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A. Fubini: COMPETITION BETWEEN NEUTRON EMISSION AND FISSION FOR U^{234}, U^{236}, Pu^{240} AND Pu^{242} COMPOUND NUCLEI.

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In recent years the insufficiency of the standard level density expression has been demonstrated[(1)] and it was found necessary to derive the compound level densities directly from the spectrum of the single particle levels[(2)]. This approach automatically accounts for the effect of nuclear shells and in addition it allows to take into account the effects of pairing in a natural way[(3)]. The problem of obtaining reliable level densities and thereby decay widths can therefore be solved if realistic single particle spectra for cases of interest are available.

This approach seems particularly useful in the actinide nuclei where the existence of a two peaked barrier is a result of the variation with deformation in the spacings of single particle levels near the Fermi surfaces[(4)]. It is now possible, knowing single particle spectra at the relevant deformations (first minimum, fist maximum, second minimum, second maximum) to calculate by a self consistent statistical model neutron, gamma and fission decay widths[(5, 6)].

One of the results of the previous calculation is the existence of a bumplike structure in the ratio Γ_n/Γ_f of the neutron emission to fission width at about 5 MeV above the neutron threshold. This structure is due to the different single particle densities relevant for the neutron and fission channels and depends on the height of the fission barrier B relative to the neutron binding energy S; however the calculated structure persits as long as $0 < S-B < 2$ MeV. Moreover a similar structure has been deduced for ^{241}Cm from the excitation function of the reaction ^{238}Pu(α, 2n) and ^{241}Am(p, 2n) and should show up with a large number of nuclei[6].

The aim of the present note is to study the existence of the expected bump for ^{234}U, ^{236}U, ^{240}Pu and ^{242}Pu. For all these nuclei S-B $\sim$ 700 keV[7] and therefore a bumplike structure is expected. The value of Γ_n/Γ_f has been deduced by the fast neutron cross sections for ^{233}U, ^{235}U, ^{239}Pu and ^{241}Pu. The ratio Γ_n/Γ_f is given by

$$\frac{\Gamma_n}{\Gamma_f} = \frac{\sigma(n,\gamma) + \sigma(n, n') + \sigma(n, n'f) + \sigma(n, 2n)}{\sigma(n, f)}$$

where $\sigma(n,\gamma)$, $\sigma(n, n')$, $\sigma(n, 2n)$, $\sigma(n, f)$ and $\sigma(n, n'f)$ are respectively capture, inelastic scattering, (n, 2n) first chance and second chance fission cross section.

The calculation has been performed using neutron cross sections below 10 MeV; the contribution from (n, 3n) and (n, 2f) reactions vanishes since, below this energy, such reaction channels are closed.

Values for the different cross sections are taken from Ref. (8, 9, 10, 11). Some problems arise in the evaluation of the ratio α of the second chance to total fission cross section as no measurement of α exists. The careful evaluation performed by Dawey[9] has been used for ^{235}U, ^{239}Pu and ^{241}Pu; for ^{233}U a similar evaluation has been performed. The Γ_n/Γ_f ratio is reported in Fig. 1; the dashed lines correspond to an estimate of Γ_n/Γ_f obtained assuming for α a value 10% higher than the previous ones.

We can observe that all the curve of Fig. 1 shows an increase between 1 and 5 MeV in agreement with the results of Ref. (5, 6). However no bumplike structure seems to be evident in any of the isotopes studied nor does such a structure seem compatible with a "reasonable"

