Proton polarization due to a two-particle splitting of a ^{3}He nucleus by linearly polarized photons

V. G. Gorbenko, A. A. Zybalov, I. M. Karnaukhov, L. Ya. Kolesnikov, O. G. Konovalov, A. L. Rubashkin, P. V. Sorokin, and Yu. O. Storozhenko
Physicotechnical Institute, Academy of Sciences of the Ukrainian SSR

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The first data on Σ, P, and T_1 parameters in the reaction $\vec{\gamma}\,{}^3\text{He}\rightarrow pd$ are presented. These data were obtained by measuring the polarization of protons in a beam of linearly polarized 200-MeV photons at a c.m. angle of 45°.

The study of the polarization parameters in the reaction of a two-particle photodisintegration of an ^{3}He nucleus with use of a beam of polarized photons and polarized targets and the measurement of the polarization of recoil nucleons yield important information about the role of meson exchange currents, isobaric configurations of nuclei, the structure of a three-nucleon system, contribution of the D states, final-state interaction,[1,2] and excitation of many-quark states (dibaryons, tribaryons).[3,4]

Experimental results of the measurement of the asymmetry of the cross sections of the reaction $\gamma\,{}^3\text{He}\rightarrow pd$ produced by linearly polarized photons at energies 100–280 MeV have now been published.[5,6] A theoretical analysis[6] of these results has shown that the asymmetry of the cross sections is highly sensitive to the choice of the NN-interaction model.

Data on other polarization observations in the reaction $\gamma\,{}^3\text{He}\rightarrow pd$ have not been published.

In the present letter we present the results of a double-polarization experiment, in which we measured the polarization of a recoil proton in the reaction $\gamma\,{}^3\text{He}\rightarrow pd$, using a beam of linearly polarized 200-MeV photons. The proton was emitted at a c.m. emission angle of 45°.

The differential cross section of the reaction $\gamma\,{}^3\text{He}\rightarrow pd$ for linearly polarized photons and polarization of a recoil proton with the vector perpendicular to the reaction plane can be described by[7]

$$\rho_N \frac{d\sigma}{d\Omega} = \frac{1}{2}\left(\frac{d\sigma}{d\Omega}\right)_0 [1 + \sigma_y P_y + P_\gamma (\Sigma + \sigma_y T_1)\cos 2\varphi], \tag{1}$$

where $\rho_N = (1/2)(1+\vec{\sigma}\mathbf{P}_N)$ is the polarization proton-density matrix,

$\vec{\sigma} = (\sigma_x, \sigma_y, \sigma_z)$ are the Pauli matrices, P_γ is the degree of linear polarization of a photon, φ is the angle between the reaction plane and the photon polarization vector, $(d\sigma/d\Omega)_0$ is the differential cross section with unpolarized photons, P_y is the polarization of a recoil proton with unpolarized photons, $\Sigma = [(d\sigma/d\Omega)^{\parallel} - (d\sigma/d\Omega)^{\perp}]/[(d\sigma/d\Omega)^{\parallel} + (d\sigma/d\Omega)^{\perp}]$ is the asymmetry of the cross sections with linearly polarized photons [$(d\sigma/d\Omega)^{\parallel(\perp)}$ is the differential cross section of the reaction in which the photon polarization vector is parallel (perpendicular) to the reaction plane], and

$$T_1 = \frac{P_y}{P_\gamma} \frac{P_y^{\parallel}(d\sigma/d\Omega)^{\parallel} - P_y^{\perp}(d\sigma/d\Omega)^{\perp}}{P_y^{\parallel}(d\sigma/d\Omega)^{\parallel} + P_y^{\perp}(d\sigma/d\Omega)^{\perp}}$$

is the asymmetry of the polarization of a proton with linearly polarized photons [$P_y^{\parallel(\perp)}$ is the proton polarization, in which the photon polarization vector is directed parallel (perpendicular) to the reaction plane]. We use the standard coordinate system for colliding particles and for particles that fly apart.[7]

In the experiment we used a beam of linearly polarized quasimonochromatic photons of the Khar'kov electron linear accelerator. The beam was obtained by coherent bremsstrahlung of 1200–MeV electrons in a 2-mm-thick diamond single crystal.[8] The experimental procedure was described in detail elsewhere.[6,9]

A target filled with liquid ^{3}He and having the shape of a cylinder 25 mm in diameter and 130 mm long was used in the experiment.

The reaction channel under study was identified by recording the proton and deuteron coincidences detected by scintillation counter telescopes placed beyond two magnetic spectrometers for the proton and deuteron channels, respectively. The *p-d* coincidences were recorded with a time-to-amplitude converters operating on line with a computer. The background of the random *p-d* coincidences was no greater than 20%.

The polarization of protons was measured by an optical spark chamber telescope with graphite electrodes which were used simultaneously as a polarimeter. This telescope was inserted into the proton channel. The spark chambers were triggered by a *p-d* coincidence signal.

The energy capture, $\Delta E_\gamma = \pm 5$ MeV, was determined by the angular and momentum capture of the spectrometers. The contribution from an empty target was no greater than 3%.

In the experiment we measured the *p-d* coincidences, $C^{\perp}$ and $C^{\parallel}$, and the corresponding polarization of the recoil protons, $P^{\perp}$ and $P^{\parallel}$, for two directions of the photon polarization vector–perpendicular and parallel to the reaction plane. From these values we determined the effective polarization of the photon beam, $\overline{P}_\gamma$, the asymmetry of the cross sections,[10]

$$\Sigma = \frac{1}{\overline{P}_\gamma} \frac{C^{\parallel} - C^{\perp}}{C^{\parallel} + C^{\perp}}, \qquad (2)$$

the polarization of the recoil proton, P_γ, and the polarization asymmetry T_1,

$$P_y = \frac{1}{2}[P_y^{\parallel}(1 + P_\gamma \Sigma) + P_y^{\perp}(1 - P_\gamma \Sigma)], \qquad (3)$$

Table I.

E_γ, MeV	θ, deg.	P_γ	$P_y^{\parallel}$	$P_y^{\perp}$	P_y	T_1	Σ	Remark
200	45	0.68±0.03	−0.31±0.10	−0.58±0.06	−0.42±0.06	0.11±0.10	0.21±0.02	Our experiment
200	45	0.71±0.04	–	–	–	–	0.25±0.02	Data taken from Ref. 6

$$T_1 = \frac{1}{2P_\gamma}[P_y^{\parallel}(1 + P_\gamma\Sigma) - P_y^{\perp}(1 - P_\gamma\Sigma)]. \tag{4}$$

The experimental results are presented in Table I. For comparison, we have included in the table the measurement data and the asymmetry of the cross sections obtained by Belyaev *et al.*[6] These data are in satisfactory agreement with our results.

We should point that the values of P_y and T_1, which were measured for the first time, have not been predicted theoretically. The fact that P_y differs substantially from zero suggests, however, that the plane-wave approximation,[6] which was used to describe the asymmetry of the cross sections in this reaction, cannot be used in this case and that the final-state interaction must be taken into account.

We wish to stress in conclusion that the final resolution of the fundamental questions of the dynamics and structure of few-nucleon systems requires further experimental and theoretical studies of the polarization observables.

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