Measurement of isotopic production cross section on ^{99}Tc *via* proton- and deuteron-induced reactions

R. Matsumura,[*1,*2] H. Otsu,[*1] H. Wang,[*3] H. Sakurai,[*1] D. Nishimura,[*4] H. Takahashi,[*4] S. Takeshige,[*5] M. Tanaka,[*1] and Y. Togano[*1,*5] for the RIBF-TM2021 Collaboration

In order to evaluate the reactions of the long-lived fission products (LLFPs) with neutron, we have measured systematically the proton- and deuteron-induced cross sections for ^{90}Sr,[1] ^{137}Cs,[1] ^{93}Zr,[2] ^{107}Pd,[3] *etc.* As a next step, we started a study on ^{99}Tc, which is known to be one of the LLFPs.

A secondary beam including ^{99m}Tc was produced by the in-flight fission of ^{238}U at 345 MeV/nucleon on a 3-mm-thick ^{9}Be target, selected and identified event-by-event using the TOF-$B\rho$-ΔE method[4] in BigRIPS. It also included ^{99m}Tc ($T_{1/2}$ = 6 h), which is indistinguishable by the same method, was irradiated to a 3-mm-thick Al plate and studied for the production ratio by in-flight fission using the Ge detector. Cocktail beams of ^{99}Tc and ^{99m}Tc at 114 MeV/nucleon were bombarded with CH_2, CD_2, and C reaction targets placed at the entrance of ZD spectrometer (ZDS). The residual nuclei produced in the reactions were identified in ZDS. Since the momentum acceptance of ZDS is limited to ±3%, the measurement was conducted using 5 different momentum settings ($\Delta(B\rho)/B\rho = -9$, -6, -3, 0, and $+3$%) for each target to accept a wide range of the mass-to-charge ratio A/Q.

Figure 1 shows particle identification of residual nuclei was realized by combining A/Q and atomic number Z, derived from the measured information in ZDS. The A/Q (relative RMS) resolution was 0.20%, which corresponds to 5.4σ separation. On the other hand, the Z resolution was 0.80%, not achieving even 3σ separation. This is probably because the integration time of the F11IC[5] Shaping Amp. was unintentionally adjusted to be too short. Although the identification resolution is insufficient compared to the previous experiments, the yield can be counted up with the superposition of 2-D Gaussian functions.

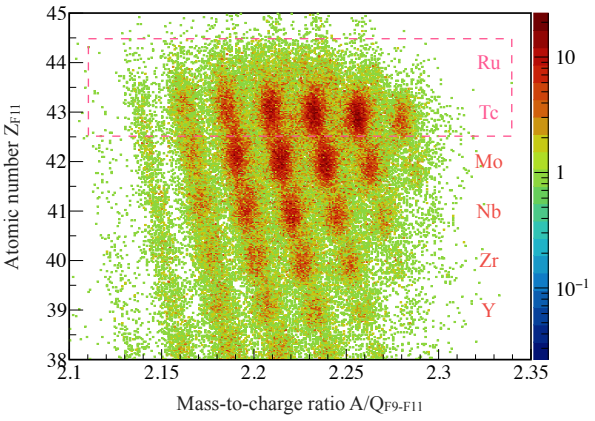

Fig. 1. Particle identifications of residual nuclei were produced in reactions with the CH_2 target at the $\Delta(B\rho)/B\rho = -6$% setting on ZDS.

Moreover, the Ru isotopes from the ^{99}Tc beam are scarcely observed in the region indicated by the dashed line in Fig. 1. It was confirmed that the Ru and Tc isotopes with large pulse heights were overflowing in some or all of the ADCs with 6 channel readout. The number of overflowed channels causes a difference in the peak position of each isotope in the A/Q spectrum. In Fig. 2, the A/Q spectrum is plotted for that overflow bit information. The peaks indicated in the blue curve are almost consistent with the unique A/Q of the Tc isotopes. Whereas the red curve is considered to be the sum of both responses because it has a peak in the middle of each A/Q of Tc and Ru. We plan to decompose the red curve into each response from the strictly defined A/Q peak positions.

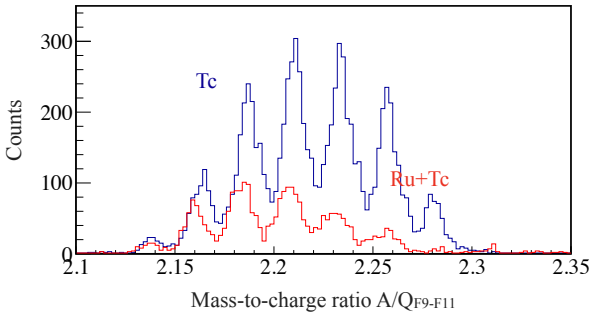

Fig. 2. A/Q spectra showing the dashed line region in Fig. 1, these are imposed overflow bit = 5, 6 for red curve and 1 for blue curve.

We have started a new study of proton- and deuteron-induced cross sections on ^{99}Tc. After the analysis method is finalized, the other remaining targets will be analyzed.

*1 RIKEN Nishina Center
*2 Department of Physics, Saitama University
*3 RIKEN Cluster for Pioneering Research
*4 Department of Natural Sciences, Tokyo City University
*5 Department of Physics, Rikkyo University

References

1) H. Wang *et al.*, Phys. Lett. B **754**, 104 (2016).
2) S. Kawase *et al.*, Prog. Theor. Exp. Phys. **2017**, 093D03 (2017).
3) H. Wang *et al.*, Prog. Theor. Exp. Phys. **2017**, 021D01 (2017).
4) N. Fukuda *et al.*, Nucl. Instrum. Methods Phys. Res. B **317**, 323 (2013).
5) K. Kimura *et al.*, Nucl. Instrum. Methods Phys. Res. A **538**, 608 (2005).