Service Work Proposal
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Here we propose service work as part of the University of Richmond's contribution to the mission of the CLAS Collaboration to operate and maintain the CLAS12 detector. In 2021 the University of Richmond group will consist of one full member, G.P.Gilfoyle and 2-3 undergraduates. We estimate the project described below will require 0.4 FTE in the next year.

The CLAS12 reconstruction code uses a Kalman filter to determine track parameters encoded in the state vector $t = \{x, y, tx = p_x/p_z, ty = p_y/p_z, p\}$ [1]. We propose to develop multi-dimensional functions for the components of the state vector to fill the covariance matrix needed at the starting point of the reconstruction code. The Kalman Filter is the optimal recursive estimator of the state vector of a discrete linear dynamic system [2] and relies on estimates of the initial state vector and initial covariance matrix to start the algorithm.

We now describe the Kalman filter. The track is described by parameters contained in the state vector t mentioned above. The code steps through the drift chamber track data and "connects the dots". In each step (*e.g.* a DC wire) the local hit data and the results from previous hit are used to predict where the next hit will occur and calculate the covariance matrix at that hit. A fourth-order Runge-Kutta calculation in the CLAS12 magnetic field is used [1]. The results are "filtered" - a weighted average is made of the predicted hit and the measured one and the covariance matrix is updated for the new hit. This process is followed to the end of the track [2, 3].

A drawback to the Kalman filter is the reliance on the initial value of the state vector and the covariance matrix [2]. We currently use the results of hit-based tracking and global estimates of the uncertainty to fill the initial covariance matrix. The goal here is to improve on that method and take advantage of recent upgrades to the CLAS12 simulation *gemc*. The impact of those changes on the reconstruction is significant as can be seen in Figure 1. It shows the reconstruction resolution for the x and y components of 6-GeV electron tracks in CLAS12. This study was performed by a University of Surrey masters student Adrian Saina working with Drs. Gilfoyle and Ziegler. Mr.

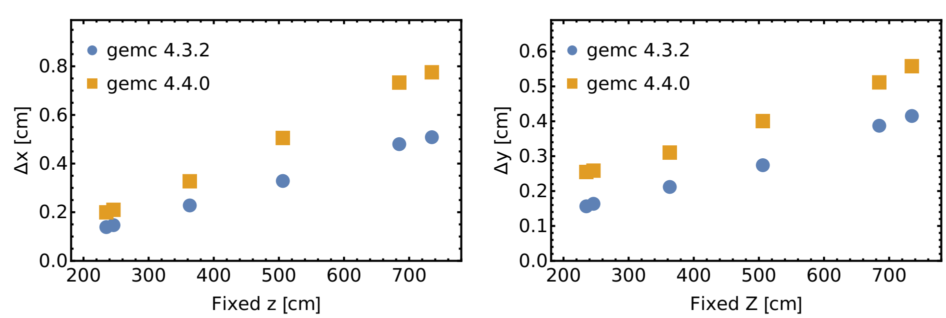

Figure 1: Fit results for the widths of the Δx (left) and Δy (right) distributions for *gemc* version 4.4.0 (yellow points) and 4.3.2 (blue points).

Saina measured in simulation the reconstruction resolution in different subsystems of CLAS12. We plan to build on Mr. Saina's work to develop an improved initial state vector and covariance matrix.

The procedure starts with simulating with *gemc* the components of the state vector in the tilted sector coordinate system (TSCS) in CLAS12. In these coordinates the z-axis is perpendicular to the detector planes (DC wire layers here) while the y-axis points along the mid-line of the sector, and

x forms a right-handed coordinate system. As in the reconstruction resolution project we use the generated vertex and 3-momentum and the simulated-and-reconstructed results to swim two tracks to the first DC wire layer in Region 1 of CLAS12 (closest DC to the target). We rotate back to the lab coordinates and generate histograms of the components of the state vector as functions of x, y, θ, and ϕ. We use the width of the distributions and fit the results to get a smooth functional form. We will also study the impact of changes to the magnetic field polarity and other dependencies as the project develops.

The codes we develop will be tested and validated. In simulation we can make controlled "experiments" on the impact of changes to the elements of the initial covariance matrix and see how they effect the reconstruction results. As mentioned above we are building on the work by Mr. Saina. That work is far along and will provide a useful comparison with this investigation. A CLAS12 Note describing Mr. Saina's work is in preparation.

1 References

[1] V. Ziegler et al. The CLAS12 software framework and event reconstruction. *Nucl. Instrum. Meth.*, A959:163472, 2020.

[2] R. Fruhwirth. Application of Kalman filtering to track and vertex fitting. *Nucl. Instrum. Meth. A*, 262:444–450, 1987.

[3] Brian Jones and Bill Tompkins. A physicist's guide to kalman filters, 1997. `https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.57.1034&rep=rep1&type=pdf`.