Proof of principle design for pre-chicane for use with 5T transverse solenoid for high current in Hall C, small SHMS angles in Hall C, or SoLID
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Discussion

Two proposals planned for PAC52 require the use of the new 5T polarized target solenoid. One uses it with full transverse field. The other uses it twisted 21° from longitudinal so Bx component is 38.4% of nominal. $\int$BdL = 1.3415E6 G-cm over [-100,100]cm with most of the field within [-25,25] cm. These two proposals require current under 100 nA. Total power is less than 1100 W at 11 GeV. It follows that the discussion in https://jlabdoc.jlab.org/docushare/dsweb/View/Collection-56294 Examination of the need for an upstream chicane for proposal "A Measurement of the Proton g2 Structure Function at Intermediate Q2" still obtains for these *as long as SHMS need not attain small angles*. A local beam dump mounted from the floor of the hall suffices given the existence of the 2 cm vertical chicane in Hall C beam line for height fine tuning.

For SoLID or experiments in Hall C which require the use of SHMS at small angle one will need a pre-chicane. SoLID extends over 10 m beyond the target so even with low current the beam will intersect things it shouldn't within the system if the bending from a transverse field, be it from a polarized target or another system, is not compensated. High current beams have to make it to the beam dump in the dump tunnel in both halls. Small angle use of SHMS requires a beam pipe which fits in notches in the magnets, not one pointing towards a beam dump on the floor.

I approximate the transverse solenoid as two horizontal dipoles of 25 cm length with the pivot located between them; no gap between the dipoles. Field of each dipole is then 26.84 kG for BdL given above. Figure 2 has the actual field.

A 5T transverse target has not been used in Hall C since the Compton polarimeter was installed for Qweak. I found an Optim file from 2000 written by either Alex Bogacz or Valeri Lebedev which used built-in header functionality I never touch to compute the chicane. The chicane was 19 m long and there is only about 9 meters available given Compton polarimeter so I did not attempt to decipher the old file. I simply adapted my existing Hall C Optim files and used dead reckoning to arrive at rough solutions for second, fourth and fifth pass, described below. The fields for the chicane dipoles remain roughly constant because the 5T solenoid is fixed. For the case with 21° rotation, the chicane dipole fields will be about 38% of those shown below.

There are four constraints and four variables, two fields and two drifts. The constraints are the linked (x,z) position at the pivot, the height at the pivot, and the vertical angle of the beam after it leaves the far field of the target magnet. The target has vertical motion so getting within a cm there suffices and proved possible. The thinned region of the dump face is a few cm in diameter so getting that Y value dead on isn't necessary either, aka exit angle can vary slightly. (x,z) constraints are most important and are linked because there are no horizontal dipoles after the alcove. There are two drifts available as variables, the one between the two dipoles and the one between the second dipole and the 5T solenoid. I tried both. Using the first keeps the center of the center dipole closer to stationary in (x,z) but not perfectly. I ended up using just the two fields and the drift between the dipoles.

The existing 1 m vertical dipole MBE3H05 must be replaced with one capable of 15.5 T. The existing 1 meter dipoles MBE3H06 and MBE3H07 are to be replaced with a 2 m dipole capable of 14.5 T.

While the FZ magnet used for the 2000 chicane has enough steel to reach the necessary BdL, the coils may melt. The 1 meter MBE cannot be pushed that hard. I suggest new magnets be fabricated with the cross-section defined for the FFA 20+ GeV hall lines which evolved in TNs 21-051 (380 cm), 22-022 (200 cm) and 23-008 (180 cm). It is likely that a new coil can be designed for the FZ steel but I have chosen not to attempt this. It seems to me better to prototype the new design and measure it as part of preparation for the energy upgrade.

Five files are attached: a spreadsheet with the orbits for three passes in which I prepared the plot and tables below, three Optim files and a spreadsheet with 2010 modeling results for the FZ. Yves Roblin of CASA has scripts to turn Optim into elegant files in which they or others competent in accelerator physics (as I am not) can refine the design. Among the choices I made which will have to be revisited are removing the entrance and exit focusing terms from the chicane dipoles. An attempt to keep the second (2m) dipole better centered in (x,z) than the cm span shown below should also be made to ease mechanical engineering requirements. If one wants to get fancy one should use the actual solenoid field instead of the dipole approximation in refining the model but that wasn't necessary in 4/6 GeV days. Again, this is a proof of principle exercise.

Table 1: positions in accelerator coordinates

	name	S[cm]	X[cm]	Y[cm]	Z[cm]	TetaY[deg]	Energy[Mev]
Pass 2	2m_midpt	13981.977	-12170.965	9962.490	-38450.090	-0.383	4483
Pass 4	2m_midpt	13979.567	-12170.247	9980.257	-38449.155	-0.167	8843
Pass 5	2m_midpt	13979.267	-12170.155	9983.809	-38449.035	-0.125	11023
nominal	iPIVOTC	14458.568	-12462.200	9999.800	-38829.405	0	11023
Pass 2	iPIVOTC	14461.803	-12462.198	10000.060	-38829.402	2.563	4483
Pass 4	iPIVOTC	14459.393	-12462.204	9999.462	-38829.409	1.315	8843
Pass 5	iPIVOTC	14459.093	-12462.200	9999.285	-38829.405	1.063	11023
nominal	END	19896.568	-15773.908	9999.800	-43142.691	0	11023
Pass 2	END	19899.803	-15773.901	9999.894	-43142.682	-0.008	4483
Pass 4	END	19897.393	-15773.910	10000.852	-43142.694	0.012	8843
Pass 5	END	19897.093	-15773.907	10001.139	-43142.690	0.017	11023

Table 1 shows that I got close to nominal values with dead reckoning both at the pivot and at the end of the dump tunnel. Beam height variation at the pivot will be taken into account with vertical target motion over an 8 mm range or improved by further work by others. Small angles remain so the beam is not perfectly centered on the dump face but it's close enough given the diameter of the thin region of the dished head. Fields in the chicane dipoles vary slightly for the three designs, within a 2% span, for full transverse field. For the 21° case, all scale.

