*Краткие сообщения ОИЯИ № 2[59]-93* *JINR Rapid Communications No.2[59]-93*
УДК 539.17+539.143

# FINE STRUCTURE IN COLD FISSION MASS DISTRIBUTION OF $^{249}$Cf($n_{th}$, $f$) REACTION

Yu.V.Pyatkov*, R.A.Shekhmametiev*, A.I.Slyusarenko*

The first results on cold fission for $^{249}$Cf($n_{th}$,$f$) reaction are presented. The fine structure in cold fission mass distributions for $^{249}$Cf($n_{th}$,$f$) drastically differs from the cold fission data for $^{252}$Cf($s$,$f$) reaction. This fact is explained within the framework of the suggested cluster concept of the multivalley fission model.

The investigation has been performed at the Laboratory of Nuclear Reactions, JINR.

# Тонкая структура массовых распределений продуктов холодной фрагментации $^{249}$Cf($n_{th}$,$f$)

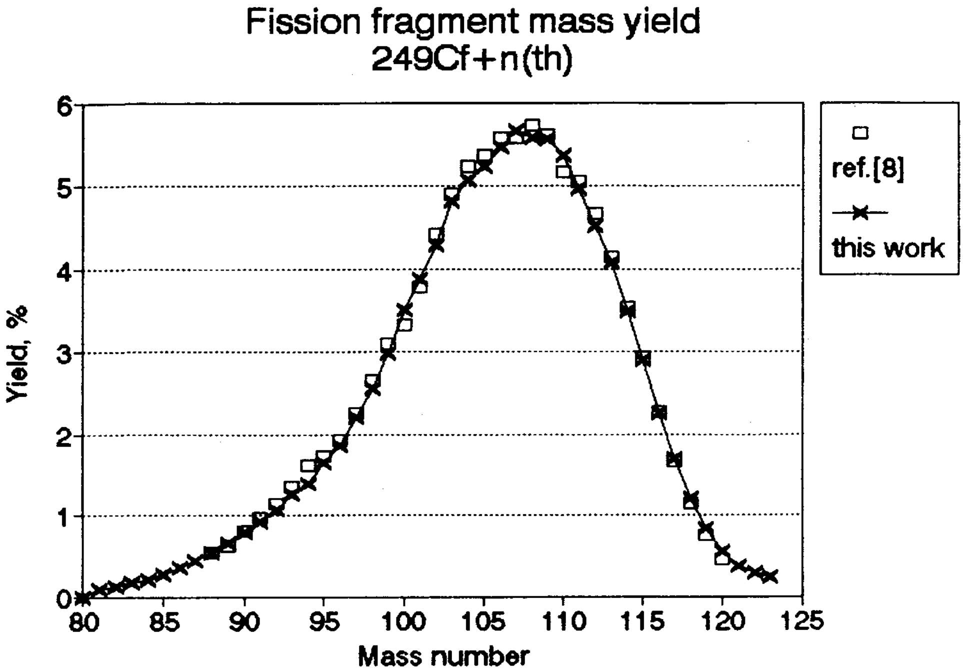
Ю.В.Пятков*, Р.А.Шехмаметьев*, А.И.Слюсаренко*

Представлены впервые полученные результаты по холодному делению в реакции $^{249}$Cf($n_{th}$,$f$). Тонкая структура массовых распределений в холодной области для реакций $^{249}$Cf($n_{th}$,$f$) и $^{252}$Cf($s$,$f$) существенно различна. Этот факт обсуждается в рамках кластерной концепции многодолинной модели деления.

Работа выполнена в Лаборатории ядерных реакций ОИЯИ.

