Aerosol and CO_2 Measurements

Study by the Fraunhofer Heinrich-Hertz-Institute

KONZERTHAUS
DORTMUND

Excerpts of the Results

from 02 - 03.11.20 & 20.11.20 at Konzerthaus Dortmund

Starting Position

What is this about?
Aerosol spread

- According to current scientific knowledge, SARS-CoV-2 viruses are transmitted / spread from person to person via aerosols / droplets when exhaled / spoken.
- Distance <2m; interaction time 10-15 mins; minimum concentration of viruses (>500 viruses must be inhaled for infection)
- Diameter of SARS-CoV-2 virus approx. 140nm; aqueous aerosols suspended in the room have diameters <1000nm
- **QUESTION: What is the dispersion of such aerosols in Konzerthaus Dortmund?**

CO_2 and indoor air quality

- CO_2 is a scientifically recognised indictor of indoor air quality.
- Ambient value: approx. 400ppm; "bad" indoor air if c(CO_2) > 1000ppm (BMU)
- **QUESTION: Are there correlations between CO_2/aerosol dispersion?**

What has been studied so far?
Previous studies have investigated the dispersion of aerosols on stage, e.g. emission from singers / choirs / musical instruments.
In the audience area of concert halls, there have been no corresponding studies so far.

This is the first published study, aiming to obtain experimental data for the assessment of a possible corona contagion risk in concert audiences.

Methodology

Normal breathing of an audience member is simulated:
The dummy “Oleg” sits in the audience area and disperses precisely defined quantities of aerosols and CO_2 through a tube from his mouth and nose.

The distribution of the aerosols (diameter of several hundred nanometres to micrometres) is measured:

- with the aid of CO_2 measuring devices as well as stationary and mobile aerosol measuring devices
- with and without mouth/nose protection
- taking into account different influence scenarios, e.g. thermal effect of audience which located around the dummy

Participating Institutions

Fraunhofer HHI

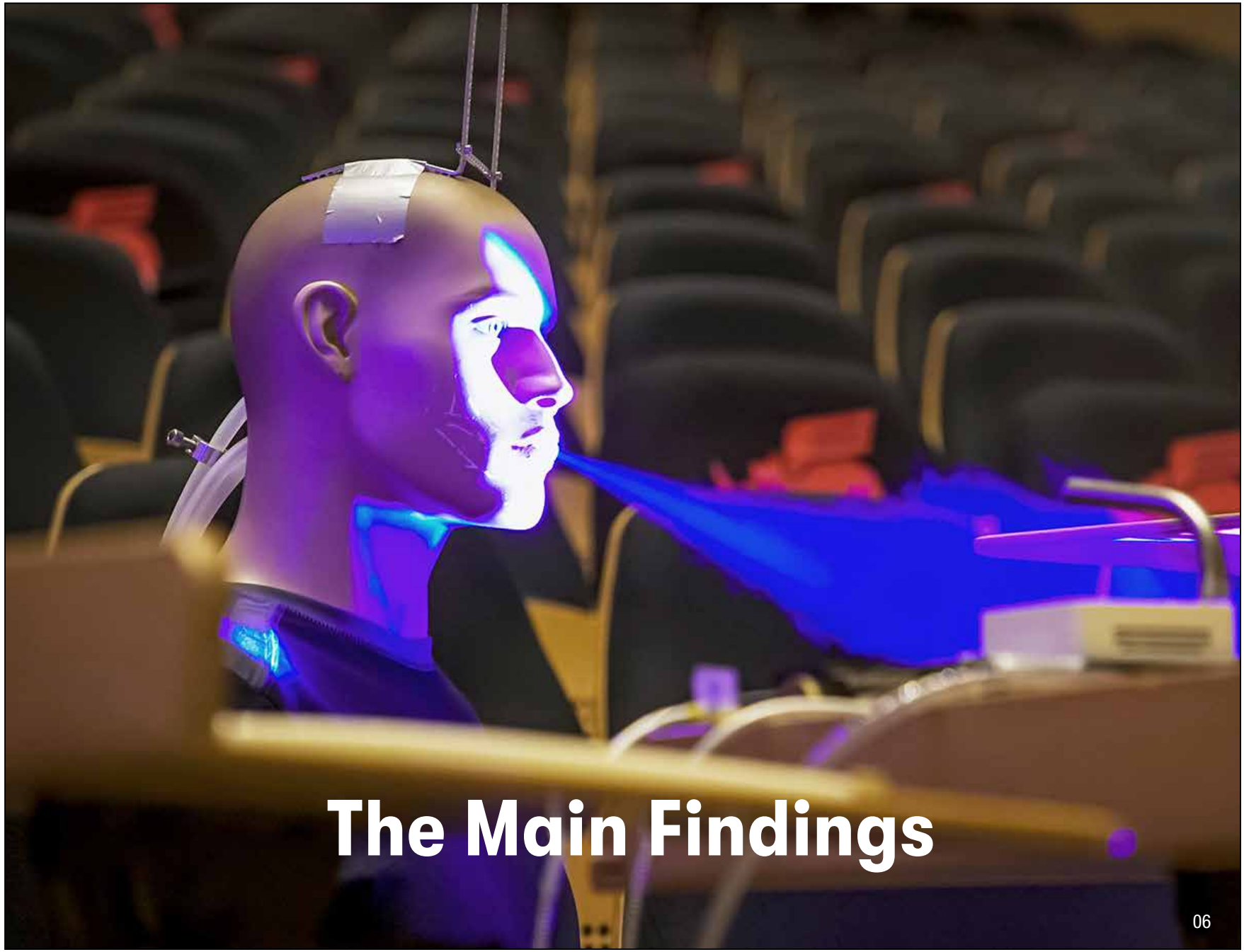
Fraunhofer Heinrich Hertz Institute (Goslar)

The Fraunhofer Institute for Telecommunications, Heinrich Hertz Institute (HHI), develops modern communication and multimedia systems. Its scientists' design principles for innovative information technologies and create new applications for new products as partners of industry. The study at Konzerthaus Dortmund was led by the Head of Fibre Optic Sensor Systems at Fraunhofer HHI (Goslar), Prof Dr Wolfgang Schade.

