The PEMs4Nano project
Measuring engine emissions below 23 nm

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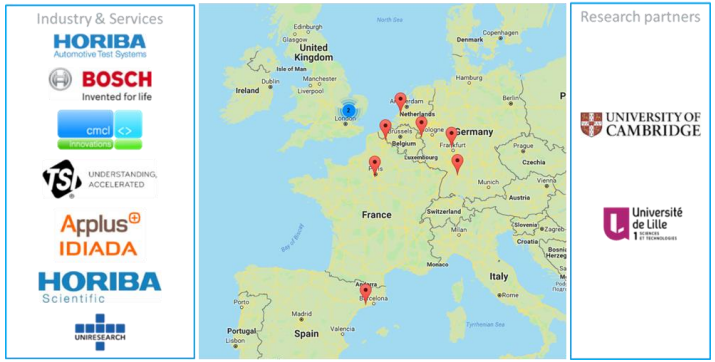
Project Outline

Project full title:	Portable Nano-Particle Emission Measurement System
Call:	H2020-GV02-2016 Technologies for low emission light duty powertrains
Budget / Funding:	3.6 M€ / 3.4 M€
Type of project:	Research & Innovation Action
Project runtime:	1 October 2016 – 30 September 2019



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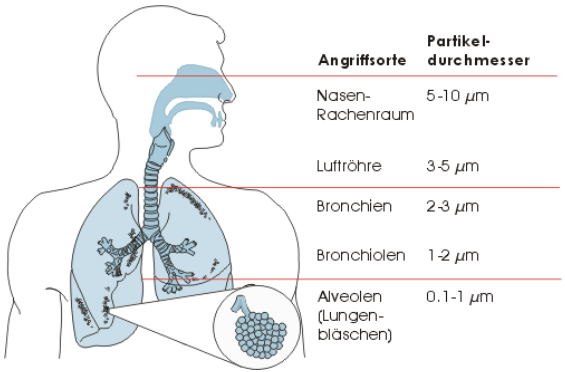
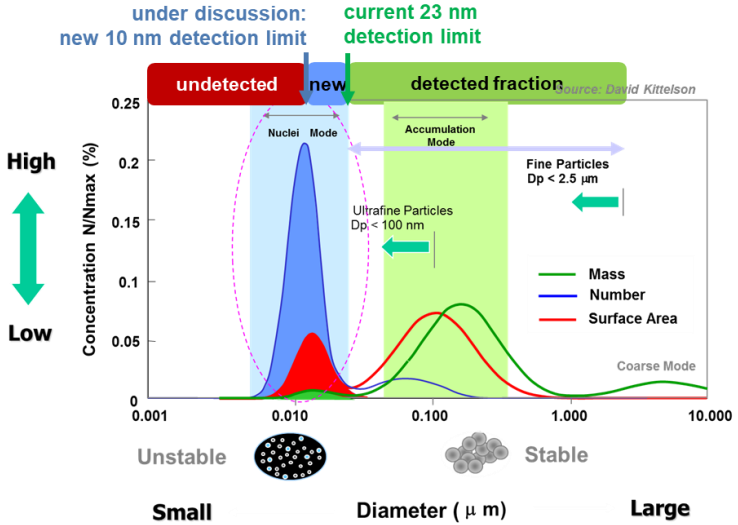
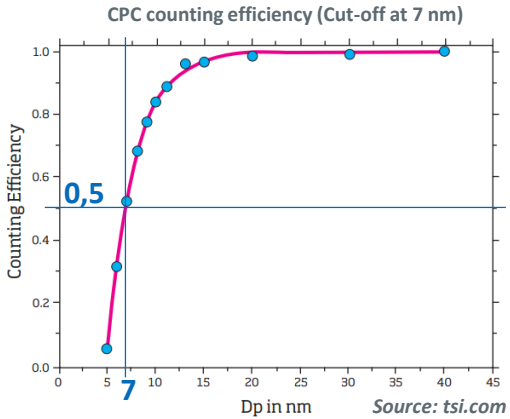
Particle Number (PN) & PM







- 1µm particle weighs 10^6 times more than one 10nm particle
  → PM limits do not represent amount of nanoparticles
  → PN limit was introduced Euro 5b
- 23nm lower-limit was chosen for technical reasons
- → reduction to 10nm currently under discussion

