The Target Asymmetry P_z in $\gamma\vec{p} \to p\pi^+\pi^-$ with the CLAS Spectrometer at Jefferson Laboratory

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Abstract. The study of baryon resonances provides a deeper understanding of the strong interaction because the dynamics and relevant degrees of freedom hidden within them are reflected by the properties of the excited states of baryons. Higher-lying excited states at and above 1.9 GeV/c^2 are generally predicted to have strong couplings to the $\pi\pi N$ final states via $\pi\Delta$ or ρN intermediate states. Double-pion photoproduction is therefore important to find and investigate properties of high-mass resonances. The CLAS g9a (FROST) experiment, as part of the $N^\star$ spectroscopy program at Jefferson Laboratory (JLab), has accumulated photoproduction data using linearly- and circularly-polarized photons incident on a longitually-polarized butanol target in the photon energy range 0.3 to 2.4 GeV. In this contribution, the extraction of the target asymmetry for the reaction $\gamma\vec{p} \to p\pi^+\pi^-$ will be described and preliminary results will be presented.

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INTRODUCTION

Effective theories and models have been developed to better understand the properties of baryon resonances. Various constituent quark models (CQMs) are currently the best approach to make predictions for parameters of the baryon ground state and its excited states. However, the predictions made by these models do not match accurately the states measured by experiment, especially at high energies. These models predict many more resonances than have been observed, leading to the so-called "missing resonance" problem. The latest results in baryon spectroscopy suggest that 3-body final states are very likely to be the key for discovery of the higher-lying unobserved resonances. Especially, the photoproduction of double-pion final states [1] may give us very useful data to investigate many high-mass resonances because their cross sections dominate above $W \approx 1.9$ GeV ($E_\gamma \approx 1.46$ GeV). Quark models predict $\gamma N \to N^\star \to \Delta\pi \to N\pi^+\pi^-$ and $\gamma N \to N^\star \to N\rho \to N\pi^+\pi^-$ as dominant resonant decay modes leading to $\gamma p \to p\pi^+\pi^-$. However, these modes are difficult to detect because detectors with a large angular acceptance are needed and a large non-resonant background contributes to these decay modes.

FROST EXPERIMENT AT JLAB

Experimental Hall B at JLab provides a unique set of experimental devices for the FROST experiment. The CEBAF Large Acceptance Spectrometer (CLAS) [2] housed in Hall B is a nearly-4π detector. The bremsstrahlung tagging technique, which is used by the broad-range photon tagging facility at JLab [3], can tag photon energies over a range from 20% to 95% of the incident electron energy and is capable of operation with beam energies up to 5.5 GeV. The remaining element which is indispensable for the double polarization experiment is a frozen-spin target [4]. The FROST target uses butanol with an effective dilution factor of approximately 13.5% as the target material. This material is cooled to approximately 0.5 K and dynamically polarized outside the spectrometer using a homogeneous magnetic field of about 5.0 T. Once polarized, the target is then cooled to a low temperature of 30 mK, enough to preserve the nuclear polarization in a more moderate holding field of about 0.5 T. The target is then moved back into the spectrometer, and data acquisition with the tagged photon beam can commence. The experiment described here was conducted from November 2007 - February 2008. In this experiment, the target polarization was longitudinal with linearly- and circularly-polarized photons. The photon energy range covered 0.5 - 2.3 GeV. The trigger required at least one charged particle in CLAS. In addition to the polarized butanol target, the experiment also used carbon and polyethylene targets downstream. They are useful for various systematics checks and for the determination of the shape of the background from bound nucleons in butanol.

PREVIEW OF THE DATA

For the reaction $\gamma p \to p\pi^+\pi^-$ without measuring the polarization of the recoiling nucleon, the differential cross section is given by:

$$\frac{d\sigma}{d\Omega} = \sigma_0 \Big\{ \Big(1 + \vec{\Lambda}_i \cdot \vec{P}\Big) + \delta_\odot \Big(I^\odot + \vec{\Lambda}_i \cdot \vec{P}^\odot\Big) + \delta_l \Big[\sin 2\beta \left(I^s + \vec{\Lambda}_i \cdot \vec{P}^s\right) + \cos 2\beta \left(I^c + \vec{\Lambda}_i \cdot \vec{P}^c\right)\Big] \Big\}$$

where $\vec{P}$ and I represent the polarization observables arising from use of polarized target and beam, respectively. $\vec{\Lambda}_i$ denote the polarization of the initial nucleon. $\delta_\odot$ is the degree of circular polarization in the photon beam, while δ_l is the degree of linear polarization, with the direction of the polarization being at an angle β to the x-axis (Fig. 1). There are 15 observables which can be measured in the experiment.

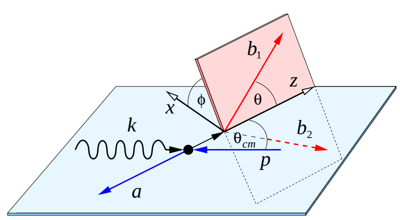

FIGURE 1. Decay angles in a 3-particle final state: a means the recoil proton, b_1 and b_2 denote the π^+ and π^-. θ and ϕ denote the polar and azimuthal angle of b_1 (π^+) in the rest frame of b_1 and b_2.

