More variations on the positron capture solenoid
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Background

Salim Ogur reported in an email that a hard-edge (non-physical) solenoid in his model would capture twice the positrons than the physical solenoid described in TN-25-011. The work discussed in this TN began with that model and altered it with the goal of providing steeper descent at entrance and exit, aka closer to a hard edge. Inner radius of steel was decreased, eliminating the 5 cm of W10Cu inside the steel in previous models. A portion of the W10Cu under the coil proper was subsequently changed into steel as was done by Sinclair in the original 100 kV injector solenoids. Both changed proved helpful.

Initial condition

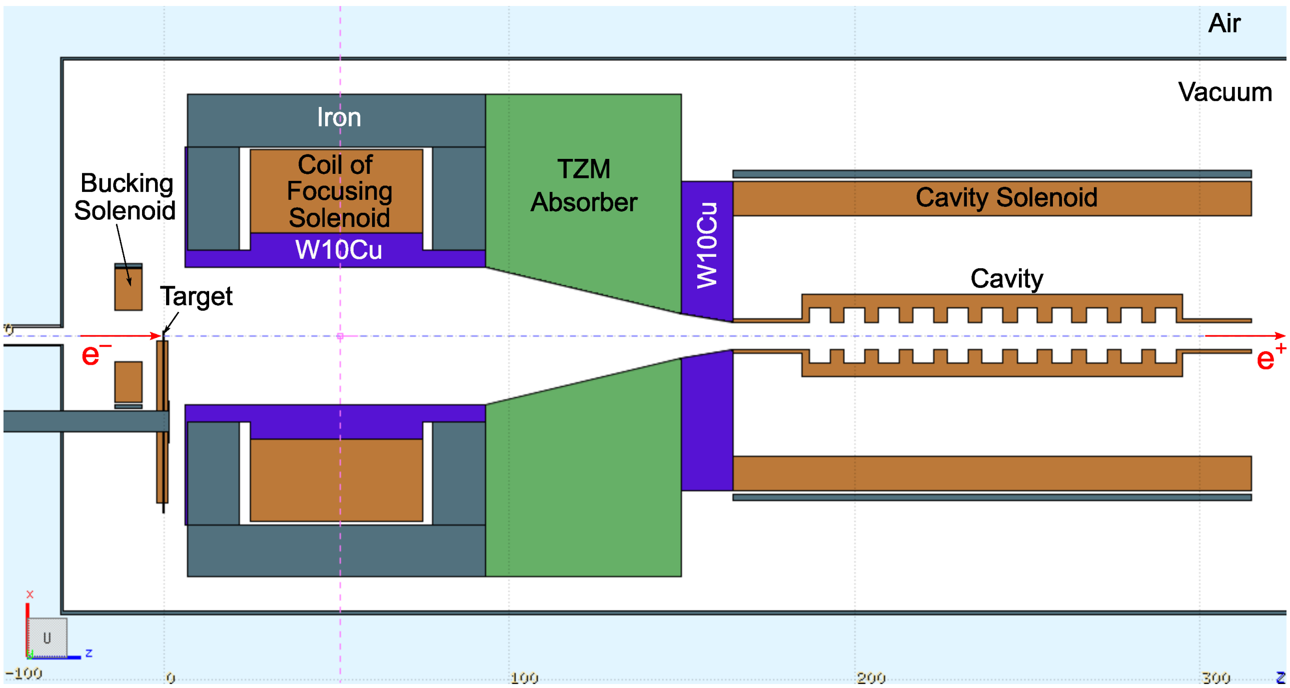

Figure 1. Layout used by Andriy Ushakov in FLUKA models. Vacuum is non-physical. The W10Cu shielding in contact with iron is altered in what follows.

Conductor in the main coil is 16 mm square Luvata 6826 conductor with 12 mm hole, wound in double pancakes with leads and water connections at the top through a 10 cm notch. Insulated conductor 17 mm. 12 double pancakes total 40.8 cm coil Z extent. Length between end plates 43 cm. 20 bar water needed for cooling. Coil IR 30 cm, OR 55.5 cm, 15 radial turns in each pancake, 30 per double pancake. Steel IR 60 cm OR 80 cm. End plates either 16.5 or 17 cm thick. The steel will have to be cast and the castings perhaps forged for full density.

