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Shielding Design of Cold Neutron Triple-axis Spectrometer using MCNP6

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1. Introduction

A new cold neutron triple-axis spectrometer(Cold-TAS) at HANARO was lately constructed.[1] The spectrometer, which is composed of neutron optical components and radiation shield, asked a redesign of the segmented shield due to reduce weight. The segmented shield was suggested while adding more radiation shield to the top cover of the monochromator chamber. To investigate the radiation, we performed MCNP6[2] simulations of a few different configurations of the Cold-TAS shield and obtained neutron and photon flux at 5 points that depend on reducing the height of the segmented shield and locating lead from the bottom of the top cover made of polyethylene.

2. Methods and Results

2.1 Geometry of the C-TAS and set up MCNP code

Cold neutron into C-TAS move through CG5 that is connected ST2 from the HANARO. Geometry of C-TAS is Figure 1 and NVS(Neutron Velocity Selector) can select specific wavelength.[3] The selected cold neutron is gathered by monochromator, first axis, at center of C-TAS again. Selected neutron move to sample table, that is second axis, and scattered neutron from sample move to analyzer that is third axis. Neutron move to detector to get sample information.

Neutron source which is from HANARO to monochromator of C-TAS is calculated using McStas[4], cold neutron intensity is 3.7×10^{9} n·sec^{-1} at monochromator. The 36 energy group was selected from 54 energy group excepting under 0.1%. The density of heavy concrete is 3.4 g/cm^3, and polyethylene is 0.97 g/cm^3.[5] Calculating points from 1 to 5 are located like figure 1

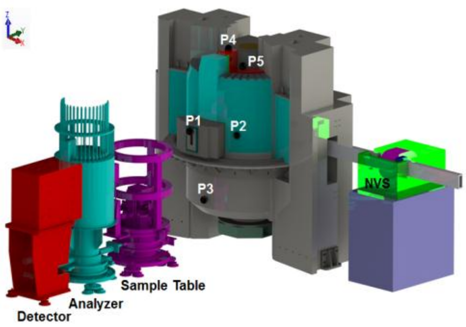

Fig. 1 Geometry of cold-TAS and positions of NVS and point 1 to 5.

2.2 Flux depended on the height of the segmented shield

Figure 2 is neutron and photon flux depend on reducing height of 20%, 25%, 30%, 35% and 40% the and add lead(5 cm) and polyethylene (40 cm) over the monochromator. In case of neutron flux, P1 is the highest, because P1 was the closest point from neutron beam among 5 points. P2 was 1/10 of P1 and P3 was 1/5 of P2. Neutron flux at P1, P2 and P3 depended on the height of the segmented shield were similar. Flux of neutron at P4, P5 make different for reducing the height. The more the height of the segmented shield reduced, the more flux increased. However, neutron flux of before changing height was the highest among any case, because of adding lead and polyethylene over monochromator.

In case of photon flux, P1, P2 and P3 were similar, because photon near by the neutron guide moved to P2, P3 without shielding that is different situation compared with neutron flux. At P4 and P5, the more the height of the segmented shield reduced, the more flux increased that likes neutron flux. However, flux level was the highest among all point for neutron and photon flux. In the result, reducing height of 20% was the best case to reduce the height of segmented shield.

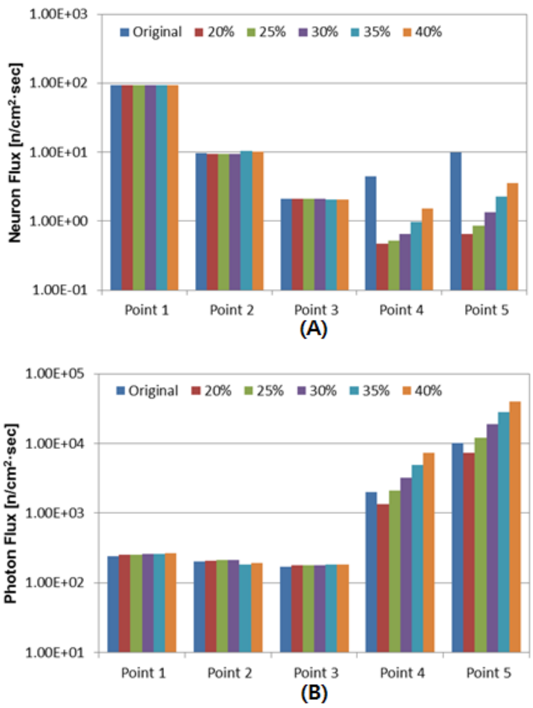

Fig. 2 Flux depended on reduced height of polyethylene and lead (A) neutron, (B) photon

2.3 Flux depended on location of lead

Photon flux of reducing the height of 20% was lower than before reducing the height. However, the more the height reduced, the more weight of shield lost that good for safe and durability of C-TAS. Neutron and photon flux was checked depended on the lead position locating 10 cm, 20 cm and 30 cm from bottom of polyethylene over the monochromator. In neutron result, flux was similar with before changed position of lead.

