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A laboratory inter-comparison of CPC and SMPS measurements of submicron aerosols



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Introduction

- Particle size distribution is one of the most important physical properties of particles. A wide range of instruments have been developed to measure size distributions.
- Four condensation particle counters (CPC) and three scanning mobility particle sizers (SMPS) (all commercial instruments) have been compared in terms of particle number concentration and size distribution.

List of instruments

ID	Sampling flow [l/min]	Size range [nm]	Max. concentration [# /cm ³]	Neutralizer	Detection
CPC#1	0.3	4-3000	10 ⁷	N/A	Butanol
CPC#2	0.3	4-3000	10 ⁷	N/A	Butanol
CPC#3	0.6	> 23	50000	N/A	Butanol
CPC#4	0.3	4-3000	10 ⁷	N/A	Butanol
SMPS#4a	0.3	5-350	10 ⁷	²⁴¹ Am	Butanol
SMPS#4b	0.3	10-1110	10 ⁷	²⁴¹ Am	Butanol
SMPS#5	1.0	300-10000	3000	N/A	Optical
SMPS#6	0.75	10-420	10 ⁶	Corona discharge	Isopropanol

➤ SMPS#4 has two different DMA (a and b), measuring two different size ranges.

➤ Diffusion loss correction has been applied for all the SMPS.

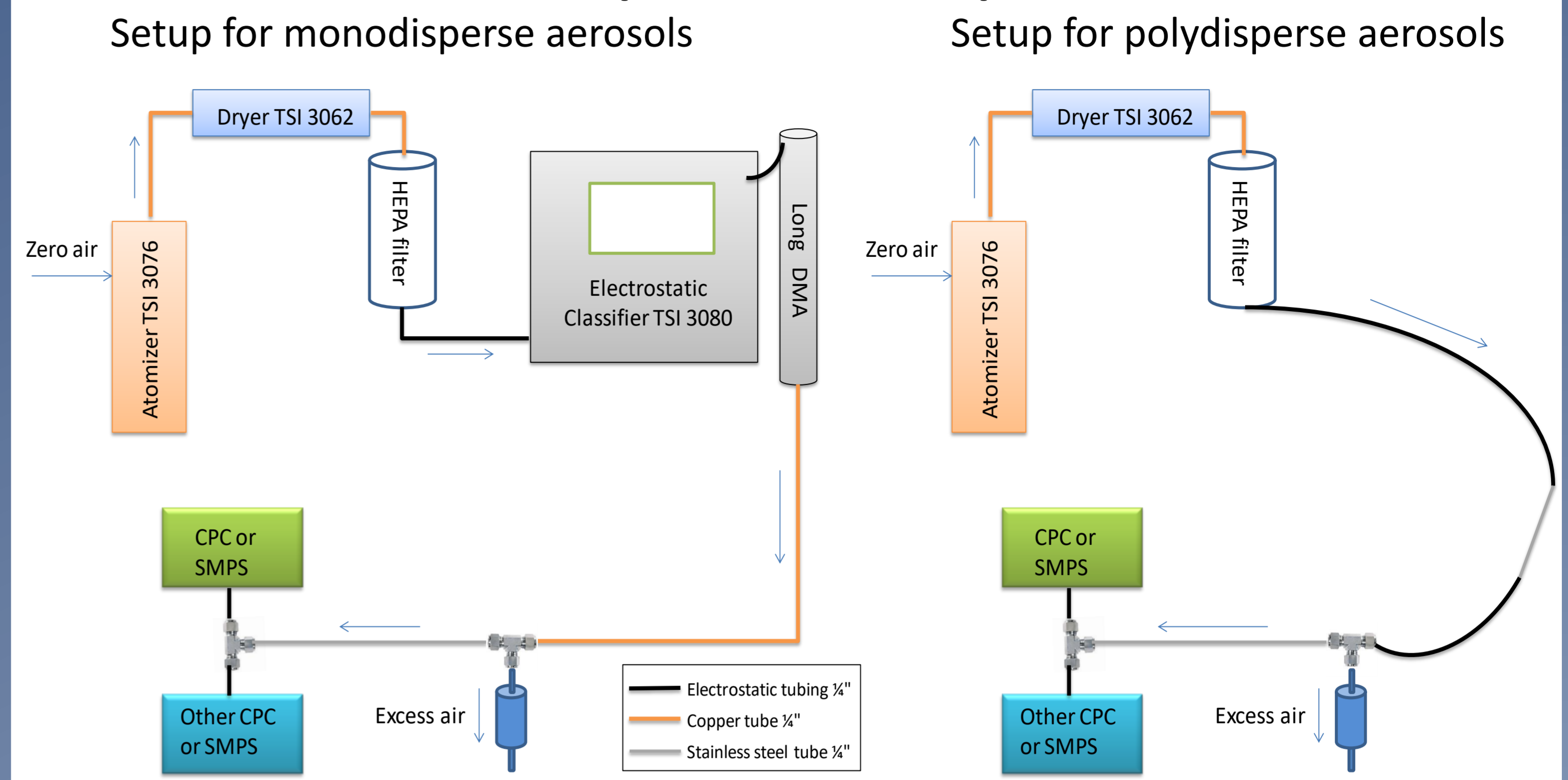
Inter-comparisons:

CPC vs. CPC: comparison of the particle number concentrations given by the CPC.

CPC vs. SMPS: the SMPS size distribution is integrated over the entire size range.

SMPS vs. SMPS: the SMPS size distributions are integrated over the same size range.

Experimental setup



Solutions: NH₄NO₃ 10⁻² M for particles of selected sizes (50, 100, 200, 300 nm)
 NH₄NO₃ 10⁻³ M for polydisperse aerosols
 PSL spheres (50, 200, 350, 500, 700, and 900 nm)

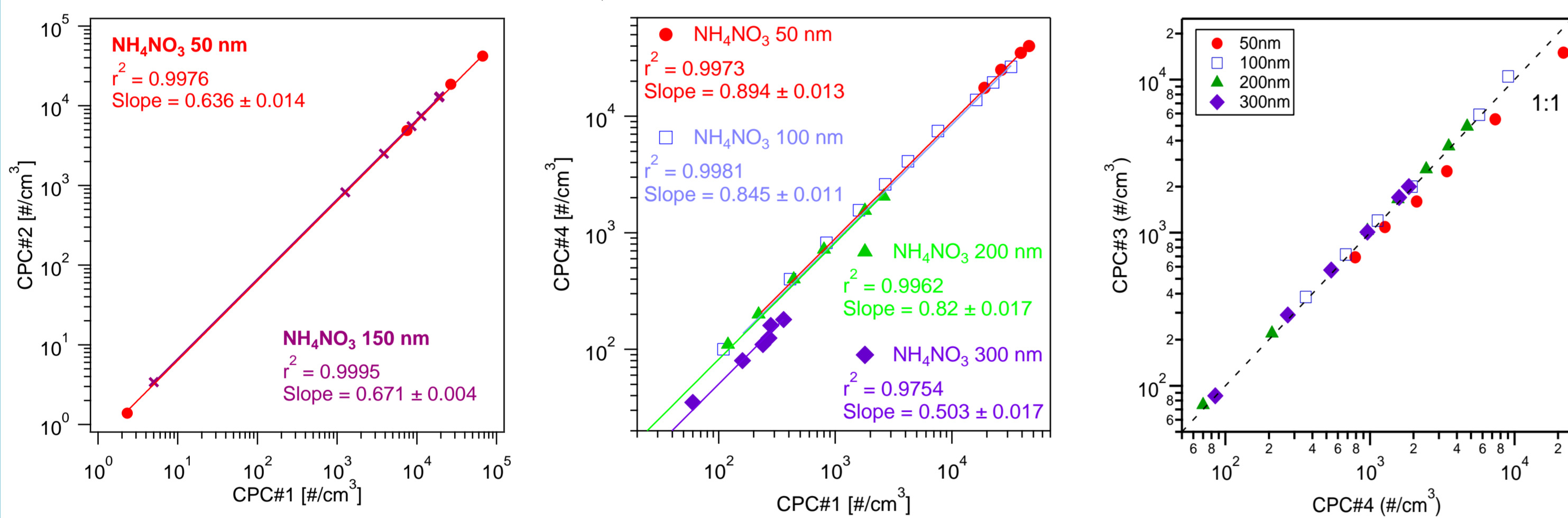
Results and discussion

Particle number concentration

➤ CPC vs. CPC:

All the instruments are very well correlated ($r^2 > 0.99$). However, CPC#1 measures much more particles than CPC#2 and CPC#4.

