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STATISTICAL MODEL CALCULATIONS OF NUCLEAR LEVEL DENSITY WITH DIFFERENT SYSTEMATICS FOR THE LEVEL DENSITY PARAMETER

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1. Introduction

The most important quantity in statistical pre-equilibrium and evaporation models is the nuclear level density. Usually, in Monte Carlo calculations of such models one uses a constant, independent of the neutron (N) and proton (Z) numbers and of the excitation energy E^* of residual nuclei, value for the level density parameter $a = a_0 A$, with $a_0 = const$ (see, e.g., [1, 2]). This approach is well-grounded in calculations of that type in the following cases: A)Not very high excitation energies of residual nuclei; B)Not very high bombarding energies (in the case when one uses the pre-equilibrium and/or evaporation models after the first, cascade stage of the reaction) when we know well the neutron and proton numbers of residual nuclei in advance; C)Residual nuclei have neutron and proton numbers lying in the middle of the nucleon shells and their level density parameter doesn't change much with a successive emission of several particles at the pre-equilibrium and/or evaporative stages of the reaction; D)For high excitation energies, when we are interested in a good description only of high energy parts of the ejectile spectra. In these cases, the corresponding experimental value for a_0 (or, in the case D, the asymptotic Fermi-gas value $\tilde{a}$ of the level density parameter at high excitation energies) may be used as an input and the approach $a_0 = const$ allows one to obtain reliable results.

On the contrary, at high incident energies residual nuclei have a wide distribution over the neutron and proton numbers and over the excitation energy (see, e.g., [1]). In this case, in different Monte Carlo simulated events of the same reaction residual nuclei may have neutron and proton numbers lying even in different nucleon shells. It is well known that at low excitation energies the level density parameter a is strongly influenced by shell effects (see, e.g., the monographs [3]-[5]). As one can see from fig. 1, clear structures of experimental values of the level density parameter a are seen. These structures correlate unambiguously with similar structures in the A-dependence of the shell correction in the nuclear mass $\delta W_{gs}(Z, N)$.

Different phenomenological approaches were developed to describe the observed anomalies in the A-dependence of the level density parameter in connection with the value of the shell correction, or with the filling of nucleon shells with increasing A (see [9]-[11], and [3]-[5] for reviews). In the present paper, we consider, as an example, Malyshev's [5] phenomenological approximation for $a = a(Z, N)$ fitted for $24 \leq A \leq 247$ in the form proposed by Newton [10]

$$a(Z,N) = \alpha \cdot 2(\bar{j}_Z + \bar{j}_N + 1)A^{2/3}, \tag{1}$$

where

$$\alpha = \alpha_0 - \beta \sin\left\{\frac{\pi}{20}\frac{A}{1+\gamma(A-A_0)/2}\right\} \cdot \cos\left\{\frac{\pi}{20}\frac{(1-\gamma A_0/2)(N-Z)}{[1+\gamma(A-A_0)/2]^2}\right\};$$

$$\alpha_0 = 0.038; \qquad \beta = 0.0125;$$

$$\gamma = \begin{cases} 6.7 \cdot 10^{-3}, & \text{for } A \geq A_0 = 80 \ ; \\ 0, & \text{for } A < A_0 \ . \end{cases}$$

The values of average proton $\bar{j}_Z$ and neutron $\bar{j}_N$ spins for $Z \leq 83$ and $N \leq 127$ are given in table 2 of ref. [5].

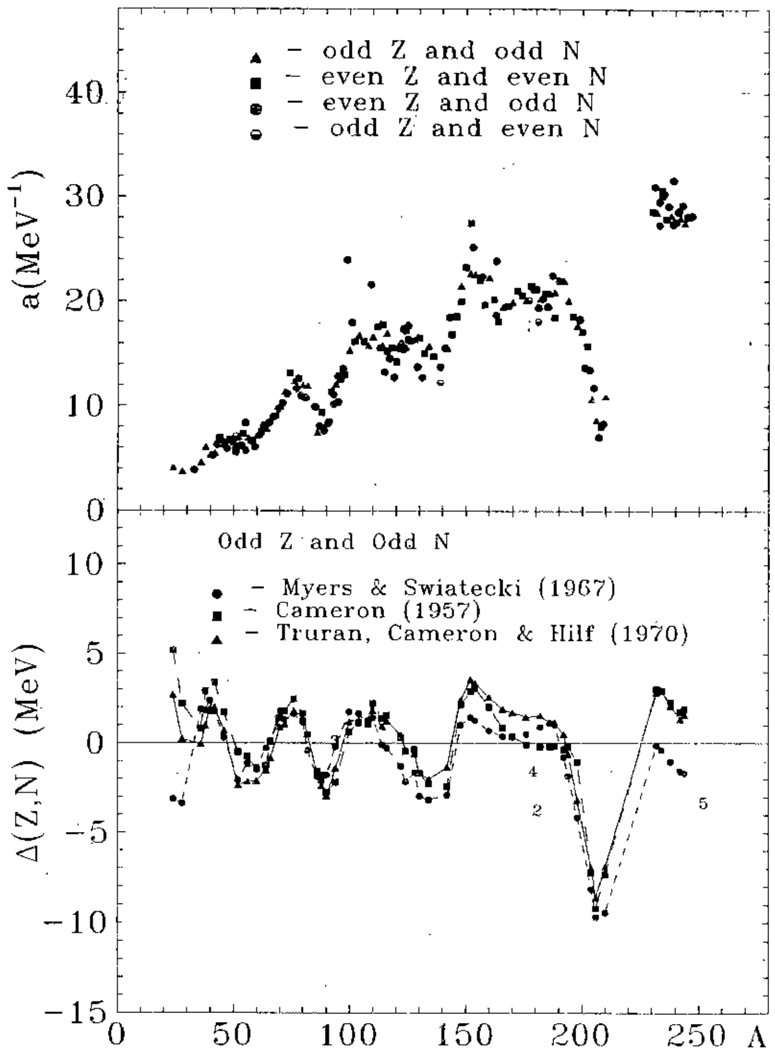

Fig. 1. Experimental values of the level density parameter obtained [5] from measurements of neutron-s-resonance spacing and Cameron's [6], Truran, Cameron and Hilf's [7] and Myers and Swiatecki's [8] ground state shell corrections for a set of odd-odd nuclei.

The results of calculation of the level density parameter by using the approximation (1) are compared with the experimental data obtained [5] from measurements of

the neutron s-resonance spacing in fig. 2. Let us recall that the approximation (1) was

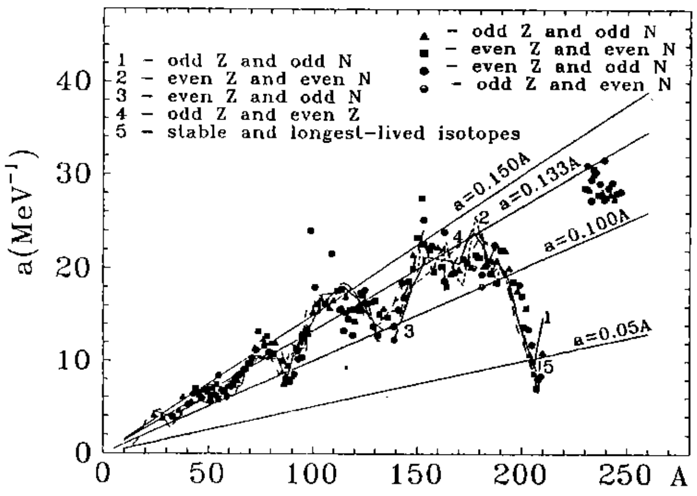

Fig. 2. Experimental values of the level density parameter from ref. [5] and the results of calculation by using Malyshev's approximation (1).

obtained for excitation energies of the compound nuclei formed after thermal neutron capture $E^* \approx B_n$ (B_n is the neutron binding energy). One can see that Malyshev's systematics (1) reproduces very well the shape and absolute value of the experimental level density parameter data. This enables us to incorporate the approximation (1) in the statistical pre-equilibrium and/or evaporation models and to use it confidently for $24 \leq A \leq 247$ and low excitation energies without knowing the corresponding experimental values of $a(Z, N)$.

