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 -

Check Applicable Boxes:

☐ Extension ☐ Update ☑ Hall B Update

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Receipt Date: 12/15/94 PR 94-123

By: [illegible]

LAB RESOURCES REQUIREMENTS LIST

CEBAF Proposal No.: ____________________ Date: 12/14/94

(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

Only base equipment is required

HAZARD IDENTIFICATION CHECKLIST

CEBAF Proposal No.: ____________ (For CEBAF User Liaison Office use only.) Date: 12/14/94

Check all items for which there is an anticipated need.

Cryogenics	Electrical Equipment	Radioactive/Hazardous Materials
___ beamline magnets ___ analysis magnets ___ target type: ___ flow rate: ___ capacity: ___	___ cryo/electrical devices ___ capacitor banks ___ high voltage ___ exposed equipment	List any radioactive or hazadorous/ toxic materials planned for use: ___ ___ ___ ___
Pressure Vessels - target 5mm inside diameter 15atm operating pressure Havar window material 2μm window thickness at 1mm φ	**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) ___ 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: ✓ Base Equipment ___ Temp. Mod. to Base Equip. ___ Permanent Mod. to Base Equipment ___ Major New Apparatus Other: ___ ___

All other hazards are standard Hall B equipment

BEAM REQUIREMENTS LIST

CEBAF Proposal No.: ______________________ Date: 12/14/94
(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/cm^2)
1	800	.1	none	^3He	18
2	2000	.1	"	"	"
3	4000	.1	"	"	"
4	800	.1	"	^4He	24
5	2000	.1	"	"	"
6	4000	.1	"	"	"
1,4	800	.1	"	Havar windows for ^3He + ^4He	3.3
2,5	2000	.1	"	"	"
3,6	4000	.1	"	"	"
7	800	.1	"	Carbon	27
8	2000	.1	"	"	"
9	4000	.1	"	"	"
10	800	.1	"	Iron	27
11	2000	.1	"	"	"
12	4000	.1	"	"	"

: 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.

Update for Proposals
89-15, 89-17, 89-27, 89-31, 89-32 and 89-36

These proposals have been grouped into a single run by the CEBAF PAC and the Nuclear Multihadron physics working group of the CLAS collaboration and are therefore being updated as a group. The common themes in these proposals are multiparticle final states, multinucleon absorption processes, nucleon resonances in nuclei and short range correlations over wide ranges in nuclear mass and momentum transfer. Original motivations include a desire to understand the role of multinucleon absorption in the quasielastic, dip and delta region cross sections, to investigate properties of the Δ and other nucleon resonances in nuclei, to study short range nucleon-nucleon correlations via fast, backward particles, and to search for exotic states such as 6q bags and the $\Delta\Delta$.

The large solid angle, moderate momentum resolution and good particle identification of the CLAS detector combine to make it an ideal tool for studying each of these topics. In addition, the high data acquisition rate and flexible trigger electronics allow the simultaneous study of all these topics. Hence, the combined run plan.

Since these proposals were written in 1989 interest in this field has remained strong, although the experiments have been greatly limited by the available facilities. More (e,e′) L/T separations have been performed at momentum transfers up to 1 GeV/c[1-3]. In contrast to the lower momentum transfer data, at q = 1 GeV/c the reduced response functions, f_T and f_L, are equal for ^{3}He and ^{4}He, although f_T is still greater than f_L for ^{56}Fe. This indicates that the nature of the reaction changes at higher momentum transfer.

There have also been many more (e,e′p) and some (e,e′d) experiments performed at Bates[4], NIKHEF[5] and SLAC[6,7] and even some multi-arm experiments. High energy SLAC data from the TPC/2γ detector at the PEP storage ring which included the (e,e′pp) and (e,e′pπ^-) reactions in the resonance region have been analyzed[8,9]. NIKHEF has measured C(e,e′pp)[10] using two large solid angle, nonmagnetic hadron detectors. Mainz has studied C(e,e′X) using a magnetic spectrometer plus the BGO ball. With the exception of SLAC all of this work has been done at beam energies below 1 GeV while the CEBAF experiments will cover 0.8 to 4.0 GeV. Many of the coauthors of these proposals have been actively involved in recent and present experiments.

Several other probes, γ, $\vec{\gamma}$, π and hadrons, have been used to provide complementary information on the same physics. There have been (γ,NN) experiments at SAL, INS, LEGS and Mainz. Photon asymmetries measured at LEGS for ^{3}He($\vec{\gamma}$,NN)[11] and ^{16}O($\vec{\gamma}$,pp) are particularly sensitive to multinucleon processes. Experimental studies of resonances in nuclei have mostly used charge exchange reactions, including recently exclusive data, to study the Δ. Pion absorption measurements on ^{4}He[12,13] clearly showed that multinucleon absorption was taking place.

