Clean and comfortable environment for occupants in offices

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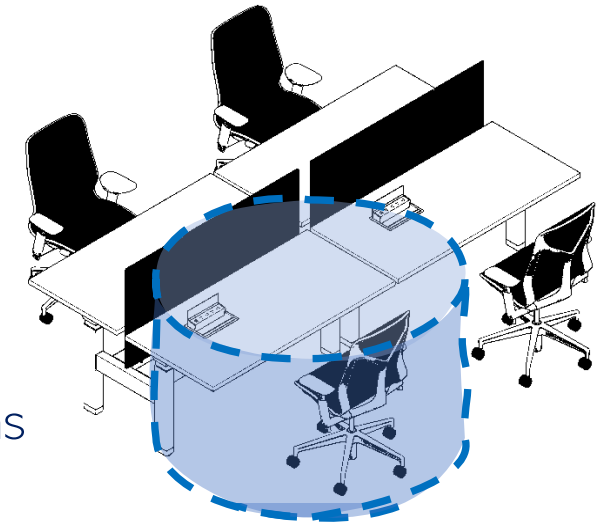
Panu Mustakallio
Product Manager, Halton Oy
Professor of Practice, Aalto University

Aku Karvinen
Senior Scientist, VTT

Indoor climate in office environment



- Indoor climate design for office environment currently based on
  - Indoor climate classifications based on European standards
  - Demands for zero emissions and ensuring of good indoor climate conditions
  - Almost fully on total volume mixing ventilation air distribution
  - Varying utilization of room air purification or advanced ventilation solutions
- Potential of Controlled micro-environment or occupant-targeted solution in offices
  - High indoor air quality or cleaner air zone for occupant (healthy/cross-infection risk reduced) energy efficiently
  - Individually adjustable indoor climate zone for occupant (high comfort/productivity)
- Studied earlier extensively with several published results
  - Still limited practical applications in real offices
  - Post-Covid time with demand for enhanced IAQ and for high energy efficiency increases the need for micro-environment solutions significantly

E3 Micro-environment use case targets

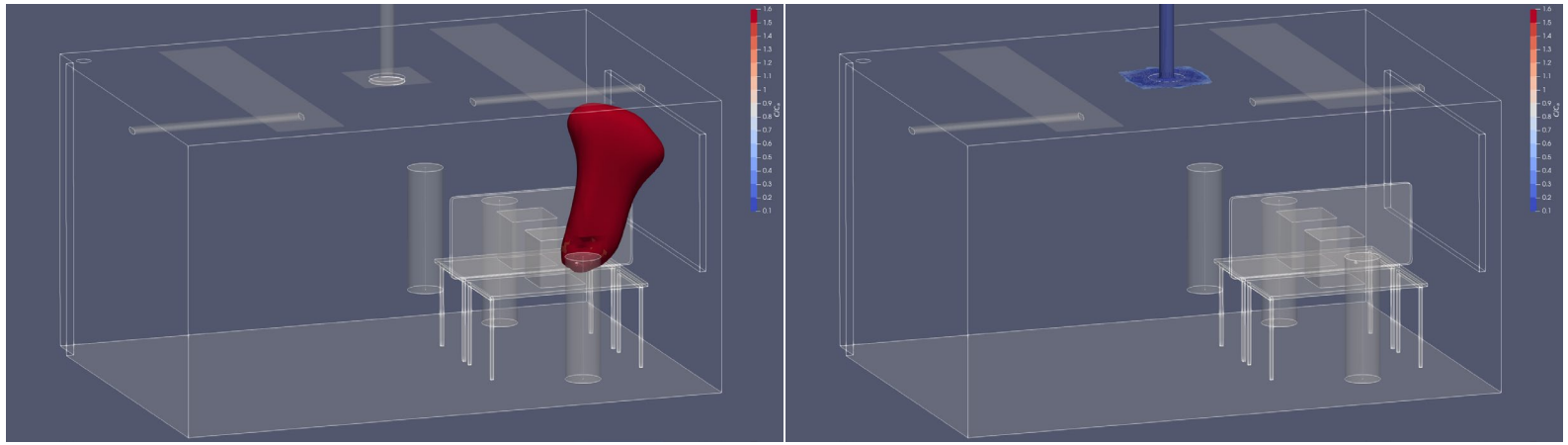
- E3 use case focused on studying promising micro-environment solutions in realistic conditions starting from
  - Typical mixing and displacement ventilation solutions in office room
    - ➢ Performance of air distribution methods and effect of ventilation airflow rate
  - Ventilation supply or exhaust located near occupants
    - ➢ Performance of specific occupant-targeted ventilation air distribution methods
  - Multiple cases with room air purifier locations and models with ventilation
    - ➢ Performance of room air purifiers in the room and near occupants with different clean air delivery rates
- Target to
  - ➢ Reveal potential of typical and advanced ventilation and air purification design options for offices
  - ➢ Add knowledge how clean and comfortable indoor environment can be designed for offices
  - ➢ Study technologies from industrial partners in E3 project to add business potential

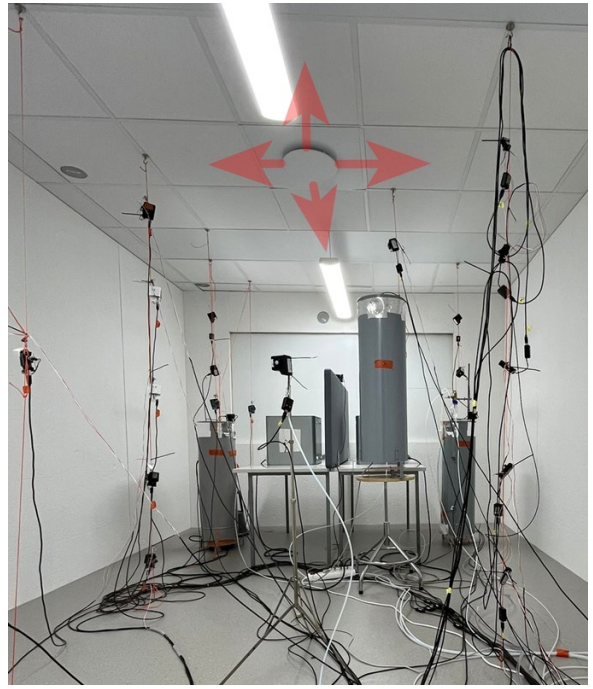
Methods

- Experiments at VTT chamber 'test office room'
  - to test and compare different ventilation and air purifying techniques and strategies, and
  - to provide reproduceable measurements in a controlled environment for CFD-model development and validation
- CFD simulations
  - to allow detailed studying of situations beyond experiments
  - to clearly show performance in addition to measurement results in specific locations

