NEW MEASUREMENTS OF LONGITUDINAL AND TRANSVERSE UNPOLARIZED STRUCTURE FUNCTIONS AND THE EXTRACTION OF RESONANCE TRANSITION FORM FACTORS

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We report on new measurements of the separated longitudinal and transverse proton structure functions in the resonance region ($1 < W^2 < 4 \text{ GeV}^2$) and spanning the four-momentum transfer range $0.2 < Q^2 < 4.0 \text{ (GeV/c)}^2$. The experiment, E94-110, measured the unpolarized inclusive electron-proton cross section, and was performed in Hall C at JLab. Results of the data analysis are presented and the impact on the extraction of resonance transition form factors is discussed.

1. Introduction

Measurements of the inclusive electroproduction cross section in the proton resonance region have been used for many years for the extraction of resonance transition form factors^{1,2}. Such studies have been quite fruitful and have provided valuable information on the Q^2 behavior of these form factors, which was not provided by the exclusive measurements which were limited to $Q^2 < 3 \text{ GeV}^2$. For example, the analysis of Stoler¹ of inclusive cross sections from SLAC resonance region data indicated that the $N\Delta$ transition form factor has an anomalously faster decline with increasing Q^2 than those extracted for the elastic and other two most prominent resonances. The latter are located in the region of the S_{11} at $W = 1535$ and the P_{15} at $W = 1680$.

However, such extractions depend on fitting^{1,2,3} the transverse component of the inclusive cross sections with both resonant and non-resonant contributions. This makes the extraction of the resonant contribution dependent on the form chosen for the non-resonant contribution.

Perhaps more significant, all previous studies have made assumptions on the size of $R(W^2, Q^2) = \sigma_L/\sigma_T$, since there existed little data on the longitudinal-transverse (L-T) separated cross sections in the resonance re-

Figure 1. World's data set on R versus Q^2 for all $Q^2 < 9$, prior to E94110.

gion. The World's data set on R in the resonance region (prior to Jefferson Lab experiment E94-110) is plotted in figure 1, for all $Q^2 < 9$ (GeV/c)², and all W^2 in the resonance region. As can be observed, the data provide neither information on the resonance structure nor the Q^2 dependence of $R(x, Q^2)$.

2. 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

$$\frac{d\sigma}{d\Omega dE'} = \Gamma [\sigma_T(W^2, Q^2) + \epsilon \sigma_L(W^2, Q^2)], \quad (1)$$

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 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

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

where x is the Bjorken scaling variable, $x = \frac{Q^2}{W^2 - M_p^2 + Q^2}$. Direct correspondence between equations 1 and 2 shows that $F_1(W^2, Q^2)$ is purely transverse, while the combination

$$F_L(W^2, Q^2) = \frac{1 + 4M_p^2 x^2}{Q^2} F_2(W^2, Q^2) - 2xF_1(W^2, Q^2) \quad (3)$$

Figure 2. R extracted from E94-110 versus W^2 at $Q^2 = 2 \text{ (GeV/c)}^2$.

is purely longitudinal.

For E94-110, the separation of the measured differential cross section into longitudinal and transverse strengths was accomplished via the Rosenbluth technique⁴. 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), while the slope gave the structure function ratio $R(W^2, Q^2) = \sigma_L/\sigma_T = F_L(W^2, Q^2)/2\pi F_1(W^2, Q^2)$. These separations were performed at all Q^2 , W^2 , where enough range in ϵ existed to allow a good linear fit. This allowed both the resonance structure and the Q^2 dependence of the separated structure functions to be studied for the first time.

Values for R extracted in a small range about $Q^2 = 2$, a subset of the Q^2 range of the data, are plotted in figure 2. For the first time ever, resonance type behavior is observed in R . Furthermore the data show a significant resonance contribution to the separated longitudinal cross section. Therefore, previous extractions of transition form factors from inclusive data made an incorrect assumption when setting this to zero.

3. Transition Form Factors

Defining the dimensionless transition form factor in terms of the helicity amplitudes, as in References^{5,1}, leads to a relationship between the resonance form factor, $F_R^*(Q^2)$, and the magnitude of the resonant component of F_1 at the resonance peak of

$$|F_R^*(Q^2)|^2 = \frac{2\pi M_R \Gamma x_R F_1(M_R, Q^2)}{Q^2}. \quad (4)$$

Figure 3.

M_R is the mass of the resonance and Γ_R is its full width assuming a Breit-Wigner shape. A fit to the transverse cross section component obtained from the Rosenbluth separated data is shown in figure 3, including both resonant and non-resonant contributions.

This fitting for form factor extraction is a work in progress. However, since the longitudinal cross section was observed to exhibit large resonant contributions in at least the second and third resonance regions, it is expected that the transition form factors extracted from these data might exhibit different strengths and Q^2 behaviors than previously reported in, for instance, References ^{1,2}.

References

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