Measuring Combustion Emissions down to 10 nm with DC-sensors

ICAD sensor

Heated Automotive Partector for the SUREAL-23 project

T. Rüggeberg and H. Burtscher
Institute of Sensors and Electronics, University of Applied Sciences, Northwestern Switzerland

M. Fierz
naneos particle solutions llc, Windisch, Switzerland

A.D. Melas, D. Deloglou, E. Papaioannou, A.G. Konstandopoulos
Aerosol & Particle Technology Laboratory, CERTH/CPERI, Thessaloniki, Greece

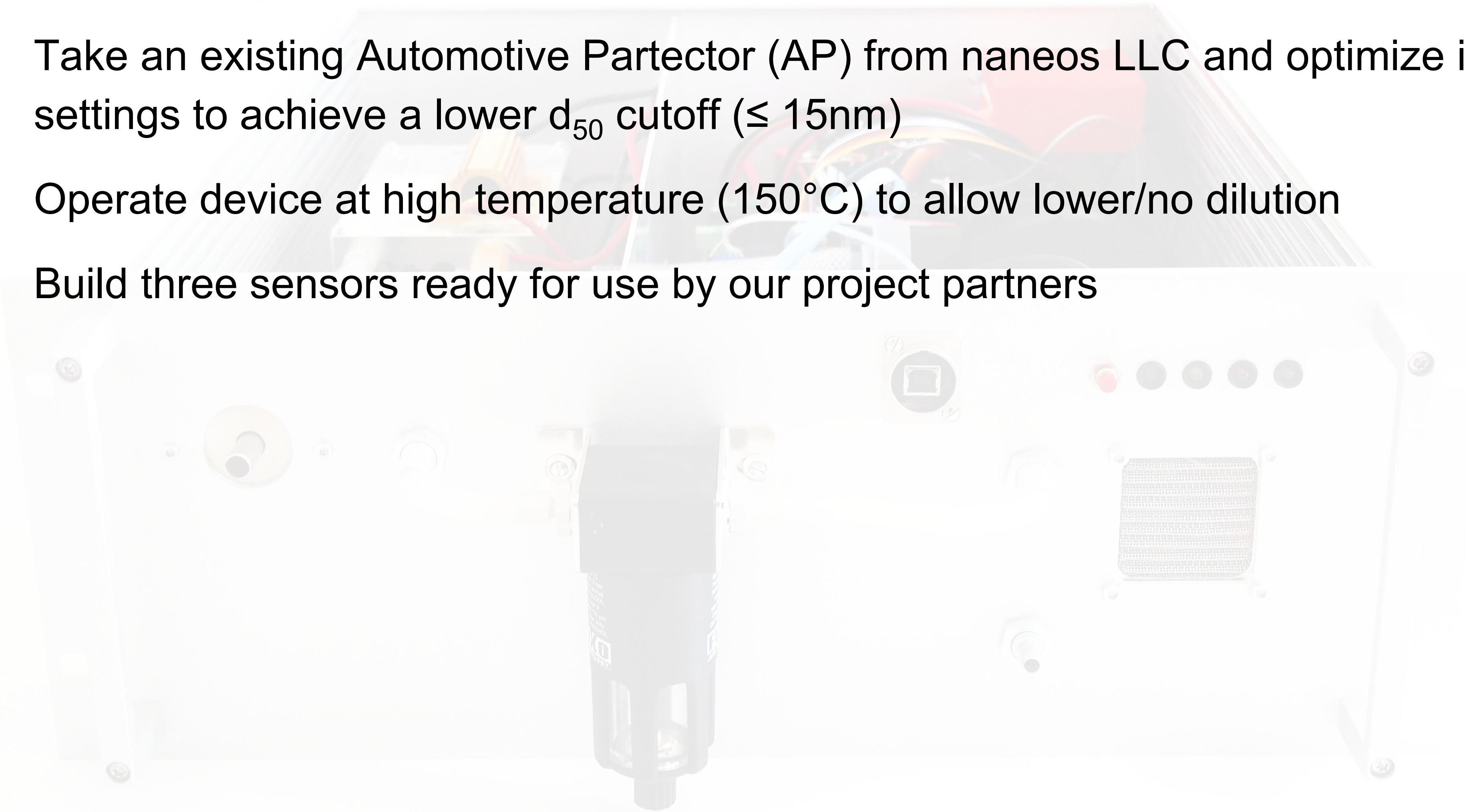
Sureal-23 project

- Sureal-23 project main goals: Understanding, measuring and regulating Sub-23 nm particle emissions from direct injection engines including real driving conditions
- The Sureal-23 project is one of three Horizon2020 EU projects investigating sub23nm particles
- Project partners: APTL, CRF, IFPEN, IM, NKT, FHNW, SEADM, TSI, YALE

