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KU LEUVEN

Real-time simulation of the near-range atmospheric dispersion using Computational Fluid Dynamics

Lieven Vervecken[1,2] , Christophe Gueibe[1], Johan Camps[1] , Johan Meyers[2]

[1] SCK•CEN, Belgian Nuclear Research Center, Belgium
[2] Department of Mechanical Engineering, KU Leuven, Belgium

NERIS Workshop 2015
Milan, April 27, 2015

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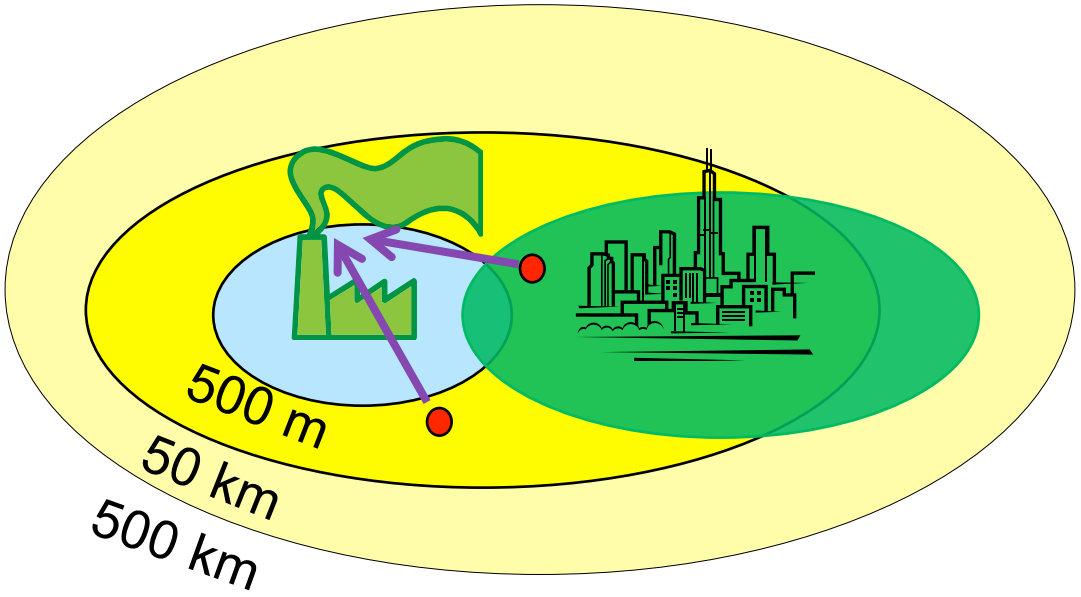
Accurate modeling results in effective countermeasures



Complexity

Model type
CFD
3D Eulerian models
Lagrangian particle models
Lagrangian puff models
Segmented Gaussian plume
Gaussian plume

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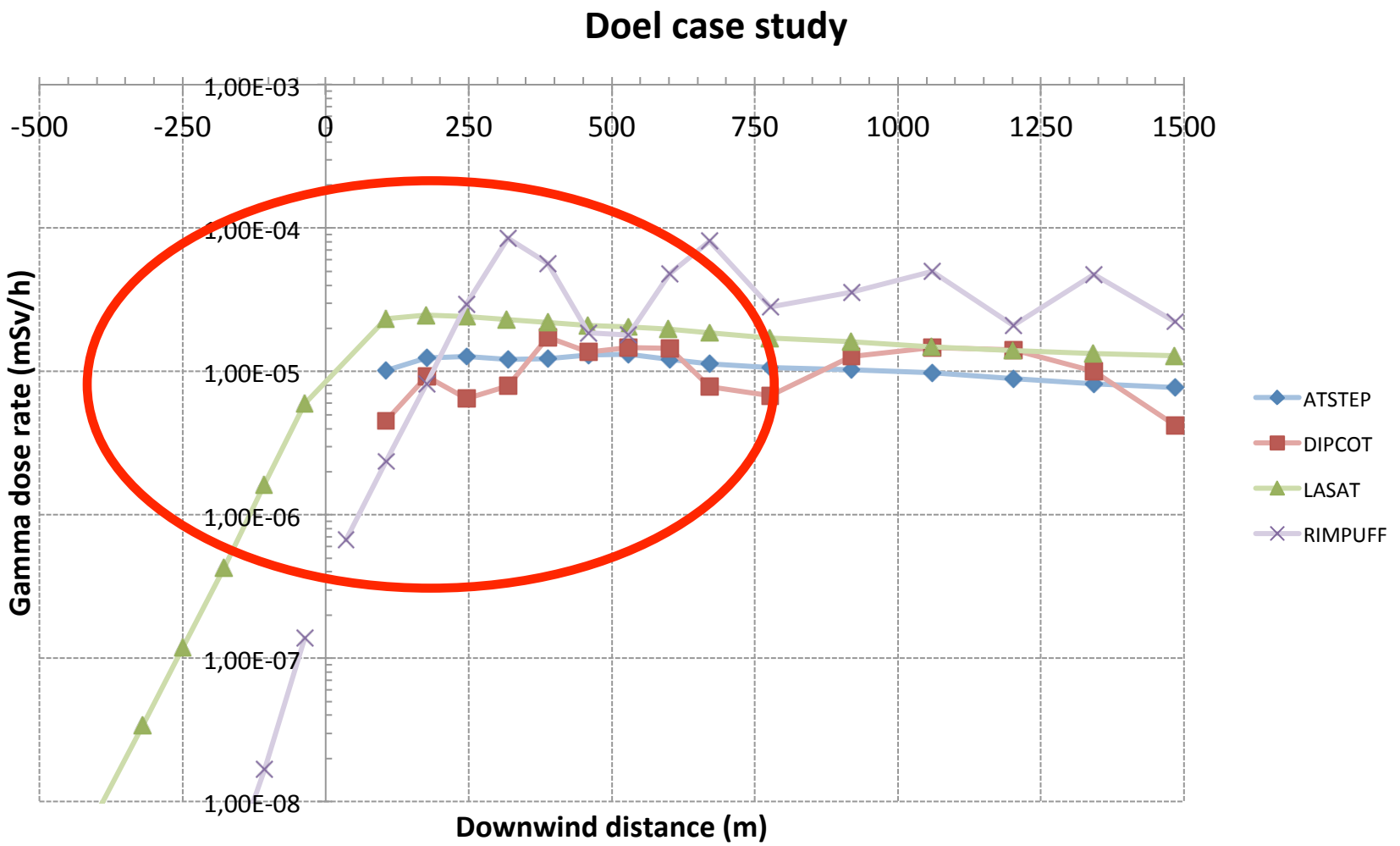
Existing models not conclusive for the near-range