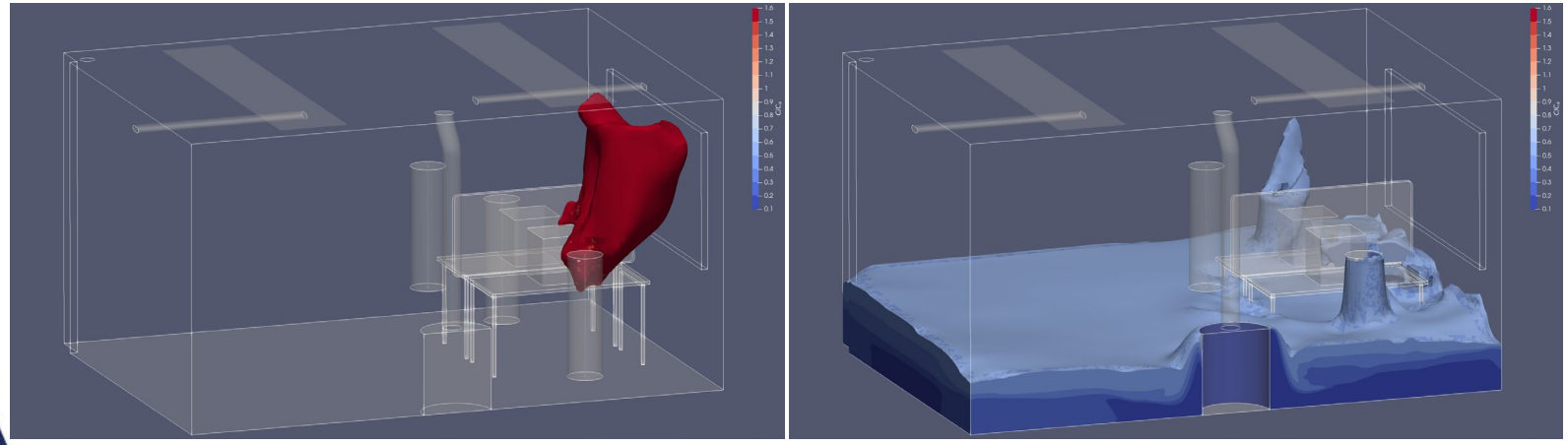
Base cases without air purifiers

- Mixing type ventilation at air flow rates 21 l/s (1.3 l/s/m^2) and 36 l/s (2.2 l/s/m^2)





- Displacement type ventilation at air flow rate 36 l/s (2.2 l/s/m^2)

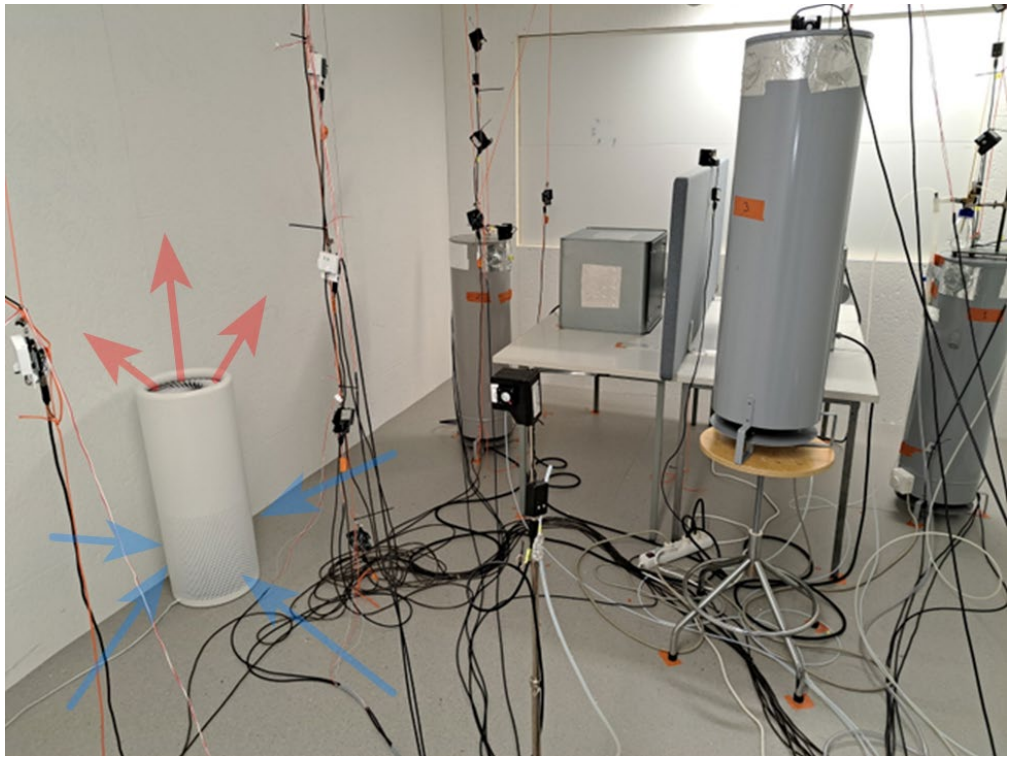


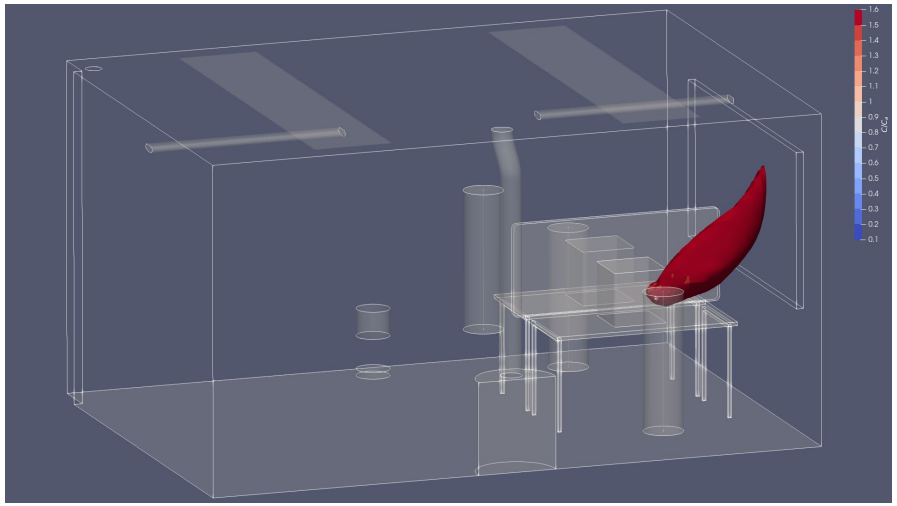
CFD simulation 36 l/s areas with >1.5 and <0.5 (fully mixed 1.0)

