The Double Spin Asymmetry in Exclusive π^+ Electro-Production with CLAS

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The eg1b run was conducted using CLAS at Jefferson Lab in 2000 by the CLAS collaboration. A 1.6 GeV - 5.6 GeV polarized electron beam and polarized nuclear targets (composed of NH_3 and ND_3) were used, allowing single and double spin asymmetries to be measured. This analysis deals with the double spin asymmetry $A_{||}$ in the exclusive production of positive pions from a polarized proton ($ep \to e\pi^+ n$). The double spin asymmetry was measured as a function of the four kinematic variables W, Q^2, $\cos\theta^*$, and ϕ^*. The value of this asymmetry can be used to help determine the spin structure of the resonances, due to its sensitivity to the spin dependent parts of the cross section. A brief description of the experimental setup will be given, and preliminary results for the asymmetry will be shown.

1 Introduction

Exclusive pion production is a useful tool for analyzing the nucleon resonances because of the large branching ratio of many of the resonances into the $N\pi$ channel, for example the $P_{11}(1440)$, or Roper resonance, $D_{13}(1520)$ and the $F_{15}(1680)$. This analysis is of the spin dependence of the $ep \to e\pi^+ N$ reaction using data taken with CLAS [3] during the eg1b run period at Jefferson Lab. A longitudinally polarized electron beam and a longitudinally polarized ammonia target were used in the eg1b run period.

2 Spin Dependence of the Cross-section

When both the electron and the proton are polarized, the virtual photon cross-section for exclusive π^+ production can be written in terms of the polarized response functions, R [2]. The response functions depend on W, Q^2 and $\cos\theta^*$ (the angle between the pion momentum and the momentum transfer q in the center of mass of the pion-neutron system). These equations all assume a reference frame where $\hat{z}$ is along $\vec{q}$, and $\hat{y}$ is normal to the hadronic scattering plane.

$$\begin{aligned}
\frac{d\sigma_\nu}{d\Omega_\pi} &= \frac{|\vec{q}|}{q_\gamma^{CM}}[R_T + P_y R_T^y + \epsilon_L(R_L + P_y R_L^y) \\
&+ \sqrt{2\epsilon_L(1+\epsilon)}((R_{LT} + P_y R_{LT}^y)\cos\phi^* + (P_x R_{LT}^x + P_z R_{LT}^z)\sin\phi^*) \\
&+ \epsilon((R_{TT} + P_y R_{TT}^y)\cos 2\phi^* + (P_x R_{TT}^x + P_z R_{TT}^z)\sin 2\phi^*) \\
&+ h\sqrt{2\epsilon_L(1-\epsilon)}((R_{LT'} + P_y R_{LT'}^y)\sin\phi^* + (P_x R_{LT'}^x + P_z R_{LT'}^z)\cos\phi^*) \\
&+ h\sqrt{1-\epsilon^2}(P_x R_{TT'}^x + P_z R_{TT'}^z)]
\end{aligned}$$

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The target polarization can be re-written in terms of ϕ^*, which is the angle between the hadronic and leptonic interaction planes, θ_γ, which is the production angle of the virtual photon, and P_T, the polarization as measured in the lab.

$$
\begin{aligned}
P_x &= P_T \sin\theta_\gamma \cos\phi^* \\
P_y &= -P_T \sin\theta_\gamma \sin\phi^* \\
P_z &= P_T \cos\theta_\gamma
\end{aligned}
$$

It is clear that the cross-section can be written in terms of a polarization independent part, a part that depends only on the beam polarization (h or P_B), a part that depends only on the target polarization P_T, and a part that depends on both the beam and target polarization.

$$\sigma = \sigma_0 + P_B\sigma_e + P_T\sigma_t - P_B P_T \sigma_{et} \quad (1)$$

Separating the double spin dependent part of the cross-section from each of the single spin dependent parts requires that both the beam and target polarizations be reversed.

$$A_{et} = \frac{\sigma_{et}}{\sigma_0} = \frac{(\sigma_{-+} - \sigma_{++}) + (\sigma_{+-} - \sigma_{--})}{(\sigma_{++} + \sigma_{-+}) + (\sigma_{+-} + \sigma_{--})}$$

3 Experiment

As mentioned in Sec. 1, the eg1b run used the CEBAF polarized electron beam and a polarized nuclear target [4]. The target consisted of an $^{15}NH_3$ sample, polarized using the dynamic nuclear polarization technique, which requires low temperatures and a very high magnetic field. The target was located 50 cm upstream of the center of the CLAS detector in experimental Hall B at Jefferson Lab.

Event selection was performed by detecting the scattered electron and the produced π^+, solving for the missing mass of the undetected particle, and doing a cut on this mass about the mass of the neutron.

