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TIME ANALYSIS OF THE NUCLEAR RESONANCE SCATTERING OF NEUTRONS

The time evolution conception was applied to study of the neutron-nucleus resonance scattering. The time delay probability density function of this process was calculated. The calculation procedure that takes into account the resonance statistics and the experimental based resonance spaces and widths has been developed. The nucleus ^{58}Ni target has been examined as a typical example. The time parameters of the intermediate nuclear system have been estimated for the backward scattering. The influence of the statistical assumptions on the time calculations result is discussed. It is shown that the effects of the incomplete equilibration of the intermediate nuclear system depend on these statistical assumptions.

1. Introduction

The problem we plan to consider here concerns specific aspects of the time evolution in the course of neutron-nucleus interaction. It is a part of long-standing problem of the collision theory [1] that has been studied for years mainly theoretically [2–4]. One of the fruitful approaches to the time analysis of nuclear reactions is associated with the Ericson theory [2]. The Ericson theory is applied to the exponential decay of an intermediate nuclear system in the state of a complete statistical equilibrium. It permits to extract the mean lifetime values from the fluctuating cross section energy autocorrelation functions as $\tau = \hbar/\gamma$, where γ is the correlation width. The current theoretical progress of the question was achieved in [5], [6]. Here we have the intention to survey the time behavior of the decaying nuclear systems under comparatively low excitations where resonances with only a few different (J, π) values exist. The situation of this kind particularly takes place when the neutron scattering on the middle weight nuclei in the region of relative movement energy around $0{,}1 < E < 1$ MeV is examined. . The specific question to be studied in this paper is the character of the time evolution when resonance neutron scattering by the ^{58}Ni nuclei takes place. There is no the experimental method to measure directly the distribution of as small nuclear reaction time delays as $t \le 10^{-17}$. Therefore it would be useful to develop the reliable model to calculate such kind of distribution. The developed model makes use of the resonance parameters and the level density parameters that have been taken from the RIPL-2 Reference Input Parameter Library [7]. The special regard was given to study of the influence of the model statistical assumptions on the results of calculations.

2. Calculation approach in the time dependent formalism

In the time dependent description of the nuclear reaction course one studies the movement of the wave packets with initial spread in energy ΔE around the average energy E of the incoming channel.

The collision time moment is fixed with the precision $\Delta t_0 = \hbar/\Delta E$. If the energy width ΔE is large enough it is possible to determine the time interval $t > \Delta t_0$ via which the particles appear in the outgoing channel under the scattering angle q and the probability density function $P_{ji}(t, \theta)$. It allows in particular the calculation of the average delay time of the nuclear reaction

$$\left\langle t_{ji}(\theta)\right\rangle_t = \int_{-\infty}^{\infty} tP_{ji}(t,\theta)dt \qquad (1)$$

and the corresponding dispersion

$$Dt_{ji}(\theta) = \left\langle [t_{ji}(\theta)]^2\right\rangle_t - \left\langle t_{ji}(\theta)\right\rangle_t^2, \qquad (2)$$

where

$$\left\langle [t_{ji}(\theta)]^2\right\rangle_t = \int_{-\infty}^{\infty} t^2 P_{ji}(t,\theta)dt. \qquad (3)$$

As was shown in [2, 3] the probability density function $P_{ji}(t, \theta)$ may be connected to the statistical attributes of the stationary reaction amplitude $f_{ji}(E, \theta)$ in the energy interval ΔE via Fourier transform. Thus if the energy autocorrelation function of the amplitude is defined as,

$$\varphi_{ji}(\varepsilon,\theta) \equiv \frac{\left\langle f_{ji}(E,\theta) f_{ji}^{*}(E-\varepsilon,\theta)\right\rangle_{\Delta E}}{\left\langle \left|f_{ji}(E,\theta)\right|^2\right\rangle_{\Delta E}} \qquad (4)$$

then the following relations take place:

$$P_{ji}(t,\theta) \cong \frac{1}{2\pi\hbar}\int_{-\infty}^{\infty} \varphi_{ji}(\varepsilon,\theta)\exp(-i\varepsilon t/\hbar)d\varepsilon. \qquad (5)$$

$$\varphi_{ji}(\varepsilon,\theta)=\int_{-\infty}^{\infty}P_{ji}(t,\theta)\exp(i\varepsilon t/\hbar)dt. \qquad (6)$$

Here ε denotes the energy shift and the symbol $\langle\ \rangle_{\Delta E}$ designates the averaging in the energy interval $\Delta E=(E_{\max}-E_{\min})$.

