STATUS AND PROBLEMS OF EXPERIMENTAL STUDY OF EXCITED NUCLEUS SUPERFLUIDITY

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Abstract.

Modern nuclear models assume a coexistence of normal and superfluid phases of nuclei, as a minimum, up to the excitation energy of neutron resonances. Experiment, accordingly, has to reveal important details of interconnection of these phases. First of all, this concerns large-scale details. An effective method to study this problem is an investigation of neutron radiative capture. The most relevant characteristics of this interconnection are energy dependence of excited level density (in given spin window*)* and radiative strength function of primary gamma-transitions from a compound-state to low lying states. These values have to be extracted from respective experimental data with maximal reliability and minimal systematic uncertainties. To reach this goal it is necessary to depart in data analysis from obsolete models of radiative strength function and density. The two-step *(n,2γ)*-reaction and in general various multi-step reactions provide favorable possibilities for such type of investigations.

On the basis of practically modeless approach there was obtained the phenomenological information on radiative strength function of primary gamma-transitions and level density for wide range of nuclei 40≤A≤200. Very important fact established in this study was a discovery of step-like behavior of level density below excitation energy $E \leq 0.5B_n$. Besides, it was revealed a presence of highly excited levels of vibrational nature in range of normal many quasi-particle excited levels.

In this paper an attempt was made to expand this approach derived for analysis of **($\bar{n}$,γ)**-reaction measured for actinide nuclei with keV neutrons. The obtained results give some evidence for similarity of general behavior of level density and radiative strength function in these wide region of investigated nuclei.

1. Introduction

Density of excited levels ρ and emission probability Γ of any product of nuclear reaction are the main sources of experimental information on properties of nuclear matter. Id est, to a high extent there is a base for both theoretical notion and concrete models of nuclear parameters. Precise nuclear models of ρ and Γ are absolutely necessary for estimation and calculation of practically important nuclear-physics constants. This determines a necessity of their predictions with maximum possible accuracy.

Just theoretical analysis of reliable experimental data on the ρ and Γ values can provide irreplaceable information on fundamental quantum-mechanical process of coexistence and interaction of two states of nuclear matter – fermion and boson types, i.e., usual and superfluid nuclear states. Final sizes of nucleus, presence of deformation, closed magic nucleon shells and so on allow one to hope for obtaining new in principle information on this process, as a minimum, up to the region of neutron resonances. Experiment, correspondingly, must reveal details of their interaction (in the first turn – large-scale details).

But, for the majority of nuclei excited in nuclear reaction, the ρ and Γ values cannot be determined in direct experiments of classical nuclear spectroscopy: mean spacing D_λ between excited levels is comparable or much less than energy resolution (FWHM) of existing spectrometers. Correspondingly, these parameters can be extracted only from the spectra measured with “bad” resolution for the nucleus excitation energy above several MeV. It is also desirable to determine level density and radiative strength functions of the excited by them primary gamma-transitions, for example, in a given variable spin window. Up to now, the ρ and Γ values were determined in one-step reactions. And only in the last time corresponding information on these parameters was derived from two-step reaction (*n,2γ*) [1,2].

2. Difference of principle between one- and two-step reactions

Intensity of the spectra registered in experiment – products of one-step nuclear reaction in all the possible interval of their energies is proportional to product of parameters discussed here:

$$I_1 \propto \rho\Gamma / \sum(\rho\Gamma) \qquad (1)$$

Energy region where is satisfied the condition D_λ>FWHM, as a rule, is a small part of that studied in experiment. In this region, both ρ and Γ can be determined separately by the use of the nuclear spectroscopy methods. The result is usually used for normalization of the ρ and Γ relative values. The known data from the neutron resonance region are used for this aim as well. In the region D_λ< FWHM determination of ρ from nucleon evaporation spectra, for example, is impossible in principle without using calculated probabilities of their emission Γ. They should be calculated for wide energy interval of the nuclear reaction products and excitation energies of final nuclei. Up to now, the ideas and potentials of the nucleus optical model are used for this aim. Moreover, the authors of corresponding experiments use without fail the hypothesis (not verified experimentally up to now) [3] on independency of the reverse reaction cross section on excitation energy of final nucleus. (Or its variant for partial widths Γ of gamma-transitions [4,5]).

