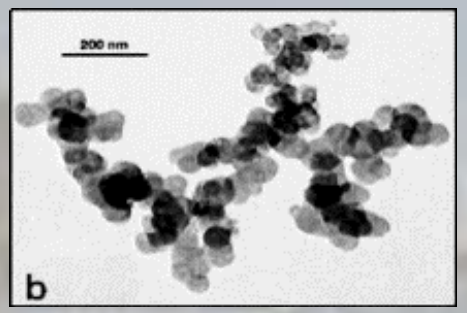
Transmission and Filtration of Bioaerosols

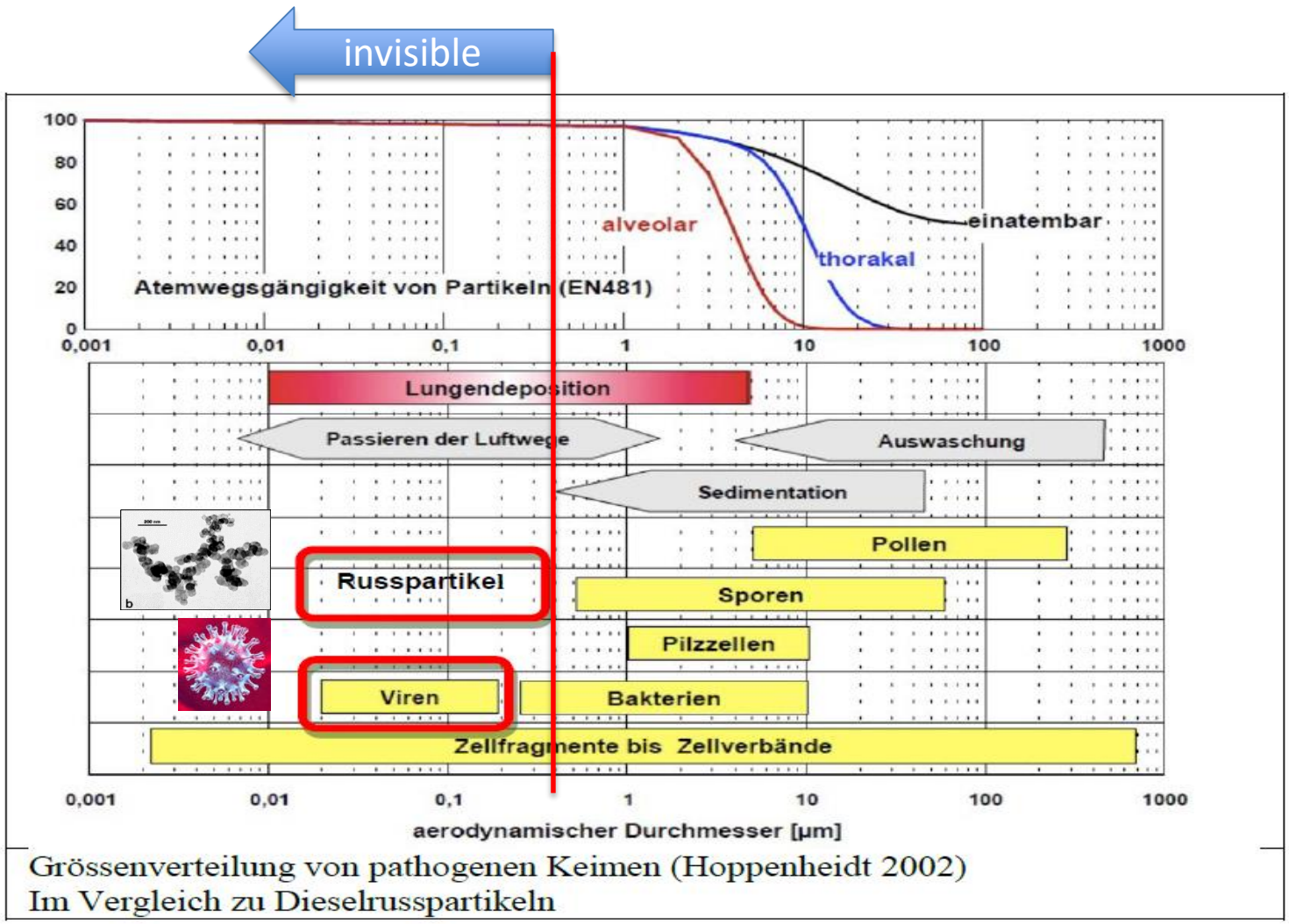
A new paradigma for cleaning air from indoor virus and from outdoor UFP contamination in one step



Andreas C.R.Mayer / NCA

Viruses are as small as diesel soot particles and form a similar very stable aerosol

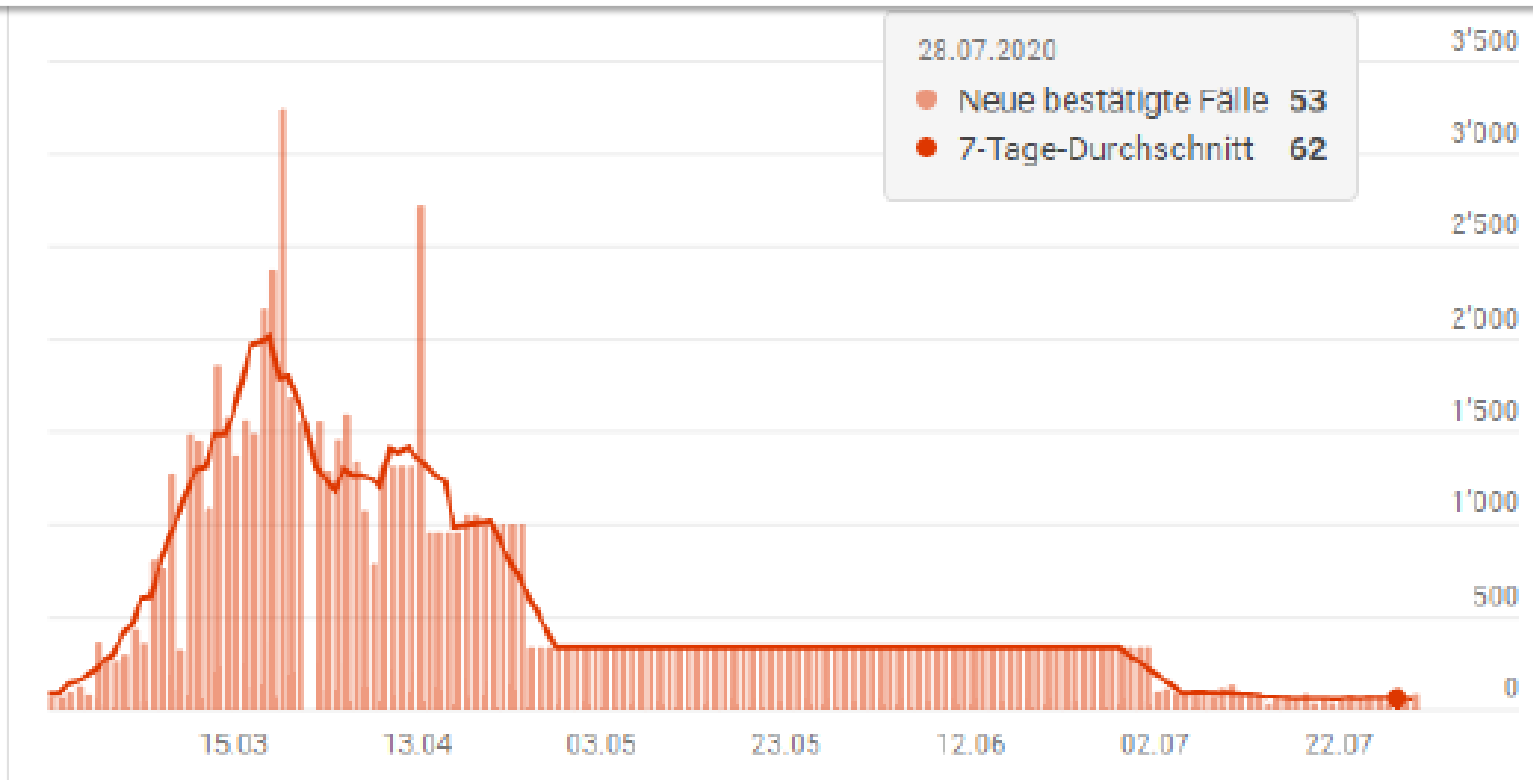
if they behave like soot particles → why not filter them as soot



Grössenverteilung von pathogenen Keimen (Hoppenheidt 2002)
Im Vergleich zu Dieselrusspartikeln

The kick off moment

teaming up with Virologists (Bern) and Microbiologists (Fribourg)



25.2.2000 mit Gehr/Frey – 2. März 200
mit Zürcher/BAFU zum Projektstart

Exhaled Air contains droplets of 5 µm

which evaporate within < 0.1 sec

remain a stable aerosol of virus clusters 50-200 nm

Größe [µm]	1	10	50	100	500	1000	2000
Verdunstungs-zeit 50% r.F. [s]	0.003	0.1	1.7				
Verdunstungs-zeit 70% r.F. [s]	0.006	0.2	2.8				
Verdunstungs-zeit 90% r.F. [s]	0.016	0.5	8.3				