Theorists have also been active in this field. There are new models[14,15] of ^{3}He and ^{4}He that describe the (e,e′) data, including f_L and f_T, very well. A model in which the high momentum component of the spectral function is considered as due to the motion of two correlated nucleons in the mean field[15] gives a good description of the ^{3}He and infinite nuclear matter spectral functions. Recently, the contributions from C(e,e′pp) and C(e,e′pn) to the semiexclusive C(e,e′p) cross sections in the dip and Δ regions have been calculated[16]. Much of the recent experimental and theoretical work was summarized at the Correlations Workshop at CEBAF in May of 1994.

These proposals were presented individually to PAC4 but the strong overlaps in running conditions were noted by the spokesmen. PAC4 gave conditional approval, requesting a single unified run plan. After several meetings of the Nuclear Multihadron physics working group of the CLAS collaboration, a common run plan was agreed upon and presented by Bill Hersman to PAC5, proposal 91-009, which was approved for 800 hours of beam.

The common run plan calls for beam energies of 0.8, 2.0 and 4.0 Gev and targets with A = 3, 4 and 12 primarily, plus a small amount of time for A = 56. Data for A = 2 of interest to this group will be collected in other runs. The 800 hours have been allocated such that all physics issues contained in the original proposals can be addressed with high quality data. The hours are divided as follows: ^{3}He - 300 hours, ^{4}He - 170, ^{12}C - 300 and Fe - 30. Given that the facilities have not existed to make any preemptive measurements, we have not seen any need to modify this run plan although we will if it would be advantageous before running in 1997.

The CLAS collaboration run plan committee has begun formulating a run plan for approximately the first three years of CLAS operation. That committee has proposed that this group of experiments be run in two halves in the early and middle running periods. These experiments are suitable for the early running period because the targets are simple and, at least initially, the trigger will be simple yet the multiparticle capability of CLAS is required. The spokesmen are currently discussing which targets and beam energies to use in the first half. A primary goal is to ensure that each experiment obtains useful data that is not only of interest by itself but also will help to guide the data collection in the second half of the run.

The list of spokesmen for these proposals includes nine full members of the CLAS collaboration who are contributing greatly to the construction of the CLAS detector. Many other full members are listed among the coauthors. Full members are committed to construction, commissioning and operation of the CLAS detector for at least the first three years of beam. The spokesmen are entirely or partly responsible for various beamline equipment (H. Baghaei, W. Bertozzi, R. Sealock), the region 2 drift chambers (Weinstein), region 1 drift chamber electronics (R. Miskimen), time of flight scintillator construction (F. W. Hersman), EGN scintillator readout, scintillator quality control and EGN assembly (K. Egiyan) and various analysis and simulation software (P. Degtyarenko, V. Gavrilov). Several spokesmen have also taken leadership roles in the CLAS collaboration.

The following pages contain submissions from the individual proponents of these experiments that describe the continuing interest in the proposed physics. They also describe new data and interpretations that have been obtained since the original proposals were written.

Given that these proposals will be run simultaneously, it is appropriate to submit a single set of checklists. These are attached.

References:

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2. Z. E. Mezziani et al., Phys. Rev. Lett. 69, 41 (1992).
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E-89-015: Study of Coincidence Reactions in the Dip and Delta Regions

H. Baghaei (spokesperson)

The goal of this experiment is to identify the various reaction mechanisms that contribute to the electron-nucleus scattering process in the dip and $\Delta(1232)$-resonace regions.

The proposal was submitted in 1989. It was motivated by the existing inclusive (e,e′) and exclusive (e,e′p) data that were indicating that non-one-body processes play an important role in the quasifree delta production region, the dip region, and even the quasielasic region (QE). Since then, more experimental data and theoretical calculations have become available. These new results not only confirm the previous findings, but further demonstrate the need for performing exclusive experiments with multihadrons in the final state. Here, due to space limitation, we just summarize some of the results:

1) In QE region, the one-body picture which describes the (e,e′) cross sections reasonably well, fails to explain the separated response functions. Despite the extensive amount of theoretical work that has been devoted to the understanding of (e,e′) data, especially in the last few years, a full explanation of both response functions in a consistent model has not yet been accomplished.[1] The ^{12}C(e,e′p) data, which are now available for momentum transfers up to 1 GeV/c, show that multinucleon knockout processes can account for 25%-40% of the total cross section.[2] Separated (e,e′p) coincidence data show a substantial enhancement of the transverse response function relative to the longitudinal above the two-body emission threshold. This enhancement could be due the presence of an additional non-quasielastic reaction mechanism.[3]

