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HPC USER FORUM

High-Performance Computational Fluid Dynamics for Virus Propagation in Closed Ventilated Domains

Florent Duchaine, Mehdi Cizeron, Nicolas Odier, Jérôme Dombard, Thierry Poinsot

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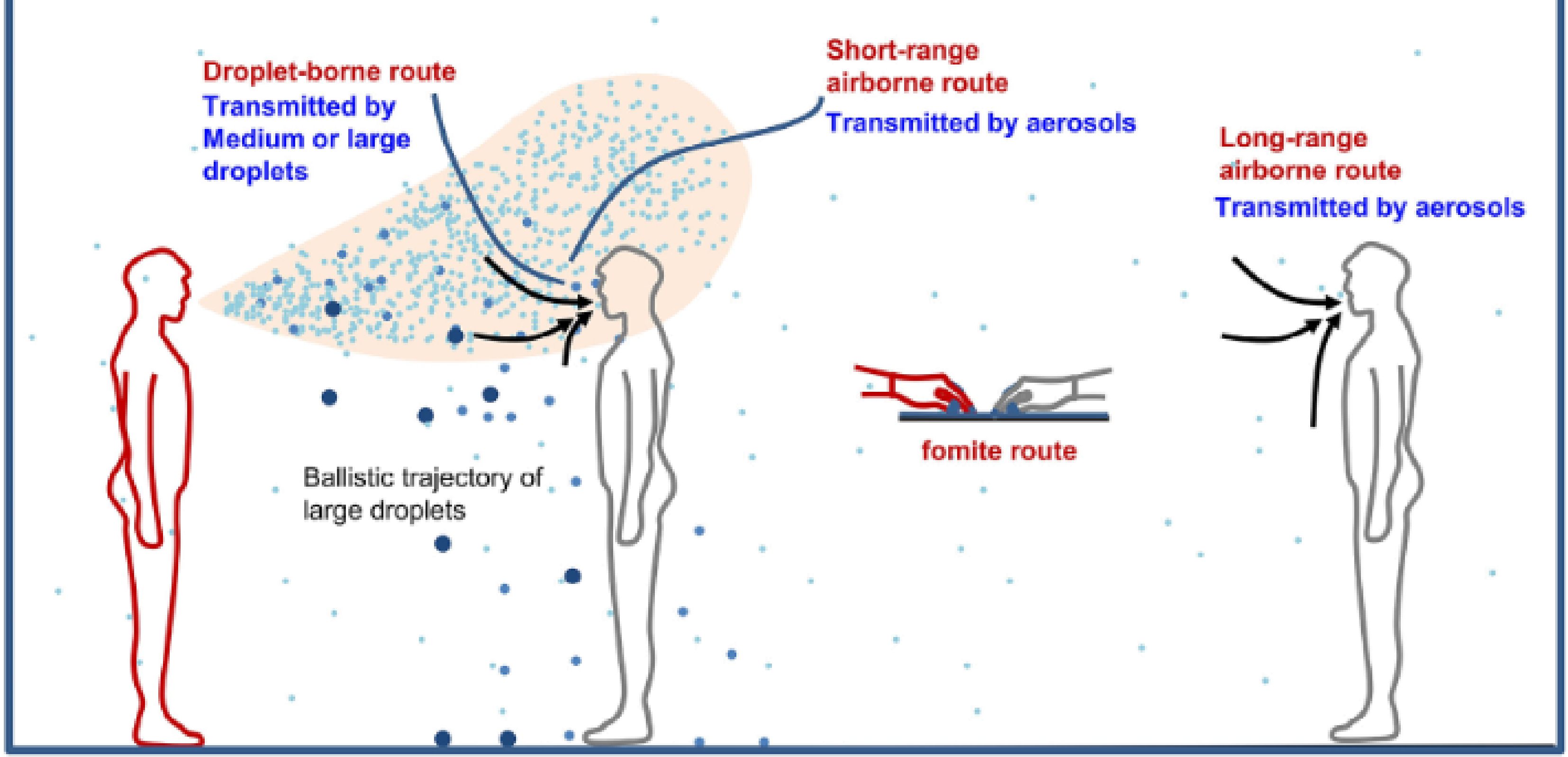
GENCI
Le calcul intensif au service de la connaissance

www.cerfacs.fr

Context – Airborne virus propagation

J. Wei, Y. Li, American Journal of Infection Control 2016, 44, S102.



- Large droplets (>100 µm) : Fast deposition due to the domination of gravitational force
- Medium droplets between 5 and 100 µm
- Small droplets or droplet nuclei, or aerosols (< 5 µm): Responsible for airborne transmission

➔ Where the respiratory droplets migrate : ***Computational Fluid Dynamics***

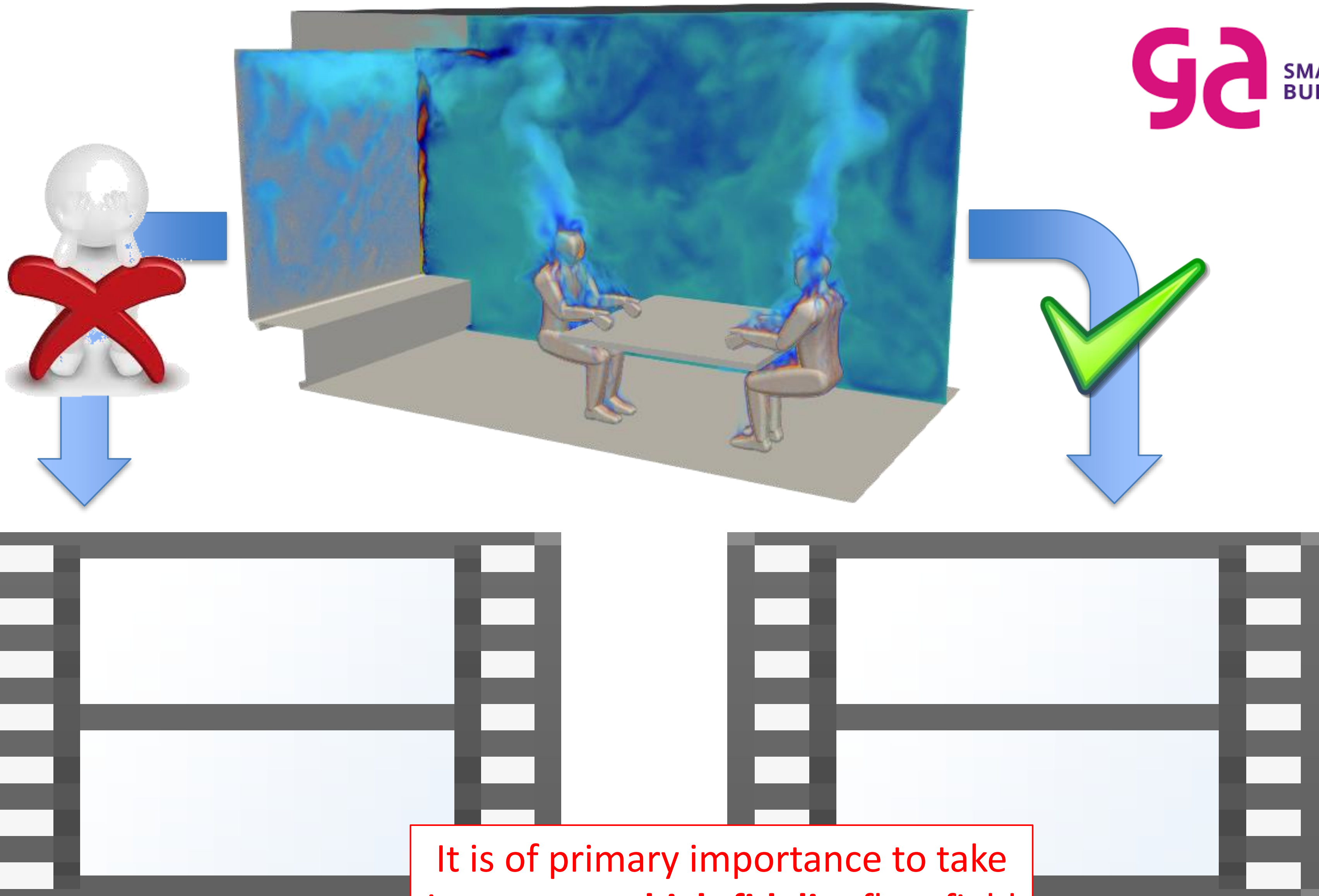
➔ How many time the virus is active : ***Biology***

