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A. TITLE:

The Transverse and Longitudinal Response Functions for Quasi Elastic Electron Scattering in the Momentum Transfer Regime $0.3 \leq Q^2 \leq 1.5\ (\mathrm{GeV}/c)^2$

B. CONTACT PERSON:

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

- [x] YES
- [ ] NO

IF YES, TITLE OF PREVIOUSLY SUBMITTED LETTER OF INTENT

The Transverse and Longitudinal Response Functions For Several Nuclei at Momentum Transfers $0.3 \leq Q^2 \leq 1(\mathrm{GeV}/c)^2$

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

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contact: Meziani

A Proposal for a **Precision Measurement** of

The Transverse and Longitudinal Response Functions for Quasi Elastic Electron Scattering in the Momentum Transfer Regime $0.3 \leq Q^2 \leq 1.5(GeV/c)^2$

submitted to

The Nuclear Physics Program at CEBAF

by

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ABSTRACT

We propose to perform a **precision measurement** of inclusive electron scattering cross sections in the quasielastic region at different scattering angles and for several nuclei (^2H,^{3}He, ^{4}He, ^{12}C, ^{27}Al, ^{56}Fe and ^{208}Pb). We will extract the longitudinal and the transverse response functions at momentum transfers in the range $0.5 \leq Q^2 \leq 1.5(GeV/c)^2$ with a precision of few percents (between 1% and 12% for the longitudinal response in the whole range of momentum transfers).

A survey of the existing data from different laboratories shows a poor precision and a limited range of momentum transfer available in these measurements leaving open speculations on the origin of the quenching of the Coulomb sum rule. Several explanations with totaly different physics consequences were proposed to explain the quenching of the Coulomb sumrule and it is to have a better quality data for a more stringent comparison with the different physics ideas that we are proposing this measurement. It is also to look into the scaling behavior of the separated response functions in order to have a better understanding of the momentum distribution of nucleons in nuclei. We would like to emphasize the importance of inclusive measurements. The main advantage of performing inclusive measurements is the possibility to have a description of the system using the closure relation especially for heavy and medium weight nuclei. In other words the sensibility to final state iteractions and contributions of many body currents will lead to a redistribution of the strength observed in the quasi-elastic region over a wider range of energy loss. The inclusive measurements are doubtlessly complementary to the exclusive program at CEBAF allowing a chek of consistency on the exclusive measurements planned to study the problem we are addressing in this proposal.

The angular range (10° to 160°) covered by the electron spectrometer in hall A combined with the energy range of the incident beam (.5 GeV to 4 GeV) and the duty cycle of a 100% make truly CEBAF a unique facility for this high precision measurement.

1. Introduction and Motivation

Just as high Q^2 deep inelastic lepton scattering probes the quark momentum distribution in the nucleon, electron scattering in the quasielastic peak region probes the nucleon Fermi momentum distribution in the nucleus. The first systematic data[1] acquired ten years ago in the quasielastic region have been successfully described by the Fermi gas model[2] using the free electromagnetic form factors of the nucleons. Since then the total response function has been separated into its transverse and longitudinal components at the Bates, Saclay linear accelerators[3–9]. The results disagree with traditional nuclear theory calculations for medium weight and heavy nuclei and indicate that inclusion of processes beyond the simple picture of the single particle degrees of freedom of nuclei is necessary. Much debate has gone into the role of two body and three body contributions in the quasi-elastic region. It was recognized early that many body contributions were present in the transverse response function through the contribution of meson exchange currents. Since then it has been experimentally demonstrated that many body contributions are significant in the longitudinal response function through the measurement[1]0 of the exclusive (e,e'p) response functions in ^{12}C. This finding suggested that the strength of the response function is shared between single and multiparticle contributions and lead to believe that it is important to measure the longitudinal response function in the high energy loss region where the missing strength will naturally be located. New results[1]1 of a measurement of the longitudinal response function in the Δ region show no significant strenght however the region scanned was a low momentum transfer region.

The main problem is not the poor description of the shape of the inclusive longitudinal response function but more the strength that seem to be missing. It is still beleived that reliable calculations for heavy nuclei are not available making any speculation on the origin of the disagreement between theory and experiment easy.

The situation about this problem became more exciting when in connection to the observation of the so-called EMC effect drastic ideas emerged in order to explain what was seen at relatively low momentum transfer and the high momentum transfer deep inelastic data from the EMC collaboration. It was suggested that the explanation of both phenomena may depend upon a modification of the nucleon structure in the nuclear medium (swollen nucleon).

From a totally different approach in relation with the success of the Dirac phenomenology in describing spin observables in polarized proton nucleus elastic scattering some effort has gone in the description of the electromagnetic response functions of the nucleus in the framework of relativistic mean field theory using an effective Lagrangien. The model used is known as the σ-ω model. The encouraging feature of the work is that two groups[25,31] have independently converged to the same conclusions showing that within the framework of this model the quenching of the Coulomb sum rule can be understood. The explanation, although different from the swollen nucleon idea can be related to it. In both cases the change of the electromagnetic properties of the nucleon in the nuclear medium are important.

Any further speculation requires a new set of high precision experimental data of the separated response functions especially at large momentum transfer where these models predict significantly different answers. A study of the A dependence and momentum transfer is strongly needed. An additional crucial point is the investigation of the density effect since we know that light nuclei do not show the same behavior as the heavy ones. However one should keep in mind that the case of ^{4}He is not settled yet and new data on this nucleus are strongly needed.

We show in Fig.1. a comparison of the existing[3–9] data for the longitudinal response function with the most refined traditional calculations. The ^{3}He data are compared with a complete calculation by Laget[12] in which two and three body contributions were computed using wave functions derived from the Reid soft core N-N potential by solving the Faddeev equations. New calculations from the Rome group[34] and from Illinois[35] show that ^{3}He and ^{3}H are reasonably well understood. For ^{12}C and ^{40}Ca the calculations by Horikawa are compared to the data. Horikawa[13] et al. used Woods-Saxon single particle wave functions and the final state interaction of the knocked out nucleon was calculated within an optical potential description. The formalism accounts for both the loss of flux in the one nucleon removal channel and the excitation of the multinucleon ones. Two major issues arise from this comparison.

- There is a significant difference between theoretical and experimental longitudinal responses functions.
- This difference increases with A and appears to show a density dependence.

