Eur Phys J A (2005) **24**, s2, 39–40
DOI: 10.1140/epjad/s2005-04-008-0

EPJ A direct
electronic only

Normal beam spin asymmetries during the G^0 forward angle measurement

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Received: 1 November 2004 / Published Online: 8 February 2005

Abstract. The vector analyzing power measured in elastic scattering of transversely polarized electrons from an unpolarized nucleon is directly proportional to the imaginary part of the two photon exchange amplitude. There has been recent interest in explorations of the two photon exchange amplitude, as the real part has been proposed as a possible resolution of the discrepancy between Rosenbluth separation and polarization observable measurements of the ratio of the electric to magnetic proton form factor. The vector analyzing power appears in the experiment as an azimuthal asymmetry. It has been measured previously in the SAMPLE and A4 experiment with different kinematics than those achievable with the G^0 apparatus. As part of the systematic checks for the G^0 forward angle measurement at TJNAF, the normal beam spin asymmetry in the G^0 detector array was measured with a 3 GeV beam incident upon a liquid hydrogen target. The experimental configuration was identical to the standard G^0 forward angle running except that the beam was transversely polarized in the plane of the accelerator. The data collected cover a range in center of mass angle from 19° to 37°, with an eight-fold azimuthal symmetry. About 30 hours of data were taken in this configuration, resulting in an extracted vector analyzing power with a precision of a few ppm, which may already be able to provide some constraint on model predictions.

PACS. 13.60.-r Photon and charged-lepton interactions with hadrons – 14.20.Dh Protons and neutrons – 29.27.Hj Polarized beams in accelerators

1 Introduction

Elastic scattering of transversely polarized electrons from an unpolarized nucleon results in an asymmetry due to two-photon exchange. The two-photon exchange produces a cross section dependence on the angle between the polarization vector, $\mathbf{P}$, and the scattering plane [1]:

$$\sigma = \sigma_0 \ [1 + A_n \mathbf{P} \cdot \hat{\mathbf{n}}] \tag{1}$$

where the vector analyzing power, A_n, is proportional to the imaginary terms of the two-photon exchange amplitude. In a parity violating electron scattering measurement, in the general case, the normal beam spin asymmetry will contribute to the measured asymmetry,

$$A(\theta,\phi) = P\cos(\theta_{spin})A_{PV}(\theta) + P\sin(\theta_{spin})\sin(\phi-\phi_{spin})A_n(\theta) \tag{2}$$

where A_{PV} is the parity violating asymmetry, θ and ϕ are the electron scattering angles, and θ_{spin} and ϕ_{spin} are the angles of the electron polarization vector.

The G^0 experiment in Hall C of Jefferson Laboratory is primarily designed to measure the parity violating electron scattering asymmetry from the proton. In the forward angle measurement, the recoil protons scattered by a 3 GeV polarized electron beam incident on a 20 cm long liquid hydrogen target are momentum analyzed by a superconducting magnet, and are detected in 8 azimuthally symmetric detector packages with 16 detectors in each octant. The parity violating asymmetry in each detector varies from about 2 ppm to about 20 ppm through the Q^2 range. To minimize the effect on the parity violating asymmetry measurement due to the normal beam spin asymmetry, we set the polarization to be longitudinal for the G^0 measurements, and conducted the measurements of A_n discussed in this paper.

2 Experiment

The transverse data collection took place from 22 March through 26 March, 2004. At Jefferson Lab, the beam spin can be oriented in the horizontal plane (the plane of the ac-

[a] The G^0 Experiment is supported by the U.S. National Science Foundation (NSF) under grant PHY94-10768, the U.S. Department of Energy (DOE), the Natural Sciences and Engineering Research Council (NSERC) of Canada, and the Centre National de la Recherche Scientifique (CNRS) of France through the Institut National de Physique Nucléaire et de Physique des Particules (IN2P3).

