Neutron emission during acceleration of ^{252}Cf fission fragments

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Abstract

We investigate neutron emission during acceleration of fission fragments in the process of spontaneous fission of ^{252}Cf. Experimental angular and energy distributions of neutrons are compared with the results of calculations of neutron evaporation during fragment acceleration.

The probability of the neutron emission during fission fragment acceleration is determined by the correlation of the time of neutron emission (t_n) and of the time of the fragment acceleration (t_a),. Eismont was the first who discussed this problem [1]. He found that this effect could be important espessially in the case of the fission of the highexcited nuclei. The role of the neutron emission during acceleration of the ^{252}Cf spontaneously fission was determined in the ref. [2-5]. In these works it was obtained, that even for spontaneous fission the effect investigated could be rather large. However theoretical predictions of the emission during fragment acceleration differ from each other by the value of the contribution of this process, both because of the simplification of the calculations and of the use of the different input parameters. At this time the experimental investigation of this effect is very interesting and valuable not only from point of view of the understanding of fission neutron emission mechanism, but also for determination of the life-time of the excited fission fragments.

In this work the search of neutron emission during fragment acceleration at ^{252}Cf spontaneous fission was carried out by comparison of experimental neutron angular and energy distributions [6,7] with the results of the calculations.

Experimental set-up and method of measurements of neutron energies and fragments characteristics were described in the ref. [6,7]. Fragment energies were determined by use of the semiconducter detectors, and their velocities- by fragment detectors on the base of the microchannel plates (MCP). The construction of detecting system allowed to carry on the measurements simulteneously both in narrow solid angle and in the

angle 2π This gave a possibility to measure the efficiency of the neutron detector constanly in the course of the experiment.

The results of the angular distribution measurements of neutrons of various energies [6,7] showed that the deviations from standard model of neutron evaporation from fully accelerated fragments (MNEFAF) were observed for neutrons of low energies in the region of the low angles, and for neutrons of medium and high energies in the region of the big angles (near 90). In fig.1 the deviations from MNEFAF are hown for various masses and total kinetic energies (energy region above 0.7 MeV).

