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Proposal Title

Deformation of the Nucleon

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CEBAF PROPOSAL
Deformation of the Nucleon

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Abstract

We propose to do an inclusive measurement $\vec{p}(\vec{e},e')$ in the region of the delta resonance. We plan to determine the longitudinal-transverse interference cross section via a measurement of the asymmetry A_{TL} to an accuracy of ± 0.01 using a polarized electron beam and polarized target. A_{TL} at the delta resonance is sensitive to L=2 amplitudes which can be related to the deformation of the nucleon wave function suggested by bag models.

1 Introduction

Pion photo- and electroproduction in the region of the delta resonance has become a topic of strong interest in recent years, the central issue being the presence (or absence) of an L=2 component in the quark wave function of the nucleon. The motivation for this interest goes back to the seventies when Glashow[1] and later Vento, Baym and Jackson[2] proposed that with a large D-state admixture in the nucleon wave function one can resolve the discrepancies encountered when calculating G_A/G_V, the SU(3) decay ratio (D+F)/(D-F) and the ratio $G_{\pi N\Delta}/G_{\pi NN}$ using the spherically symmetric quark model.

Spherically symmetric quark models have been quite successful in predicting a whole range of fundamental observables, such as the mass spectrum and the magnetic moments of baryons [3][4] and it is considered unlikely that the discrepancies are a basic deficiency of the model. In addition the presence of a deformed bag resulting in the addition of a D-state is made plausible by several model predictions. In potential quark models color magnetic effects from one-gluon exchange may lead to a mixing of S and D states [5]. In chiral bag models the pion couples to the quarks primarily at the poles of the nucleon spin. The pressure exerted by the pion at the poles leads to an oblate deformation of the nucleon [6]. It has been shown that in bag models a bag deformation leads to a lower ground state energy than the spherical solution [7]. In the Skyrme model, the $N_c \to \infty$ limit of QCD, the nucleon again acquires a significant deformation [8].

Unambiguous evidence for such a D-state is not easily obtained for the nucleon as its spin is 1/2. To date only indirect experimental indications exist for the presence of a deformation.

- The recent data on deep inelastic muon-proton scattering [9] appear to indicate that much of the proton spin is not carried by the valence quarks; it has been suggested [10] that part of the spin is due to $L \neq 0$ components, a possibility that one could hope to elucidate by a study of the D-state.

- The finite neutron charge radius may be taken as another indication of admixture of D-state in the nucleon [11].

A *direct consequence* of a D-state contribution in the nucleon wave function is that the electromagnetic transition of the nucleon to the delta ($N(938) \to \Delta(1232)$) can no longer be described by a pure magnetic dipole M1 spin-flip transition as is done in spherically symmetric quark models. Contributions from *longitudinal quadrupole* and *transverse quadrupole* amplitudes arise through $L = 2$ transitions. These amplitudes are measurable experimentally, and test the fundamental assumption of a D-state contribution in the nucleon wave function. One observable that is sensitive to the longitudinal $L = 2$ amplitude is the inclusive longitudinal-transverse cross section σ_{TL} of the $N \to \Delta$ transition which we propose to measure.

2 Theory

2.1 Formalism

The cross section for inelastic $\vec{p}(\vec{e},e')$ scattering with polarized proton and electron can be written with the well known expression

$$\frac{d^2\sigma}{d\Omega dE'} = \Gamma_T \cdot \left(\sigma_T + \epsilon\sigma_L + h(\sqrt{1-\epsilon^2}\sigma_{TT}\cos\theta^* + \sqrt{2\epsilon(1-\epsilon)}\sigma_{TL}\sin\theta^*\cos\phi^*)\right) \quad (1)$$

In this expression Γ_T denotes the virtual photon flux per electron and ϵ the polarization of the virtual photon. σ_L and σ_T are the longitudinal and transverse part of the cross section accessible without polarization. The new contributions denoted by σ_{TL} and σ_{TT} can only be measured using longitudinally polarized electrons defined with helicity h = +1(−1) for polarization parallel (opposite) to the direction of the beam. The angles θ^* and ϕ^* define the direction of the nucleon spin with respect to the direction $\vec{q}$ of the virtual photon as illustrated in figure 1.