ParteQ

Parteq

Parteq GmbH was founded in 2016 by Dr Karsten Wegner and Dr Martin Seipenbusch. Both were previously active in university research for many years and ran independent engineering firms in the field of aerosol technology. Through the foundation of Parteq, extensive know-how from the fields of synthesis, functionalisation, characterisation, and separation in aerosol and particle technology have been brought together. Dr Martin Seipenbusch was involved in the study at Konzerthaus Dortmund.



The Main Findings

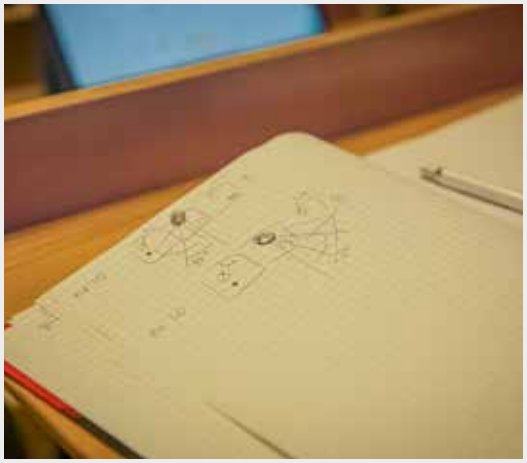
Prerequisites & Basic Assumptions

Complete air exchange in the concert hall every 20 minutes at 100% ventilation capacity

The prerequisite for a new infection is a direct interaction time of at least 12-15 minutes with an infected person (Phys. Fluids 32, 107108 (2020); https://doi.org/10.1063/5.0027844)

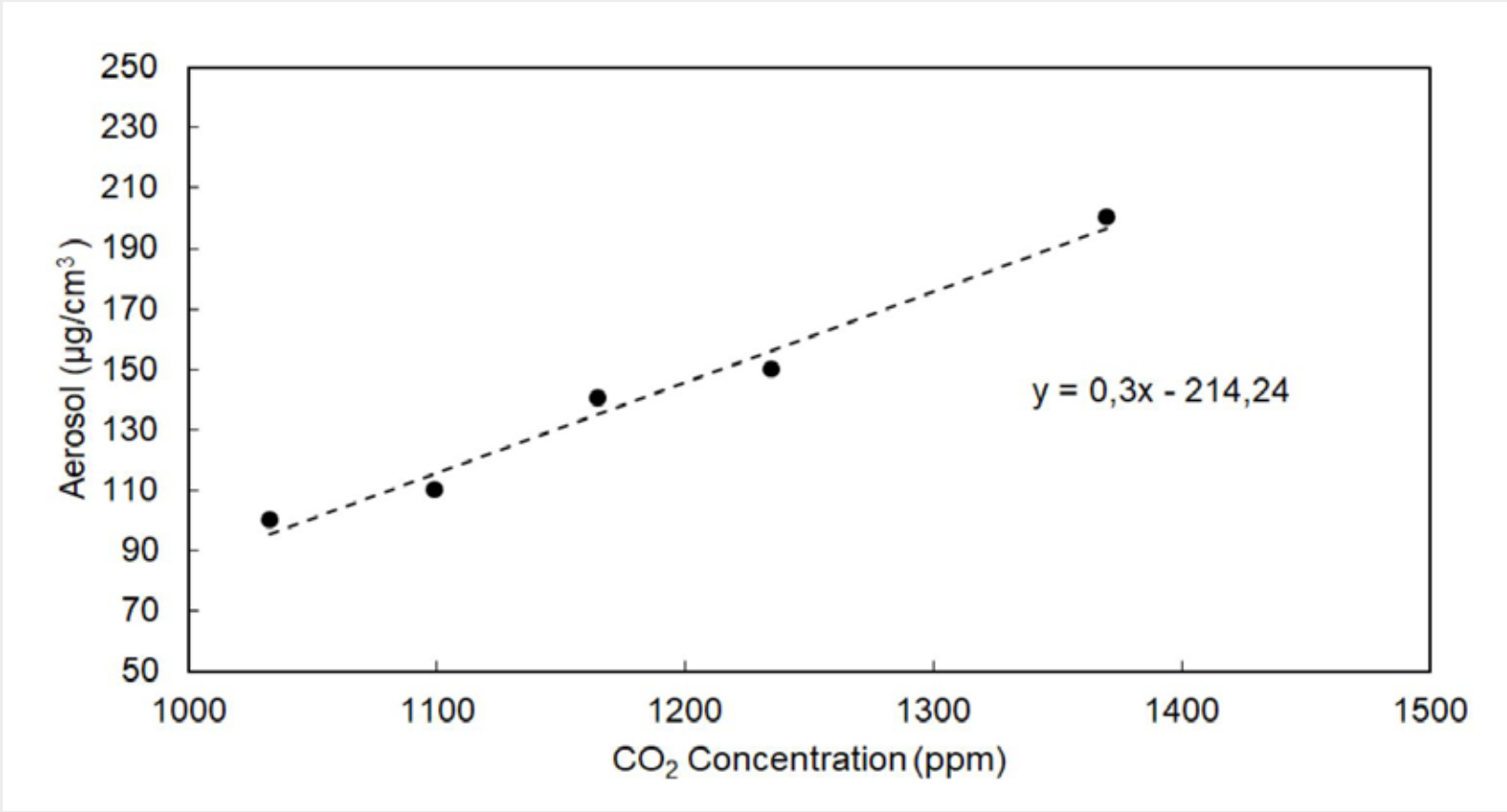
A human has an average of 16 breaths per minute, “Oleg” emits continuously i.e., his emissions of aerosols / CO_2 is on average a factor of 4 too high

