The CLAS12 Reconstruction Resolution

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About Jefferson Lab and CLAS12

Jefferson Lab is an electron accelerator facility that studies the quark-gluon structure of nuclei. Two linear accelerators are connected with recirculation arcs to form a racetrack-shaped machine capable of delivering a 12 GeV beam to four halls seen in *Figure 1*. Hall B houses the CLAS12 spectrometer, seen in *Figure 2*, consisting of an array of detectors built around six superconducting coils producing a toroidal magnetic field. The Forward Detector measures the trajectories of particles that scatter at $5^\circ - 35^\circ$ in polar angle.

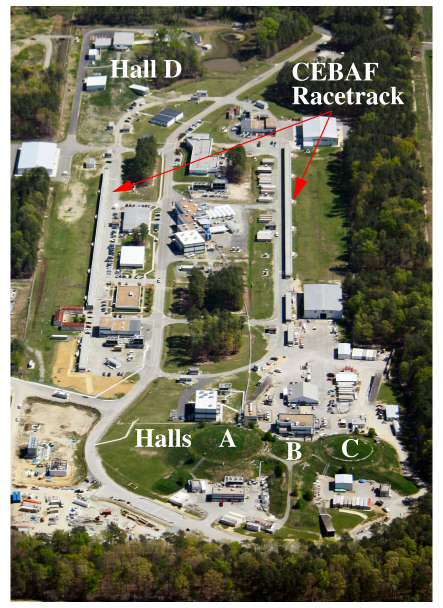
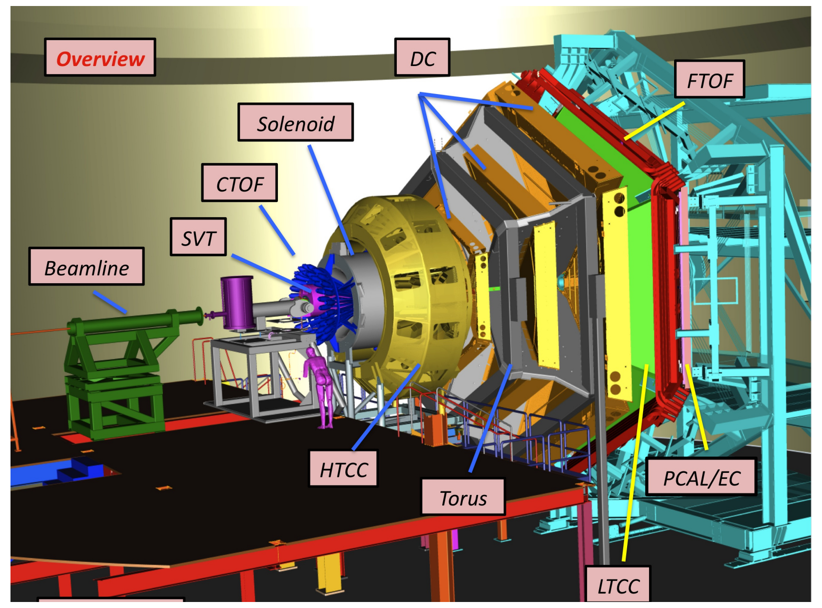


Figure 1 Aerial view of the JLab facility, the racetrack shape and the halls are marked.

Figure 2 The CLAS12 spectrometer, with all of its subsystems labeled.



The CLAS12 Detector

The CLAS12 detector has over 100,000 readout channels and collects data at a rate of up to 15 kHz. The CLAS12 reconstruction software processes all this data and extracts the starting point or vertex and 4-momentum of the detected particles in a collision. The Forward Detector consists of several layers, see *Figure 3*.

- The High-Threshold Cerenkov Counter (HTCC in *Figure 2*) uses the Cherenkov light emitted by near-light-speed electrons for particle identification.
- The Drift Chambers (DC in *Figure 2*) measure the charged particle trajectories as they bend in the torus field to determine their momentum.
- The Forward Time-of-Flight (FTOF in *Figure 2*) counters measure the time of flight to determine the event start time and measure particle velocities.
- The calorimeters (PCAL/EC in *Figure 2*) measure the charged particle energy.

