Update Proposal for E02-109: Measurement of $R = \sigma_L/\sigma_T$ on Deuterium in the Nucleon Resonance Region

June 25, 2005

M.E. Christy (spokesperson), Chandana Jayalath, C. Keppel (spokesperson), Simona Malace, Edwin Segbefia, Vladas Tvaskis
Hampton University, Hampton, VA

E. Kinney
University of Colorado, Boulder, Colorado

P. Markowitz, J. Reinhold
Florida International University, University Park, FL

I. Niculescu, G. Niculescu
James Madison University, Harrisonburg, VA

J. Dunne
Mississippi State University, Mississippi State, MS

A. Gasparian
North Carolina A&T State University, Greensboro, NC

P. Bosted, R. Ent, D. Gaskell, M. Jones, D. Mack, S. Wood
Thomas Jefferson National Accelerator Facility, Newport News, Virginia, VA

O. Rondon
University of Virginia, Charlottesville, VA

H.P. Blok
Vrije Universiteit, Amsterdam, Netherlands

H. Mkrtchyan, R. Asaturyan, S. Stepanyan, V. Tadevosyan
Yerevan Physics Institute, Yerevan, Armenia

Abstract

We propose to measure the longitudinal-transverse (L-T) separated structure functions on deuterium throughout the nucleon resonance region ($1 < W^2 < 4\,\mathrm{GeV}^2$) and spanning the four-momentum transfer range $0.5 < Q^2 < 4.5\ (\mathrm{GeV/c})^2$. Experiment E02-109 was previously approved for 13 days by the PAC but has reached jeopardy status before completion of the approved program. In January 2005, E02-109 successfully completed 1/3 of the approved 13 PAC days, emphasizing the low Q^2 data. This update proposal to E02-109 (original proposal attached) requests beam time to take the remaining 9 PAC days.

The separation of the inclusive electroproduction cross sections into longitudinal and transverse strengths will be accomplished both by performing Rosenbluth separations and through a global (iterative) fitting procedure. This will allow for an extraction of the transverse structure function $F_1(x, Q^2)$, the longitudinal structure function $F_L(x, Q^2)$, and the ratio $R = \sigma_L/\sigma_T$ across this entire kinematic range in both W^2 and Q^2. This proposal represents the first global survey of these fundamental quantities in the resonance region for the deuteron. In light of recent experimental and theoretical developments, we believe that the physics case for these measurements is even more compelling today than when the experiment was originally proposed.

1 Status of E02-109

During January of 2005, beam time was available in Hall C to complete a portion of both the E02-109 and E04-001 (measurements of $R = \sigma_L/\sigma_T$ on nuclei in the resonance region) programs. Both experiments were scheduled for 1/3 of the approved beam time (13 PAC days for E02-109) and this period was dedicated to emphasizing the low $Q^2 < 2.0$ GeV^2 (referred to hereafter as phase I) portion of the data. Due to identical experimental requirements, these experiments were run simultaneously in order to significantly reduce the overall time overhead, which is dominated by the frequent kinematic changes required for these measurements. Furthermore, it is anticipated that the $Q^2 > 2.0$ GeV^2 (referred to hereafter as phase II) data will also be taken simultaneously with the approved E04-001 data, further minimizing the beam time required to run these experiments individually.

The analysis of the phase I data is well underway and preliminary checks indicate that the data is on par with the quality proposed. The core team leading the analysis of the phase I data has extensive experience in the analysis of precision L-T separation experiments [1, 2] performed in Hall C and the previously developed and rigorously tested analysis machinery has been, and will continue to be heavily utilized. As an example of the quality of the data, preliminary spectra for the deuterium resonance region cross sections which have been extracted are shown in Figure 1 for $E_{\mathrm{beam}} = 4.63$ GeV and $\theta = 10.65$, 16, 20, and 25°.