Which is correct?

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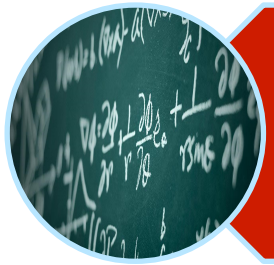
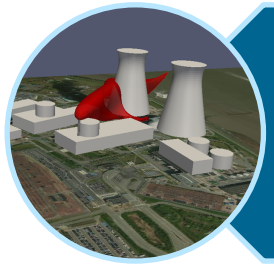
Introduction



Transport model



Case study

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Pollutant transport model

- Time-dependent advection-diffusion with radioactive decay

$$\partial c/\partial t + \nabla\cdot(\boldsymbol{u}c) = \nabla\cdot\nu\downarrow t\ /\mathrm{Sc}\downarrow t\ \nabla c - \lambda c + S$$

Local time derivative

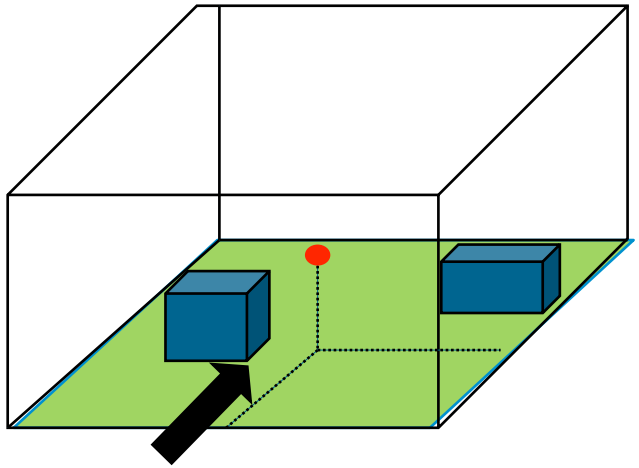
Convection

Turbulent diffusion

Radioactive decay

Source term

- CFD with RANS turbulence modeling
  - $\boldsymbol{u}$ and $\nu\downarrow t$
  - Standard $k-\epsilon$ model