Significant correlation between aerosols / CO_2 dispersion in space



Prerequisites & Basic Assumptions

Correlation of simultaneously emitted CO_2 and aerosols (diameter approx. 250 nm)
(correlation factor R = 0.99)



Results Based on the Measurement Data

With mouth / nose protection and sufficient fresh air supply via the existing ventilation system, practically **no influence of test aerosols** on all neighbouring places of an emitting test person (experiments no. 4, 6, 9)
☞ Risk of infections through aerosol transmission in the hall is **almost impossible.**

Large room volume ensures strong **dilution** of polluted aerosols, due to the supply and exhaust air operation without recirculation function, aerosols are effectively removed and cannot accumulate (experiments no. 2 & 10).

Without mouth / nose protection, the seat directly in front should always be kept free, an infection is very unlikely with remaining neighbouring seats (dilution / air exchange, experiment no. 8).
☞ **Checkerboard style occupation of the hall without masks** is conceivable.

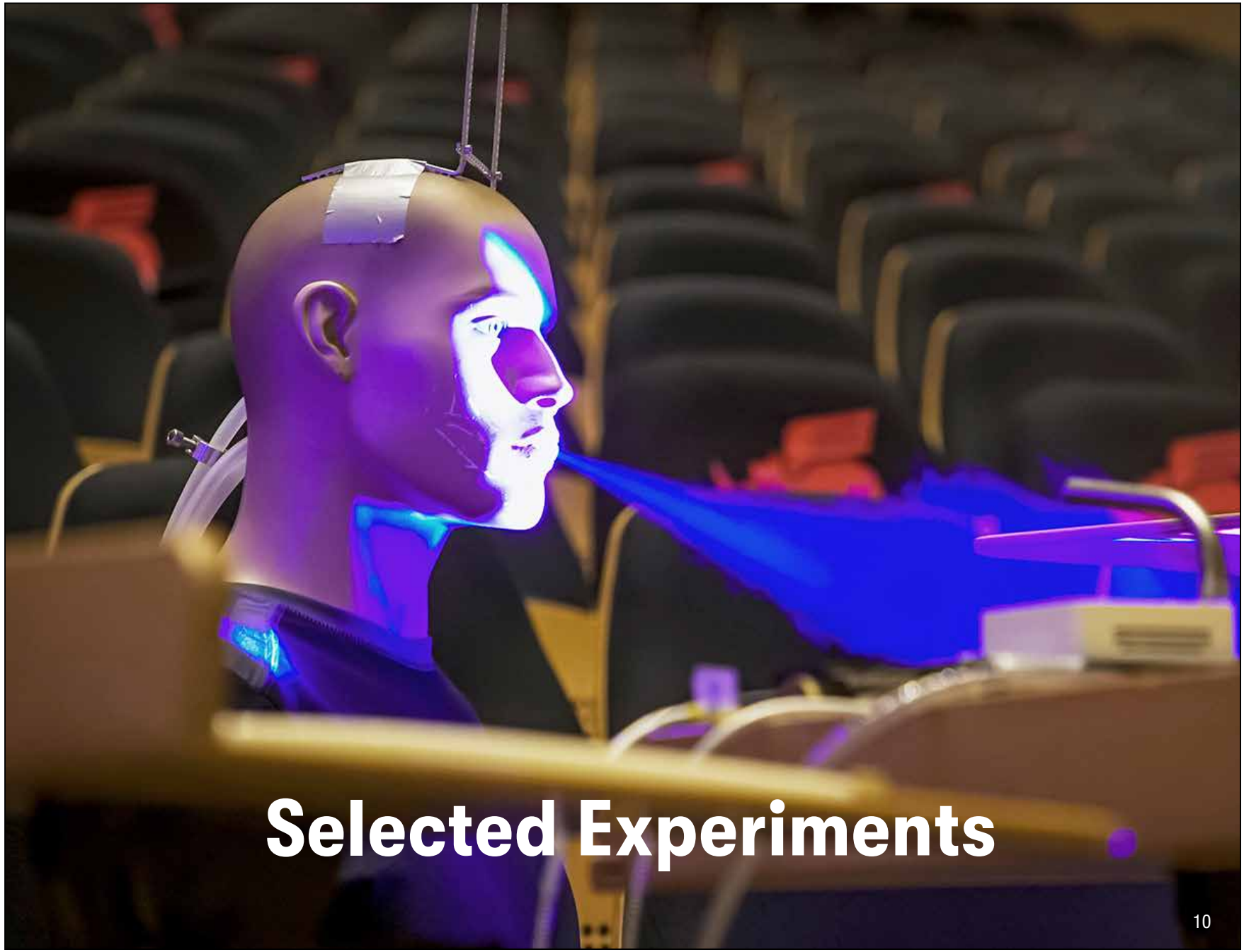
Occupation of the concert hall with **many people** does not disturb the air exchange upwards, but rather promotes it through additional thermal effects.

Wearing mouth / nose protection in corridors, in the break area, and in the foyers is generally necessary (different ventilation than in the hall, stronger distribution of aerosols / CO_2 due to undirected air currents).

Konzerthaus Dortmund cannot provoke a superspreading event with the ventilation system in place.