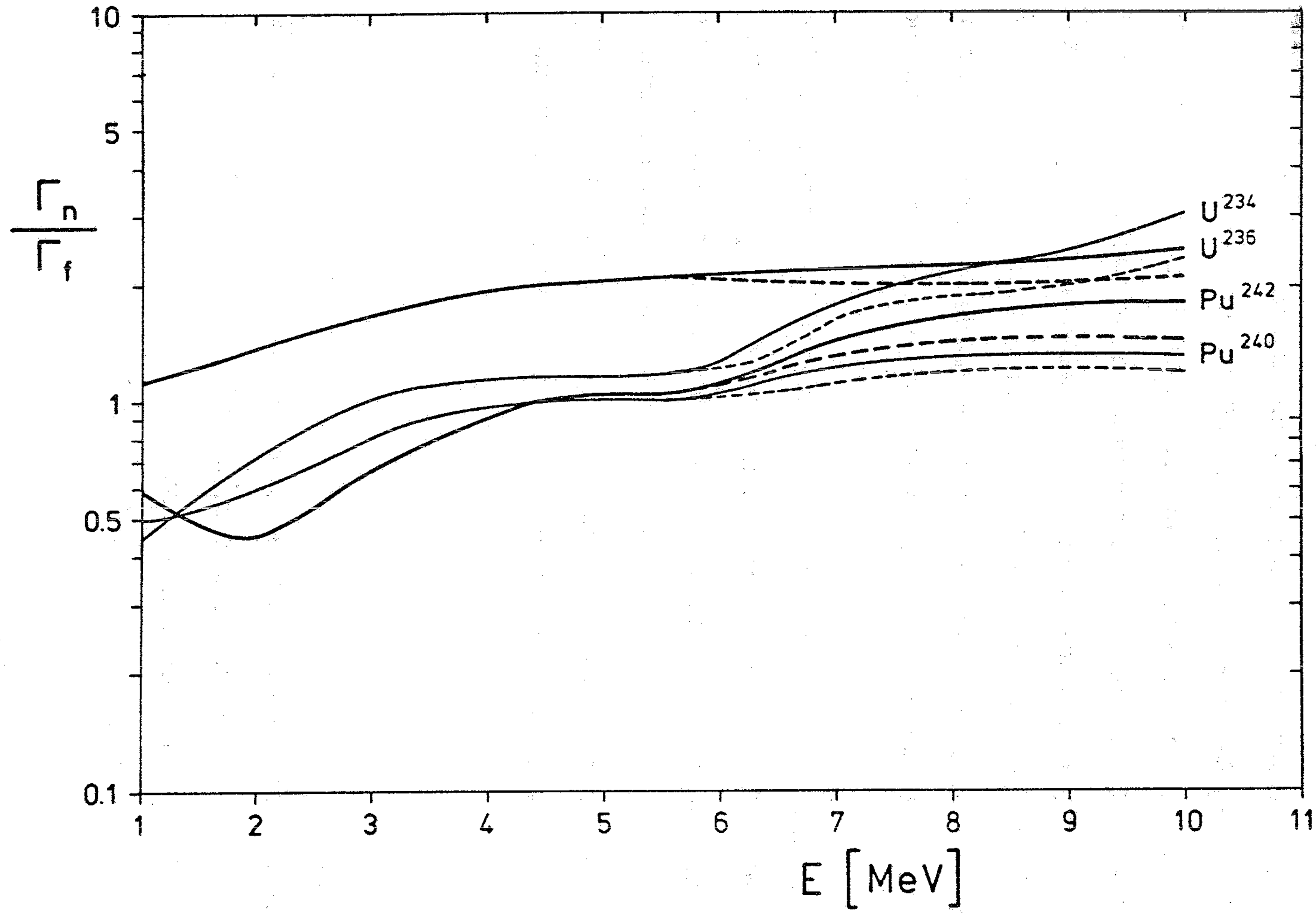

FIG. 1 - The quantity (Γ_n/Γ_f) calculated for the compound nuclei ^{234}U, ^{236}U, ^{240}Pu and ^{242}Pu as a function of the excitation energy. The dashed curves are obtained assuming a "reasonable" estimate of the error in the cross section used, see text.

estimate of the error in the neutron cross section used (dashed lines in Fig. 1).

The absence of the expected bumplike structure in the ratio of the two decay widths seems very puzzling and must be deeply investigated. It should be noted that in Ref. (5, 6) the gamma instabilities at the first saddle are not taken into account. The effect of an equilibrium gamma deformation at the first saddle would be to decrease the shell energy and the density of single particle states near the Fermi surface[12, 13, 14]. From this one would expect the calculated structure to be less prounounced. This effect seems negligible for Uranium isotopes but must be taken into account for Plutonium and heavier actinide nuclei.

Concluding more experimental and theoretical work seems necessary to clarify the absence of a structure in the Γ_n/Γ_f ratio for Uranium and Plutonium isotopes. On one hand it would be interesting to study if a bumplike structure is present in some other actinide nuclei; on the other hand a more realistic model taking into account the equilibrium gamma deformation at the first saddle can certainly be useful.

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REFERENCES. -

(1) - L. G. Moretto, S. G. Thompson, J. Routi and R. C. Gatti, Phys. Letters 38B, 471 (1972).

(2) - L. G. Moretto and R. Stella, Phys. Letters 32B, 558 (1970) ; L. G. Moretto, Phys. Letters 34B, 191 (1971) ; Nuclear Phys. A180, 337 (1972)

(3) - P. Decowski, W. Grochulsky, A. Marcinkowski, K. Siwek and Z. Wilhelmi, Nuclear Phys. A110, 129 (1968).

(4) - V. M. Strutinsky, Nuclear Phys. A95, 420 (1967) ; A122, 1 (1968); S. Bjørnholm and V. M. Strutinsky, Nuclear Phys. A136, 1 (1969).

(5) - H. C. Britt, M. Borsterli, J. R. Nix and J. L. Norton, Phys. Rev. C7, 801 (1973).

(6) - V. Metag, S. M. Lee, E. Liukkonen, G. Sletten, S. Bjørnholm and A. S. Jensen, Nuclear Phys. A213, 801 (1973).

(7) - H. C. Pauli, Phys. Reports 7C, 37 (1973) ; N. B. Gove and A. W. Wapstra, Nuclear Data Tables 11, 127 (1972).

(8) - I. Langner, J. J. Schmidt and D. Woll, KFK 750 (1968).

(9) - M. C. Drake, GA 7076 (1966).

(10) - W. C. Davey, Nuclear Sci. Eng. 32, 35 (1968).

(11) - W. C. Davey, Nuclear Sci. Eng. 44, 345 (1971).

(12) - V. V. Pashkevich, Nuclear Phys. A133, 400 (1969).

(13) - S. E. Larson, I. Ragnarson and S. G. Nilson, Phys. Letters 38B, 269 (1971).

(14) - H. Götz, H. C. Pauli and K. Junker, Phys. Letters 39B, 436 (1972).