Legislation	PN23 Limit	PM Limit
LDV Euro 6c, 6d	**$6x10^{11}$#/km**	4,5 mg/km
HDV Euro VI	**$6x10^{11}$#/kWh**	10 mg/kWh
NRMM Stage V	**$1x10^{12}$#/kWh**	15 mg/kWh

+ PN23 RDE limits

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Objectives

Measurements

- Particle Analysis Methods: LII, AFM, TERS
- Measurement Single Cylinder Engine
- Measurement Multi Cylinder Engine
- Validation of full vehicle

Technology, procedures and understanding at task level

- Optimized CPC
- Optimized Catalytic Stripper
- Optimized Calibration
- Particle Characterization
- Population Balance Model
- Computational surrogates
- Optimized Calibration
- Implementation of calibration
- Evaluation of robustness

Focus areas

- Measurement Technology
- Model Guided Application (MGA)
- Measurement Procedure & Application

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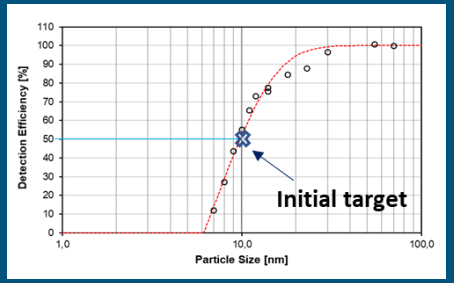
Objectives

Technology
Demonstrate and evaluate the application and measurement technology in the development process

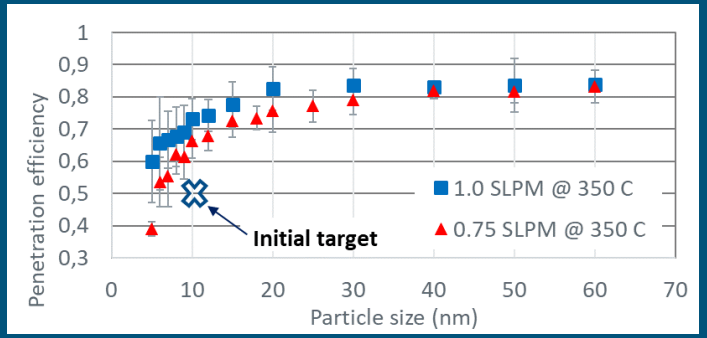
Understanding
Fundamental understanding of the particle formation, composition, size distribution and transport and the impact on the measurement procedure + demonstrate usability of model

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

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**

CPC and System efficiency

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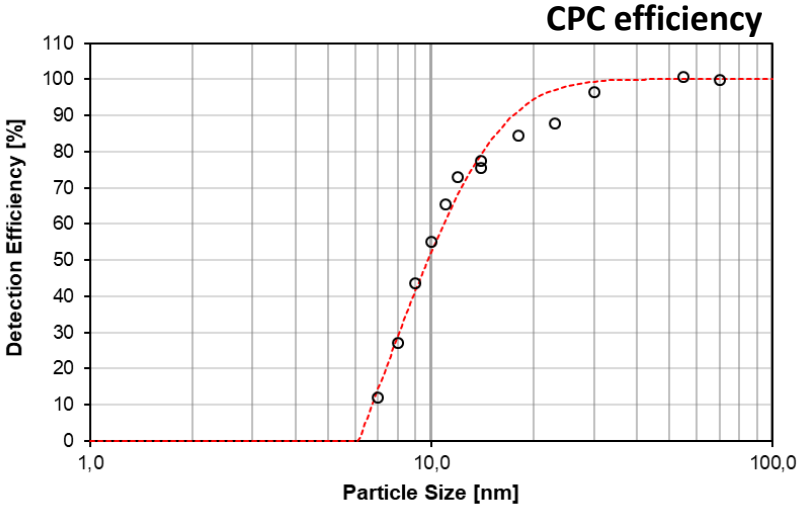
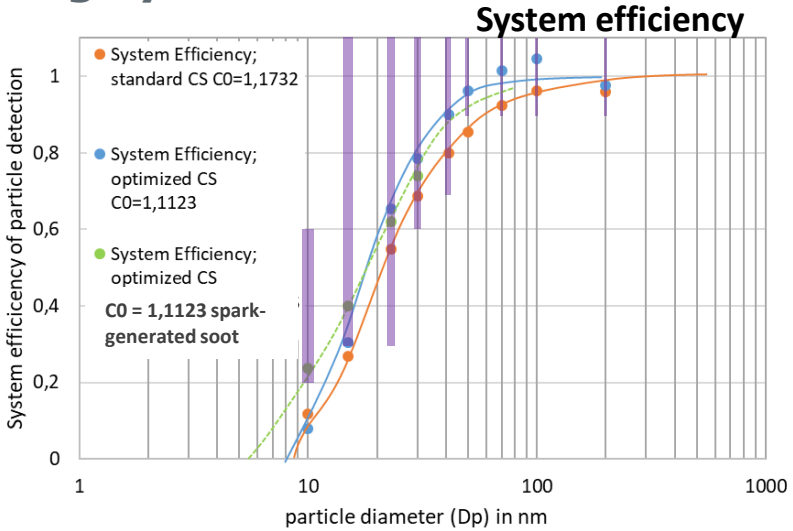
set target

