ANALYSIS OF $^{16}O(\gamma, 4\alpha)$ REACTION MECHANISM

V.N. Guryev[*]

National Science Center "Kharkov Institute of Physics and Technology", 61108, Kharkov, Ukraine

(Received March 18, 2009)

The mechanism of triangular and quadrangular ^8Be and ^{12}C Feynman diagrams for the $^{16}O(\gamma, 4\alpha)$ reaction in the field of photon energy $E_\gamma = 15 \ldots 45\,MeV$ was analyzed. The paper presents the calculation results on the peak positions in the energy dependence of total reaction cross-sections with consideration of the ^8Be and ^{12}C exitation spectra. It is shown that the radical extremes of triangular diagrams can manifest themselves in the form of "ghosts" of ^8Be, $^8Be^*$ and $^{12}C^*$ nuclei in the excited states of 2α and 3α- particles in the final state. The distributions of energy correlations of two α- particle pairs in the approximation of the pole ^8Be- diagram at $E_\gamma = 20 \ldots 40\,MeV$ were calculated.

PACS: 21.60.Gx, 25.20.X

1. INTRODUCTION

Investigation into the total α-particle photodisintegration of α-cluster nuclei is of particular interest for the study of properties of virtual α-cluster structures in nuclei and their influence on the nuclear reaction mechanism and on the α-synthesis dynamics in the Universe. In connection with these problems a complex experimental and theoretical investigation of the $^{16}O(\gamma, 4\alpha)$ reaction in the field of it manifestation at photon energies $E_\gamma = 14, 42 \ldots 50\,MeV$ is much promising. In earlier works [1]-[3], one has carried out experimental investigations on the energy dependence of total reaction cross-sections $\sigma_t(E_\gamma)$, energy and angular distributions of α-particles and distributions in the excitation energies of 2α- and 3α-particles in the final state with the use of photoemulsions on the bremsstrahlung photon beams in the energy interval $E_\gamma = 14, 42 \ldots 70\,MeV$. In later works [4] one has carried out experimental investigations on the same reaction characteristics and on the energy and angular correlations of α-particles at $E_\gamma = 18 \ldots 48\,MeV$ with the use of photoemulsions on the bremsstrahlung photon beams having the maximum energy of $300\,MeV$. It should be noted, that the available experimental data have a contradictory character. So, in [1]-[4] evident discrepancies are observed between the positions of maxima in $\sigma_t(E_\gamma)$. For example, in [1] (180 reaction events) the peaks at $E_\gamma^m \sim 23$; 28; 30 and $35\,MeV$ were observed (ibidem presented are the findings of D.L.Livesey, C.L.Smith (1956) at $E_\gamma^m \sim 22$; $26 \ldots 27$; 29; 32 and $35\,MeV$); in [2] (53 events)- at $E_\gamma^m \sim 18,5$ and $20,5\,MeV$; in [3]- two narrow peaks at $E_\gamma^m \sim 23$ and $25\,MeV$ and a broad resonance with the centre at $E_\gamma^m \sim 30\,MeV$; in [4] (540 events)-a small peak at $E_\gamma^m \sim 20$ and a broad resonance at $E_\gamma^m \sim 30\,MeV$. Also, there are disagreements in the interpretation of the reaction mechanism with taking into account a possible realization of partial channels: $\gamma + {}^{16}O \rightarrow 4\alpha$; $\alpha + {}^{12}C^*$; $^8Be(^8Be^*) + {}^8Be(^8Be^*)$; $\alpha + \alpha + {}^8Be(^8Be^*)$. Besides, all the qualitative theoretical construct were considered in the two-particle approximation without taking into account the interaction particles in the final state. So, in [2] one expected appearance of the second (with the excitation energy $E_{C^*} = 7,7\,MeV$) and the third (with $E_{Be^*} = 3\,MeV$) partial channels at $E_\gamma = 17, 5 \ldots 19, 5\,MeV$ and higher excitatons of ^8Be and ^{12}C nuclei at $E_\gamma = 19, 5 \ldots 21, 5\,MeV$, as well as, a probable manifestation of the fourth partial channel; in [3] a contribution of the E2-transition up to $E_\gamma = 40\,MeV$ was supposed to interpret the structures in the function of reaction excitation. In [4] basing on the analysis of distributions by the relative energies of α-particles $\eta_{\alpha_i} \equiv E_{\alpha_i}/(E_\gamma - \epsilon)$ (where $i = 1 \ldots 4$, ϵ is the reaction threshold) and manifestation of excited states of intermediate $^8Be^*$ and $^{12}C^*$ nuclei, it has been concluded that the mechanism of the statistical decay of ^{16}O nucleus up to $E_\gamma = 28\,MeV$ plays a main role. When E_γ increases the quasi-direct interaction between the photons and the 2α- 3α- clusters of ^{16}O nucleus, followed by the formation of intermediate $^8Be^*$ and $^{12}C^*$ nuclei in the state with $J^\pi = 2^+$, is the major mechanism. Here of interest is the manifestation of peaks in the experimental spectra of ^{8}Be excitation at $E_{Be}^* \sim 3\,MeV$ and of ^{12}C excitation at $E_C^* \sim 15 \ldots 16\,MeV$ in both intervals: $E_\gamma = 18 \ldots 28\,MeV$, in the case of coincidence with the phase distribution, as well as, $E_\gamma = 28 \ldots 48\,MeV$, when the phase distribution is distinctly displaced into the region of high excitation energy E_x^*. The same independence on E_γ was observed in the experimental relative energy distribution η_{α_1} for the most energetic α_1- particle with the peak position at $\eta_{\alpha_1}^m \simeq 0,37$ in energy inter-

