Measurements of spin observables in pseudo-scalar meson photo-production using polarized neutrons in solid HD

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Abstract

A measurement of psuedo-scalar meson photo production from longitudinally polarized solid HD has been carried out with the CLAS at Thomas Jefferson National Accelerator Facility (Jlab) with circularly and linearly polarized photon beams. Its aim is to measure a complete set of spin observables for the neutron simultaneously from the same experiment. As a polarized neutron, deutron in HD was used. Preliminary asymmetries are shown for the π^- channel.

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1 Introduction

Understanding the quark models based on QCD is an important issue for nuclear physics. Lattice calculations have recently confirmed the long-standing quark model predictions of many resonance states which are missing experimentally [1]. The resonances overlap each other due to their widths. They might not be coupled strongly to channels for which partial wave analyses have been performed in the past. This experiment aims to explore this issue by observing a large number of spin observables simultaneously under the same experimental conditions, which will greatly improve the partial wave analyses.

The spin asymmetries can be decomposed into three amplitudes two with I = 1/2 and one with 3/2, resulting from coupling the I = 1/2 nucleon with iso-scalar and iso-vector components of the photon field to yield a total isospin of 1/2. The I = 3/2 amplitudes characterize the Δ states and ones with I = 1/2 the N* states. The I = 3/2 Δ resonances can be determined either from proton or neutron data alone, while I = 1/2 N* ones need both p and n data. Proton data taken by another CLAS experiment at Jlab are described by B. Briscoe in this conference. The neutron data are very poorly known; the experiment was carried out from December 2011 through May

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2012 in Hall B at Jlab, to take data for neutron using D in HD as a polarized neutron target.

2 Experimental setup

Circularly polarized photons were obtained via bremsstrahlung from longitudinally polarized electron beams from CEBAF and linearly polarized photons via coherent bremsstrahlung off a 30 μm thin diamond crystal. The energies of circularly and linearly polarized photon beams have been measured by tagging [2] and ranged from 0.85 to 2.4 GeV and from 1.6 to 2.2 GeV, respectively.

The CLAS consists of drift chambers built around a torus magnet, time-of-flight counters, gas Cherenkov counters, electromagnetic calorimeters and Start Counter [3] [4].

The newly installed frozen-spin HD solid target had a small dilution factor and a long spin relaxation time. HD was condensed into a Kel-F cylindrical cell of 1.5 cm diameter and 5 cm length. Pure thin aluminum wires inside of the cell were used to conduct the conversion heat from H_2 and D_2, which are present at the 10^{-3} level in HD. Ortho-H_2 and para-D_2 are used to polarize HD at 20 mK and 15 Tesla in an Oxford dilution fridge; in three months, the most of these spin states are converted into para-H_2 and ortho-D_2 which do not spin exchange with HD resulting in frozen spin states. The contributions of the target cell and aluminum wires to the spin-asymmetries can be subtracted to obtain the yield from pure HD, by measuring the yield from the target cell alone. Target polarizations were calibrated, measured and monitored by NMR. An In-Beam cryostat was designed and constructed at Jlab, which was a dilution fridge to cool to 50 mK in the mixing chamber and has a superconducting solenoid of 1 Tesla longitudinal holding field. The details of the HD target are described in the conference contribution by X. Wei.

3 Experimental running conditions and preliminary results

1-prong or 2-prong triggers in which at least one or two charged particles were detected in CLAS were used during the first month; in the remainder of the experiment, 2-prong with pre-scaled 1-prong triggers were applied. The 1-prong trigger was aimed to collect data for reactions like $\gamma + p \rightarrow \pi^+ +$

X and γ + n(p) $\rightarrow \pi^-$ + X where (p) means the spectator proton, while the 2-prong one was used to select ones like γ + n(p) $\rightarrow \pi^-$ + p + X(0, π^0, ...). Data were taken on circularly and linearly polarized photon beams for 64 days (11x10^9 events) and 30 days (4x10^9 events), respectively. The target H polarization was transferred to D using a saturated forbidden transition to get a higher D polarization. The average D polarization in HD target was about 20% during the data taking. D polarization was flipped, while H polarization was flipped and zeroed during different periods. The spin relaxation times for D and H were observed to be more than a year.

