Solid XL - last look with CLEO steel?
Jay Benesch
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Abstract

A revised magnetic model of the SoLID system with the ME-specified layout at the magnet-endcap interface has been created. This model still uses the CLEO steel even though it may be replaced. It uses a 1010 BH curve rather than the Opera default "good magnet steel" as in previous documents. This increases stray field outside the iron from 5G to 10G where PMTs and detector readouts are to be placed. It also increase the field at PMT locations inside the endcap from ~60 G to ~80 G. It follows that holes covering 2% of the surface area of the end cap may increase these fields similar amounts. The effect of the nose taper required to maintain acceptance to the end of the PVDIS target on the field in these regions is shown to be small (~2%), contrary to my expectations.

Discussion

As a result of my discovery, detailed in TN17-032 on the HRS resistive quads, that moving from 2 cm to 1 cm mesh maximum made a 0.25% change in quadrupole term and caused the dipole term to go from strange to making sense, I decided to create two volumes of "detector air" with finer mesh than the steel and remainder of the interior. This resulted in a model with ~300M non-zeroes in the matrices with eight-fold symmetry. I could not later break the symmetry with the turret cut-out within Opera's limit of 2147M non-zeroes so I had to cut back on elements. From Whit Seay I got inner radii of the new support systems in the solenoid and end cap. From Xiaochao Zheng I got the length of the region behind the shashliks. These changes, and some I made to the air surrounding the steel, got the model down to 246M non-zeroes. "Detector_air1" is now R132 Z [-188,188]. "Detector_air2" is now OR 258, dR 173 Z [224.79,508.79]. The mesh is shown in figure 1.

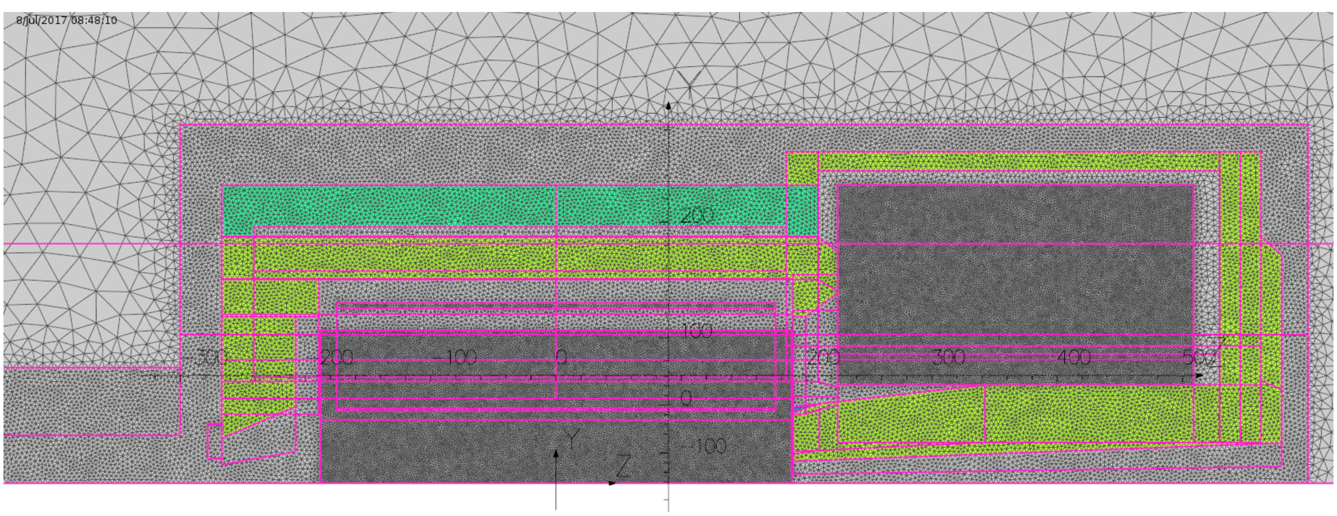

Figure 1. Mesh of markV_try3 models. The two large dark rectangles are "detector air". The thin R dark block above the left one contains the solenoid. Dark mesh has 2 cm maximum elements. Medium grey and green steel has 4 cm maximum mesh. Light grey scales from 4 cm to 32 cm maximum.

Question for collaboration: May I reduce the OR of "detector_air2" from 258 cm to 250 cm?
The latter is the OR of the volume I was given for the LGC and HGC PMTs. **Or even smaller?**

Try1

There were four try1 models solved with varying upstream plug thicknesses. The first three had plug thicknesses of 76, 66 and 61 cm. Opera calculated forces on the solenoid for each. I plotted, added a quadratic fit line, and solved the quadratic. The fourth model used the solution, 58.8 cm. The four-point plot and fit are shown below. The solution for this fit is 58.95 cm thick aka -207.75 cm.

