Asymmetry of the (γ,p) and (γ,n) cross sections in the disintegration of the ^{4}He nucleus by linearly polarized 40-MeV γ rays

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The asymmetry of the cross sections for the (γ,p) and (γ,n) reactions in the two-particle disintegration of the ^{4}He nucleus by linearly polarized γ rays with an energy of 40 MeV has been measured for the first time. The asymmetry is pronounced for both of these reactions.

Extensive experimental results have now been accumulated on the two-particle disintegration of helium-4 by unpolarized γ rays.[1–4] The mechanisms for these reactions have not yet been identified, despite a detailed analysis of these results. In experiments with polarized γ beams it becomes possible to obtain information on the asymmetry of the cross sections. A study of the asymmetry may serve as a further test of our understanding of the role played by meson exchange currents,[5] of the effects of the final-state interaction,[6] and of the effects of the antisymmetry of the nuclear wave functions[7] in these reactions.

In this letter we report the first results of measurements of the asymmetry of the cross sections for the reactions ^{4}He(γ,p)^{3}H and ^{4}He(γ,n)^{3}He in the disintegration of ^{4}He by linearly polarized γ rays with an energy of 40 MeV.

The experiments are carried out in the SK-600 streamer chamber[8], with dimensions of $600 \times 600 \times 120$ mm, filled with pure helium to a pressure of 1 ata. The magnetic field in the chamber is 8 kG. The experimental arrangement is shown in Fig. 1. A beam of linearly polarized γ rays, produced through the coherent bremsstrahlung of 500-MeV electrons in a diamond crystal[9] 0.3 mm thick, is hardened over 3.73 radiation lengths in LiH and enters the streamer chamber. The position of the first peak in the spectrum of the coherent emission of the electrons ($E_\gamma = 40$ MeV) and the degree of polarization of the emission in the peak of the coherent bremsstrahlung ($P = 80\%$) are determined from the proton yield in the disintegration of deuterium.[10] The intensity of the γ beam is monitored with ionization chambers. The measurements of the reactions ^{4}He(γ,p)^{3}H and ^{4}He(γ,n)^{3}He are carried out simultaneously in a common experimental geometry.

From the experiments we selected 32 000 stereo photographs. Analysis of the results in the γ energy range $31 \leqslant E_\gamma \leqslant 47$ MeV, in which the average degree of polarization of the beam is $P = 0.67 \pm 0.06$, yielded 349 events of ^{4}He(γ,p)^{3}H reactions and 371 events of ^{4}He(γ,n)^{3}He reactions.

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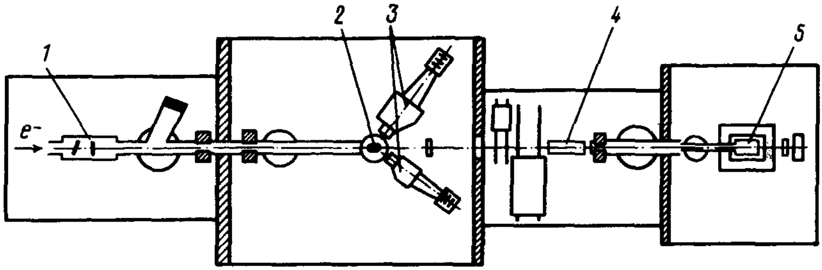

FIG. 1. The experimental arrangement. 1—γ-ray target (a diamond crystal); 2—liquid deuterium target; 3—magnetic spectrometers; 4—hardener; 5—streamer chamber.

The asymmetry of the cross section, $\Sigma(\theta_N)$, is determined by fitting the experimental φ_N distributions of the reaction products by the expression

$$\frac{dN^{\lambda}}{d\Omega_N} = \frac{dN^0}{d\Omega_N}\,[\,1 + P\,\Sigma\,(\theta_N)\cos 2\varphi_N\,]\;,$$

where $(dN^{\lambda}/d\Omega_N)(dN^0/d\Omega_N)$ is the yield of the (γ,N) reaction for incident γ rays in polarization state λ (unpolarized γ rays), and θ_N and φ_N are the polar and azimuthal angles of the emission of the nucleon in the laboratory frame.

