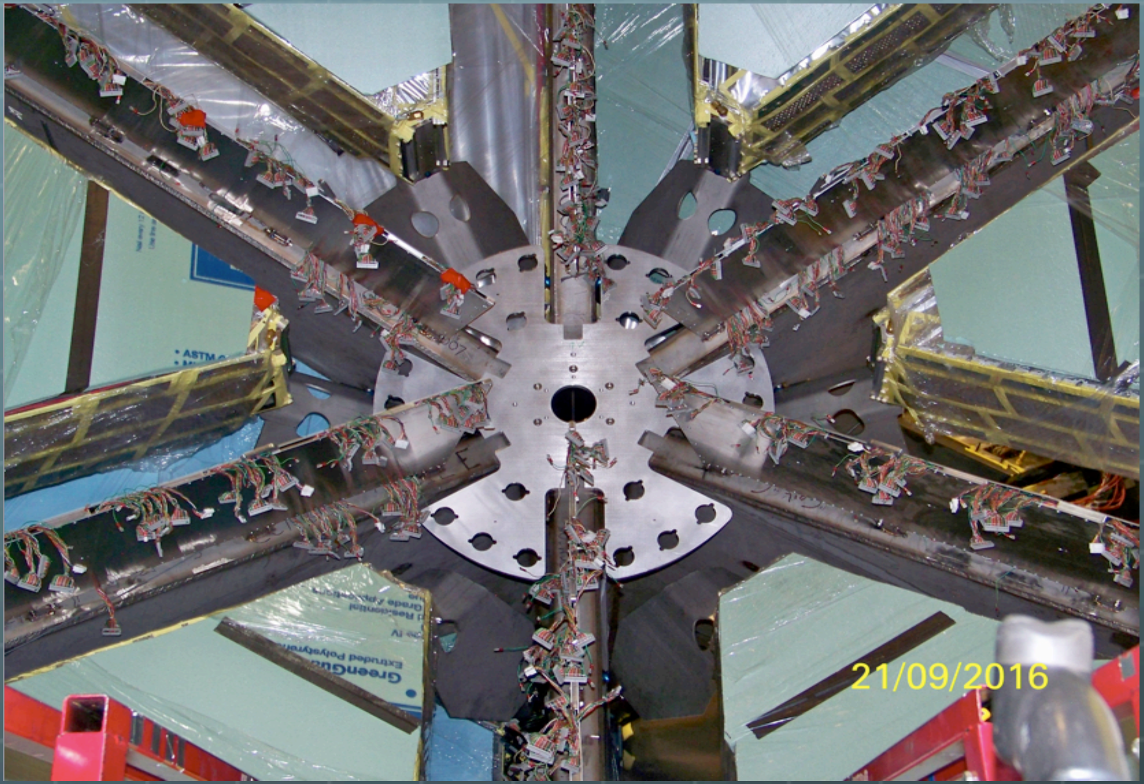

TORUS Field Mapping

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CLAS Collaboration Meeting March 2017

Objectives and Physics Specifications

- TORUS consists of six superconducting coils which produces a symmetric, mainly azimuthal field

- Joint-effort by Jefferson Lab and Fermilab

- Design allows for large acceptance of forward going particles (50% acceptance at 5 degrees from the beam axis)