Table 2: ∫BdL for chicane dipoles

	1 m G-cm	2 m G-cm	solenoid
Pass 2	-1540000	2880000	-1342000
Pass 4	-1520000	2868000	-1342000
Pass 5	-1513000	2866000	-1342000

Note that there is 54 m from pivot to end of dump tunnel. My magnet model ends ~18 m.

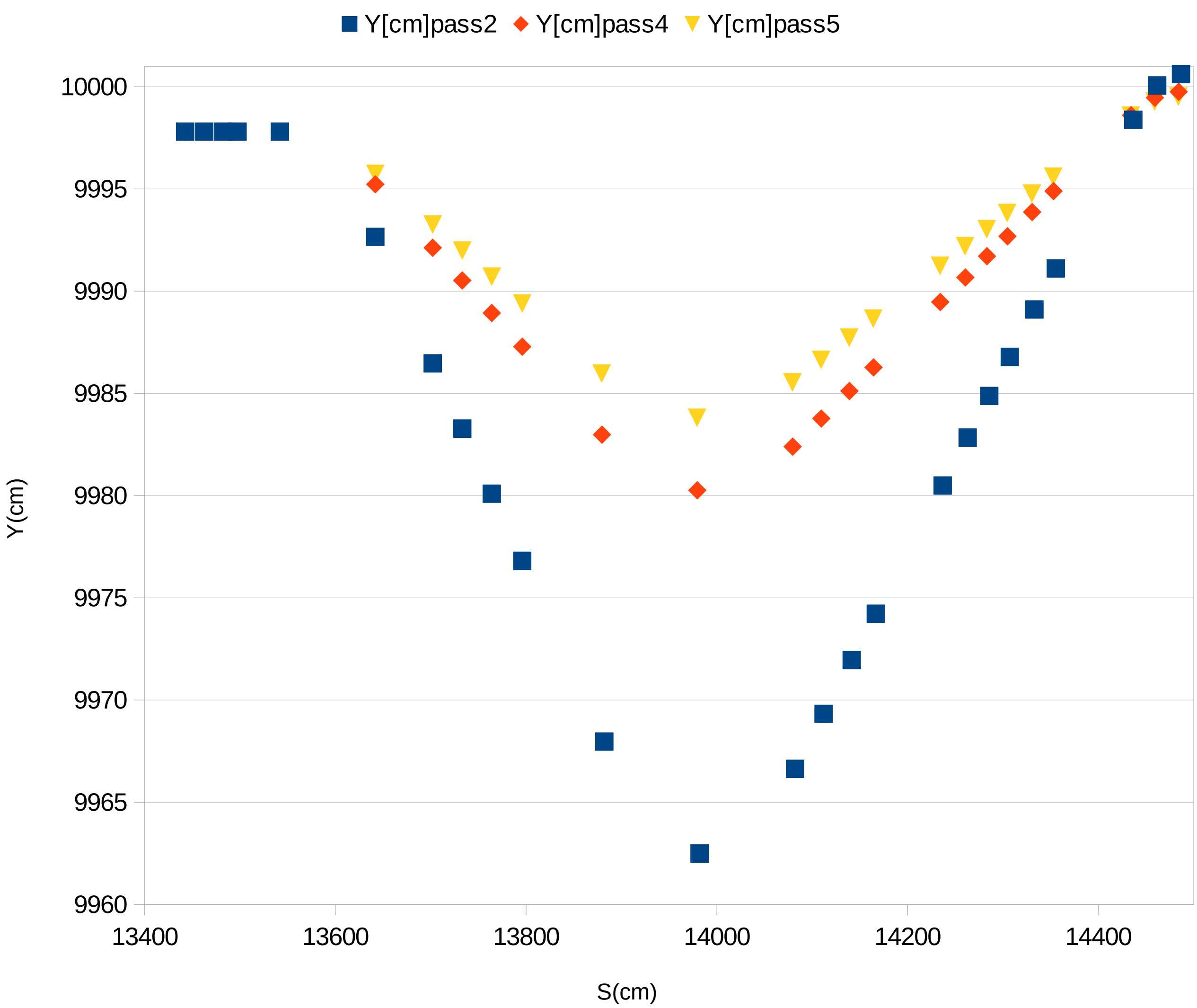

Figure 1 Vertical excursions in the chicane as a function of pass (beam energy). Pivot is at S~14460 as seen in Table 1.

Conclusion

It is possible to create an upstream chicane which will locate the beam at the pivot and at the beam dump. At least one new magnet and preferably two are required. Responsibility for the mechanical design to allow the vertical motion shown in Figure 1, the detailed magnet design and the detailed optics design rests elsewhere. This is just a proof of principle.

More Discussion

The Hall C beam leaves the Lambertson at y=9997.8 cm in accelerator coordinates. The pivot was built at 10000 cm in accelerator coordinates; it has settled to 9999.8 cm for experiments with the standard spectrometers. There is a 2 cm vertical chicane using two one-meter dipoles in the hall, followed by an unpowered one meter horizontal dipole. The space these occupy was used in this design. All diagnostics were left in existing positions. The diagnostic girders will have to be tilted to match beam path through the chicane.

