Dekati® ELPI+™

Ambient particle research, occupational health, nanoparticle research

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Ambient sampling – things to consider

- Particles are not the only things flying around in air – use PM10 or TSP inlets

- Effect of humidity and volatiles on measured particle mass can be significant for different measurement methods – check correlation and adjust sampling if needed

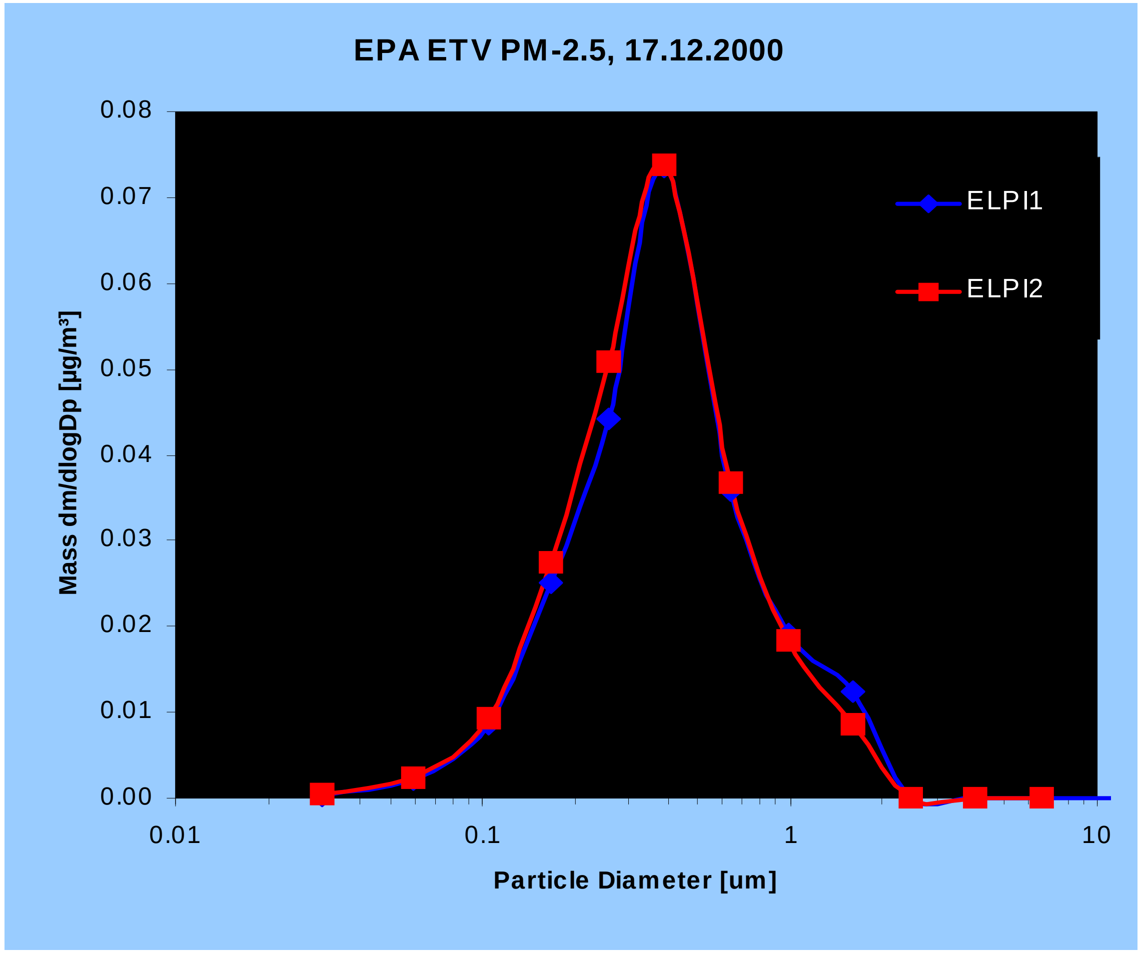
- Full setups available from Dekati

Outdoor, Indoor and occupational health measurements

- Similar applications in terms of sample conditioning

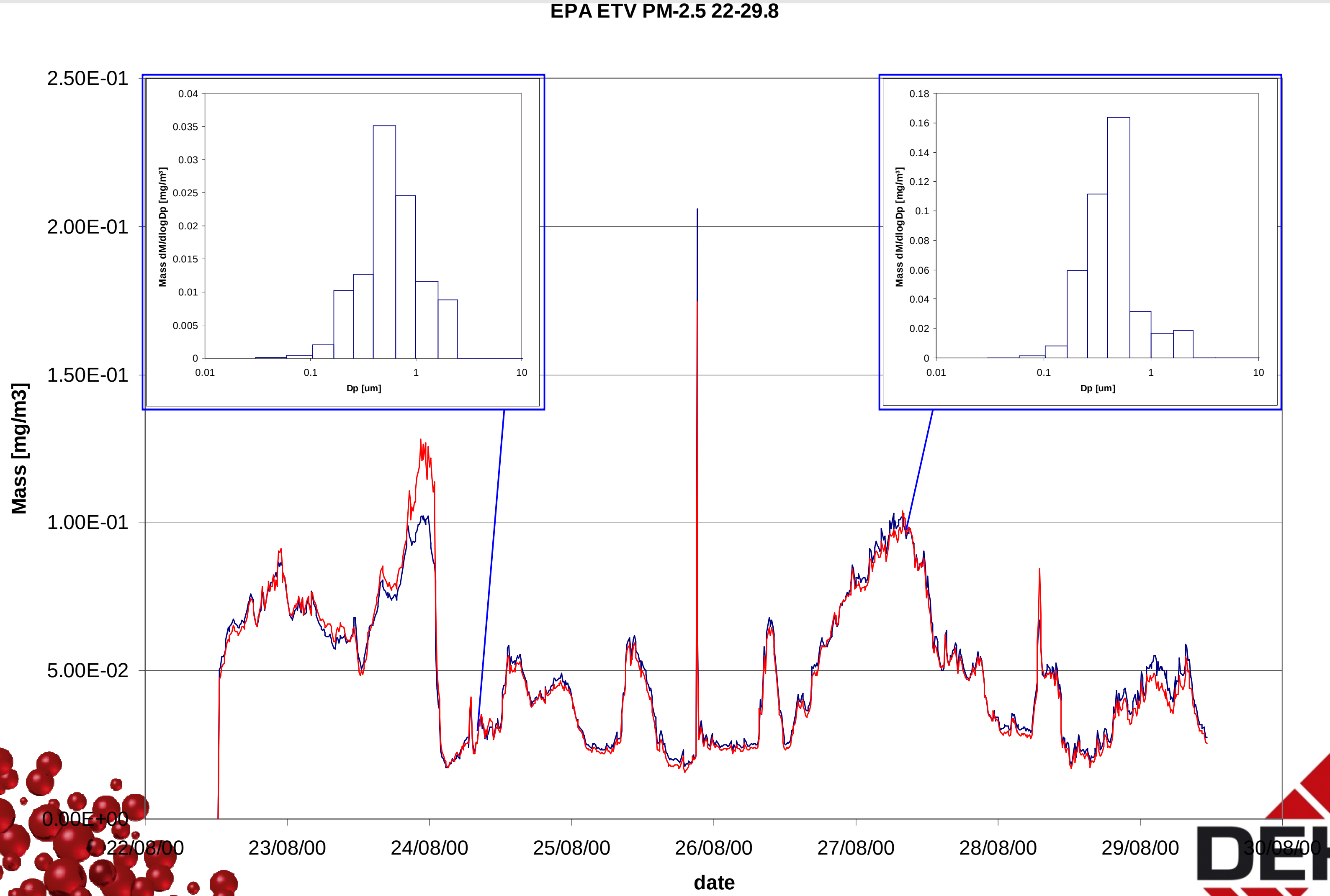
- Difficulty from selection of measurement location and from evaluation of data
- Description of surroundings and changes in conditions critical
- Wind speed and direction data important for source apportionment studies
- For occupational health, a choice between detailed data and measurement from exactly worker breathing zone

US-EPA mass distribution tests for two ELPIs



Data courtesy of EPA

US-EPA ELPI instrument comparison



Data courtesy of EPA

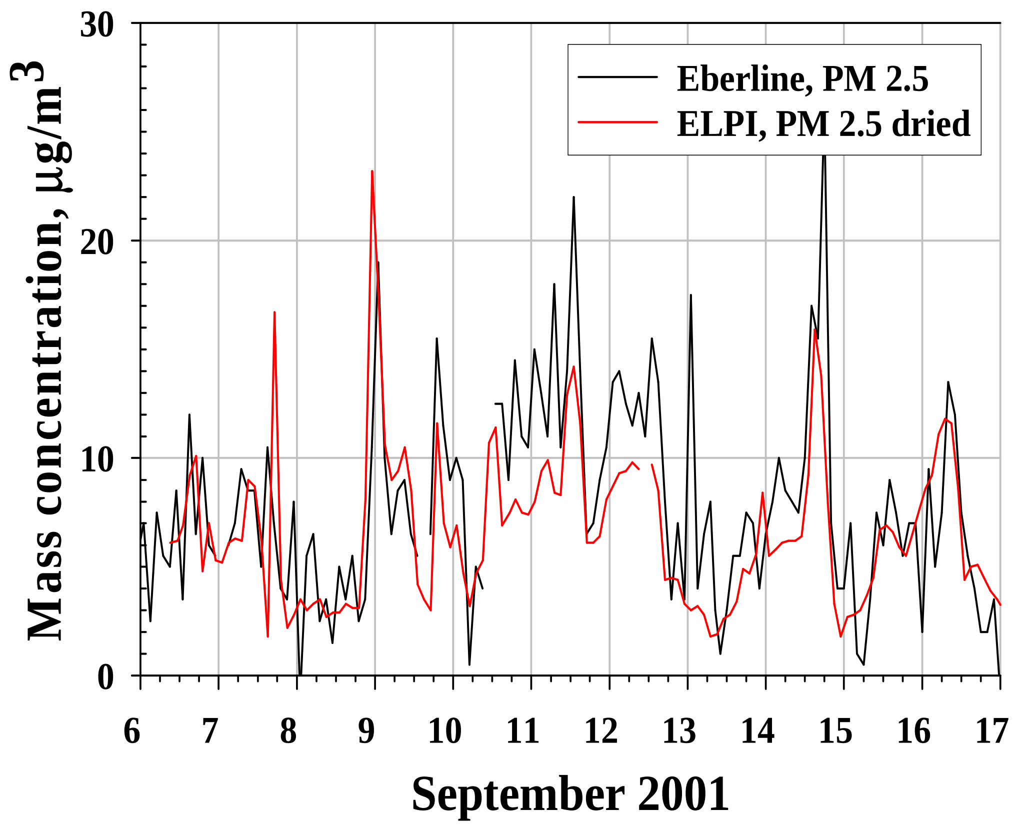
Ambient

- Measurement setup for ELPI+™/ Dekati® impactor ambient measurements consists of
  - Inlet
  - sample transfer pipe
  - optional dryer
- It is recommended to have a dryer if the ELPI+™ is used for ambient PM mass determination,
  - standard PM mass measurement methods do not measure particle-bound water.

