EUROPEAN SPALLATION SOURCE

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Bunker Activation Report

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1. INTRODUCTION

The bunker is a common shielding structure, which extends from the outer surfaces of the monolith, located at 5.5 m from the target coordinate system (TCS) [1], to 15 m in the short instrument sectors and to 28 m in the long instrument sectors. The primary purpose of the bunker is to allow the harmoniousness extraction of beamlines and to confine radiation coming from the monolith and the first sections of the neutron instruments in order to provide a safe working environment immediately outside of the bunker. The current design takes advantage of an 'open' shielding design, as described in [2]. In this design, the bunker is essentially a contained void with a 1.8 m roof about 3 m above the internal bunker floor and a 3.5 m wall, starting at either 11.5 m or 24.5 m, depending on the sector. The open design, which supports quick access to the equipment inside the bunker, will expose the workers to a potentially greater dose due to the various different activated components within the bunker, such as choppers and guides. These activation levels will play an important role in determining the serviceability and time-scales for accessing these components. This document reports on the initial calculations of the activation levels within the bunker for a number of different components and operating conditions.

2. METHODOLOGY

The activation calculations were carried out with modified versions of MCNP 6.1 and CINDER 1.05 along with an internally developed activation code, CombLayer [3]. MCNP 6.1 was modified to include the generation of htape files, based on the source code from MCNPX 2.7.0, while CINDER 1.05 was modified to increase the size of arrays it could handle in order to increase the number of possible components which could calculated on. MCNP6.1 was also modified so that the .ssw file was not bound to a surface and a source particle could start from any valid coordinate in the model. However, it shall be stated at this point that the changes made to the code only effect the memory allocation, maximum length of filenames and post-simulation routines, but not the physics part of the code. In the case of htape output, it was verified that the 108, 114 and 115 tables were identical to those produced by MCNPX 2.7.0 when running with the same physics options. The basic procedure is as follows,

1. Generate an MCNP6.1 file using CombLayer with the '-cinder' flag and indicate the objects of interest to tally the flux in.

2. Run the file through MCNP 6.1 to generate the htape file and the neutron flux in the region of interest.

3. Use a modified activation script, which runs CINDER1.05 for each cell within the selected tallies, to produce a nuclear inventory for each cell.

4. CombLayer is run with the same geometry as in step 1 to sample the gamma flux from the tally cells based on a region of interest and the relative volume and total

integrated gamma flux of each cell. The output is written into an .ssw file for input into MCNP 6.1.

5. Run MCNP 6.1 with the .ssw file to get an activation dose map.

For the calculations presented in this report, BIFROST was selected as an example case as it has the largest aperture at the monolith wall of all currently approved designs. The aperture has a size of 12x9 cm^2. The design of the bunker included the 3.5 m wall and the reduced 1.8 m thick roof. The dose activations were calculated for 10 years at full power operation at 5 MW. This was modelled by using 10 intervals of 5400 hours beam on [4] inter spaced with 9 intervals of 3360 hours beam off. Four components were investigated at shut-down time periods of 1 hour, 1 day, 3 days, 7 days and 365 days. These components included the neutron guide with a collimator, the bunker wall, a double disk chopper and a T_0 chopper. The dose conversion coefficients were taken from [5].

The neutron guide consisted of the following components: a rectangular guide substrate (aluminium 5083), where the coherent coating was not modelled, housed within an aluminium 5083 vacuum pipe with front and back flanges and eight bolts (high-carbon steel with no cobalt) and with single-crystal silicon windows.

The collimator was made from machinable tungsten (93%W) and directly surrounded the guide.

The choppers were contained in a multiflange octagonal housing with the length and void space adjusted for the chopper discs' radii and gaps. All the flange bolts and flange thickness's were modelled to the design. The non-T_0 choppers were modelled as carbon fiber discs with 3 mm B4C hammers. The housing was assumed to be aluminium 5083 and the bolts were brass. The T_0 choppers were modelled with inconel 80A discs (non-cobalt) with tungsten hammers. The housing was high-tensile steel and bolts were nickel high-tensile steel.

The wall was modelled as described in [2].

3. RESULTS

The results of the calculations are summarized in Tables 1 and 2 while selected data is given in the appendices. In the tables, the colors of the cells indicate the type of zoning area described in [6]. Red indicates a highly restricted area, yellow a restricted controlled area, blue an unrestricted controlled area, green a supervised area, and white a public area.

