University of Applied Sciences
Biel-Bienne, Switzerland

IC-Engines and Exhaust Gas Control

NanoMet a potential analyzer for legal nanoparticle measurements

Swiss contribution to GRPE Particulate Measurement Programme, Reports 2 & 3

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- Abstracts

Part I: Peugeot with DPF, VW Passat w/o DPF

- Experimental set-up
- Particulate emissions analysis
- Measuring procedure
- Results & correlations

Part II: DPF with Bypass (Opel Astra)

- Results & correlations
- Conclusions

Abstracts

The UNECE subgroup GRPE (Groupe Rapporteurs Pollution Energie) started a Particulate Measurement Program (PMP) to improve the legal exhaust gas measuring procedures for the diesel vehicles with particle filters (DPF).

For those very low emitting vehicles new special measuring devises for particles emissions or eventual modifications of measuring procedures are necessary. In this context the Swiss Federal Roads Authority (FEDRO) together with the Swiss Federal Office of Environment, Forests and Landscape (FOEFL) mandated several investigations to claire up the possibilities and necessities of supplementing the legal measuring procedures.

The Swiss nanoparticles experts group under the auspices of the Swiss Federal Office of Environment, Forests and Landscape (FOEFL) proposes a new apparatus - the NanoMet.

In the 1st part of the preliminary research program (GRPE phase 1), it was confirmed that:

- there is a good correlation between the NanoMet and SMPS results,
- due to the possibility of on-line measurement, the NanoMet has an interesting potential of analysing the nanoparticles (NP)-concentrations and NP-composition during the transient operating conditions.

In the 2nd part of the preliminary research program of FEDRO and FOEFL with NanoMet used on a modern Diesel passenger car more correlation measurements, more statistical comparisons and more data allowing the assessment of: repeatability, stability, sensitivity and dynamic aptitude were elabored.

By means of a by-pass of the DPF the particle emission level of the vehicle was simulated between the values with and without DPF.

As previously in this preliminary research program the NanoMet was correlated with:
- Gravimetry
- SMPS and
- Opacimetry.

The research program was realised on the chassis dynamometer of Exhaust Gas Control Laboratory, University of Applied Sciences, Biel-Bienne, Switzerland (AFHB).

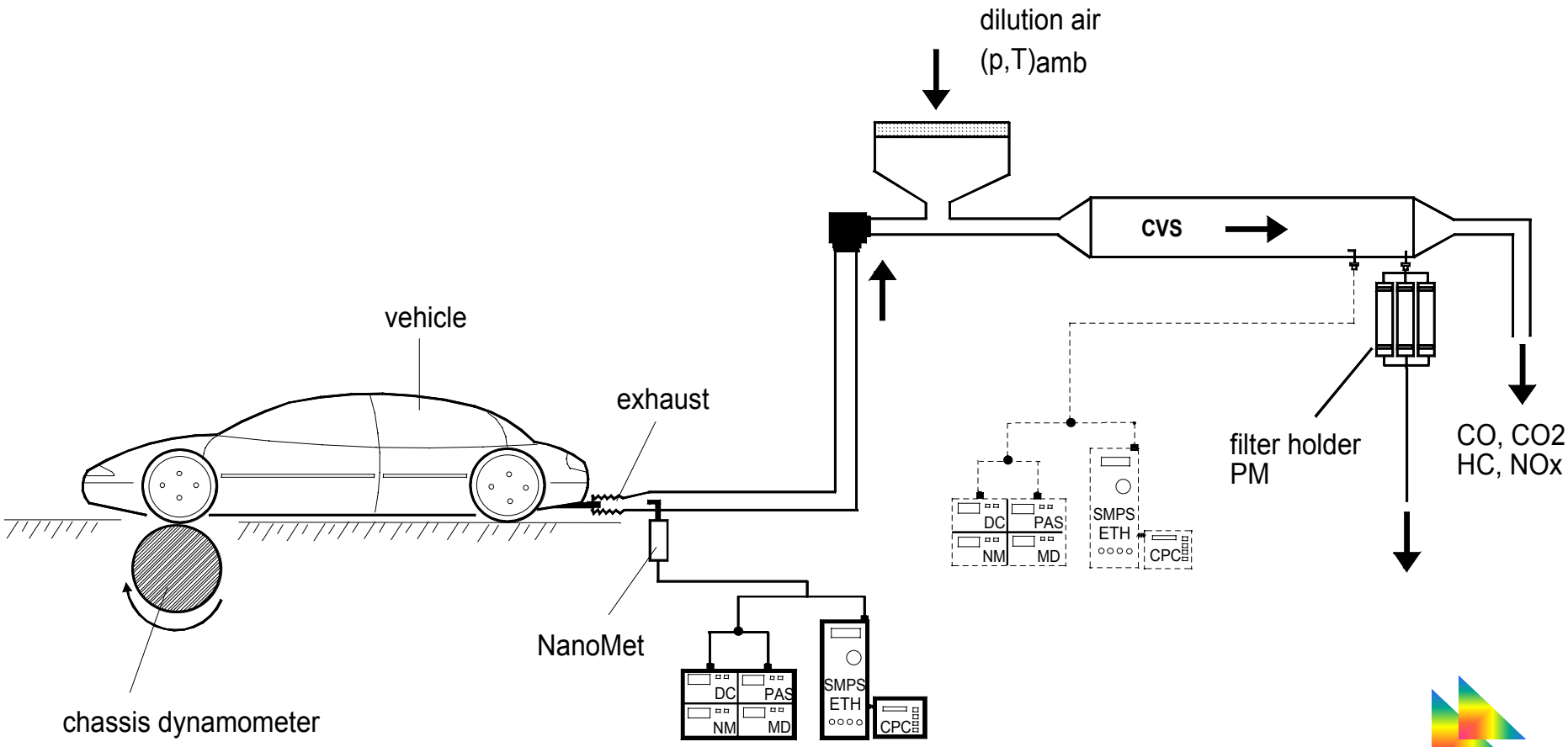
The most important results concerning NanoMet can be summarised as follows:

- There are very good correlations between the NanoMet- and SMPS-results at stationary and at transient operating conditions.
- It was demonstrated that PAS & DC-signals (NanoMet) are much more sensitive for low emitting cases, than the gravimetry, or opacimetry.
- The aptitude of dynamic response of PAS & DC during the free acceleration is sufficient, the sensitivity is higher, than for SMPS set on one NP-size, or for opacimetry.
- The NanoMet is calibrated by the manufacturer according to a fix procedure. There are also recommendations and different calibration possibilities for the user.
- CAST a system supplying combustion standard aerosols for calibration purposes offers a high quality of calibration.
- Diffusion battery a future option for NanoMet, which enables an on-line particle size distribution scanning showed the first very promising results.

The investigated measuring procedures for particle emissions and their most important features can be summarized in the following table:

Opacimetry	**NanoMet**		**SMPS set on 60 nm**	**Gravimetry**
	PAS	**DC**		
	• sensitive to low NP-emissions • calibration procedures available			
• low cost, simplicity • transient ability • field application			• cost, complexity • laboratory application	

Sampling and measuring set-up for nanoparticulates analysis on the chassis dynamometer



Particle Analysis

- SMPS – Scanning Mobility Particle Sizer, TSI (DMA TSI 3071, CPC TSI 3025 A)
- NanoMet – System consisting of:

  PAS – Photoelectric Aerosol Sensor (Eco Chem PAS 2000)

  DC – Diffusion Charging Sensor (Matter Eng. LQ1- DC)

