CEBAF Program Advisory Committee Eight Cover Sheet

This proposal must be received by close of business on Thursday, April 14, 1994 at:

CEBAF
User Liaison Office, Mail Stop 12 B
12000 Jefferson Avenue
Newport News, VA 23606

Proposal Title

Study of the Δ(1232) Using Double Polarization Asymmetries

Contact Person

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Experimental Hall: B
Total Days Requested for Approval: Beam time already approved for Exp. 91-23. Additional 300 hrs conditional see text
Minimum and Maximum Beam Energies (GeV): 4.0
Minimum and Maximum Beam Currents (μAmps): see exp 91-23

CEBAF Use Only

Receipt Date: 4/13/94 PR 94-003

By: [illegible]

HAZARD IDENTIFICATION CHECKLIST

CEBAF Experiment: ______________________ Date: ______________

Check all items for which there is an anticipated need—do not check items that are part of the CEBAF standard experiment (HRSE, HRSH, CLAS, HMS, SOS in standard configurations).

Cryogenics _____ beamline magnets _____ analysis magnets _____ target _____ drift chambers _____ other	**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** (incl. target) 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 _____ other
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) ______________ ______________ ______________	**Notes:** ______________ ______________ ______________ ______________ ______________ ______________

Proposal to PAC 8

Study of the $\Delta(1232)$ Using Double Polarization Asymmetries

A Hall B CLAS N* Collaboration Experiment

Spokespersons:

P. Stoler, RPI (contactperson)
V. Burkert, Z. Li, CEBAF
R. Minehart, U. Va

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Abstract: We propose to use polarized beam and target to measure double polarization asymmetries for the $\Delta(1232)$ resonance over a Q^2 range from about 0.5 to 4 GeV^2/c^2. We will measure the kinematically complete reactions $p(e,e'p)\pi^\circ$ and $p(e,e'\pi^+)n$ over the full $\Delta(1232)$ mass range, and obtain nearly a full 4π angular distribution for several kinematic regions in Q^2.

This experiment will provide us with unique information about the $N \rightarrow \Delta$ transition amplitudes, M_{1+} , E_{1+} and S_{1+}, and their interferences, which is complementary to measurements of cross sections using unpolarized beam or target. Also, the measurement of asymmetries will give rize to much smaller systematic errors which occur in absolute cross section measurements.

The, experiment is especially well suited to Hall B since the maximum acceptable luminosity of the polarized $^{15}NH_3$ target matches that of the CLAS spectrometer. In this experiment it will only be necessary to detect the scattered electrons and one of the emitted hadrons to achieve full kinematic reconstruction. Most of the experiment, especially the low Q^2 part, will utilize beam time already approved in conjunction with experiment E-91-23. In addition, we request an additional 300 hours of beam at 4 GeV to obtain increased statistical accuracy at higher Q^2, contingent upon successful utilization of the already approved beam time. Even though at these cm energies only single meson production is kinematically allowed missing mass reconstruction will enable us to eliminate most of the backgrounds associated with the polarized target.

1 Introduction

One of the major themes which will occupy the future CEBAF program is the structure of hadronic matter in the non-perturbative regime. A large part of this program will be devoted to the study of baryons by means of exclusive reactions and in particular a detailed study of the properties of electromagnetic transitions to resonant excited states is a very important area for testing models of baryon structure. Because of the richness of the spectrum of states, there is a potential for pinning down and differentiating in a detailed way assumptions which are inherent in models which are designed to deal with strongly interacting matter in different kinematic regimes. The investigation and elaboration of these properties is the one of the primary CEBAF programs and the central task of The Structure of Hadrons, (or N^*) Collaboration. Resonances are broad and strongly overlapping, with a significant underlay of non-resonant background. Thus, to unambiguously obtain the amplitudes even for the most prominent resonances will require a multi-faceted approach, including measurement of polarization observables as well as non-polarized cross sections.

Currently there are three Hall B experiments by the N^* collaboration which focus on the study the Δ^+.

- E-89-37 Electroproduction of the $P_{33}(1232)$ Resonance. (spokespersons: V. Burkert, R. Minehart)
- E-89-42 A Measurement of the Electron Asymmetry in $p(e,e'p)\pi^\circ$, $p(e,e'\pi^+)n$ in the Mass Region of the $P_{33}(1232)$ for $Q^2 < 2\ Gev^2/c^2$. (spokespersons: V. Burkert and R. Minehart)
- E-91-2 A Study of Excited Baryons at High Momentum Transfer with the CLAS Spectrometer. (spokespersons: P. Stoler, V. Burkert)

Experiments E-89-37 and E-91-02 will measure absolute differential cross sections using unpolarized beam and target in the lower and higher ranges of Q^2 respectively. Experiment E-89-42 will utilize polarized beam and unpolarized target to measure asymmetries, which are expected to be sensitive to longitudinal amplitudes through interference with the Born backgrounds. Here, we propose to measure polarization asymmetries using both polarized target and electron beam.

Apropos, we mention two experiments which will utilize polarized beam and hydrogen target. Experiment E-91-23 has been awarded beam time to study the Q^2 dependence of the GDH sum rule. Experiment E-93-36 which points out the feasibility to study polarization asymmetries in the resonance region, and focuses mainly on single pion production in the second and third resonance region, will utilize the beam time awarded in E-91-93.

Polarization asymmetry measurements a have two attractive features. First, they have much smaller systematic errors than differential cross section measurements since one is measuring ratios at identical kinematic conditions. Second, polarization observables are sensitive to interesting physical quantities in ways which are very different, and complementary to non-polarized cross sections.

Normally polarization measurements are counting rate limited due to the limitations on luminosity imposed by the polarized target. However, the use of the CLAS spectrometer has a very important advantage in that it has a very large acceptance, and in the case of a polarized hydrogen target, the limitations on the luminosity are matched very closely by the expected luminosity limitations of the spectrometer.

2 Physics Background

The $\Delta(1232)$ has been the most studied of all the resonances since it is the most accessible. It is the only resonance which does not strongly overlap any of the others, and its only strong decay is by single pion emission. From the physics point of view the $\Delta(1232)$ has the additionally attractive feature that $J = 3/2$, so that there are three contributing complex multipoles, E_{1+}, M_{1+}, and S_{1+}. Their determination is model dependent since the available data, especially double polarization data, are insufficient to experimentally determine them. Also, since $I = 3/2$ there are four charge states. In the present proposal we consider only the Δ^+ and its two strong decay channels $\Delta^+ \rightarrow p+\pi^\circ$ and $\Delta^+ \rightarrow n+\pi^+$.

