SINGLE-SPIN ASYMMETRIES AT CLAS

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We report the first measurement of the beam-spin asymmetry in the electroproduction of positive pions above the baryon resonance region at CLAS at beam energy of 4.25 GeV. At large fractions of virtual photon momentum carried by the pion the amplitude of measured $\sin \phi$ modulation is 0.037 ± 0.006 .

Single-spin asymmetries (SSA) in azimuthal distributions of final state particles in deep inelastic scattering (DIS) give access to subtle distribution and fragmentation functions, which cannot easily be accessed in other ways.

The total cross section for single pion production by longitudinally polarized leptons scattering off unpolarized protons is defined by a set of structure functions and contains two main contributions. The beam-spin independent part of the cross section (σ_{UU}) arises from the symmetric part of hadronic tensor and the helicity (λ_e) dependent part (σ_{LU}), arises from the anti-symmetric part of the hadronic tensor ¹:

$$\frac{d\sigma_{LU}}{dx_B dy dz d^2P_{\perp}} = \lambda_e \frac{4\pi\alpha^2 s}{Q^4} x_B y \sqrt{1-y} \sin \phi \mathcal{H}'_{LT},$$

The ϕ is the azimuthal angle between scattering plane formed by the initial k_1 and final k_2 momenta of the electron and the production plane formed by the transverse momentum $P_{\perp}$ of the observed hadron and the virtual photon. The relevant kinematical (scale) variables are defined as: $x_B = Q^2/2(P_1 q)$, $y = (P_1 q)/(P_1 k_1)$, $z = (P_1 P)/(P_1 q)$, where $Q^2 = -q^2$, $q = k_1 - k_2$ is the momentum of the virtual photon, P_1 and P are the target and observed final-state hadron momenta.

Assuming that the quark scattering process and the fragmentation process factorize and that the fragmentation functions scale and only depend on the fractional energy z , the structure functions could be presented as a convolution of a distribution function (DF) and a fragmentation function (FF). Both assumptions have yet to be experimentally confirmed at CEBAF energies. The DF and FF responsible for non zero $\mathcal{H}'_{LT}$ in semi-inclusive deep inelastic scattering (SIDIS) were first identified by Levelt and Mulders ¹. They include the twist-3 unpolarized distribution function introduced by Jaffe and Ji ² and the polarized fragmentation function first discussed by Collins ³.

Though large SSA have been observed in hadronic reactions for decades ⁴ and recently in SIDIS with polarized targets ^{5,6} the only existing measurement of the beam-spin asymmetry in semi-inclusive lepto-production of pions in DIS, so far is the measurement of asymmetry consistent with 0 at relatively low z ($z < 0.7$), within large statistical errors, reported recently by the HERMES collaboration ⁵.

Results of our analysis of data from Jefferson Lab's CLAS detector reveal very significant single-beam spin asymmetries in pion azimuthal distributions in electroproduction in DIS range ($Q^2 > 1, W^2 > 4$) at large z .

The Experiment

In this analysis, we used CLAS electroproduction data taken in March 1999. Scattering of 4.25 GeV longitudinally polarized electrons from a liquid hydrogen target was studied in a wide range of kinematics. The average electron polarization was measured with a Møller polarimeter and was 70 % with fractional uncertainty of 3%. Scattered electron and proton were measured using the CLAS detector. Electrons were selected by a hardware trigger using a coincidence of the gas Cerenkov counters and the lead-scintillator electromagnetic calorimeters. Pions were identified using momentum reconstruction in the tracking system and time of flight from the target to the scintillators. The total number of π^+ events after all quality, vertex, acceptance, fiducial and kinematic cuts was $\sim 400k$.

The CLAS data was compared with LUND (PEPSI+LEPTO+JETSET) ⁷ based Monte-Carlo. Very good agreement in different kinematic distributions of data and LUND predictions was found. The cuts used to extract the asymmetry for semi-inclusive sample were defined from the comparison of CLAS data and LUND MC. At CEBAF energies (4-6GeV) the data exhibit behavior consistent with scattering in the current dominated regime at relatively large z . A cut $x_F > 0.15$ ($x_F = P_L/|\vec{q}|$) was used for a minimum longitudinal momentum fraction of the pion in the CM frame. A second cut $z > 0.5$ was applied to the fraction of virtual photon energy carried by the pion to restrict the kinematics to region where the predictions based on the semi-inclusive approach are consistent with the data. In this region the major part of π^+ are in fact produced directly from string fragmentation according to the LUND model. The upper limit $z < 0.8$ was chosen to exclude the kinematic region, where the higher-twist effects and diffractive effects could be dominant. In addition in this intermediate range of z ($0.5 < z < 0.8$) the z -distribution of final state pions at CLAS are in good agreement with

