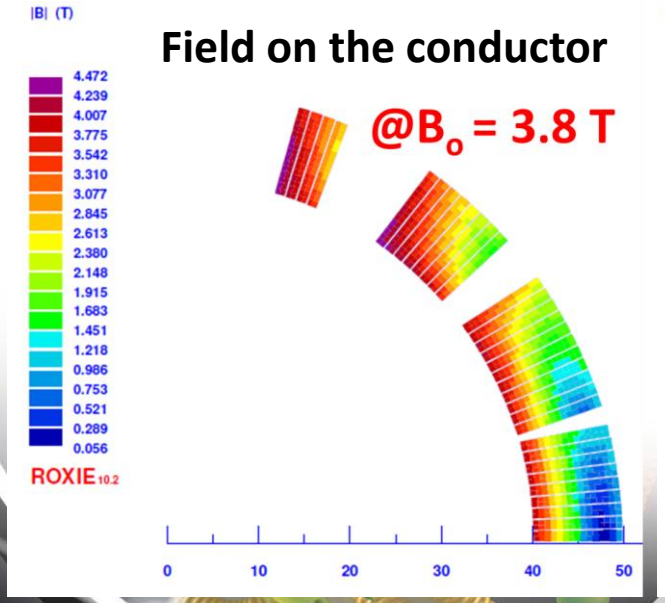


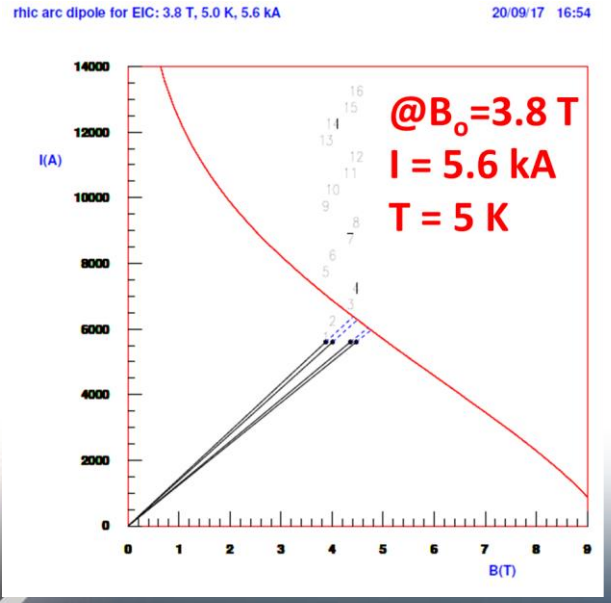
Figure 3 Quench performance of 51 arc dipoles, tested at 4.5 K. The average plateau quench current of these 51 magnets was 7101 A; the field at this average quench current is 4.52 T.

