A novel airborne nanoparticle size distribution spectrometer

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A novel portable instrument SAC to record nanoparticle size distributions has recently been developed. It is based upon the principle of diffusion selection of particles drawn through a semi-penetrable net at various flow rates. The SAC instrument contains a size selective unit, condensation unit and an optical detector of particles. The instrument does not require charging particles, therefore, there are no uncertainties associated with the charge transfer process. The instrument enables nanoparticle size distributions to be recorded *in-situ* on-line in the range from 5 nm to 500 nm (www.naneum.com).

Description

The principle of operation is as follows: Aerosol particles enter the size selective unit through the inlet. In the unit some particles are captured by the diffusion element. The number concentration of aerosol particles exiting the outlet of the size selectice unit is measured subsequently by a particle counter and recorded by a PC. The number of particles captured by the size selective unit is influenced by the flow rate through it and the size distribution. The penetration of aerosol particles through net or screen type diffusion element is described in many publications, e.g. Yeh Hsu-Chi and Cheng Yung-Sung (1980). The variable flow rate is maintained by a pump, controlled by the PC and recorded by a mass flow sensor. Therefore, the instrument provides a number of measurements of particle concentrations at various flow rates.

A novel highly effective technique for aerosol particle size distribution reconstruction has been developed. It enables complicated size distributions to be obtained from measurements with the instrument developed.

Preliminary tests results

The SAC instrument has been tested using atmospheric aerosols including products of combustion and some engineered nanoparticles. The engineered nanoparticles were produced by different generators: (i) electrosprayed sucrose, (ii) tungsten obtained with a hot-wire generator, and (iii) NaCl using an atomizer aerosol generator. Aerosols obtained were characterised by the novel instrument and reference methods. The SAC instrument was compared in a series of comparative measurements with TSI hand-held CPC and TSI SMPS.

For the experiments undertaken, the size distributions varied having a median diameter between ~15 and ~80 nm and a geometric standard deviation between ~1.4 and ~2.3. The comparison between the TSI SMPS measurements and the corresponding measurements obtained with the novel instrument showed a ratio between the median diameters to be ~1.2 $\pm$ 0.2 and the ratio between the geometric standard deviations to be varying between ~0.85 and ~1.2, see Figure 1. Meanwhile, the total number concentration measured with our instrument was at least ~80%

compared to the measurement with the TSI hand-held CPC. Therefore, the developed portable instrument can be used to characterise nanoparticle size distributions.

References

Yeh Hsu-Chi and Cheng Yung-Sung (1980) Theory of a Screen-Type Diffusion Battery, J. Aerosol Sci., **11**, pp. 313-320.

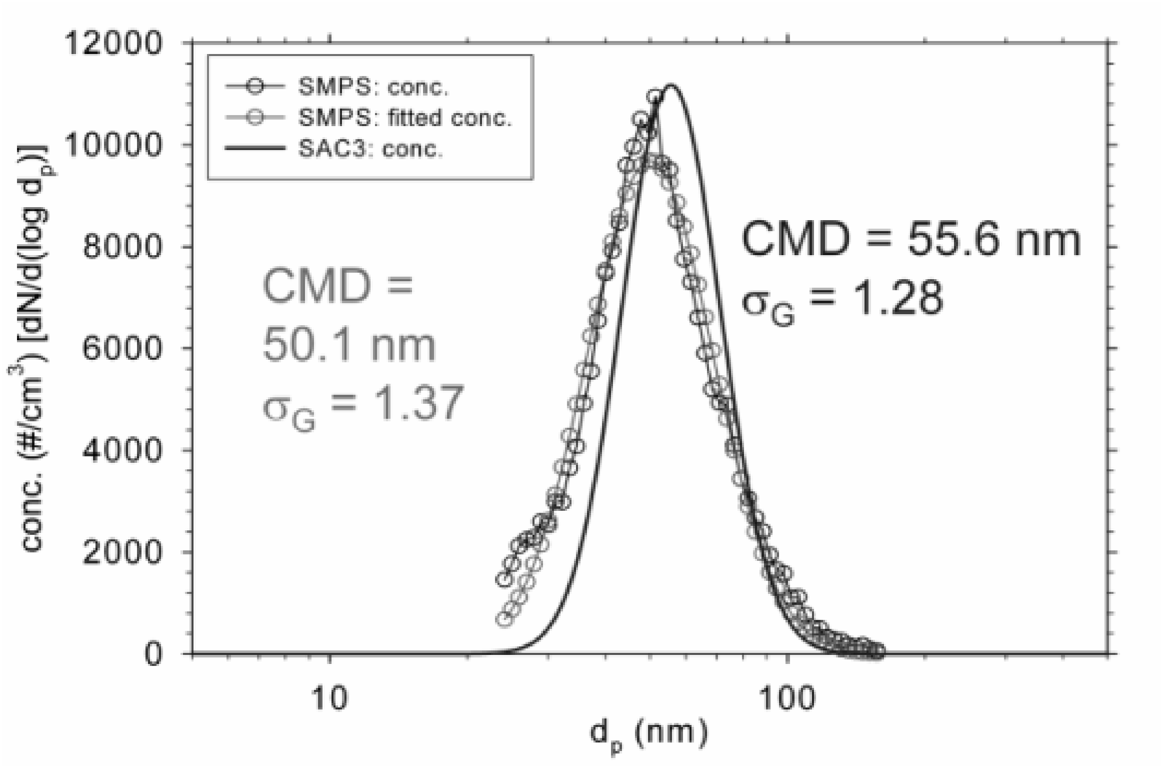

Figure 1. A typical aerosol size distribution (Tungsten) obtained with SAC NANEUM and SMPS TSI.