1.1 Coulomb Sum Rule Approach

To study these effects in a model independent way, comparisons with the Coulomb sum rule should be made. If one integrates the longitudinal response function divided by the nucleon electric form factors along the path of energy loss for a constant momentum transfer, one measures the charge of the nucleus to the first order approximation. As pointed out by de Forest[14] in the region of momentum transfer where Pauli correlations no longer contribute, all independent-particle models predict the same result, namely Z. This result is exact in the case of the non-relativistic Coulomb sum rule. Nevertheless, relativistic effects and off-shell ambiguities do not spoil this simple result for momentum transfers near $2k_F$ i.e. twice the Fermi momentum. We show in Figure 2 experimental results analyzed in terms of the following expression,

$$C(Q^2) = \int \frac{R_L(Q^2,\omega)}{(Z|G_E^p|^2 + N|G_E^n|^2)} d\omega \tag{1.1}$$

where $C(Q^2)$ is the Coulomb sum and G_E^p and G_E^n are the free proton and neutron electric form factors. The results cover the region of three momentum transfer 300 MeV/c $\leq |\vec{q}| \leq$ 550 MeV/c. It is clear that around $Q^2 < 6.5$ fm^{-2} $((0.25 GeV/c)^2)$ the Coulomb sum rule is saturated for ^{3}He whereas it shows a suppression of about 20% for ^{12}C and becomes more severely suppressed for heavier nuclei, reaching

40% in the ^{40}Ca region. **New results on ^{208}Pb nucleus not displayed in figure 2 show the same Q^2 behavior as ^{40}Ca and with a slightly larger effect.** This result suggests that ground state correlations might be more important than expected or that use of the free electromagnetic form factors of the nucleon is inappropriate. Several theoretical studies[15-19] on the effect of ground state correlations on the Coulomb sum rule reveal that they don't subtract more than 10% to the Coulomb sum rule at momentum transfer. It is this difficult to attribute the lack of strength to this effect.

An example of the ideas that emerged in connection with the EMC result is the theoretical approach Celenza et al.[20]. Using a soliton model for the nucleon, they calculated the modification of nucleon properties in nuclei and suggested an explanation of the EMC effect through an increase in the size of the nucleon. The same model has been applied to describe the charge distribution of ^{208}Pb in the central region and the quasielastic region. These authors, following the formalism used in ref. 21 calculated the longitudinal response function with the Fermi gas and shell models using modified electromagnetic form factors. The agreement for the longitudinal response function is good, as shown in fig. 3, however the same calculation leads to severe disagreement in the transverse response function. The authors argues about the other processes that have not been included in evaluating the transverse response function.

Another approach followed by several authors[22-25] to explain the data is to modify the current of the nucleon through the effective mass. The relativistic $\sigma-\omega$ model is used within the Hartree approximation. Due to the $\sigma - N$ interaction the effective mass of the nucleon in the Hartree field is about .56 M. The main effect of the scalar (σ) and vector (ω) fields is to modify the mass and energy terms in the Dirac equation as follows : $M^{*}=$ M+U_s and E^{*} = E - U_v where $U_s \approx$ - 400 MeV is the attractive scalar field and $U_v \approx$ 300 MeV is the repulsive vector field. The consequences of these modifications are a decrease in the longitudinal interaction and an increase in the transverse interaction.

Recently the above approach ha been improved in a significant way. Calculations within the relativistic model framework using the random phase approximation have been performed [31] improving the early approach of the relativistic models. The result shows that besides the direct effect of the scalar potential on the electromagnetic current of the nucleons the nucleon-antinucleon pairs excitations describing the vaccuum excitations contribute to the quenching of the longitudinal electromagnetic response function. Two groups independently reached the same conclusion.

One can ask then, what is the physics underlying the use of the effective mass and what is the relation between using an effective mass and modifying the intrinsic electromagnetic properties through a change of the form factors? The Q^2 dependence of the different approches will help us to disentangle between these very intersting options. The experiment we propose will provide a very stringent set of data to look at the Q^2 dependence of the Coulomb sum rule.

1.2 Y Scaling Approach

An elegant approach to the analysis of the quasielastic data is y scaling as proposed by G. West[26]. If one assumes the Plane Wave Impulse Approximation in the description of the electron-nucleus cross section in the quasielastic region then the relation between the spectral function S(k,ϵ) and the measured inclusive cross section is given by[32]:

$$\frac{d\sigma}{d\Omega d\omega} = \left\{ Z\overline{\frac{d\sigma}{d\Omega_p}} + N\overline{\frac{d\sigma}{d\Omega_n}} \right\} \left| \overline{\frac{\partial\omega}{k\partial cos\alpha}} \right|^{-1} \int_{\epsilon_-}^{\epsilon_+}, d\epsilon \int_{k_{min}(q,\omega,\epsilon)}^{k_{max}(q,\omega,\epsilon)} S(k,\epsilon)kdk \qquad (1.2)$$

where $|\overline{d\sigma/d\Omega_{p(n)}}|$ is the electron proton (neutron) cross section evaluated at $k_{min}(q,\omega,\epsilon_{min})$, $\cos\alpha = \vec{q}\cdot\vec{k}/|q\cdot k|$ defines the angle between the struck nucleon momentum $\vec{k}$ and the incoming virtual photon momentum $\vec{q}$. k_{max} and k_{min} are defined by pure kinematical conditions. $S(k,\epsilon)$ is a probability of finding a nucleon in the nucleus with the momentum k and binding energy ϵ

Experimentally, we are interested in extracting the so called scaling function $F(y)$ expressed as the following ratio:

$$F(y) = \frac{d\sigma}{d\Omega d\omega} / \left\{ Z \overline{\frac{d\sigma}{d\Omega_p}} + N \overline{\frac{d\sigma}{d\Omega_n}} \right\} \left| \overline{\frac{\partial \omega}{k \partial cos\alpha}} \right|^{-1}$$
$$= \int_{\epsilon_-}^{\epsilon_+}, d\epsilon \int_{k_{min}(q,\omega,\epsilon)}^{k_{max}(q,\omega,\epsilon)} S(k,\epsilon) k dk \tag{1.3}$$

where y is the momentum solution of the total energy conservation equation evaluated at $\epsilon = \epsilon_{min}$ and $\cos\alpha = -1$. In other words y is the minimal momentum of the struck nucleon verifying the energy conservation of the process as follow;

$$\omega + M_A = (M^2 + q^2 + y^2 + 2yq)^{1/2} + (M_{A-1}^2 + k^2)^{1/2} \tag{1.4}$$

where M_A and M_{A-1} are respectively the total mass of the initial and the recoil nucleus, k and q are the magnitudes of the nucleon and the virtual photon momenta, respectively.

