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LETTER TO THE EDITOR

MEASUREMENT OF THE DEUTERON ELASTIC STRUCTURE FUNCTIONS $A(Q^2)$ AND $B(Q^2)$ AT LARGE MOMENTUM TRANSFERS

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The cross section for elastic electron-deuteron scattering was measured in Jefferson Lab experiment 91-026. The deuteron elastic structure functions $A(Q^2)$ and $B(Q^2)$ have been extracted from the data. The final results for the "electric" structure function, $A(Q^2)$, in the range of $0.7 \leq Q^2 \leq 6.0$ (GeV/c)^2, are presented. Preliminary results for the "magnetic" structure function, $B(Q^2)$, are presented in the range of $0.7 \leq Q^2 \leq 1.35$ (GeV/c)^2. These data are compared to the theoretical predictions of both meson-nucleon and quark-gluon based models.

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The cross section for elastic electron-deuteron scattering is described by

$$\frac{d\sigma}{d\Omega} = \sigma_m[A(Q^2) + B(Q^2)\tan^2(\theta/2)], \tag{1}$$

where σ_m is the Mott cross section, $Q^2 = 4EE'\sin^2(\theta/2)$ is the four-momentum transfer squared and θ is the electron scattering angle. From Eq. 1 we see that $A(Q^2)$ and $B(Q^2)$ can be separated by measuring the cross section at several different electron scattering angles while keeping the momentum transfer constant (Rosenbluth separation technique).

The structure functions $A(Q^2)$ and $B(Q^2)$ can be expressed in terms of the charge monopole, charge quadrupole and magnetic dipole form factors of the deuteron (F_c, F_q and F_m, respectively):

$$A(Q^2) = F_c^2(Q^2) + \frac{8}{9}\tau^2 F_q^2(Q^2) + \frac{2}{3}\tau F_m^2(Q^2) \tag{2}$$

$$B(Q^2) = \frac{4}{3}\tau(1+\tau)F_m^2(Q^2) \tag{3}$$

where $\tau = Q^2/4M_d^2$ and M_d is the deuteron mass. $B(Q^2)$ is a direct measure of the magnetic form factor, whereas more information is needed to separate F_c and F_q (i.e. polarization observables).

This experiment was performed in Hall A at Jefferson Laboratory. This was a double arm exclusive measurement where the scattered electrons were detected in the electron-arm high-resolution spectrometer (HRSE) and the recoil deuterons were detected in the hadron-arm high-resolution spectrometer (HRSH). The HRSE detector package consisted of two vertical drift chambers for particle tracking, two planes of trigger scintillators, a CO_2 gas Cherenkov detector for particle identification and a segmented lead-glass calorimeter. Electrons were identified from a minimal signal in the Cherenkov counter and an energy deposited in the calorimeter consistent with the particle tracking. The HRSH detector package consisted of two vertical drift chambers and two planes of trigger scintillators. Coincidence events were identified using the relative time-of-flight between the electron and deuteron triggers. The target for the data runs was a 15 cm liquid deuterium target, maintained at a temperature of 22 K and a pressure of 152 kPa (22 psia). A 15 cm liquid hydrogen target, maintained at 19 K and 179 kPa (26 psia), was used for calibration runs. Other Hall A instrumentation included two beam current monitors to determine the charge incident on the target and several beam position monitors to monitor the beam position and angle at the target.

$A(Q^2)$ has been extracted in the range of $0.7 \leq Q^2 \leq 6.0$ (GeV/c)^2. These values were extracted from the measured e-d cross sections under the assumption that $B(Q^2)$ does not contribute to the cross section (supported by the existing $B(Q^2)$ data [1]). The extracted $A(Q^2)$ values are shown in Figs. 1 and 2. The

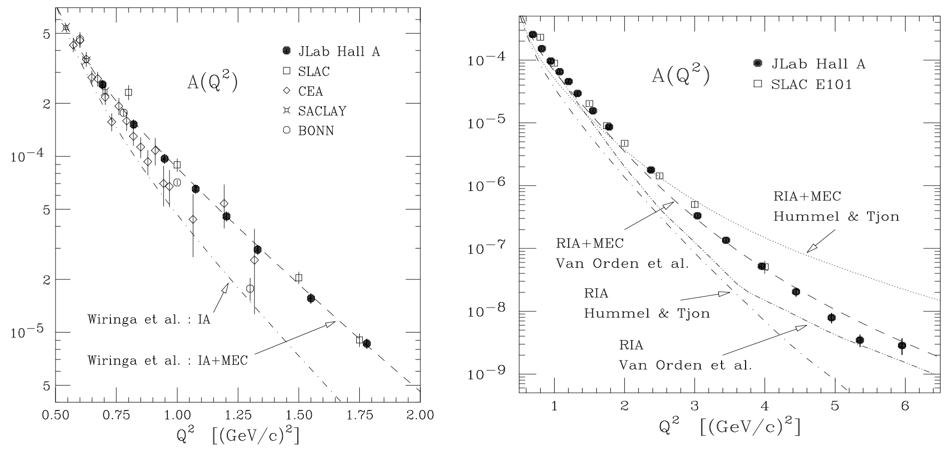

Fig. 1. The deuteron elastic structure function $A(Q^2)$ from this experiment; on the left the "low" Q^2 data, along with the previous data from SLAC [2], Saclay [3], CEA [4] and Bonn [5] and the theoretical calculations of [6]; on the right our full $A(Q^2)$ data set and previous SLAC data [2], compared to the theoretical calculations of Refs. 7 and 8.

