The Most Precise Measurement of the Beam Normal Spin Asymmetry in Electron-Proton Scattering Using the QWEAK Setup

by

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Introduction

We have used the QWEAK setup to make a 3.2% (preliminary) measurement of the Beam Normal Spin Asymmetry from the Proton at a Q^2 of 0.025 $(GeV/c)^2$. This observable provides direct access to the imaginary part of the two-photon exchange process. The measurement, analysis and preliminary results are discussed.

Normal Spin Asymmetry in Electron Scattering

- Directly proportional to the imaginary part of the two-photon exchange
- Parity conserving and time-reversal invariant

$$A = \frac{\left| \; e \; P \; + \; e \; P \; \right|^2 - \left| \; e \; P \; \right|^2}{\left| \; e \; P \; \right|^2 + \left| \; e \; P \; \right|^2} = \frac{\mathcal{I}m(\mathcal{M}_\gamma^* \mathcal{M}_{\gamma\gamma})}{|\mathcal{M}_\gamma|^2}$$

Beam Normal Spin Asymmetry (B_n)

Generated when electrons with spins polarized transverse to the direction of motion scatter from unpolarized nucleons

$$e(k_1, S) + P \rightarrow e(k_2, S) + P(p_2)$$

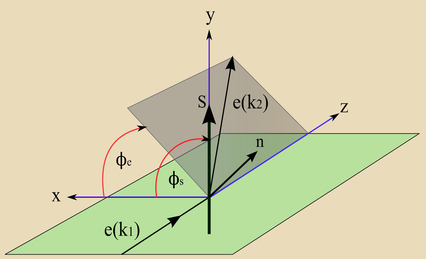


Figure 1. Kinematics of the transversely polarized electron scattering from an unpolarized target in the lab frame.

$$\hat{n} = \frac{k_1 \times k_2}{|k_1 \times k_2|}$$

The measured asymmetry has an azimuthal dependence given by

$$A_{Msr} = \frac{\sigma^\uparrow - \sigma^\downarrow}{\sigma^\uparrow + \sigma^\downarrow} = B_n \overrightarrow{S} \bullet \hat{n} = -B_n \sin(\phi_e - \phi_s)$$

Physics Interest

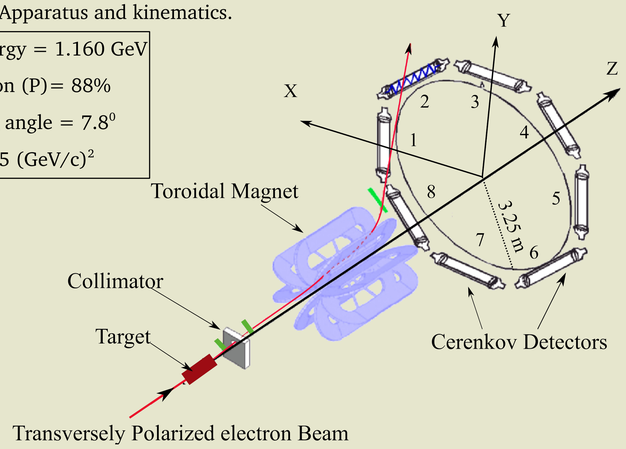
Magnitude of B_n ⟷ Imaginary part of Two-photon exchange

- Nucleon structure information.
- Interpretation of radiative corrections for electron scattering beyond Born approximation.
- Determining the false asymmetry due to residual transverse polarization in parity-violating asymmetry measurements.

QWEAK Setup Overview

Figure 2. Apparatus and kinematics.

