IGF

Institut für Gefahrstoff-Forschung
der Bergbau-Berufsgenossenschaft
an der Ruhr-Universität Bochum

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Report

About comparative measurements between a *Philips Aerasense NanoTracer*, Philips Research Europe, and a *Scanning Mobility Particle Sizer*, TSI Inc.

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Contents

1 Preliminary remarks

The Institut für Gefahrstoff-Forschung -IGF- performed comparative measurements between a direct-reading ultrafine particle measurement device, the *Philips Aerasense NanoTracer* (hereafter referred to as "NanoTracer"), and a *Scanning Mobility Particle Sizer* (hereafter referred to as "SMPS"), TSI Inc., in the technical facility of IGF in Dortmund at 26.5.2009.

In this report a detailed description of the NanoTracer instrument is purposely not given as the instrument is still in the process of optimization and adaptation. A complete description of the instrument is available from the Aerasense group at Philips Research Eindhoven. The instrument was used as provided.

The NanoTracer infers from its measurements a number-averaged particle diameter $d_{p,av}$ and an integral particle number concentration N within the limits of its measurement range. The NanoTracer is designed for measuring airborne particles above 10 nm in diameter, which is usually equivalent to a measurement in the 10 – 400 nm particle size range. Larger particles are also measured but will not normally give a significant contribution to the measured signals. The 10 – 400 nm particle size range is also measured by the SMPS device used in this comparison experiment (see below).

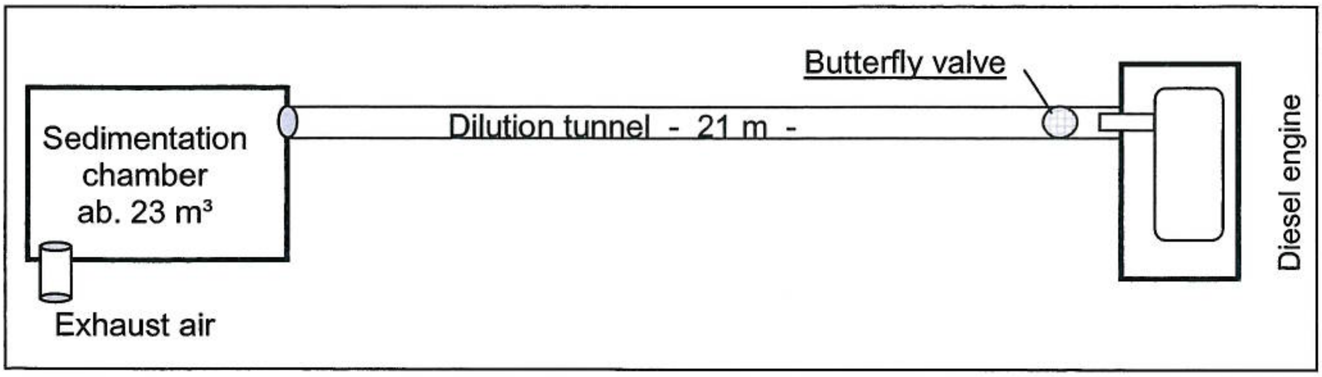
2 Procedure

The comparative measurements have been performed at the diesel test stand of the IGF's technical facility in Dortmund.

2.1 Description of the test stand

The diesel test stand consists of the following main components:

- Diesel engine (aerosol generator),
- Diluting tunnel,
- Sedimentation chamber.



2.2 Principle of the aerosol generation

The aerosol generated by the diesel engine is passed into the dilution tunnel via a butterfly valve by which it can be varied in concentration. In the tunnel it is:

a) homogenously diluted with ambient air and
b) cooled to room temperature.

Within the whole volume of the sedimentation chamber under stationary conditions a constant and homogenous concentration of diesel particulate matter/ultrafine particles is generated within a few minutes. This has been demonstrated in several previous large inter-comparisons and experiments (see e.g. Dahmann, 1997).

The concentration in the tunnel and subsequently in the chamber can be varied across a very large range by means of the butterfly valve and deduction of a defined partial engine exhaust flow under an otherwise constant ambient air flow into the dilution tunnel.

2.3 Experimental design and description of experiments

To avoid diffusion losses before the aerosol enters the respective instruments the NanoTracer, as well as the SMPS-device, were placed inside the sedimentation chamber (centre of the room). This set-up guaranteed an identical aerosol concentration entering both devices as well as minimizing their mutual influence. For orientation purposes a *Condensation Particle Counter* (CPC), TSI Inc., was additionally placed into the sedimentation chamber. The data generated by this instrument were not used in the following as the aerosol concentrations were in some cases found to be outside the CPC's specified measurement range.

The SMPS device (DMA Model #3080, CPC #3010) was operated in a particle diameter range between 9.82 nm and 414 nm for a total scan time of 180 s (scan-up-time = 150 s, scan-retrace time = 30 s).

A total of 5 different aerosol concentrations were generated within the sedimentation chamber for typical measurement durations of 12 to 15 minutes, respectively, enabling 4 or 5 scans under the conditions of the respective aerosol generation to be carried out (see chapter 3, "n"). Though a modification of the diesel engine itself with respect to e.g. the engine load would have been possible, it was avoided for the experimental set-up described in this report in order to limit the effort. The resulting aerosols consequently did not vary very much with respect to their particle size distribution.

Measurement 1: Motor runs	Complete engine exhaust is fed out of the system
Measurement 2: Motor stopped	Blank conditions, inlet of ambient air only
Measurement 3: Motor runs	Butterfly valve 10 mm opened
Measurement 4: Motor runs	Butterfly valve closed
Measurement 5: Motor runs	Butterfly valve 20 mm opened

For the complete description of the aerosol conditions used in the experiments see Appendix A which gives the particle number concentrations and the mean diameters recorded by both instruments over the course of the experiments.

3 Measurement results

TSI performs a so-called diffusion correction taking into account diffusion losses within the SMPS device (Diffusion Correction, “dc”) as well as possible multiple charging of aerosols (Multiple Charge Correction, “mcc”) in its SMPS software.

