

# AGP Shield

## CFD Study of Droplets and Aerosol Airpaths

**7<sup>th</sup> May 2020**

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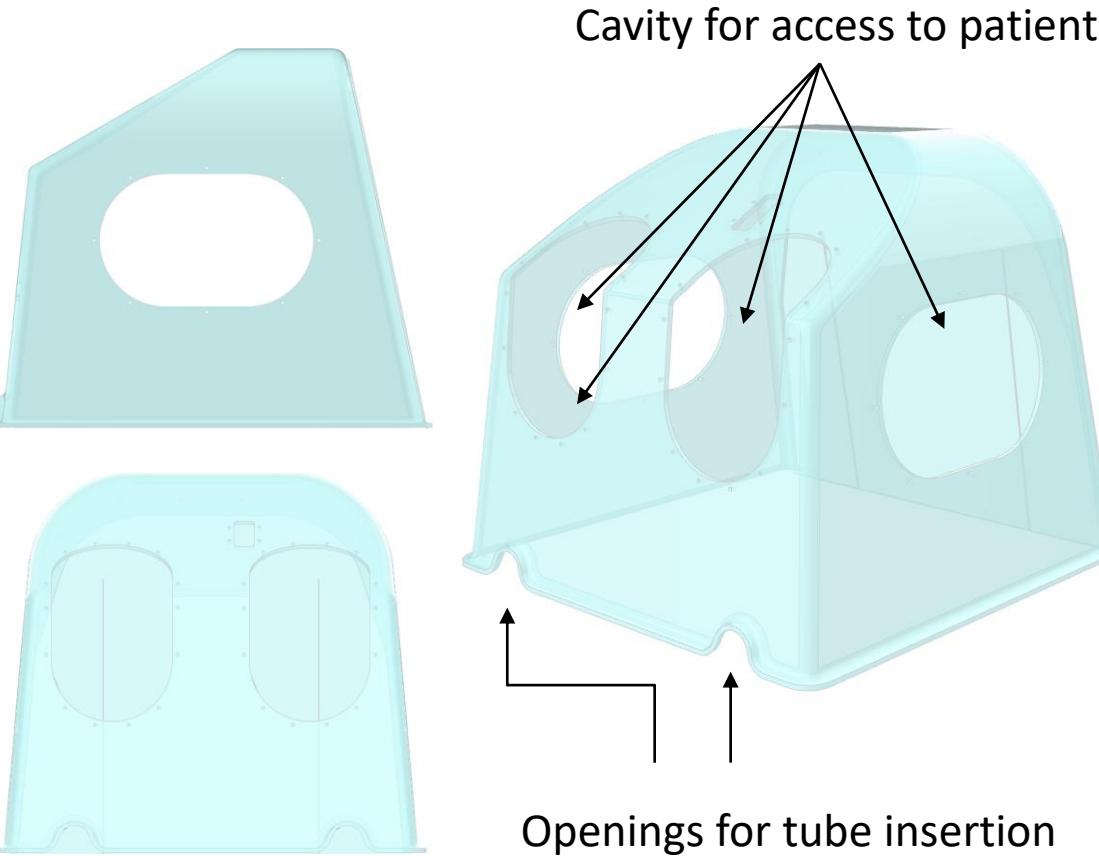


Figure 1: Shield model

Objective:

To simulate the airflow patterns and identify the trajectories of the viral particles emitted from a typical COVID-19 patient during coughing / normal passive breathing cycles; with the aim of optimising the location of a suction tube inside the AGP shield to maximise the capture of the airborne particles and minimise the dispersion of viral particles in the larger room.

Summary of the input parameters:

- Extraction from the box: 40, 80, 120, 160 l/min
- Ambient Temperature 23°C
- Cough particle velocity: 8 m/s
- Cough dispersion cone angle: 30°
- Particle model: inert, not affecting flow field
- Breath temperature: 35°C

Table 1: Particles released during a cough (as water droplets)

Particle diameter	No. particles
1 µm	410
2 µm	410
8 µm	36
20 µm	36
40 µm	36
200 µm	36
500 µm	36

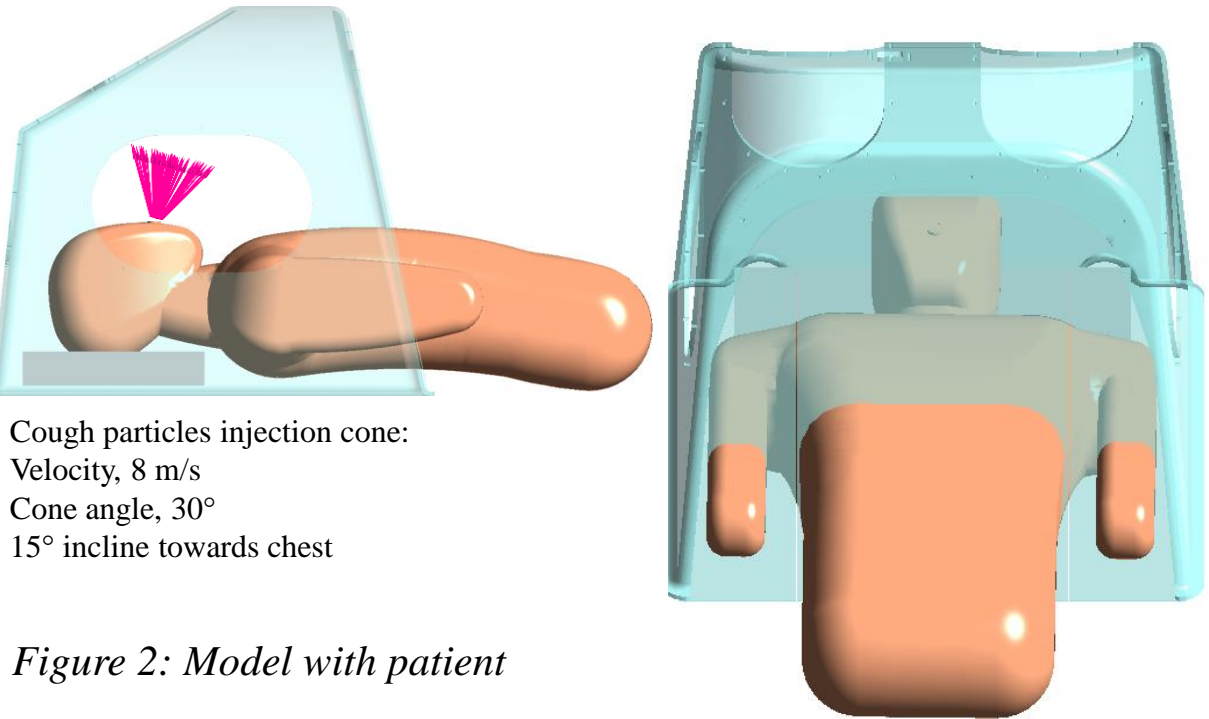


Figure 2: Model with patient

In this CFD study, a nominal 1000 particles (modelled as water droplets) ranging in size from 1 to 500 microns, are modelled during an initial cough and tracked in time. It is observed that the heavier droplets generally fall faster or land on the internal walls of the shield box and are thus taken out of the flow domain, whereas the tiny pathogens remain airborne and suspended for longer in the box until extracted. Apart from the standard Navier-Stokes equations governing the three-dimensional features of the fluid (conservation of mass, momentum and energy), the simulation also uses a Discrete Phase Model that tracks the individual particles in Lagrangian coordinates. The interaction of the particles with the airflow is modelled as a one-way coupling and applied as a post-processing exercise. This means the flow affects the momentum and energy of the particles, but the surrounding fluid flow remains unaffected by the particles motion.

