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Dispersion Model

Particle Spread due to Fire in Instrument Hall Initiated by Moderator Hydrogen

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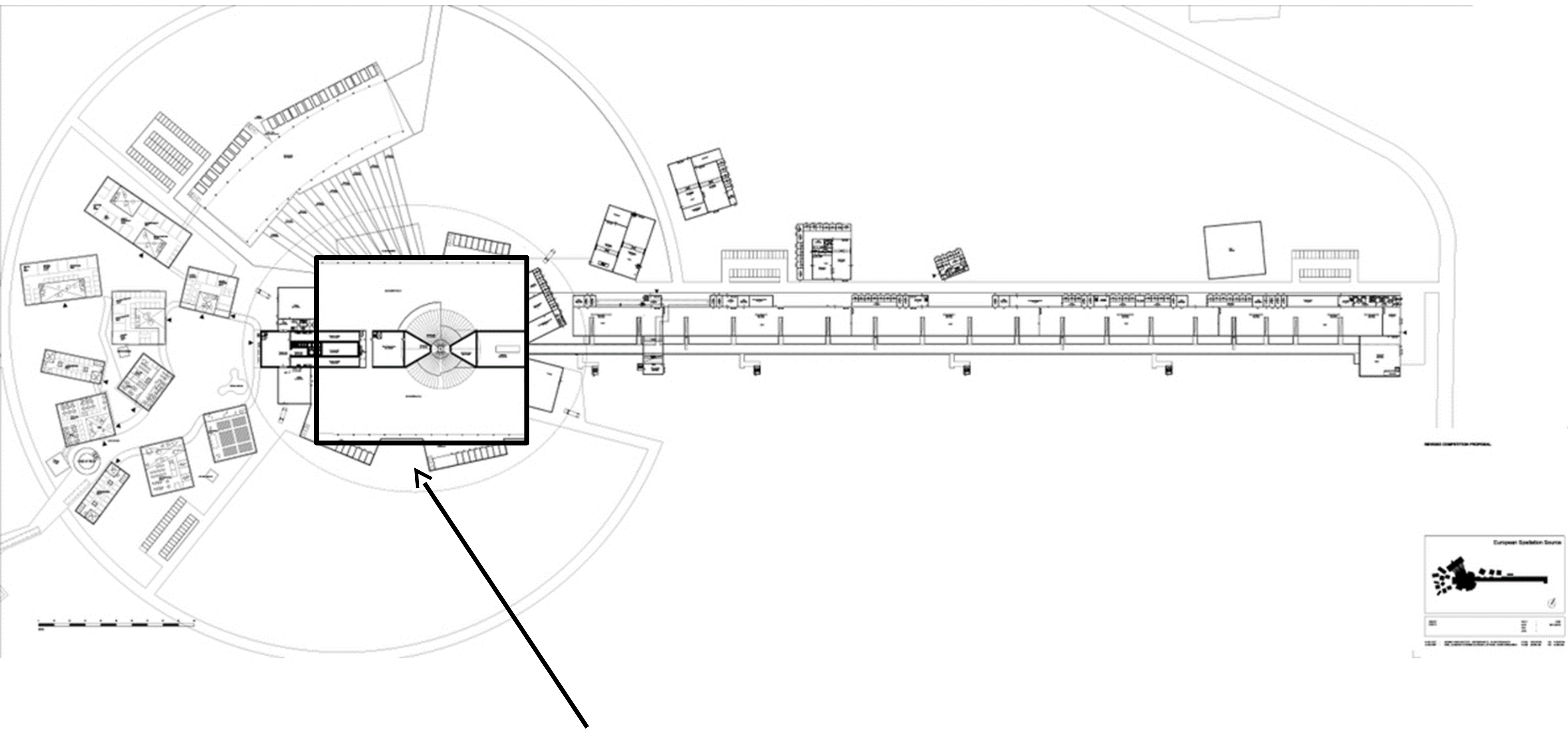
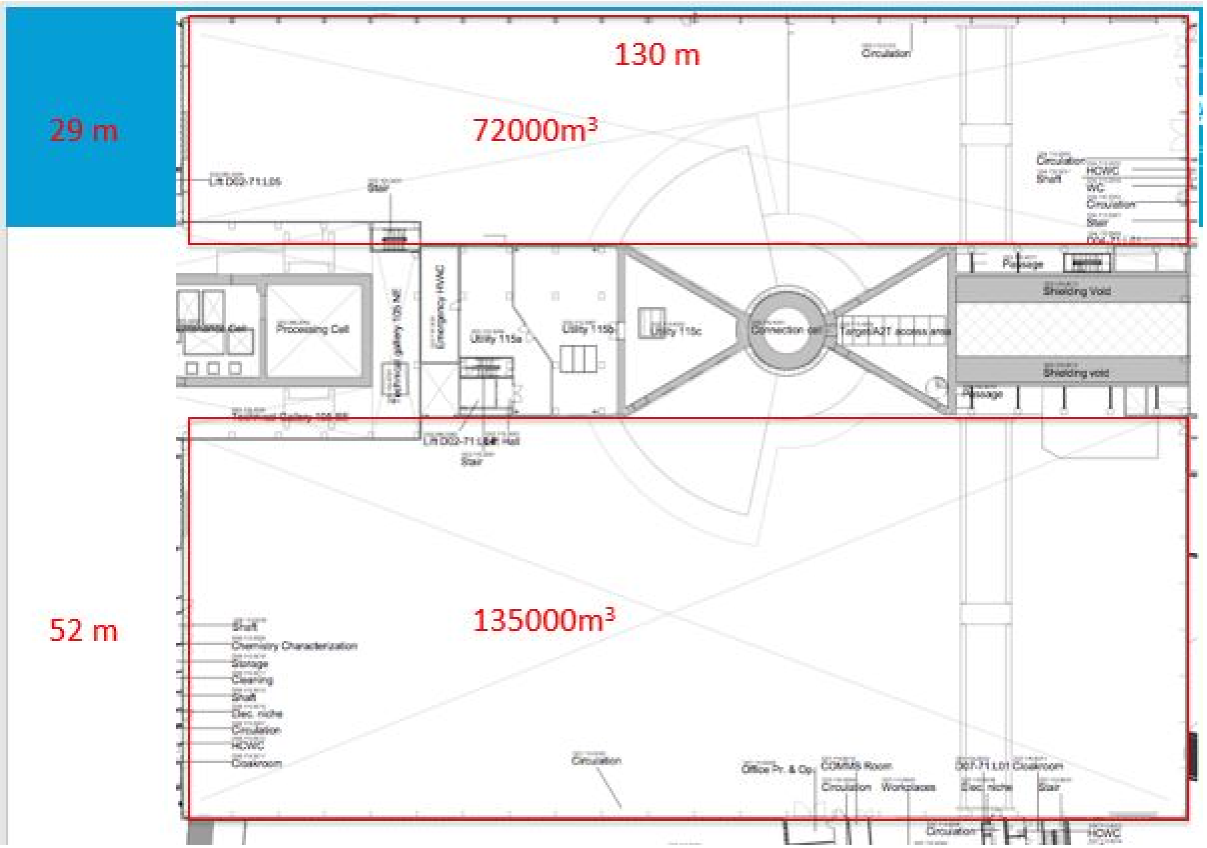
The ESS Facility



