Experiment 94-110 Phase II Update

Measurement Of $R = \sigma_L/\sigma_T$ In The Nucleon Resonance Region

June 1, 2000

We propose to perform a global survey of longitudinal strength throughout the nucleon resonance region ($1 < W^2 < 4$ GeV^2) and spanning the four-momentum transfer range $4.5 < Q^2 < 7.5$ (GeV/c)^2. Inclusive nucleon resonance electroproduction cross sections will be used to perform Rosenbluth separations to extract the ratio $R = \sigma_L/\sigma_T$. We intend to measure R with an order of magnitude less uncertainty (≈ 0.05), than the current errors on R which have uncertainties greater than 0.5. A first phase of this experiment ran in the summer of 1999, where R was measured in the nucleon resonance region out to $Q^2 = 4.5$ (GeV/c)^2. The second phase being addressed here, an extension to higher Q^2, is conditionally approved. The 1997 Program Advisory Committee (PAC) 11 noted that this experiment will "improve the existing data base significantly", and conditionally approved Phase II based on a review of Phase I with particular attention to systematic uncertainties.

In this update, we report on the achieved precision running Phase I in Hall C and apply this to our proposed higher Q^2 measurements. Additionally, we introduce some recently submitted results of relevance from studies of inclusive resonance electroproduction data and parton-hadron duality in Hall C.

Review of Motivation and Goals

We present here a brief overview of the physics motivation and goals of this proposal. We refer to the original proposal and update (attached) for a more detailed discussion.

The ratio of longitudinal to transverse electron scattering off the proton is a fundamental quantity. Electron scattering is well approximated by the exchange of a single virtual photon, due to the relatively small values of the electromagnetic coupling constant, and so theoretical calculations work well. This and the pointlike nature of the electron allow for clarity and precision in understanding electron-nucleon scattering experiments; the reaction can be interpreted unambiguously in terms of the charge and current structure of the nucleon or nucleon resonance.

Rosenbluth separations have been performed on precision electron-proton elastic cross sections out to $Q^2 = 8.83$ (GeV/c)^2 [1, 2, 3, 4, 5]. These separations allow the direct measurement of the proton electric and magnetic form factors, $G_{Ep}(Q^2)$ and $G_{Mp}(Q^2)$. Measurements in this moderate Q^2 region are important because it is here that the virtual photon becomes sensitive to the internal quark structure of the proton. Measurements in this intermediate momentum transfer region provide valuable constraints on competing models which ultimately must describe the nucleon form factors to be considered fundamental theories.

The small values of $R = \sigma_L/\sigma_T$, the ratio of the contributions to the cross section from longitudinally and transversely polarized virtual photons, measured in deep inelastic electron-proton scattering are interpreted to be a consequence of the spin-$\frac{1}{2}$ property of the charged partons involved in the quasi-free lepton-quark scattering process. For deep inelastic scattering, i.e. scattering off pointlike quarks, it has been well established that perturbative QCD (pQCD) is a useful approximation for momentum transfers as low as a few $(\mathrm{GeV/c})^2$ and higher. This interaction is described by the coupling between a virtual photon and a single asymptotically free quark, followed by a complicated hadronization processes. Measurements have been made to extract the ratio R from deep inelastic cross sections at momentum transfers as high as $Q^2 \approx 50$ $(\mathrm{GeV/c})^2$ [6, 7, 8, 9].

In contrast to both the elastic and the deep inelastic, there exist few separation measurements of the ratio R in the resonance region at moderate or high momentum transfers. In a resonance excitation probed at moderate momentum transfer the partons are not free, and the arguments applied to the deep inelastic scaling data are not necessarily applicable. Large values of R could in principle be possible in the resonance region due to hard gluon exchanges between the quarks. Experiment 94-110 proposes to measure R to approximately 0.05, a substantial improvement over the presently available errors on R which are greater than 0.5 [11, 12, 13, 14, 15].

Figure 1 shows the world data on R in the resonance region (open and closed circles) from SLAC and from DESY. The error bars are typically $\geq$ 200%. These data are averaged over $1 < W^2 < 4$ GeV^2. The proposed points for the Δ $P_{33}(1232)$ are plotted at a constant value of $R = 0.06$, a weighted average of the existing data, for comparison. They are labelled phase I (triangles) and phase II (squares). Similar error bars will be obtained for the higher mass resonances. Statistical errors only are plotted. The systematic uncertainty in R is expected to be less than 0.05 and will be discussed in detail in the following section.

Figure 2 is a scatterplot depicting both the existing SLAC measurements and the obtained phase I measurements in W^2 and Q^2. Also indicated is the kinematic range to be covered by phase II. The E94-110 points shown are not L/T separated points, but rather the obtained inclusive spectra for central soectrometer momentum and angle values. Within the spectrometer acceptance, full spectra in W^2, i.e. typically $0.88 < W^2 < 5.0$, were obtained. It is planned that complete spectra will also be obtained in phase II. It is to be noted that the E94-110 measurements overlap the existing precision SLAC deep inelastic measurements as suggested by the PAC. However, the lower W SLAC measurements do not have the high degree of precision that the higher W ones do. Phase II has a greater overlap with the high precision data points than Phase I.

