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On new experimental data manifesting the time resonances (or explosions)

Short Communication

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Abstract: Some new applications of the time resonances (explosions) to new experimental data on high-energy nuclear processes are presented. These new experimental data are fitted rather well by the approach of the time resonances for the compound nuclei and clots.

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1. Introduction

The theoretic origin of the earlier revealed phenomena "time resonances (explosions)" rises either from the strict self-consistent time analysis of the compound nuclei or clots at the range of strongly overlapped *energy resonances* (see [1]), or, in an alternative way, from the qualitative analysis of eigen values of the time operator T defined by appropriate complex values of the compound-nucleus Hamiltonian H through the commutation relation $[H, T] = i\hbar$ (see [2]).

Experimentally, for not very heavy projectiles (from p to ^{20}Ne) with energies above $1-10$ GeV/nucl there had been observed structureless, exponentially decaying energy spectra, often accompanied by slight oscillations, and the behavior of the reaction amplitudes by a simplified manner like

$$f_{\alpha\beta}^{(n)}(E) = C_{\alpha\beta}^{n} \exp\left(-E\frac{\tau_n}{2\hbar} + iE\frac{t_n}{\hbar}\right), \tag{1}$$

where τ_n and t_n determine the exponential dependence on energy for the correspondent cross section and the linear dependence on energy for the amplitude phase, respectively, and $C_{\alpha\beta}^{n}$ is a constant (inside ΔE). The correspondent cross section, under the condition

$$\Delta E \ll \frac{2\hbar}{\tau_n},$$

will be

$$\sigma_{\alpha\beta} = \left|f_{\alpha\beta}^{(n)}\right|^2 = \text{const} \cdot \exp\left(-E\frac{\tau_n}{\hbar}\right), \tag{2}$$

and the emission probability, as it was shown in [1], will be

$$I(t) = \frac{\frac{\tau_n}{2\pi}}{(t-t_n)^2 + \frac{\tau_n^2}{4}}. \tag{3}$$

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With respect to Ref. [1], the *evolution of the surviving compound nucleus* (at an instant t during the life and decay after its formation) can be described by the following function

$$L^c(t) = 1 - \int_0^\infty dt\, I(t). \tag{4}$$

From relations (3) and (4) one can deduce the strongly non-exponential form of $I(t)$ and $L^c(t)$, like sketched in Fig. 1.

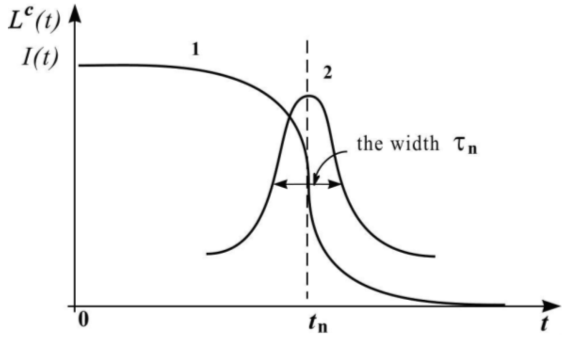

Figure 1. $L^c(t)$ (curve 1) and $I(t)$ (curve 2).

The phenomenon of the resonance shape in the time dependence of the emission probability $L^c(t)$ was defined in Ref. [1] by "time resonance (or explosion)".

In the previous above-mentioned paper [1] it was shown that the reaction amplitude $f_{\alpha\beta}$ can have a more general form like

$$f_{\alpha\beta}(E) = \sum_{n=1}^{\nu} C_{\alpha\beta}^{(n)} \exp\left(-E\frac{\tau_n}{2\hbar} + iE\frac{t_n}{\hbar}\right) \tag{5}$$

up to several terms, and the cross section $\sigma_{\alpha\beta} = |f_{\alpha\beta}|^2$. In the case of two terms only ($\nu = 2$) it can be transformed for the single (inclusive) energy spectrum of the k-th final fragment in the following form:

$$\begin{aligned}\sigma_{\text{inc},k}(E_k) &= \sum_{n=1}^{2}\left|C_n \exp\left[\frac{\left(it_n - \frac{\tau_n}{2}\right)E_k}{\hbar}\right]\right|^2 \\ &= \sum_{n=1}^{2}|C_n|^2 \exp\left(-E_k\frac{\tau_n}{\hbar}\right) \\ &\quad + 2ReC_1^*C_2 \exp\left\{\frac{\left[\frac{i(t_2-t_1)-(\tau_1+\tau_2)}{2}\right]E_k}{\hbar}\right\}.\end{aligned} \tag{6}$$

2. New calculations

In Figs. 2 and 3 the new inclusive energy spectra $\sigma_{\text{inc},k}(E_k)$ calculated by (6), in semi-logarithmic scale, are presented in comparison with the experimental data taken from Refs. [3, 4] (where θ is the detected angle of the k-fragment emission).

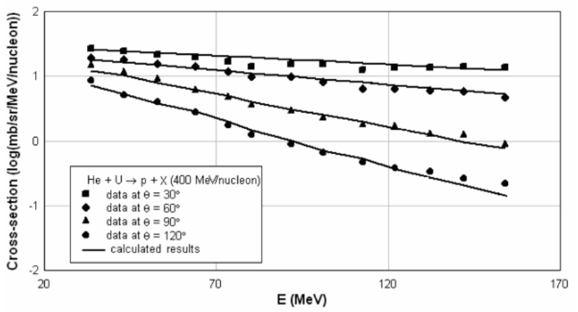

Figure 2. Inclusive energy spectrum of $^4He + U \to p + X$ at 400 MeV/nucleon, taken from Ref. [3].

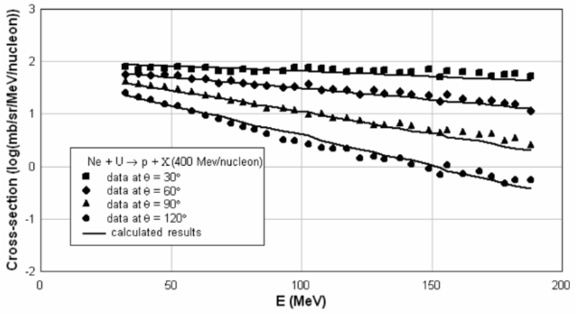

Figure 3. Inclusive energy spectrum of $^{20}Ne + U \to p + X$ at 400 MeV/nucleon, taken from Ref. [4].

The values of τ_1, τ_2 and $t_2 - t_1$, which were found from fitting the theoretical curves with the experimental data, are presented in Tables 1 and 2 by Figs. 2 and 3, respectively.

Table 1.

Θ (°)	τ_1 (10^{-23} s)	τ_2 (10^{-23} s)	$t_2 - t_1$ (10^{-23} s)	C_1	C_2
30	0.38	0.38	0.25	2.8	2.8
60	0.64	0.64	0.25	2.6	2.6
90	1.5	1.5	0.25	2.5	2.5
120	2.1	2.1	0.25	2.3	2.3

Table 2.

Θ (°)	τ_1 $(10^{-23}$ s$)$	τ_2 $(10^{-23}$ s$)$	t_2-t_1 $(10^{-23}$ s$)$	C_1	C_2
30	0.25	0.25	0.25	5	5
60	0.6	0.6	0.25	4.5	4.5
90	1.2	1.2	0.25	4.2	4.2
120	1.7	1.7	0.25	3.6	3.6

3. Conclusions

Some new useful applications of *time resonances* (or *explosions*) to the new experimental data on high-energy nuclear processes are presented. As one can see, the experimental points are fitted to the average sufficiently well by the theoretical approach of the time resonances (explosions) for the compound nuclei and clots, with some deviations due to the weak oscillations in the experimental data, which are more noticeable than in our calculations.

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