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and received on or before 1 October 1991.

A. TITLE: The STUDY OF EXCITED BARYONS AT HIGH MOMENTUM TRANSFER WITH The CLAS SPECTROMETER

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C. IS THIS PROPOSAL BASED ON A PREVIOUSLY SUBMITTED PROPOSAL OR LETT OF INTENT?

[X] YES [ ] NO

IF YES, TITLE OF PREVIOUSLY SUBMITTED PROPOSAL OR LETTER OF INTENT

ELECTROPRODUCTION OF BARYON RESONANCES AT HIGH Q^2

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Proposal to the

CEBAF

Program Advisory Committee

The Study of Excited Baryons at High Momentum Transfer with the CLAS Spectrometer

The N* Collaboration +

P. Stoler and V. Burkert + M. TAIUTI

Spokespersons

Abstract: We propose to measure the properties of excited nucleons at high Q^2 by means of exclusive single meson production using the CLAS spectrometer. The motivation is to investigate short range phenomena in baryon structure, and to investigate the transition from the low Q^2 non-perturbative QCD regime, where theoretical descriptions have used mean field models, to the higher Q^2 where many people believe perturbative QCD plays an increasingly important role. Measurements will be carried out at the highest possible electron energy and luminosity. Initial measurements will utilize an incident electron energy of 4 GeV. The presently proposed experiment will be run concurrently with other already approved N* experiments. This will yield high quality angular distribution data in the range $Q^2 \sim 3$ - 4 GeV^2/c^2 . Later measurements will be extended to higher Q^2 as electron energy and detection acceptance and luminosity capabilities increase. Issues we wish to investigate are the evolution of form-factors of the larger amplitude transitions, and whether there is evidence for the Q^2 dependence predicted by perturbative QCD calculations. Among the specific issues which will be investigated in the present proposal are the anomalous decrease in the $P_{33}(1232)$ form factor with increasing Q^2 and whether the the E_{1+} multipole exhibits an increase at higher Q^2 . We will also investigate whether the anomalous evolution of the $S_{11}(1535)$ form factor continues at high Q^2 .

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I. Proposal Summary

It is proposed to measure exclusive single meson production on nucleons in the resonance region (W = 1.2 to 1.8 GeV) at high Q^2 ($Q^2 > 3$ GeV^2/c^2) using the CLAS spectrometer. The motivation is to study the evolution of resonance form factors and short range phenomena in a kinematic region which has never before been studied by exclusive reactions. A specific goal is to address the issue of the transition from the non-perturbative QCD (npQCD) regime , where theoretical descriptions have used non-relativistic, and relativized mean field models, toward those involving leading order perturbative QCD (pQCD). In the proposed experiment we will study the magnitudes, decay angular distributions, and Q^2 dependences for the most prominent resonances, ie. the $P_{33}(1232)$, $D_{13}(1530)$, $S_{11}(1535)$, and $F_{15}(1688)$.

This is a long range program which will incrementally make use of the maximum CEBAF electron beam energies, and the maximum acceptance and luminosity capabilities of the CLAS spectrometer. The initial measurements will utilize an electron energy of 4 GeV, and the initial complement of CLAS detectors, enabling us to accumulate data concurrently with the other approved N* experiments. We will investigate phenomena in the range of Q^2 from 3 to 4 GeV^2/c^2 . As the available acceptance and energy increase, studies will be extended to higher Q^2 . Typical kinematic intervals for sorting the obtained cross sections will be $\Delta Q^2 = 1$ GeV^2/c^2 and $\Delta W = 50$ MeV.

II. Physics Background

One of the fundamental problems in physics concerns the structure of baryons and their excitations in terms of elementary quark and gluon constituents. A central question relates to which models are valid for describing these excitations in different domains of Q^2. At low Q^2 (< 1 GeV^2/c^2), constituent quark models do a fairly good job of explaining the available data - sparse as they are (Bu-89, Ca-89). In the limit of very high Q^2, perturbative QCD descriptions should be valid. However, there is currently strong disagreement as to what domain of Q^2 corresponds to the transition from npQCD to pQCD descriptions. Some believe the transition may take place for Q^2 as low as a few GeV^2/c^2 (Br-89, Ca-89, Ga-86), while others maintain that the transition should occur in a much higher region of Q^2 (Is-89, Ra-90, Ne-83).

During the past several years, proton elastic scattering form factor data (Ar-86) have provided the primary focus for testing pQCD calculations. However, this body of data in itself has not diminished the controversy. To test theories in a systematic way and further constrain wave functions, measurements of the evolution of baryon resonance transition form factors at high Q^2 will be important.

