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:** CLAS γ_2 running period -- Expts. 89-045, 93-008, 93-017, 94-008, 94-103

☐ **Letter-of-Intent Title:**

Contact Person

Name: Prof. Barry G. Ritchie

Institution: Arizona State University

Address: Department of Physics and Astronomy

Address: Arizona State University

City, State, ZIP/Country: Tempe, AZ 85287-1504

Phone: (602) 965-4707 **FAX:** (602) 965-7954

E-mail--Internet: barry.ritchie@asu.edu

Experimental Hall: B **Days Requested for Approval:** ________

CEBAF Use Only

Receipt Date: 12/15/95 PR 95-019

By: gp

Arizona State University *Tempe, AZ 85287-1504*

Professor Barry G. Ritchie, Associate Chair *(602) 965-4707*
Department of Physics and Astronomy *(602) 965-1504*
Box 871504 *FAX: (602) 965-7954*
Internet: barry.ritchie@asu.edu *WWW: http://groucho.la.asu.edu/~ritchie*

December 10, 1995

Program Advisory Committee 10
CEBAF User Liaison Office, Mail Stop 12B
12000 Jefferson Avenue
Newport News, VA 23606

Dear Colleagues:

Due to constraints coming from the Nuclear Sciences Advisory Committee's Long Range Plan activities, scientific ratings were not provided by PAC9 for the Hall B experiments based on the update materials submitted to it. For PAC10, Hall B users were requested to submit further updates if they felt significant changes had been made.

Enclosed please find an updated version of the overall γ_2 running period summary. This running period includes approved experiments 89-045, 93-008, 93-017, 94-008, and 94-103. This new summary should replace that submitted for PAC9

Also enclosed are updates for Experiments 93-008 and 94-103. These updates should replace any previous versions for those experiments from PAC9. The PAC9 updates for Experiments 89-045, 93-017, and 94-008 are acceptable as is for PAC10.

On behalf of the spokespersons for these experiments, I express our appreciation for your consideration of these materials.

Sincerely yours,

Barry G. Ritchie
Associate Professor and Associate Chair

A Summary of the CLAS $\gamma 2$ Running Period

B. G. Ritchie, Arizona State University,
for the
$\gamma 2$ Experiment Group
[December 10, 1995]

Introduction

During previous Program Advisory Committee meetings, the PAC has urged experiment participants to maximize the scientific output from beam delivered to Hall B by exploiting the capability of the CLAS to simultaneously obtain data for experiments with similar trigger, beam, and target combinations. At the same time, however, all experiments were evaluated on their individual merits as "stand-alone" experiments.

The CLAS collaboration has identified a number of experiment combinations which will run simultaneously with minor compromises in terms of event rates and resolution. One such combination identified by the CLAS Collaboration, which has been labelled as the "$\gamma 2$" running period, involves the following approved experiments with similar target/trigger/beam requirements as described below:

- E89-045–Study of Kaon Photoproduction on Deuterium, B. A. Mecking, *et al.*
- E93-008–Inclusive η Photoproduction in Nuclei, M. F. Vineyard, *et al.*
- E93-017–Study of the $\gamma d \rightarrow pn$ and $\gamma d \rightarrow p\Delta^0$ Reactions for Small Momentum Transfers, P. Rossi, *et al.*
- E94-008–Photoproduction of η and η' from Deuterium, B. G. Ritchie *et al.*
- E94-103–Photoproduction of Pions, W. J. Briscoe, J. Ficenec, D. Jenkins, *et al.*

The purpose of this communication is to provide a brief synopsis of the motivations and design parameters which make this grouping of experiments feasible and appealing in terms of physics to be produced and in terms of efficient utilization of beam time.

Scientific motivations

The scientific motivations for these studies span much of the intersection between particle and nuclear physics, and especially concentrates on one the most historically fruitful areas of inquiry in nuclear and particle physics, meson photoproduction. Cross sections measurements for photoproduction of pions (E94-103), kaons (E89-045) and eta mesons (E93-008 and E94-008) on deuterium will provide insight into the photoproduction amplitudes on the neutron, complementing similar studies on the proton, while also allowing the possibility of investigating nuclear effects in coherent photoproduction. The combination of data from the various channels will permit critical investigations of models of nucleon resonances and the mesons themselves, as well as providing a test of the role of final state interactions in this very simple nucleus. Existing data on these photoproduction processes is either very limited or non-existent.

Running in parallel with these measurements, E93-017 will provide accurate cross sections over a broad kinematical range for the photodisintegration of the deuteron. The present database is limited in kinematical coverage and accuracy, leading to significant ambiguities in the theoretical description of the process. As the simplest nucleus, electromagnetic studies of the deuteron are crucial in elucidating the important reaction mechanisms and phenomena present in heavier nuclei. Previous studies of photodisintegration have been crucial in establishing the limits of meson field theory models of the process. This experiment will also pay particular attention to the channel $\gamma d \rightarrow p\Delta^0$ in order to yield stringent tests of conventional meson/isobar-based and quark-gluon-string-based models of the photodisintegration process at energies where quark degrees of freedom may prove useful.

