Σ-asymmetry of the reaction $\gamma + {}^7Li \to {}^4He + {}^3H$ near the threshold

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The Σ-asymmetry of the reaction $\gamma^7Li \to {}^4He^3H$ has been measured near the threshold in a beam of linearly polarized photons produced through planar channeling of electrons in a silicon crystal. The results are compared with results calculated on the basis of the $\alpha - t$ cluster model.

The ground state of the nucleus ^7Li presents us with a two-cluster system in its purest form, in this case consisting of an α particle and a triton.[1] Other components of the wave function do not play any important role here.[2] For this reason, a description of the ^7Li nucleus on the basis of the binary cluster model with a deep attractive potential and forbidden states[3] might be successful in describing the entire set of experimental observables.

Of particular interest for testing this idea are experiments near the threshold for the reaction $\gamma + {}^7Li \to {}^4He + {}^3H$, where, according to the calculations of Ref. 4, the cross section is dominated by $E1$ transitions due to the s and d waves in the final state: The s-wave contribution is dominant right at the threshold; at a γ energy E_γ by a few MeV higher the d wave becomes dominant. The amplitudes corresponding to these waves interfere destructively.

The "overflow" of the waves has little effect on the reaction cross section in the case of unpolarized photons, so it is difficult to observe in experiments carried out to measure cross sections. On the other hand, this phenomenon leads to an effect which is quite observable in the dependence of the Σ-asymmetry A_Σ on E_γ near the reaction threshold. According to Ref. 4, the transition from the s wave to the d wave results in a pronounced change in A_Σ, from -0.5 to $+1$.

Our purpose in the present study was to measure A_Σ in order to test the predictions of the model of Ref. 4.

The experiment was carried out in the direct beam of the 2-GeV linear electron accelerator of the Khar'kov Physicotechnical Institute of the Academy of Sciences of the Ukrainian SSR. Linearly polarized γ rays were produced by passing electrons with an energy $E_0 = 1200$ MeV along the (110) plane (far from the axes) of a silicon crystal 500 μm thick.

The experimental target was a free-standing foil of the isotope ^7Li, with a thickness of 1 mg/cm^2, in a vacuum chamber.

The events from the reaction of interest were identified, and the energies of the γ rays were reconstructed by measuring the energy spectra of the charged products of photonuclear reactions by two silicon surface-barrier semiconductor detectors, positioned on different sides of the target, at angles (90° and − 85°) corresponding to the kinematics of the reaction of interest. These detectors were connected in a coincidence circuit.

The energy spectra were measured for three orientations of the crystal, corresponding to the cases in which the polarization vector of the γ rays was parallel to ($N_{\parallel}$) and perpendicular to ($N_{\perp}$) the reaction plane and to the case of a disoriented crystal (N_0). The Σ-asymmetry of the reaction was found from the formula

$$A_{\Sigma} = \frac{N_{\parallel}^k - N_{\perp}^k}{P_{\gamma}^k (N_{\parallel}^k + N_{\perp}^k)} ,$$

where $N_{\parallel,\perp}^k = N_{\parallel,\perp} - N_0$, and P_{γ}^k is the degree of linear polarization in the coherent part of the γ spectrum.

The value of P_{γ}^k was measured with a polarimeter based on a gaseous deuterium target and a surface-barrier semiconductor detector, on the basis of the asymmetry of the proton yield for the coherent part of the γ spectrum:

$$P_{\gamma}^k = A_{\Sigma}^k / A_{\Sigma}^{\gamma d \to np},$$

where

$$A_{\Sigma}^k = \frac{N_{\parallel}^k - N_{\perp}^k}{N_{\parallel}^k + N_{\perp}^k}, \quad N_{\parallel,\perp}^k = N_{\parallel,\perp} - N_0,$$

and $N_{\parallel}$, $N_{\perp}$, and N_0 are the proton yields for the three orientations of the crystal, i.e., parallel and perpendicular to the reaction plane and a disoriented crystal. In addition, $A_{\Sigma}^{\gamma d \to np}$ is an approximation of the existing experimental data on the Σ-asymmetry of the reaction $\gamma d \to np$. In the region $E_{\gamma} < 10$ MeV, where no experimental data are available, values of A_{Σ} were taken from the calculations of Ref. 5.

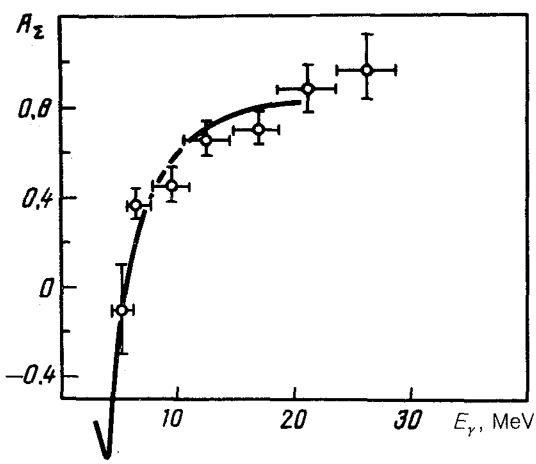

FIG. 1. Σ-asymmetry of the reaction $\gamma + {}^7Li \to {}^4He + {}^3H$.

Figure 1 shows values of the Σ-asymmetry of the reaction $\gamma + {}^7Li \rightarrow {}^4He + {}^3H$ found through an analysis of the data. The vertical bars are the statistical errors; the horizontal bars are the E_γ averaging intervals. The systematic errors associated with the measurement of the degree of linear polarization of the γ rays (not shown in this figure) amount to 5% at the beginning of the measurement interval and 15% at the end. The solid curve here shows the results of a calculation carried out[4] on the basis of the $\alpha - t$ cluster model with parameter values extracted from the phase shifts in elastic $\gamma - t$ scattering. There is a qualitative agreement between the calculations and the experimental results, which constitutes evidence that the model is correctly describing such a subtle effect as an interference of s and d waves near the threshold.

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