In Hall A the MOLLER target is centered 5 m upstream of the pivot and is almost 2 m in diameter. SoLID will be placed about 5 m after the pivot. Since the chicane herein is less than 7 meters long there is sufficient room for it in Hall A for use with SoLID. Mechanical design is another question, as is the placement of diagnostics.

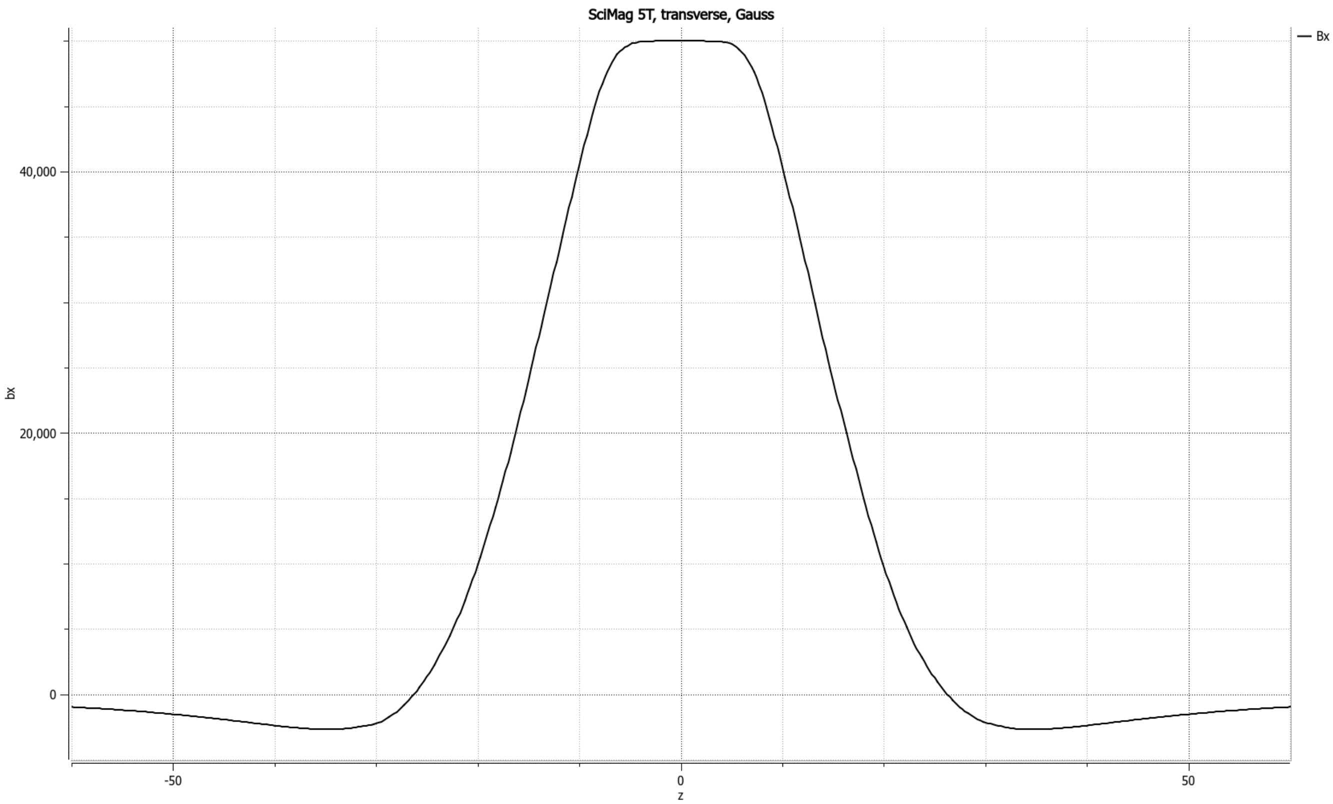

Figure 2. Field of solenoid in transverse mount, Bx (Gauss). As mentioned in the third paragraph of page 1, I approximated this as two dipoles 25 cm long with the zero-length pivot between them.

