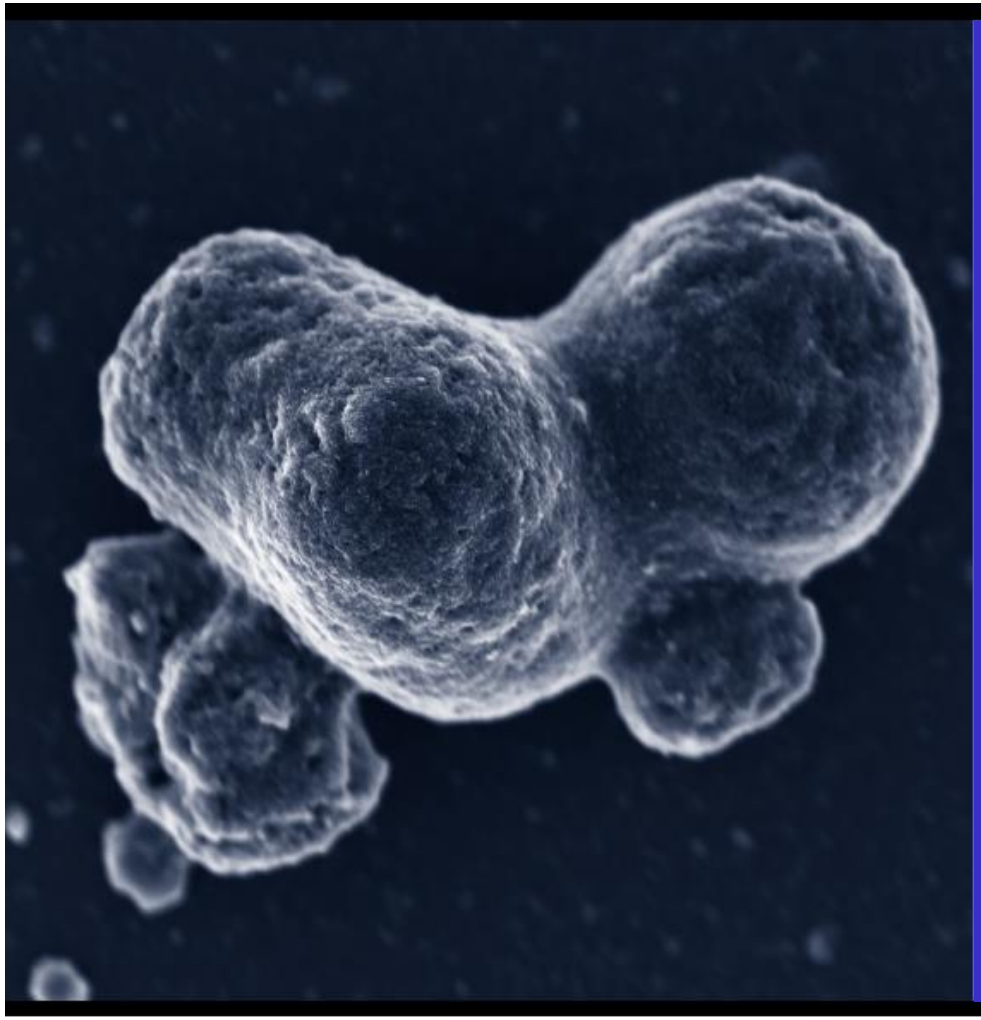

Reliable measurements of exposure to airborne engineered nanomaterials

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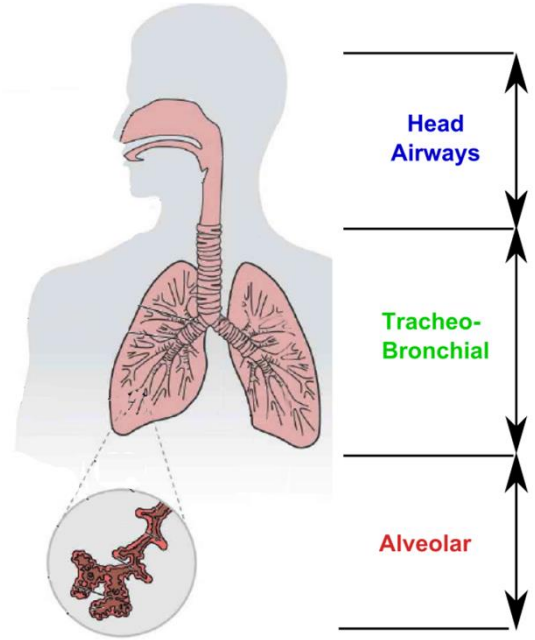
Innovation Fund Denmark
RESEARCH, TECHNOLOGY & GROWTH

