CEBAF Program Advisory Committee Ten Proposal Cover Sheet

This document must be received by close of business on Tuesday, December 19, 1995 at:

CEBAF
User Liaison Office, Mail Stop 12 B
12000 Jefferson Avenue
Newport News, VA 23606

(Choose one)

☐ New Proposal Title:

☒ Update Experiment Number: E 93-038

☐ Letter-of-Intent Title:

Contact Person

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Experimental Hall: C Days Requested for Approval: 60
Days Approved by PAC 6: 60

CEBAF Use Only

Receipt Date: 12/19/95 PR 95-014

By: go

LAB RESOURCES REQUIREMENTS LIST

CEBAF Proposal No.: ____________________ (For CEBAF User Liaison Office use only.) Date: ____________

List below significant resources — both equipment and human — that you are requesting *from CEBAF* 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 CEBAF)*

- Neutron Polarimeter
- Dipole Magnet [Charybdis] to precess neutron spin
- Shadow shield

New Support Structures:

- Shield House for Neutron Polarimeter
- Support structure for Shadow shield

Data Acquisition/Reduction

Computing Resources:

New Software:

Major Equipment

Magnets: HMS

Power Supplies: HMS
SOS [for Charybdis]

Targets: LD_2, LH_2, Empty
Solid

Detectors:

Electronics:

Computer Hardware:

Other:

Other

HAZARD IDENTIFICATION CHECKLIST

CEBAF Experiment: E93-038 Date: 12/15/95

Check all items for which there is an anticipated need—do not check items that are part of the CEBAF standard experiment (HRSE, HRSH, CLAS, HMS, SOS in standard configurations).

Cryogenics
- ___ beamline magnets
- ___ analysis magnets
- ✓ target
- ___ drift chambers
- ___ other

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

(incl. target)

type: ______

flow rate: ______

capacity: ______

Other Target Materials
- ___ Beryllium (Be)
- ___ Lithium (Li)
- ___ Mercury (Hg)
- ___ Lead (Pb)
- ___ Tungsten (W)
- ___ Uranium (U)
- ___ Other (list below)

______

______

Vacuum Vessels
- ___ inside diameter
- ___ operating pressure
- ___ window material
- ___ window thickness

Radioactive Sources
- ___ permanent installation
- ✓ temporary use

type: 228 Th

strength: ~ 10 uC

Large Mech. Structure/System
- ___ lifting devices
- ___ motion controllers
- ✓ scaffolding or elevated platforms
- ___ other

Lasers

type: ______

wattage: ______

class: ______

Installation
- ___ permanent
- ___ temporary

Use
- ___ calibration
- ___ alignment

Hazardous Materials
- ___ cyanide plating materials
- ___ scintillation oil (from)
- ___ PCBs
- ___ methane
- ___ TMAE
- ___ TEA
- ___ photographic developers
- ___ other (list below)

______

______

______

Notes:

______

BEAM REQUIREMENTS LIST

CEBAF Proposal No.: E93-038 (For CEBAF User Liaison Office use only) Date: 15-DEC-1995

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 #	Beam Energy (MeV)	Beam Current (μA)	Polarization and Other Special Requirements (e.g., time structure)	Target Material (use multiple rows for complex targets — e.g., w/windows)	Target Material Thickness (mg/cm²)
G_E^n					
1	1645	10	CW Beam HMS INVERSE OPTICS TUNE	^{12}C, BeO	THIN & THICK ^{12}C STD. BeO
2	1645	38	CW Beam & Polarized	15cm LD_2	2.52
3	1645	38	CW Beam & Polarized	15cm LH_2	1.06
4	3245	38	CW Beam & Polarized	15cm LD_2	2.52
5	3245	38	CW Beam & Polarized	15cm LH_2	1.06
G_M^n					
6	3245	10	CW Beam HMS Std. OPTICS TUNE	^{12}C, BeO.	THIN & THICK ^{12}C STD. BeO
7	3245	38	CW Beam	15cm LD_2	2.52
8	3245	38	CW Beam	15cm LH_2	1.06
9	1645	38	CW Beam	15cm LD_2	2.52
10	1645	38	CW Beam	15cm LH_2	1.06

