Project overview and preliminary results

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  - Optimization of Laboratory System (SPCS)
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Objectives

Technology

- Development of robust and reliable measurement equipment for particles down to 10 nm supporting research and legislation
- Laboratory based equipment for research/certification and PN PEMS for RDE
- Optimization of Condensation Particle Counter (CPC) with D50 ≤10 nm
- Optimization of PEMS Catalytic Stripper (CS) to at least 50 % detection efficiency at 10 nm

Understanding

- Fundamental understanding of formation, composition, size distribution and transport of exhaust particles (PN)
- Supporting the development of the measurement equipment
- Including the impact on the measurement procedure

Procedures

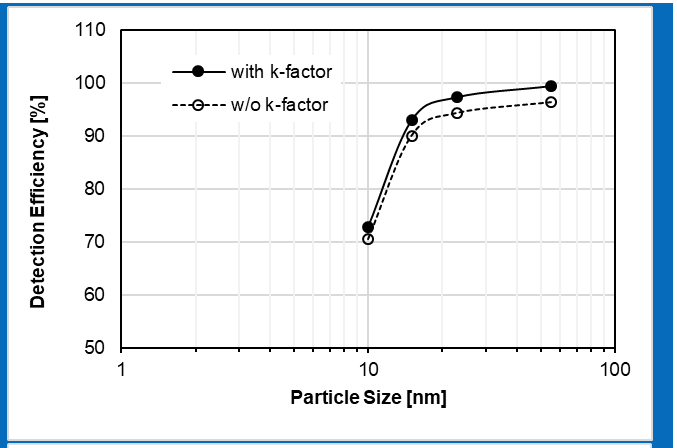
- Robust and reliable measurement procedures for particles down to 10 nm verified under real driving conditions

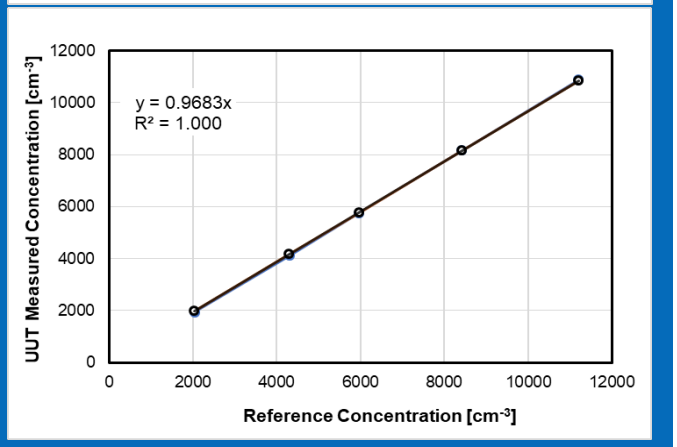
Calibration CPC (SPCS & OBS)

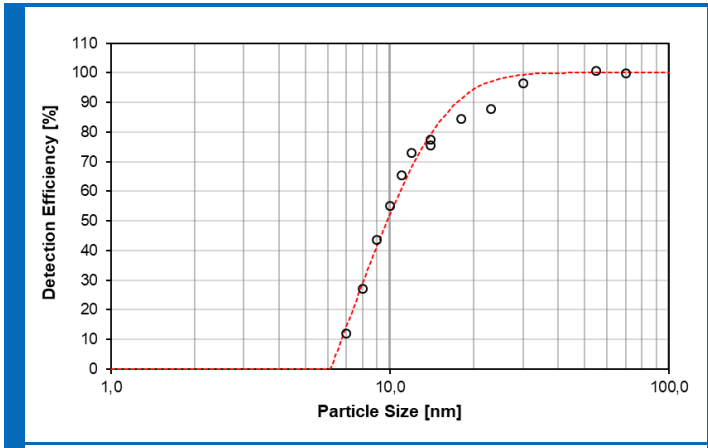
CPC integrated into Horiba SPCS optimized for 10 nm laboratory measurement

