Cross section for photodisintegration of the deuteron off the mass shell

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(Submitted 18 April 1985)
Pis'ma Zh. Eksp. Teor. Fiz. **42**, No. 3, 103–105 (10 August 1985)

Experimental data on the reaction $^4He(\gamma,pn)^2H$ are analyzed. The cross section for photodisintegration of the deuteron off the mass shell at energies $E_\gamma = 40$–150 MeV is determined (for the first time).

An experimental study of the reaction $^4He(\gamma,pn)^2H$ in the energy region $E_\gamma = 30$–150 MeV has been carried out by a track method at the Khar'kov Physicotechnical Institute, and the complex program of identifying the reaction mechanism which was formulated in Ref. 1 has been carried out completely. It has been shown[2] that the primary mechanism for the $^4He(\gamma,pn)^2H$ reaction in the region studied is a pole mechanism of a quasideuteron type. It has thus become possible to pursue the study to determine the role played by off-mass-shell effects and related questions, e.g., the range of applicability of the impulse approximation and a more accurate determination of the vertex functions.

For this purpose, we have analyzed our experimental data with the help of the expression[3,4]

$$\frac{d^2\sigma}{dtds} = \frac{1}{8\pi}\frac{1}{G^2}\frac{|F(t)|^2}{(t-m_d^2)^2}E_\gamma\sqrt{s}\,\sigma(s,t), \qquad (1)$$

where E_γ is the energy of the γ ray in the rest frame of the quasideuteron; $\sigma(s,t)$ is the cross section for photodisintegration of the deuteron off the mass shell; $F(t)$ is the form factor of the $He \to d + d$ vertex; $s = (p_p + p_n)^2$; $t = (p_d - p_{He})^2$; p_i is the 4-momentum of particle $i(i = p,n,d,{}^4He)$; $G^2 = m_{He}^2 E_\gamma'^2$; E_γ' is the energy of the γ ray in the laboratory frame; and m_k is the mass of particle k ($k = d$, ^4He). The form factor $F(t)$ of the $^4He \to d + d$ vertex is determined primarily by the wave function of the relative motion of the deuterons. If we ignore the Coulomb interaction, we can write this form factor as[1,3]

$$|F(q)|^2 = K'(\gamma_0^2 f_0^2(q) + \gamma_2^2 f_2^2(q)), \qquad (2)$$

where q is the 3-momentum of the deuteron in the laboratory frame; $f_l(q) = i\eta[\eta j_l(\xi)h_{l-1}(\eta) - \xi j_{l-1}(\xi)h_l(\eta)]$; $\xi = qR$; $\eta = i\kappa R$; $\kappa^2 = m_d\epsilon$; $\epsilon = 2m_d - m_{He}$; $j_l(h_l)$ are spherical first-order Bessel (or Hankel functions T is the channel radius; γ_0^2 (γ_2^2) is a constant which determines the probability for the emission of a quasideuteron with $l = 0$ ($l = 2$), where l is the relative angular momentum of the deuteron and the quasideuteron; and the factor K' is independent of q.

Over the t range studied, the cross section $\sigma(s,t)$ is parametrized by

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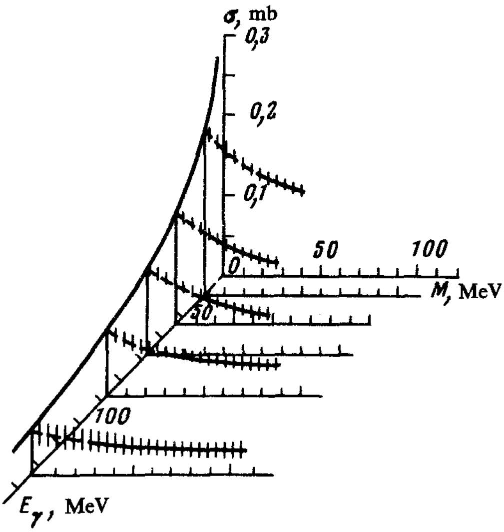

FIG. 1.

$\sigma(s,t) = A(s)(1 + B(s) \cdot M + c(s) \cdot M^2)$, where $M = m_d - \sqrt{t}$ is the deviation of the mass of the quasideuteron from that of the deuteron.

Figure 1 shows the cross section for photodisintegration of the deuteron off the mass shell as a function of M (solid line) for several values of E_γ, found by approximating the experimental data with expression (1). The normalization at the points $M = 0$ (the dashed line; an extrapolation of our results) leads to the known cross section for photodisintegration of the deuteron on the mass shell.[5] The hatching shows the error corridor. Table I shows estimates of A, B, and C found from the experimental data for the same values of E_γ. In the approximation used here we have $R = 2.95 \pm 0.04$ fm and $\gamma_0^2 : \gamma_2^2 = 1:(0.12 \pm 0.02)$.

It can be seen from Fig. 1 that the values found for $\sigma(s,t)$ off the mass shell in this E_γ range are smaller than the cross sections on the mass shell (which are ordinarily used in the impulse approximation) and tend to decrease with increasing M. This circumstance must be taken into account in analyzing direct photonuclear reactions which result in the emission of (pn) pairs.

TABLE I.

E_γ, MeV	A, mb	B, MeV^{-1}	$C \cdot 10^4$, MeV^{-2}
35 – 45	0,216 ± 0,01	−0,016 ± 0,004	0,15 ± 0,01
45 – 60	0,150 ± 0,01	−0,019 ± 0,004	0,18 ± 0,01
60 – 75	0,111 ± 0,01	−0,017 ± 0,003	0,32 ± 0,01
75 – 100	0,08 ± 0,01	−0,012 ± 0,002	0,65 ± 0,02
100 – 150	0,05 ± 0,01	−0,0086 ± 0,002	0,51 ± 0,02

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Translated by Dave Parsons