Measurements of spin observables in single pion photo-production from polarized quasi-free neutrons in solid HD

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Abstract Psuedo-scalar meson photo production measurements have been carried out with longitudinally-polarized neutrons using the circularly and linearly polarized photon beams and the CLAS at Thomas Jefferson National Accelerator Facility (Jlab). The experiment aims to obtain a complete set of spin observables on an effective neutron target using D in HD. Preliminary E and Σ asymmetries for the exclusive reaction, γ + n(p) $\rightarrow \pi^-$ + p(p), are discussed.

KEYWORDS: polarized neutron, photo-production, spin, HDice, CLAS

1. Introduction

The g14 experiments were performed from December 2012 to May 2013. Data used for this analysis were taken with circularly (21 days and 4.1 10^9 trigger events) and linearly polarized (30 days and 3.7 10^9 trigger events) photon beams whose energy ranged from 0.85 to 2.4 GeV and 1.3 to 2.3 GeV, respectively.

Frozen-spin Hydrogen Deuteride (HD) targets [1] were successfully used to access longitudinally polarized quasi-free neutron targets in Hall B measurements at the Thomas Jefferson National Accelerator Facility (Jlab). The HD In-Beam Cryostat (IBC) inserted into CEBAF Large Acceptance Spectrometer (CLAS) was designed and constructed by the HDice group at Jlab. Its dilution refrigerator cooled down targets to 50 mK at the mixing chamber and a superconducting magnet maintained a longitudinal holding field of 1 T. The target polarizations were calibrated in a separate production dewar and monitored by NMR in the IBC. The average D polarizations in HD were about 26% and 25% during experiments with the circularly and linearly polarized photon beams, respectively, and the relaxation time for D was measured to be more than one year for the run periods in this analysis.

E asymmetries were measured with circularly polarized photon beams off longitudinally polarized HD targets, while Σ ones were obtained from the single spin linearly polarized beam asymmetries. Preliminary results are shown.

2. Data reductions

To obtain the E asymmetries, the following corrections, cuts and background subtraction were applied to select quasi fee neutron reactions for γ + n (p) $\rightarrow \pi^-$ + p (p); for the Σ asymmetries the missing momentum cut and background subtraction were not applied.

For the calculations of the E asymmetries, the following six are applied,

(1) π^- and proton were identified using the correlation between the velocity beta, calculated from the time of flight measurement, and the particle momentum, measured by the drift chamber in the CLAS torus. The events in which only one π^- and one proton were identified were selected.

(2) Three sets of corrections were applied:(i) the photon beam energy correction on the tagger;(ii) the energy losses of the produced charged particles passing through the materials surrounding the target (like the radiation shields) were considered and (iii) the momenta corrections coming from the imperfections of the drift chamber and torus magnetic fields were performed.

(3) Events in which azimuthal angle difference between the proton and the π^- is within 180 ± 20 degrees were selected.

(4) The missing mass squared of the spectator proton was constructed for the reaction, $\gamma + D \rightarrow \pi^- + p + X$ and events were selected for which the squared value of the missing mass is below 1.1 GeV^2.

(5) A missing momentum cut for the reaction, $\gamma + n(p) \rightarrow \pi^- + p(p)$ (≤ 0.1 GeV) has been carried out to select quasi-free neutrons.

(6) The background contribution (target cell and thin pure Aluminum cooling wires [1]) is obtained by taking data with an empty target cell, and the subtraction of the selected empty target events, scaled by the incoming photon fluxes, is used to extract a pure HD contribution [2].

3. Preliminary results

3.1 E asymmetries with circularly polarized photon beams

The preliminary E asymmetries vs cos θ_{π^-} calculated in the center of mass of the reaction, for total energies W = 1.5 and 1.9 GeV are shown in Figure 1 (a) and (b). Two partial wave analysis (PWA) predictions are shown as solid and doted curves for SAID(CM12) [3] and BG(2011-02) [4], respectively.

