NEUTRON ELECTRIC FORM FACTOR VIA RECOIL POLARIMETRY

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The ratio of the electric to the magnetic form factor of the neutron, G_{En}/G_{Mn}, was measured via recoil polarimetry from the quasielastic $d(\vec{e},e'\vec{n})p$ reaction at three values of Q^2 [viz., 0.45, 1.15, and 1.47 $(\mathrm{GeV/c})^2$] in Hall C of the Thomas Jefferson National Accelerator Facility. Preliminary data indicate that G_{En} follows the Galster parameterization up to $Q^2 = 1.15$ $(\mathrm{GeV/c})^2$ and appears to rise above the Galster parameterization at $Q^2 = 1.47$ $(\mathrm{GeV/c})^2$.

1 Introduction

The electric form factor of the neutron, G_{En}, is a fundamental quantity needed for understanding both nucleon and nuclear structure. The Jefferson Laboratory E93-038 Collaboration conducted quasielastic scattering measurements on a liquid deuterium target at three values of Q^2 [viz., 0.45, 1.15, and 1.47 $(\mathrm{GeV/c})^2$], the squared four-momentum transfer.

2 Description of the Experiment

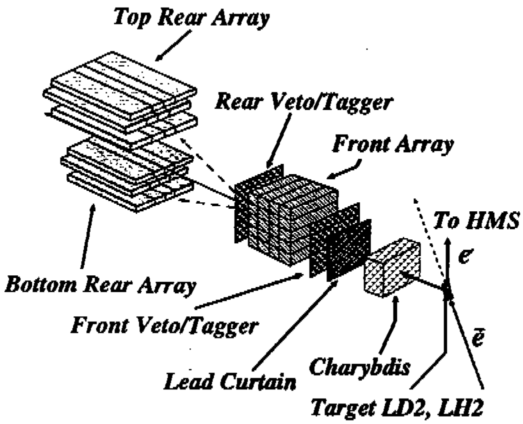

Figure 1. Experimental Arrangement.

The experimental arrangement is shown in Fig. 1. A beam of longitudinally polarized electrons scattered quasielastically from a neutron in the deuteron in a 15-cm long liquid deuterium target. The scattered electron was detected in the High Momentum Spectrometer (HMS) in coincidence with the recoil neutron. The polarization vector of the neutron lies in the scattering plane. A neutron polarimeter (NPOL) measured the up-down scattering asymmetry from the component of the neutron polarization vector projected on the axis that is perpendicular to the momentum vector of the neutron. The dipole magnet (Charybdis) ahead of NPOL precessed the neutron's polarization vector through an angle χ.

We extracted $g \equiv G_{En}/G_{Mn}$ via two different sets of precession angles. For sequential measurements with $\chi = 0$, ± 90 deg.,

$$g = -K_R \left(\xi_{S'}/\xi_{L'}\right) \tag{1}$$

where K_R is a kinematic function of the electron scattering angle θ and Q^2, and $\xi_{S'}$ ($\xi_{L'}$) is the scattering asymmetry from the sideways (longitudinal) component of the neutron polarization vector. For sequential measurements with the polarization vector precessed through an angle $\pm\chi$

$$g = -K_R \left(\frac{1+\eta}{1-\eta}\right) \tan\chi\,; \qquad \eta \equiv \xi_-/\xi_+\,. \tag{2}$$

where ξ_- (ξ_+) is the scattering asymmetry from the projection of the neutron polarization vector on the transverse axis when the precession angle is $-\chi$ ($+\chi$). We chose $\chi = \pm$ 40 deg. A significant advantage of the ratio technique is that the scale and systematic uncertainties are small; in particular, the analyzing power of the polarimeter cancels in the ratio of the scattering asymmetries, and the beam polarization cancels also because it varied little during sequential measurements.