Precision measurements of R will greatly aid efforts to develop reliable global descriptions of existing inclusive electroproduction data at moderate to high Q^2. These global models are necessary for electron-nucleon scattering model development and for accurate radiative correction calculations. The proposed measurements will be useful in the extraction of resonance form factors and spin-dependent structure functions from inclusive electron scattering experiments.

Additionally, the ratio R will be used to investigate an observed scaling relation-

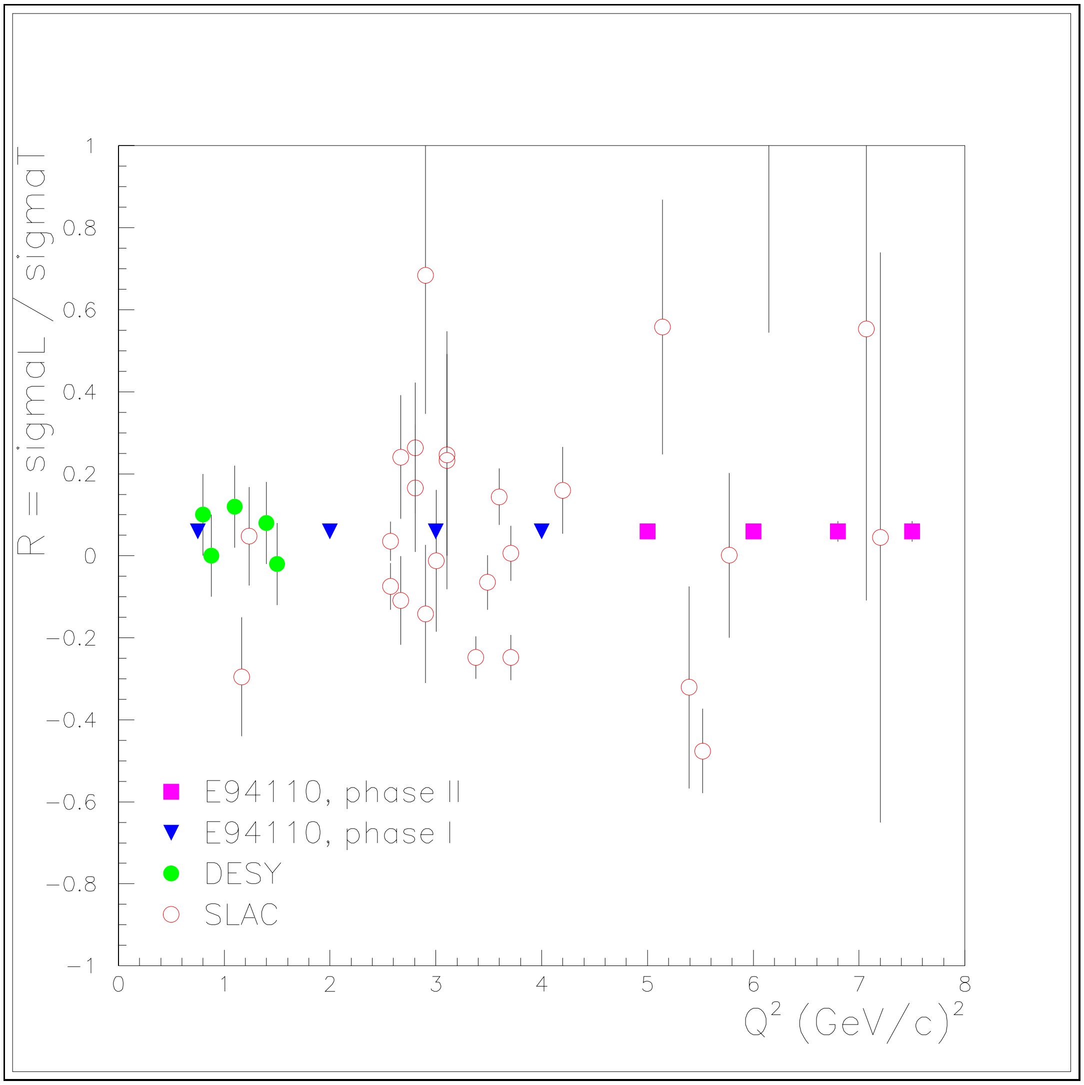

Figure 1: The world data on $R = \sigma_L/\sigma_T$ in the nucleon resonance region (circles) plotted as a function of Q^2 in $(\mathrm{GeV/c})^2$ averaged between $1 \leq W^2 \leq 4$ $(\mathrm{GeV/c})^2$. The proposed points for the Δ $P_{33}(1232)$ only are plotted at a constant value of $R = 0.06$ for comparison. Obtained phase 1 points are triangles and phase 2 points are squares.Errors shown are statistical only.

