Helicity Asymmetry E Measurement for Single π^0 Photoproduction with a Frozen Spin Target

Hideko Iwamoto (for the CLAS Collaboration)

The George Washington University, Washington, DC 20052

Abstract. The helicity asymmetry for single neutral pion photoproduction was measured using the CLAS detector in Hall B at the Thomas Jefferson National Accelerator Facility. This measurement used longitudinally polarized protons and circularly polarized photons with photon energis between 0.35 GeV to 2.4 GeV. The target was a frozen-spin butanol (C_4H_9OH) target, polarized at about 85%. The helicity asymmetry E for the $\gamma p \to p\pi^0$ was measured with missing-mass technique at the high statistics of about 12×10^6 events.

The experimental results are compared to three available theoretical predictions, SAID, MAID, and EBAC. The preliminary results are in good agreement with the model calculations at low E_γ energy bins. However, a significant deviation is observed at high energy bins. Therefore, the new data will help to constrain the parameters of the theoretical models.

Keywords: helicity asymmetry, double polarization measurement, baryon resonance
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INTRODUCTION

A large number of excited states of the nucleon have been identified in the energy range of $1 \sim 3$ GeV. These excited states decay strongly to their ground states, and typically have a width in the range of $100 \sim 300$ MeV. Nucleon resonances were mostly found in $N\pi$ scattering and in pion photo- and electroproduction. Strong interactions have only two independent scattering amplitudes corresponding to the isospin $I = \frac{1}{2}$ and $I = \frac{3}{2}$. A few low-lying prominent resonances are visible in the total πN cross section. However, the majority of resonances were found through careful partial wave analysis of the data. This analysis comprises of a partial wave decomposition of the scattering amplitude. Since a unique set of partial wave parameters cannot be extracted from the data alone, it is necessary to apply theoretical constraints of analyticity through dispersion relations. Each partial wave is analyzed using a smoothly varying background term and Breit-Wigner type resonance terms.

Many hadronic experiments were performed since 1960's, and the measurements of the experimental observables evolved from cross section and single-polarization experiments to double-polarization experiments. There are three types of double-spin observables: beam-target, beam-recoil, and target-recoil. These double polarization observables and also single polarization observables can be expressed by helicity amplitudes and partial waves. The helicity amplitudes can be determined without any ambiguity if at least eight carefully selected measurements of these single and double polarization observables are performed [1].

The FROST (FROzen Spin Target) experiment is a double polarization experiment with polarized photon beam and polarized target. The FROST experiments are very important experiments since double polarization observables H, F, G, and E can be obtained.

In this paper, the measurement of the double polarization observable E for the $\gamma p \to \pi^0 p$ using circularly polarized photons and longitudinally polarized protons is reported.

EXPERIMENT

The FROST experiments had been performed with polarized photon beams and a polarized frozen spin butanol target using the Hall-B photon beam facility and the CLAS detector [2]. The photon beam is generated via the bremsstrahlung process from a relativistic electron beam. Free protons in a frozen butanol target were highly polarized via a technique called Dynamic Nuclear Polarization. The measurements cover almost the full polar and azimuthal angular ranges, and a large energy range. With the experiments, a large set of double-polarization observables in pseudoscalar meson (π, η, K) and charged double-pion production are being studied.

The measurement of the observables E and G with longitudinally polarized target using circularly and linearly polarized photon beam was carried out during about 100 days between November 2007 and February 2008. In total more than 10.5 billion events with at least one charged track were recorded. For the observable E, two different energies of electron beams, 1.465 GeV and 2.478 GeV, were used to produce photon beams covering the energy range from 0.35 to 2.35 GeV. The average electron-beam polarization was about 84 %. The polarization of the photon beam depends on the ratio of photon energy to electron energy and the degree of polarization of the incident electrons [3]. The average target polarization was about 85%. An additional carbon target was used to remove the background of bound nucleon reaction from π^0 production because of bound nucleons in the butanol target.

RESULT

The FROST data were reduced for the $\gamma p \to p\pi^0$ channel using the missing-mass technique assuming the two-body reaction $\gamma p \to pX$, where X is the particle hypothesized to be missing. The recoil protons from the butanol target were selected by several cuts and their vertex positions.

Figure 1 shows the missing-mass squared distributions for events from the butanol and carbon targets after the carbon events were scaled. This scale factor was derived from the ratio of events produced in the carbon target to those produced in the butanol target. The differences between the butanol events and the scaled carbon events within the missing-mass squared range $\pm 3\sigma$ might contribute to the helicity asymmetry E for the $\gamma p \to p\pi^0$. This difference within $\pm 3\sigma$ is used to derive a dilution factor.

