Comparison of Calculation Codes in Radiation Detector Placement and Performance Analysis

Serpent 2 gamma radiation transport modelling in practise

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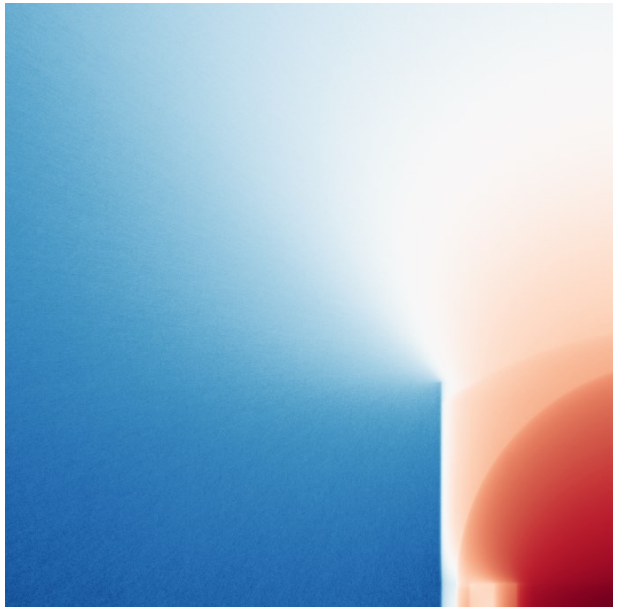
What was done?

- Master’s Thesis on comparing two Monte Carlo calculation codes (MCNP6.2 and Serpent 2) in gamma radiation transport
- Calculation case was to determine an optimal detector location for monitoring radioactive release during (severe) accidents in Loviisa NPP
- Performance and overall utility of the two codes were compared
- This work can also be seen as a verification study for Serpent 2

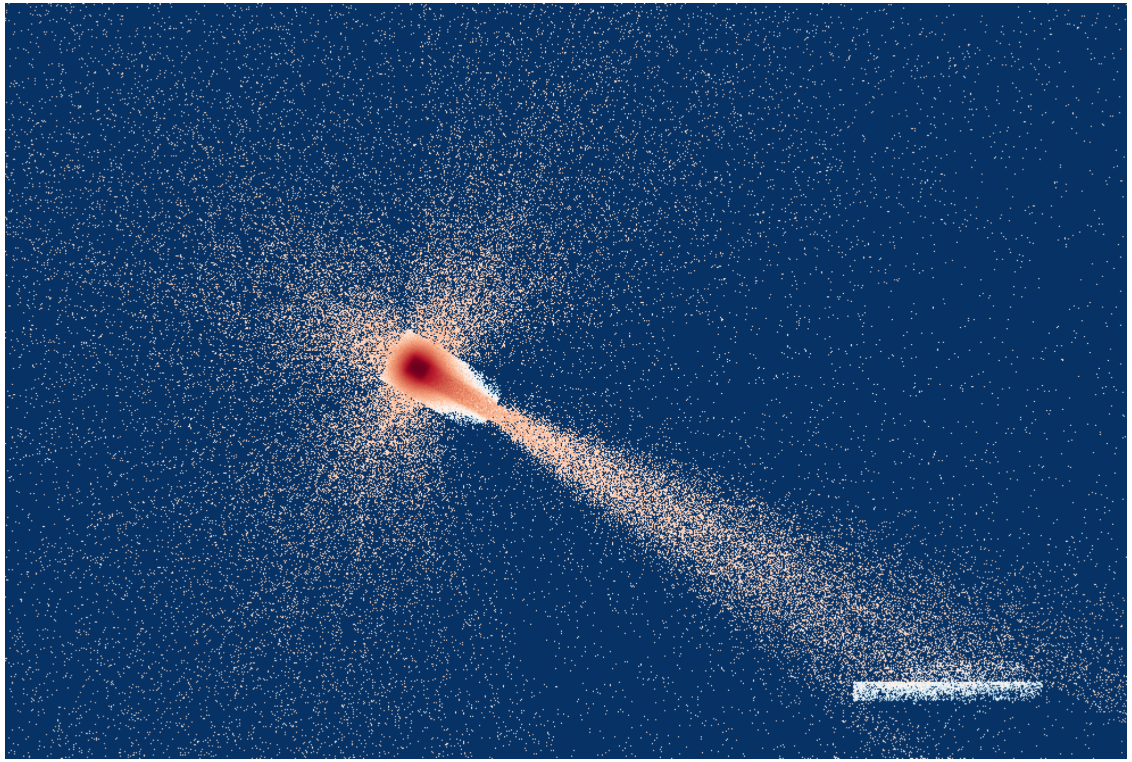


Skyshine radiation in action

Monte Carlo simulation

- Process of simulating individual particles
- Used in various applications like neutronics, criticality studies, gamma radiation propagation studies, etc..
- Large amounts of experimental and theoretical data provide the information used to model interactions
- Results are statistical
- Millions of particles are transported to obtain adequate results
- Results are computed by tallying interactions or track-lengths inside calculation cells or meshes

Graphical results may look something like this:
(Every point is an interaction)



A fictional radiation source inside a lead collimator

Which codes were compared?