# Model 1 – Suction tube vertically on the side, access cavities closed

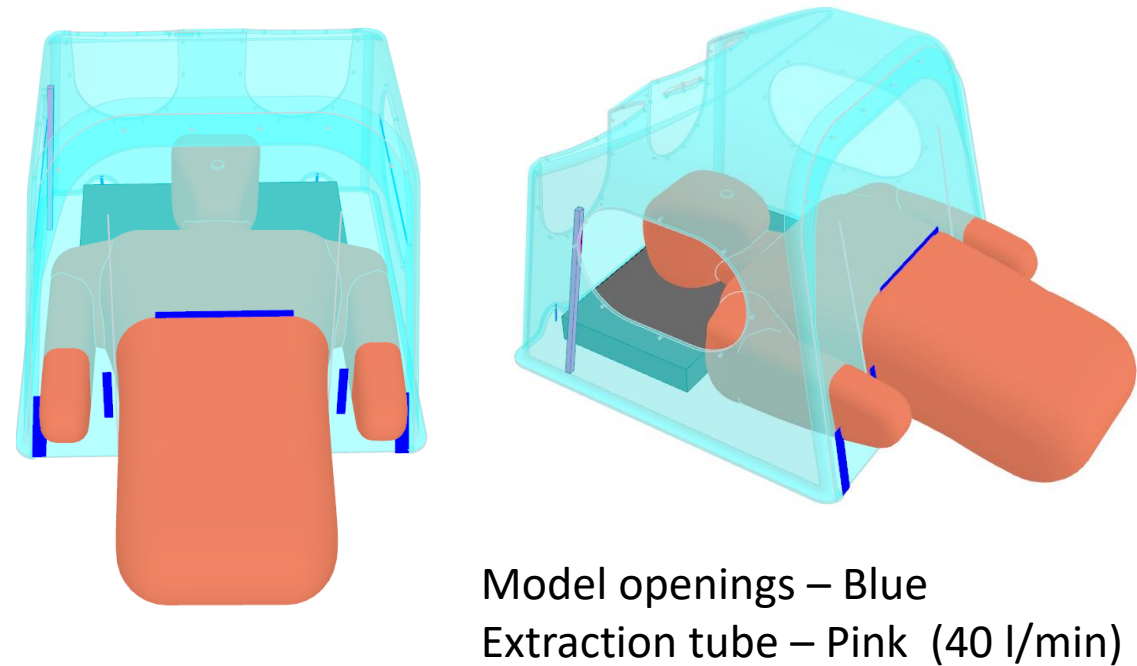


Figure 3: Model 1 boundary conditions

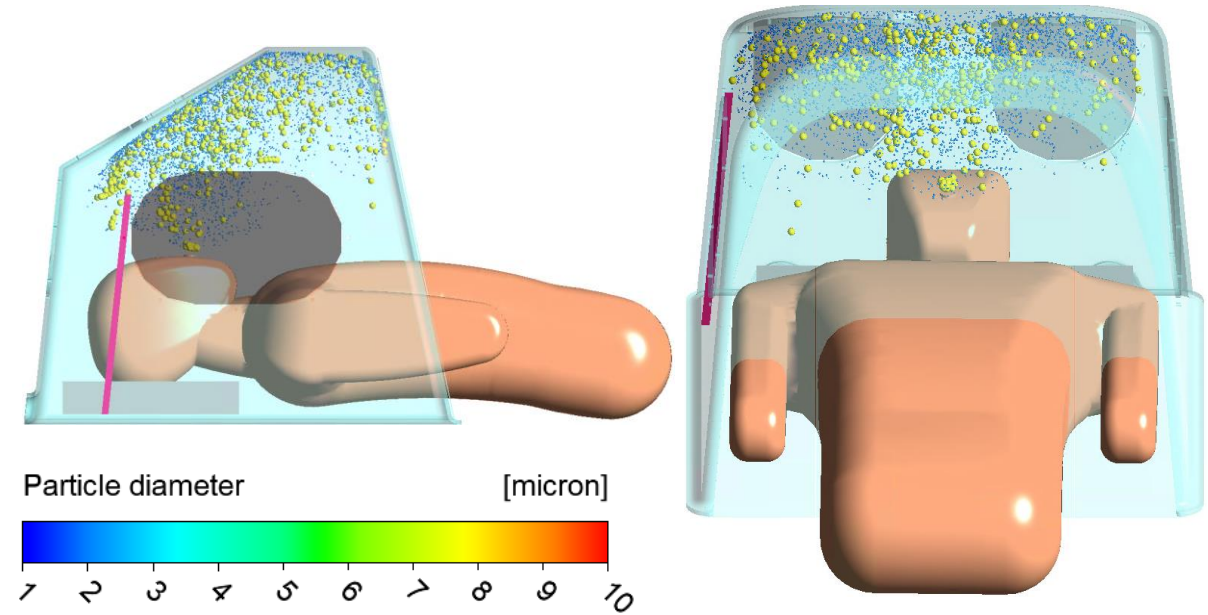


Figure 4: Airborne cough particle tracker, Model 1

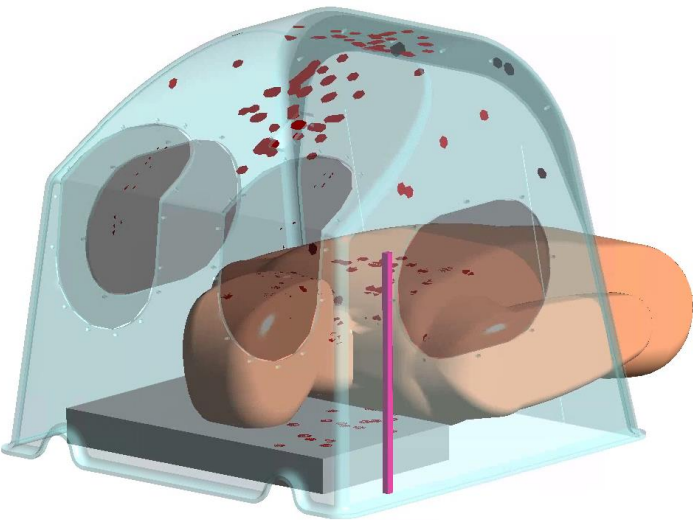


Figure 5: Trapped particles on internal shield surfaces, Model 1

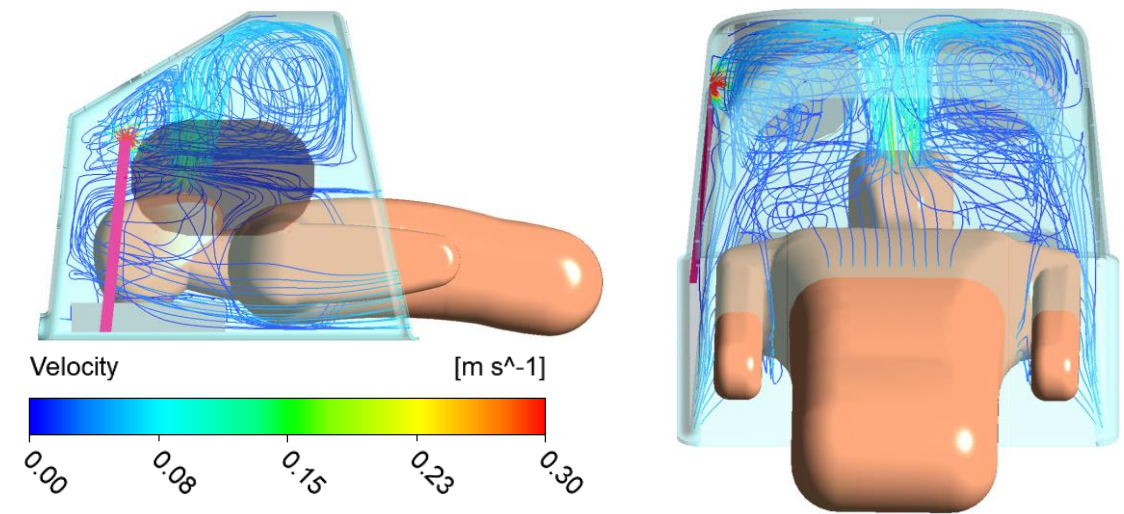


Figure 6: Velocity streamlines from pressure outlets, model 1

Table 2: Particle location, model 1

Particle diameter	No. particles trapped	No. particles extracted	No. particles escaped	No. particles floating
1 µm	37	366	0	7
2 µm	23	385	0	2
8 µm	4	32	0	0
20 µm	26	10	0	0
40 µm	36	0	0	0
200 µm	36	0	0	0
500 µm	36	0	0	0

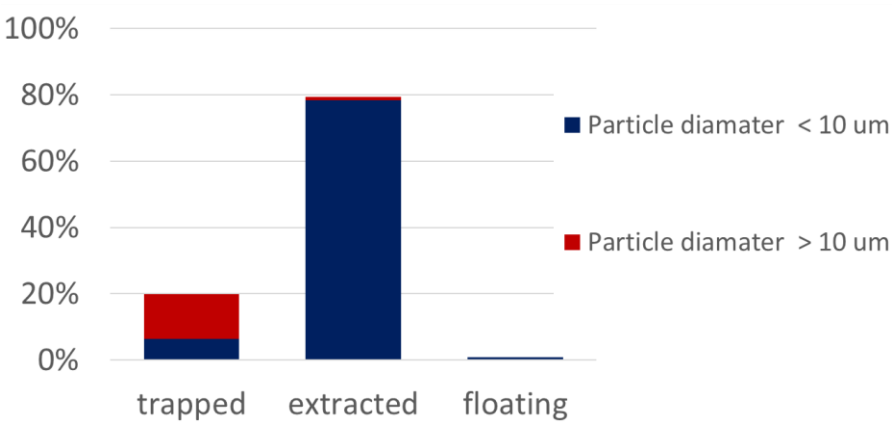


Figure 7: Particle distribution, model 1

## Findings of Model 1:

- With the suction tube placed vertically on the side, the AGP shield is highly effective in trapping and extracting particles (~99%)
- Of all particles, some 20% are trapped on the wall, 79% are extracted through the suction tube and 1% remain floating in the box.
- ~90% of the airborne particles ( $\leq 8 \mu\text{m}$ ) inside the shield box are extracted from the tube during first four and a half minutes of simulation time