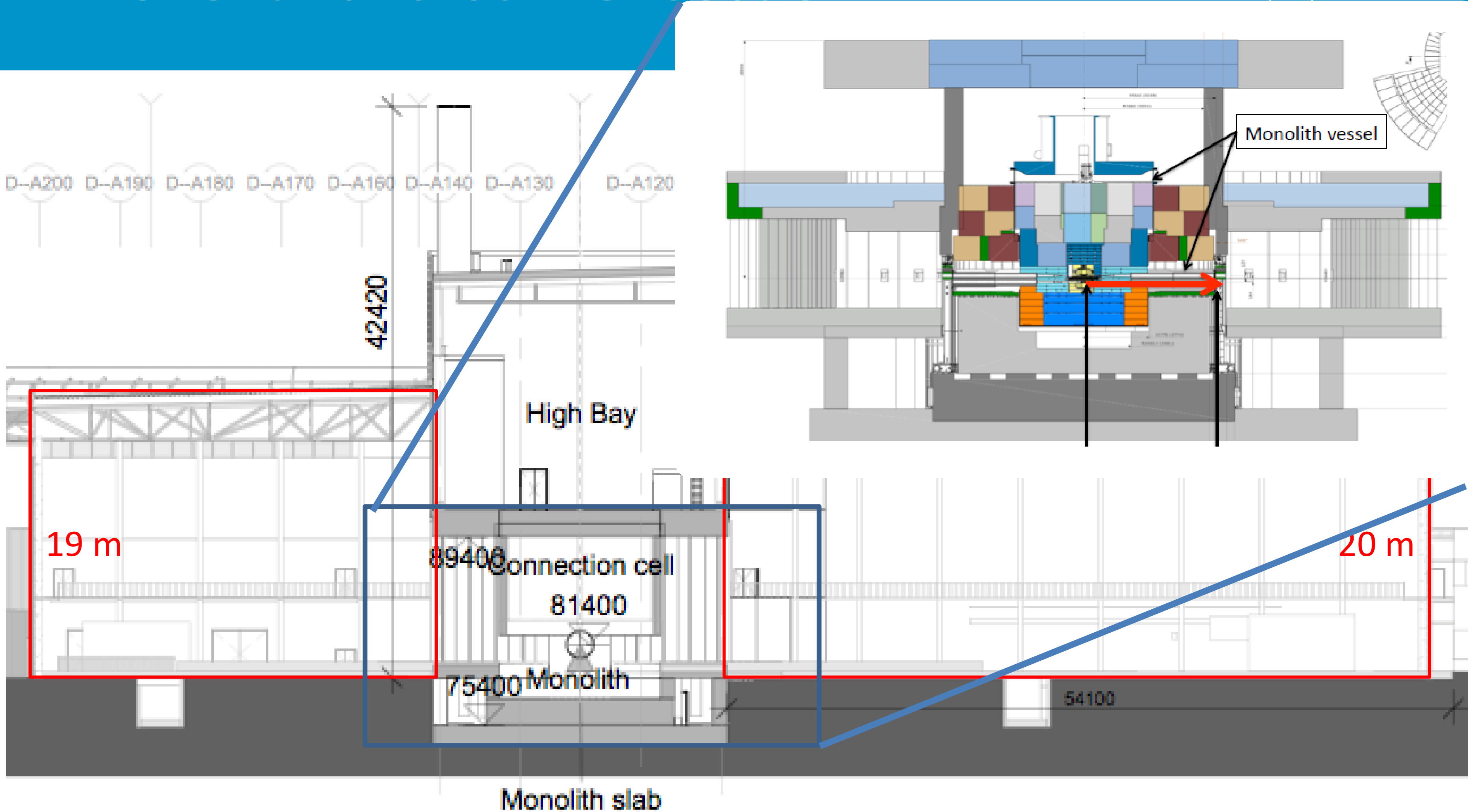
The monolith building where the target tungsten wheel is placed, sided by the instrument halls