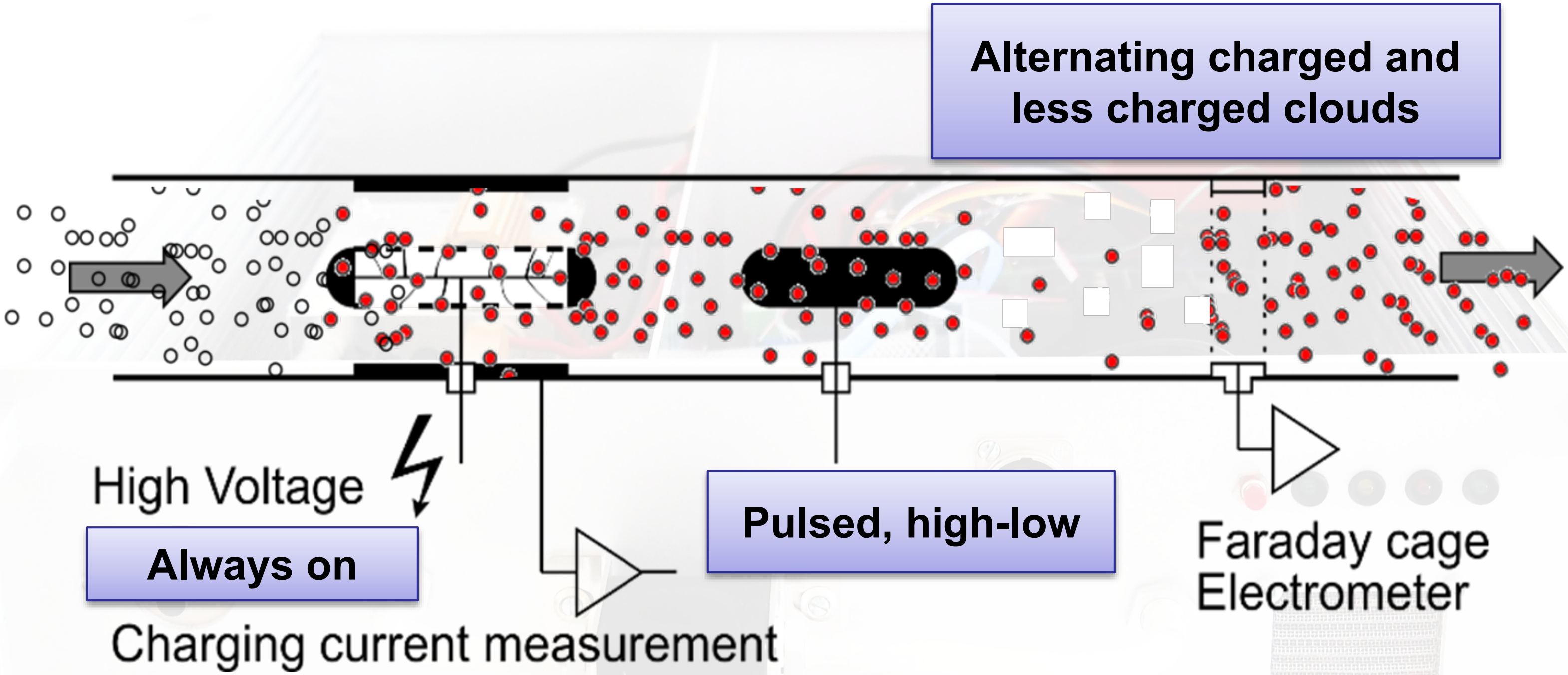
→ **In the framework of the project we developed a diffusion charger based particle number sensor**

Project goals (FHNW)

- Take an existing Automotive Partector (AP) from naneos LLC and optimize its settings to achieve a lower d_{50} cutoff (≤ 15nm)
- Operate device at high temperature (150°C) to allow lower/no dilution
- Build three sensors ready for use by our project partners



Principle of operation



Advantages compared to traditional CPC based methods:

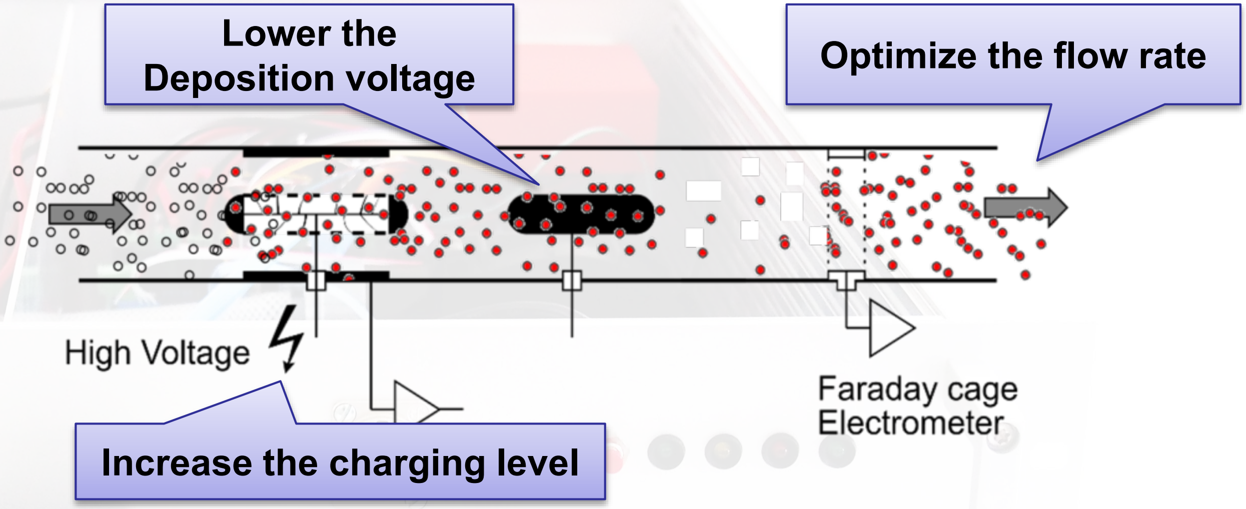
→Small size / lower power consumption / no working fluids

→Suitable for PEMS

Principle of operation

Relevant sensor parameters:

- Charging level
- Deposition voltage
- Flow rate



To lower the cut-off size:

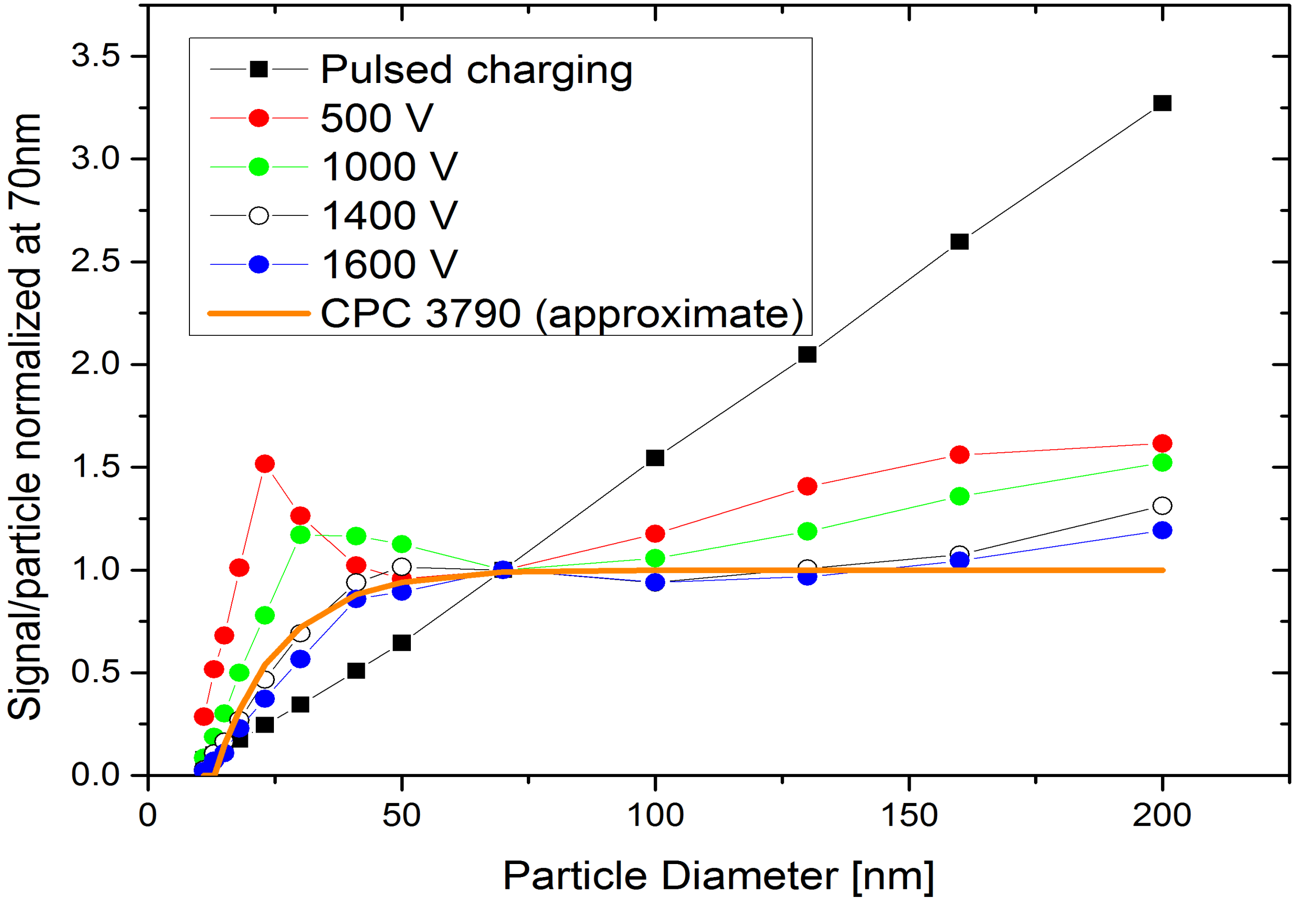
- Lower the deposition voltage
- Optimize the flow rate
- Increase charging level

Modifications for high temperature operation (150°C):

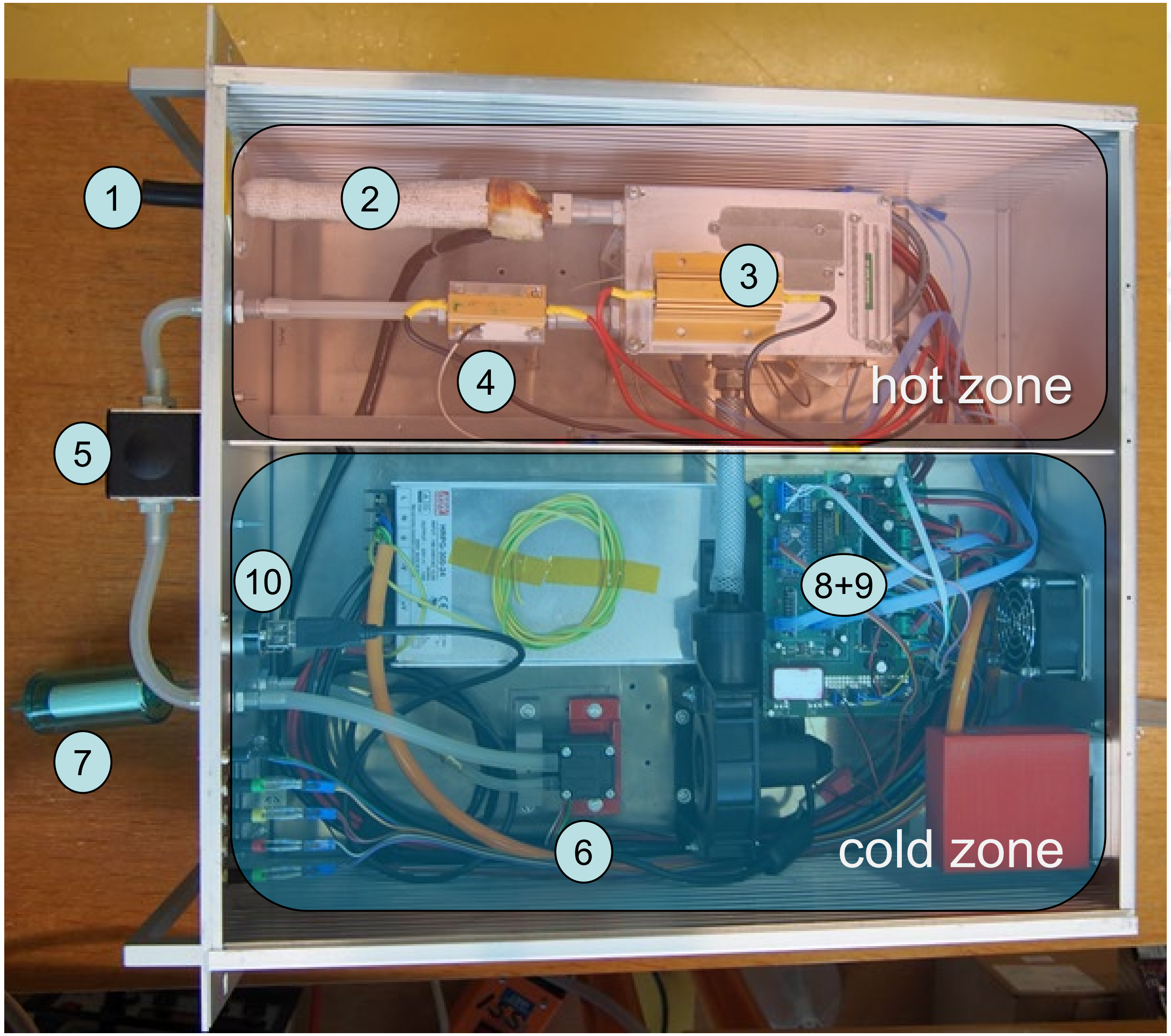
- Separate sensor electronics from standard housing
- Actively cooled electrometer amplifier