Because of beam energy constraints imposed by experiments running concurrently in the other halls during the E02-109 Phase I period, the data were taken utilizing only a single linac energy with multiple passes corresponding to energies of E = 1.21, 2.35, 3.49, and 4.63 GeV. We note that the approved kinematics include two separate linac energies, as listed in Table 4 of the original proposal (reproduced here as Table 1 for convenience).

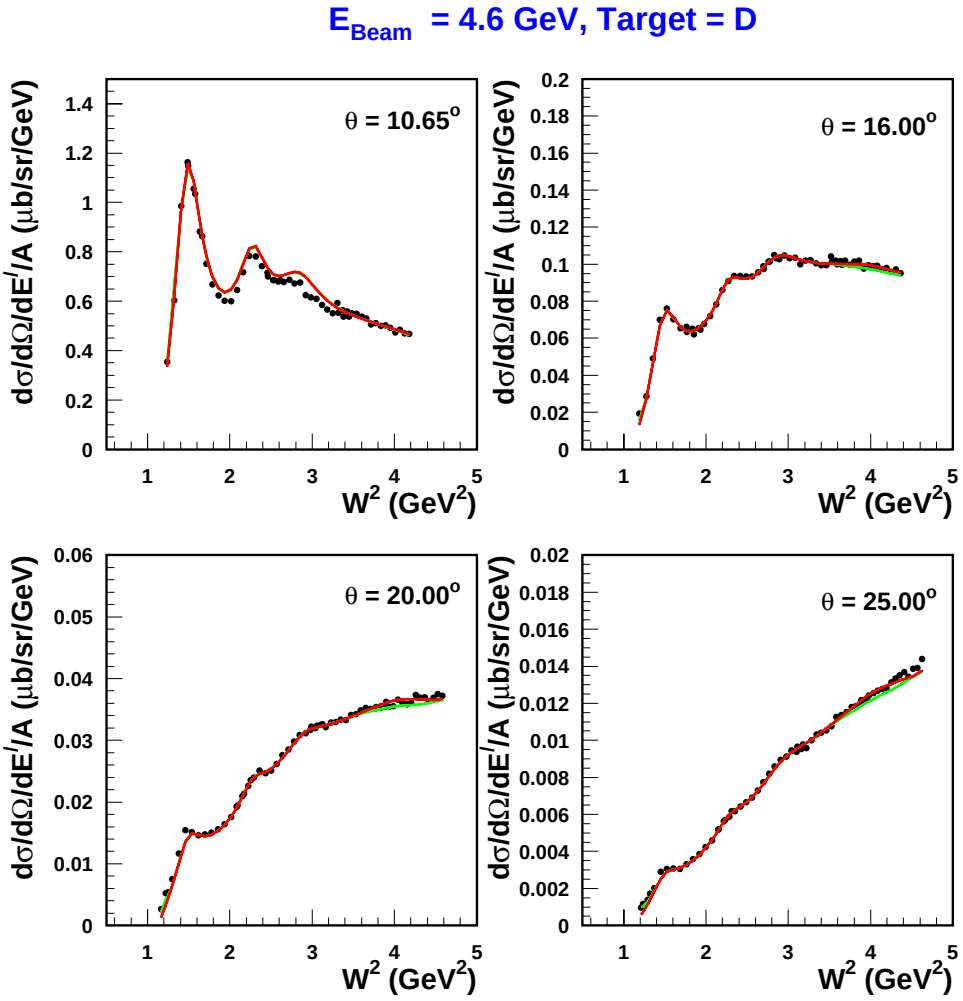

Figure 1: Preliminary Deuterium cross section spectra extracted from E02-109 data taken in January, 2005. Also shown is a fit [6] to previous Hall C deuterium cross sections (red curve). Error bars are statistical only.