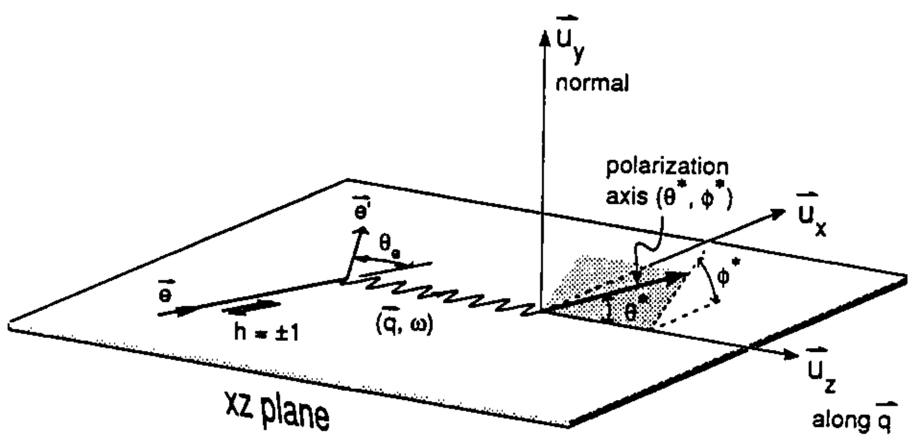

Figure 1: Coordinate system for $\vec{p}(\vec{e},e')$ with orientation of polarization axis shown.

If the direction of the nucleon spin is in the scattering plane ($\phi^* = 0$) the asymmetry

$$A = \sqrt{1-\epsilon^2}A_{TT}\cos\theta^* + \sqrt{2\epsilon(1-\epsilon)}A_{TL}\sin\theta^* \quad (2)$$

is measured in $\vec{p}(\vec{e},e')$ scattering. The two asymmetries A_{TL} and A_{TT} relate to the interference cross sections via

$$A_{TL} = \frac{\sigma_{TL}}{(\sigma_T + \epsilon\sigma_L)} \quad (3)$$

and

$$A_{TT} = \frac{\sigma_{TT}}{(\sigma_T + \epsilon\sigma_L)}. \quad (4)$$

As A_{TL} is an interference term of the longitudinal and the transverse response, A_{TL} is sensitive to small scalar amplitudes; the contribution of the small term is enhanced by the dominant transverse term. With the appropriate choice of the direction of the nucleon spin it is possible to separate the two interference terms A_{TL} ($\theta^* = 90^o$), from A_{TT} ($\theta^* = 0^o$).

Such a situation is found in the region of the Δ-resonance. The response is dominated by the transverse magnetic dipole form factor G_M whereas the longitudinal response with a possible non-zero quadrupole charge form factor G_C is small and cannot be measured without the use of polarized beam and polarized target. However with a measurement of A_{TL} the assumption of a nonzero G_C contribution can be tested due to the enhancement via the interference term.

2.2 Status

To date no data exist for A_{TL}. Only estimates based on the positivity limit $|A_{TL}| \leq \sqrt{R}$ with R = σ_L/σ_T can be made. The only inclusive separated data on the delta resonance which can give such an estimate on R have been taken at Bonn [12] and are displayed in figure 2. These data were taken with the intent to extract information on the large M1 amplitude via a Rosenbluth separation. No statements can be made about the small σ_L-term given the large errors of the data and the systematic errors that enter as a consequence of the method employed. The Bonn data in this figure are in good agreement with a recent calculation of S. Nozawa and T.-S.H. Lee [13].

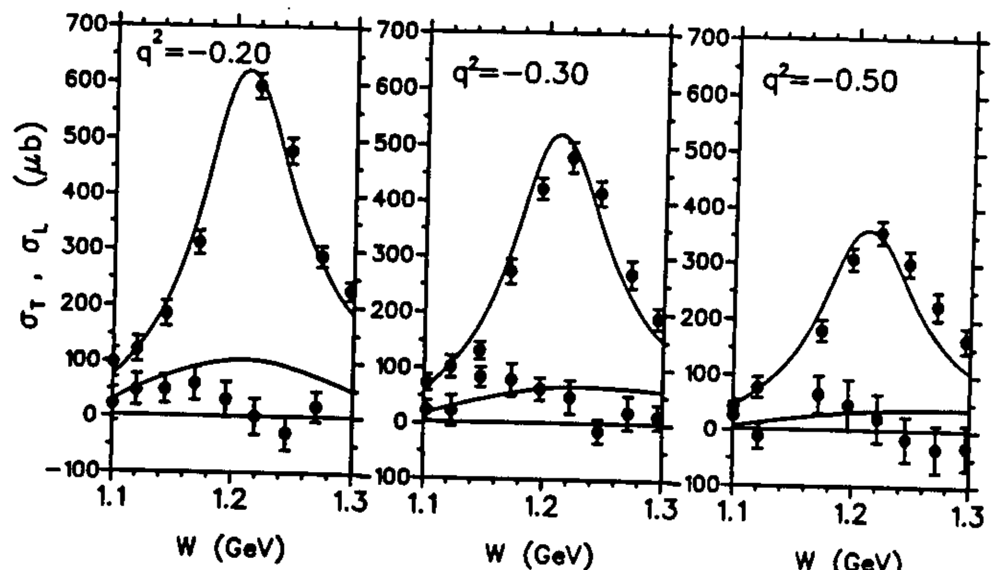

Figure 2: Inclusive separated data from reference [12]. the solid line is the calculation of S.Nozawa and T.-S.H. Lee.