Scenario location: the instrument halls

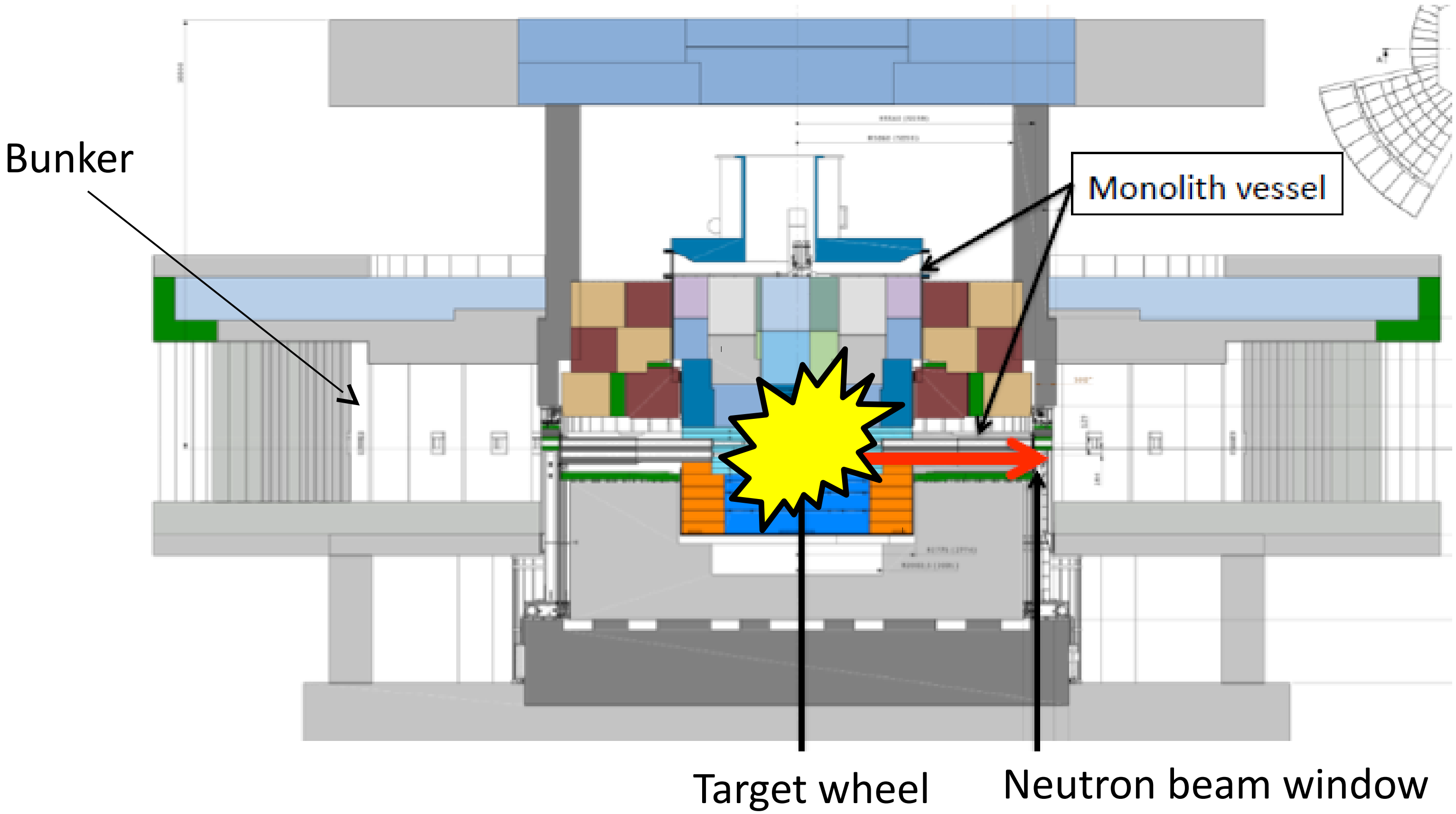
The instrument halls will be adjacent to the monolith target building.
A bunker is placed between the monolith and the halls.



