SPIN STRUCTURE FUNCTIONS: PROTON/DEUTERON MEASUREMENTS IN THE RESONANCE REGION

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The *RSS* experiment ran in Hall C at Jefferson Lab and measured the proton and deuteron beam-target asymmetries for parallel and perpendicular target fields over a W range from pion threshold to 1.9 GeV at $Q^2 \approx 1.3 \text{ GeV}^2$. Preliminary results for the proton spin structure functions g_1 and g_2 are presented.

1. Introduction

This workshop has highlighted the large amount of data that is available for studying quark-hadron duality in the unpolarized structure functions and making precision tests of duality (see review ¹). With precision measurements in the resonance region, examination of duality in the g_1 and g_2 spin structure functions (SSFs) can also be done. A model independent determination of g_1 and g_2 can be done with measurement of the beam-target asymmetry at two different orientations of the target spin. g_1 has been measured in the DIS region for a wide range of Q^2 . At SLAC, g_2 and g_1 were measured in the resonance region, but with large W bins. In Hall B at Jefferson Lab, precision data for the parallel beam-target asymmetries on the proton and deuteron in the DIS and resonance regions have been measured^{2,3,4} over a large range of moderate Q^2 and g_1 was extracted using estimates of g_2 . Recent measurements⁵ of neutron g_1 and g_2 in the resonance region using a polarized ^3He target have been done at Jefferson Lab

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at $Q^2 < 1$ and preliminary results of another Hall A experiment⁶, which studied the dependence of neutron g_1 and g_2 in the resonance region for $1 < Q^2 < 4$ GeV², have been presented at this workshop. A lack of data for the proton g_2 in the resonance region at low Q^2 is a glaring hole in the kinematic map of SSFs. The goal of the Hall C *RSS* experiment is to measure the W dependence of proton and deuteron g_1 and g_2 in the resonance region at a $Q^2 \approx 1.3$ GeV².

In the *RSS* experiment, beam-target asymmetries were measured for proton and deuteron targets with the target spin parallel ($A_{\parallel}$) and perpendicular ($A_{\perp}$) to the beam helicity. The $A_{\parallel}$ and $A_{\perp}$ can be combined to determine the spin structure functions g_1 and g_2 or the related spin asymmetries A_1 and A_2 . Duality can be studied for both g_1 and g_2 and, with precision data in small W bins, local quark-hadron duality can be investigated. While g_2 does not have a simple partonic interpretation, g_2 is sensitive to higher twist.

2. Experiment

The *RSS* experiment was performed in Hall C at the Thomas Jefferson National Accelerator Facility (Jefferson Lab). Polarized electrons with 5.76 GeV/c momentum were scattered from polarized frozen ammonia (NH₃) and deuterated ammonia (ND₃) targets. The spin of the polarized target was aligned anti-parallel and perpendicular to the beam. The scattered electrons were detected at 13.15° in the High Momentum Spectrometer (HMS). Electron particle identification was done by a combination of a gas Cerenkov detector and lead-glass calorimeter. To cover the range of W from 0.6 GeV to 1.9 GeV, data was taken with the HMS at two central momentum settings of 4.73 and 4.09 GeV/c. The average momentum transfer-squared, Q^2 , was centered at 1.3 ± 0.3 GeV² for $1.1 < W < 1.9$ GeV.

The ammonia targets were polarized by dynamic nuclear polarization and operated at 1 K in a 5 T magnetic field. To maintain reasonable target polarization, the beam current was limited to <100 nA and was uniformly rastered over a 2 cm diameter circle. The target polarization, P_T , was measured continuously by the NMR technique. The average proton polarization was 70% and the average deuteron polarization was 20%. The polarization of the beam, P_B , was measured in Hall C using the Moller polarimeter. The average P_B was 65.6% (71%) for perpendicular (parallel) target field.

The measured asymmetry, A_m , is defined as $\frac{N^+ - N^-}{N^+ + N^-}$ where N^+ and N^- are the raw counts normalized for deadtime and charge for opposite beam helicities. The asymmetry for parallel and perpendicular target field is

$$A_{\parallel, \perp} = \frac{1}{C_N f_{RC}} \left(\frac{A_m}{f P_B P_T} - C_D \right) + A_{RC} \quad (1)$$

where the measured asymmetry is normalized by P_T , P_B and the dilution factor, f . The dilution factor is the ratio of the yield from polarized free protons to yield from all target material. The asymmetry is also corrected for radiative effects (f_{RC} and A_{RC}) and the contribution from the small nitrogen polarization (C_N, C_D). The C_N correction is ≈ 1.02 has not been applied to the preliminary data that is being shown. The C_D correction is for deuteron target only.

Elastic ep asymmetry, A_{ep} , was measured when the HMS central momentum was 4.73 GeV/c. The sensitivity of A_{ep} to the ratio of the proton electric to magnetic form factor, $\frac{G_E}{G_M}$, depends on angle between the target spin and the momentum transfer. For parallel target field, A_{ep} is insensitive to $\frac{G_E}{G_M}$ and was used to determine $P_B P_T$ to a combined relative statistical and systematic error of 1.9%. For the perpendicular target field, the sensitivity of A_{ep} to $\frac{G_E}{G_M}$ is large enough that $\frac{G_E}{G_M}$ can be determined from A_{ep} using $P_B P_T$ determined by NMR technique and Moller polarimeter.

3. Results

Preliminary results for the proton spin structure functions, g_1^p and g_2^p , from the *RSS* experiment are plotted versus Bjorken x_{bj} in Fig. 1a and Fig. 1b respectively. In Fig. 1a, previous g_1^p data⁷ from SLAC E143 at $Q^2 \approx 5$ GeV² and data² from Jefferson Lab Hall B at $Q^2 \approx 1.35$ GeV² are plotted for comparison. While agreement is good for $x_{bj} > 0.5$, the *RSS* data exhibit more structure in the $0.5 > x_{bj} > 0.3$ region compared to the Hall B data. But at this time, the *RSS* data are still preliminary and radiative corrections are being finalized. The *RSS* g_1^p are compared with calculations from three different PDFs (BSB⁹, GRSV¹⁰ and AAC¹¹) which have been evolved to $Q^2 = 1.3$ GeV². The GRSV and AAC PDFs have target mass corrections. The *RSS* data oscillate around the PDF curves.

In Fig. 1b, arrows indicate the associated W for the given x_{bj} for the *RSS* experiment. Here, data⁸ for g_2^p from SLAC E155 are plotted. The SLAC data are at higher Q^2 and in the DIS region. The *RSS* g_2^p has significant structure in the $0.5 > x_{bj} > 0.3$ region.

Figure 1. The proton structure functions g_1^p and g_2^p . The curves are described in the text.

Once the data are finalized, ratios of data to the PDFs can be made that will enable quantitative tests of duality in proton SSFs. In addition, the *RSS* experiment measured deuteron beam-target asymmetries and these data will be combined with the proton data to extract neutron SSFs.

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