On the other hand the $P_{ji}(t,\theta)$ may be found via the time power spectrum $S_{ji}(t,\theta)$ of the collision:

$$P_{ji}(t,\theta)=\frac{S_{ji}(t,\theta)}{\int_{-\infty}^{\infty}S_{ji}(t,\theta)dt} \qquad (7)$$

$$S_{ji}(t,\theta)=\frac{\left|\int_{E\min}^{E\max}f_{ji}(E,\theta)\exp(-iEt/\hbar)dE\right|^2}{2\pi\hbar(E\max-E\min)}. \qquad (8)$$

3. The model amplitude for the scattering of resonance neutrons by the ^{58}Ni nuclei

The details of the nuclear scattering evolution might be obtained on the basis of equations (4–8). Of course, they are useful only if the scattering amplitude $f_{nn}(E,\theta)$ is known. Then the time probability density function $P_{nn}(t,\theta)$ or the energy autocorrelation function $\varphi_{nn}(\varepsilon,\theta)$ would be found in a direct way. In the statistical sense this gives the complete time description of the scattering process.

Keeping in mind the main interest to the analysis of the delayed time process we will be concentrated on the backward $(\theta=\pi)$ scattering. Here the instant scattering component is expected to be relatively small.

To clear up the situation with the time picture of the neutron backward scattering by ^{58}Ni the nuclei we utilized the computational model of the resonance scattering. The model amplitude construction takes into account that under neutron energies $E\approx 500$–800 keV for this target nucleus only s- and p- orbital waves contribute significantly and only total angular moments

$$J^{\pi}=\frac{1}{2}^{+},\frac{1}{2}^{-},\frac{3}{2}^{-}$$

are present as far as target nucleus has zero spin. It is known that the channel of neutron elastic scattering by nuclei ^{58}Ni prevails for the energies under consideration. Consequently the small contribution of the other open channels (namely the radiative capture) was ignored. Then the backward scattering amplitude can be written as follows:

$$f_{nn}(E,\pi)=\frac{1}{2ik_n(E)}\times \times(f_{1/2^+,0}(E)-f_{1/2^-,1}(E)-2f_{3/2^-,1}(E)), \qquad (9)$$

where the addends $f_{J^\pi,l}(E)$ are defined as

$$f_{J^\pi,l}(E)=\exp[2i\sum_{n=1}^{N_{J^\pi}}\delta_{J^\pi,n}(E)+\xi_l(E)]-1. \qquad (10)$$

Here the resonance phases are given by

$$\delta_{J^\pi,n}(E)=arctg[\frac{\Gamma_{J^\pi,n}}{2(E_{J^\pi,n}-E)}], \qquad (11)$$

where the terms $E_{J^\pi,n}$ and $\Gamma_{J^\pi,n}$ stand for the position and the width of the nth resonance with appropriate J^π value.

The potential scattering phases were accepted to be in accordance with [8]:

$$\xi_0(E)=-k_n(E)R \qquad (12)$$

$$\xi_1(E)=-k_n(E)R+\frac{1}{2}\arcsin^{-1}\frac{2k_n(E)R}{1+[k_n(E)R]^2}, \qquad (13)$$

where the radial parameter for the nucleus with the mass number A is given by $R=r_0A^{1/3}$ and $r_0\approx 1.1-1.2$ fm.

It was assumed that the energy points $E_{J^\pi,n}$ on the averaging interval ΔE are distributed randomly. More precisely, it is the spacings between neighbouring resonances $D_{J^\pi,n}$ with the mean level spacing D_{J^π} that obey the Wigner distribution. In addition the calculations have been carried out when all the resonances of the same spin-parity J^π had the identical value D_{J^π}.