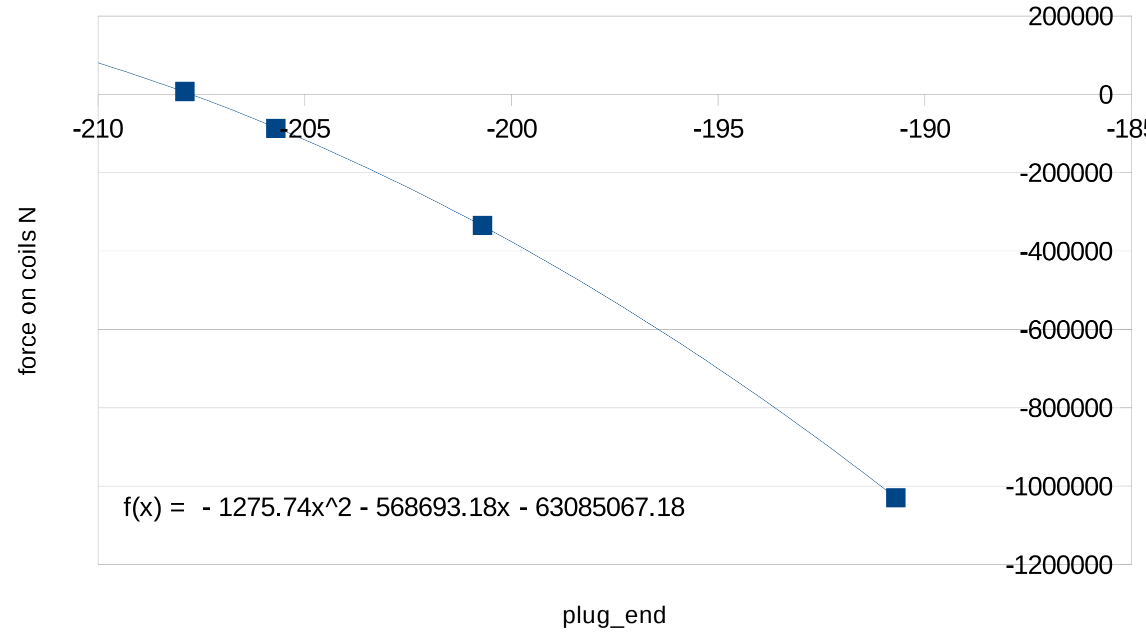

Figure 2. Force on the solenoid coils (Newtons) as a function of the downstream end of the upstream plug. The upstream end is at Z=-266.7. One zero of the fit equation is -207.75. The four axial load cells can handle 5000 kgf each, aka ~200 kN total. The pair of points at upper left yield 43 kN/cm. With Opera Default steel BH curve the plug ended at -205 cm (DocDB 9-v1). Assuming 1010 and Opera's Default span the likely BH curve parameter space, ~200 kN capacity should suffice.

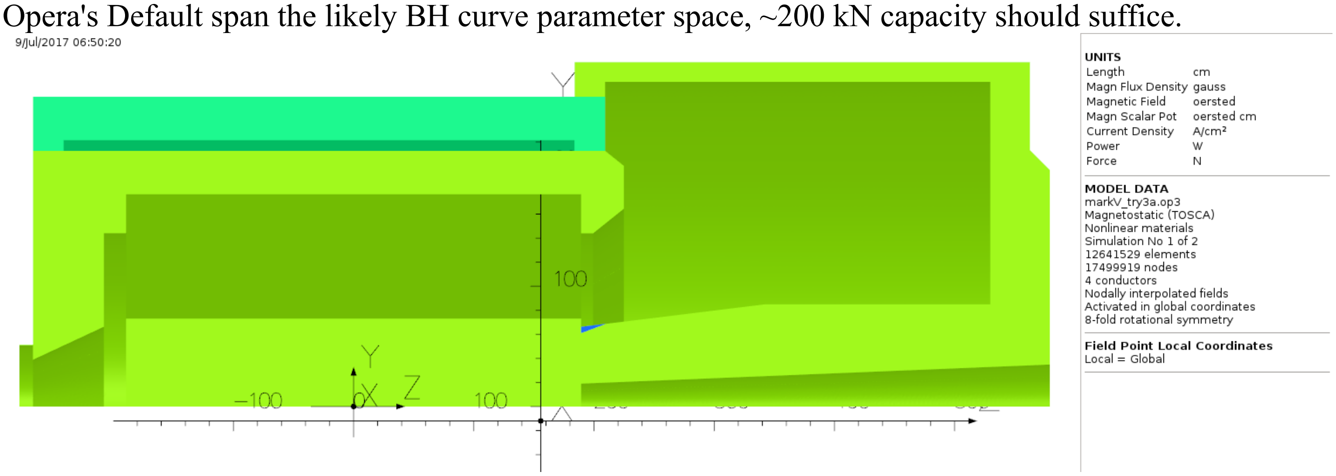

Figure 3. This is a quarter-section of the try3a model. The small blue region on the nose cone is the region Zhiwen wishes to remove to provide acceptance of the full length of the PVDIS target. Solving the model with that region having BH curves of 1010 steel (sim 1) and air (sim 2) yields a change in the coil force from +827 N to -19.5 kN, 20.3 kN total. About the same as 5 mm of thickness change in the upstream plug.

Contrary to my expectation, the field in the region where the LGC and HGC PMTs reside dropped by 2% when the BH curve for the blue region was changed from 1010 to air. The field in the region just above the cone increased a similar fraction. Peak field on the surface of the model dropped 3% because the peak was at the edge that was removed. It follows that we can cut that volume out of the nose and gain the desired acceptance without significant detriment. Location of the upstream plug end should therefore be -207.25.

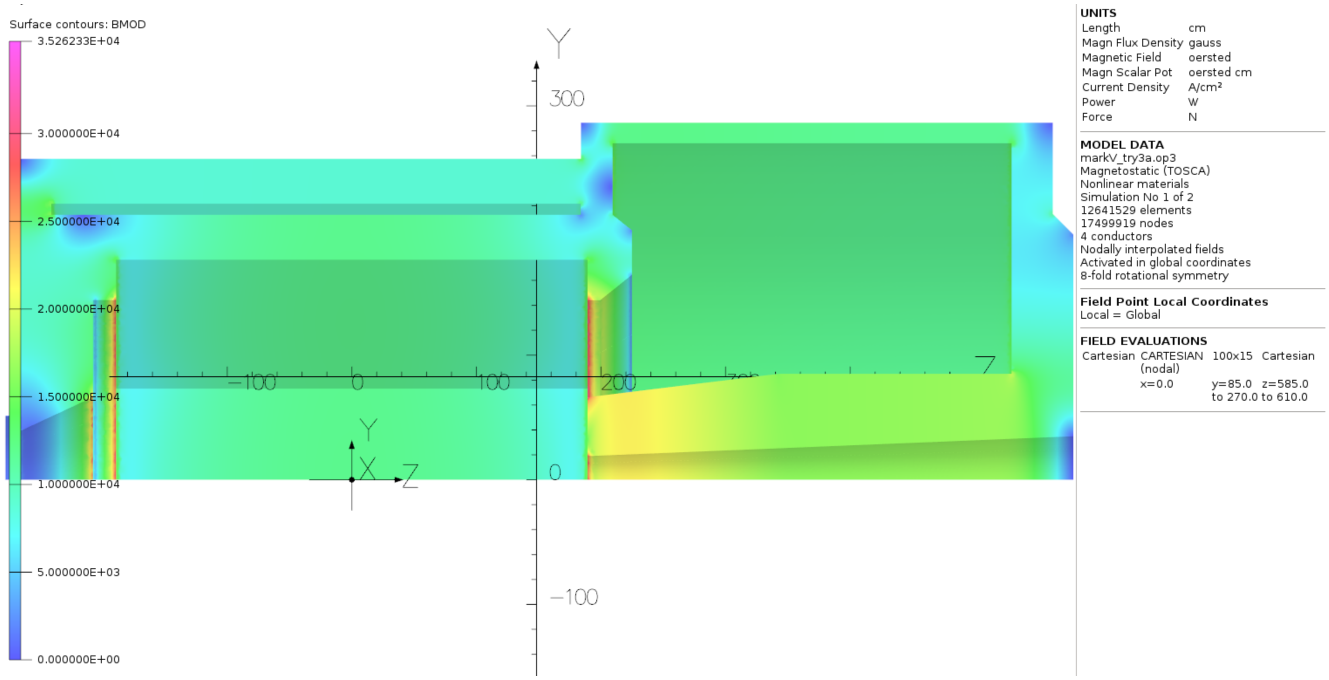

Figure 4. Bmodulus on surface with single nose taper (aka blue in figure 3 = steel). Peak 3.526 T

