Atmospheric Aerosol Physics, Physical Measurements, and Sampling

Particle Counter & Mobility Particle Size Spectrometer

SAMLAC
San Juan, Puerto Rico
November 2018

Member of Leibniz Association

ECAC
European Center for Aerosol Calibration

WCCAP
World Calibration Centre for Aerosol Physics

TROPOS
Leibniz Institute for Tropospheric Research

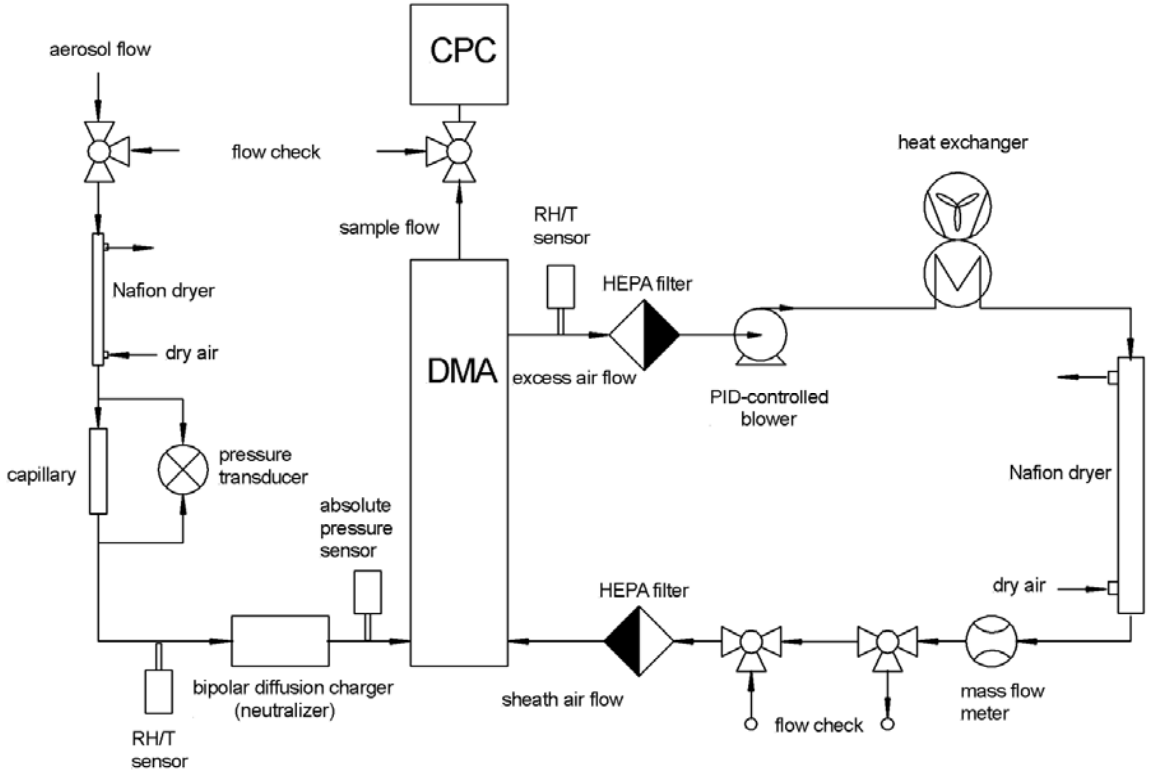
Mobility Particle Size Spectrometer

Mobility Particle Size Spectrometer (MPSS)

Main components:

- Pre-impactor
- Bipolar diffusion charger (old: neutralizer)
- Differential Mobility Analyzer (DMA)
- Condensation Particle Counter (CPC)

MPSS – Recommended Setup



Wiedensohler et al., 2012, Atmos. Meas. Tech., 5, 657–685.

Why a Pre-Impactor?

- In a MPSS, an electrical mobility distributions is measured.
- The particle number size distribution is determined, knowing the bipolar charge distribution.
- A pre-impactor in front of the MPSS is needed:

  → to eliminate the influence of multiple-charged particles larger than the nominal measured size range

- A pre-impactor in front of the MPSS might be not needed:

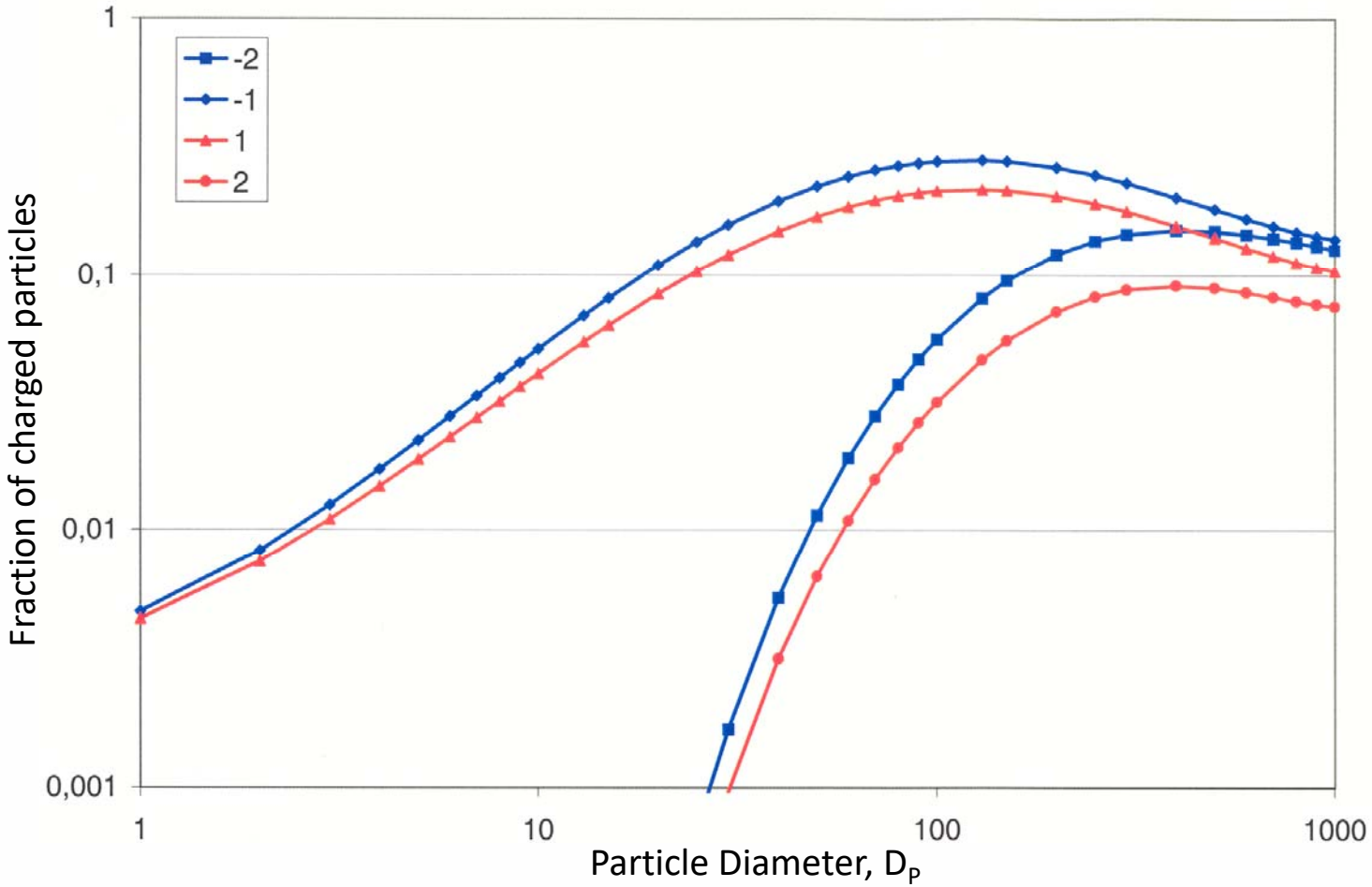
  → if the MPSS size range is up to 800 nm and if there is no significant course mode

Bipolar Diffusion Charger

Bipolar Diffusion Charger

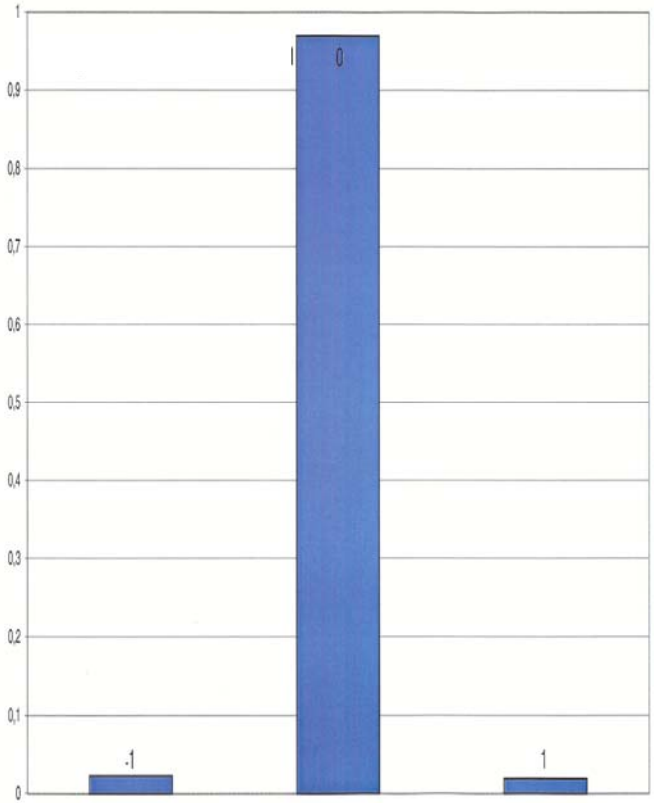
- The aim of a bipolar diffusion charger is to bring the whole aerosol particle population in a “known” charge equilibrium.
- This is the advantage to be able to do a correct multiple charge correction.
- One can assume that bipolar diffusion chargers based on a radioactive source behave similar (Kr85, Am241, Po210, Ni63).
- The activity of the bipolar charger must be sufficient, e.g. 370MBq.
- Devices based on soft-X-ray, produce a different bipolar charge equilibrium, since they may alter.