---

[*] Corresponding author E-mail address: guryev@kipt.kharkov.ua

val E$_\gamma = 18 \dots 48\, MeV$, as well as,in the position of maxima in the distributions of experimental events by the variable $t_{\alpha\alpha}$ at $t_{\alpha\alpha} \simeq 0,05$ and $0,5$, where $t_{\alpha\alpha} \equiv E_{\alpha\alpha}/(E_\gamma - \epsilon)$ and $E_{\alpha\alpha}$ is the relative energy of 2α-particles.

In p.2 of the present paper the above-mentioned problems, concerning the interpretation of the peak positions in $\sigma_t(E_\gamma)$ of the $^{16}O(\gamma, 4\alpha)$ reaction,the manifestation of excited, independent on E_γ, states in the (2α) and (3α)-systems in the final states, and the singularities in the distributions η_{α_1} are considered using the triangular and quadrangular ^8Be and ^{12}C Feynman diagrams at $E_\gamma = 15 \dots 45\, MeV$. The equations for kinetic energies of 4α-particles, necessary for the experimental verification of the triangular diagrams under consideration were obtained. The paper presents the numerical estimates of event distributions by the variables $t_{\alpha_1\alpha_2}$ and $t_{\alpha_3\alpha_4}$ in the approximation of the pole ^8Be-diagram, respectively, for 2α-particles at the photon and the spectator vertices at $E_\gamma = 20 \dots 40\, MeV$. In p.3 the results obtained are discussed.

2. METHODS AND RESULTS

In connection with experimental ambiguities in the energy positions and in the interpretation of quantum peak characteristics in $\sigma_t(E_\gamma)$ of the $^{16}O(\gamma, 4\alpha)$ reaction [1-4], as well as, taking into account the stable, independent on E_γ, positions of maxima in the excitation spectra of 2α and 3α-particles in the energy interval $E_\gamma = 18 \dots 48\, MeV$ [4], we have applied, for calculation of this characteristics, the method in the approximation of triangular and quadrangular Feynman diagrams presented in Fig.1 and Fig.2.