But the situation changes at high excitation energies. The use of approximations like (1) at high excitation energies means that shell effects are assumed to manifest themselves in the level density in the same manner as at low energies. This contradicts the well-known fact of thermal damping of the shell effects in nuclei: different authors have shown that shell effects are the strongest at low excitation energies, and disappear at $E^* > 50 - 100$ MeV (see, e.g., [3, 12] and references given therein). Moreover, let us recall that in the Fermi-gas model the level density parameter depends only on the mass number $a = a_0 A$, with $a_0 = const$ [3, 12, 13].

By now, different phenomenological methods taking into account the damping of shell effects with increasing excitation energy have been developed [14]-[22] to calculate the level density parameter $a(Z, N, E^*)$. In the present work, we compare different easy-computing approaches for calculating the level density parameter to find out their applicability for statistical pre-equilibrium and evaporation models.

2. Comparison of phenomenological systematics with data on the level density parameter

The first semiempirical systematics for description of the level density parameter by taking into account the thermal damping of shell effects, i.e., the excitation energy E^* dependence of the parameter a, has been performed by Ignatyuk *et al.* [14]. In this approach, the function which describes the thermal damping of shell effects was found from the microscopic calculations. Ignatyuk's *et al.* [14] formula for $a(Z, N, E^*)$ has the following form:

$$a(Z,N,E^*) = \tilde{a}(A)\left\{1 + \delta W_{gs}(Z,N)\frac{f(E^* - \Delta)}{E^* - \Delta}\right\}, \tag{2}$$

where

$$\tilde{a}(A) = (\alpha + \beta A)A \tag{3}$$

is the asymptotic Fermi-gas value of the level density parameter at a high excitation energy;

$$f(E^*) = 1 - exp(-\gamma E^*) . \tag{4}$$

The parameters α, β and γ were fitted to the experimental resonance spacing, and therefore, include collective effects in a non-explicit, phenomenological way. It was found that

$$\alpha = 0.154; \quad \beta = -6.3 \cdot 10^{-5}; \quad \gamma = 0.054 \text{ MeV}^{-1} . \tag{5}$$

(Below we will name these values the "first" set of Ignatyuk's *et al.* parameters). Shell effects are included in the term $\delta W_{gs}(Z, N)$. In the present paper, we will use three different approximations for $\delta W_{gs}(Z, N)$, namely, Cameron's [6], Truran, Cameron and Hilf's [7] and Myers and Swiatecki's [8] ones.

In the subsequent paper [15], Ignatyuk *et al.* have proposed to use the following, "second" form for $\tilde{a}(A)$

$$\tilde{a}(A) = \alpha A + \beta A^{2/3} b_s , \tag{6}$$

where b_s is the surface area of the nucleus in units of the surface for the sphere of equal volume (for the ground state of nucleus $b_s \approx 1$), and

$$\alpha = 0.114; \quad \beta = 0.162; \quad \gamma = 0.054 \text{ MeV}^{-1} . \tag{7}$$

(Below we will name these values the "second" set of Ignatyuk's *et al.* parameters). As Ignatyuk's systematics are very simple and suitable for using in the pre-equilibrium and evaporation calculations, they are well known, cited and probably the most frequently used by now in literature.

Later on Cherepanov and Iljinov [16] have performed a systematics analogous to the Ignatyuk's *et al.* ones by using not only the neutron resonance data to fit the parameters but also the data at higher excitation energies E^*. In addition, Cherepanov and Iljinov performed a systematics by taking into account in an explicit form the contribution from collective (rotational and vibrational) states to level densities. Cherepanov and Iljinov used Ignatyuk's *et al.* functional form for parametrization (2-4) and obtained, in the case when the collective states were not explicitly taken into account, the following values for the parameters:

$$\alpha = 0.148; \quad \beta = -1.39 \cdot 10^{-4}; \quad \gamma = 6 \cdot 10^{-2} \text{ MeV}^{-1} . \tag{8}$$

(Below we will name these values the "first" set of Cherepanov and Iljinov's parameters). When the collective states were taken explicitly into account Cherepanov and Iljinov obtained

$$\alpha = 0.134; \quad \beta = -1.21 \cdot 10^{-4}; \quad \gamma = 6.1 \cdot 10^{-2} \text{ MeV}^{-1} . \tag{9}$$

(Below we will name these values the "second" set of Cherepanov and Iljinov's parameters).

Recently, Iljinov, Mebel *et al.* [17] have performed a new systematics of all existing by now data on level densities. The authors of [17] have used again Ignatyuk's *et al.* [15] functional form for $a(Z, N, E^*)$ with the asymptotic Fermi-gas value of the level density parameter at a high energy in the form (6). Iljinov, Mebel *et al.* used two sets (from [7] and [8]) of "empirical" shell corrections in their fitting procedure; performed the fits with and without explicitly taking into account collective effects; and, in addition, performed two different sets of fits: A) with the energy dependence $f(E^*)$ in a universal form (4) for all the nuclei, and B) following Schmidt *et al.* [18] assuming the parameter γ to be A-dependent:

$$\gamma = \frac{\tilde{a}}{\epsilon A^{4/3}} , \tag{10}$$

where ϵ is a phenomenological parameter.

The eight sets of parameters values obtained by Iljinov, Mebel *et al.* [17] are shown in table 1.

Table 1. Iljinov, Mebel's *et al.* results of level density analysis for different variants of the phenomenological systematics [17]

No. of fit	α	β	γ [MeV^{-1}]	f-factor	Shell corrections
Without collective effects ($K_{rot} = 1$, $K_{vib} = 1$)					
1	0.114	0.098	0.051	1.68	Myers, Swiatecki [8]
2	0.111	0.107	$\tilde{a}/0.46A^{4/3}$	1.71	Myers, Swiatecki [8]
3	0.072	0.257	0.059	2.31	Cameron *et al.* [7]
4	0.077	0.229	$\tilde{a}/0.37A^{4/3}$	2.48	Cameron *et al.* [7]
With collective effects ($K_{rot} \neq 1$, $K_{vib} \neq 1$)					
5	0.090	-0.040	0.070	1.63	Myers, Swiatecki [8]
6	0.034	0.312	0.011	5.00 (*)	Myers, Swiatecki [8]
7	0.052	0.113	0.086	2.20	Cameron *et al.* [7]
8	0.029	0.332	0.012	5.47 (*)	Cameron *et al.* [7]

(*) Nuclides with deformation $\beta < 0.2$ were assumed to be spherical ($K_{rot} = 1$).

To have a quantitative overall estimation of the agreement between the calculated and experimental data on the level density ρ, in table 1 values of the averaged ratio (f-factor) obtained by Iljinov, Mebel *et al.* [17]

$$f \equiv < \frac{\rho_{calc}}{\rho_{exp}} > = exp\left[\frac{1}{n}\sum_{i=1}^{n}\left(ln\frac{\rho^{i}_{calc}}{\rho^{i}_{exp}}\right)^{2}\right]^{1/2}$$

are also given (n is the number of the considered experimental points).

