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: E 93-044

Check Applicable Boxes:

- ☐ Extension
- ☐ Update
- ☒ Hall B Update

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Receipt Date: 12/15/94

By: sp

PR 94-131

Summary of the $\gamma 3$ Running Period for the CLAS Collaboration

M. F. Vineyard, University of Richmond
for the
γ3 Experiment Group

[December 15, 1994]

The CLAS Collaboration has developed a run plan to maximize the scientific output of Hall B by exploiting the capability of the CLAS to simultaneously obtain data for experiments with similar running conditions. A number of experiment combinations have been identified which can run simultaneously with minor compromises. One of these combinations, which has been identified as the "$\gamma 3$" running period, includes the following approved experiments:

- E-91-014: Quasi-Free Strangeness Production in Nuclei, C. E. Hyde-Wright, Spokesperson
- E-93-008: Inclusive η Photoproduction in Nuclei, M. F. Vineyard, Spokesperson
- E-93-044: Photoreactions on ^3He, B. L. Berman, P. Corvisiero, and G. Audit, Spokespersons

While these experiments have multiple physics goals, there is one motivation that is common to all three: the study of the formation and propagation of nucleon resonances in nuclear matter. One experiment (E-91-014) will study this phenomenon through the photoproduction of kaons. Another (E-93-008) will use η meson photoproduction to investigate the S_{11} and P_{11} resonances. The third experiment (E-93-044) will study the D_{13} and F_{15} resonances through the exclusive Nπ and N$\pi\pi$ channels.

The other scientific motivations of the three experiments are diverse and address a number of important physics issues. The strangeness production experiment (E-91-014) will investigate kaon-nucleus and hyperon-nucleus interactions and photon coupling to correlated nucleon-nucleon pairs in the nucleus. Experiment E-93-008 will provide information on the η-nucleon interaction. The study of photoreactions on ^3He (E-93-044) will investigate the three-body effects in the NNN breakup channel and the ΔNN component of the ^3He wave function.

It is important to point out that these experiments are integral components of the Hall B physics program. There are significant connections between these studies and photoproduction experiments on other targets and electroproduction measurements that address topics that are related to those outlined above.

The basic running conditions of the three experiments are the same, and all the spokespersons agree that the details of the running period can be worked out with only minor compromises. The spokespersons also agree that it is important that the running period be broken up into several periods, as proposed for the early stages of Hall B operation, and that the first running period of these experiments be as early as possible. This will allow us to gain a better understanding of the Hall B equipment and to optimize the running conditions for the later periods, which will result in higher quality measurements.

The collaborations of the $\gamma 3$ experiment group are responsible for many significant and critical elements of the Hall B instrumentation, as detailed in the individual updates. These include two substantial contributions from outside the United States: the cryogenic target system from Saclay and the large-angle calorimeters from our Italian collaborators. Other components include the region-2 drift chambers, the pair spectrometer, the photon collimation system, the drift-chamber gas system, the focal-plane detector array for the tagger, and software.

Update for Experiment 93-044: Photoreactions on ^{3}He

B.L. Berman, P. Corvisiero, and G. Audit, Co-Spokespersons

December, 1994

This experiment will use real photons to study three different physical phenomena in ^{3}He: the formation and propagation of nucleon resonances in nuclear matter, three-body-force effects in the NNN breakup channel of ^{3}He, and the ΔNN component of the ^{3}He nuclear wave function. The physics we shall uncover in each of these three areas remains at least as interesting as when we proposed them last year. With the Hall-B Photon Tagger and the CLAS, each of these phenomena will be studied in exclusive reaction channels.

Recent total photoabsorption data on various nuclei for photon energies from 0.2 to 1.2 GeV show strong suppression of the cross section ($\sim 35\%$) in the region of the D_{13} and F_{15} resonances, compared with data on the free proton and the loosely-bound deuteron. The Δ resonance, by contrast, shows only broadening effects. Because ^{3}He is intermediate in nuclear density and binding between the deuteron and heavier nuclei, it constitutes the ideal case for studying the effect of the nuclear medium on the propagation of these resonances. We shall study the degree of suppression of the D_{13} and F_{15} resonances in ^{3}He by detecting the exclusive $N\pi$ and $N\pi\pi$ channels.

