Permanent Magnet Designs with Large Variations in Field Strength*

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Superconducting Magnet Division
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Abstract—The use of permanent magnets has been investigated as an option for electron cooling ring for the proposed luminosity upgrade of RHIC. Several methods have been developed that allow a large variation in field strength. These design concepts were verified with computer simulations using finite element codes. It will be shown that the field uniformity is maintained while the field strength is mechanically adjusted.

Low Field Design

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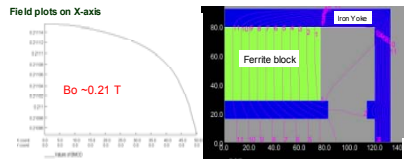
Dipole and Quadrupole Magnets for RHIC e-cooling Experiment Ring

Pole tip field requirements: 1.4 kG in dipoles. Low pole tip field requirement allows cheap permanent magnets.

Field plots on X-axis



"Permanent magnet"

Magnet aperture:
Horizontal 180 mm, Vertical 40 mm;
Good field (10^{-3}) to x=+/-50 mm.

Medium Field Design

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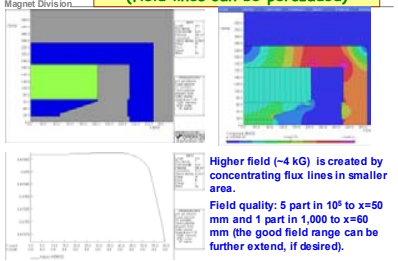
Getting Higher Field (field lines can be persuaded)



Higher field (~4 kG) is created by concentrating flux lines in smaller area.

Field quality: 5 part in 10^5 to x=50 mm and 1 part in 1,000 to x=60 mm (the good field range can be further extend, if desired).

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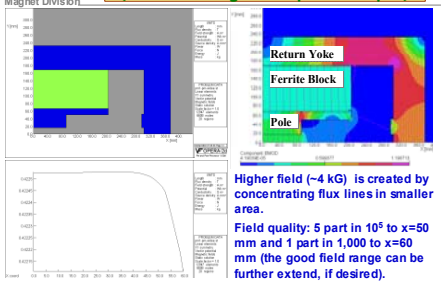
Getting Higher Field (contd.) (another design – simpler/cheaper)



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ADJUSTMENT IN THE FIELD STRENGTH BY VARYING THE AMOUNT OF SHUNT IN THE MAGNET CROSS-SECTION

Low Field Designs

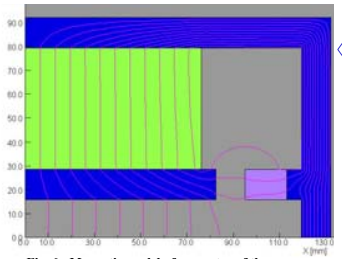

Fig. 6.: Magnetic model of a quarter of the magnet in the method where a shunt of full height is partially inserted (Shunt Type A).

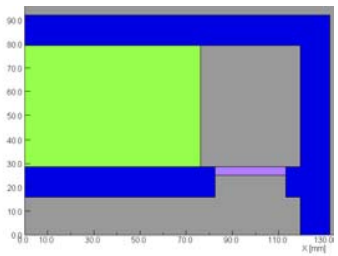

Fig. 7: Magnetic model of a quarter of the magnet in the method where a shunt of partial height is fully inserted (Shunt Type B).

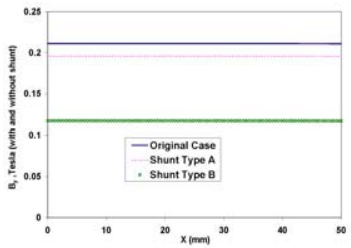

Fig 8: Field along the X-axis without shunt (Fig. 1) and with two types of shunts (Fig. 6 and Fig. 7). The shunt can be adjusted to change the field.