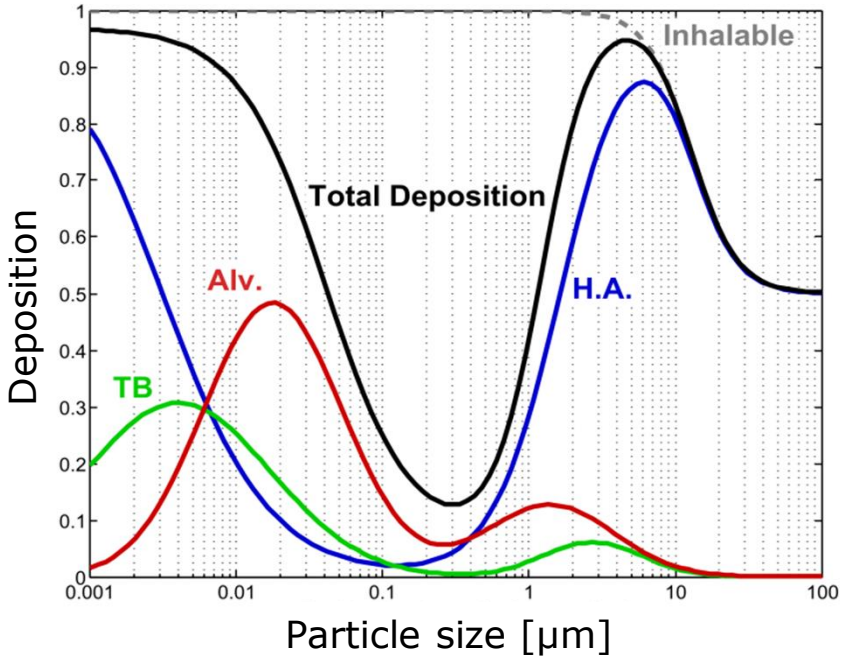
ADVANCE CLEANTECH

Exposure to Engineered nanomaterials

INHALATION

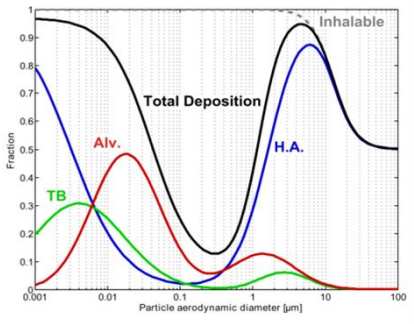
- Most important route due to high uptake and strong toxic effects
- Inhaled particle will deposit in different regions of the lungs; Head airways (**H.A**), Tracheo-bronchial (**TB**) and Alveolar (**Alv.**) depending on particle size.
- Unclear what metric drives toxic response – **Number, Mass, Surface Area**