Context – Airborne virus propagation

We started to play with short-range airborne route ➔ **~ seconds**

What happen in enclosed ventilated spaces when considering long-range airborne routes ➔ **~ Hours**

Requirement for high-fidelity flow predictions



It is of primary importance to take into account **high-fidelity** flow field (ventilation, buoyancy …)

Computational solution

AVBP Solver - CERFACS

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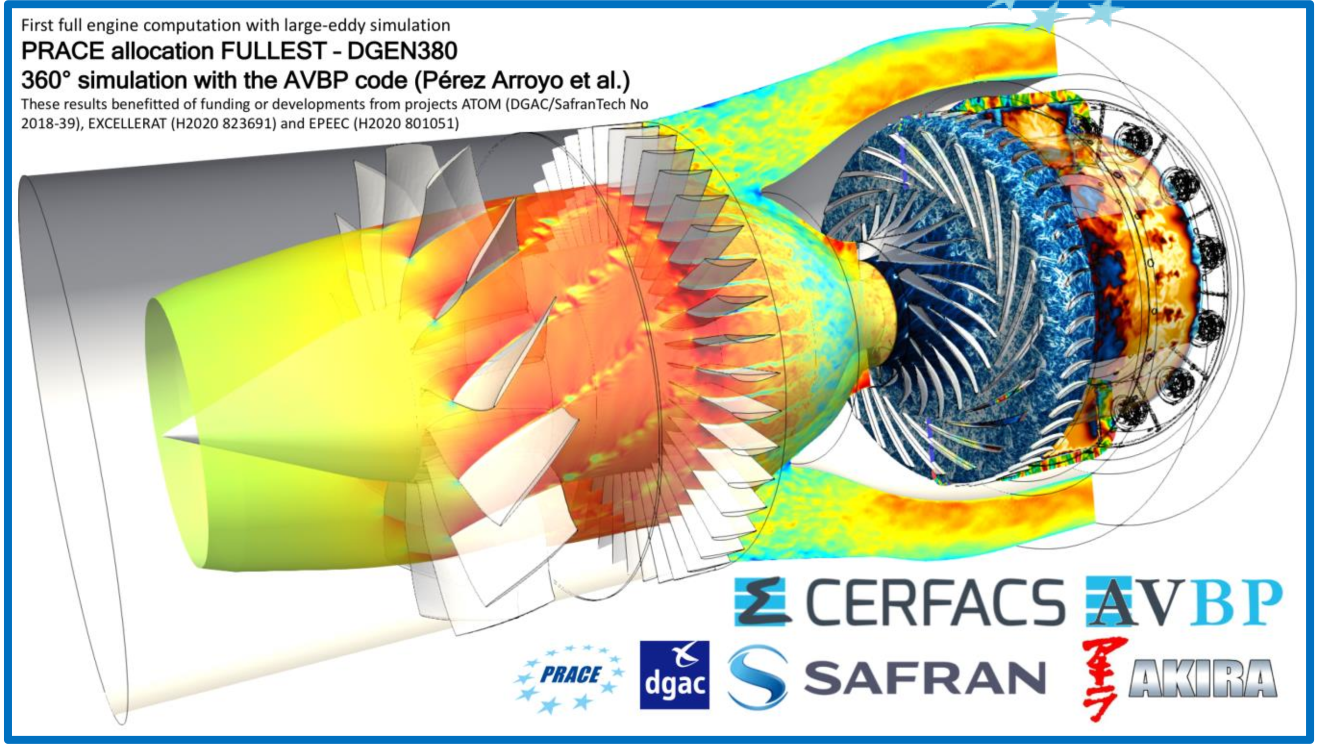
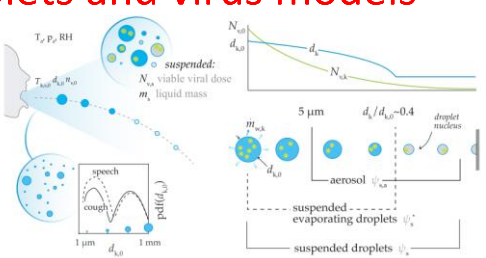


