Na¿ve KOPIO neutral beam dump simulation studies (Rev. 2)

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Calculations were done to determine the performance of the beam dump and the differences in back-scattering radiation between three configurations. MCNPX (versions 2.5.c and 2.5.d) were used in this simulation.

The source term is in the simulation is a neutron distribution based on the K0PI0 TDR [1] with a simplified exponential representation such that the kinetic energy spectrum is $e^{-0.001535 \bullet E}$, where E is the energy in MeV. The radial acceptances are 105 milli-radians horizontally and 5 milli-radians vertically and the distance between the source and beam dump is about 37.2 m. Therefore, the spatial distribution is uniform over the plane of 390.6 cm (horizontal) × 18.6 cm (vertical) in front of the beam dump. The neutron intensity is assumed to be 10^9 s^{-1}.♣

The simulated shape of the beam dump is shown in Figure 1. The 3 main layers of materials (heavy concrete and steel) are each 150 cm thick in the beam direction. The entire horizontal and vertical lengths are 10 m and 3 m respectively. The four sides whose plane axes are perpendicular to the beam direction are covered by light concrete of 50 cm thick in both the horizontal and vertical directions.

♣ From [2], the incident proton intensity is 2×10^{-6} per μ-steradian. Assuming the proton intensity to be 1×10^{14} with a cycle of 5 second, the neutron intensity is therefore:
$105 \times 5 / (4\pi) \times 2 \times 10^{-6} \times 10^{14} / 5$ or 1.7×10^9 s^{-1}.
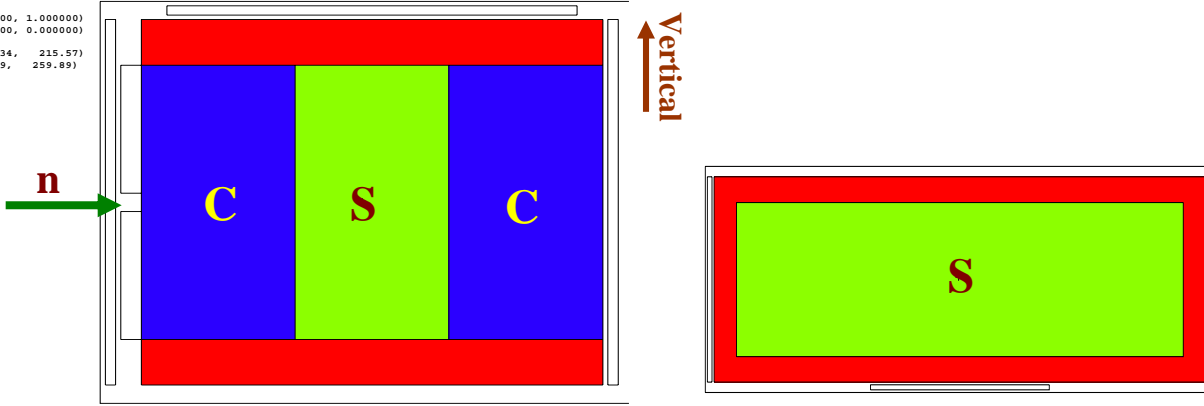
Figure 1: *Left*: The beam dump with configuration CSC (concrete-steel-concrete) along the beam direction. The four sides are covered by light concrete. The colorless/empty blocks (as seen in the figure) are empty volumes defined in the MCNPX which are the places where radiation levels are calculated. The arrow gives the direction of the incoming neutrons. *Right*: The cross-sectional (in the XYplane perpendicular to the beam direction) view of the beam dump. The four sides are covered by light concrete.

