

Characterization of particles emitted from modern 2- stroke scooters by electron microscopy and tandem DMA

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Outline

- ❖ **Motivation and background**
- ❖ **Experimental setup**
- ❖ **Investigated 2- stroke scooter**
- ❖ **Results**
 - **DMA, TEM**
- ❖ **Conclusion**

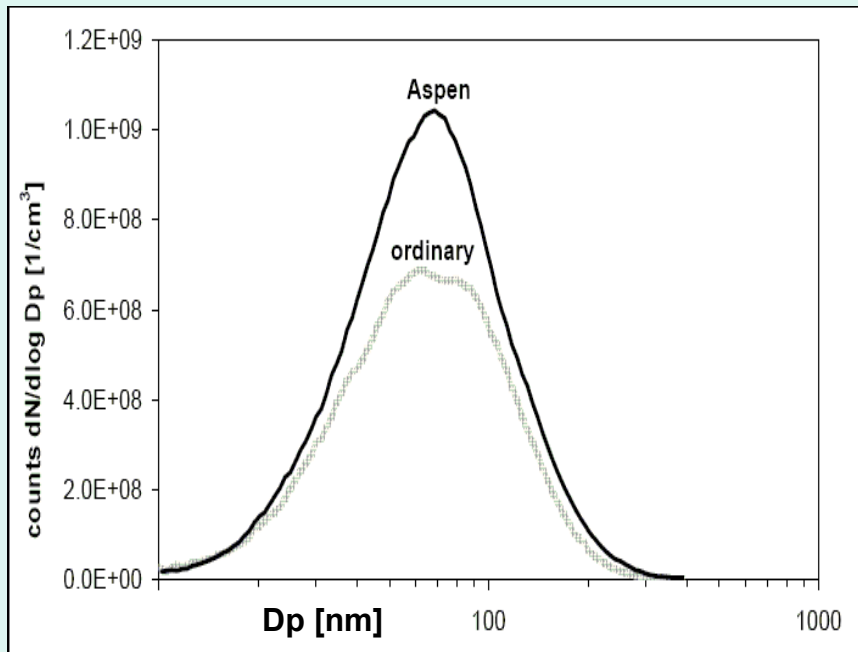
Motivation

- Significant emissions and pollution effects of 2-stroke engine
- Structure and composition of exhaust particles are not well known

Motivation and background

Measurements on dynamometer

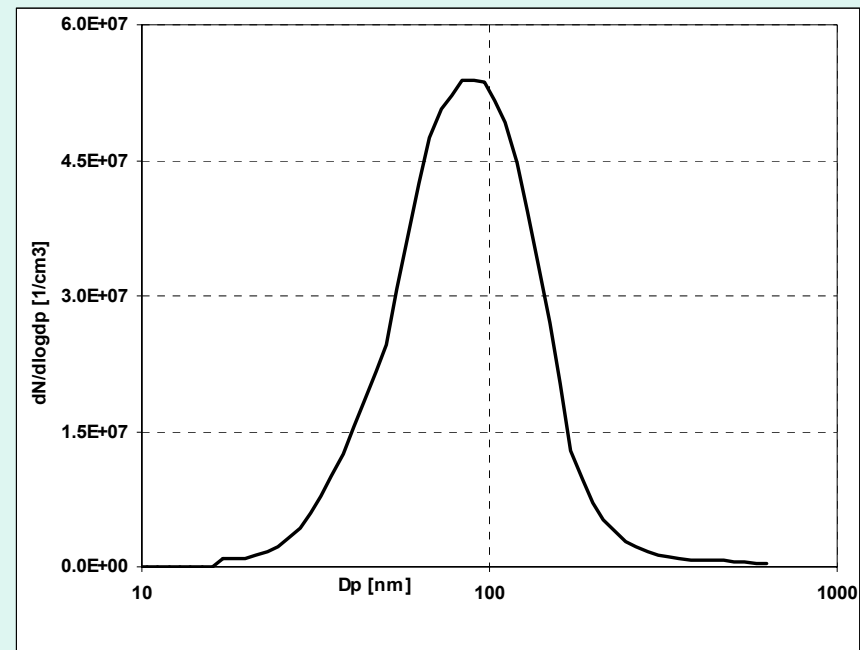
2-stroke scooter



Source: Emission Factors & Influences on Particle Emissions modern 2-Stroke Scooters. Final rep. BUWAL / VLR.03.05 (50 cm³, speed 30 km/h with catalytic convert, Oil : Panolin Synth Aqua gasoline)

J. Czerwinski, Dipl. Ing. Dr. techn.

Diesel passenger car



Source: Particle emission of different combustion sources, Dept. IC., EMPA (Diesel passenger car, 50km/h)

Objective

- To get a better understanding of the nature of the particles emitted from two stroke scooters
- Influence of engine technology on the emitted particles
- Influence of catalytic converter on the emitted particles

Investigated 2 –stroke scooters

	Peugeot	Kymco
	Direct injection	Carburetor
Displacement [cm ³]	49	49
Power [kW]	4.8	3.9
Model [Y]	2002	2001



