Asymmetry of the photodisintegration of the deuteron by linearly polarized γ rays below the pion production threshold for the angle $\vartheta'_p=60°$

I. E. Vnukov, I. V. Glavanakov, B. N. Kalinin, Yu. F. Krechetov,
A. V. Moiseenko, A. P. Potylitsyn, A. N. Tabachenko, E. N. Shuvalov,
and N. P. Fedorov

Scientific-Research Institute of Nuclear Physics, Tomsk Polytechnical University, 634050 Tomsk, Russia

(Submitted 7 September 1994)
Pis'ma Zh. Eksp. Teor. Fiz. **60**, No. 8, 560–562 (25 October 1994)

The asymmetry of the photodisintegration of the deuteron by linearly polarized γ rays with energies of 100–140 MeV has been measured for the proton emission angle $\theta_p^* = 60°$. The data confirm that the contribution of meson degrees of freedom to the reaction amplitude is important. © *1994 American Institute of Physics.*

Effects due to meson exchange currents and isobar configurations in the asymmetry of the photodisintegration of the deuteron by linearly polarized γ rays arise at γ-ray energies above 60 MeV and then strengthen rapidly with further increases in the energy, up to the pion production threshold.[1-3] At present, there is exceedingly little experimental information on the asymmetry in this energy region. Furthermore, for forward proton emission angles in the c.m. frame and at γ-ray energies above 100 MeV, at which the theoretical models predict a large spread, there are no data on the asymmetry. Accordingly, experiments in this energy region are clearly of interest. In this letter we are reporting measurements of the asymmetry of the photodisintegration of the deuteron by linearly polarized γ rays with energies in the interval $E_\gamma = 100-140$ MeV for a proton emission angle $\theta_p^* = 60°$ in the c.m. frame.

As in our previous study,[4] the linearly polarized γ rays were generated by the method of coherent bremsstrahlung of electrons with an energy of 900 MeV in a diamond single crystal 10 mm thick. The crystal was oriented with the help of a goniometer in such a way that the axis of the electron beam made an angle of 2.9 mrad with the $(0\bar{1}1)$ crystallographic plane in one case, and the same angle with the $(00\bar{1})$ plane in another. The angle (~ 40 mrad) between the directions of the electron beam and the $\langle 100 \rangle$ axis did not change. It was thus possible to generate γ beams with mutually perpendicular polarization vectors and identical intensity spectra. The beam was shaped by a system of collimators. Its divergence was 6×10^{-4} rad. The crystal orientations selected maximized the reduced intensity of the radiation.[5] The parameters of the polarized γ beam (its intensity spectrum, the total energy, and the intensity distribution) were calculated from coherent-bremsstrahlung theory with allowance for multiple scattering and collimation of the beam.[6] The polarization reached a value of 70% in the energy region 100–140 MeV.

Figure 1 shows the experimental layout. The γ beam is incident on a target of deuterated polyethylene (a carbon target was installed for measuring the background due

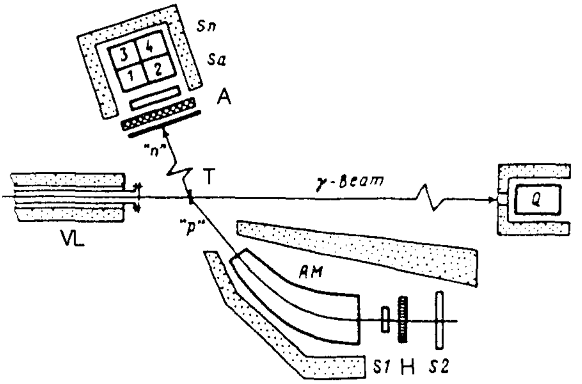

FIG. 1. Experimental layout. *VL*—Vacuum line; *T*—target; *Q*—Gauss quantometer; *AM*—analyzing magnet; S_n (1–4)—scintillation counters; *H*—scintillation hodoscope; *A*—absorbers.

to ^{12}C). The target made an angle of 30° with the beam axis. The beam was monitored by a Gauss quantometer.

The channel for detecting protons included a strongly focusing magnet *AM* for momentum separation of the particles,[7] scintillation counters S_1 and S_2 for detecting charged particles and identifying protons, and a hodoscope[8] *H* for a more precise determination of the proton momentum. The momentum acceptance of the proton channel was 30%; the error of the measurements of the proton momentum was 1%.

The neutron channel consisted of four scintillation counters S_n, which detected neutrons on the basis of recoil protons in scattering by a plastic scintillator containing hydrogen (each scintillator had dimensions of $10\times10\times50$ cm), and an anticoincidence scintillation counter S_a for selecting charged particles. A lead converter $\sim 2X_0$ thick in front of the counters suppressed γ rays and a polyethylene absorber reduced the background of low-energy charged particles. The energy threshold for detection by the neutron counters was 0.4 MeV.

