Extracting the Fifth Structure Function in ^{2}H(e, e'p)n

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Fifth Structure Function

One of the goals of Jefferson Lab is to explore the underlying quark-gluon structure of atomic nuclei [1]. To accomplish that goal we need to first understand atomic nuclei as collections of protons and neutrons. We have to establish a baseline for the hadronic model to see where that model begins to fail at higher energies. Measuring the fifth structure function probes a seldom-measured part of the deuteron response where the proton-neutron force is expected to dominate.

CEBAF

The data were acquired with the Continuous Electron Beam Accelerator Facility (CEBAF) at the Thomas Jefferson National Accelerator Facility (JLab) in Newport News, Virginia. CEBAF can produce 6 GeV electron beams at velocities close to the speed of light around its 7/8-mile-long racetrack-like accelerator.

Figure 1: Jefferson Laboratory in Newport News, Virginia

CLAS 6

In this experiment, 2.6 GeV electron beams were aimed at a deuteron target in Hall B's CEBAF Large Acceptance Spectrometer (CLAS 6). CLAS is a 45-ton, three-story, spectrometer which is composed of six identical sectors covering almost all solid angles. CLAS also has two toroidal magnet polarity settings (normal/reversed) which bend charged particles in opposite directions.

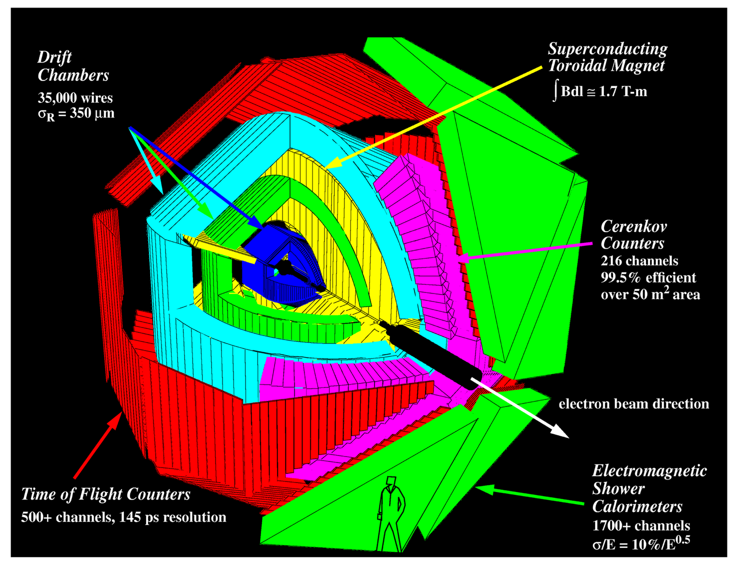

Figure 2: CLAS 6

Probing the Fifth Structure Function

In order to study the fifth structure function, we use an asymmetry A'_{LT}. To extract A'_{LT} from our data, we start with the differential cross section for the quasielastic reaction ^{2}H(e,e'p)n with polarized beams.

$$\frac{d^5\sigma}{dQ^2 dp_m d\phi_{pq} d\Omega_e d\Omega_p} = \sigma^{\pm} = \sigma_L + \sigma_T + \sigma_{LT}\cos\phi_{pq} + \sigma_{TT}\cos 2\phi_{PQ} + h\sigma_{LT'}\sin\phi_{pq} \qquad (1)$$

The symbol ± refers to the beam helicity, Φ_{pq} is shown in Figure 3, p_m is the missing momentum defined as $\vec{p}_m = \vec{q} - \vec{p}_p$, where $\vec{q}$ is the 3-momentum transfer and $\vec{p}_p$ is the ejected proton 3-momentum. The σ_i's are the partial cross sections for each component. The helicity asymmetry is

$$A_h(Q^2, p_m, \phi_{pq}) = \frac{\sigma^+ - \sigma^-}{\sigma^+ + \sigma^-} \qquad (2)$$

where Q^2 is the square of the 4-momentum transfer.

The magnitude of p_m grows with increasing θ_{pq} where θ_{pq} is the angle between the 3-momentum transfer $\vec{q}$ and the proton 3-momentum $\vec{p}_p$ (see Figure 3).

