Fachhochschule Nordwestschweiz
Hochschule für Technik

1. INTERNATIONAL REAL-LIFE EMISSIONS WORKSHOP ON SMALL-SCALE COMBUSTION

DiSC Dilution Size Classifier

Particle count and diameter as an alternative to the filter method

LDSA as a new metric

Content

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2. The DiSC Measurement Principle
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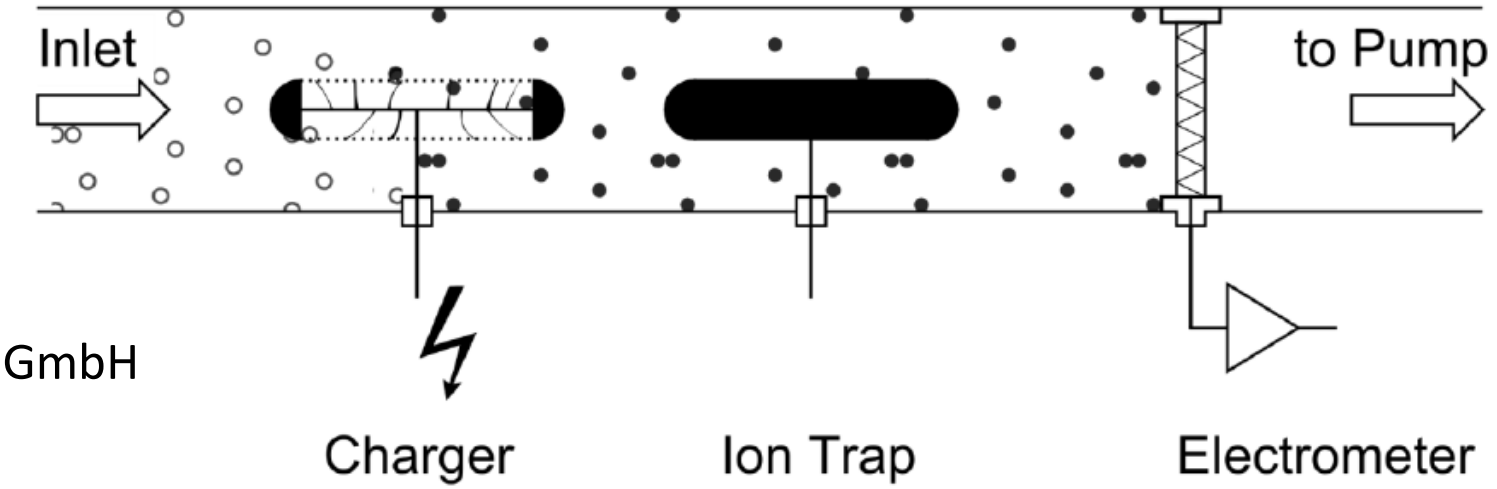
6. Application of DIEM
7. Conclusion
8. CO_2-Measurement as Standardisation to 13%O_2
9. Dilution …..

Diffusion Charging Instrument

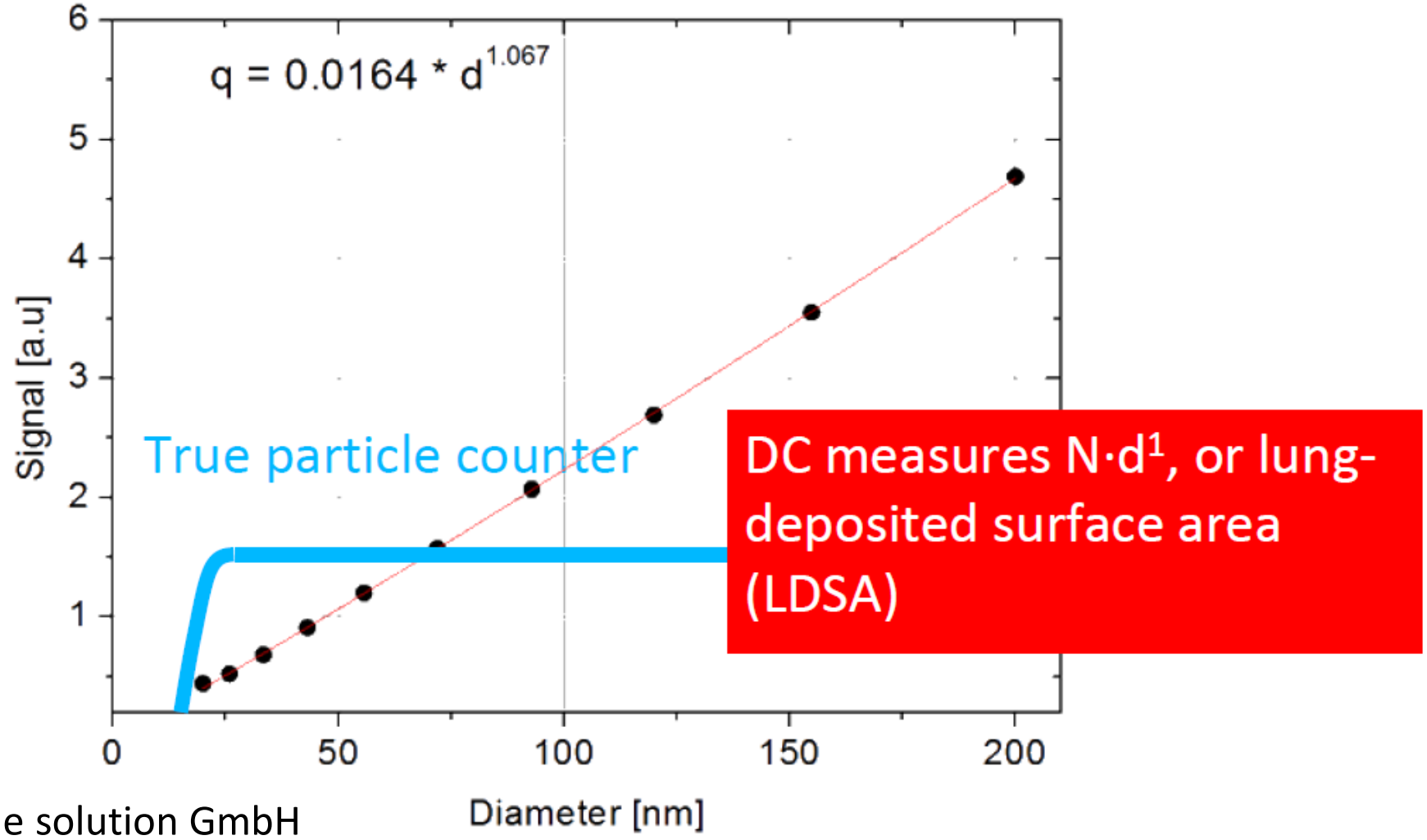
Diffusion charging: the principle

- Simple technique (just 3 elements)
- No consumables (filter needs periodic exchange)
- Sensitive to nanoparticles (unlike light scattering)
- Unspecific (no material dependence)