left-half of Fig. 1 shows our $A(Q^2)$ data up to 2 $(\mathrm{GeV/c})^2$, together with previous

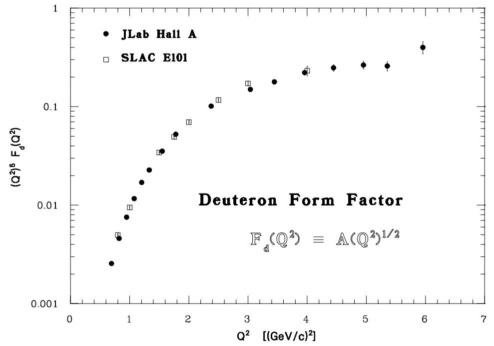

Fig. 2. $F_d \equiv \sqrt{A(Q^2)} \times (Q^2)^5$ *from this experiment and from SLAC E101. Above about* Q^2=4 *(GeV/c),* F_d *exibits a flattening, consistent with the onset of the predicted scaling behavior.*

SLAC [2], Saclay [3], CEA [4], and Bonn [5] data. Our data agree with the trend of the SLAC and Saclay data. Also shown is an impulse approximation (IA) prediction [6], both with and without meson exchange current (MEC) contributions included. The right-half of Fig. 1 shows the complete data set, up to Q^2=6 $(\mathrm{GeV/c})^2$, together with previous SLAC data [2] and theoretical calculations. The error bars include statistical (ranging from ± 1% to ± 28% at 6 $(\mathrm{GeV/c})^2$) and systematic (± 5.9%) uncertainties added in quadrature. Our results agree very well with previous SLAC data and continue to follow the trend of a smooth fall-off versus momentum transfer. Shown are two relativistic impulse approximation (RIA) calculations and the same two RIA's with meson exchange current terms included [7–8]. The MEC terms for the two different groups differ in their choice of the strength of the coupling between the virtual photon and the exchanged mesons and in the form factor used to describe the vertex. At sufficiently high momentum transfers, dimensional scaling [9] and pQCD [10] predict that $F_d \equiv \sqrt{A(Q^2)}$ should fall off as $(Q^2)^{-5}$. Our data, along with the previous SLAC $A(Q^2)$ data, are shown in Fig. 2, multiplied by $(Q^2)^5$. They exhibit a flattening above approximately Q^2=4 $(\mathrm{GeV/c})^2$, consistent with the onset of the predicted scaling behavior.

The preliminary results for our extraction of $B(Q^2)$ are shown in Fig. 3, along with previous data from SLAC [1], Saclay [11] and Bonn [12]. The error bars include statistical and systematic uncertainties added in quadrature and range from 5% to 20% at 1.35 $(\mathrm{GeV/c})^2$. Also shown in Fig. 3 are the theoretical predictions of Wiringa *et al.* [6] and Van Orden *et al.* [7]. The two models with MEC included have had success in describing our $A(Q^2)$ data (cf. Fig. 1), but they either overestimate or underestimate our preliminary $B(Q^2)$ data.

We have also measured the deuteron elastic electric and magnetic structure functions in Experiment 91-026 at Jefferson Lab. We have extended the measured range of $A(Q^2)$ to 6 $(\mathrm{GeV/c})^2$ and significantly improved the precision of the $B(Q^2)$ data in the low momentum transfer range. The data have been compared to both meson-nucleon and quark-gluon model predictions.

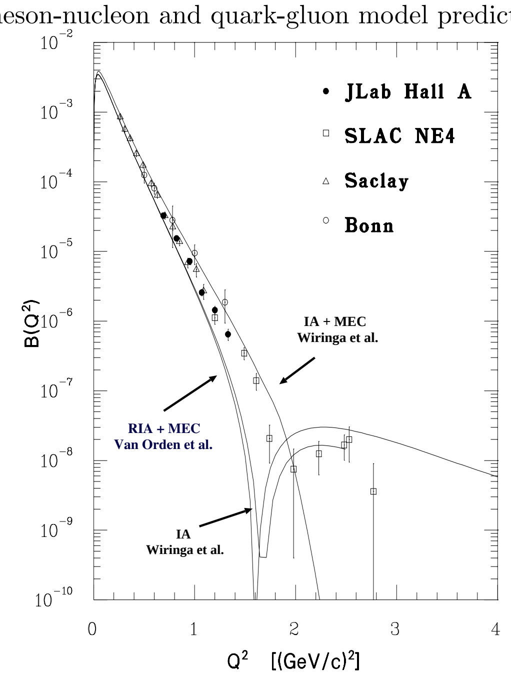

Fig. 3. Preliminary results for the deuteron magnetic elastic structure function $B(Q^2)$ from this experiment. Also shown are previous SLAC [1], Saclay [11] and Bonn [12] data and the theoretical calculations of Refs. 6 and 7.

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ELASTIČNE STRUKTURNE FUNKCIJE $A(Q^2)$ AND $B(Q^2)$ DEUTERONA

Mjerili smo udarne presjeke za elastično raspršenje elektrona na deuteronu i odredili elastične strukturne funkcije deuterona $A(Q^2)$ and $B(Q^2)$.