# Jefferson Lab
## Proposal Cover Sheet (Generic)

**Experimental Hall:** _A_

**Days Requested for Approval:** _____

**Submission Date:** _5/94_

**Other:** _PAC 8_

□ **New Proposal Title:**

☒ **Update Experiment Number:** _89-044_

□ **Letter-of-Intent Title:**

(Choose one)

## Proposal Physics Goals

Indicate any experiments that have physics goals similar to those in your proposal.

**Approved, Conditionally Approved, and/or Deferred Experiment(s) or proposals:**

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# Update on Experiment 89-044

## Selected Studies of the $^3$He and $^4$He Nuclei through Electrodisintegration at High Momentum Transfer

### The Hall A Collaboration

Spokespersons: M.B. Epstein (Cal. State Univ. L.A.), R.W. Lourie (Univ. Virginia), J. Mougey (Saclay), and A. Saha (CEBAF)

The objectives of this experiment are to measure the $^{3,4}$He(e, e'p) reactions at large momentum transfer to explore short range effects such as nucleon-nucleon correlations, and to examine nuclear structure in extreme conditions by concentrating on the high momentum part of the wavefunctions. Since this experiment was approved new data on these reactions has been published by groups working at Saclay and Bates. There also have been improvements in theoretical calculations for these reactions, particulary for the case of $^4$He(e, e'p). Some of the Saclay data are shown in the figure, and the Bates data are shown in the table. The data are shown in terms of the separated longitudinal (L) and transverse (T) response functions and the Bates data also have a measurement of the LT interference response function. The Bates data shown are for a missing momentum, $p_m$, of 260 MeV/c and the Saclay data are for $p_m$ of 90 MeV/c. For the Saclay data, we note that the calculations tend to agree better with the $^3$He(e, e'p) and $^2$H(e, e'p) data than with the $^4$He(e, e'p) results, and that R. Schiavilla's calculations may agree better with the $^4$He data. For the $^3$He reaction there is some indication that theory and data converge at the higher momentum transfers while the Saclay $^4$He data continue to differ from Schiavilla's calculations at the highest momentum transfer, particularly for the longitudinal response functions measured. The Bates data suggest that higher $p_m$ may be particularly sensitive to different types of theoretical calculations, with Schiavilla's calculations fitting these particular data better than Laget's calculations do. These new data only reinforce the original objectives of this CEBAF experiment, which will determine response functions in perpendicular and parallel kinematics for $Q^2$ between 0.33 to 4.1 (GeV/c)$^2$ and $p_m$ from 0 to 500 MeV/c. We note that the CEBAF measurements will begin at at values of $\vec{q}$ and $Q^2$ where the existing data stop.

This experiment requires the basic Hall A configuration of two magnetic spectrometers and a cryogenic target. The Cal. State L.A. group has made substantial progress in the construction and testing of the cryogenic target, and it is expected to be available during the first year of the Hall A experimental program. Most if not all of these proposed measurements can be done using the measurement precision for the magnetic spectrometers that the Hall A collaboration plans to achieve during the first year of operation of Hall A. In addition a large portion of the proposed kinematics do not require the highest luminosity design requirements of the cryotarget system and could in fact run at less than one half of the ultimate design luminosity. The original run plans for this experiment are still valid and need only to be slightly changed to accomodate the specific beam energies that are dictated by the requirements of simultaneous beam operation. In general this experiment incorporates many of the the experimental requirements of most of the approved Hall A coincidence program and we believe that it would provide a good way to begin this series of experiments.

