Jefferson Lab PAC16
Proposal Cover Sheet

This document must be received by close of business Thursday, June 8, 1999 at:

Jefferson Lab
User Liaison,
Mail Stop 12B
12000 Jefferson Ave.
Newport News, VA
23606

Experimental Hall: C

Days Requested for Approval: 16

❒ Proposal Title:

Measurement of the Nuclear Dependence of R =sigma_L/sigma_T at Low Q^2

Proposal Physics Goals

Indicate any experiments that have physics goals similar to those in your propos

E94-110

Approved, Conditionally Approved, and/or Deferred Experiment(s) or proposals:

Contact Person

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Jefferson Lab Use Onl

Receipt Date: 6/8/99

By: [signature]

PR 99-118

BEAM REQUIREMENTS LIST

JLab Proposal No.: ______ Date: 6/8/99

Hall: C Anticipated Run Date: ______ PAC Approved Days: ______

Spokesperson: Cynthia Keppel
Phone: (757) 727-5823
E-mail: keppel@jlab.org

Hall Liaison: Roger Carlini

List all combinations of anticipated targets and beam conditions required to execute the experiment. (This list will form the primary basis for the Radiation Safety Assesment Document (RSAD) calculations that must be performed for each experiment.)

Condition No.	Beam Energy (MeV)	Mean Beam Current (μA)	Polarization and Other Special Requirements (e.g., time structure)	Target Material (use multiple rows for complex targets — e.g., w/windows)	Material Thickness (mg/cm²)	Est. Beam-On Time for Cond. No. (hours)
1	2.056	100		H_2	283	2.0
		100		D_2	648	1.5
		50		C	1281	1.5
		50		Al	720	2.0
		50		Fe	830	2.0
		50		Au	390	4.0
2	2.468	50,100*		Same as above	Same as above	39.0
3	3.056	"		"	"	45.0
4	3.668	"		"	"	69.0
5	4.056	"		"	"	45.0
6	4.868	"		"	"	39.0
7	5.056	"		"	"	39.0
8	6.068	"		"	"	75.0

* 50 microA for Solid targets, 100 microA for cryotargets

The beam energies, E_{Beam}, available are: $E_{Beam} = N \times E_{Linac}$ where N = 1, 2, 3, 4, or 5. E_{Linac} = 800 MeV, i.e., available E_{Beam} are 800, 1600, 2400, 3200, and 4000 MeV. Other energies should be arranged with the Hall Leader before listing.

HAZARD IDENTIFICATION CHECKLIST

JLab Proposal No.: ____________ (For CEBAF User Liaison Office use only.)

Date: 6/8/99

Check all items for which there is an anticipated need.

Cryogenics	Electrical Equipment	Radioactive/Hazardous Materials
___ beamline magnets x analysis magnets x target type: 4cm LH_2/LD_2 flow rate: 12 g/s capacity: 15K	___ cryo/electrical devices ___ capacitor banks ___ high voltage ___ exposed equipment More unique to this experiment	List any radioactive or hazadorous/ toxic materials planned for use: none
Pressure Vessels	**Flammable Gas or Liquids**	**Other Target Materials**
___ inside diameter ___ operating pressure ___ window material ___ window thickness None unique to this experiment	type: LH_2, LD_2 flow rate: 12 g/s capacity: 15K **Drift Chambers** type: Standard Hall C flow rate: ___ capacity: ___	___ Beryllium (Be) ___ Lithium (Li) ___ Mercury (Hg) ___ Lead (Pb) ___ Tungsten (W) ___ Uranium (U) x Other (list below) C, Al, Fe, Au
Vacuum Vessels	**Radioactive Sources**	**Large Mech. Structure/System**
___ inside diameter ___ operating pressure ___ window material ___ window thickness None unique to this exp.	___ permanent installation ___ temporary use type: ___ strength: ___ None	___ lifting devices ___ motion controllers ___ scaffolding or elevated platforms None unique to this exp.
Lasers	**Hazardous Materials**	**General:**
type: None wattage: ___ class: ___ Installation: ___ permanent ___ temporary Use: ___ calibration ___ alignment	___ cyanide plating materials ___ scintillation oil (from) ___ PCBs ___ methane ___ TMAE ___ TEA ___ photographic developers ___ other (list below) None	Experiment Class: x Base Equipment ___ Temp. Mod. to Base Equip. ___ Permanent Mod. to Base Equipment ___ Major New Apparatus Other: ___

LAB RESOURCES LIST

JLab Proposal No.: ______________ Date 6/8/99

(For JLab ULO use only.)