2.1 Physics Issues

At low Q^2 in a pure $SU(6)$ *non − relativistic* CQM the $N \rightarrow \Delta$ transition is purely M_{1+} in character, involving a single-quark spin-flip with $\Delta L = 0$. An E_{1+} contribution is not permitted since the Δ and N are both in $L = 0$ states which cannot be connected by an operator involving $L > 0$. The addition of a residual quark-quark color magnetic interaction adds $L = 2$ components to the Δ wave function, and thus introduces a small E_{1+} component of perhaps a few percent. The measurement of this small E_{1+}/M_{1+} ratio is one of the most interesting problems in baryon resonance physics in that it will give very powerful tests of the CQM in the low Q^2 regime. At Q^2= 0 the experimental data supports the CQM prediction of M_{1+} dominance. However, although E_{1+}/M_{1+} is known to be at the few percent level, the magnitude $\Delta E_{1+}/E_{1+}$ is virtually unknown, despite many years of controversy. In any case one should not give too much weight to the theoretical agreement of the nearly total dominance M_{1+} over E_{1+} since theory fails rather badly to predict the absolute value of M_{1+} The current status of the experimental helicity amplitudes and

multipoles amplitudes, evaluated by the Particle Data Group (PDG-92) and Davidson and Mukhopadhyay (Da-90) respectively are compared with the results of a recent relativized calculation by Capstick (Ca-92a,b) in Table I below.

Table I. Current status of photoproduction amplitudes for the $\Delta(1232)$ in units of $10^{-3}\ GeV^{-1/2}$

	theory	*experiment*
$A_{1/2}$	-108	-141±5
$A_{3/2}$	-186	-258±19
M_{1+}	156	285±37
E_{1+}	-0.2	-4.6±2.6

As Q^2 increases there is no reason to expect the E_{1+}/M_{1+} ratio to remain very small. Indeed, CQM based calculations give very different evolutions of E_{1+}/M_{1+}, as well as the ratio S_{1+}/M_{1+}, depending upon the input ingredients. For example, Figure 1 shows the results of a recent calculation by Capstick (Ca-92b).

For $Q^2 > 0$ the experimental situation is shown in Figure 2 as summarized by Burkert (Bu-92). Most of the data at values of Q^2 below 1 GeV^2/c^2. Clearly, the uncertainties are much too great to constrain current theory. In any case, as Q^2 increases we know that the simple CQM must become less valid, and other corrections to the model must play an increasingly important role. In the asymptotically high Q^2 limit the amplitudes should be dominated by the participation of the three valence *current* quarks , and *helicity conservation* requires $E_{1+}/M_{1+} \rightarrow 1$ (see eg. Carlson (Ca-86)). Concomitant predictions of *PQCD scaling* seem to be satisfied for some reactions, even for resonances, at surprisingly low Q^2. However, it is argued this *scaling* can in fact be simulated by the dominance of soft processes (most recently Br-94,Zh-94), and that the dominance of minimal number of valence quarks should occur at very high values of Q^2. Even if this point of view is correct one still needs an insightful and useful model which accounts for these soft processes, and at $Q^2 >$ a few GeV^2/c^2 it is not necessarily the CQM. Currently we have no idea where in Q^2 it is necessary to give up the CQM for another model basis. Certainly, the evolution of quantities such as E_{1+}/M_{1+} and other amplitudes which are accessible by polarization and non-polarization experiments should help decide such issues. The one experimental point at $Q^2 = 3\ GeV^2/c^2$ ($E_{1+}/M_{1+} = 0.8 \pm 0.6$) is statistically not significant enough to make any conclusions as to whether there is any increase in E_{1+}/M_{1+}.

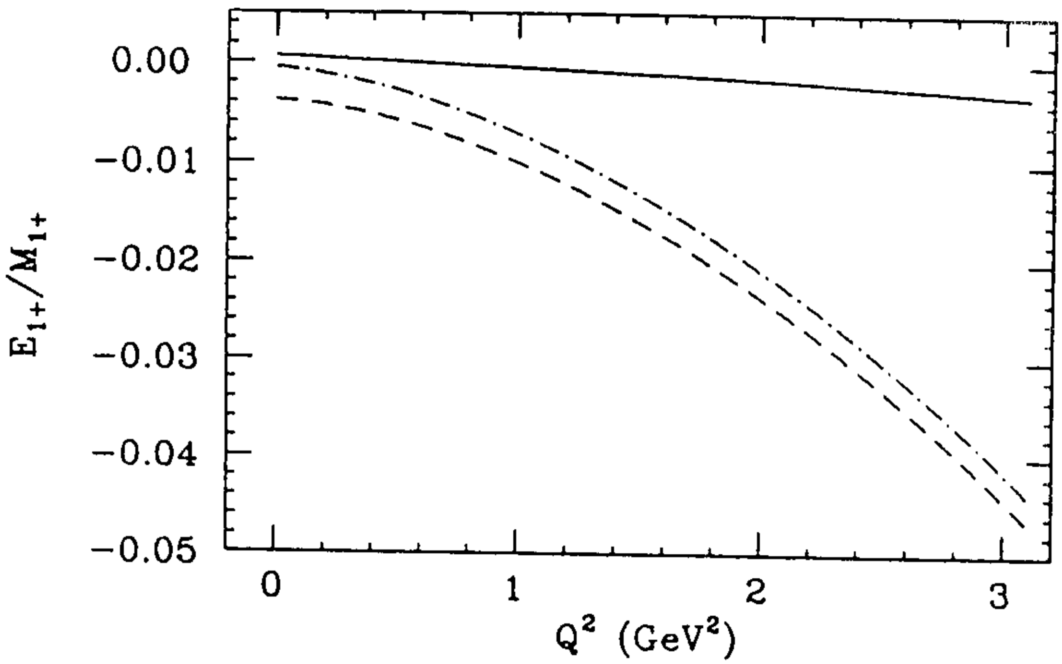

Figure 1: The results of a calculation in a CQM basis of the ratio E_{1+}/M_{1+} by Capstick (Ca-92b). The solid curve is due to a relativized calculation in the framework of the Isgur-Karl model. The dashed and dot-dashed curves are the result of non-relativized calculations.