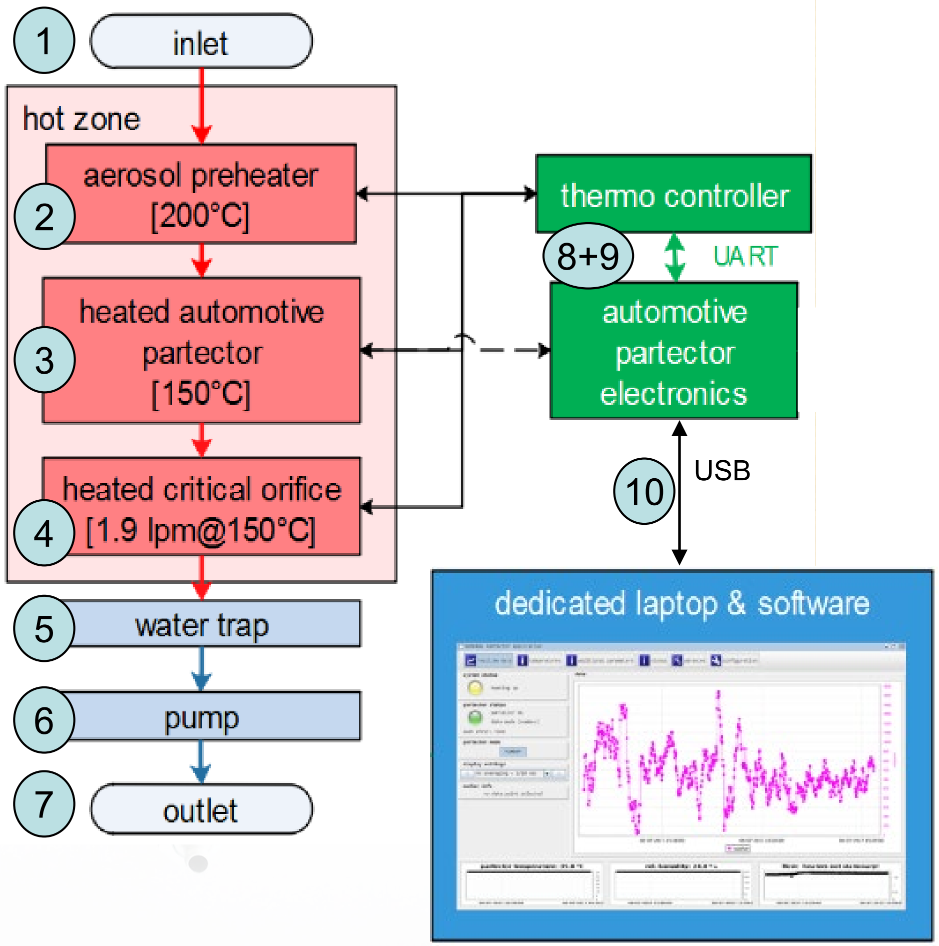
Principle of operation

Size dependency for different (pulsed) deposition voltages:



Prototype


1
2
3
4
hot zone
5
10
8+9
7
6
cold zone


1
inlet
hot zone
2
aerosol preheater [200°C]
3
heated automotive partector [150°C]
4
heated critical orifice [1.9 lpm@150°C]
5
water trap
6
pump
7
outlet
thermo controller
8+9
UART
automotive partector electronics
10
USB
dedicated laptop & software

Instrument characterization

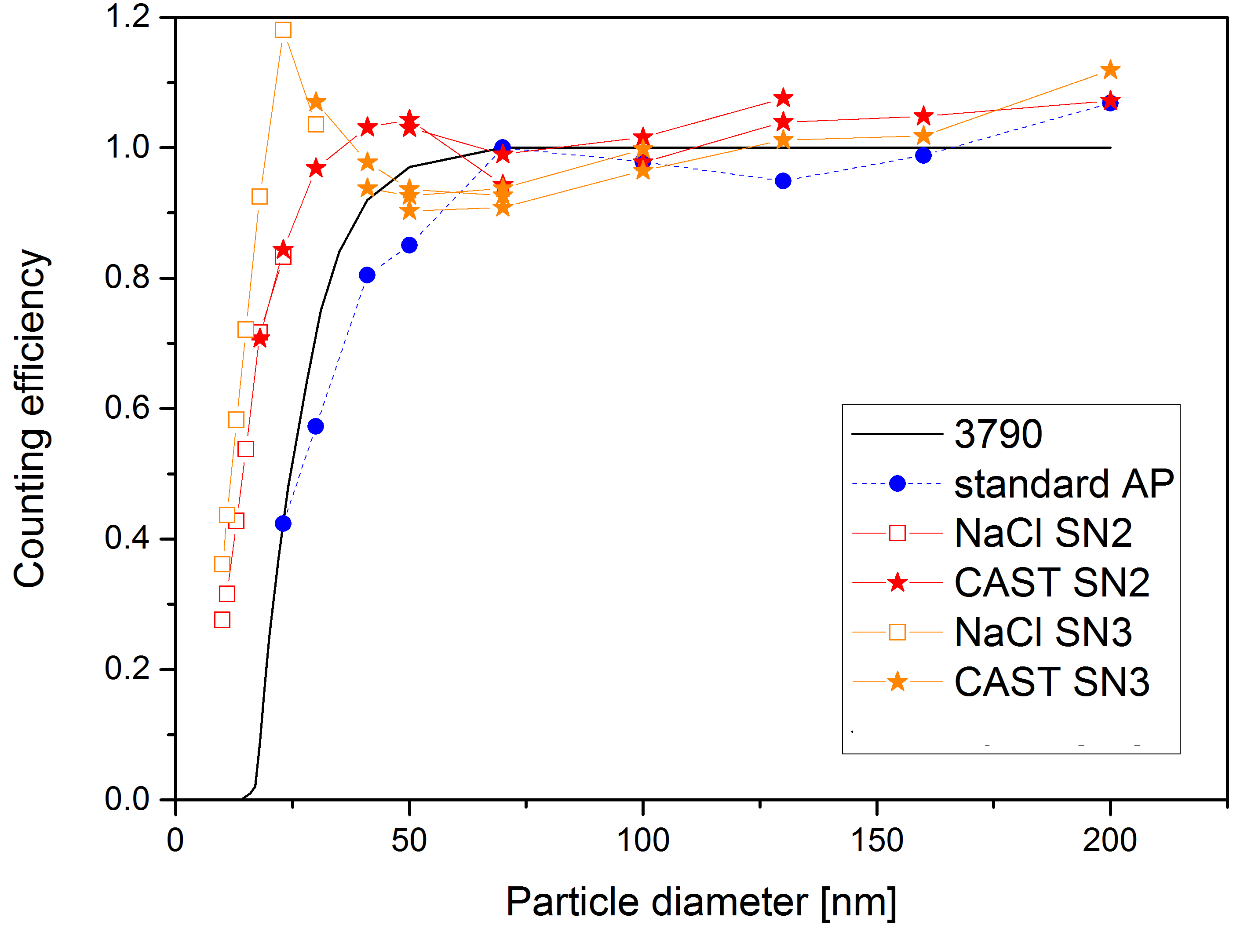
Measurements done at our lab (FHNW):

