High Lying N^* Studies in the Phenomenological Analysis of Charged Double Pion Production.

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Abstract

We present results of a preliminary physical analysis of double charged pion electroproduction data obtained by CLAS collaboration in E93–006 experiment. First results on electromagnetic form factors for the high lying nucleon resonances ($M_{N^*} > 1.6$ GeV) are obtained and a possible signal from the new "missing" state is discussed.

1 Introduction

Double charged pion production channel offers promissing opportunity for studies of high lying N^* ($N_{N^*} > 1.6$ GeV) electromagnetic form factors, snice such states decay preferably in many pion final states. Currently for main part of high lying nucleon excitations the data on electromagnetic form factors are absent, however these data are necessary for our understanding of baryon structure. in non-perturbative domain.

Moreover constituent quark models, in the frame of general principles, predict many states not observed so far [1],[2], the so called "missing" baryon states. Search for "missing" states represents an important direction in modern studies of confinement. According to the model expectation [1],[2] the couplings of "missing" states with double pion final state are significantly higher than with single pion final state, while photocouplings for missing and conventional states are comparable. Therefore double charged pion production channel opens promissing opportunity for missing baryon states search.

The particular feature of two pion channels is a large contribution of non resonant processes and many resonances overlap in the W range > 1.6 GeV. It prevents the application of model independent approaches to extract the information about structure of separate resonances and requires development of models relating N^* electromagnetic form factors with measured cross sections, allowing to extract them from data fit.

In this proceeding we present the preliminary results of physical analysis of the CLAS collaboration data [5] on double charged electroproduction by virtual photons ($0.5 < Q^2 < 1.5$ GeV^2. $1.4 < W < 2.1$ GeV) performed in the frame of phenomenological approach developed by Moscow-Genova collaboration [3], [4], [6] and aimed to extract Q^2-dependence of high lying N^* photocouplings and search for possible signals from missing baryon states.

2 The main features of approach

We described double charged pion production mechanisms at tree diagram level as a superposition of quasi-two-body mechanisms

$$\gamma p \to \pi^-\Delta^{++} \to \pi^-\pi^+ p$$
$$\gamma p \to \pi^+\Delta^0 \to \pi^+\pi^- p$$
$$\gamma p \to \rho p \to \pi^-\pi^+ p$$

The rest of the processes was parametrized as phase space fitted to data in each (W, Q^2)-bin separately [4]. Each mentioned above quasi-two-body channel was treated as a superposition of s-channel N^* excitation and non resonant mechanisms. N^* excitation was described in Breit-Wigner ansatz [3] with strong amplitudes taken from [8], where photocouplings were considered as free parameters to be extracted from data fit. Twelve well established states with masses below 2 GeV and sizable decay widths into $\pi\Delta$ and ρp final states were included [3], [7]. The non-resonant processes in ρ-meson production were described in diffractive approximation [3], while for $\pi\Delta$ channel non-resonant mechanisms we used reggezied gauge invariant Born terms [3]. The special approach for treating initial and final state interaction effects essential in $\pi\Delta$ production was developed.

We found our model provides reasonable description of all available world data on double charged pion production and therefore can be used for physical analysis of new CLAS collaboration data [5].

3 CLAS collaboration data analysis

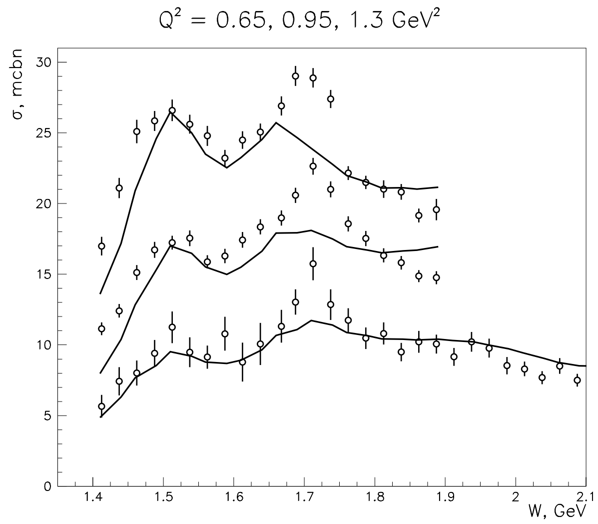

Figure 1: Total cross section for $\gamma p \to \pi^+\pi^- p$ channel as a function of W in comparison with CLAS data [5]. The curves correspond to our calculations with SQTM N^* photocouplings [9].

