

A photograph of a snow-capped mountain peak against a clear blue sky. The mountain is rugged and covered in patches of snow and ice. The sky is a deep, clear blue.

# **NANOPARTICLE EMISSIONS OF COMBUSTION ENGINES**

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**VERT Focus Event, EMPA 16.03.2018**

# CONTENTS

- **PM 10 vs. NP**
- **PM and PN from engines**
- **Examples of PN emissions**
- **What to do ? – exhaust gas filtration**
- **Conclusions**



# PM 10 Versus Nanoparticles

# WHAT IS FINE DUST?

**PM<sub>10</sub>** Particles with aerodynamic diameter of 10 µm and less.  
(PM = particulate matter)

**Komplex mixture from natural and antropogenic sources:**

- primary, emitted,
- secondary, produced components.

**organic carbon**, minerals, sulphates, nitrates, oxides, metals, HC & PAH.

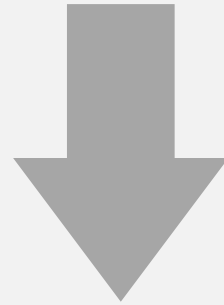


# PM-10 MEASUREMENT EMPA

(Nabel Network)

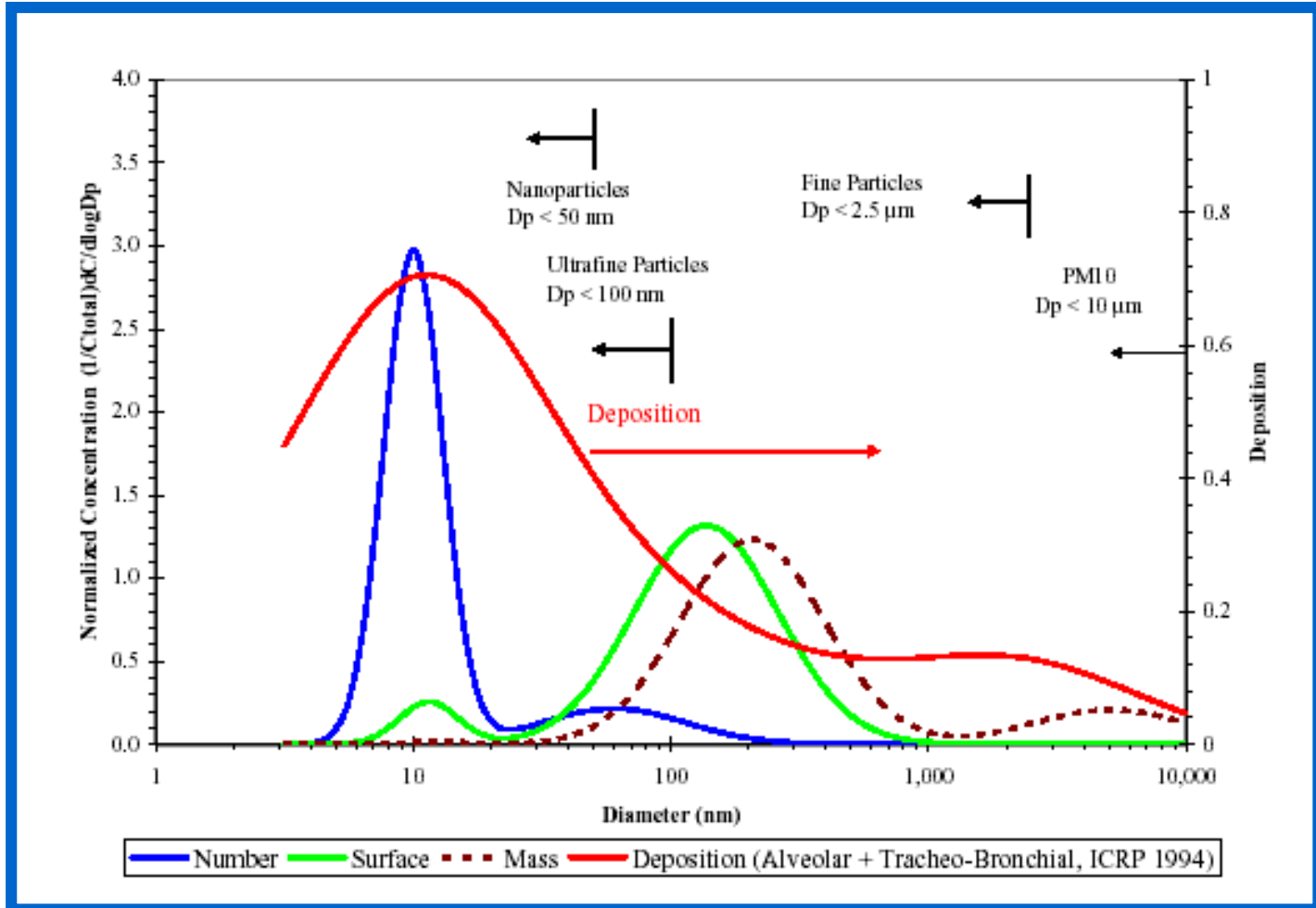


**Smoke + Fog**

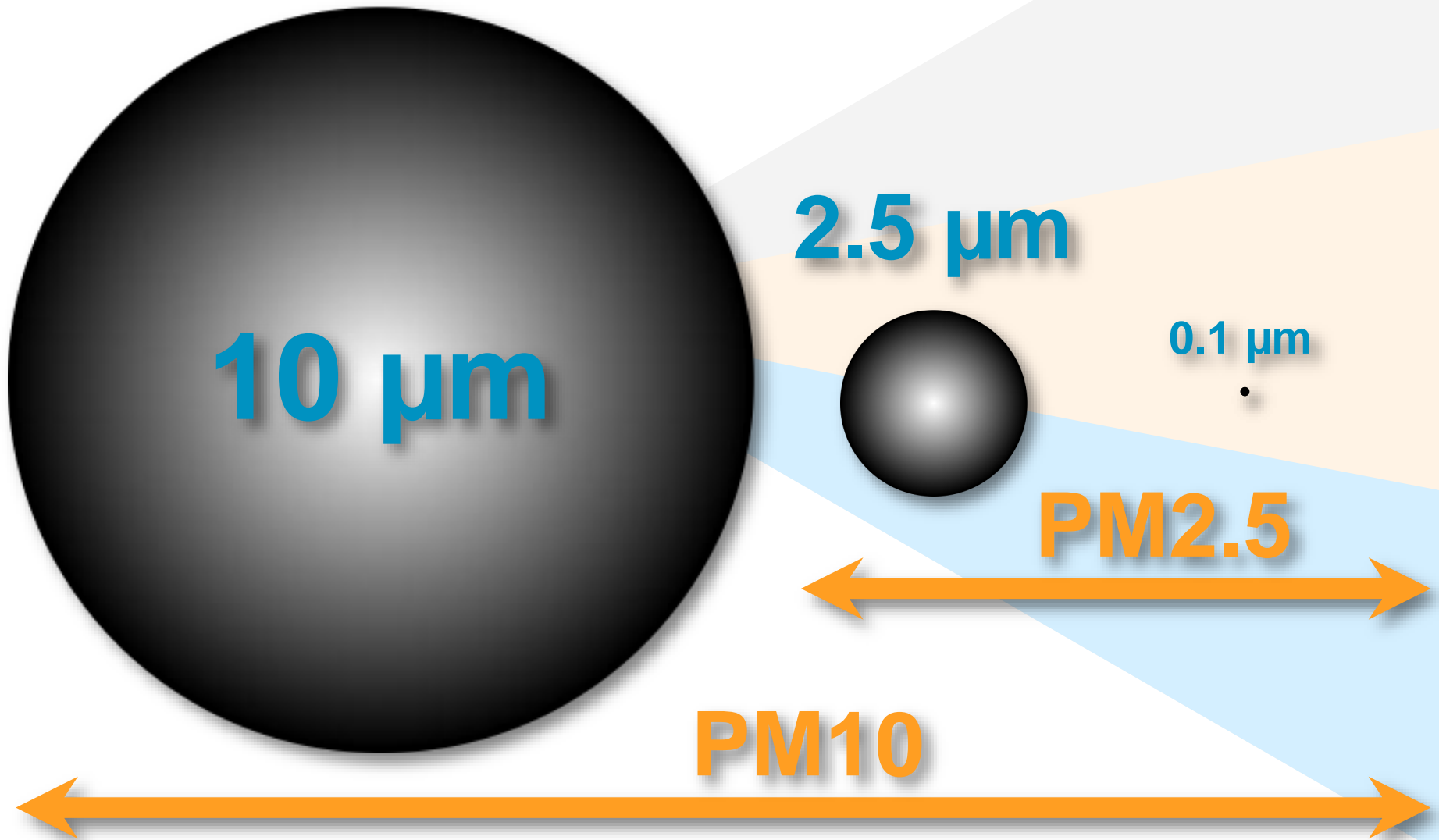


