The G^0 experiment at Jefferson laboratory :

Measurement of the weak neutral form factors of the nucleon

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Abstract. The G^0 experiment aims to measure parity-violating asymmetries in elastic electron-proton and quasi-elastic electron-deuteron scattering. This experimental program allows to perform the separation of the electric and magnetic weak neutral and axial form factors for three different momentum transfers 0.3, 0.5 and 0.8 (GeV/c)^2. The first part of the experiment has been performed in Hall C of Jefferson Laboratory with a commissioned setup. A preliminary analysis of the data has provided a first estimate of the main systematic uncertainties. The analysis to determine the actual physics asymmetries is proceeding.

INTRODUCTION

In Quantum Chromo Dynamics the nucleon can be described in terms of three valence quarks (u and d) surrounded by gluons and sea quarks (quark-antiquark pairs of all flavours u, d, s ...). However, only partial information exist on the contribution of the sea quarks to the nucleon structure. In this context, parity-violating experiments as G^0 propose to provide new constraints on the strange quark contribution to the internal structure of the nucleon, i.e. to the electric and magnetic nucleon form factors.

In electron-nucleon scattering, the electroweak interaction takes place at first order through two diagrams with very different amplitudes: $\mathscr{M}_\gamma$ corresponding to the exchange of a virtual photon and $\mathscr{M}_Z$ to the exchange of a Z^0 boson with $\mathscr{M}_Z \simeq 10^{-5}\mathscr{M}_\gamma$. Because the weak interaction does not conserve parity, $\mathscr{M}_Z$ is accessible through interference terms, leading to the asymmetry in the elastic scattering of longitudinaly polarized electrons. The asymmetry can also be written in terms of the three form factors, the weak electric $G_E^{(Z,p)}$, weak magnetic $G_M^{(Z,p)}$ and axial G_A^{ep},

$$A_{PV}^p = -\left(\frac{G_F Q^2}{4\sqrt{2}\pi\alpha}\right)\frac{\varepsilon\, G_E^{(\gamma,p)}G_E^{(Z,p)} + \tau\, G_M^{(\gamma,p)}G_M^{(Z,p)} - (1-4sin^2\theta_W)\varepsilon'\, G_M^{(\gamma,p)}G_A^{ep}}{\varepsilon\left(G_E^{(\gamma,p)}\right)^2 + \tau\left(G_M^{(\gamma,p)}\right)^2} \quad (1)$$

where ε and ε' depend on electron energy and scattering angle and can thus be varied.

The G^0 experiment can provide a complete separation of $G_E^{(Z,p)}$, $G_M^{(Z,p)}$ and G_A^{ep} for three different momentum tranfers 0.3, 0.5 and 0.8 (GeV/c)^2. A first asymmetry measurement was performed for forward angle electron scattering for a Q^2 range between 0.1 and 1 (GeV/c)^2. Two further measurements will be performed at backward angle electron scattering on hydrogen and deuterium targets for different incident beam ener-

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gies corresponding to Q^2 values of 0.3, 0.5 and 0.8 $(\text{GeV/c})^2$. The contribution of the strange quarks to the electric and magnetic nucleon form factors can then directly be extracted from $G_E^{(Z,p)}$ and $G_M^{(Z,p)}$ using the quark decomposition in u, d and s flavours and assuming p-n charge symmetry.

In the forward angle configuration, the G^0 experiment used a 3 GeV beam with high intensity (40 μA) and high polarization ($\geq$ 70%) but with a different time structure than usually available at the *CEBAF* accelerator (31 MHz instead of 500 MHz). The polarization, which is reversed randomly at 30 Hz frequency, has been measured with an accuracy of about 2% using a Moller polarimeter. A beam feedback has been applied to the beam intensity and position to minimize beam helicity-correlated effects.