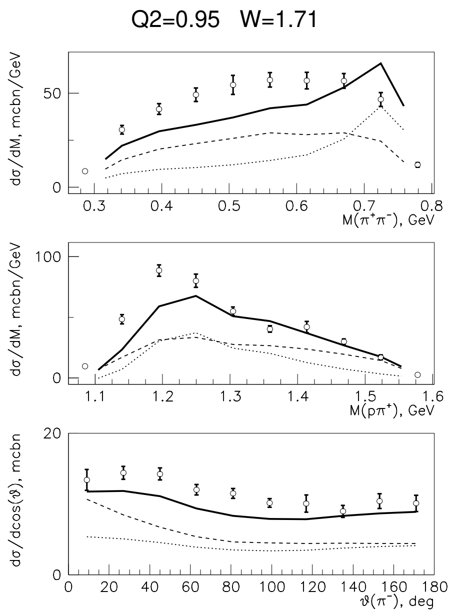

Figure 2: $(\pi^-\pi+)$ and (π^+p) ivariant masses and π^- angular distributions in CMS. The curves correspond to our calculations with SQTM N^* photocouplings [9]. Dashed lines represent non-resonant part while dotted line is resonance part of the cross sections.

First we the check the ability of our model to reproduce CLAS collaboration data [5] using SQTM interpolation of world data for N^* photocouplings [9]. The free model parameters (phase space $C(W, Q^2)$, regeon coupling, the magnitude of ρ diffractive amplitude) were extracted from data fit. As data input we had measured $(p\pi^+)$, $(\pi^-\pi+)$ invariant masses and θ polar angle of outgoing π^- in each W, Q^2-bin shown in fig.1, where the calculated in mentioned above assumptions cross sections are confronted with CLAS data [5]. The gross features of the cross section are reproduced. However theres is a strong discrepancy at $W \sim 1.7$ GeV as well as at $W < 1.5$ GeV. Experimental points notably exceed the calculation. Invariant mass and angular differential cross sections in $W = 1.71$ GeV bin for $Q^2 = 0.95$ GeV.are presented in fig.2. The resonant part creates a peak in $(\pi^-\pi+)$ invariant mass not supported by the data. To eliminate this peak in calculation we were forced to decrease the $P_{13}(1720)$ state photocouplings more than factor 2 with respect to SQTM prediction, since this state represents a main contributor in (ρp) production at $W = 1.71$ GeV. In addition we introduced strong longitudinal photocoupling $C_{1/2}$ for Ropper resonance to fit experimental data at low $W < 1.5$ GeV. For the states $D_{13}(1700)$ and $D_{15}(1675)$ the SQTM fit predicts zero values and we used non relativistic quark model (NRQM) [9] prediction for that couplings. Finally we varied randomly $\pm 20\%$ in σ the photocouplings for all included states and selected the best solution according to minimal χ^2 estimated from comparison between calculated and measured one differential cross section and averaged over all W-bins in each Q^2 interval separately. The best solution is shown in fig.3. It reproduces available cross section reasonably apart from the structure around 1.7 GeV. We found this structure is composed with three states:

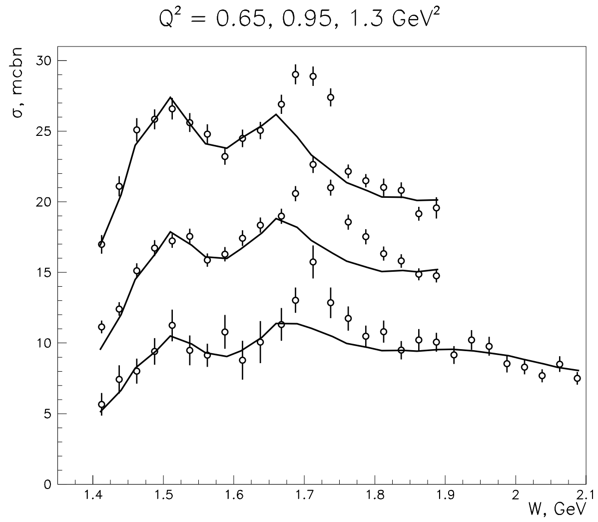

Figure 3: Total cross section for $\gamma p \to \pi^+\pi^- p$ channel as a function of W in comparison with CLAS data [5]. Solid curves correspond to our best fit (see text).