Bipolar Charge Distribution

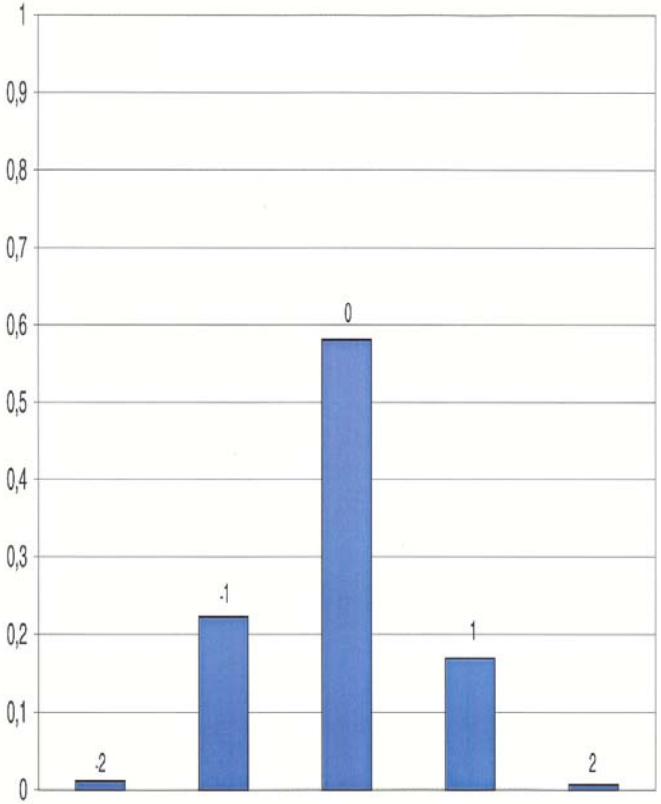


Bipolar Charge Distribution

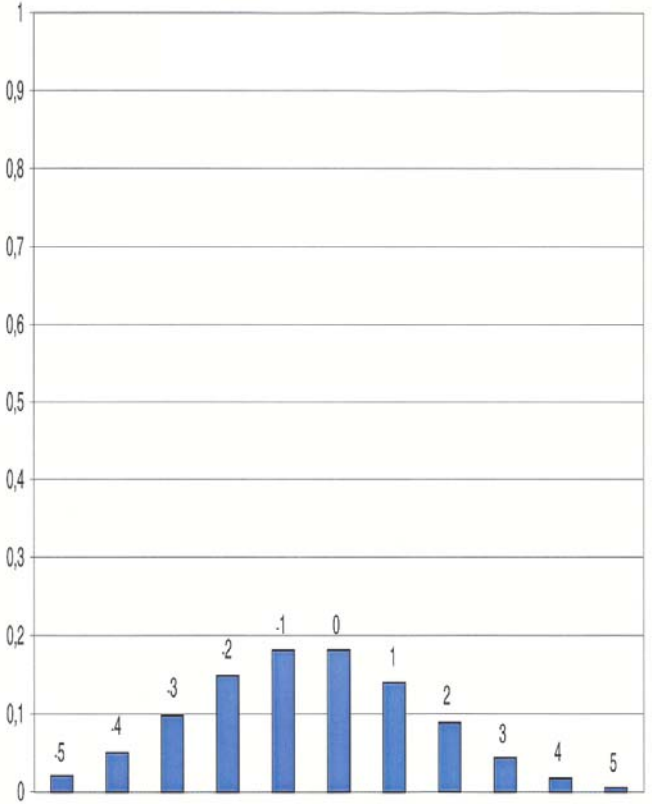
5 nm



50 nm

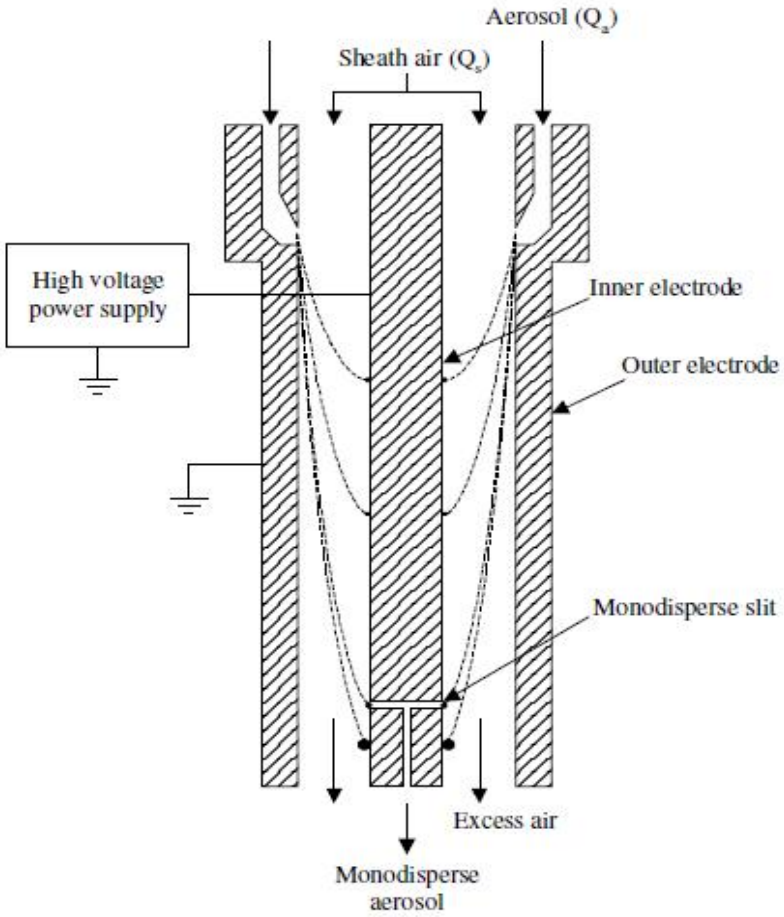


500 nm

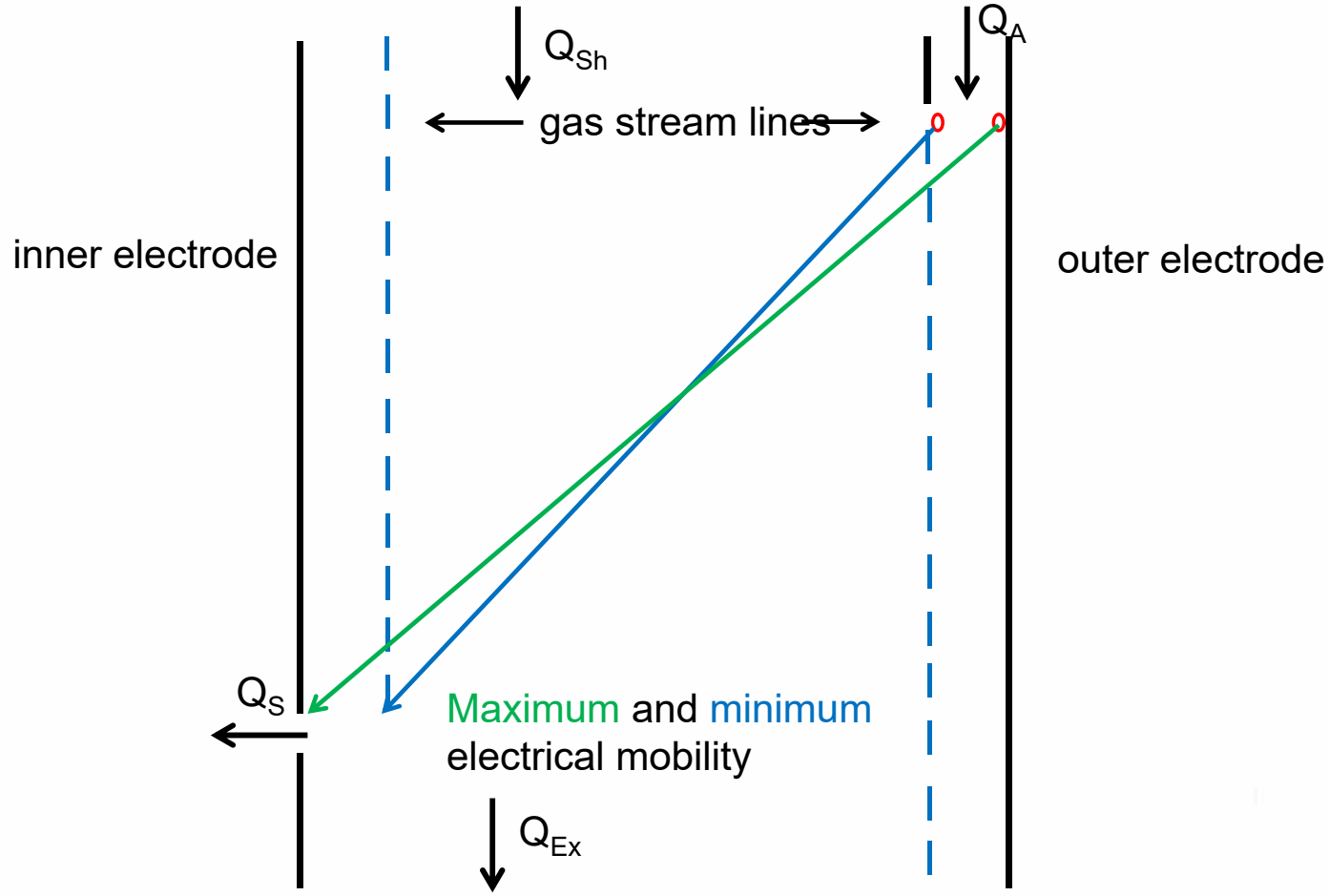


Differential Mobility Analyzer-Principle

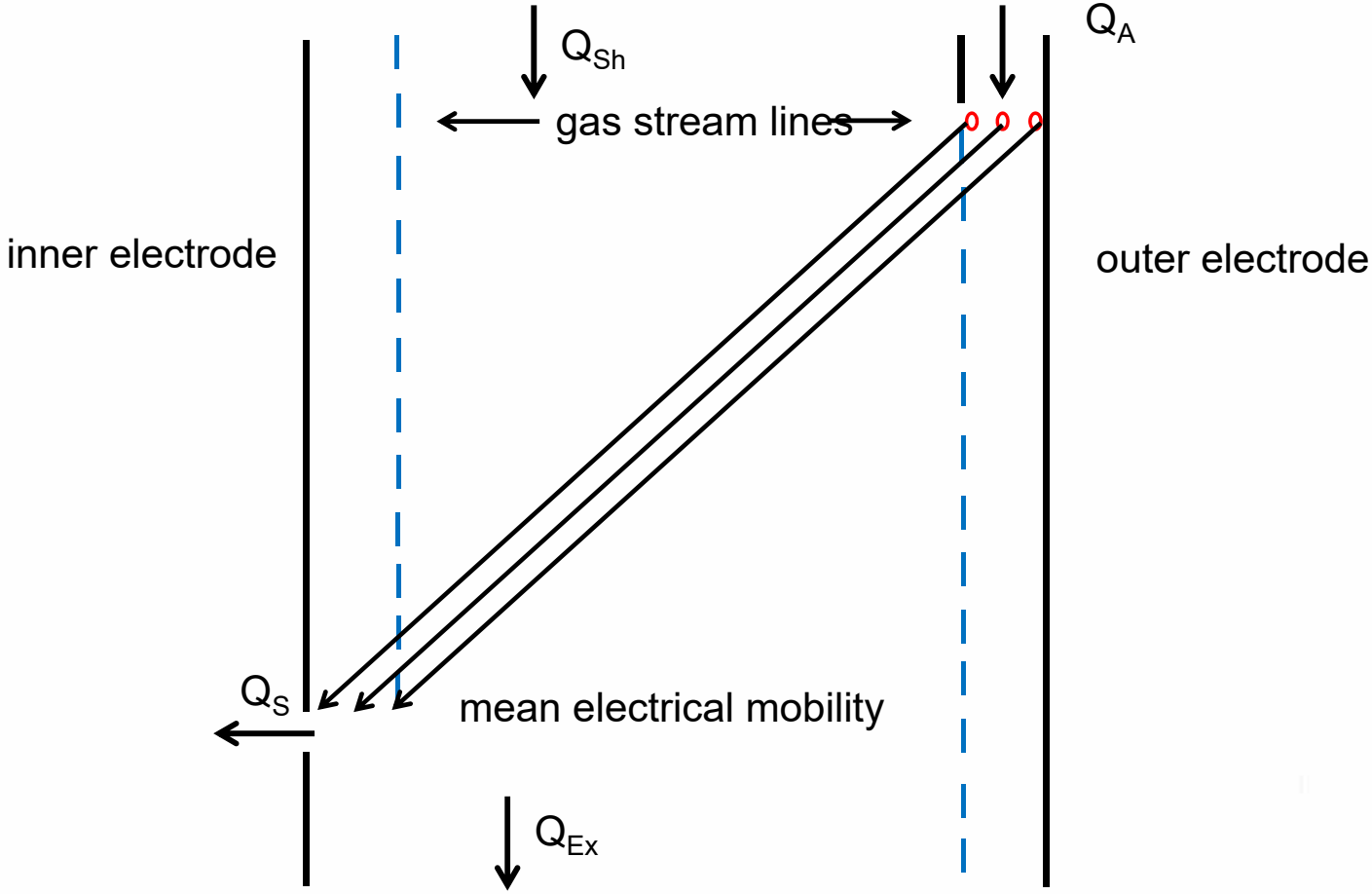
Differential Mobility Analyzer



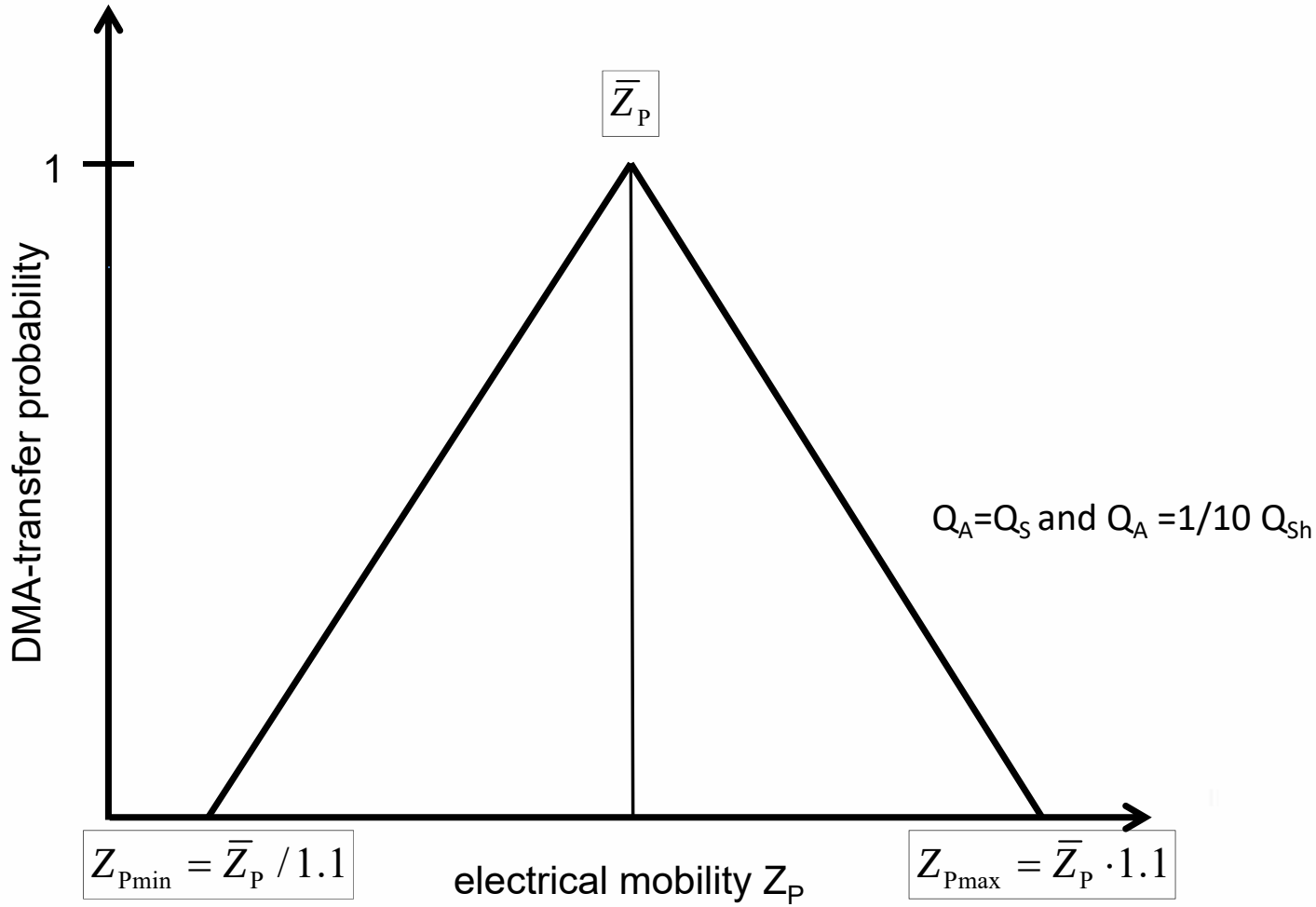
DMA - Transfer Function



DMA - Transfer Function



DMA - Transfer Function



DMA - Equations

Mean electrical mobility

$$\bar{Z}_P = \frac{Q_{Sh} \cdot \ln(r_o / r_i)}{2\pi \cdot U \cdot l}$$

Mobility range

$$\Delta Z_P = \frac{(Q_s + Q_A) \cdot \ln(r_o / r_i)}{2\pi \cdot U \cdot l}$$