Figure 2 shows values of the asymmetry of the (γ,p) and (γ,n) reactions at the ^{4}He nucleus as a function of θ_N. The curves here were calculated in the plane-wave impulse approximation with allowance for the direct ejection of a nucleon and for the recoil mechanism[6] for $E_\gamma = 40$ MeV. The open circles with error bars (the crosses) show the results of these experiments (theoretical results) averaged over the intervals $30° \leqslant \theta_N \leqslant 90°$ and $90° \leqslant \theta_N \leqslant 150°$ near the angles $\theta_N = 60°$ and $\theta_N = 120°$, respectively.

There is a satisfactory agreement between the theory and experiment. The nonzero asymmetry of the cross section for the (γ,n) reaction indicates that the direct-ejection mechanism in not dominant at $E_\gamma = 40$ MeV. Under certain assumptions (a single-particle mechanism for the electromagnetic interaction with the nucleus and the omission of effects of the final-state interaction of the ejected nucleon), this asymmetry

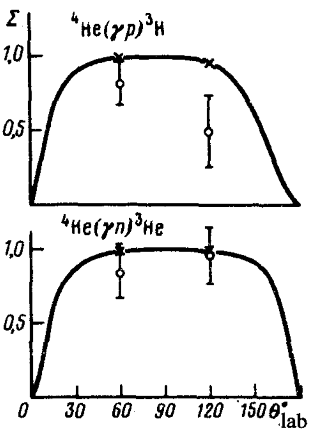

FIG. 2. Asymmetry of the yield of nucleons from the reactions ^{4}He$(\gamma,p)^3$H and ^{4}He$(\gamma,n)^3$He.

would vanish, according to Ref. 7, if the antisymmetry of the final states were ignored.

Two-particle currents caused by the exchange of mesons between the nucleons of the nucleus and due to a (p,n) charge exchange[11] accompanying the absorption of a photon, etc., could also give rise to a significant asymmetry in the (γ,N) reaction.

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[1]Yu. M. Arkatov, P. I. Vatset, V. I. Voloshcuk, *et al.*, Ukr. Fiz. Zh. **23**, 1818 (1978).
[2]A. N. Gorbunov, in: Trudy FIAN (Proceedings of the Lebedev Physics Institute), Nauka, Moscow, 1974, pp. 3-119.
[3]L. Busso, R. Garfagnini, G. Piragino, *et al.*, Lett. Nuovo Cimento **1**, 941 (1971).
[4]T. W. Phillips, B. L. Berman, *et al.*, Phys. Rev. **19C**, 2091 (1979).
[5]M. Gari and H. Hebach, Phys. Rep. **72**, 1 (1981).
[6]I. S. Shapiro, Usp. Fiz. Nauk **92**, 549 (1967) [Sov. Phys. Usp. **10**, 515 (1968)]; S. Boffi, C. Giusti, and F. D. Pacati, Phys. Lett. **B98**, 11 (1981).
[7]Yu. P. Mel'nik and A. V. Shebeko, Preprint KhFTI 84-2, Khar'kov Physicotechnical Institute, 1984.
[8]S. G. Tonapetyan, V. A. Nikitin, V. M. Khvorostyan, *et al.*, VANT, seriya: Obshaya i yadernaya fizika (General and Nuclear Physics), No. 1, 1980, p. 69.
[9]V. G. Gorbenko, Yu. V. Zhebrovskiĭ, *et al.*, Yad. Fiz. **11**, 1044 (1970) [Sov. J. Nucl. Phys. **11**, 580 (1970)].
[10]V. P. Barannik, V. G. Gorbenko, V. A. Gushin *et al.*, Yad. Fiz. **38**, 1108 (1983) [Sov. J. Nucl. Phys. **38**, 667 (1983)].
[11]S. R. Cotanch, Phys. Lett. **76B**, 19 (1978).

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