The G^0 setup, which is installed in Hall C of *Jefferson Laboratory*, is centered around a 20 cm LH_2 target, inserted in a spectrometer, which consists of a superconducting toroidal magnet with eight sectors placed around the beam axis. The recoil protons corresponding to elastic scattering are selected in momentum by a high magnetic field. The eight octants are composed of 16 detectors of plastic scintillators, located at the focal plane of the spectrometer. Each detector covers a well defined Q^2 range in the 0.1-1 $(\text{GeV/c})^2$ domain. Elastic protons are discriminated from other particles (protons, pions etc ...) produced in inelastic processes using a time of flight measurement. Custom electronics has been designed, which provide TOF histogramming during a 30 ms period, corresponding to the helicity flip. This allows handling counting rates of a few MHz per detector. A more detailed description of the G^0 experiment can be found in references [1, 2].

PRELIMINARY RESULTS

The data taking in the forward angle configuration has been performed between October 2003 and May 2004. Preliminary results from a first-pass analysis has allowed to estimate the main contributions to systematic uncertainties.

Helicity correlated beam parameters. An important issue in parity-violating experiments is related to the systematic errors associated with the beam properties. Using a beam feedback system to minimize helicity-correlated effects, the measured beam asymmetries, which are listed in table 1, have been kept within the specifications. The false asymmetries on the elastic counting rates have been estimated to be less than 10^{-8} and can be measured with good accuracy.

TABLE 1. Beam properties after 750 hours of data taking.

Beam parameters	Measured asymmetries	Specifications
Charge	-0.28 ± 0.28 ppm	1 ppm
X position	6 ± 4 nm	20 nm
Y position	8 ± 4 nm	20 nm
X angle	2 ± 0.3 nrd	2 nrd
Y angle	3 ± 0.5 nrd	2 nrd
Energy	58 ± 4 eV	75 eV

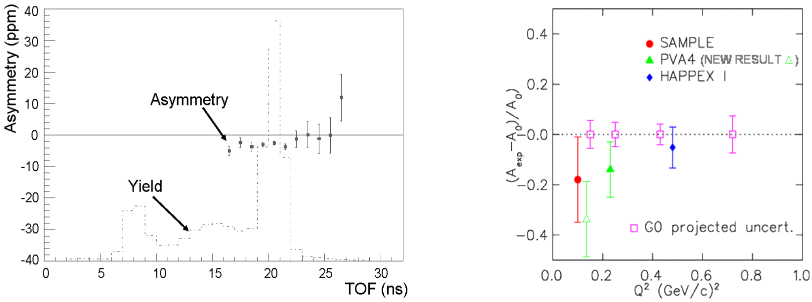

FIGURE 1. *Left:* Counting rates and asymmetries for detector 8. *Right:* Expected G^0 results in the Forward angle configuration.

Background contribution. The background can be divided in two parts: First a small ($\simeq 40\,nA$) leakage current coming from the beams delivered to the other halls with large asymmetries ($\simeq -340\,ppm$), generate a sizeable asymmetries in the TOF spectra due to the different beam time structure used in the G^0 experiment. The false asymmetries, within the TOF range corresponding to elastic protons, has been estimated to be about $0.3 \pm 0.1\,ppm$.

The second contribution is due to inelastic processes taking place in the target walls and the LH_2 which cannot be fully separated from the elastic protons using the TOF information (see Fig. 1-left). The inelastic contribution under the elastic proton peak, about 8 to 18% depending on the detector, has been estimated using data from several different running conditions (empty and dummy targets ...). The final contribution of the inelastics to the asymmetry was found to be relatively large for the detectors measuring the highest Q^2. The resulting uncertainties on the corrected asymmetries will likely dominate the overall systematic uncertainties however within the limits stated in the proposal.

SUMMARY

The final results of the G^0 forward angle measurements should be available by the end of 2004. They will be compared to other parity-violating asymmetries (see Fig. 1-right) in order to improve constraints on theoretical models. The turn-around of the spectrometer has been performed and the first backward angle measurement is scheduled at the end of 2005, providing a first separation of G_E^s and G_M^s at 0.8 $(\mathrm{GeV/c})^2$. The G^0 experiment is supported in part by the DOE (U.S.), CNRS/IN2P3 (France), NSERC (Canada) and NSF (U.S.).

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