JOINT FINAL EVENT

12&13TH NOVEMBER 2019, SANTA OLIVA, SPAIN
(near Barcelona)

PaREGEn + PEMs 4Nano

PEMS4Nano Project Overview

Prof. Dr. Marcus Rieker HORIBA Europe (Coordinator)

Project: PaREGEn / PEMs4Nano

HORIBA

An **Expert** in **Analysis** and **Measurement** Technologies

Founded in Kyoto in 1945, HORIBA is an international Group specializing in the design and production of analysis and measurement systems for liquids, gases and solids. Its instruments meet the needs of a wide range of public and private sectors, both in fundamental research and development and industrial production or management of environmental impact.

HORIBA Business Segments

Automotive Test Systems

Emission Measurement Systems (EMS)
Mechatronics Devices (MCT)
Test Automation Systems (TAS)
Driving Control Systems (ITS)

Process & Environmental

Environmental Systems
Environmental Radiation Monitor
Environmental Regulation & Process Business

Medical

In-Vitro Diagnostic (IVD) Systems
Integration of HORIBA ABX's
Technology & Marketing Know-How

Semiconductor

Mass Flow Controller
In-situ Analysis

Scientific

Synergy of HORIBA and
HORIBA Jobin Yvon's Technologies
Raman, Grating, and Fluorescence

HORIBA Worldwide

Split into regions

Sales of FY2017 : 210.5 BJPY (1,897 MUSD)			
America	Europe	Asia	Japan
Sales Ratio by Region			
16%	22%	31%	31%
The Number of Group Companies by region (Total 48)			Included in Asia
9	22	18	4
Employees by Region (Total: 7,943)			
991 12%	2,637 33%	1,297 17%	3,018 38%

(As of December 31, 2018)

HORIZON 2020

Horizon 2020 is the biggest EU research and innovation program ever. Almost €80 billion of funding is available over 7 years (2014 to 2020). EU research funding under previous framework programs has already brought together scientists and industry both within Europe and from around the world to find solutions to a vast array of challenges. Their innovations have improved lives, helped protect the environment and made European industry more sustainable and competitive.

HORIZON 2020 Domains

- Health, demographic change and wellbeing
- Food security, sustainable agriculture and forestry, marine and maritime, inland water research and bioeconomy
- Secure, clean and efficient energy
- **Smart, green and integrated transport**
- Climate action, environment, resource efficiency and raw materials
- Europe in a changing world - inclusive, innovative and reflective societies
- Secure societies - protecting freedom and security of Europe and its citizens.

Smart Green and Integrated Transport

Growing road traffic in Europe results in detrimental effects on the environment and public health to a level that is becoming unsustainable (this in spite of increasingly stringent emission standards)

- CO2 and noxious emissions are not sufficiently reduced in real driving
- Higher injection pressures led to a shift towards the emission of nanoparticles undetected by certification procedures.

New generation of non-hybrid engines based on existing engine technologies (short term):

- Combination of engine and after-treatment technologies modelling and testing to improve design/control capability.
- Assessment and reduction of particle emissions below 23 nm (Current legislation 23 nm and above)

