CEBAF PROPOSAL COVER SHEET

This Proposal must be mailed to:

CEBAF
Scientific Director's Office
12000 Jefferson Avenue
Newport News, VA 23606

and received on or before OCTOBER 30, 1989

A. TITLE: Electroexcitation of the $\Delta(1232)$ in Nuclei

B. CONTACT PERSON: Richard Sealock

ADDRESS, PHONE AND BITNET:
Dept. of Physics, McCormick Rd.
Univ. of Virginia, Charlottesville, Virginia 22901

C. THIS PROPOSAL IS BASED ON A PREVIOUSLY SUBMITTED LETTER OF INTENT

☑ YES
☐ NO

IF YES, TITLE OF PREVIOUSLY SUBMITTED LETTER OF INTENT

Electroexcitation of The $\Delta(1232)$ in the Nuclear Environment

D. ATTACH A SEPARATE PAGE LISTING ALL COLLABORATION MEMBERS AND THEIR INSTITUTIONS

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(CEBAF USE ONLY)

Letter Received 10-31-89

g Number Assigned PR-89-017

By KES

contact: Sealock

October 27, 1989

Dear members of the PAC,

At present the role of multinucleon absorption processes in deep inelastic electron scattering and the properties of the Δ resonance in nuclei are poorly understood and potentially very interesting and exciting subjects. The interest in this field is shown by the three CLAS experiments proposed to study various aspects of the (e,e$'$) reaction mechanism.

- 'Coincidence Reaction Studies with the LAS' (spokesman: L. Weinstein, MIT) proposes to examine the various (e,e$'$) reaction mechanisms in the quasielastic, dip, quasifree delta, and quasifree resonance regions at four beam energies from 600 to 2000 MeV with five targets from Deuterium to Lead.

- 'Study of Coincidence Reactions in the Dip and Delta-Resonance Regions' (spokesman: H. Baghaei, UMass) proposes to study the different processes that contribute to electron scattering in the dip and quasifree delta resonance regions and also to investigate the possible medium modifications of the Δ in nuclei at various energies with four targets from Helium to Lead.

- 'Electroexcitation of the $\Delta(1232)$ in the Nuclear Environment' (spokesman: R. Sealock, UVa) proposes to examine the position, width, and form factor of the delta resonance as a function of A, and Q^2.

These experiments overlap significantly. They each intend to examine all reaction channels for a given (overlapping) set of electron kinematics. They will use similar targets, beam energies, luminosities, CLAS polarity, and triggering schemes. We expect that most of the data will be taken simultaneously, initially triggering data acquisition by detection of an electron so as to have an unbiased look at the hadronic final state. Later, we will use more selective triggers, that include hadronic requirements, to emphasize one or more aspects of these experiments. We plan to collaborate during the next few years on more thorough modeling of the CLAS acceptances and efficiencies as they affect these experiments so that we can optimize the various experimental plans.

Yours Sincerely,

Richard M. Sealock

Hossain Baghaei
Richard Sealock
Larry Weinstein

Proposal

Electroexcitation of the $\Delta(1232)$ in Nuclei

V. Burkert[1], L. Dennis[2], S. Dytman[3], K. Giovanetti[4], K. Kemper[2], B. Mecking[1],
M. Mestayer[1], R. Minehart[5], B. Niczyporuk[1], O. Rondon-Aramayo[5], R.M. Sealock[5],
E. Smith[1], P. Stoler[6], S.T. Thornton[5], and H.-J. Weber[5].

Contact Person: R.M. Sealock

Abstract

We propose to measure the A and Q^2 dependences of $\Delta(1232)$ electroexcitation in nuclei in order to determine the Δ-nucleus potential, study Δ decay modes specific to the nuclear environment and determine the Q^2 dependence of the form factor for Δ production in nuclei. The CLAS will be used so that we can identify and simultaneously measure all contributing reaction mechanisms in the Δ region. We will use H, ^{3,4}He, C, Fe and Pb targets and beam energies ranging from 1 to 1.5 GeV. A total of two weeks of beam are requested.

1. CEBAF, Newport News, Virginia
2. Florida State University, Tallahassee, Florida
3. University of Pittsburgh, Pittsburgh, Pennsylvania
4. James Madison University, Harrisonburg, Virginia
5. University of Virginia, Charlottesville, Virginia
6. Rensselaer Polytechnic Institute, Troy, New York

Physics Motivation

Electroproduction of nucleon resonances in nuclei is a good tool for studying the interplay between the strong interaction and baryon structure. There are two fundamental questions that such studies can address. How does baryon structure influence the strength of the interaction between baryons and does the nuclear environment modify the structure of nucleon resonances? The electron is a particularly good probe for these studies because it interacts throughout the nuclear volume and complements hadronic probes which interact mostly on the nuclear surface.

