Shorter positron capture solenoid

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Background

My previous design, TN-24-021, has two half-coils, total length 54.4 cm, within the iron return. Field maps with both coils and only the first coil were provided to Andriy Ushakov. In his presentation to the 18 December 2024 CE+BAF meeting, he showed that pushing the first coil alone to the boiling point of the cooling water provided about the same capture efficiency as the full magnet at lower excitation. https://jeffersonlab.sharepoint.com/sites/PositronSource/SitePages/2024-12-18-Ce+BAF.aspx

Discussion

Since cooling on the 27.2 cm half-coil was marginal, I decided to model a solenoid with a 34 cm coil within a similar iron return, reducing the total length of the magnet by 20 cm. Compensation coil was not changed in the model. Multiple simulations were run, needed to get the current in the compensation coil adjusted to exactly null the main field at the target, Z=-40 cm in this model. At a current of 1395 A in the 300 turns of Luvata 6826, 16 mm square with 12 mm hole, peak field is 10.5 kG and the temperature rise in 4C water at 20 bar is 37 C, so the water pressure need not be 20 bar. At a current of 2023, peak field 14.4 kG and temperature rise 78 C so 20 bar is needed. The field is close enough to linear, 1.39 multiplier for 1.4x the current density, that the field map with the lower current, which was provided to Andriy for additional simulations, will suffice.

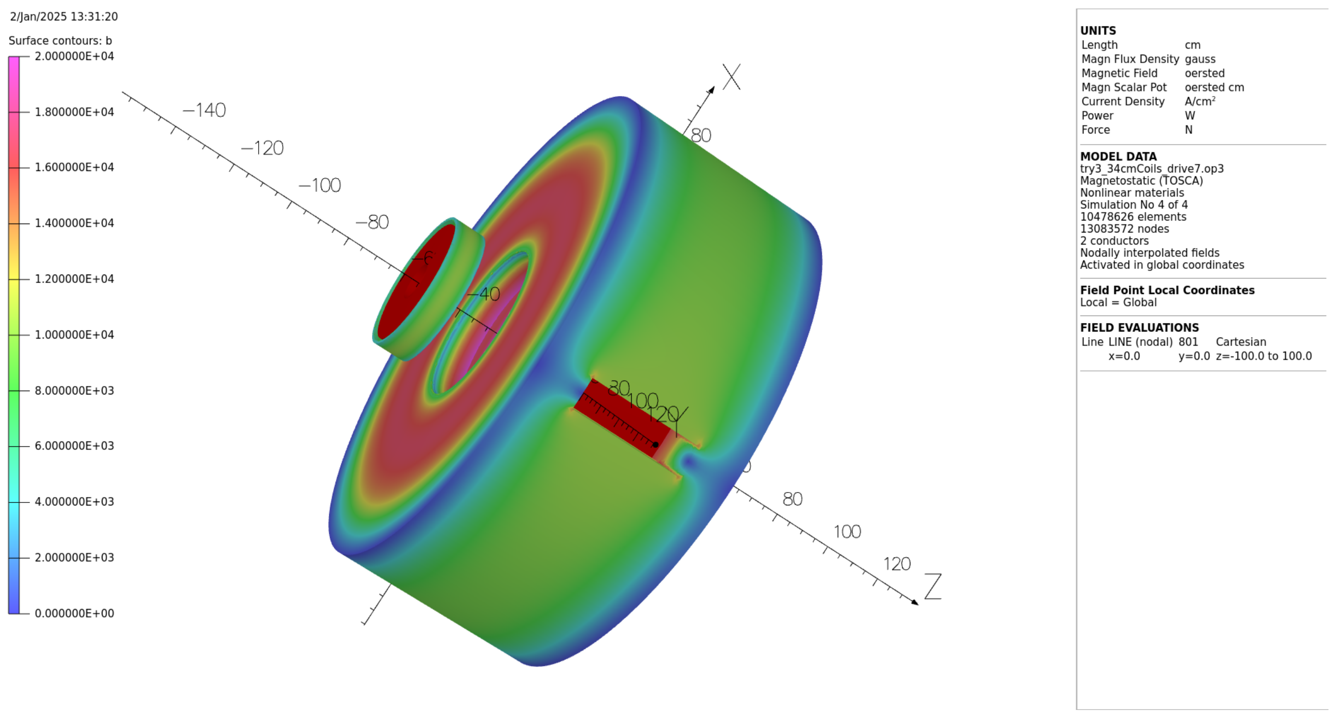

Figure 1. Model with 10 kG peak field. Note that surface field scale is 0-20kG. Notch in the steel allows the leads of the double pancakes to be connected in series for current and parallel for cooling.

