Target Magnetic Field Direction Measurement

A_1^n and d_2^n Experiments

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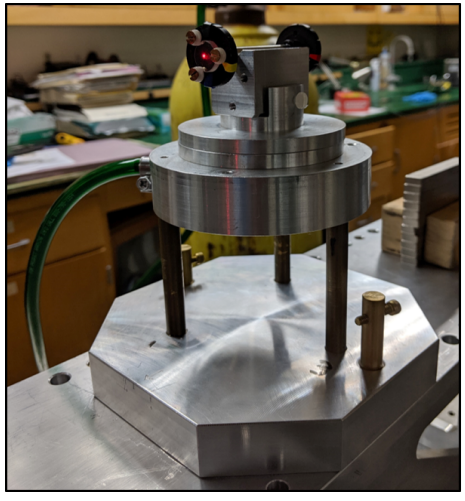
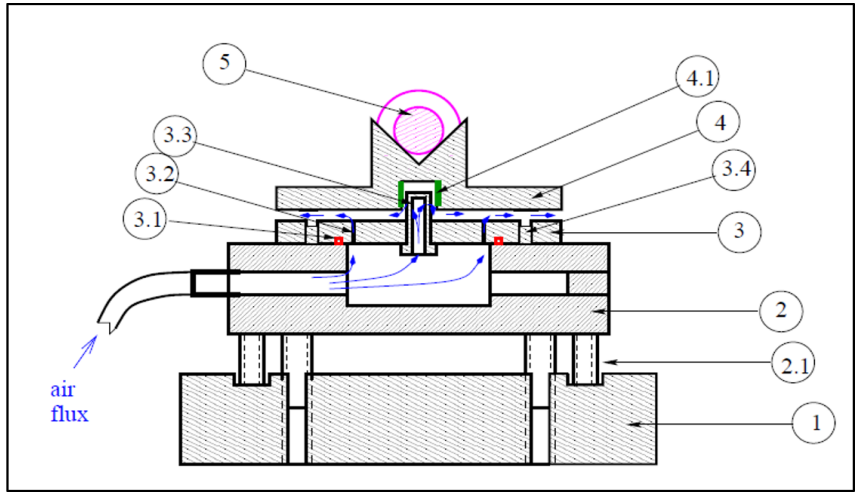
Outline

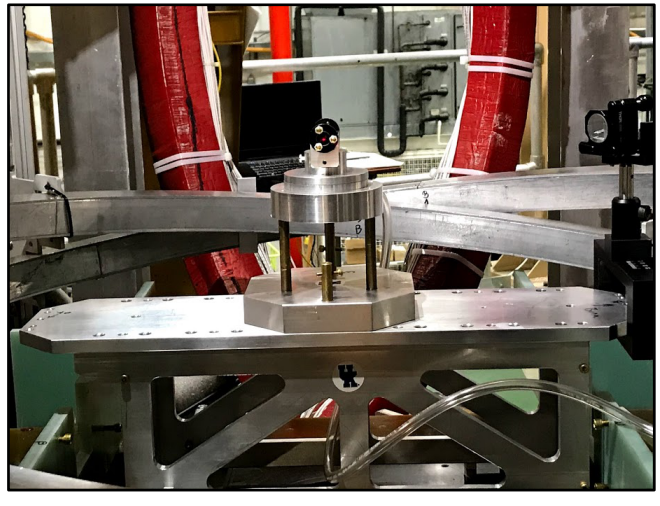
- The Horizontal Compass
- Uncertainty Minimization in Field Direction Measurement
- Measurements in Hall C
- Survey Data Analysis and Results
- Summary and Future Work

The Horizontal Compass





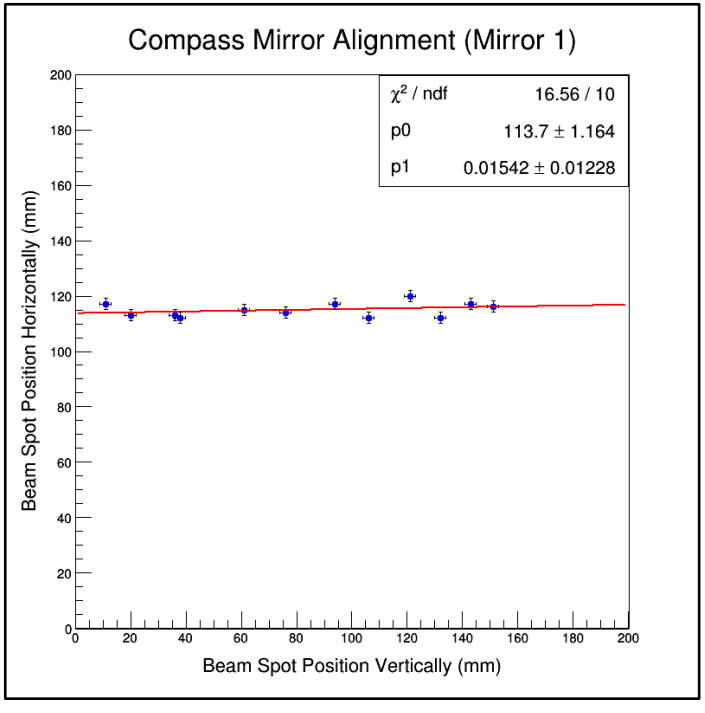
- An air-floated compass was built at the University of Kentucky.
- Goal was to measure absolute direction of the target magnetic field in the Hall C coordinate system precisely to about ±0.1°.
- Field direction was measured by reflecting a laser beam off the compass mirrors, aligned exactly perpendicular to the magnetic axis of the magnet.