The most significant feature of the inclusive electron scattering cross section in the resonance region, shown in Figure 1, is the existence of three broad maxima: the first,

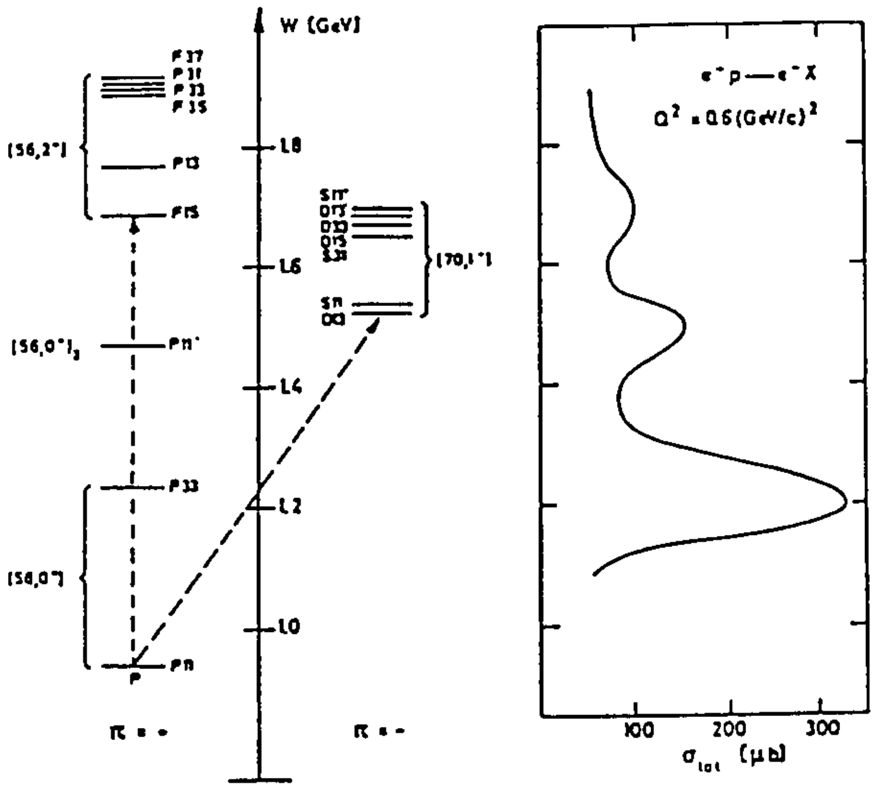

Figure 1. The virtual photon excitation curve for electron scattering at $Q^2 = 0.6$ GeV^2/c^2 , showing the known contributing resonances, and their SU(6) classifications (From Bu-89).

second and third resonance regions.

In this interval there are about 20 known non-strange resonances. The standard resonance notation is $L_{IJ}(W_R)$, in which L is the orbital angular momentum in the single pion decay channel, I and J are respectively the resonance isospin and spin, and W_R is its central invariant mass. The first maximum is due to the $P_{33}(1232)$ or $\Delta(1232)$ resonance. At low Q^2 the second resonance region is dominated by two strong negative-parity states, the $D_{13}(1520)$ and the $S_{11}(1535)$. Near $Q^2 \sim 0$ the $D_{13}(1520)$ dominates, whereas near $Q^2 \sim 2$ GeV^2/c^2) the $S_{11}(1535)$ becomes greater (Br-84) . In the third resonance region, the strongest excitation at low Q^2 is the $F_{15}(1680)$ state. The relative strength of the other states is not well determined, especially at increasing Q^2 .

The current experimental situation for the resonances is that there are no exclusive data for Q^2 above 3 GeV^2/c^2 , and in fact no published exclusive data above 1 GeV^2/c^2 Existing single-arm inclusive electron scattering data have recently been evaluated (St-91), and form factors extracted for the first, second and third resonance regions. The results are quite provocative.

Transverse resonance form factors G_T can be defined in analogy with elastic scattering form factors:

$$\sigma(W_R) = \frac{4\pi\alpha Q^2}{\Gamma M_R(W_R^2 - M_N^2)} G_T^2$$

where $\sigma(W_R)$ is the virtual photon cross section at the resonance energy W_R. The quantity Γ is the virtual photon flux factor.

Transition form factors for the three dominant resonances near W = 1232, 1535 and 1680 MeV, extracted as a function of Q^2 by fitting Breit-Wigner resonances together with a phenomenological background to existing inclusive data, are shown in Figure 2a relative to a dipole shape $G(Q^2)_{dipole} = 3/(1 + Q^2/0.71)^2$. Included in Figure 2 is the proton elastic form factor (Ar-86). Also shown at lower Q^2 are form factors extracted from data obtained from exclusive $(e,e',p)\pi^o$ and $(e,e',p)\eta$ experiments (Ha-79, Fo-83, Bu-91). Figure 2b shows the same data in the Q^2 range 0 to 5 GeV^2/c^2 . The interval covered in this proposal is indicated by the hatched area.

Form factors at high Q^2 can be factorized utilizing quark helicity conservation (Br-89, Le-80):

$$F(Q^2) = \int_0^1 \int_0^1 dxdy \; \Phi(x)^* \; T_H \; \Phi(y),$$

where $x = (x_1, x_2, x_3)$ and $y = (y_1, y_2, y_3)$ denote the longitudinal momentum fractions of the initial and final baryon state. Since quark helicity conservation in this case implies baryon helicity conservation F(Q) corresponds to the helicity conserving Dirac form factor F_1 in elastic scattering. The two main ingredients are the hard transition operator T_H, which is purely perturbative and the three-quark distribution amplitudes Φ, which reflect the non perturbative interaction of the quarks with the QCD vacuum.

