Measurement of the Neutron Electric Form Factor G_E^n in $\vec{D}(\vec{e}, e'n)p$ Quasi-Elastic Scattering at $Q^2 = 0.5(GeV/c)^2$

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Abstract. We have determined the electric form factor of the neutron G_E^n from the reaction $\vec{D}(\vec{e}, e'n)p$ using a longitudinally polarized electron beam and a polarized deuterium target at Jefferson Lab's Hall C. The knocked out neutron was detected in coincidence with the electron in a shielded neutron detector. The beam–target asymmetry of quasi-elastically scattered electrons was measured for opposite orientations of the beam helicity which allowed the extraction of G_E^n. This method is insensitive to the deuteron structure and avoids longitudinal/transverse Rosenbluth separation, both potential sources of large systematic errors. We present the results of a preliminary analysis for G_E^n at $Q^2 = 0.5(GeV/c)^2$.

INTRODUCTION

G_E^n is related to the charge distribution of the neutron and is thus of fundamental importance for our understanding of the structure of nucleons. It provides a unique test for QCD and meson theory.

Recently it has become technically possible to perform double polarization experiments which measure asymmetries and detect the neutron in coincidence with the electron. This type of experiment avoids Rosenbluth separation and subtraction of the proton contribution and is less sensitive to the structure of the deuteron. Thus it avoids the main systematic difficulties of both elastic and inelastic inclusive cross section measurements, which were designed in the past to determine G_E^n.

The experiment described here used a longitudinally polarized electron beam in combination with a polarized deuterium target. To minimize the influence of the magnetic form factor G_M^n and to be most sensitive to G_E^n the direction of the target polarization was chosen to be perpendicular to the three momentum transfer $\vec{q}$ and to lie in the scattering plane. For a free neutron then the electron–neutron asymmetry A_n is given as

$$A_n = \frac{-2\sqrt{\tau(1+\tau)}\tan\left(\Theta_e/2\right) G_E^n G_M^n}{\left(G_E^n\right)^2 + \tau\left(1 + 2\left(1+\tau\right)\tan^2\left(\Theta_e/2\right)\right)\left(G_M^n\right)^2}; \qquad \tau = \frac{Q^2}{4M^2}$$

with electron scattering angle Θ_e and neutron mass M.

The electron–deuteron asymmetry A_{ed}^V has been calculated by Arenhövel [1] for electrodisintegration of the deuteron for different kinematic regions. The quasielastic region with a neutron emission in the direction of $\vec{q}$ shows negligible sensitivity to potential models, final state interactions and subnuclear degrees of freedom (meson exchange currents, isobar contributions).

EXPERIMENT E93-026

The experiment was performed in Hall C at Thomas Jefferson National Accelerator Facility (Jlab) in Newport News, Virginia, USA. The measurements took place from August to October 1998 and will be continued in 2001. The kinematics measured were $Q^2 = 0.5(GeV/c)^2$ and $Q^2 = 1(GeV/c)^2$. Results are presented here only for $Q^2 = 0.5(GeV/c)^2$.

The longitudinally polarized electron beam had an energy of 2.723 GeV. The beam helicity was reversed every second. The average beam polarization was 76% and was determined with an accuracy of 1% using a high precision moller polarimeter [2].

The polarized target [3] consisted of a superconducting magnet operating at 5 Tesla and a ^4He evaporation refrigerator operating at 1 K. Deuterized ammonia ($^{15}ND_3$), doped by irradiation was used as target material. The polarization was achieved dynamically by means of micro waves. A NMR circuit was used to determine the magnitude of polarization which averaged to 21% over the whole experiment.

A raster system was used to distribute the beam over the entire target surface and chicane magnets were installed before and after the target to compensate for the influence of the target magnet on the electron beam. Scattered electrons were detected in quasielastic kinematics in Hall C's standard high momentum spectrometer (HMS) while hadrons were detected in coincidence in a neutron detector enclosed in a concrete hut.

The neutron detector consisted of plastic scintillator detectors equipped with photo-multiplier tubes on each end. 79 Bars with a cross section of 10 $\times$ 10 cm^2 were arranged in 5 planes covering an area of 160 $\times$ 160 cm^2 at a distance of 400 cm from the target. 39 paddles with a thickness of 1 cm were arranged in two planes in front of the bars to veto the dominant proton contribution and to allow for a clean identification of the neutrons.

ANALYSIS AND RESULTS

Events were reconstructed using the standard HMS reconstruction code extended for the effects of beam raster and target magnetic field. On the neutron detector side a tracking algorithm was developped for proper particle identification. After event reconstruction and event selection charge and dead-time normalized yields were produced for each beam helicity state: $N^{\uparrow\downarrow}$. From these yields asymmetries ϵ were calculated and with the knowledge of target (P_T) and beam (P_B) polarization and the dilution factor (f) it was possible to extract experimental deuteron asymmetries A^V_{ed},

$$\varepsilon = \frac{N^{\uparrow} - N^{\downarrow}}{N^{\uparrow} + N^{\downarrow}} = P_B \cdot P_T \cdot f \cdot A^V_{ed}.$$

The dilution factor f accounts for scattering from nuclei other than deuterium and was determined from Monte Carlo simulations which were calibrated on data taken with a ^{12}C target. Additionally the experimental asymmetries were corrected for radiative effects and accidental background. Arenhövel provided theoretical calculations of A^V_{ed} on a kinematical grid and for different values of G^n_E. Using Monte Carlo technique we averaged the theoretical calculations over our experimental acceptance and compared it with the experimental A^V_{ed}. Figure 1 presents the experimental A^V_{ed} along with the theoretical A^V_{ed} averaged over our acceptance for three values of G^n_E in units of the Galster parametrization [4]. The asymmetries are plotted vs. θ_{nq} which is the lab angle between the $\vec{q}$ vector and the neutron track.

