INFLUENCIA DE LA DEFORMACION EN LA DENSIDAD DE NIVELES DE LOS NUCLEOS ACTINIDOS

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ABSTRACT
The shape dependence in nuclear level density is studied, taking into account the influence of collective modes in this process. The behavior of intrinsic state density, collective enhancement and total level density in dependence of deformation are studied. The Casinian ovals parameterization is used. Varying the main parameter epsilon of this parameterization we can study approximately the fission path. The influence of collective modes in level density is taken into account. The use of Combined Method to calculate level density shows to be a good procedure for level density description in dependence of nuclear deformation.

RESUMEN
Se estudia la dependencia de la forma en la densidad de niveles de los núcleos, tomando en consideración la influencia de los modos colectivos, en este proceso. Se estudia el comportamiento de la densidad de estados interna, del acomplamiento colectivo y de la densidad total de niveles en dependencia de la deformación. Se utiliza la parametrización de los óvalos de Cassini. Variando el parámetro de deformación de dicha parametrización se reproduce el camino de fisión. La influencia de los modos colectivos en la densidad de niveles se toma en consideración. El uso del método combinado de cálculo de la densidad de niveles resulta adecuado en la descripción de la dependencia de la formación nuclear en la densidades de niveles.

I. INTRODUCTION

The calculations of some observables of the fission process, e.g., cross sections, angular anisotropies, etc require the use of a good system of nuclear level densities in different important points along the fission path. In this regard, the question of level densities depending of the nuclear shape deformation parameters play a very important role because through these parameters it is possible to describe the evolution of the fissioning system during the process.

Usually, the level densities at the barrier deformations have been extrapolated from the scheme at equilibrium. This approximation offers good results but a lot of different *"at hoc"* parameters should be introduced to obtain a satisfactory fitting of the experimental cross sections. Another fact, wich should be considered, is that to solve the problem from a microscopical point of view, the single particle spectrum matrix should be obtained. However, a reliable model for this aim is far to be reliable [1,2]. This picture pointed out the role of the theoretical calculations in level densities at high deformations and the need of using more realistic method for level densities estimation, which should avoid the difficulties arising from the overestimated observations. In doing so, attention should be brawn to the lack of spectroscopy experimental data at high deformations.

The objetive of the present paper is to obtain level densities for all interest deformation regions starting from a statistical approach of the fission problem. It means that at each set of deformation parameter the nucleus has been considered "frozen".

For this aim, a Combined Method (CM) for level density calculations for high deformed nuclei were proposed by Egorov S.A. **et al**. [3]. In this method, the discrete features of spectrum at low energies are considered. At high energies, where the number of states grows, statistical calculation is carried out. Thus, a great amount of free parameters, that appear in other formulations (e.g., Fermi gas model with phenomenological shell and pairing effects), is suppressed.

To calculate the spectrum of excited states, the superfluid model was used. In this model, to determine the intrinsic state densities a blocking effect is used. Therefore, a great amount of fictitious excited states are avoided, in spite of ref. [4].

In fission cross section calculations, the level density behavior for all competing channels is required. For neutron channel, the level density features are determined at equilibrium deformation. In fission channel, the level density calculations at barrier deformations must consider violations of symmetry at barriers.

II. RESULTS

The main contributions are the level density calculations with deformation dependence from semimicroscopical point of view. In this method, shell effects have been regarded from single particle spectrum and not phenomenologically. Pairing effects are considered from superfluid model.

The single particle spectrum for different isotopes was calculated using DIANA code [5]. In this code, a nuclear shape parameterization proposed by Pashkevich [1] has been used. The intrinsic state densities were calculated using DENCOM code [6]. This code includes a Combined Method for level density. In Fig. 1 intrinsic state density as a function of deformation and energy is shown for U^{238} The structure of single particle spectrum is shown in the characteristics of Figs. 1, 2. A weak dependence of deformation is shown in these figures. This agrees with Britt [2].

At first saddle point deformation, the nucleus can be represented as a triaxial ellipse [1]. The nucleus rotation can take place around any three axes. The axial symmetry violation can be considered if a number of states is increased in (2I+1)/2 times. Then, the hypothesis about a weak anisotropy in the moments of inertia of the three axes is assumed. Therefore, states can be characterized by the quantum numbers K, I.

Fig. 3 shows the rotational enhancement for transition states at first saddle point deformations.

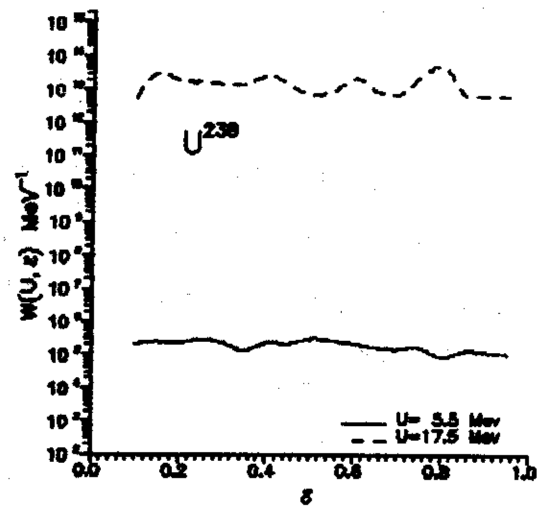

Figura 1. Intrinsic state density vs deformation for ^{238}U.

