Preliminary Results for a Precision Measurement of the Neutron d_2: Probing the Lorentz Color Force

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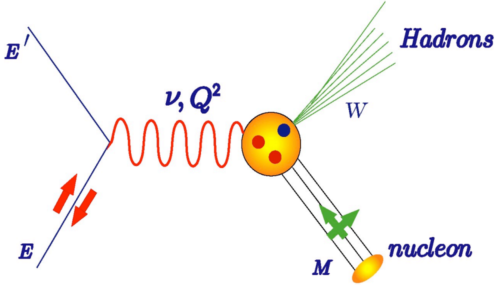
Hall A Collaboration Meeting, 12/16/11

Outline

Polarized DIS

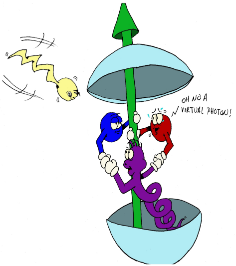


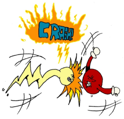
- Scatter longitudinally-polarized electrons off of a longitudinally (or transversely) polarized nucleon
- They interact via an exchanged virtual photon
- Probes the spin content of the nucleon
- We measure physics observables like the electron's scattering cross-section and asymmetries

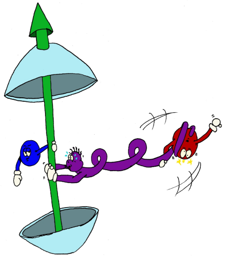
What is d_2^n?

The Lorentz Color Force

- A virtual photon probes inside the nucleon and strikes a quark
- The active quark in the interaction feels a force due to the spectator constituents
- d_2^n is a measure of this transverse Lorentz color force (M. Burkardt, hep-ph/0905.4079v1)

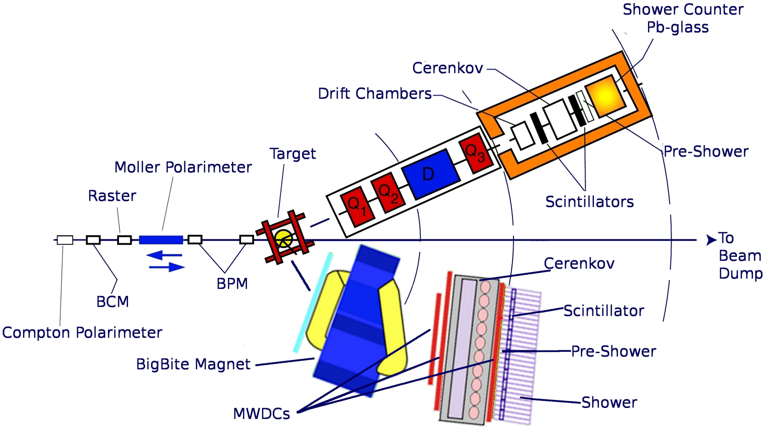






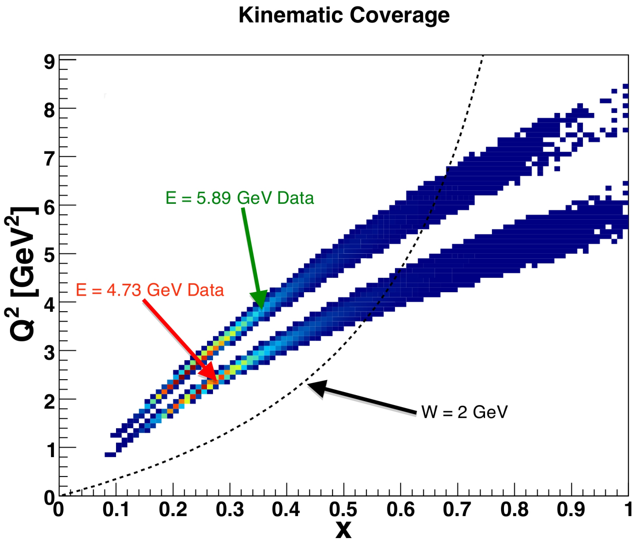
The E06-014 Experiment

Setup



The E06-014 Experiment

Kinematic Coverage



The E06-014 Experiment

Electron Beam Polarization

- Two methods: Møller and Compton measurements
- Combine both methods to acheive an error of $\sim 1.6\%$

