First Study of the Triple-Humped Fission Barrier in an Odd-Odd Actinide: ^{232}Pa*

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The successful experimental program at the Garching Q3D spectrograph to study the multiple-humped potential energy landscape in actinide nuclei, that led to the establishment of the existence of a hyperdeformed deep third minimum, was continued. Employing a bombarding energy of 12 MeV, the transfer reaction ^{231}Pa(d,pf) was used to investigate the fission probability of ^{232}Pa to search for hyperdeformed (HD) transmission resonances [1]. With an energy resolution of 5.5 keV, two groups of transmission resonances could be observed at excitation energies around 5.75 MeV and 5.9 MeV, respectively. Figure 1 shows the measured fission probability of ^{232}Pa between 5.6 and 6.2 MeV. Below 5.82 MeV, a magnified scale was used to enhance the visibility of the resonances.

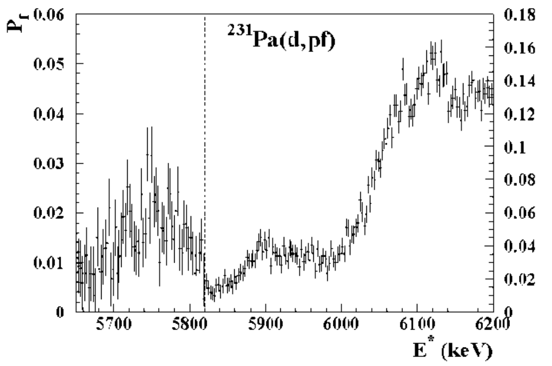

Fig. 1: Fission probability of ^{232}Pa (magnified scale below 5.82 MeV).

The fine structure of the resonance group around 5.75 MeV could be interpreted as 3 overlapping HD rotational bands (rotational parameter: 2.10(15) keV). Fig. 2 shows the corresponding fit result, where the band heads (5717 keV/K=3, 5740 keV/K=4 and 5745 keV/K=4) and intensities of the band members were treated as free parameters. An alternative scenario assuming a superdeformed nuclear shape resulted in a significantly less significant fit result. The depth of the 3rd minimum was determined by comparing the experimentally obtained average level spacings of the J=4 members ($D_{J=4}$= 9 keV) of the HD rotational bands (Fig. 2) with the calculated ones using the back-shifted Fermi-gas description of the level density. The best description of the data was achieved for $E_{III} = 5.05^{+0.4}_{-0.1}$ MeV as the excitation energy of the 3rd well.

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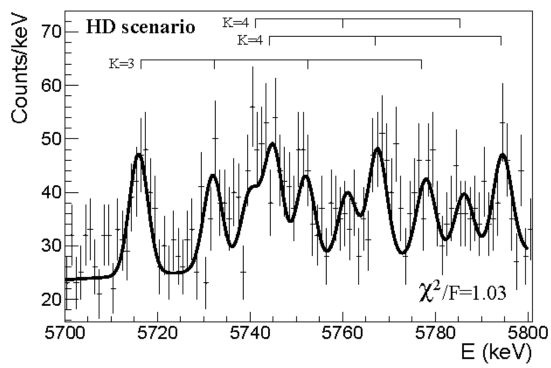

Fig. 2: Excitation energy spectrum of ^{232}Pa within a fit by HD rotational bands (solid line). The picket fence band structure with their respective K values is indicated.

In order to extract the fission barrier parameters of 232Pa, we performed cross section calculations on the ^{231}Pa(d,pf) reaction using the TALYS 1.2 nuclear reaction code [2]. The resulting parameters lead to the shape of the fission barrier of ^{232}Pa as shown in Fig. 3. In contrast to the chain of uranium isotopes, the odd-odd nuclide ^{232}Pa shows a reduced depth of the 3rd minimum of about 1.3 MeV.

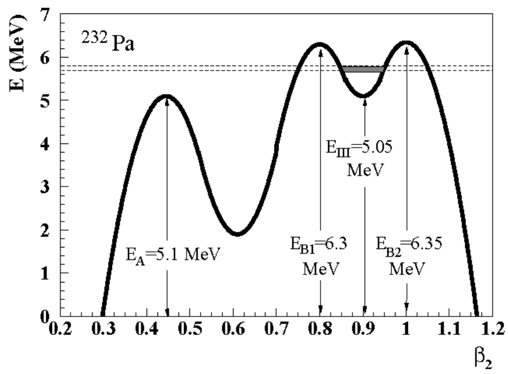

Fig. 3: Triple-humped fission barrier of ^{232}Pa as a result of the present study. The energy region of the observed HD resonances is indicated by horizontal dashed lines.

A similar experiment was recently successfully performed to study the potential landscape in ^{238}Np via the (d,pf) reaction on a ^{237}Np target, holding promise to yield further insight to the multiple-humped potential barrier landscape in actinide nuclei.

[1] L. Csige et al., Phys. Rev. C **85, 054306** (2012).
[2] M. Sin et al., Phys. Rev. C **74**, 014608 (2006).