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The technology of the size spectrometer

A novel portable instrument to record aerosol size distributions SAC is based upon the principle of **diffusion selection** of particles drawn through a semi-penetrable net at **various flow rates**

Specification

- The size range - 2 nm to 500 nm equivalent diameter
- Measurement time – 20 s to 3 min
- Flow rates – 0.05 to 3 l/min
- Dimensions (LWH , cm) - 30 x 20 x 23
- Weight - 5 k g
- Power – 5 NiMH batteries

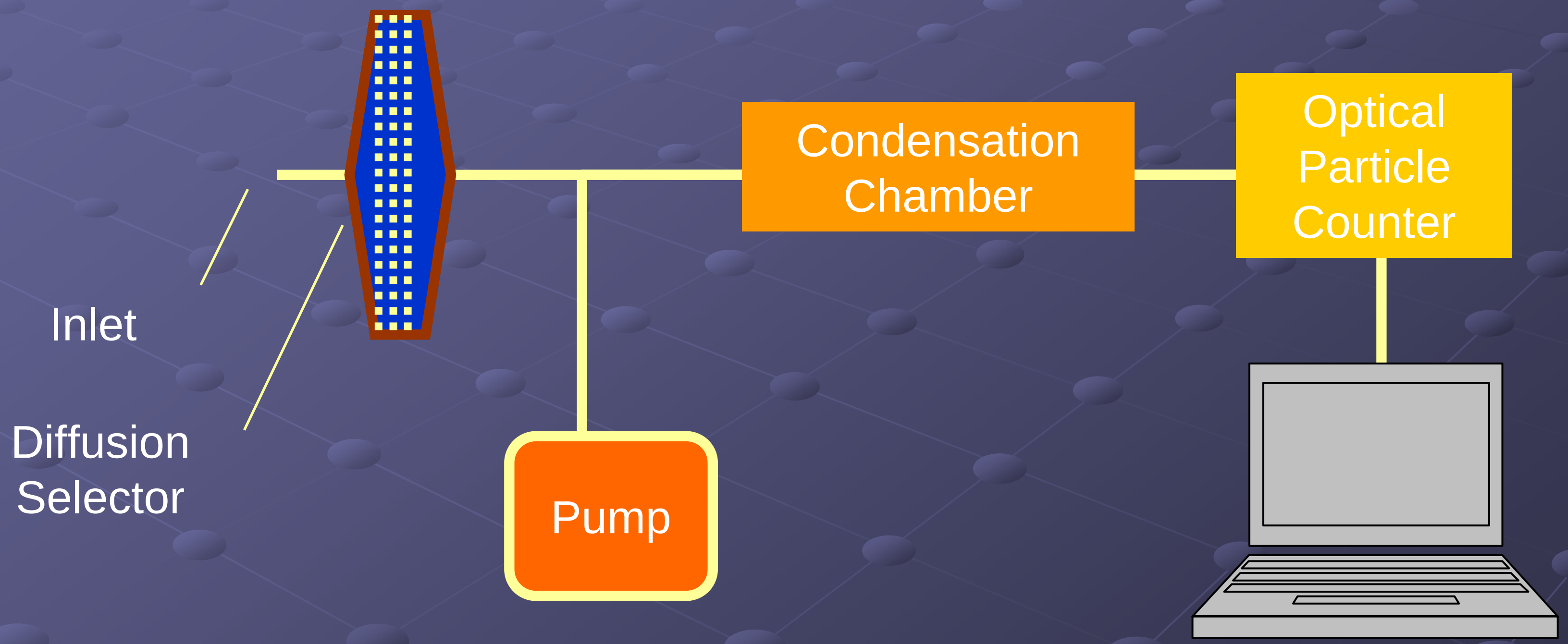

naneum

Main elements

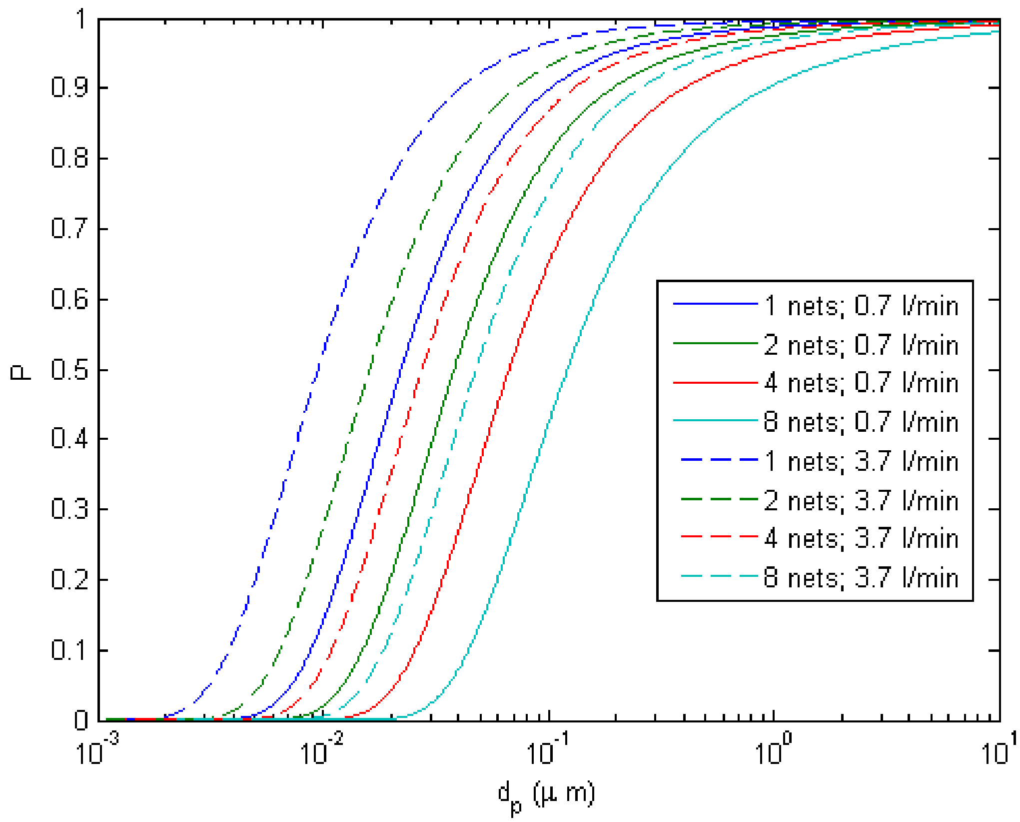
The SAC instrument contains:

- a size selective unit,
- condensation unit and
- an optical detector of particles