2) In the dip region, the underestimation of the inclusive cross section by the theoretical calculations has not been solved. The first exclusive ^{12}C(e,e′p) data indicated a strong contribution of multinucleon processes that could not be explained by rescattering effects.[4] Similar observations are made in ^{3}He(e,e'p) data in the dip region and also in more recent ^{12}C(e,e′p) experiments at non-parallel kinematics.[5]

3) In the delta region, the theoretical calculations that include medium effects in the delta-excitation, in the framework of the delta-hole model, generally reproduce the broad shape of the (e,e′) peak relatively well, but underestimate the data. These results suggest the presence of more complex multinucleon processes, and perhaps the need for a better treatment of the modification of the Δ in the nuclear

medium. The exclusive $^{12}C(e,e'p)$ data in this region clearly show a strength beyond the region populated by the one-body process and below the pion threshold.[6] Theoretical calculations, that only recently have become available, show that this region is dominated by two-body knockout processes and their contribution may well extend to the pion production region.[7] Three-body absorption, which is not yet included in the existing calculations, is expected to contribute mainly to the region above pion threshold. The more recent $^{12}C(e,e'p)$ data that have been taken at non-parallel kinematics also show similar features.[5,7]

We should mention that in the last few years, several exclusive experiments have been performed to study the role of multinucleon processes in photon[8] and pion absorption[9] reactions. These results also show the presence of multinucleon absorption processes.

There are plans at other electron accelerator facilities, e.g. MIT-Bates, NIKHEF and Mainz, to make measurements similar to what we are planning at CEBAF. However, since the beam energy of these facilities is limited to 1 GeV, their results will be complementary to our data. In fact, our low energy data will overlap the high energy data from other labs.

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[4] R.W. Lourie *et al.*, Phys. Rev. Lett. **56**, 2364 (1986); T. Takaki, Phys. Rev. Lett., **62**, 395 (1989).

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[6] H. Baghaei *et al.*, Phys. Rev. C **39**, 177 (1989).

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[8]J. Ryckebusch *et al.*., Phys. Rev. C **49**, 2704 (1994); Phys. Lett. B **316**, 17 1993); S.M. Doran *et al.*, Nucl. Phys. A**559** 347 (1993); T. Emura *et al.*, Phys. Lett. B **267**, 460 (1991).

[9] T. Alteholz *et al.*, Phys. Rev. Lett. **73**, 1336 (1994); M.J. Vicente Vacas and E. Oset, Nucl. Phys. A**568**, 855 (1994); P. Weber *et al.*, Phys. Rev. C **43**, 1553 (1991); L.C. Smith *et al.*, Phys. Rev. C **40**, 1347 (1989).

Electroexcitation of the Δ(1232) in Nuclei
Update for Proposal 89-17
Spokesman: R. M. Sealock

This experiment is motivated in general by a desire to understand the interplay between the strong interaction and baryon structure. Another general motivation is a desire to investigate whether a resonance has modified structure in the nuclear environment. In the absence of excited nucleon beams and targets, resonance-nucleus potentials must be determined. The Δ, being the most prominent resonance, is the logical starting point. A structure modification will most clearly be seen by measuring the form factor for Δ electroexcitation in nuclei. Pauli blocking and π reabsorption, $N\Delta \rightarrow NN$, both modify the width of the Δ peak but in opposite directions and they must be disentangled to understand nuclear Δ production. Also one can search for the predicted double Δ mechanism[1], $N\Delta \rightarrow \Delta\Delta \rightarrow 4N$, which can only occur in a nucleus.

Specific motivation comes from the existing data on resonance production in nuclei with electron, photon and hadron probes. Inclusive electron scattering data clearly show that the observed invariant mass, W_Δ, at the Δ peak centroid shifts upward as momentum transfer increases[2]. This effect was first reported by Sealock et al.[3] and has since been confirmed by all new data. All available high quality (e,e′) data have been compiled by Gerbi and Sealock[4].

An inclusive electron scattering spectrum shows that the Δ peak is not completely isolated but rather there are competing reaction mechanisms: quasielastic scattering, quasideuteron scattering, nonresonant π production and deep inelastic scattering. These mechanisms, which are the primary subject of other proposals in this group, can cause shifts in the apparent position of the Δ which cannot be correctly accounted for without exclusive data. Until exclusive data is available one can only resort to approximate corrections guided by a general model. Figure 1 shows the results of an attempt to correct for background using the QFS code of Lightbody and O'Connell[5]. The momentum transfer dependent shift in W_Δ, although weakened, remains, and is not contradicted by data from charge exchange reactions[6,7] or the available (e,e′pπ⁻) data[8].