Since the Δ is the most prominent and isolated of the nucleon resonances it is the logical first choice for such studies. The above questions can be answered in principle by measuring the depth and momentum dependence of the Δ-nucleus potential and the Q^2 dependence of the transition form factor. However, measurements of inclusive electron scattering from nuclei demonstrate that these quantities cannot be unambiguously extracted from the Δ peak invariant mass or the Q^2 dependence of the Δ region cross sections. This is because competing reaction mechanisms, whose individual cross sections and energy and Q^2 dependences are poorly known, are responsible for a major part of the cross section. These mechanisms are the high energy loss tail from the quasielastic peak, two body processes in the dip region, nonresonant π production, low energy tails from production of higher lying resonances and deep inelastic scattering. Disentangling these processes will require exclusive measurements involving two, three or more particle final states.

Another property of interest is the lifetime of the Δ in nuclei because it is affected by processes that are unique to production in nuclei. These are Pauli blocking of the Δ decay, the additional decay channel, NΔ-->NN and the hypothesized double delta[1] or NΔ-->ΔΔ-->4N mechanism. Pauli blocking increases the Δ lifetime thereby reducing its width while the NΔ-->NN channel has the opposite effect (and is dominant). The Δ peak width is a measure of the combined effects of these processes. Since they have different momentum transfer dependences one would like to measure the Δ peak width over the widest possible kinematic range. Unfortunately it is impossible to extract a meaningful peak width from existing inclusive data. For high Q^2 the quasielastic and Δ peaks merge and at low Q^2 dip region processes obscure the low energy loss side of the Δ peak.

Inclusive electron scattering in the Δ region for targets with a wide A range has been studied at low[2-5], high[6,7] and most recently at intermediate[8] Q^2. These data all show that the cross section per nucleon is independent of A at the Δ peak implying quasifree Δ production from individual nucleons. There have been some (e,e'p) measurements from C in the dip and Δ regions[9,10] at low Q^2. The (e,e'p) data indicate that scattering from quasideuterons is a major component of the dip region cross section and that this component extends, although decreasing, under the Δ peak. O'Connell et al.[2,3] found that the cross sections per nucleon integrated over the Δ peak were 34% greater for light nuclei than for the proton. At higher Q^2 Sealock et al.[8] found much less enhancement - 8% at $Q^2 = 0.2$ $(\mathrm{GeV/c})^2$, decreasing to only 1% at $Q^2 = 0.4$ $(\mathrm{GeV/c})^2$. Such results are to be expected because the probability of scattering from a quasideuteron, being a larger object than a nucleon, will decrease more rapidly as Q^2 increases than that for exciting a nucleon to a Δ. Clearly this background component will affect the shape of the Δ peak in a way that varies with kinematic parameters. Other background components may be expected to do the same.

The attractive Δ-nucleus potential is expected to cause a shift of the Δ peak to greater energy loss as is observed for the quasielastic peak. Results from many inclusive electron scattering experiments[2-8] are summarised in Fig. 1 which shows the apparent centroid of the Δ peak for Q^2 at the Δ peak ranging from 0.05 to 0.9 $(\mathrm{GeV/c})^2$. There is a striking Q^2 dependence of the Δ position which is independent of target mass for $A > 2$ and $Q^2 > 0.25$ $(\mathrm{GeV/c})^2$. In contrast to the quasielastic peak, at low Q^2 the Δ peak invariant mass is lower than that for production from the free nucleon which appears at

1220 MeV independent of Q^2. In the case of iron the Δ peak is seen as low as 1165 MeV! ^{2}H, ^{3}He and ^{3}H do not show negative Δ peak shifts at low Q^2 although all heavier nuclei do. A peak shift toward lower invariant mass, independent of A, has also been seen in the A(^{3}He,t) reaction[11].

In principle the strength and momentum dependence of the Δ-nucleus potential can be extracted from peak positions. Theoretical frameworks within which to calculate these quantities are the Δ-hole model or the approach of O'Connell and Sealock[12]. In ref. 12 the peak shifts were described phenomenologically in terms of a momentum dependent potential of the form: $V(p) = -V_o/(1 + p^2/p_o{}^2) + V_1$. All available carbon data were fitted with $V_o = 153$ MeV, $p_o = 628$ MeV/c and $V_1 = 38$ MeV. The depth of this potential is similar to that found by Danos and Williams[13] in an effective shell model for the Δ-nucleus system. On the other hand, Horikawa, Thies and Lenz[14] state that "...the Δ-nucleus interaction has been found to be less attractive than the nucleon-nucleus interaction...".

