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**Federal Institute of Metrology METAS**

# Investigation of the flow characteristics in an aerosol mixing facility

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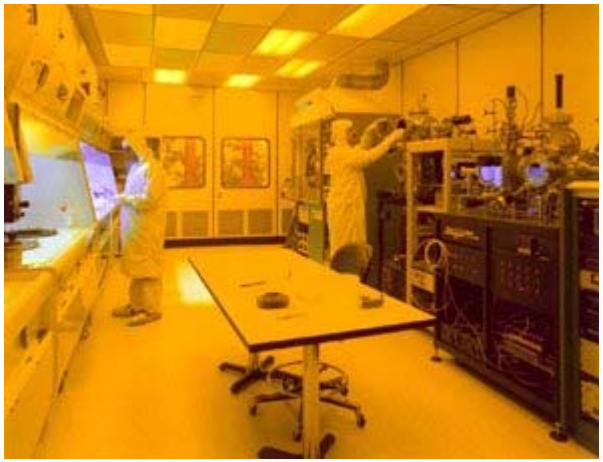
Federal Institute of Metrology METAS – Comsol Conference 2018, Lausanne

# Agenda

1. Motivation – Calibration of particle detectors and issue certificates
2. A facility as primary standard for particle concentrations 1 to 100 $cm^{-1}$ (0.3 to 5 micron)
3. Measurement and simulation of flow and mixing characteristics
4. Conclusions - Outlook

# Motivation -1

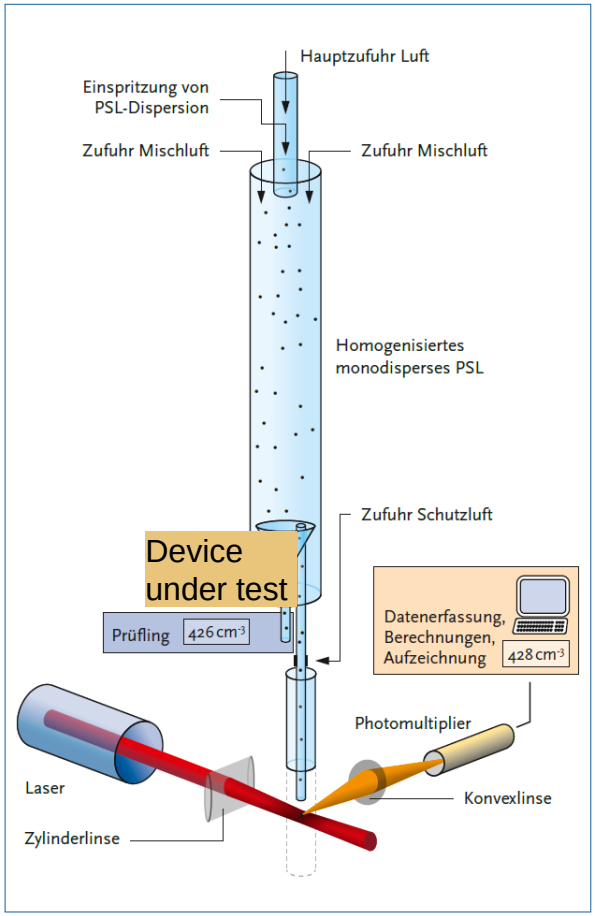
- Why measuring accurately small particle number concentrations? Why are national metrology institutes involved?
- **Clean rooms**: need to be certified and controlled
  This is done by optical particle counters which need to be calibrated – **METAS** has a facility to create a primary standard
- **Air pollution** (particulate fraction): Emissions and Imissions need to be monitored with known accuracy for fair and save regulations