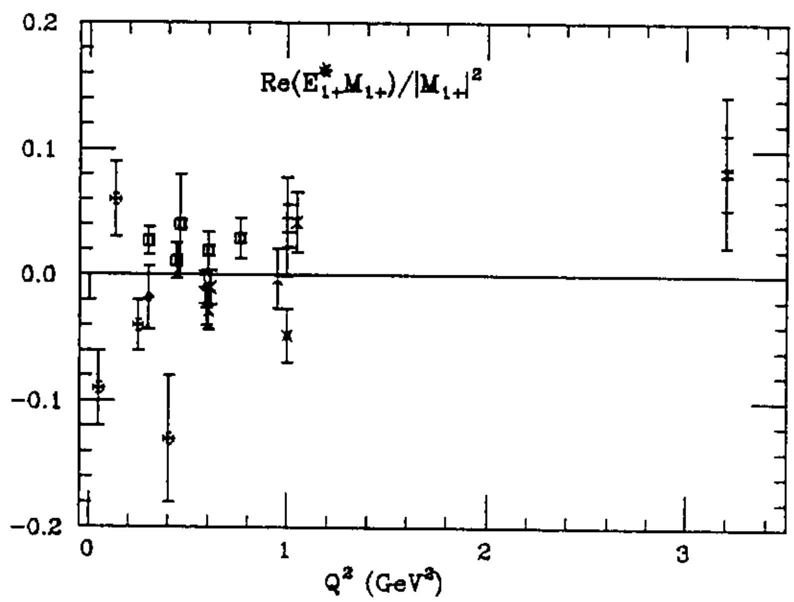

Figure 2: Evaluation of the $Re(E^*_{1+}M_{1+})/|M_{1+}|^2$ evaluated by Bu-92.

Warren and Carlson (Wa-89) claim that one can obtain an equally consistent fit to the data in which the analysis assumes in fact that $E_{1+}/M_{1+} \sim 1$. On the other hand, an analysis by Burkert (Bu-94) indicates that no consistent fit to the data is possible with this assumption. In any case, both agree that double polarization asymmetries, similar to those which are proposed here will considerably clarify the question of the relative importance of the amplitudes. In summary then, our goals are the following:

- We wish to map the amplitudes of resonances from low Q^2 to the highest possible Q^2 in order to constrain calculations based upon the CQM and to look for evidence of a transition from the validity of the *constituent quark* basis to one requiring other degrees of freedom, eg. valence current quarks + modeling of soft processes. The Q^2 evolution of M_{1+}, E_{1+}, S_{1+}, and especially E_{1+}/M_{1+} can be a unique window on the evolution of these models.

- To span the largest range of Q^2 the $\Delta(1232)$ is technically the most favorable.

- Since the $\Delta(1232)$ has J=3/2 and I=3/2 there is a rich complement of amplitudes which can be accessed, M_{1+}, E_{1+} and S_{1+}, in four charge states.

- Measurement of double polarization asymmetries yield combinations of amplitudes which are complementary to unpolarized and single polarization experiments. Since beam polarization asymmetries involve ratios of cross sections taken under identical conditions systematic errors are smaller than those encountered in obtaining absolute cross sections or for asymmetries involving involving non-identical spacial conditions such as different detector angles.

3 Cross Section and Asymmetry Notation

3.1 Differential Cross Sections

Differential cross sections for single pion production are usually defined in terms by

$$\frac{d\sigma}{dp_e d\Omega_e d\Omega_\pi} = \Gamma(E_e, W, Q^2)\,\frac{d\sigma}{d\Omega_\pi}$$

where $\Gamma(E_e, W, Q^2)$ is the virtual photon flux factor, and $d\sigma/d\Omega_\pi$ is the differential cross section for pion production by a virtual photon, which can be written as

$$\frac{d\sigma}{d\Omega} = \sigma_o + h\sigma_e + \vec{P}\cdot\vec{\sigma}_t + h\vec{P}\cdot\vec{\sigma}_{et}.$$

Here h is the electron beam helicity and $\vec{P}$ is the target polarization vector. The subscripts o, e, t and et refer to the state of polarization. When neither the beam nor target are polarized only σ_o is non-zero. σ_o can be expressed in terms of $transverse(U)$, $longitudinal(L)$, $transverse - transverse(TT)$ and $longitudinal - transverse(LT)$ cross sections as follows.

$$\sigma_o = \sigma_U + \epsilon\sigma_L + \epsilon\sigma_T cos2\phi + \sqrt{1/2\epsilon(1+\epsilon)}\sigma_{LT} cos\phi$$

When the beam is polarized, σ_e contributes in proportion to the beam helicity h. When the target is polarized, σ_t , contributes, and can be written

$$\vec{P} \cdot \vec{\sigma}_t = P_x\sigma_{tx} + P_y\sigma_{ty} + P_z\sigma_{tz}$$

Finally, when both electron beam and target are polarized σ_{et} also contributes one can write

$$h\vec{P} \cdot \vec{\sigma}_{et} = h(P_x\sigma_{etx} + P_y\sigma_{ety} + P_z\sigma_{etz})$$

Note that in this case a knowledge of the products hP is necessary to extract $\sigma_{etx}, \sigma_{ety}$, and σ_{etz}. The cross sections $\sigma_o, \sigma_e, \sigma_t, \sigma_{et}$ can be written in terms of the contributing multipole amplitudes. Near the peak of the $\Delta(1232)$ we have the E_{1+}, M_{1+} and S_{1+}, and additionally contributing background multipoles.

3.1.1 Non-resonant Backgrounds

Additional multipoles contribute to the underlying non-resonant Born contributions which must be understood in order to unambiguously extract the amplitudes. Another advantage of studying the $\Delta(1232)$ excitation region is that at these low excitations, the Born terms are rather well determined. The level of non-resonant contribution can be strongly reduced by selecting the π° channel, since the normally dominant *seagull* and $t - channel$ background terms are absent. However, in the π^+ channel this contribution is always large and must be dealt with. The tails of higher resonances must also be taken into account, but fortunately in the region of the Δ these are relatively small.