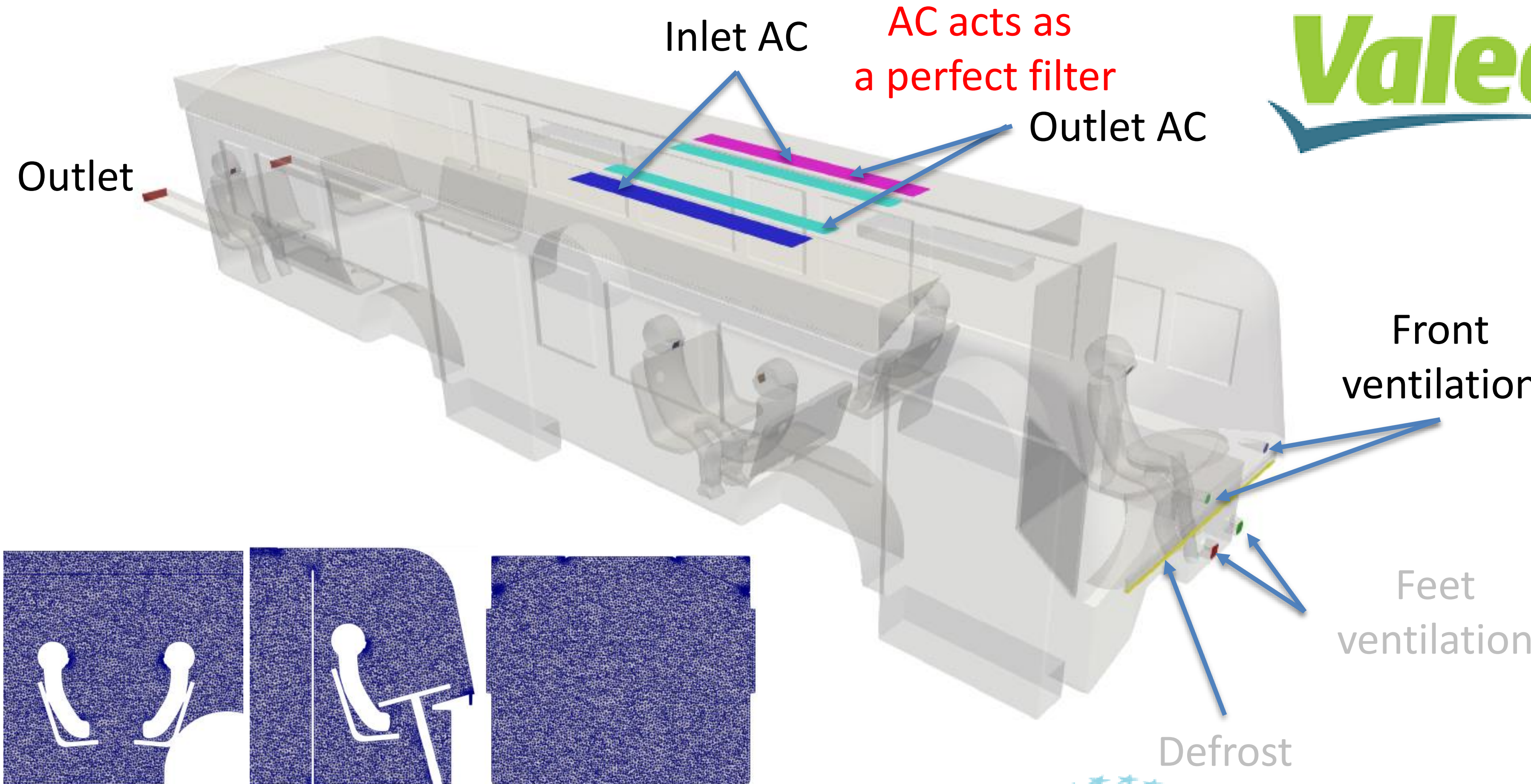
+ Droplets and virus models



+ Respiratory droplets dispersion during long times

- ➢ High-fidelity Large Eddy Simulations
- ➢ Droplet dispersion on mean fields

Applications – Bus – Setup



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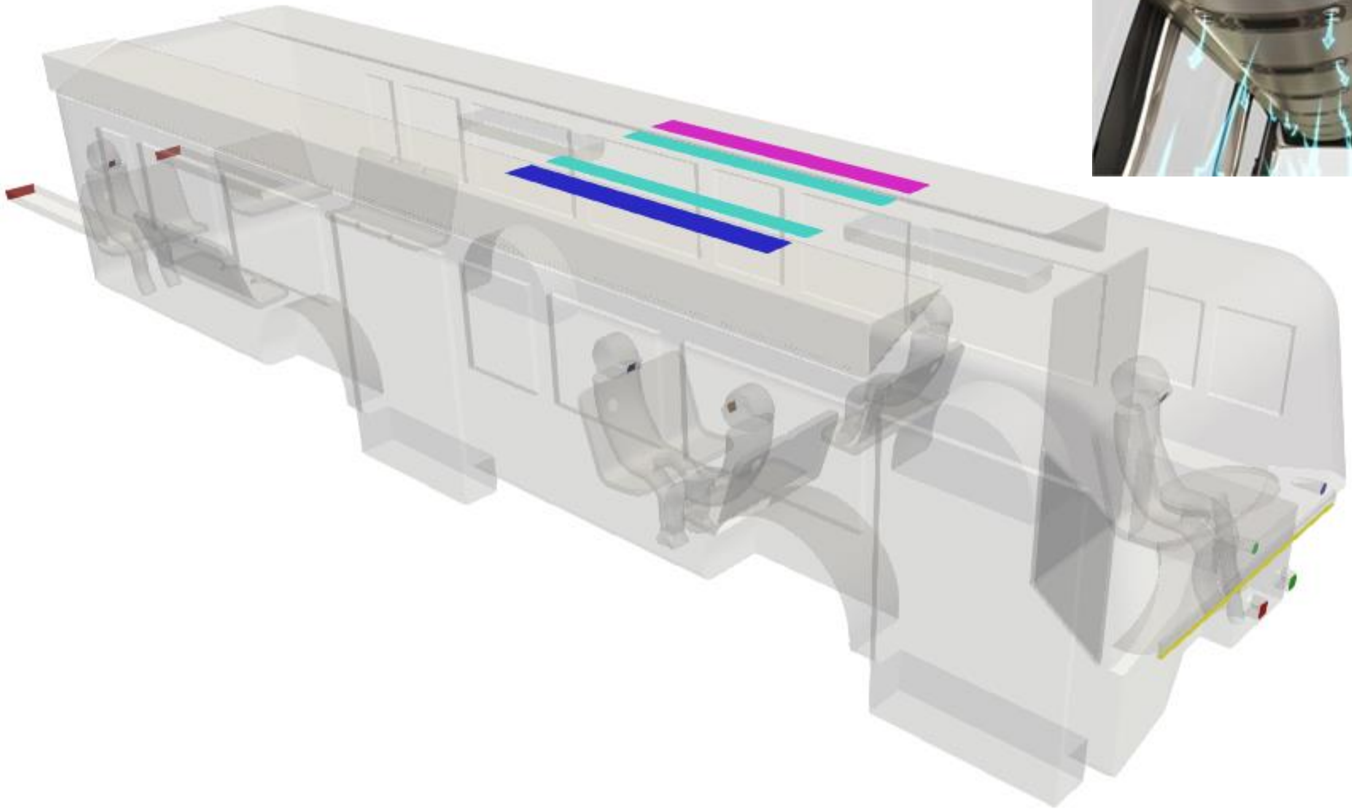
- 40 M cells
- TTGC numerical scheme [Colin and Rudgyard 2000]
- WALE sub-grid scale model [Nicoud and Ducros 1999]

Applications – Bus – Setup

AC acts as a perfect filter:
Idealization of a air
purification system



https://www.valeo-thermalbus.com/eu_en/Innovation/UV-air-purification

Applications – Bus – Operating Conditions

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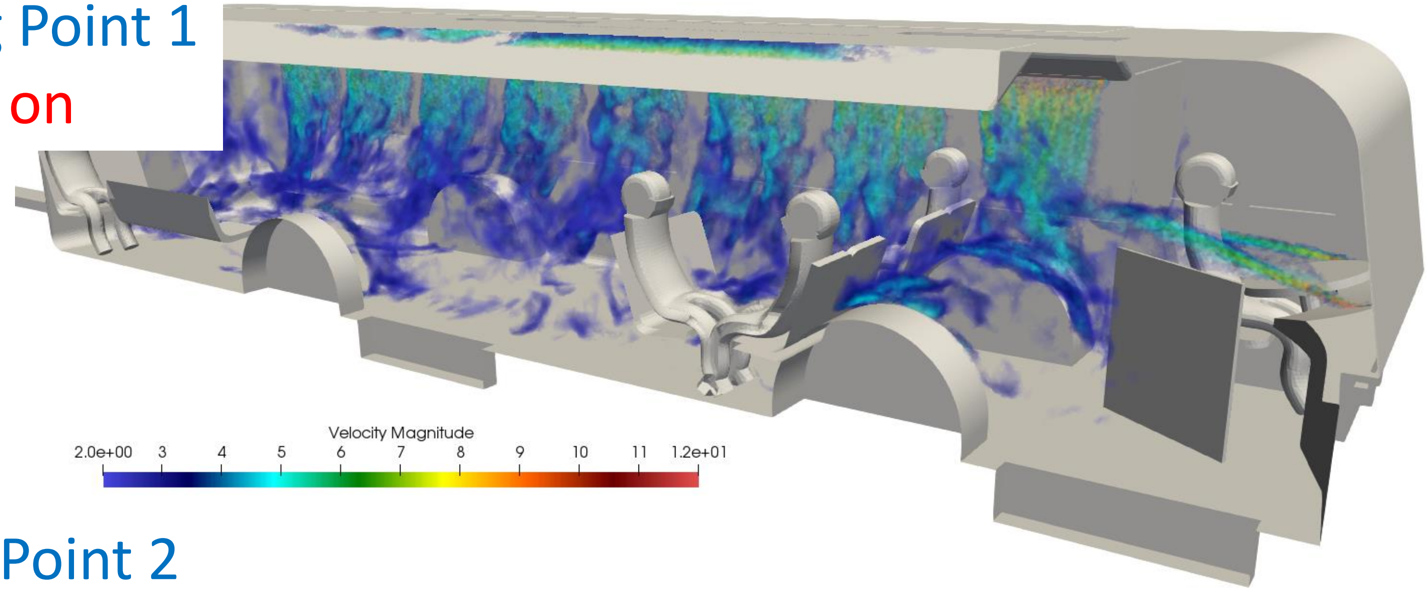
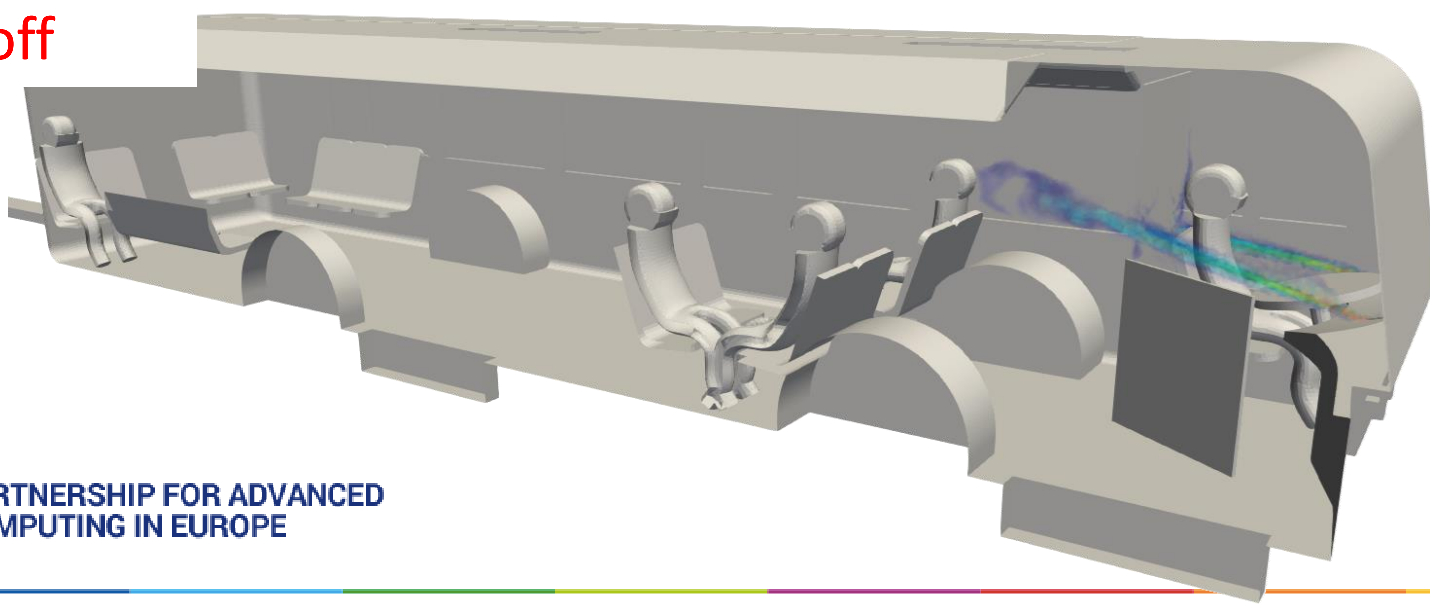
Operating Point 1
➔ AC on



