Study of Shielding Performance with Box Shielding Block of the HANARO Cold Neutron Triple-Axis Spectrometer II

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1. Introduction

The concrete shielding blocks of the HANARO cold neutron triple-axis spectrometer required redesign and reconstruction due to deformation. Neutron and gamma flux were evaluated for the changed structure of the shielding blocks which include segmented polyethylene, and the top and the back shielding. [1] As shown in Fig. 1, the box shielding block surrounding the monochromator chamber is added to shield gamma radiation effectively. The box shielding block has three holes for guide entrance, beam dump entrance, and scattered neutron beam path from the monochromator. We evaluated neutron and gamma distribution around the monochromator based on the thickness and the material of the box shielding block and by using MCNP.

Fig. 1 Box shielding block

2. Method and Results

2.1 A box shielding block with 0.5 cm B_4C and 5 cm lead, and a 20 cm lead on the top of segmented polyethylene

The interior dimension of the monochromator chamber is determined by the rotational motion of the monochromator and the motors. The introduction of the box shielding block, hence, inevitably reduces the thickness of the top and back concrete shielding blocks.

The box shielding block consists of 0.5 cm thick B_4C and 5 cm thick lead 5 cm. Top shielding block consists of 5 cm polyethylene, 10 cm lead and a thick high density concrete, with its top at the same height as the guide shielding. The density of concrete is 4.0 g/cm3.

Figure 2 shows the distribution of neutron and gamma flux on the YZ plane. Neutron flux is mostly shielded by B_4C. Although neutron flux is distributed below the segmented shielding blocks, the height of distributed neutron is lowered by 20 cm than without the box shielding block.

Gamma flux at segmented polyethylene reduces to one tenth of the previous level by adding the box shielding block. It is easily shielded with a few centimeters of lead on the top of segmented polyethylene. Regardless it is necessary to change the material from polyethylene to lead to shield the gamma flux.

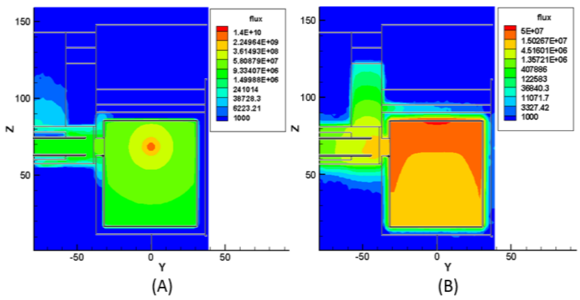

Fig. 2 Distribution of (A) neutron and (B) gamma flux with the box shielding block of 0.5 cm B_4C and 5 cm lead

2.2. A box shielding block with 0.5 cm B_4C and 5 cm lead, and a 10 cm stainless steel on top of the segmented polyethylene

In order to shield upward gamma from the monochromator with the top shielding block, materials such as polyethylene and lead were changed to the high-density concrete of 4.0 g/cm^3. 20 cm lead on top of the segmented polyethylene was changed to 10 cm stainless steel.

Neutron flux distribution is similar to the previous configuration. Gamma flux is blocked by the top shielding block more effectively. Also, gamma flux is completely shielded on top of the segmented polyethylene despite the change of the material and reduction of height.

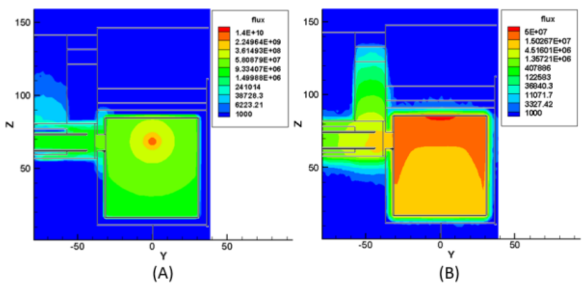

Fig. 3 Distribution of (A) neutron and (B) gamma flux with the box shielding block of 0.5 cm B_4C and 5 cm lead, and 10 cm stainless steel on top of segmented polyethylene

2.3. A box shielding block with 0.5 cm B_4C and 5 cm lead, heavy concrete top shielding block, and segmented polyethylene shielding

With the addition of the box shielding block, the gamma flux on top of the segmented polyethylene was lower than before. Gamma flux under and above the segmented polyethylene dropped respectively to one-third and one-fortieth the level. We could attempt to remove the stainless steel on top of the segmented polyethylene encouraged by this result.

