I. PHYSICS MOTIVATION

In this analysis-note we present the new set of differential and fully integrated cross sections for exclusive reaction $ep \to e'p'\pi^+\pi^-$ from the data of e1e run collected with the CLAS detector in the kinematic area of $1.35 < W < 1.8$ GeV and $0.3 < Q^2 < 1.0$ GeV^2. In each bin of W and Q^2 nine independent one-fold differential cross sections were obtained. They consist of: a) three differential cross sections over invariant masses of the final hadron pairs; b) three CM-angular distributions over polar θ-angles of the final π^+, π^-, and p', and c) three CM-angular distributions over the rotational angles of the planes composed by the three-momenta of the final hadron pairs around directions along three-momentum of the remaining third hadron for the three different choices between the pairs of the final hadrons. These data were obtained for the first time in the kinematic area $Q^2 < 0.6$ GeV^2 and $W > 1.55$ GeV. At $0.6 < Q^2 < 1.0$ GeV^2 similar $\pi^+\pi^-p$ one-fold differential cross sections were measured with CLAS [6]. However, in our data set these cross sections were obtained in the Q^2-bins of bin size which is around factor of six smaller than that achieved in the data [6].

The studies of exclusive $\pi^+\pi^-p$ electroproduction off protons represents an important avenue in the studies of the N^* spectrum and structure from the data on exclusive meson electroproduction with CLAS. The CLAS detector has provided the dominant portion of all data on meson electroproduction in the resonance excitation region. The studies of transition helicity amplitudes from the proton ground state to its excited states represent a key aspect of the N^* program with CLAS [1, 2]. Meson-electroproduction data off nucleons in the N^* region obtained with CLAS open up an opportunity to determine the Q^2-evolution of the $\gamma_v NN^*$ electrocouplings both in the comparative analyses and from a combined analysis of various meson-electroproduction channels for the first time. The electroexcitation amplitudes for the low-lying resonances $\Delta(1232)3/2^+$, $N(1440)1/2^+$, $N(1520)3/2^-$, and $N(1535)1/2^-$ were determined over a wide range of Q^2 in a comprehensive analysis of JLab-CLAS $N\pi$ electroproduction off protons data on differential cross sections, longitudinally polarized beam asymmetries, and longitudinal target and beam-target asymmetries [3]. Recently $\gamma_v NN^*$ electrocouplings of several higher-lying nucleon resonances: $N(1675)5/2^-$, $N(1680)5/2^+$, and $N(1710)1/2^+$ have become available for the first time for 1.5 GeV^2 $< Q^2 <$ 4.5 GeV^2 from analysis of exclusive π^+n electroproduction off the proton [4]. Electrocouplings for the $N(1440)1/2^+$ and $N(1520)3/2^-$ resonances for $Q^2 < 0.6$ GeV^2 have been determined from the data [8] on exclusive $\pi^+\pi^-p$ electroproduction off the proton [9]. Recent analysis [5] of the CLAS $\pi^+\pi^-p$ electroproduction off protons data [6] provided the results on these state electrocouplings in a wider Q^2-range up to 1.5 GeV^2. Furthermore, electrocoupling of $\Delta(1620)3/2^-$ resonance that decay preferentially to the $N\pi\pi$ final states have become available from this analysis for the first time. Consistent results for the $\gamma_v pN^*$ electrocouplings of the $N(1440)1/2^+$ and $N(1520)3/2^-$resonances, that have been determined in independent analyses of the dominant meson electroproduction channels, $N\pi$ and $\pi^+\pi^-p$ with completely different non-resonant contributions demonstrated reliable extraction of these fundamental quantities. This success also support the capability of the reaction models developed for the extraction of the resonance parameters from the analyses of the data on single- [3] and double-pion [7] electroproduction off protons to provide reliable information on the N^* parameters from independent studies of either of these major exclusive channels.

