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Neutronics of the Bunker Wall and Roof

	Name	Role/Title
Owner	Stuart Ansell Douglas Di Julio	Senior Beamline Scientist Neutron Beam and Shielding Scientist
Reviewer	Valentina Santoro	Neutron Beam and Shielding Scientist
Approver	Peter Jacobsson Günter Muhrer Zvonko Lazic	Head of ES&H Division ESS Shield Design Coordinator Bunker Project Leader
Distribution list		

TABLE OF CONTENT PAGE

1. SCOPE

This report describes simulations to determine the expected radiation dose arising from neutrons exiting the bunker wall and roof under full operating conditions. These calculations are based on a more updated design compared to those presented in version 1 of this document and also initially in [1].

2. CONTRIBUTORS

The calculations were carried out by Stuart Ansell and the document was written together with Douglas Di Julio.

3. ISSUING ORGANISATION

European Spallation Source ERIC

4. METHODOLOGY

The radiation transport calculations were performed using MCNP6.1 driven with an input file created by CombLayer [2]. The bunker model is based on an updated design of the wall and roof since those presented in [1]. The new design contains polyethylene instead of PE-B4C-concrete [3]. Table 1 gives the description of the wall used in the calculations. Table 2 shows the geometry of the roof used in the calculations.

MCNP6.1 has been modified to allow both cell and mesh-based weight window variance reduction with preference to mesh weight windows when both are available. Furthermore, the mesh-based weight-window variance map has been extended to have bins for the px, py, and pz directional vector of the post-scattered neutron. The variance reduction map was generated by CombLayer and post checking showed that the maximum weight-window step was 10^{22}. However, splitting was set to a maximum of 5 per bin step and the weight-window splitting game was carried out on collisions only.

Table 1: Description of the wall geometry used in the calculations.

Layer	Material	Thickness (cm)
1	Borated polyethylene	45
2	Steel	15
3	Polyethylene	15
4	Steel	30
5	Polyethylene	15
6	Steel	20
7	Polyethylene	15
8	Steel	20
9	Polyethylene	30
10	Steel	15
11	Polyethylene	31
12	Steel	15.5
13	Polyethylene	25.5
14	Steel	15.5
15	Polyethylene	42.5

Table 2: Description of the roof geometry used in the calculations.

Layer	Material	Thickness (cm)
1	Borated Polyethylene	30
2	Steel	40
3	Polyethylene	40
4	Steel	30
5	Borated Polyethylene	15

5. ACCEPTANCE CRITERIA

[4] shows that the instrument halls are supervised zones. [5] sets the dose limit for a supervised area is 3 μSv/h. In accordance with [6] the acceptance criteria therefore is 1.5 μSv/h.

6. OPEN ITEMS

For the roof calculations, it was assumed that a beamline with a straight guide focusing to a point was the worst-case scenario. While preliminary calculations for other beam line configurations, in particular adding a chopper seems to support this theory, this needs to be verified before the CDR of the bunker project.

Secondly, this report assumes that the beamlines have installed their optics in the monolith, choosing to view either the upper or lower moderator, i.e. no dummy “double decker” inserts. In case a beam line does only have the monolith optics installed, but not the wall penetration, it will need to be evaluated on an instrument by instrument basis, if a special temporary beam stop inside the bunker is required. For calculations involving the roof, it was assumed that the instruments have installed a bunker wall penetration optic. For the wall calculations, no penetration was assumed.

Thirdly, the bunker roof and wall were modelled as perfect structures and no engineering design was included in the calculations. These will be handled separately in future work.

Fourthly, this report only addresses the radiation dose due to neutrons and does not include the contribution from photons.

7. ASSUMPTIONS

Borated concrete includes 0.15 wt% B_4C. The simulations started from a 2 m source .ssw card which had been biased to remove all neutrons in the backward direction and all other particles except photons. In the forward direction, weight-biased selection was carried out on a cosine angle distribution over the port size +/- 2 cm. Therefore, neutrons on the outer angular selection will enter the monolith shielding but still have a probability to either penetrate through the shielding or scatter back into the monolith void. A long instrument was used for the calculations and put in a forward going position relative to the spallation target in the long sector.

8. LIMITATIONS

Limitations are related to the above open items, assumptions and statistical sampling and biasing of the .ssw card.

9. COMPUTER HARDWARE AND SOFTWARE

MCNP6.1 and CombLayer. The CombLayer Git version number is
feb7679db398726c72c2ca137b7c39c96a9f4277

10. CALCULATION INPUTS

As described in section 7.

11. CALCULATIONS

The results of the calculations for the wall are highlighted in Fig. 1, which shows a 16x16 cm^2 cross-section of the dose through the bunker wall. The dose rate map for this case is shown in Appendix A. From the figure, it can be seen that the dose reaches a level around 1 μSv/h at the end of the wall. It is interesting to point out that the hump like structure in Fig. 1 was also observed in the target shielding analysis in the forward direction [7].

