Single Spin Asymmetries from semi-inclusive pion electroproduction

For decades, experiments in deep inelastic scattering (DIS) have mapped out the momentum distributions in the nucleon in terms of one-dimensional parton distribution functions (PDFs). While these measurements provided significant insight into the nucleon structure, some questions arose that could not be addressed in this one-dimensional picture. Most notably, the EMC experiment at CERN found that the quark-spin contribution to the proton's spin is only about 30%. Recent measurements of the gluon contribution to the proton spin have shown this contribution to be too small to saturate the spin sum rule. These results necessitate an understanding of the orbital motion of quarks in the proton.

In recent years, the hadronic physics community has extended the investigation of the partonic structure of hadrons beyond the collinear PDFs by exploring the parton's motion and its spatial distribution in the direction perpendicular to the parent hadron's momentum. Two sets of non-perturbative functions have been introduced to investigate and describe the structure of hadrons at the quark-gluon level. Transverse-momentum-dependent parton distributions (TMDs) carry information on the longitudinal and transverse momentum distributions. Generalized parton distributions (GPDs) carry information on the longitudinal momentum distribution and transverse position of partons. GPDs and TMDs are connected through the Wigner distributions or generalized transverse momentum distributions (GTMDs) and provide a complete description of the three-dimensional structure of the nucleon.

Measurements of azimuthal moments, in particular the single spin asymmetries (SSAs), have emerged recently as a powerful tool to probe the nucleon structure through measurements of GPDs and TMDs in the hard exclusive and semi-inclusive electroproduction of mesons and photons, respectively. Pion electroproduction in semi-inclusive DIS (SIDIS), when a final-state pion is detected with the final-state lepton, is an important tool for studying the TMD of partons.

We have measured the moment $A^{LU}_{\sin\phi}$ corresponding to the polarized electron beam-spin asymmetry in semi-inclusive deep inelastic scattering [1]. This moment is a twist-3 quantity providing information about quark-gluon correlations. Data were taken with the CLAS Spectrometer at Jefferson Lab using a 5.498 GeV longitudinally polarized electron beam and an unpolarized liquid hydrogen target. All three pion channels (π^+, π^0, and π^-) were measured simultaneously over a large range of kinematics within the virtuality range $Q^2 \approx 1.0$–4.5 GeV^2. The observable was measured with better than 1% statistical precision over a large range of z, P_T, x_B, and Q^2, which permits comparison with several reaction models. The discussed measurements provide an upgrade in statistics over previous measurements, and serve as the first evidence for the negative sign of the π^- $\sin\phi$ moment.

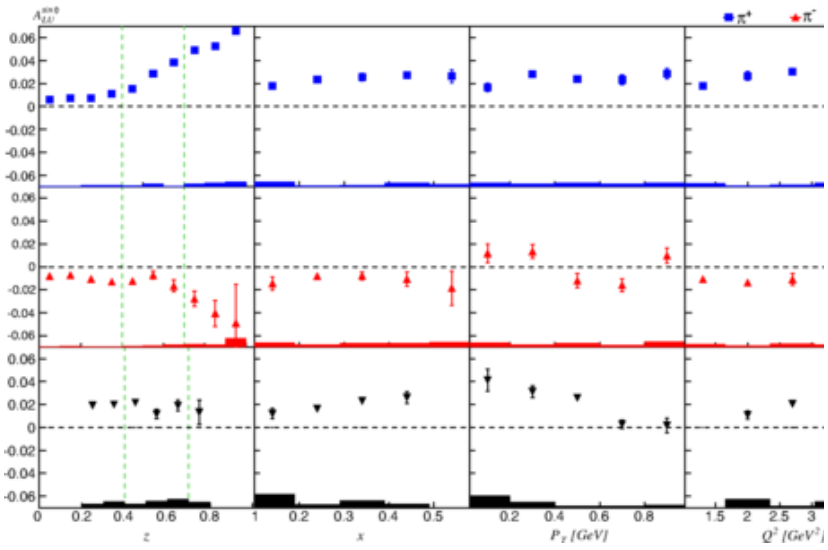

Figure: $A^{LU}_{\sin\phi}$ vs. z, x_B, P_T, and Q^2 after integration over the other kinematic variables for each pion channel. The integration range in z for SIDIS kinematics is for $0.4<z<0.7$. The error bars represent statistical uncertainties and the shaded regions represent the systematic uncertainties. The top row shows $\pi+$, the center row shows $\pi-$, and the bottom row shows π^0.

[1] W. Gohn *et al. (CLAS Collaboration)*, Phys. Rev. D 89, 072011 (2014).