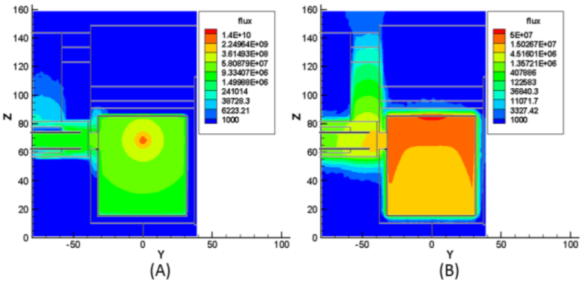

Fig. 4 Distribution of (A) neutron and (B) gamma with the box shielding block with 0.5 cm B_4C and 5 cm lead, a concrete top-shielding block on the YZ plane

2.4. A box shielding block with 0.5 cm B_4C and 5 cm stainless steel, a concrete top shielding block, and segmented polyethylene without metal tops

Lead is a great material to shield gamma, but it is expensive. To reduce the cost of fabrication, stainless steel was considered in place of the lead when designing the box shielding block. The geometry was the same as previous. The density of the concrete blocks around the box shielding block was 4.0 g/cm^3.

The resulting neutron flux distribution was similar to the previous result. Gamma flux could be found up to 20 cm from the outer surface of the box shielding block because of the lower gamma shielding efficiency of stainless steel. As gamma distribution extended, gamma flux leaking to the top of segmented polyethylene was increased 3 fold compared to the previous case. Therefore, using stainless steel for the box shielding block necessitates a thicker shielding to reduce overall radiation.

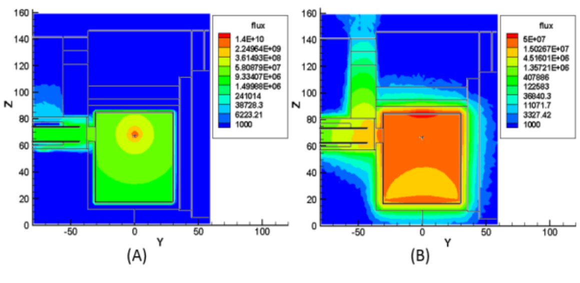

Fig. 5 Distribution of (A) neutron and (B) gamma with the box shielding block with 0.5 cm B_4C and 5 cm lead on the YZ plane

2.5. A box shielding block with 0.5 cm B_4C and 10 cm stainless steel, a concrete top-shielding block, and segmented polyethylene without metal tops

In order to reinforce the shielding, the thickness of the box shielding block was increased from 5 cm to 10 cm. The thickness of the concrete blocks was decreased in consequence. Neutron flux distribution from this configuration is similar to the previous result. While the box shielding block stopped more gamma radiation from leaking, still large gamma flux was observed inside the concrete shielding. The penetration of gamma was about the same regardless of the thickness of the stainless steel. Meanwhile, the gamma flux leakage above the topmost surface of the segmented polyethylene became one-third the level compared to the previous case.

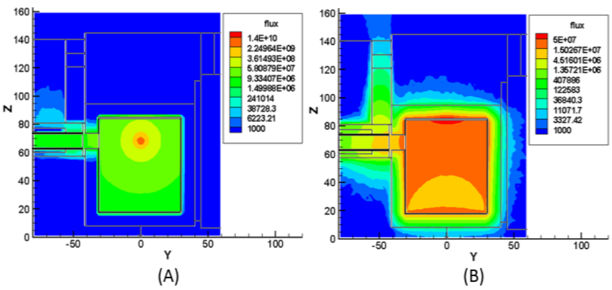

Fig. 6 Distribution of (A) neutron and (B) gamma with the box shielding block with 0.5 cm B_4C and 10 cm stainless steel on the YZ plane

3. Conclusion

Based on the analysis presented in this abstract, the dimension and composition of the box shielding block were determined. For shielding performance, the box shielding block was made of 0.5 cm B4C and lead. The thickness of lead was conservatively decided to be 10 cm. The material on top of the segmented polyethylene was changed to a 10 cm stainless steel to block gamma. Additionally, the top shielding block was changed to the heavy density concrete of 4.0 g/cm^3. Because the fabrication of shielding blocks requires changes owing to the manufacturing limitations, we will re-evaluate the shielding performance with MCNP and with neutron beam after fabrication and installation.

REFERENCES

[1] J. Ryu, J. M. S. Park, and B. Seong, Study of the Monochromator Shielding Block Redesign of the HANARO Cold Neutron Triple-Axis Spectrometer, *Transactions of the Korean Nuclear Society Spring Meeting*, 2016.