Precise Measurements of Beam Spin Asymmetries in Semi-Inclusive π^0 Production

In recent years it has become clear that understanding the orbital motion of partons is crucial for the construction of a more complete picture of the nucleon in terms of elementary quarks and gluons. Parton distribution functions have been generalized to contain information not only on the longitudinal momentum but also on the transverse momentum distributions (TMDs) of partons in a fast moving hadron. Two fundamental mechanisms have been identified leading to single-spin asymmetries (SSAs) in hard processes: the Sivers mechanism, which generates an azimuthal asymmetry in the distribution of quarks in the nucleon due to their orbital motion, and the Collins mechanism, which generates an asymmetry during the hadronization of quarks. The structure function responsible for the beam-spin asymmetry in single-pion production off an unpolarized target in semi-inclusive deep-inelastic scattering, first measured by the CLAS and HERMES Collaborations, is higher-twist by nature and can only be accessed at moderate values of Q^2.
An experiment performed at Jefferson Lab using the CLAS detector, measured single-spin asymmetries for neutral pion electroproduction in semi-inclusive deep-inelastic scattering of 5.776 GeV polarized electrons from an unpolarized hydrogen target [1]. A substantial sin φ_h amplitude has been measured in the distribution of the cross section asymmetry as a function of the azimuthal angle φ_h of the produced neutral pion. The dependence of this amplitude on Bjorken x and on the pion transverse momentum is extracted with significantly higher precision than previous data and is compared to model calculations. The CLAS data provide significant improvements in the precision of beam SSA for neutral pions for the kinematic region where the CLAS and HERMES data sets overlap, and they extend the measurements to the large x region not accessible at HERMES. Two measurements are found to be consistent with each other, indicating that at energies as low as 4-6 GeV, the behavior of the beam spin asymmetries is similar to higher-energy measurements. The beam-spin asymmetry for π^0 measured by CLAS is comparable with the π^+ asymmetry from an older CLAS data set both in magnitude and sign, suggesting that contributions from the Collins mechanism cannot be the dominant ones assuming favored and unflavored Collins functions are roughly equal and opposite in sign.

Higher-twist observables, such as the beam spin asymmetry, are a key for understanding long-range quark-gluon dynamics. They have also been interpreted in terms of average transverse forces acting on a quark at the instant after absorbing the virtual photon [2]. The CLAS measurement provides new evidence that binding effects at the partonic level may be very significant.

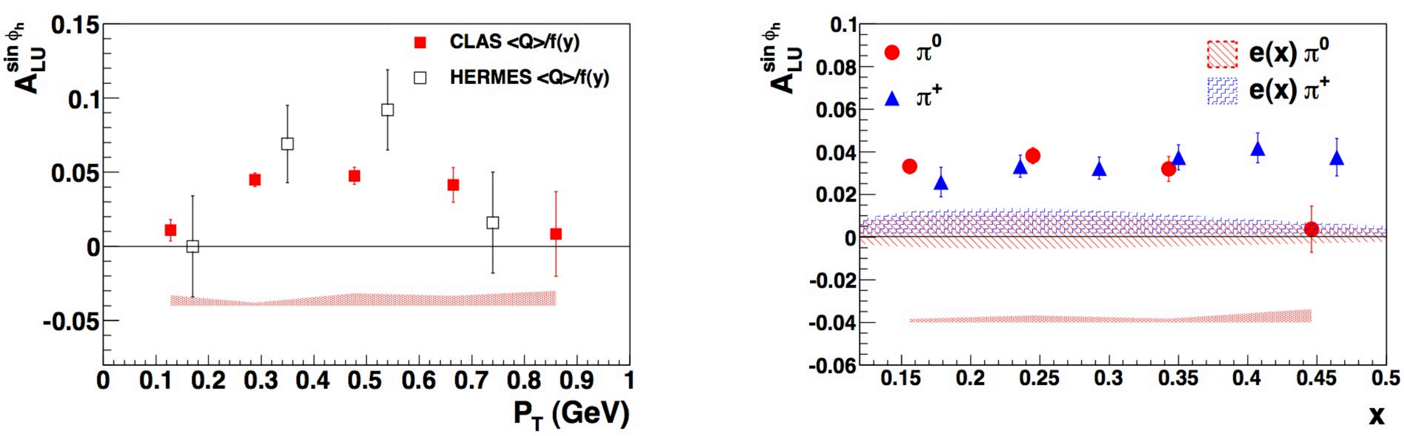

Figure: (Left) The π^0 beam-spin asymmetry moment $A^{\sin}_{LU}$ vs. P_T multiplied by the kinematic factor <Q>/f(y) from CLAS and HERMES. The 0.1<x<0.2 range of the CLAS data is used to compare with HERMES, as this yields average kinematics closest to HERMES and the π^0 beam-spin asymmetry moment $A^{\sin}_{LU}$ vs. x (right) compared to that of the π^+ from an earlier CLAS measurement. The error bars correspond to statistical and the bands to systematic uncertainties. For both data sets $P_T \approx$ 0.38 GeV and 0.4<z<0.7. The hatched bands are model calculations involving solely the contribution from the Collins effect.

[1] M. Aghasyan *et al. (CLAS Collaboration)*, Phys. Lett. B 704, 397 (2011).
[2] M. Burkardt, Proceedings of *Transversity 2008* (Ferrara, Italy), arXiv:0807.2599 (2008).