A Preliminary Study for Safety Shutter design to Protect Streaming of Residual Radiation Passing through Beamline in Pre-Separator Room of ISOL

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1. Introduction

RAON is a heavy ion accelerator under construction by the Institute for Basic Science (IBS) in Korea [1]. As one part of the RAON accelerator, ISOL is a facility to generate and separate rare isotopes for various experiments. In ISOL facility, isotopes generated from the reaction between 70 MeV proton beam and UC_2 target are transferred to pre-separator room. Almost all isotopes accumulated in slit of pre-separator except specific isobars, which are set for experiments. Residual radiations are generated from accumulated isotopes because these isotopes are unstable. Streaming of residual radiation by the beamline is weak point for radiation shielding design.

Therefore, in this preliminary study, to prevent streaming, optimized safety shutter diameter and thickness was evaluated. Also, additional shielding structure of safety shutter device was estimated.

2. Methods and Results

In this section, safety shutter was design according to established computational procedure. First of all, residual radiation generated from radioactive isotopes accumulated at slit in pre-separator should be properly estimated. Source term was evaluated as following condition: (1) the isotopes generated by proton-target reactions are accumulated at slit with 10 % accumulation rate; (2) it was assumed that the radioactive isotopes are uniformly distributed in the cylindrical slit which have 1 cm height and 15 diameter; (3) operation period of ISOL system was assumed to 2 week operation with 2 weeks cooling and operation time are set at 1 year. And then, to design optimized safety shutter, following computational steps were performed: (1) thickness and diameter of the bulk shield material were evaluated to optimize safety shutter material; (2) additional shielding structure was designed.

For the safety of the worker, design of RAON accelerator has criteria that the residual dose level in working area must be satisfied dose limit (5 μSv/h). For radiation analysis, region of Interest (ROI) was determined as a space with 30 cm x 30 cm x 30 cm behind concrete wall in beam line.

Fig. 1 shows dose map of residual radiation in pre-separator room to check dose level without safety shutter. The ORNL regular concrete [2] with 2.30 g/cc density was used. Dose rate in ROI was estimated as 4.76E+04 μSv/h with 0.0069 relative error. Therefore, to satisfy the dose limit, safety shutter must be installed at beam line near the concrete wall. Also, safety shutter should be optimized because to handle the heavy shutter in vacuum system is difficult problem to open and close.

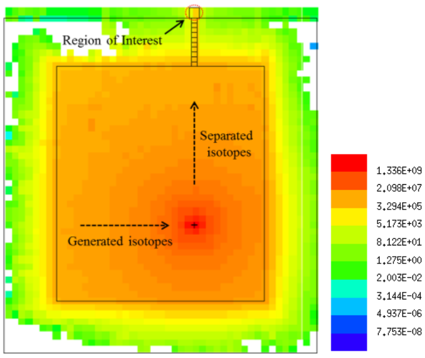


Fig. 1. Dose map of residual radiation in pre-separator room without safety shutter

MCNPX 2.7.0 code [3] was used to analyze the particle transport with mcplib84 photon cross section libraries. Also, ICRP 116 AP direction dose conversion factor was used for estimation of residual radiation dose [4].

2.2 Evaluation of the Thickness and Diameter of Safety Shutter

Generally, heavy shielding material is better to protect the radiation. However, in vacuum system, handling the heavy shutter to open and close is difficult. Therefore, safety shutter material should be optimized as small as possible. Also, tungsten is set for the shutter because of compatible material in vacuum.

To evaluate thickness of the shield materials, bulk shielding calculation to satisfy dose limit was performed without considering the streaming effect. Evaluated thickness of tungsten, which has 19.30 g/cc density, was given in Table I.

Table I: Shield Thickness for Satisfying Dose Limit

	Concrete	Tungsten
Thickness (cm)	140	14

Also, diameter of safety shutter should be properly estimated with considering streaming effect of residual radiation to ROI. Fig. 2 shows the contribution ratio to ROI from beamline inlet according to diameter from 15 cm to 23 cm. The decrease rate of dose longer than 18 cm diameter was lower than 2 %. Therefore, 18 cm diameter was selected for efficient shielding performance.

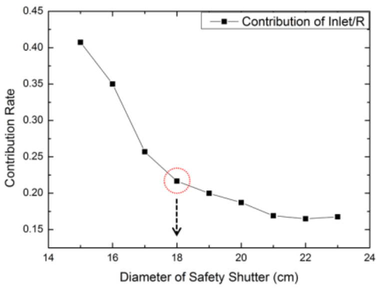


Fig. 2. Contribution rate from beamline inlet to ROI according to diameter of shutter

2.3 Evaluation of additional Shielding Structure

After safety shutter was installed, radiation dose in ROI was 45.75 μSv/hr with 0.018 relative error as shown in Fig. 3.

