Preliminary results for the helicity asymmetry E for η photoproduction on the proton

B. T. Morrison, M. Dugger, and B. G. Ritchie for the CLAS Collaboration

Arizona State University, Tempe, AZ 85287-1504, USA

Abstract. Polarization observables are an important tool for clarifying the nucleon resonance spectrum. No previous measurements for double polarization asymmetries have been published for η photoproduction. Double polarization measurements have been made at Jefferson Lab using a polarized photon beam and protons in a polarized frozen spin target (FROST). Data were taken during the first running period of FROST using the CLAS detector with photon energies from 0.33 to 2.35 GeV. Preliminary results for the E polarization observable for eta meson photoproduction from the proton at threshold and above, along with comparisons to several theoretical predictions are presented.

Keywords: meson production, photoproduction reactions, polarization in interactions and scattering, partial-wave analysis
PACS: 13.60.Le, 13.88.+e, 11.80.Et, 25.20.Lj

INTRODUCTION

Quark models provide detailed predictions for the nucleon resonance spectrum. However, those theories predict many more resonances than are observed [1]. To clarify the nucleon resonance spectrum, more data on spin observables for photoproduction is necessary. So-called complete experiments require measurements of eight carefully chosen observables: differential cross sections, three single spin observables, and four double polarization observables. A majority of the existing photoproduction data is on unpolarized cross sections and single-spin observables. In particular, there exist no published double polarization asymmetry measurements for η photoproduction. Photoproduction of the η meson from the proton is particularly useful as the η is a relatively light meson, the threshold energy region is dominated by an S_{11} resonance which pins the E asymmetry measurement to nearly 1, and, as an isospin-0 meson, possible resonance couplings are restricted to N^* resonances.

EXPERIMENT

Data for this experiment was collected at Thomas Jefferson National Accelerator Facility (Jefferson Lab) using the CEBAF Large Acceptance Spectrometer (CLAS) [2] in experimental Hall B between November 2007 and February 2008. Longitudinally-polarized electron beams with energies of 1.65 GeV and 2.48 GeV were used in conjunction with the Photon Tagger [3] to produce circularly polarized photons with energies ranging from 0.35 to 2.35 GeV with a polarization value of $\approx 85\%$ for the initial electron. The photon helicity was flipped at a rate of 30 Hz. The frozen spin target (FROST), containing beads of butanol C_4H_9OH, was held at an average proton spin state polarization of $\approx 82\%$ parallel to the beam axis and $\approx 85\%$ anti-parallel to the beam axis. Average target temperature was 30 mK with beam on target. Degradation of target polarization occurred at rates of $\approx 0.9\%$ (parallel) and $\approx 1.5\%$ (anti-parallel) per day. A re-polarization of the target was performed once per week, often coupled with a change in polarization direction. Data was collected simultaneously for the butanol target and a carbon target located 3.5 cm downstream from the butanol target. The carbon target was used to simulate the bound nucleon photoproduction contribution within the butanol. Particle identification was performed using time-of-flight information and reconstructed momentum. A total of 10.1 billion events were recorded with a trigger condition of at least one charged particle detected in CLAS.

RESULTS

Taking into consideration that CLAS is primarily a charged particle detector, five unique charged-particle topologies were selected for studying E for η photoproduction. These topologies are defined in Table 1, from which 2 and 5 were selected for use in this analysis.

TABLE 1. Topologies studied in this work. The reaction is $\gamma + p \rightarrow p + X$ where X is the missing mass of the meson. All values are integrated over $\cos\theta^{X}_{c.m.}$ angles for the missing mass X and summed over both helicities at W=1.50-1.55 GeV.

Topology number	**Requires in addition to a recoil proton**	**Signal-to-background ratio**	**Approximate η events observed** ($\times 10^3$)
1	Anything	1:4	25
2	No other charged particles detected	1:3	25
3	Single charged pion detected	3:5	3
4	Two charged pions detected	6:1	0.6
5	Same as 2 but with 1+ photon(s)	3:1	10

To extract asymmetries, three fits were made to the data. The first set of fits were performed on the combined helicity spectrum from the butanol target using a Gaussian function and a third-order polynomial. The next two sets of fits used the Gaussian centroids and widths from the combined helicity spectrum fit. The scaled carbon histogram, used to subtract the bound nucleon content, also used a third-order polynomial combined with a Gaussian. The subtracted yields for the helicity spectra, using the spin-1/2 minus the spin-3/2 state by convention, were fit with a polynomial plus Gaussian. Example fits can be seen in Fig. 1 for center-of-mass energy W=1.525 GeV.