Table 1 shows the data for the whole body dose at 30 cm, which is relevant for accessing the bunker during shutdown periods. The choppers present the highest potential source of radiation for a worker, with the T_0 chopper giving around 1 mSv/h for a 1 h cooldown. However, after 7 days the T_0 chopper has cooled down to 25 μSv/h and all other dose levels are below 3 μSv/h. These results indicate that the radiation levels in the bunker during shutdown will not inhibit access inside. For shutdown periods of less than 7 days it could be foreseen that access is restricted using administrative procedures and authorization would be required on a task per task basis.

Table 2 shows the data for the calculated contact dose rates for the individual components, which can be used to infer about hands-on maintenance of the components. As in the case described above, the choppers present the highest potential dose rates for hands-on work. After 1 h, both the T_0 chopper and the chopper with no steel have contact dose rates of 20 mSv/h, which means highly restricted controlled access. After 3 days of shutdown, all contact doses have dropped to unrestricted controlled access except for the T_0 chopper which remains around 100 µSv/h even after 1 year.

Table 1: The calculated whole body dose rates for the indicated components and for different time intervals after shutdown.

whole body dose @ about 30 cm [µSv/h]					
time after beam shutdown	1h	1 day	3 days	7 days	1 year
guide before the first chopper	200	<3	<0.5	<0.5	<0.5
only guide	<25	<3	<0.5	<0.5	<0.5
guide collimator position	<50	<25	<3	<3	<3
chopper no steel	300	<50	<3	<0.5	<0.5
T_0 chopper	1000	100	<50	<25	<25
wall	<3	<3	<3	<3	<0.5

Table 2: The calculated contact dose rates for the indicated components and for different time intervals after shutdown.

contact dose [µSv/h]					
time after beam shutdown	1h	1 day	3 days	7 days	1 year
guide before the first chopper	1000	50	<3	<3	<3
only guide	40	<3	<3	<0.5	<0.5
guide collimator position	1000	200	<25	<25	<25
chopper no steel	15000	200	<25	<3	<3
T_0 chopper	20000	1000	500	<100	<100
wall	<3	<3	<3	<3	<0.5

4. SUMMARY

In summary, activation calculations were carried out in order to investigate the impact of the activation on the access/operation of components within the bunker. Four components were studied, which included an example guide, T_0 chopper, double-disc chopper, and the bunker wall. It was found that in general the levels would not limit access into the bunker during shutdown periods, with the condition that for shutdown periods of less than 7 days administrative procedures would be required. As for hands on maintenance, after 3 days of shutdown all components had contact doses classifying them has unrestricted controlled access, with the exception of the T_0 chopper, which still had the classification of a restricted controlled area even after a year.

5. REFERENCES

[1] ESS-0035090, Main Coordinate Systems at the ESS

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

[3] 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.

[4] ESS-0011768, Updated Report on Operations

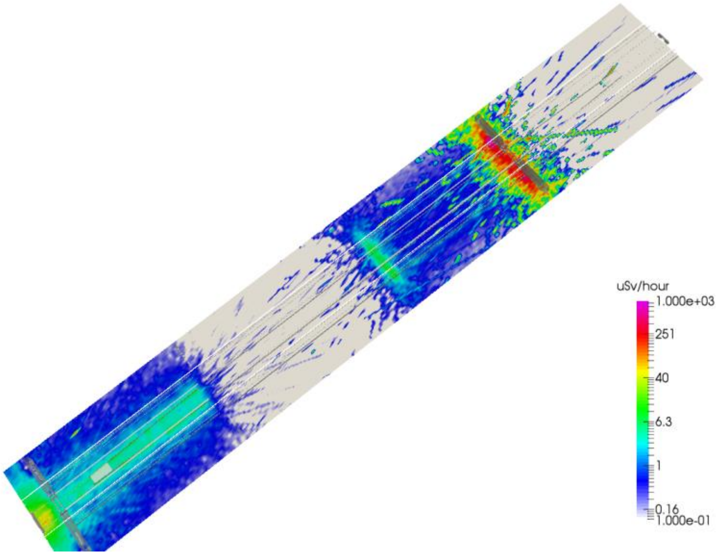
[5] ESS-0019931, ESS Procedure for designing shielding for safety

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

DOCUMENT REVISION HISTORY

Revision	Reason for and description of change	Author	Date
1	First issue	Douglas Di Julio Stuart Ansell	2016-12-07

