PhD Proposal

Measurement of Polarized Valence Quark Distribution Functions using Polarized Proton and Deuteron Targets

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Outline

- Motivation
- Physics
- Experimental Setup
- Prelim Results
- Conclusions
Motivation

- Semi-Inclusive Double Spin Asymmetry Measurement
- Extraction of \( \Delta d/d \) observable
- The perturbative Quantum Chromodynamics (pQCD) vs The hyperfine perturbed Constituent Quark Model (CQM)
The Standard Model

- The theory of the three fundamental interactions
- Three kinds of elementary particles
- 12 – leptons, 36 – quarks, 4 – force mediators
Quantum Chromodynamics vs Constituent Quark Model

- Valence, sea quarks and gluons
- Asymptotic Freedom
- Confinement

- Three types of quarks
- Baryon – qqq
- Meson – quark-antiquark
- Quark confinement
Deep Inelastic Scattering vs $Q^2$

$Q^2$ - Four Momentum Transferred Squared, $d=(0.2\text{GeV} \times \text{fm})/Q$
Deep Inelastic Scattering and Valence Quark Region

\[ W(\text{Invariant Mass}) > 2\text{GeV} \]

\[ X_{bj} > 0.3 \]
Semi Inclusive Deep Inelastic Scattering (SIDIS) Diagram
Semi Inclusive Double Spin Asymmetry

\[ A_1^h = \frac{\sigma_{1/2}^h - \sigma_{3/2}^h}{\sigma_{1/2}^h + \sigma_{3/2}^h} \]

\[ \frac{d^3\sigma_{1/2(3/2)}^h}{dx dQ^2 dz} \approx \sum_q e_q^2 q^{+(-)}(x, Q^2) D_q^h(z, Q^2) \]

Semi Inclusive deep inelastic scattering provides and opportunity to determine the struck quark flavor.
Polarized and Unpolarized Structure Functions

\[ A(x, Q^2) = \frac{g_1(x)}{F_1(x)} \]  
Asymmetry

\[ F_1(x) = M_h W_1 = \frac{1}{2} \sum_q e_q^2 q(x) \]
Unpolarized structure function

\[ g_1(x) = \frac{1}{2} \sum_q e_q^2 (q^+(x) - q^-(x)) = \frac{1}{2} \sum_q e_q^2 \Delta q(x) \]
Polarized structure function
Asymmetry and Quark distribution functions

\[ A_{1,p}^{\pi^+\pi^-} = \frac{4\Delta u_v(x) \pm \Delta d_v(x)}{4u_v(x) \pm d_v(x)} \]

\[ A_{1,2H}^{\pi^+\pi^-} = \frac{\Delta u_v(x) + \Delta d_v(x)}{u_v(x) + d_v(x)} \]

\[ \Delta u_v(x, Q^2) = \frac{\Delta \sigma_p^{\pi^+\pi^-} + \Delta \sigma_{2H}^{\pi^+\pi^-}}{\sigma_p^{\pi^+\pi^-} + \sigma_{2H}^{\pi^+\pi^-}} (x, Q^2) \]

\[ \Delta d_v(x, Q^2) = \frac{\Delta \sigma_p^{\pi^+\pi^-} - 4\Delta \sigma_{2H}^{\pi^+\pi^-}}{\sigma_p^{\pi^+\pi^-} - 4\sigma_{2H}^{\pi^+\pi^-}} (x, Q^2) \]
The CEBAF Large Acceptance Spectrometer at JLab

- Polarized electron beam
- Polarized targets
- Superconducting toroid magnet
- Drift chambers
- Cherenkov counter
- Electromagnetic calorimeter
Target Materials

- Frozen ammonia: the polarized proton and neutron
- For background elimination: C12, liquid Helium and Nitrogen
- Polarized using the Dynamic Nuclear Polarization (DNP) Method
- ~96% and ~46% polarization for the proton and neutron targets
Drift Chambers

- The trajectory of the charged particle
- Three regions
- ArCO₂ (90/10%) - gas mixture
- The drift time and drift velocity
Cherenkov Detector

- The threshold detector
- Differentiate electrons from pions
- Gas – C$_4$F$_{10}$ (n=1.00153, high photon yield)
- Thresholds: 9 MeV for electrons and 2.5 GeV for pions
CLAS Scintillators

- 288 scintillators
- The time of flight for charged particle
- Coincidence for particle
- 120ps – 250ps time resolution
- The length from 30 cm to 450 cm
The CLAS Calorimeter

- 8 electromagnetic calorimeter modules
- Measures the total energy deposited by the crossing particle
- Neutron detection
- Electron detection above 0.5 GeV
- Photon detection above 0.2 GeV
Kinematics of single pion electroproduction

- The virtual photon negative four-momentum transferred squared
- Invariant mass of the photon-nucleon system
- The polar angle of the outgoing pion in CMF
- The azimuthal angle of the outgoing pion in CMF
- The scattered electron angle
The Five-Fold Differential Cross Section

\[
\frac{\partial^5 \sigma}{\partial E_f \partial \Omega_e \partial \Omega_\pi^*} = \frac{1}{2\pi} \sum L_{int} A_{cc} \epsilon_{CC} \Delta W \Delta Q^2 \Delta \cos \theta_\pi^* \Delta \phi_\pi^* \frac{d(W,Q^2)}{d(E_f, \cos \theta_e)}
\]

\[
\frac{d(W,Q^2)}{d(E_f, \cos \theta_e)} = \frac{2M_p E_i E_f}{W}
\]
Particle Identification Using Electromagnetic calorimeter

Cuts on the energy deposited in the electromagnetic calorimeter (EC_{total}>0.2*p and EC_{inner}>0.06*p)
Pion Removal From The Electron Sample
Using Cherenkov Counter

The pion contamination in electron sample is ~ 9.6 %, and for NPHE>2.5 ~ 4.03 %
Data Comparison
The Expected Precision of This Analysis

The ratio of polarized to unpolarized valence down quark distribution function vs $X_{Bj}$
Future Plans

- Measure asymmetries using the knowledge of the probe and target's polarization state
- The double spin asymmetries
- About three data points will be extracted from this analysis