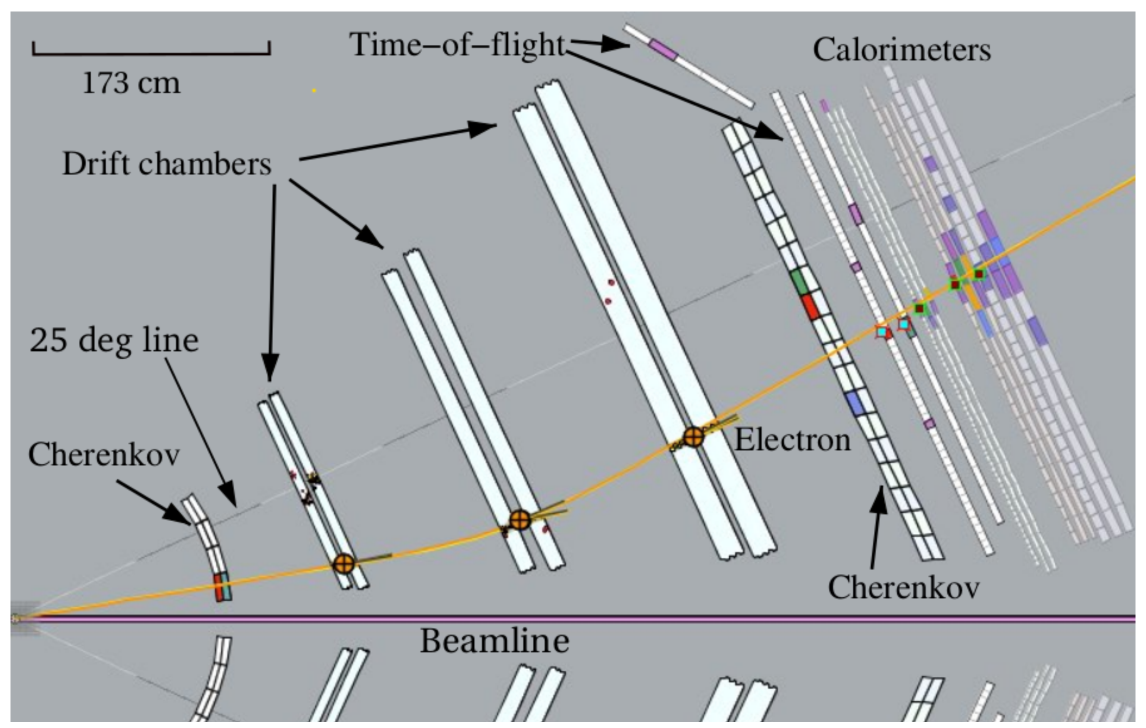


Figure 3 A CLAS Event Display application window showing the relevant detectors. The beamline and the line perpendicular to the layers of the subsystems, the 25 degree line here, are also shown.

The Reconstruction Resolutions

- The CLAS12 reconstruction software consists of more than 88k executable lines of code that analyzes the CLAS12 data. We obtain the vertex of each track and its 4-momentum. In this project we have measured in simulation the reconstruction resolution or precision of the software.
- We use the CLAS12, physics-based simulation program gemc to produce events. Resolutions were obtained by 'swimming' particle tracks through CLAS12 using their generated inputs and reconstructed track parameters and then comparing the results.
- We measure the resolution in simulation to provide benchmarks for software and hardware developers.
- Investigated effects of particle energy, species, torus polarity, and upgrades to the simulation software.

Method

1. We obtain two vertex positions and 3-momenta for each track; one set of data is from gemc's event generator, and one was obtained from reconstruction after simulation.
2. Both sets of positions and 3-momenta are rotated to the tilted sector coordinate system (TSCS), a frame where the z axis is perpendicular to the detector layers.
3. Two tracks are swum using fourth order Runge-Kutta integration. The positions and components of momenta of the two tracks are collected at the surfaces of subsystems: the HTCC, the three DC regions, the FTOF system and the calorimeters.
4. The positions and momenta at the track points are rotated back to the CLAS12 lab coordinates
5. Differences $\Delta x, \Delta y, \Delta z, \Delta\phi, \Delta\theta$ are obtained in CLAS12 lab coordinates, the distance between points on the detector surfaces ($b = \sqrt{x^2 + y^2}$), the impact parameter, is obtained in the TSCS.
6. The histograms of differences in the observables of the two tracks are fitted with Gaussian functions, and the standard deviations of these fits are a measure of the resolution.