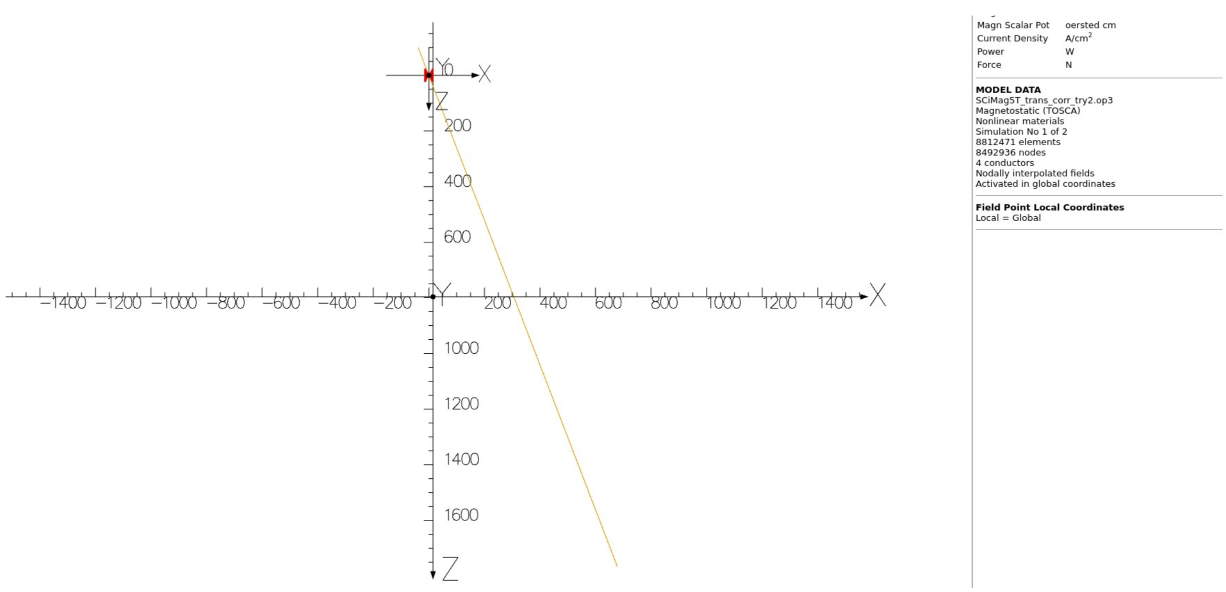

Figure 3. Top view of beam entering **transverse** solenoid at 21° angle as that's easier than making a new model. **This figure and the next four were created in error and are included because they exist. Rotated longitudinal solenoid figures 8-12. Full transverse figures 13 and 14.**

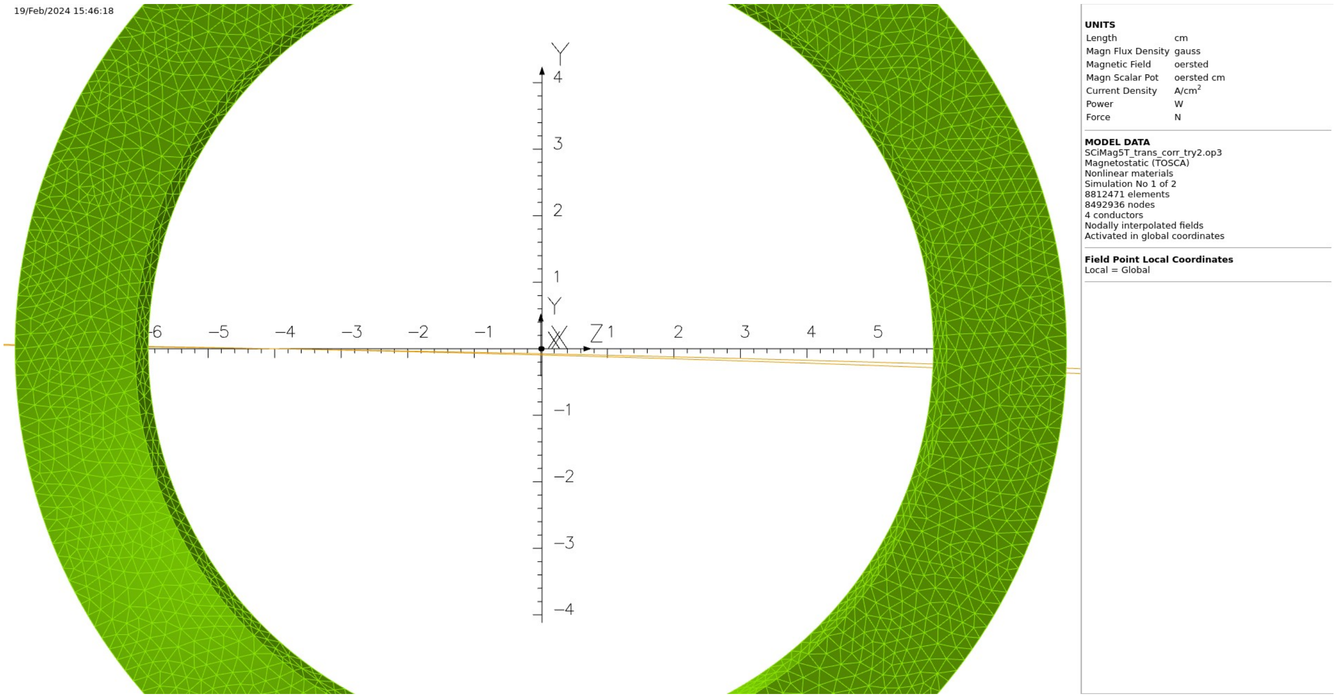

Figure 4. Side view of Figure 3 showing slight vertical deflection at center. 8.84 and 11 GeV beams.

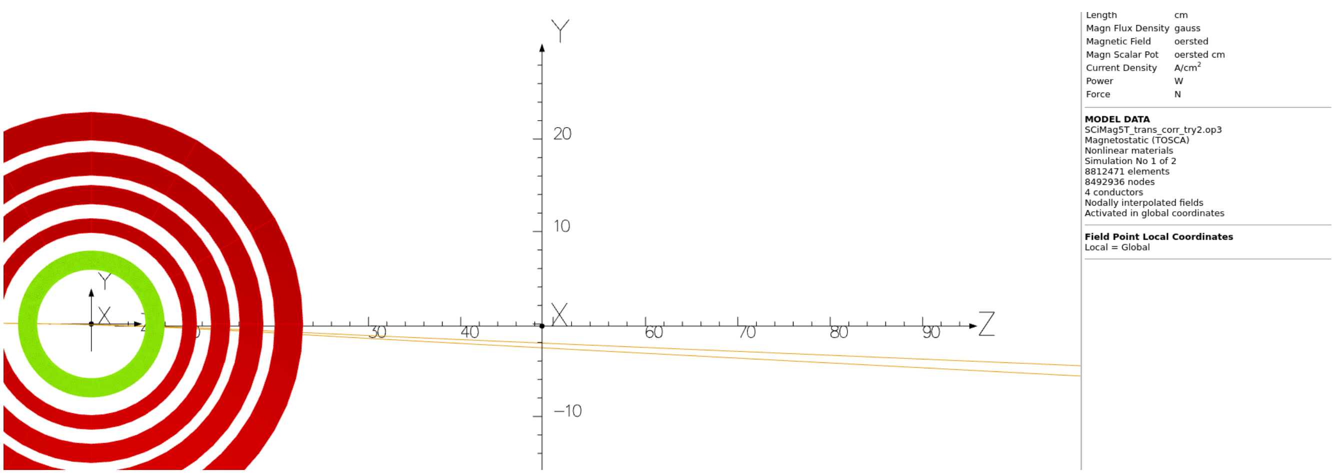

Figure 5. Side view of Figure 3 past end of target chamber. 7.5 cm diameter exit beam pipe desirable given scattered beam if no chicane is to be used. 5 cm possible given low current.