The scaling function was extracted in a significant region of momentum transfer to study its scaling behavior by Day et al.[3]6. The new available data allowed the extraction of the scaling function F(y) for nuclear matter.

1.3 Transverse and Longitudinal Scaling functions

One further step can be achieved in inclusive experiments,in studying either the momentum distribution or the electromagnetic properties of the nucleon in the nucleus, by expressing the equation (1.2) in such a way that the electric and magnetic contributions of the electron nucleon cross section are explicitly separated. We can obtain expressions of the scaling function F(y) in terms of the transverse and longitudinal response functions:

$$R_T(y) = \left|\frac{\partial\omega}{k\partial\cos\alpha}\right|^{-1} \frac{-q_n^2}{2E_k E_{k'}} \widetilde{G}_M^2 F_T(y) \tag{1.5}$$

$$\begin{aligned} R_L(Q,\omega) = \left|\frac{\partial\omega}{k\partial\cos\alpha}\right|^{-1} & \widetilde{G}_E^2 \frac{(E_k + E_{k'})^2}{4E_k E_{k'}(1+\tau)} F_L(y) \\ & - \frac{1}{2E_k E_{k'}}\Big(q^2 - \frac{(E_k + E_{k'})^2}{2(1+\tau)}\Big) \widetilde{G}_M^2 F_L(y) \end{aligned} \tag{1.6}$$

$$\tau = \frac{Q^2}{4M^2}$$

where (E_k, k) and ($E_{k'}$, k') are respectively the energy-momentum of the struck and outgoing nucleons. $\widetilde{G}_E^2$ and $\widetilde{G}_M^2$ are the effective electric and magnetic form factors of the nucleus;

$$\begin{aligned} \widetilde{G}_E^2 &= ZG_E^{p2} + NG_E^{n2} \\ \widetilde{G}_M^2 &= ZG_M^{p2} + NG_M^{n2} \end{aligned} \tag{1.7}$$

We want to emphasize that besides the PWIA no further approximations are needed to obtain the relations ((1.5)),((1.6)). This consequently imposes the following relation:

$$F_L(y) = F_T(y) = F(y)$$

This relation can be checked experimentally if one has data of the transverse and longitudinal response functions obtained by the Rosenbluth technique. These separated response functions are not available in the region of high momentum transfer. However, if one restricts the range of four momentum transfer from .1 (GeV/c)^2 to .25 (GeV)^2 the results of the existing data analysed following ((1.5)) ((1.6)) exhibit an interesting behavior. Fig. 5 shows the extracted longitudinal F_L(y) and transverse $F_T(y)$ scaling functions from the data[9] of ^{3}He according to Ref 32. It is surprising to see that these two functions are different but tend to converge to the same value at the three value of momentum transfer $|\vec{q}| = 0.5$ (GeV/c).

These results show that the impulse approximation is not valid for this nucleus at transfers lower than about 0.5 (GeV/c). As an example, a heavier nucleus[7] has been analysed the same way and the result are shown in Fig. 5. The situation in this case is more critical, since the scaling regime seems to be reached around 0.5 (GeV/c) in momentum transfer, however, no convergence of the two scaling functions is observed.

At this stage it is important to notice that if one assumes that the free nucleon form factors we have used in the analysis are correct, then this result is an obvious breakdown of the impulse approximation. However the separate scaling behavior of each function is disturbing and can lead to the following question: Could a modification of the nucleon electromagnetic form factors lead to a convergence of these functions and maintain their scaling behavior? As suggested by Mulders for ^{12}C in Ref.[33] if one modifies the electric and magnetic form factors as follow;

$$\begin{aligned} G_E^\star &= \Big(1. + \frac{Q^2}{0.54(GeV/c)^2}\Big)^{-2} \\ G_M^\star &= \mu^\star_{p,(n)}\Big(1. + \frac{Q^2}{0.69(GeV/c)^2}\Big)^{-2} \end{aligned} \tag{1.8}$$

the overlap of the two scaling functions can be obtained. One cannot make the same statement about ^{3}He since the effect seems to be density dependent, it must be small in this nucleus. Therefore it is important to know if this behavior is pronounced in ^{4}He compared to ^{3}He since the former is strongly bound. These issues can be studied as soon as high precision separated response functions data become available for ^{4}He and ^{3}He at high momentum transfers.

This experiment will do the separation at high Q^2 and provide a consistent set of data to study these effects. The data are very important to understand whether the current operator or nucleon structure are modified in the nuclear medium It is also true that if nucleon-nucleon correlations are the key effect in this problem, this inclusive measurement is therefore crucial. The various theoretical models that have been invoked to explain both the reduction of R_L and the EMC effect show significant and different Q dependence in the region this experiment will cover.

2. Estimates of the Accuracy on σ_L and σ_T

In connection with the total real photoabsorption cross-section it is convenient to express the inclusive inelastic cross-section employing the absorption cross-sections σ_T and σ_L, for virtual photons with transverse and longitudinal polarization components. One notices that when the four-momentum transfer reaches zero the longitudinal cross-section vanishes whereas the transverse part coincides with the real photon cross-section. Under the assumption of the one-photon exchange, the differential cross- section in the laboratory frame can be written as follows:

$$\frac{d\sigma}{d\Omega d\omega}(e,e',\theta) = \Gamma_v \Big[\sigma_T(Q^2,\omega) + \epsilon\sigma_L(Q^2,\omega)\Big]$$

where

$$\Gamma_v = \frac{\alpha}{4\pi^2}\frac{K}{Q^2}\frac{e'}{e}\Big(\frac{2}{1-\epsilon}\Big)$$

is the flux of virtual photons and

$$\epsilon = \Big[1 + 2(1+\frac{\omega^2}{Q^2})tan^2\frac{\theta}{2}\Big]^{-1}$$

their polarization

Measurements at two different angles keeping the pair (Q^2,ω) constant are required to extract σ_T and σ_L. Let us call σ_f^r and σ_b^r the reduced cross-sections measured at the forward (f) and backward (b) angles respectively, using:

$$\sigma^r = \frac{1}{\Gamma_v}\frac{d\sigma}{d\Omega d\omega}$$

The transverse and longitudinal cross-sections are obtained from the following relations:

$$\sigma_T = \frac{\epsilon_f \sigma_b^r - \epsilon_b \sigma_f^r}{\epsilon_f - \epsilon_b}$$