MCNP6.2

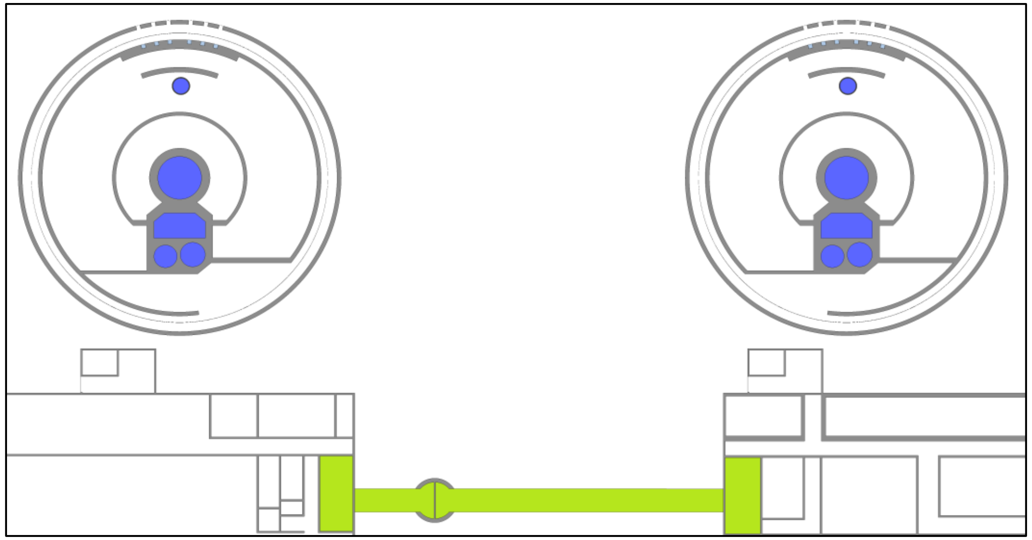
- General purpose Monte Carlo code
- Used for modelling the propagation of various different particles including neutrons, electrons, photons etc.
- Developed by Los Alamos National Laboratory since 1957
- Is widely used when gamma transport calculations are needed

Serpent 2

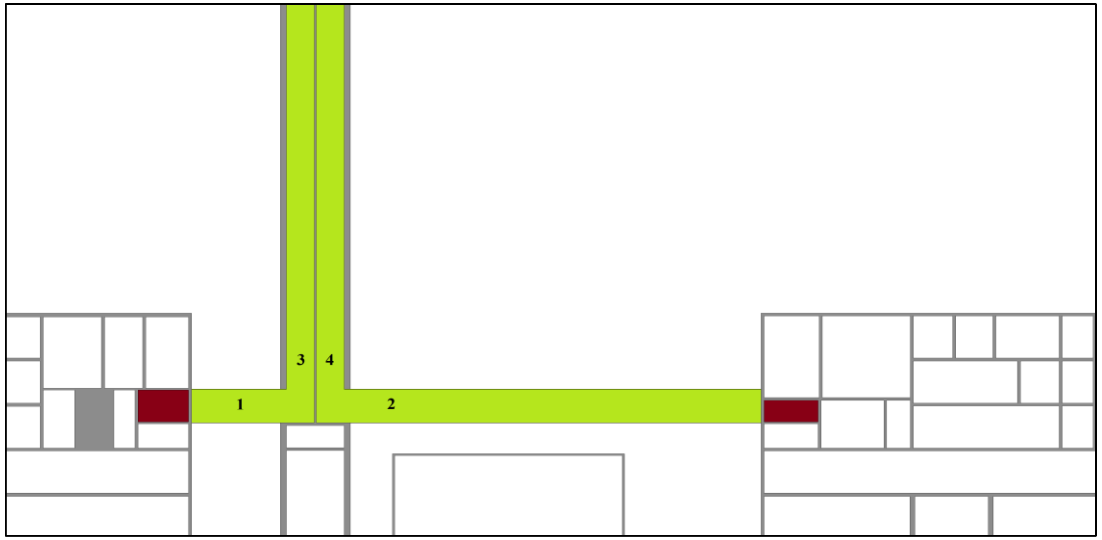
- Multi-purpose continous-energy Monte Carlo code
- Used for modelling neutrons and photons
- Developed by VTT since 2004
- Widely used for group constant generation for nodal codes
- Gamma transport recently added
- Demonstrates advanced geometry types and variance reduction methods