4 Definition of Asymmetries

4.1 Conventional Definitions

In the usual definition of polarization asymmetries, eg. Bartl and Majerotto (Ba-73) (BM) the electron polarization points forward ($h \equiv +$) or backward ($h \equiv -$) relative to the incident electron beam direction. The target polarization is then given in a coordinate

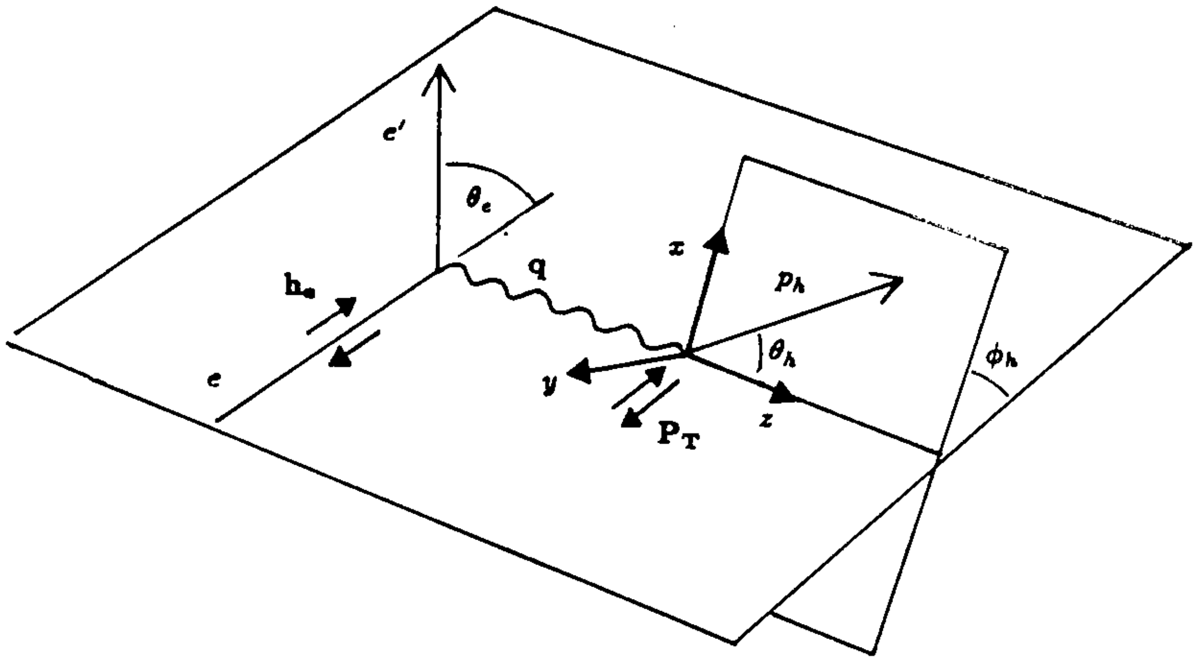

Figure 3: The coordinate system relating to the asymmetries defined in the present proposal.

system whose z axis points in the *direction of the momentum transfer* $\vec{q}$. BM define 13 asymmetries corresponding to polarized beam, target and beam and target. We have checked all the defined double polarization asymmetries for sensitivity to variations in E_{1+}/M_{1+} andS_{1+}/M_{1+} We find that polarizations involving P_z are rather sensitive to E_{1+}/M_{1+} , while those sensitive to S_{1+}/M_{1+} involve P_x and P_y.

4.2 Present Definitions

Typically, defined asymmetries such as those appearing in BM are more useful for conventional small acceptance magnetic spectrometers, and less useful for large acceptance spectrometers such as CLAS which are naturally symmetric around the electron beam rather than the virtual photon direction. Thus, in the following we consider the situation in which the electron beam and target are both polarized along the beam, as shown in Figure 3.

The connection with the BM defined asymmetries is as follows. Since the $\vec{q}$ always points in the forward direction the dominant component of $\vec{P}$ is along P_z. Thus we can expect that the the measured asymmetries will be sensitive to E_{1+}/M_{1+} and less sensitive to S_{1+}/M_{1+} . The components P_x and P_y vary with $P_{\perp} = \sqrt{P_x^2 + P_y^2}$ a constant and typically smaller than P_z

We then define the double polarization asymmetry as follows.

$$\delta^2 S_{et} = \frac{\sigma(\uparrow\uparrow) - \sigma(\uparrow\downarrow) - \sigma(\downarrow\uparrow) + \sigma(\downarrow\downarrow)}{\sigma(\uparrow\uparrow) + \sigma(\uparrow\downarrow) + \sigma(\downarrow\uparrow) + \sigma(\downarrow\downarrow)}.$$

In the above expression the arrows correspond to the electron and target helicity respectively, ie $\sigma(\vec{h}\vec{P})$.

There is an additional simplicity that we can make use of in this proposal. The result of keeping the electron polarization fixed while flipping the target polarization is nearly the same as keeping the target polarization fixed while flipping the electron helicity. Since the latter is the technically simpler process we choose to adopt the convention where the target polarization is kept fixed along the beam axis and the electron helicity is fixed.

$$\delta S_{et} \equiv \frac{\sigma(\uparrow\uparrow) - \sigma(\downarrow\uparrow)}{\sigma(\uparrow\uparrow) + \sigma(\downarrow\uparrow)}$$

4.3 Sensitivities of Asymmetries to Multipole Amplitudes.

The sensitivities of the asymmetries for the reaction $P(e, e'p)\pi^\circ$ and $P(e, e'\pi^+)n$ were calculated as a function of hadron decay angle θ and ϕ for kinematical conditions corresponding to Table II, with the condition that the total cross section at each Q^2 is fixed at the experimental values.

Table II. Kinematics considered for simulations performed for this proposal.

$Q^2(GeV^2/c^2)$	$E_e(GeV)$	E_{1+}/M_{1+}			C_{1+}/M_{1+}		
0.5	1.6	0	.05	.1	0	.05	.1
1	1.6	0	.05	.1	0	.05	.1
2	4.0	0	0.1	0.2	0	0.1	0.2
4	4.0	0	0.1	0.2	0	0.1	0.2

For small values of Q^2 E_{1+}/M_{1+} is expected to be small so that ratios of 0.0, 0.05, and 0.1 were considered. For greater values of Q^2 theory suggests that E_{1+}/M_{1+} may not be so small so that ratios of 0.0, 0.1 and 0.2 were considered. Figures 4,5 and 6 display sample results for the reaction $p(e, e'p)\pi^\circ$. It is seen that there are considerable sensitivities. Simulated data is also shown for a running time of 600 hrs, taking into account experimental conditions shown in Table III, and in the figure-caption. For this reaction we will detect the scattered electron and decay proton. The resolution of the CLAS spectrometer is more than adequate to easily reconstruct the missing mass of the single pion in the final state. Since $W = 1232$ defined by the electron kinematics is below the 2-pion emission threshold the separation should be very clean. We also will have to use the missing mass to eliminate most of the quasi-free yield from the ^{15}N in the target (see below). The CLAS acceptances were taken into account using the A-O simulation code developed at CEBAF (Bu-91). We note that for each Q^2, data over the entire range of W spanning the region of the Δ resonance, including the tails, will be obtained simultaneously so that we will be able to assess the effects of the non-resonant backgrounds.