As to the resonance widths $\Gamma_{J^\pi,n}$ several approaches to calculate the scattering amplitude were adopted too. The first one supposed the Porter-Thomas distribution of the resonance widths with the mean values Γ_{J^π} (the chi-squared distribution with one degree of freedom). The second one was the chi-squared distribution with three degrees of freedom. And the last approach supposed that all the resonances of the same spin-parity J^π have the identical value Γ_{J^π}.

To be defined in such a way the scattering amplitude $f_{nn}(E,\pi)$ is the random function of E. Now the randomizing procedure makes it possible to reproduce the resonance structure on the energy interval $\Delta E=E_{\max}-E_{\min}$ if the mean resonance parameters D_{J^π} and Γ_{J^π} are given. Any realization of this procedure may be taken as the representative of the real behaviour of the scattering amplitude. A better approximation will be obtained from some kind of averaging on a number of realizations. Of course, it is true only if the mean resonance parameters correspond to the experimental data.

The necessary data were taken from the RIPL-2 Library [7]. Table 1 lists the main values from the RIPL-2 Library that have been used to find mean resonance parameters $D_{J\pi}$ and $\Gamma_{J\pi}$ for the target nucleus ^{58}Ni around mean neutron energy $\langle E \rangle \cong$ $\cong 650$ keV.

Table 1. **The main values from the RIPL-2 Library for the target nucleus ^{58}Ni**

B_n (MeV)	a (MeV^{-1})	Δ (MeV)	D^0 (keV)	D^1 (keV)	S_0 (10^{-4})	S_1 (10^{-4})
8,999	5,075 ± 0.04	–1,797 ± 0,015	13,4 ± 0.9	4.46 ± 0,27	3.26 ± 0,59	1.4 ± 0.5

The listed values are as follows: D^0 and D^1 are the mean level spacings for *s*- and *p*-wave neutrons, respectively; S_0 and S_1 are the *s*- and *p*-wave neutron strength functions. These values are applied to the compound nucleus ^{59}Ni with the excitation energy of $U_0 \cong B_n$, where B_n is the neutron separation energy for this compound nucleus. The values a and Δ are the level density parameter and the excitation energy shift for the Back-shifted Fermi Gas (BSFG) model.

Really we need to know the mean resonance parameters $D_{J\pi}$ and $\Gamma_{J\pi}$ for the compound nucleus ^{59}Ni with the excitation energy

$$U(\langle E \rangle) \cong B_n + \langle E \rangle. \quad (14)$$

However the data of the table 1 refer to the excitation energy $U_0 \cong B_n$. But the necessary values of $D_{J\pi}$ can be readily obtained from the data of the table 1 by using the level density formula of the BSFG model. The necessary values of $\Gamma_{J\pi}$ can be obtained in a similar way on the assumption of the definition of the neutron strength function. In addition the interrelation of the neutron widths with the reduced neutron widths of resonances must be used.

As a result the following mean values were used in the scattering amplitude calculation

$$D_{1/2^+} = D_{1/2^-} = 9{,}7\,\text{keV},\ D_{3/2^-} = 4{,}8\,\text{keV} \quad (15)$$

$$\Gamma_{1/2^+} = 3{,}5\,\text{keV},\ \Gamma_{1/2^-} = 0{,}6\,\text{keV},\ \Gamma_{3/2^-} = 0{,}3\,\text{keV}. \quad (16)$$

Now we are ready to use the time dependent formalism of the division 2 in the model calculations of the time probability density function $P_{nn}(t,\pi)$ from equations (7) and (8). Really we intend to calculate only the time probability density function $P_{nn}(t,\pi)_{comp}$ for the delayed scattering events. Thereafter we have use in the equation (8) the scattering amplitude for the events that take place with the creation of the composite nuclear system:

$$f_{nn}(E,\pi)_{comp} = f_{nn}(E,\pi) - \langle f_{nn}(E,\pi) \rangle_{\Delta E}, \quad (17)$$

where $\langle f_{nn}(E,\pi) \rangle_{\Delta E} = \int_{E_{min}}^{E_{max}} f_{nn}(E,\pi) dE / \Delta E$ is the energy averaged amplitude in the interval $\Delta E = E_{max} - E_{min}$.

