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MASS DISTRIBUTION STRUCTURES AS A FUNCTION OF EXCITATION ENERGY OF THE ^{252}Cf SPONTANEOUS FISSION FRAGMENTS

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Abstract: Structures with a period of 5 amu were found in the fragment mass distributions in the ^{252}Cf spontaneous fission. The structures were observed for both the maximal and minimal fragment excitation energies as well as for the most asymmetric excitation energy partition between the fragments.

(^{252}Cf, spontaneous fission, neutron multiplicities, mass distributions, fragment excitation energy)

Partial multiplicities of neutrons emitted in spontaneous fission of ^{252}Cf by each of complementary fragments were simultaneously measured by means of a set-up comprising a combination of two large liquid scintillators. The fragment kinetic energies were also measured using silicon SB-detectors. Scintillator tanks were separated one from another by a combined shield to avoid their mutual influence /1/.

The initial two-dimensional distribution $P(\nu_1, \nu_2)$ of neutrons emitted by both complementary fragments were reconstructed as a function of the fragment mass A and total kinetic energy with corrections for background, time resolution and neutron detection efficiency introduced. Finite mass and energy resolution of the fragment registration was allowed for /2/.

To perform the $P(\nu_1, \nu_2)$ distribution unfolding a method of statistical regularization was employed using prior information on the initial distribution momenta /3/. The $P(\nu_1, \nu_2)$ distributions for various A were then converted into preneutron mass distributions of fragments emitted fixed numbers of neutrons - $Y_A(\nu_1, \nu_2)$. (Figures ν_1 and ν_2 in this case denote the numbers of neutrons emitted by a fragment with mass A and by its complement with mass 252 - A)

Fig. 1 presents such a mass distribution $Y_A(0,0)$ for the case when no neut-

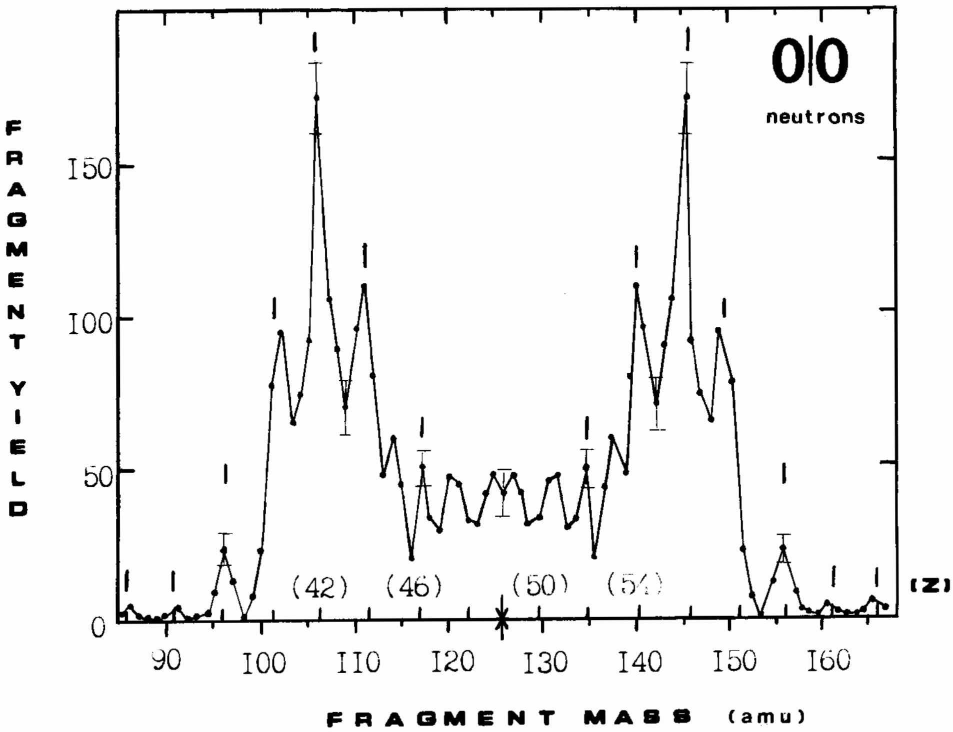

Fig.1 Preneutron mass distribution of the fission fragments in the case when no neutrons are emitted

