



Schweizerische Eidgenossenschaft
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Swiss Confederation

Swiss Federal Office of Metrology METAS

Comparisons of particle number concentration and particle size measurements

Congrès de métrologie, 24. juin 2009, Paris, France



Outline

Introduction

Definition of quantities and Motivation for Metrology

Particle counting principles

Areas with lowest uncertainties

Experimental

particle generation and distribution

Results of 7th national comparison workshop

particle number concentrations (10^3 cm^{-3} to 10^6 cm^{-3})

particle sizes (40 nm to 170 nm)

Summary and Outlook



Number concentration and size range

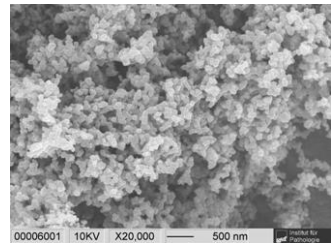
Examples of number concentrations:

Diesel exhaust fumes:	1 000 000 000 cm ⁻³
Urban air:	1 000 000 cm ⁻³
Rural air:	10 000 cm ⁻³
Mountain air (Jungfrauoch):	100 cm ⁻³
METAS particle laboratory air:	100 cm ⁻³
Clean room class 9 (> 0.5 μm):	35 cm ⁻³
Clean room class 6 (> 0.1 μm):	1 cm ⁻³



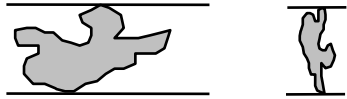
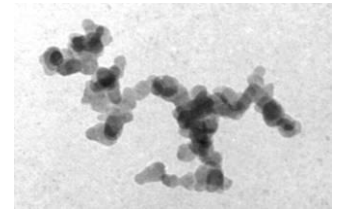
Examples of particle sizes:

Water molecule	0.1 nm
Viruses	1 nm – 5 nm
Tobacco and Engine smoke	10 nm – 1000 nm
Bacteria	0.5 μm – 50 μm
Coal dust	1 μm – 100 μm



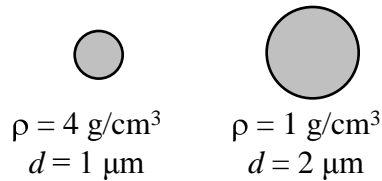


Size of combustion particles



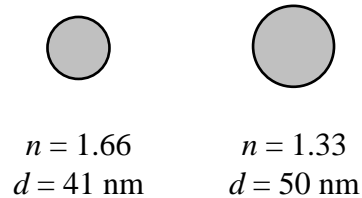
Geometric diameter:

Considering their vertical size, the two particles are approximately the same. e.g. microscopy



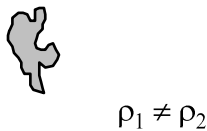
Aerodynamic diameter:

Considering the sedimentation velocity, the two particles are approximately the same. e.g. impactor



Optical diameter:

Considering the light scattering properties, the two particles are approximately the same. e.g. optical particle counter



Mobility diameter:

Considering the diffusion behavior, the two particles are approx. the same. e.g. diffusion battery, electronic mobility analyzer

National comparisons: electronic mobility diameter



Motivation for metrology



ambient measurements



clean-room monitoring



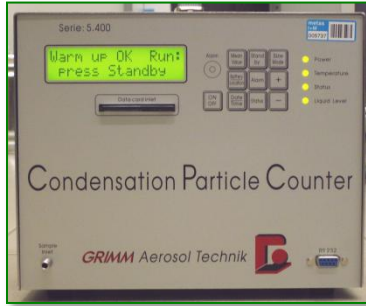
emission measurements



human protection / security



Particle counting principles - I



1. Condensation particle counters (CPC)

count individual particles that are transported at a particular volumetric flow rate. Particles are magnified with a condensation growth mechanism of a working fluid and are detected using light-scattering techniques,