Operating Point 2
➔ AC off



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Applications – Bus – Flow fields

Operating Point 1
➔ AC on

Operating Point 2
➔ AC off

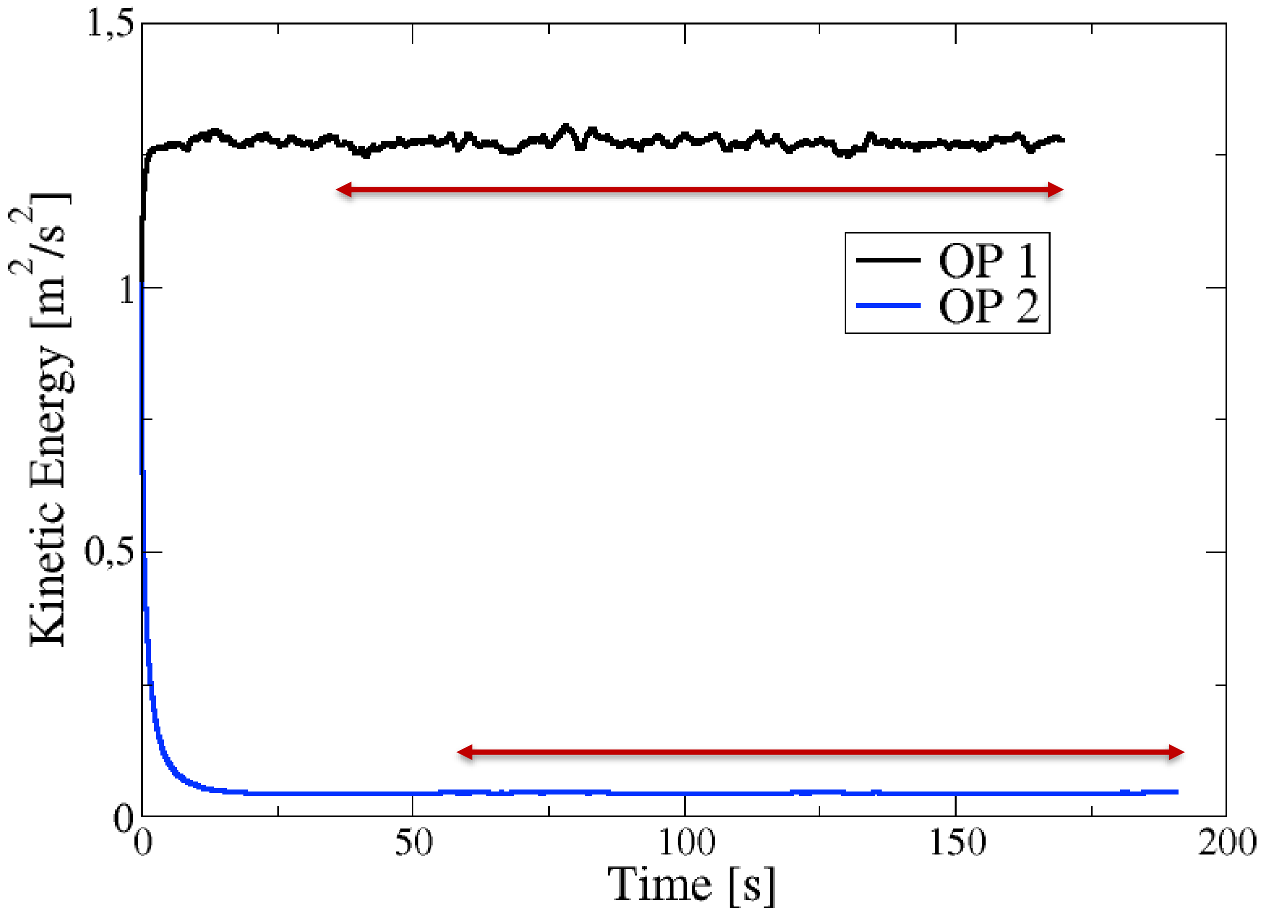
Very different flow fields and turbulent activity

Applications – Bus – Flow fields

Convergence of the gaseous fields:

➔ Transient evacuation in 15 s for OP1 and 40 s for OP2

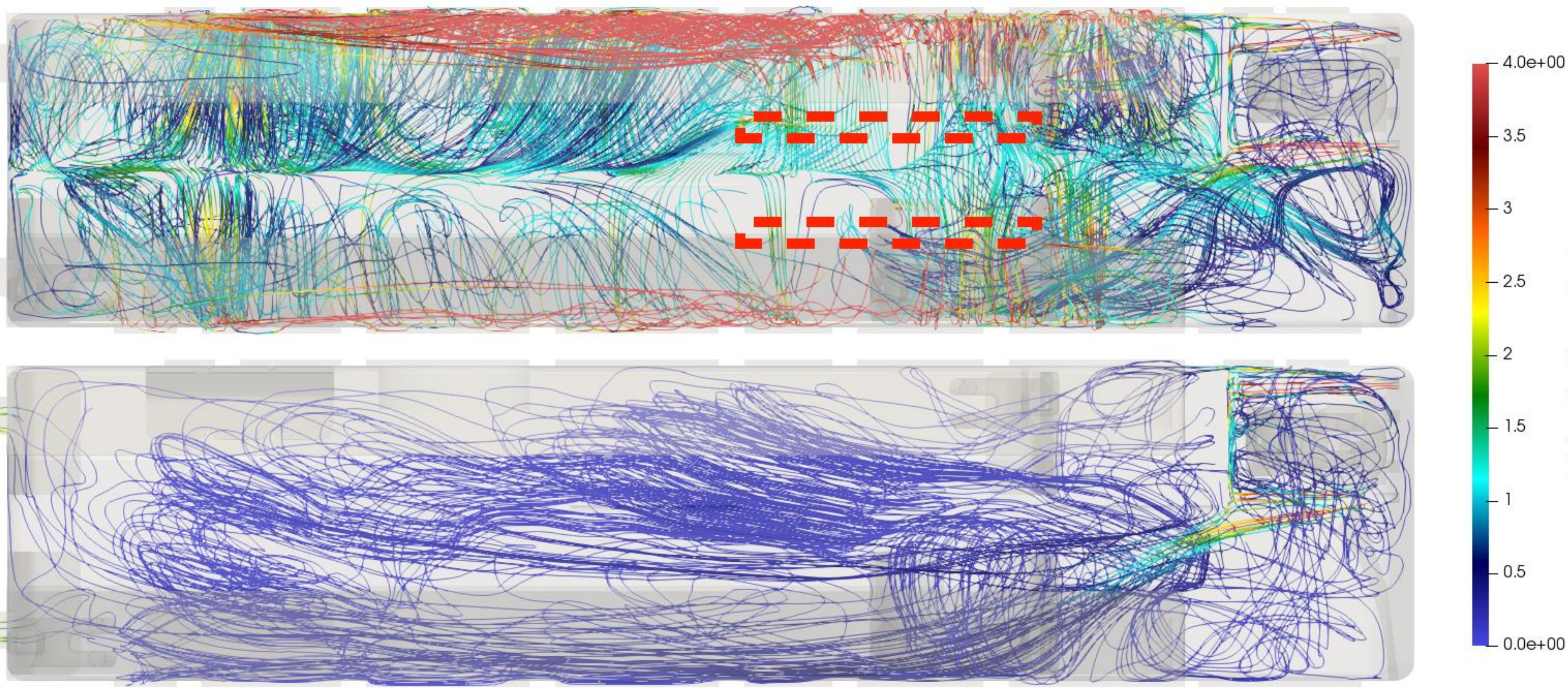
➔ Time averaged on the last 130 seconds



Very different flow organization

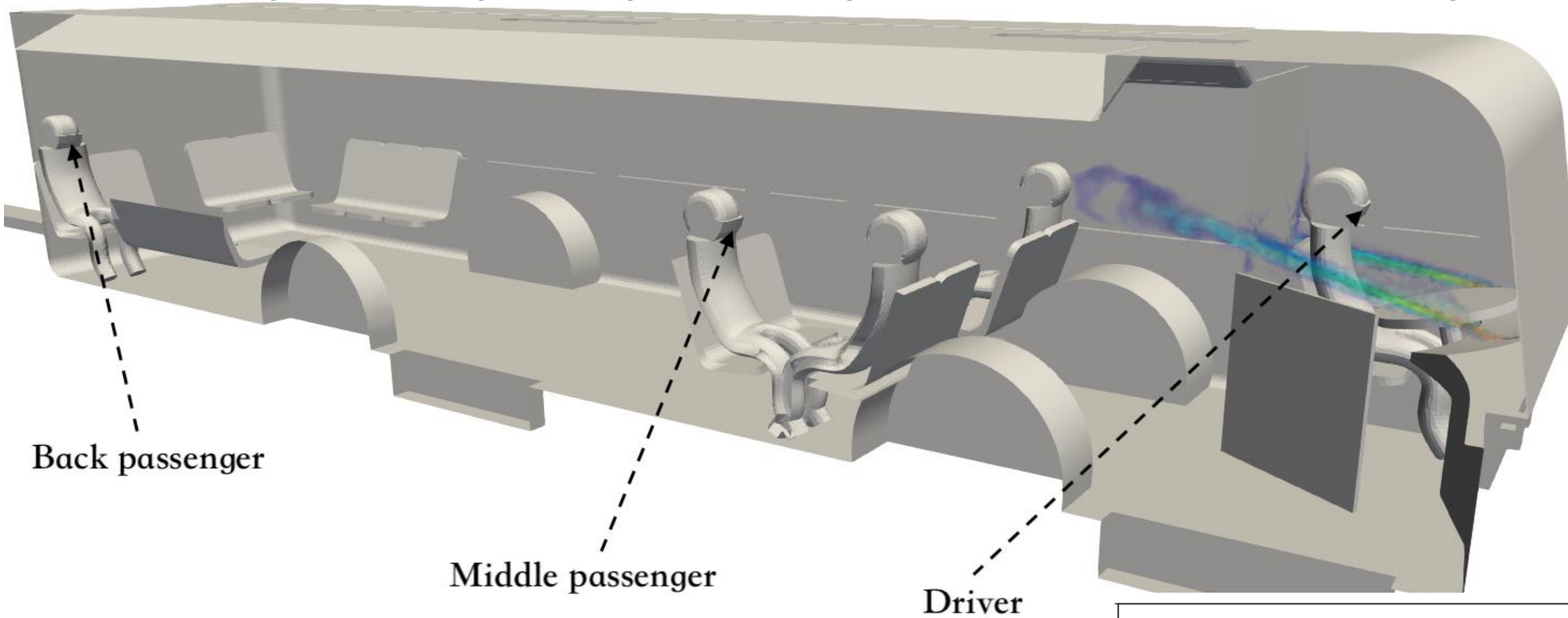
➔ impact on respiratory droplet dispersion

Operating Point 1



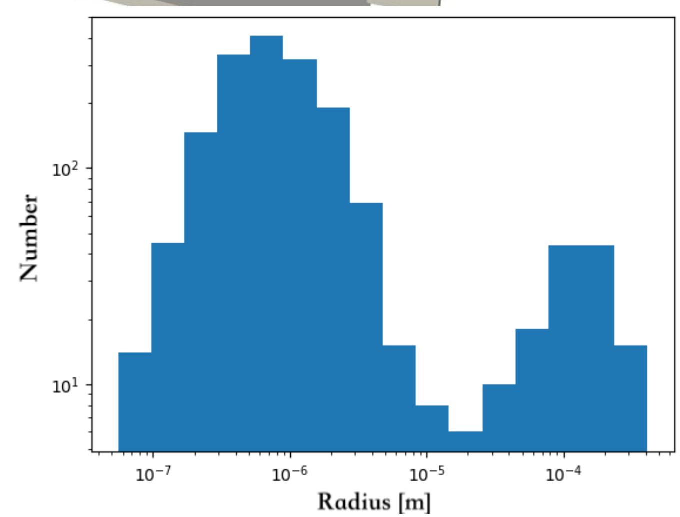
Operating Point 2

Three respiratory droplet dispersion simulations per OP



Two mean LES fields

➔ 6 droplet dispersion computations



Respiratory droplet distribution
(de Oliveira et al. 2020)

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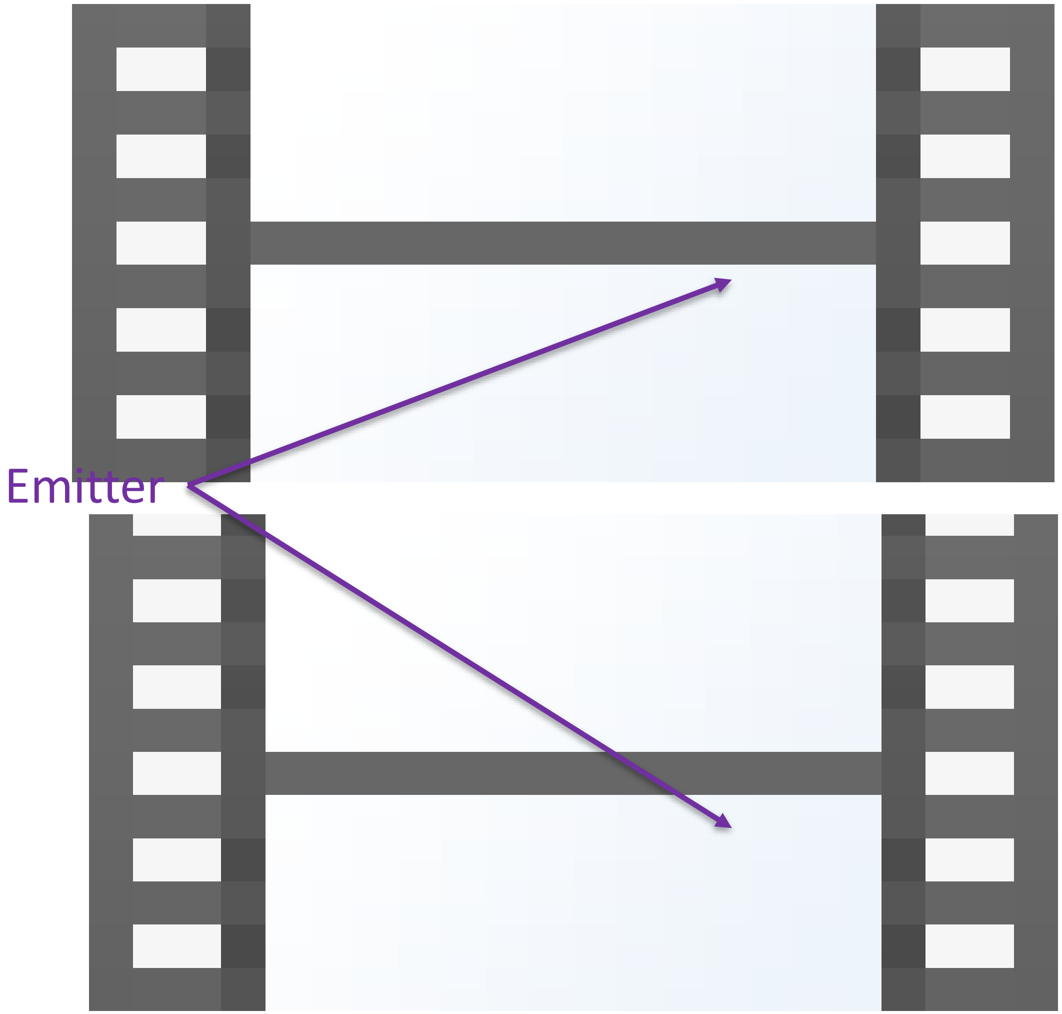
After One hour respiratory droplet dispersion simulation