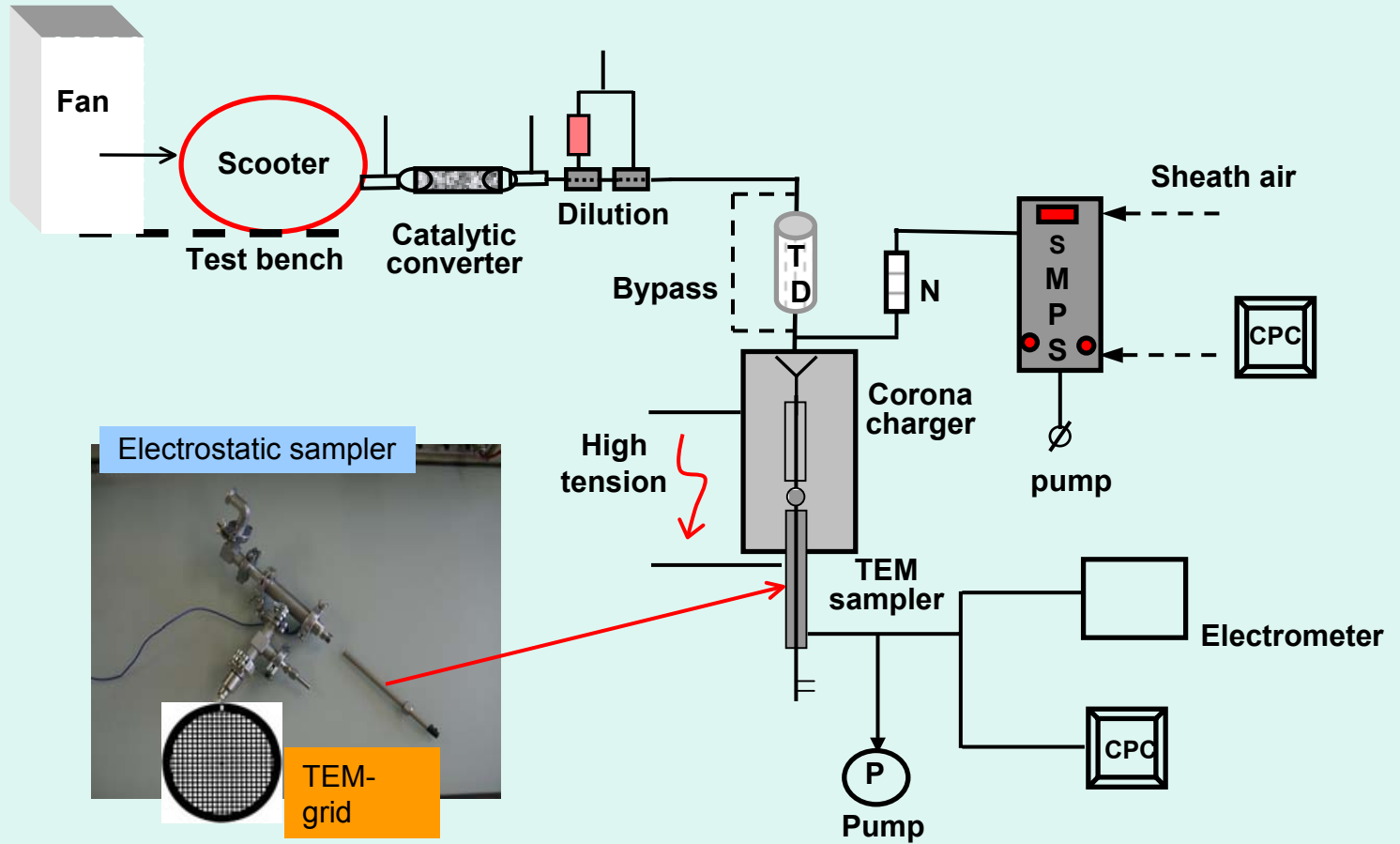
Methods for particle analysis

- SMPS (7 to 322 nm)
- Tandem DMA
- Thermodesorber (25 – 400°C)
- TEM – EDX
- Cryo electron microscopy

Measuring procedures

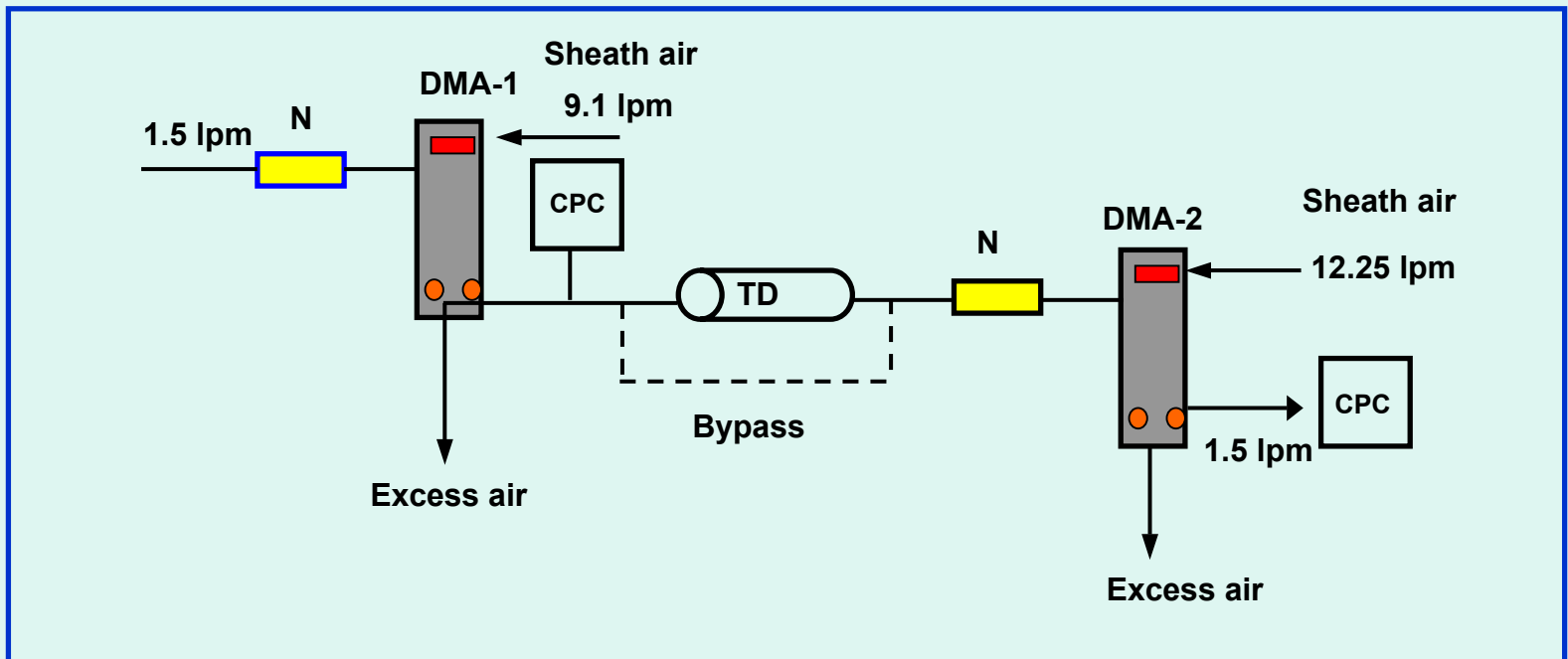
- constant speed: 60 km/h
- before and after catalytic converter
- raw gas sampling
- quick two step dilution
(first stage heated to 150 °C)