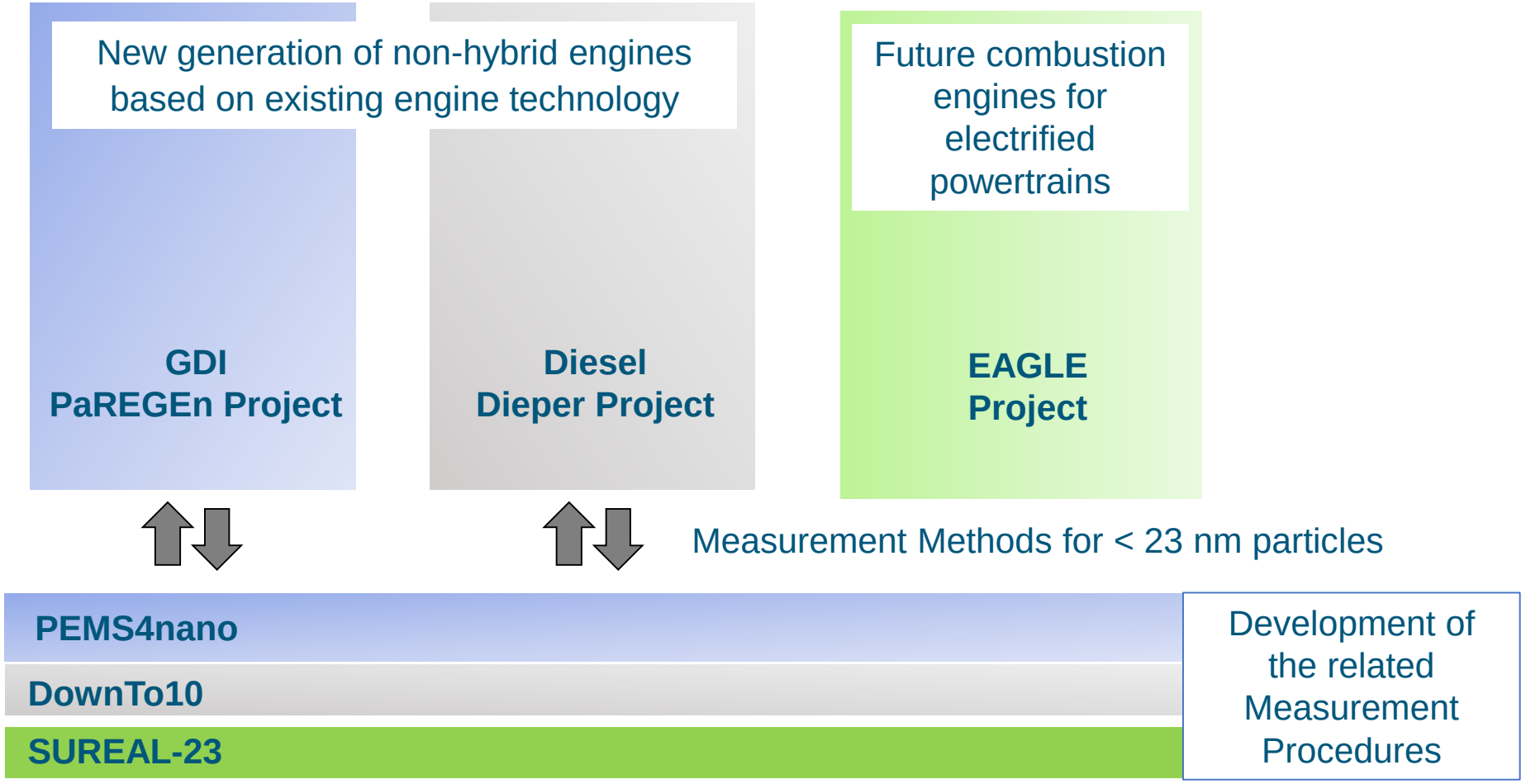
Future combustion engines for electrified powertrains (longer term developments):

- New combustion processes, sensing, control and after treatment systems,
- advanced modelling technologies attention given to the assessment and reduction of particle emissions below 23 nm

Development (based on current direct injection engines)

- of the related measurement procedures down to 10nm, providing a contribution to future regulation on particle emissions, in particular in real driving conditions

