Structure functions for the electrodisintegration of the deuteron at a momentum transfer of 1.8 GeV²

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Structure functions are found for the electrodisintegration of the deuteron near the threshold in the relativistic region with $q^2_{max} = 1.8$ GeV^2 and $\nu = 0.5$–0.65 GeV.

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One of the fundamental problems of hadron physics is to determine the nucleon-nucleon (NN) potential. Information on the NN interaction slightly off the mass shell is particularly important. Such information can be found from the electrodisintegration of the deuteron at large momentum transfer. Under these conditions there should be a cumulative effect, interpreted as scattering by a state which is an "overlap" of two nucleons.[1,2] The overlap gives rise to a six-quark ($6Q$) state, which apparently plays a major role in the NN potential at distances less than 10^{-13} cm.

It has previously been assumed that most of the information about the $6Q$ state will come from the structure function $A(q^2)$ in the elastic scattering of electrons by the deuteron.[1] According to the quark counting rules, the relation $A(q^2) \sim q^{-20}$ should hold for large values of the square of the 4-momentum transfer q^2. Even at q^2 near 6 GeV^2, however, the exponent does not exceed[3] 12. Furthermore, the dependence $A(q^2)$ can be described by the dipole expression, i.e., with an exponent of[4] 8. At far smaller q^2 (1–2 GeV^2) the magnetic form factor of the deuteron has been predicted[1] to be highly sensitive to a contribution from a $6Q$ state. The projects[1,5] which are underway to measure this form factor at such large values of q^2, however, are still far from completion. Information analogous to the magnetic form factor can also be extracted from the structure function for the electrodisintegration of the deuteron, $W_1(q^2,\nu)$. The data obtained previously, at small angles,[6] are not sufficient for determining this structure function at $q^2 = 1$–$2\ \text{GeV}^2$. Measurements are necessary at large electron scattering angles. This experiment can be carried out on the Khar'kov LUE-2000 accelerator. In this letter we are reporting the first results on the magnetic structure function of the deuteron, W_1, at relativistic momentum transfers.

The electron spectrum was measured near the threshold for the disintegration of the deuteron at an initial energy $E_1 = 1.45$ GeV and at a scattering angle $\theta = 70°$ with a maximum square momentum transfer $q^2 = 1.8\ \text{GeV}^2$. We used a liquid deuterium target, 5 cm thick; a liquid hydrogen target for calibration; and an empty appendix target for background subtraction. The experimental apparatus had been used previously to study the electroproduction of pions.[7] The measured spectrum is shown in Fig. 1. Near the threshold for the disintegration of the deuteron, marked by the arrow, part of the cross section is due to elastic scattering, but this part is quantitatively negligible. In the analysis of the spectrum the experimental resolution was taken into account along with the radiation correction.[7]

At the quasielastic scattering peak the cross section in Fig. 1 is comparable to the predictions of Durand's dispersion theory.[8] Despite the large value of q^2, the agreement near the top of the peak is completely satisfactory. Near the threshold, a different approach must be taken to explain the experimental data. Frankfurt and Strikman[9] have carried out a relativistic quantum-chromodynamics calculation for this region, but they reported a final expression for only the structure function W_2.

The cross section for the electrodisintegration of the deuteron has also been measured on the SLAC accelerator for the same ranges of the energy transfer ν and the momentum transfer q^2 as in the present experiments; those measurements were carried out for an angle of 8° and an initial electron energy of about 10 GeV (Ref. 6). It is thus possible to single out the contributions of the structure functions W_1 and W_2, defined by

$$\frac{d^2\sigma}{d\Omega dE_2} = \frac{\sigma_M}{\nu}\left[\nu W_2(q^2,\nu) + 2\nu\, \mathrm{tg}^2\frac{\theta}{2}\, W_1(q^2,\nu)\right]. \tag{1}$$

The results of this extraction are shown in Fig. 2. The filled circles show the dimensionless structure function νW_1, which corresponds to magnetic scattering, while the

