High Field Magnet Design

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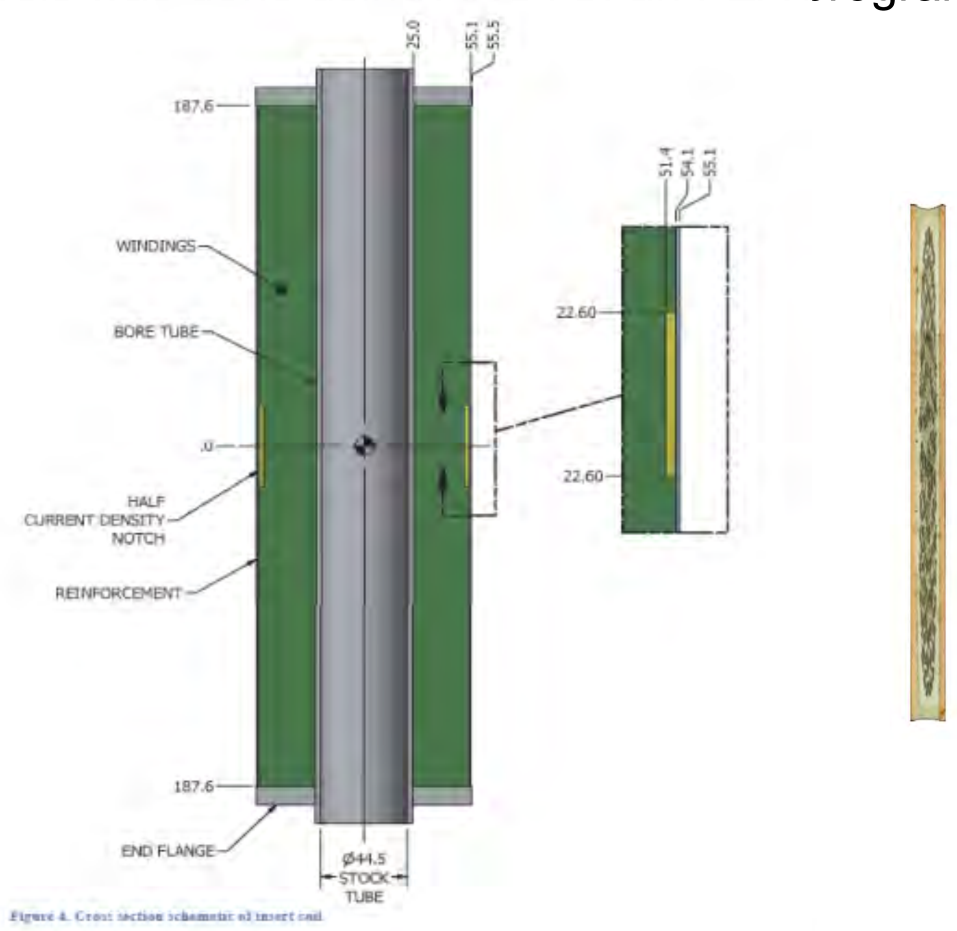
NATIONAL MAGLAB

Task:

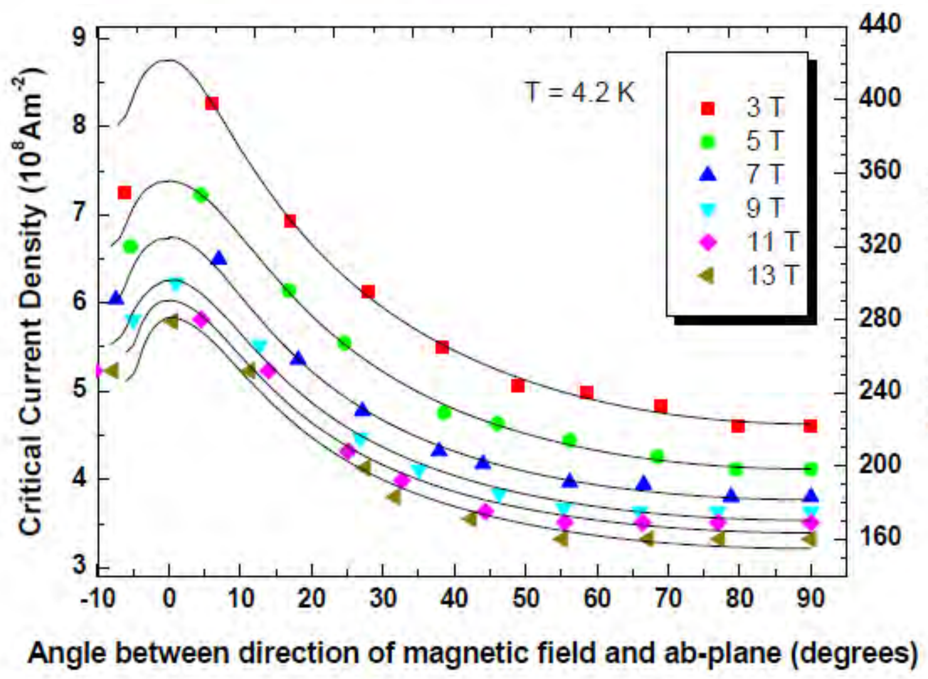
To assist magnet designers in the magnet science and technology group by conducting numerical analyses.

