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Measurement of differential cross sections of $p(e, e'\pi^+)n$ for high-lying resonances at $Q^2 < 5$ GeV^2

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The exclusive electro-production process $ep \to e'n\pi^+$ was measured in the range of the invariant mass for $n\pi^+$ system 1.6 GeV $\leq$ W $\leq$ 2.0 GeV, and the photon virtuality 1.8 GeV^2 $\leq$ Q^2 $\leq$ 4.0 GeV^2 using CLAS. For the first time, these kinematics are probed in exclusive π^+ production from the protons with nearly full coverage in the azimuthal and polar angles of the $n\pi^+$ center-of-mass system. In this experiment, approximately 39,000 differential cross-section data points were measured. In this proceeding, preliminary results of our latest analysis work are presented on differential cross sections and structure functions as well as helicity amplitudes for the $N(1680)5/2^+$ and the $N(1720)3/2^+$ states, in particular.

Keywords: CLAS; exclusive single pion; electro-production; helicity amplitudes.

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1. Introduction

The exclusive meson electro-production off protons is a powerful tool to probe the effective degrees of freedom in excited nucleon states at different distance scales, where the transition from the contributions of both quark-core and meson-baryon cloud to the quark core dominance takes place. Several low-lying nucleon resonance states ($W < 1.6$ GeV), such as $\Delta(1230)3/2^+$, $N(1440)1/2^+$, $N(1520)3/2^-$, and $N(1535)1/2^-$ [1,2,3] have been studied to give new insights into nucleon structure. The $SU(6)$x$O(3)$ symmetry scheme and meson scattering experiments predict many resonances in the high mass region that have not been observed. There is also a big gap between the dressed quark regime and the perturbative QCD domain. In order to establish a better understanding of the connection between the two regimes at high Q^2, it is important to measure fundamental observables, such as cross sections or asymmetries in the excited resonance region. The various current quark models

*Suit5 Room 12-1/A102, 12000 Jefferson Ave. Newport News VA 23606 predict not only different excitation spectra but also different Q^2 dependences of transition form factors. For example, the light cone sum rule has been used to predict the Q^2 evolution of the $N(1535)1/2^-$ resonance for both the transverse ($A_{1/2}$) and longitudinal ($S_{1/2}$) helicity amplitudes [4]. The mapping of the transition form factors for high-lying resonances will help us to better understand the underlying hadronic structure [5]. With new data on π^0, π^+, 2π, and η electro-production, combined with the large coverage in Q^2, W, and center-of-mass angles, the study of nucleon resonances will become an even more powerful tool in the exploration of nucleon structure in the transition from strong QCD and confinement to perturbative QCD.

In this proceeding, preliminary differential cross sections for $p(e, e'\pi^+)n$ are presented in the invariant mass region, $W = 1.6 - 2.0$ GeV, for $Q^2 = 1.8 - 4.0$ GeV^2. This measurement has been performed by utilizing CLAS in Hall-B. CLAS is a large acceptance instrument with sufficient resolution to measure the exclusive electro-production of mesons with nearly complete coverage in the center-of-mass angles, that allows for a detailed study of the excitation of nucleon resonances. The measurement of the differential cross sections in the high W, Q^2 kinematic region allows us to extract helicity amplitudes for the high-lying resonance states, $N(1680)5/2^+$, and $N(1720)3/2^+$.

2. Results

Preliminary results have been obtained by utilizing the $e1f$ data. The data were taken in Hall B in the spring of 2003. The $e1f$ run conditions entailed an electron beam of energy 5.5 GeV, with a typical intensity of 7 nA, incident on a 5 cm long Hydrogen target. The particle identification (PID) and kinematic corrections are applied for two entire kinematic region. The CLAS electron identification at the trigger level is done by requiring a minimum amount of energy in the electromagnetic calorimeter (EC) in coincidence with a signal in the Cherenkov counter (CC). Pions (π^+) are identified by a coincidence of drift chamber (DC) and time-of-flight counter (TOF). Kinematic corrections and proper geometrical fiducial cuts are applied to both simulation and experimental data. The fiducial cuts are to select areas of uniform detector response that can be reproduced by the GEANT Simulations (GSIM) [6]. The single charged pion electro-production cross section factorizes under the one-photon-exchange approximation,