Outline of Cluster Approach



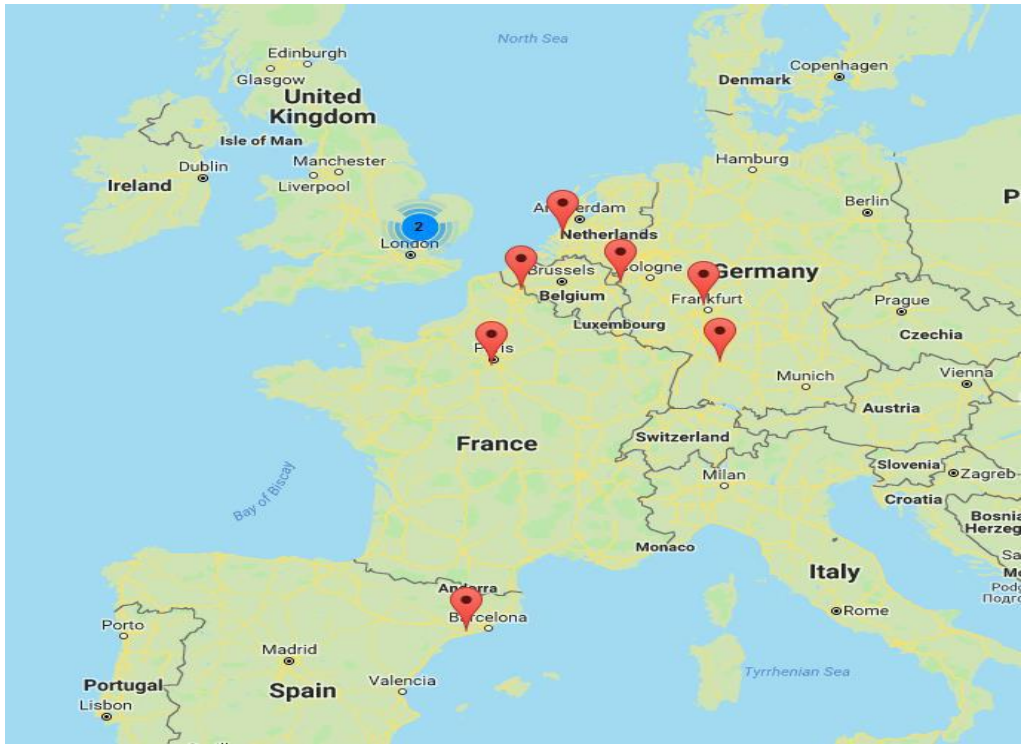
Project Outline

Portable Nano-Particle Emission Measurement System

Coordinator: HORIBA Europe GmbH
Call: H2020-GV02-2016 Technologies for low emission light duty powertrains
Type of project: Research & Innovation Action
Project runtime: October 1st 2016 – December 31st 2019

Industry & Services

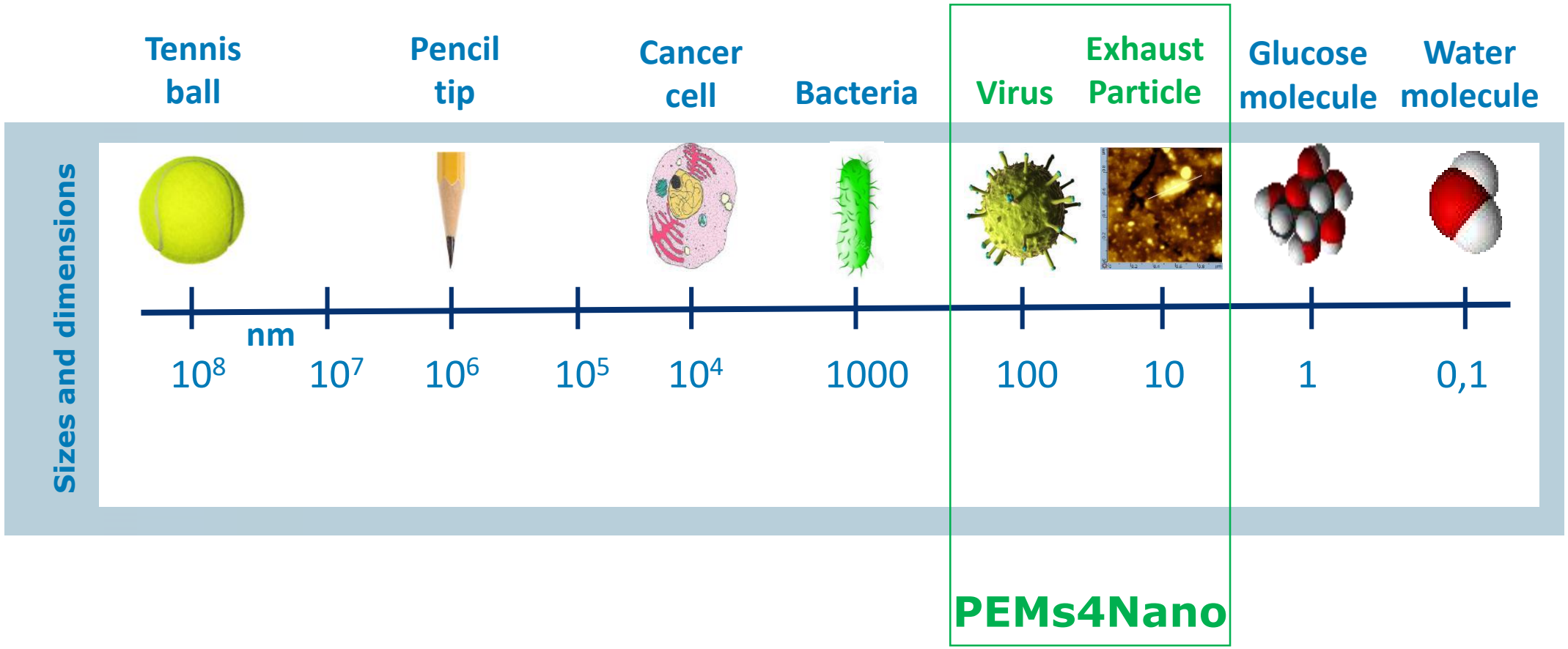
HORIBA Automotive Test Systems
BOSCH Invented for life
cmcl innovations
TSI UNDERSTANDING, ACCELERATED
Applus IDIADA
HORIBA Scientific
UNIRESEARCH