List below significant resources — both equipment and human — that you are requesting from Jefferson Lab in support of mounting and executing the proposed experiment. Do not include items that will be routinely supplied to all running experiments such as the base equipment for the hall and technical support for routine operation, installation, and maintenance.

There is no new equipment required for this experiment

Major Installations *(either your equip. or new equip. requested from JLab)*

New Support Structures:

Data Acquisition/Reduction

Computing Resources:

Standard Hall C

DAQ systems and

JLab compùter clusters

New Software: None

Major Equipment

Magnets:

Power Supplies:

Targets:

Detectors:

Electronics:

Computer Hardware:

Other:

Other:

Measurement of the Nuclear Dependence of R $= \sigma_L/\sigma_T$ at Low Q^2

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June 8, 1999

Abstract. We propose to measure inclusive, inelastic ($3.1 < W^2 < 8.5$ GeV^2), electron-nucleon and electron-nucleus scatttering cross sections in the region of Bjorken scaling variable ($0.02 < x < 0.5$), and spanning the four-momentum transfer range $0.07 < Q^2 < 2.2$ (GeV/c)^2. The cross sections will be used to perform Rosenbluth-type separations to extract the ratio $R = \sigma_L/\sigma_T$. The ratio R has been reasonably well measured in deep inelastic scattering up to $Q^2 = 50$ and down to $Q^2 = 1.5$ (GeV/c)^2 using hydrogen and deuterium targets. However, very few measurements exist on nuclei. Of all the functions measured in deep inelastic scattering, R is still one of the most poorly understood, despite numerous attempts to extract it from the cross sections. R is a fundamental quantity which has direct bearing on our understanding of the underlying quark structure of the nucleus. Existing data at moderate to large values of Q^2 rule out significant A-dependent effects in R. However, substantial effects are possible at low Q^2 and have been recently reported by the HERMES collaboration for a measurement at low x and low Q^2. We request sixteen days of beam time to measure inclusive electron scattering cross sections from hydrogen, deuterium, carbon, aluminum, iron, and gold. The proposed data will significantly expand the kinematic range of existing measurements, as well as decrease the uncertainty. The experiment will utilize the existing equipment in Hall C with electron beam energies of 2.468, 3.668, 4.868 and 6.068, and of 2.056, 3.056, 4.056 and 5.056 GeV. Scattered electrons will be detected in the High Momentum Spectrometer (HMS) and the Short Orbit Spectrometer (SOS), utilized in simultaneous single arm mode.

1 MOTIVATION

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 point-like nature of the electron allow for clarity and precision in the interpretation of electron-nucleon scattering experiments; the reaction can be interpreted unambiguously in terms of the charge and current structure of the nucleon. The process of lepton-nucleon scattering has proven to be an effective tool in probing the structure of nucleons. In this process, the leptonic part of the interaction can be calculated within the framework of quantum electrodynamics, and hence the results can be interpreted solely in terms of the structure of the probed nucleons. There are two structure functions F_1 and F_2 which parameterize the hadronic vertex in this scattering. Naive parton model predictions of the scale independence of F_1 and F_2 at large values of momentum transfer, and a simple kinematic relation between F_1 and F_2, were consistent with early experiments [1, 2, 3]. In more accurate later experiments, scaling violations were observed at moderate values of momentum transfer [4, 5]. These latter experiments left open the precise form of the relationship between F_1 and F_2.

The ratio $R = \sigma_L/\sigma_T$ of the longitudinal and transverse virtual photon absorption cross sections relates the two structure functions. R yields information about the spin and transverse momentum of the nucleon constituents.

In a model with spin-1/2 partons, R is expected to be small, and to decrease rapidly with increasing four momentum transfer Q^2. Accurate knowledge of R is essential, however, to extract F_2 and F_1 precisely from cross sections at low and moderate values of Q^2.