Schematic of SAC aerosol size spectrometer

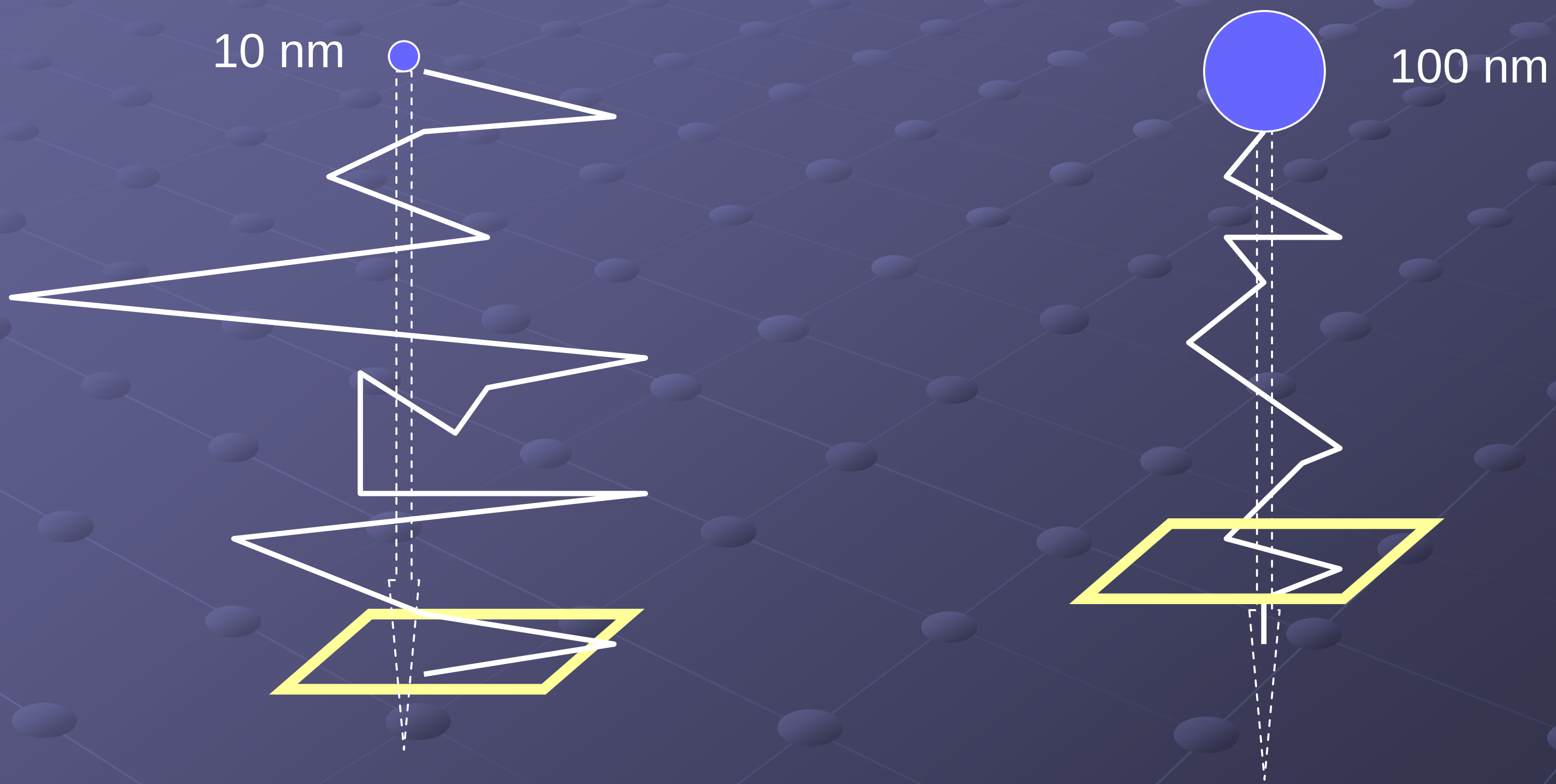


Theory of particle deposition

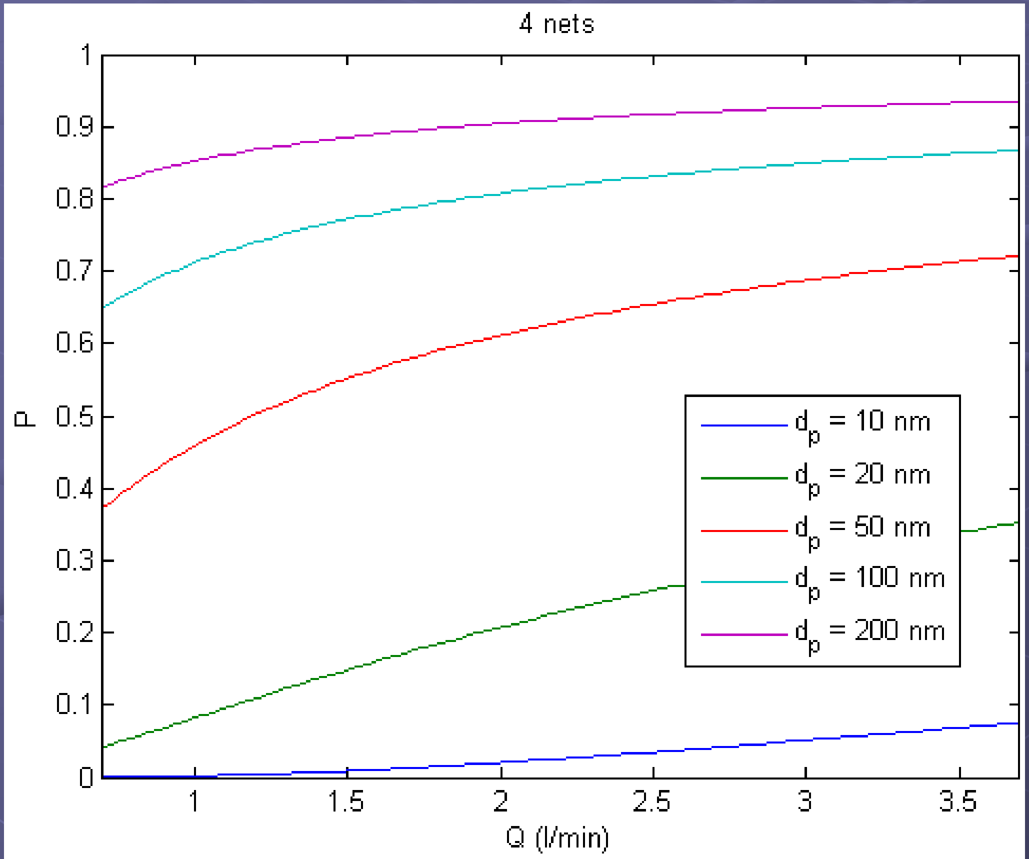


Penetration P versus particle diameter d_p for various numbers of screens (nets) and flow rates (only diffusion as underlying deposition principle considered)

