# CEBAF Program Advisory Committee Nine
# Extension and Update Cover Sheet

This update must be received by close of business on Thursday, December 1, 1994 at:

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

**Experiment:** Hall B EG1 running period

**Check Applicable Boxes:**

☐ Extension ☐ Update ☒ Hall B Update

**Contact Person**

**Name:** Information given in the individual updates.
**Institution:**
**Address:**
**Address:**
**City, State ZIP/Country:**
**Phone:** **FAX:**
**E-Mail → Internet:**

**CEBAF Use Only**

Receipt Date: 12/15/94

By: 

PR 94-126

# BEAM REQUIREMENTS LIST

CEBAF Proposal No.: ______________________ Date: ______________
(For CEBAF User Liaison Office use only.)

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 ($mg/cm^2$) |
|---|---|---|---|---|---|
| 1 | 1,200 | 0.005 | | $NH_3$, $ND_3$ | 1,000. |
| 2 | 1,600 | 0.005 | Polarized | Aluminum | |
| 3 | 2,400 | 0.005 | Target | | |
| 4 | 3,200 | 0.01 | | | |
| 5 | 4,000 | 0.01 | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | for Hall B eg1 running period | | | |
| | | seeing experiments | | | |
| | | | | | |
| | | | E-91-023 | | |
| | | | E-93-009 | | |
| | | | E-93-036 | | |
| | | | E-91-015 | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

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.

# HAZARD IDENTIFICATION CHECKLIST

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

Check all items for which there is an anticipated need.

**Cryogenics**
- ____ beamline magnets
- CLAS analysis magnets
- ____ target

type: polarized NH3
flow rate: ______
capacity: ______

**Electrical Equipment**
- ____ cryo/electrical devices
- ____ capacitor banks
- ____ high voltage
- ____ exposed equipment

Standard Hall B

**Radioactive/Hazardous Materials**
List any radioactive or hazadorous/ toxic materials planned for use:

None

**Pressure Vessels**
- ____ inside diameter
- ____ operating pressure
- ____ window material
- ____ window thickness

None

**Flammable Gas or Liquids**
type: ______
flow rate: ______
capacity: ______

**Drift Chambers**
type: Standard CLAS
flow rate: drift chambers
capacity: ______

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

None

**Vacuum Vessels**
- ____ inside diameter
- ____ operating pressure
- ____ window material
- ____ window thickness

CLAS magnet + beam pipe

**Radioactive Sources**
- ____ permanent installation
- ____ temporary use

type: ______
strength: ______

None

**Large Mech. Structure/System**
- ____ lifting devices
- ____ motion controllers
- ____ scaffolding or
- ____ elevated platforms

Standard Hall B

**Lasers**
type: ______
wattage: ______
class: ______

Installation:
- ____ permanent
- ____ temporary

Use:
- ✓ calibration
- ____ alignment

several low power lasers for PMT calibration (Standard Hall B equipment!)

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

**General:**

Experiment Class:
- X Base Equipment
- ____ Temp. Mod. to Base Equip.
- ____ Permanent Mod. to Base Equipment
- ____ Major New Apparatus

Other: Polarized solid state target.

Standard Hall B equipment + polarized target for experiments: E-91-015, E-91-023, E-93-009, E-93-031

# 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)*

Standard Hall B equipment

CLAS +
Photon tagging system +
Polarized $NH_3$, $ND_3$
Target +
Polarized $e^-$-beam

New Support Structures:

***Data Acquisition/Reduction***

Computing Resources:

New Software:

***Major Equipment***

Magnets

Power Supplies

Targets: Polarized $NH_3$, $ND_3$ target

Detectors: CLAS in standard configuration

Electronics

Computer Hardware

Other

***Other***

Hall B eg1 Run Period

Experiments:

E-91-015
E-91-023
E-93-009
E-93-026

# UPDATES OF POLARIZATION EXPERIMENTS IN CLAS

## Run Period: eg1

## Experiments: 91-015, 91-023, 93-009, 93-036

## OUTLINE

Overview of eg1 Run Period Experiments

Status of Polarized Target Development for CLAS

Update Experiment 91-015

Update Experiment 91-023

Update Experiment 93-009

Update Experiment 93-036

## Overview of eg1 Run Period Experiments

V. Burkert

The experimental updates contained in this session are grouped together because of their similar running conditions. They also represent rather unified physics as well. These are generically labelled the 'eg1' run period. All four experiments use a polarized electron beam and a polarized solid state target $NH_3$ or $ND_3$ for the electron-beam experiments, butanol for the photon experiment. Three of the experiments use the electron beam directly whereas one (E-91-015) uses the longitudinally polarized electrons to generate a circularly polarized photon beam. All four experiments have related physics themes, oriented toward a better understanding of the spin structure of the proton or neutron, respectively.