for

$Q_A = Q_S$ and $Q_A = 1/10\ Q_{Sh}$

$$\frac{\Delta Z_P}{Z_P} = \frac{1}{5}$$

$$Z_P = \bar{Z}_P \pm 0.1 \cdot \bar{Z}_P$$

Voltage to select a the mean electrical particle mobility

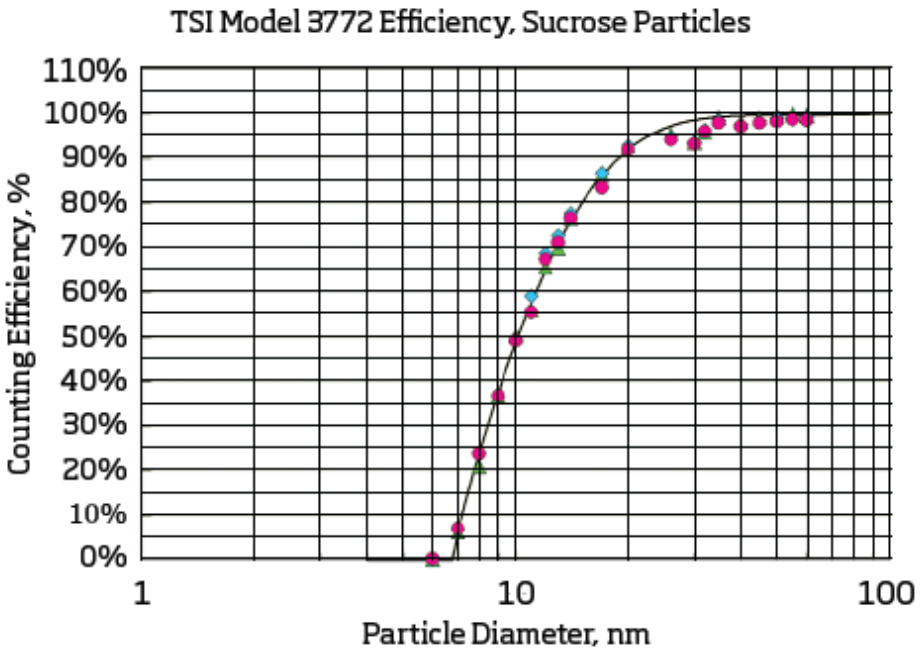
$$U = \frac{3\eta \cdot \bar{D}_P \cdot Q_{Sh} \cdot \ln(r_o / r_i)}{2 \cdot l \cdot n \cdot e \cdot C_C(\bar{D}_P)}$$

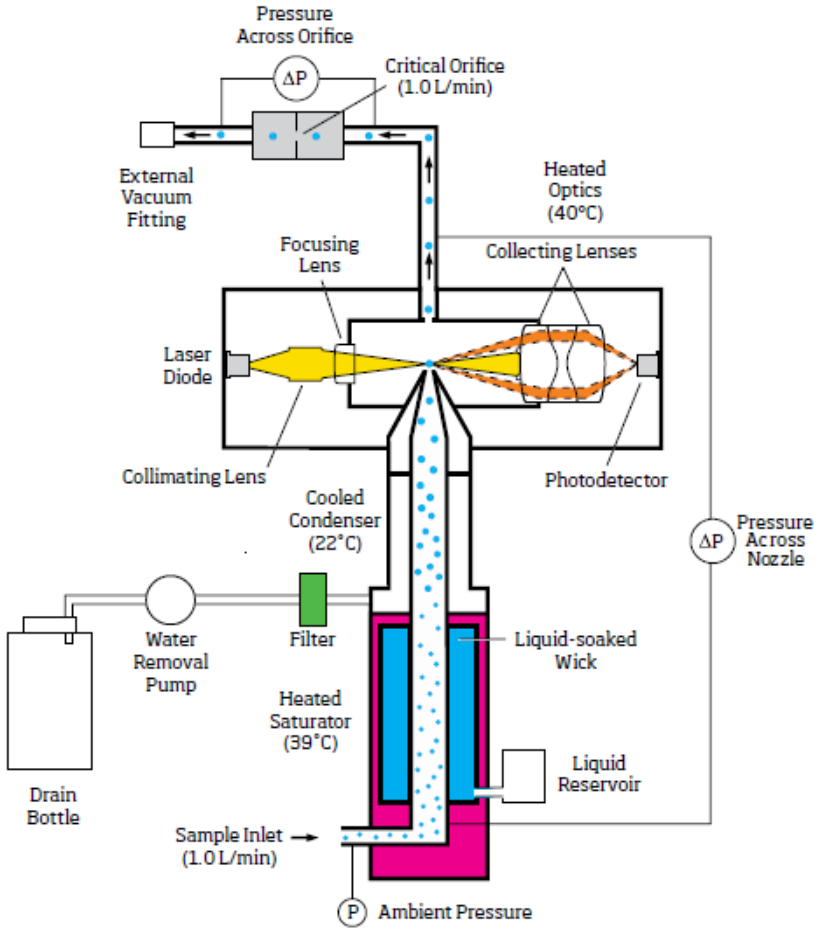
DMA – General Comments

- The particle size range of a mobility particle size spectrometer is defined by geometry of the DMA
- An exact volumetric sheath air flow rate determines a correct sizing.
- The penetration efficiency (transfer function) is size-dependent and has to be considered for particles < 100nm

