Yield development of KEK isotope separation system

Y. X. Watanabe,[*1] Y. Hirayama,[*1] M. Mukai,[*2,*3] Y. Kakiguchi,[*1] H. Miyatake,[*1] M. Oyaizu,[*1] P. Schury,[*1] M. Wada[*1,*2] M. Ahmed,[*1,*3] S. Kimura,[*2,*3] J. Y. Moon,[*4] J. H. Park,[*4] A. Taniguchi,[*5] H. Watanabe,[*2,*6] A. Odahara,[*7] S. Kanaya,[*2,*7] and H. Muhammad[*7]

We have been developing the KEK Isotope Separation System (KISS)[1] for the lifetime measurements of neutron-rich (n-rich) nuclei around $N = 126$, which is relevant to the r-process nucleosynthesis.[2] The multinucleon transfer reaction between the ^{136}Xe beam and the ^{198}Pt target is considered as one of the promising candidates for the efficient production of those n-rich nuclei.[3] The reaction products are thermalized and neutralized in a gas cell filled with argon gas. They are transported to the exit of the gas cell by a laminar gas flow, where they are irradiated by lasers to be element-selectively ionized using the laser resonance ionization technique. The extracted ions are mass-separated to be implanted into an aluminized Mylar tape, where β-γ spectroscopy is performed to measure their lifetimes and nuclear structures.

Only the vicinity of the target nucleus could be accessed in the transfer of a few neutrons and protons at the present KISS, because of the limited extraction efficiency and acceptable beam intensity. The yield development is essential for KISS to achieve lifetime measurements of n-rich nuclei around $N = 126$. The GRAZING calculations[4] predict more production yields when using the ^{238}U beam than the ^{136}Xe beam. We performed an R&D experiment using the ^{238}U beam in order to investigate its feasibility.

The doughnut-shaped gas cell[5] was introduced to accept intense beams. A rotating ^{198}Pt target of 12.5 mg/cm^2 thickness was bombarded by a ^{238}U beam that was accelerated up to 10.75 MeV/nucleon by RRC. The beam energy on the target was tuned by rotating energy degraders to approximately 8.9 MeV/nucleon, which is the optimal value in the calculations. The multi-segmented proportional gas counter[6] was used to detect β-rays from the extracted radioactive isotopes in order to identify them by measuring their lifetimes.

The extraction of ^{199,201}Pt, ^{196,197}Ir and ^{196}Os was confirmed in the experiment. Crosses in the upper panel of Fig. 1 show the extraction yields of ^{199}Pt as a function of the ^{238}U beam intensity. They are smaller than those with the ^{136}Xe beam (circles) for all beam intensities, and the discrepancy becomes larger as the beam intensity increases. The lower panel shows a comparison between the extraction yields of various isotopes with the ^{238}U beam (crosses (26 pnA) and diamonds (36 pnA)) and the ^{136}Xe beam (circles (50 pnA)). The extraction yields with the ^{238}U beam were smaller than those with the ^{136}Xe beam by about one order of magnitude in contrast to the expectations from the GRAZING calculations. The reduction in extraction yields with the ^{238}U beam is supposed to be caused by the re-neutralization of the laser-ionized atoms by the radiation from the dense plasma in the argon gas induced by the scattered ^{238}U beam. We will investigate such a plasma effect systematically using the beam of a lighter nucleus.

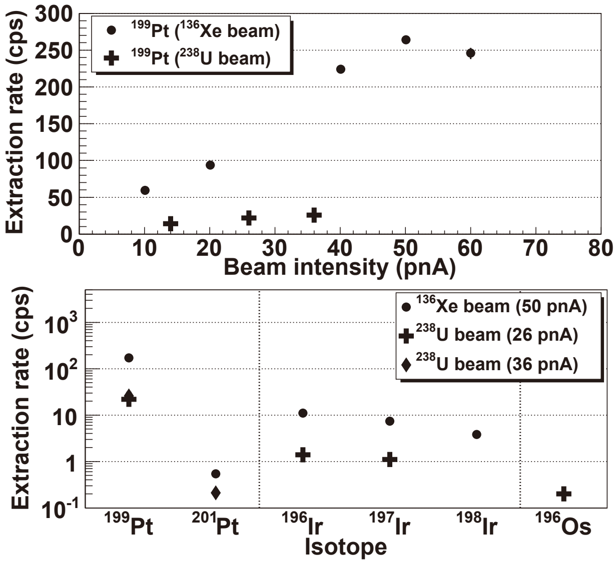

Fig. 1. (Upper) Beam intensity dependence of the measured extraction yields of ^{199}Pt for the ^{136}Xe (circles) and ^{238}U (crosses) beams. (Lower) Extraction yields of various isotopes for the ^{238}U (crosses and diamonds) and ^{136}Xe (circles) beams.

*1 Wako Nuclear Science Center (WNSC), Institute of Particle and Nuclear Studies (IPNS), High Energy Accelerator Research Organization (KEK)
*2 RIKEN Nishina Center
*3 Department of Physics, University of Tsukuba
*4 Institute for Basic Science (IBS)
*5 Research Reactor Institute, Kyoto University
*6 School of Physics and Nuclear Energy Engineering, Beihang University
*7 Department of Physics, Osaka University

References

1) Y. Hirayama *et al.*, Nucl. Instrum. Methods B **383**, 4 (2015).
2) S. C. Jeong *et al.*, KEK Report **2010-2**, (2010).
3) Y. X. Watanabe *et al.*, Phys. Rev. Lett. **115**, 172503 (2015).
4) A. Winther, Nucl. Phys. A **572**, 191 (1994); **594**, 203 (1995).
5) Y. Hirayama *et al.*, Nucl. Instrum. Methods B **412**, 11 (2017).
6) M. Mukai *et al.*, Nucl. Instrum. Methods A **884**, 1 (2018).