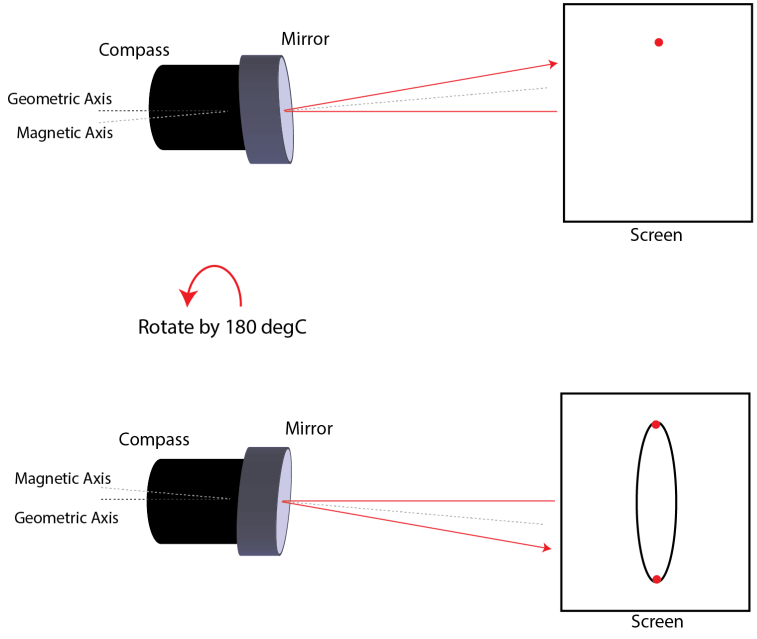
Compass installed in Hall C

Uncertainty Minimization in Field Direction Measurement

- Reflected laser beam from the compass mirror inscribed an ellipse on a screen as a result of 360° scan of the magnet.
- Three brass screws and springs were used to align the mirrors on the compass magnet.

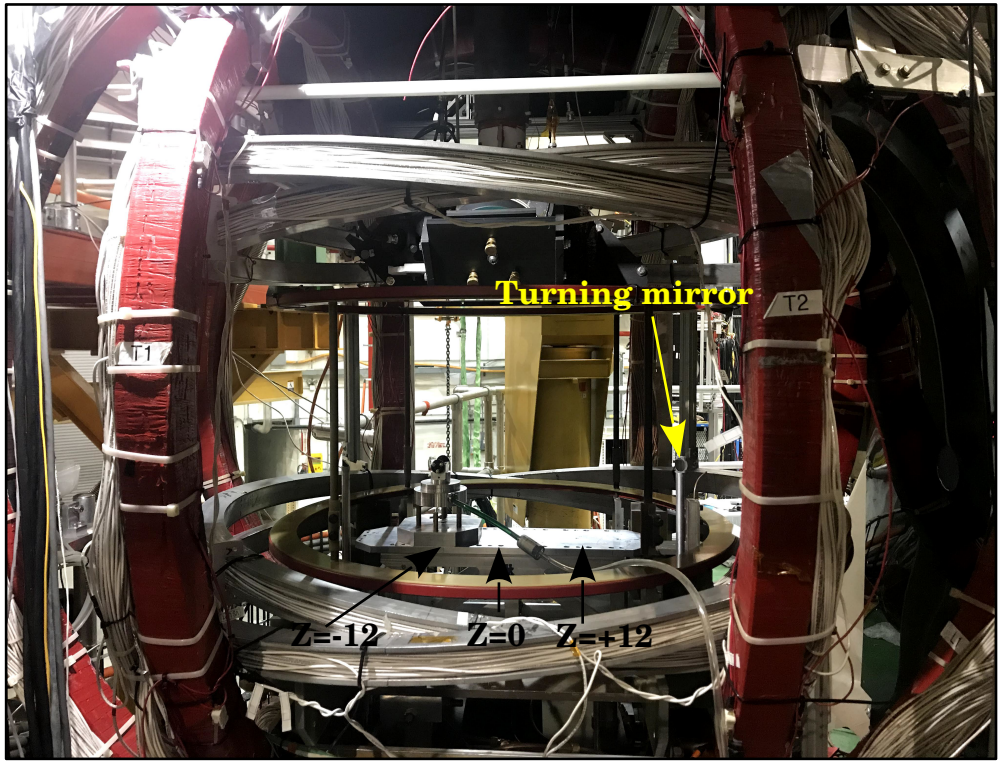


Horizontal error from mirror 1 alignment: ±0.04° (March 2020)