The bucking solenoid is wound of #4 solid conductor, 5.36 mm MMC, heavy polyimide film insulated. 16 turns by 26 layers. The width in the model is 17 turns, allowing for layer to layer transition during winding. 70411 AT for the best solution discussed, 169.3 A. Resistance ~0.23 Ω Assume 170 A, 40 V hence 6800 W to remove. Power supply likely 10 kW, 200 A at 50 V. Side area 1070 cm^2 so an upstream cooling plate should suffice. If not, both sides and the solenoid moved back one cm to allow for downstream plate. Current will increase about 10 A if moved but double the cooling, so fine.

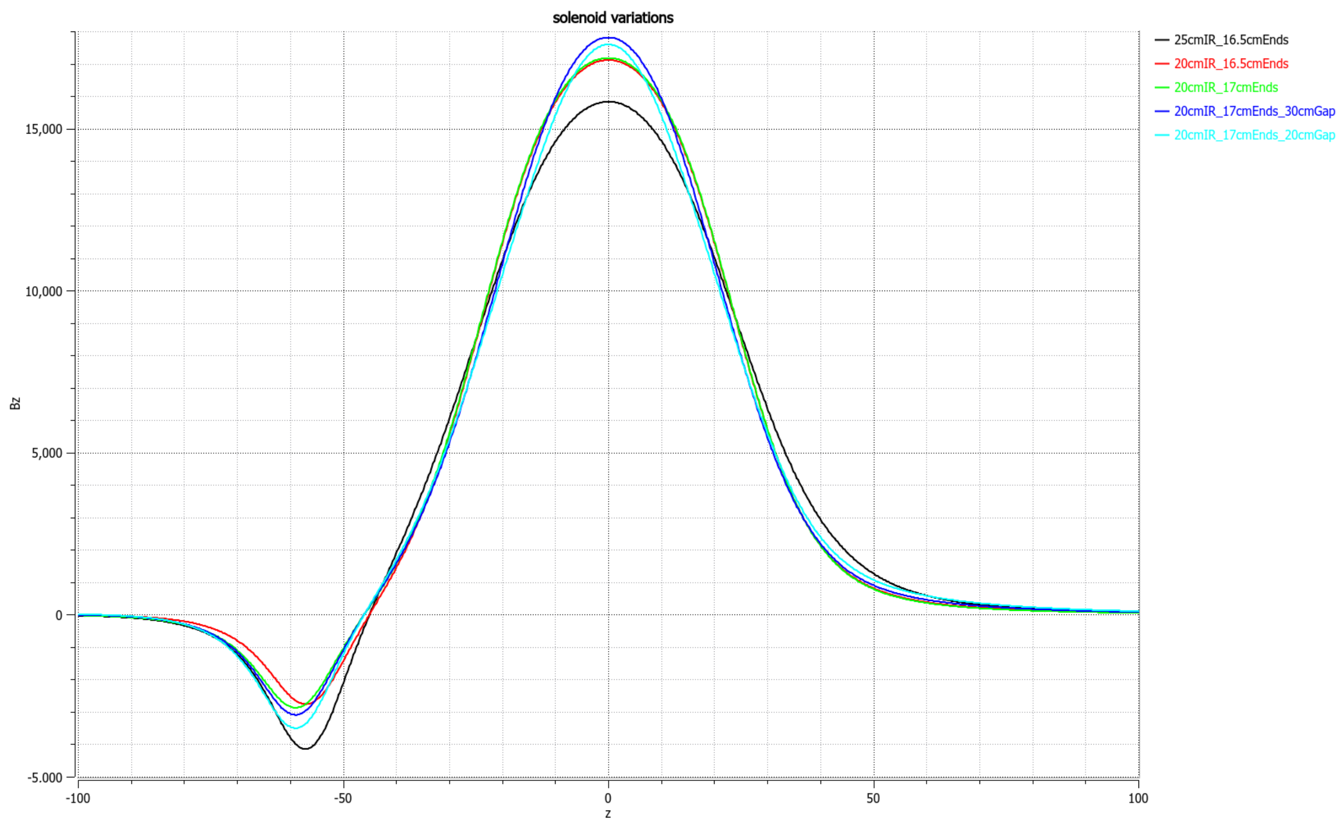

Figure 2. Five variations discussed herein. For black and red traces the target was assumed at z= -45. For the other three traces the target is at z= -46. The black trace is the model discussed in TN-25-011.