An approved proposal for Hall B[14] describes an experiment that also plans to extract information on the interference terms. The focus of the Hall B proposal is on the transverse-transverse interference term A_{TT}, and not on A_{TL} aimed at here, as the polarized target has to be oriented with its spin parallel to the beam. In this case A_{TT} dominates by far. Due to this specific setup data on A_{TL} will have rather large errorbars $\geq$0.1 which are not sufficient to put significant limits on the G_C-contribution.

2.3 Relation to Exclusive Measurements

Exclusive p(e,e'p) and p(e,e'π^+) experiments have been usually analyzed in terms of a multipole decomposition. In the notation of Alder[15] the response in the delta region in particular for the p + π^o channel is dominated by the magnetic dipole amplitude M_{1+}, with 1+ referring to the relative angular momentum and the total angular momentum $j = l \pm 1/2$ of the p + π-system. In this notation a possible resonant quadrupole transition would contribute to the scalar S_{1+}-amplitude and the transverse E_{1+}-amplitude only. In the approximation that the process is determined by M_{1+}, E_{1+} and S_{1+} only, A_{TL} and A_{TT} can be written as

$$A_{TL} = \frac{\sqrt{\rho}(Re(S^*_{1+}M_{1+}) - 3Re(S^*_{1+}E_{1+}))}{\epsilon \cdot \rho \cdot 4S^2_{1+} + M^2_{1+} + 3E^2_{1+}} \tag{5}$$

$$A_{TT} = \frac{(|M^2_{1+}| - 3|E^2_{1+}| + 6Re(E^*_{1+}M_{1+}))}{\epsilon \cdot \rho \cdot 8S^2_{1+} + 2M^2_{1+} + 6E^2_{1+}} \tag{6}$$

with $\rho = Q^2/q^2 \cdot (W/M)^2$ and M the nucleon mass. One can see immediately that A_{TL} is proportional to S_{1+} whereas A_{TT} is primarily determined by the dominant $|M^2_{1+}|$-term. Thus A_{TL} is clearly the preferred observable to study the effects of a quadrupole contribution. We note however that the S_{1+}-amplitude is not due to resonant contributions alone. Non-resonant terms also contribute to S_{1+}. This "background" will be discussed further in 2.4.

A rather limited set of data on S_{1+}/M_{1+} and E_{1+}/M_{1+} has been obtained from $p(e,e'p)\pi^o$ coincidence experiments [16] [15]. These data indicate that S_{1+}/M_{1+} is ≈ -5 to -10%. However, the data show significant discrepancies as a function of Q^2 and their accuracy is limited by systematic errors. No statement about a possible resonant S_{1+}-term can be made. One should keep in mind that all these measurements were taken in order to establish the general behaviour of nucleon resonances. They predate the theoretical considerations outlined in the introduction.

A number of exclusive measurements planned or in progress are expected to improve this situation. Measurements of the type $p(\vec{e},e'p\gamma)$ [17] and $p(\vec{e},e'\vec{p})\pi^o$ [18] are planned at Bates. Similar plans for a $p(\vec{e},e'\vec{p})\pi^o$ experiment exist also in Mainz[19]. These experiments are however restricted to very low Q^2 ($Q^2 \leq$ 0.12 GeV/c^2) were the contribution of G_C is small. Only the $p(e,e'p)\pi^o$ [20] and $p(\vec{e},e'p)\pi^o$ [21] experiments proposed by the Hall B collaboration as well as the conditionally approved $p(\vec{e},e'\vec{p})\pi^o$ measurement at Hall A[22] will produce data in the delta region in the range $Q^2 \leq 2$ GeV/c^2. Determining the resonant part from the measured S_{1+}-amplitude will not be easy as it has been demonstrated[23] that this separation is to some extent model dependent in particular at high Q^2.

The measurement of A_{TL} proposed here is complementary to the exclusive measurements as different interference terms contribute. In the exclusive measurements not only the S_{1+} amplitude interferes with the dominant M_{1+} term. For inclusive data angular momentum considerations imply that S_{1+} is the only multipole amplitude that interferes with M_{1+} in A_{TL} [24], hereby suppressing other small contributions. A_{TL} measures basically $Re(S^*_{1+}M_{1+})$ thus enhancing the resonant contribution of S_{1+} which has the same phase as M_{1+} (which at resonance is purely imaginary).