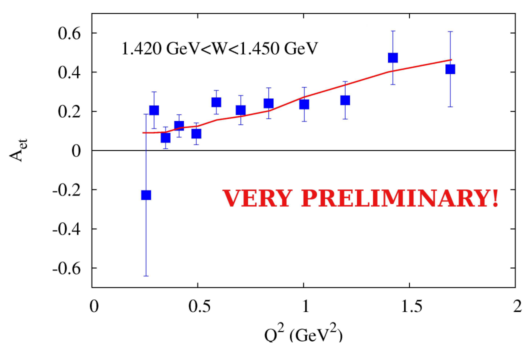

Figure 1: A_{et} as a function of Q^2 for fixed 1.420< W <1.450 GeV, averaged over $\cos\theta^*$ and ϕ^*. MAID2003 is shown for comparison

Equation 2 shows the relation between the double spin asymmetry and the measured counts in each helicity state. The terms N' represent the charge normalized counts for each combination of beam and target helicity. P_B is the polarization of the beam, P_T is the polarization of the target, and f_D is the dilution factor. The product of the beam and target polarizations was measured by the asymmetry for elastic scattering on the proton and comparing that to the known asymmetry. The beam polarization is known independently from runs using a Moeller polarimeter, meaning that the two can be separated.

$$A_{et} = \frac{\sigma_{et}}{\sigma_0} = \frac{1}{P_B^+ P_T^-} \frac{(N'_{-+} - N'_{++}) + r_B(N'_{+-} - N'_{--})}{(N'_{++} + N'_{-+}) + r_T(N'_{+-} + N'_{--})} \tag{2}$$

The target polarization is only reversed once per beam energy setting, and the positive and negative target polarizations are not generally equal. This requires that in addition to the counts for each helicity state being normalized to the accumulated charge on the target during that configuration, the beam and target polarizations for each given configuration must be normalized to each other. This is done in Equation 2 with the terms r_B and r_T which are the ratios of the beam and target polarization respectively for the periods when the target had negative polarization and the target had positive polarization.

Contributions from the ^{15}N and other materials, such as the liquid He surrounding the target and the target window material, are accounted for with a dilution factor f_D, which is the ratio of counts from polarizable protons to the total counts. This ratio is determined in each kinematic bin by scaling up the missing mass spectrum obtained from dedicated ^{12}C runs to approximate the unpolarized part of the $^{15}NH_3$ spectrum.

4 Results

The data have been analyzed and the double spin asymmetries have been extracted. The asymmetry was extracted as an independent function of the four kinematic variables W, Q^2, $\cos\theta^*$, and ϕ^*, as previously defined. In order to display the results, one or more kinematic variable is often averaged over. This is done by averaging the asymmetry, not simply integrating the counts. The advantage of this is that it limits the effects of acceptance on the results.

All of the results shown here are from the 4.2 GeV beam energy run. In all of the figures, comparisons are shown to MAID2003 [5]. The values for MAID2003 were generated over the same four dimensional space as the asymmetries were measured in, and then averaged together with the same weight as the asymmetry. Statistical error associated with the background subtraction and the measurement of the product of beam and target polarization are included in the statistical error bars shown, although systematic errors are not.

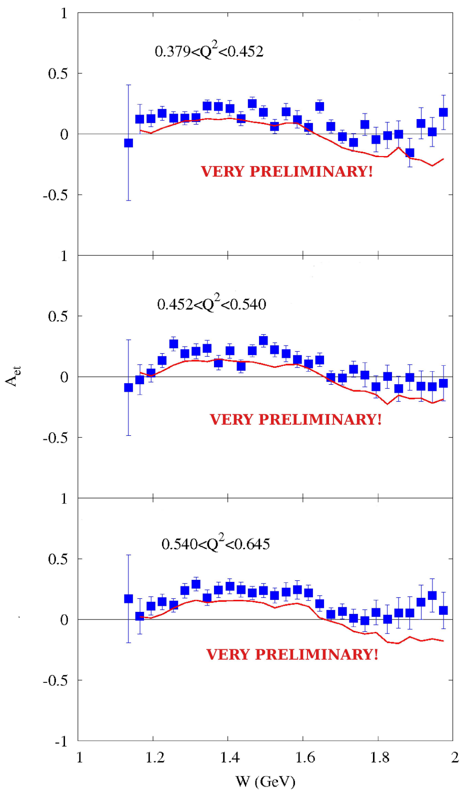

Figure 2: A_{et} as a function of W for fixed Q^2 values, averaged over $\cos\theta^*$ and ϕ^*. MAID2003 is shown for comparison

5 Conclusions and Outlook

The large amount of data collected in this experiment will enable us to significantly increase our knowledge of the spin structure of the resonances. This is already apparent from the preliminary figures shown, which have rather small error bars for fairly small bins. The addition of this data set should help in the development and enhancement of models of the multi-pole terms associated with the resonances.

Analysis of the asymmetry from the other energy settings of the experiment is proceeding, as is systematic error calculation. The additional energy settings will provide greater kinematic coverage. In addition, the single spin asymmetries are being measured. This allows access to different response functions, giving more information about the spin structure of the resonances. The high statistics and high polarizations of the eg1b run allow for the data be used for a variety of purposes. The data are being analyzed for inclusive asymmetries on both the proton and deuteron (which was the primary motivation for the run), as well as other exclusive and semi-inclusive reactions.

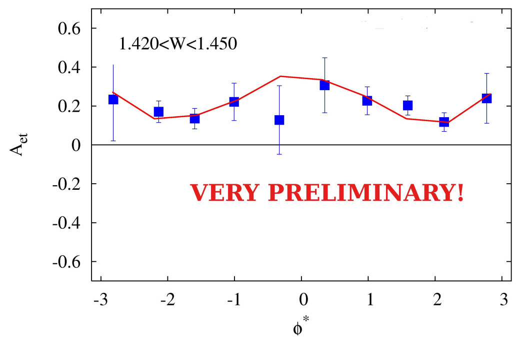

Figure 3: A_{et} as a function of ϕ^* for fixed 1.420$<W<$1.450 GeV, averaged over $\cos\theta^*$ and Q^2. MAID2003 is shown for comparison

References

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