Heated Automotive Partector
(aka ICAD)

An Electrical Detector for Particle Counting below 23 nm

SUREAL-23 project

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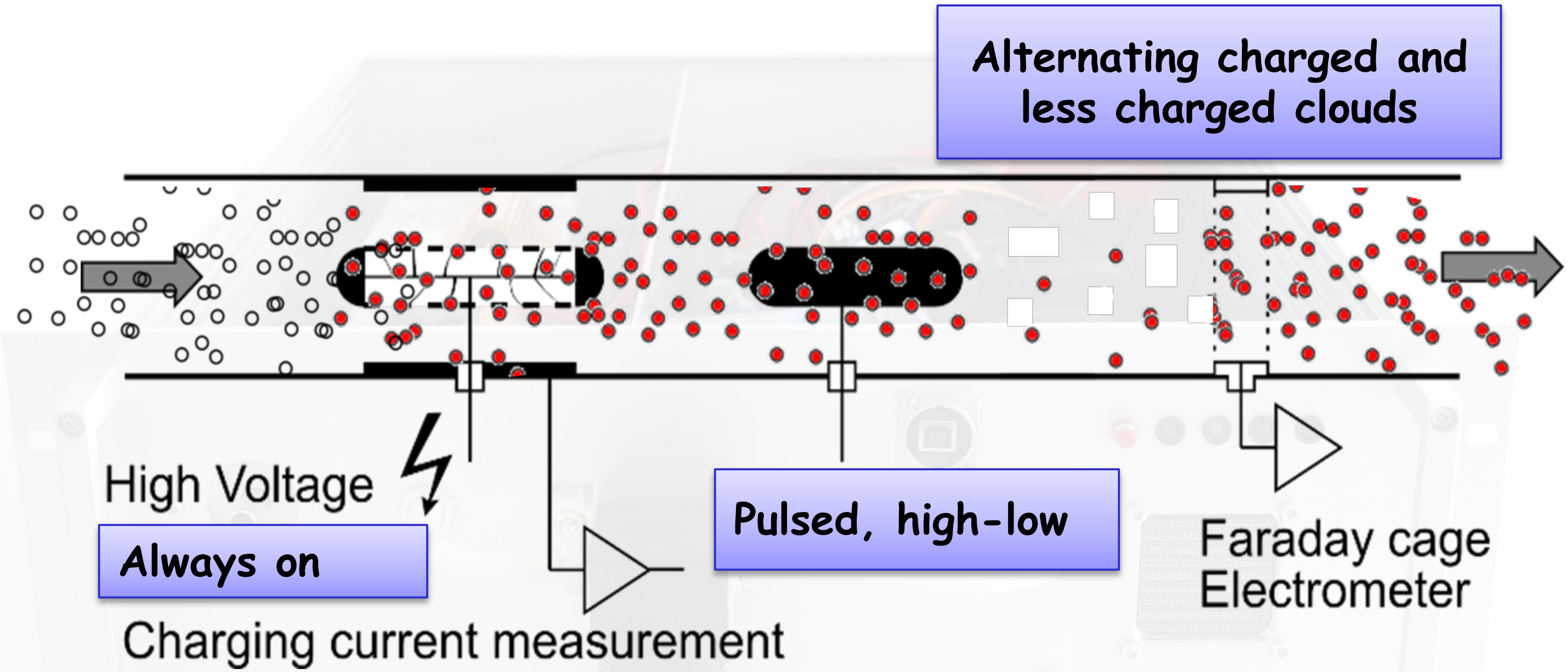
SUREAL-23

- The Sureal-23 project is one of three Horizon2020 EU projects
- Main goals: Understanding, Measuring and Regulating Sub-23 nm Particle Emissions from Direct Injection Engines Including Real Driving Conditions
- Project partners: APTL, CRF, IFPEN, IM, NKT, FHNW, SEADM, TSI, YALE
- Our role (FHNW): develop a diffusion charge 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 (~10nm)
- Operate device at high temperature (150°C) to allow lower/no dilution
- Build 3 heated Automotive Partectors (HAP) ready for testing by our project partners