Recently, we have been studying the contribution of final-state interactions to resonance damping, by calculating the mean free path of pions in ^{3}He and simulating the FSI arising both from pion scattering and nucleon scattering. In the naive model that we have employed thus far, these effects appear to be very small (as one might expect in as small a nucleus as ^{3}He), especially in the pion angular distributions, as shown at the energies of the peaks of the D_{13} and F_{15} resonances in Fig. 1. A more sophisticated theoretical approach is currently being worked out in collaboration with Dr S. Simula (INFN Sanita, Rome), and we expect to have more accurate theoretical estimates soon.

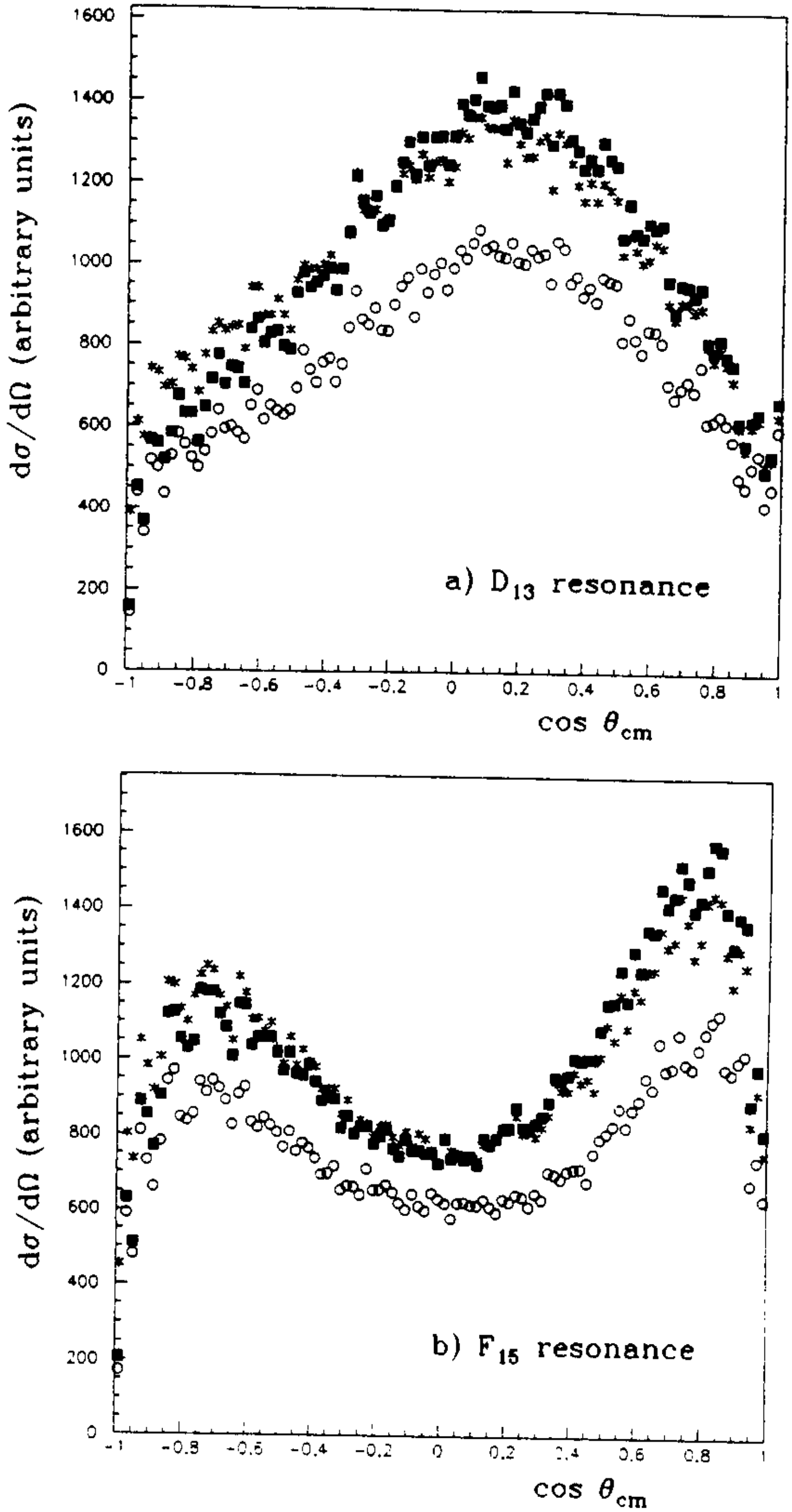
The nature of the interaction of two nucleons in the presence of a third is one of the fundamental unsolved problems of nuclear physics. In ^{3}He, the two-body NN force dominates the wave function at low energies (and hence long distances) to such an extent that the very existence of a three-body component is still a subject of debate. We shall look for manifestations of the three-body force at the higher photon energies available at CEBAF (up to 1.5 GeV, corresponding to a reduced photon wavelength of nearly 0.1 fm). The main difficulty of this measurement will be to distinguish the effects of true three-body forces from effects of sequential two-body processes. One likely signature is the "star" configuration in the NNN channel, when the three nucleons are emitted 120° apart with equal momenta in the center-of-mass frame. Additionally, the plane of any two nucleon momenta need not include the direction of the incident photon. In this way, the background from two-body processes is minimized.