Q^2_Δ $(GeV/c)^2$	E (GeV)	E'_Δ (GeV)	θ_Δ (deg)	ϵ_Δ	$Rate_\Delta$ (Hz)	Time (Hours)
0.5	1.16	0.55	52*	0.54	1 K	0.5
	1.64	1.0	33	0.78	1 K	0.5
	4.04	3.4	11	0.97	1 K	0.5
1.0	1.64	0.77	52*	0.53	1 K	0.5
	2.28	1.4	33	0.77	1 K	0.5
	4.52	3.6	14	0.95	1 K	0.5
2.0	2.28	0.87	60*	0.43	65	0.5
	3.24	1.8	35	0.73	285	0.5
	5.64	4.2	17	0.92	1 K	0.5
3.0	3.24	1.3	52*	0.51	16	2
	4.04	2.1	35*	0.70	40	1
	5.64	3.7	22	0.86	172	0.5
4.0	3.24	0.77	79*	0.23	1	22
	4.04	1.6	47*	0.51	3	8
	5.64	3.2	27	0.77	53	1
5.0	4.04	1.0	66*	0.29	1	22
	4.52	1.4	52*	0.42	3	8
	5.64	2.5	35	0.66	6	4
						Total **73**

Table 1: Kinematics table with beam time requirements reproduced from original proposal. All kinematics and rates shown are for a single bin in W^2 of (25 MeV)^2 width at the Δ resonance. Positron data will be taken in the SOS for the angles indicated by an asterisk.

2 New Developments

In the time since the original proposal, developments in experiment and theory have served to enhance both the relevance and timeliness of the proposed measurements. The first of these is the calculation of the nucleon non-singlet QCD moments which have now been performed [3] on the lattice for $Q^2 = 4$ GeV^2. The proposed deuterium measurements combined with the corresponding proton measurements already performed in Hall C [1, 4], will allow for a direct confrontation of these calculations with data. At $Q^2 = 4$ GeV^2 the proposed data are critical since the resonance region (defined here as $W^2 < 4$ GeV^2) extends down to about $x_{bj} = 0.6$ and comprises a significant (and in the case of the higher moments, the dominant) contribution to the moments. These measurements will allow for a determination of the Q^2 evolution of these moments. This could play a crucial role in understanding the transition from perturbative to nonperturbative QCD in nucleon structure.

In regards to determining the structure of the neutron, it is a particularly exciting time. A measurement by the BoNuS (Bound Nucleon Structure) collaboration designed to determine the neutron F_2 structure function at moderate to high x_{bj} has been sched-