# Model 2 – Suction tube horizontally on patient’s chest, access cavities closed

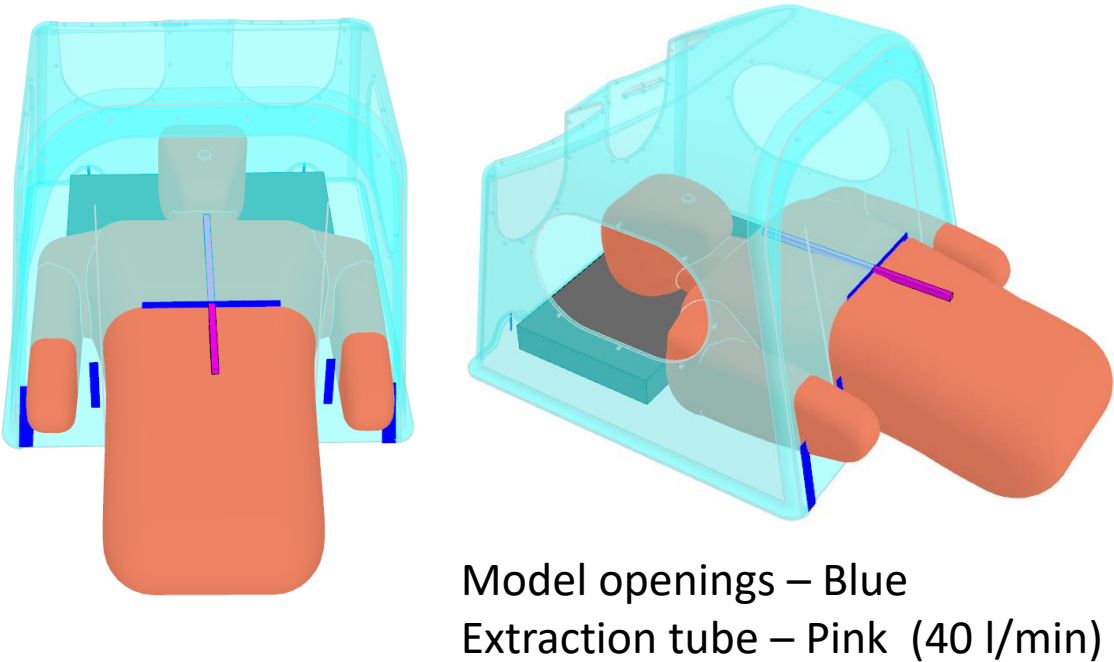


Figure 8: Model 2 boundary conditions

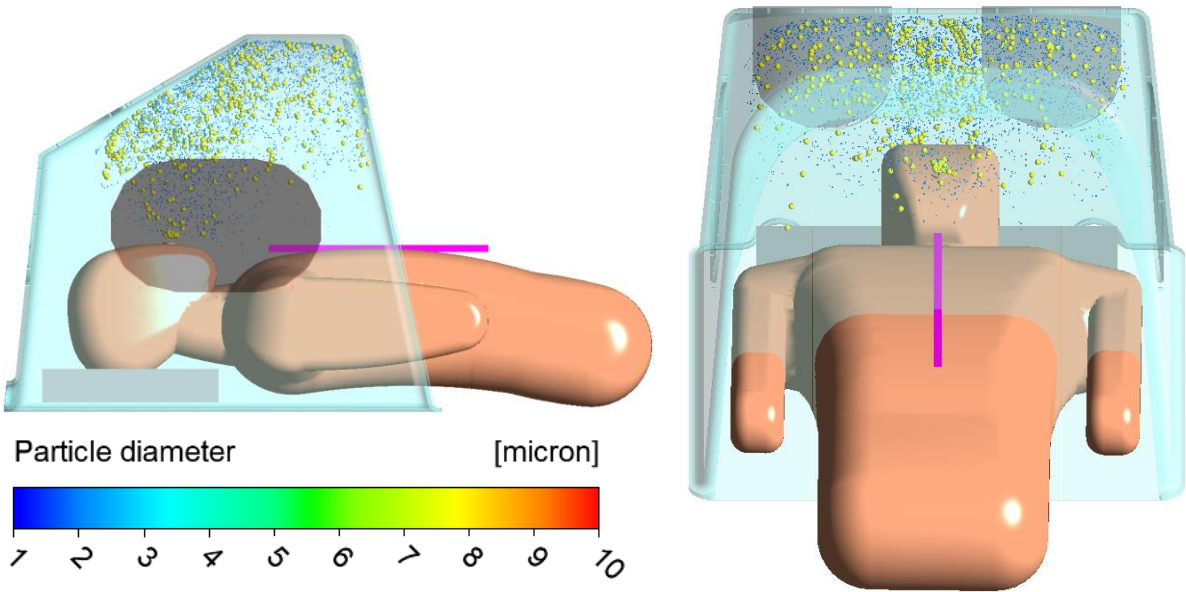


Figure 9: Airborne cough particle tracker, Model 2

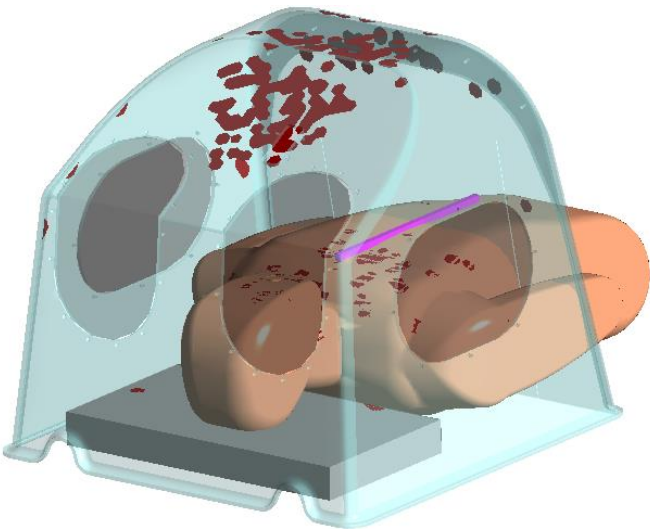


Figure 10: Trapped particles on internal shield surfaces, Model 2

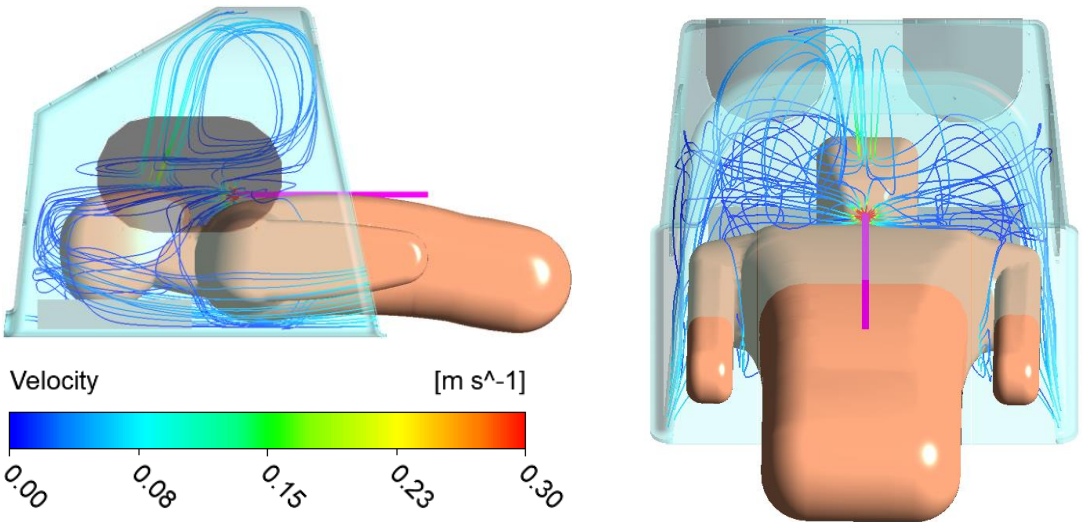


Figure 11: Velocity streamlines from pressure outlets

Table 3: Particle location, model 2

Particle diameter	No. particles trapped	No. particles extracted	No. particles floating	No. particles escaped
1 µm	94	246	47	23
2 µm	84	263	30	33
8 µm	7	29	0	0
20 µm	19	17	0	0
40 µm	33	3	0	0
200 µm	36	0	0	0
500 µm	36	0	0	0

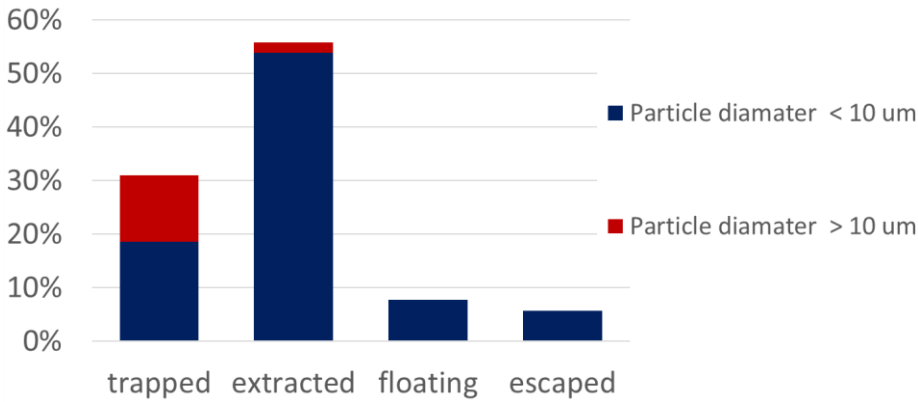
