Mass measurements of ^{252}Cf fission fragments via MRTOF-MS

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The rapid neutron-capture (r-) process path is governed by the balance between the β^--decay rate and neutron-capture rate. Masses of nuclei involved in the r-process path play a crucial role in determining the final isotopic abundance. It is difficult to access the r-process nuclei due to their locations far from stability; thus, theoretical predictions are needed to obtain the final isotopic abundances. However, in the region where there are no experimental data on nuclear masses, the predicted mass values show a large variance.[1] Thus, accurate and precise mass data of neutron-rich nuclei are required.

Here, we report mass measurements of the neutron-rich nuclei produced by the spontaneous fission ^{252}Cf with multi-reflection time-of-flight mass spectroscopy (MRTOF-MS).[2] The MRTOF-MS system consists of a cryogenic gas cell (GC) with a 0.5 μm Mylar window, an ion transport system having two linear RF quadrupole traps, and an ejection system to the MRTOF device. A 350 kBq ^{252}Cf source (SF: 3.09%) with 6 μm Ti degrader was installed in front of the GC window. Throughout the measurements, the GC was cryogenically cooled blow 70 K while the He gas pressure was regulated to maintain a density equivalent to 150 mbar at room temperature.

The measurement results are summarized in Fig. 1. In the present study, we observed 78 isotopes from iodine ($Z = 53$) to europium ($Z = 63$) in the TOF spectra. The masses of the observed isotopes were

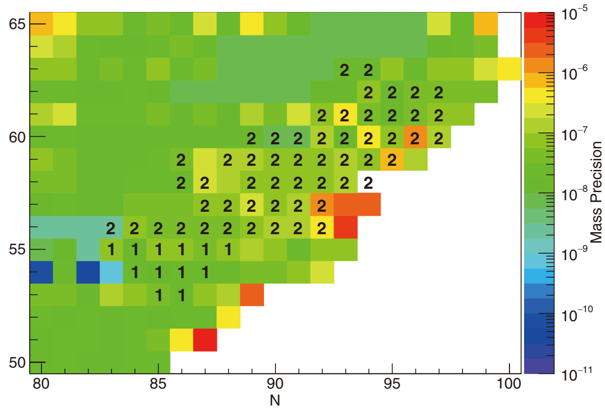

Fig. 1. Location of the observed isotopes on the nuclear chart. The numbers, 1 or 2, indicate the observed charge state. The color bar represents the precision of experimental mass data taken from the 2016 Atomic Mass Evaluation (AME16).

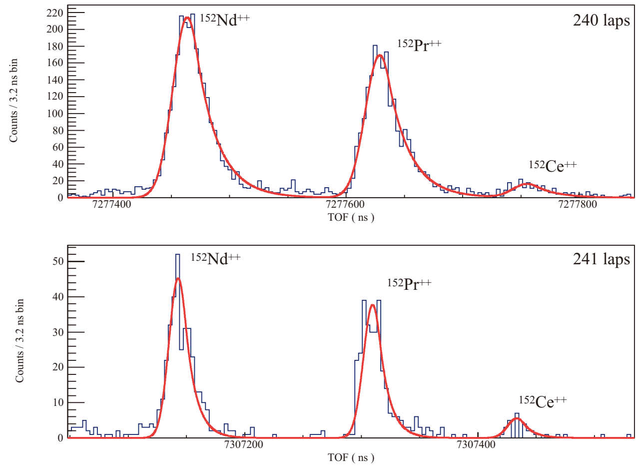

Fig. 2. TOF spectra of doubly charged $A = 152$ series. The red line indicates a fit obtained using an exponential-Gaussian hybrid function.[3]

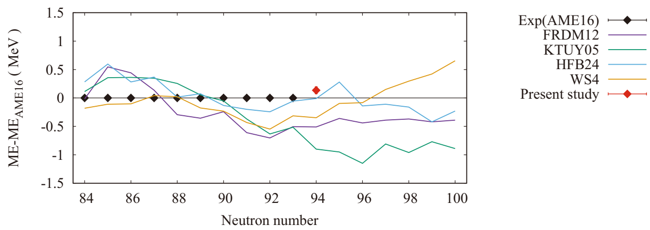

Fig. 3. Neutron-number dependence of cerium-isotope mass excess. Each line indicates a theoretical prediction. In the region of $N > 93$, the zero line corresponds to the extrapolated masses listed in AME16.

determined by a single reference method.[3] A typical measurement achieved a relative precision of $\delta m/m \sim 10^{-7}$. Figure 2 shows TOF spectra of the doubly charged $A = 152$ series with different numbers of laps. As the relative position and intensity remain constant when the number of laps is varied, we can infer that the three peaks are isobaric. In this case, ^{152}Nd was used as a mass reference, and we experimentally determine the mass of ^{152}Ce for the first time. The measured mass excess of ^{152}Ce is $ME = -58845(61)$ keV and indicated in Fig. 3 with several theoretical predictions. This result shows that the ground state of ^{152}Ce is less bound than all the predictions listed in Fig. 3.

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