A well-known A-dependent effect, termed the EMC effect, has been observed in the structure function F_2 measured in lepton-nucleus scattering [6, 7, 8, 9]. This discovery, that the structure functions (and therefore the quark and gluon distributions) in heavy nuclei are different from those in the nucleon, had a significant impact on our description of the structure of nuclei, and spurred the application of QCD to nuclear physics. It is not inconceivable that such effects exist also in the longitudinal channel as probed by R. However, A-dependent effects in R are difficult to measure, as R is small at large Q^2. The only possibility to search for such effects is at low Q^2. Preliminary results from the HERMES collaboration show an unexpected large A dependence in the cross section ratio of σ_{N14}/σ_D and σ_{He3}/σ_d which is interpreted as a large dependence of R at x below 0.1 and Q^2 below $1(\text{GeV/c})^2$ [10]. Thus, it is of great interest to measure the fundamental quantity R at low Q^2 over a substantial range in x and for various nuclei. Few direct measurements of the nuclear dependence of R are currently available in this regime.

Figure 1 shows the world's data on $R_A - R_D$, the difference between R in electron-nucleus scattering and electron-deuterium scattering as a function of x and Q^2 [13, 14]. The bands depict the kinematic regions and expected total (statistical and systematical) $\pm$ 1σ uncertainty in the quantity R as proposed. Typically, in this region of x and Q^2, the values of R from electron-hydrogen measurements are around 0.3 [15], making low Q^2 measurements less limited than high where this quantity is quite small. The kinematics required for measurements in this regime are ideally suited to Jefferson Lab energies. Additionally, while previous experiments were statistically limited due to beam luminosity and spectrometer acceptance, no such difficulties will hinder the proposed Jefferson Lab measurement. In Figure 1, the error bars depict the total uncertainties. For the existing measurements these error bars are dominated by statistics, while the proposed Jefferson Lab error bars are dominated by systematics. The systematic errors of the existing measurements are comparable to those we propose to obtain.

The new and preliminary HERMES data are shown as the ratio of R_A/R_D for different x bins as functions of Q^2 in Figure 2. The expected precision of the proposed measurement will certainly allow a cross check of this surprising result and further investigate the observed x, A, and Q^2 dependence.

While it is clear that accurate measurements of R for heavy nuclei are crucial to a better understanding of the EMC effect, accurate data on R is generally needed for studies of the spin-dependent and spin-independent structure functions measured in other experiments, particularly since most of the world's data on inelastic muon and neutrino scattering have been measured with nuclear targets. In its own right, the kinematic variation of

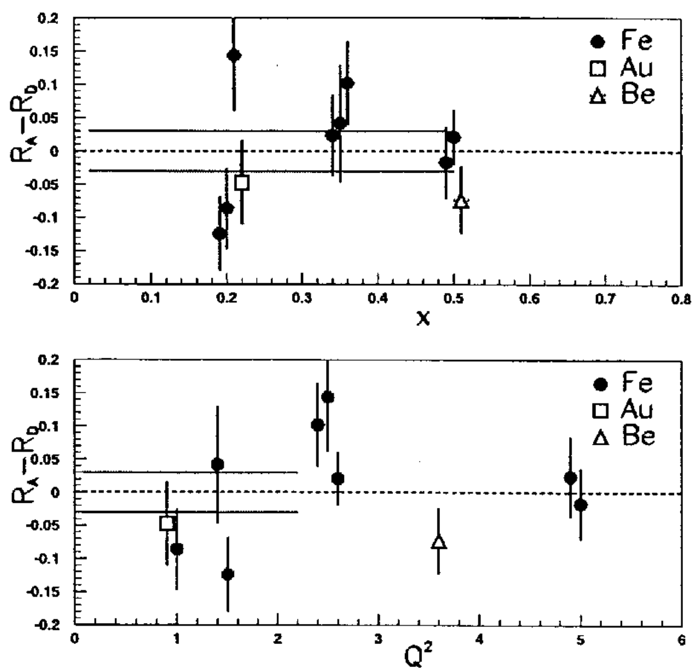

Fig. 1. The quantity $R_D - R_A$ is plotted as a function of Bjorken scaling variable x and momentum transfer Q^2, in $(\text{GeV/c})^2$, for all existing data as compared to the kinematic range and total (statistical and systematic) $\pm$ 1σ uncertainty of the proposed data.