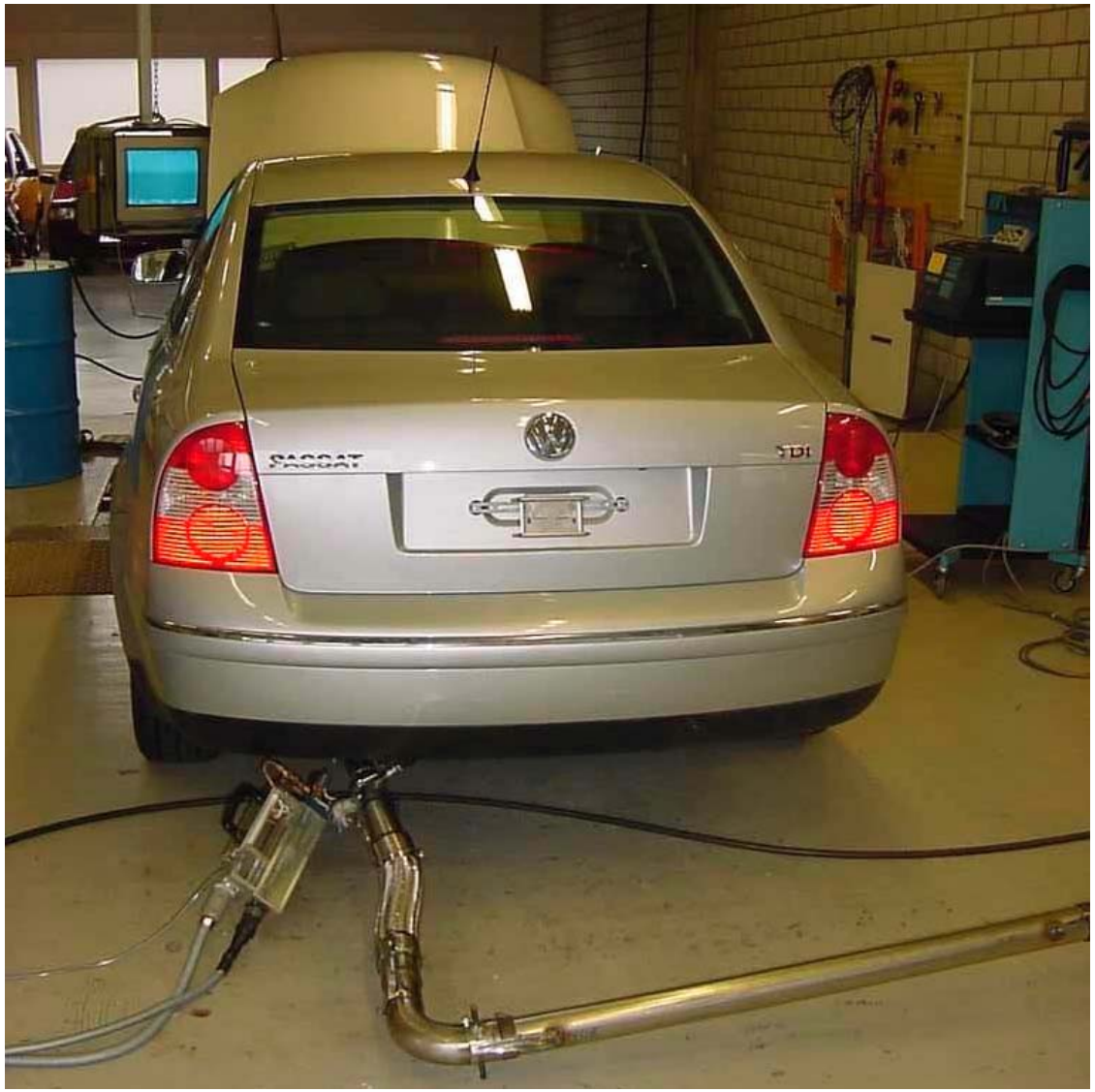
  MD19 tunable minidiluter (Matter Eng. MD19-2E)

Test Procedures

- Constant speeds:
  50, 80, 110 km/h
- Parts of driving cycles warm:
  EURO-city, EURO-EUDC, FTP 75 (ht)
- Free accelerations

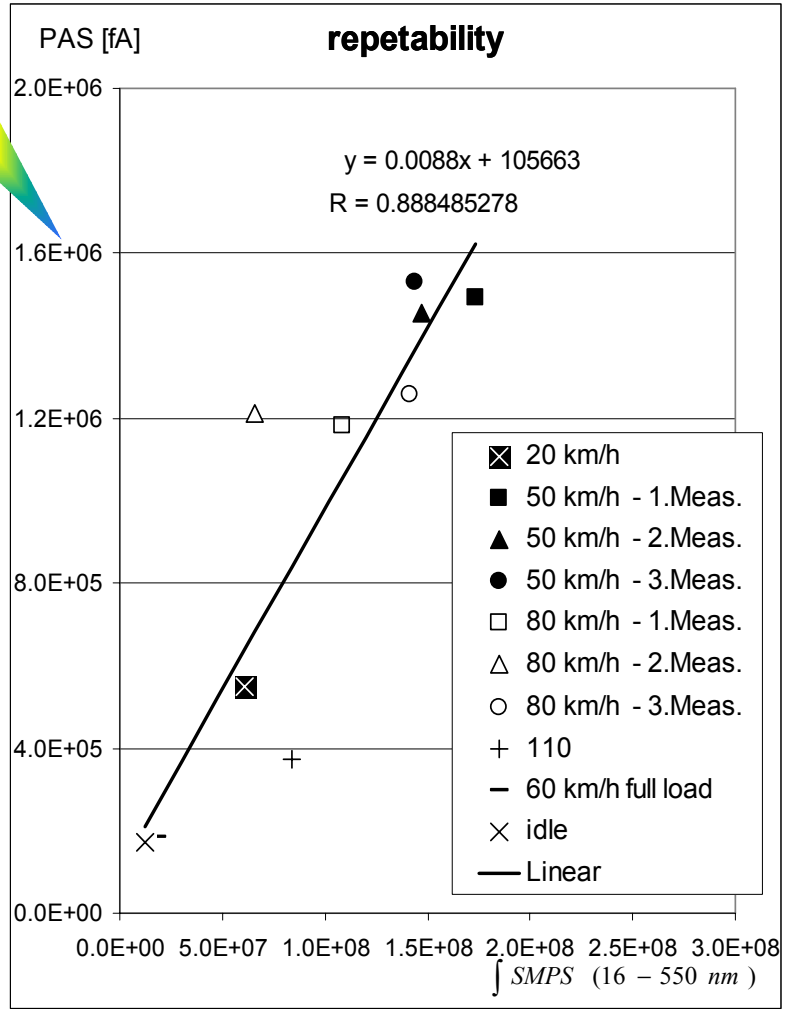
Peugeot 607 2.2L with DPF

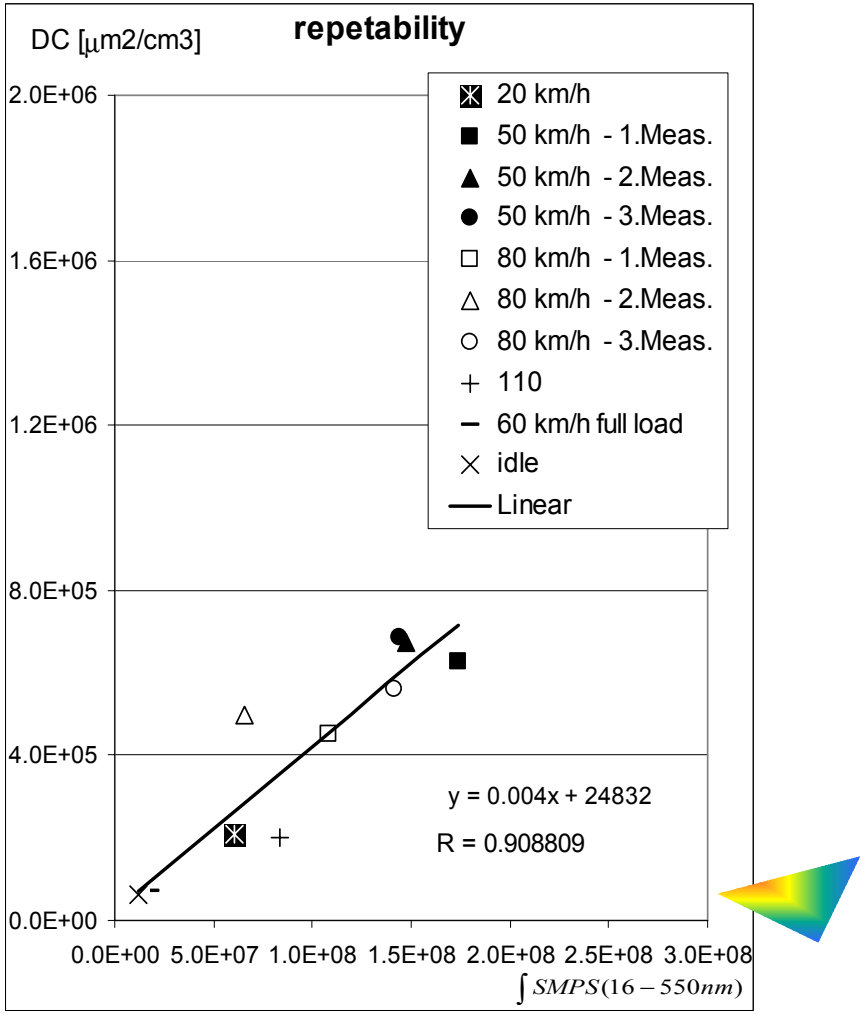
VW Passat TDI 1.9 L (w/o DPF)