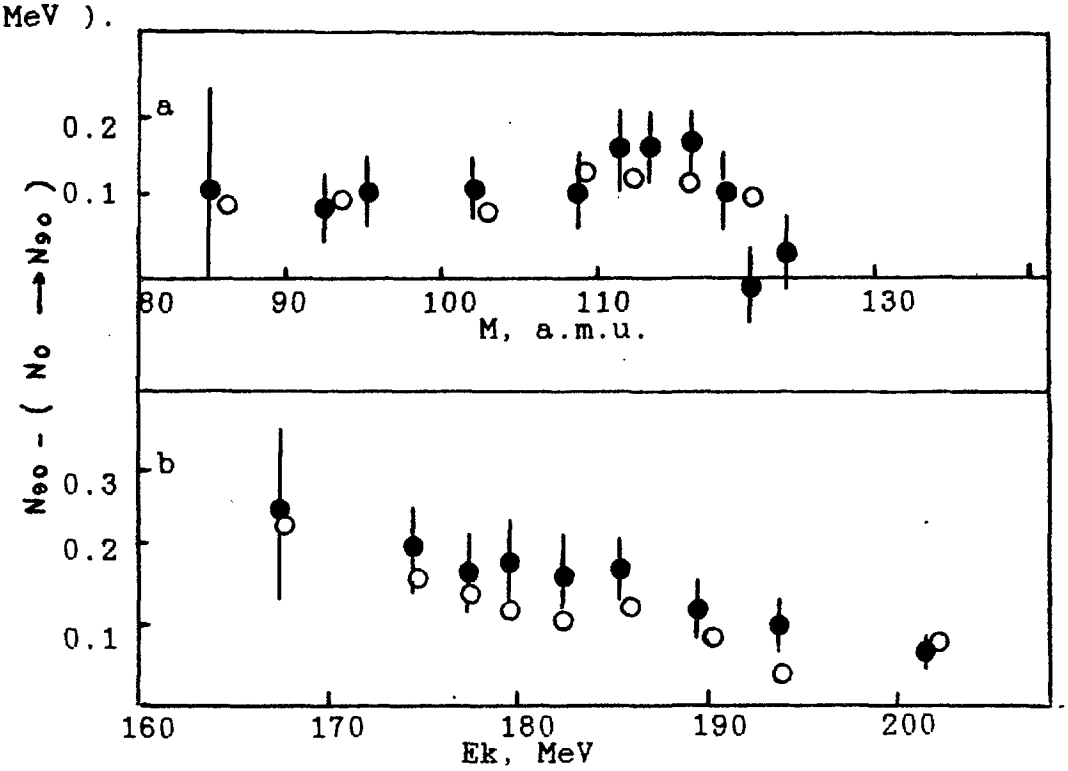

FIG.1 The difference of neutron number at the angle 90° in dependence on mass (a) and total kinetic energy (Ek) (b)

- ● - directy measured one at the angle 90 (N_{90}) and calculated from the data for the angle 0° ($N_0 \rightarrow N''_{90}$) without taking into account of the neutron emission during fragment acceleration.
- O - calculated from the data for the angle 0 ($N_0 \rightarrow N''_{90}$) with taking into account of the neutron emission during fragment acceleration and without this effect.

For clearing up the reason of the deviation of the data from standard model MNEFAF, we carried out the calculations of neutron evaporation during fragment acceleration. The calculation

was made supposing that the time of dissipation of collective fragment energy ($t_д$) essentially less than the acceleration time $t_д << t_а$. Experimental evidence for that was given in the work [6].

We considered the acceleration of the two rigid spherial fragments in mutual Coulomb fields. In fig. 2 the dependence of fragment velocity on acceleration time after scission point is shown.

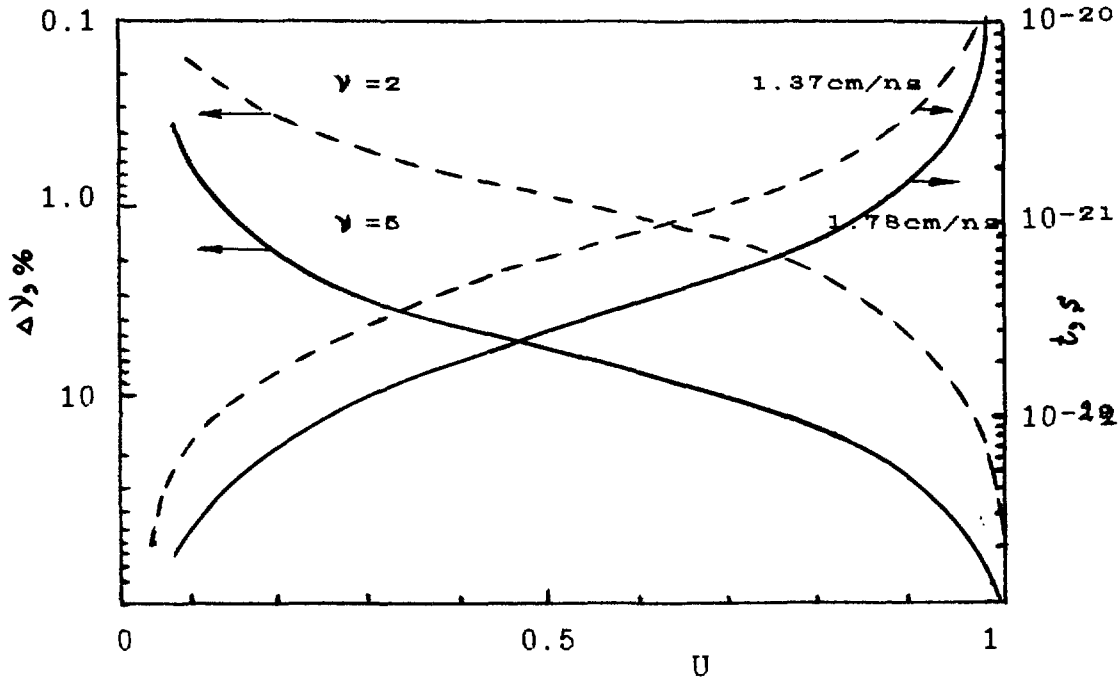

FIG.2 The dependence of fragment velocity $U=(V/V_{\infty})$ on the acceleration time t.
The share of neutrons ($\Delta\nu$), emitted during the time t.