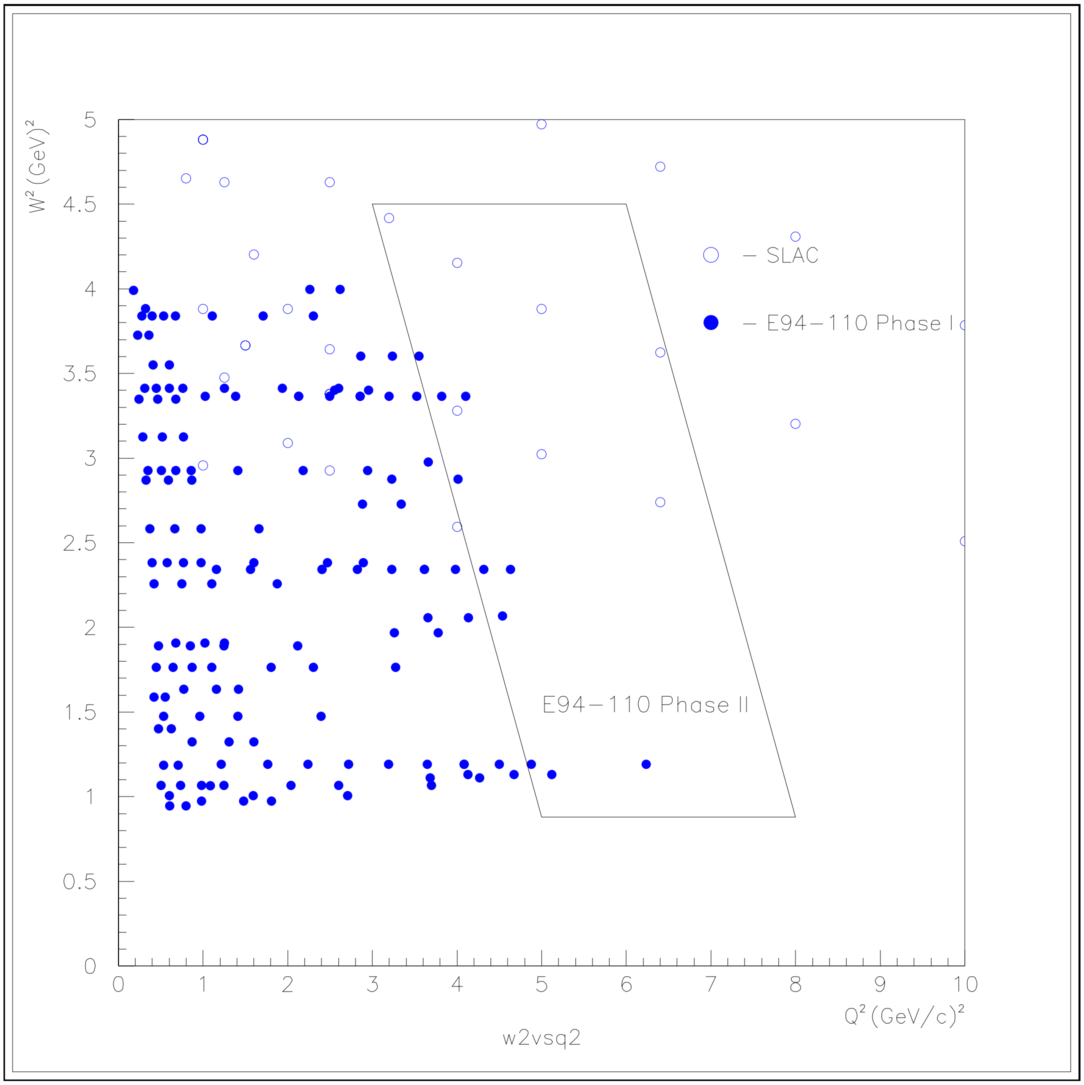

Figure 2: The kinematics of obtained E94-110 phase I inclusive resonance electroproduction data in Q^2 and W^2, as well as existing SLAC measurements of R. The proposed kinematic region of phase II is outlined.

ship between resonance electroproduction and deep inelastic scattering, termed Bloom-Gilman or parton-hadron duality. This duality suggests a common origin of both phenomena and studies of duality with new resonance data and better measurements of R may enable a fundamental quark description for both properties of electroproduction. Explanations from QCD and pQCD [16, 17, 18, 19] of the empirical connection between the scaling and resonance regimes indicate that both the transverse and the longitudinal contributions to the resonance cross section should manifest this duality. These models of duality may be tested for the first time with the proposed measurements of R. We further note that very preliminary studies using the available world's deep inelastic scattering data on R hint that duality may indeed be manifested in the longitudinal channel [20]. The proposed data are necessary to verify and study this observation.

