Radial Alignment of the EG6 RTPC

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I. INTRODUCTION

Due to its small size, proximity to the beamline, and beamline constraint in track fitting, the RTPC is sensitive to radial misalignment as small as a few-hundred μm. This results in effects on momentum reconstruction that modulate systematically with the azimuth around the detector.

Measuring a misalignment requires a reference. The higher energy tracks in CLAS leave small signals in the RTPC, and the two detectors have small overlap in acceptance. Instead of measuring the same track in both detectors, elastic scattering is used where the electron is measured in CLAS and the ^{4}He is measured in the RTPC. This same event selection has also been the source of drift paths and gain calibrations of the RTPC [1, 2], and those calibration methods have proven sensitive to misalignment.

The method described here is similar to that for measuring the beam position relative to CLAS [3] in that misalignment results in a modulation in a reconstructed quantity as a function of ϕ. In the latter case, the beam window is the reference and the z-vertex reconstructed by CLAS is what modulates, while here it is CLAS's electron that serves as a reference and the RTPC's measured ϕ and momentum that modulate.

II. MOTIVATION

The beamline constraint on each track in the RTPC reconstruction code is implmenented as one additional point in the helix fit with zero weight on its z-coordinate. The effect of this constraint was investigated by simply fitting each track in the real data twice with two different beamline positions. For tracks at average elastic kinematics, the effect on reconstructed momentum and ϕ is shown in Fig. 1 for four different beam positions relative to the RTPC axis. At these kinematics there is no significant effect on z-vertex and θ, but there is 20% variation in momentum and 5° variation in ϕ from a 1 mm offset.

The simple modulations of the following equations, with amplitude and phase that correlate to the beam position (x_0, y_0) relative to the RTPC, are sufficient to describe the effects near elastic