- Complete setup for ambient sample conditioning including the dryer DD-603 for ELPI+™
  - includes also a PM10 inlet, sampling lines and all required connectors.
  - In addition to these parts, an instrument enclosure is needed as the ELPI+™ instrument is not weatherproof.

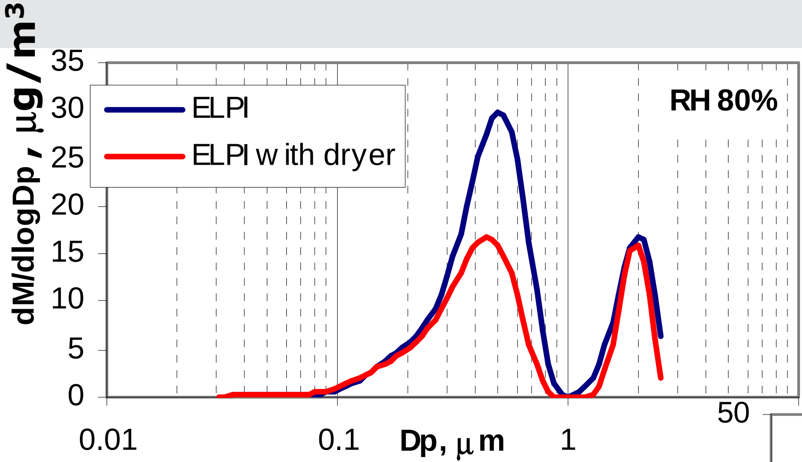
Outdoor particle mass concentration measurement

- ELPI vs. BAM
- $PM_{2.5}$ mass concentration comparison



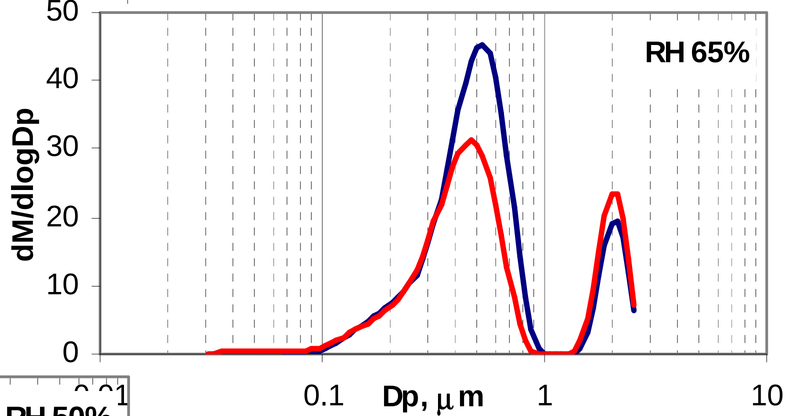
Data courtesy of Finnish Meteorological Institute

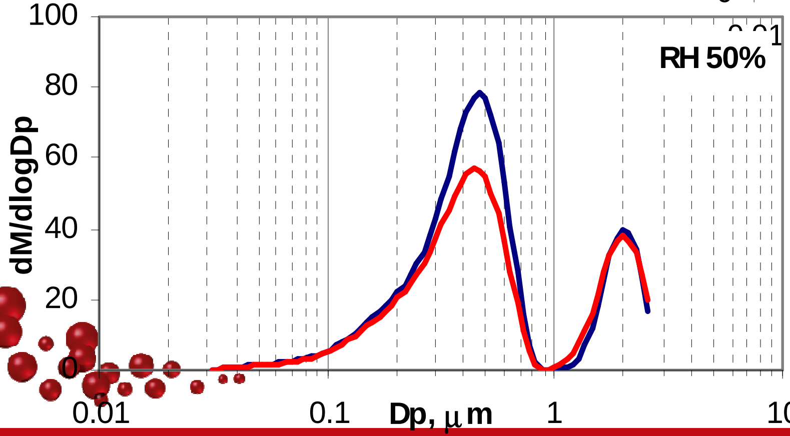
Mass size distributions in different RHs



Decreasing RH

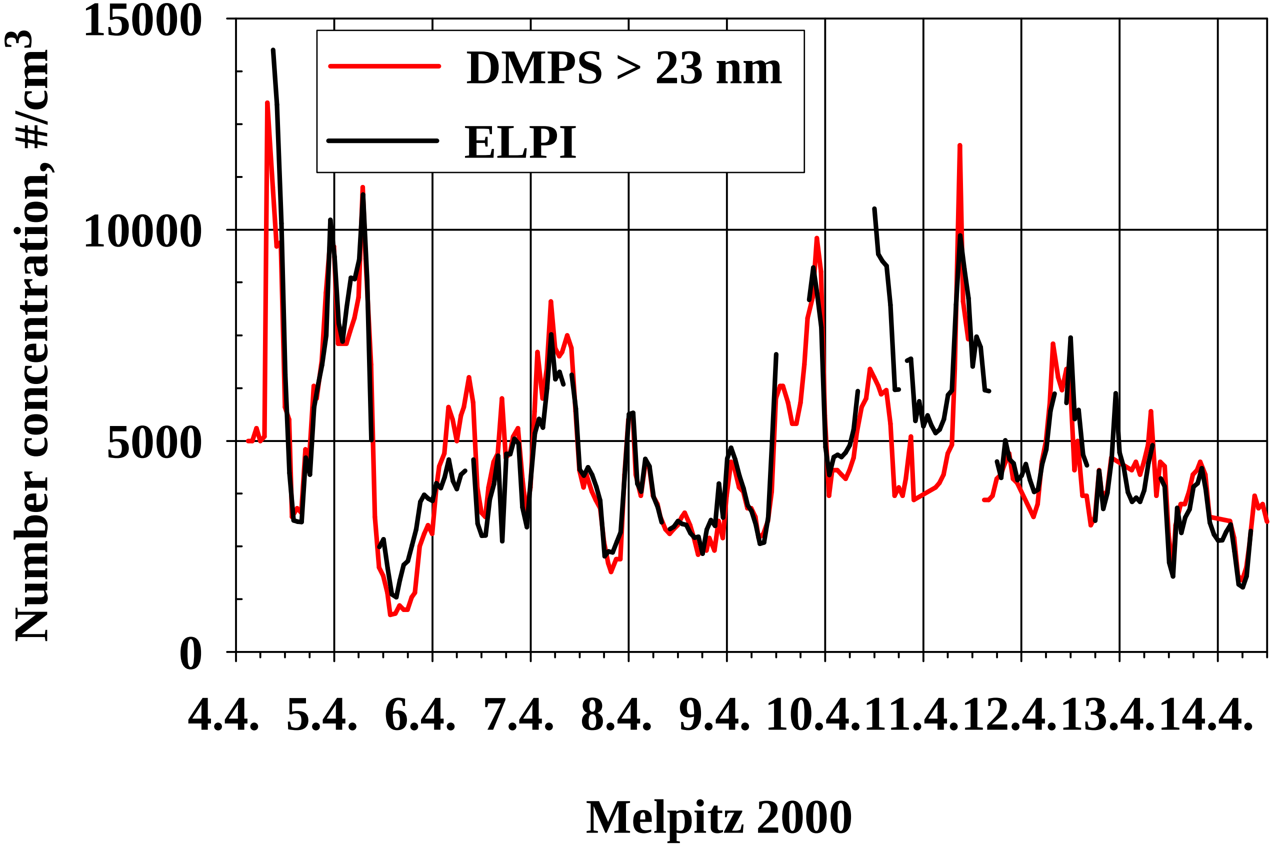
Slight decrease in MMD due to drying





Inversions by FMI

Intercomparison: Melpitz, Germany



Hitzenberger R., Berner A., Galambos Z., Maenhaut W., Cafmeyer J., Schwarz J., Müller K., Spindler G., Wieprecht W., Acker K., Hillamo R., Mäkelä T.(2004) Intercomparison of methods to measure the mass concentration of the atmospheric aerosol during INTERCOMP2000 —influence of instrumentation and size cuts. *Atmos. Environ* 38, 6467-6476.