Comparison between forms of functional dependency of the $\rho=f(E)$ and $\Gamma=\varphi(E)$ values obtained in one-step reactions (spectra of evaporated nucleons, different gamma-spectra) [6,7] and the data from two-step reactions (cascades of gamma-transitions) points to their principal incompatibility. It appears itself in presence [1] or absence [7] of sharp changes in determined parameters when change nuclear excitation energy and energy of registered product. This comparison allows one also to determine in the first approach the sources of systematical errors and to evaluate their magnitudes for different experimental methods.

Therefore, one can conclude that quality of extracting ρ and Γ values from the spectra of one-step reactions changes to the worse to unknown extent due to following reasons:

1. the maximum possible transfer coefficients of errors δS of the spectra S measured in one-step reaction onto the errors $\delta\rho$ and $\delta\Gamma$;
2. the use of unverified hypotheses (first of all, on independence of the reverse reaction cross sections on excitation energy of final nucleus);
3. inevitable subjectivity in performed analysis (selection [7] of type and parameters of optical potential by determining ρ from evaporation spectra).

In the case of the two-step reaction (process of interest – two emitted gamma-quanta) distortion of the observed ρ and Γ values owing to two first reasons considerably decreases, and inevitable ambiguity in determination of parameters from degenerated systems of nonlinear equations is comparable with required accuracy in determination of nuclear parameters. This principle difference is due to another form of energy dependence for the second registered product than (1). Here is supposed that both the first and the second steps correspond to excitation of either individual final level or group of final levels limited by experimental conditions.

So, intensities of the two-step gamma-cascades following thermal neutron capture are determined for fixed initial compound state λ, group of several low-lying levels f and all intermediate levels i lying in a given energy interval ΔE_j number j. In these experimental conditions, probability of a given secondary step of reaction

$$I_2 = \Gamma_{if} / \sum_j \Gamma_{ij} \qquad (2)$$

is inversely proportional to level number $M = \sum \rho \Delta E$ excited at decay of levels i.

Products $I_1 * I_2$ measured in all the possible excitation energy intervals can be reproduced by infinite set of different ρ and Γ values. But all their values are physically limited by some region of possible magnitudes

$$\rho_1 \le \rho \le \rho_2$$
$$\Gamma_1 \le \Gamma \le \Gamma_2 \qquad (3)$$

for arbitrary excitation energy interval. Really this limitation is not hard and simple. But starting from some values of system (3), parameter χ^2 very quickly increases as both increasing maximum and decreasing minimum ρ and Γ values. Its least value, as it was obtained for the total set of experimental data analyzed in [1,2] was observed for $(\rho_2 - \rho_1)/\rho \approx 20\text{-}40\%$ and $(\Gamma_2 - \Gamma_1)/\Gamma \approx 20\text{-}40\%$. But only under observation of the following obligatory conditions:

(a) unambiguously given rule of ratio between radiative strength functions of the primary and secondary gamma-transitions with the same multipolarity and energy;

(b) extracting two-step reaction intensities from the experimental spectra in function on energy of their product at the first step.

Possible values of parameters determining intensities I_1, satisfy this condition, but their minimum (index 1) and maximum (index 2) values equal zero and infinity, respectively. Just this mathematical condition provides for significantly larger reliability of the parameters derived from two-step reaction as compared with one-step reaction from one hand, and possibility for model free, practically unique simultaneous determination of both ρ_1, ρ_2 and Γ_1, Γ_2. Distribution of $I_1 * I_2$ can be measured with high precision for different types of registered reaction products. For the same reaction products (two successive gamma-quanta, for example) the component corresponding to the first step of reaction must be selected from experimental spectrum although with some systematical error. This approximate decomposition [8] can be done due to different forms of dependence of ρ and Γ on energy of levels i .