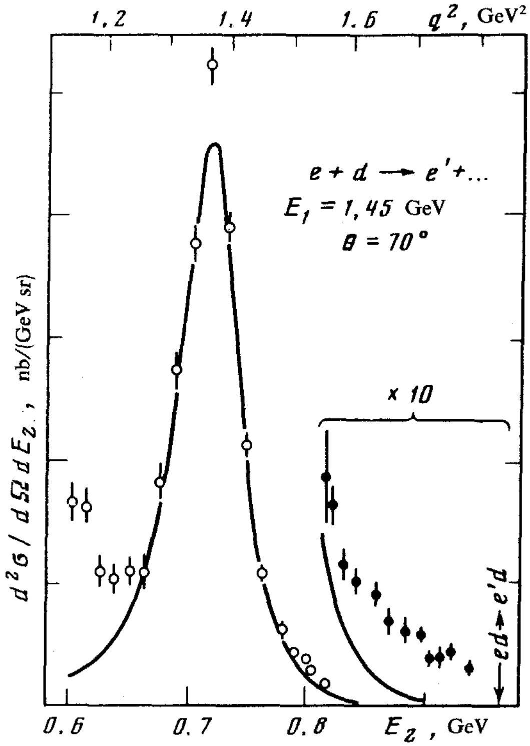

FIG. 1. Cross section for inelastic electron scattering by the deuteron.

open circles show νW_2. The systematic error in νW_1 is 8% at $\nu \cong 0.5$ GeV and rises to 18% at $\nu \cong 0.64$ GeV. The systematic error in the function νW_2 is 20% (Ref. 6).

The structure functions of the deuteron in inelastic electron scattering have previously been singled out only in the nonrelativistic region, at q^2 values an order of magnitude lower.[10] At these high values of q^2 we see several new features. The energy transfer (0.5–0.6 GeV) is a substantial fraction of the initial energy (1.45 GeV); i.e., the process has become deep-inelastic scattering. The momentum of the nucleon which does the scattering reaches 720 MeV/c at the threshold. Such a high momentum of the

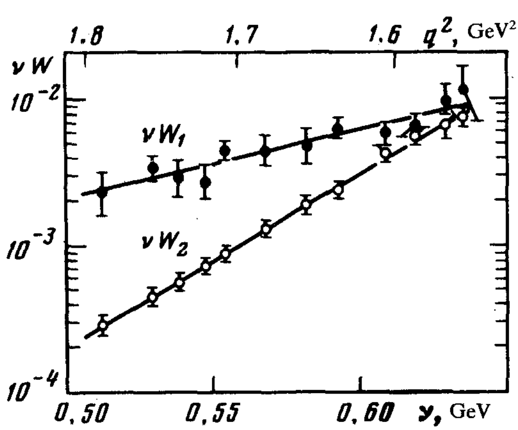

FIG. 2. Structure functions for the electrodisintegration of the deuteron.

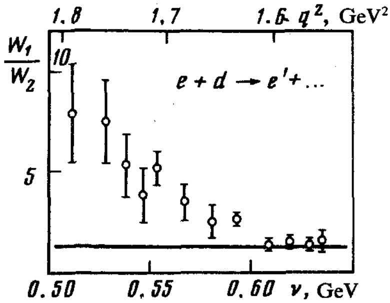

FIG. 3. Ratio of the structure functions for the electrodisintegration of the deuteron. The curve shows the ratio W_1/W_2 for elastic scattering of electrons by the proton and the neutron.

initial nucleon (or of the recoil nucleon in the impulse approximation) can in fact be attributed to scattering by a $6Q$ state of the deuteron. Another point which is quite pertinent to the interpretation of the data is the relative momentum of the nucleons that are flying apart. At the threshold for electrodisintegration this momentum is zero, but it rises rapidly with increasing energy transfer. Exchange meson currents and the final-state interaction are thus important only in a narrow part of the spectrum near the threshold. For this reason, the electrodisintegration of the deuteron can provide some less ambiguous information about the quark structure than can be obtained from the magnetic form factor of the deuteron, in which exchange-meson currents mask the contribution of the $6Q$ state.

Figure 3 shows the ratio W_1/W_2. It reaches 7.9 near the threshold and drops off with increasing ν. Near the top of the quasielastic peak the ratio W_1/W_2 tends toward the ratio of the structure functions for elastic scattering by the proton and the neutron, shown by the solid curve. The large value of W_1/W_2 found from this experiment shows that the scattering near the threshold is primarily magnetic even at the angle of 70°. It thus becomes possible to determine the structure function W_1 reliably and accurately from experiments.

The theories currently available do not allow a quantitative interpretation of these results, but further progress on the question will apparently provide information on the short-range NN potential and the $6Q$ state of the deuteron.

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