$$\sigma_L = \frac{\sigma_f^r - \sigma_b^r}{\epsilon_f - \epsilon_b}$$

We can estimate the resulting uncertainty in the extracted cross-sections if we treat both the ratio $\frac{\sigma_L}{\sigma_T} = R$ and the relative statistical uncertainty $\frac{\Delta\sigma}{\sigma}$ as known quantities. To derive the following results we considered only the propagation of statistical errors, however if the systematic errors are independent between the forward and the backward angle the formula is usable to treat also the propagation of systematic errors:

$$\frac{\Delta\sigma_L}{\sigma_L} = \frac{\Delta\sigma}{\sigma}.\frac{1}{\Delta\epsilon}\sqrt{(\frac{1}{R}+\epsilon_f)^2 + (\frac{1}{R}+\epsilon_b)^2}$$

$$\frac{\Delta\sigma_T}{\sigma_T} = \frac{\Delta\sigma}{\sigma}.\frac{R}{\Delta\epsilon}\sqrt{\epsilon_f^2(\frac{1}{R}+\epsilon_b)^2 + \epsilon_b^2(\frac{1}{R}+\epsilon_f)^2}$$

Plots of the resulting uncertainties of both response functions as functions of R are shown in figure 7. $Q^2 = 1$ GeV/c and ω=.52 GeV are the values of energy and four momentum transfer choosen for this plot. The region correspond to the top of the quasielastic peak where a typical value of the ratio is R= 0.25 if one assumes the free nucleon form factors. We assumed also that the absolute error where statistical and systematic has been combined quadratically on the cross section at each angle will be no more than 1%. Under these conditions the longitudinal response function can be determined with 7% uncertainty. We have to notice that the ratio R varies over the range of excitation energies of the quasielastic peak falling to very small values (less then 5%) at the wings of the peak. We will only give an upper limit of the longitudinal response function when the ratio R is about 5% since the uncertainty in the result is greater than a 100%.

3. Experiment

We propose to measure inelastic cross sections on ^2H, ^{3}He, ^{4}He, ^{12}C, ^{27}Al, ^{40}Ca, ^{56}Fe and ^{208}Pb for four different angles 15°, 40°, 90°, 140° and energies ranging from 500 MeV to 4 GeV (6 GeV). The choice of the targets is dictated by several considerations. First we want to study the A and density dependence of any modification in the intrinsic properties of the nucleon. The deuterium and helium targets are needed in order to disentangle between an atomic mass and density dependent effects. Furthermore, elastic form factors of the targets should be known in order to subtract the radiative elastic tails from the measured inelastic cross sections especially at the largest angle where the final electron energies are small.

In order to perform Rosenbluth separations the minimum number of angles needed is two. However to check for angle dependent systematic errors and to study the validity of the first order Born approximation and the needed corrections to this approximation for large atomic number nuclei a measurement at two additional angles are needed. To minimize the uncertainty in the longitudinal response function one needs to measure at the most forward and backward angle accessible. This could be done using the Hall A electron spectrometer at fifteen degrees. The incident electron beam energies needed for the forward angle measurements are between 1 and 4. GeV in .3 GeV steps allowing fits to be performed for radiative corrections and to cover the region of momentum transfer of interest. The incident electron energies for the backward angle measurements will range between .5 and 1.5 GeV. The lowest scattered electron energy we will detect is 200 MeV corresponding to an energy transfer ω of 800 MeV which is close to $\omega = |\vec{q}| = 1 GeV/c$. At this scattered energy the contribution of electrons from (e^+, e^-) pairs created by bremsstrahlung photons produced in the target needs to be subtracted from the electron yields. By reversing the polarity of the spectrometer and leaving the detection system unchangedone can measure the positron yields from this process and subtract an equal amount from the electron yields assuming symmetry of the process. This needs to be done only for the cross sections measured at the backward angles(90°,160°)

The third and fourth angles will be used to test the experimental consistency, and to check the validity of the first order Born approximation for light nuclei and to monitor the Coulomb correction effects for heavy nuclei. At each electron scattering angle and electron incident energy a calibration of the spectrometer will be performed by measuring e-p elastic scattering cross sections using a liquid hydrogen target and comparing the results to the world data. A study of the angular and momentum acceptance of the spectrometer will be also performed.

Figure 6 shows the (Q^2,ω) plane where the transverse and longitudinal response function will be extracted. For a given (Q^2,ω) the cross sections for the corresponding incident energy and scattering angle (E_i,θ) couple are obtained by interpolating between the two closest measured spectra. The experiment will use from the lowest (.5 GeV) to the highest (4 GeV) energy beam available from CEBAF, and requires the ability for a change of the energy in a continuous way.

4. Count rates

To estimate the cross-sections we used measurements already performed measurement at SLAC at a forward angle[33]. For the backward angle, a calculation by Laget using the shell model has been used to obtain the cross section at the quasielastic peak. One half of the quasielastic cross-section has been used as the average value over the entire region of the energy excitation spectrum. This is believed to be a realistic estimate since one has to include the differences between the shape of ^{3}He, ^{4}He and ^{12}C. Thus we will give a detailed experimental running time estimate for ^{12}C and then a rescaling of this time is used to deduce the running time for ^{4}He and ^{3}He.

The table below gives our assumptions to estimate the counting rates we expect when performing this experiment.

Beam properties	Average current	10 μA
elec. spec.	Solid angle	8×10^{-3} sr
properties	Momentum acceptance	-4% +4%

In the following paragraph we describe the evaluation of the time required to take the data on one target, namely ^{12}C.

The number of counts per second is given by the following formula:

$$N_e/s = \frac{d\sigma}{d\Omega d\omega}.\Delta\omega.\Delta\Omega.\frac{\aleph}{A}.\frac{T}{\cos\theta_t}.N_i,$$

where N_i is the number of incident electrons per second. For the beam conditions indicated above $N_i = 6.25\times10^{13}$.

T(g/cm^2) is the intrinsic target thickness For this calculation we used T(^{12}C) = 50 (mg/cm^2).

θ_t is the angle between the targets and the beam. This angle will be fixed at 45° for all solid targets.

$\aleph = 6.022\times10^{23}$ is the Avogadro number

A is the mass number for the target nucleus

Statistic of 10000 counts per 10 MeV energy bin ($\Delta\omega$=10 MeV) is assumed.

With these parameters the experiment can take place in a month period of beam time. A detailed list of all momenta to be measured is available upon request.