Histogram Fitting

- The differences in observables at track points have tails and narrow peaks.
- We first fit the full distribution and locate the central peak.
- Then we performed a second fit within 1.5 σ from the mean, starting with the parameters of the first fit. We iterate and we use the first and final fits to get an effective width:

$\sigma^2 = \langle\delta^2\rangle - \langle\delta\rangle^2$, where

$\langle\delta^2\rangle = \frac{A_1}{A_2 A_1}(\mu_1^2 + \sigma_1^2) + \frac{A_2}{A_2 A_1}(\mu_2^2 + \sigma_2^2)$

and $\langle\delta\rangle = (\frac{A_1}{A_2 A_1}\mu_1 + \frac{A_2}{A_2 A_1}\mu_2)^2$

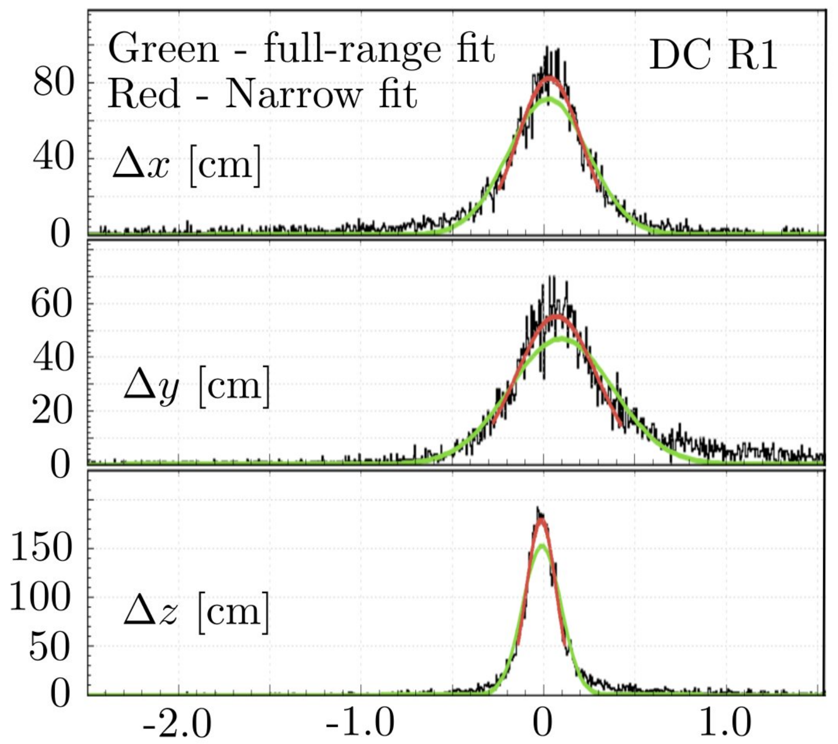


Figure 4 Differences in x, y, z position in first DC region

The Results

In this section we show a representative sample of our results. *Figure 5* shows Δz at track points plotted as a function of distance to the origin of local coordinates. The data sets are ten thousand events at five particle energies. The resolution decreases with increasing particle energy. *Figure 6* shows Δb at track points, with the data sets representing 6 GeV e^-, μ^- and π^- events. The electron events have slightly higher resolutions due to the larger impact of radiative corrections.