Experimental Setup - I



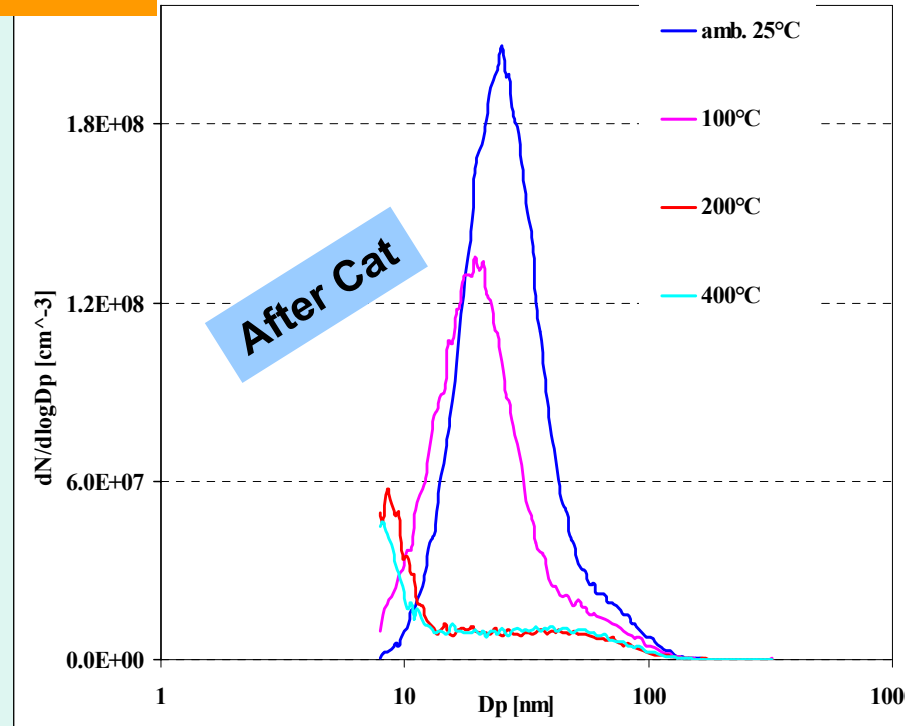
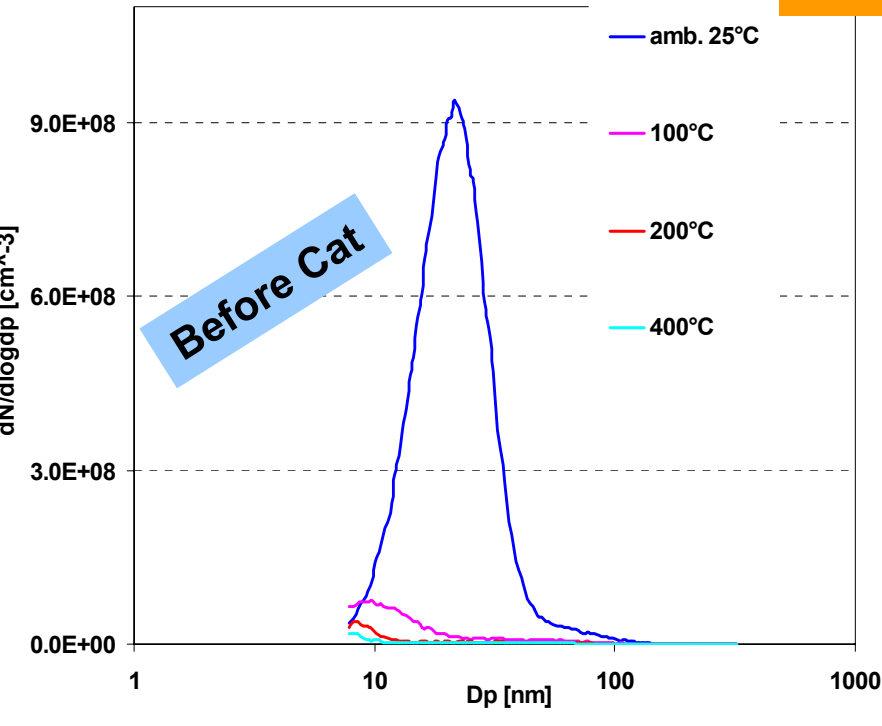
Experimental setup - II