Particle identification for charged particles has been done using β versus momentum distributions to select $\pi^\pm$ and protons. The missing mass distributions have been made from the photon beam energies and reconstructed 4-momenta of $\pi^\pm$; clear peaks are observed at proton and neutron masses which give the missing mass cuts.

Preliminary inclusive E asymmetries using circularly polarized photon beams on longitudinally polarized nucleon target ($\sim$ 10% of the data) is shown in Figure 1 for the reaction, γ + n(p) $\rightarrow \pi^-$ + X. Significant asymmetries are observed. Calibrations for the tagger, the CLAS detectors as well as the determinations of the target polarizations are ongoing. A further analysis for an exclusive reaction, γ + n(p) $\rightarrow \pi^-$ + p in which both of π^- and p were detected in CLAS, will be done with an coplanarity cut and the empty target subtractions.

4 Summary

Double spin polarization experiments have been carried out in Hall B at Jlab using polarized photon beams, CLAS and polarized HD solid targets. Preliminary E asymmetries are shown in this contribution and more analyses are ongoing for different channels to obtain other spin observables.

References

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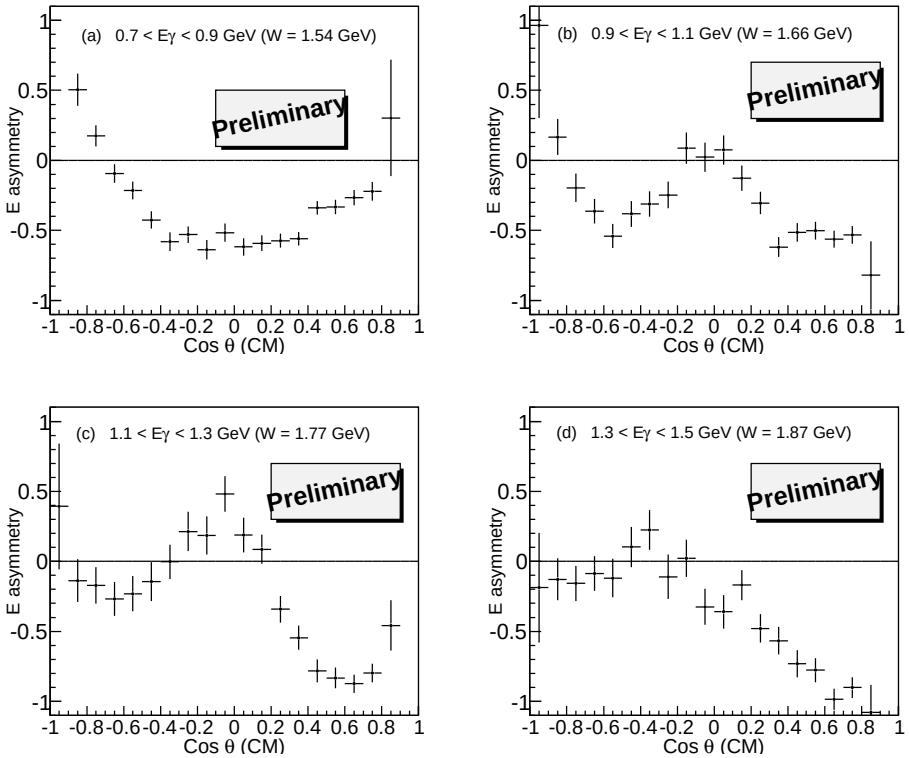

Figure 1: Preliminary double spin E asymmetries (polar angle dependences at CM) for γ + n(p) $\rightarrow$ π^- + X(p), after the particle identification of π^- and missing mass cuts (about 10% of data used), where E asymmetry is obtained for circularly polarized photon beams on longitudinally polarized nucleon target. (a) $0.7 \leq E_\gamma \leq 0.9$ GeV (W = 1.54 GeV), (b) $0.9 \leq E_\gamma \leq 1.1$ GeV (W = 1.66 GeV), (c) $1.1 \leq E_\gamma \leq 1.3$ GeV (W = 1.77 GeV) and (d) $1.3 \leq E_\gamma \leq 1.5$ GeV (W = 1.87 GeV) where P_D is assumed to be 26.5%. Only statistical errors are shown.