Fast electronic units formed a trigger pulse in a $S_1 \wedge S_2 \wedge (S_{n_1} \vee S_{n_2} \vee S_{n_3} \vee S_{n_4}) \wedge \bar{S}_a$ logic circuit. When the trigger pulse appeared, the following quantities were measured: the pulse height of counter S_1, for identifying protons against the background of pions and positrons, on the basis of the ionization loss in the scintillator; the time interval between the pulses from counter S_1 and the hodoscopic photomultiplier of hodoscope *H*, which is linearly related to the coordinate of the particle near the focal plane of *AM*; and the time interval between the instants at which particles were detected by the proton and neutron channels, to estimate the level of random coincidences and to identify neutrons against the background of γ rays which did not convert into e^+e^- pairs in the lead converter. The half-width of the correlation peak in the spectrum of time intervals of deuteron photodisintegration events did not exceed 4 ns. The difference in the transit times of neutrons and γ rays from the target to the neutron counters was greater than 15 ns, so neutrons could be reliably identified.

The asymmetry was determined from the measured yields of *np* coincidences, $Y_\perp$ and $Y_\parallel$, in the cases in which the polarization vector of the γ beam was oriented perpendicular and parallel to the reaction plane, respectively:

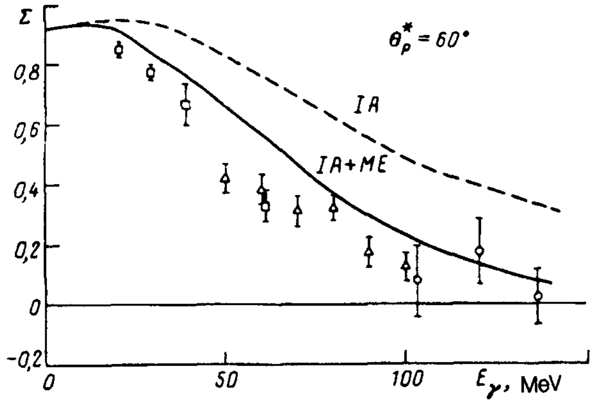

FIG. 2. Energy dependence of the asymmetry of the cross section for the photodisintegration of the deuteron for the angle $\theta_p^* = 60°$. Experimental results: □—Reference 9; △—Ref. 4; ○—present study. The curves are theoretical[3] (see the text proper).

$$\sum (E_\gamma, \theta_p^*) = \frac{1-R}{P_\gamma^{\text{eff}}(1+R)} .$$

Here $R = Y_\perp / Y_\parallel$ is the ratio of the reaction yields corrected to a single equivalent γ ray at the beam energy, and P_γ^{eff} is the effective polarization of the γ beam in the averaging region $\Delta E_\gamma = 16$ MeV.

The values of the asymmetry were found for three values of the γ-ray energy: $E_\gamma = 103$, 120, and 136 MeV. The results are, respectively, 0.073 ± 0.120, 0.17 ± 0.11 and 0.022 ± 0.092. The indicated measurement errors are statistical.

Figure 2 shows the results of measurements of the energy dependence of the asymmetry for a proton emission angle of 60°, along with our earlier data from measurements at a lower energy[4] and the results of Ref. 9. Also shown here are results of theoretical predictions of the asymmetry derived in Ref. 3 by a Feynman-diagram approach, in which the amplitude for photodisintegration of the deuteron was represented as a contribution from pole diagrams and from diagrams which incorporate final-state interactions and the meson exchange. The dashed curve shows the asymmetry calculated in the distorted-wave impulse approximation (IA) with the Paris potential. The solid curve is the asymmetry calculated in the impulse approximation with an additional contribution from meson exchange currents (ME). This curve was calculated by a method which incorporated only 1π and 1ρ exchange, in accordance with the choice of the Paris potential. The nucleon form factors and the width of the Δ isobar were incorporated in the expression for the exchange current $J_{ME}^{\mu,1\pi}$.

We see from this figure that the values we found for the asymmetry at $\theta_p^* = 60°$ for γ-ray energies of 100–140 MeV agree with the results we found previously at lower energies. The new results confirm that meson degrees of freedom make an important contribution to the reaction amplitude in the disintegration of the deuteron by linearly polarized γ rays.

---

[1] H. Arenhovel, Z. Phys. A **302**, 25 (1981); Nucl. Phys. A **34**, 521 (1982); Nuovo Cim. A **76**, 256 (1983).
[2] A. Combi *et al.*, Phys. Rev. C **26**, 2358 (1982); J. Phys. G **10**, L11 (1984).

[3] M. I. Levchook, "Preprint 567/1990, Institute of Physics, Academy of Sciences of the Belorussian SSR.
[4] I. E. Vnukov *et al.*, Yad. Fiz. **47**, 913 (1988) [Sov. J. Nucl. Phys. **47**, 581 (1988)].
[5] I. E. Vnukov *et al.*, JETP Lett. **43**, 659 (1986); Vopr. At. Nauki Tekh. Ser. Obshch. Yad. Fiz., No. 3(35), 75 (1986).
[6] I. E. Vnukov *et al.*, Izv. Vyssh. Uchebn. Zaved., Fiz. **16**, 21 (1991).
[7] B. N. Kalnin *et al.*, Prib. Tekh. Eksp., No. 3, 45 (1978).
[8] V. G. Vasil'chenkov and V. N. Rykalin, Preprint 85-153, Institute of High-Energy Physics, Serpukhov, 1985.
[9] M. P. de Pascall *et al.*, Phys. Rev. C **32**, 1830 (1985).

Translated by D. Parsons