$D_{13}(1700)$, $D_{33}(1700)$ and $P_{13}(1720)$ and we could try to reach an agreement with data varying the couplings of these states. However, we excluded from variation procedure $D_{33}(1700)$, since it has a 300 MeV width. So we varied photocouplings and poorly known position and strong decay couplings of $D_{13}(1700)$. For $P_{13}(1720)$ only photocouplings were varied, while strong widths were kept on results of [8] and normalized to PDG [7] total width. The best solution for W dependence of calculated cross-section is shown in fig.4. It was obtained with a strong enhancement of $D_{13}(1700)$ photocouplings (> 2.5) with respect to SQTM expectation. The calculated set of one dimetional cross sections for this fit in comparison with data at $Q^2 = 0.65$ GeV^2, $W = 1.71$ GeV is presented on fig.5. We succeded to reproduce W-dependence of the integrated cross section and invariant mass distributions in complete kinematics region, while (see fig.5) we still have sizable deviation between measured and calculated angular distributions at 1.69, 1.71 and 1.74 GeV in all available Q^2.

This discrepancy force us to analyze also other hypothesis like implementation of missing baryon state at $W = 1.7$ GeV, sizable departure of strong couplings from reported in literature [8], [10] for $P_{13}(1720)$ considering high inelastisity of this state. This analysis is now in progress.

4 Conclusions

The phenomenological model for double charged pion production on a proton by virtual photons were applied to the CLAS data [5]. Analysis results can be summarized as:

– all measured integrated and one differential cross sections can be reproduced with N^* $A_{1/2}$ and $A_{3/2}$ photocouplings being within ±30% around SQTM prediction [9] apart

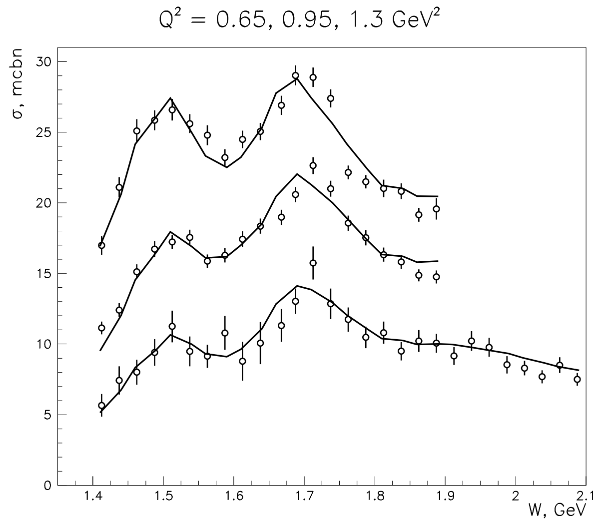

Figure 4: Total cross section for $\gamma p \to \pi^+\pi^- p$ channel as a function of W in comparison with CLAS data [5]. Solid line corresponds to the best solution with variation of photocouplings of $D_{13}(1700)$, $P_{13}(1720)$ and strong decay couplings for $D_{13}(1700)$.

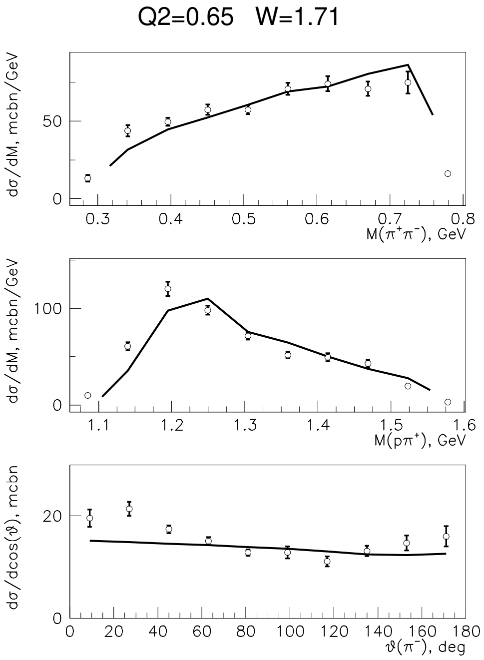

Figure 5: $(\pi^-\pi+)$ and (π^+p) ivariant masses and π^- angular distributions in CMS for the fit shown in fig.4

from $P_{13}(1720)$. For this state we have to decrease photocouplings by factor 2 with respect to SQTM prediction. It may be an indication of its particular structure.

– The observed at 1.7 GeV structure in W-dependence of integrated cross section could be reproduced assuming strong enhancement (> 2.5) of $D_{13}(1700)$ photocouplings with respect to NRQM [9] expectation. However we still have sizable discrepancy in π^- angular distribution, indicating a possible presence of missing baryon state or sizable deviation of $P_{13}(1720)$ strong couplings with respect to presented in literature [8], [10].

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