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Preliminary Results of T and F Asymmetries for η Photoproduction from the Proton

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We present preliminary data for the T and F asymmetries in η photoproduction from the proton, along with comparisons to theoretical predictions. The data used in the present analysis were taken using the CEBAF Large Acceptance Spectrometer (CLAS) at Jefferson Lab, a cryogenic target which utilized transversely polarized protons in a butanol target, and incident tagged photons with energy between 0.62 and 2.93 GeV.

Keywords: helicity observables; eta photoproduction; polarized target

1. Introduction

Untangling baryon spectra is nontrivial, as there are many broad overlapping states. In addition, quark models and lattice QCD simulations generally predict more resonances than are experimentally observed. Therefore, measurements of the cross section alone are not sufficient to untangle the excited states. We present preliminary results for two polarization observables for η photoproduction from the proton. Improved understanding of different observables will aid in the identification of nucleon resonances. The pseudoscalar nature of the η also eliminates contributions from Δ ($I=3/2$) excitations.

The T and F polarization observables may be obtained with a circularly polarized photon beam incident on a transversely polarized target. These observables modulate the unpolarized cross section as

$$\frac{d\sigma}{d\Omega} = \frac{d\sigma}{d\Omega_0} (1 + P_T T \sin \varphi + P_T P_\gamma F \cos \varphi), \quad (1)$$

where the subscript 0 indicates the unpolarized cross section, P denotes the degree of beam (P_γ) or target (P_T) polarization, and φ is the angle between the target polarization plane and the reaction plane.

2. Experimental Setup

During the running period, tagged polarized photon beams with energy between 0.62 and 2.93 GeV were produced at Jefferson Lab using the CEBAF electron beam by

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means of bremsstrahlung from a thin radiator in experimental Hall B. The energies of the post-bremsstrahlung electrons were measured on the trigger focal plane. This determines the energies of the photons incident on the target.

The FROST target consisted of a sample of butanol held at 30 mK in a helium dilution refrigerator. Dynamic nuclear polarization is employed to polarize the constituent protons in the hydrogen content of the butanol. The typical polarization fraction for the hydrogen content in the butanol was 85%¹. A carbon secondary target for bound-nucleon background subtraction was located downstream of the butanol target.

Final state particles were detected in the CLAS, a charged particle detector with a toroidal magnetic field. Drift chambers were used for tracking and momentum determination and a scintillator-based time-of-flight system aided in particle identification.

3. Analysis

The η meson was reconstructed via the missing mass technique by using the momentum information on the charged recoiling particle in CLAS. The bound-nucleon background was removed by subtracting the signal from the butanol target from the signal from the carbon secondary target, weighted by a scale factor. The scale factor was obtained by taking a ratio of carbon and butanol signals with kinematics which correspond to bound-nucleon events. Scale factors were binned in proton scattering angle θ and momentum \mathbf{p} .

Observables were extracted in 50 MeV center-of-mass energy W bins and variable-width center-of-mass production polar angle $\cos\theta_{cm}$ bins. Extraction of T and F was performed by a Fourier-moment analysis of the yield, normalized for photon flux.² The moment method encompasses effects related to detector efficiency, and allows the simultaneous fitting of all data in the angular range for the given W bin. Photon flux was estimated by integrating all π^+ events from the (amorphous) carbon target. Events were weighted by moments as they were binned, resulting in a set of normalized yields, Y_{moment} . By combining runs with different polarization signs, we can extract preliminary estimates of the observables in equation (1). We obtain

$$T = \frac{2 \left(Y_{\sin\varphi}^+ - Y_{\sin\varphi}^- \right)}{|P_T^-| \left(Y^+ - Y_{\cos 2\varphi}^+ \right) + |P_T^+| \left(Y^- - Y_{\cos 2\varphi}^- \right)} \quad (2)$$

and

$$F = \frac{2 \left(X_{\cos\varphi}^+ - X_{\cos\varphi}^- \right)}{|P_T^- P_\gamma^-| \left(X^+ + X_{\cos 2\varphi}^+ \right) + |P_T^+ P_\gamma^+| \left(X^- + X_{\cos 2\varphi}^- \right)} \quad (3)$$

where the superscript indicates the orientation of the target polarization (for the T expression) or the orientation of the target polarization times the sign of the photon helicity (for the F expression), Y_{moment} indicates the normalized η yields which were

weighted by the indicated moment of φ , and $X^\pm = \frac{|P_T^+ P_T^-|}{|P_T^+| + |P_T^-|} (Y^{\pm+} + Y^{\pm-})$ where now the second superscript indicates the sign of the photon helicity and the moment subscript has been omitted for clarity.

4. Results

Figure 1 shows our results for T , shown with previously published data³ and phenomenological fits^{4–6} not yet constrained by our measurements. Figure 2 shows our results for F along with the same fits as in figure 1. There are no published measurements for F in the world database. In general, these preliminary data for T agree best with the MAID analysis and the new F asymmetry data are in fair agreement with the SAID model and less so with the MAID and BG models. These data should provide important information in improving these analyses. The preliminary results shown represent only part (50%) of the data collected in our experiment. Our final results will use all of the data. Additionally, analysis of systematic uncertainties is in progress and will be included.

