Measurement of activation around the He gas stripper at RIBF

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The activation of the He gas stripper setup caused by a uranium beam was evaluated. There are several types of gas and solid stripper setup in RIBF, and a stripper setup is selected for the beam nuclide, such as uranium, xenon, and calcium. The He gas stripper setup has been developed for uranium beam acceleration at RIBF. [1] The stripper setups are often exchanged with other types to change the beam nuclide of the RIBF accelerator. The radiation exposure caused by the residual dose during the exchange and maintenance works is a serious issue. Thus, evaluating the residual dose and studying the origin of the dose are important to improve future setups. This evaluation is also applicable for the shielding design of future facilities.

In this study, the activation method was applied for the He gas stripper irradiated by a uranium beam. During the machine operation in the autumn of 2014, the samples were placed both inside and outside the stripper chamber. After uranium beam irradiation, the γ rays emitted from the samples were measured using a Ge detector.

The energy of the uranium beam on the stripper was 10.75 A MeV and the beam intensity in operation was 1200 particle nA. The beam irradiated for one month. The He gas pressure was 7 kPa, and the gas thickness was approximately 50 cm which corresponds to 0.7 mg/cm^2. The sample materials were aluminum and bismuth. The aluminum sample is made of the same material as the gas stripper chamber. Bismuth is a useful element for neutron measurement. Radioactive isotopes of bismuth are generated by neutron irradiation, and the generated isotope nuclides depend on the neutron energy because of the threshold energy of the reactions, as listed in table 1.

Some of the aluminum samples were set in the gas stripper chamber where the He gas pressure was highest. The distance between the nearest sample and the uranium beam was 47.25 mm. The samples placed inside the stripper chamber were hit by the nuclei of the fission products of the uranium beam. The other aluminum samples set outside the striper chamber are sensitive to the neutron only because the fission products stop in the chamber wall and do not reach outside. Thus, the aluminum samples are the benchmark of the neutron activation of aluminum chamber itself. The bismuth samples are set with the aluminum samples outside the chamber to obtain the neutron energy on the aluminum samples.

Figure 1 shows the measured γ-ray spectrum obtained from the aluminum sample set inside the chamber after cooling for 13.5 days. Table 2 lists the identified nuclides with short half lives. Typical nuclides of the fission products from the ^{238}U beam were observed. γ ray peaks from long-lived nuclides were not observed yet in the spectrum owing to the high background γ rays from the short-lived nuclides. γ-ray peaks of aluminum itself, such as ^{24}Na with a 15 hour half life, were not found.

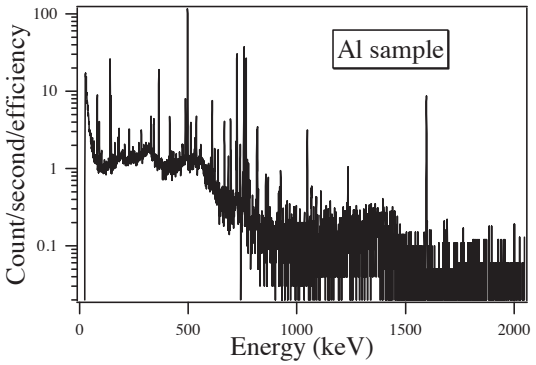

Fig. 1. Typical γ ray spectrum of the Al sample set in the gas stripper chamber. Many energy peaks caused by radioactive isotopes generated from the fission of ^{238}U were observed.

Table 1 lists the observed bismuth isotopes in the natural ^{209}Bi samples that were set outside the stripper chamber. The result suggests that the energy of irradiated neutrons on the bismuth samples was up to 22.55 MeV, since γ rays from the ^{205}Bi nucleus, which have a threshold energy of 28.6 MeV, were not detected.

After cooling the samples for a long time and background levels become low, γ rays from the long-lived nuclides will be detected. The result will be compared with a Monte Carlo simulation result to evaluate radiation issues in the future.

Table 1. Threshold of neutron energy corresponding to the production of radioactive bismuth isotopes observed in this study.

Nuclide	Half life	Reaction	Threshold
^{207}Bi	31.6 year	^{209}Bi(n,3n)^{207}Bi	14.12
^{206}Bi	6.4 day	^{209}Bi(n,4n)^{206}Bi	22.55

Table 2. Typical radioactive nuclei observed in the aluminum sample inside the stripper chamber.

Nuclide	Half life	Nuclide	Half life
^{95}Zr	64 day	^{136}Cs	13 day
^{95}Nb	35 day	^{140}Ba	13 day
^{99}Mo	2.8 day	^{140}La	1.7 day
^{99m}Tc	6.0 hour	^{141}Ce	32.6 day
^{103}Ru	39 day	^{147}Nd	11 day
^{131}I	8.0 day		

References

1) H. Imao et al.: Proc. of IPAC2013, Shanghai, China, May 2013 THPWO038, p.3851 (2013).

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