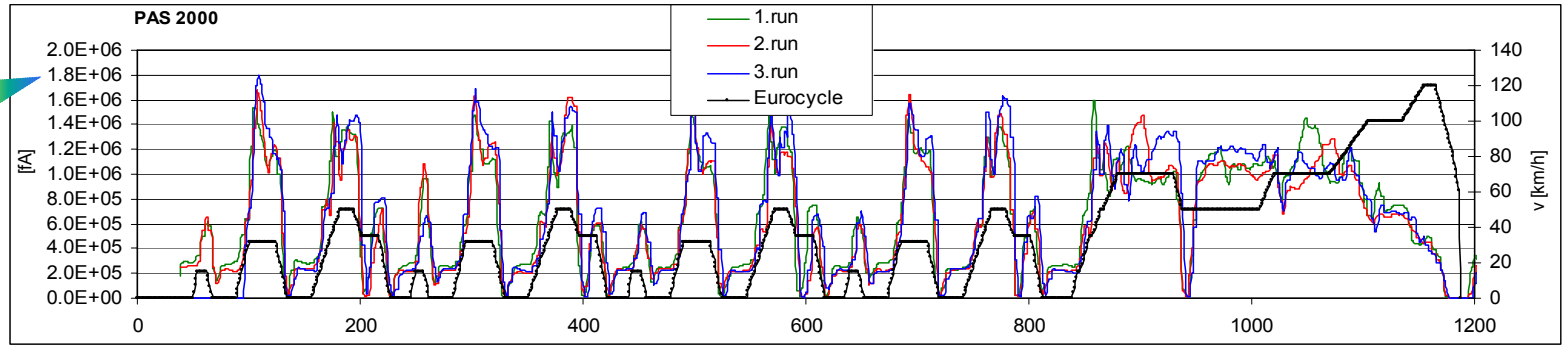
Constant speeds

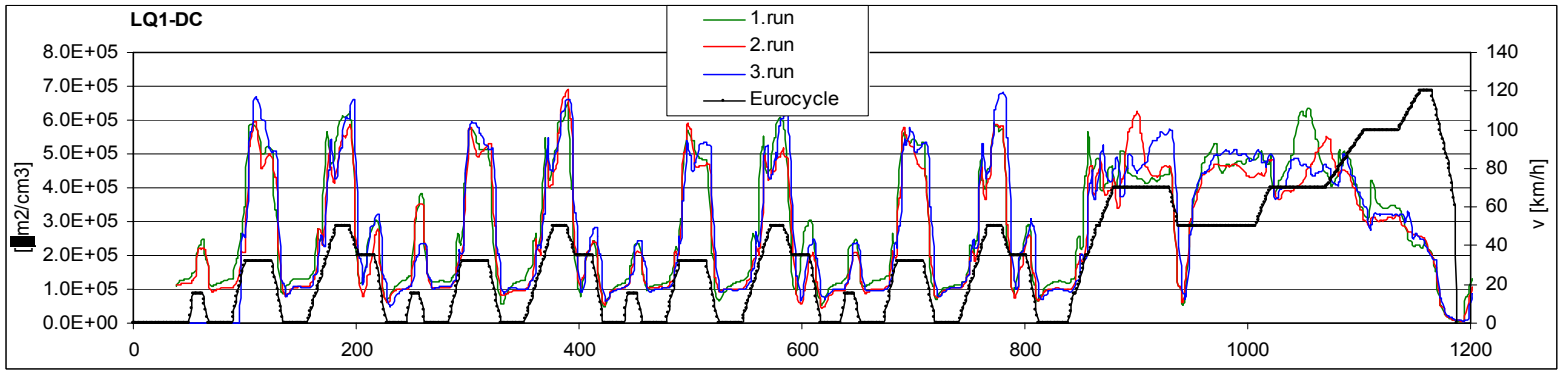
Correlation between the integrated results of NanoMet and SMPS
VW Passat