R with x and Q^2 provides an important test of QCD and an independent estimate of the strong coupling constant [11, 12].

Further, the body of data measuring R in deuterium exists only for momentum transfers greater than ≈ 1.5 GeV/c^2 (the only exception being at x = 0.1 and Q^2 = 0.5 and 1.0) [13, 14, 15, 16]. This proposal also extends the deuterium data down to lower values of Q^2, over a larger range in x.

2 KINEMATIC DEFINITIONS AND ROSENBLUTH TECHNIQUE

In this proposal we adopt a notation such that an electron with incident energy E scattering from the proton emerges with a final energy E' at a scattered angle θ. The exchanged virtual photon transfers a four-momentum q_μ to the target producing an undetected hadronic final state of mass W.

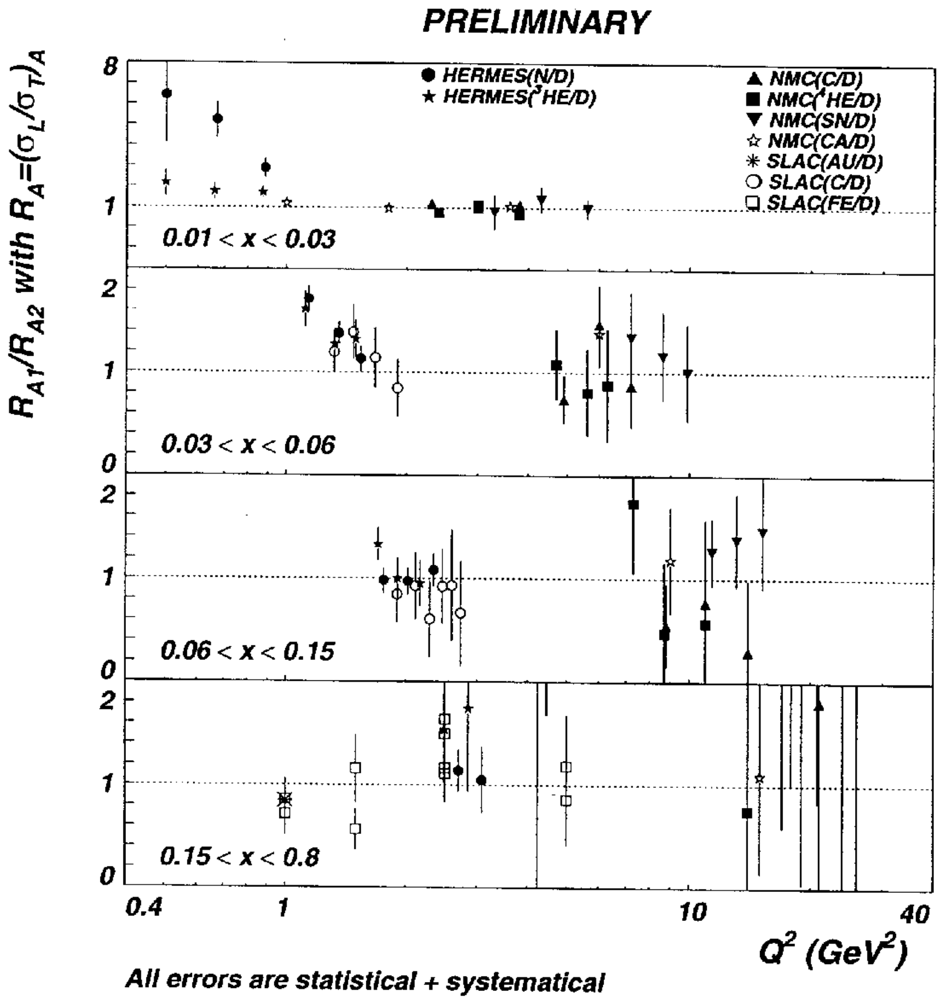

Fig. 2. Recent results from the HERMES collaboration depicting the quantity R_A/R_D as a function of Q^2 for different x bins.