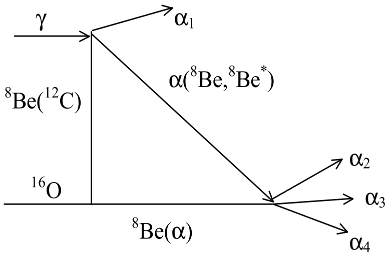

Fig.1. *Triangular ^8Be- and ^{12}C- diagrams for the $^{16}O(\gamma, 4\alpha)$ reaction*

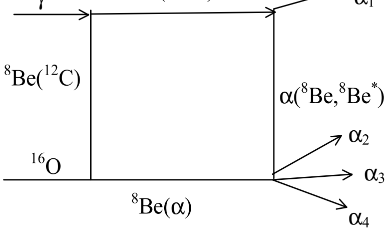

Fig.2. *Quadrangular ^8Be- and ^{12}C- diagrams for the $^{16}O(\gamma, 4\alpha)$ reaction*

The quadrangular diagrams are the detailed representation of triangular diagrams taking into account a probable resonance excitation of primary clusters at the photon vertices. For three-particle photonuclear reactions a similar approximation was considered in [5, 6]. Near the singularities of amplitudes, presented by the quadrangular diagrams in Fig. 2, it is possible to neglect the virtual particle going out from the mass surface [7, 8] and to consider the resonance processes as the processes on free particles. Then the approximate estimates of photon energies E_γ^m, at which the resonance peaks in $\sigma_t(E_\gamma)$ arise, can be obtained for quadrangular ^8Be and ^{12}C diagrams of Fig.2, from equations

$$E_\gamma^m(Be) = E_{Be}^* + 2m_{Be} - m_0, \qquad (1)$$

$$E_\gamma^m(C) = E_C^* + m_C + m_{He} - m_O, \qquad (2)$$

where m_{He}, m_{Be}, m_C, m_O and E_{Be}^*, E_C^* are the masses of nuclei ^4He, ^8Be, ^{12}C, ^{16}O and the excitation energies of $^8Be^*$ and $^{12}C^*$ nuclei respectively. The calculations of $E_\gamma^m(Be)$ and $E_\gamma^m(C)$ by (1) and (2) are given in Tables 1 and 2 with taking into account the levels of ^8Be [9] and ^{12}C nuclei [10]. As is seen from Tables 1 and 2, the energy position of peaks in $\sigma_t(E_\gamma)$ does not contradict to the data set given in [1-4].

Table 1

$E_{Be}^*(J^\pi)$, MeV	$E_\gamma^m(Be)$, MeV
3.04 ± 0.03(2^+)	17.66 ± 0.03
11.4 ± 0.3(4^+)	26.0 ± 0.3
16 - 17(2^+)	31 - 32
20.1 - 20.2(0^+)	34.7 - 34.8
22.2(0^+)	36.8
25.2(0^+)	39.8
25.5(4^+)	40.1
27.4(0^+)	42.1

Table 2

$E_C^*(J^\pi)$, MeV	$E_\gamma^m(C)$, MeV
7.65 ± 0.15(0^+)	14.82 ± 0.15
10.3 ± 0.3(0^+)	17.5 ± 0.3
11.16 ± 0.05(2^+)	18.33 ± 0.05
14.08 ± 0.01(4^+)	21.25 ± 0.01
15.44 ± 0.09(2^+)	22.61 ± 0.09
17.76 ± 0.20(0^+)	24.93 ± 0.02
21.6 ± 0.1(4^+)	28.8 ± 0.1

On the other hand, according to the general approximation in [11], the radical singularities of triangular diagrams in Fig.1 look as extremes in the center-of-mass system of α_2, α_3, α_4-particles in the final state at excitation energies

$$E_x^* = m_{He} + m_{Be} + a - 3m_{He}, \qquad (3)$$

where $x = 2\alpha$, 3α; $a = 0$, E_{Be}^*, $E_{Be,s}^*$. In (3) we have considered, for generality, also the contribution of the $^8Be_s^*$- cluster in the spectator channel of triangular and quadrangular ^8Be diagrams in Fig.1 and 2. Then there take place a displacement by the value $E^*_{Be,s}$ in the $E^m_\gamma(Be)$ estimates of Table 1. In accordance with (3) the presence in the triangular ^8Be- and ^{12}C- diagrams Fig.1 of a virtual $^8Be(0^+)$ cluster (at $a = 0$) can manifest itself, with taking into account the energy balance, as a ”ghost” of $^8Be(0^+)$ nucleus in the system of 2α-particles at $E^*_{2\alpha} = 0,092\,MeV$ with a kinetic energy 0f the third α- particle in the center-of-mass system of 3α equal to zero, or as a ”ghost” of ^{12}C nucleus in the excited state of 3α-particles with $E^*_{C,g} \sim 7,4\ldots 7,5\,MeV$. The presence of exited $^8Be^*$ and $^8Be^*_s$ clusters, at $a \neq 0$ in (3), can manifest itself as a ”ghost” of $^8Be^*$ and $^{12}C^*$ nucleus with the excitation energies $E^*_{Be,g}$ and $E^*_{C,g}$ respectively