Fig. 2 shows the results of the calculations for the roof. The dose rate map is given in Appendix B. The integration was carried out through the roof with a circular area of one square meter selecting the position for the center of the circle which maximizes the dose rate. Again, the neutron dose rate is around 1 μSv/h at the top of the roof.

Neither of these results are surprising because the steel content of the roof and the wall was minimized while maintaining the 1 μSv/h external dose rate.

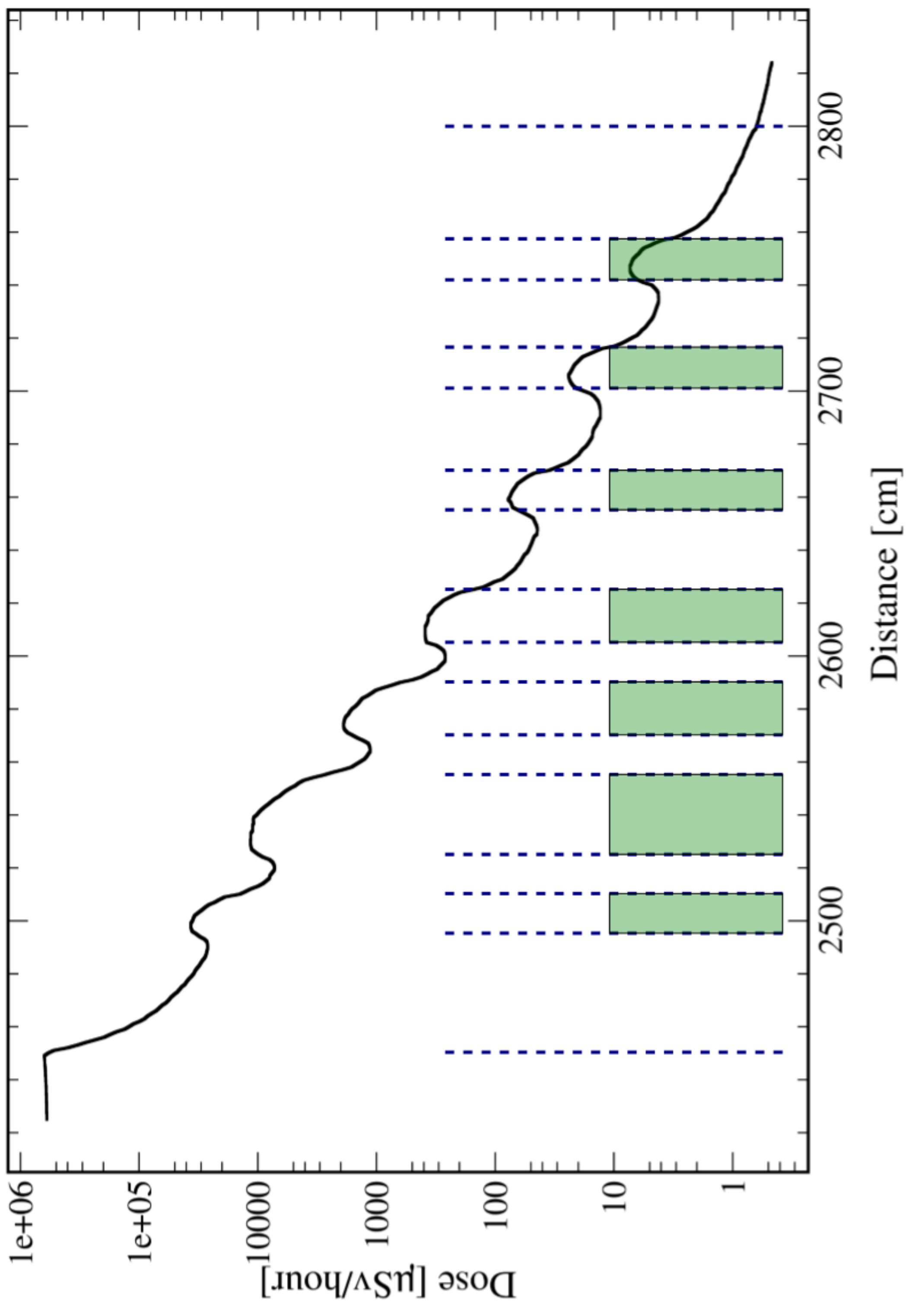

Fig. 1. The neutron dose rate profile through the wall. The dashed lines represent the layer boundaries. The green shaded regions represent the steel layers.