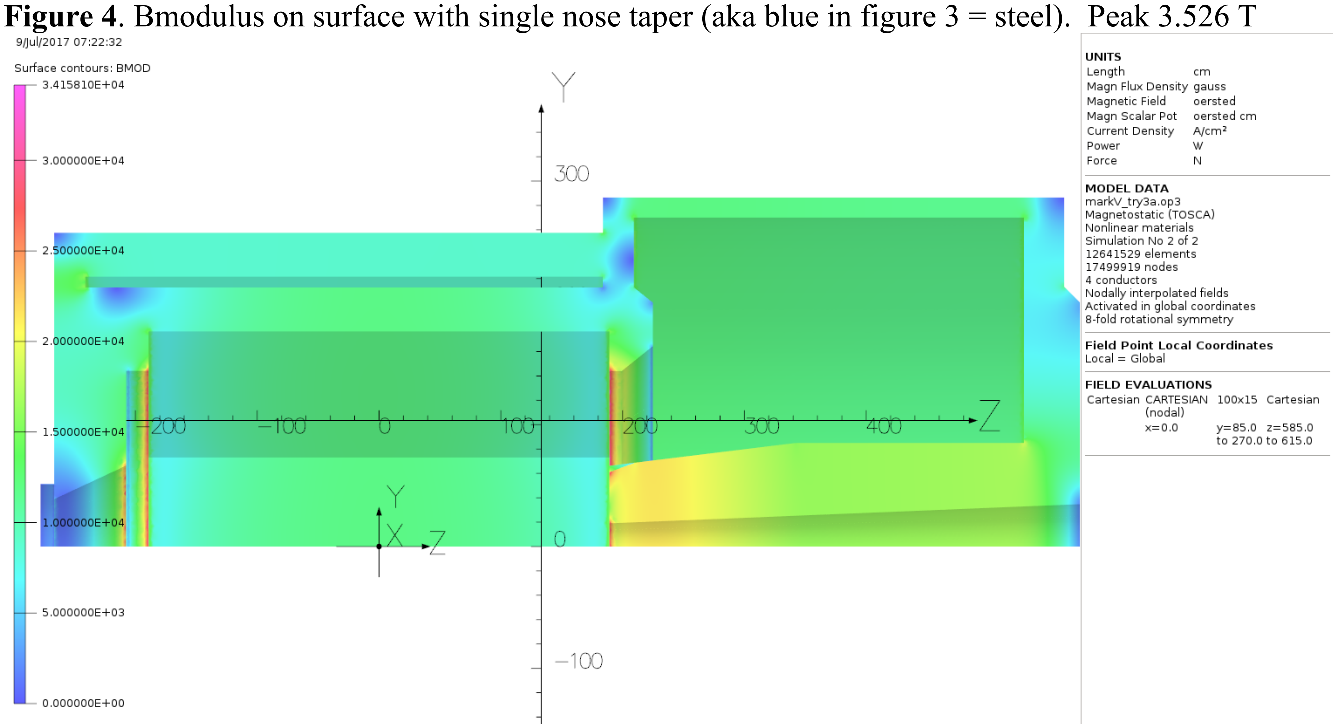

Figure 5. Bmodulus on surface with double nose taper (aka blue in figure 3 = air). Peak 3.415 T

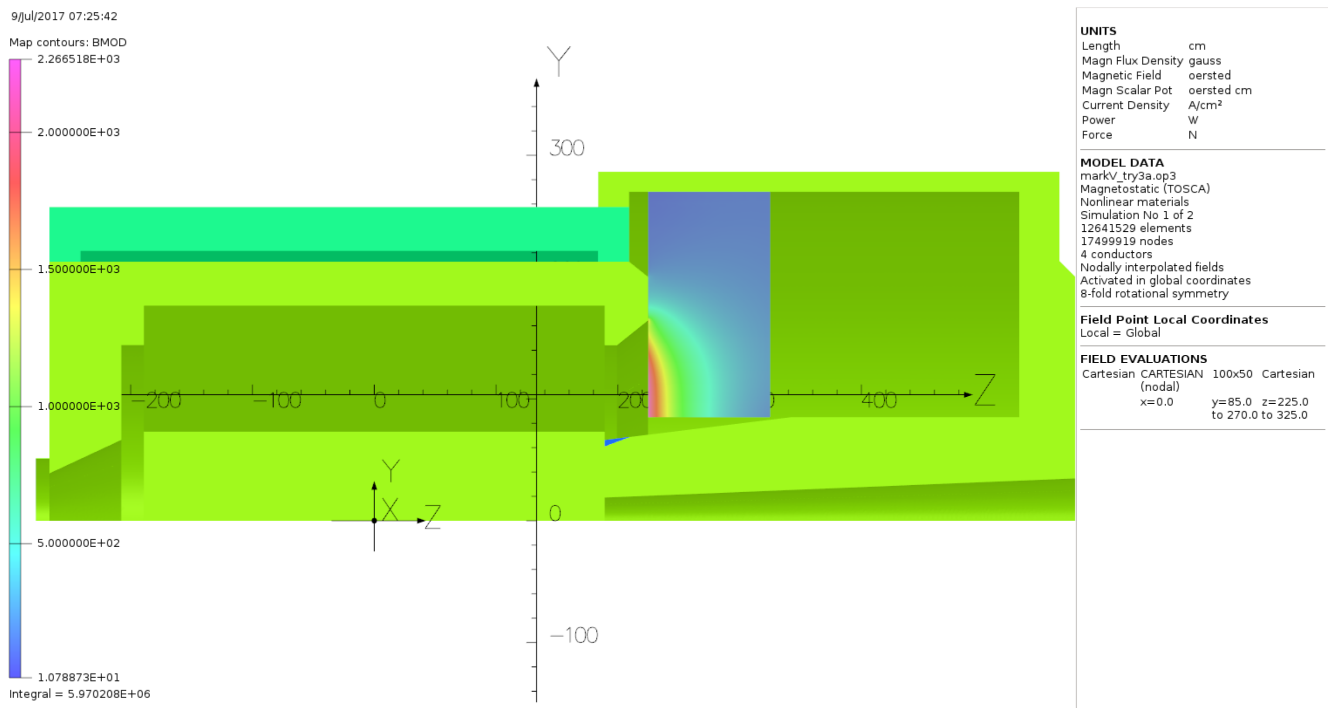

Figure 6. Bmodulus in endcap over the cone, single taper on nose (blue=steel) . Peak 0.227 T