Beam Energy = 1.160 GeV
Polarization (P)= 88%
Scattering angle = 7.8^0
Q^2 = 0.025 $(GeV/c)^2$



Signals to Asymmetries

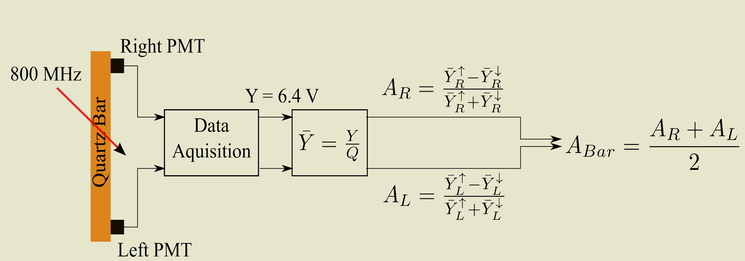
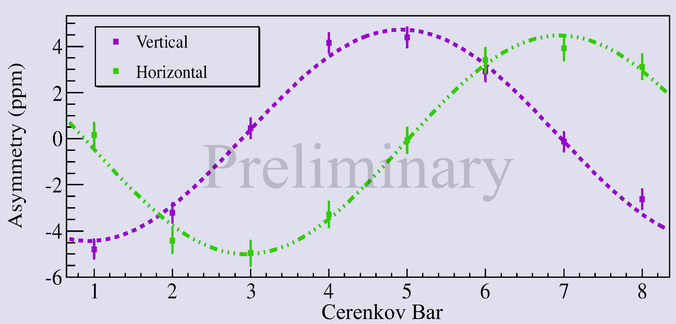


Figure 3. Forming the asymmetry of a single quartz bar using the left and right PMT asymmetries.

Measured Asymmetries

Figure 3. Vertical and Horizontal asymmetries measured from Hydrogen (not corrected for backgrounds or polarization)



$$\text{Fit}: A_{Bar}(\phi) = A_{Phys} \sin(\phi - \phi_0) + C$$

- Observed the 90^0 phase offset between vertical and horizontal asymmetries.
- A_{Phys} extracted from the Hydrogen cell target = -4.8 ppm

Analysis and Preliminary Result

Extract Azimuthal Dependance

$A_{Bar}(\phi) = A_{Phys} \sin(\phi - \phi_0) + C$
where ϕ =(octant-1) $\times 45^0$
ϕ_0 = phase offset

→ **Remove Backgrounds and Polarization**

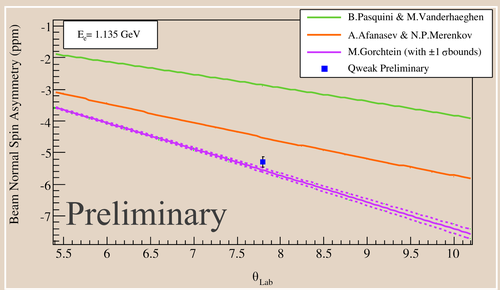
$$B_n = R \left(\frac{(A_{Phys}/P) - \sum_i A_i^B f_i^B}{\sum_i (1 - f_i^B)} \right)$$

$$B_n = -5.30 \pm 0.07_{(stat)} \pm 0.15_{(sys)} \text{ ppm}$$

Table 2. Relative contributions to the final error from statistical and systematic sources

Error Source	Relative dB/B
Beam polarization	2.2 %
Statistics	1.3 %
Q^2 Bias of the detectors	1.2 %
Detector non-linearity	1.0 %
Helicity correlated beam asymmetries	0.9 %
Aluminum background	0.3 %
Total Relative Error	**3.2 %**

Comparison to Theory



Pasquini & Vanderhaeghen
Phys. Rev. C 70, 045206 (2004).
(Intermediate state only includes single pion excitations)

Afanasev & Merenkov
Phys. Rev. D 70, 073002 (2004).

M.Gorchtein
Phys. Rev. C 73,055201 (2006).

Figure 4. Comparison between three theoretical model calculations and QWEAK preliminary measurement. The differences between the models lies in the treatment of the inelastic intermediate state in the two-photon exchange process.

Conclusions and Outlook

- We have made a 3.2% measurement of B_n from elastic electron-proton scattering. Its the most precise measurement of this quantity yet.
- Our measurement clearly indicates the model dependence of the two-photon estimation due to the different treatment of the intermediate states in the two-photon exchange.

Acknowledgements

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