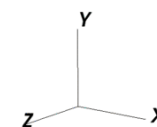
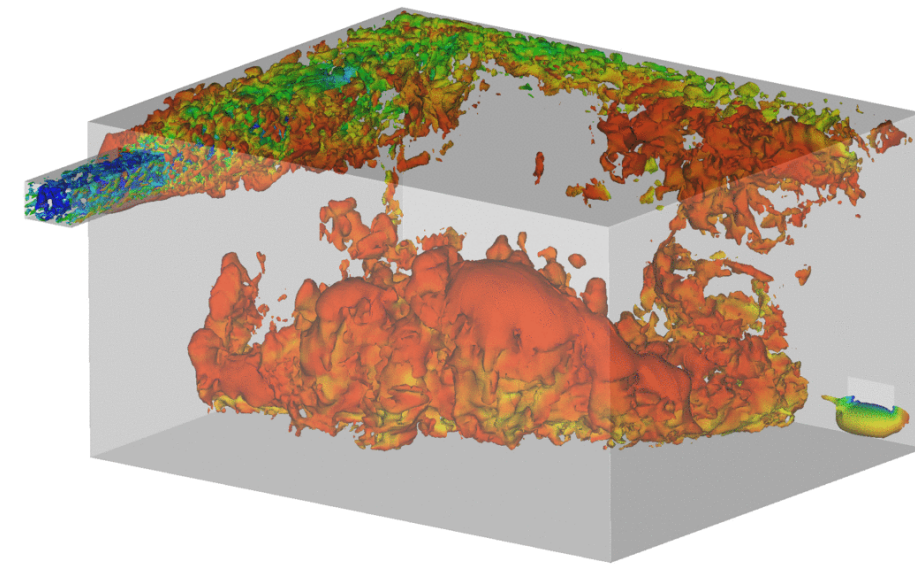


# Quantifying the Potential of Covid-19 Transmission Across Scales: Using SEM based Navier-Stokes solver to the CEAT

**Som Dutta**

Mechanical & Aerospace Engineering  
Utah State University

Alex Fabregat, Universitat Rovira i Virgili  
Jordi Pallares, Universitat Rovira i Virgili  
Ketan Mittal, LLNL  
K Rao, ANL  
Brian J. Schimmoller, Signature Sc. LLC  
Afshin Beheshti, NASA & Cov-IRT  
Nídia S. Trovão, NIH  
Paul Fischer, UIUC  
Neil Lindquist,  
Misun Min  
Ramesh Balakrishnan, ANL



# GOAL: Accurate Prediction of Virus Loading in Indoor Environments

- Currently it is motivated by COVID-19, but the methodology can be used for other respiratory viruses in the future
- Understand the process involved in virus-laden aerosol mixing and transport
- Predict the most probable regions of virus-laden aerosol accumulation and deposition, which will help us to plan

## Mitigation Strategies & Compute Risk of Transmission

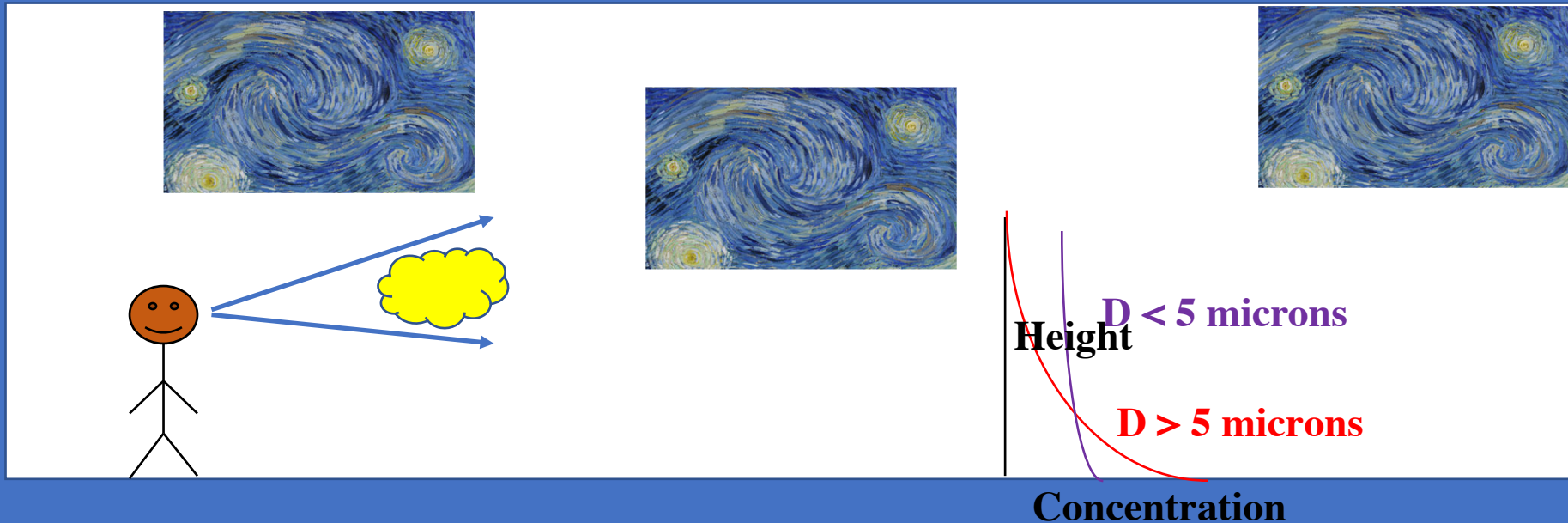
IPNAS

### Infectious virus in exhaled breath of symptomatic seasonal influenza cases from a college community

Jing Yan<sup>a,b</sup>, Michael Grantham<sup>a,1</sup>, Jovan Pantelic<sup>a,2</sup>, P. Jacob Bueno de Mesquita<sup>a</sup>, Barbara Albert<sup>a</sup>, Fengjie Liu<sup>a,3</sup>, Sheryl Ehrman<sup>b,4</sup>, Donald K. Milton<sup>a,5</sup>, and EMIT Consortium<sup>6</sup>

<sup>a</sup>Maryland Institute for Applied Environmental Health, School of Public Health, University of Maryland, College Park, MD 20742; and <sup>b</sup>Department of Chemical and Biomolecular Engineering, Clark School of Engineering, University of Maryland, College Park, MD 20742

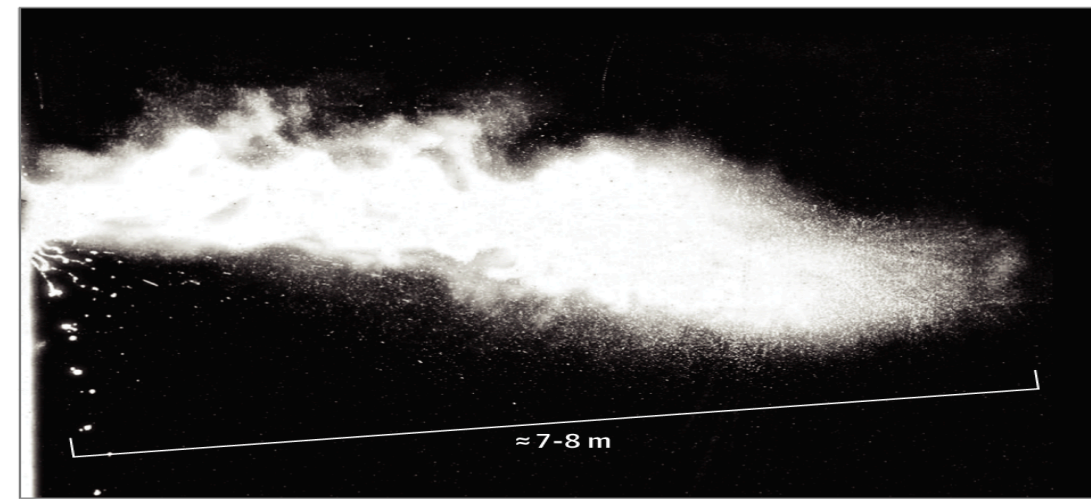
Edited by Peter Palese, Icahn School of Medicine at Mount Sinai, New York, NY, and approved December 15, 2017 (received for review September 15, 2017)





# Modes of Airborne Virus Spreading in the Indoor Environment

- Pre-pandemic, we thought the main mode of airborne transmission of viruses is through coughing and sneezing

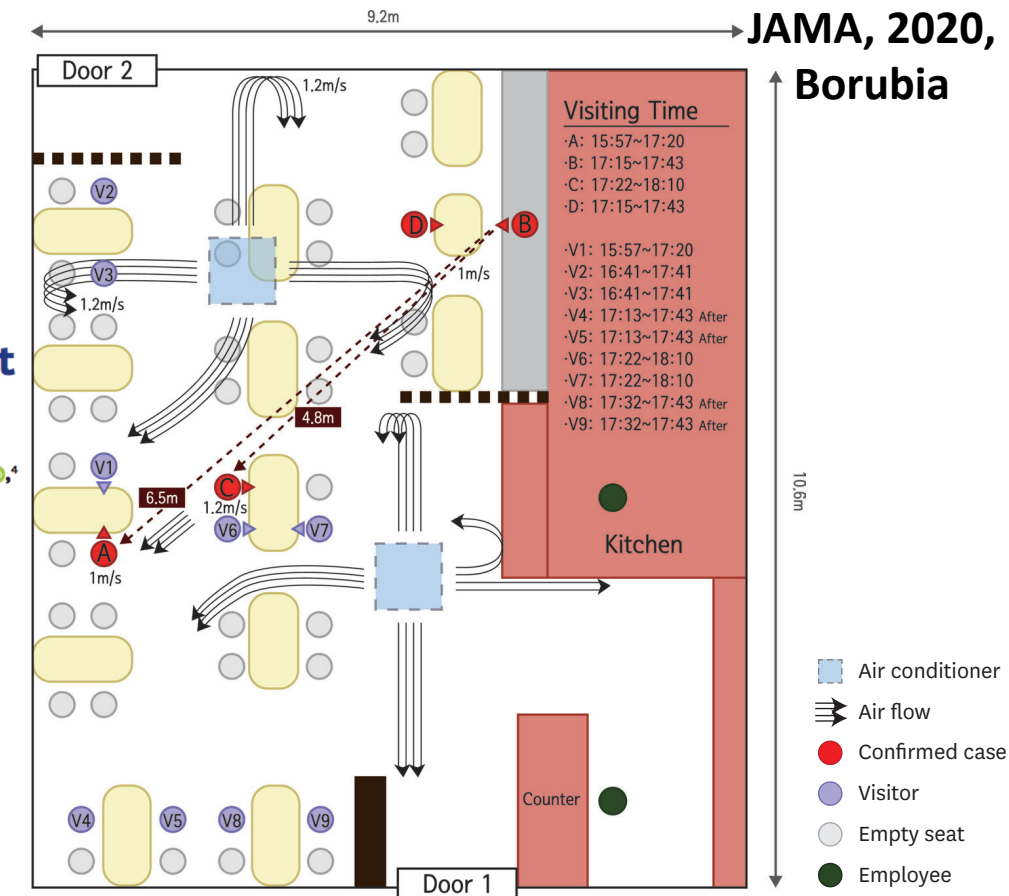


- “Asymptomatic” or “Pre-symptomatic” transmission of Covid-19 has made us question our existing understanding of airborne transmission, especially in the indoor environment

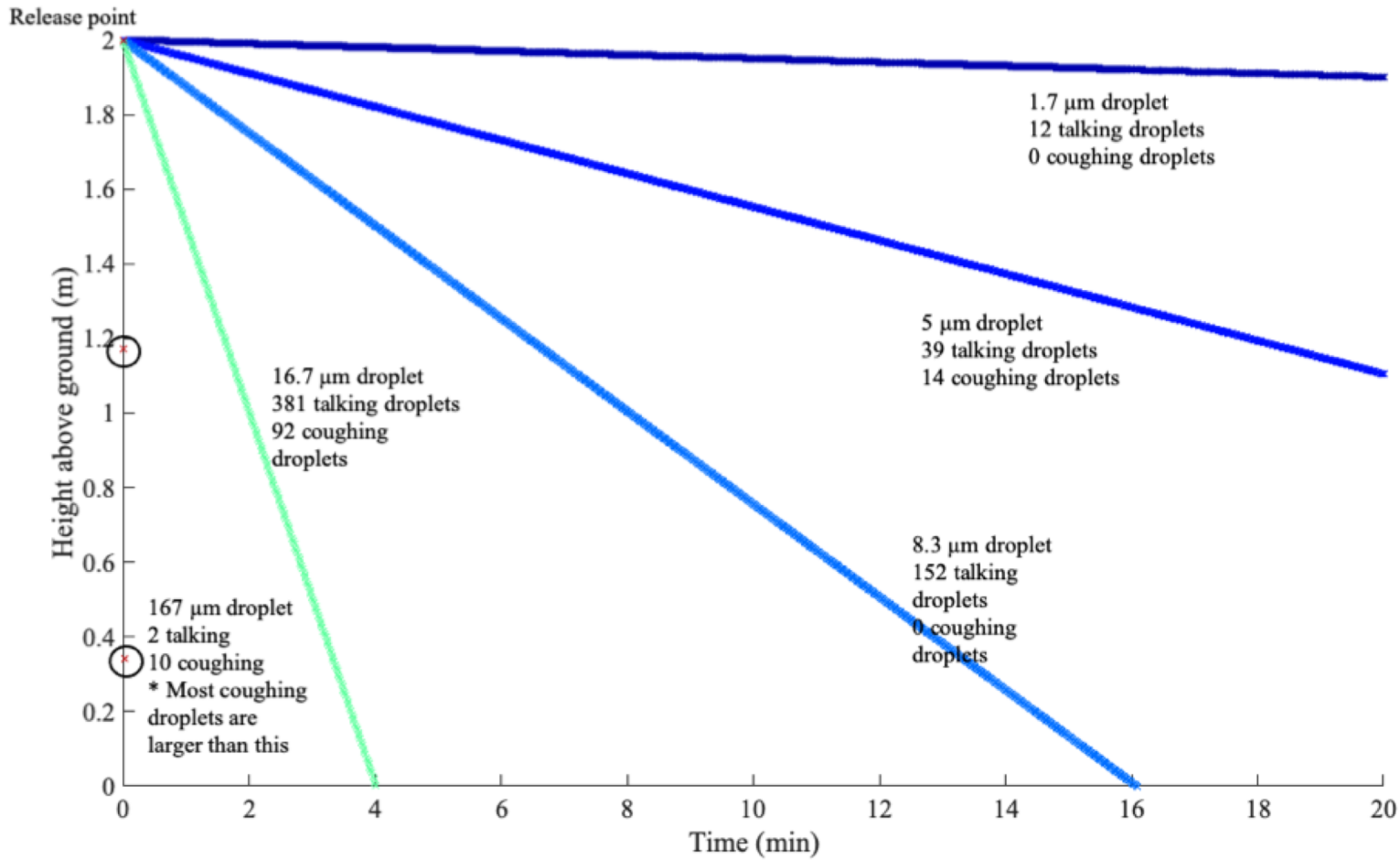
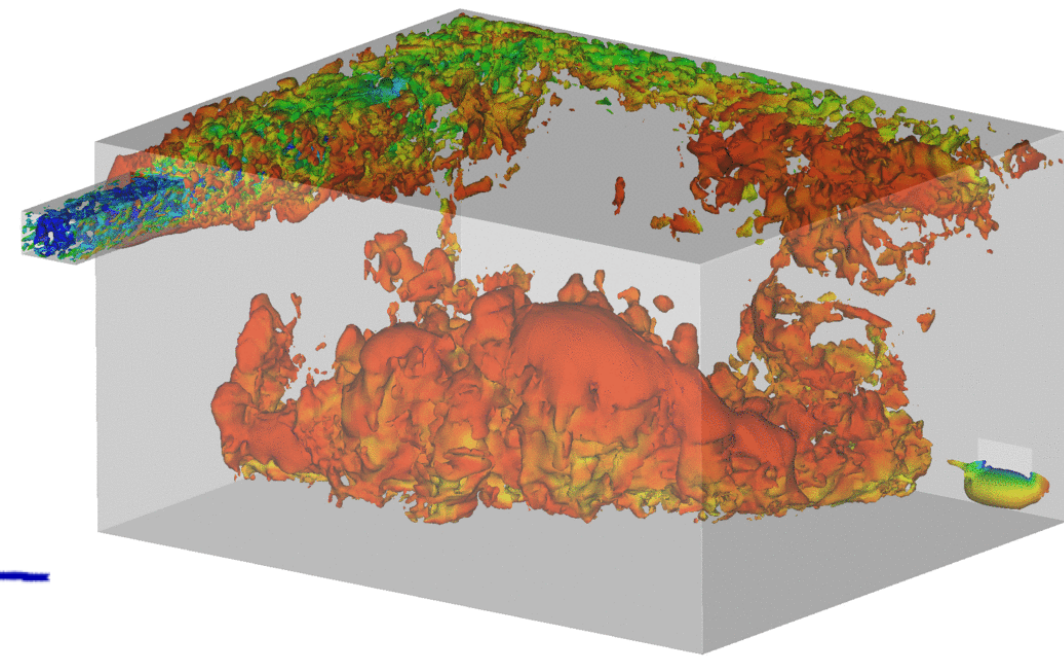
## Evidence of Long-Distance Droplet Transmission of SARS-CoV-2 by Direct Air Flow in a Restaurant in Korea

Keun-Sang Kwon <sup>1,2</sup>, Jung-Im Park <sup>2</sup>, Young Joon Park <sup>3</sup>, Don-Myung Jung <sup>4</sup>, Ki-Wahn Ryu <sup>5</sup> and Ju-Hyung Lee <sup>1,2</sup>

- If the virus-laden aerosols are helping spread SARS-CoV-2, then it is extremely important understand the spatio-temporal evolution of the aerosols especially in the size range of 0.5 – 20 microns



# Size of Virus-Laden Aerosol Cloud and what mode will it be transmitted



— x

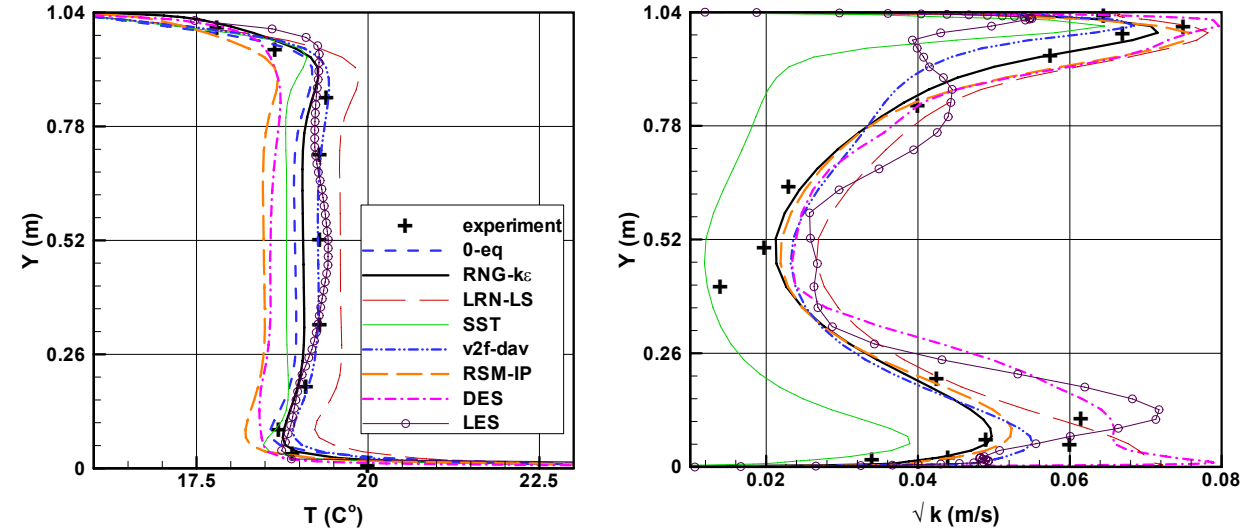
Som Dutta, Ketan Mittal and Paul Fischer

**Isosurface of vertical velocity zones that are high enough to keep 5 micron or lower, aerosols in suspension**

# If we are using Computational Fluid Dynamics, what level of fidelity is required to accurately capture the aerosol transport ?

