A Resolution Study for an Inner Tracking Detector for CLAS

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In any discussion of an upgrade of the CLAS detector, the idea of increasing the geometric acceptance for charged particle detection naturally arises. The areas that need improvement are at small polar angles and in the regions of azimuth occupied by the main torus magnet coils. Since meaningful tracking in or behind the coils is not possible, attention has focused on the volume inside the coils. The main problem here is that without a magnetic field, momentum analysis cannot be done. However, it may be possible to realize significant improvements by performing tracking which only yields direction information in this inner region.

There would be several benefits to better geometric acceptance, even if momentum information is not obtained for all tracks. It would help with background rejection for exclusive processes. The extra information would allow access to new kinematic quantities as well has improve the resolution in quantities that would otherwise be accessible only through missing mass techniques. This study addresses the final point. It should help to answer the basic questions about what angular resolution we need and what can we afford.

We consider a simple reaction as a test case:

$$e^- p \to e^- p \pi^+ \pi^-$$

where we will assume that the final state electron and proton are fully reconstructed in the drift chambers, but that the π^+ and π^- have only their directions measured, *i. e.*, there is no measurement of the magnitude of their momenta.

Events were generated at the four-vector level. The electron beam energy was set at 6.0 GeV. The Q^2 distribution of the generated events is shown in Fig. 1. Events were required to have $\theta_{e,p} > 10^\circ$ and $\theta_{\pi^\pm} > 5^\circ$, where θ refers to the polar angle of the particle trajectory at the vertex. For simplicity, the generated momenta of the electron and proton were smeared in a Gaussian distribution by 5 MeV, separately for p_x, p_y and p_z. This yields roughly the missing mass resolution we are currently obtaining with

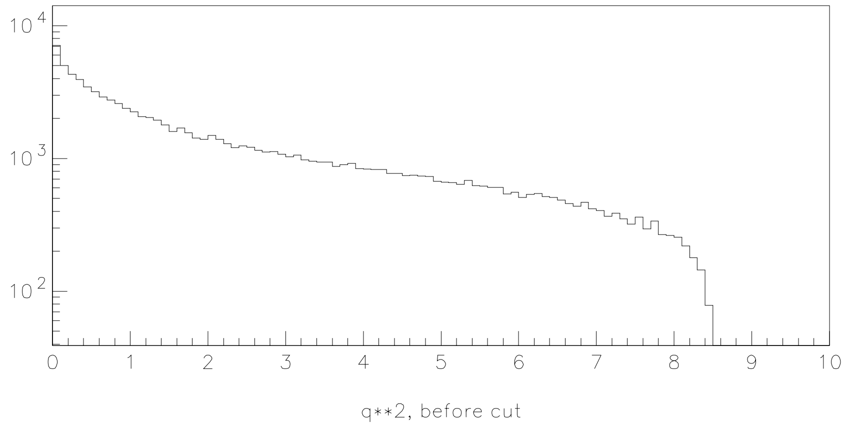

Figure 1: The Q^2 distribution of the generated events.

CLAS. The missing mass distribution after smearing, with these assumptions on the measured electron and proton is shown in Fig. 2. The pions are "undetected" in this case.

To assess the improvement obtained by measuring the angles of the two pions, a constrained kinematic fitting procedure was used. First the directions of the two pions were smeared in a Gaussian distribution by some fixed amount, separately for the azimuthal and polar angles. The entire study was repeated for various values of this smearing. In the fit, the particle masses were assumed to be known. Energy and momentum conservation were required (four constraints) and by construction, the magnitudes of the pion momenta were unknown (two unmeasured variables). This gives a 2-C fit. Since the fit gives complete information on all kinematic quantities, we can form a di-pion invariant mass spectrum, as shown in Fig. 3 for 5 milliradian angular smearing. This is to be compared with the missing mass spectrum of Fig. 2; these two are essentially the same kinematic quantity.

Quantitatively, the improvement in resolution is shown in Fig. 4 for events with $4 < Q^2 < 6$ GeV. Di-pion mass resolution in MeV is plotted versus pion angular resolution in milliradians. Curves for other Q^2 ranges are similar. The asymptotic value of 20 MeV on the right corresponds to the missing mass resolution without any fit, *i. e.*, in the limit of very poor