$$E^*_{Be,g} = E^*_x + 2m_{He} - m_{Be} = E^*_{Be}(E^*_{Be,s}), \qquad (4)$$

$$E^*_{C,g} = E^*_x + 3m_{He} - m_C = m_{He} + m_{Be} - m_C + E^*_{Be}(E^*_{Be,s}). \qquad (5)$$

Then, the presence of excited $^8Be^*$ and $^8Be^*_s$ clusters in the diagrams of the Fig.1 at $E^*_{Be} = 3,04\,MeV$ can manifested itself as ”ghost” of $^8Be^*$ nucleus in the system of 2α- particles with the excitation energy $E^*_{Be,g} = 3,04\,MeV$ and with the of the third α- particle close to zero, or according (5) as a ”ghost” of $^{12}C^*$ nucleus in the final excited state of 3α- particles with $E^*_{C,g} \simeq 10,34\,MeV$. Then the exited state of $^8Be^*$ in the triangular ^{12}C- diagram at $E^*_{Be} \sim 7\ldots 8\,MeV$, that has been found in the $^{12}C(\alpha, 4\alpha)$ reaction [12], can manifest itself as a ”ghost” of $^{12}C^*$ nucleus in the final state of 3α- particles with $E^*_{C,g} = 15,4\,MeV$, discussed in [4]. Real manifestation of one of two variants of ”ghost” $^8Be^*_g$ or $^{12}C^*_g$ states can be observed only in experiments. At that, the positions of radical extremes of the triangular diagrams does not depend on E_γ. Independent experimental information about the contributions of ^8Be- and ^{12}C- triangular diagrams can be obtained from the estimates of maxima positions in the distribution by the relative kinetic energy of α_1- particle at the photon vertex $\eta_{\alpha_1}= E_{\alpha_1}/(E_\gamma$-$\varepsilon)$ and in the distributions of experimental events of the reaction by the value ($E_{\alpha_2} + E_{\alpha_3} + E_{\alpha_4}$ -nE_{α_1}), where n=1 and 0,5, respectively, for these diagrams. So, from the energy balance on the mass surface for the virtual processes in the photon and spectator vertices we have, correspondingly, for the ^8Be- and ^{12}C- triangular diagrams

$$E_{\alpha_1}(Be) = 0,5(E_\gamma - \varepsilon_1 - \varepsilon_2), \qquad (6)$$

$$E_{\alpha_1}(C) = 2(E_\gamma - \varepsilon - E^*_{Be})/3, \qquad (7)$$

where ε_1=$2m_{Be}$ + $(E_{Be,s})$ - m_O, ε_2= $2m_{He}$ - m_{Be}, ε= $4m_{He}$ - m_O. Note, that taking into account the two-particle channel γ + $^{16}O\longrightarrow$ ^8Be + ^8Be, for which

$$E_{\alpha_1} = 0,25(E_\gamma - \varepsilon) \qquad (8)$$

and Eq.(6) at $E_{Be,s}$= 0, we have for the average value of the relative energy $\langle\eta_{\alpha_1}\rangle\approx$ 0,37, which is followed from the distributions $E_{\alpha_1}/(E_\gamma$ - $\varepsilon)$ in [4] for $E_\gamma = 18\ldots 48\,MeV$. For the two-particle $\gamma +^{16} O \longrightarrow \alpha_1 +^{12} C^*$ channel we obtain