– Monodisperse counting efficiency with soot (and NaCl)

Verification measurements performed by APTL:

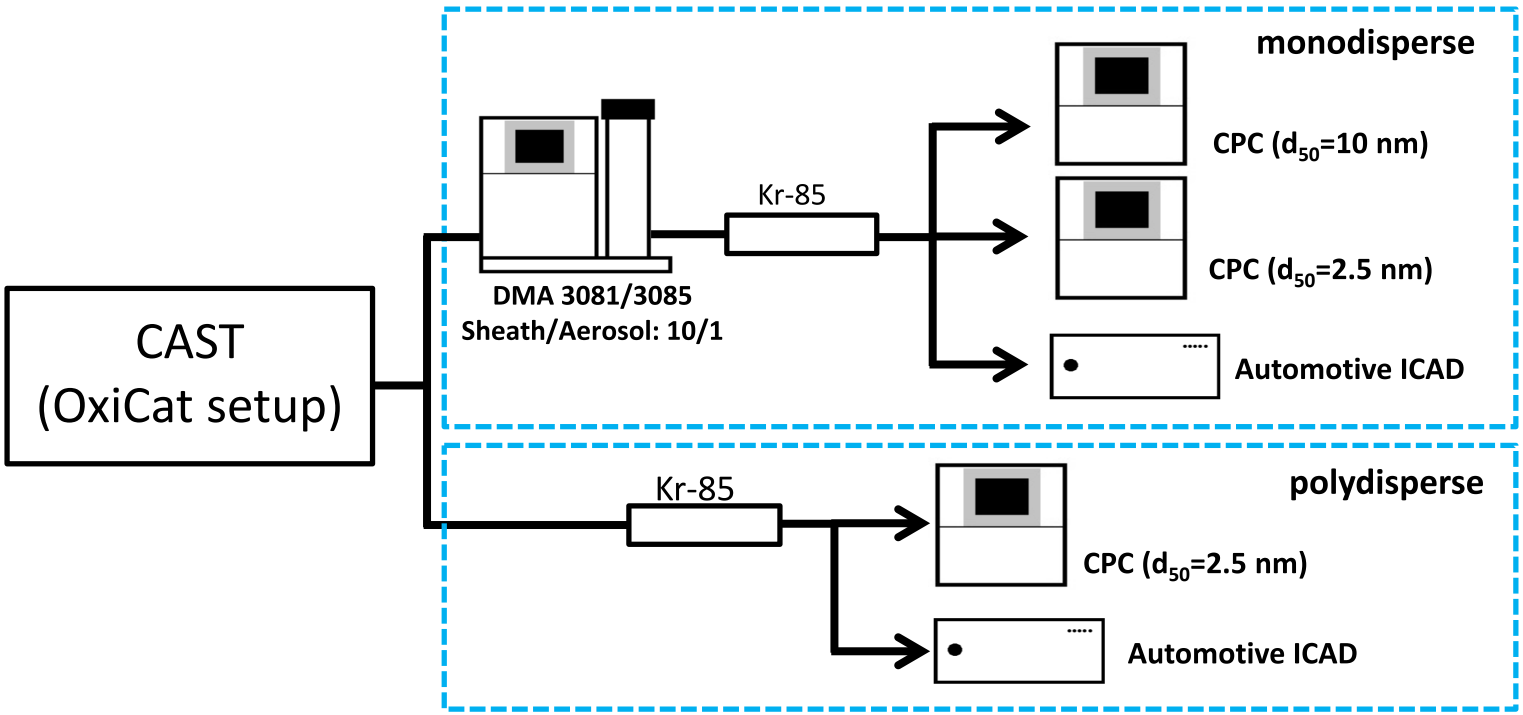
– Mono- and polydisperse counting efficiency with soot
– Linearity check
– Diesel engine measurements