**Smog**

# Ultrafine particles are deposited on the deep lung regions more efficiently than fine particles



# Particle Mass vs. Particle Number







# PM and PN from engines

# EMISSIONS OF SOLID PARTICLES FROM DIESEL ENGINES

**1995**

**gravimetry**

**counts**

**PM ...particulate  
 matter**

**PN ...particle  
 number**

**actual Legislation**

**new component**



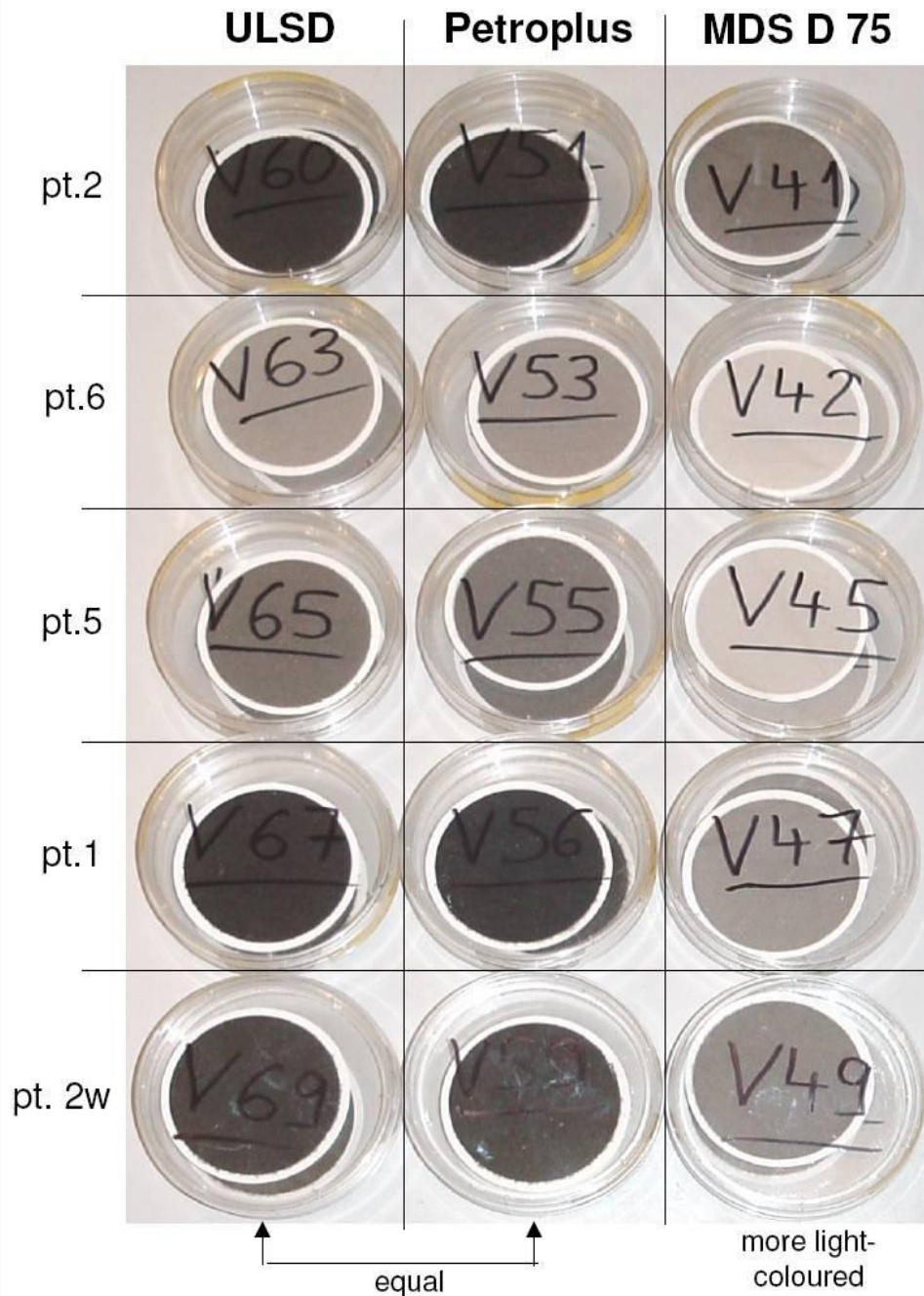
## GRAVIMETRY

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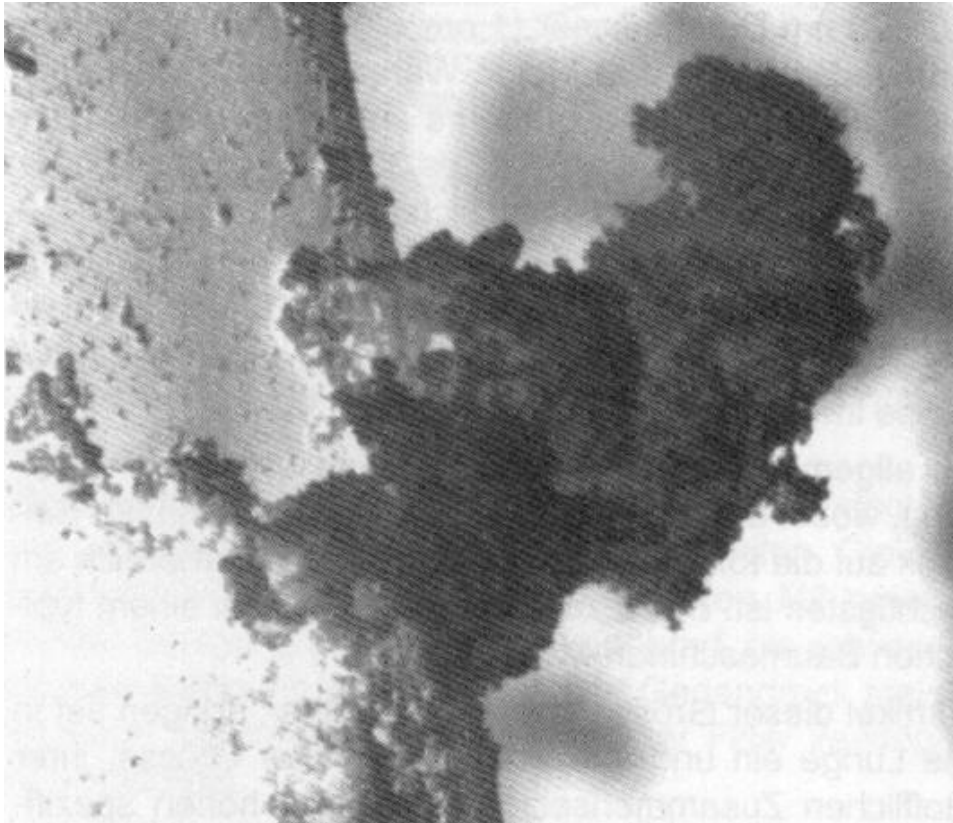




# GRAVIMETRY WITHOUT DPF



**(PN)<sub>max</sub>**



**Diesel:**

$$10^6 - 10^7 = \left[ \frac{1}{\text{cm}^3} \right]$$

**Ambient air:**

$$\sim 2,5 \times 10^4 \left[ \frac{1}{\text{cm}^3} \right]$$

$$\sim 2,5 \times 10^{13} \text{ Molecules}$$

Soot deposition on a 10 μm filter fiber;  
 a large agglomerate, formed on the fiber and  
 many ultrafine particles in the size range of 100 nm



# NANOPARTICLES

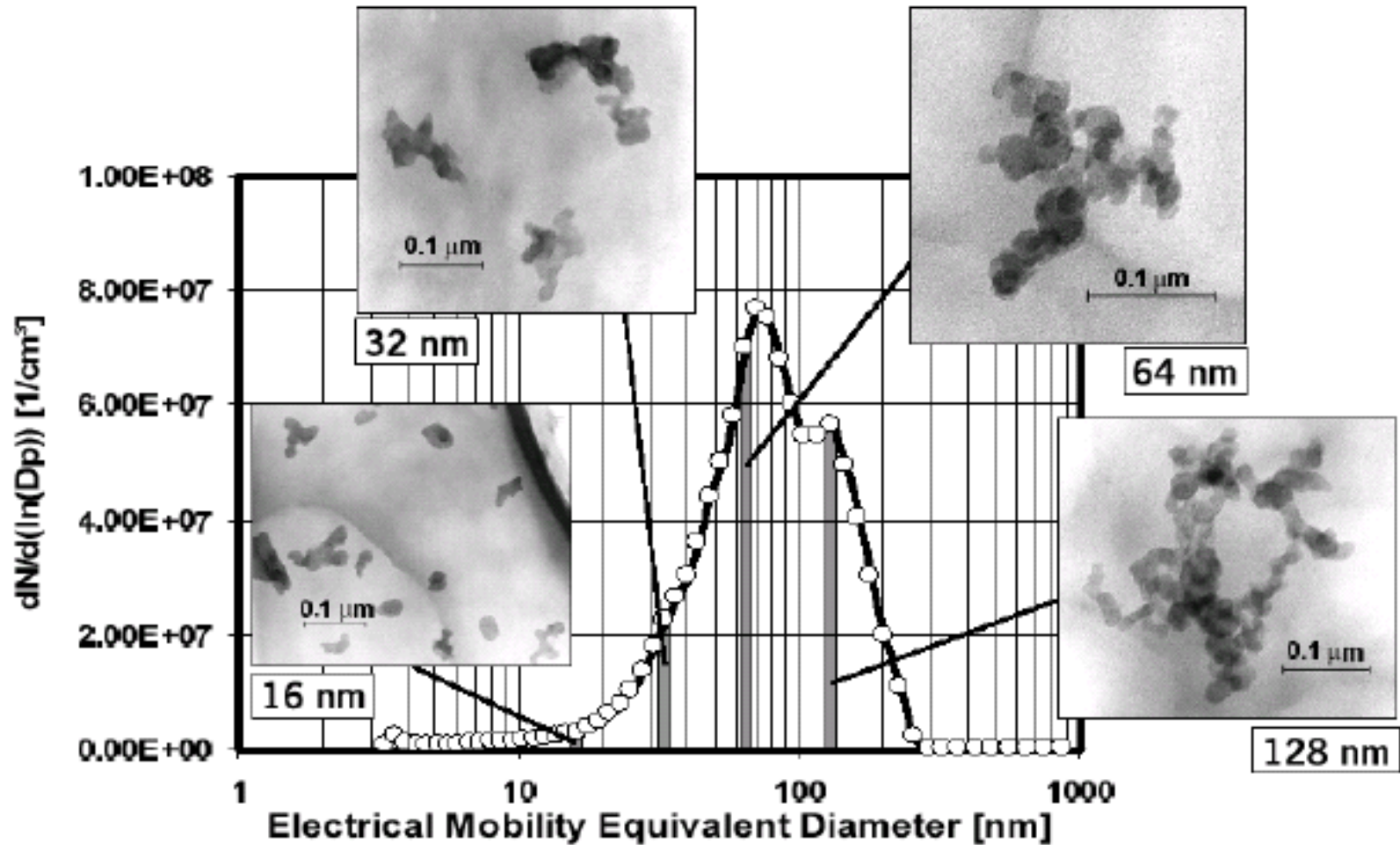
- **negligible mass**
- **astronomically high numbers**
- **penetration like gases**