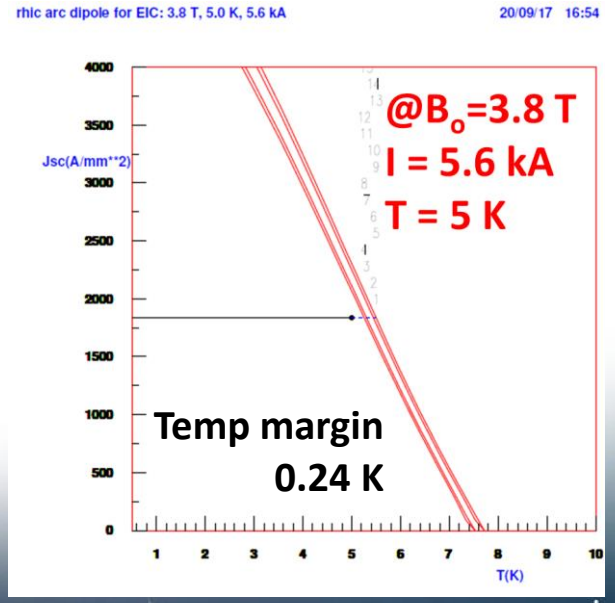
Analytic Calculations



Field on the conductor



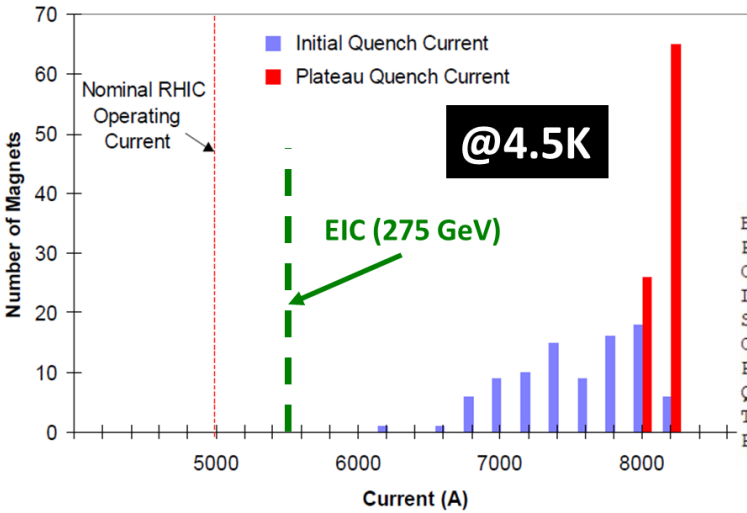




RHIC 80 mm Quadrupoles (in a good shape)

Quench Performance of RHIC 80 mm Quadrupoles (measured in 91 magnets)

RHIC 80 mm arc quadrupoles have a large quench and "*mechanical*" margin for EIC 275 GeV operation



ROXIE Calculations

Summary of Calculations for 275 GeV @5 K

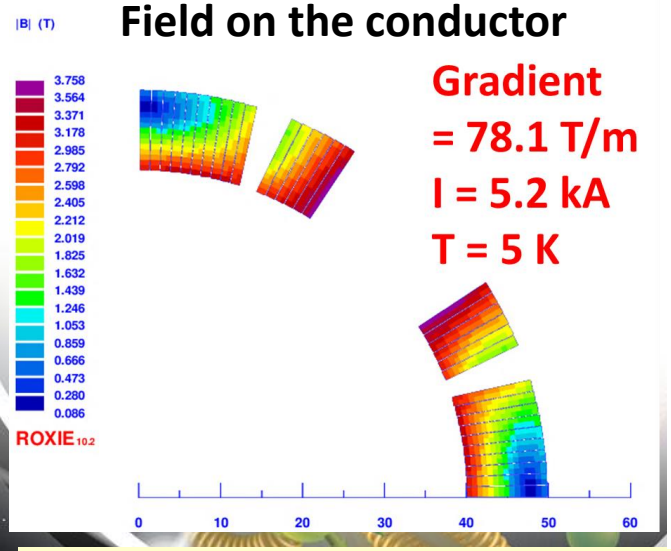
MAIN FIELD (T)	-3.841283
BLOCK NUMBER	2
PEAK FIELD IN CONDUCTOR 16 (T)	3.7571
CURRENT IN CONDUCTOR 16 (A)	5220.0000
LOWEST FIELD IN CONDUCTOR 11 (T)	1.5822
SUPERCONDUCTOR CURRENT DENSITY (A/MM2)	1709.4420
COPPER CURRENT DENSITY (A/MM2)	763.1437
PERCENTAGE ON THE LOAD LINE	83.3229
QUENCHFIELD (T)	4.5091
TEMPERATURE MARGIN TO QUENCH (K)	0.6821
PERCENTAGE OF SHORT SAMPLE CURRENT	72.6244

rhic arc quad for EIC 275 GeV: 78.1 T/m, 4.5 K, 5.22 kA 21/03/19 10:06

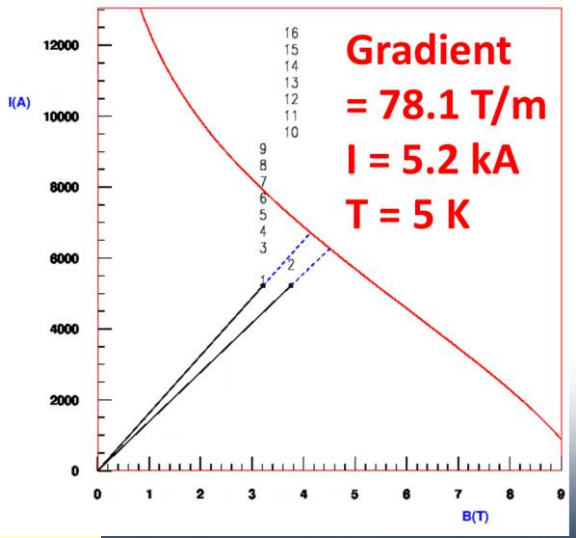
rhic arc quad for EIC 275 GeV: 78.1 T/m, 5.0 K, 5.22 kA 21/03/19 09:15