The only significant change from this proposal as approved by the PAC is that we would like to run the $^4$He(e, e'p) part of these measurements first rather than start with the $^3$He(e, e'p) measurements that the PAC recommended. This change is justified by both theoretical and experimental considerations. On the theoretical side we note that calculations for the $^4$He(e, e'p) reaction have improved considerably since the PAC reviewed this experimental proposal. Schiavilla's calculations incorporate realistic wavefunctions for $^4$He and more sophisticated treatments of the reaction mechanisms. He includes final state interactions, via an optical model, short range correlations between

the ejected proton and the recoiling nucleus, two body exchange currents, and orthogonality corrections. There no longer seems to be any strong reason to trust the $^3$He calculations more than those for $^4$He. In addition the high density $^4$He system is in some ways more interesting than the $^3$He nucleus since this higher density should provide a better environment for the study of short range effects and more realistically simulate more complex nuclear systems. On the experimental side the $^4$He(e, e'p) reaction is easier to measure since it puts less stringent requirements on the missing energy resolution that is needed to separate the three body final state from the four body continuum. In addition the use of $^4$He rather than $^3$He for the target material removes the requirement that a relatively complex gas recovery system be available for the cryotarget and it also reduces the cost of the target material.

We believe that at least part of this experiment should run in the first year or two of the operation of Hall A. We would start by running the high count rate $p_m = 0$ zero points then go to a few of the larger of the proposed $Q^2$ and $p_m$ points to sample some of the more interesting physics. Most of the approved Hall A coincidence experiments require the use of the cryotarget and the initial phases of this experiment, as proposed here, would provide one of the best ways to initiate the use of the Hall A two spectrometer system in conjunction with the extended length cryotarget.

In summary we believe that the physics addressed by this experiment is more interesting than ever due in part to improvements in theoretical calculations. We believe that the $^4$He reaction should be measured before the $^3$He reaction and that we could do this during the first year or two of Hall A operations.

## Response Functions (Bates)

|  | Data | Theory Laget FULL | Theory Schiavilla +FSI | Theory Schiavilla FULL |
|---|---|---|---|---|
| $R_L$ | $2.7 \pm 0.5 \pm 0.3 \mathrm{x} 10^{-7}$ | $0.84 \mathrm{x} 10^{-7}$ | $1.5 \mathrm{x} 10^{-7}$ | $1.5 \mathrm{x} 10^{-7}$ |
| $R_T$ | $6.2 \pm 1.9 \pm 1.1 \mathrm{x} 10^{-8}$ | $2.3 \mathrm{x} 10^{-8}$ | $7.4 \mathrm{x} 10^{-8}$ | $9.5 \mathrm{x} 10^{-8}$ |
| $R_{LT}$ | $1.96 \pm 0.14 \pm 0.16 \mathrm{x} 10^{-7}$ | $9.4 \mathrm{x} 10^{-8}$ | $0.85 \mathrm{x} 10^{-7}$ | $1.8 \mathrm{x} 10^{-7}$ |
| $R'_L$ | $2.4 \pm 0.2 \pm 0.2 \mathrm{x} 10^{-7}$ | $0.84 \mathrm{x} 10^{-7}$ | $1.5 \mathrm{x} 10^{-7}$ | $1.5 \mathrm{x} 10^{-7}$ |
| $R'_T$ | $6.9 \pm 1.5 \pm 1.3 \mathrm{x} 10^{-8}$ | $2.3 \mathrm{x} 10^{-8}$ | $7.4 \mathrm{x} 10^{-8}$ | $9.5 \mathrm{x} 10^{-8}$ |

**S(p=100 MeV/c) ((GeV/c)⁻³.sr⁻¹)**

legend: ● L, ▲ T, H. A. (L), H. A. (T)

$^2$H(e,e'p)n Saclay



**S(p=90 MeV/c) ((GeV/c)⁻³sr⁻¹)**

$^3$He(e,e'p)$^2$H Saclay

legend: ● L, ▲ T, J.M.L. (L), J.M.L. (T)



