JLAB USER GROUP

Jefferson Lab PAC16
Proposal Cover Sheet

This document must be received by close of business Thursday, June 8, 1999 at:

Jefferson Lab
User Liaison,
Mail Stop 12B
12000 Jefferson Ave.
Newport News, VA
23606

Experimental Hall: A

Days Requested for Approval: 15 additional
14 already approved

☐ Proposal Title:
The Electric Form Factor of the Neutron Extracted from the $^3\vec{He}(\vec{e},e'n)pp$ Reaction

Proposal # 95-006 (Update)

Proposal Physics Goals Extract $G_E^n(Q^2)$ for three different values of Q^2
Indicate any experiments that have physics goals similar to those in your propos
Experiment 96-004, Hall C
Approved, Conditionally Approved, and/or Deferred Experiment(s) or proposals:

Contact Person

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Jefferson Lab Use Only

Receipt Date: 6/7/99

By: [redacted]

PR 99-103

BEAM REQUIREMENTS LIST

JLab Proposal No.: 95-006 Date: June 2, 1999

Hall: A Anticipated Run Date: 2000 PAC Approved Days: _____

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List all combinations of anticipated targets and beam conditions required to execute the experiment. (This list will form the primary basis for the Radiation Safety Assesment Document (RSAD) calculations that must be performed for each experiment.)

Condition No.	Beam Energy (MeV)	Mean Beam Current (μA)	Polarization and Other Special Requirements (e.g., time structure)	Target Material (use multiple rows for complex targets — e.g., w/windows)	Material Thickness (mg/cm²)	Est. Beam-On Time for Cond. No. (hours)
1	3245	>12	75%, CW beam	^{3}He gas	50.1	132
2	4045	>12	75%, CW beam	^{3}He gas	50.1	564

The beam energies, E_{Beam}, available are: $E_{Beam} = N \times E_{Linac}$ where N = 1, 2, 3, 4, or 5. E_{Linac} = 800 MeV, i.e., available E_{Beam} are 800, 1600, 2400, 3200, and 4000 MeV. Other energies should be arranged with the Hall Leader before listing.

LAB RESOURCES LIST

JLab Proposal No.: 95-006 (For JLab ULO use only.) Date June 2, 1999

List below significant resources — both equipment and human — that you are requesting from Jefferson Lab in support of mounting and executing the proposed experiment. Do not include items that will be routinely supplied to all running experiments such as the base equipment for the hall and technical support for routine operation, installation, and maintenance.

Major Installations *(either your equip. or new equip. requested from JLab)*

Neutron Detector Carray of scintillator modules)

Request from JLab:

- support for target installation and Laser hut
- working Møller polarimeter
- neutron detector shielding

New Support Structures:

- neutron detector shielding
- Laser hut

Data Acquisition/Reduction

Computing Resources:

New Software:

Major Equipment

Magnets:

Power Supplies:

Targets:

Detectors: Neutron Detector

Electronics:

Computer Hardware:

Other:

Other:

HAZARD IDENTIFICATION CHECKLIST

JLab Proposal No.: 95 - 006 (For CEBAF User Liaison Office use only.) Date: June 2, 1999

Check all items for which there is an anticipated need.

Cryogenics ____ beamline magnets ____ analysis magnets ____ target type: ____ flow rate: ____ capacity: ____	**Electrical Equipment** ____ cryo/electrical devices ____ capacitor banks ____ high voltage ____ exposed equipment	**Radioactive/Hazardous Materials** List any radioactive or hazadorous/ toxic materials planned for use: ____
Pressure Vessels ____ inside diameter ____ operating pressure ____ window material ____ window thickness	**Flammable Gas or Liquids** type: ____ flow rate: ____ capacity: ____ **Drift Chambers** type: ____ flow rate: ____ capacity: ____	**Other Target Materials** ___ Beryllium (Be) ___ Lithium (Li) ___ Mercury (Hg) ___ Lead (Pb) ___ Tungsten (W) ___ Uranium (U) x Other (list below) ^{3}He gas, Rb, N_2, H_2 gas
Vacuum Vessels ____ inside diameter ____ operating pressure ____ window material ____ window thickness	**Radioactive Sources** ____ permanent installation ____ temporary use type: ____ strength: ____	**Large Mech. Structure/System** ____ lifting devices ____ motion controllers ____ scaffolding or ____ elevated platforms
Lasers type: Diode Laser wattage: ~100W class: IV Installation: x permanent ____ temporary (for experiment) Use: ____ calibration ____ alignment for $^3\vec{He}$ Target	**Hazardous Materials** ____ cyanide plating materials ____ scintillation oil (from) ____ PCBs ____ methane ____ TMAE ____ TEA ____ photographic developers ____ other (list below)	**General:** Experiment Class: ____ Base Equipment ____ Temp. Mod. to Base Equip. ____ Permanent Mod. to Base Equipment ____ Major New Apparatus Other: ____