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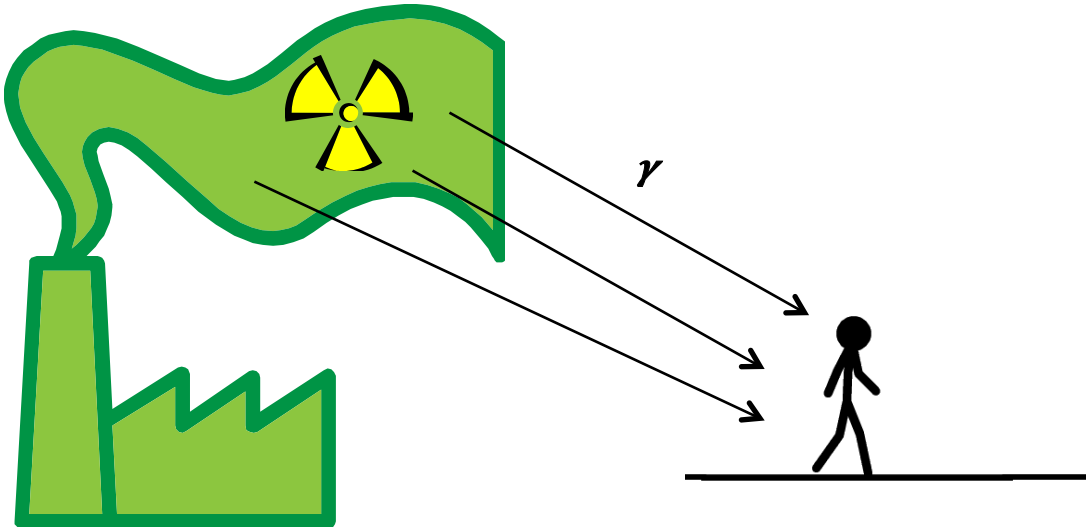
Gamma dose rate model

- Point-kernel method with buildup factors [Gy] [Slade, 1968

$$d\downarrow\gamma,x\downarrow 0 = E\downarrow\gamma\ \mu\downarrow en/\rho \iiint V\uparrow \square B(\mu,r)/4\pi r\uparrow 2\ e\uparrow -\mu r\ \lambda c(x\uparrow\prime, y\uparrow\prime, z\uparrow\prime)\ d x\uparrow\prime\ dy\uparrow\prime\ dz\uparrow\prime$$

- Account for biological effect [Sv]

$$h = Qd\downarrow\gamma,x\downarrow 0$$



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Model reduction

Physical system

Modeling

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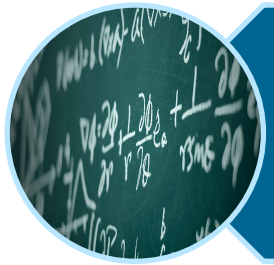
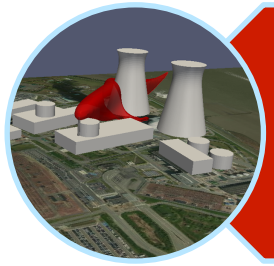


Transport model



Case study

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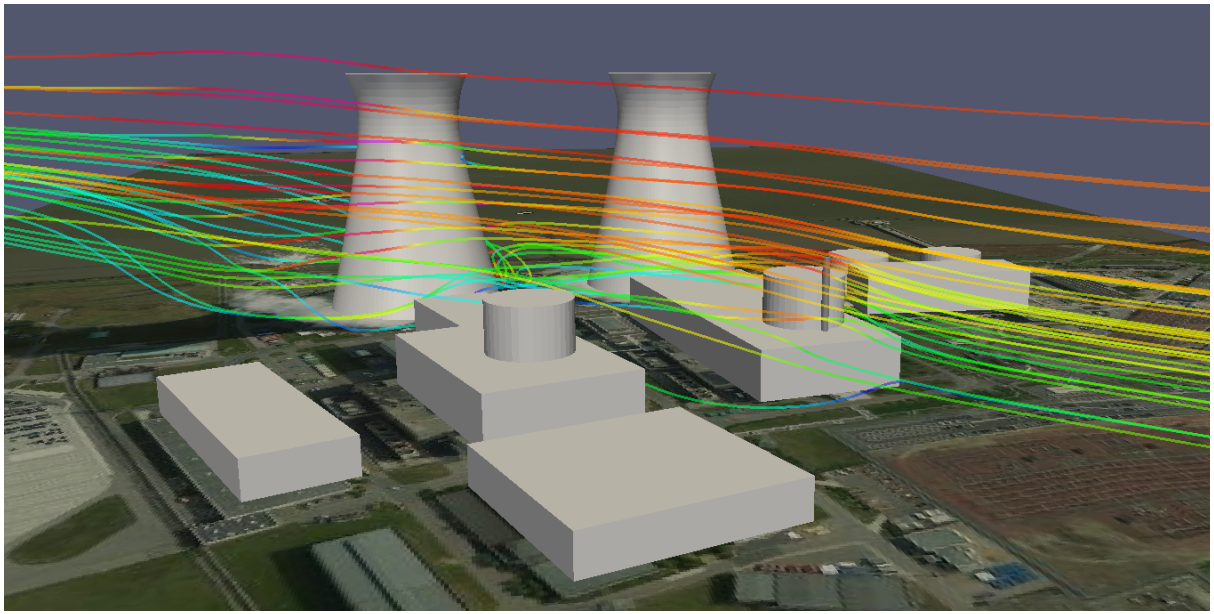
Case setup