## Evaluation of Various Turbulence Models in Predicting Airflow and Turbulence in Enclosed Environments by CFD: Part-2: Comparison with Experimental Data from Literature (2007)

Zhao Zhang                      Wei Zhang                      Zhiqiang Zhai                      Qingyan Chen\*  
Student Member ASHRAE      Member ASHRAE              Member ASHRAE              Fellow ASHRAE

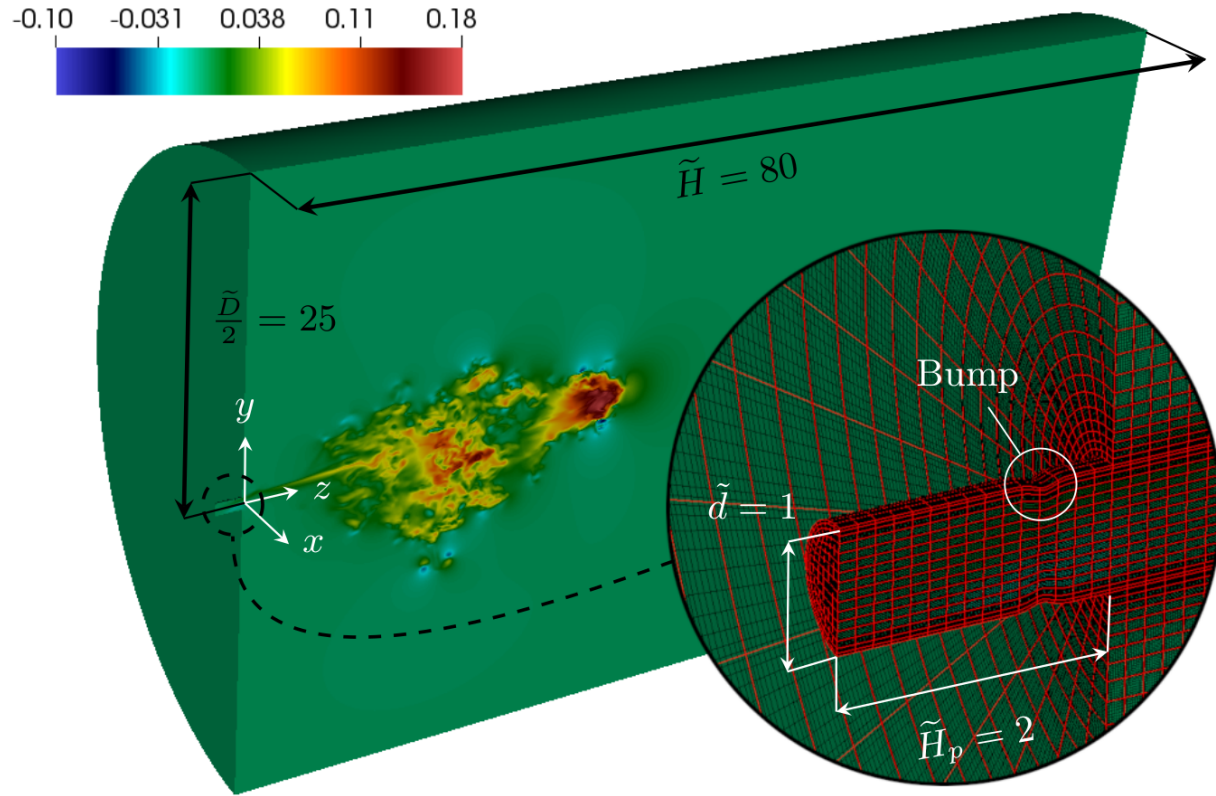


*While each turbulence model has good accuracy in certain flow categories, each flow type favors different turbulence models. Therefore, we summarize both the performance of each particular model in different flows and the best suited turbulence models for each flow category in the conclusions and recommendations.*

---

**So we decided to do Direct Numerical Simulation (DNS) or highly-resolution LES, which resolves almost all the relevant scales of turbulence**

# First problem we targeted is: DNS of a small cough



$$w_0(t) = \begin{cases} \frac{w_m}{t_m} t, & 0 \leq t < t_m \\ w_m - \frac{w_m}{t_c - t_m} (t - t_m), & t_m \leq t \leq t_c \\ 0, & t > t_c \end{cases}$$

$$\frac{\partial \tilde{u}_i}{\partial \tilde{x}_i} = 0,$$

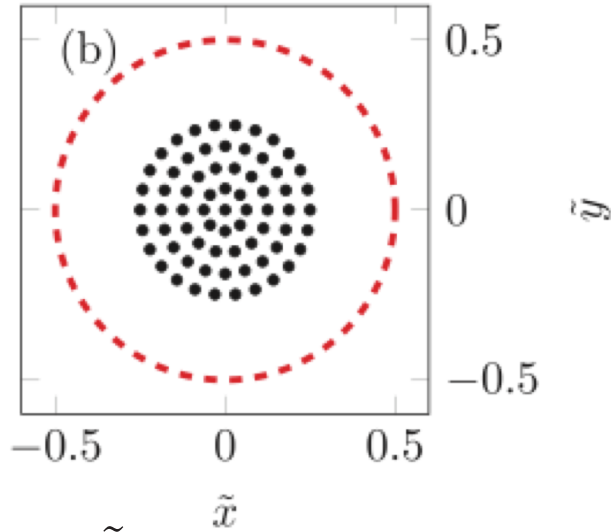
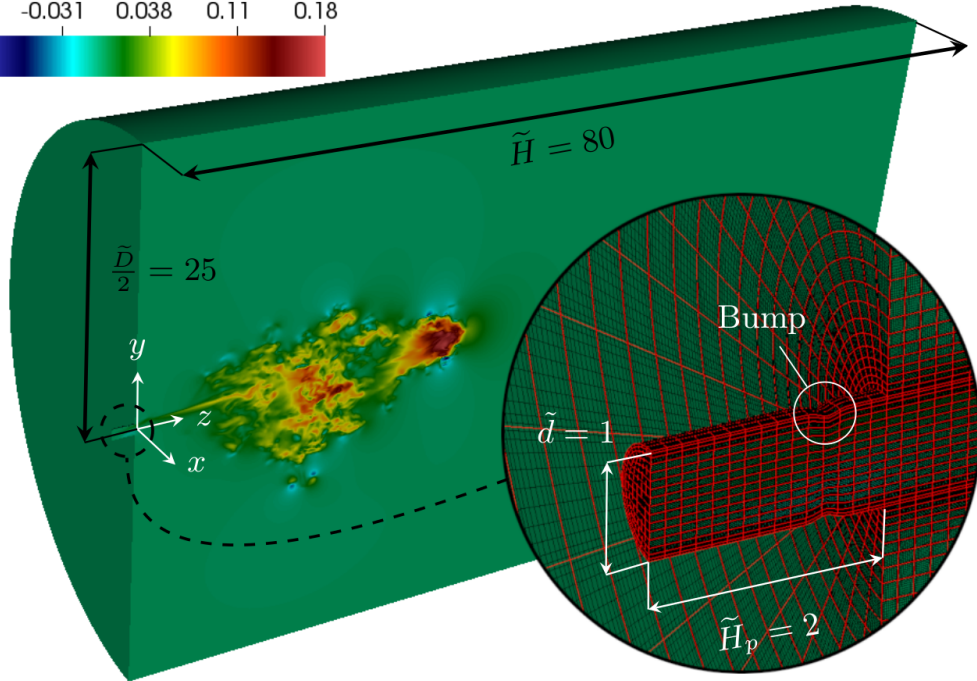
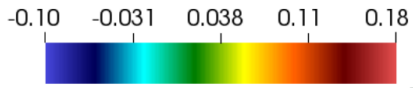
$$\frac{\partial \tilde{u}_i}{\partial \tilde{t}} + \tilde{u}_j \frac{\partial \tilde{u}_i}{\partial \tilde{x}_j} = -\frac{\partial \tilde{p}}{\partial \tilde{x}_i} + \frac{1}{Re} \frac{\partial^2 \tilde{u}_i}{\partial \tilde{x}_j \partial \tilde{x}_j} + Ri \tilde{\theta} \delta_{i2},$$

$$\frac{\partial \tilde{\theta}}{\partial \tilde{t}} + \tilde{u}_j \frac{\partial \tilde{\theta}}{\partial \tilde{x}_j} = \frac{1}{Pe} \frac{\partial^2 \tilde{\theta}}{\partial \tilde{x}_j \partial \tilde{x}_j},$$

$$Re = w_m d / \nu_a = 6000, \quad Ri = g \beta_a \Delta T d / w_m^2 = 5.61 \times 10^{-4} \quad \text{and} \quad Pe = w_m d / \alpha_a = 4200.$$



# First problem we targeted is: DNS of a small cough



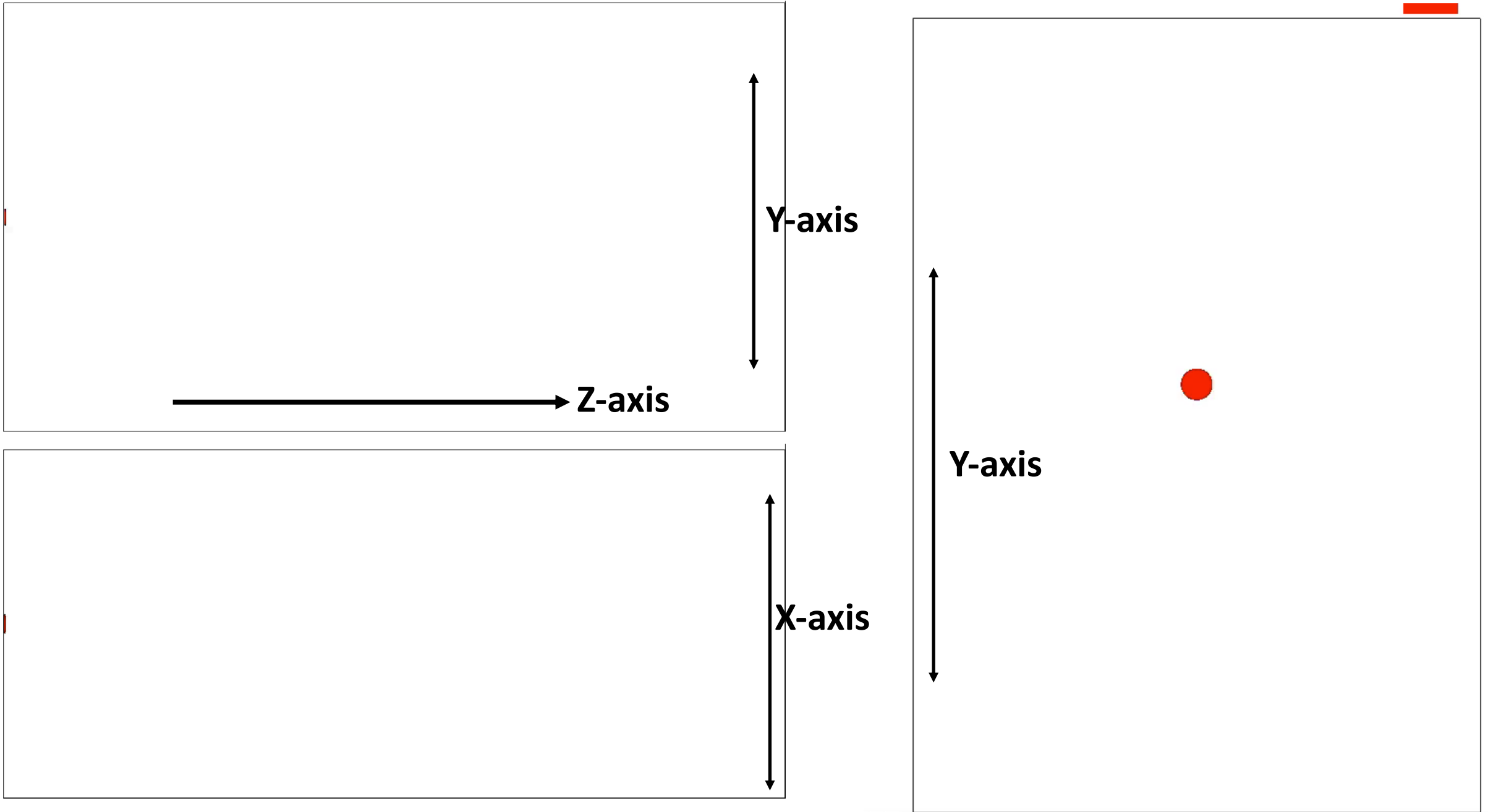
$$\frac{d\tilde{X}_i}{d\tilde{t}} = \tilde{U}_i,$$

$$\frac{d\tilde{U}_i}{d\tilde{t}} = \underbrace{\frac{\tilde{u}_i - \tilde{U}_i}{\tau_p}}_{\text{Drag}} + \underbrace{n_g \delta_{i2}}_{\text{Buoyancy}} + \underbrace{n_{th} \frac{\partial \tilde{\theta}}{\partial \tilde{x}_i}}_{\text{Thermophoresis}}, \quad \tau_p = Re \frac{\tilde{d}_p^2 \rho_p}{18 C_c \rho_a} \left(1 + 0.15 Re_p^{0.687}\right)^{-1}$$

$$\frac{d\tilde{d}_p}{d\tilde{t}} = \frac{4}{Re Sc_v} \frac{\rho_f - \rho_s}{\rho_p} \frac{1}{\tilde{d}_p}, \quad \frac{d\tilde{\theta}_p}{d\tilde{t}} = \frac{12}{Re Pr_p} \frac{1}{\tilde{d}_p^2} \left[ \frac{k_v}{k_p} (\tilde{\theta}_f - \tilde{\theta}_p) + \frac{D_v \Delta H_v}{k_p \Delta T} (\rho_f - \rho_s) \right]$$

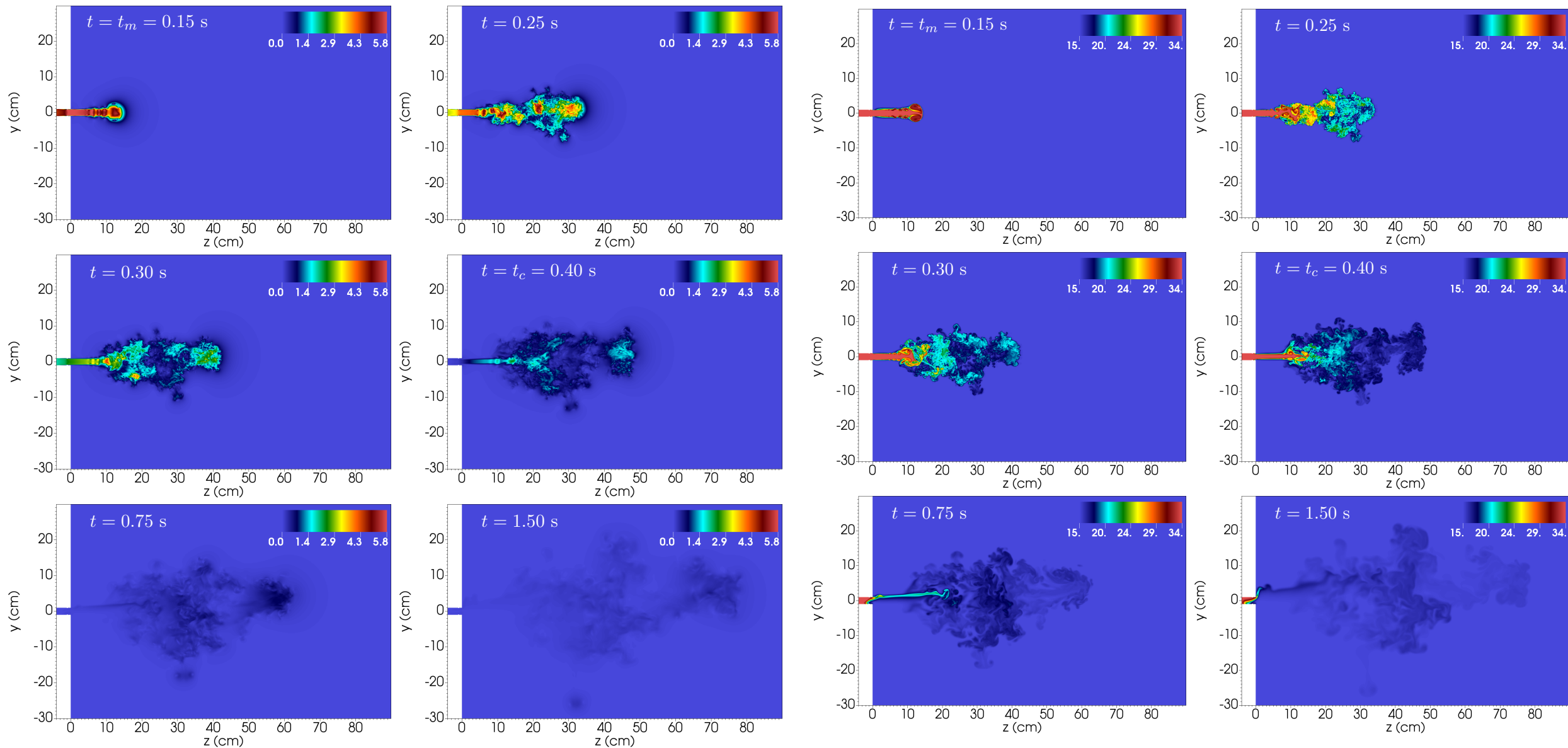
- Spatial discretization using high-order Spectral Element Methods (SEM) [Nek5000]
- 3<sup>rd</sup>-order semi-implicit time-stepping, *EXT-BDF*
- Current simulation has around 300 million computational points, needing  $5.2 \times 10^5$  CPU hours
- 4, 8, 16, 32, 64, 128 and 256 micron aerosols
- Evaporative and non-Evaporative
- 200 batches of 69 aerosols
- ~ 200,000 particles

