

AVL TechDay 2013
JRC, Ispra



PN to PM Correlation

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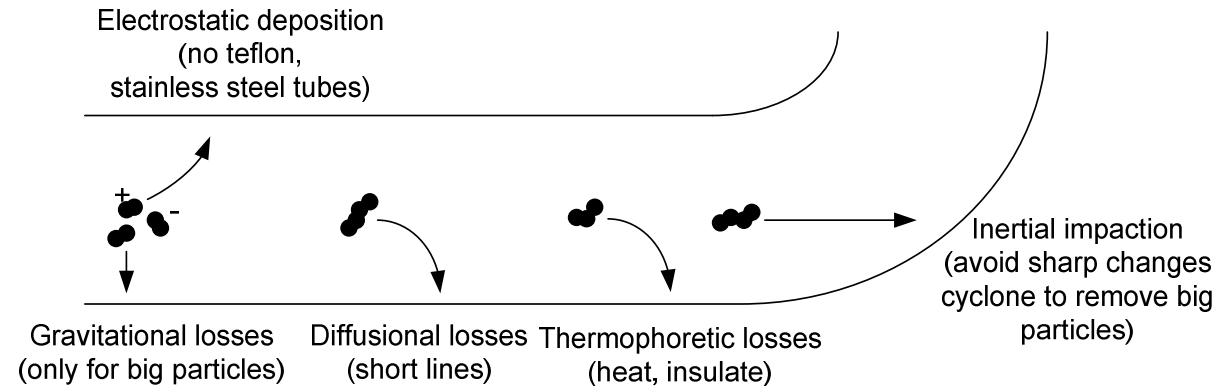
OUTLINE



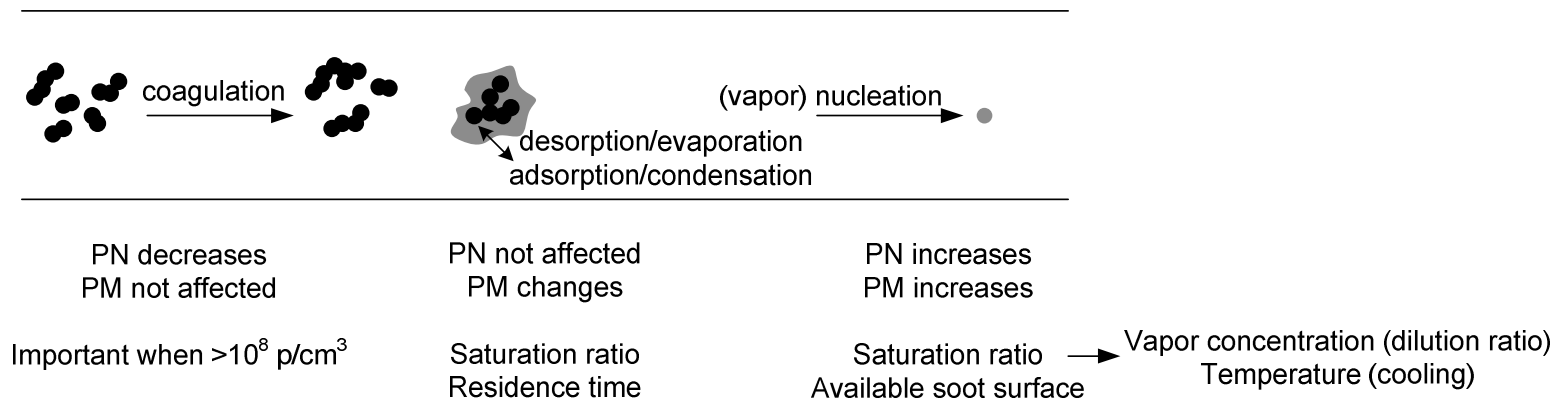
- Overview about particle formation, losses and dynamics
- Relation between PM and PN: How do they fit together?
- PM and soot mass vs. PN – Discussion of examples
- Conclusions

PARTICLE LOSSES AND DYNAMICS

PARTICLE LOSSES

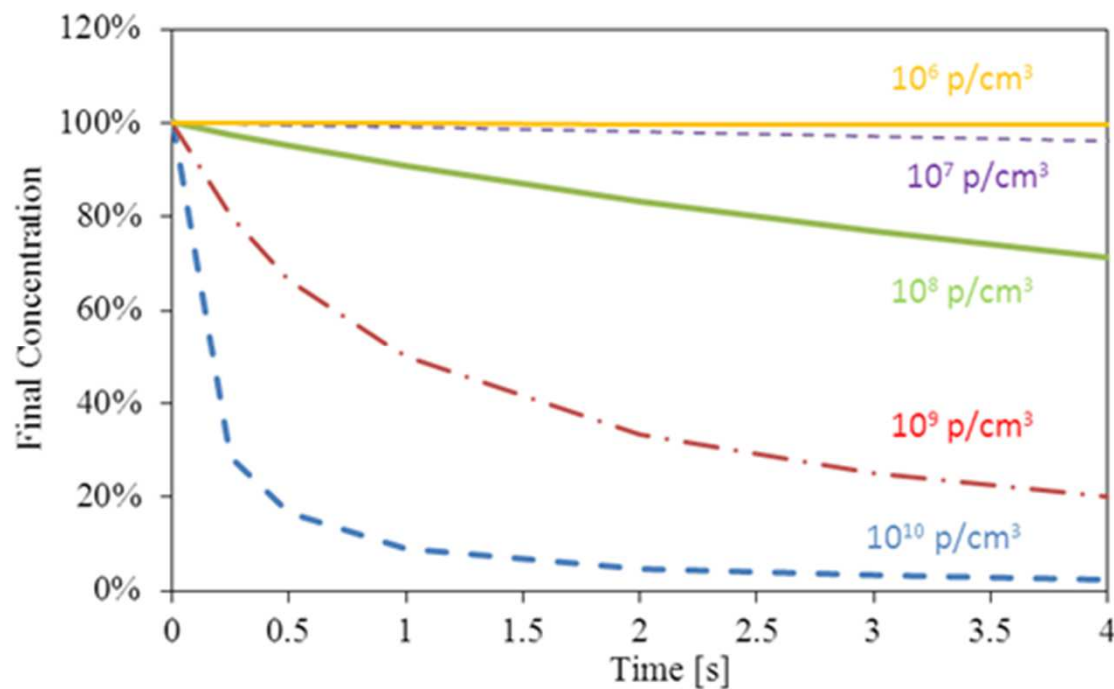


PARTICLE DYNAMICS & TRANSFORMATION



Kittelson et al. (1999) Review of diesel particulate matter sampling methods. Final report for EPA