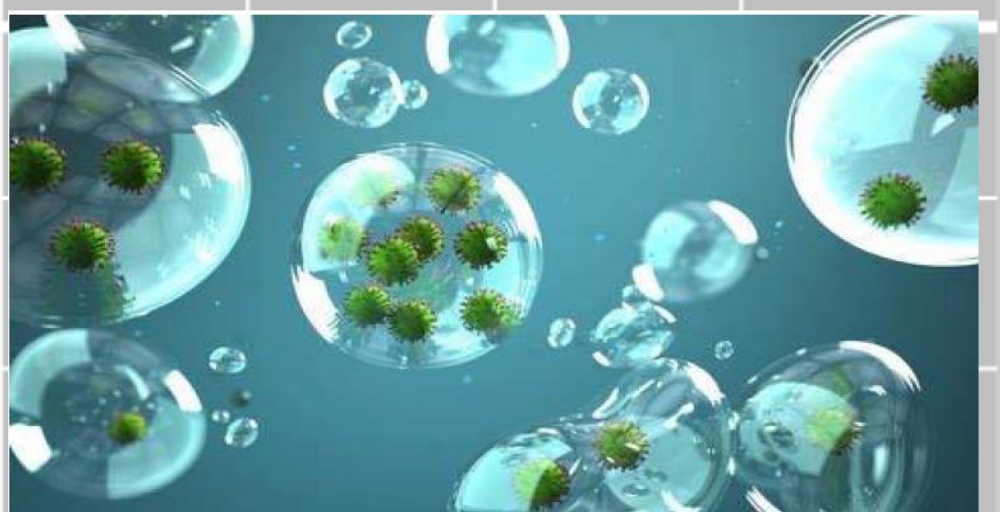


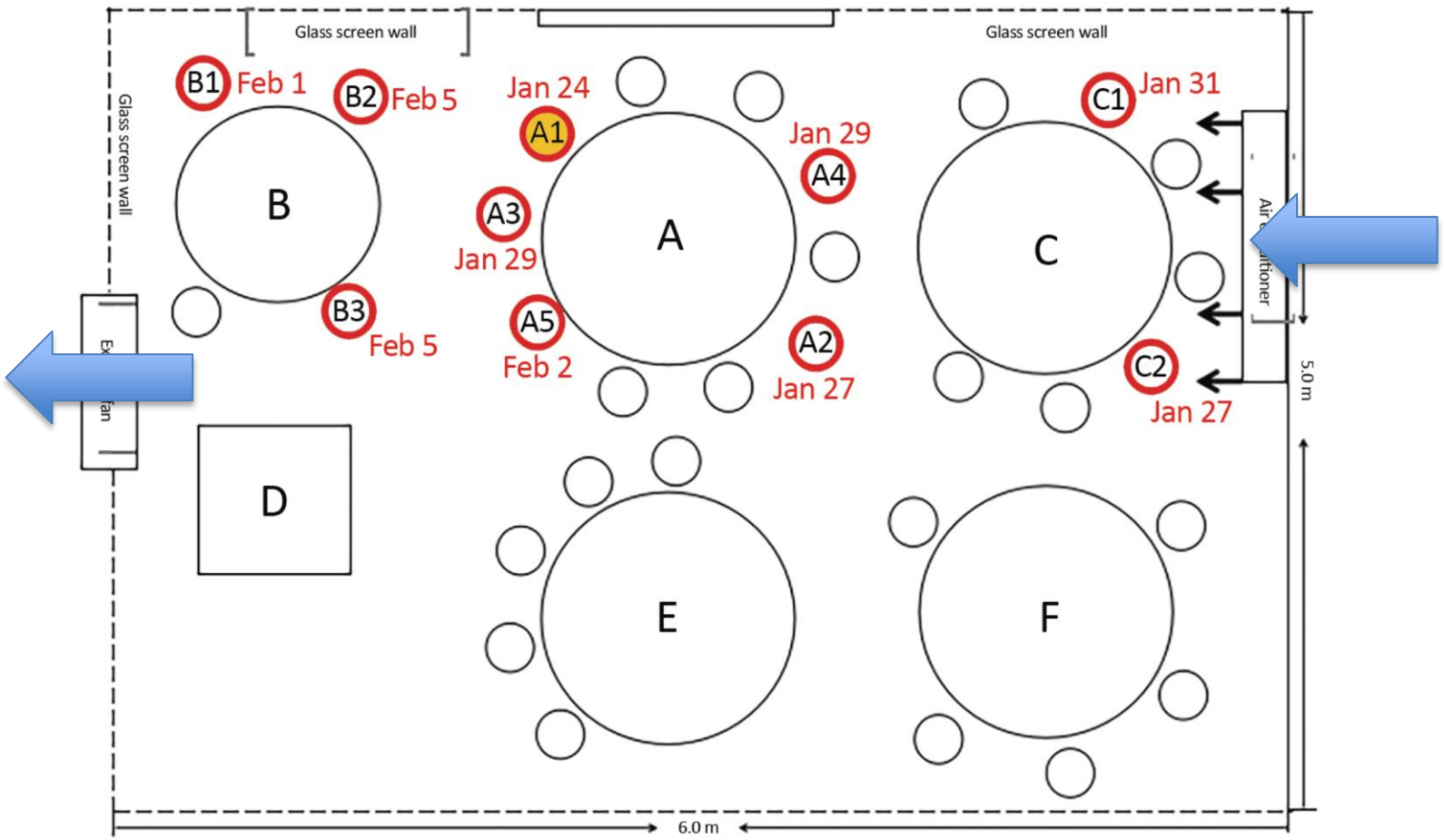
Tabelle 2: Zeiten in denen Tröpfchen der Dichte 1 g/cm³ bei ruhender Luft von 20 °C Temperatur und 1013 hPa Druck von der angegebenen Größe (in Mikrometern, µm) bis auf die Größe des SARS-CoV-2 Virus (140 Nanometer Durchmesser) durch Verdampfung schrumpfen. Berechnung ohne Ventilation.

F.Drewnick; Max Planck Institut für Chemie, Mainz April 2020

Clean air ventilated horizontally carries the virus from infected emitter to many receivers

Ventilation horizontal or vertical is not reducing but creating the risk

The negative effect of distribution is stonger than the positive effect of dilution



COVID-19 Outbreak Associated with Air Conditioning in Restaurant, Guangzhou, China, 2020

Jianyun Lu,[1] Jieni Gu,[1] Kuibiao Li,[1] Conghui Xu,[1] Wenzhe Su, Zhisheng Lai, Deqian Zhou, Chao Yu, Bin Xu, Zhicong Yang

Volume 26, Number 11—November 2020

Research

Centers for Disease Control and Prevention

Transmission of Severe Acute Respiratory Syndrome Coronavirus 2 During Long Flight

Superclean Air with 20 cabine air changes per hour is no protection
Clean air carries the virus from the infected person to many others

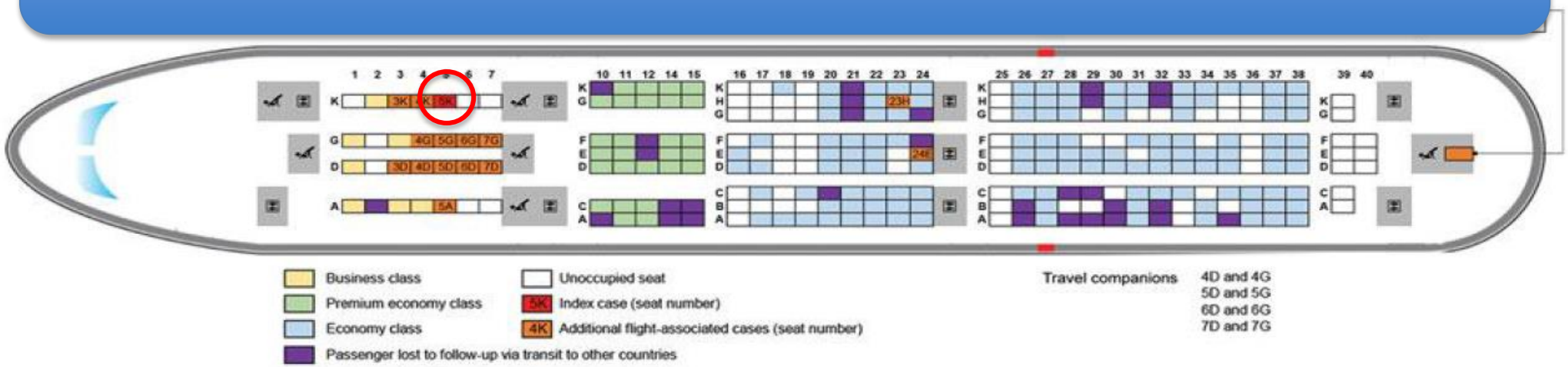


Figure 1. Seating location of passengers on Vietnam Airlines flight 54 from London, UK, to Hanoi, Vietnam, on March 2, 2020, for whom severe acute respiratory syndrome coronavirus 2 infection was later confirmed.