It is possible, however, that the peak position is heavily influenced by the Q^2 and invariant mass dependences of background contributions. At low Q^2 the two body component has a slope[9,10] that could shift the centroid of the apparent Δ peak to lower invariant mass. This effect decreases as Q^2 increases. At higher Q^2 the sloping nonresonant background[15] could shift the centroid to higher invariant mass. This effect increases as Q^2 increases. An approximate method of correcting for background effects is described in ref. 12. In that work the observed Δ peak shifts were corrected by from +10 to -15 MeV. Without a complete and precise knowledge of background cross sections any interpretation of the Δ position will be limited by uncertainties in models of the background. The best measurement of the Δ position will be made in the $N\pi^o$ channel because the nonresonant contribution is considerably smaller than for the charged pion generated. The commitments of the non-CEBAF authors of this proposal to the construction of the CLAS include the shower counter, the Cherenkov detectors and software. It is expected that this experiment will be done by the whole CLAS collaboration.

References

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channels. The CLAS detector provides the capability of separating the final states to give the individual cross sections.

One explanation of the EMC effect is that nucleons in a nucleus have a greater radius than free nucleons. A nucleon resonance produced from such a nucleon would also be expected to have a modified radius. A signature of modification of the Δ size in the nuclear environment would be a change in the transition form factor from that observed for the free nucleon. Fig. 2 shows the transition form factor calculated from the carbon data of ref's 3 and 8. If these data are fitted with a dipole form factor the results indicate that the Δ radius in the nuclear medium is within 10% of the free Δ radius. However, there are many effects that must be taken into account before meaning can be ascribed to the form factor. Fermi broadening, Pauli blocking and pion absorption change the Δ peak cross section while Q^2 dependent peak shifts raise and lower the cross section at a given invariant mass. Form factors calculated from cross sections for the $N\pi$ final state must be corrected for losses due to final state interactions and the pion absorption channel and their Q^2 dependences. It will require extensive analysis to determine what part of the e'NN final state comes from quasideuteron scattering and what part from Δ production leading to pion absorption. These questions can't be seriously addressed without having the data in hand.

Experimental Method

A successful study of the physics described above requires the identification of reaction mechanisms through their various multiparticle final states. Therefore the CLAS detector is the only suitable instrument at CEBAF for this experiment.

The range of Q^2 at the Δ peak which we wish to study is from 0.05 to about 0.5 $(GeV/c)^2$. At the low end of this range the Δ peak is dominated by the quasielastic scattering peak and at the upper end higher lying resonances begin to dominate. The entire A range is of interest both because of the intriguing A dependences seen in the position versus Q^2 plot and because of the wide range in nuclear density. The targets that we propose to use are ^{3}He, ^{4}He, C, Fe and Pb and we will need a hydrogen target for calibration. Thin foils of natural isotopic abundance for the solid targets and simple pressurized, room temperature containers of the gaseous targets will suffice. The parameters for these targets that result in a luminosity of 10^{33} cm^{-2}s^{-1} with a beam current of 10 nA are given in Table I.

Because we want to simultaneously measure several reactions the data collection must be triggered by a very general criterion. The common feature of all the reaction mechanisms is a scattered electron so we will record all events where an electron is detected in the shower counter. Forward peaking of the reaction products may require that we prescale or ignore events from forward parts of the shower counter in order to optimize and balance the data rates at different values of Q^2.

We have simulated events in the CLAS detector using the programs CELEG and FASTMC. As an example we show results for a limited kinematic range chosen to be comparable to existing data taken at SLAC with a beam energy of 1.1 GeV and a spectrometer angle of 37.5°, resulting in a value of Q^2 at the Δ peak of 0.3 (GeV/c)^2. Events were generated by CELEG in the Q^2 range of 0.275 to 0.325 (GeV/c)^2 from a Fermi smeared nucleon for the Δ resonance only. FASTMC was used to follow all generated particles through the detector. Using these events we investigated the polarity and magnitude of the CLAS magnetic field. In Table II the acceptances, defined below, are given for both polarities and each particle type. It is likely that the experiment will use both polarities. For this limited set of events we chose a field that bends negative particles towards the beam axis and has a strength of 25% of the nominal value. Under these conditions the number of each particle type detected in each component of the CLAS is given in Table III. Single particle acceptances, also in Table III, are calculated from these results under the following assumptions. Electrons and neutral pions were detected if they or their decay products hit the shower counter. Protons and charged pions were detected if they hit the scintillators. Neutrons were detected with an energy dependent probability if they hit the shower counter. Acceptances were calculated as the ratio of detected to generated particles. Momentum and angle spectra for generated particles and accepted particles are shown in figures 3 - 5.

We believe that the above simulations demonstrate that the CLAS detector can provide excellent data to address the physics that we are interested in. Furthermore, the 1% momentum resolution of the CLAS is completely adequate. Scattered electrons will typically have energies near 1 GeV so 1% resolution gives 10 Mev spread which is small compared to the width of any of the resonances or other structure in the cross section and equal to the bin size we intend to use.