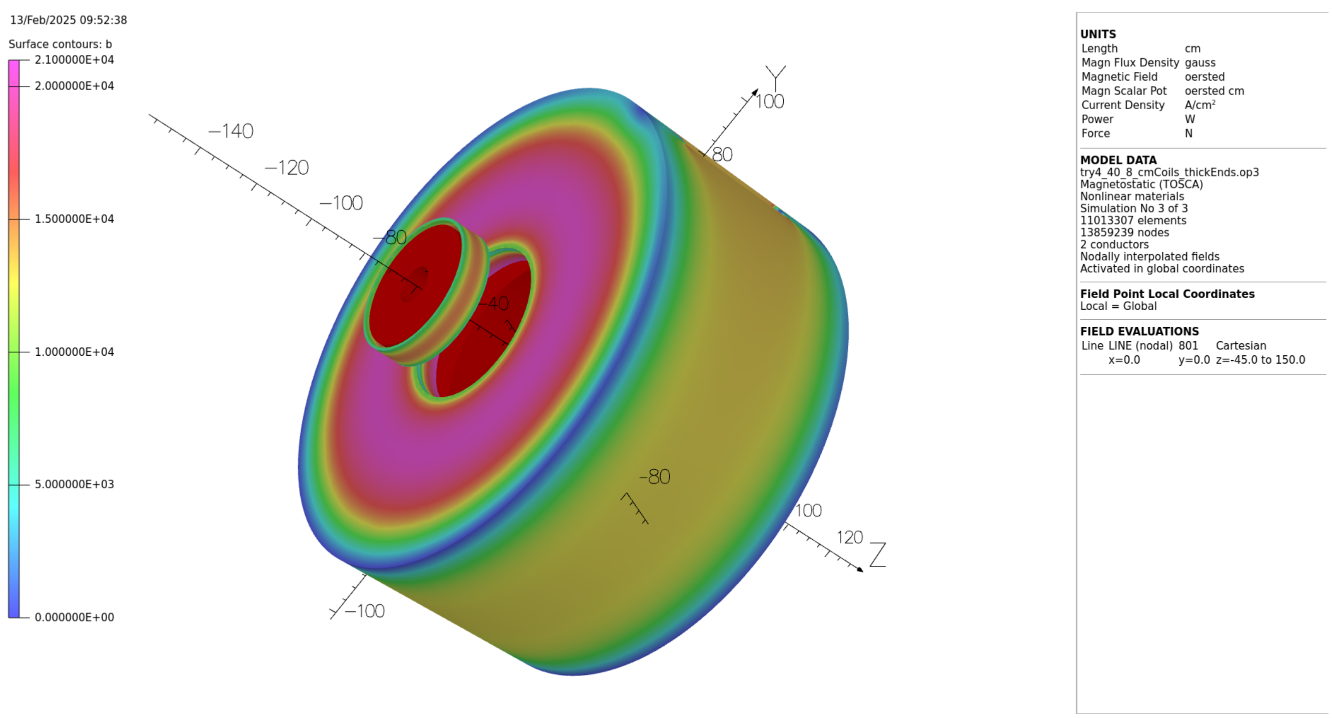

Figure 3. Field on the surface of the model with 25 cm IR end plates with 16.5 cm thickness. Most of the pink area disappears if the upper bound is reduced to 20 kG from 21 kG.