Also, final state interactions (FSI) are expected to contribute less in the inclusive measurements as is generally the case. This will be discussed in the next section. Here we only want to quote T.W.Donnelly [24] who made an early study of $\vec{p}(\vec{e},e')$:

"The merits of using inclusive electron scattering with polarizations to complement the exclusive (coincident) reactions with their accompanying final state interactions should be clear".

2.4 Sensitivity and Background

We now want to illustrate the sensitivity of A_{TL} to G_C and discuss the contribution of non-resonant background terms and FSI to A_{TL} in the framework of the model developed by S. Nozawa and T.-S.H. Lee[13, 25]. This microscopic model is gauge invariant and unitary and includes for the first time effects fro- -shell FSI. In figure 3, 4 and 5 we show A_{TL} as a function of Q^2 at the peak, belo (W=1100 MeV) and above the Δ-resonance (W=1300MeV)[26].

At the peak of the Δ (figure 3) we see the large contribution of the resonant G_C form factor which increases with increasing Q^2. We emphasize that A_{TL} is actually sensitive to the ratio G_C/G_M which makes the measurement independent of the normalization and thus less model dependent. From figure 3 we infer that a measurement of A_{TL} to ± 0.01 allows to test contributions of G_C/G_M at the 2% level.

In a measurement of A_{TL} we do not separate the two isospin channels $p + \pi^o$ and $n + \pi^+$. It is known that threshold non-resonant contributions are particularly important in the $n + \pi^+$-channel (pion pole and contact term). Thus non-resonant contributions are present at a significant level even at resonance as indicated by the dashed line in figure 3. In the wings of the resonance (figure 4 and 5) the response is almost uniquely determined by the non-resonant terms with a negligible contribution of G_C. Given that these non-resonant contributions are structureless across the resonance a determination in the wings will allow to constrain models of these "background" terms across the entire resonance and allow an accurate estimate at the Δ-peak.

Figure 6 shows the effect of FSI to A_{TL}. As expected the effects are small over most of the Q^2-range. This has to be compared with exclusive measurements where FSI can change the cross section by up to a factor of two[13] whereas the effect of a finite G_C/G_M of 15% changes the cross section by typically $\sim$10%.

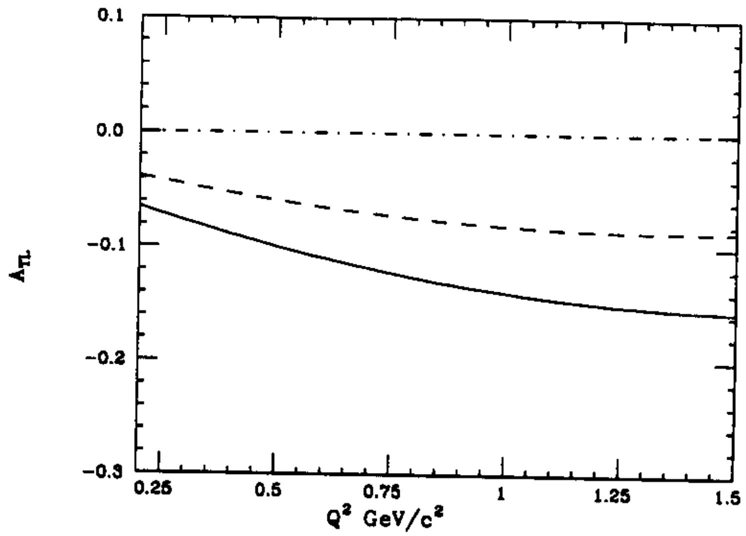

Figure 3: Prediction of A_{TL} with the model of S.Nozawa and T.-S. H. Lee for an invariant mass W = 1220 MeV as a function of Q^2. The solid and the dashed line are full calculations with G_C/G_M = -15% and 0% respectively. We also draw the zero line (dashdot) which would correspond to the trivial case of a pure Δ-term with $G_C = 0$.

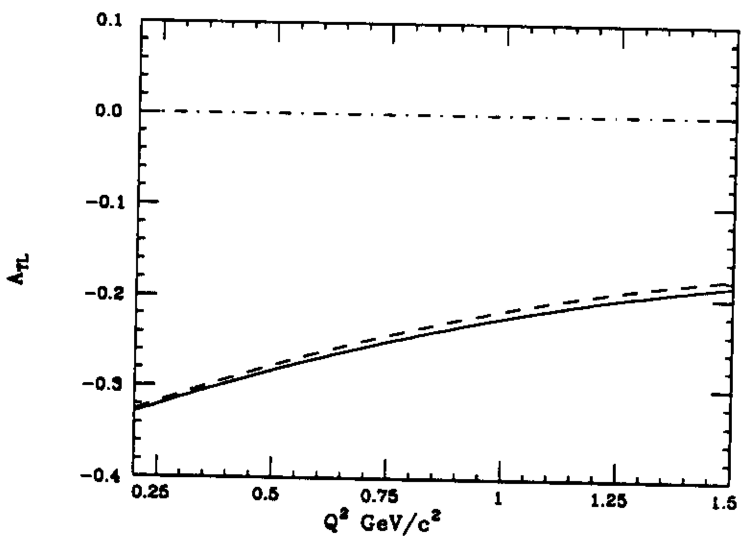

Figure 4: Same as figure 3 at W = 1100 MeV, 130 MeV below the resonance.