2. Faraday cup electrometers (FCE)

count charges of particles at a certain volumetric flow rate. The FCE needs an assumption on the number of charges for the calculation of the particle concentration,

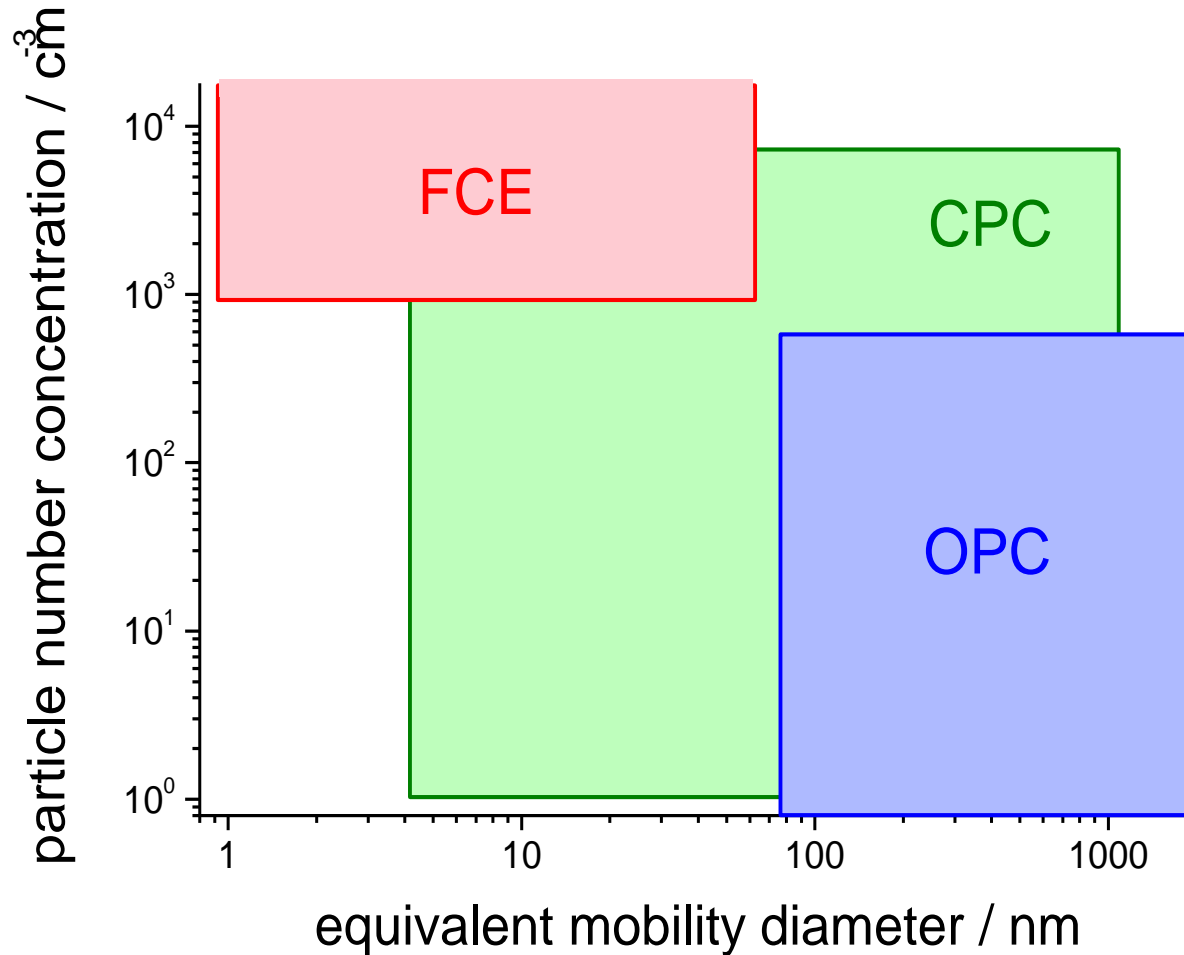


3. Optical particle counter (OPC)

measure the scattered light of individual particles that are transported through a measured volume. The OPC technique is only applicable for particles above 100 nm.