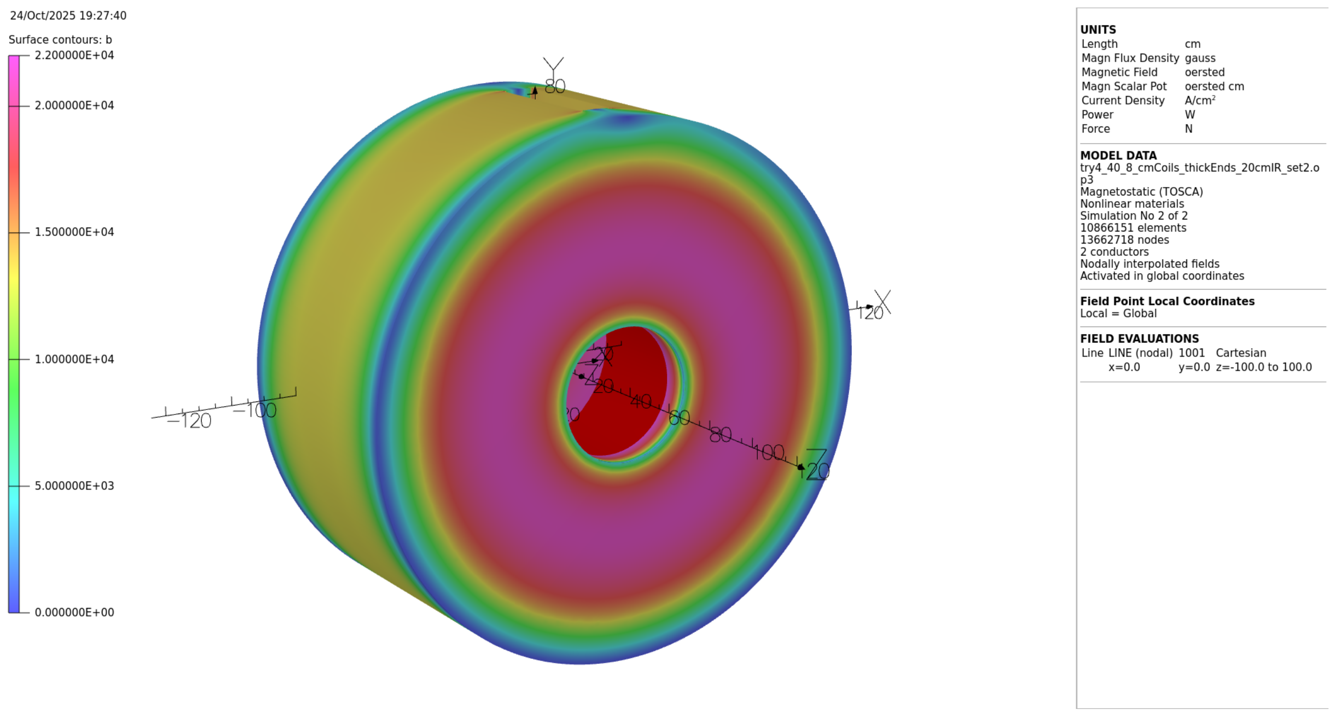

Figure 4. Same main coil current and 16.5 cm end plate thickness, IR of end plate now 20 cm. As seen in Figure 2, peak field is higher in bore and resulting upper bound on surface is now 22 kG.