For the reaction $p(e, e'\pi^+)n$ the experimental situation is more difficult for several reasons. The Born backgrounds are known to be quite large, and the resonance cross sections are a factor of 2 smaller than in the π° case. Also, experimentally there are major difficulties. Unlike the protons from the reaction $p(e, e'p)\pi^\circ$, which emerge at relatively small angles relative to $\vec{q}$, we must measure the emitted pions which emerge over a broad angular range, and have lower momentum, so that many appear outside the θ acceptance of the CLAS spectrometer. Thus, for angles in θ greater than about 60° the ϕ acceptance is essentially limited to angles from - 100° to +100°.

Nevertheless, the calculated asymmetries are quite sensitive to ratios E_{1+}/M_{1+}. As an example Figure 7 shows the calculate asymmetries at $Q^2 = 1\ GeV^2/c^2$, together with simulated data.

It is remarkable that the asymmetries described here are relatively insensitive to longitudinal multipoles, ie. S_{1+}/M_{1+}. An example of this insensitivity is shown in Figure 8. The greatest sensitivities to longitudinal multipoles occur in situations involving target polarizations which are perpendicular to the hadron decay plane, ie corresponding to dominant values of P_x or P_y. There is also a significant sensitivity to S_{1+}/M_{1+} in the asymmetry corresponding to polarized electrons, non-polarized target, which comes from the interference between the resonant and non-resonant amplitudes. These issues form the basis of experiment E-89-42, which will measure the asymmetries with polarized electrons and unpolarized target.

5 Experimental Considerations.

5.1 Compatibility with other CLAS Experiments.

Beam time to run polarized beam with a polarized proton target in the configuration described above at several beam energies ranging from 1.2 to 4 GeV^2/c^2 has been authorized at a total of 1000 *hrs* (40 *days*) for experiment E-91-23 "Measurement of the Polarized Structure Functions in Inelastic Electron Proton Scattering using the CEBAF Large Acceptance Spectrometer". In addition, experiment E-93-36 "Measurement of Single Pion Electropro-

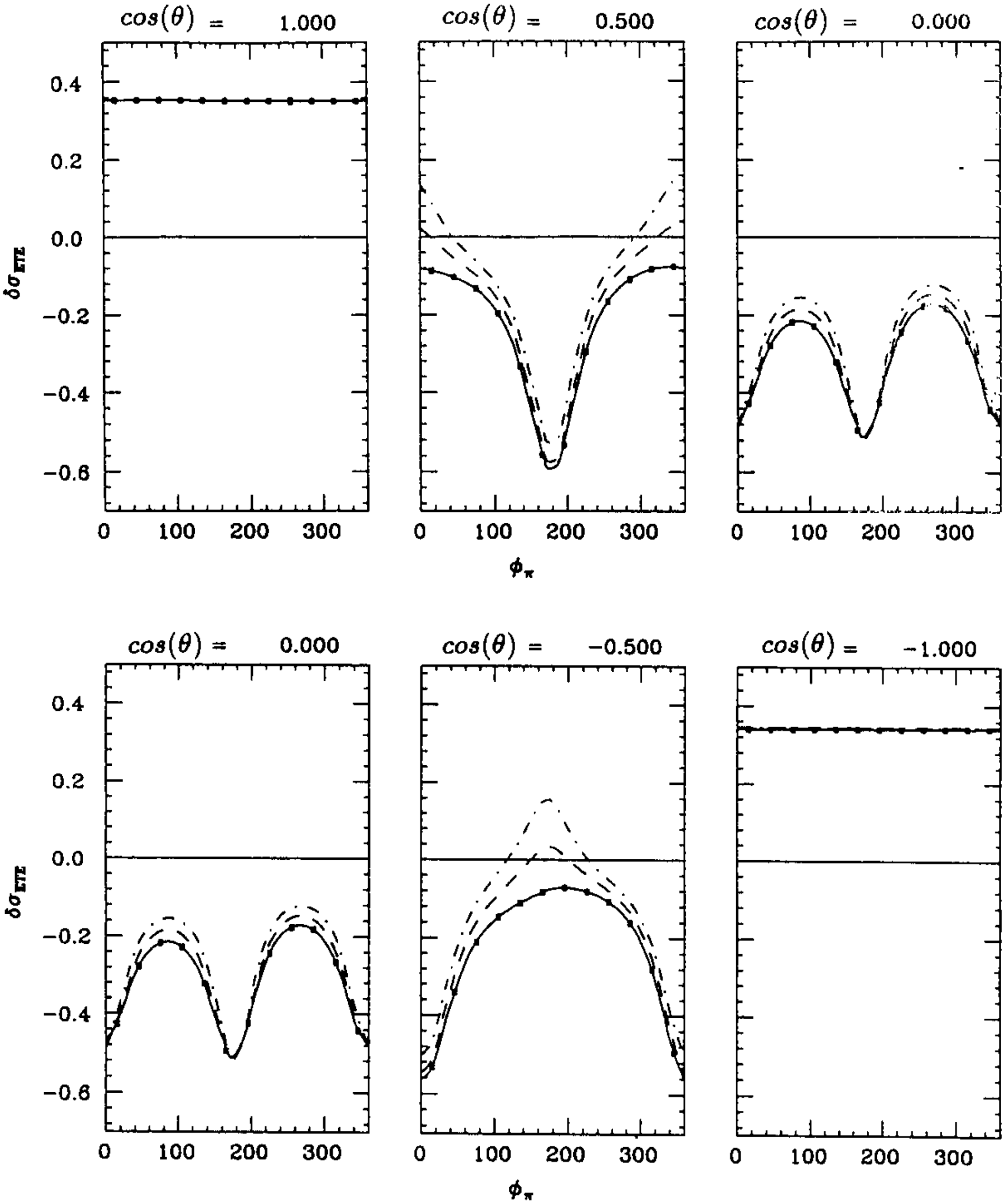

Figure 4: Calculated asymmetries for the reaction $p(e, e'p)\pi^0$ for $E_{1+}/M_{1+} = 0.0, 0.05$, and 0.10, as functions of hadron decay angles at $Q^2 = 0.5\, GeV^2/c^2$. Each combination of the amplitudes E_{1+} and M_{1+} yield the same total cross section corresponding to the experimental values. Non-resonant Born backgrounds are included in each calculated curve. The statistics correspond to the experimental conditions of Tables II and III. The total beam time = 600 hr. The acceptances for each point are $\Delta Q^2/Q^2 = 0.1$, $\Delta W = 0.1 GeV$, $\Delta cos(\theta) = 0.4$, and $\Delta\phi = 30°$. CLAS acceptances are calculated using the code $A - O$