An interesting feature of the inclusive data is that they suggest a momentum transfer dependence of the N-Δ mass splitting. The splitting increases from 250 MeV to 280 MeV as the three momentum transfer is increased from 400 to 900 MeV/c. An N-Δ mass splitting value reduced below the free value, about 290 MeV, is consistent with speculations on a nucleon radius increase in the nuclear environment but a momentum transfer dependence is not[9]. This dependence cannot be considered as established given the uncertainties associated with inclusive data but they do serve as motivation for exclusive measurements.

Inclusive data suggest puzzles but do not provide sufficient data to constrain theories and the exclusive data base is still small. As a result there are no comprehensive calculations that cover the complete range of A and Q^2. However, considerable theoretical effort has gone into explaining the large, negative Δ position shifts seen in charge exchange data[10] in terms of spin longitudinal versus spin transverse interactions.

Experiment 89-17 will simultaneously measure cross sections for all the major reaction channels that contribute in the Δ region. The object is to separate the Δ peak from all competing reaction mechanisms so that its position and width can be studied as a function of target mass and momentum transfer. The targets will be $^{3,4}He$, C and Fe and the beam energies will be 0.8, and 2.0 Gev. Thus a wide range of A and Q^2 will be studied. Data on the π^0 production channel will be especially valuable because the nonresonant background is smaller. The forward calorimeter of the CLAS detector will be able to identify the two decay γ rays.

The authors of this proposal have been very active in design and construction of the CLAS detector. Sealock helped construct and test the prototype for the EGN detector, has served as user coordinator for beamline instrumentation and is on the technical advisory committee of the CLAS collaboration. The data compilation of Gerbi and Sealock will be useful during data collection and has already been useful in constraining the CLAS event generator written by P. Degtyarenko. Sealock will construct the absolute photon beam intensity monitor for Hall B real photon experiments.

References:

1. G. E. Brown et el., Phys. Lett. B118, 39 (1982).
2. R. M. Sealock, "Delta Excitation in Nuclei", ed. H. Toki, M.Ichimura and M. Ishihara, World Scientific, Singapore, 1994, p.55.
3. R. M. Sealock et al., Phys. Rev. Lett. 62, 1350 (1989).
4. J. E. Gerbi and R. M. Sealock, "Data Compilation for Δ Electroexcitation in Nuclei " CLASnote 93-10.
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6. D. Contardo et al., Phys Lett. B168, 331 (1986).
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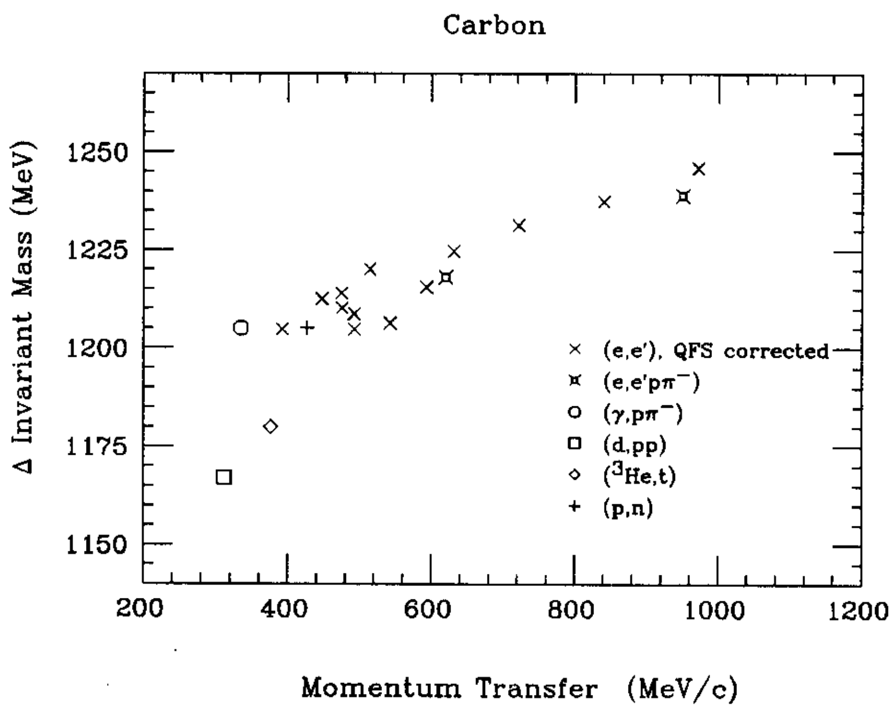

Figure 1 Invariant mass of the carbon Δ peak centroid versus three momentum transfer for a variety of reactions.