Table 1. Elastic proton kinematic coverage for the G^0 forward angle measurements. The estimated error corresponds to the statistical error on the measurements only

Detectors	$\langle Q^2 \rangle$	$\langle \theta_{CM} \rangle$	Est. Error
1-4	0.13	19.03	1.3 ppm
5-8	0.17	21.65	1.3 ppm
9-12	0.25	26.12	1.3 ppm
13-14	0.38	32.35	2.4 ppm
15	0.6	37.4	2.9 ppm

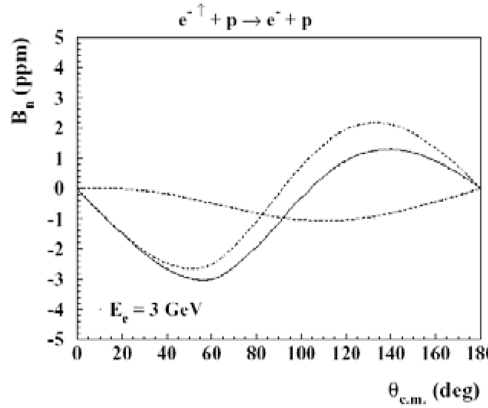

Fig. 1. Theory prediction for G^0 forward angle beam energy from [2]. The *dashed line* is the nucleon intermediate state, the *dash-dot line* is the π-N intermediate states, and the *solid line* is the total

celerator) by adjusting the Wien filter in the injector. The Hall C Møller polarimeter is only sensitive to the longitudinal component of the beam polarization. To determine the Wien filter setting which would produce transversely polarized beam in Hall C, a set of polarization measurements were made with Wien filter settings corresponding to spin angles of -95° to +100°. The data were fit to a cosine to find the setting which gave a zero of the longitudinal polarization; this was at a Wien angle of -85°. A set of three points at ±5° from the zero crossing were also taken at the beginning and end of the transverse running period, to check for drift of the zero-crossing; the zero crossing was found to have drifted by 3° during the four days of the measurement. The total spin precession through the accelerator was about 23π.

The detector, target, and spectrometer magnet configurations were identical to those used in the standard G^0 running. Data are simultaneously collected for elastically scattered protons, pions, and inelastic protons, which are separated by time-of-flight from the target. The analysis is primarily concerned with the elastic protons, and will apply corrections for the contributions to the background under the proton peak which come from the pions and inelastic protons.

The kinematic coverage and statistical error for the G^0 detectors are shown in Table 1. The systematic error estimates are not shown. The detectors cover a range in center of mass scattering angle from 19° to 38°. The statistical errors should be compared to the results of a calculation [2], shown in Fig. 1, for the G^0 beam energy which included intermediate states of the proton and π-N states with $W < 2$ GeV.

3 Future plans

The G^0 collaboration had submitted a proposal to the Jefferson Lab PAC26 to carry out transverse asymmetry measurements in conjunction with the three beam energy running periods of the G^0 backward angle measurement. The goal of this proposal was to make a 3 ppm measurement at a center of mass angle of about 130° at the three beam energies of 0.424, 0.585, and 0.799 GeV. At the highest beam energy, this would be a 10% measurement of the predictions of [2], as shown in Fig. 2.

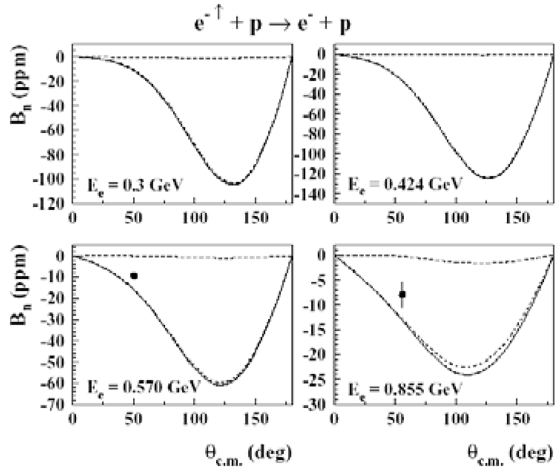

Fig. 2. Theory prediction for beam energies comparable to the G^0 backward angle measurements from [2]. The *line* types have the same meaning as in Fig. 1. The *points* are from the A4 measurements

4 Conclusion

We have made measurements of the beam normal asymmetry for elastic e-p scattering at a beam energy of 3 GeV for center of mass angles of 19-38 degrees, with an estimated statistical precision of a few ppm. We plan to make measurements at backward angles, with center of mass angles of about 130 degrees, at beam energies of 799, 585, and 424 MeV. The projected statistical error, for a dedicated experiment, is 3 ppm.

References

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