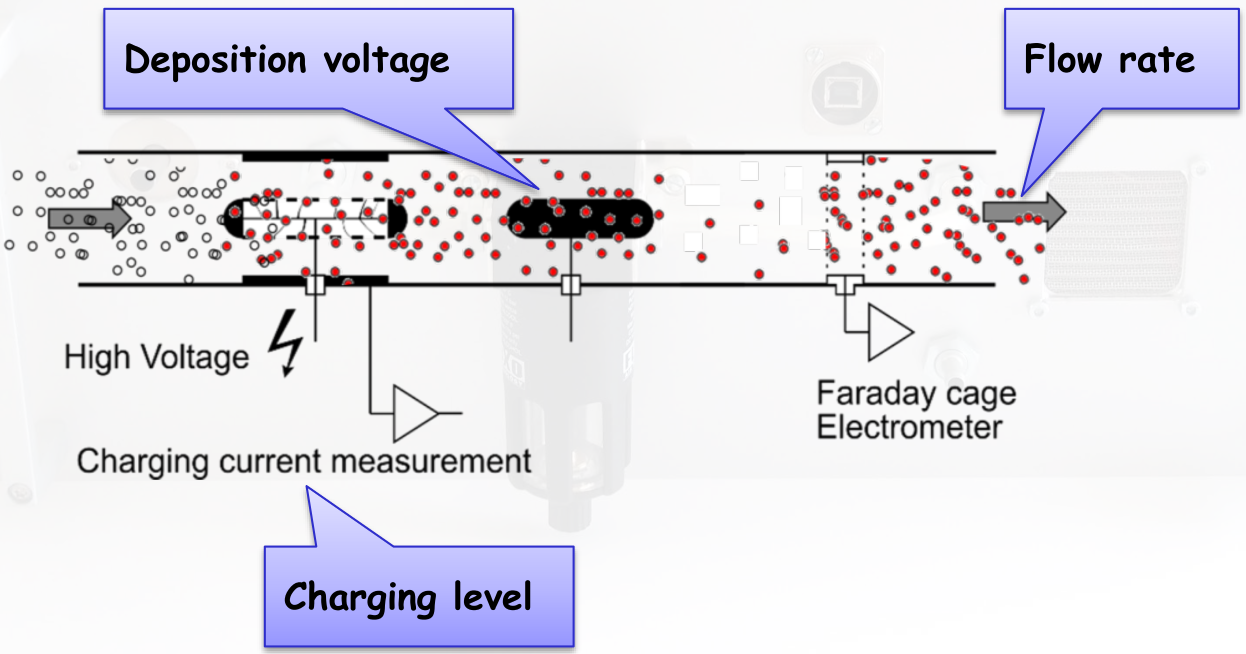
HAP - Principle of operation



- Advantages
  - Small size / lower power consumption / no working fluids
  - Suitable for PEMS

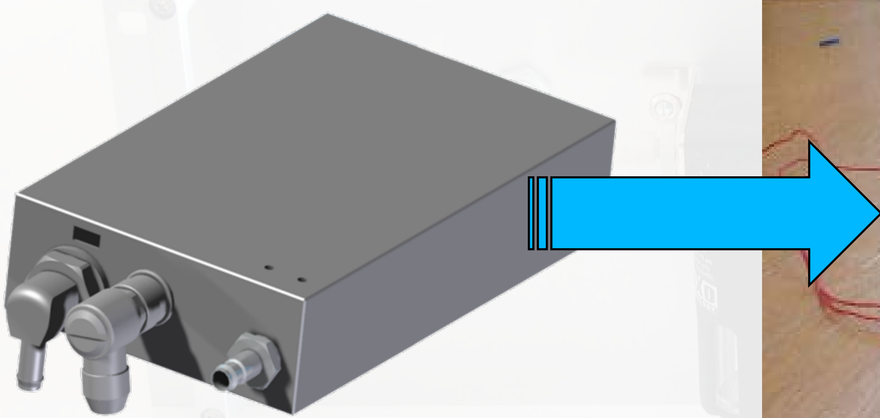
HAP - Principle of operation

- Modifications to lower the cut-off size:
  - Increase charging level
  - Lower the deposition voltage
  - Optimize the flow rate

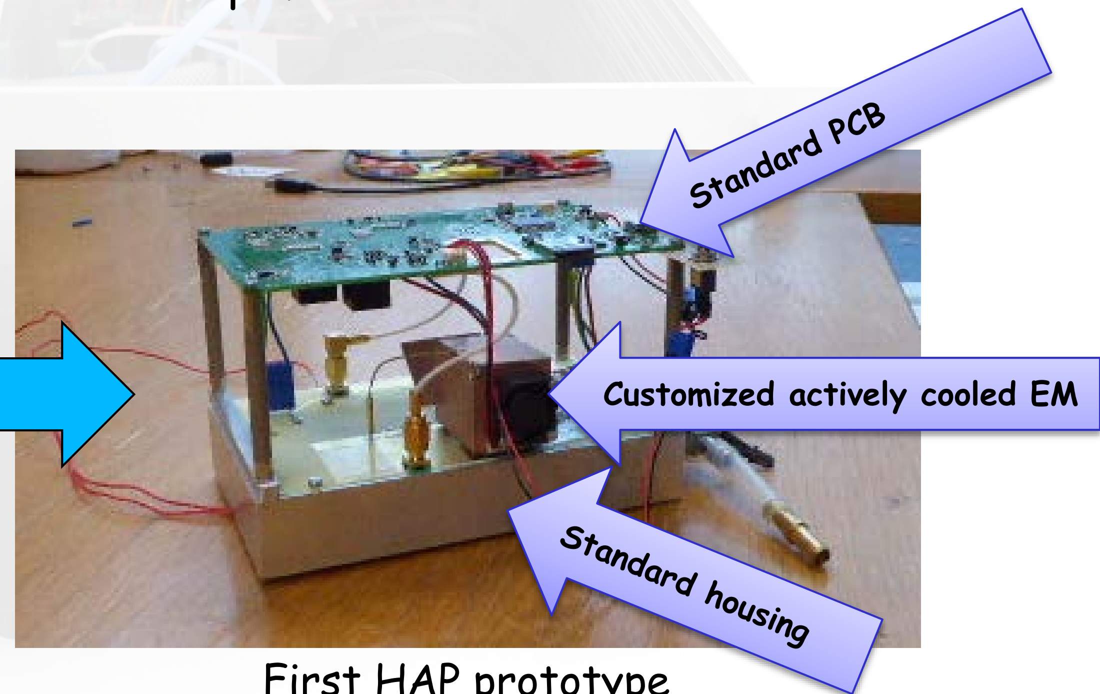


HAP - Principle of operation

- Modifications for high temperature operation:
  - Separate sensor electronics from standard housing
  - Actively cooled electrometer amplifier