While the motivations for these experiments are discussed more fully within the original proposals and updates, it is important to underscore that these experiments fall into a context including much of the physics to be accomplished in Hall B. They provide important connections and extensions to experiments using other targets and using electroproduction measurements to address similar physics interests as those outlined above.

Experiment design parameters

While their scientific motivations and goals are diverse, these experiments share the following experiment design features:

- **Electron beam energy**: 1.6 GeV
- **Tagged photon energy**: 0.6 to 1.5 GeV
- **Target:** CLAS standard liquid deuterium target
- **Trigger:** Tagged photon + one hadron in CLAS
- **Photon tagger rate:** about 10^7/sec
- **CLAS event rate:** ≤ 1500/sec
- **CLAS magnetic field:** full field, with positive particles bent outward

Two of these experiments, E93-017 and E94-103, require an additional running period of about 3 days to cover the photon energy range from 0.4 to 1.5 GeV. These experiments have been approved for approximately 23 days of running on a liquid deuterium target. With set-up time, the $\gamma 2$ running period would require about 28 days. Should the running period be broken up into several periods, as might be expected during the early stages of Hall B operation, additional set-up time of about 5 days per period would be anticipated.

The various collaborations responsible for each of these experiments have provided significant and critical components of the instrumentation in Hall B, as detailed in their individual updates. All of the experiments were reviewed and approved by the CLAS Collaboration, and all are designated CLAS Collaboration experiments.

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 - 008

☐ **Letter-of-Intent Title:**

Contact Person

Name: Michael F. Vineyard

Institution: University of Richmond

Address: Department of Physics

Address: University of Richmond

City, State ZIP/Country: Richmond, VA 23173

Phone: (804) 289-8257 **FAX:** (804) 289-8482

E-Mail → Internet: vineyard@urvax.urich.edu

Experimental Hall: B **Days Requested for Approval:** ____________

CEBAF Use Only

Receipt Date: 12/15/95

By: SP

Update for Experiment 93-008

Inclusive η Photoproduction in Nuclei

M. F. Vineyard (Spokesperson)
University of Richmond, Richmond, VA 23173

[December 5, 1995]

Through the study of the excitation, propagation, and decay of nucleon resonances in the nuclear environment one ultimately expects to understand how the strong interaction is affected by baryon structure. Over the last twenty years, a wealth of information on the $\Delta(1232)$ and its dynamics within the nuclear medium has been obtained through pion studies. However, very little is known about medium properties of the higher energy excited states of the nucleon. This is primarily due to the fact that the dominance of the Δ and the overlapping of higher resonances prevents studying one specific state by π-production experiments. The η meson, on the other hand, couples only with isospin-1/2 N^* resonances since it is an isoscalar particle, and therefore provides an excellent way to isolate these resonances. In this experiment, inclusive measurements of the photoproduction of η mesons in nuclei will be performed to investigate medium modifications of the $S_{11}(1535)$ and $P_{11}(1710)$ resonances which are the only nucleon resonances of mass less than 2 GeV with significant η decay branches.

These measurements will also provide information on the η-nucleon interaction. Due to the lack of η beams, very little is known about the interaction of η mesons with nucleons. In this experiment, final-state interactions of the η meson propagating through the nucleus will be used to investigate the ηN interaction. The study of η interactions with nucleons and nuclei can provide significant tests of our understanding of meson interactions which has been developed through pion studies. Also a comparative study of the response of η and η' mesons in the nuclear medium may provide insight into the mixing in these two mesons and the structure of the η'.

Recently, Carrasco [1] calculated inclusive η photoproduction cross sections through the excitation of the $S_{11}(1535)$ resonance with a model that includes nuclear-medium modifications of the decay width, Fermi motion, Pauli blocking, and final-state interactions. The results indicate that the inclusive cross sections are sensitive to both nuclear-medium modifications and final-state interactions at energies around the $S_{11}(1535)$.

Since the experiment was approved by PAC6 in the summer of 1993, we have performed simulations to investigate the CLAS acceptance for the recoil nucleons in coincidence with the η mesons assuming quasi-free photoproduction. The angle-summed acceptance at an incident photon energy of 0.8 GeV is 2% for either (proton + 2γ) or (neutron + 2γ) coincidences, and increases to 7% and 4% at 1.5 GeV for (proton + 2γ) and (neutron + 2γ) detection, respectively. Detection of the recoil nucleons will allow the reconstruction of the invariant mass squared s $= (p_\eta + p_N)^2$ of the system which should provide an independent measure of the in-medium mass and width of the resonances. It will also enable the use of the missing mass from the recoil baryon kinematics, in addition to the invariant mass from the 2γ decay, to improve the η identification.