The energy transfer is $\nu = E - E'$. Defining M to be the mass of the proton and neglecting the electron mass,

$$Q^2 = -q_\mu^2 = 4E_\circ E' \sin^2\left(\frac{\theta}{2}\right) \tag{1}$$

is the four-momentum transfer squared and

$$W^2 = M^2 + 2M\nu - Q^2 \tag{2}$$

is the square of the invariant mass of the hadronic final state. This assumes natural units wherein $\hbar = c = 1$.

If the scattering process is viewed as the Born approximation of production and absorption of a single virtual photon, the differential cross section for inelastic scattering is given by [17]:

$$\frac{d^2\sigma}{d\Omega dE'} = \sigma_m \left[W_2(x, Q^2) + 2W_1(x, Q^2) \tan^2\left(\frac{\theta}{2}\right)\right]. \tag{3}$$

Here, σ_m is the Mott cross section for scattering from a pointlike object:

$$\sigma_m = \frac{d\sigma}{d\Omega} = \frac{\alpha^2 \cos^2\theta/2}{4E_\circ^2 \sin^4\theta/2}. \tag{4}$$

The fine structure constant is $\alpha = e^2/4\pi = 1/137$ and $\Omega(\theta, \phi)$ is the laboratory solid angle of the scattered electron. The two structure functions $W_1 = F_1(x, Q^2)$ and $W_2 = (M/\nu)F_2(x, Q^2)$ contain information concerning the electromagnetic structure of the nucleon.

The Bjorken scaling variable x, interpretable as the fraction of momentum carried by the struck quark in deep inelastic scattering at high Q^2, is given by

$$x = \frac{Q^2}{2M\nu}. \tag{5}$$

We define all cross sections and structure function quantities for nuclear targets in terms of cross sections or structure functions per nucleon. Similarly, all kinematics are defined with respect to a stationary free proton target. Under such a definition, x ranges from 0 to 1 for a proton target, and from 0 to M_A/M for nuclear targets where $M_A = AM$ is the mass of a nucleus of atomic weight A.

In order to study the behavior of R, the ratio of longitudinal to transverse photon absorption cross sections σ_L and σ_T, we intend to carry out a series of inclusive inelastic scattering measurements, using the Rosenbluth separation technique. To this effect, we write the differential cross section measured by the detector system as:

$$\frac{d^2\sigma}{d\Omega dE'} = \Gamma[\sigma_T(W^2, Q^2) + \epsilon\sigma_L(W^2, Q^2)]. \tag{6}$$

This is known as the Rosenbluth formula. Here, Γ is the transverse virtual photon flux given by

$$\Gamma = \frac{\alpha\kappa E'}{4\pi^2 Q^2 E}\left(\frac{2}{1-\epsilon}\right) \tag{7}$$

and ϵ is the relative longitudinal virtual photon polarization parameter given by

$$\epsilon = \left[1 + 2(1+\tau)\tan^2\left(\frac{\theta}{2}\right)\right]^{-1}. \tag{8}$$

Here,

$$\tau = \frac{\nu^2}{Q^2}. \tag{9}$$

These total virtual photon cross sections may be related to the structure functions $W_1(x, Q^2)$ and $W_2(x, Q^2)$ as follows:

$$\sigma_T = \frac{4\pi^2\alpha}{\kappa} W_1(x, Q^2) \tag{10}$$

and

$$\sigma_L = \frac{4\pi^2\alpha}{\kappa}\left[(1+\tau)W_2(x, Q^2) - W_1(x, Q^2)\right]. \tag{11}$$

The energy of an equivalent on-mass-shell (real) photon producing a final mass state W is κ. This is a model dependent quantity chosen here to be:

$$\kappa = (W^2 - M^2)/2M. \tag{12}$$

Dividing the measured differential cross section by Γ yields the reduced Rosenbluth cross section σ_R given by

$$\sigma_R = \frac{1}{\Gamma}\frac{d^2\sigma}{d\Omega dE'}. \tag{13}$$

The Rosenbluth equation for the reduced cross section is linear in ϵ. The slope of the line is σ_L and the vertical intercept is σ_T.

We propose to employ the Rosenbluth separation method using linear fits to reduced measured differential cross sections to obtain the quantity $R = \sigma_L/\sigma_T$.

