CEBAF Program Advisory Committee Nine
Extension and Update Cover Sheet

This update must be received by close of business on Thursday, December 1, 1994 at:

CEBAF
User Liaison Office, Mail Stop 12 B
12000 Jefferson Avenue
Newport News, VA 23606

Experiment: E 93 - 022

Check Applicable Boxes:

- [x] Extension
- [ ] Update
- [ ] Hall B Update

Contact Person

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CEBAF Use Only

Receipt Date: 12/14/94

By: gp PR 94-140

BEAM REQUIREMENTS LIST

CEBAF Proposal No.: EXTENSION E93-022 (For CEBAF User Liaison Office use only.) Date: 12/14/94

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 #	Beam Energy (MeV)	Beam Current (μA)	Polarization and Other Special Requirements (e.g., time structure)	Target Material (use multiple rows for complex targets — e.g., w/windows)	Target Material Thickness (mg/cm²)
1††	2400	0.160	none	STANDARD CLAS HIGH-P H_2 TGT	8
2††	2800	0.320	"	"	8
3††	3200	0.320	"	"	8
4†	4000	0.320	"	"	8
5*	6000	0.320	"	"	8
* NEW BEAM TIME REQUEST					
† APPROVED BEAM TIME FOR E-93-022					
†† APPROVED BEAM TIME FOR OTHER EXPERIMENTS					

The beam energies, E_{Beam}, available are: $E_{Beam} = N \times E_{Linac}$ where N = 1, 2, 3, 4, or 5. For 1995, E_{Linac} = 800 MeV, i.e., available E_{Beam} are ?, 1600, 2400, 3200, and 4000 MeV. Starting in 1996, in an evolutionary way (and not necessarily in the order given) the following additional values of E_{Linac} will become available: E_{Linac} = 400, 500, 600, 700, 900, 1000, 1100, and 1200 MeV. The sequence and timing of the available resultant energies, E_{Beam}, will be determined by physics priorities and technical capabilities.

LAB RESOURCES REQUIREMENTS LIST

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List below significant resources — both equipment and human — that you are requesting *from CEBAF* 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.

REQUEST STANDARD CLAS OPERATION

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

New Support Structures:

Data Acquisition/Reduction

Computing Resources:

New Software:

Major Equipment

Magnets

Power Supplies

Targets

Detectors

Electronics

Computer Hardware

Other

Other

HAZARD IDENTIFICATION CHECKLIST

CEBAF Proposal No.: ~~Resu~~ EXTENSION E93-022 (For CEBAF User Liaison Office use only.) Date: 12/14/94

Check all items for which there is an anticipated need. STANDARD CLAS

Cryogenics ✓ CLAS TOROID
- ___ beamline magnets
- ___ analysis magnets
- ___ target

type: ___
flow rate: ___
capacity: ___

Electrical Equipment
- ___ cryo/electrical devices
- ___ capacitor banks
- ✓ high voltage (PMTs) (DCs)
- ___ exposed equipment

Radioactive/Hazardous Materials
List any radioactive or hazadorous/toxic materials planned for use:

___

Pressure Vessels
- ___ inside diameter
- ___ operating pressure
- ___ window material
- ___ window thickness
- ✓ H_2 gas Target @ 10atm. Standard CLAS target.

Flammable Gas or Liquids
type: H_2 target
flow rate: – none –
capacity: 79 cm³ @ STP

Drift Chambers
type: Region 1,2,3 CLAS
flow rate: ___
capacity: ___

Other Target Materials
- ___ Beryllium (Be)
- ___ Lithium (Li)
- ___ Mercury (Hg)
- ___ Lead (Pb)
- ___ Tungsten (W)
- ___ Uranium (U)
- ___ Other (list below)

Vacuum Vessels
- ___ inside diameter
- ___ operating pressure
- ___ window material
- ___ window thickness

Radioactive Sources
- ___ permanent installation
- ___ temporary use

type: ___
strength: ___

Large Mech. Structure/System
- ___ lifting devices
- ___ motion controllers
- ___ scaffolding or elevated platforms
- ✓ CLAS space frame

Lasers
type: LN 120C
wattage: 0.5mW
class: IIIb

Installation:
- ___ permanent
- ___ temporary

Use:
- ✓ calibration
- ___ alignment

Hazardous Materials
- ___ cyanide plating materials
- ___ scintillation oil (from)
- ___ PCBs
- ___ methane
- ___ TMAE
- ___ TEA
- ___ photographic developers
- ___ other (list below)