- Emission of Xenon-133 from Doel 3
  - Release height 74 m
    1. Steady release
    2. Gaussian-shaped release
  - Release rate 3.6 TBq/h
- Wind field
  - 20 km/h at 74 m
  - Southwest
  - Neutral stability



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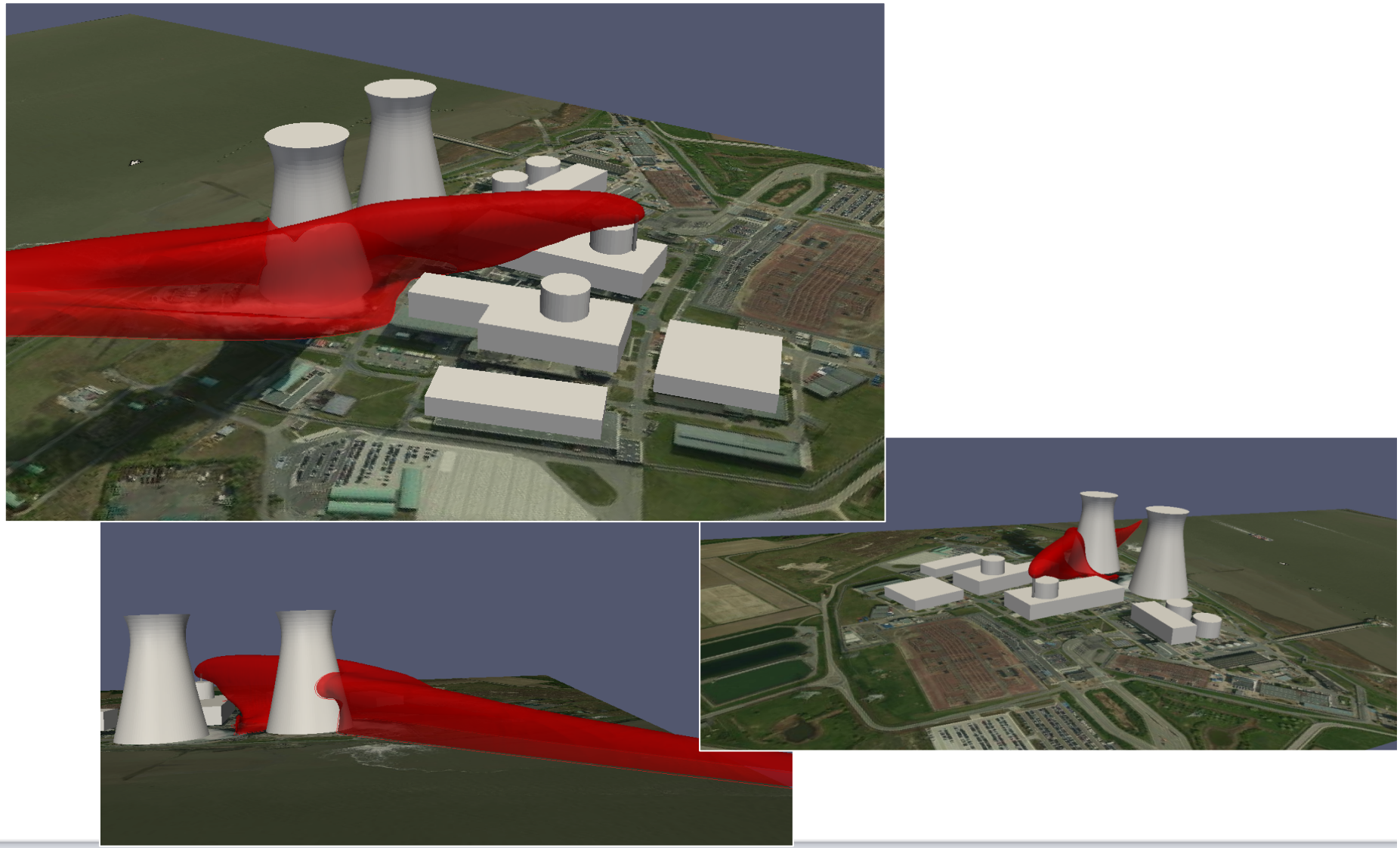
1. Steady release