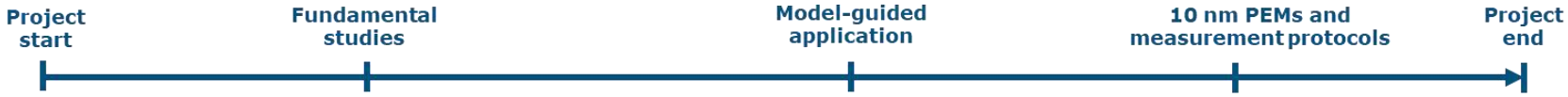
Research partners

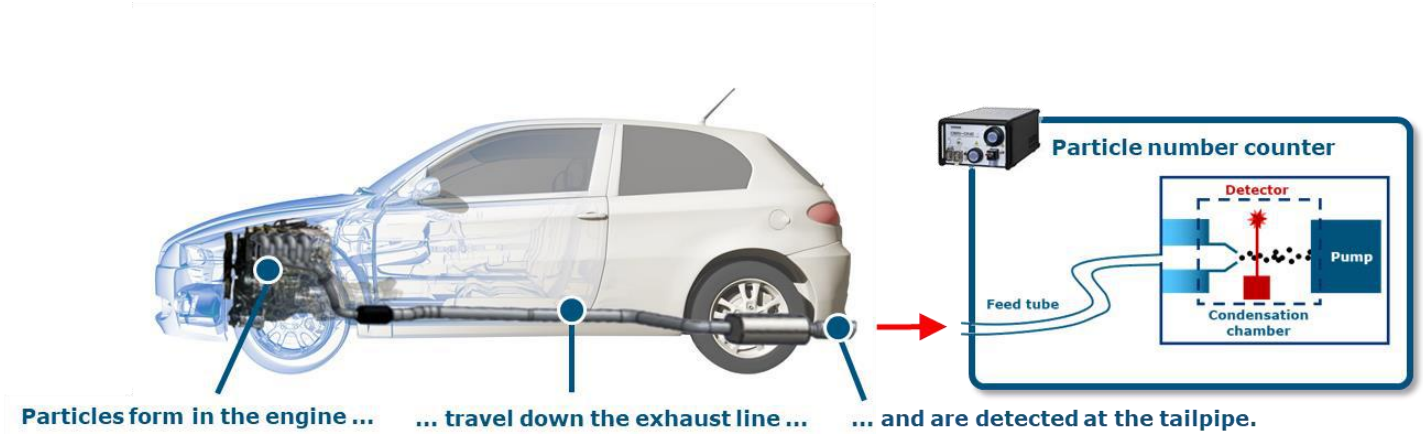
UNIVERSITY OF CAMBRIDGE
Université de Lille 1 SCIENCES ET TECHNOLOGIES