Our experimental value for G^n_E was then determined by fitting a linear interpolation of the theoretical curves to the data with the result $G^n_E = 0.90 \times (G^n_E)_{Galster}$ This procedure was repeated for other kinematic variables than θ_{nq} and produced consistent results.

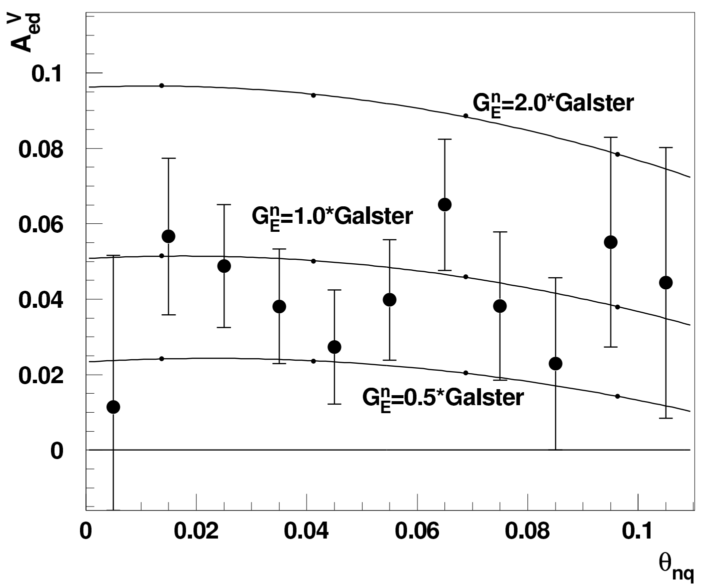

FIGURE 1. Deuteron asymmetries A^V_{ed} are plotted vs. θ_{nq}. The curves represent theoretical calculations averaged over our kinematical acceptance for different values of G^n_E. The points are measured A^V_{ed} for single bins of θ_{nq}.

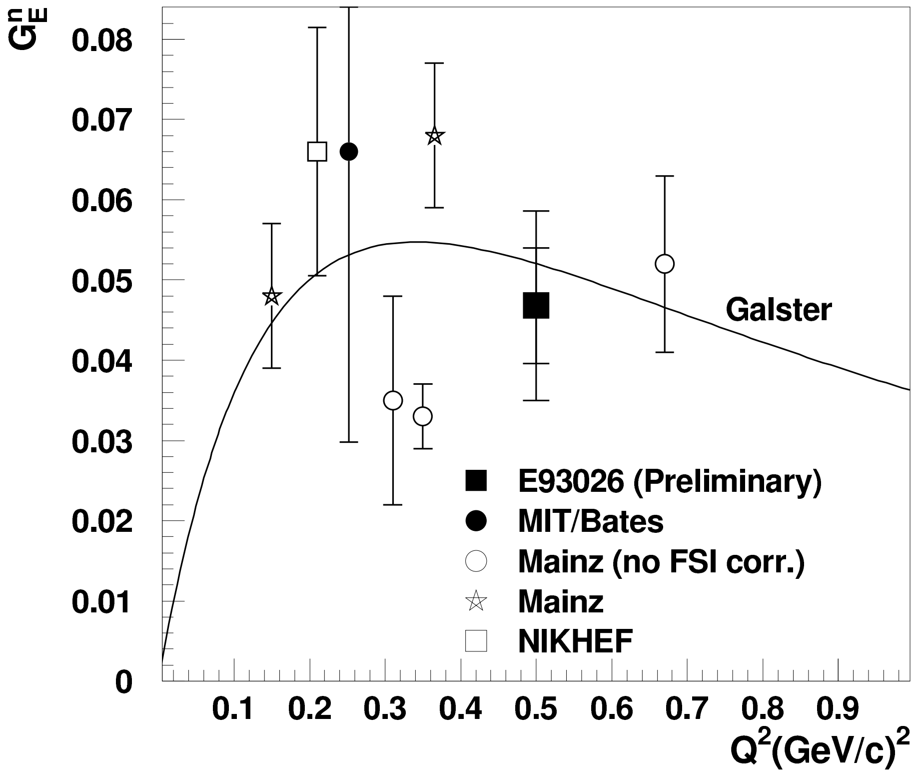

FIGURE 2. G_E^n World data from double polarization experiments. The solid line represents the Galster parameterization. The error bar of the E93026 point includes a 20% systematic error for now. The open circles are results from Mainz with polarized ^3He target and do not include corrections for final state interactions.

Our preliminary result for G_E^n at $Q^2 = 0.5(GeV/c)^2$ is:

$$G_E^n = 0.0468 \pm 0.0072_{stat}$$

Systematic studies are still in progress. The systematic error will be dominated by the target polarization (5%) and dilution factor (>4%) and is expected to be smaller than 10%. For now we quote a 20% systematic error. Figure 2 shows our experimental result together with other double polarization results from Mainz, NIKHEF and MIT/Bates.

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