The transition operator T_H to leading order in pQCD is determined by diagrams such as in Figure 3, where three quarks absorb the virtual photon and remain intact by the exchange of two hard gluons. This leads to the functional form

$$T_H = \frac{\alpha_s^2(Q^2)}{Q^4} f(x,y).$$

The form factor is then predicted to scale as Q^{-4}. There is also a logarithmic decrease due to the Q^2 dependence of the running coupling constant α_s, but this would presumably be observable only over a large range of Q^2 . One of the most controversial issues in theory

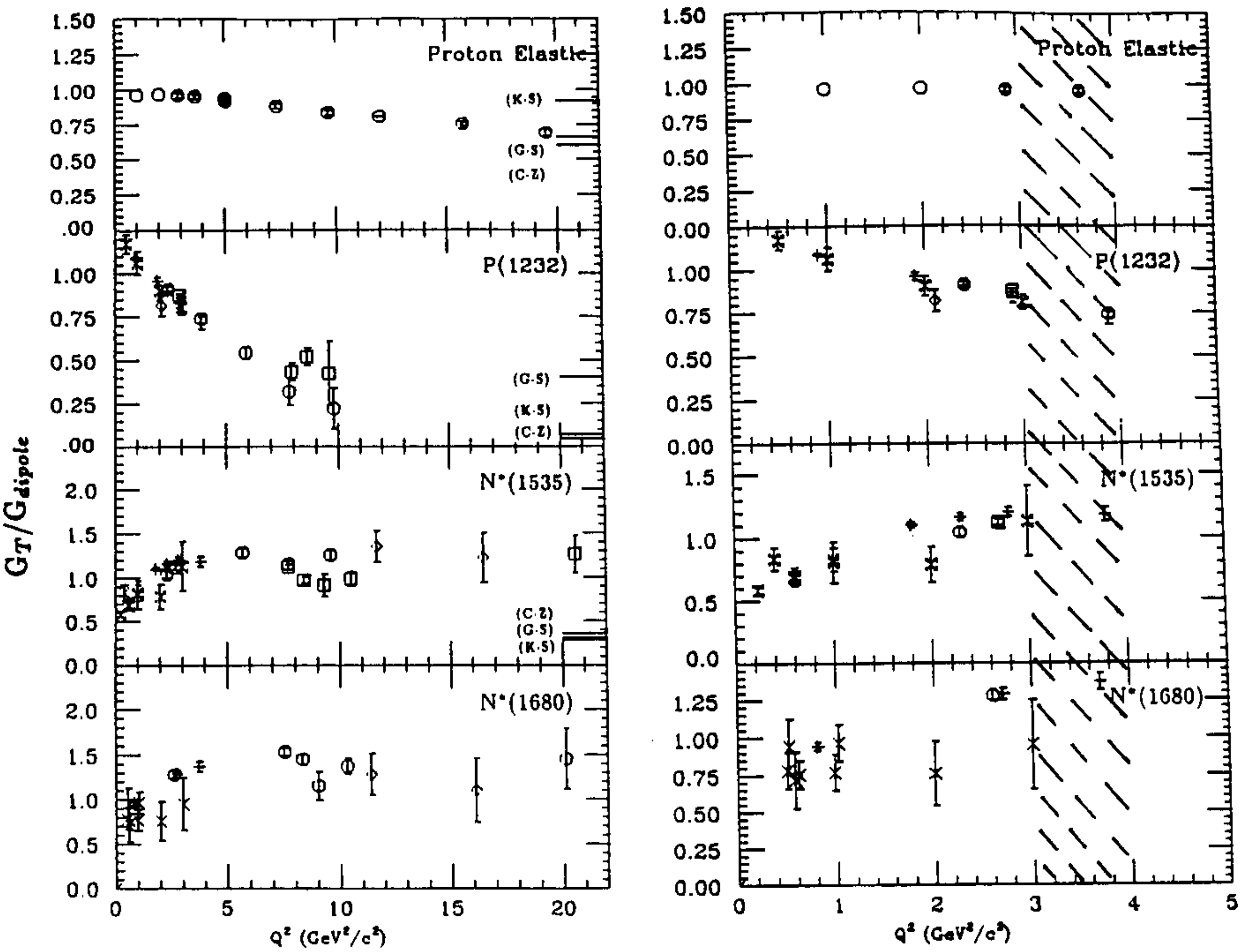

Figure 2a left. (a) The the transverse form factor divided by the dipole shape G_M/G_{dipole} verses Q^2 for elastic scattering from the proton. The data are from Ar-86. The solid curves are the results of calculations (Ji-87) at $Q^2 = 20$ GeV^2/c^2 using proton distribution functions C-Z (Ch-84), G-S (Ga-86), and K-S (Ki-87). (b - d) The analogous transverse form factors G_T/G_{dipole} verses Q^2 obtained in St-91 for transitions to the first, second and third resonances respectively, where $G(Q^2)_{dipole} = 3/(1 + Q^2/0.71)^2$. The first resonance (b) is the $\Delta(1232)$. The second resonance (c) at lower Q^2 ($\sim$ 3 GeV^2/c^2) is mostly due to the $S_{12}(1535)$. The third resonance at low Q^2 is dominated by the $F_{15}(1680)$. The resonance form factor G_T is defined in the text. The fits for G_T were based on available inclusive data reconstructed from data referred to in St-91. Also shown at lower Q^2 denoted by (×) are form factors derived from amplitudes obtained from exclusive $(e,e',p)\pi^0$ and $(e,e',p)\eta$ data, also referred to in St-91. The errors shown are statistical. **Figure 2b right.** The same as in Figure 2a left, but for a Q^2 range 0 to 5 GeV^2/c^2 . The hatched area is the extent of the presently proposed experiment.

concerns the use of a gluon effective mass in α_s, and whether such mass should also appear in the gluon propagator part of T_H.