Schematic diagram of the Tandem DMA



SMPS Results

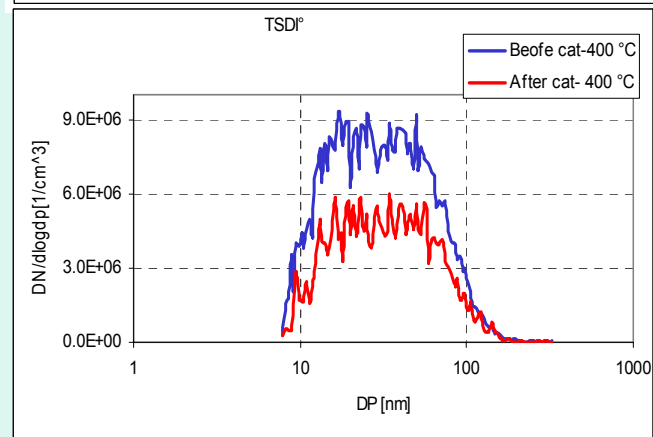
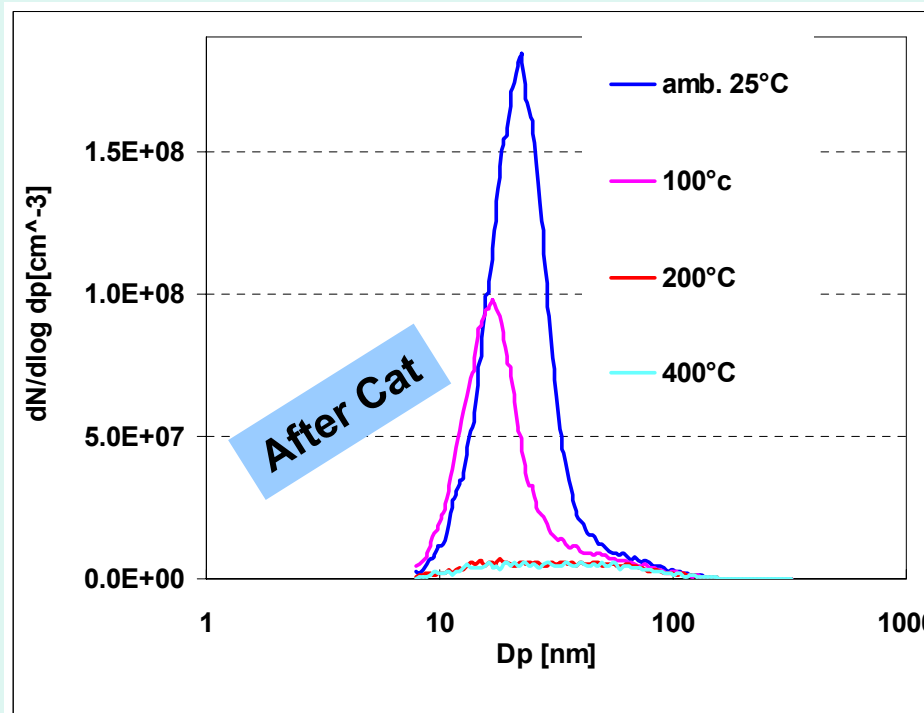
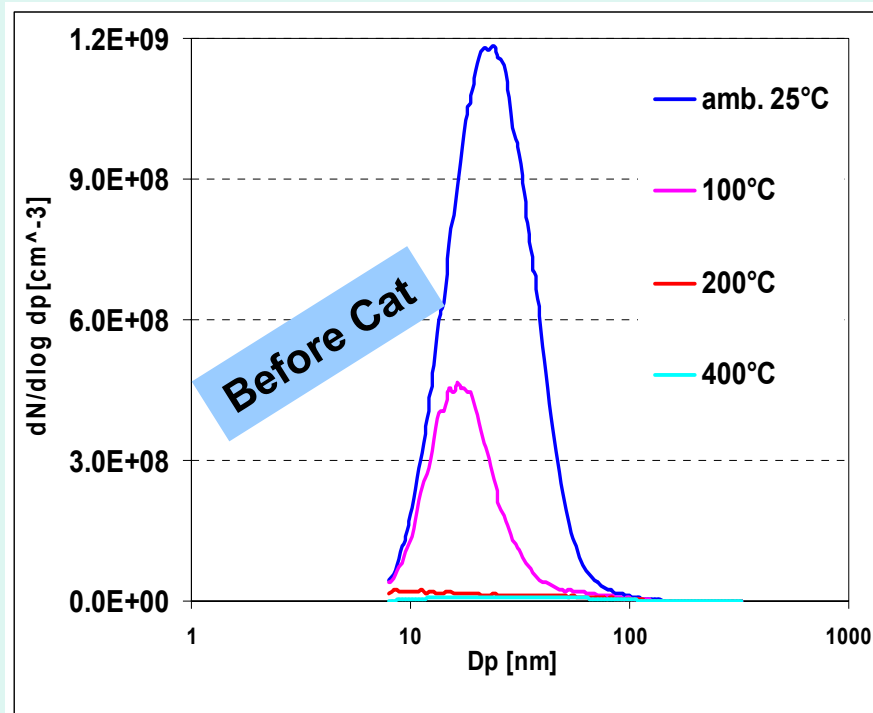
Carburetor