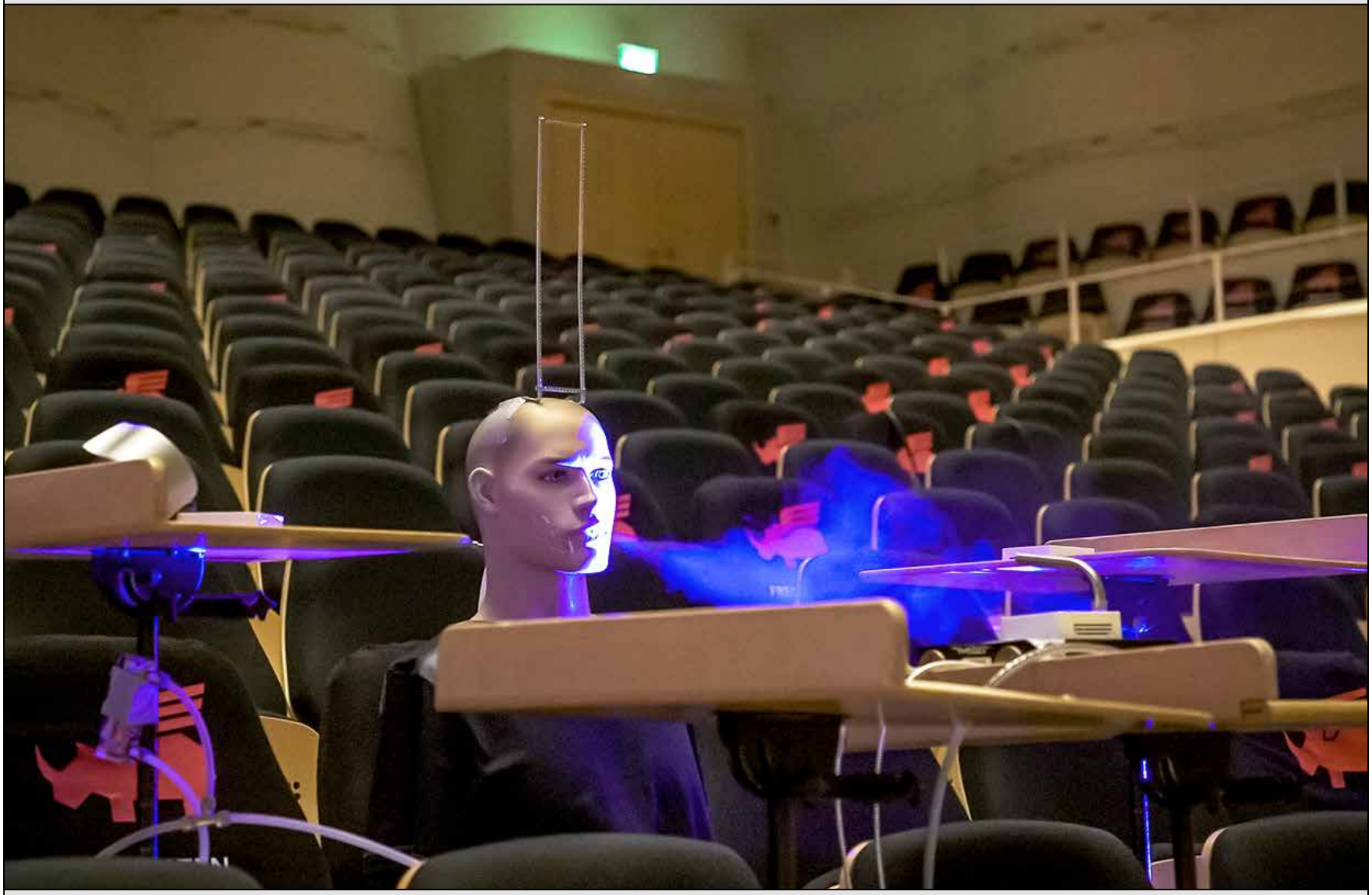
CO_2 measurements during operation can help to assess the dispersion of aerosols (diameter <1000nm).

Statements **for other concert halls or theatres** with comparable framework conditions is possible on the basis of this study.



Selected Experiments

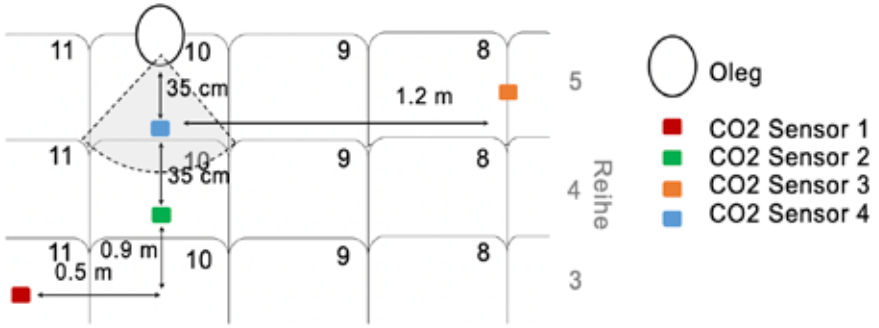
Experiment No. 2 – Ventilation

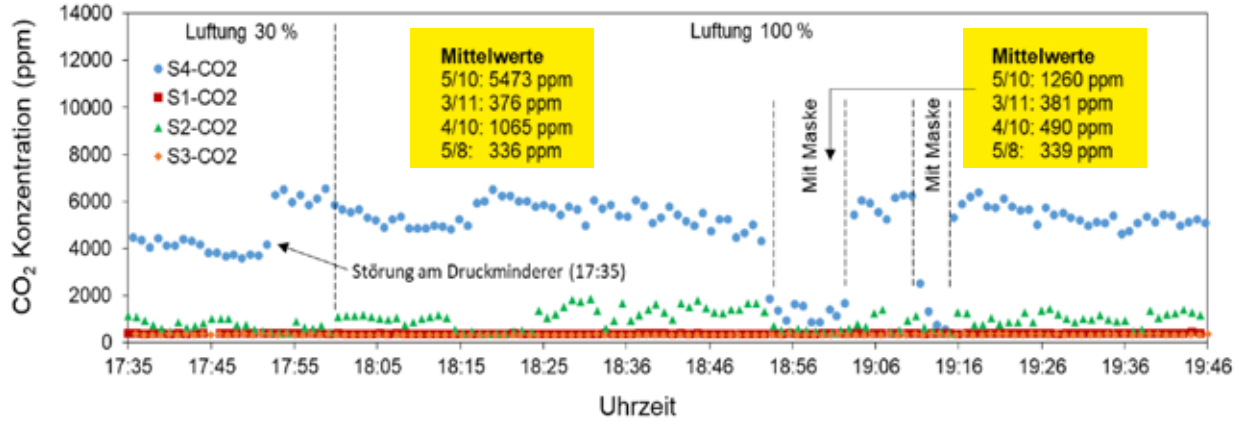


Experiment No. 2 – Ventilation

Influence of ventilation

Switching the ventilation from 30% to 100% ventilation capacity leads to a reduction in emission values.





