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HYPERDEFORMED ROTATIONAL BANDS IN ^{234}U*

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The fission probability has been measured in the ^{233}U$(d,pf)^{234}$U reaction as a function of the excitation energy. Octupole rotational bands have been identified with rotational parameters of $\hbar^2/2\theta = 2$ keV, which is characteristic to the hyperdeformed nuclear shape.

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One of the main goals of a very large community with 4π γ-arrays such as EUROBALL or GAMMASPHERE is to search for hyperdeformed (HD) nuclear shapes with a ratio of 3:1 for the long to short axis in deformed nuclei. Until now only some signs of HD rotational bands have been found, but no discrete HD levels have been identified.

In the actinide region a third minimum in the potential energy (which contains HD states) was predicted already more than twenty years ago by Möller *et al.* [1]. According to the recent calculations, in these nuclei the so-called third minimum of the potential barrier appears at deformation parameters of $\beta_2 \approx 0.90$ and $\beta_3 \approx 0.35$ [2–5].

In our previous work [6] we reanalyzed the fission resonances measured by Blons *et al.* [7] concerning ^{234}U and showed that the unresolved peaks

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around $E^* = 4.9$ MeV could be interpreted as being the consequences of HD states lying in the third well of the potential barrier.

The aim of the present work was to study the $^{233}U(d,pf)^{234}U$ reaction with better energy resolution than Blons *et al.* [7] and to resolve the HD rotational bands.

In order to investigate the HD bands the excitation energy was chosen between the energy of the inner and outer barriers of the second well *i.e.* between 4.5 and 5.2 MeV [6]. In this energy range the widths of the SD resonances caused by excited states in the second well should be much broader due to the strong coupling to the normal deformed states, while those of the HD states remain below the experimental resolution of ≈5 keV due to the higher outer barriers separating the third well.

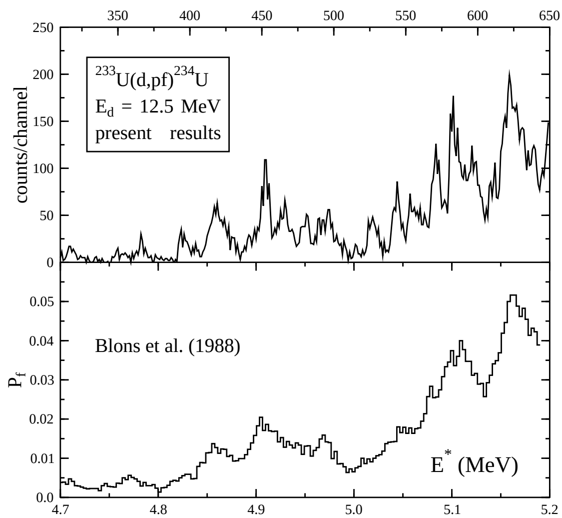

Fig. 1. Part of the proton spectrum measured in coincidence with the fission fragments and compared to the result of Blons *et al.* [7].

The experiment on ^{234}U was carried out in the $E_d = 12.5$ MeV deuteron beam of the Munich Tandem accelerator. Enriched (99 %) ≈30 μg/cm^2 thick targets of ^{233}U were used. The energy of the outgoing protons was analyzed by a Q3D magnetic spectrograph with a solid angle of 10 msr, which was set at $\Theta_{\rm Lab} = 130°$ relative to the incoming beam. The position of the analyzed particles in the focal plane was measured by a light-ion focal-plane detector [8]. Fission fragments were detected by two position-sensitive avalanche detectors (PSAD) having two wire planes (with delay-line read-out) corresponding to horizontal and vertical directions. Protons were measured in coincidence with fission fragments. A preliminary proton energy spectrum is shown in Fig. 1 as a function of excitation energy in comparison with the corresponding spectrum of Blons *et al.* The energy instability of the Tandem + Q3D system will be corrected in the off-line analysis. We note that we have observed many more resonances at higher energy up to $E^* \approx 5.5$ MeV. Their widths are very similar to the ones we analyzed here. Comparing the spectra we can immediately conclude that his energy resolution was at least a factor of two worse than 7 keV quoted in reference [7].

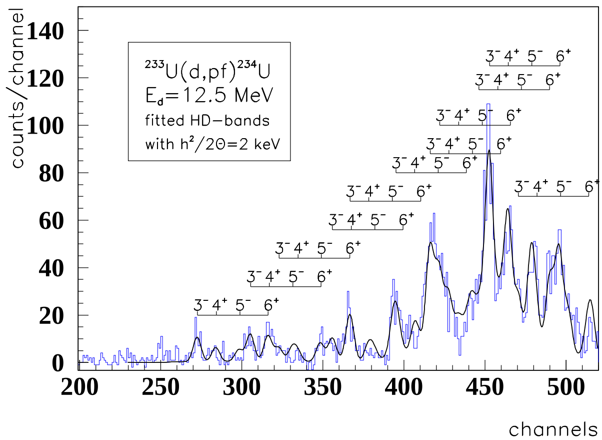

Fig. 2. Part of the measured proton energy spectrum fitted with 12 rotational bands with a common rotational parameter of $\hbar^2/2\theta = 2$ keV.

Experimentally the very large quadrupole and octupole moments of the HD states should manifest themselves by the presence of alternating parity bands with very large moments of inertia. Assuming overlapping rotational bands with the same moment of inertia and the same intensity ratio for the members in a band, we fit our experimental results by using simple Gaussians for describing the different members of the bands in the same way as in our previous work [6]. The result of the fit is shown in Fig. 2. We have used the following free parameters during the fitting procedure: (1) energy of the band head, (2) absolute intensity of the band, (3) rotational parameter ($\hbar^2/2\theta$) of the band.

Assuming that we saw a rotational band built on an excited state, we varied the K value of the band head as well during the fitting procedure. Unfortunately the results of the fit was found to be almost independent of the K values when it was varied between 0 and 3 as the relative intensity of the members of the band with a $J \leq 2$ is much less compared to the intensity of the $J^\pi = 3^-$ line.

The interpretation of the angular distributions of the fission fragments is still in progress. We hope that from the angular distribution data we can get some information on the K value of the hyperdeformed rotational bands as well as for the J values of the particular band members.

In summary, we have measured the fission probability of ^{234}U as a function of excitation energy with the (d,pf) reaction in order to search for the presence of a third minimum of the fission barrier. Our deduced moments of inertia support the existence of a deep HD minimum predicted by Ćwiok *et al.* [4]. In this potential well the transmission resonances observed in the fission probability might correspond to some higher-lying (*e.g.* two-neutron) states built on the basic vibrational states. The density of the bands ($D \approx$30 keV) corresponds to an excitation energy $E^* \approx 3$ MeV in the third well of the potential barrier, the depth of which agrees well with the recent theoretical results [4].

Taking into account the shapes of the potential barriers shown in Fig.1 of Ref. [6], it was expected that the fission width of ^{234}U is much smaller compared to the ones measured in ^{231,233}Th where the fission resonances are located closer to the top of the barriers. In this way, ^{234}U might be the best case to study further the members of the HD rotational bands with even better energy resolution.

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