$$E_{\alpha_1} = 3(E_\gamma - \varepsilon)/4\,. \qquad (9)$$

While, taking into account (7), $0 \le E_{\alpha_1}(C)/(E_\gamma - \varepsilon) \le 0,4$ at $E^*_{Be} + \varepsilon \le E_\gamma \le 2,5E^*_{Be} + \varepsilon$. From Eqs.(6,7) and from the balance of energies and pulses on the mass surface for virtual processes in the three vertices of triangular ^8Be- and ^{12}C- diagrams we have respectively

$$E_{\alpha_2}+E_{\alpha_3}+E_{\alpha_4}-E_{\alpha_1} = m_{Be}-2m_{He}+(E^*_{Be,s}), \qquad (10)$$

$$E_{\alpha_2}+E_{\alpha_3}+E_{\alpha_4}-0,5E_{\alpha_1} = m_{Be}-2m_{He}+E^*_{Be}. \qquad (11)$$

An additional possibility in the determination of the mechanism of the reaction under consideration arises in the experimental and theoretical analysis of energy correlation distributions of two pairs of α- particles by the variable $t_{\alpha_i\alpha_k}\equiv E_{\alpha_i\alpha_k}/(E_\gamma - \varepsilon)$, where $E_{\alpha_i\alpha_k}$ is the relative energy of α_i and α_k- particles. In [13] the similar problem was considered for the analysis of the mechanism of four- particle photonuclear $^{12}C(\gamma, pt)2\alpha$ reaction in the approximation of the pole α- cluster diagram. Thus, firstly, the general formulas have been obtained for calculations of the distributions of differential probabilities $d\Lambda_4/dt_{\alpha_i\alpha_k}$ in the approximation of the pole ”i”- cluster diagram with constant vertex functions, represented in Fig.3, for two pairs of (a, b) and (c, d)- particles in the photon- and spectator vertices respectively

$$\frac{d\Lambda_4}{dt_{ab}} = C_1\frac{(1-t_{ab})^2\sqrt{t_{ab}}}{[\varepsilon_0/T_0 + b(1-t_{ab})]^2}F(2, 3/2; 3; z), \qquad (12)$$

$$\frac{d\Lambda_4}{dt_{cd}} = C_2\frac{(1-t_{cd})^2\sqrt{t_{cd}}}{[\varepsilon_0/T_0 + b(1-b)t_{cd})]^2}F(2, 3/2; 3; z^{'}), \qquad (13)$$

where C_1 and C_2 are the arbitrary constants, $F(\alpha, \beta; \gamma; z)$ is the hypergeometric Gaussian series [14],

$$z = \frac{(b-1)(1-t_{ab})}{\varepsilon_0/T_0 + b(1-t_{ab})}, \qquad (14)$$

$$z^{'} = \frac{b(1-t_{cd})}{\varepsilon_0/T_0 + b + (1-b)t_{cd}}, \qquad (15)$$

$$b = \frac{(m_a + m_b)(m_i + m_c + m_d)}{m_i(m_a + m_b + m_c + m_d)}, \qquad (16)$$

$$\varepsilon_0 = m_i + m_c + m_d - m_A, \qquad (17)$$

$$T_0 = E_\gamma - \varepsilon, \qquad (18)$$

ε is the reaction threshold, m_k is the particle mass ”k”. Eqs. (12), (13) are obtained in the factorized form, where the four-particle phase volume is exactly determined

$$\frac{dV_4}{dt_{kn}} = C_3(1-t_{kn})^{2)}\sqrt{t_{kn}}. \qquad (19)$$

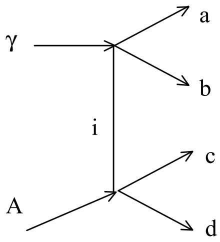

Fig.3. *Pole diagram for the photonuclear* $\gamma + A \longrightarrow a + b + c + d$ *reaction*