Particle counting principles - II



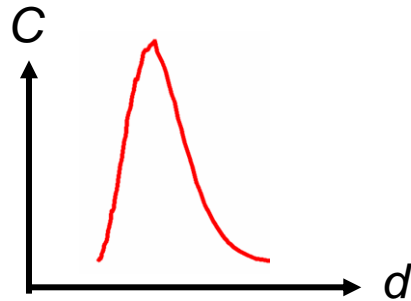
Each counting principle has a region of measurement values of lowest uncertainties.



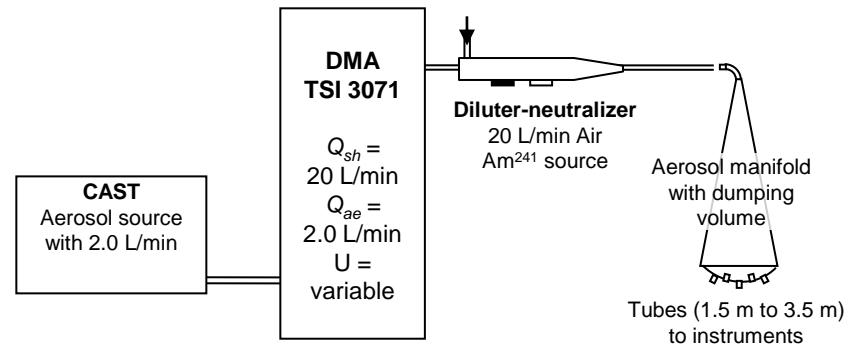
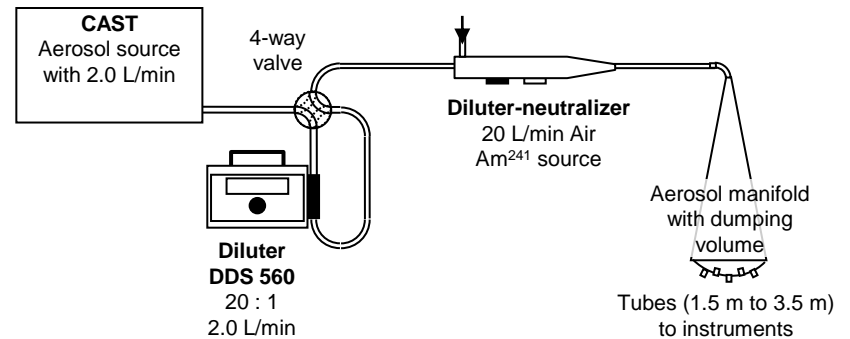
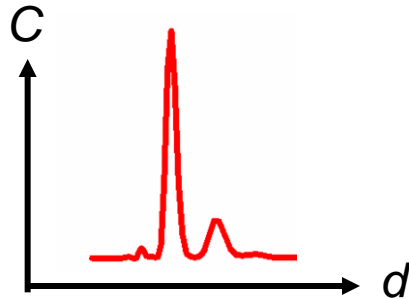
Experimental setup – Aerosol Generation

Particle generation:

"natural" size distribution



monodisperse size distribution





Experimental setup – METAS standards



Standard for particle number concentration C_N :

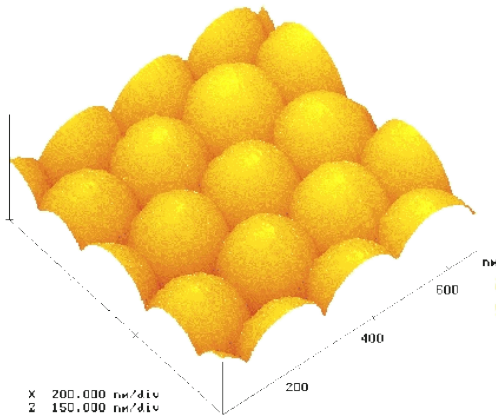
Mean of at least two different particle counting principles

$$U(C_N) = 15 \% (k = 2) \text{ for } d_g < 100 \text{ nm}$$
$$U(C_N) = 10 \% (k = 2) \text{ for } d_g \geq 100 \text{ nm}$$