5. The collaboration

Part of this collaboration has been involved in similar type of measurements at Bates, Saclay and Slac and has proven its competence. It is the best collaboration to attack the new challenge of high precision measurements. An important part of this proposal are the cryogenic targets. University of Virginia and California State University are involved in the development of these targets for Hall A. This collaboration is involved in many technical developments of Hall A for other experiments that have been proposed by the so-called Hall A collaboration.

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FIGURE CAPTIONS

Figure 1. Longitudinal response functions of ^{3}He, ^{12}C and ^{40}Ca at constant three momentum transfer. The curves are from Refs. 12 and 13; For the ^{3}He the figure shows the calculation by Laget, where the dotted (dashed) line is the two- and three-body contribution. The solid line is the total. For the heavier nuclei the curves are the calculation by Horikawa et al. as explained in the text.The data are from Refs. 6 , 7 and 9.

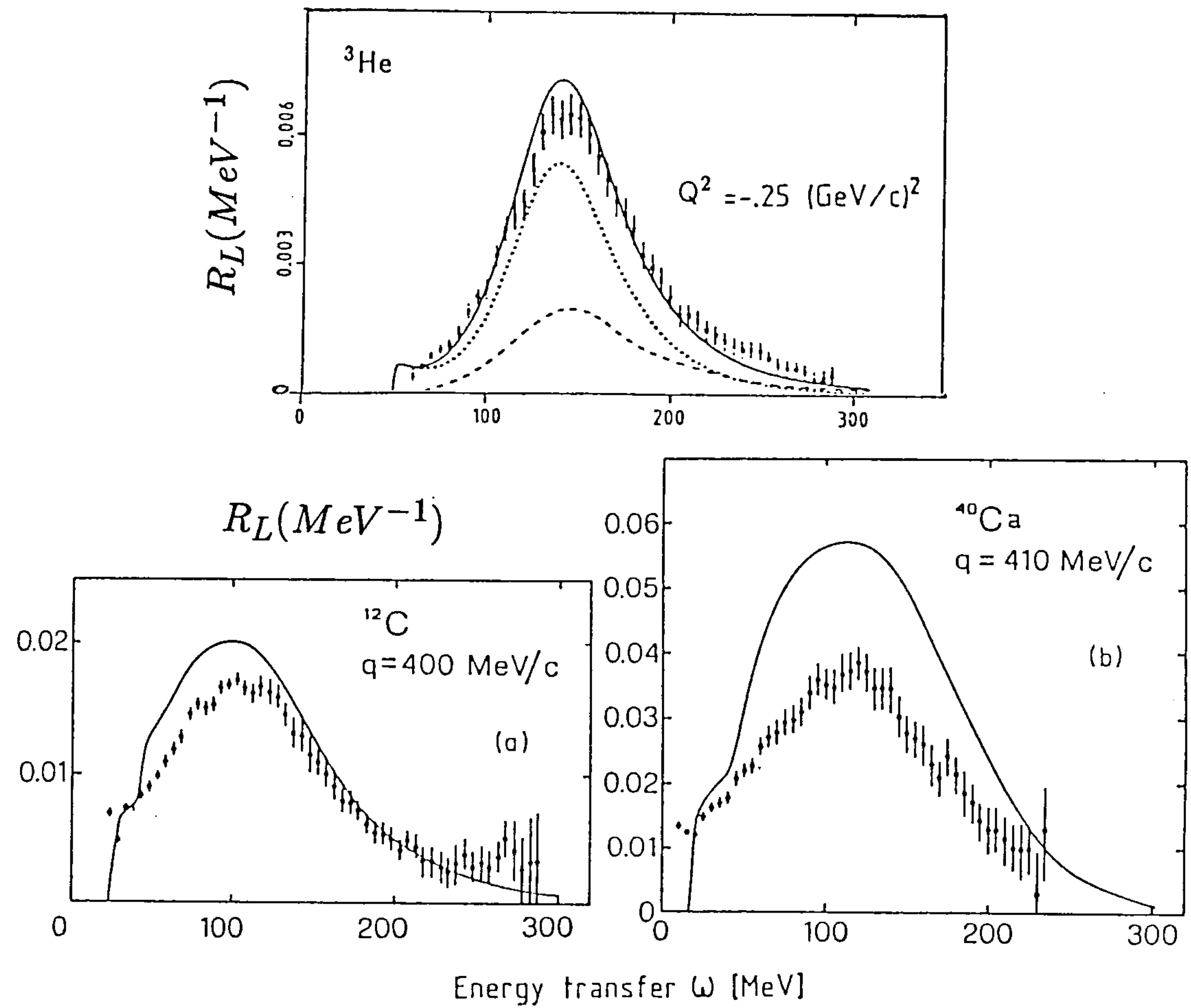
Figure 2. Coulomb sum rule for ^{3}He, ^{12}C, ^{40}Ca, ^{48}Ca and ^{56}Fe. The data are from Refs. 6, 7 and 9. Experimental uncertainties are larger than the data points but are not shown. The solid line is a calculation by de Forest[11] for ^{12}C.

Figure 3. Longitudinal response function for ^{12}C and ^{56}Fe calculated by Celenza et al.[20,21] compared to the data of Refs. 5 and 6. The dashed line (solid) line is the calculation using the free (modified) electromagnetic form factors of the nucleon.

Figure 4. Scaling function extracted from longitudinal (square and star) and transverse (diamond and plus) response functions for ^{3}He, ^{12}C and ^{40}Ca using the free nucleon mass. The data are from Refs. 6, 7 and 9. The three momentum transfers used for ^{12}C and ^{40}Ca are 400 MeV/c and 500 MeV/c. For ^{3}He data at constant four momentum transfer of Q^2=0.2 (GeV/c)^2 and Q^2= 0.3 (GeV/c)^2 have been used.