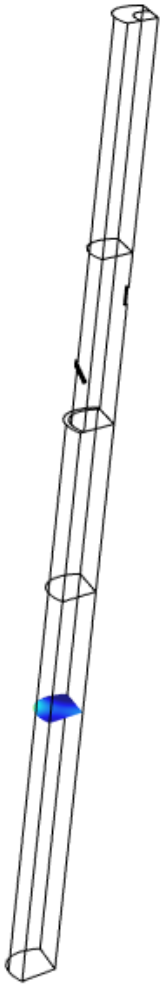


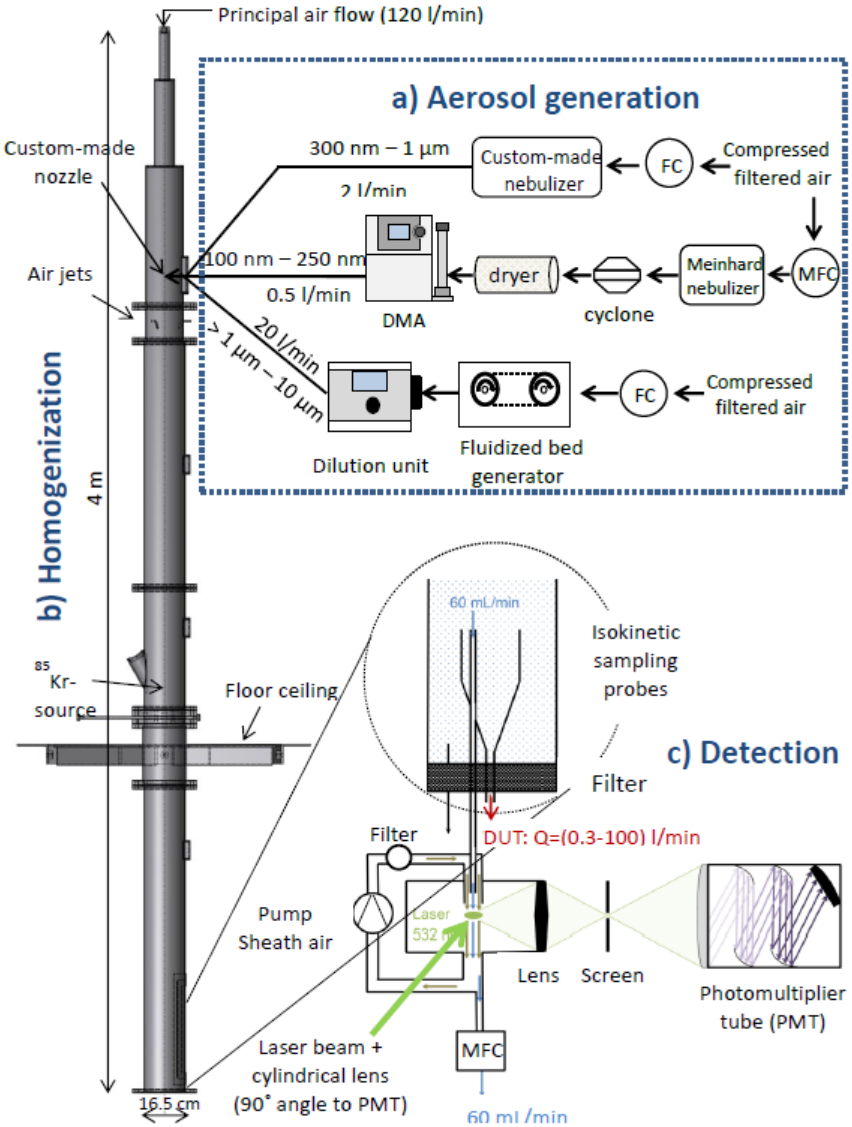
*Source: Wikipedia*

# Particle concentration standard facility

- Reynoldsnumber around 1800
  - just turbulent!?



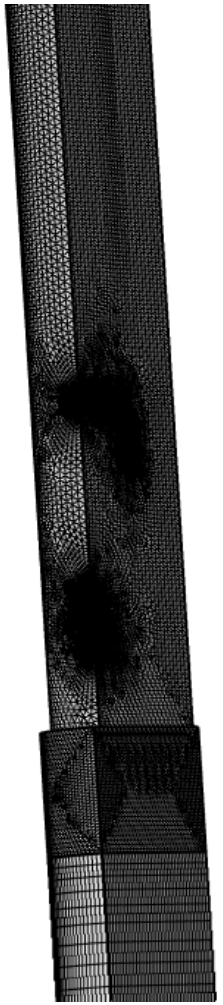






Turbulence Literature: Huff et al., Sibulkin (1962)