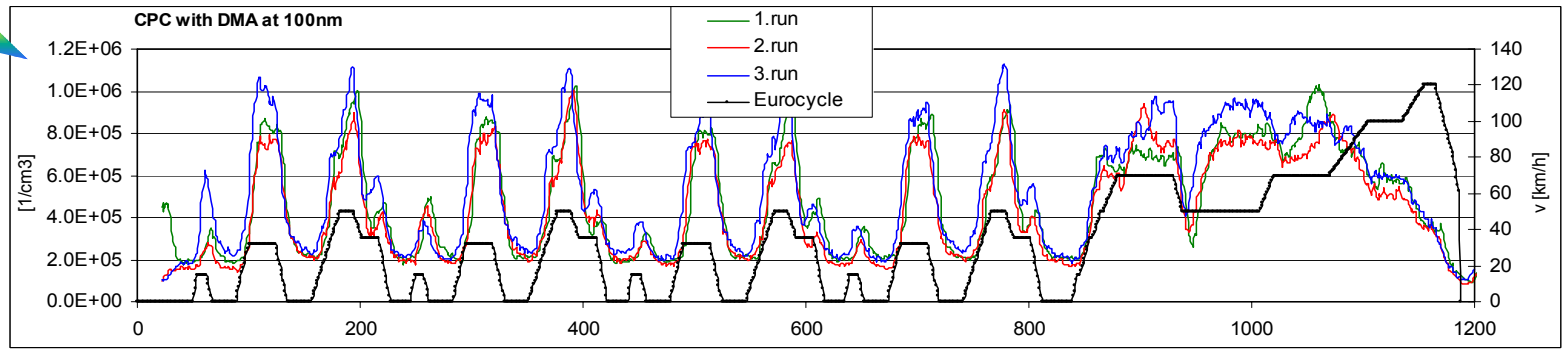




VW Passat - EURO + EUDC cycle, NanoMet & CPC (SMPS) at 100 nm

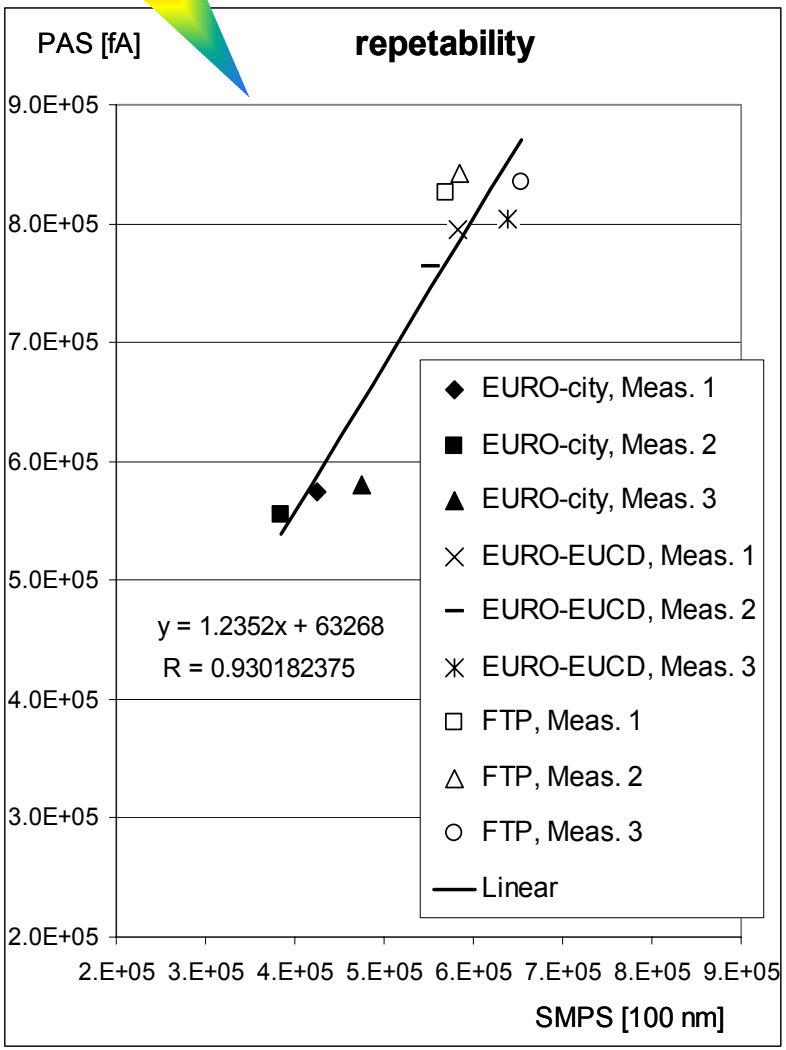


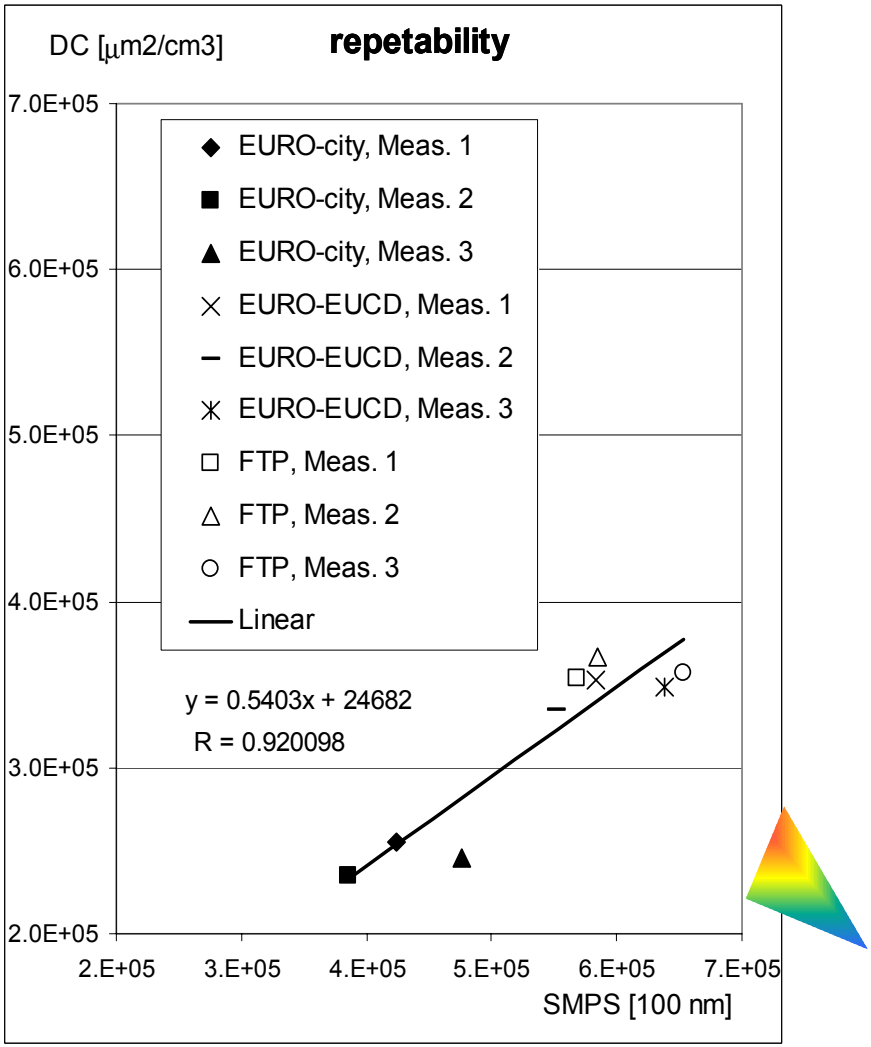




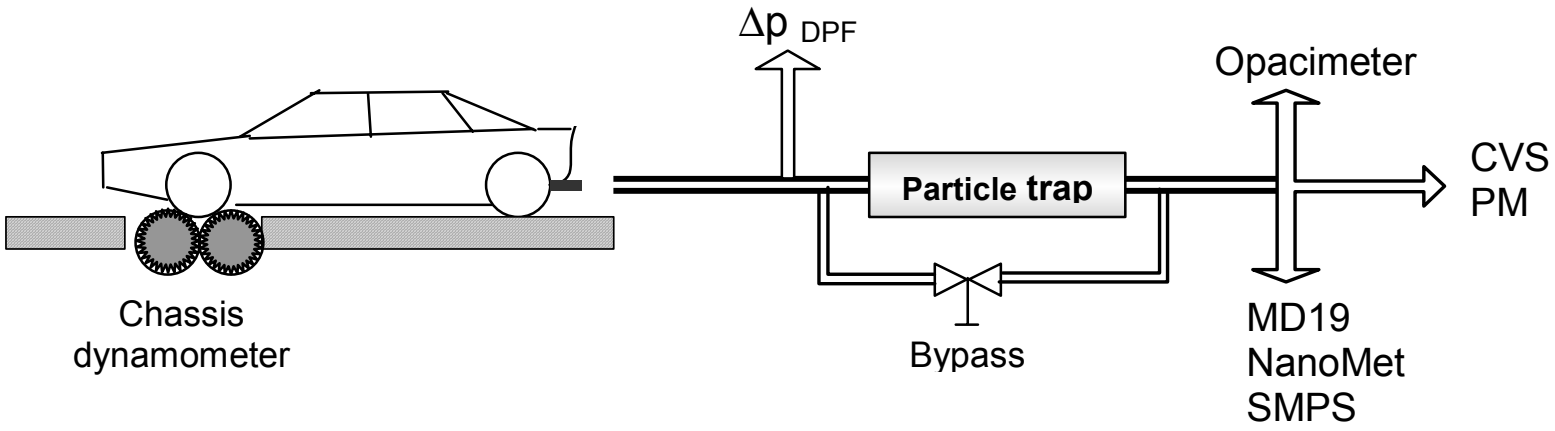
Transient driving cycles

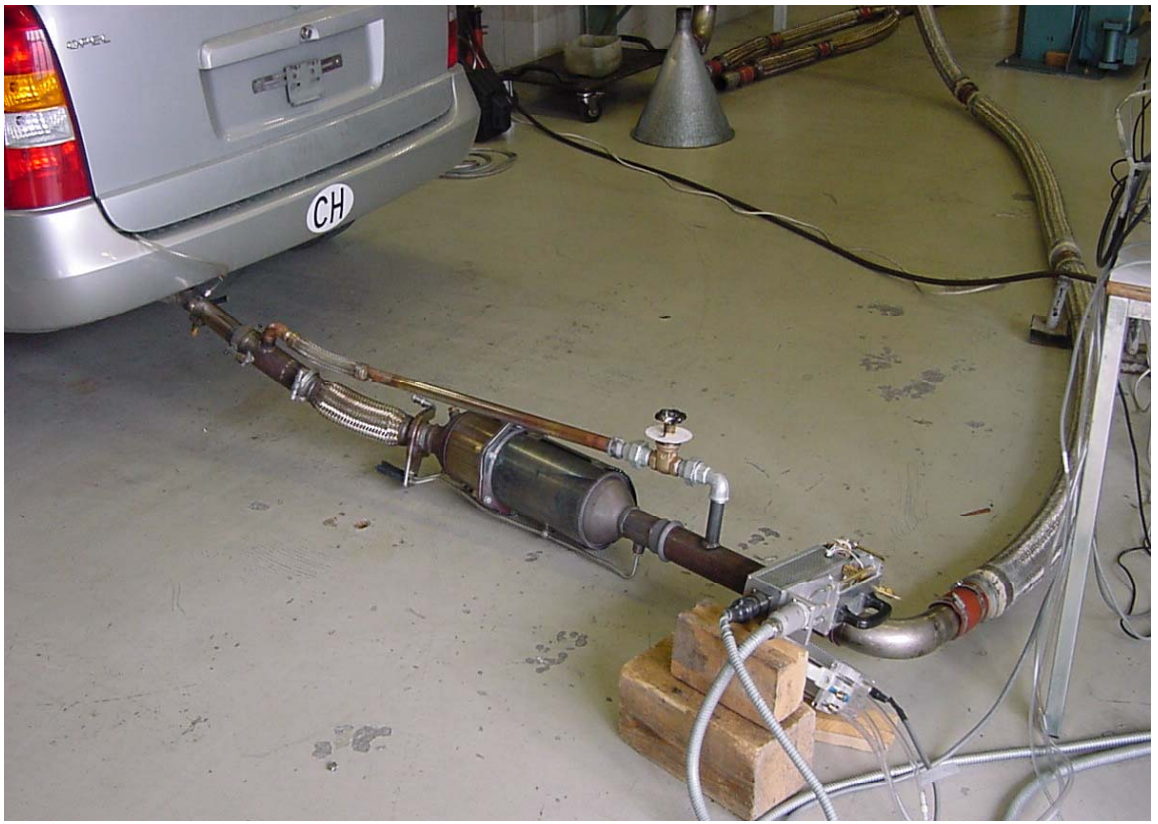
Correlation between the integral average results of NanoMet and SMPS
VW Passat