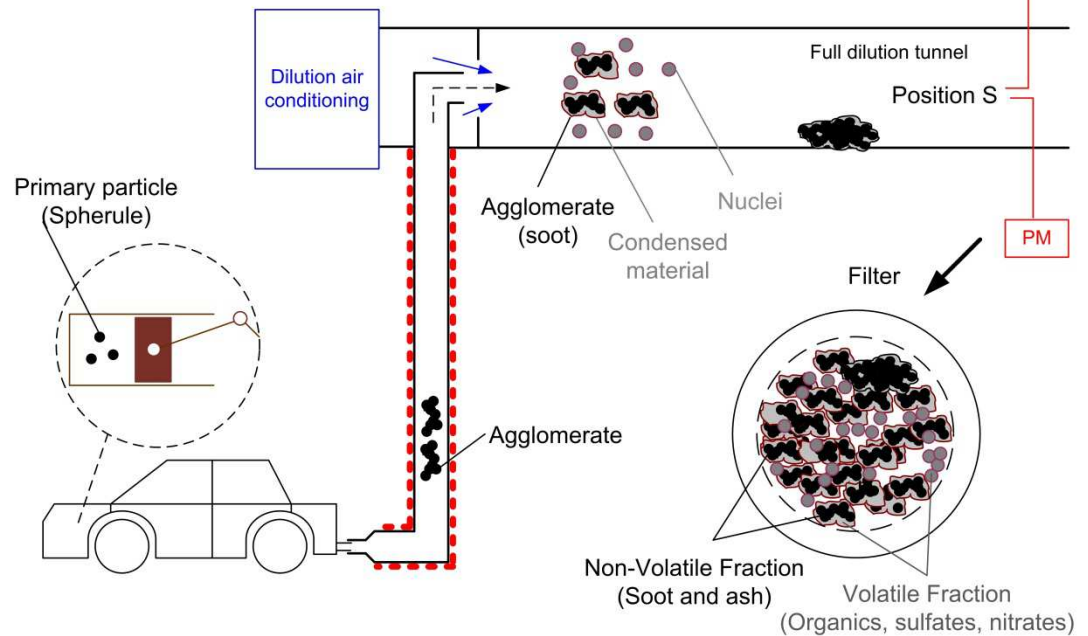
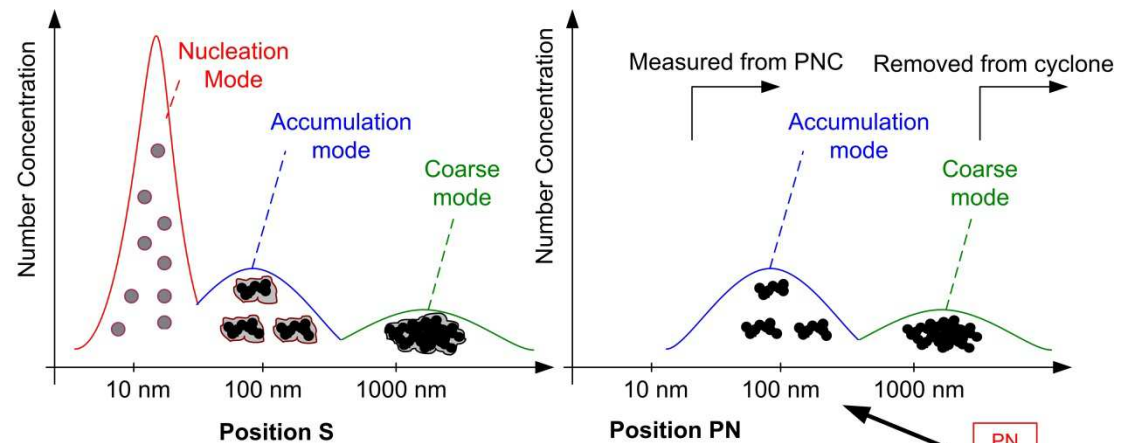
EFFECT OF AGGLOMERATION