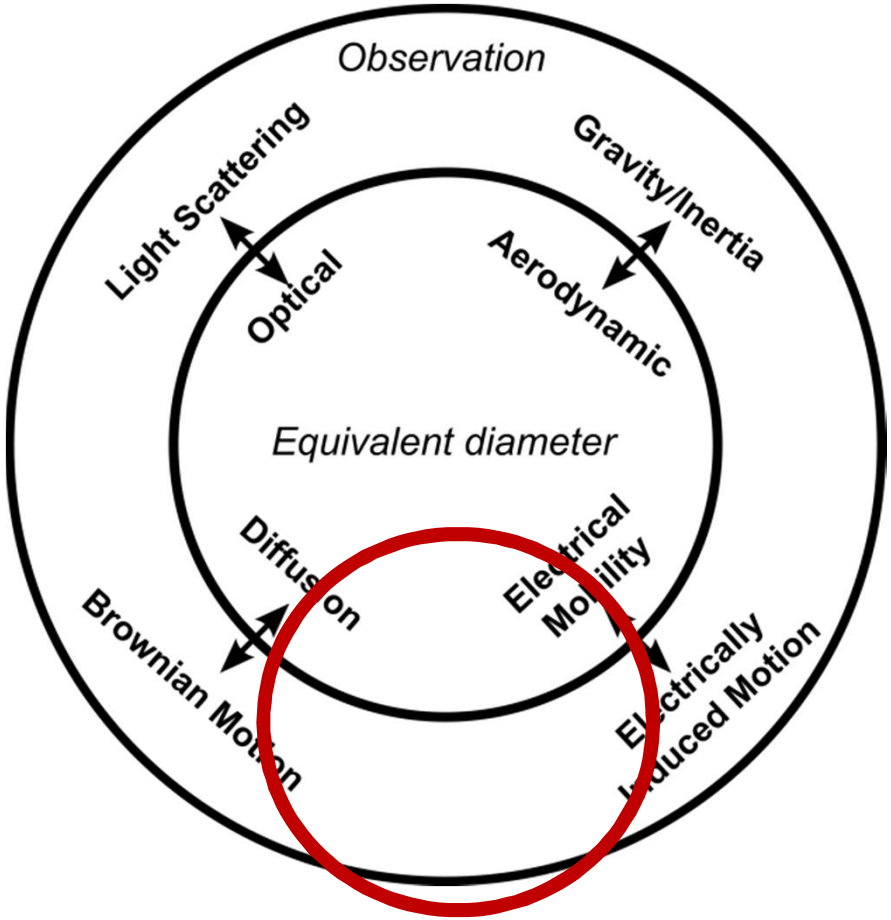
Measurement metrics

Aerosol A	**High/Low**	*Aerosol B*
Dp = 20 nm	**Size**	**Dp = 200 nm**
10 000 cm^{-3}	**Number**	**100 cm^{-3}**
12 $\mu m^2/cm^3$	**Surface Area ~ D_p^2**	**12 $\mu m^2/cm^3$**
0.04 $\mu m^3/cm^3$	**Volume ~ D_p^3**	**0.4 $\mu m^3/cm^3$**
6 $\mu m^2/cm^3$	**Lung Deposited Surface Area (Alv)**	**0.8 $\mu m^2/cm^3$**



Size is always important!

Size measurement

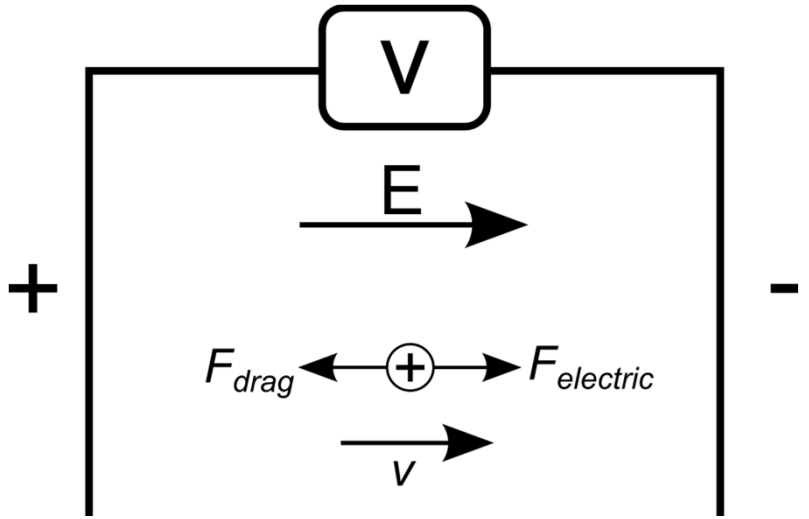


- **”True” particle size not feasible to measure**
- **Measured size is based on method of observation**

Electrical Mobility Measurements

Electrical Mobility, *Z* – Charged particles move through a medium in response to an electric field

Mobility equivalent diameter – Diameter of a sphere having the same mobility as the observed particle

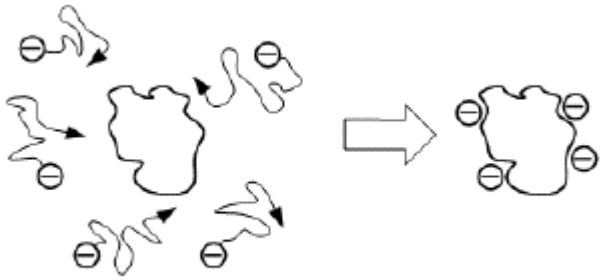


Used in e.g.:

- Scanning Pobility Particle Sizer
- Fast Mobility Particle Sizer
- NanoScan

With balance of electrostatic & drag forces: □ □ □/□

Aerosol charging

- **Objective is to create a known charge of each particle**
- **Diffusion Charging** 

(Unipolar or Bipolar)

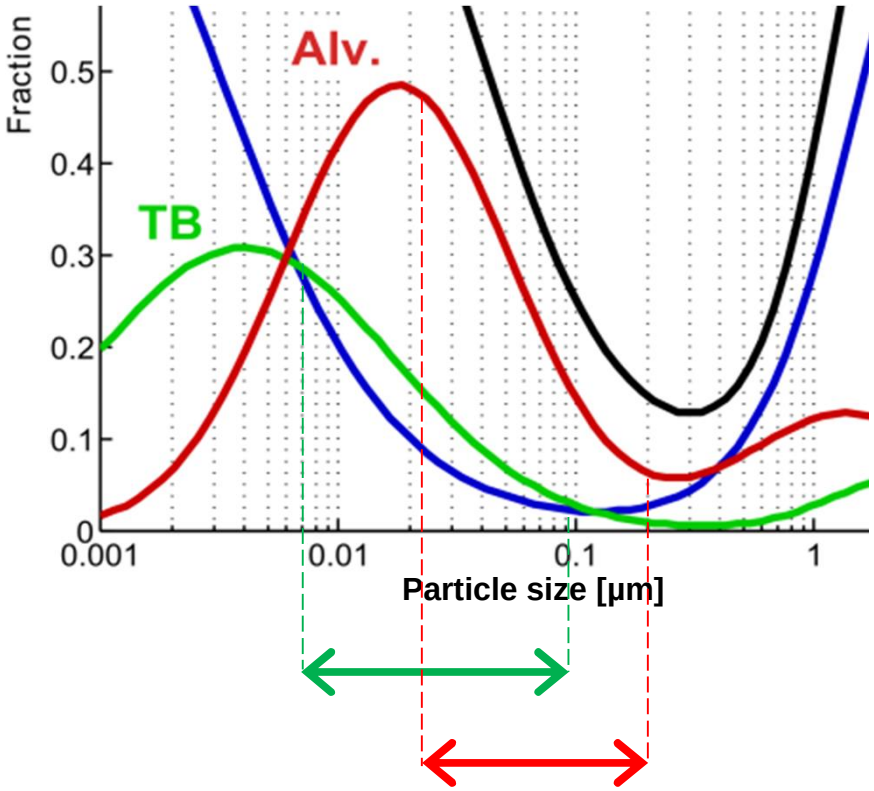
$$n_p \propto d_p^2$$

$$q_p = \frac{n_p d_p^2 \pi}{4 E_0}$$

Lung Deposited Surface Area (LDSA)

Measurement of LDSA concentration:

- Deposition fractions ~ □□
- Surface area ~ □□
- **DF (□□) X SA (□□) = LDSA (□□)**
- Diffusion charging with an electrometer yields a □□ response

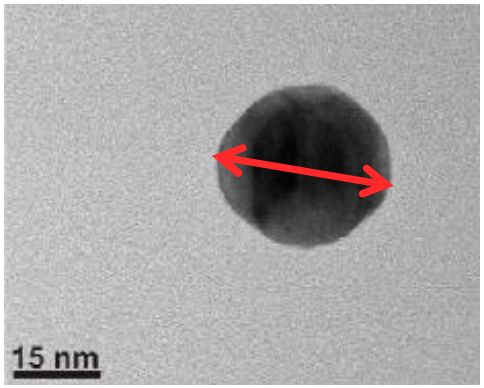


Nanoparticle Surface Area Monitor (NSAM)