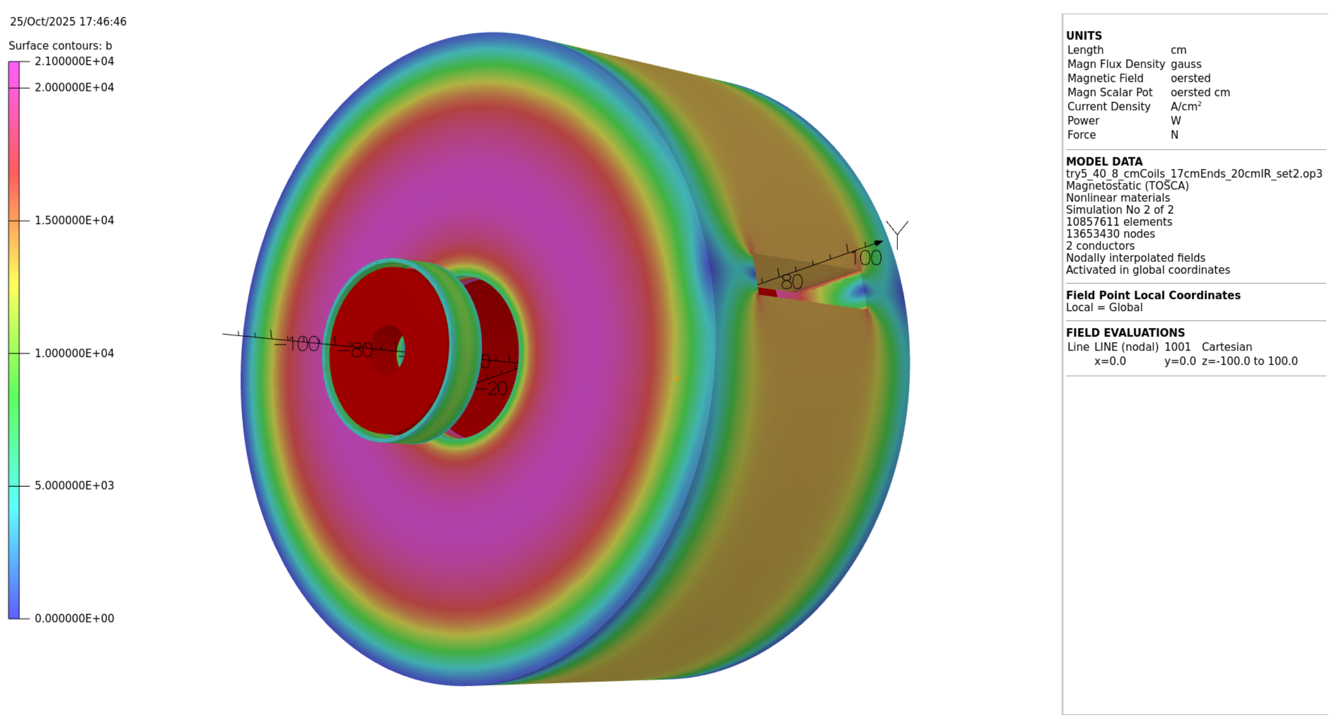

Figure 5. Same as Figure 4 except end plates now 17 cm and compensation coil has been moved out so there's 15 cm between it and the main coil. Target at z = -46 cm. Note that the field scale now ends at 21 kG versus 22 kG in Figure 4. The 10 cm notch for conductors and water is more obvious in this view.

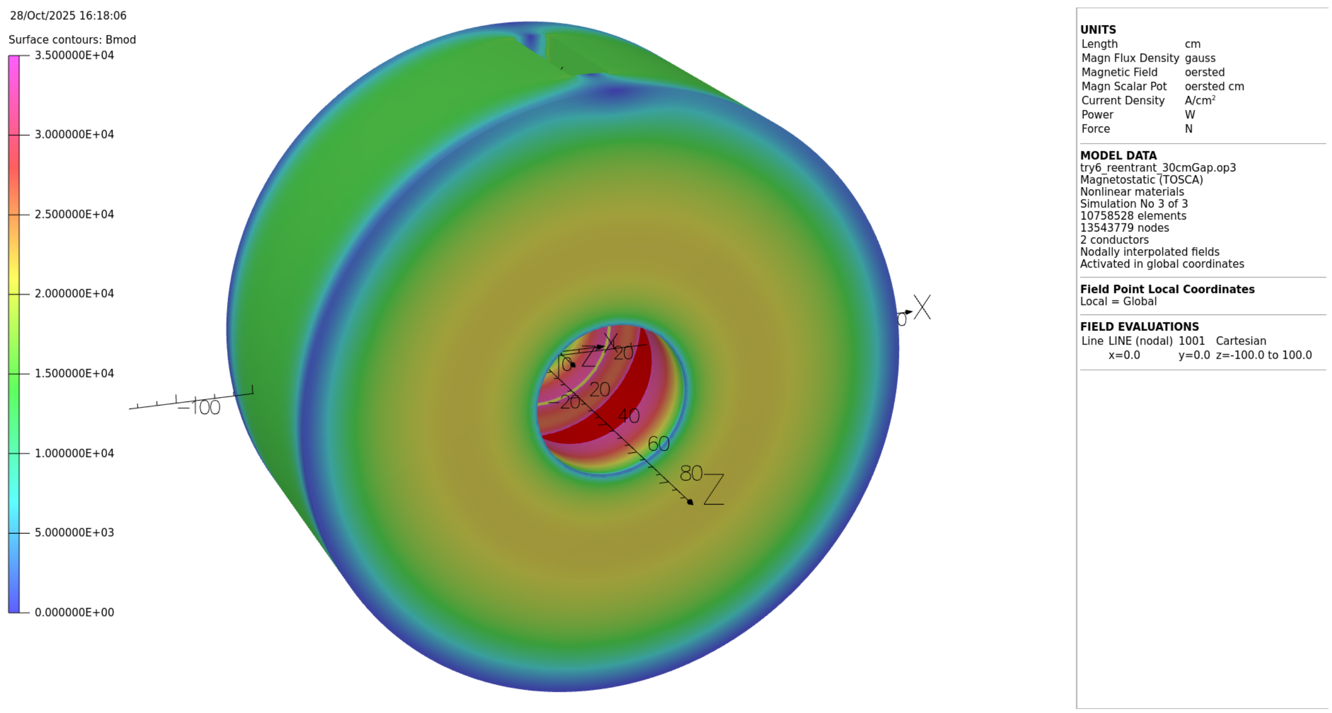

Figure 6. Model with 9.5 cm steel under the coils as part of the end plates. 0.5 cm gap between coil and steel eases calculation and need not be physical aka the coil can be mounted on the 10 cm steel lip. The 30 cm Z gap in the steel would be filled with W10Cu, much reduced from that shown in Figure 1. Note that the field scale extends to 35 kG. The steel under the coil would not be seen at all if it were set at 25 kG. The field on the end flange is essentially the same as that in Figure 5 given the scale range change.