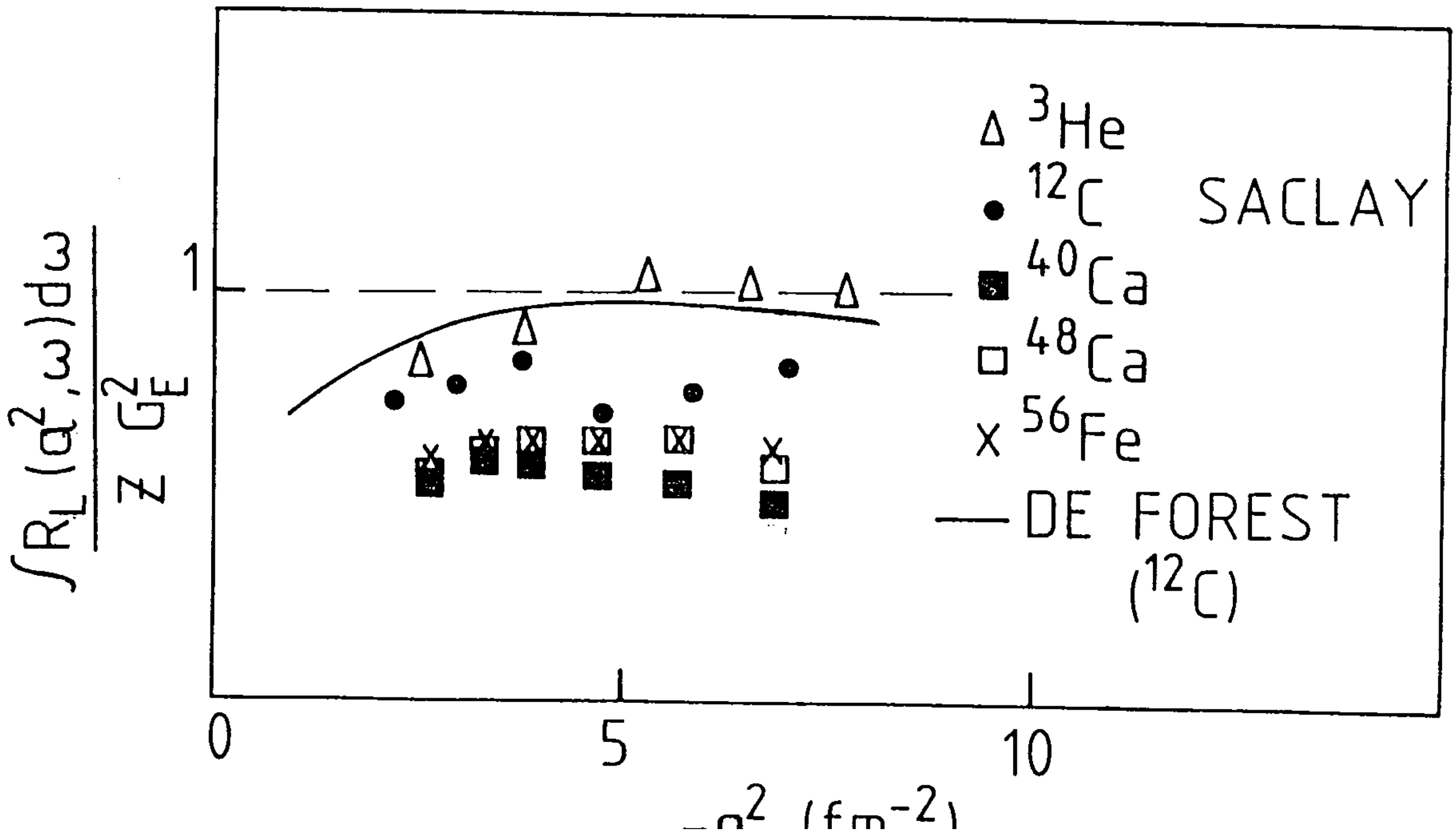
Figure 5. Region of the (Q^2,ω) plane which should be covered by the measurements proposed. Each line is for a single incident electron energy and scattering angle. The 40° angle is not shown for clarity. The elastic limit is calculated for ^{12}C.

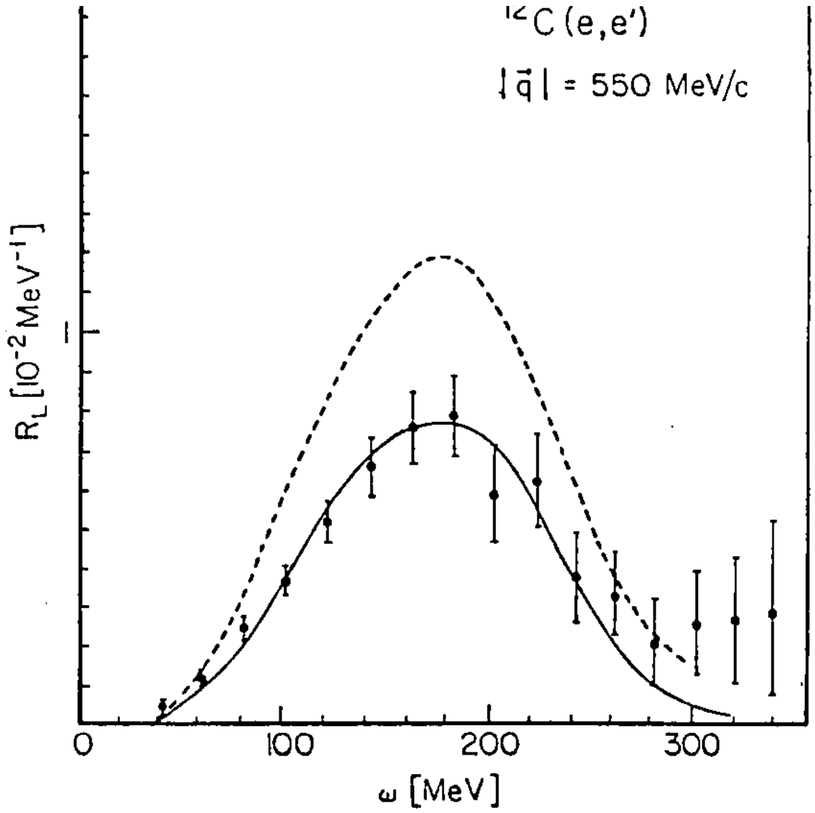
figure 6. Uncertainty on the transverse and the longitudinal extracted cross section as a function of the ratio R at the top of the quasielastic peak and $Q^2 = 1.(GeV/c)^2$