Monolith and bunker section

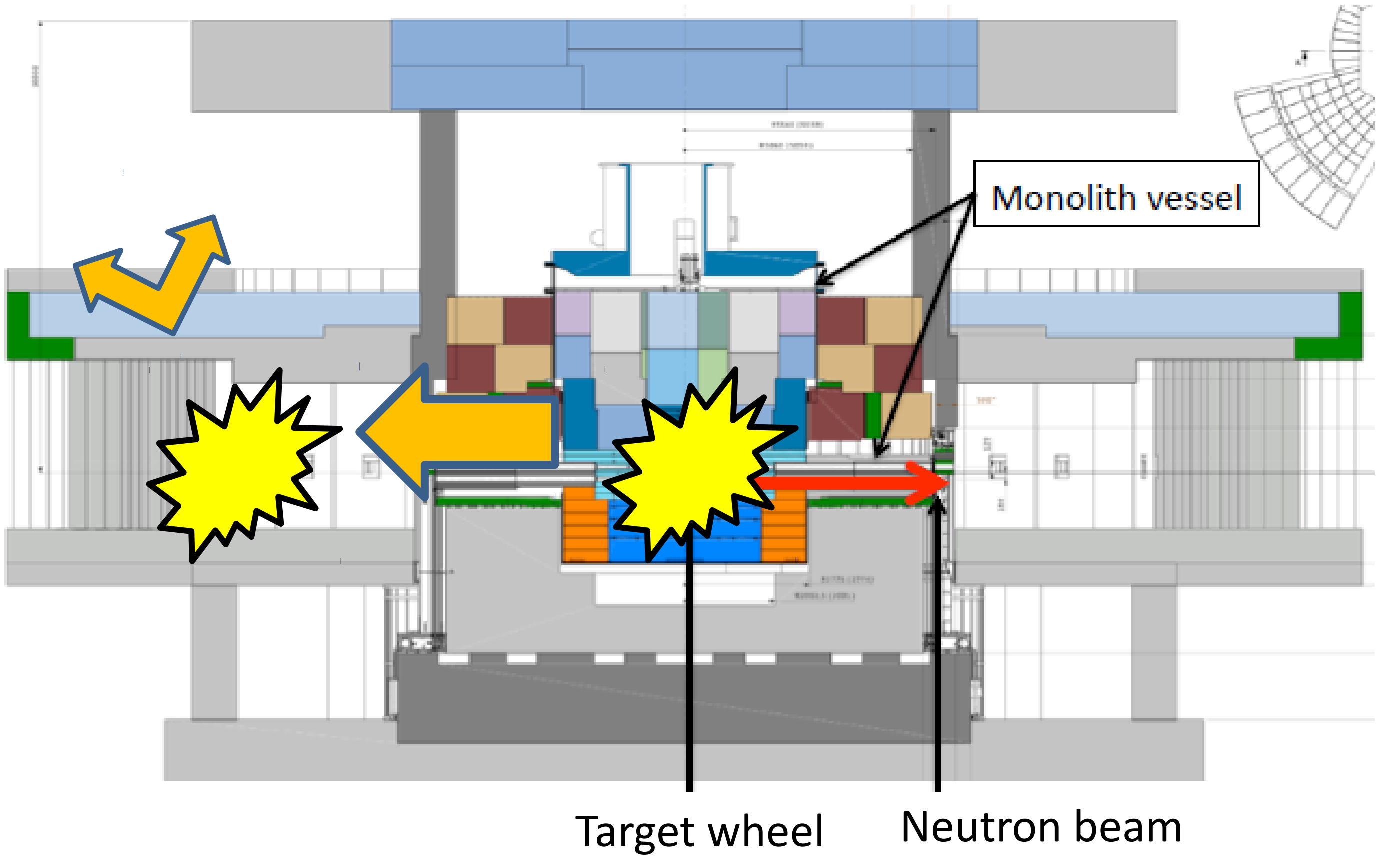


Scenario description



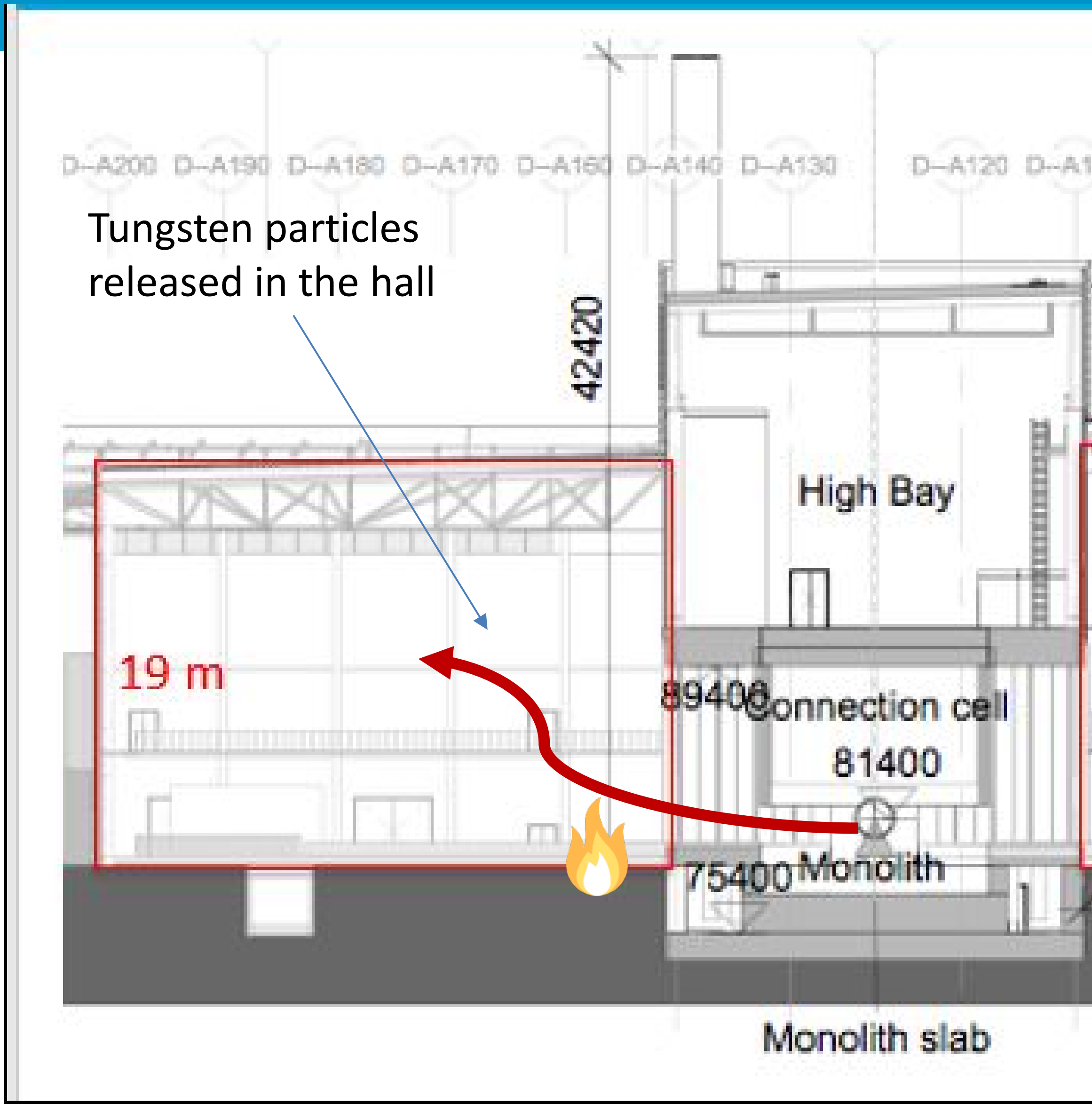
A failure in one of the neutron beams, concurrent with a failure in the liquid hydrogen moderator, causes a deflagration in the monolith, damaging the target wheel and releasing tungsten particles

