Asymmetry in the reaction $d(e,e'd)$ at a momentum transfer of 1–1.5 fm^{-1}

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The asymmetry in the cross section for the reaction $d(e,e'd)$ has been studied at $E_e = 400$ MeV and $\theta_e = 30–50°$ with a tensor-polarized jet target of atomic deuterium in the VÉPP-2 electron storage ring. An analyzing power $F_{20} = 0.18 \pm 0.07$ is found. This power determines the ratio of the quadrupole and monopole electric form factors of the deuteron.

Polarization experiments with deuterium can resolve several questions of current interest in the physics of nucleon-nucleon interactions.[1] The experiment which we are reporting in the present letter is a continuation of a study[2] being carried out to separately measure the monopole and quadrupole electric form factors of the deuteron.

We write the reaction cross section at $q < 2$ fm^{-1} as

$$d\sigma / d\Omega_e = (d\sigma_0/d\Omega_e)\left\{1 - \frac{1}{\sqrt{2}}F_{20}P_{zz}P_2\,(\cos(\mathbf{hq}/|\,\mathbf{q}\,|))\right\},$$

where $d\sigma_0/d\Omega_e$ is the scattering cross section of the unpolarized deuteron, F_{20} is the analyzing power, P_{zz} is the degree of tensor polarization, **h** is a unit vector along the polarization direction, and **q** is the momentum transfer. At small values of the momentum transfer, F_{20} is equal to

$$\sqrt{\tfrac{2}{9}}\,\frac{q^2}{M_d^2}G_Q/G_E$$

where G_E and G_Q are the monopole and quadrupole form factors of the deuteron, and M_d is the mass of the deuteron.

By measuring the reaction cross section for various angles between **h** and **q** and also for various values of $P_{zz}{}'$ we can determine F_{20}.

The experimental arrangement is shown in Fig. 1. An electron beam (average current of 0.25 A, diameter of 3–4 mm) intersects a jet of deuteron atoms[3] (density $\sim 10^{11}$ atoms/cm^3, diameter of 7 mm). The polarization direction of the deuterons in the region in which the electron beam intersects the jet is determined by the magnetic field, whose vector lies in the reaction plane (for the case $\varphi = 0°$), making an angle $\theta = 44°$ or $132°$ with the beam axis (the cases $\mathbf{H}_1$ or $\mathbf{H}_2$ in Fig. 1). The degree of polarization of the atoms in the jet is determined from the distribution of their deflec-

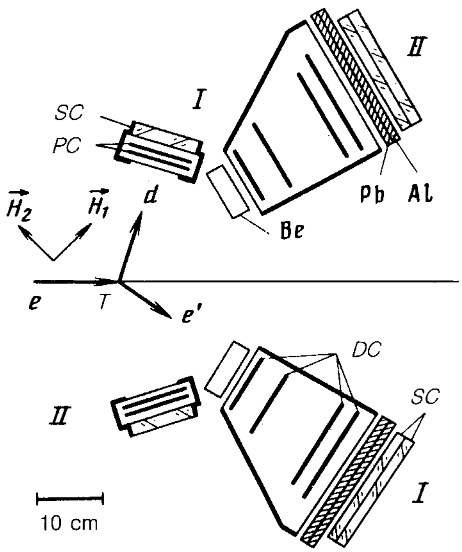

FIG. 1. Schematic arrangement of the $d(e,e'd)$ experiment. T—target; DC—drift chambers; PC—proportional chambers; SC—scintillation counters; Be, Pb, Al—absorbers; $\mathbf{H}_1$ ($\mathbf{H}_2$)—magnetic field directing the polarization of the target.

tions in a nonuniform magnetic field.[3] To detect the elastic and inelastic scattering events (*ed* and *ep* events), we use two identical systems to detect the electrons which are scattered at angles θ from 30° to 50°, $|\varphi|\leqslant 10°$, in coincidence with secondary particles.

The working cycle includes measurements in four polarization states. Specifically, we vary the polarization direction and the type of high-frequency transition between the hyperfine components in the deuteron atom (which determines the sign of P_{zz}). The polarization state is switched at intervals of 2–3 min over the 100 h during which the statistical base is accumulated. The asymmetry averaged over the four states of the target is (in a first approximation) insensitive to the systematic errors which stem from the differences in the efficiencies and solid angles of the detectors. A total of $\sim$3900 *ed* events and a total of $\sim$8000 *ep* events were detected.

Elastic-scattering events were identified on the basis of a $\Delta E/E$ analysis in the deuteron detectors and on the basis of the relation between the energy E and the electron scattering angle (Fig. 2). Among the events classified as belonging to the $d(e,e'd)$ reaction, the fraction of *ep* events was $4\pm 1\%$.