Two of the experiments (E-91-023, E-93-036) will take data in parallel using the beam time originally allocated for E-91-023. The physics focus of E-91-023 is a measurement of the spin structure functions of the proton in the non perturbative regime of QCD. E-93-036 will measure spin structure functions of exclusive single pion production needed for the overall $N^*$ program, as well as providing independent, and more detailed, information on the proton spin structure. Experiment E-93-009 will use the identical setup with the $NH_3$ target replaced by a $ND_3$ target to measure the spin structure functions of the deuteron. Experiment E-91-023 and E-93-009 analysed together will provide information about the neutron spin structure function, and also allow tests of various sum rules, especially the extended Gerasimov-Drell-Hearn sum rule. Experiment E-91-015 will measure the dominant single pion and two pion contributions to the GDH spin sum rule at $Q^2 = 0$.

The main reason why these experiments should run in a common run period is the use of the polarized target. The installation, testing, and operation of a polarized target represents a significant effort. Also, use of polarized electrons and the electron polarimeter may not be a routine operation as for example switching the beam energy. On the other hand, switching from an electron beam operation to a photon beam operation in Hall B should be a rather small effort compared to the installation and operation of a polarized beam and a polarized target.

The experiments belonging to run period eg1 are listed in the table.

| **Proposal** | **Spokespersons** | **Title** |
|---|---|---|
| 91-015 | Sober | Helicity Structure of Pion Photoproduction |
| 91-023 | Burkert, Crabb, Minehart | Measurement of Polarized Structure Functions in Inelastic Electron Proton Scattering using CLAS |
| 93-009 | Kuhn | The Polarized Structure Function $G_{1n}$ and the $Q^2$ dependence of the Gerasimov-Drell-Hearn Sum Rule for Neutrons |
| 93-036 | Weller, Chasteler, Minehart | Measurement of Single Pion Production from the Proton with Polarized Beam and Polarized Target using CLAS |

# Status of Polarized Target Developments for CLAS

Don Crabb

The trend of the past few years in the development of dynamically polarized solid targets have been mainly in two directions. One way, where the target operates in an intense beam, uses high power $^4$He evaporation refrigerators, together with high field superconducting magnets and radiation resistant materials, such as ammonia. The other way allows operation of dilution refrigerators in a routine manner, particularly in the frozen spin mode. Here the emphasis is on low beam intensity with large acceptance for the scattered particles. Target materials such as butanol or pentanol are used. Both types of refrigerators are being developed for CLAS.

It should be remarked that the use of $^3$He evaporation refrigerators has declined as the more versatile dilution refrigerators have developed into routine use. There is no intent at present to use a $^3$He refrigerator in CLAS.

## $^4$He Refrigerators

The first refrigerator and magnet built with CLAS in mind was assembled and tested in 1992. This system uses a vertical, top loading refrigerator with a 5 Tesla split pair magnet. This polarized target has recently been used in experiment E143 at SLAC and obtained proton and deuteron polarizations of 96% and 42% in $^{15}NH_3$ and $^{15}ND_3$ respectively. Beams of $5 \cdot 10^{11}$ electrons/sec on target were used routinely.

The original expectation was that the target would return to CEBAF and operate first in Hall C, before moving to CLAS. The magnet was designed so that the coil package could be removed from its cryostat and installed in another one tailored to CLAS. Because of the difficulty of using a vertical refrigerator another one was to be built. Since that time, schedule changes, experimental criteria and technical advances in magnet fabrication have made it advantageous to custom build a new magnet for CLAS. Various design possibilities and a matching refrigerator are being discussed to provide the best combination for the experiments.