SiC DPF with bypass (BP) at the tailpipe



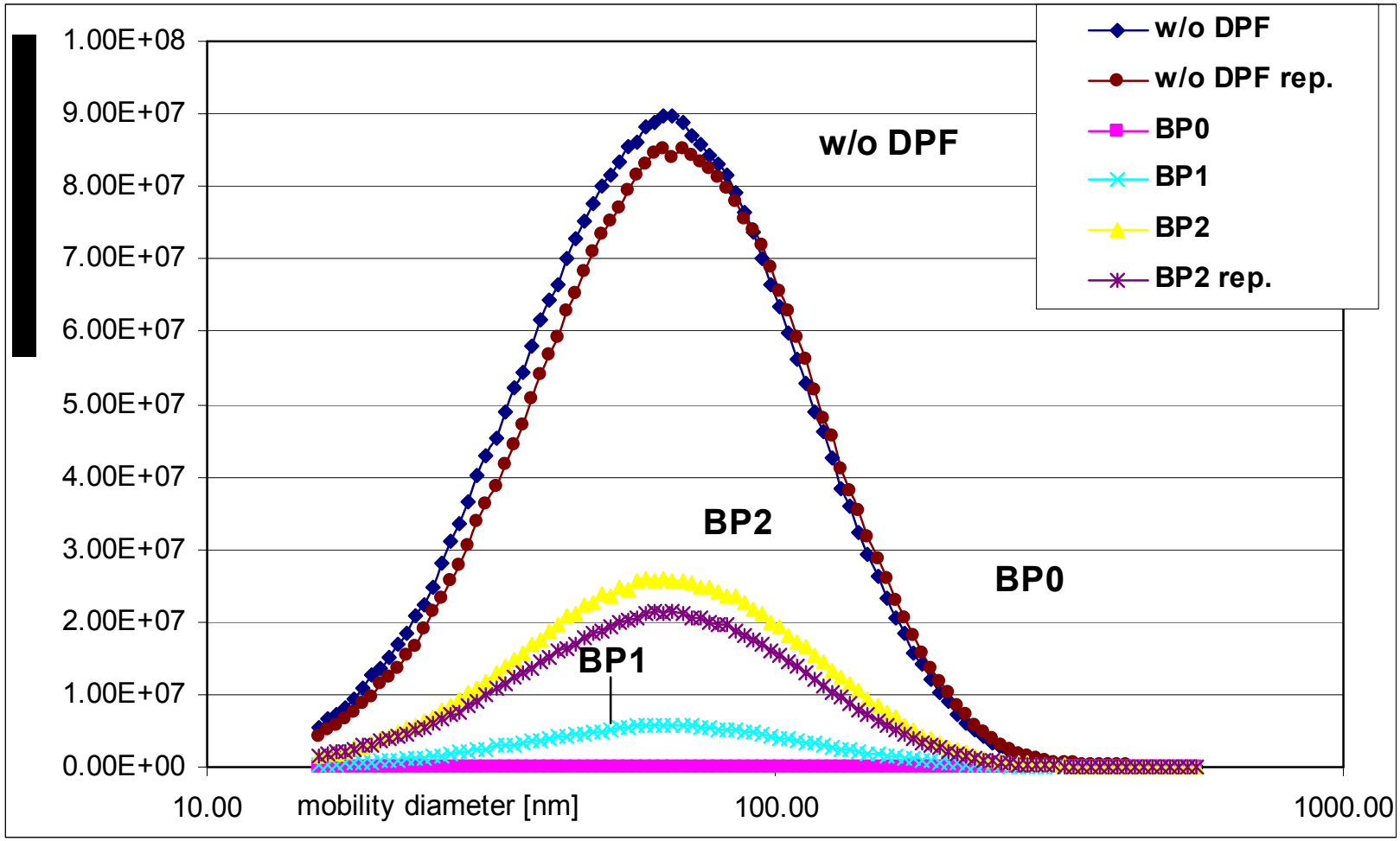


DPF-BP-variants

without DPF	w/o DPF
with DPF, bypass closed	DPF + BP 0
with DPF, bypass partially open	DPF + BP 1
with DPF, bypass 100 % open	DPF + BP 2

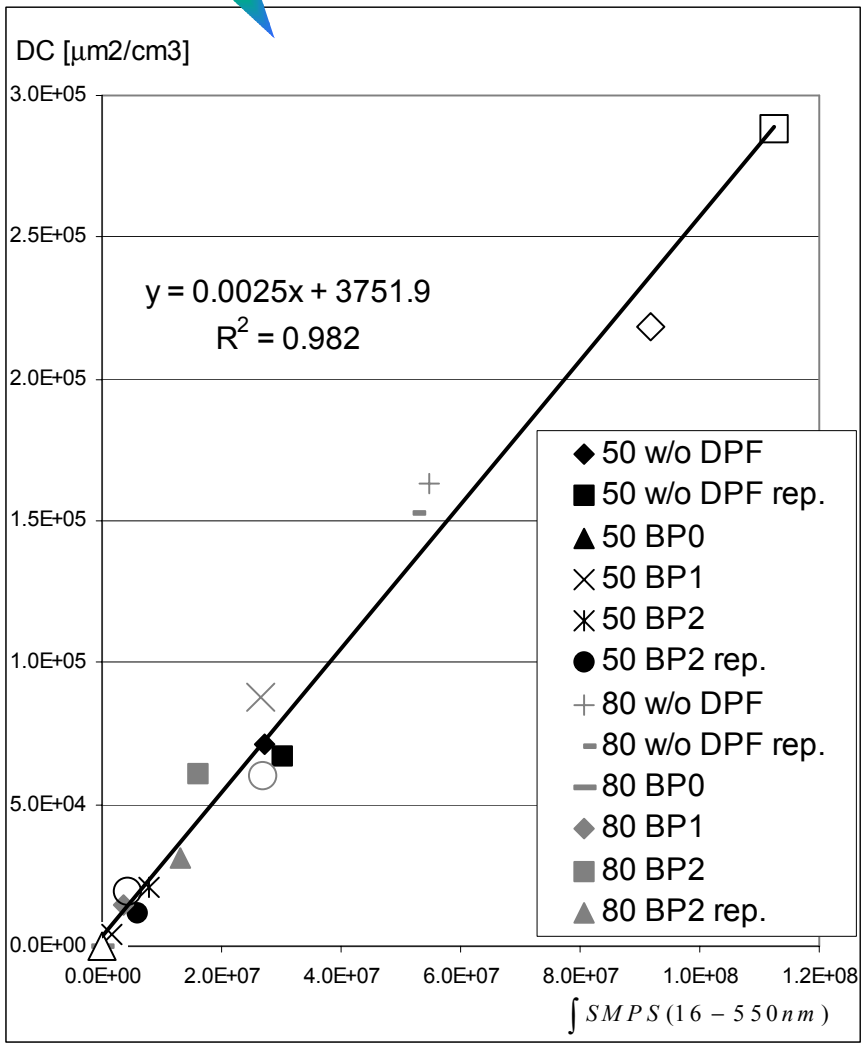
SMPS-Particle Size Distribution at v=80 km/h with different bypass settings (BP)