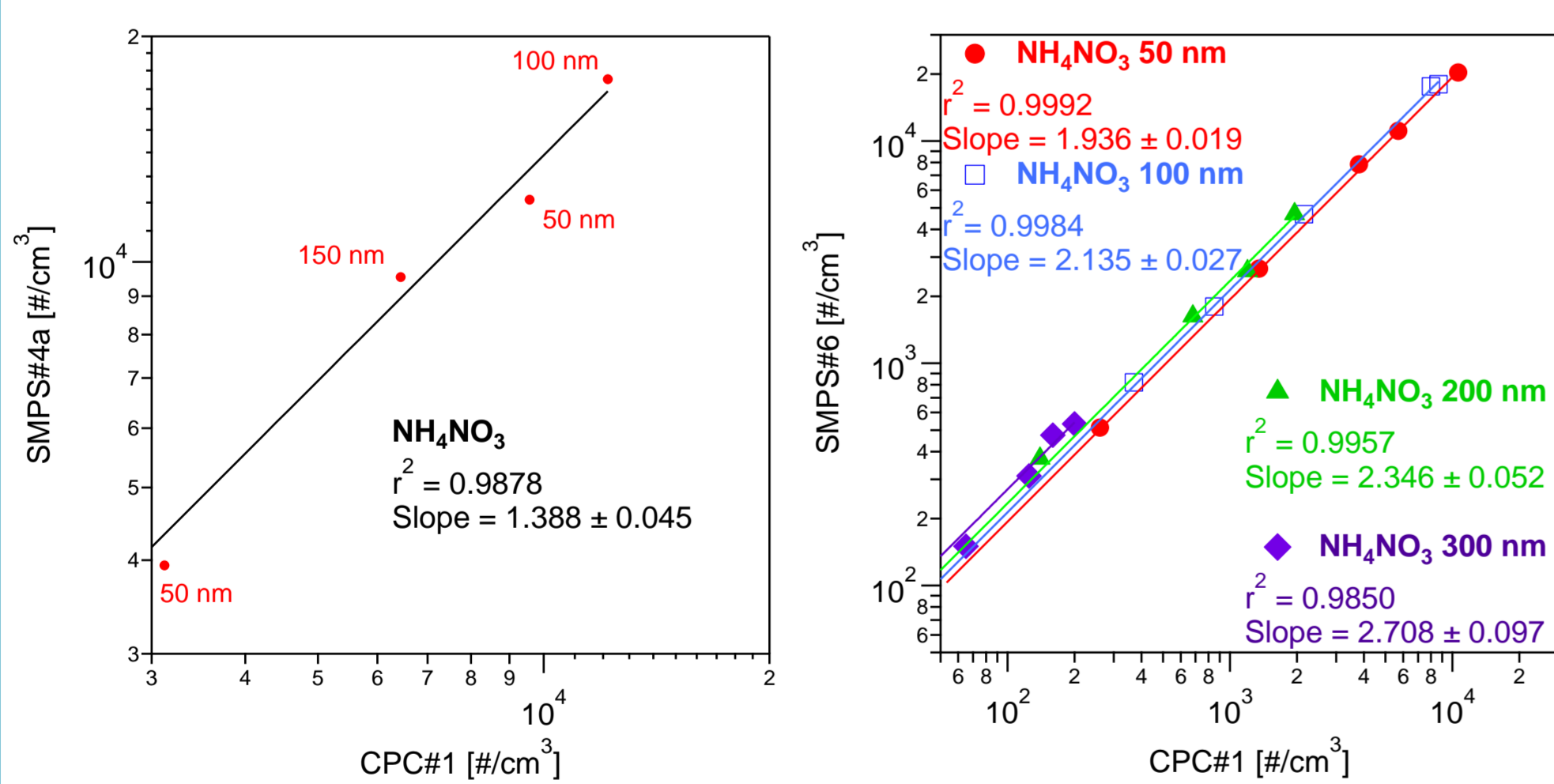
For CPC#1, the counting efficiency increases for large particles (>200 nm).