The polarimeter consisted of twenty detectors in the front array and twelve detectors in each of the two (upper and lower) rear arrays for a total of 44 plastic scintillation detectors. The 100 cm × 10 cm × 10 cm dimensions of each scintillator in the front array were small enough to permit high luminosity. A double layer of "veto/tagger" detectors directly ahead of and behind the front array identified charged particles. Each layer of the rear array consisted of two central scintillators, each 25.4 cm × 10.16 cm × 101.6 cm, with a 50.8 cm × 10.16 cm × 101.6 cm scintillator on each side. The detectors in each rear array were shielded from the direct path of neutrons from the target. A 10-cm thick Pb curtain attenuated the flux of electromagnetic radiation and charged particles incident on the polarimeter; the singles rate in a front veto detector was nearly five times higher with a 5-cm thick Pb curtain. The flight path from the target to the center of the front array was 7.0 m.

3 Extraction of Scattering Asymmetries

Each event is a triple coincidence event between an electron in the HMS, a neutral particle in the polarimeter front array, and either a neutral or charged particle in the polarimeter rear array. To suppress accidentals, we generated a coincidence time-of- flight ($cTOF$) spectrum with the timing from the polarimeter established by a neutron event in the front array. Also, we generated four additional time-of flight spectra, termed ΔTOF, between a neutron event in the front array and an event in the rear array for scattering either to the upper (U) or lower (D) rear array for each (+ or -) helicity state of the beam. From the yields in the ΔTOF peak for each of these four spectra, we calculated the cross ratio r , which is defined as the ratio of two geometric means, $(N_U^+ \cdot N_D^-)^{1/2}$ and $(N_U^- \cdot N_D^+)^{1/2}$, where N_U^+ (N_D^-) is the yield in the ΔTOF peak for nucleons scattered up (down) when the beam helicity was positive (negative). The physical scattering asymmetry is then given by $(r-1)/(r+1)$.

4 Preliminary Results

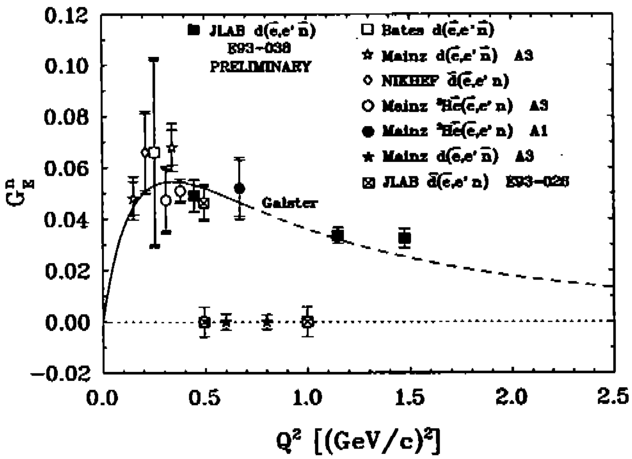

Figure 2. World data on G_{En} versus Q^2 as obtained from polarization measurements. The points on the abscissa [$G_{En} = 0$] are projections.

Preliminary results for G_{En} are plotted vs Q^2 in Fig. 2 together with the current world data on G_{En} as obtained from polarization measurements[1−9]. Data from E93-038 indicate that G_{En} continues to follow the parameterization of Galster *et al.*[10] up to $Q^2 = 1.15$ (GeV/c)^2 and appears to rise above the Galster parameterization at $Q^2 = 1.47$ (GeV/c)^2. Schiavilla and Sick[11] extracted values of G_{En} from nuclear physics data on the quadrupole form factor of the deuteron, and obtained results up to $Q^2 \sim 1.65$ $(\mathrm{GeV/c})^2$ consistent with the Galster parameterization, which is a simple two-parameter fit to data below $Q^2 \sim 0.7$ $(\mathrm{GeV/c})^2$. Our preliminary data will serve to test predictions of various models[12–18]. A successful model must be able to predict both G_{En} and G_{Ep}. These preliminary data reduce the uncertainty in our knowledge of the interior charge density of the neutron, as seen from the radial distribution of the charge density in the paper of Kelly[19].

Acknowledgments

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