Toward the mass measurement of neutron-rich nuclei in the vicinity of $N = 126$ isotones with SLOWRI/ZD-MRTOF

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Despite the first observation of an r-process production site (GW170817) in 2017, confirming neutron-star mergers as probably the most important site, many open questions remain to understand r-process nucleosynthesis fully. A major unanswered question is whether neutron star merger r-process products alone can explain the observed large scatter of Eu/Fe and other r-process elements at [Fe/H] < 3 metalicites.[1)] The shape and position of the 3rd peak on r-process element abundances would serve as an anchor point to confirm the reproducibility of the element abundances in the reaction network calculations when investigating an astrophysical site for r-process nucleosynthesis. However, there is no experimental data for nuclear physics inputs such as masses, half-lives, and neutron branching ratios in the vicinity of $N = 126$ waiting point nuclei, which critically affect the formation of the 3rd peak.[2)] Therefore, direct mass measurement of neutron-rich nuclei in the vicinity of $N = 126$ waiting point nuclei, which are considered to be the progenitors for the 3rd peak formation, is strongly desired.

RIBF199 experiment was performed to measure the masses of these nuclides with MRTOF in combination with an RF carpet type He gas cell (RFGC) of SLOWRI installed at F11 of BigRIPS (ZD-MRTOF).[3)] No neutron-rich nuclei in this region were observed with ZD-MRTOF during the beam time. There are two possible reasons why we could not observe any RIs. One possible reason was the 'low' extraction efficiency from the RFGC. Unfortunately, the ion guide was found to be defective. Therefore, the RFGC chamber was opened, and the ion guide replaced just before the beamtime. We had no sufficient baking time to suppress contaminant molecules which reduces the extraction efficiency due to various molecular formations of RI atoms. After our beamtime, the RFGC was long baked for about 10 days. Then, the extraction efficiency was examined using a ^{248}Cm fission source installed inside the RFGC. The extraction efficiencies after stopping inside RFGC for the fission fragments such as Tc and Mo have been recovered to be roughly 10%.

The second and most important reason is that yields on RIs of interest provided by BigRIPS were too low. Figure 1 shows the intensities of RIs measured in this region using BigRIPS/ZDS detectors. As shown in Fig. 1, almost measured intensities for RIs of interest are 10^{-2} pps or less, roughly two orders of magnitude lower than expected values estimated with LISE++. The production yield from uranium beam fragmentation seems insufficient to measure the masses in this region, even if the extraction efficiency is recovered.

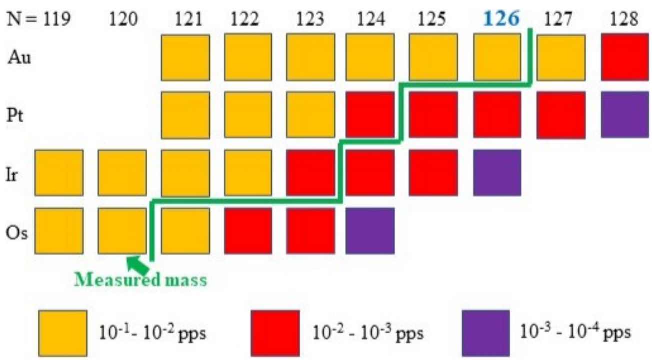

Fig. 1. Measured yields for RIs of interest at F11. The production reaction is ^{238}U + ^{9}Be with the beam energy of 345 MeV/nucleon and the intensity of 70 particle nA.

We are currently considering using lead beam fragmentation to produce RIs in this region. In the southwest part of $N = 126$ down to $Z = 70$, higher production cross-sections are expected to be obtained with ^{208}Pb beam than with ^{238}U beam.[4)] A Letter of Intent was submitted to NP-PAC 2022 to request the development of a Pb beam at RIBF, and the PAC "enthusiastically endorsed" it. We hope to continue the experiment with the Pb beam.

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