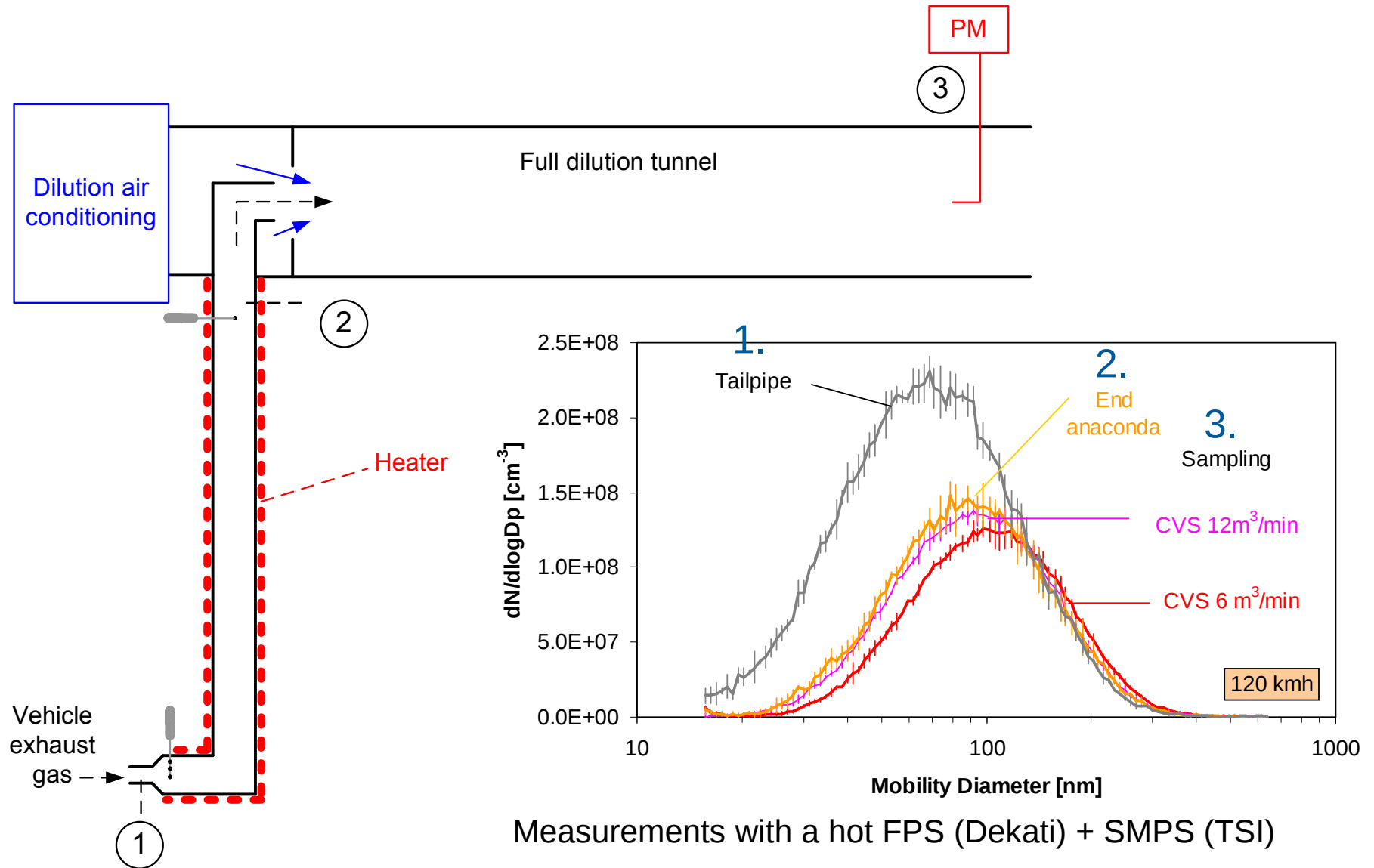
Effect of agglomeration on particle number concentration ($K=10^{-15} \text{ m}^3/\text{s}$).

- Concentration remains almost constant at low initial concentrations ($<10^7 \text{ p/cm}^3$)
- A concentration of 10^8 p/cm^3 for 50 nm particles decreases by ~23% in 3 s, and the particle diameter increases by ~4.6 nm.
- Agglomeration is not important for post-DPF applications

