Searching for Hyperdeformed Transmission Resonances in ^{232}U ◇

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The fission probability of ^{232}U as a function of the excitation energy has been measured with high energy resolution using the ^{231}Pa(^{3}He,df) reaction on a ^{231}Pa radioactive target in order to study hyperdeformed (HD) rotational bands. In spite of the largest effort in the history of nuclear structure research performed with heavy-ions, discrete transitions from the predicted hyperdeformed states could not be observed. However, in the actinide region experimental evidence for the third minimum comes from the regular rotational structure of the observed fission resonances [1,2,3,4]. These fission resonances caused by resonant tunneling through the excited states developed in the third minimum appears with measurable probability when the height of the inner and outer barriers have similar height [4]. These states are predicted as a consequence of the large shell correction energy superimposed upon a Coulomb flattened liquid drop energy [5]. The calculations could reproduce the measured values of the fission barriers and the energies of the second and third minima. According to those predictions the energy of the outer barrier is constant for the lighter Th and U isotopes, while the inner barrier decreases, which favors the γ-decay of those hyperdeformed states. This effect can already be seen in ^{232}U as shown in Fig. 1, where predictions of the potential energy curve a function of the nuclear deformation are displayed. In these calculations Ćwiok et al. [5] predicted two deep third minima for different values of the reflection-asymmetry (the deeper minimum predicted for the more reflection-asymmetric configuration indicated by the dashed line in Fig. 1).

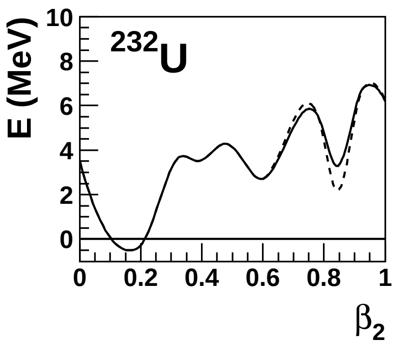

Fig. 1: Potential energy curve of ^{232}U as a function of the nuclear deformation [5,6].

At sufficiently high spin (J≤30) these HD states become yrast, while the depth of the third minimum is predicted to remain the same as calculated for low spin. So we can hope to observe discrete γ-lines from those hyperdeformed states. In this context it was also important to check the theoretical predictions for the lightest accessible isotope ^{232}U. In the experiment a ^{3}He beam of E_d = 38.1 MeV was used, bombarding an enriched (99.89 %), 80 μg/cm^2 thick target of $^{231}Pa_2O_3$ on a 22 μg/cm^2 thick carbon backing. The energy of the proton ejectiles was analyzed with a Q3D magnetic spectrograph placed at $\Theta_L = 35°$ relative to the incident beam (solid angle 10 msr). The position of the particles detected in the focal plane was measured with a light-ion, position-sensitive, cathode-strip focal-plane detector [7]. The energy resolution obtained from the ^{208}Pb(^{3}He,d) reaction was ≈11 keV, dominated by the energy loss in the target. Fission fragments were detected by a position-sensitive avalanche detector (PSAD) equipped with two wire planes with delay-line read-out. An active area of 10.5×10.5 cm^2 resulted in a solid-angle coverage of ≈10% of 4π. A preliminary deuteron - fission fragment coincidence spectrum is shown in Fig. 2 as a function of the excitation energy.

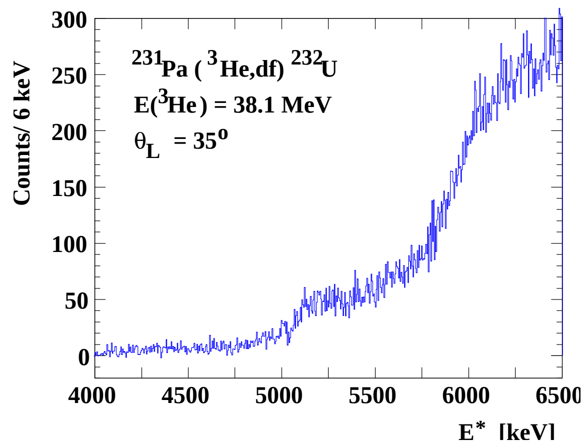

Fig. 2: Excitation energy spectrum measured in the ^{231}Pa(^{3}He,df)^{232}U reaction.

In contrast to our previous results obtained so far for ^{240}Pu, ^{234}U and ^{236}U sharp transmission resonances were not observed this time. This may partly be explained by the asymmetry of the inner and outer fission barrier heights which does not favor the occurrence of the transmission resonances. As an alternative the non-observation of a resolved rotational substructure may be attributed to the reduced rotational energy differences due to the lower target spin in ^{231}Pa ($3/2^-$) compared to $7/2^-$ in ^{235}U. Together with the also reduced present energy resolution of 11 keV compared to 5 keV in the experiment with a deuteron beam leading to ^{236}U this may inhibit the resolved observation of rotational states. A more detailed analysis of this interesting result is in progress.

References

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