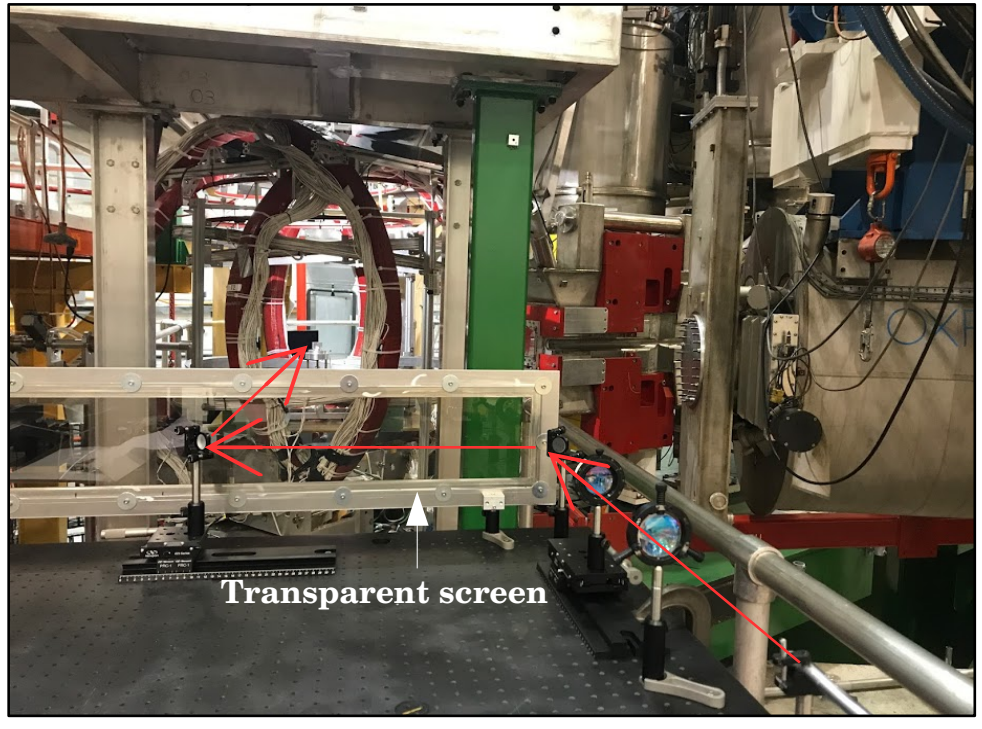


- The magnetic field direction was given by the surface normal of the compass mirror.
- The compass mirrors were aligned parallel to the magnetic axis of the compass magnet to minimize the horizontal error by reducing the ellipse to a vertical line.

The Compass Setup in Hall C

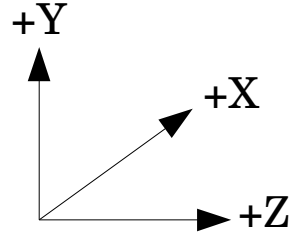


Compass Installed along the Target



Optics Setup for Compass Measurement

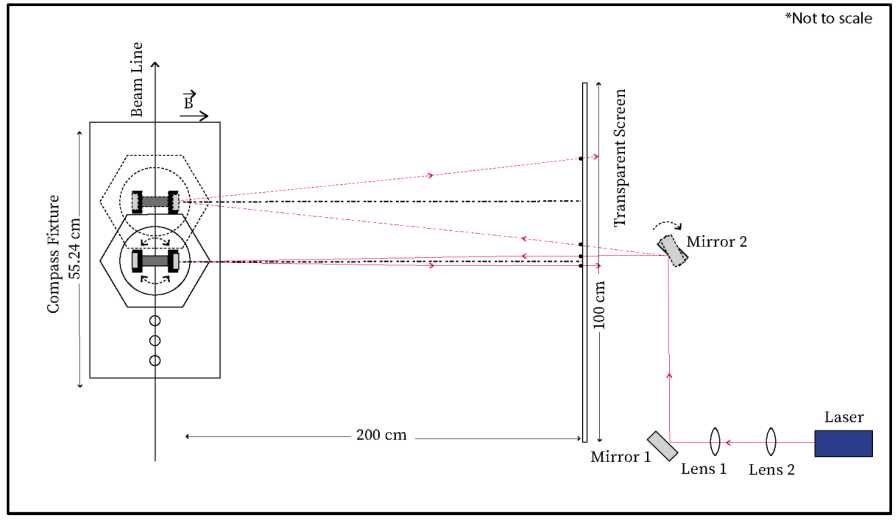
- Optics were installed ~ 2 m away from the target and aligned to obtain a circular beam spot with ~ 2 mm diameter.
- Incident and reflected laser beam spots were mapped on the transparent screen for each kinematic setting.



