CLAS Capabilities at Higher Energies

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Abstract

In order to study the capability of the Hall B CLAS detector at high energies, we studied the resolution and the acceptance for various final states in the electroproduction on a proton target at 10 GeV beam energy. We find that, although CLAS can do some of the interesting physics at higher energies in the present configuration, several modifications can significantly improve the overall physics acceptable to CLAS at high energies. In this report, we present some of the results of those studies with suggestions on possible detector improvements to optimize the physics capabilities of CLAS.

1.0 Introduction

Increasing the energy of the CEBAF accelerator will allow to perform experiments at higher values of Q^2 (transferred momentum squared) and W (mass of the final hadronic state). Obviously, these experiments will lead to the higher multiplicity and momentum of the final state particles, and also boost them more to the forward region, where CLAS has limited acceptance.

In order to see the impact of those effects on CLAS performance (acceptance, particle ID, resolution) simulations for various reactions were performed. Two types of reactions, related to the physics program accessible on CLAS, were studied - production of baryon resonances at high Q^2 (~7-10 $(GeV/c)^2$) and production of t-channel high mass mesonic states at large W (up to 4.4 GeV), low Q^2 and t. The main goal of these kinematical studies was to get limits of CLAS performances at higher beam energies, and possible upgrade options [2].

2.0 Simulation and Detector Performance

Various final states in the (ep) scattering were simulated at E_e = 10 GeV. For electroproduction of baryon resonances the CELEG event generator was used [3]. Events were simulated in the wide range of Q^2 = 2. - 10. $(GeV/c)^2$ with all resonances turned on in the energy range W < 2. GeV. Electroproduction of t-channel meson final states were studied using a phase space event generator. The possibility of detection and identification of electrons, charged hadrons, and photons (therefore neutral mesons like π^o, η) were studied.

Electron detection and identification -
Identification of electrons in CLAS is based on the detection of electromagnetic shower in the calorimeter with a corresponding signal in the gas Cherenkov counter and the reconstructed negative track in the drift chambers [4]. While the Cherenkov detector can not be used for e/π separation at momenta above 3 GeV/c, the performance of the electromagnetic calorimeter in identifying electromagnetic showers becomes better with increasing momentum. The main effect of high momenta in electron detection will be the degradation of momentum resolution. Also to cover wide range of Q^2 and W measurements in both polarities of the torus will be need, which requires good electron detection efficiency for both cases.

Hadron detection and identification -

In the present design, identification of charged hadrons is based on measurements of the time-of-flight from the target to the scintillator counters, and the momentum in the magnetic field [4]. This method allows to separate π/K with momenta up to 2 GeV/c, and π/p up to 3 GeV/c. In Fig.1, distributions of final state particles in the angular-momentum space in the (ep) scattering at 10 GeV are shown. As one can see, in the range of scattering angles $8^o < \theta$ (acceptable range) the momentum of final hadrons (Fig.1a,b,c for p,π and K, respectively) are becoming larger then 3 - 4 GeV/c. That is at the limit of particle ID system of the current CLAS. Therefore, additional detectors in the angular range up to 35^o are need for reliable identification of charged hadrons. The effect on resolution will be minimal, since high momentum tracks (4-5 GeV/c) are going to the forward region, where momentum resolution will remain ≤1%. A simple parametrization was used to study the effect of the degradation of momentum and angular resolution on the reconstruction of missing and invariant masses.