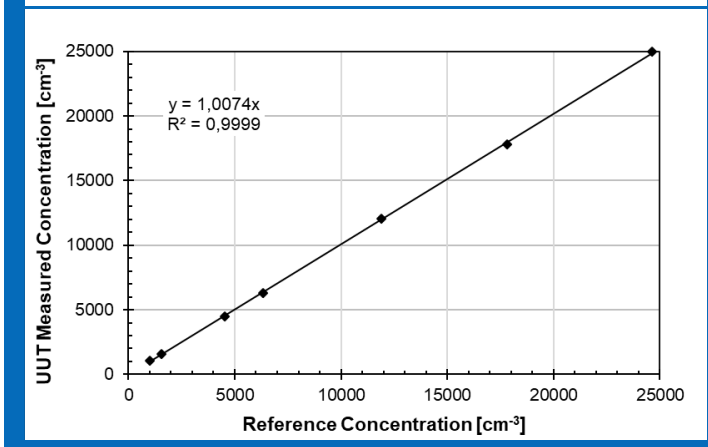
Laboratory CPC calibrated with PAO-4 aerosol, optimized for 70% PAO-4 detection efficiency (~50% efficiency for 350°C conditioned flame soot) at 10 nm

Linearity of response measured with monodisperse PAO-4 at 55 nm









CPC integrated into Horiba OBS-ONE PN optimized for 10 nm PEMS measurement

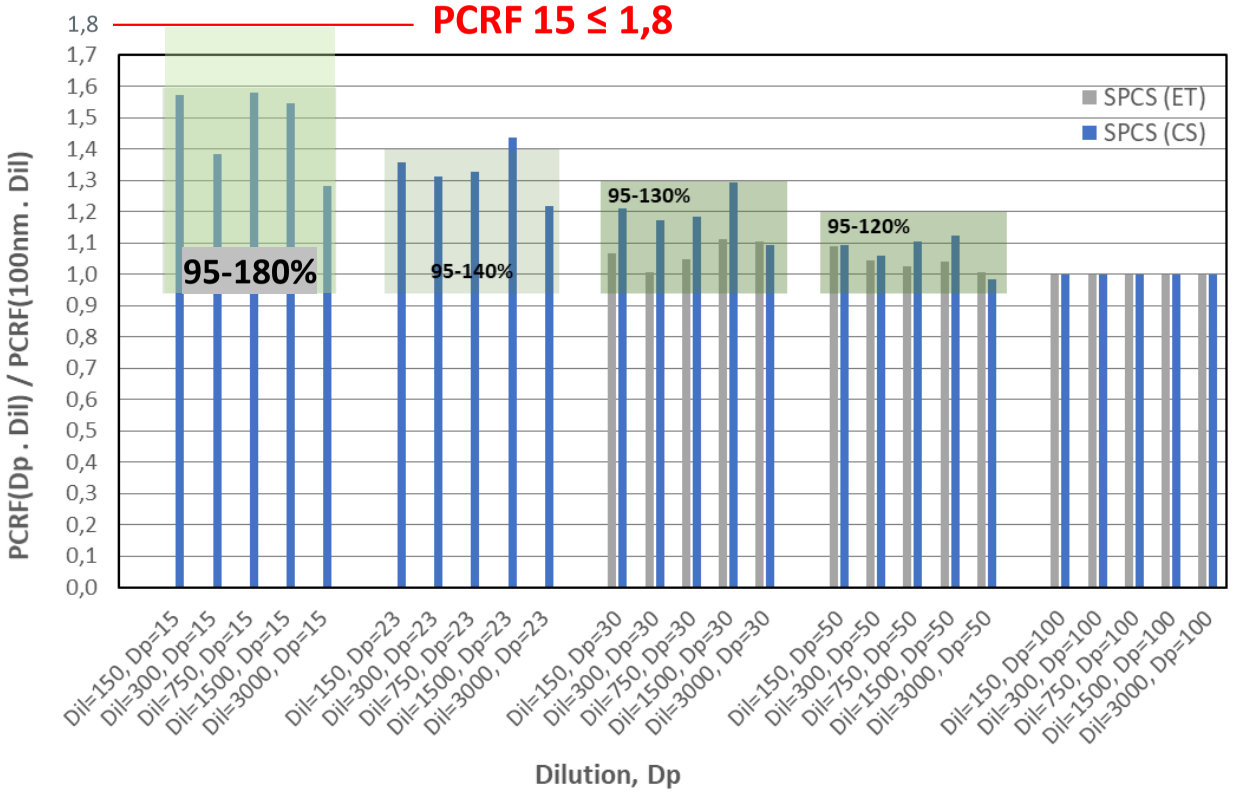
PEMS CPC calibrated with 350°C conditioned flame soot aerosol, optimized for 50% detection efficiency at 10 nm

