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Measurements of spin observables in pseudoscalar-meson photoproduction using polarized neutrons in solid HD

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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 efficient neutron target. Preliminary E asymmetries for the exclusive reaction, γ + n(p) $\rightarrow \pi^-$ + p(p), selecting quasi free neutron kinematics are discussed.

Keywords: spin; quark-model; HD.

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1. Introduction

We aim to search for the missing resonances predicted by quark models based on QCD that have not been observed experimentally. The resonances overlap each other due to their widths and some are not coupled strongly to channels for which partial wave analyses have been performed in the past. Lattice calculations have recently supported the long-standing quark model predictions of many resonance states which are missing experimentally[1].

The I = 3/2 Δ resonances can be determined either from proton or neutron data alone. In order to study N* states with I = 1/2, both data from the proton and the neutron are required. The data for the neutron are very sparse. The g14 experiment in Hall-B was performed from December 2011 through May 2012 to observe a large number of spin observables for polarized neutrons in the deuteron using HD solid targets with circularly and linearly polarized photon beams[2]. The data are expected to greatly improve partial wave analyses.

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2. Data reductions and preliminary results for γ + n(p) $\rightarrow \pi^-$ + p(p)

Data were taken with circularly polarized beams (64 days of 11x10^9 events) and linearly polarized photons (30 days of 4x10^9 events) whose energy ranged from 0.85 to 2.4 GeV and from 1.6 to 2.2 GeV, respectively.

Frozen-spin Hydrogen Deuteride (HD) targets[3] were successfully used as polarized neutron targets in the measurements in Hall B. The HD In-Beam Cryostat inserted into 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 holding field of 1 T. The average D polarization in HD was about 20% for the entire run period, monitored by NMR and its spin relaxation time was observed to be more than a year during the data taking.

For the exclusive reaction measurements, particle identification for charged particles has been carried out using β versus momentum distributions to select events in which one π^- and one proton were detected in the CLAS. In order to select quasi free neutron events, the following three distributions have been made and cuts applied. In Figure 1(a), an azimuthal angle difference between π^- and proton events is shown to have a peak at around 180 degrees where the quasi free neutron events are located. Cuts are applied between 160 and 200 degrees as indicated by the shaded area. A missing-mass-squared distribution for γ + n(p) $\rightarrow \pi^-$ + p + X is shown in Figure 1(b). The clear peak at around zero is observed; the peak at around 0.03 GeV^2 could be mainly from two pion events and the tail to the left from other background events. A cut has been applied to select the shaded area, as shown in the figure. The missing momentum distribution for the reaction is shown in Figure 1(c). A dashed curve shown in Figure 1(c) based on P_N from Hamada-Johnson NN potential[4] reproduces the data shape which suggests that our cuts are appropriate. A cut has been applied to select the missing momentum to be lower than 0.2 GeV to minimize final-state interactions.

The background contribution from the target cell, which includes pure thin aluminum cooling wires, is obtained by taking data with only the target cell, and its subtraction is used to extract a pure HD contribution. Figure 1(d) shows the reconstructed vertex distributions; the pure HD (solid curve) can be obtained by subtracting the target cell (dashed dotted curve) from the full target (HD and target cell-dashed curve), where the distribution from the target cell has been normalized to the flux. The vertex cut as shown in the same figure as shaded area between two arrows has been applied for this purpose.

Preliminary exclusive E asymmetries, after the above cuts, using circularly polarized photon beams on longitudinally polarized neutrons ($\sim$ 10% of the data) are shown in Figure 2 for the reaction, γ + n(p) $\rightarrow \pi^-$ + p(p). Significant asymmetries are observed. Only statistical errors are shown and their sizes will be decreased as CLAS calibrations proceed and more data are combined. In the same figure, predictions from SAID (SN11)[5] and MAID[6] are shown with solid and dashed curves,