Standard for particle size d_g (mobility diameter):

obtained from a SMPS; calibrated with certified polystyrene particles; which are occasionally checked by AFM:

$$U(d_g) = 7 \text{ nm} + 0.01 \cdot d_g$$





Experimental setup – calibration routine

Particle number concentrations and sizes:

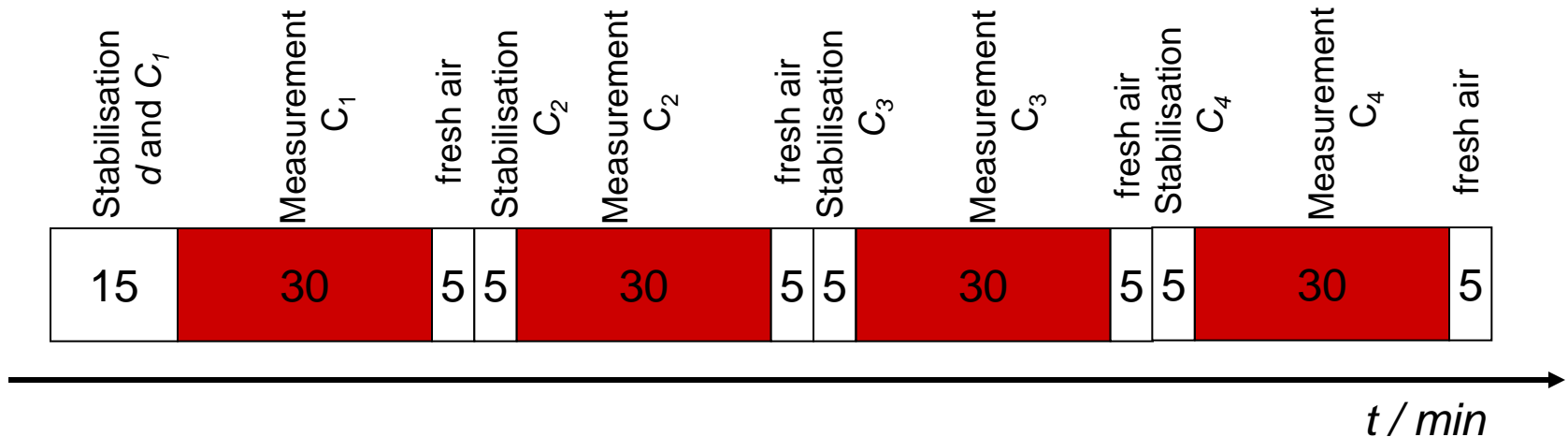
“natural” size distributions:

d : 40 nm, 70 nm, 100 nm and 170 nm

at different number concentrations:

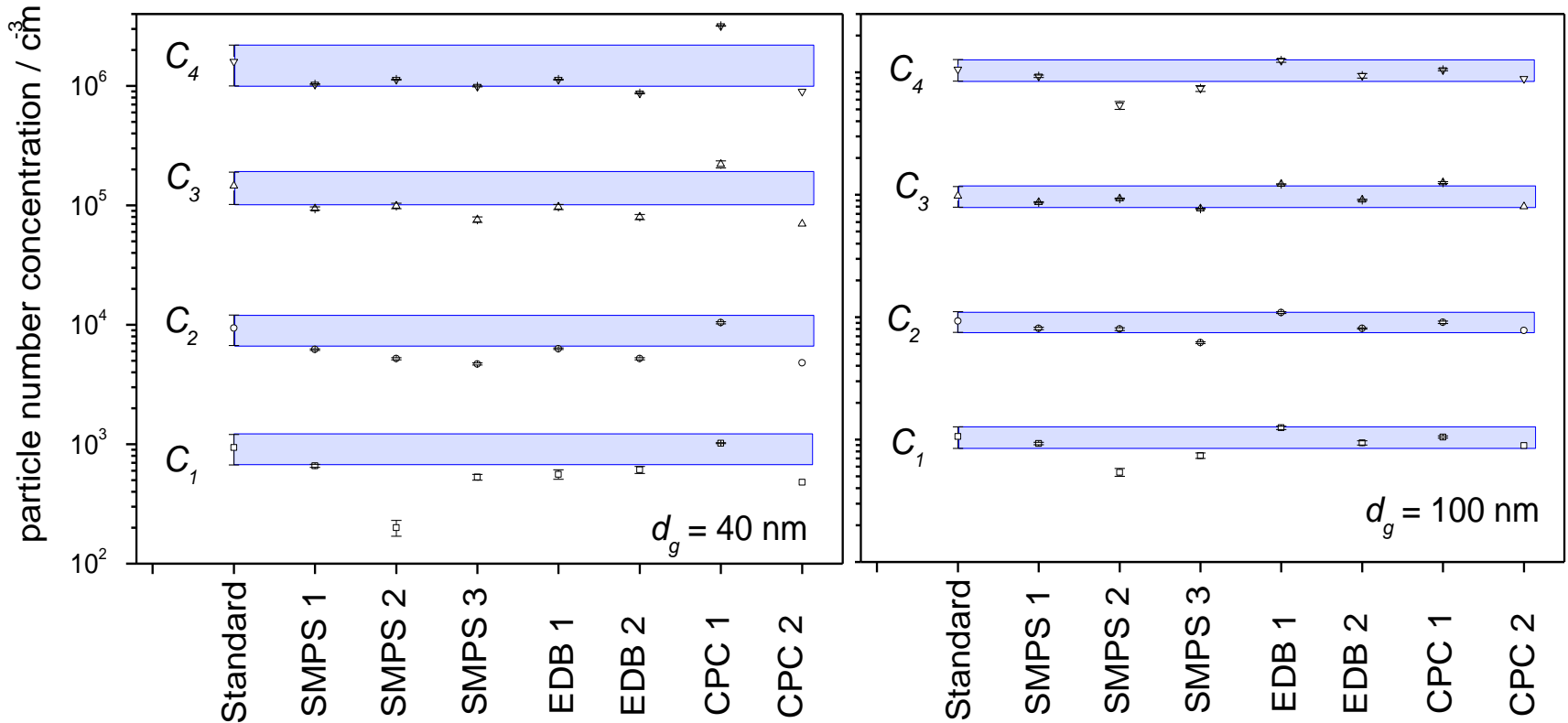
C_1 to C_4 : 10^3 cm^{-3} to 10^6 cm^{-3}

cycle per particle size:





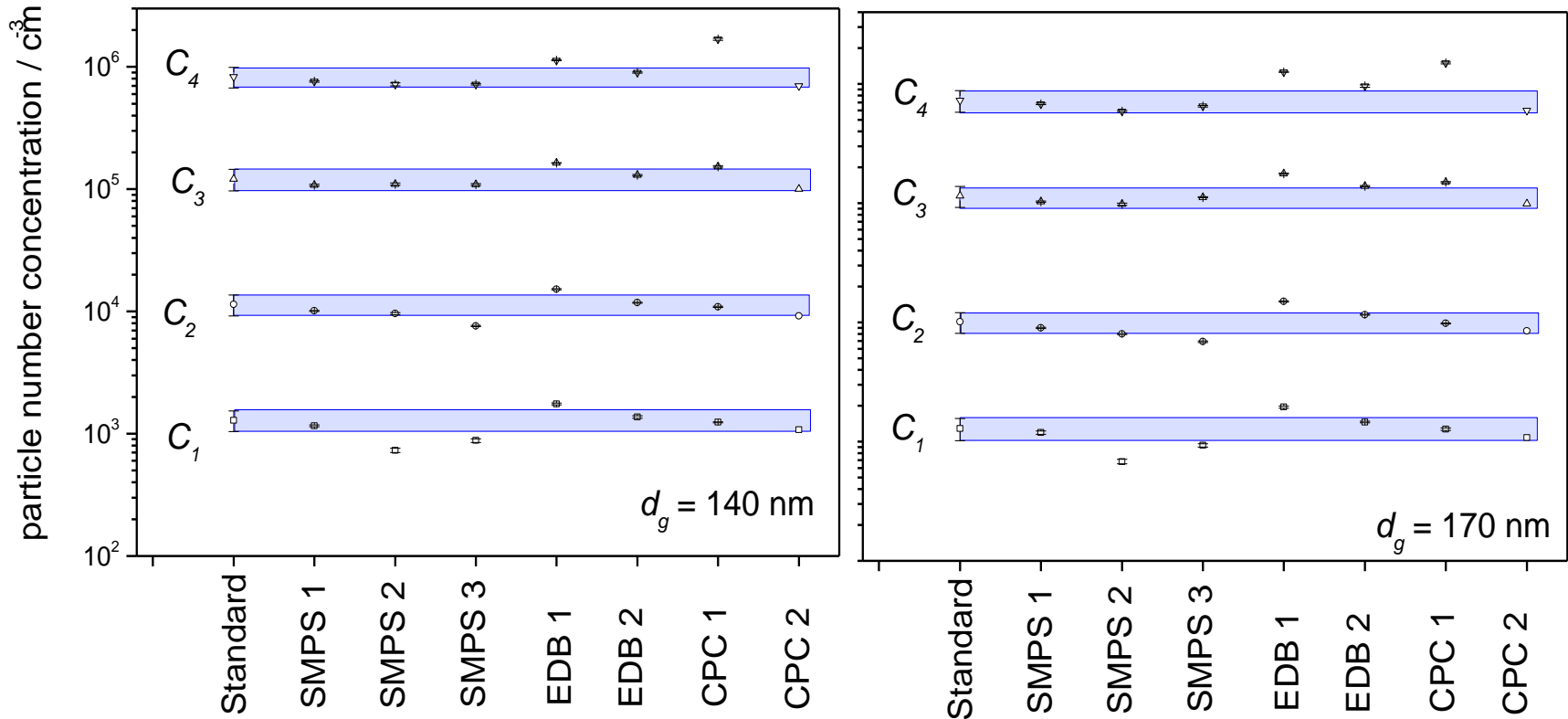
Results workshop 2008 – C_N – I



40 nm: Better agreement with higher number concentrations
100 nm: Generally agreement within 10 %
simplified screen diffusion battery (EDB) differs -40 % to +150 %