E-89-027: Coincidence Reaction Studies with the CLAS

W. Bertozzi, W. Boeglin, L.B. Weinstein (contactperson)

This experiment will study the nuclear structure beyond the mean field model of the nucleus. By detecting almost all of the particles knocked out in electron-nucleus collisions, we hope to disentangle the various reaction mechanisms (single-nucleon, multi-nucleon, Δ, N^*, etc) and the various correlations (single-nucleon, 2-nucleon, etc). In addition to studying the interaction of the virtual photon with the nuclear medium, we can also examine the production and propagation of nucleon resonances in the nuclear medium. Studying the interaction of nucleon resonances with the nuclear medium will help us elucidate the baryon-baryon interaction.

We proposed this experiment 5 years ago to explain many anomalies observed in (e,e′) and (e,e′p) data. These anomalies excited widespread interest in the field, as shown by the fact that there were six similar proposals (E-89-015, E-89-017, E-89-027, E-89-031, E-89-032, E-89-036) presented to the same PAC.

As of 1989, the anomalies observed in inclusive electron scattering, (e,e′), included the enhanced transverse/longitudinal ratio in the quasielastic region, enhanced yields in the dip region and problems of yield and shape in the delta region. The enhanced transverse/longitudinal ratio is an especially good good example of the failure of our simple models because the reduced response functions, f_L and f_T are equal for $A = 3$ but f_T is much greater than f_L for $A > 4$. This A-dependence is clear evidence of a non-single-nucleon response.

The anomalies observed in coincidence electron scattering, (e,e′p), included the different shapes of the missing energy spectra for the longitudinal and transverse response functions, the missing strength in the spectroscopic factors, and the very large strength at large missing energies.

In the last five years, there has been a lot of activity in this field, both experimental and theoretical. More (e,e′) L/T separations have been performed at momentum transfers up to 1 GeV.[1] [2] [3] The results indicate that the nature of the reaction changes at larger momentum transfer.

There have been more (e,e′p) experiments performed, at Bates, NIKHEF, SLAC and Mainz. [4] [5] [6] [7] The MAMI-B accelerator at Mainz has started operations and a large part of the program of the A1-collaboration is exploring (e,e′p) on various nuclei at large recoil momenta. They have an excellent beam and excellent spectrometers but are limited by their beam energy of 880 MeV. [8]

In addition to single arm, (e,e′), and double arm, (e,e′p) and (e,e′d), experiments, there have also been some multi-arm experiments. NIKHEF has built two large solid angle (200 and 500 msr), non-magnetic hadron detectors for (e,e′pp) measurements. The first results, with the prototype detector system, on C(e,e′pp), have recently been published.[9] [10] One of the first experiments at MAMI-B measured C(e,e′X) using one magnetic spectrometer to detect electrons and the BGO-Ball to detect hadrons. The Ball covered almost the full solid angle for angles larger than 45^o with very limited resolution.[11]

There have also been a number of large solid angle photon experiments at KEK using the TAGX spectrometer,[12] at Saskatoon using the SALAD spectrometer,[13] and at Mainz using the Daphne detector.[14]

On the theoretical side, models of ^{3}He and ^{4}He are becoming much better. There is now a complete nonrelativistic model of ^{3}He[15] including both the initial state wavefunction and the continuum interactions. There is also a nonrelativistic model of the ^{3}He and ^{4}He groundstates using the Green's Function Monte Carlo method[16] that describes the (e,e′) data very well, including the change in f_L and f_T from ^{3}He to ^{4}He. Complete models of the ground-state wave-function of heavier nuclei are progressing.[17] There are also models that add correlations to shell-model wave functions. [18] [19] [20] In addition to these nuclear structure calculations, there are also calculations of the various reaction mechanisms. The model of Ryckebusch et al. includes MEC and Δ interactions.[21].

The vitality of the field is also shown by the Correlations Workshop held at CEBAF last May. Physicists from North America, Europe and Japan discussed experimental and theoretical progress in the field with an emphasis on what could be done at CEBAF. Invited speakers included R. Schiavilla, W. Glockle, V. Pandharipande, G. Rosner, W. Bertozzi, E. Offerman, J. Feldman, K. Maruyama, W. Hesselink, and L. Weinstein.

To summarize the progress, experimentally there is a lot more negative evidence for multinucleon effects in nuclei (that is: data unexplained by single-nucleon knockout calculations) but there are still no kinematically-complete good-resolution experiments to help us disentangle these effects. Theoretically, we now have consistent models of ^{3}He and of the groundstate of ^{4}He. There is still room for improvement. A description of the groundstate of ^{16}O is in progress. There are a number of models of correlations and of other reaction mechanisms that can provide a useful guide to the phenomenology, both for experimentalists and for consistent theories.

