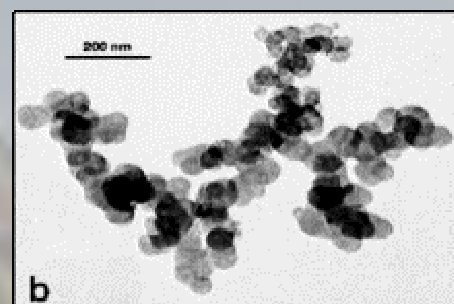
EFCA Brussels, 05.07.2022

Minimize UFP-Pollution and Virus Infection Risk in Closed Rooms by Nanofiltration and Laminar Air Exchange



Andreas C.R.Mayer / NCA

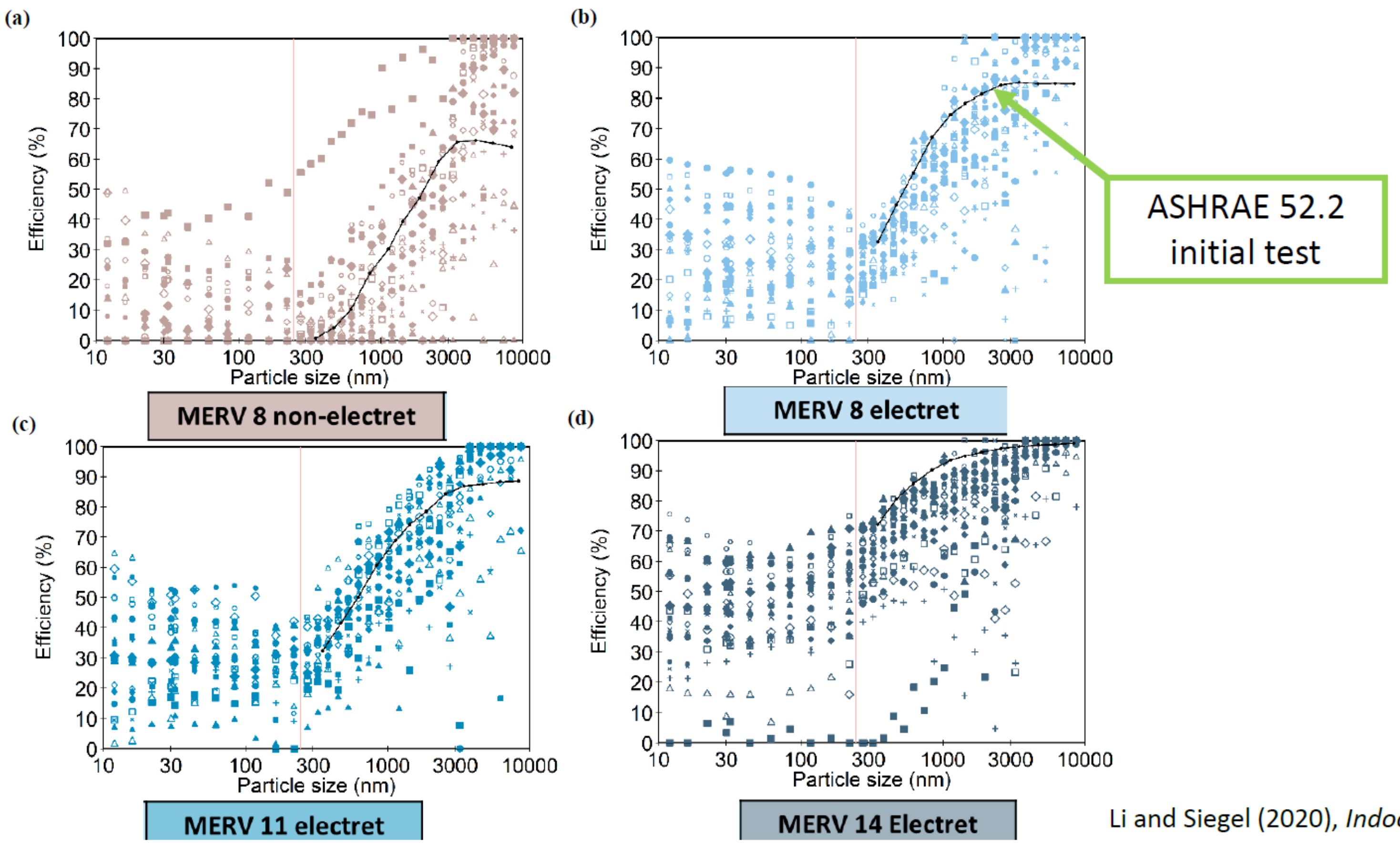
Health risk indoor by external and internal nano-aerosol contamination how to eliminate both

- Indoor: buildings, escalators, cars, trains, aircraft
- Outdoor aerosol: **traffic combustion particles**, pathogens, allergens,
- Nanosize particles penetrate from outdoor to indoor
- Indoor aerosol: **virus,** bacteria, combustion particles
- Technologies must deal with all ultrafine particles + trace gases
- No aerosol number concentration limits implemented yet
- WHO acknowledges the risk but only recommends measurements
- Our Target: < 1000 P/cc and < 100 Viruses/m^3

Most air filters used indoors suffer below 1000 nm

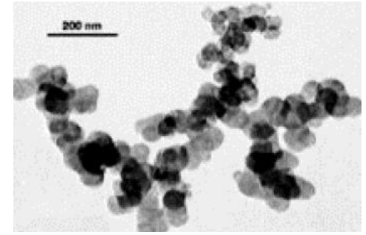
because of high space velocity, vibration, aging, humidity

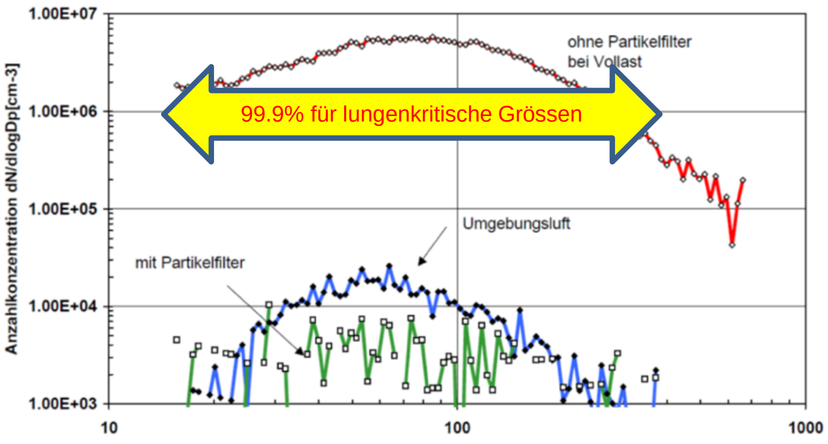
Filtration <1000 nm by diffusion requires **low face velocity** HEPA fibre deep bed filters can reach this but In real life they operate at higher velocity thus improve impaction but lose diffusion efficiency

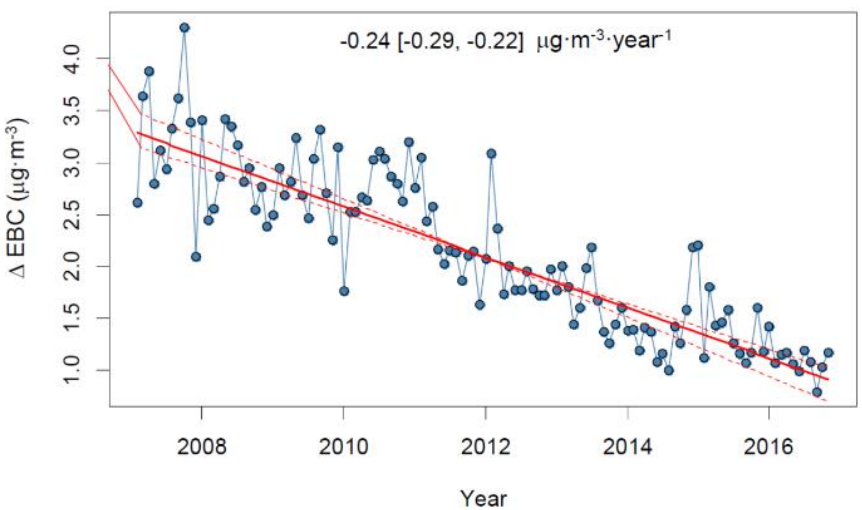


Li and Siegel (2020), *Indoor Air*

Best available technology to clean exhaust but also ambient air from nanoparticles are fine cellular ceramic wall flow filters







BC and PN reduction at a bussy Swiss motorway due to introduction of DPF

Diesel Particle Filters – Swiss Contribution

the interdisciplinary VERT Research Network

1994 developped for tunneling NEAT
2000 some hundrets DPF in tunnel
2002-10 Swiss Construction 25‘000

2011 EU adopts for Diesel, 2017 Petrol
2018 China, 2020 India
today > 300 Millionen worldwide

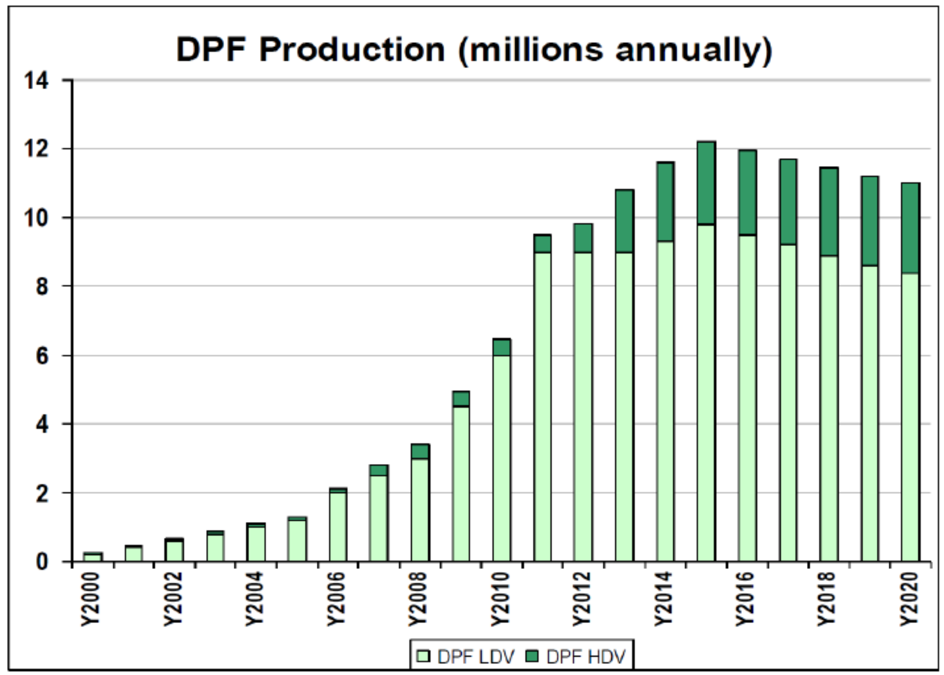


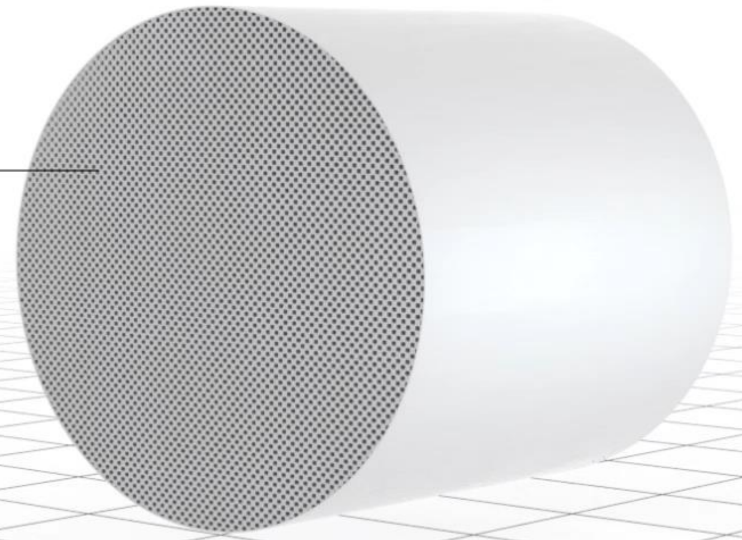
Fig. 6 DPF-Production annually for LDV and HDV – USA and Europe