Appendix A: Guide Plots



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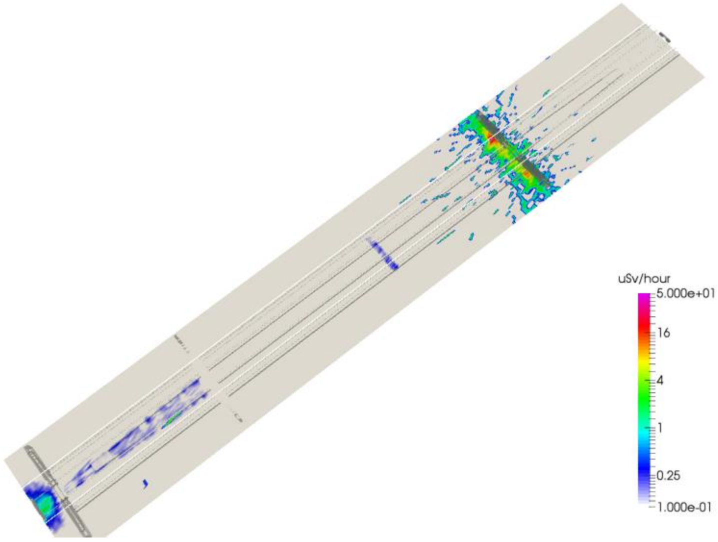
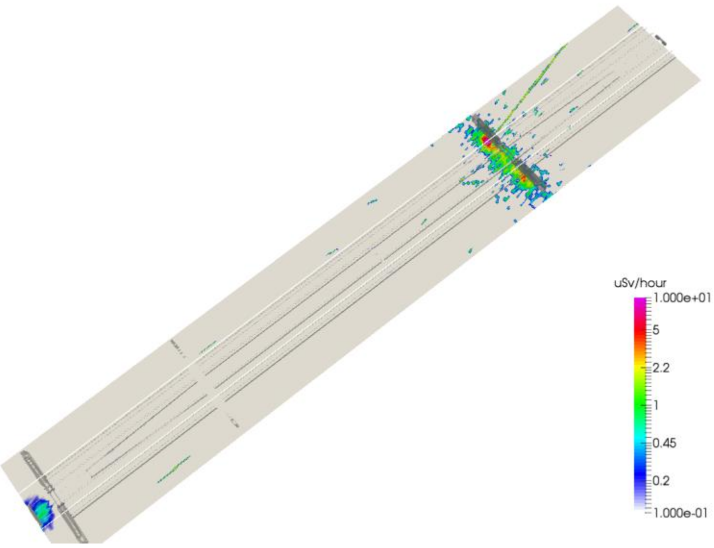
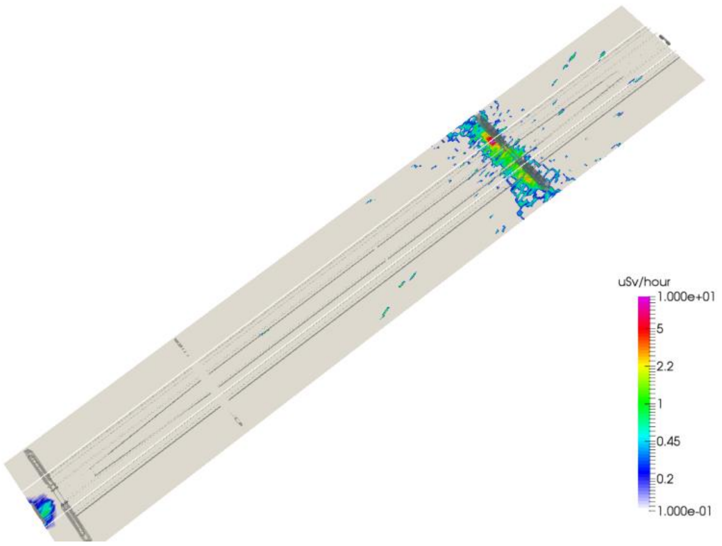