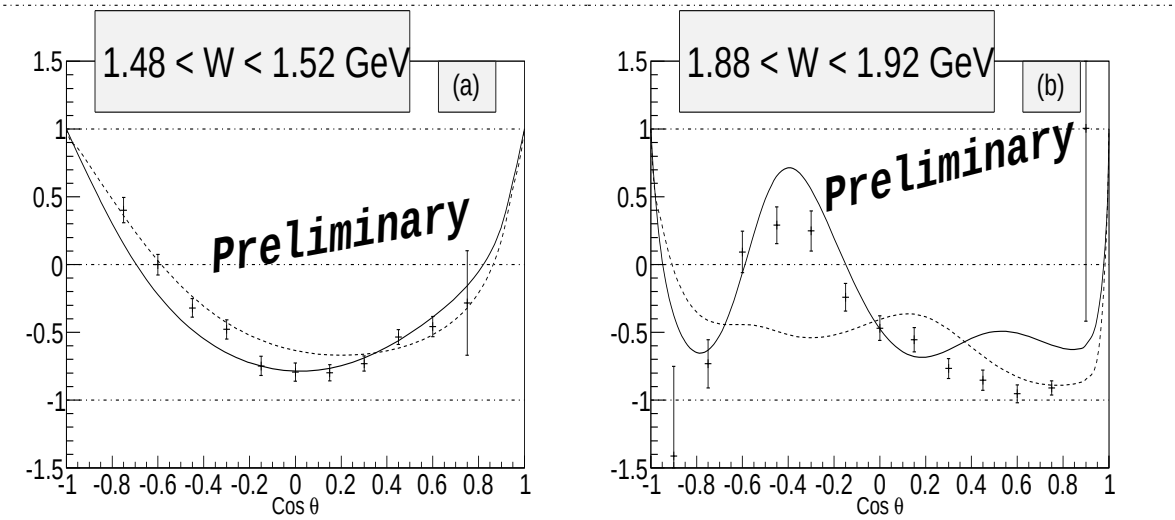

Fig. 1. Preliminary E asymmetries are plotted as a function of cos θ_{π^-} in the CM frame for (a) 1.48 ≤ W ≤ 1.52 GeV and (b) 1.88 ≤ W ≤ 1.92 GeV. Two PWA predictions are shown for AID(CM12) [3] (solid) and BG(2011-02) [4] (dotted).

In Figure 2, E asymmetries vs cos θ_{π^-} for twenty-one W bins, ranging from 1.5 (left top) to 2.3 GeV (left bottom) are shown with two PWA prediction curves in solid: SAID(CM12) [3] and dotted: BG(2011-02) [4]).