- Maximum current is at 3770 A with the full field at 3.58 T

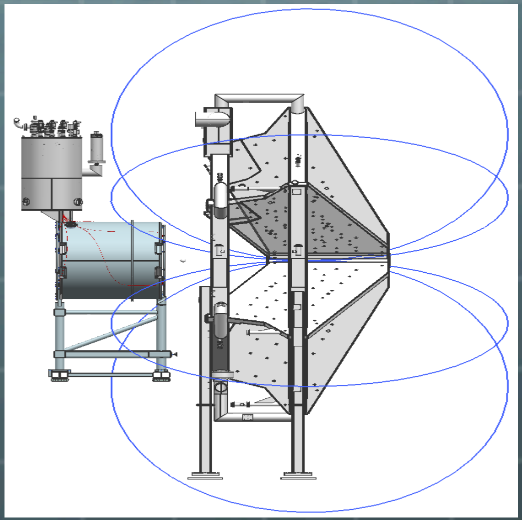


Fig. 1. Schematic of TORUS magnet and direction of the field lines

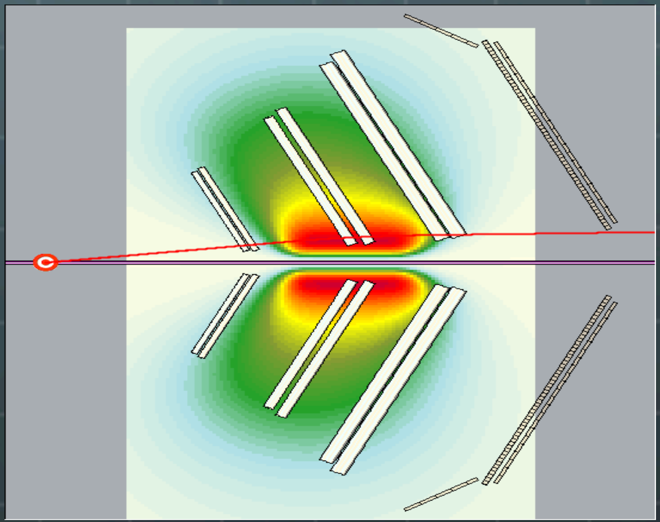


Fig. 2. In-bending track in the presence of the TORUS nominal field configuration

- Momentum resolution is aimed for 0.1%

- Requires that the TORUS field must be known within 0.1% of the full field (2 Tesla)

- Must understand the deviations of the coil positions and angular orientations due to manufacturing and installation process

Anticipated Coil Movements

- Pre-Calculated “distortion fields”, which are the difference between nominal and real, are a superposition of several coil geometry changes
- Field distortions are anticipated based off the input of designers of the Torus
- **Azimuthal Shift** (Entire Coil’s Angle in the XY axis changes)
- **Radial Shift** (Coil Moves in Radial Direction)
- **Coil Stack Height Change** (coil height change due to winding)

