180 cm Dipoles for Hall Line Use at 22 GeV (FFA)
Jay Benesch
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Abstract

A 180 cm dipole with the same cross-section as previously used in the 380 cm (TN-21-051) and 200 cm (TN-22-022) dipoles has been modeled. This length is needed because the 200 cm dipole would preclude function of the Compton polarimeter. It is also used to close the dispersion created by the Lambertson magnet (TN-22-041). Ten will be required for the 22 GeV upgrade Hall A and C lines.

Description

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. The coil pack is 75 mm wide by 90 mm high including insulation, five turns wide by three double pancakes high for a total of 30 turns in each of two coils. The coil is 200 cm long overall. The double pancake is about 44 m long including the ends. Via http://www.pressure-drop.com/Online-Calculator/ I calculate that 130 cc/s of water in a straight 44 m tube with 8 mm ID yields 4.8 bar pressure drop. The LCW system can provide this as is. The necessary field is produced by 675 A. The resistance of a double pancake is 5.76 mΩ per the assumptions above, yielding 2625 W. The temperature rise assuming perfect heat transfer from copper to water is 20 C so the assumption of 60 C copper is conservative. Six double pancakes per magnet and four magnets in the Compton chicane yield 140 mΩ implying 94.5 V at 675 A. Call it 100 V with lead resistance.

Inside radius of the coil is 4.5 cm, strain 14.3%. Keystoning should not be a significant issue. This radius rather than 6 cm was chosen to shorten the coil by 3 cm overall as the space available in the Compton chicane is limited. From the start of the steel in the first dipole to the end of the steel in the second is 446 cm in the present layout. Since the 200 cm dipole design is 220 cm overall it would not allow any space for the electron detector. The 180 cm design does not allow for enough drift within 446 cm so the field would have been 2T, too high. There is now 131 cm after the Compton chicane for a differential pumping (DP) station and vacuum valves. This was removed and 50 cm added to the drift between the pairs of Compton dipole magnets, allowing the field to be reduced to “only” 1.68 T. Laser table allowance was not touched. The small aperture of the downstream beam pipe provides enough of a conductance limit that the DP station is superfluous. It's a relic of the 4 GeV design. The 31 cm left after the Compton will suffice for vacuum valves. Before the 50 cm drift was added a 1.5 cm by 1.5 cm chamfer was added to the full length of the magnet poles to increase the field, in addition to the end chamfer. This would degrade field quality and so is not preferred but results are shown in Figure 3.

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.

The poles of this magnet are chamfered at the ends, 1 cm in X and 1.5 cm in Z, to allow the coils to be brought closer to the steel than in present arc dipoles and reduce the overall length of the magnet.

