CLAS12 Reconstruction Resolution

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Jefferson National Laboratory

Started in 1984, Jefferson National Laboratory uses the Continuous Electron Beam Accelerator Facility (CEBAF), to study the quark-gluon structure of nucleons and nuclei. Two linear accelerators are connected by recirculation arcs to form the racetrack shape shown in *Figure 1*. After circling the track five times, the electron beam achieves an energy up to 12 GeV and is then delivered to the different halls, also shown in *Figure 1*. The CLAS12 detector, shown in *Figure 2,* is housed in Hall B. The detector is split into two main regions; the Central and Forward Detectors, with the latter being the focus of this work.
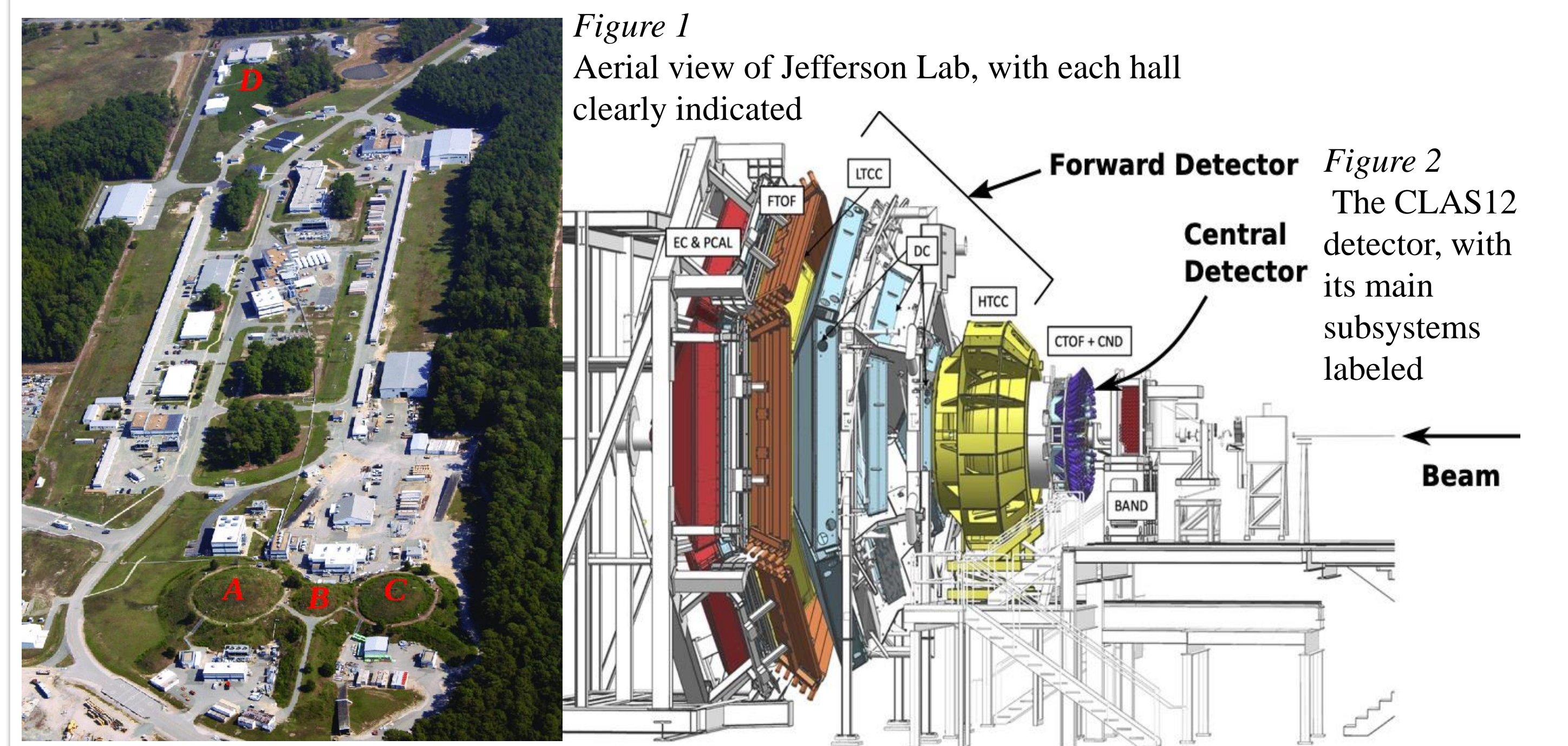