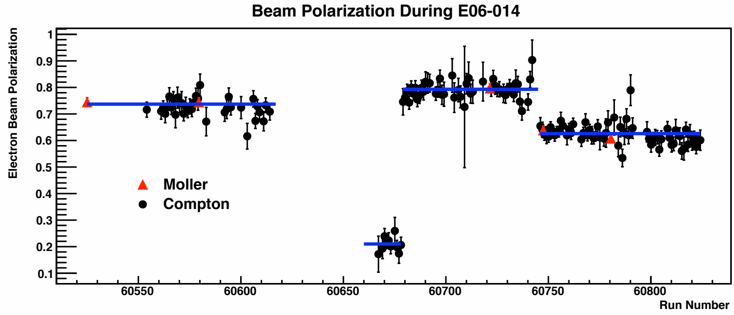


Figure: Compton data analysis by D. Parno. Plot from D. Parno's thesis.

The E06-014 Experiment

^{3}He Target Polarization

- NMR measurement every four hours (target chamber)
- EPR measurement (pumping chamber)
  - Polarization values in plot: valid for pumping chamber
  - EPR calibration: achieve an error of $\sim 4.9\%$

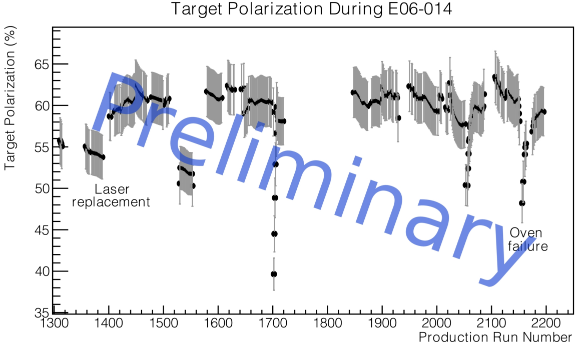


Figure: Target polarization analysis by Y. Zhang.

The Measurement of d_2^n

- Combine our measured cross-sections and asymmetries:

$$d_2^n = \int_0^1 dx \frac{MQ^2}{4\alpha^2} \frac{x^2 y^2}{(1-y)(2-y)} \sigma_0 \times \left[\left(3 \frac{1+(1-y)\cos\theta}{(1-y)\sin\theta} + \frac{4}{y}\tan(\theta/2) \right) A_\perp + \left(\frac{4}{y} - 3 \right) A_\parallel \right]$$

$$A_\parallel = \frac{\sigma^{\downarrow\Uparrow} - \sigma^{\uparrow\Uparrow}}{\sigma^{\downarrow\Uparrow} + \sigma^{\uparrow\Uparrow}} \quad A_\perp = \frac{\sigma^{\downarrow\Rightarrow} - \sigma^{\uparrow\Rightarrow}}{\sigma^{\downarrow\Rightarrow} + \sigma^{\uparrow\Rightarrow}} \quad \sigma_0 = \frac{ps \cdot N}{(Q/e)\rho t_{LT}\varepsilon} \frac{1}{w\Delta E' \Delta\Omega \Delta Z}$$

$\uparrow, \downarrow = e^-$ beam spin $\quad \Uparrow, \Rightarrow =$ Target spin

LHRS Analysis (1)