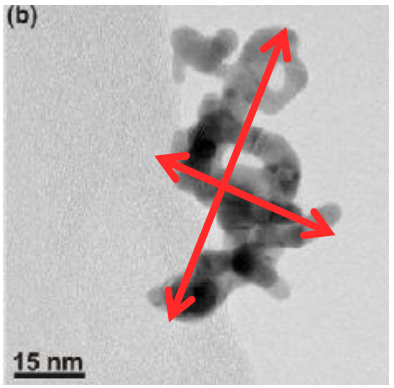
Non-spherical particles

Airborne particles are not just spheres with various diameters

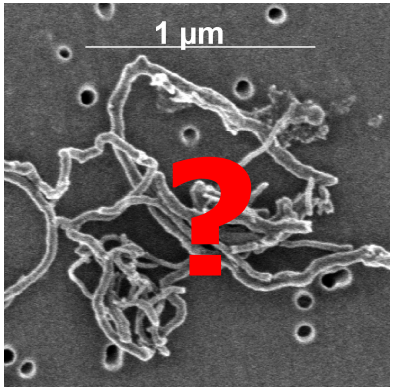
Spherical



Agglomerate



Fibrous



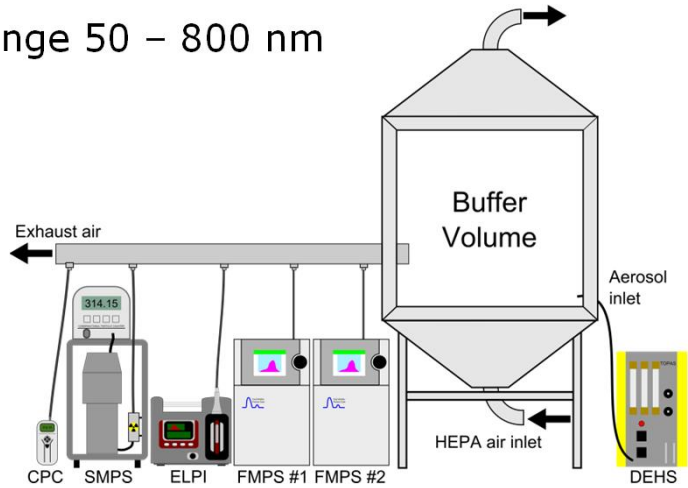
- **Charging effects from particle shape hard to predict**
- **Additional density/drag/etc. effects**
- **Agglomerate ”problem” from powder handling**

Instrument reliability

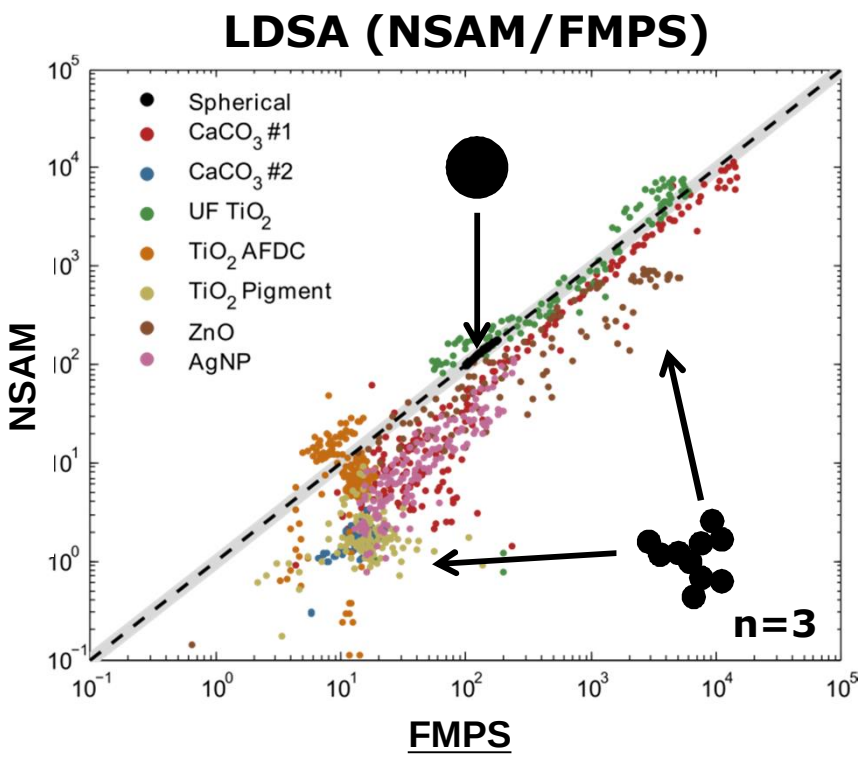
- Compare methods for real-time measurement of lung-deposited surface area (LDSA)
- Investigate to applicability of SMPS, FMPS, ELPI and NSAM in measurements of ENMs
  - Scanning Mobility Particle Sizer (SMPS)
  - Fast Mobility Particle Sizer (FMPS)
  - Electrical Low Pressure Impactor (ELPI)
  - Nanoparticle Surface Area Monitor