# DNS of a small cough (iso-surface of temperature)

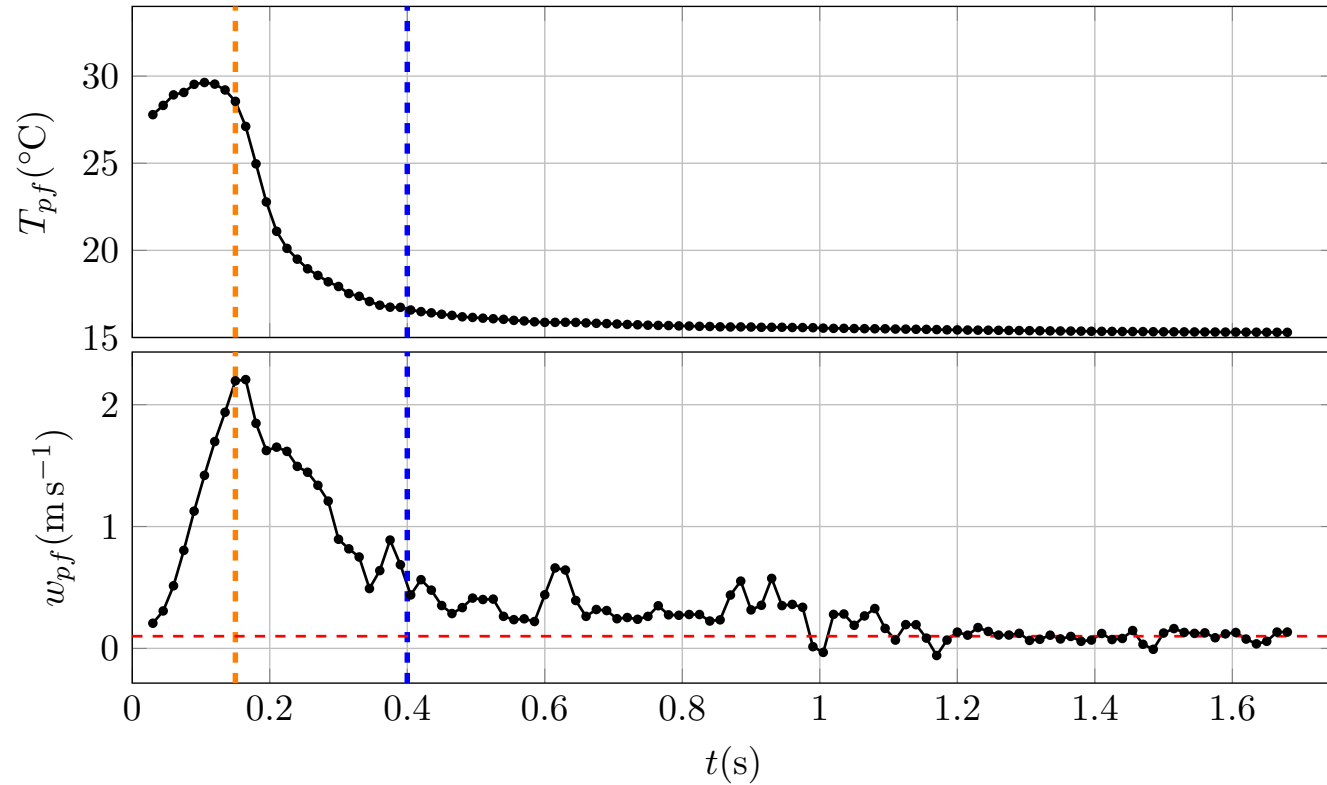


# DNS of a small cough

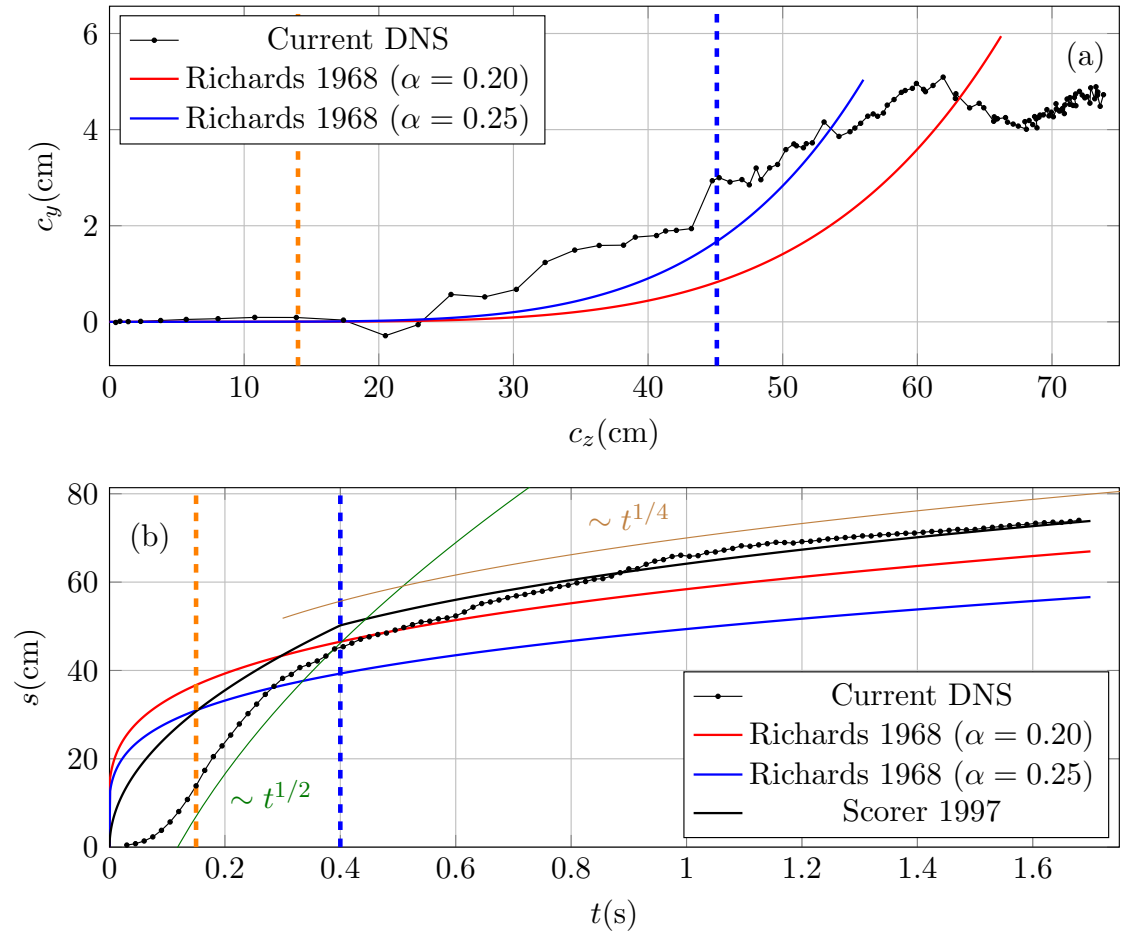
(velocity magnitude [m/s] and temperature [C] of the cough in space and time)



# DNS of a small cough (Puff front evolution and Centroid Location)



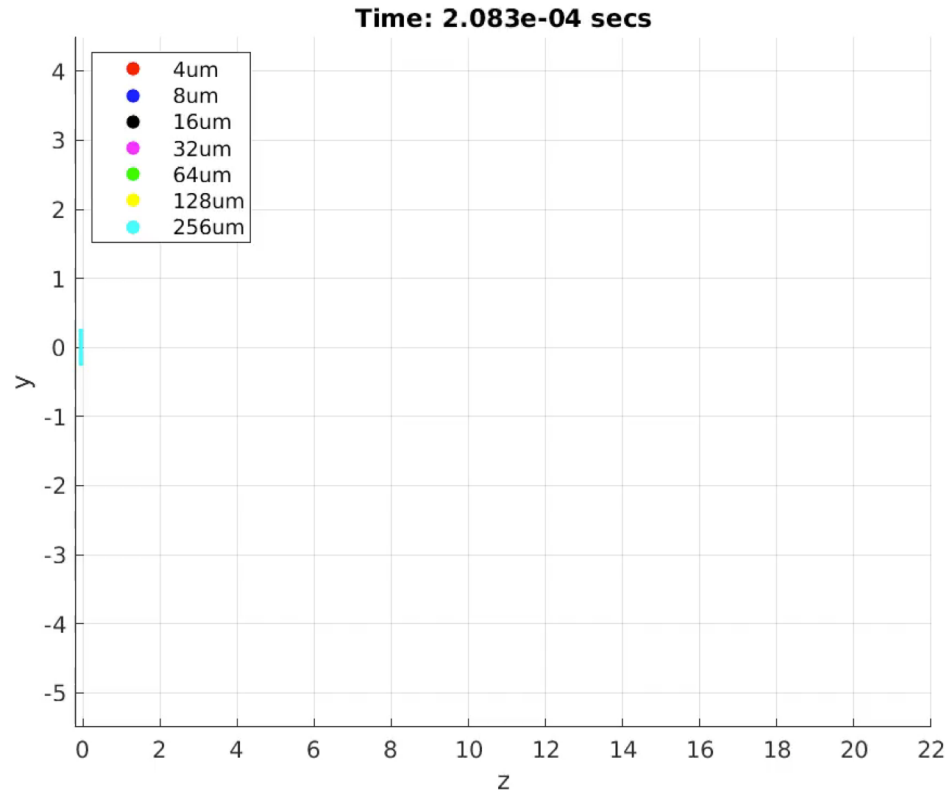
Puff front temperature and vertical velocity