Results: Calibrated solid particle counting system for PEMS use

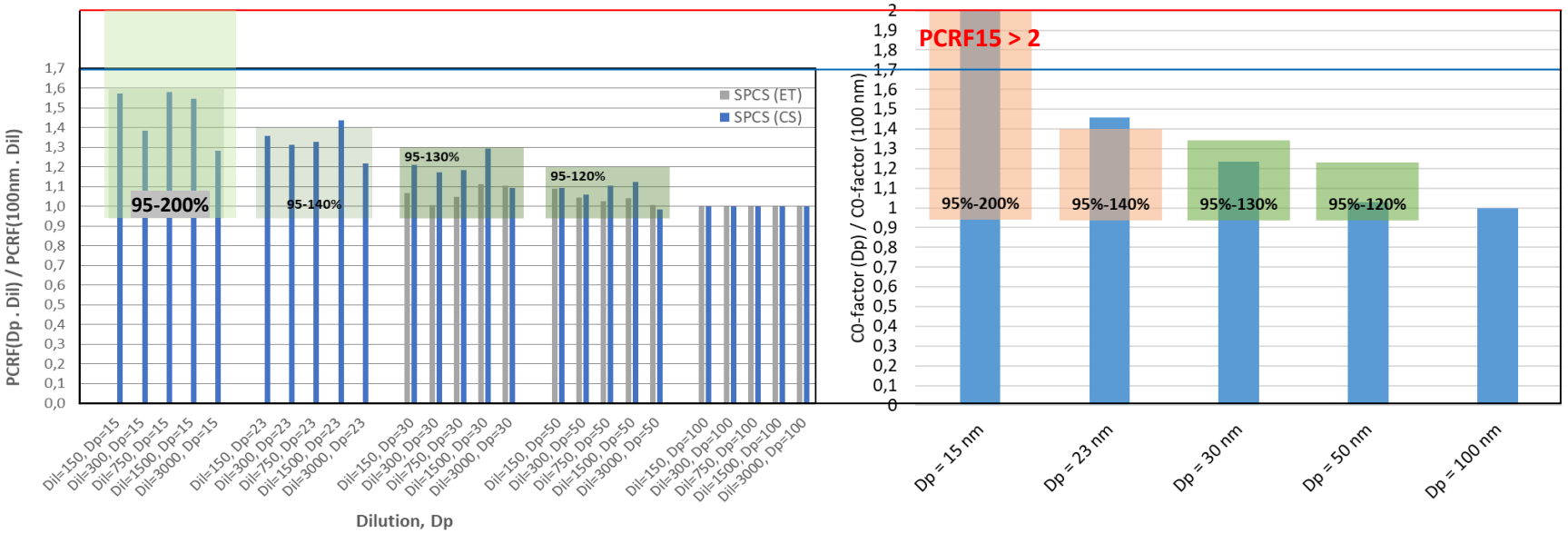




- CPC for PEMS has been calibrated to at least 50 % detection efficiency at 10 nm
- This leads to a system efficiency of > 20 % at 10nm with spark generated soot
- **The focus on further investigation is to increase system efficiency of the PEMS**

Calibration of SPCS and OBS

PCRF/C0-factor evaluation and comparison



- PCRF at 23nm; 30nm; 50nm and 100nm between SPCS and OBS compares very well
- **Further optimization of PEMS necessary to increase counting efficiency at 15nm**