Medium Field Designs

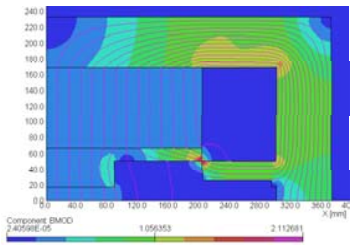

Fig. 9: Magnetic model of a quarter of the medium field magnet with a shunt that reduces the field in the magnet aperture from 0.42 T to 0.33 T. A deeper insertion of the shunt will give a larger reduction in field.

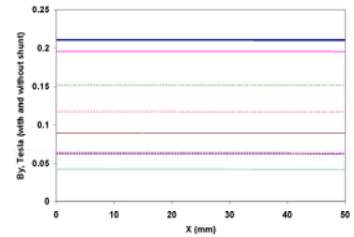

Fig 10: Field along the X-axis without shunt (top line, model of Fig. 1). and with various shunts. This figure shows that the magnitude of the field can be varied by a significant amount without producing a large distortion in the field.

ADJUSTMENT IN THE FIELD STRENGTH BY VARYING THE AMOUNT OF SHUNT IN THE MAGNET LENGTH

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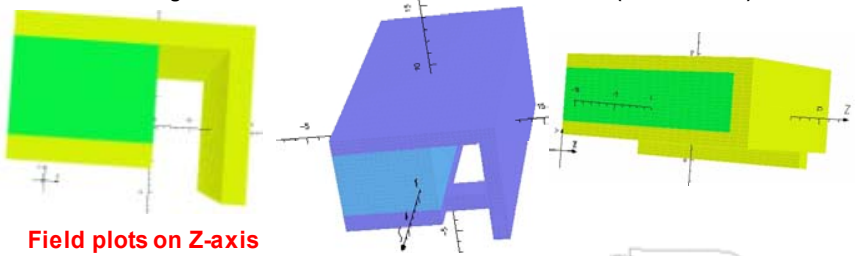
Field Strength Adjustment in Permanent Magnets – 3d Modeling

All models show only a quadrant of the magnet

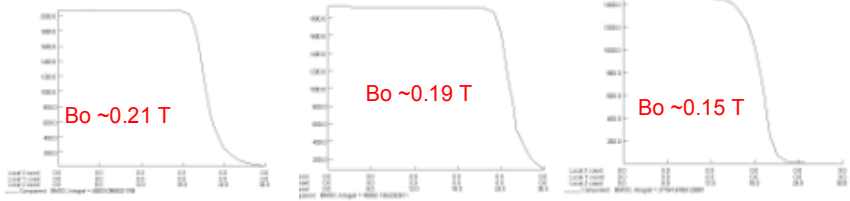
Maximum strength case

Fe Rods from the side

Fe Plates in the ends (or in between)



Field plots on Z-axis



SUMMARY

A number of techniques for adjusting (reducing) field in permanent magnets have been presented. These techniques rely on an adjustable shunt that provides a low reluctance path to bypasses field lines from the aperture of a magnet to the return yoke. Designs are also investigated where the field in the aperture can be increased beyond the residual field of the magnetized bricks by concentrating flux lines at the iron pole.

References

[1] I. Ben-Zvi, et al., "R&D Towards Cooling of the RHIC Collider", Proceedings of the 2003 Particle Accelerator Conference, Portland, Oregon, May 12-16, 2003.

[2] J. Kewish, et al., "Layout and Optics for RHIC Electron Cooler", Proceedings of the 2003 Particle Accelerator Conference, Portland, Oregon, May 12-16, 2003.

[3] W. Foster, et al., "Experience with Permanent Magnets in the Fermilab 8 GeV Line and Recycler Ring", 6th European Particle Accelerator Conference, Stockholm, June 22-26, 1998.

[4] J. Volk, et al., "Time Evolution of Fields in Strontium Ferrite Permanent Magnets", 2001 Particle Accelerator Conference, Chicago, June 18-22, 2001.

[5] OPERA 2-d and OPERA 3-d are among a set of finite element computer codes from Vector Fields, Inc. http://www.vectorfields.com.