General:

Experiment Class:
- ✓ Base Equipment
- ___ Temp. Mod. to Base Equip.
- ___ Permanent Mod. to Base Equipment
- ___ Major New Apparatus

Other: ___

Production of Vector Mesons by Longitudinal Photons

Extension to E-93-022

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STRUCTURE OF THE NUCLEON PHYSICS WORKING GROUP

Spokespersons: H. Funsten, P. Rubin and E.S. Smith

1 Overview

In E-93-022, we proposed to measure the final state polarization of the ϕ meson in the reaction $e^- \ p \ \rightarrow \ e^- \ p \ \phi$, at a beam energy of 4 GeV. The high sensitivity available at CEBAF with CLAS will significantly constrain possible production mechanisms. We now propose to extend our investigation of this reaction by measuring production rates of both the ϕ and ρ° mesons via (virtual) photons of known polarization. Running at beam energies from 2.4 to 6 GeV, the standard Rosenbluth technique may be employed to determine the ratio of longitudinal to transverse cross sections in exclusive vector meson production in a model-independent way for the first time. The extension to 6 GeV will double the accessible Q^2 range of the measurement.

2 Motivation

The ratio, $R \equiv \frac{\sigma_L}{\sigma_T}$, defines the character of electron-proton scattering, since the Ioffe time (the effective time between quark-pair formation and nuclear interaction in deep-inelastic scattering) depends directly on the polarization of the virtual photon [1]. It is nearly twice as long for transverse as for longitudinal photons. The transverse size of a hadronizing photon also depends on the polarization.

Precision results of model-independent investigations of vector meson production, furthermore, can constrain effective theories of the production. For example, an attempt has been made to extend perturbative QCD into the soft-momentum-transfer region [2] by associating the pomeron with a two-gluon exchange mechanism. Quark interchange and OZI suppression make exclusive ϕ meson production a particularly sensitive measure of the two-gluon exchange. A parametrization of the inclusive behavior for R, normalized to indirect measurements of the exclusive reaction, is shown in Figure 1 along with the prediction of the QCD-inspired model.

3 Indirect Measurements

No model-independent experimental determination of R exists. Vector meson production at low momentum transfer appears consistent with diffraction and so analyzable within the context of the VMD model, where R is proportional

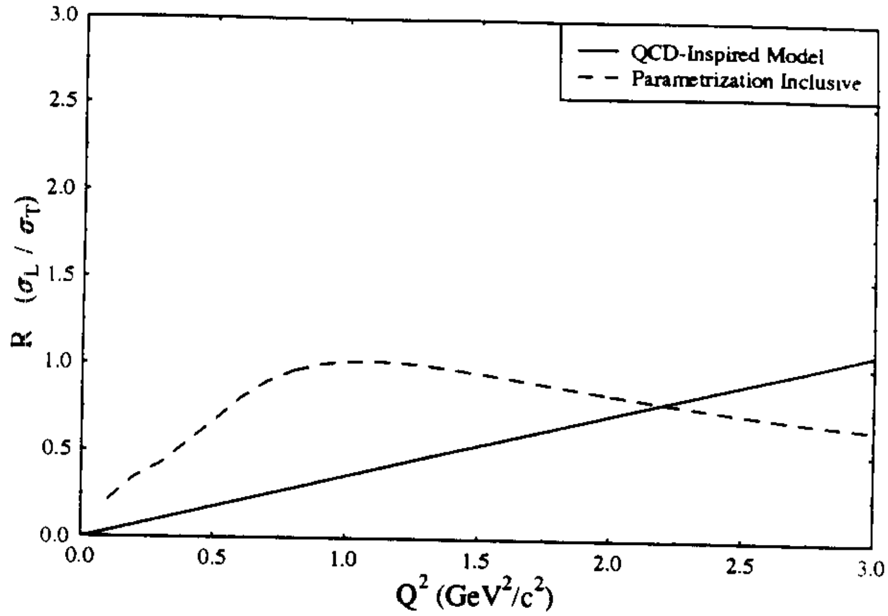

Figure 1: The expected behavior of R is plotted as a function of Q^2 for a) the inclusive cross section, but normalized to indirect measurements of the exclusive reaction, and b) predictions of a two-gluon exchange mechanism for vector meson production.

to Q^2. Under the assumption of s-channel helicity conservation (SCHC), R can be fitted as a parameter of the angular decay distribution in the vector meson's rest frame. A compilation of measurements of this type is given in Figure 2.

