Recent Results from N^* Electroproduction Studies with CLAS

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Abstract. During the last eight years a large amount of data on single and two pion electroproduction have been collected using the CEBAF Large Acceptance Spectrometer (CLAS) at Jefferson Lab. The large kinematical coverage of the detector allowed us to perform isobar model fits to extract the transition form factors for the excited states in the second and third resonance regions. The preliminary results for the photocoupling amplitudes from these analyses were presented in this report.

Keywords: resonance, excited states, baryon, transition form factor

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The internal structure of the nucleon and the excited states has been a subject of investigation for decades because it provides a unique window into the nature of the strong interactions and it helps us test the underlying theory - Quantum Chromodynamics (QCD). While the elastic electron scattering off the nucleon provides information about the ground state nucleon, the electroexcitation of the baryon resonances allows us to study the structure of the excited states.

The present work is based on the data obtained from experiments using the CLAS detector [1] at Jefferson Lab located in Newport News, Virginia, USA. CLAS is a nearly 4π detector which is well suited for investigation of photo- and electroproduction reactions with multiple charged particles in the final state. A large amount of data on single and double pion electroproduction processes has been taken since 1998, and the differential cross sections for various channels have been extracted.

In order to obtain the photoexcitation amplitudes for various nucleon resonances analysis tools have been developed at Jefferson Lab based on the isobar approach for both single and double pion electroproduction. The single pion analysis framework, JLab Analysis of Nucleon Resonances (*JANR*), is a unitary isobar model [2], where the resonant amplitudes are parameterized in Breit-Wigner form, while the background is represented by fixed contributions from Born terms and ω and ρ meson exchange. The full amplitude is unitarized in K-matrix approximation. The model for the two pion electroproduction data analysis (*JLab-MSU*) [3, 4] includes Breit-Wigner amplitudes and parameterized background terms which provide the best description of the data.

The data set presented in this report mainly consists of the five-fold differential cross sections and beam spin asymmetries for single pion electroproduction on proton target in both $p\pi^0$ and $n\pi^+$ channels [5, 6, 7, 8, 9]. Using the *JANR* program the helicity amplitudes were obtained for $P_{11}(1440)$, $S_{11}(1535)$, $D_{13}(1520)$ and $F_{15}(1680)$ in $0.3 \text{ GeV}^2 < Q^2 < 4.5 \text{ GeV}^2$ range. In addition, previously published one dimensional differential cross sections from CLAS [3] for two pion electroproduction were analyzed

FIGURE 1. Preliminary results for the photocoupling amplitudes for $S_{11}(1535)$. The full circles are from published CLAS data [2], the full squares are the preliminary results of the analysis of the new data. The shaded areas represent the the range given by the analysis of the previous data within SQTM [10]. The open boxes are the result from the analysis of η production data using the same approach [2, 11]. Solid, dashed, dash-dotted and dotted curves correspond to Ref. [12, 13, 14, 15].

along with the single pion data at $Q^2 = 0.65 \text{ GeV}^2$ [4]. The “combined” analysis of the single and double electroproduction data was done in multiple steps to find the photocouplings for the states in the second and third resonance regions which describe best both the single and two-pion electroproduction data at $Q^2 = 0.65 \text{ GeV}^2$ (see Ref. [4]).

The preliminary results for the Q^2 dependence of the photocoupling amplitudes for $S_{11}(1535)$ is shown in Fig. 1 with solid squares. The $A_{1/2}$ amplitude from the new pion analysis indicates a slower fall-off at $Q^2 < 2 \text{ GeV}^2$ compared to the previous measurements which are dominated by η electroproduction data (shaded areas in Fig. 1), while the older CLAS pion data at $Q^2 < 0.7 \text{ GeV}^2$ [2], shown with full circles, are in better agreement with the η channel results. The present analysis also allowed us to obtain the longitudinal helicity amplitude $S_{1/2}$ which appears to be small and negative at $Q^2 > 1 \text{ GeV}^2$.

The preliminary results for the Q^2 evolution of the helicity amplitudes for $D_{13}(1520)$ are shown in Fig. 2. Clearly, at low Q^2 the $D_{13}(1520)$ transition is dominated by the $A_{3/2}$ amplitude, while at higher $Q^2 > 0.4 \text{ GeV}^2$ $A_{1/2}$ becomes larger, and asymptotically falls off slower than $A_{3/2}$. Also it is very useful to note that the “combined” analysis results, shown with open circles, and the results from only single pion analysis give consistent results at $Q^2 = 0.65 \text{ GeV}^2$. The existing theoretical models, although following the general trends of the Q^2 dependence, fail to describe the experimental data quantitatively.

SUMMARY

There is a comprehensive program at Jefferson Lab to study the N^* physics using CLAS detector. A large amount of experimental data has already been accumulated, and the differential cross sections and polarization observables have been extracted for many reaction channels. The single and two-pion electroproduction data have been analyzed using isobar models, and the photocoupling amplitudes for $S_{11}(1535)$, $P_{11}(1440)$, $D_{13}(1520)$

FIGURE 2. Preliminary results for the photocoupling amplitudes for $D_{13}(1520)$. The empty circle is the result of the “combined” analysis. The shaded areas represent the the range given by the analysis of the previous data within SQTm [10]. The rest of the notation is the same as in Fig. 1.

and $F_{15}(1680)$ have been extracted. For $Q^2 = 0.65 \text{ GeV}^2$ a combined analysis was performed which allowed us to obtained transition amplitudes describing both single and two pion production data.

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