In fact the elastic form factor G_M does appear to approach this behavior above $Q^2 \sim$

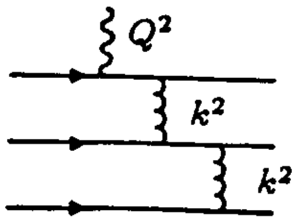

Figure 3. Example of a leading order diagram contributing to the perturbative hard scattering amplitude T_H.

5 GeV^2/c^2 out to the highest measured Q^2 ($\sim$ 35 GeV^2/c^2) (Ar-86). In Figure 2 the ratio $G_M(Q^2)/G(Q^2)_{dipole}$ is plotted rather than $Q^4G_M(Q^2)$ in order to better display the low Q^2 behavior. For high Q^2 the quantity $Q^4G(Q^2)_{dipole} \rightarrow$ const. This Q^2 behavior as well as the magnitude (see below) has been one of the key elements in support of the proponents of pQCD at lower values of Q^2 .

The second and third resonance transition form factors also appear to approach the predicted Q^{-4} behavior, within quite large statistical errors.

Generally, form factors may be expressed in terms of helicity conserving ($\lambda = 1/2$) and helicity non-conserving ($\lambda = 3/2$) parts. In the pQCD limit $G_{T(1/2)} \propto Q^2G_{T(3/2)}$. For the $D_{13}(1520)$ and $F_{15}(1680)$ resonances it is well known from exclusive electroproduction (Fo-83,Bu-89) that the helicity 1/2 amplitude becomes dominant over the helicity 3/2 amplitude already near a Q^2 of 1 GeV^2/c^2 . In fact, this is even predicted by low Q^2 constituent quark models. Figure 4 shows the separated helicity 1/2 and 3/2 form factors for the $D_{13}(1520)$, $S_{11}(1535)$, and $F_{15}(1680)$. Due to large statistical errors it is not clear whether $G_{T(1/2)}$ begins to exhibit the dipole shape at a small value of Q^2 . However, for the $D_{13}(1520)$ $G_{T(3/2)}$ becomes very small already in the $Q^2 \sim$ 1 to 2 GeV^2/c^2 range.

The $\Delta(1232)$ form factor decreases faster than Q^{-4} at all observed Q^2 . The reason for this anomalous behavior is not currently understood, however it has been suggested (Ca-88) that this may be due to the suppression of the leading order pQCD amplitude, and the dominance of higher order amplitudes at low Q^2 .

The **three quark distribution amplitudes** $\Phi(x)$ determine the form factor normalizations and signs. Using sum rule techniques nucleon distribution functions have been obtained by several groups (Ch-84, Ki-26, Ga-86), which can account for elastic proton magnetic form factor to within the uncertainties of the theory. The curves in Figure 2 are the results of a calculation (Ji-87) using three model distribution amplitudes. However, The form factor normalization in this range of Q^2 is one of the most controversial aspects of the theory since it depends on the nucleon distribution amplitude having a large asymmetry, and most of the elastic form factor comes from a small region near the kinematic