10 Million premature death annually due to combusion particles **= 10 x Covid**

Thanks to Particle Filters > 3.5 Mio premature death less

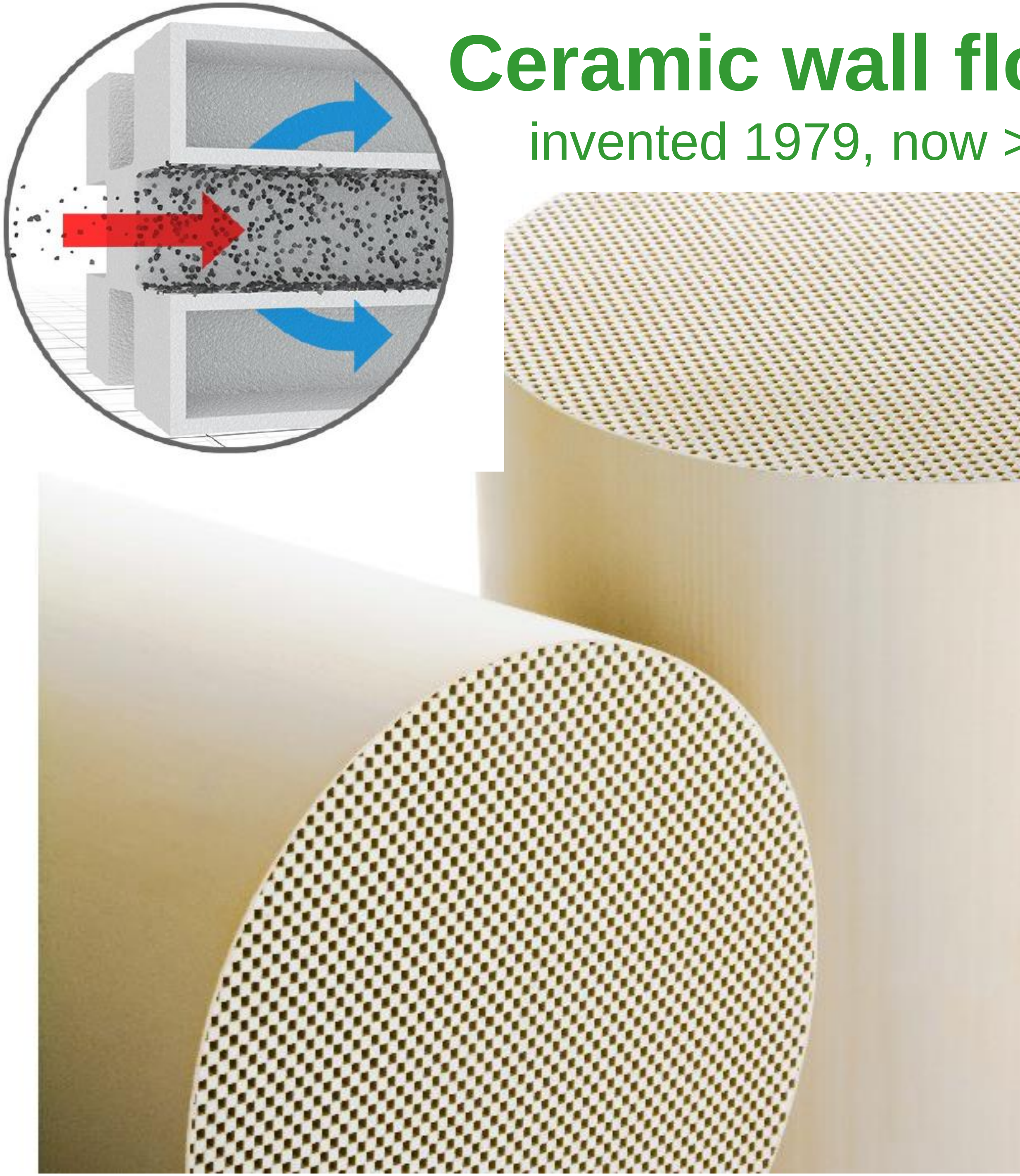
Corning® DuraTrap® GC

Gasoline Particulate Filter

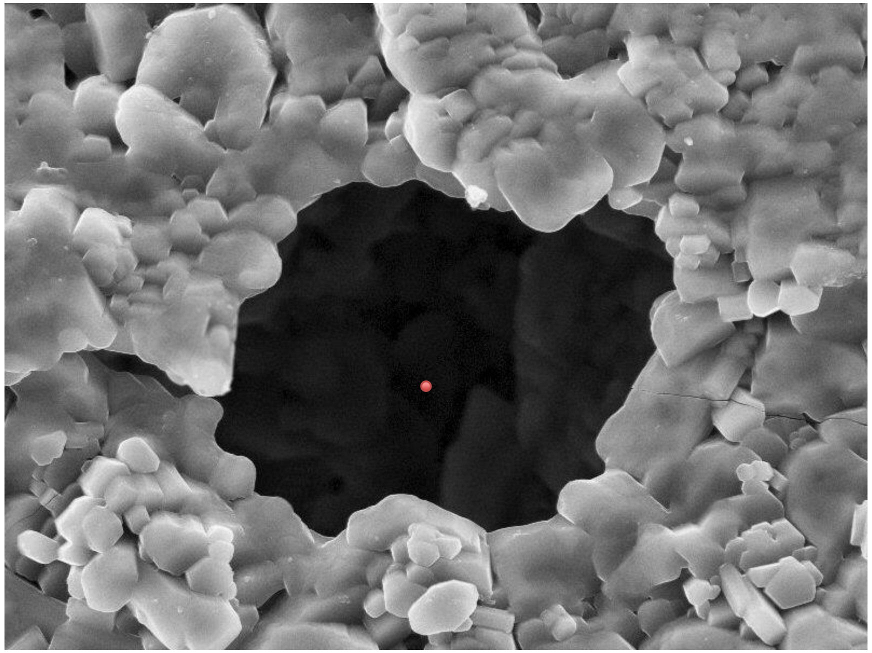


Ceramic wall flow multicell filter

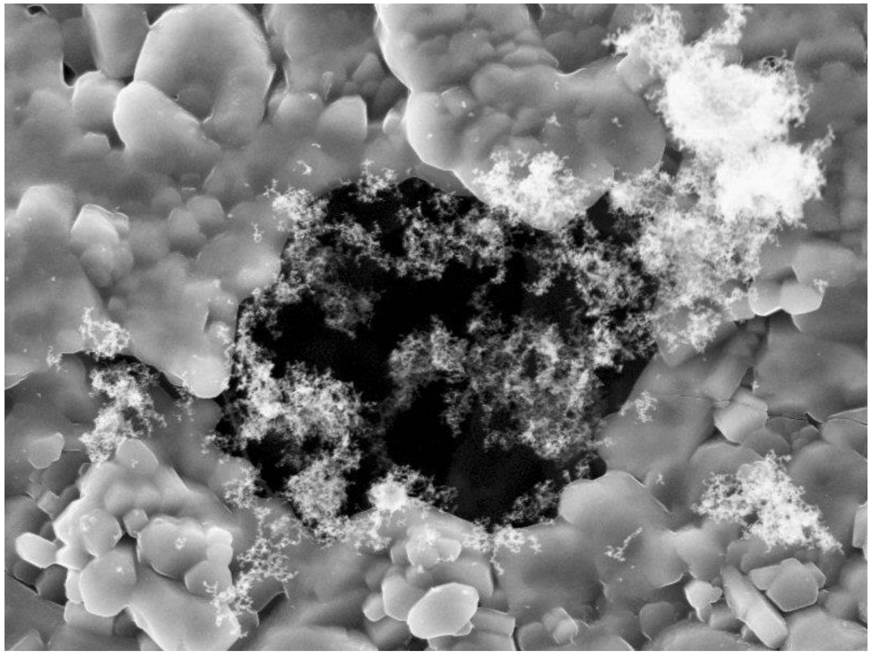
invented 1979, now > 200 Mio in Diesel cars



- 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
- Sustainable mass product
- Circular economy



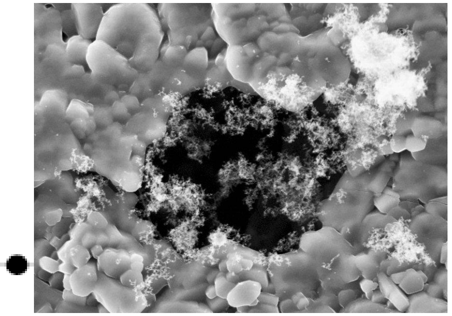
particles 10-100 nm
are 100 - 1000 x smaller
than pores 10-20 µm