Preliminary determinations of the asymmetry E at threshold for η photoproduction were made using the equation

$$E = \frac{1}{P_{\circ} \cdot P_t \cdot f_d} \cdot \frac{N_{\frac{1}{2}} - N_{\frac{3}{2}}}{N_{\frac{1}{2}} + N_{\frac{3}{2}}} \tag{1}$$

where $P_{\circ}$ [5] is the beam polarization factor, P_t is the target polarization, f_d is the dilution factor, N is the yield for the helicity indicated by the subscript, and the subscripts

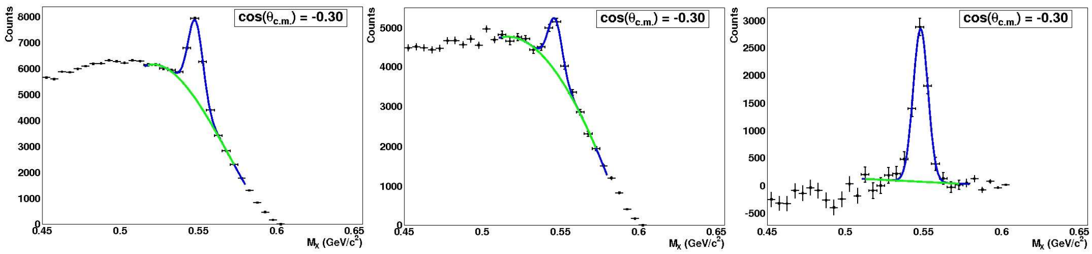

FIGURE 1. Sample fits for topology 2 at $\cos\theta^{\eta}_{c.m.} = -0.3$ and W = 1.525 GeV. Shown from left to right are the combined helicity spectrum fit, the scaled carbon fit, and the subtracted helicity spectrum fit.

represent spin-1/2 and spin-3/2 states. Plots for the topologies 2 and 5 can be seen in Fig. 2. Fitting each plot with a zeroth-order polynomial gives 1.02 ± 0.04 (left) and 0.98 ± 0.04 (right). A value of unity is expected due to the dominance of the $S_{11}(1535)$ resonance, confirming that the methodology used is reliable.

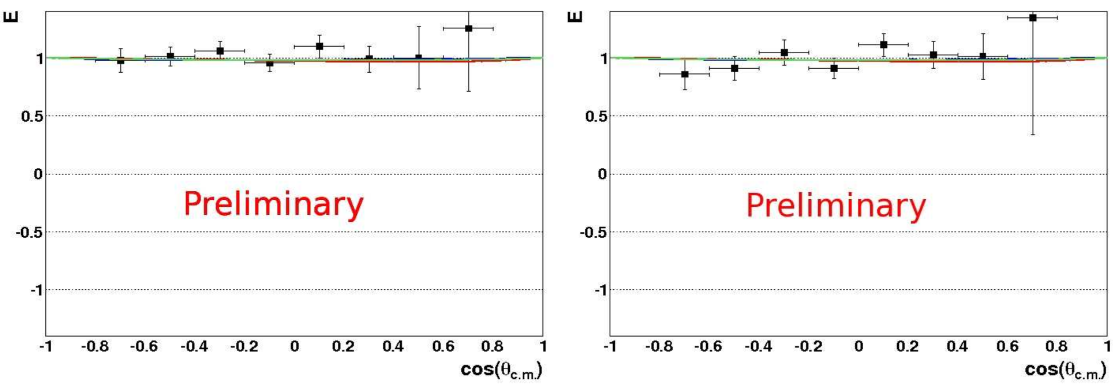

FIGURE 2. E asymmetry for η photoproduction at W=1.525 GeV using topology 2 (left) and 5 (right). The curves from SAID [7], η-MAID [6], and Bonn-Gatchina [8] are all shown but are virtually indistinguishable because of the dominance of the S_{11} resonance.

With reasonable results at threshold energy for η photoproduction, preliminary estimates of the helicity asymmetry E at energies beyond threshold have been made using Eq. 1 with comparisons to theoretical predictions. These theoretical predictions are an isobar model (η-MAID [6]) and two partial wave analyses (SAID [7] and Bonn-Gatchina [8]). Shown in Fig. 3 are the excitation plots for individual $\cos\theta^{\eta}_{c.m.}$ bins.

CONCLUSIONS

The preliminary values obtained at threshold confirm that the methodology used is sound, and values for E in η photoproduction should be obtainable up to 1.925 GeV in W. Preliminary results show more structure than predicted by η-MAID and Bonn-Gatchina. Final results from this experiment will help clarify the nucleon resonance spectrum.