Computing Requirements

This experiment will need one spectrometer (HRSE) and a neutron detector. We plan to use the existing CODA system for data acquisiton. A typical event length for a spectrometer event is about 500 bytes, so a coincidence event using two spectrometers is 1000 bytes. We use this as an upper limit, since we expect the event length for the neutron detector to be smaller. Our maximum signal rate for the $Q^2 = 0.7$ GeV^2 point is about 3 Hz. The background rates from (p,n) conversions in the Pb shielding wall are less than 1 Hz. This gives a total of about 4 kbytes/s. The total amount of data coming from real events will be less than 3 Gbytes for the whole experiment. Background rates are expected to be small and will not add significantly to the data rates. These amounts of data can easily be processed and stored by the present JLab data acquisition resources.

The data will be analyzed at JLab as well as at collaborating institutes.

Update on TJNAF PROPOSAL 95-006

The Electric Form Factor of the Neutron Extracted from the $^3\vec{\mathrm{He}}(\vec{\mathrm{e}}, \mathrm{e}'\mathrm{n})\mathrm{pp}$ Reaction

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Introduction

Experiment 96-005, "Electric Form Factor of the Neutron Extracted from the ^{3}He$(e, e'n)pp$ Reaction" was approved with B+ scientific rating at the February 1997 PAC meeting. Since then there have been many important developments in the field that we believe motivate submission of an update at this time. Our goal is to obtain an upgrade of the scientific rating and approval for a modest increase in the scope of the approved measurements.

The successful measurements of G_E^n at lower Q^2 at Mainz[1-4] and NIKHEF[5] coupled with the delays associated with executing the G_E^n program in Hall C at JLAB strongly suggest that we should have the option of mounting the polarized ^{3}He experiment in Hall A as soon as possible. This will require two issues to be resolved at this time. First, the scientific rating should be increased to a value that is commensurate with the high interest in these measurements in the scientific community and with the competitive Hall A schedule. Second, the collaboration strongly feels that the program must include a range of Q^2 that connects with the Mainz data and offers a view of the Q^2 evolution of the results. Thus we are requesting an additional 15 days to include Q^2 points of 0.7 and 1.3 GeV^2. This range of Q^2 is lower than our previous proposal (1-2 GeV^2) to facilitate comparison with Mainz and to better connect with the region where precise non-relativistic calculations are now possible.

Recent Developments

There are several important recent developments regarding G_E^n measurements and the performance of polarized ^{3}He experiments. Figure 1 shows the recent measurements performed at Mainz and NIKHEF in the low Q^2 range ($Q^2 < 0.7$ GeV^2). It is clear that there has been considerable progress and that the strategy of comparing measurements from deuteron and ^{3}He targets will be crucial in establishing a reliable and accurate picture. The apparent disagreement between the deuteron measurement[2] and the polarized ^{3}He target measurement[3] near $Q^2 = 0.35$ GeV^2 has led to increased efforts to examine the corrections due to FSI and MEC in both methods. Indeed, substantial FSI corrections have led to revisions in the extracted values of G_E^n from the deuteron data (particularly at the lowest $Q^2 < 0.2$ GeV^2). In addition, new theoretical calculations are in progress to address the role of FSI and MEC in the polarized ^{3}He case[6]. It is likely that the PWIA analysis used to obtain the polarized ^{3}He result is not sufficient for reliable extraction G_E^n at this low Q^2 and a more complete theoretical treatment is required. Indeed, FSI effects are not negligible for the deuteron at this Q^2 and one expects that ^{3}He will require even larger corrections. It is clear that when this discrepancy is resolved we will have a great deal of confidence in the results.

The polarized ^{3}He results[4] at $Q^2 = 0.67$ GeV^2 seem to connect well with the trend of the lower Q^2 deuteron measurements. It is expected that the effects of FSI are significantly smaller at this higher Q^2 because the (p, n) cross section decreases rapidly with energy in this range of Q^2. This argument is supported quantitatively by the calculations of Laget[7]. The correction to the extracted value of G_E^n for these effects is estimated to be less than 10% at the $Q^2 = 0.67$ GeV^2 Mainz kinematics[4]. Thus it appears that at $Q^2 > 0.7$ GeV^2 the PWIA analysis should provide a reliable baseline for extraction of G_E^n.