Our recent work on the NNN channel explores the effects of using circularly polarized photons, which should be available by the time the CLAS is commissioned. In our previous studies, reported in our original proposal, we found enhanced three-body effects for the neutron azimuthal angle φ near 30° for a photon energy of 800 MeV, but we performed these calculations only for star coplanar kinematics, shown in Fig. 2, where there can be no polarization effects. Now, we have extended these calculations at $\varphi = 30°$ to all out-of-plane angles ϑ, and we find a striking enhancement of three-body effects near $\vartheta = 50°$ in the predicted polarization, as shown in Fig. 3. Even though the cross section for these kinematics is only about 15% of that at $\vartheta = 0°$, as can be seen in the lower part of Fig. 3, the counting rate might still be sufficient to measure this effect unambiguously. Clearly, we need to flesh out these calculations with a more complete mapping, as a function of ϑ, φ, and E_γ, but these preliminary results are striking, and certainly intriguing. Although at this time we have not investigated the implications of these calculations well enough to change the parameters of our experiment, it does appear that if circularly polarized photons are available (at essentially no cost in intensity or running time), it would behoove us to take full advantage of their availability.

The third objective of this experiment is to look for the small Δ-isobar part of the nuclear wave function. The ^{3}He wave function is dominated by the NNN configuration; however, the contribution of the ΔNN configuration has been calculated to be between a few tenths and several percent, and contributes to the high-momentum tail of the momentum distribution. The clearest signature of such a configuration is the direct knockout of a delta. To minimize background from the much more probable Δ-production events, we shall look for Δ^{++} knockout events (Δ photoproduction from nucleons will contribute directly only to Δ^0 and Δ^+ production). These events will be identified by a missing-mass reconstruction analysis of $p\pi^+$ events in the CLAS.

In our proposal, we presented calculations for $E_\gamma = 500$ MeV. Recently, we have performed new calculations for $E_\gamma = 900$ MeV, including both polar and azimuthal angular distributions of the π^+ from Δ^{++} decay. It appears from a first look that we can obtain more information from these distributions which would help to identify the elusive Δ-knockout events. More detailed calculations are underway.

Meanwhile, we are making good progress on our various contributions to the Hall-B facilities and equipment. Construction of the focal-plane detector array for the Photon Tagger is proceeding on schedule at GW, construction of the cryogenic-liquid target system is proceeding on schedule at Saclay, construction of the large-angle sector of the shower-counter array is proceeding on schedule at Genoa and Frascati, and we now have 1000 liters of ^{3}He gas, scheduled to undergo final purification (at Los Alamos) in 1995 so that it will be ready to be shipped to CEBAF in mid-1996. We look forward to very fruitful experimental measurements in the near future.



full ■: Fermi motion
open o : Fermi motion + 0.2 damping
(resonance amplitude = 0.8*full amplitude)
*: Fermi motion + FSI

Figure 1. C.M. angular distribution of the π° for the reaction $^3He(\gamma,\pi^\circ p)pn$: a) at W=1520 MeV (peak of D_{13} resonance); b) at W=1688 MeV (peak of F_{15} resonance)