$$\frac{k^*_\gamma}{p^*_\pi}\frac{d^2\sigma}{d\Omega} = \sigma_T + \epsilon\sigma_L + \epsilon\sigma_{TT}\sin^2\theta^*_\pi\cos 2\phi^*_\pi + \frac{1}{\sqrt{2\epsilon(1+\epsilon)}}\sigma_{LT}\sin\theta^*_\pi\cos\phi^*_\pi \ , \quad (1)$$

where p^*_π, θ^*_π are the π^+ momentum and polar angle in the center-of-mass frame. ϕ^*_π is the azimuthal rotation of the $n\pi^+$ plane with respect to the electron scattering plane (e, e'), k^*_γ is the equivalent photon energy, and ϵ is the virtual photon polarization.

Figure 1 shows an example of preliminary cross sections as a function of ϕ^*_π (left) and their fit (right) at $W = 1.74$ GeV, $Q^2 = 2.2$ GeV^2. The cross section is compared with various models, such as Dubna-Mainz-Taipai (DMT), MAID2003 and

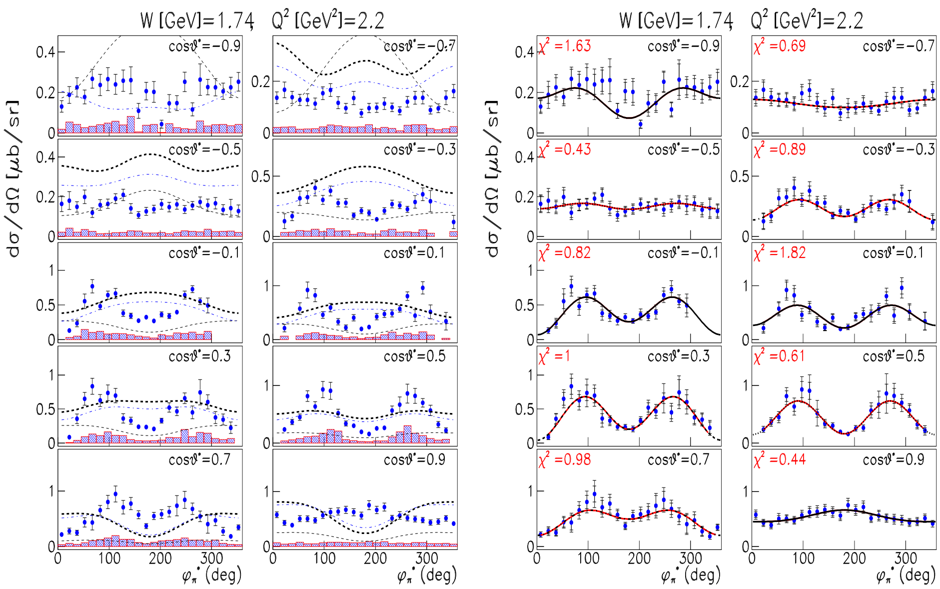

Fig. 1. (Color online) An example of the preliminary $d\sigma/d\Omega$ with various model predictions (left) and fit (right) at $W = 1.74$ GeV, $Q^2 = 2.2$ GeV^2. Shaded bars on the left plot along x-axis as well as outer error bars on the right plot show the systematic uncertainties. References in text.

MAID2007, which are thin dashed, dash-dotted, and bold dashed lines, respectively. The fit to the ϕ^*_π-dependent cross sections allows us to obtain the structure functions defined in Eq. 1. The overall systematic uncertainty is approximately $8\%-10\%$. The fit function for $d\sigma/d\Omega$ has three parameters, $d\sigma/d\Omega = P_1 + P_2 \cos\phi^*_\pi + P_3 \cos 2\phi^*_\pi$, which corresponds to the structure functions $P_1 = \sigma_T + \epsilon\sigma_L$, $P_2 = \sigma_{LT}$ and $P_3 = \sigma_{TT}$, respectively.