➤ Particles sampled before catalyst are more volatile than downstream of it

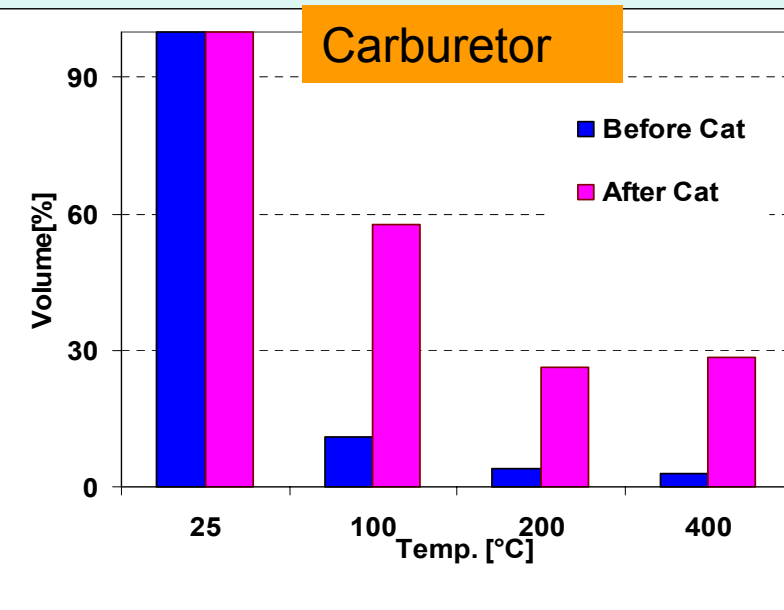
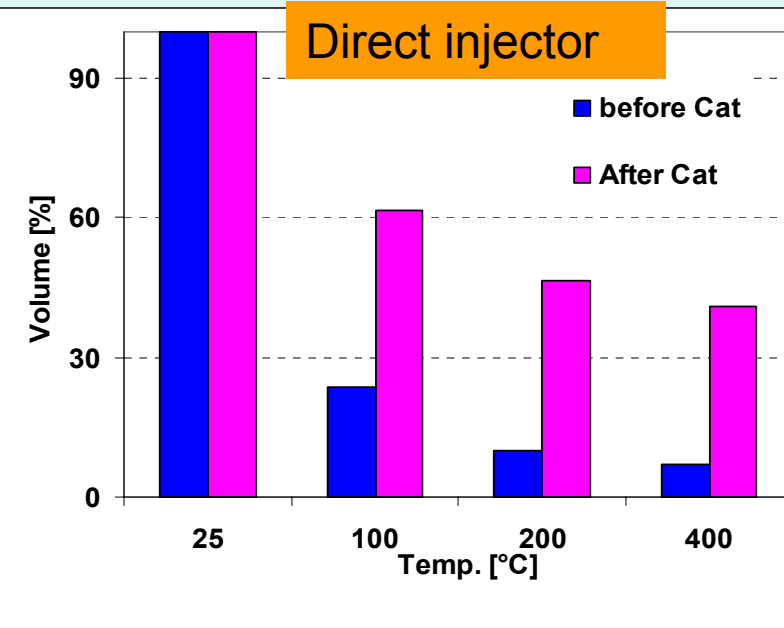
SMPS Results

2- stroke direct injector



➤ Thermal treatment strongly provoke evaporation of the particles

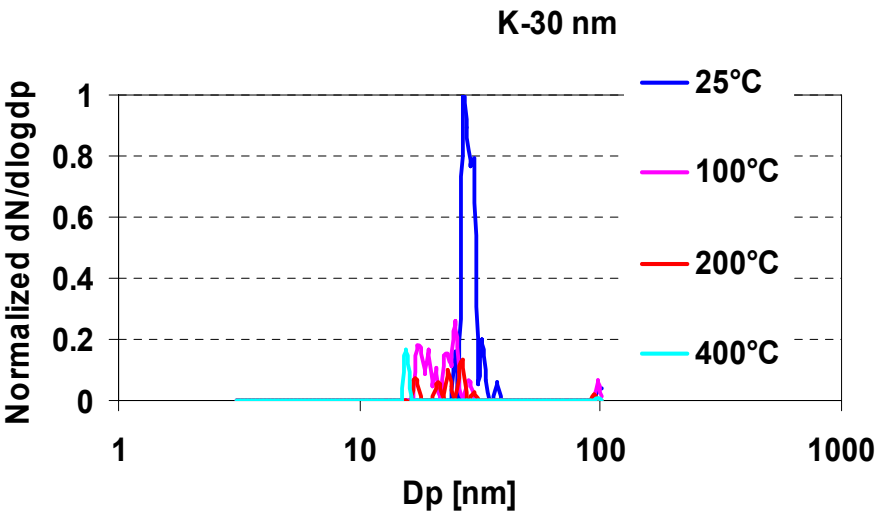
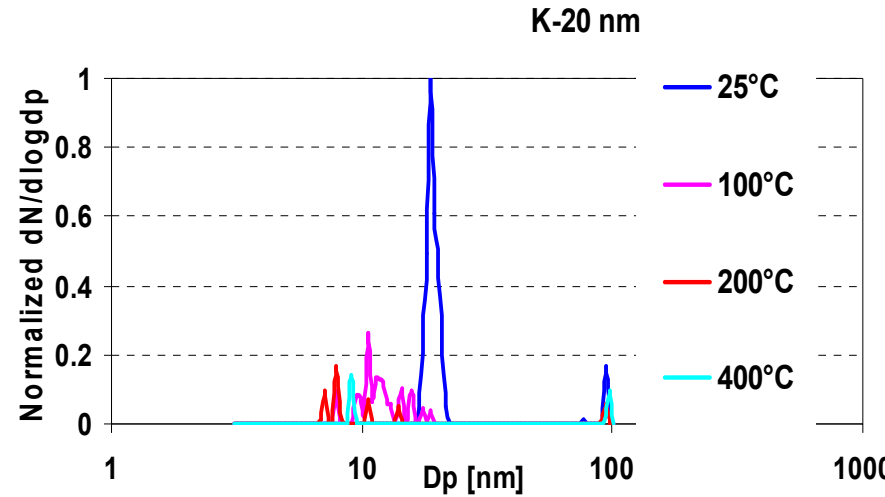
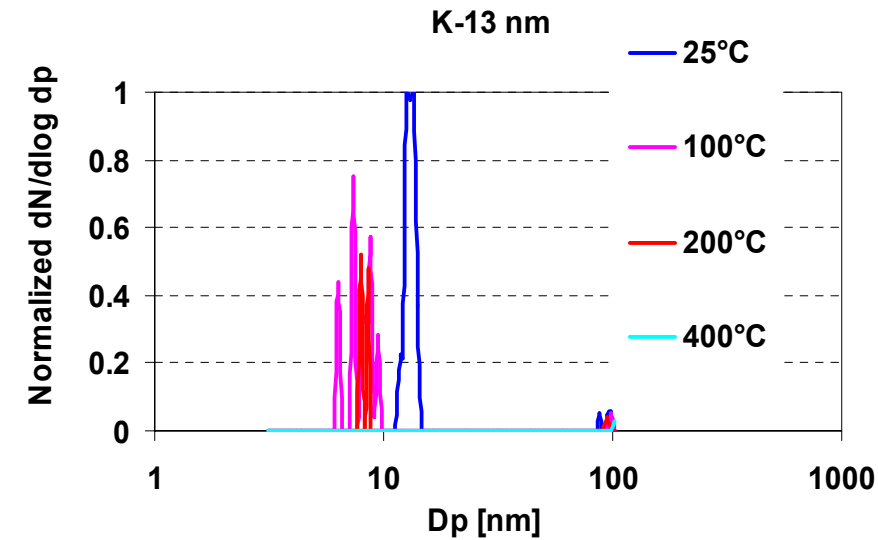
Effect of catalytic converter