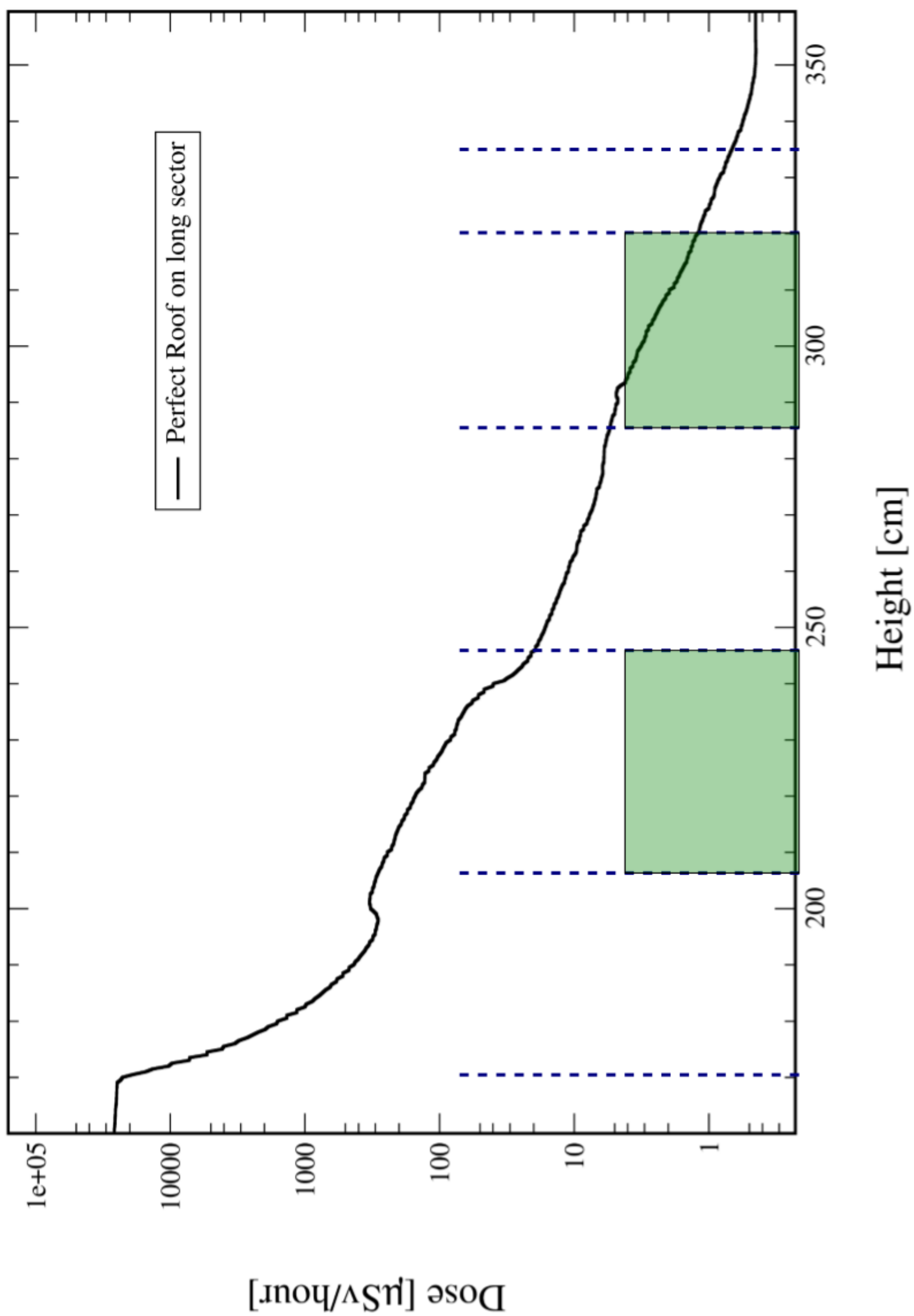

Fig. 2. The neutron dose rate profile through the roof. The dashed lines represent the layer boundaries. The green shaded regions represent the steel layers.

12. CONCLUSIONS AND RECOMMENDATIONS

This document presents a set of neutronic calculations carried out in order to investigate the neutron dose rate levels at the end of the bunker wall and top of the roof using a more updated designed than found in [1] and version 1 of this report. The results indicate that the perfectly modelled roof and wall meet the neutron dose requirements, however further simulations based on engineering details should be carried out.