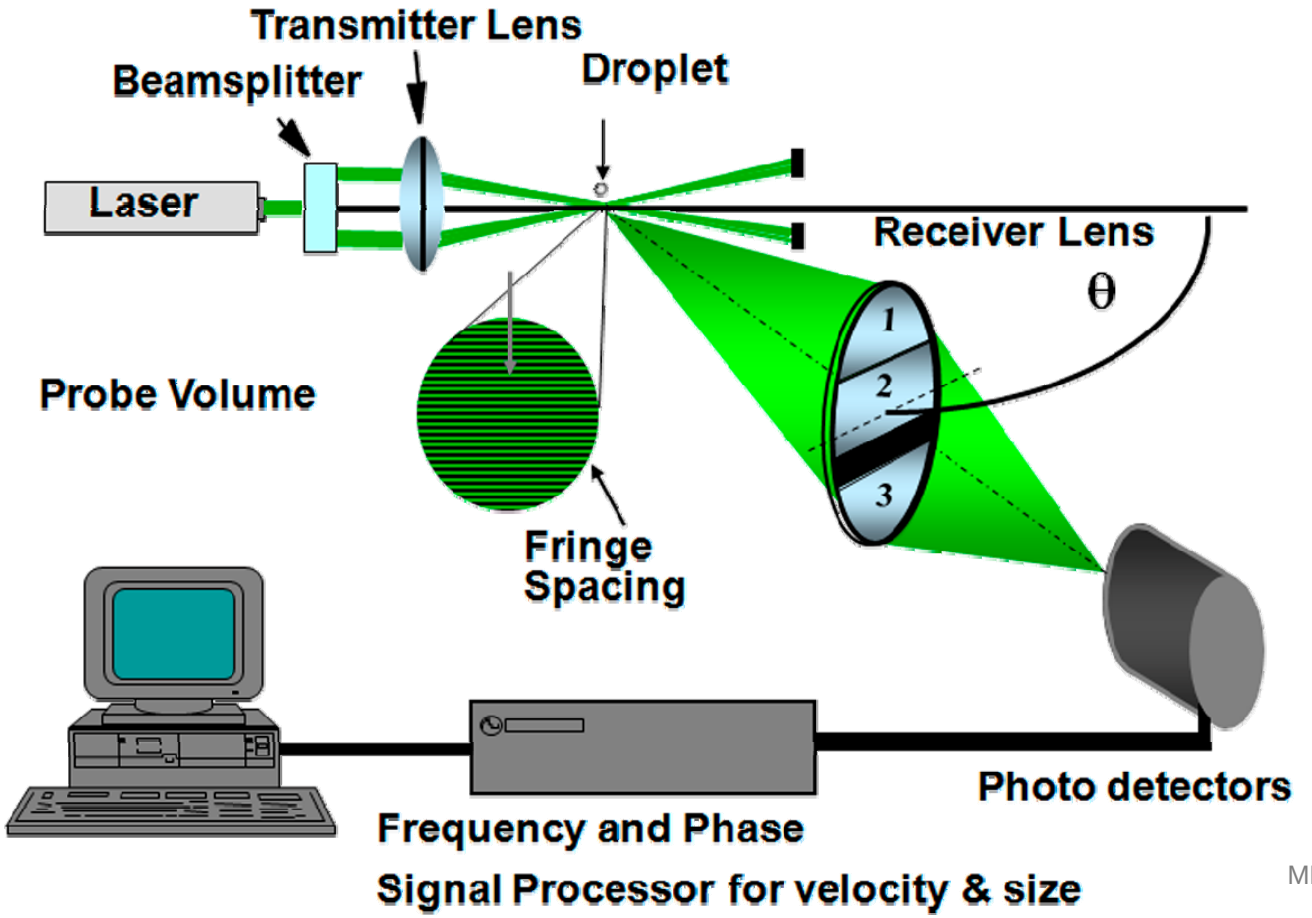
# Particle concentration standard facility – CFD

- Flow Characterization with CFD module of Comsol
- How to **model turbulence**?
- Standard k-epsilon model and wall functions did not work well
- **Low-Reynolds number model** that resolves the boundary layer at the wall
- However, huge numerical effort – app. 1Mio cells
  **Symmetry used** (half or 1/3)
- Calculation time 6-12 hours
- Lagrangian particle tracking even worse, since the equations become numerically “stiff” for small particles – small time steps needed, particles trapped at wall
- Hence, **transport equation for dilute species** with large diffusivity solved



