CLAS12 Drift Chamber Reconstruction Code Validation

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CEBAF Large Acceptance Spectrometer

Jefferson Lab

The Thomas Jefferson National Accelerator Facility (JLab) is home to the Continuous Electron Beam Accelerator Facility (CEBAF) which is used to perform electron scattering experiments on nuclear targets that investigate the fundamental components of hadronic matter (quarks and gluons). Fig.1 is an overview of how CEBAF accelerates electrons.

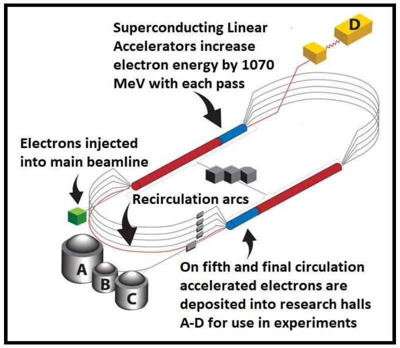

Figure 1. CEBAF Overview [1]

Within CEBAF's research Hall B is the CEBAF Large Acceptance Spectrometer at 12GeV (CLAS12). CLAS12 measures the trajectories, momenta, vertices and identities of particles produced in electron-nucleon collisions enabling it to probe the nature of these interactions. Fig.2 shows a cross section of CLAS12's major detector systems including three drift chambers (DC).

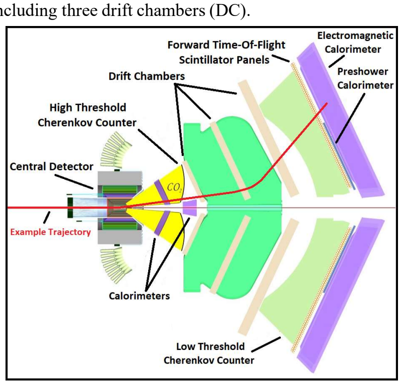

Figure 2. CLAS Cross Section [2]

These chambers are made up of 6 layers of hexagonal cells containing an Argon-CO_2 mixture. As particles pass through, they ionize electrons from the gas molecules. These electrons accelerate towards the anode sense wires central to each cell and create current signals that indicate the passage of a particle. The pattern of cell hits can be used to reconstruct a particle path as illustrated in Fig.3. [3]

Reconstruction

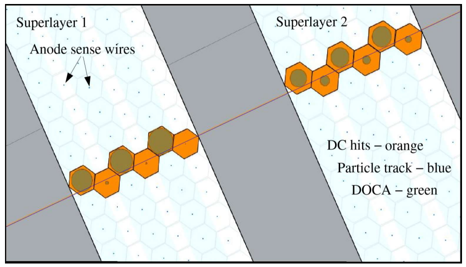

Figure3. DC Path Reconstruction [4]

A powerful toroidal magnetic field permeates the middle DC region. As charged particles travel through this field their paths bend, the degree of curvature depends upon the particles' momenta.[2][3]

Unit Test

Reconstruction is performed with the CLAS Offline Analysis Tools (COATJAVA) software package. COATJAVA is split into many smaller modules that makes developing its more than 84,000 lines of code more manageable. Each module comes with a unit test that runs each night to validate its performance. A unit test is a software testing method by which individual units of source code are tested to see if they function as intended.

The purpose of this project is to update and enhance the DC unit test. This test takes detector data representing a single particle event and reconstructs its trajectory and momentum, comparing the output to past results. The existing unit test falsely signals software failures every time it runs due to recent changes to the reconstruction code.

The first step toward updating the unit test was to study the performance of the reconstruction code with simulations. The CLAS12 physics-based simulation software GEMC (Geant Event Monte-Carlo) was used to simulate 20,000 electrons in the CLAS12 DC, each under the same conditions as the original test event. COATJAVA was used to reconstruct this data and produce histograms of reconstructed particle momenta and vertices.