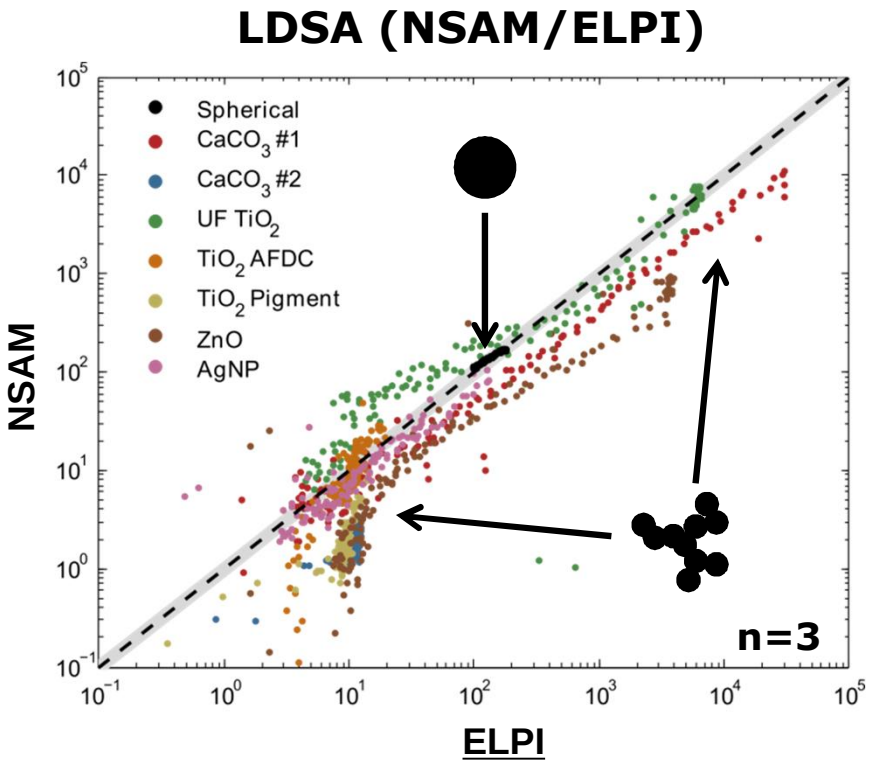
Test aerosols used:

- **LDSA measurements**: 7 powder nanomaterials aerosolized with dustiness drum
- **Instrument performance**: Spherical oil particles, size range 50 – 800 nm