Linearity of response measured with 350°C conditioned mono-disperse flame soot at 70 nm

Calibration of SPCS (PCRF)

PCRF calibration

- Performed with NaCl generator
- At 15nm maximum concentration of around 8000 P/cm³ achieved
- In comparison of Evaporation Tube (ET) vs Catalytic Stripper (CS) the PCRF for 30nm and 50nm increases slightly



➢ The Target of current PMP discussion for PCRF at **15nm ≤ 1,8** can be achieved with NaCl

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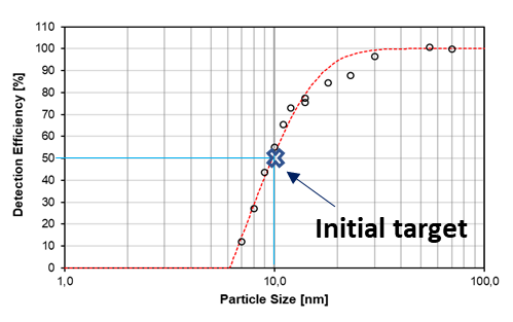
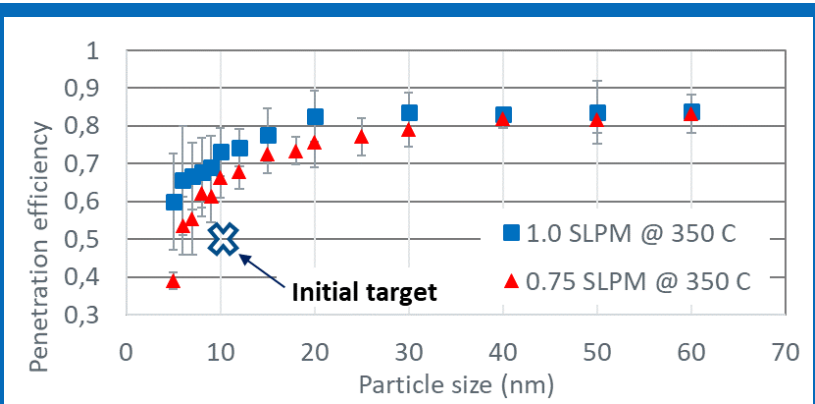
Optimization of CPC and CS (PEMS)



- CPC integrated into Horiba OBS-ONE PN optimized for 10 nm PEMS measurement
- PEMS CPC calibrated with 350°C conditioned flame soot aerosol, optimized for at least 50% detection efficiency at 10 nm



Solid particle penetration (CS)

- 10-15% improvement in solid particle penetration
- 65-75% solid particle(silver) penetration at 10 nm size
- Meets 60% penetration even at 8 nm.