We plan to take data from 6 targets at 6 Q^2 values from 0.05 to 0.5 $(GeV/c)^2$. Beam energies suitable for this experiment are in the range of 1 - 1.5 GeV. For each of the 36 data sets we will use 10 MeV bins for an invariant mass range of about 500 MeV. By collecting 10^4 events per bin we will have good statistical accuracy for each of the cross section components, even for the important $N\pi^0$ channel for which the detector acceptance is low. The required data set thus totals $2x10^7$ events. At the nominal data acquisition rate of the CLAS of 100 events per second the total data set could in principle be acquired in less than three days. Allowing for inefficiencies, we request a week of beam time for data taking. Approximately a week of detector checkout should be sufficient before taking data. A detailed run strategy will have to await further simulations of the CLAS that include quasielastic scattering and two body mechanisms as well as Δ production. These studies will tell us what magnetic fields to use and what portions of the shower counter to use in the trigger.

This experiment is a candidate tuneup experiment because the simplest possible targets can be used, the required luminosity is low and a good variety of particle types is

Figure Captions

Fig. 1. Invariant mass versus Q^2 at the Δ centroid. For the nucleon the Δ centroid appears at about 1220 MeV independent of Q^2.

Fig. 2. Transition form factor, F_T^2, versus four momentum transfer, Q^2, for carbon. X - from ref. 3. O - from ref. 8.

Fig. 3. Energy and angle spectra for electrons and protons from 5000 events for the Δ resonance for $Q^2 = 0.275$ to 0.325 $(\mathrm{GeV}/c)^2$. The histogram shows all events generated and the plotted symbol shows events accepted by the CLAS. See text for an explanation of acceptance.

Fig. 4. Energy and angle spectra for neutrons and neutral pions under the same conditions as in Fig. 3.

Fig. 5. Energy and angle spectra for charged pions under the same conditions as in Fig. 3.

Table I

Target Thicknesses for L = 10^{33} $cm^{-2}s^{-1}$ with 10 nA Beam Current

Element	Thickness (cm)	Thickness %R.L.
H^*	30	.04
$^3He^*$	20	.04
$^4He^*$	15	.03
C	.013	.07
Fe	.0034	.2
Pb	.0023	.4

*10 Atmosphere pressure at STP

Table II

Acceptance versus Field Polarity

E_o = 1.1 GeV, B = 0.25, Q^2 = 0.275 - 0.325

Particle	Acceptance + polarity*	Acceptance - polarity	Preferred Polarity
e^-	.67	.29	+
π^+	.08	.22	-
π^-	.19	.09	+
π^o	.20	.20	
p	.30	.43	-
n	.13	.13	

*For + polarity negatively charged particles bend towards the beam axis

Table III

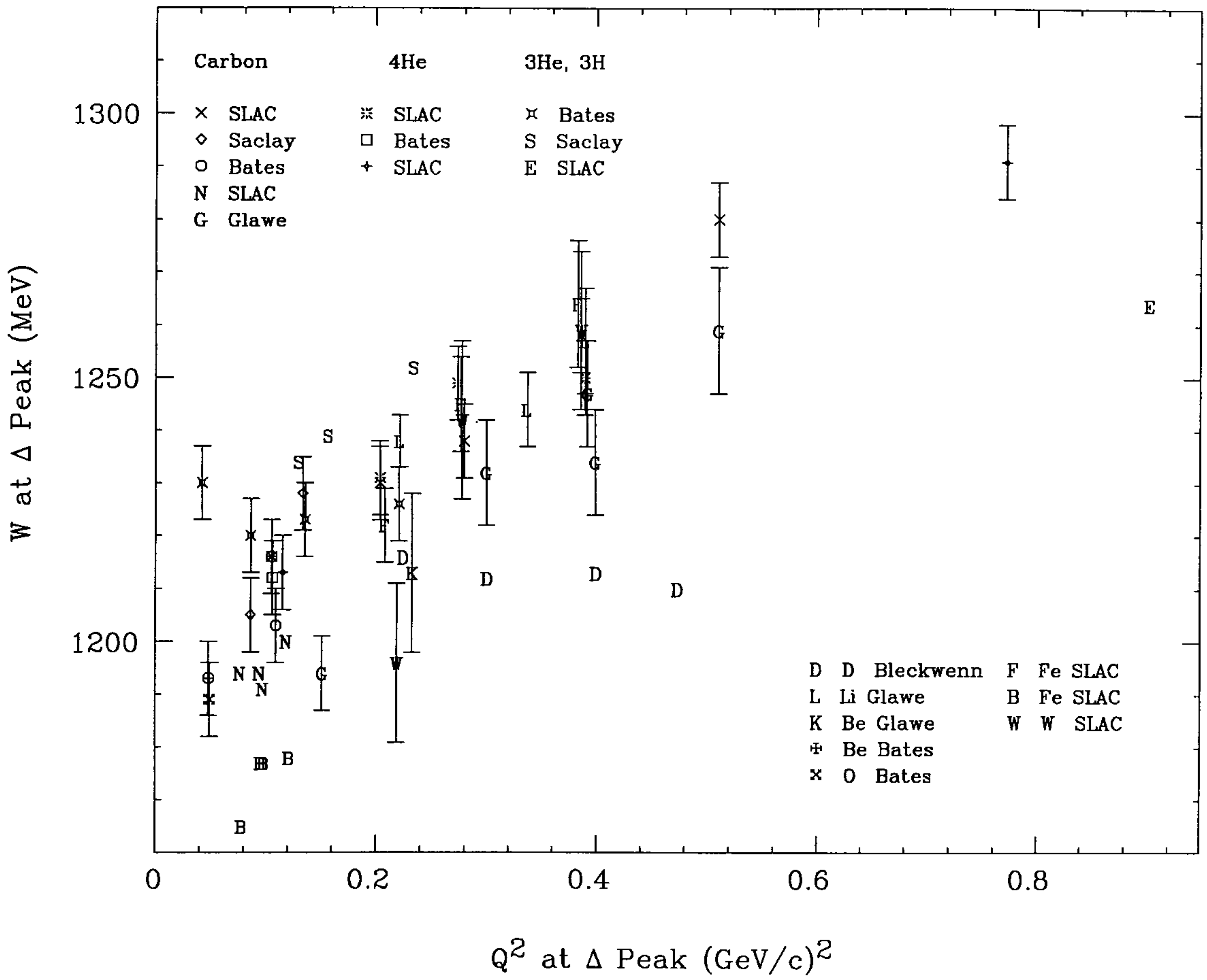
Number of Detected Particles for 5000 Delta Events Generated