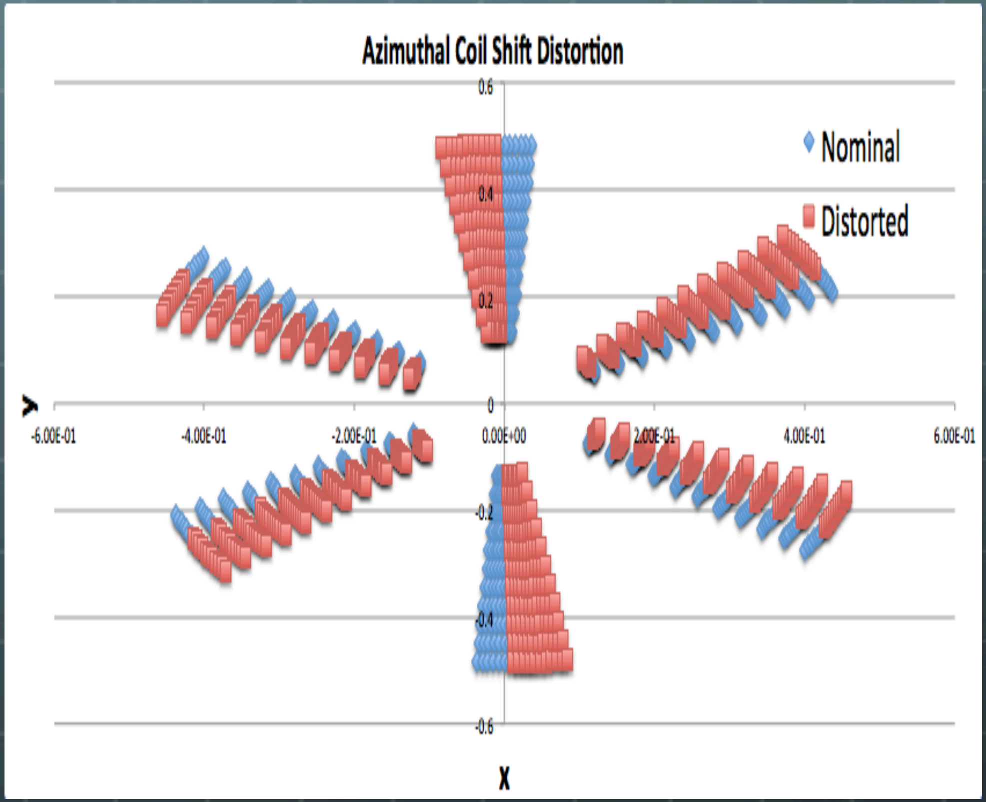


Fig. 3. An example of a possible coil displacement, a shift in azimuth

Fitting Procedure

- Measure all components of the TORUS field at 24 positions in the XY plane along 40 positions along the z-axis and calculate the "distortion field"
- Minimize a chi-squared function that compares the measured and modeled "distortion fields" caused by the anticipated movements of the six coils

Simulated Azimuthal Movement (degrees)	MINUIT Result (degrees)
1.0	0.982719
0.5	0.497469
0.8	0.795112
2.0	2.02476
0.9	0.881792
2.0	2.00441

Fig. 4. 2D toy model result using MINUIT for azimuthal movement

Simulated Radial Movement (mm)	MINUIT Result (mm)
1.0	0.866603
0.0	-0.261949
2.0	2.08819
0.0	-0.150095
0.5	0.825937
1.0	0.95094

Fig. 5. 2D toy model result using MINUIT for radial offset

Simulated Coil Winding Change (mm)	MINUIT Result (mm)
1.0	0.883163
2.0	1.62248
1.0	0.925097
0.0	-0.0613878
0.5	0.935336
0.0	-0.0719708

Fig. 6. 2D toy model result using MINUIT for change in coil stack winding height

Mapping Procedure

- **Hall Probes measured the field and were pushed by a LabView-controlled apparatus into non-magnetic Carbon tubes**
- **Current was at 3000 Amps (roughly 75% of the maximum field)**
- **Data was taken from November 3 through November 6**

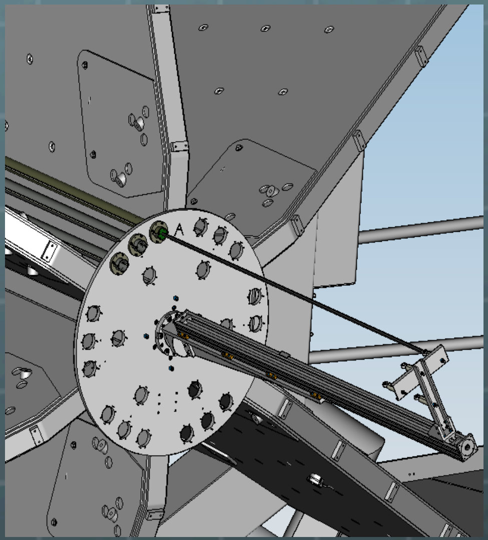


Fig. 7. Visual model of the Hall probe being pushed by a motor along the beam axis inside a non-magnetic Carbon tube