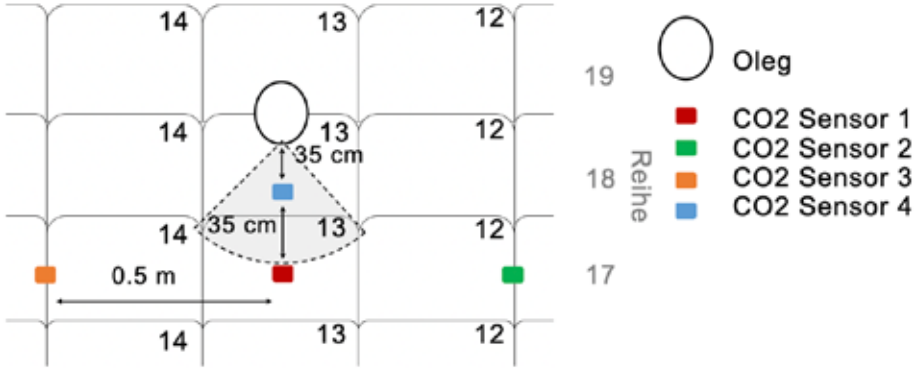
Experiment No. 4 – Mouth / Nose Protection

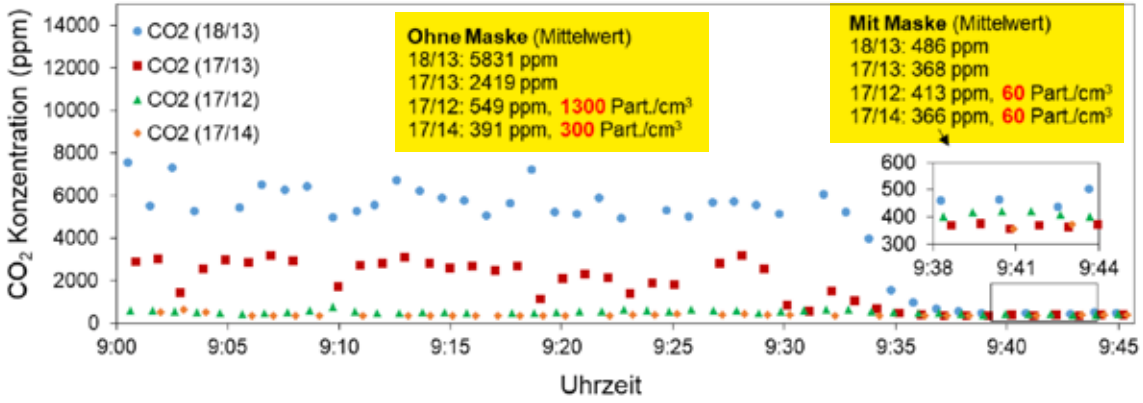
Dummy “Oleg” with mouth / nose protection

Experiment No. 4 – Mouth / Nose Protection

Measurements with mouth/nose protection

No aerosol / CO_2 value increased by the emitter (dummy “Oleg”) is measured for any seat neighbour (front / back / side / diagonal).





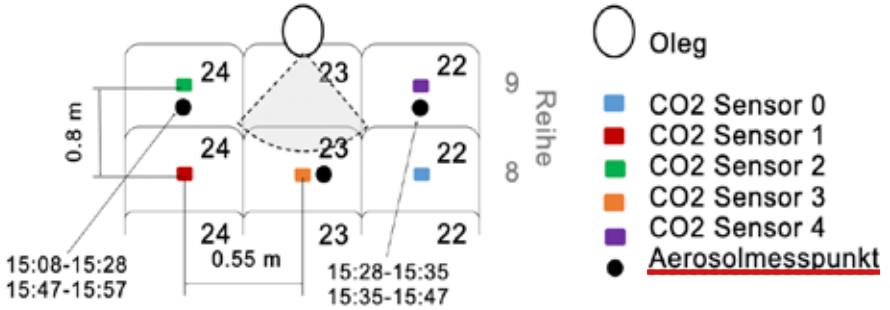
Experiment No. 9 – Stalls with 52 People

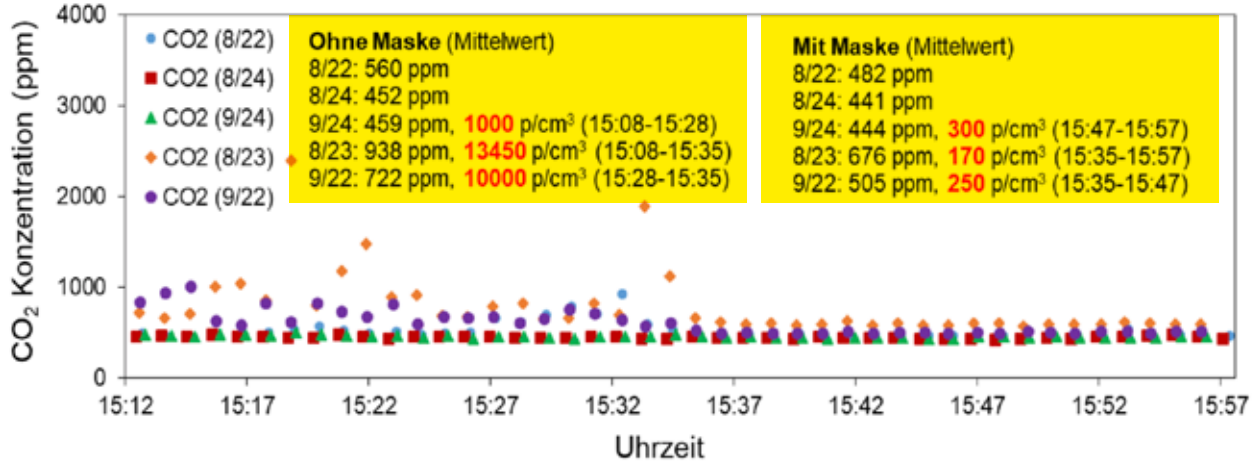
Real people sitting around “Oleg” in the checkerboard pattern and with mouth / nose protection