B) 3 Days

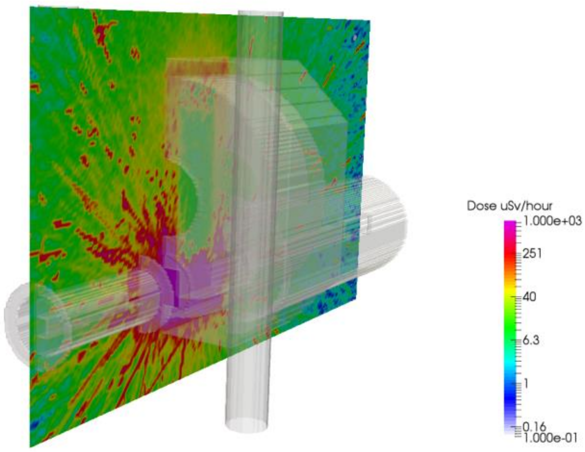


C) 7 Days



D) 365 Days

Appendix B: T_0 chopper plots



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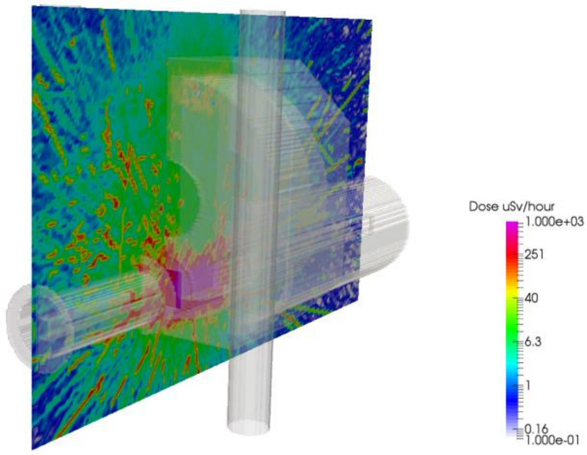

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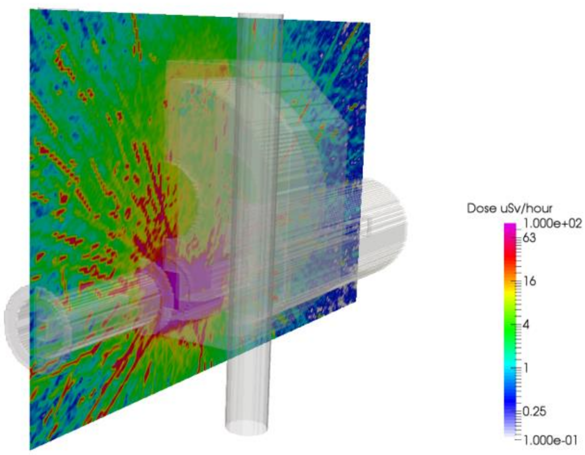

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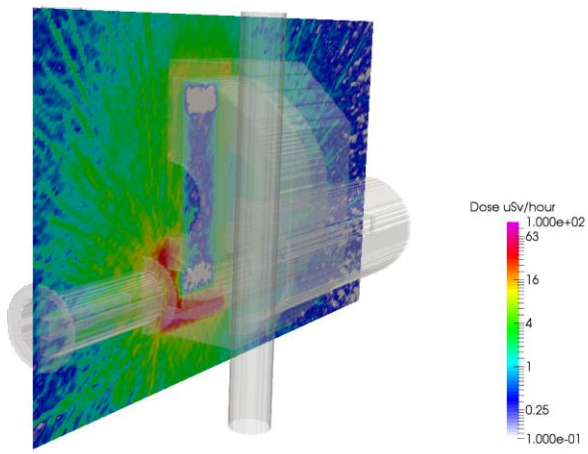

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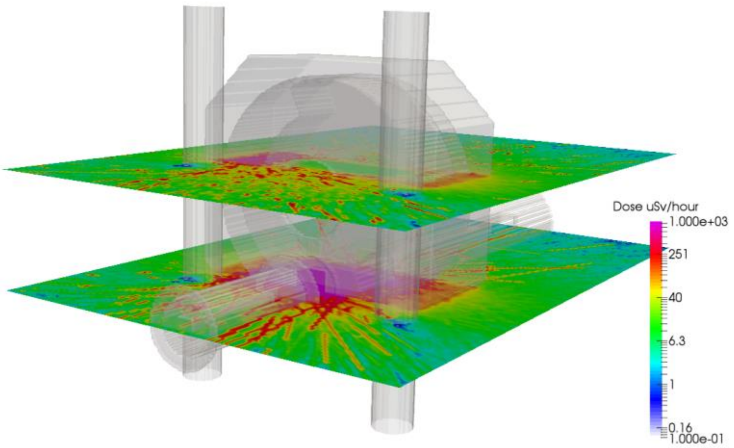