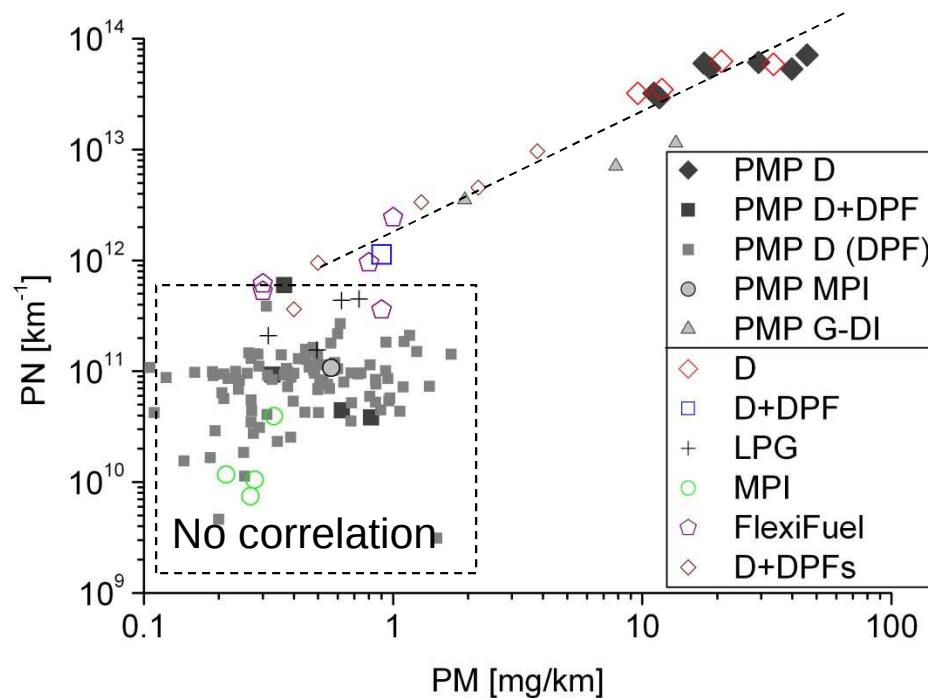
PM & PN FORMATION AND DYNAMICS



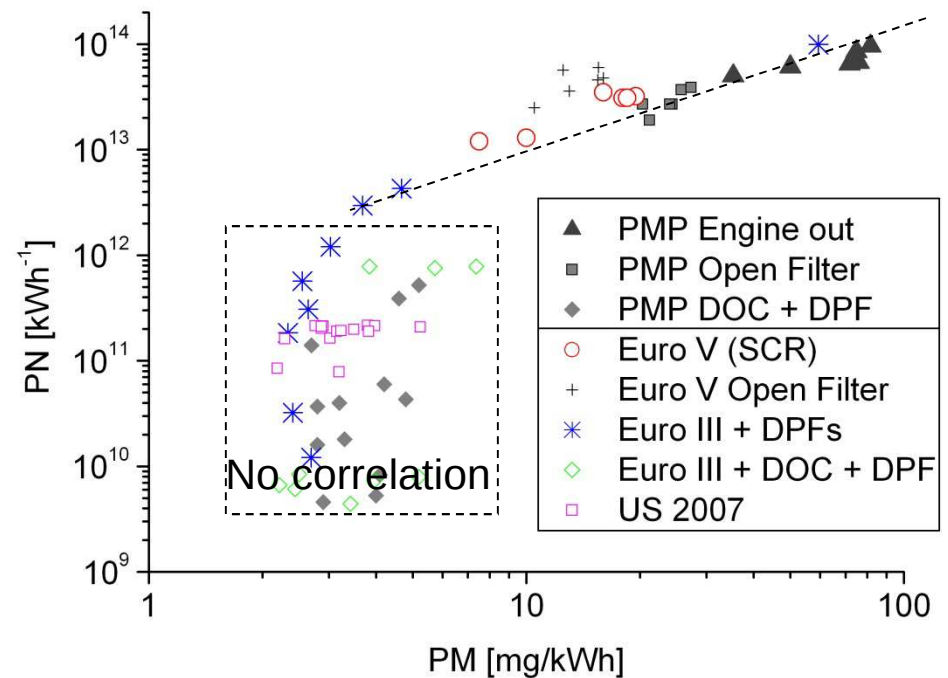
SAMPLING POSITION EFFECT ON PN AND SIZE DISTRIBUTION



CORRELATION BETWEEN PN AND TOTOAL PM

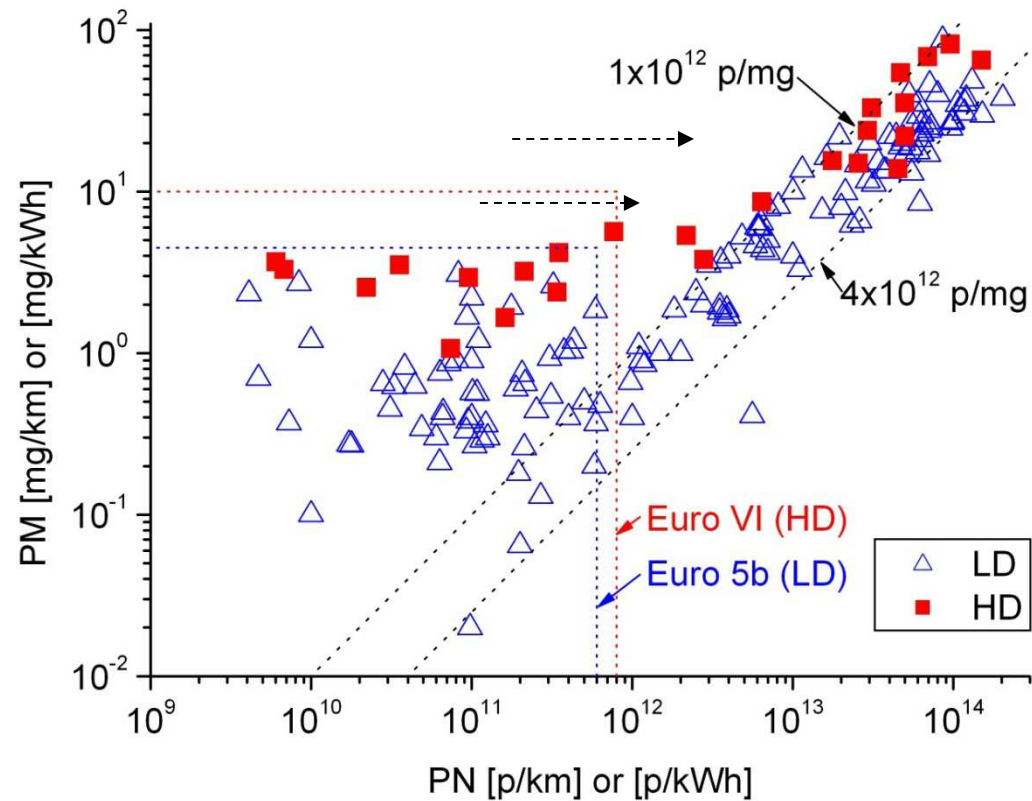


Grey solid symbols are data from the PMP light duty inter-laboratory exercise with the light duty golden instrument (Rotating disk type from Matter Eng.). Colored open symbols are data with APCs at various laboratories. Each point is a different vehicle or a different fuel (exception for D (DPF) PMP, which is the golden vehicle, all labs results are given). D=Diesel, DPF=Diesel Particulate Filter, MPI=Multi Point Injection, G-DI=Gasoline Direct Injection, LPG=Liquefied Petroleum Gas.



