The $g_2^p$ Experiment

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On Behalf of the E08-027 Collaboration
Overview

• Theory
• Motivation
• Experimental Setup
• Analysis
• Online Results
• Conclusions
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Inclusive Electron Scattering

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

Unpolarized nucleon structure functions.
Inclusive Electron Scattering

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

Polarized nucleon spin structure functions.

Polarized \( e^- \) beam

Polarized target
Inclusive Electron Scattering

\[ \Delta \sigma_{\parallel} = \sigma_{\uparrow\uparrow} - \sigma_{\downarrow\downarrow} = \frac{4\alpha^2 E'}{MvQ^2E} \left[ (E + E'\cos\theta)g_1(x, Q^2) - \frac{Q^2}{v} g_2(x, Q^2) \right] \]

\[ \Delta \sigma_{\perp} = \sigma_{\uparrow\downarrow} - \sigma_{\downarrow\uparrow} = \frac{4\alpha^2 \sin\theta E'Q^2}{Mv^2Q^2E} \left[ \nu g_1(x, Q^2) + 2E g_2(x, Q^2) \right] \]
Motivation

• Measure the proton structure function, $g_2$, in the low $Q^2$ region for the first time.

• 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.

• Improve calculations of Proton Hyperfine Splitting.
The Burkhardt-Cottingham Sum Rule

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

This Sum Rule will fail if \( g_2 \):

- exhibits non-Regge behavior.
- exhibits a delta function at \( x = 0 \).
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 large deviation from \( \chi_{PT} \) calculations.
- No proton data yet.
- A disagreement with \( \chi_{PT} \) calculations could indicate short distance contributions.
Existing $g_2^p$ Data at large $Q^2$

SLAC

JLAB SANE

Very Preliminary
Experimental Setup

Jefferson Lab Linear Accelerator Facility
Experimental Setup

Jefferson Lab Linear Accelerator Facility

Hall A
Experimental Setup

Hall A beamline and High Resolution Spectrometer layout
Experimental Setup

Hall A beamline and High Resolution Spectrometer layout

\textbf{NH}_3 \textbf{Target}: 5T superconducting split-pair magnet for polarizing solid \textit{NH}_3 target material.
Experimental Setup

Hall A beamline and High Resolution Spectrometer layout

**Slow/Fast Raster**: Two dipole magnets in each raster force beam to trace out a \(~2\text{cm}\) circular pattern at target
Experimental Setup

Hall A beamline and High Resolution Spectrometer layout

**Chicane**: Two dipole magnets bend beam to compensate for target field.
Experimental Setup

Hall A beamline and High Resolution Spectrometer layout

**Local Dump**: For some energy/target field settings beam cannot make it to hall dump so it is deposited in a local dump immediately downstream of the target.
Experimental Setup

Hall A beamline and High Resolution Spectrometer layout

**Beam Current Monitors**: Resonant cavities with antenna tuned to beam frequency. Calibrated using a Tungsten Calorimeter.
Experimental Setup

Hall A beamline and High Resolution Spectrometer layout

**Beam Position Monitors**: Four antenna situated at 90° to each other, perpendicular to the beamline for high resolution position measurement.
Hall A beamline and High Resolution Spectrometer layout

**High Resolution Spectrometers:** Two Hall A spectrometer arms rotated to ± 12.5° relative to beamline.
Hall A beamline and High Resolution Spectrometer layout

**Septum Magnets**: Allow access to lowest possible $Q^2$ by bending $5.6^\circ$ scattered electrons to $12.5^\circ$ (HRS minimum)
Kinematics and Projections

\[ 0.02 < Q^2 < 0.2 GeV^2 \]

<table>
<thead>
<tr>
<th>Beam Energy (GeV)</th>
<th>Target Field (T)</th>
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</thead>
<tbody>
<tr>
<td>2.254</td>
<td>2.5</td>
</tr>
<tr>
<td>1.706</td>
<td>2.5</td>
</tr>
<tr>
<td>1.158</td>
<td>2.5</td>
</tr>
<tr>
<td>2.254</td>
<td>5.0</td>
</tr>
<tr>
<td>3.352</td>
<td>5.0</td>
</tr>
</tbody>
</table>

Used Local Dump
Detector Calibrations and Efficiencies

Left Arm:
Gas Cherenkov
Scintillator 1, Scintillator 2
Vertical Drift Chamber
PionRejector 1, Pion Rejector 2

Right Arm:
Gas Cherenkov
Scintillator 1, Scintillator 2m
Vertical Drift Chamber
Preshower, Shower
Detector Calibrations and Efficiencies

- Gas Cherenkov calibrated by aligning single photo electron peaks to ADC channel 100.

LHRS Gas Cherenkov Calibration Stability Check

![Graph showing calibration stability check for different energy levels across ADC channels and momentum.](image)

Courtesy M. Cummings
Detector Calibrations and Efficiencies

- Shower calibrated using Fumili minimization technique. Checked by plotting $\frac{E_{tot}}{p}$.

Courtesy J. Liu and M. Cummings
Trigger Efficiencies

![Graph showing trigger efficiencies versus run number.]( Courtesy R. Zielinski)
BPM Calibration

- BPM consists of 4 antenna: $x_+, x_-, y_+, y_-$

- Harp data used to calibrate BPM antenna using new method (due to chicane and low current.)

- Position reconstruction in the target still underway.
Target Polarization Analysis

- Target polarization measured via NMR and recorded every 30s.
Target Polarization Analysis

- Offline calibration done using thermal equilibrium measurements on each of 18 different target materials used.
- Polarization averaged across each production run.
- Detailed systematic uncertainty study in progress.
Optics

- Due to the right septum magnet catching on fire twice, production is broken up into three “septum settings”.

<table>
<thead>
<tr>
<th>Right Septum Configuration</th>
<th>Number of Turns</th>
</tr>
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<tbody>
<tr>
<td>1 (Ideal)</td>
<td>48-48-16</td>
</tr>
<tr>
<td>2</td>
<td>40-32-16</td>
</tr>
<tr>
<td>3</td>
<td>40-0-16</td>
</tr>
</tbody>
</table>
Optics

- 1\textsuperscript{st} and 3\textsuperscript{rd} Septum Configuration calibrations complete for 5.0T 0° target field setting.

- No target field optics complete.

- 1\textsuperscript{st} iteration of pointing calibration to determine central angle complete.

- Simulation work being done to help target field ‘on’ optics.

- Work is currently being done to calibrate transverse target field optics.
Optics

LHRS Delta Scan at 6°, no target field.

Sieve slit data before calibration

After optics matrix calibration

Optics Matrix Calibration

Courtesy M. Huang
Online Results

Nitrogen Elastic

Proton Elastic/Nitrogen Quasi-Elastic

E = 2.2 GeV HRS-L

Δ - Resonance

W (MeV)

Toby Badman GHP April 2013

Courtesy R. Zielinski
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 now complete and data quality checks are underway!
- We hope to have offline asymmetries and cross-sections by fall of this year.

Thank You!

Toby Badman GHP April 2013