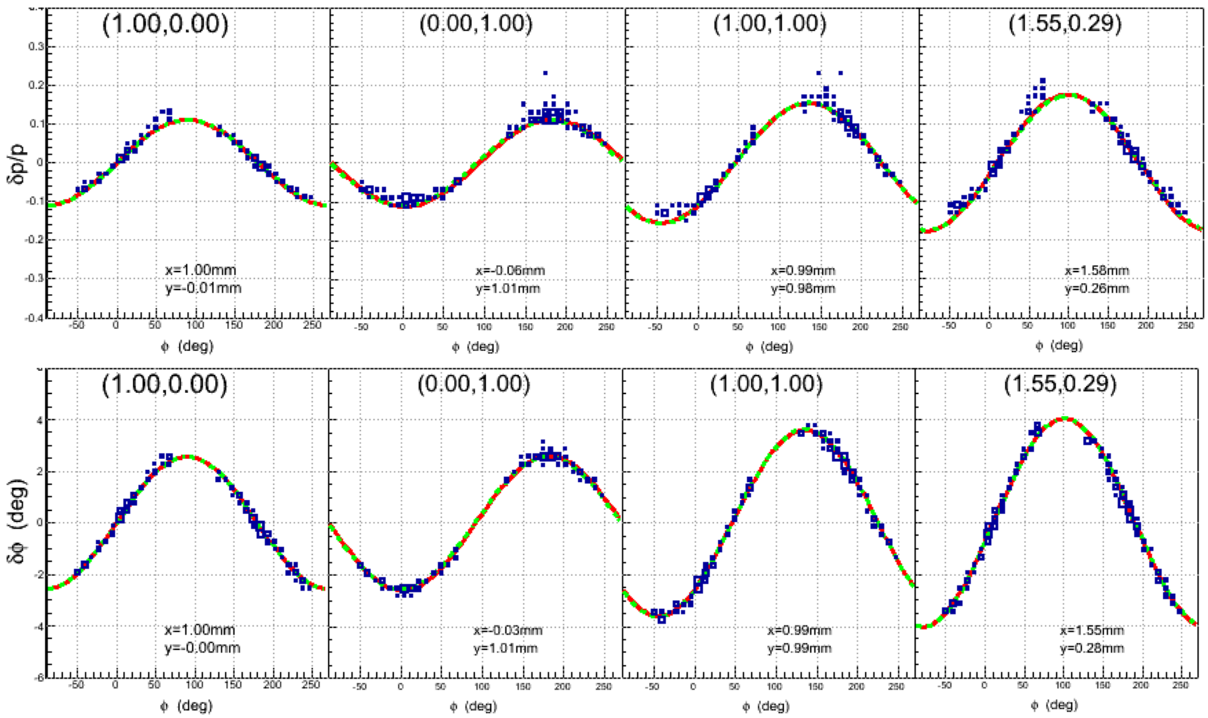

FIG. 1. The effect on reconstructed momentum (top) and ϕ (bottom) as a function of the track's ϕ of moving the beamline constraint from $(0, 0)$ to the position (x_0, y_0) shown in mm at the top of each figure. The data points are for tracks with $p/q = 150 \pm 5$ MeV/c and $\theta = 78 \pm 3°$.

kinematics.

$$\Delta\phi = \left[\frac{2.56°}{mm}\right]\Big(-y_0\cos\phi + x_0\sin\phi\Big) \tag{1}$$

$$\frac{\Delta p}{p} = \left[\frac{p\sin\theta}{1078\ MeV\cdot mm}\right]\Big(-y_0\cos\phi + x_0\sin\phi\Big) \tag{2}$$

The red curves in Fig. 1 are the results of fitting these functions to the data, and the (x_0, y_0) values at the bottom of each plot are the result of the fit. For large momentum or small θ this parameterization starts to fail. While it could be possible in the future to find a global function that applies over all kinematics as an ad-hoc correction after the raw data has been processed, it is desireable to determine the correct beam position for the purpose of drift-path and gain calibrations and also to minimize future corrections.

III. METHOD

In order to apply the idea of the Section II, it is neccessary to measure a modulation reconstructed by the RTPC by comparing with a reference. Elastic scattering provides a correlated electron measured in CLAS suited for this purpose.

The assumption required is that the electron is well-measured and has no ϕ-oscillation of its own. This is not unreasonable, as no global periodic modulation of ϕ has been observed before in CLAS. It is also noteworthy that the $\Delta\phi$ between CLAS and RTPC for elastics is largely independent of z-vertex in Fig. 2, while the electrons have traveled through much different solenoid $\int \vec{B} \cdot \vec{dl}$ for different z.

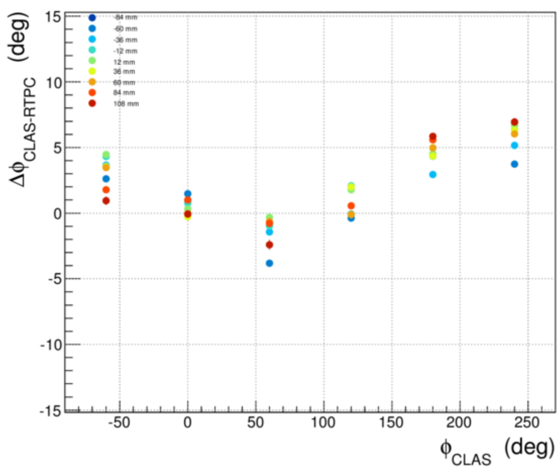

FIG. 2. The difference between ϕ reconstructed from CLAS's electron and RTPC's ^{4}He for elastic scattering. Colors correspond to different z-vertex positions over the 20 cm range of the RTPC.

Using the electron's ϕ measured by CLAS as a reference, the $\Delta\phi_{CLAS-RTPC}$ oscillation is then attributed entirely to RTPC misalignment. By fitting its modulation with Eq. 1, the beam position relative to the RTPC can be extracted.

IV. RESULTS

The left panel in Fig. 3 shows the oscillation fit and the resulting beam offset in the first two fit parameters. That data was cooked with an offset of $(1.55, 0.29)$, and adjusting for that results in a current best estimate of the beam position of $x = 0.28$ mm and $y = 0.97$ mm relative to the RTPC. After reconstructing the elastic ^{4}He tracks with this new beam position, the result is as expected in the right plot of Fig. 3: the modulation is removed.