Figure 1
Aerial view of Jefferson Lab, with each hall clearly indicated

Figure 2
The CLAS12 detector, with its main subsystems labeled

CLAS12 Detector

CLAS12 is a large particle detector with more than 100,000 readouts. The Forward Detector is made up of several subsystems, see *Figure 3*.
 - The Cherenkov Counters (Cherenkov in *Figure 3* and LTCC/HTCC in *Figure 2*) detect Cherenkov light emitted by above light-speed particles for particle identification.
 - The Drift Chambers (DC in *Figure 2*), are spread over three distinct regions and measure particle trajectories as they bend in the toroidal magnetic field in order to determine the momenta.
 - The Forward Time-of-Flights (FTOF in *Figure 2*) measure the time of flight to the detector and determine the start time of the event.
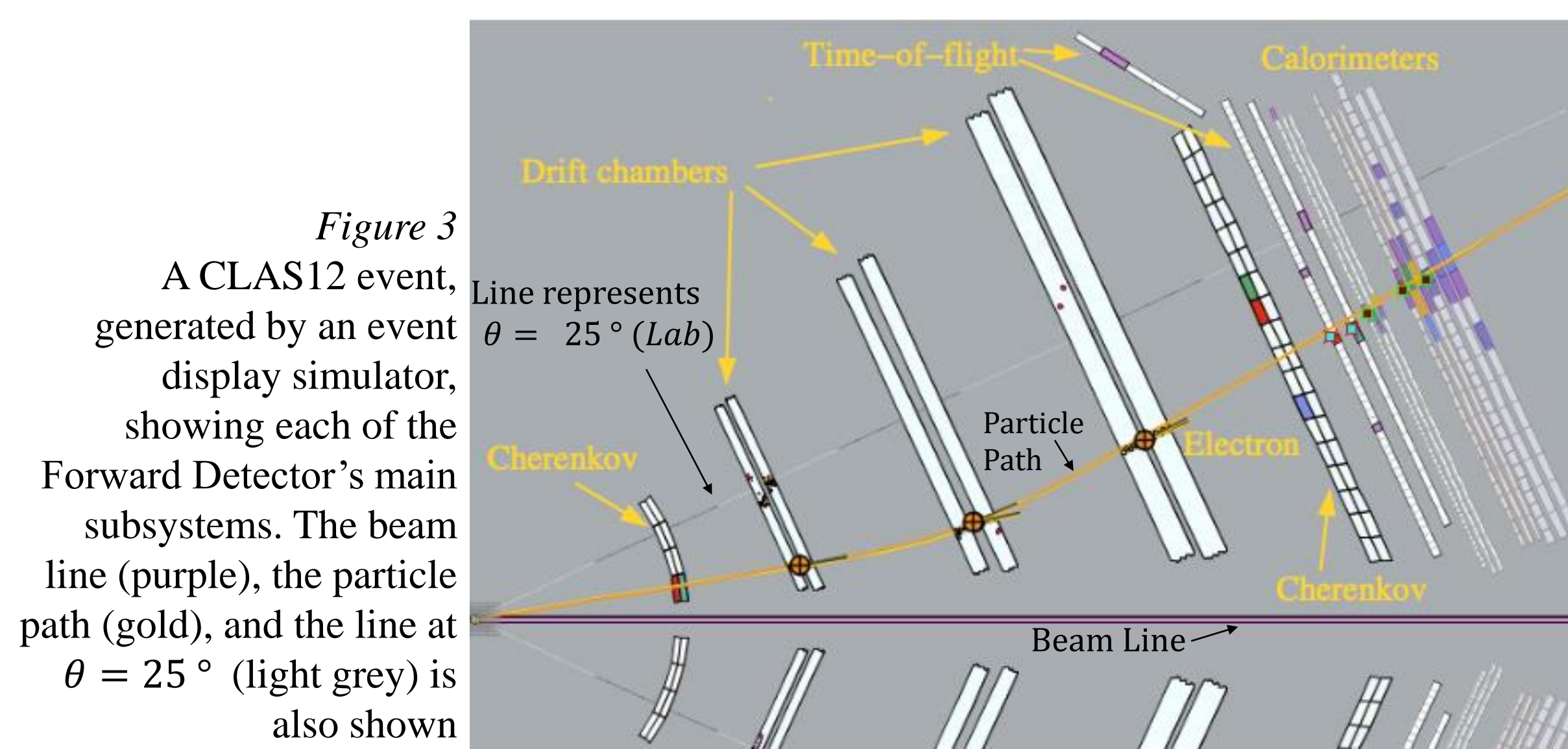 - The Calorimeters (PCAL and EC in *Figure 2*) measure charged particle energy.