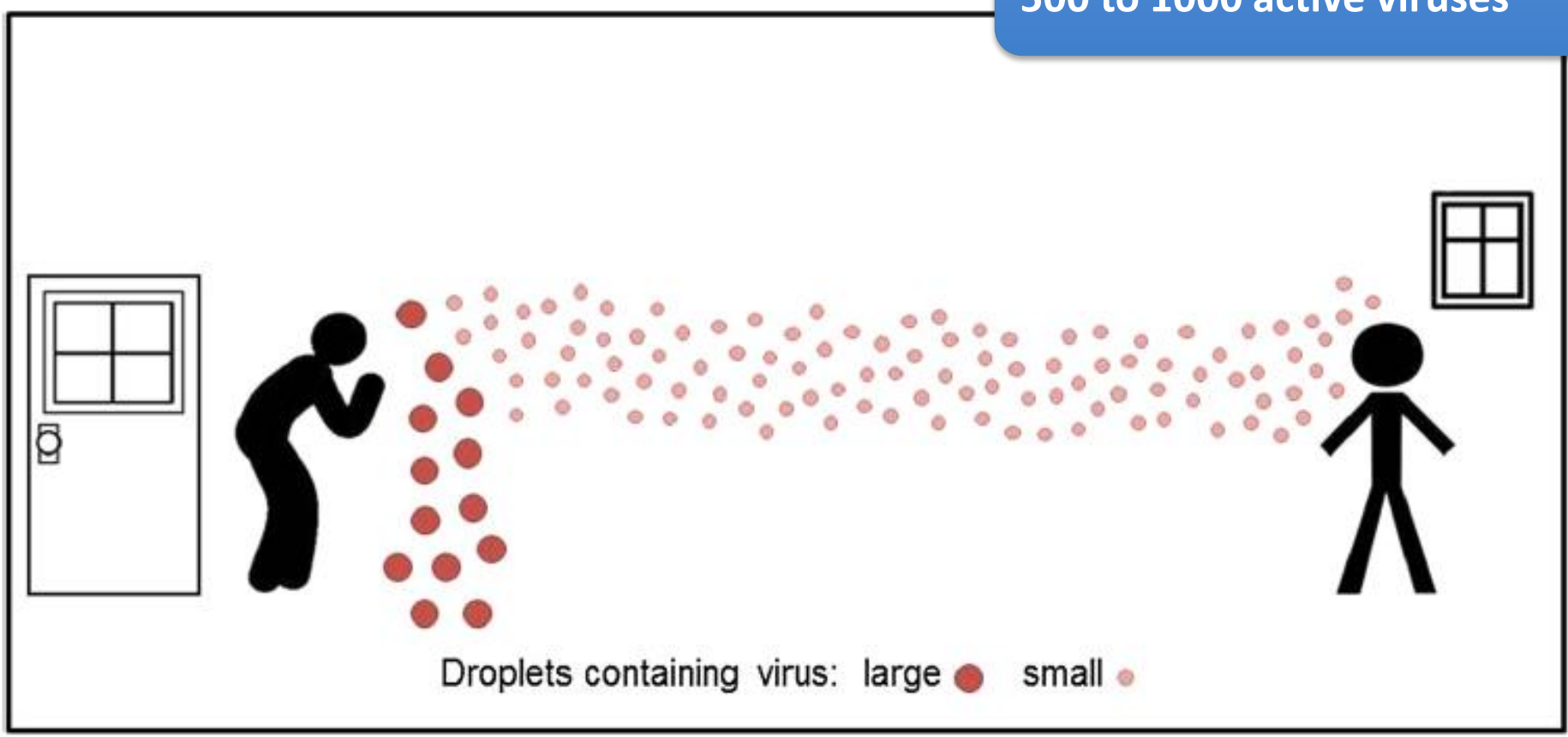
Among the 217 passengers and crew members on a direct flight from London to Hanoi in early March 2020, we identified a cluster of 16 laboratory-confirmed COVID-19 cases. In-depth epidemiologic investigations strongly suggest that 1 symptomatic passenger (case 1) transmitted SARS-CoV-2 infection during the flight to at least 12 other passengers in business class (probable secondary cases).

Opening the window may create a problem and not solve it

Emission of the infected person
> 10^7 viruses per m^3

to compare to

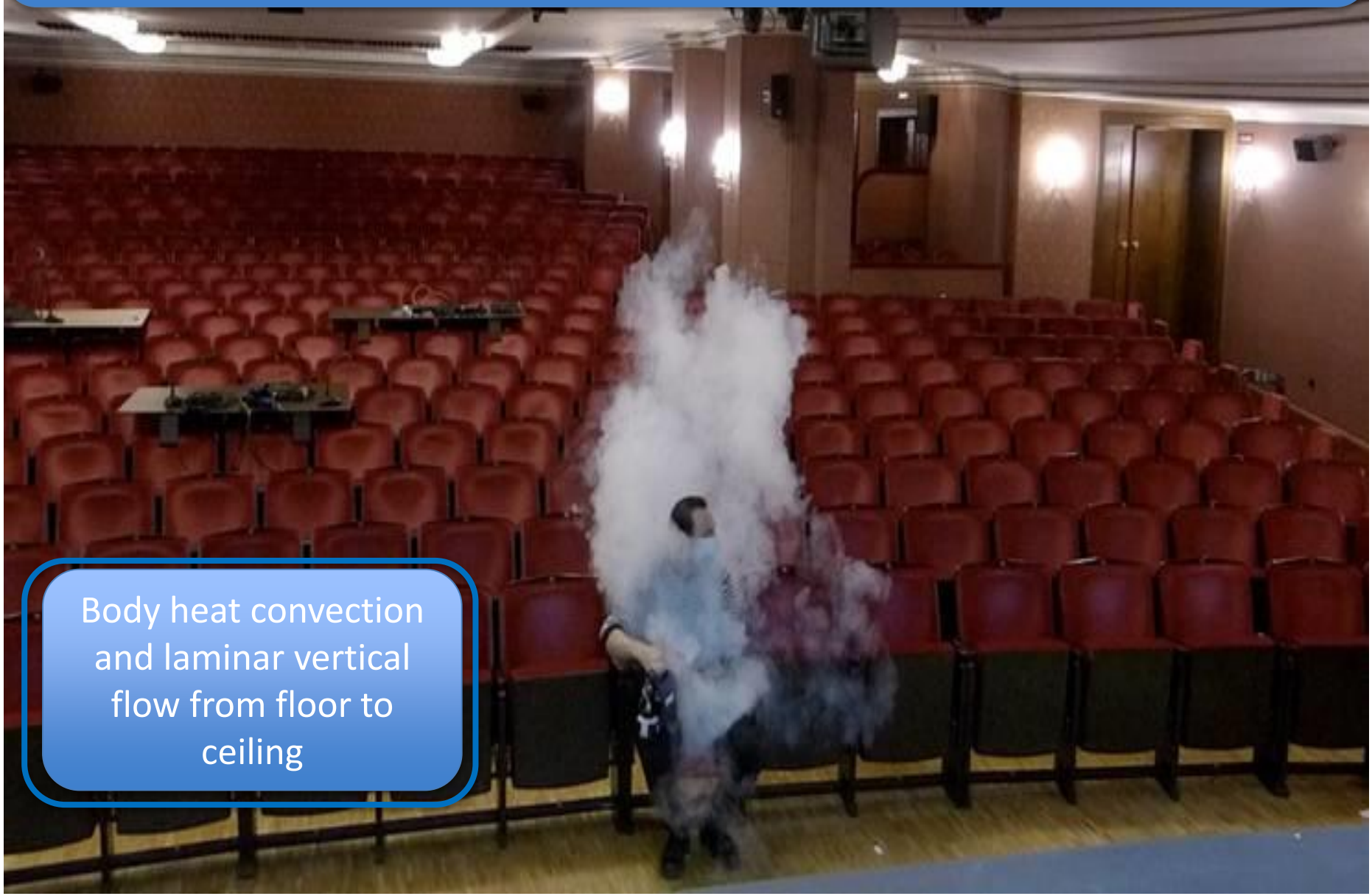
Infection Dosis:
500 to 1000 active viruses



L.Morawska, University Queensland; Env. Int. 139/2020

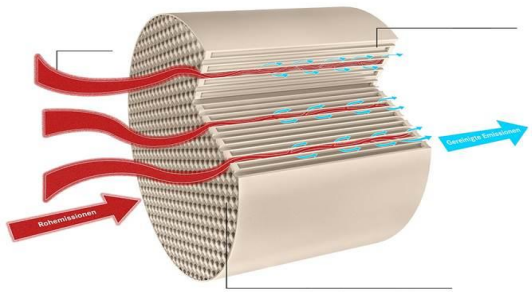
New approach: the only safe place is overhad

Perfect Solution in the KKL concert hall Lucerne



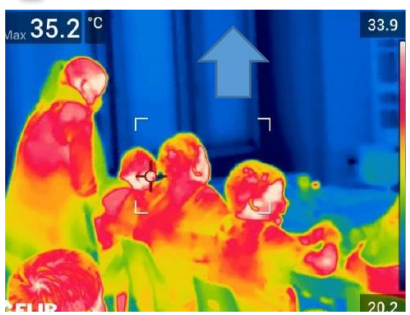
Application to a classroom

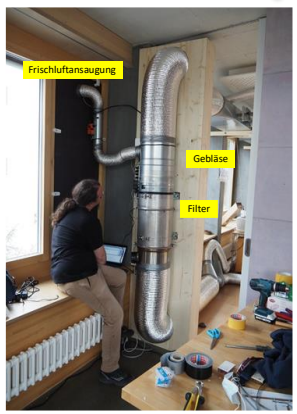
Take the virus contaminated air away at the ceiling (5 x room volume p.hr.). Mix with fresh (but UFP filtered) outdoor air to control CO_2, heat exchange and coarse particle prefilter, followed by nanofiltration