Applications:

Occupational health

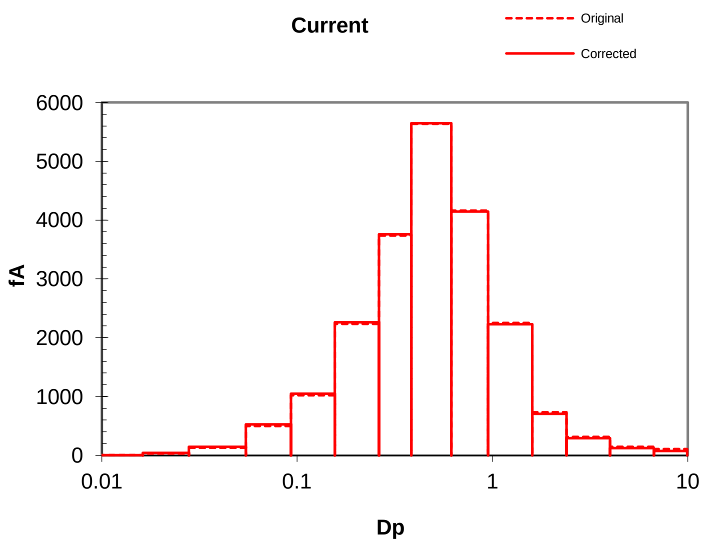
Air quality research

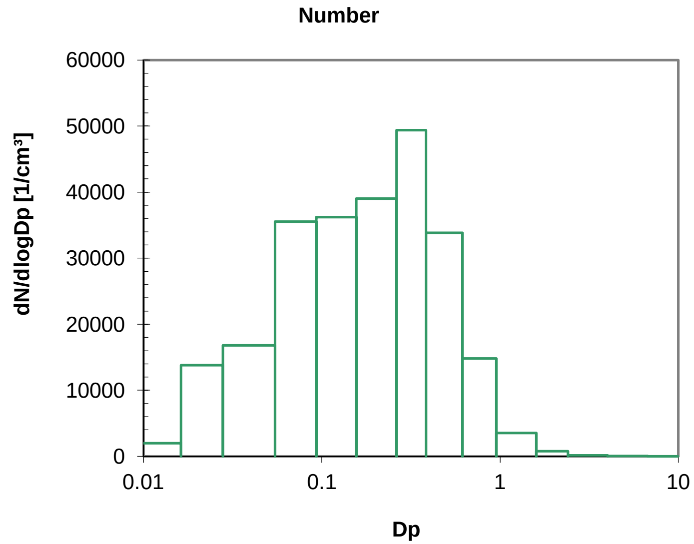
Inhalation particle

Industrial hygiene measurements with Dekati Products

- Health effect studies require measurements up to 10 microns
- Real-time measurement of the entire size range
- Collection of samples is an effective tool to determine the source and exact chemical composition of the particles
- Real-time aerodynamic size classified measurement of active surface area

Example: TiO_2 agglomerates





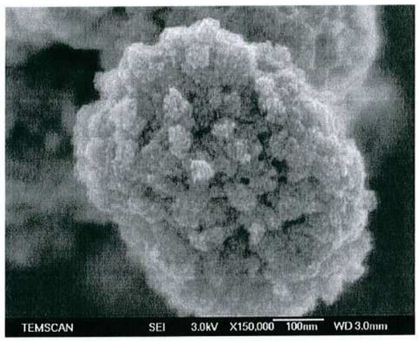


Fig. 3a Titanium dioxide (TiO_2).

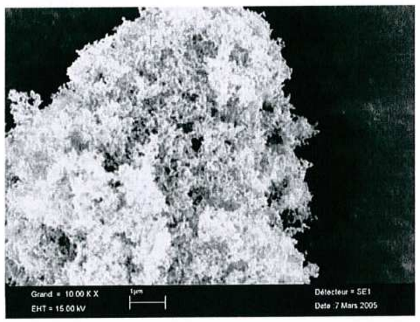


Fig. 3b Fumed silica (SiO_2).

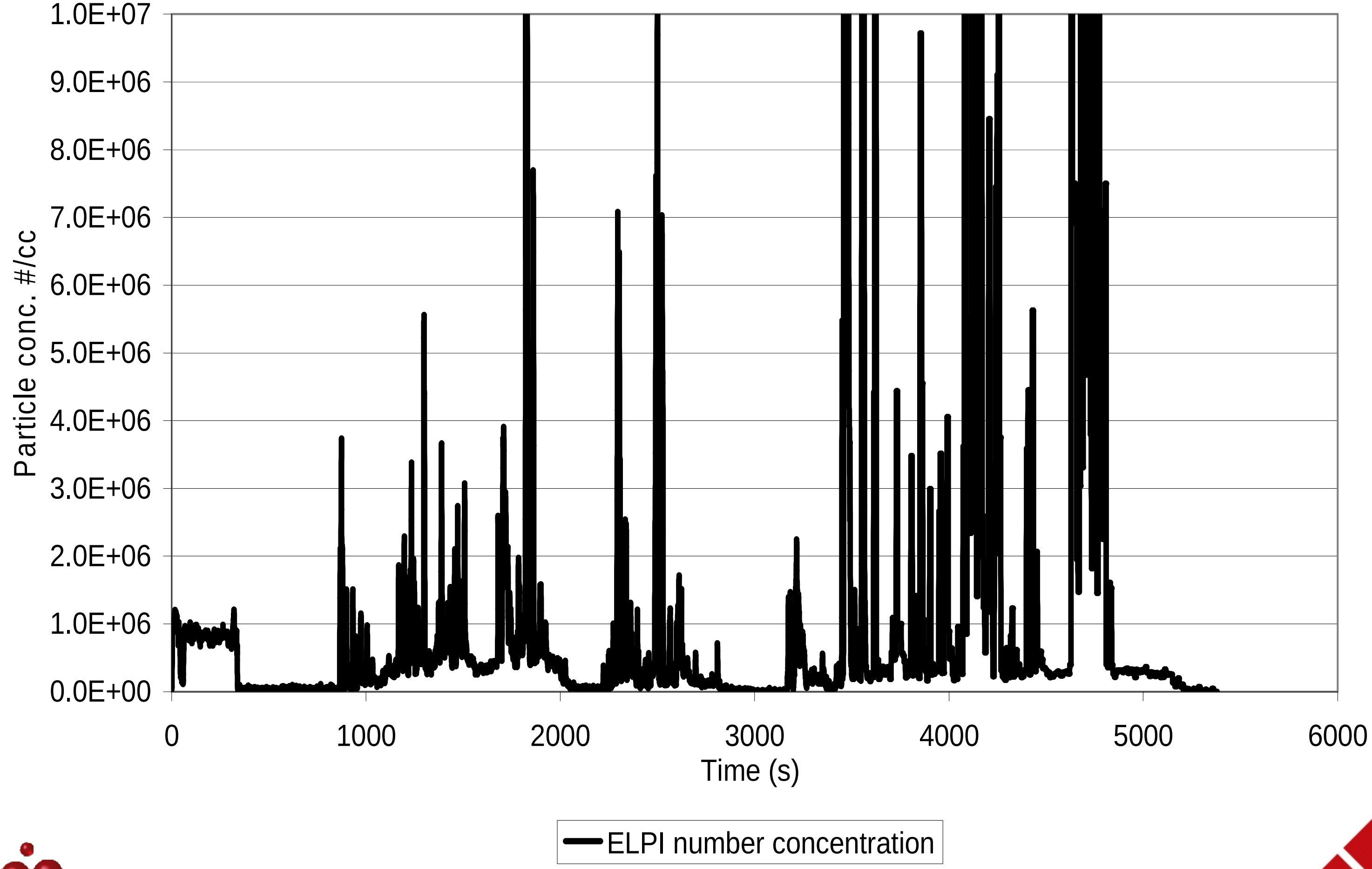
Fig. 3 SEM photographs of the nanostructured powders.

- Ibaseta, N. & Biscans, B. 2007. Ultrafine Aerosol Emission from the Free Fall of TiO2 and SiO2 Nanopowders
- TUT studies

Welding

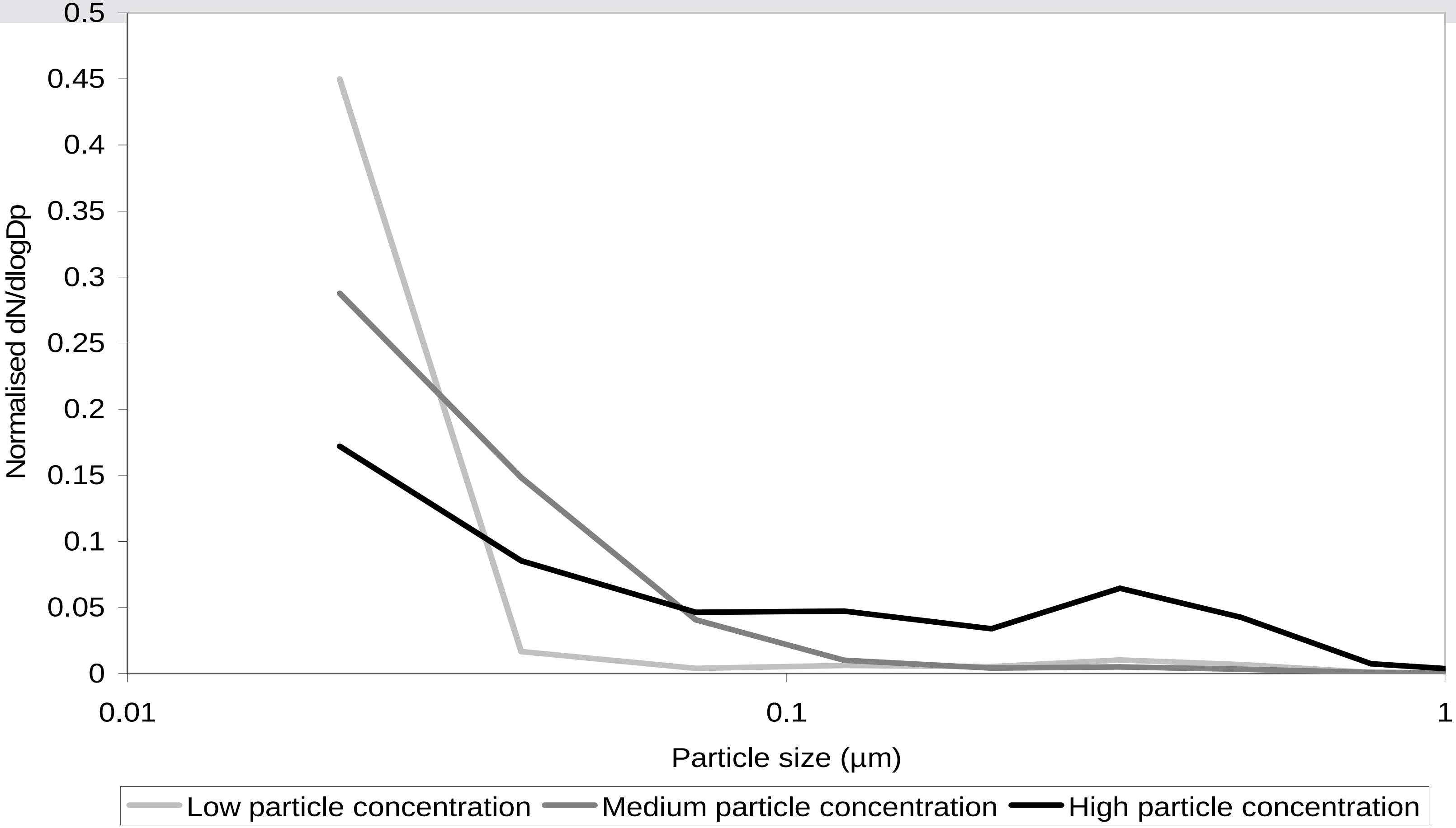
- MIG welding station
- Measurement at worker breathing area
- Effect of
  - Welding process
  - Sample transport