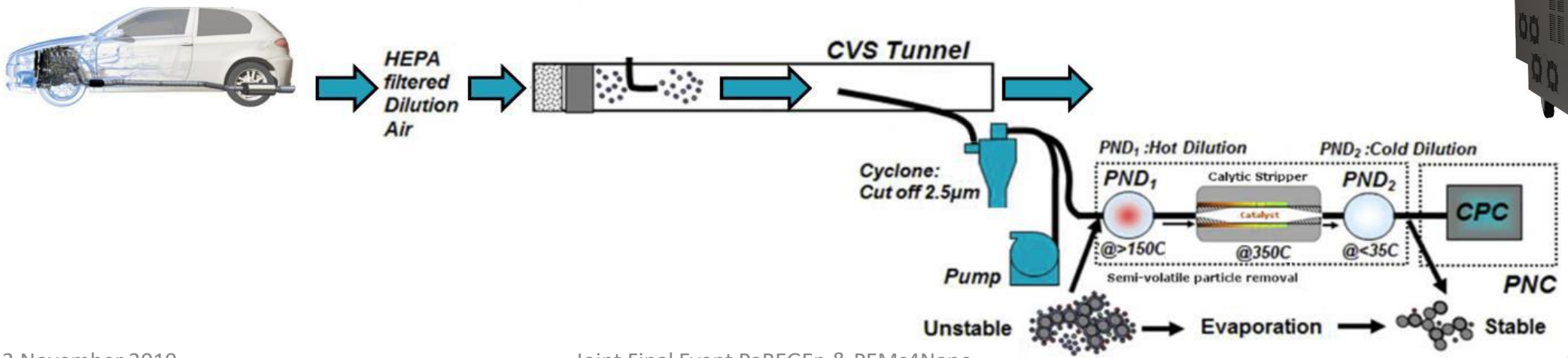
Particle Size and Dimensions



Technological Areas







PEMs4Nano Focus Areas

Measurements

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

Technology, procedures and understanding

- CPC
- Catalytic Stripper
- Calibration
- Particle Characterization
- Population Balance Model
- Computational surrogates
- Calibration procedure
- Robustness

Focus areas

- Measurement Technology
- Model Guided Application
- Measurement Procedure & Application

Objectives

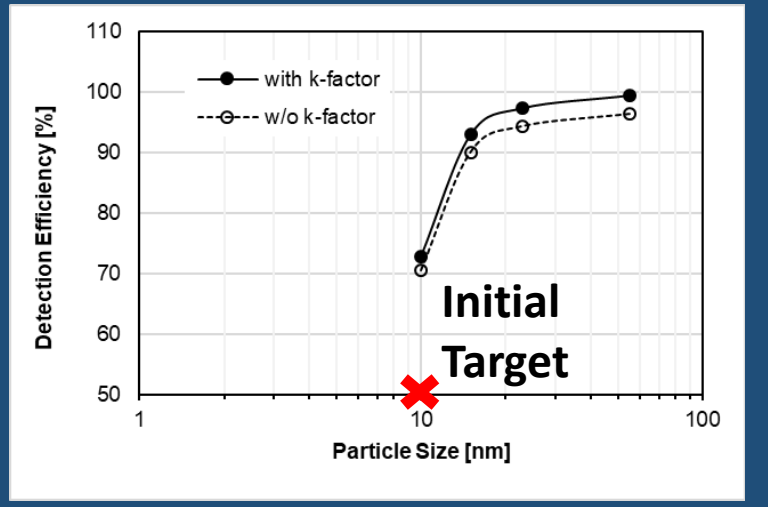
- Technology for particles down to 10 nm
- Fundamental understanding
- Robust and reliable procedures

Technological Objectives

- Redesign existing and established solid particle counting systems for
  - laboratory and
  - on-road measurements
- Adapt semi-volatile particle removal system to
  - remove non-solid particles while
  - allowing penetration of solid particles above 10 nm range
- Demonstrate and evaluate the application and measurement