Understanding of the fact, that it is not possible to describe the process of fission making conclusions only from gross structures, maybe, is one of the main results of low energy fission investigation of the last years. This conclusion, to a great extent,based on the calculations and experiments, which demonstrate the multivalley character of the potential-energy landscape and fine structures in mass distributions of «cold» fission fragments. «Cold» fission is a rare fission mode, fission fragments being born with extremely low intrinsic excitation energy. Cold fission is related to the boundary parts of the phase-space [1], to the beginning and ending of the fission process [2,3]. That is why cold fission data are the necessary and rigid test for energy fission model. For nearly ten years of cold fission investigation a great amount of data was collected on its dependence on fissility, excitation energy, etc.

* Moscow Engineering Physics Institute


Fission fragment mass yield
249Cf+n(th)
Yield, %
Mass number
ref.[8]
this work

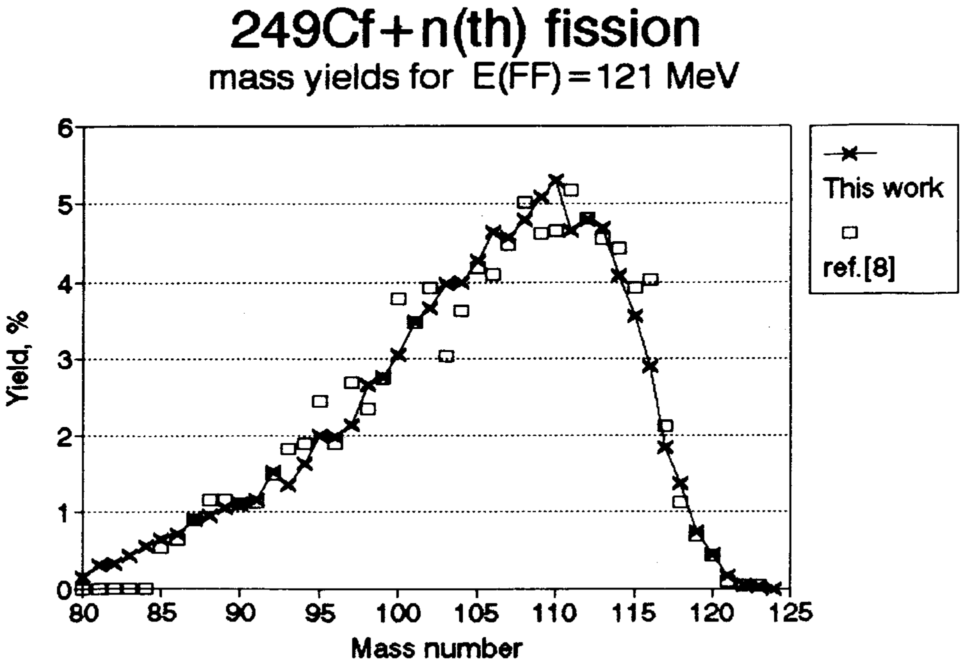

249Cf+n(th) fission
mass yields for E(FF)=121 MeV
Yield, %
Mass number
This work
ref.[8]

Fig.1

The comparison of spontaneous vs induced fission for one and the same system can considerably enlarge the experimental data base. The deformation of the compound at the starting point of the descent is varied in this case. This parameter influence on cold fission is not studied yet.

One possible pair for such investigation can be $^{249}$Cf($n_{th}$,$f$) and $^{250}$Cf($s$,$f$) reactions. Results on cold fission for the first system are presented here.

The measurements were performed on the time-of-flight spectrometer of unslowed fission products [4] at the research MEPHI reactor. The energy measurement was made with a gas ionization chamber [5]. The energy calibration procedure was described in [6]. It is based on the well-known Schmitt parameterization for energy-amplitude-mass dependence. Coefficients for the formula were obtained as a result of the fitting procedure of the experimental $^{235}$U($n_{th}$,$f$) mass distribution to the tabulated one. The Californium target was produced by electrodepositing $^{249}$Cf onto the stainless steel backing, the target thickness was about 20 $\mu$g/cm$^2$. The overall statistics collected in the experiment is $6 \cdot 10^6$ events. The integral mass yield distribution of fission fragments (FF) as well as the mass distibutions of FF with fixed kinetic energies are in good agreement with the previous results [7,8] (fig.1).