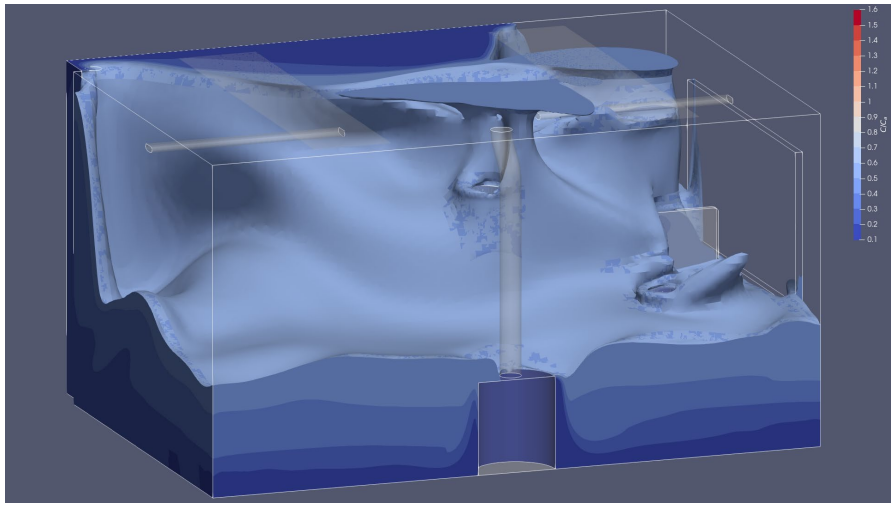
Displacement ventilation with floor room air purifier

- Air purifier on the floor combined either with displacement or mixing ventilation at 36 dm³/s
- Purifier clean air delivery rate CADR 62 dm³/s in all of the runs
- Power consumption 10 W
- Code ‘PF’

CFD simulation 36 l/s areas with >1.5 and <0.5 (fully mixed 1.0), normalized to ventilation airflow