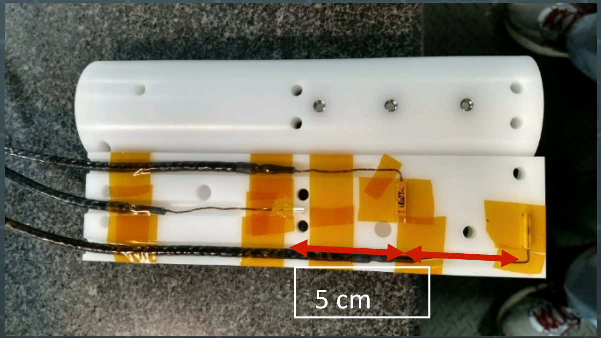


Fig. 8. The inside of the Hall probe

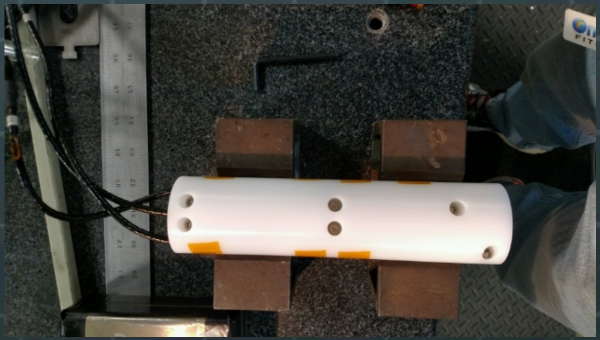