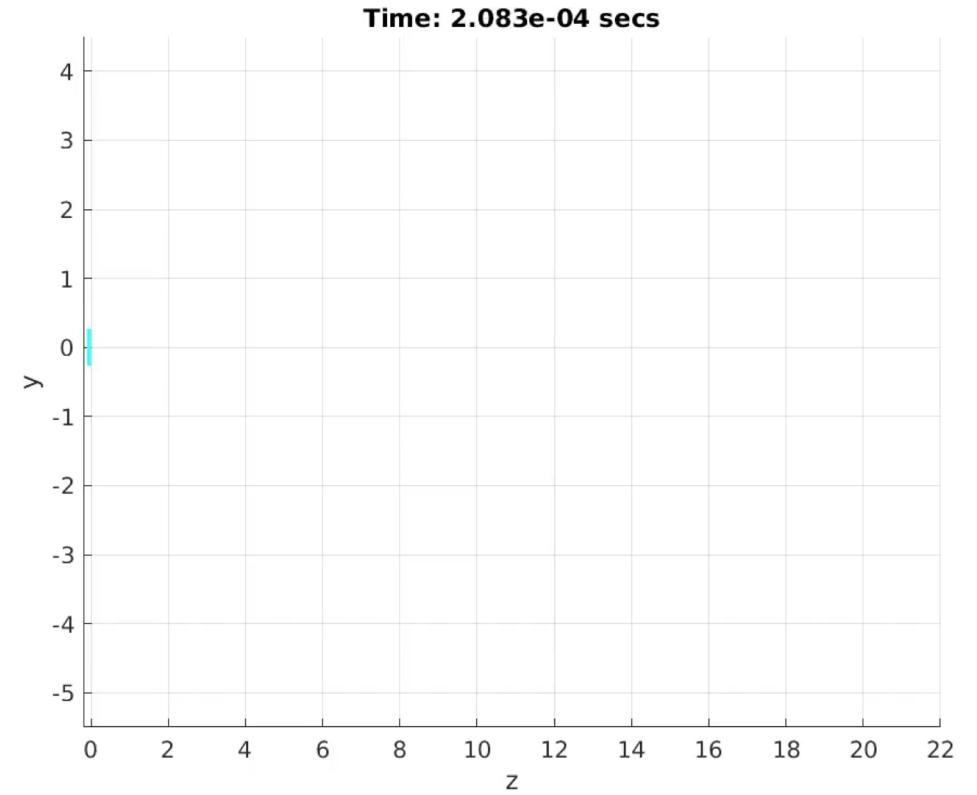
Puff centroid location and time



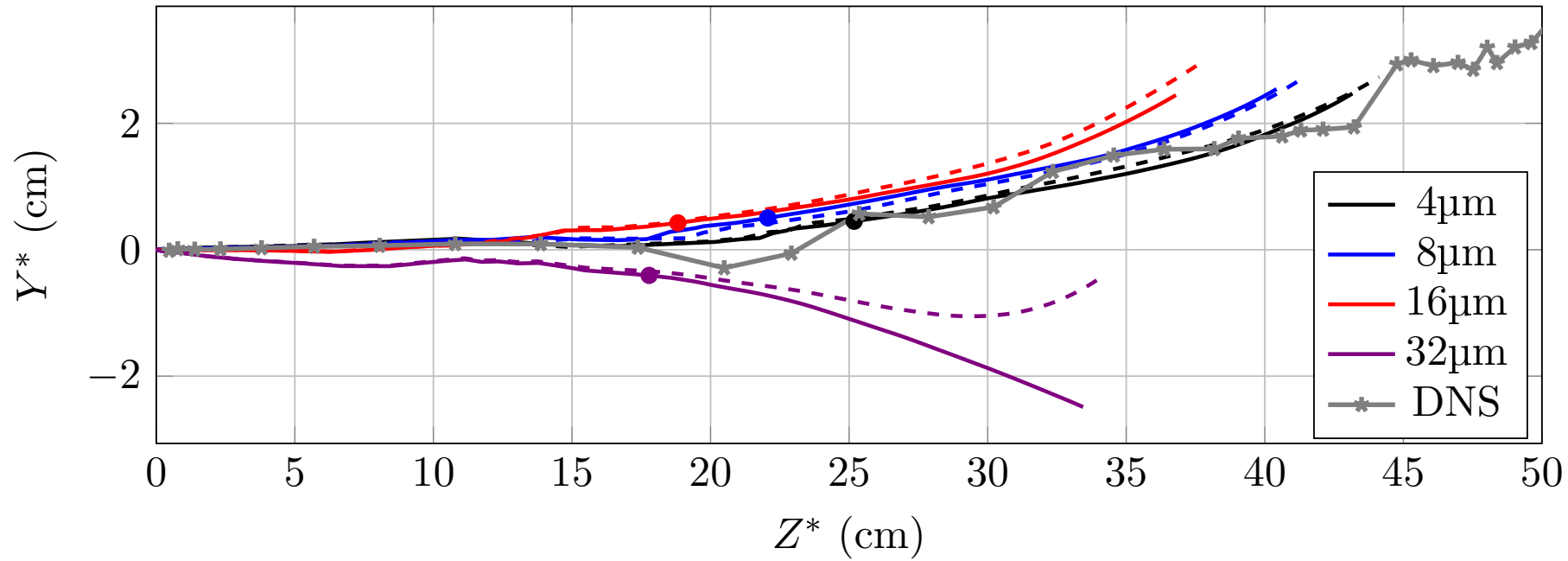
# The Dispersed Phase



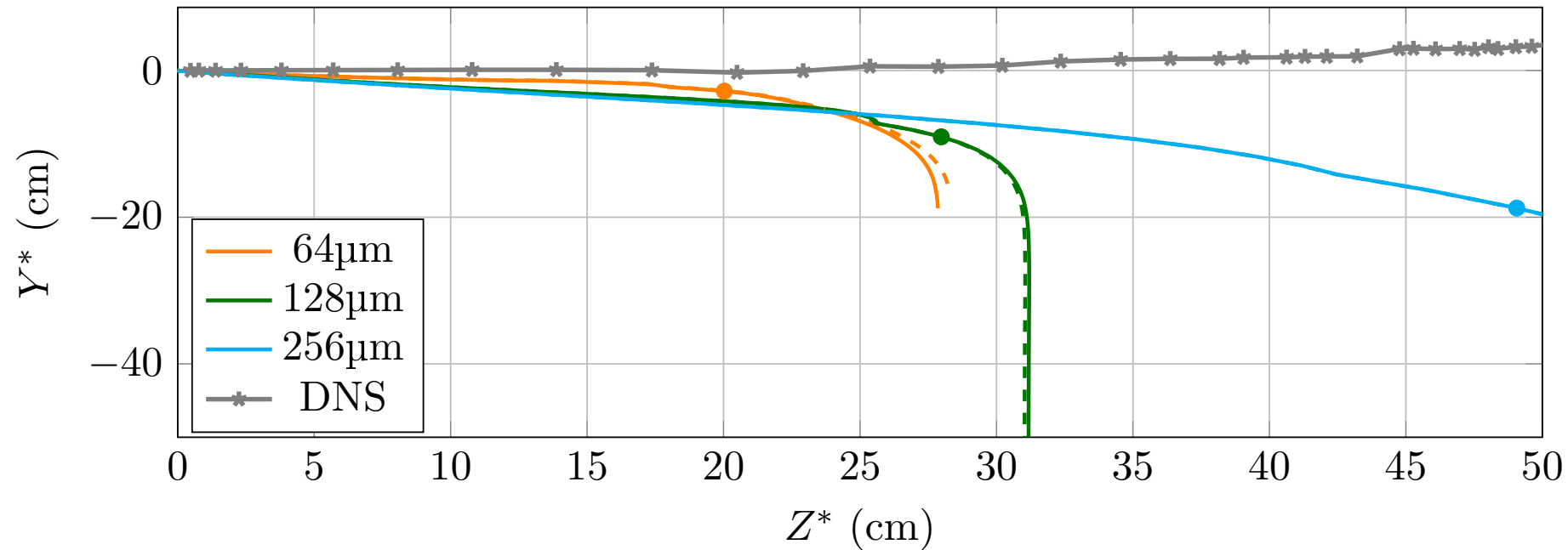
**Non-Evaporating**



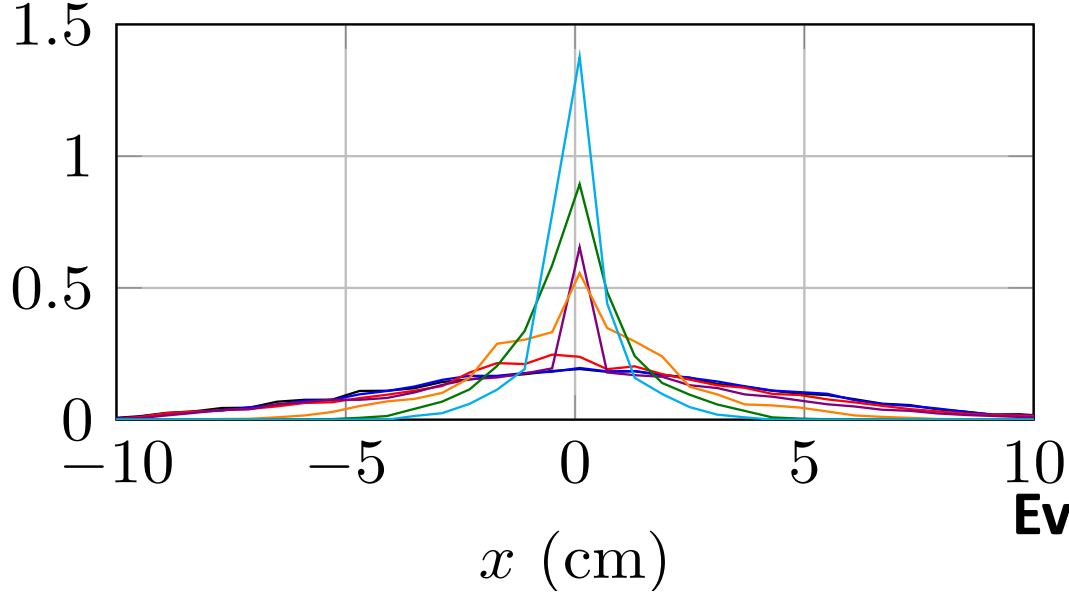
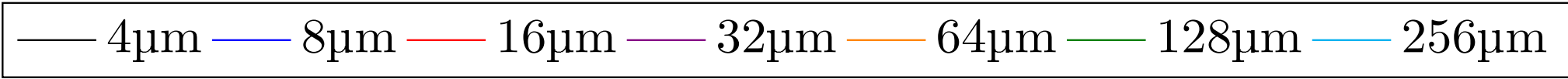
**Evaporating**



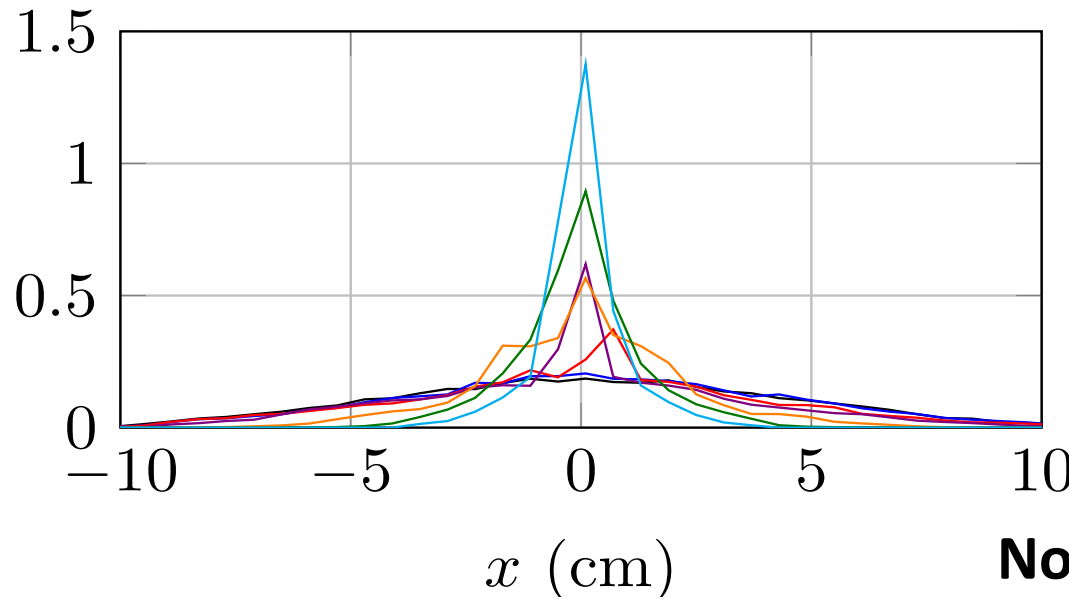
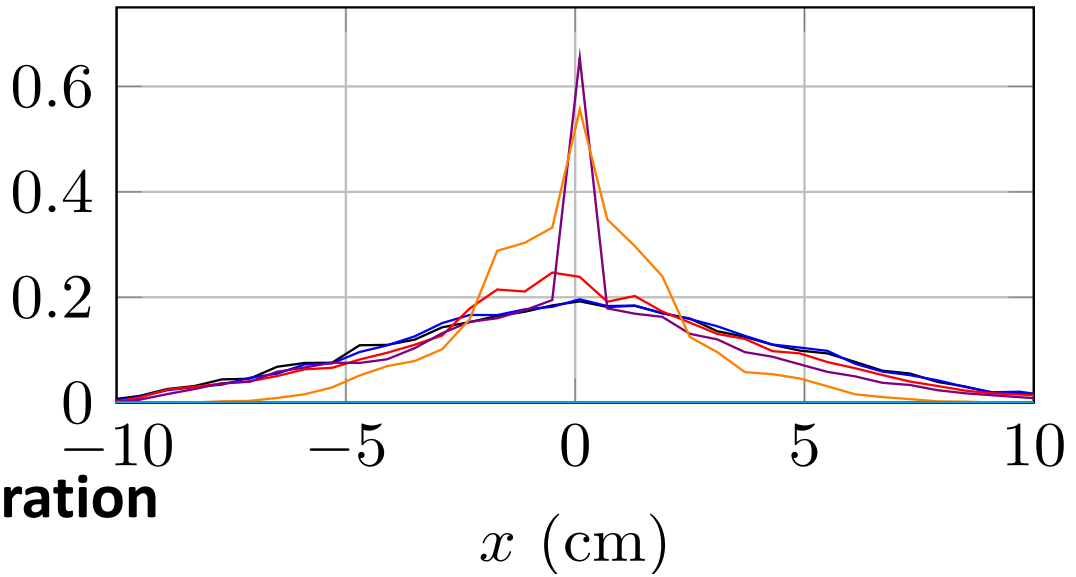
**Dashed –  
Evaporation**



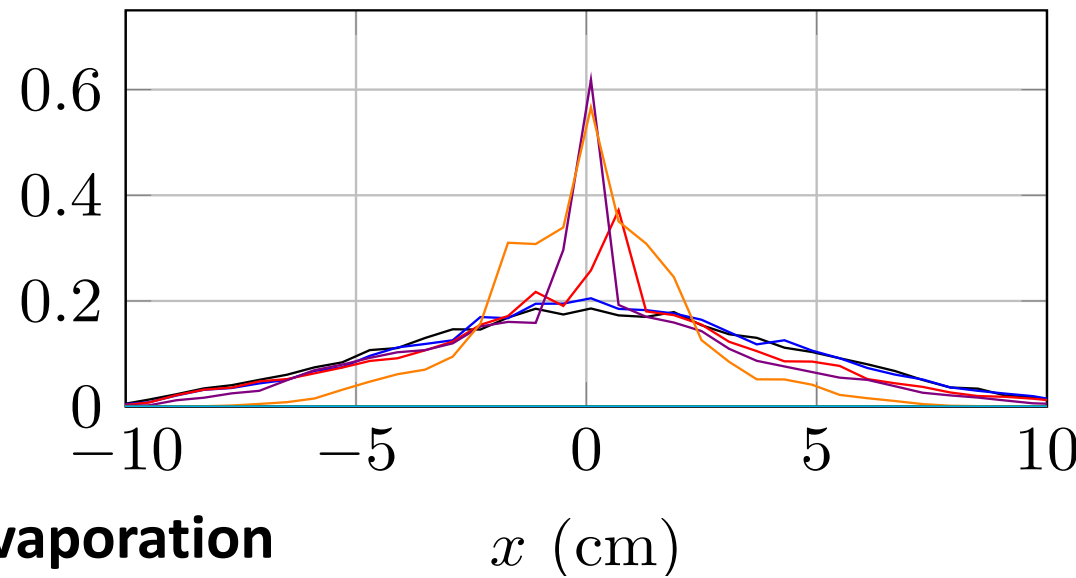
**Solid –  
non-Evaporation**

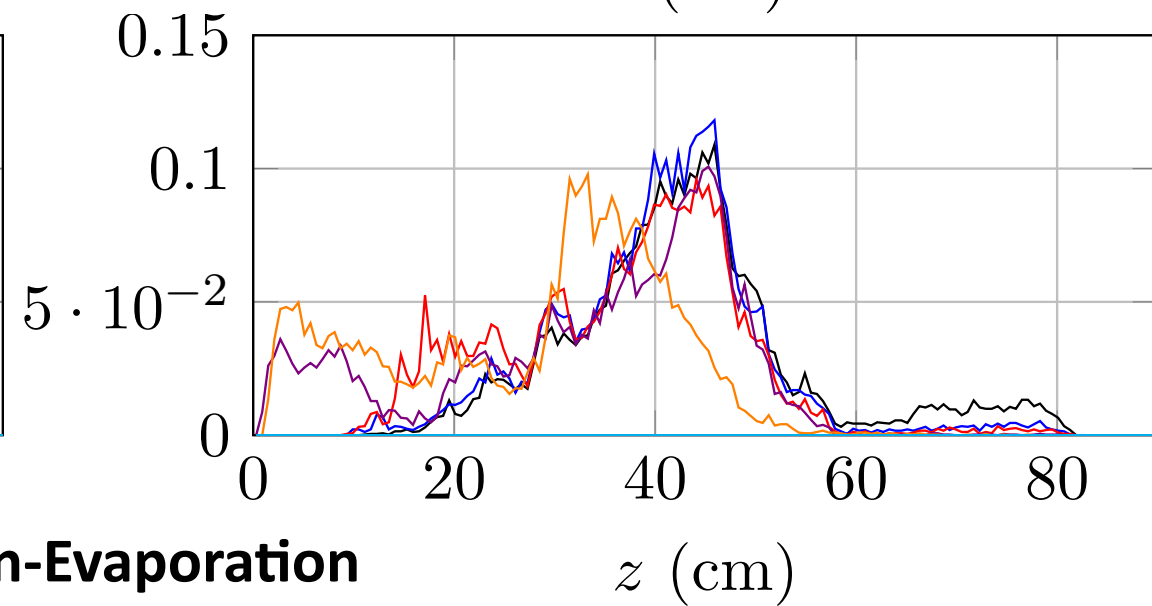
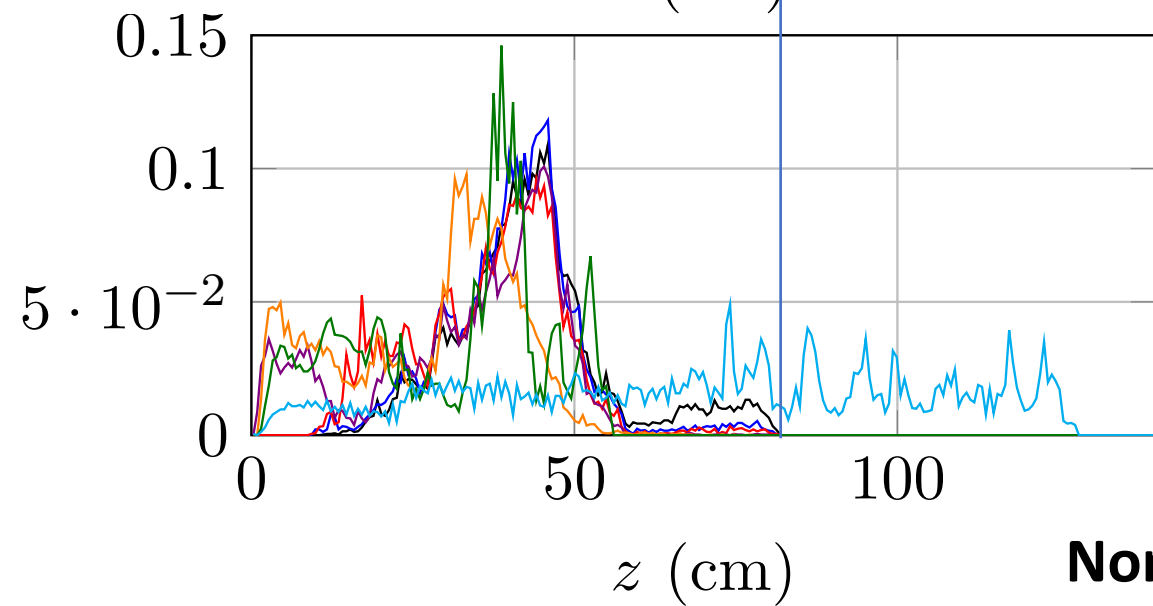
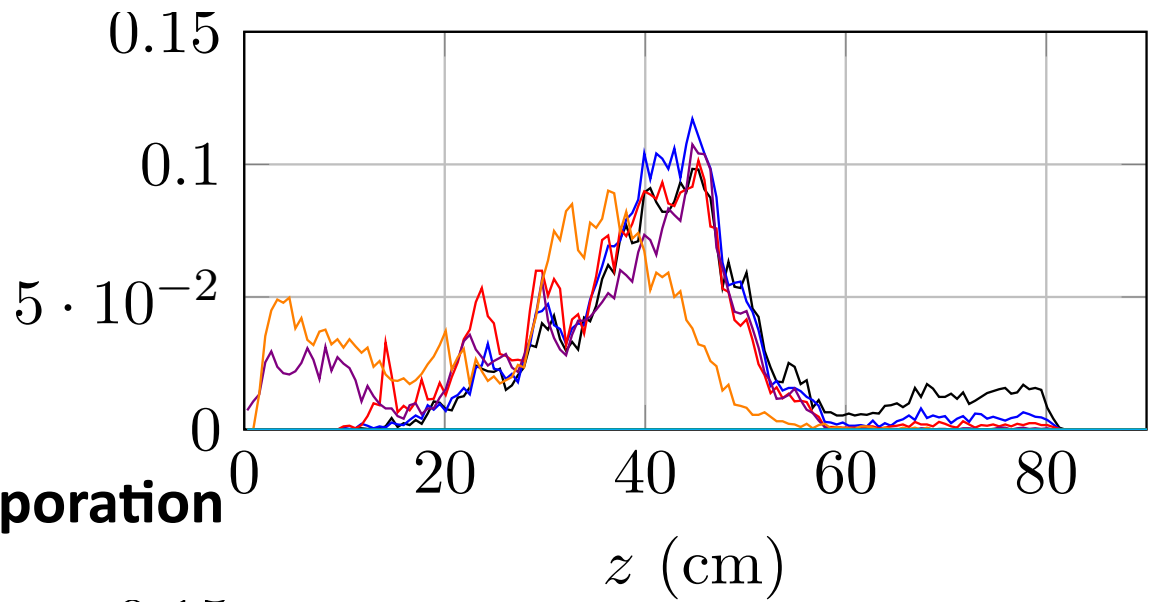
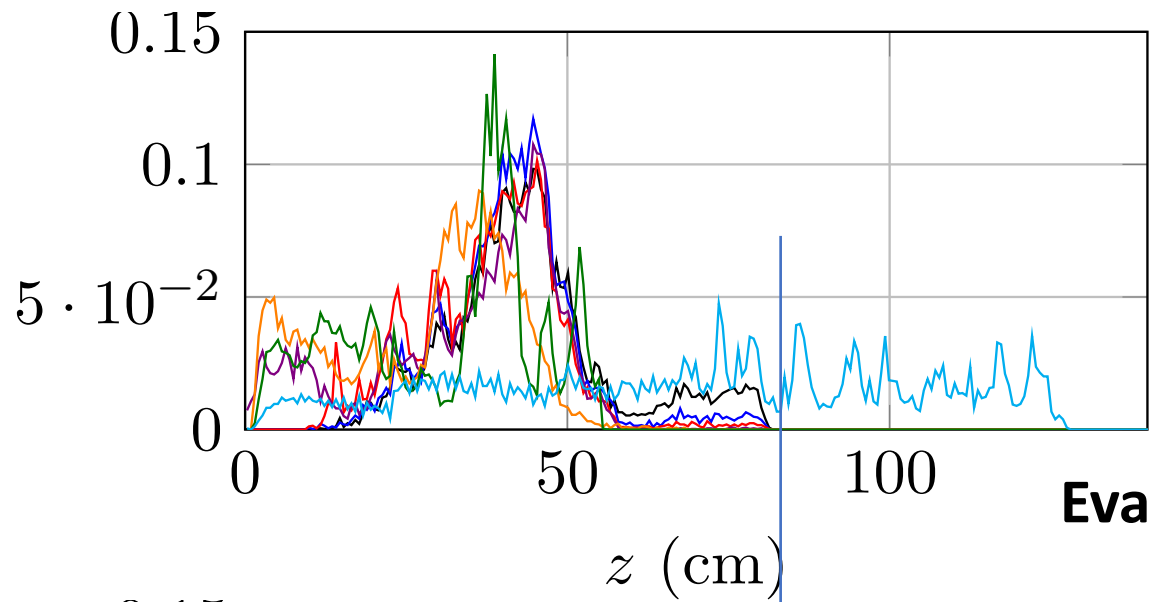
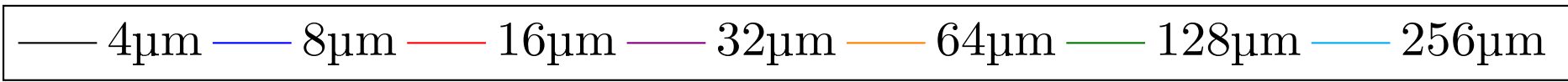