The size selection is based upon diffusion

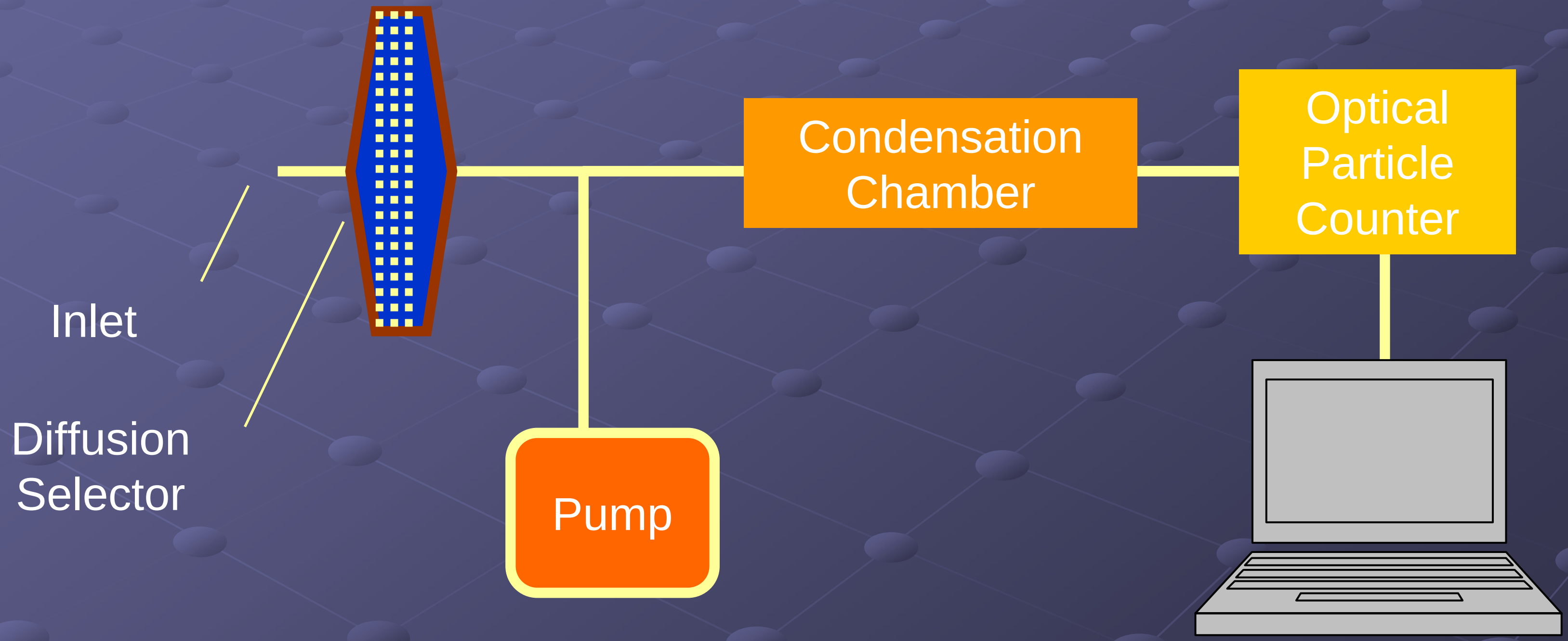


Theory of particle deposition for SAC aerosol particle size spectrometer

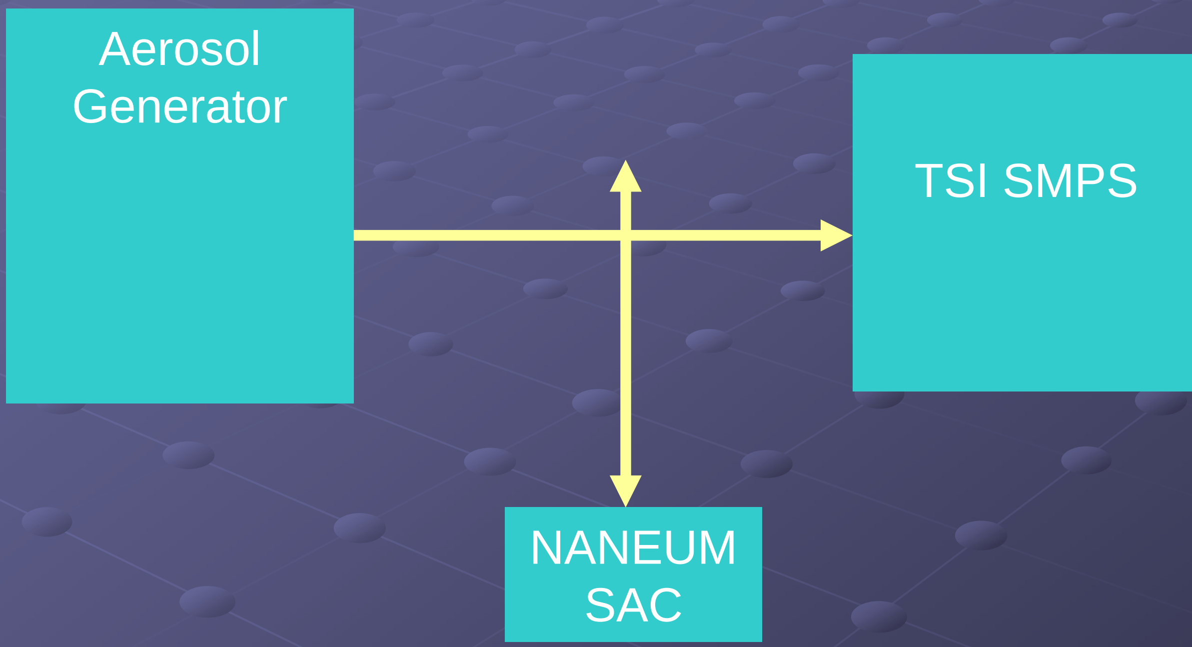