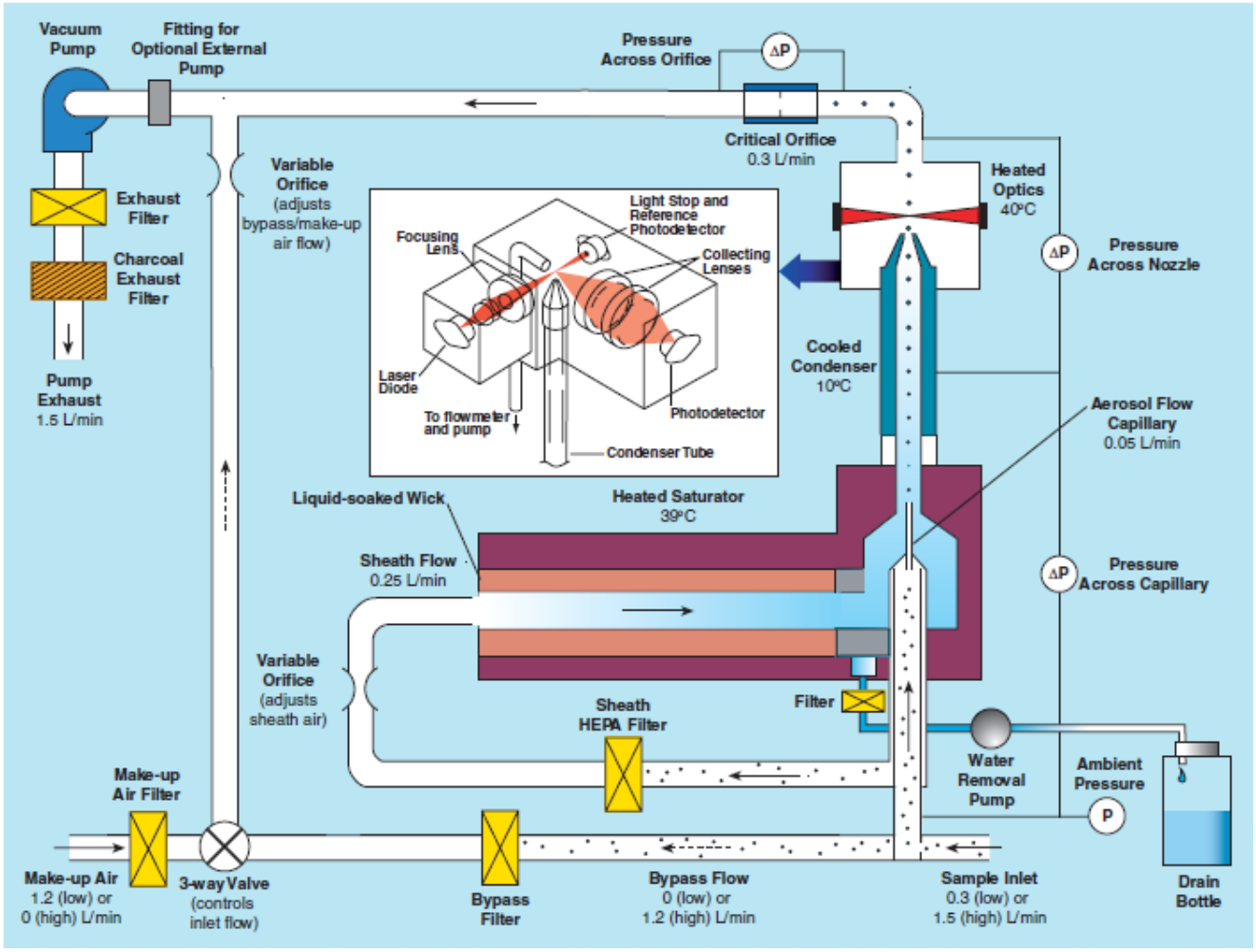
Condensation Particle Counter - Principle

