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Bulk Shielding Calculation for 90° Bending Section of RISP

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1. Introduction

The shielding analysis had been carried out for 90° bending section of heavy ion accelerator facility of RISP (Rare Isotope Science Project). One of main projectile beams is 17.5 MeV/nucleon, 11.76 pμA $^{238}U^{33+,\ 34+}$ (50% - 33+ ion, 50% - 34+ ion). A thin quadrangle carbon stripper is placed to generate higher charged ^{238}U beams at the front of the 90° bending section. The charge state of ^{238}U beams with maximum intensity was 79+ among multi-charge states of 70+ to 89+, which were estimated by using LISE++ code [1]. The bending section consists of twenty four quadrupoles, two dipoles, two two-cell type superconducting RF cavities and eleven slits. The complicated radiation environment is caused by the beam losses occurred normally during the stripping process and when the produced ^{238}U beams are transported along the beam line. Secondary radiations generated by ^{238}U beams irradiation are very important for predicting the prompt and residual doses and the radiation damage at the component.

The production characteristics of neutron and photon from thin carbon and thick iron were studied to set up the shielding strategy. The dose estimation was done to the pre-designed the tunnel structure. In these calculations, major Monte Carlo codes, PHITS[2] and FLUKA[3], were used.

2. Methods and Results

2.1 Source term evaluation for shielding analysis

The incident ^{238}U beam generates nucleus-nucleus interaction with a matter like carbon stripper and thick magnet. In the Monte Carlo codes, it was simulated using Quantum Molecular Dynamics or Quark-Gluon String Model according to ion energy. In PHITS code, the JQMD (JAERI Quantum Molecular Dynamics) models [4] and the evaporation and fission model, GEM (General evaporation model) [5] were employed for simulating for nucleus-induced reactions. Both models are adopted for heavy ion energies between 10 MeV/nucleon and 100 GeV/nucleon. In FLUKA code, a Dual Parton Model and a RQMD (Relativistic Quantum Molecular Dynamics) are adopted above 5 GeV/nucleon and from 125 MeV/nucleon up to 5 GeV/nucleon, respectively. A BME (Boltzmann Master Equation) model covers the lower energy range. An evaporation, fission and break-up modules are based on the Weisskopf-Ewing formalism.

The source term of bulk shielding analysis was evaluated for a thin target and a thick target. The thin charge stripper and the thick magnet body at the 90° bending section of RISP facility are considered as representative target materials, which are interacted with 17.5 MeV/nucleon ^{238}U beam. A thin and thick targets were assumed as the carbon foil (5 μm-thickness, 5 mm × 5 mm, 2 g/cm^3) and the cylindrical iron (20 cm-thickness, 10 cm-diameter, 7.87 g/cm^3). Using both of the Monte Carlo codes, the neutron and photon production yields were calculated as shown partly in figure 1. The angular ring detectors were employed and were set to the thirty-seven angles of every 5° from 0° to 180° with a width of ± 0.5° at 1 m distance from the target.

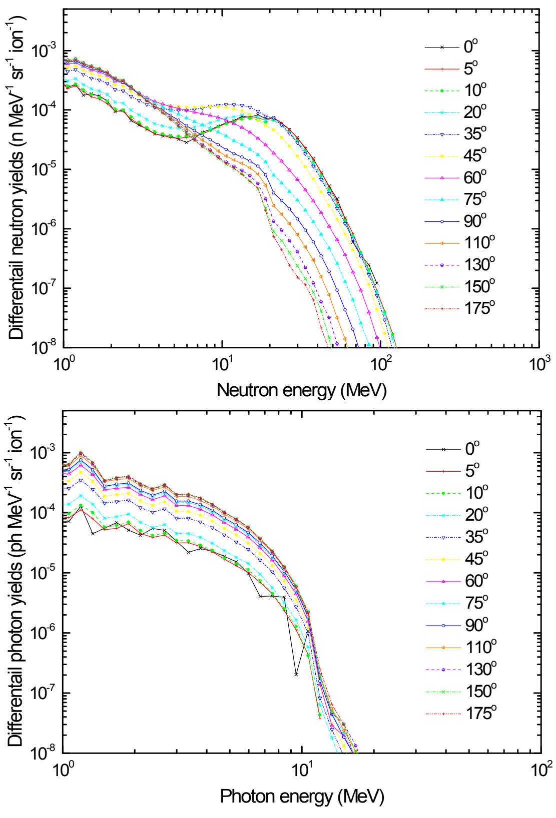

Fig. 1. Differential yields of (a) neutron and (b) photon produced from thick iron target irradiated by 17.5 MeV/nucleon ^{238}U beams using PHITS code.