nano mist

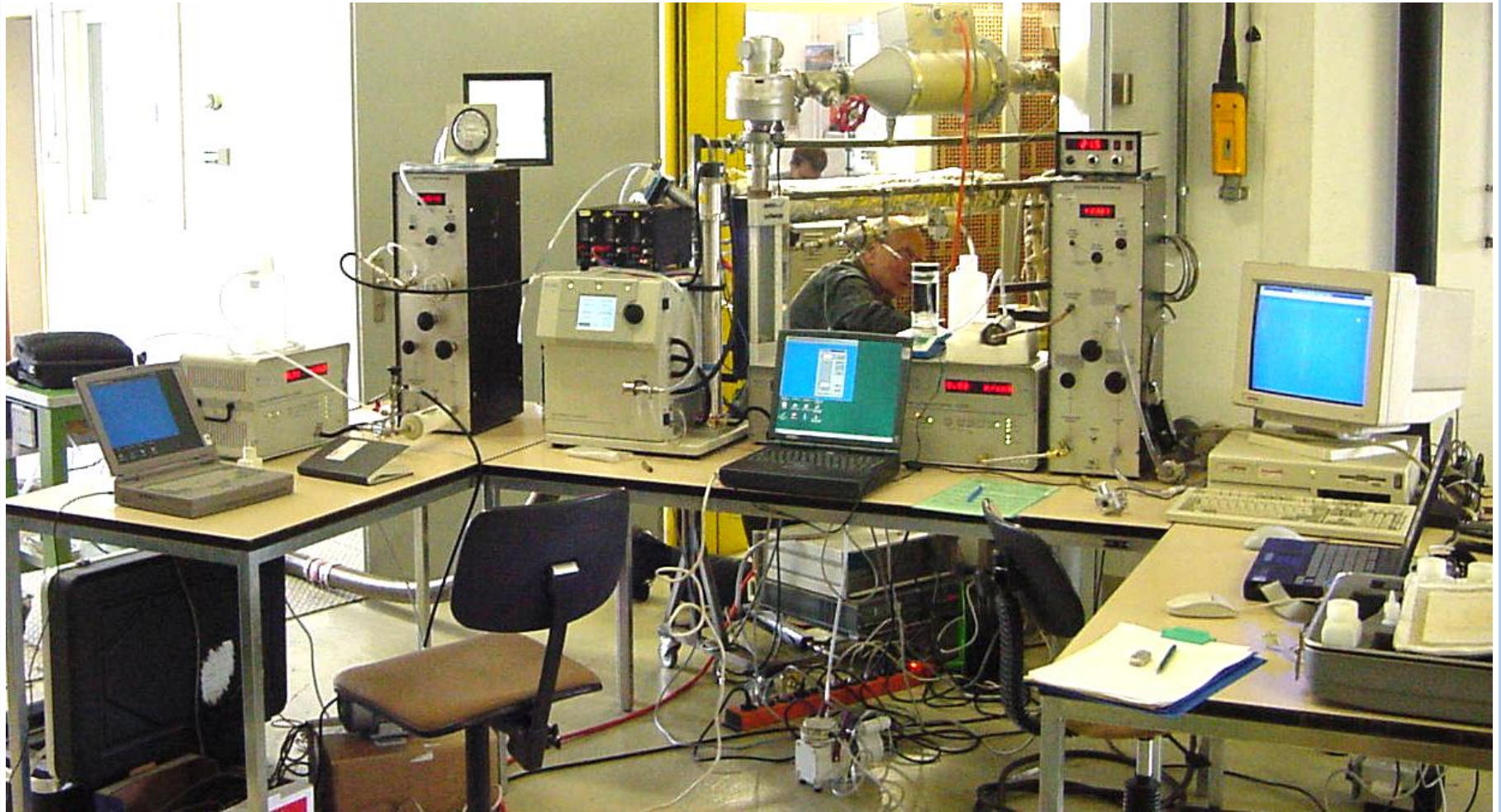
nano dust

nano soot

# MORPHOLOGY OF NANOPARTICLES





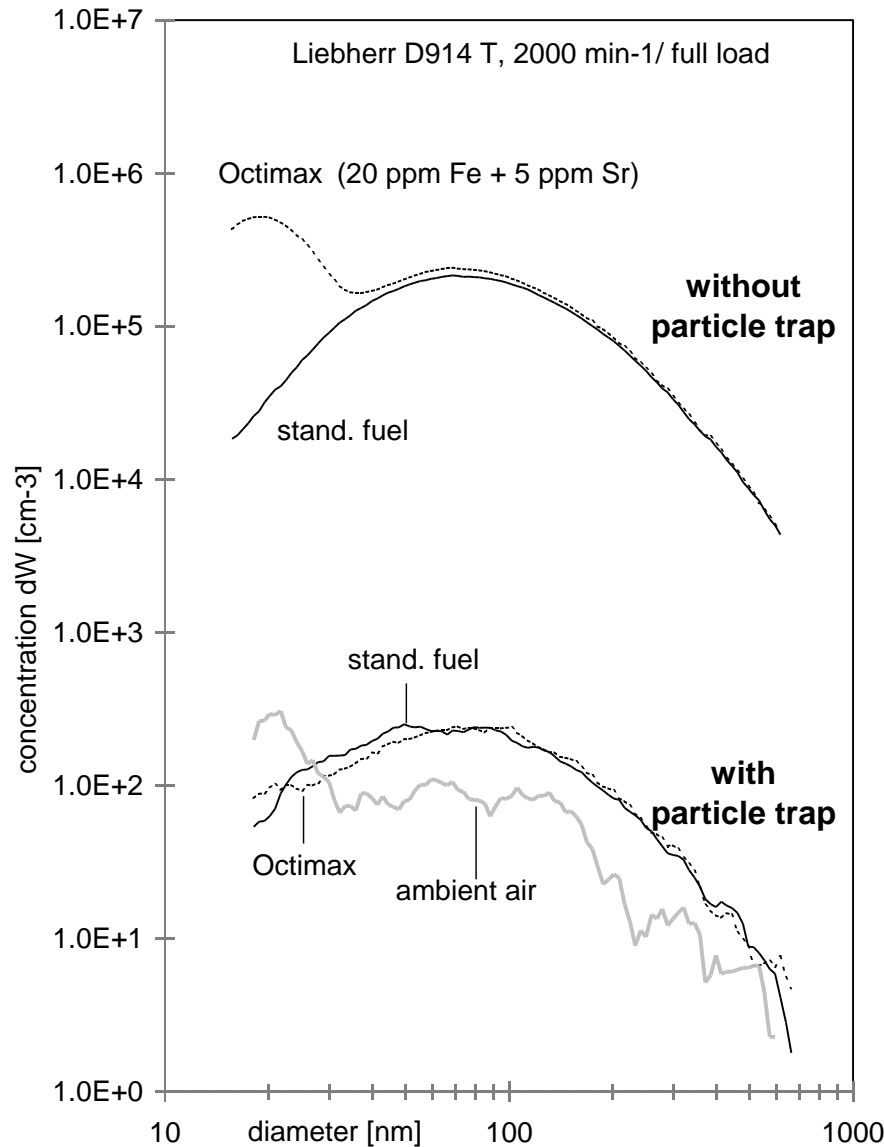




# Examples of PN emissions

# DIESEL ENGINE

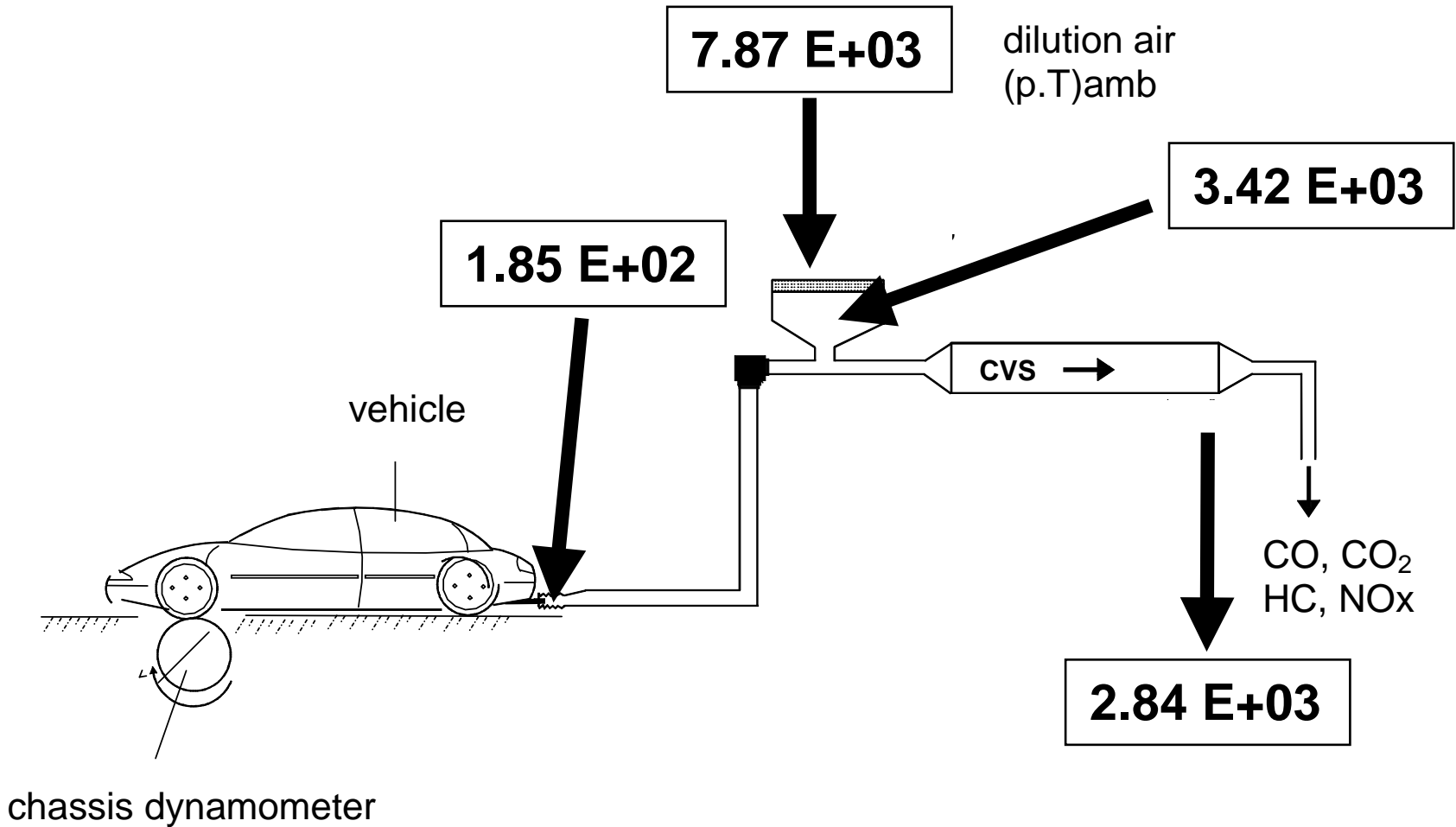
## PARTICLE SIZE SPECTRA WITH/WITHOUT PARTICLE TRAP CORNING, WITH/WITHOUT ADDITIVE OCTIMAX



1995