Independent confirmation of this method is provided by the effect on momentum, which from Fig. 1 is expected to be significant for an offset of this size. The momentum measured by the RTPC for elastic ^{4}He tracks had previously been shifted by well over 10% in one half of the

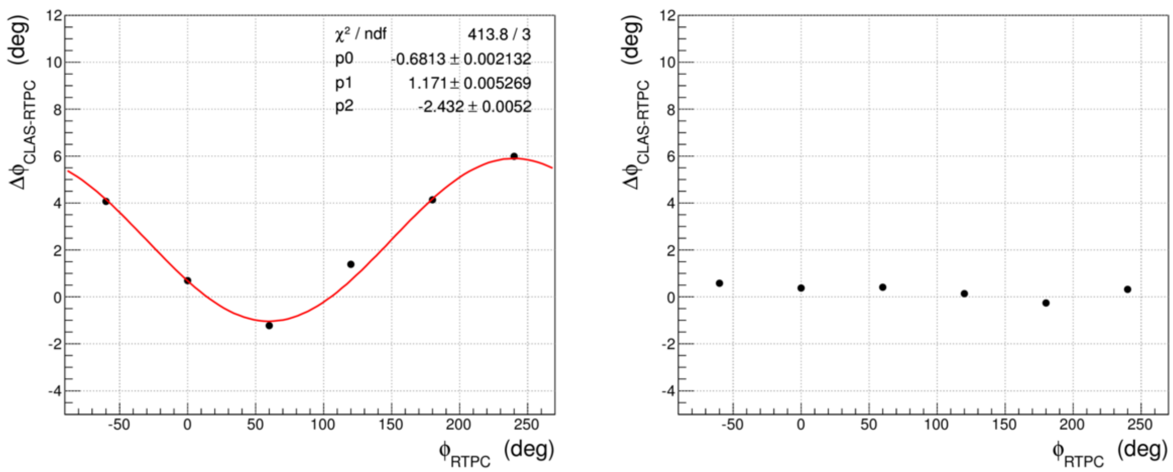

FIG. 3. The difference between ϕ reconstructed from CLAS's electron and RTPC's ^{4}He for elastic scattering for two different values of the beamline constraint (see text).

detector relative to the other. After using the correct beam position, the momentum distributions are much more symmetric as shown in the right panel of Fig. 4.

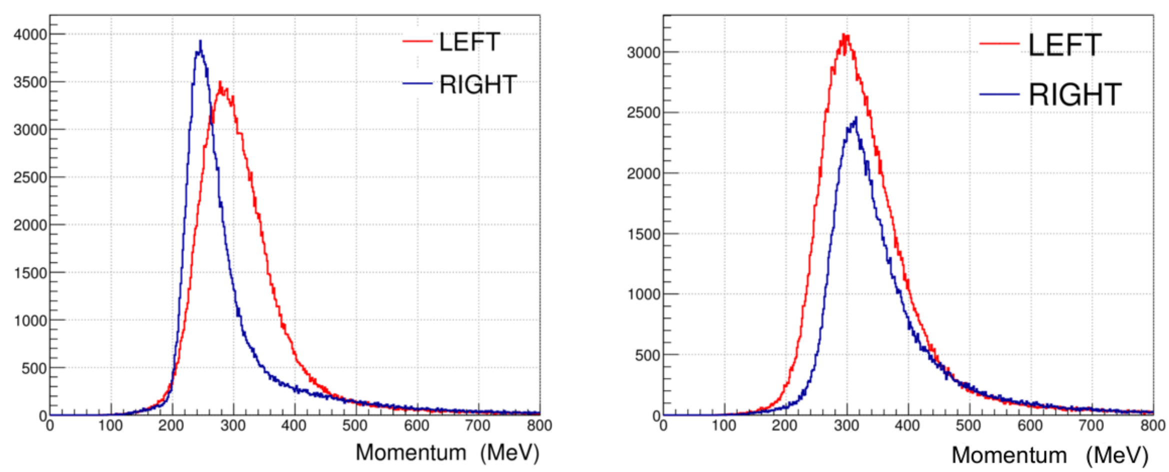

FIG. 4. The momentum distributions for elastic ^{4}He measured by the two halves of the RTPC (LEFT/RIGHT). The figure on left is before this study, while the figure on the right is using the correct beam offset.

[1] M. Hattaway and R. Dupre, "*Drift Path Calibrations for EG6 RTPC*," (2013).

[2] N. Baltzell, "*Gain Calibrations for EG6 RTPC*," (2013).

[3] N. Baltzell and S. Stepanyan, "*Beam X-Y Position at the Target for EG6*," (2013).