➤ relative volume loss of the particles emitted by 2- stroke scooters (DI, Carburetor) sampled upstream of the catalyst were higher than that of the downstream of the catalyst

Tandem DMA

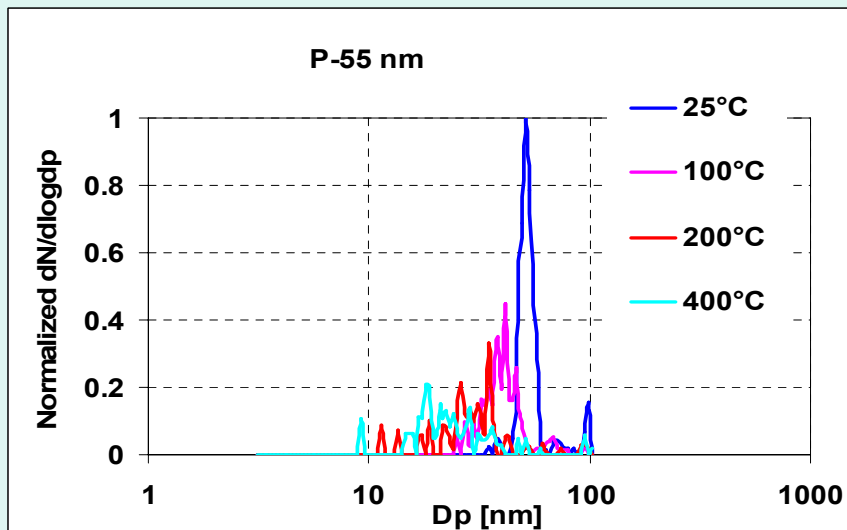
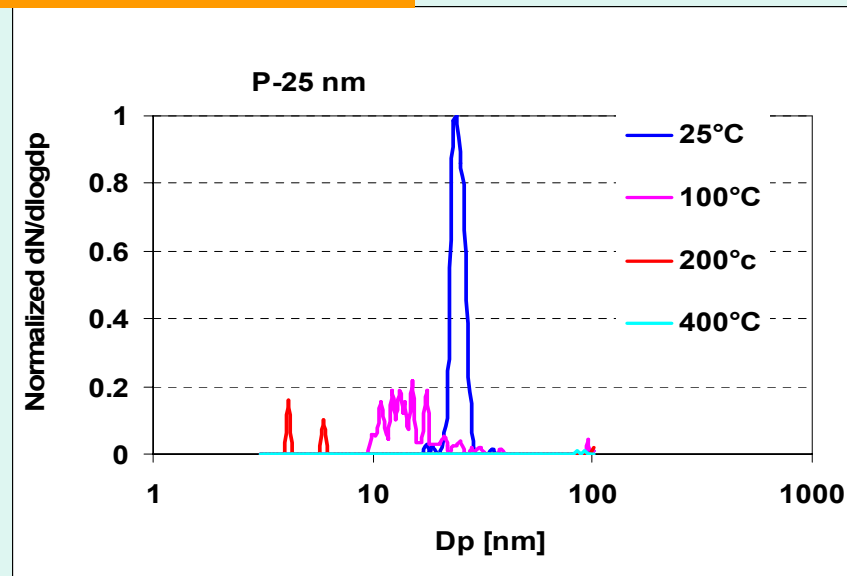
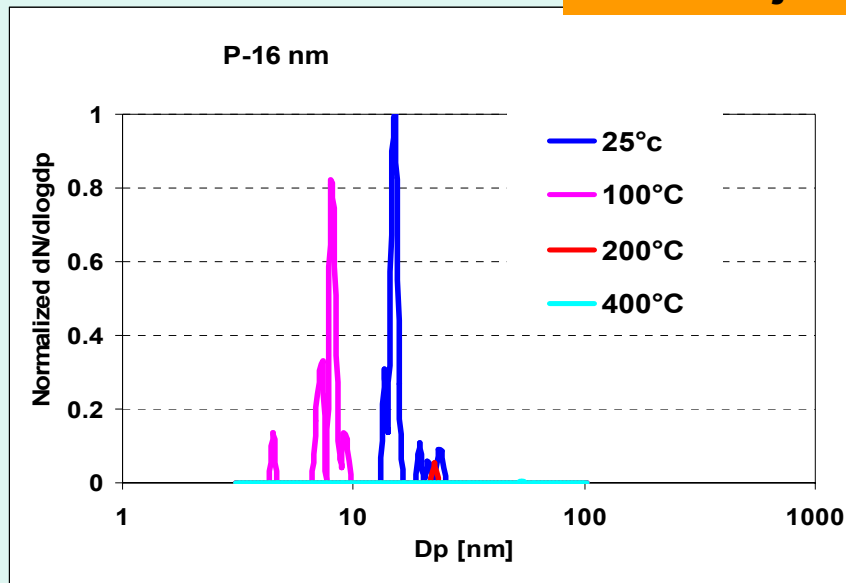
Carburetor- after catalyst