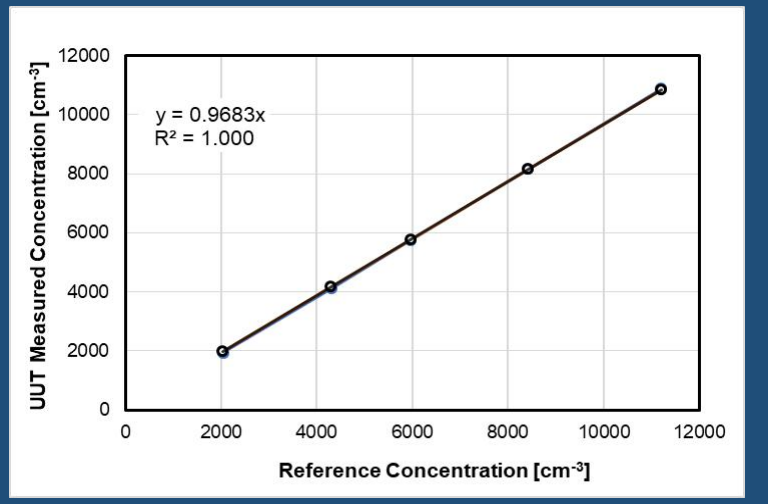
Optimization of CPC (Lab and PEMS)

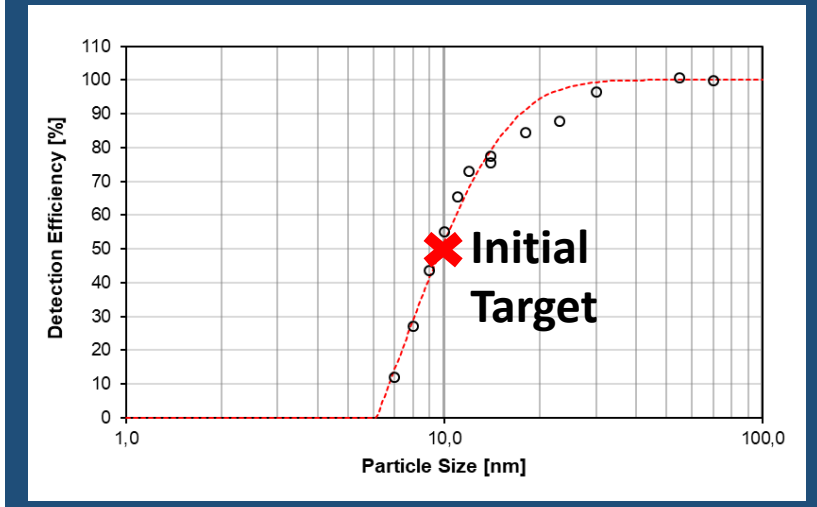
CPC integrated into Horiba SPCS optimized for 10 nm laboratory measurement



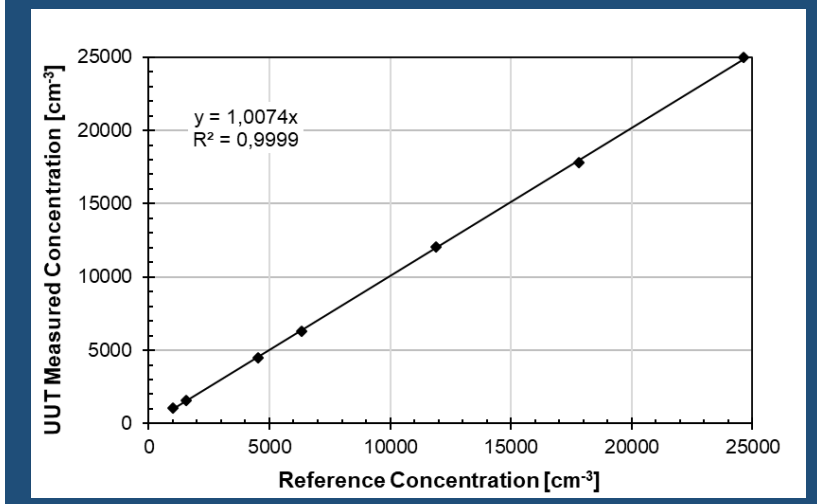
Laboratory CPC calibrated with PAO-4 aerosol, optimized for 70% PAO-4 detection efficiency (~50% efficiency for 350°C conditioned flame soot) at 10 nm