# SUMMARY

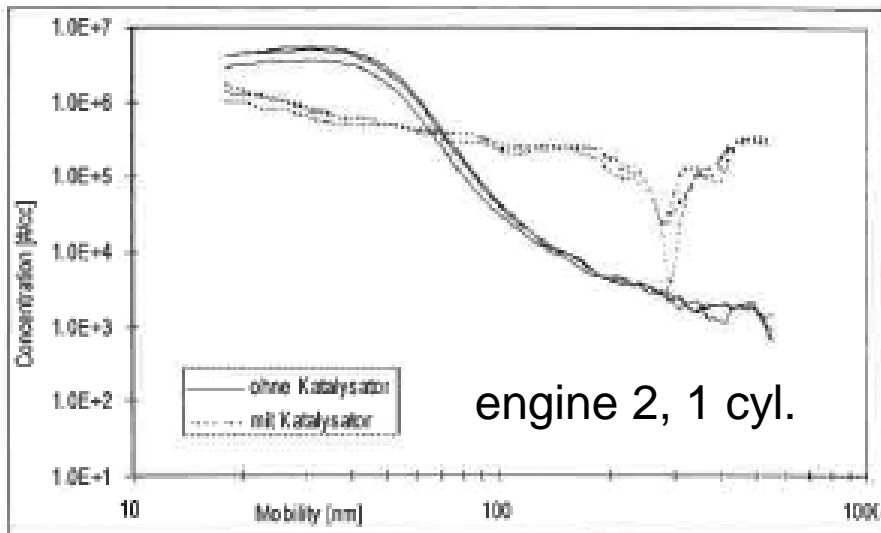
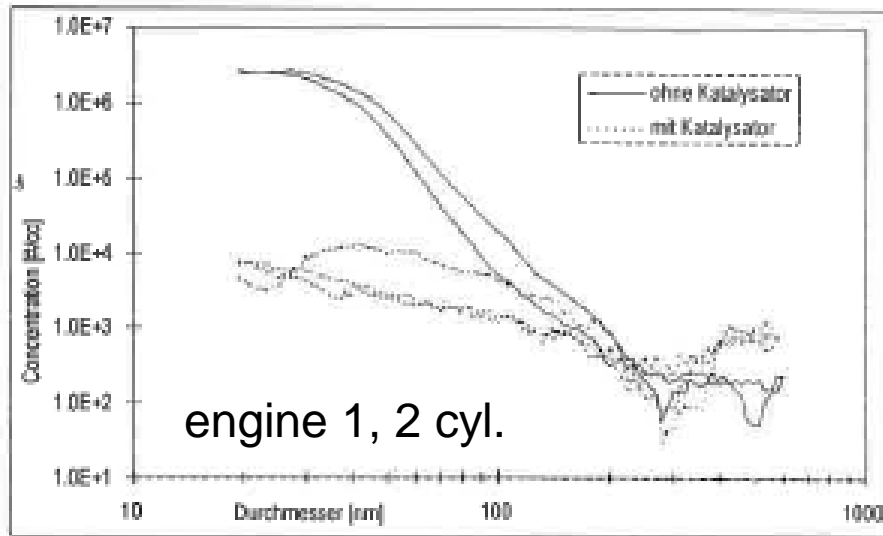


Example at 80 km/h



## YOKE MOVER

### SIMPLE SI 4S-ENGINE



# NUMBER COUNT AS A FUNCTION OF THE MOBILITY DIAMETER (SMPS METHOD) FOR BOTH ENGINES AT FULL LOAD WITH/WITHOUT CATALYTIC CONVERTER 2800 rpm