Penetration P versus flow rate Q for different particle diameters

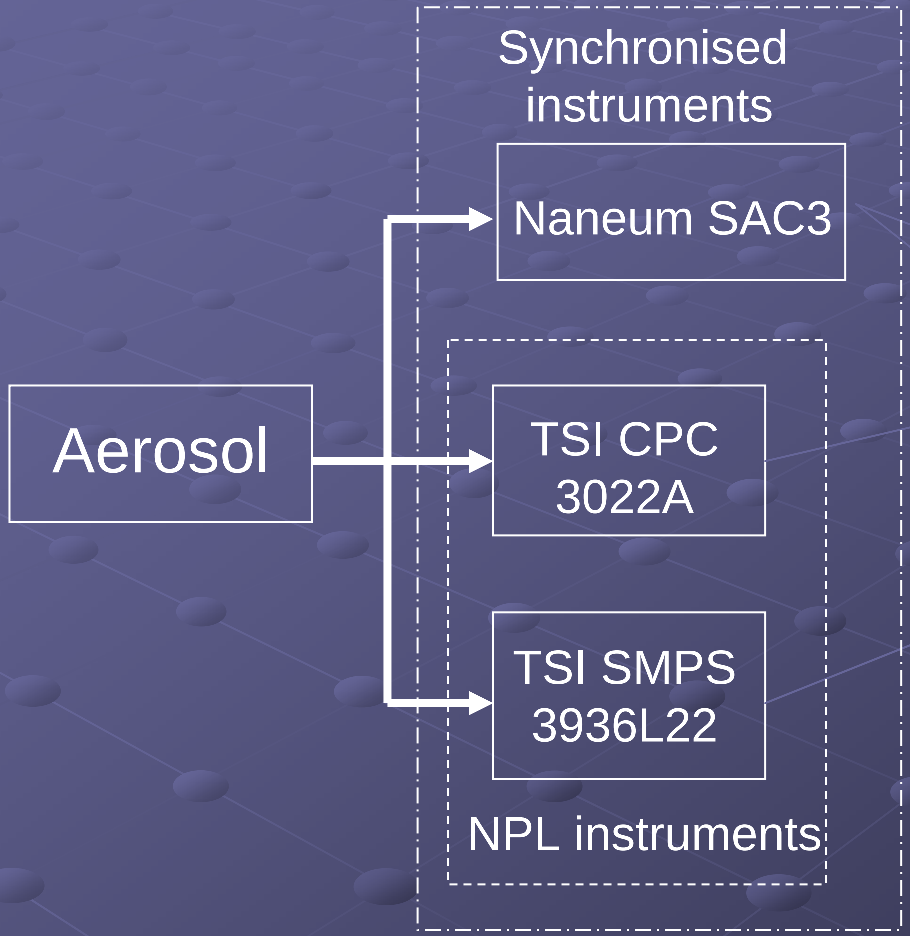
Schematic of SAC aerosol size spectrometer



Comparison: SAC vs. SMPS



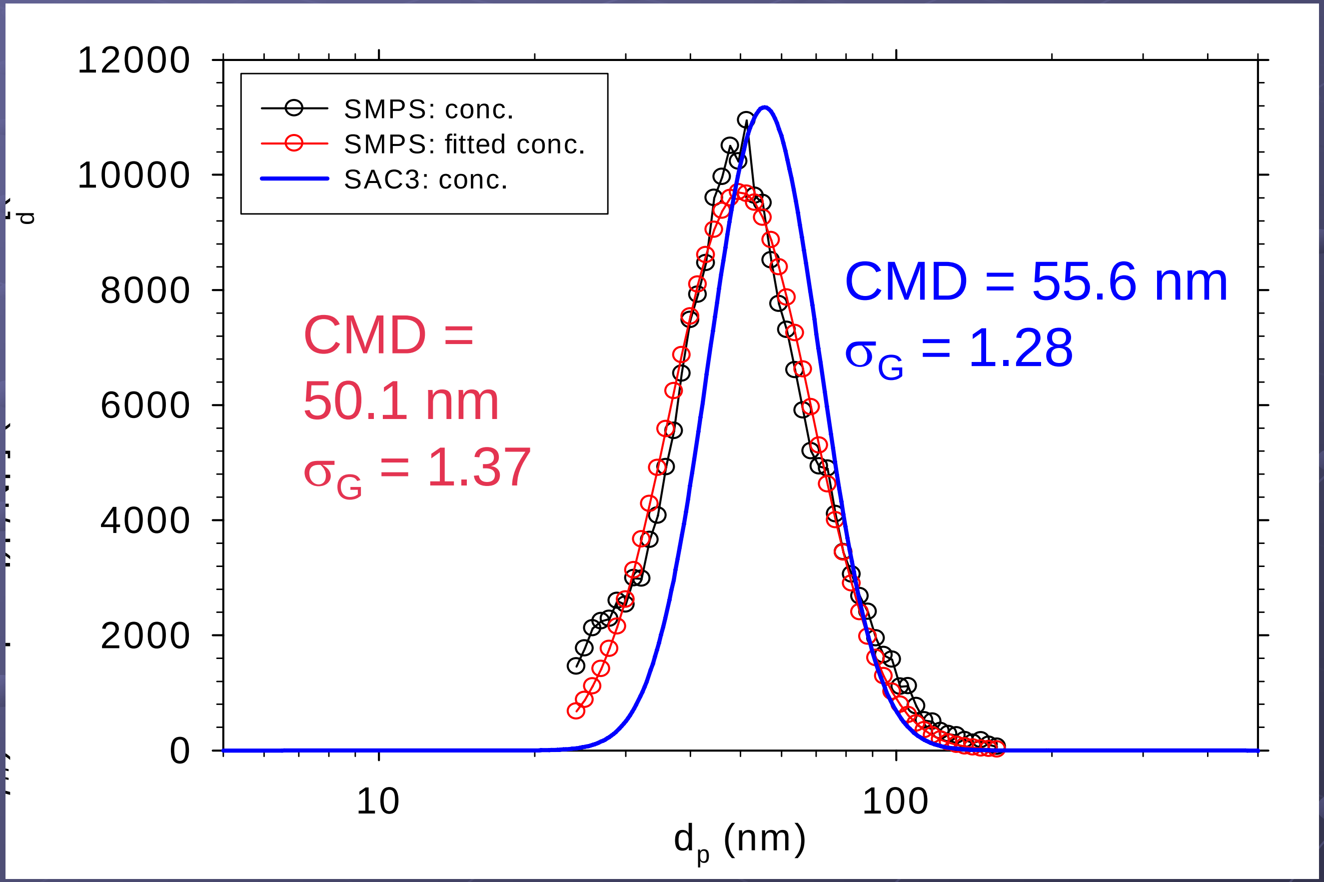
Measurement protocol at NPL :