The CLAS results on the $\gamma_v pN^*$ electrocouplings [1, 3–5, 9, 10] have had a stimulating impact on the theory of the excited nucleon state structure, in particular, on the QCD-based approaches. The light cone sum rule (LCSR) approach [11, 12] for the first time provided access to the quark distribution amplitudes (DA) inside the $N(1535)1/2^-$ resonance from analysis of the CLAS results on the $\gamma_v pN^*$ electrocouplings of this state [3]. Confronting the quark DA's of excited nucleon states determined from the experimental results on the $\gamma_v pN^*$ electrocouplings to the LQCD expectations, makes it possible to explore the emergence of the resonance structure starting from the QCD Lagrangian. The moments of the $N(1535)1/2^-$ quark DA's derived from the CLAS data are consistent with the LQCD expectations [12]. The Dyson-Schwinger Equations of QCD (DSEQCD) provide a conceptually different avenue for relating the $\gamma_v pN^*$ electrocouplings to the fundamental QCD Lagrangian [13–15]. The DSEQCD approach allows for the evaluation of the contribution of the three bound dressed quarks, the so-called quark core, to the structure of excited nucleon states starting from the QCD Lagrangian. A successful description of the nucleon elastic form factors and the CLAS results on the $N \to \Delta$, $N \to N(1440)1/2^+$ transition electromagnetic form factors [1, 3, 9, 10] at photon virtualities $Q^2 > 2.0$ GeV^2 has been recently achieved within the DSEQCD framework [13, 15, 16].A successful description of the elastic and transition form factors to nucleon resonances of distinctively different structure achieved with the same dressed quark mass function strongly underlines:

- the relevance of dynamical dressed quarks with the properties predicted by the DSEQCD approach [17] as constituents of the quark cores for the structure of the ground and excited nucleon states;
- the capability of the DSEQCD approach [13, 15] to map out the dressed quark mass function from the experimental results on the Q^2-evolution of the nucleon elastic and $p \to N^*$ transition form factors ($\gamma_v pN^*$ electrocouplings) from a combined analysis.

Physics analyses of the CLAS results [3, 9, 10] on the $\gamma_v pN^*$ electrocouplings revealed the structure of excited

nucleon states at photon virtualities $Q^2 < 5.0$ GeV^2 as a complex interplay between meson-baryon and quark degrees of freedom. The relative contributions from the meson-baryon cloud and the quark core are strongly dependent on the quantum numbers of the excited nucleons. Analyses of the $A_{1/2}$ electrocouplings of the $N(1520)3/2^-$ resonance [18, 19] demonstrated that this amplitude is dominated by quark core contributions in the entire range of $Q^2 < 5.0$ GeV^2 measured by CLAS. However, the recent analysis [20] of the first CLAS results [4] on the $N(1675)5/2^-$ $\gamma_v pN^*$ electrocouplings suggested a dominance of the meson-baryon cloud. Pronounced differences in the structure of the N^* states of different quantum numbers demonstrated different manifestation of non-perturbative strong interaction in generation of excited nucleons as the bound systems of infinite amount of quarks and gluons. The studies of $\gamma_v pN^*$ electrocouplings for all prominent nucleon resonances offer a unique information on many facets of non-perturbative strong interaction and motivate the extension of the studies of $\gamma_v pN^*$ electrocouplings over full spectrum of excited nucleons.

Currently the results on resonance electrocouplings in mass range above 1.6 GeV are rather limited. The recent studies of $N\pi$ electroproduction [4] delivered the results on electrocouplings of only those high mass states which have a substantial branching fraction for decays to the $N\pi$ final states. Several high-lying nucleon excitations $\Delta(1620)1/2^-$, $\Delta(1700)3/2^-$, $N(1720)3/2^+$ decay preferentially to the $N\pi\pi$ final states making the $\pi^+\pi^-p$ electroproduction off proton channel the major source of the information on electrocouplings of these state. In the future these electrocouplings can be checked in independent analyses of KY exclusive electroproduction channels [21]. The data on electrocouplings of high-lying resonances, which decay both to the $N\pi$ and the $N\pi\pi$ final states available from $\pi^+\pi^-p$ electroproduction channel will make it possible to test consistency of these results with those from independent analyses of $N\pi$ electroproduction, offering the sensitive and model independent check for a reliability of these fundamental parameters.