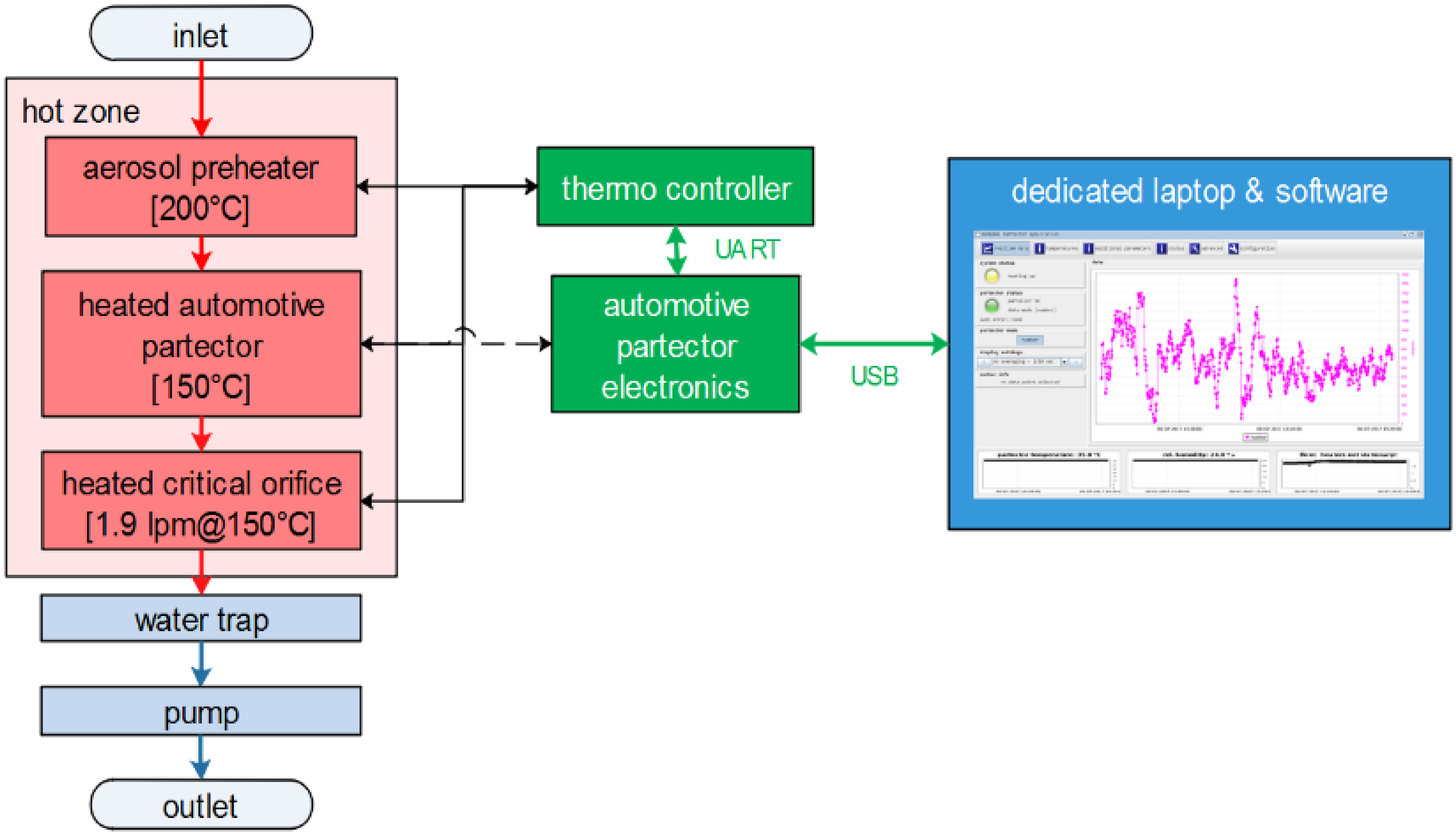


Standard Automotive Partector



First HAP prototype

HAP - Prototype



HAP - Specification

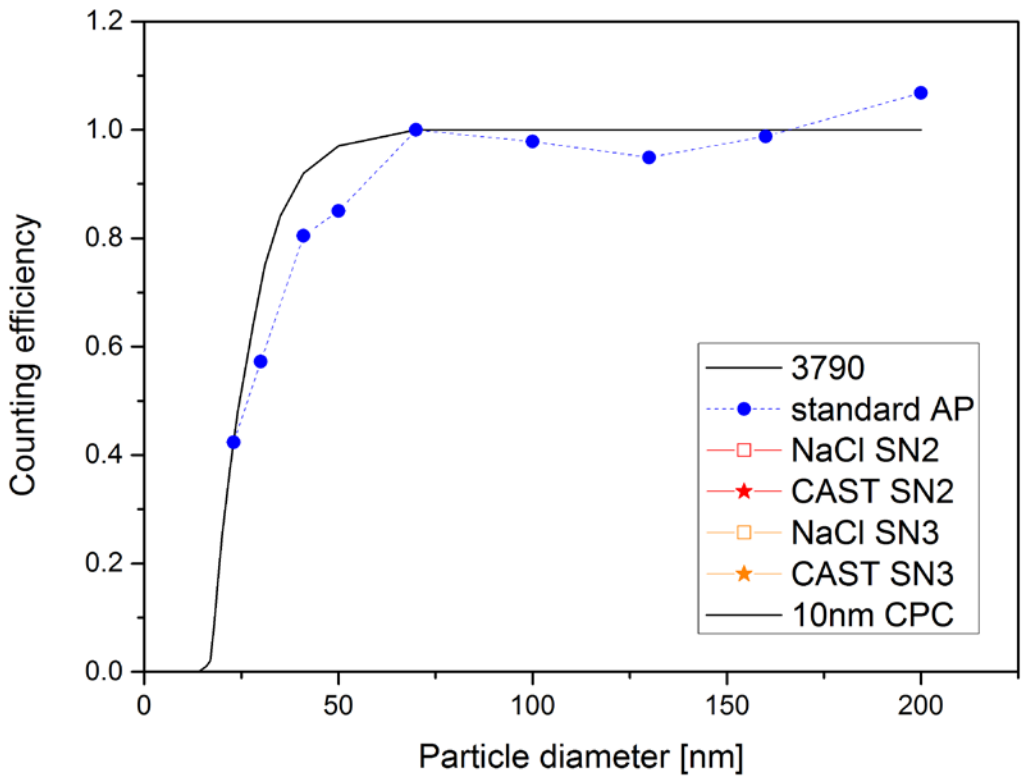
Size	178x430x460mm 4HE 19"
Weight	10 kg
Sample flow rate	1.72 lpm (external flow @ 20°C)
d_{50} cutoff	11-14nm
Concentration range	~ 10^3 - 10^6 pt/cm^3
Pressure range	Δp at inlet should not exceed ±5% of ambient pressure
Inlet gas temperature	0 – 400°C