The many determinations of R from ρ° production [3] agree well with the VMD prediction at low Q^2, but show a jump at about $Q^2 = 0.8$ GeV^2/c^2. Furthermore, data from exclusive ρ° muoproduction at high energies [4] show that the decay distribution of the VMD framework is incompatible with cross section measurements. Finally, ϕ production data [5] are limited to a few hundred events and cover only 0.23 GeV^2/c$^2 \leq Q^2 \leq 1$ GeV^2/c^2.

4 Simulation of the Experiment

The Rosenbluth determination of R requires measuring the total exclusive cross section at the same Q^2 and W but at different virtual photon polarizations, that is, different incident beam energies. With the CLAS magnetic field set at half the nominal value and oriented to bend negative particles toward the axis, accessible ranges of Q^2 and W are 0.3 GeV^2/c$^2 \leq Q^2 \leq 2.0$ GeV^2/c^{2}and 2.0 GeV $\leq W \leq$ 2.6 GeV for beam energies between 2.4 GeV and 6.0 GeV.

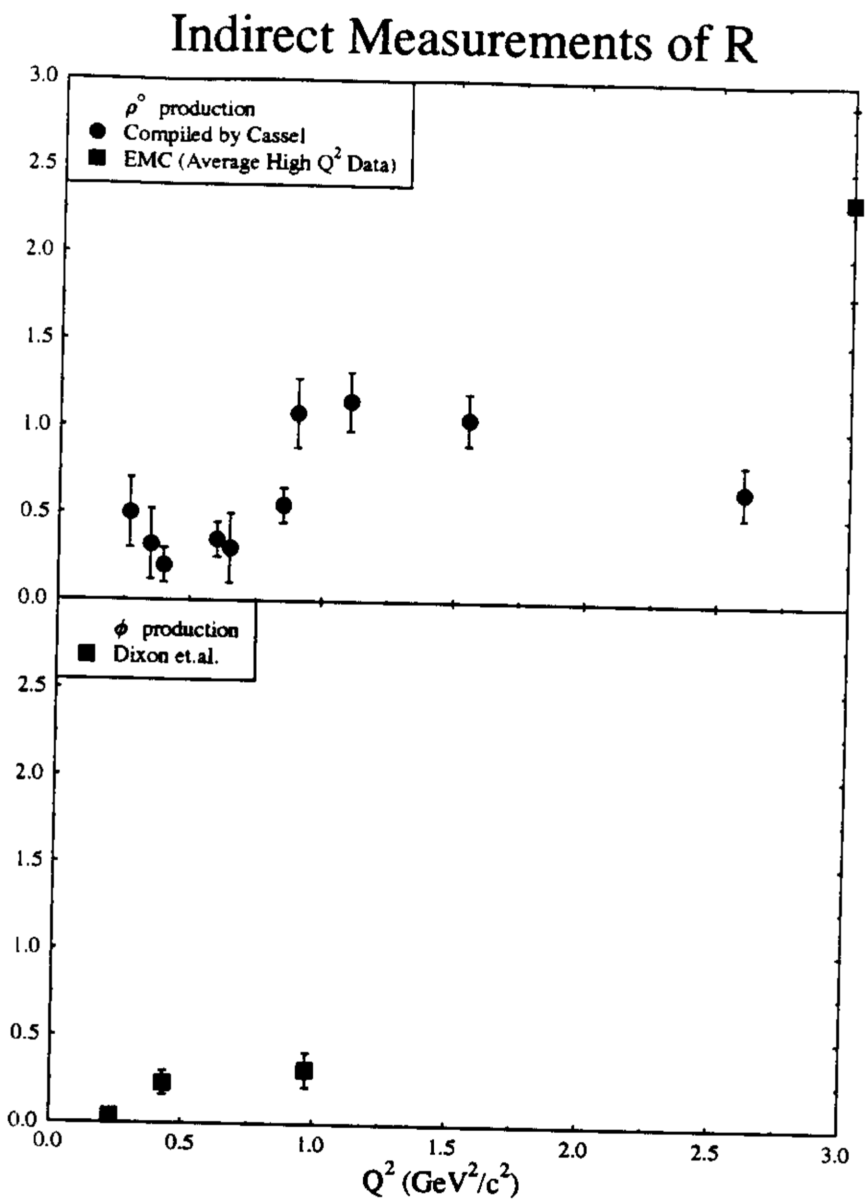

Figure 2: Indirect measurements of R extracted from fits to the angular decay distribution of the vector meson. For clarity, data on ρ° production with large uncertainties have been omitted. The average value for EMC data (average $Q^2 \sim 8$ GeV^2/c^2) is shown to indicate the measured behavior at high energy.

