Asymmetry of the cross sections for the reaction $\gamma He^3 \to pd$ with linearly polarized γ rays

A. A. Belyaev, V. A. Get'man, V. G. Gorbenko, A. V. Glamazdin, V. A. Gushchin, Yu. V. Zhebrovskiĭ, I. M. Karnaukhov, L. Ya. Kolesnikov, V. V. Kotlyar, A. A. Lukhanin, A. L. Rubashkin, P. V. Sorokin, E. A. Sporov, Yu. N. Telegin, and A. V. Shebeko
Khar'kov Physicotechnical Institute, Academy of Sciences of the Ukrainian SSR

(Submitted 16 August 1984; resubmitted 17 October 1984)
Pis'ma Zh. Eksp. Teor. Fiz. **40**, No. 10, 448–450 (25 November 1984)

Experimental data are reported on the asymmetry of the cross section for the photodisintegration of the He^3 nucleus by linearly polarized γ rays in the energy range 100–250 MeV for a c.m. proton emission angle of 110° and at a γ-ray energy of 200 MeV for proton emission angles in the range 45–140°. The experimental results are compared with theoretical predictions calculated in the momentum representation through the use of a single-particle electromagnetic-current operator and Faddeev wave functions for the He^3 nucleus.

A study of the two-particle photodisintegration of the He^3 nucleus can yield important information about the structure of the three-nucleon system, the role played by meson exchange currents, the contribution of isobar configurations in nuclei, etc.

Experimental data[1–5] and theoretical predictions[6–8] are available for the energy range $E_\gamma = 100$–300 MeV. Most of this information is on the total and differential cross sections; the asymmetry $\Sigma = (d\sigma_\parallel - d\sigma_\perp)/(d\sigma_\parallel + d\sigma_\perp)$ has been measured only for an angle of 90° in a beam of linearly polarized γ rays.[9] The significant deviation from unity of the values found for the asymmetry led Fabbri *et al.*[9] to conclude that the photoelectric absorption is not dominant in the two-particle photodisintegration of the He^3 nucleus.

In this letter we report preliminary results on the asymmetry coefficient Σ in the reaction $\gamma He^3 \to pd$ induced by a beam of linearly polarized γ rays on the LUÉ-2000 accelerator of the Khar'kov Physicotechnical Institute. Measurements were carried out over the γ energy range 100–250 MeV for the angle $\theta_p^* = 110°$ and for the energy $E_\gamma = 200$ MeV over the angular interval 45–140°.

The beam of quasimonochromatic, linearly polarized γ rays[10] is produced by a method of coherent bremsstrahlung of electrons in a 2-mm-thick diamond single crystal. The initial energies of the electron beam are 700 and 1200 MeV for measurements in the γ energy ranges 100–150 MeV and 150–250 MeV, respectively. The degree of polarization of the γ rays is calculated from the magnitude of the coherent effect[11]; in the experiments, this degree of polarization ranged from 57 to 74%.

The target with liquid He^3 was a cylinder 25 mm in diameter and $l = 130$ mm long. The He^3 was held at a temperature of 1.5 K by pumping He^4 vapor.

The secondary particles were detected by two magnetic spectrometers with telescopes of scintillation counters. The reaction channel under study was distinguished

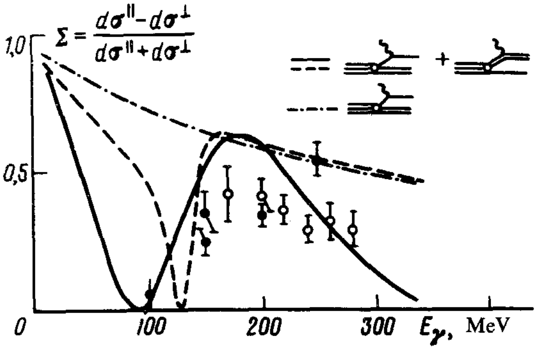

FIG. 1. Energy dependence of the asymmetry coefficient Σ. Filled circles—Present study ($\theta_p^* = 110°$); open circles—results from Ref. 9 ($\theta_p^* = 90°$); solid and dashed curves—theoretical, with the wave functions for the Reid potential, for angles $\theta_p^* = 110°$ and 90°, respectively; dot-dashed curve—theoretical, incorporating only the direct photoemission of the proton ($\theta_p^* = 110°$).

by detecting coincidences of protons and deuterons. The random-coincidence background was no more than 20%; the contribution from the target walls was 0.5%.

The procedure for studying the asymmetry coefficient Σ in a beam of linearly polarized γ rays is described in detail in Ref. 12.