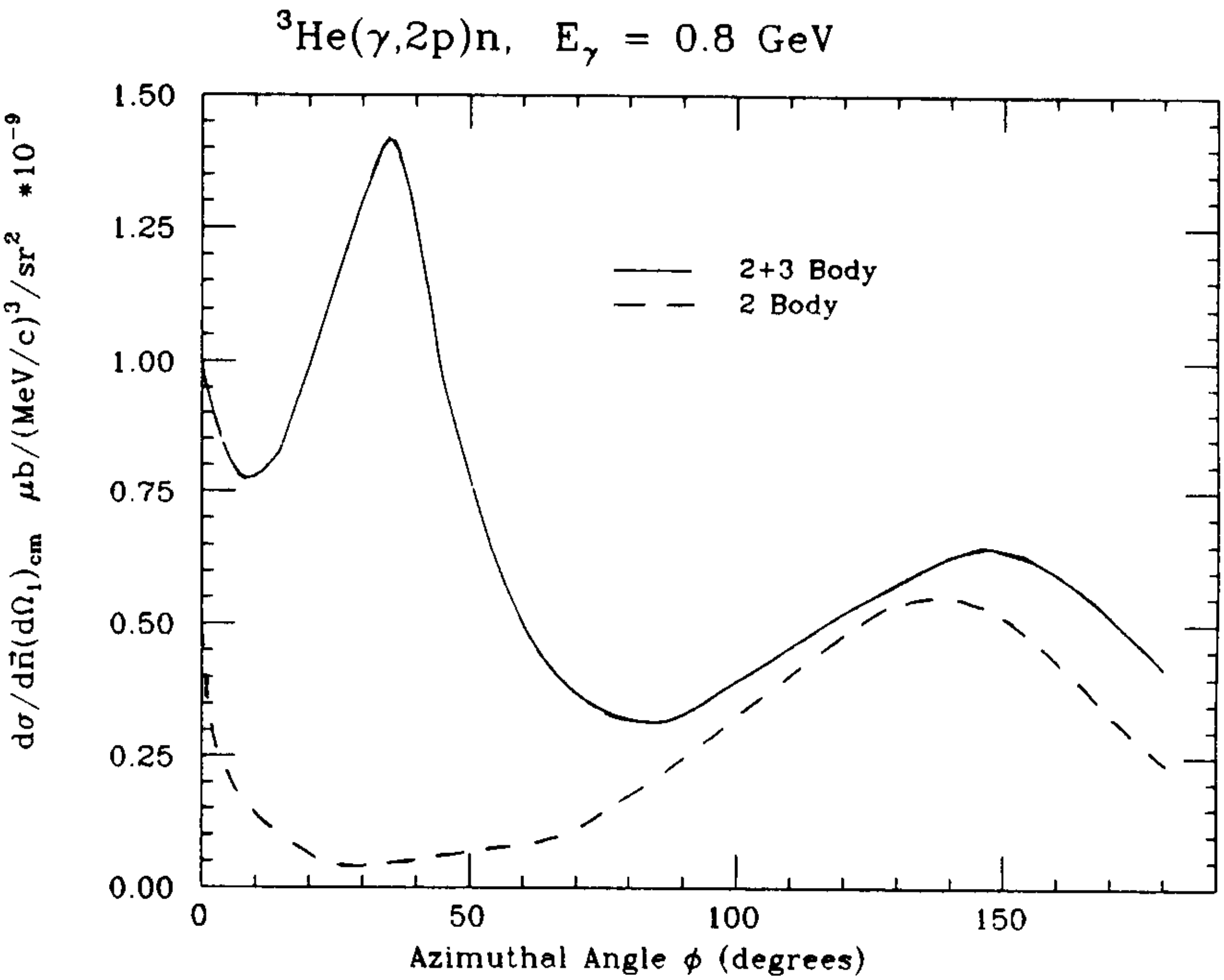


Figure 2. Star Coplanar Kinematics (θ=0°).

