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Design of radiation shield for RI production beam line by PHITS/PHITS を用いた RI 製造ビームラインの遮蔽設計

A new beamline for the production of astatine-211 is to be installed at the RIBF accelerator facility. At the beamline, an alpha beam is irradiated to the bismuth target. The RI production requires a high intensity beam, which generates a large amount of radiation from the target. A shielding system with sufficient capacity is necessary to keep the radiation dose rate in the surrounding area low. In this study, the shield was designed with the goal of achieving a radiation dose rate of less than 10 μSv/h on the outside of the shield using the Particle and Heavy Ion Transport code System (PHITS)[1], and the compact shield was designed by combining multiple shielding materials.

Because a shield made of one type of material is not effective enough against high energy neutron, its weight and size became large. A size of the shield is limited because the beamline is installed in a narrow space. In addition, the floor load-bearing capacity is also limited due to the structure of the building.

The radiation dose rate around the target by an alpha beam with an energy of about 29 MeV and an intensity of 100 pμA is estimated to be 300 Sv/h. Thus, the shielding to reduce the radiation dose rate by seven orders of magnitude is requested. Neutrons with energies up to 15 MeV are generated by the objective reaction. In general, neutrons less than a few MeV are shielded well by hydrogen-rich materials, such as polyethylene or water. To shield high-energy neutrons, firstly inelastic scatterings with heavy materials are applied to reduce the neutron energy. Secondary, polyethylene is used outside the heavy material part to shield low-energy neutron effectively. Primary and secondary gamma rays are shielded by metals such as iron and lead.

The optimized shielding configuration was 30 cm thicknesses of iron, 10 cm of polyethylene containing 10 % B_2O_3, and 40 cm of polyethylene. Since neutrons are absorbed with protons in the polyethylene shield and it provides secondary gamma rays, lead was additionally installed to reduce the gamma rays.

In addition to the shielding around the target, the shielding of the concrete building was also taken into consideration to keep the radiation dose rate on the border of the radiation-controlled area below the legal limit.

References

[1] T. Sato, Y. Iwamoto, S. Hashimoto et al., "Features of Particle and Heavy Ion Transport code System (PHITS) version 3.02", J. Nucl. Sci. Technol. 55(5-6), (2018), pp. 684-690.

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