Helicity asymmetry E is given by the difference of the yields between the total helicity states 3/2 and 1/2,

$$E = \frac{1}{D_f \cdot P_\odot \cdot P_T} \left(\frac{N_{\frac{3}{2}} - N_{\frac{1}{2}}}{N_{\frac{3}{2}} + N_{\frac{1}{2}}} \right), \tag{1}$$

where D_f, $P_\odot$, P_T, and N are the dilution factor, the photon polarization, the target polarization, and the yield for the helicity indicated by the subscript, respectively. Since

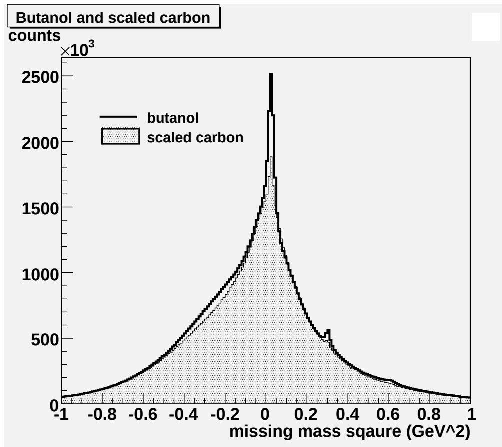

FIGURE 1. Missing-mass squared distribution for $\gamma p \to p\pi^0$ using the missing-mass technique assuming the two-body reaction $\gamma p \to pX$. The carbon yield is scaled and used to describe reactions on bound nucleons in the butanol target. Only the range $\pm 3\sigma$ is studied for the helicity asymmetry E.

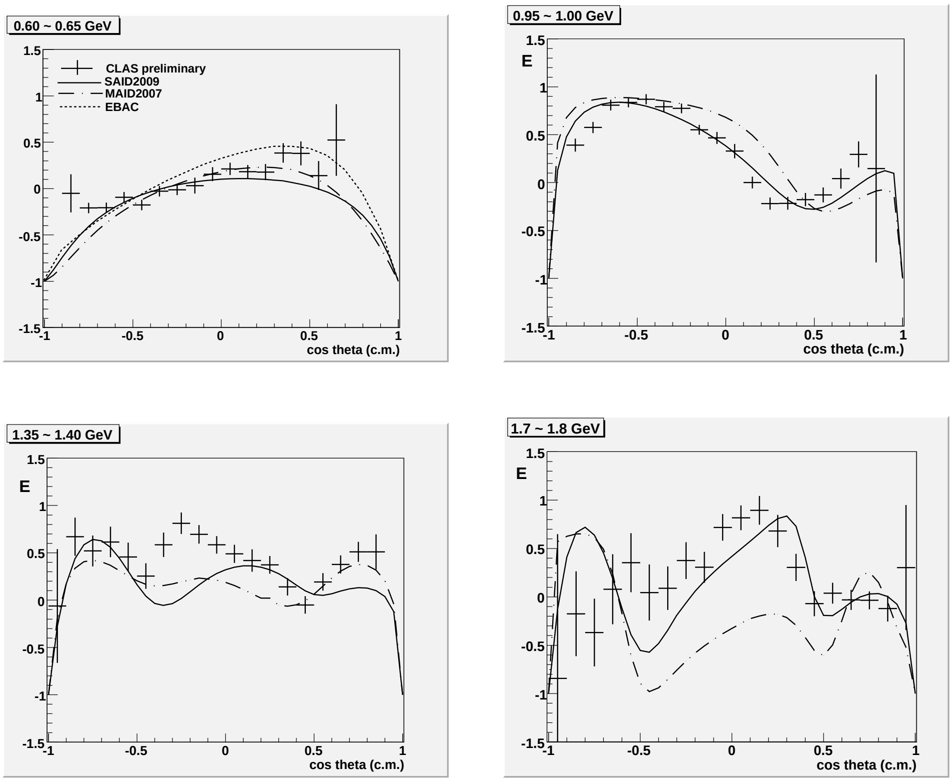

FIGURE 2. Preliminary result of the helicity asymmetry E for the $\gamma p \to \pi^0 p$ reaction for different photon energy ranges. The error indicates the statistical uncertainties of counts. The result is compared with SAID2009, MAID2007, and EBAC predictions.

beam and target polarizations changed during the experiment, run-by-run based polarizations were used for the result. Since the dilution factor depends on proton momentum, different values of dilution factors depending on proton momentum were used.

Figure 2 shows the helicity asymmetry E for different photon energy bins. The result is compared with three theoretical predictions, SAID2009 [4], MAID2007 [5], and EBAC [6] (under E_γ = 900 MeV). The result has a good agreement up to $E_\gamma = 1.35$ GeV with the model calculations. However, a significant deviation is observed above $E_\gamma = 1.35$ GeV especially at the backward pion scattering angle. The helicity asymmetry is very sensitive to various dynamical reaction effects. Thus, the new data will help to constrain the parameters of the theoretical models.

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REFERENCES

1. F. Tabakin, and W. Chiang, *Phys. Rev.* **C55**, 2054–2066 (1997).
2. E. S. Smith, and *et al*., *Nucl. Instr. Meth.* **A503**, 513–553 (2003).
3. L. C. Maximon, and H. Olsen, *Phys. Rev.* **114**, 887 (1959).
4. M. Dugger, and *et al*., *Phys. Rev.* **C79**, 065206 (2009).
5. D. Drechsel, S. Kamalov, and L. Tiator, *Phys. Rev.* **106**, 27–46 (2007).
6. T.-S. H. Lee, A. Matsuyama, and T. Sato, *Phys. Rep.* **439**, 193–253 (2007).