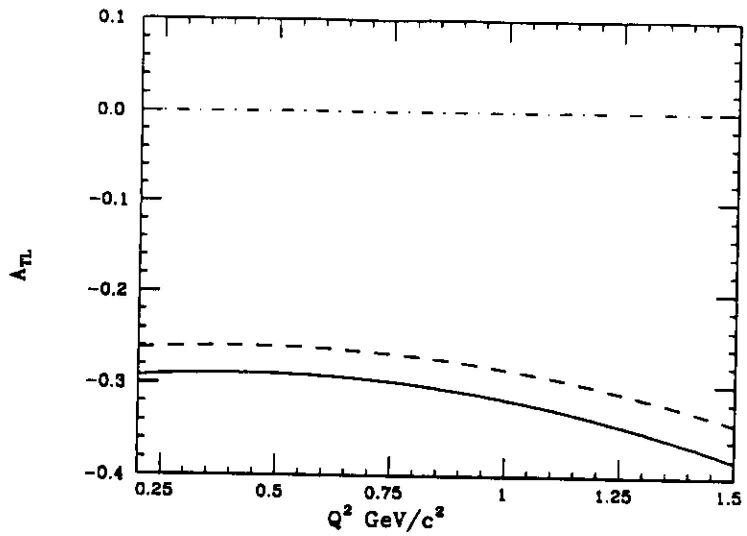

Figure 5: Same as figure 3 at W = 1300 MeV, 70 MeV above the resonance.

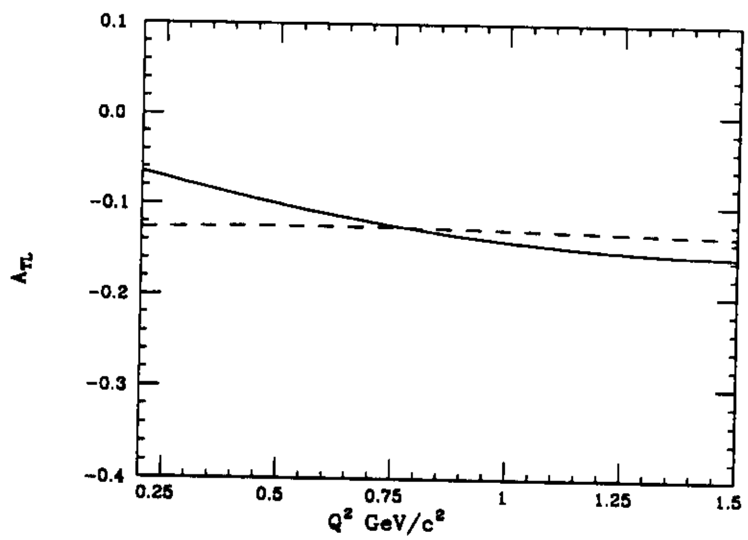

Figure 6: A_{TL} as a function of Q^2 at W=1220 MeV. The solid line is again the full model Nozawa and Lee; the dashed line indicates the result without the off-shell rescattering contribution.

3 Experiment

We propose to perform an inclusive measurement of the asymmetry A_{TL} defined in 2.1 across the Δ-resonance in the Q^2 range of 0.2 - 1.4 GeV/c^2. The nucleon spin will be aligned in the electron scattering plane, and perpendicular to $\vec{q}$, the direction of the virtual photon. The measured asymmetry is then written as

$$\epsilon_{exp} = \frac{N^+ - N^-}{N^+ + N^-} = P_e \cdot P_p \cdot f \cdot A_{TL} \tag{7}$$

with N^+ and N^- being the normalized counts for beam polarization along and opposite to the beam direction. P_e (P_p) denote the polarization of the electron beam (proton target). The dilution factor $f = N_{pol}/N_{tot}$ arises from the presence of unpolarized nuclei in targets that are a mixture of polarizable and unpolarizable material such as NH_3. It is defined as the ratio of interactions with the polarized protons to the total number of interactions.

The main advantage of the experiment proposed here is due to the exploitation of polarization observables. For a measurement of the asymmetry, only the electron spin has to be flipped. Change of the target polarization via a change of the RF frequency may only be desirable as a check. The target magnetic field never needs to be reversed.