High field flux bending for critical current

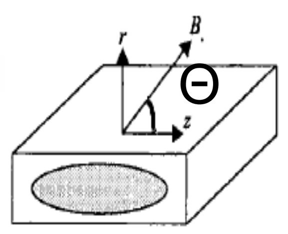
In this research solenoid caps were designed and modeled for a prototype NMR insert magnet to beneficially guide the magnetic field and raise the critical current and overall performance. The insert is “Platypus”, the 6T Bi-2223 layer wound superconducting magnet with a lower current density notch for < 1 ppm homogeneity. The magnet providing the background field is the 16T IMPDAHMA. Cap materials used were iron and holmium as they are ferromagnetic, possess high magnetic permeability's and have large saturation points (2-3T). Analysis was done using ANSYS, an FEA program.

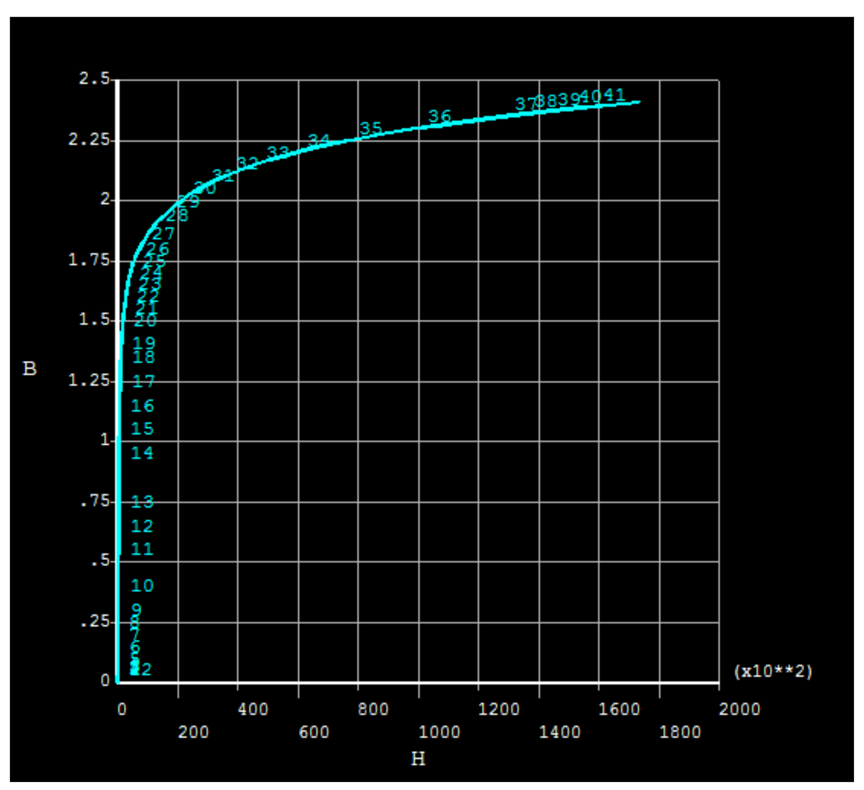


(1) Modeled 6T NMR insert
(2) Bi 2223 tape cross section



Critical current vs field angle for Bi 2223 tapes. Shows the strong dependence on field angle.

