RECENT MEASUREMENTS OF LONGITUDINAL AND TRANSVERSE UNPOLARIZED STRUCTURE FUNCTIONS, AND THEIR IMPACT ON SPIN ASYMMETRY MEASUREMENTS

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We report on new measurements of the separated longitudinal and transverse proton structure functions in the resonance region ($1 < W^2 < 4$ GeV^2) and spanning the four-momentum transfer range $0.2 < Q^2 < 4.0$ (GeV/c)^2. The experiment, E94-110, measured the unpolarized inclusive electron-proton cross section, and was performed in Hall C at JLAB. Results of the analysis of the data are presented, as well as a discussion of the impact on spin asymmetry measurements in the resonance region.

1. Motivation

The determination of the nucleon spin structure functions, g_1 and g_2, from electron spin asymmetry measurements requires knowledge of the longitudinal/transverse (L/T) separated unpolarized structure functions. As $Q^2 \to 0$, the region of the nucleon resonances covers an ever larger fraction of the range in bjorken x. Determining the small Q^2 behavior of the structure functions at large x, therefore, requires precision measurements in the resonance region. High precision measurements of $R(x,Q^2) = \sigma_L/\sigma_T$, the ratio of longitudinal to transverse cross sections, have been available for over a decade in the deep inelastic scattering (DIS) region. However, in the region of the resonances there is very little data on $R(x,Q^2)$, and therefore, the longitudinal and transverse structure functions, $F_L(x, Q^2)$ and $F_1(x, Q^2)$. The small number of measurements that exist vary in the range ($-0.1 < R < 0.4$) and have typical errors of 100% or more. Because of this the current world's resonance region data set provides neither information on the resonance structure nor the Q^2 dependence of $R(x,Q^2)$ in this regime.

2. Unpolarized Structure Functions and Spin Asymmetries

Both the virtual photon spin asymmetries, A_1 and A_2, and the spin structure functions can be determined from measurements of the parallel and perpendicular electron spin asymmetries, $A_{||}$ and $A_{\perp}$. For the transverse asymmetry,

$$A_1 = \frac{C}{D}(A_{||} - dA_{\perp}). \tag{1}$$

The factors C, $C^{'}$, d, and $d^{'}$ are kinematic only, while the photon depolarization factor,

$$D = \frac{1 - \epsilon E^{'}/E)}{1 + \epsilon R}, \tag{2}$$

is a function of the unpolarized structure function ratio R. For $\epsilon R << 1$, the fractional uncertainty in A_1 coming from an uncertainty in R of δR is

$$\frac{\Delta A_1(\delta R)}{A_1} = \frac{\epsilon}{1 + \epsilon R}\delta R \approx \epsilon \delta R. \tag{3}$$

At $\epsilon = 0.5$ this leads to an uncertainty in A_1 of 9% for $\delta R = 0.15$.

The spin structure function g_1 can be extracted via

$$g_1 = \frac{F_1(A_1 - \gamma A_2)}{(1 + \gamma^2)} \propto F_1(1 + \epsilon R) \propto \frac{F_2(1 + \epsilon R)}{1 + R}. \tag{4}$$

Therefore at $\epsilon \approx 1$ only knowledge of F_2 is needed for the extraction of g_1. However, F_2 can not be measured independently from R except at $\epsilon = 1$, and all previous extractions of F_2 in the resonance region have required an assumption for the value of R. The percent difference in F_2 extracted from cross section measurements assuming a value for R of either 0.2 or 0.0 varies from $\approx 2\%$ to $\approx 16\%$ at typical JLab resonance region kinematics. [?]

3. Experiment

In the one photon exchange approximation, the cross section for unpolarized inclusive electron-proton scattering can be expressed in terms of the helicity coupling between the photon and proton as

$$\frac{d\sigma}{d\Omega dE'} = \Gamma \left[\sigma_T(x, Q^2) + \epsilon \sigma_L(x, Q^2)\right], \tag{5}$$

where σ_T and σ_L are the photo-absorption cross sections for pure transversely and longitudinally polarized photons, respectively, Γ is the flux of

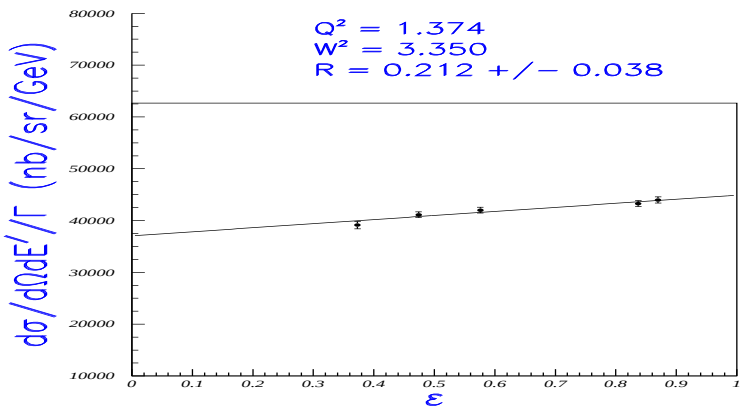

Figure 1. A single Rosenbluth separation, with the W^2, Q^2 and extracted value for $R(W^2,Q^2)$ listed on the plot.