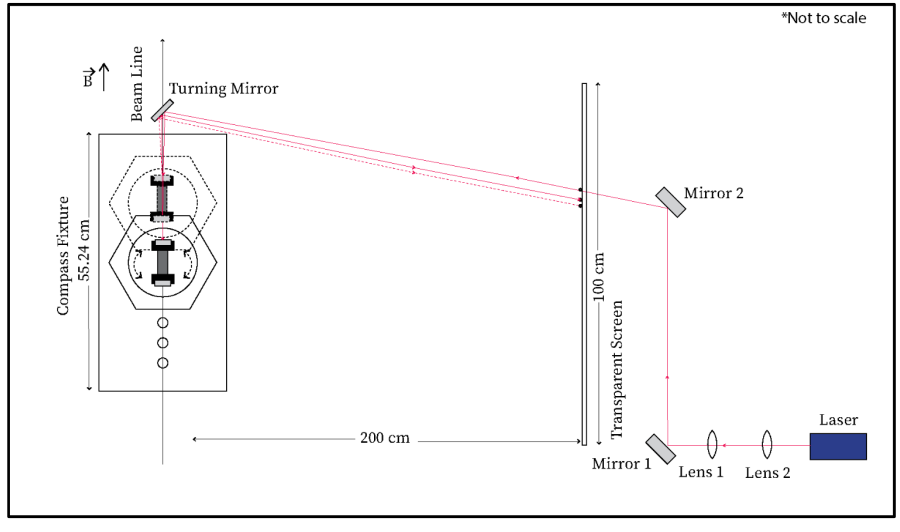
Hall C co-ordinate system

Measurements in Hall C

- Magnetic field direction measurement for A_1^n was done in October, 2019 before the experiment.
- Magnetic field direction measurement for d_2^n was done in March, 2020 before the experiment and was repeated in September, 2020 after the completion of the d_2^n experiment.
- Target polarization direction was scanned in three different locations along the target length for all four polarization direction (+X, -X, +Z, -Z).
- The alignment group at JLab surveyed the measured points in the absolute Hall C coordinate system.



Transverse Field Direction Measurement

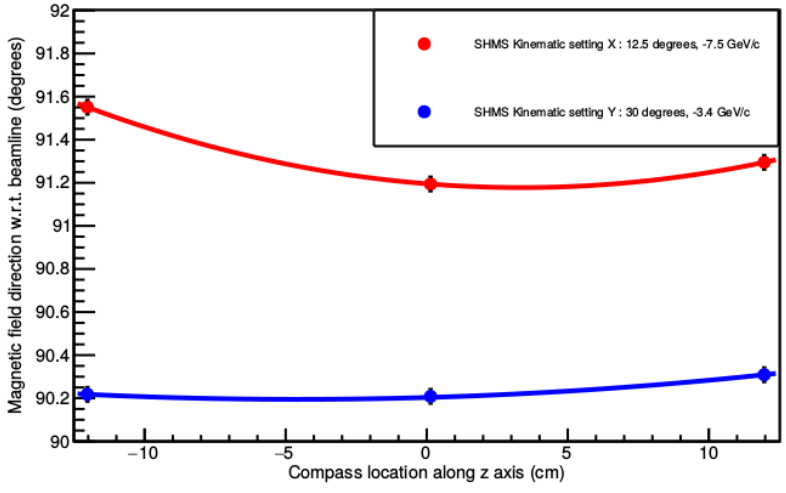


Longitudinal Field Direction Measurement

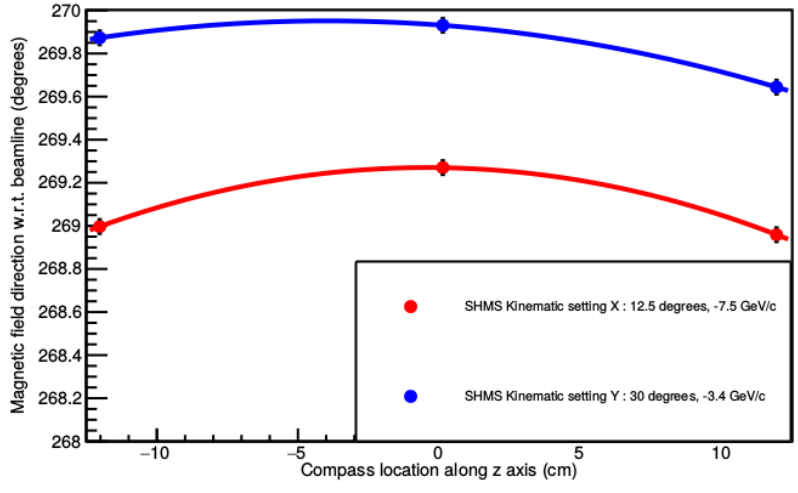
Survey Data Analysis and Results

A_1^n Kinematic Settings

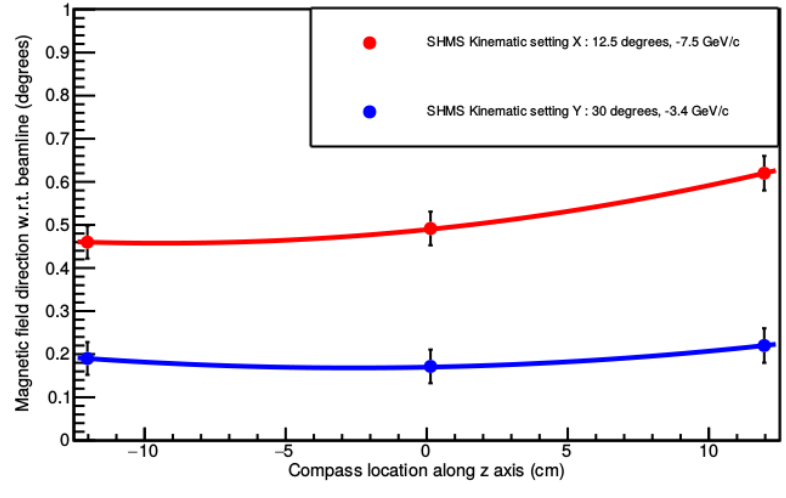
Transverse +X (90 deg, beam right)