Welding



1.0E+07
9.0E+06
8.0E+06
7.0E+06
6.0E+06
5.0E+06
4.0E+06
3.0E+06
2.0E+06
1.0E+06
0.0E+00
Particle conc. #/cc
0
1000
2000
3000
4000
5000
6000
Time (s)
ELPI number concentration

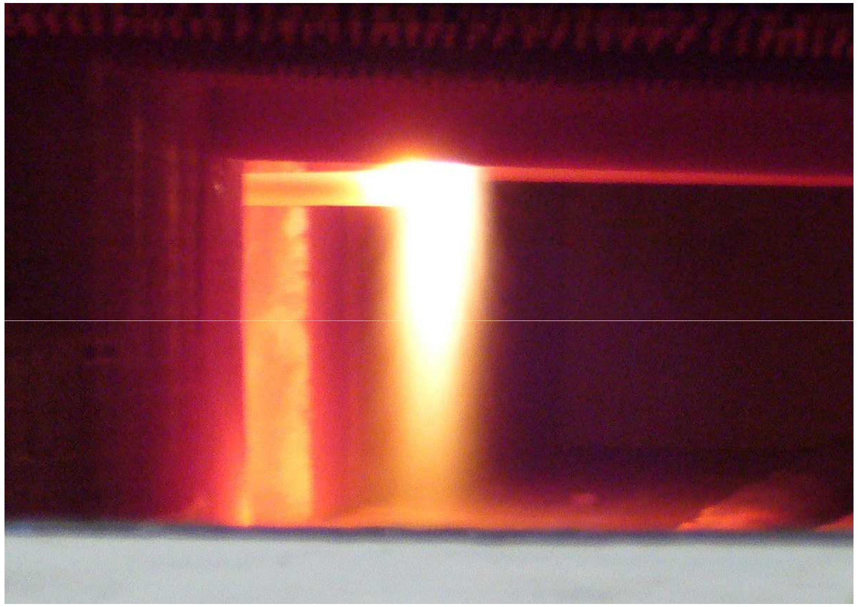
Welding



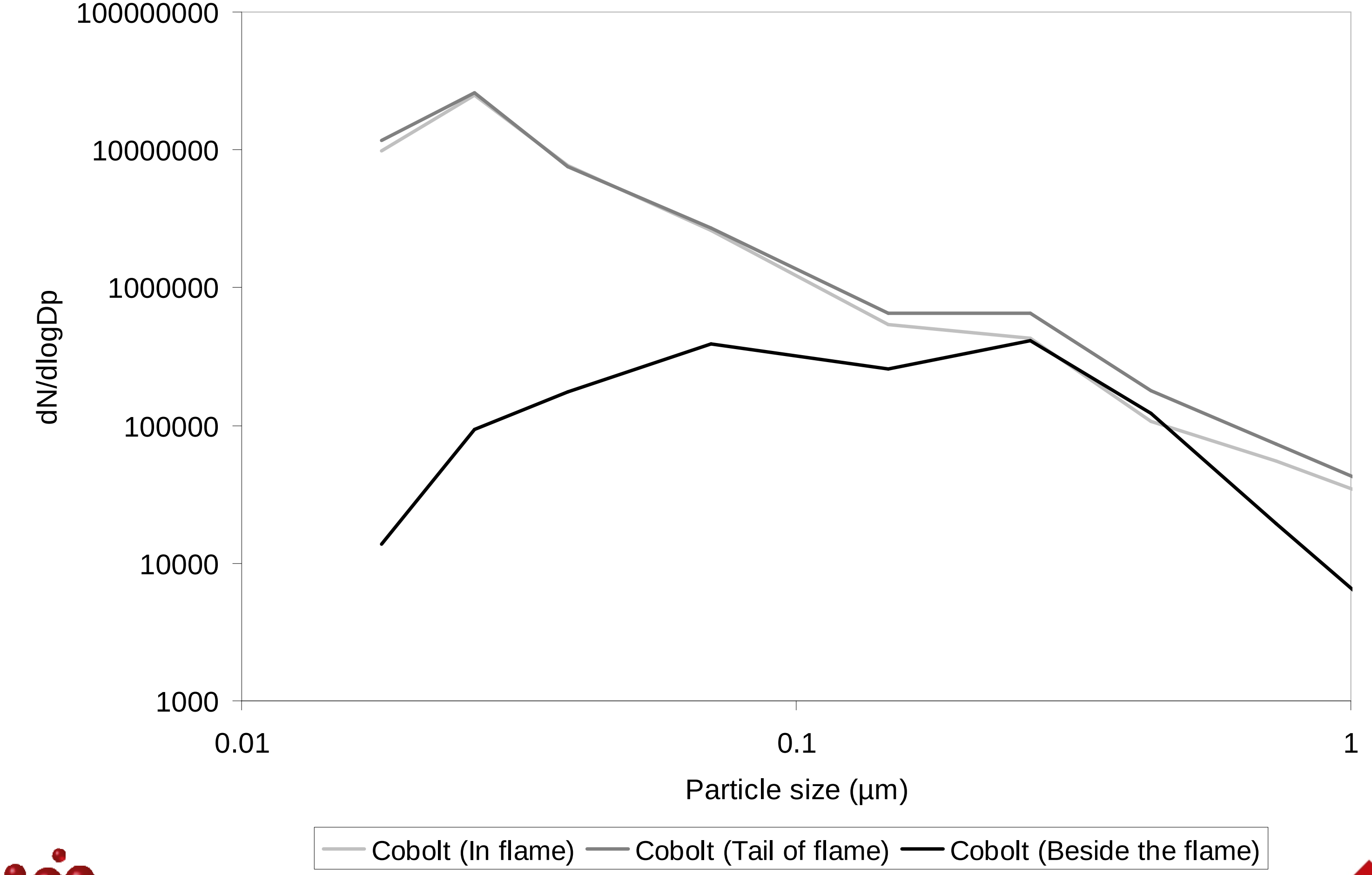
Normalised dN/dlogDp
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0.01
0.1
1
Particle size (µm)
Low particle concentration
Medium particle concentration
High particle concentration

Nanoparticle generation

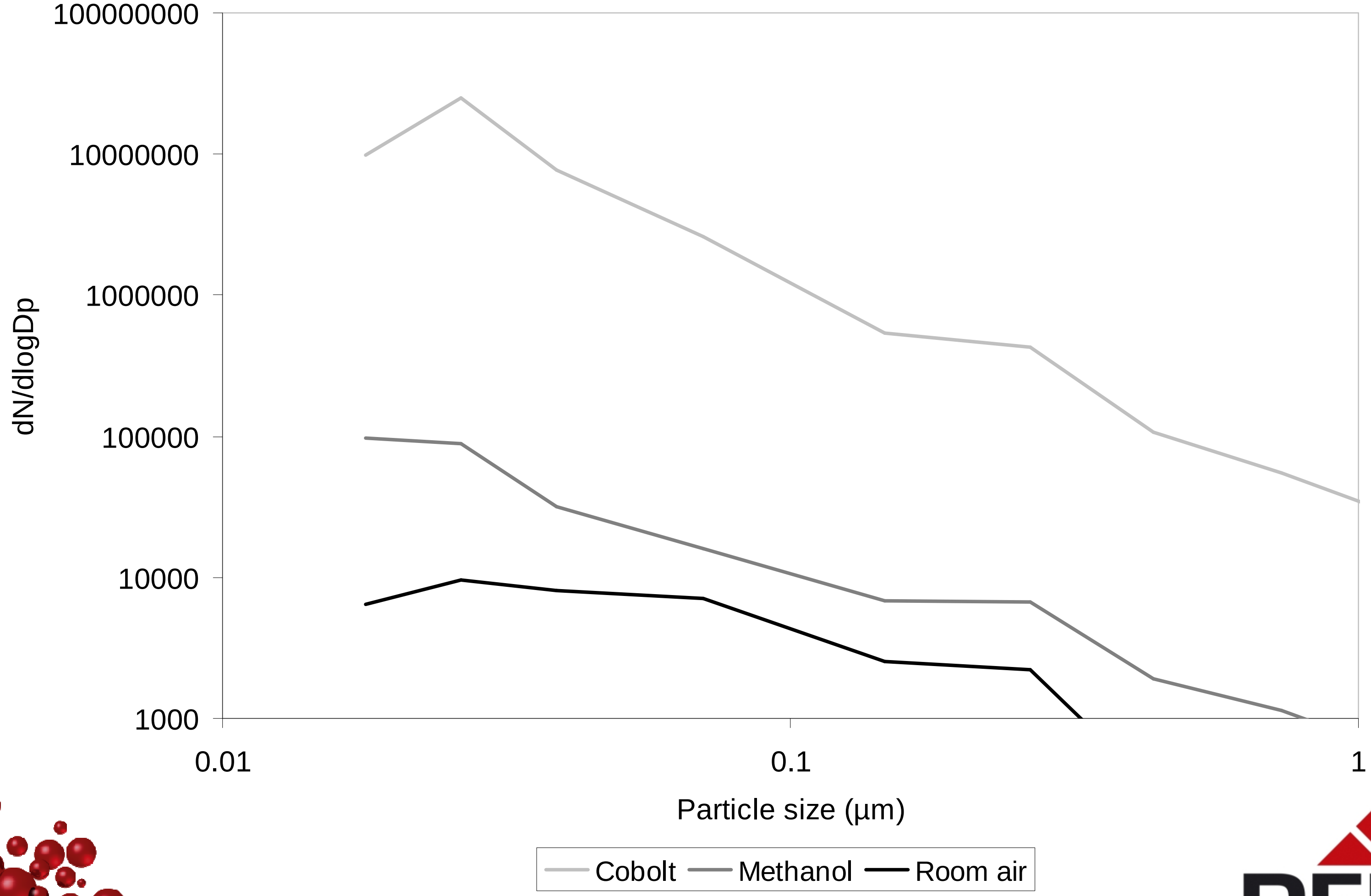
- Nanoparticle flame spray
  - Coating of materials
- Measurements from
  - Flame
  - Room air
- Effect of
  - Spatial location around flame
  - Spray liquid