Two η photoproduction experiments have been performed recently at other laboratories. Measurements were made at MAMI on ^1H, ^2H, ^{12}C, ^{40}Ca, ^{93}Zr, and ^{nat}Pb targets over the photon energy range from 600 to 790 MeV [2]. The preliminary results of these measurements indicate that the data is of high quality, however, the energy range covered is only from threshold to just below the peak of the $S_{11}(1535)$ resonance. The other experiment was performed at Bonn on ^1H, ^2H, and ^{14}N targets from threshold to 1.15 GeV. The preliminary results for the energy dependence of the inclusive cross sections measured in this experiment show a depletion and broadening of the $S_{11}(1535)$ resonance in the nuclear medium [3]. A comparison of their ^{14}N results with Carrasco's calculation for ^{16}O shows good agreement up to 900 MeV which is the high energy limit of the calculation. The CEBAF experiment discussed here will extend these measurements to higher energies and more targets. The extended energy range will allow the investigation of the contributions to the cross section from the $S_{11}(1535)$ and $P_{11}(1710)$ resonances, and non-resonant production. The measurements will be made on ^2H, ^3He, ^4He, and ^{12}C targets enabling the study of the evolution of medium effects with target mass.

The members of this experiment collaboration are making various important contributions to the experimental equipment in Hall B. The University of Richmond group is responsible for the construction of the drift-chamber gas system and the associated control system. The group is also working on the development of drift-chamber and data-acquisition software.

[1] R. C. Carrasco, Phys. Rev. **C48**, 2333 (1993).

[2] H. Stroeher, private communication.

[3] M. Breuer *et al.*, Bonn preprint.

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: 94 - 103**

☐ **Letter-of-Intent Title:**

Contact Person

Name: Prof. John R. Ficenec

Institution: Virginia Polytechnic Institute and State University

Address: Department of Physics

Address: Virginia Polytechnic Institute and State University

City, State, ZIP/Country: Blacksburg, VA 24061

Phone: (703) 231-7890 **FAX:** (703) 231-7511

E-mail--Internet: jficenec@vt.edu

Experimental Hall: B **Days Requested for Approval:** ____________

CEBAF Use Only

Receipt Date: 12/15/95

By: SA

CEBAF EXPERIMENT 94-103

The Photoproduction of Pions

W.J. Briscoe (Spokesperson)
The Center for Nuclear Studies of The George Washington University
E-mail: briscoe@gwis2.circ.gwu.edu
Ph: (202) 994-6788; (703) 729-8340 Fax: (202) 994-3001

J. Ficenec (Spokesperson/Contact)
Department of Physics, Virginia Polytechnic Institute and State University
E-mail: jficenec@vt.edu Ph: (703) 231-7890 Fax: (703) 231-7511

D. Jenkins (Spokesperson)
Department of Physics, Virginia Polytechnic Institute and State University
E-mail: jenkins@vt.edu Ph: (703) 231-6712 Fax: (703) 231-7511

W.J. Briscoe, C. Bennhold, J.P. Connelly, L. Maximon, T. Morrison,
M.F. Taragin, Z. Papandreou, S. Philips, R. Pratt, and J. Prokop,
The Center for Nuclear Studies of The George Washington University

J. Ficenec, D. Jenkins, R. Arndt, I. Strakovsky, and R. Workman,
Department of Physics, Virginia Polytechnic Institute and State University

H. Crannell, S.K. Matthews, J.T. O'Brien, and D.I. Sober,
Department of Physics, The Catholic University of America

E. Smith
CEBAF

D.M. Manley
Department of Physics, Kent State University

R. Alarcon and J.R. Comfort
Department of Physics, Arizona State University

W. Roberts
Department of Physics, Old Dominion University & CEBAF

Z. Li
Department of Physics, Christopher Newport University & CEBAF

The Photoproduction of Pions
CEBAF Experiment 94-103
Update

The γN interaction is one of the most powerful ways of investigating hadron structure. In reactions with the nucleon, one may study the radiative-decay amplitudes of the N(I=1/2) and Δ(I=3/2) resonances without the complexities involved in heavier nuclei. These amplitudes are essential in testing theories of the strong interaction, especially those based on the quark model. In particular, pion photoproduction provides a means by which intermediate resonance states can be scrutinized in a straightforward manner, given the well-known nature of the electromagnetic interaction. The radiative decay of a resonance is sensitive to the dynamics of quarks within the hadron. However, the radiative amplitudes for many resonances are not well-known, e.g. $S_{11}(1535)$, $P_{13}(1720)$, and $F_{17}(1990)$ to name a few; thus, current checks on the validity of some models are often difficult and inconclusive The lack of good data, as well as other factors, such as the reliance on pion-nucleon elastic-scattering analyses, often precludes extraction of accurate decay amplitudes.

