THE Q^2 DEPENDENCE OF POLARIZED STRUCTURE FUNCTIONS

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A comprehensive program to measure polarized structure functions in the resonance region and beyond using the CEBAF Large Acceptance Spectrometer (CLAS) at Jefferson Lab has completed taking data. One of the experimental goals is to measure the first moment (Γ_1) of the polarized structure function, g_1 , as a function of Q^2 by scattering polarized electrons from polarized proton (NH_3) and deuteron (ND_3) targets. Deep inelastic scattering measurements obtain positive values for the first moment at large Q^2 . The first moment is constrained by the Gerasimov-Drell-Hearn sum rule ¹ to have a negative slope at the photon point. The CLAS measurements encompass the transition from the low Q^2 region dominated by resonances and other non-perturbative effects to the high Q^2 region where quasi-free partons dominate the interaction. Inclusive results for the double spin asymmetry A_1 and the first moment of g_1 are reported which span a range in Q^2 from 0.2 to 1.5 (GeV/c)² and up to $W=2.5$ GeV, thus probing a range in Bjorken- x from 0.04 to 0.8.

1 Introduction

A wealth of polarized structure function data has been collected over the past quarter century by scattering polarized leptons from polarized nuclear targets at very high energies ². Qualitatively, these scattering experiments probed the nucleon in an asymptotic free region where its constituents, quarks and gluons, dominate the interaction as quasi-free partons. These deep inelastic measurements have revealed that the constituent quark spins are not the dominant contribution to the spin of a nucleon, at least in the region of asymptotic freedom. As the squared four momentum (Q^2) transferred to the nucleon decreases, the virtual photon interaction becomes more sensitive to a region of prominent resonances indicative of coherent scattering. Finally at the photon point, the interaction is predominantly sensitive to the macroscopic properties of the nucleon such as its magnetic moment. To get a more complete and consistent picture, the EG1 run group has measured polarized structure functions over a range in Q^2 which encompasses a large portion of this transition region. This was done by using the nearly 4π coverage of the CLAS ³ to detect the reactants which emerged when polarized electrons interact with polarized NH_3 and ND_3 nuclear targets.

Figure 1. The measured asymmetry in the bin $0.4 < Q^2 < 0.6$. The squares represent measurements made at SLAC. The solid circles are the results from the EG1 experiment. The dashed line indicates the impact of the kinematically weighted asymmetry A_2 . The solid line is a parametrization of the world data set which was used for radiative corrections. Systematic errors are shown on the horizontal axis.

2 Results

The transition region is probed, quantitatively, in terms of the first moment (Γ_1) of the polarized structure function g_1 . The structure function g_1 is expressed in terms of the nucleon momentum fraction carried by the struck constituent, Bjorken- $x = Q^2/2M\nu$, the unpolarized structure function F_1 and a linear combination of the transverse asymmetry A_1 and the transverse-longitudinal asymmetry A_2 such that

$$g_1(x, Q^2) = \frac{\nu^2}{Q^2 + \nu^2} F_1(\nu, Q^2) \left(A_1(\nu, Q^2) + \frac{Q}{\nu} A_2(\nu, Q^2) \right) \quad (1)$$

where A_1 is the transverse asymmetry determined by taking the difference in the spin 1/2 transverse cross-section with the spin 3/2 and dividing by their sum. A_2 is the transverse-longitudinal interference cross-section divided by

Figure 2. The first moment as a function of Q^2 . The solid squares are from SLAC. The open circles represent measurements from EG1 which only include contributions from the resonance region ($W < 2$ GeV). The open squares combine measurements from EG1 with a parametrization of the world data set for the kinematic regions not measured. Systematic errors are given along the horizontal axis. The dash-dot line represents the slope of the GDH sum rule. The solid line is a pQCD calculation by Larin. The dashed and dotted lines are models based on parameterizations by Burkert and Soffer, respectively.

the total cross-section used to determine A_1 . Figure 1 shows the asymmetry measured for one Q^2 bin which includes measurements taken at SLAC⁴ at the same kinematics. The lines represent fits to the world data set. The dashed line identifies the limited impact of the kinematically weighted asymmetry A_2 on the total asymmetry and has been absorbed by the reported systematic error.

The first moment Γ_1 is determined by integrating the polarized structure function measurements with respect to Bjorken- x and within a particular Q^2 bin

$$\Gamma_1(Q^2) = \int_0^1 g_1(x, Q^2) dx \quad (2)$$

At the photon point, the GDH sum rule requires that the first moment approach with a negative slope as illustrated by the dash-dot lines in Figure 2. At large Q^2 , deep inelastic scattering measurements indicate that the moment has values greater than zero. The line in Figure 2b represents the next

to leading order QCD approximation to the first moment ⁶ which agrees with the EMC measurements at $Q^2 \approx 11 \text{ GeV}^2$ to within 2%. Until recently the experimental data in the intermediate Q^2 region below 2 GeV^2 was limited to measurements from SLAC ⁴ and HERMES ⁵. While these experiments were among the first to explore this region, it was not clear where in Q^2 the transition would pass through zero, or more importantly if this moment would follow the expectations derived from the GDH sum rule. The first installment of data from the EG1 group using CLAS clearly indicate the Q^2 region in which the moment becomes negative. The data currently under analysis will be used to evaluate the slope prediction at the photon point based on the GDH sum rule.

3 Conclusions

A data set is now available which constrains theoretical descriptions of the polarized structure function first moment from the DIS region down to Q^2 values of 0.2 for the proton and 0.5 for the Deuteron $(\text{GeV}/c)^2$. The proton data disagree with the pQCD calculation ⁶ and the prediction by Soffer ⁸ for Q^2 around 1 $(\text{GeV}/c)^2$ while the parametrization by Burkert and Ioffe ⁷ appears to describe the data well. The data also show a transition of the first moment to values less than zero occurring near Q^2 values of 0.25 $(\text{GeV}/c)^2$ for the proton and 0.75 $(\text{GeV}/c)^2$ for the Deuteron. Resonances contribute to the proton first moment at the 40% level for values of Q^2 above 0.5 $(\text{GeV}/c)^2$. After analyzing the recently accumulated data, the kinematic range will be extended down to Q^2 of 0.05 $(\text{GeV}/c)^2$ and up to 4.5 $(\text{GeV}/c)^2$.

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