Nanoparticle generation



Nanoparticle generation



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Effective density

Density

Density 0.85 g/cm³

Density 1 g/cm³

Density 2 g/cm³

d_{me}
Mobility size

Particle size is difficult to measure directly. Measurement instruments measure a quantity which is related to particle size.

d_a
Aerodynamic size

1 g/cm³

Density decreases, d_a decreases.

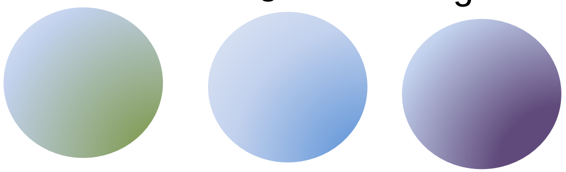
Density increases, d_a increases.

Different instruments measure different quantity → related to different particle size.

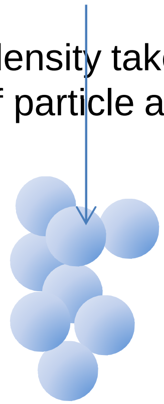
Effective density of particle

Different materials can have different density

Density 0.85 g/cm³ | Density 1 g/cm³ | Density 2 g/cm³



Effective density takes account shape of particle and cavity

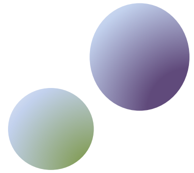


Effective density < 1 g/cm³

The effective density of non-spherical particle is alway smaller than bulk/material density of particle

Density of particle can give information about:

material



shape

Growth and formation processes of particle

Publications of particle density studies

Example:

- Ristimäki, J., Virtanen, A., Marjamäki, M., Rostedt, A., Keskinen J.: On-line measurement of size distribution and effective density of submicron aerosol particles. J. Aerosol Sci., 33, 1541-1557, 2002.
- Ristimäki, J. & Keskinen, J. 2006. Mass Measurement of Non-spherical Particles: TDMA-ELPI Setup and Performance Tests. Aerosol Science and Technology, vol. 40 pp. 997-1001.
- J. Yli-Ojanperä, J. Kannosto, M. Marjamäki, J. Keskinen, Improving the nanoparticle resolution of the ELPI, Aerosol and Air Quality Research, 10, 360–366, 2010
- J. Kannosto, A. Virtanen, M. Lemmetty, J.M. Mäkelä, J. Keskinen, H. Junninen, T. Hussein, P. Aalto, M. Kulmala, Mode resolved density of atmospheric aerosol particle, Atmospheric Chemistry and Physics, 8, 5327-5337, 2008.
- Virtanen, A., Rönkkö, T., Kannosto, J., Mäkelä, J.M., Keskinen, J., Pakkanen, T., Hillamo, R., Pirjola, L. & Hämeri, K. 2006. Winter and summer time size distribution and densities of traffic related aerosol particles at a busy highway in Helsinki. Atmospheric Chemistry and Physics, vol 6, pp. 2411-2421.

Solidity of particle

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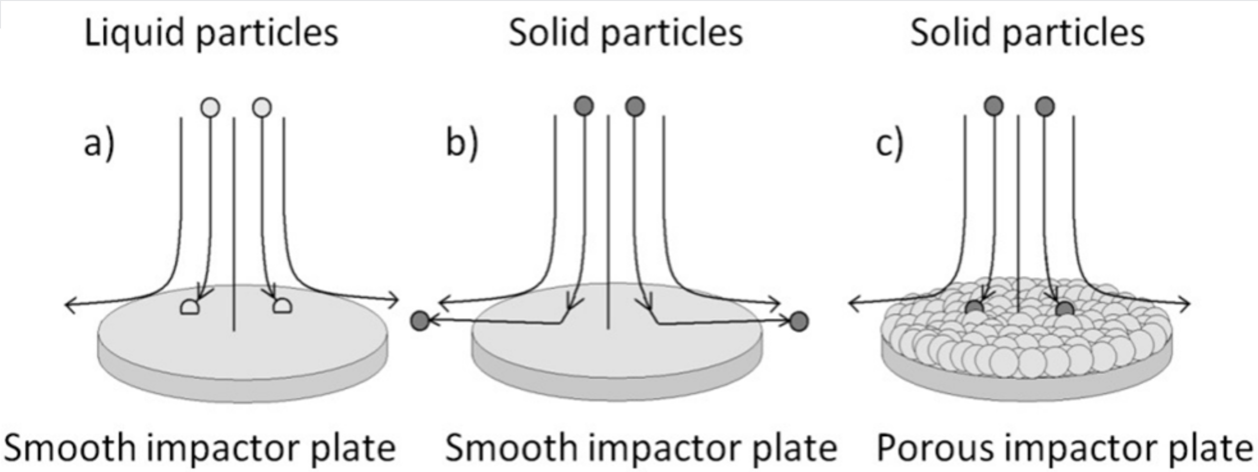
Particle bounce



- Liquid particles do not bounce
  - If particles are bouncing

→ Particles are solid

ELPI+ can be used as an indicator of solid physical state

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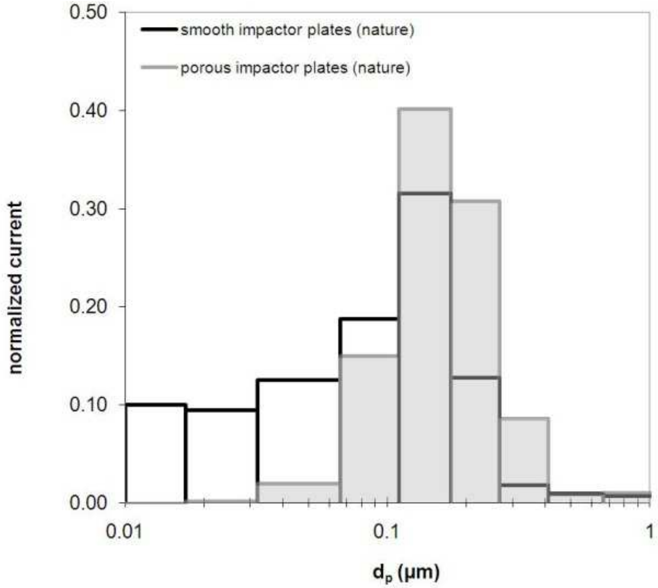
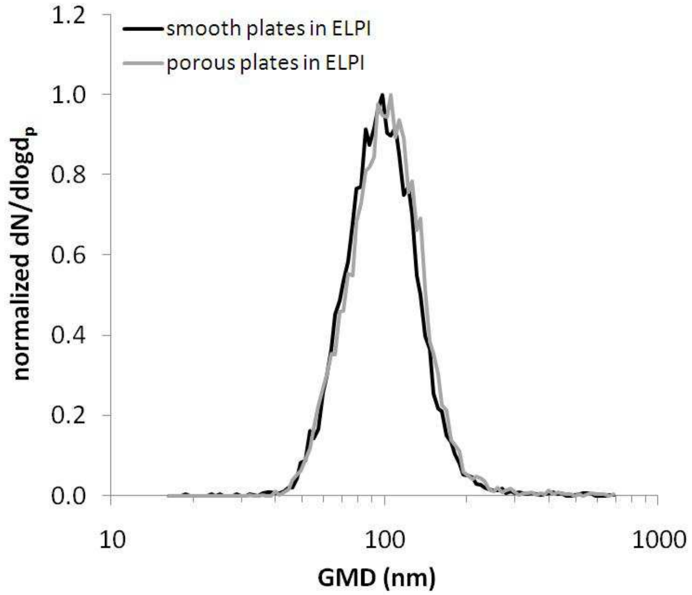
Excess current

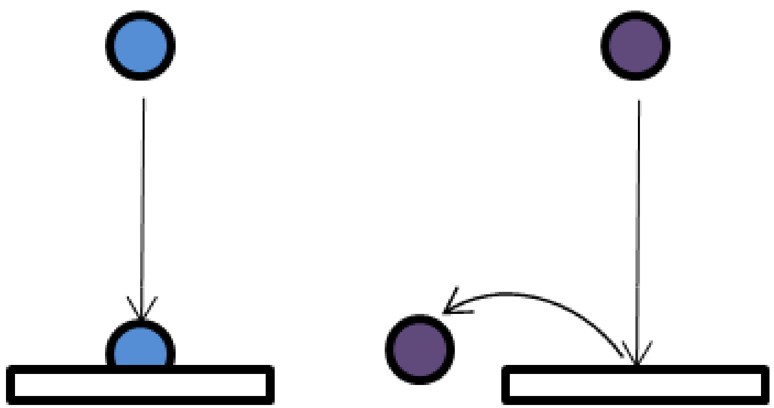
- Bounce factor ~ ratio of excess current : total current



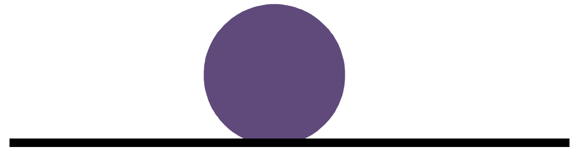


Physical phase of particle

Liquid or Solid ?