The beam energies, E_{Beam}, available are: $E_{Beam} = N \times E_{Linac}$ where N = 1, 2, 3, 4, or 5. For 1995, E_{Linac} = 800 MeV, i.e., available E_{Beam} are 800, 1600, 2400, 3200, and 4000 MeV. Starting in 1996, in an evolutionary way (and not necessarily in the order given) the following additional values of E_{Linac} will become available: E_{Linac} = 400, 500, 600, 700, 900, 1000, 1100, and 1200 MeV. The sequence and timing of the available resultant energies, E_{Beam}, will be determined by physics priorities and technical capabilities.

19 December 1995

UPDATE OF CEBAF E93-038

THE ELECTRIC FORM FACTOR OF THE NEUTRON FROM THE d($\vec{e}$, e'$\vec{n}$)p REACTION

The purpose of this update of E93-038 is to inform PAC 10 of an improvement in our plans for running this experiment. Our beam time request for 1440 hours, which was made orally at the PAC 6 presentation, was to run two Q^2 points [*viz.*, $Q^2 = 1.00$ and 1.50 (GeV/c)^2] in *separately scheduled* runs to permit moving the neutron polarimeter and its shielding. With an adjustment of the kinematics, it is possible to use the same physical setup to measure G_E^n at four possible values of Q^2 [*viz.*, $Q^2 = 0.49$, 1.00, 1.41, and 1.73 (GeV/c)^2] with the neutron polarimeter and its shielding fixed at 42.3 degrees. This improvement will require one installation (instead of two) with consequent savings in time and costs. With the beam time approved for E93-038, we plan to extract G_E^n at two of these values of Q^2;in view of the scientific situation at this time, the two most likely values of Q^2 will be 1.00 and 1.73 (GeV/c)^2. Measurements at Mainz at $Q^2 = 0.35$ (GeV/c)^2 from the $^3\vec{H}e(\vec{e}, e'n)$ reaction achieved a statistical error in $g[\equiv G_E^n/G_M^n]$ of about 7% after 600 hours of data acquisition; Mainz is investigating systematic uncertainties in this measurement.[1] Additional measurements at $Q^2 = 0.70$ (GeV/c)^2 with the $^3\vec{H}e(\vec{e}, e'n)$ reaction are planned to start in spring 1996. Mainz measurements with the $^2H(\vec{e}, e'\vec{n})^1H$ reaction are underway at $Q^2 = 0.35$ (GeV/c)^2; additional measurements with the liquid deuterium target appear to be restricted at Mainz to $Q^2 \sim 0.5$ (GeV/c)^2.

The experimental arrangement is shown in Figure 1. A neutron polarimeter detects the recoil neutron from the quasielastic ^{2}H($\vec{e}, e'\vec{n}$)^{1}H reaction and measures the scattering asymmetries $\xi_{S'}$ and $\xi_{L'}$ related to $P_{S'}$ and $P_{L'}$, the sideways and longitudinal polarization components of the neutron, respectively. The scattered electron from the ^{2}H($\vec{e}, e'\vec{n}$)^{1}H reaction is detected with the high-momentum spectrometer (HMS) in coincidence with the recoil neutron. A dipole magnet placed in front of the neutron polarimeter with sufficient magnetic field strength to precess the neutron longitudinal polarization $P_{L'}$ into the sideways direction permits measuring the neutron scattering asymmetry $\xi_{L'}$. With another measurement of $\xi_{S'}$ (with the dipole magnet turned off) for the same kinematics as that of the measurement of $\xi_{L'}$, the ratio of G_E^n and G_M^n is simply the ratio of the scattering asymmetries scaled by a kinematic function K_R:

$$g \equiv \frac{G_E^n}{G_M^n} = -K_R \frac{\xi_{S'}}{\xi_{L'}}$$

The kinematic function K_R is determined by the electron scattering angle θ_e in the ^{2}H($\vec{e}, e'\vec{n}$)^{1}H reaction. For a total data acquisition time T, the time fractions for measuring $\xi_{S'}$ and $\xi_{L'}$ are optimized to minimize the statistical uncertainty in g.