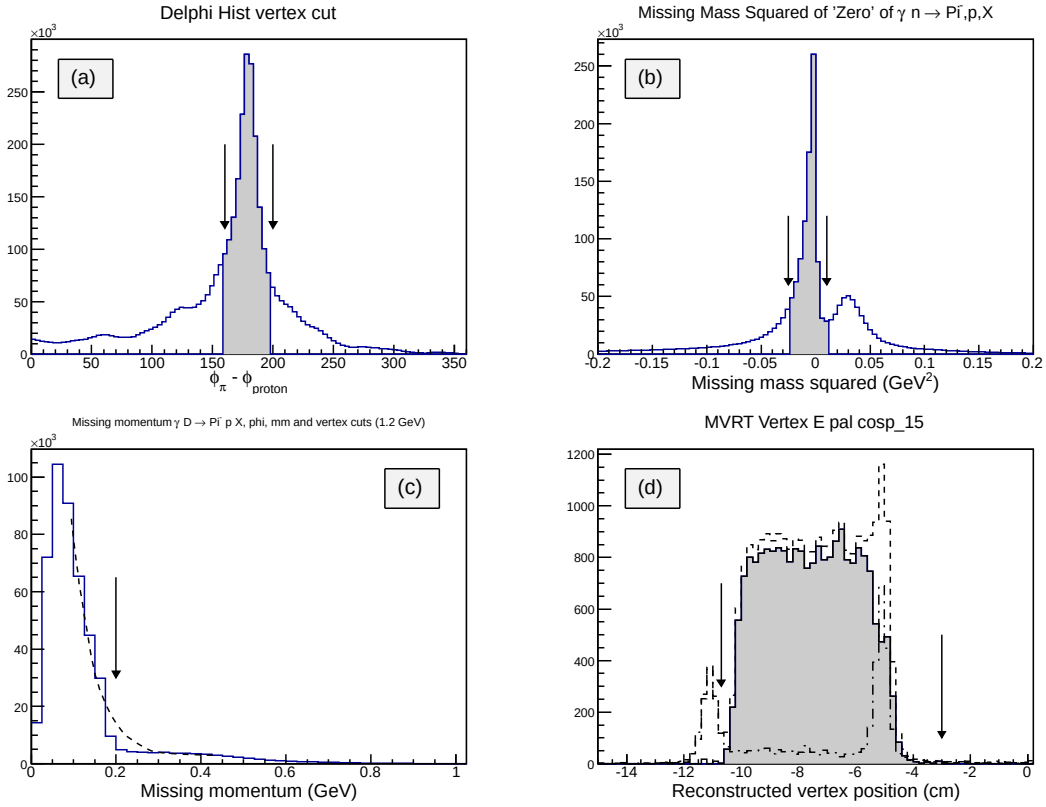

Fig. 1. Data reductions to extract quasi free neutron reactions; (a) co-planarity requirement from the azimuthal angle difference between π^- and proton; (b) missing-mass-squared distribution and cut; (c) missing momentum and cut. The distributions are from data for the range of $1.48 \leq W \leq 1.82$ GeV. The selected areas are shown as shaded ones between two arrows ((a) and (b)) and a requirement for events less than 0.2 GeV is applied to (c). A predictions for the nucleon momentum in deuterium, using Hamada-Johnson NN potential normalized to the data, is also shown as the dashed curve in (c). (d) shows the vertex distributions reconstructed by CLAS from data taken for $0.4 \leq \cos\theta_{\pi^-} \leq 0.5$ and $1.72 \leq W \leq 1.82$ GeV; the pure HD contributions (shaded) are obtained by subtracting the target cell (dashed dotted) from data taken with HD (dashed). A vertex cut between two arrows has been applied.

respectively.

3. 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. Calibrations of CLAS detectors have been ongoing and determinations of target polarizations have been performed. Preliminary exclusive E asymmetries are shown in this contribution and more analyses are ongoing for different channels to

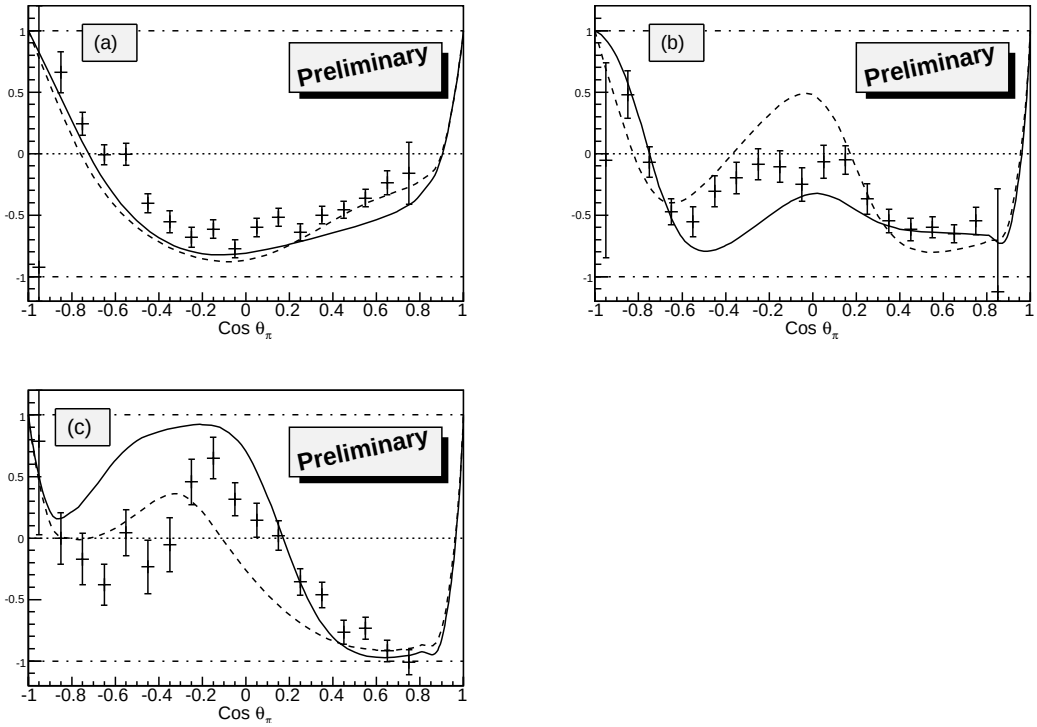

Fig. 2. Preliminary exclusive E asymmetries (π^- polar angle dependences at CM) for γ + n(p) $\rightarrow$ π^- + p(p). (a) 1.48 $\leq$ W $\leq$ 1.60 GeV, (b) 1.6 $\leq$ W $\leq$ 1.72 GeV and (c) 1.72 $\leq$ W $\leq$ 1.82 GeV, where about 10 % of well calibrated data are used and P_D is estimated to be 26.5%. Only statistical errors are shown. Solid and dashed curves are predictions from SAID (SN11) and MAID, respectively.

obtain other spin observables.

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