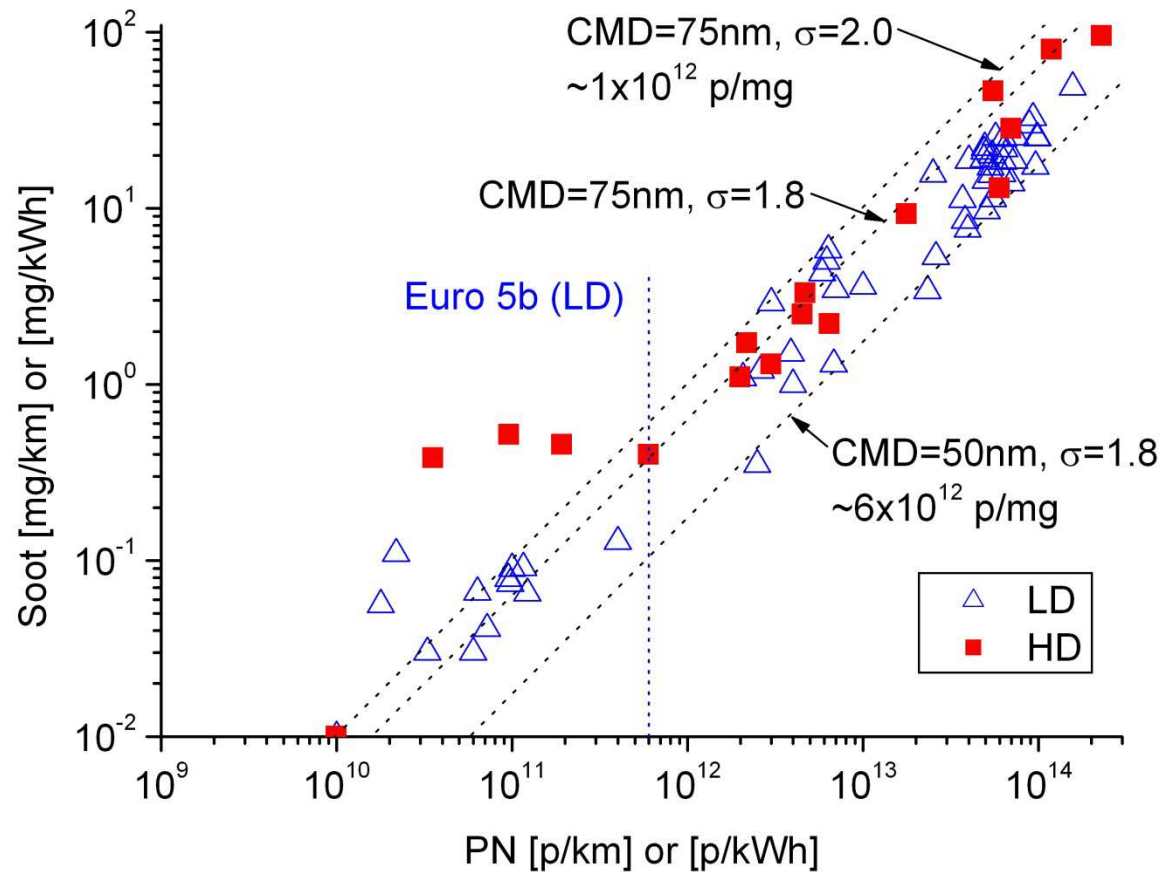
Comparison of the PN with the regulated PM emissions for different heavy duty engine technologies. Grey solid symbols are data from the PMP heavy duty inter-laboratory exercise with the heavy duty Golden instrument (SPCS prototype). Colored open symbols are measurements with APCs at JRC and AVL. Each point is a different engine or test cycle. DOC=Diesel Oxidation Catalyst, DPF=Diesel Particulate Filter, SCR=Selective Catalytic Reduction for NOx.

CORRELATION BETWEEN PN AND TOTOAL PM



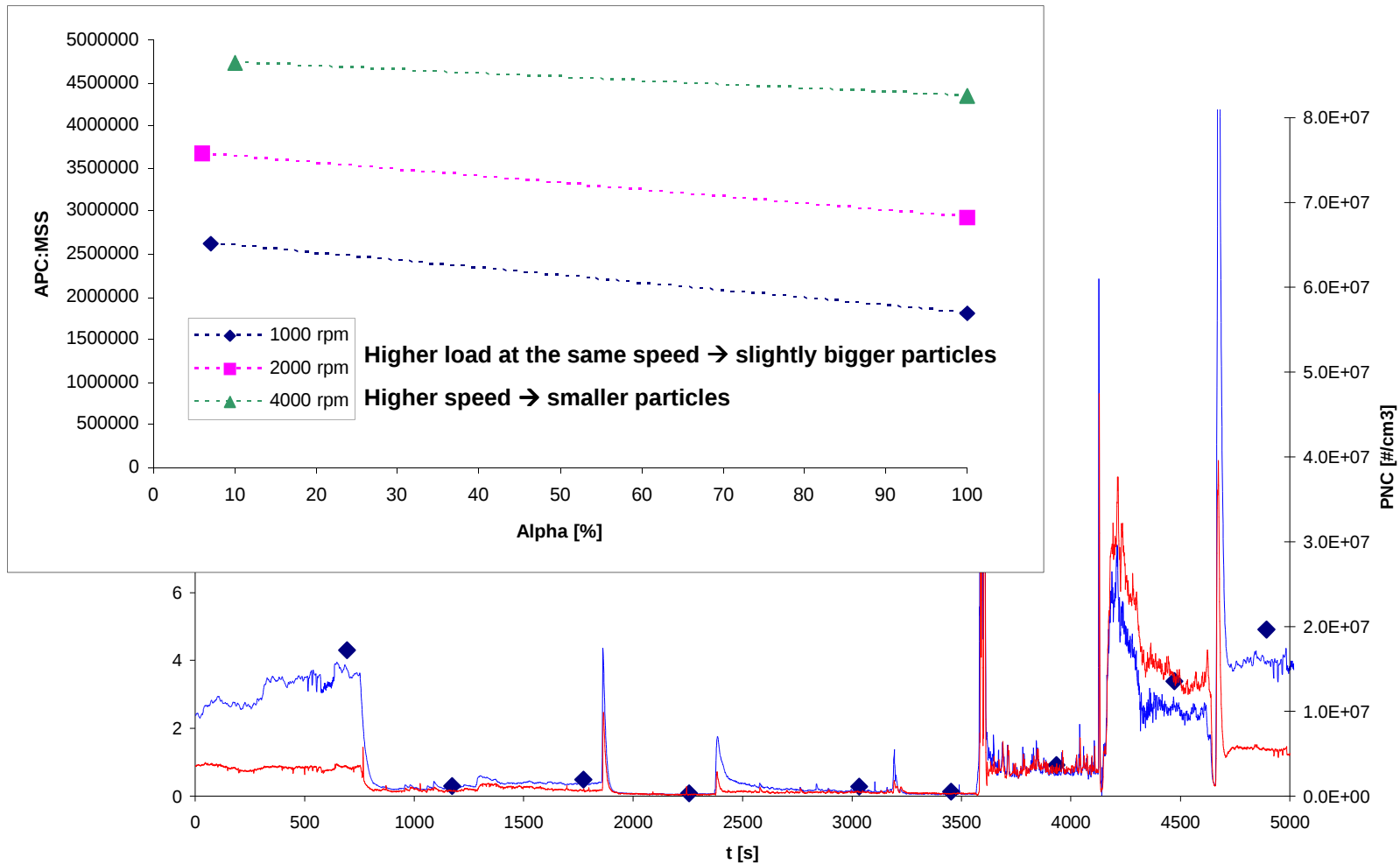
- Correlation is given for quite high PM values.
- At high PM usually a quite high non-volatile fraction (soot) is found. increases by ~4.6 nm.

