Alpha-decay correlated mass measurement of ^{206,207}Ra using an MRTOF-MS system equipped with an α-TOF detector

T. Niwase,[*1,*2,*3] M. Wada,[*3] P. Schury,[*3] P. Brionnet,[*2] S. D. Chen,[*4,*3] T. Hashimoto,[*5] H. Haba,[*2] Y. Hirayama,[*3] D. S. Hou,[*6,*7,*8] S. Iimura,[*9,*2,*3] H. Ishiyama,[*2] S. Ishizawa,[*10,*2] Y. Ito,[*11] D. Kaji,[*2] S. Kimura,[*2] J. Liu,[*4,*3] H. Miyatake,[*3] J. Y. Moon,[*5] K. Morimoto,[*2] K. Morita,[*1,*2] D. Nagae,[*1] M. Rosenbusch,[*3] A. Takamine,[*2] T. Tanaka,[*12] Y. X. Watanabe,[*3] H. Wollnik,[*13] W. Xian,[*4,*3] and S. X. Yan[*14]

Toward the precise mass measurement of heavy and superheavy nuclides, the SHE-Mass-II facility[1)] was constructed with a multi-reflection time-of-flight mass spectrograph (MRTOF-MS)[2)] coupled with the gas-filled recoil ion separator GARIS-II.[3)] We installed an α-TOF[4)] detector, which simultaneously records the time-of-flight (TOF) signal and subsequent α-decay. In order to demonstrate the α-TOF detector, an experiment was performed using the ^{51}V + ^{159}Tb reaction. A ^{51}V beam was accelerated to 6.0 MeV/nucleon by the RIKEN Ring Cyclotron (RRC). The beam energy on the target was reduced by an aluminum degrader to 4.8 MeV/nucleon. The beam impinged upon 460 μg/cm^2-thick ^{159}Tb targets with a 3 μm Ti backing, mounted in a rotating target wheel.

The fusion evaporation residues (ERs) were separated from the primary beam and transported using GARIS-II. After decelerating ERs using a Mylar foil, the ERs were stopped in a cryogenic helium gas catcher, and the thermalized ions were extracted by a radio frequency (RF) carpet and transported to the MRTOF-MS via multiple RF ion traps.

We observed ERs, ^{206,207}Fr, and ^{206,207}Ra as doubly charged ions. The subsequent α-decays were additionally detected by the α-TOF detector. Using ^{206,207}Fr as the isobaric references, the masses of ^{206,207}Ra were directly determined. The mass excess of ^{206}Ra was 3540(54) keV, which agrees with the values reported in AME2016.[5)]

The TOF spectrum for the A/q = 103.5 region is shown in Fig. 1. The singles events and ^{207}Ra decay-correlated events are plotted. In the case of the ground state of ^{207}Ra, the correlated events of the TOF and the α-decay could not be observed, because the incoming rate was higher than the decay rate, while the decay-correlated events were observed in the isomeric state ^{207m}Ra owing to its short half-life. The energies of the α-decay were selected as higher than 7.32 MeV, 2σ apart from the centroid of ^{207g}Ra, to avoid contamination from ^{207g}Ra.

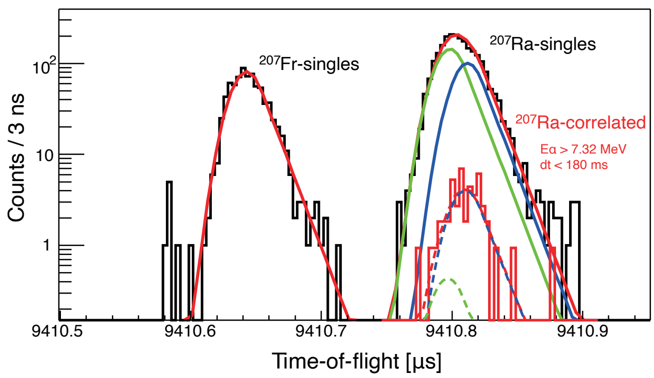

Fig. 1. Time-of-flight spectrum around the ^{207}Ra^{2+} region. The red histogram indicates the decay-correlated events. The green and blue lines show the fitting of the ground and isomeric states of the singles (solid lines) and decay-correlated events (dot lines).

The peaks of singles $^{207g/m}$Ra^{2+} and decay-correlated ^{207m}Ra^{2+} were fitted. The shape of the peak was determined by ^{207}Fr^{2+}. The mass excess of ^{207g}Ra was determined to be 3538(15) keV, and the excitation energy of ^{207m}Ra was $E_{\rm ex}$ = 552(42) keV from the α-decay correlated TOF spectrum. These values are consistent with those evaluated by α-decay spectroscopy.[5)]

The alpha branching ratio of ^{207m}Ra was determined from the counting of TOF and α-decay events. The spin parity was expected to be $13/2^+$ based on its single-particle level energy and the analogous reduced alpha width to the neighboring nuclei.

*1 Department of Physics, Kyushu University
*2 RIKEN Nishina Center
*3 Wako Nuclear Science Center (WNSC), KEK
*4 Department of Physics, The University of Hong Kong
*5 Institute for Basic Science, Rare Isotope Science Project
*6 Institute of Modern Physics, Chinese Academy of Science
*7 University of Chinese Academy of Science
*8 School of Nuclear Science and Technology, Lanzhou University
*9 Department of Physics, Osaka University.
*10 Graduate School of Science and Engineering, Yamagata University
*11 Japan Atomic Energy Agency
*12 Department of Nuclear Physics, The Australian National University
*13 Department of Chemistry and Biochemistry, New Mexico State University
*14 Institute of Mass Spectrometer and Atmospheric Environment, Jinan University

References

1) M. Wada *et al.*, RIKEN Accl. Prog. Rep. **52**, 136 (2019).
2) P. Schury *et al.*, Nucl. Instrum. Methods Phys. Res. B **335**, 39 (2014).
3) D. Kaji *et al.*, Nucl. Instrum. Methods Phys. Res. B **317**, 311 (2013).
4) T. Niwase *et al.*, Nucl. Instrum. Methods Phys. Res. A **953**, 163198 (2020).
5) M. Wang *et al.*, Chin. Phys. C **41**, 030003 (2017).