➢ CPC and Catalytic Stripper have been optimized according to initial set targets

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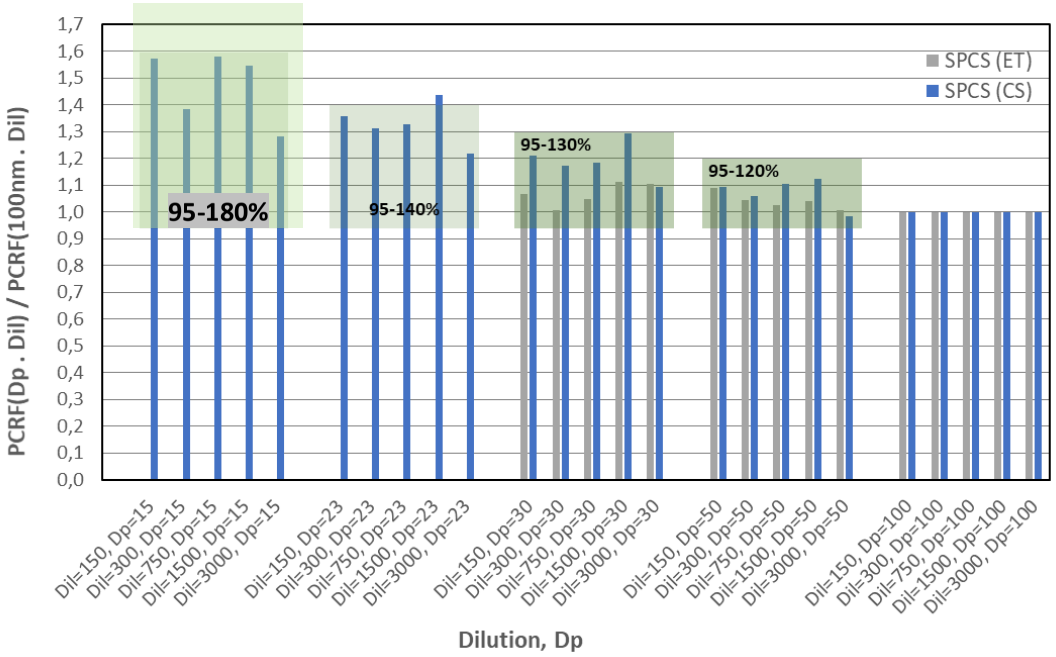
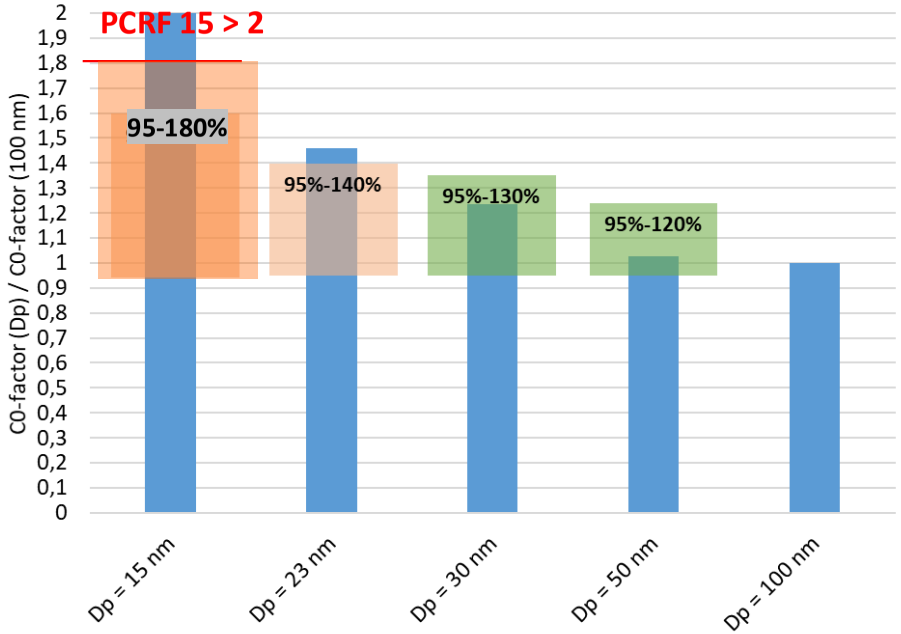
Calibration of SPCS and OBS