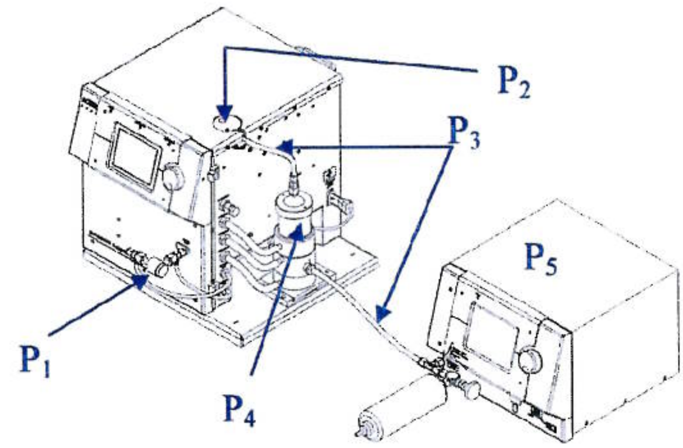
P1 = Penetration through the impactor inlet

P2 = Penetration through the bi-polar neutralizer and internal plumbing

P3 = Penetration through the tubing to the Differential Mobility Analyzer (DMA) and CPC

P4 = Penetration through the DMA

P5 = Penetration through the CPC

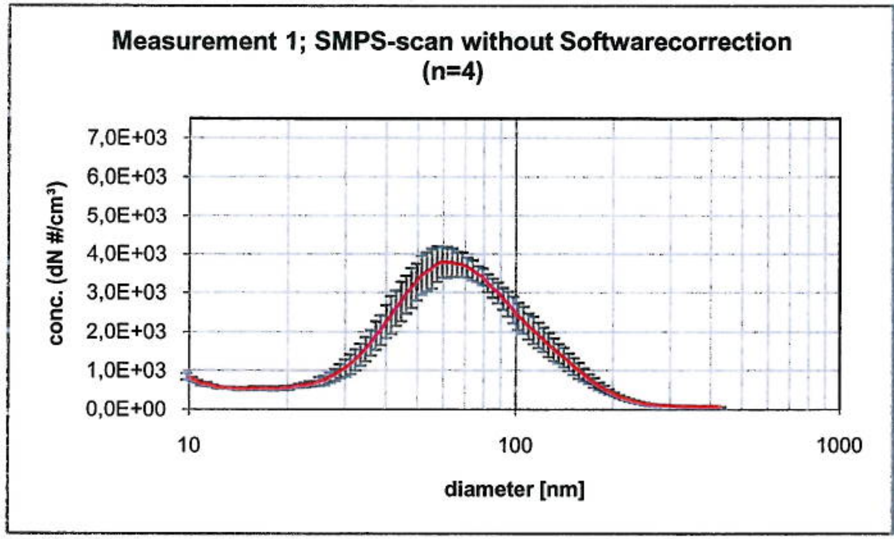


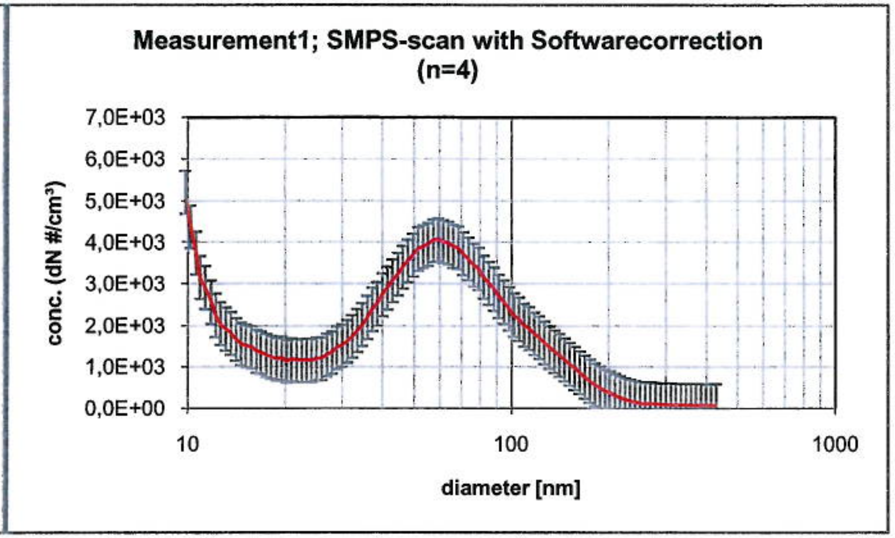
The total penetration through the system (P_G) is therefore $P_G = P_1xP_2xP_3xP_4xP_5$.

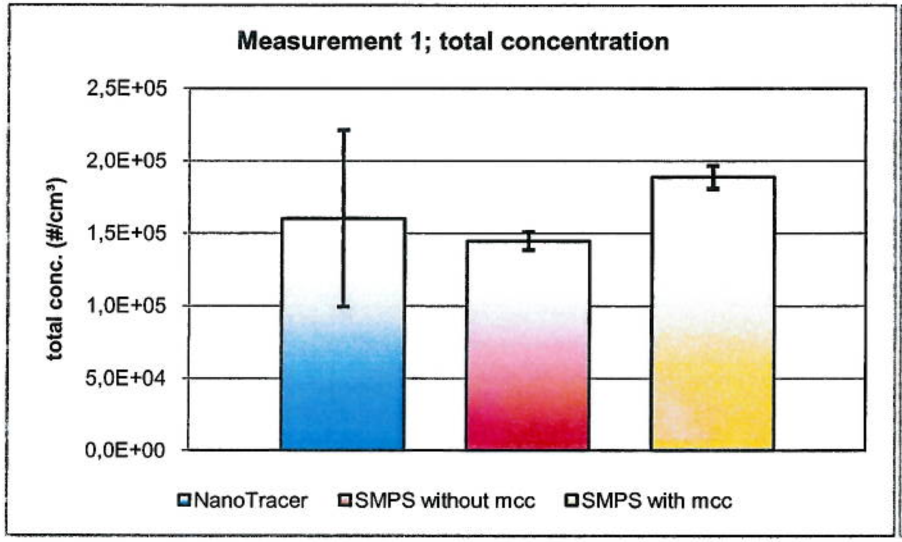
For the SMPS device the corrected and uncorrected measurement results will be displayed below.

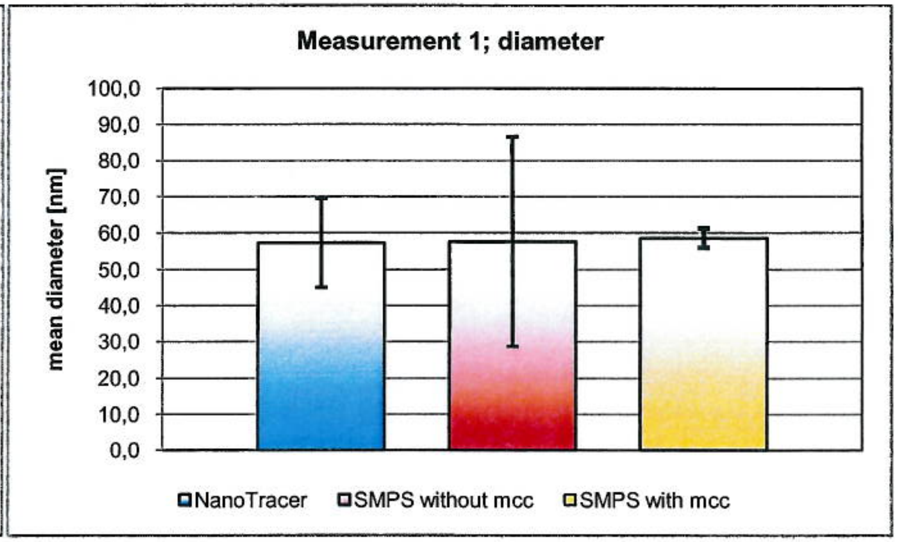
The diagrams also display the standard deviations of the measurement results. It should be noted that the standard deviations in all cases also reflect inhomogeneities of the test aerosol which can play a role when the aerosol concentrations were changed, i.e. for the very first experiment in any of the measurements described below (see Appendix A for details). In this respect the direct-reading NanoTracer instrument is more prone to reflect this effect compared to the “integrating” SMPS with a recording time of 4 minutes.