LUND-MC and high energy experiments like SLAC and HERMES, showing no dependence on x_B , which suggests a "precocious" onset of scaling already at energies as low as 4.25 GeV. A cut on the missing mass of $e'\pi^+$ system $M_X > 1.1$ is used to eliminate pure exclusive events. To minimize the radiative corrections a cut on the fraction of the energy of incoming electron carried by the virtual photon $y = \nu/E < 0.85$ is imposed, limiting corrections to unpolarized cross section to a few percent ⁸.

The ϕ -dependent spin asymmetries are isolated by extracting moments of the cross section for two helicity states weighted by the corresponding ϕ -dependent functions ($W(\phi) = \sin \phi, \sin 2\phi \dots$). These moments are given by

$$A_{LU}^{W\pm} = \frac{1}{P^\pm N^\pm} \sum_{i=1}^{N^\pm} W(\phi_i), \quad (1)$$

where $N^\pm$ and $P^\pm$ are the number of events and luminosity weighted polarizations for positive/negative helicities of the electron, respectively.

Beam SSA $A_{LU}^{\sin \phi}$ for opposite helicities and their sum extracted from the CLAS data as azimuthal moments compared to the same quantity extracted as a spin asymmetry are in good agreement indicating acceptance corrections are not significant within statistical uncertainties. Main contributions to systematic error coming from the beam polarization error and $\sin \phi, \cos \phi, \cos 2\phi$ modulations of the CLAS acceptance are estimated to be less than 20% of the value of statistical errors. The $A_{LU}^{\sin \phi}$ averaged over 2 spin states as a function of z and x_B is plotted in Fig. 1. The $A_{LU}^{\sin \phi}$ is positive for the positive electron helicity in the range of $0.15 < x_B < 0.4$.

Within statistical errors no significant dependence on x_B was observed in single-spin asymmetry z -dependence for different ranges of x_B . This behavior is consistent with factorization in the kinematic range $0.5 < z < 0.8$.

The target SSA measured by HERMES ⁵, analyzed in terms of the fragmentation effect, in addition to a contribution from the Collins function contain other contributions which in certain kinematic range might be significant ^{9,10}. This makes the beam-spin SSA a cleaner observable for extraction of the Collins fragmentation function at large z , where the analyzing power is large. The preliminary analysis of target SSA (A_{UL}) with the CLAS polarized target is in agreement with HERMES result confirming the striking difference in the z -dependence of beam and target SSA.

In conclusion, we have presented the first measurement of the beam-spin asymmetry in semi-inclusive pion electroproduction above the baryon resonance region. The z -dependence of beam SSA in SIDIS analyzed in terms of the fragmentation effect probes the polarized FF ¹. The study of transversity

Figure 1. The beam-spin azimuthal asymmetry ($\sin \phi$ moment in the cross section) extracted from hydrogen data at 4.25 GeV as a function of z (left plot) and Bjorken x_B in the range $0.5 < z < 0.8$ (right plot). Error bars show the statistical uncertainty and the band represents the systematic uncertainties.

in semi-inclusive DIS is one of the aims of the upgraded HERMES experiment at HERA¹¹ and of the COMPASS experiment at the CERN SPS¹² and the knowledge of Collins fragmentation function is its important missing part.

References

1. J. Levelt and P. J. Mulders, *Phys. Lett. B* **338**, 357 (1994)
2. R.L. Jaffe and X. Ji *Nucl. Phys. B* **375**, 527 (1992)
3. J. Collins, *Nucl. Phys. B* **396**, 161 (1993)
4. K. Heller et al. 'Proceedings of Spin 96', Amsterdam, Sep. 1996, p23
5. HERMES collaboration, *Phys. Rev. Lett.* **84**, 4047 (2000)
6. A. Bravar, *Nucl. Phys. (Proc. Suppl.)* **B79** (1999) 521.
7. L. Mankiewicz et al. *Comput. Phys. Commun.* **71**, 305 (1992)
8. A. Akushevich et al. *Eur. Phys. J.C.* **10**, 681 (1999).
9. P. J. Mulders, R. M. Boglione, *Phys. Lett B* **478** (2000) 114;
10. H. Avakian, Proceedings of DIS-2000, Liverpool University 2000.
11. HERMES Collaboration, HERMES 00-003.
12. COMPASS Collaboration, CERN/SPSLC 96-14.