➤ CPC vs. SMPS:

SMPS#4a and SMPS#6 count much more particles than CPC#1 (slopes between 1.4 and 2.7).

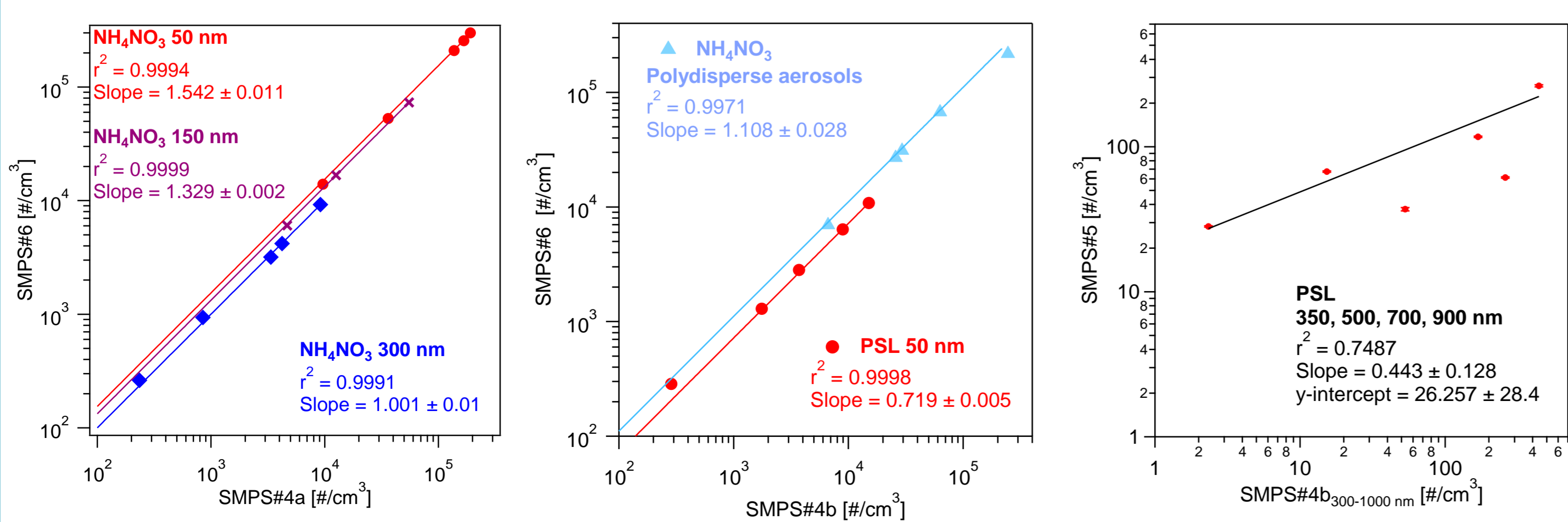
SMPS#6 vs. CPC#1 shows very large variation of the slope, as a function of the particle size.



➤ SMPS vs. SMPS:

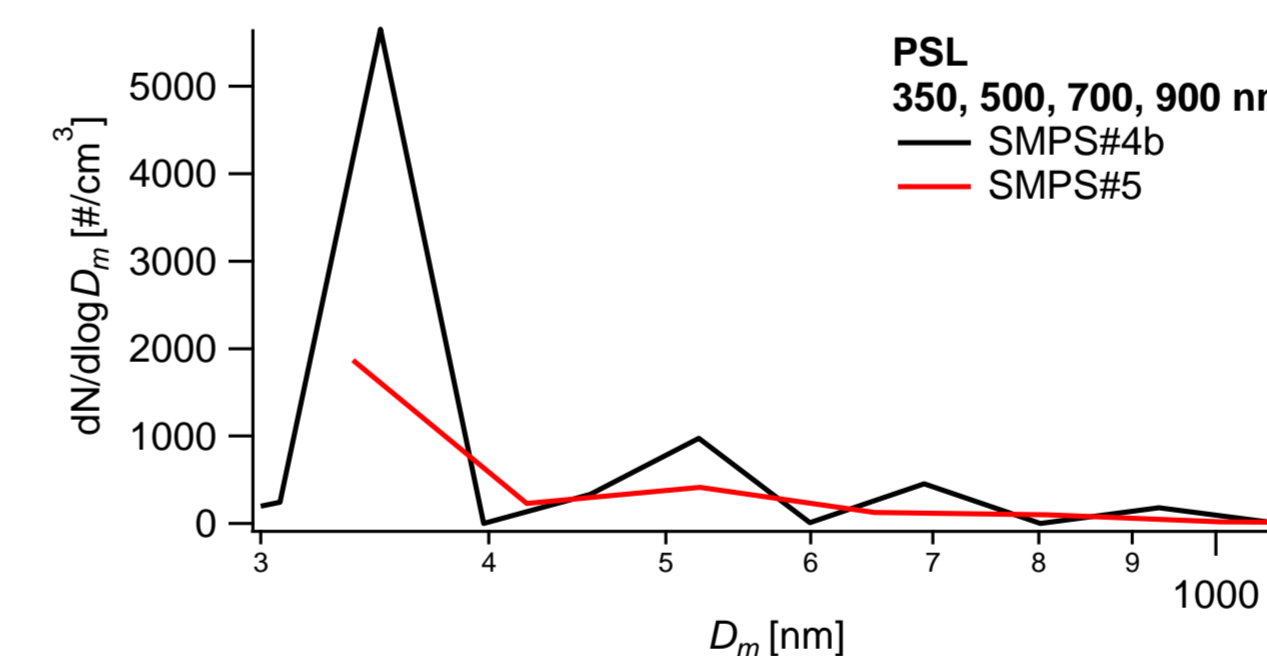
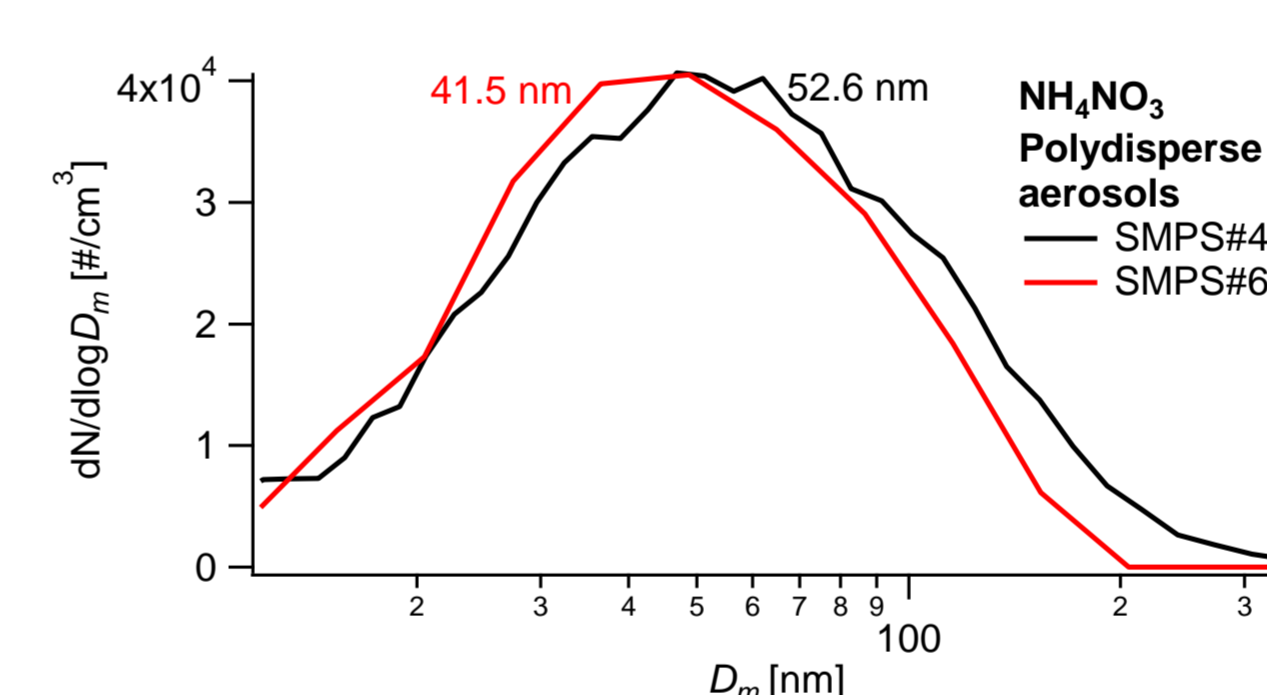
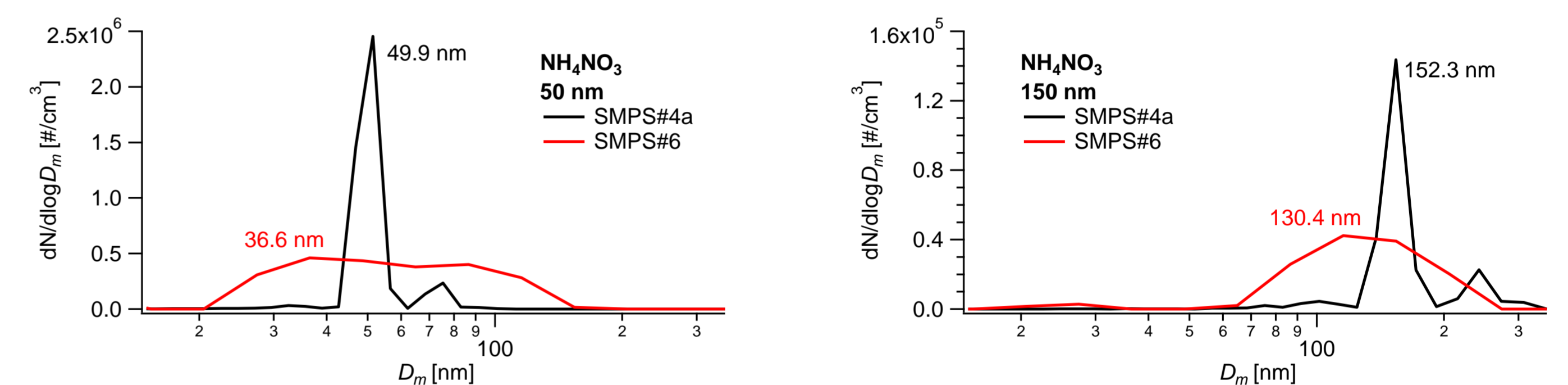
SMPS#4(a and b) and SMPS#6 show different counting efficiencies, as a function of the particle size. For small particles, SMPS#6 counts much more particles than SMPS#4a.