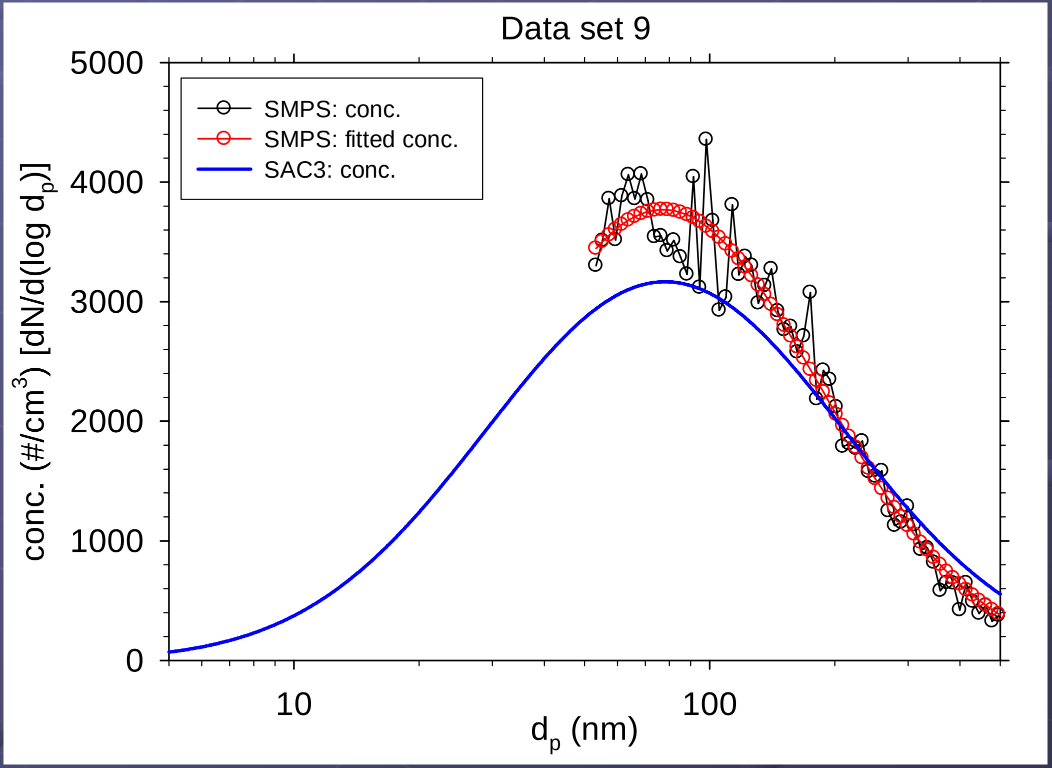
Compare :

- (Size-integral) Particle concentrations
- Spectral particle size distribution densities