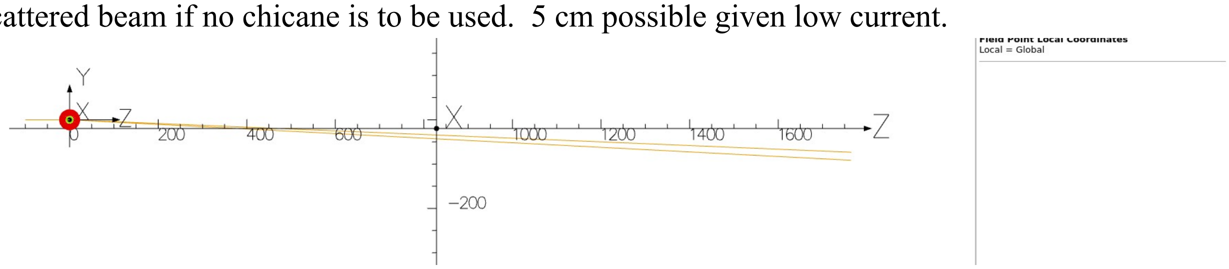

Figure 6. Side view of Figure 3 through the end of the model. 8.84 and 11 GeV beams

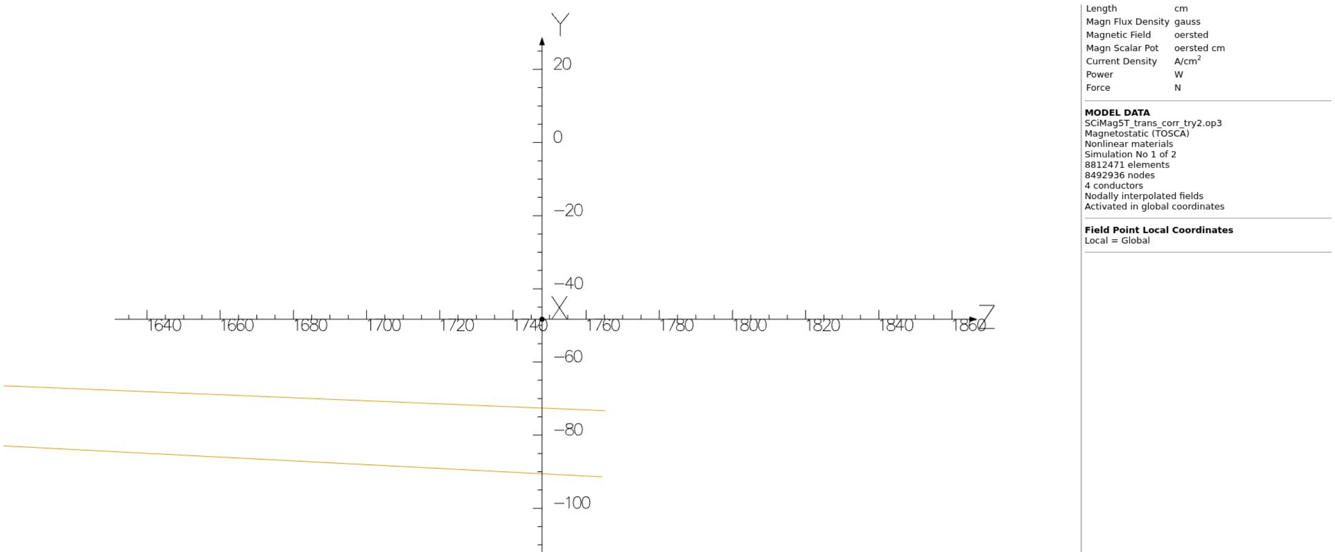

Figure 7. Side view of Figure 3, end of Fig. 6. 8.84 and 11 GeV beams.