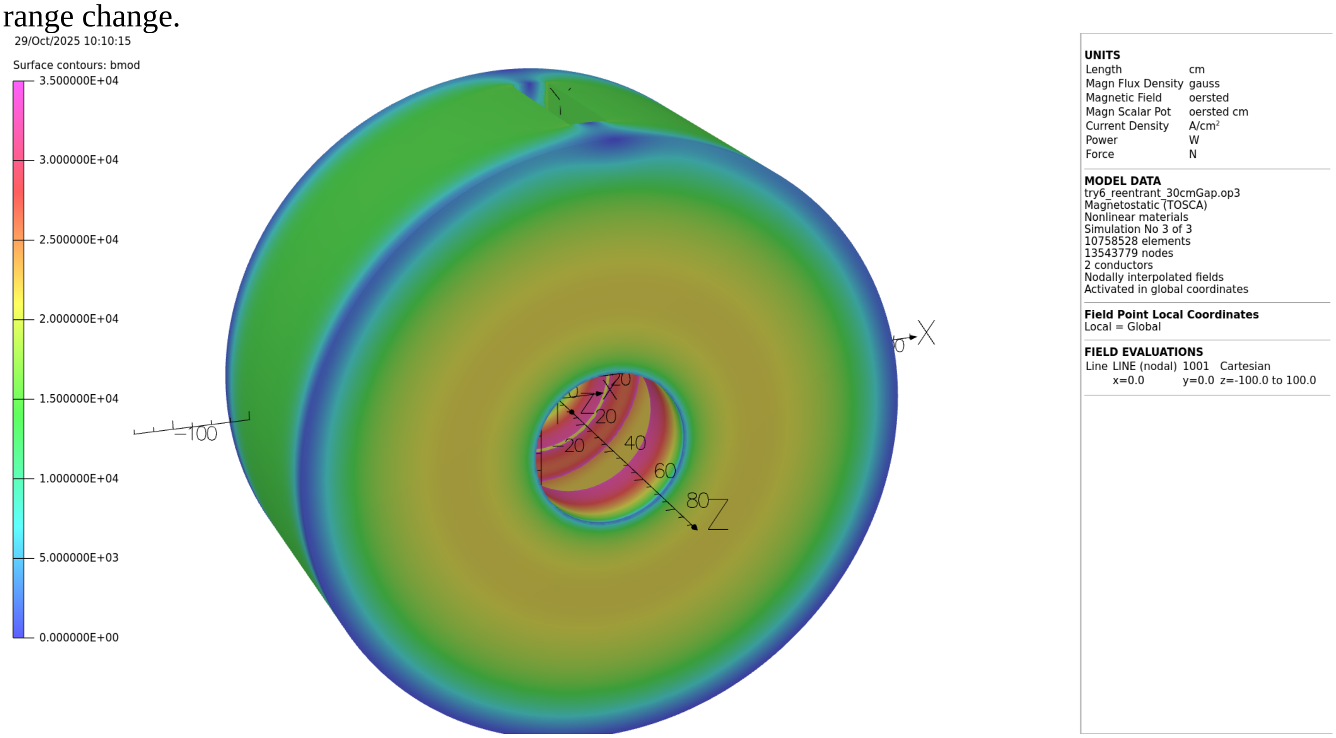

Figure 7. Same as Figure 6 except coil has been hidden. The edges of the steel under the coil are not visible because their calculated value is over 35 kG.

Since Figure 2 shows that the model with 20 cm steel gap under the coil is inferior to the 30 cm gap models, that is not shown.