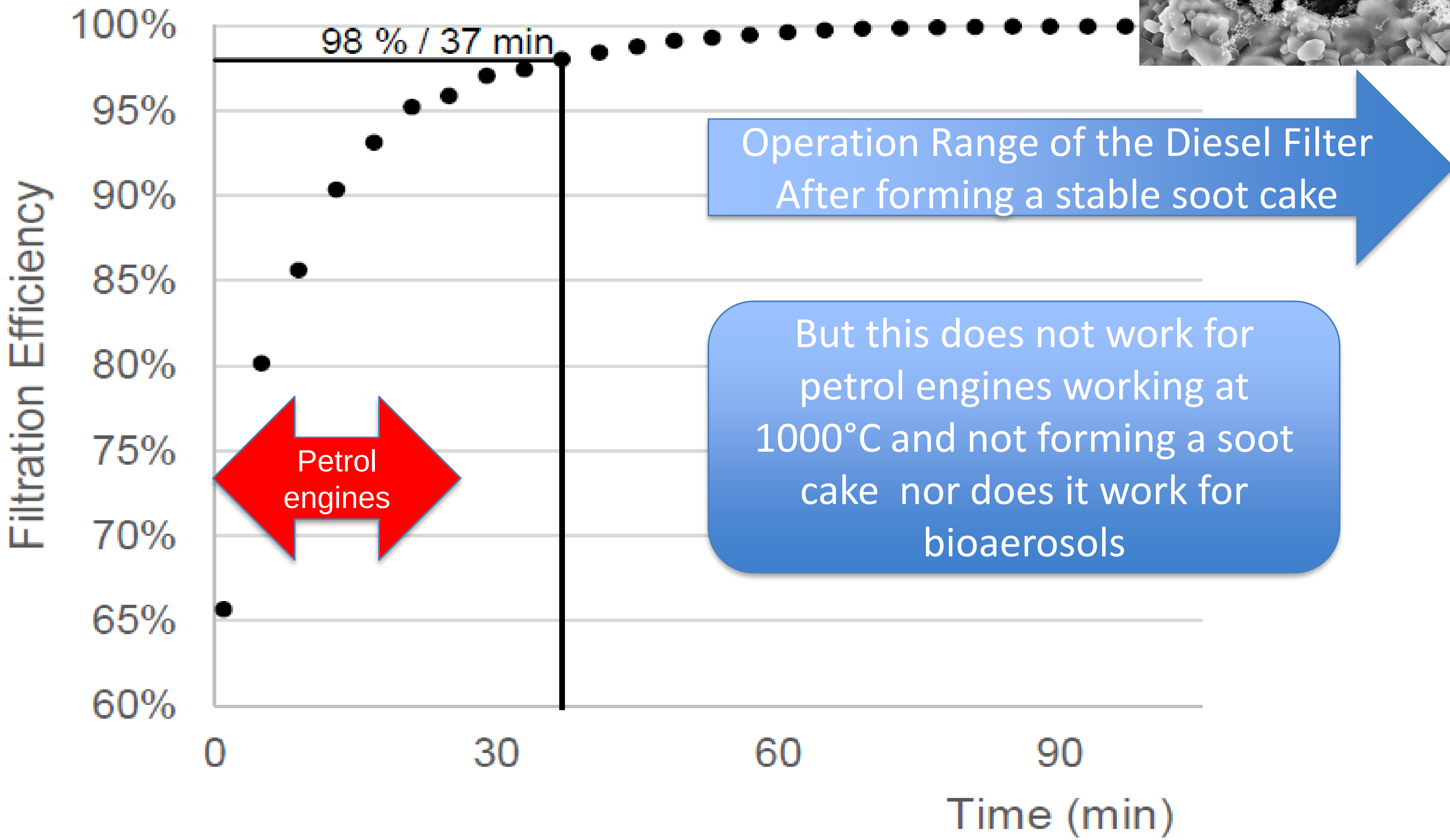


membrane like
formation of soot
particles to improve
filtration

Simon Payne, ETH-NPC 2012

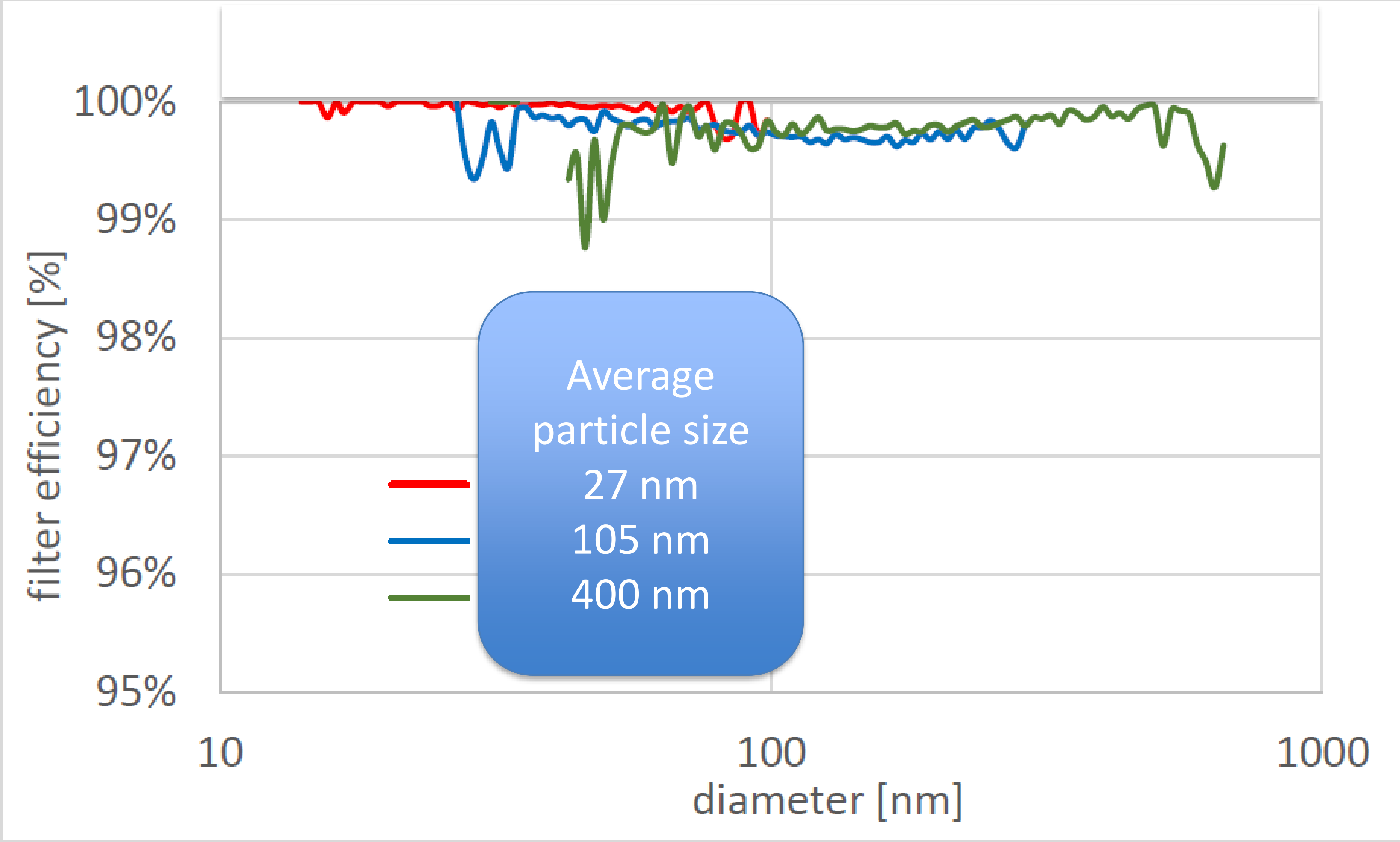
Diesel soot loading over time



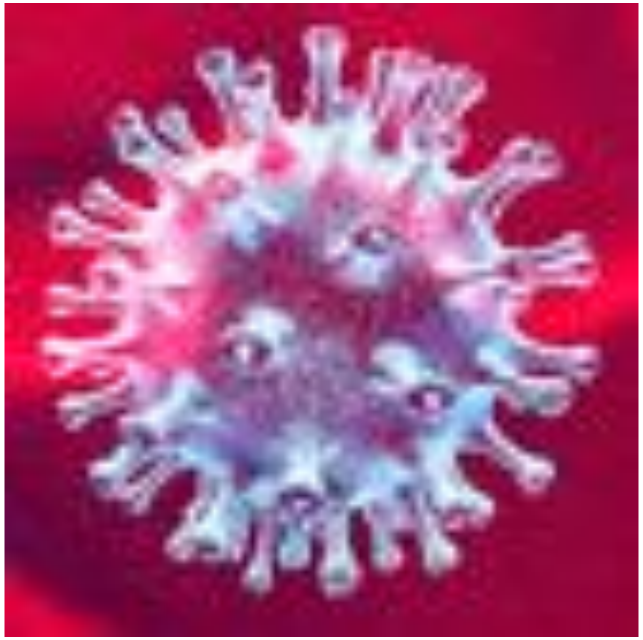


But new Technology is now available

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

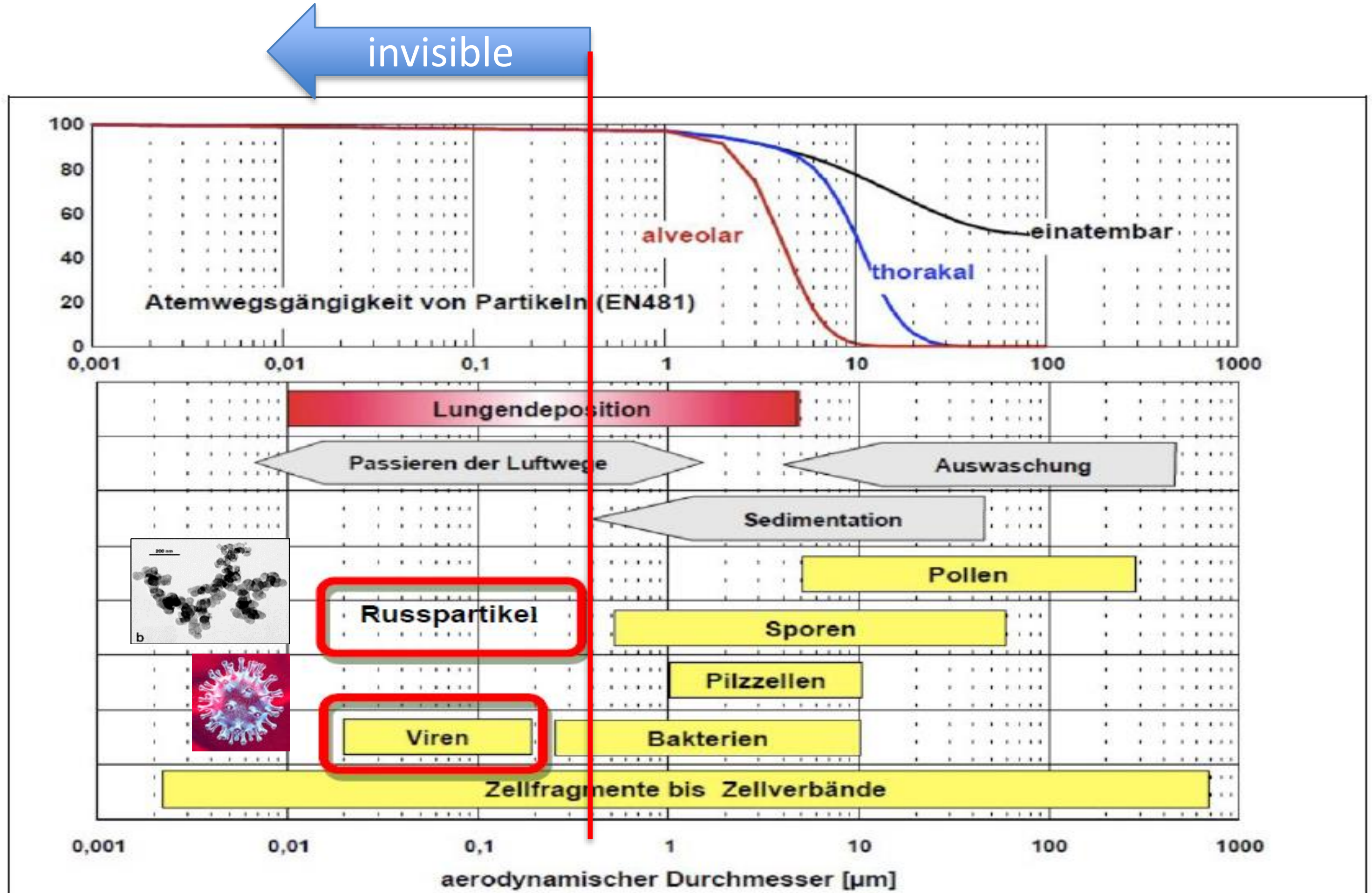


and what about Bio-Aerosols ? can we filter them as well and de-activate?



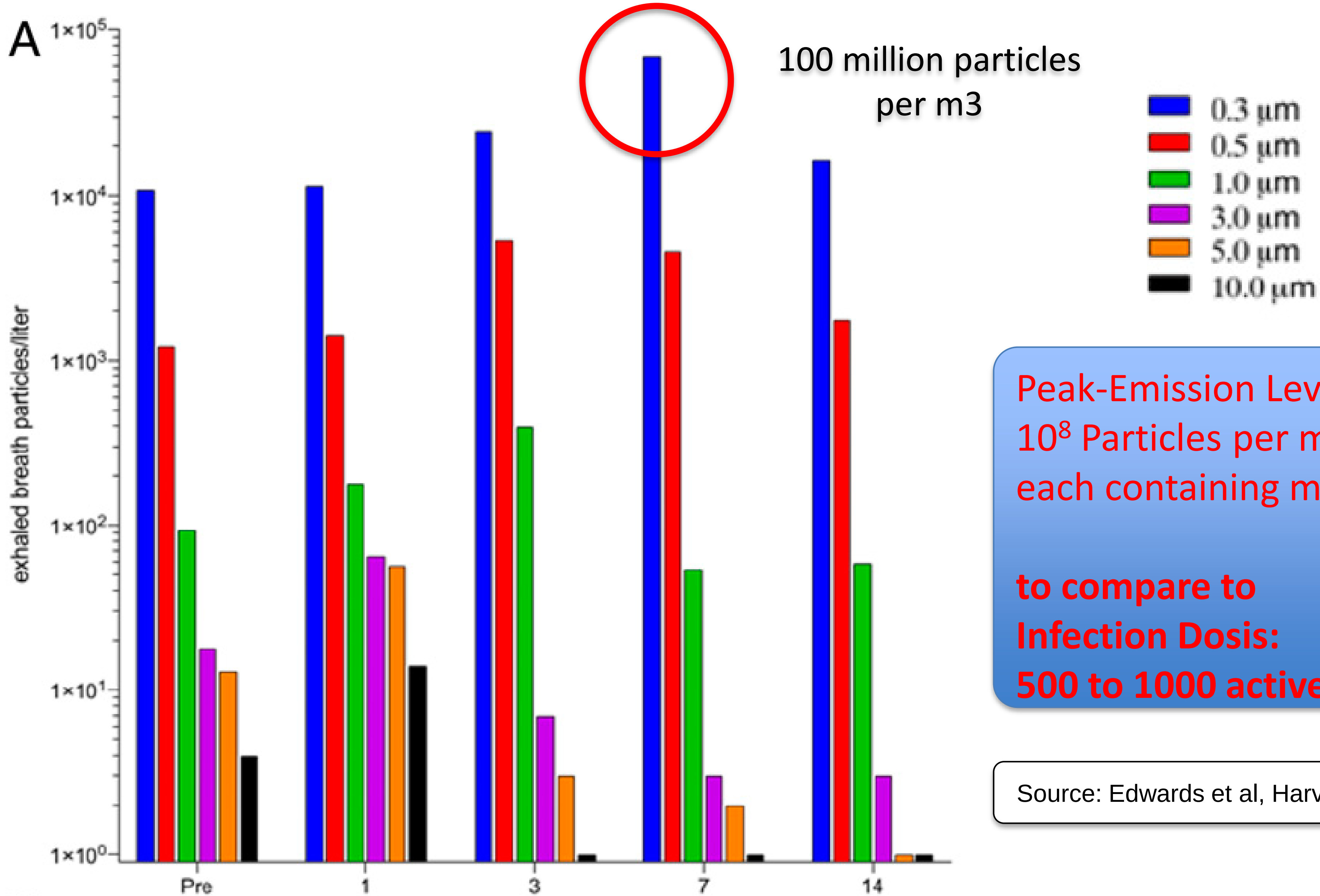
Viruses are as small as diesel soot particles and form a similar very stable aerosol

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



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

Numbers: Exhaled particle count in Corona infected Rhesus macaques in function of days after infection