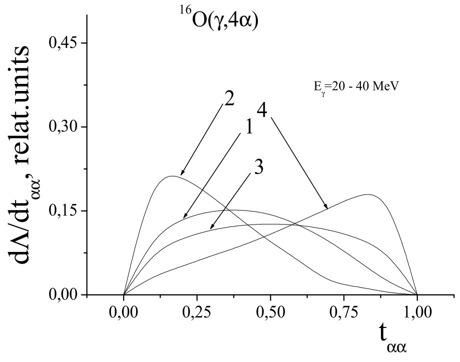

Fig.4. *Energy (α, α) correlations for the* $^{16}O(\gamma, 4\alpha)$ *reaction calculated by (12) (curve 1), by (13) (curve 2), by (23) (curve 3), by (20) (curve 4) at* $m_i \equiv m_{Be}$ *and* $m_a = m_b = m_c = m_d \equiv m_\alpha$

For comparison, we have considered also the three-particle photonuclear $\gamma + A \longrightarrow a + b + B$ reaction in the pole "i"- diagram with a single-particle spectator B for which

$$\frac{d\Lambda_3}{dt_{ab}} = C_4 \frac{\sqrt{t_{ab}(1-t_{ab})}}{[\varepsilon_i/T_0 + b^{'}(1-t_{ab})]^2}, \tag{20}$$

where

$$b^{'} = \frac{(m_a + m_b)(m_i + m_B)}{m_i(m_a + m_b + m_B)}, \tag{21}$$

$$\varepsilon_i = m_i + m_B - m_A, \tag{22}$$

and the phase volume

$$\frac{dV_3}{dt_{kn}} = C_5 \sqrt{t_{kn}(1-t_{kn})}. \tag{23}$$

In (19), (20) and (23) C_3, C_4, C_5 are the arbitrary constants. $Fig.4$ presents the calculations of $d\Lambda_4/dt_{\alpha_1\alpha_2}$ (curve 1), $d\Lambda_4/dt_{\alpha_3\alpha_4}$ (curve 2) and $dV_3/dt_{\alpha_1\alpha_2}$ (curve 3), $d\Lambda_3/dt_{\alpha_1\alpha_2}$ (curve 4) by (12), (13) and (23), (20) with $m_a = m_b = m_c = m_d \equiv m_\alpha$ and $m_i = m_B \equiv m_{Be}$ for the $^{16}O(\gamma, 4\alpha)$ and $^{16}O(\gamma, 2\alpha)^8Be$ reactions respectively at $E_\gamma = 20 \ldots 40\,MeV$. The calculations are made in the pole ^8Be cluster approximation with normalization of all the curves on the identical integral area. For the distributions $d\Lambda_4/dt_{\alpha_1\alpha_2}$ and $d\Lambda_4/dt_{\alpha_3\alpha_4}$ characteristic is the position of maxima independent on E_γ at $t^m_{\alpha_1\alpha_2} \approx 0,5$ in correspondence with experimental data at $E_\gamma = 18 \ldots 48\,MeV$ [4] and with $t^m_{\alpha_3\alpha_4} \approx 0,2$, practically coinciding with the phase volume (19). This fact is confirmed by our calculations at $E_\gamma = 20 \ldots 25$, $25 \ldots 30$ and $30 \ldots 40\,MeV$, which, almost do not differ from the given calculations of curves 1 and 2 in $Fig.4$. The coincidence of calculated curves 1 and 3,as well as, the position of the maximum of curve 4 at $t^m_{\alpha\alpha} \approx 0,8$ in Fig.4 indicates the incorrectness of the application of an approximation of the three-particle $^{16}O(\gamma, 2\alpha)^8Be$ reaction in the calculations of energy $\alpha\alpha$-correlations in the $^{16}O(\gamma, 4\alpha)$ reaction. Probably, the use of a realistic vertex function in the spectator channel may improve the agreement with experiment in the estimate $t^m_{\alpha_3\alpha_4} \approx 0,05$.