Calculation geometry

- Vast geometry including most of the power plant area buildings
- Reactor buildings, some parts of auxiliary building and ventilation stack modelled more in detail.
- Areas of geometry that were closely examined during the work are highlighted in green



Horizontal cross section of
the important parts of geometry



Vertical cross section
of the ventilation stack

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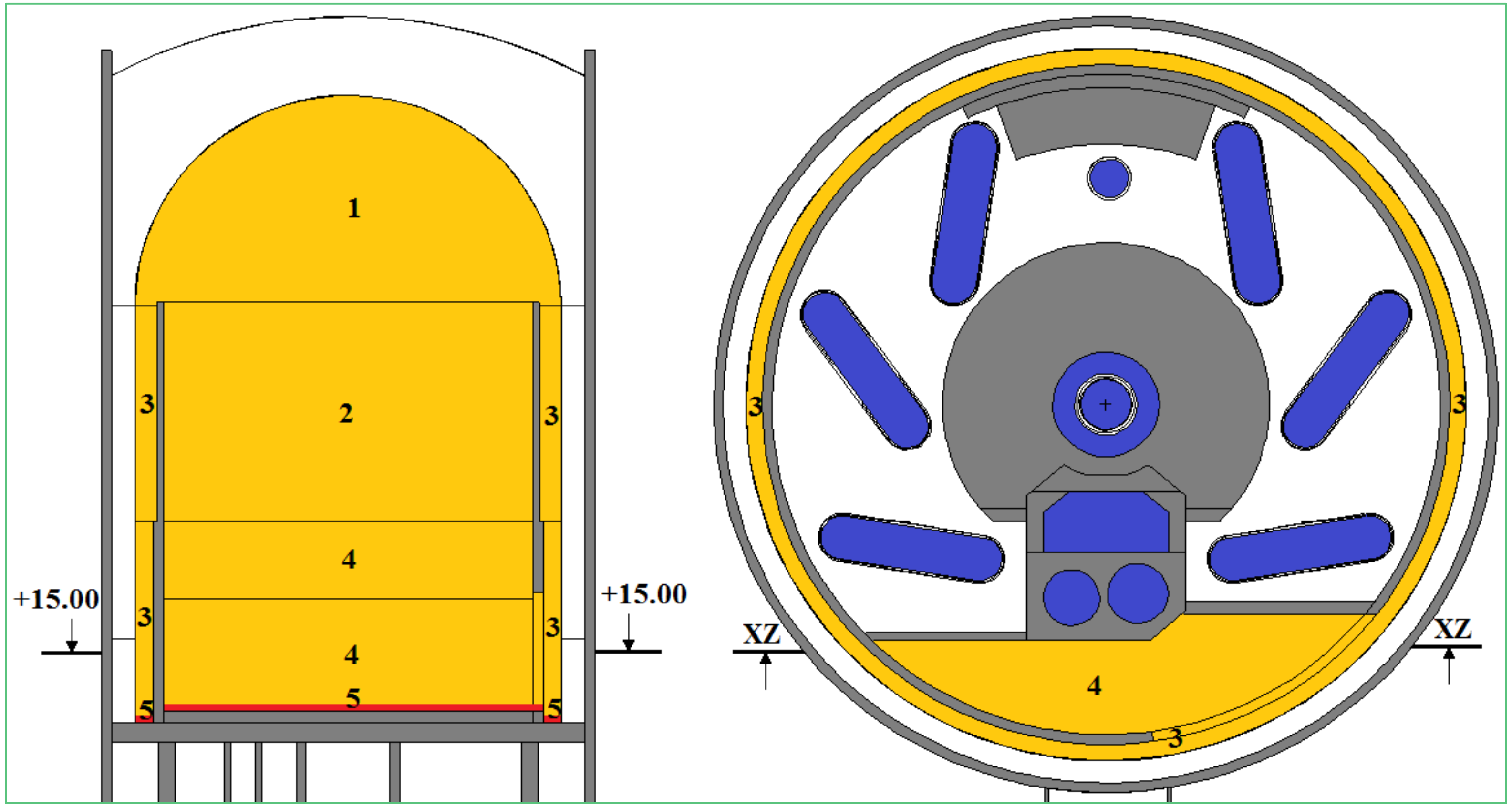
Source volumes inside reactor buildings

1. Dome
2. Reactor hall
3. Inner annulus
4. Lower segment
5. Contaminated water

These were split into 2 groups:

- Dome = Dome
- Segment = Rest of the sources



Vertical cross section

Horizontal cross section

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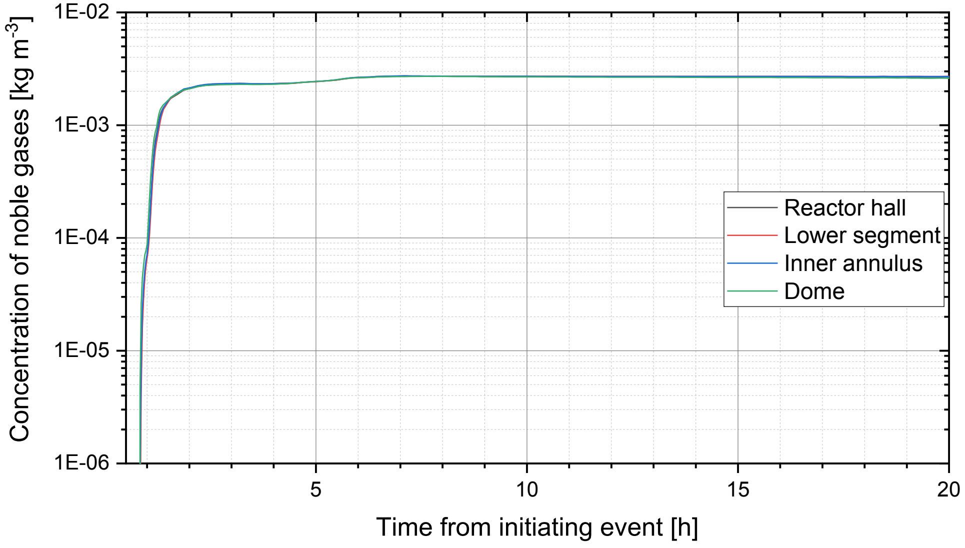
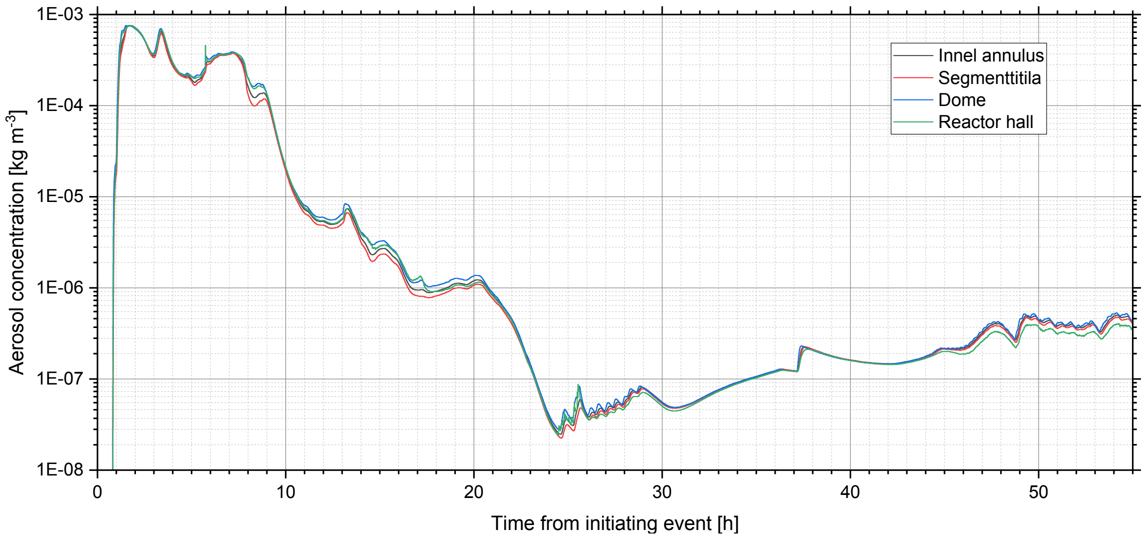
Calculation case: LBLOCA SBO leading to SA

- Objective in source definition was to produce the maximal skyshine radiation
- Large Break Loss-of-Coolant (LBLOCA) accident combined with Station Blackout (SBO) which leads to a Severe Accident (SA) was chosen
- Large portion of the core inventory is released quickly
- Nuclide group concentrations for each source volume were acquired using MELCOR (no decay)
- MELCOR is an engineering-level computer code to model the progression of severe accidents