Figure 3
A CLAS12 event, generated by an event display simulator, showing each of the Forward Detector's main subsystems. The beam line (purple), the particle path (gold), and the line at $\theta = 25°$ (light grey) is also shown

The Reconstruction Resolution

❑ The CLAS12 reconstruction software has over 88,000 executable lines of code to analyze data collected by CLAS12. The reconstruction resolution is the accuracy of the code.
❑ The CLAS12 reconstruction software processes all the data and extracts the 4-momenta and vertex of the detected particles.
❑ The analysis of the resolution provides quality, efficiency, and accuracy benchmarks for software and hardware developers.
❑ The resolution can also provide information on the difference in contribution of different hardware and software.

Method

1. We obtain two vertex positions and the 3-momenta for each track; one is the data from *gemc's* event generator and the other is obtained from the reconstruction.
2. Both sets of data are rotated to the Tilted Sector Coordinate System (TSCS), where the z-axis is perpendicular to the face of the detector layers.
3. The two tracks are then swum with a method in the CLAS12 Common Tools. The positions and 3-momenta of the two tracks are collected at the face of the detector's subsystems. We collect data for the $x, y, z, \theta,$ and φ observables.
4. Positions and 3-momenta are rotated back to the Lab Coordinate System.
5. Differences in the track observables, $\Delta x, \Delta y, \Delta z, \Delta \theta,$ and $\Delta \varphi$ are obtained in the Lab. The impact parameter ($b = \sqrt{(\Delta x)^2 + (\Delta y)^2}$), is obtained in the TSCS.
6. Differences are histogrammed as functions of energy, particle species, sector, torus polarity, geometry, beam background, and software version.
7. Effective Widths (Histogram Fits)
- The standard deviations of each of the difference distributions is the reconstruction resolution for each observable. The histograms for each observable typically consist of a broader background and a sharper peak near zero (*Figure 4*).
 - We fit both the narrow peak and the full-range of the distribution and use an iterative process that uses the first fit to locate the peak.
- After iterating again, we refit within a range of $\pm 1.5\sigma$, where σ is the width from the first fit. [4]