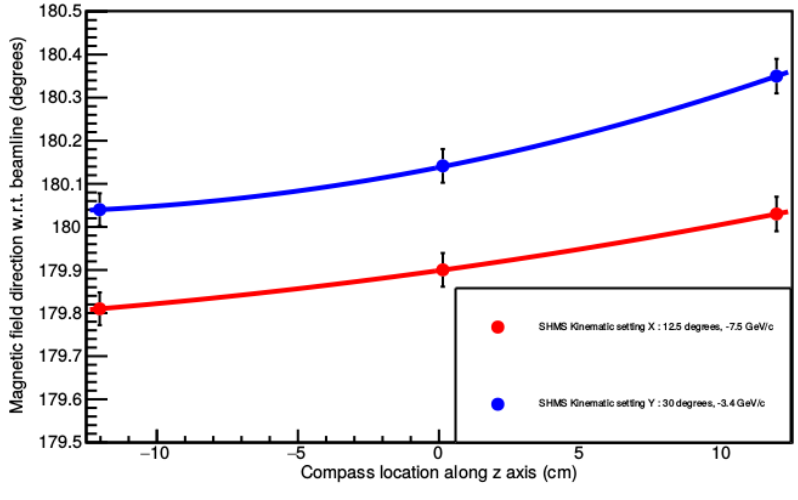
Transverse -X (270 deg, beam left)



Longitudinal +Z (0 deg, downstream)

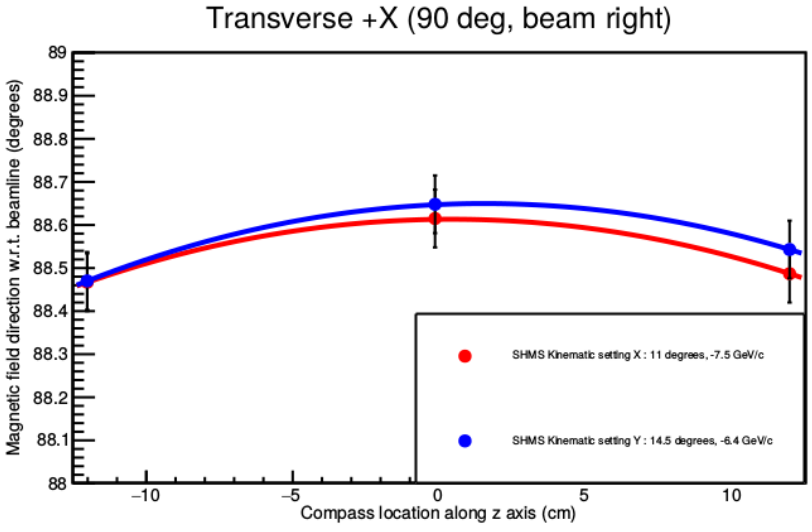


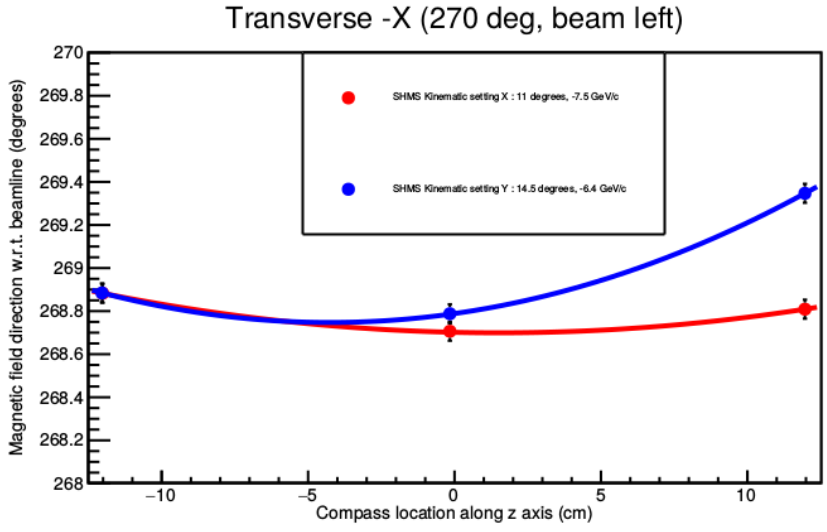
Longitudinal -Z (180 deg, upstream)

