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π and $\pi\pi$ electro-production in the region of low-lying nucleon resonances

S. Širca[a,b]

[a] Faculty of Mathematics and Physics, University of Ljubljana, 1000 Ljubljana, Slovenia
[b] J. Stefan Institute, 1000 Ljubljana, Slovenia

Abstract. Highlights of experiments devoted to low-lying nucleon resonances at MAMI and Jefferson Laboratory were reported in this talk. The structure of the nucleon-to-Δ transition and the electro-excitation and electro-production amplitudes of the P11(1440) Roper resonance, as well as its neighbors S11(1535), S11(1650), and D13(1520) were discussed. In this written contribution, only our work on the recent Roper experiment at MAMI is briefly presented.

The $P_{11}(1440)$ (Roper) resonance [1] is the lowest positive-parity $N^{\star}$ state. The study of its properties remains one of the major theoretical challenges (quark models and Lattice QCD) as well as one of the cornerstones of nucleon resonance experimental programmes at MAMI and Jefferson Lab.

The most fruitful way to study the structure of the Roper appears to lead through measurements of double-polarization observables in pion electro-production off protons. This strategy benefits substantially from the experience gained in the well-studied $N \to \Delta$ transition, the showcase of which were given in the landmark JLab [2] and MAMI [3] experiments In the JLab experiment, measurements in the $p(\mathbf{e}, e'\mathbf{p})\pi^0$ channel were performed at relatively high momentum transfer of $Q^2 = (1.0 \pm 0.2)\,(\mathrm{GeV}/c)^2$ and $W = (1.23 \pm 0.02)\,\mathrm{GeV}$, where two Rosenbluth combinations and 14 structure functions were separated [4].

A similar experiment, but much more restricted in scope, has been designed for the MAMI/A1 experimental setup, partly motivated by the proposal [5]. Instrumental constraints at Mainz prevent us from measuring in parallel or anti-parallel kinematics for the proton and at the same time achieve complete coverage in terms of the proton azimuthal angle. Our measurement was therefore performed at $Q^2 = 0.1\,\mathrm{GeV}^2$ with the invariant mass of $W \approx 1440\,\mathrm{MeV}$, and at a single value of the center-of-mass angle, $\theta_{\mathrm{cms}} = 90^\circ$. The proton kinetic energy in the center of the carbon secondary scatterer was $T_{\mathrm{cc}} \approx 200\,\mathrm{MeV}$, which allows for optimal figures-of-merit of the focal-plane polarimeter. The low value of Q^2 is not favourable only because of the kinematics reach of the setup; according to state-of-the-art calculations in the MAID [6,7] and DMT [8–10] models, the sensitivities of the multipole amplitudes to the Roper couplings appear to be larger at smaller Q^2.

Data was taken with a beam current of $\approx 10\,\mu$A impinging on a 5 cm LH2 target in a beamtime lasting approximately two weeks. We have collected enough data to allow us to determine the three components of the proton recoil polarization to within a few percent statistical accuracy, i.e. $\Delta P'_x \approx 0.03$, $\Delta P_y \approx 0.03$, and $\Delta P'_z \approx 0.051$. The analysis of this data is work in progress. Gain-matching and time-calibration of the scintillation detectors has been done. Odd-even parameters for the horizontal drift chambers have been adjusted. Figure 1 shows preliminary azimuthal distributions in the focal-plane polarimeter.

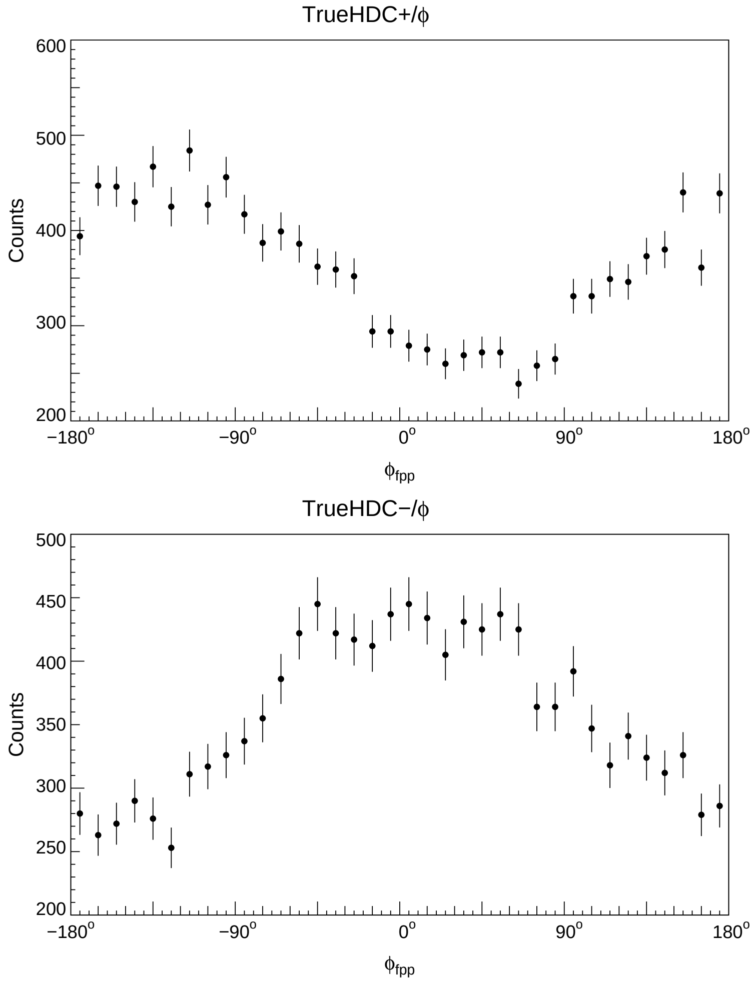

Fig. 1. The distributions of events in terms of the azimuthal angle in the focal-plane polarimeter (secondary scattering) for two helicity states of the electron beam. Top: helicity sum $N_+ + N_-$. Apart from acceptance corrections and possible false asymmetries, this distribution should be flat. Bottom: helicity difference $N_+ - N_-$. By taking into account the spin transport properties of the spectrometers, this asymmetry directly maps into proton polarization components at the target.

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