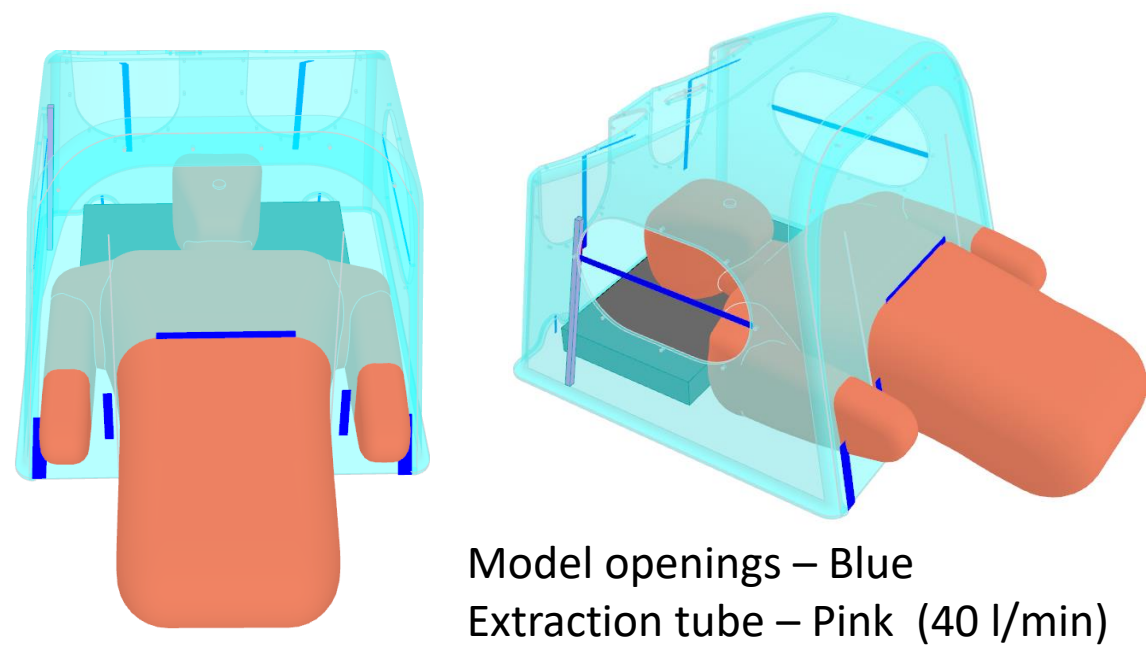


Figure 12: Particle distribution, Model 2

## Findings of Model 2:

- Placing the extraction tube horizontally on the patient’s chest, changes the airflow patterns and deteriorates the purging performance.
- Of all particles, some 31% are trapped on the wall, 56% are extracted through the suction tube, 7% still remain floating in the box and 6% escape.
- The suction tube on the chest is less able to draw air through the entire volume of the box and extracts fewer particles.
- It is important to ensure the dominant airflow is away from the body, so that the air entering through the air gaps purge the box as far as possible.
- More particles are trapped on the body and shield walls as the air is drawn towards the patients chest.

