Photodisintegration of the deuteron by linearly polarized photons with energies 50–100 MeV

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The asymmetry of the differential cross section for the photodisintegration of the deuteron by linearly polarized photons with energies 50–100 MeV has been measured for proton emission angles of 45°, 60°, and 90° in the c.m. frame.

An important source of information on nonnucleonic degrees of freedom in nuclei is study of the polarization parameters in the photodisintegration of the deuteron by polarized photons. In particular, the asymmetry of the differential cross section for the photodisintegration of the deuteron by polarized photons below the threshold for the production of a π meson in the photon energy range 40 MeV$\leqslant E_\gamma \leqslant$140 MeV depends strongly on the contribution of mesonic and isobaric degrees of freedom in the deuteron.[1,2]

The asymmetry of the photodisintegration of the deuteron by polarized photons has been measured in the energy interval 40 MeV$\leqslant E_\gamma \leqslant$140 MeV in a polarized beam at the Khar'kov linear accelerator[3] for $E_\gamma \geqslant 40$ MeV and proton emission angles $\theta \geqslant 75°$ in the c.m. frame, in the Ladon polarized beam[4,5] at $E_\gamma \leqslant 70$ MeV, and in the polarized bremsstrahlung beam at the Stanford Linear Accelerator[6] for $E_\gamma \geqslant 75$ MeV at $\theta = 45°$, 90°, and 135°. There have been no systematic measurements of the asymmetry at energies $E_\gamma \geqslant 40$ MeV for "forward" angles, $\theta < 90°$.

These gaps in the experimental data on the asymmetry of the photodisintegration of the deuteron prevent definite conclusions regarding the roles of mesonic and isobaric degrees of freedom in the deuteron. Arenhovel[1] worked from experimental data at $E_\gamma \geqslant 60$ MeV and the angle $\theta = 90°$—for which the most experiments have been carried out—and concluded that mesonic exchange currents and isobaric configurations play an important role in the deuteron. The sole experiment[6] which has been carried out to measure the asymmetry of the photodisintegration of the deuteron at

$E_\gamma > 75$ MeV and $\theta = 45°$ supports the predictions of the standard Partovi theory,[7] in which mesonic and isobaric degrees of freedom are ignored. It is therefore necessary to measure the asymmetry of the photodisintegration of the deuteron below the pion production threshold, especially for the "forward" angles $\theta \leqslant 75°$, where they are nearly absent.

In this letter we report measurements of the asymmetry of the photodisintegration of the deuteron by linearly polarized photons in the energy interval $E_\gamma = 50$–100 MeV for proton emission angles $\theta = 45°$, $60°$, and $90°$. The experiments were carried out with the beam of linearly polarized photons at the Tomsk synchrotron. The experimental arrangement is shown in Fig. 1.

The beam of linearly polarized photons is produced by the method of coherent bremsstrahlung of 900-MeV electrons in a diamond single crystal 10 mm thick. A beam with a divergence of 6×10^{-4} is produced by a system of collimators (2). The diamond crystal (1), with faces perpendicular to the $\langle 100 \rangle$, $\langle 011 \rangle$, and $\langle 01\bar{1} \rangle$ crystallographic axes, is mounted on a goniometer in such a way that the directions of the axes coincide with the electrons of the electron beam and of the vertical and horizontal rotation axes of the goniometer, respectively. The crystal is oriented in such a way that the electron beam is incident at angles in the interval 0.9–2.2 mrad with respect to the (011) crystallographic plane in one case and with respect to the $(01\bar{1})$ plane in the other case. The angle ~40 mrad between the direction of the electron beam and the $\langle 100 \rangle$ axis is not changed. These two positions of the target make it possible to obtain polarized, coherent photon beams with mutually perpendicular polarization vectors and identical intensity spectra. The crystal orientations selected maximize the reduced beam intensity.[8] The spectral distribution of the beam is measured with a double magnetic spectrometer (3). The total beam energy is measured within $\pm 3\%$ with a Gauss γ-detector (6). The parameters of the polarized beam—its intensity spectrum, its total energy, and the polarization distribution—were calculated from the theory of coherent bremsstrahlung with multiple scattering for the particular beam collimation conditions. The calculated intensity spectrum and total energy of the beam agree satisfactorily with the experimental results. The calculated polarization is 0.74–0.7 for $E_\gamma = 50$–100 MeV.

The protons are detected by a magnetic spectrometer which includes a strongly focusing magnet[9] (5) and scintillation counters S_1 and S_2, separated by an absorber A.

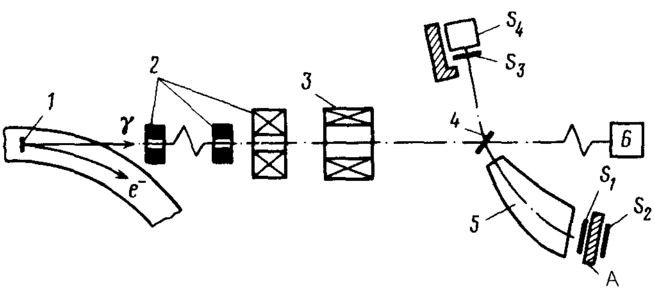


FIG. 1. The experimental arrangement.