Measurement of LDSA

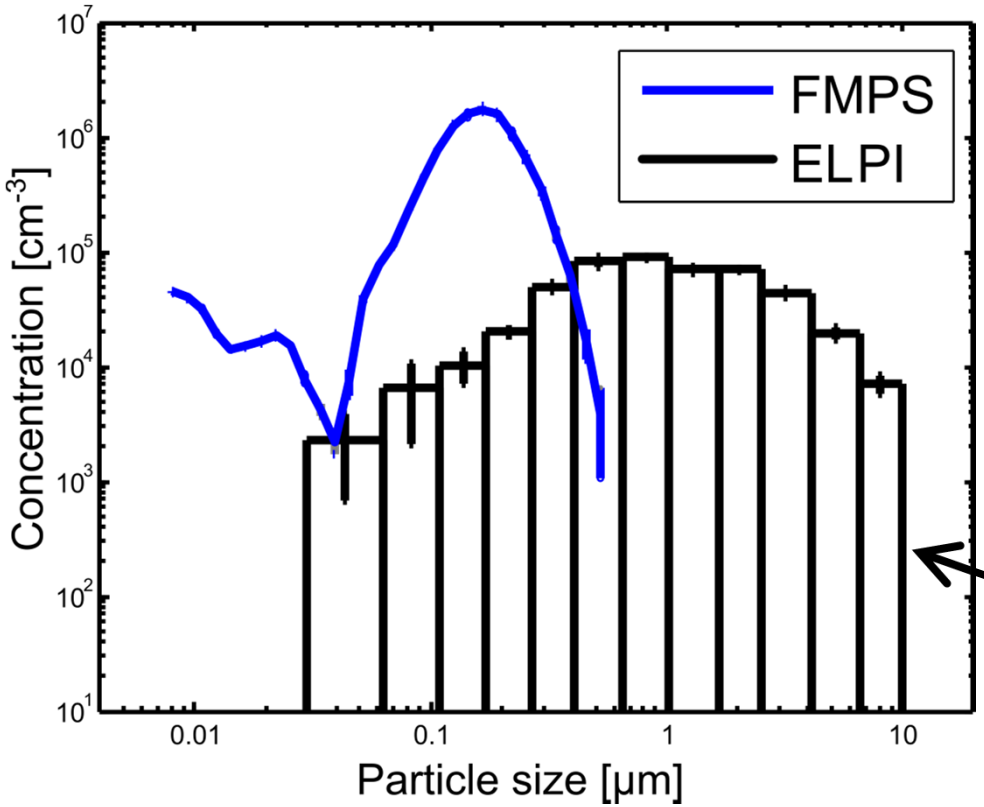


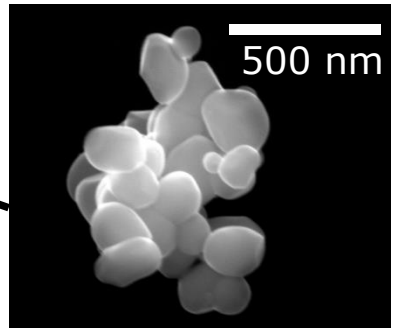


- **LDSA time-series comparison from dustiness generation**
- **Excellent agreement for spherical particles (40 nm)**
- **Material dependent for agglomerates**

Levin et al. 2015b

Measurements of complex particles



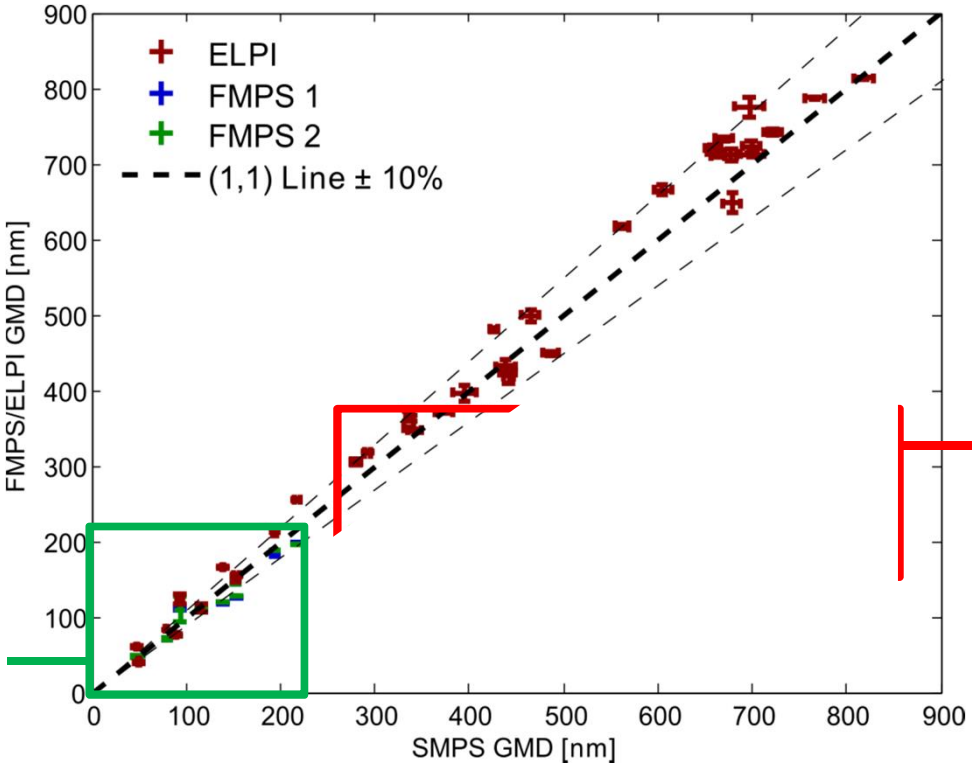


Compared to ELPI:

- **FMPS underestimate particle geometric mean diamater**
- **FMPS overestimate number concentration**