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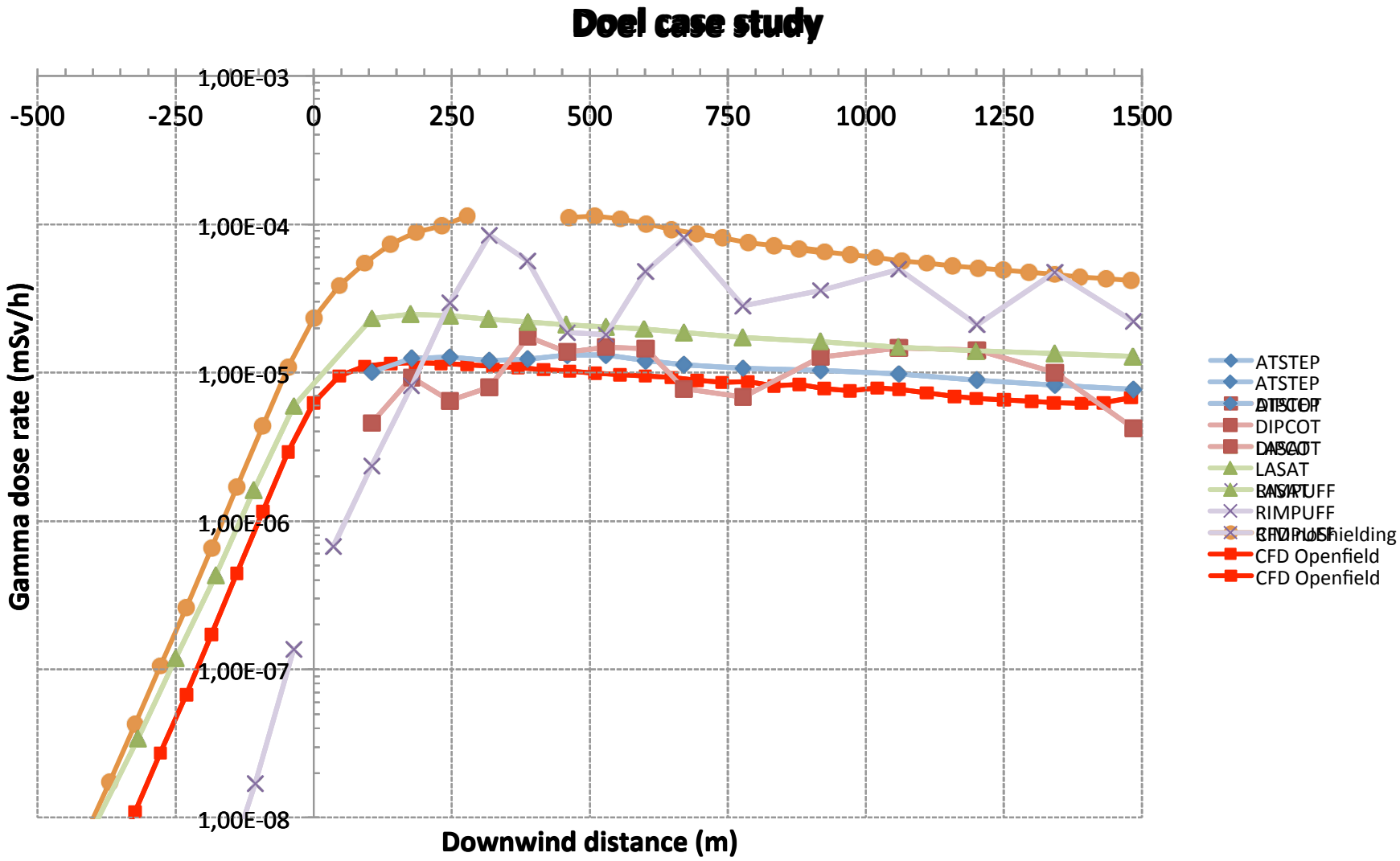
Dose rate at near-range significantly higher