Quelle: Naneos Particle solution GmbH

Instrument response (linear in particle diameter)



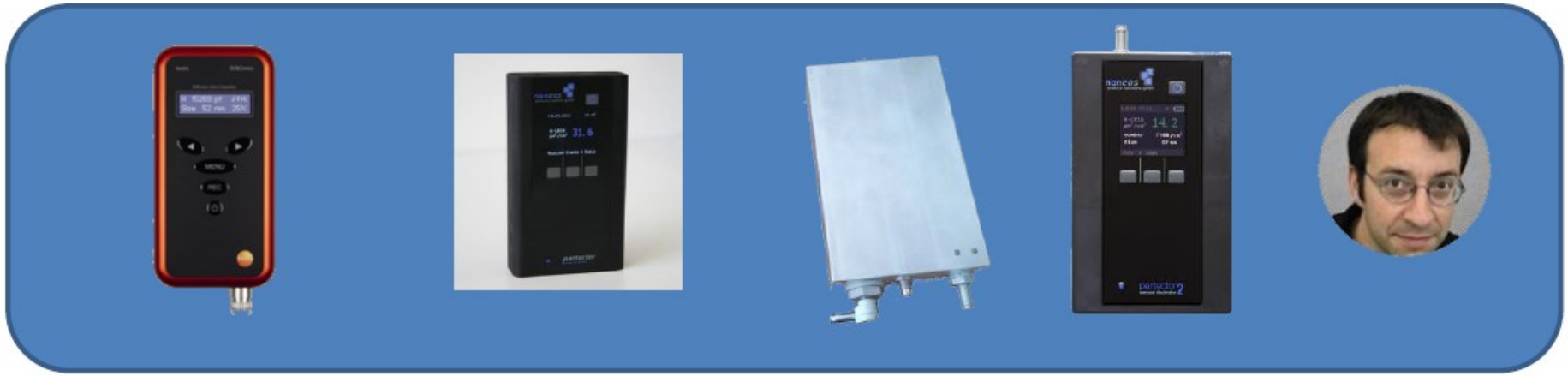
Quelle: Naneos Particle solution GmbH

Many suppliers

- Dekati
- Naneos
- Pegasor
- Philips
- Testo
- TSI

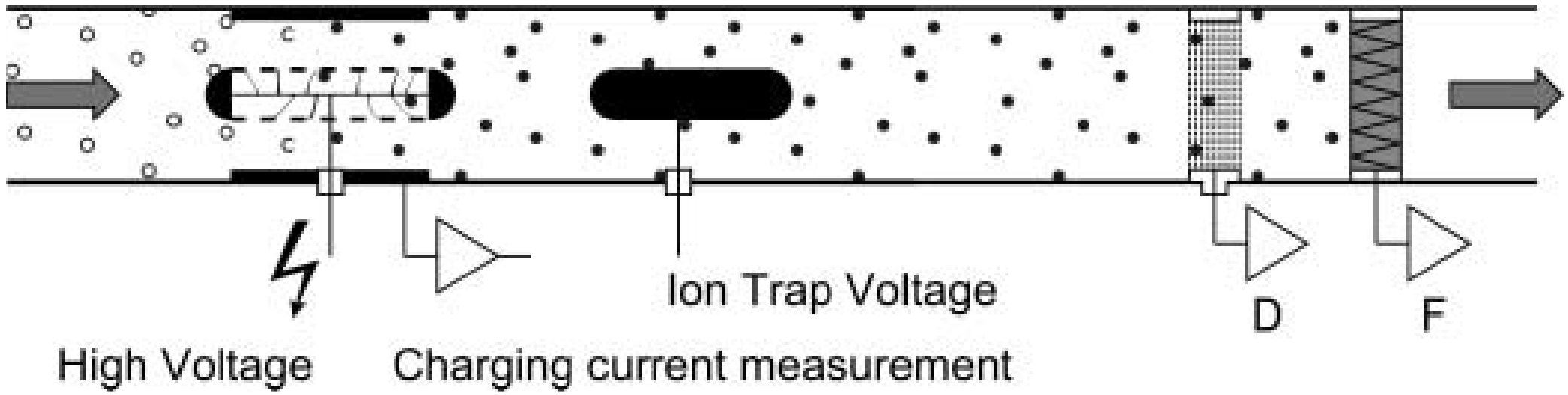
even more devices

- **The basic principle is simple and robust**
- **Many different implementations have been realized**



Quelle: Naneos Particle solution GmbH

Measuring Principle DiSC Diffusion Size Classifier (Enhanced DC Instrument)