In the present paper we test both Ignatyuk's *et al.* systematics [14, 15], both sets of Cherepanov and Iljinov's [16] parameters, and the first four sets of Iljinov, Mebel's *et al.* [17] parameters obtained without taking explicitly into account the collective effects. For every systematics, we will use three approaches for shell corrections, namely, Cameron's [6], Truran, Cameron and Hilf's [7], and Myers and Swiatecki's [8] ones. The results of our calculations for a collection of odd-odd nuclei for excitation energies $E^* = 5$, 50, 100, and 300 MeV together with the experimental values of the level density parameter are shown in figs. 3a-3h. One can see that all systematics regarded here provide very close speeds of thermal damping of shell effects with increasing excitation energies of nuclei. For $E^* > 100$ MeV shell effects disappear practically completely in all systematics.

Myers and Swiatecki's [8] shell corrections are very popular in literature and are widely used for the description of nuclear fission. Though they are easy-computing, their use in Monte Carlo simulations may need much computer time to have a satisfactory statistics. On the contrary, Cameron's [6, 7] shell corrections are published in a tabulated form, do not need any time for their calculation and, therefore, are more convenient for Monte Carlo calculations. As one can see from figs. 3a-3h, the use of Cameron's [6] or Cameron's *et al.* [7] shell corrections allows one to describe the level density parameters practically as well as the calculations with Myers and Swiatecki's shell corrections. To have a more reliable conclusion about what shell corrections may be used in the Monte Carlo calculation of pre-equilibrium and/or evaporation cascades, it is desirable to compare not only calculated level density parameters but also the proper level densities of excited nuclei and various concrete characteristics of nuclear reactions calculated with different shell corrections.

3. Calculation of nuclear level densities with different systematics for level density parameters

In this section, we will calculate level densities of nuclei using different systematics for the level density parameter and different shell corrections following the scheme used by Iljinov, Mebel *et al.* [17]. In the adiabatic approximation for the selection between rotational and vibrational modes, the nuclear level density $\rho(E^*)$ is generally described by the following expression [3, 21]:

$$\rho(E^*) = K_{rot}K_{vib}\rho_{intr}(E^*) , \tag{11}$$

where K_{rot} and K_{vib} are the coefficients for rotational and vibrational enhancement of the noncollective intrinsic excitations $\rho_{intr}(E^*)$.

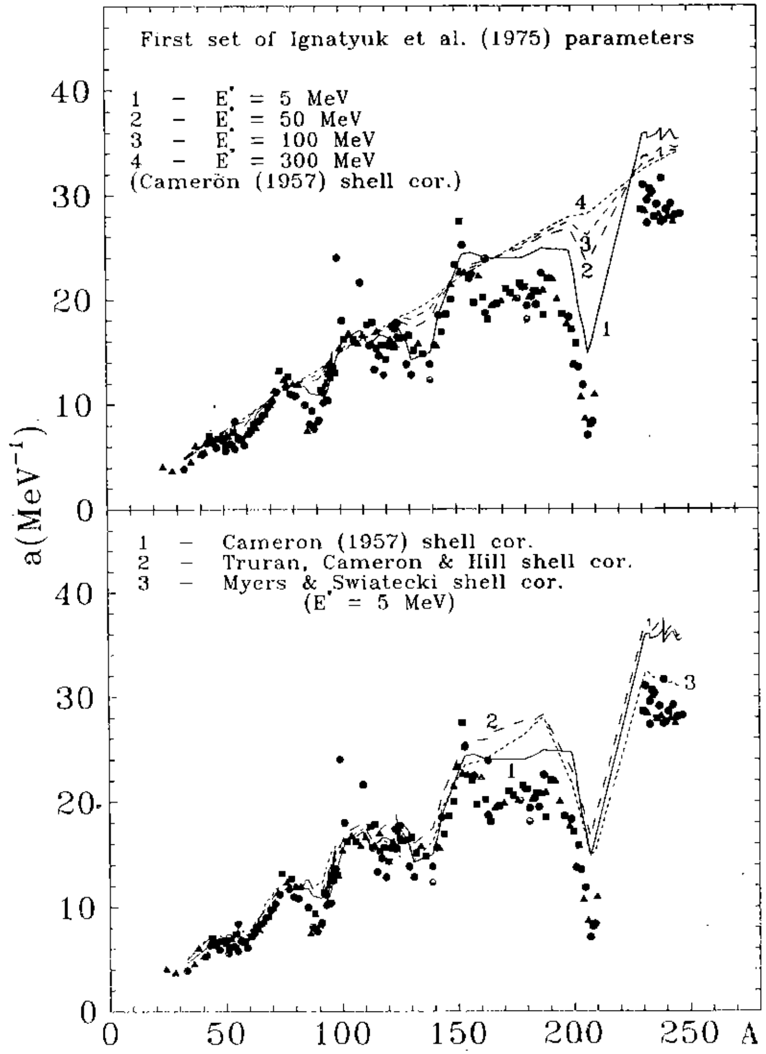

Fig. 3a. Experimental values of the level density parameter from ref. [5] and the results of calculation with the first systematics (2-5) of Ignatyuk *et al.* [14].

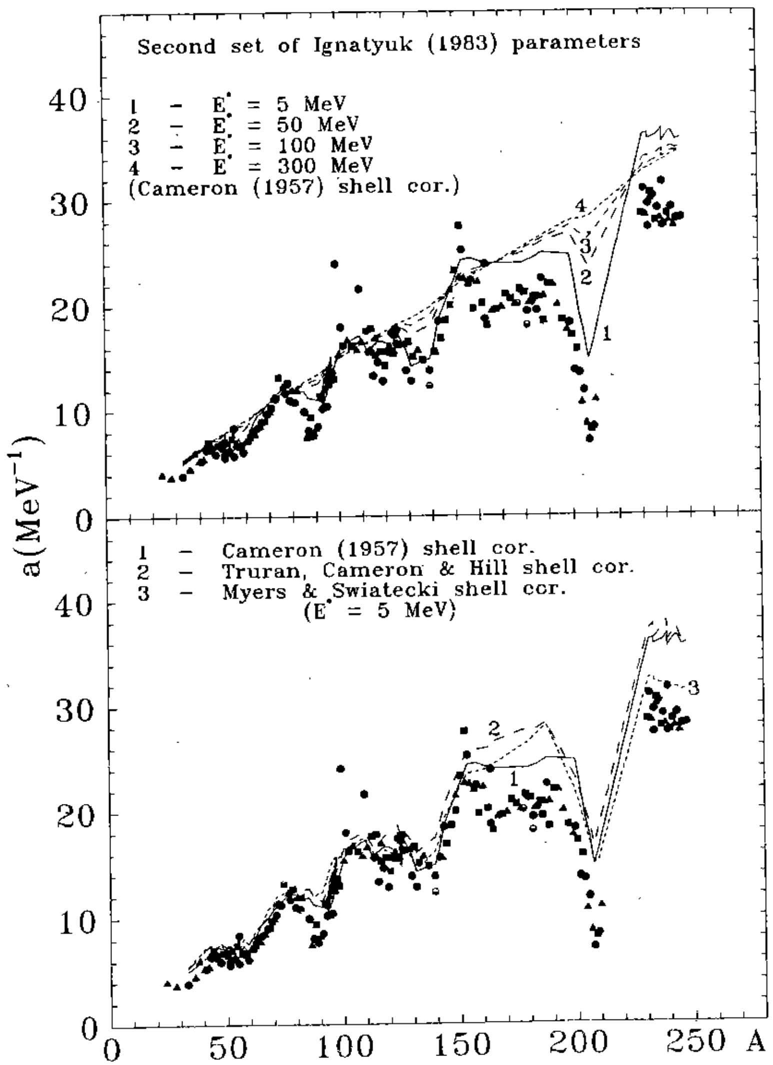

Fig. 3b. Experimental values of the level density parameter from ref. [5] and the results of calculation under the second systematics of Ignatyuk *et al.* [15], i.e., by using formulae (2), (4) and (6-7).