The Δ $P_{33}(1232)$ resonance is of particular interest in light of Bloom-Gilman duality. Although the behavior of the proton and of higher mass resonance form factors follows the leading order pQCD Q^{-4} prediction, the Δ resonance form factor is an anomaly and decreases significantly faster (at least for $Q^2 < 2$ (GeV/c)^2). To preserve Bloom-Gilman duality it has been suggested [18] that R is quite large for the Δ, i.e. that the cross section has a significant longitudinal component, allowing the observed scaling behavior of the structure function νW_2 for the Δ to be similar to the other resonances and to the proton. The precision high momentum transfer measurements of R proposed here will test this notion.

Systematic Uncertainties

At present, the world's best precision L-T separation measurements have been performed by SLAC experiment E140X, to measure R in deep inelastic scattering. The point-to-point uncertainties for E140X are given in Table 1. It was proposed that a comparable level of precision be achieved with E94-110. Currently, much effort is being put into both understanding and reducing the systematic uncertainties for the E94-110 phase I analysis. Substantial progress has been made, and the current point-to-point uncertainties for phase-one are listed in Table 2. Also listed are the projected contributions due to these uncertainties to ΔR, the uncertainty in R on the Δ and F_{15}, as indicated, for E94-110 phase II.

ΔR was calculated by varying the cross section within its uncertainty ($\Delta\sigma$) at the largest and smallest ϵ for each (Q^2, W^2) setting and extracting R from a standard Rosenbluth separation. For calculating the cross section, a model of SLAC resonance data, which connects smoothly with deep inelastic data, was used. For uncertainties in the kinematics, the corresponding uncertainty in Q^2 was used to determine $\Delta\sigma$ from the model.

The largest contributions to ΔR come from uncertainties in beam energy and scattered electron energy and angle. These uncertainties have been slightly modified from the previous proposal to reflect the results of a study of single-arm elastic data from E94-110 phase I. One of the advantages of this experiment is that elastic scattering data is taken at every beam energy and with varying HMS angle and momentum. For elastic scattering, the difference of the reconstructed invariant mass, W, from the proton mass (ΔW = W - M_p) can be constructed and the dependence of ΔW on energy and angle offsets from the nominal values can be studied.

Fitting the ΔW dependence on energy and angle offsets allows an extraction of these offsets and has yielded an uncertainty in the corrected beam energy of 0.04%, less than half that typically quoted from Hall C arc measurements. Two such fits are shown in figure , for E94-110 phase I data taken at beam energies of 2.2 GeV and 5.5 GeV. ΔW is plotted verses the scattered momentum in the HMS. The shape of the fit (the solid curve) is dependent on the offsets and these are adjusted to give the best fit to the data. The uncertainties are given by the point-to-point variations which can not be accounted for with a common set of offsets. The uncertainties in HMS momentum and angle are 0.04% and 0.2 mrad, respectively.

Accelerator cavity RF instabilities have been observed to cause variations in the beam energy on the order 0.05%. These variations of the beam energy can be measured using the BPMs (beam position monitors) in the Hall C Arc. These BPMs are read into the data stream every second and can be used to make relative beam energy corrections for the beam energy drift. Such corrections have been made by previous experiments and have resulted in the narrowing of missing mass peaks. Corrections for such beam energy variations are currently included in the E94-110 phase I analysis.

Furthermore, significant progress has been made in the installation of a far-infrared laser to measure the beam energy via Compton back-scattering. When fully commissioned, this should allow a measurement of the centroid energy of the electron beam to $\approx 10^{-4}$ accuracy.

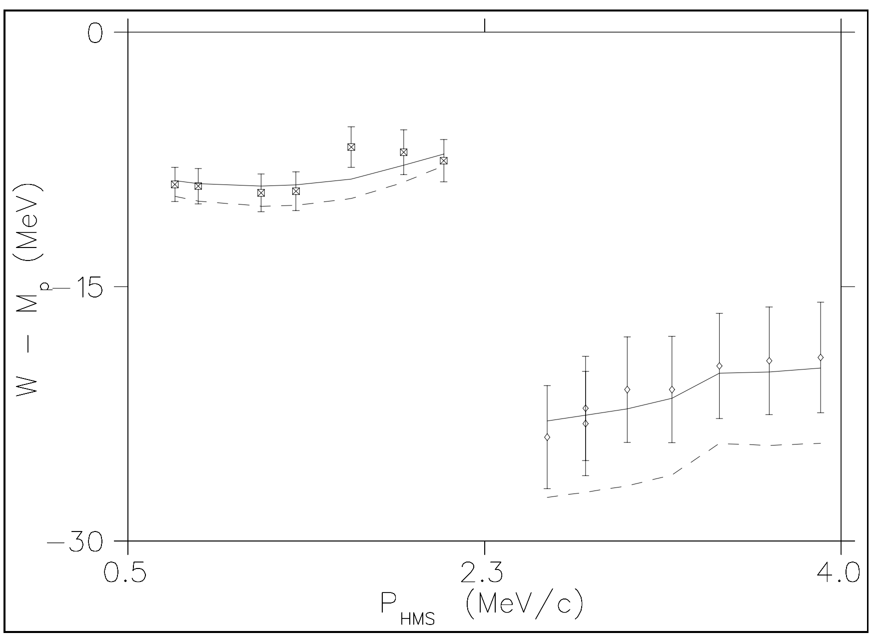

Figure 3: ΔW vs. HMS momentum. Open triangles represent data taken with a beam energy of 5.5 GeV, while the squares are data taken with a beam energy of 2.2 GeV. Solid lines represent the calculated ΔW for the set of offsets which best reproduce the data. The dashed lines show the sensitivity of the calculated ΔW on an additional +0.5 mrad angle offset and allow the uncertainty in this offset to be determined.