3.1 Measurement 1

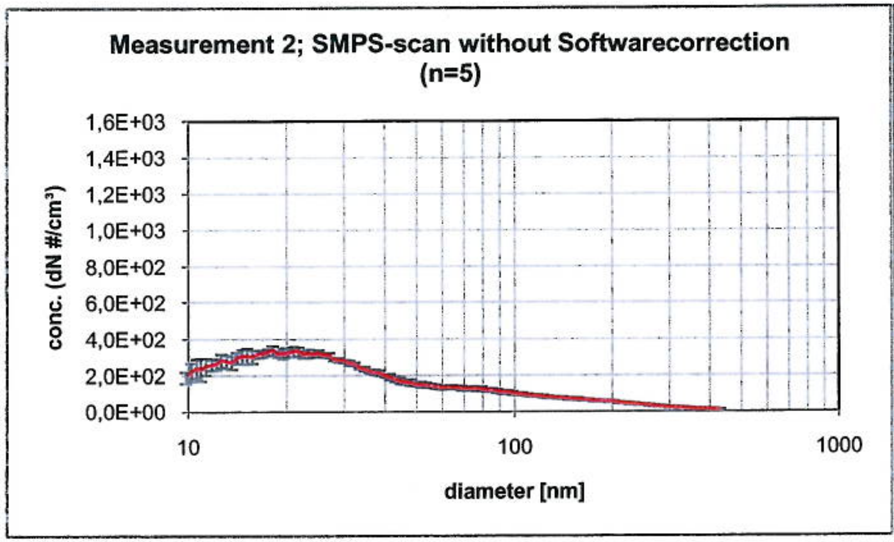


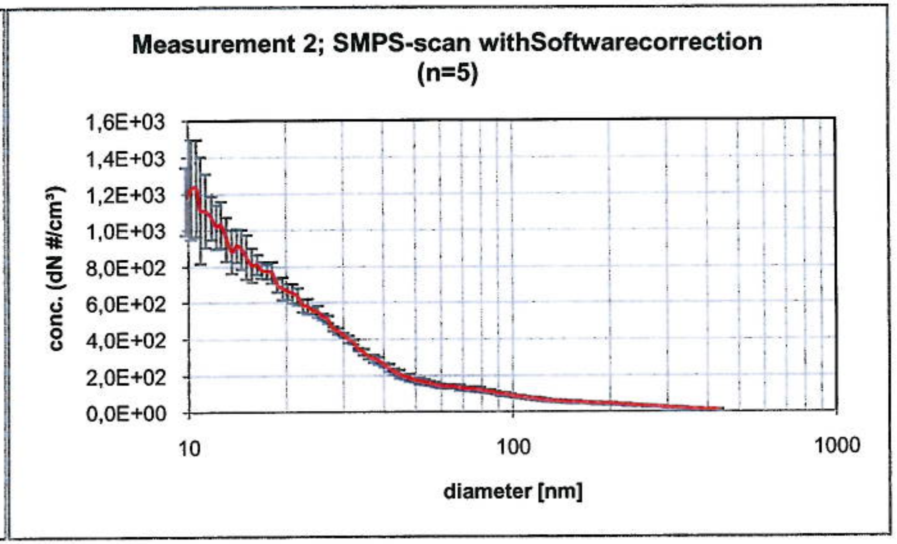


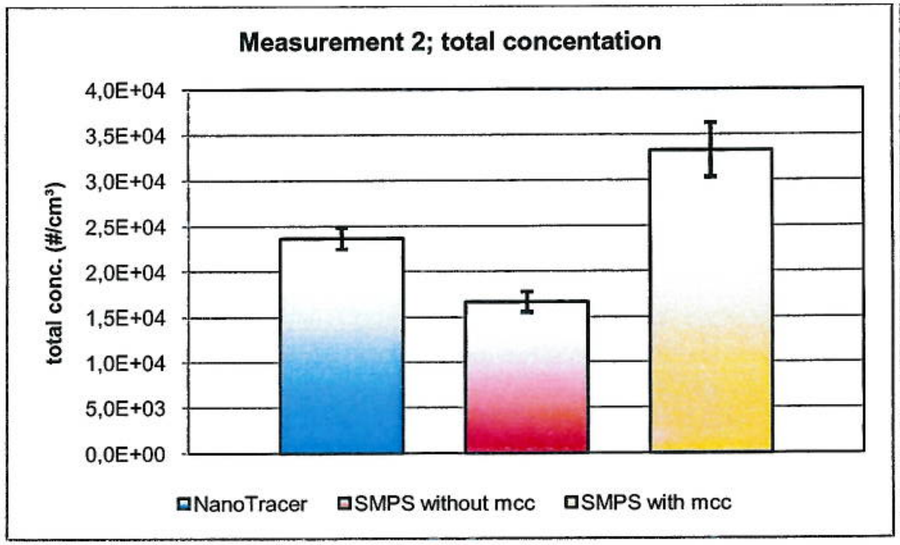


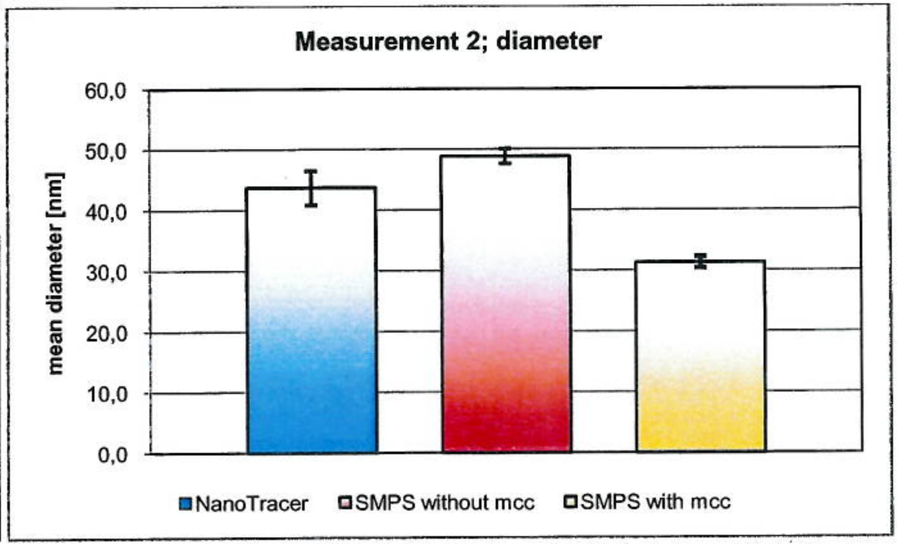


3.2 Measurement 2