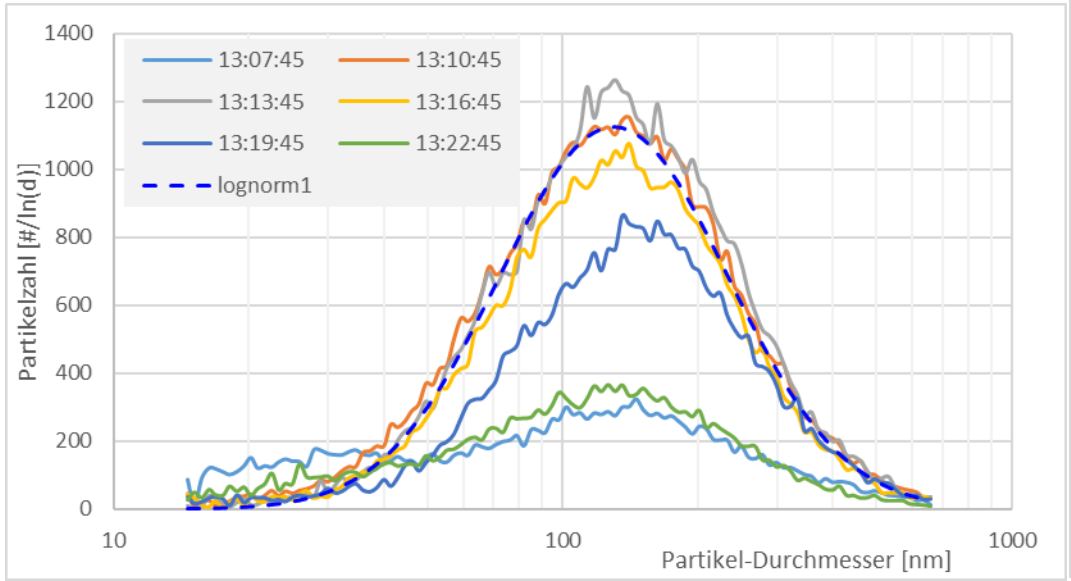


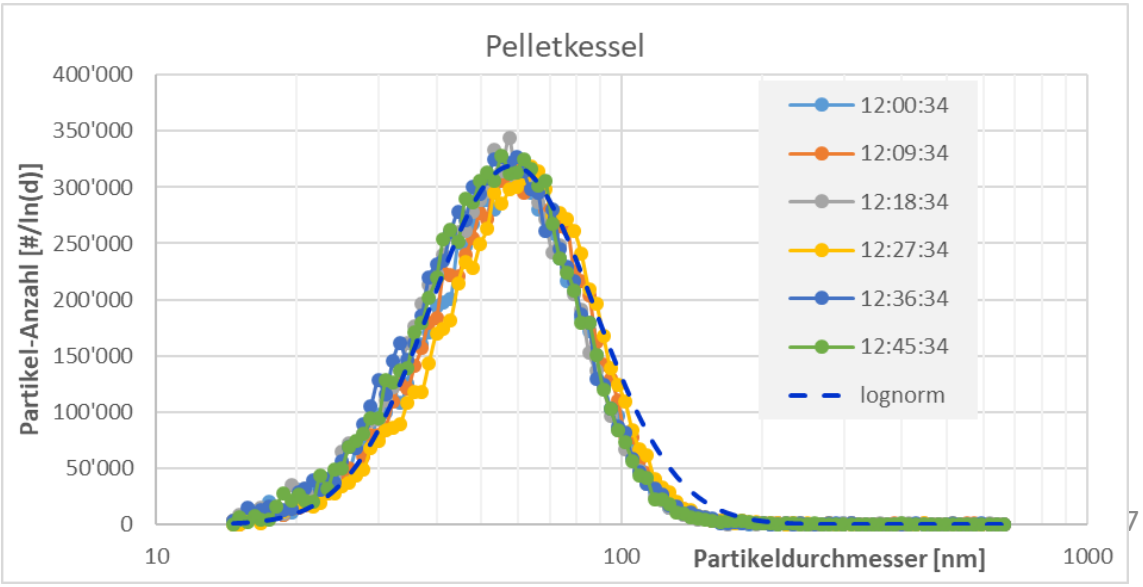
1. Diffusions-Charger (positive) via unipolar Corona-charger
2. Excess ions are trapped
3. Measure the current in the diffusion stage (I_D) and in the filter stage (I_F).

Measuring principle DiSC / Measuring Parameters

1. Measure the current in the diffusion stage (I_D) and in the filter stage (I_F).
2. **LDSA** (surface) is proportional to total current $I_{total} = I_D + I_F$.
3. **<d>** [nm] is proportional to (a polynomic function) of I_F/I_D
4. **N** [#/ccm] is proportional to LDSA/<d>

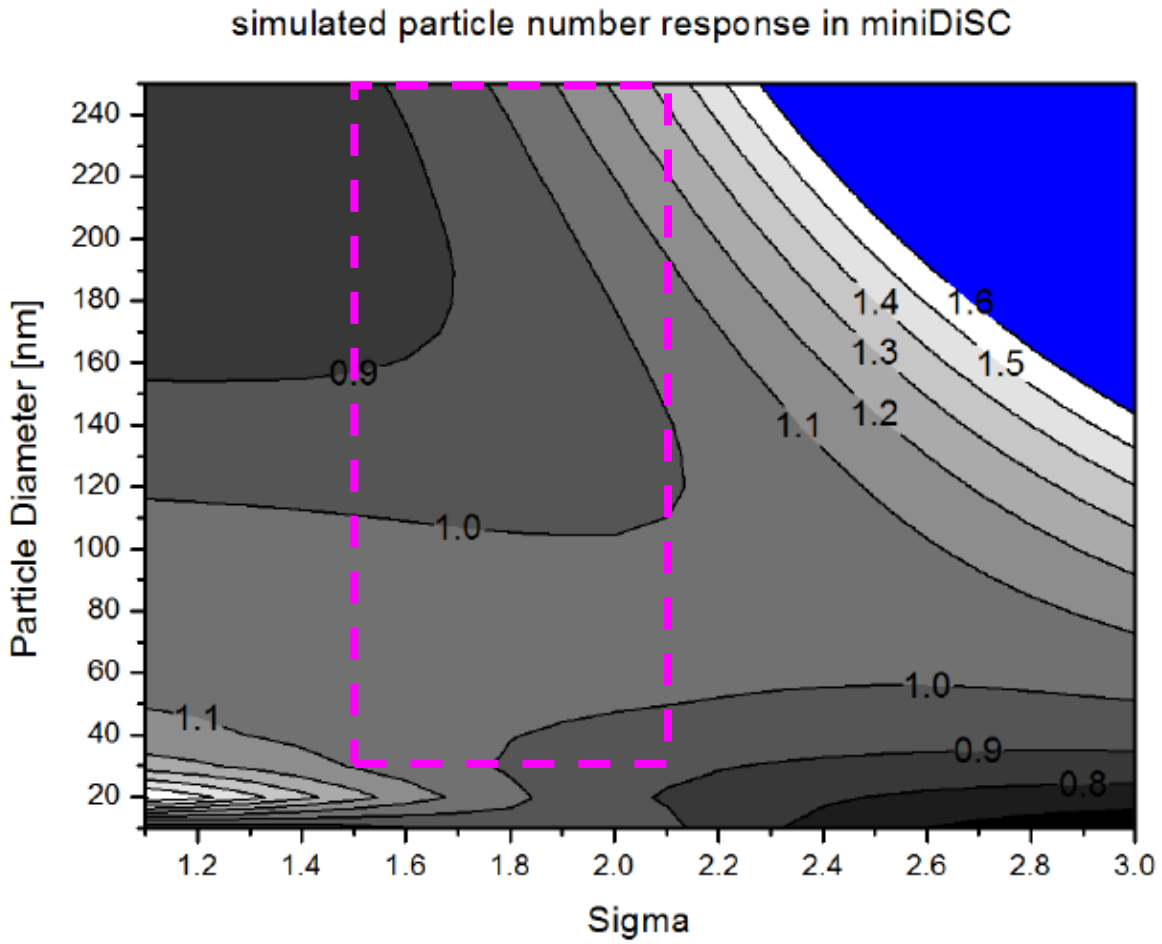
Reason of uncertainty of <d> is the “unknown/estimated” lognorm-distribution.