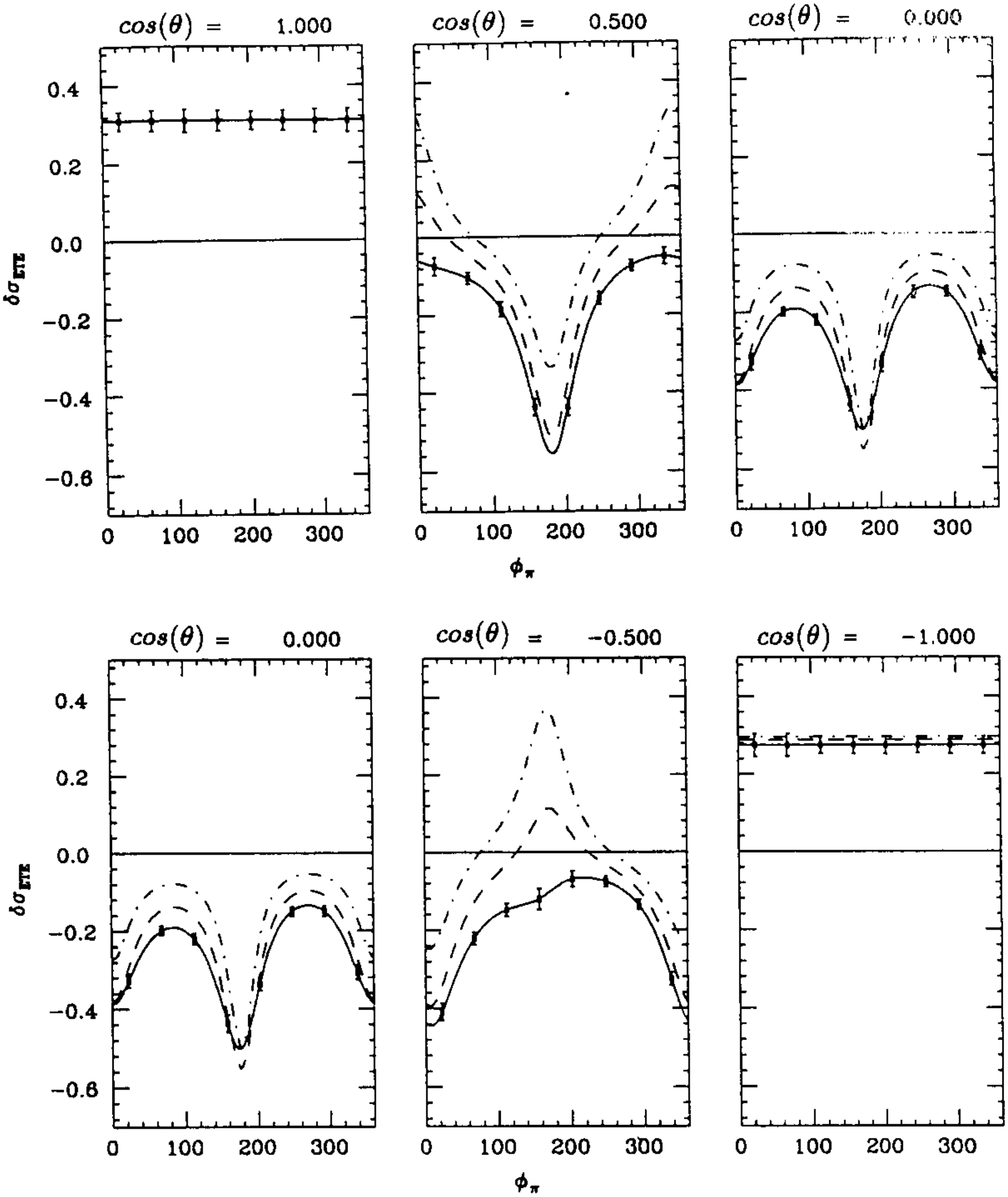

Figure 5: As in Figure 4, symmetries for the reaction $p(e,e'p)\pi^0$ but at $Q^2 = 2.0\ GeV^2/c^2$, and $E_{1+}/M_{1+} = 0.0, 0.1$, and 0.2, and in the statistical simulation $\Delta\phi = 45°$.