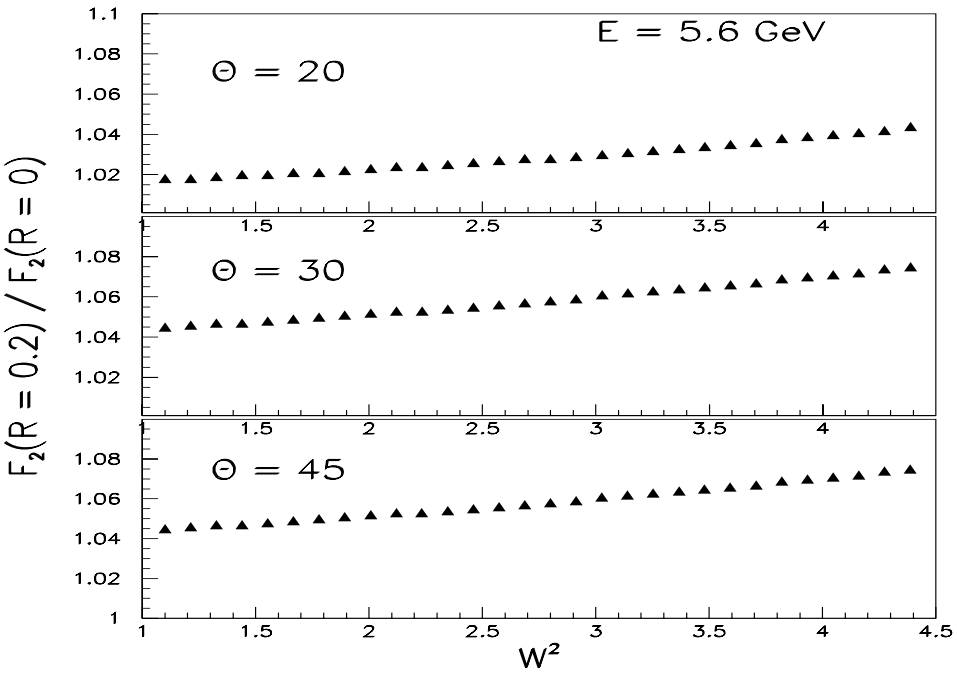

Figure 2: ratio of F_2 extracted assuming R=0.2 to that extracted assuming R=0 versus W^2 for typical BoNuS electron kinematics of $E_{beam} = 5.6$ GeV and $\theta = 20$, 30 and 45°.

uled to take first production data in October of 2005. This will be accomplished by tagging the recoiling spectator protons produced when an electron scatters from a nearly free neutron in a deuterium gas target. Utilizing data from BoNuS and the deuteron measurements proposed here will provide important information on the L-T separated unpolarized structure functions of the neutron. It is also important to note that BoNuS will measure cross sections and will extract F_2^N utilizing assumptions for R, which is not known for the neutron in this kinematic range. The ratio of F_2 extracted from cross section measurements assuming R=0.2 to that extracted assuming R=0 is plotted versus W^2 in figure 2 for typical BoNuS electron kinematics. For electron scattering angles of 45° the average difference of the extracted values of F_2^N is about 5% in the resonance region.

The measurements proposed are also a vital component in a broader program (with JLab E04-001 [5]) to determine both the vector structure functions of nucleons and their nuclear dependence. For specific isospin states, conservation of vector current (CVC) allows these structure functions to be related to their counterparts in neutrino scattering. This is critical Monte Carlo input for the current and next generation of neutrino oscillation experiments, which are now pushing to lower energies and into the resonance production regime. Because of this, the Phase I run period received significant support from the neutrino community, including the manning of many shifts in Hall C.

3 Beam Energy and Time Requirements

As already noted, the Phase I data represent 33% of the total required beam time for the previously approved program of 13 beam days. We therefore request 0.67 $\times$ 13 days = 9 days for Phase II. The beam energies required to complete Phase II are: E_{beam} = 3.49, 4.63, 5.76 GeV (E_{linac} = 1.14 GeV), and 1.64, 4.04 GeV (E_{linac} = 0.8 GeV). The base energy of E_{linac} = 1.14 GeV is different from that originally proposed, but we assume this energy for consistency with Phase I energies. We note, however, that small modifications to this base energy do not impact the quality of the proposed measurements.

The Collaboration

The collaboration consists of physicists who have participated in a substantial amount of Hall C running. The collaboration has implemented and proven successful techniques to reduce systematic uncertainties in Hall C experiments, including detailed studies of the HMS acceptance, efficiencies, and optics, as well as beam line instrumentation. This collaboration has the on-site experience, knowledge and expertise requisite to perform a precision measurement of the type proposed.

Conclusion

We propose to complete the measurements of the L-T separated structure functions on deuterium throughout the nucleon resonance region ($1 < W^2 < 4$ GeV^2) and spanning the four-momentum transfer range $0.5 < Q^2 < 4.5$ (GeV/c)^2. These measurements were previously approved for 13 days as Experiment E02-109, which has utilized 33% of the approved time before reaching jeopardy status. We, therefore, request the remaining 9 days required to complete E02-109 program.

REFERENCES

1. JLAB experiment 94-110, C.E. Keppel spokesperson
2. JLAB experiment 99-118, A. Bruell, J. Dunne, and C.E. Keppel spokespersons
3. D. Dolgov *etal.*, Phys.Rev.D66:034506,2002
4. nucl-ex/0410027
5. JLAB experiment 04-001, A. Bodek and C.E. Keppel spokespersons
6. I. Niculescu. Ph.D. Thesis, Hampton University (1999)