Testing the Analysis Algorithms of the ^{2}H(e,e'p)n Reaction

Liam Murray and Gerard Gilfoyle
Department of Physics, University of Richmond

Fifth Structure Function

One of the goals of Jefferson Lab is to explore the quark-gluon structure of atomic nuclei [1]. To do that, we first need to understand atomic nuclei as collections of protons and neutrons to see where that picture begins to fail revealing the underlying quark gluon structure. By measuring the helicity asymmetry A'_{LT}, we can explore the fifth structure function, 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 (Figure 1). CEBAF produces 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

CLAS6

In this experiment, 2.6 GeV electron beams were aimed at a deuteron target in Hall B's CEBAF Large Acceptance Spectrometer (CLAS6). 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 to determine their momenta.

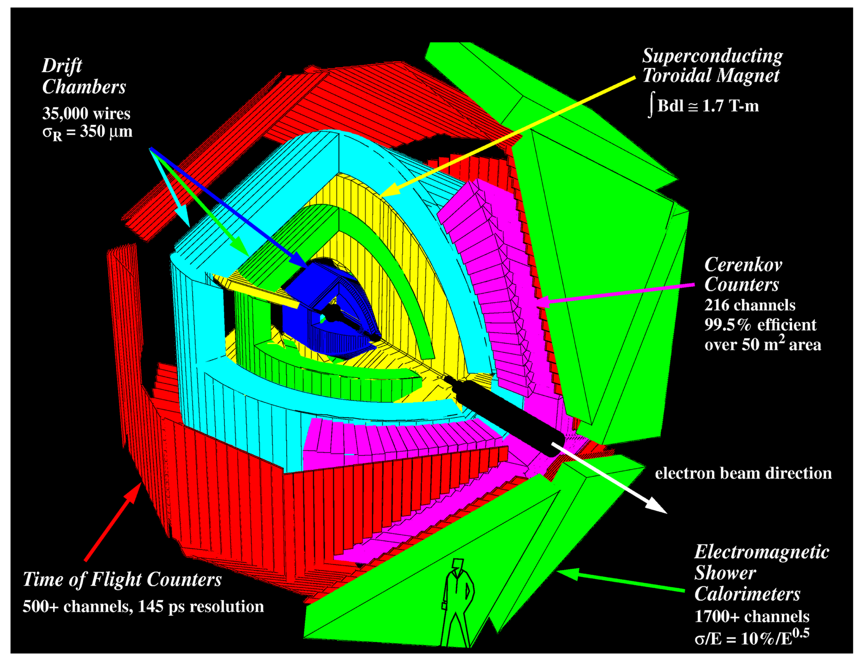

Figure 2: CLAS6

Probing the Fifth Structure Function

The goal of this project is to test the accuracy of our analysis of the asymmetry A'_{LT} as part of an effort to measure the fifth structure function of the deuteron σ'_{LT} in quasielastic kinematics. To do this, we will take the analysis code that was used on the actual data, and perform the same analysis on a simulation of CLAS6. We will then compare the simulated results with a fit to the data. By fitting the measured A'_{LT} from the actual data and then using the fit in a CLAS6 simulation, we will be able to accurately simulate the experiment. The results should be the same within the uncertainties.

In order to study the fifth structure function, we use an asymmetry A'_{LT}. 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. The helicity asymmetry is defined as

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

We substitute Equation 1 into Equation 2 and obtain a numerator proportional to $\sin\phi_{pq}$ and the denominator is approximately constant (σ_{LT} and σ_{TT} are small and can be ignored). One obtains,

$$A_h(Q^2, p_m, \Phi_{pq}) \approx \frac{\sigma_{LT'}\sin\phi_{pq}}{\sigma_L + \sigma_T} = A'_{LT}\sin\phi_{pq} \qquad (3)$$

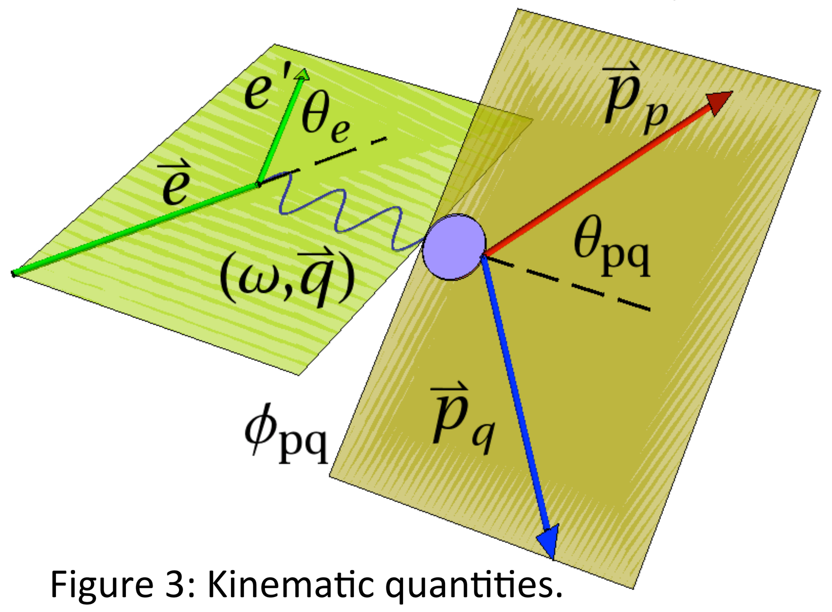

Figure 3: Kinematic quantities.