Example: CPC TSI model 3772





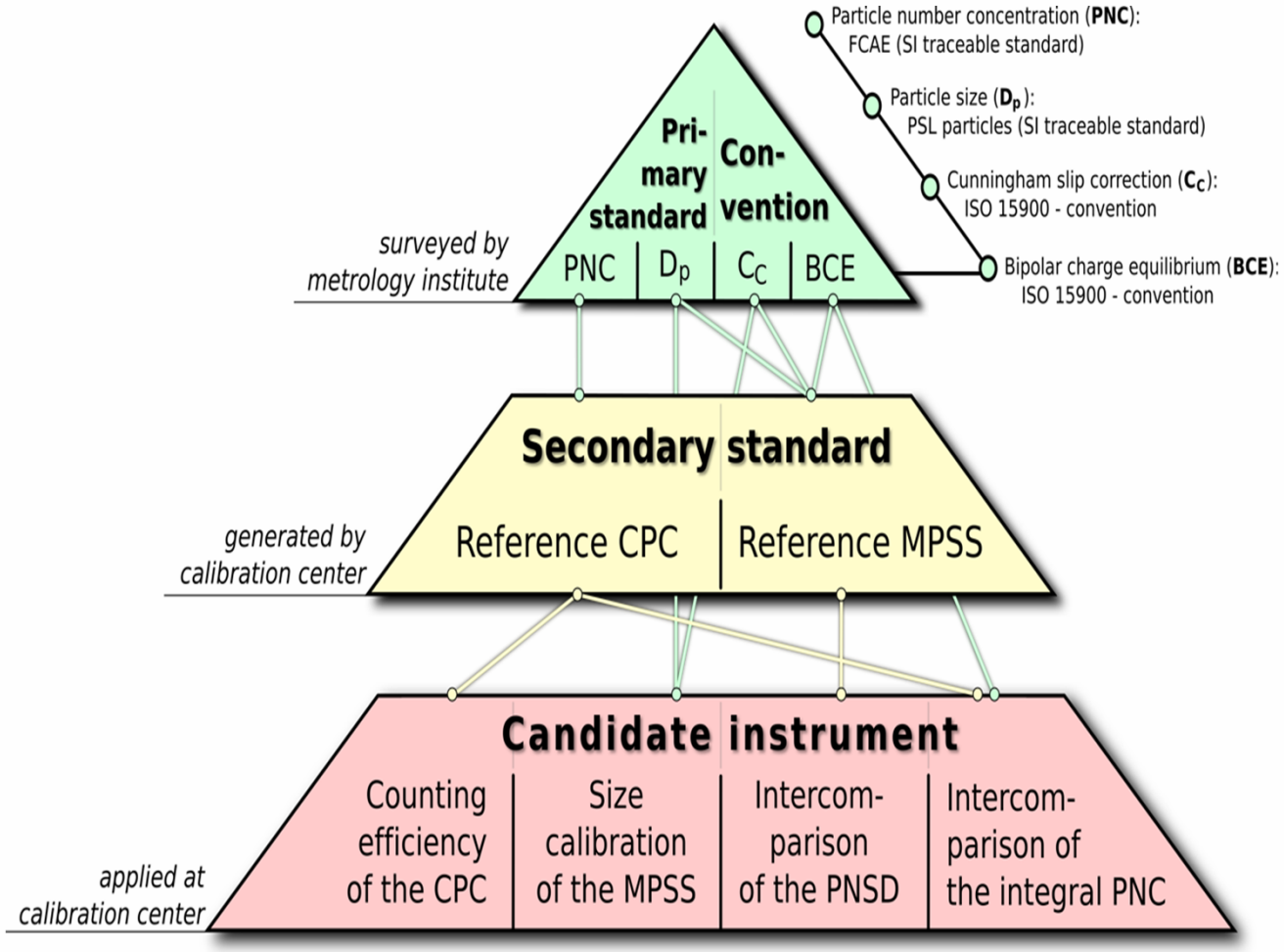
Example: CPC TSI model 3776



MPSS & CPC

Calibration & Traceability

Traceability of MPSS Measurements



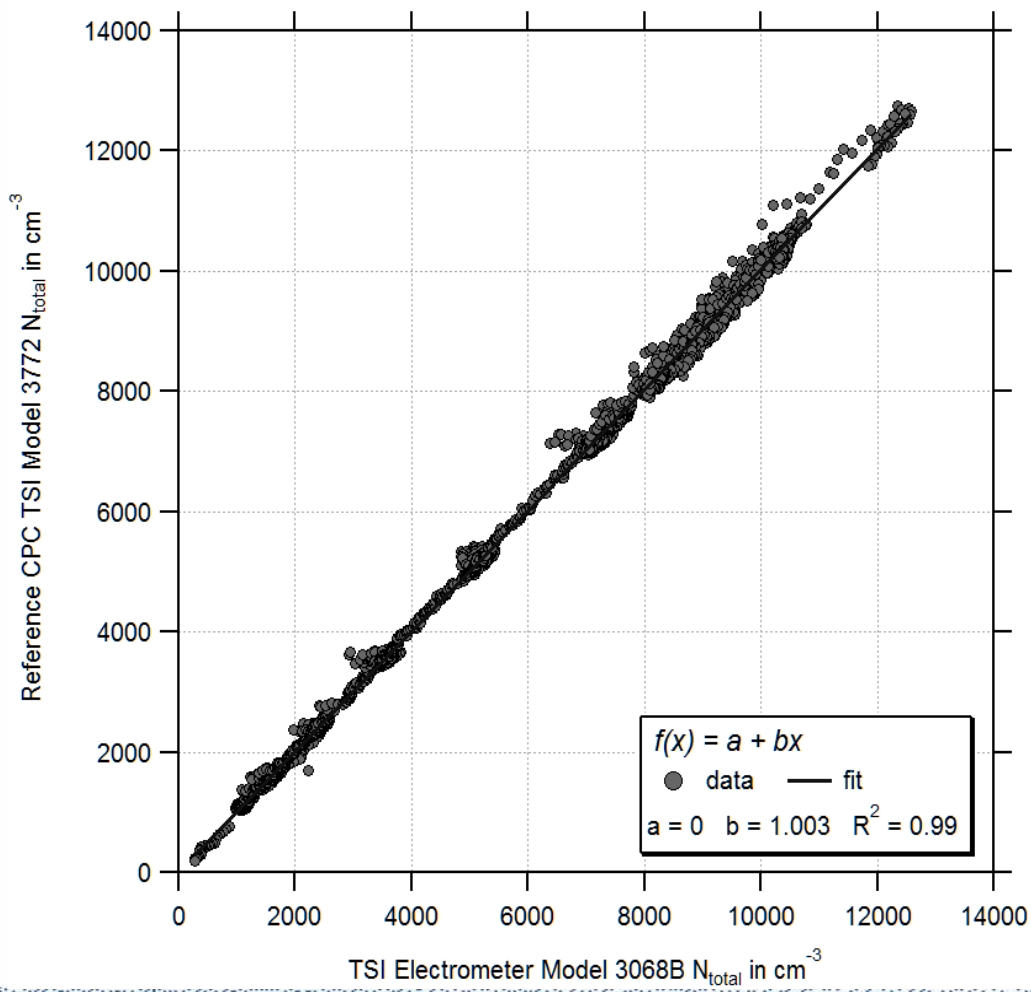
CPC - Traceability & Calibration

Wiedensohler, A. et al. (2018). Mobility Particle Size Spectrometers: Calibration Procedures and Measurement Uncertainties. Aerosol Science & Technology **52**(2), 146–164.

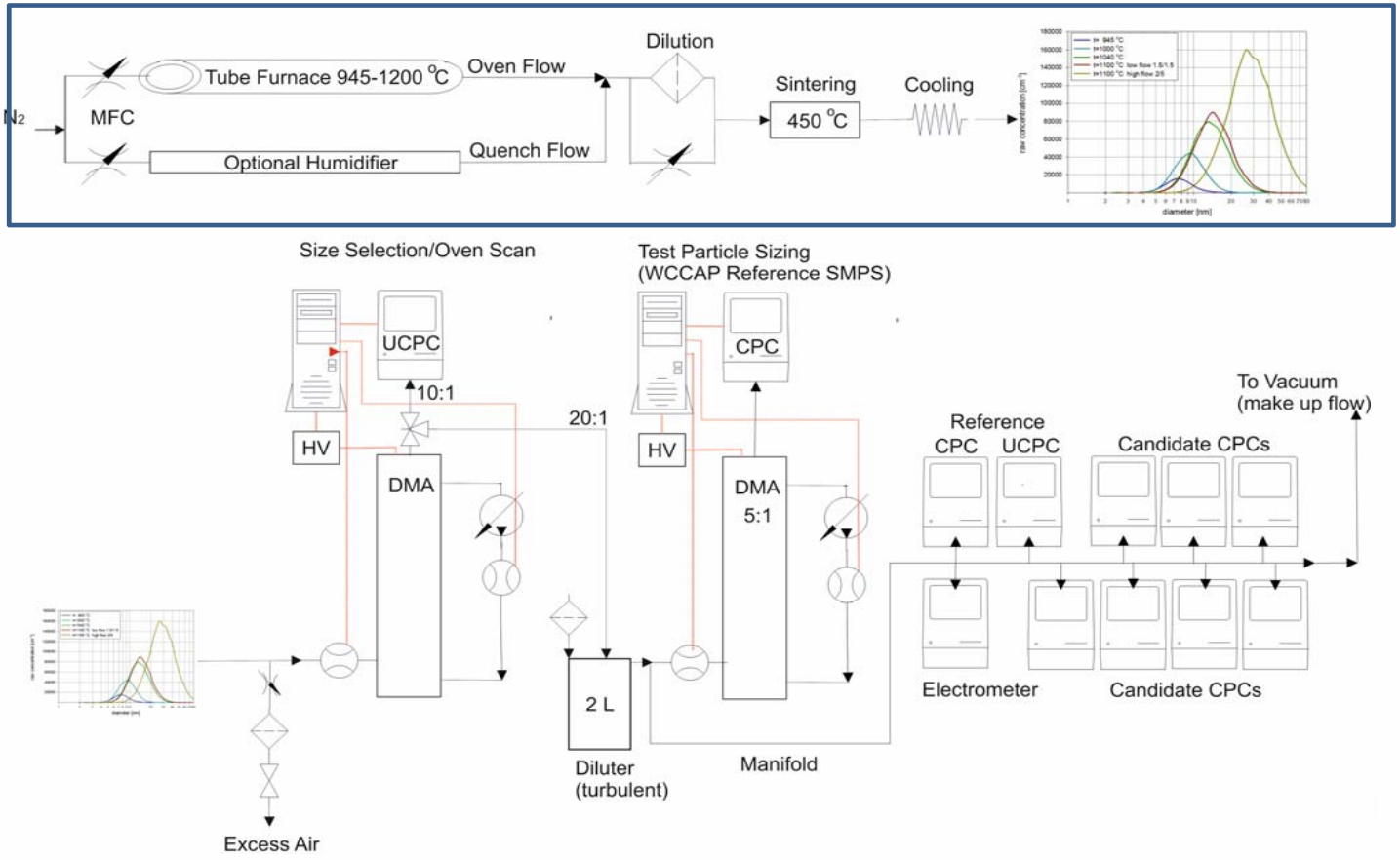
Particle Number Concentration

- There is no direct standard for a particle number concentration!
- The reference concentration is determined from an independent aerosol electrometer measurement
- Following calibration chain is applied:
  - Calibration of an aerosol electrometer against a femto-A source (at a metrology institute such as NIST, NPL, PTB)
  - Calibration of reference condensation particle counter
  - Calibration of individual instruments