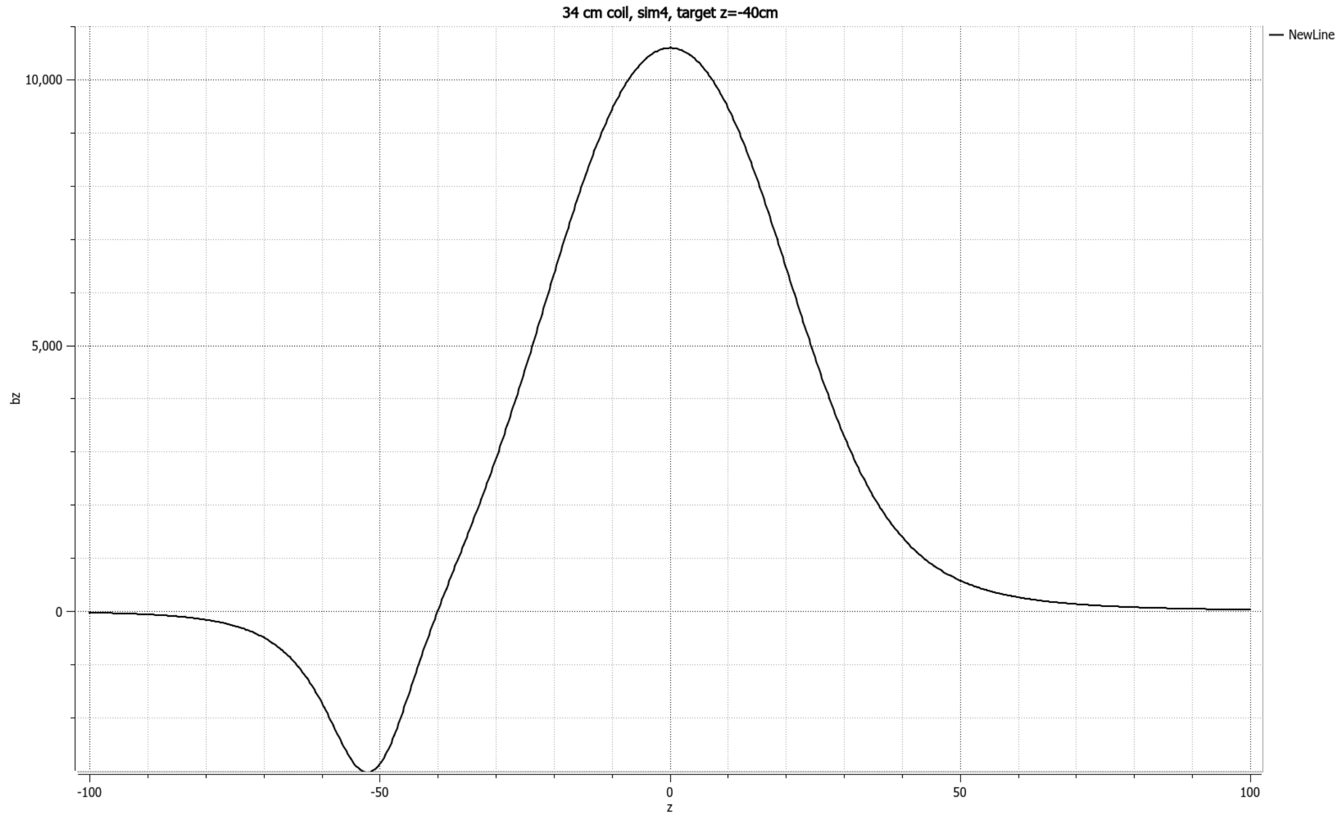

Figure 2. Field along the Z axis for the model of figure 1

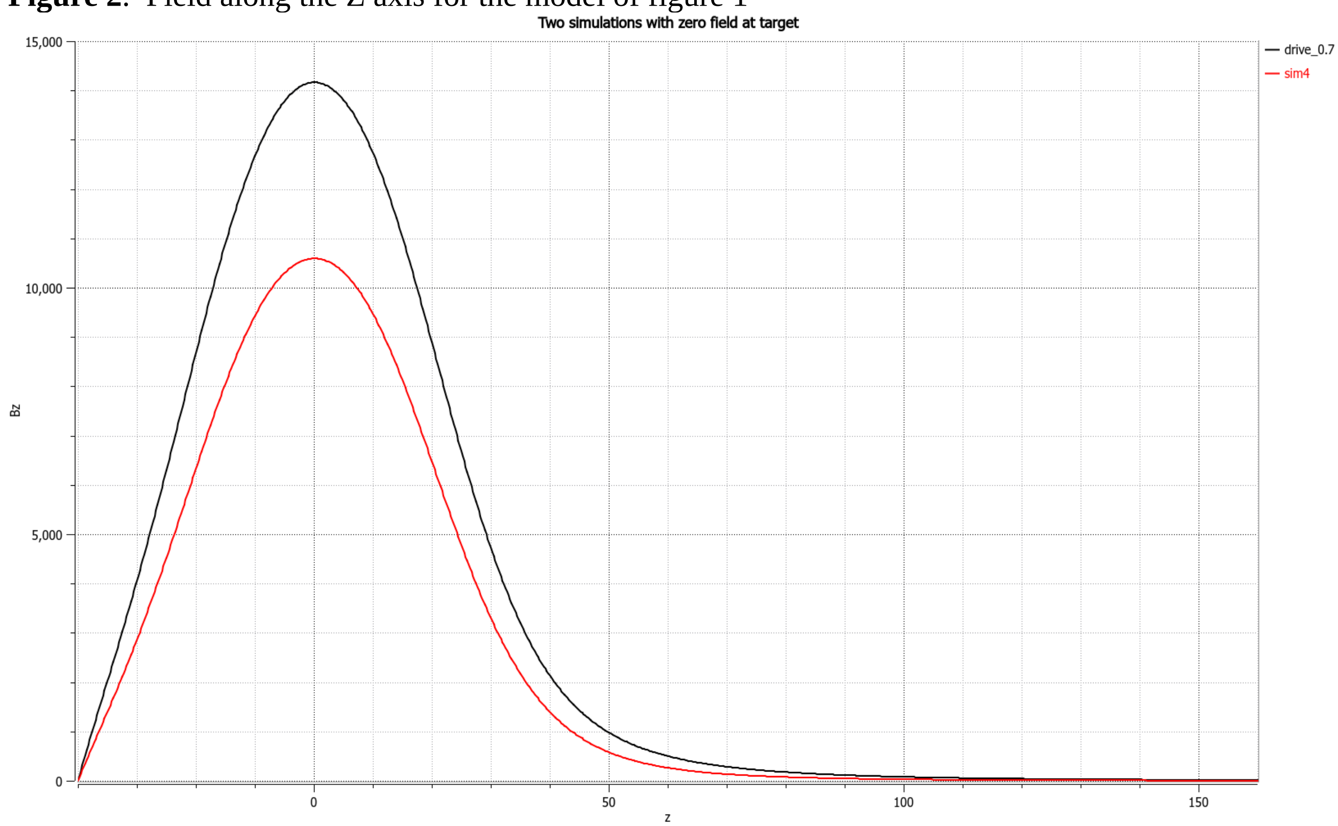

Figure 3. Field along the Z axis starting at the target, Z=-40 cm, and continuing for 200 cm. Both the model of figure 1 (red) and the higher field model (black) are shown.
∫Bdl = 512900 G-cm (red), 707200 G-cm (black)