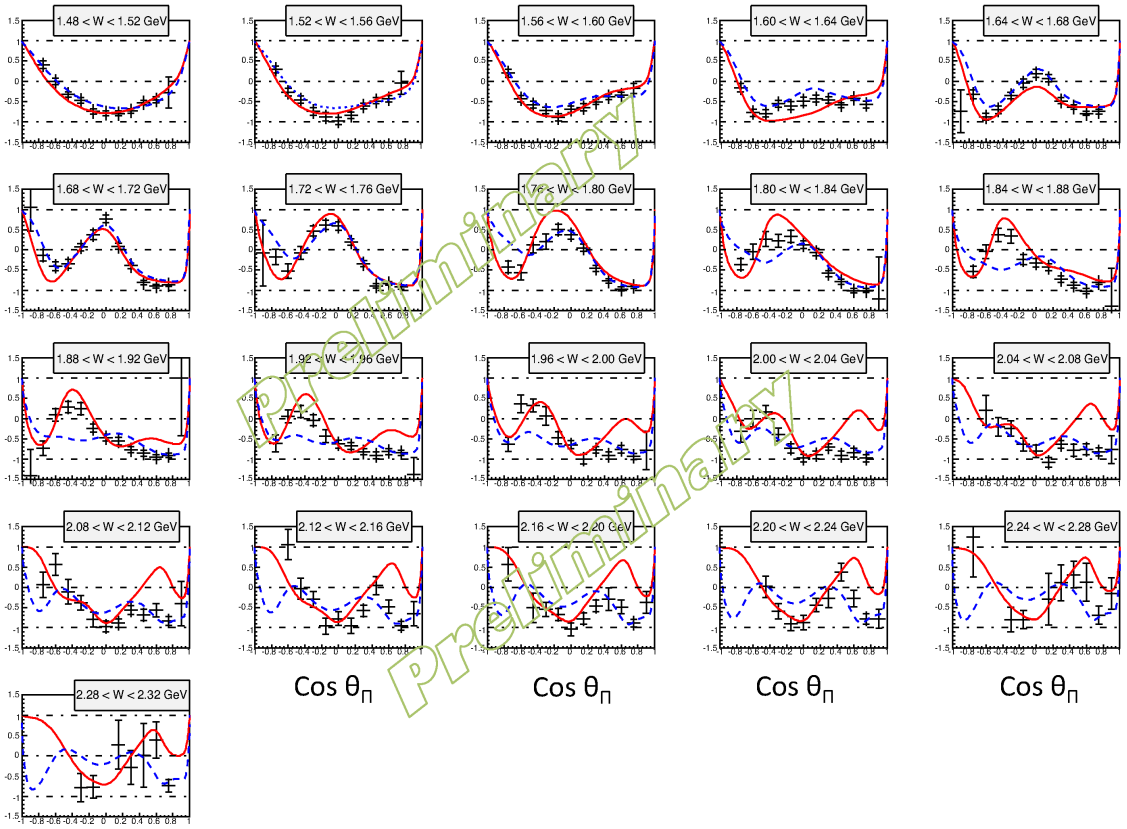

Fig. 2. Preliminary exclusive E asymmetries as a function of cos θ_{π^-}. The figures cover twenty-one W ranges from 1.5 (top left) to 2.3 GeV (bottom left). Only statistical errors are shown. Two PWA analysis predictions are shown for SAID [3](solid curve) and BG [4](dotted curve).

3.2 Σ asymmetries with linearly polarized photon beams

From four combinations of target (parallel and anti-parallel to the longitudinal field) and beam (parallel and perpendicular) polarizations, very preliminary Σ asymmetries are obtained; the missing momentum cuts and background subtraction have not been applied to this analysis. Figure 3 (a) shows the product of the Σ beam asymmetry, the linear photon degree of polarization, and cos(2ϕ) vs the azimuthal angle ϕ for one of the cosine (θ) bins. The angles refer to the π^- detected by CLAS. The curve is a fit of the distribution to a cosine (2ϕ) function. Σ asymmetries are extracted from the fit on each bin of cosine (θ) for three different runs and are shown in Figure 3 (b) for photons scattered in the coherent Bremsstrahlung peak at 1.8 GeV (1.3 $\leq$ E_γ $\leq$ 2 GeV), while Figure 3 (c) and (d) show the Σ asymmetries whose coherent peaks are at 2 GeV (1.6 $\leq$ E_γ $\leq$ 2.1 GeV) and 2.2 GeV (1.8 $\leq$ E_γ $\leq$ 2.3 GeV), respectively.

4. Summary

Double spin polarization experiments with a quasi free neutron have been carried out in Hall B at Jlab using polarized photon beams, CLAS and frozen spin HD solid targets. Preliminary exclusive E and Σ asymmetries are shown.