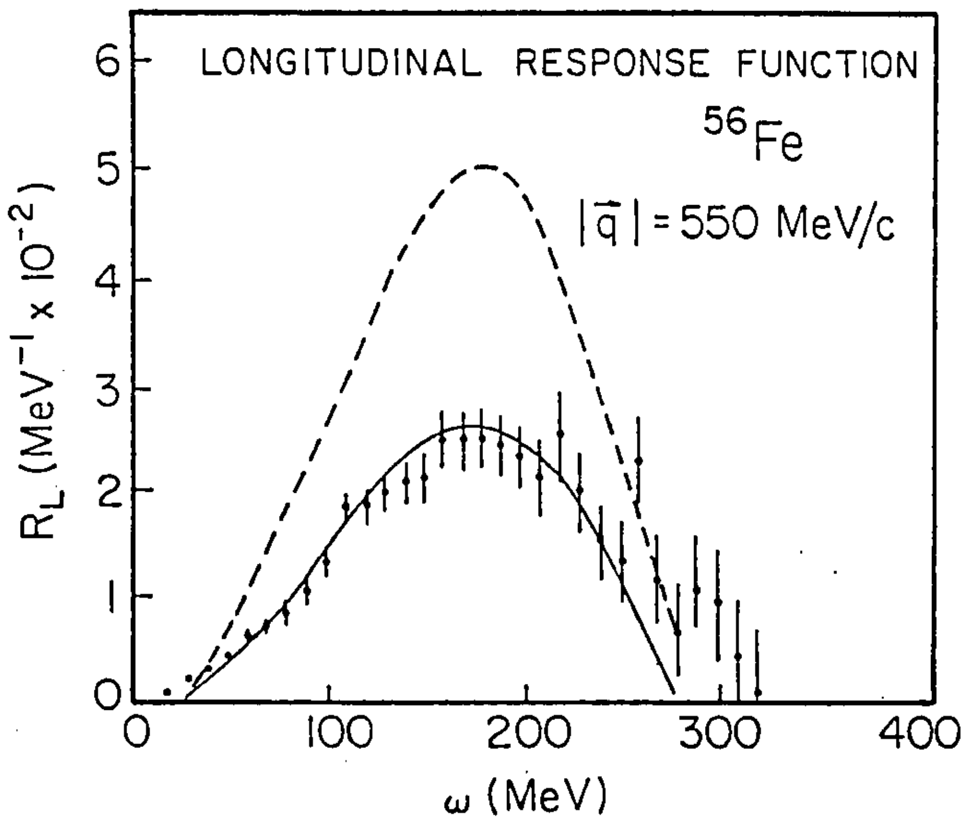
$R_L(MeV^{-1})$
^{3}He
Q^2 =-.25 (GeV/c)^2
0.006
0.003
0
0
100
200
300
$R_L(MeV^{-1})$
^{12}C
q=400 MeV/c
(a)
0.02
0.01
0
100
200
300
^{40}Ca
q = 410 MeV/c
(b)
0.06
0.05
0.04
0.03
0.02
0.01
0
0
100
200
300
Energy transfer ω [MeV]

COULOMB SUM RULE



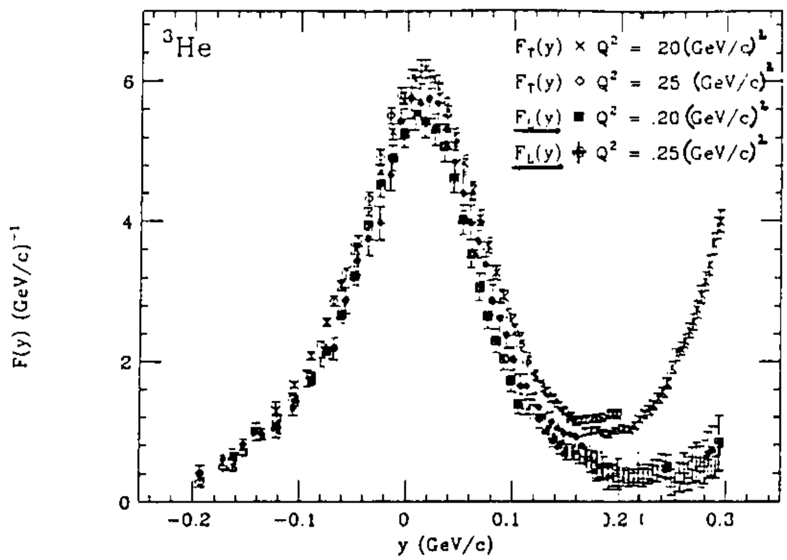


$^{12}C(e,e')$
$|\vec{q}| = 550$ MeV/c
$R_L\,[10^{-2}\,MeV^{-1}]$
0
100
200
300
ω [MeV]

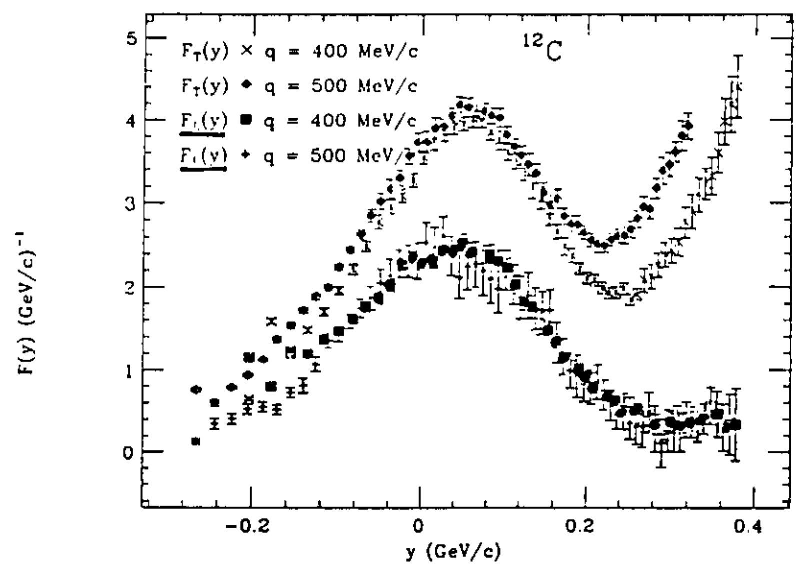


LONGITUDINAL RESPONSE FUNCTION
^{56}Fe
$|\vec{q}| = 550$ MeV/c
$R_L\,(MeV^{-1} \times 10^{-2})$
0
1
2
3
4
5
6
0
100
200
300
400
ω (MeV)