By substituting Equation 1 into Equation 2, we get the following.

$$A_h(Q^2, p_m, \phi_{pq}) = \frac{\sigma_{LT'}\sin\phi_{pq}}{\sigma_L + \sigma_T + \sigma_{LT}\cos\phi_{pq} + \sigma_{TT}\cos 2\phi_{PQ}} \qquad (3)$$

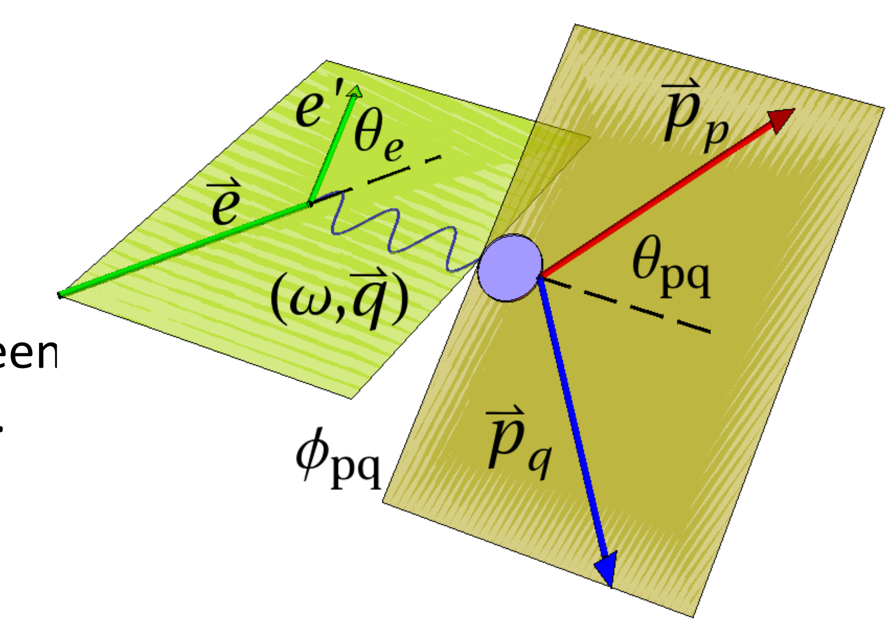

Figure 3: Kinematic quantities.

The numerator in the equation is proportional to $\sin\Phi_{pq}$ and the denominator is approximately constant (σ_{LT} and σ_{TT} are small and can be ignored). One obtains,

$$A_h(Q^2, p_m, \Phi_{pq}) \approx \frac{\sigma_{LT'}\sin\phi_{pq}}{\sigma_L + \sigma_T} = A'_{LT}\sin\phi_{pq} \qquad (4)$$

Therefore, the amplitude of a fit of A_h would be A'_{LT}.

Extracting the Asymmetry A'_{LT}

We analyzed the data using a C++ code based on the ROOT package from CERN. We generated ROOT 2D histograms for both beam helicities as a function of the missing momentum p_m and the out-of-plane angle Φ_{pq}. We calculated the ratio of the difference of the opposite beam helicity histograms divided by their sum (see Equation 2) to create a new set of 2D histograms in p_m and Φ_{pq} bins. Data for a given p_m bin were projected out and the Φ_{pq} dependence was fitted to a sinusoidal curve (see Figure 4 and Figure 5 for examples) over the range p_m=0-0.7 GeV/c in nine bins. We completed these steps for both the normal and reversed magnetic polarities of the CLAS toroidal magnetic field.