4. The analysis of the time probability density function for the delayed backward scattering of resonance neutrons by the ^{58}Ni nuclei

To make use of the time dependent formalism, presented in the division 2, one would like to select the large enough interval of the incident neutrons energies $\Delta E = E_{max} - E_{min}$. In this set of the calculations we accepted the value $\Delta E \cong 100$ keV from $E_{min} \cong 600$ keV up to $E_{max} \cong 700$ keV. Then the moment of the neutron-nucleus collision is fixed with the precision of $\Delta t_0 = \hbar / \Delta E \cong 6.6 \times 10^{-21}$ s. This makes it possible to use the concept of the probability density function $P_{nn}(t,\pi)_{comp}$ (time power spectrum) for the time intervals via which the back scattered neutrons appear.

Another important point that influences on the results is the resonance statistics. The approaches to the time evolution in the course of nuclear reactions often ignore of the resonance widths statistics and use to some extent arbitrary assumption about resonance spacings statistics (for instance see [3]). This makes the analytical calculation simpler. Actually the reasonable assumption is that level spacings must obey the Wigner distribution and the resonance widths must have the Porter-Thomas distribution [8].

Nevertheless we shall start with the calculation of the model time probability density function under the assumption that all the resonances of the same spin-parity J^π have the identical value $\Gamma_{J\pi}$ and spasings $D_{J\pi,n}$ have the Wigner distribution. The mean values $\Gamma_{J\pi}$ and $D_{J\pi,n}$ from the equations (15) and (16) were used in the scattering amplitude calculation.

Thus we can check the adequacy of the model by the comparison of the experimental data on the neutron scattering cross sections [9], [10] and the theoretical estimations of the time parameters [3] with the present calculations. Table 2 lists the appropriate energy averaged values that have been chosen for the comparison.

Table 2. **The intercomparison of the data**

	$\langle \sigma_t \rangle_{\Delta E}$	$\langle \sigma_t^2 \rangle_{\Delta E}$	$\langle \sigma_s(0^0) \rangle_{\Delta E}$	$\langle t_{nn}(\pi) \rangle_t^{(comp)}$	$\alpha_{nn}(\pi)^{comp}$
Exp. [9], [10]	3,85 ± 0,043	19.1 ± 0.4	0.67 ± 0,14		
Calc. [3]				18	0,89
This work	3,84	19,9	0,7	17,7	1,06

It is clear from the table 2 that there is a good agreement of our calculations and the high resolution experimental total cross sections moments

$\langle \sigma_t{}^m \rangle_{\Delta E}$ (m = 1, 2) and the average zero angle differential cross section $\langle \sigma_s(0^\circ) \rangle_{\Delta E}$. The average time parameters $< t_{nn}(\pi) >_t^{(comp)}$ and $Dt_{nn}(\pi)^{(comp)}$ have been calculated making use of equations (1–3). The model time probability density function $P_{nn}(t,\pi)_{comp}$ for the fixed $\Gamma_{J\pi}$ values has been used in these calculations. The Table 2 gives also the results of the average time parameters calculations as per [3] for the compound neutron scattering by the nuclei ^{58}Ni at $\langle E \rangle$ = 0,65 MeV. Really the approach [3] gives the average time parameters for the specific J, π values. To be of use it was necessary to average these values taking into account the contribution of the different $J\pi$ quantities to the whole scattering pattern. Thereby the appropriate resonance densities $\rho_{J\pi} = 1/D_{J\pi}$ have been used as the weighed factors. One may state that there is the visible agreement of both mean time delay $\alpha_{nn}^{comp} = (Dt_{nn} / < t_{nn} >_t^2)_{comp}^{1/2}$ estimations. The difference between the relative fluctuations of the time delay may originate from the different statistics for the resonance spacing. It was the Poisson distribution that has been used by Lyuboshits [3] when we used the Wigner distribution.