Vector mesons produced in e^-p scattering can be identified by missing mass once the kinematics of the scattered electron and proton are measured. Both ρ° and ϕ have very high decay branching ratios to a pair of pseudoscalar mesons, however, and backgrounds are effectively reduced by detecting at least one of the pair. CLAS's particle identification capabilities are more than adequate to separate daughter kaons from unrelated pions, even at the 6 GeV beam energy.

To determine detector acceptance and to estimate counting rates, we generated approximately 2000 events in each of 48 Q^2-W bins at each beam energy, assuming diffractive production, and processed them with FASTMC [6], which models the acceptance and resolution of the CLAS detector. We find that ϕ detection efficiency varies between 5% and 10% and ρ° detection efficiency varies between 15% and 30%. Given published values for the cross sections and 350 hours of beam at 6 GeV, we expect to detect twenty million ρ°'s and twenty thousand ϕ's integrated over all kinematic quantities. The statistical depth of the sample will allow detailed systematic studies of the production processes as a function of all kinematic variables, including the momentum transfer, t.

4.1 Systematic Errors

The dominant sources of error in this determination of R are systematic uncertainties in experimental parameters such as beam energy E_b, scattered electron energy E_e, and scattering angle θ. The variations in the cross section due to shifts in these parameters are given in Table 1. The shifts taken in quadrature result in errors between 4–6%. We review each of the contributions in turn.

The absolute beam energy of the machine can be determined up to 6.1 GeV using the Hall B tagger magnet. The field of the magnet was mapped using the Fermilab Zip-track system. Preliminary ray-tracing calculations through the field maps show that the field quality is sufficient to provide the design energy resolution of 0.2% (FWHM) over the entire tagged photon energy range. With the estimates of the surveying group that the magnet can be located to better than 1 mm, a measurement of E_b to better than 0.1% absolute should be attainable. We use the conservative estimate of 0.3%.

Two strategies are being investigated to align the drift chamber system to an absolute precision of 0.2 mrad. The first involves precise surveys of the

Table 1: Shifts in the measured rate at Q^2=0.5 GeV^2/c^2 and W=2.15 GeV, in percent, due to changes in the beam energy E_b, electron scattered energy E_e, electron scattering angle θ, acceptance and expected radiative corrections. To obtain the total error, the individual contributions are added in quadrature.

Source of Shift	E_b= 2.4 GeV Shift (%)	E_b= 4 GeV Shift (%)	E_b= 6 GeV Shift (%)
$E_b \rightarrow$ +0.3%	0.0	+0.4	+1.0
$E_e \rightarrow$ +0.5%	-1.5	-2.1	-3.1
$\theta \rightarrow$ +0.5 mrad	-0.2	-1.0	-1.7
Acceptance and Efficiency	1	2	2
Radiative Corrections	3.5	3.5	3.5
Total	4.0	4.7	5.5

Region 1 drift chamber. The second would use angle-defining slits machined to a precision of 0.1 mrad. Multiple scattering contributions degrade the angular resolution of CLAS to σ=0.4–0.7 mrad. As a source of uncertainty in the extraction of R, we use the conservative estimate of 0.5 mrad.

The magnetic field of the CLAS torus will be calculated using the known positions of the coils. The location of the coils within the cryostats will be determined to within 1 mm by measuring the magnetic field near the coils at various excitations of the magnet. Missalignment of coils at this level results in typical shifts in the reconstructed momentum of 0.3%. We adopt 0.5% as an estimate of our uncertainty, which is typical of our momentum resolution.

The proton and mesons are detected in roughly the same regions of CLAS for all energies. Therefore, the main uncertainty in acceptance results from precise determination of the Cerenkov counter coverage, where at small angles a 1 cm error results in a 2% systematic uncertainty.