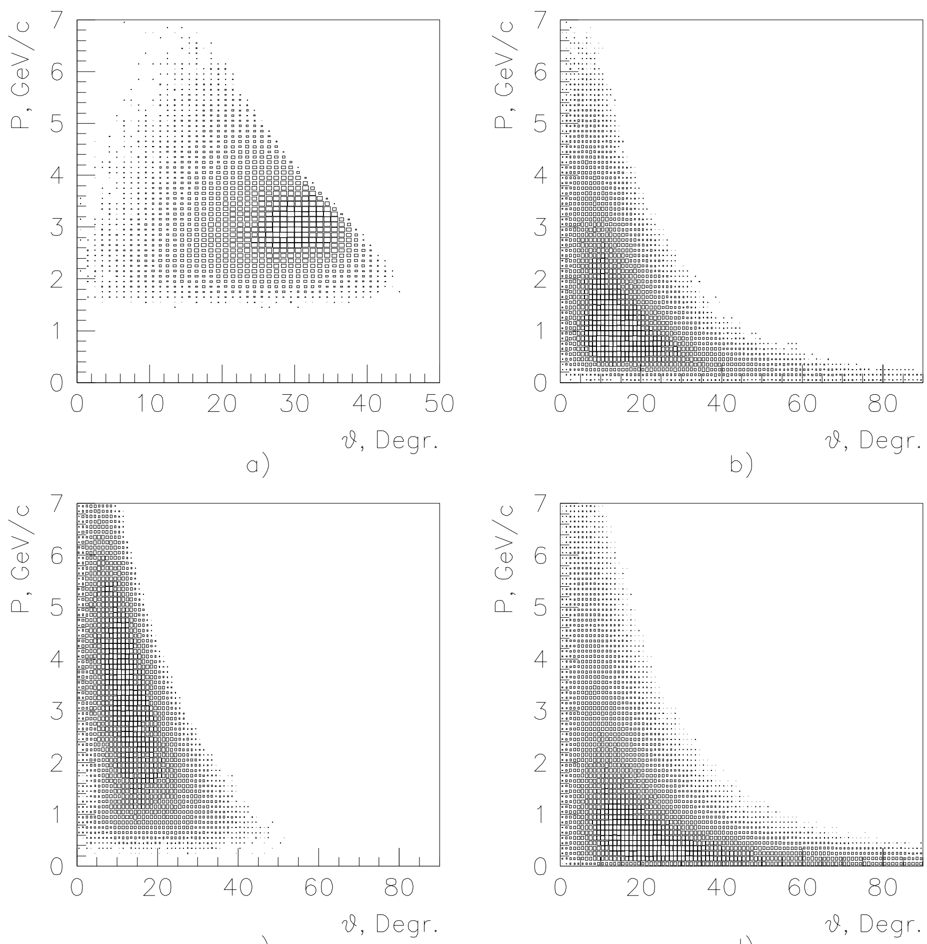


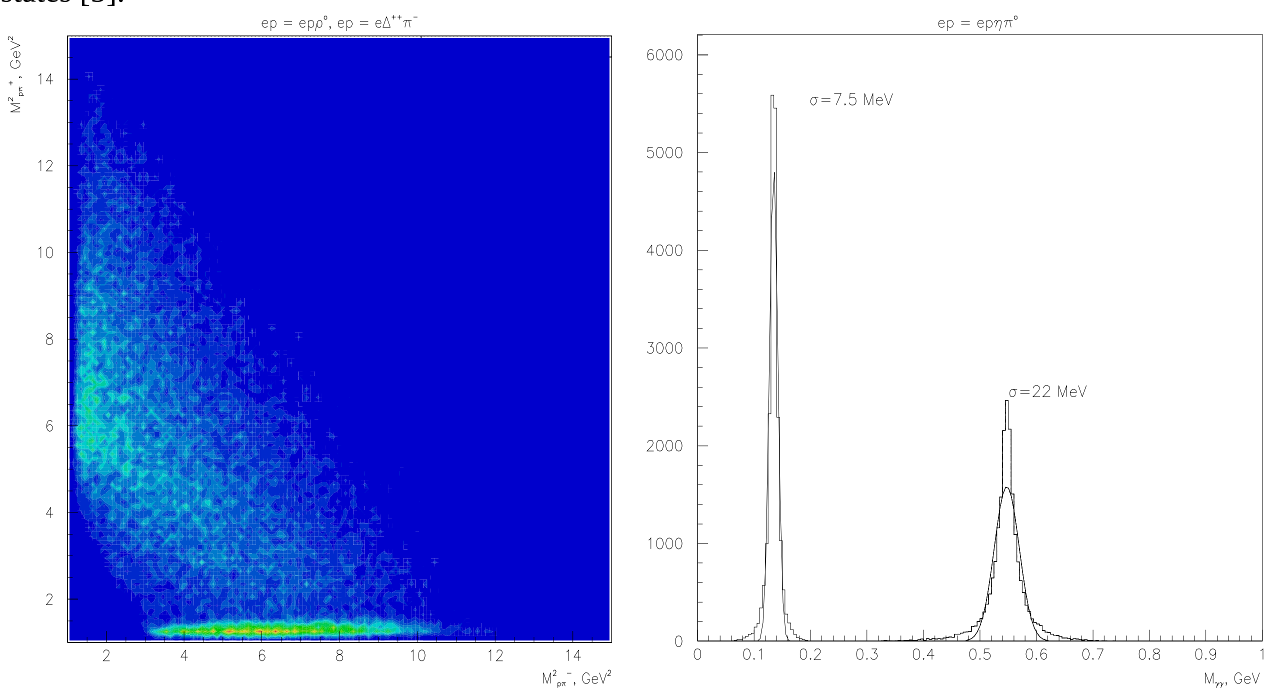
Fig.1 Angular and momentum distributions for protons (a), pions (b), K-mesons (c) and photons (d) in the (ep) scattering at E_e = 10 GeV.