The experimental data on $\pi^+\pi^-p$ electroproduction off protons presented in this analysis-note will be analyzed within the framework of meson-baryon reaction model JM [5, 7, 9] which is currently the only available approach worldwide for the extraction of resonance electrocouplings from this exclusive channel. The aforementioned approach already provided reliable results on electrocouplings of all resonances in mass range below 1.65 GeV with sizable decays to the $N\pi\pi$ final states. Analysis of experimental data presented in this analysis-note eventually will allow us:

- determine evolution of the electrocouplings of most nucleon resonances in mass range up to 1.8 GeV with photon virtuality Q^2 up to 1.0 GeV^2 from exclusive $\pi^+\pi^-p$ electroproduction off protons with the bin size over Q^2 much smaller than that achieved in all previous experiments;
- provide information on electrocouplings of high-lying N^* ($M_{N^*} > 1.6$ GeV) that decay preferentially to the $N\pi\pi$ final states for the first time;
- combining with the results from $N\pi$ electroproduction to explore electrocouplings of all orbital excitations (L=1) of [70,1$^-$] spin-flavor $SU(6)$-supermultiplet.

Studies of the CLAS $\pi^+\pi^-p$ preliminary photo- and electroproduction [6] combined within the framework of the JM meson-baryon reaction models have provided further convincing evidences for existence of new baryon state $N'(1720)3/2^+$ [22]. So far, it is the only candidate state for which the information on internal structure have become available from the results on $\gamma_v pN^*$ electrocouplings at $Q^2 < 1.5$ GeV^2. However, right now, only four data points for this new state electrocouplings are available. From the data of this analysis-note, the $N'(1720)3/2^+$ electrocoupling values will become available at ten additional Q^2-bins of bin size at least factor of six smaller than available from the old CLAS experiment [6]. The expected results for the first time will offer a deep insight to the structure of new baryon state $N'(1720)3/2^+$.

The expected results will extends considerably available information on interplay between meson-baryon cloud and quark core in the structure of excited nucleon states in particular in mass range from 1.6 to 1.8 GeV.

[1] I.G. Aznauryan and V.D. Burkert, Prog. Part. Nucl. Phys. **67**, 1 (2012).
[2] I.G. Aznauryan, V.D. Burkert, T-S. H. Lee, and V.I. Mokeev, J. Phys: Conf. Ser. **299**, 012008 (2011).
[3] I.G. Aznauryan *et al. (CLAS Collaboration)*, Phys. Rev. C **80**, 055203 (2009).
[4] K. Park *et al. (CLAS Collaboration)*, Phys. Rev. C **91**, 045203 (2015).
[5] V. I. Mokeev, V. D. Burkert, D. S. Carman *et al.*, Phys. Rev. C **93**, 025206 (2016).
[6] M. Ripani *et al. (CLAS Collaboration)*, Phys. Rev. Lett. **91**, 022002 (2003).
[7] V.I. Mokeev *et al.*, Phys. Rev. C **80**, 045212 (2009).
[8] G.V. Fedotov *et al. (CLAS Collaboration)*, Phys. Rev. C **79**, 015204 (2009).
[9] V.I. Mokeev *et al. (CLAS Collaboration)*, Phys. Rev. C **86**, 055203 (2012).
[10] V.I. Mokeev and I.G. Aznauryan, Int. J. Mod. Phys. Conf. Ser. **26**, 146080 (2014).
[11] I.V. Anikin, V.M. Braun, and N. Offen, Phys. Rev. D **92**, 014018 (2015).
[12] V. M. Braun *et al.*, Phys. Rev. D **89**, 0722001 (2014).

[13] J. Segovia *et al.*, Few Body Syst. **55**, 1185 (2014).
[14] D. Binosi, L. Chang, J. Papavassiliou, and C.D. Roberts, Phys. Lett. B **742**, 183 (2015).
[15] J. Segovia *et al.*, Phys. Rev. Lett. **115**, 171801 (2015).
[16] I.C. Clöet, C.D. Roberts and A.W. Thomas, Phys. Rev. Lett. **111**, 101803 (2013).
[17] I.C. Clöet and C.D. Roberts, Prog. Part. Nucl. Phys. **77**, 1 (2014).
[18] B. Julia-Diaz *et al.*, Phys. Rev. C **77**, 045205 (2008)
[19] E. Santopinto and M.M. Giannini, Phys. Rev. C **86**, 065202 (2012).
[20] I.G. Aznauryan and V.D. Burkert, Phys. Rev. C **92**, 015203 (2015).
[21] D. S. Carman, arXiv:1601:02488[nucl-ex].
[22] V. I. Mokeev *et al.*, Eur. Phys. J. Conf. **113**, 01013 (2016).