The First Measurement of Neutron Transversity on a Transversely Polarized ^3He Target

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Abstract. We recently measured the neutron target single spin asymmetry in the semi-inclusive deep inelastic $^3\text{He}^\uparrow(e, e'\pi^\pm)X$ reactions with a transversely polarized ^3He target. The experiment was performed in Hall A at Jefferson Lab from October 2008 to February 2009. Pions were detected in the high-resolution spectrometer in coincidence with scattered electrons detected by the BigBite spectrometer. The kinematic coverage focuses on the valence quark region, $x = 0.1 - 0.4$, at $Q^2 = 1 - 3 \text{ (GeV}/c)^2$. With good particle identifications using a RICH detector and an aerogel Cherenkov counter, data on kaons were obtained at the same time. The data from this experiment, when combined with the world data, will provide constraints on the Transversity and Sivers distributions on both u -quark and d -quark in the valence quark region.

Keywords: Transversity, TMD, neutron

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INTRODUCTION

The unpolarized parton distribution function (PDF), $f_1(x, Q^2)$, has been extracted with excellent precision over a large range of the longitudinal momentum fraction x and momentum transfer Q^2 from deep inelastic scattering (DIS), Drell-Yan and other processes after several decades of experimental and theoretical efforts. Motivated by the original “spin crisis” from the EMC experiment in the 1980s, mapping of the longitudinal polarized parton distribution function, $g_1(x, Q^2)$, from polarized DIS experiments has been carried out for more than two decades. What remains least known among the three leading twist parton distribution functions is the Transversity function, $h_1(x, Q^2)$. The nucleon Transversity distribution describes the net quark transverse polarization in a transversely polarized nucleon. In the non-relativistic limit, the Transversity distribution function is the same as $g_1(x, Q^2)$. Therefore, the Transversity distribution function probes the relativistic nature of the quarks inside the nucleon.

Besides these three parton distributions (f_1 , g_1 and h_1), there are five more transverse momentum dependent distribution functions (TMDs) identified at leading twist [1, 2]. The TMDs give the description of the parton distributions beyond the collinear approximation. So they depend not only on x , but also on the transverse momentum (k_T) of the quark.

Because of the chiral-odd nature of Transversity, its experimental determination requires processes where an additional chiral-odd function is involved. One possible way

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is to measure single spin asymmetries in semi-inclusive DIS (SIDIS) ($e, e'h$) reaction with a transversely polarized target. Transversity convoluted with the Collins fragmentation function [3] gives rise to an azimuthal asymmetry in $\sin(\phi_h + \phi_S)$, where azimuthal angles of both the hadron (ϕ_h) and the target spin (ϕ_S) are about the virtual photon axis with respect to the lepton scattering plane. In addition to this Collins asymmetry, two more leading twist TMDs contribute to the azimuthal asymmetries.

- the Sivers function [4] convoluted with the unpolarized fragmentation function refers to an azimuthal asymmetry of $\sin(\phi_h - \phi_S)$ due to the correlation between the nucleon's transverse spin and the quark's transverse momentum;
- Pretzelosity convoluted with the Collins fragmentation function generates a $\sin(3\phi_h - \phi_S)$ asymmetry in SIDIS. In certain models, it is related with the difference between the helicity and Transversity distribution and measures the relativistic effects in the nucleon [5].

The different angular dependencies in azimuthal asymmetries give an unambiguous separation of these TMDs in SIDIS.

Recently, the HERMES Collaboration [6] and the COMPASS Collaboration [7, 8, 9] reported results on single-spin asymmetries from SIDIS on transversely polarized proton and deuteron targets. The asymmetry related to the Collins fragmentation function was also measured by the BELLE Collaboration [10] in the $e^+e^- \rightarrow h_1 h_2 X$ reaction. In order to extract various TMDs for different quark flavors, a measurement on neutron is essential.

THE JLAB EXPERIMENT E06-010

The goal of the reported experiment, E06-010 [11], is to get the first direct data of the neutron single spin asymmetry in the SIDIS $^3\text{He}^\uparrow(e, e'\pi^\pm)X$ reactions on a transversely polarized ^3He target. It was performed in Jefferson Lab Hall A from Oct 22, 2008 through Feb 5, 2009.

A 15 μA 5.9 GeV electron beam was used on a 40 cm ^3He target. The large acceptance BigBite spectrometer was put at 30° beam-right as electron arm. The coincident hadrons were detected by the Hall A left side high resolution spectrometer (HRS_L) at 16°.

The kinematics was selected to cover the valence quark region and the highest possible invariance mass of the whole hadronic system with a 5.9 GeV beam, $0.1 < x < 0.4$ and $2.2 < W < 3 \text{ GeV}/c^2$. Therefore, the hadron arm momentum setting was fixed at $p = 2.35 \text{ GeV}/c$. And because of the large acceptance bite of the BigBite spectrometer ($\Delta\Omega \sim 64 \text{ msr}$ and $p = 0.7 - 1.8 \text{ GeV}/c$), only one BigBite setting is needed to cover the whole kinematic range.

By switching the polarity of the HRS_L magnets, SIDIS asymmetries of both positively and negatively charged pions were measured. With an aerogel Cherenkov counter, a ring imaging Cherenkov detector and TOF detectors, the Kaon asymmetries can be extracted as well.

Three Rb-K hybrid high pressure ^3He cells were used throughout the experiment. The ^3He nuclei were polarized in vertical and horizontal transverse directions. To reduce the systematics, the target spin was flipped every 20 minutes using adiabatic fast passage

FIGURE 1. Preliminary ^3He polarization history during E06-010 neutron Transversity experiment.

(AFP). It had already been demonstrated that these newly developed hybrid cells have significantly shorter spin-up times and higher polarization. To further improve the target performance, 3 narrow linewidth lasers were used for the first time in Hall A. As a result, the in beam polarization reached an unmatched 65%, see Figure 1 (compared to 42% in the original proposal!). The whole target system including both hardware and software was redesigned for better reliability and to accommodate all new features required by the experiment such as fast spin flip and vertical optical pumping. Throughout the experiment, the new system was running very stable.

DATA PROJECTION AND IMPACT

The total statistics has exceeded the PAC approved goal mainly due to the extraordinary ^3He target performance. The data will allow us to extract the three azimuthal asymmetries for the neutron related to the Transversity, Sivers and Pretzelosity distribution functions. The projected statistics of the Collins and Sivers asymmetries are shown in Figure 2. When combined with world data, the results will provide important constraints on the TMDs of u , d and s quarks in the valence quark region.

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FIGURE 2. Projected statistics on Collins and Sivers asymmetries

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