Shell evolution beyond ^{208}Pb: Isomer and β-decay spectroscopy of neutron-rich $N > 126$ nuclei

A. I. Morales,[*1,*2] V. H. Phong,[*2] S. Nishimura,[*2] Zs. Podolyák,[*3] T. T. Yeung,[*4,*2] Q. Zeng,[*5,*2] N. Fukuda,[*2] J. Agramunt,[*1] A. Algora,[*1] Y. Anuar,[*6] H. Baba,[*2] G. Bartram,[*3] J. S. Cachaya,[*2] M. L. Cortés,[*2] P. Doornenbal,[*2] S. Hanai,[*6] T. Isobe,[*2] C. Jones,[*3] G. G. Kiss,[*7] N. Kitamura,[*6] Z. Liu,[*5] S. Michimasa,[*2] S. Momota,[*2] Z. Nunns,[*3] S. G. Posada,[*2] D. Rodríguez-García,[*1] H. Sakurai,[*2] Y. Shimizu,[*2] T. Sumikama,[*2] H. Suzuki,[*2] J. L. Tain,[*1] H. Takeda,[*2] A. Tolosa-Delgado,[*1] Y. Togano,[*2] W. Yingfeng,[*5] R. Yokoyama,[*6] and M. Yoshimoto[*2]

Exploring the heavy neutron-rich region around and beyond $N = 126$ is one of the major aims of nuclear facilities worldwide. The foremost reason for setting this goal is understanding the nucleosynthesis of the heaviest elements existing in nature, which are formed only by the rapid neutron-capture process (r-process). The only sistematic measurements recorded to date concern the waiting point nuclei associated with the third r-process peak. Some β-decay half-lives near stability reveal the largest discrepancies among the models used to calculate nuclear inputs for r-process simulations.The measurement of other observables is better suited for obtaining detailed structural information in nuclei beyond the $N = 126$ shell closure, which is crucial to obtaining higher-quality calculated nuclear inputs that are far from stability in the inaccessible regions of the r-process reaction path.

To achieve this goal, the Total Absorption spectroscopy Technique Applied to Key Isotopes in r-Process nucleosynthesis (TATAKI-Pro) β-decay setup was exploited for the first time in November 2024 at RIBF in the heavy $N > 126$ mass region. The two central detectors were WAS3ABi[1)] and DTAS.[2)] The first consists of two layers of Double-Sided Silicon Strip Detectors (DSSSD), each of which is 1 mm in thickness. The DSSSD detectors are segmented into 64 horizontal and 64 vertical strips with a 1 mm pitch, providing 4096 pixels with a position sensitivity of 1 mm^2 for spatial correlations between implanted fragments and β decays. DTAS is made of 16 large-volume ($15 \times 15 \times 25$ cm^3) NaI(Tl) crystals arranged in a rectangular geometry around WAS3ABi to maximize the total γ-ray efficiency of the array. Owing to its modularity, DTAS can be used in dual mode: as an advanced total-absorption γ-ray calorimeter to obtain β-intensity distributions and as a highly efficient, low-energy resolution γ-ray spectrometer to measure key structural properties such as isomeric states, nuclear lifetimes, decay schemes, and, in combination with WAS3ABi, Meitner–Ellis electrons.

The nuclei of interest were produced by the fragmentation of ^{238}U at 345 MeV/nucleon on a 5 mm Be target. The average intensity of the primary beam was 50 particle nA. New diamond detectors and a Xe ionization chamber were used in BigRIPS[3)] to achieve excellent resolution in the time-of-flight and atomic energy loss of the fragments. Moreover, the 1e$^-$ charge-state selection along the spectrometer allowed for a significant suppression of fission contaminants. In total, more than 50 nuclear species between Ir and Ac were implanted in WAS3ABi, with rates up to 50 counts per second. β-decay curves, Meitner-Ellis electrons, and isomeric transition spectra were extracted in the preliminary analysis conducted during the experiment. As an example, Fig. 1 shows the total energy versus crystal energy matrices of the $J^\pi = (8^+)$ seniority isomers in ^{210}Hg (top) and ^{212}Hg (bottom) for a subset of the data taken. Our experiment confirms the existence of a unique μs isomer in ^{210}Hg, supporting the previous BRIKEN results[4)] and dismissing the lowering of the 3^- octupole state proposed by Ref. 5).

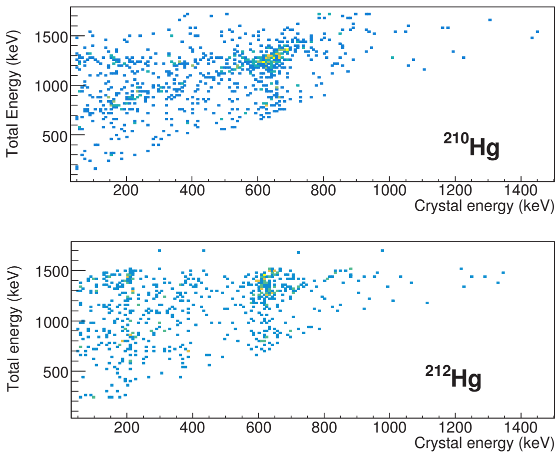

Fig. 1. Total versus crystal energy matrices of the (8^+) isomers in ^{210}Hg (top) and ^{212}Hg (bottom).

References
1) S. Nishimura, Prog. Theor. Exp. Phys. **2012**, 03C006 (2012).
2) J. L. Tain *et al.*, Nucl. Instrum. Methods Phys. Res. A **803**, 36 (2015).
3) N. Fukuda *et al.*, Nucl. Instrum. Methods Phys. Res. B **317**, 323 (2013).
4) J. Wu *et al.*, submitted to Phys. Rev. Lett.
5) A. Gottardo *el al.*, Phys. Lett. B **725**, 292 (2013).

*1 IFIC, CSIC-UV
*2 Radioactive Isotope Physics Group, RIKEN Nishina Center
*3 Department of Physics, University of Surrey
*4 Department of Physics, University of Tokyo
*5 Institute of Modern Physics, Chinese Academy of Sciences
*6 Center for Nuclear Study, University of Tokyo
*7 HUN-REN Institute for Nuclear Research

DOI:10.34448/RIKEN.APR.58-049