Development of large-volume argon gas cell at KISS

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The KEK Isotope Separation System (KISS) provides radioactive isotope (RI) beams produced by multinucleon transfer reactions between two colliding heavy ions especially for the nuclear spectroscopy of neutron-rich nuclei from $N = 126$ to actinoids.[1)] The reaction products are thermalized and neutralized in argon gas, and the neutral atoms are irradiated by two-color lasers for element selection by resonance ionization. Those ions are transported by multipole radio frequency ion guides, accelerated by a 20 kV high voltage, and mass selected by a dipole magnet. The extraction efficiency decreases at lower beam intensities with an increasing in the atomic number of the primary beam,[2)] which indicates that the dense plasma in the gas induced by the elastic scattered particles, reduces the extraction efficiency. This can be attributed to the radiation from the dense plasma ionizing remote gases, which ionizes neutral atoms to promote molecule formation or reneutralizes laser ionized ions.

We are developing a large-volume argon gas cell (LVAGC) with a volume of ∼50 L, which is almost 100 times larger than the current doughnut-shaped gas cell (DSGC),[3)] and we are also exploring the possibility of improving the extraction efficiency by reducing the plasma density in the one-fifth pressure gas. The LVAGC was designed using SOLIDWORKS Flow Simulation and has slits that generate a laminar gas flow to enable the fast transport of the reaction products. Figure 1 shows the simulated extraction time distribution. The ions are extracted from ∼20 s after the beam irradiation for ∼100 s. We attempted to extract the reaction products with the LVAGC using the ^{136}Xe beam from the RIKEN Ring Cyclotron bombarding three 3-μm titanium energy-degrading foils and a 12.9-mg/cm^2 ^{nat}Pt target at the energy of 10.75 MeV/nucleon. No significant response to the laser was observed. Figure 2 shows the time distribution of ion counts with the mass selection of $A = 196$ when the beam was turned on at 100 s and off at 400 s. The background after beam irradiation was higher than that before. The dotted line was obtained by convoluting the simulated time response function in Fig. 1 to the rectangular beam-on time, with the background (dashed line) assumed to be increasing linearly during the beam-on time. It takes ∼100 s after the beam is turned on until the rate

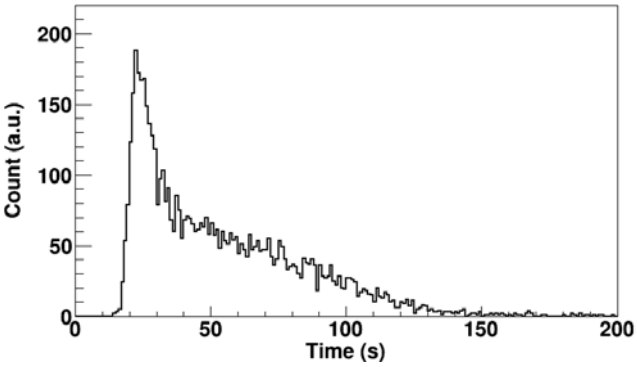

Fig. 1. Simulated extraction time distribution of multinucleon transfer reaction products.

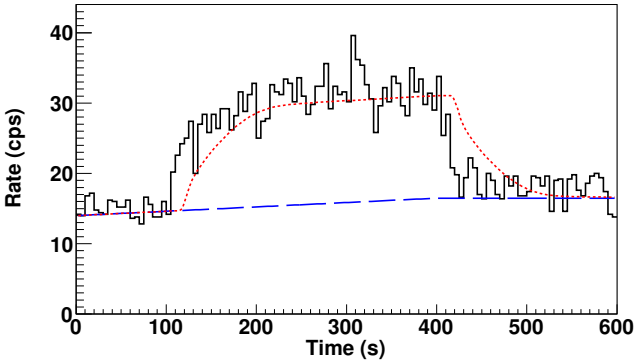

Fig. 2. Time distribution of ion counts extracted when the beam was turned on at 100 s and off at 400 s. See text for details.

is saturated and is consistent with that in the simulation. However, the ions are extracted immediately after beam irradiation without a 20 s delay. When the beam is turned off, the rate decreases immediately and swiftly in comparison to that in the simulation. The LVAGC reduces the gas pressure by one fifth; however, the extraction time is approximately 60 times longer than that of the DSGC.[3)] Such longer extraction times and more impurities dissociating from the larger inner wall of the gas cell can increase the chance of molecule formation, which can make it unresponsive to the lasers. Those molecules may be ionized immediately after the beam is turned on and neutralized immediately after beam is turned off. Optimizing the argon gas cell to balance extraction time and plasma density is essential for improving extraction efficiency.

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