200 cm dipole for use in Halls A/B/C at 22 GeV

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Background

The Hall B optics in TN-04-033 requires 4*1.65E6 G-cm in two or four dipoles at 22 GeV. In that TN I simply re-arranged existing material; here I need all new magnets. A 200 cm version of the 380 cm FFA dipole of TN-21-051 provides 3.3E6 G-cm and so will serve. The same dipole can be used to close the dispersion from the Lambertson in the A and C lines and for the Compton chicanes in both. This TN copies conductor data from the previous one and shows response curve. Turns count for all uses except the dispersion closure will be 30; in those two locations it may be 24 to make the shunt work but that cannot be determined until the Lambertson is modeled.

Material Adapted from TN-21-052

Ten turn (total) double pancakes of approximate length 45 meters were assumed. Luvata 6815 was chosen as the design conductor. It is 14.5 mm square with a 8 mm diameter cooling hole and 1.5 mm radius corners. Copper area is 1.529 cm^2. To make the numbers easy, average resistivity of 2E-6 Ω-cm was used in calculation, this corresponds to an average conductor temperature ~60 C. Resistance of the double pancake is then 5.9 mΩ. Via http://www.pressure-drop.com/Online-Calculator/ I calculate that 150 cc/s of water in a straight 45 m tube with 8 mm ID yields 6.3 bar pressure drop. With bends, likely still within 7 bar of our present LCW system. Inside bend radius of inner turn 6 cm, four times the insulated conductor width so strain 11.1% and keystoning is very unlikely. If the inside radius were 4.5 cm, three times the insulated conductor width, strain 14.3%. This choice would shorten the unit another 3 cm but pressure drop would increase. If there were perfect heat transfer from copper to water, 150 cc/s with 40 C temperature rise corresponds to 6 kW of power. As will be seen below, the current needed for 22 GeV in Hall B is 675 A so the resulting power per double pancake is ~2700 W. Temperature rise then 18 C and the 60 C average copper temperature assumed is conservative with 35 C entry temperature and the calculated temperature rise. Six double pancakes per magnet and four magnets yields 0.142 Ω for the string and 100 V. A 750 A, 150 V power supply would provide ample margin for this calculation, prudent.

While it would be possible to design with a smaller conductor given the shorter double pancake the cost savings via commonality of both steel and copper sections is likely enough to favor using the same size that I chose not to.

The BH curve used in the model is one which corresponds to the steel chemistry specification used for both CEBAF and the 12 GeV upgrade models and checked against the actual field maps. The default “good magnet steel” BH curve in TOSCA would provide about 1% more field at the high end of the curve. Mild steel would provide so much less that it was not considered.