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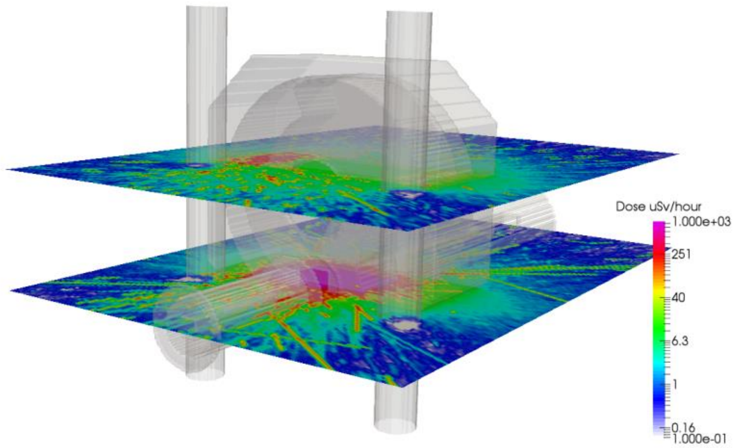

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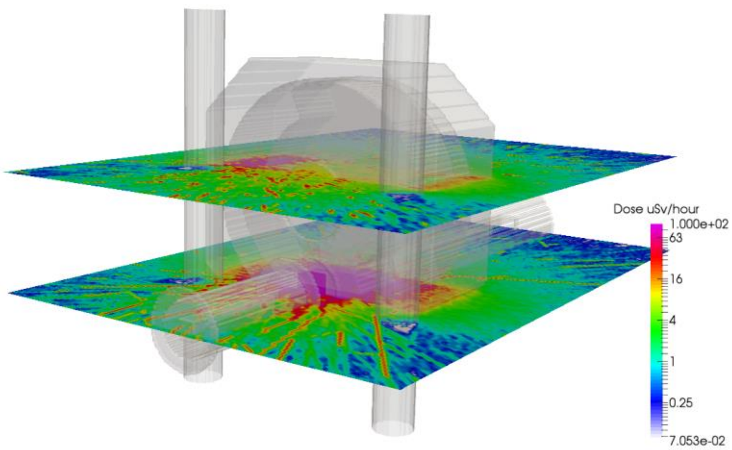

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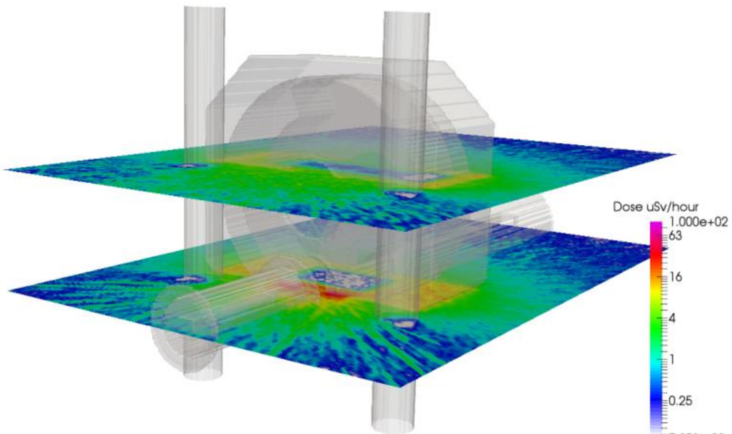

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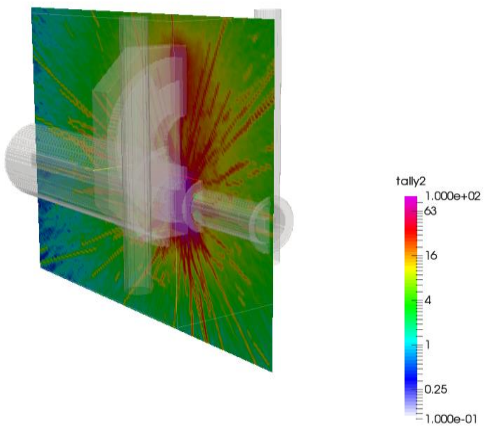
Appendix C: Double disk chopper plots