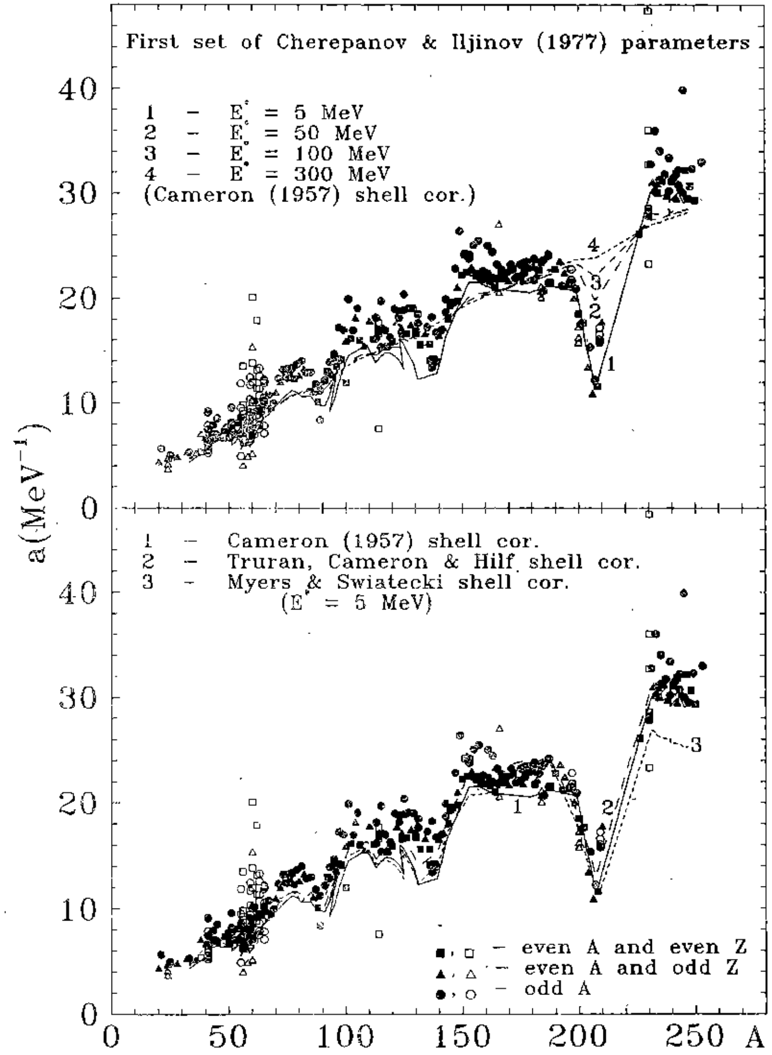

Fig. 3c. Experimental values of the level density parameter obtained by Cherepanov and Iljinov [16] from measurements of neutron resonance spacing (full symbols), for a larger interval of excitation energy from data counting low-lying levels and from level spacing data from different reactions (open symbols) as well as the results of calculation under Cherepanov and Iljinov's systematics with the first set of parameters (8).

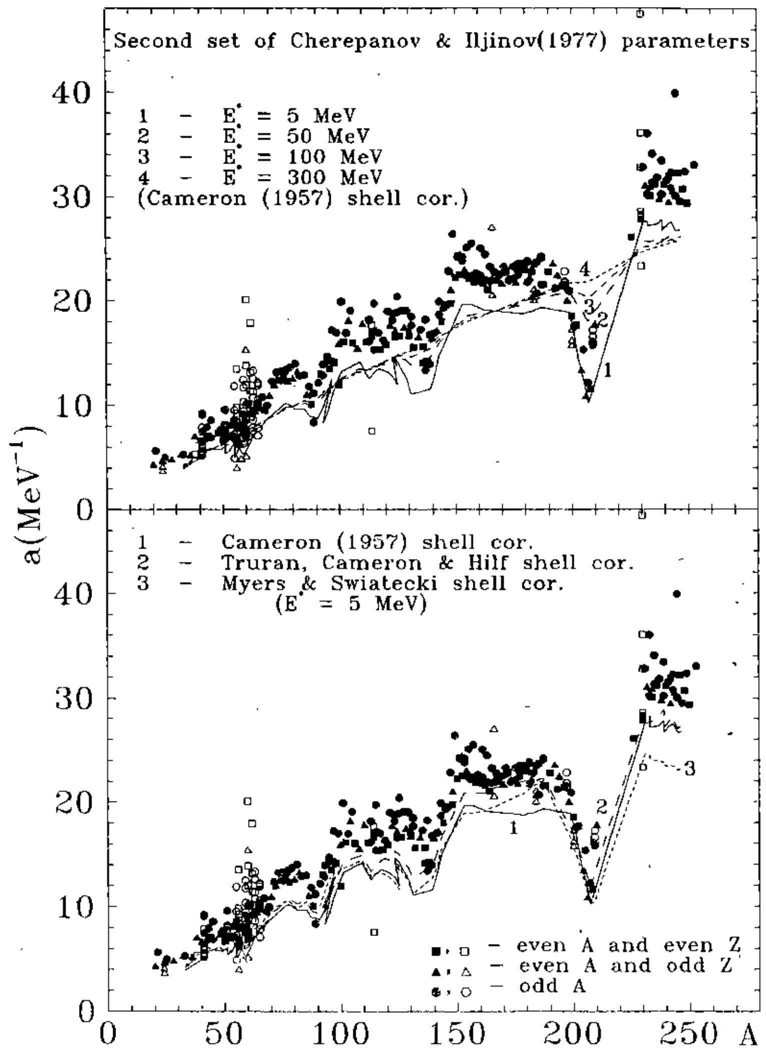

Fig. 3d. The same as in fig. 3c but for calculations performed with the second set of Cherepanov and Iljinov's parameters (9).