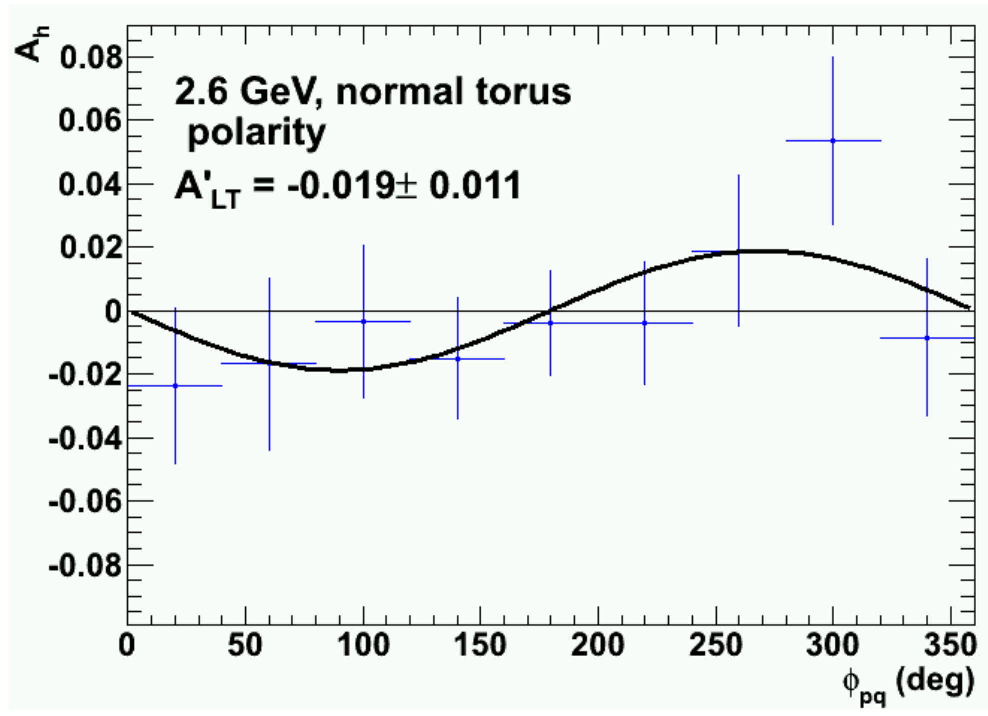

Figure 4: A_h, Normal Polarity, p_m=0.30 GeV/c

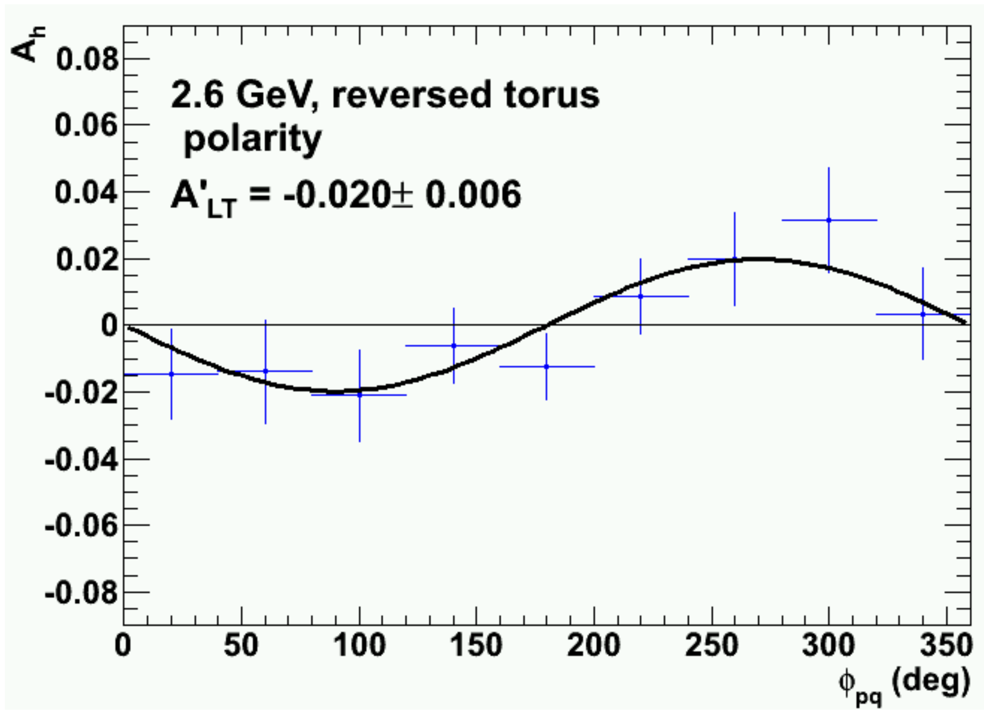

Figure 5: A_h, Reversed Polarity, p_m=0.30 GeV/c

Results

In Figures 6 and 7, the asymmetry A'_{LT} is shown as a function of the missing momentum p_m for both the normal (Figure 6) and the reversed (Figure 7) magnetic polarities of the toroidal magnetic field. The red points are from a different method of measuring A'_{LT} using a $\sin\Phi_{pq}$-weighted average [2]. The blue points are results of the fits to A_h from above. Both methods of extracting A'_{LT} are consistent. The average difference between the two methods was 0.0004±0.0012 for the normal torus polarity and 0.0001±0.0010 for the reversed torus polarity.