Vertical laminar ventilation to the safe spot over head

Nanofiltration > 99.9% > 10 nm and deactivation of active virus

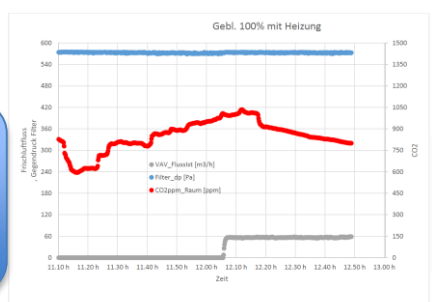




Thermal drift by body heat 50-100 W, 2-5 cm/s

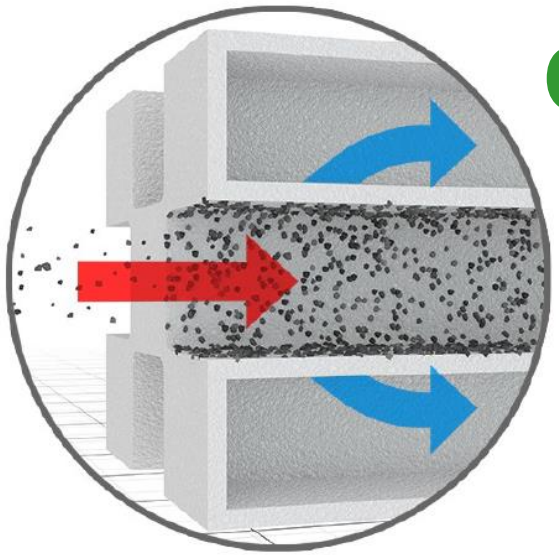
Return superclean air at floor level

Neighbor **cross contamination** < 1% of source concentration



Half time for cleaning 8 min reaching < 1% of outdoor contamination

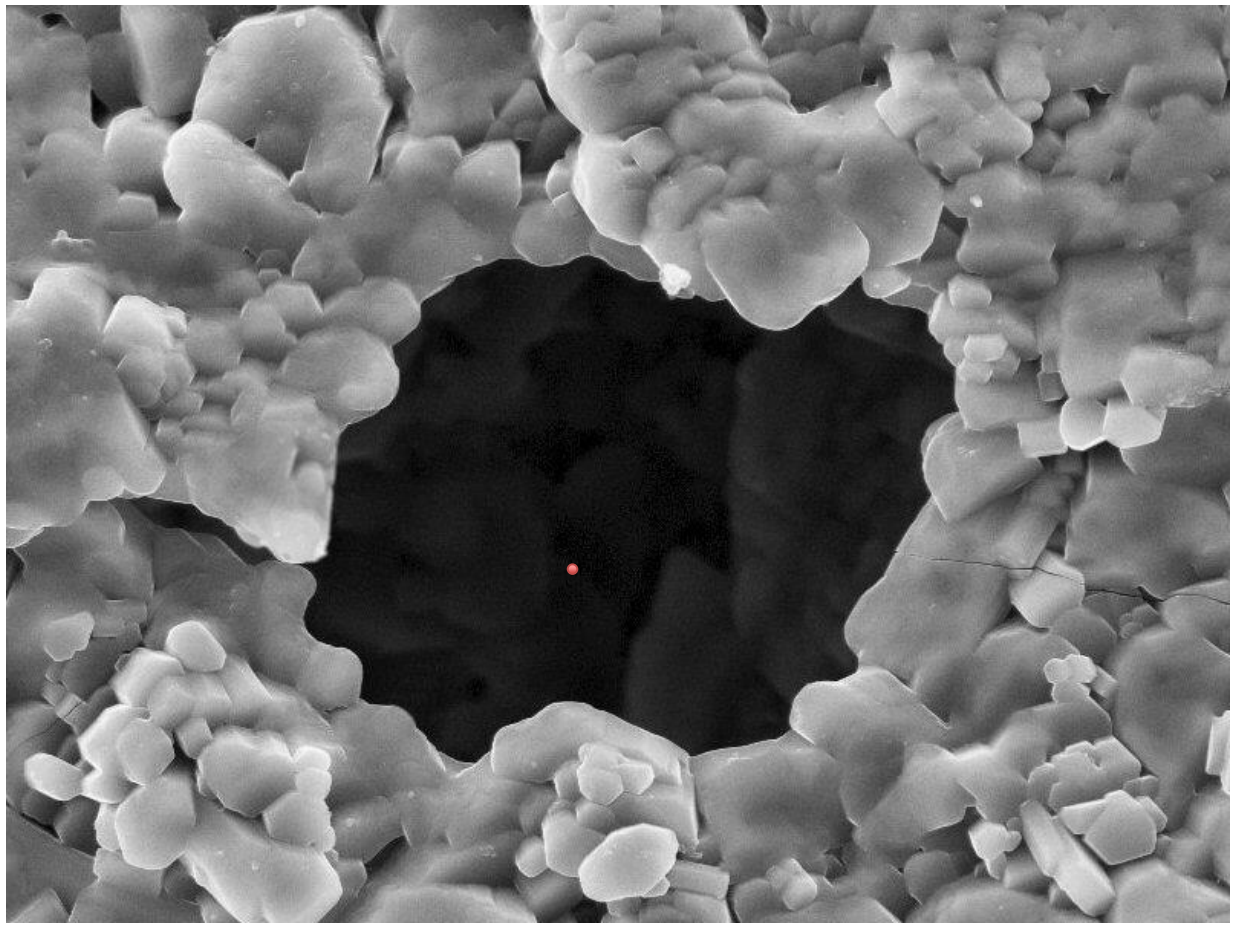
CO_2 control 800-1200 ppm



Ceramic wall flow multicell filter

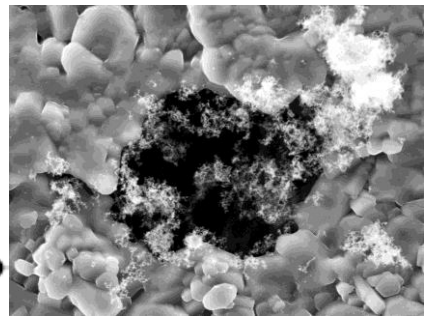
invented 1979, now > 200 Mio in Diesel cars

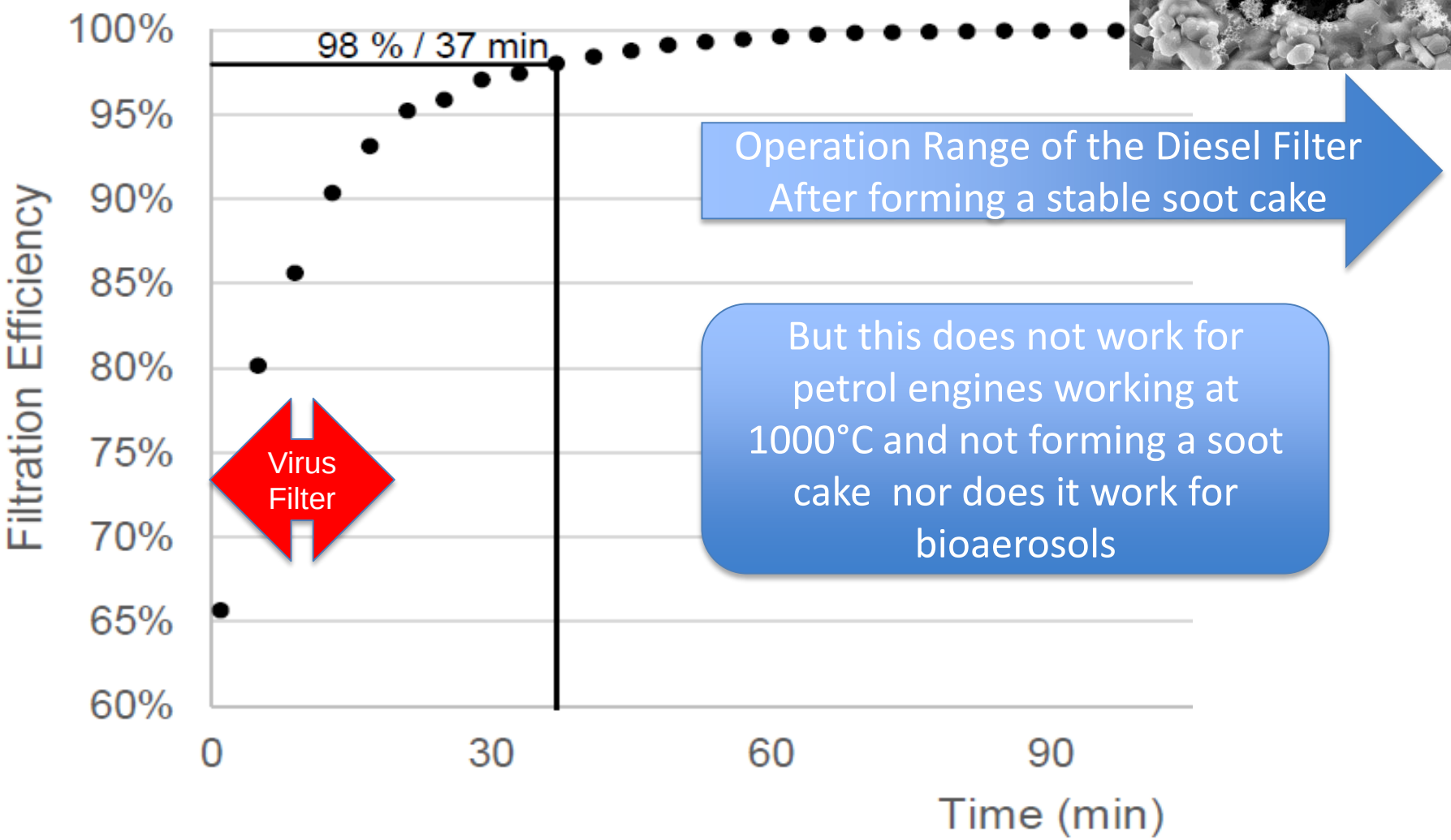
- pore size 10-20 µm
- porosity 45-65%
- 200 cpsi
- >1 m^2 per 1 ltr bulk volume
- High inflow speed but low face velocity some cm/s
- filtration efficiency >99%
- particle size 10 – 500 nm
- soot storage 10 g/ltr
- different materials
- any shape and size
- temperature > 1000° C
- no aging over vehicle life
- no vibration problem
- easy to clean
- Heating or coating to desinfect