With the configuration CSC, ie, concrete-steel-concrete, for the 3 main layers of the beam dump, the upstream radiation level due to back-scattering is found to be about (1660 ± 9) mrem/hour. The dose equivalent is used because the original purpose was to study the radiation. "Concrete" here is meant to simulate the heavy concrete (13% H, 45% O, 1.5% Al, 15% Si, 2.5% Ca, and 23% Fe) and the density is assumed to be 3.9 g cm^{-3}
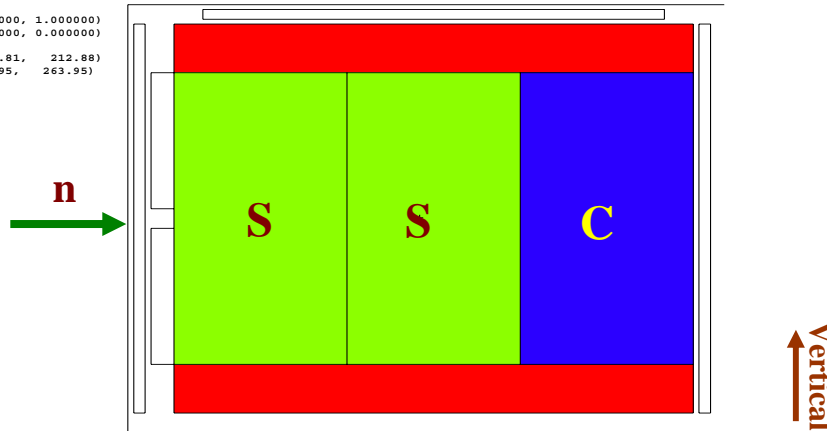
Figure 2: The beam dump, similar to Figure 1, but in the CSS (concrete-steel-steel) configuration. The arrow gives the direction of the incoming neutrons. The empty blocks are empty volumes where radiation levels are calculated.

If we use SSC, ie., steel-steel-concrete, with steel facing the beam as shown in Figure 2, the upstream radiation level is found to be (2463 ± 10) mrem/hour, which is almost 50% higher than that of configuration of CSC.
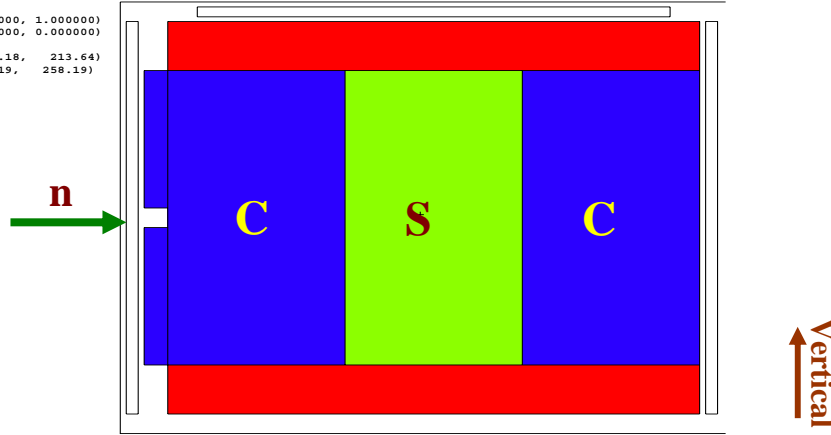
Figure 3: The beam dump, similar to Figure 1, but with more concrete at the front leaving a hole in the middle. The arrow gives the direction of the incoming neutrons. The empty blocks are empty volumes where radiation levels are calculated.

If we put more concrete at the side facing the beam for the first configuration CSC but leave a hole in the middle as shown in Figure 3, the upstream radiation level is found to be (1170 ± 10) mrem/hour. The dimension of the hole is 400 cm $\times$ 20 cm, which is made to be similar to the size of neutron beam hitting the beam dump. This is almost 30% less than that of the original CSC configuration.

The radiation levels in dose equivalent in all these cases are calculated in the same location and volume.

The radiation at the side and behind the beam dump is significantly smaller. The radiation levels for shielding configuration as show in Figure 3 are estimated to be:

	Dose equivalent (mrem/hour)
Side	0.0010 ± 0.0005
Top	0.90 ± 0.04
Behind	$(4 \pm 2) \times 10^{-5}$

The values and statistical errors, after a lot of CPU's computation in parallel mode, given above tend to be reasonably conservative.

With the corrected kinetic spectrum

The exponential kinetic energy representation mentioned in the 2nd paragraph does not drop as much as mentioned in [1]. A more correct representation is $e^{-0.00453 \bullet E}$, where E is the kinetic energy. With this representation and using the configuration in Figure 3, the radiation level is found to be (803 ± 10) mrem/hour, about 31% less than if

we use the kinetic energy spectrum in the 2nd paragraph. The radiation levels at the side/top of the dump and behind the dump are even a few times less.

References

[1] Fig. 18 on p. 29, "K0PI0 Technical Design Report (for the National Science Foundation)", K0PI0 Collaboration, June 8, 2001.

[2] K0PI0 Technical Note Note TN007, "Measurement of neutral particle production in proton-induced reactions at 24 GeV/c", M. Grigoriev, Yu. Kudenko, O. Mineev, April 22, 1998.