Differential Cross Section Measurements for $\gamma n \to \pi^- p$ Above the First Nucleon Resonance Region

P.T. Mattione *et al.* *(CLAS Collaboration)*, Phys. Rev. C **96**, 035204 (2017)

The determination of the resonance properties for all accessible baryon states is a central objective in nuclear physics. The extracted resonance parameters provide a crucial body of information for understanding the nucleon excitation spectrum and for testing models of the nucleon inspired by Quantum Chromodynamics (QCD) and, more recently, lattice QCD calculations.

Knowledge of the N^* and Δ^* resonance photo-decay amplitudes has largely been restricted to the charged states. This work focuses on negative pion photoproduction off the neutron using a deuteron target. A large body of new precision $\gamma n \to \pi^- p$ differential cross sections from the CLAS g13 experiment for $E_\gamma = 0.445$ GeV to 2.510 GeV in laboratory photon energy, corresponding to an invariant energy range from $W = 1.311$ GeV to 2.366 GeV, are reported spanning pion center-of-mass (c.m.) angles from $\theta_\pi^{c.m.} = 26°$ to 135°. These new data have nearly tripled the world $\gamma n \to \pi^- p$ database below $E_\gamma = 2.700$ GeV. They span a broad energy range from just above the Δ isobar through the second, third, and fourth resonance regions, and extend far into the poorly studied high-mass region above $W \sim 1.8$ GeV where many resonances are expected to exist but have not been firmly established. Fig. 1 shows selected g13 data from this work.

To extract the γn cross section from the γd data, FSI corrections were included using a diagrammatic technique that takes into account a kinematic cut with momenta below (above) 200 MeV/c to select slow (fast) outgoing protons. In this analysis, the FSI correction factor depended on the photon energy and meson production angle, and was averaged over the rest of the variables in the region of the quasi-free process on the neutron.

With the new high-precision $\gamma n \to \pi^- p$ cross sections from the CLAS g13 dataset, a new SAID multipole analysis called MA27 has been completed. This energy-dependent solution provides an improved understanding of the N^* resonance parameters for several states, compared to the previous GB12 SAID solution that does not include the g13 CLAS data. In the MA27 solution, several photo-decay amplitudes $N^* \to \gamma n$ have been extracted at their pole positions on the complex plane with very small uncertainties (see Table I). This is the first-ever full determination of the excited neutron multipoles for the $N(1440)1/2^+$, $N(1535)1/2^-$, $N(1650)1/2^-$, and $N(1720)3/2^+$ resonances, contributing a crucial complement to the excited proton spectra. These new precision $\gamma n \to \pi^- p$ data will provide important and necessary constraints to advance coupled-channel analysis fits that are sorely lacking γn data over nearly the full nucleon resonance region.

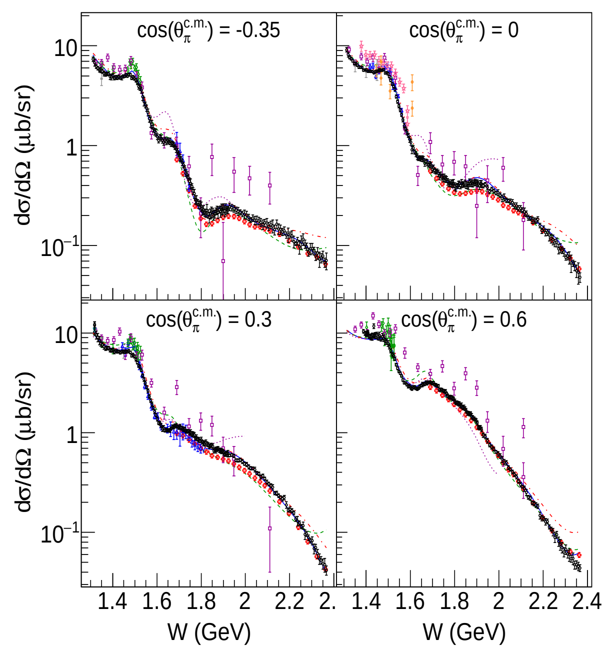

FIG. 1. Selected cross section data for $\gamma n \to \pi^- p$ vs. W: CLAS g13 (black open circles), CLAS g10 (red open pluses), SLAC (blue open triangles), DESY (violet open squares), MAMI-B (cyan open down-triangles), and Frascati (pink open stars); $\pi^- p \to \gamma n$ data: BNL (green open diamonds), LBL (orange closed diamonds), and LAMPF (gray closed circles); fits: SAID MA27 (blue solid lines), SAID PR15 (red dot-dashed lines), BG2014-02 (green dashed lines), and MAID2007 (which terminates at $W = 2$ GeV or $E_\gamma = 1.65$ GeV) (violet dotted lines).

State	Coupl.	SAID Fits Modulus, Phase	PDG 2016 BW
$N(1440)$	$A_{1/2}$	0.065±0.005, 5°±3°	0.040±0.010
$N(1535)$	$A_{1/2}$	-0.055±0.005, 5°±2°	-0.075±0.020
$N(1650)$	$A_{1/2}$	0.014±0.002, -30°±10°	-0.050±0.020
$N(1720)$	$A_{1/2}$	-0.016±0.006, 10°±5°	-0.080±0.050
$N(1720)$	$A_{3/2}$	0.017±0.005, 90°±10°	-0.140±0.065

TABLE I. Moduli (in $(\text{GeV})^{-1/2}$) and phases (in degrees) of the neutron helicity amplitudes $A_{1/2}(n)$ and $A_{3/2}(n)$ from the SAID MA27 solutions compared to the current PDG Breit-Wigner (BW) values.