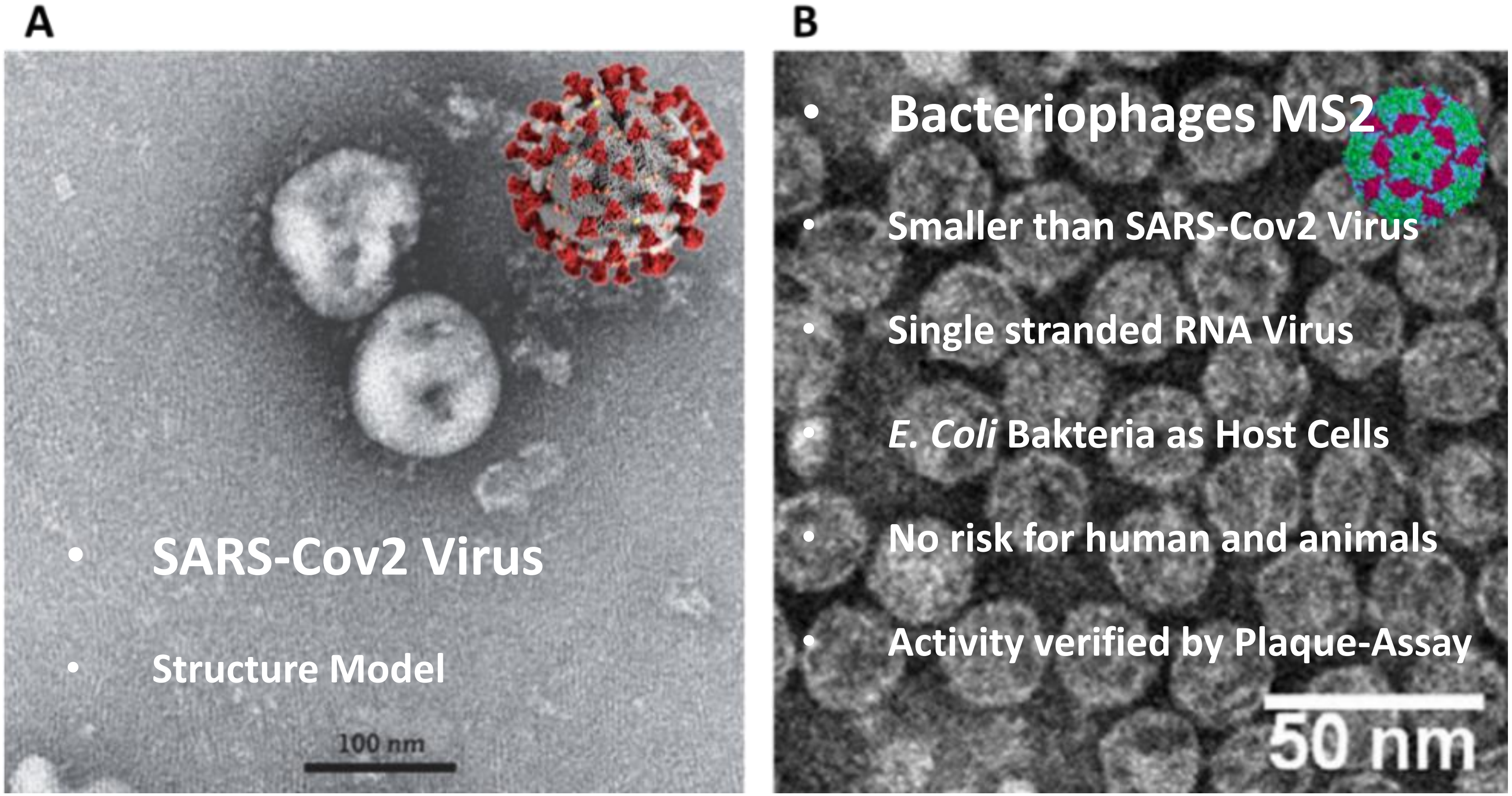
Peak-Emission Level
10^8 Particles per m^3
each containing many viruses

to compare to
Infection Dosis:
500 to 1000 active viruses

Source: Edwards et al, Harvard PNAS 2021 Nr.8

COVID 19-Virus and Bacteriophages MS2

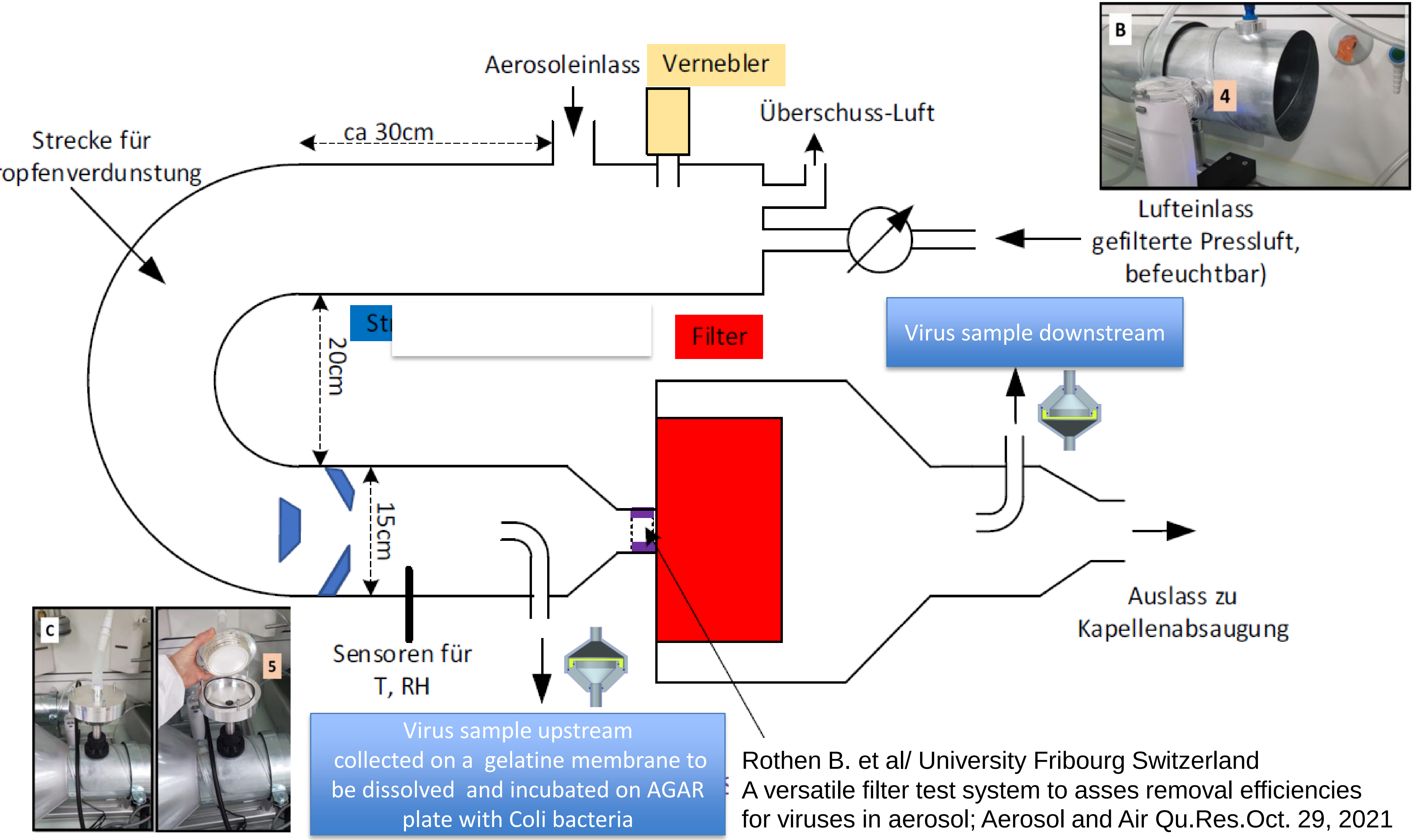
MS2 are the standard surrogate for microcell research



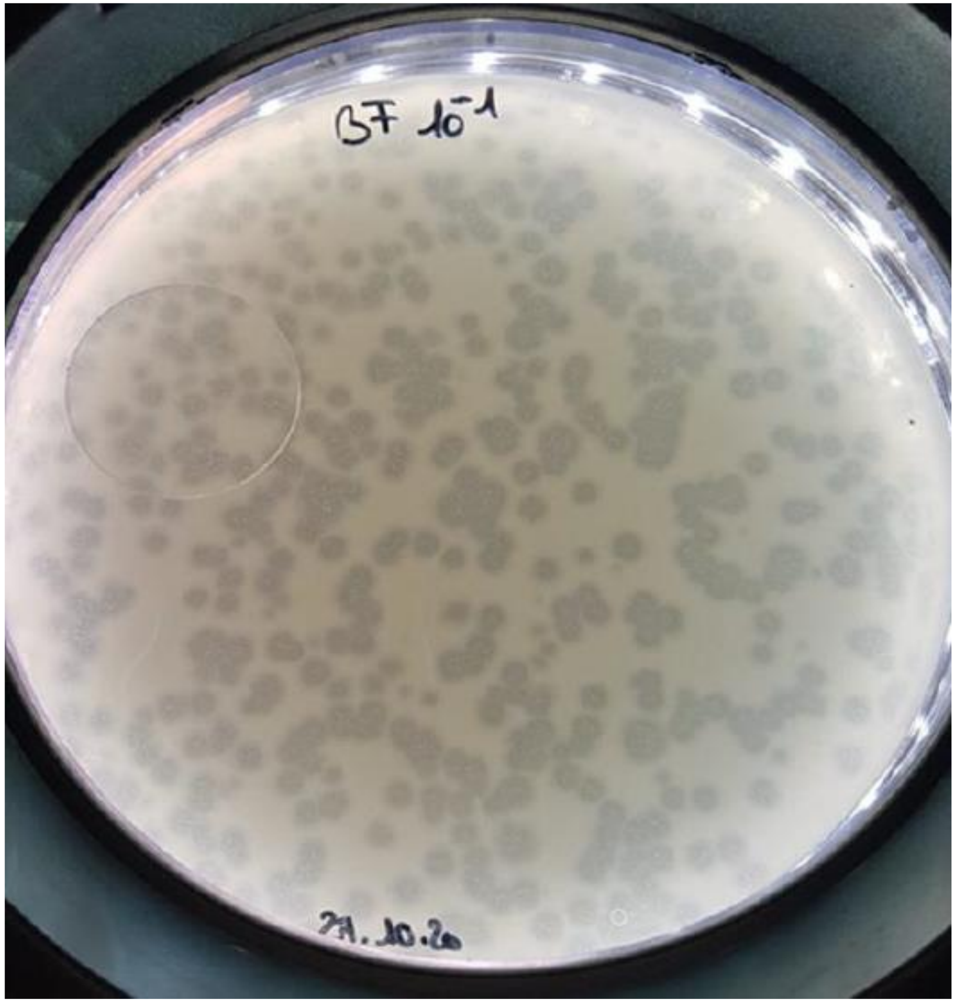
Electron microscopy micrograph and a structure model of A) COVID 19 virus (https://www.pharmaceutical-business-review.com/news/gsk-cepi-coronavirus/; Zhu et al., 2020) B) MS2 bacteriophage (https://de.wikipedia.org/wiki/Enterobakteriophage_MS2; Nguyen et al., 2011)

