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Shutdown Dose Calculations for the IFMIF-DONES Lithium Loop Cell Using Variance Reduction Techniques

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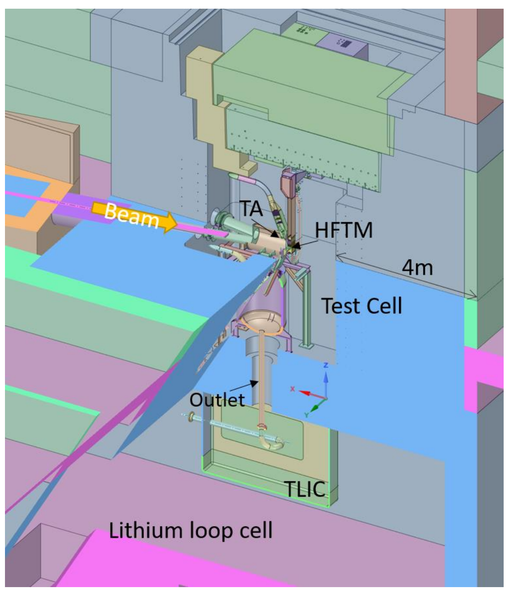
Introduction

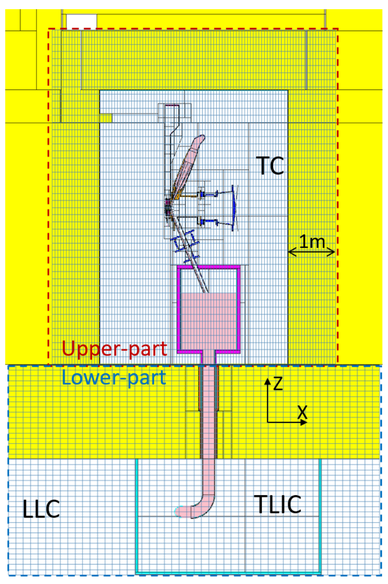
- IFMIF-DONES is a **D**EMO **O**riented **NE**utron **S**ource providing the irradiation data needed for the construction of DEMO. The Lithium Loop Cell (LLC) is a room below the test cell (TC) housing the equipment for the lithium system.
- The shutdown dose from the activated components in the TC is a concern for the maintenance and radiation safety in the LLC.

Neutron flux calculation

- Neutron flux calculation using McDeLicious-17 (MCNP version 6) and FENDL-3.1d neutron cross-section.
- Mesh tallies cover two domains. upper-part: 1 m of the TC wall; lower-part: 2 m of the floor.
- Fine mesh resolution ~1 neutron mean free path (mfp, ~4 cm) , coarse mesh 3 - 5 mfp.



CAD model



MCNP model

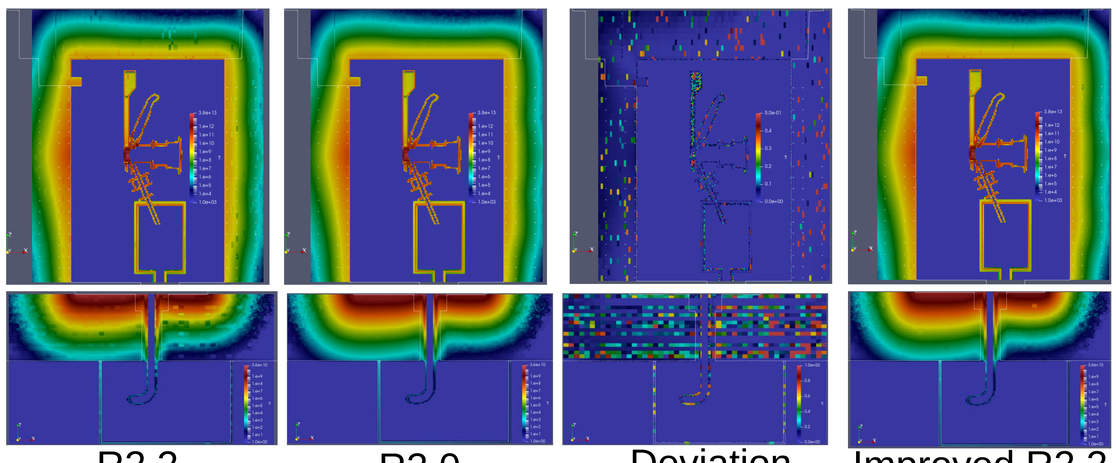
R2S Code verification

- New version of Rigorous 2-step (R2S) code R2Smesh-3.0 (R3.0) was recently released (https://github.com/travleev/r2smesh-at).
- R3.0 shows several advantages over the previous version R2Smesh-2.2 (R2.2)

