MEASUREMENT OF THE NEUTRON ELECTRIC FORM FACTOR AT LOW MOMENTUM TRANSFER

R. ALARCON, E. GEIS, M. KOHL, R. MILNER, AND V. ZISKIN
FOR THE BLAST COLLABORATION

Massachusetts Institute of Technology
Cambridge, MA, USA 02139
E-mail: vziskin@mit.edu

Measurement of the neutron's electric form factor, G_E^n, by means of quasi-elastic electron scattering from polarized deuterium with polarized beam and target, $^2\vec{H}(\vec{e}, e'n)p$, is in progress at the South Hall Ring of the MIT-Bates Linear Accelerator Center using the Bates Large Acceptance Spectrometer Toroid (BLAST). The spin-perpendicular vector-polarized beam-target asymmetry, A_{ed}^V provides the ratio, G_E^n/G_M^n over a range of momentum transfer Q^2 between 0.12 and 0.80 $(\mathrm{GeV/c})^2$. Preliminary results will be presented.

1. Introduction

Measurements of nucleon form factors, such as the electric form factor of the neutron, are important for the understanding of the structure of baryons in the non-perturbative QCD regime. Until recently a purely phenomenological parametrization by Galster[1] has served as the best description of G_E^n data. Lately, calculations of G_E^n based on effective field theories of QCD became available. The neutron's electric form factor provides a sensitive test of many of these models. Thus, precision G_E^n data at low momentum transfer is essential to constrain theoretical calculations of nucleon structure.

At the same time precise knowledge of the neutron's electric form factor is important for an interpretation of the results from parity-violating scattering experiments designed to probe the strangeness content of the nucleon. Recent parity-violation experiments[2] have indicated that the uncertainty of the elastic form factors of the nucleons, G_E^n in particular, is one of the largest contributions to the systematic error. A special interest of the parity-violating experiments is in the region of extremely low Q^2. This work should be of great value for such low momentum transfer experiments.

2. Measurement of G_E^n using the $^2\vec{H}(\vec{e}, e'n)p$ reaction

Since there are no free neutron targets, the form factors of the neutron are measured using nuclear targets where corrections due to the nucleon-nucleon interactions are small and well understood. Typically these targets are ^2H and ^3He, with a neutron detected in the final state. In unpolarized quasi-elastic scattering, however, the fact that G_E^n is order of magnitude smaller than G_M^n, greatly limits the precision with which the G_E^n/G_M^n ratio can be measured. A new generation of polarization experiments either make use of scattering of longitudinally polarized electrons from a vector polarized target or involve the polarimetry of the recoil neutron.

The differential cross section, $S(h, P_z, P_{zz})$, for beam-target polarized scattering can be written in terms of polarization observables as[3]

$$S(h, P_z, P_{zz}) =$$
$$S(0,0,0)\left\{1 + \sqrt{\tfrac{3}{2}}P_z A_d^V + \sqrt{\tfrac{1}{2}}P_{zz}A_d^T + h\left(A_e + \sqrt{\tfrac{3}{2}}P_z A_{ed}^V + \sqrt{\tfrac{1}{2}}P_{zz}A_{ed}^T\right)\right\}, \tag{1}$$

where P_z, P_{zz} and h are the vector and tensor polarizations of the target and the polarization of the beam, respectively. When the momentum transfer vector is perpendicular to the target polarization vector (spin-perpendicular kinematics), the beam-target vector asymmetry, $A_{ed}^V(\frac{\pi}{2}, 0)$ is given in Plane Wave Born Approximation (PWBA) by

$$A_{ed}^V(\frac{\pi}{2}, 0) = -\sqrt{\frac{3}{2}}hP_z \frac{2\sqrt{2\tau}\rho'_{LT}G_E^n G_M^n}{\rho_L(G_E^n)^2 + 2\tau\rho_T(G_M^n)^2}, \tag{2}$$

where ρ_L, ρ_T and ρ'_{LT} are kinematic factors and $\tau = \frac{Q^2}{4M^2}$.

3. The BLAST Experiment

This measurement is performed at the South Hall Ring complex of the Bates Linear Accelerator Center using an internal target and the BLAST detector. The detector consists of 8 magnetic coils producing a toroidal field, with two sectors symmetrically equipped with wire drift chambers, Cerenkov counters and thin time-of-flight plastic scintillators. The neutron detection capabilities (thick arrays of plastic scintillators) were enhanced in the right sector, where the momentum transfer vector is perpendicular to the direction of the target polarization. A combination of the drift chambers and time-of-flight scintillators provides a charged particle veto with an efficiency of $\sim 99.9\%$.