Nevertheless, a necessity to test method of simultaneous determining ρ and Γ even at so favorable for its study cases calls no doubts. From the one hand always exist ordinary systematical errors in determination of cascade intensities, on the other hand – it is necessary to use some generally accepted notions on nuclear properties. This can be, for example, the idea of independency of the level decay modes on way of its excitation for lifetime of about several femtoseconds and so on.

3. The most important results of studying the two-step ($n,2\gamma$) reaction

Comparison of the ρ and Γ values obtained from the two-step cascade intensities with known experimental data and model ideas [9] permits one to conclude:

1. It is necessary to test experimentally the hypothesis [3] in application to calculation of interaction cross sections of evaporated nucleons for different excitation energies of final nuclei. In case of incorrectness of this hypothesis, all the ρ values derived earlier from evaporation spectra must be re-determined. Just the use of hypothesis [3] brings the main and really unknown error in value of level density extracted from spectra of evaporation nucleons. Evident and very strong violation [3] (in variant [4,5] for the cascade gamma-decay process) can be easily revealed [2] from comparison between intensities i_1, i_2 of the primary E_1 and secondary E_2 gamma-transitions following thermal neutron capture and intensities $i_{\gamma\gamma} = i_1 \times i_2 / \sum i_2$ of the two-step gamma-cascades.

Determined from ratio $P=i_1*i_2/i_{\gamma\gamma}$ total or only cascade's $P-i_1$ population of individual levels is recurrent folding of interaction cross-section of gamma-quanta with excited nucleus (beginning with maximum excitation energies of levels of final nucleus). This is the only found up to now possibility for indirect testing hypothesis [3] (realized in [2]).

Model notions of Qusiparticle-Phonon Nuclear Model [10] of matrix elements of emission of gamma-quantum and, for example, neutron show that their values are determined by type and value of the wave function components of decaying and excited levels. It is sufficient condition for advance of alternative (with respect to [3]) hypothesis and for the case of emission of nucleon products in nuclear reaction. Its indirect examination can be done in the only way: comparison between the $\rho=f(E)$ functions obtained in different experiments.

Therefore, extrapolation of conclusions made in [2] on inapplicability of ideas of [3-5] for reactions with nucleon emission calls doubts about all the level densities obtained from evaporation spectra.

2. Averaged sums of the radiative strength functions of the dipole primary gamma-transitions over nuclei with different masses but the same parities of neutrons and protons point to existence of two excitation regions below B_n where occurs rather sharp change in values of this gamma-decay parameter (Fig. 1). Analogous averaging of level density deviations from the simplest exponential interpolation of this parameter in the region between low-lying levels and neutron resonances completely confirms (Fig. 2) this conclusion.

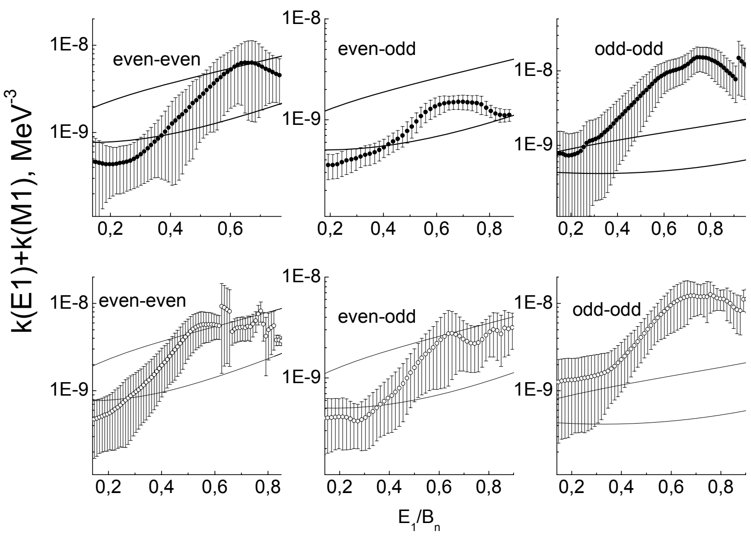

Fig. 1. Comparison between the averaged radiative strength function sums for nuclei with different parities of neutron and proton numbers. Full circles with errors represent nuclei with determined [2] level density. Open circles show results of analysis [1] without accounting for difference in energy

dependence of primary and secondary gamma-transitions. The upper and lower curves represent predictions according to models [4] and [11] in sum with *k(M1)*=const, respectively.