Model Results

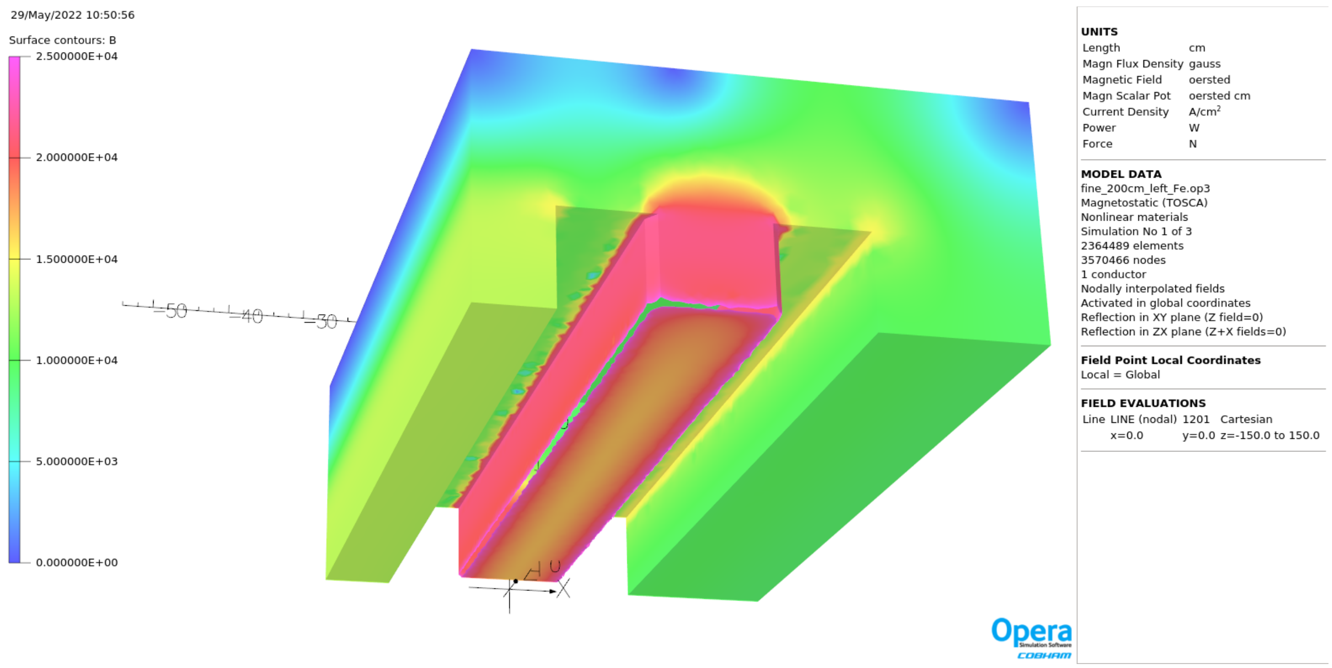

Figure 1. Field on the surface of the steel at 675A in a 30 turn coil.

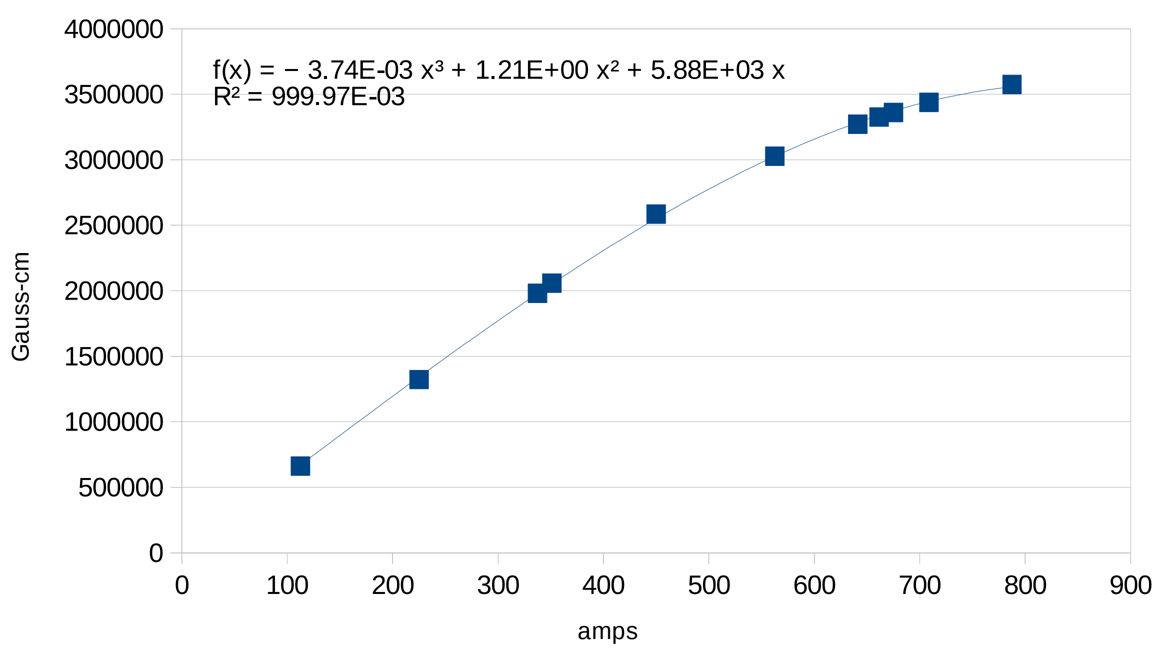

Figure 2. BdL as a function of current in the 30 turn coil.

Conclusion

The conceptual design of a 200 cm dipole for use in the Hall B ramp, the Compton polarimeters in Halls A and C and to close the horizontal dispersion from the Lambertson has been completed. Turns count for the last units to allow shunts from the Lambertson power supply is likely 24 but the Lambertson must be modeled to confirm.