Experiment No. 9 – Stalls with 52 People

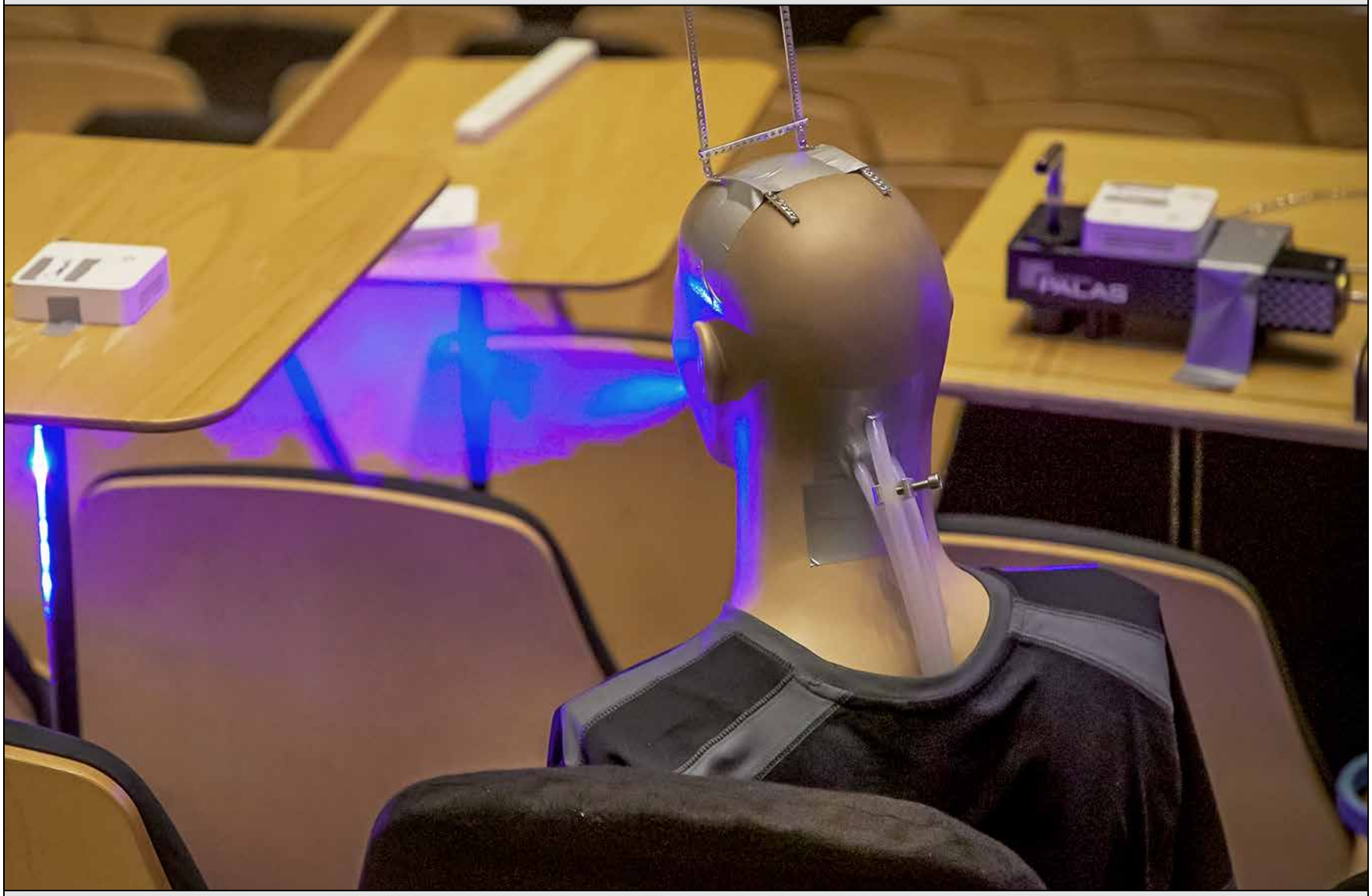
Real people sitting in the checkerboard pattern (with mouth/nose protection)

Real people around the emitted (dummy "Oleg") provide comparable results as in the case of the emitted sitting isolated for aerosol / CO_2 distributions (see experiment no. 4): no increased aerosol / CO_2 values.