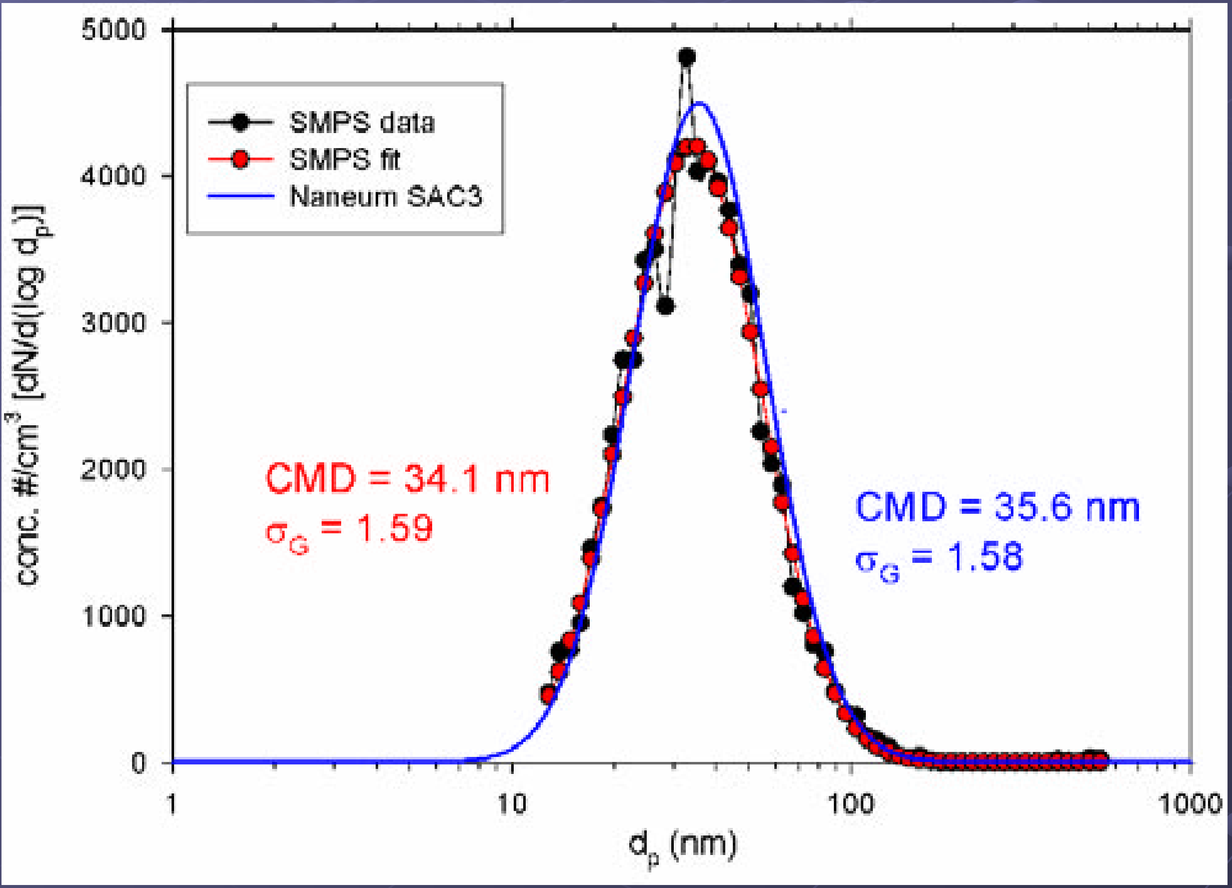
Comparison with SMPS TSI (NPL) Sucrose



Sodium Chloride aerosol generated by an atomiser



Tungsten aerosol

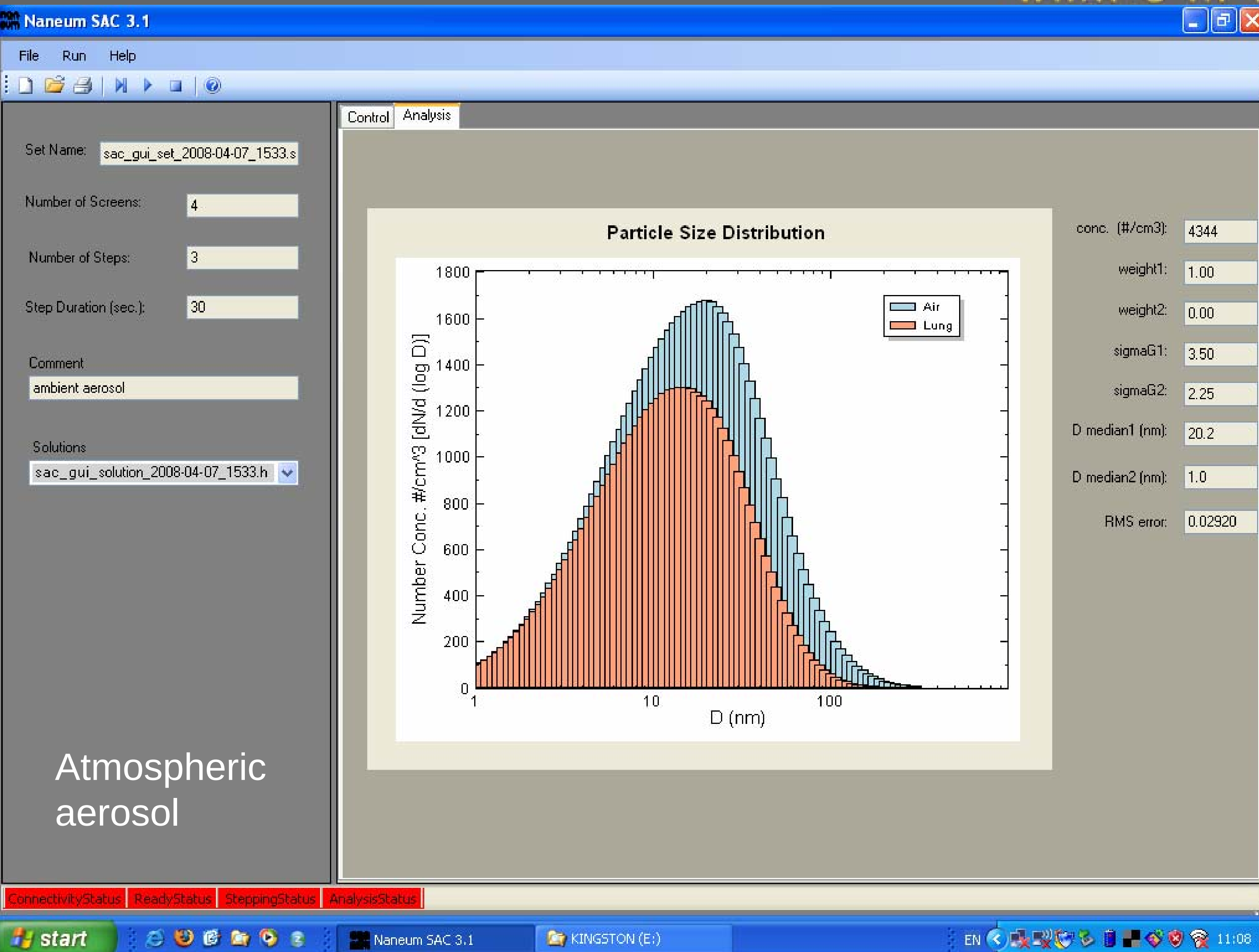


Preliminary tests results

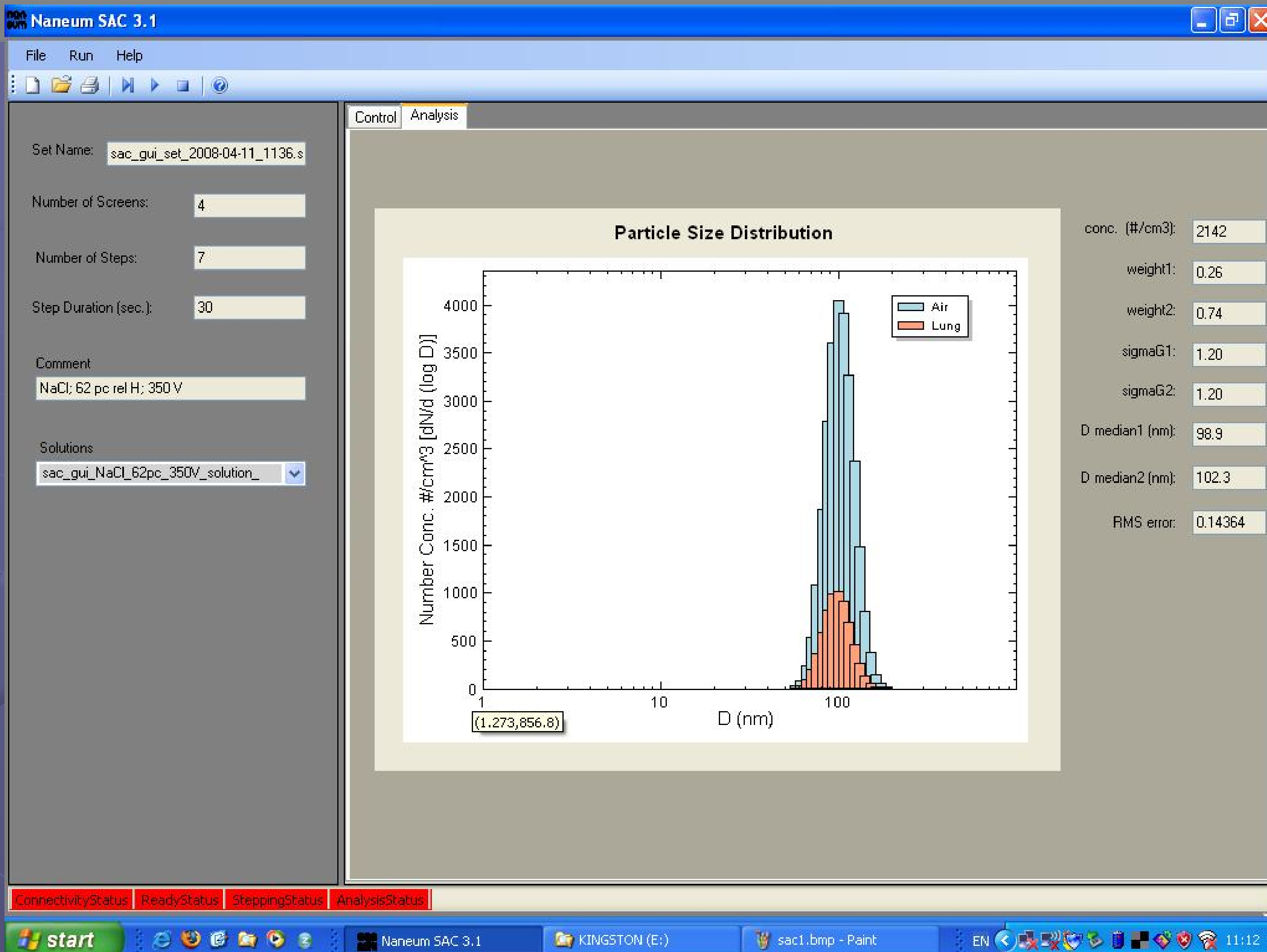
- The SAC instrument has been tested using atmospheric aerosols including products of combustion and some engineered nanoparticles (median diameter between ~15 and ~80 nm and a geometric standard deviation between ~1.4 and ~2.3).

