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COLD FRAGMENTATION PROPERTIES: A CRUCIAL TEST OF THE DYNAMICS OF FISSION

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Communication présentée à : Conference on 50 Years with Nuclear Fission

Gaithersburg, MD (US)
26-28 Apr 1989

COLD FRAGMENTATION PROPERTIES :
A CRUCIAL TEST OF THE DYNAMICS OF FISSION

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Summary

Very often in the literature, the descent from saddle to scission in the low energy fission of even-even actinides is cited as an example of a process in which a large scale collective rearrangement of nuclear matter is realized without (or with a very low) dissipation of the collective kinetic energy into quasi-particle excitation. As a matter of fact, a systematic and strong even-odd effect in fragment charge distributions as well as a fine structure in mass distributions have been interpreted as an indication that the superfluidity of these fissionning systems (known to be completely paired at the saddle point) should be, to a large extent, preserved up to scission[1]. We present here a set of experimental results concerning the thermal neutron induced fission of ^{233}U, ^{235}U, ^{239}Pu and the spontaneous fission of ^{252}Cf, which are in contradiction with such an interpretation.

We have measured the yields of individual **primary** fragments in the **"cold fragmentation region"** (namely the region of high kinetic energy fission events giving birth to two fragments so weakly excited that neither can emit any prompt neutrons, so that the primary masses are directly observed). For these measurements, we have used a set-up of two high resolution Frisch gridded ionisation chambers placed on both sides of an exceedingly thin target. The mass and charge of the fragments are directly deduced from the correlated measurement of their kinetic energies and their ranges in the gas[2].

Figure 1 shows a typical example of the light fragment mass distribution obtained in a window placed at a high value of the kinetic energy.

One observes that :

- The mass separation is total.
- The cold fragmentation events cover almost the entire mass range (for comparison, the global mass distribution is also shown).
- The well-known fine structure is nicely observed.
- There is no systematic odd-even effect in the mass yield ; this is true even for the highest values of the kinetic energy.

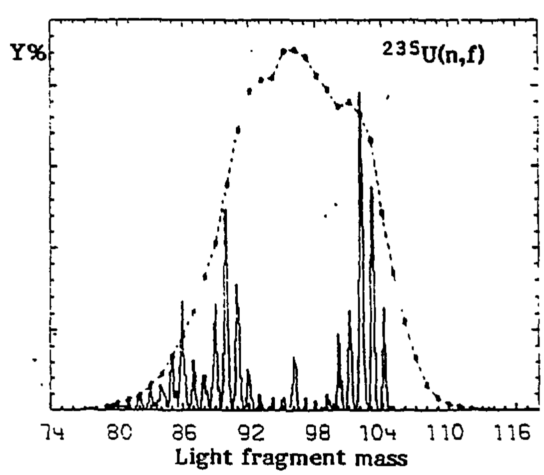

Fig. 1

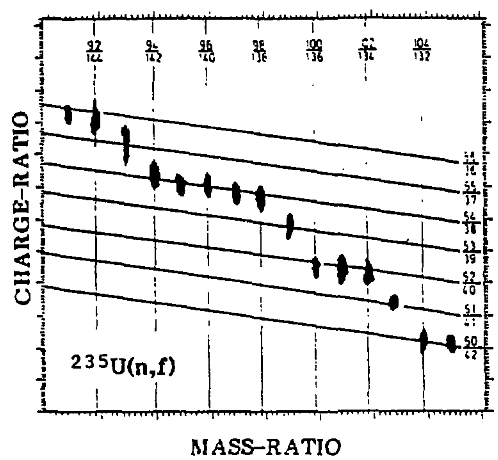

Fig. 2

For these cold fragmentation events, properly selected in mass and kinetic energy, the range-ratio distribution reflects the charge-ratio distribution[2]. Figure 2 shows a plot of the charge-ratio versus the mass-ratio for events selected in a window placed, for each mass-ratio, on the highest values of the kinetic energy.

This figure shows that the charge identification is quite good ; for each mass-ratio only one charge-ratio is observed, the one which makes maximum the Q-value. Nevertheless there are some interesting exceptions, which are clearly related to cases in which one of the two fragments has an oblate shape in its ground state (from the Möller-Nix tables). The explanation of this "anomaly" is quite evident : in order that the Coulomb repulsion energy do not exceed the Q-value, the fragments at scission have to be deformed and the most compact scission configurations select fragment pairs in which one of the two has a prolate shape.

Another interesting piece of information can also be obtained from figure 2 : it concerns the odd-even effect in the charge distribution. This effect appears to be related to the integration on the mass distribution and not at all to a preponderance of even-even fragments.

In summary, our analysis of the set of data for the four systems studied leads us to conclusions which are clearly in favour of a statistical competition between the different modes of fragmentation.

First, the similarity of the cold fragmentation properties between the induced and spontaneous fission suggests that the final state of the process is independant of the initial conditions.

Secondly, all the energetically allowed fragmentations are effectively observed.

Thirdly, the relative fragment yields (for a given excitation energy window) do not show any preference for fragmentations into two even-even nuclei ; actually fragmentations into odd or odd-odd nuclei are slightly favoured as expected from level density considerations.

Finally, the odd-even effect in the charge distributions and the fine structure in the mass distributions which have been used previously as a basis for the preservation of superfluidity during the fission process, have been reinterpreted : they appear to reflect, trivially, the systematics of the Q-values.

Références

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