**Evaporation**



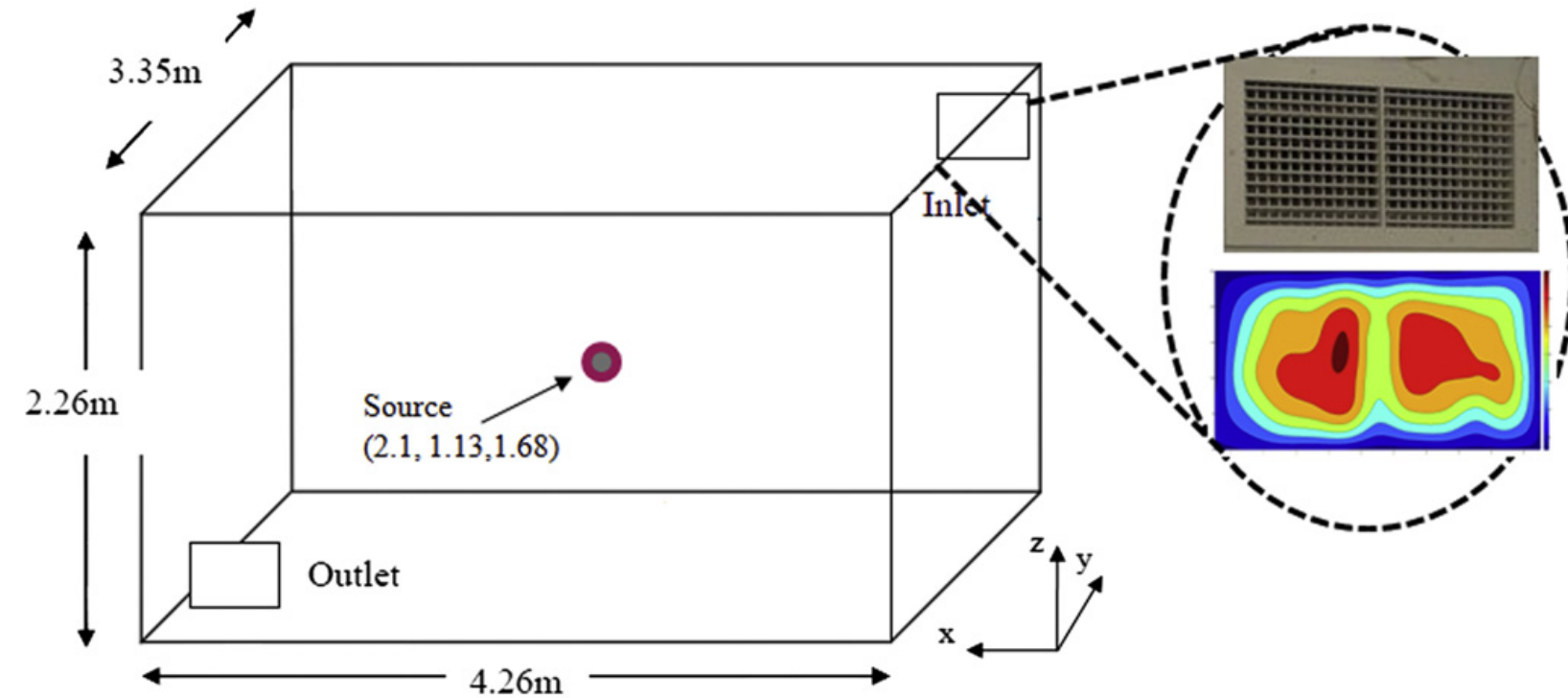
**Non-Evaporation**







# High-Resolution LES of flow and particle transport in a room

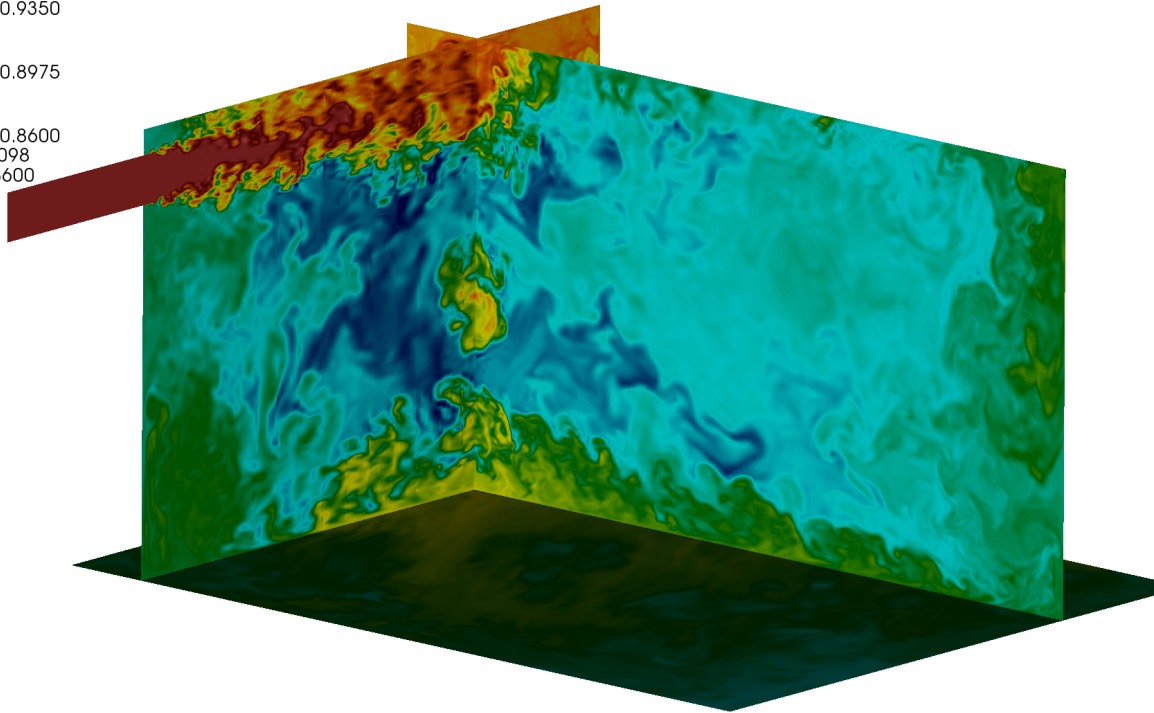


- High-Resolution Large Eddy Simulations (LES) coupled with Lagrangian particle tracking for the aerosols.
- Using high-order Spectral Element Methods for spatial discretization
- Reynolds number: 8000 - 15,000 ~ (4-6-8 ACH)
- Current simulation has 100 million computational points
- 500,000 aerosols (0.5 – 4 -32 microns)
- More expensive, as simulation has to be run longer

# Even in a “simple” Empty room the Mixing Process is Complicated

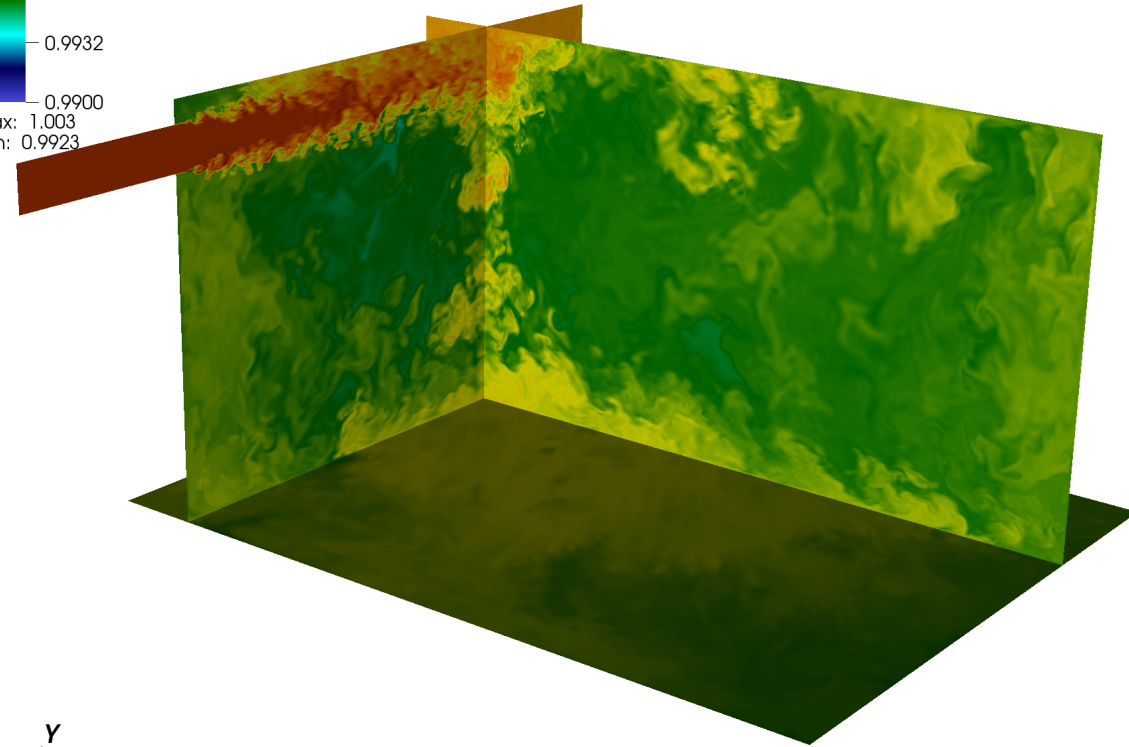
Pseudocolor  
Var: temperature  
1.010  
0.9725  
0.9350  
0.8975  
0.8600  
Max: 1.098  
Min: 0.8600

6 ach



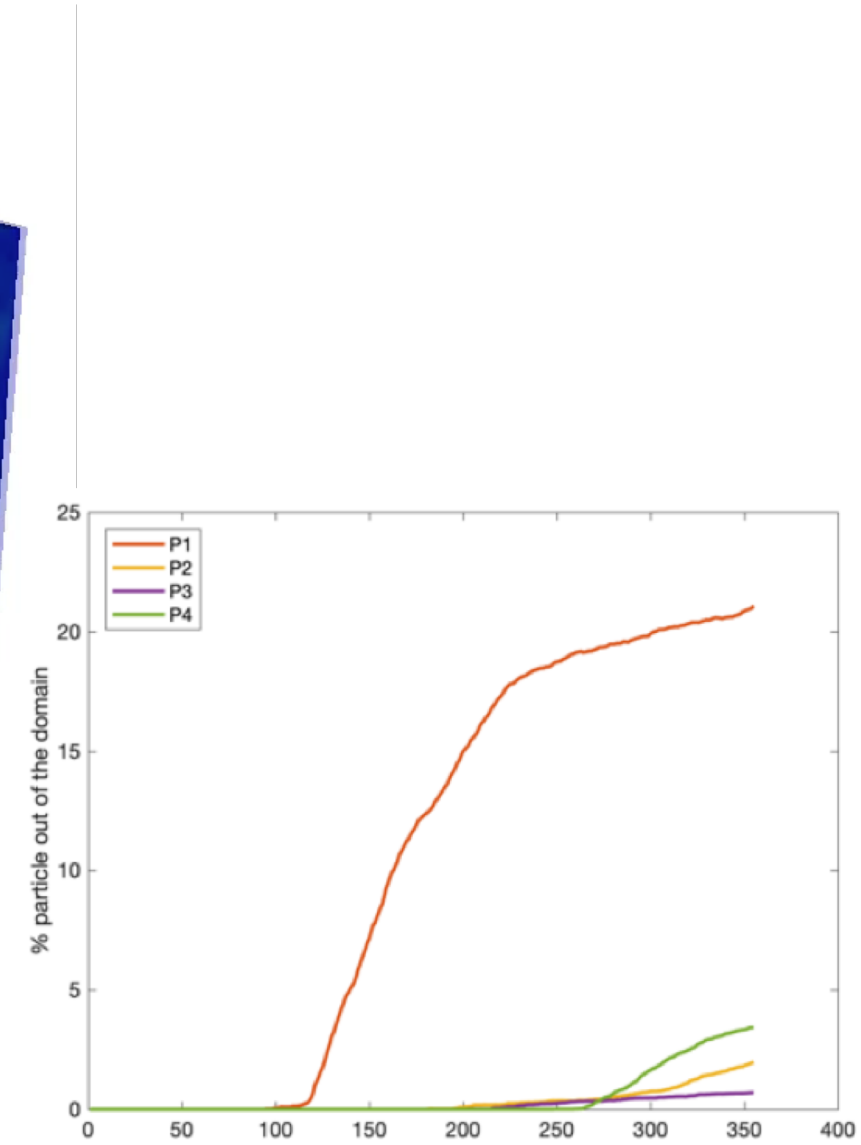
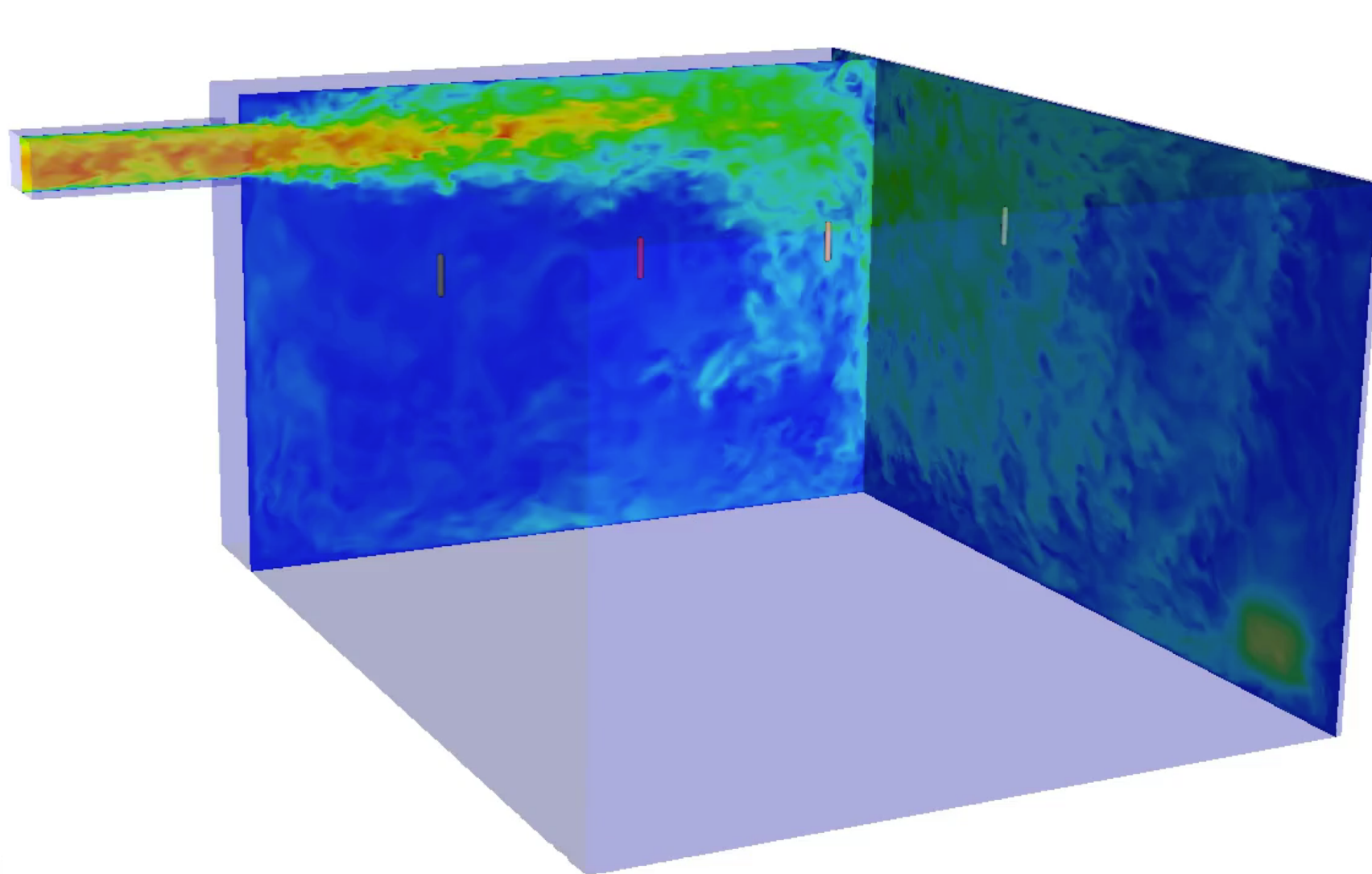
Pseudocolor  
Var: temperature  
1.003  
0.9997  
0.9965  
0.9932  
0.9900  
Max: 1.003  
Min: 0.9923