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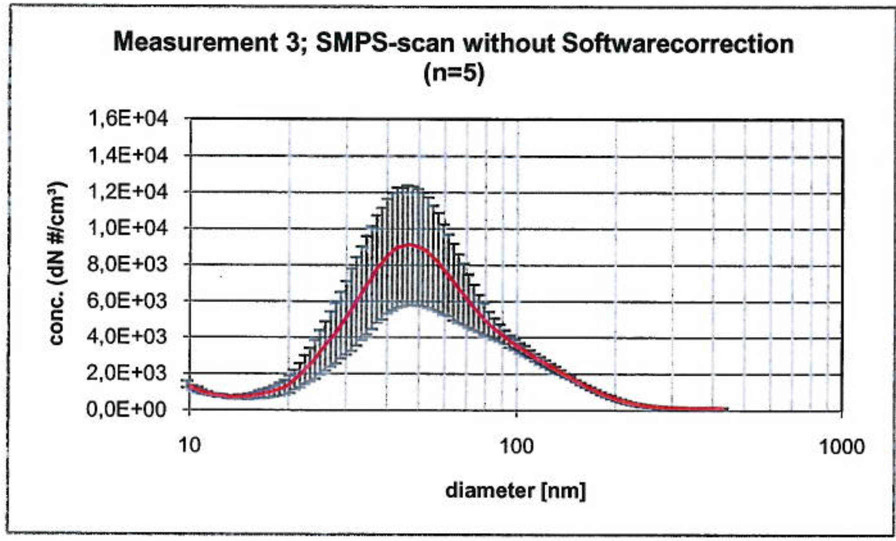
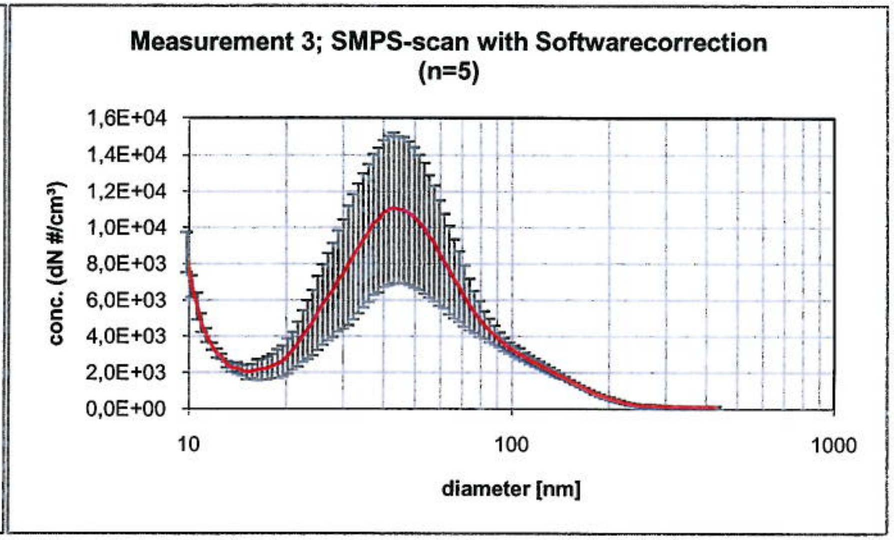
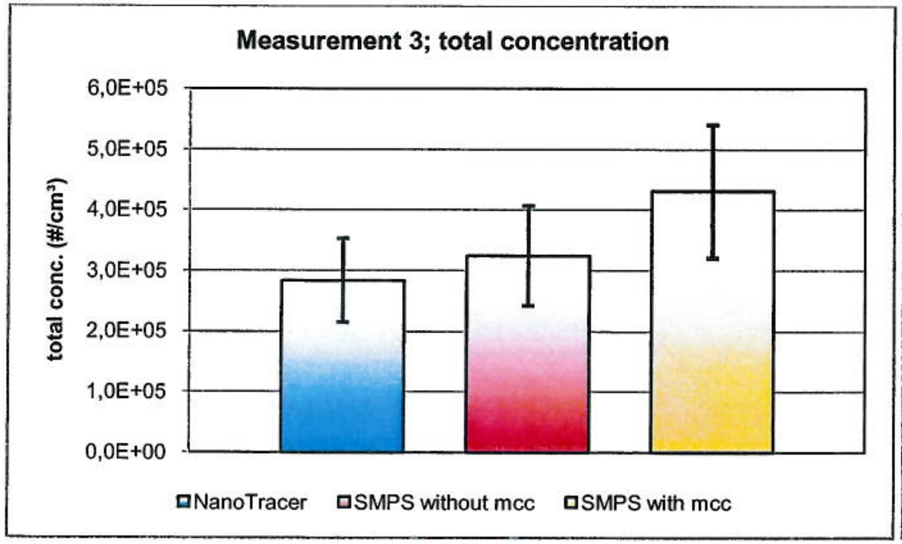
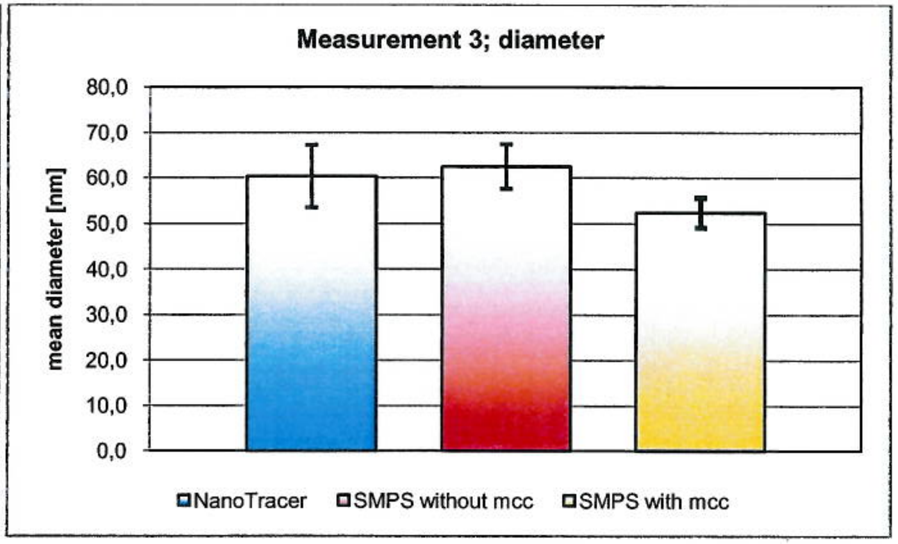
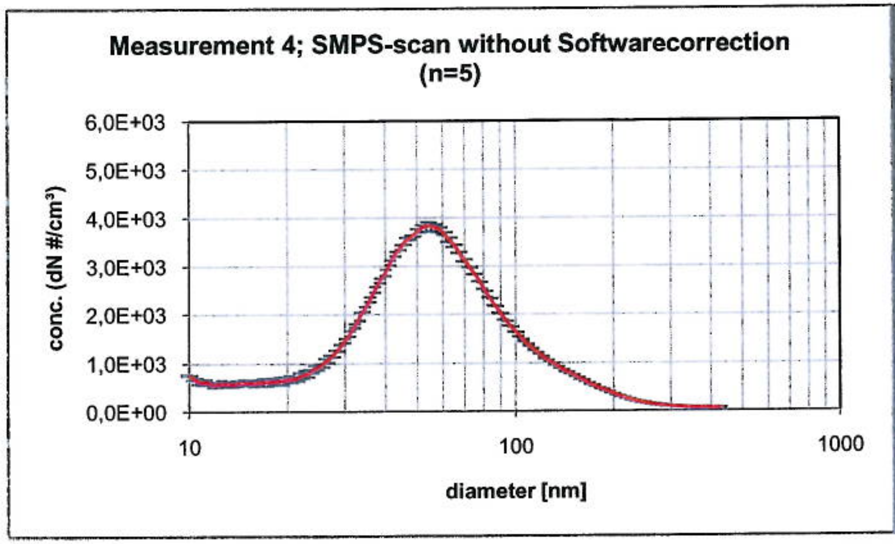


