Determination of the Azimuthal Asymmetry of Deuteron Photodisintegration in the Energy Region $E_\gamma = 1.1 - 2.3$ GeV

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Introduction

The deuteron photodisintegration process is important for the investigation of the role of quarks and gluons in nuclear reactions. The main reason for conducting such an experiment is to identify the energy at which the transition from the hadronic picture of the deuteron (established in the reaction at low energies; usually below 1 GeV) to the quark-gluon picture (expected to hold for energies above several GeV) takes place.

Spin-dependent observables are crucial for identifying the underlying dynamics. The polarization observable $\Sigma$ is predicted to have large sensitivity on the mechanism of deuteron photodisintegration. In an attempt to better understand this mechanism, we determined the azimuthal asymmetry of deuteron photodisintegration in the energy region $E_\gamma = 1.1 - 2.3$ GeV.

Framework

The asymmetry $\Sigma$ is related to the doubly-differential cross section for the reaction of deuteron photodisintegration

$$\frac{d^2\sigma}{d\Omega dE}(x,t,\phi) = \frac{1}{2\pi} \frac{d^2\sigma}{d\Omega dE}(x,t)[1 + P_x \Sigma(x,t) \cos 2\phi]$$

where $d\Omega/dE$ is the unpolarized cross section for the reaction and $\phi$ is the azimuthal angle between the beam polarization and the observed nucleon transverse momentum.

For two different polarizations the above equation becomes

$$\frac{dN^{(1)}}{d\Omega dE} = \frac{dN^{(2)}}{d\Omega dE} = (1 + P_x \Sigma(x,t) \cos 2\phi)A(\phi)$$

with $dN^{(1)}(x,t)/d\Omega dE$ the azimuthal distributions of the events taken with the photon polarization parallel ($+$), and parallel ($-$) to the Hall-B floor, respectively.

The asymmetry is then determined by fitting the ratio

$$\frac{dN^{(1)}}{d\Omega dE} + dN^{(2)}}{d\Omega dE}$$

with the function

$$A = 1 + \frac{dN^{(1)}}{dN^{(2)}} \cos(2\phi - D)$$

$$B = 1 + \frac{dN^{(1)}}{dN^{(2)}} \cos(2\phi + D)$$

to determine the incident photon flux ratios, $A = \frac{N^{(1)}}{N^{(2)}}$, the photon polarization ratio, $B = \frac{P_x \Sigma(x,t)}{P_x \Sigma(x,t)^*}$, the product of the average photon polarization and the azimuthal asymmetry, $P_x \Sigma(x,t)$, and the photon polarization offset, $D = 0$.

The QGSM predictions are very sensitive to the relative phase between different helicity amplitudes and thus do not provide predictions for $P_x$ and $C_x$. Both of these models predict with the same degree of success the data on the longitudinal polarization transfer.

There is currently only one data set available for the azimuthal asymmetry from Virev. These data are restricted to $P_x = 0$, and energies up to 1.6 GeV. These results are also associated with large uncertainties that do not allow a test of the theoretical predictions.

Experiment

The data for this analysis were collected during the pJ3 experiment which was carried out in Hall-B of the Thomas Jefferson National Laboratory. The characteristics of this experiment are as follows:

• Liquid deuterium target (40 cm long)
• Linearly-polarized photon beam produced using the coherent bremsstrahlung technique (two orientations: + and -)
• Collected data for six photon energy bins 200 MeV wide between 1.1 and 2.3 GeV
• Use of the tagger spectrometer to identify the energy of the photon that initiated the reaction
• Use of the CLAS to collect data over a large fraction of the full solid angle

Previous Results

Main theoretical models

• Quark-Gluon String Model (QGSM)
• Hard Scattering Mechanism (HSM).

These two models describe the reaction’s differential cross section with the same degree of success.

Reaction Reconstruction (continued)

Missing Mass

Z-Vertex cut

Background Subtraction

Performed on an event-by-event basis using probabilistic event weighting (method developed at Carnegie Mellon)

Photon Polarization

Determined using Analytic Bremsstrahlung Calculation. From fitting the enhancement distributions we were able to determine:

• Coherence effects
• Beam collimation
• Beam divergence

These parameters were then used to calculate the degree of photon polarization.

Systematic Studies

Results

Angular Dependence

Energy Dependence

• Azimuthal asymmetry as a function of the proton energy in the center-of-mass frame

Summary and Outlook

• We have determined the azimuthal asymmetry of deuteron photodisintegration between 1.1 and 2.3 GeV over a large fraction of the proton polar angle
• The available theoretical models, at their current state, fail to describe the results on the azimuthal asymmetry
• A collaboration with theorists is necessary to provide a better interpretation of the azimuthal asymmetry
• The results from this work can be used to place new constraints on the existing non-pQCD-based models or aid in the development of new theoretical models

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