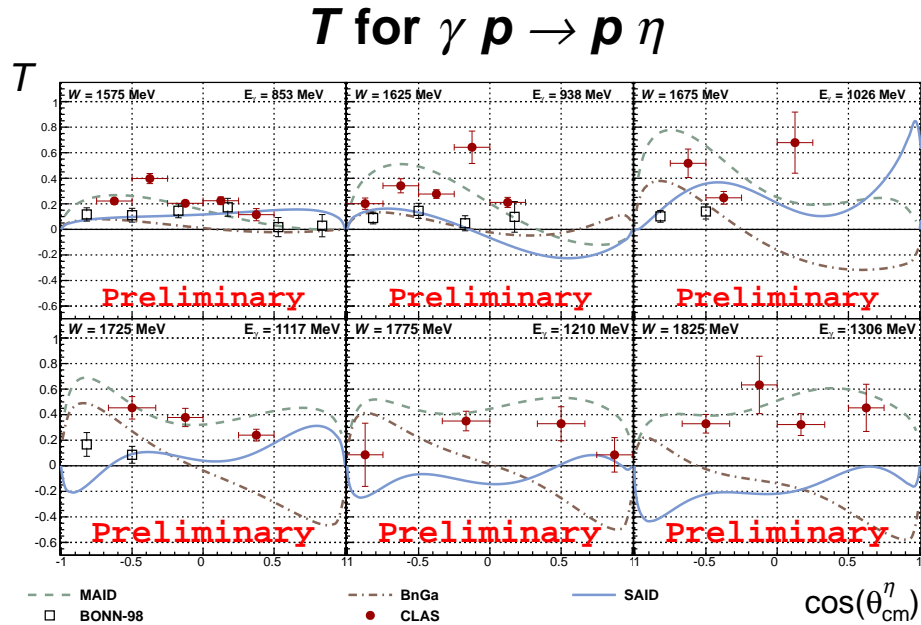


Fig. 1. Preliminary values of the T observable as a function of polar angle $\cos\theta_{cm}^\eta$ at different center-of-mass energies W and photon energies E_γ labeled on each panel. Filled circles are the CLAS results and the open squares represent previously published data from Bock *et al.* [3]. Curves represent predictions made by phenomenological fits, where the solid lines are from SAID [6], the dashed lines are from MAID [5], and the dash-dotted lines are from Bonn-Gatchina [4].

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5. Conclusion

The preliminary results for F and T presented here will extend coverage of the world database of these reactions. There are currently only 38 published measurements of T and none of F . Existing predictions for these observables describe the data somewhat but much improvement will be facilitated by inclusion of these data by providing important constraints to those fits.

Acknowledgments

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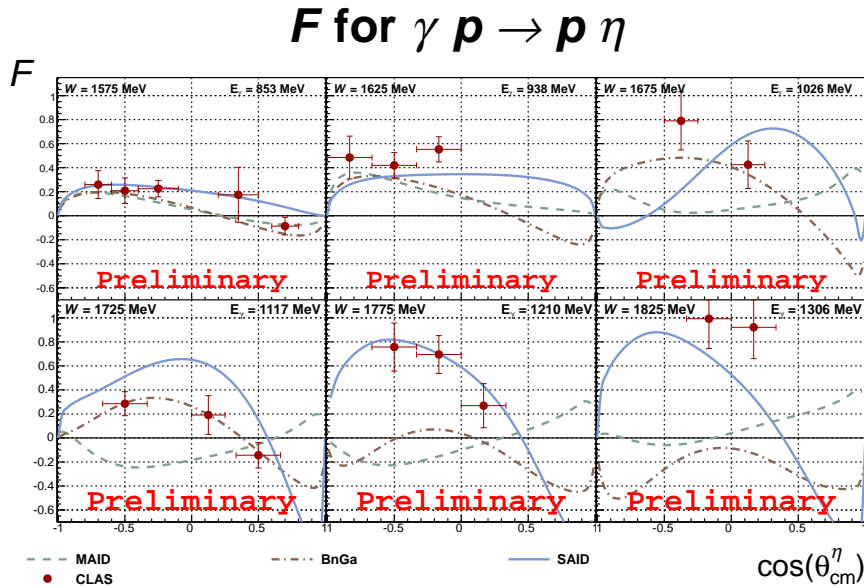


Fig. 2. Preliminary values of the F observable as a function of polar angle $\cos\theta_{cm}^{\eta}$ at different center-of-mass energies W . Filled circles are the CLAS results. Curves represent predictions made by phenomenological fits, where the solid lines are from SAID [6], the dashed lines are from MAID [5], and the dash-dotted lines are from Bonn-Gatchina [4].