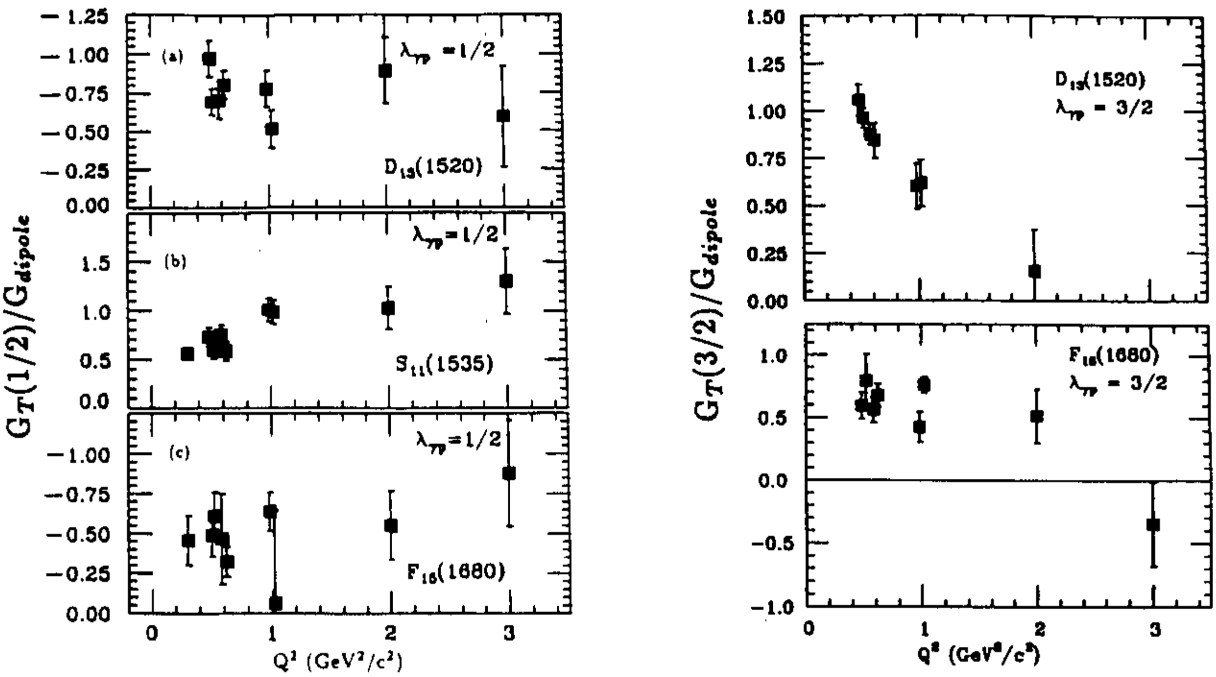

Figure 4. Left - the helicity 1/2 form factors G_T/G_{dipole} versus Q^2 , (a): the $D_{13}(1520)$. (b): the $S_{11}(1535)$. (c): the $F_{15}(1680)$. Right - the helicity 3/2 form factors The figure is from St-91. The form factors were constructed from helicity amplitudes given in Bu-90.

limits of x and y.

The elastic proton helicity conserving form factor is one of the few pieces of data available to challenge theory. Clearly, exclusive data on the individual resonances should be of great value in assessing conflicting theoretical approaches.

III Proposed Experimental Program

We propose to measure the form factors of the most prominent resonances over a range of Q^2 from 3 GeV^2/c^2 to the highest possible value obtainable at CEBAF. In particular, we will observe the kinematic regions where constituent quark models break down, and look for indications of the growing importance of perturbation phenomena. To separate individual resonances and their contributing electromagnetic multipoles requires angular distribution measurement of exclusive reactions such as $(e,e'\pi)$ and $(e,e'\eta)$. In addition to isolating resonances and separating their multipoles, exclusive angular distributions will yield a great deal of reduction of the non-resonant background through the selection of decay channel and decay angle kinematic space. With the CLAS spectrometer angular distributions for all excitation energies, over a significant range of Q^2 , for π°, π^+ and η are obtained simultaneously so that a large quantity of valuable data will be obtained. The neutral π° and η channels will be measured by detecting the protons in the kinematically complete $p(e,e'p)\eta, \pi^\circ$ reactions. The charged π^+ will be directly detected. The following are examples of the kind of information we will access.

The $P_{33}(1232)$ multipoles: The Q^2 behavior of the delta resonance remains a controversial puzzle. Figure 1. shows that the form factor decreases significantly as a function of Q^2 compared with that of the other states. At low Q^2 in a pure SU(6) constituent mean-field model the $N \rightarrow \Delta$ transition is purely M_{1+} involving a single-quark spin-flip. The addition of residual quark-quark color magnetic interaction 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 resonance structure and effects of gluons in the constituent quark model.

Beyond SI(6) the E_{1+}/M_{1+} ratio is is expected to increase steadily with Q^2 . Helicity conservation requires the helicity conserving ($\lambda = 1/2$) amplitude to dominate over the helicity non-conserving ($\lambda = 3/2$) amplitude. This implies the asymptotic equality $M_{1+} = E_{1+}$. Experimentally one finds at low Q^2 that $E_{1+} \ll M_{1+}$. A crucial test of our understanding of excited baryon structure, and the regions of validity of the extremely different models is to observe the expected increase in the E_{1+}/M_{1+} ratio.

The situation encountered here is quite different from those at low Q^2 . At low Q^2 the very small relative contribution of the E_{1+} component means that the only way to measure it is to observe its interference with the dominant M_{1+} multipole in a polarization experiment. On the other hand, when E_{1+} becomes comparable to M_{1+} the non-polarized pion angular distributions are very different than for a predominantly M_{1+} transition. A very recent evaluation (Bu-91) of the World's near $Q^2 = 3$ GeV^2/c^2 yields a value of $E_{1+}/M_{1+} = 0.1 \pm 0.08$, in other words, the ratio is consistent with values from 0 to about 0.2.

Figure 5 shows the calculated angular distributions for $E_{1+}/M_{1+} = 0.0$, 0.1 and 0.2 at Q^2 of 3 GeV^2/c^2 for π° production. One observes a significant sensitivity to the E_{1+}/M_{1+} ratio.

Also shown in Figure 5 is a simulated angular distribution expected in a running time of 1000 hrs under the proposed experimental conditions (see below for details). We expect to make a significant improvement in our knowledge of this all important ratio. At this value of Q^2 the cross section is large enough to provide excellent statistics, so that it will be especially important to get as low systematic uncertainties as possible.