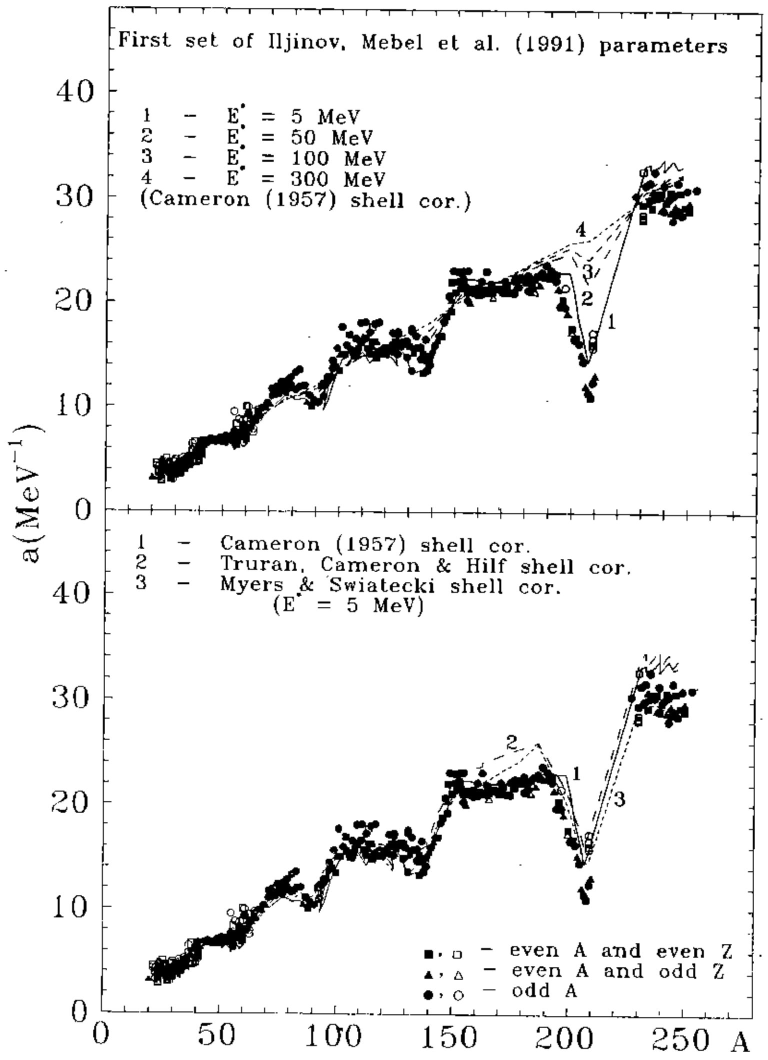

Fig. 3e. Experimental values of the level density parameter obtained by Iljinov, Mebel *et al.* [17] from measurements of neutron resonance spacing (full symbols), for a larger interval of excitation energy from data counting low-lying levels and from level spacing data from several reactions [$(\gamma,n),(p,\gamma),(p,p'),(\alpha,\gamma),(\alpha,p),(^3He,d)$, and $(^3He,\alpha)$] (open symbols) as well as present calculation under Iljinov, Mebel's *et al.* systematics with the first set of parameters (the first line of table 1).

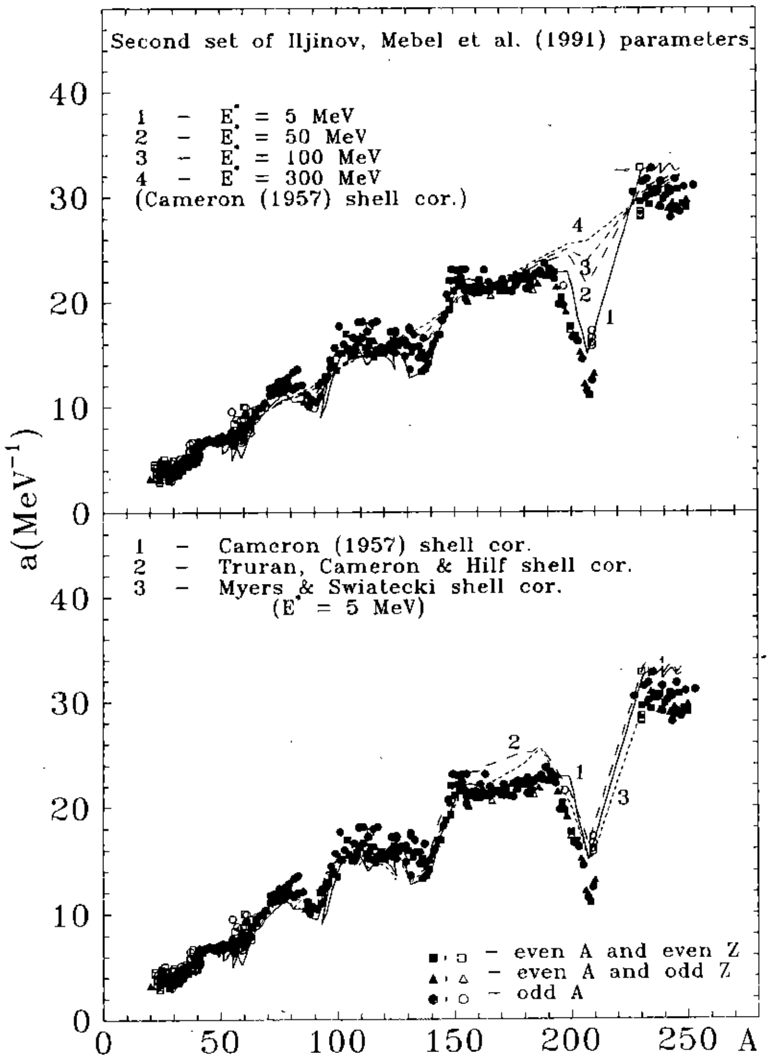

Fig. 3f. The same as in fig. 3e but for the second set of Iljinov, Mebel's *et al.* parameters (second line of table 1).

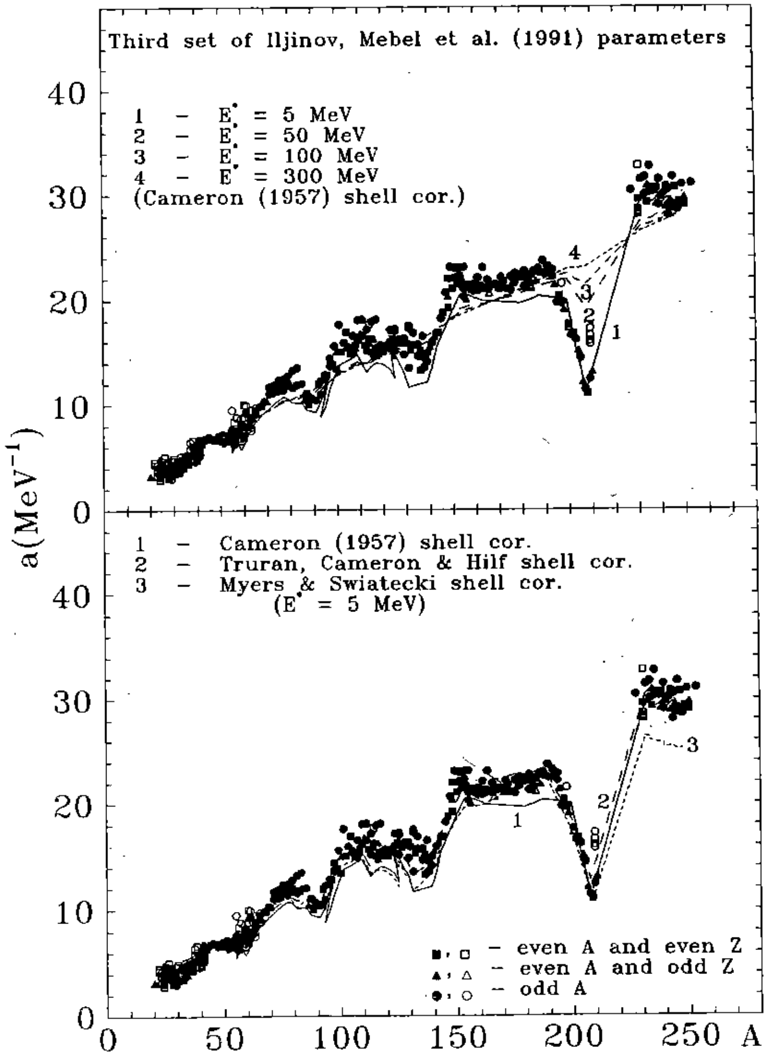

Fig. 3g. The same as in fig. 3e but for the third set of Iljinov, Mebel's *et al.* parameters (third line of table 1).