SMPS#5 measures particles larger than 300 nm and uses optical detector. Its correlation towards SMPS#4b, which uses butanol CPC, is low.



Particle size distribution

➤ Size distributions measured by SMPS#4a agree very well with those of NH₄NO₃ selected by the electrostatic classifier. SMPS#6 has a very wide size distribution, and is obviously not suitable for the measurement of monodisperse aerosols.



➤ SMPS#4b and SMPS#6 have very similar size distributions, with a slight shift in the mode. SMPS#6 seems to measure size distributions of polydisperse aerosols much better than those of monodisperse aerosols.

➤ SMPS have usually very poor size resolution beyond 300 nm. SMPS#4b and SMPS#5 see PSL particles in the range 300-1000 nm, but the integration of these signals has very large uncertainties.

Conclusion

- All the instruments are very well correlated in terms of particle number concentrations ($r^2 > 0.99$). However, scatterplots have slopes very far from 1 in some cases.
- Counting efficiencies of several instruments seem to depend highly on the particle size.
- Good agreement between the different SMPS in terms of size distributions, except for SMPS#6 with monodisperse aerosols.
- These discrepancies in particle counting between different instruments may be a serious problem in field campaigns or lab experiments, since people often bring just one SMPS or one CPC to calibrate instruments, and to measure particle concentrations and size distributions.

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