Trapezoidal common dipoles - tilting isn't worth it

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Abstract

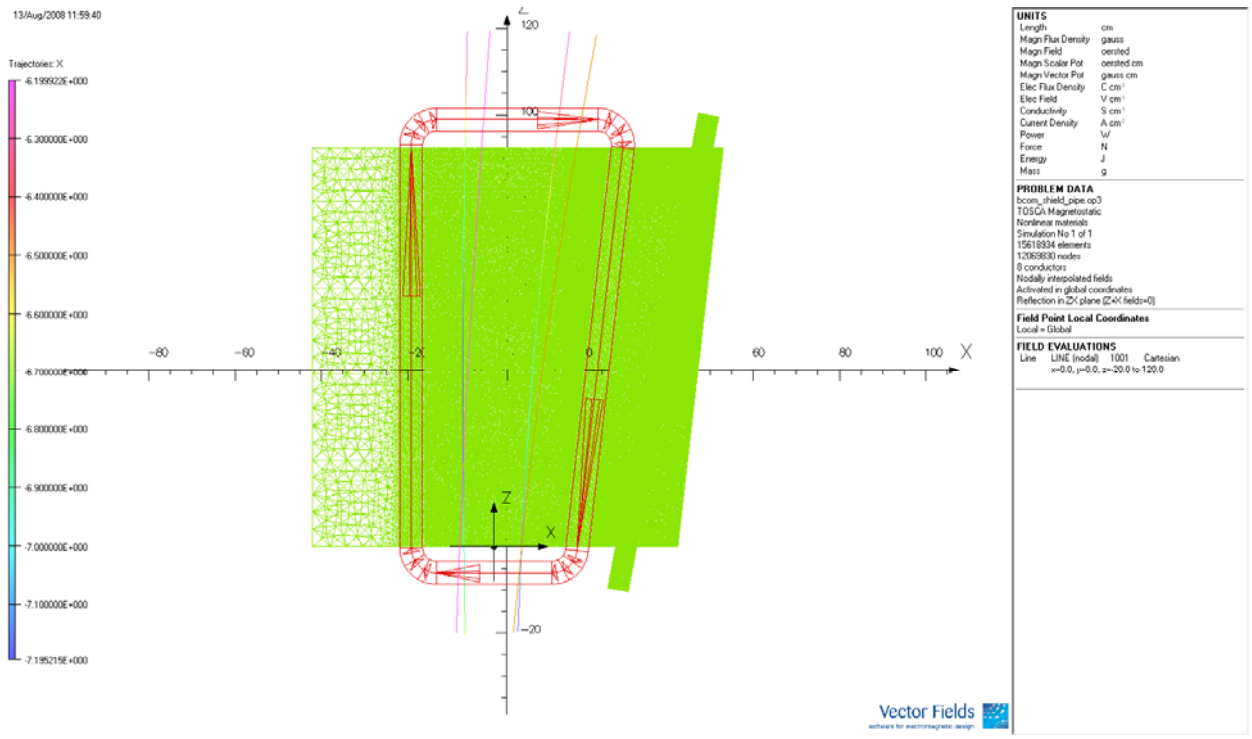
During original CEBAF construction there was a debate about the installation of the trapezoidal common dipoles. Accelerator Physics wanted to install them tilted to center both entrance and exit beam groups in the pole for highest field quality. Beam Transport wanted to install them flat to the ground. No formal decision was made by project management, so beam transport installed them as they wished. I present here beam orbits and multipoles along those orbits for the west (even arcs) trapezoidal dipole at the field required for the 12 GeV upgrade. I was surprised to find that the numerically integrated field quality is similar, so tilting appears unwarranted.

This TN was sent to the 12 GeV Project team for review August 14, 2008. One comment was received Nov. 13, 2008. One word was changed on page 4 (tapered to chamfered) as a result of the comment.