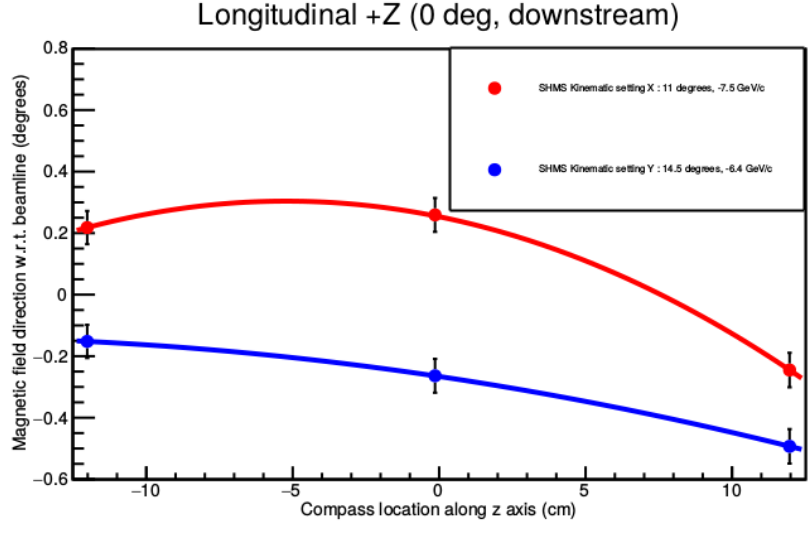


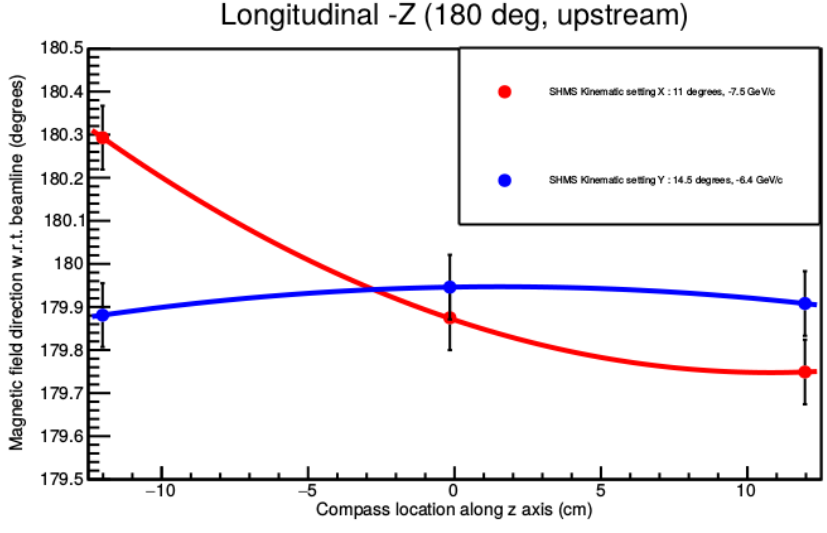
Survey Data Analysis and Results

d_2^n Kinematic Settings (March 2020)



