EFFECTS OF THE THIRD MINIMUM ON THE FISSION CHARACTERISTICS IN THE ACTINIDE REGION*

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(Received October 29, 2002)

The HD states were excited in the ^{232}Th(n,f) reaction. By studying the mass and TKE distributions in the ^{232}Th(n,f) reaction, some effect of the HD states was observed in the case of cold fission. The obtained data can be understood by assuming a predicted heavy clusterization.

PACS numbers: 25.85.–w, 25.85.Ec, 27.90.+b

1. Introduction

Nuclear fission is usually a very complicated process involving large scale collective motion of nucleons. Full theoretical understanding of this process is still missing [1]. It would be desirable to prepare experimentally a simpler nuclear state which is already close to the scission point and study its fission properties.

These states could be the hyper-deformed states, which were predicted more than twenty years ago by Möller *et al.*, [2] in the actinide region and identified experimentally by Blons *et al.*, [3,4] in thorium isotopes and Krasznahorkay *et al.*, [5, 6] in uranium ones.

* Presented at the XXXVII Zakopane School of Physics "Trends in Nuclear Physics", Zakopane, Poland, September 3–10, 2002.

An interesting observation in the shell model calculations is that the shape of ^{232}Th nucleus in the third minimum looks like a superposition of the shapes of a spherical heavy fragment around ^{132}Sn and a well-deformed lighter fragment around ^{100}Zr [7]. Based on this, Shneidman *et al.*, [8] described the HD states as molecular-like touching dinuclear configurations. The nice agreement between the experimentally determined moments of inertia and the calculated ones also supports the above configuration. Such a clustering is a dramatic manifestation of the nuclear shell structure at very large elongations.

The aim of our investigations was to excite HD states in the ^{232}Th(n,f) reaction [3] and study the possible effects of these states on the fission characteristics.

2. Experiment

In order to study the effects of the predicted clusterization [7,8], the mass and TKE distribution of the fission fragments were investigated from the ^{232}Th(n,f) reaction. The monoenergetic fast neutron beam was produced in the ^{7}Li(p,n) reaction at $E_p = 3.2$–3.425 MeV proton energies. The Van de Graaff accelerator of Forschungszentrum Karlsruhe produced the 50 μA proton beam bombarding a 200 μg/cm^2 metallic Li target providing an energy resolution of better than 16 keV at the position of the ^{232}Th target. The average neutron flux at the Th target was $\sim 1.8 \times 10^6$ neutron/cm^{2}s. The kinetic energy of the fission fragments was measured in a twin ionization chamber constructed in Debrecen. The parameters were similar to those published by Budtz-Jorgensen [9]. The ^{232}ThO$_2$ target (12.6 cm^2 $\times$ 100μg/cm^2) was placed into the center plane of this detector, which was filled with 90% Ar+10% CH$_4$ gas mixture at 1 atm pressure.

3. Results

For the binary fission events the two complementary fragments were recorded in coincidence in the two chambers. By measuring the kinetic energy of the fragments the total kinetic energy (TKE) and the mass distribution were deduced. The TKE as a function of the mass distribution of the fission fragments is shown in Fig. 1.

A definite sharpening of the mass distribution at higher TKE values is clearly visible. The lighter fragment is centered around $A = 100$, the heavier is centered around $A = 132$. Selecting different conditions in the TKE of the fragments, the mass distribution was analyzed and fitted by two Gaussians with equal width and hight. The σ is shown in Fig. 2(a) as a function of the bombarding neutron energy with different conditions in TKE.