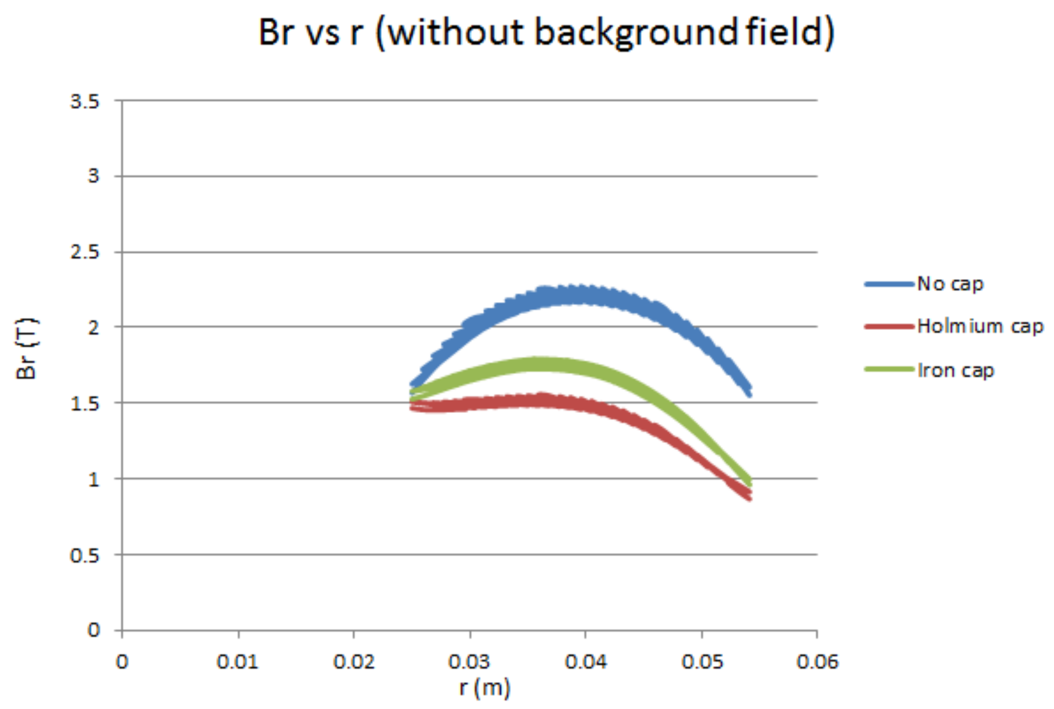


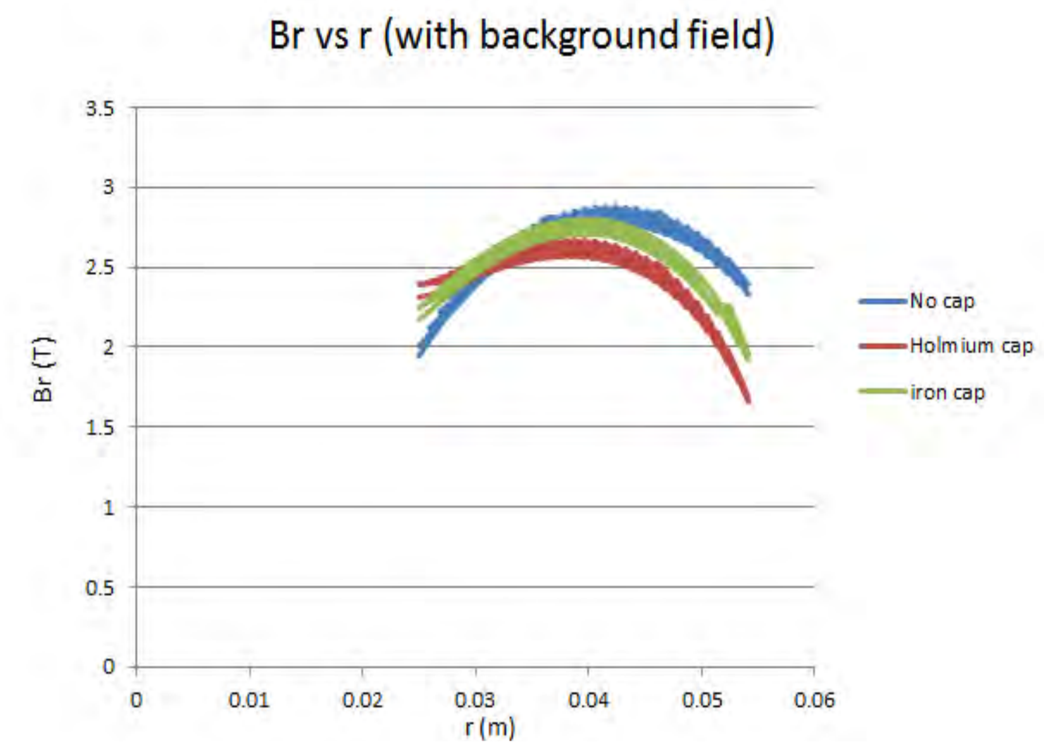


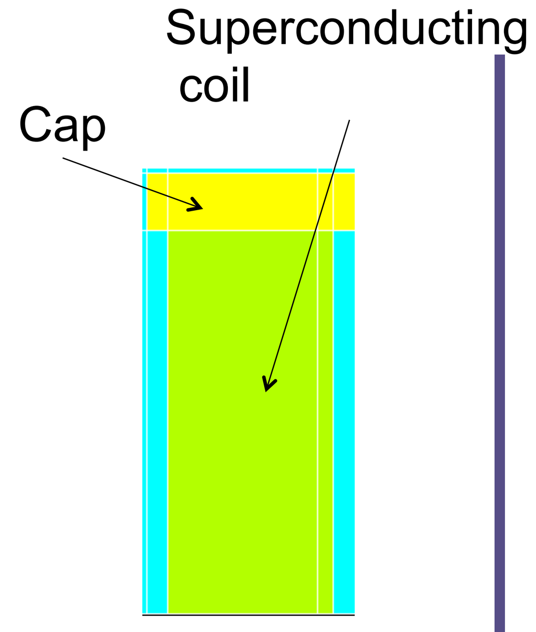
BH curve input data used for low carbon steel (iron).