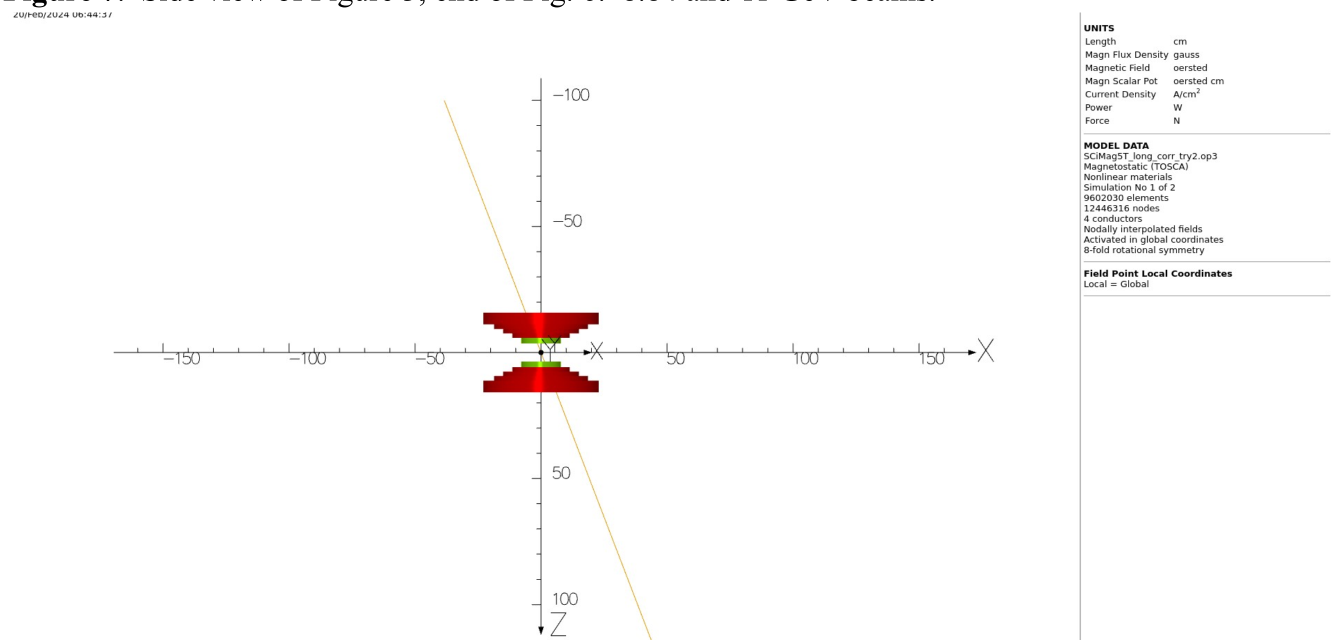

Figure 8 Top view of beam entering **longitudinal** solenoid at 21° angle

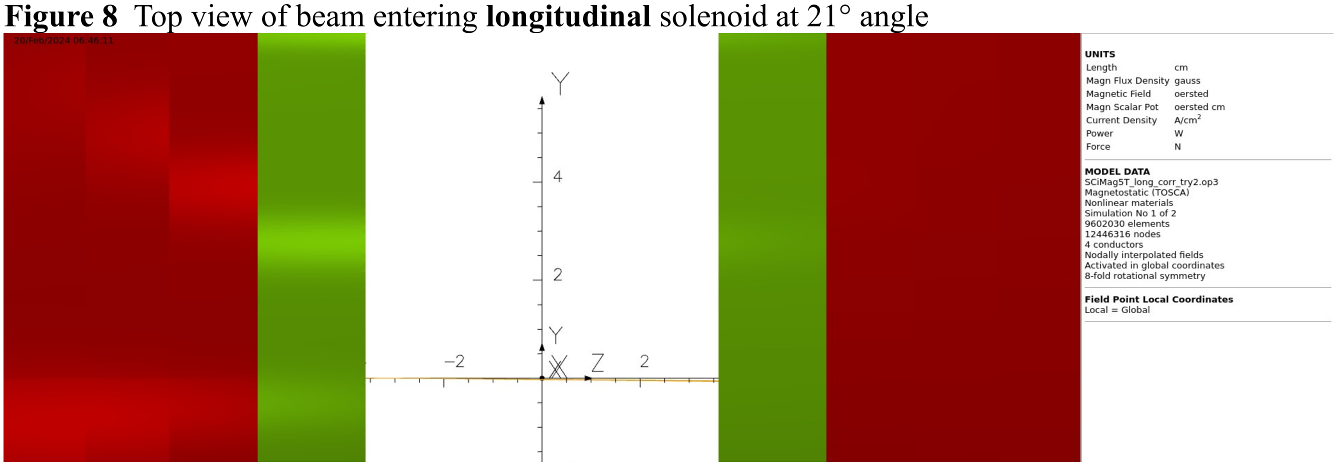

Figure 9. Side view of Fig. 8 with 8.84 and 11 GeV beams

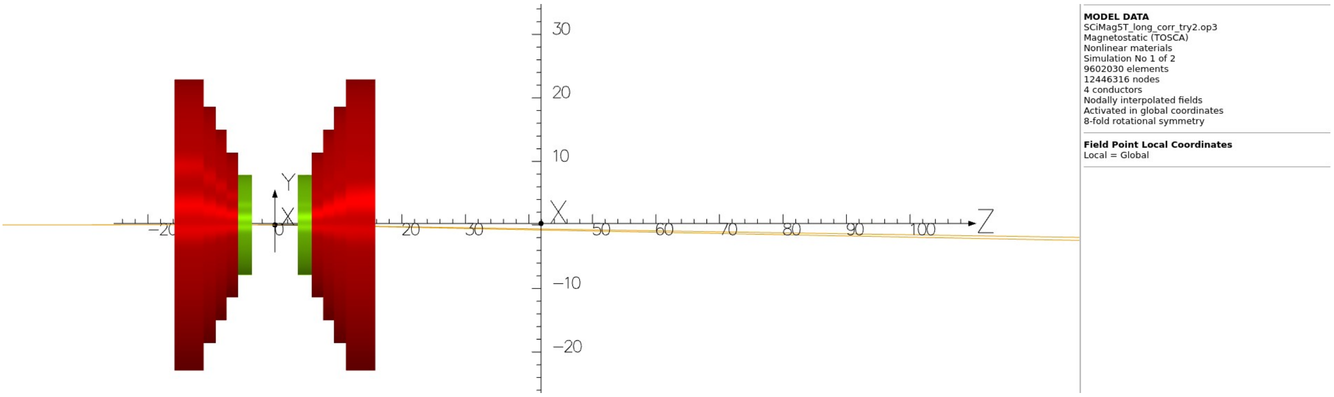

Figure 10. Side view of Fig. 8 with 8.84 and 11 GeV beams. About 1 cm deflection at exit of target chamber for unscattered beam so small beam pipe should suffice if the collaboration doesn't need SHMS to be too close to the beam line. Notches in SHMS magnets may be an issue.

