0.1 E-01-006

Resonances' Spin Structure - *RSS*
The *RSS* Collaboration[1]

0.1.1 Introduction

This experiment was designed to make high precision and high resolution measurements of the spin structure of the proton and the deuteron in the region of the nucleon resonances (final state invariant mass $W \lesssim 2$ GeV), at the four-momentum transfer $Q^2 \sim 1.3$ [GeV/c]^2. The physics goals were to explore fundamental properties of the nucleon and QCD and to test local duality for the polarized structure functions. The neutron spin asymmetries will be extracted from the measured proton and deuteron asymmetries.

The spin asymmetries $A_1(\nu, Q^2)$ and $A_2(\nu, Q^2)$ extend the Deep Inelastic Scattering (DIS) description of the nucleon spin structure functions (SSF's) to the region of the resonances ($\nu = E - E'$ is the lepton energy loss, E and E' are the beam and scattered electron energies). In the scaling limit of DIS, the SSF's $g_1(x)$ and $g_2(x)$ depend (up to logarithmic corrections) only on the scaling variable $x = Q^2/(2M\nu)$. In the resonance region the spin structure can be described in terms of either the non-scaling form $G_1(\nu, Q^2)$ and $G_2(\nu, Q^2)$ or of the spin asymmetries, which are related to virtual photon absorption cross sections $\sigma^T_{1/2}$, $\sigma^T_{3/2}$, and $\sigma^{TL}_{1/2}$ for photon helicities +1, -1, 0, respectively:

$$A_1 = \frac{\sigma^T_{1/2} - \sigma^T_{3/2}}{\sigma^T_{1/2} + \sigma^T_{3/2}} = \frac{M\nu G_1(\nu, Q^2) - Q^2 G_2(\nu, Q^2)}{W_1(\nu, Q^2)}$$

$$A_2 = \frac{\sigma^{TL}}{2\sigma^T} = \frac{\sqrt{Q^2}(M G_1(\nu, Q^2) + \nu G_2(\nu, Q^2))}{W_1(\nu, Q^2)}, \qquad (1)$$

where $2\sigma^T = \sigma^T_{3/2} + \sigma^T_{1/2}$, M is the nucleon mass and $W_1(\nu, Q^2)$ is transverse unpolarized structure function.

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In unpolarized lepton-nucleon scattering, DIS and the resonances are connected by Bloom-Gilman (B-G) or local duality [Bl70]. B-G duality can be summarized as the averaging out of the magnitude of the unpolarized structure function (SF), νW_2, in the resonance region compared to the extrapolation of its DIS counterpart, F_2. Quantitatively, local duality is expressed as the equality of the integrals of νW_2 and F_2 taken at constant Q^2 over the same limited W range. Unpolarized local duality has been confirmed at JLab [Ni00] for the F_2 structure functions of the proton and the deuteron.

The earliest mention of local duality for the SSF's can be found in the original proposal of this experiment [Ro95]. If local duality is a reflection of some fundamental nucleon properties and not just the result of some fortuitous coincidences, it should also be present for the neutron and for the polarized structure functions [Cl01]. If local duality obtains for all SF's, it can be a powerful tool to extend our understanding of the nucleon, by allowing indirect but quantitative access to experimentally inaccessible kinematic regions. Existing spin structure data [Ab98, Mepc, Kupc, Ai03] hint at duality in the SSF's. One of *RSS* goals is to contribute with model independent data on SSF'S for a quantitative confirmation of local spin duality.

The precise measurement of A_1 and A_2 in *RSS* will also improve our understanding of the quarks' contribution to the nucleon spin and explore the effects of quark-gluon interactions which can be represented by twist-3 matrix elements calculable in Lattice QCD.

0.1.2 Experiment Status

The experiment took data in Hall C from January to early March, 2003. Polarized electrons of 5.755 GeV beam energy were incident on the University of Virginia (UVA) polarized target. The scattered electrons were detected in the High Momentum Spectrometer – HMS, parked at 13.15°, at two central momentum settings of 4.7 and 4.09 GeV/c, which allowed coverage of W to $\sim$ 2 GeV.

