The structure and decay of high-K isomers in ^{187}Ta

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High-K isomers in the neutron-rich, mass 180–190 region are predicted to be exceptionally favoured energetically,[1)] leading to the expectation of long half-lives that may exceed those of the corresponding ground states. At the same time, a prolate-to-oblate shape transition is predicted to result in prolate high-K isomers co-existing with oblate low-K states.[2)] Furthermore, the hexadecapole deformation is predicted to reach a maximum,[3)] which will influence both the single-particle states which are close to the neutron and proton Fermi surfaces, and the K-mixing effects. The unique features of this shape-transition/high-K region are related to reinforcing effects, with both the proton and neutron Fermi levels being high in their respective shells. However, experimental investigation is at an early stage on account of the neutron richness, combined with the refractory chemical properties of key elements, which severely limit the experimental opportunities.

Progress in the last decade includes the discovery[4)] of long-lived ($>$ 1 s) isomers at MeV excitation energies in ^{183,184,186}Hf ($Z = 72$) and ^{187}Ta ($Z = 73$) in the experimental storage ring at GSI, exploiting projectile fragmentation reactions. Now we report progress with the KISS (KEK Isotope Separation System)[5)] facility at RIKEN, giving access to detailed spectroscopic investigation of these high-K isomers, populated using multi-nucleon transfer (MNT) reactions. The technique is complementary to other isomer studies in the neutron-rich rare-earth region at RIKEN, including recent experiments with EURICA (see Ref. 6) for example) where the greatest sensitivity is for $T_{1/2} < 1$ s, and projectile-fission reactions have been employed.

The study of long-lived ($>$ 1 s) isomers at KISS[5)] makes use of an Ar gas stopping cell that avoids the chemical problems often associated with the $Z = 72$–79 refractory elements. Z selectivity is achieved by laser resonance ionization, and there is mass separation with a dipole magnet. The KISS detection system includes four super-Clover germanium detectors for γ rays, and a multi-segmented proportional gas counter[7)] for low-background β particles, X-rays and conversion electrons. There a tape transport system that is synchronized with beam pulsing for half-life selection.

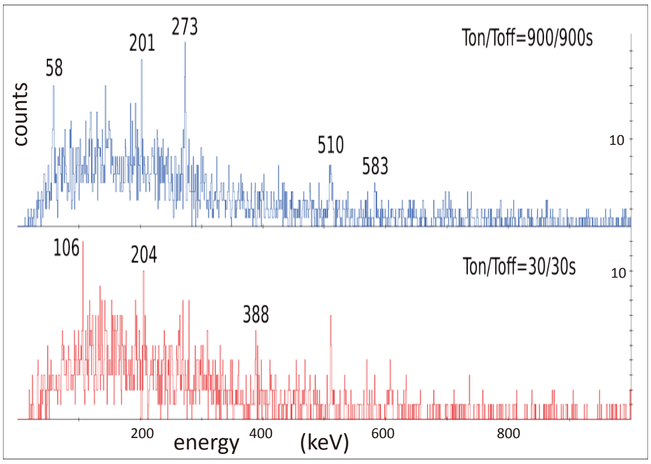

Fig. 1. Gamma rays associated with laser-ionized ^{187}Ta reaction products, measured at the tape-implantation point and with β-counter coincidences. Two different tape-cycle times are illustrated. The longer cycle (900 s beam-on, 900 s beam-off, tape movement) in the upper panel shows γ rays from the ground-state decay ($T_{1/2} = 140$ s) while the shorter cycle (30 s beam-on, 30 s beam-off, tape movement) in the lower panel shows different transitions (*e.g.* those labelled) which are candidates for the shorter-lived isomeric decay ($T_{1/2} < 22$ s).

In a recent test experiment (July 2017) on neutron-rich Ta isotopes, yields of $^{185g,186m+g,187g}$Ta have been measured following MNT reactions between a ^{136}Xe beam (50 pnA at 7.2 A.MeV) and a natural W target. Under these conditions, β-delayed γ rays from the ^{187}Ta ground state were identified for the first time, and candidate isomeric decays were observed, as illustrated in Fig. 1. Note that the 201 and 273 keV transitions (upper panel) are known transitions from in-beam studies[8)] of 187 W, though no previous measurements of ^{187}Ta β-decay to 187 W have been reported. This establishes the capability to produce separated beams of neutron-rich Ta isotopes, and hence the viability of the technique for future spectroscopic studies.

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