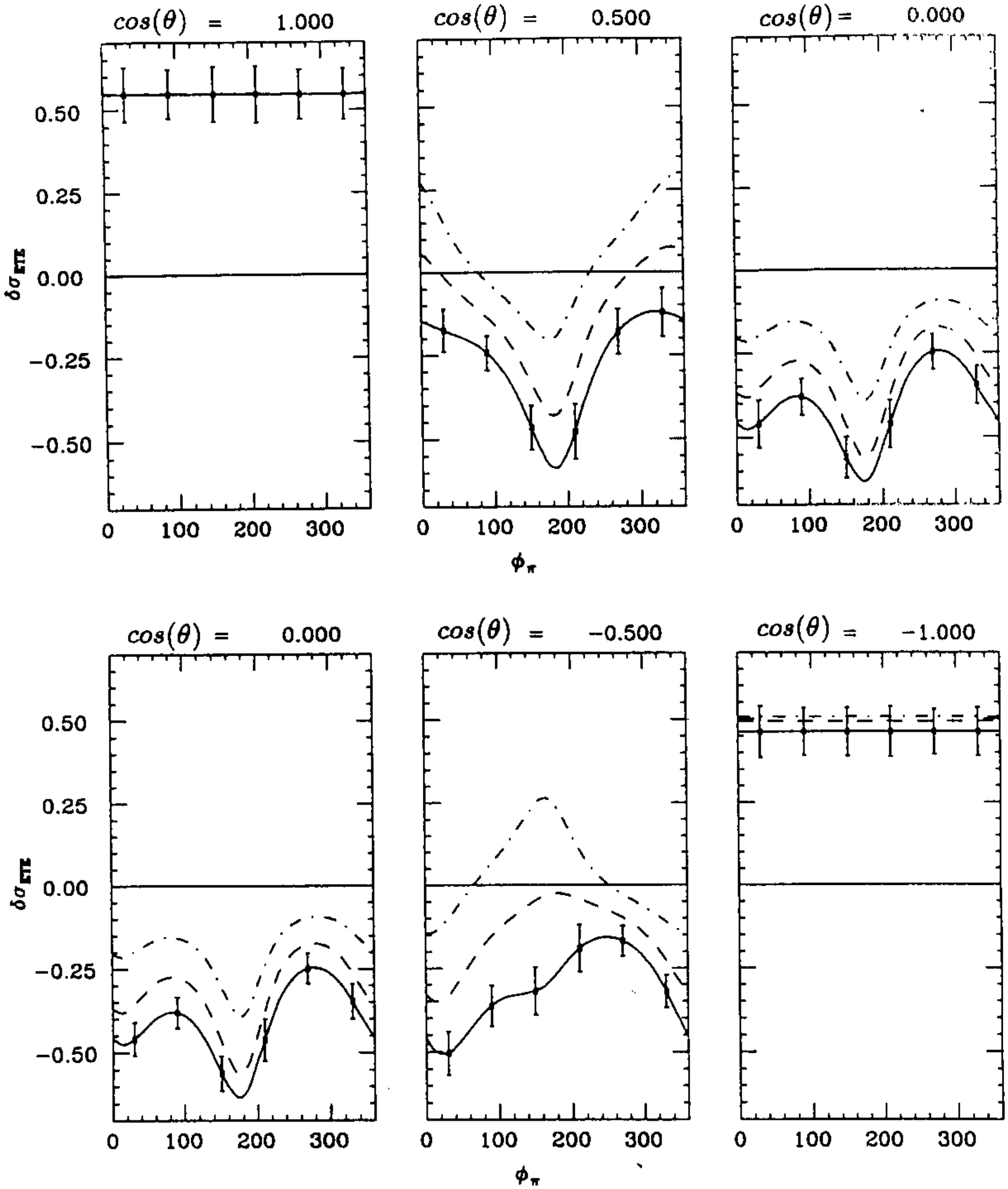

Figure 6: As in Figure 4, symmetries for the reaction $p(e,e'p)\pi^0$ but at $Q^2 = 4.0\ GeV^2/c^2$, and $E_{1+}/M_{1+} = 0.0$, 0.1, and 0.2, and in the statistical simulation $\Delta\phi = 45°$.

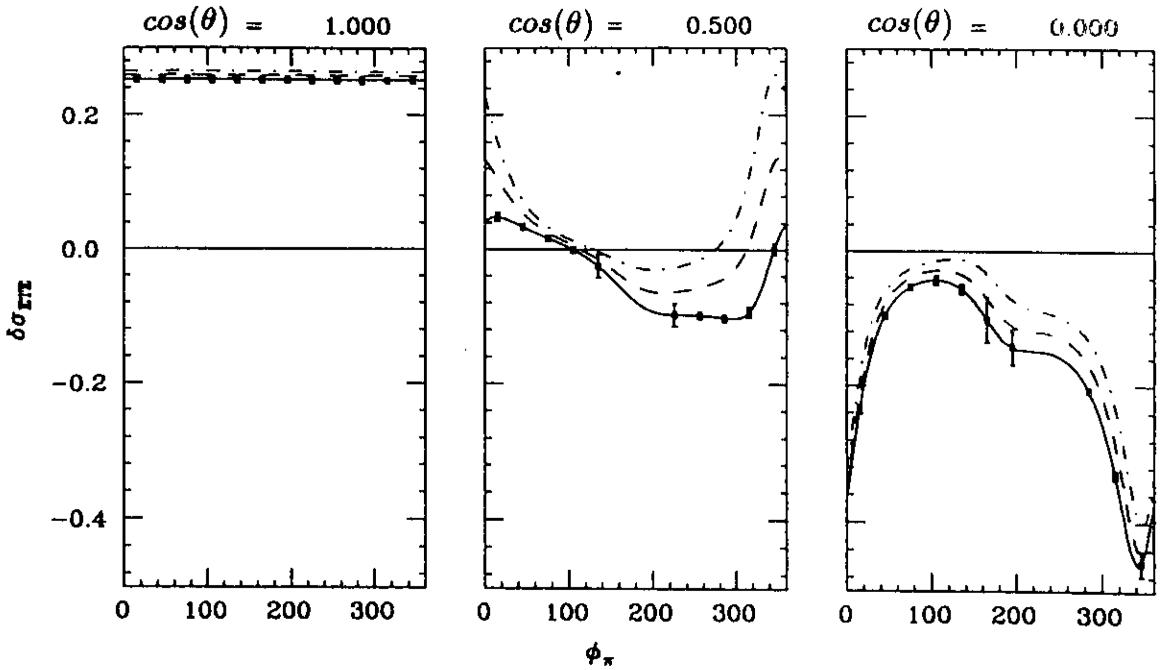

Figure 7: a.) As in Figure 4, but for the reaction $p(e, e'\pi^+)n$ at $Q^2 = 1.0\ GeV^2/c^2$, and $E_{1+}/M_{1+} = 0.0$, 0.1, and 0.2 and in the statistical simulation $\Delta o = 30°$. Note that where there are no data points corresponds to the kinematic regions outside the CLAS acceptance.