Comp. time (h) ➡

Decay gamma source (p/s) ⬇

Steps	R2.2	R3.0
Material detection(Parallel)	34.5	**5.1**
Prepare activation input (sequential)	5.2	**0**
Activation calculation (Parallel)	336	1166
Extract gamma source (sequential)	3.15	**0.16**
Decay gamma transport (Parallel)	98.7	1088



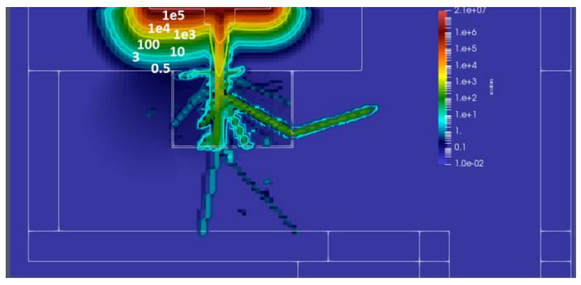
R2.2 | R3.0 | Deviation | Improved R2.2

Shutdown dose calculation

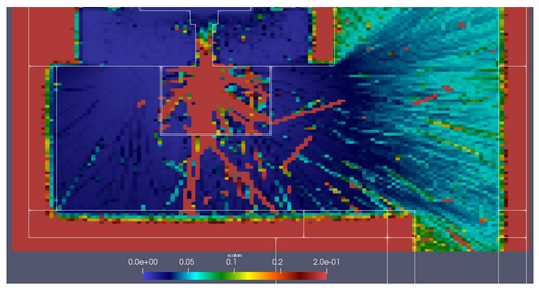
- Irradiation time 345 days, cooling time 1 day. Using R3.0 with MCNP5, FISPACT-II and EAF-2010.
- Maintenance scenario: lithium is drained out; shielding plus above TA is removed; TA and HFTM are moved out of TC.
- 10^{10} particle histories being simulated, resulted on two domains were summed. Average relative error is calculated.

$$E = (A \times E_A + B \times E_B) / (A + B)$$

- Gamma streaming from TC to LLC is the main contribution, while it causes high statistical uncertainty.
- Weight-window mesh (WWM) is not applicable to R2.2/R3.0 decay gamma transport, since the source particle weight is associated with gamma intensity.



Shutdown dose rate (μSv/h)



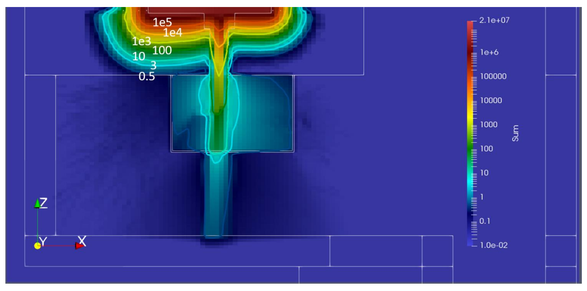
Relative error

Variance reduction

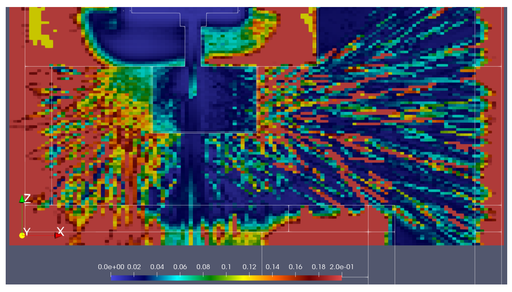
- Intensity based source sampling method in the “Common R2S” package was used, In order to obtain constant source particle weight.
- ADVANTG code was used to produce a WWM using a 1-MeV uniform gamma source in the first 0.5 m layer of the inner TC shielding.
- Statistics of dose results in the TLIC is improved, the dose rate outside the TLIC is < 0.5 μSv/h.

Uniform sampling, source weight = gamma intensity

Source intensity based sampling, source weight = 1



Shutdown dose rate (μSv/h) with variance reduction



Relative error

Summary

- The shutdown dose in the LLC has been calculated using new R2Smesh code and a variance reduction approach.
- New version 3.0 of R2Smesh code shows good efficiency and reliability in the verification comparison.
- Weight window mesh generated using ADVANTG code has been used together with an intensity based source sampling.
- The dose in the LLC is < 0.5 μSv/h for most of the region except TLIC.

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