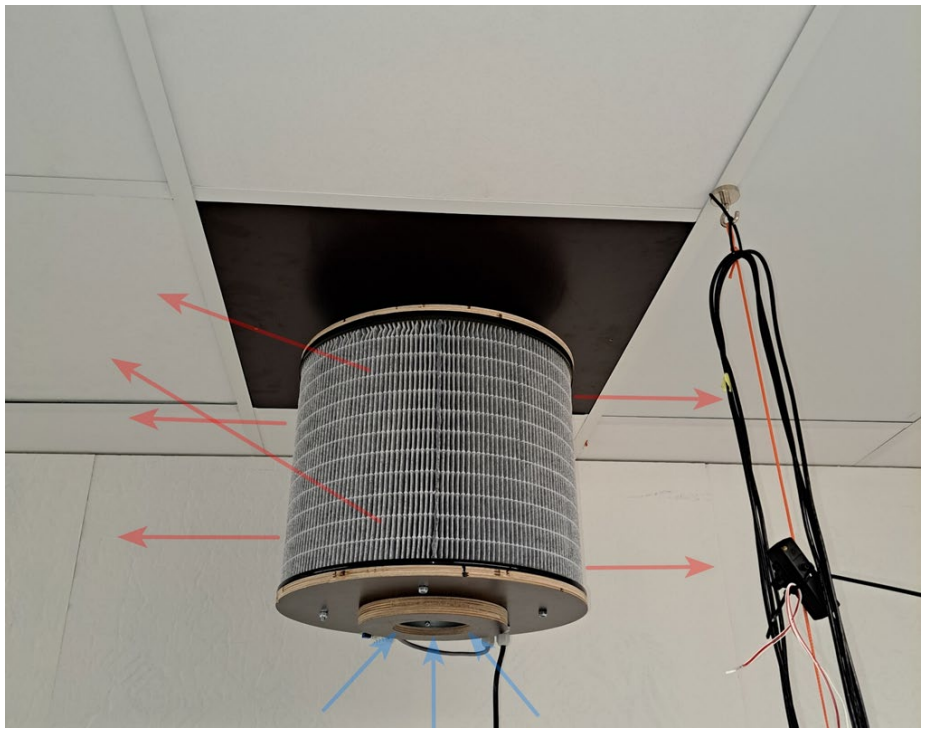




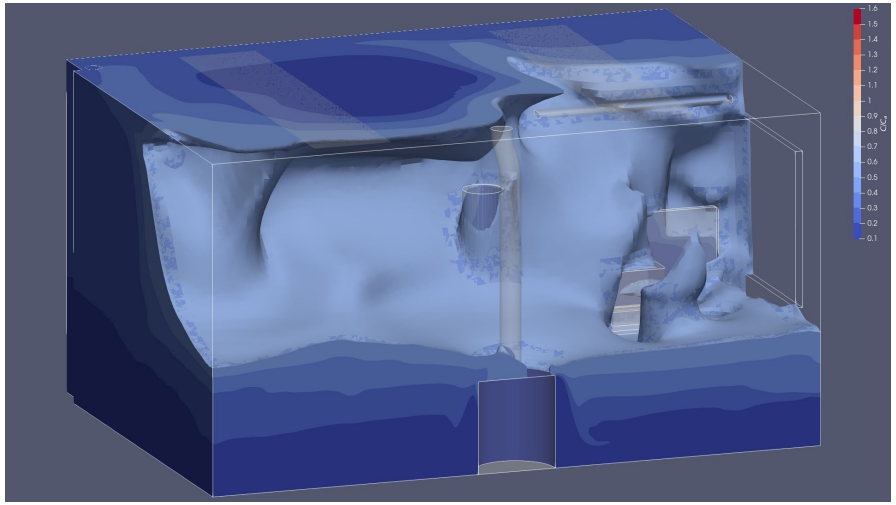


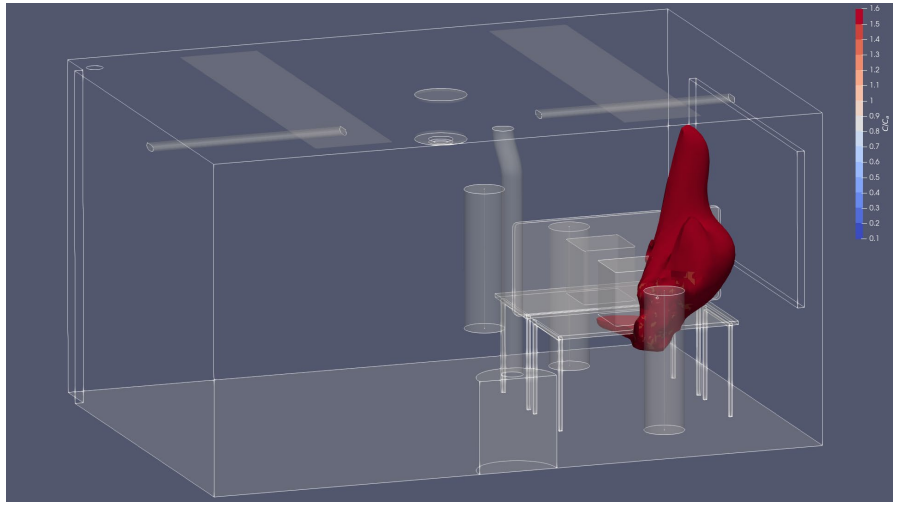
Displacement ventilation with ceiling room air purifier

- Ceiling mounted air purifier combined with displacement ventilation at 36 dm^3/s
- Purifier CADR 62 l/s
- Code ‘PC’



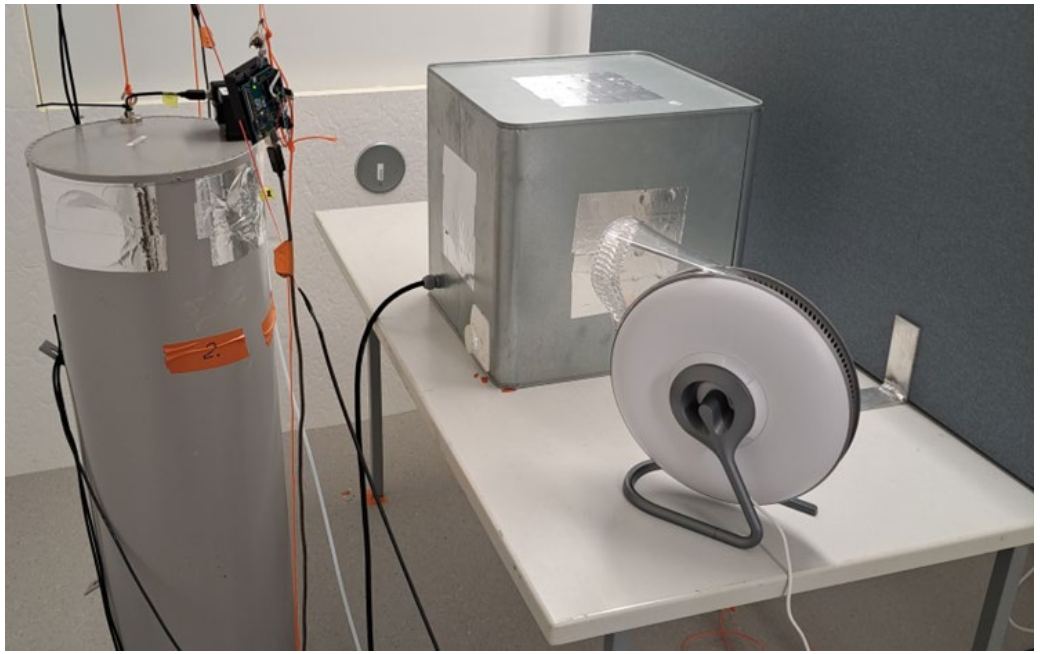
CFD simulation 36 l/s areas with >1.5 and <0.5 (fully mixed 1.0), normalized to ventilation airflow



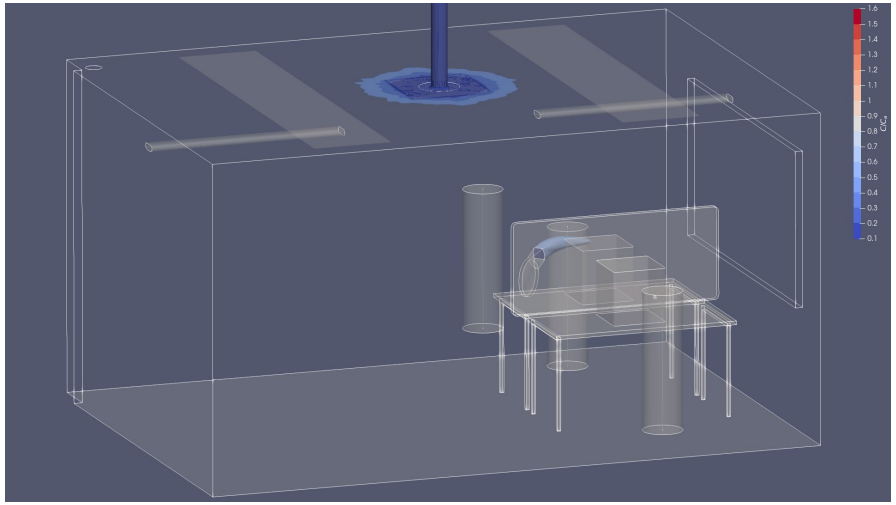


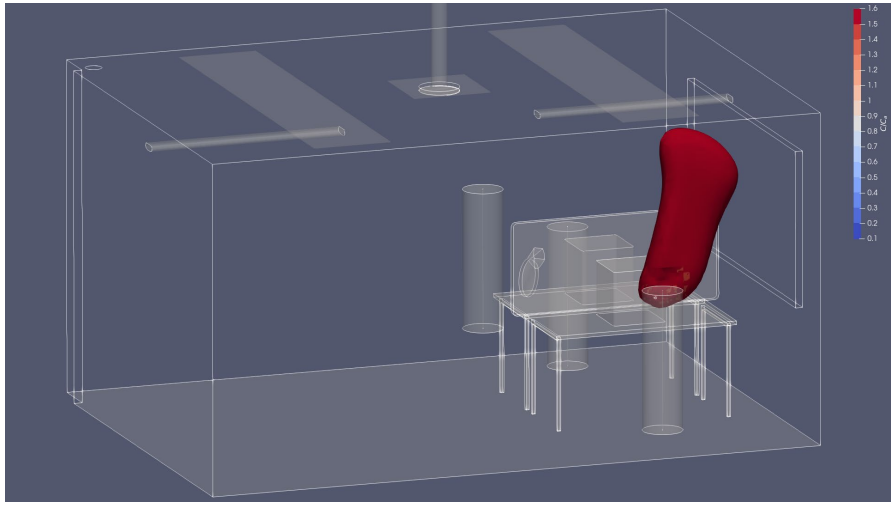
Mixing ventilation with personal air purifier on desk