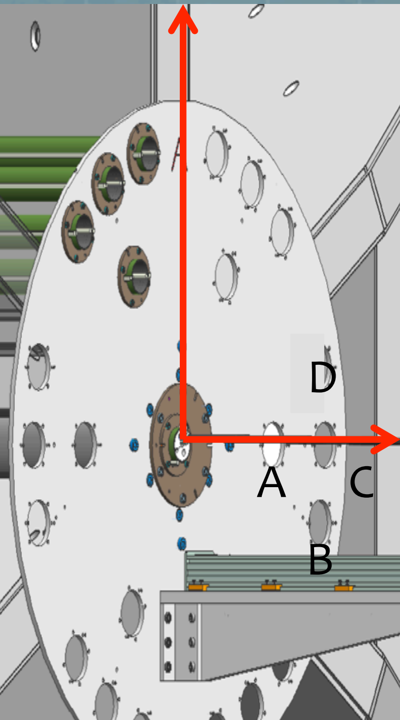
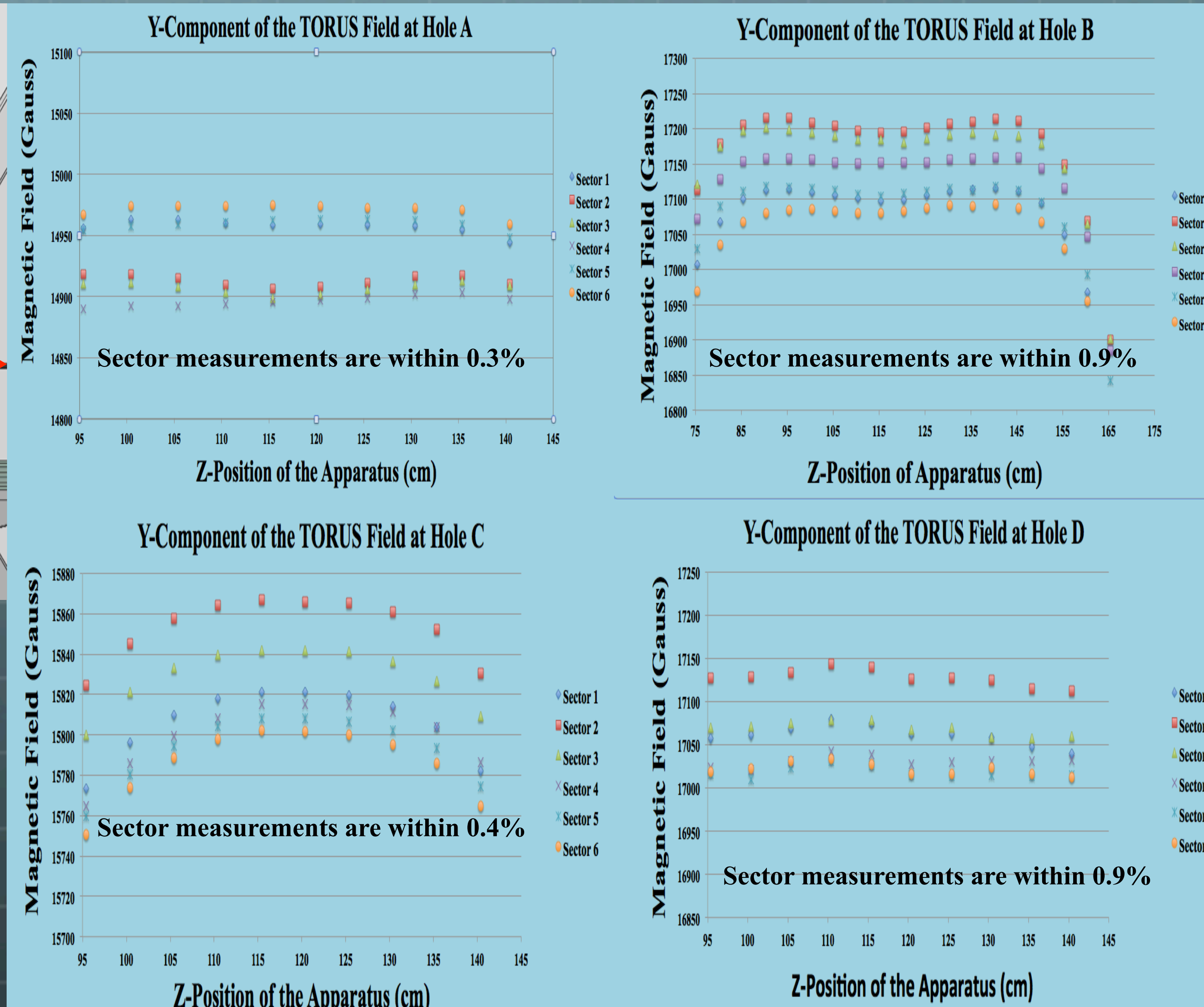