It demonstrates the importance of the statistical assumptions for the results of the higher time delay moments estimations. More grave difference appears when we consider the time probability density functions. The time delay probability density function of [3] is a smooth curve which becomes non-exponential when the resonance overlap parameter

$$x_{J\pi} = \frac{2\pi\Gamma_{J\pi}}{D_{J\pi}}$$

is large enough.

But as shown in fig.1 (the thin curve) the time delay power spectrum $P_{nn}(t,\pi)_{comp}$ demonstrates

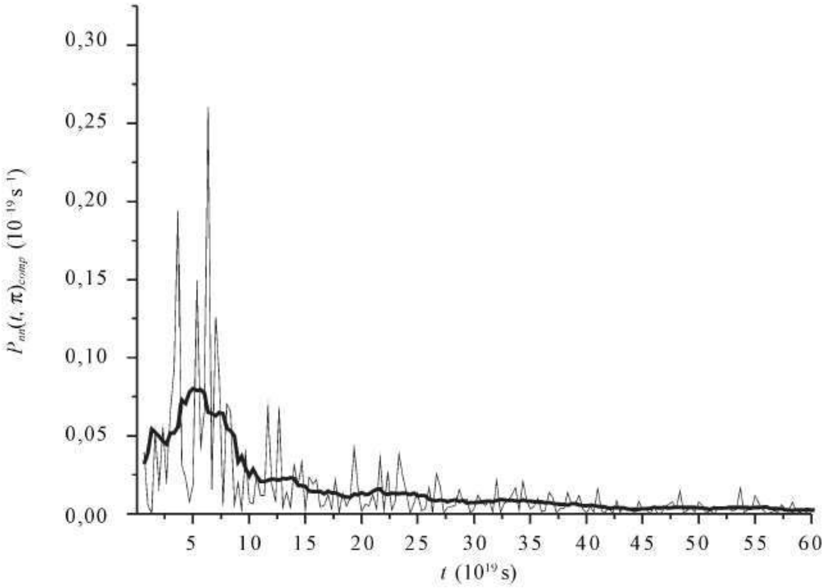

Fig. 1. The model ($\Gamma_{J\pi}$-const., $D_{J\pi}$- the Wigner distribution) time delay power spectrum $P_{nn}(t, \pi)_{comp}$ (the thin curve) for the backward neutron scattering by the ^{58}Ni nuclei (0,7 > E > 0,6 MeV). The thick curve depicts the smoothed data

the prominent peak structure. The sharpest deviations from the exponent take place at $t \leq\, \leq < t_{nn}(\pi) >_t^{(comp)}$. After the smooth (the thick curve) the data in fig. 1 take up the shape that is expected from [3]. Then the deflection from the exponential curve at the small delay times is present because of large enough resonance overlap parameter $x_{1/2^+} = 2,27$ for the s-orbital wave.

Even more expressive peak structure shows up when further to the Wigner distribution for the resonance spacing the resonance widths statistics is taking into consideration. Figure 2 gives the results of $P_{nn}(t,\pi)_{comp}$ calculations with using of the chi-squared distribution with three degrees of freedom of the resonance widths. Figure 3 is the same for the chi-squared distribution with one degree of freedom (the Porter-Thomas distribution). The source of this peak structure may be seen if we calculate $P_{nn}(t)_{comp}$ the distribution for the only J, π wave neglecting of the statistics Γ and D. Figure 4 shows the result. Quite unexpectedly one does not see a smooth exponential curve which is characteristic for the isolated resonance. Instead of this the regular peak structure of monotone decreasing amplitudes is apparent when only one J^π value takes part in the scattering process and all the resonances have the same widths Γ and spacings D. The time interval between peaks is about $T = 2\pi\hbar / D$

that is the time of the Poincare cycle and the decreasing is governed by Γ. This regular peak structure becomes non-regular if the resonances on the finite averaging interval ΔE are distributed randomly or (and) are overlapped. Further complication of the structure causes by the statistically distributed widths and by the superposition of the waves with the different J^{π} values. Still the discrete peak structure survives (see figures 1–3). There is a trend to concentrate the time spectrum intensity near the single peak at the small delay when one passes from figure 1 to figure 3 cases. This fact may be the mark of the incomplete equilibration in the intermediate nuclear system on the early stage.