CORRELATION BETWEEN PN AND BC



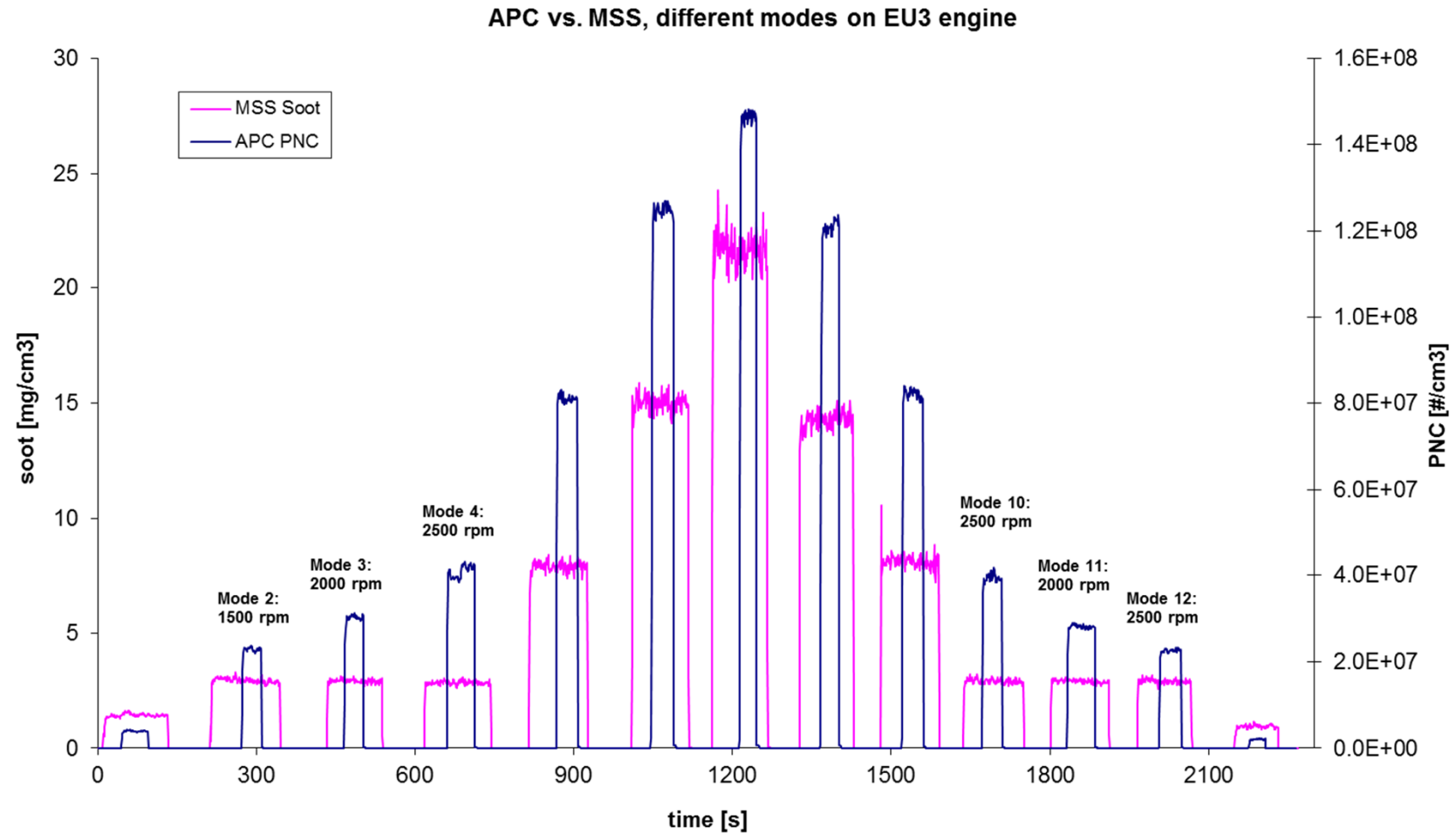
BC measurement correlates quite well to PN (PMP), because in many cases soot is the main contributor to PN after removing volatiles in the VPR