Experimental Quantity	Uncertainty	$\Delta\sigma$	ΔR
Beam Angle on Target	.05 mrad (.003^o)	0.1	0.005
Beam Energy	$1 \cdot 10^{-3}$	0.3	0.014
Scattered Electron Energy	0.05%	0.1	0.005
Target Density	0.2%	0.2	0.009
Scattering Angle	0.04 mrad (.002^o)	0.1	0.005
Beam Charge	$3 \cdot 10^{-3}$	0.3	0.014
Acceptance vs. θ	0.1%	0.1	0.005
Acceptance vs. p	0.1%	0.1	0.005
Detector Efficiency	0.1%	0.1	0.005
e^+/e^- background	0.1%	0.1	.005
	Total	1.1	0.039

Table 1: Published point-to-point systematic uncertainties from E140X

Experimental Quantity	Uncertainty	ΔR	ΔR
		Δ	F_{15}
Beam Angle on Target	.04 mrad (.002^o)	0.003	0.003
Beam Energy	$4 \cdot 10^{-4} \rightarrow 1 \cdot 10^{-4}$	0.020	0.003
Scattered Electron Energy	$4 \cdot 10^{-4} \rightarrow 2 \cdot 10^{-4}$	0.030	0.010
Target Density	0.05%	0.002	0.002
Scattering Angle	0.2 mrad	0.020	0.005
Beam Charge	$1 \cdot 10^{-3}$ relative	0.005	0.005
Acceptance	0.2%	0.010	0.010
Detector Efficiency	0.2%	0.010	0.010
Deadtime Corrections	0.1%	0.005	0.005
	Total	0.044	0.020
	Total for $\Delta E \approx 10^{-4}$	0.044	0.020

Table 2: E94-110 phase I point-to-point systematic uncertainties used to calculate the uncertainty in R at the highest Q^2 values (7.5 GeV) for the $P_{33}(\Delta)$ and F_{15} resonances for phase II.

However, at least two months of single pass running is planned for year 2000 experiments and should provide the time needed to fully commission this technique. It should also be noted that this technique has recently been used elsewhere with great success.

HMS	x_{fp}	x'_{fp}	y_{fp}	y'_{fp}
x_{tar}	-3.0821	0.05681	0	0
x'_{tar}	0.1555	-.3273	0	0
y_{tar}	0	0	-2.2456	-2.569
y'_{tar}	0	0	1.4135	-.2836
δ	3.7044	-0.001688	0	0

Table 3: HMS $1st$-order forward matrix elements.

The laser which is currently used in the prototype setup in the hall (10.6 micron CO_2) requires the running of single pass beam as Compton scattered γ rays from higher beam energies are not within the calibrated range of the Germanium detector which is currently used to measure the scattered γ energies. Because of this, the high beam energies used by experiments in 1999 has not allowed opportunities to make studies with the prototype. A final far-infrared ($\lambda = 118$ micron) laser for higher beam energies has been purchased and is on site and working via remote control, but has not yet been installed in the Hall C arc.

Just as the arc BPMs allow corrections for variations in beam energy to be made, information from the Hall C beamline BPMs allow corrections for beam position and angle on target to be made. In contrast to the arc BPMs, information from these BPMs are fed into the data stream on an event-by-event basis. Uncertainties in the beam position and angle on target directly translate into uncertainties in the reconstructed kinematics. We plan to use the Hall C fast raster with a spot size on target of $\pm$ 1 mm. Deviations in the the vertical position of the beam will appear as a momentum offset in spectrometers. The effect of a beam position offset can be calculated from the optical matrix elements for the spectrometer. The first-order forward matrix elements for the HMS spectrometer are given in Table 3. The effect on the reconstructed momentum due to a 1 mm offset of the beam on target in the spectrometer dispersive direction (x_{tar}) is

$$\Delta P(1 \text{ mm}) = \pm 0.1 \text{ cm} \cdot (-3.0821) \cdot 0.27 \text{ (\%/cm)} = \pm 0.08\%, \tag{1}$$

where the reverse matrix element (≈ 0.27 %/cm) has been used to convert x'_{fp} to δ.