The Hall C Møller polarimeter was used to measure the beam polarization. The average effective beam polarizations for the two configurations of asymmetry measurements (beam and target spins perpendicular($A_\perp$) and

Configuration	Beam polarization	Target	Beam I [nA]	Target polarization
$A_\perp$	65.6%	NH_3	100	68.9%
		ND_3	115	19.8%
$A_{\|\|}$	71.0%	NH_3	91	66.4%
		ND_3	112	15.1%

Table 1: Average beam polarization, beam current and target polarization.

parallel ($A_{||}$) to each other) are summarized in Table 1. The deflection of the beam by the target field upstream of the target was corrected by the Hall C's two-magnet chicane. Downstream of the target a special beam pipe and helium bag were used. The Hall C beam raster system, as modified for E93-026 (*GEn01*) [Da93], was used to distribute the beam uniformly over the target cell face. The relative positions of the beam and the target cells were monitored with an optics cell with tungsten wire cross-hairs.

Data were taken on 3 cm long solid ammonia and deuterated ammonia targets ($^{15}NH_3$ and $^{15}N^2H_3$ – ND_3 for short). The ammonia was polarized by Dynamic Nuclear Polarization in a 5 T magnetic field cooled to ~ 1 K by a ^{4}He evaporation refrigerator. The polarization was measured by NMR. Table 1 lists the average polarizations for each species during the corresponding measurement periods. The Jefferson Lab and UVA target groups provided full support for the target operation.

0.1.3 Preliminary Measured Asymmetries

In addition to the asymmetry data, data on a C disk target and on a cell alternately empty or filled only with LHe were taken for optics studies of the HMS and to correct for the dilution introduced by the unpolarized materials in the target. The packing fraction of ammonia in the cells is calculated by comparing the measured C and He rates to model rates. The same model is used to calculate the dilution factor. Model vs data agreement at the 10% level has been achieved (better for the parallel configuration than for the perpendicular one). Work to improve the agreement is ongoing.

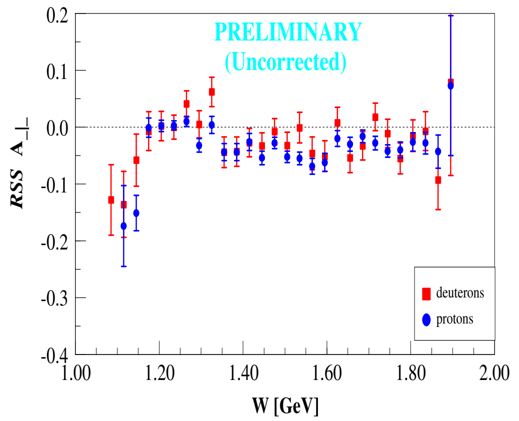

Figure 1: Preliminary measured asymmetry for the perpendicular configuration (left panel) and parallel configuration (right panel) for protons (blue circles) and deuterons (red squares), without corrections (see text for details).

The measured asymmetries are extracted from the counts asymmetries $\epsilon = (L-R)/(L+R)$, where L, R are charge normalized numbers of counts for opposite beam helicities, corrected for dead time and pion contamination. $A_{\|}$ and $A_{\perp}$ are related to ϵ by

$$A_{\|,\perp} = \frac{1}{C_N f_{RC}}\Big(\frac{\epsilon}{f P_b P_t} - C_D\Big) + A_{RC}. \tag{2}$$

where C_N, C_D are corrections for the small contribution of the polarized proton in ^{15}N, f is the dilution factor, f_{RC} and A_{RC} are multiplicative and additive radiation corrections, and P_b and P_t are the beam and target polarizations, respectively.

Preliminary uncorrected asymmetries $A_{\perp,\|}$, based on preliminary dilution factors, are shown in Figure 1. The asymmetries are shown only for the restricted kinematic region 1.1 GeV $\leq W \leq$ 1.9 GeV. Data below and above these limits are still being analyzed. Corrections for the actual packing fractions, electromagnetic radiative effects and nitrogen polarization are not included. The $A_{\perp}$ results are the first and only ones of their kind in the world. A clear difference between the proton and deuteron asymmetries can be seen, in particular for $A_{\|}$. A clean extraction of the neutron asymmetry is expected on this basis.

A_1 and A_2 are related to the measured asymmetries $A_{\|}$ and $A_{\perp}$ by the simplified expressions (neglecting the out-of-plane angle)

$$A_1 = \frac{C}{D}\Big(A_{\|} - dA_{\perp}\Big), \qquad\qquad A_2 = \frac{C}{D}\Big(c' A_{\|} + d' A_{\perp}\Big),$$

where C, c', d, d' and D are functions of kinematic variables only (D has an additional mild dependence on the unpolarized structure function $R(\nu, Q^2)$). Exact expressions are available at the *RSS* Web site
`http://www.jlab.org/~jones/rss/technotes`.
Work to obtain the SSF's from the measured asymmetries is ongoing.

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