The differential yields of secondary neutron and photon from thick iron target at different detection angles are shown in figure 1. Most of high energy neutron is emitted into the forward direction at the energies above 10 MeV, while the energy distribution of produced photon is independent of the emission angle but the amount difference for the angle extend to 1 order. But the photon is not effective to determine bulk shielding thickness. All of photons, which appeared at outside of thick shield are generated from high energy neutron of the source spectrum.

2.3 Bulk shielding using simple opened tunnel structure

Bulk shielding calculation was carried out to estimate a dose level behind the thick shielding wall surrounding targets. Opened tunnel structure was chosen to remove the contribution of recoil particles from the backside wall of the target. Figure 2 shows the input geometry and materials for Monte Carlo calculation. Because of low penetration rate at thick concrete shield, the variance reduction technique of an importance splitting was applied to increase the calculation precision. The distribution of the produced secondary neutron fluences is shown in figure 3. The thick iron target and PHITS code were employed in this results. As a result, the maximum dose rates of neutrons and photons by full beam losses were 0.151 mSv/h and 1.39 × 10^{-3} mSv/h behind of front shielding wall. Such a high neutron dose result leads to the activation of soil around concrete tunnel.

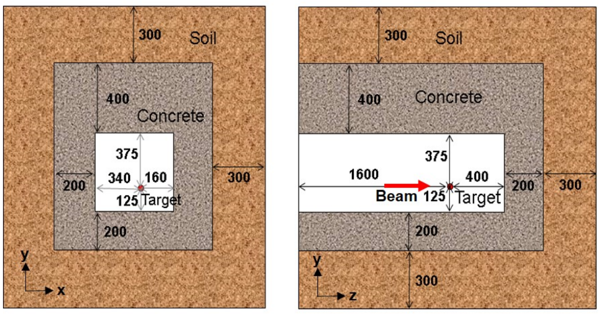

Fig. 2. The configuration of geometry for the calculation of bulk shielding using Monte Carlo code (unit: cm)

3. Conclusions

The present study provided information of shielding analysis for the 90° bending section of RISP facility. The source term was evaluated to determine fundamental parameter of the shielding analysis using PHITS and FLUKA codes. And the distribution of the dose rate at the outside of thick shielding wall was presented. The proposed shield thickness of 2 m ordinary concrete may be proper for side wall shielding but is not sufficient for the forward direction. All calculations were performed using PHITS and FLUKA codes and both results were compared.

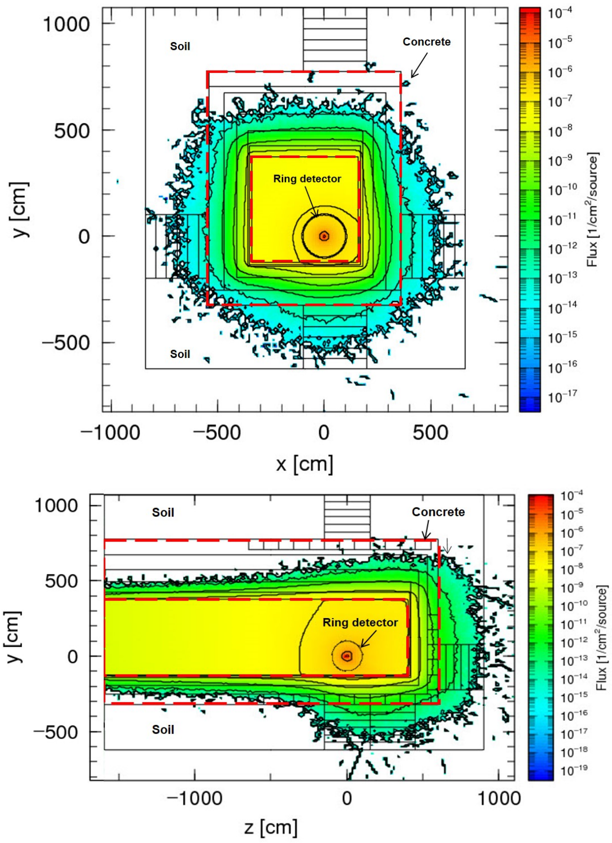

Fig. 3. The secondary neutron distribution of bulk shielding calculation at 90° bending section of RISP using PHITS code.

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