Testing Channel

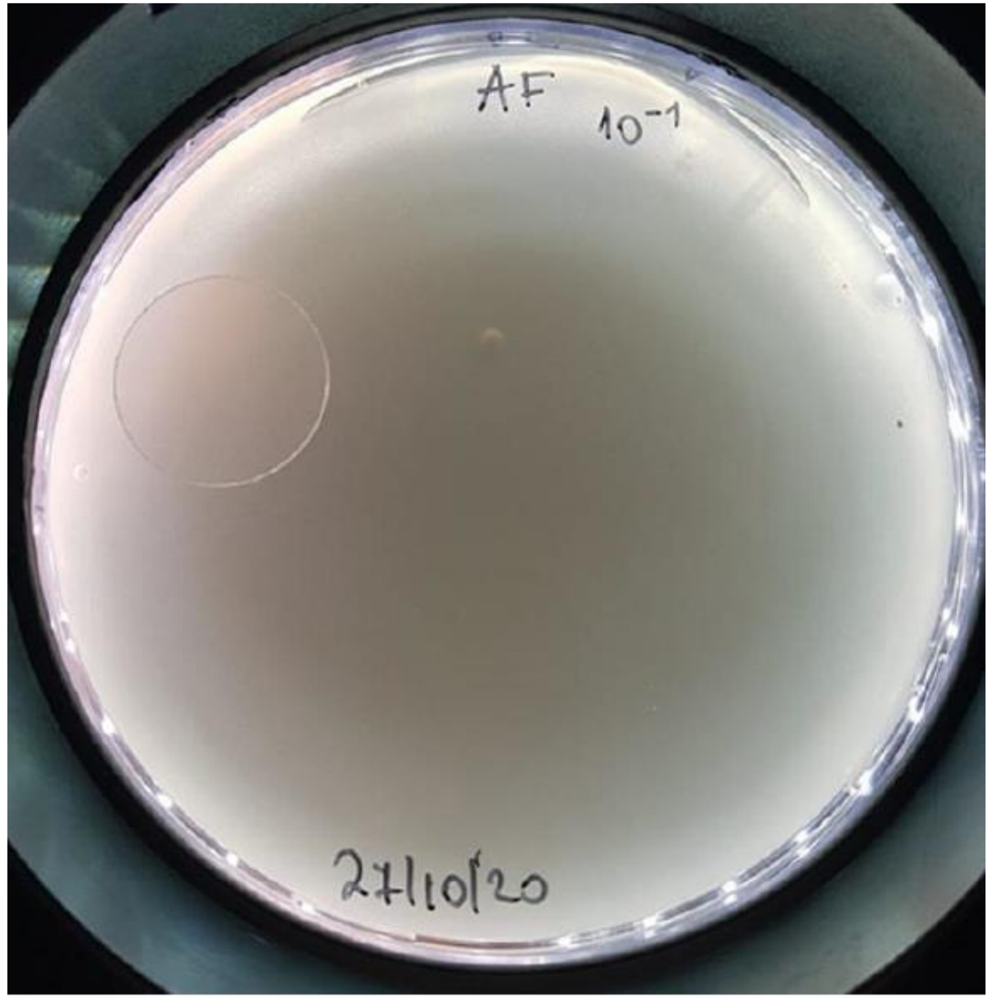
with aerosol source or MS2-source via nebulizer



Rothen B. et al/ University Fribourg Switzerland
A versatile filter test system to asses removal efficiencies for viruses in aerosol; Aerosol and Air Qu.Res.Oct. 29, 2021



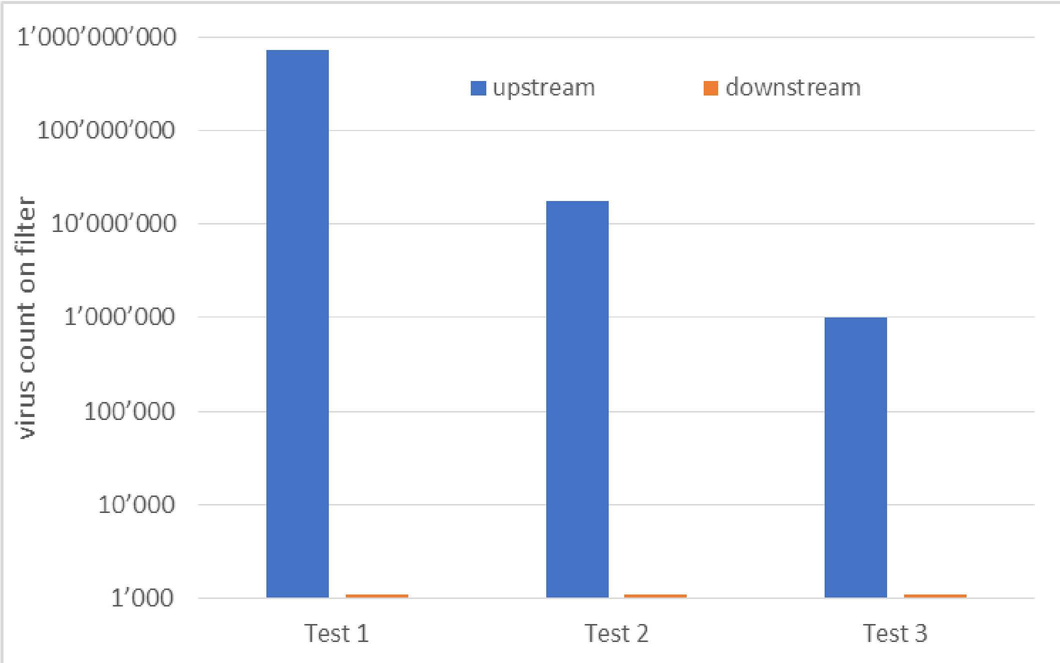
PFU: Plaques formed by a diluted active virus sample mixed with coli bacteria after 24 hrs Sampled upstream filter; each plaque starts with one virus but contains about 1 Mio reproduced new virus
after 24 hours→ burst
We only count active viruses while other tests like PCR also count de-activated

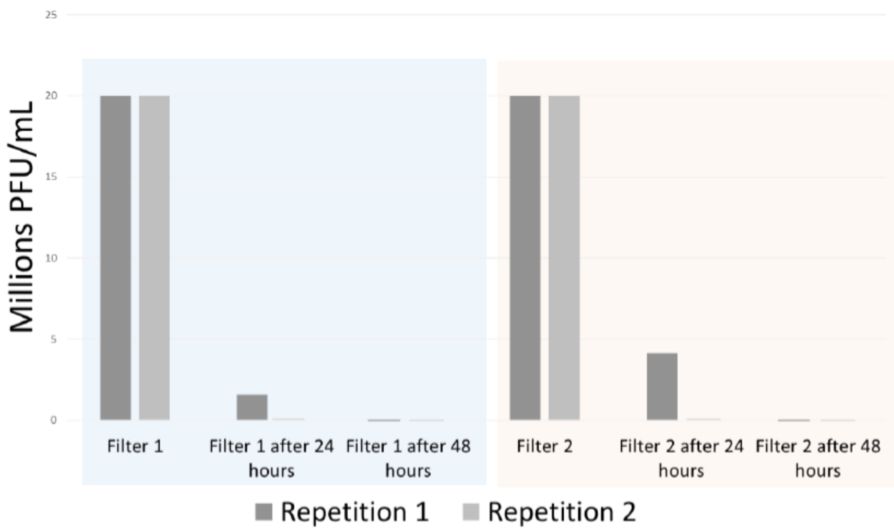


Agar plate with sample from downstream filter
After 24 hours of the plaques forming process
no PFU visible

Rothen B. et al/ University Fribourg Switzerland
A versatile filter test system to asses removal efficiencies for viruses in aerosol; Aerosol and Air Qu.Res.Oct. 29, 2021

Filtration and De-Activation of Virus (2020)





Filtration by number
> 99.9999 %

De-Activation after 48 hrs
99%

Rothen B. et al/ University Fribourg Switzerland
A versatile filter test system to asses removal efficiencies for viruses in aerosol; Aerosol and Air Qu.Res.Oct. 29, 2021

Filtration works perfect for Virus and NP

can also be combined with UV-C, Ionizing, ESP

But what about Ventilation ?

How can we catch

and eliminate the virus by filtration

before it reaches victims

and starts infection

Flow control is the much more difficult part

and what about Ventilation?

air mix

versus air

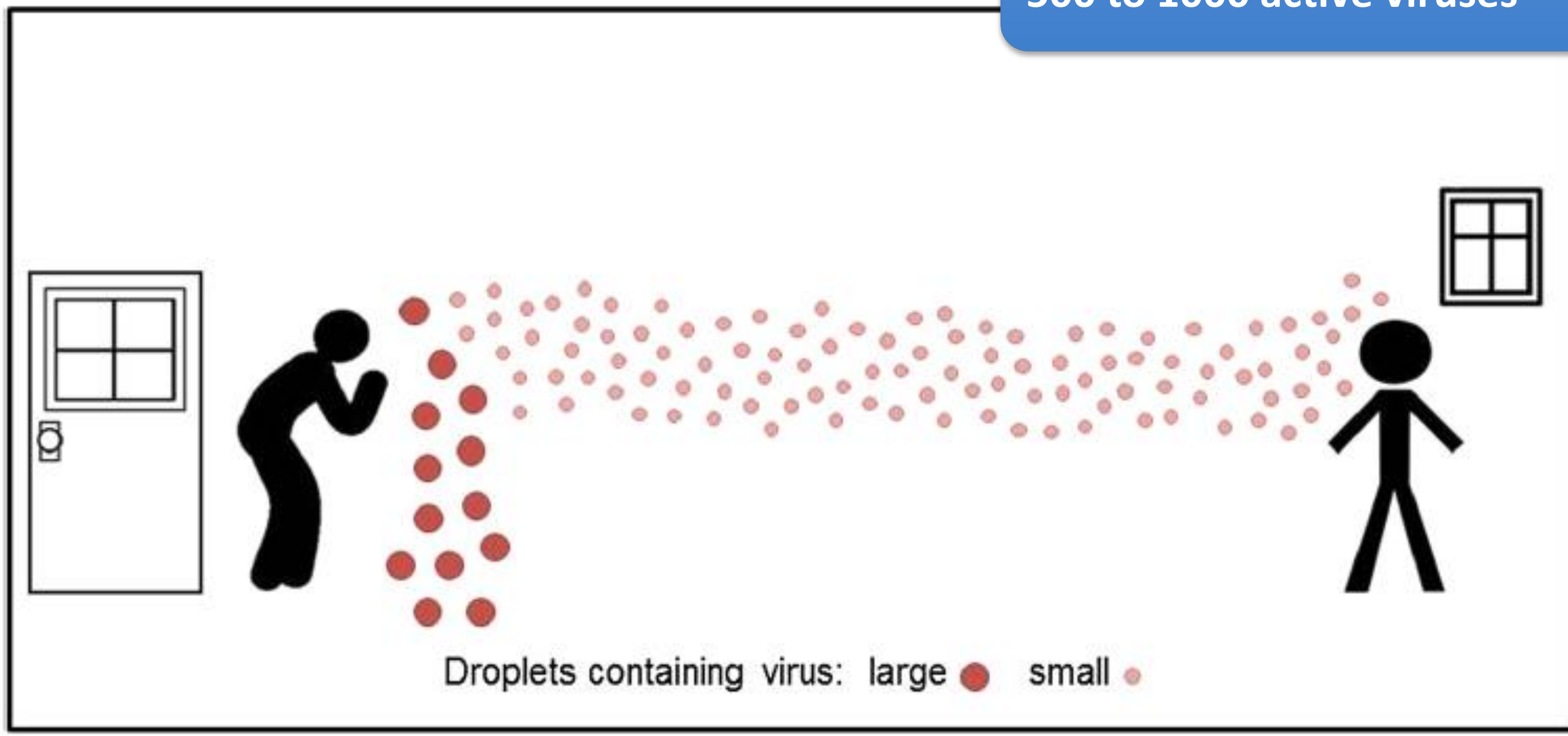
exchange

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



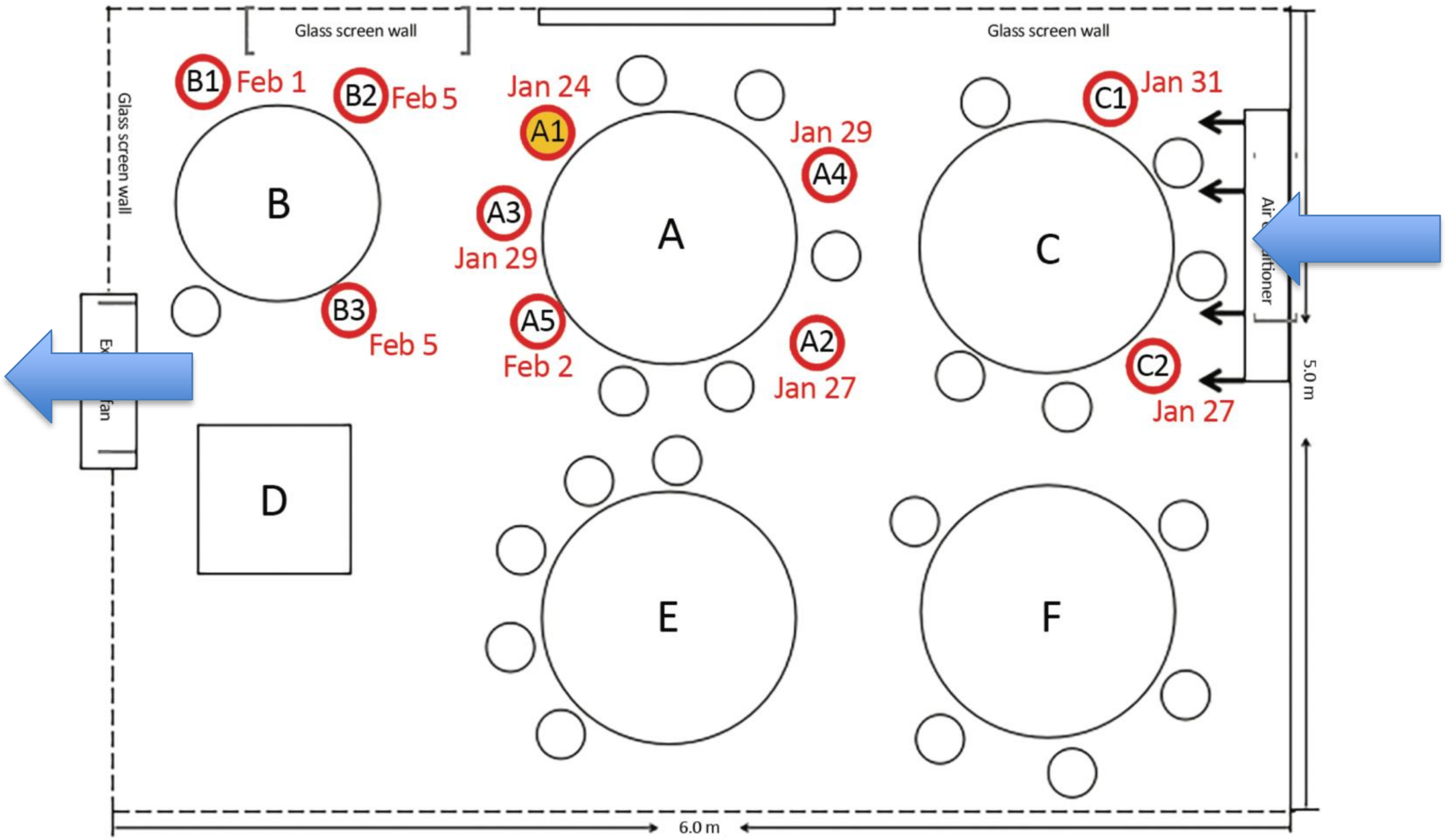
Morawska L. Airborne Transmission of SARS-CoV-2; Environment International; April 7 2020.