Solid particle can bounce

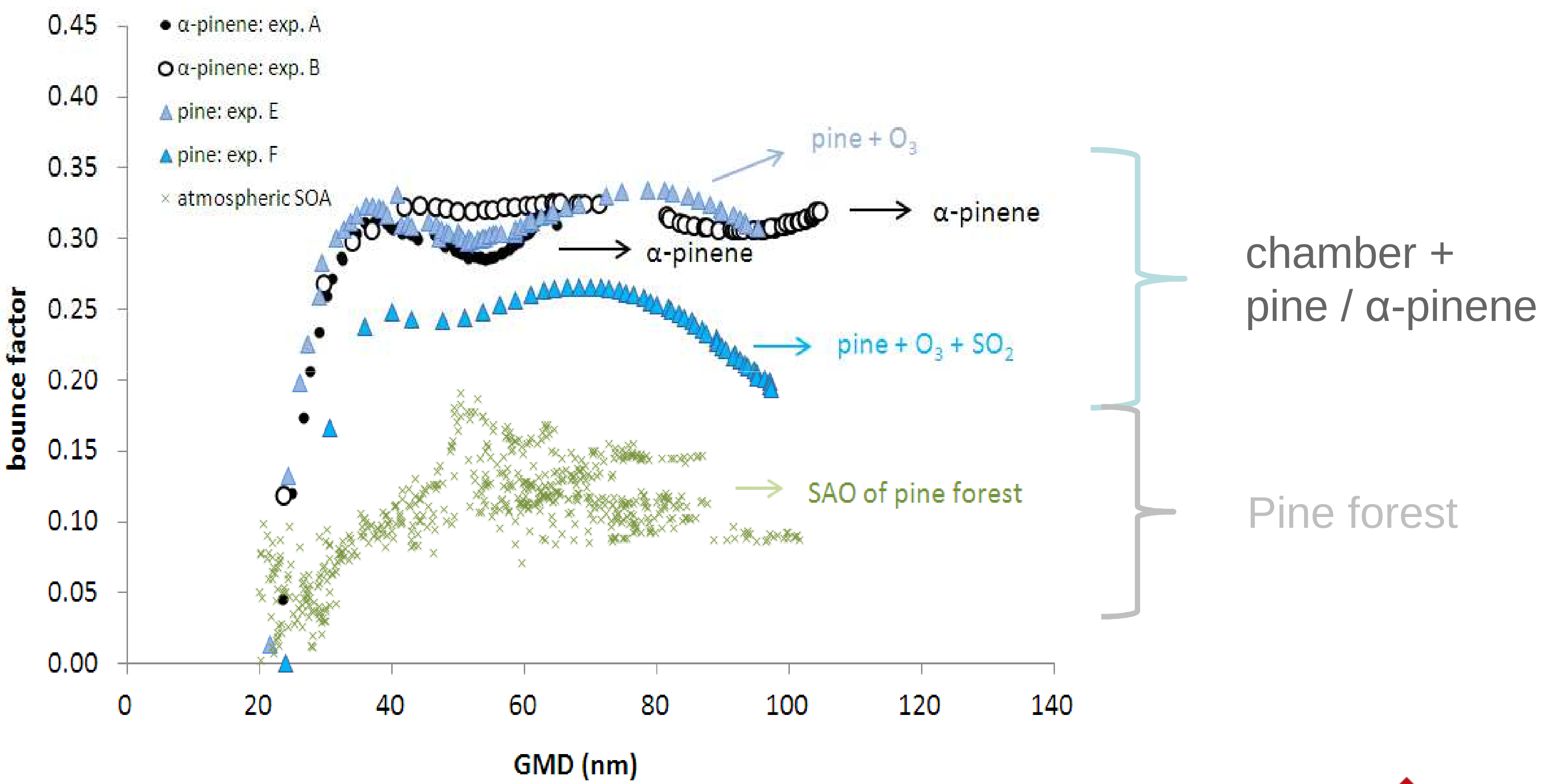


If particle bounces → solid

~~If particle does NOT bounce → liquid~~

Physical phase of particle can affect on particle water uptake and condensation/ evaporation

Example of bounce of SOA particles



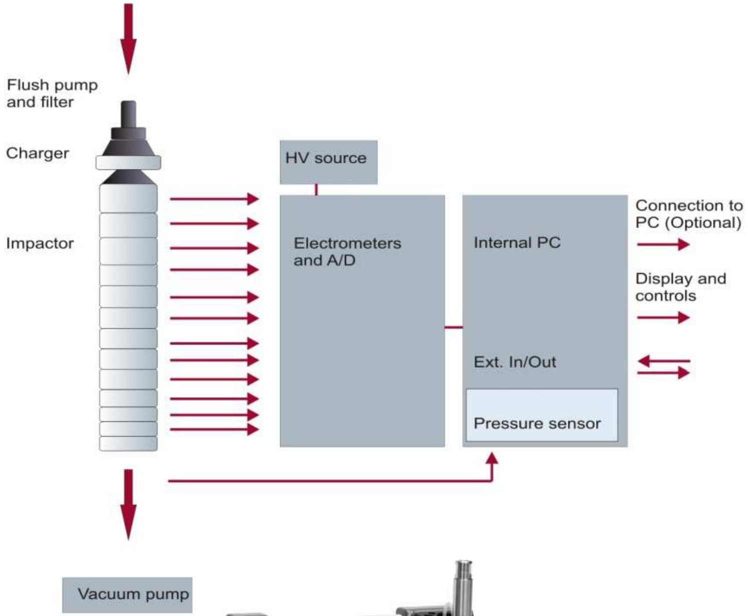
Virtanen et al. 2010, Nature

Publications of solidity studies

Example:

- A.Virtanen, J. Joutsensaari, T. Koop, J. Kannosto, P. Yli-Pirilä, J. Leskinen, J. Mäkelä, J. Holopainen, U. Pöschl, M. Kulmala, D. Worsnop, A. Laaksonen, An amorphous solid state of biogenic secondary organic aerosol particles, *Nature*, **467**, 824-827, 2010
- A.Virtanen, J. Kannosto, J. Joutsensaari, E. Saukko, H. Kuuluvainen, L. Hao, P. Yli-Pirilä, P. Tiitta, J. K. Holopainen, D. R. Worsnop, J. N. Smith, A. Laaksonen, Bounce behavior of freshly nucleated biogenic secondary organic aerosol particles, *Atmospheric Chemistry and Physics*, **11**, 8759-8766, 2011
- J. Kannosto, P. Yli-Pirilä, L. Hao, J. Mäkelä, J. Joutsensaari, A. Laaksonen, D. R. Worsnop, J. Keskinen, A. Virtanen, Bounce characteristics of α-pinene derived SOA particles with implications to physical phase, *Boreal Environment Research*, 2012

Active surface measurements: ELPI+™



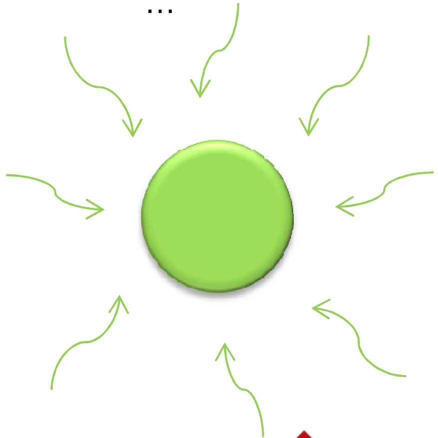
- Real-time particle:
  - Active surface distribution
  - Active surface concentration
  - Number size distribution
  - Number concentration
- 14 size fractions
- 6nm – 10µm
- 10Hz data
- Particles can be analyzed after the measurement

Atmospheric aerosols

- Particles are omnipresent in atmosphere
  - → Involved in many atmospheric processes
  - → Affects global climate system
- Particles are grown mainly by condensation
  - – Condensation sink describes particle potential to adsorb condensables
- Ions are always present in ambient air
  - – Ion sink describes the potential of an aerosol population to collect free ions

Particle size and growth affects:

- Cloud formation
- Particle lifetime
- Air quality
- Visibility
- Light scattering
- Light absorption
- …



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Active surface, Ion - and condensation sink

Active surface $A_{tot} = \frac{1}{\sqrt{\frac{3kT}{m}}n}\frac{dn}{dt} = \frac{1}{\sqrt{\frac{3kT}{m}}n}\frac{I}{e}$

