# Correlated measurement of mass and decay of fusion evaporation products for $^{51}$V+$^{159}$Tb reactions via MRTOF+$\alpha$-TOF detector

T. Niwase,[*1,*2,*3] M. Wada,[*3] P. Schury,[*3] Y. Ito,[*4] S. Kimura,[*2] D. Kaji,[*2] M. Rosenbusch,[*2] Y. X. Watanabe,[*3] Y. Hirayama,[*3] H. Miyatake,[*3] J. Y. Moon,[*9] H. Ishiyama,[*2] K. Morimoto,[*2] H. Haba,[*2] T. Tanaka,[*7] S. Ishizawa,[*5,*2,*3] P. Brionnet,[*2] S. Iimura,[*8,*2,*3] A. Takamine,[*2] K. Morita,[*1,*2] and H. Wollnik[*6]

The SHE-Mass-II facility[1] is a system with a multi-reflection time-of-flight mass spectrograph (MRTOF-MS[2]) coupled with the gas-filled recoil ion separator GARIS-II[3] in the E6 experimental room for the mass measurement of fusion evaporation products, such as very low yield nuclei in the superheavy region.

Recently, we developed and installed a novel detector named $\alpha$-TOF[4], which simultaneously records the time-of-flight (TOF) signal and successive $\alpha$-decay. The $\alpha$-TOF detector has the capability to significantly reduce the background level.

The experiment was performed using $^{51}$V+$^{159}$Tb reactions. A $^{51}$V beam was accelerated up to 6.0 MeV/nucleon by RRC. The beam energy on the target was reduced by an aluminum degrader to approximately 4.8 MeV/nucleon. A 460-$\mu$g/cm$^2$-thick $^{159}$Tb target was prepared by a sputtering method on a 3.0 $\mu$m Ti backing foil.

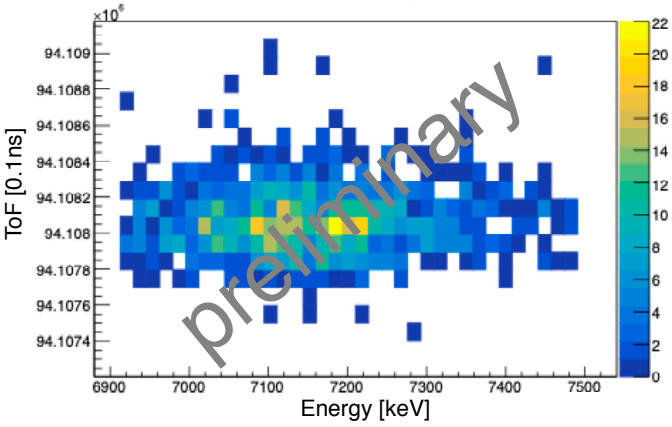


Fig. 2. Two-dimensional mapping of TOF versus correlated $\alpha$-decay energies.

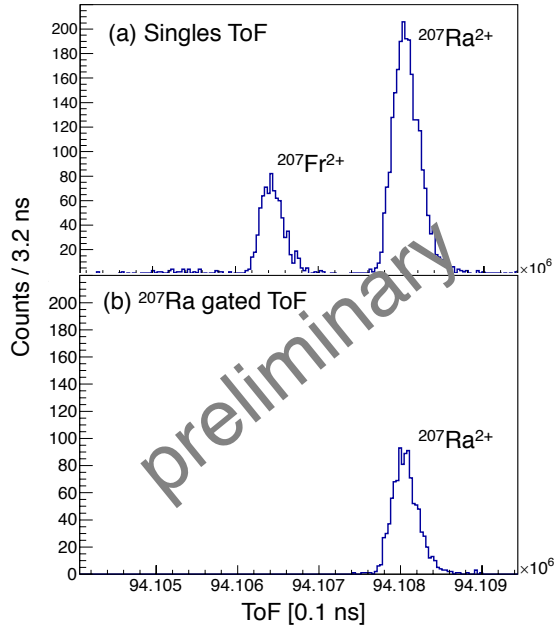


Fig. 1. (a) Singles TOF spectrum. (b) TOF spectrum in coincidence with $^{207}$Ra $\alpha$-decays obtained using a time gate of 5s.

The fusion evaporation residues (ERs) were separated from the primary beam and efficiently transported using GARIS-II. After decelerating ERs using a Mylar foil, the ERs were captured in a cryogenic high-purity He gas catcher, and the thermalized ions were extracted by an RF-carpet and transported to the MRTOF-MS via multiple RF ion traps. We observed the $^{206,207}$Fr, $^{206,207}$Ra and $^{204}$Rn isotopes extracted as doubly charged ions. In this measurement, we focused on $^{206,207}$Ra isotopes having relatively short half-lives, *i.e.*, $T_{1/2}$ = 240 ms for $^{206}$Ra and $T_{1/2}$ = 1.38 s for $^{207}$Ra.

Figure 1 shows a part of the TOF spectrum at $A$ = 207. When we gated the ToF spectrum by the $\alpha$-ray energy of $^{207}$Ra with a coincident time of 5 s (3.5 half-lives), we clearly discriminated the decay-correlated TOF events (Fig. 1(b)).

Figure 2 shows a part of the two-dimensional spectrum for TOF and the correlated $\alpha$-decay energies. From the correlation mapping, we obtained the information of TOF, as well as decay properties such as $\alpha$-energy and decay time, atom by atom. Further analysis is in progress.

*1 Department of Physics, Kyushu University
*2 RIKEN Nishina Center
*3 Wako Nuclear Science Center (WNSC), KEK
*4 Japan Atomic Energy Agency
*5 Graduate School of Science and Engineering, Yamagata University
*6 Department of Chemistry and Biochemistry, New Mexico State University
*7 Department of Nuclear Physics, The Australian National University
*8 Department of Physics, Osaka University.
*9 Institute for Basic Science

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).