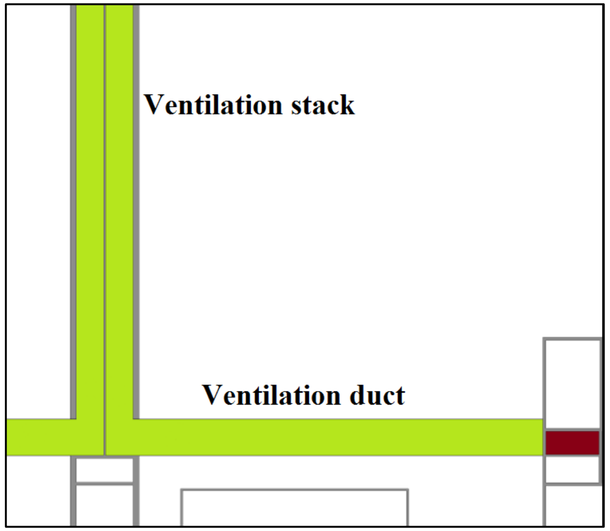


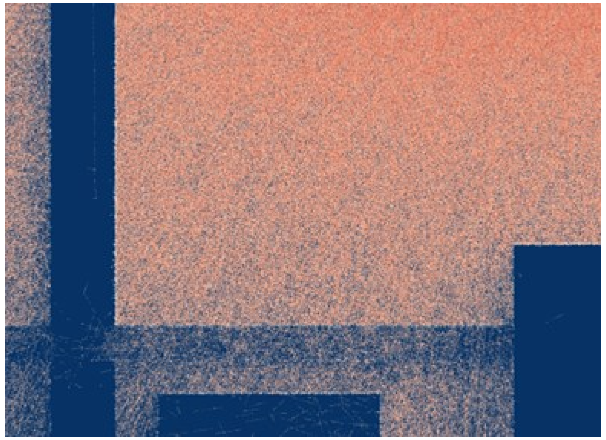
Evolution of Noble Gases

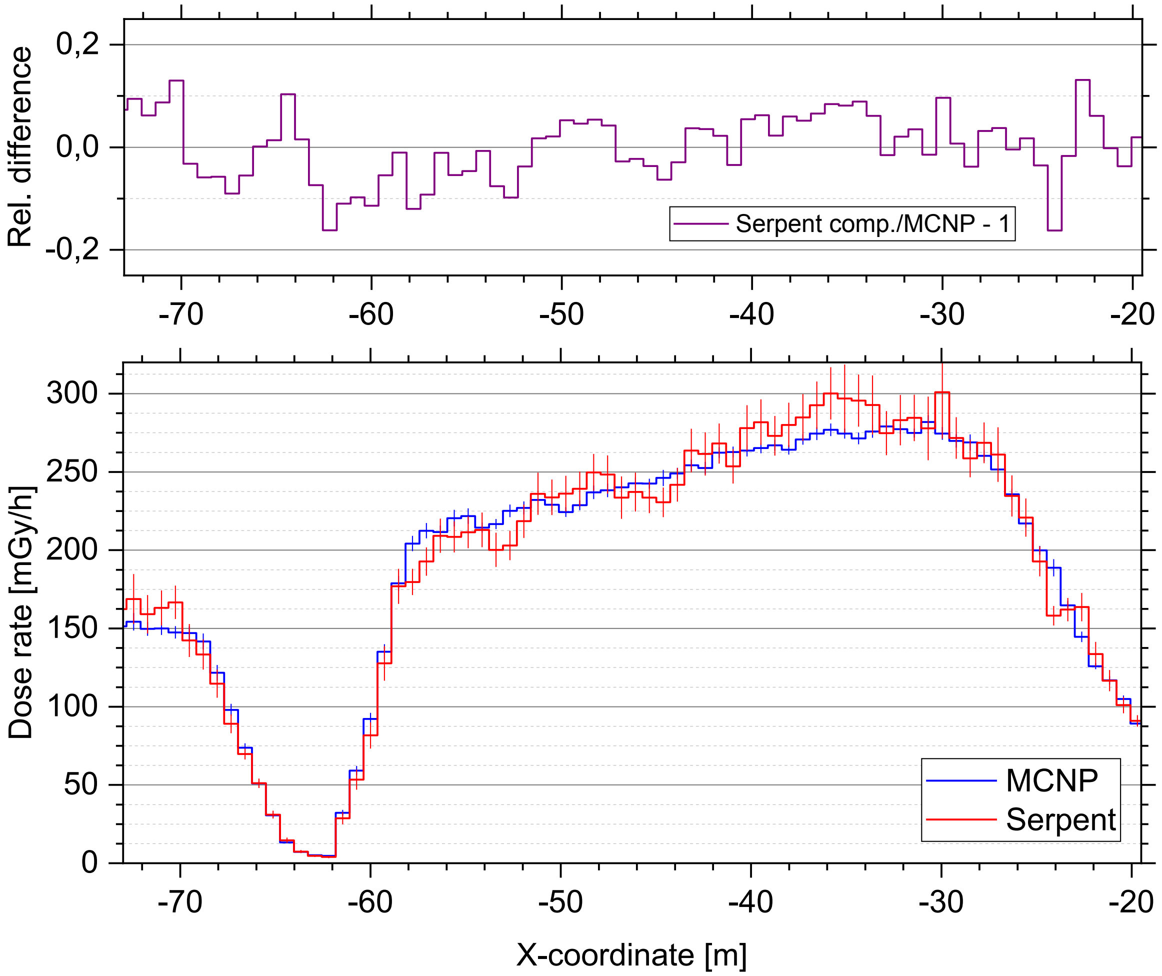


Evolution of Aerosols

Calculating dose rates in locations of interest: Ventilation duct, Loviisa 2 unit (LO2)

