Choice of injector solenoid steel IR driven by tolerance stackup

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Abstract

Tolerance stackup studies were undertaken on models of the low momentum injector solenoid (see TN-19-010). Tolerances used were chosen to be readily achieveable in a modern machining environment, 100 and 300 microns. IR of the steel plates in the solenoid was either 45 mm or 57.2 mm. Before this study I advocated the 57 mm version as the focusing strength is flatter across the beam and concept is simpler. This study showed that the 45 mm IR is 2-3x **less** susceptible to manufacturing variance and produces about 60% more focusing strength (B2) for the same current, so that version is suggested.

Results with 3A in 528 turns per coil.

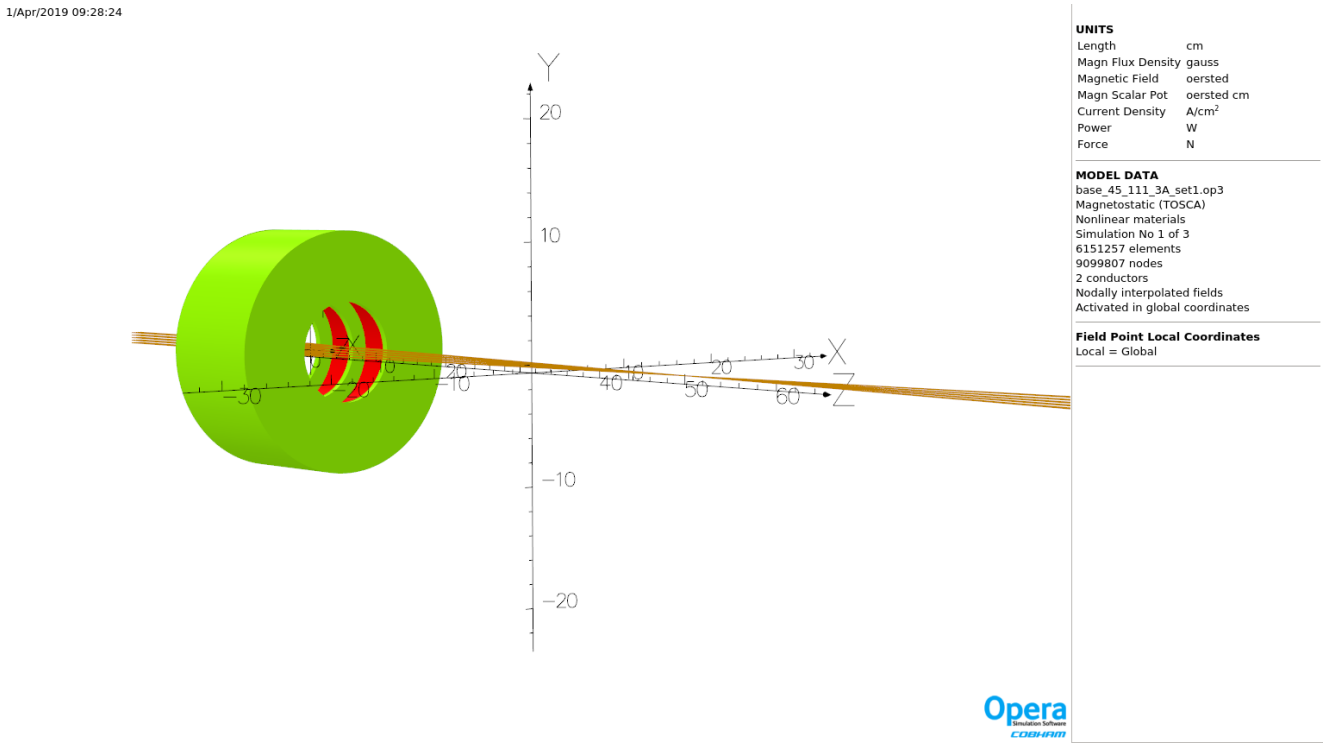
description	45 mm	57 mm
integral B^2dL over [-30,30] at 3A at y=0 (G^2-cm)	289004	173523
keV KE for 50 cm focal length, 1 cm square on axis, 3A	250	160
improvement factor over FA at 6 mm radius	5.64	7.33
improvement factor over FD [12-18 mm]	2.94	3.82
change due to 300 micron single coil move	0.9 ppt	2.1 ppt
change due to both coils moving 300 µm same direction	none	none
change due to coils moving 300 µm opposite directions	1.8 ppt	4.2 ppt
non-concentricity of left coil vs other, steel, 300 µm	0.1 ppt	0.1 ppt
move left plate 100 µm with respect to coils, shell	0.7 ppt	1.8 ppt
0.001 of int(B^2) beyond z= (z=0 at center of assembly)	11 cm	13.5 cm
1% of peak B at z= (z=0 at center of assembly)	17.5 cm	21.6 cm

While the change in focal length (B^2dL) over radii of interest is 30% greater for the 45 mm option than the 57 mm option, the integral at 3A is 60% greater for the smaller aperture so the coils will run cooler. The tolerance for manufacturing error is much better in the 45 mm design and this will likely make their cost comparable to the 57 mm design for the same error budget. This might be allocated:

a. coils must be symmetric about center of central steel piece within 0.3 mm (1.8 ppt)
b. steel plates must be symmetric around central steel piece within 0.2 mm (2*2*0.7 ppt = 2.8 ppt
c. steel concentricity 0.1 mm should be easy due to copper mandrel machining
d. coil concentricity 0.3 mm should be achiveable in winding per specification

All the units should then be identical within 0.5%. If tighter grouping is desired, cut (b) in half and (a) by a third to get 0.26%. Given the 3x larger effect of steel offset to coil offset, it may be desirable to have three 8.75” diameter plates with two short steel 8.5” OD tubes, through bolted, so the plate separations can be measured after assembly.

Resistance per coil ~2 ohm so with water cooling the 45 mm design should be fine for 375 keV.



1 cm square bunch of 250 keV rays focused by the design with 45 mm IR on steel plates.

I checked difference in Fourier components of the design above vs that below, which has notches to allow 0.25” water cooling tubes. Differences at the 0.2 ppt level, less than most on page one.