## Dilution Refrigerators

Although the experiments so far approved could use the $^4$He target system, those using photon beams would greatly benefit from a dilution refrigerator operating in the frozen spin mode.

The most efficient way of moving forward so that the provision of a dilution refrigerator becomes a reality is to obtain a system which is already built and which can be readily modified to meet our needs. Two such dilution refrigerators together with pumps and gas handling system have been located at CERN. Negotiations are at a preliminary stage and will require an agreement between CEBAF, CERN and Oxford Instruments. If all parties agree then the refrigerators would be sent to Oxford for refurbishing, modification and testing to our specification.

The polarizing and holding field for the dilution refrigerator in CLAS could be the magnet discussed in the previous section, if specified at an early stage. On the other hand, a holding field could be provided by a coil built into the refrigerator. These and other possibilities are being discussed among the interested parties.

Research and development on these and other topics, such as material studies, are continuing at the U. of Virginia. In addition, work on further optimization of the $^4$He polarized target is underway at Virginia and SLAC.

On a final note, the past year has seen the emergence of solid HD as a possible polarized target to be used, in particular, with low intensity photon beams. It is being considered by one group for CLAS. The production of such targets requires very low temperatures (10 mK) and high magnetic fields (15T - 20T) and before its use in a photon beam a number of technical issues have to be resolved. The LEGS project at Brookhaven is making the investment to produce targets for experiments there. Progress there should be monitored closely.

Update to Experiment 91-015:

## Helicity Structure of Pion Photoproduction

*Spokesperson: D. Sober*

The scientific interest in the question of the Drell-Hearn- Gerasimov sum rule and its experimental determination has not diminished since the submission and approval of the proposal. Theoretical work continues, and several new proposals to test aspects of the DHG sum rule have been approved at other laboratories. Recent results on the polarized deep-inelastic structure functions of the neutron[1] have given rise to interesting questions about the relationship between the spin structures of the neutron and proton, and a proposal for a testing the DHG sum rule on the neutron at CEBAF and is being submitted to this PAC[2]. We address here some of the implications of these new developments.

### Recent theoretical work

In addition to many papers dealing with the $Q^2$-evolution of the DHG sum rule, some new approaches to the original real-photon sum rule have appeared. D. Drechsel and M. Giannini[3] have shown that in the constituent quark model the sum rule depends on large cancellations between resonances and that there is a slow saturation with energy. L. N. Chang, Y. Liang and R. L. Workman[4] have shown that current algebra calculations predict a deviation from the sum rule that is in qualitative agreement with recent phenomenological predictions.

### Comparison of 91-015 to proposals elsewhere

Since the approval of Experiment 91-015, two additional programs of experiments have been initiated. A unified experimental program involving collaborators from a large number of European institutions has been approved to run both at the Mainz microtron MAMI (Experiment A2/2-93, contact person H.J. Arends) and at the storage ring ELSA at Bonn (spokesperson G. Anton). Another program has been proposed at the LEGS laser-backscattering facility at Brookhaven National Laboratory (Experiments L18 and L19).

The program at LEGS involves measuring the contributions to both the neutron and proton DHG sum rules at energies up to 470 MeV, using a large-aperture detector array. The experiment depends on the development of a unique frozen-spin HD target (SPHICE), in which the polarization of the protons and deuterons can be individually adjusted to be zero or non-zero as desired. This target makes it possible to control very precisely the difference between the neutron and proton sum rules, and the experimental program will emphasize this capability.

The existence of these additional programs in no way obviates the necessity for the CEBAF program. The angular distribution of the contributing processes are rapidly varying, especially in the forward direction, and are substantially different in the two helicity states (when known), so that the extrapolation to zero angle can affect the results substantially. For the case of single-pion production, the extrapolation using partial-wave analyses is straightforward. All of the proposals are equally capable of extracting an unambiguous result for the contributions to the DHG sum rule up to about 500 MeV.

Above 500 MeV, when multiple-pion production becomes important, complete solid angle coverage becomes increasingly necessary. Between 500 and 800 MeV, Mainz has an advantage over the CEBAF experiment because of the complete azimuthal coverage and more extensive forward-angle capability, and one might argue that the 800 MeV endpoint run time at CEBAF would be unnecessary (except for cross-calibration purposes) if the Mainz experiment has already run successfully at that time.