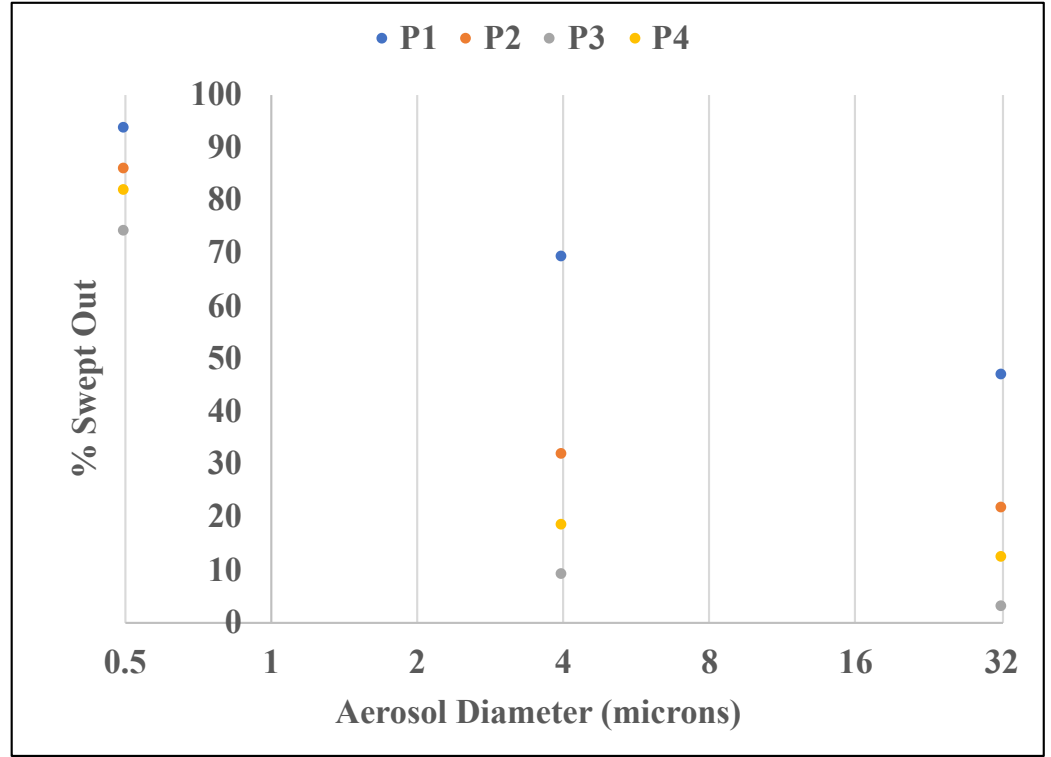
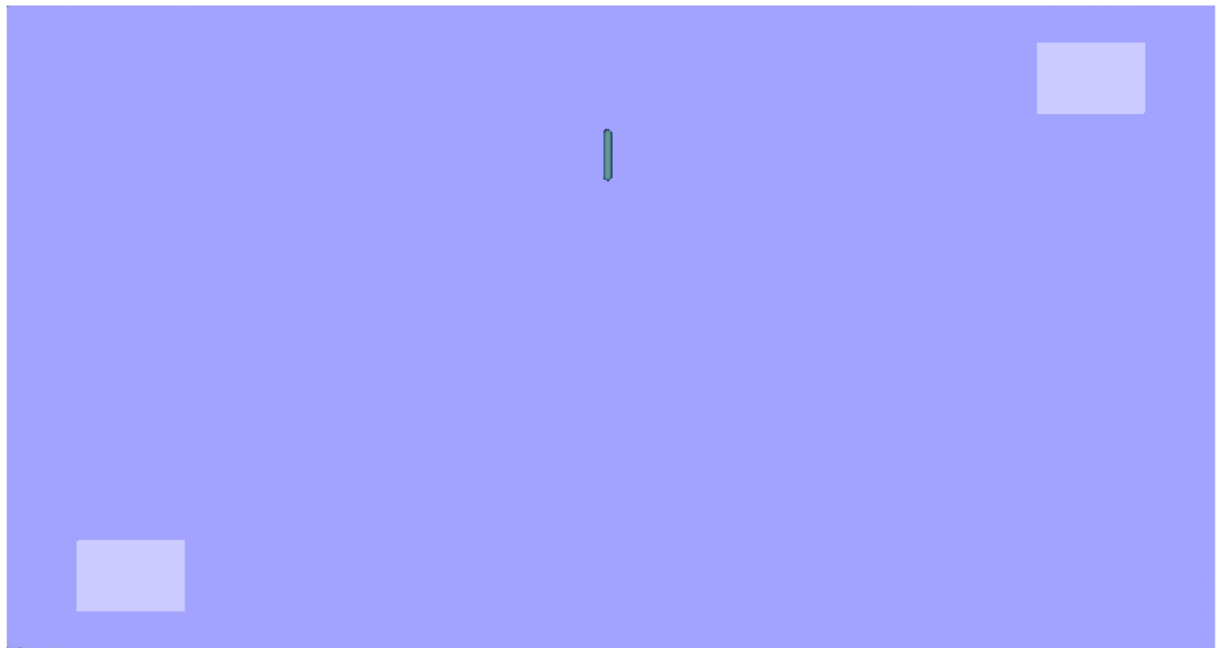
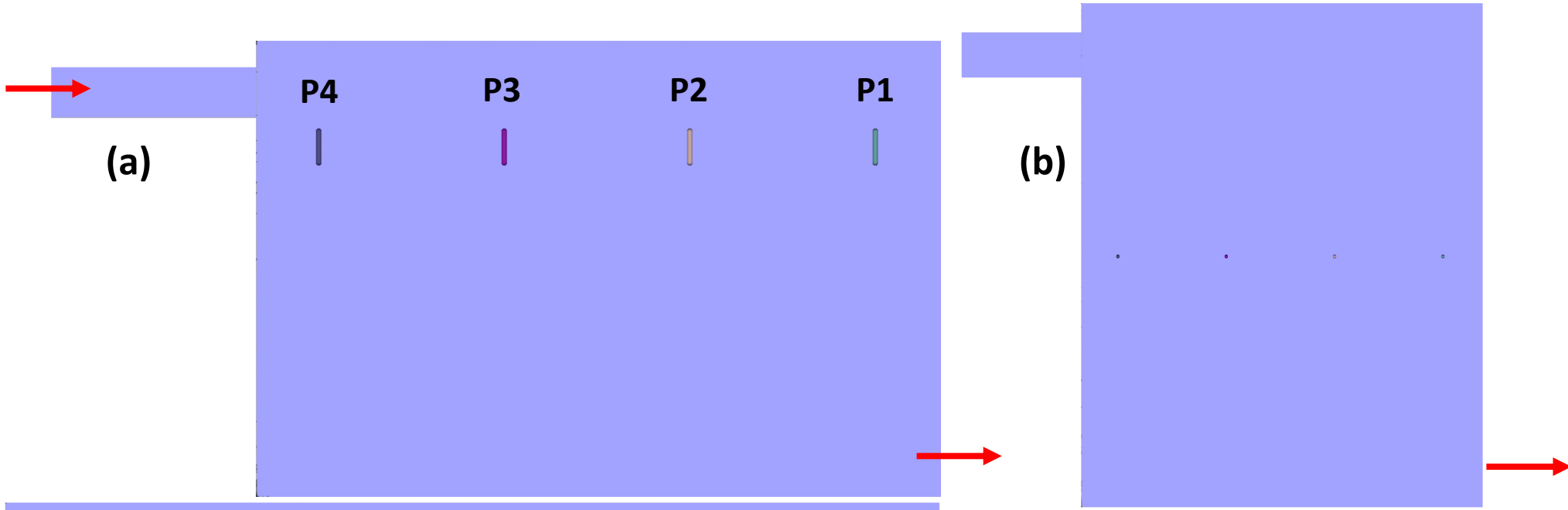
8 ach



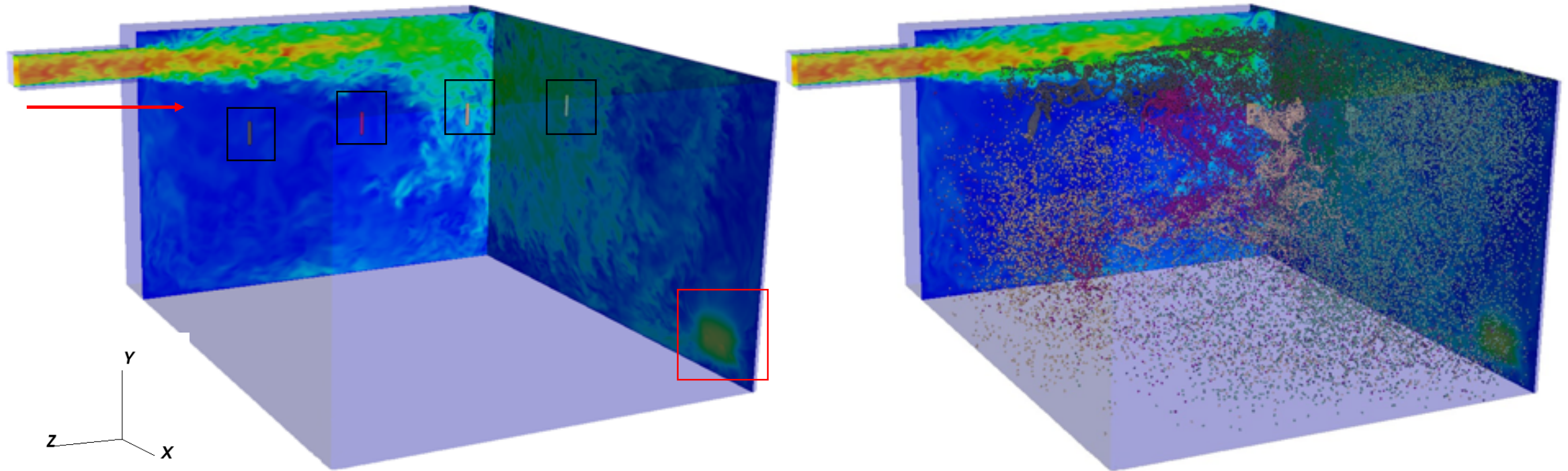
Y

# Difference in Dispersion of Aerosols in the Room Based on Location









- Need substantial time to reach a statistical steady state, before aerosols can be injected
- 1.5 mins of real time takes 768 node hours on Frontera (~ 50,000 cpu hours)
- We need to run for at least 30 – 60 mins = 31,000 node hours
- Though it takes about 50,000 node hours to reach a statistically steady state, so each simulation of this size is costing about 100,000 node hours

# Fast & Accurate Prediction of Virus Loading in Heterogenous Indoor Environments : CEAT

### 1 Describe the Group

**A Group's infection likelihood compared to the community**  
The Group is composed of people who, prior to this activity, you estimate have a likelihood COVID-19 infection that is ...

	Scenario A	Scenario B
100X LOWER than the community's average due to their adhering to public health guidance on distancing, masking, and exposure to crowds/people.	<input type="checkbox"/>	<input type="checkbox"/>
10X LOWER than the community's average due to their adhering to public health guidance on distancing, masking, and exposure to crowds/people.	<input type="checkbox"/>	<input type="checkbox"/>
EQUAL TO the community's average.	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
10X HIGHER than the community's average due to their not adhering to public health guidance on distancing, masking, and exposure to crowds/people.	<input type="checkbox"/>	<input type="checkbox"/>
100 PERCENT since they are known to be infected with COVID-19.	<input type="checkbox"/>	<input type="checkbox"/>

**B Group's vaccination rate:** 100 %  Check here to apply Group's Vaccination Rate to the Exposure Calculations

**C Group members use of viral genome or protein surveillance testing**

All members are tested within 3 days prior to event  All unvaccinated members are tested within 3 days prior to event  Testing not required or testing status unknown

### 2 Number of People

	Scenario A	Scenario B
Number of People Sharing Activity Space (Must be between 2 and 250)	30	30

### 3 Distance Between People (meters)

Either enter distance below... Or select a distance.

	Scenario A	Scenario B
4.5 m	<input type="checkbox"/>	<input type="checkbox"/>
3 m	<input type="checkbox"/>	<input type="checkbox"/>
2 m	<input type="checkbox"/>	<input type="checkbox"/>
1 m	<input type="checkbox"/>	<input checked="" type="checkbox"/>
0.5 m	<input type="checkbox"/>	<input type="checkbox"/>

### 4 Mask Type and Percent Wearing Masks

Mask Type	Scenario A	Scenario B	% of People Wearing Masks	Scenario A	Scenario B
Fitted N95	<input type="checkbox"/>	<input type="checkbox"/>	100%	<input type="checkbox"/>	<input type="checkbox"/>
KN95/KN95	<input type="checkbox"/>	<input type="checkbox"/>	90%	<input type="checkbox"/>	<input type="checkbox"/>
Double Surgical Mask	<input type="checkbox"/>	<input type="checkbox"/>	75%	<input type="checkbox"/>	<input type="checkbox"/>
Surgical Mask	<input type="checkbox"/>	<input type="checkbox"/>	50%	<input type="checkbox"/>	<input type="checkbox"/>
Average Mask	<input type="checkbox"/>	<input type="checkbox"/>	25%	<input type="checkbox"/>	<input type="checkbox"/>
Cloth Mask	<input type="checkbox"/>	<input type="checkbox"/>	0%	<input type="checkbox"/>	<input type="checkbox"/>
No Mask	<input type="checkbox"/>	<input type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>

### 5 Vocalization Intensity

	Resting		Standing		Light Exercise		Heavy Exercise	
	Silent	Spoken	Silent	Spoken	Silent	Spoken	Silent	Spoken
Scenario A	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Scenario B	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

### 6 Breathing Rate

Select Breathing Rate	Sleep	Resting	Light Activity	Moderate Exertion	Heavy Exertion
Scenario A	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Scenario B	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

### 7 Duration of Activity

Duration of Activity in Hours (Must be between 0.08 hr (5 min) and 12 hr)	Scenario A	Scenario B
3.00	3.00	3.00

### 8 Indoors or Outdoors

Scenario A  Outdoor  Indoor Scenario B  Outdoor  Indoor

### A For Outdoor Activities: Select Wind Conditions

Wind Condition	Description	Scenario A	Scenario B
Moderate (21-29 km/h)	Raises dust and loose paper, small branches are moved.	<input type="checkbox"/>	<input type="checkbox"/>
Gentle (13-19 km/h)	Leaves/small twigs in constant motion, wind extends light flag.	<input type="checkbox"/>	<input type="checkbox"/>
Light (6-11 km/h)	Wind felt on face, leaves rustle.	<input type="checkbox"/>	<input type="checkbox"/>
Calm (2-5 km/h)	Direction of wind shown by smoke drift.	<input type="checkbox"/>	<input type="checkbox"/>
Very Calm (0.8-1.5 km/h)	No direction or flow observed.	<input type="checkbox"/>	<input type="checkbox"/>

### B For Indoor Activities: Enter indoor ACH (Air Changes/Hour)

ACH can be acquired from building engineers or H&S  
Alternatively, select an ACH value from table to the right  
AER (Air Exchange Rate) is another name for ACH

	Scenario A	Scenario B
3.00	3.00	3.00

### C Room Filtration

Option 1: Use a default assumption of flow of filtered air of 5 L/sec/m<sup>2</sup>  
Option 2: Enter a specific filtration flow rate

Filter	Efficiency	Scenario A	Scenario B
HEPA Filters	95%	<input type="checkbox"/>	<input type="checkbox"/>
MERV 13	80%	<input type="checkbox"/>	<input type="checkbox"/>
MERV 8	50%	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
No Filters	0%	<input type="checkbox"/>	<input type="checkbox"/>

Flowrate: 0 L/sec

### 9 If Indoors, Room Dimensions

	Scenario A	Scenario B
Room Length (m)	12.0	12.0
Room Width (m)	12.0	12.0
Ceiling Height (m)	3.00	3.00
Room Area (m <sup>2</sup> )	144.96	144.96
Room Volume (m <sup>3</sup> )	434.88	434.88

### 10 Adjustments to Current Local Conditions

Average Daily Cases per 100,000 in the last week: 230.00  
Average Days Infectious (Set to 5 if unknown): 5.00  
Undiagnosed Factor for Area (Set to 3 if unknown): 3.0  
Active Infections per 100,000: 3.4027

WHO Variant Name	Estimate of Portion of Active Infections (%)	Comparative Increased Transmission versus Wild-Type Virus (%)
Alpha	0.0	0.0
Beta	0.0	0.0
Delta	20.0	100.0
Omicron	80.0	980.0

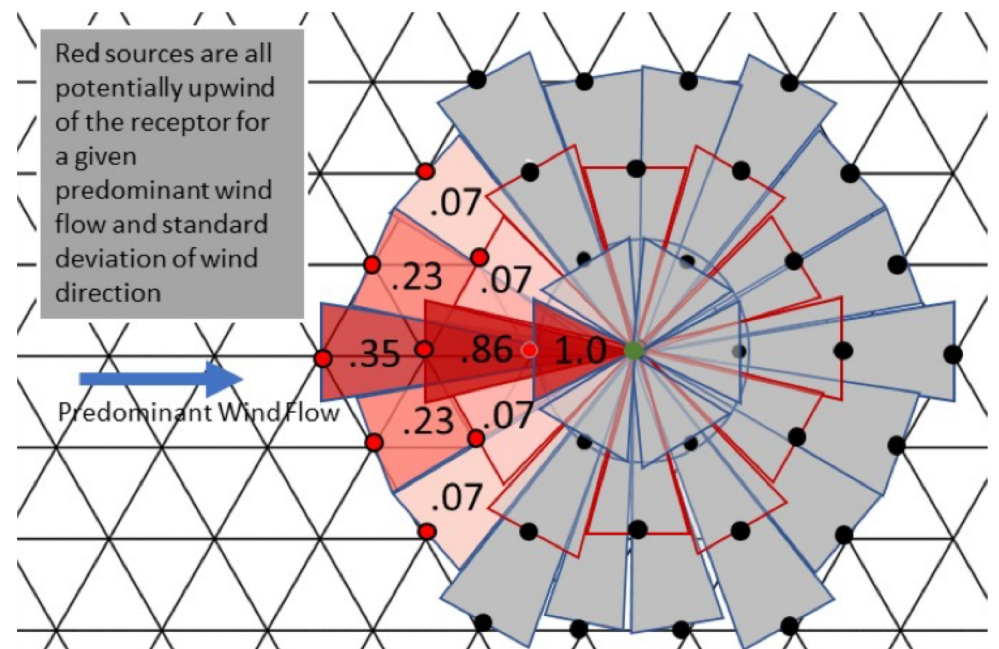
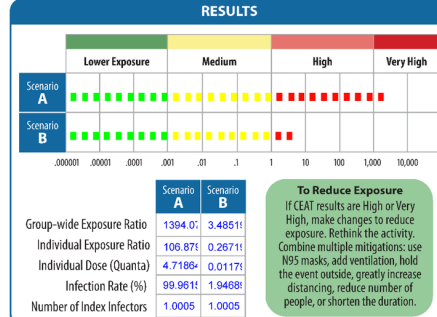
Immunity Prevalence: Population Vaccinated 70.0%, Population Recovered 32.0%, Effectiveness of Immunity 37.0%