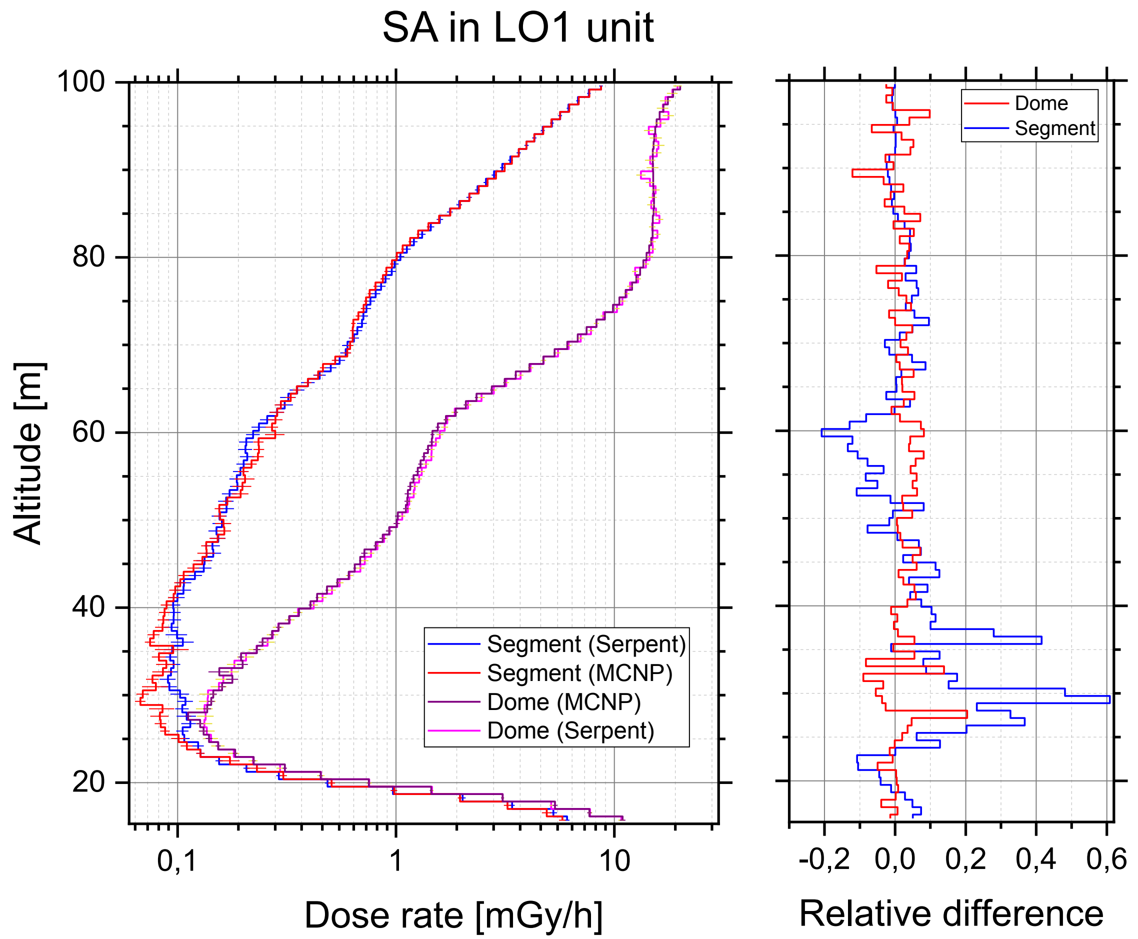


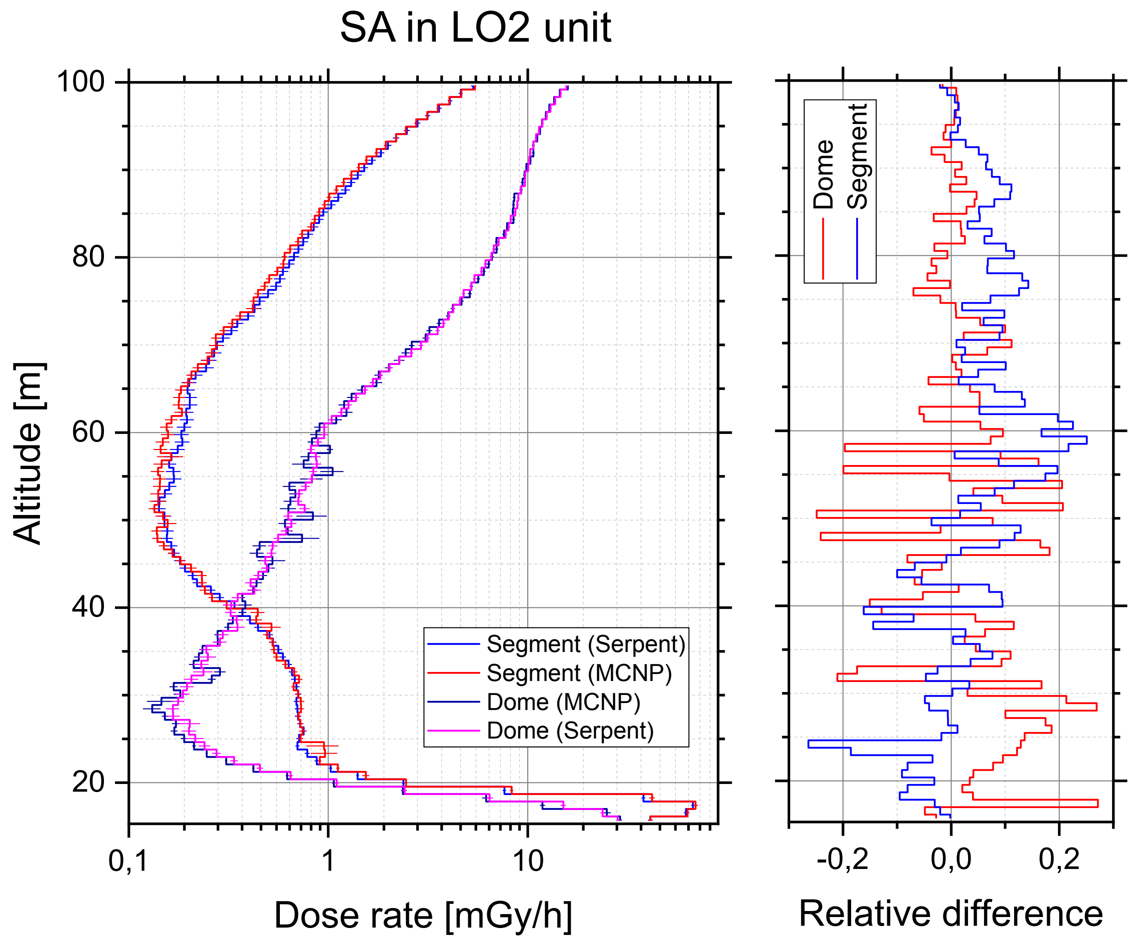




SA in LO2 unit