➤ highly volatile and no indication of solid core

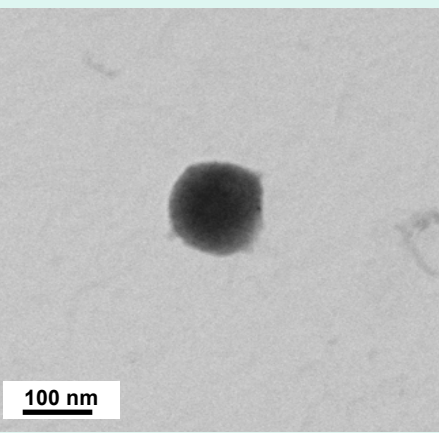
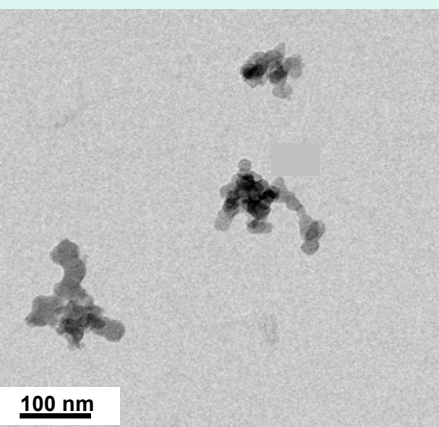
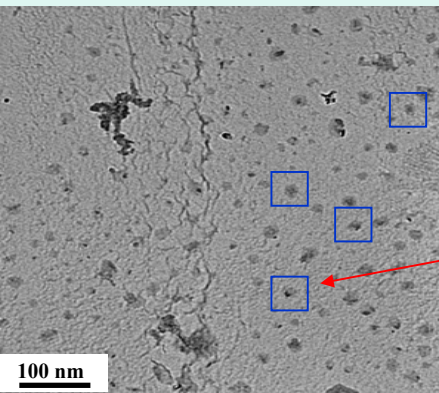
Tandem DMA

Direct injector- after catalyst



➤ Particles selected at 16, 25 and 55 nm are highly volatile particles

TEM images



Cryo microscopy investigation

Volatile particles

size 15- 30 nm

➤ the size in agreement with the SMPS measurement

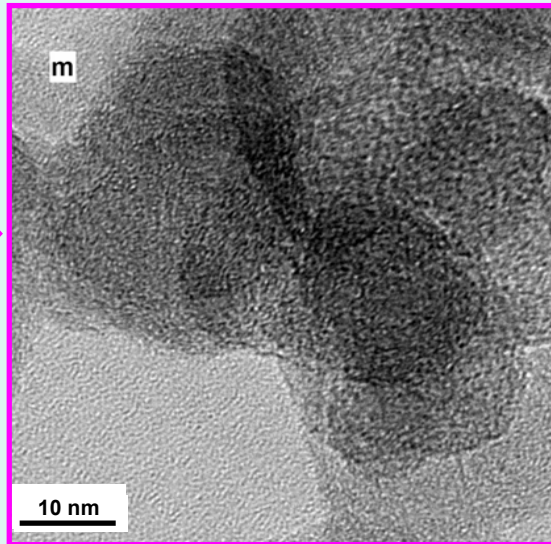
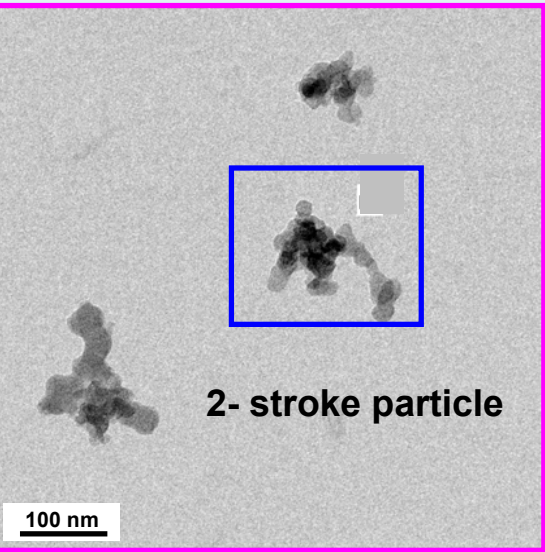
Soot like particles

➤ HRTEM showed the internal structure of soot like particles are not graphitized

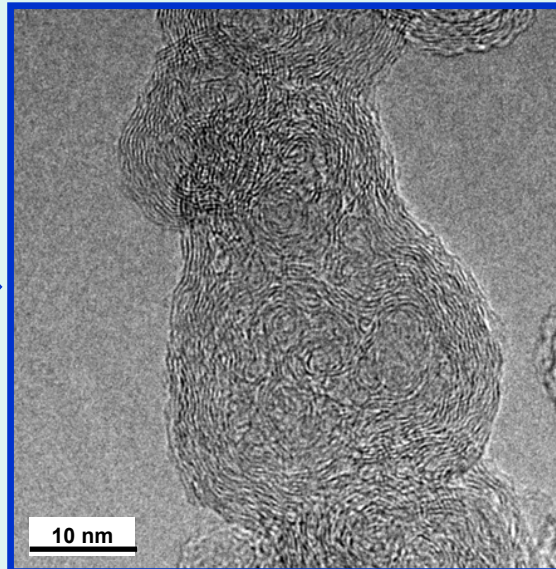
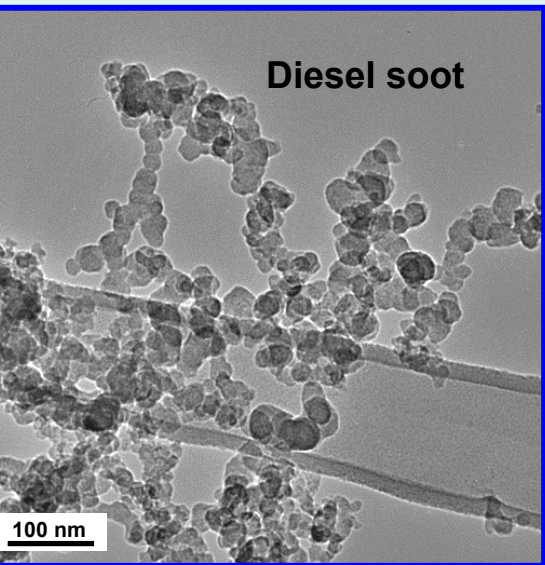
Calcium rich particles