Correlation Factor: Poisson Distribution Adjustment Factor 0.60

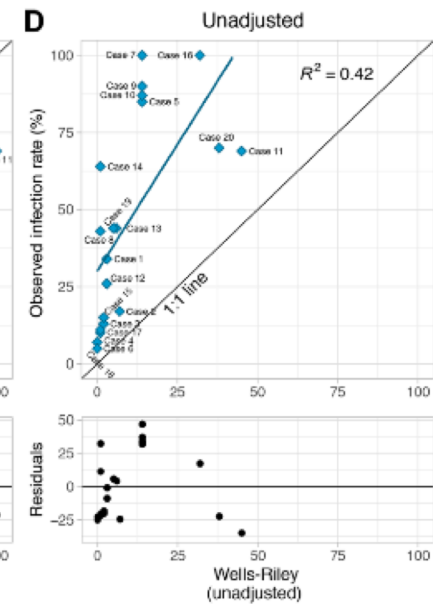
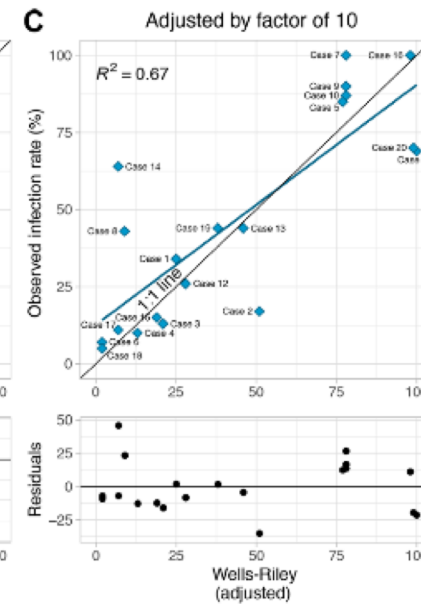
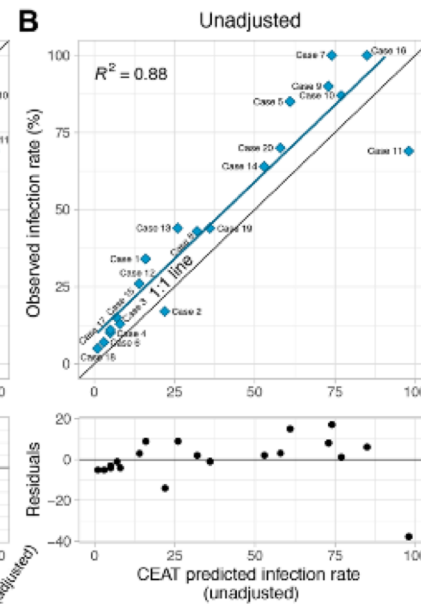
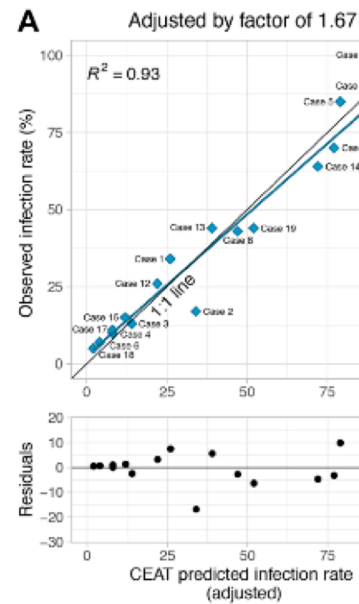
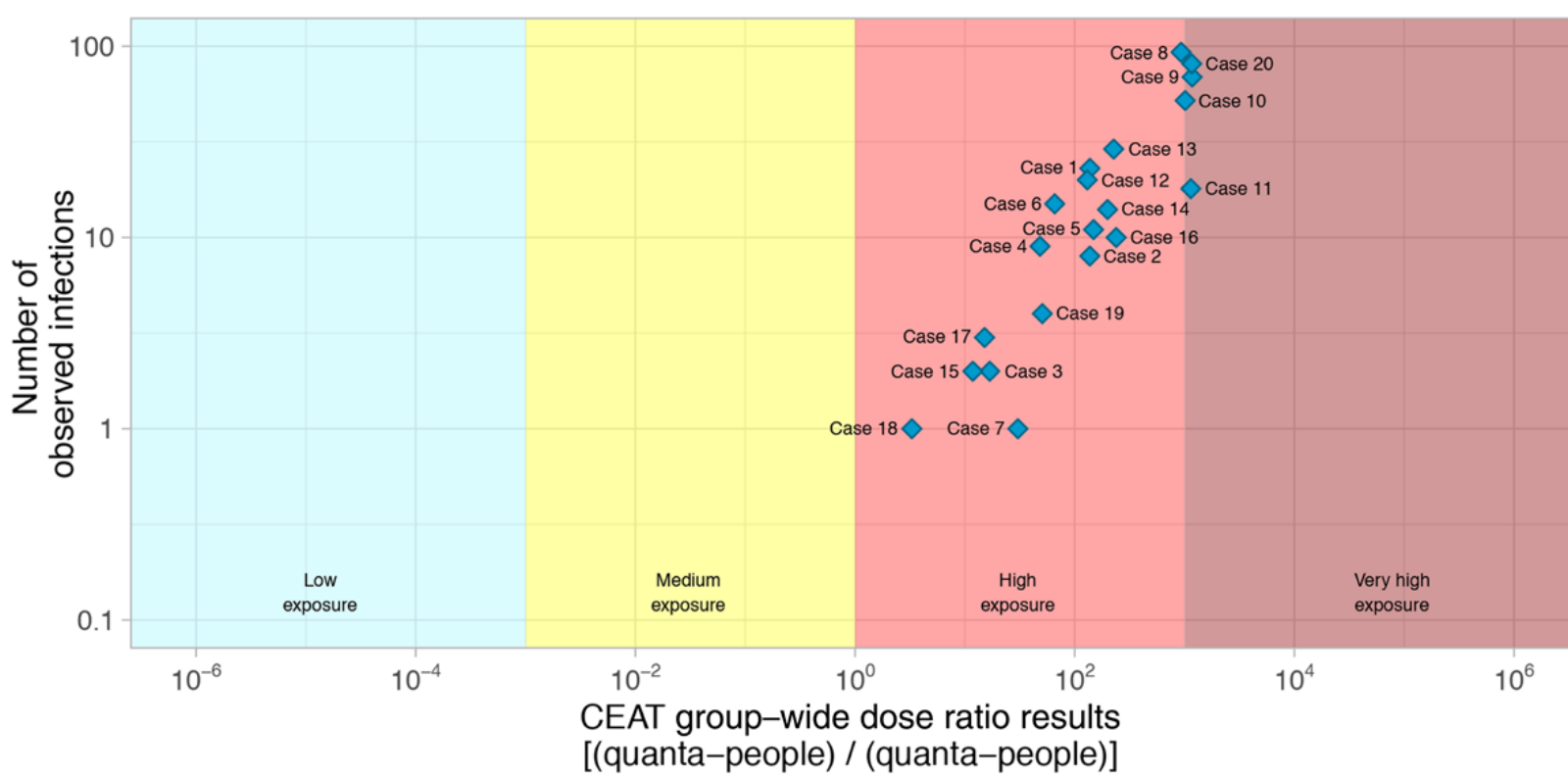
**Disclaimer Statement:** By using this tool you agree to be bound by this disclaimer. This tool does not provide a prediction of the likelihood of infection or transmission of disease, nor does the tool provide advice or guarantee outcome. It solely provides a means for the user to estimate theoretical relative exposure. It is intended for informational purposes only and users should not rely on output for decision-making. Information is gathered from various sources and Signature Science, LLC, COV-IRT or its members are not responsible for errors or omissions in data. No warranties are given in relation to this tool and it is not guaranteed as fit for purpose.

### ACH VALUES

Medical General	6	Education Classrooms (Age 5 to 8)	2	Manufacturing Manufacturing Floor	1.5
Laboratory	6	Classrooms (Age 9+)	2	Residential Homes with Closed Windows	0.5
Treatment Room	6	Daycare (Through Age 4)	2.5	Rooms with 1 Open Window	1.75
Examination Room	6	Multiple Rooming	5	Homes with All Open Windows	3
Retail Sales (Except as Noted Below)	1.5	Lecture Classroom	7	Libraries	1.5
Barbershop	1.5	Lecture Classroom	7	Music/Theater/Dance	2.5
Hair and Nail Salons	3.75	Supersupermarket	1	Office Office	20
Supermarket	1	Supersupermarket	1	Reception Area	1.25
Fast Food	6	Restaurants	2-6	Meeting/Conference Rooms	2
Bars	2-6	Restaurants	2-4	Trains	6
Restaurants	2-4	Restaurants	2-4	Buses	6
				Cars (Windows Closed)	6
				Cars (Windows Open)	19



# CEAT's ability in predicting Super Spreader Events



# Can we Improve the Computational Performance using GPUs ? (NekRS)

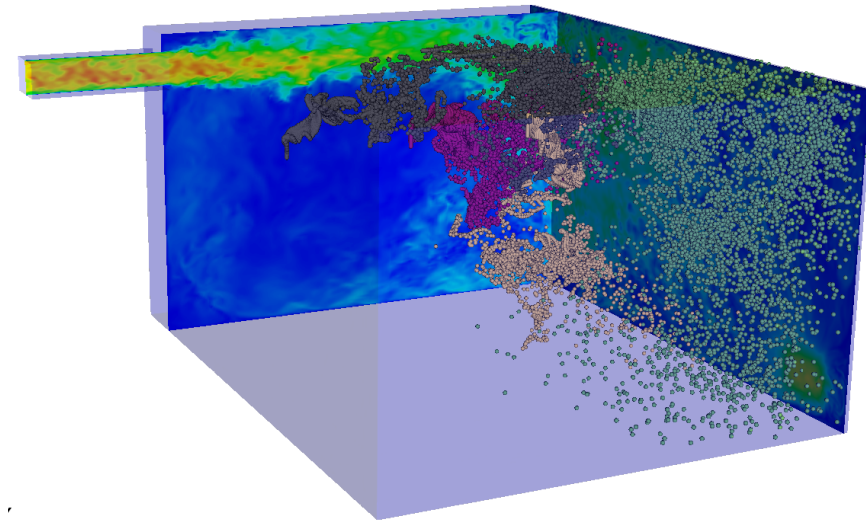
- Tests run on 10 nodes of Summit (60 GPUs)
- With a uniform distribution of particles
- **Migration** (Yes/No): Exchanges particle ownership so that each process owns the particles that are present in its elements. (using a fast all-to-all data exchange using *crystal router*)

Findpts implementation Migration particle count	GPU						CPU			
	Yes			No			Yes		No	
	100 <sup>3</sup>	150 <sup>3</sup>	200 <sup>3</sup>	100 <sup>3</sup>	150 <sup>3</sup>	200 <sup>3</sup>	100 <sup>3</sup>	150 <sup>3</sup>	100 <sup>3</sup>	150 <sup>3</sup>
Fluid Solve	98.2	98.1	98.5	99.2	98.2	107.5	97.9	98.7	101.2	100.1
Particle Creation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Particle Update	3.6	8.5	19.1	18.6	60.8	146.1	277.0	910.2	288.3	953.9
- Copy fluid vel. to host	-	-	-	-	-	-	15.7	13.9	16.4	15.5
- findpts	2.7	6.4	14.3	8.9	29.0	69.1	225.3	746.5	234.1	775.9
- - Memcpy	0.4	0.7	1.2	0.8	1.8	4.2	-	-	-	-
- - Kernel	1.8	4.9	11.3	1.9	6.4	14.6	219.7	735.7	220.4	734.7
- migration	0.1	0.1	0.3	-	-	-	0.1	0.2	-	-
- findpts_eval	0.6	1.3	3.1	9.4	31.0	74.9	49.7	158.5	54.0	177.1
- - Memcpy	0.2	0.4	0.9	0.3	1.0	2.0	-	-	-	-
- - Kernel	0.5	0.9	2.2	0.3	0.8	1.4	49.6	158.5	43.2	141.9
- Advance position	0.2	0.5	1.2	0.2	0.5	1.3	0.2	0.5	0.1	0.5
- Barrier	0.0	0.1	0.2	0.1	0.3	0.8	1.8	4.4	0.1	0.3

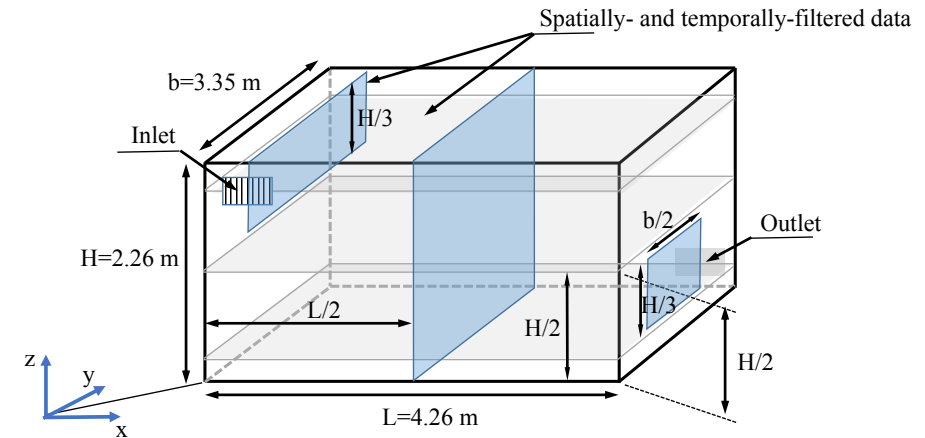


# Conclusions and Future Directions from Room-scale Simulations

- We are conducting some of the first high-fidelity turbulence resolved simulations of aerosol transport in indoor environment.
- These simulations will be used as benchmark results to compare/improve lower-fidelity models (e.g. RANS based)
- Improved understanding of effect of aerosol size, release location, air-flow rates and evaporation on residence time and deposition pattern of virus-laden aerosols
- The high-resolution model results are being used to analyze and understand the large and small scale turbulent structure of the flow



Basic Measurement Setup



Temporal states: Development and Stationary





# Final Objective: Development of a robust Covid-19 Exposure Assessment Tool (CEAT)

**Part Step 1** Enter information that describes the Group.

Group's Infection Likelihood compared to the Community

The Group is composed of people who, prior to this activity, you estimate have a likelihood COVID-19 infection that is...	A	B
100x lower than the community's average due to their adhering to public health guidance on distancing, masking, and exposure to crowds/people.	<input type="checkbox"/>	<input type="checkbox"/>
10x lower than the community's average due to their adhering to public health guidance on distancing, masking, and exposure to crowds/people.	<input type="checkbox"/>	<input type="checkbox"/>
Equal to the community average.	<input type="checkbox"/>	<input type="checkbox"/>
10x higher than the community's average due to their not adhering to public health guidance on distancing, masking, and exposures to crowds.	<input type="checkbox"/>	<input type="checkbox"/>
100 percent, since they are known to be diagnosed with active COVID-19.	<input type="checkbox"/>	<input type="checkbox"/>

Group's Vaccination Rate:  %  Click to apply Group's Vaccination Rate to the Exposure Calculations

Group members use of viral genome or protein surveillance testing

All members are tested within 3-days prior to event  All unvaccinated members are tested within 3-days prior to event  Testing not required (or testing status unknown)

**Step 2** Enter the number of people sharing the space for the activity. Must be between 2 and 250 people.

Number of People Sharing Activity Space:

**Step 3** Enter distance (Option 1) or select distance (Option 2)

Option 1:  ft  ft

Option 2:  ~15 ft  ~10 ft  ~6 ft  ~3 ft  ~1.5 ft

**Step 4** Select Mask Type and Prevalence of mask wearing

Filter Type	A	B
Fitted N95	<input type="checkbox"/>	<input type="checkbox"/>
N95/KN95	<input type="checkbox"/>	<input type="checkbox"/>
Double Surgical Mask	<input type="checkbox"/>	<input type="checkbox"/>
Surgical Mask	<input type="checkbox"/>	<input type="checkbox"/>
Average Mask	<input type="checkbox"/>	<input type="checkbox"/>
Cloth Mask	<input type="checkbox"/>	<input type="checkbox"/>
No Mask	<input type="checkbox"/>	<input type="checkbox"/>

% of People Wearing Masks:  %  %

**Step 5** Select Vocalization Intensity

Activity Exhalation Type  A  B

**Step 6** Select Breathing Rate

Activity  A  B

**Step 7** Enter the duration that most closely matches activity.

Duration of Activity in Hours:

**Step 8** Select whether outdoor or indoor

a. Outdoor:  A:  B:  Outdoor activities: Select wind conditions that best match.

	A	B
Moderate 13 - 18 mph Raises dust and loose paper; small branches are moved	<input type="checkbox"/>	<input type="checkbox"/>
Gentle 8 - 12 mph Leaves/small twigs in constant motion. wind extends light flag	<input type="checkbox"/>	<input type="checkbox"/>
Light 4 - 7 mph Wind felt on face, leaves rustle	<input type="checkbox"/>	<input type="checkbox"/>
Calm 1 - 3 mph Direction of wind shown by smoke drift	<input type="checkbox"/>	<input type="checkbox"/>
Very Calm 0.1 - 1 mph No direction or flow observed	<input type="checkbox"/>	<input type="checkbox"/>

b. Indoor:  A:  B:

Obtain the Air Changes per Hour (ACH) using Option 1 or 2:

- Option 1 - Use ACH provided by building engineers or H&S.
- Option 2 - from Table 1 on right, select the facility type and ACH that best matches the activity location.