Above 800 MeV, the CEBAF proposal is in competition only with the Bonn experiment. Although they address the same physics, these experiments are largely complementary. The Bonn technique is purely inclusive, but relies on a forward-angle extrapolation which is complicated by the necessity to exclude $e^+e^-$ pairs. In the crucial energy region between 0.8 and 2.0 GeV (see Figure 1 of CEBAF Proposal 91-015), nearly half of the cross section consists of two-pion photoproduction, whose multiplicity is not high enough to guarantee that the forward-angle corrections to the Bonn method are small. In order to set realistic uncertainties for the Bonn technique, exclusive measurements of the angular distributions of the individual processes in each helicity state are necessary, and these will be provided by the CEBAF experiment.

### Options for polarized targets

Experiment 91-015 was approved under the assumption that the available polarized target would be a high-magnetic-field target system which is also suitable for electron-beam experiments (e.g. Experiments 91-023, 93-036). However, the PAC 5 report on the proposal states "The possibility of using a frozen spin target should be seriously explored, especially as an investment for future experiments." The principal advantage to be obtained from using such a target is that the magnet required to produce the holding field can be much less obstructive than the massive split-field magnet planned for the electron experiments, allowing particles to be detected over a full range of angles. This is particularly advantageous at the higher energies, where the more complete solid angle coverage would vastly increase the acceptance for reconstructing the two- and three-pion final states.

According to the polarized target group at the University of Virginia, the only major impediment to constructing a frozen-spin butanol target system is the cost of the dilution refrigerator. In a minimal modification to the planned electron-beam target system, the holding field could be provided by the fringe field of the existing split-field magnet displaced upstream, thus providing an unobstructed view of the target in the forward hemisphere. At additional cost, a thin solenoidal holding-field magnet could be provided, allowing access to a still wider range of angles. We strongly support both of these additions.

Another possible scenario would follow from the successful construction and testing of the SPHICE frozen-spin HD target at LEGS. If the technique succeeds, using such a target for Experiment 91-015 at CEBAF would confer two additional major advantages as compared to a "conventional" frozen-spin target: (1) a much lower "dilution" factor for polarization effects (number of bound nucleons per free nucleon = 2:1 for HD, compared to 64:10 for butanol); and (2) compatibility with the proposed measurement of the neutron DHG sum rule (since the signal in each experiment would comprise part of the background of the other.)

At the present time, we feel the most prudent course of action is to continue planning to run Experiment 91-015 as part of the "eg1" run period, sharing target setup time with the electron beam experiments 91-023 and 93-036. If funding for the "conventional" frozen-spin target can be obtained, then we would strongly prefer to pursue that option, if necessary delaying the start of the run by up to one year to do so. The future of the HD target development is too uncertain for it to enter into our plans at the present time.

## References


[1] B. Adeva et al., Phys. Lett. B302, 533 (1993);
P.L. Anthony et al., Phys. Rev. Lett. 71, 959 (1993)

[2] Zh. Li, S. Whisnant, private communication

[3] D. Drechsel and M. Giannini, Mainz preprint MZPH-T-93-12 (1993); Few-Body Systems 15, 99 (1993)

[4] L. N. Chang, Y. Liang and R.L. Workman, Physics Letters B 329, 514 (1994)

Update of Experiment CEBAF 91-023:

## Measurement of Polarized Structure Functions in Inelastic Electron Scattering using CLAS

*The $N^*$ Collaboration*

*Spokespersons: V. Burkert (contact), D. Crabb, R. Minehart*

### Proposed measurements:

The cross section asymmetry will be measured in $\vec{e}\vec{p} \to eX$ using a polarized electron beam and a dynamically polarized $^{15}N\vec{H}_3$ solid state target. The kinematical range covered consists of small and moderate $Q^2$, and energy transfers covering the nucleon resonance region and part of the deep inelastic region. The target will be polarized in the direction of the beam. Measuring the polarized cross section asymmetries for reversed electron helicities at fixed $Q^2 and W$, but at different beam energies allows the separation of the two polarized structure functions. Required energies range from 1.2 GeV to 4.0 GeV. The known asymmetries for elastic electron proton scattering will be used to accurately determine the product of target and beam polarization.