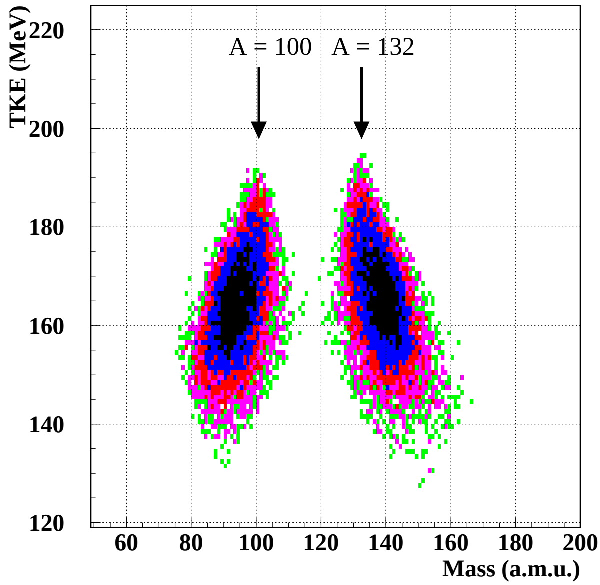

Fig. 1. TKE as a function of the mass distribution of the fission fragments.

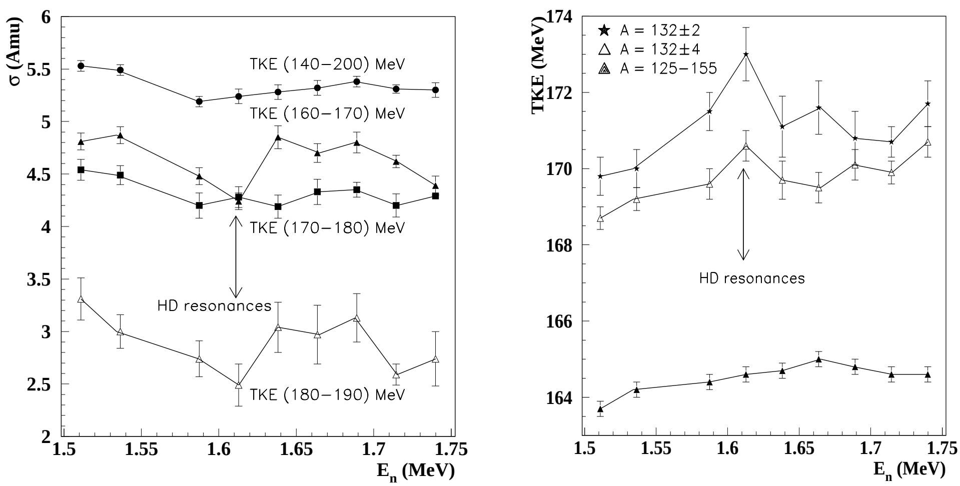

Fig. 2. (a) The width σ of the mass distribution as a function of the bombarding neutron energy with different conditions applied to the TKE. (b) TKE of the fission fragments as a function of the neutron energy calculated for different mass-number cuts around $A = 132$. The vertical arrows indicate the place of HD resonance observed by Blons *et al.*, at 1.6 MeV neutron energy [3].

In the case of the whole TKE range, the σ decreases at the resonance energy, but the change is only a few percent. After selecting fragments with higher TKE, the fragments are less excited, the fission is getting colder, the mass distribution is getting narrower. In the case of the cold fission, the fragments have high TKE, the σ is decreasing as a function of bombarding energy and the smallest is at the resonance energy.

The mean value of the TKE as a function of the bombarding energy is shown in Fig. 2(b). The average value of the TKE for the whole mass region ($A = 125$–155) is about 164 MeV, which is much smaller than the available energy calculated from the Q values. This means that the fragments are highly excited even at the resonance energy. Selecting a specific mass region around $A = 132$, the TKE increases. Choosing a narrow region around $A = 132$, at the resonance energy the TKE is much larger, indicating that the fragments are less excited.

4. Discussion and conclusion

It seems that hot fission always dominates the fission process and blurres the possible effects of the HD states on the mass distribution. However, there is tentative evidence for the observation of the effect of HD states for cold fission events. These effects can be understood by assuming a dinuclear cluster configuration for these states.

This work has been supported by the Hungarian Fund for Science Research (OTKA) No. N32570 and No. T038404 and it has been performed as part of the research program of the Stichting voor Fundamenteel Onderzoek der Materie (FOM) with financial support from the Nederlandse Organisatie voor Wetenschapelijk Onderzoek (NWO).

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