Enter indoor ACH (or AER<sup>1</sup>) Values:

Indoor ACH

<sup>1</sup>ACH (Air Changes per Hour) is synonymous with AER (Air Exchange Rate [Exchanges/Hour])

c. Room Filtration

HEPA Filters  A  B

MERV 13  A  B

MERV 8  A  B

Select Flowrate Option:  
 Flow Option 1 - Use a default assumption of flow of filtered air of 1 cfm/ft<sup>2</sup>.  
 Flow Option 2 - Enter a specific filtration flow rate if known

Table 1: Typical ACH Values (Option 2)

Medical	ACH
General	6
Laboratory	6
Treatment room	6
Examination room	6
Retail	
Sales (except as below)	1.5
Barbershop	1.5
Hair and nail salons	3.75
Supermarket	1
Fast Food	6
Bars	2-6
Restaurants	2-4
Education	
Classrooms (ages 5 to 8)	2
Classrooms (age 9 plus)	2
Daycare (through age 4)	2.5
Multituse assembly	5
Lecture hall (fixed seats)	7
Lecture classroom	3
Libraries	1.5
Music/theater/dance	2.5
Office	
Office space	0.5
Reception Area	1.25
Meeting/ Conference Rooms	2
Manufacturing	
Manufacturing Floor	1.5
Residential	
Homes with closed windows	0.5
Rooms with one open window	1.75
Homes with all open windows	3

signature science LLC

CEAT COVID-19 Exposure Assessment Tool

Notes

Enter notes here

US Customary Units (US)  
23 January 2022 V B.34\_US BETA

Important: CEAT must be opened with Adobe Acrobat® or Adobe Reader® to function. See Page 2 for a technical summary and Page 3 for instructions.

**Step 10** Calculate Adjustment to Local Community's Current Conditions

Average Daily Cases per 100,000 in the Last Week:  → Average Days Infectious (Set to 5 if not known):  → Undiagnosed Factor for Area (Set to 3 if not known):  = Active Infections per 100,000<sup>2</sup>:

Variant Prevalence

WHO Variant Label	Estimate of Portion of Active Infections (%)	Comparative Increased Transmission versus Wild-Type Virus (%)
Alpha	<input type="text" value="0.00"/>	<input type="text" value="0.00"/>
Beta	<input type="text" value="0.00"/>	<input type="text" value="0.00"/>
Delta	<input type="text" value="2.00"/>	<input type="text" value="100.00"/>
Omicron	<input type="text" value="98.00"/>	<input type="text" value="940.00"/>

Immunity Prevalence

Population Vaccination Rate (%)	<input type="text" value="65.00"/>
Population Recovered (%)	<input type="text" value="35.00"/>
Protection Effectiveness of Immunity (%)	<input type="text" value="37.00"/>
Correlation Factor	<input type="text" value="0.60"/>

Results

Group-wide Exposure Ratio

	Lower Exposure	Medium	High	Very High
A	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
B	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Group-wide Exposure Ratio:

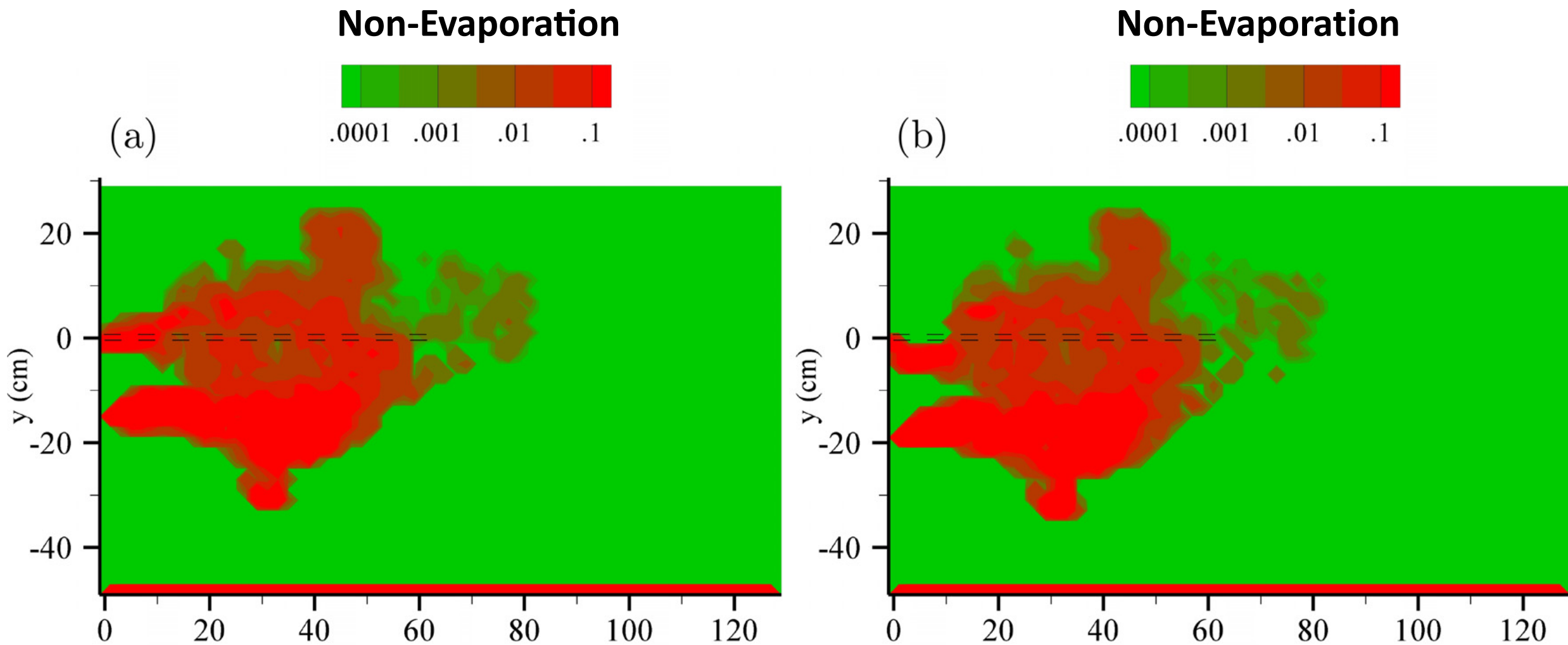
Near Field:

Far Field:

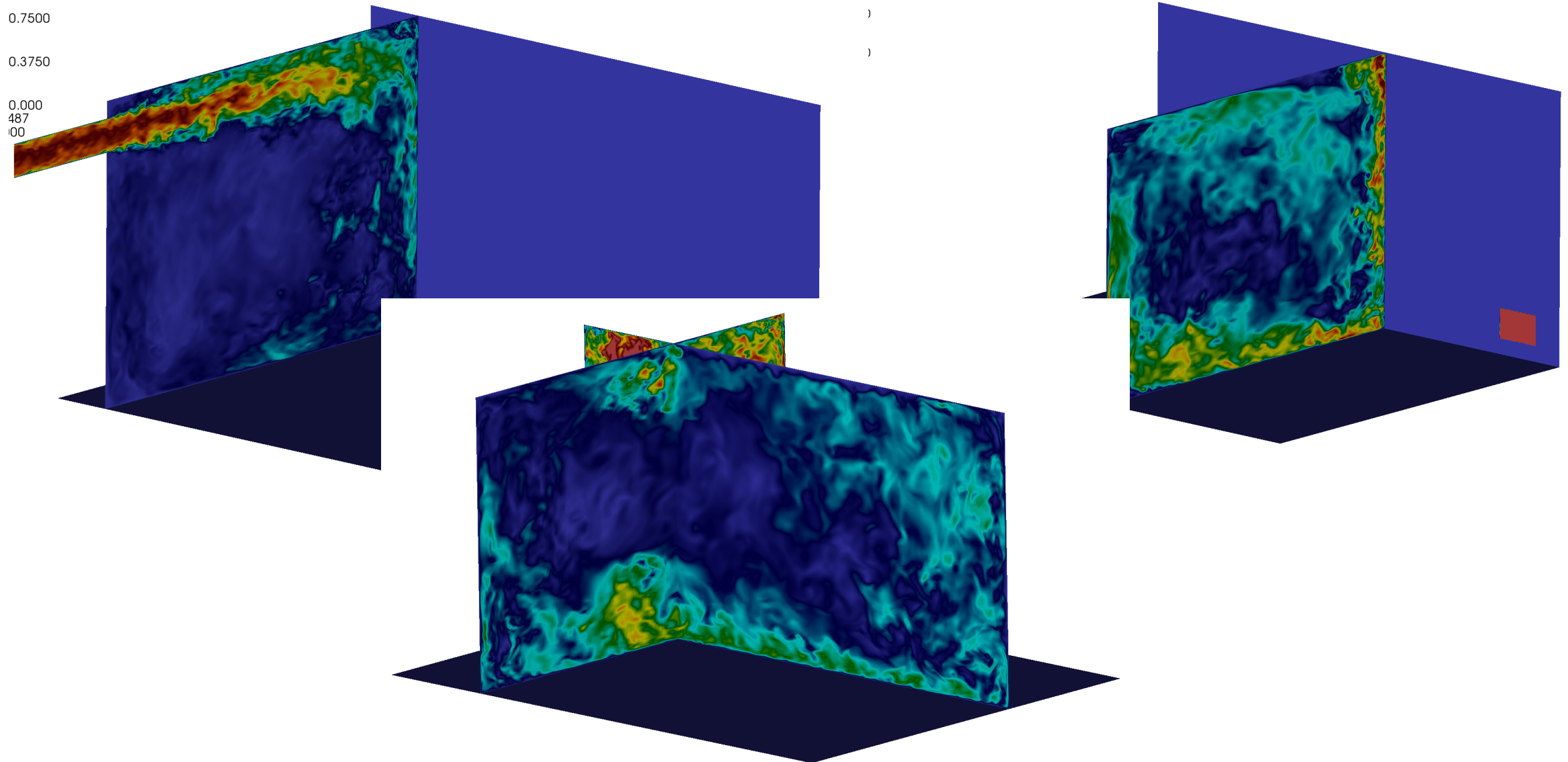
Individual (Indv.) Exposure Ratio:

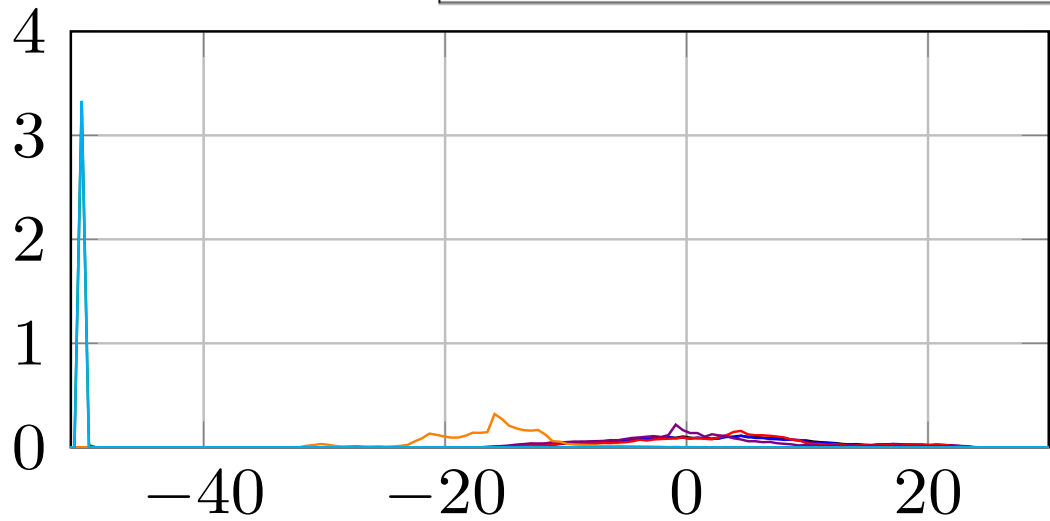
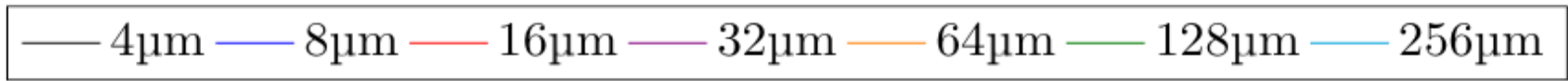
Indv. Dose (Quanta):   %

# Potential Viral Load (based on particle size and concentration) from the Cough

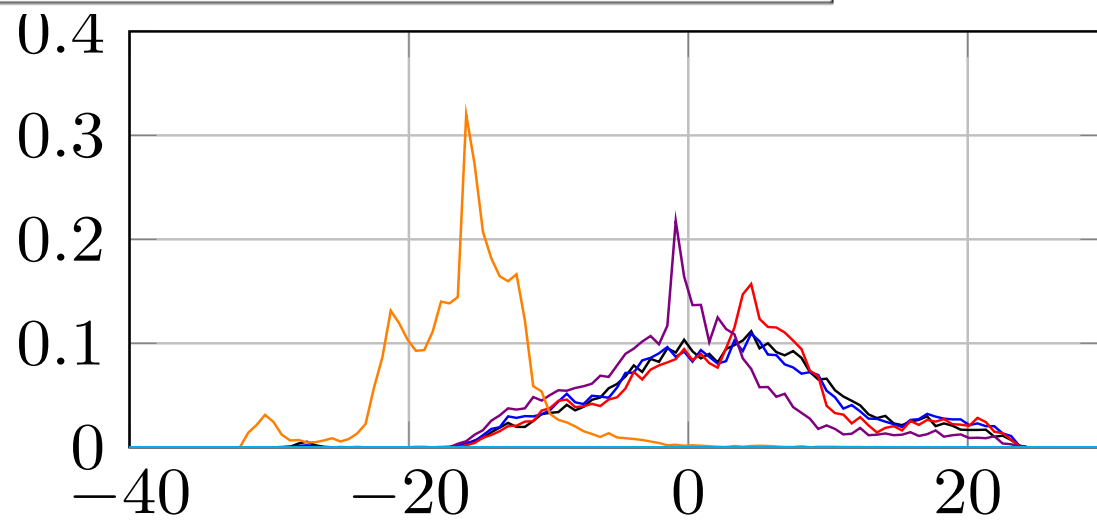


# Room scale flow structure at 6 ACH



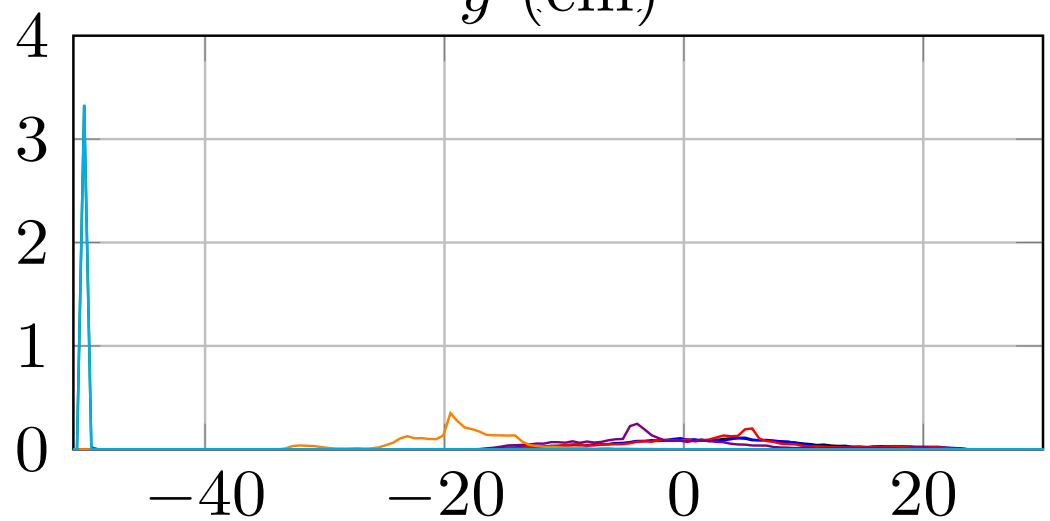


**Evaporation**

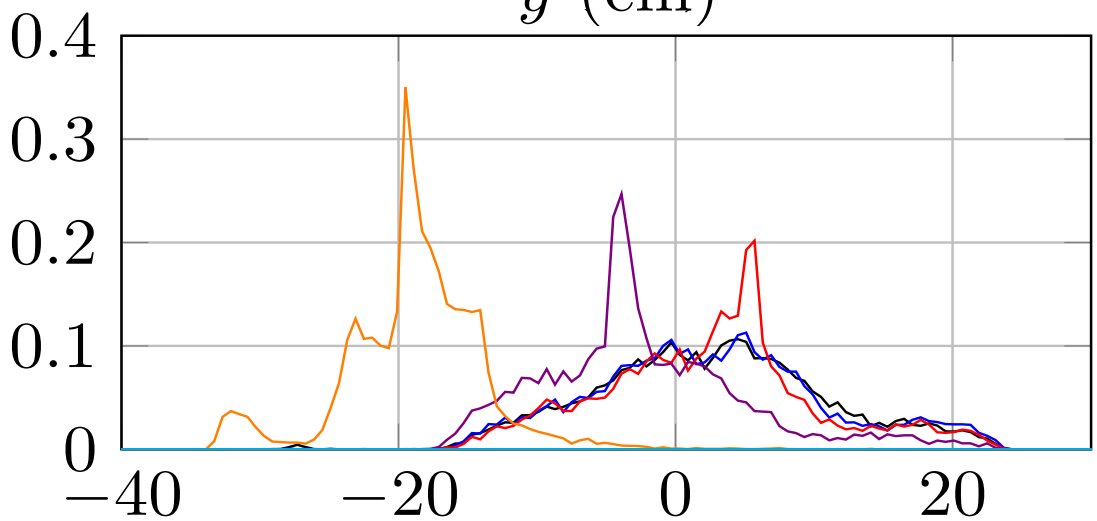


$y$  (cm)

$y$  (cm)



**Non-Evaporation**



$y$  (cm)

$y$  (cm)