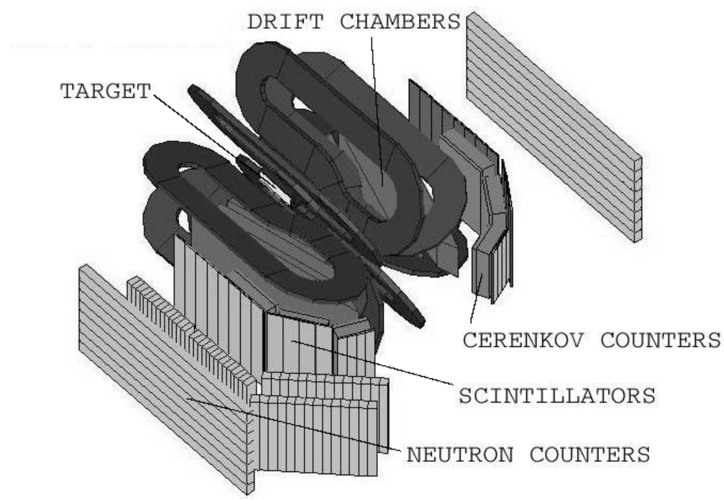

Figure 1. Schematic of the BLAST detector. In the middle are the storage cell and the eight magnetic field coils. In the order away from the target are the wire drift chambers, Cerenkov counters, time-of-flight scintillators and neutron detectors.

Polarized deuterium atoms are injected into the target by an atomic beam source (ABS). ABS randomly switches between three polarization states[4], $P_z = \pm 1$ and $P_{zz} = -2$. This allows to measure all polarization observables in Eq. (1) simultaneously.

4. Preliminary Results

The BLAST data cover a large momentum transfer range[a], $0.12 < Q^2 < 0.8$ $(\mathrm{GeV/c})^2$. At this time about 60% of the data taken in 2004 has been analyzed, corresponding to a collected charge of 250 kC in three spin states. The average stored beam current has been 100 mA. With a target gas thickness of 6×10^{13} atoms/cm^2 luminosity of 4×10^{31} cm^{-2}s^{-1} has been achieved. The vector polarization of deuterium atoms was $P_z \approx 72\%$ and remained stable over the course of the experiment.

The spin-perpendicular asymmetry $A^V_{ed}(\frac{\pi}{2}, 0)$ is compared to the BLASTMC Monte-Carlo simulations based on calculations by H. Arenhövel[3] and a GEANT model of the full BLAST detector. The radiative corrections are not yet performed.

Figure 2 shows in black squares three preliminary data points for G_E^n

[a]In this work only data up to $Q^2 = 0.35$ $(\mathrm{GeV/c})^2$ have been analyzed

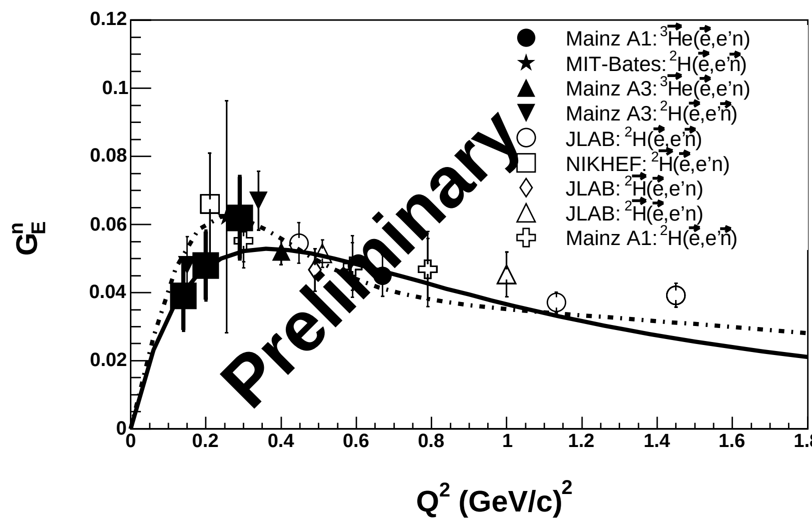

Figure 2. Preliminary G_E^n data (large squares) from the BLAST experiment with the world's polarization data[5−16] The solid line is the Galster parametrization, and the dot-dashed curve is a parametrization by Friedrich and Walcher[17] inspired by a non-relativistic constituent quark model.

with purely statistical errors. Systematic errors are not finalized yet, but are expected to be small.

References

1. S. Galster et al. *Nucl. Phys.* **B32**, 221 (1971)
2. F. E. Maas et al. *Phys. Rev. Lett.* **93**, 022002 (2004)
3. H. Arenhövel et al., *Phys. Rev.* **C46**, 455 (1992)
4. E. Tsentalovich et al., *Spin2004 Conference Proceedings*, World Scientific (2004)
5. R. Madey et al., *Phys. Rev. Lett.* **91**, 122002 (2003)
6. J. Becker et al., *Eur. Phys. J.* **A6**, 329 (1999)
7. J. Golak et al., *Phys. Rev* **C63**, 034006 (2001)
8. D. Rohe et al., *Phys. Rev. Lett.* **21**, 4257 (1999)
9. J. Bermuth et al., *Phys. Lett.* **B564**, 199 (2003)
10. I. Passchier et al., *Phys. Rev. Lett.* **82**, 4988 (1999)
11. H. Zhu et al., *Phys. Rev. Lett.* **87**, 081801 (2001)
12. T. Eden et al., *Phys. Rev.* **C4**, 1749 (1994)
13. M. Ostrick et al., *Phys. Rev. Lett.* **83**, 276 (1999)

14. C. Herberg et al., *Eur. Phys. J.* **A5**, 131 (1999)
15. G. Warren et al., *Phys. Rev. Lett.* **92**, 042301 (2004)
16. D. I. Glazier et al., *nucl-ex/0410026* (2004)
17. J. Friedrich and T. Walcher, *Eur. Phys. J.* **A17**, 607 (2003)