E0 = 1.1 GeV, Q**2 = 0.275 - 0.325, B = .25, polarity = +

Particle	Total	CH1	CH2	CH3	Cerenkov	Scint	Shower	Acceptance
PI -	821.	541.	468.	395.	0.	351.	0.	.43
E -	5000.	3549.	3549.	3549.	3462.	3549.	3339.	.67
PI +	793.	540.	472.	421.	0.	394.	0.	.50
PI0	3386.	0.	0.	0.	0.	0.	690.	.20
p +	2514.	1639.	1622.	1622.	0.	1622.	291.	.65
n	2486.	0.	0.	0.	0.	81.	246.	.13

CHi refers to the region i wire chambers

See text for a definition of acceptance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× SLAC
◇ Saclay
○ Bates
N SLAC
G Glawe
4He
※ SLAC
□ Bates
✦ SLAC
3He, 3H
¤ Bates
S Saclay
E SLAC
D D Bleckwenn
L Li Glawe
K Be Glawe
⊕ Be Bates
× O Bates
F Fe SLAC
B Fe SLAC
W W SLAC
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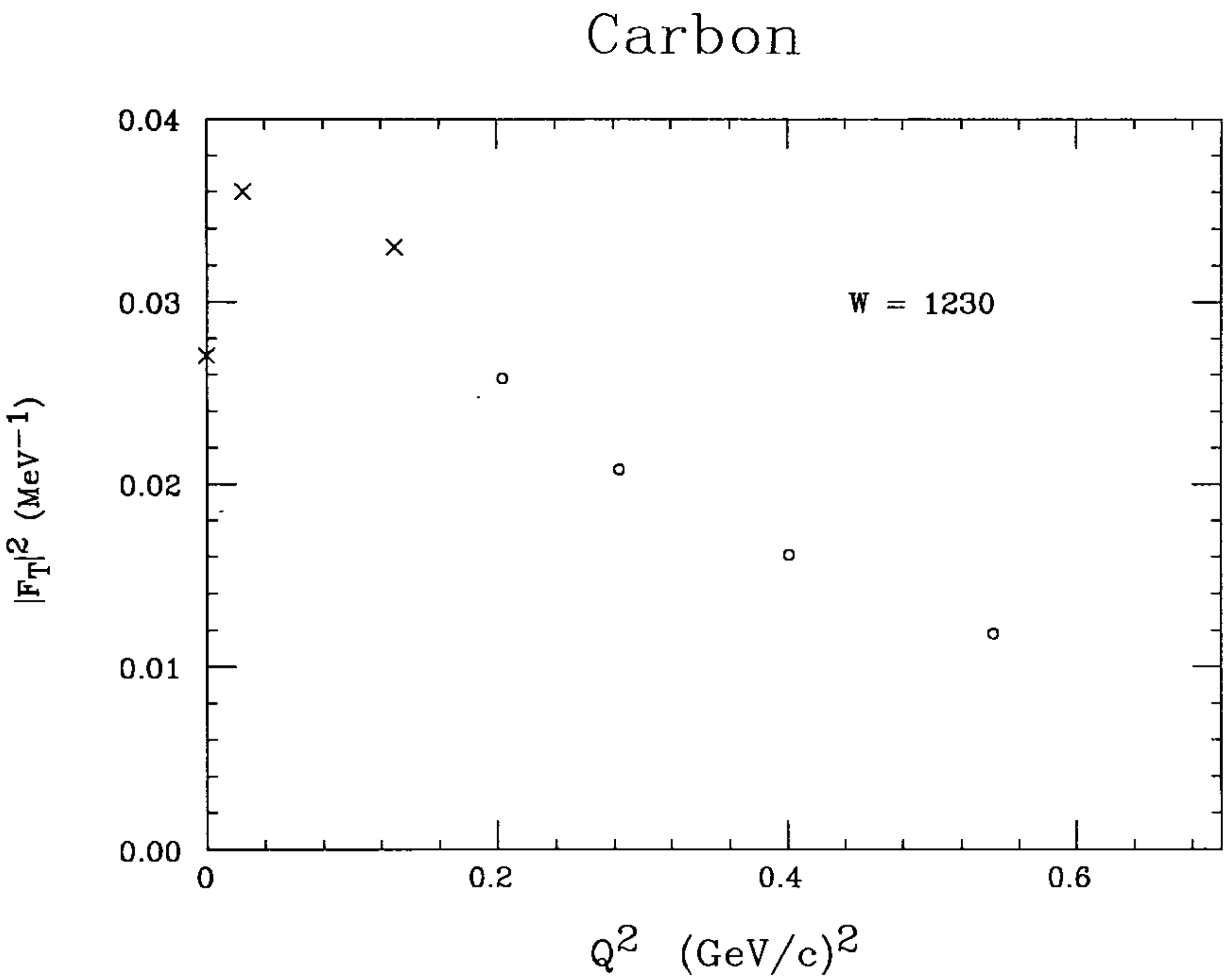
1300
0
0.2
0.4
0.6
0.8
W at Δ Peak (MeV)
Q^2 at Δ Peak (GeV/c)^2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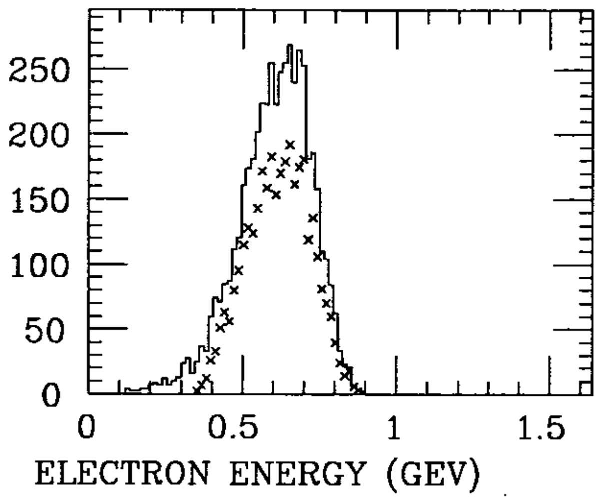
0.6
Q^2 (GeV/c)^2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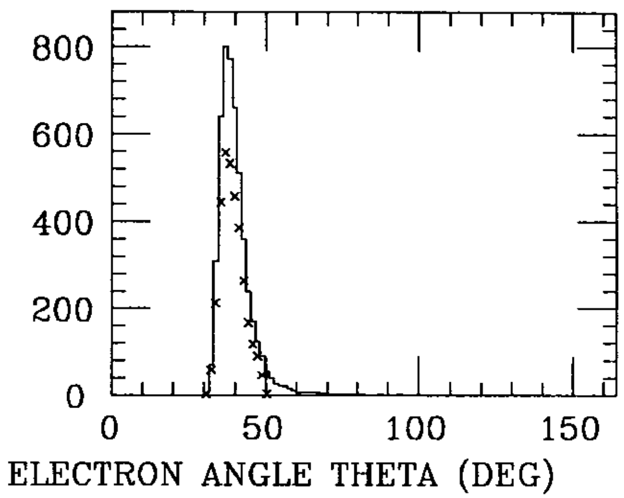
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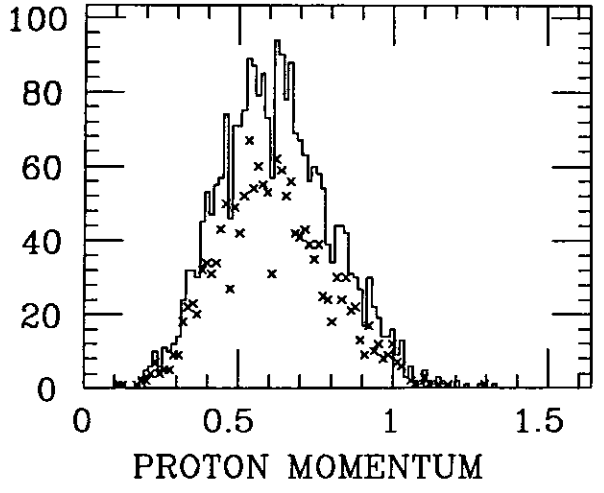
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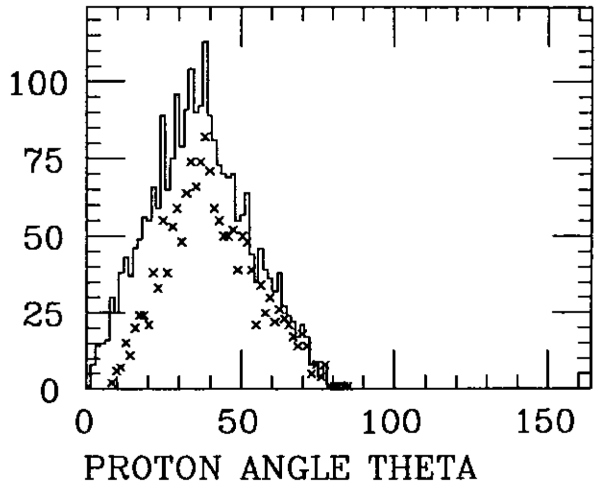
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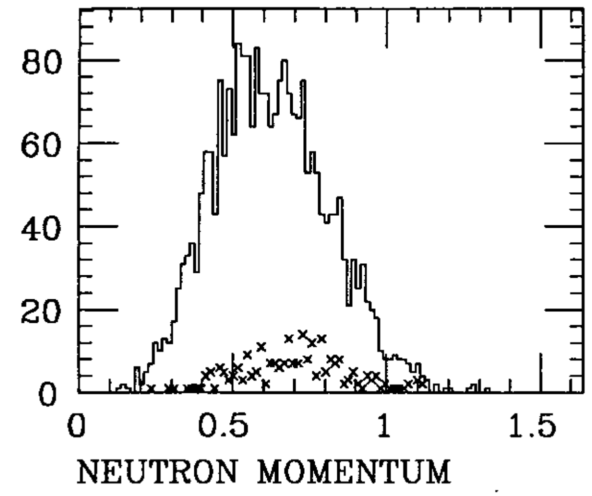
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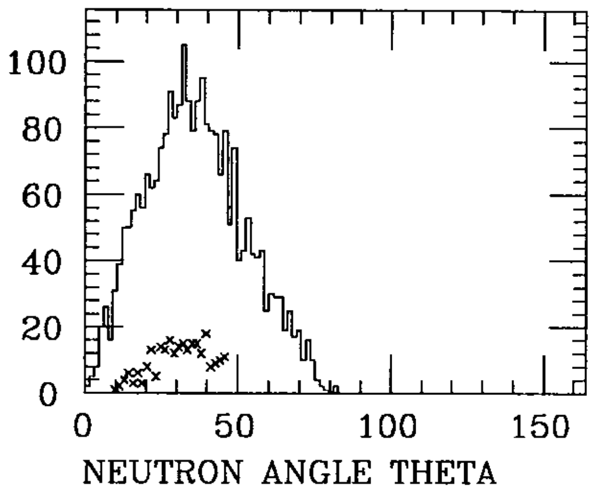