rons are emitted. The main features of this distribution are a narrow peak at the mass A = 145 corresponding to the neutron deformed shell N = 88, and besides a pronounced structure with a period of about 5 amu. The peaks of this structure correspond to even fragment charges and are connected with the proton pairing effects. Values of the most probable charges as a function of fragment mass for the ^{252}Cf spontaneous fission were taken from /4/. Such shell and even--odd charge structures which are characteristic for cold compact fission and vanish with the fragment excitation increase are found in a number of works /5--8/ and can be regarded as established.

Fig.2 presents preneutron mass distributions for various combinations of (ν_A, ν_{252-A}) at ν_{total} = 2 and 6. It can be seen that the even-odd charge structure disappears at ν_{total} = 2 and at the same time a new shell peak arises at A = 132 together with that at A = 145, which corresponds to the double magic shell (Z=50, N=82). In the case of ν_{total} = 6 structures with the period of 5 amu appear again being the more pronounced the more asymmetric is excitation energy partition between the fragments (cf. the cases (3,3), (2,4), (1,5)).

Existence of structures similar to those at the cold compact fission at the fragment excitation energy over 60 MeV (which is equivalent to the emission of 6 neutrons or more) suggests that strongly deformed configurations can be "cold" in the scission point and the final fragment excitation energy is conditioned by their deformation energy.