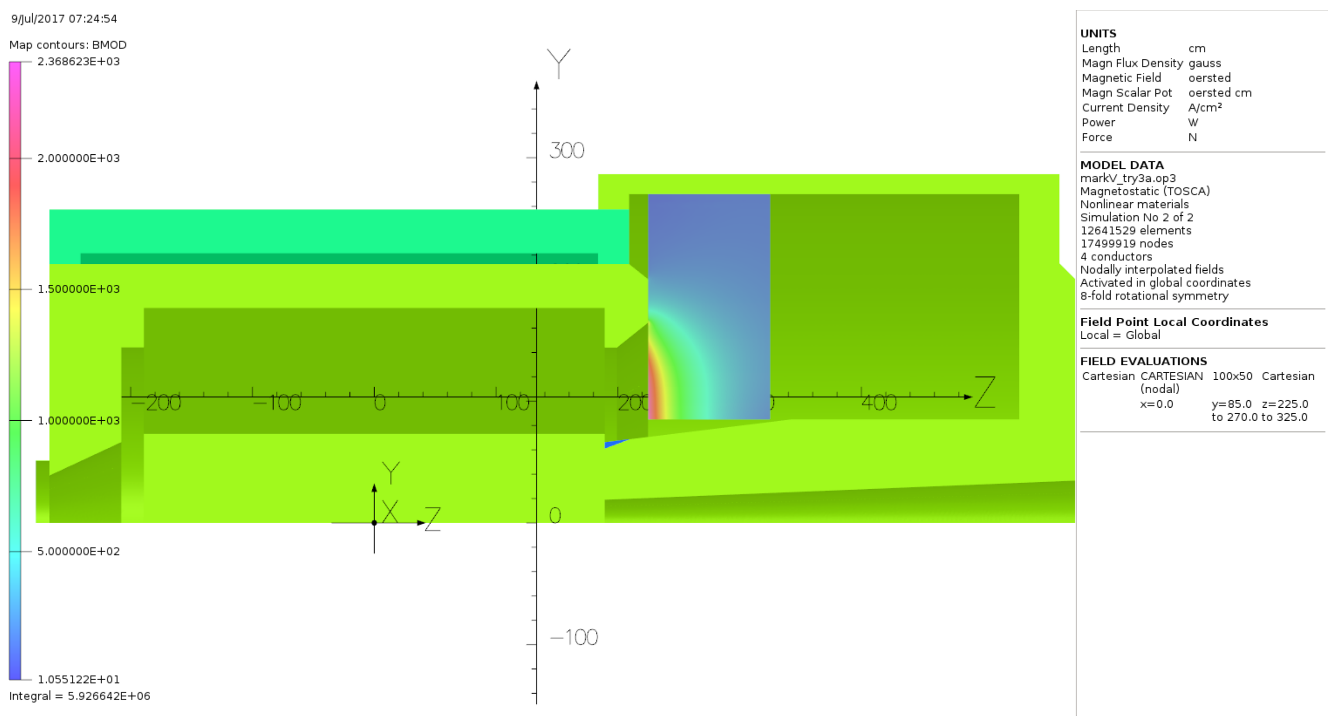

Figure 7. Bmodulus in endcap over the cone, double taper on nose (blue=air) . Peak 0.237 T. Some flux which would have been conducted through the nose and around the entire endcap now jumps directly to the downstream coil collar. This is what I didn't consider at the collaboration meeting.

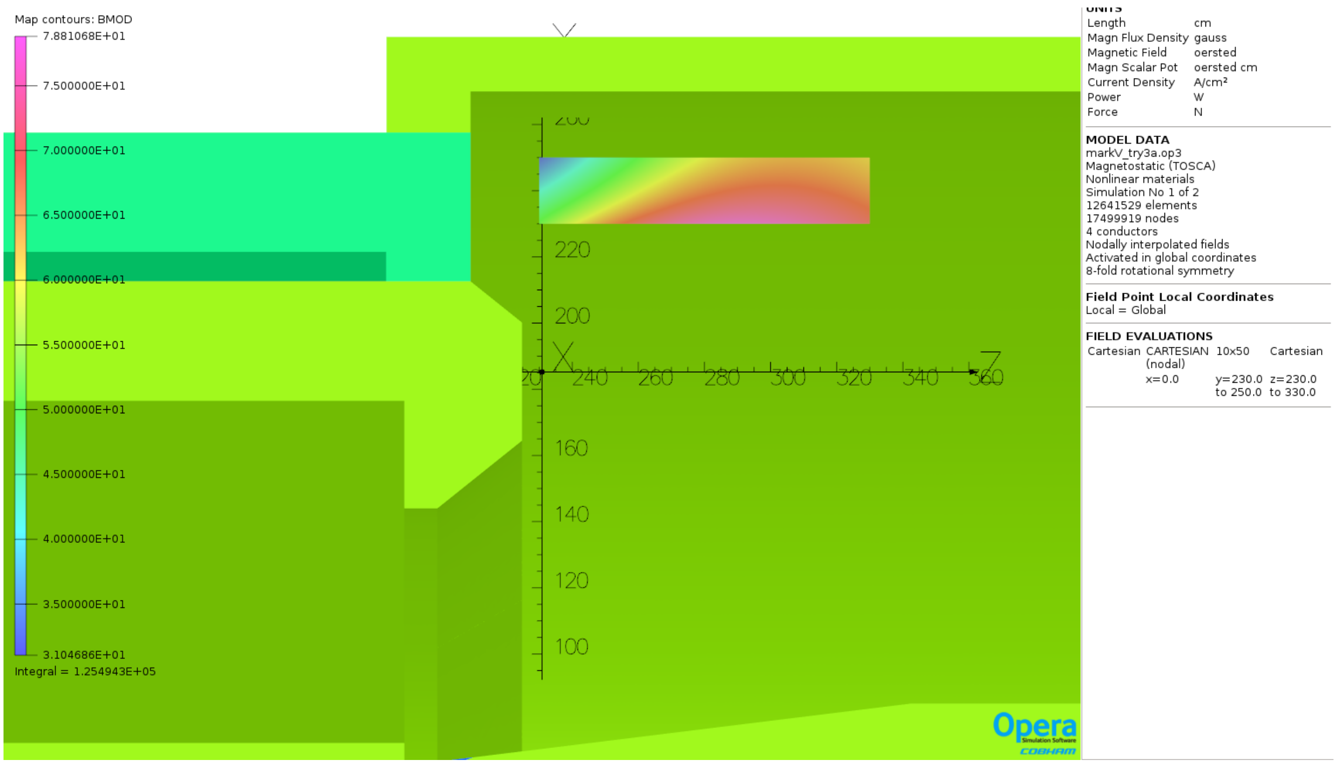

Figure 8. Bmodulus in vicinity of LGC and HGC PMTs. Compare with figures in DocDB 9-v1 where I used the Opera Default BH curve. Values there were under 60 G. 1010 BH curve used here. Single taper on nose.