PCRF/C0 evaluation and comparison

- PCRF at 23nm; 30nm; 50nm and 100nm between SPCS and OBS compares very well





➢ **Further optimization of PCRF for PEMS device necessary at 15nm**

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Current Targets for 23nm PEMS

System Efficiency: Legislation Targets PEMS (2017/1154)

D_p [nm]	Sub-23	23	30	50	70	100	200
$E(d_p)$ PN analyser	To be determined	0,2 – 0,6	0,3 – 1,2	0,6 – 1,3	0,7 – 1,3	0,7 – 1,3	0,5 – 2,0

- Current 23nm values for PEMS System Efficiency should be applicable for 10nm equipment
- A simple modification (**23nm is the new 10nm**) would generate the following targets:

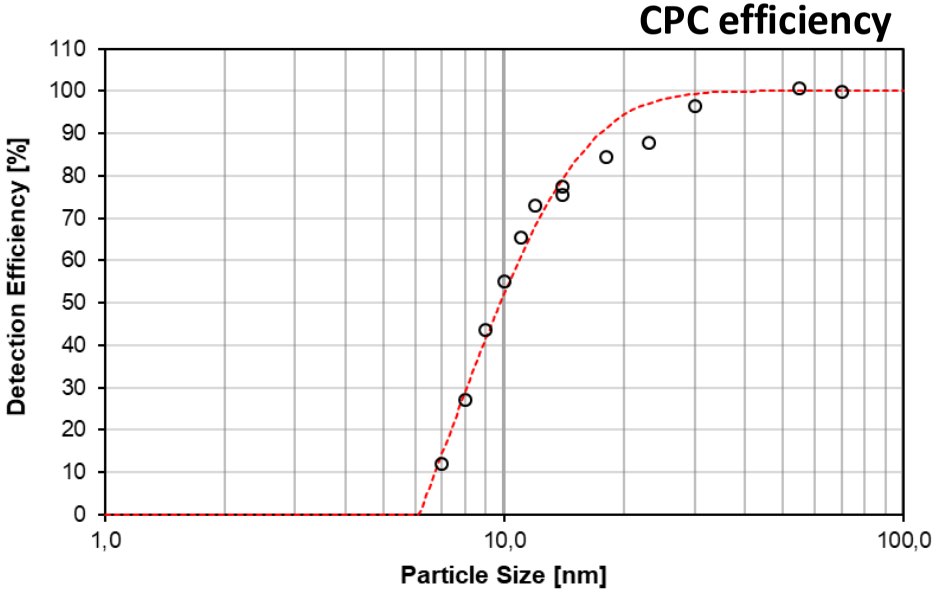
d_p [nm]	Sub-10	10	15	23	30	41	50	70	100	200
$E(d_p)$ PN in %	To be determined	20-60	30-110	30-110	60-110	70-110	90-110	90-110	90-110	90-110