Mech.Ventilation with HEPA Filtration

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

Centers for Disease Control and Prevention

Research

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

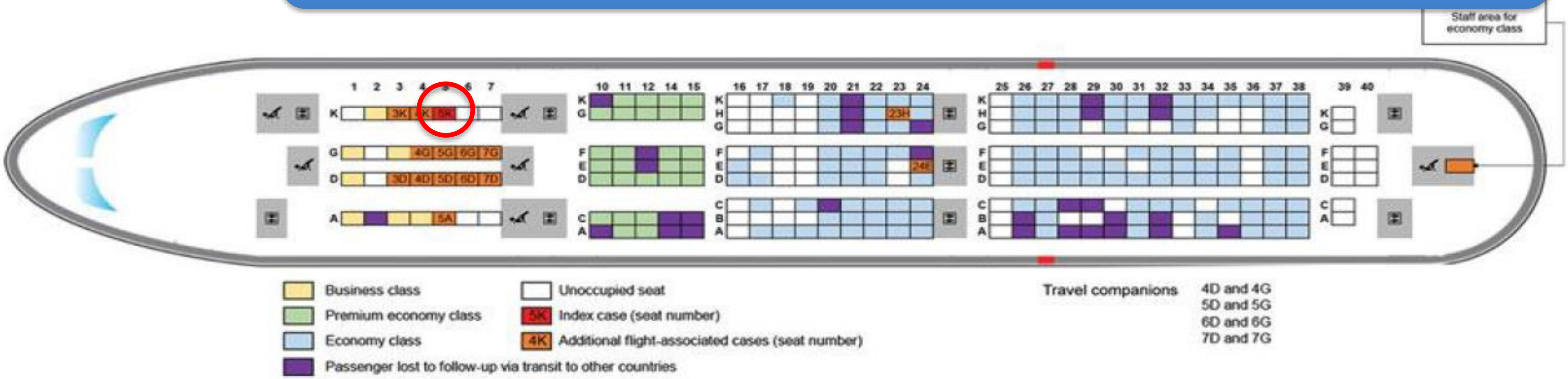
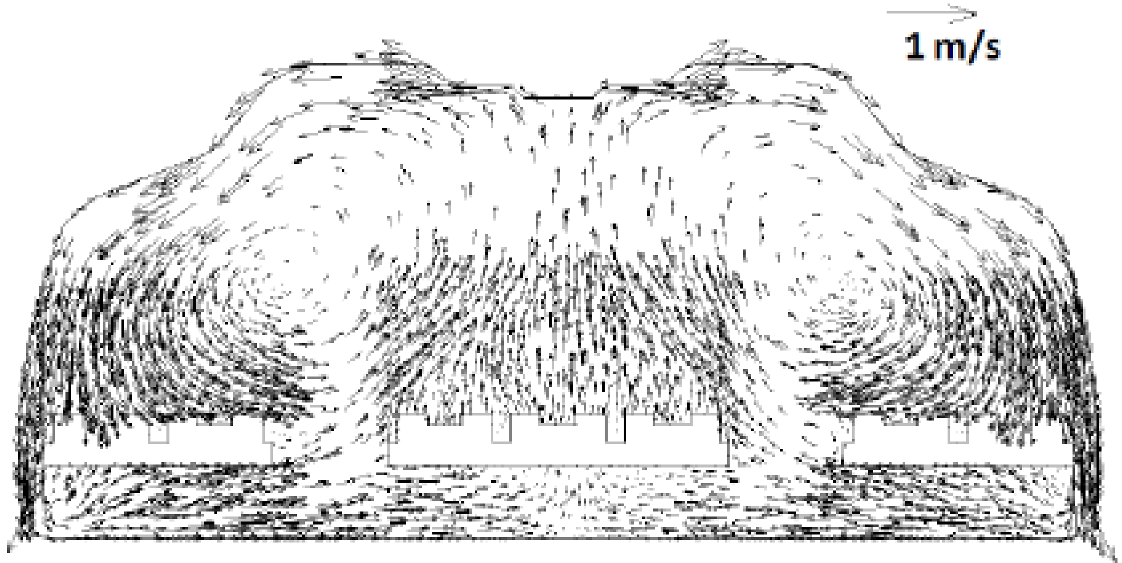


Figure 1. Seating location of passengers on Vietnam Airlines flight 54 from London, UK, to Hanoi, Vietnam, on March 2, 2020, for whom severe acute respiratory syndrome coronavirus 2 infection was later confirmed.

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).

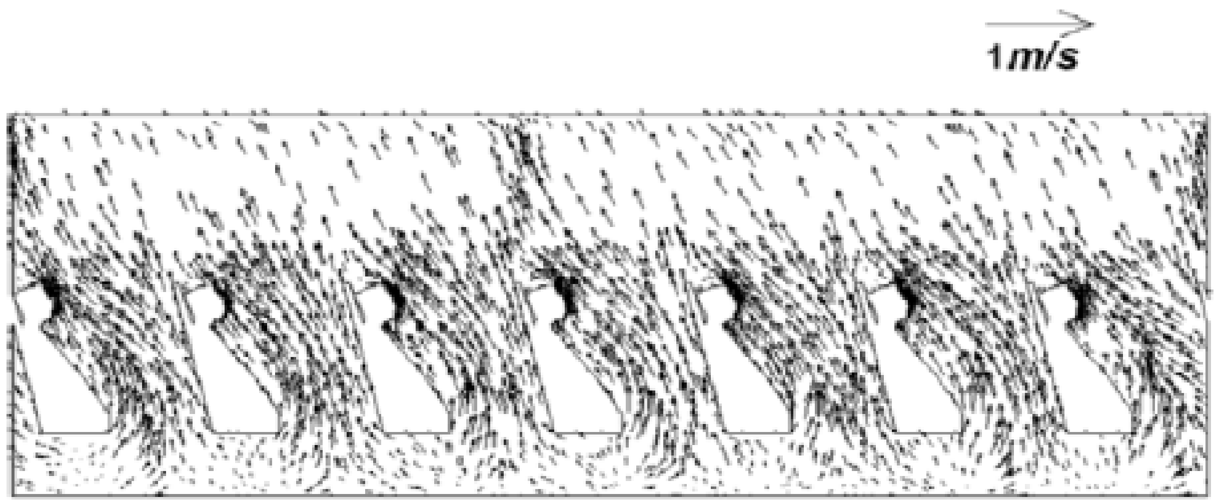
Direct Seat Vicinity → cross-contamination

Aerodynamics
by warm bodies
and cool windows
convection



(a)

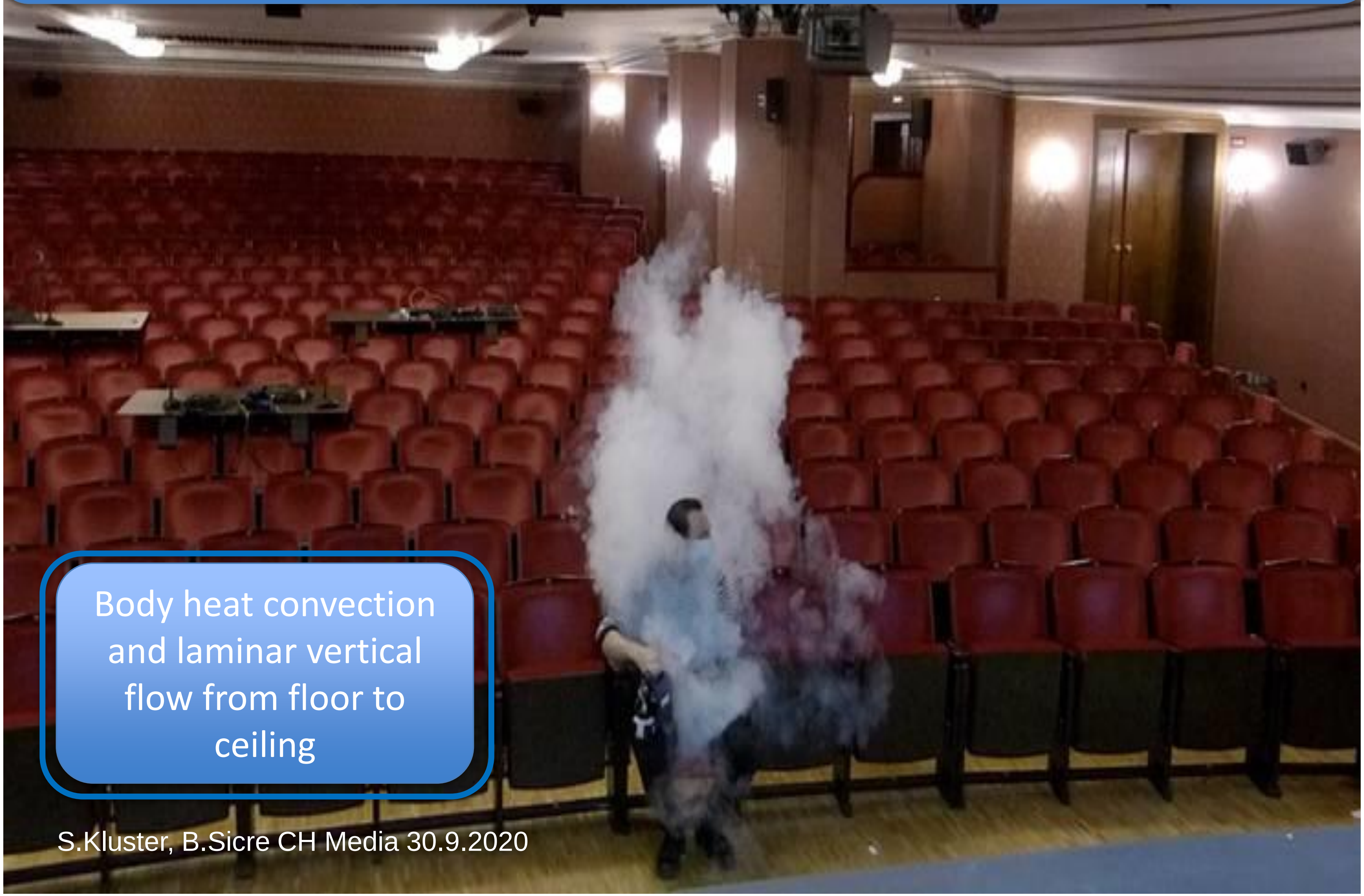
Flow direction
inverted
Would this be
the solution ?