All of these developments mentioned provide even more motivation for performing the CEBAF experiments than existed when they were proposed. They do not change the conditions of the CEBAF experiments since these will cover an energy range unreached by almost all of the present experiments and will be the first kinematically-complete good-resolution (e,e′X)

References

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Study of Multi-nucleon Knockout with the CLAS
Proposal PR-89-031
Spokespersons: F. W. Hersman, J. Lightbody, and R. A. Miskimen

Exclusive $(e, e'p)$ and (γ, NN) experiments and pion absorption measurements have shown that multi-nucleon emission in the quasielastic and $\Delta(1232)$ resonance regions is a surprisingly large and little understood part of the inclusive cross section [1]. The objective of this proposal is the study of the Q^2, ν and A dependence of the multi-nucleon reaction. Since this proposal was submitted in 1989, $(e, e'pp)$ data have become available from Mainz and NIKHEF. Since these data have relatively sparse statistics and are for energies less than 1 GeV, the motivation for PR-89-031 is still valid. For ^{3}He we plan to measure the out-of-plane response function, R_{LT}, from the azimuthal distribution of protons around $\vec{q}$, and will make a direct separation of the longitudinal and transverse cross sections by Rosenbluth separation. We estimate that the longitudinal and transverse response in the quasielastic region can be separated at the 20% level. The longitudinal cross section is of particular interest because it is sensitive to nucleon-nucleon correlations. Data over a wide range of energy transfer are needed in order to study multi-nucleon knockout from the quasi-elastic peak into the deep inelastic region. To study the connection between resonance absorption and multi-nucleon emission it is also important to take data in N^* production channels, such as $(e, e'p\pi^-)$, $(e, e'p\pi^0)$, and $(e, e'p\eta)$.

To obtain experience with the analysis and interpretation of data from 4π detectors, such as CLAS, the UMass group studied nuclear interaction data from the SLAC TPC/2γ detector. These data have recently been published in part, and we briefly discuss some results from the analysis here [2]. Analysis of the missing momentum distribution for C$(e, e'pp)$ indicates that n-body emission, where $n \geq 3$, is the dominant nucleon emission process in the resonance region, approximately $80 \pm 8\%$ of total pp emission. The probability for pp emission is approximately 50% of $p\pi^-$ production in the region of the Δ peak. The W dependence of the pp data, while showing some correlation with the Δ peak, is broader than the Δ and appears to extend with significant strength into the dip region between the quasi-elastic and Δ peaks. These results are similar to the conclusions of pion absorption measurements and ^{12}C$(e, e'p)$ experiments, where in the latter case it was necessary to invoke a three-body mechanism to explain the excess strength at high missing energy. The analysis of the $(e, e'p\pi^-)$ data show that the fitted Δ masses are in near agreement with 1.232 GeV, independent of target and Q^2. This does not agree with the results of inclusive ^{12}C(e, e'), and it is likely that the inclusive Δ peaks are influenced by competing reaction mechanisms, including multi-nucleon emission.

The University of New Hampshire group is actively preparing for their specific role in the multihadron program, as well as contributing substantially to the development of CLAS. In 1989 UNH proposed the first $(e, e'pp)$ coincidence experiment at NIKHEF-K using large acceptance scintillator arrays. The measurement was completed in 1991, and the data analysis was recently finished. They developed and applied an approach, novel to nuclear physics, to the extraction of triples from a random coincidence background. Theoreticians, motivated by the NIKHEF data, have significantly advanced the sophistication of their calculations. A considerable theoretical effort is being made at UNH to understand correlations and their influence on the nuclear electromagnetic response. In one approach they use a Fermi gas model with a G-matrix calculated in infinite nuclear matter. The advantage of a Fermi gas calculation is that final state interactions between the nucleons can be carried out. The second, more ambitious, approach starts with a hard core potential and uses the e^S method (with a very large basis) to calculate an effective interaction inside a finite nucleus. They will use these developments to identify kinematics particularly sensitive to the underlying dynamics.

Personnel at UMass and UNH are actively involved in the development and construction of CLAS, and have taken on service roles within the collaboration. R. Miskimen recently spent a sabbatical year at CEBAF where much of his time focused on the design of electronics for the CLAS region 1 drift chamber, and he is continuing this work at UMass. He currently chairs the Membership Committee of the CLAS collaboration. The UNH group, led by F. W. Hersman, has completed fabrication of the forward angle time-of-flight system and recently began fabrication of the large angle time-of-flight system. F. W. Hersman chaired the Nuclear Multihadron Reactions Physics Working Group for three years, and served on the CLAS Coordinating Committee during that period.

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Update of CEBAF Proposal 89-032

"Study of Local Properties of Nuclear Matter in Electron-Nucleus and Photon-Nucleus Interactions with Backward Particle Production Using CLAS Detector".