1 W. Heil, Private Communication to R. Madey.

We plan to use the Charybdis dipole magnet, which is being refurbished by M.I.T., to precess the longitudinal component of the neutron polarization through 90 degrees. CHARYBDIS has a sufficiently large $\int Bdl$ to permit measurements of G_E^n at the above four values of Q^2. The maximum integrated $\int Bdl$ [based on the sister magnet, SCYLLA, at Los Alamos] is 2.39 Tesla-meters, which is sufficient to precess the neutron polarization through 90 degrees for the point at $Q^2 = 1.73$ (GeV/c)^2. Table 1 lists the kinematic conditions, the $\int Bdl$ required to precess the neutron polarization through 90°, and the neutron energy resolution at a mean flight path of 7.0 m. The neutron energy resolution is sufficient to discriminate against neutrons associated with pion production.

Table 1. Kinematics at $\theta_n = 42.3°$

Q^2 (GeV/c)^2	E (GeV)$^{(i)}$	θ_e (deg)	$P_{e'}$ (MeV/c)	T_n (MeV)	P_n (MeV/c)	$\int Bdl_n$ (Tm)$^{(ii)}$	ΔT_{hwhm} (MeV)$^{(iii)}$
0.49	0.845	60.0	581	261	748	1.604	9
1.00	1.645	43.5	1109	533	1135	1.984	30
1.41	2.445	33.9	1693	749	1404	2.141	55
1.73	3.245	27.7	2323	919	1605	2.223	80

(i) Injection energy is 45 MeV.

(ii) Maximum $\int Bdl_n = 2.39$ Tm for Charybdis.

(iii) Mean flight path x = 7.0 m.

The relative uncertainties in $g(\equiv G_E^n/G_M^n)$ projected at $Q^2 = 1.00$ (GeV/c)^2 for an average analyzing power $\langle A_y \rangle$ of 15.9 percent, an electron beam polarization of 40 percent, and a total data acquisition time of 300 hours on an LD_2 target are 7.4 % (statistical) and 1.9% (scale and systematic). This projection is based on the Galster parameterization for G_E^n. These uncertainties are substantialy smaller than those proposed to PAC 6. The scale and systematic uncertainties of 1.9% (when a spin rotator magnet is used) are less than one-third of the 6.5% value projected at PAC 6 when g is extracted from the polarization transfer coefficient $D_{LS'} \equiv P_{S'}/A_y P_L$. The statistical uncertainty of 7.4% is less than half of the 16.8% projected at PAC 6, after scaling to the same data acquisition time of 300 hours and the same beam polarization of 40%.The value of $\langle A_y \rangle$ was obtained from our GEANT simulation which combined the contributions from hydrogen and carbon in the scintillator. As shown in Table 2, GEANT results for $\langle A_y \rangle$ for all events agree well with the values measured for 160 and 195 MeV neutrons in July 1994 from IUCF E377. The analyzing power $\langle A_y \rangle$ of 15.9 percent is a conservative value based on including all scattering events from both hydrogen and carbon in the analyzer scintillators. This value is obtainable readily from an analysis of the time-of-flight spectra of *all* events in the neutron polarimeter; however, by retaining fewer events, the proportion of scattering events from carbon becomes smaller and the analyzing power becomes larger. The above projections are based on a polarimeter efficiency of about one percent at these higher neutron energies. Polarimeter efficiency measurements at lower energies increased with neutron energy from 0.61% at 120 MeV, to 0.79% at 160 MeV, and 0.80% at 195 MeV.