(b)

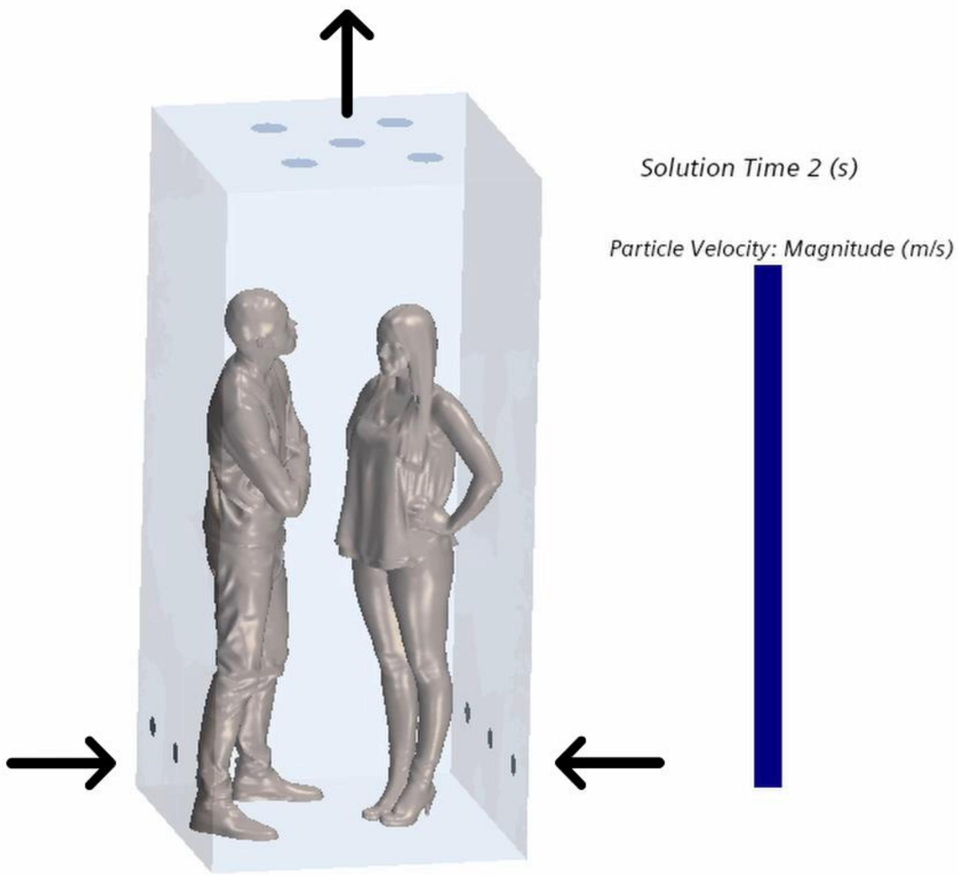
New approach: the only safe place is overhead

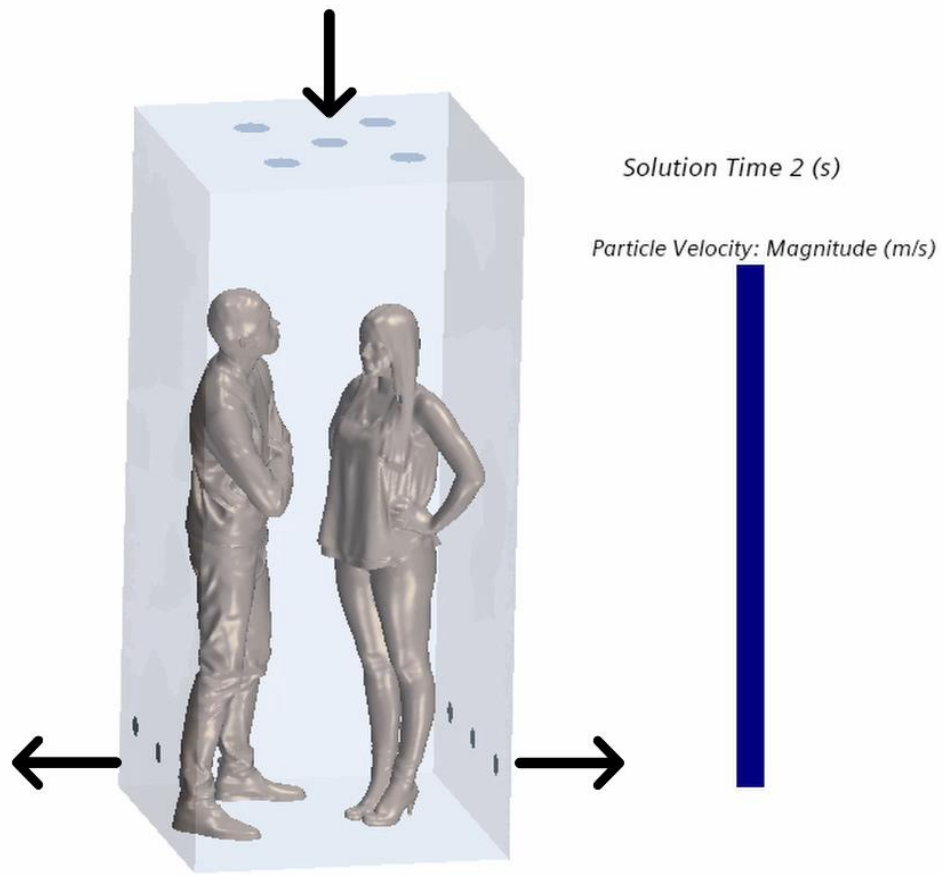
Perfect Solution in the KKL concert hall Lucerne



Aerosol Flow in an elevator cabine

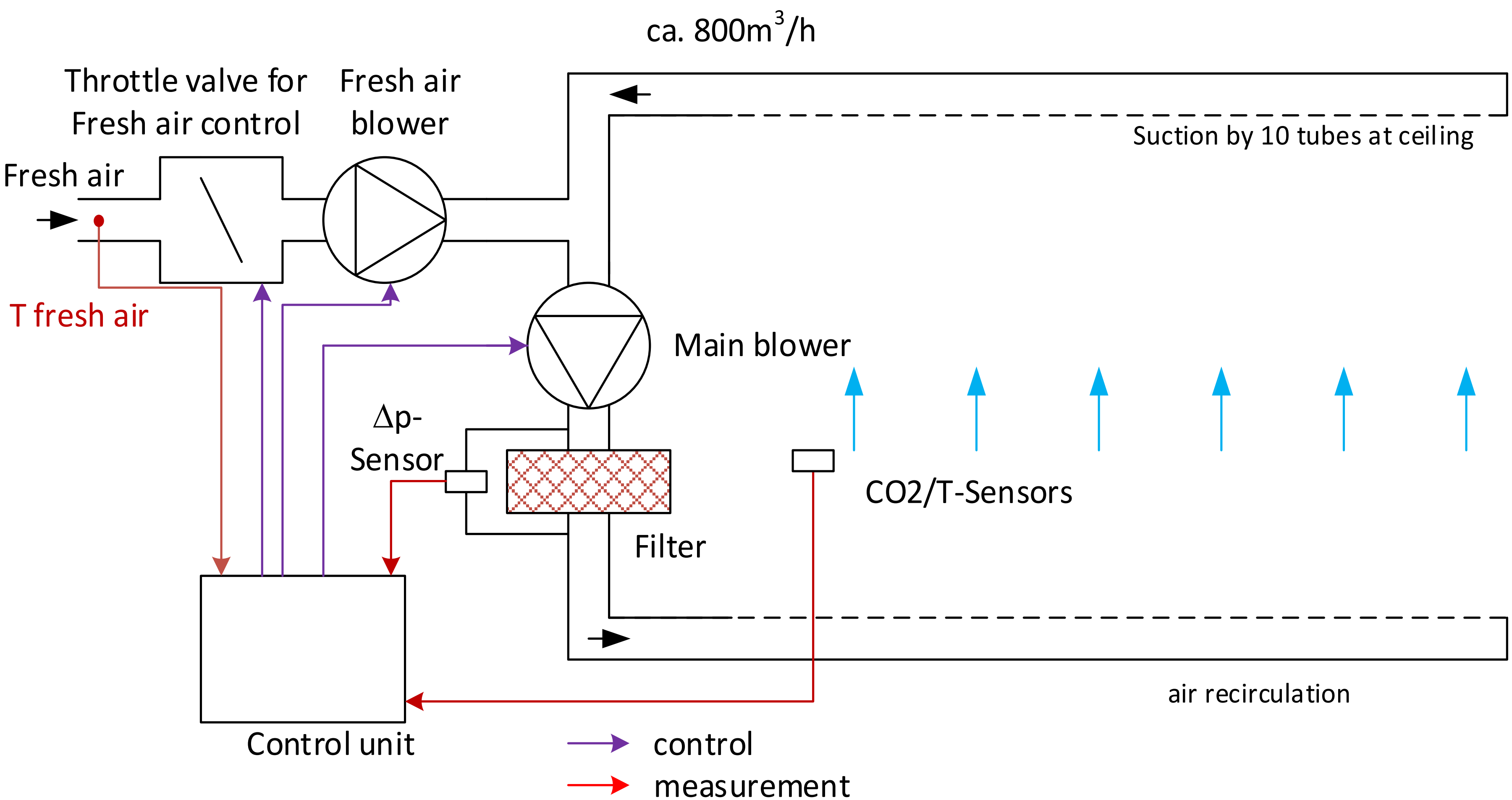
Ventilation „floor →ceiling“ and ventilation „ceiling →floor“





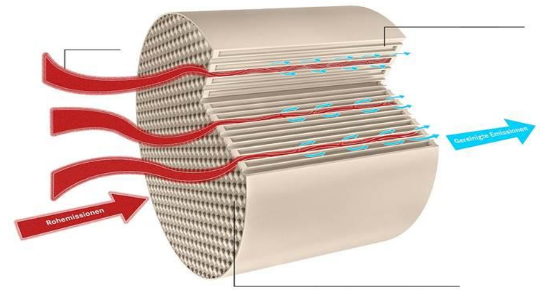
Drift over head the only safe and efficient solution

Classroom Cleaning from UPF and Bioaerosols outdoor and indoor de-contamination

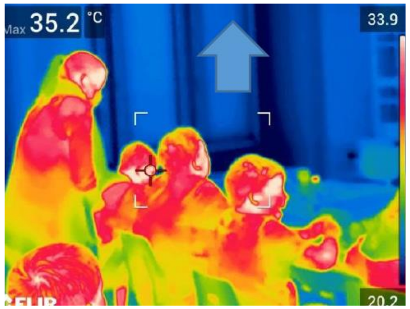


What can be reached in a classroom

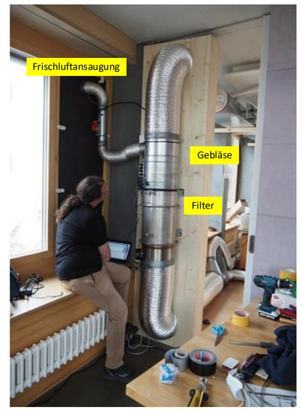
Take the virus contaminated air away at the ceiling (6 x room volume p.hr.). Mix with fresh (but UFP contaminated) outdoor air to control CO_2, heat exchange and coarse particle prefilter, followed by nanofiltration



Vertical laminar ventilation to the safe spot over head



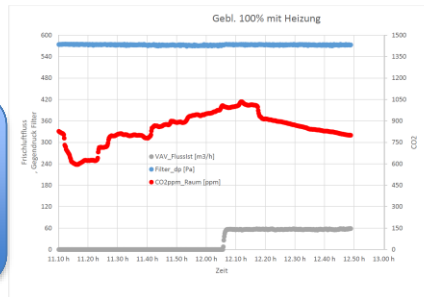
Nanofiltration > 99.9% > 10 nm and deactivation of active virus