Another very important feature in Figure 5 is that the underlying non-resonant Born terms are rather small for the π° channel, which would not be the case for the charged pion channels, where in fact the Born term contributions would always be large.

The $S_{11}(1535)$ form factor. This is one of the most interesting transitions to study. At low Q^2 the form factor has an anomalously small Q^2 decrease and appears to becomes dominant for Q^2 a few GeV^2/c^2, above which if begins to join onto a Q^{-4} behavior. In addition the $S_{11}(1530)$ is one of the few large resonances which has a strong coupling

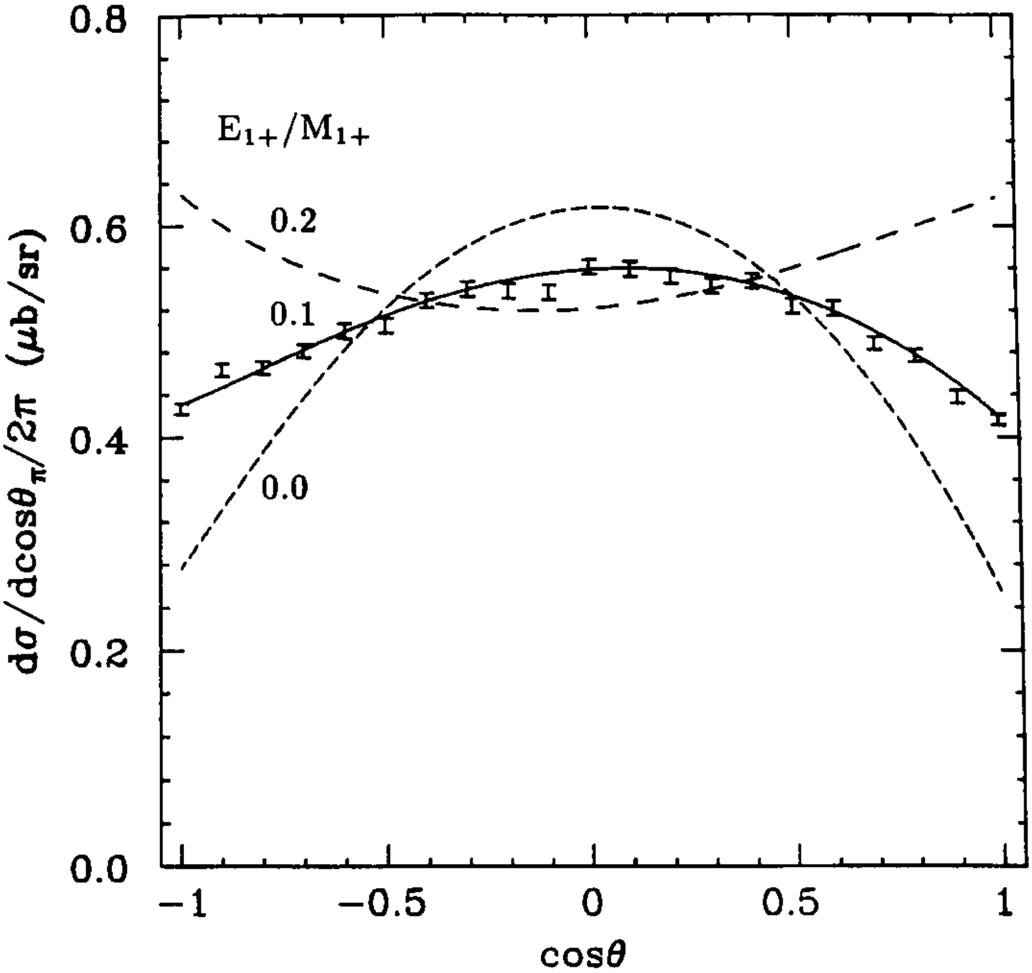

Figure 5. Angular distribution at the peak of the $\Delta(1232)$ at $Q^2 = 3$ GeV^2/c^2 under three assumptions for the contributing multipoles; $E_{1+}/M_{1+} = 0.0$, 0.1 and 0.2. The data is a simulation for 1000 hrs. of running, and reflects statistical fluctuations only. The kinematic intervals used were $\Delta Q^2 = 1$ GeV^2/c^2 , $\Delta W = 50$ MeV, and $\Delta\phi_\pi = 2\pi$. The electron beam energy was assumed to be 4 GeV, and the luminosity 1×10^{34} cm^{-2} s^{-1}. CLAS acceptances and efficiencies were folded in using codes by Ni-91 and Sm-89.

to the η decay channel. At lower Q^2 the reaction $p(e,e'p)\eta$ is totally dominated by s-wave production and exhibits a clear resonant behavior with only small non-resonant contributions (Br-84). For s-wave production the differential cross section contains only two terms.

$$\frac{d\sigma}{d\Omega_\eta} = \frac{|\vec{P}^*_\eta|\,W}{MK}(|\,A_{o+}\,|^2 + \epsilon\frac{Q_o^2}{\vec{Q}^2}\,|\,C_{o+}\,|^2)$$

where

$$K = \frac{W^2 - M_N^2}{2M_N}$$

and A_{o+} and C_{o+} are the Walker (Wa-69) helicity amplitudes. At smaller Q^2, experiments to separate σ_L/σ_T were performed, showing that the longitudinal coupling of the $S_{11}(1535)$ is very small. Therefore the resonant. transverse multipoles can be directly extracted from this data, with small corrections due to non-resonant contributions.