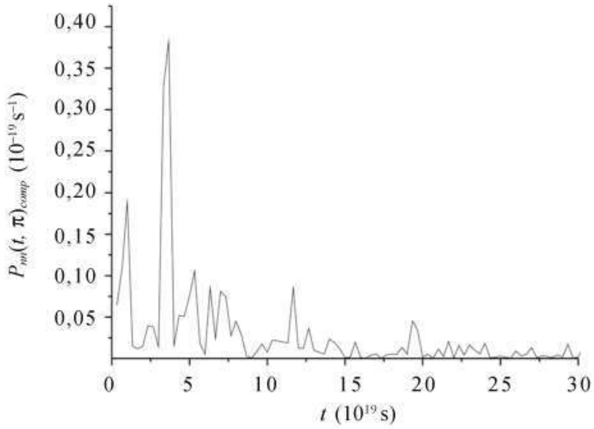

Fig. 2. The model ($\Gamma_{J\pi}$-the chi-squared distribution with three degrees of freedom, $D_{J\pi}$- the Wigner distribution) time delay power spectrum $P_{nn}(t, \pi)_{comp}$ for the backward neutron scattering by the ^{58}Ni nuclei (0,7 > E > 0,6 MeV)

The important observation is that the degree of this incompleteness is determined by the underlying statistical assumptions and by the energy scale of the averaging.

5. Parametrization

The stochastic character of the time power spectra in figures 1–3 is obvious. Now let us use the analytic simplification of the situation. If we refer back to figure 4 we find that the periodic and aperiodic components may be seen there. The dashed curve shows the approximation of $P_{nn}(t)_{comp}$ for $t > 0$ with the expression

$$P_{nn}(t)_{comp} = \frac{\left[\frac{1}{2}+\frac{\mathrm{arctg}(L*(t-s))}{\pi}\right] e^{\left(-\frac{\left(\sin\left(\frac{tD}{2\hbar}\right)\right)^2}{2\delta^2}\right)} e^{\left(-\frac{t\Gamma}{\hbar}\right)} \frac{\Gamma}{\hbar}}{N} + (1-\beta)\frac{e^{-\frac{t}{\tau}}}{\tau}. \qquad (18)$$

Here the first addend represents the periodic contribution and the second addend represents aperiodic one to the whole $P_{nn}(t)_{comp}$ pattern.

The term in the square brackets serves for the exclusion of the very small near zero delays. Consequently $L \approx 10^3$ is an arbitrary large number and s determines the point of truncation. The other parameters are as follow:

D and Γ are the resonance spacing and width when δ is the parameter of the time peak shape;

τ is the mean time delay of the exponential part of $P_{nn}(t)_{comp}$ and β is the relative contribution of the periodic component.

At last N is the normalizing constant that ensures the equality

$$\int_0^{\infty} P_{nn}(t)_{comp} = 1.$$

The dashed curve in figure 4 shows the excellent agreement of the approximation (18) and the model $P_{nn}(t)_{comp}$ (coefficient of determination $R^2 = 0{,}991$) when only one J^{π} value takes part in the