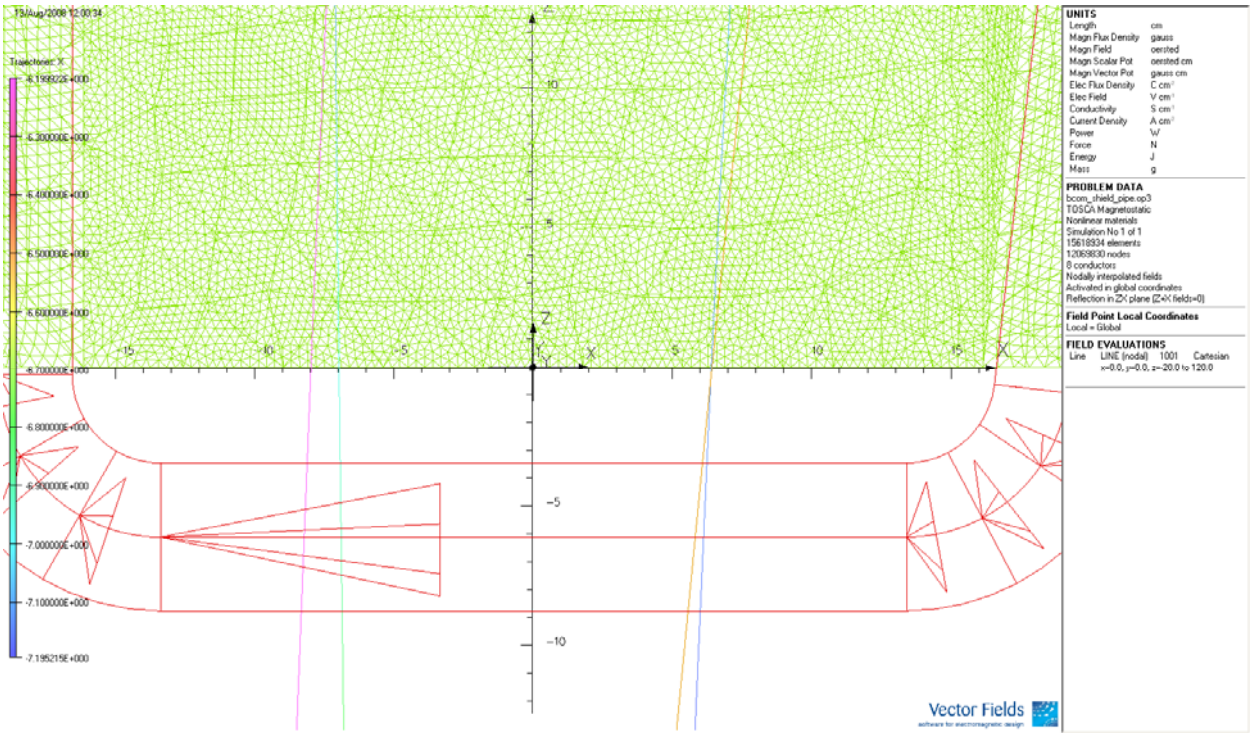
Introduction

I modeled the trapezoidal dipole for the even S/R because the first pass beam must pass through the new return steel for its full length. I found that a 54mm hole with a schedule 40 carbon steel pipe of appropriate diameter shielded the first pass beam from the flux in the return steel to ~1G/cm. I used this pre-existing model for this work. The field in the odd S/R dipole of the same type is 0.7% higher. This is unlikely to change the multipoles significantly.

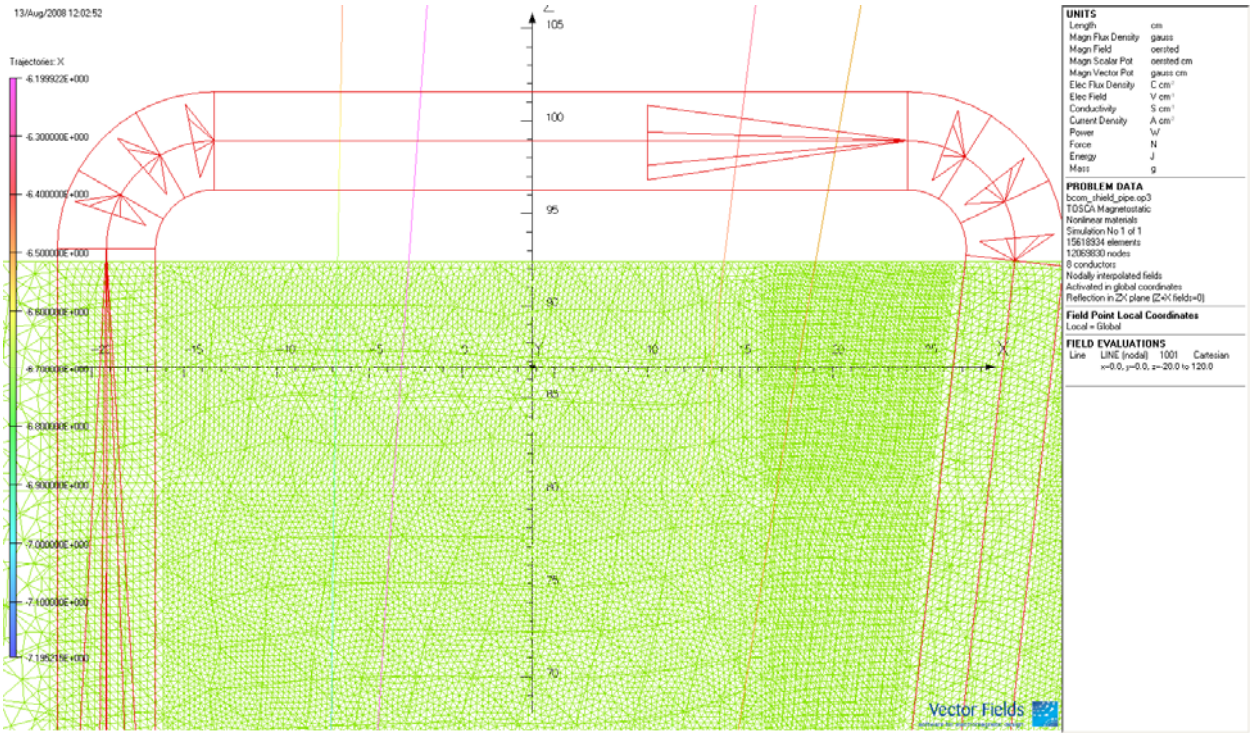
There is no easy way to rotate just the magnet in the post-processor. It is possible to set up a new local coordinate system which is rotated with respect to that originally defined. The origins of the trajectories necessarily shift in X with the 3 degree rotation of the system.