3.DISCUSSION

In p.2 we have demonstrated an important role of triangular and quadrangular ^8Be- and ^{12}C-diagrams, as well as, of a ^8Be- pole diagram in interpretation of the $^{16}O(\gamma, 4\alpha)$ reaction mechanism. The equations were first obtained for the calculation of peak positions in the energy dependence of the total reaction cross-section in the photon energy interval $E_\gamma = 15 \ldots 45\,MeV$ with taking into account the contribution of resonance $^8Be^*$ and $^{12}C^*$ states (see (1), (2) and Tables 1, 2) permitting to investigate the quantum characteristics of structure peculiarities in the experimental function excitation of reaction. We have offered, with taking into account (3), the interpretation of the appearance of the excited states, being independent on E_γ, in the systems of 2α and 3α-particles in the final state. They have a form of "ghosts" of ^8Be, $^8Be^*$ and $^{12}C^*$ nuclei, as manifestations of radical singularities of triangular diagrams, represented in Fig.1, with ^8Be, $^8Be^*$ clusters on the mass surface. Unlike the reaction under our consideration, in [6] the triangular ^8Be-diagram for the $^{12}C(\gamma, 3\alpha)$ reaction has at the output an $\alpha + \alpha \longrightarrow \alpha + \alpha$ vertex with a radical singularity $E^*_x(2\alpha) = 0$. However, the amplitude contribution of this diagram into the cross-section will be insignificant because the phase volume of the reaction is proportional to the factor $\sqrt{E\alpha\alpha}$. The authors [6] assume that such diagram is realized when a real excited state of $^8Be^*$ arises in the $\alpha + \alpha \longrightarrow {}^8Be^* \longrightarrow \alpha + \alpha$ process in the final state. The experimental estimate of the relative kinetic energy of α_1-particles $E_{\alpha_1}/(E_\gamma - \varepsilon) \approx 0,37$ in the energy interval $E_\gamma = 18 \ldots 48\,MeV$ [4] probably is the evidence, according to (6) at $E^*_{Be,s} = 0$ and (8), of some contribution also from the mechanism of the two-particle partial $\gamma + {}^{16}O \longrightarrow {}^8Be + {}^8Be$ channel. Detailed experimental analysis of the E^m_γ estimates, given in Tables 1 and 2,the energy distributions in (6), (7) (with taking into account (8), (9)), as well as (10), (11),is very necessary to substantiate the mechanism of triangular and quadrangular ^8Be- and ^{12}C-diagrams for the $^{16}O(\gamma, 4\alpha)$ reaction in the energy interval $E_\gamma = 14,\, 42 \ldots 50\,MeV$. Consideration of the pole ^8Be-diagram mechanism (Fig.3) opens an additional possibility (see Fig.4) for calculation of the energy correlation in the (α_1, α_2) and (α_3, α_4)-particle systems testifying to the probable appearance of the $\gamma + {}^{16}O \longrightarrow 2\alpha + {}^8Be, s \longrightarrow 2\alpha + (2\alpha)_s$ channel with the experimental estimate $t^m_{\alpha_3\alpha_4} \approx 0,05$. Besides, it seems necessary to separate, in each of experimental events, two pairs of α-particles, correspondingly with maximum and minimum energies, for the more detailed correct description of $d\Lambda_4/dt_{\alpha_1\alpha_2}$ and $d\Lambda_4/dt_{\alpha_3\alpha_4}$- distributions. Verification of such distribution independence on the energy E_γ requires to decrease significantly the investigated energy intervals that is also necessary for construction of realistic photon and spectator vertex functions for the pole ^8Be-diagram. The author is grateful to S.N.Afanasyev for discussions of experimental problems being considered in the present paper.