Table 2. Measured [IUCF E377] A_y compared to GEANT simulation

	Measured IUCF E377	GEANT
T_n (MeV)	A_y (%)	A_y (%)
160	15.9	14.2
195	16.1	16.4

Figure 2 is a projection of the total uncertainty (ΔG_E^n) in G_E^n at Q^2 = 1.00 and 1.73 $(\text{GeV}/c)^2$ for the Galster parameterization and for a relative uncertainty in the magnetic form factor $\Delta G_M^n/G_M^n = 0.030$ after 300 hours on an LD_2 target for each Q^2 point; in these circumstances, the total uncertainty ΔG_E^n projects to 0.003 at $Q^2 = 1.00$ $(\text{GeV}/c)^2$ and 0.004 at $Q^2 = 1.73$ $(\text{GeV}/c)^2$. At $Q^2 = 0.49$ $(\text{GeV}/c)^2$, it is worth noting that we project a relative statistical uncertainty in g of only 5.4 percent after 250 hours on LD_2 target, and a total uncertainty ΔG_E^n of 0.003.

Summarized in Table 3 are above projected uncertainties with a data acquisition time of 250 hours at $Q^2 = 0.49$ $(\text{GeV}/c)^2$ and 300 hours at the higher Q^2 points. If we allow the projected uncertainty in G_E^n to increase to $\Delta G_E^n \sim 0.005$. the data acquisition times listed in Table 4 would permit running three of four Q^2 points within the beam time approved at PAC 6 for E93-038.

Table 3. Projected Uncertainties

Q^2 $(\text{GeV}/c)^2$	T (hr)	$(\Delta g/g)_{stat}$ (%)	$(\Delta g/g)_{syst}$ (%)	$G_E^n \pm \Delta G_E^n$ (i)
0.49	250	5.4	1.5	0.0522 ± 0.0032
1.00	300	7.4	1.3	0.0361 ± 0.0029
1.41	300	9.9	1.3	0.0264 ± 0.0027
1.73	300	16.9	1.4	0.0212 ± 0.0036

(i) For $\Delta G_M^n/G_M^n = 0.030$

Table 4. Data Acquisition Times for $\Delta G_E^n \sim 0.005$

Q^2 $(\mathrm{GeV}/c)^2$	T (hr)	$(\Delta g/g)_{stat}$ (%)	$(\Delta g/g)_{syst}$ (%)	$G_E^n \pm \Delta G_E^n$ (i)
0.49	100	8.4	1.5	0.0522 ± 0.0047
1.00	100	12.8	1.3	0.0361 ± 0.0048
1.41	100	15.6	1.3	0.0264 ± 0.0042
1.73	200	20.8	1.4	0.0212 ± 0.0045

On August 31, 1995 to September 2, 1995, an adhoc Hall C Large Experiment Technical Review Panel, chaired by Lewis P. Keller, reviewed CEBAF E93-038 and three other large installation experiments [*viz.* , E93-026, E89-009, and E94-018]. This committee concluded that E93-038 can be ready to run in winter 1997 and possibly in summer 1996.

On 5 December 1995, the Saturne PAC recommended approval of 18 shifts, as requested, to measure the analyzing power and the efficiency of the G_E^n polarimeter at neutron energies relevant to E93-038. This recommendation came with an A scientific priority – – – the highest priority given at Saturne. Saturne indicates that this calibration run will be scheduled most likely in April or May.

We welcome comments from PAC 10 on this update of E93-038; more particularly, we request that PAC 10 reaffirm the high scientific priority of this experiment.