Second and fifth pass beam paths with magnet base parallel to floor (solid colors) and with magnet angled up 3 degrees by raising back end 5cm (multicolored lines).



Entrance detail. Left lines of the pairs here are the ones with the magnet "flat" and right lines are tilted.

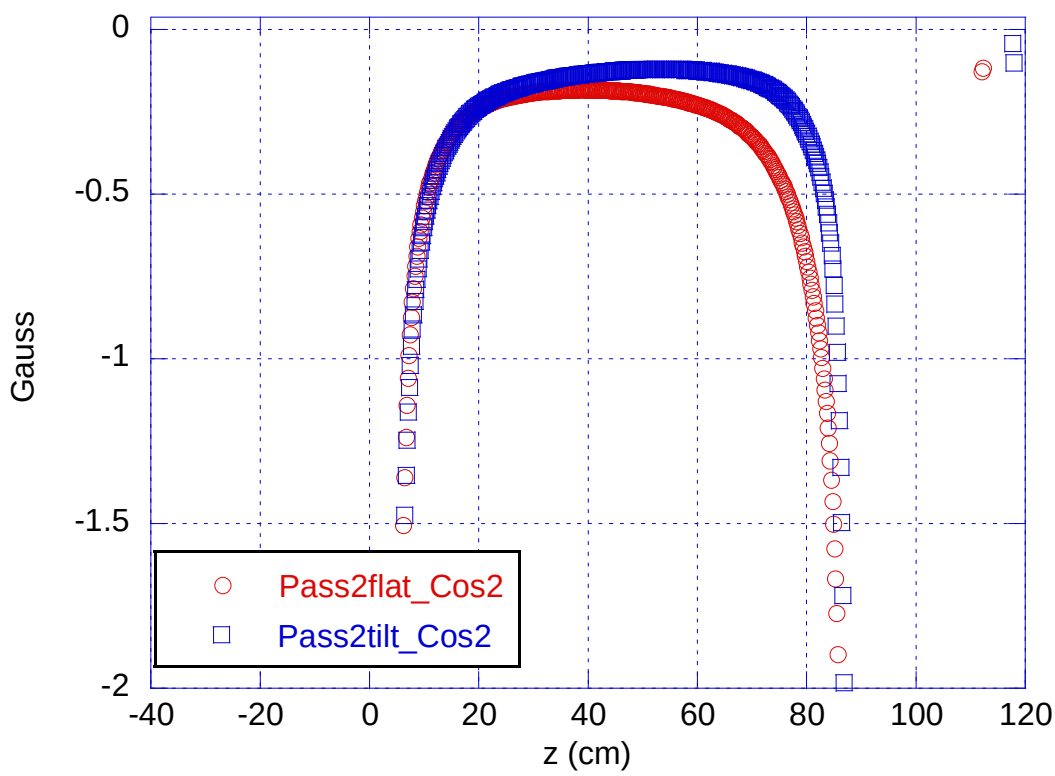


Exit detail. Here the left lines of the pairs are with the magnet tilted and the right lines in each pair are with it flat. Tilting the magnet centers the group of beams, second through fifth pass, in