# PEUGEOT SCOOTERS: LEFT TSDI, RIGHT “CARBURETOR”



TSDI

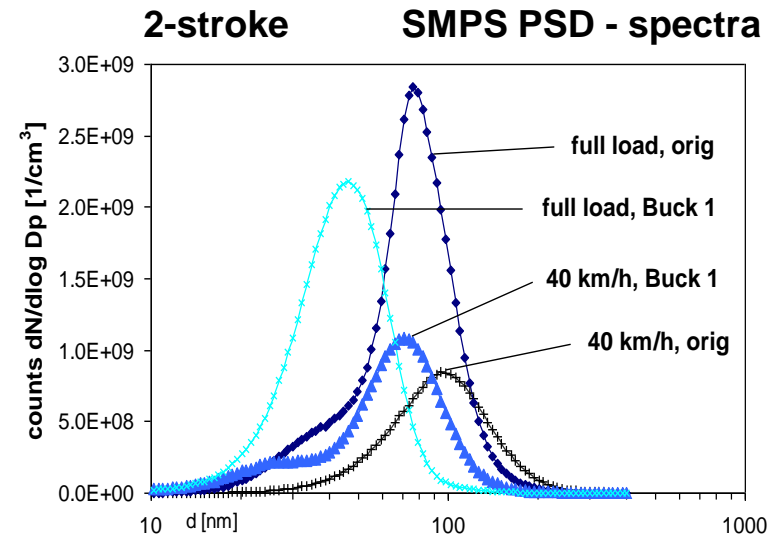
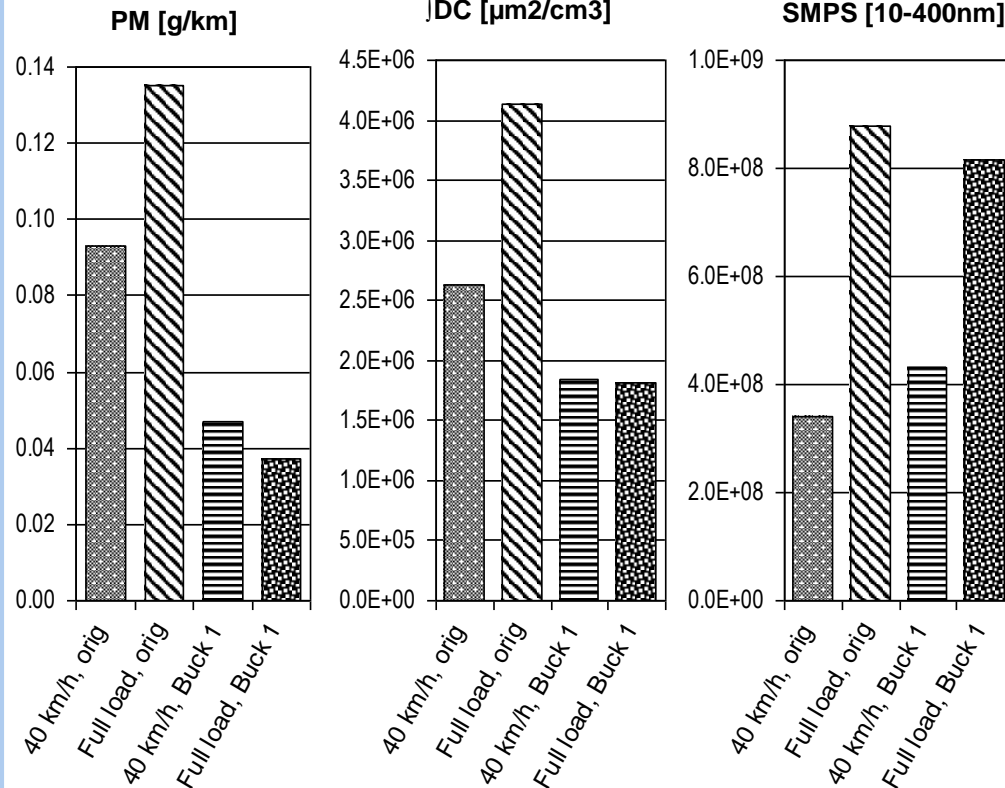
Carburetor

**2007**

# PARTICLE MASS AND NANOPARTICLES AT 40 KM/H AND FULL LOAD, WARM, WITH ORIGINAL MUFFLER AND BUCK 1 PEUGEOT LOOXOR TSDI; GASOLINE; LUBE OIL MOTOREX N°2

$t_{40} \sim 250^{\circ} \text{ C}$

$t_{FL} \sim 330^{\circ} \text{ C}$





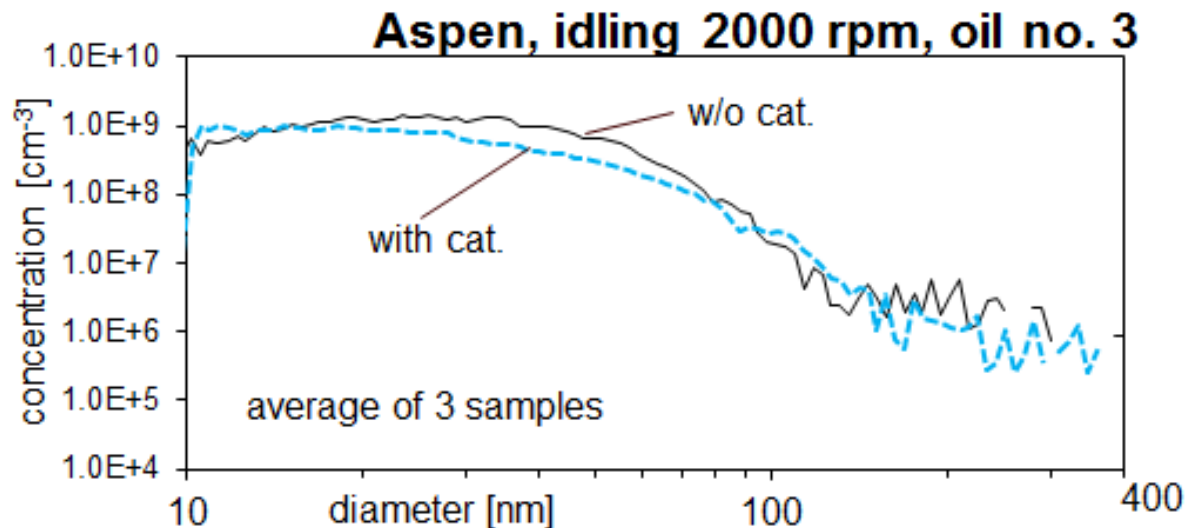
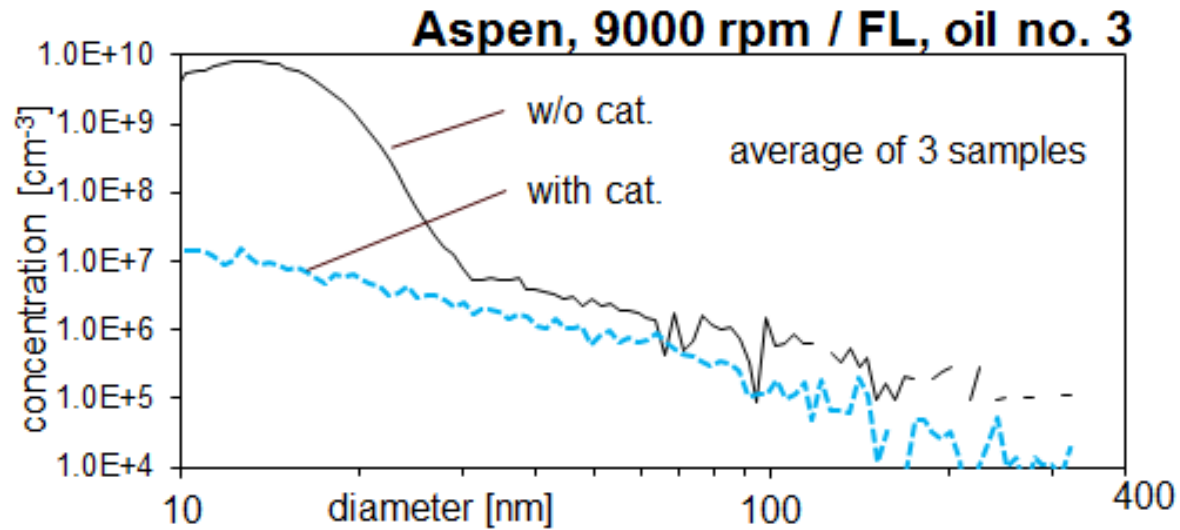
# CHAIN SAW