We will measure single-pion photoproduction using CLAS and the Tagger Facility in Hall B at CEBAF with tagged photons having energies between 400 and 3040 MeV. Differential cross sections for the reactions $\gamma p \rightarrow \pi^o p$ and $\gamma p \rightarrow \pi^+ n$, and for $\gamma n \rightarrow \pi^- p$ will be measured to an accuracy better than 4% in hydrogen and 6% in deuterium, for center of mass angular increments of 3° to 6° between 20° and 140°, and for energy increments of 4.9 to 12.5 MeV. These measurements will provide unique and coherent results from tagged photons over a broad range of angle and energy; and with a few exceptions, represent the only pion photoproduction data above 1800 MeV. The differential cross sections extracted from this data will be analyzed to determine the partial-wave amplitudes and the photocouplings for some 25 baryon resonances in the energy range of the experiment.

Many of the resonances which are predicted by the quark model between threshold and our energy cutoff are not observed in analyses of the current pion-photoproduction data. Our new results, which in some cases will yield partial-wave amplitudes with uncertainties a factor of five smaller than current results, will determine current photocouplings more accurately, and can reveal currently unidentified weakly-produced resonance states. The photocouplings of baryon resonances are a crucial test of our understanding of nonperturbative quantum chromodynamics (QCD). The results will be compared with quark-model predictions; with predictions from multichannel analyses, e.g. $\gamma N \rightarrow \pi N$, $\gamma N \rightarrow \pi\pi N$, $\gamma N \rightarrow \eta N$, $\pi N \rightarrow \pi N$, $\pi N \rightarrow \pi\pi N$ and $\pi N \rightarrow \eta N$; and with other timely physics models. The establishment of the $Q^2 = 0$ electroproduction point in the more fundamental photoproduction processes will provide an important constraint on any results obtained in electroproduction experiments.

The beam-time request presented in the proposal did not include calibration runs which will be performed for all experiments during the commissioning phase of CLAS. Phase I of this experimet has been approved to run concurrently in CLAS with the other approved experiments that have been allocated time in running periods "Gamma 1" and "Gamma 2". These include experiments 89-004, 89-024, 91-008, 93-033, 94-015, and 89-045, 93-008, 93-017, 94-008, respectively. Some conditions for running period "Gamma 1" are listed in the first two rows of Table 1; and some conditions for running period "Gamma 2" are listed in the third row of Table1. Assuming the running time, tagger, and trigger conditions that are currently envisioned by the approved experiments, we will measure single pion differential cross sections of 1 μb/sr in energy bins, ΔE, and angular bins, $\Delta[\cos(\theta_{CM})]$, with the statistical uncertainties shown in the last column of the first three rows (Phase I) in Table 1. Of course, at photon energies below the largest tagged energy, in an energy region of constant trigger prescaling, the uncertainties will be less than they are at the highest tagged energy. We will adjust the angular bins continuously and energy bins in fixed increments as a function of photon energy to best match the systematic uncertainties.

Table 1. Statistical Uncertainties in Differential Cross Section for 1μb/sr

Target	E_e (GeV)	E_γ (GeV)	Time (days)	ΔE (MeV)	$\Delta[\cos(\theta_{CM})]$	Error (%)
Phase I -- Beam Time Allocated for Running Periods Gamma 1 and Gamma 2						
hydrogen	**2.4**	**2.28**	**52**	**4.9**	**0.05**	**2.0**
hydrogen	**3.2**	**3.04**	**7**	**12.5**	**0.10**	**2.5**
deuterium	**1.6**	**1.52**	**23**	**6.2**	**0.05**	**2.0**
Phase II -- Beam Time Allocation Deferred by the PAC						
deuterium	**3.2**	**3.04**	**10**	**12.5**	**0.10**	**2.4**

Phase II of this experiment, which requires new beam time(1 day of setup and 10 days of running with 3.2 GeV electrons and a deuterium target), has had its allocation of beam time deferred to a later date by the PAC. The tagging range would be 47% to 95%, or 1.52 to 3.04 GeV, at a rate of 0.63×10^7 photons/second. The magnetic field setting would be 100% of nominal with negative particles bending out. The uncertainty listed in the last row and column of Table 1 assumes a 50% accidentals rate, a 40% dead time, a 80% azimuthal acceptance over the polar angular range of interest, a 80% trigger and reconstruction efficiency, and a 75% tagger and spectrometer operating efficiency. These assumptions are comparable to those used in the 3.2 GeV run with hydrogen.