In Fig.2a, a Dalitz plot of ($p\pi^+\pi^-$) final state in the reactions $ep \to e\Delta^{++}\pi^-$ and $ep \to ep\rho^o$ is shown. As one can see there is a clear separation between Δ^{++} and ρ^o in the invariant mass distribution of two charge hadrons.

Photon detection -

Angular-momentum distribution for photons (from π^o and η decays) is shown in Fig.1d. As in the case of charged hadrons, photons are also boosted more forward. Unlike hadrons, the torus and tracking are not needed for photon detection. This gives a possibility to increase photon detection acceptance in the forward region by putting a new “inner” electromagnetic calorimeter in the front of the magnet coils [2]. That will not only increase the acceptance but could improve the resolution by using better detectors. To see the effect of inner calorimeter the reaction $ep \to ep\pi^o\eta$ was simulated. In the reconstruction response of the inner [2] and the outer (forward) [3] calorimeters was parametrized. The resolution of inner calorimeter was taken as $\sigma/E^{1/2} \sim 4\%$. The detection efficiency of ($ep\gamma\gamma\gamma\gamma$) final state relative to the (ep) in the reaction $ep \to ep\pi^o\eta$ was about 30%. In Fig.2b, mass distributions of reconstructed π^o and η via two photon decays are shown. One can see clean separation of two neutral mesons.

The same device in combination with improved tracking in the inner region of CLAS can be used to determine the direction of charged particles going into the dead regions of the detector [2]. Knowing the directions of missing hadrons will be beneficial for the reconstruction of many final states [5].



a) b)

Fig.2 Dalitz plot for final state $p\pi^+\pi^-$ reactions $ep \to e\Delta^{++}\pi^- \to ep\pi^+\pi^-$, $ep \to ep\rho^o \to ep\pi^+\pi^-$ (a). Reconstruction of π^o and η via two photon decays in the reaction $ep \to ep\pi^o\eta$ (b).

3.0 Summary

In high energy scattering events contain high momentum particles with higher multiplicity. Since CLAS has an open acceptance, there is no limitation on maximum momentum. The main effect of increasing momentum is a degradation of the resolution.

Important limitations for performing studies at higher energies can be particle ID and acceptance in the forward region. Based on simulations of various final states in (ep) scattering, the following minimal improvements of CLAS detection system are suggested [2]:

Energy independent upgrades -

- Full coverage (six sectors) of large angle electromagnetic calorimeters (up to 75^o).
- Possibility of measuring dE/dX before or in the magnet region (for low momenta charged particles).

With the energy upgrade -

- π/K separation above p = 2 GeV/c in forward region ($\theta < 45^o$).
- π/p separation above p = 3 GeV/c in forward region ($\theta < 45^o$).
- Photon detection acceptance in the forward region.

One more upgrade option can be the post target spectrometer for very forward scattered electrons (quasi-real photoproduction). This is an excellent source for high rate "photoproduction" of hadrons on CLAS.

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