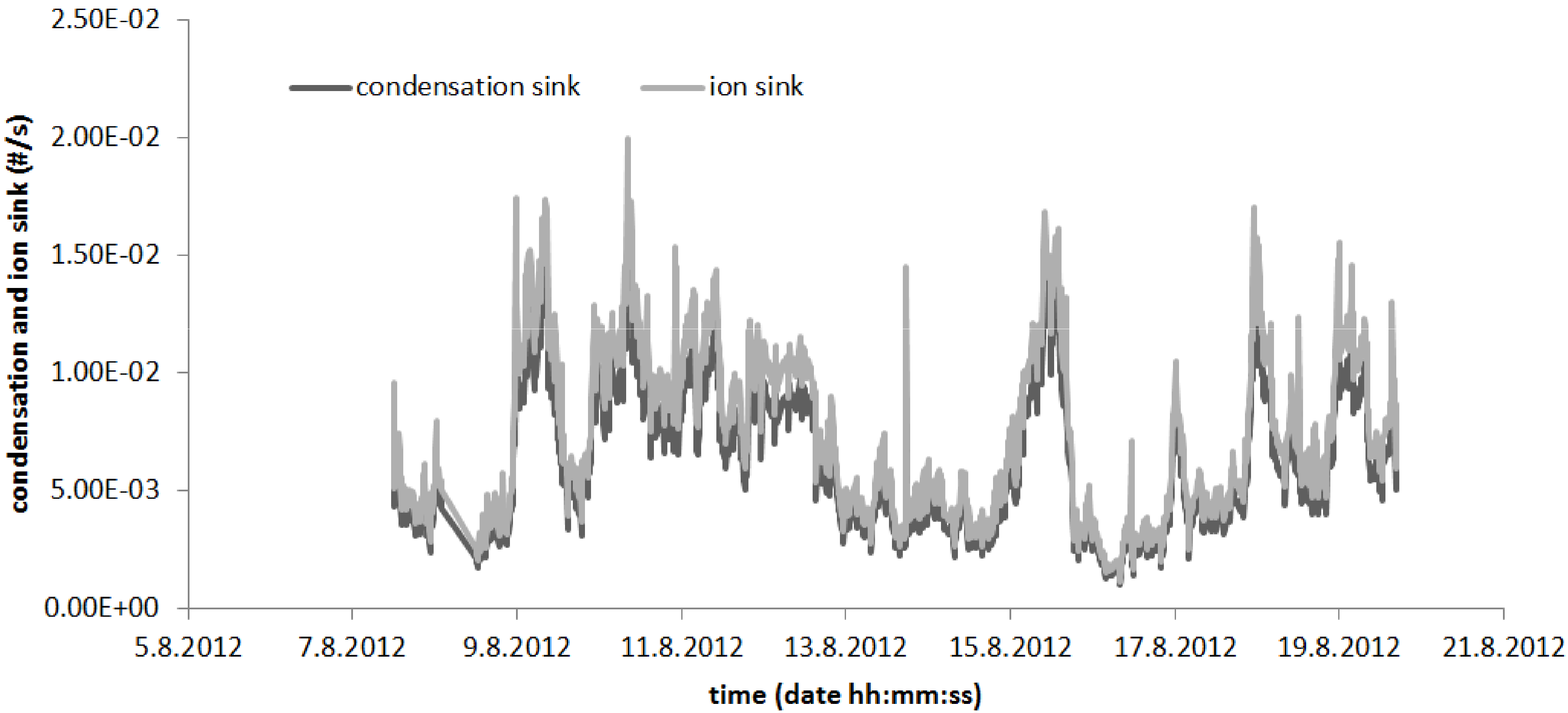
- A_{tot}=constant x ELPI current
- Willeke & Baron, Aerosol Measurement, 2nd edition

Ion and condensation sink.

- Ion sink: = 8.55E-06 $s^{-1}fA^{-1}$ x ELPI+ total current
- Condensation sink = 7.27E-06 $s^{-1}fA^{-1}$ x ELPI+ total current

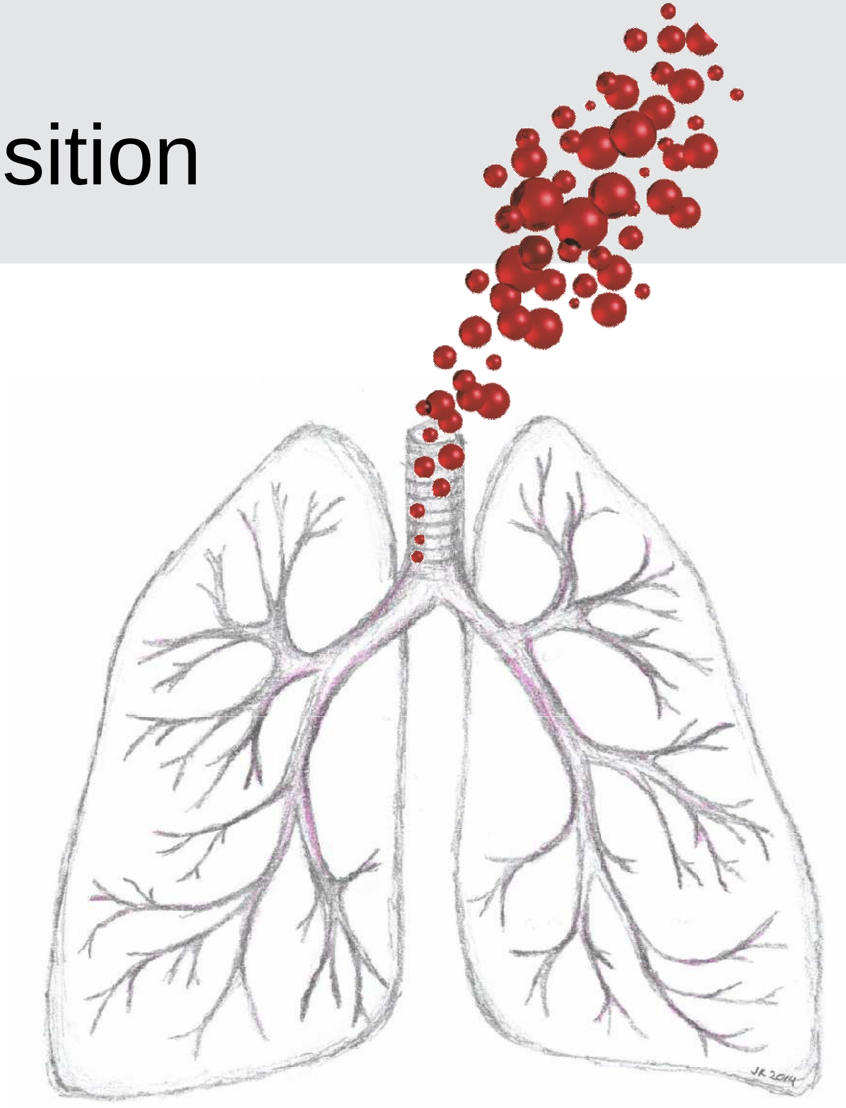
- Kuuluvainen, H., Kannosto, J., Virtanen, A., Mäkelä, J. M., Kulmala, M., Aalto, P., Keskinen, J. , Technical Note: Measuring condensation sink and ion sink of atmospheric aerosols with the electrical low pressure impactor (ELPI), Atmos. Chem. Phys., 10, 1361-1368, 2010.

Real-time data: condensation and ion sink



Particles and lung deposition

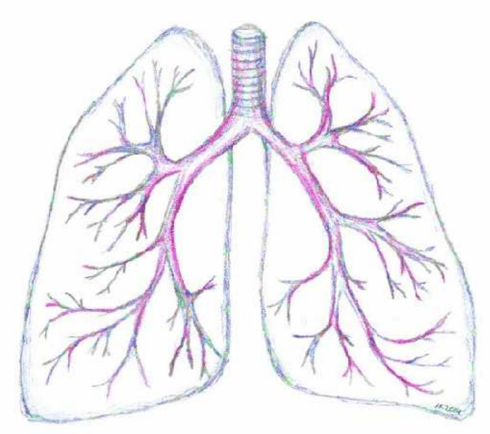
- Inertial impaction
- Diffusion
- Electrostatic attraction
- Gravitational sedimentation
- Interception



ELPI+: Lung deposited area

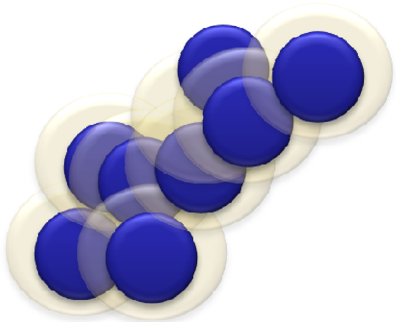
Lung deposited area = 60 µm²/(cm³*pA) **x** (ELPI+ currents)

Lung deposition
(Alveolar region)



+

Surface chemistry
(ROS, *Reactive Oxygen Species*)



Chemistry effect cannot be measured with ELPI+

Lung deposited surface area concentration

- Correlates with the diffusion charging of particles
- Possible to measure in real time
- **Exposure** in different environments
- Measuring **size distributions** provide more information on sources

