PhD Proposal

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

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Motivation

Physics

Experimental Setup

Prelim Results

Conclusions
Motivation

- “The proton spin crisis”
- 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)
Deep Inelastic Scattering vs $Q^2$

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

\[ Q^2 = 5 \text{ GeV}^2 \]

- NLO (94)
- NLO
- LO

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

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

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

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

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

Semi Inclusive deep inelastic scattering provides and opportunity to determine the struck quark flavor.
The CEBAF Large Acceptance Spectrometer at JLab

- Polarized electron beam
- Polarized targets
- Superconducting toroid magnet
- Drift chambers
- Cherenkov counter
- Electromagnetic calorimeter
Event Display

NH3 Target, inbending, 5.7 GeV beam energy
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 and momentum
- Three regions
- $\text{ArCO}_2$ (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
The CLAS TOF Scintillators

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

- 8 electromagnetic calorimeter modules
- Measures the total energy deposited by the crossing particle
- Neutron detection, efficiency > 50% for $E_n > 0.5 \text{GeV}$
- Electron detection above 0.5 GeV
- Photon detection above 0.2 GeV

Kinematics of the exclusive 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

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

\[
\frac{\partial^3 \sigma}{\partial E_f \partial \Omega_e \partial \Omega_{\pi^+}} = \sum \frac{1}{2\pi} L_{int} A_{cc} \epsilon_{CC} \Delta W \Delta Q^2 \Delta \cos \theta_{\pi^+} \Delta \phi_{\pi^+} \frac{d(W, Q^2)}{d(E_f, \cos \theta_e)}
\]
Particle Identification Using Electromagnetic calorimeter

Cuts on the energy deposited in the electromagnetic calorimeter (ECtotal>0.2*p and ECinner>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

\[ \varphi_{\pi^*} \text{ vs Relative rate for fixed } \cos \theta_{pion}^{CM} = 0.5 \text{ and } W = 1.45\text{GeV} \]

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