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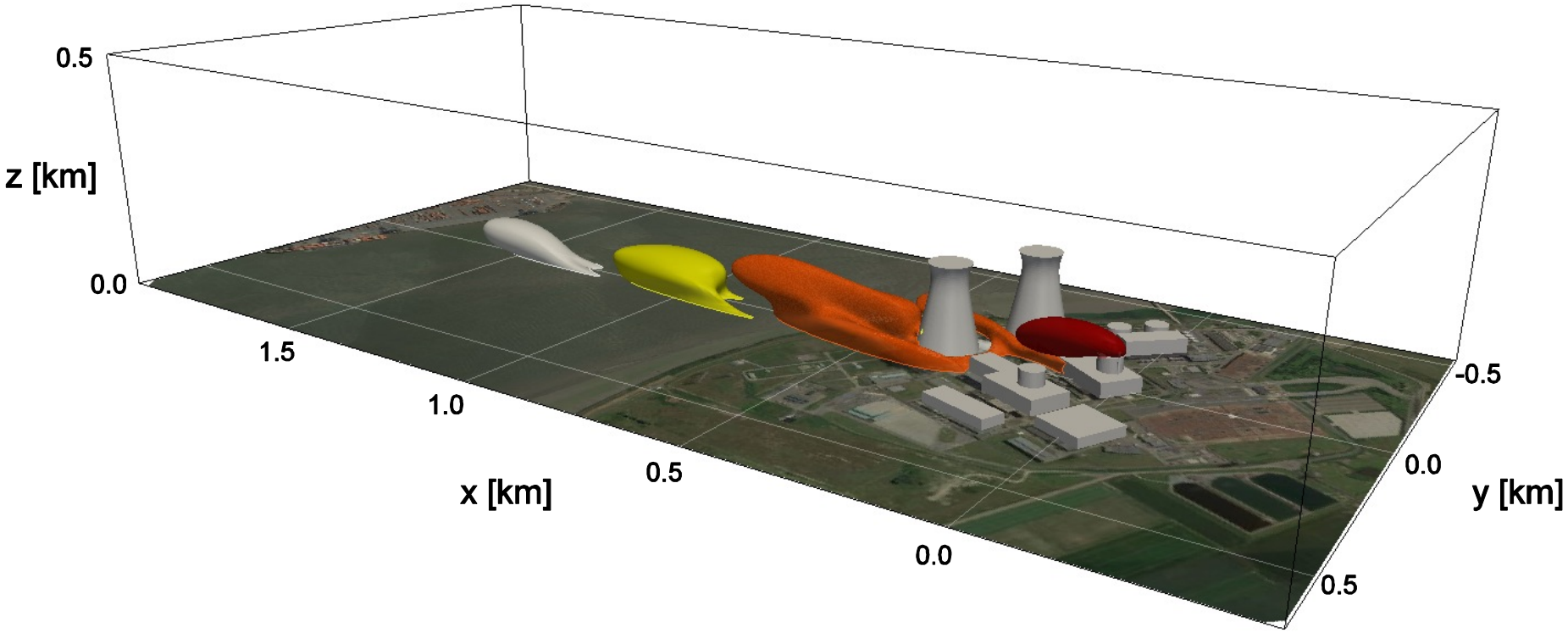
2. Gaussian shaped release



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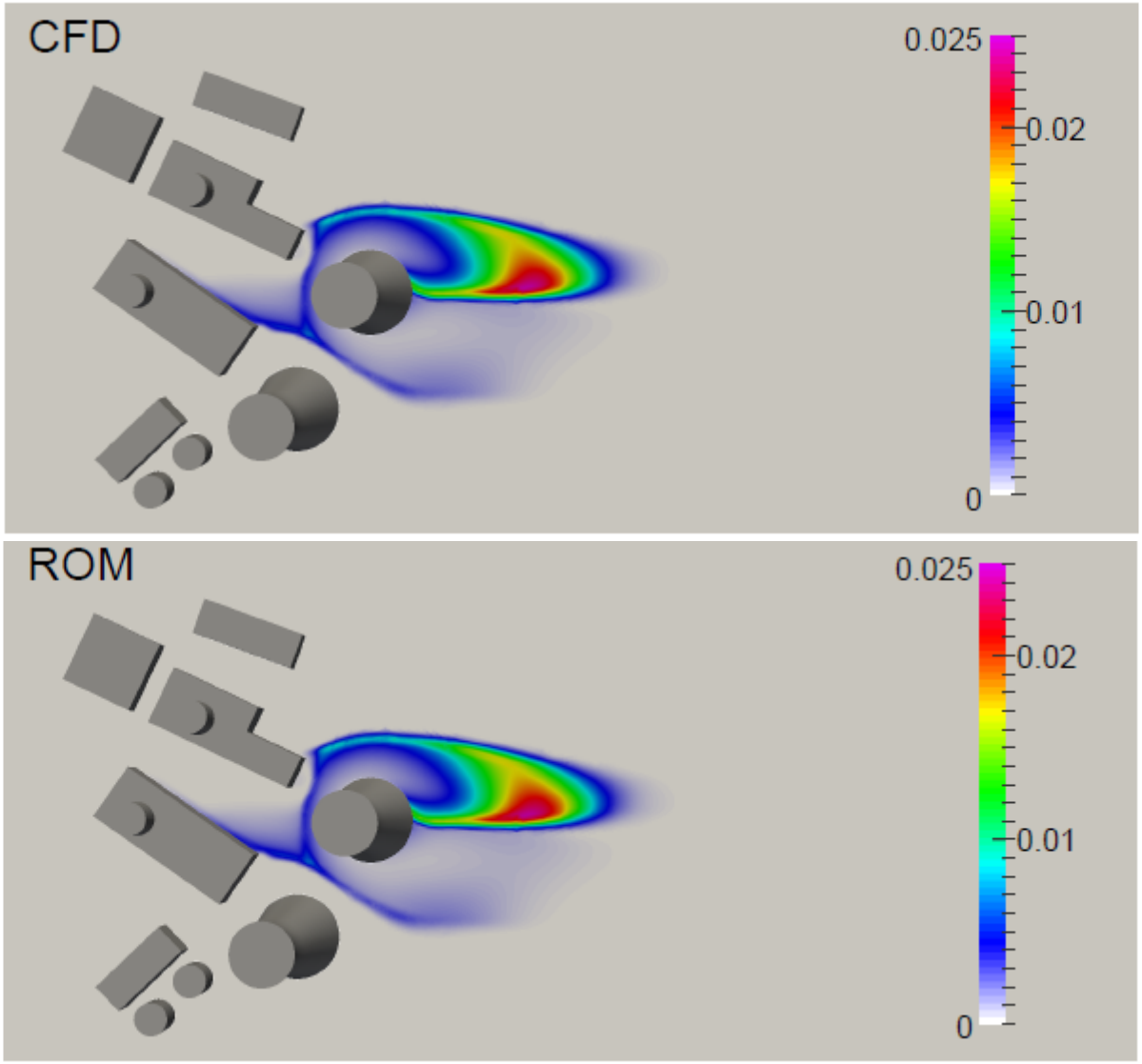
CFD = ROM