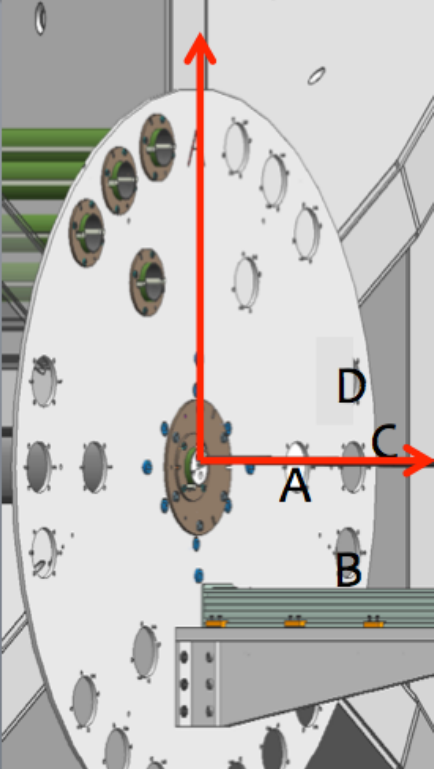
Fig. 9. Closed hall probe as it appeared during the mapping effort

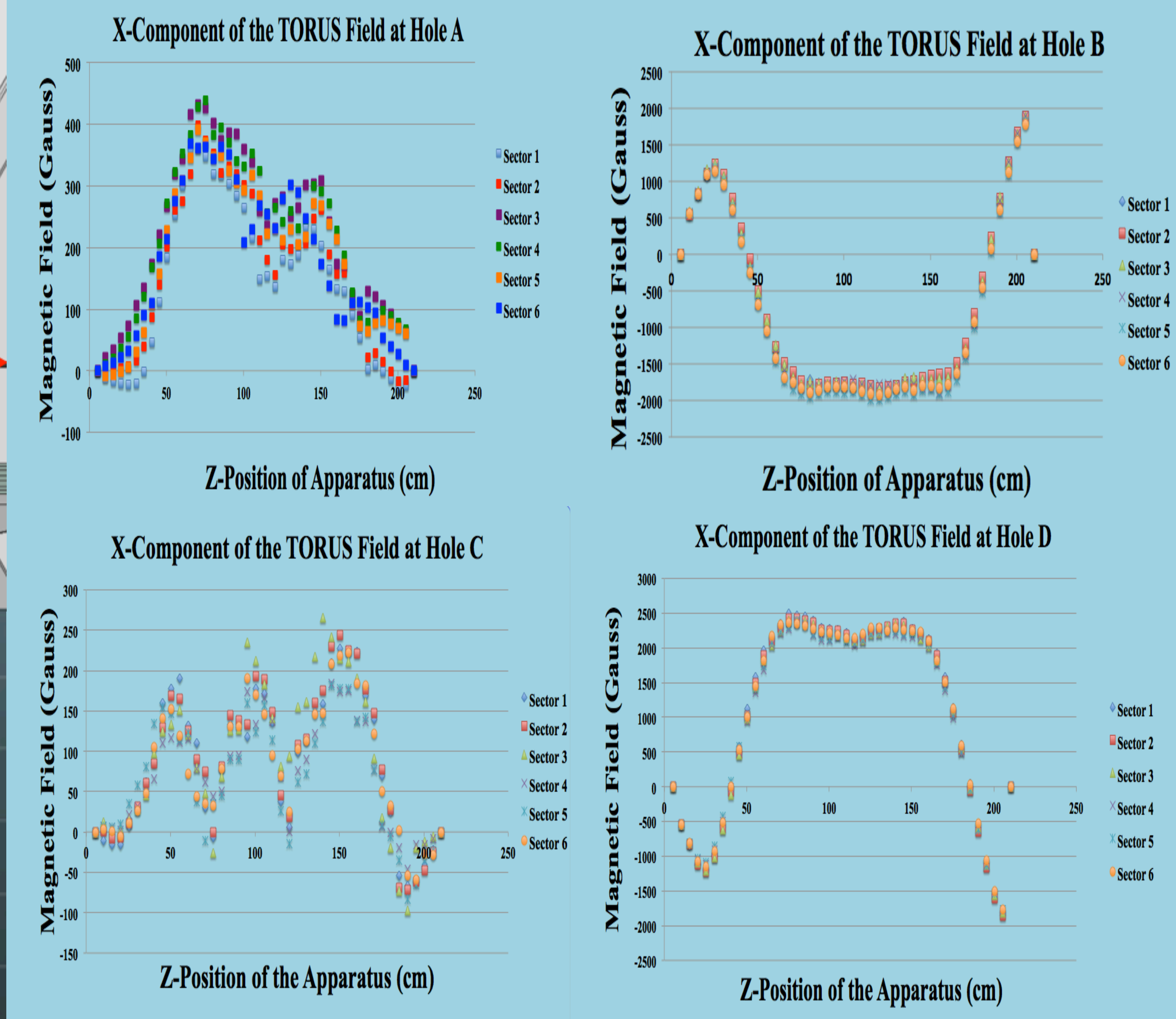




The y-component, which points in azimuth, was measured with great precision

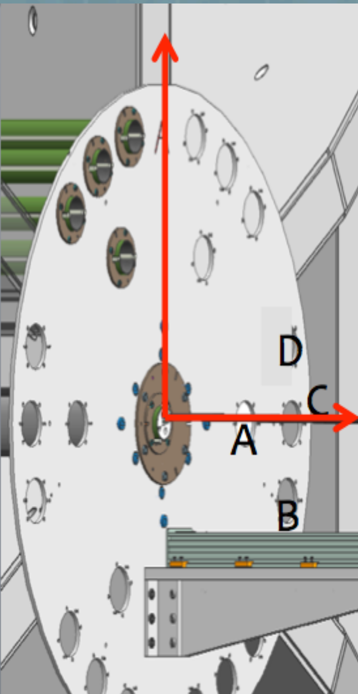
Fig. 10. Large component of the TORUS field at Holes A-D as measured in all six sectors.





The x-component, especially at Holes A and C, are viable ways of checking for non-field effects

Fig. 11. X-component of the TORUS field at Holes A-D in Sectors 1-6.



Holes A and C, which radially divide each sector should see no magnetic field. Any field can be an indication of a rotating reference frame