Scenario description/2



The eject from the monolith triggers another deflagration that damages the adjacent bunker, exposing it to the instrument hall; subsequently, a fire develops in the bunker

Scenario description/3



The instrument hall is therefore exposed to the bunker fire and the release of tungsten particles from the damaged target wheel

Software tools for the modelling of the scenario

- Ansys Workbench 17.2 (Geometry modelling)
- Ansys Fluent 17.2 (CFD simulation software)
- FDS 6 (CFD software, fire model validation)
- ARGOS (Fire evaluation software, fire modelling)

Modelling of the bunker fire

- To focus on the effect on the particle motion and save computation power, the fire is simplified to a mass flow of hot air, discarding radiation and smoke effects

- The mass flow rate and initial temperature are obtained from the ARGOS fire calculator software

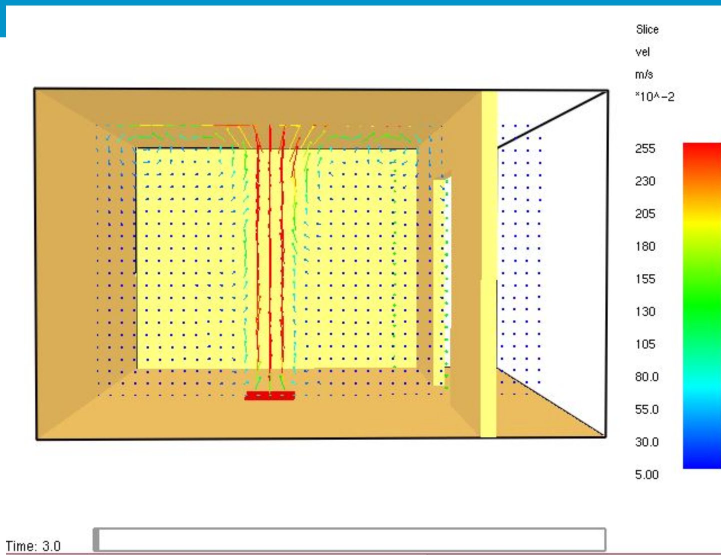
Verification and validation of fire

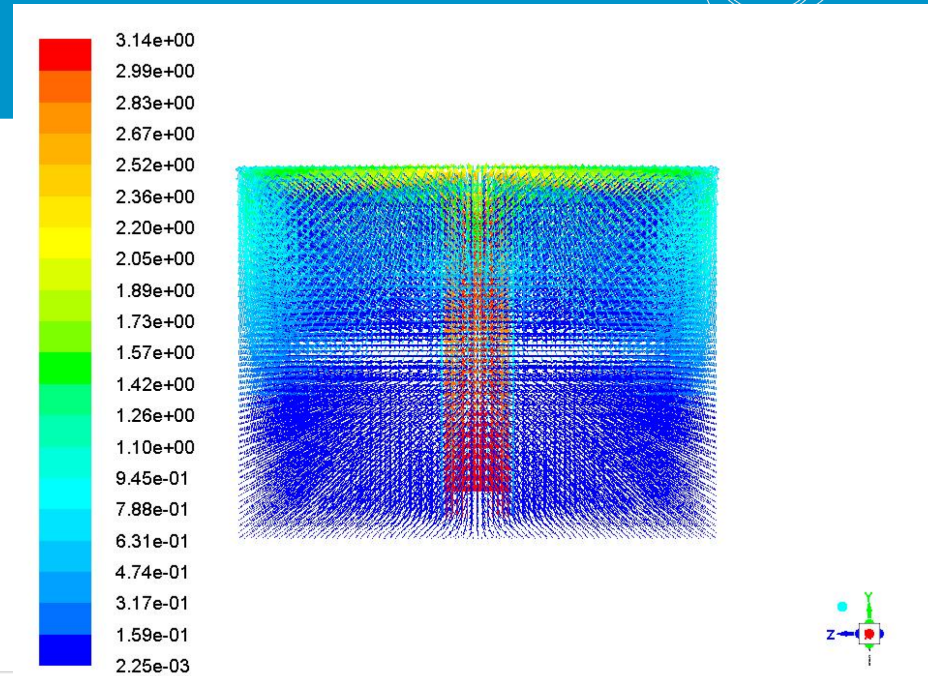
To verify the fire model, a comparison is made with a validated FDS case, the Steckler 16 room.

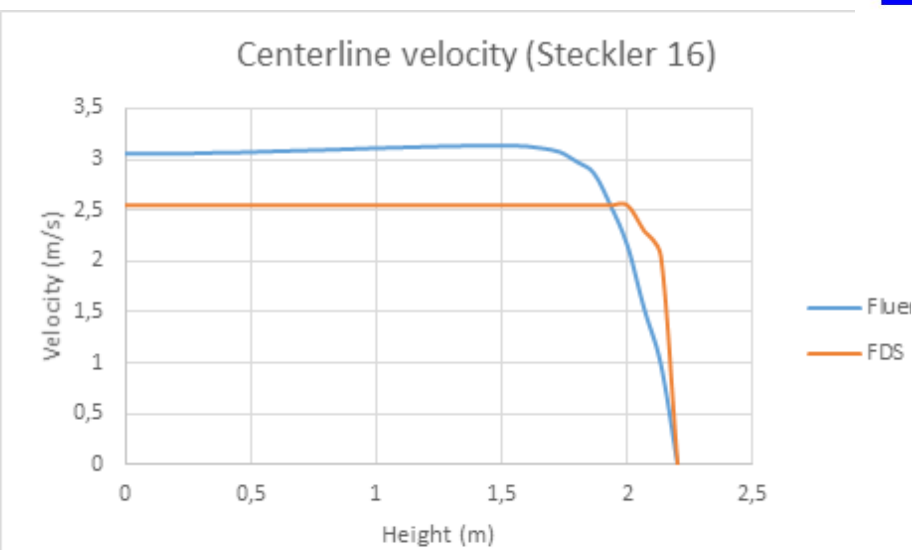
The comparison to a well-known benchmark case provides direct verification and validation for the fire model to use in the case scenario.