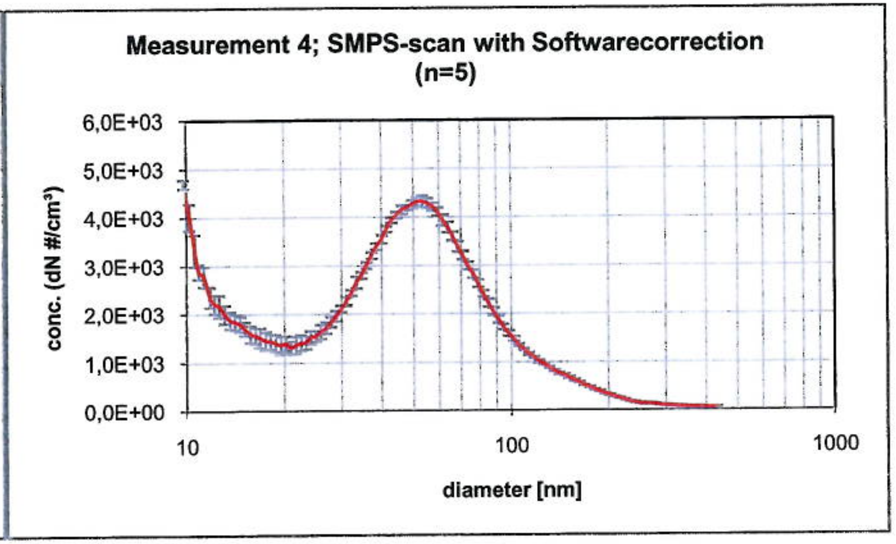


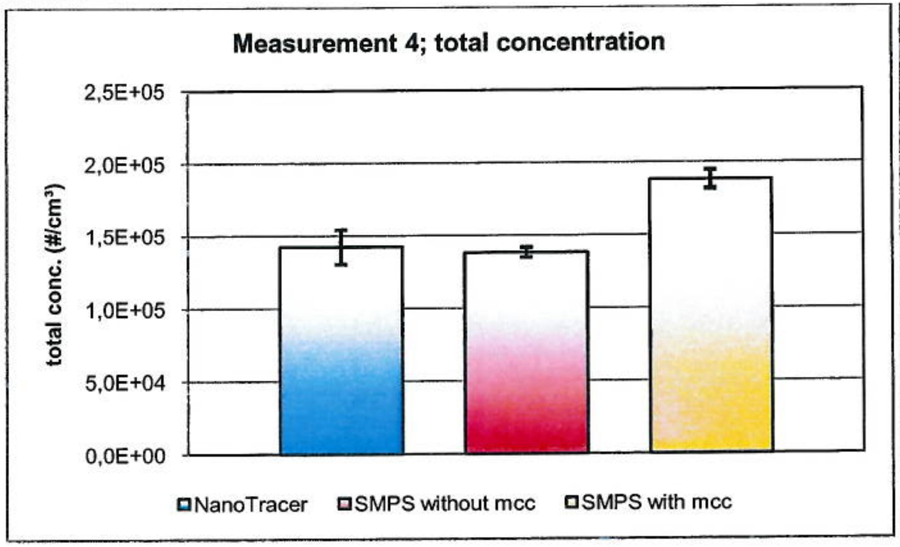


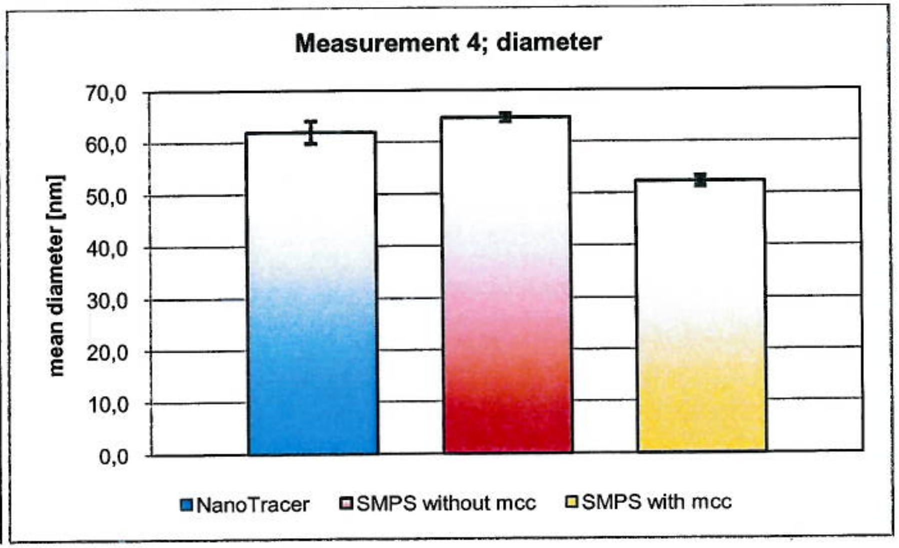


3.4 Measurement 4

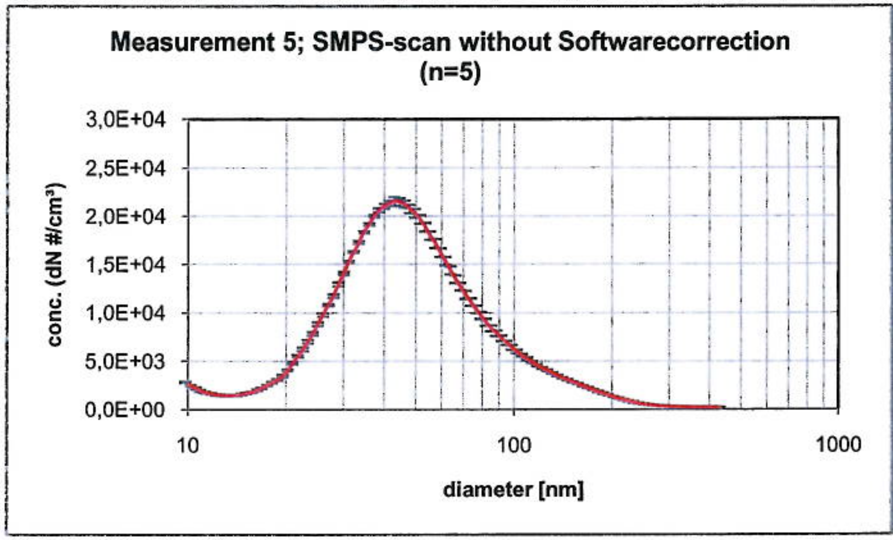


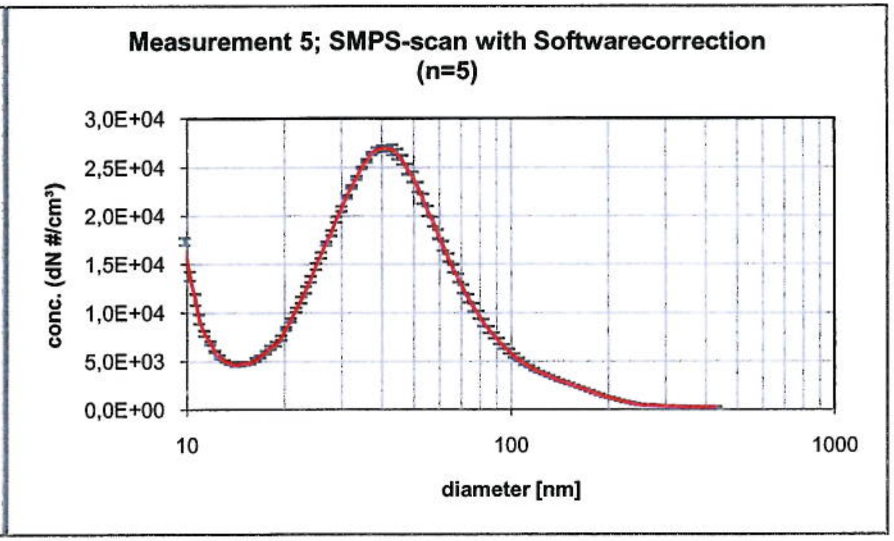


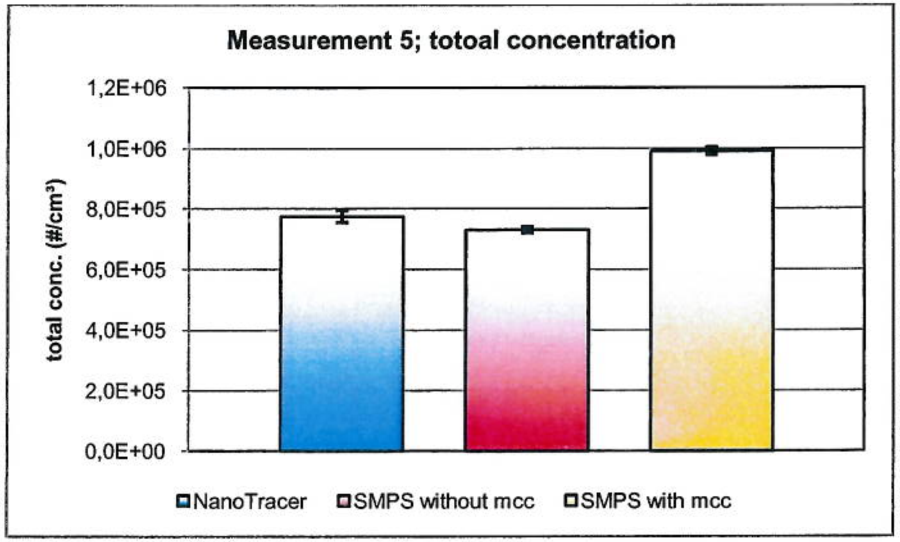