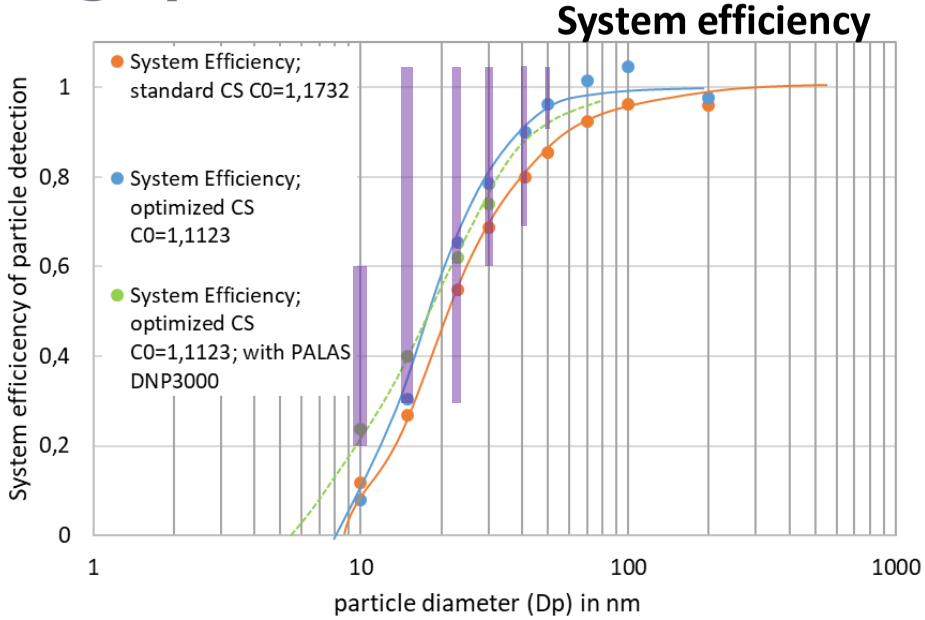
- In example: At 10nm the detection efficiency of the system should be between 20% and 60% in comparison to a reference CPC
- Targets for sub-23nm legislation are not set yet
- In PEMs4Nano it has been investigated which system efficiency can be achieved