Approximation (Fig. 3) of the experimental ρ values by density of *n*-quasiparticle excitations [13] and radiative strength functions by the semi-phenomenological approach [14] (Fig. 4) allows one to connect [15] this effect partially or completely with break of, as minimum, one and, most probably, two or several Cooper's nucleon pairs.

3. There is a potential possibility for unambiguous determination of dependence of correlation functions Δ_N for nucleon pairs (N=1, 2, 3...) on excitation energy of heated nuclei. By now, corresponding functions were obtained in Obninsk [16] only on the data on level density derived from the nucleon evaporation spectra. Due to this reason they have unknown systematical uncertainty.

Approximation of experimental level density from the data [1,2] is ambiguous. Parameters of this fitting by density of *n*-quasiparticle levels (breaking threshold for next pair, coefficients of collective enhancement, necessary number of breaking pairs below a given excitation energy) depend on form of functional relation of enumerated parameters with nucleus excitation energy.

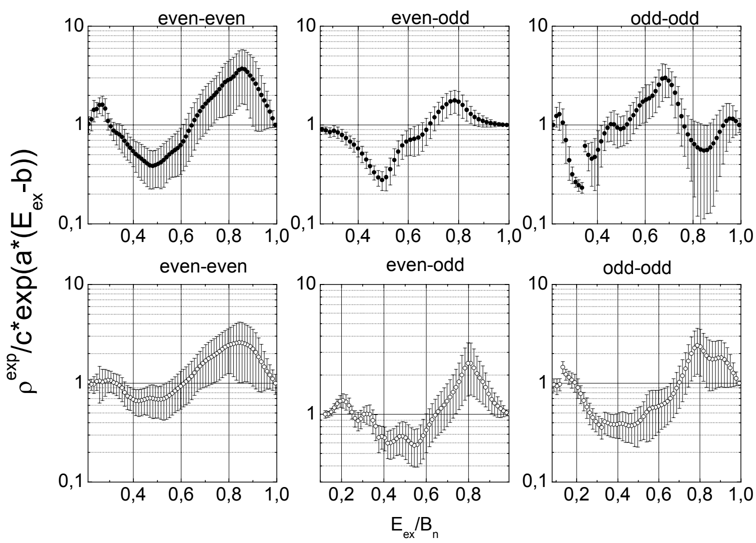

Fig. 2. The mean relative variations of level density. The notations are the same, as in Fig. 1.

Unambiguous choice requires, as minimum, additional development of the radiative strength function models

$$k = f/A^{2/3} = \Gamma/(D_\lambda E_\gamma^3 A^{2/3})$$

accounting for coexistence, interaction and different influence of quasiparticle and phonon excitations of nucleus on the primary gamma-transition strength functions and determination of parameters of required models. One can expect that joint model reproduction of the Γ values together the level density parameters for different dependences $\Delta_N=f(E_{ex})$ will allow revealing of main peculiarities of this nuclear parameter, at least, for 2-3 Cooper pairs of nucleons. The basis for this is strong correlation of regions of maximum change in the ρ and Γ values.

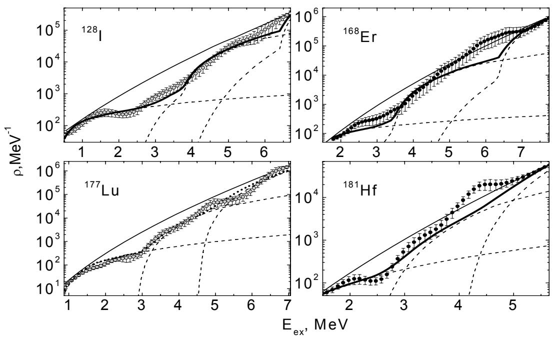

Fig. 3. The examples of approximation of the experimental data for ^{128}I, ^{168}Er, ^{177}Lu and ^{181}Hf by partial level densities in analogous to [15] variant of analysis under condition *g=const*. Closed points with errors represent experimental data [2], open points – data [1]. Thin dashed curves show partial densities, thick curve demonstrates the sum of partial densities. Solid thin curve corresponds to predictions according to model [12].