Experiment No. 8 – Head Rotation

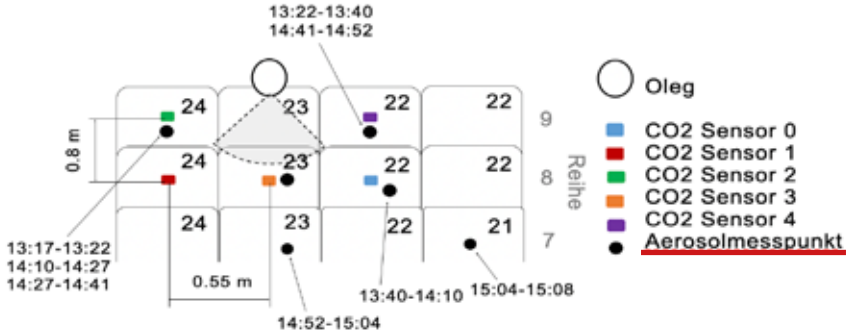


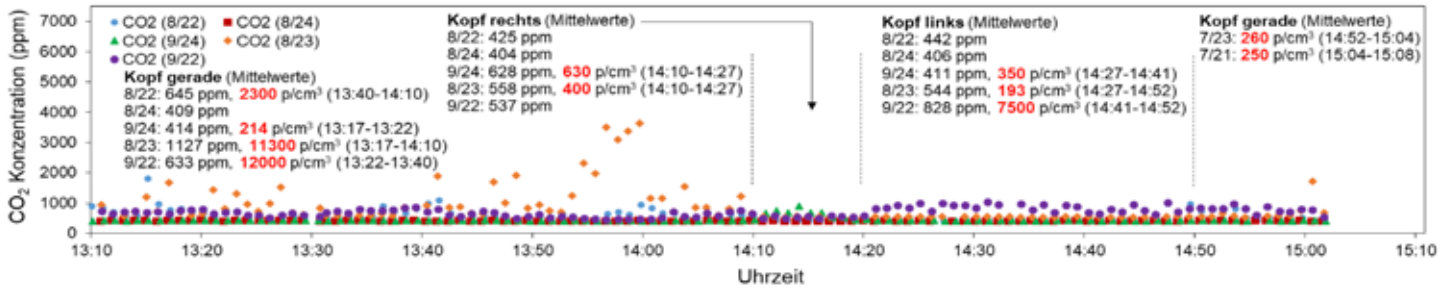
Measurements when head turned

Experiment No. 8 – Head Rotation

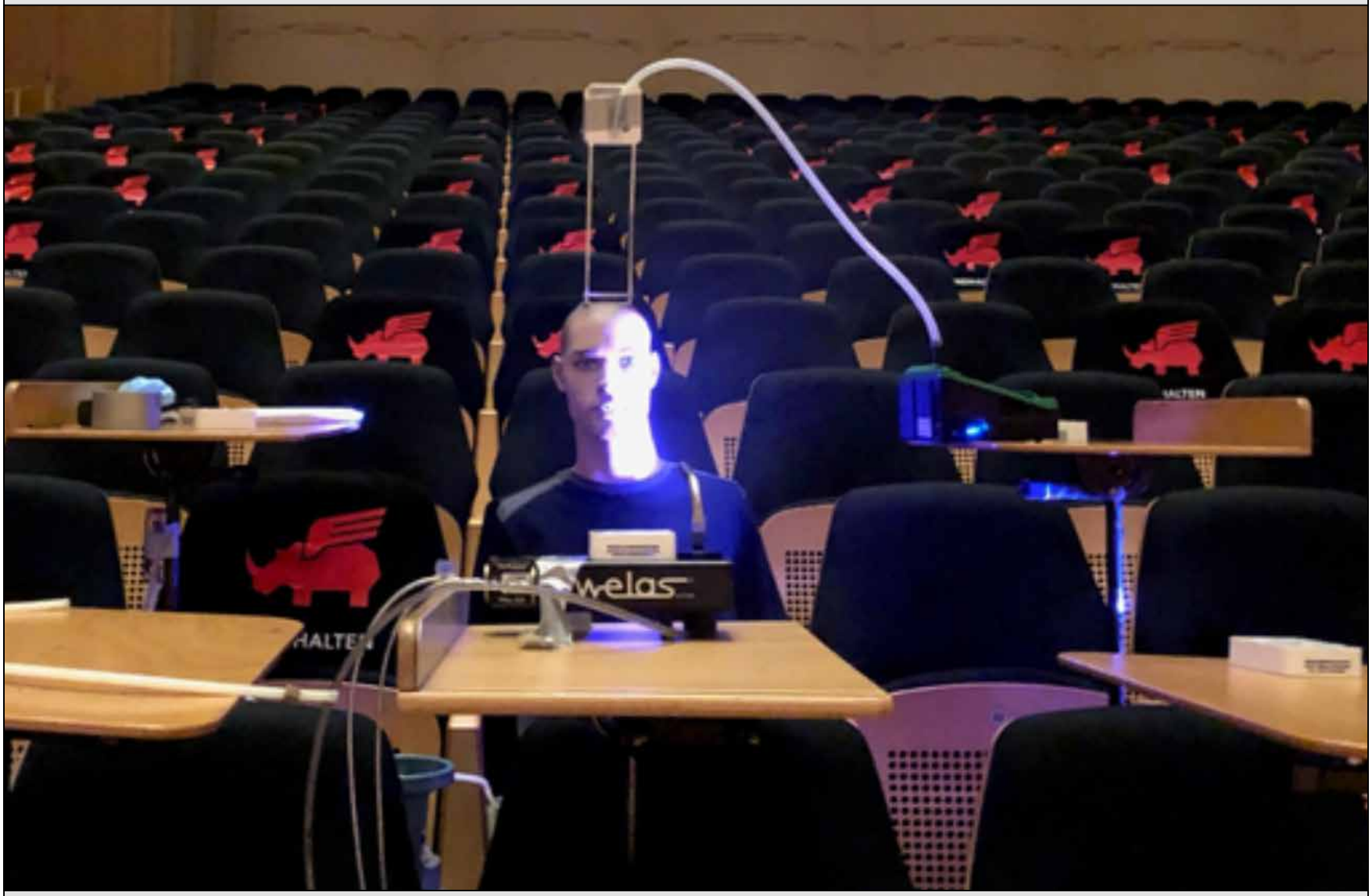
Head rotation influence (without mouth / nose protection)