At the calculation of the number of emitted neutrons the exponential decay of excited fragments, continuous character of the emission, characteristics of the neutron cascade were taken into account. We used experimental values of fragment temperatures. As these values are averaged over the cascades, so on their base the temperatures on various stages of the cascade were calculated. The parameters of level density were determined in accordance to the results of the ref.[8]. In fig.2 the results of the statistical calculations of the contribution of neutrons, evaporated during acceleration process for the cases of emission of two and five neutrons from fragment are shown.

From fig.2 it is seen, that though this effect is not large, but it is necessary to take it into account at the analysis of the experimental data. In fig.3 the ratio of the average num-

ber of neutrons (for fragment mass M = 110 a.m.u.), directly measured at the angle 90° to calculated one from the experimental data for angle 0° (N_0 --> N_{90})is presented. In this figure it the ratio the neutron numbers (N_{90} and N_0 --> N_{90}), calculated with taking into account of the neutron emission during acceleration (for the same mass of fragment) and without it is shown. The neutron number was determined only for energy range 0.7-10 MeV for excluding of low-energy component. From fig.3 it is seen, that in the fragment exitation energy region, corresponding to the emission from one up to three neutrons, the anisotropy of neutrons N_0/N_{90} equals the calculation results with taking in account of the neutron emission during acceleration.

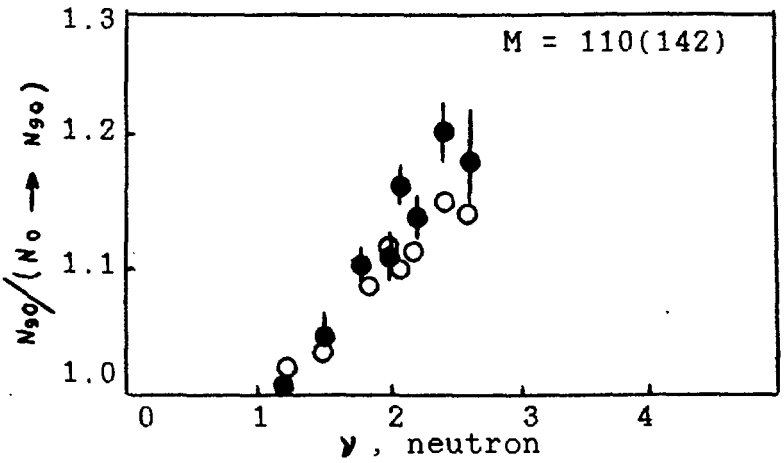

FIG.3 The ratio of the number of neutrons (energy range 0.7-10 MeV) in the l.s. for M=110 (142) a.m.u.

● - measured at the angle 90° to that calculated from the data at φ=0° without taking into account of the neutron emission during fragment acceleration.

○ - calculated from the data at φ= 0° with taking into account of the emission during acceleration process to the one calculated from φ=0° without this effect.

The data, given in fig.1, for neutrons emitted by fragments of various mass and total kinetic energies show the deviation (in average 2%) from the neutron emission from the fully accelerated fragments. The calculations with the incorporation the emission during acceleration, as it is seen from fig.1, agree with the experimental data both by the absolute values and by the character of the dependence on M and Ek. Consequently at the taking into account of the effect considered the various experimental angular and energy dependences for ^{252}Cf spontaneous fission can be explained. It is quite possible the

deviations, connected with low-energy component are determined by nonequilibrium emission of neutrons at the time close to scission moment.

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