Operating Point 1

Droplets colored by diameter
Small Big



Operating Point 2

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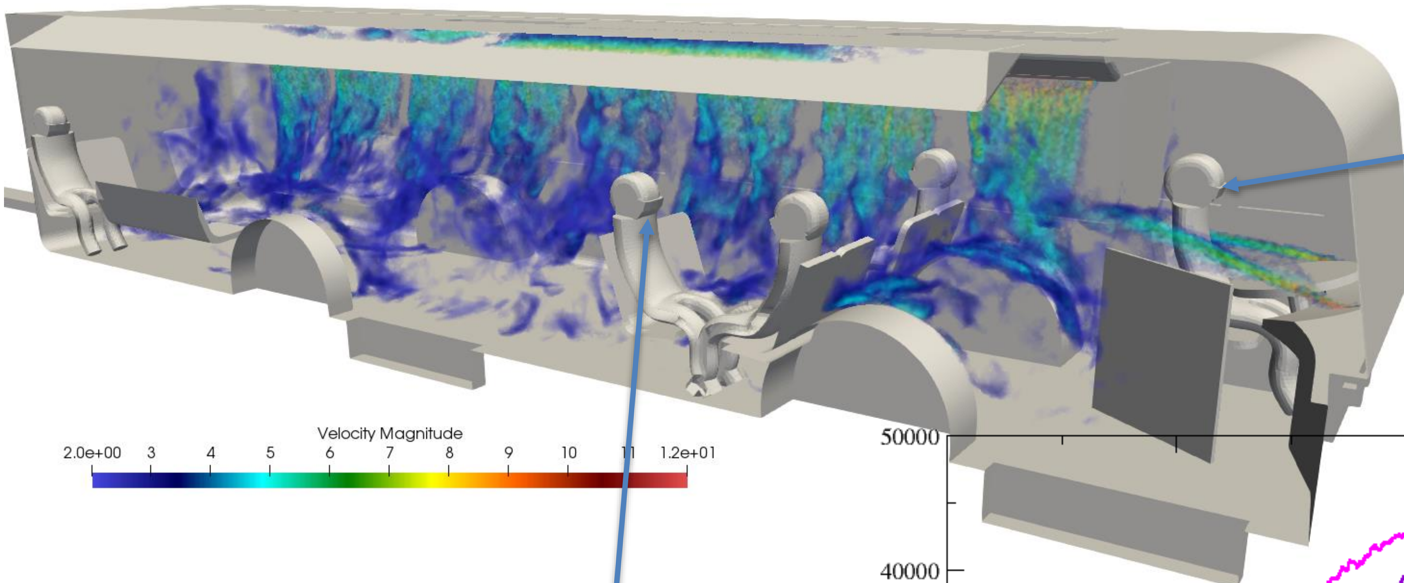
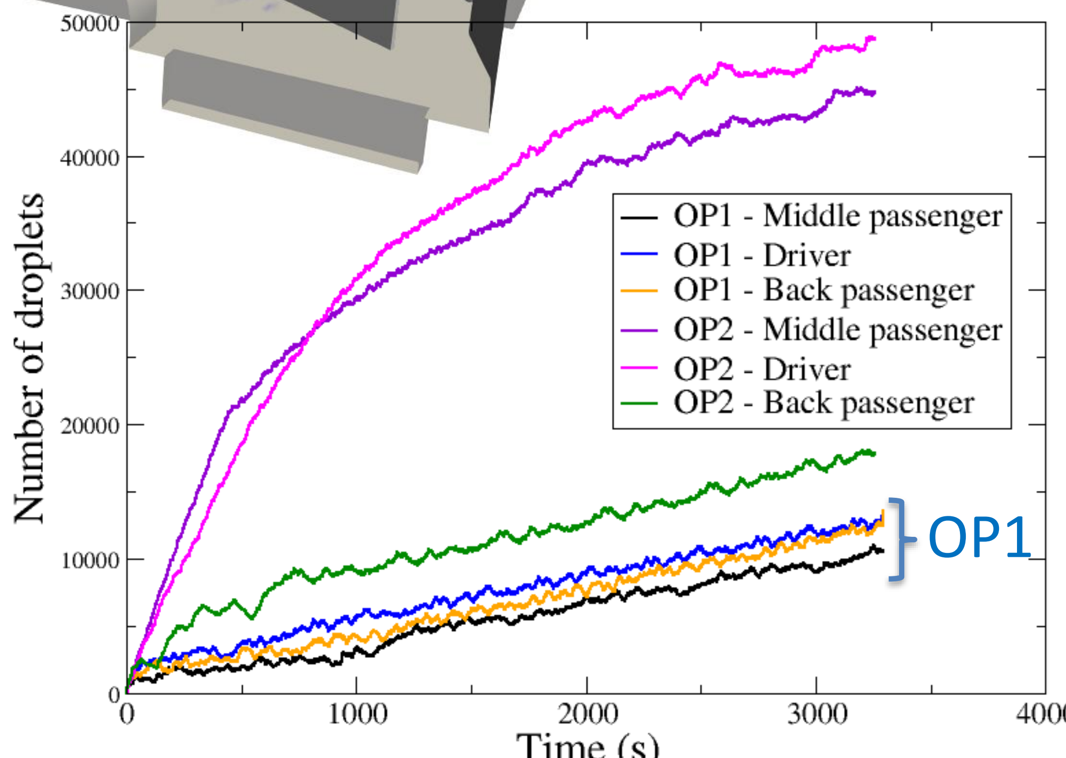
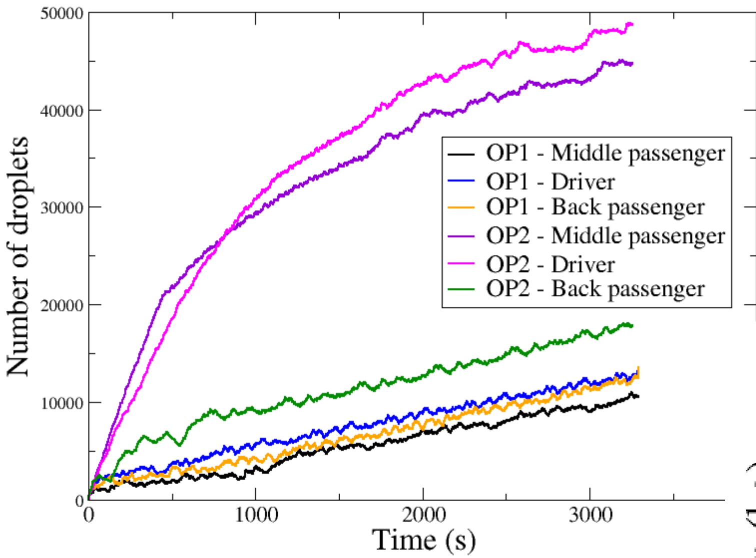