The greater statistics, obtained in our experiment, gives the possibility of studying mass yields in the energy region with clearly observed fine structure (fig.2.). The increased yield near the mass split 115/135 is clearly visible in all distributions for fixed kinetic energies $E = 124$ —128 MeV where fine structure is observed.

The fine structure in cold fission mass distributions for $^{249}Cf(n_{th},f)$ drastically differs from the cold fission data for $^{252}$Cf($s$,$f$) [9], used because of the data absence for $^{250}$Cf($s$,$f$).

Mass distributions of the $^{250}$Cf($s$,$f$) reaction for energy bins of the total kinetic energy TKE = ($\overline{Q}$ − 5) MeV and TKE = ($\overline{Q}$ − 7) MeV, where $\overline{Q}$ is the average energy release for every mass split, are presented in fig.3. The value $\overline{Q}$ was obtained in ref. [9] by linear interpolation of the $Q_{max}$ dependence vs mass. Our data for $^{249}$Cf($n_{th}$,$f$) reaction, presented in fig.3, were obtained for energy bings (fig.3a) TKE = ($\overline{Q}$ − 5) MeV and (fig.3b) TKE = ($\overline{Q}$ − 7) MeV bearing in mind negligible between $Q_{max}$ and $\overline{Q}$ values.

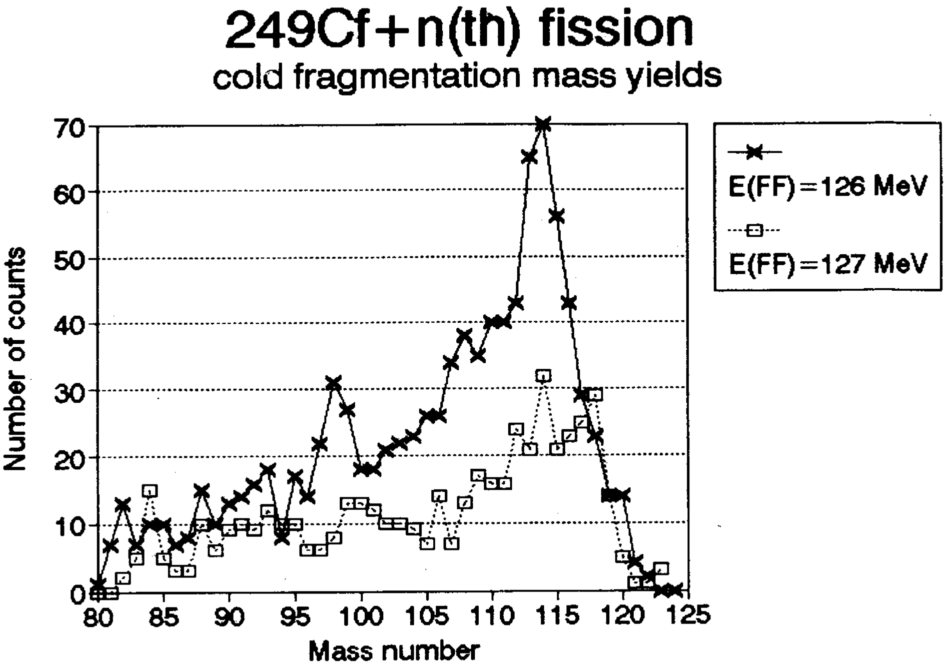