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

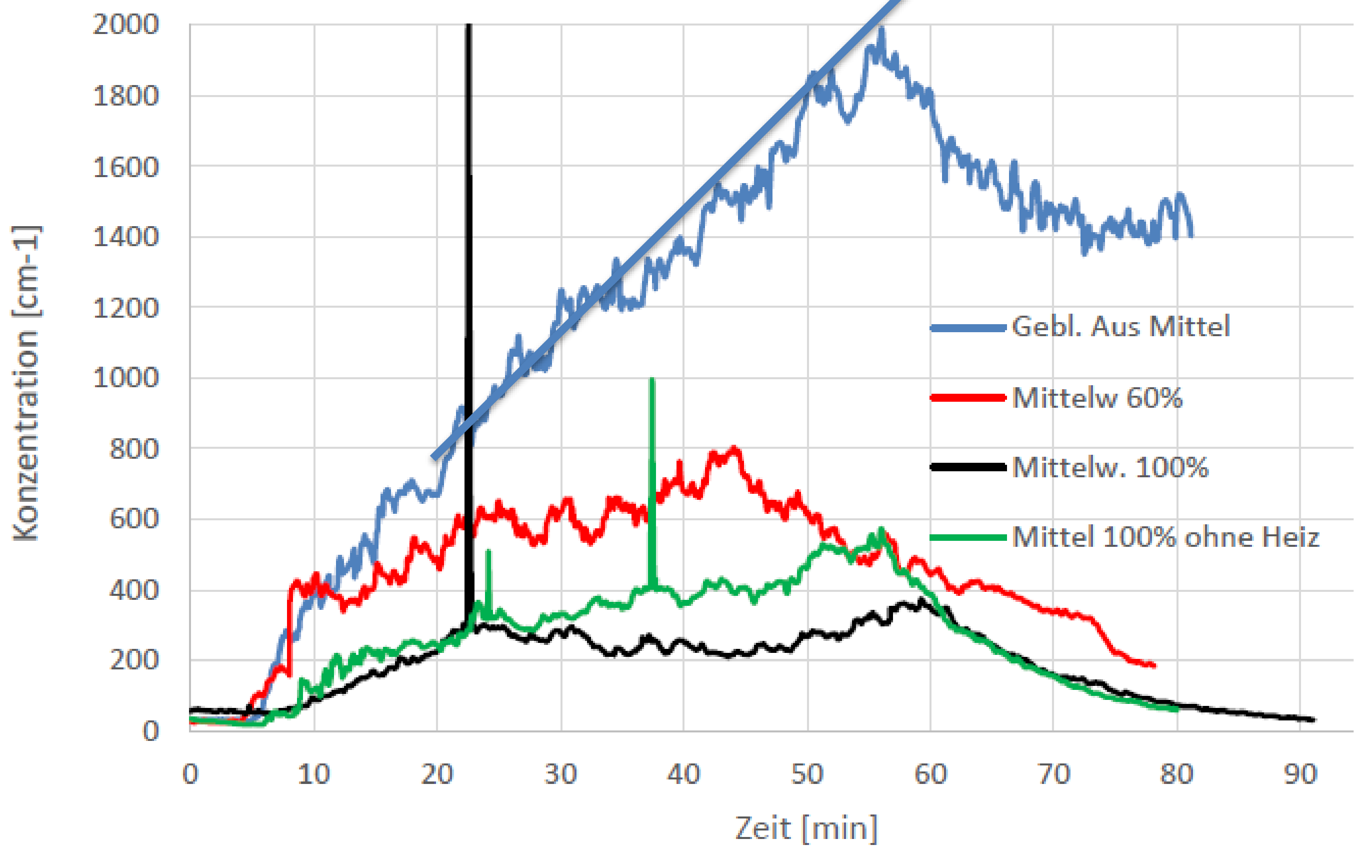


CO_2 control 800-1200 ppm

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

Vertical laminar flow – at a high flow setting

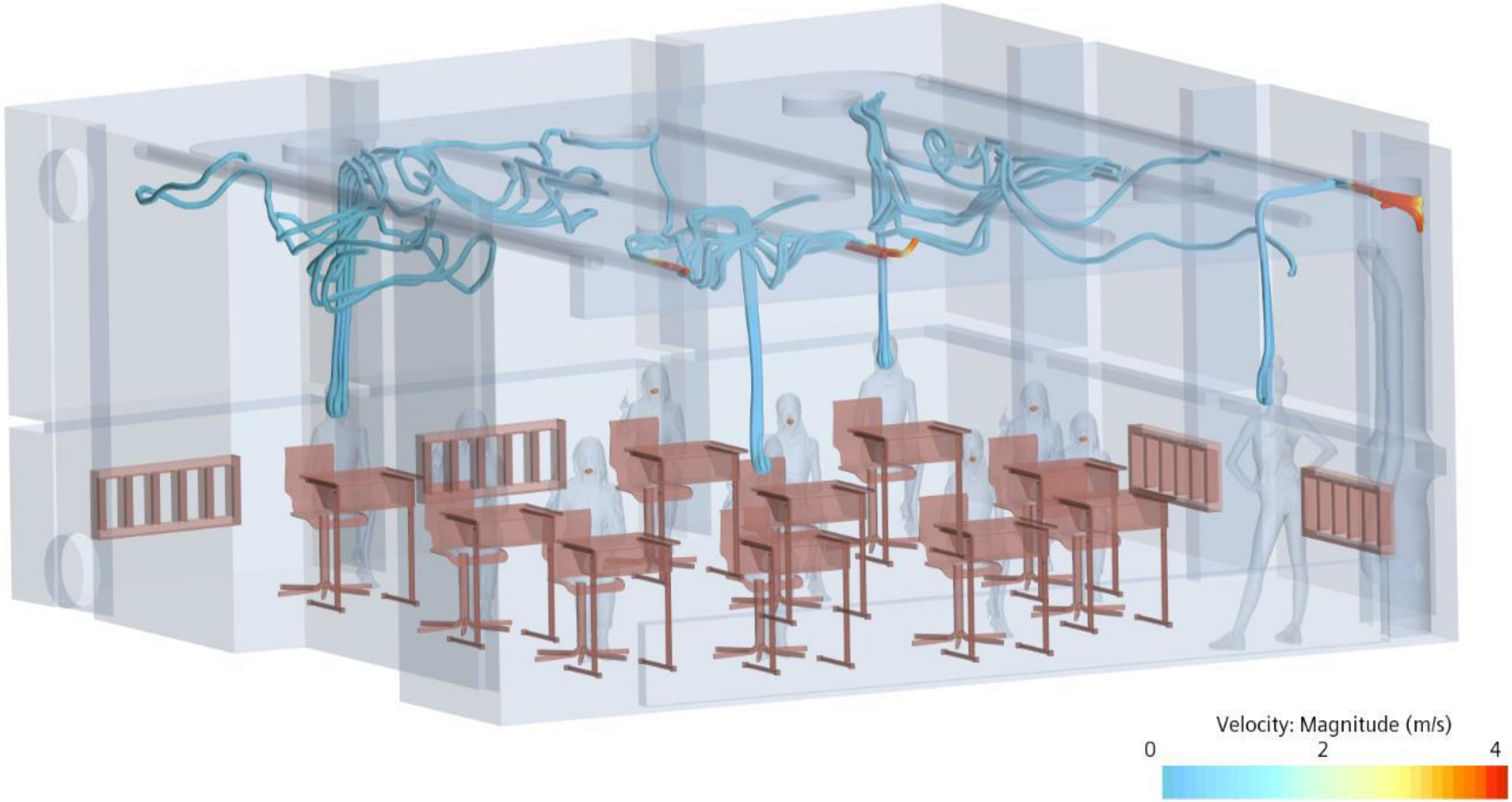
Overall particle content in the room climbs up as long as the partile source (salt) is active but remains on a low level with the activation of the system



Overall particle content is rather unimportant

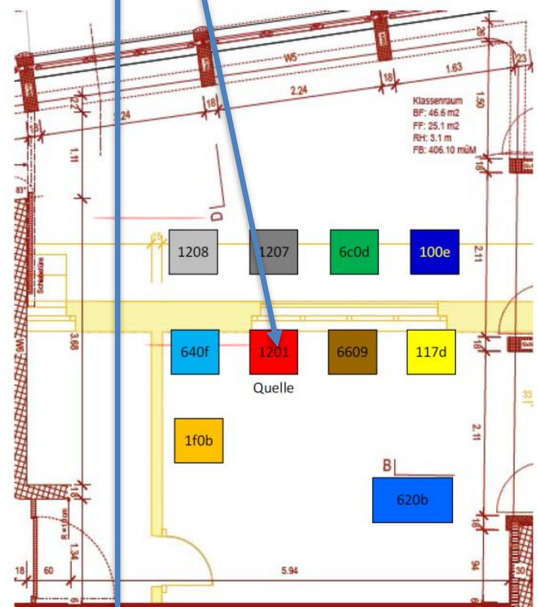
Key is cross-contamination

from the infected person to its immediate vicinity



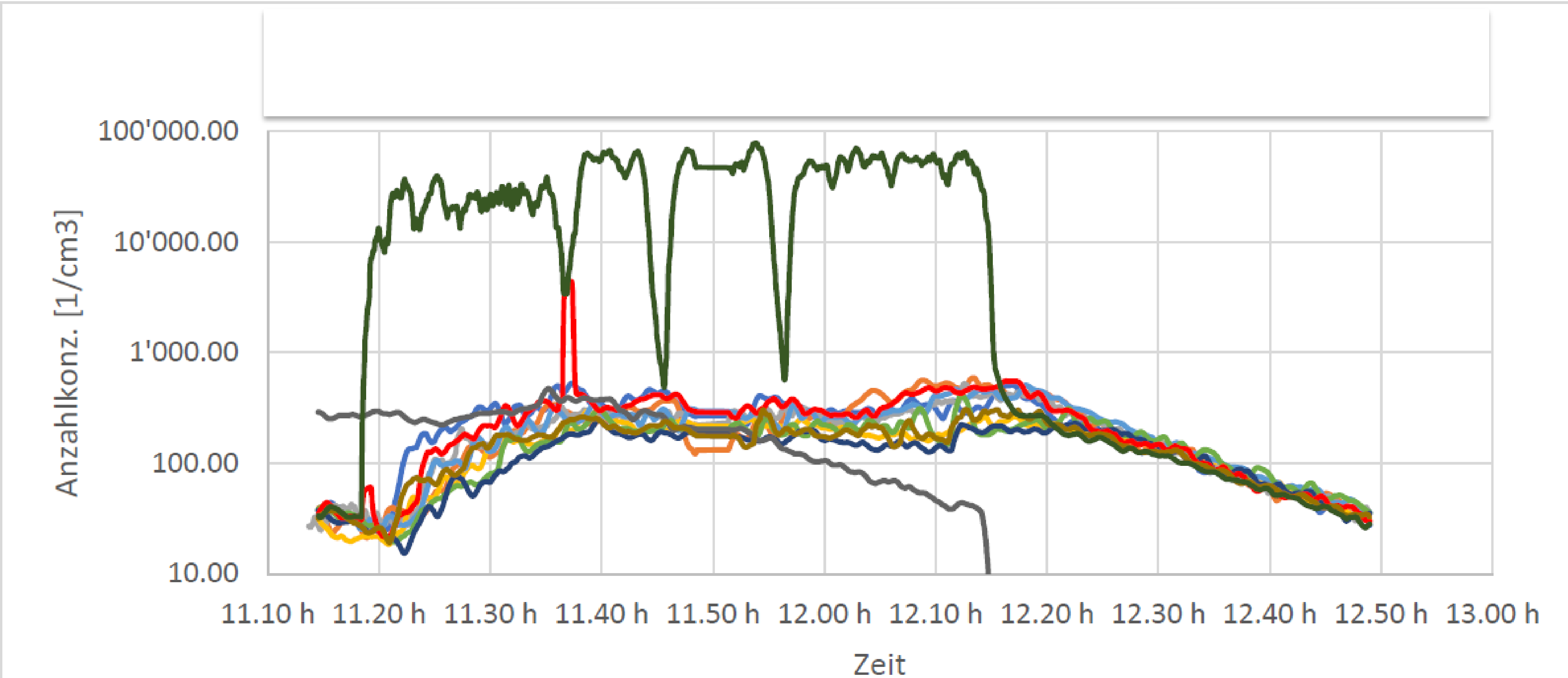
Testing cross-contamination

- 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 reduction even in immediate vicinity of the infected person and homogeneous distribution in the room



A.Mayer, NCA GmbH et al
Nanofiltration combined with laminar vertical flow to minimize virus infection risk
FILTEC Cologne, March 2022

Conclusions in numbers

→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

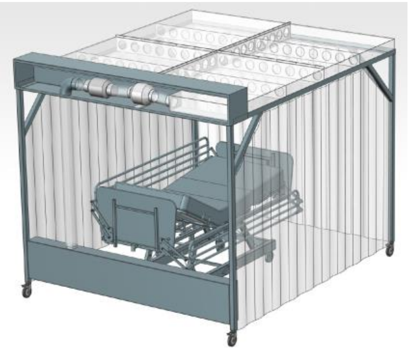
→No aging, easy cleaning, easy desinfection

Conclusions on how to clean breathing air for nanoparticles and bioaerosols

- Conventional Ventilation (fix installed or mobile) does not suppress cross contamination and is thus not recommended
- Fibre filters, even HEPA quality are not recommendet because of aging, low nano-efficiency, disposal problems, humidity
- Fresh air, if not nanofiltered, is UFP contaminated
- Vertical laminar air flow from floor to ceiling is recommended
- Body heat convection to overhead must not be disturbed
- Air recirculation is recommended for energy conservation
- Fresh air is nanofiltered and CO_2 controlled
- New multicell ceramic wall flow filters are used

Applications

- Classroom: one year without any infection – no masks
- Elevator Cabin
- Hospital bed for IMC zoned protection
- Restaurant
- Working places with dense population
- Supermarket, sales and bank counter
- Dentist and similar close-to-patient situations
- Aircraft cabin
- Bus and train cabins



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