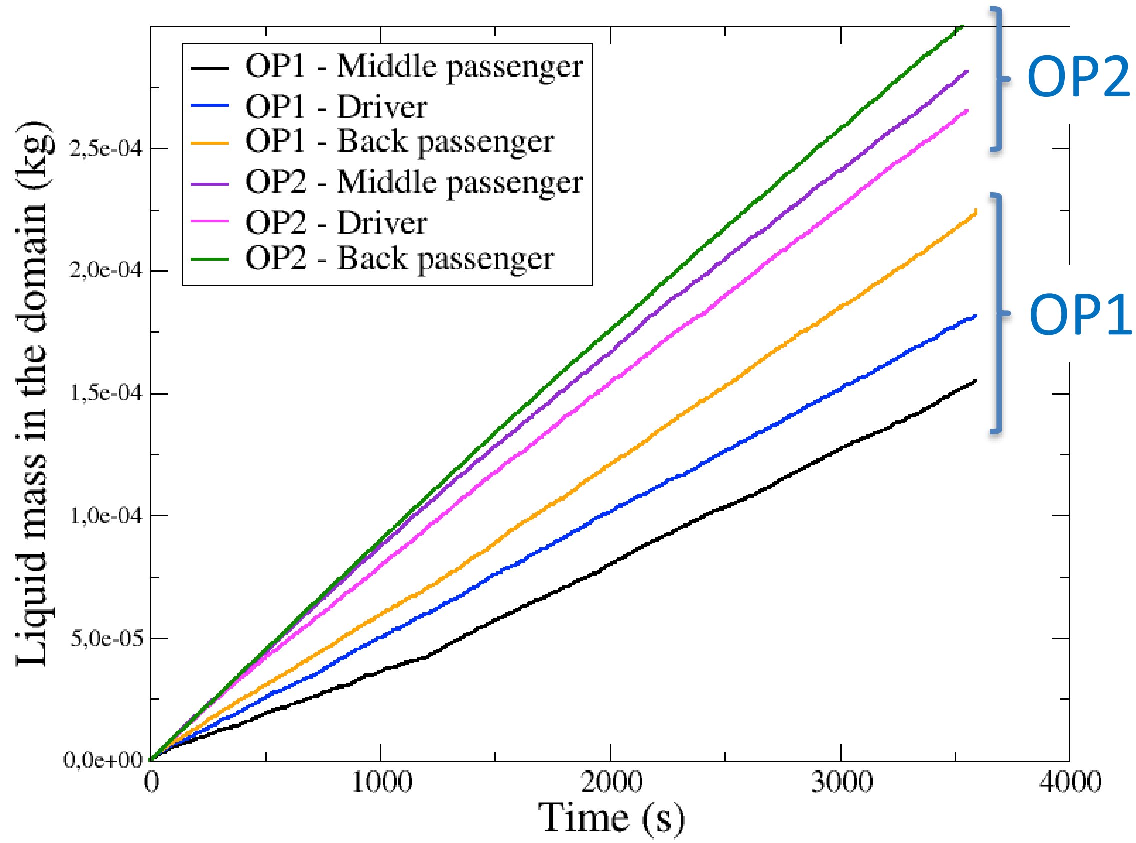


- ➔ No equilibrium after one hour
- ➔ Important droplet accumulation in OP2

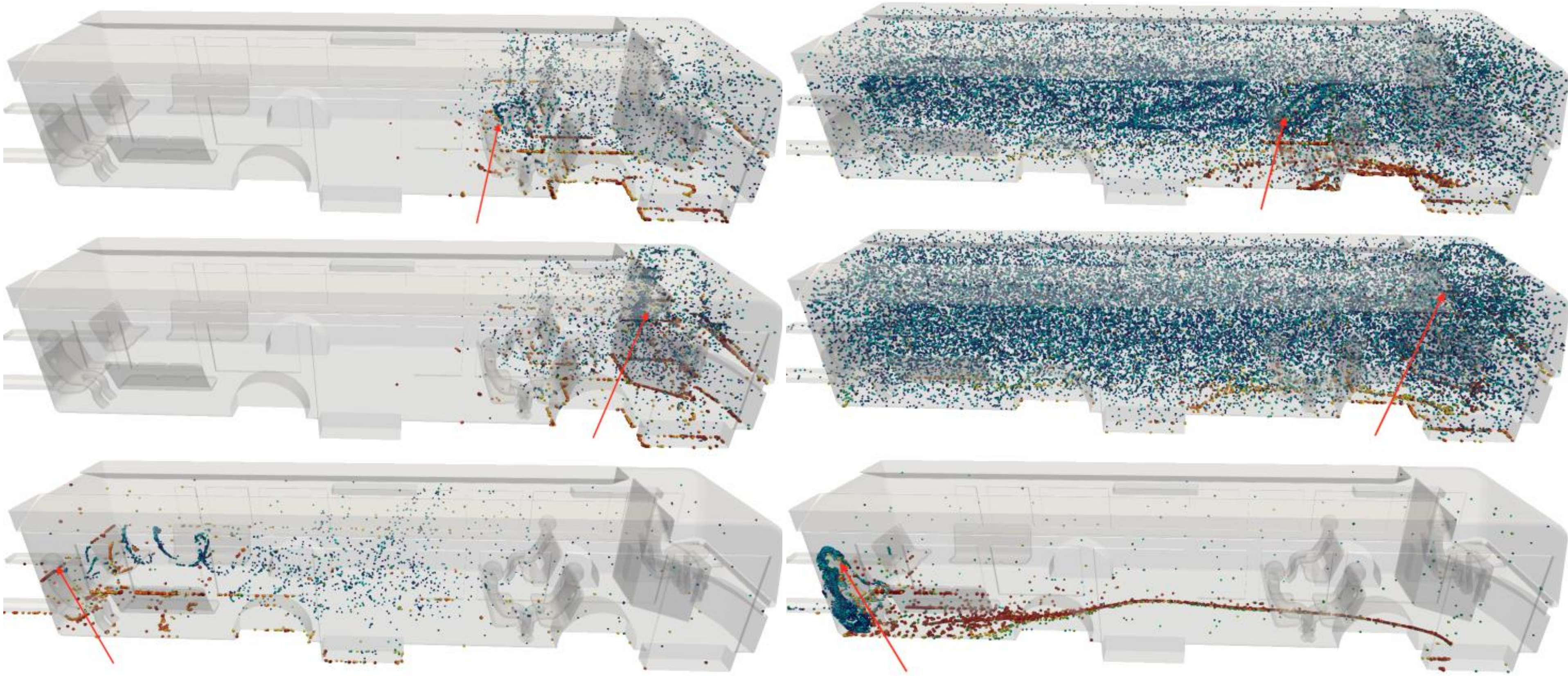
Applications – Bus – Droplet dispersion



Small droplet (aerosols) are preferentially evacuated

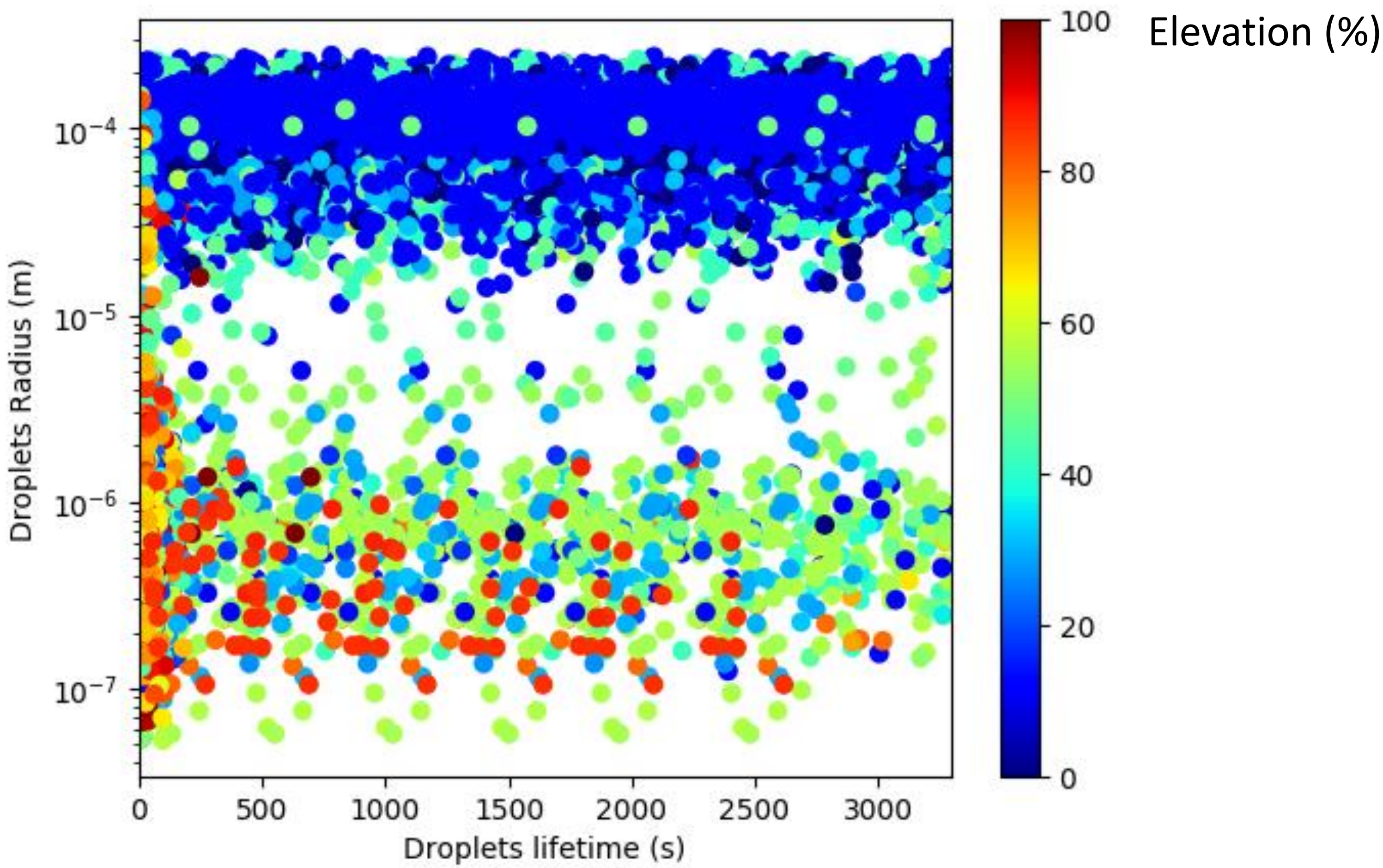


Operating Point 1	Operating Point 2
➔ AC on	➔ AC off

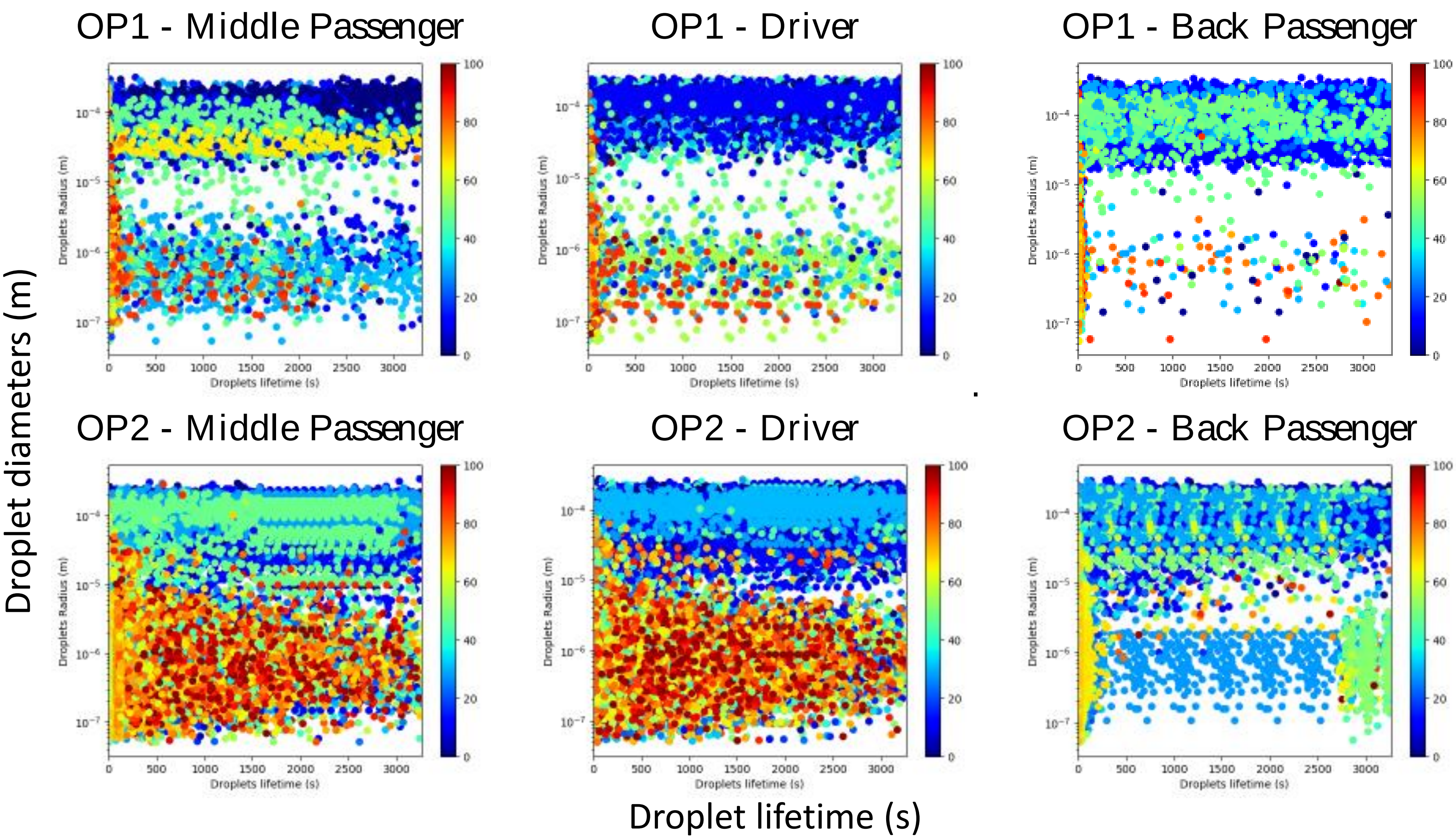


AC allows to evacuate small droplets and avoid dispersion in all the bus

Scatter plot of droplet lifetime VS radius colored by elevation in the bus (%) at the end of the simulations



Applications – Bus – Droplet dispersion



AC allows to evacuate small droplets and avoid dispersion in all the bus

Take home messages

- **High-fidelity** Computational Fluid Dynamics is able to discriminate **flow behavior** in different scenarios and thus **turbulent droplet dispersion** and help to design systems to provide **safer environments**

