Instrumentation for the g2p experiment

➢ Target
➢ Beamline
➢ Detector
➢ DAQ

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Review for g2p

Ran in Hall A from February to May in 2012

\[ Q^2 \, 0.02 - 0.20 \text{GeV}^2 \]

6° forward angle detection

Luminosity: \(10^{34} - 10^{35} \text{ cm}^{-2} \text{ s}^{-1} \)

Energy: 1.1 – 3.3GeV

Expected Uncertainty ~ 5~7%

Inclusive Polarized Cross Section

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

Chao Gu talked about it in detail in previous talk

Two additional Structure Functions needed
Instrumentation for g2p

Beamline

NH3 Target

Detector
Polarized NH3 target

- 1K Refrigerator
- 2.5/5T Transverse target field
  (1.1GeV need to use lower field because of large bending caused by target field)
- 3W microwave, powered at 1k

Target magnet coils were damaged in Nov, 2011, JLab target group replacing them with coils from the Hall B target magnet. The repair was successful but caused g2p a delay of about 3 months.
g2p polarized target

Dynamic Nuclear Polarization

Why NH3?
High radiation damage resistance
Can be completely recovered by annealing sample at a low temperature (~77k) and can be repeated many times

Calibrate NMR:
Thermal equilibrium

\[
Polarization = \tanh \left( \frac{\mu_B H}{kT} \right)
\]
Online Polarimetry

Maximum Polarization (without beam)

~55% at 2.5 Tesla/70 GHz
~92% at 5.0 Tesla/140 GHz

Average Polarization (with 50nA beam)

>30% at 2.5 Tesla/70 GHz
>75% at 5.0 Tesla/140 GHz

Polarization influencing factors:
- Temperature
- Radiation damage
- ...

Need to run in low current!
~50nA

Thank you to J. Maxwell
g2p beamline

Red: New in Hall A for g2p
Blue: Added for g2p (used before)
Pink: Old equipment, new receiver

Beam Position Monitor
Super Harp
Tungsten Calorimeter
Beam Current Monitor
Fast Raster
Slow Raster
Moller Polarimeter
Chicane Dipole
Septum
Local Beam Dump

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Raster System

- Fast Raster ~2mm
- Slow Raster ~2cm

- minimize depolarization
- reduce radiation damage
- less systematic error for target polarization measurement
New BPM and BCM Receiver

Improved signal-to-noise ratio for low current

Resolution:
- 0.18mm with 50nA
- 0.12mm with 100nA

Works well with 50nA~100nA

Thanks to John Musson, Trent Allison, Keith Cole
Super Harp --------- Calibrate 2 BPMs

50um wires
Worked in pulsed beam mode

Calibrated in Straight Through Configuration

Did the harp scan in ~5uA **pulsed beam**
At the same position took run in 100~50nA CW beam
Tungsten Calorimeter  ------->  Calibrate Beam Current Monitor

Get Total Charge from Temperature
Then Calibrate BCM count
Chicane Magnet

2.5/5T Transverse Target Magnet Field
Used for bending beam to hall A dump and minimizing out of plane angle

Used for dumping the primary beam during 5T run. Radiation effects carefully studied before running. Worked well during experiment, radiation damage was not excessive.
g2p Detectors

3rd Arm Detector

Septum

Dipole & Quadruple

Q₁, Q₂, D, Q₃

High Resolution Spectrometers

Q₁, Q₂, D, Q₃
Septum

HRS Minimum Angle: 12.5 deg

Reduce to 6 deg

Left HRS

Right HRS

Scattered electron

Septum

Coils were damaged two times during experiment but fixed quickly
Hall A High Resolution Spectrometers

➢ High momentum resolution: 10e-4 level over a range of 0.8-4.0 GeV/c
➢ High momentum acceptance: $|\delta p/p|<4.5\%$
➢ Wide range of angular settings
  • 12.5 - 150 deg (LHRS)
  • 12.5 - 130 deg (RHRS)
➢ Solid angle at $\delta p/p=0,y_0=0$: 6 msr
➢ Angular acceptance:
  • Horizontal: ±30 mrad
  • Vertical: ±60 mrad

Gas Cherenkov
Used for particle identification
Efficiency trigger

Drift Chambers
Used for tracking

Lead Glass Calorimeters
Used for particle identification
Pion Rejection

Scintillators
Used for trigger
Third Arm

- Measure elastic asymmetry to monitor beam and target polarization (10% level)
  - \[ A_{\text{raw}} = P_b \times P_t \times D \times A_{\text{phy}} \]
- Cross-check for beam (Moller) and target (NMR) polarization measurement
- Used for tuning beam during experiment

Asymmetry

![Graph showing asymmetry measurements](image)

Thanks to Kalyan Allada and ChaoGu
Data Acquisition System
--Single arm DAQ

- LHRS and RHRS DAQ operate independently (singles)
- 3 fastbus crates, 2 VME crate on each arm
Helicity and BCM diagram

- **Pockels Cell HV**
  - Circular polarization of laser light
  - Spin of photo-emitted electrons
  - Change
  - Output

- **Helicity Board**
  - Change
  - Quartet +-- or -++-
  - (30bit register generated Pseudo-random bits controlled)

- **Injector**

- **Can be predicted!**

- **Hall A Counting House**
  - Pair Sync
  - Delayed Helicity
  - QRT
  - MPS
  - Fiber

- **Hall C Checking**
  - Left Arm
  - Moller
  - Right Arm
  - Third Arm

- **Beam Current Signal**
Get Asymmetry

Each event have helicity information

DATA
EVENT DATA
RingBuffer DATA

Helicity
Predict, Compare, Check

Charge Asymmetry
Physics Asymmetry

Each element in ringbuffer contains 1 helicity status and 1 bcm information
Production running **6.5 kHz** with **~25% deadtime** at prescale=1!
Before in Hall A it is 4kHz(20% deadtime)

**Hall A Record!**
Summary

The target magnet coil failed prior to start of the experiment. It was replaced by the target group causing a 3 month delay. The target then performed extremely well.

Upgraded beamline instrumentation worked well to accommodate the low beam current and pre-bending required by the polarized target operation.

Septum magnets were used to reach forward angle of 6 degrees.

The third arm will provide an independent cross check of the product PbPt at the 10% level.

DAQ performance improved and stay on low deadtime (25%) in high rate (6kHz)

New Record in Hall A

E08-027 will provide the definitive measurement of $g_2$ at low $Q_2$
Thanks!

Thanks for target group in Jlab and Uva's hard work for reliable target performance during experiment
Thanks for Alexandre's help for beamline study
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