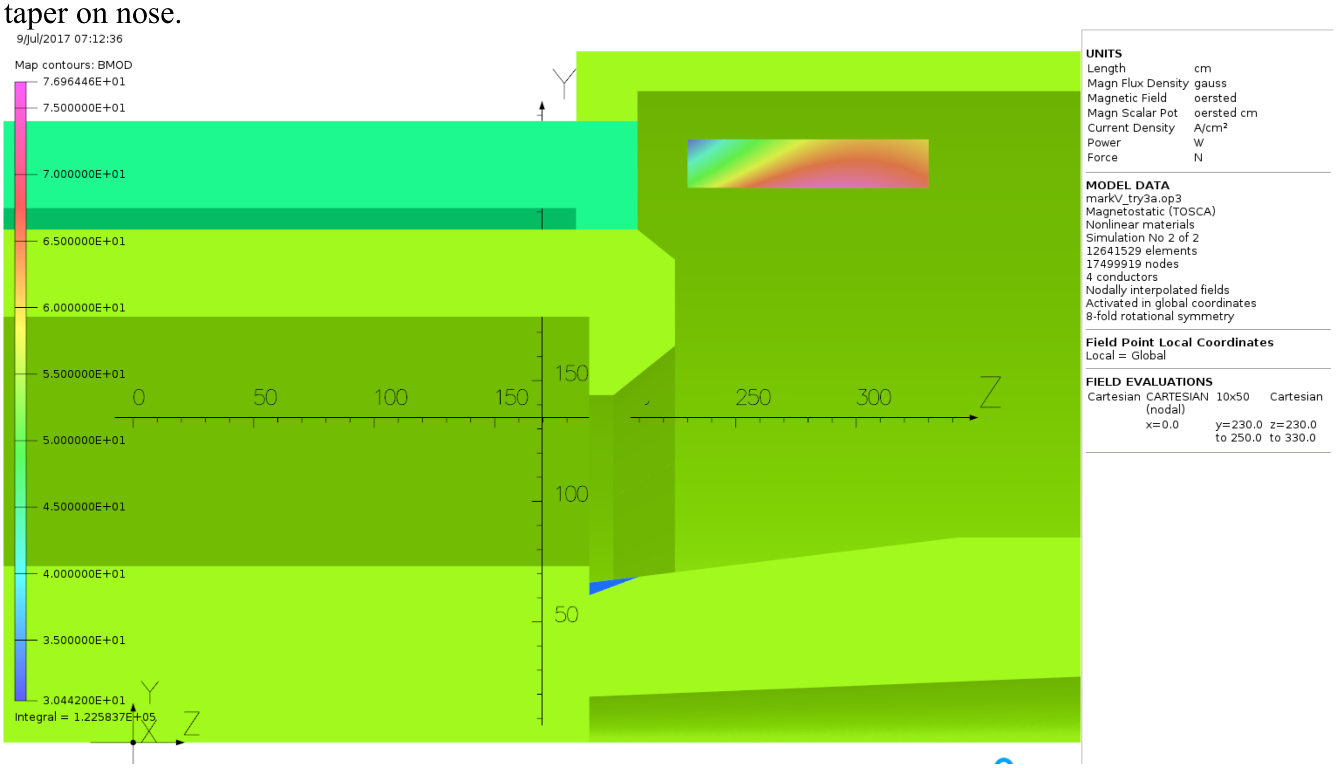

Figure 9. Bmodulus in vicinity of LGC and HGC PMTs. Compare with figures in DocDB 9-v1 where I used the Opera Default BH curve. Values there were under 60 G. 1010 BH curve used here. Double taper on nose. Peak 77 G here vs 79 G in figure 8.