- Personal air purifier on desk no. 2 combined with mixing ventilation at 36 dm^3/s
- Purifier CADR 4 at 2/3 setting and 2 dm^3/s at 1/3 setting
- Code ‘PD4’
  or ‘PD2’



CFD simulation 36 l/s areas with >1.5 and <0.5 (fully mixed 1.0), normalized to ventilation airflow

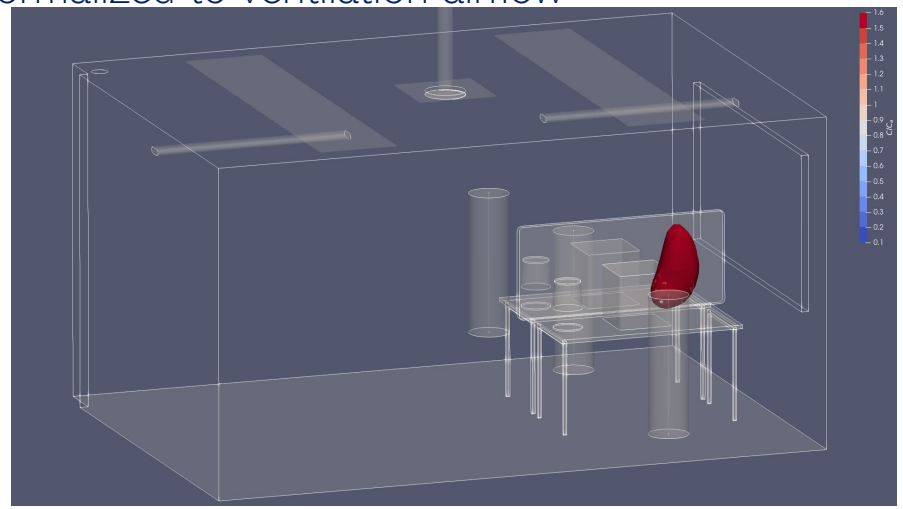


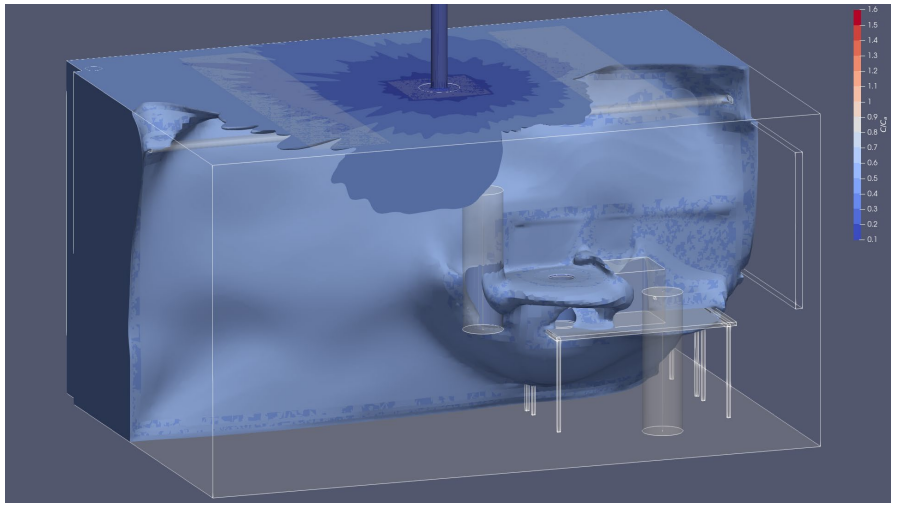


Mixing ventilation with personal air purifier on desks

- Personal air purifiers on both desks or one desk, combined with mixing ventilation at 36 dm³/s
- Purifier CADR 28 or 22 dm³/s for one unit (56 or 44 dm³/s for two)
- Codes ‘2PD56’, ‘2PD44’, ‘PD28’, ‘PD22’
- Measured with and without ”caps” on outlet. Attached picture shows purifiers on both desks without caps.

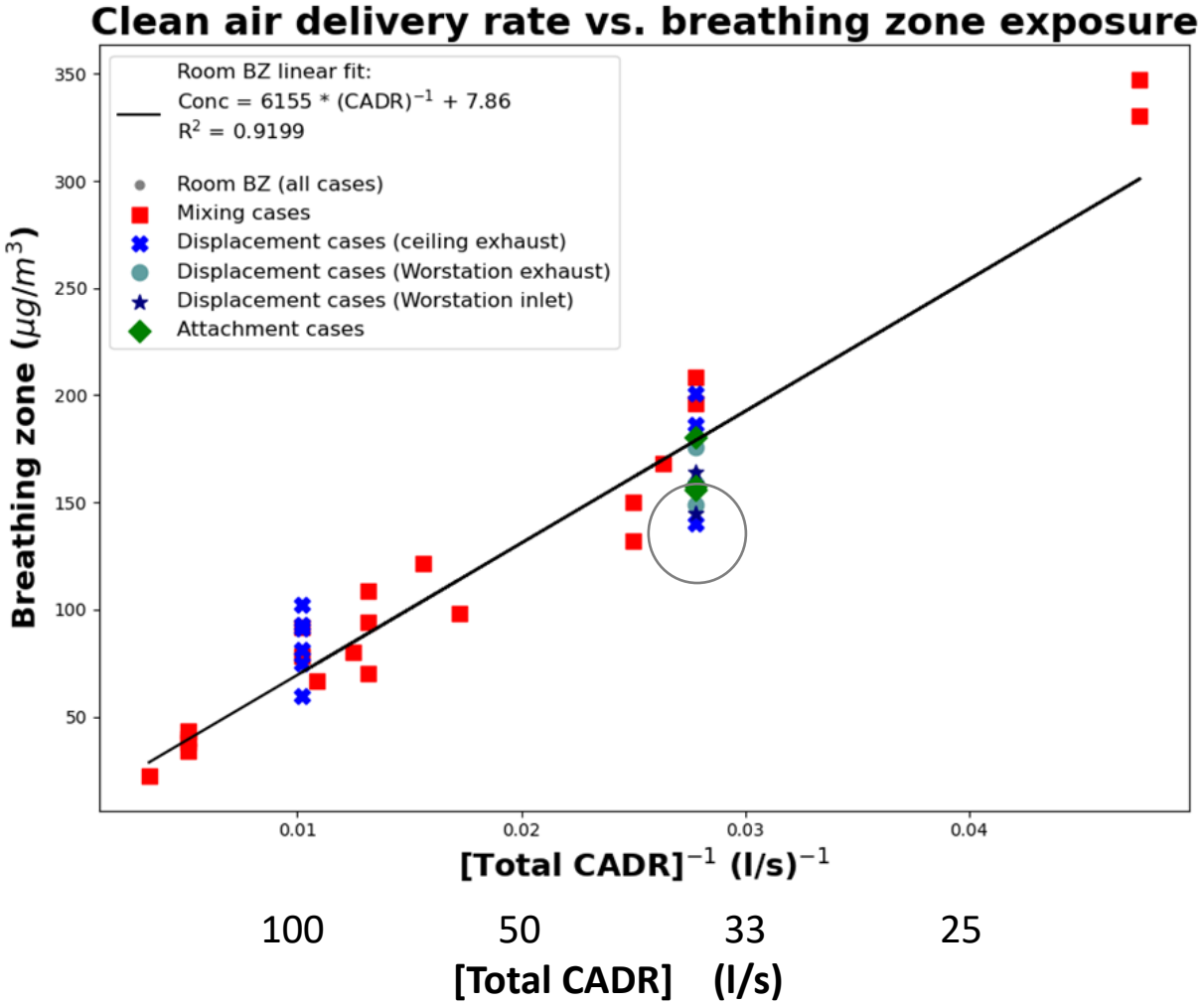
CFD simulation 36 l/s 2PD44 areas with >1.5 and <0.5 (fully mixed 1.0), normalized to ventilation airflow





