Measurement of the activation of helium gas stripper by ^{238}U beam irradiation at 11 A MeV

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The activation of the helium gas stripper setup[1] for uranium beam was evaluated. At RIBF, a charge stripper of helium gas has been applied for the uranium beam as a substitute for one of solid material to avoid the limited lifetime of solid material charge stripper[1]. However, the residual dose around the setup is a serious problem for maintenance. Radiation properties such as the strong source point and lifetime of radioactive nuclei were obtained in this study. The activation around the gas stripper setup was measured using activation samples. The activation was evaluated using the PHITS Monte-Carlo simulation code[2] and the result was compared with the measured one.

A uranium beam with an energy of 10.75 MeV/u and intensity of 0.86 particle μA irradiated and passed through the helium gas cell. The helium-gas pressure in the region of highest pressure was 7 kPa, and the thickness of the helium layer was about 500 mm, which corresponds to 0.7 mg/cm^2. The helium gas was irradiated with 5.4×10^{18} uranium ions (20% accuracy) during about 18 days of the operation of the accelerator in 2015.

The activation samples were located inside the gas stripper chamber. The aluminum and bismuth samples were 10 × 10 mm in size and 1 mm thick. Figure 1 shows the setup of the helium stripper by PHITS. The distance of the samples from the beam axis was 47.25 mm. After the beam irradiation on the helium gas, the γ-rays from the samples were measured using a Ge detector after about three months of cooling. In addition, the several source RIs in the samples were identified and the number of RI nuclei were counted. The identified nuclei are listed in Table 1.

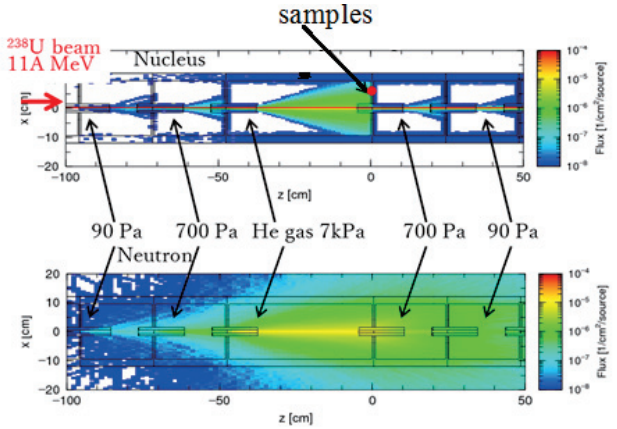

Fig.1 Flux of the nuclei (upper) and neutrons (lower) calculated by PHITS.

The calculation was performed using PHITS ver. 2.76[1] for the geometry shown in Fig. 1, which shows the flux of the generated nuclei and neutrons. The fission products were generated from uranium beam nuclei. Part of the fission products reached and were stopped at the samples. The number of generated RIs at the samples were counted and compared with the observed number of RIs. Figure 2 shows the preliminary ratios of the number of nuclei calculated by PHITS to the observed number of nuclei at the samples. The errors in the plots arise mainly from the statistics of the γ-ray and PHITS calculations and the 20% accuracy of the beam intensity. The PHITS result for the fission products of uranium beam irradiation on helium gas reproduced well the observed nuclei. These nuclides mainly concentrate the downward interior of the helium stripper chamber.

Table 1. Identified nuclei of fission products in the aluminum sample after about three months of cooling.

Nuclide	Half-life	Nuclide	Half-life
^{91}Y	58.5 day	^{134}Cs	2.06 year
^{95}Zr	64.0 day	^{137}Cs	30.1 year
^{103}Ru	39.3 day	^{141}Ce	32.5 day
^{106}Ru	371 day	^{144}Ce	285 day
^{124}Sb	60.2 day	^{155}Eu	4.75 year
^{125}Sb	2.76 year		

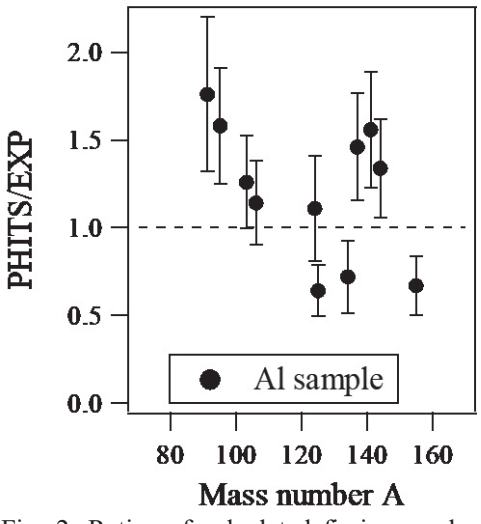

Fig. 2. Ratios of calculated fission products to the observed fission products.

References

1) H. Imao et al. Proc. of IPAC2013, Shanghai, China, May 2013 THPWO038, p.3851 (2013).
2) D. Sato et al., Nucl. Inst. Meth. A, **583**, 507 (2007).

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