Studies of excited nucleon state structure with CLAS and CLAS12 [1]

Inna G. Aznauryan[3], Volker D. Burkert[1], and **Victor I. Mokeev**[1,2]

[1]Thomas Jefferson National Accelerator Facility, Newport News, Virginia 23606, USA

[2]Skobeltsyn Nuclear Physics Institute at Moscow State University, Moscow 119899, Russia

[3]Yerevan Physics Institute, Yerevan 375036, Armenia

Studies of nucleon resonance electroexcitation amplitudes (i.e. the $\gamma_v NN^*$ electrocouplings) at different photon virtualities Q^2 offer unique information on many facets of the non-perturbative strong interaction in the generation of excited nucleon states N^* of different quantum numbers. The current status of the exploration of N^* structure from exclusive meson electroproduction data will be reviewed, as well as the future prospects after completion of the JLab 12 GeV Upgrade Project.

The CLAS detector in Hall B at JLab has provided the dominant part of the data on exclusive meson electroproduction in the resonance excitation region. For the first time a large body of data on $\pi^+ n$, $\pi^0 p$, ηp, KY, and $\pi^+\pi^- p$ exclusive electroproduction off protons have become available at photon virtualities Q^2 up to 5.0 GeV^2 with almost complete coverage of the final state kinematics. Analyses of $N\pi$ electroproduction considerably extended the data on the $N \rightarrow \Delta$ electromagnetic form factors and provided the first results on the $\gamma_v NN^*$ electrocouplings of almost all N^* states with substantial $N\pi$ decay widths in the mass range up to 1.7 GeV and for photon virtualities Q^2 up to 5.0 GeV^2 [1, 2]. The electrocouplings of the $N(1440)1/2^+$ and $N(1520)3/2^-$ resonances have also become available from analysis of $\pi^+\pi^- p$ electroproduction for Q^2 up to 1.5 GeV^2 [3, 4]. Consistent results on the electrocouplings of these resonances from independent analyses of the major $N\pi$ and $\pi^+\pi^- p$ exclusive channels strongly support reliable extraction of these fundamental quantities. The first preliminary results on the electrocouplings and the $\pi\Delta$ and ρp hadronic decay widths of several high-lying N^* states ($M > 1.6$ GeV) that decay preferentially to the $N\pi\pi$ final states were obtained from the data on $\pi^+\pi^- p$ electroproduc-

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tion [4]. New evidence in support of a $3/2^+(1720)$ candidate N^* state come from the recent studies of this channel.

Physics analyses of $\gamma_v NN^*$ electrocouplings have revealed the N^* structure as a complex interplay between the inner core of the three dressed quarks and the external meson-baryon cloud with relative contributions strongly dependent on the quantum numbers of the excited N^* states [1, 2, 3]. Recent developments in continuous-QCD approaches [5] have demonstrated that the combined analysis of spin-flavor flip, radial, and orbital nucleon excitation electrocouplings will offer credible access to the dressed quark mass function that determines the major features of the strong interaction responsible for the generation of the ground and excited nucleon states.

The relative contribution of the inner quark core to the N^* structure increases with photon virtuality and becomes dominant for $Q^2 > 5.0$ GeV^2. The CLAS12 detector will be the only facility foreseen worldwide capable of determining the electrocouplings of all prominent N^* resonances at the highest photon virtualities ever achieved $5 < Q^2 < 12$ GeV^2 from the studies of exclusive $N\pi$, KY, and $\pi^+\pi^- p$ electroproduction off protons. In the future experiments with CLAS12, we will be able to explore the quark core and the quark interactions inside different N^* states in the transition from quark-gluon confinement to the pQCD regimes. These studies will address the challenging and still open problems on the nature of the dominant part of hadron masses, and on quark-gluon confinement and its emergence from QCD [6].

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