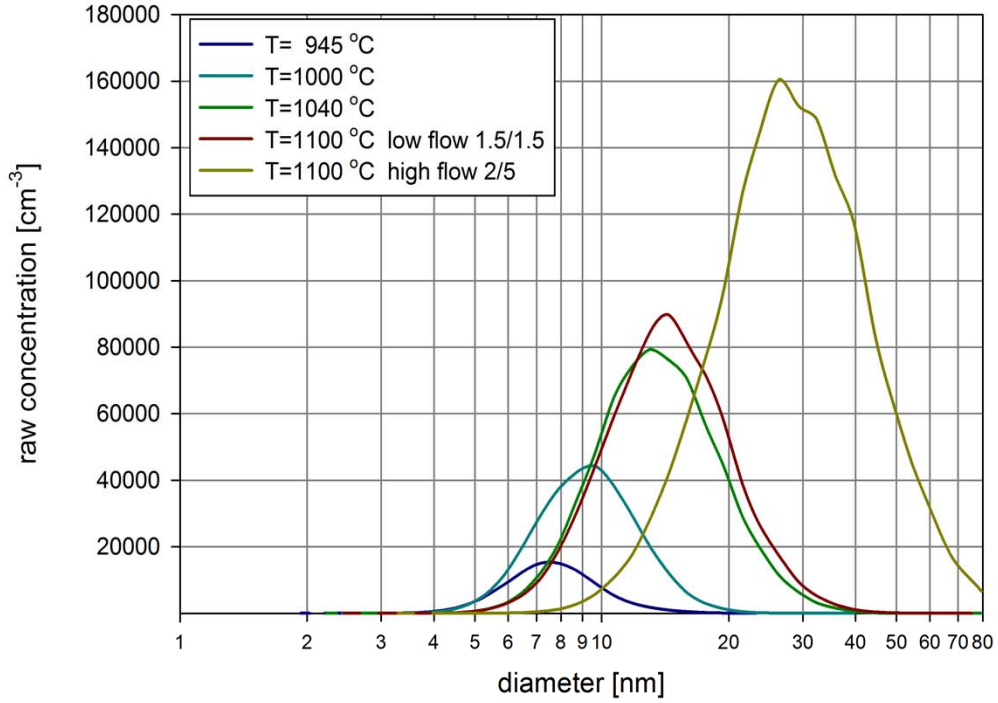
Reference Electrometer - CPC

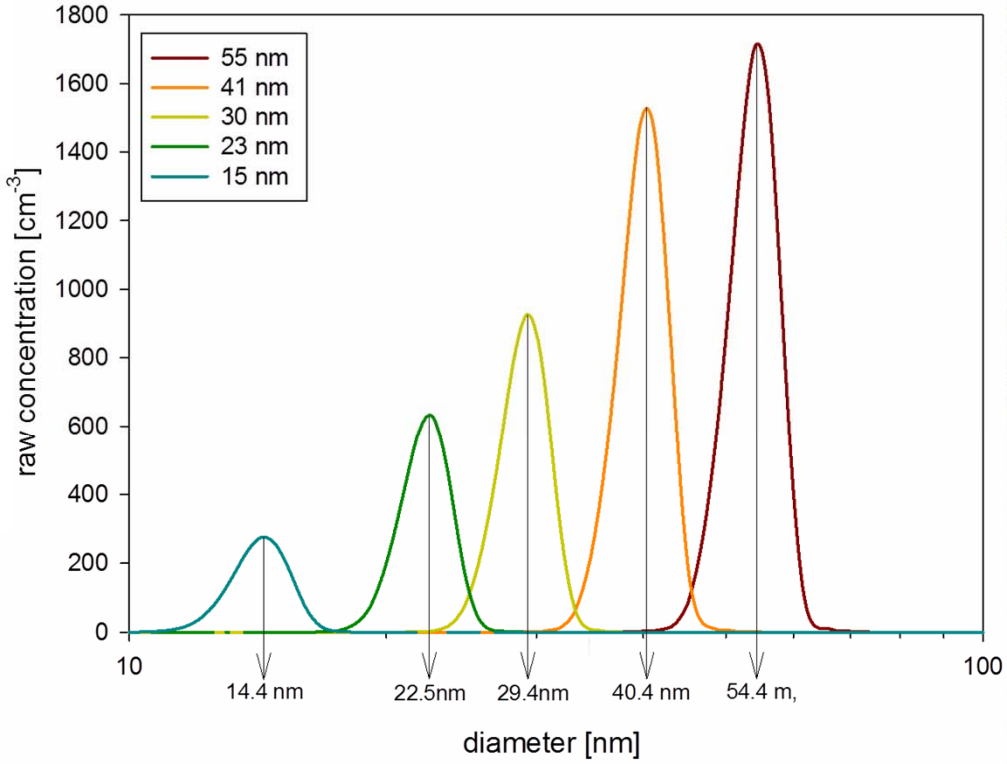


CPC - Calibration Set-Up

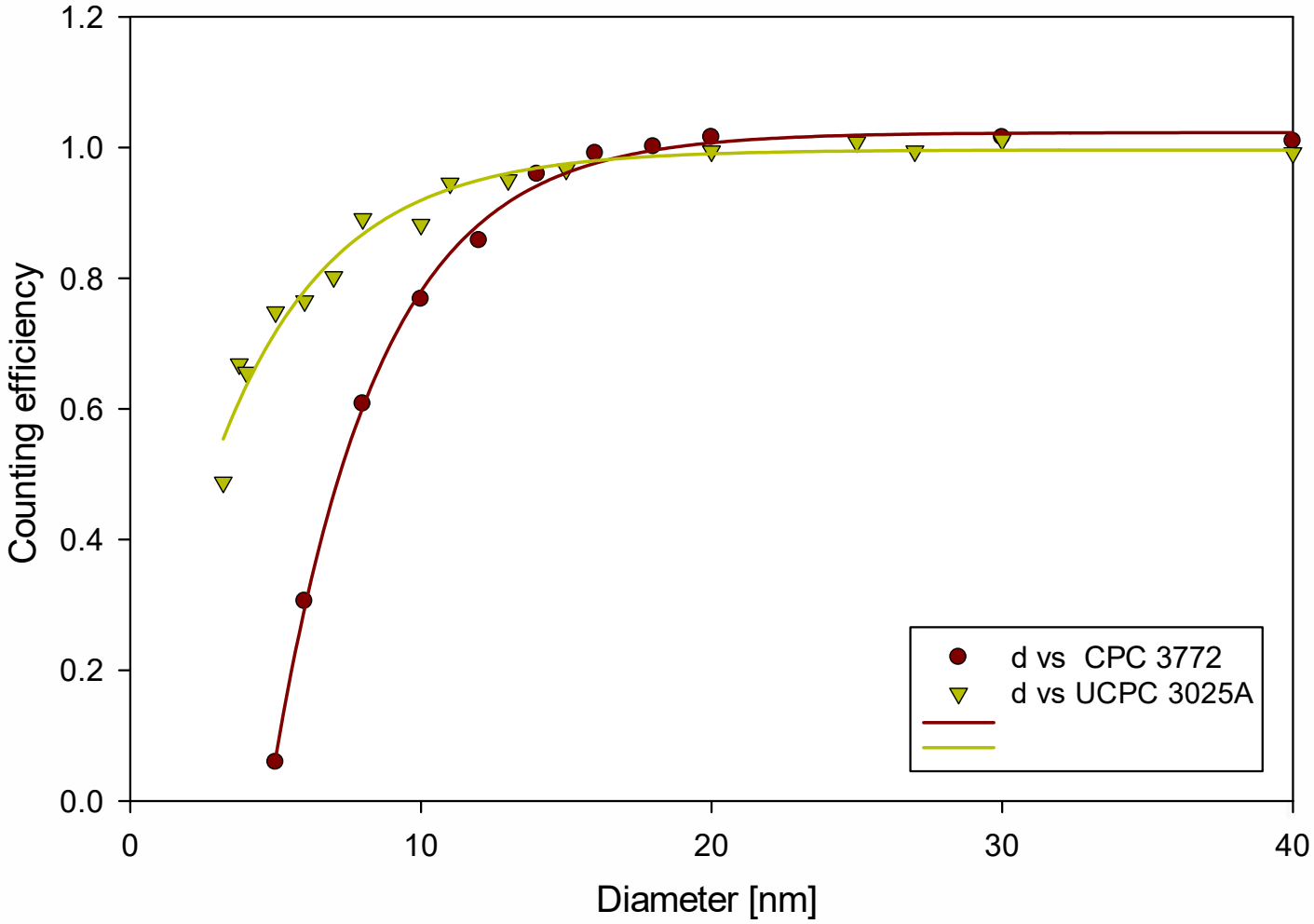


Tube Furnace Generator & Particle Selection





Calibration: CPC TSI models 3772, 3776



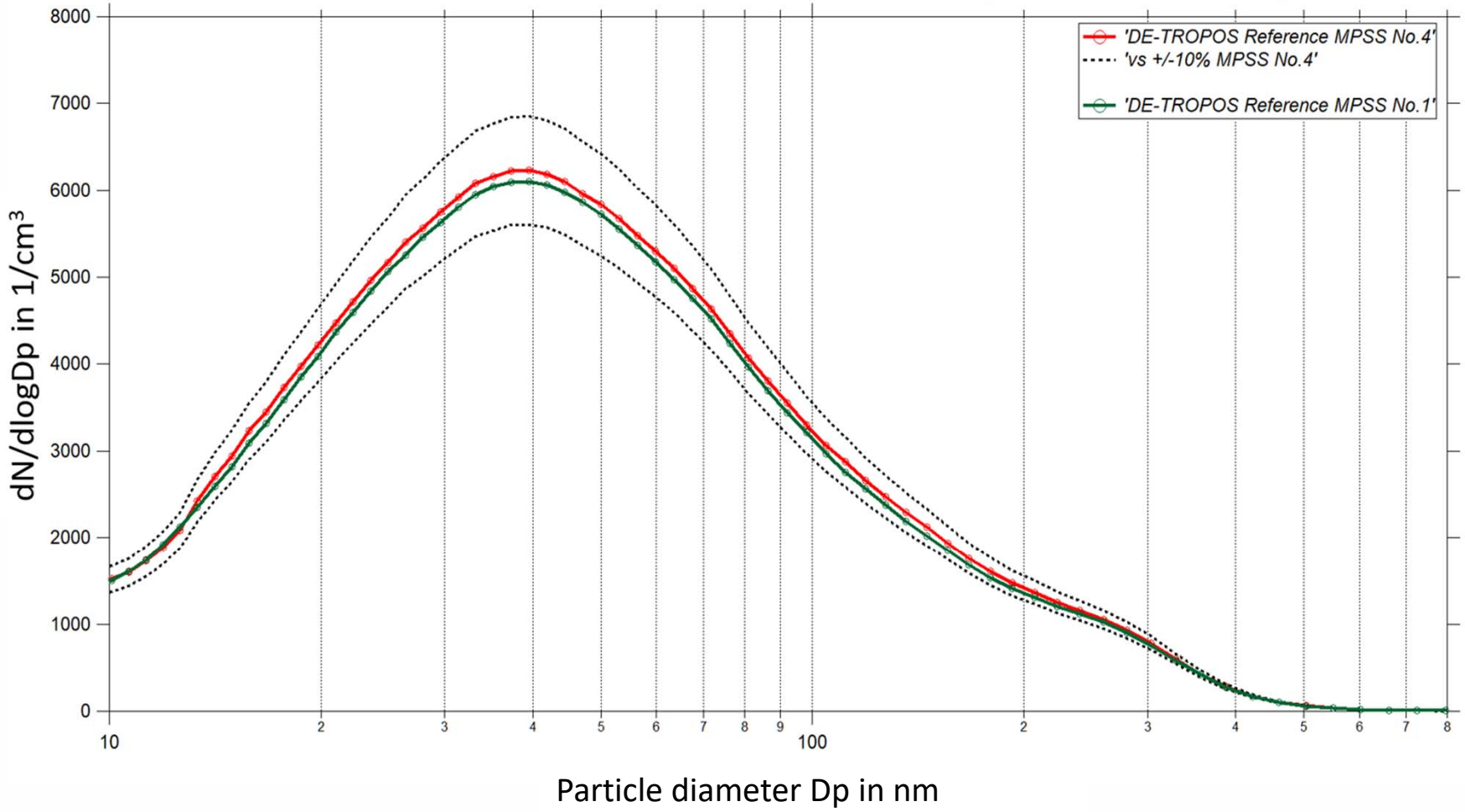
CPC – Quality Assurance

Recommendations:

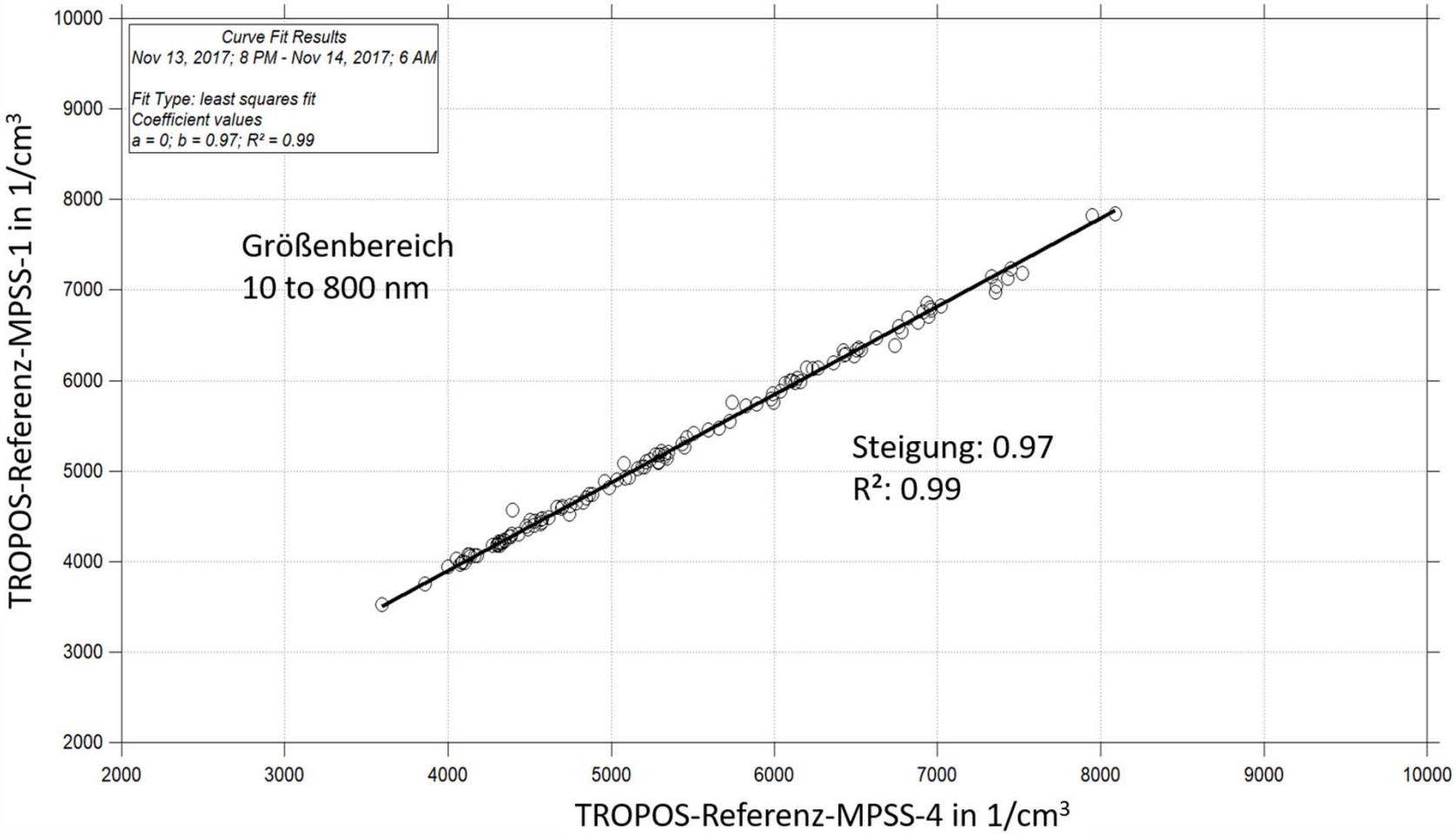
- check frequently the volumetric CPC inlet flow rate
  - if too low, check the focusing nozzle (or critical orifice)
- check a possible internal CPC aerosol flow rate
  - difficult for the TSI-UCPC 3776
- clean aerosol saturator (felt wick etc.)
  - have a spare parts available
- frequent calibration of the detection efficiency curve (annually)
  - Is usually not provided by the manufacturer (→ calibration facility)