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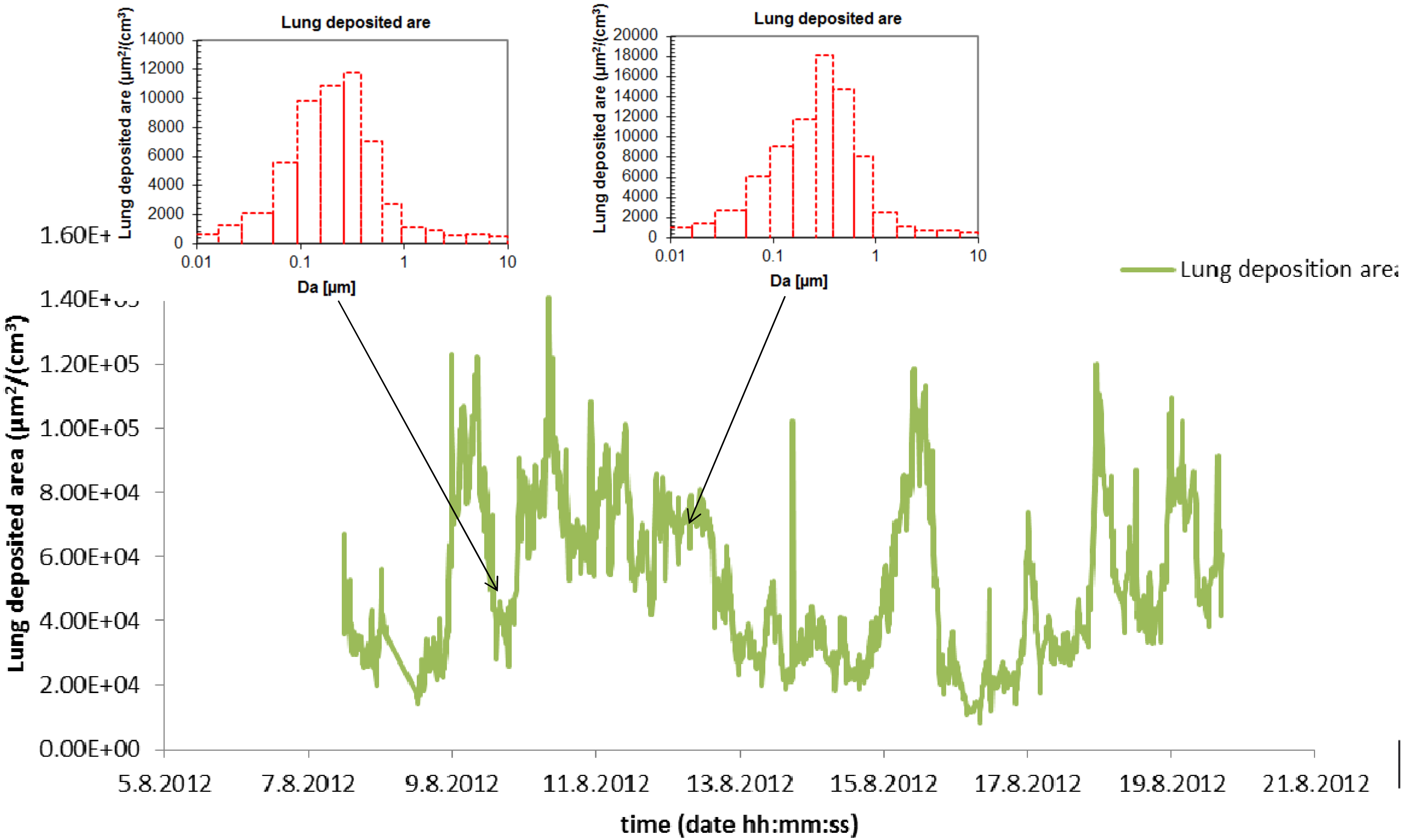
Real-time data: Lung deposited area



ELPI+™ samples from Santiago (city center)

Office in city center
Collection time: ~4 days

Collection: Chemical analysis

- Source apportionment
- Chemical Analysis of size classified particles

- D. Temesi et al: Size resolved chemical mass balance of aerosol particles over rural Hungary. Atmospheric Environment 35 (2001) 4347–4355

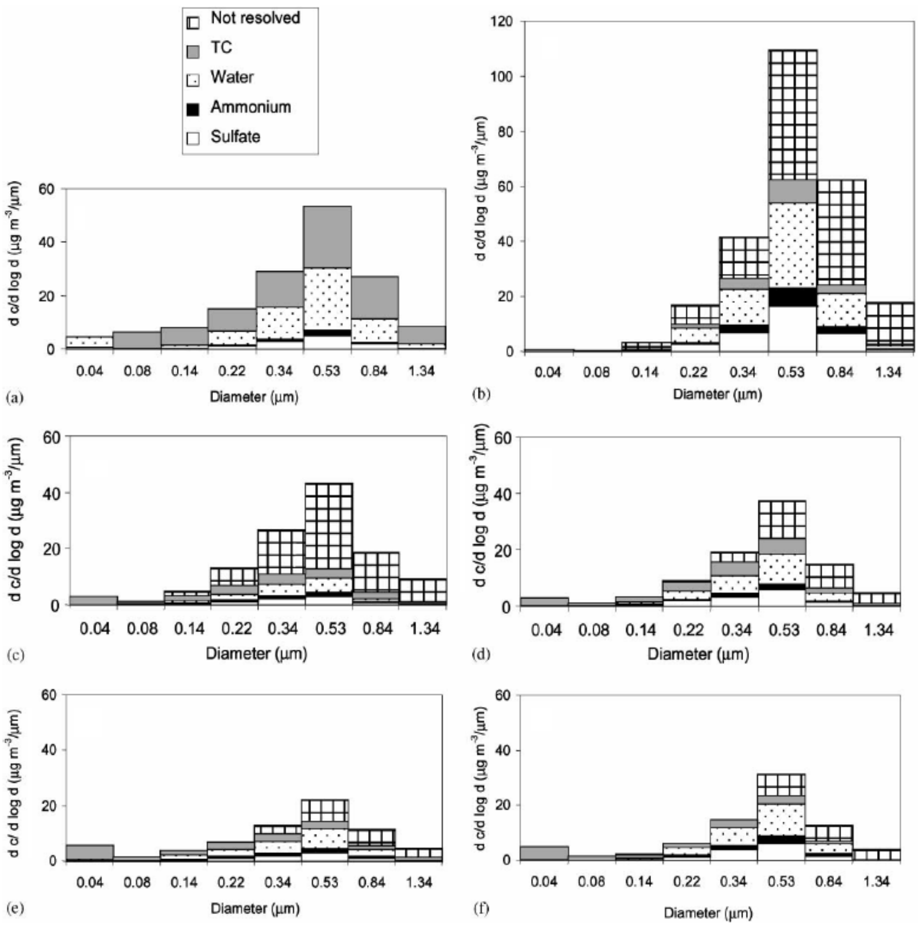
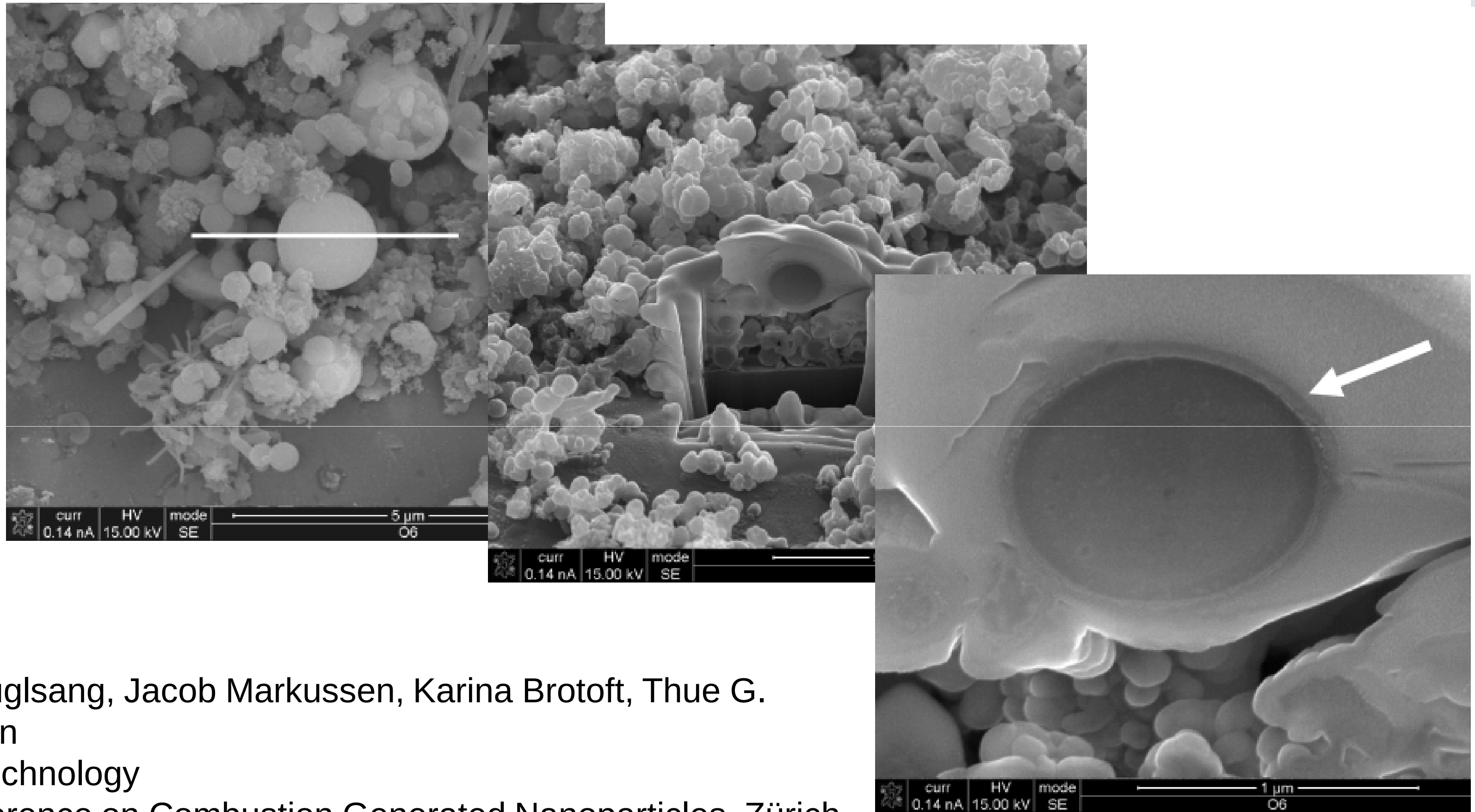


Fig. 3. Mass balances of different air masses. Air masses: east European (a), southwest European (b), northeast European (c), west European (d), northwest European (e) and local (f).

Collection: SEM and TEM



Karsten Fuglsang, Jacob Markussen, Karina Brotoft, Thue G. Frederiksen
FORCE Technology

ETH Conference on Combustion Generated Nanoparticles, Zürich, 4 Aug. 2010