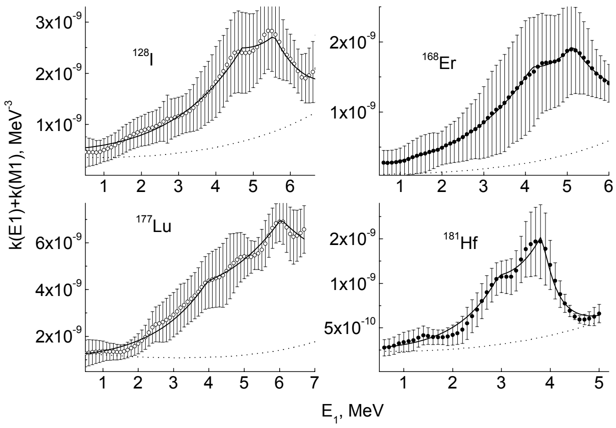

Fig. 4. The most probable radiative strength function sums and interval of their values corresponding to minimal values of the χ^2 parameter for the ^{128}I, ^{168}Er, ^{177}Lu and ^{181}Hf nuclei. Solid curve shows the best fit, dotted curve represents the component corresponding to expression (5a): open points show data [1], full points – data [2].

4. Requirements to experimental data on two-step reaction

Guarantied reliability of notions of ρ and Γ being enough for the practical use requires one to determine these parameters with minimum possible systematical errors. For example, overestimation or underestimation of these parameters must not exceed a factor of ~2 in the region of maximum total uncertainty. This region for available information on density of low-lying levels, neutron resonances and other reference data [17] is located at $\approx 0.5B_n$. Achievement of this very high for real situation precision demands, first of all, to exclude not grounded and obviously obsolete hypotheses from analysis of experimental data. Such hypotheses must be replaced by experimental data. Potential possibility to solve this task is measurement of cross-sections and spectra of reactions with different number of steps.

Maximum decreasing in systematical errors of determination of both form of dependence of the two-step reaction spectra on energy of the reaction first step product and absolute partial cross-sections of $I_1 * I_2$ for the fixed initial and final levels practically waits for its solution.

On the whole, the transition from measuring cross-sections of any one- and two-step nuclear reactions to maximum variety of multi-step reactions seems to be desirable and absolutely necessary. It is necessary to use different methods of experiment and its maximum correct analysis for investigation of the same nucleus. Considerable error transfer coefficients of the measured spectra onto the nucleus parameters under study require very careful evaluation of them and necessary reduction of the largest systematical errors of experiment.

5. Verification of results obtained in two-step reactions

Investigation of two-step gamma-cascades in nuclei from the mass region $40 \le A \le 200$ allowed us to reveal [15,18] the region of the dominant phonon type excitations. It manifests itself as the clearly expressed step-wise structure in level density with a width of $\approx 2\Delta_0$ below probable threshold of four- or five-quasiparticle excitations. Analogous conclusions about relation between the levels of quasiparticle and phonon types for higher excitation energy cannot be done – the coefficient of collective enhancement of level density is determined [9] by the ratio

$$\rho(U,J,\pi) = \rho_{qp}(U,J,\pi) K_{coll}(U,J,\pi). \tag{4}$$

Therefore, for the unambiguously determined experimental level density, the ρ_{qp} values for two- or three-quasiparticle excitations are determined with some ambiguity, as well. And the ρ_{qp} values with 4 and more quasiparticles for a given U, due to strong energy dependence [9,13] depend on breaking thresholds of the second and following Cooper pairs. Therefore, the K_{coll} values anti-correlate with the birth thresholds of multi-quasiparticle levels. Its value for "step-wise" structure averages [15,18] 10-20. (Concrete values depend on form of function $\Delta_N = F(E_{ex})$ used for calculation of the n-quasiparticle excitation density in model [13].) But, both the primary and following cascade quanta terminating at the nuclear levels lying in region of this structure are considerably enhanced with respect to any other gamma-transitions of the same energy. This conclusion was made by approximation [14] of the experimental data on the primary gamma-transition strength functions [1,2] by the following function:

$$k(E1,E_\gamma) + k(M1,E_\gamma) = w\frac{1}{3\pi^2\hbar^2c^2A^{2/3}}\frac{0.7\sigma_G\Gamma_G^2(E_\gamma^2+\kappa 4\pi^2T^2)}{E_G(E_\gamma^2-E_G^2)^2} + \tag{5a}$$

$$+P\delta^-\exp(\alpha(E_\gamma - E_p)) + P\delta^+\exp(\beta(E_p - E_\gamma)). \tag{5b}$$

The first item is the radiative strength function [11] weighed over probable contribution of quasiparticle excitations in the experimental strength function (with accounting for nuclear temperature, being less than thermodynamics value). The second and the third items describe the left (δ^-) and right (δ^+) respectively, parts of peaks in strength functions which are absent in existing [9] model notions. Location of peaks at some energies of the primary gamma-transitions can be explained only by strong difference in structure of levels at different excitation energy of a nucleus under study.

Change of existing [4,5] notions of the Γ values for gamma-transitions of the same energy and multipolarity on excitation energy of studied nucleus by realistic experimental evaluation [2] reduces the most important systematical error in determination of the cascade gamma-decay parameters from the spectra of two-step reaction. But, absolute lack of experimental data on population of levels above $\approx 0.5B_n$, practically, in all the studied nuclei does not allow one to remove this error at all.

The obtained ρ and Γ values are additionally distorted by ordinary experimental errors. Although, for example, variation of the cascade intensity in limits ±25% changes the obtained ρ value by a factor not more than 2, as maximum [19]. But reliability of the made conclusions on the determined in [1,2] ρ and Γ values needs in additional verification.

Usually performed calculation of the gamma-transition spectra and neutron capture cross-sections does not provide for absolute guarantee of absolute reliability in determining ρ

and Γ due to small magnitude of the error transport coefficients of these parameters on calculated spectra and cress-sections. Nevertheless, comparison [20] between calculation for different sets of ρ and Γ and experimental data permits one to reveal the parameter's set having the smallest systematical errors. There is necessary but insufficient condition for reliability of the ρ and Γ values obtained in experiment.

6. Direct model-less estimation of level density and radiative strength functions

At present, the most precise but incomplete test of results obtained in two-step nuclear reactions can be done only by means of maximum model-free analysis of the primary gamma-transitions from reaction $(\overline{n},\gamma)$ (capture in "averaged" resonances). Analogous results can be obtained also in any accelerator beam experiment in the fixed (several keV) excitation energy interval and (it is desirable) in limited and known spin window of excited levels of studied nucleus. Practical possibility for this is provided by established in [1,2] fact of relatively small level density in nuclei of any type below $\approx 0.5B_n$ excited by the dipole primary gamma-transitions following decay of compound-states with one or two possible spins.

Resolution of modern HPGe-detectors permits one to determine parameters of corresponding peaks with negligibly small statistical error up to the values $\rho\sim$100-200 МэВ$^{-1}$. The presence of step-like structure in level density below $\approx 0.5B_n$ provides execution of this condition for even-odd deformed compound nucleus, for example, up to excitation energy ~3 MeV.

Random character of amplitudes ($\Gamma^{1/2}$) of any primary gamma-transition was verified experimentally by studying neutron capture in neutron resonances. Therefore, averaging of partial widths over larger or lesser set of decaying initial levels decreases partial width fluctuations for any distribution of their deviations from the average and decreases portion of the primary gamma-transitions whose intensities are lying below the experimental detection threshold.

In this situation, verification of the experimental data on level densities from one- and two-step reactions at minimum number of hypothesis used must and can be done by approximation of distribution of these averaged intensities above registration threshold and its extrapolation in the intensity region below detection threshold.

In dependence on spin values, experimental distribution can be superposition of two and more individual distributions. The desired parameters for each of them are the most probable number of intensities, mean value, dispersion and their detection threshold.