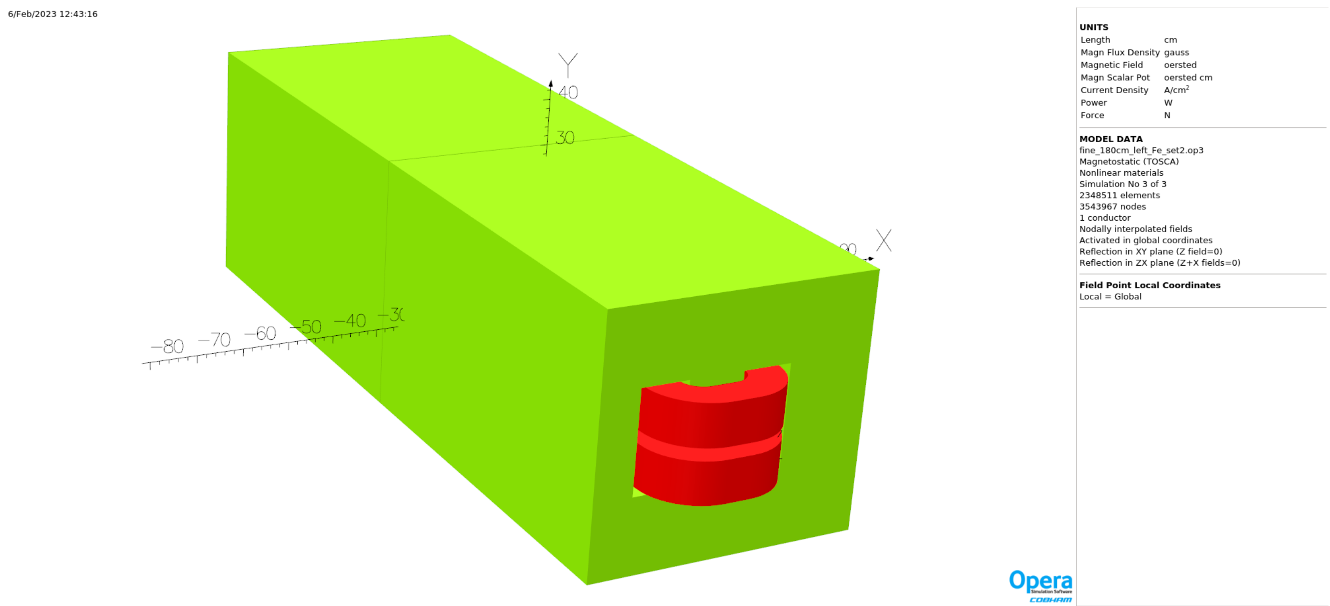

Figure 1. Perspective of the model. X extent of steel [-25, 35]. Y extent of steel [-27.5,27.5] Z extent of steel [-90,90] Steel return at left is 8.5 cm wide while that at the right is 18.5 cm wide. Pole gap [-1.3,1.3]. Pole width 14 cm. Coil pockets are 9.5 cm wide and Y=[-11,11], they are symmetric about the center of the pole. The width provides for the layer to layer transition within a double pancake. Implied dimensions: pole center is 25 cm from left edge of steel and 35 cm from right edge of steel. Coil straight is 88 cm with 4.5 cm inner radius. Pole chamfer 1 cm along X axis, 1.5 cm along Z axis.