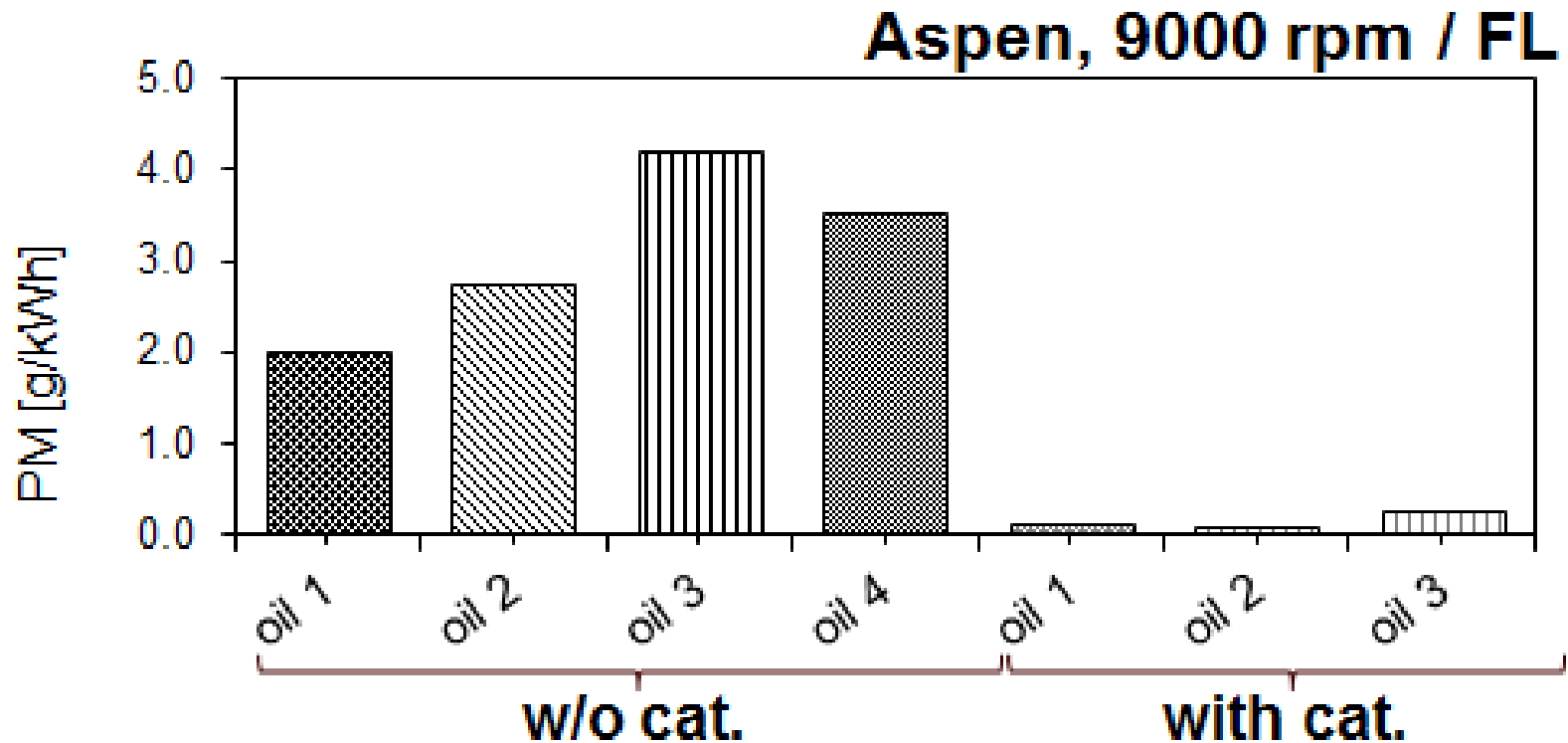
**1999/2014**



# INFLUENCES OF OXIDATION CATALYST ON PARTICLE SIZE DISTRIBUTIONS (PSD) AT FULL LOAD & IDLING



# PARTICLE MASS (PM) WITH DIFFERENT LUBE OILS AT FULL LOAD

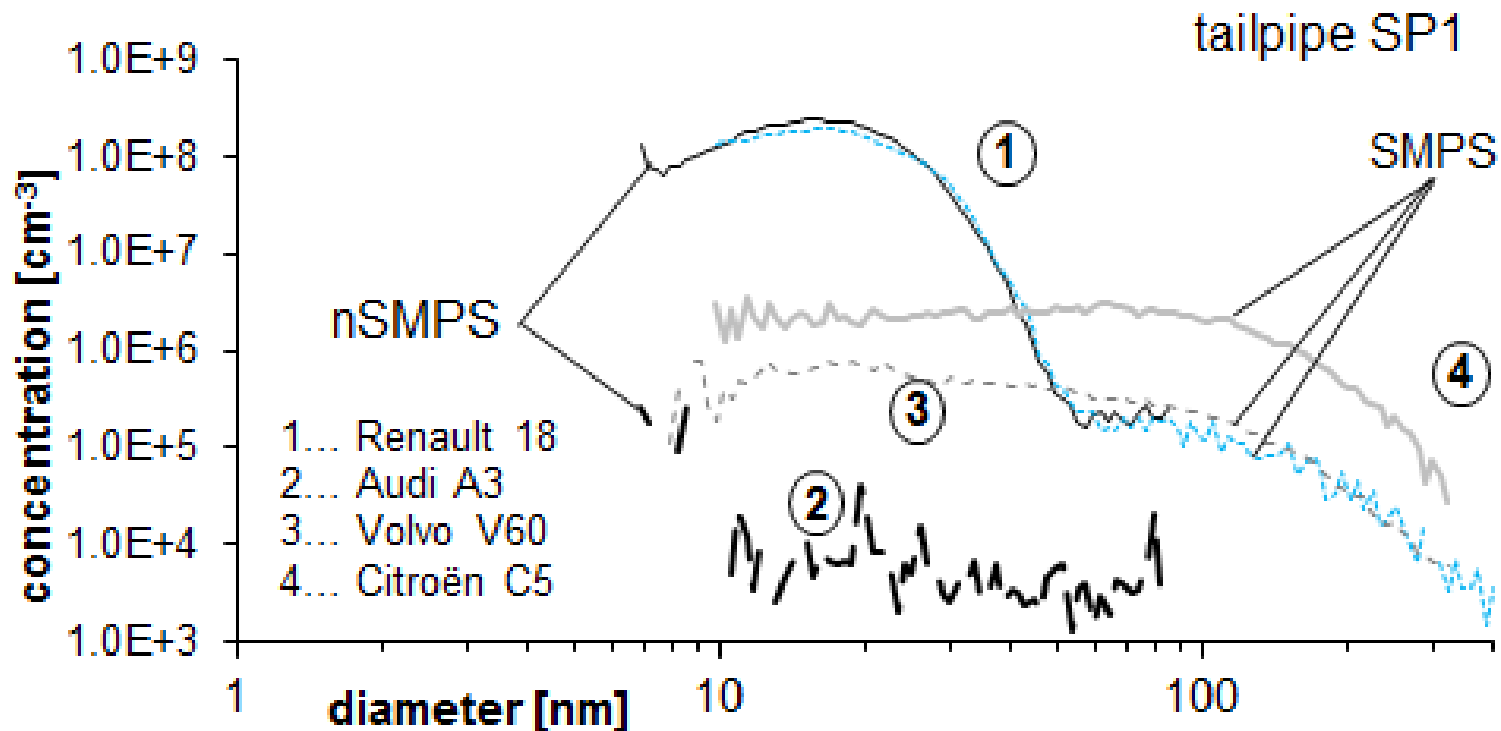


# GASOLINE CARS

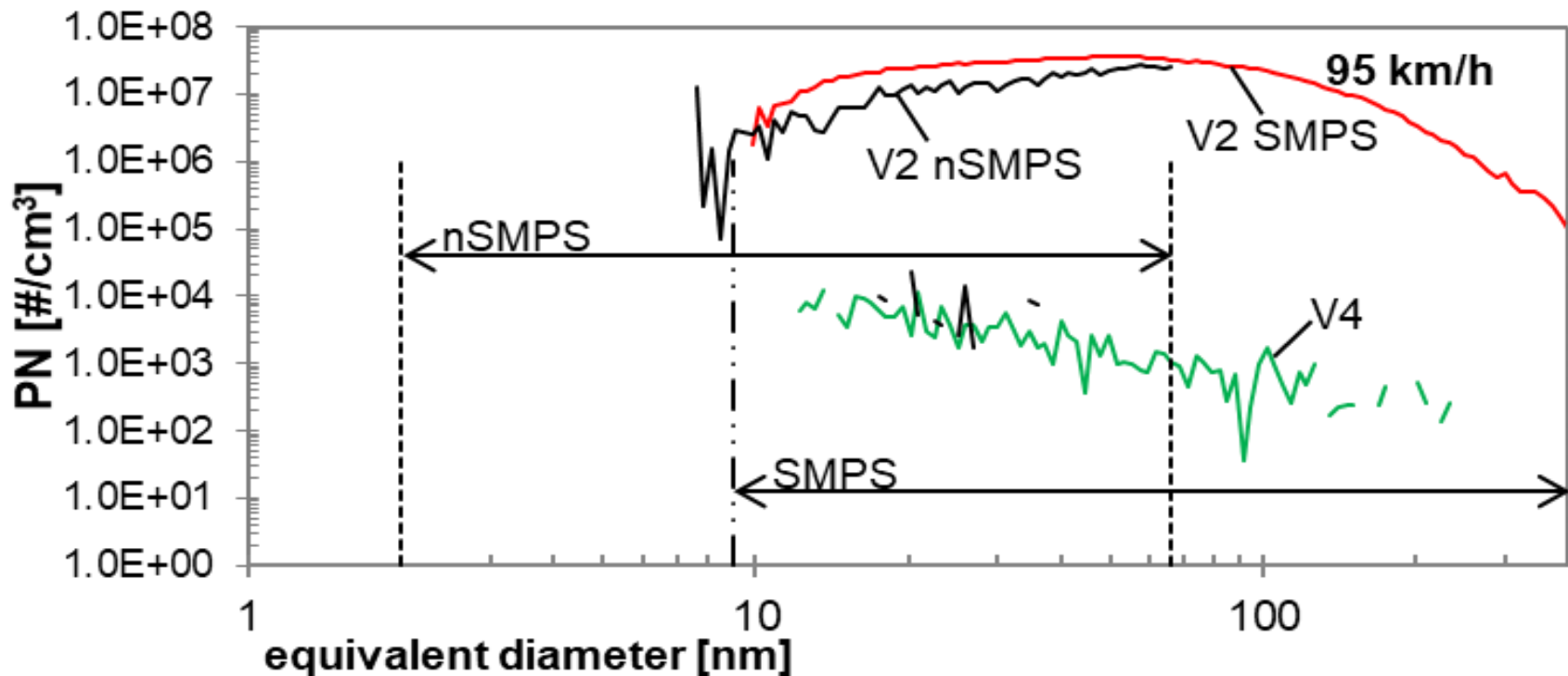