MPSS - Reference Instrument

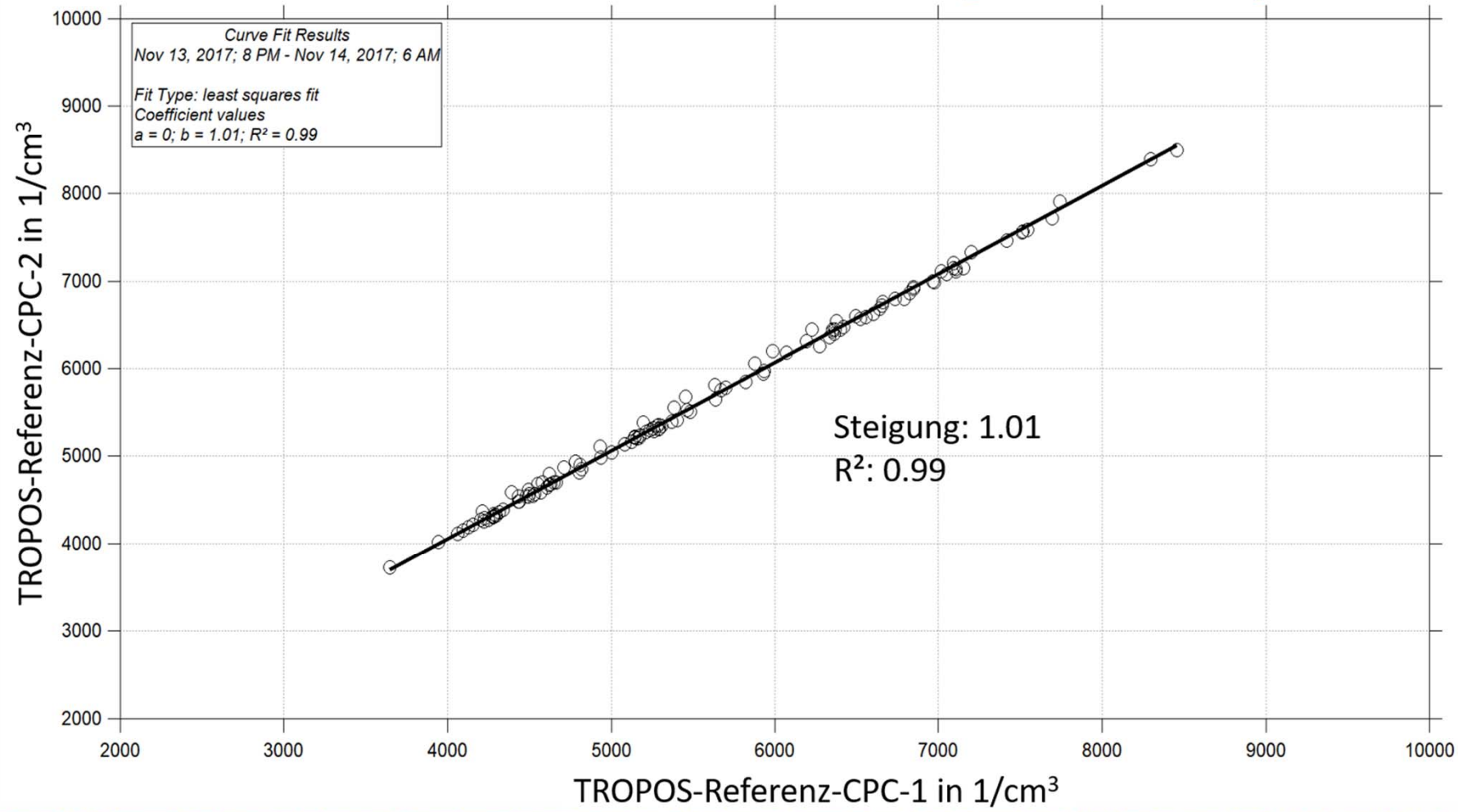
Reference MPSS: Comparability



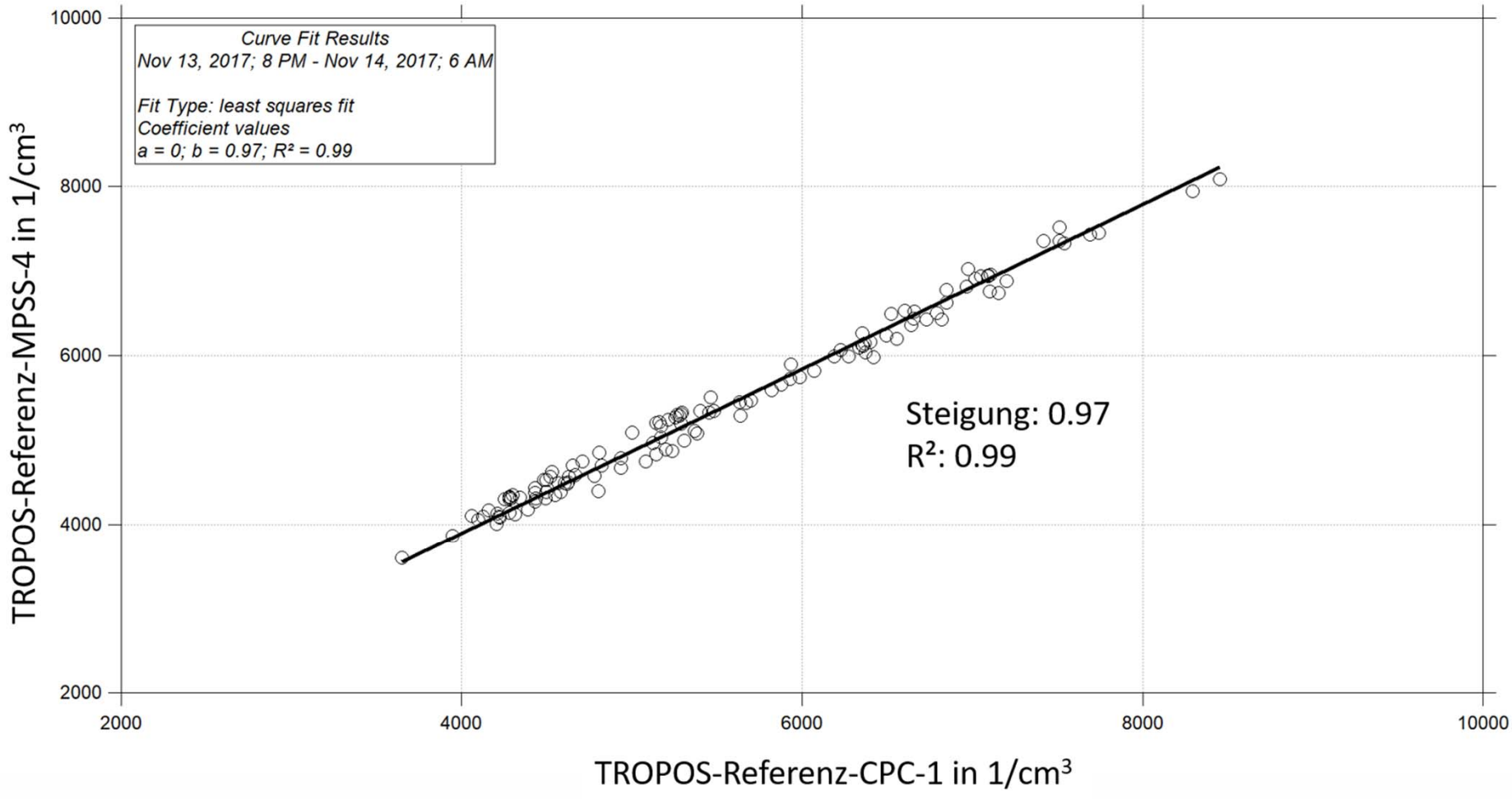
Reference MPSS: Comparability



Reference CPCs: Comparability



Reference CPC vs MPSS

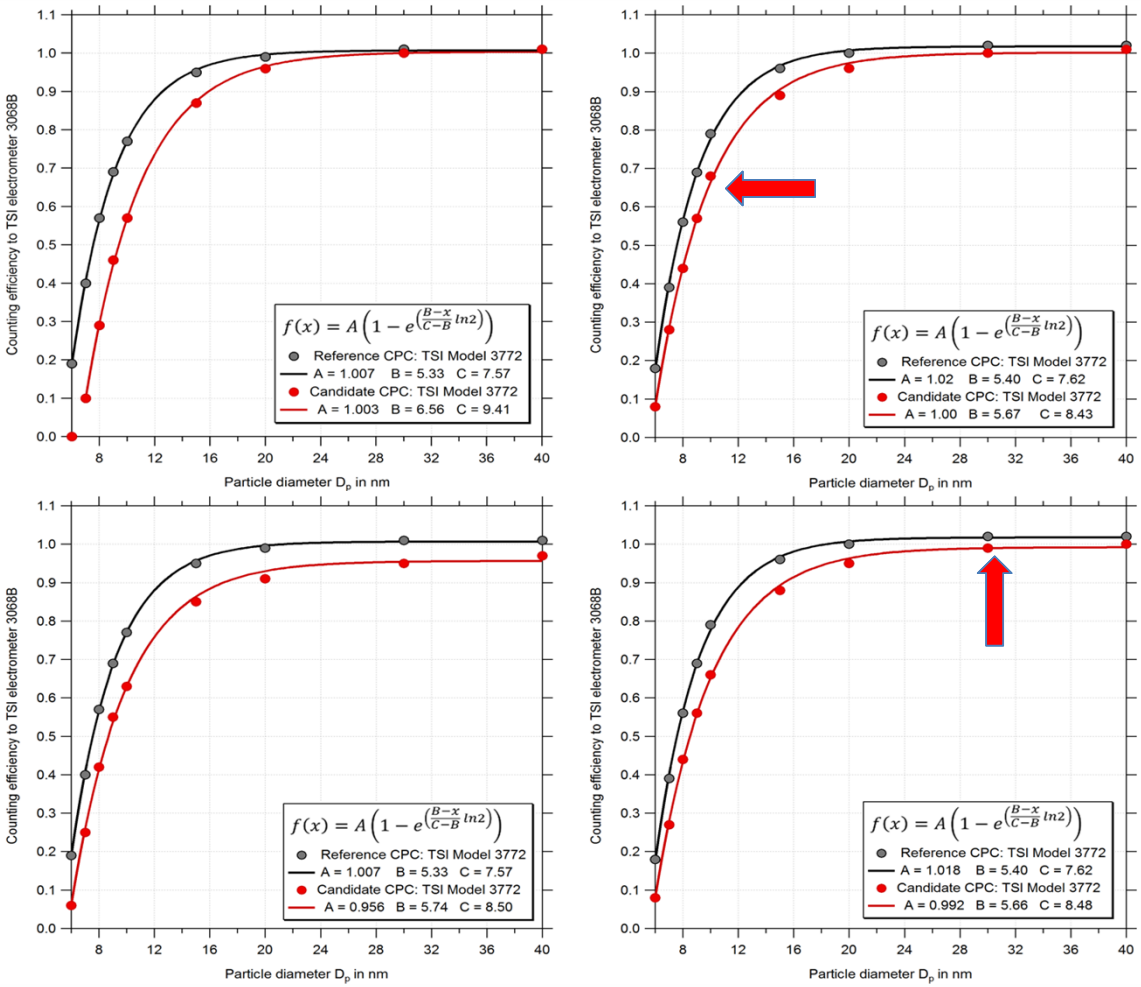


MPSS & CPC

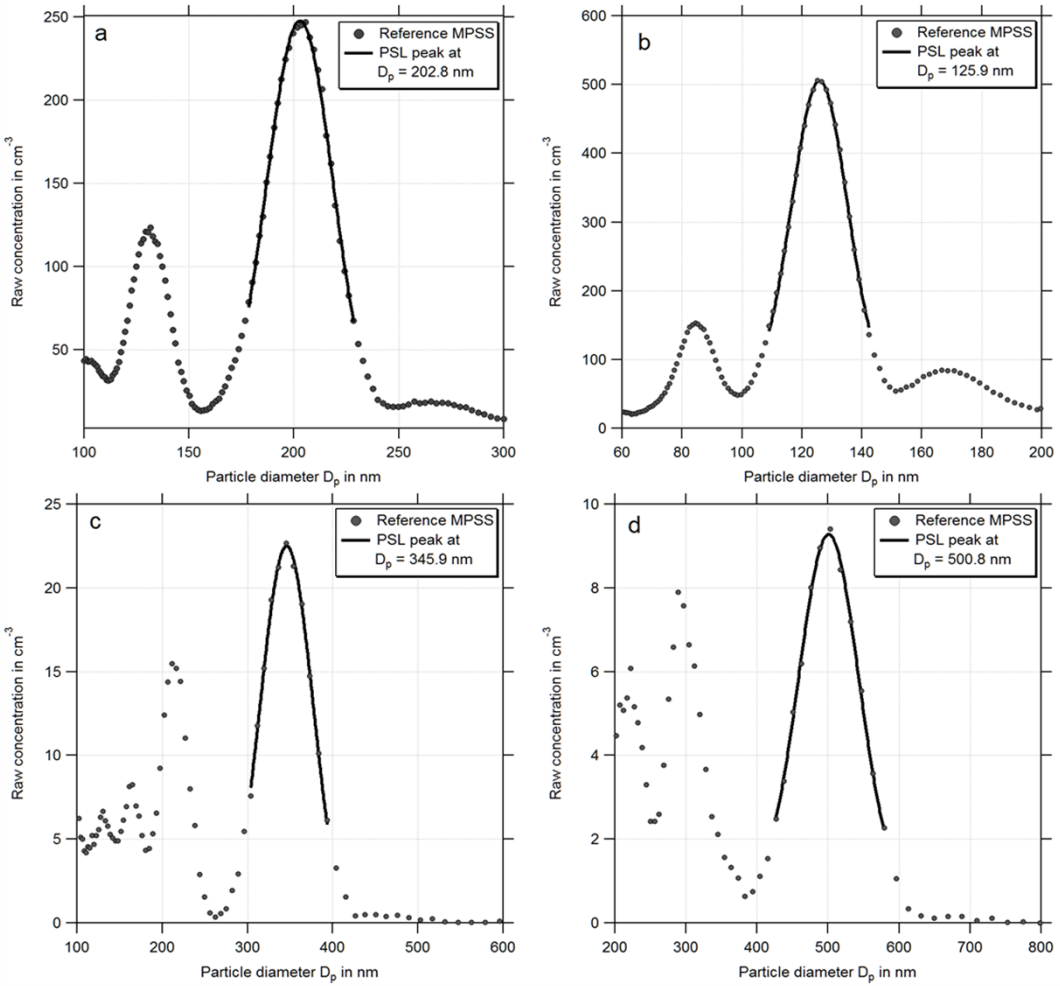
Calibration & Uncertainties

Wiedensohler, A. et al. (2018). Mobility Particle Size Spectrometers: Calibration Procedures and Measurement Uncertainties. Aerosol Science & Technology **52**(2), 146–164.

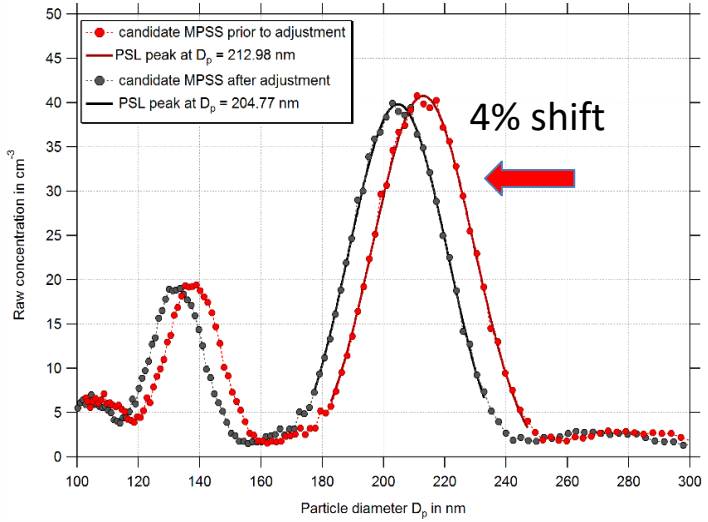
Example: Initial and Final CPC Calibration after Cleaning & Adjustment

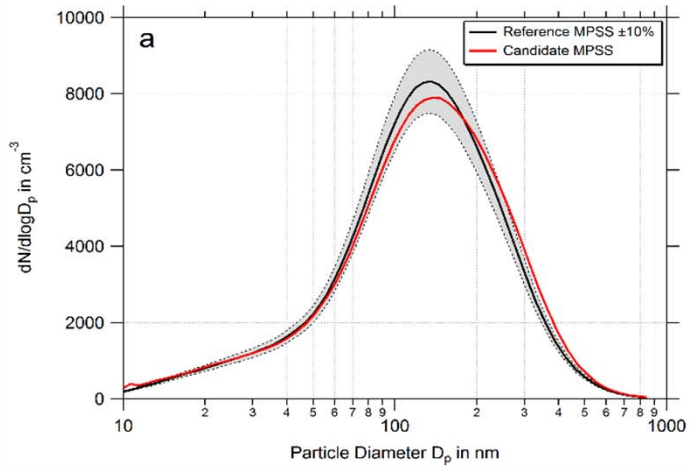


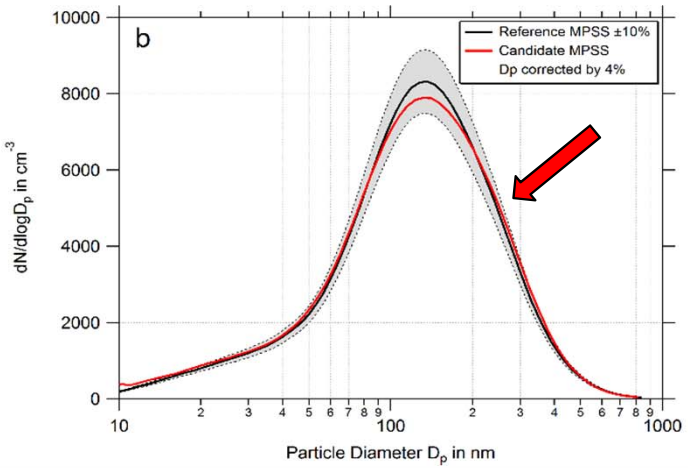
MPSS – Size Calibration Using PSL-Spheres



Example: Initial and Final PSL Calibration & Adjustment







Mobility Particle Size Spectrometer

Data Handling

MPSS - Data Correction

After the multiple charge correction, the calculated particle number size distribution has to be corrected for:

- The CPC counting efficiency curve
- Internal losses due to particle diffusion
- Losses due to diffusion in the inlet and sampling tubes

The internal losses can be calculated by the method of the “equivalent pipe length”.

Wiedensohler et al. (2012). Mobility Particle Size Spectrometers: Harmonization of Technical Standards and Data Structure to Facilitate High Quality Long-term Observations of Atmospheric Particle Number Size Distributions. AMT 5, 657–685.

Method of the Equivalent Length

Instruments or parts	Equivalent length	
Hauke-type medium-DMA (28 cm effective length)	4.6m	Karlsson and Martinsson (2003)
Hauke-type short-DMA (11 cm effective length)	4.6m	TROPOS internal calibration
TSI long-DMA (444mm effective length)	7.1m	Karlsson and Martinsson(2003)
TSI nano-DMA (49.9mm effective length)	3.64m	Jiang et al. (2011)
Permapure Nafion dryer SS2400	2.5m	Dick et al. (1995)
Permapure Nafion dryer SS1200	1.25m	Dick et al. (1995)
Diffusion dryer (e.g. TOPAS)	5m	estimated from Tuch et al. (2009)
90 bend (less than 5 cm radius)	0.15m	estimated from Wang et al. (2002)
Bipolar diffusion charger (TROPOS custom-made)	1m	Covert et al. (1997)