Lab (FHNW) – Monodisperse counting efficiency



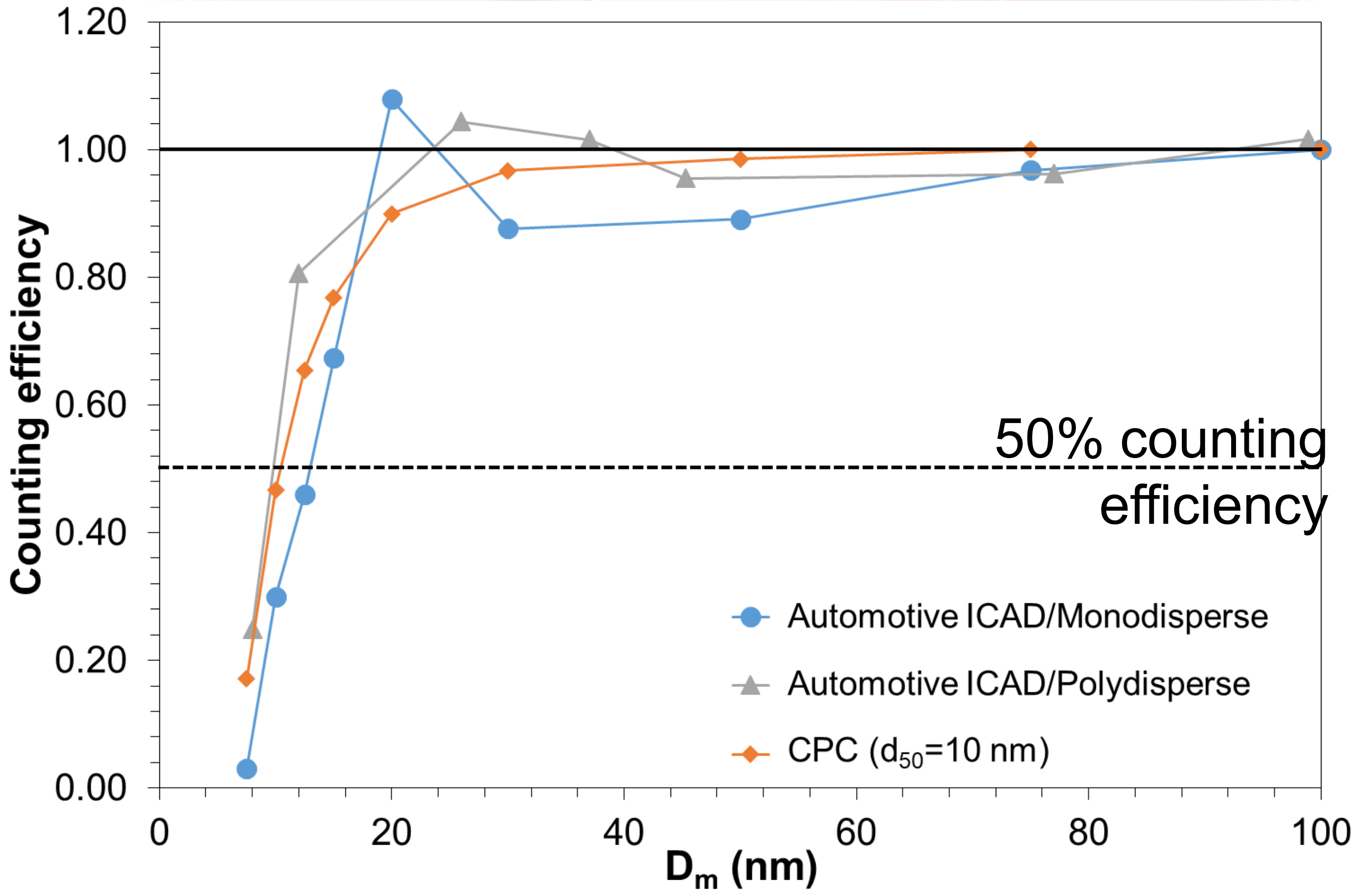
Lab (APTL) – Mono- and polydisperse counting efficiency

Monodisperse and polydisperse counting efficiency setup at APTL:

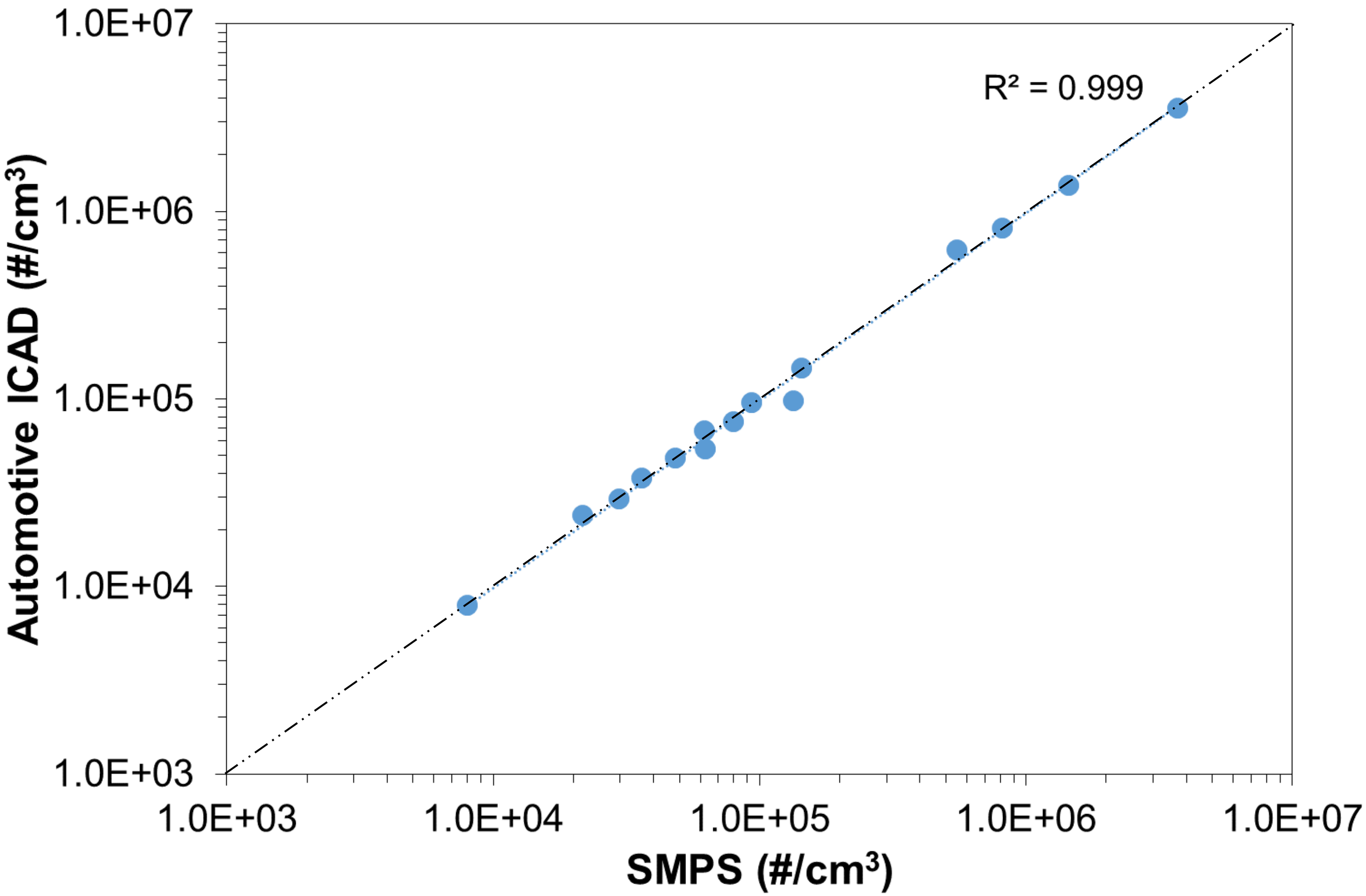


Lab (APTL) – Verification of the counting efficiency

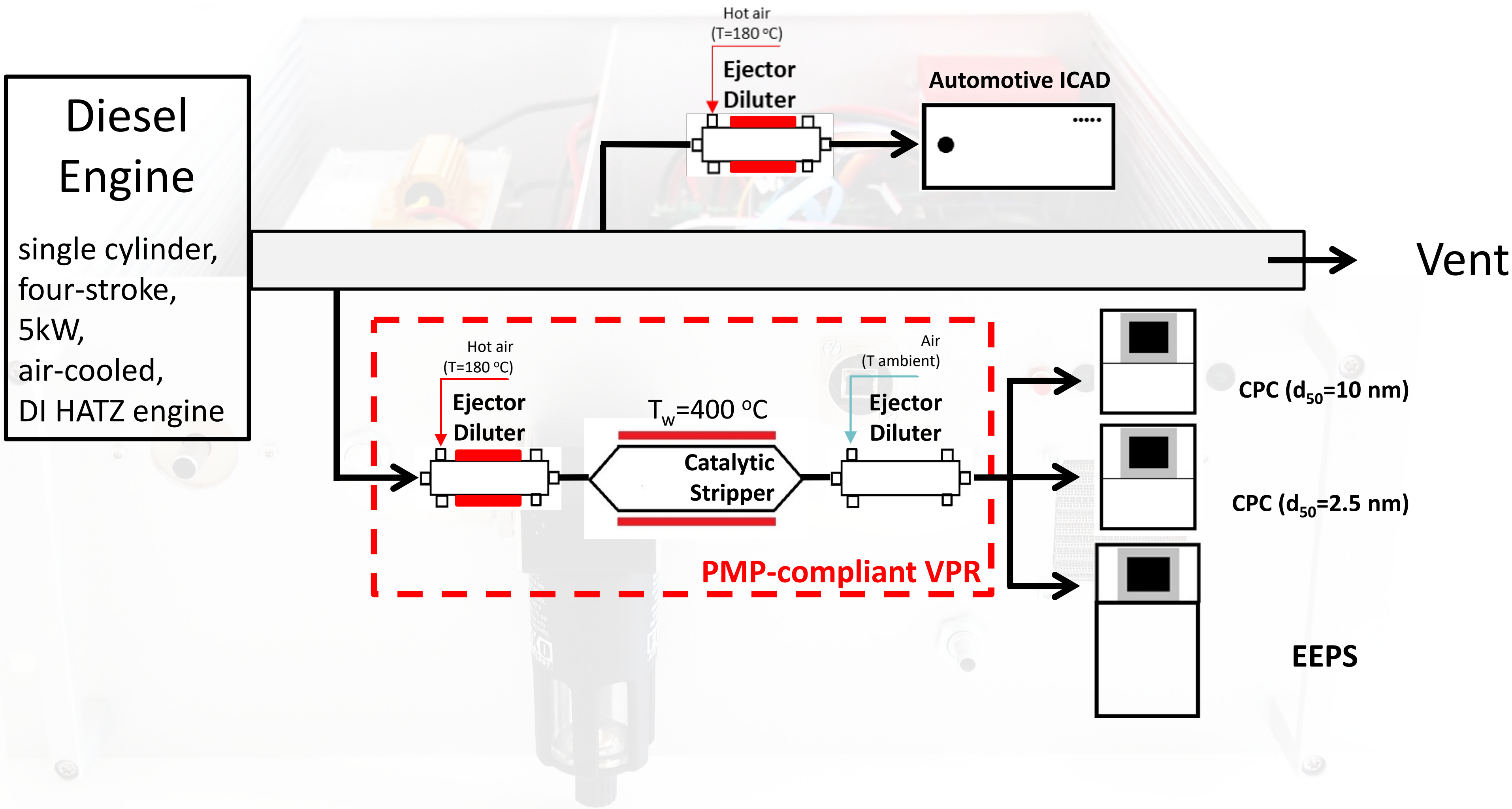
Counting efficiency verified by APTL:



Lab (APTL) – Linearity check – ICAD vs. SMPS

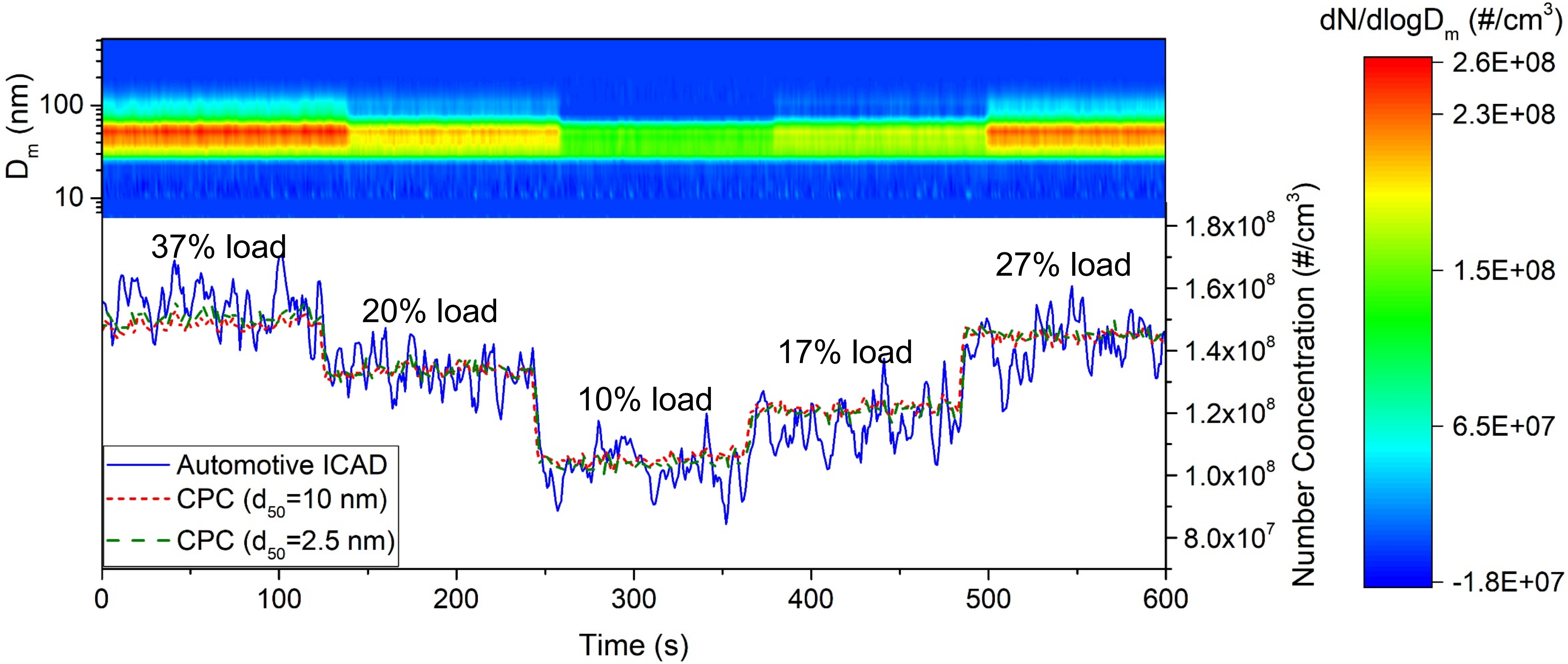


Lab (APTL) – Diesel engine tests – Measurement setup



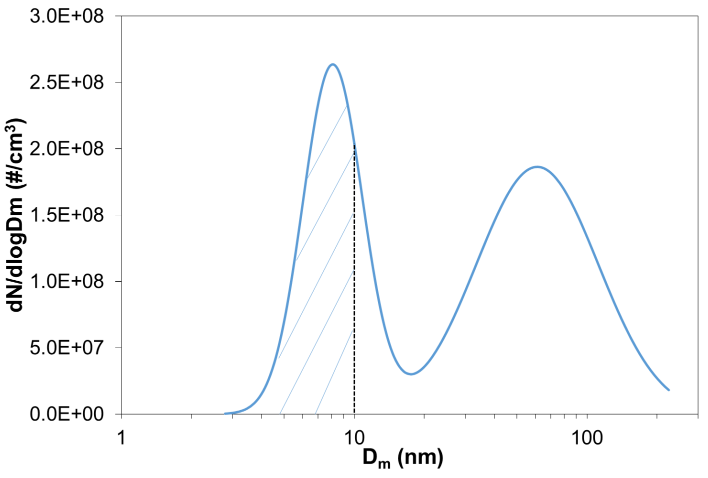
Lab (APTL) – Diesel engine tests

Low sulphur diesel (6 ppm S) results:

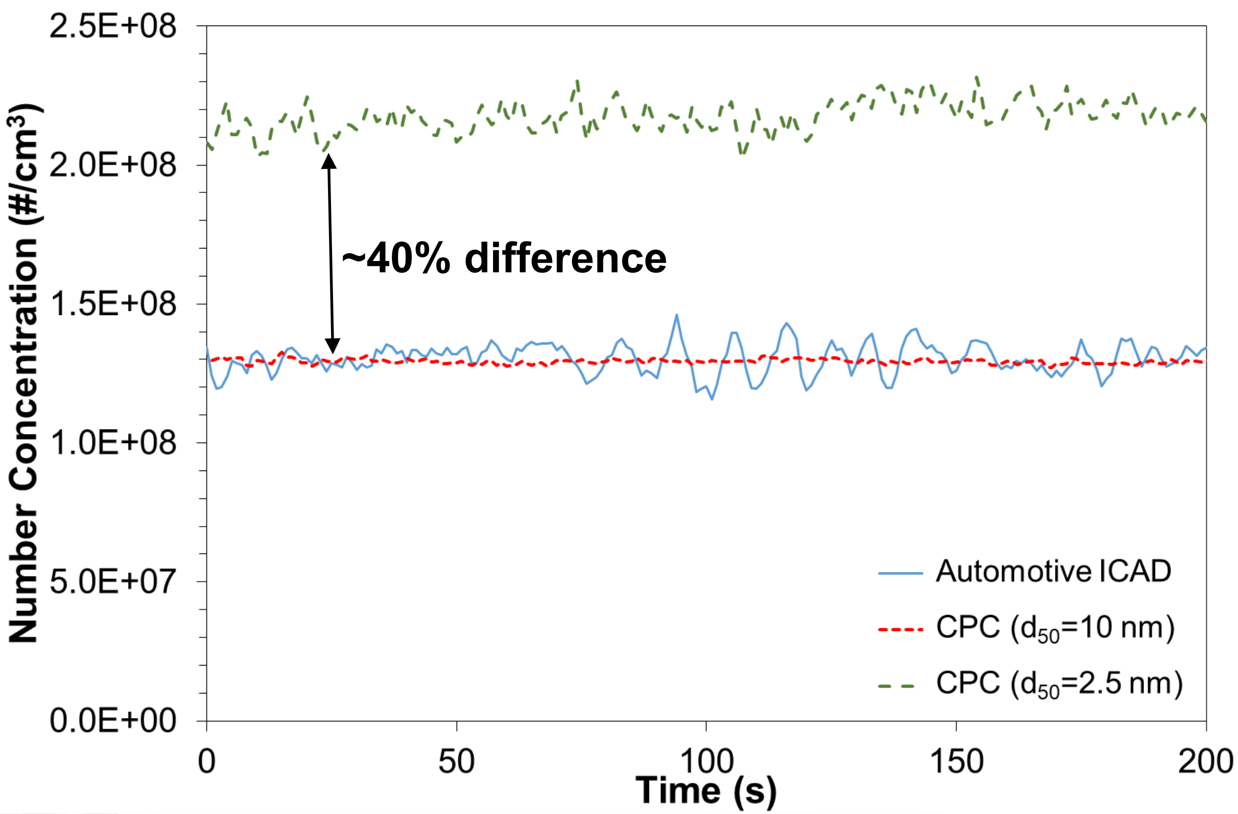


Lab (APTL) – Diesel engine tests

Low sulphur diesel with 10 ml/l of a Ce-based fuel additive:



35% of the particles ≤ 10nm size



Summary and Conclusion

Our research prototypes perform as specified with only minor issues so far

- high temperature operation: ok (150°C)
- d_{50} cutoff: ok (10-14nm)
- CPC like counting efficiency: ok (for this application)
- linearity: ok (R^2=0.999)

→Diffusion charger based particle number sensors are perfectly able to measure sub-23nm exhaust emissions

Q&A

Size	178x430x460mm 4HE 19"
Weight	10 kg
Sample flow rate	1.72 lpm (external flow @ 20°C)
d_{50} cutoff	11-14nm
Concentration range	~ 10^3 - 10^6 pt/cm^3
Pressure range	Δp at inlet should not exceed ±5% of ambient pressure
Inlet gas temperature	0 – 400°C