Authors of experiments performed up to now have analyzed the data in frameworks of notions of limited "statistical" theory of the gamma-decay. The data [1,2,14] unambiguously require their re-analysis within apparatus of mathematics statistic with accounting for possibility of:

(a) strong dependence of the gamma-transition intensities on structure of excited levels;

(b) violation of the Porter-Thomas distribution [21] for larger or lesser part of experimental data and

(c) significant variation of mean widths and their dispersion for gamma-transitions of different multipolarity as changing the level excitation energy.

The necessary re-analysis calls no difficulties:

(a) the random intensity distribution is easily approximated in integral form (cumulative sum of reduced intensities in function of current intensity value) even for small sets of experimental values;

(b) the best value of the distribution dispersion is set in form $\sigma^2=2/\nu$ with the desired parameter ν;

(c) detection threshold for gamma-transition registration and the most probable number of of gamma-transitions of a given multipolarity (the same for the dipole *E1*- and *M1*-transitions) is unambiguous enough.

Only the determination of ratio R_k for mean reduced intensities of *M1*- and *E1*-transitions in every 200-300 keV excitation energy intervals can be ambiguous. But near R_k~0 and R_k~1 they are indiscernible for approximation procedure (but, correspondingly they differ by two times in desired number of gamma-transitions).

Unfortunately, the data on ρ and Γ obtained in this way can be to the more or less extent doubtful. This can be due to significant systematical errors in determined experimental sets of the primary transition intensities or due to analysis performed within unverified hypothesis that gamma-transitions of equal multipolarity, the same spin values of decaying compound-states and excited levels have practically equal mean values, at least, in the narrow excitation energy intervals.

If this hypothesis is true in wide enough energy interval of the observed primary gamma-transitions, then such verification confirms [22] presence of step-wise structure and increasing in probability of gamma-transitions to corresponding levels. Moreover, one can conclude that the level densities in [1,2] are considerably overestimated because of underestimation of intensity of the secondary gamma-transitions to these levels.

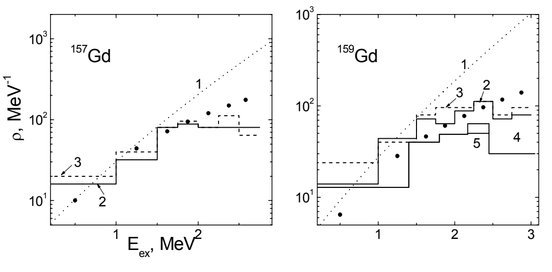

Fig. 5. The level density of both parities (histograms) excited by dipole primary transitions after resonance neutron capture in two gadolinium isotopes [22]: histogram 2 -E_n ≈2 keV, histogram 3 - E_n ≈24 keV, 4 - E_n >1 eV, 5 – isolated resonances, Dotted curve represents level density calculated according to model [12].

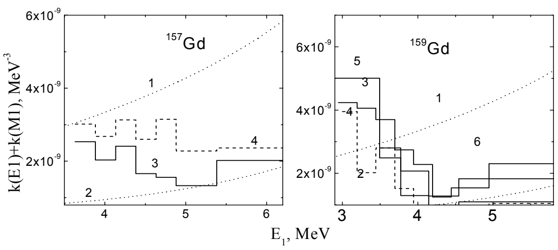

Fig. 6. The sum of the probable radiative strength functions of E1- and M1-transitions. The upper (1) and lower (2) dotted curves represent calculation within the models [4] and [11] in sum with *k(M1)*=const, respectively. The histograms show the data [22]: 3 — for E_n ≈2 keV, 4 – for E_n ≈24 keV, 5 – for E_n >1 eV and histogram 6 – for isolated neutron resonances.