- Speedup = 2500x
- 25x real-time
- Only 1 CPU core
- No loss in accuracy
- Source reconstruction

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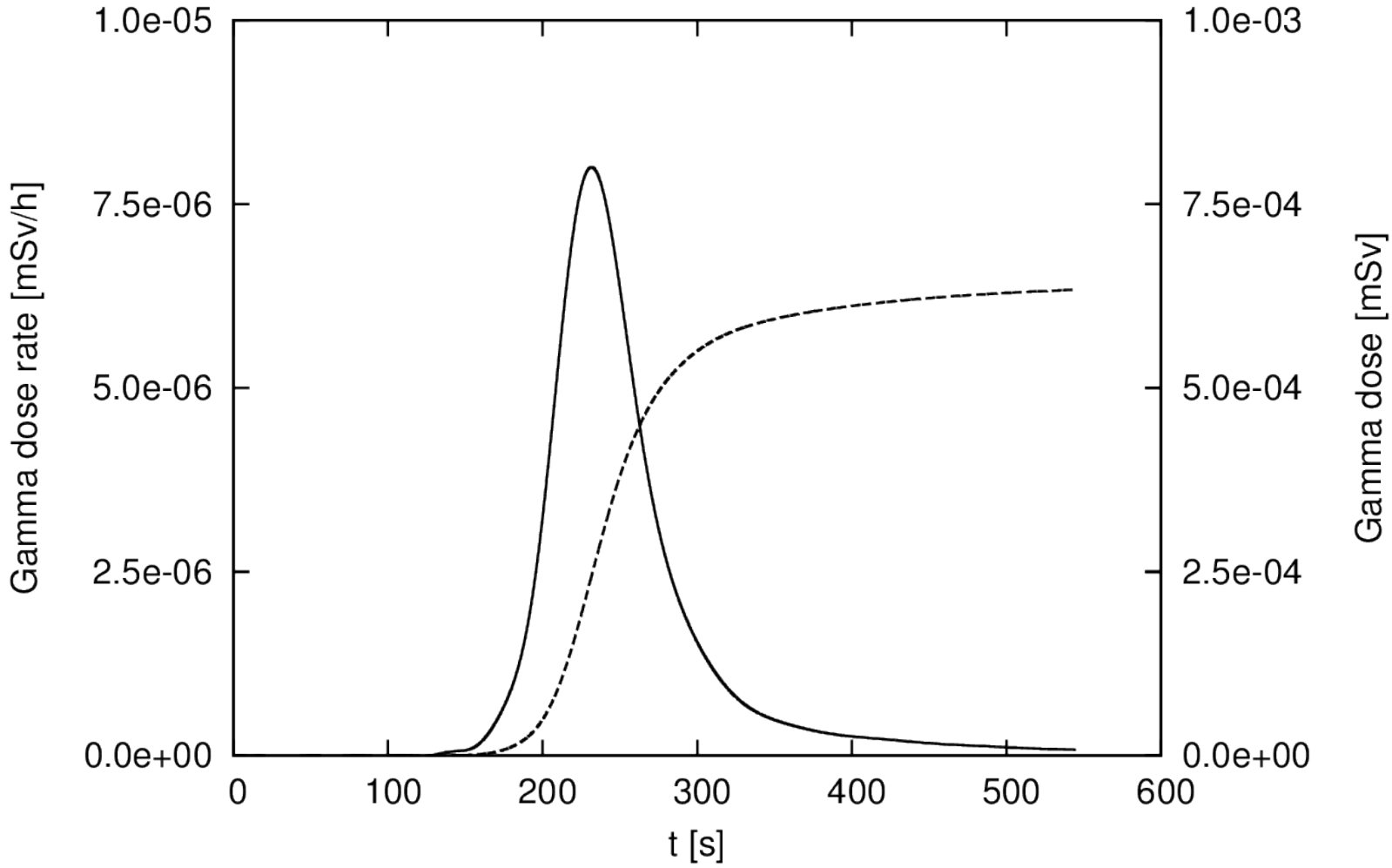
Gaussian-shaped release: measurement point 1