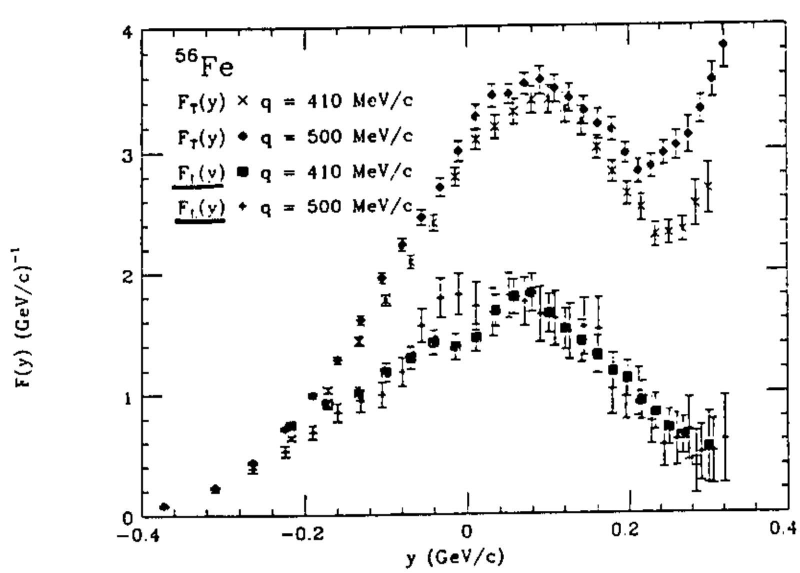
Fig 3



^{3}He
$F_T(y)$ × Q^2 = .20 (GeV/c)^2
$F_T(y)$ ◇ Q^2 = .25 (GeV/c)^2
$F_L(y)$ ■ Q^2 = .20 (GeV/c)^2
$F_L(y)$ ◆ Q^2 = .25 (GeV/c)^2
F(y) (GeV/c)$^{-1}$
y (GeV/c)



^{12}C
$F_T(y)$ × q = 400 MeV/c
$F_T(y)$ ◆ q = 500 MeV/c
$F_L(y)$ ■ q = 400 MeV/c
$F_L(y)$ + q = 500 MeV/c
F(y) (GeV/c)$^{-1}$
y (GeV/c)



^{56}Fe
$F_T(y)$ × q = 410 MeV/c
$F_T(y)$ ◆ q = 500 MeV/c
$F_L(y)$ ■ q = 410 MeV/c
$F_L(y)$ + q = 500 MeV/c
F(y) (GeV/c)$^{-1}$
y (GeV/c)

Fig 4

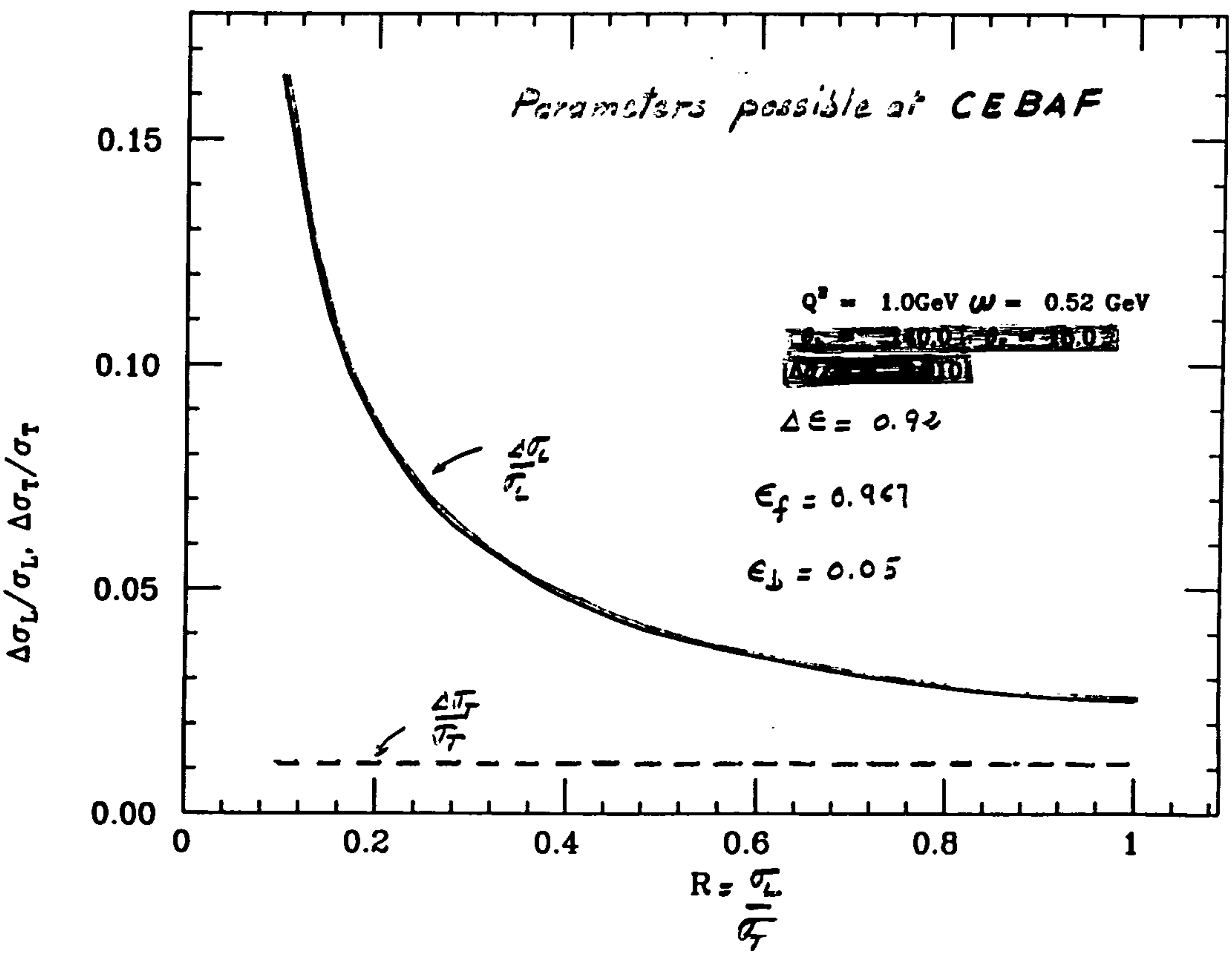

Parameters possible at CEBAF
Q² = 1.0GeV ω = 0.52 GeV
[redacted]
ΔE = 0.92
εf = 0.967
εb = 0.05
Δσ_L/σ_L
Δσ_T/σ_T
Δσ_L/σ_L, Δσ_T/σ_T
0.00
0.05
0.10
0.15
0
0.2
0.4
0.6
0.8
1
R = σ_L/σ_T

Fig 6