Figure 2 shows an example of the structure functions that were obtained from the fit and compared to model predictions. The figure shows three structure functions as function of $\cos\theta^*_\pi$ at $W = 1.74$ GeV, $Q^2 = 1.8$ GeV^2. Overall, the preliminary cross sections from this new analysis for 1.6 GeV < W < 1.7 GeV are consistent with already published data within systematic uncertainty [6]. However, most of existing physics models do not support any of the results at high W. Figure 3 shows the Q^2-dependent helicity amplitude ($A_{1/2}$) for $N(1680)5/2^+$ (left) and the $N(1720)3/2^+$ (right) states. These amplitudes were obtained by fit this cross-section data using the Unitary Isobar model [8]. Solid red bullets are from this work, other symbols (triangles, open squares) are the published world data [1,7,9]. Curves are models (solid: MAID, dashes: hCQM [10]).

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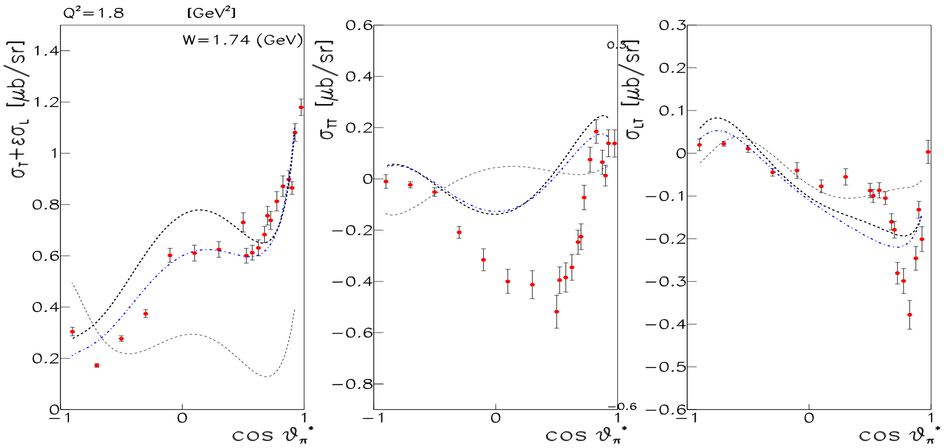

Fig. 2. (Color online) An example of the structure functions ($\sigma_T + \epsilon\sigma_L$, σ_{TT}, and σ_{LT}) as a function of $\cos\theta^*_\pi$ at $W = 1.74$ GeV, $Q^2 = 1.8$ GeV^2. Curves are same as in Fig. 1.

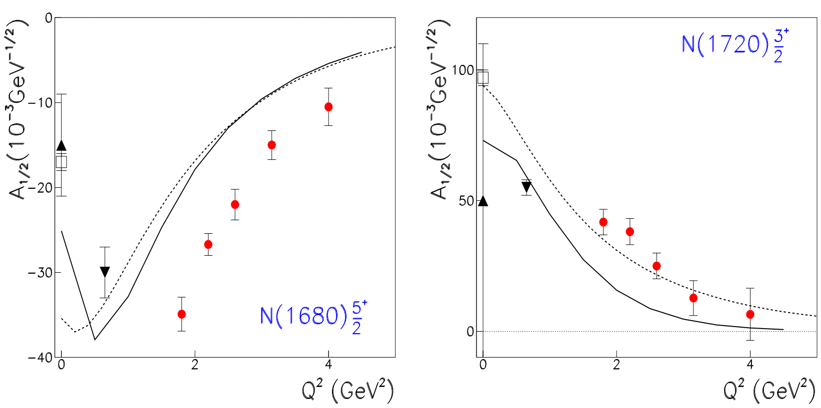

Fig. 3. (Color online) Q^2 evolution of the helicity amplitudes ($A_{1/2}$) for the $N(1680)5/2^+$ (left) and $N(1720)3/2^+$ (right). Solid bullets are preliminary CLAS data from this analysis, opened squares and triangles are world data, and curves are various physics models (for references see text).

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