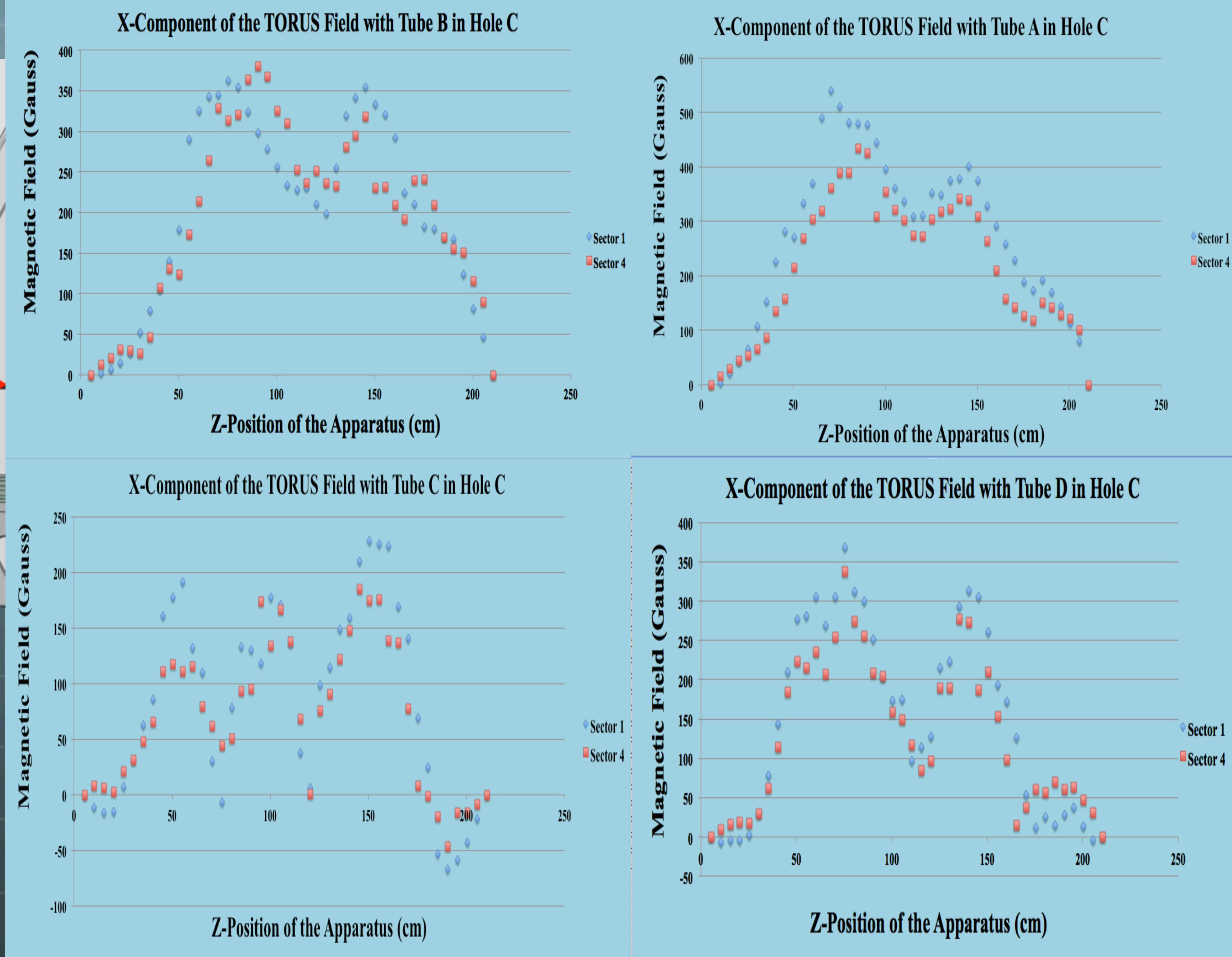


Fig. 12. X-component of the TORUS field at Hole C using different non-magnetic tubes to test for non-field effects to data