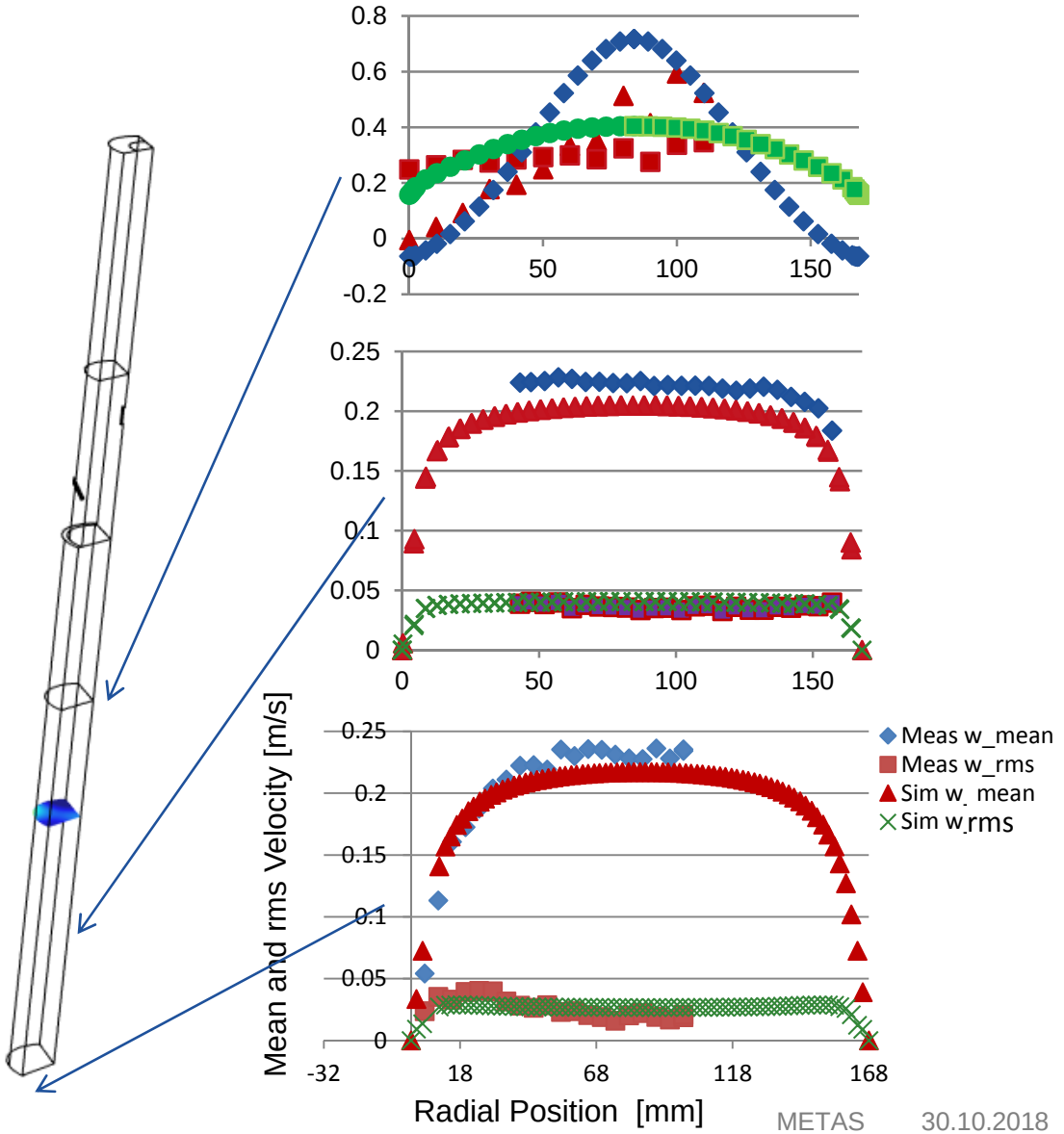
# Particle concentration standard facility – flow measurements

- Flow Characterization with Laser Doppler Anemometer (LDA) based on two crossed Laser beam and special effect smoke
- Delivers a velocity for each particle–> mean and rms