transverse virtual photons and ϵ is the photon relative longitudinal polarization. In terms of the structure functions $F_1(x,Q^2)$ and $F_L(x,Q^2)$, the double differential cross section can be written as

$$\frac{d\sigma}{d\Omega dE'} = \Gamma \frac{4\pi^2\alpha}{x(W^2 - M_p^2)} \left[2xF_1(x,Q^2) + \epsilon F_L(x,Q^2)\right]. \tag{6}$$

Direct correspondence between equations 5 and 6 shows that $F_1(x,Q^2)$ is purely transverse, while the combination

$$F_L(x,Q^2) = (1 + \frac{4M_p^2x^2}{Q^2})F_2(x,Q^2) - 2xF_1(x,Q^2) \tag{7}$$

is purely longitudinal.

For E94-110, the separation of the measured differential cross section into longitudinal and transverse strengths was accomplished via the Rosenbluth technique [1]. Measurements were made over a range in ϵ at fixed x, Q^2 and $d\sigma/\Gamma$ was fit linearly with ϵ. The intercept of the fit gave σ_T (and therefore $F_1(x,Q^2)$), while the slope gave the structure function ratio $R(x,Q^2) = \sigma_L/\sigma_T = F_L(x,Q^2)/2xF_1(x,Q^2)$. These separations were performed at all Q^2, W^2, where enough range in ϵ existed to allow a good linear fit. A single Rosenbluth fit and the extracted value of R is shown in figure 1. In total, over 180 Rosenbluth fits were performed, allowing for the first time both the resonance structure and the Q^2 dependence of the separated structure functions to be studied. In addition to the Rosenbluth

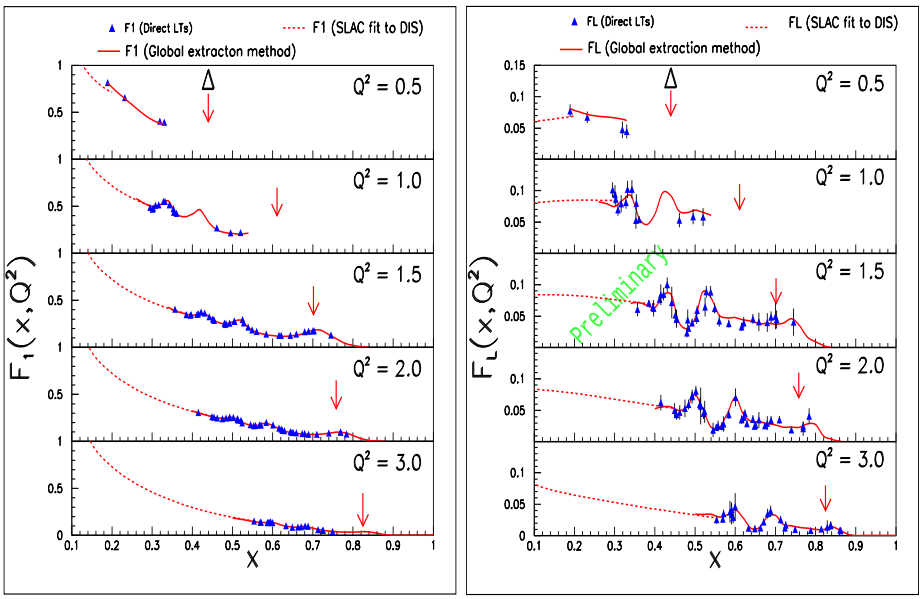

Figure 2. Extracted F_1 (Left), and F_L (Right), as a function of bjorken x for various ranges in Q^2. The Rosenbluth separated data (blue triangles) are plotted with the full uncertainties (statistical + systematic). The structure function model (red curve) determined from an iterative procedure is seen to describe the data well. The position of the Δ $P_{33}(1232)$ resonance is indicated by the red arrow.

extactions, a global fitting procedure was employed to separate the longitudinal and transverse strength. Provided that enough of the kinematic space was measured, there is only one unique way of doing this separation, and checks were performed to test the uniqueness of the final fit.

4. Results and Conclusions

The Rosenbluth extracted values (triangles) of F_1 and F_L are plotted in figure 2 as a function of x for various Q^2 bins and include ≈ 80 of the data. Not included are the data at small Q^2 for the region near the Δ resonance. The analysis of this subset of the data is nearing completion now. Also plotted are the results of the global extraction procedure (solid line). It should be stressed that the curve representing the global extraction is not a fit to the Rosenbluth data, but is an independent extraction. The agreement between the two techniques is quite good. A fit to DIS data from SLAC [9] (dashed line) is seen to extend smoothly to the current data and this allows the small Q^2 moments of the separated structure functions

to be extracted for the first time.

The data represent the first high precision measurement of the resonance region L/T separated unpolarized structure functions for the proton. The large kinematic range measured allowed for a determination of the Q^2 dependence of individual resonance regions. This allows the systematic uncertainties in asymmetry measurements associated with uncertainties in the unpolarized structure functions to be reduced significantly by the use of this new data.

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