### Physics objectives of the experiment

The main goal of the experiment is to study the spin structure of the proton in the nonperturbative regime of QCD. We will measure separately the polarized structure functions $A_1^p(Q^2, W)$, $A_2^p(Q^2, W)$ (or $g_1^p(x, Q^2)$, $g_2^p(x, Q^2)$). With the exception of an early, low statistics experiment at SLAC (which also did not attempt to separate $A_1, A_2$), these structure functions have not been measured before in the kinematical region covered by this experiment. One of the puzzles of the deep inelastic experiments at CERN and SLAC is the result that the quarks carry only about 1/2 of the spin fraction predicted in widely accepted theoretical pictures (Ellis - Jaffe spin sum rule). Other possible sources contributing to the nucleon spin are gluons, whose contributions via the axial anomaly were found to be small at best, and orbital angular momentum of the 3-quark system. The latter contributions are necessarily connected with extended objects such as excited 3-quark states, and cannot be probed in deep inelastic scattering experiments, but they may be accessible at lower energies and momentum transfers.

Another result of the deep inelastic experiments is the conspicuous absence of a significant $Q^2$ dependence for the integral $\Gamma_1^p = \int g_1(x, Q^2)dx \sim 0.132$ at $Q^2 > 2\text{GeV}^2$, while at $Q^2 = 0$ this integral should be constraint by the Gerasimov-Drell-Hearn sum rule:

$$\frac{M^2}{8\pi^2\alpha}\int(\sigma_{1/2} - \sigma_{3/2})\frac{d\nu}{\nu} = -\frac{1}{4}\chi^2$$

via the relation (note the negative slope of $\Gamma_1^p$!):

$$\Gamma_1^p = -\frac{Q^2}{8M^2}\chi^2 \quad (Q^2 \to 0)$$

forcing $\Gamma_1^p$ to have a zero at $Q^2 > 0$. To study the expected dramatic $Q^2$ dependence of $\Gamma_1^p$ at small $Q^2$ is one of the objectives of this experiment.

The expected data will also be used to determine the contributions of the resonance region to the integral: $I_2(Q^2) = \int g_2(x, Q^2)dx$, and examine the low $Q^2$ behavior of the Burkhard-Cottingham sum rule, which predicts $I_2 = 0$ in the deep inelastic region.

### New theoretical developments

Proposal 91-023 generated considerable activity in the literature[1,2,3,4,5,6], to generalize the GDH sum rule to finite $Q^2$ and to link the non-perturbative regime with the deep inelastic regime. It has become clear[1] that nucleon resonances are not only the dominant contributions to the GDH sum rule at $Q^2 = 0$, but they play an essential role in understanding the transition to the deep inelastic regime. Even the sign change of the spin integral may be explained by the $Q^2$ evolution of the resonance transition amplitudes. Their contributions are not even negligible in the $Q^2$ range of the SLAC experiments E142, E143. In some models[1,4], corrections for resonance contributions are found to affect the resulting spin fraction carried by the quarks to values consistent with about 50%. This makes it even more important to obtain precise measurements of the inclusive spin structure functions in this kinematical regime.

### Relation to other experiments

Following the approval of E-91-023, experiment E-93-009 was approved with same physics goals for neutrons using polarized $ND_3$ as a target. E-93-009 needs the result of E-91-023 to extract the spin structure functions of the neutron. Experiment E-93-036 will measure exclusive spin structure functions for single pion production, and the unpolarized $N^*$ program will give detailed information about the spin structure of resonance excitations.

These experiments combined will provide the detailed information needed for a comprehensive analysis of the nucleon spin structure in the resonance region.

### Hardware developments

Don Crabb of the University of Virginia, with engineering help from CEBAF is designing a polarized $^{15}NH_3$ solid state target for use in CLAS. Ralph Minehart (UVa) and Volker Burkert(CEBAF) are co-chairing the CLAS/EGN working group to build the electromagnetic forward calorimeter to be used in conjunction with the gas Cerenkov counters to identify electrons at the trigger level 1. Volker Burkert is in charge of the calorimeter project at CEBAF. Ralph Minehart is in charge of the design and construction of the trigger electronics for the calorimeter and the testing of most of the scintillators. All six calorimeter modules are expected to be completed by the middle of 1996.