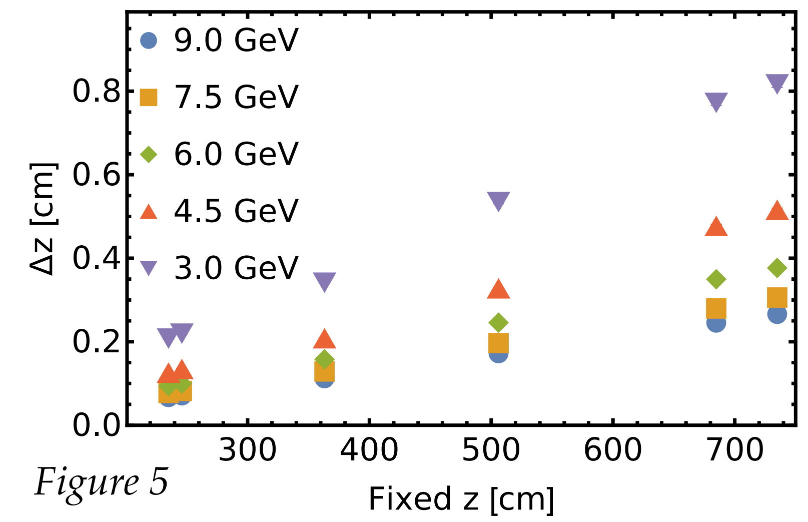


Figure 5

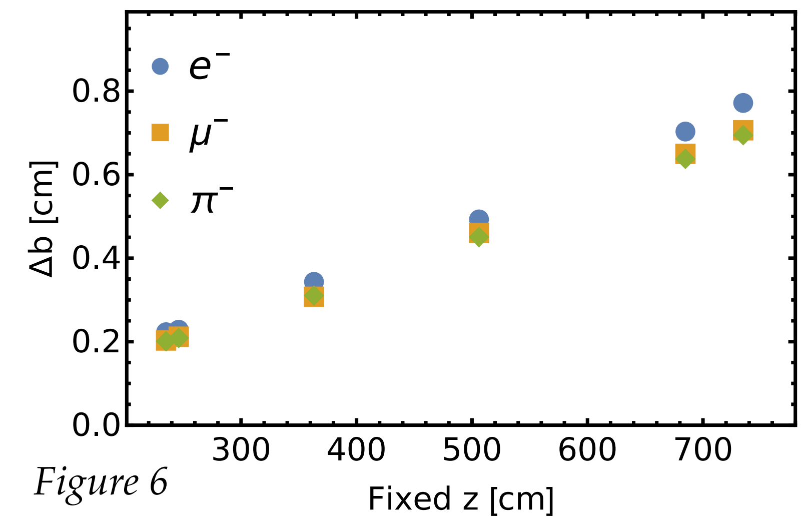


Figure 6

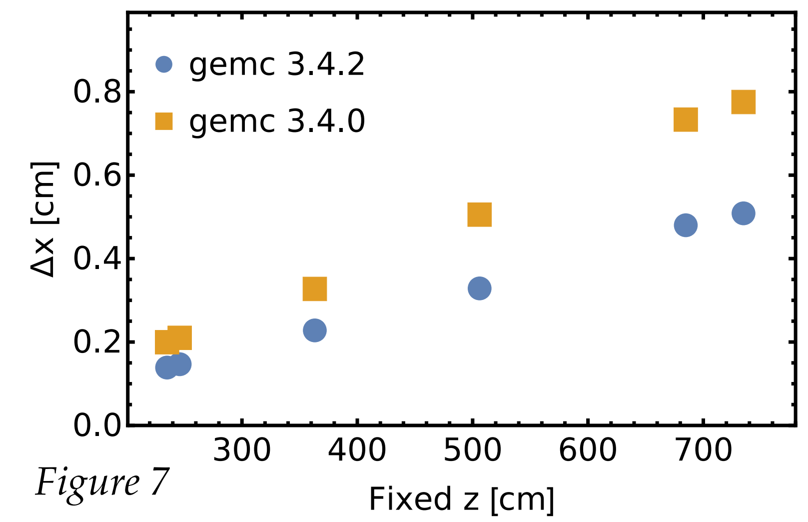


Figure 7

In *Figure 7* the results for Δx at track points are plotted as a function of distance to origin in local coordinates. The points in blue show resolutions of events created with the new version of the simulation software, while the points in yellow show resolutions of events created with the old version of gemc. We see an increase in the reconstruction resolution in the new, more realistic version of gemc.

Conclusions

- The reconstruction resolution of all observables follows expected trends, validating our method of swimming particles from their simulated and reconstructed vertices.
- The resolutions decrease with energy, following the trend seen in real data where lower energy beams are more sensitive to multiple scattering
- The resolutions are higher for electrons than negative muons and pions, due to the larger impact of radiative corrections on electron trajectories.
- The resolution increases for events created with the new version of gemc, as expected due to the changes made to the digitization routines to make the simulation more realistic.

References

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