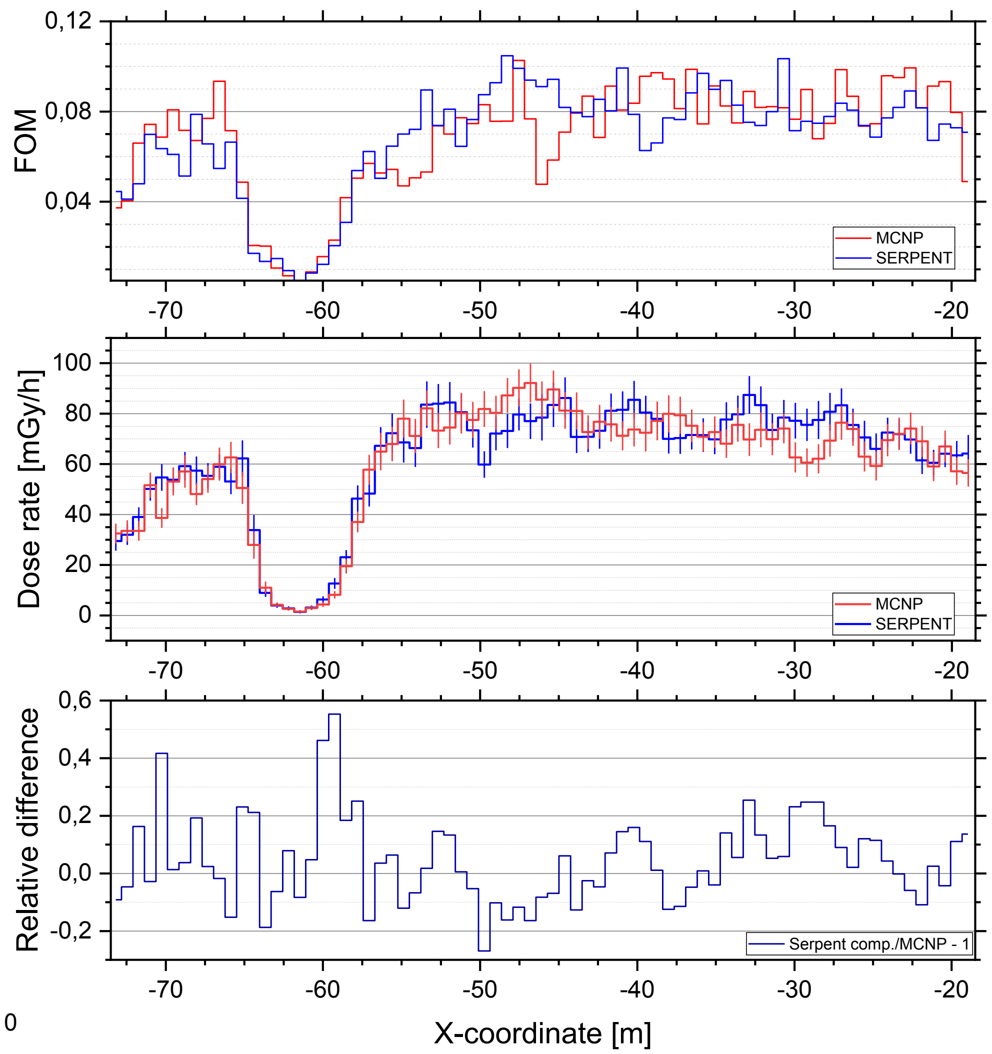
Calculating dose rates in locations of interest: Ventilation stack