The data existing for set of actinides [23] on $(\overline{n},\gamma)$ reaction allow one to expect level densities and radiative strength functions for them (figs. 7,8) analogous to those obtained for lighter nuclei [1,2]. Experimental data from reaction $(\overline{n},\gamma)$ give unique possibility for experimental determination of ratio between the level densities with different parity in rather wide excitation energy region of nuclei studied in $(\overline{n},\gamma)$ reaction. Strong correlation between the strength functions of the different multipolarity gamma-transitions and density of levels of different parity does not allow one to get in [1,2] unambiguous ratios *k(M1)/k(E1)* and *ρ(π=-)/ρ(π=+)*. But, as it was obtained in [22], the ratios *k(M1)/k(E1)* are determined experimentally. And due to strong correlation of parameters under consideration, this provides for direct experimental determination and of ratio *ρ(π=-)/ρ(π=+)* in the iterative process [1,2].

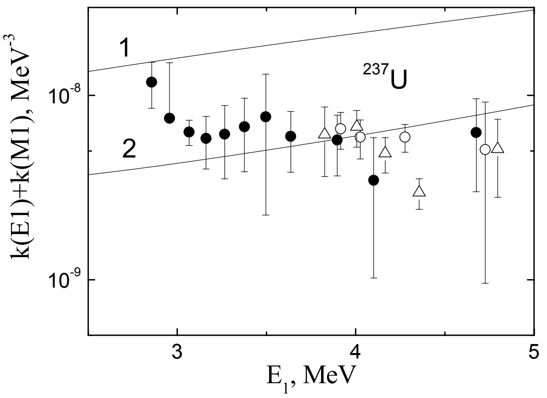

Fig. 7. The sum of the radiative strength functions of E1- and M1-transitions for ^{237}U. Black points represent data for the neutron energy region $5 < E_n < 125$ eV, open points – for $E_n \approx 2$ keV, triangles – for $E_n \approx 24$ keV. The upper and lower curves show predictions of the models [4] and [11] in sum with *k(M1)*=const, respecvtively.

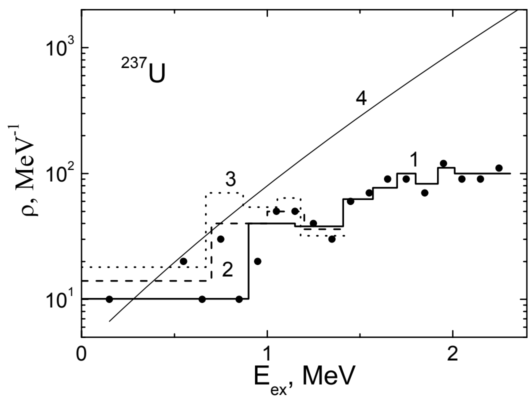

Fig. 8. The same, as in Fig. 5, for density of excited levels. The solid curve corresponds to predictions according to model [11] for spin values *J*=1/2 and 3/2. Points show the numbers of levels observed in resolved resonances.

7. Aims and possibilities of future experiments

Comparison between the experimental data on ρ and Γ derived from the spectra of two-step reactions with realistic enough model ideas provides [14,15,18] for potential possibility for obtaining the most reliable data on correlation functions of nucleons in heated nuclei. Id est., for practical studying superfluidity in such rather specific system as heated nuclei.

For maximal decrease in systematical errors in determination of nuclear parameters, it is necessary, first of all, to improve experimental methodology. It can be done in the following directions:

(a) accumulation of the maximum reliable data on the primary gamma-transition intensities following resonance neutron capture on “filtered” beams;

(b) measurement of cascade intensities with two and more quanta on beams of thermal and resonance neutrons;

(c) measurement of spectra of two-step reactions like (particle, gamma-quantum) on accelerator beams with high energy resolution of particle registration. Besides, two possibilities enumerated above should be used in order to derive information from the gamma-cascades following emission of particle with excitation of high-lying levels of final nucleus.

These experimental data must be analyzed with accounting for potentially strong influence of nuclear structure on emission probability of reaction products.

8. Conclusion

Modern experimental technique at correct (from the point of view of mathematical statistics and with exclusion of superfluous hypotheses) analysis of its data provided for possibility of detailed search for interaction process between fermion and boson components of nuclear matter. Potentially possible information can de obtained under conditions completely being absent in macrosystems (limited sizes, change in ratio of different type excitations, shell structure and so on).

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