Commissioning of helium gas-cell + MRTOF-MS system for studies of multi-nucleon transfer reactions

S. Kimura,[*1,*2] M. Wada,[*1] A. Andreyev,[*3] H. Haba,[*2] Y. Hirayama,[*1] H. Ishiyama,[*2] Y. Ito,[*4] D. Kaji,[*2] Z. Liu,[*5] H. Miyatake,[*1] K. Morimoto,[*2] T. Niwase,[*6] M. Rosenbusch,[*2] P. Schury,[*1] A. Takamine,[*2] and Y. X. Watanabe[*1]

The multi-nucleon transfer (MNT) reactions have recently garnered interest for producing neutron-rich exotic isotopes that cannot be reached by conventional methods, for example, fragmentation, in-flight fission, and complete fusion. We recently proposed a plan to probe the existence of the $N = 152$ sub-shell closure in the lighter actinide region by using the MNT reactions with a ^{248}Cm target. However, there are technical difficulties peculiar to the MNT reactions; their products have wide energy and angular distributions. To solve this, we proposed the upgradation of the experimental setup composed of a cryogenic helium gas cell (GC) and a multi-reflection time-of-flight mass spectrograph (MRTOF-MS) used for the mass measurements of super-heavy nuclei.[1)]

The setup is located downstream of the focal plane of the gas-filled recoil separator GARIS-II; the schematic view of the setup is shown in Fig. 1. The GARIS-II is used in vacuum mode to transport the primary beam to the target. The isotopes of interest are produced via MNT reactions by irradiating the primary beam on a fixed target, which is mounted in a target cassette directly before the GC. A Ti degrader is placed immediately after the target to adjust the reaction products' stopping ranges inside the GC. A beam dump is also set on the cassette exit to stop the unreacted primary beam from entering the GC. A small beam spot is required to collect the MNT reaction products efficiently, and some additional primary beam adjustment equipment is installed in the GARIS-II focal plane chamber to this end.

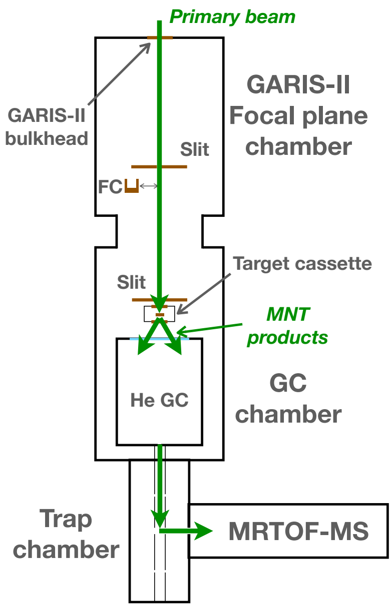

Fig. 1. Schematic view of the experimental setup.

The first commissioning experiment was performed with the MNT reaction of ^{136}Xe + ^{nat}Pb. A 1.6 mg/cm^2 ^{nat}Pb target was prepared through evaporation on a 3 μm Ti backing. The energy of the ^{136}Xe primary beam was 6.5 MeV/nucleon on the target. The doubly charged $A = 209$ and 207 isobar series were observed in the experiment. The counting rate of ^{209}Bi^{2+} was 0.21 cps with a primary beam intensity of 0.9 particle nA at the FC. This is approximately 3 times lower than the predictions from the GRAZING code.[2)] The experimental value may be explained by the fraction of the primary beam lost owing to the second slit between the FC and the target. Figure 2 shows the GC extraction yield of the doubly charged $A = 207$ isobar series as a function of the primary beam intensity. It shows linearity up to at least 1 particle nA at the FC. These results prove the proposed setup is suitable for the planned study with the MNT reactions.

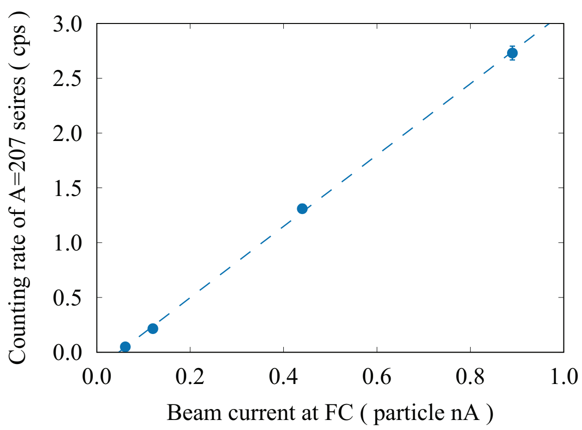

Fig. 2. Gas cell extraction efficiency as a function of primary beam current. The dashed line is a guide for the eye.

*1 Wako Nuclear Science Center (WNSC), IPNS, KEK
*2 RIKEN Nishina Center
*3 School of Physics, Engineering and Technology, University of York
*4 Advanced Science Research Center, Japan Atomic Energy Agency
*5 Institute of Modern Physics, Chinese Academy of Sciences
*6 Department of Physics, Kyushu University

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