Since the submission of our original proposal, the measurement techniques we propose to use have been shown to be a powerful method of addressing the neutron form factors. The

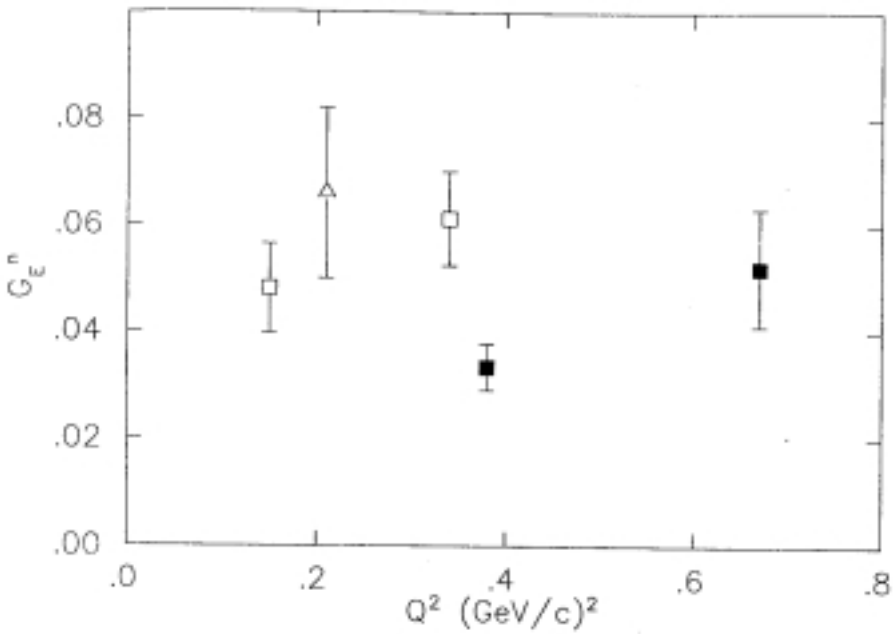

Figure 1: G_E^n results from recent experiments. The open squares are $d(\vec{e}, e'\vec{n})$ measurements from Mainz[1,2]. The filled squares are $^3\vec{\mathrm{He}}(\vec{e}, e'n)$ measurements from Mainz[3,4]. The open triangle is a $\vec{d}(\vec{e}, e'n)$ measurement from NIKHEF[5].

Mainz program of measurements of G_E^n at low Q^2 has been very successful. The feasibility of using a polarized ^{3}He target and the coincidence $(e, e'n)$ has been definitively established. In addition, the extremely successful running of two experiments at JLAB in Hall A in 1998-9 demonstrated that the polarized ^{3}He target developed by our collaboration is reliable, robust and, when coupled with the superb performance of the JLAB accelerator and spectrometers, provides an outstanding facility for measurements of the properties of ^{3}He and the neutron. (One of these recent experiments addresses the important related question of a precise determination of G_M^n.)

Taken together, these developments demonstrate that the feasibility of the proposed measurements is beyond question. The experience at JLAB shows also that the polarized ^{3}He target experiments are, from an experimental viewpoint, relatively straightforward. On the other hand, the experiments to be performed at JLAB on the deuteron are technically more complex, requiring substantial new equipment setups and a high-field polarized target with all its associated difficulties. We believe that the polarized ^{3}He method currently presents a more straightforward and reliable experimental technique which will provide significant new information about G_E^n on a short time scale. Thus, timely scheduling of the polarized ^{3}He measurements provides Jefferson Lab with a unique opportunity to address the issue of G_E^n in a complete and responsible manner in this interesting kinematic range.

Physics Issues

The basic issue regarding the measurement proposed here concerns the theoretical calculation of the asymmetry in quasielastic electron scattering from polarized ^{3}He as a function of the value of G_E^n. Important early theoretical studies confirmed the basic concept that polarized ^{3}He could be used as an effective neutron target[8]. Largely motivated by experimental data, the theoretical community has made great progress in the treatment of this problem in the last few years. We now have complete spin-dependent spectral functions[9] that allow essentially exact treatment of the initial state and facilitate much-improved PWIA calculations. Treatment of the three-body final state has seen tremendous recent progress. The group of Glöckle, Ishikawa, *et al.* has developed a method of exact non-relativistic treatment of the 3N final state[10,11]. This technique enables calculation of the important FSI effects in the ^{3}He$(e,e'n)$ reaction, the same one we propose to employ in our measurements. This group of theorists is presently working to include MEC effects in the calculations as well. At that point, we will have an essentially exact non-relativistic theoretical treatment of the ^{3}He$(e,e'n)$ reaction. This will allow a complete study of the corrections due to FSI and MEC as a function of Q^2 in the non-relativistic region covered at Mainz, NIKHEF, and Bates. Thus there will be a detailed study of the Q^2 evolution of these effects and comparison with ever more precise measurements. (Note that our proposed higher precision measurement at $Q^2 = 0.7$ will be an important part of this study.) This will then enable a convincing quantitative estimate of the small corrections that are expected in the range of Q^2 we propose for the JLAB measurements. Since one expects the PWIA to become an increasingly better approximation in the higher Q^2 kinematic regime, it should serve as an excellent baseline for extraction of G_E^n from the proposed ^{3}He$(e,e'n)$ asymmetry measurements.

