Mass measurement by using newly developed doughnut-shaped helium gas cell at KISS

Y. Hirayama,[*1] M. Mukai,[*1] P. Schury,[*1] Y. X. Watanabe,[*1] S. Iimura,[*2] H. Ishiyama,[*2] S. C. Jeong,[*1] H. Miyatake,[*1] T. Niwase,[*3] M. Rosenbusch,[*1] A. Takamine,[*2] A. Taniguchi,[*4] Y. Yamanouchi,[*3] and M. Wada[*1]

At the KEK Isotope Separation System,[1)] multinucleon transfer (MNT) reactions have been used to efficiently produce neutron-rich short-lived nuclei around neutron number $N = 126$ and uranium, which are difficult to produce at any other facilities. These nuclei are efficiently accumulated in a gas cell to produce low-energy ion beams for nuclear spectroscopy. To further promote nuclear spectroscopy for multiple short-lived nuclei, a large-volume doughnut-shaped helium gas cell (DSHeGC, see Fig. 1), capable of utilizing high-intensity heavy-ion beams of ^{136}Xe/^{238}U for higher production yields, has been developed.

Helium has a very high first ionization potential compared to those of the other elements, allowing short-lived nuclei of heavy elements tosurvive as ions without neutralizing. This enables the simultaneous use of ion beams of short-lived nuclei with different mass numbers (over 100 nuclides). The short-lived nuclear ions in the gas cell are quickly transported to the surface of a radio-frequency (RF) wire-carpet (WC) unit (indicated by yellow in Fig. 1) by a DC electric field (green arrows). Subsequently, the ions are transported to the exit aperture of the gas cell in approximately 100 ms by clockwise and counter-clockwise RF traveling waves (RFTW, blue arrows). As a result, 10 to 100 times more nuclei than are permitted in previous methods can be used.[2)] This gas cell is also adopted as the heart of the next KISS-1.5 for producing short-lived nuclei.

An online experiment was performed to study the extraction of short-lived nuclear ions by combining the DSHeGC with a multi-reflection time-of-flight mass spectrometer (MRTOF-MS). When the gas cell was cooled to a low temperature (120 K), the generation of impurity ions was suppressed, and efficient ion transport was achieved using the RFWC units, successfully extracting short-lived nuclear ions from the gas cell. Figure 2 shows some of the results of particle identification and precise mass measurement using the MRTOF-MS. We were able to identify ^{198}Ir and ^{198}Os, whose masses had not been measured before. Additionally, we identified ^{197,199}Os, whose masses had also been previously unmeasured. After the measurements, we could optimize the RFTW and DC fields for the ion transport in the gas cell, and could find the capability to increase the primary beam intensity by a factor of 5. In the next experiment, we plan to increase the statistics by more than tenfold and determine the masses with a precision of 10^{-6}.

*1 Wako Nuclear Science Center (WNSC), IPNS, KEK
*2 RIKEN Nishina Center
*3 Department of Physics, Kyushu University
*4 Institute for Integrated Radiation and Nuclear Science, Kyoto University (KURNS)

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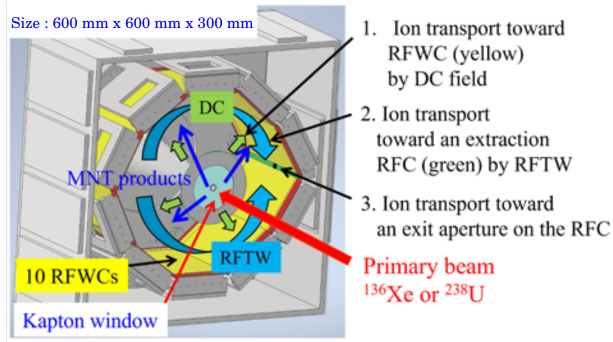

Fig. 1. Schematic drawing of the doughnut-shaped helium gas cell. To increase the efficiency of short-lived nuclear ion transport, the primary beam is designed to pass through the doughnut aperture at the center of the gas cell. MNT products are implanted into the gas cell through a thin Kapton window.

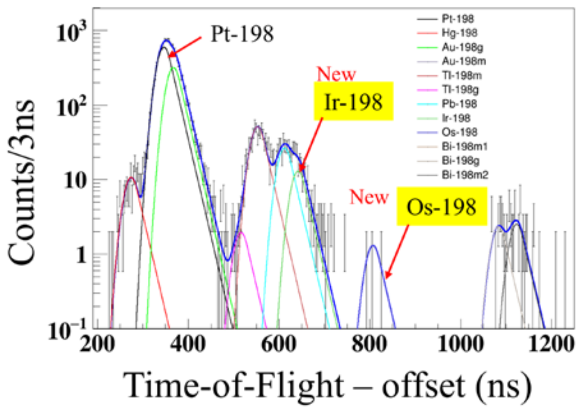

Fig. 2. Time-of-flight spectra of nuclei with mass number $A = 198$ measured by MRTOF-MS. The response function of the time-of-flight spectra was determined using ^{198}Pt ions, whose mass has already been precisely measured. Through careful analysis of the spectra of other short-lived nuclei, systematic errors can be reduced.

References

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