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The problem of understanding highly excited nuclear matter remains very important in modern strong interaction physics. Since submitting CEBAF Proposal 89-032, both theoretical[1] and experimental[2] reviews of the problem stressed the importance of new inclusive and semi-inclusive measurements of multihadron final states with electron probes and nuclear targets. The so-called "Cumulative effect", i.e. particle production off nuclei in a kinematical region which is forbidden for reactions on quasi-free nucleons, the EMC effect, and other experimental evidence indicate that for certain conditions nuclei may not be considered as groups of quasi-free nucleons, and that the properties of nucleons inside nuclei, such as their structure functions, are different from those of free nucleons. Possible theoretical approaches to understand these phenomena include models using the projectile local interactions with multiquark bags, droplets of quark-gluon plasma, closely correlated groups of nucleons (few-nucleon short range correlations) in the nucleus. The cumulative phenomena could be linked to short-distance features of the nuclear wave-function which may be treated in terms of quark and gluon degrees of freedom.

In the proposed experiment we will use measurements of the multihadron final states in electron-nucleus interactions to study the space - time picture of the cumulative particle production and investigate the properties of the local excitations inside nuclei that give origin to the cumulative particles. The advantage of using the CEBAF electron accelerator and CLAS detector is the unique possibility to explore the multihadron reactions in a wide range of transferred energy and momentum measured in the reaction, with good statistical accuracy, and in wide angular and momentum ranges of the secondary hadrons including production of cumulative hadrons. Using CLAS unprecedented data acquisition rates combined with good identification of the scattered electron and multiparticle final states in electron-nucleus reactions we are looking forward to obtaining valuable physics results.

The activities of the ITEP group connected with preparations for the experiment include:

- participation in the development and construction of the CLAS detector;
- development of data analysis technique which will be applied to extract physics results;
- continuation of research in the field, using available experimental data measured in electron-nucleus interactions.

The two most important results with respect to the proposed experiment have been obtained in re-analysis of events of 5 GeV electron interactions with the nuclei of residual gas taken with the ARGUS detector at the e^+e^- storage ring DORIS-II[3], and the data measured with the TPC/2γ detector at SLAC[4], where multiple proton and pion electroproduction from nuclei have been studied at 14.5 GeV initial energy. We have found that in electron-nucleus interactions at low transferred four-momentum squared (Q^2) the spectra of secondary protons and charged pions, and the radius of the particle emission region, measured using the method of like-particle correlations, are similar to those of pion-nucleus interactions in a comparable range of energy transfers. We have observed the independence of the shapes of the spectra on Q^2 in the Q^2 range 0.1 - 2.0 $(GeV/c)^2$, limited by relatively low statistics, and the dependence of the spectra on the energy transfer in the reaction, which may be understood within a phenomenological model of the process. The results gave us an opportunity to better estimate the expected behaviour of the cross-sections in the future CEBAF experiment and to develop the analysis techniques. As compared to these results, the proposed experiment will provide much more detailed information on the energy and momentum transfer in the reaction and much greater statistics.

Complex large acceptance detectors like CLAS have to be provided with sophisticated simulation and event reconstruction software, and realistic input generators of electro-nuclear interaction events in order to make correct calculations of detector and trigger efficiencies and acceptances. As a part of our preparation to the experiment we are developing a computer program -- exclusive Monte-Carlo generator of electron-nucleus interaction events. Early versions of the program[5-7] have been used in acceptance calculations for the analyses[3,4]. A new version is being developed to be used within the framework of CLAS detector software.

Participation of the ITEP group in the development and construction of the CLAS detector began in accordance with the Memorandum of Understanding (MOU) between CEBAF and joint YerPhI-ITEP-KhIT group in the design and construction of the CLAS electromagnetic calorimeter[8,9], and then proceeded in accordance with MOU between CEBAF and ITEP, in the development of the CLAS detector software. We envisage participation in the test and data taking runs of CLAS, and in the off-line analysis of the data.

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STUDY OF SHORT-RANGE PROPERTIES OF NUCLEAR MATTER IN ELECTRON-NUCLEUS INTERACTIONS WITH BACKWARD PARTICLE PRODUCTION

Update of Proposal 89-36

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The main aim of this experiment is to study the structure of short-range correlations (SRC) in nuclei using as a trigger production of backward particles, primarily protons. Since the experiment was accepted considerable progress has been made in the calculation of SRC in nuclear matter as well as in experimental studies of short-range correlations in the intermediate energy and high-energy electroproduction of nuclei in the (e,e') and (e,e'p) reactions. For reviews see Refs.[1]. Impressive evidence for dominance of SRC in the high momentum component was obtained in the SACLAY $^{3,4}He(e,e'p)$ experiments [2]. Also it was understood that the final state interaction (FSI) can be reliably accounted for within the Glauber approximation in a wide range of high energies [3]. This is confirmed recently by the NE18 data on $(e,e'p)$ scattering at large Q^2 [4].