In addition to the target asymmetry, a preliminary analysis of the beam asymmetry, I^s, in the reaction $\vec{\gamma}p \to p\pi^+\pi^-$ was done. To check the status of the current analysis, we compare the polarization observable I^s from the FROST experiment with other data [6]. The overall shapes of both show very nice consistency. For this analysis, selected events were binned in photon energy, $\cos\theta_{\pi^+}$ and ϕ_{π^+} described in Fig. 1.

In each bin, the measured asymmetry is determined by:

$$A = \frac{\left\{N(\to\Rightarrow)+N(\leftarrow\Rightarrow)\right\} - \left\{N(\to\Leftarrow)+N(\leftarrow\Leftarrow)\right\}}{\left\{N(\to\Rightarrow)+N(\leftarrow\Rightarrow)\right\} + \left\{N(\to\Leftarrow)+N(\leftarrow\Leftarrow)\right\}} \quad ,$$

where the N terms indicate the number of events for the different polarization configuration. To determine the target asymmetry, P_z, the raw asymmetry was corrected by the target polarization, Λ_z, and the effective dilution factor, f [5]. The equation is given by:

$$P_z = \frac{1}{\Lambda_z \cdot f} \cdot A$$

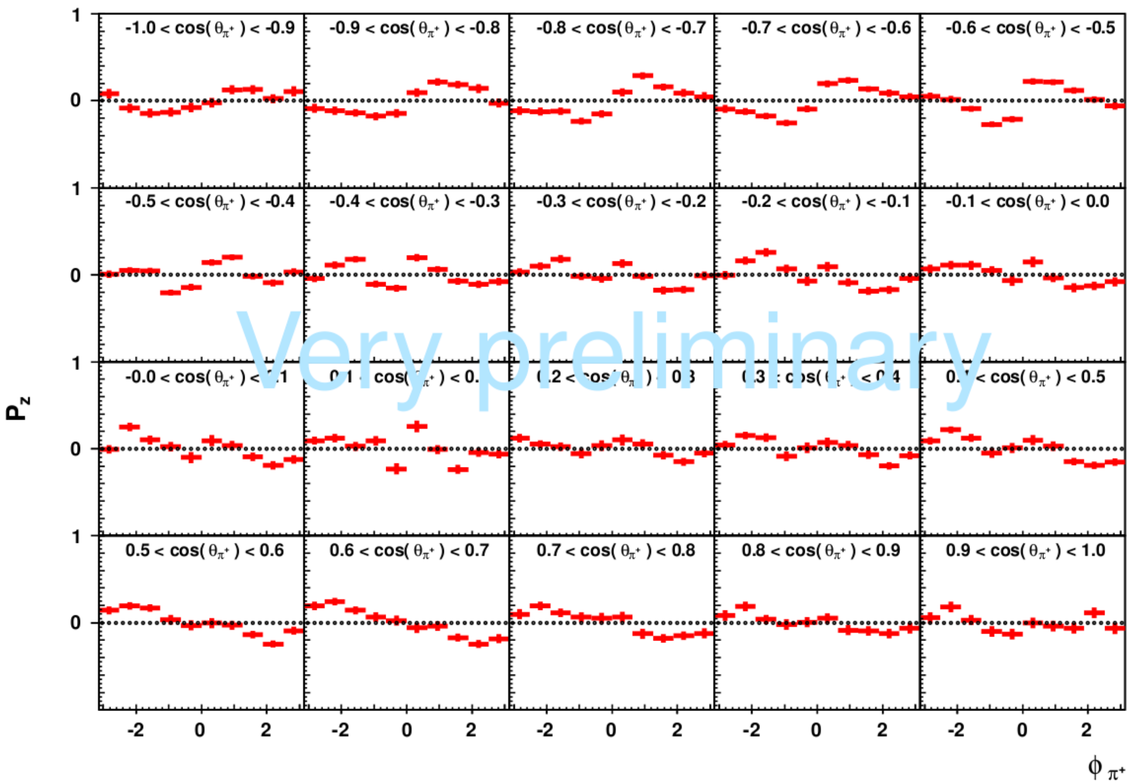

FIGURE 2. Polarization observable P_z for $E_\gamma \in [1.0, 1.1]$ GeV. The shown errors are statistical only.

In FROST, only the hydrogen nucleons of the butanol are polarized longitudinally. That is, the carbon and oxygen nucleons in the butanol target remain unpolarized. The dilution factor is defined as the ratio between the hydrogen and the full butanol contribution to the cross section. At this stage of the analysis, preliminary estimates of the target polarization and the dilution factor are used for correction. Preliminary results for the target asymmetry for $\pi^+ \pi^-$ photoproduction are presented in Fig. 2. The asymmetry shows a sinusoidal shape for $-1.0 < \cos\theta_{\pi^+} < -0.5$. As $\cos\theta_{\pi^+}$ progresses, this shape disappears, and then reappears in a reversed form once $\cos\theta_{\pi^+} > 0.5$. Even at this early stage of the analysis, this behavior of the asymmetries can be observed.

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