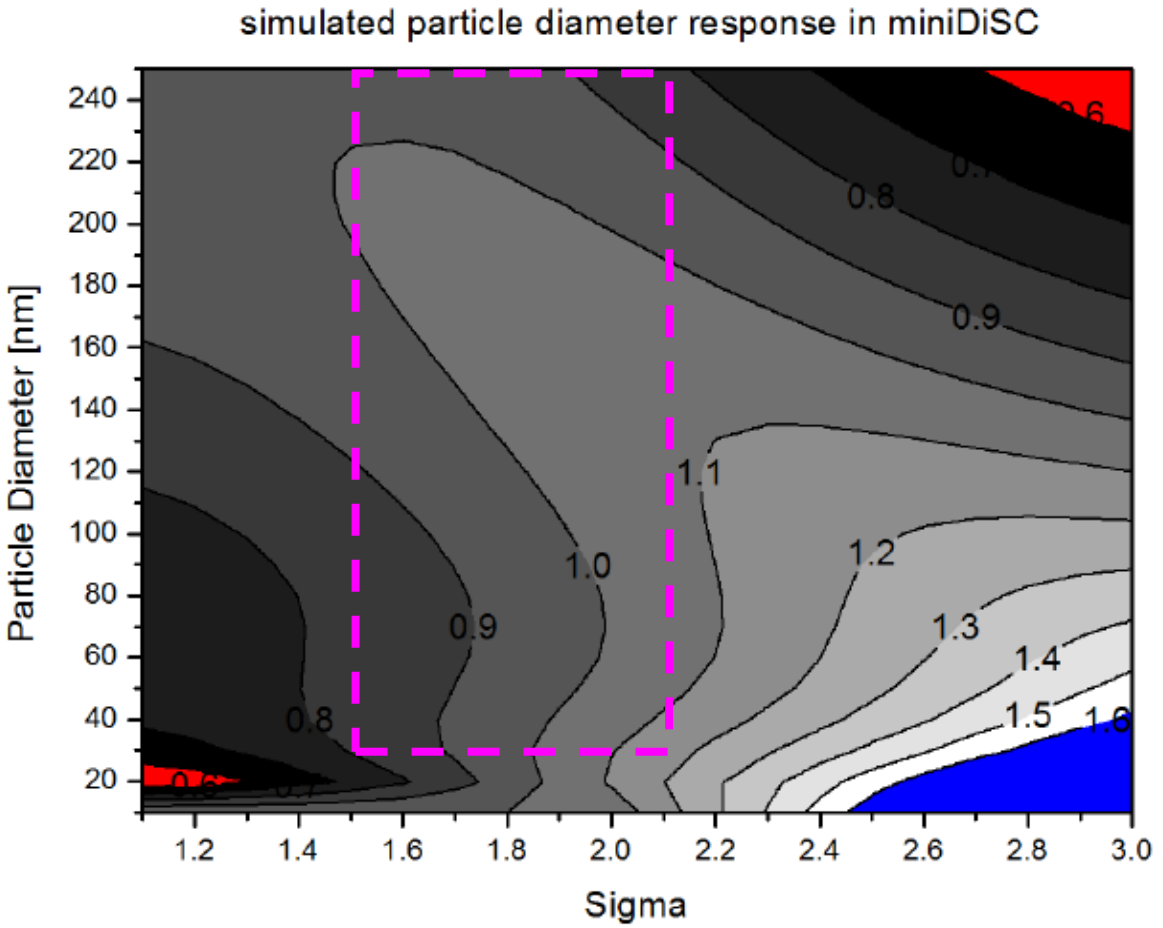




Measuring principle DiSC / Uncertainty

Reason of uncertainty of N and <d> is the “unknown/estimated” lognorm-distribution.