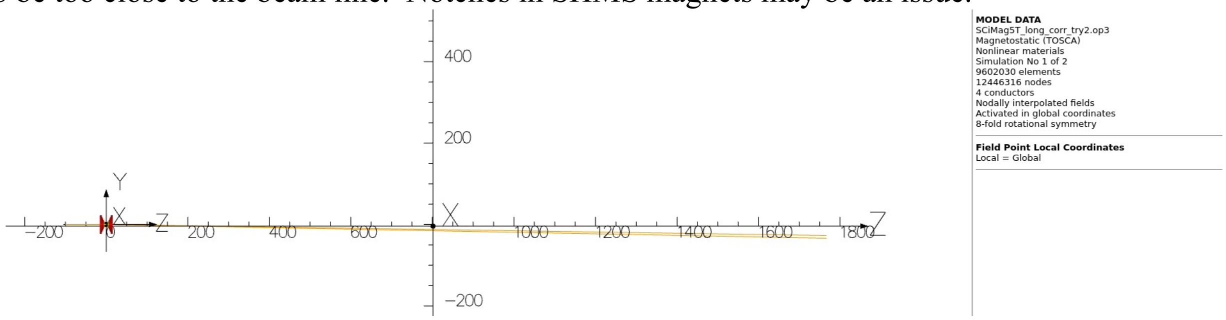

Figure 11. Side view of Fig. 8 with 8.84 and 11 GeV beams to end of model.

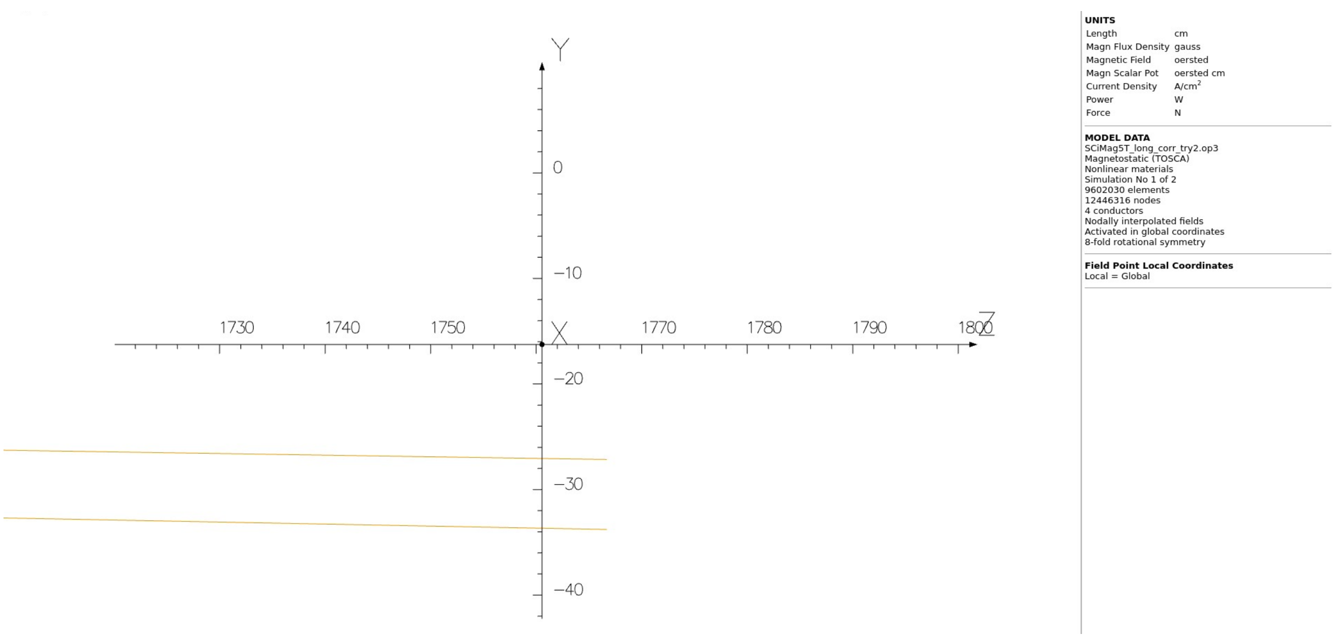

Figure 12. Side view of Fig. 8 with 8.84 and 11 GeV beams at end of model so one sees the difference in deflection.

The proposal cited in the first paragraph wants to use SHMS at small angles. It may be that the chicane will be necessary to allow this given the small exit beam pipe which fits in the notches in the SHMS magnets. The figures below shows 4.44 and 8.84 GeV beam going through the 5 T transverse magnet normal to the field.