Particles 10-100 nm are 100 - 1000 x smaller than pores 10-20 µm

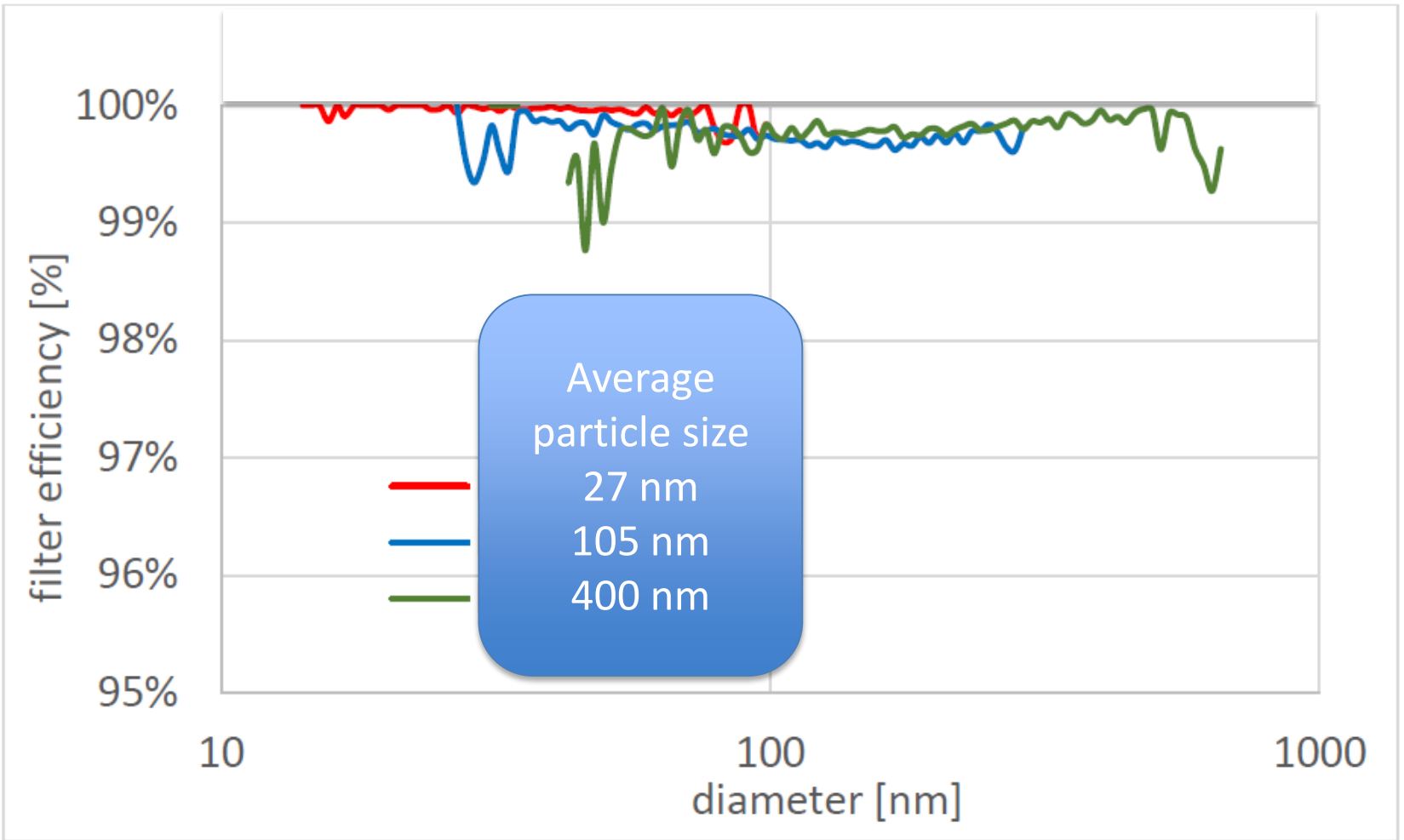
Diesel soot loading over time



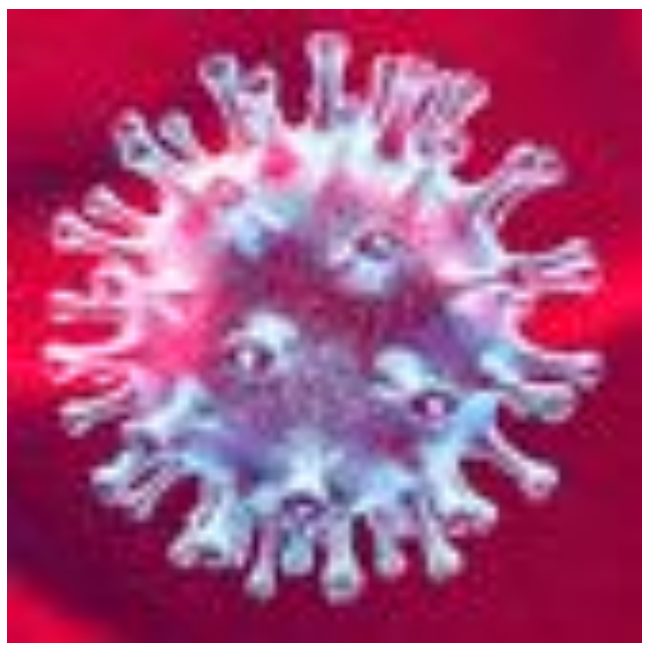


But new Technology is now available

without deficits in the Alveoli critial size range (99.9 %)

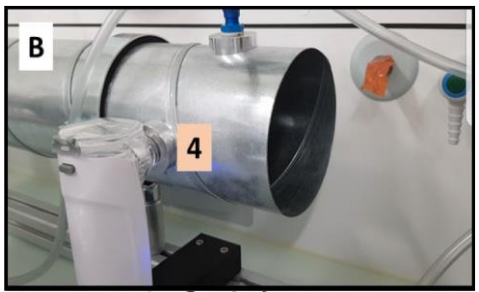


and what about Bio-Aerosols ?



Testing Channel

with aerosol source or MS2-source via nebulizer



Aerosoleinlass

Vernebler

Überschuss-Luft

Strecke für Tropfenverdunstung

ca 30cm

Lufteinlass gefilterte Pressluft, befeuchtbar)