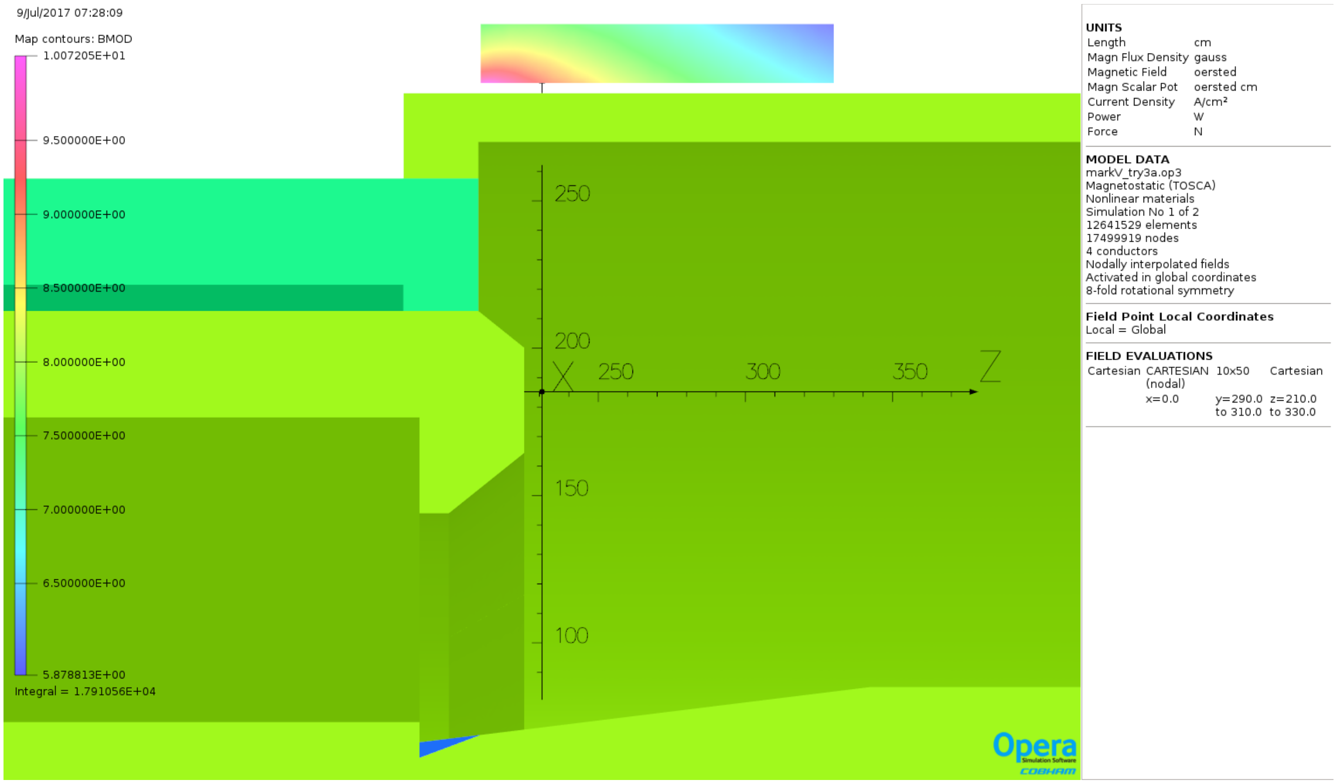

Figure 10. Bmodulus in vicinity of GEM electronics. Single taper on nose. Peak 10 G. 1010 BH curve used here. Again, compare with DocDB 9-v1.

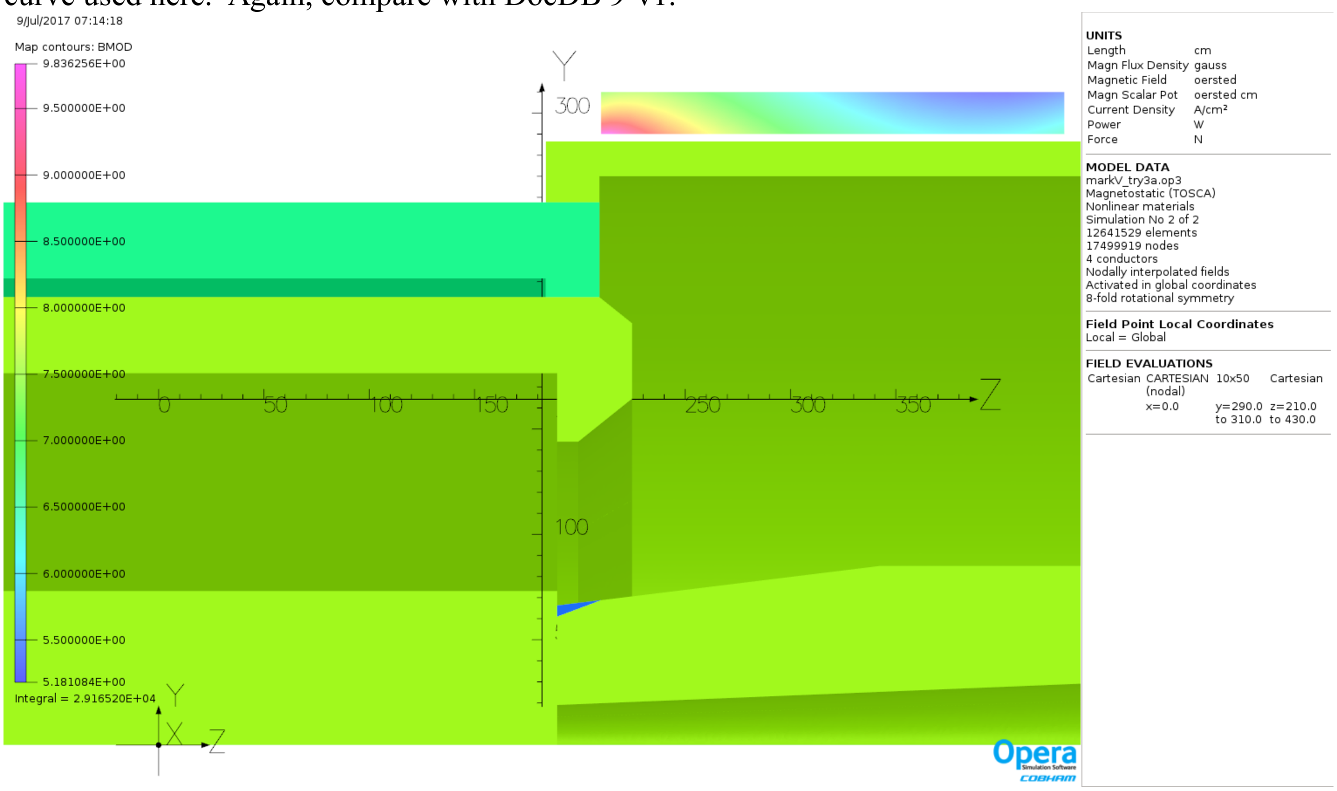

Figure 11. Bmodulus in vicinity of GEM electronics. Double taper on nose. Peak 9.8 G, slightly less than figure 10. 1010 BH curve used here. Again, compare with DocDB 9-v1.