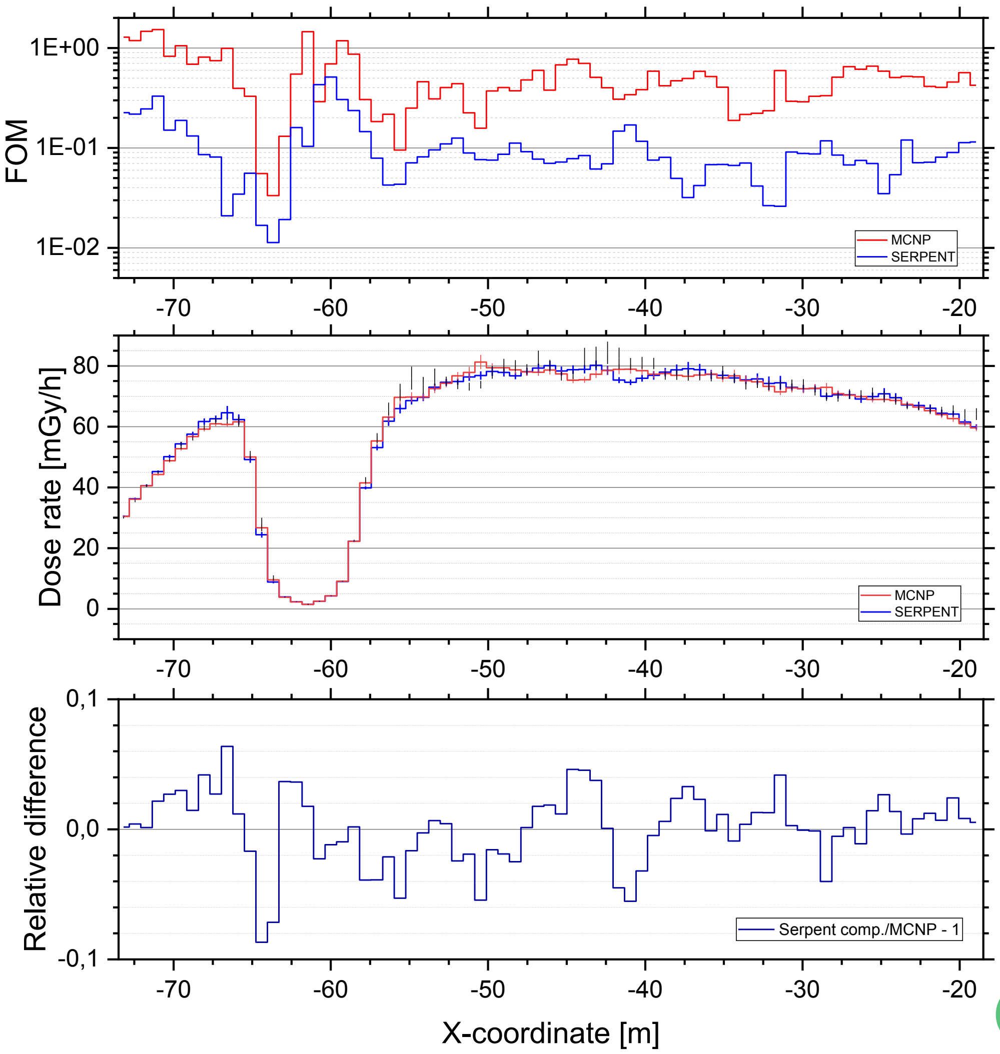


Performance comparison: Simplified duct case

Analog calculation



With variance reduction



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Conclusions

- Good agreement between Serpent 2 and MCNP6.2 results
- Both codes perform in similar speed in analog calculations
- MCNP6.2 variance reduction works better in skyshine cases
- Serpent 2 has automated and adaptive method for variance reduction
- Collision based graphical mesh plots in Serpent 2 provide useful graphical feedback for user

After this Master's Thesis, Serpent 2 has been succesfully used in Fortum in various other gamma transport calculation cases.

Thank you!

Questions?