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
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Experiment: **Check Applicable Boxes:**

E 93 - 033 ☐ Extension ☐ Update ☒ Hall B Update

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By: gp PR 94-130

PAC9 UPDATE FOR CEBAF EXPERIMENT 93-033

A Search for Missing Baryons Formed in $\gamma p \to p\pi^+\pi^-$ Using the CLAS at CEBAF

J. Napolitano, Spokesperson

This experiment attempts to solve a long outstanding problem in baryon structure. This "missing baryons" problem is as crucial today as it was when this experiment was approved by PAC6 in 1993.

Briefly stated, the missing baryons problem represents a mismatch between the number of states predicted by the quark model and the number that are observed experimentally. The predicted states and their quantum numbers follow rigorously from the underlying $SU(6) \times O(3)$ symmetry for quarks with spin and orbital angular momentum. An intriguing solution to this problem was originally put forth by Lichtenberg[1] who suggested that pairs of quarks bind tightly into "diquarks" with a particular set of quantum numbers. Baryons, then, would be *quark-diquark* systems, and the reduced symmetry nicely accounts for the missing states, including their quantum numbers.

However, nearly all data on non-strange baryons is from s-channel formation experiments with $N\pi$ in the initial or final state, or both. If the missing baryons do not couple to $N\pi$, they would not have been discovered. This was first suggested many years ago, and modern dynamical quark model calculations support this hypothesis [2]. On the other hand, these states do not have anomalously small couplings to photons [3], or to $N\pi\pi$ final states such as $\Delta\pi$ or $N\rho$ [4]. This experiment will search for the missing states using the reaction $\gamma p \to p\pi^+\pi^-$, which therefore includes various final states including $\Delta^{++}\pi^-$, $\Delta^0\pi^+$, and $N\rho^0$, as well as those with the $\pi^+\pi^-$ in a relative S-state or with excited baryons such $N\frac{1}{2}^+(1440)$ and $\Delta\frac{3}{2}^+(1600)$. Dynamical models predict the masses of these states to be ~ 2 GeV, and therefore $\sqrt{s}$ is very nicely covered by the 2.4 GeV beam energy which dominates the $\gamma 1$ running period.

Some of the recent progress on this experiment has been theoretical. The number of possible quasi-twobody states which can end up as $p\pi^+\pi^-$ is quite large, and it is very useful to have some idea where to look. Capstick and Roberts [4] have calculated these branches in the framework of the relativized quark model, with this and other experiments in mind, and we will use these results to help direct the data analysis.

A different observation has been made which allows this experiment to confront the diquark model directly. In the Lichtenberg diquark model, there can be no $\frac{7}{2}^+$ nucleon although this is a perfectly reasonable state in the quark model. In fact, weak evidence [5] exists for such a state at 1980 MeV in elastic πN scattering, and the extracted elastic amplitude is consistent with calculations [2]. In fact Capstick and Roberts [4] predict this state decays predominantly to $\Delta\pi$. The relative amounts of $\Delta^{++}\pi^-$ and $\Delta^0\pi^+$ in the photoproduction analysis will be used to separate an intermediate nucleon state from the nearby well known $\Delta\frac{7}{2}^+(1950)$, following a partial wave analysis.

The partial wave analysis is in fact nontrivial, especially because of the various overlapping final states in $p\pi^+\pi^-$. We have started to study the problem in some detail. Good examples exist for s-channel formation in πN scattering [5] and in photoproduction [6], and we are of course studying this work. We have also embarked on an analysis of $p\pi^+\pi^-$ final states produced in $K^\pm$ inelastic scattering, using data acquired at SLAC by the LASS/E135 collaboration. We are guided by previous analyses [7, 8] of this system, albeit with far poorer statistics than what we now have on hand.

This experiment will accumulate an enormous number (several $\times 10^8$) of events, and we must be prepared to deal with them. We are rapidly converting our data analysis facility at Rensselaer from a VAX/VMS system to an IBM/RS6000 UNIX system, compatible with the data analysis setups for the CLAS. We will use this system shortly to analyze the E135 data, as well as the massive data set from experiment E852 at Brookhaven National Laboratory. We intend to be fully prepared to analyze the data for missing baryons soon after it is acquired.

Finally, of course, Rensselaer has a large instrumental commitment to the CLAS in the gas Čerenkov detector system. The design for this detector is virtually complete, and nearly all the outside orders have been placed. The first of six mechanical structures has been machined and assembled, including mirrors, Winston cones, magnetic shields, and support hardware. The photomultipliers are being tested and calibrated. All this work is going on at Rensselaer, and all six sectors will be ready for installation in the CLAS in the summer of 1996. For the energies encountered in E93-033, however, it is unlikely that the Čerenkov detector would be sensitive to $\pi^\pm$, but as demonstrated to PAC6, this experiment has no difficulty with particle identification.

References

[1] D.B. Lichtenberg, Phys.Rev. **178**(1969)2197

[2] S. Capstick and W. Roberts, Phys.Rev.D. **47**(1993)1994

[3] S. Capstick, Phys.Rev.D. **46**(1992)2864

[4] S. Capstick and W. Roberts, Phys.Rev.D. **49**(1994)4570

[5] D.M. Manley and E.M. Saleski, Phys.Rev.D. **45**(1992)4002

[6] R.A. Arndt, et.al., Phys.Rev.C. **42**(1990)1853

[7] G. Otter, et.al., Nucl.Phys. **B139**(1978)365

[8] J.N. Carney, et.al., Nucl.Phys. **B110**(1976)248

The $\gamma 1$ Running Period at CLAS

December, 1994

The CLAS running period entitled $\gamma 1$ (Gamma 1) presently consists of those experiments which use a liquid hydrogen target and the real photon tagger. The running requirements of the experiments are overlapping and will be outlined here. The experiments are:

- 89-004 Electromagnetic Production of Hyperons (Schumacher *et al*)
- 89-024 Radiative Decays of the Low-Lying Hyperons (Mutchler *et al*)
- 91-008 Photoproduction of η and η' Mesons (Ritchie *et al*)
- 93-033 Search for Missing Baryons Formed in $\gamma p \rightarrow p\pi^+\pi^-$ Using the CLAS at CEBAF (Napolitano *et al*)
- 94-015 Study of the Axial Anomaly Using the $\gamma\pi^+ \rightarrow \pi^+\pi^o$ Reaction Near Threshold (Miskimen, Wang, Yegneswaran *et al*)

As can be seen from the titles, the range of physics addressed by these experiments is broad. Two involve the production and decay of strange particles, one seeks to determine the presently unknown eta photoproduction cross sections, while the others exploit the relative simplicity of photoproduction to probe poorly known sectors of hadronic physics. E89-004 will explore the photoproduction of the ground state hyperons Λ, Σ^o and Σ^+, adding abundant polarization data available for the first time. This will make it possible to extract several hadronic couplings and definitively describe the resonance structure of these reactions. E89-034 will use CLAS as a copious source of excited hyperons, such as the $\Lambda(1405)$, and extract the small radiative decay branching ratios by reconstruction of the hadronic decay products. These provide particularly sensitive tests of quark model structure of the hyperons. E91-008 plans to measure the differential cross sections for η and η' photoproduction using detection of the recoil protons in CLAS. These measurements are viewed as providing a foundation for later eta production measurements in nuclei, and for studying baryon resonances which couple to etas. E93-033 will search for firmly predicted yet undiscovered baryon states which decay to, for example, $\Delta\pi$ instead of the better-studied Nπ. This experiment will undertake the analysis of $p\pi^+\pi^-$ final states and do the necessary partial wave analysis to extract new intermediate states. E94-015 seeks to measure an amplitude strictly forbidden by the full QCD Lagrangian, but which is present as an "anomaly" in the simplest effective Lagrangian which is solvable. The experiment will actually use the reaction $\gamma p \rightarrow \pi^+\pi^o n$, and hinges on extraction of the t-channel pole term corresponding to the anomalous reaction.

It should be noted that each of the groups involved in these experiments is playing a substantial role in developing the hardware for the CLAS spectrometer or photon tagger.

For several years there has been an understanding within the collaboration that several of the real photon experiments would gather data in parallel. At the present time the plan is for all of these experiments to accumulate data within the same 65 day running period. This concept was endorsed by PAC6. Compromises in running conditions mean that no experiment collects data at an optimal rate, but all participants have so far expressed agreement with the proposed running scenario. This scenario pre-supposes that the trigger for the CLAS will work as advertised, that is, up to a full 1,500/sec single-particle event rate will be recorded with acceptably small deadtime. In other words, the trigger can be "minimum bias," with no on-line selection of rare types of events necessary. Because the tagged photon spectrum goes roughly as 1/E, data taking will be prescaled at the trigger level to suitably even out the recorded rate as a function of energy. The present running scenario is as follows:

Beam endpoint energy: $E_o = 2.4$ GeV 5 days setup, 52 days running

- Liquid hydrogen target, 1.0 gm/cm^2
- Tagging range: 20% to 95% of E_o for 0.48 to 2.28 GeV
- Total tagging rate of 1×10^7 photons/second
- Prescale factors:

  16 - from 0.48 to 0.85 GeV (10% of all tagged photons)

  4 - from 0.85 to 1.40 GeV (26%)

  1 - from 1.40 to 2.28 GeV (64%)
- Trigger: the estimated single-charged particle rate under these running conditions is 360/sec, without correcting for acceptances. The estimated deadtime is then 24%. The total hadronic rate in the spectrometer will be about 3000 /sec.
- Magnetic field setting: 20% of nominal field with negative particles bending out. This configuration maximizes acceptance for low momentum particles, especially negative pions from hyperon decays.

Beam Endpoint energy: 3.2 GeV 1 day setup, 7 days running

- Tagging range: 71% to 95% of E_o for 2.28 to 3.04 GeV
- Total tagging rate of 1×10^7 photons/second
- Prescale factors: unity
- Trigger: One charged particle
- Magnetic field setting: 50% of nominal field with negative particles bending out.

Discussions now underway suggest that this running period may be split over three calendar years. It must be expected that some addition setup time will be needed in each year to reestablish and continue the run from previous years.

BEAM REQUIREMENTS LIST

CEBAF Proposal No.: 89-004, 89-024, 91-008, 93-033, 94-015 (For CEBAF User Liaison Office use only.) Date: 12-94

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	2400	0.1	Circular Polarization	LH2	1 gm/cm^2
			(if available)		
2	3200	0.1	Circular Polarization	LH2	1 gm/cm^2
			(if available)		

T[illegible] 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 [illegible] 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.: 89-004, 89-024, 91-008, 93-033, 94-015 (For CEBAF User Liaison Office use only.)

Date: 12-94

Check all items for which there is an anticipated need.

Cryogenics X beamline magnets X analysis magnets X target type: LH2 flow rate: ____ capacity: ____	**Electrical Equipment** X cryo/electrical devices __ capacitor banks X high voltage __ exposed equipment	**Radioactive/Hazardous Materials** List any radioactive or hazadorous/ toxic materials planned for use: NONE
Pressure Vessels __ inside diameter __ operating pressure __ window material __ window thickness	**Flammable Gas or Liquids** type: LH2 flow rate: ____ capacity: ____ **Drift Chambers** type: CLAS 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: ____ 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: ____