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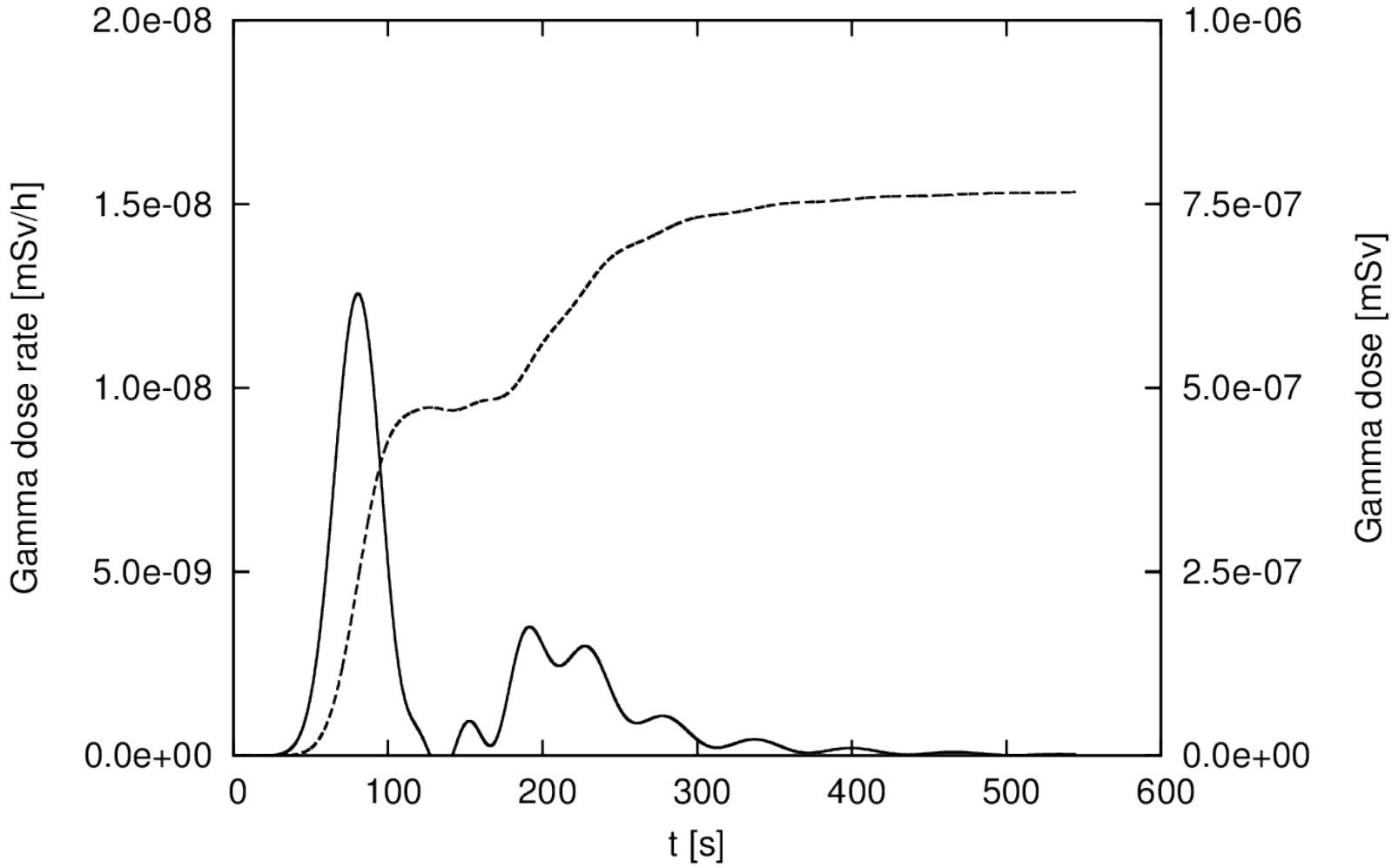
Gaussian-shaped release: measurement point 2



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Conclusion & Additional research challenges

- Dispersion simulation
  - Significantly higher dose rate at near-range
  - CFD not for fast dose assessment
  - Model reduction method very effective

- Additional research challenges
  - Non-zero pollutant emission velocity
  - Buoyancy effects
  - Thermal stratification
  - Experimental validation

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Centre d'Etude de l'Energie Nucléaire
Belgian Nuclear Research Centre

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Registered Office: Avenue Herrmann-Debrouxlaan 40 – BE-1160 BRUSSELS
Operational Office: Boeretang 200 – BE-2400 MOL