Flavor Decomposition of Nucleon Spin Structure: A Proposed Experiment at Jefferson Lab Hall C

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Abstract. We propose to measure the semi-inclusive double-spin asymmetries in deep-inelastic $\bar{p}(\vec{e}, e'h)X$ and $d(\vec{e}, e'h)X$ reactions ($h = \pi^+, \pi^-, K^+$ and K^-) on longitudinally polarized NH_3 and LiD targets. The high statistic data will allow a leading order five-flavor decomposition (Δu , Δd , $\Delta \bar{u}$, $\Delta \bar{d}$, $\Delta s = \Delta \bar{s}$) of the nucleon spin structure in the region of $x = 0.12 \sim 0.43$ at a Q^2 of $1.21 \sim 3.22 \text{ GeV}^2$. The combined spin dependent $\pi^+ + \pi^-$ yield ratios will be measured, since the acceptance and the hadron efficiencies of the detectors can be accurately determined. Independent of fragmentation functions and parton distributions, the z -dependence ($z = 0.38 \sim 0.71$) of the combined ratios provides a build-in test of factorization at the moderate Q^2 . We estimate statistical uncertainties associated with such measurements.

INTRODUCTION

At the Thomas Jefferson National Accelerator Facility, the combination of a CW polarized electron beam and the use of polarized targets presents many new physics opportunities, especially in the measurements of spin observables of deep inelastic semi-inclusive scattering (SIDIS). If factorization between quark scattering and quark fragmentation can be clearly demonstrated, SIDIS can provide accesses to quark polarization distributions. In the current fragmentation regime, the leading hadron from the fragmentation is strongly correlated with the struck quark, and the virtual photon asymmetry A_1^h is related to quark polarization at the leading order as:

$$A_1^h(x, Q^2, z) = \frac{\sum_f e_f^2 \Delta q_f(x, Q^2) \cdot D_f^h(z, Q^2)}{\sum_f e_f^2 q_f(x, Q^2) \cdot D_f^h(z, Q^2)}. \quad (1)$$

Once factorization can be demonstrated at a reasonable level, flavor decomposition of nucleon spin structure can be achieved based on data sets of double-spin asymmetries [1]. In this proposed experiment, we will use asymmetries of $A_{1p}^{\pi^\pm}$, $A_{1p}^{K^\pm}$, $A_{1d}^{\pi^\pm}$, $A_{1d}^{K^\pm}$ and the better-known inclusive asymmetries A_{1p} and A_{1d} .

To quantitatively demonstrate factorization in SIDIS, it is crucial to perform precision measurements on observables that are sensitive to the violation of factorization. A schematic strategy of factorization tests was suggested [2] which requires no prior knowledge of fragmentation functions nor parton distributions. The major experimental challenge in this strategy is to observe the z -dependence of the combined $\pi^+ + \pi^-$ helicity asymmetries.

THE PROPOSED MEASUREMENTS

We propose to measure the $\bar{p}(\vec{e}, e'h)X$ and $\bar{d}(\vec{e}, e'h)X$ ($h = \pi^+, \pi^-, K^+$ and K^-) spin-dependent cross sections with longitudinally polarized NH_3 and LiD targets in Jefferson Lab Hall C with a 6 GeV polarized electron beam [3]. The existing HMS spectrometer will be located at 10.8° as the hadron arm detector. Three HMS momentum settings (2.00, 2.62 and 3.22 GeV/c) will be taken for both positive and negative polarities. A large calorimeter array, with a solid angle of 200 msr, will be centered at 30° as the electron arm in conjunction with a threshold gas Cherenkov detector. A polarized proton luminosity of $8.5 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$ with 80% polarization can be achieved with the UVa polarized NH_3 target. For a total of 24 days of beam time, the expected statistical errors on A_{1p}^π and A_{1d}^π are shown in Fig. 1, and the expected errors on $A_{1p}^{\pi^+\pi^-}$ are shown in Fig. 2. The expected accuracies on the spin-flavor decomposition are shown in Fig 3.

FIGURE 1. The expected statistical accuracy of $A_{1p}^{\pi^+}$, $A_{1p}^{\pi^-}$, $A_{1d}^{\pi^+}$ and $A_{1d}^{\pi^-}$ as functions of x . The HERMES preliminary results [1] are also shown. The dashed lines are the expected asymmetries for $\langle Q^2 \rangle = 2.5 \text{ GeV}^2$ and $\langle z \rangle = 0.5$ using the CTEQ5 and the AAC quark distributions.

FIGURE 2. The expected statistical accuracy of spin-dependent yield ratio $A_{1p}^{\pi^+\pi^-}$ as functions of z are plotted for each x -bins. The solid line indicates the expected value from the factorization assumption, CETEQ5 and AAC parameterization. The dashed lines indicate an absolute variation of $\pm 2\%$.

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FIGURE 3. The expected statistical accuracy of 5-flavor decomposition compared with the preliminary HERMES data (1996-2000). The error bars on the projected JLab data are statistical only while the HERMES data includes both statistical (inner bars) and the systematic errors.