Figure .4 P_z

Analysis

Fig.4 is a histogram of the reconstructed P_z and shows us the test event is reconstructed outside the limits expected in the unit test. The unit test acceptance limits were updated to reflect the current version of the code.

We also studied the vertex reconstruction. The histogram in Fig.5 shows us that the test particle V_z was being reconstructed more then eight sigma from the mean in our simulation. This test particle is therefore unrepresentative of the event.

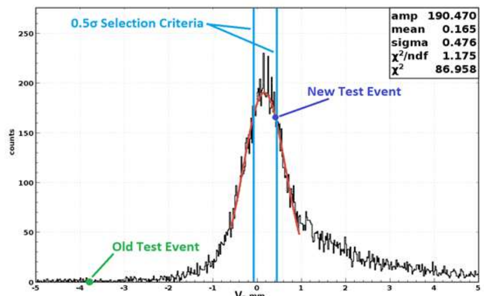

Figure 5. V_z Reconstruction

Results

The new test particle was selected from the GEMC simulation data to represent an event with momentum and vertex properties within 0.5 σ of the mean of each distribution. This selection process is illustrated in Fig.5 with the final numbers presented in Table.1

Property	Test Value (± Acceptance)
P_x	1.00±0.28 GeV/c
P_y	0.18±0.26 GeV/c
P_z	2.04±0.36 GeV/c
V_x	0.0±0.20 mm
V_y	0.0±0.20 mm
V_z	0.40±0.49 mm

Table .1 New Test Event and Limits

The new unit test limits are based upon the simulation distributions of the momentum and vertex components. The resolution can be extracted by finding the difference between the reconstructed values and the ones used as the starting points in the simulation.

Results

This difference (a measure of reconstruction resolution) is plotted as a histogram for ΔV_y (where $\Delta V_y = V_{ystart} - V_{yrecon}$) in Fig.6 At one sigma the error is 0.204mm meaning 68.2% of V_y reconstructions were accurate to within this value.

The new test event has a y vertex at zero, the new unit test limit is therefore put at $V_y = 0.0\pm0.204$mm.

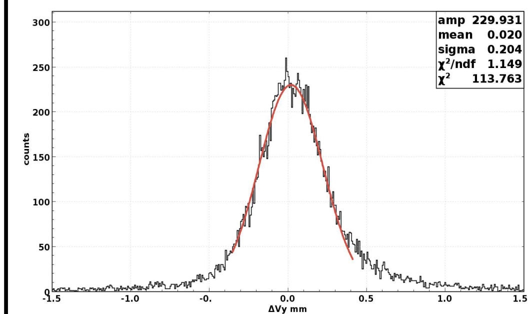

Figure 6. ΔV_y

Performing a similar analysis on each component of the momentum and vertex lead the new unit test acceptance ranges listed in Table.1

Conclusion

The CLAS12 DC unit test was found to produce false positives because it was reconstructing its test particle data outside its acceptance limits. The test particle had a V_z component more than eight sigma from the mean for similar particles.

The DC unit test acceptance limits were updated to better reflect the current version of the reconstruction code. The test was expanded to include the test particle's vertex and the test event was replaced with a more typical one.

References

[1] – Edited version of Image from G. Hull, J.Bettane, " Clas12, Study of the Time resolution of a plastic scintillator assembly for the central neutron detector of CLAS12", Institui de Physique Nucléaire Orsay, URL: ipnwww.in2p3.fr/Clas12, [Accessed 10/03/2019]

[2] - "CLAS12 Technical Design Report", 2008, Jlab.org, URL: jlab.org/Hall-B/clas12 tdr.pdf, [Accessed: 07/25/2019]

[3] - G.F. Knoll, "Radiation Detection and Measurement 3rd edition", 2000, Wiley. ISBN:978-0-471-07338-3.

[4] – Screenshot from CLAS12 Event Display (CED), Christopher Newport University, Jefferson Lab