The experiment can be ready for testing at the beginning of 1997, and for taking data by the middle of 1997. At this time, polarized beam at the appropriate current levels of 1nA - 1 $\mu$A have been requested for Hall B[7]. The experiment would also greatly benefit from the implementation of a high polarization strained GaAs electron source.

## References:


[1] V. Burkert and Zh. Li, Phys. Rev. D47, 46 (1993); V. Burkert and B.L. Ioffe, Phys.Lett.B296, 223 (1992); V. Burkert and B.L. Ioffe, JETP, Vol. 105, 1153 (1994)

[2] J. Soffer and O. Teryaev, Phys. Rev. Lett. 70, 3373 (1993); Phys. Rev. Lett. 71, 360 (1993)

[3] V. Bernard, N. Kaiser, U. Meissner, Phys.Rev. D48, 3062 (1993)

[4] Z.P. Li, Phys. Rev. D47, 1854 (1993)

[5] Z.P. Li, Zh. Li; Phys. Rev. D50, 3119 (1994)

[6] D. Drechsel, University Mainz preprint MKPH/T-94-18 (1994)

[7] L. Cardman, MEMO to CEBAFs Accelerator Division, August 3, 1994.

Update of Experiment 93-009 in Hall B:

## The Polarized Structure Function $G_{1n}$ and the $Q^2$ Dependence of the Gerasimov-Drell-Hearn Sum Rule for the Neutron

*The $N^*$ collaboration*
*Sebastian E. Kuhn (spokesperson)*
*Old Dominion University, Norfolk VA 23529*

Experiment 93-009 will measure inclusive $\vec{e}\vec{n} \rightarrow eX$ scattering at low to moderate $Q^2$ both in the resonance region and at higher energy transfers. It will complement experiment 91-023 (polarized structure functions of the proton). We will use the same high field (5T) cryogenic (1K) target as 91-023, but with deuterated ammonia ($ND_3$) instead of ammonia ($NH_3$) as the polarized target material. We will extract the neutron asymmetry from the deuteron data after subtraction of the independently measured proton contribution. We expect high statistics data on the polarized structure function $G_{1n}$ for momentum transfers from $Q^2 \leq 0.2$ to $Q^2 = 2.0$ GeV$^2$/c$^2$ and for energy transfers from threshold to near beam energy (4 GeV). These data will allow us to measure the $Q^2$-dependence of the Ellis-Jaffe sum, $\int g_{1n}(x, Q^2)\, dx$, for the neutron and of the Björkèn sum, $\int (g_{1p}(x, Q^2) - g_{1n}(x, Q^2))\, dx$, for the proton-neutron difference at low $Q^2$. The data will also shed light on the transition from the deep-inelastic QCD sum rules to the photon point (GDH sum rule) [1,2].

In the short time since this experiment was approved (by PAC VI) with high priority, much work has been done, both within our group and elsewhere, making the physics motivation even stronger and preparing the ground for a successful experiment in Hall B. The spin structure functions of the nucleon continue to be a hotly discussed topic, where major new experimental [3,4] and theoretical [2] results have been obtained in the last year and more are expected soon. New data on the proton have been published by the E143 collaboration at SLAC [3] and by the SMC collaboration [4], and new data on the deuteron at high $Q^2$ are forthcoming from SLAC and CERN. Several additional experiments are preparing to take data (SLAC E154/5, Hermes, SMC). The results so far give a tantalizing glimpse on the (relatively flat) $Q^2$ behaviour of the spin structure function $g_1$ for protons and neutrons at high $Q^2$.