*Figure 4* Differences in x position in first DC superlayer
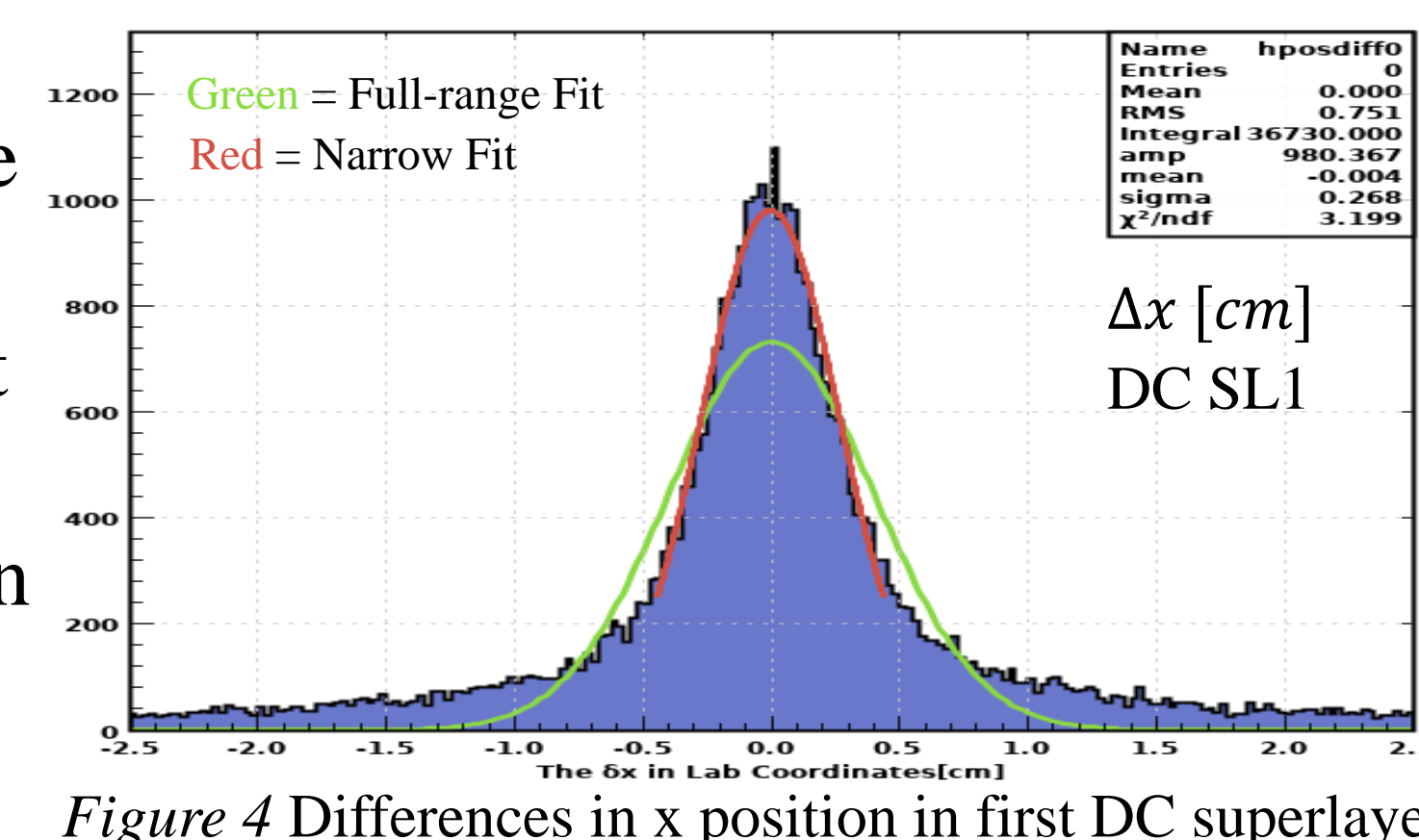
References

[1] "CLAS12." *Jefferson Lab Experimental Hall B*. N.p., n.d. Web. 27 Sept. 2016.
[2] Ziegler, Veronique, et al. "The CLAS12 Software Framework and Event Reconstruction" Nucl. Instrum. Meth., A959:163472, 2020
[3] Mestayer, M. D. , et al. "The CLAS12 Drift Camber System" Nucl. Instrum. Meth., A959:163518, 2020
[4] Adrian Saina. "The Resolution of the CLAS12 Reconstruction Software". 2020. University of Surrey, Masters Thesis