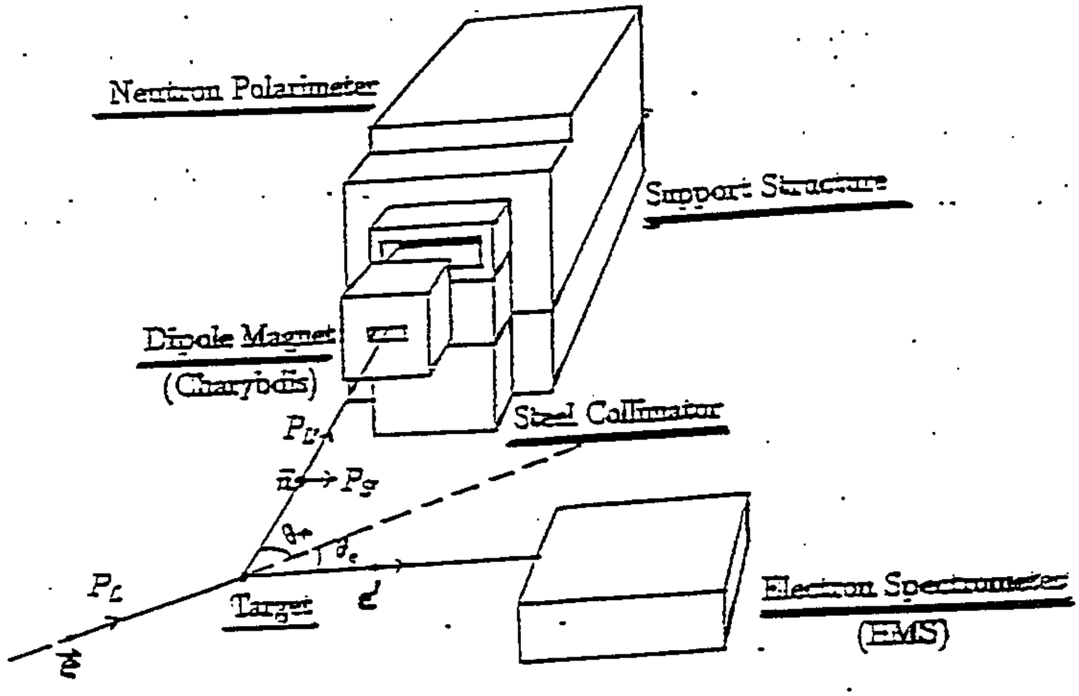

Fig. 1 Experimental arrangement for the G_E^n measurement. A dipole magnet is placed ahead of the neutron polarimeter (NPOL) to precess $P_{L'}$ into the sideways direction. For the G_M^n measurement, the NPOL is replaced by a single neutron detector and the magnet is not used.

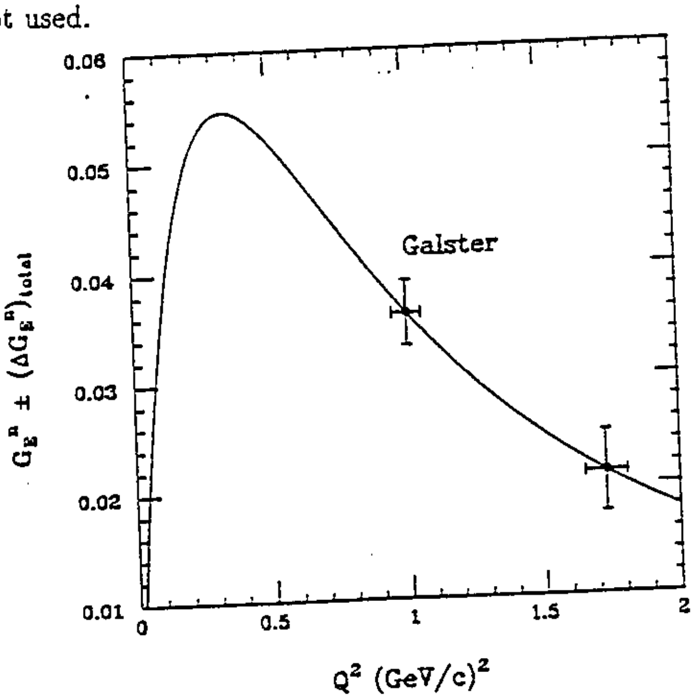

Fig. 2 Projected results for G_E^n measurements for CEBAF E93-038 [Q^2 = 1.00 and 1.73 (GeV/c)^2].