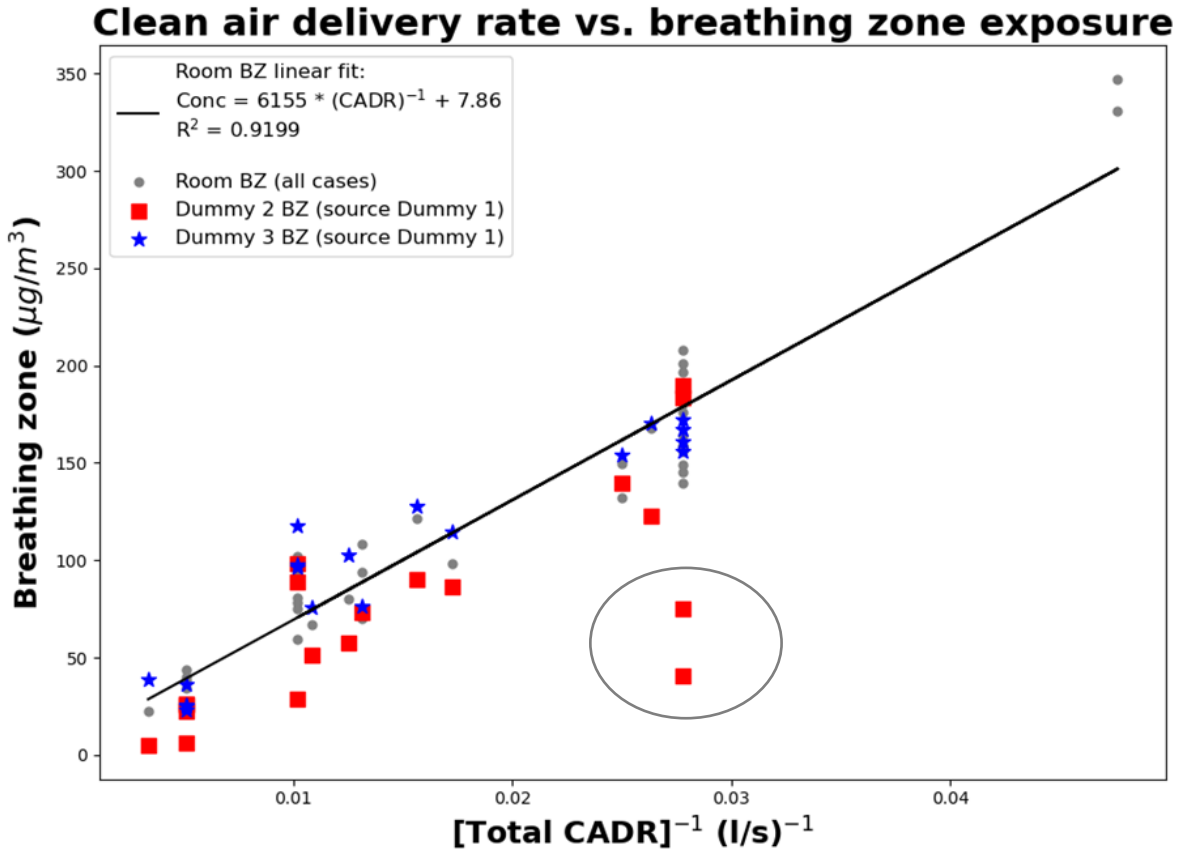
Results: Impact of CADR (ventilation+purification)

- Reduction of exposure at room breathing zone is roughly linear with inverse of clean air delivery rate (CADR), in line with theoretical expectation. The higher CADR, the higher the reduction.