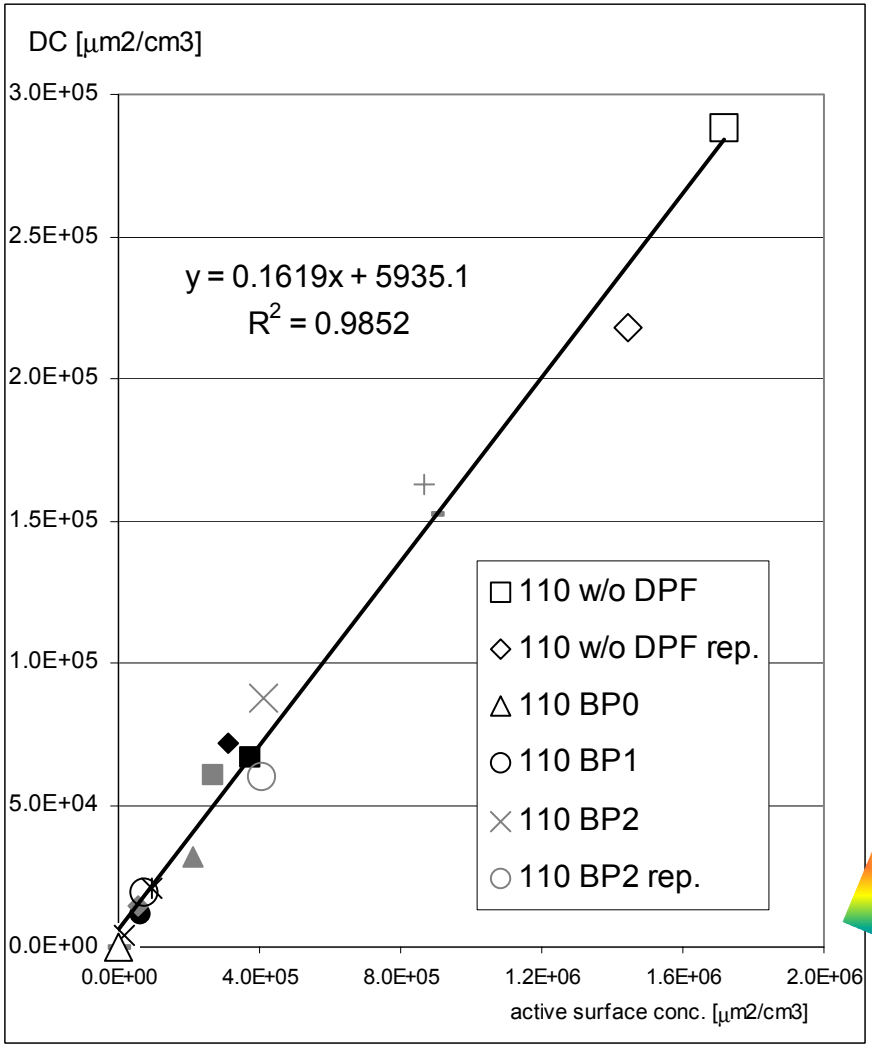
mean of 3 samples



Constant speeds

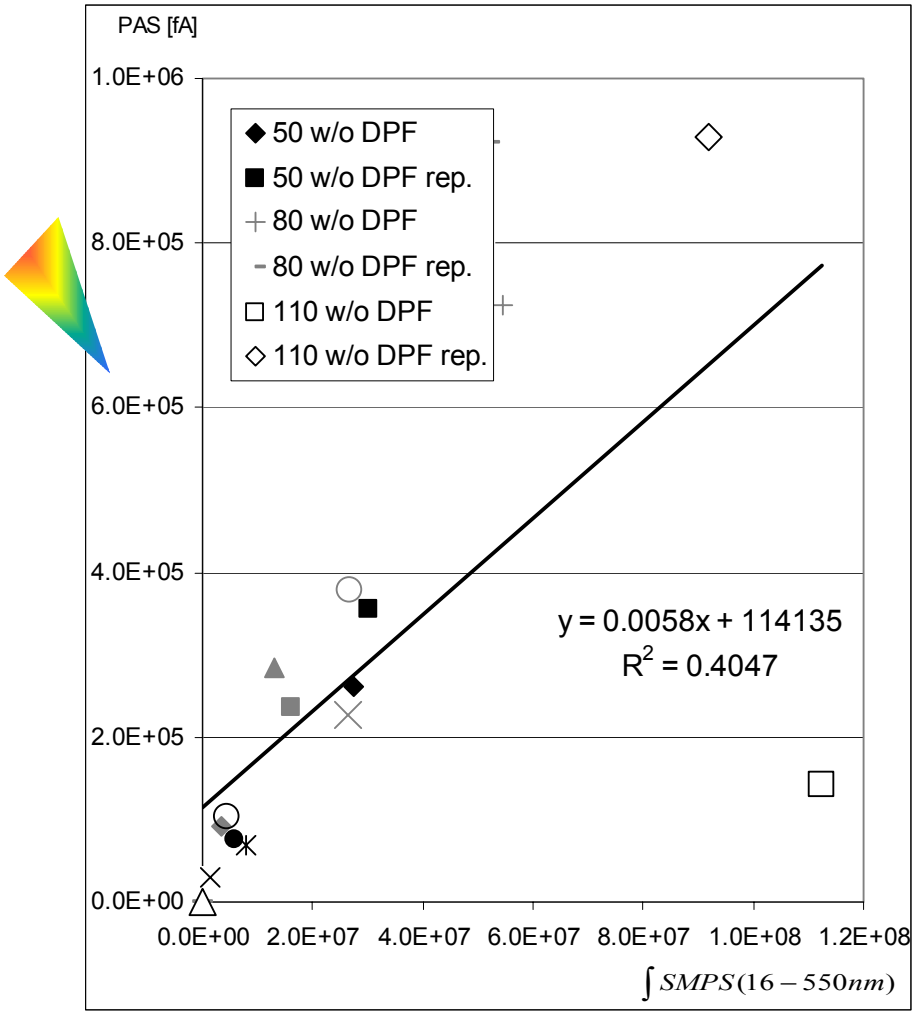
Correlations: DC ---> SMPS (16 - 550 nm)

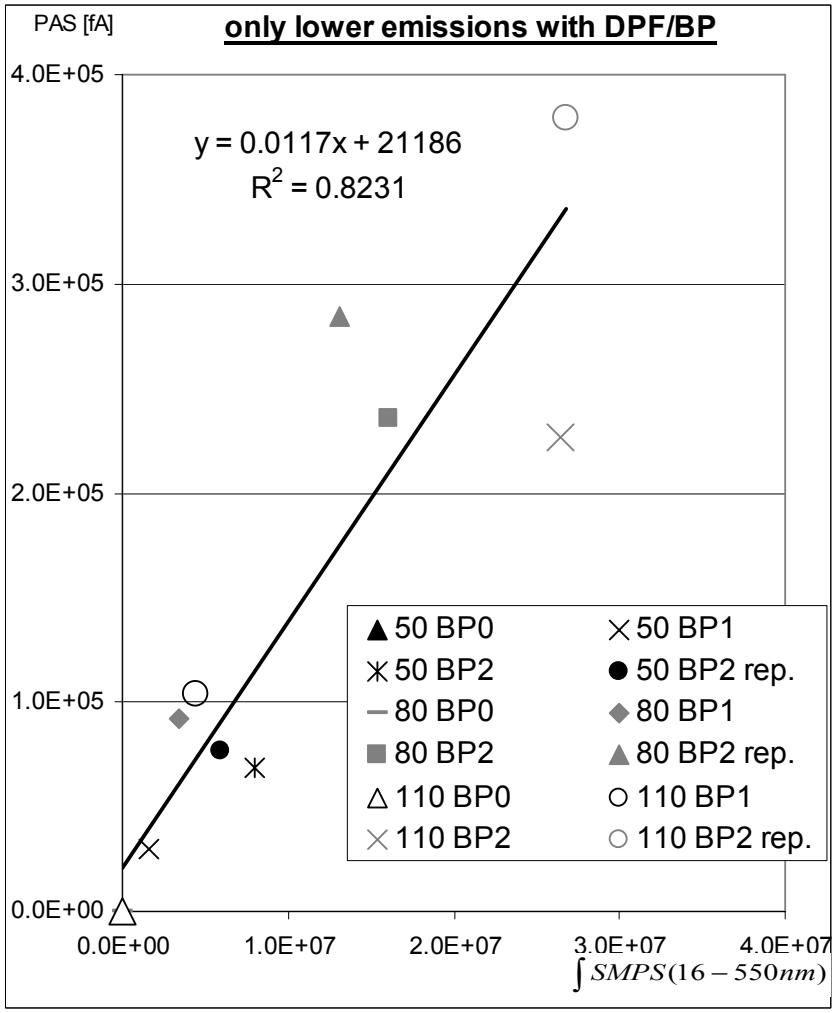




Constant speeds

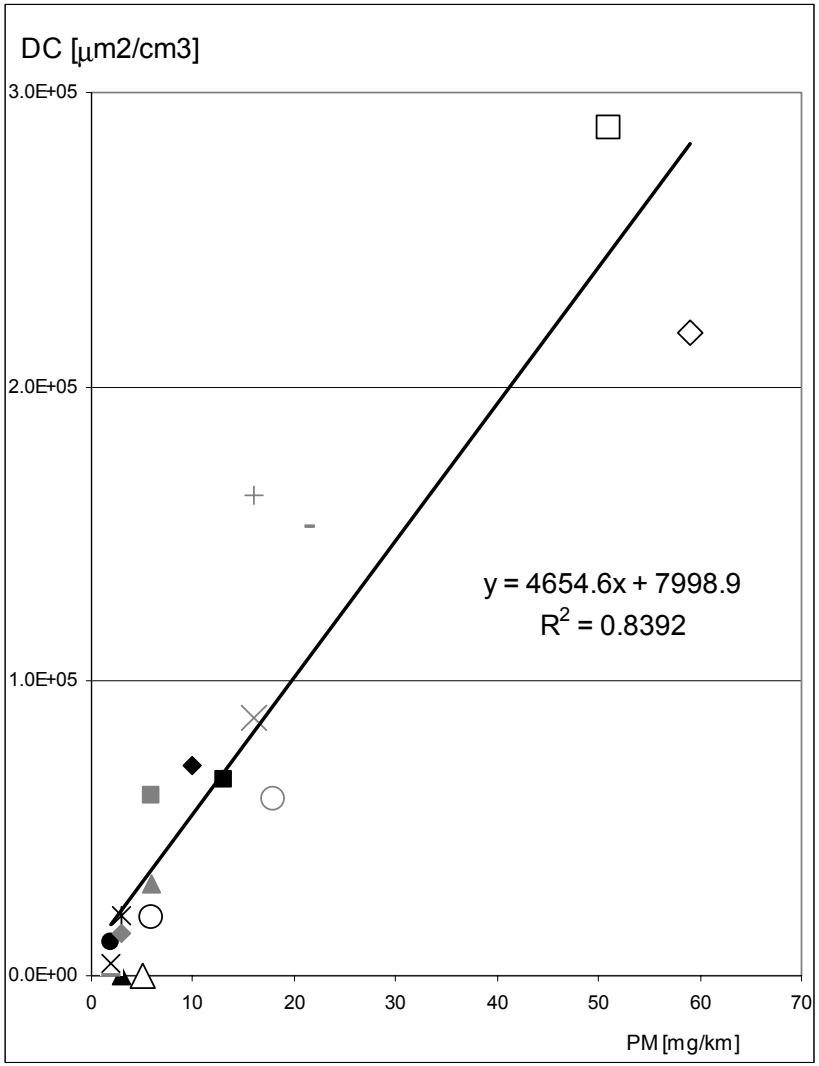
Correlations: PAS ---> SMPS (16 - 550nm)