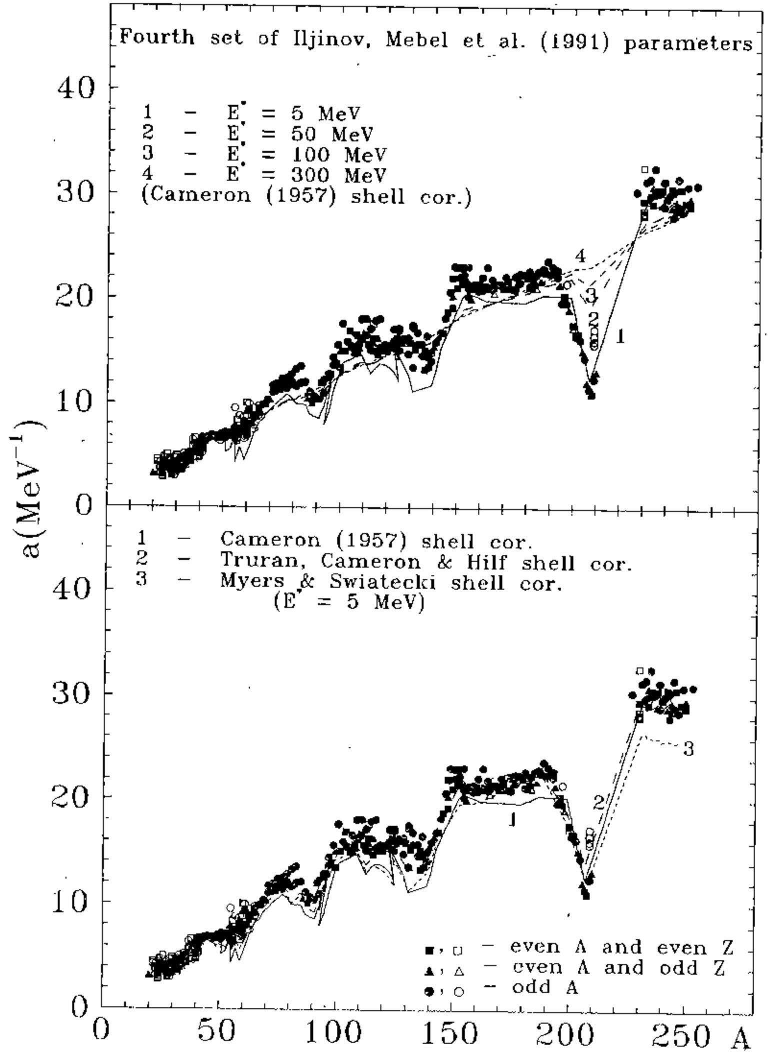

Fig. 3h. The same as in fig. 3e but for the fourth set of Iljinov, Mebel's *et al.* parameters (fourth line of table 1).

To describe this quantity, one often uses the Fermi-gas expression [3, 12, 13]

$$\rho_{intr}(E^*) = \frac{\sqrt{\pi}}{12a^{1/4}(E^* - \Delta)^{5/4}} exp\left(2\sqrt{a(E^* - \Delta)}\right), \tag{12}$$

where a is the level density parameter, and

$$\Delta = \chi \frac{12}{\sqrt{A}} \text{ [MeV]} \tag{13}$$

is the pairing energy ($\chi = 0$, 1, or 2, respectively, for odd-odd, odd-even, or even-even nuclei).

The observed level density $\rho_{exp}(E^*)$ is connected with the total level density (state density) by the relation

$$\rho_{exp}(E^*) = \sum_L \rho(E^*, L) \approx \frac{\rho(E^*)}{\sqrt{2\pi}\sigma} . \tag{14}$$

Here $\rho(E^*, L)$ is the level density of a nucleus having the angular momentum L and excitation energy E^* and is connected with the total level density $\rho(E^*)$ by the relation [12, 13]

$$\rho(E^*, L) = \frac{2L+1}{2\sqrt{2\pi}\sigma^3} exp\left[-\frac{(L+1/2)^2}{2\sigma^2}\right] \rho(E^*) . \tag{15}$$

The spin-cutoff parameter σ is usually calculated by the formula

$$\sigma^2 = \frac{T J_{rb}}{\hbar^2} , \tag{16}$$

where $T = \sqrt{(E^* - \Delta)/a}$ is the nuclear temperature and $J_{rb} = 0.4 M_n r_0^2 A^{5/3}$ is the rigid body moment of inertia, M_n is the nucleon mass; for the nuclear radius $R = r_0 A^{1/3}$ we use $r_0 = 1.2$ fm.

The collective enhancement of the level density is especially large in the case of deformed nuclei. The coefficient of rotational increase of the level density K_{rot} in (11) is defined by the expression [3, 21]

$$K_{rot} = \begin{cases} 1, & \text{for spherical nuclei;} \\ J_\perp T, & \text{for deformed nuclei,} \end{cases} \tag{17}$$

where $J_\perp = J_{rb} f(\beta_2, \beta_4)$ is the perpendicular moment of inertia;

$$f(\beta_2, \beta_4) = 1 + \sqrt{\frac{5}{16}\pi}\beta_2 + \frac{45}{28\pi}\beta_2^2 + \frac{15}{7\pi\sqrt{5}}\beta_2\beta_4 ; \tag{18}$$

β_2 and β_4 are the parameters of quadrupole and octupole deformations of the nucleus [22]. The liquid drop model estimation for the vibrational coefficient K_{vib} is [3]:

$$K_{vib} \approx exp(0.0555 A^{2/3} T^{4/3}) . \tag{19}$$

The rotational enhancement of the level density of deformed nuclei $K_{rot} \simeq (10 - 10^2)$ is considerably larger than the vibrational enhancement $K_{vib} \approx 3$ at energy $E^* \approx B_n$ [3, 17].

To calculate the collective enhancement of the nuclear level density in accordance with (11-19), it is necessary to know the values of the parameters β_2 and β_4 of nuclear deformation. In the Monte Carlo simulation of pre-equilibrium and evaporation cascades this is not always possible because after random successive emission of several particles a residual nucleus may have such proton and neutron numbers for which there are no available data for β_2 and β_4. Besides that, let us remind that statistical pre-equilibrium and evaporation models deal not directly with the nuclear level density but with their ratios. At last, it should be noted that systematics for the description of the level density parameters fitted to experimental resonance spacings without explicit taking into account collective effects (i.e., with $K_{rot} = 1$ and $K_{vib} = 1$) also include collective effects in a phenomenological, nonexplicit way. On the whole, the question of redefinition of the level density parameter $a(Z, N, E^*)$ arises (see [17]). From the aforesaid we will use here the systematics obtained without explicit taking into account collective effects.

The results of calculations of level densities by the formulae (11-16) for $K_{rot} = 1$ and $K_{vib} = 1$ with different systematics for the level density parameter and by using different shell corrections are shown in figs. 4-6. One can see that on the whole Malyshev's systematics for $a(Z, N)$ without excitation energy dependence allows one to describe satisfactorily the experimental data only at low excitation energies E^*. Independently of the concrete shell corrections used in the calculation, all systematics used here with excitation energy dependence of the level density parameter permit one to reproduce correctly (with a factor of 3) the absolute values of the measured level density up to $E^* \approx 20 - 25$ MeV for medium (fig. 4) and heavy (fig. 5) spherical or weak deformed nuclei and a little worse for light deformed nuclei (fig. 6). To describe better the data at higher energies or for strongly deformed nuclei, the systematics with collective effects must be used [16, 17]. One can see that the systematics of Cherepanov and Iljinov [16] and Iljinov, Mebel *et al.* reproduce very close results and seem to describe the data better than the systematics of Ignatyuk *et al.* [14].

However, it is desirable to analyze other characteristics of the decay of excited nuclei before drawing a more definite conclusion about the advantage of a concrete systematics for $a(Z, N, E^*)$.

4. Fissility of exited nuclei

In this section we will use the systematics for $a(Z, N, E^*)$ regarded above to analyze the energy dependence of nuclear fissility. For a nuclear reaction the fissility is the ratio of the fission cross-section to the inelastic interaction cross-section $P_f = \sigma_f/\sigma_{in}$. But for a given excited compound nucleus the fissility may be estimated as the ratio of partial widths Γ_f/Γ_{tot}. Here $\Gamma_{tot} = \Gamma_f + \sum_j \Gamma_j$ is the total decay width of the compound nucleus, equal to the fission partial width Γ_f plus the sum of the emission widths Γ_j of the jth-type particles.