Results workshop 2008 – C_N – II



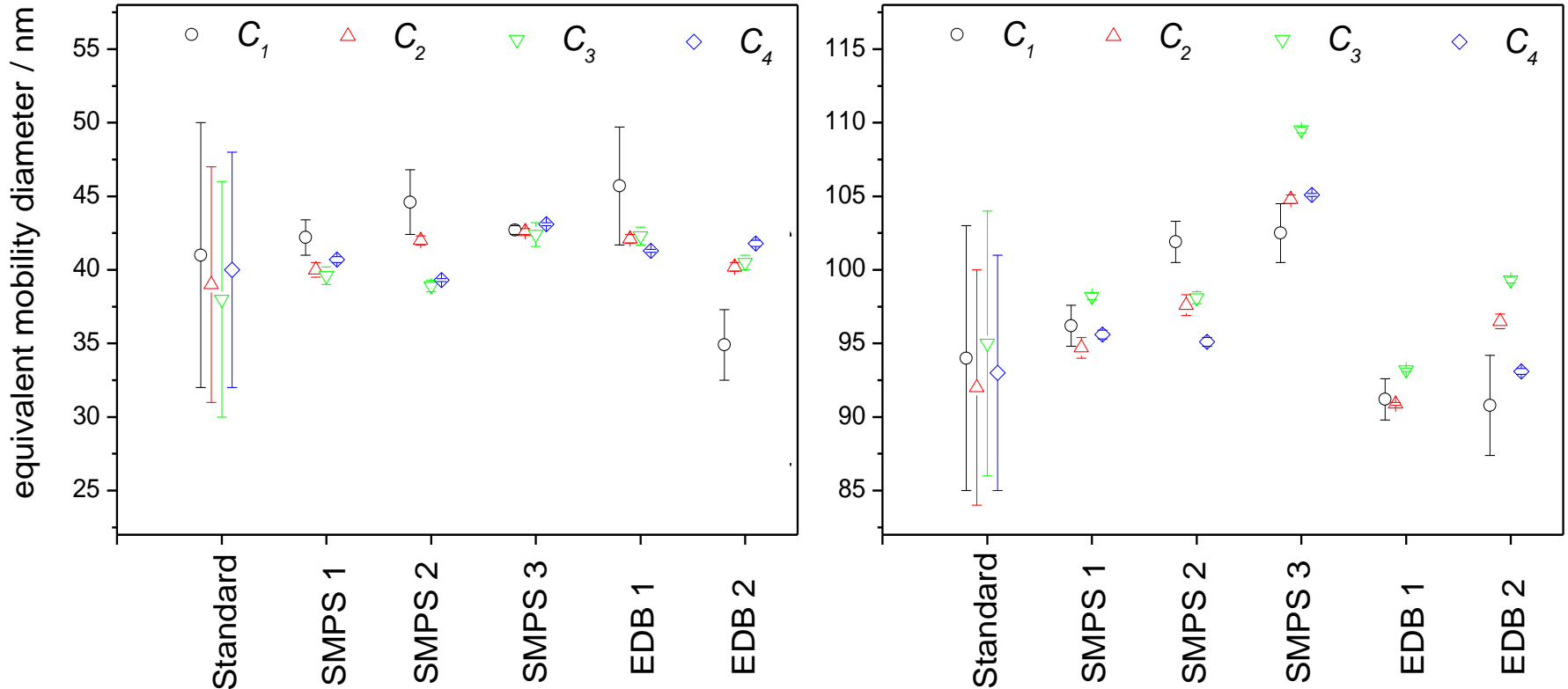
140 nm: Generally agreement within 10 %

170 nm: Generally agreement within 10 %

CPC 1 changes to photometric mode at higher concentrations



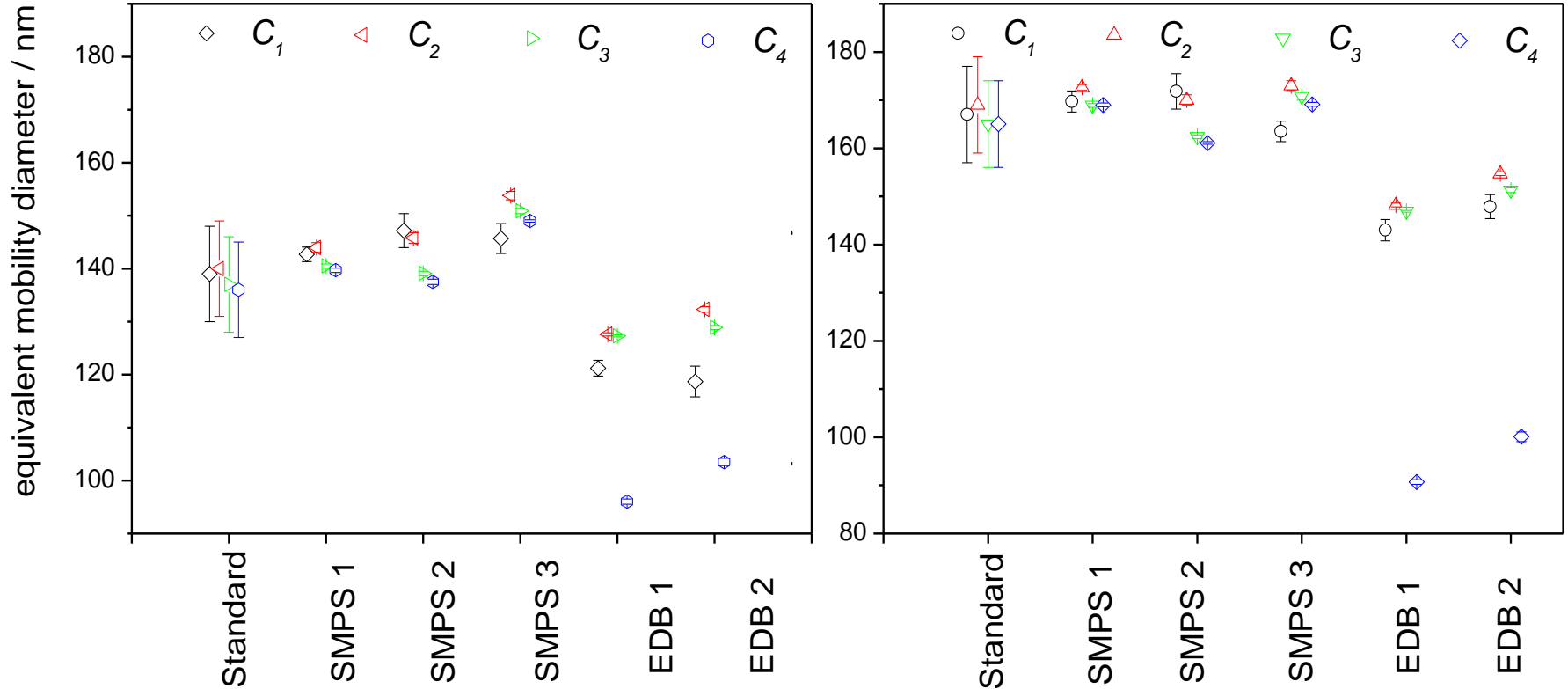
Results workshop 2008 – d_g – I



40 nm: Generally agreement within 15 %; larger variations at C₁
100 nm: Generally agreement within 15 %; larger variations at C₁
simplified screen diffusion battery (EDB) agrees well with SMPS



Results workshop 2008 – d_g – II



140 nm: Generally agreement within 15 %;

170 nm: Generally agreement within 15 %;

simplified screen diffusion battery (EDB) deviates with higher C_N



Results workshop 2000 - 2008

Comparability of particle number concentration and particle size measurement has increased in the years 2000 to 2008.

Important factors are:

- accurate flow measurements.
- regular maintenance of instruments
- regular participation in comparisons



In several cases even instrument malfunction was discovered during the comparison workshop. The latter show that the calibration of particle measurement instrument is indispensable, because deviations can only be discovered and quantified with standards.

8th METAS calibration workshop: 26th to 28th august 2009



Summary and Outlook

- ❑ Particle number concentration and particle size are important quantities in environmental protection and occupational safety.
- ❑ Regular national comparisons with recognized international standards for particle number concentration and particle size ensure comparability of measurement result.
- ❑ International comparison of national standards of particle number concentration and particle size ensure comparability of measurement results worldwide.

EURAMET 1027: Comparison of national standards for C_N and d_g ; participants CH, DK, UK, DE and JP.