The suitability of the Ansys Fluent CFD software for this kind of simulation is also tested

Fire model validation

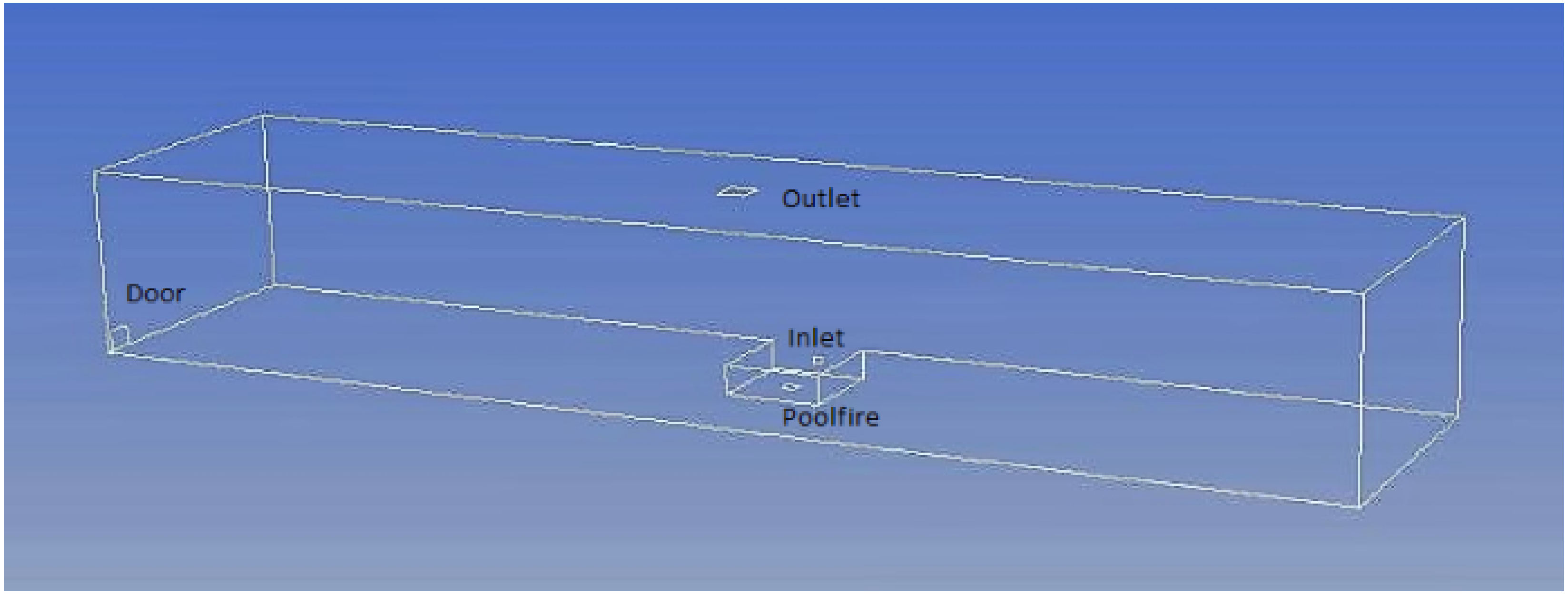






The centerline velocities in the pool fire are compared for the two cases; the Fluent modeled fire speed is slightly higher but with a similar pattern.

Modelling of the geometry



- The instrument hall is modelled with its original dimensions of 130x29x19 m; a inlet door and an outlet window are placed to establish an air flow in the hall
- The bunker is modelled as a 10x10x3 m chamber placed underneath the instrument building. The fire is assumed as a poolfire while the particles are injected from a velocity inlet.

Modelling of geometry and scenario

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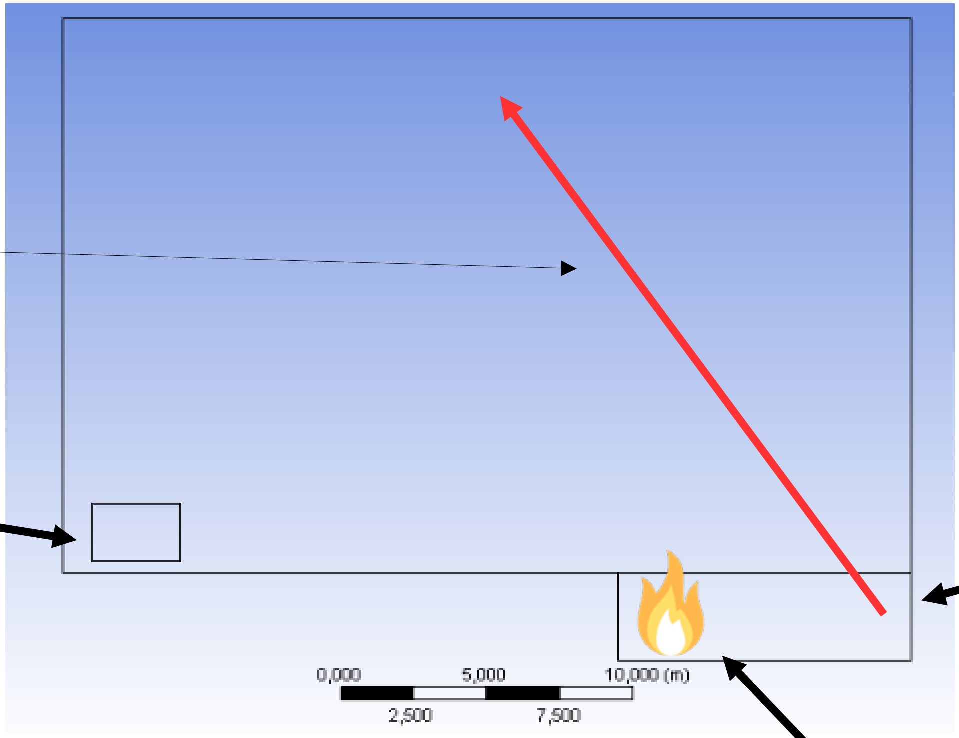