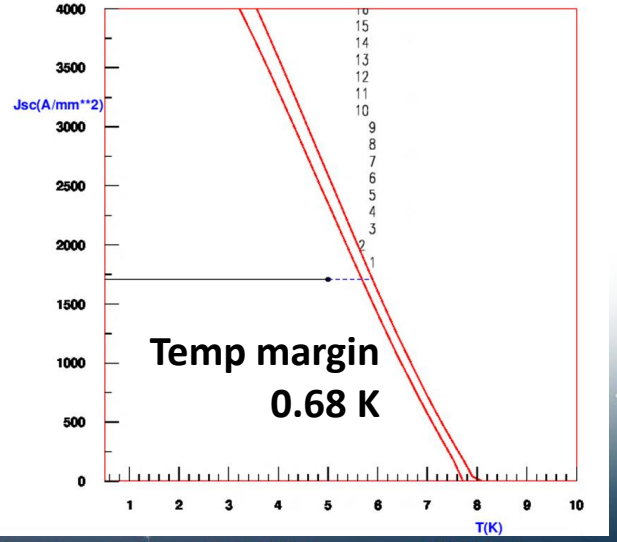
rhic arc quad for EIC 275 GeV: 78.1 T/m, 5.0 K, 5.22 kA 21/03/19 09:15

Field on the conductor



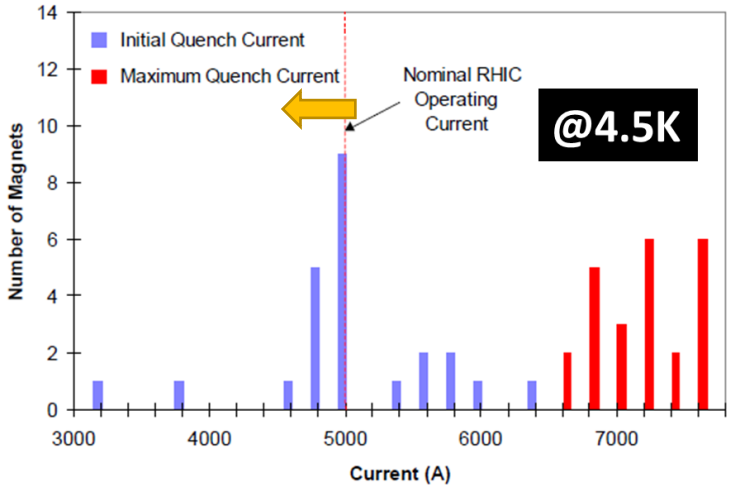
Gradient = 78.1 T/m
I = 5.2 kA
T = 5 K





RHIC 100 mm dipoles (in a good shape because of lower field requirements)

Measurements show that RHIC 100 mm dipoles have sufficient "*mechanical*" margin for EIC operation at 275 GeV (lower field required since DX is removed)