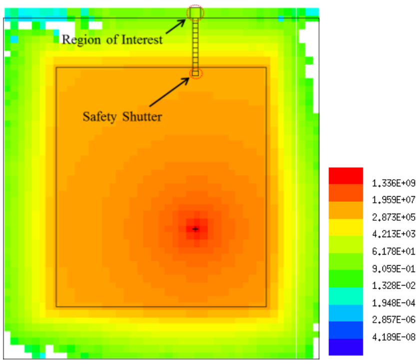
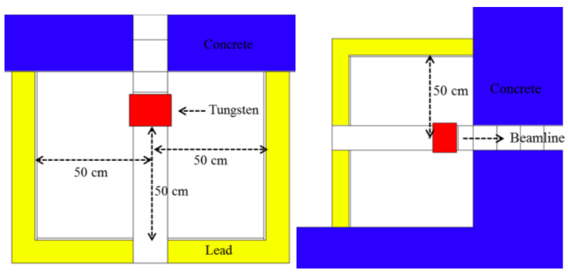


Fig. 3. Dose map of residual radiation in pre-separator room with safety shutter

It still has higher level than dose limits caused by streaming. Thus, additional shielding should be needed. To set the additional shielding, it was assumed that the device of safety shutter need 50 cm distance from center of beamline as shown in Fig. 4.



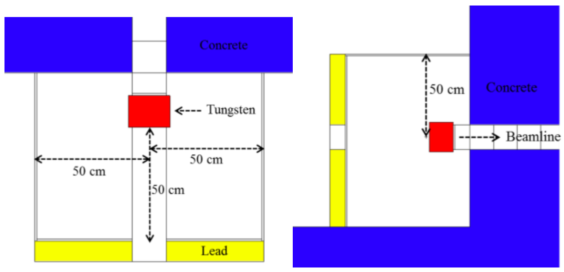
(a) xy modeling (b) yz modeling
Fig. 4. Modeling for the dose rate contribution

For deciding the additional shielding thickness, it was calculated that dose contributed to ROI from following areas: front, left, right, top shielding and shutter. Each area was set at inside of shutter and device surface. To get the contribution, each lead wall, with 11.34 g/cc, was set as 10 cm thickness.

Table II: Dose rate Contribution of each wall and shutter for ROI

	Shutter	Front	Left	Right	Top
Contributed Dose [μSv/hr]	0.18	1.69	0.0019	0.0017	0.0020
Relative Error	0.0167	0.0115	0.1105	0.0492	0.1994

Table II is results of dose rate contribution of each wall and shutter for ROI. Using these results, wall thickness was recalculated. Lead shielding wall of front direction needed to have thickness of 8 cm. other directions didn't needed to shield residual radiation. Based on this result, additional shielding was proposed as shown Fig. 5.



(a) xy modeling (b) yz modeling
Fig. 5. Modified safety shutter device in pre-separator

The results of final design are Fig. 6 and Table III. Dose rate in ROI is 4.79 μSv/hr with 0.0411 relative error. It shows that the residual radiation dose in ROI was properly protected by proposed design safety shutter and additional shielding.

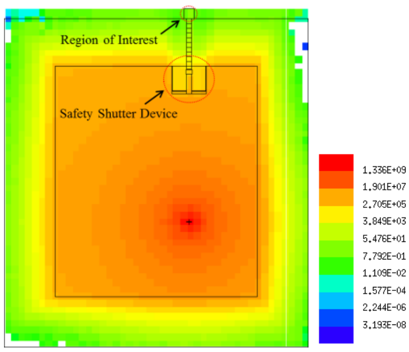


Fig. 6. Dose map of residual radiation in pre-separator room with proposed safety shutter device

Table III: Dose rate Contribution of each wall and shutter for ROI using proposed design

	Shutter	Front	Left	Right	Top	ROI
Contributed Dose [μSv/hr]	0.31	2.41	0.27	0.44	0.25	3.92
Relative Error	0.0336	0.015	0.0255	0.0291	0.1844	0.0159

3. Conclusions

In this study, safety shutter was designed. Residual radiation generated from accumulated isotopes at slit of pre-separator was estimated using following conditions: (1) the isotopes generated by proton-target reactions are accumulated at slit with 10 % accumulation rate; (2) it was assumed that the radioactive isotopes are uniformly distributed in the cylindrical slit which have 1 cm height and 15 diameter; (3) operation period of ISOL system was assumed to 2 week operation with 2 weeks cooling and operation time are set at 1 year. To design optimized safety shutter, following steps were performed: (1) thickness and diameter of the bulk shield material were evaluated to optimize safety shutter material; (2) additional shielding structure was proposed using dose contribution of each additional shielding wall. The residual dose in ROI properly reduced by using proposed shielding design. It is expected that this results can be used for safety shielding design in pre-separator room of ISOL facility.

Acknowledgement

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