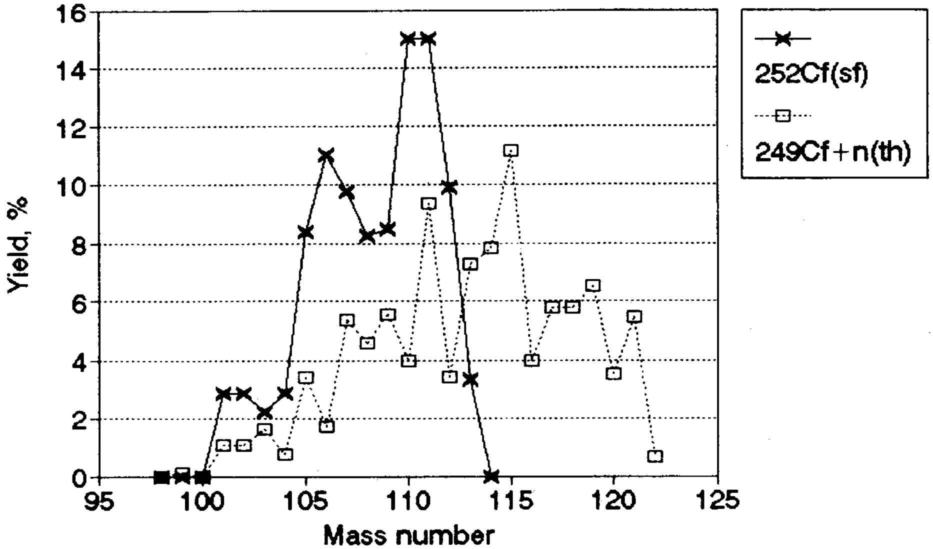

Fig.2

Presented in fug.3 spectra comparison gives the following. In both mass distributions for $^{250}Cf^*$ and $^{252}Cf$ reactions the yield of *FF* with neutron number close to the deformed shell $N = 88$ is visible, just as in the $^{229}Th(n_{th},f)$ reaction [10,11].

As it was mentioned by authors [10,11] it is difficult to explain the presence of the deformed shell N = 88 ($\beta$ = 0.65) in cold fission because of the necessity for both fragments to be formed in their ground state, as it follows from the energy balance of the reaction. One more peculiarity is the difference in *FF* yields in the mass region 132—138 amu. In the $^{252}Cf(s,f)$ reaction yields associated with the spheric shell N = 82 are suppressed to a great extent.

It seems that all these facts can be explained within the framework of the suggested cluster concept of the multivalley fission model [12]. This model suggests the following dynamics of the fission process. In the process of the irreversible elongation of the compound, at the elongation equal to the sum of diameters of $^{129}_{50}Sn$ and $^{84}_{34}Se$ nuclei with certain probability clusterization can take place. This point can be considered as the bifurcation