Outlet

Tungsten trioxide particles released from the inlet

Ground level door

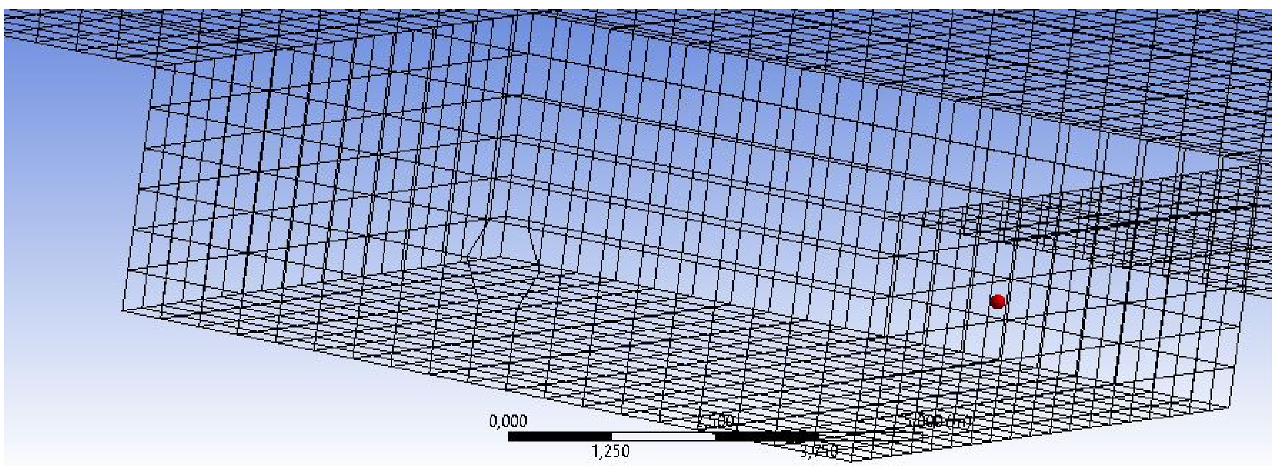
Inlet

Bunker fire

Side view of the modeled geometry

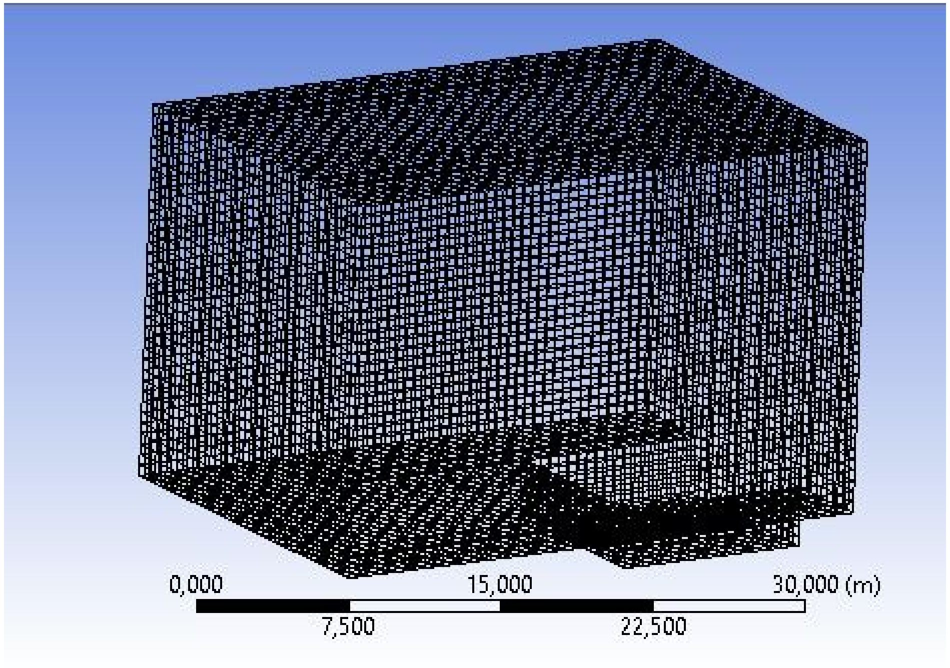
Discretization and turbulence modelling

- Computational domain discretized in ≈ 450000 hexahedral cells
- Flow turbulence modelled with Large Eddy Simulation (LES) method; computationally expensive but accurate



