Polarized Deep Inelastic Scattering

What is d_2^n ?

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Projected Error or

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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

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- The E06-014 Experiment Setup and Kinematics Polarized Electron Beam Polarized ³He Target Physics Measurements
- 4 Preliminary Results
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What is d_2^n

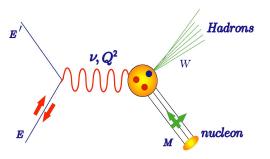
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Polarized DIS



- 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



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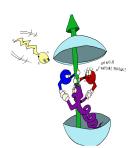
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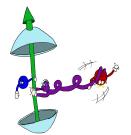
What is d_2^n ?

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
- d₂ⁿ is a measure of this transverse Lorentz color force (M. Burkardt, hep-ph/0905.4079v1)









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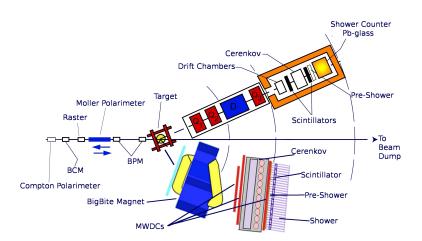
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The E06-014 Experiment Setup



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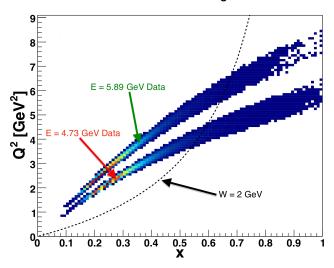
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The E06-014 Experiment

Kinematic Coverage

Kinematic Coverage



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Electron Beam Polarization

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

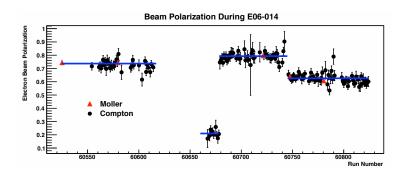


Figure: Compton data analysis by D. Parno. Plot from D. Parno's thesis.

Polarized 3He Target

The E06-014 Experiment

³He 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 $\sim 4.9\%$



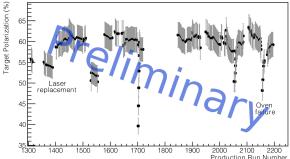


Figure: Target polarization analysis by Y. Zhang.



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The Measurement of d_2^n

 Combine our measured cross-sections and asymmetries:

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

$$\mathbf{A}_{\parallel} = \frac{\sigma^{\downarrow \uparrow \uparrow} - \sigma^{\uparrow \uparrow \uparrow}}{\sigma^{\downarrow \uparrow \uparrow} + \sigma^{\uparrow \uparrow \uparrow}} \quad \mathbf{A}_{\perp} = \frac{\sigma^{\downarrow \Rightarrow} - \sigma^{\uparrow \Rightarrow}}{\sigma^{\downarrow \Rightarrow} + \sigma^{\uparrow \Rightarrow}} \quad \mathbf{\sigma}_{0} = \frac{ps \cdot N}{(Q/e)\rho t_{LT}\varepsilon} \frac{1}{w\Delta E'\Delta\Omega\Delta Z'}$$

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

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LHRS Analysis (1)

E = 4.73 GeV Data: Cross Sections

 3 He Cross Section (E = 4.73 GeV, θ = 45 $^\circ$)

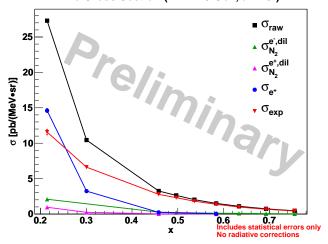


Figure: Cross section analysis by D. Flay.



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LHRS Analysis (2)

E = 5.89 GeV Data: Cross Sections

³He Cross Section (E = 5.89 GeV, θ = 45°)

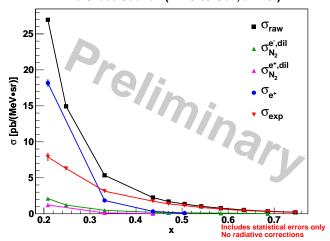


Figure: Cross section analysis by D. Flay.



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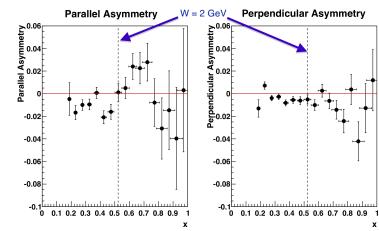
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BigBite Analysis (1)

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



Includes both statistical and systematic errors. No radiative or pair-production corrections.

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BigBite Analysis (2)

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

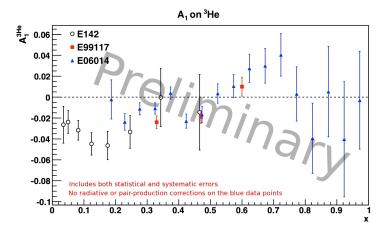


Figure: Asymmetry analysis by D. Parno and M. Posik. Plot from D. Parno's thesis.

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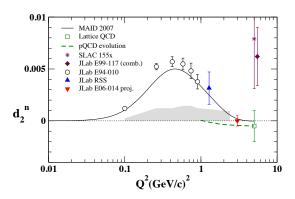
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Projected Error on d_2^n Comparison to Current Data



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

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- 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 $A_1^{^3{
 m He}}$ 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

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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 , $d_2^{^3{\rm He},n}$ and the spin structure functions $g_1^{^3{\rm He},n}$, $g_2^{^3{\rm He},n}$

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Acknowledgements

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 M. Posik, Y. Zhang, G. Franklin, Z.-E. Meziani
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The E06-014 Experiment

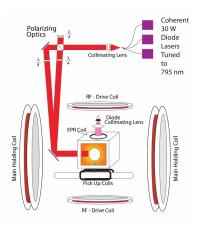
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Backup (1) 3 He Target



- 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 ³He nuclei

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Backup (2)

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• The spin structure functions:

$$g_{1} = \frac{MQ^{2}}{4\alpha^{2}} \frac{2y}{(1-y)(2-y)} \sigma_{0} \left[A_{\parallel} + \tan(\theta/2) A_{\perp} \right]$$

$$g_{2} = \frac{MQ^{2}}{4\alpha^{2}} \frac{y^{2}}{(1-y)(2-y)} \sigma_{0} \left[-A_{\parallel} + \frac{1+(1-y)\cos\theta}{(1-y)\sin\theta} A_{\perp} \right]$$