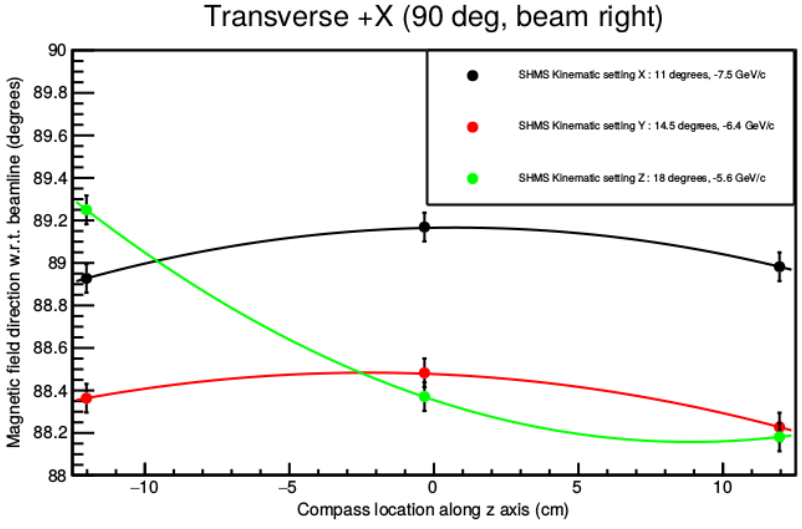


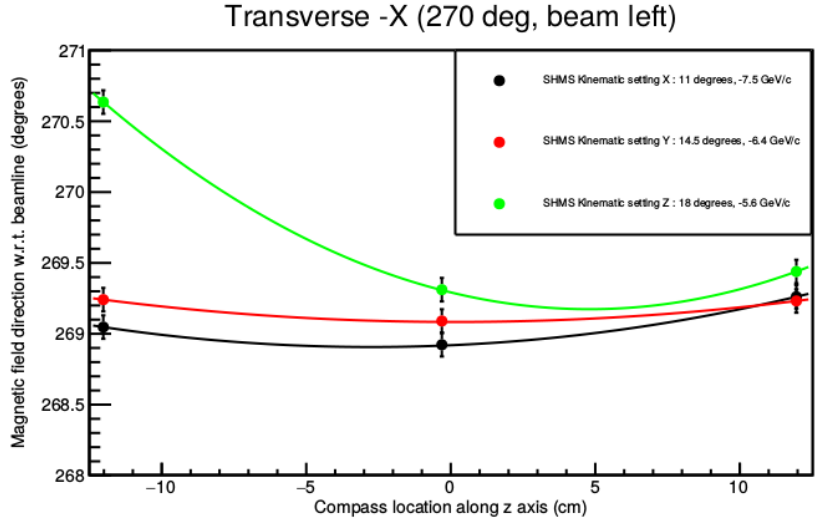


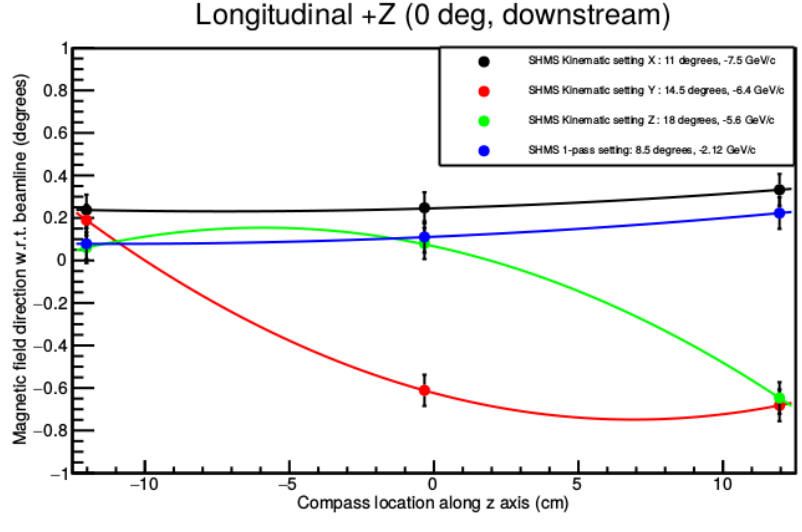


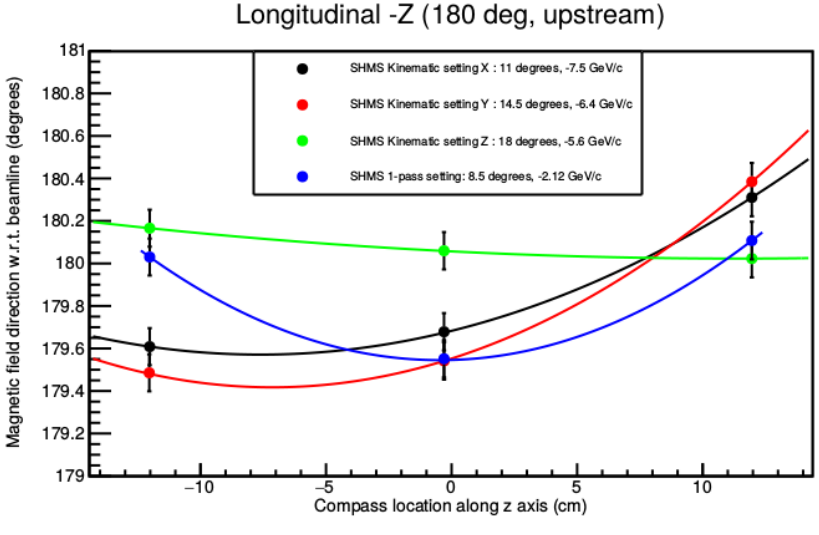
Survey Data Analysis and Results

d_2^n Kinematic Settings (September 2020)