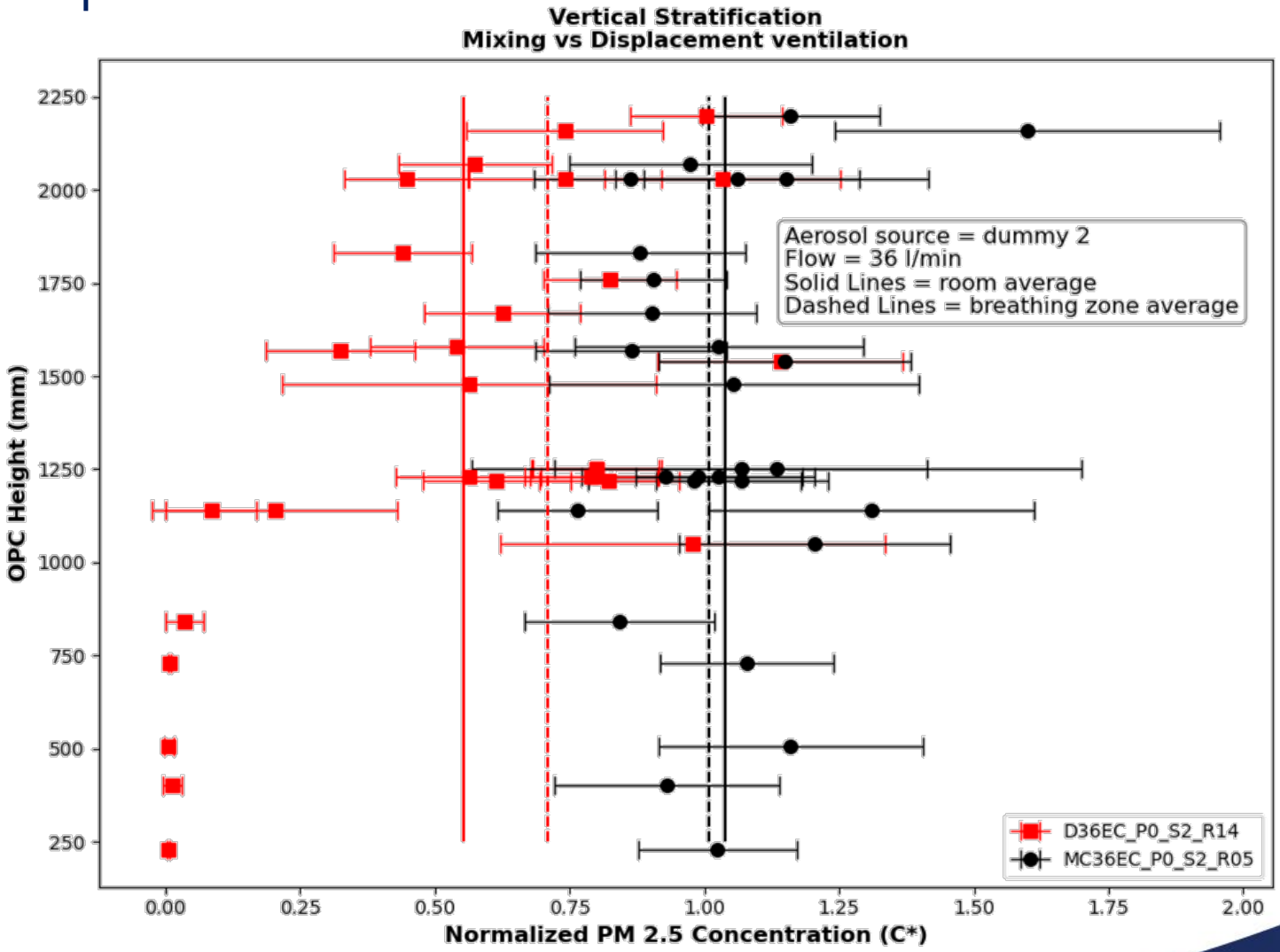
Results: Impact of CADR (ventilation+purification)

- Reduction of exposure at personal breathing zone of standing dummy 3 is in line with the theoretical 'CADR expectation' for room breathing zone, but
- Reduction of exposure at the sitting dummy 2 exceeds the theoretical room breathing zone expectation showing the impact of micro-environment
  - The circled two squares with low exposure are due to stratification in the case of displacement ventilation without purifiers. A good local micro-environment was created with this location of infected occupant and supply air diffuser.



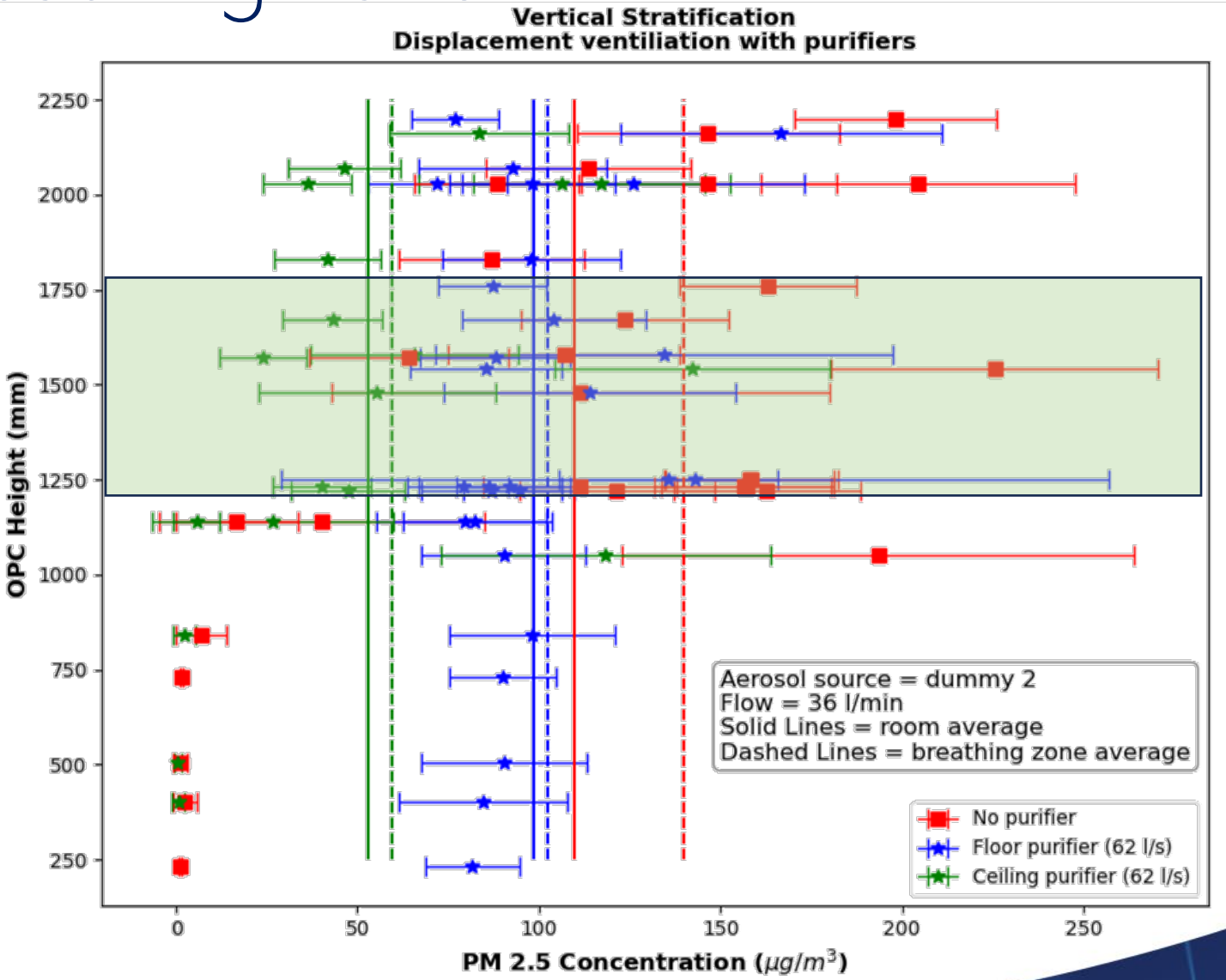
Results: Mixing vs. displacement ventilation