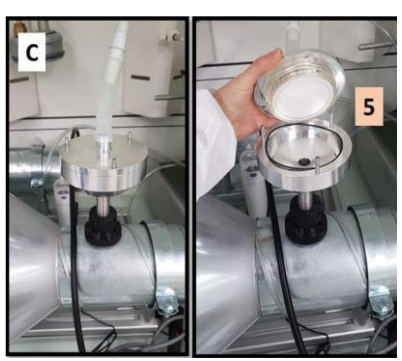
20cm

Filter

Virus sample downstream

15cm

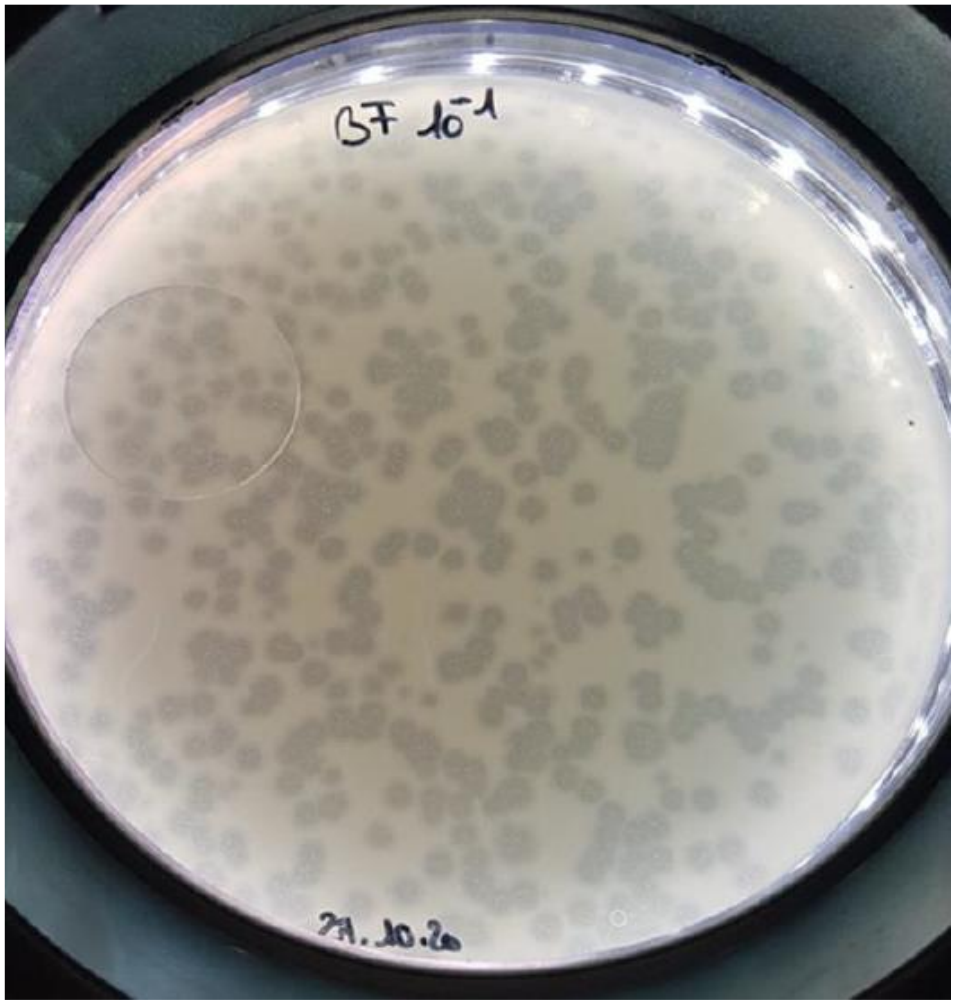
Auslass zu Kapellenabsaugung



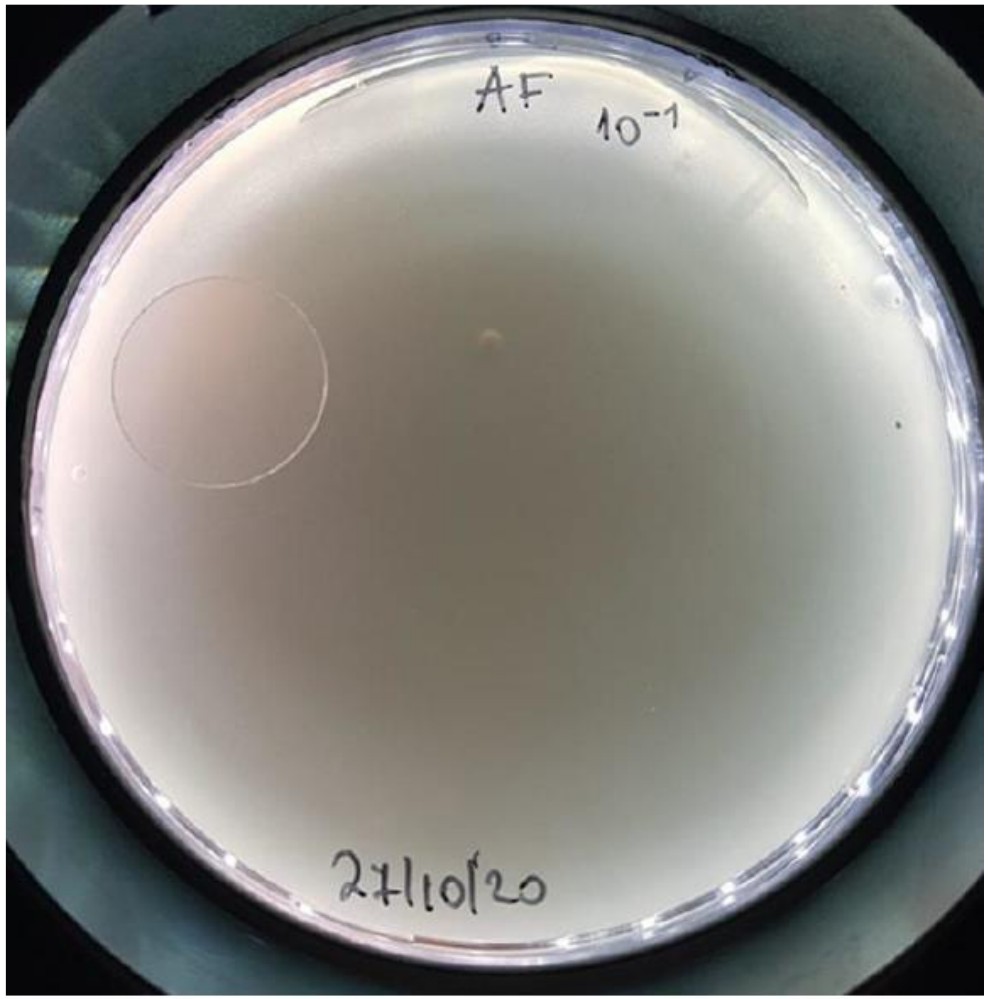
Sensoren für T, RH

Virus sample upstream collected on a gelatine membrane to be dissolved and incubated on AGAR plate with Coli bacteria

Blende zur Strömungsreduktion

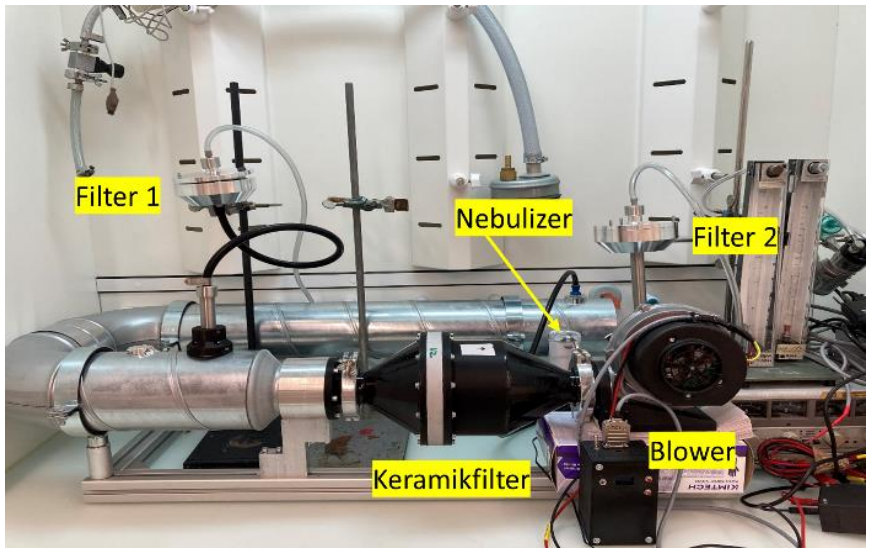


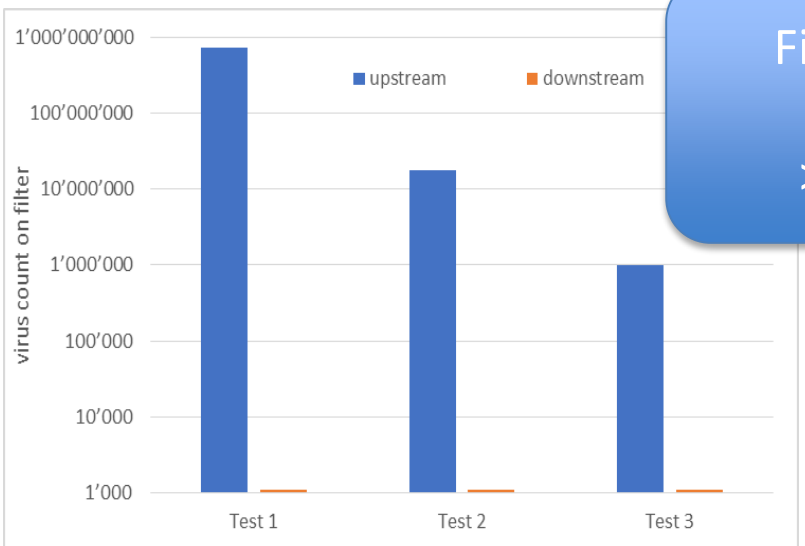
PFU: Plaques formed by a diluted active virus sample mixed with coli bacteria after 24 hrs
Sampled upstream filter; each plaque starts with one virus but contains about 1 Mio reproduced new virus
after 24 hours→ burst
We only count active viruses while other tests like PCR also count de-activated



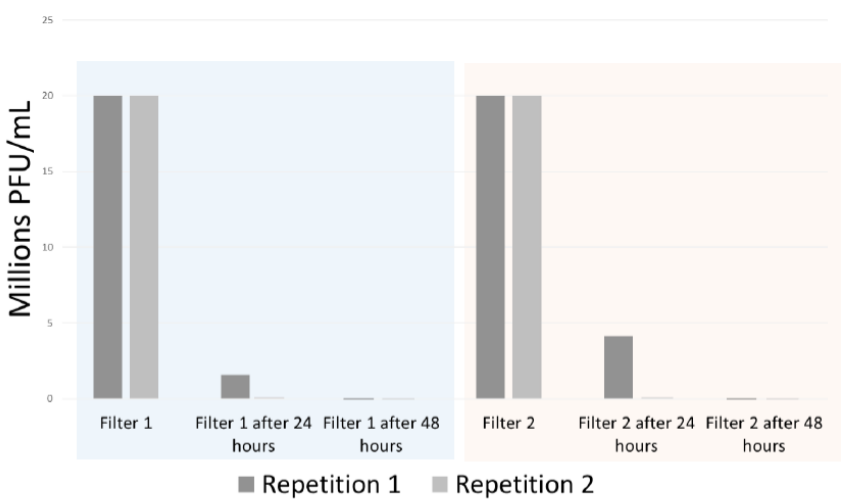
Agar plate with sample from downstram filter
After 24 hours of the plaques forming process no PFU visible

Filtration and De-Activation of Virus





Filtration by number
> 99.99 %



De-Activation after 48 hrs
99%

Applications

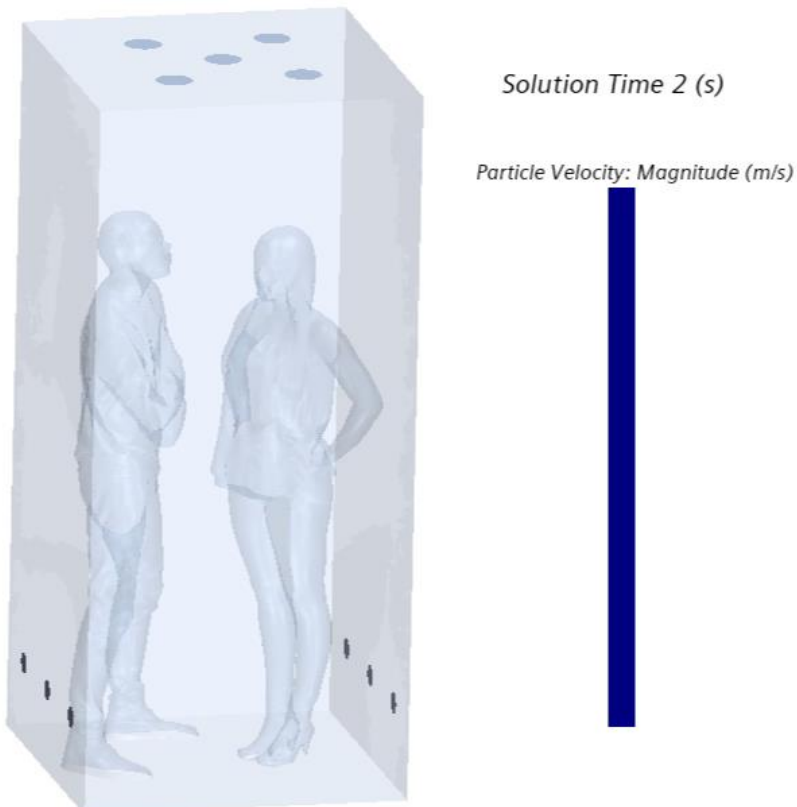
- Elevator Cabin
- Classroom
- Restaurant
- Working Places
- Supermarket
- Dentist
- Hospital bed
- Aircraft Cabin
- Bus and train cabins

Elevator Cabin
Computational Flow Simulation

Lingtao Liu reported in July 2020 about an outbreak in China where one single infected person Infected 71 others who just shared the same elevator of their apartment house without even meeting with them