We should also note that substantial experimental effort will be devoted to studying the related unpolarized ^{3}He$(e,e'p)$ reaction in our proposed kinematic range next year at JLAB (E89-044). This study includes separation of the unpolarized response functions and will provide precise data to test the theoretical techniques that are relevant to the interpretation of our experiment.

The recent history of this subject clearly illustrates that the measurements of spin-dependent quasielastic electron scattering from polarized ^{3}He have motivated the development of improved theoretical treatments[11]. The early measurements of inclusive scattering at Bates by the MIT/Caltech collaboration and the recent measurements at Mainz were essential in focussing the attention of the theoretical community on this topic. Although the theory that was originally used to motivate those measurements needed substantial enhancements, this program has in fact led us to the present era where the new theoretical tools motivate increasing the precision and kinematic range of these measurements. The history of this subject clearly indicates that it is imperative to vigorously pursue the experimental program, and that the theoretical community will respond with the tools to better interpret the measurements. We believe that this is still the case at present and that approval of these proposed measurements with increased scientific priority will add the necessary impetus to move the subject forward.

Proposed Run Plan

The run plan we propose includes three Q^2 points at 0.7, 1.0, and 1.3 GeV^2. The parameters used in the estimates of running times and experimental uncertainties are based on the recent running experience in Hall A for experiments 94-010 and 95-001 over a period of several months in 1998-99. We take the target polarization to be 32%, the beam polarization as 70%, the spectrometer solid angle as 5 msr, and the momentum acceptance of HRS is ±4%. We conservatively assume 12μA beam current, although there is evidence that the target could reliably run with the 15μA we assumed in our original proposal. The neutron detection efficiency (12%) and the neutron detector area (120 cm × 120 cm) are also as before. For incident beam energies of 3.245 and 4.045 GeV, we obtain the rates and uncertainties shown in Table 1. We plan to lower the beam energy for the lowest Q^2 point to increase the scattering angle. This helps to minimize the background from the end windows of the target. The uncertainty listed is a quadratic sum of the statistical and systematic errors. Time is included for beam and target polarization measurements; we will need to add 2 additional days for background studies.

Table 1: Estimated running parameters

E [GeV]	Q^2 [GeV^2]	θ_e	Rate [Hz]	Beam time [days]	$\frac{\Delta G_E^n}{G_E^n}$
3.245	0.7	15.8°	2.8	5	9.7%
4.045	1.0	15.3°	1.5	8	10.8%
4.045	1.3	17.8°	0.5	14	12.2%

Thus we request a total of 29 days, an increase of 15 days over our approved 14 days, to enable measurements at the additional Q^2 points at 0.7 and 1.3 GeV^2. The projected measurements and uncertainties are shown in Figure 2.

This will provide a data set that connects with the lower Q^2 data from other laboratories (with better statistical precision) and that shows the Q^2 evolution in the expanded kinematics available at Jefferson Lab.

Collaboration Responsibilities

The collaboration has developed considerable experience and expertise during the two experiments using the polarized ^{3}He target that ran at JLAB during the last year. Both of these experiments were extremely successful. The polarized target is currently set up off-line at JLAB for tests and will be maintained in a state of readiness for future experiments.

The other major item we need to supply is the neutron detector array. The Kent State collaborators already have the hardware in hand for this detector and are prepared to provide it for this experiment subject to scheduling constraints from other commitments.

Finally, Jefferson Lab is requested to provide the items as for our previous two polarized ^{3}He experiments with the addition of neutron detector shielding.

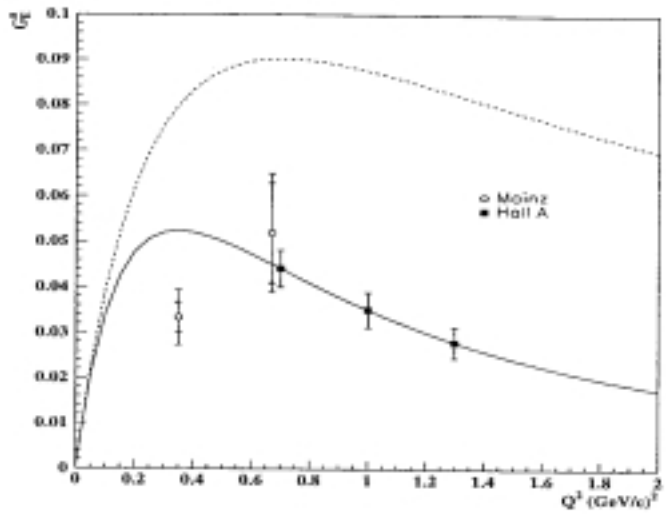

Figure 2: Projected results (solid squares) for the proposed JLAB measurements along with previously reported results (open circles) from Mainz.

References

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