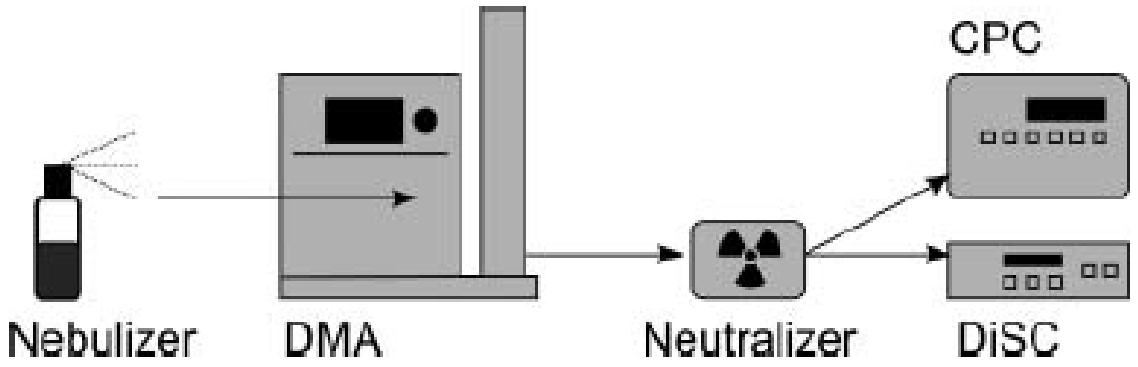




Quelle: M.Fierz miniDiSC application note #11

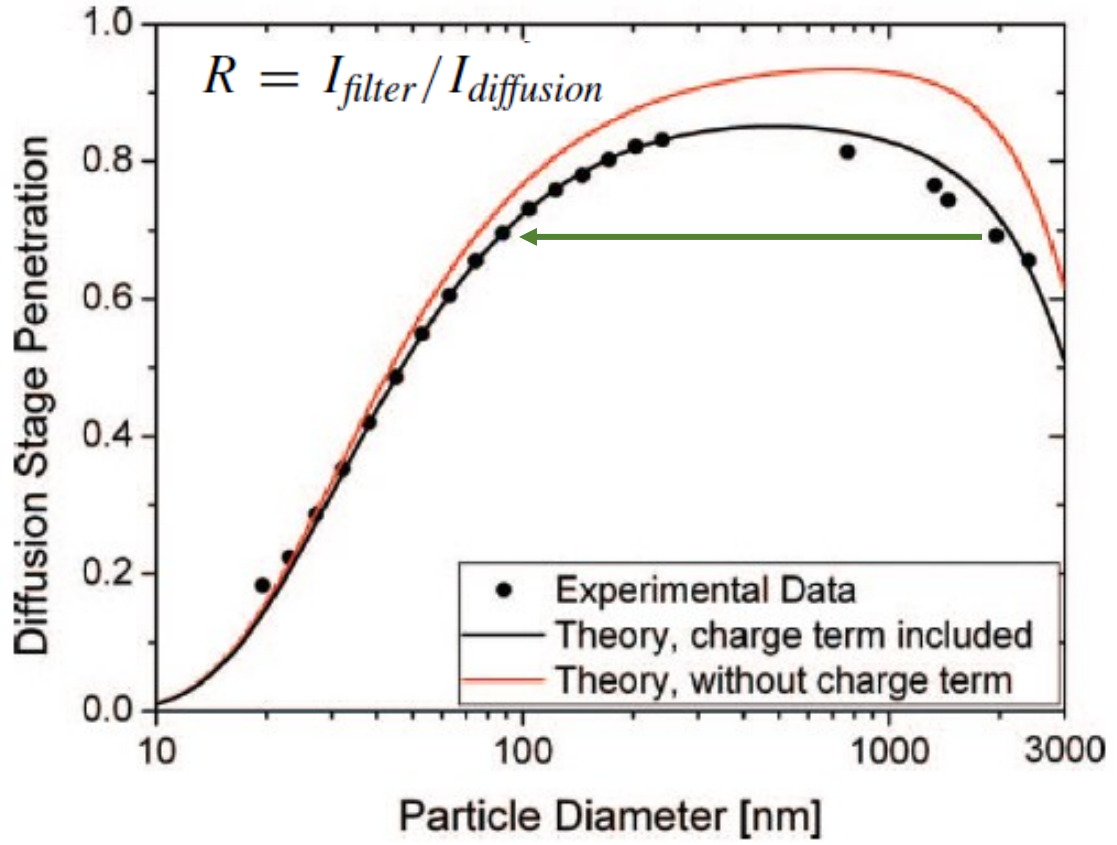
Calibration of the DiSC

Monodisperse aerosol is generated by DMA and measured in parallel with DiSC and CPC.

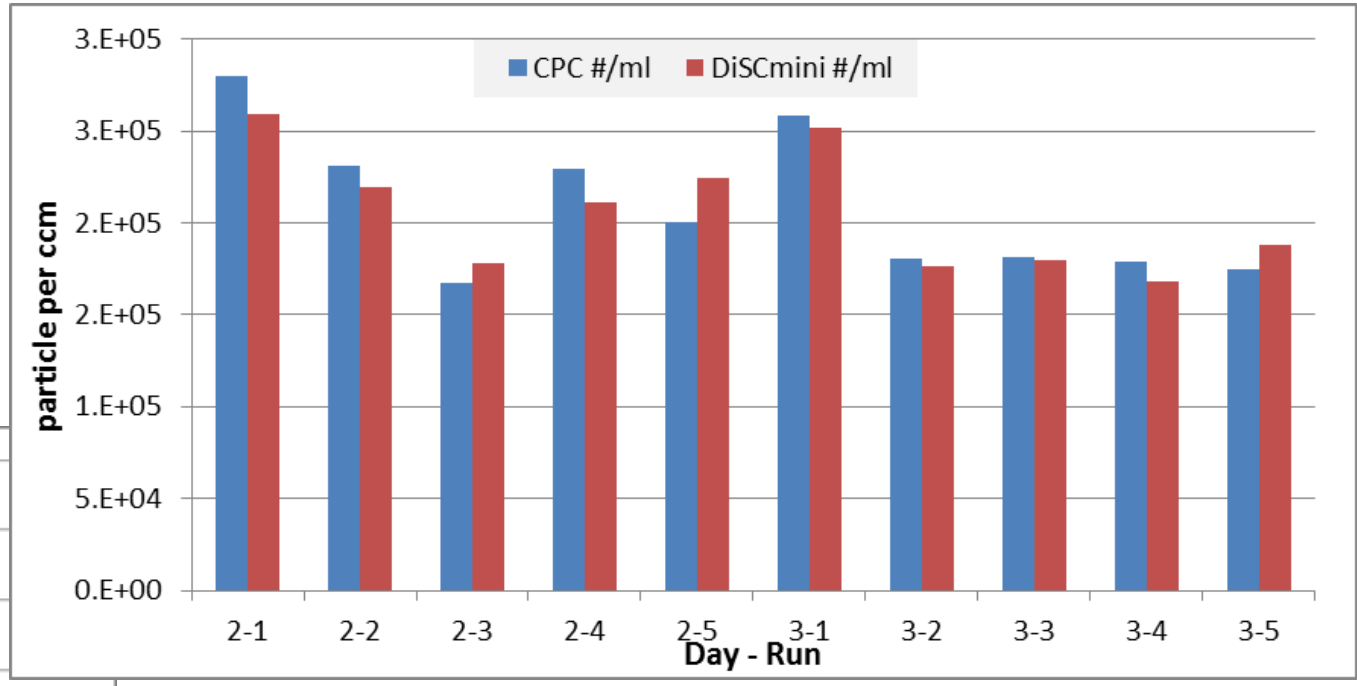


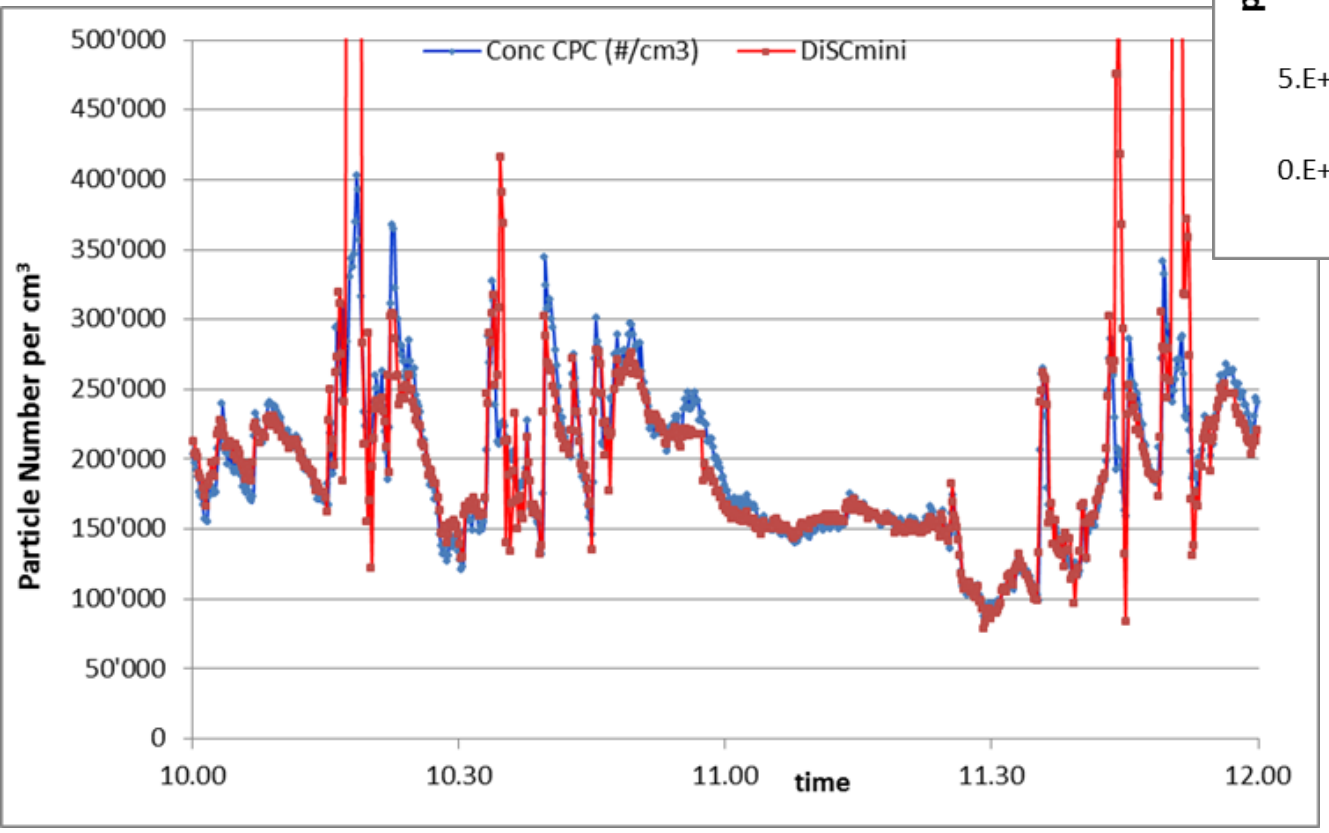
Quelle: Fierz et al.