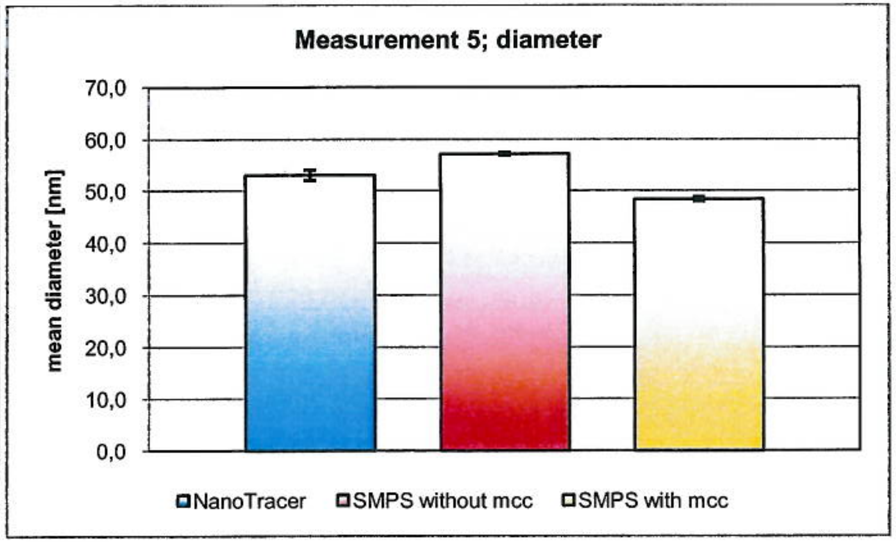


3.5 Measurement 5









4 Discussion

The SMPS and the NanoTracer show a very good correlation with respect to particle number concentrations. Software corrections for the SMPS results only have a marginal influence (see figure 2; $R^2 > 0.99$ in both cases).