Spontaneous vs.induced fission
cold fragmentation yields Q-5 MeV bar




Spontaneous vs.induced fission
cold fragmentation yields Q-7 MeV bar

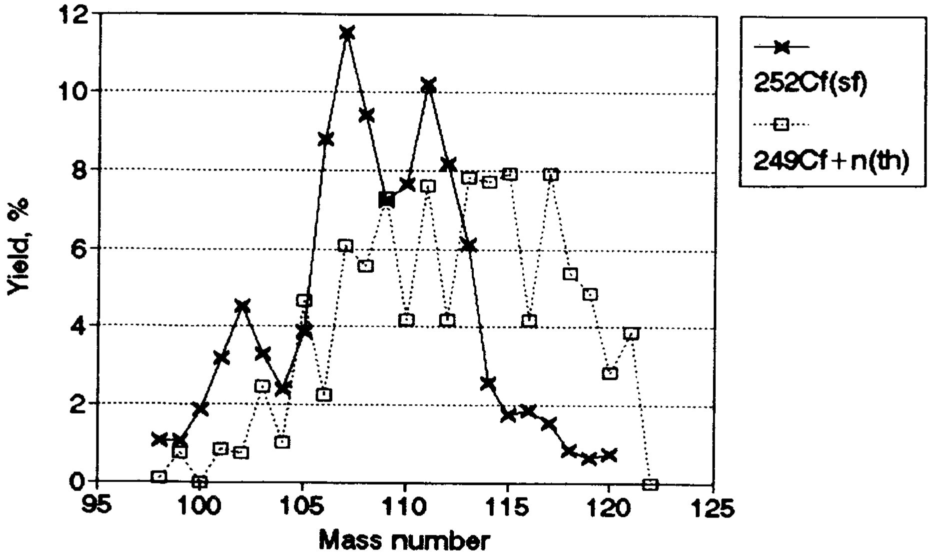



Fig.3

point and the valley can be called as Sn-valley. The free remaining nucleons, equivalent to $^{37}_{14}$Si (for $^{250}$Cf*-reaction), form the neck betweem two big clusters. If clusterization does not take place, the elongation of $^{250}$Cf compound, described by the shell-model wave function, continues. Then during the following elongation the clasterization with $^{142}_{54}$Xe as one of the by-clusters becomes possible, or, in other words, bifurcation to the Xe-valley, and so on. In the case of Sn- and Se-clusterization, nucleons equivalent to $^{37}_{14}$Si do not form it until big clusters are distanced enough to make appearance of Si cluster between them possible from the energy and geometrical factors. Up to this moment 14 protons and 23 neutrons form a kind of a plasma consisting of light He-clusters, pairs, etc.

The cold compact fragmentation is realized only in Sn-valley as a subbarier tunneling to the divided fragments valley. In this case cold fragments are two big spherical clusters surrounded by light ones from plasma. This cold fission mechanism will always produce fragments with small deformation.

The fragments with A = 142 a.m.u., observed in cold fission, are born in their ground state and connected with Sn-valley. The suppression of mass yields around mass 134 a.m.u. in cold fission of $^{252}$Cf($s,f$) is explained by more suitable elongation of the compound at the exit point from the barrier to form deformed in their ground state fragments 111/141 a.m.u., so the affection of cold fission probability by the spectroscopic factor being observed.

In this paper we present only preliminary results on the $^{250}$Cf fission measurements. Elaborated conclusions can be made only after direct $^{249}$Cf($n_{th},f$) and $^{250}$Cf($sf$) reactions comparison, the experiment with $^{250}$Cf($sf$) now being in progress.


## Acknowledgment

We would like to thank B.Pustylnik, Yu.Muzychka and A.Rusanov for stimulating discussions and interest towards this work.

This work has been funded by Russion Federation Ministry of Science, High Education and Technical Policy, under the grant number 2-62-3-15.


## References


1. Marten H. — Proceedings of the Int. Workshop on Dynamical Aspects of Nuclear Fission. Smolenice, CSFR, 1991, p.32.

2. Gönnenwein F., Kaufmann J., Maleenkopf W. et al. — Ibid.p10.
3. Berger J.F., Girod M., Gorny D. — Nucl. Phys., 1984, A428, p.23C.
4. Alexandrov A.A., Alexandrova I.A., Ermolenko A.V. et. al. — Nucl. Instr. and Meth., 1991, A303, p.323.
5. Podshibyakin S., Pyatkov Yu., Slyusarenko A. et. al.— Experimental Methods in Applied and Fundamental Nuclear Physics, Moscow, 1991, p.19.
6. Alexandrov A.A., Alexandrova I.A., Podshibyakin S.L. et. al. — Nucl. Instr. and Meth., 1991, A302, p.478.
7. Djebara M., Asghar M., Bocquet J.P. et. al. — Nucl. Phys., 1988, A496, p.346.
8. Aker E. — Dissertation. Karlsrue. 1987.
9. Knitter H.H., Hambsch F.-J., Budz-Jorgensen C. — Nucl. Phys., 1992, 536, N 2, p.221.
10. Boucheneb N., Geltenbort P., Asghar M. et. al. — Nucl. Phys., 1989, A502, p.261.
11. Asghar M., Gaitucoli F., Leroux B. et. al. — Nucl. Phys. 1982, A373, p.225.
12. Pyatkov Yu.V., Shekhmametiev R.A., Slyusarenko A.I., Taranenko A.V. — Proceedings of the Int. Conf. on Nuclear Structure and Nuclear Reactions at Low and Intermediate Energies. Dubna, 1991, in press.

Received on March 4, 1993.