500 nm d max penetration. Then effect due to impaction of large particles leads to misinterpretation



Comparison CPC - DiSC





Online comparison number of CPC (TSI, Fi) and DiSCmin (Testo, FHNW) at comparative measurements in Ostrava.

Correlation = 0.99 ± 0.07

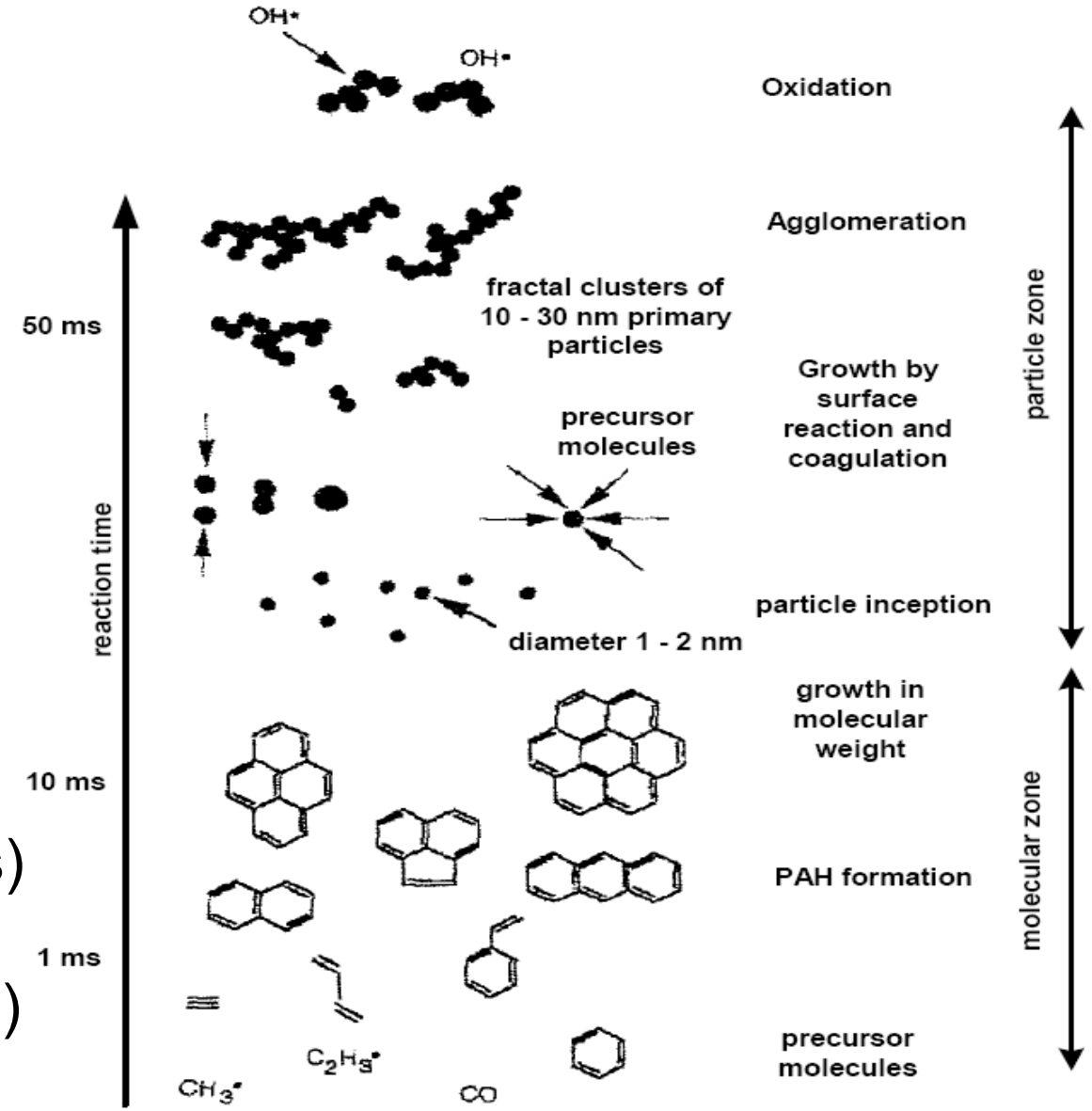
Calculation of the particulate mass

$$m = N \cdot \rho \cdot \frac{\pi}{6} \cdot d^3 \cdot e^{\left(4.5 \cdot ln(\sigma)^2\right)}$$

Agglomeration leads to relatively large fractal particles.