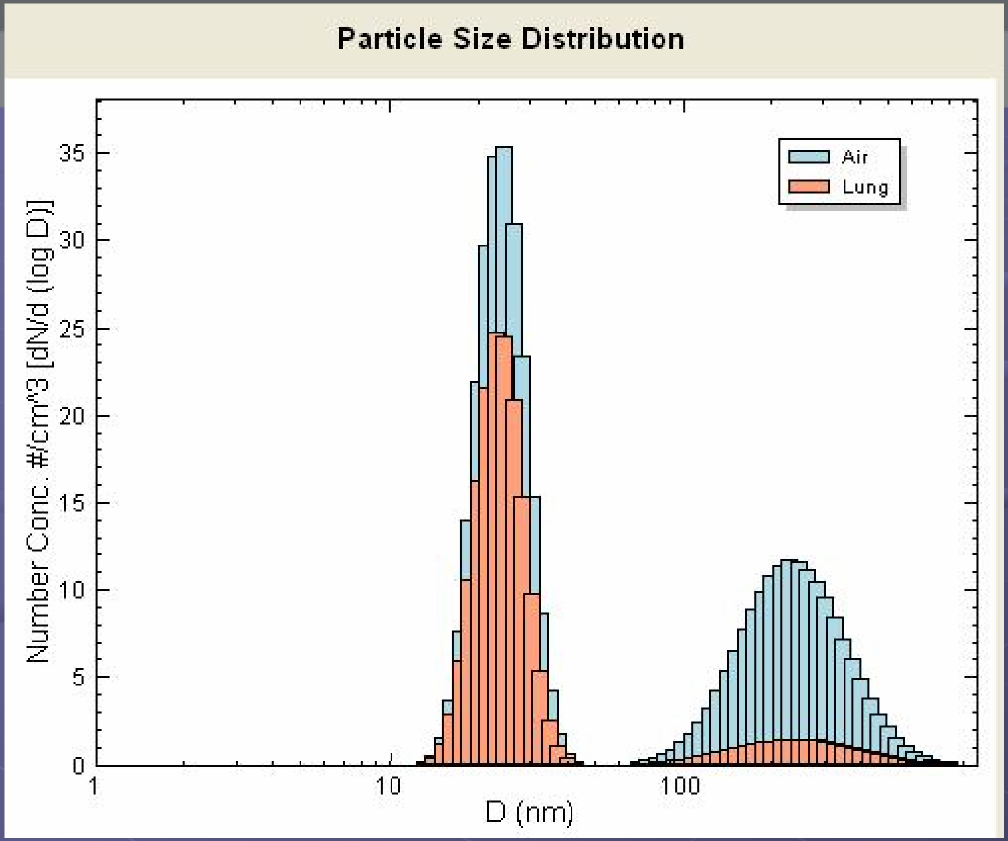
- The engineered nanoparticles were produced by different generators: (i) electrosprayed sucrose, (ii) tungsten obtained with a hot-wire generator, and (iii) NaCl using an atomizer aerosol generator.

- The SAC instrument and TSI SMPS were in a good agreement of quantifying aerosol number particle size distributions



Atmospheric aerosol


Naneum SAC 3.1
File
Run
Help
Control
Analysis
Set Name:
sac_gui_set_2008-04-11_1136.s
Number of Screens:
4
Number of Steps:
7
Step Duration (sec.):
30
Comment
NaCl; 62 pc rel H; 350 V
Solutions
sac_gui_NaCl_62pc_350V_solution_
Particle Size Distribution
Air
Lung
Number Conc. #/cm^3 [dN/d (log D)]
0
500
1000
1500
2000
2500
3000
3500
4000
1
10
100
D (nm)
(1.273,856.8)
conc. (#/cm3):
2142
weight1:
0.26
weight2:
0.74
sigmaG1:
1.20
sigmaG2:
1.20
D median1 (nm):
98.9
D median2 (nm):
102.3
RMS error:
0.14364
ConnectivityStatus
ReadyStatus
SteppingStatus
AnalysisStatus
start
Naneum SAC 3.1
KINGSTON (E:)
sac1.bmp - Paint
EN
11:12



An example of bi-modal size distribution measured with SAC Aerosol Size Spectrometer

Conclusions

1. The comparison showed a ratio between the median diameters to be ~1.2 ± 0.2 and the ratio between the geometric standard deviations to be varying between ~0.85 and ~1.2

2. The instrument developed can be used to quantify complex, bimodal aerosol particle size distributions *in situ* in real time

3. The instrument is robust, reliable and easy to use

4. There is no ionisation stage in measuring size distributions and, therefore, uncertainties associated with charging particles

Naneum: Product Features

- Naneum products are state of the art and are designed for use in the field
- They are portable, robust and easy to use
- They operate untended and can be used as remote monitors.
- Naneum technology is based on Diffusion and Impaction Phenomena:
  - Reflects what happens in respiratory tract
  - Designed for ultra low pressure drop- no problems with volatiles and semi-volatiles
  - Does not involve charging- important in certain environments e.g. Carbon Nanotubes where issues such as multiple charging can distort distribution
  - No need for radiation sources or high voltage.
  - Affordable.