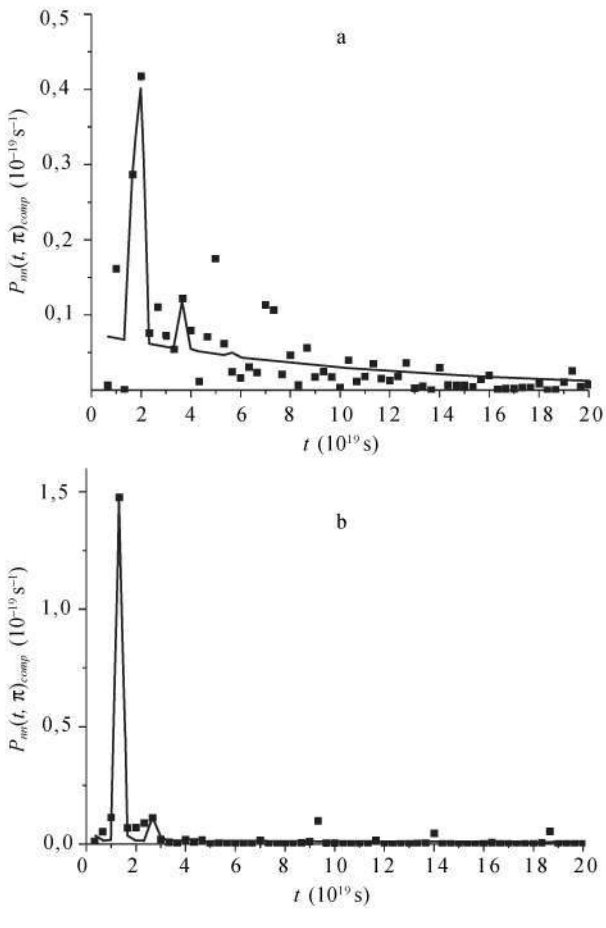

Fig. 3. The model ($\Gamma_{J\pi}$-the Porter-Thomas distribution, $D_{J\pi}$- the Wigner distribution) time delay power spectrum $P_{nn}(t, \pi)_{comp}$ (points) for the backward neutron scattering by the ^{58}Ni nuclei: 0,7 > E > 0,6 MeV (a) and 0,8 > E > 0,5 MeV (b). The solid curves show the approximation of $P_{nn}(t, \pi)_{comp}$ with (18): $R^2 = 0{,}85$ for (a) and $R^2 = 0{,}98$ for (b) cas

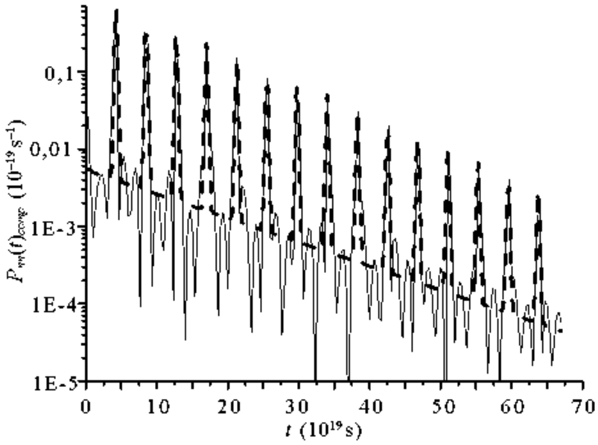

Fig. 4. The model ($\Gamma_{1/2^-}$-constant, $D_{1/2^-}$-constant) time delay power spectrum $P_{nn}(t)_{comp}$ (the thin curve) for the $p_{1/2}$ wave neutron scattering by the ^{58}Ni nuclei (0,7 > E > 0,6 MeV). The dashed curve shows the approximation of $P_{nn}(t)_{comp}$ with (18)

scattering process and all the resonances have the same widths and spacings D. The most remarkable fact is that the values D = (9,725 ± 0,002) keV and Γ (0,596 ± 0,009) keV extracted from the least squares fit are the same as $D_{1/2^-}$ and $\Gamma_{1/2^-}$ values in the equations (15) and (16).

These circumstances let us hope that the expression (18) will be fruitful for the approximate estimation of the regular parts of the time power spectra. Namely we intend to apply the expression (18) to the least squares fit of the model time power spectra that have been calculated at the different statistical assumptions. The figures 3a and 3b demonstrate the quality of this fit for the model $\Gamma_{J\pi}$ – the Porter-Thomas distribution, $D_{J\pi}$ – the Wigner distribution. Mainly the dependence of the parameters D, Γ and β on the statistical assumptions would be of special interest. The table 3 demonstrates the set of the extracted parameters values.