The experimental data are compared with theoretical results from the Khar'kov Physicotechnical Institute in Figs. 1 and 2. These calculations used (1) a single-particle electromagnetic-current operator (see Ref. 13, for example), the sum of a convection current and a nucleon magnetization current, and (2) the wave function for the He^3 nucleus from Ref. 15, based on the Reid soft-core potential,[14] and the wave function for a separable Mongan interaction.[16] The latter wave function was derived through a program that we developed for solving the Faddeev equations in the momentum representation.[17] We considered the contribution of only S waves to the $\psi^{(1)}$ component of these wave functions. The deuteron wave functions were chosen for the corresponding potentials, i.e., in a self-consistent way. The final-state interaction between the proton and the deuteron was ignored.

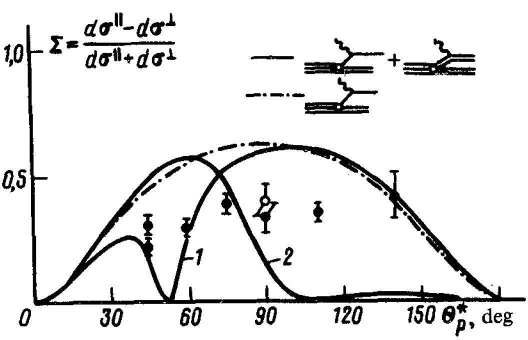

FIG. 2. Angular distribution of the asymmetry coefficient Σ at $E_\gamma = 200$ MeV. Filled circles—Present study; open circles—Ref. 9; solid curves—theoretical, with the wave functions for the Reid potential (1) and for the Mongan potential (2); dot-dashed curve—theoretical, the same as in Fig. 1.

When only the direct photoemission of protons is taken into account, the asymmetry coefficient Σ does not depend on the nuclear structure, and the angular distribution becomes symmetric with respect to $\theta_p^* = 90°$ (see the dot-dashed curve in Fig. 2). Incorporating the exchange diagram gives rise to some structure in the energy and angular dependences of Σ. We do not rule out the possibility that this behavior of the asymmetry coefficient would be smoothed over by taking into account the D components in the wave functions of the He^3 nucleus.[7]

The calculations show that the asymmetry coefficient Σ for the reaction $\gamma He^3 \to pd$ is quite sensitive to the choice of model for the NN interaction (Fig. 2). The observed difference in the results for the Reid and Mongan potentials is attributed to the different positions of the nodes in the corresponding wave functions of the He^3 nucleus in the momentum representation. The positions of these nodes are in turn determined by the nature of the repulsion in the particular model used for the NN forces.

We intend to pursue the measurements of the asymmetry coefficient of the cross sections over broader ranges of the γ-ray energy and the proton emission angle. We also intend to pursue the theoretical calculations, taking into account meson-exchange currents and D waves in the wave functions of the deuteron and of the He^3 nucleus.

[1] N. M. O'Fallon *et al.*, Phys. Rev. C **5**, 1926 (1972).
[2] P. Picozza *et al.*, Nucl. Phys. **A157**, 190 (1970).
[3] P. E. Argan *et al.*, Nucl. Phys. **A237**, 347 (1975).
[4] H. T. Gassen *et al.*, Z. Phys. **A303**, 35 (1981).
[5] D. Sober *et al.*, Phys. Rev. C **28**, 2234 (1983).
[6] J. Finjord, Nucl. Phys. **A274**, 495 (1976).
[7] B. A. Craver *et al.*, Nucl. Phys. **A276**, 237 (1977).
[8] F. Prats, Phys. Lett. **B88**, 23 (1979).
[9] F. L. Fabbri *et al.*, Lett. Nuovo Cimento **3**, 63 (1972).
[10] V. G. Gorbenko *et al.*, Yad. Fiz. **11**, 1044 (1970) [Sov. J. Nucl. Phys. **11**, 580 (1970)].
[11] V. G. Gorbenko *et al.*, Yad. Fiz. **17**, 793 (1973) [Sov. J. Nucl. Phys. **17**, 413 (1973)].
[12] V. G. Gorbenko *et al.*, Yad. Fiz. **35**, 1073 (1982) [Sov. J. Nucl. Phys. **35**, 627 (1982)].
[13] K. W. Mc Voy and L. Van Hove, Phys. Rev. **125**, 1034 (1962).
[14] R. V. Reid, Ann. Phys. **50**, 411 (1968).
[15] Ch. Hajduck and A. M. Green, Nucl. Phys. **A337**, 13 (1980).
[16] T. R. Mongan, Phys. Rev. **178**, 1597 (1969).
[17] V. V. Kotlyar and A. V. Shebeko, Preprint KhFTI-84-26, Khar'kov Physicotechnical Institute, Khar'kov, 1984.

Translated by Dave Parsons
Edited by S. J. Amoretty