Further studies of (e,e'p) with the proton measured in the knock-out kinematics are planed at CEBAF. Use of a backward particle as a trigger will provide **complementary** information about SRC since it would allow to study *how SRC decays after one of the nucleons of the correlation is removed from the nucleus.* Among other things this would allow to measure the relative contributions of (pn) and (pp) correlations. Also the study of events with backward Δ isobar will allow to search for exotic components in the SRC.

Theoretical status of proposal

Recent theoretical activities in SRC physics mainly concerned the following issues:

- *Center of mass (CM) motion of SRC*: As a first step to modeling of the backward nucleon production we constructed in Ref.[5] a model of the high-momentum component of the spectral function as due to the motion of two nucleon correlation in the mean field. This model provides a good description of ^3He and the infinite matter spectral functions and provides a smooth interpolation between these two limiting cases where calculations based on many-body Hamiltonians are available. It was recently demonstrated in Ref. [6] that taking account of the Fermi motion improves the agreement of SRC predictions with the data [7] on production of backward protons in νA scattering.

We have developed a Monte-Carlo code based on this model for production of backward nucleons in the kinematics of our experiment.

- *Final state interaction(FSI) structure of SRC*:

Considerable interest in the effects of FSI originated from the prediction of large FSI effects in the interactions with SRC. It was argued in Ref.[8] that if FSI in $A(e,e')$ reaction at $x > 1$ is dominated by FSI within SRC, the ratio of inclusive $(eA)/(ed)$ cross sections at $x > 1$ will exhibit the specific scaling behavior. The experimental data seems to confirm this prediction. Further, it was demonstrated in Ref.[9] that explicit account of the the FSI effect in the scattering off SRC [9] improves the description of the absolute $A(e,e')$ cross sections at $x > 1$.

Recently we started a program of building a microscopic description of the final state interaction of the knocked out nucleon with the residual nuclear system based on the Glauber approximation including effects of color transparency. Currently we developed a detailed theory for high Q^2 $d(e,e'pn)$ reaction [10] and for A(e,e'p) reactions in knock out kinematics [3]. These methods will allow us to calculate cross sections of various exclusive reactions with $^3He, ^4He$ like A(e,e'pn) based on the microscopic NN dynamics.

Experimental status of proposal

The analysis of experimental data on backward proton electroproduction in the semiinclusive $(e,e'p)$ reaction [11, 12] shows reasonable agreement with SRC predictions. Obtained signature on shifts of scattered electron spectra [13] and the form of spectra of backward protons [14] give important information on the structure of SRC. However, the small Q^2 range and restricted acceptance of the experiment did not allow to investigate the details of the mechanism of backward particle production. An interesting experimental result is that comparison of the results of electroproduction with the data from νA scattering with backward protons[7], and inclusive (e,e') scattering at $x > 1$ predict the similar value for two-nucleon SRC probability per nucleon in ^{12}C - a factor ~ 5 larger than for the deuteron. This indicates that it would be fruitful to compare the results of this experiment with the forthcoming data from pA scattering with backward nucleon production [15]. Another important point is that the large acceptance of CLAS will allow to detect the backward particles in coincidence with forward nucleons. This is a most important advantage for detailed investigation of the SRC structure since it allows to suppress the effects of CM motion. The specific angular dependence of backward protons can be indicative also of the predicted large FSI effects.

The simultaneous investigation of backward particle production off light and medium nuclei and comparison with the data at higher energies will allow to search for different manifestations of the off-shell effects[16].

Group Contributions to the CLAS Detector

The group of authors of PR-89-36 is mainly involved in the design, calculation of characteristics, construction and tests of six modules of the forward electromagnetic shower calorimeter of the CLAS detector (according to MEMO).

In particular this group did the following:

- Design of the light readout system of the calorimeter, implementing Fiber Readout of the Wavelength Shifters, which makes a significant improvement in light transmission. Complete design of technology for and production of the Fiber Light guides. Almost 40% of the light guides are now done (more than for two modules).
- Measurements of the light transmission quality of all scintillators with length more than $3m$. Tests of scintillators for four modules are completed.

• Participation in the assembly of the calorimeter modules (assembly of mechanical parts and scintillators and lead stacking). Two out of six modules are assembled.

• GEANT simulations of detector for real scintillator characteristics.

Yerevan Physics Institute is producing all fiber connectors and 1296 lucite transition light guides for connecting fibers to PMT.

All these activities will be continued, including participation in the cosmic ray test of the complete modules.

The group is also involved in the development of software for analysis of future experimental data from CLAS.

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