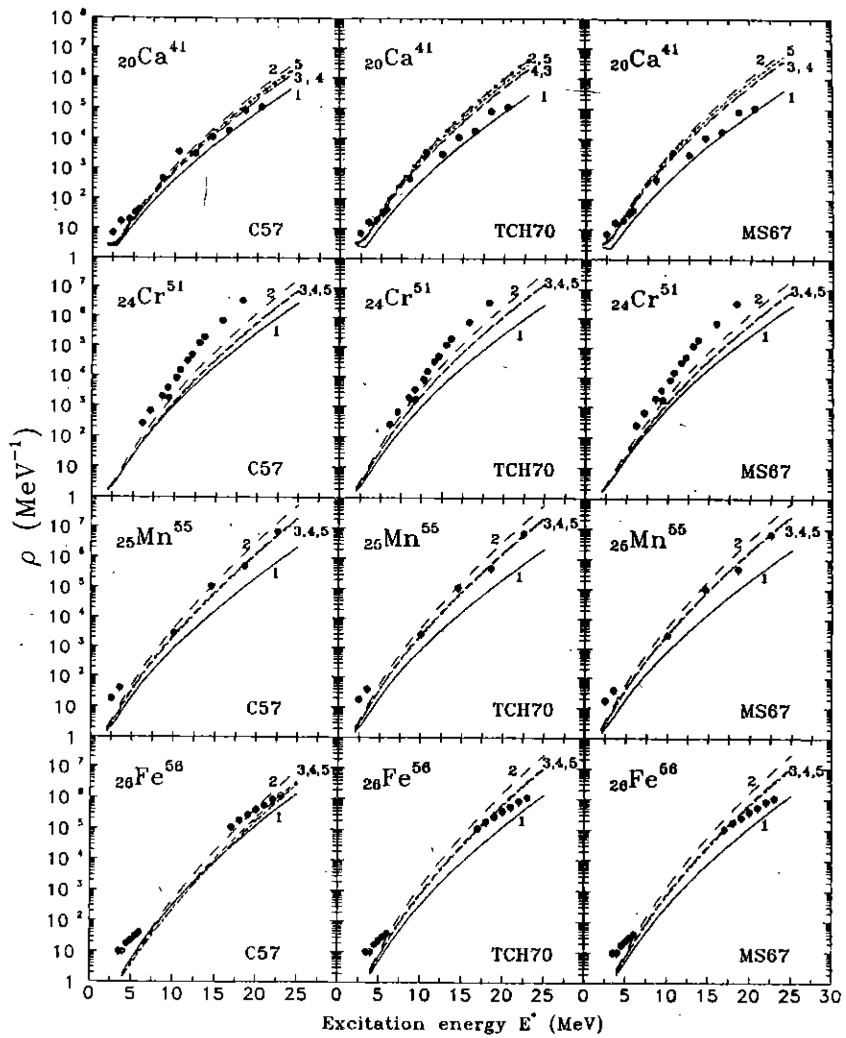

Fig. 4. Energy dependence of the level densities of nuclides ^{41}Ca, ^{51}Cr, ^{55}Mn, and ^{56}Fe. Points are the experimental data from the summary table 2 of ref. [16]. The curves denoted as 1, 2, 3, 4, and 5 are the results of calculation with Malyshev's [5], first Ignatyuk's *et al.* [14], first Cherepanov and Iljinov's [16], first and third Iljinov, Mebel's *et al.* [17] systematics for the level density parameter, respectively. In the left, center, and right parts of the figure the results of calculations with Cameron's [6] (marked as $C57$), Truran, Cameron and Hilf's [7] (marked as $TCH70$), and Myers and Swiatecki's [8] (marked as $MS67$) shell corrections, respectively, are shown.

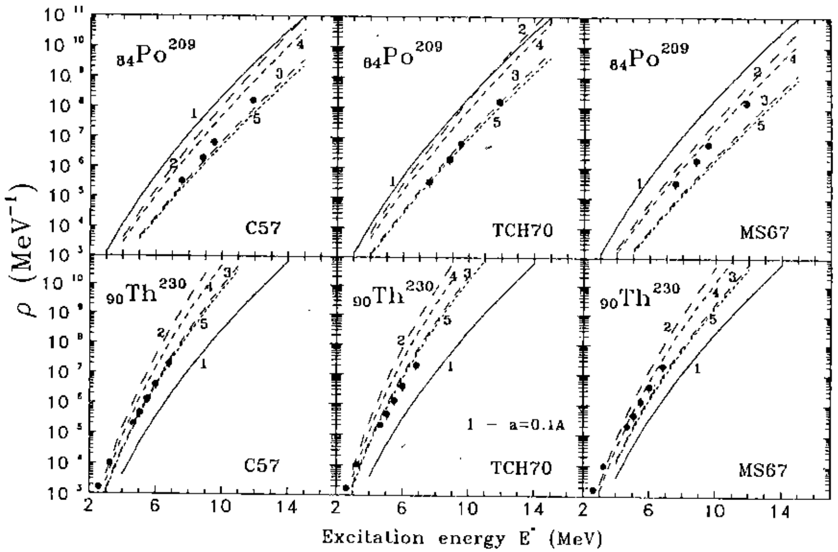

Fig. 5. The same as in fig. 4 but for ^{209}Po and ^{230}Th nuclides.

In the Weisskopf statistical theory of particle emission [23] and Bohr and Wheeler [24] theory of fission the partial widths Γ_j for the emission of a particle j ($j \equiv n, p, d, t, {}^3He, \alpha$) and Γ_f for fission are expressed by the following approximate formulae (units: $\hbar = c = 1$; see, e.g., [17]):

$$\Gamma_j = \frac{(2s_j + 1)m_j}{\pi^2 \rho_c(U_c)} \int_{V_j}^{U_j - B_j} \sigma^j_{inv}(E)\rho_j(U_j - B_j - E)EdE\ , \tag{20}$$

$$\Gamma_f = \frac{1}{2\pi\rho_c(U_c)} \int_0^{U_f - B_f} \rho_f(U_f - B_f - E)dE\ . \tag{21}$$

Here ρ_c, ρ_j, and ρ_f are the level densities of a compound nucleus, a residual nucleus produced after the emission of the j-th particle, and for the fission saddle point, respectively; m_j, s_j and B_j are the mass, spin and the binding energy of the j-th particle, respectively; B_f is the fission barrier height. In the present work we calculate the binding energies of particles through the use of Cameron's [6] formulae. $\sigma^j_{inv}(E)$ is the inverse cross-section for absorption of j-th particle with kinetic energy E by the residual nucleus.