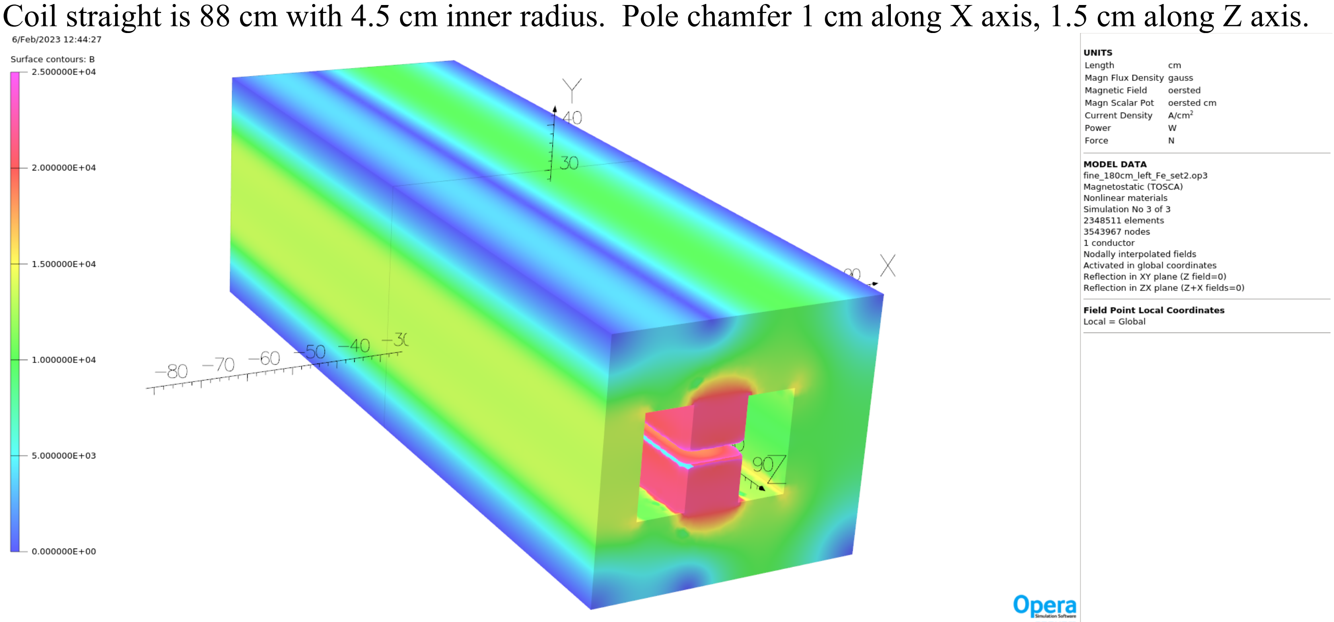

Figure 2. |B| on the surface of the model The blue on the corner of the pole indicates that a volume is missing because the field is over 25 kG. Truncating peak field allows for clearer display of most of the surface field. If one looks closely one can see the chamfer on the end of the pole.

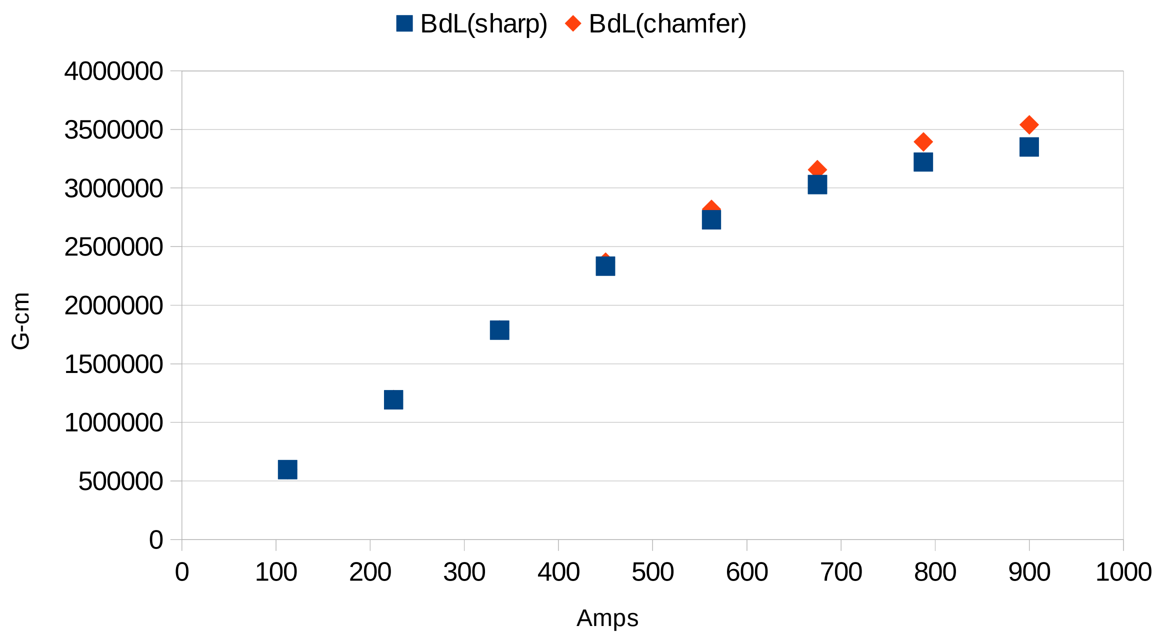

Figure 3. BdL as a function of current for sharp-cornered and chamfered pole. Chamfering increase the field about 5% at the higher current values. 3.02E6 G-cm needed for the Compton chicane so 675 A in the sharp-cornered model suffices.

Harmonics were calculated along two orbits of 22 GeV beam, starting at x=1 cm and at x=1.5 cm, in the model with sharp corners the length of the poles. Normal incidence as is usual for the Compton chicane. Energy ~0.3% low for the BdL in the model so both orbits move slightly more from the middle of the pole than if the energy was increased. Clearly the orbit starting at x=1.5 cm is better: less than one unit of quadrupole and ~5 units of sextapole.

start	Cos0	Cos1	Cos2	Cos3	Cos4
x=1	-3027564.36	-1318.28	1589.07	-84.43	6.80
x=1.5	-3027853.58	204.89	1550.94	11.49	9.41

Conclusion

The conceptual design of a 180 cm dipole for use in the Hall A and C lines in Compton polarimeters and to close the dispersion from the Lambertson has been completed.