Radiative corrections to the basic scattering process can be large, of order 15–30%. To estimate the systematic uncertainties resulting from various approximation procedures, we use published errors of inclusive deep-inelastic experiments to estimate an achievable uncertainty of 3.5%. We will also use the sample of fully reconstructed events to determine the radiative tails experimentally. This will allow us to determine these corrections empirically, thereby minimizing this source of error.

4.2 Sensitivity

The sensitivity of the experiment was estimated by assuming that each data point consisted of 1000 events. The error assigned to the data point was the statistical error added in quadrature with a systematic error of 5%. The systematic error clearly dominates the sensitivity. Three typical cases were considered for Q^2= 0.5 , 1.0 and 1.5 GeV^2/c^2. The expected data for each case are shown in Figure 3 along with the fitted values for σ_T and the sum $\sigma_L+\sigma_T$.

The errors on the fitted value of R vary from δR= 0.15 at the lowest Q^2, where we have up to five measurements at different beam energies, up to 0.25 when we have only three data points. The absolute error δR is approximately independent of R, so the relative error improves when σ_L is large. We conclude that these direct measurements of R will have uncertainties which are comparable to those extracted from fitting to the angular distribution of vector meson decays within the context of VMD.

5 Summary

The measurement of the ratio of longitudinal to transverse cross sections, R, is a sensitive probe of the dynamics of the electron-nucleon interaction. Both theoretical expectations and indirect measurements indicate that R is quite large, approximately one, for these exclusive reactions. Direct measurements of R at the level of $\delta R \sim$ 0.15–0.25 is achievable in the Q^2 range between 0.3 and 2.0 GeV^2/c^2 (see Figure 4) for the exclusive production of $\rho^\circ$and ϕ vector mesons. We note that the beam time at 6 GeV is essential for measurements above Q^2= 1 GeV^2/c^2. These would be the first measurements of exclusive vector meson production by longitudinal photons. To complete this measurement we request the following running conditions:

- Proton Target, Luminosity = 10^{34} $cm^{-2}s^{-1}$, Magnetic field set at half maximum with negative particles bending toward the axis.
- Electron Beam Energies: 2.4, 2.8, 3.2, 4 and 6 GeV. Concurrent running with approved experiments for lowest four beam energies.
- 350 hours of CLAS operation at 6 GeV.