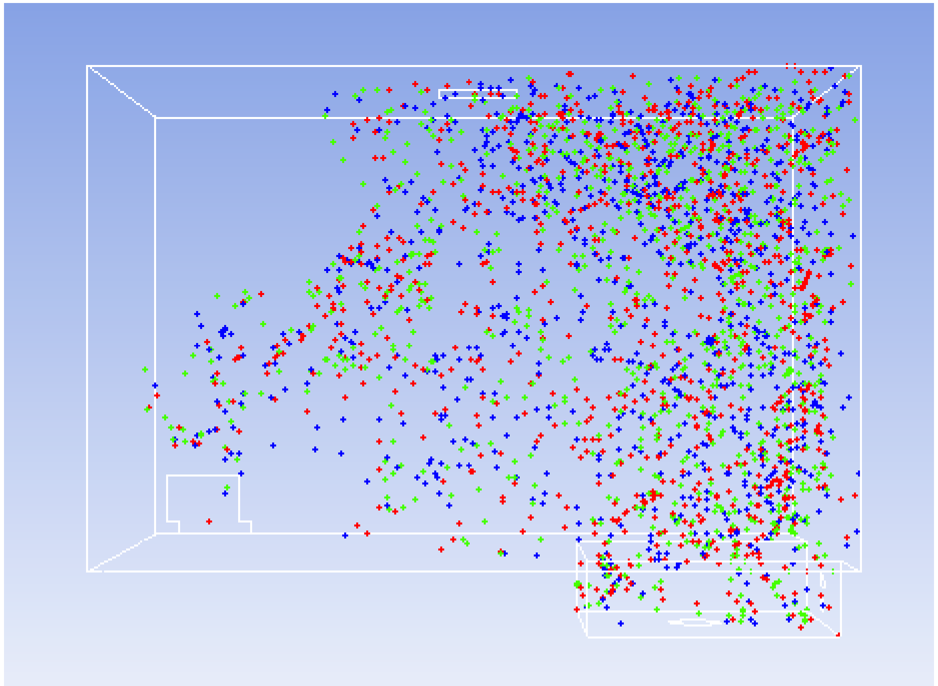
Scaled down simulation setup

- To focus on the upward movement of particles and save computational power, a scaled down geometry, consisting of a 20 m central section of the original one, is used
- The simulation is calculated for a 330 kW and a 1 MW bunker fire
- 1 g of tungsten trioxide (WO3) particles is released
- The particle diameters' range is between 0,1 µm and 2,3 µm
- The running time is 200 s, where the particles are injected after 20 s

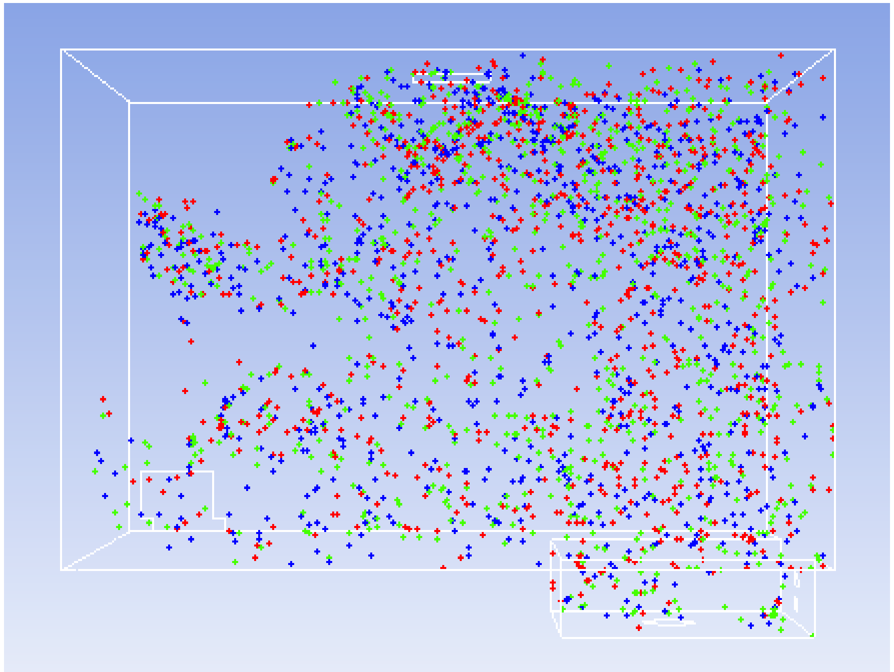


Isometric view of the scaled down geometry

Scaled down simulation/Results



Particle dispersion with a 330 kW bunker fire 3 minutes after injection



Particle dispersion with a 1 MW bunker fire 3 minutes after injection

Scaled down simulation/Results

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	330 kW	1 MW
Escaped particle mass after 3 minutes	0,029 g (2,9%)	0,079 g (7,9%)

- All particles in the 330 kW case left from the outlet ceiling window
- In the 1 MW case, 0,0008 g of particles escaped from the ground level door, less than 1% of all escaped particles

	330 kW	1 MW
Time for particles to start escape from outlet	82,8 s	60,1 s
“” from door	/	146,5 s

Scaled down simulation/Results

Diameter distribution of the tungsten particles inside the instrument building at release and after 3 minutes in the two cases

	Initial	330 kW	1 MW
0,1-0,5 µm	99,5%	95,7%	95,9%
0,5-1 µm	0,02%	2,2%	3,8%
1-2,3 µm	0,02%	2,1%	0,3%

Conclusions

- Ansys Fluent is a suitable CFD software for modelling fire simulations and manages to implement the proposed fire model

- The HRR magnitude of the bunker fire influences the number of particles escaping the building; a higher HRR causes more tungsten particles to be dispersed in the environment.
- Higher HRRs cause particles to be more evenly spread in the building, and to escape in shorter times

- A clear majority of the particles disperses inside the building; the dominant diameter range of diameters is 0,1-0,2 µm

- Almost no tungsten particles escape through ground level

Future developments

- Simulation of the same scenario in the full-scale geometry of the instrument building, for longer simulation durations (up to 20 min.)
- Evolution of the model with more detailed building layout and improved fire definition
- Usage of the model as a base for risk assessment of different hazardous situations

Acknowledgments

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