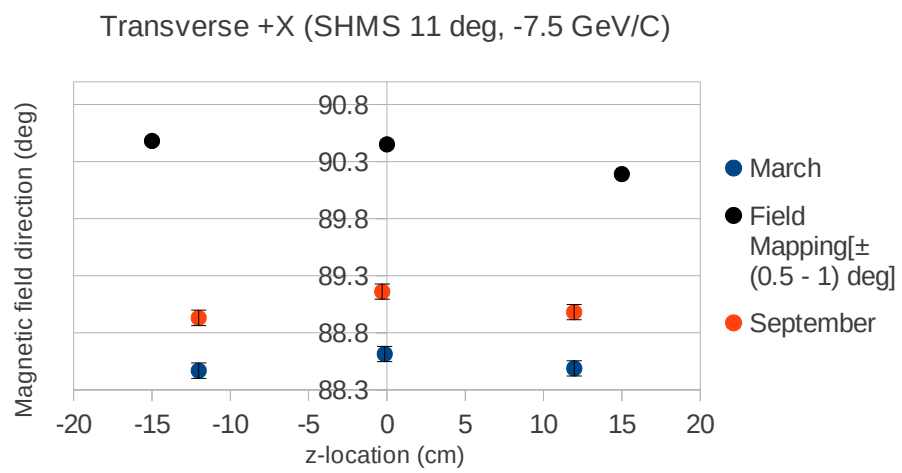


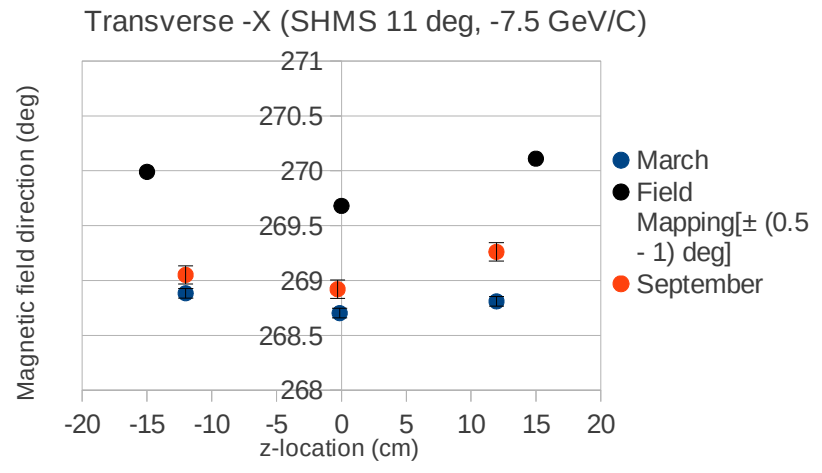


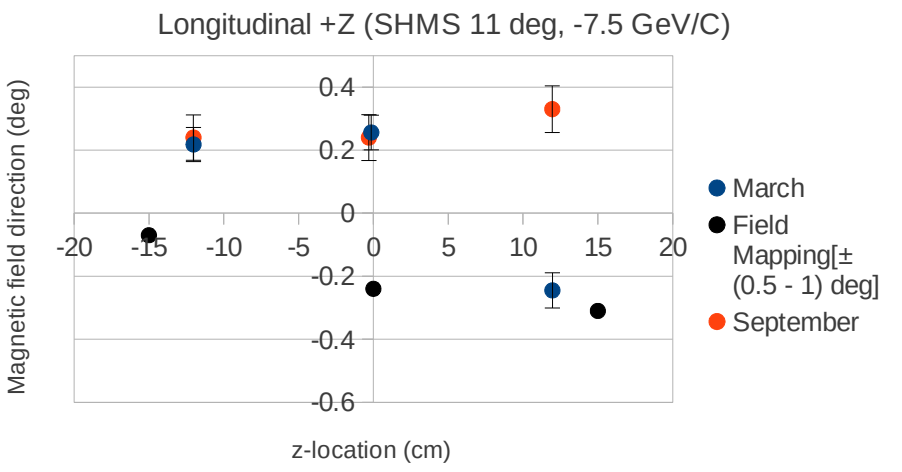


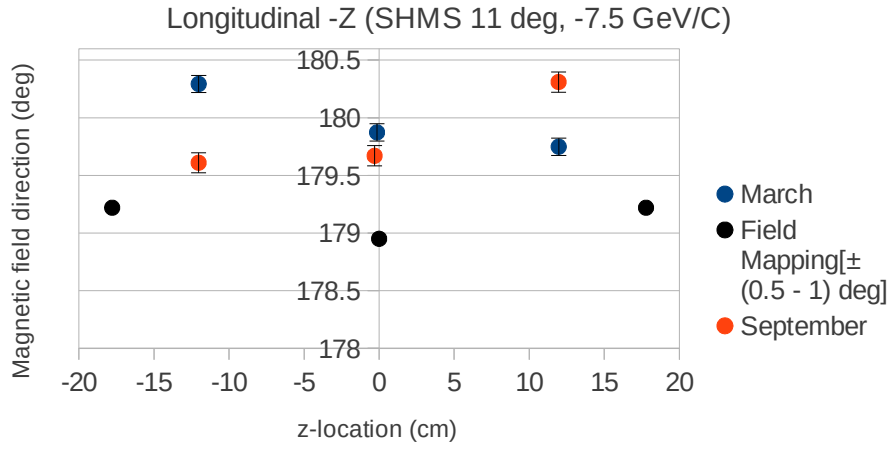
Survey Data Analysis and Results

Comparison of March Compass Data, September Compass Data and Calculated Magnetic Field Direction from Field Mapping Data for d_2^n Kinematic Settings









* For this setting, the field mapping was done at y=+7.9 cm and the compass measurements were at y=0.

Sources of Systematic Uncertainties

1. Error in determining the angle (θ) the magnetic field makes with beam line: **~ ±(0.01°-0.03°)**

$$\sigma_\theta = \sqrt{\sum_i \left[\left(\frac{\partial \theta}{\partial x_i} \right)^2 \sigma_{x_i}^2 \right]}$$

Where θ was the function of all the surveyed coordinate variables (x_i) and σ_{x_i} is the error associated with that particular coordinate.

σ_{x_i} for compass and fiducial location = 0.28 mm

σ_{x_i} for points on screen = 0.5 mm

2. Errors from the compass mirror alignment (θ_M): **~ ±(0.04°-0.08°)**

The misalignment between magnetic axis of the cylindrical magnet and compass mirror generated additional errors-

A. Projection of the fitted straight line on the horizontal axis

B. Fit parameter errors

3. Laser beam spot size: **~ ±0.006°**

Lenses were used to make the laser beam spot diameter ~2 millimeters.

4. Position of incident laser beam on the compass mirror: **~ ±0.01°**

The laser beam always reflected off the center of the compass mirror within 0.5 mm uncertainty.

Total uncertainty was within ±0.1° for each compass measurement!

Survey Data Analysis and Results

Studies being done to solve the discrepancy between March and September data:

- What was different in the two sets of measurement?

  1. Beam pipes were not installed during March measurements but they were present in September.

  2. Helmholtz coil power supply was changed.

✔ • Analysis was done to confirm that the compass was placed at the surveyed locations each time.

- Studies being done to check if any offset was introduced in the surveyed points for any one of the measurements.

✔ 1. Transverse data : Offset in compass location for each measurement were computed to match the September results with March within a uncertainty of ±0.05°. They do not look consistent in every setting.

2. Longitudinal data: Study in progress (more parameters to consider).

Summary and Future Work

- The magnetic field direction was measured for A_1^n and d_2^n (twice) experiments with less than ±0.1° uncertainty.

- The March and September data were not in agreement, might lead to increased total uncertainty.

- Future work: Continue compass data analysis to understand the discrepancy between the two sets of magnetic field direction measurements for d_2^n experiment.

- Thanks to JLab Alignment group, other students and postdocs for their help in all the compass measurements in Hall C.