E = 4.73 GeV Data: Cross Sections

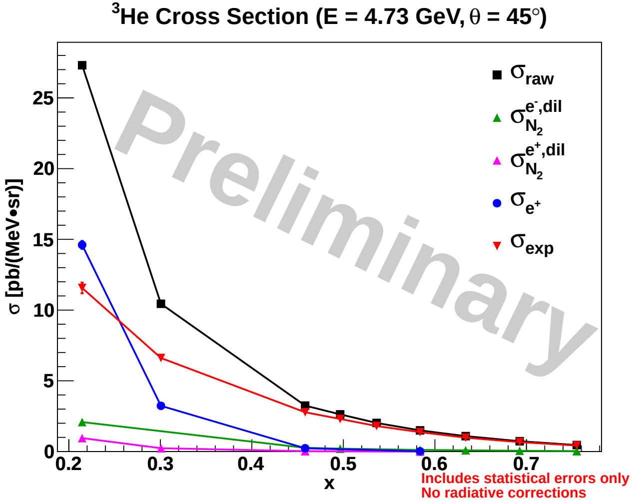


Figure: Cross section analysis by D. Flay.

LHRS Analysis (2)

E = 5.89 GeV Data: Cross Sections

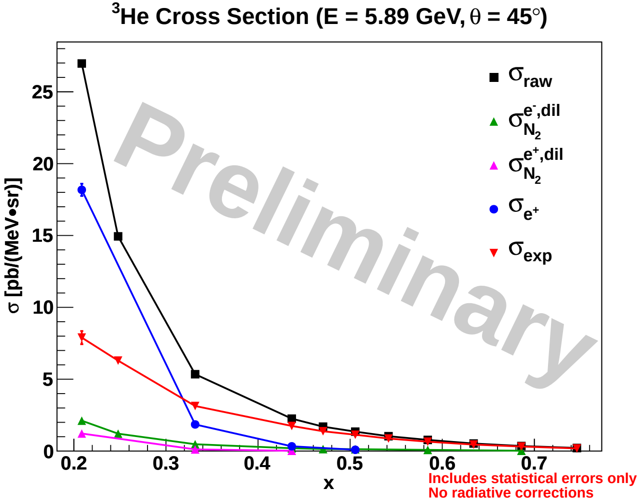


Figure: Cross section analysis by D. Flay.

BigBite Analysis (1)

E = 4.73 GeV Data: $A_{\parallel}$ and $A_{\perp}$

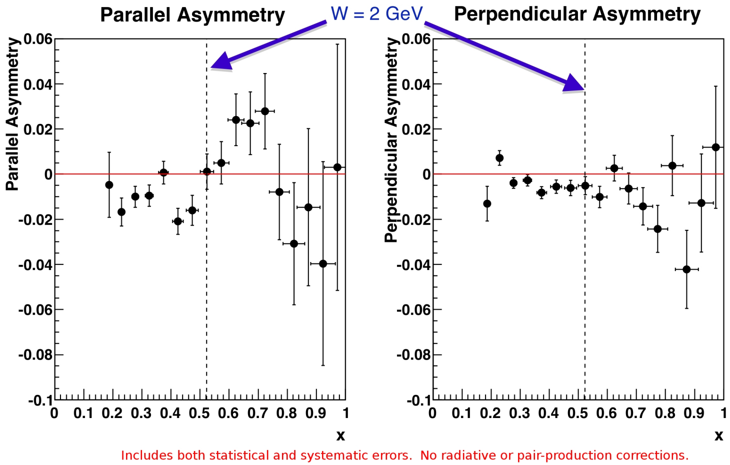


Figure: Asymmetry analysis by D. Parno and M. Posik. Plots from D. Parno's thesis.