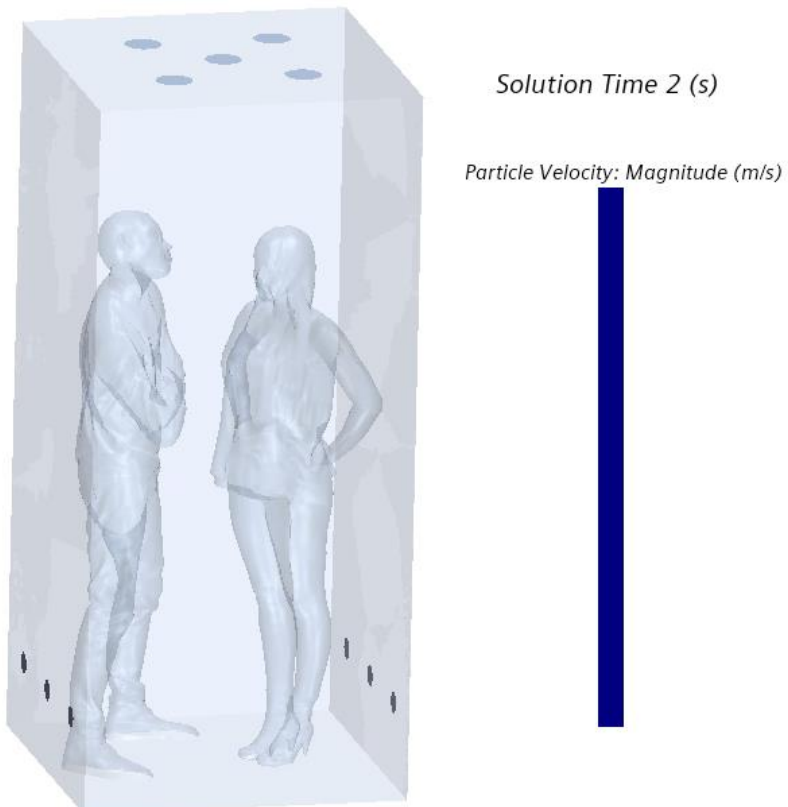
Based on
Lingtao Liu et al; CDC July 2000; Large SARS –CoV-2 Outbreak

3D CFD with one infected person **without ventilation**

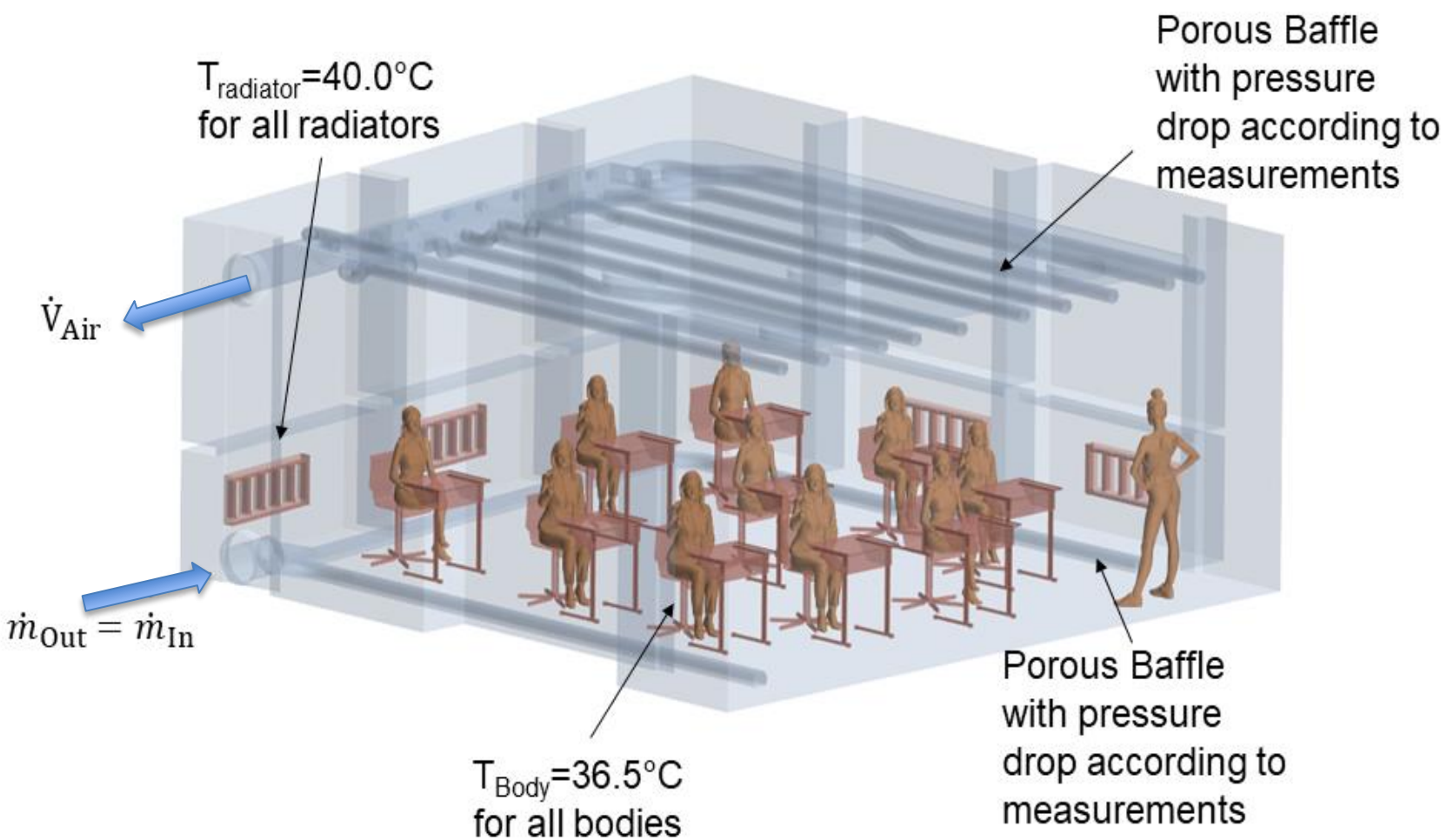


Computin Time
31 hours / 6 cores

3D CFD with one infected person **with ventilation from floor to ceiling**



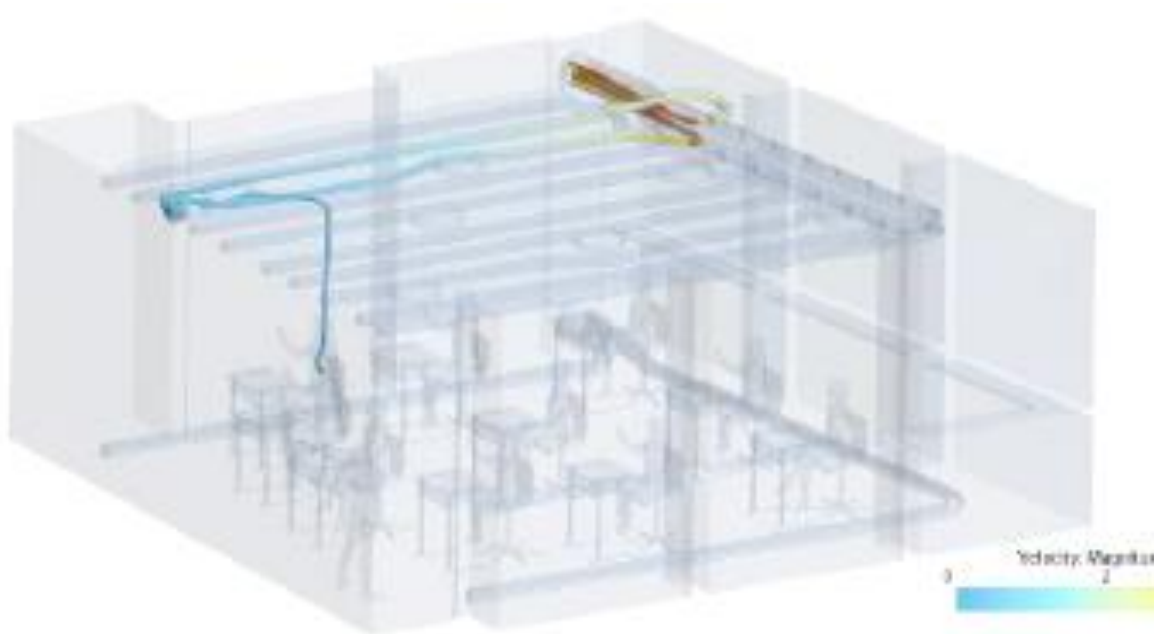
Classroom with ventilation from floor to ceiling



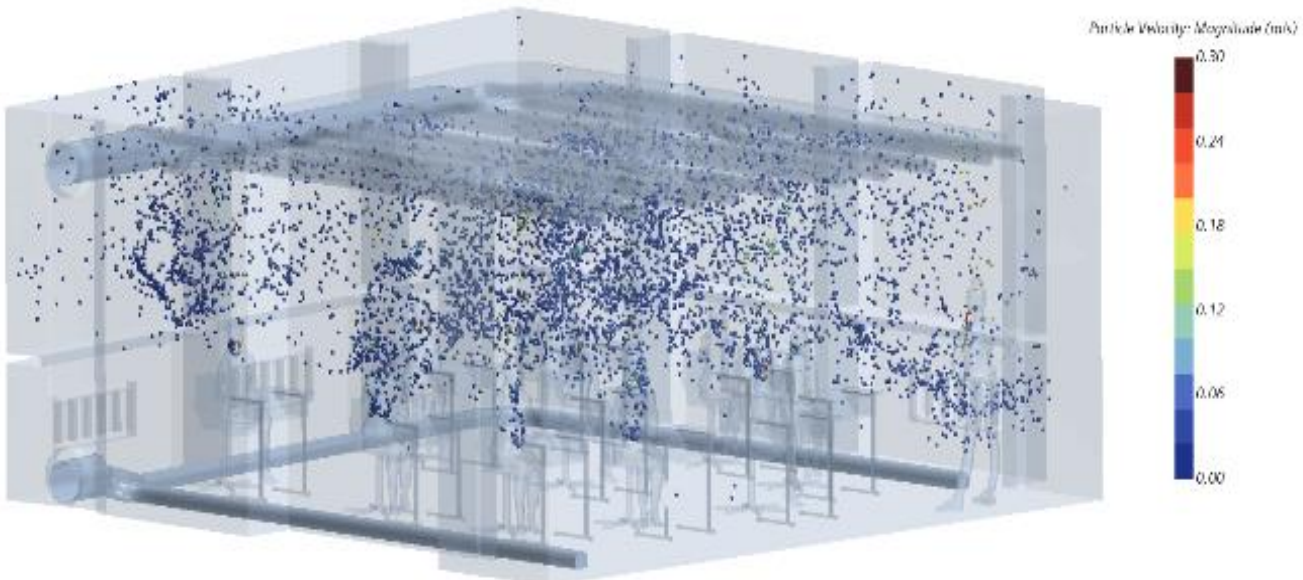
Vertical laminar flow – at a high flow setting