A study of the run-to-run beam steering stability was made during the running of E94-110 phase I. From this study, we measure run-to-run variations in x_{tar} of $\delta x_{tar} <$ .2 mm. We use this as a worst case, and calculate a corresponding point-to-point uncertainty in in spectrometer momentum, P, of

$$\Delta P = \pm 0.2 \cdot \Delta P(1\text{mm}) = .024\% \qquad (2)$$

The angle of the beam on target (x'_{tar}) enters as a direct uncertainty in the scattering angle if not corrected for. Again, the BPM information allows a correction to be made for this. The worst case point-to-point error is found to be the run-to-run x'_{tar} variations of $\Delta x'_{tar} \approx .04$ mrad.

The disadvantage of using a small raster size is an increase in localized target density fluctuation. Localized target density fluxuation, induced by an intense incident beam, can significantly modify the average density of a cryogenic target. Point-to-point uncertainties in the target density enter directly as point-to-point uncertainties in the total cross section and are current-dependent. The current-dependence can be measured by comparing the yields from fixed kinematics at varying beam currents. The deadtime-corrected yields should be proportional to the luminosity (and, therefore, the target density).

The result of such a 'luminosity scan' for E94-110 phase I is shown in Figure 4, where the luminosity relative to that for zero current has been plotted on the vertical axis. The error bars on the data are statistical only and do not reflect fluctuations in the beam current. Assuming an error in the fit of $\pm 10\%$, due to systematic errors in the fit data, and a run-to-run error in the current of ± 2 μA, the estimated point-to-point uncertainty in the target density is

$$\Delta \rho_t = 0.2 \cdot 0.1 \cdot 0.24\% = 0.05\% \qquad (3)$$

Other quantities which contribute to a systematic uncertainty in the total cross section are corrections for acceptance, detector efficiencies, and deadtime. All of these have been studied for a variety of Hall C experiments and are believed to be well-understood. Reliable Monte Carlo models for both spectrometers exist, and have been shown to accurately reproduce the data for many different processes and kinematics.

The point-to-point uncertainty in the acceptance corrections given in Table 2 has been estimated using these models. For an extended target, there can be a relatively large difference in the acceptance for forward and backward angle scattering. For scattering at 20° and 90°, the model predicts a difference of $\approx 2\%$. The largest fraction of this difference comes from events which are lost in the second quadrapole (Q2). The difference due to events lost after Q2 is $< 0.1\%$. Assuming an upper limit of $\approx 10\%$ on the uncertainty due to the optics model, the point-to-point uncertainty in the acceptance is $10.0\% \cdot 2.0\% = 0.2\%$.

The efficiencies for the HMS shower and Cerenkov counters have previously been studied for inelastic (e,e') scattering [21]. Since the efficiency of the shower counter calorimeter increases with scattered electron energy, our worst case for the present experiment is for the kinematics in which the scattering is at high W and Q^2, and, therefore, low momenta. The uncertainties in the efficiencies for this case are $\pm 0.10\%$ for

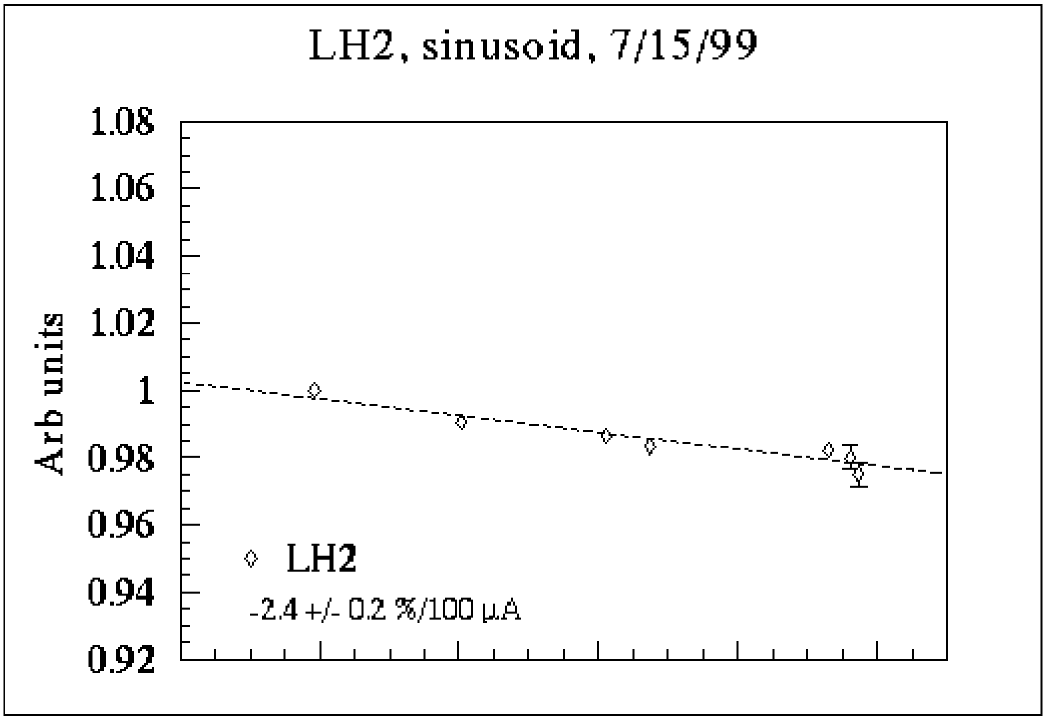

Figure 4: Luminosity scan data and fit taken 7/99. The range of the horizontal axis is 0 to 100 μA.