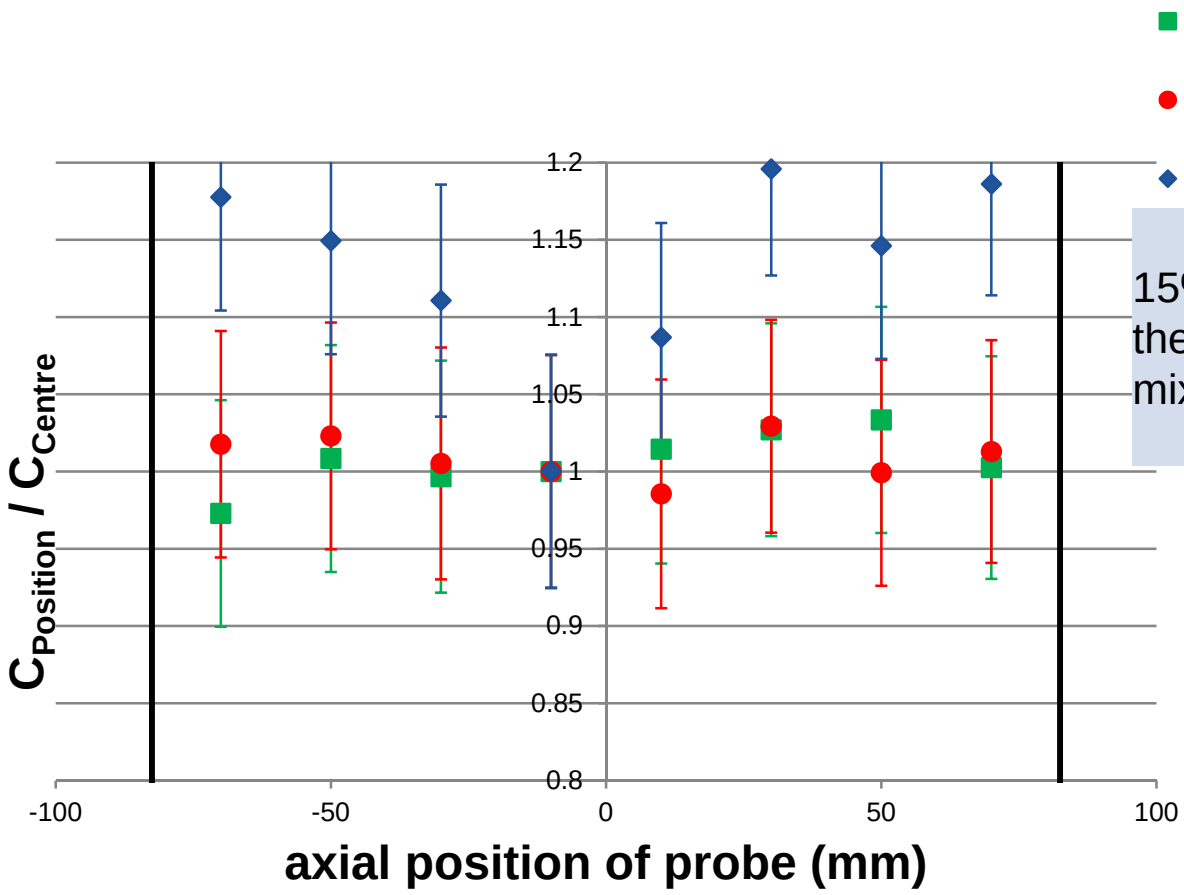
# Particle concentration standard facility – flow results

- CFD simulations and measurements of flow velocities in streamwise direction
- Reasonably agreement, especially further downstream



# Particle standard facility – concentration measurements

- Characterization of homogeneity of injected 500nm PSL particle concentration – **measured with two Condensation Particle Counters**




15% lower concentration in the centre probably due to mixing jets

Simulations predicted a much faster homogenisation already after app. 1m

-> Turbulent Schmidt number around 8 gave reasonable results (Lit: Huq et al. Geophys. Res Lett 2008), needs more work!

# Conclusion

- Characterization of the METAS particle concentration standard in terms of flow velocity experimentally (LDA) and numerically (CFD)
- After some model tests – good agreement of LDA and CFD for velocity
- Mixing is less well predicted
- Turbulent Schmidt number tuning might be necessary

# Outlook

- Why CFD, since it is a lot of work?
  It not only (re)produces the flow in the facility, it helps to get a better idea of the physics
- Try a refined grid in the injection part
- Try novel LES model
- Study turbulent Schmidt number literature
- Publication for Aerosol Sci. Tech. in preparation, where this work will be part of it, focus on uncertainties
- We currently built a new similar facility to mix different types of aerosols (soot, salt, dust, pollen…)
  - should be shorter, only 2m instead of 3m to fit in one room

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# Thank you very much for your attention – comments and questions are welcome

*this work is sponsored within the EMPIR framework*