$$\mu r = \mu / \mu 0$$

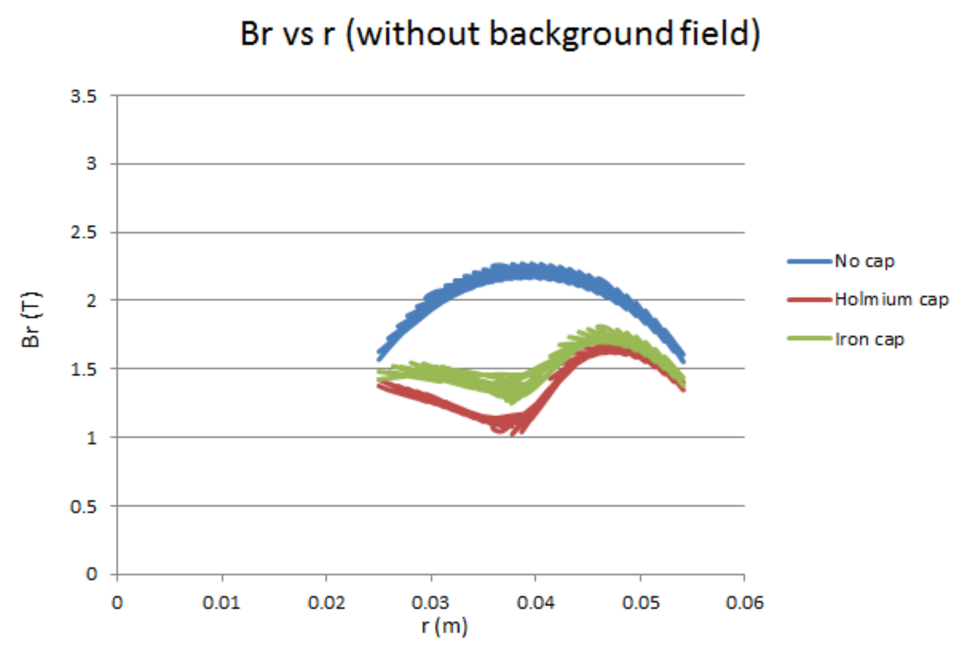
$$B = \mu r(H + M)$$

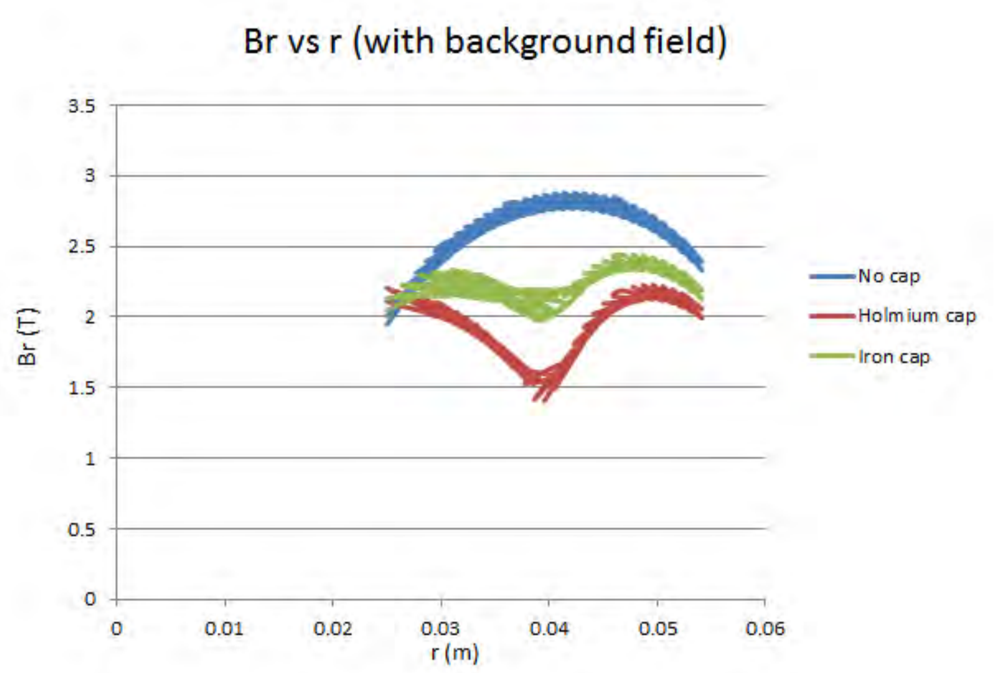


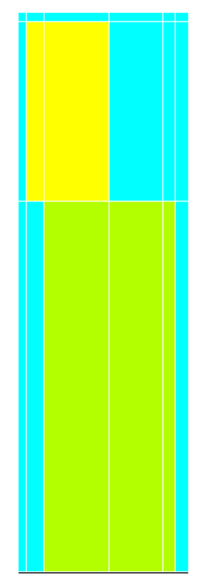




Radial field at top edge of coil graphs for shown axisymmetric cap design. Gains without background field were 30% (0.7T) and only 7.4% (0.2T) with.





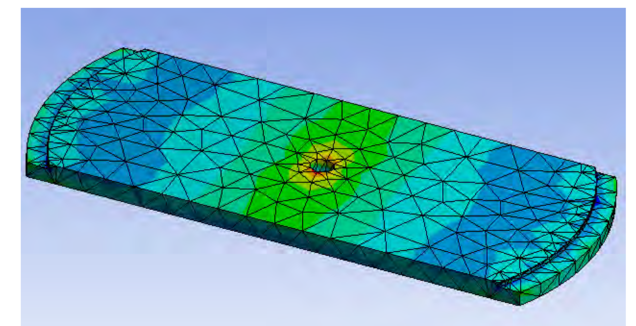


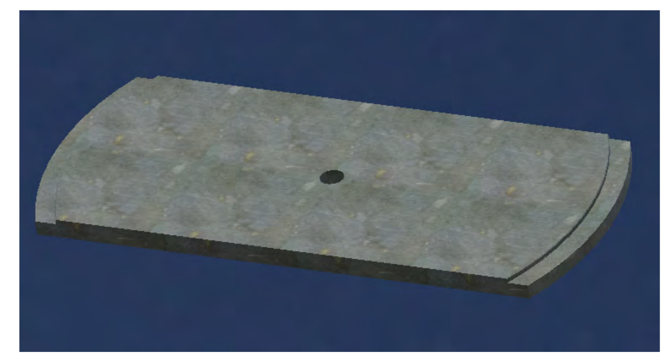
Radial field at top edge of coil graphs for shown axisymmetric cap design. Gains without background field were 40% (1.15T) and 22.7% (0.65T) with.

Best designs used larger volumes of material to increase the field gradient at the coil ends. The higher permeable holmium out performed iron in every instance. Saturation appeared to be the key factor in poor absorption in high fields. Holmium has the greatest known saturation points of all elements and still leaves around 20T ignored. Coils with fields near the saturation point benefit greatest from endcaps.

28 MW Tooling

A spreadsheet of all the parts required to build the magnet was modified and improved to be comprehensive. This analysis ensures that every part is safe for operation.