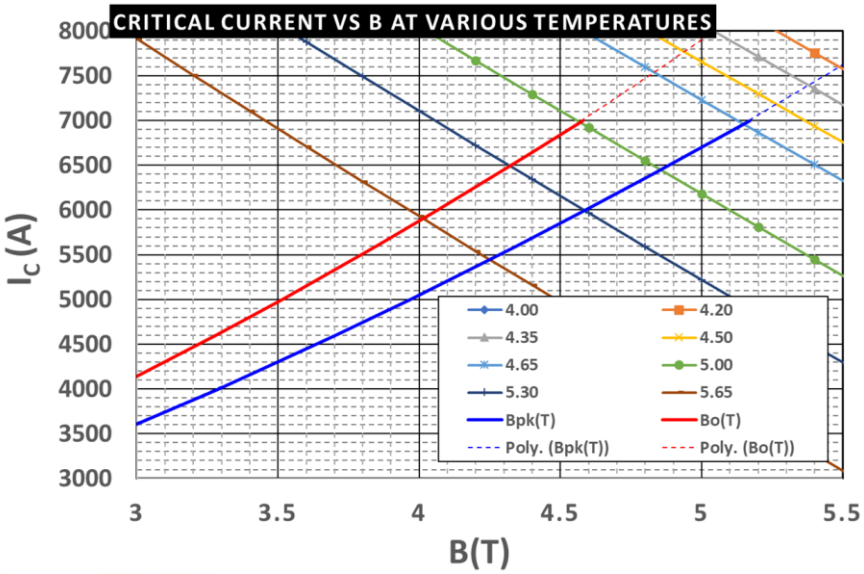


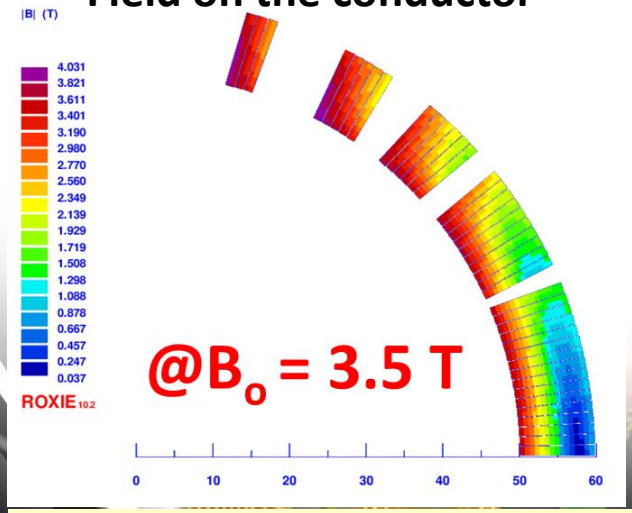
Figure 42 Quench performance of 24 large aperture (100 mm) dipoles, test

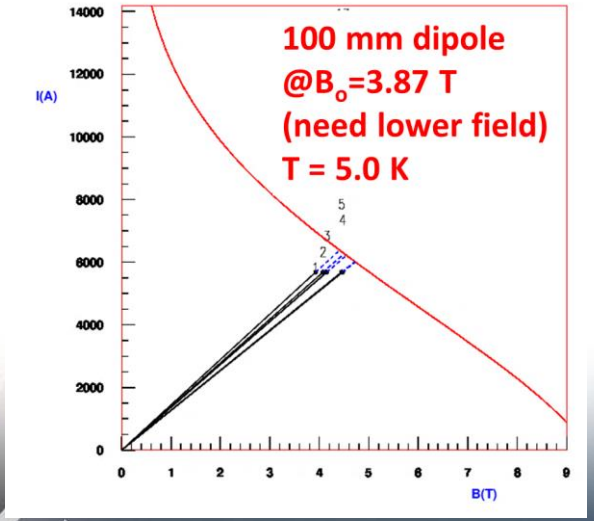
rhic 10 cm dipole for EIC 250 GeV: 3.87 T, 5.0 K, 4.5 kA 21/03/19 09:57

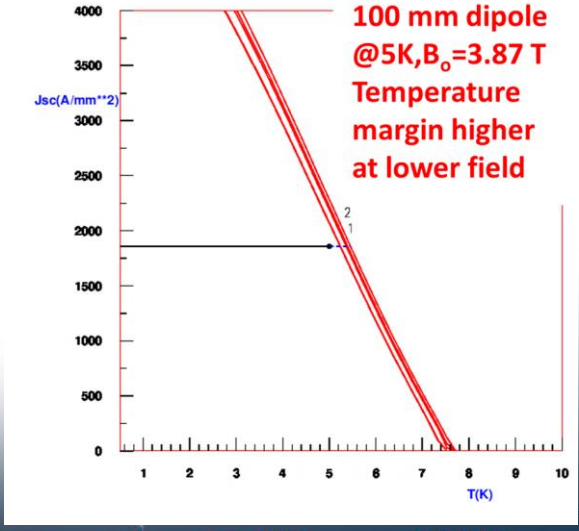
rhic 10 cm dipole for EIC 275 GeV: 3.87 T, 5.0 K, 5.675 kA 21/03/19 09:26

rhic 10 cm dipole for EIC 275 GeV: 3.87 T, 5.0 K, 5.675 kA 21/03/19 09:26

Field on the conductor







General Considerations and Other Magnets (1)

- **The three magnets mentioned so far (arc dipoles, arc quadrupoles and D0 10 cm insertion dipole) seem to be in a good position for EIC. Reaching the EIC design current, even at 4.5 K, means that they have the required mechanical margin.**
- **The test of those magnets at 4.9 K would check if there are any surprises in terms of number of training quenches, etc.**
- **However, the situation is not so comfortable for other magnets such as 13 cm insertion quads where we needed a lot of training and never reached close to the quench field. Higher temperature operation complicates the situation further.**

General Considerations and Other Magnets (2)

- **For the other magnets, we need to know what the EIC operation requirements are? If they are more that what we are using in RHIC, then I would recommend testing at the end of this RHIC run. We don't want to surprise EIC project.**
- **The theoretical calculations of quench current is not sufficient. Many superconducting magnets, unfortunately, never reach the quench limit - even after a very large number of quenches. And a large number of quenches for each magnet in tunnel is not practical.**
- **Proposed higher temperature, higher field run at the end of current RHIC run is not a sufficient test for EIC but may be a useful test to see if there are early sign of issues that we need to worry about.**