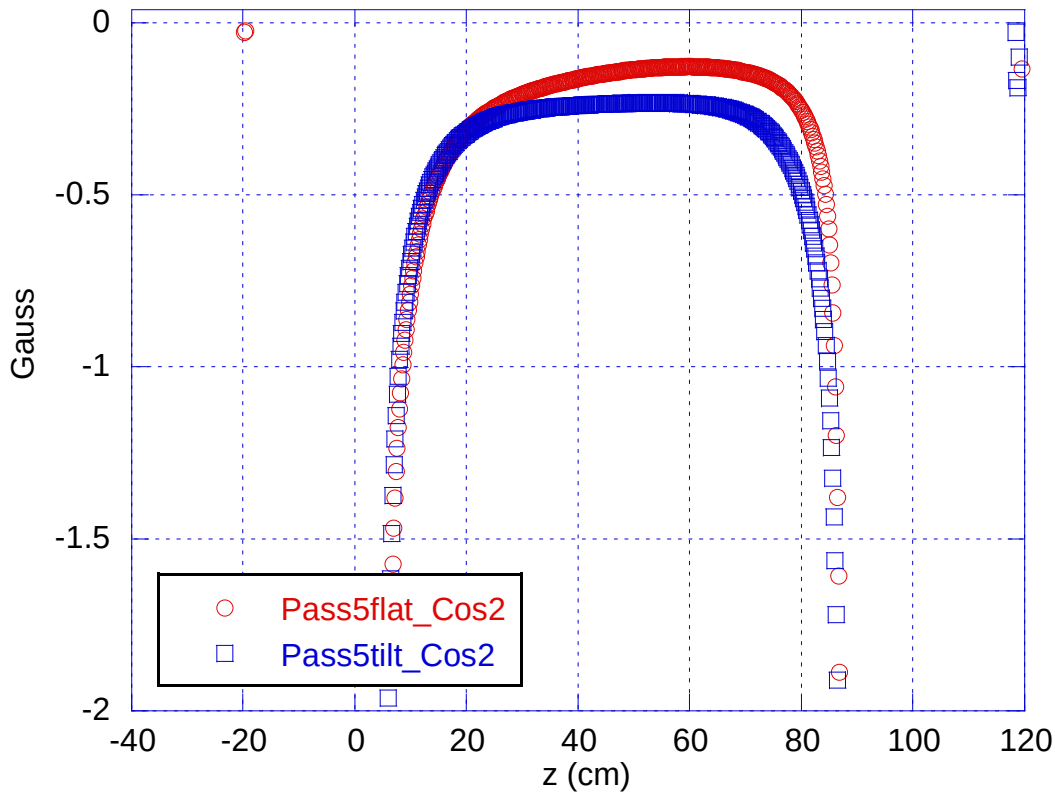
the good field region at the end of the magnet without compromising field quality at the entrance unduly. I use the 700 point orbits displayed here to calculate multipoles. Opera writes (x,y,z,v_x, v_y, v_z) to an output file while one is running the post-processor. One can use this information to create a command file which has 1cm radius circles normal to the beam path along the orbits plotted and compute multipoles on each circle. See TN-08-024 for more details on multipole calculation. For the table below I simply summed the output and divided by 5 since I used 2mm intervals. This is not appropriate for quadrupole since it doesn't include the "sector" focusing. It's not bad for higher orders.

beam	dipole	quad	sextupole	octupole	10-pole	12-pole	14-pole	16-pole	18-pole	20-pole
pass 2 flat	1187808	-134	-171	-61	5	-24	-22	-18	18	-17
pass 2 tilt	1182652	264	-74	-8	11	-36	-20	-29	18	0
pass 5 flat	1180227	1030	-82	-10	61	-31	24	-6	31	-13
pass 5 tilt	1177893	1167	-89	-12	-6	-5	-2	-10	13	6

The gains do not appear to be worth the trouble, surprising me. Plotting just the sextupole:



Tilting helps on pass 2, as expected.



Tilting increases sextupole a bit in the body for pass 5.

Possible pole change

The pole gap is 4.75 cm on this magnet. The vacuum vessel has 1cm thick walls to keep the deflection due to atmospheric pressure under 1mm. One could add ~7mm thick pole pieces chamfered on the long edges to reduce saturation effects if one replaced the vacuum vessel with a new one which has 3mm walls and internal posts to minimize deflection due to air pressure. There are ample locations for such posts which cannot encounter beam. The improvement in homogeneity due to the smaller gap should more than compensate for the decreased pole area "seen" by the beam.

Conclusions

Contrary to the qualitative statement that having a beam one pole gap away from the edge of the pole is bad, it appears that the effect of the "corner" seen by the pass 2 beam is small enough that it doesn't make sense to tilt the trapezoidal dipole.

Addition of tapered pole pieces should be studied to determine if the benefits outweigh the cost of a new vacuum vessel.