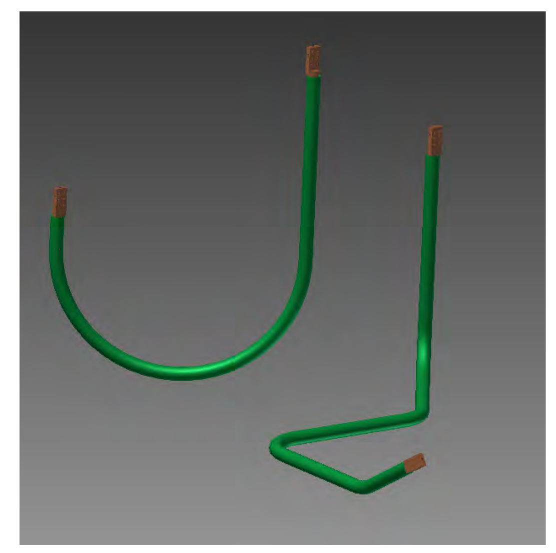


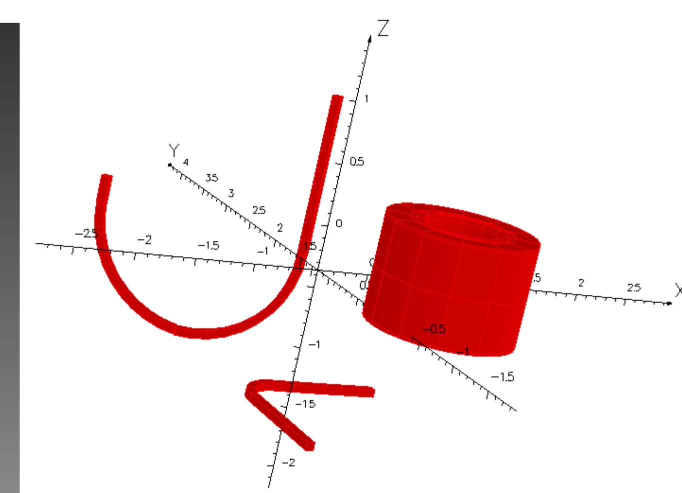
(1) Example from C coil.
(2) FEA stress analysis of plate
(3) New plate model.

A plate used to lift the outer “E” coil was too weak under bending stress. It was remade out of much stronger carbon steel.

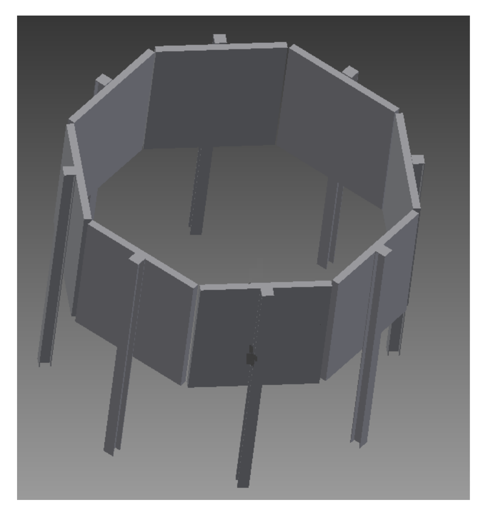
Force calculations for SCH bus bars and iron shield

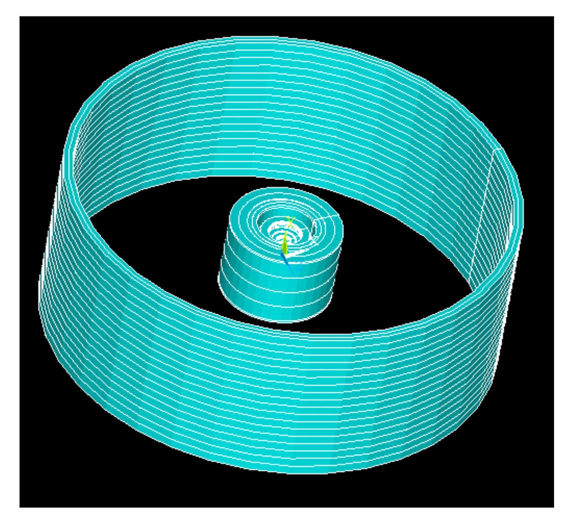
An iron shield has been used to absorb flux to reduce forces on the bus bars and increase working area in the magnet cell.
The bus bars were not previously analyzed and were modeled in Opera to find forces without the shield. The octagonal iron shield was modeled as a cylinder to take advantage of 2D axisymmetric solutions.





(Left) Configuration of bus bars (Right) Bus bars and SCH coils





(Left) Design model (Right) Simplified model

Forces on the cables confirmed that supports were adequate.

Acknowledgements

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Works Cited - Prapaiwan Sunwong *et al*, Journal of Physics: Conference Series 234 (2010) 022013