POLARIZATION DEGREES OF FREEDOM IN CHARGED DOUBLE PION PRODUCTION BY VIRTUAL PHOTONS

E.GOLOVACH^a, V.BURKERT^b, V.MOKEEV^{a,c}, M.RIPANI^d,
M.ANGHINOLFI^d, M.BATTAGLIERI^d, A.BOLUCHEVSKII^e, G.FEDOTOV^a,
R.DE VITA^d, B.ISHKHANOV^{a,e}, N.MARKOV^e, M.OSIPENKO^{a,d},
G.RICCO^d, N.SHVEDUNOV^e, M.TAIUTI^d.

^a *Nuclear Physics Institute, Moscow State University,
Vorob'evy gory, 119992 Moscow. Russia.*

^b *Thomas Jefferson National Accelerator Facility,
Newport News, VA 23606. USA.*

^c *Christopher Newport University,
Newport News, Virginia 23602, USA*

^d *Istituto Nazionale di Fisica Nucleare,*

Via Dodecanneso 33, I-16146 Genova. Italy.

^e *Physics Department, Moscow State University,
Vorob'evy gory, 119992 Moscow. Russia.*

Polarization degrees of freedom in exclusive channel of two charged pion electro production are studied in the Q^2 region from 0.6 to 1.3 GeV². Predictions for the contribution to the GDH integral as well as helicity components of the cross section are estimated in the framework of the phenomenological approach developed for the analysis of the two pion production data from CLAS (JLAB). Calculations show high sensitivity of the helicity difference $\sigma_{1/2} - \sigma_{3/2}$ to baryon resonances with strongly different $A_{1/2}$ and $A_{3/2}$ photocouplings.

1. Introduction

The studies of exclusive channels and their contributions to the generalized GDH integral enable us to unravel the individual resonance contributions, and to come to a better understanding of the striking Q^2 dependence predicted for this integral ^{1,2} and now also seen in the data ³. Understanding this behavior in detail provides deep insight into spin structure of the nucleon.

Single and double pion production channels account for the most part of the total real and virtual photon cross-section at the CMS energies $W < 2.0$ GeV. Comprehensive studies of single pion channel contribution to the GDH integral have been performed in the framework of the

approach given in ref.⁴. In this paper we present an evaluation of double charged pion production contributions to the GDH-integral in the Q^2 range 0.6–1.5 GeV². Here we employ the approach^{5,6,7}, successfully used for the description of the CLAS data^{8,9,10} on double charged pion production by virtual photons at $W < 2.1$ GeV and the same Q^2 -interval. For the first time these data provide information on the excitations of nucleon states with masses below 2.0 GeV in electroproduction. N^* photocouplings as well as free parameters in the model^{5,6,7} were fitted to the experimental data^{8,9,10}, which provided a sizeable reduction of model uncertainties.

2. Evaluation of helicity components $\sigma_{1/2}$, $\sigma_{3/2}$ in double charged pion production.

A phenomenological approach^{5,6,7} has been developed to describe double charged pion production, relating N^* photo couplings and hadronic couplings to the measured cross-sections and asymmetries. This allowed the extraction of the N^* parameters from the data fit.

Excitations of well-established states with hadronic two pion decays are described in the Breit-Wigner ansatz⁵. The hadronic decay couplings were taken from hadronic data analysis^{11,12} while the photocoupling values were treated as free parameters to be determined by a fit to the CLAS data^{8,9,10}. Non-resonant mechanisms in the $\pi\Delta$ sub-channel are described by Reggeized gauge-invariant Born terms⁵. A diffractive ansatz is used to account for non-resonant mechanisms in the $\rho^0 p$ sub-channel^{6,7}. Our approach provides a reasonable description of previous world data^{6,7} as well as recent CLAS data^{8,9,10} in the kinematical range of interest $W < 3.5$ GeV $Q^2, -t \sim \text{few GeV}^2$. Calculating the 1/2- and 3/2- total helicity components in the respective amplitudes, we estimated $\sigma_{1/2,3/2}$ values and difference $\Delta\sigma = \sigma_{1/2} - \sigma_{3/2}$ for the $p\pi^+\pi^-$ channel. This quantity was decomposed into resonant and non-resonant parts. The normalization used is

$$\sigma_{1/2} + \sigma_{3/2} = 2\sigma_T \quad (1)$$

where σ_T is the transverse part of the virtual photon cross-section. N^* photocouplings and the free model parameters were fitted to the data as described in ref.¹³. The three-body phase space background^{5,6,7} was assumed to be spin-independent and equally subdivided between the helicity amplitudes.