SOOT MASS (MSS) VS. PARTICLE NUMBER (APC) @ GDI SINGLE CYLINDER RESEARCH ENGINE



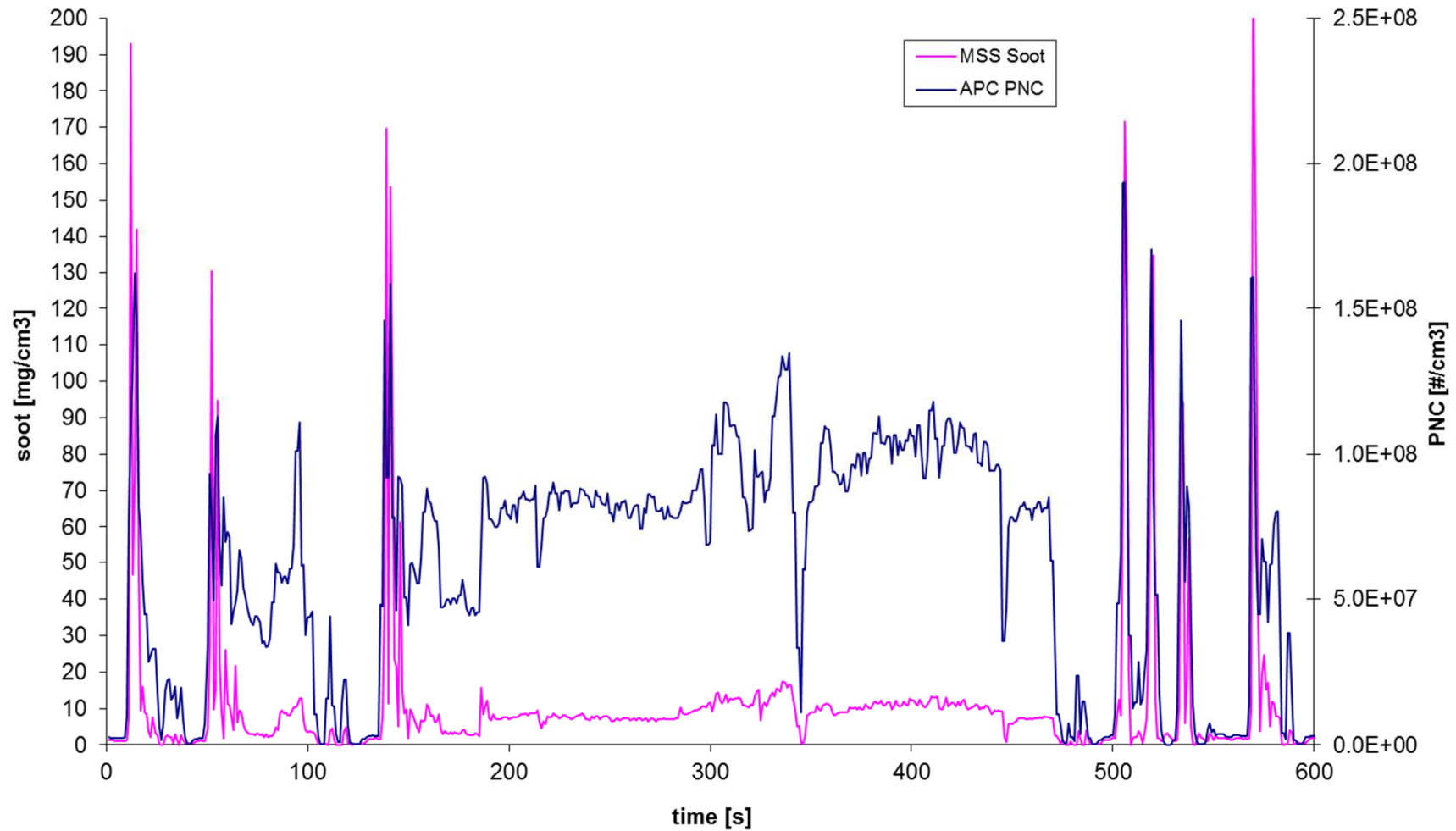
Raw exhaust sampling on a „dirty“ GDI engine