# Model 3 – Suction tube vertically on the side, access cavities semi-open



Model openings – Blue  
Extraction tube – Pink (40 l/min)

Figure 13: Model 3 boundary conditions

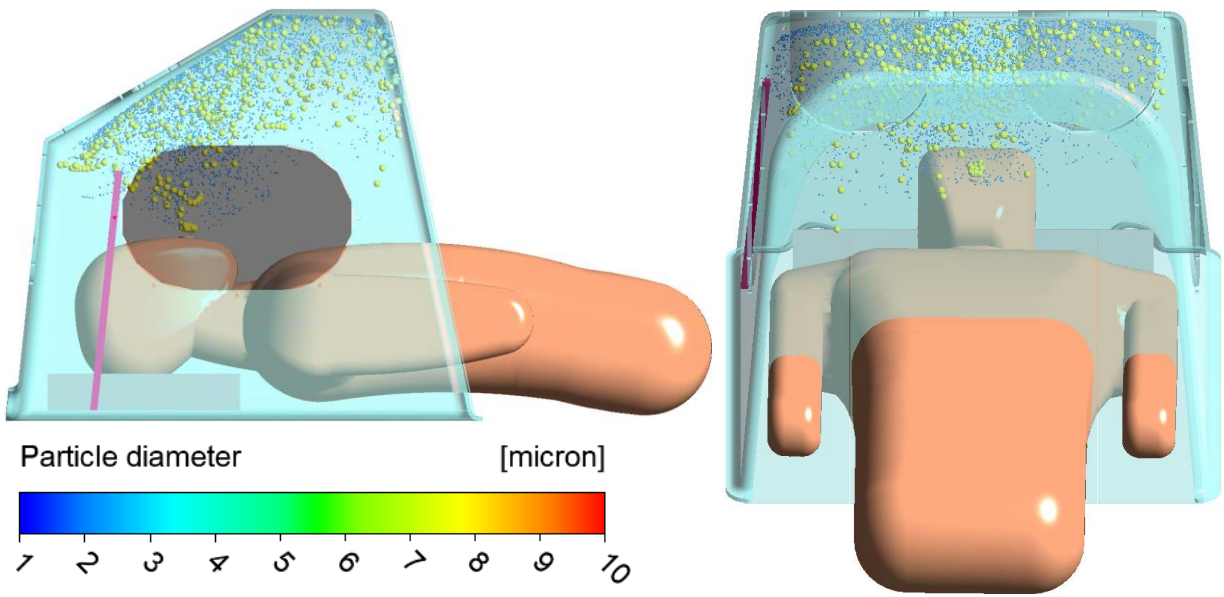


Figure 14: Airborne cough particle tracker, Model 3

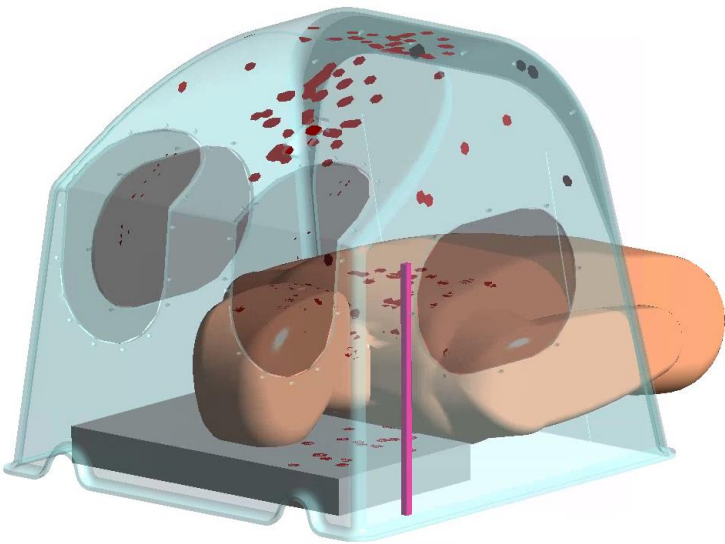


Figure 15: Trapped particles on internal shield surfaces, Model 3

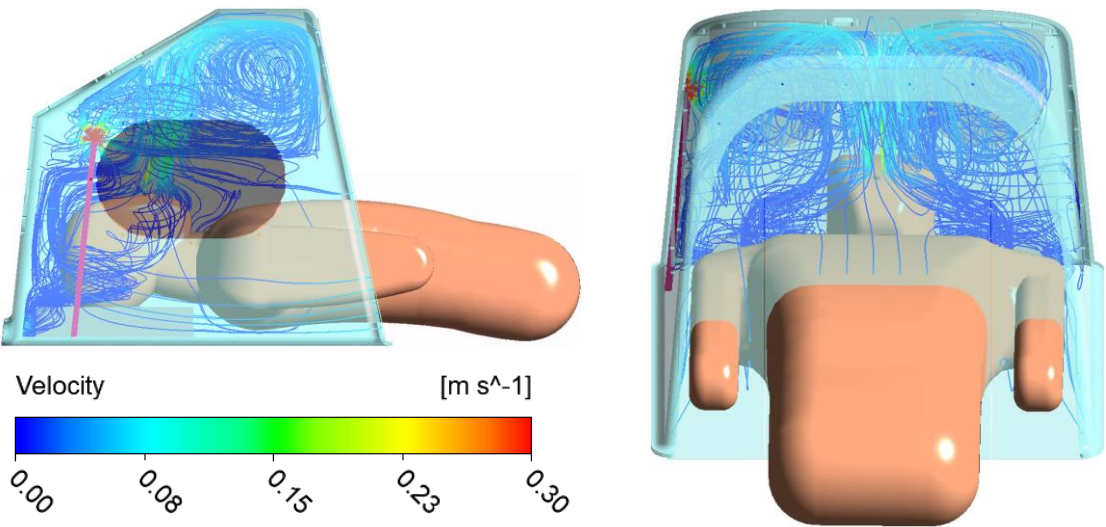


Figure 16: Velocity streamlines from pressure outlets, Model 3

Table 4: Particle location, Model 3

Particle diameter	No. particles trapped	No. particles extracted	No. particles escaped	No. particles floating
1 µm	50	209	151	0
2 µm	34	212	163	1
8 µm	2	22	12	0
20 µm	29	6	1	0
40 µm	36	0	0	0
200 µm	36	0	0	0
500 µm	36	0	0	0