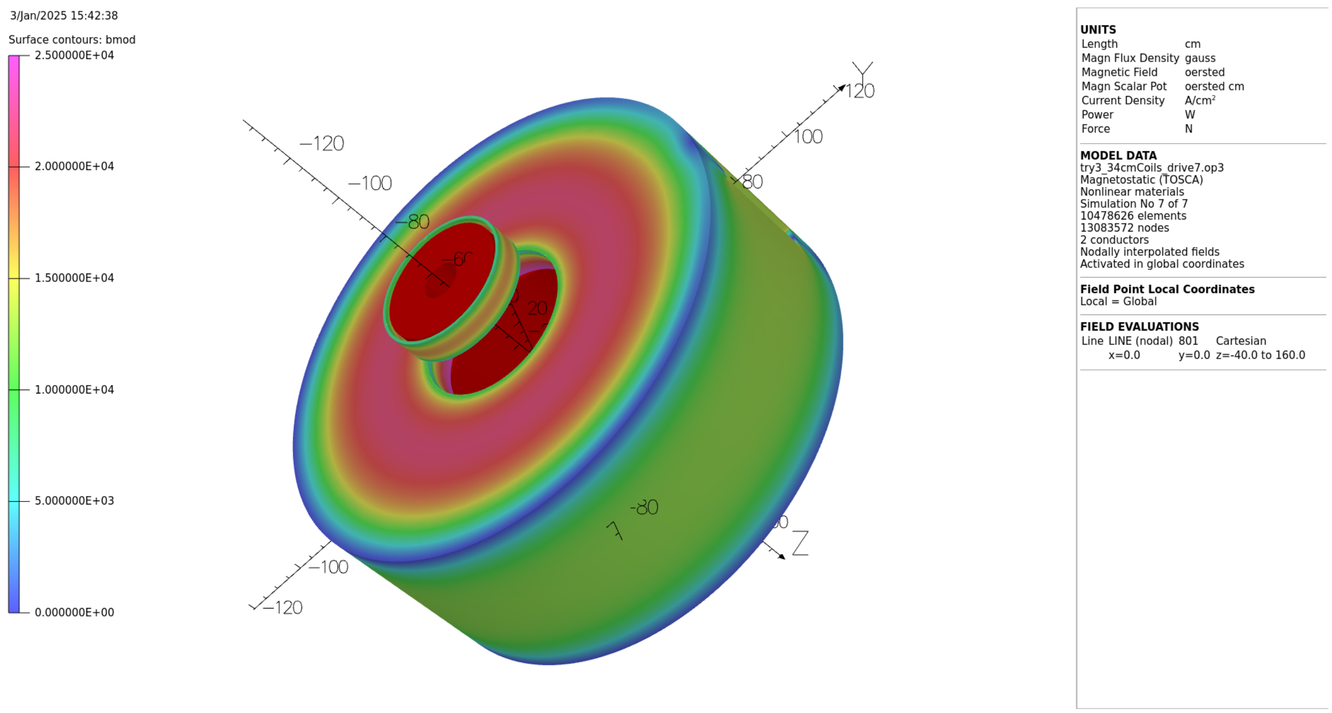

Figure 4. Model with 14 kG peak field. Note that surface field scale is 0-25kG.

The current density in the compensation coil of this model is too high for the solid conductor specified in TN-24-021. I will not modify the coil in the model to increase turns count (solid) or change to hollow conductor until Andriy's simulations indicate what field is required for efficient capture.

As mentioned above, Luvata 6826 was assumed. 16 mm square copper, assumed 17 mm square insulated. Double pancakes with 15 radial turns, 30 turns per double pancake. Ten such double pancakes yield 34 cm coil length and 300 turns. 30 cm IR, 55.5 cm OR. End plates 15 cm thick. Steel cylinder 36 cm long, 60 cm IR, 80 cm OR with 10 cm wide notch for conductors. Cylinder thickness can be reduced but not to 15 cm due to the notch; perhaps 18 cm thick. It will have to be cast for cylindricity. There's no way one can roll 18-20 cm steel on a 60 cm radius and not have it spring open at the notch, affecting the field profile. One might complete the cylinder with tooling and then match drill holes in the end plates to restrain its conformation, but casting will be easier and likely cheaper. 6” plate ground flat on one side to mate to the cylinder yields the 15 cm modeled. 6” plate is available in 8' widths, 160 cm = 63” so a lot of waste. Or cast the end plates too, to avoid making lots of chips when one starts from plate.

If a field at/below 10.4 kG peak is adequate, 14 bar water at 35 C would provide a temperature rise of 45 C for an exit temperature of 80 C, 0.5 l/s flow rate. A booster pump would be required but a chiller would not.

Conclusion

A shorter solenoid which may be as effective for positron capture has been designed. Another iteration will likely be required once positron simulations are done. Field map from the model shown in Figures 1 and 2 was supplied to Andriy Ushakov January 2, 2025. It can be scaled in field strength in his simulations.