Levin et al. 2015b

Spherical particles –Geometric Mean Diameter



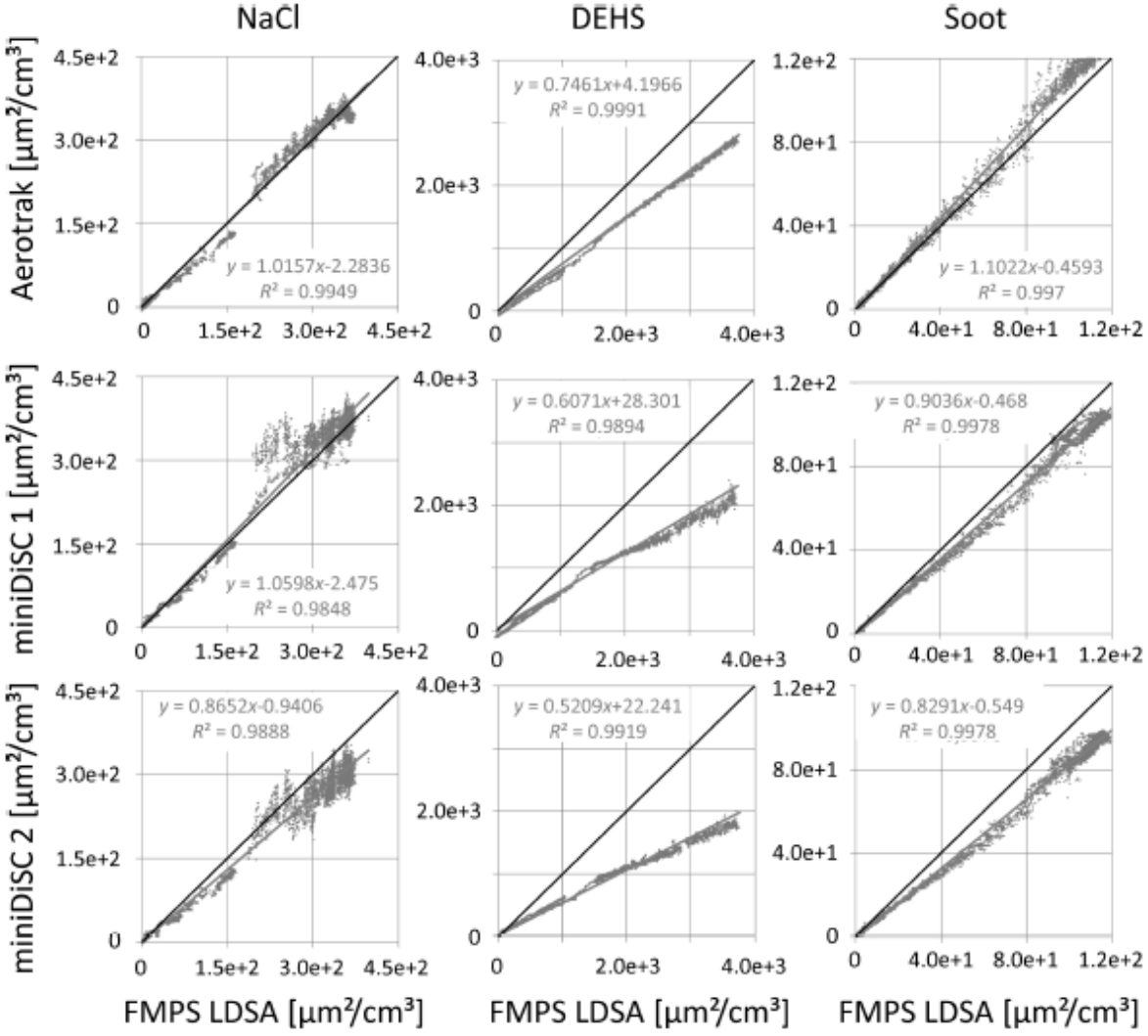
Good agreement

Poor agreement

- **Good agreement in GMD between SMPS and ELPI (p=0.97)**
- **Good agreement between SMPS and FMPS up until 200 nm**
- **GMD of 200-300 nm remains with FMPS as particles grow.**

Levin et al. 2015a

Comparison - LDSA



Correlation dependent on particle type!

Asbach et al. 2012

Key conclusions

- Current instrumentation is not reliable:
  - Specific instrument problems (e.g. FMPS)
  - General problem of non-sphericity

- Further development of strategies and techniques needed for occupational exposure limits to be based on lung deposited surface area

- Comparabiltiy can be achieved through:
  - Harmonization and ”relative” measurements
  - New techniques for ”absolute” measurements