both the shower counter and Cerenkov counter. Studies of the tracking efficiencies [22] have shown that once the rate dependence has been corrected for, the run-to-run variations are dominated by statistics. For the typical statistics expected per kinematic setting, the uncertainty in overall detector efficiency is calculated to be 0.2%.

Recent Results from Parton-Hadron Duality Studies in Hall C

Proposed Kinematics

Table 4 lists the kinematics and cross sections we propose to measure in phase II, as well as a breakdown of beam time requirements. A minimum time of one half hour per kinematic setting and a maximum rate of 1000 Hz are used. A beam current of 80 μA was used. The calculated rates listed are for the $W^2 = 1.52$ (GeV/c)^2 data. The data for the higher resonances comes in at higher rates and requires $\approx$ 50% additional beam time. The data aquistion time listed in Table 4 reflects the total time required for all resonances. The SOS data can be obtained in a simultaneous single arm mode with the HMS data and, so, adds no time to the beam time request.

The differential cross sections for inclusive electron scattering will be measured according to the following definition:

$$\frac{d^2\sigma}{d\Omega dE'} = \frac{\Delta N}{\Delta\Omega\Delta E'}\frac{1}{Qnd}. \tag{4}$$

The counting rate per energy bin, ΔN, has been estimated for the purposes of this proposal from a global fit to all existing SLAC resonance region data [11]. This fit both agreed with the recent Jefferson Lab inclusive data to within 5% and smoothly links with the global fit to SLAC deep inelastic scattering [6], providing a valuable tool for rate calculations as well as for testing electron nucleon scattering models and for input to radiative correction calculations. The fit is to data spanning the kinematic ranges $1.15 < W^2 < 4.0$ GeV^2 and $0.5 < Q^2 < 10.0$ (GeV/c)^2.

The scattered electron energy bins, $\Delta E'$, used to predict counting rates for this proposal were $\pm 8.0\%$ of the central spectrometer momentum of the HMS. A solid angle, $\Delta\Omega$, of 6.5 msr was assumed for the HMS. A minimum central spectrometer momentum setting of 380 MeV/c was used. All proposed measurements will use the Hall C 4 cm hydrogen target. In the above equation, n represents the density of hydrogen and d the target thickness.

The integrated number of incident electrons on target is the quantity Q. For the purposes of this proposal update, we assumed an average current of 80 μA. The chosen beam energies in the table are multiples of 1.2 GeV (3.6, 4.8, 6.0), with the exception of the beam energy of 4.0 GeV, which is required to reach the lowest ϵ points for the $Q^2 = 5, 6$ (GeV/c)^2 data.

The run time requests were determined by the desired accuracy of the measurement of the longitudinal cross section component σ_L. The statistical error on σ_L is given by the equation

$$\frac{\Delta\sigma_L}{\sigma_L} \approx \sqrt{2}\left(\frac{\Delta\sigma}{\sigma}\right)\left(\frac{\sigma}{\sigma_L}\right)\frac{1}{\Delta\epsilon} \tag{5}$$

which may be rewritten in terms of R to be

$$\frac{\Delta\sigma_L}{\sigma_L} \approx \sqrt{2}\,(\Delta\sigma/\sigma)\left(\frac{1+\epsilon R}{R}\right)\frac{1}{\Delta\epsilon}. \tag{6}$$

This equation was used to determine the requisite statistical error, $\Delta\sigma/\sigma$, of the differential cross sections to bemeasured from thedesired accuracy of the longitudinal component measurement. The required beam time for each kinematic setting was determined from the resultant $\Delta\sigma/\sigma$ using the counting rates per hour calculated from the SLAC global resonance cross section fit and given in Table 4. A value of $R = 0.06$ was assumed for all the tabulated calculations. The ϵ ranges are given in Table 4. It is to be noted that the proposed 6 GeV run plan includes three ϵ points for every L/T separation, other than the highest Q^2 values, where a new beam energy tune would be required.

The statistical accuracy of the proposed differential cross section measurements (typically $\approx 1\%$) will be a significant improvement over the accuracy of existing data at moderate to high momentum transfers (typically $\approx 5-10\%$). The beam time requested for this experiment is listed in Table 5. The total data acquistion time listed, reflects the total time from Table 4, as well as, an additional 50 hours need to complete positron rate studies at the most backward angles.