3. Estimated helicity component difference and contribution to the GDH integral.

The estimated double charged pion channel contribution to the GDH-integral together with its decomposition into resonant and non-resonant part are shown on Fig 1 as a function of Q^2 . The contributions to the GDH-integral were estimated at three Q^2 bins using the CLAS data. The upper limits of the GDH integration determined by the covered W -domain are at 1.9 GeV for $Q^2 = 0.65, 0.95$ GeV² and at 2.1 GeV for $Q^2 = 1.3$ GeV². The error bars reflect uncertainties of N^* photocouplings, extracted as described in refs.^{10,13}.

Figure 1. Double charged pion contribution in GDH integral (circles) and its decomposition in resonant (squares) and non-resonant (triangles) parts

The predicted W dependence of $\Delta\sigma$ difference and its decomposition into resonant and non-resonant parts are shown on Fig 2.

The $p\pi+\pi-$ contribution to the GDH integral varies strongly with Q^2 and crosses zero between 0.7 and 0.9 GeV². The total contribution to GDH integral is less than 10%

Both resonant and non-resonant parts contribute to the steep Q^2 -dependence, estimated for the two pion contribution to the GDH integral.

Figure 2. W -dependence of $\sigma_{1/2} - \sigma_{3/2}$ helicity component difference (solid line) and decomposition through resonant (dashed lines) and non-resonant (dashed-dotted lines) part contributions

We found that the sharp Q^2 -dependence of the N^* part, clearly seen both in the W -dependence of $\Delta\sigma$ (Fig 2) and in the GDH-integral (Fig 1) results from the faster drop of the 3/2-helicity component with respect to 1/2-component. The Q^2 range studied represents the transition domain with comparable helicity 1/2 and helicity 3/2 contributions at low Q^2 and helicity-1/2 dominance at high Q^2 .

The W -dependence of $\Delta\sigma$ shows a pronounced dip at W at 1.7 GeV for all Q^2 . This dip is related to the resonance part shown in Fig 2. It is due to the state with maximal excitation strength among the N^* 's and Δ^* 's that contribute around 1.7 GeV. According to the analysis^{10,13} the state has drastically asymmetric $A_{1/2}$ and $A_{3/2}$ couplings. It is the asymmetry of the dominant state inside the 1.7 GeV structure that gives rise to the

rapid change in the W -dependence of $\Delta\sigma$.

Therefore, investigation of the W -dependence of $\Delta\sigma$ offers a promising tool to search for new baryon states with strongly asymmetric 1/2 and 3/2 photocouplings.

The N^* contributions in $\Delta\sigma$ increase with Q^2 as seen in Fig 2.

N^* contribution to $\Delta\sigma$ becomes largest at $Q^2 = 1.3 \text{ GeV}^2$. This feature demonstrates encouraging opportunities to study resonance excitations at higher Q^2 , that will be accessible after the JLAB 12 GeV upgrade.

References

1. V. D. Burkert and Zh Li *Phys. Rev.* **D47** (1999) 46
2. V. D. Burkert and B.L.Ioffe *Phys. Rev. Lett.* **B296** (1992) 223
3. R.Fatacci, et al (CLAS Collaboration) to be submitted to PRL
4. D. Drechsel, et al., *Nucl. Phys.* **A645** (1999) 145
5. M. Ripani, et al., *Nucl. Phys.* **A672**, 220 (2000)
6. M. Ripani, et al., *Phys. of Atom. Nucl.* **63**, 76 (2000)
7. V. I. Mokeev, et al., *Phys. of Atom. Nucl.* **64**, 1292 (2001)
8. V. D. Burkert, to be published in the conference proceedings of *BARYON2002 conference*.
9. M. Ripani, *Proceedings of the Workshop NSTAR2001*, ed D.Drechsel, L.Tiator. p.429.
10. M. Ripani,et al., to be submitted to *Phys. Rev. Lett.*
11. D. M. Manley, E. M. Salesky *Phys. Rev.* **D43**, 4002 (1992)
12. T. P. Vrana, et al., *Phys. Rep.* **328**, 181 (2000)
13. E. N. Golovach,et al., Proc of ICHEP2002 (to be published)
14. V. D. Burkert, *Czech. Journ. of Phys.* **46**, 627 (1996)