It must be stated that parameters D and Γ one may consider as the effective values for the precompound decay of the nuclear composite system when β value is the measure of the pre-compound process contribution.

Table 3. **The parameters of the time power spectra for the resonance neutron scattering by the ^{58}Ni nuclei. For 0,7 > E > 0,6 MeV interval:1-the resonance spacings and widths are fixed; 2–4 – the resonance spacings obey the Wigner distribution and as to resonance widths 2 satisfies the fixed resonance widths, 3 – satisfies the chi-squared distribution with three degrees of freedom and 4 – satisfies the Porter-Thomas distribution. For 0,5 > E > 0,8 MeV interval 5 is the same as 4**

	1	2	3	4	5
D keV	9,718 ± 0,012	13,00 ± 0,04	11,780 ± 0,006	22,3 ± 0,8	32,77 ± 0,07
Γ keV	1,09 ± 0,06	1,9 ± 0,5	8,3 ± 1,3	12	9,5 ± 0,5
β	0,84 ± 0,12	0,10 ± 0,07	0,18 ± 0,05	0,16 ± 0,04	0,57 ± 0,05
$< t_{nn}(\pi) >_t^{(comp)}$ (10^{19}s)	14,9	17,7	14,5	10,4	13
$\alpha_{nn}(\pi)^{(comp)}$	1,13	1,06	1,36	1,48	1,78

6. Final remarks

In this paper we have applied the conception of the time evolution study to the analysis of the scattering of the resonance neutrons by the medium mass nuclei. Specifically it was the ^{58}Ni nuclei bombarded by the neutrons with mean energy $< E >\cong$ 0,65 MeV. The mean time delays and the time delays $< t_{nn}(\pi) >_t^{(comp)}$ relative standard deviations $\alpha_{nn}(\pi)^{(comp)}$ for the backward scattering were determined by using of the time dependent formalism under different statistical assumptions. The multi-resonance model amplitude with the experimental based resonance spaces and widths have been employed in these calculations. There is a good agreement of the experimental data on the neutron scattering cross sections [9], [10] and the theoretical estimations of the time parameters [3] with the present model calculations. At last the time power spectra $P_{nn}(t,\pi)_{comp}$ for the delayed backward neutron scattering have been found. The corresponding calculations have been carried out using different approaches to the statistical behaviour of the resonance spacings and widths. The time probability density distribution $P_{nn}(t,\pi)_{comp}$ demonstrates the prominent peak structure. The sharpest deviations from the exponent take place at $t \leq< t_{nn}(\pi) >_t^{(comp)}$. To our opinion this fact is the mark of the incomplete equilibration in the intermediate nuclear system on the early stage. To study the problem the approximate formula (18) has been applied to fit the model distributions $P_{nn}(t,\pi)_{comp}$. The effective spacing D and Γ width for the non-equilibrium part of the time power spectra have been found. The important conclusion is that these values and the degree of the nuclear equilibration (1 – β) are determined by the underlying statistical assumptions and by the energy scale of the averaging.

Finally it may be stated that the study of the time evolution in the course of the nuclear reactions brings rather fruitful results and may be a good addition to the traditional analysis of the experiments with energy broadened beams.

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Г. Прокопець

ЧАСОВИЙ АНАЛІЗ РОЗСІЯННЯ РЕЗОНАНСНИХ НЕЙТРОНІВ ЯДРАМИ

Розсіяння резонансних нейтронів ядрами розглядається з точки зору еволюції у часі. Розраховано щільність імовірності часу затримки у даному процесі. З цією метою було розвинуто процедуру розрахунків, що враховує статистику резонансів і базується на експериментальних значеннях середніх міжрезонансних відстаней і середніх ширин резонансів. Як типовий приклад розглянуто випадок, коли мішенню є ядра ізотопу ^{58}Ni. Для розсіяння назад було оцінено середні часові параметри проміжної ядерної системи. Дискутується вплив статистичних припущень на результат часових розрахунків. Показано, що ефект неповного врівноваження проміжної ядерної системи залежить від цих статистичних припущень.