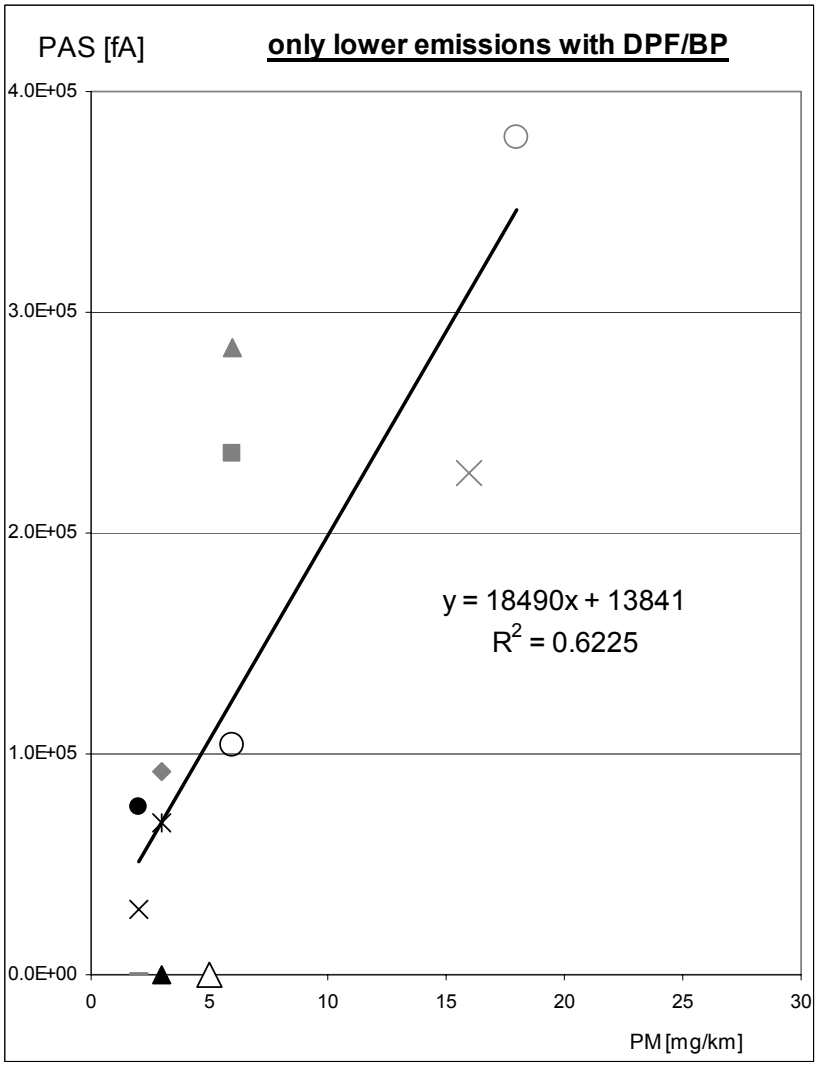




Constant speeds

Correlations: DC ---> PM; PAS ---> PM





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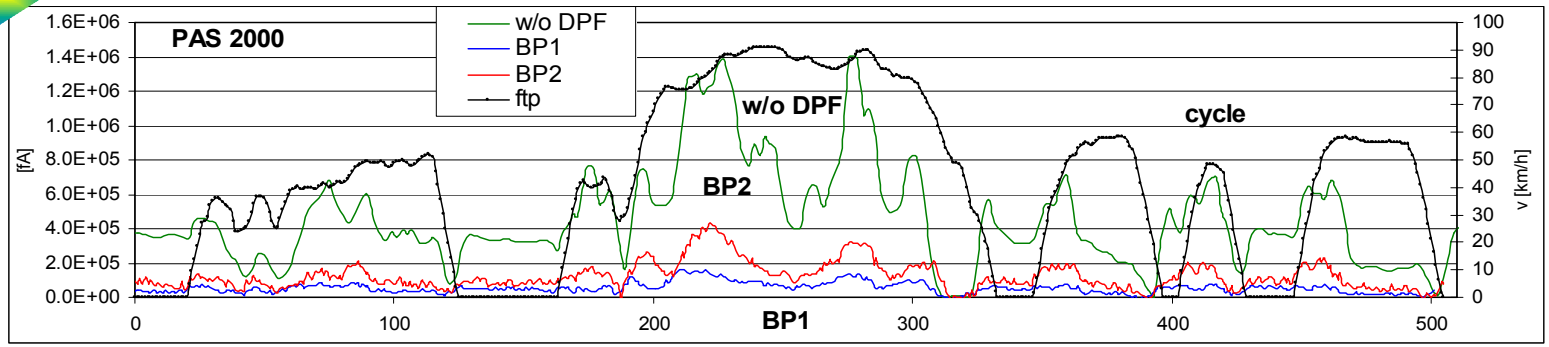
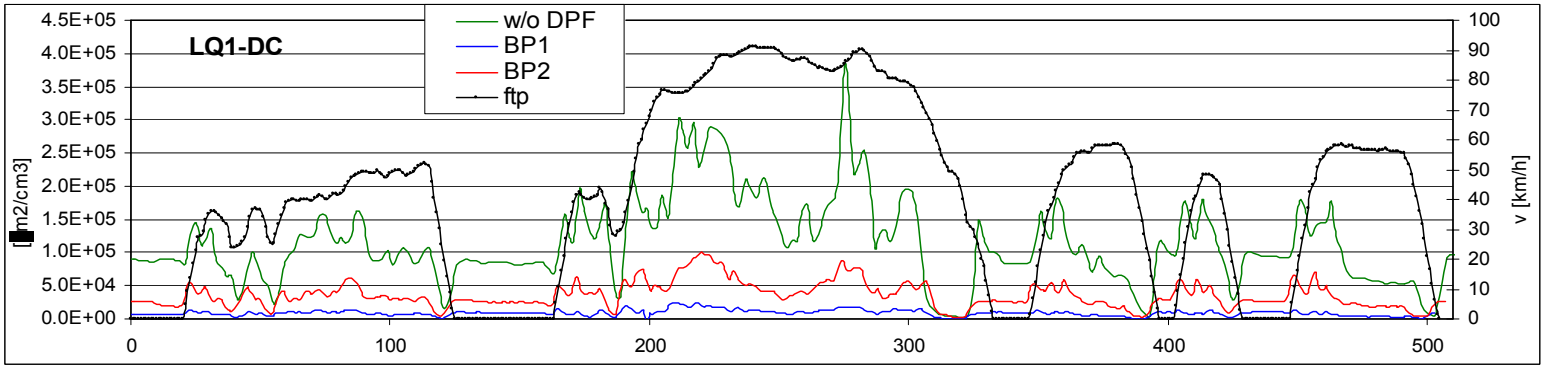
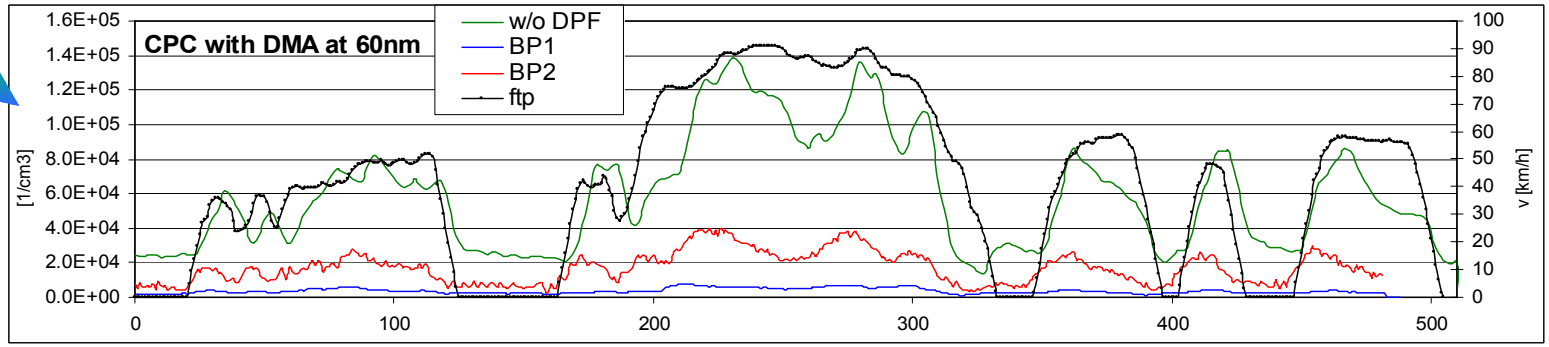
NanoMet and CPC – FTP-Cycle