**GDI & MPI**  
**Since 2013**



# PARTICLE SIZE DISTRIBUTIONS OF DIFFERENT VEHICLES AT TAILPIPE & 40 KM/H

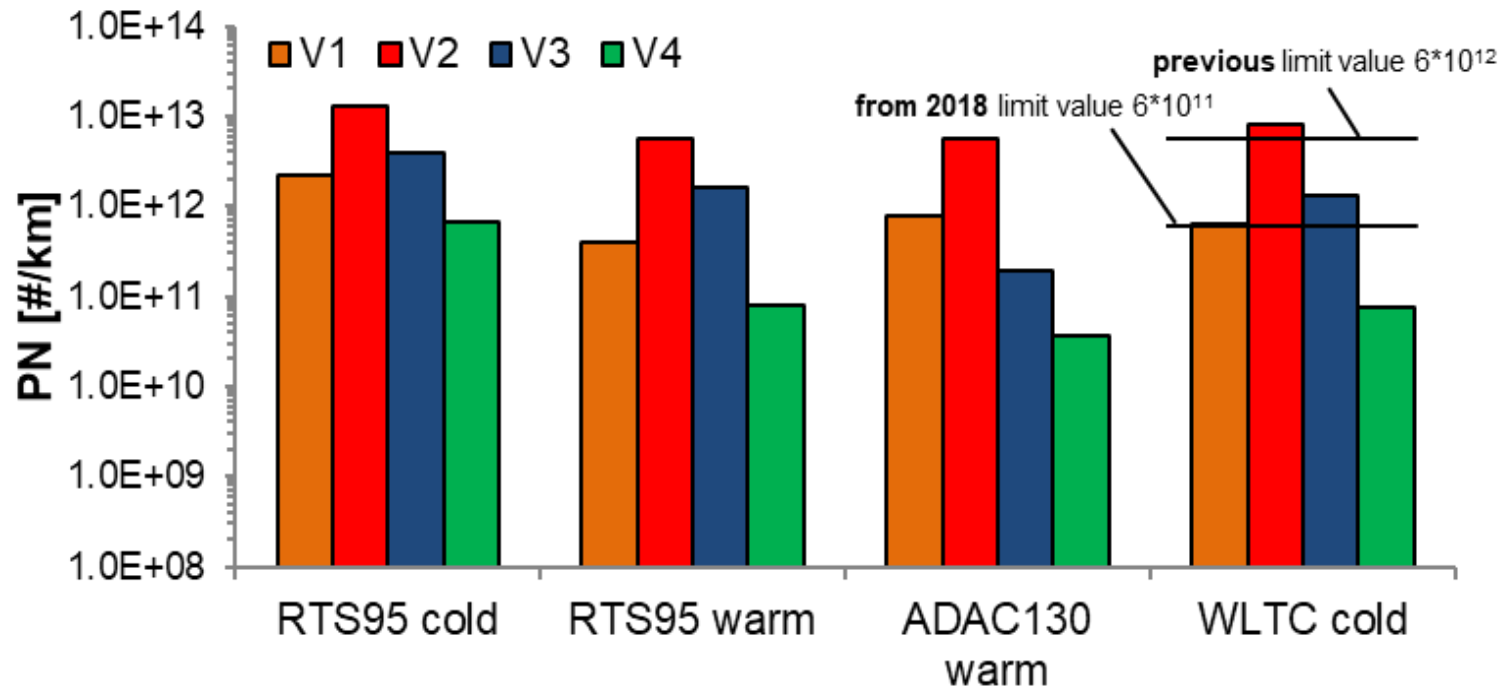


# PARTICLE SIZE DISTRIBUTION OF MPI VEHICLES (MIN/MAX EMISSIONS) AT 95 KM/H.





# PN RESULTS IN ALL DRIVING CYCLES





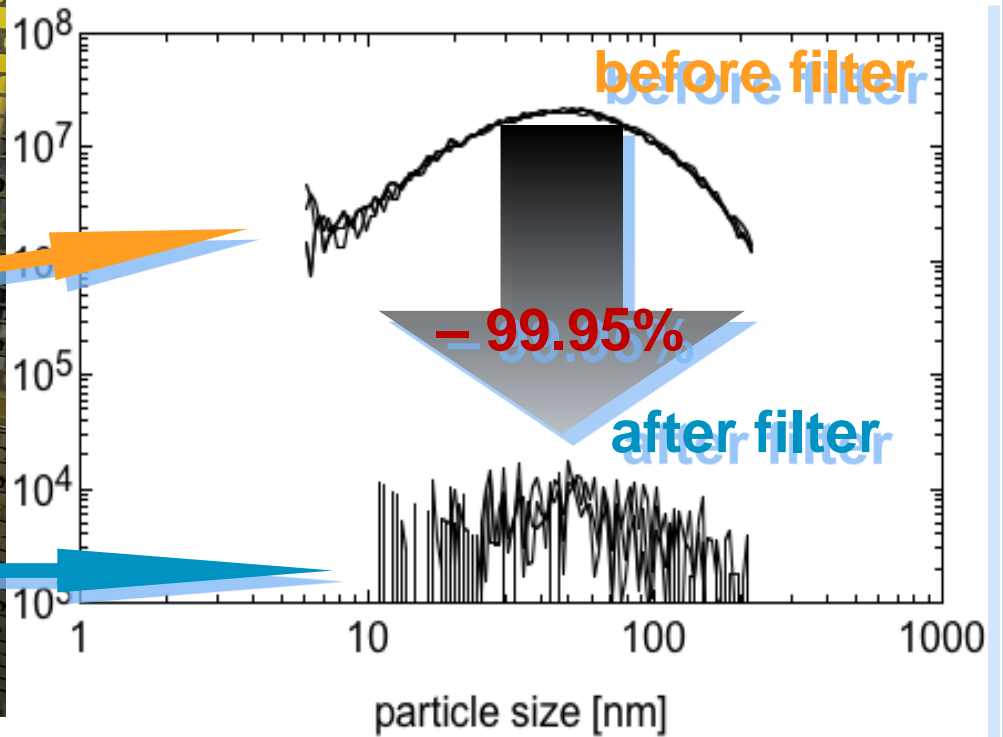
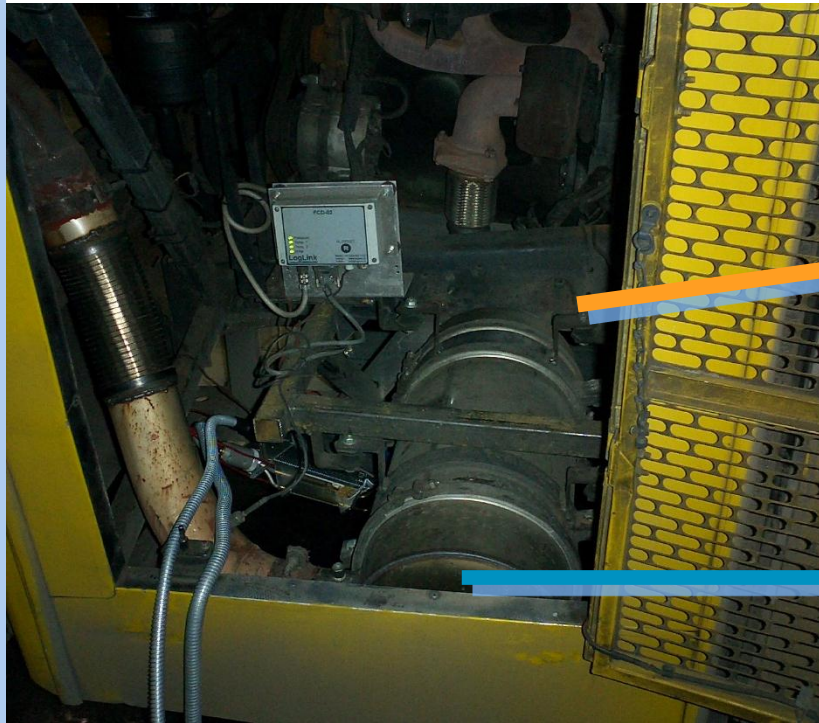
**What to do**



