Fission Fragment Mass Distribution in the Third Minimum of Actinide Nuclei ◇

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The presence of a (hyperdeformed, $\beta_2 \sim 0.8$) third well in the fission barrier of light actinides is already well-known [2]. However, from the rotational bands only the moment of inertia and the reflection asymmetry is known for the nuclear shape in the third well. Theoretical predictions expect an octupole-type nuclear shape consisting of a superposition of a nearly-spherical nucleus around the doubly-magic nucleus ^{132}Sn and a well-deformed fragment from the neutron-rich A∼100 region [3]. This configuration should manifest itself in a highly characteristic fission fragment mass distribution, since the transition path from the third minimum to scission is rather short.
In a first experiment, the reaction ^{235}U(d,pf)^{236}U was used at the ATOMKI-Institute at Debrecen to measure the fission fragment masses via their time-of-flight. The fission fragments were detected in two position sensitive parallel plate detectors, while the energy of the protons was measured in an array of four Si-detectors. The resulting coincident proton energy spectrum is shown in the upper panel of fig. 1. The dark shaded regions have been identified as resonances in the third well already in a previous work [1]. An analysis of the fission fragment mass distribution gated on these hyperdeformed resonances in comparison with neighbouring off-resonance excitation energy regions is shown in the bottom panel of fig. 1.

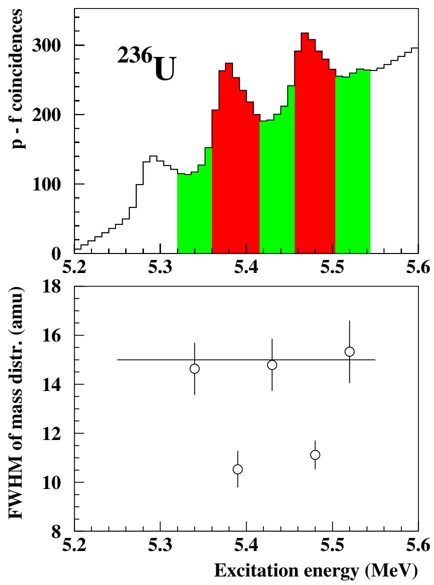

Fig. 1: Upper panel: Excitation energy spectrum from coincidences between protons and fission fragments measured via ^{235}U(d,pf)^{236}U. The dark shadowed energy regions mark resonances in the third well [1]. The light shadowed regions were used for off-resonance comparison. Bottom panel: Half-width of the fission fragment mass distributions obtained for the excitation energy regions marked in the upper panel.

A significant narrowing of the mass distribution is clearly visible for the hyperdeformed resonances, thus giving strong experimental evidence for the predicted fission of a di-nuclear system. It is planned to repeat this experiment with improved resolution and efficiency at Garching using the Q3D magnet spectrograph.

Considering the fission probability of resonances in the third well, ^{231}Th is even a more promising candidate to study this effect. Therefore we measured the fission mass distribution of ^{231}Th via the ^{230}Th(d,pf)-reaction at E_d =12.5 MeV, detecting the fission fragments in two position sensitive avalanche detectors in coincidence with the proton ejectils using the Munich Q3D magnet spectrograph. In order to achieve an optimized mass resolution via an enhanced flight path for the fission fragments, the scattering chamber of the Q3D was removed in favor of a chamber built at Debrecen that allowed a flight distance of almost 50 cm. The fission fragment mass distribution in coincidence with the transmission resonance (E^* =5.85 MeV) of the fission probability in the third well is displayed in fig. 2 after subtraction of random background. A narrow mass distribution concentrated around characteristic masses is apparent, which will, after completion of the yet very preliminary analysis, give for the first time clear evidence on the nuclear shape in the third minimum of the potential surface.

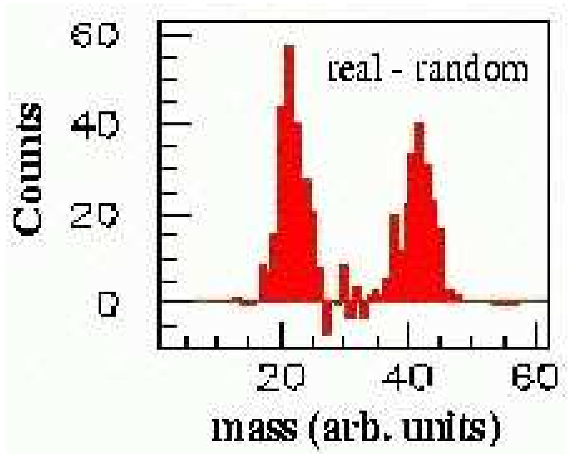

Fig. 2: Fission fragment mass distribution obtained from proton-fragment coincidences in the reaction ^{230}Th(d,pf)^{231}Th. Fission events from the third minimum were selected by gating on the 5.85 MeV resonance in the third well in the proton energy spectrum. Random background events have been subtracted.

References

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