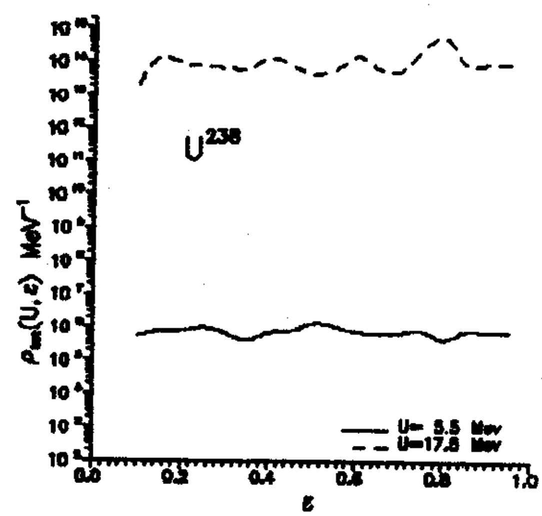

Figure 2 .Total level density vs deformation for ^{238}U.

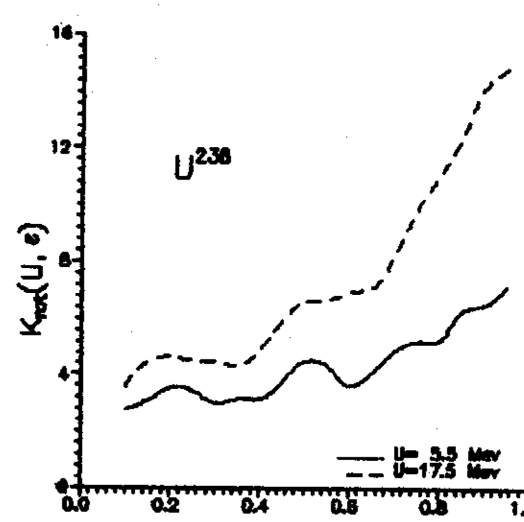

Figure 3. Collective enhancement vs deformation for ^{238}U.

As shown in this figure, the rotational enhancement increases suddenly from ϵ = 0.6. This fact is in accordance with the deformation dependence of the moment of inertia of the Cassinian ovals. This fact is very important to fission cross section calculations at energies below threshold. Therefore, the level density calculations should include the deformation dependence.

In second barrier the reflex symmetry is violated. Thus, the transition states have not a specified parity. This fact can be considered if the number of states is duplicated. the moment of inertia in second barrier is lower than corresponding to equilibrium deformation. Therefore, the level density increases at the second barrier deformation.

Level density calculation, using quatum-statistical model, agrees with the experimental data. Fig. 4 shows the calculation results for U^{238}; and similar behavior was achieved for U^{235}-U^{239}. A comparison with the values of analysis of low energy spectrum is made. The phenomenological models [7] cannont obtain a good agreement with the experimental data. Their results underestimate the experimental data. The level density calculation and combinatorial method are joined smoothly (Fig. 4). This is another advantage of this method. The Combined Method allows to calculate the level density for a wide range of energy and deformations in a successful way.

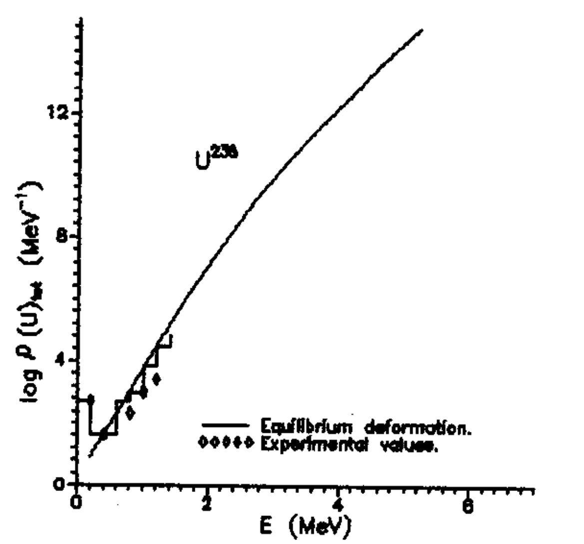

Figura 4. Level density for Uranium isotopes at eguilibrium deformation.

If averaged field parameters, pairing constants and rotational band parameters are averaged over a set of nuclei, a great amount of calculations could be reduce. For example, actinides could split in theree regions: lights, medium and heavy. As shown in Fig.1, this could be a good procedure. The use of fission cross sections as a test to study the used level density models is no a new procedure. On the contrary, it is enough applied. This method had allowed to study not only static problems but also dynamic problems of the atomic nuclei. Neverthless, the microscopic analysis of this problem only had been carried out in a few cases [4]. An important progress had been obtained taking the nuclear shape as Cassinian ovals. Furthermore, this is connected with the importance to consider quatum effects in the quasiclasic procedure to calculate the level density as a function of deformation.

III. CONCLUSIONS

The nuclear shape parameterization of Pashkevich [1,5] allows us to build a single particle spectra matrix to caltulate level density following the fission path without symmetry consideration. Thus, it is possible to make a systematic analysis of level density as a function of deformation.

The Combined Method is a good procedure of analysis of the behavior of the level density as a function of energy and deformation. The use of the Combined Method allows to **obtain** a good agreement with experimental data. This is in contrast with the phenomenological models.

A systematic of level density at equilibrium, first and second saddle point deformations for U^{238} were obtained. The level density was calculated for all range of deformations of the fission process.

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