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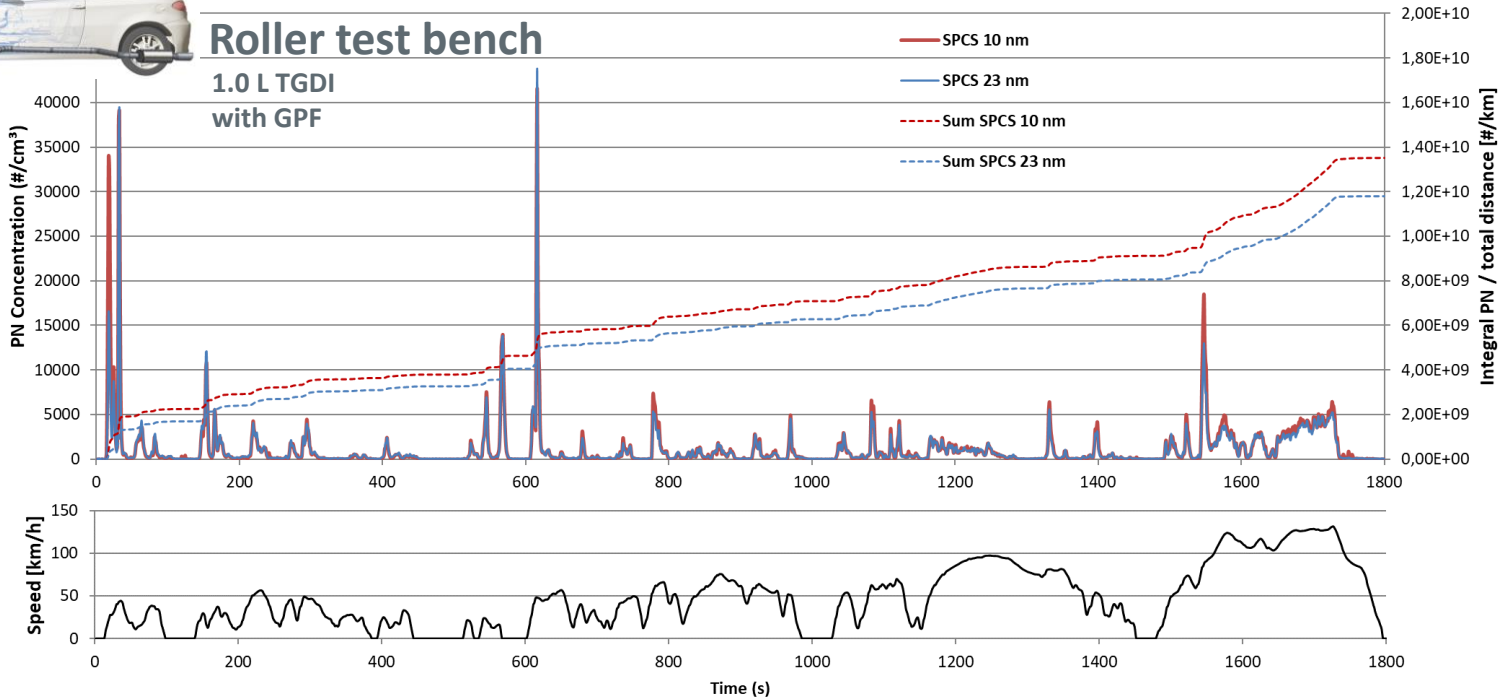
Results WLTC SPCS

Distance [km]	23,236
Time [s]	1800
PN23 [#/km]	1,18E+10
PN10 [#/km]	1,35E+10
PN23 vs PN 10	**14,36%**