Under these circumstances, the experience with polarized hadron beams shows that extremely small systematical errors can be achieved. The main uncertainty in the asymmetry, besides statistics, will come from the knowledge of target polarization and beam polarization. We will show that neither of these systematical errors will be a limiting factor.

3.1 Setup and Kinematics

We plan to carry out the measurements in Hall C and use the apparatus that is *identical* to the one discussed in the proposal of our collaboration to measure G_{en} via $\vec{d}(\vec{e}, e'n)$ [27]. In particular we plan to use the polarized $^{15}NH_3$ target that has been built by the Basel/UVa collaboration and is being used in experiment E143 at SLAC which will run in fall 1993. To compensate the strong target holding field, we also will use the chicane system that is designed for the G_{en}-experiment. For detection of the scattered electron we also will use the high momentum spectrometer (HMS). For details of target, spectrometer, polarimetry and beam transport system we refer the reader to the referenced proposal. The only difference to the G_{en}-proposal is the reduced complication in that no neutron detection is needed in the present measurement.

The polarized $^{15}NH_3$ target will be able to point the direction of polarization to an "arbitrary" angle in the scattering plane. To minimize the contribution of A_{TT} the polarization of the target has been chosen to be perpendicular to the angle of $\vec{q}$. Though possible, it is not practical to change the angle of the target polarization for every kinematic setting. Thus the kinematics has been designed with the constraint to keep the angle of $\vec{q}$ as constant as possible over the entire Q^2-region of the Δ resonance. With an incident energy of 2.5 GeV for the low Q^2-points, and 4 GeV for the high Q^2-points, and an angle of the target polarization of 50°, this could be realized with a maximal deviation from the optimal kinematics ($\vec{q} \perp \vec{P}_p$) of 2° only. However in the wings of the spectrometer acceptance there are significant deviations of several degrees. We will discuss this point in more detail below.

The HMS for the electron will be used in its standard configuration i.e. a solid angle of 6.4msr, a momentum bite of ±10% and a momentum resolution of 10^{-3}. The large momentum bite allows the entire delta resonance to be covered in one spectrometer setting. This also allows to cover simultaneously the response function up to values of 1400 MeV in invariant mass, close to the so called second resonance region.

With these considerations we designed the kinematics shown in table 1. Listed are Q^2, the incident (scattered) electron energy E(E'), the photon polarization ϵ the angle of the $\vec{q}$-vector θ_q and the invariant mass range covered with the acceptance of ±10%. The kinematical parameters are given for an invariant mass W = 1232 MeV.

Q^2 $(GeV/c)^2$	E GeV/c	E' GeV/c	W - W GeV	ϵ	Θ_e deg	Θ_q deg
0.21	2.5	2.044	1.08 – 1.40	0.96	11.62	-39.56
0.40	2.5	1.942	1.08 – 1.40	0.93	16.48	-40.85
0.60	2.5	1.837	1.08 – 1.40	0.89	20.80	-39.79
0.80	2.5	1.731	1.08 – 1.40	0.86	24.81	-38.01
1.00	4.0	3.125	1.08 – 1.50	0.93	16.25	-41.17
1.20	4.0	3.019	1.08 – 1.50	0.92	18.13	-39.71
1.40	4.0	2.913	1.08 – 1.50	0.90	19.96	-38.23

Table 1: Kinematics

Before we discuss rates and running times we want to address the contribution of the ^{15}N-Background and the contribution of A_{TT} at low and high invariant mass.

3.2 ^{15}N-Background

To extract A_{TL} from the measured asymmetry ϵ_{exp} we need to know the dilution factor f (see eq 7). Contrary to the G_{en} and the G_{ep}-measurements, where the different responses of Nitrogen and Deuteron(Proton) enhance the dilution factor, the contribution in the resonance region is of the same order for all nucleons and thus $f \sim 3/18$. To determine the contribution of Nitrogen we plan to take data using a pure unpolarized ^{15}N-target. The relative normalization of the two targets can be measured at low energy loss, beyond the elastic peak of the protons. Even for a small dilution factor of order 3/18 these measurements will allow to determine f with sufficient precision ($\leq 2\%$) in a short amount of running time. Detailed running times will be presented in 3.4.

The Nitrogen in the NH_3-target is partially polarized due to the unpaired proton in ^{15}N. Thus the presence of ^{15}N not only dilutes the polarization of the hydrogen but also contributes to the asymmetry. The polarization of this unpaired proton is known to be about 0.16 for a proton polarization of 0.9[28]. Taking into account the dilution factor for this polarized ^{15}N proton, assuming again that all nucleons contribute equally ($f_N = 1/18$), an effective polarization of 0.009 results. Under the resonable assumption that A_{TL} is similar for the free proton and the bound ^{15}N-proton we expect a relative $\pm 1\%$ correction to the measured asymmetry.