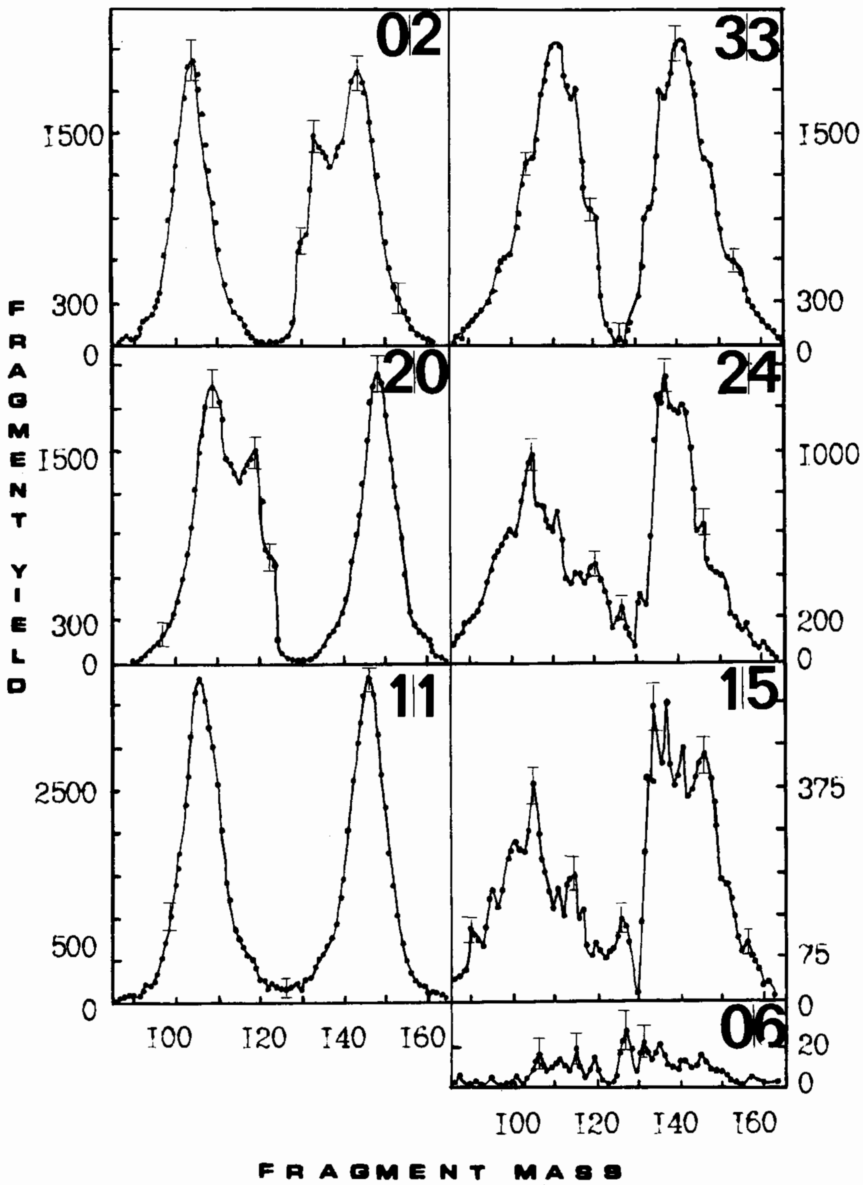

Fig.2 Partial fragment mass distribution in the cases when ν_{total} = 2 and ν_{total} = 6

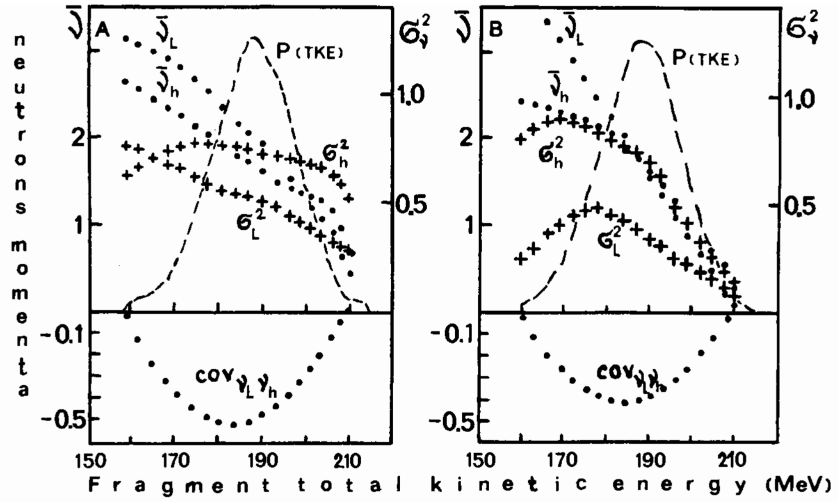

Fig.3 Momenta of multiplicity distributions of neutrons emitted by the complementary fragments with the mass A = 108-144 amu as a function of TKE
(a) data from this work (b) data from /10/