These experimentally attractive features will enable us to study this transition at a very early stage in the program.

The $P_{11}(1440)$, or Roper resonance, has been the the subject of considerable interest. In the non-relativistic quark model this state is in a $N = 2$ oscillator level with the same quantum numbers as the $N = 0$ nucleon. If it is largely a radial excitation of the nucleon it will be excited primarily by means of longitudinal photons. There has also been speculation that its P_{11} character makes it a candidate for the lightest hybrid baryon. At low Q^2 it is obscured by its proximity to the much more strongly excited delta, which of course is primarily transverse in character. On the other hand, it has been pointed out (Cl-78) if it is indeed an $N = 2$ excitation, the Roper resonance may become more strongly excited than states such as the D_{13}. Also, the Δ falls off quite a bit faster than the other strong resonances, perhaps leaving the Roper strongly enough excited to be cleanly separated from the S_{11} and Δ. If such a behaviour is not observed at high Q^2 , the Roper would be a candidate for the lowest mass hybrid baryon (Ca-91,Li-91).

It is further noted (Cl-89) that the ratio of the $\lambda = 1/2$ amplitudes due to neutron and proton excitation should be -2/3, if the transition were a magnetic excitation of the $(56, 0^+)$. Thus, data on this resonance will needed from a neutron target.

The extraction of longitudinal components of resonances would be extremely difficult with inclusive data. This is because the non-resonant contribution has a large longitudinal component due primarily to the pion-current, or "t" channel Born diagram which is present exclusively in the π^+ channel. With exclusive experiments, one avoids this by observing non-charged meson production (π°, or η). Since the "t" channel is forward peaked in pion angle, even for the π^+ channel, a great deal of background is eliminated by observing the pion emitted at backward angles.

The non-resonant contributions are in themselves physically interesting. Usually they are treated in terms of Born diagrams. At low Q^2 and low "t" they are dominated by the pionic current term, with "s" and "u" channels also contributing significantly. At higher Q^2 and "t", the "s" and "u" channels are expected to dominate. However, the Q^2 dependence rather appears to track the resonant Q^2 dependence. This phenomenon is known as the Bloom-Gilman duality (Bl-71). Recently, this has been discussed in the framework of QCD (Ca-90). The explanation seems to grossly account for this behavior, however one really needs a more reliable non-resonant separation to check the theory. It also would make sense to extend this to W > 2 GeV to see how it connects into the scaling region.

A proper treatment of the resonant channels will require a reliable description of the non-resonant channels.

IV Experimental Consideration

Counting rates. Limitations in counting rates are due to a combination of available incident electron energy , maximum angular acceptance of CLAS, and luminosity, since the form factors are rapidly decreasing with increasing Q^2 .

As with lower Q^2 , the goals are to obtain the amplitudes and multipoles for individual resonances. This decomposition will require angular distribution measurements of the exclusive meson decay channels. An important question is how far one can go with the CLAS, given its luminosity limitations. Assuming a luminosity of 1×10^{34} we have calculated global and differential rates for exclusive production of various mesons at high Q^2 at the peaks of the $P_{33}(1232)$, $P_{11}(1440)$, $S_{11}(1535)$, and $F_{15}(1688)$, for intervals ΔW = 50 MeV and $\Delta\ Q^2 = 1\ \text{GeV}^2$. Differential counting rates are for $\Delta\phi_\pi = 2\pi$. The CLAS acceptances were folded in employing locally developed codes (Sm-89, Ni-90).

Figure 5 shows a statistically simulated angular distribution of for the reaction $p(e,e'p)\pi^\circ$ at the peak of the Δ, at $Q^2 = 3\ \text{GeV}^2/c^2$ corresponding to the above conditions, based on 1000 hrs of running, assuming the initial CLAS configuration and an electron beam energy of 4 GeV. The rates are quite favorable, and would easily permit us to distinguish a pure M_{1+} transition from one containing a significant E_{1+}. At higher Q^2 the statistical accuracy diminishes, so this should be taken as a starting point.

The estimated resonance global counting rates for a 1000 hr experiment, for incident electron energy 4 GeV, and initial CLAS detector coverage (full coverage through $\theta_e = 45^\circ$, one sector between $\theta_e = 45^\circ$ through $\theta_e = 90^\circ$) are summarized in Table I. The main limitation in Q^2 is due to the scattered electron angle exceeding the Cerenkov detector coverage. If we require 5000 events as the minimum then we can make significant measurements on the $P_{33}(1232)$, $S_{11}(1535)$, and $F_{15}(1688)$ up to a Q^2 of about 4 GeV^2/c^2.