Results

In this section we present a sample of results from a total of 66 plots representing the reconstruction resolution of the five observables and seven dependencies. All the figures depict reconstruction resolution taken over a *gemc* simulation of 10,000 events. *Figure 5* shows a plot of $\Delta x,$ which shows the expected increase in the width/resolution as the track traverses more material and suffers more multiple scattering. We see little effect on the resolution when the polarity of the CLAS12 torus is flipped. In *Figure 6* we see the same increase in the width with fixedZ for different particle species. *Figure 7* shows Δb, for two different versions of *gemc*. A software upgrade to match the resolution of the simulation to the detector has a significant impact on our measurement. In *Figure 8* we see results for $\Delta \varphi$ plotted at the z coordinates of the different superlayers of the DCs for the same two versions of *gemc*. Following the upgrade, we see a sharp increase in width in Region 1. This is surprising since the tracks experience more multiple scattering at larger fixedZ which should increase the width. We note that throughout our plots, the spike in width is only observed for plots for $\Delta \varphi$.
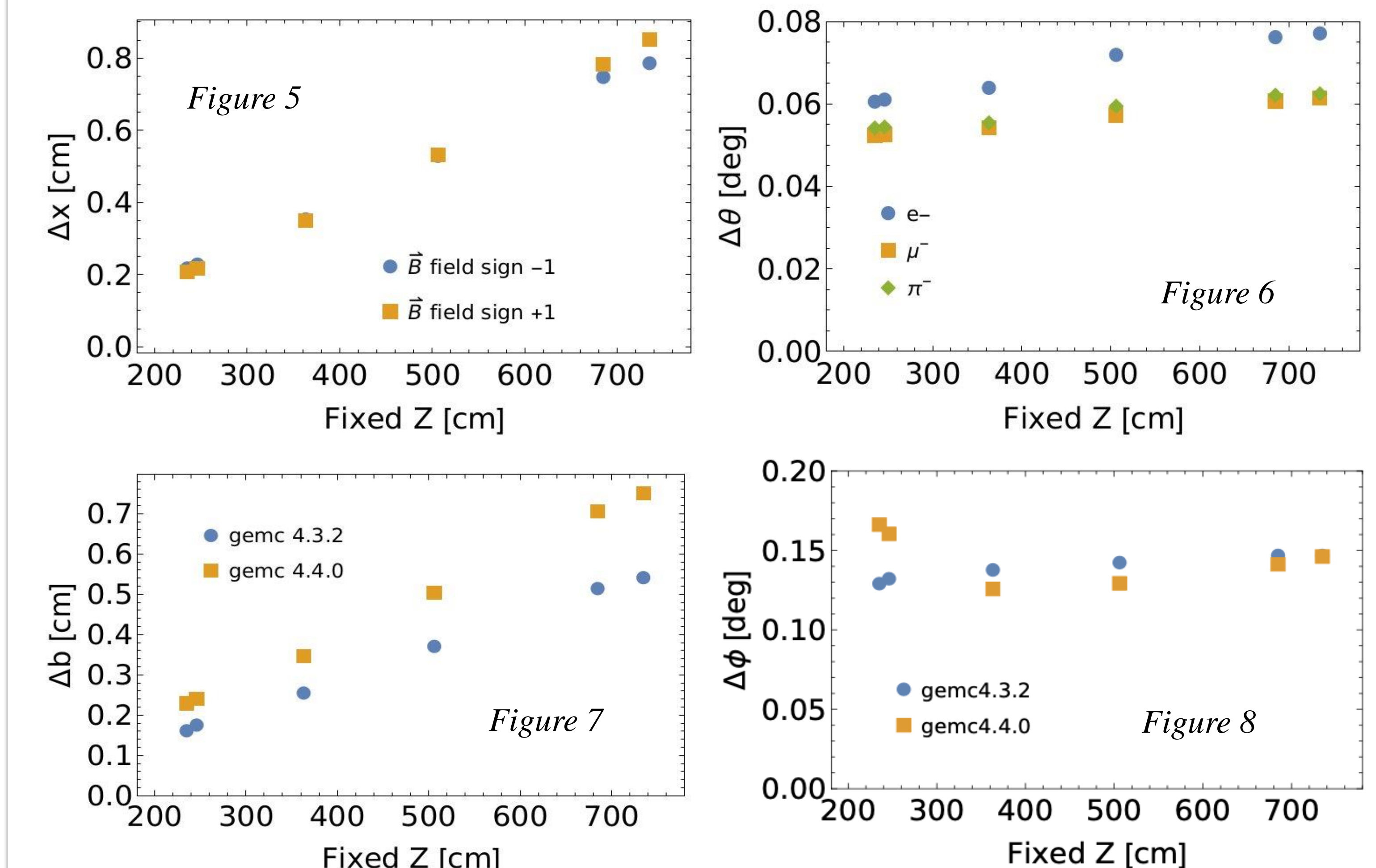
We validated our results in several ways:
(1) We reproduced the complete chain from event generation through simulation to extracting the widths and obtained the same results.
(2) We varied the range of the track's initial θ and φ angles from a point to the complete Forward Detector.
(3) We tested different codes to perform rotations required in the method. Each code gave the same results. These included codes we wrote ourselves and ones in the CLAS12 Common Tools.

Conclusions

We generated a baseline for the reconstruction resolution for five observables and seven dependencies. Most of our results agree with expectations. For $\Delta \varphi$, however, we observe an increase in the resolution in Region 1 of the DCs that is unexplained.