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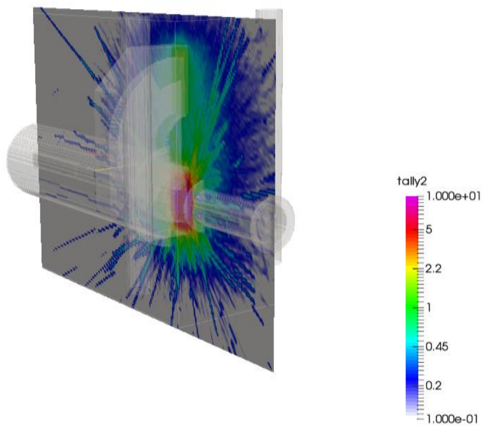

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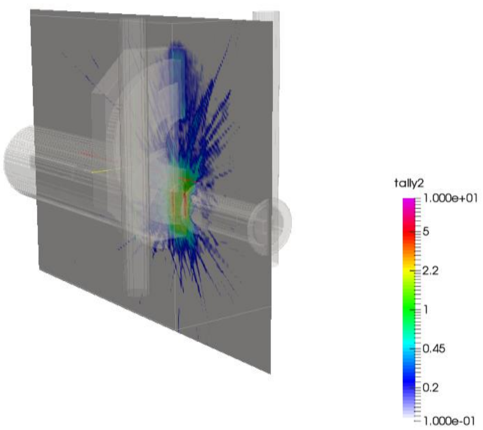

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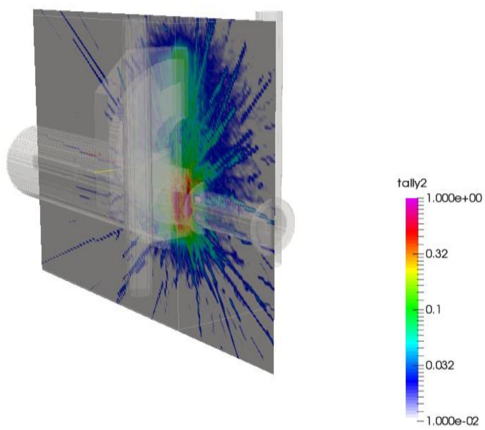
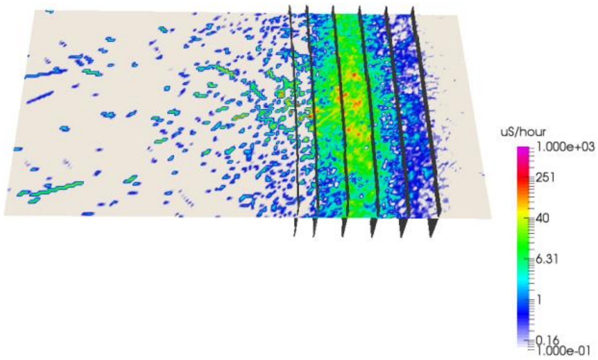


D) 365 Days

Appendix D: Bunker wall plots



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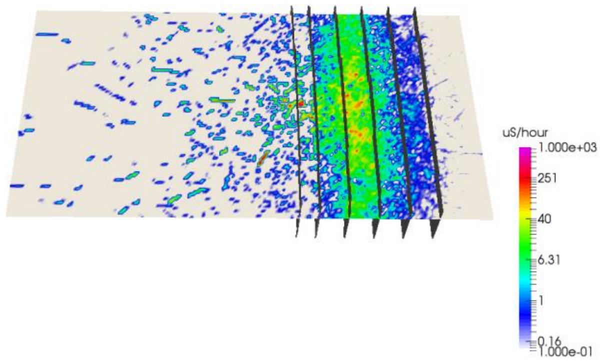

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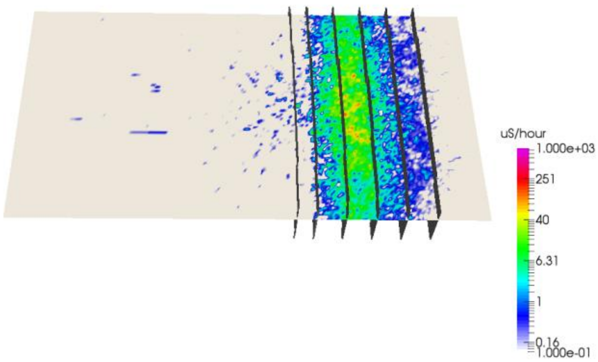

C) 7 Days