The $g_2^p$ Experiment

Toby Badman
The University of New Hampshire
On Behalf of the E08-027 Collaboration
Inclusive Electron Scattering

\[ \frac{d\sigma}{d\Omega dE'} = \sigma_{\text{Mott}} \left[ \frac{1}{v} F_2(x, Q^2) + \frac{2}{M} F_1(x, Q^2) \tan^2 \theta \right] \]

Unpolarized nucleon structure functions.
Inclusive Electron Scattering

\[
\frac{d\sigma}{d\Omega dE'} = \sigma_{\text{Mott}} \left[ \frac{1}{v} F_2(x, Q^2) + \frac{2}{M} F_1(x, Q^2) \tan^2 \frac{\theta}{2} + \gamma g_1(x, Q^2) + \delta g_2(x, Q^2) \right]
\]

Polarized nucleon spin structure functions.
Inclusive Electron Scattering

\[
\Delta \sigma_\parallel = \frac{d^2 \sigma_{\uparrow \uparrow}}{d\Omega dE} - \frac{d^2 \sigma_{\downarrow \uparrow}}{d\Omega dE} \propto \alpha g_1(x, Q^2) - \beta g_2(x, Q^2)
\]

\[
\Delta \sigma_\perp = \frac{d^2 \sigma_{\uparrow \Rightarrow}}{d\Omega dE} - \frac{d^2 \sigma_{\downarrow \Rightarrow}}{d\Omega dE} \propto \gamma g_1(x, Q^2) + \delta g_2(x, Q^2)
\]
Inclusive Electron Scattering

\[ g_1(x, Q^2) \propto \Delta \sigma_\parallel + \tan \frac{\theta}{2} \Delta \sigma_\perp \]

\[ g_2(x, Q^2) \propto -\Delta \sigma_\parallel + \frac{1 + (1 - y) \cos \theta}{(1 - y) \sin \theta} \Delta \sigma_\perp \]

- \( \Delta \sigma_\parallel \) is highly suppressed in the kinematic range where we are measuring \( g_2 \) (2-8% of total contribution to \( g_2 \)).

- For kinematic settings where we will not measure \( \Delta \sigma_\parallel \), EG4 data will be combined with our \( \Delta \sigma_\perp \) data to calculate \( g_2 \).
Motivation

• Measure the proton structure function, $g_2$, in the low $Q^2$ region for the first time.
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• Provides a unique opportunity to test the Burkhardt-Cottingham Sum Rule in the low $Q^2$ region.
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The $0^{th}$ moment of $g_2$ should satisfy (for all $Q^2$):

$$\int_0^1 g_2(x, Q^2) \, dx = 0$$

- Good agreement with existing Neutron data.
- Some disagreement with existing proton data.
- More proton data is needed.
Motivation

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• Provides a unique opportunity to test the Burkhardt-Cottingham Sum Rule in the low $Q^2$ region.

• Benchmark test of Chiral Perturbation Theory by extracting the generalized longitudinal-transverse spin polarizability.
Spin Polarizability

\[ \delta_{LT}(Q^2) = \frac{16\alpha M^2}{Q^6} \int_0^{x_0} dx\, x^2 [g_1(x, Q^2) + g_2(x, Q^2)] \]

- Neutron data shows deviations from \( \chi_{PT} \) calculations.
- No proton data yet!
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• Benchmark test of Chiral Perturbation Theory by extracting the generalized longitudinal-transverse spin polarizability.

• Improve calculations of Proton Hyperfine Splitting.
Experimental Setup

Continuous Electron Beam Accelerator Facility (CEBAF)

• Maximum Energy 12GeV
• 200\(\mu A\) current
• Electron polarization \(\sim 85\%\)

Thomas Jefferson National Laboratory
Newport News, Virginia
Experimental Setup

- New beamline equipment installed for low current running (<100nA)
- Chicane installed for transverse target field requirements.
- Rotatable 2.5T/5T scattering chamber.
- Local dump and septum magnets
Kinematics and Projections

\[ 0.02 < Q^2 < 0.2 \text{GeV}^2 \]

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<th>Beam Energy (GeV)</th>
<th>Target Field (T)</th>
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Kinematics and Projections

BC Sum Integral

LT Spin Polarizability

Toby Badman DNP 2014
Analysis Progress

Completed
• Run DB
• HRS Optics
  • Field Measurement Analysis
  • VDC $t_0$ calibration
  • Simulation Package
  • Optics Reconstruction
• Detector Calibrations/Efficiencies
• Scalers
  • Helicity Decoding
  • BCM calibrations
  • Deadtime calculations
• Target Polarizations
• BPM calibrations
• Raster size calibration

In Progress
• Packing fraction/dilution analysis
• Elastic $P_B P_t$ check
• Radiative corrections
• Acceptance study
Online Results

Nitrogen Elastic

Proton Elastic/Nitrogen Quasi-Elastic

$E = 2.2$ GeV HRS-L

$\Delta$ - Resonance

$W$ (MeV)
Online Results

Longitudinal 5T Physics Asymmetry at E=2254MeV
Summary

• The $g_2^p$ Experiment ran very successfully in spring, 2012.

• New instrumentation and beam requirements (and fires) introduced many challenges to the running and analysis.

• A first pass of production data is complete and analysis is well underway!

• We hope to have offline asymmetries and cross-sections by spring of next year

• $g_2$ calculation shortly after, possibly by summer, 2015.
E08-027 Collaboration

Spokespeople
Alexander Camsonne
J.P. Chen
Don Crabb
Karl Slifer

Post Docs
Kalyan Allada
Ellie Long
James Maxwell
Vince Sulkosky
Jixie Zhang

Graduate Students
Toby Badman
Melissa Cummings
Chao Gu
Min Huang
Jie Liu
Pengjia Zhu
Ryan Zielinski

Thank You!