We note that the subtraction of this ^{15}N contribution a priori is not needed. The physics of the ^{15}N asymmetry is, except for the small contribution of the quasielastic tail[29], the same as the one of the proton, only folded with the Fermi motion (which hardly matters for a peak as wide as the one of the Δ).

3.3 Contribution of A_{TT}

As mentioned in 3.1 the contribution of A_{TT} can only be eliminated completely at one specific value of the invariant mass W which we selected to be the delta peak. However at extreme values of the accepted W-region of the HMS (see table 1) the deviation is typically $\sim 7^o$. Assuming a realistic estimate for $A_{TT} \leq 0.5$ this gives a contribution of 0.05 to the measured asymmetry A for the extreme acceptance region.

In order to avoid introducing model-dependent calculated corrections, we plan to take data also for A_{TT}. For this measurement we will point the target polarization along the direction of the beam and take data under otherwise identical conditions as listed in table 1. This change of polarization angle, which takes about 16–24 hours, has to be done only once during the experiment. The chicane system will not be needed for these measurements as the incident beam is not affected by the target holding field. The chicane system allows to run the electron beam unaffected, and no mechanical modifications are needed. Based on the maximal contribution of 0.10 we plan to determine A_{TT} to 0.05 – 0.08 depending on the kinematics. Such a determination will allow to correct for A_{TT} to better than the statistical error of A_{TL}. We note that the optimal way of measuring A_{TT}, with $\vec{P}_p \| \vec{q}$ is not possible as the scattered electron would be blocked by the magnet coil of the target.

A measurement of A_{TT} is interesting on its own. In inelastic scattering A_{TT} is directly related to $\sigma_{1/2} - \sigma_{3/2}$ where $\sigma_{1/2}$ and $\sigma_{3/2}$ are the virtual photon-nucleon absorption cross sections with photon plus nucleon helicity 1/2 and 3/2, respectively. This structure function has been measured recently at CERN[9] at large Q^2; the observation that the associated sum rule is too small has lead to numerous speculations about the spin structure of the proton. It also has renewed the interest in the Drell-Hearn-Gerasimov sum rule (DHG) for $Q^2 = 0$ [30, 31] which has a large negative value. The Q^2-evolution of this sum rule, which has to change from the large negative value at $Q^2 = 0$ to a small positive result as found by the CERN group at high Q^2, is crucial for an understanding of the spin structure of the proton in the non-perturbative domain of QCD. Recent studies [32] have shown that the Q^2-evolution is dominated by contributions of the Δ-resonance in the Q^2-region of the present proposal. Thus an accurate measurement allows a study of this evolution.

3.4 Rates

The running conditions relevant for the rate estimate are summarized in table 2. The $^{15}NH_3$ target is designed to stand a beam current of 100nA on a 2.5cm target cell, resulting in a luminosity of $7 * 10^{35}$ (nucleons $cm^{-2} * sec^{-1}$). It is assumed that HMS can handle a rate of ~2kHz which means that for the lowest Q^2-point the luminosity has to be reduced by a factor of 2.5.

The target polarization is expected to be 0.9, resulting in an effective polarization of 0.15 due to the dilution of the unpolarized nucleons in nitrogen.

Solid Angle of HMS	6.4 msr
Momentum Acceptance	±10%
Angular Range	11.5° - 30°
Beam Current	100 nA
Beam Polarization	0.5
Target Polarization	0.9
Target Length	2.5 cm

Table 2: Assumed Run Conditions

For the cross section estimate, a parameterization of the inelastic p(e,e') cross section by A.Bodek [33] that fits the existing data is used. The running times are calculated with the following expression

$$t = (Rate \cdot (P_e \cdot P_p \cdot f \cdot \Delta A_{TL})^2)^{-1} \tag{8}$$

An absolute statistical error of order ±0.01-0.02 in ΔA_{TL} with a bin size in ΔW of 30 MeV is assumed in the calculation of the running times. Within the frame work of the model of Nozawa and Lee this corresponds to a sensitivity of ~0.02 in the charge form factor contribution. In table 3 we list the statistical accuracy for one W-bin which varies slightly with Q^2. The variation takes into account the increasing contribution of the transition charge form factor with increasing Q^2. The indicated rates are the total rates integrated over the ±10% acceptance. Included in the table are also the running times and the statistical errors for the A_{TT} measurements as well as the running times for the ^{15}N contribution.