Instrument characterization

- Measurements done at our lab (FHNW):
  - Monodisperse counting efficiency with soot and NaCl
- Verification measurements performed by APTL:
  - Polydisperse counting efficiency with soot
  - Linearity check
- Vehicle measurements performed by IFPEN:
  - WLTC cycle

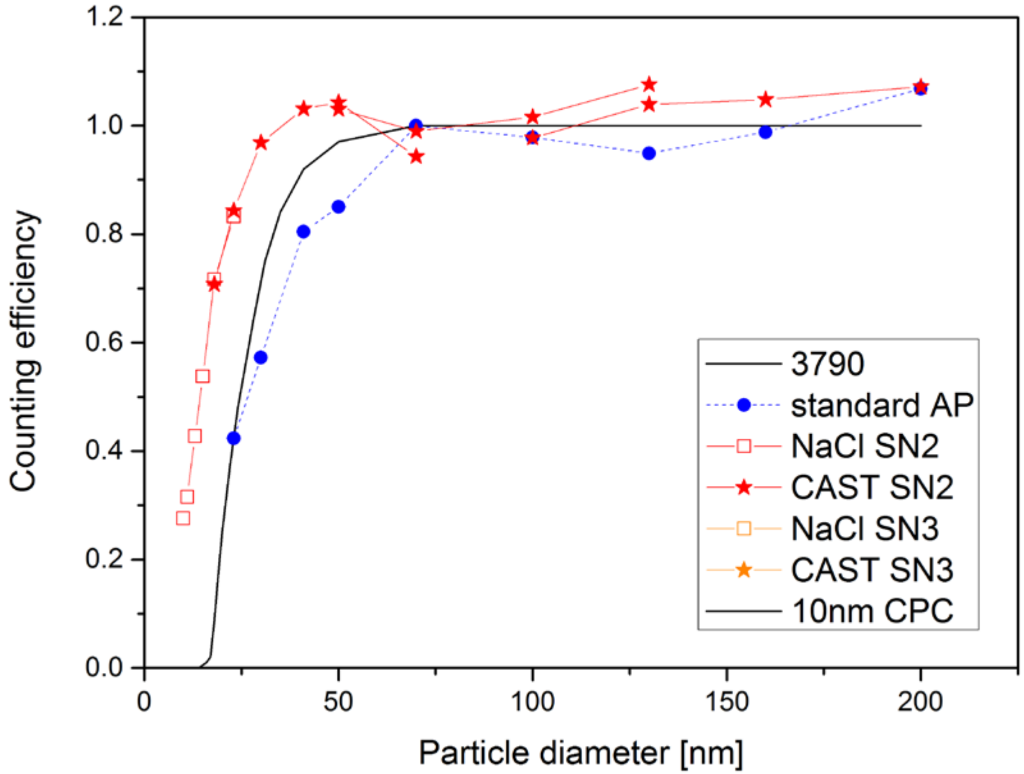
Lab (FHNW) – Counting efficiency

- Monodisperse counting efficiency:



Lab (FHNW) – Counting efficiency

- Monodisperse counting efficiency:



Lab (FHNW) – Counting efficiency

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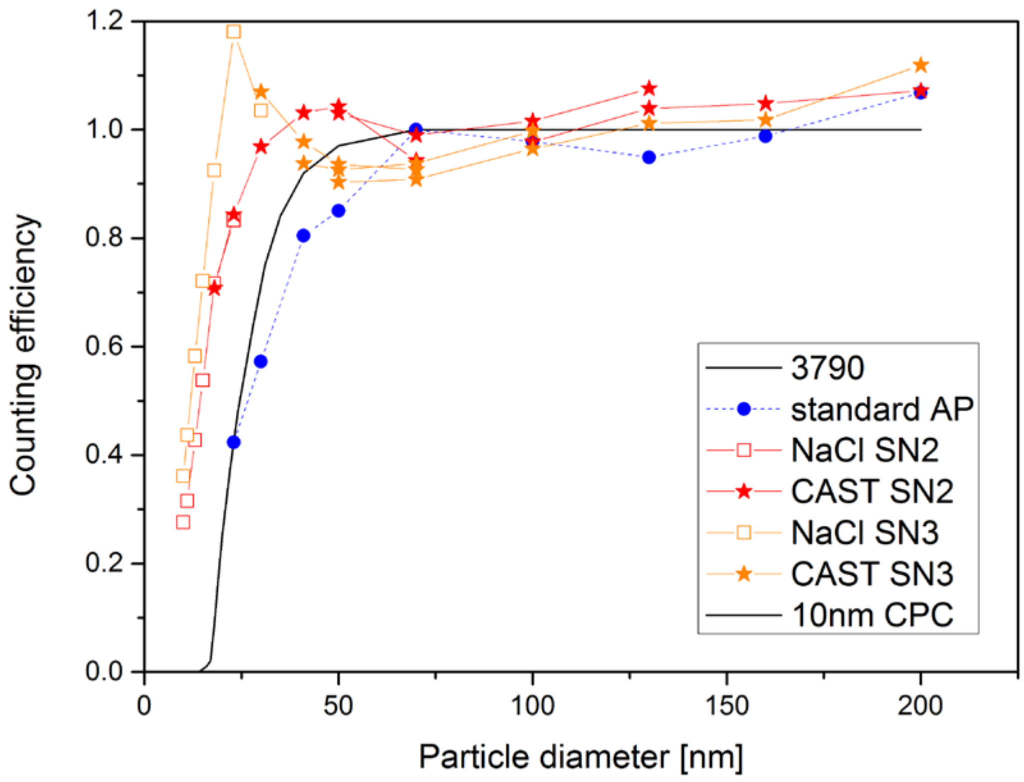
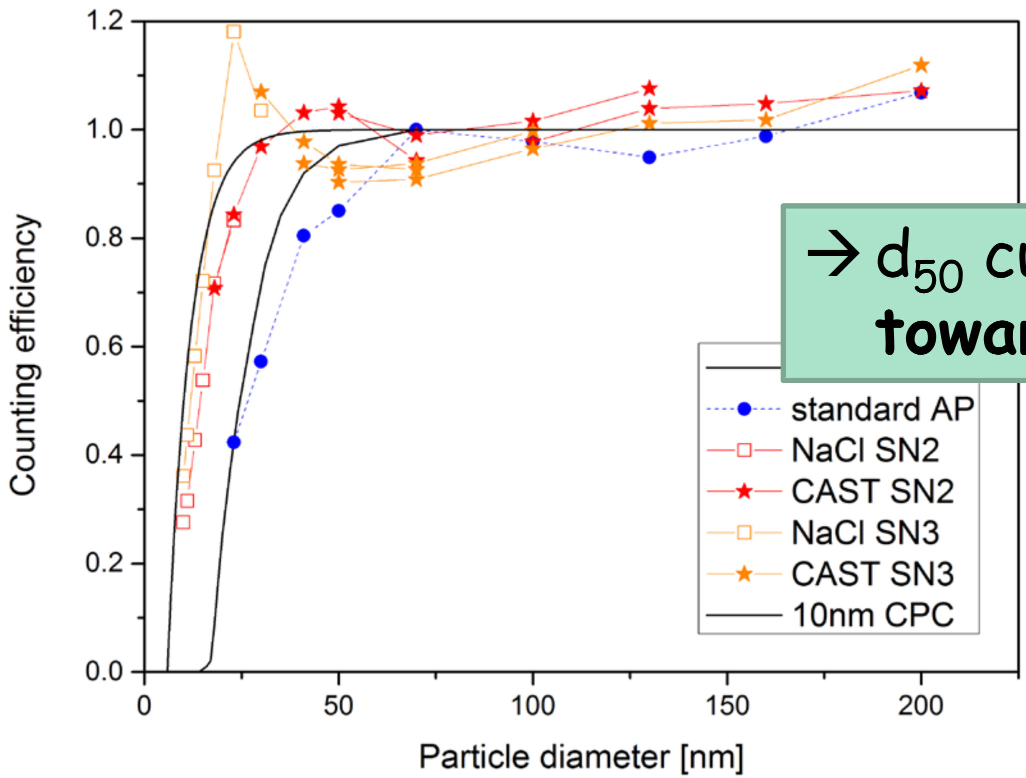


Lab (FHNW) – Counting efficiency

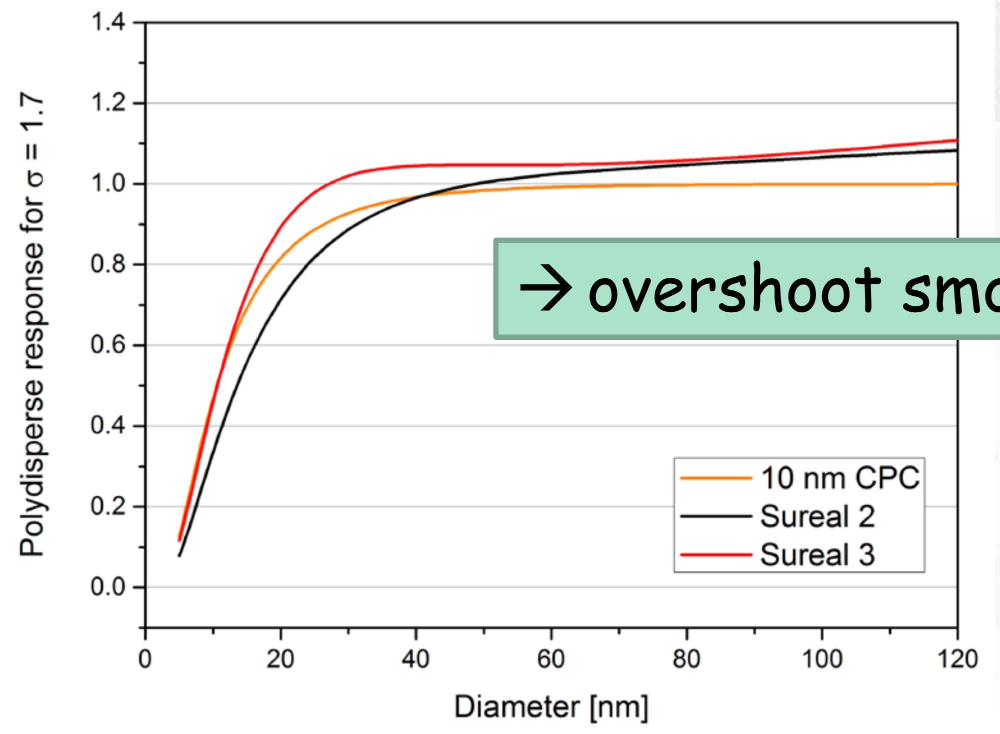
- Monodisperse counting efficiency:



→ d_{50} cut off **shifted towards 10nm**

Lab (FHNW) – Polydisp. efficiency

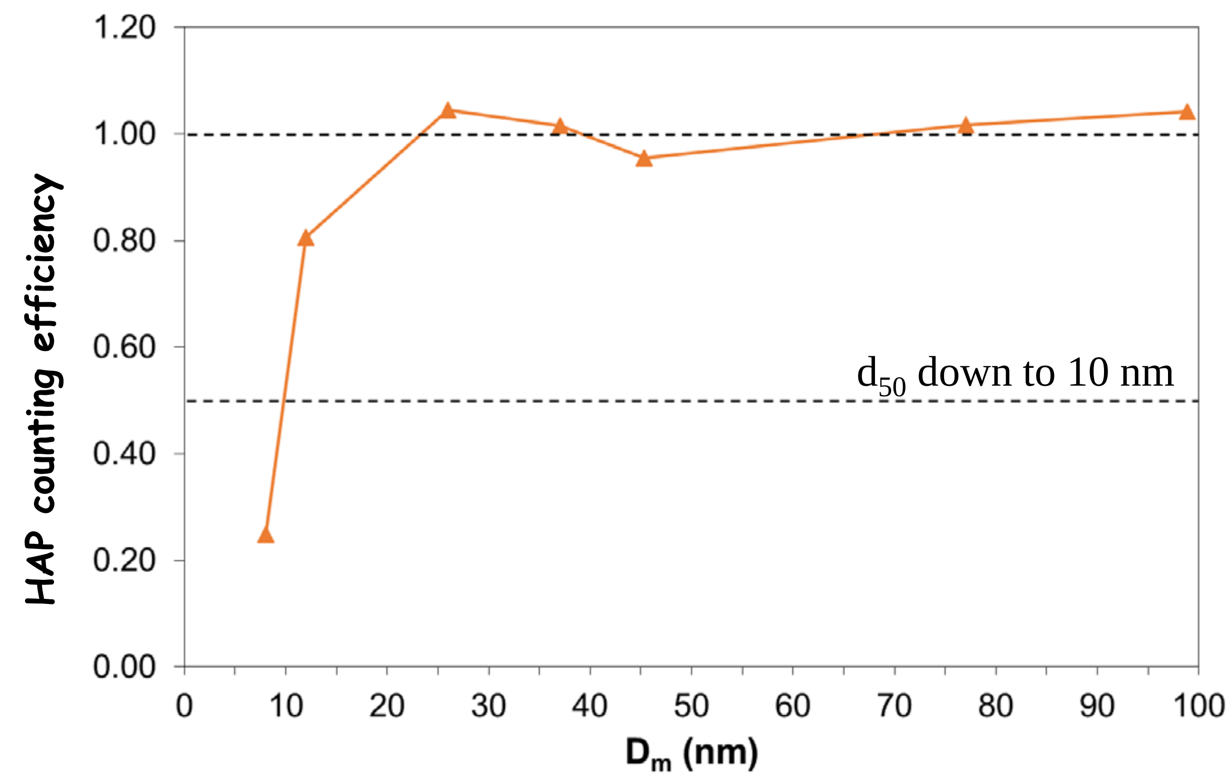
- calculated counting efficiency for a polydisperse aerosol with lognormal size distribution (σ = 1.7)