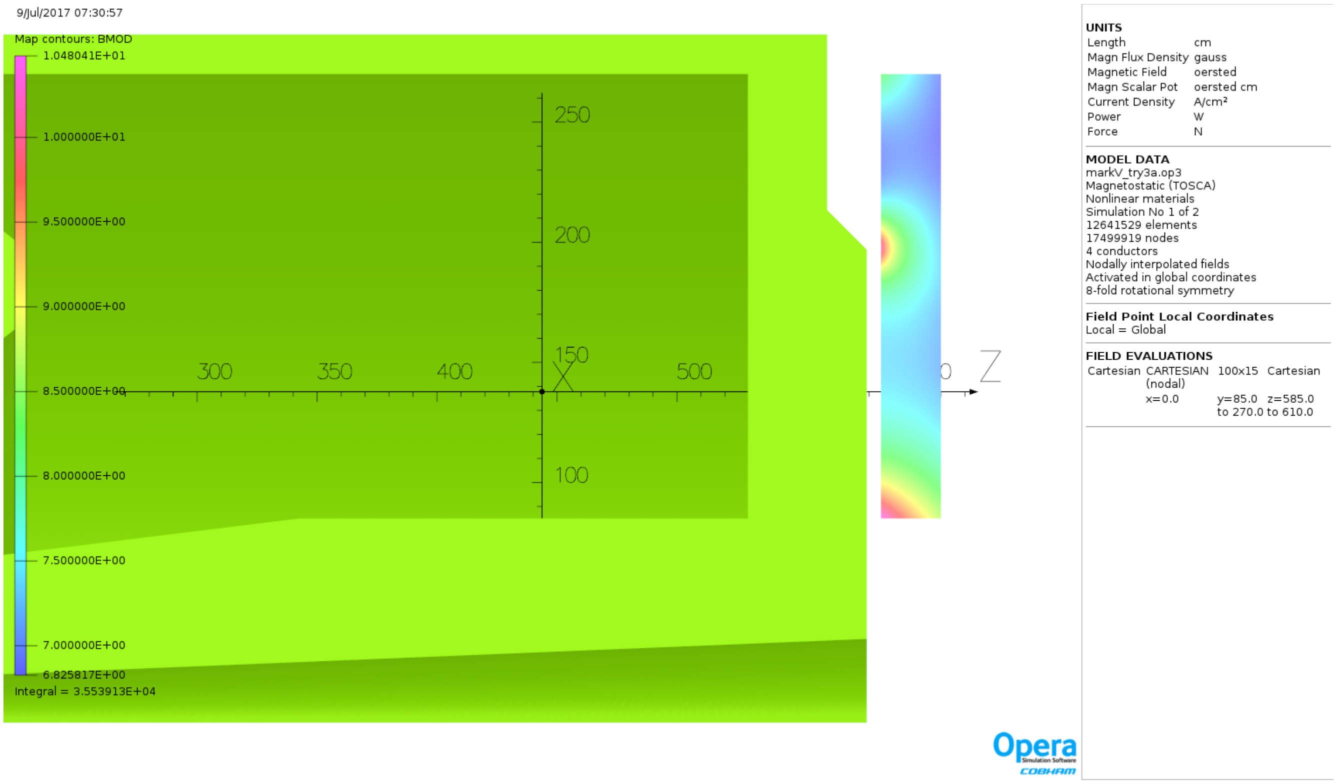

Figure 12. Bmodulus in vicinity of ECAL PMTs. Single taper on nose. Peak 10.5 G. 1010 BH curve used here. Again, compare with DocDB 9-v1.

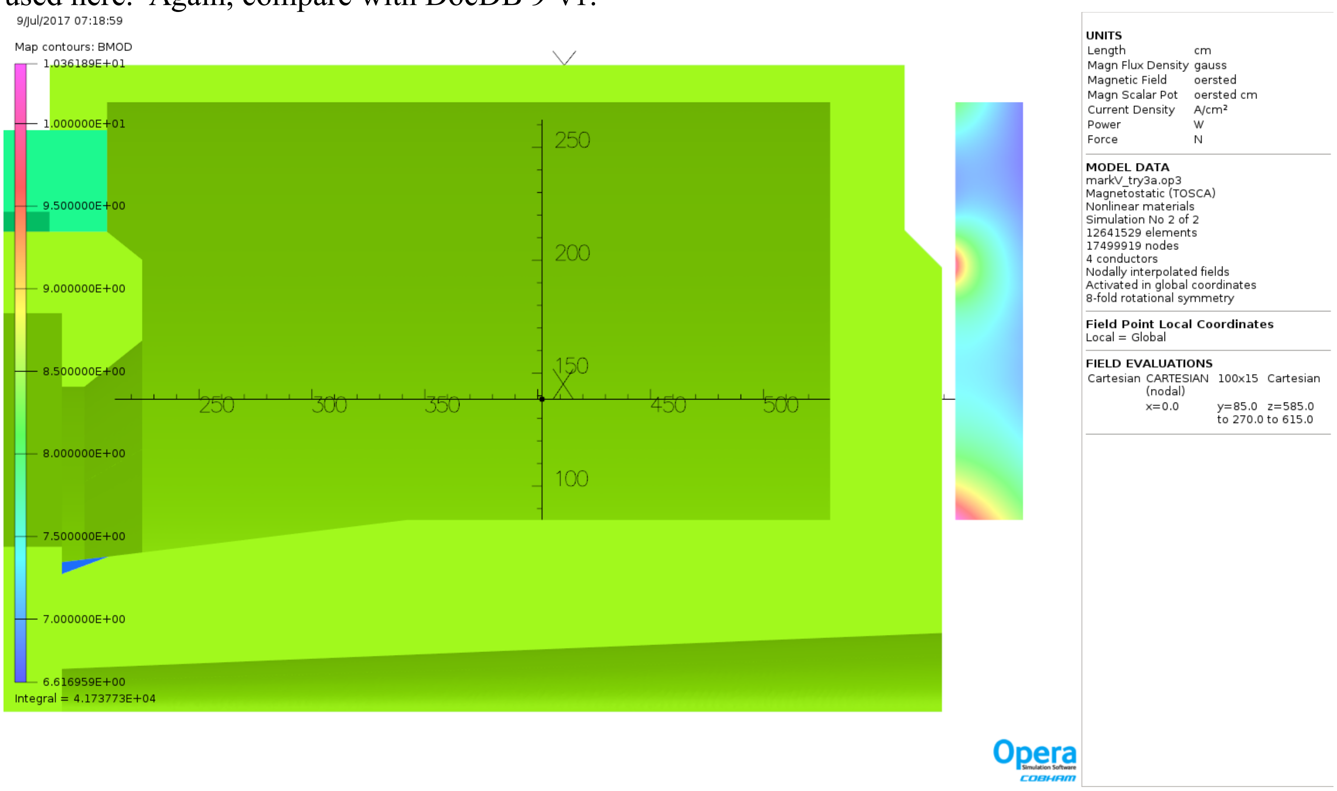

Figure 13. Bmodulus in vicinity of ECAL PMTs. Double taper on nose. Peak 10.4 G. 1010 BH curve used here. Again, compare with DocDB 9-v1.

Conclusions

1. It is OK to make a double taper on the nose to get acceptance of particles from the downstream end of the PVDIS target
2. Use of a 1010 BH curve instead of the Opera Default “good magnet steel” changes the force on the coils by ~115 kN, equivalent to changing the upstream plug thickness by 2.75 cm.
3. Measuring the BH curves for the upstream plug and the cone steel when fabricated and re-running the calculations would be helpful in defining final thickness of the upstream plug.
4. Given the change in stray field inside the end cap with BH curve, the model should be rebuilt with the endcap cylinder and end plates assigned yet another BH curve, one in which B is multiplied by 0.98 to account for 2% area reduction for cable holes.
5. The field in the inner octagon peaks at 1.18T at (x,z)=(0,0). In the outer octagon, 0.87T. It follows that three layers of the same 6.5” steel used in the model for the end cap and end plates would do as well as the two layers of 14.2” CLEO steel shown here.

Question 2 for collaboration: Should (4) or (5) above be next on my list?