Table 3 shows that in a short time an important measurement can be done over a large Q^2-range. This is important as QCD calculations become increasingly feasible

Q^2 $(GeV/c)^2$	Total Rate Hz	ΔA_{TL}	Acc. Time $(\vec{P}_p \perp \vec{q})$ hr	Acc. Time $(\vec{P}_p \| e-beam)$ hr	Acc. Time ^{15}N hr
0.21	2248	0.012	10	2	1
0.40	1193	0.012	10	2	1
0.60	361	0.013	20	3	2
0.80	134	0.014	40	4	4
1.00	309	0.013	55	6	6
1.20	156	0.016	65	7	7
1.40	84	0.018	80	8	8
Total Running Times			280	32	29

Table 3: Rates and Running Times assuming a Beam Polarization of 0.5

at higher Q^2. We will outline in the next section that, with an increase in beam polarization, an additional extension in Q^2 is possible.

The short amount of running time compared to the inclusive measurement proposed by the Hall B collaboration [14] ($\sim$ 1200 hours) is due to the fact that in the present proposal one is not limited by an open detector arrangement; one thus can make use of the full current that is allowed by the polarized target (100nA). This is an increase of $\sim$40 in luminosity compared to an open detector arrangement and allows a very precise measurement of the inclusive asymmetries.

The main systematic errors which have to be added to the statistical accuracy are the accuracy of beam and target polarization. As described in the G_{en}-proposal[27] we will measure the beam polarization to better than $\pm 3\%$ using Moller polarimetry. The target polarization will be known with an accuracy of $\pm 5\%$. The absolute combined systematic error assuming $A_{TL} \leq 0.3$ will be of order 0.015, and thus is of similar order as the statistical error proposed.

3.5 Options and Future Extensions

We note that the planned increase of the beam polarization from 0.5 to 0.8 (with stressed photocathodes) would reduce the running time (which is already low) even further, or – more interestingly – would allow to extend the Q^2-range to 2.3 GeV/c^2 in the *same* running time. In table 4 we present the rates and running times for this alternative.

As a possible future extension we note that without significant modifications one can easily extend these measurements to higher invariant mass and study the second and third resonance region. With the large acceptance of the HMS one could extend the region to W $\sim$ 1.8 GeV with *one* additional setting only, and thus cover most of

Q^2 $(GeV/c)^2$	Rate Hz	ΔA_{TL}	Acc. Time $^{15}NH_3$ hr	Acc. Time $^{15}NH_3$ hr	Acc. Time ^{15}N hr
0.21	2248	0.012	4	1	1
0.40	1193	0.012	4	1	1
0.60	361	0.013	8	1	1
0.80	134	0.014	16	2	2
1.00	309	0.013	22	2	2
1.20	156	0.016	26	3	3
1.40	84	0.018	32	3	3
1.70	36	0.020	45	5	5
2.00	17	0.026	55	6	6
2.30	8	0.030	68	7	7
Total Running Times			280	31	31

Table 4: Rates and Running Times assuming a Beam Polarization of 0.8

the resonance region. In particular, these measurements would allow to study the properties of the relatively unknown "Roper" resonance which, due to the suggested large longitudinal cross section, is expected to give significant contribution to A_{TL}.

4 Beam Time Request

Based on the estimates given in table 3 we need a total of 340 hours for data taking to perform this measurement. In addition we need time for the change of the target polarization angle, determination of the beam polarization and annealing of NH_3. We add a contingency time for unforeseen difficulties, additional calibrations, etc. The beam time request is summarized in the following table.

Data taking	340 hours
$\vec{e}$ polarimetry	50 hours
Change of P_p angle	25 hours
Material annealing	50 hours
Contingency	85 hours
Total	550 hours

Table 5: Beam Time Request

5 Conclusions and Commitment of Participants

In this proposal we have shown that it is possible to do an important measurement of A_{TL} –which is sensitive to the longitudinal quadrupole contribution of the $N-\Delta$ transition– in the Q^2-range of $0.2 - 1.4(GeV/c)^2$ at CEBAF using a 2.5–4 GeV longitudinally polarized electron beam and a polarized hydrogen target. The required spectrometer, beam and target can be expected to be available shortly after turn on of CEBAF. An experiment of fundamental interest can therefore be done at an early stage.

As mentioned already, the experiment outlined in this proposal is not a "stand-alone" experiment. It depends on the hardware (polarized target, chicane, beam polarimeter) to be developed for the G_{en}-experiment proposed by the same collaboration. As should be clear, the G_{en}-experiment is the prime motivation for undertaking the difficult development of a polarized target. It may be likely, however, that this Δ-experiment would be carried out *before* the G_{en}-experiment. It uses strictly the same target and spectrometer, but is less complicated due to its single arm nature and the absence of a neutron detector. To a degree, this Δ-experiment might be seen as a "tune-up" experiment for the measurement of G_{en}.

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