Fitting the Asymmetry A'_{LT}

To accurately simulate the reaction in CLAS, we use fits of the measured asymmetries to serve as models. Equation 4 was used to fit the data. The equation fits the asymmetry data well and decreases to zero as expected as the missing momentum decreases to zero. See the black curves in Figures 4 and 5. The fit equations were then incorporated into the Monte Carlo simulation GSIM. Table 1 provides the values of each parameter and their uncertainties.

$$A'_{LT}(p_m) = \frac{\delta_1 p_m^2 + \delta_2 p_m^4}{1 + \delta_3 p_m + \delta_4 p_m^2 + \delta_5 p_m^4 + \delta_6 p_m^6} \qquad (4)$$

Simulating a Reaction in CLAS6

Using a sequence of programs, we simulated events in CLAS6 and extracted A'_{LT}. The sequence first generates quasi-elastic electron events by generating electron and proton 4-vectors with **QUEEG** and then **txt2part** converts the output files into BOS data files. BOS is the CLAS6 data format. We then simulate CLAS6 with **GSIM** which is based on GEANT3. The program **gppjlab** removes dead wires in the detector. **RECSIS** is the standard program for reconstruction of CLAS data, and **n10tmake**r converts the output into hbook ntuples. After converting the ntuples into ROOT ntuples from n10tmaker, we used ROOT to extract A'_{LT}.

We used a shell script to run the sequence of programs from QUEEG to ROOT. We then wrote a Perl script which submits the shell script to remote nodes on the University of Richmond cluster.

Results

Figure 4 and 5 show the results of the analysis algorithms on the simulated data (red points). The bin-averaged fit points (blue points) were found by integrating the fit to the asymmetry and averaging over each bin. The bin-averaged points and the simulation are consistent within uncertainties.

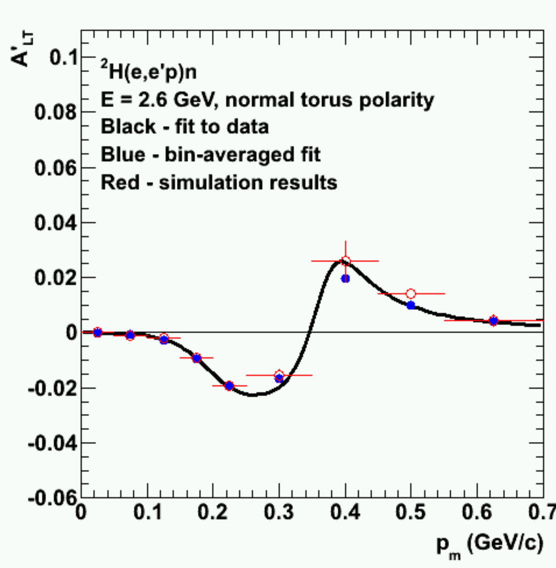

Figure 4: Asymmetries A'_{LT} for normal torus polarity

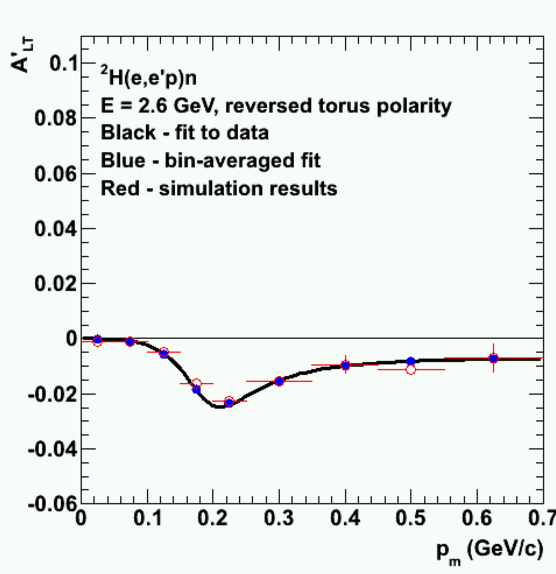

Figure 5: Asymmetries A'_{LT} for reversed torus polarity

	Normal Torus Polarity	Reversed Torus Polarity
Parameter	Value	Value
δ_1	$-3.0 \pm 0.5 \times 10^{-2}$	$-6.8 \pm 2.6 \times 10^{-2}$
δ_2	$2.5 \pm 2.1 \times 10^{-1}$	$-1.5 \pm 12 \times 10^{-2}$
δ_3	$-1.1 \pm 7.8 \times 10^{-1}$	$-9.7 \pm 3.8 \times 10^{-1}$
δ_4	$3.6 \pm 0.18 \times 10^{1}$	$2.7 \pm 1.9 \times 10^{1}$
δ_5	$-15 \pm 3.8 \times 10^{1}$	$-1.1 \pm 2.5 \times 10^{1}$
δ_6	$3.6 \pm 1.2 \times 10^{2}$	$1.2 \pm 8.3 \times 10^{2}$

Table 1: Parameter values for normal and reversed torus polarity fit

Conclusion

We have generated Monte Carlo events with asymmetries modeled after our own data. Those events were passed through the CLAS6 standard simulation code and A'_{LT} extracted with our analysis codes. Because of the consistency between the inputs and the extracted asymmetry, we have validated our analysis codes. We continue to refine our Monte Carlo calculations to improve their precision.

References

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