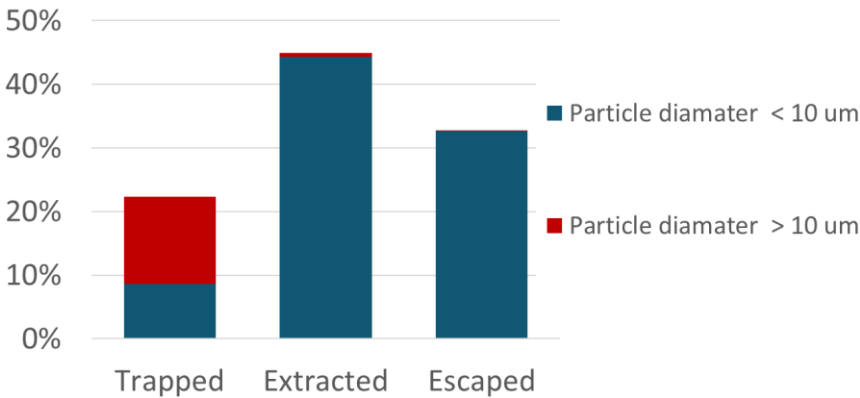
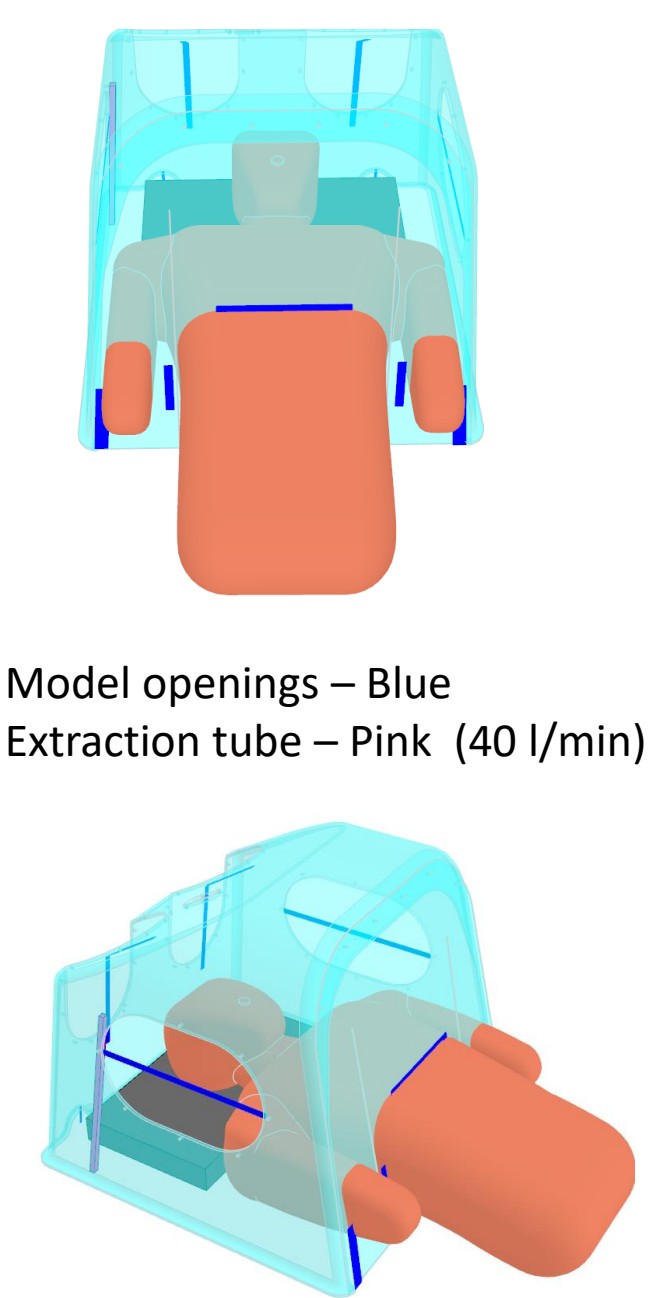


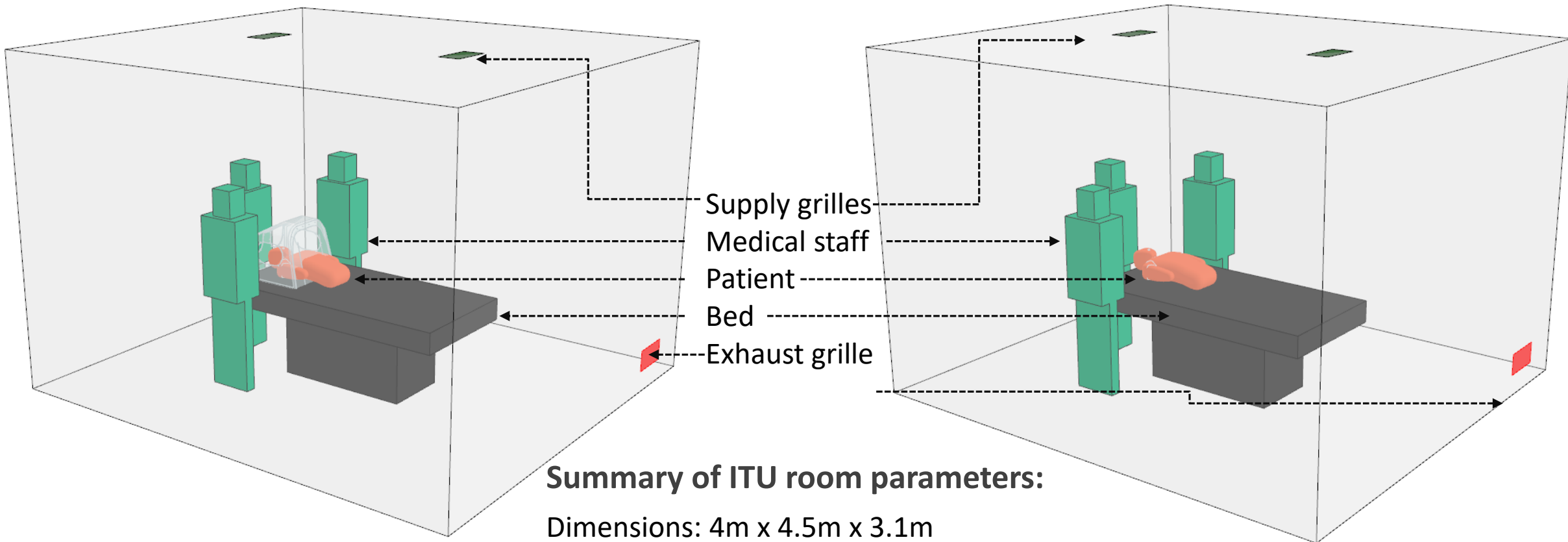
Figure 17: Particle distribution, Model 3

## Findings of Model 3:

- The effectiveness of the shield reduces when the access cavities are opened, especially sensitive to the access point from the top.
- In this scenario ~99% of the large particles are either trapped in the shield or extracted through the suction.
- The shield and extraction are effective in clearing two thirds of the total particles.



Model openings – Blue  
Extraction tube – Pink (40 l/min)



**Summary of ITU room parameters:**

Dimensions: 4m x 4.5m x 3.1m  
Air change rate: 10 air changes per hour  
Ambient Temperature: 23°C

Figure 19: Intensive treatment unit with shield (left), without shield (right)

Figure 18: AGP shield boundary conditions in ITU room

**Aim:**

To highlight the effectiveness of using the AGP shield during intubation/extubation of patient, an ITU room with 10 air changes per hour was simulated, both with and without the presence of an AGP shield. From the previous 3 analyses, the AGP model selected for this simulation is Model 3, suction mounted vertically with access cavities semi-open.