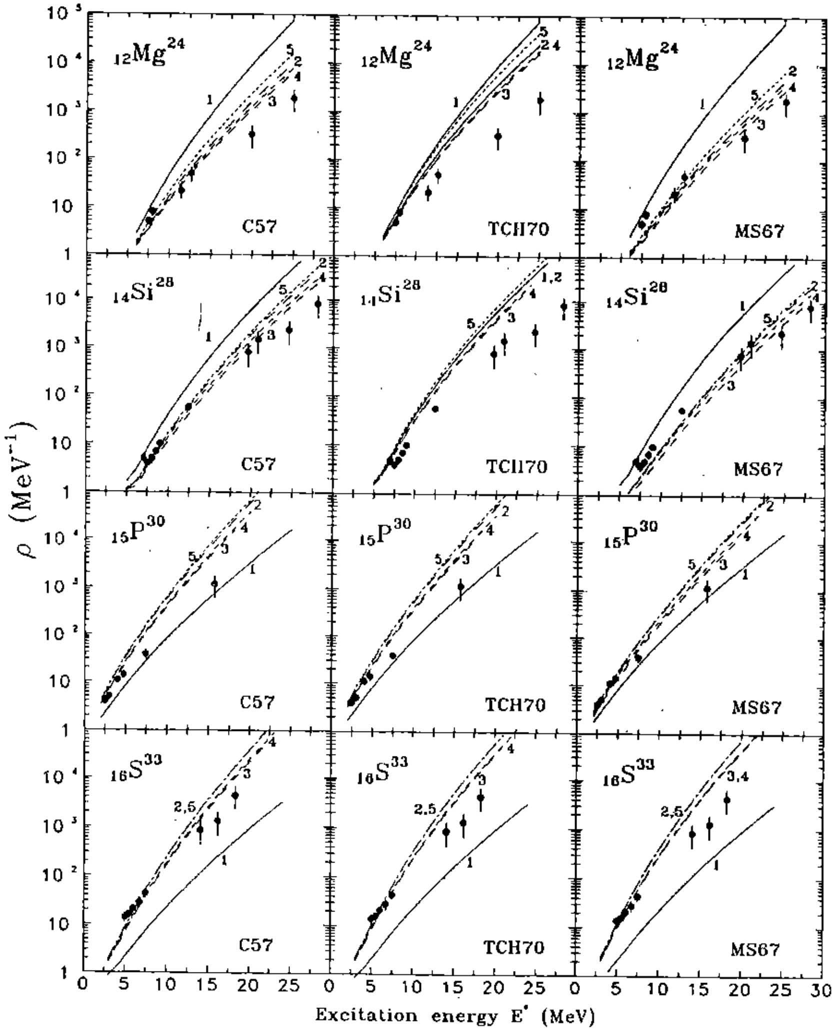

Fig. 6. The same as in fig. 4 but for ^{24}Mg, ^{28}Si, ^{30}P, and ^{33}S nuclides. The experimental data are taken from the summary table 2 of ref. [17].

We here use for $\sigma_{inv}^{j}(E)$ the approximation proposed by Dostrovsky [25].

$$U_c = E^* - \Delta_c \; ; \; U_j = E^* - \Delta_j \; ; \; U_f = E^* - \Delta_f \text{ , where}$$

$$\Delta_c = \chi \cdot 12/\sqrt{A_c} \; ; \; \Delta_j = \chi \cdot 12/\sqrt{A_{fj}} \; ; \text{ and } \Delta_f = \chi \cdot 14/\sqrt{A_c} \text{ (in MeV)}$$

are the pairing energies for the compound and residual nuclei, and for the fission saddle point, respectively; $A_{fj} = A_c - A_j$, where A_c and A_j are the mass numbers of the compound nucleus and of j-th particle, respectively.

We have analyzed, by using the formulae (20-21) and the systematics for the level density parameter regarded above, a lot of experimental data on nuclear fissility published in the review [26]. This analysis will be published in the following separate paper. Let us show here only an exemplary result. In fig. 7 measured [26] and calculated fissilities for ^{189}Ir nuclide are shown.

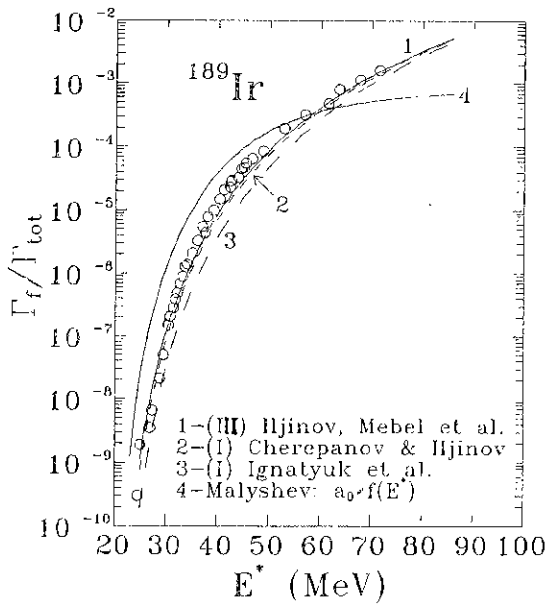

Fig. 7. Excitation energy dependence of the fissility Γ_f/Γ_{tot} of the exited ^{189}Ir compound nucleus. Curves are our calculation results with fission barriers from ref. [27], Cameron's [6] shell and pairing corrections, $a_f/a_n = 1.114$, for the third Iljinov, Mebel's *et al.* [17], first Cherepanov and Iljinov's [16], first Ignatyuk's *et al.* [14], and Malyshev's [5] systematics for the level density parameter. Experimental points were taken from the review [26].

These calculation were performed with fission barriers from ref. [27], Cameron's [6] shell and pairing corrections, the value for the ratio $a_f/a_n = 1.114$ by using the third Iljinov, Mebel's *et al.* [17], first Cherepanov and Iljinov's [16], first Ignatyuk's *et al.* [14], and Malyshev's [5] systematics for the level density parameter. One can see that Malyshev's [5] systematics for $a(Z, N)$ provides a good description of the shape (and by fitting the ratio a_f/a_n – of the absolute value) of the nuclear fissility as function of E^* only for low values of E^*. Cherepanov and Iljinov's [16] and Iljinov, Mebel's *et al.* [17] systematics for $a(Z, N, E^*)$ allow one to obtain a good description of the data in a larger interval of E^*, reproduce very close results and seem to describe the data better than the systematics proposed in ref. [14].

5. Summary and conclusion

Thus, a review and a comparative analysis of a number of systematics for the description of the level density parameter of excited nuclei are given. All systematics for $a(Z, N, E^*)$ regarded here provide very close speeds of the thermal damping of the shell effects with increasing excitation energy of nuclei. For $E^* > 100$ MeV shell effects disappear practically completely in all systematics.

Myers and Swiatecki's [8] shell correction are very popular in literature, and, though are easy-computing, their use in Monte Carlo simulations of pre-equilibrium and evaporative cascades may need much computer time to have a satisfactory statistics. On the contrary, Cameron's [6, 7] shell corrections are published in a tabulated form very convenient for users, and so do not need any time for their calculation and, therefore, are more convenient for Monte Carlo simulations. Our calculations have shown that Cameron's [6] or Cameron's *et al.* [7] shell corrections allow one to describe the experimental values of $a(Z, N, E^*)$, $\rho(E^*)$ and Γ_f/Γ_n practically as well as the Myers and Swiatecki's [8] shell corrections do.

It is shown that all regarded here systematics for $a(Z, N, E^*)$ permit one to reproduce correctly (up to a factor of 3) the absolute value of the measured level density up to $E^* \sim 20 - 30$ MeV for medium and heavy spherical or weak-deformed nuclei without taking explicitly into account the collective effects. To describe better the data in the high-energy region or for strongly deformed nuclei, it is necessary to take into account the contribution from collective states to the level density and to use the systematics for $a(Z, N, E^*)$ obtained with $K_{rot} \neq 1$ and $K_{vib} \neq 1$

The analysis of level densities and nuclear fissility has shown that Malyshev's [5] systematics for $a(Z, N)$ provides a satisfactory description of the experimental data only for low values of excitation energies E^*. Cherepanov and Iljinov's [16] and Iljinov, Mebel's *et al.* [17] systematics for $a(Z, N, E^*)$ allow one to obtain a good description of the data in a larger interval of E^*, reproduce very close results and seem to describe the data better than the systematics of Ignutyuk *et al.* [14].

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