- Base cases without air purification
- **Finding:** Displacement ventilation leads to clear vertical stratification of aerosol load within room, clean air at the bottom of room
- Breathing zone at z = ~120 – 180 cm
- Breathing zone exposure with displacement is 29% lower than with mixing ventilation
- $C^* = \frac{c}{c_{exhaust}}$



Results: Focus to breathing zone

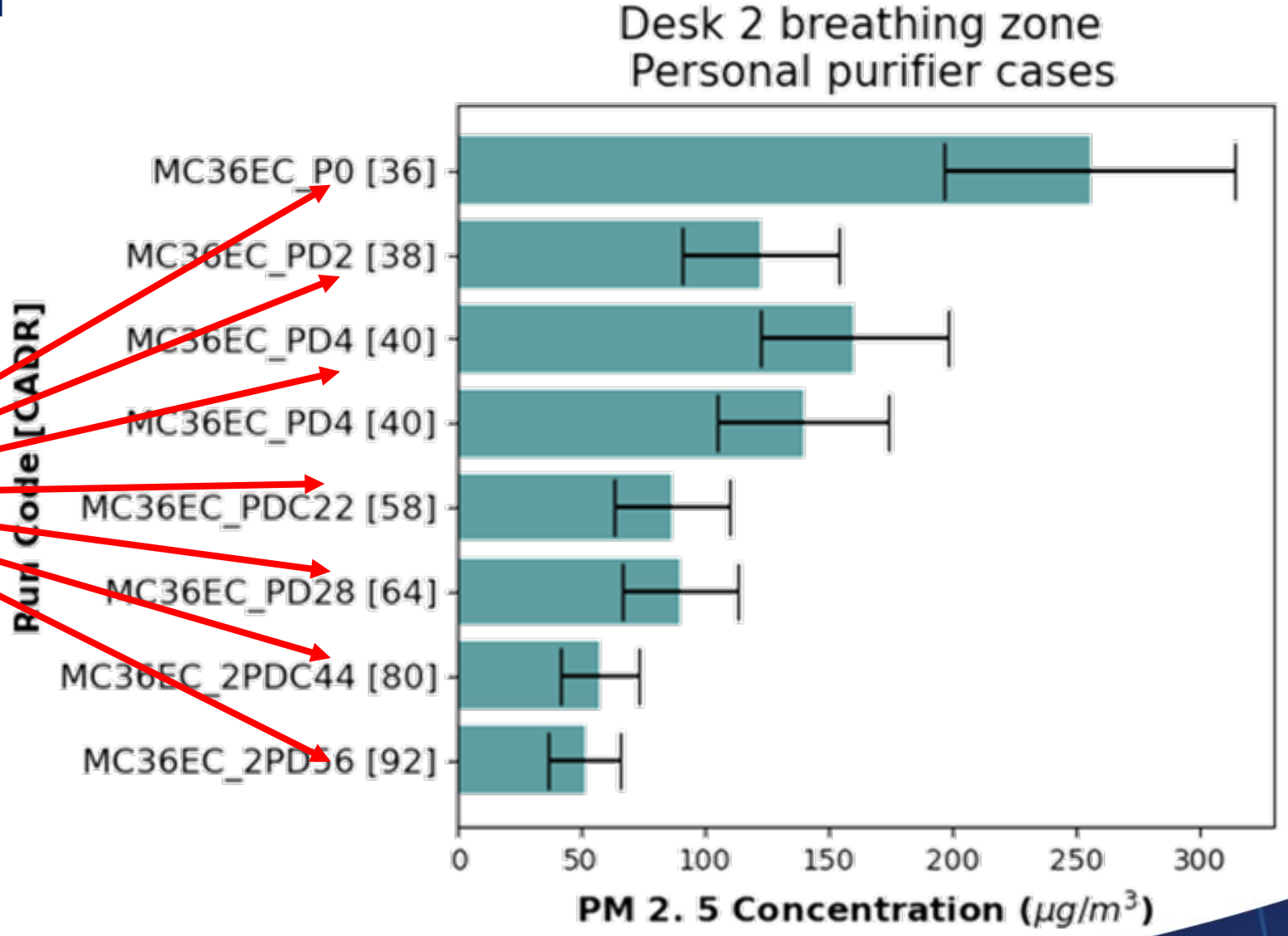
- Focus on the area that matters for personal exposure (micro-environment):
- Breathing zone measurement
  - z = ~120 – 180 cm, average over entire room
  - OPCs set up at dummy locations
- Breathing zone exposure reduction in displacement ventilation cases:
  - Floor purifier: 26%
  - Ceiling purifier: 57%



Results: Personal purifier cases

Key findings

- Desktop purifiers clearly reduce exposure at desk position (personal breathing zone of dummy 2), arranged according to purifier CADR.
- Already with very small CADR, exposure can be lowered if clean air reaches breathing zone



Conclusions

1. Clean and comfortable environment for occupants in offices is achievable both by general ventilation, advanced controlled micro-environment ventilation or room air purification solutions.
2. Locations of supply air diffusers, exhaust air devices and room air purifiers are important and should be selected carefully.
3. According to the findings from E3 UC2 research revealing different factors affecting to the occupant breathing zone, indoor climate design with advanced tools like CFD simulation or full-scale testing is recommended when designing advanced solutions.

Conclusions

4. Ventilation and every room air purifier type essentially reduce aerosol exposure at the breathing zone
5. Reduction of exposure is roughly linear with inverse of clean air delivery rate, in line with theoretical expectation. The higher the clean air delivery rate, the higher the reduction.
6. Displacement ventilation lowered exposure compared to mixing ventilation cases also without an additional air purifier
7. Advanced air distribution and purification methods focusing to personal breathing reduces aerosol exposures at the personal breathing zone more than at room breathing zone, thus creating controlled micro-environment

Thank You!

Questions?

E3 UC2 Team

- Lead & analysis: Jaakko Paasi (VTT), Panu Mustakallio (Halton)
- VTT's experimental team: Jani Hakala, Mikko Kultanen, Arto Säämänen
- VTT's CFD simulation team: Aku Karvinen
- FMI's analysis team: Michael Todt, Mikko Auvinen, Eija Asmi

Air purification device providers:

- Janette Mäkipää (Lifa-Air)
- Jani Moberg (Alme Solutions)
- Risto Salin (ISEC)