- Sub-23nm particles are generated at engine start and acceleration phases

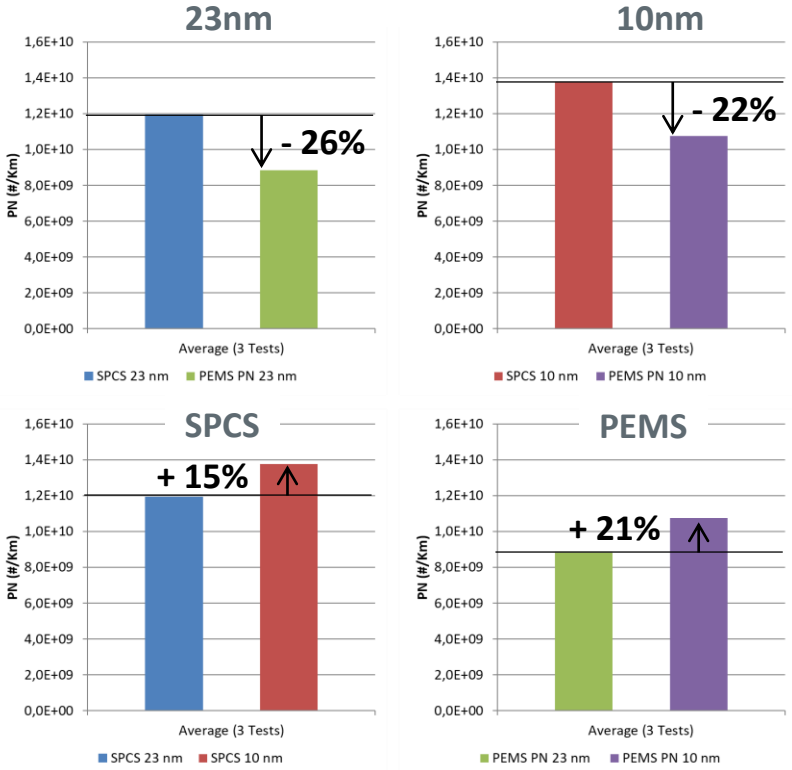
Results WLTC SPCS & PEMS

1.0 L TGDI equipped with GPF

- Tests performed with following configuration
  - PEMS 10 & 23 with **Y-Split at Tailpipe**
  - SPCS 10 & 23 at **CVS-Tunnel**

Average (3 Tests)		*PN (#/Km)*
Lab System Data	SPCS PN23	1,2E+10
	SPCS PN10	1,4E+10
Correlation SPCS 10 vs SPCS 23		**15%**
OBS System Data	OBS PN23	8,8E+09
	OBS PN10	1,1E+10
Correlation OBS PN 10 vs OBS PN 23		**21%**
Correlation SPCS 10 vs OBS PN 10		**22%**
Correlation SPCS 23 vs OBS PN 23		**26%**

➢ **PN increase in sub-23nm regime between 15-22 % on average**



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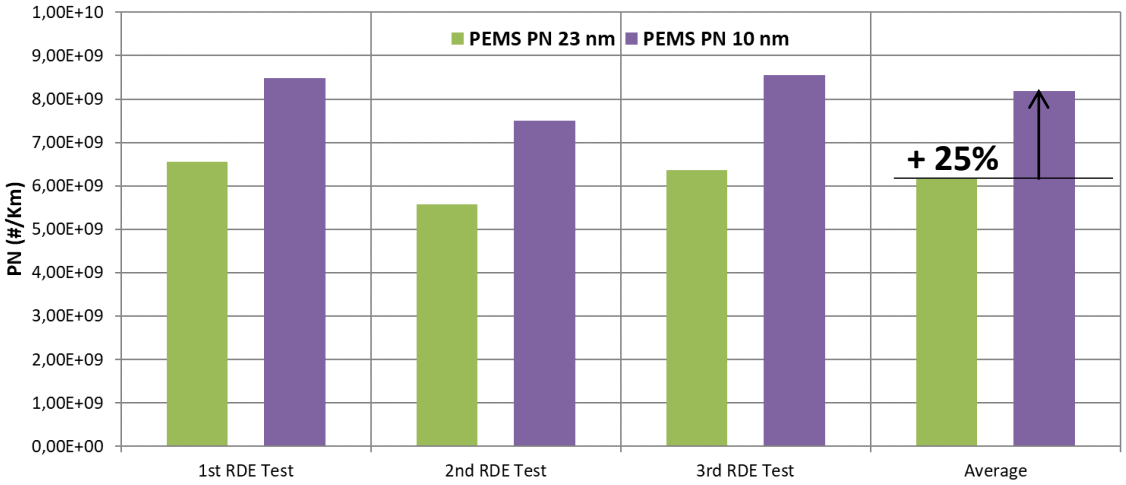
Results RDE PEMS