In result of photon, before changed location of lead likes changed at P1, P2 and P3. Photon flux was decreased for moving lead from 30 cm to 10 cm at P4 and P5. The lowest flux condition that lead was located 10 cm from the bottom of polyethylene increased 25% at P4 and 18% at P5 compared with before original geometry. However, photon flux decreased 116% at P4 and 153% at P5 compared with reducing height of 35%. It was the best condition that reducing the 35% height of segmented shield and located 10 cm lead from the bottom of the top cover unless increased flux reached to detector.

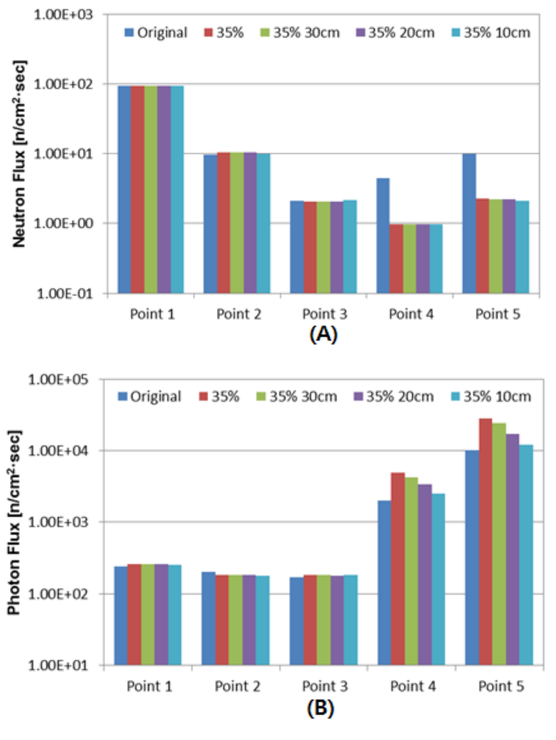

Fig. 3 Flux depended on position of lead over the monochromator (A) neutron, (B) photon

2.4 Distribution of photon flux

The neutron source, shield component and density were same with previous calculation. For considering resolution, mesh size was 4 cm on Y-Z plane, figure 4 is the result. The minimum and maximum of photon flux were decided 1000~40000 $n\cdot cm^{-2}\cdot sec^{-1}$ from figure 3(B) at P4 and P5. Radiation was in inverse proportion to length square, legend increased exponentially.

Photon of original geometry at P4 moved 60 cm from surface segmented shield(Fig. 4 (A)) and 75 cm after changed shield geometry(Fig. 4 (C)). Photon of original geometry at P5 moved 90 cm from surface segmented shield(Fig. 4 (B)) and 100 cm after changed shield geometry.(Fig. 4 (D)) However, despite increased photon flux, absolute height was lower(approximately 220 cm) than original geometry(approximately 240 cm), because the reduced height was lower than before changed.

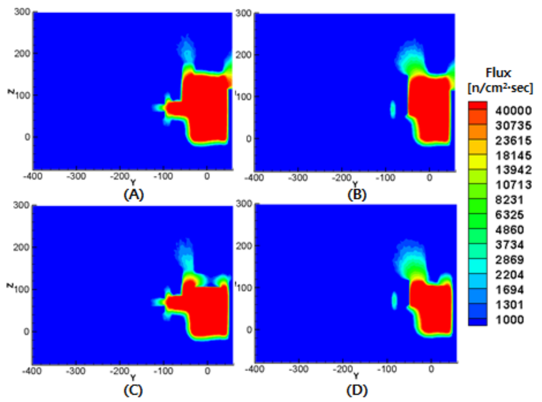

Fig. 4 Distribution of photon flux on Y-Z plane original geometry (A) point 4, (B) point 5, reduced height 35% and lead at 10cm from bottom (C) point 4, (D) point 5.

3. Conclusions

Cold neutron three-axis spectrometer was collapsed by weight of segmented shield. For normal condition of instrument, the 35% height of segmented shield was reduced and lead at over the monochromator was located 10cm bottom over the shield by calculating MCNP6. Photon flux increased 18% and 25% at P4 and P5 than original geometry, but absolute height was lower. Moreover, increased flux didn't reach to detector which is located 300 cm from center of C-TAS. In this paper, we got the best case of shield geometry using MCNP6.

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