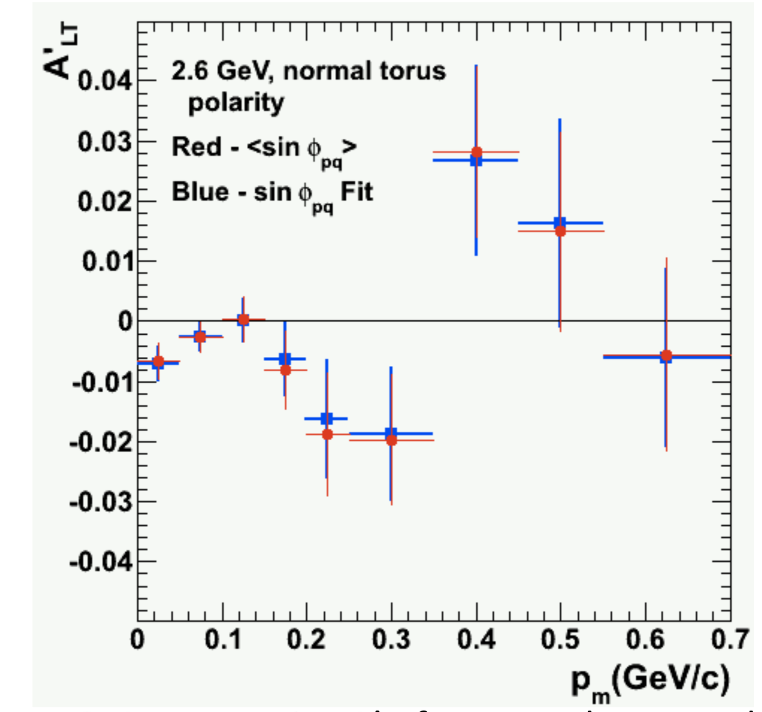

Figure 6: Asymmetries A'_{LT} for normal torus polarity

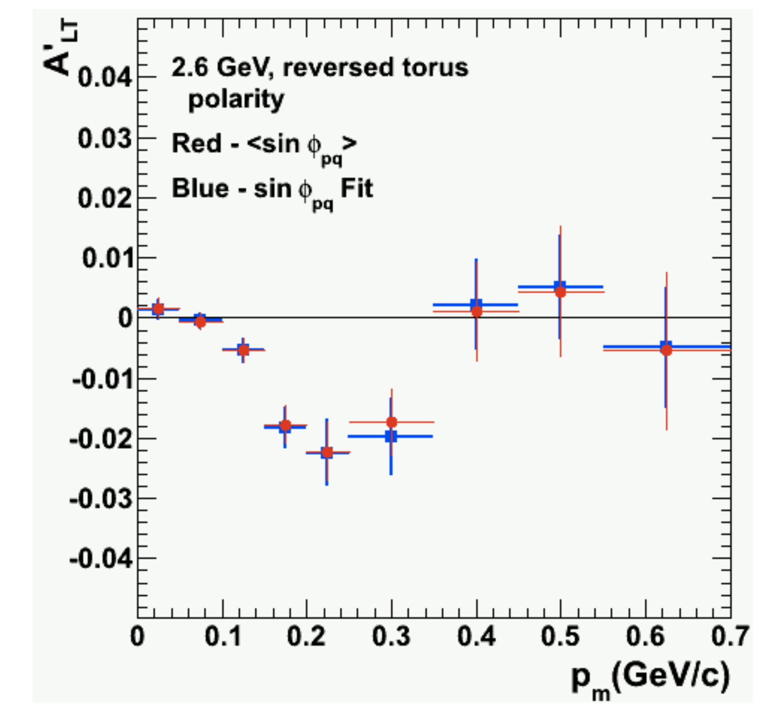

Figure 7: Asymmetries A'_{LT} for reversed torus polarity

Conclusions

We have developed a method to extract the asymmetry A'_{LT} from fits to the helicity asymmetry. We measured A'_{LT} for both torus polarities using this method and compared our results to the $\sin\Phi_{pq}$-weighted method. The differences are consistent with zero within uncertainties for both torus polarities. Both methods of extracting A'_{LT} are equivalent.

References

[1] *The Frontiers of Nuclear Science: A Long Range Plan*; US Department of Energy/National Science Foundation, Washington, DC, 2007.

[2] G.P. Gilfoyle et al., Bull. Am. Phys. Soc. DF.00010 (2006).