On the other hand, no data for the neutron exist (or will be taken at the high-energy machines) in the $Q^2$ region ($Q^2 < 2$) where one expects the most dramatic change (even in sign) of the spin structure functions. This "missing link" between the deep inelastic sum rules and the Gerasimov-Drell-Hearn sum rule at the photon point can only be explored at CEBAF. The interest in this region remains very high. Having both proton and neutron data is important for several reasons. In the resonance region, data on the neutron can be used to extract information largely orthogonal to that from proton data since isospin symmetry alone does not determine the relationship between transition amplitudes on both nucleons. For comparisons with non-relativistic quark-model calculations, the neutron is even the preferred target, since spurious translation effects play no role (because of the neutron charge being zero)[5]. The neutron data are also necessary to determine the $Q^2$-dependence of the very fundamental Björkèn sum rule which will allow us to study the transition from perturbative QCD to the low-energy region of bound multi-quark systems. Finally, near the photon point, $Q^2 \leq 0.2$, we will be able to shed light on the apparent large discrepancy between the prediction of the GDH sum rule for the neutron-proton difference and the result from recent analyses of pion photoproduction data, which even disagree in sign[6].

Meanwhile, progress toward realizing the present experiment has been steady. Several members of our group (both from ODU and from UVa) have been very actively involved in experiment E143 at SLAC. Our experience will be very helpful in every aspect of the experiment at CEBAF. This is most obviously true for the design and operation of the polarized ammonia ($NH_3$ and $ND_3$) target to be used for experiments 91-023 and 93-009, which will be built in close analogy to the target used at SLAC. The design work which is ongoing now can be based on experience with the day-to-day operation of a real target, allowing us to optimize all parameters.

Other aspects of E143 for which our group was responsible include Monte Carlo simulations and estimates of nuclear effects in deuterium. The latter is an especially important question at lower $Q^2$; one needs a rather realistic model of the nucleus used (deuterium in this case) to extract reliable information on the neutron. The computer codes we developed to study this issue will be directly applicable to experiment 93-009. There are also recent theoretical studies of this problem which include both off-shell and relativistic effects[7].

Finally, the ODU group is building the Region 2 drift chambers (with support from CEBAF). These are 6 large ($\simeq 4m$ long) drift chambers with curved endplates placed between the coils of the CLAS cryostat. They will contain a total of 50,000 wires in 12 layers (6 axial and 6 stereo). The design of all parts for these chambers is either finished or close to completion. Most major items (end plates, structural parts, trumpets and feedthroughs) are either in hand or have been ordered. We expect stringing to begin early in 1995. The UVa and CEBAF members of our collaboration are leading the effort to build the front part of the electromagnetic calorimeter which will also be crucial for our experiment. The collaborators from Duke University are responsible for parts of the Møller polarimeter that will measure the electron beam polarization. The UVa group is responsible for the polarized target as described above.

We expect all components of the experiment to be ready to take beam in the first half of 1997. In view of the high priority given to this experiment by PAC VI, we hope to start collecting data for experiments 91-023 and 93-009 very soon thereafter.

**References.**


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Update to CEBAF 93-036:

## Measurement of the $\vec{p}(\vec{e}, e'\pi^+)n$ and $\vec{p}(\vec{e}, e'p)\pi^0$

*The $N^*$ collaboration*

*Spokespersons: R. Chasteler, R.Minehart, H. Weller (contact)*

### Description of the proposed experiment:

The CLAS detector will be used to measure asymmetry data for the exclusive reactions $\vec{e}\vec{p} \rightarrow e\pi^+n$ and $\vec{e}\vec{p} \rightarrow e\pi^0p$ using polarized electrons on the protons in a polarized solid state $^{15}NH_3$ target for the first time. This experiment will run concurrently with the inclusive experiment (Proposal 91-023). The invariant mass region $1100 < W < 1800$ MeV will be studied for $Q^2$ from 0.25 to 1.25 $(\mathrm{GeV/c})^2$, using incident electron energies of from 1.2 to 4 GeV. Three independent asymmetry ratios can be obtained in bins in a four dimensional parameter space, $(Q^2, W, \theta, \phi)$, free of uncertainties associated with the CLAS acceptance.

Proposal 93-036 presents estimates of the order of magnitude of the asymmetries we can expect, based on the AO code, developed at CEBAF. There, we showed that the proposed experiment will provide asymmetry measurements over a large range of Q2 and W with significant statistical precision. Results in this region are partcularly important since this region of the N* spectrum includes several resonances, some strongly and some weakly excited. Our results show that the polarization observables can be extremely sensitive to the presence of and the detailed properties of these resonances. These data are also very important in that they will provide a major step in the effort to obtain a model independent determination of the helicity amplitudes. The anticipated measurements will yield a wealth of data in a region that is presently limited to total cross sections plus a few measurements of differential cross sections. The large angular acceptance of the CLAS will open a new era in the study of the structure of nucleon resonances.