Event identification: Since the event rate for the proposed experiments will be a small fraction of the available data, an efficient sorting procedure will have to be implemented. The first level cut will be based on a Cerenkov signal at a rather large angle, indicating the candidacy for an electron involved in a high Q^2 process. Shower counter information should significantly reduce the pion contamination, especially at forward angles. Analysis of drift chamber analog information will also be a powerful tool, especially in the lower momentum regime (p $\sim$ .3 to 1 GeV/c) where the pion dE/dx is near its minimum, while the electron dE/dx has ascended to the fully relativistic value. An assessment of the role of Cerenkov detectors and drift chamber information on the CLAS, relating to experiments of the type proposed here is the subject of a CEBAF-CLAS report (St-89).

The final identification of the event will involve a missing mass reconstruction of the detected particles, thereby identifying the exclusive channel. For a proton target the exclusive single neutral meson channel is clearly isolated by detecting the recoiling proton, and reconstructing the missing mass of the undetected meson. This can be done quite unambiguously, with a moderate resolution ($\sim 10^{-2}$) detection system. Figure 6 shows an example of an experimental missing mass spectrum obtained at DESY (Br-84) in the study of the reaction $p(e, e'p)\eta$, using spectrometers with a typical resolution of $\delta p/p \sim 1\%$.

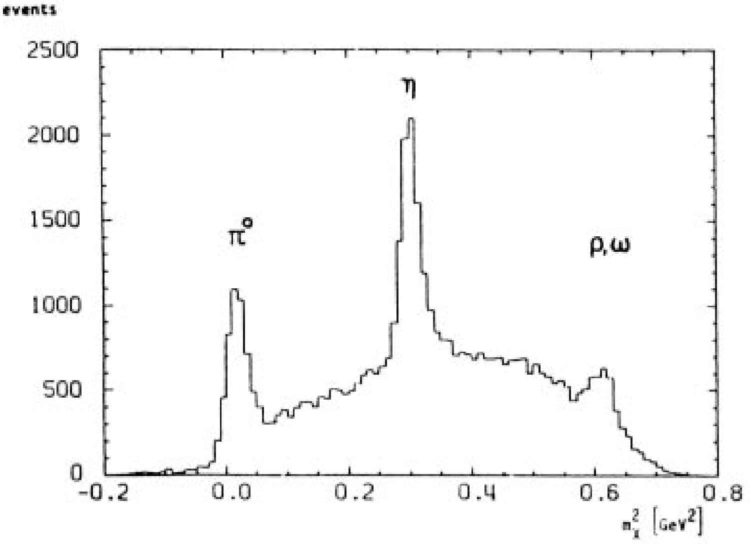

Figure 6. Missing mass spectrum for the reaction $p(e, e'p)X$ clearly showing the η, π^0, and ρ, ω peaks. Data from Br-84

Simulations of the potential effectiveness of this technique for the CLAS have been carried out using the acceptance codes for CLAS (Ni-91,Sm-89). Simulations at lower Q^2 indicate a favorable prognosis for employing this technique with the CLAS. The CLAS resolution will be approximately a factor of 2 better than in the DESY experiment. We therefore should expect a correspondingly improved signal to background ratio. Moreover, because of the large acceptance, certain event patterns may be vetoed against. For example, if one accepts losing about 2/3 of all η events, the signal to background ratio may be further improved, by accepting only events with no charged tracks, and eliminating events with more than two photons in the calorimeter.

This technique is also applicable for $\pi^{+/-}$ production, where the recoiling neutrons/protons are identified by their reconstructed masses.

****** $P_{33}(1.232)$ ******

Q^2 (GeV^2/c^2)	3	4	5
Rate/1000 hrs =	$.1\times 10^7$	$.2\times 10^6$	$.1\times 10^5$
π^o =	$.2\times 10^6$	$.5\times 10^5$	$.1\times 10^4$
π^+ =	$.8\times 10^5$	$.2\times 10^5$	$.5\times 10^3$

****** $P_{11}(1440)$ ******

Rate/1000 hrs =	*	$.3\times 10^5$	$.1\times 10^5$
π^o =	*	$.8\times 10^3$	$.2\times 10^3$
π^+ =	*	$.1\times 10^4$	$.6\times 10^3$

****** $S_{11}(1535)$ ******

Rate/1000 hrs =	$.3\times 10^7$	$.1\times 10^6$	$.4\times 105$
π^o =	$.6\times 10^5$	$.2\times 10^4$	$.6\times 10^3$
π^+ =	$.1\times 10^6$	$.7\times 10^4$	*
η =	$.3\times 10^6$	$.1\times 10^5$	*

****** $F_{15}(1688)$ ******

Rate/1000 hrs =	$.4\times 10^7$	$.1\times 10^6$	*
π^o =	$.7\times 10^5$	$.3\times 10^4$	*
π^+ =	$.2\times 10^6$	$.1\times 105$	*

Table I Estimated inclusive rates, and exclusive single meson angle integrated resonance rates, per 1000 hrs. at $Q^2 = 3$, 4 and 5 GeV^2/c^2. The rates were estimated at the resonance peaks for kinematic intervals dW = 50 MeV, and $dQ^2 = 1.0$ GeV^2/c^2 The electron beam energy is assumed to be $E_1 = 4$ GeV, and luminosity $= 1 \times 10^{34}$ $cm^{-2}s^{-1}$. The electron detection coverage is 45° for five sectors, and 90° for one sector of CLAS. Efficiencies were folded in using the code Fast-MC.

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