- Directional emission cone in line of sight, directly in front of person aerosol / CO_2 (11300p / cm3; 1127ppm) dilution after 70 cm (1 row of seats) 260p/cm3; 400ppm
- Direct neighbours to the side and diagonal seats in front of an emitter (dummy "Oleg") do not experience increased aerosol / CO_2 emissions; only a slight increase of aerosol / CO_2 when turning the head to direct neighbouring seats (slight flow difference possible depending on seat)





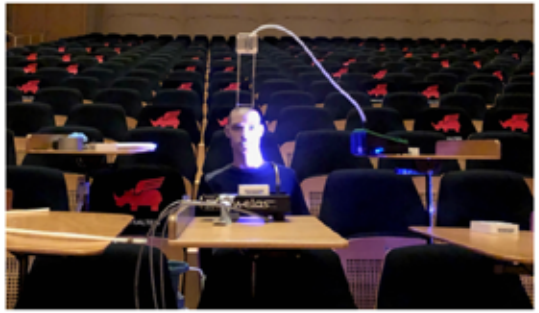
Experiment No. 10 – Aerosol/CO_2 Measurements Above the Head

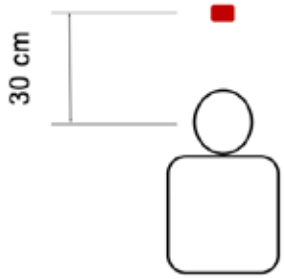


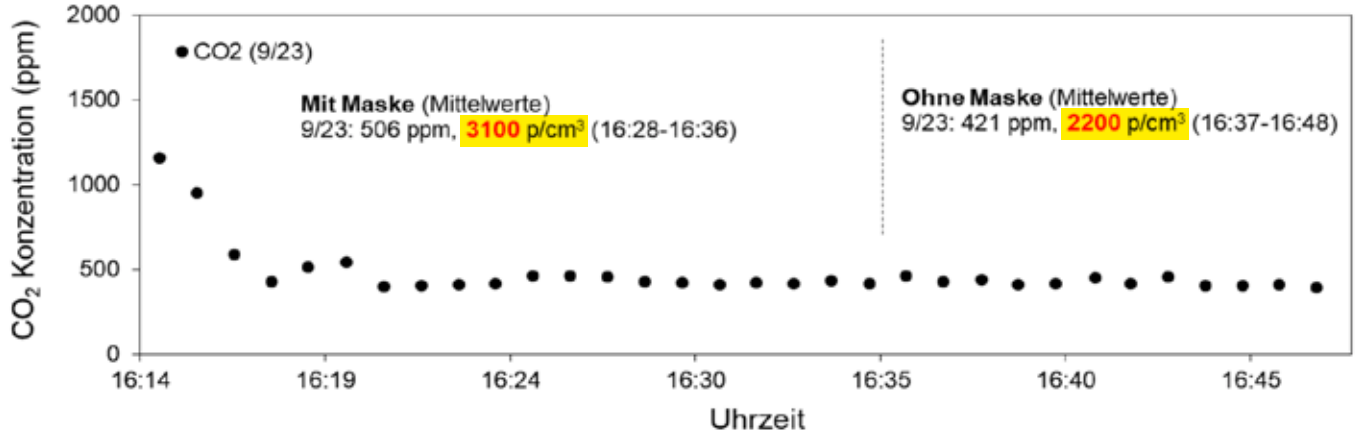
Experiment No. 10 – Aerosol/CO_2 Measurements Above the Head

Measurements above the head

- **With mouth/nose protection:** no directed aerosol/CO_2 emission to the front – diffuse distribution around the head due to ventilation / temperature gradient upwards (significant increase in aerosol mean average, slight increase in CO_2 mean average)







Contact

Fraunhofer HHI

Contact for study enquires - Fraunhofer HHI

Prof Dr Wolfgang Shade
Head of Department Fibre Optic Sensor Systems
Fraunhofer Heinrich-Hertz-Institute
wolfgang.schade@hhi.fraunhofer.de

KONZERTHAUS DORTMUND

Contact for KONZERTHAUS DORTMUND

Britta Lefarth
Assistant to the Director
britta.lefarth@konzerthaus-dortmund.de

Our special thanks to Dr Heinz-Jörn Moriske, Director and Professor at the Federal Environment Agency, and Hygiene Expert Professor Dr Martin Exner for their extensive professional support

KONZERTHAUS DORTMUND

- one of the leading concert halls in Europe with renowned artists, international orchestras, and innovative programmes
- concert hall conforming to the highest acoustic standards
- opened in autumn 2002 in the heart of Dortmund
- Artistic Director since 2018/19: Dr. Raphael von Hoensbroech
- 1,550 seats
- approx. 200 events per year / approx. 180,000 visitors per year
- focus on classical music, but also jazz, cabaret, pop
- a member of the European Concert Hall Organisation since 2012, one of just four German concert halls to be a member (collective of the 22 leading European concert halls)
- exclusive artists since 2010/11: Esa-Pekka Salonen, Yannick Nézet-Séguin, Andris Nelsons, Mirga Gražinytė-Tyla
- "Junge Wilde" series since 2005/06: young artists on the threshold of an international career (including Janine Jansen, Jan Lisiecki, Ray Chen, Yuja Wang, Gautier Capuçon and Khatia Buniatishvili)
- London Symphony Orchestra has been a resident orchestra for three years since 2019/20
- further programmatic focal points such as Zeitinsel, Curating Artist, Neuland
- first concert hall in Germany to include community music in its programme

KONZERTHAUS DORTMUND
Brückstraße 21 | 44135 Dortmund
T 0231 – 22 696 200 | F 0231 – 22 696 222
info@konzerthaus-dortmund.de
www.konzerthaus-dortmund.de

KONZERTHAUS
DORTMUND