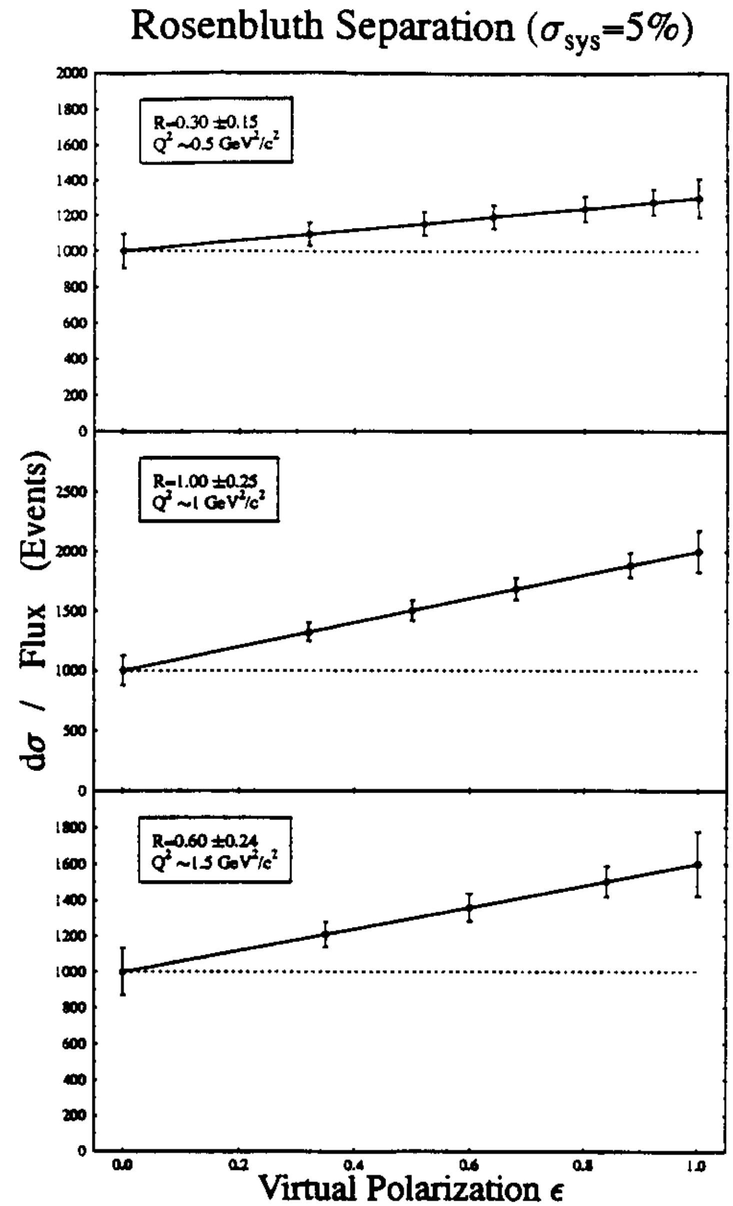

Figure 3: We show the expected sensitivity of this experiment to the model-independent determination of R at three different Q^2. Indicated are the simulated measurements at several values of ϵ and the extrapolation to $\epsilon = 0$ (σ_T) and $\epsilon = 1$ ($\sigma_T + \sigma_L$). We assume a 5% systematic error in quadrature with the statistical error corresponding to 1000 events at $\epsilon = 0$.

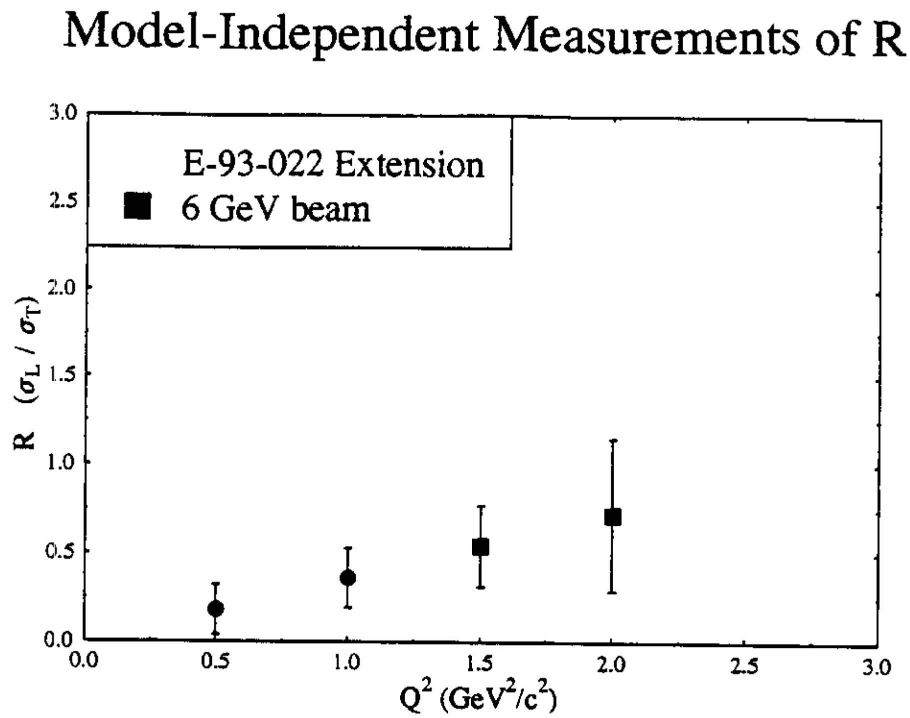

Figure 4: Expected results for the extraction of R from this experiment as a function of Q^2. The additional beam time at 6 GeV allows measurements up to $Q^2 = 2$ GeV^2/c^2.

References

[1] V. Del Duca, S.J. Brodsky and P. Hoyer, Phys. Rev. **D46**, 931 (1992).

[2] J.-M. Laget and R. Mendez-Galain, "Exclusive Photo- and Electro-production of Vector Mesons at Large Momentum Transfer," CEA-DAPNIA-SPHN-94-24, May, 1994.

[3] D.G. Cassel *et al.*, Phys. Rev. D **24**, 2787 (1981).

[4] EM Collab., J.J. Aubert *et al.*, Phys. Lett. **B161**, 203 (1985).

[5] R. Dixon *et al.*, Phys. Rev. Lett. **39**, 516 (1977).

[6] H. Funsten, P. Rubin and E.S. Smith, "Production of Vector Mesons by Longitudinal Photons," CLAS-NOTE in preparation, and references therein.