References

1. V.N. Maikov. Some photo-reaction on light nuclei // *ZhETF.* 1958, v. 34, p.1406-1419 (in Russian).
2. R.M.E. Toms. Photoalpha reaction below $21,5\,MeV$ with ^{14}N and ^{16}O //*Nucl. Phys.* 1964, v. 54, p. 625-640.
3. E.G. Fuller. Photonuclear reaction cross-sections for ^{12}C, ^{14}N and ^{16}O //*Phys. Report.* 1985, v.127, N3, p.185-231.
4. R.A. Golubev and V.V. Kirichenko. $^{16}O(\gamma, 4\alpha)$ reaction mechanism investigation //*Nucl. Phys.* 1995, v. A587, N2, p.241-251.
5. E.I. Dubovoj, G.I. Chinatava. Theory of the $\gamma + A \longrightarrow b + y + z$ reaction near the $\gamma + A \longrightarrow 1 + 2 + z$ opening threshold //*Yadernaya Fizika.* 1987, v. 45, N3, p.677-687 (in Russian).
6. E.A. Kotikov, E.D. Makhnovsky, A.A. Tsyganova. Photodisintegration of the nuclear ^{12}C mechanism on three α-particles //*Izvestiya Rossijskoy Akademiya Nauk. Ser. Fizich.* 2002, v. 66, N3, p.445-448 (in Russian).
7. L.D. Landau. On analytic properties of vertex parts in quantum field theory //*Nucl. Phys.* 1959, v. 13, p.181-192.
8. L.D. Blokhinsev, E.I. Dolinsky, V.S. Popov. Analytic properties of nonrelativistic diagrams //*Zhurnal Ehkseperimental'noj i Teoreticheskoj Fiziki.* 1962, v. 42, p.1636-1646 (in Russian).
9. F. Ajzenberg-Selove. Energy levels of light nuclei A= 5-10 //*Nucl. Phys.* 1988, v. A490, p.1-225.
10. F. Ajzenberg-Selove. Energy levels of light nuclei A= 11-12 //*Nucl. Phys.* 1990, v. A506, p.1-158.
11. E.I. Dubovoi, I.S. Shapiro. Identification of the mechanism of three-particle direct reactions //*ZhETF.* 1967, v. 53, N4, p.1395-1399 (in Russian).
12. O.K. Gorpinich, O.M. Povoroznyk, B.G. Struzhko. Study of excited states of a ^8Be nucleus in the correlative experiment //*Ukr. Fiz. Zh.* 2002, v. 48, N5, p.407-410 (in Ukrainian).
13. V.N. Guryev. Analysis of the $^{12}C(\gamma, pt)2\alpha$ reaction mechanism //*PAST. Ser. "Nucl. Phys. Invest."(48).* 2007, N5, p.9-12.
14. *Handbook of mathematical functions* Edited by M.Abramowitz and I.Stegun. Nation. Bureau stand. Mathem. Ser. 55, 1964. M.: *"Nauka",* 1979, 830 p. (Russian translation).

АНАЛИЗ МЕХАНИЗМА РЕАКЦИИ $^{16}O(\gamma, 4\alpha)$

В.Н. Гурьев

Проведен анализ механизма трех- и четырехугольных ^8Be- и ^{12}C- фейнмановских диаграмм для реакции $^{16}O(\gamma, 4\alpha)$ в области энергии фотонов $E_\gamma = 15\ldots45$ МэВ. Проведен расчет положения пиков в энергетической зависимости полных сечений реакции с учетом спектров возбуждения ядер ^8Be и ^{12}C. Показана возможность проявления корневых особенностей треугольных диаграмм в виде «призраков» ядер ^8Be, $^8Be^*$ и $^{12}C^*$ в возбужденных состояниях 2α- и 3α-частиц в конечном состоянии. Проведен расчет распределений энергетических корреляций двух пар α-частиц в приближении полюсной ^8Be-диаграммы при $E_\gamma = 20\ldots40$ МэВ.

АНАЛІЗ МЕХАНІЗМУ РЕАКЦІЇ $^{16}O(\gamma, 4\alpha)$

В.М. Гур'єв

Проведено аналіз механізму трьох- і чотирикутних ^8Be- і ^{12}C- фейнмановських діаграм для реакції $^{16}O(\gamma, 4\alpha)$ в області енергій фотонів $E_\gamma = 15\ldots45$ MeB. Проведено розрахунок розташування піків в енергетичній залежності повних перерізів реакції з розрахунком спектрів збудження ядер ^8Be и ^{12}C. Показано можливість проявлення корінних особливостей трикутних діаграм у вигляді «примар» ядер ^8Be, $^8Be^*$ и $^{12}C^*$ в збуджених станах 2α- і 3α-частинок в кінцевому стані. Проведено розрахунок розподілів енергетичних кореляцій двох пар α-частинок в наближенні полюсної ^8Be- діаграми при $E_\gamma = 20\ldots40$ MeB.