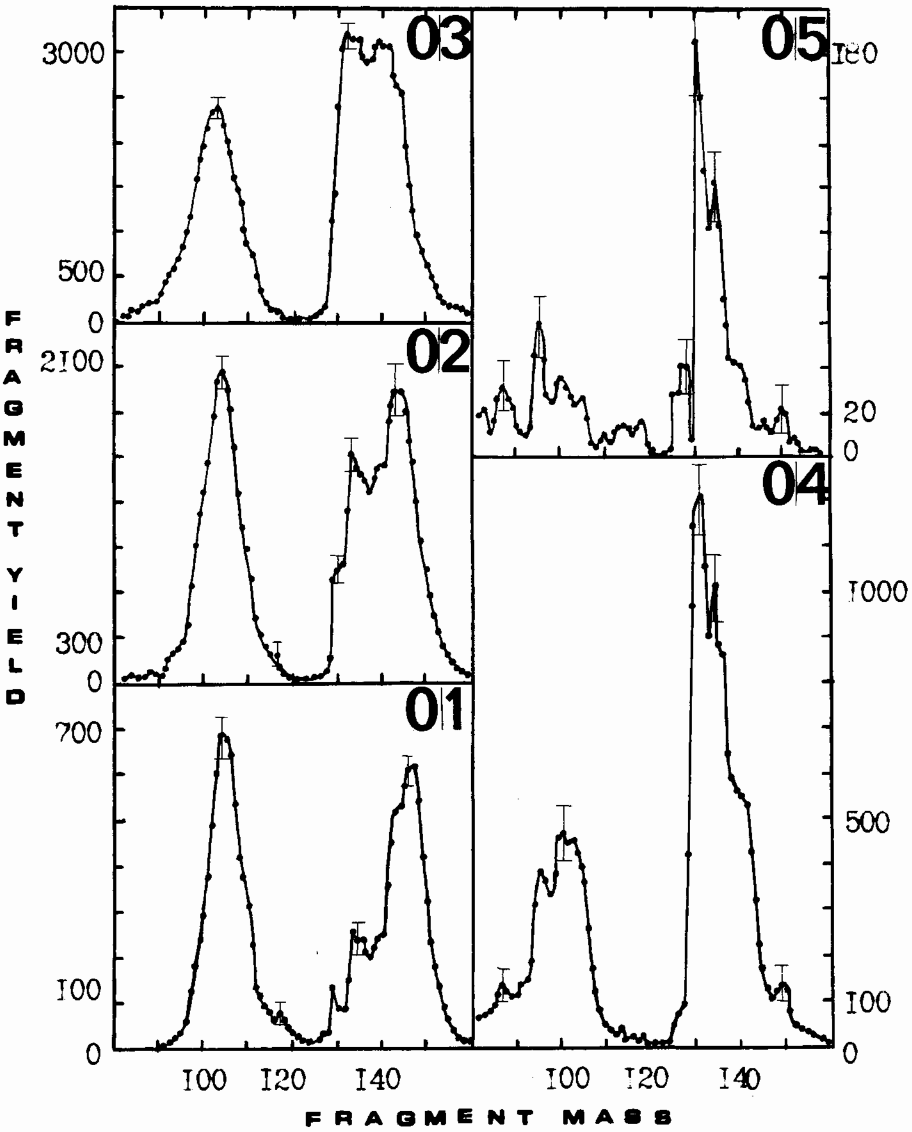

Fig.4 Preneutron fragment mass distributions for fixed compact configuration of one fragment (ν_1 = 0)

The possibility of strongly deformed cold fission was proposed by Hasse /9/ proceedings from the fact experimentally observed by Nifenecker et al. /10/ that covariance of the number of neutrons emitted by complementary fragments for fixed A is reduced to zero both at maximal and minimal values of TKE. A similar experimental fact was also obtained in our measurements (see Fig.3). According to Nifeneckers calculations /10/, the zero value of $Cov(\nu_1, \nu_2)$ corresponds to zero variance of the fragment excitation energy which means reducing to zero of free energy and consequently the intrinsic excitation in the scission point.

However, on the basis of our results it can be proposed that cold deformed fission is conditioned rather by deformation of one fragment than by deformation of the whole system. If one fixes a compact configuration of one fragment with mass A ($\nu_1 = 0$) and considers the behaviour of mass distributions with the other fragment deformation (i.e. the number of neutrons emitted) (Fig.4), it can be seen that at the very asymmetric deformation (for example, the case (0,4)) the even-odd charge structure appears at a rather modest deformation or excitation energy, that is at $\nu_{total} = 4$, which is close to $\bar{\nu}(^{252}Cf) = 3.75$.

The data obtained suggest that there can be two types of cold scission configurations:

1. With small deformations of both fragments and with minimal values of total excitation energy-cold compact fission;

2. With large fragment deformations and/or total excitation energies, being more pronounced as both the excitation energy and the asymmetry of its partition between fragments are higher.

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