The spectrometer "captures" protons over a momentum interval of 10% in an angular interval of 3.4 msr. The neutrons are detected in coincidence with the protons by counter S_4 (Ref. 10), which uses a plastic scintillator 30 cm in diameter and 30 cm long. Counter S_4 is positioned 2 m from the target and has a resolving time of 2.5 ns. A thin scintillation counter (S_3) in front of S_4 removes charged particles.

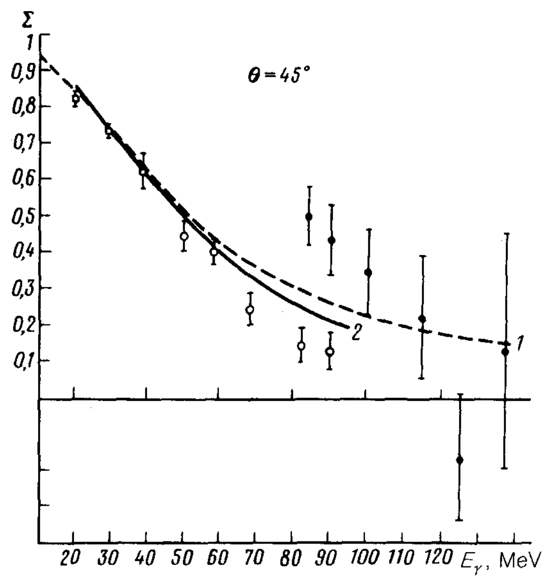
The energy resolution $\Delta E_\gamma / E_\gamma$ determined by the parameters of the proton spectrometer is 10%. The asymmetry was measured at the deuterated polyethylene target (4), 40 mm in diameter and 1 mm thick. Measurements were carried out in a carbon target to take account of the background contributions, which amounted to 3–6%.

The asymmetry was determined from the yields $Y_\perp, Y_\parallel$ of *np* coincidences with the polarization vector of the photon beam, respectively, perpendicular and parallel to the reaction plane:

$$\Sigma(E_\gamma, \theta) = \frac{1-R}{P_\gamma^e(1+R)} ,$$

where $R = (Y_\perp/Q_\perp)/(Y_\parallel/Q_\parallel)$, $Q_{\perp,\parallel}$ is the total energy of the beam of photons incident on the target, and P_γ^e is the polarization of the photon beam, averaged over the energy interval "captured" by the apparatus.

Figures 2 and 3 show the results of the measurement of the energy dependence of the asymmetry for proton emission angles of 45° and 60°. The indicated measurement errors are statistical. For the angle $\theta = 45°$, our results are shown along with the results of Refs. 5 and 6. This is the first time the energy dependence of the asymmetry has been found for the angle $\theta = 60°$. The asymmetry which we measured for $\theta = 90°$ and $E_\gamma = 50$ MeV and $E_\gamma = 100$ MeV agrees with the earlier experimental data. Figures 2 and 3 also show theoretical predictions of the asymmetry. Curve 1 corresponds



FIGS. 2 and 3. Energy dependence of the asymmetry (Σ) of the cross section for angles $\theta = 45°$ and 60°, respectively. Open circles—present study; squares—Frascati results[5]; filled circles—SLAC results.[6] 1) Predictions of the model of Ref. 9, without mesonic and isobaric degrees of freedom; 2) predictions of the Partovi model,[7] supplemented with mesonic exchange currents.

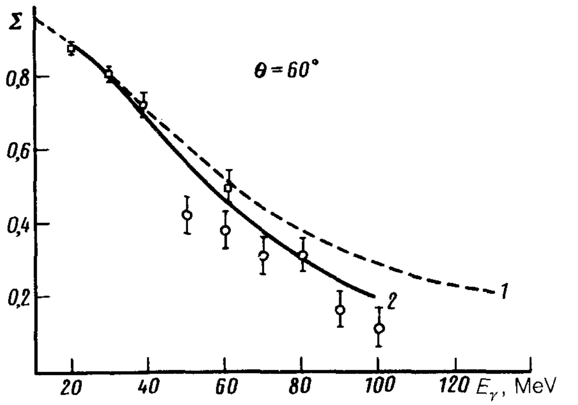


FIG. 3

to a calculation of the asymmetry with the Paris potential in the approach of Ref. 11, which is analogous to the Partovi approach, without mesonic exchange currents or isobaric configurations. Curve 2 corresponds to a calculation with the RSC potential[12] in the Partovi model, supplemented with mesonic exchange currents. It follows from these results that our experimental values of the asymmetry in the photodisintegration of the deuteron by polarized photons for angles $\theta = 45°$ and 60° and for $E_\gamma = 50$–100 MeV agree better with the asymmetries predicted by the calculations with mesonic exchange currents, and at $\theta = 45°$ our results do not support the experimental data of Ref. 6.

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