Q^2_Δ $(GeV/c)^2$	E_Δ (GeV)	E'_Δ (GeV)	θ_Δ (deg)	ϵ_Δ	$Rate_\Delta$ (Hz)	Time (Hours)	Spect
4.0	3.6	1.3	56	0.41	8.6	**11.5**	HMS
	4.8	2.4	34	0.68	52	**2.5**	HMS
	6.0	3.6	25	0.80	174	**.5**	HMS
5.0	4.0	1.1	64	0.30	2.7	**34**	HMS
	4.8	1.8	44	0.52	10.2	**9.5**	HMS
	6.0	3.0	30	0.71	41	**3**	HMS
6.0	4.0	0.5	110*	0.07	.29	**56**/56	HMS/SOS
	4.8	1.3	58	0.35	1.75	**36**	HMS
	6.0	2.5	37	0.60	9.8	**7**	HMS
7.0	4.8	0.8	84*	0.15	0.28	**198**	HMS
	6.0	2.0	45	0.47	2.7	24	SOS
7.5	4.8	0.5	115*	0.05	0.11	202	SOS
	6.0	1.7	50	0.40	1.39	**16**	HMS

Table 4: Beam time requirements for all proposed measurements. The time requested is based on the values in boldface. All kinematics and rates shown are for the Δ resonance only. Positron data will be taken will be taken in the SOS for the angles indicated by an asterisk.

	Time Required (Hours)
Data acquisition	430
8 angle changes	8
Major beam energy changes	8
2 minor beam energy changes	4
Checkout	24
Total	**474**

Table 5: Breakdown and tabulation of the total time requested. Based on previous experience, we assume one-half hour for each angle change, eight hours for linac energy changes (major), and two hours for each energy change accomplished by changing the number of cycles (minor).

We require twelve half hour spectrometer angle changes for phase II during which the spectrometer central momentum may also be changed. These total 4 hours as some may be accomplished during beam energy changes. Phase II requires an additional 8 momentum changes at a halfhour each, totalling 8 hours. Combined with one day for checkout, phase II may be accomplished in 20 days total.

The Collaboration

The E94-110 collaboration consists largely of locally-based people who have participated in a substantial amount of Hall C running. Collaboration members have been responsible for the design, construction, and commissioning of the HMS drift chambers, thin vacuum windows, hodoscope, and lead glass shower counter; and for the SOS drift chamber commissioning, and hodoscope and lead glass design, construction and commissioning.

The collaboration has implemented and proven successful techniques to reduce systematical uncertainties in Hall C experiments, including detailed studies of spectrometer optics, spectrometer survey studies, raster phase analysis, and additional beam line instrumentation. This collaboration has the on-site experience and knowledge requisite to perform the proposed precision measurement.

Several spokespeople from completed Hall C experiments are collaboration members. At least one dissertation students and one postdoctoral research associate will be on site at TJNAF for the year preceding an experiment schedule date.

Conclusion

Using the existing Hall C apparatus, it is possible to perform a global survey of longitudinal strength throughout the nucleon resonance region with an order of magnitude better precision than has been achieved before. PAC 9 stated that R is a fundamental quantity that should be measured with the best possible accuracy. After the successful completion of phase I, we now request that phase II be approved, so that a complete kinematic range of longitudinal strength may be measured.

REFERENCES

1. R.C. Walker et al., Phys. Lett. B224, 353 (1989)
2. R.C. Walker et al., Phys. Lett. B240, 522 (1990)
3. P.E. Bosted et al., Phys. Rev. C42, 38 (1990)
4. L. Andivahis et al., submitted to Phys. Rev. D
5. L. Andivahis, Ph.D. Thesis, The American University (1993)
6. L.W. Whitlow et al., Phys. Lett. B250, 193 (1990)
7. A. Bodek et al., Phys. Rev. D20, 1471 (1979)
8. S. Dasu et al., Phys. Rev. Lett. 61, 1061 (1988)
9. L.H. Tao, Ph.D. Thesis, The American University (1994)
10. D. Mack, private communication
11. C.E. Keppel, Ph.D. Thesis, The American University (1994)
12. F.W. Brasse et al., Nucl. Phys. B110, 413 (1976)
13. J. Drees et al., Z. Phy. C7, 183 (1981)
14. J.C. Alder et al., Nucl. Phys. B48 (1972)
15. B. Gerhardt et al., Z. Phy. C7, 11 (1981)
16. C.E. Carlson, Phys. Rev. D34, 2704 (1986)
17. G.R. Farrar and D.R. Jackson, Phys. Rev. Lett. 35, 21 (1975)
18. C.E. Carlson and N.C. Mukhopadhyay, Phys. Rev. D41, 2343 (1990)
19. C.E. Carlson and N.C. Mukhopadhyay, Phys. Rev. D47, 1737 (1993)
20. R. Ent, C.E. Keppel, I. Niculescu, accepted by Phys. Rev. D (2000)
21. I. Niculescu. Ph.D. Thesis, Hampton University (1999)
22. I.L. Shin, M.Sc. Thesis, Kyung Pook National University (1999)

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