Three valid RDE tests have been performed

- Configuration: PEMS 10nm & 23nm with **Y-Split at Tailpipe**

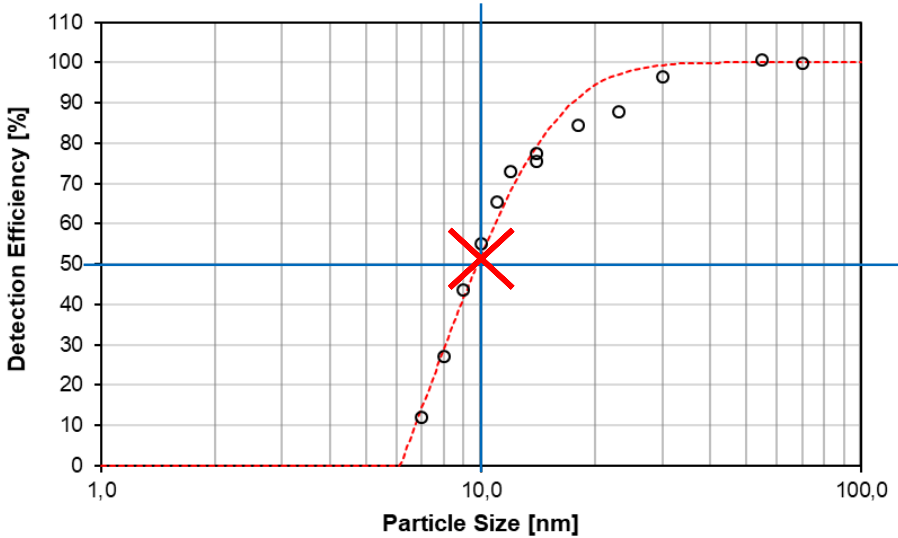
		PN (#/Km)
1st RDE Test	OBS PN23	6,55E+09
	OBS PN10	8,48E+09
	Correlation	23%
2nd RDE Test	OBS PN23	5,57E+09
	OBS PN10	7,50E+09
	Correlation	26%
3rd RDE Test	OBS PN23	6,37E+09
	OBS PN10	8,55E+09
	Correlation	26%
Average	OBS PN23	6,16E+09
	OBS PN10	8,18E+09
	Correlation	25%



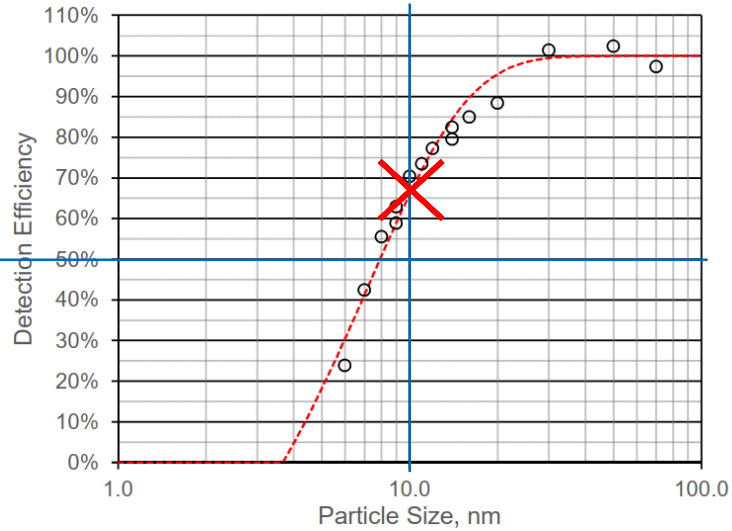
➢ **PN increase in sub-23nm regime between 23% to 26% which compares well to 21% in average WLTC cycle** (PEMS device only)

Outlook: PEMS Development

- 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 increase from 9.6nm to 7.9nm achieved
- **Additional optimization steps considered regarding particle penetration**

Conclusion

- Two systems (SPCS & OBS) have been developed for sub-23nm measurements
  - Sub-components have been optimized according to initial set targets
- Sub-23nm SPCS (PN10) can be applied and handled like an established PN23 measurement system
- Determination for existing robust and reliable laboratory and PEMS devices for sub-23nm under evaluation
  - Initial results show good comparability over wide range of particle sizes
  - Both PEMS devices (10nm & 23nm) measure within uncertainty range
  - Ambitious Target of ± 20 % for SPCS/PEMS correlation in some tests achieved

- Further improvements were identified and are implemented
- **Full evaluation and comparison of the equipment is ongoing**

End of presentation

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