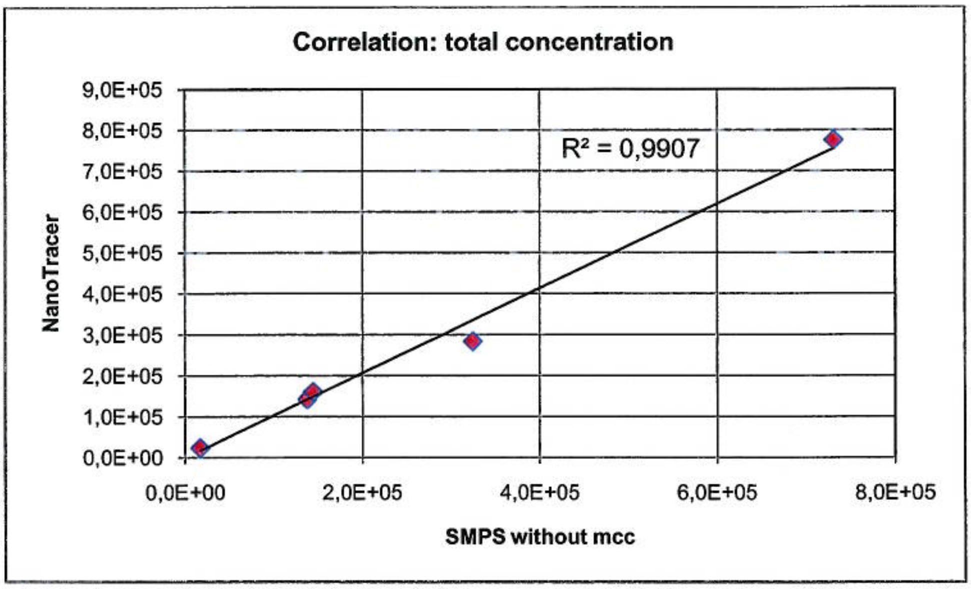


Figure 1 (Correlation total particle number concentration, SMPS without mcc)

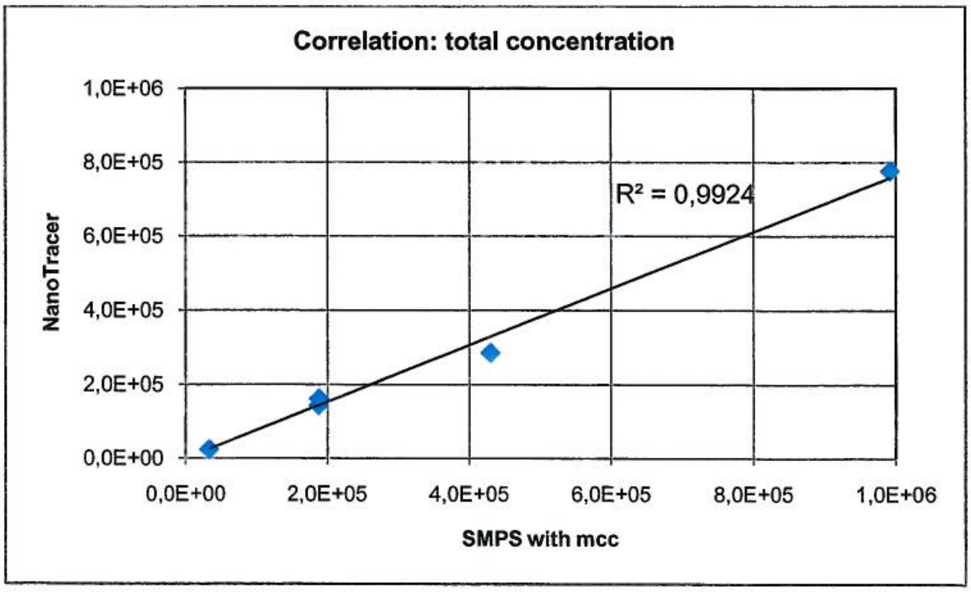


Figure 2 (Correlation total particle number concentration, SMPS with mcc)

When the average/mean particle diameters are compared, the mathematical correction of the multiple charging shows a larger effect when the two devices' results are correlated. („SMPS without mcc": R^2 = 0,955 (Figure 3), „SMPS with mcc" R^2 = 0,77)). This is undoubtedly related to the fact that only a small variation of the aerosol composition/size distribution was realized in the experiments. Therefore a proper correlation cannot really be done here and the correlation diagram can only give a rough indication about the relation between the two instruments . Random factors will have a large influence on correlation coefficients. A detailed discussion about the findings in this respect will therefore not be performed.

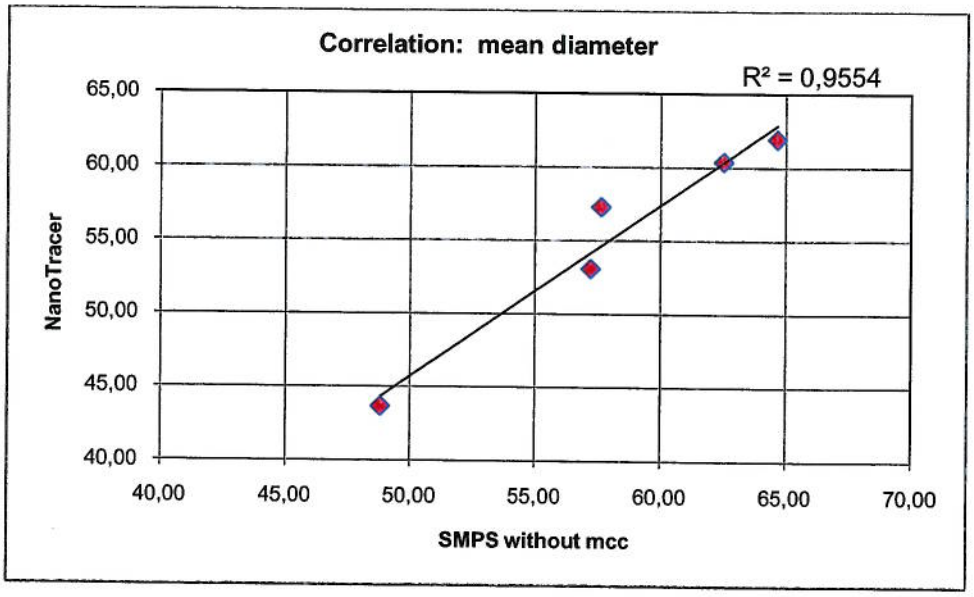


Figure 3 (Correlation mean particle diameter, SMPS without mcc)