Introduction of **Df = fractal dimension**

Df=3: spherical structure (tar-like particles)
Df=2: plate-like structure (mineral dusts)
Df=1: rod- or chain-shaped (soot particles)



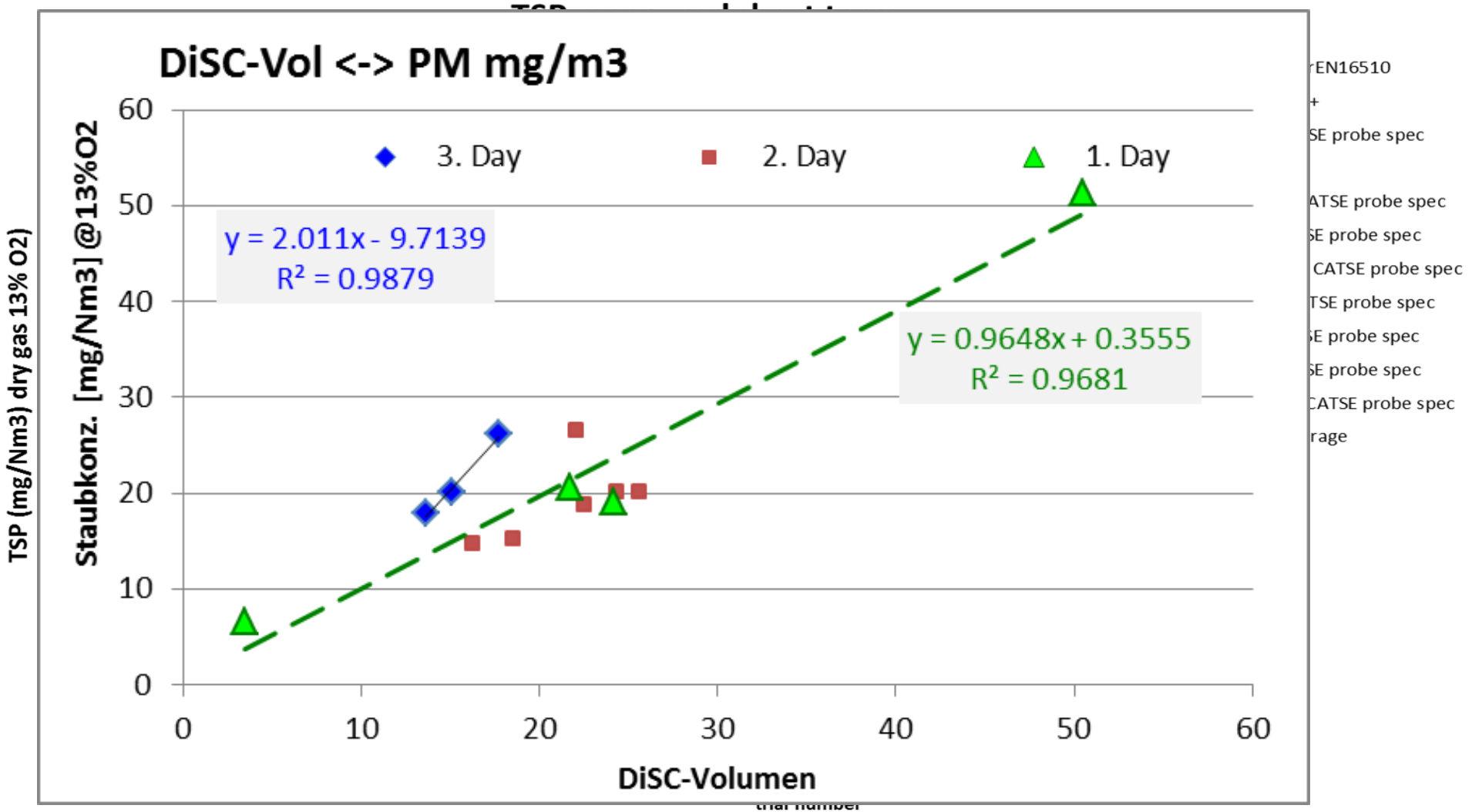
Fraktal Korrektur

$$\frac{M}{m} = \left(\frac{d_0}{d}\right)^{(3-Df)} \cdot e^{\left(\left(\frac{Df^2}{2}-4.5\right)\cdot ln(\sigma)^2\right)} = A \cdot d^{-B}$$

d_0 = particle diameter before agglomeration; primary particles (10 – 30 nm)
Df = fractal dimension

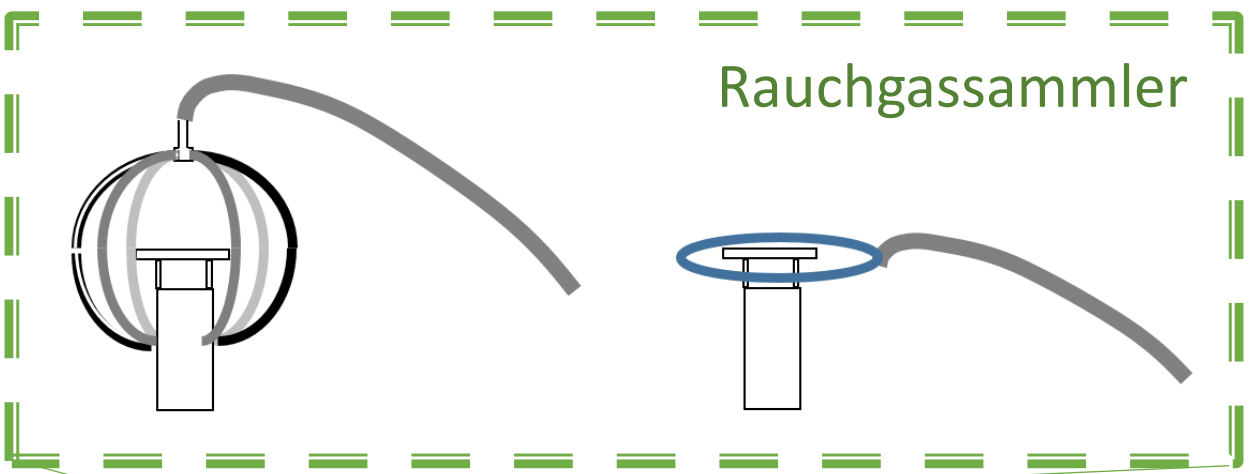
The surface area and thus the loading of fractal particles Df < 3 is much larger than that of spherical particles of the same diameter. → DiSC measuring principle
Overestimation of the particle mass of large fractal particles in the DiSC.
jw: ⇨ Introducing a fractal correction
See also Matti Maricq, Monitoring Motor Vehicle PM Emissions, AST 47, 2013