3 PROPOSED EXPERIMENT

Table 1 lists the kinematics we propose to measure. In all cases, data will be obtained utilizing 4 cm hydrogen, 4 cm deuterium, 6% (radiation length) gold, 6% iron, 3% carbon, and 3% aluminum targets. In all cases other than the lowest (x, Q^2) separation point, the epsilon range is 0.3 or greater and the Rosenbluth linear fit will be performed with three or more data points. If the preliminary HERMES results are borne out in subsequent measurements, then the value of R at the lowest kinematic point here proposed will be quite large and the reduced epsilon range and number of points should be sufficient in this case.

Figure 3 shows the proposed kinematics as a function of x and Q^2, in conjunction with the kinematics for the SLAC data shown in Figure 1 and the HERMES kinematics shown in Figure 2. The proposed kinematics to measure the nuclear dependence of R joins smoothly with the existing data.

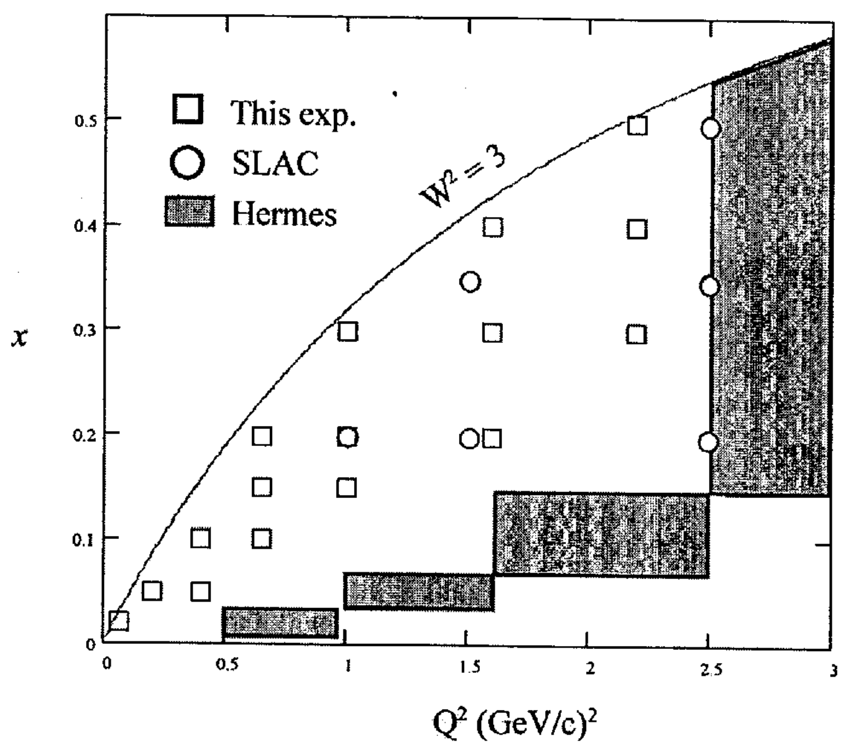

Fig. 3. Overview of the proposed kinematics (squares). Circles indicate the existing data set of Figure 1, while the shaded areas indicate the regions of the recent HERMES measurements.

Table 1. Kinematics for the proposed measurements.