**S(p=90 MeV/c) ((GeV/c)⁻³.sr⁻¹)**

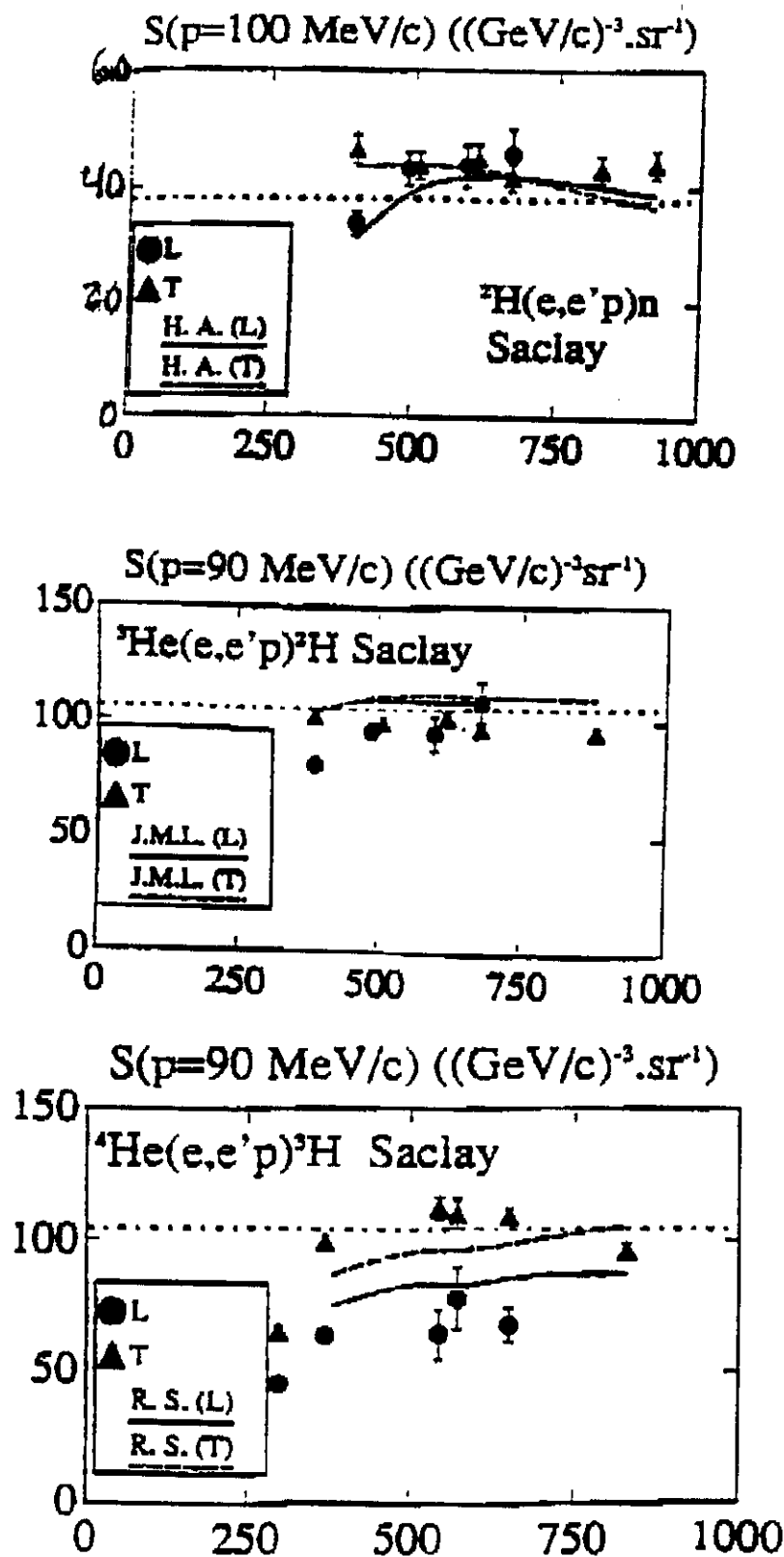$^4$He(e,e'p)$^3$H Saclay

legend: ● L, ▲ T, R. S. (L), R. S. (T)

**Figure Caption**

$S_L^{exp}$(L) and $S_T^{exp}$(T) as functions of $\bar{q}$ in MeV/c for $^2$H, $^3$He, and $^4$He (Saclay). The dot dash line is the PWIA prediction, H.A. is Arenhovels's calculations, J.M.L. is Laget's calculations, and R.S. is Schiavilla's calculations. $S_L^{exp} = R_L/\sigma^L(e-p)$, $S_T^{exp} = R_T/\sigma^T(e-p)$.