The measured values of P_{zz} for the atoms of the jet are $+0.92\pm 0.09$ and -0.84 ± 0.11 for the two types of high-frequency transitions. The effective degree of polarization of the deuteron in the jet-beam intersection region falls off because of the finite magnetic field, $H_1(H_2) = 670$ Oe, because of *ep* events which were not eliminated, and because of deuteron ions trapped by the electrostatic field of the electron beam. The last of these effects is the most important. Its magnitude was determined in auxiliary measurements without the target, for various partial deuterium pressures in the vacuum chamber of the storage ring. The effective values found as a result are $P_{zz} = +0.71\pm 0.08$ and -0.64 ± 0.09.

Denoting by D^{I}_{1+} the number of counts in system I (Fig. 1) for magnetic field

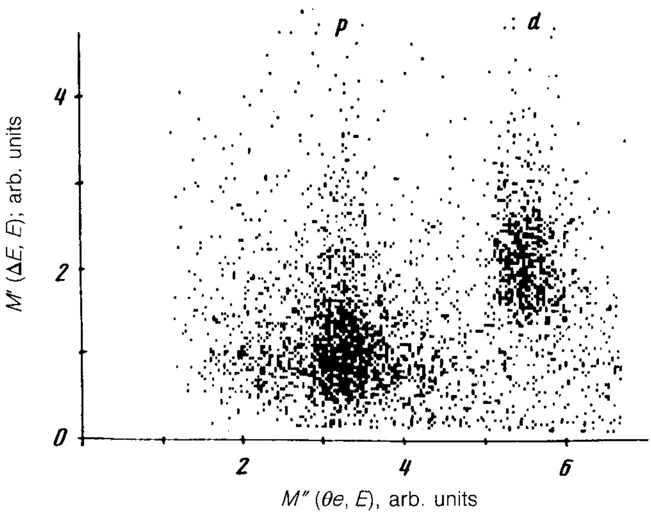

FIG. 2. Distribution of events in the parameters $M' \sim \Delta EE$ and $M'' \sim \sin^2(\theta_e/2)/E$.

direction H_1 and for $P_{zz} > 0$, and denoting the corresponding number of counts for system II by D^{II}_{1+}, we determine the asymmetry of the cross section averaged over the four polarization states as follows:

$$a = \frac{1}{4}\left\{\frac{D^{II}_{1+} - D^{I}_{1+}}{D^{II}_{1+} + D^{I}_{1+}} - \frac{D^{II}_{2+} - D^{I}_{2+}}{D^{II}_{2+} + D^{I}_{2+}} - \frac{D^{II}_{1-} - D^{I}_{1-}}{D^{II}_{1-} + D^{I}_{1-}} + \frac{D^{II}_{2-} - D^{I}_{2-}}{D^{II}_{2-} + D^{I}_{2-}}\right\}.$$

The value found experimentally is $a = 0.036 \pm 0.016$. For electrodisintegration events (ep events), we find the corresponding quantity from the region of the quasielastic

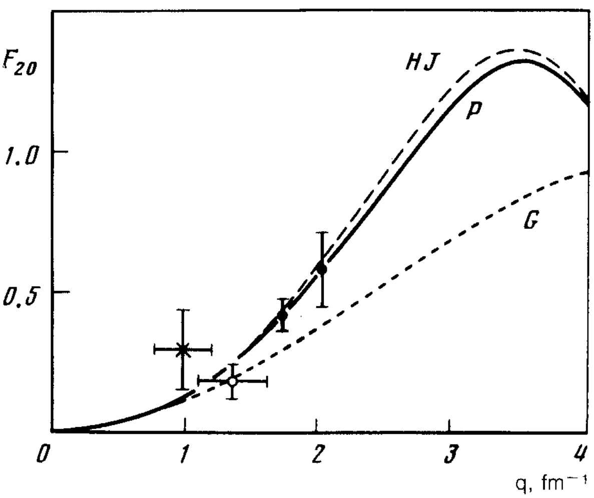

FIG. 3. Reaction analyzing power F_{20} as a function of the momentum transfer. *HJ*—calculations in the impulse approximation with the Hamada-Johnston potential[5]; *G*—the same, with the Graz potential[6]; *P*—the same, with the Paris potential[7]; ×—Ref. 2; ●—Ref. 4; ○—present experiment.

peak to be 0.003 ± 0.011, in agreement with the zero value expected.

The value of F_{20} averaged over the detection solid angle, with allowance for the change in the angle between **h** and **q**, turned out to be 0.18 ± 0.07. The error indicated here includes the statistical error and the uncertainty in P_{zz}.

Figure 3 shows plots of F_{20}, where all of its terms are taken into account, for several potentials, the results of Refs. 2 and 4, and the results of the present study.

Improving the jet target will make it possible to raise the density of this target by a factor of 2 or 3 and to lower the error in the determination of P_{zz}. There is the possibility of carrying out measurements at $q > 1.5$ fm^{-1} at the VÉPP-3 storage ring, where plans call for pumping off the ions and increasing the detection solid angle.

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