x	Q^2 $(GeV/c)^2$	E (GeV)	E' (GeV)	θ (deg)	ϵ	W^2 $(GeV)^2$
0.02	0.07	2.056	0.50	15.0	0.45	3.73
		2.468	0.91	10.1	0.64	
0.05	0.20	2.468	0.34	28.4	0.25	4.68
		3.056	0.92	15.3	0.54	
		3.668	1.54	10.8	0.70	
0.05	0.40	4.868	0.60	21.2	0.23	8.48
		5.056	0.79	18.2	0.30	
		6.068	1.80	11.0	0.54	
0.10	0.40	2.468	0.34	40.6	0.23	4.48
		3.056	0.92	21.7	0.52	
		3.668	1.54	15.3	0.69	
		4.056	1.91	13.0	0.76	
0.10	0.65	4.056	0.59	30.1	0.26	6.73
		4.868	1.40	17.7	0.51	
		6.068	2.60	11.6	0.71	
0.15	0.65	3.056	0.75	31.0	0.41	4.56
		3.668	1.36	20.8	0.62	
		5.056	2.75	12.4	0.82	
0.15	1.00	4.056	0.50	41.0	0.21	6.55
		4.868	1.32	22.8	0.47	
		6.068	2.52	14.7	0.69	
0.20	0.65	2.468	0.74	34.8	0.48	3.48
		3.668	1.94	17.4	0.79	
		5.056	3.32	11.3	0.90	
0.20	1.00	3.056	0.39	54.4	0.19	4.88
		3.668	1.00	30.2	0.46	
		4.056	1.39	24.3	0.57	
		6.068	3.40	12.6	0.83	
0.20	1.60	4.868	0.60	43.3	0.20	7.28
		5.056	0.79	36.8	0.27	
		6.068	1.80	22.0	0.52	
0.30	1.00	2.468	0.69	45.0	0.41	3.21
		3.668	1.89	21.9	0.76	
		6.068	4.29	11.2	0.93	
0.30	1.60	3.668	0.83	42.6	0.35	4.61
		4.056	1.21	33.1	0.48	
		6.068	3.23	16.4	0.80	
0.30	2.20	4.868	0.78	45.7	0.25	6.01
		5.056	0.97	40.0	0.31	
		6.068	1.98	25.3	0.55	
0.40	1.60	3.056	0.92	44.2	0.44	3.28
		3.668	1.54	30.9	0.63	
		6.068	3.94	14.9	0.88	
0.40	2.20	3.668	0.74	53.6	0.29	4.18
		4.056	1.13	40.6	0.43	
		6.068	3.14	19.6	0.77	
0.50	2.20	3.056	0.71	60.4	0.30	3.08
		3.668	1.32	39.3	0.53	
		6.068	3.72	18.0	0.85	

Many different energies will be required for the entire experiment. Since it is easier to change the angle and momentum of the spectrometer than the beam energy, we propose to take all of the data at a particular energy (several x and Q^2 points) before moving to the next energy.

To reduce systematics we will accumulate all data solely with the HMS spectrometer (the SOS spectrometer is limited to central momenta smaller than 1.78 GeV/c and scattering angles larger than 13.5°). The SOS spectrometer will mainly be used as a luminosity monitor at backward angles, but will have some dedicated runs to determine the positron rates. In addition, SOS will be used as proton spectrometer for ^{1}H(e,e'p) systematics checks. An overview of the expected systematic uncertainties in R is given in Table 2. We have chosen one of the worst kinematics (not counting the low-x kinematics with small ϵ range) for this example. Note that in practice the systematic uncertainty in $R_A - R_D$ is comparable to the systematic uncertainty in R [13, 14].

Table 2. Systematic uncertainties at $Q^2 = 2.2$ (GeV/c)^2 and $x = 0.5$, using a hydrogen target.

		ΔR
Beam Steering	0.2 mrad	0.005
Beam Energy	$1 \cdot 10^{-3}$	0.013
Acceptance	0.2%	0.010
Scattering Angle	0.03° ($\approx$ 0.5 mr)	0.016
Beam Charge	$1 \cdot 10^{-3}$ relative	0.005
Target Density	$< 0.3\%$	0.015
Scattered Electron Energy	$1 \cdot 10^{-3}$	0.005
Detector Efficiency	0.1%	0.005
Deadtime Corrections	0.1%	0.005
	Total	0.030

4 CONCLUSIONS AND BEAM TIME REQUEST

The run time requests were determined in part by the desired accuracy of the measurement of the longitudinal cross section component σ_L. The state-of-the-art measurements of the quantity $R_A - R_D$ have a 0.02 systematic uncertainty [14]. We propose to replicate this accuracy, which will not be as challenging a task at the lower Q^2 values of the proposed measurements. The existing measurements, obtained under far more difficult conditions than the proposed measurement, were typically limited by statistics. The proposed measurement will be dominated by a 10^{-3} uncertainty in knowledge of beam energy, and scattered particle momenta and angles. Statistical precision is not an issue with the high luminosities obtainable at Jefferson Lab. The kinematics allow for a wide range in ϵ, and the quantity R should be larger in the lower Q^2 range of the proposed data. Furthermore, there exists an approved hall C experiment which will precisely measure R in the nucleon resonance region[18]. As above, the measurements here proposed are at more favorable kinematics (lower Q^2). In addition, compared to that experiment, the x and Q^2 dependence of the measured cross sections will be less dramatic as we measure above the resonance region.