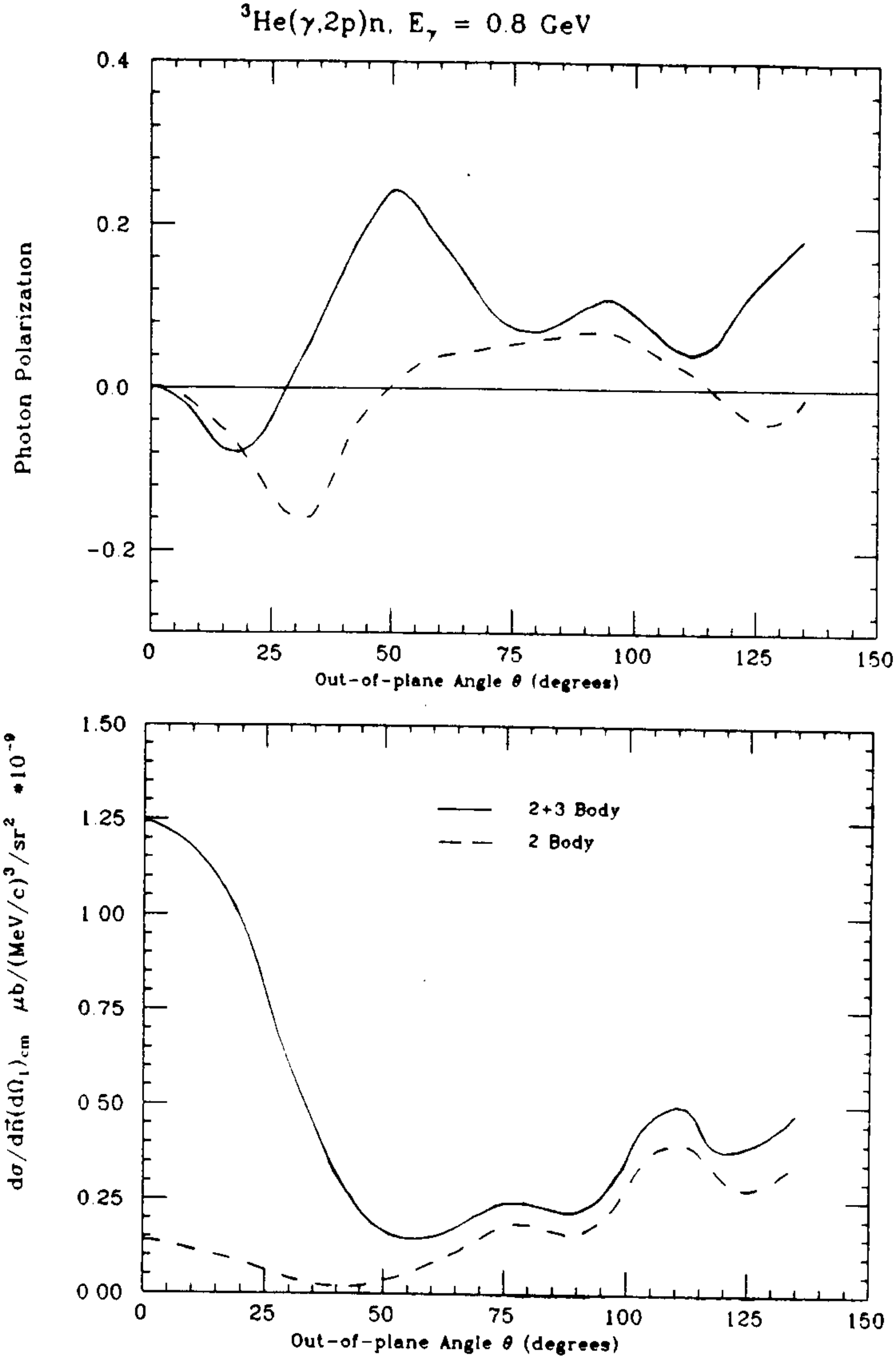


Figure 3. Star Out-of-Plane Kinematics at ϕ=30°.

BEAM REQUIREMENTS LIST

Hall B γ3 Running Period

CEBAF Proposal No.: E-91-014, E-93-008, E-93-044 Date: 12/15/94

(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/cm²)
1	1600	$2\text{-}50\times10^{-3}$	Circularly polarized	cryo.liquid ^{3}He	1
			photons (from longitudinally	cryo.liquid ^{4}He	1
			polarized electrons) may	C	1
			be used, but not required		

ıe 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

The Hall B X3 Running Period
E-91-014, E-93-008, E-93-044

CEBAF Proposal No.: ______________________ Date: 12/15/94
(For CEBAF User Liaison Office use only.)

Check all items for which there is an anticipated need.

Cryogenics

- ___ beamline magnets
- ___ analysis magnets
- X target
  - type: Liquid He
  - flow rate: ______
  - capacity: 120 cm^3

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)
  - carbon

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: ______
- 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)

______

General:

Experiment Class:

- X Base Equipment
- ___ Temp. Mod. to Base Equip.
- ___ Permanent Mod. to Base Equipment
- ___ Major New Apparatus

Other: ______

LAB RESOURCES REQUIREMENTS LIST

Hall B γ3 Running Period

CEBAF Proposal No.: E-91-014, E-93-008, E-93-044 Date: 12/15/94

(For CEBAF User Liaison Office use only.)

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)*

New Support Structures:

Data Acquisition/Reduction

Computing Resources:

New Software:

Major Equipment

Magnets

Power Supplies

Targets

Detectors

Electronics

Computer Hardware

Other

Other