# Particle Distribution

## *Shield vs no Shield*

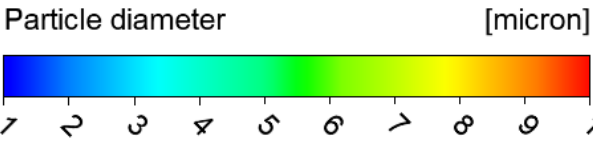
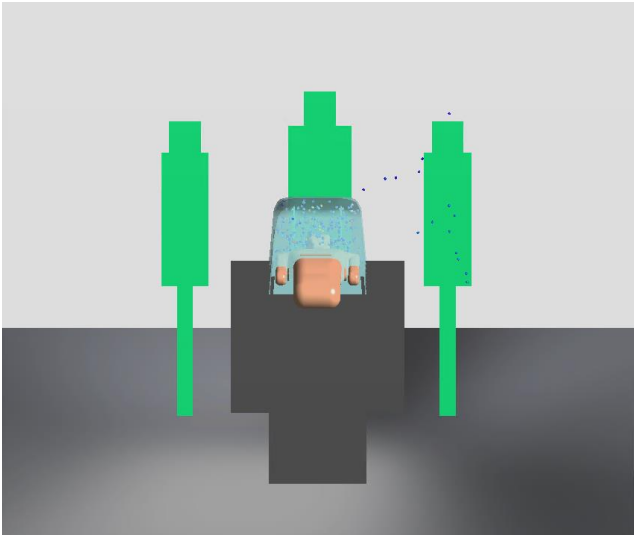
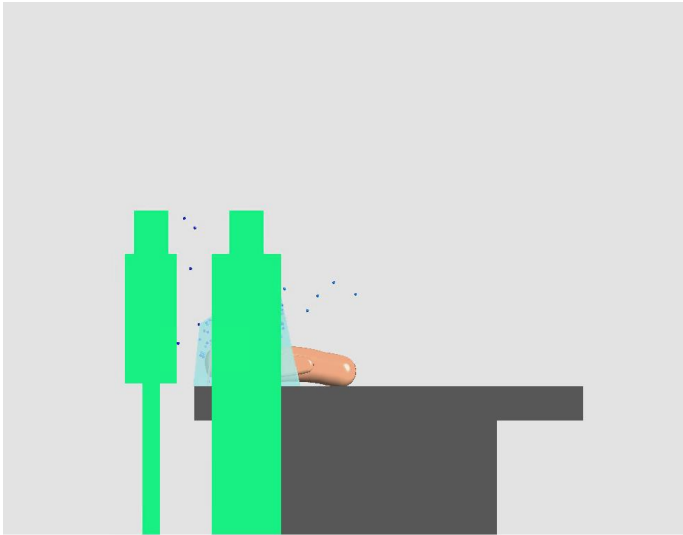
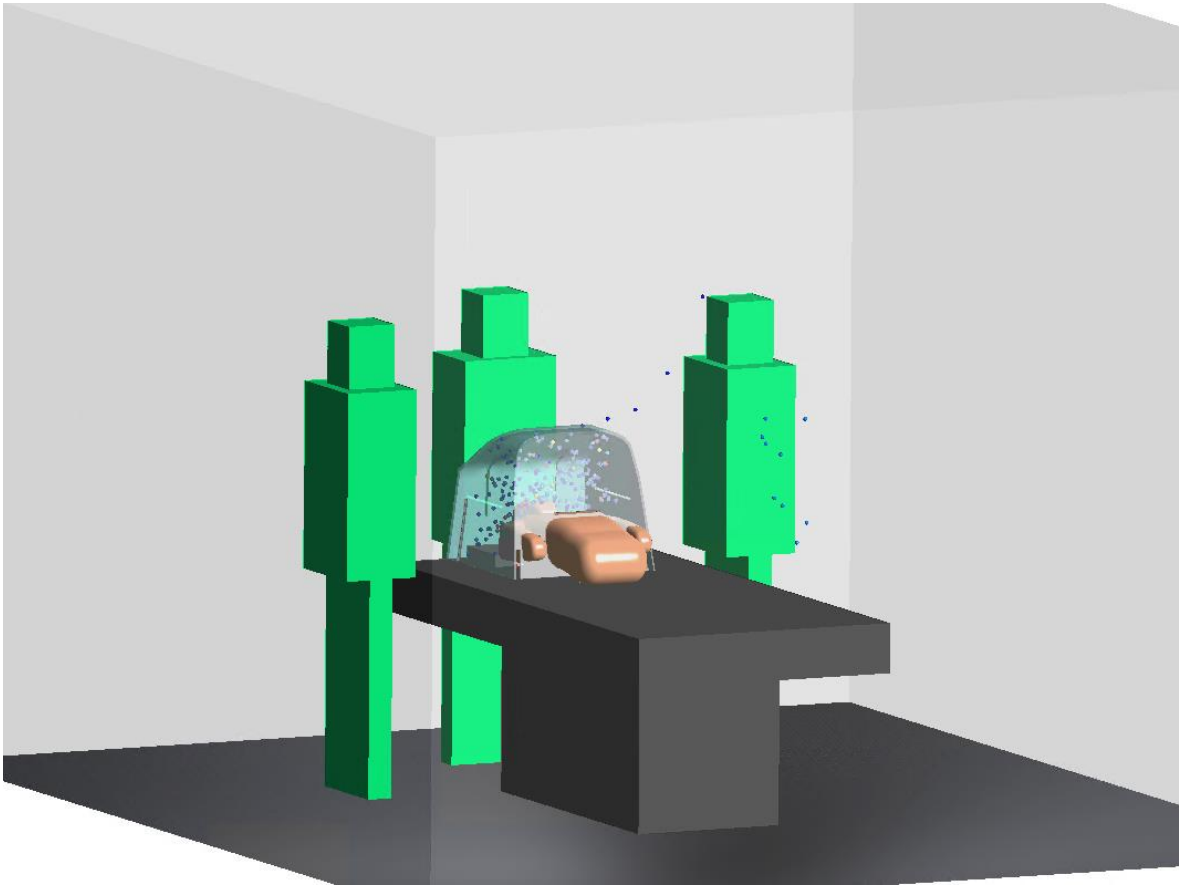