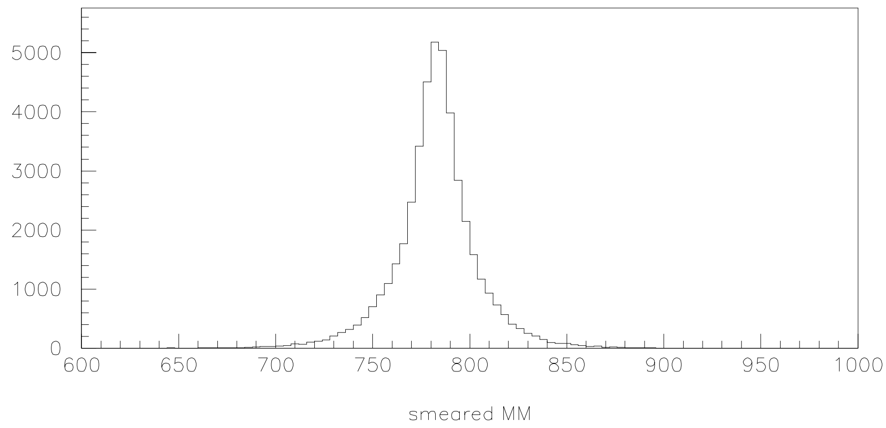

Figure 2: The missing mass spectrum, after smearing and after cuts.

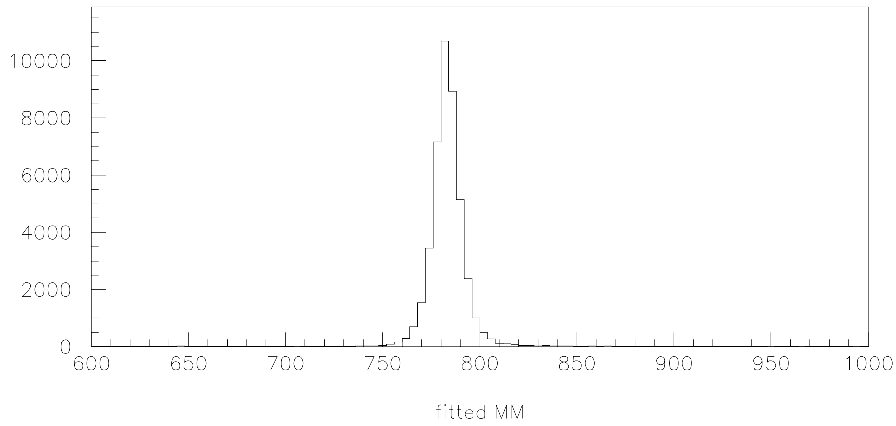

Figure 3: The di-pion invariant mass, after smearing and after cuts. The pion angular smearing is 5 mR.

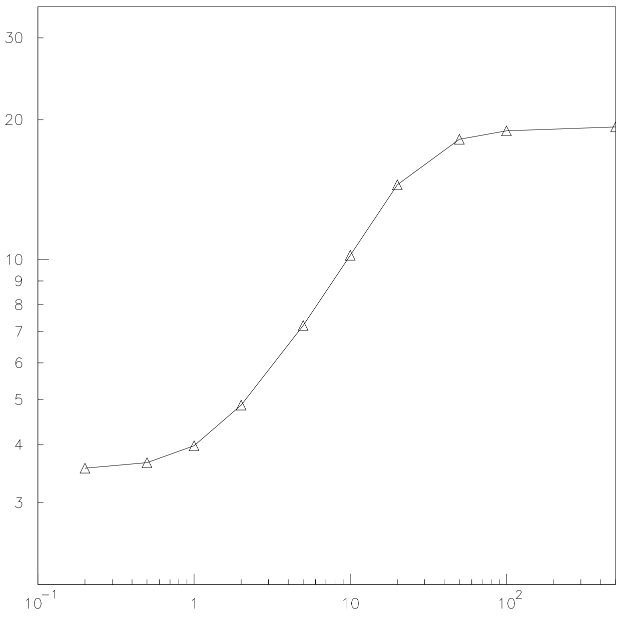

Figure 4: Di-pion invariant mass resolution (in MeV) vs. pion angular resolution (in milliradians).

angular resolution, the pion angles do not contribute at all to the kinematic information. The asymptotic value of a little less than 4 MeV on the left corresponds to the effect of the momentum resolution on the electron and proton, *i. e.*, perfect information on pion angles alone does not give perfect information on event kinematics.

In conclusion, we see that kinematic fitting is a powerful tool for few-body final states. In particular, for $\pi\pi$ electroproduction, an improvement factor of three in missing mass resolution requires 0.5 degree angular resolution. In addition, angular information will help background rejection since bad χ^2 from the fit will indicate events that are assigned the wrong hypothesis for the final state. Also angular information will help with studying detector systematics since the "pulls" or "stretch functions" that result from the fit give information on misalignments and/or miscalibrations.