MICRO SOOT SENSOR VS. PARTICLE COUNTER

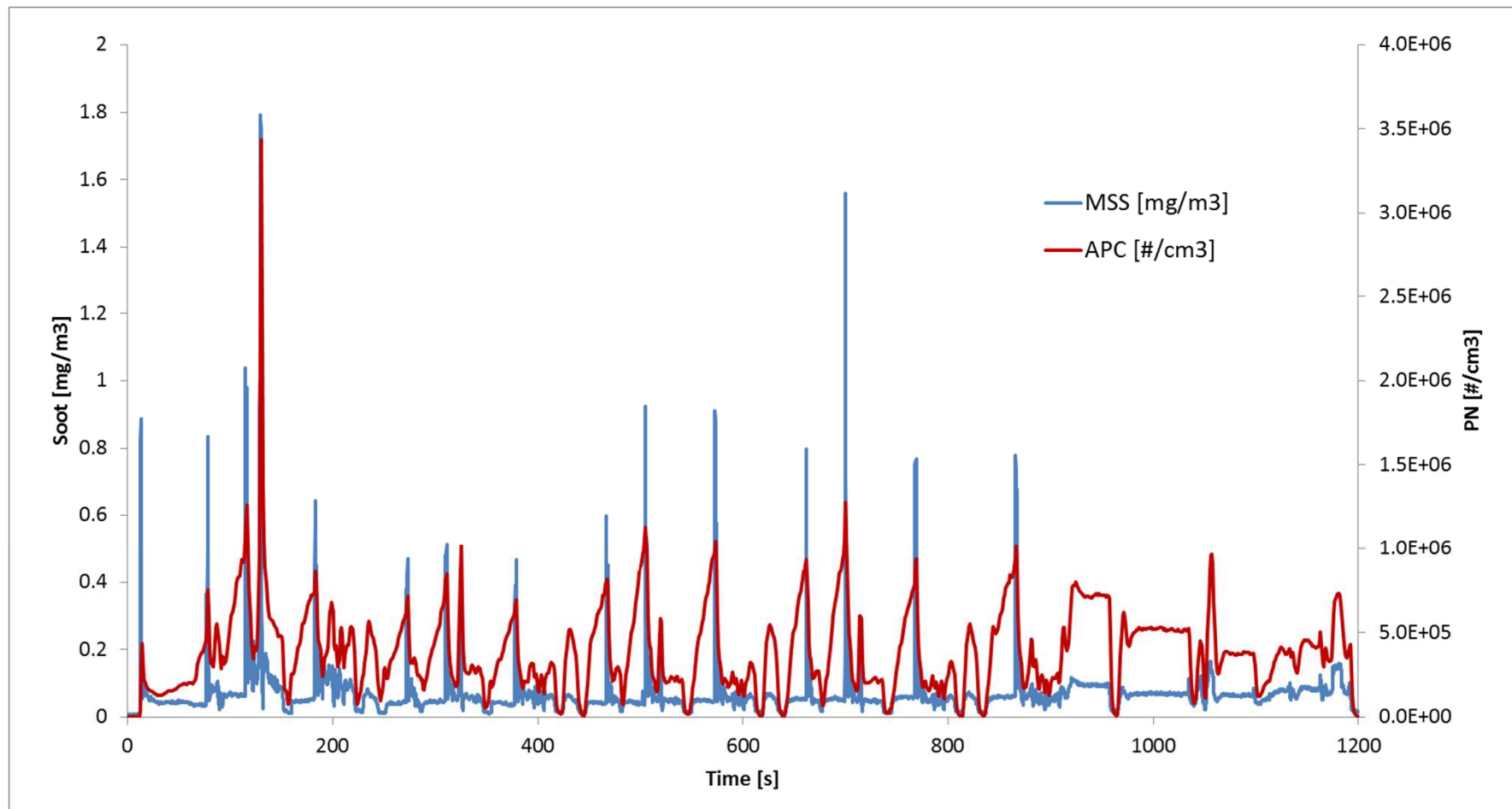


MICRO SOOT SENSOR VS. PARTICLE COUNTER

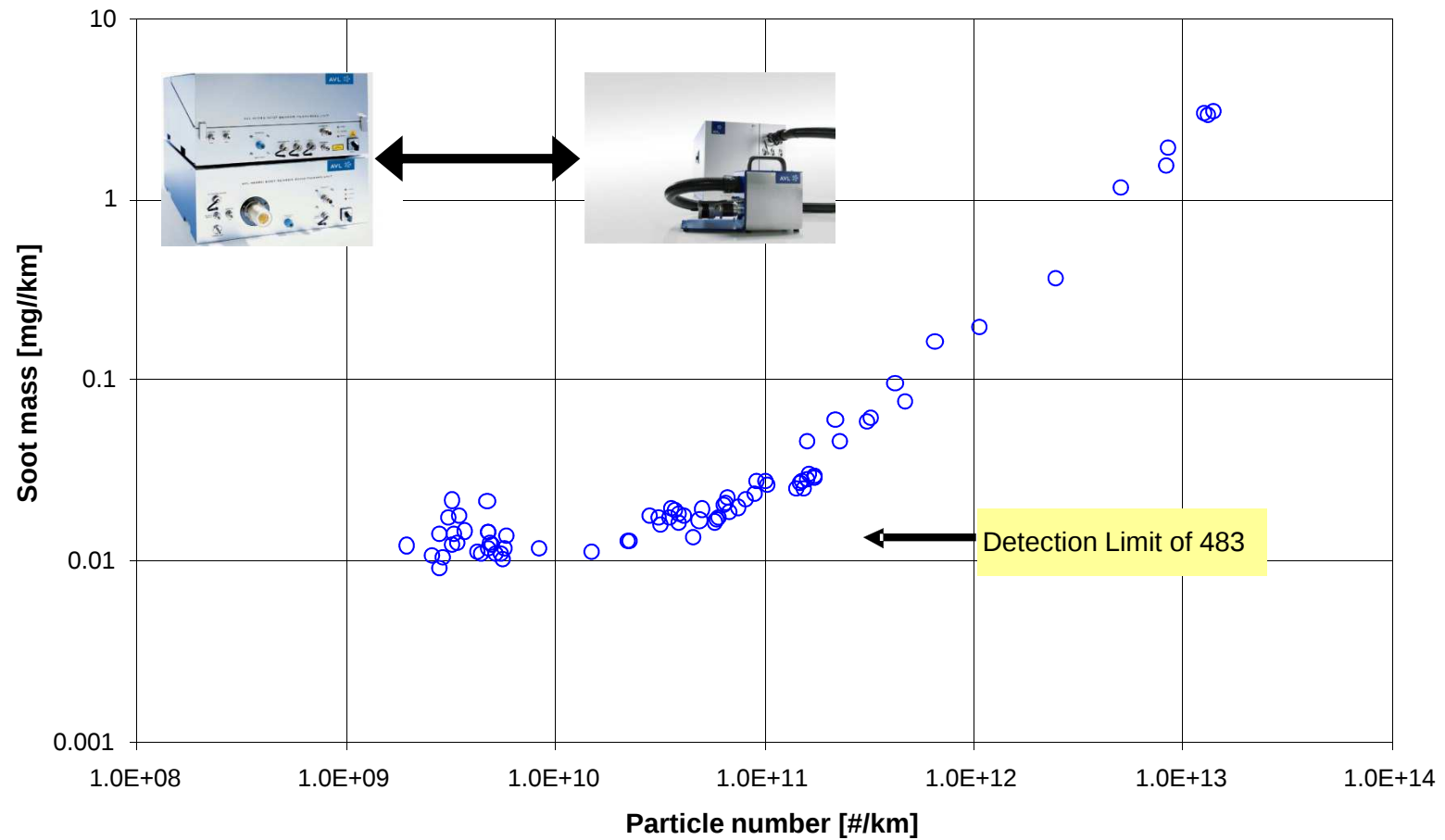
Test 6: APC+MSS - US06



MICRO SOOT SENSOR VS. PARTICLE COUNTER



MICRO SOOT SENSOR VS. PARTICLE COUNTER



Comparison between soot mass and particle number on NEDC

CONCLUSIONS

- There is an obvious relationship between PN and PM
- There seems to be an even better correlation between soot and PN (PMP)
- When the MSS is sampling from the tailpipe with dilution ratios between 2 and 5, it is sensitive enough to measure the soot mass when PN is at the certification limit
- When the MSS doesn't see any soot at all, the engine will quote likely not fail certification according to PMP
- For transient cycles the PN can be roughly calculated from soot mass concentration, the available data suggest a conversion factor of $\sim 3 \times 10^{12} \text{p/mg}$

CONCLUSIONS

But...

- PM to PN correlation is only stable when agglomeration rate is low. As a consequence particle counting on raw exhaust only makes sense for small PN concentration
- Semi-volatile particles, which are not removed completely by a VPR, will make any PM-PN correlation difficult
- Alternative fuels may lead to different correlations due to the chemical nature of particles as well as different size distributions
- Aftertreatment devices like SCR will also influence the correlation

**If all different measurement technologies
for particles would correlate, we would
need only one instrument...**

**... which would be bad for instrument
manufacturers like AVL!**



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Thank you
for your attention!

