Evaluation of residual radiation from the production target at ERIS

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The electron-beam-driven radioactive isotope separator for SCRIT (ERIS),[1] located at the SCRIT electron scattering facility[2] is an online isotope-separator system (ISOL) used to produce low-energy radioactive isotope (RI) beams using the photofission of uranium. Recently, the world's first electron scattering with online-produced unstable nuclei[3] was successfully conducted using RI beams provided by ERIS. Electron scattering with short-lived unstable nuclei is the next milestone of the SCRIT project. To achieve this, it is necessary to upgrade the electron beam power to approximately 1 kW in order to produce the required intensity of short-lived unstable nuclei. One of the challenges in handling a high-intensity RI beams is the residual radiation emitted by the uranium-carbide production target at ERIS. For the safe post-irradiation work around the ion source, it is critical to estimate in advance timing of work and working hours for planning the maintenance scenario. Therefore, the evaluation of residual radiation is an important issue. In this paper, we report the results of the comparison between measurements and calculations of residual radiation.

Measurements of the residual radiation were conducted just after ^{137}Cs experiment.[3] During the experiment, electron beams, accelerated to 150 MeV, irradiated the uranium carbide target with the average beam power of 15 W. The total amount of uranium was approximately 28 g. The total irradiation period was approximately two week. After the irradiation, the dose rate just besides the vacuum chamber of the ion source was measured using a survey meter, AE-133 manufactured by APPLIED ENGINIERING INC.. The distance between the target and the survey meter was approximately 20 cm. Figure 1 shows the time dependence of residual radiation after irradiation. Red circles in Fig. 1 show the measured values. The measured value at 180 hour becomes large again, because the re-irradiation was performed to investigate the property of the ion source. After 20 days, the residual radiation remained at 40 μSv/h, which corresponds to an estimated 2.7 mSv/h for a 1 W beam. With such a high radiation level, the allowed working time will be about 20 minutes.

The residual radiation was estimated using the PHITS (version 3.33) + dchain-sp code[4] at RIKEN HOKUSAI BigWaterfall2. The calculation was performed in three steps. Firstly, the rate of produced RIs inside the production target were calculated. Secondly, the time dependence of the γ-ray intensity and energy distribution inside the production target were evaluated considering the irradiation and non-irradiation time. For this evaluation, the lifetime and γ-ray energy of each produced RI calculated in the first step were used. Finally, the location dependence of the residual radiation at each time was calculated using the γ-ray distribution inside the production target evaluated in the second step. Blue squares in Fig. 1 show the calculated results. Although the calculated and measured values showed similar time dependence, the calculated values were approximately ten times higher. Solid and dashed lines in Fig. 1 show the calculation results using the empirical formula[5] and the results reduced to 1/10, respectively. Since two calculations of the PHITS code and the empirical formula behave the same time dependence, the main components of the residual radiation are considered to be reproduced. Details of the difference in absolute values are currently under investigation.

In summary, we compared the measured and calculated the residual radiation. Although the calculation reproduces the time dependence, the difference is large for absolute values. Despite this situation, the distribution of the residual radiation including complex geometries can be calculated. This is very useful when considering maintenance scenarios, and we plan to continue to improve the calculation of residual radiation.

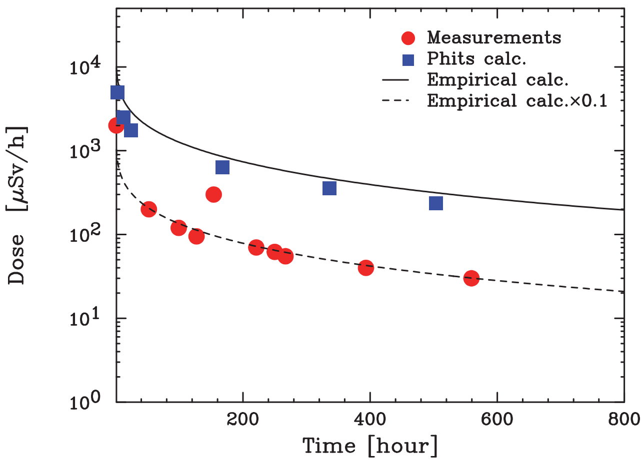

Fig. 1. Time dependence of residual radiation after irradiation. Details are described in the text.

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