CPC and System efficiency

set target

Results: Calibrated solid particle counting system for PEMS use

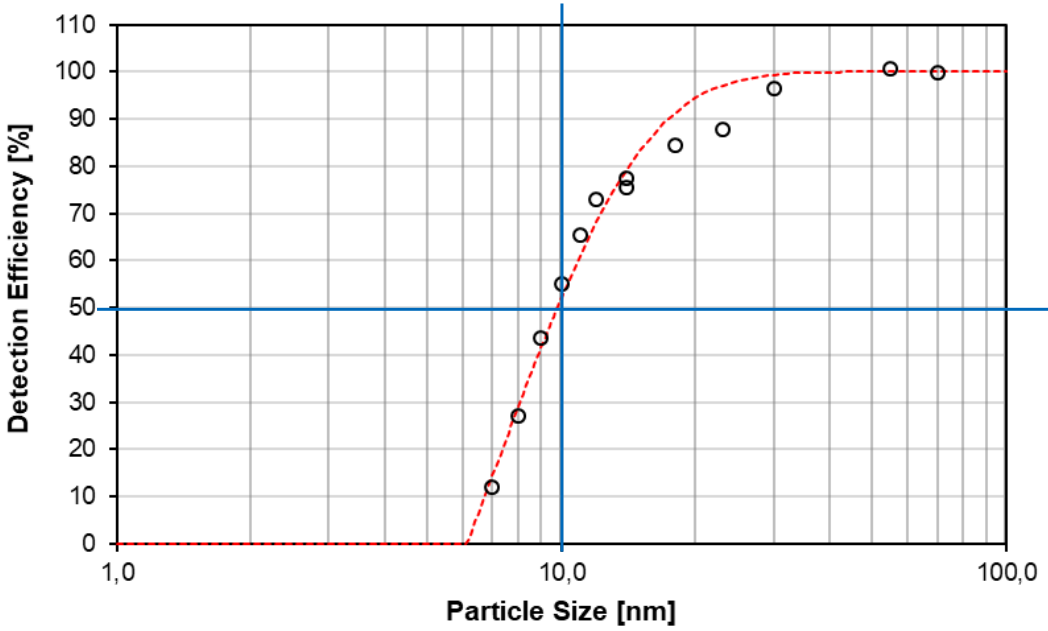




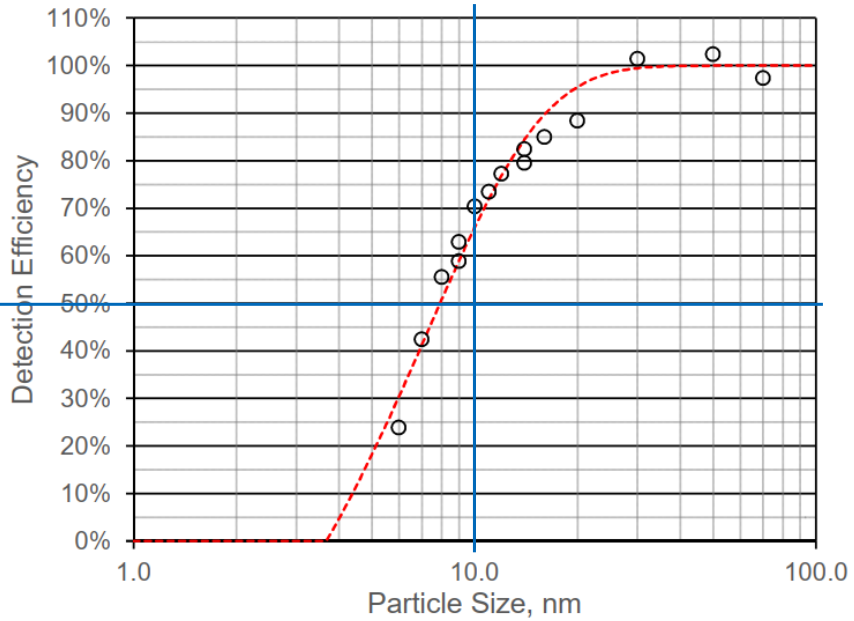
- CPC for PEMS has been calibrated to at least 50 % detection efficiency at 10 nm
- This leads to a system efficiency of > 20 % at 10nm with Palas soot
- **The focus on further investigation is to increase system efficiency of the PEMS**

Outlook: OBS Development #2

- A 2nd prototype is developed and the CPC is further modified



Solid Particle Detection Efficiency of OBS-ONE PN PEMs4Nano Prototype #1



Solid Particle Detection Efficiency of OBS-ONE PN PEMs4Nano Prototype #2

- **D50 change from 9.6nm to 7.9nm should lead to significant performance increase**

→ Evaluation ongoing of improvements

Requested Q & A

Requested Question	Answers within PEMs4Nano	
Calibration material for PN-system PCRF and CPC efficiency at sub23nm-size range	CPC SPCS: **Emery Oil** PCRF SPCS: **NaCl** CPC OBS: **miniCAST soot** System (C0): **miniCAST soot / Palas** *(not possible with Emery Oil)	**Evaluation open**
Sub23nm emissions with different technologies, fuels, etc.	Focus on **gasoline engines** **EU5** fuel vs. **EU6** fuel investigation	**Evaluation open**
Evaporation Tube (ET) or Catalytic Stripper (CS) as volatile particle remover (pros/cons)	**Catalytic effect in VPR seems necessary** as there is high possibility of sub-23nm volatile formation after ET	**CS preferred solution**
Current methodology Vs. optimized system	SPCS sub-23nm can be handled like current PMP compliant system	**SPCS handled like PMP** **PEMS tbd**

Conclusion

- Two systems (Laboratory + PEMS) including subcomponents (e.g. CPC, CS) have been optimized for sub-23 nm measurements
- **Laboratory system** can be applied and handled according to PMP-recommendation (with detection limits below 23 nm)
- Validation of **PEMS** equipment at calibration laboratory showed that current calibration procedure e.g. PCRF factor evaluation might be reconsidered for sub-23 nm
- Goal is to develop comparable Laboratory and PEMS devices for sub-23 nm
  - First results show good comparability over wide range of particle sizes
  - Further improvements were identified and implemented
  - Full evaluation and comparison of the equipment ongoing
- **PEMs4Nano providing technology at high TRL** (Technology Readiness Level) **for robust and reliable RDE measurements**

End of presentation

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