Rotation of Hall Probes

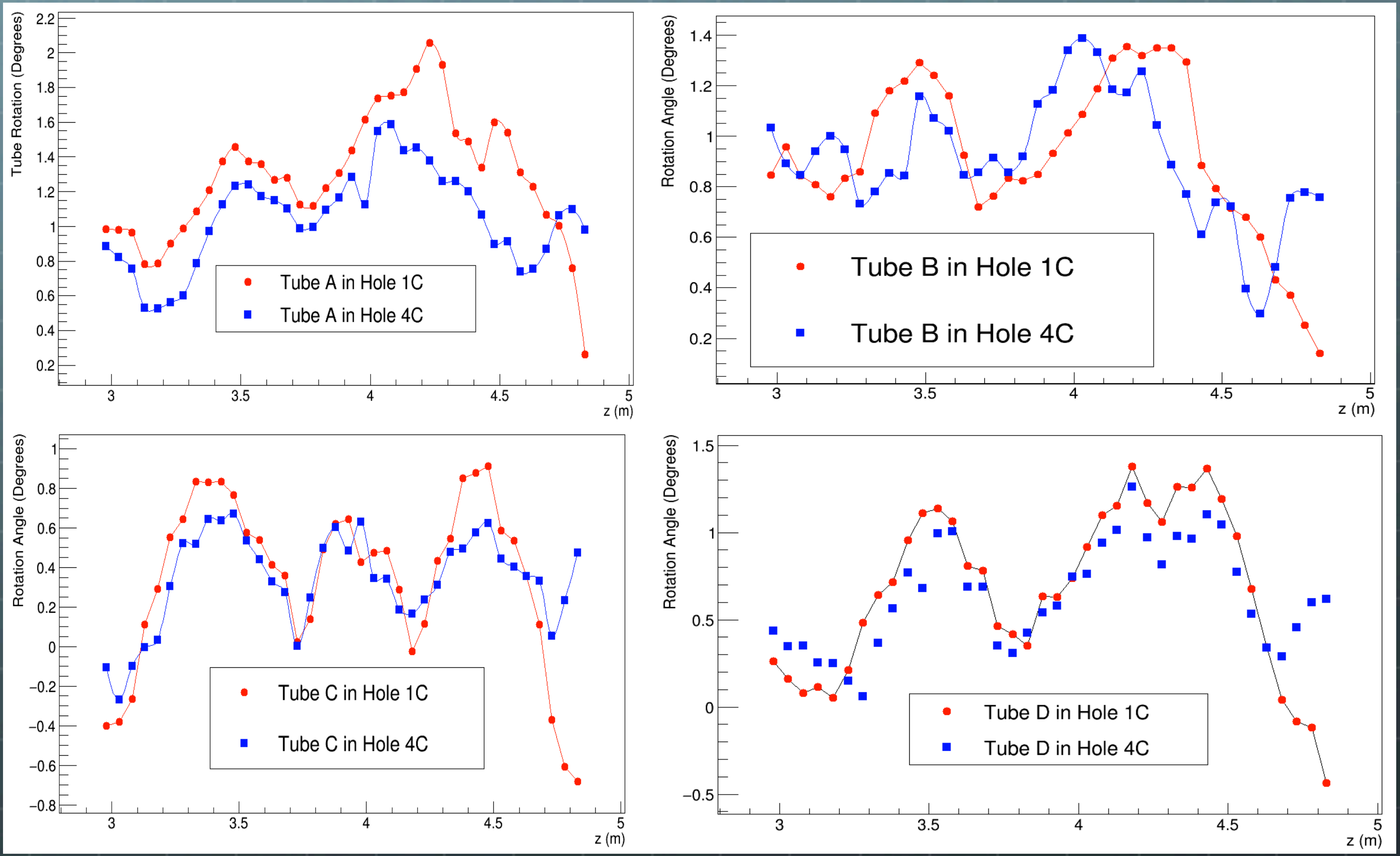


Fig. 13. Effect of tube on the rotation of the Hall probes.

Next Steps

- Obtain theoretical field calculations from the nominal configuration (and displacements of the field) with Opera software
- Correct mapping data with rotation matrix
- Fit the data and determine the true coil positions using measured data, modeled data, and MINUIT

Acknowledgements

- Thanks to our project managers: Mac Mestayer and Renuka Rajput-Ghoshal
- Thanks to our design team: Cyril Wiggins, Mike Beck, Joseph Meyers, Ruben Fair, Robert Miller, Mark Taylor, and Orlando Pastor
- Thanks to all of our shift workers from the CLAS collaboration: Harut Avagyan, Dan Carman, Jixie Zhang, Olga Cortes Beccera, Eugene Pasyuk, Stepan Stepanyan, Maurizio Ungaro, Victoria Lagerquist