Exhaled air moves straight over head to the ceiling – no cross contamination

and this movement must be supported by ventilation vertical lamanar

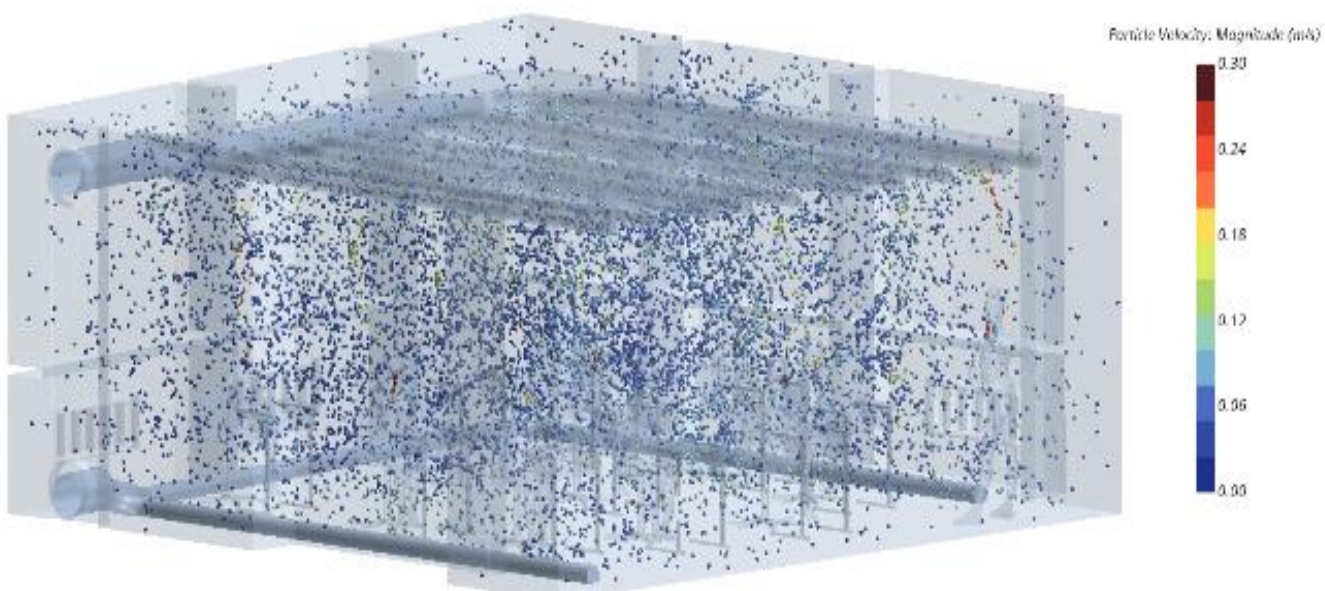


Flow directions from floor to ceiling and inverse



Ventilation from floor to ceiling is supporting body heat convection
Virus moves over head into the safe room and is taken away via porous tubes

Solution

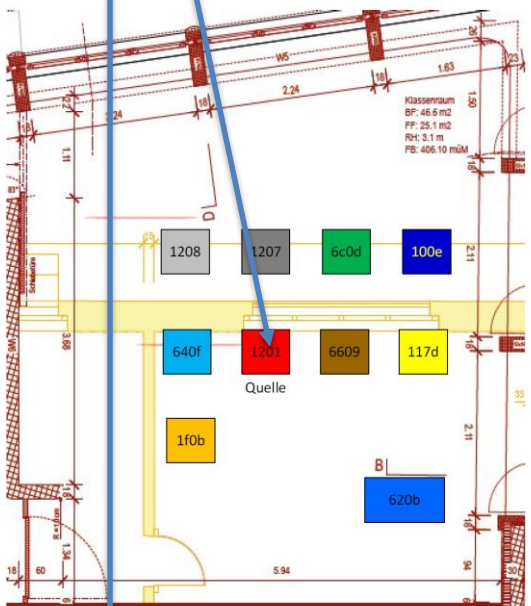


Standard ventilation from ceiling to floor interacts with vertical body heat convection and enriches virus concentration in the breathing zone

Solution Time 300 (s)

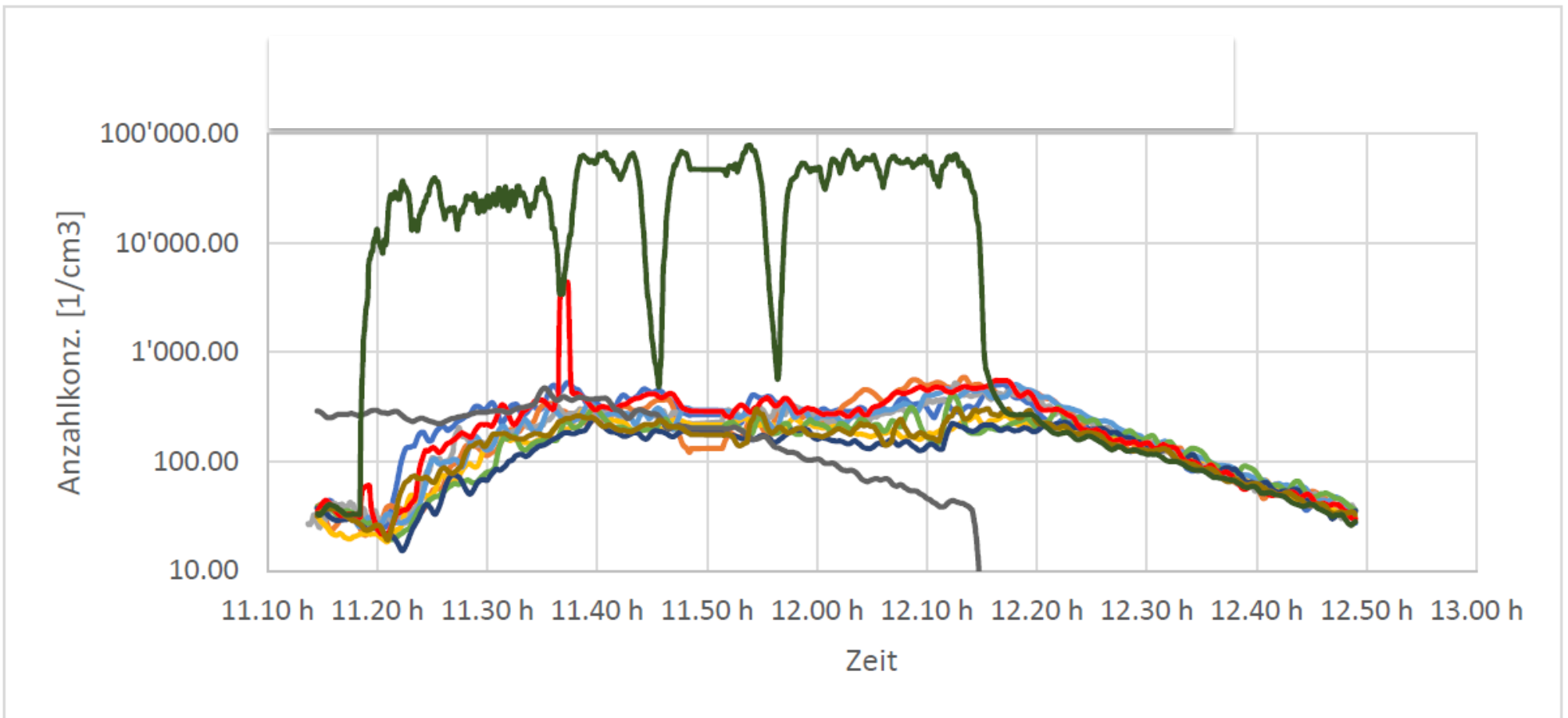
Testing cross contamination

- salt water nebulizer: 80‘000 P/cc at 30 nm at the front desk
- warming plates simulating body heat
- particle counters at each desk



Particle concentration at 10 desks
compared to the particle source (log scale)

two orders of magnitude risk reduction even in immediate vicinity of the infected person



Facts and Figures
for a highly effective virus protection

→ Cross contamination < 1%

→ Virus filtration > 99,99%

→ Anorganic nanofiltration > 99% at alveoli size

→ Virus de-activation 99% within 48 hours

→ Half time 8 minutes

→ to a final level of 1% outside particle concentration

→ No aging, easy cleaning, easy desinfection

Applications in classrooms, other populated rooms, elevator cabins, hospitals, aircraft cabins, public transport et cetera.

Team and Sponsors

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Joachim Frey

FOEN-UTF, the Swiss federal office for the environment is financially supporting this project as well as the
Swiss Lung Foundation and private sponsors W.Johann, Dr.J.Schiltknecht, Dr.J.Mayer and the Rudolf Steiner Schule Lenzburg.