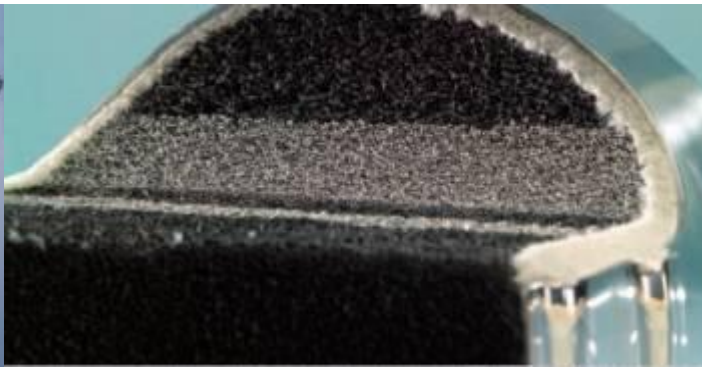


# Exhaust gas filtration

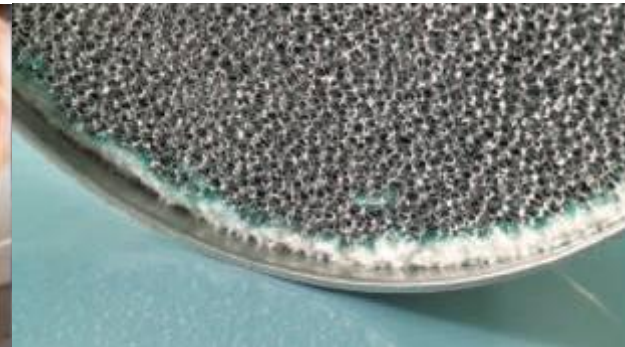
# FILTER EFFICIENCY MEASUREMENT







**PM – CAT  
(CAT. YES, FILTER NO!!!)**





# BUCK - WFC

Wiremesh filter-catalyst - for scooter application

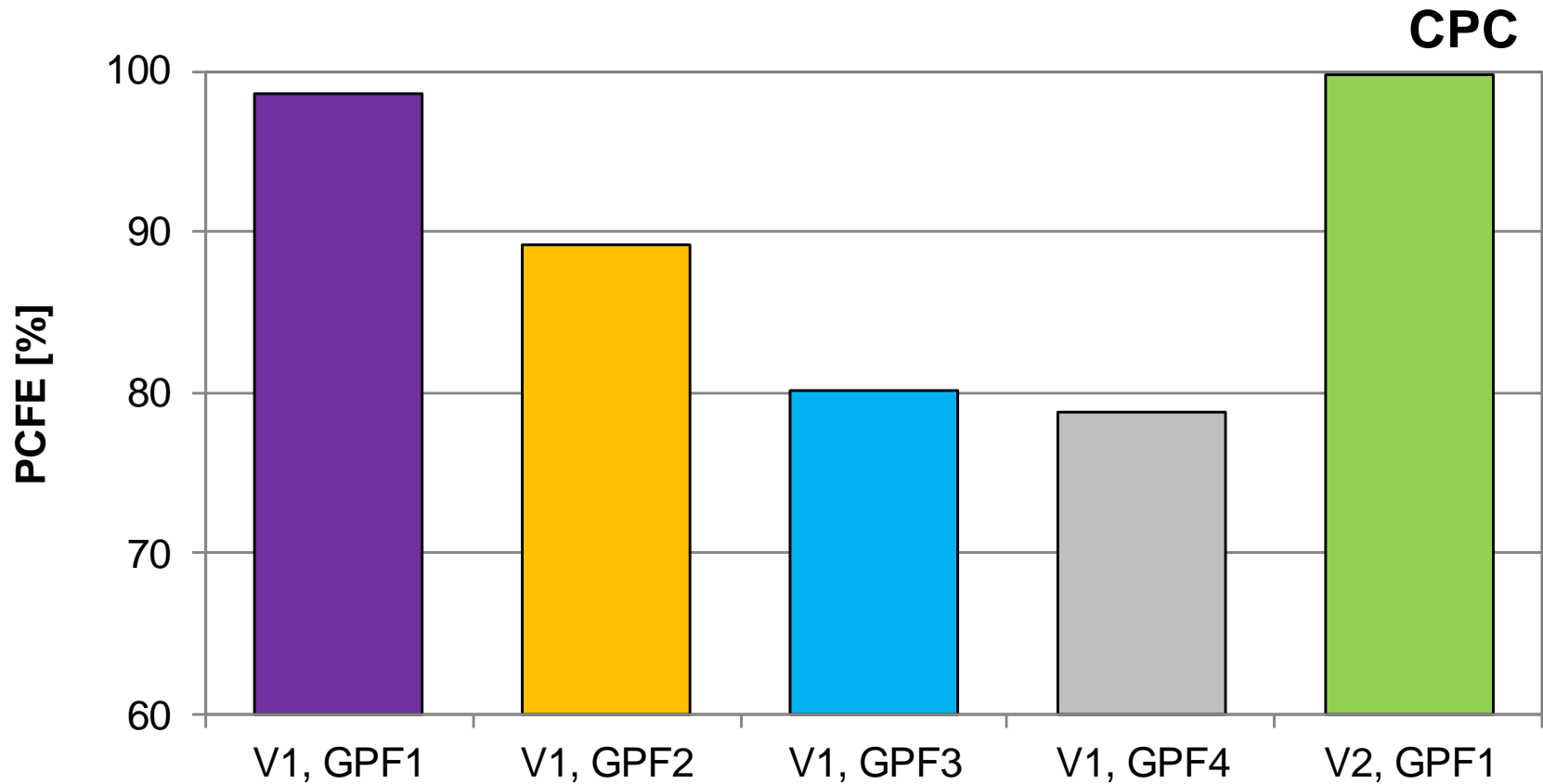


WFC

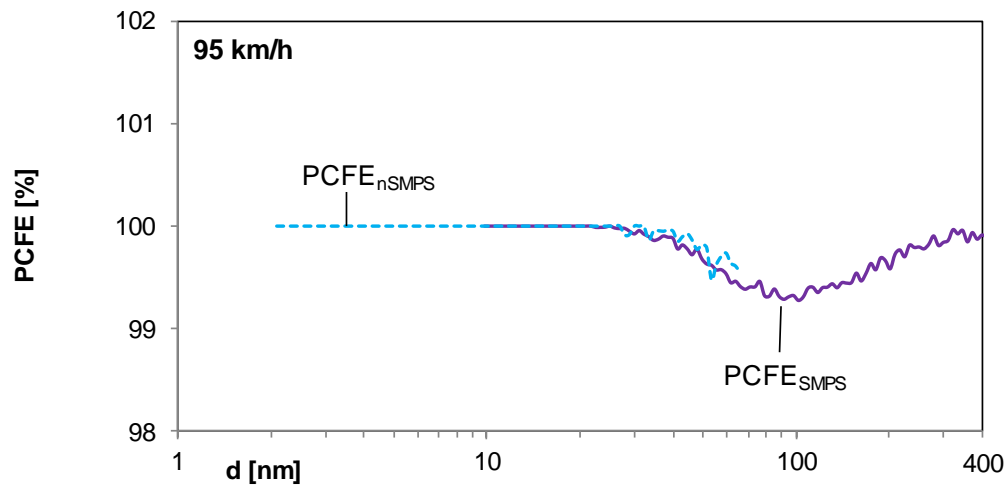
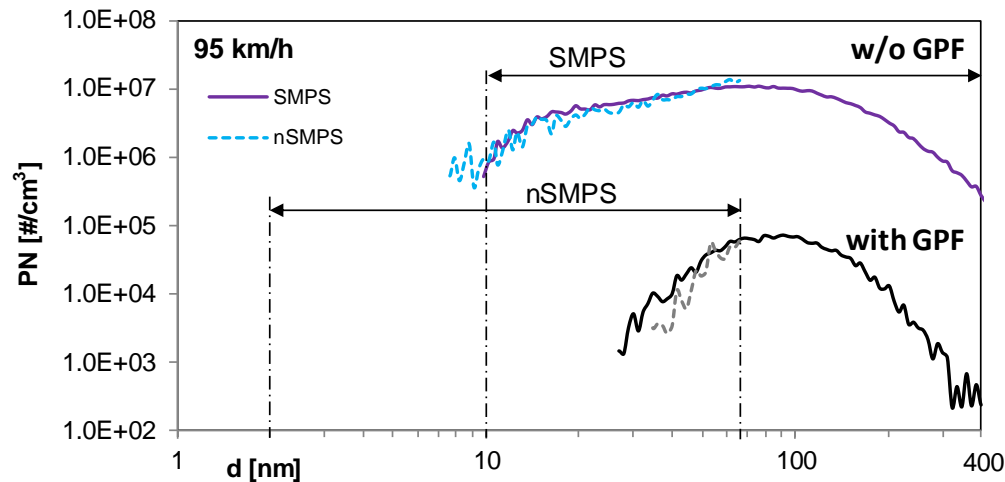
For chain saw →



# PCFE'S OF THE INVESTIGATED GPF'S IN WLTC HOT

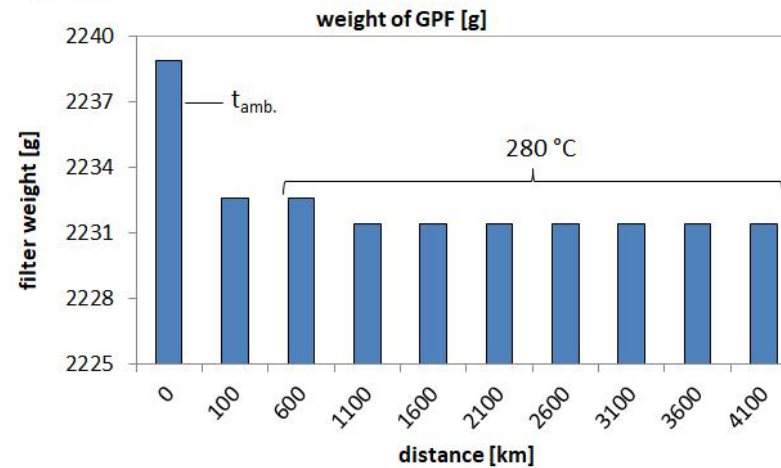


# EXAMPLE OF PSD'S WITH SMPS & NSMPS AND PARTICLE COUNTS FILTRATION EFFICIENCY (PCFE) WITH V1, GPF 1 AT 95 KM/H



# ATTEMPT OF SOOT-LOADING OVER 4100 KM IN REAL DRIVING; ADD-ON-GPF (UNCOATED); V2

Weighing of GPF



GPF entrance after 2100 km



# Conclusions

- Ambient PM 10, PM 2.5 are far from NP (size, composition, penetration)
- Engine PM  $\neq$  PN
- PN is a very sensitive parameter
- Nearly all engines have operating conditions with high PN
- ... and not only engines
- Filtration can help





**Thank you for  
your attention**