Case	Mesh Size	Physical time (s)	CPU hours	Droplet time (s)	CPU hours	Acceleration
Bus	40 M	130 →	500 000	3600	2 000	7 500

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Need to continue to work on

- Turbulent droplet dispersion model
- Biology aspects: virus loading and lifetime
- mitigation solutions modeling

Thank you for your attention

How important has HPC been for COVID research?

- CPU hours provided by PRACE and GENCI helped us to rapidly compute flow fields in many configuration and adjust some numerical models

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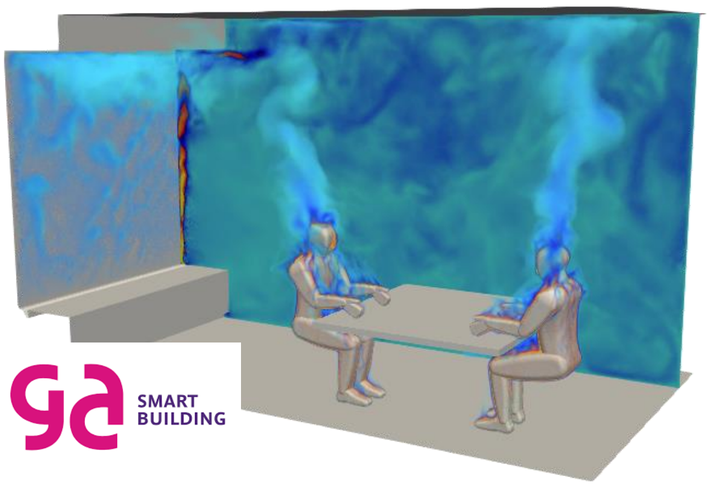
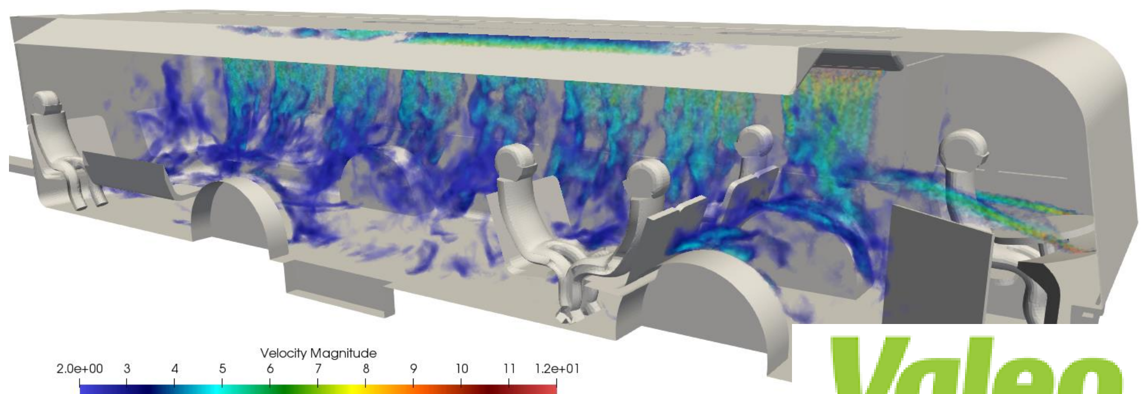


ga SMART BUILDING



Valeo

florent.duchaine@cerfacs.fr
http://www.cerfacs.fr/~duchaine