Appendix: Modeller primitives used to build Opera models revised 7/5/2017

Inner octagon steel1 level 92 4cm

inside Y 69.5" = 176.53 cm * (1/cos 22.5)= 191.075 IR
outside Y 83.71" =212.62 cm * (1/cos 22.5) = 230.142 OR
radial thickness 39.069 cm.
Z -266.7 to 224.79

Opera has a operation: make n-sided polygon. Using 230.142 OR and thickness 39.069 one arrives at an octagon with the inside and outside heights on the Cornell drawing 6052-303 sheet 3.

Chamfer at Z 224.79 OR 15.56 in Z by 12.45 in R

Notch construction air at end of inner octagon

Whit has a 1.5" notch running Z=189.23 to 224.79 which is 1.5" deep to match hexagonal OD of new coil collar. But coil collar has round ID. So I have to make a hexagonal notch in inner octagon and then trim overlap. As above, the OR 71" = 180.34*(1/cos 22.5) = 195.2,
IR 69.5" =176.53*(1/cos 22.5) = 191.075 but use deltaR 4.25 and Z 225 max to grab it.

Outer octagon steel2 level 91 4cm (so I can make it air BH later)

outside Y 101.42" = 257.61*(1/cos 22.5) = 278.832 OR
radial thickness 39.069 cm
Z -266.7 to 209.23
Again, make n=8 polygon of this Opera "tube"

Spacer bars steel2 level 91 4cm (so I can make them air BH later)
Between octagons: I figured out the volume of the bars and determined that cutting the Z extent to 25.5 cm would maintain the steel volume. Z extent: -266.7 to -241.2, 183.73 to 209.23. This simplifies the model a lot. These end annuli are merged with the outer octagons in the model and trimmed by inner - no air gaps.

Coils used cold dimensions from OMT manual, including Z shrinkage, and warm Z lengths of outer segment from winding drawing.

IR 151.7 OR 154.9
Z1 -173.75 to -85.45 3814.273 A/cm^2
Z2 -85.45 to 85.45 3708.32 A/cm^2
Z3 85.35 to 173.75 3814.273 A/cm^2

Current densities were derived by looking at total turns, 1281, and conductor sizes from IEEE paper and estimating winding pattern. Only later did I see the winding drawing. I can't find turns count on it. I did learn that the 4.9 mm conductor is used only on the outer winding outer layer, not both layers. More recently I've multiplied the current densities above by -1.0072 (ends) and -0.9961 (center) to get the ratio closer to 1.04 quoted in the paper. Correction solenoid 9 cm square, -1.2

Upstream coil collar steel1 93 4cm
OR 194.145 cm, 113.50" ID => 144.145 cm IR, deltaR 50, Z -266.7 to -189.23 cm (30.5" extent).
Trim overlap with inner octagon.

Coil air: level 100 2cm
OR 156 cm, thickness 5 cm, Z -175 to 175 cm

<u>Upstream plug</u> steel1 93 4cm
Z -266.7 to **-207.25** cm with Zhiwen taper steel set to air. **-207.75** if set to steel. OR 144.145 cm. Solid to start. Create a cone with 1 mm R tip at Z=-350 and base 74.61 cm R at Z=-190, aka 25 degree angle. Trim overlap of steel with air, then delete air leaving conical hole. *Bold value will be varied to null force on coils.*

<u>Downstream collar</u> steel1 94 4cm
Z 189.23 to 224.79
tube OR 195.20 deltaR 51.2
at IR 144, Z 224.79 chamfer R 20.447 Z 25.56
trim overlap to inner octagon notch made on previous page

<u>Cone</u> steel1 95 4cm
R66.25 at Z 189.23 from 7 degree constraint
R85 at Z 342.27 from 7 degree constraint and 85 cm OR maximum

<u>Zhiwen_taper</u> steel3 96 4cm
R61 Z189.23
R68.759 Z210
trim overlap with cone above. Check for errors before and after.

<u>CylinderA</u> steel1 95 4cm
OR 85 Z 342.27 to 579.12

<u>Endcap_cyl</u> steel1 90 4cm
OR 286.51delta R 16.51 (6.5”) Z 209.23 to 529.59

<u>End_plate1</u> steel1 90 4cm
OR 286.51 delta R 201.51 (leaving 85 cm for CylinderA), Z 529.59 to 546.1

<u>End_plate2</u> steel1 90 4cm
OR 286.51 delta R 201.51 (leaving 85 cm for CylinderA), Z 546.1 to 562.61

<u>Cone_plate</u> steel1 95 4cm
OR 213.36 delta R 128.36 (leaving 85 cm for CylinderA), Z 562.61 to579.12.
chamfer at OR 16.51 by 16.51

Hole in cone: IR 19 cm at Z 189.23, IR 35 at Z 581.85 from 2 and 3.5 degree constraints

<u>Interface_endcap</u> steel1 90 4cm
OR 286.51 delta R 32 Z 183.83 to 209.23 aka 10”: interface octagons to end cap cylinder. Trim overap with outer octagon.

<u>Inner_air</u> level 80 4cm
R310 Z -300 to 600. R100 Z -450 to -300
And in gap between octagons: Z -240 to 184 overlaps bars a bit OR 240 deltaR 10 should cover gap. Use cut plane at Z=0 to see gap and trim overlap sequentially.

Detector air, level 82 2cm
part 1: R132 Z [-188,188] *part 2*: OR 258, dR 173 Z [224.79,508.79] shorter OK per Xiaochao

Outer air 70 32cm
R500 Z -500 to 800. level 70.

Background cylinder has multipliers applied to stuff I defined. Z 9 R 8 320 cm max mesh. Meshes out to 5000 cm both directions.

corrector_ring steel1 97 2cm

OR 51.435 deltaR 0.635 so IR 50.8 (20")

Z -266.7 to -278

correction_coil IR 40 cm vs end plug hole 38.84 IR. Cross section 9 cm square. J 100 A/cm^2 Offset -277 cm so downstream end is at -268, 1.3 cm from plug face. #8 square conductor is 0.1298+0.005 = 0.1348 maximum dimension. 0.3424 cm. Assume conductor is butted within layers and there is 0.010" glass between layers to wick epoxy. 25 turns/layer +1 for transition, 24 layers, 600 turns total.

Service turret steel removal. I built a rectangular parallelopiped of air inclined at 22.5 degrees with 13.2" X width and 14" Z width. I made it substantially longer than the chord of the paired octagons. I moved it to 30.75" from -Z end at the edge of the top plate. I trimmed the overlap of the steel and air, then deleted the air. "Inner air" above fills the gap created.