We request a total of sixteen days, as outlined in Table 3. Data rates are large, the lowest rate for hydrogen being 100 Hz for the high Q^2, backward angle kinematics. We assume a minimum data taking time of half an hour per kinematics. The data acquisition time in Table 3 assumes half an hour data taking for hydrogen and deuterium targets, with 100% efficiency, normalized by a figure of merit for the solid targets, taking into account assumed target thicknesses and beam currents. The figures of merit for the gold, iron, carbon, and aluminum targets, normalized to the hydrogen and deuterium targets, are 0.33, 0.67, 1.00, and 0.60, respectively. This assumes 100 μAmps on the liquid targets, and 50 μAmps on the solid. The aluminum target to be utilized will also serve to simulate an empty liquid target cell for liquid cell wall subtraction. Rates were calculated using a global fit to SLAC data on hydrogen and deuterium [15].

We assume that the spectrometer angle and momentum can be changed simultaneously, which is estimated to take one half hour. For each kinematic setting, an additional 60 minutes is requested, 12 minutes for changing each of the five additional targets. We request eight different beam energies, but in this there is only one base linac energy change required. We assume that this will take eight hours, but that energy pass changes will require only two hours each. We request also three days of calibration time which will be used for elastic runs for energy and momentum calibrations, optics scans with sieve slits, liquid target luminosity scans, and spectrometer pointing checks. These checks may be interspersed as required throughout the run period.

In conclusion, we request 16 days in Hall C to measure the quantity $R = \sigma_L/\sigma_T$ for missing mass squared, W^2, typically above the resonance region at low Bjorken scaling variable x and momentum transfer squared, Q^2. We propose to perform a study of the difference between R for heavy nuclear targets and R for the nucleon in the low x and Q^2 regime where A-dependent effects should be measureable. The quantity R is essentially unmeasured in this regime, and will have bearing on additional structure function measurements, in particular F_2 studies of the EMC effect. The difference $\Delta(R_A - R_D)$ will be measured with a typical systematic uncertainty of 0.03.

Table 3. Outline of total beam time request.

	time (hours)
data acquisition	221
spectrometer angle, momentum changes	24
target changes	49
beam energy tune change	8
beam energy pass changes	12
calibrations	70
TOTAL	384

References

1. E.D. Bloom *et al.*, Phys. Rev. Lett. **23**, 930 (1969).
2. M. Breidenbach *et al.*, Phys. Rev. Lett. **23**, 935 (1969)
3. G. Miller *et al.*, Phys. Rev. D **5**, 528 (1972)
4. A. Bodek *et al.*, Phys. Rev. D **20**, 1471 (1979)
5. M.D. Mestayer *et al.* Phys. Rev. D **27**, 285 (1983)
6. J.J. Aubert *et al.*, Phys. Lett. **123B**, 275 (1983); G. Bari *et al.*, *ibid.* **163B**, 282 (1985)
7. A. Bodek *et al.*, Phys. Rev. Lett. **50**, 1431 (1983); **51**, 534 (1983)
8. R.G. Arnold *et al.*, Phys. Rev. Lett. **52**, 727 (1984)
9. M. Arneodo *et al.*, Z. Phys. C **51**, 387 (1991)
10. G. van der Steenhoven, talk at PANIC99
11. L.F. Abbott and R.M. Barnett, Ann. Phys. **125**, 276 (1980)
12. A. Devoto, D.W. Duke, J.F. Owens, and R.G. Roberts, Phys. Rev. **D27**, 508 (1979)
13. S. Dasu *et al.*, Phys. Rev. D **49**, 5641 (1994)
14. L.H. Tao *et al.*, Z. Phys. C **70**, 387 (1996)
15. L.W. Whitlow *et al.*, Phys. Lett. B250, 193 (1990)
16. M. Arneodo *et al.*, Nucl. Phys. B **487**, 3 (1997); Phys Lett. **249B**, 366 (1990)
17. S.D. Drell and J.D. Walecka, Ann. Phys. 28, 18 (1964)
18. CEBAF Proposal E94-110, C. Keppel, spokesperson