➤ Lubrication oil related particles

HRTEM images of particles from 2- stroke scooter and Diesel passenger cars



- 2-stroke particle showing amorphous microstructures



- stacked graphitic layers of the soot primary particles

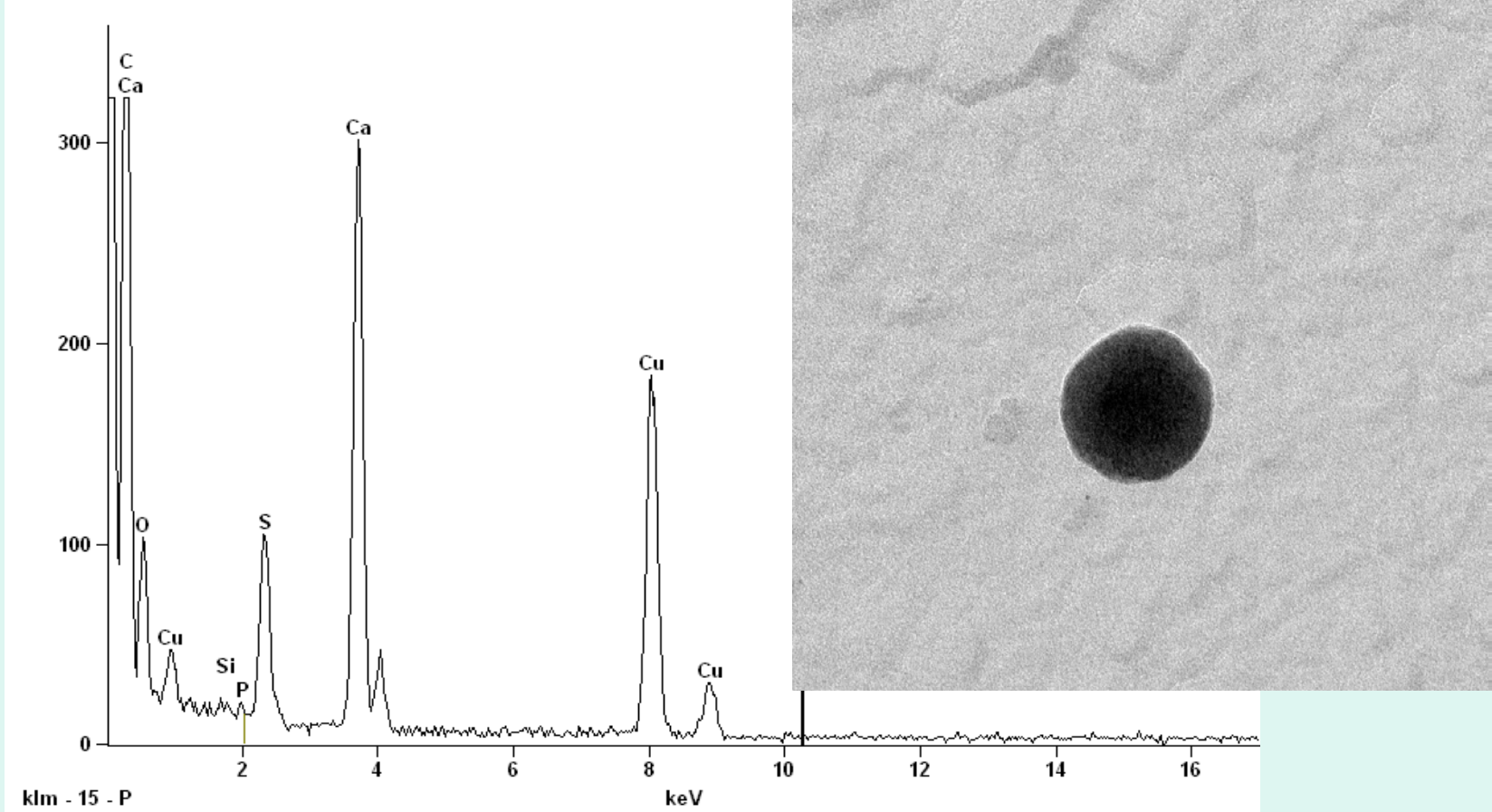
EDX- Spectra

➤ The EDX spectra of these group of particles shows Carbon, Oxygen, Sulphur and Calcium

Full scale counts: 323

particle.3

Cursor: 10.257 keV



➤ the presence Ca and S in the spectra is most probably from lub oil

➤ the Cu signal is from the carbon coated copper TEM-grids

Conclusion

- **Particles emitted from 2-stroke scooters were highly volatile.**
- **The relative volume loss of the exhaust particles upstream of the catalyst is higher than their downstream counterparts. This is, most likely, due to the removal of highly volatile particles by the catalytic converter**
- **No solid core was detected within the size range of the SMPS**
- **No significant difference could be identified between particles sampled from the two different scooters (TSDI, carburetor) .**
- **Volatile particles observed under cryo-electron microscopy are in agreement with the SMPS measurement.**
- **The microstructure of the soot like particles seem to be less graphitized than diesel engine soot particles.**
- **The presence of Ca and S in some particles gives clear indication on the contribution of lubrication oil.**

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Thank you for your attention