Missing mass measurements will be used to extract the yields of the exclusive reactions $p(e, e'\pi^+)n$, and $p(e, e'p)\pi^0$. Simulations (by B. Niczyporuk) indicate that we can clearly resolve the elastic scattering from the pion production peak. It also is seen that the background due to $^{15}N$ makes a rather small contribution to our errors.

With good particle identification and good momentum and angular resolution for charged particles the CLAS is ideally suited for an accurate study of these reactions.

A simulation code was used to calculate the CLAS acceptance for pion production with the polarized target in place. We require the pion or proton lab angle to be less than $50^o$ with respect to the beam in order to miss the polarized target magnet coil. The results indicate acceptances of between 0.2 and 0.4 for the full angular range.

### Physical Motivation:

The motivation for these measurements has not changed in any substantial way since our original proposal. In the region of this experiment, the cross section is dominated by four states,$P_{33}(1232)$, $S_{11}(1535)$, $D_{13}(1520)$,and $F_{15}(1690)$. The controversial Roper resonance, the $P_{11}(1440)$, also lies in this region. As discussed in our original proposal, the asymmetries of this experiment are extremely sensitive to the details of the models used to describe the Roper resonance. The $Q^2$ dependence of the asymmetries is an important and sensitive means for distinguishing between a number of competing models for nucleon structure. Precise data on the Roper resonance will be used to select among a variety of models and can be expected to resolve many issues, such as the configuration of its quark structure and whether it is a hybrid resonance exhibiting gluon excitation.

As stated in our proposal, the experiment is expected to yield high quality data that by itself is expected to produce a great improvement in our understanding of the nucleon resonances and their coupling to the electron. However, it must be emphasized that, to a large extent, this is a discovery measurement to determine the order of magnitude and the functional dependence of the heretofore unmeasured asymmetries.

**Relationship to other experiments:**

No measurements have been made in the intervening period to eliminate the need for our measurements. Proposed experiments at Bates, or at European facilities such as MAMI and ELSA, appear to be limited to very low $Q^2$ studies in the region of the $\Delta$. None of these laboratories have apparatus or energies that will compete with the CLAS detector at CEBAF. And none are proposing to use polarized beams and targets. As discussed in the original proposal, there are presently no measurements of these asymmetries available. The improvement to be expected from the proposed measurements will therefore be enormous.

It should be pointed out that the much more complete unpolarized measurements of experiments E-89-037 and E-89-038 will be needed in working toward a model-independent analysis of the resonance region.

**Theoretical activity:**

Since the submission of our $N^*$ proposals, theoretical activity in the field has accelerated. Several calculations[1−4] using relativized versions of the quark model, and motivated by the CEBAF program have been published. A specific calculation of Li, Burkert and Li[5] finds some success in explaining the $Q^2$ dependence of the Roper electroproduction in terms of a model including gluonic degrees of freedom in its structure. Much better data that reduce the model dependence of the resonance extractions are needed to choose among various models and to get insight into their specific strengths and weaknesses.

**Current activities of the group:**

As discussed in the update for Exp. 89-037 and 89-042, a program to develop data analysis techniques is under way. The computer programs provided by this work will be applied to simulated data to test the effects of systematic errors in this experiment. In addition, the proponents of this experiment have been contributing to the construction of the CLAS. Volker Burkert is in charge of the calorimeter project at CEBAF. The Virginia group represented by Ralph Minehart is responsible for the testing and characterization of all scintillators ( 6000) shorter than 3 m in length, and they are designing and producing the analog electronics for the EGN trigger. The polarized target is being developed jointly by CEBAF and Virginia under the direction of Don Crabb.

The Duke University Group is responsible for installing a Moller Polarimeter in Hall B. The polarimeter will operate over beam energies from 800 MeV to 6 GeV. The major systems to be used in this device are the magnetized- foil target, two large quadrupole magnets to detect the scattered electrons, and the detectors for detecting the electrons. The quadrupoles exist, and the electron detectors will be obtained from the components of the EGN prototype calorimeter. Other elements of the polarimeter are currently being tested in prototype form.

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