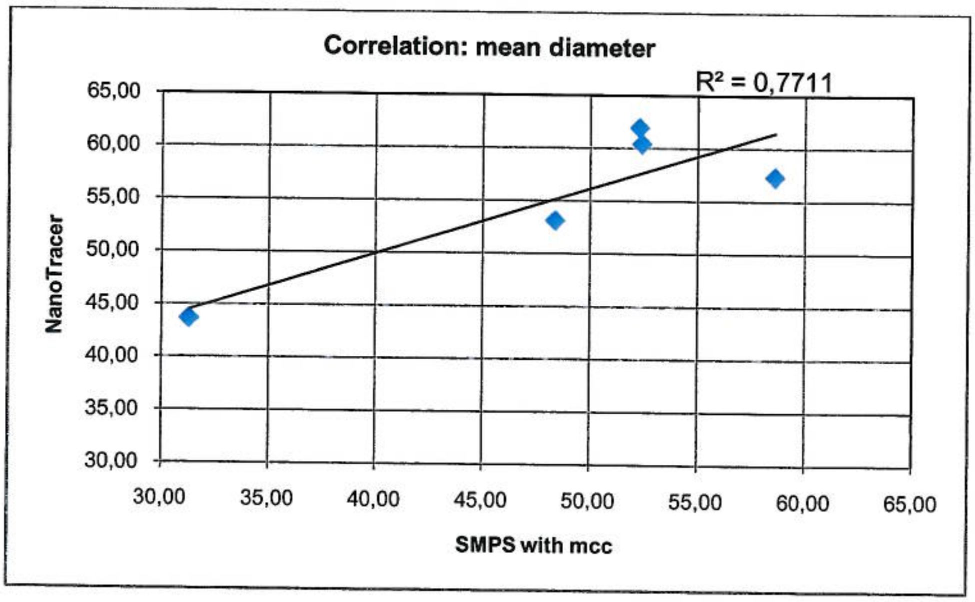


Figure 4 (Correlation mean particle diameter, SMPS with mcc)

A recent comparison of 4 different mobility particle sizers under comparable conditions resulted in number concentration correlations of R^2 between 0.995 and 0.999. [Asbach et al. 2009]

5 Summary

The experiments show very promising preliminary results with respect to the determination of particle number concentrations when ultrafine combustion aerosols like diesel particulate matter are concerned. The direct reading measurement of number concentrations where these types of aerosols are the dominant aerosol constituents does not seem to be a problem with the *Philips Aerasense NanoTracer* device. Correlations with $R^2 > 0.99$ with respect to the currently mainly used instrument for the detailed measurement of particle number concentration distributions are quite satisfactory.

When average particle diameters are concerned, the correlation gets less well defined due to the encountered limited variation in particle sizes, but can still be described as sufficient. This can also be said because it can be safely assumed that the determination of number concentrations will probably be more important than exactly determining the average particle diameters.

It must be stressed that all findings described in this report are only valid under the side parameters/conditions (e.g. type of aerosol, temperature and humidity) applied in the respective experiments. Whether the general tendencies described here are also valid under different circumstances can currently only be assumed.

Messung und Berichtserstellung:

Institut für Gefahrstoff-Forschung der Bergbau-Berufsgenossenschaft

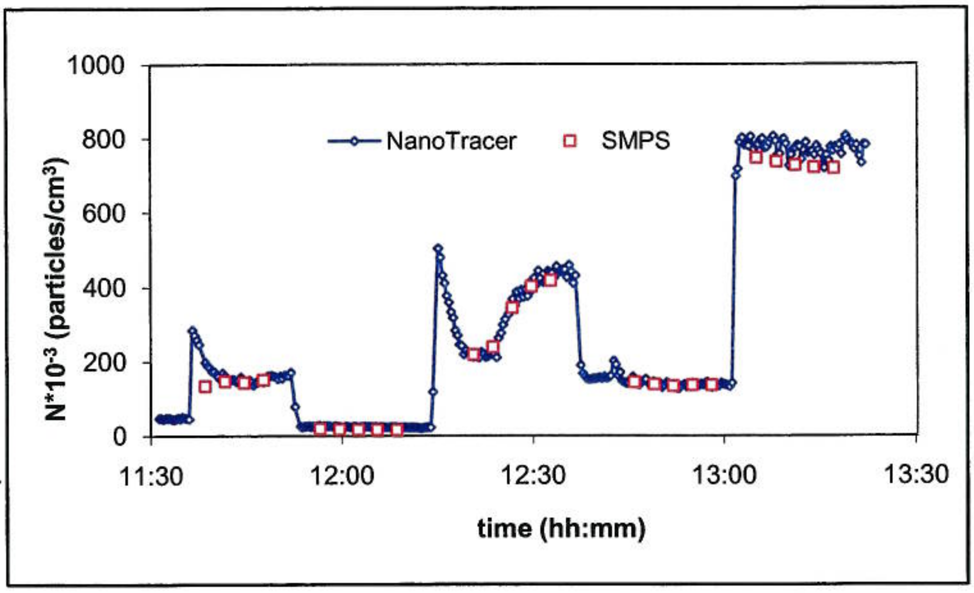
(Dipl.Ing. Christian Monz) (Dr. rer.nat. Dahmann)

Literature:

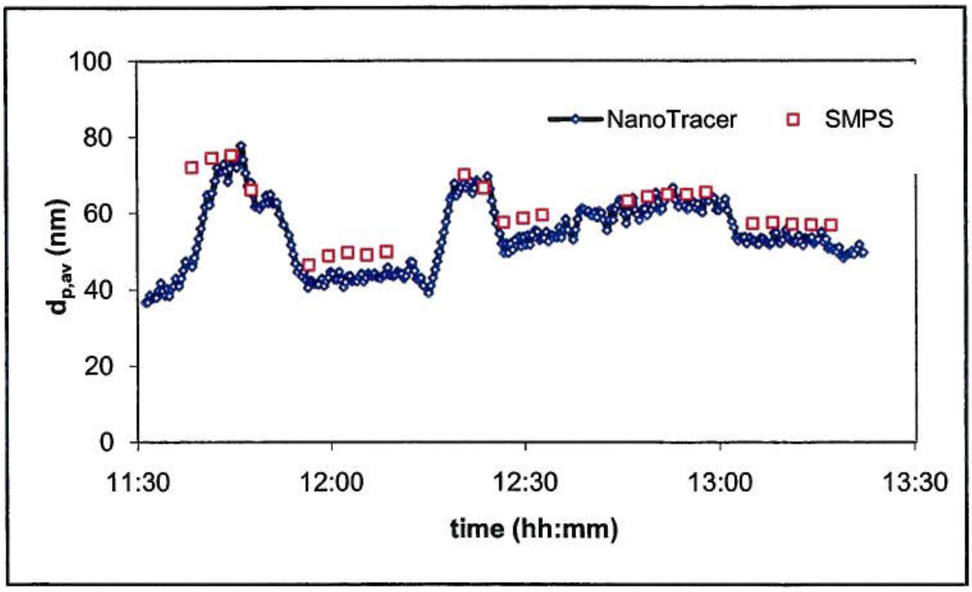
C. Asbach, H. Kaminski, H. Fissan, C. Monz, D. Dahmann, S. Mülhopt, H. R. Paur, H. Kiesling, F. Herrmann, M. Voetz, T. A. J. Kuhlbusch „Comparison of four mobility particle sizers with different time resolution for stationary exposure measurements“, Journal of Nanoparticle Research, in print

D. Dahmann "A Novel Test Stand for the Generation of Diesel Particulate Matter", Ann. occup. Hyg. **41**, Supplement 1, 43-48

Appendix A: Measurement results and description of the aerosols



Particle number concentrations



Mean particle diameters