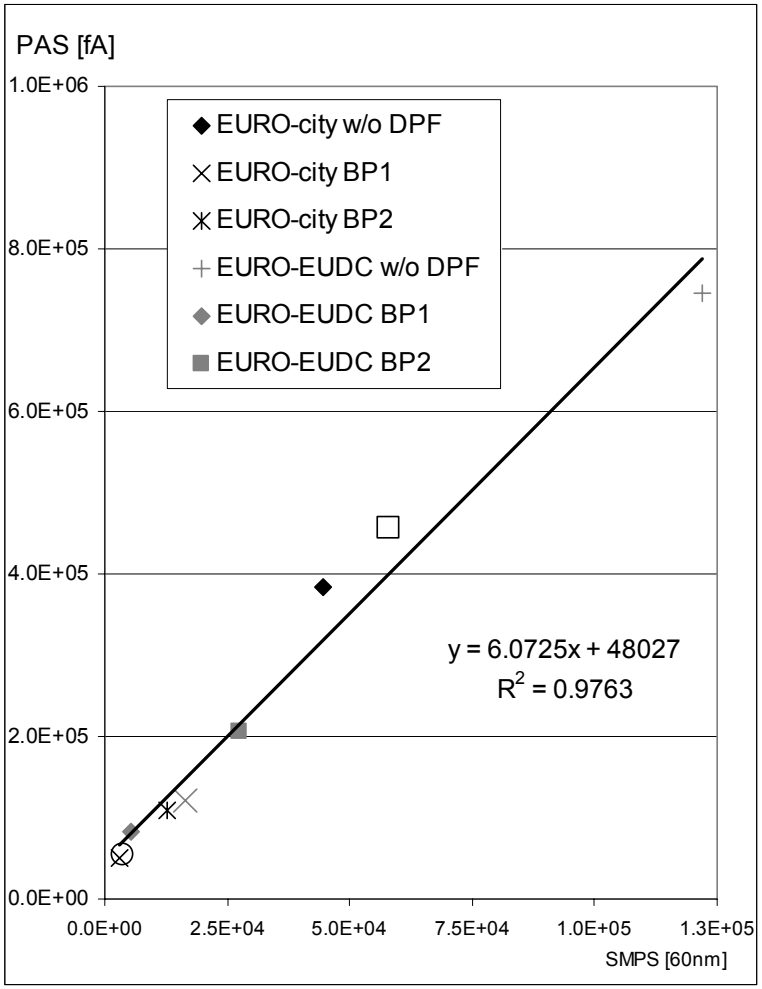


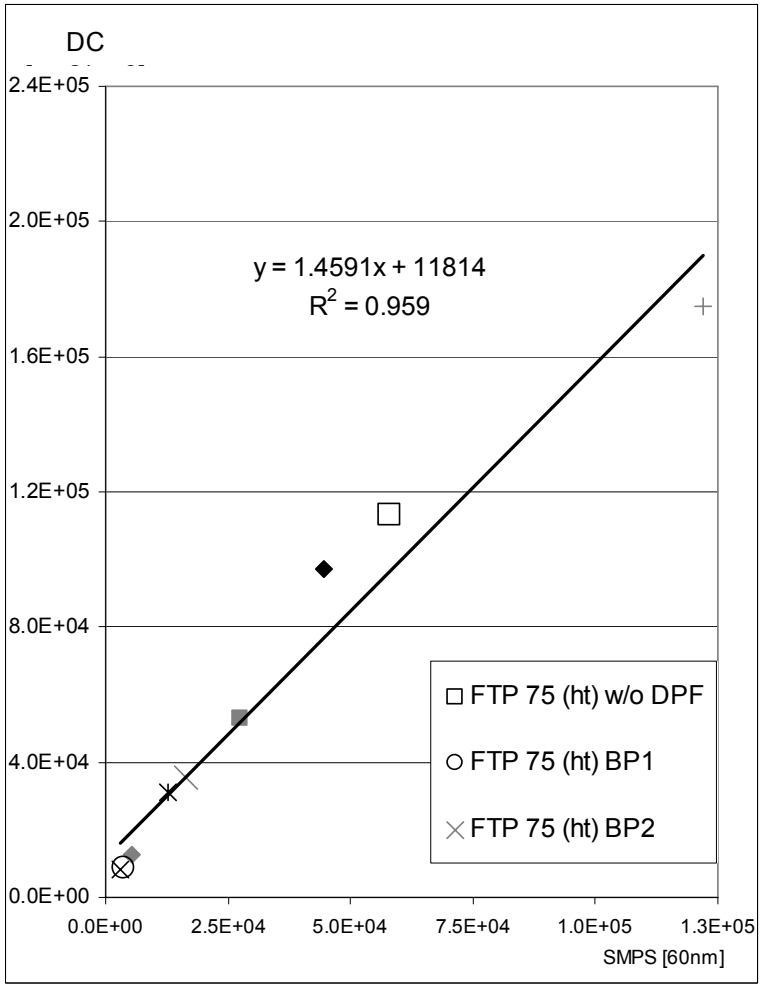


Transient driving cycles

Correlation between the integrated results of NanoMet and SMPS

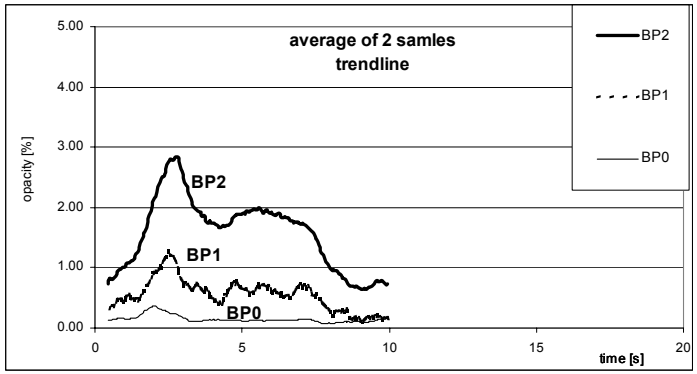
(time integral average, SMPS at 60nm)

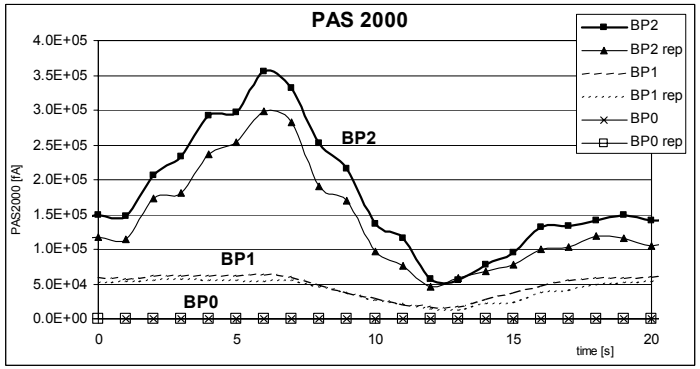


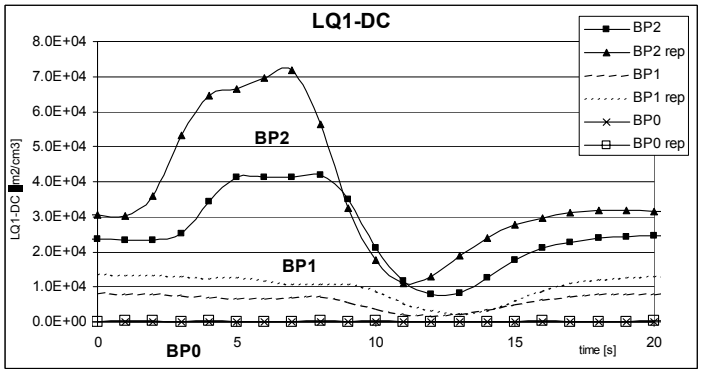


Nanomet & opacity during the free acceleration

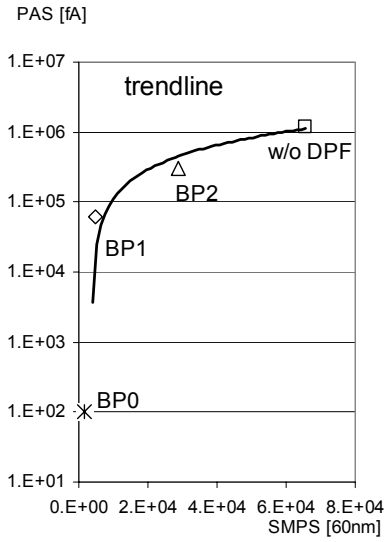
larger scale for lowest values

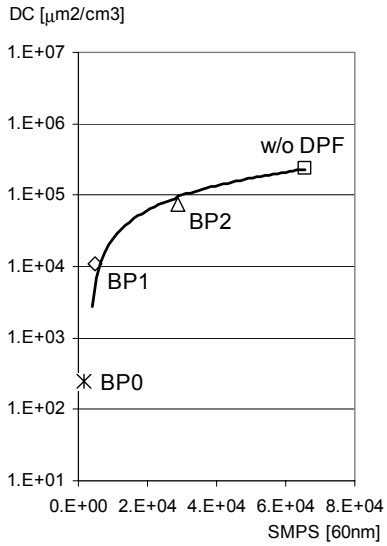


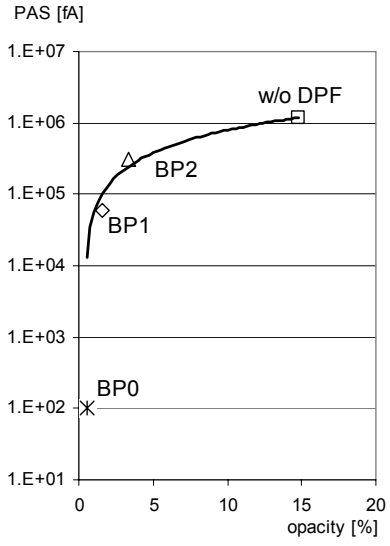


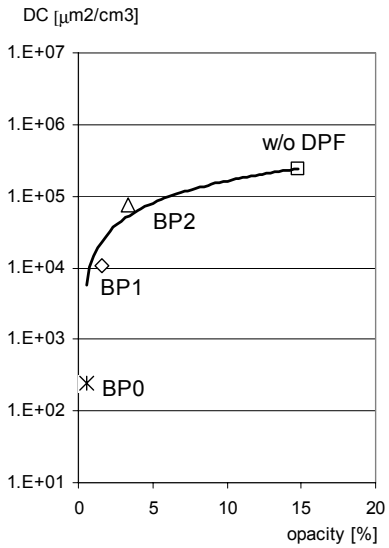


Correlations of the maximal values of the particle emission parameters during the free acceleration









Conclusions

- There are very good correlations between the NanoMet- and SMPS-results at stationary and at transient operating conditions.
- It was demonstrated that PAS & DC-signals (NanoMet) are much more sensitive for low emitting cases, than the gravimetry, or opacimetry.
- The aptitude of dynamic response of PAS & DC during the free acceleration is sufficient, the sensitivity is higher, than for SMPS 60 nm, or opacimetry.
- Calibration procedures are resolved.
- Diffusion Battery (available in the near future) is an option of NanoMet to scan the PSD-spectra.