Electrodisintegration of the deuteron at a relativistic momentum transfer

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The cross section for electrodisintegration of the deuteron at an angle of 127° has been measured over the momentum-transfer interval 16–30 fm^{-2}. The process is analyzed in light-front dynamics.

Studies of nontraditional degrees of freedom of the deuteron (baryon, quark, and exchange meson currents) constitute a new field of research: relativistic nuclear physics.[1] This field requires experimental data on the large-angle scattering of electrons by deuterons near the threshold, at the maximum possible momentum transfer. A substantial advance into this region was recently made at Saclay[2] in measurements carried out at a momentum transfer up to $q^2 = 18$ fm^{-2}. Leidemann and Arenhivel[3] have recently carried out some calculations in a nonrelativistic approach. In order to study even larger values of q^2 it becomes necessary to measure very small electrodisintegration cross sections: on the order of 10^{-38} $cm^2/(MeV\cdot sr)$.

In this letter we report experimental data on the magnetic electrodisintegration of the deuteron near the threshold at substantially higher values of the momentum transfer: from 16 to 30 fm^{-2}. To analyze the results we use relativistic calculations in light-front dynamics,[4] in which the cross section is written in the form

$$\frac{d^2\sigma}{d\omega\, dE_2} = \frac{\alpha^2}{q^2}\frac{E_2}{E_1}\frac{l_{\mu\nu}W_{\mu\nu}}{2M}, \tag{1}$$

where

$$W_{\mu\nu} = \left(-g_{\mu\nu} + \frac{q_\mu q_\nu}{q^2}\right)W_1 + \frac{1}{M^2}\left(d_\mu - \frac{\mu\nu}{q^2}q_\mu\right)\left(d_\nu - \frac{\mu\nu}{q^2}q_\nu\right)W_2,$$

and $l_{\mu\nu}$ is the electromagnetic tensor.

To calculate the tensor $W_{\mu\nu}$ we use an infinite-momentum system, and we ignore the virtuality of the Fock components. Using only the "good" components of the electromagnetic current,[4] and requiring gauge invariance, we can reconstruct the entire tensor $W_{\mu\nu}$ from its "good" components. The structure function $W_2(q^2,\nu)$ is determined unambiguously from the equations with $P^2 (P\to\infty)$. On the other hand, there is some latitude in the determination of the structure function $W_1(q^2,\nu)$ found from the equation with P^0. The condition $W_{\mu\nu} l^L_\mu l^L_\nu \geqslant 0$ (l^L_μ are the photon polarization vectors), however, resolves the ambiguity in the determination of $W_1(q^2,\nu)$. Making use of this criterion, and choosing a special direction of the infinite momentum for the transformation from the laboratory system to the infinite-momentum system, we can suppress the contribution of many-particle intermediate states to the maximum extent possible. The cross section can be then written in the traditional form ing deviation of the experimental points from the theoretical curves derived by the nonrelativistic approach. At $0.7 \leqslant q^2 \leqslant 1.16$ GeV^2 we have in fact lost the qualitative agreement. Significantly, instead of the minimum predicted by the theory of Ref. 3, the experimental data show only a slight jog at $q^2 = 17$ fm^{-2} against the background of a smooth trend. The primary reason for the discrepancy with the experimental data at $q^2 > 17$ fm^{-2} is that the new data were obtained in a definitely relativistic region: q^2/M^2 reaches 1.3, and $P_{\min}/M$ for the point of maximum q^2 is 0.6.

Curve 4 in Fig. 2 (the dashed curve) shows our calculations in light-front dynamics for $E_{np} = 2.2$ MeV As in Fig. 1, a soft-core Reid potential was used. At $q^2 \leqslant 0.7$ GeV^2 this curve does not agree with experiment, because we did not include in our calculations the $^1S_0$ quasibound state of the deuteron. At large values of q^2, the singlet peak fades in importance, and the calculations in the infinite-momentum system correctly describe the behavior of the experimental curve.

In summary, we have obtained the first experimental data on the magnetic electrodisintegration of the deuteron at essentially relativistic values of q^2. The data show that nonrelativistic calculations are unsuccessful.

An important feature of these calculations in light-front dynamics is the special orientation of the hypersurface with respect to the momenta of the particles involved in the reaction. This orientation suppresses the contribution of loop diagrams to the maximum extent possible, allowing a satisfactory agreement with experiment.

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