→ overshoot smoothed out

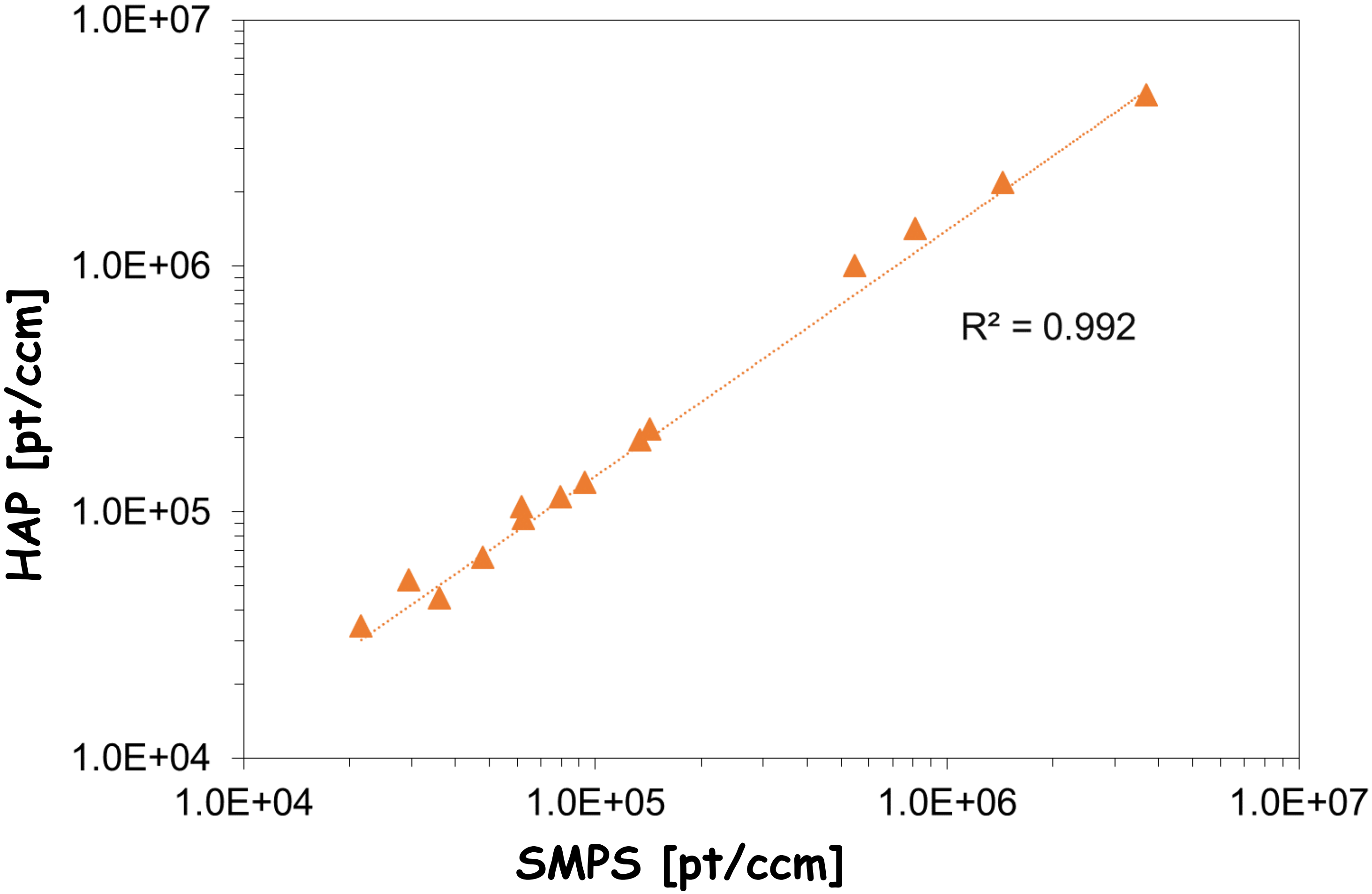
Lab (APTL) – Polydisp. efficiency

- Polydisperse counting efficiency verified by APTL:

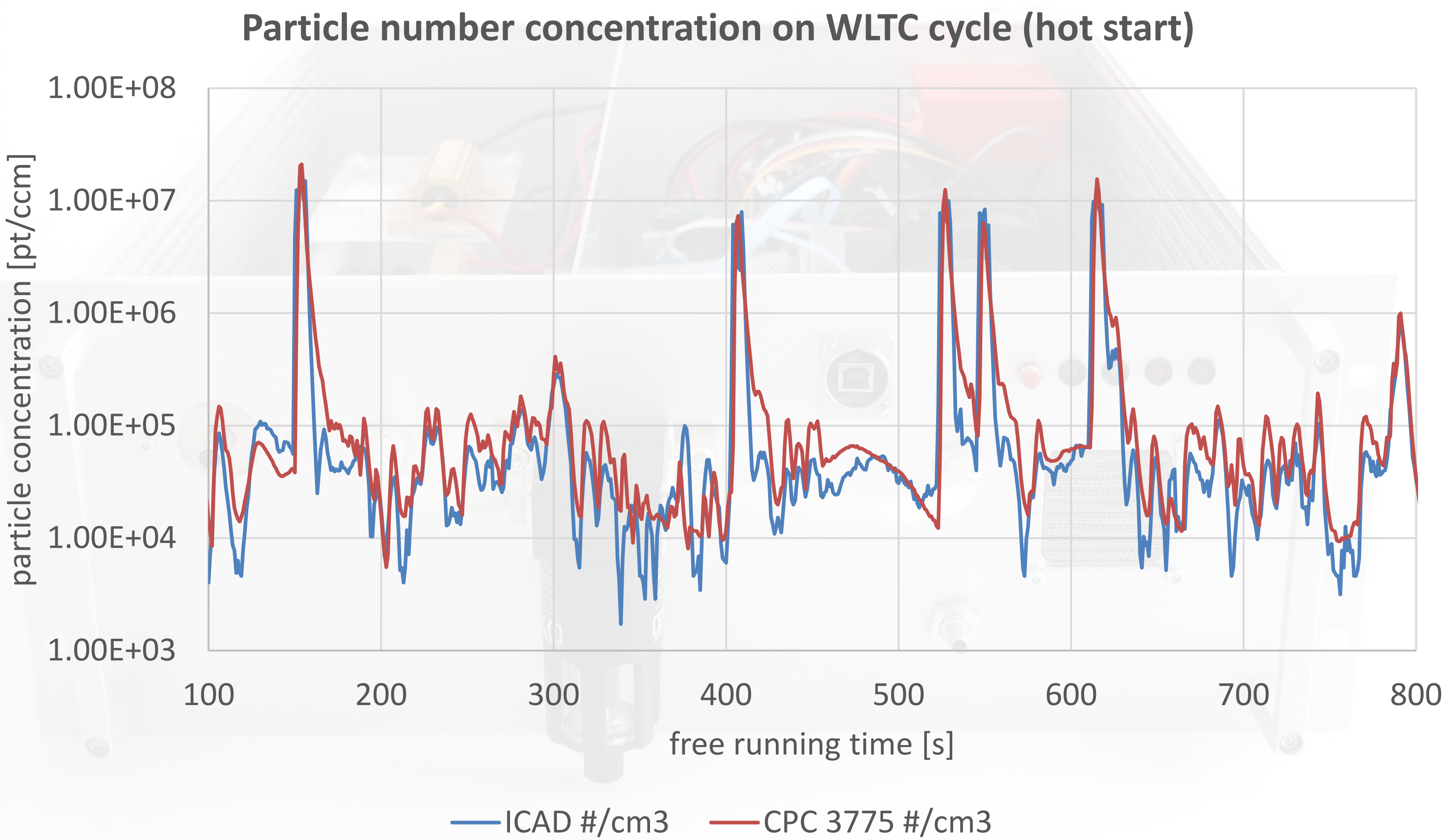


Polydisperse counting efficiency measured by APTL

Lab (APTL) – Linearity check



WLTC data (IFPEN)



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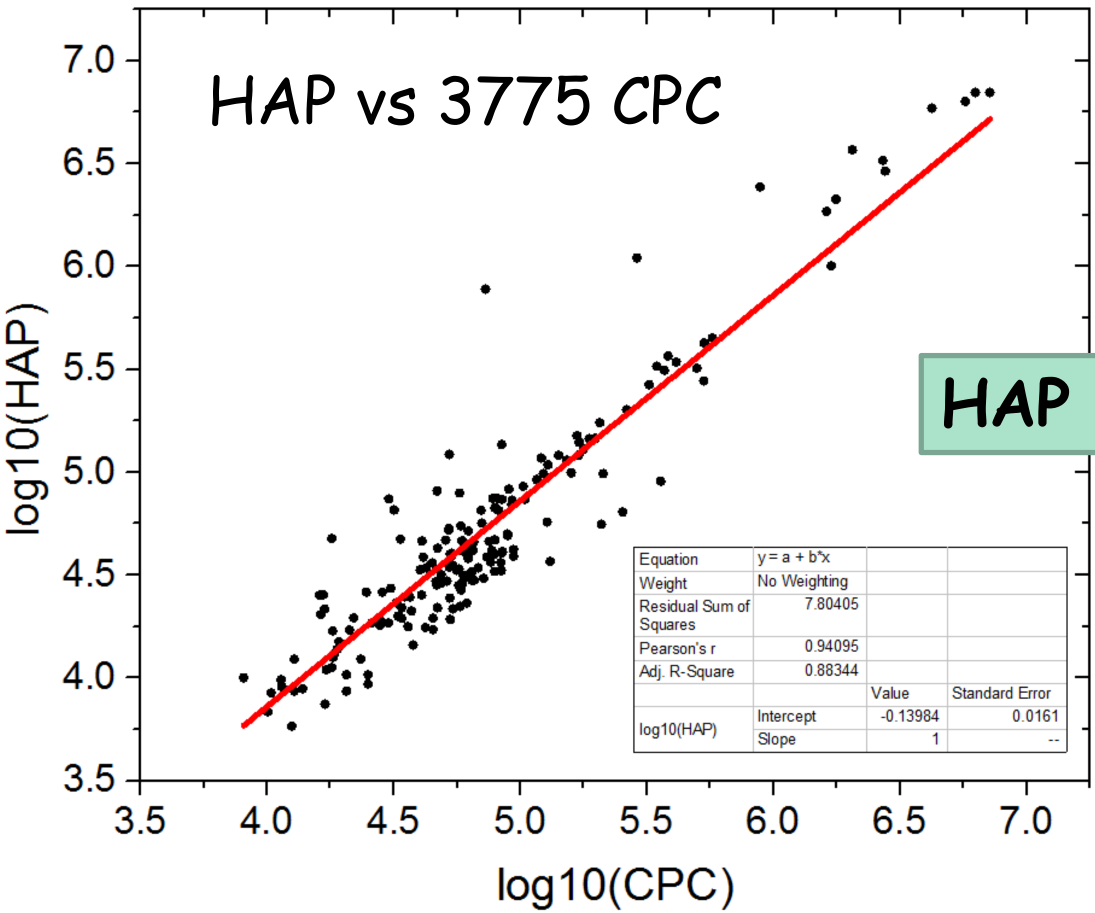

HAP = 0.72·CPC

Summary and Conclusion

- Our sensors perform as specified with only minor issues so far
  - High temperature operation: ok (150°C)
  - Lower d_{50} cutoff: ok (11-14nm)
  - CPC like counting efficiency: ok (sort of)
  - Linearity: ok (R^2=0.992)
- Long term stability of the HAP prototypes has to be evaluated by our project partners
- The sensor prototype can be further miniaturized if needed

Acknowledgments

- FHNW:
  - Daniel Egli
  - Peter Steigmeier
- APTL (evaluation + verification):
  - Nickolas Vlachos and colleagues
- IFPEN (vehicle measurements):
  - Stephane Zinola
  - Mickael Leblanc
  - Loic Rouleau

Q&A