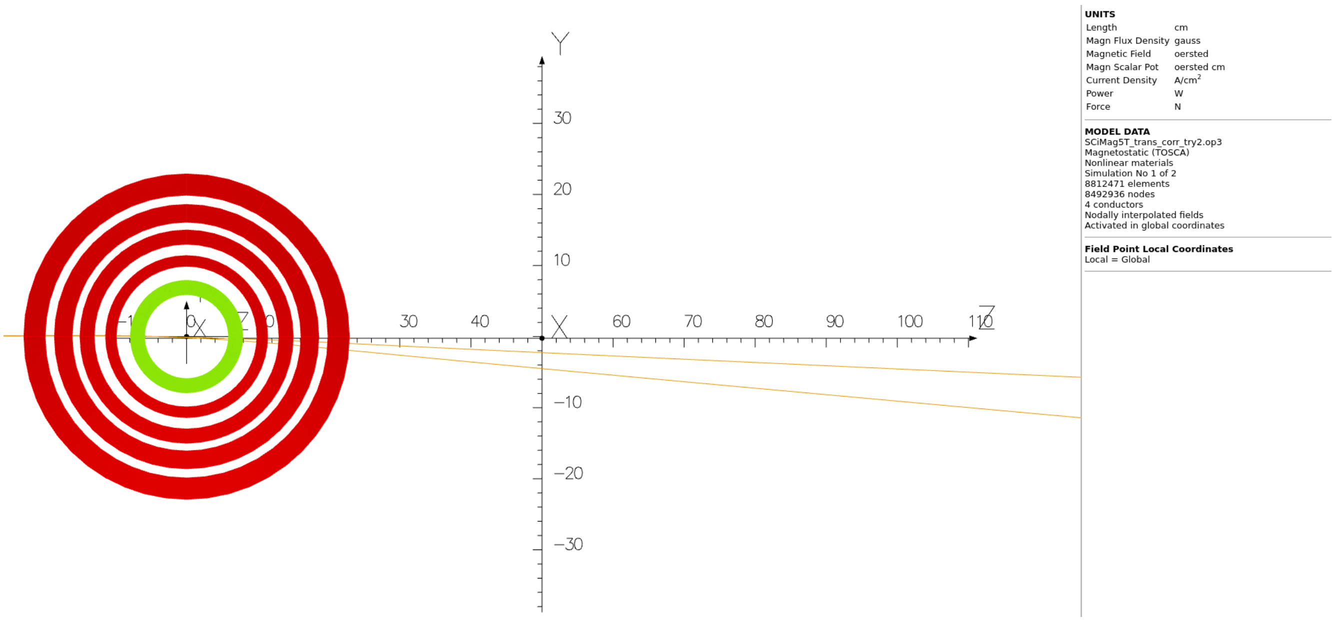

Figure 13. Side view of transverse magnet with 4.44 and 8.84 GeV beams. Axes cross at Z=50 cm because the target chamber is roughly 100 cm in diameter. The 4.44 GeV unscattered beam is a bit more than 4 cm below the axis. If memory serves this doesn't fit in the small beam pipe needed for SHMS at minimum angle.

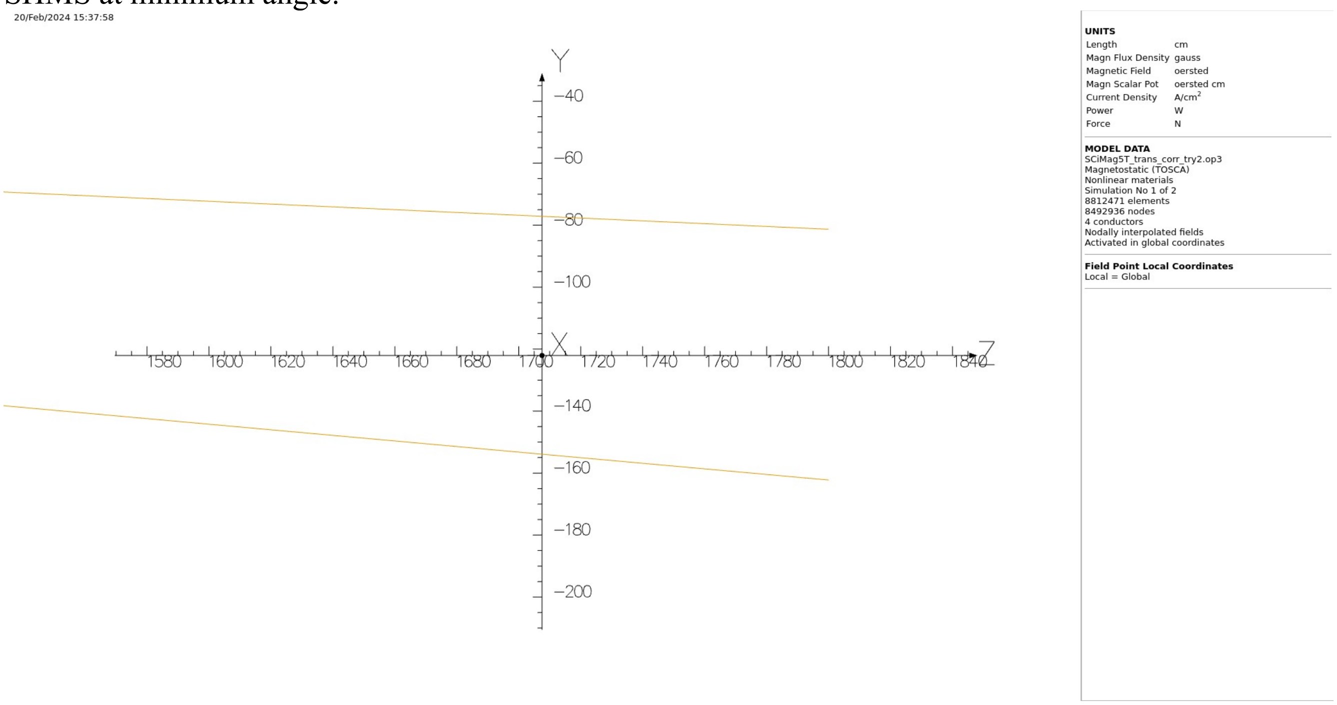

Figure 14. As Figure 13, 4.44 and 8.84 GeV beams at end of the magnet model. End wall of the hall is well beyond this but beam will not reach the floor starting 10' above it.

Conclusion Two

If low current experiments need to use the SHMS at small angle the chicane will be required.

Support column used ~2000 for 2m dipole is in Physics storage building