13. GLOSSARY

Term	Definition

14. REFERENCES

[1] ESS-0052629, Neutronic Design of the Bunker

[2] S. Ansell, "CombLayer: A fast parametric MCNP(X) model constructor", Proceedings of the 21st Meeting of the International Collaboration on Advanced Neutron Sources, Mito, Japan, Feb. 2016

[3] ESS-0086269, PE-B4C-concrete report

[4] ESS-0057090, Zoning Plans for G-buildings

[5] ESS-0001786, Definition of Supervised and Controlled Radiation Areas

[6] ESS-0019931, ESS Procedure for designing shielding for safety

[7] ESS-0045930, Target shielding analysis in the forward direction

DOCUMENT REVISION HISTORY

Revision	Reason for and description of change	Author	Date
1	First issue	Stuart Ansell Douglas Di Julio	2016-12-09
2	Updated roof and wall calculations and revised the report	Stuart Ansell Douglas Di Julio	2017-06-22

Appendix A

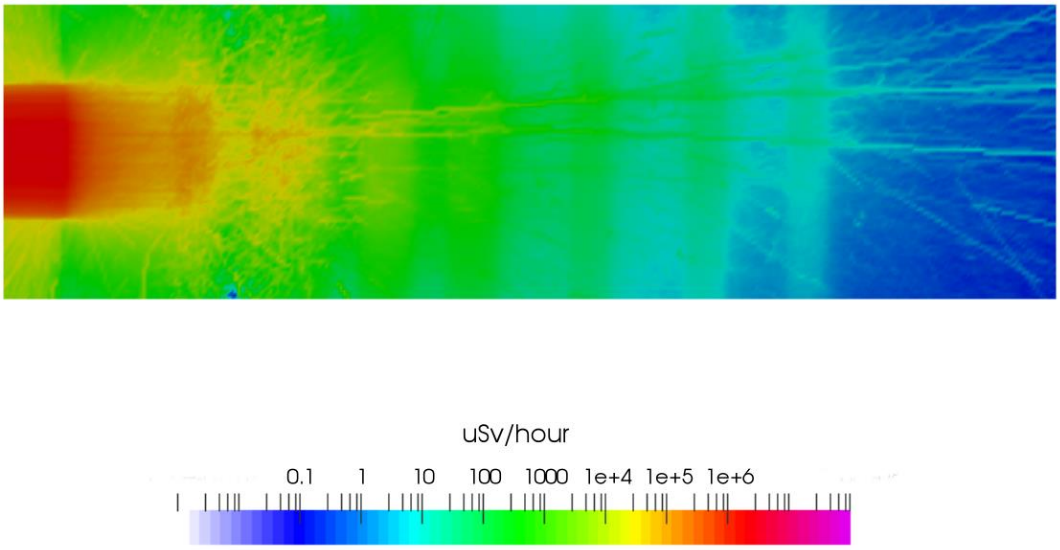

Fig. A.1. A neutron dose profile through the wall.

Appendix B

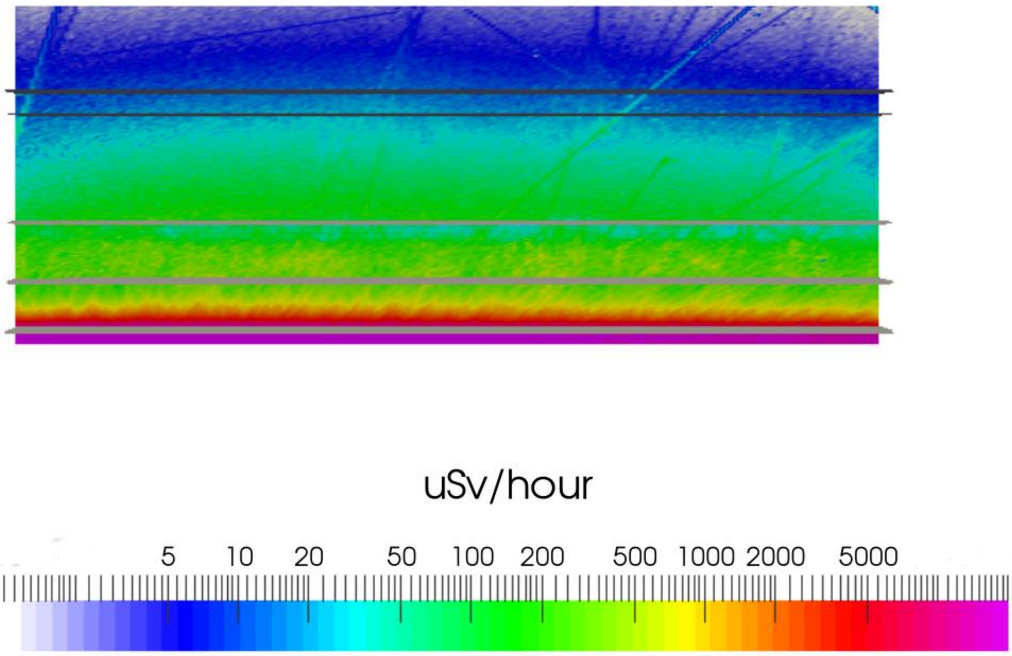

Fig. B.1. A neutron dose profile through the roof.