Table 1 - model information

model	sim	end_cm	end_IR_cm	target_z_cm	Bz(target)	comp_coil_J
try4_40_8_cmCoils_thickEnds.opc	3	16.5	25	-45	1.24	-0.756
try4_40_8_cmCoils_thickEnds_20cmIR_set2	2	16.5	20	-45	10.7	-0.5
try5_40_8_cmCoils_17cmEnds_20cmIR_set2	3	17	20	-46	-0.3	-0.504
try6_reentrant_30cmGap	3	17	20	-46	0.35	-0.554
try7_reentrant_20cmGap	3	17	20	-46	0.08	-0.6366

Compensation coil J unit is 1000 A/cm^2. The main coil is at 700 A/cm^2 in all models. High pressure cooling water at 4^o C is required for the main coil because of the length of conductor per double pancake and I^2R. Current is 2023 A in main coil vs 170 A in compensation coil.

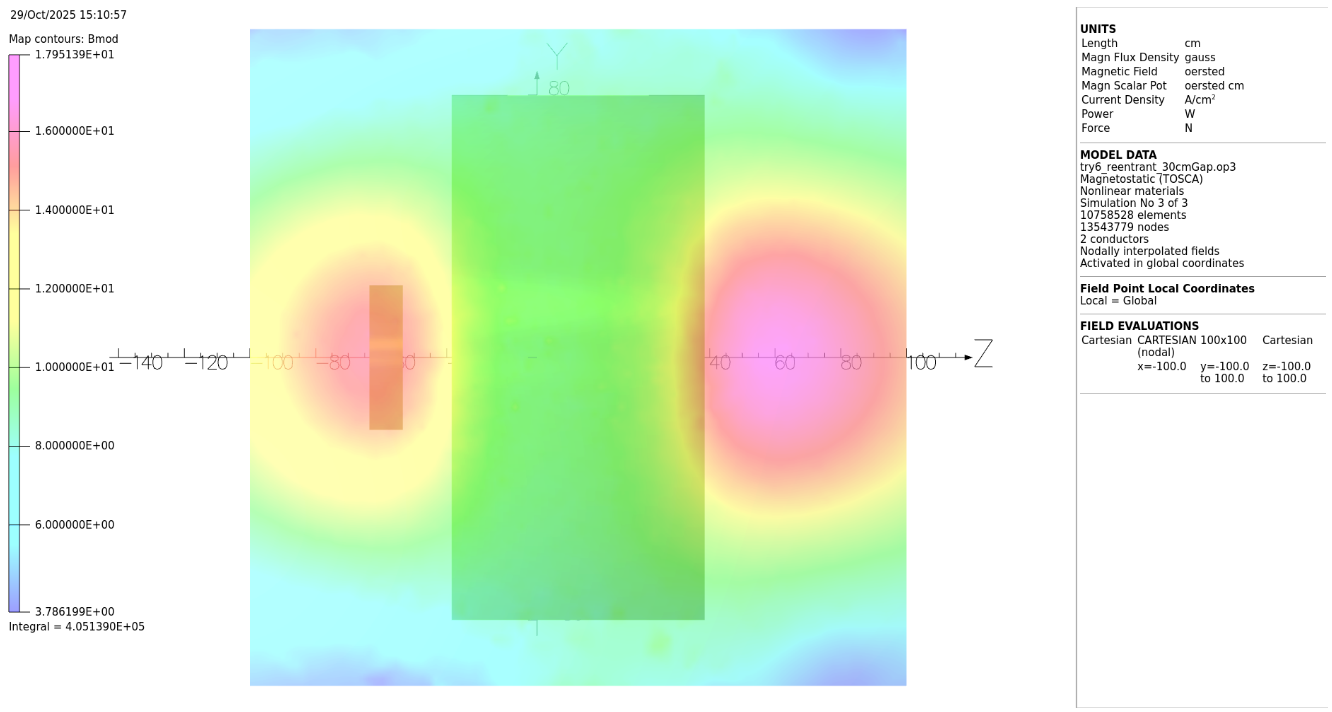

Figure 8. Stray field 100 cm from the beam line. 5G line is 200 cm from the beam line. Model: try6.

Conclusion

Yet another solenoid which can be built has been modeled. It has slightly steeper descent of field as a function of Z than the one in TN-25-011. Andriy Ushakov and Salim Ogur are evaluating the likely-modest improvement in positron yield over the previous design. Radiation dose to the coil due to the removal of much of the W10Cu shield under it must be determined. The trade-off of yield versus coil radiation damage may be unfavorable. Tungstem has about three times the density of steel so it's a lot better as a shield.