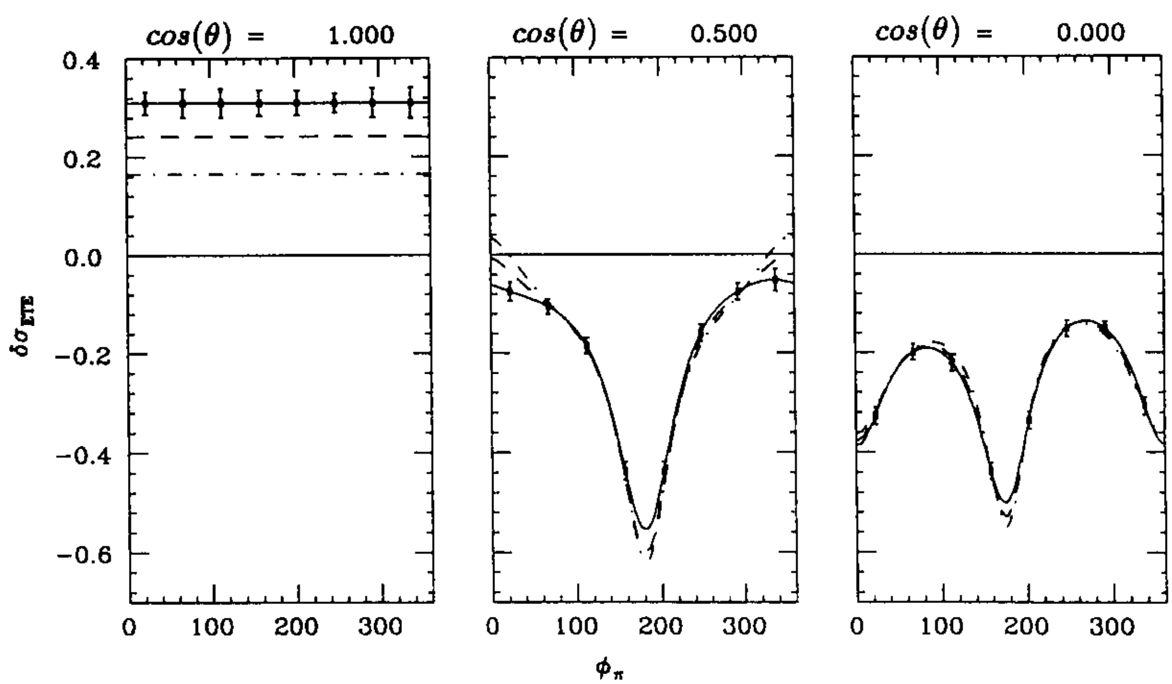

Figure 8: a.) The calculated asymmetry for the reaction $p(e, e'p\pi^0$ at $Q^2 = 2.0\ GeV^2/c^2$, for three values of the ratio $C_{1+}/M_{1+} = 0.0$,0.1, and 0.2. Compare with Figure 5.

duction from the Proton with Polarized Beam and Polarized Target Using CLAS" has been approved to run contemporaneously.

The requirements of the present proposed experiment will be completely compatible with the conditions of the other approved experiments. An additional 300 *hrs* (12 *days*) is requested to improve the statistics of the highest Q^2 data where cross sections become small.

5.2 Target.

Experimental conditions relating to a polarized $^{15}NH_3$ in a holding field such that $\int B \cdot dl \sim 5T$ are described in proposal for experiment E-91-23. We repeat some of their conclusions here.

For the 3 free protons the polarization can be expected to be > 0.9 each. The unpaired protons in the ^{15}N nuclei are estimated to have a polarization of about 0.16, so that they contribute about $0.16/(3 \times 0.9) \sim 0.006$ to the total polarization. Suppose 75% of the events from quasielastic scattering of the protons in ^{15}N can be eliminated with missing-mass cuts, then the contribution of the unpaired proton will be reduced to ~ 0.0015. Finally, those remaining will be near the zero recoil momentum part of the quasielastic spectrum so their asymmetries should be expected to be the same as for free protons. Thus, no correction in the asymmetry should be expected from polarized unpaired protons in ^{15}N.

The denominator in the asymmetry will have the full contribution from all nucleons in the target, including ^{15}N. Again, missing-mass reconstruction should eliminate most of these. The remainder may be subtracted by measuring spectra of pure ^{15}N under identical conditions, normalizing to the ^{15}N tails in the $^{15}NH_3$ target, and subtracting.

5.3 Target and Beam Polarization.

The magnitude of the asymmetry is proportional to the product of the beam and target polarizations, $h \cdot P$. The uncertainty in this quantity will be the major systematic uncertainty in the obtained asymmetries. The beam and target polarizations will be determined in two ways.

5.3.1 Direct Measurement.

The beam polarization will be measured directly with a Möller polarimeter. The expected polarization will be about $h = 0.8$ with an accuracy $\delta h/h \sim 0.05$. Direct measurement of the target polarization can be accomplished with an uncertainty $\delta P/P \sim 0.03$.

5.3.2 Measurement of the Product $h \cdot P$.

Proton elastic scattering data will be obtained coincidentally with the inelastic data. The intrinsic asymmetry function A^{ep} in the elastic scattering depends on the ratio G_E^p/G_M^p in a well known way, so that the overall experimental elastic asymmetry can be written

$$A^{exp} = h \cdot P \cdot A^{ep}.$$

A measurement of A^{exp} then determines the product $h \cdot P$. It is estimated in E-91-23 that this technique will yield $\delta(h \cdot P)/(h \cdot P) \sim 0.01$. Since the uncertainty in G_E^p/G_M^p depends upon Q^2, the systematic error in $h \cdot P$ will vary accordingly.

5.3.3 Luminosity.

We expect to run with a luminosity from 2×10^{33} $cm^{-2}sec^{-1}$ at the lowest energies to at least 10^{34} $cm^{-2}sec^{-1}$ at 4 GeV. The strong holding field of the target will substantially suppress the main components of charged background which consists primarily of low energy electrons.

5.3.4 Acceptances.

We have modeled the $e-p$, and $e-\pi^+$ combined acceptances for the kinematics proposed here using the code $A-O$. For the reaction $p(e,e'p)\pi^\circ$ the acceptances are quite good and moderately ϕ independent. For the reaction $p(e,e'\pi^+)n$ the acceptance in ϕ is a strong function of θ. In particular, for larger θ the acceptance becomes very small for ϕ_π corresponding to pion emitted at the largest spectrometer angles. This is reflected in the absence of simulated data in certain regions of Figure 7.

5.4 Running Conditions

Data for this experiment will be obtained during all the running period already approved for experiment E-91-23. The electron beam energy will vary from 1.2 to 4 GeV. This will enable us to cover the full range of Q^2 from 0.5 to 4 GeV^2/c^2. An additional 300 hrs (12 days) are requested to enable us to improve the statistics of the data obtained at higher values of Q^2, where the cross sections are becoming small. These additional hours can be conditional upon successful completion of the program utilizing the currently approved beam time.

6 Simulated Data.

A large body of data will be obtained during the 1000 hours of already approved beam time. We have simulated the data that we are likely to obtain at several representative values of Q^2. Clearly, not all values of Q^2 will be obtained at all the incident beam energies. Thus, for simplicity we assume that a total of 600 hours will be available at each simulated setting. Examples of these data are shown in Figures 4 - 7. The assumed conditions of the simulations are shown in Table III.

Table III. Experimental Assumptions

Luminosity	1×10^{34}
Polarization	
Electron	0.8
Target	0.9
Dilution factor	3/18
Time per point	600 *hrs*

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