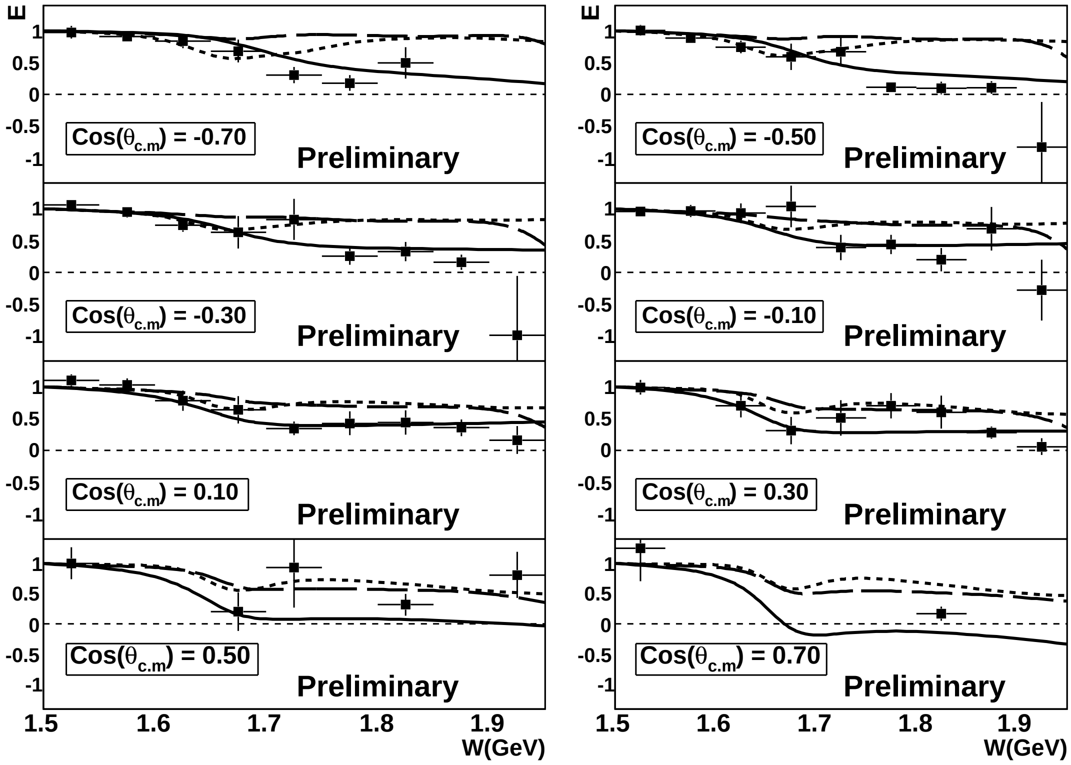

FIGURE 3. Preliminary E asymmetry for energies W=1.525-1.925 GeV. Curves for η-MAID (dotted line), the Bonn-Gatchina analysis (dashed line), and SAID (solid line) are shown.

ACKNOWLEDGMENTS

Work supported in part by the U.S. National Science Foundation under award PHY-0969201. Jefferson Science Associates operates the Thomas Jefferson National Accelerator Facility under DOE contract DE-AC05-06OR23177.

REFERENCES

1. S. Capstick, and W. Roberts, *Progress in Particle and Nuclear Physics.* **45**, 2000, pp. S241-S331.
2. B. A. Mecking, et al., *Nucl. Instrum. Meth.* **A503**, 2003, pp. 513-553.
3. D. Sober, et al., *Nucl. Instrum. Meth.* **A440**, 2000, pp. 263-284.
4. E. Pasyuk, *CLAS Analysis Note* 2007-2008, `http://www1.jlab.org/ul/Physics/HallB/clas/public/2007-008.pdf`.
5. H. Olsen, and L. C. Maximon, *Phys. Rev.***114**, 1959, pp. 887-904.
6. W. T. Chiang, S. N. Yang, L. Tiator, M. Vanderhaeghen and D. Drechsel, *Phys. Rev. C* **68**, 2003, 045202.
7. E. F. McNicoll, et al. [Crystal Ball Collaboration at MAMI], *Phys. Rev. C* **82**, 035208 (2010)
8. A. V. Anisovich, E. Klempt, V. A. Nikonov, M. A. Matveev, A. V. Sarantsev and U. Thoma, *Eur. Phys. J. A* **44**, 2010, pp. 203-220.