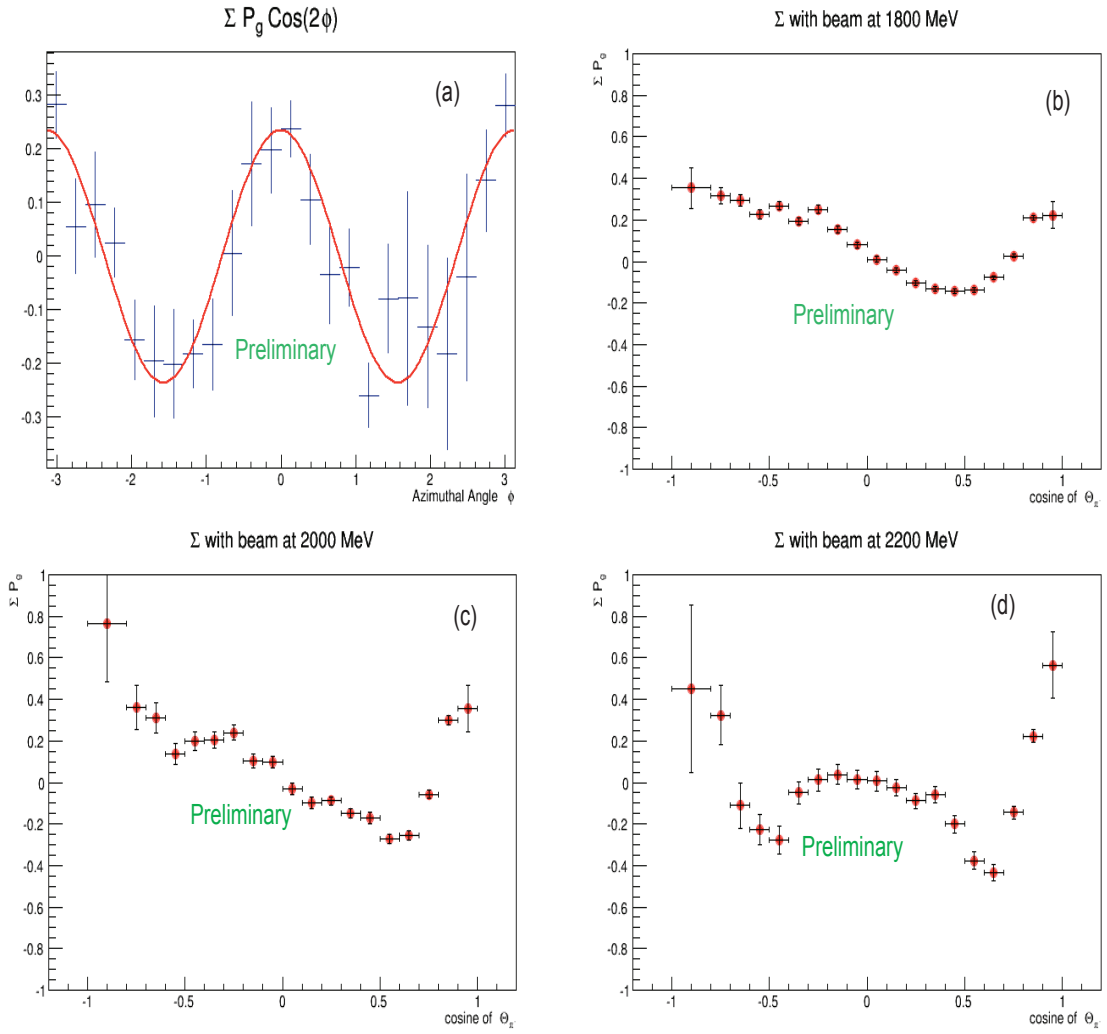

Fig. 3. Preliminary exclusive Σ asymmetries. (a) top left: an example of the product of the Sigma asymmetry to the beam polarization degree and cosine(2ϕ) distribution vs the azimuthal angle ϕ for one of the cosine (θ) bins. The angles are for π^- detected in CLAS. The curve is a fit to a function of ϕ. (b) Top right: Σ asymmetries vs cosine (θ) extracted from the fit on ϕ. This data set has a coherent peak at 1.8 GeV, while (c) bottom left and (d) bottom right figures show the asymmetries whose coherent peaks are at 2 GeV and 2.2 GeV, respectively.

References

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