## Measurement of excitation functions of evaporation residues in ${}^{51}V+{}^{159}Tb$ system by direct ion counting using MRTOF-MS

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The multi-reflection time-of-flight mass spectrograph (MRTOF-MS)<sup>1)</sup> is a device used for highprecision mass measurement of unstable nuclides. The MRTOF-MS is not merely a high-precision mass measurement device, but a device capable of highly accurate identification of nuclides through direct ion counting. We have successfully demonstrated the use of MRTOF-MS to measure the excitation function of fusion evaporation residues without using conventional decay spectroscopic methods.<sup>2)</sup> Following the demonstration experiment, we conducted the measurement of the excitation function of evaporation residues in the <sup>51</sup>V + <sup>159</sup>Tb system in the SHE-Mass facility.

The details of the experimental setup can be found in a separate publication.<sup>3)</sup> A <sup>51</sup>V beam was accelerated to 6.0 MeV/nucleon in the RIKEN Ring Cyclotron (RRC). To change the incident beam energy, a rotating 5  $\mu$ m Ti degrader was installed upstream of the target. The rotatable Ti degrader, which can rotate from 0° to 60° enables the energy at the center of target to be selected from 214.0 to 241.7 MeV. The energy-degraded <sup>51</sup>V beam was irradiated upon a 350- $\mu$ g/cm<sup>2</sup>-thick <sup>159</sup>Tb target with a 2.8- $\mu$ m Ti backing.

The time-of-flight spectra at several typical beam energy points are presented in Fig. 1. In this measurement, the in-MRTOF deflector<sup>4</sup>) was open for A/q =203, 204 and 206, 207 species. The abundances of each nuclide are seen to vary as independent functions of the incident energy. In all, 13 energy points were changed to measure the yields of the produced nuclides. The preliminary yield curves for the fusion reaction of the <sup>51</sup>V + <sup>159</sup>Tb system obtained in the experiment are presented in Fig. 2. The counts at each data point are normalized by counting the elastic scatterings of 45° from the beam axis. Eight isotopes have been observed in this measurement, which correspond to the evaporation channel of xn (Ra), pxn (Fr),  $\alpha xn$ (Rn), and  $\alpha pxn$  (At). The detailed analysis is cur-



Fig. 1. Time-of-flight spectrum of A/q = 203, 204 and 206, 207 species with three different beam energy points: 241, 231, and 225 MeV.

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Fig. 2. Preliminary result of the yield curve of the fusion reaction of the  ${}^{51}V + {}^{159}Tb$  system. Each color marker indicates the different elements produced by the different evaporation channels, xn (Ra), pxn (Fr),  $\alpha xn$  (Rn), and  $\alpha pxn$  (At).

rently in progress. From this yield curve and comparison with decay measurement data,<sup>5)</sup> the absolute cross sections of the nuclides will be evaluated by correcting the transport efficiency of GARIS-II, and the competition between neutron and alpha evaporation channels will be discussed in the future.

## References

- P. Schury *et al.*, Nucl. Instrum. Methods Phys. Res. B 376, 425 (2016).
- 2) T. Niwase *et al.*, in this report.
- 3) T. Niwase et al., Phys. Rev. C 104, 044617 (2021).
- M. Rosenbusch *et al.*, Nucl. Instrum. Methods Phys. Res. A **1047**, 167824 (2020).
- P. Brionnet *et al.*, RIKEN Accel. Prog. Rep. 56, 16 (2023).