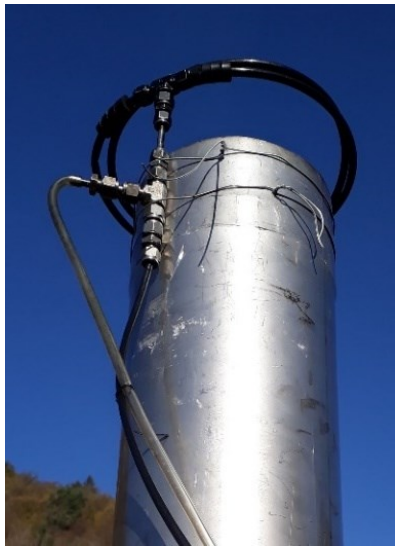
Comparison gravimetry - DiSC

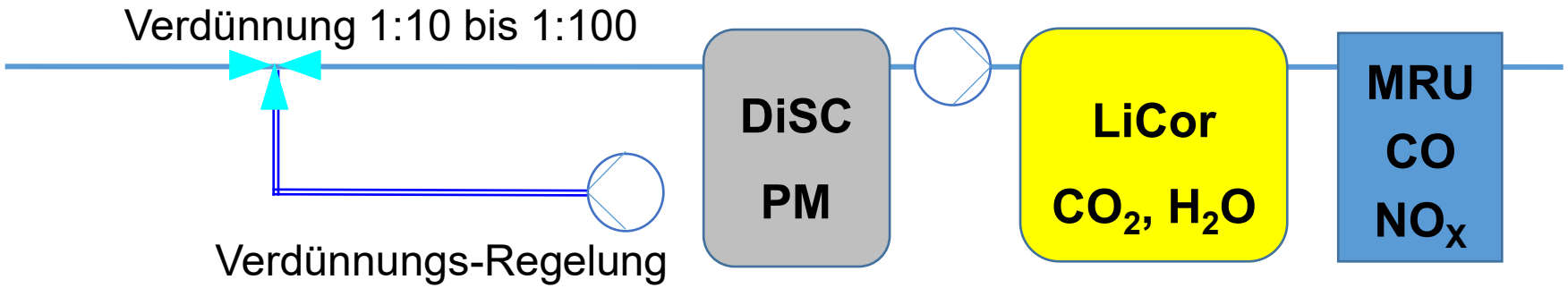


Comparisons of gravimetry measured in EN-PME (Paris) and calculated dust volumes [ml/m3] from DiSC diameter and number.

Application of this measuring technique in our DIEM (**D**ilution-**I**ndependent **E**mission **M**easurement method)







Conclusion, measured variables and influencing variables 1/2

- “DiSC” is a simple, robust and comparatively cheap measuring method (instrument) which delivers mainly :
- **LDSA [$\mu m^2/cm^3$]** lung-deposited surface area, but also
- **N** [#/cm^3] particle number.
- **<d>** [nm] mean particle diameter (with according lognorm distribution)
- **m** [$\mu g/m^3$] mass determination taking into account the fractal dimension.
- Particle mass concentrations down to below 0.1 mg/m3@13%O_2 are measurable.
- Uncertainty due to unknown dilution, lognorm distribution and fractal dimension.

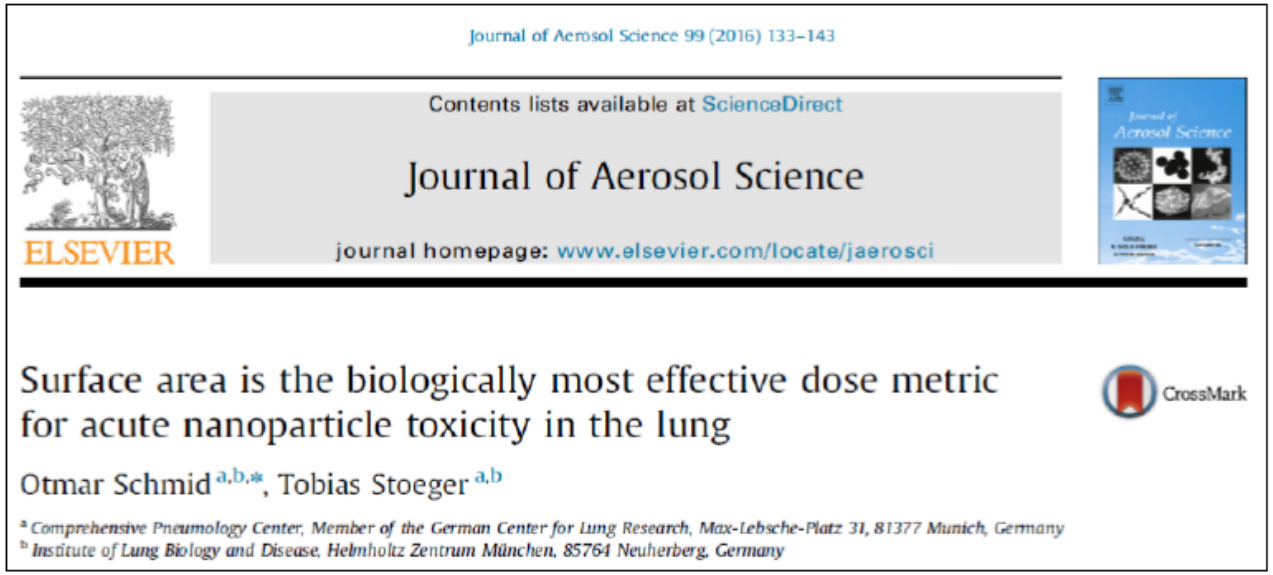
Conclusion, measured variables and influencing variables 2/2

- High emissions require strong dilution (protects the unit from contamination); determinable via CO_2.
- The normalisation of CO and dust (particles) to 13%O_2 by means of accurate CO_2 measurement.
- The cleaner the combustion, the smaller the dilution and the more accurate the result.
- Unlike handheld CPC's, the DiSC (partector) needs no working fluids that need to be refilled every few hours.
- Measure particle concentrations between 10^3 - 10^7 particles/cm^3, and covers all typical ambient particle concentrations, from very clean to very polluted air.

Particle number is the wrong metric

With a DiSC you have nearly all information about particles to find the right metric for future

- We know (and have known for a long time…) that lung-deposited surface area (which is measured by DCs) is a more health relevant metric than particle number
- We should declare LDSA as equivalent for this application rather than pretend that we are measuring particle number with DCs
- More information:



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Surface area is the biologically most effective dose metric for acute nanoparticle toxicity in the lung

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Literatur

- Hindds, Aerosol Technology
- Fierz. Et al. Geräte zur Messung der Anzahlkonzentration von Nanopartikel, Nanotechnologie 70 (2010) Nr 11/12 S. 469 - 477
- Testo Whitepaper: Partikelmessung für Praktiker
- CH. Gaegauf et. al. Partikelemissionen aus Holzfeuerungen, Langenbruck 2001
- Matti Maricq, Monitoring Motor Vehicle PM Emissions, AST 47, 2013 (Aerosol Science and Technology)

Questions?

Always available for questions:

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