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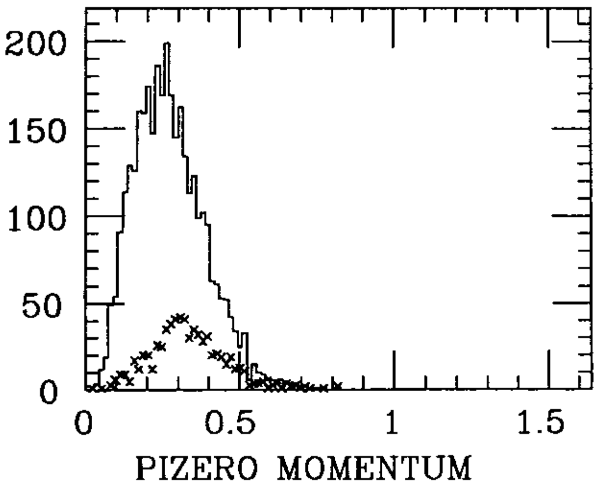
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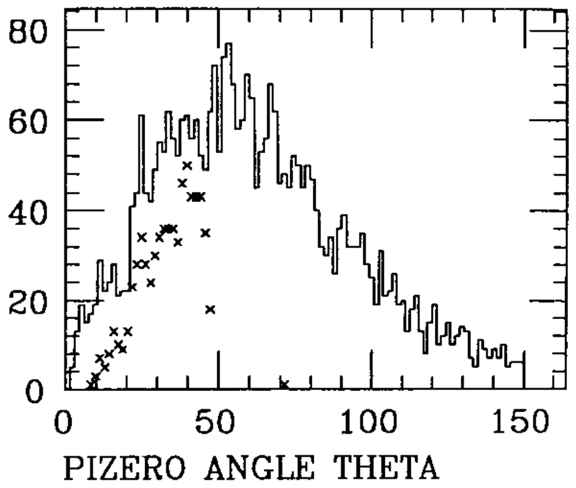
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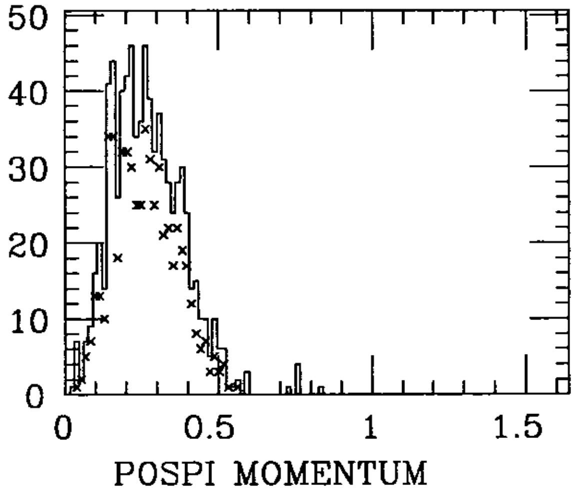
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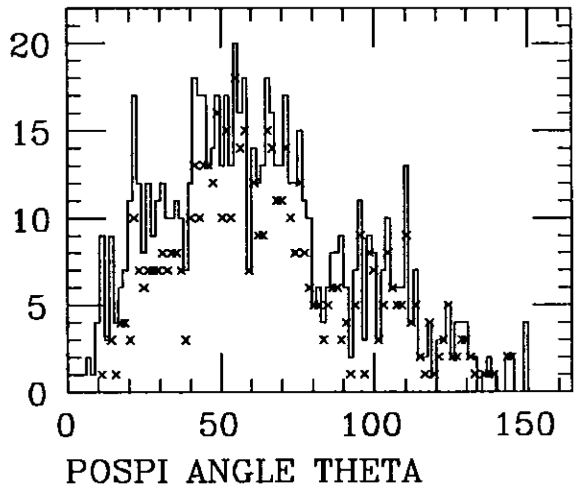
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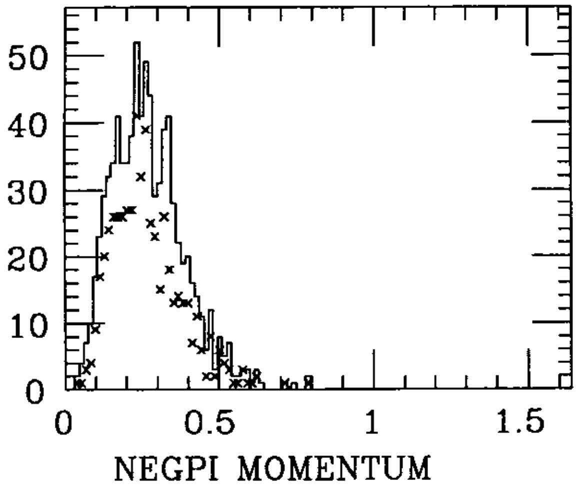
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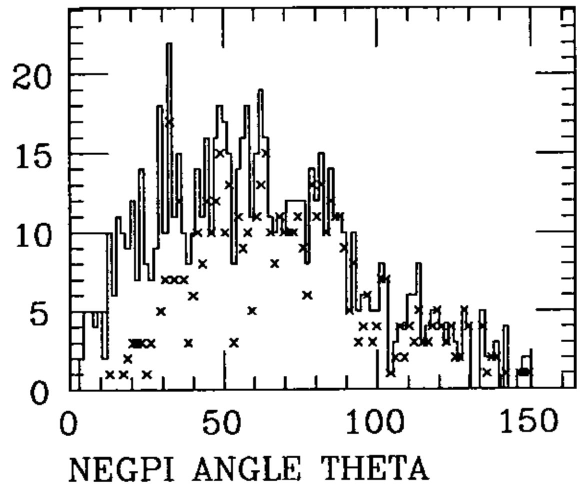
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NEGPI ANGLE THETA

Continuous Electron Beam Accelerator Facility
12000 Jefferson Avenue
Newport News, Virginia 23606
(804) 249-7100

Proposal Number: PR-89-017

Proposal Title: Electroexcitation of the $\Delta(1232)$ in Nuclei

Spokespersons/Contact Persons: R. Sealock

Proposal Status at CEBAF:

Conditional approval. The overlap of proposals PR-89-015, -017, -027, -031, -032, and -036 is high but not complete. The proponents should attempt to coordinate beam energies, targets, and data acquisition, so that the six experiments can run simultaneously. The present feeling of the PAC is that the initial measurements should be limited to ^{3}He and one heavy nucleus, ^{3}He having priority, and that the optimal beam energies and kinematics are close to those in PR-89-031.

Dirk Walecka

John Dirk Walecka
Scientific Director