BigBite Analysis (2)

E = 4.73 GeV Data: $A_1^{^3\mathrm{He}}$

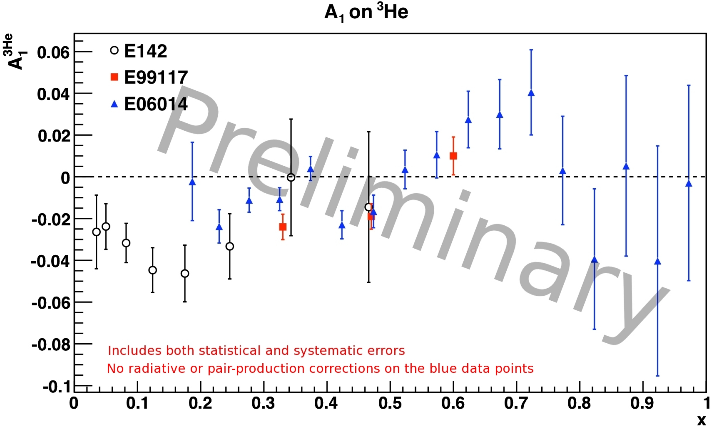
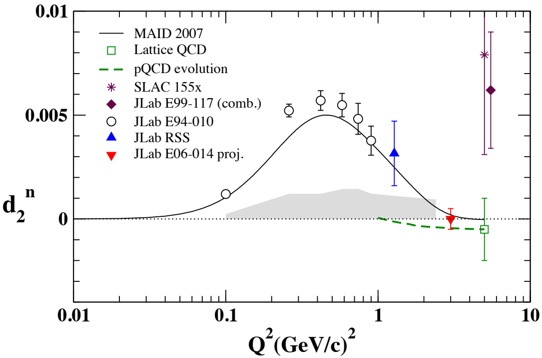


Figure: Asymmetry analysis by D. Parno and M. Posik. Plot from D. Parno's thesis.

Projected Error on d_2^n

Comparison to Current Data



- Projected statistical error: $\sim 5 \times 10^{-4}$
    - Four times better than current world average
    - Direct test of Lattice QCD

Summary

- Interested in quark-gluon correlations
  - Exploit transverse spin interactions through the g_2 structure function, leading to higher twist effects seen in the matrix element d_2^n
  - Sheds light upon the Lorentz color force inside the nucleon
- Preliminary results for $A_1^{^3\mathrm{He}}$ are in good agreement with the JLab E99-117 result and provides more complete kinematic coverage with more data points and better statistics
- Our calculation of d_2^n will provide a benchmark test for Lattice QCD

Current and Future Work

- Radiative corrections to the cross section and asymmetry data, including finishing up the positron dilution calculations
- Computing the asymmetries for the primary (E = 5.89 GeV) data set
- Extracting the asymmetry A_1^n, $d_2^{^3\mathrm{He},n}$ and the spin structure functions $g_1^{^3\mathrm{He},n}$, $g_2^{^3\mathrm{He},n}$

Acknowledgements

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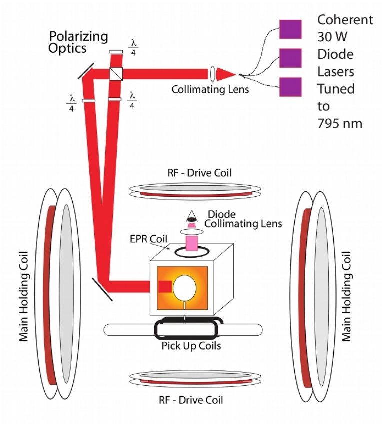
Backup (1)

^{3}He Target



- Vaporized Rb is optically pumped using circularly polarized light to polarize its electrons
- Through hybrid spin-exchange the Rb electrons transfer their spin to K atoms, then K to ^{3}He nuclei

Backup (2)

Physics Measurements

- The spin structure functions:

$$g_1 = \frac{MQ^2}{4\alpha^2}\frac{2y}{(1-y)(2-y)}\sigma_0\left[A_{\parallel} + \tan(\theta/2)\, A_{\perp}\right]$$

$$g_2 = \frac{MQ^2}{4\alpha^2}\frac{y^2}{(1-y)(2-y)}\sigma_0\left[-A_{\parallel} + \frac{1+(1-y)\cos\theta}{(1-y)\sin\theta}A_{\perp}\right]$$