Figure 20: Airborne cough particle tracker, with AGP shield

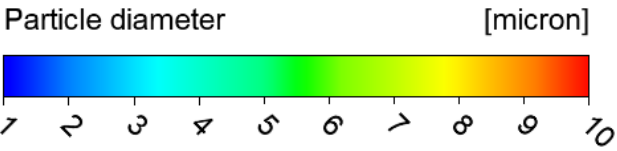
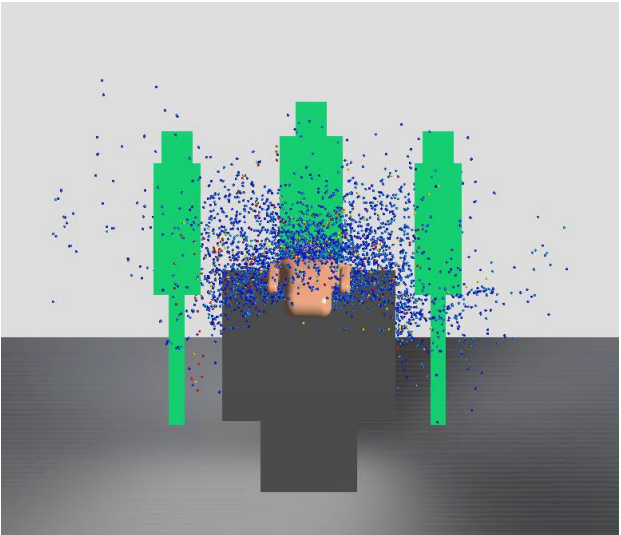
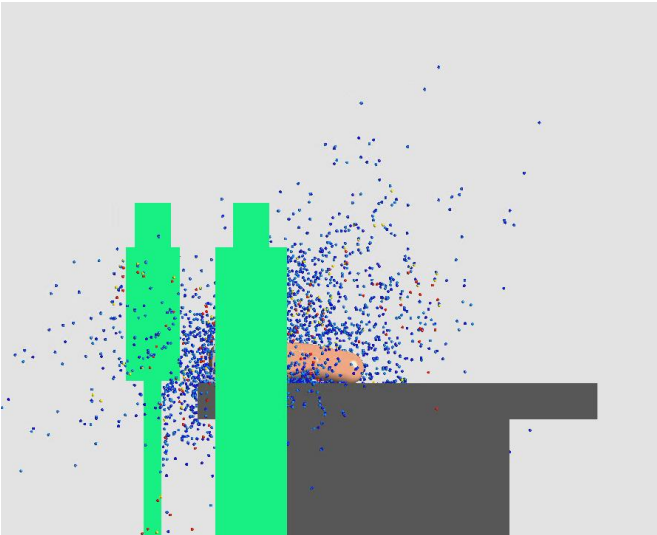
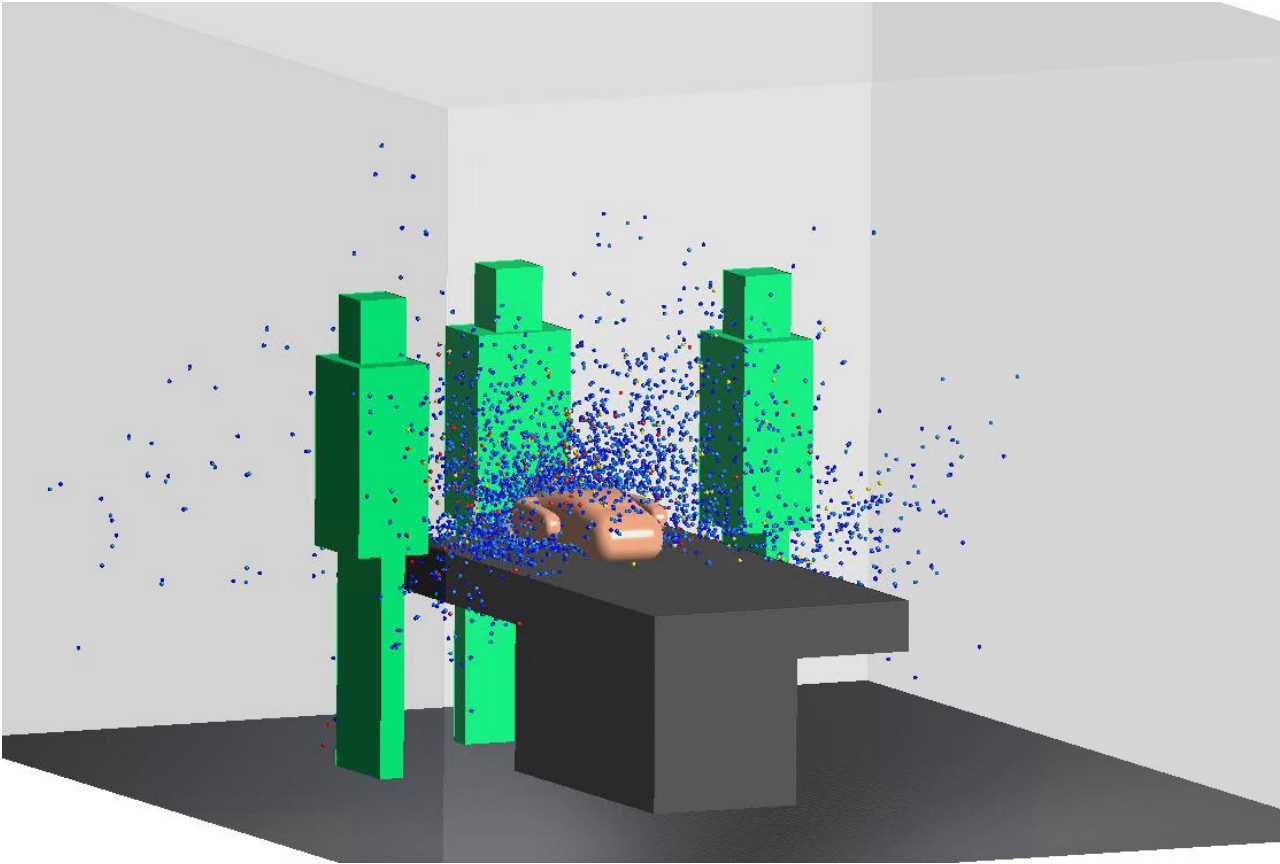


Figure 21: Airborne cough particle tracker, without AGP shield

### Parametric study aim:

To analyse the effect of increasing the extraction rate on removing aerosolised particles

Table 5: Parametric study, Model 1

Extraction rate (l/min)	Particles trapped	Particles extracted	Particles floating	Particles escaped
40	20%	79%	1%	0%
80	19%	81%	0%	0%
120	16%	84%	0%	0%
160	18%	82%	0%	0%

Table 6: Parametric study, Model 3

Extraction rate (l/min)	Particles trapped	Particles extracted	Particles floating	Particles escaped
40	22%	45%	0%	33%
80	20%	62%	0%	19%
120	19%	68%	0%	13%
160	19%	80%	0%	1%

### Parametric study findings:

- The larger particles have enough momentum to travel until they stick to the top shield wall, hence 16-22% of particles are trapped in all simulations.
- Higher extraction rates increase the performance of Model 3 significantly (percentage of escaped particles decreases from 33% to 1%)
- Increasing the extraction rate has very little effect on Model 1, in which case the openings from the flaps are minimal.

### Conclusions

- The AGP shield box provides a cleaner, safer environment for frontline medical staff dealing with Covid-19 patients during intubation / extubation.
- Through the use of the already available suction tube, airborne pathogens can be removed from the space around the infected patient.
- The smaller, lighter particles ( $\leq 8 \mu\text{m}$ ) constituting the majority of the total particles ( $>82\%$ ) have smaller momentum and are carried by the flow field inside the box, as shown by velocity streamlines.
- The presence of the shield provides a physical barrier, capturing larger particles. These droplet particles discharged when coughing have much higher momentum, and thus stick on the walls of the shield.
- The suction tube is most effective in removing particles following a cough when it is placed vertically at the head side of the AGP shield.
- The high point of suction tube above the patient’s head performs well in purging the box volume.
- Note the study neglects the naturally occurring evaporation of the larger droplets. Including evaporation is expected to decrease the particle residence time in the box significantly.
- For optimum performance, attention must be paid to seal the top half of the drapes over the patient’s body, and allow air to leak in through gaps at the lower half of the drapes.