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





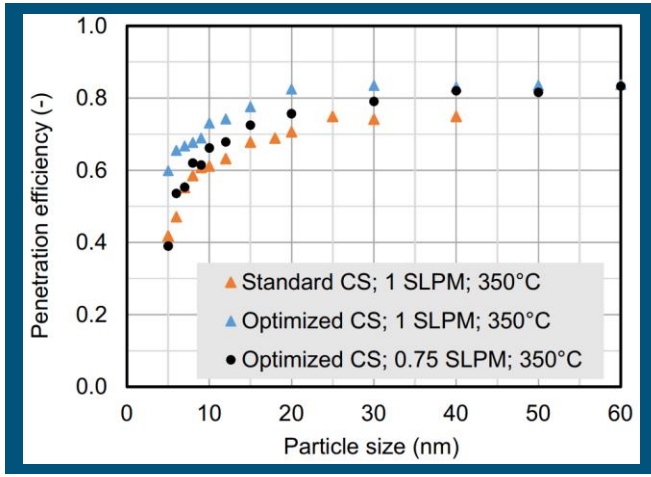
CPC integrated into Horiba OBS-ONE PN optimized for 10 nm PEMS measurement



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

Optimization of PEMS – Catalytic Stripper

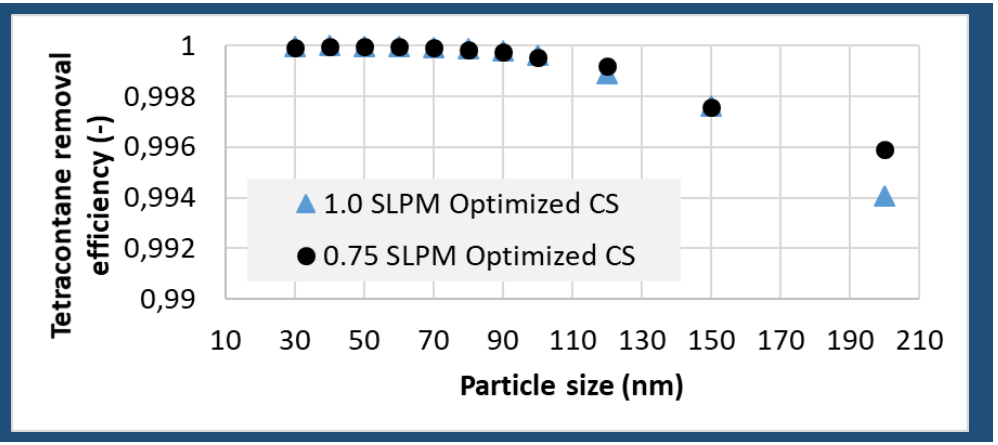


Solid particle penetration (CS)

- 10-15% solid particle penetration increase at 10 nm in comparison to original used CS
- 65-75% solid particle (silver) penetration at 10 nm size
- A > 60% penetration efficiency is achieved even at 8 nm.

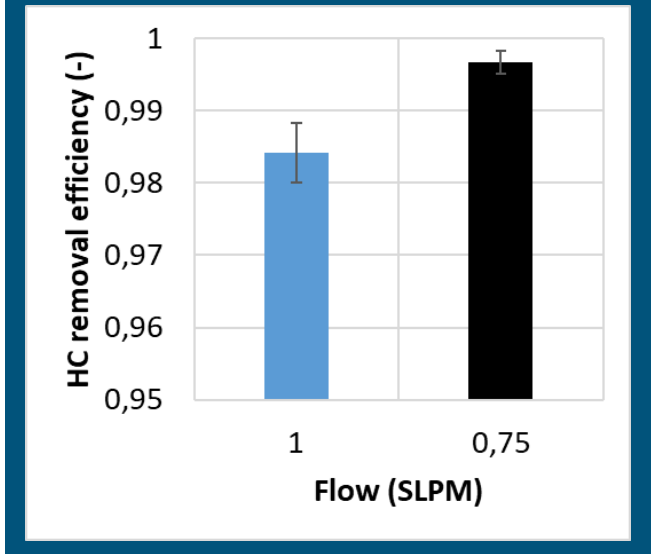
Semi-Volatile Removal Efficiency

- > 99% semi-volatile particle (tetracontane) removal (> 10^4 #/cm^3) at 30 nm size



Gas Phase HC Removal Efficiency

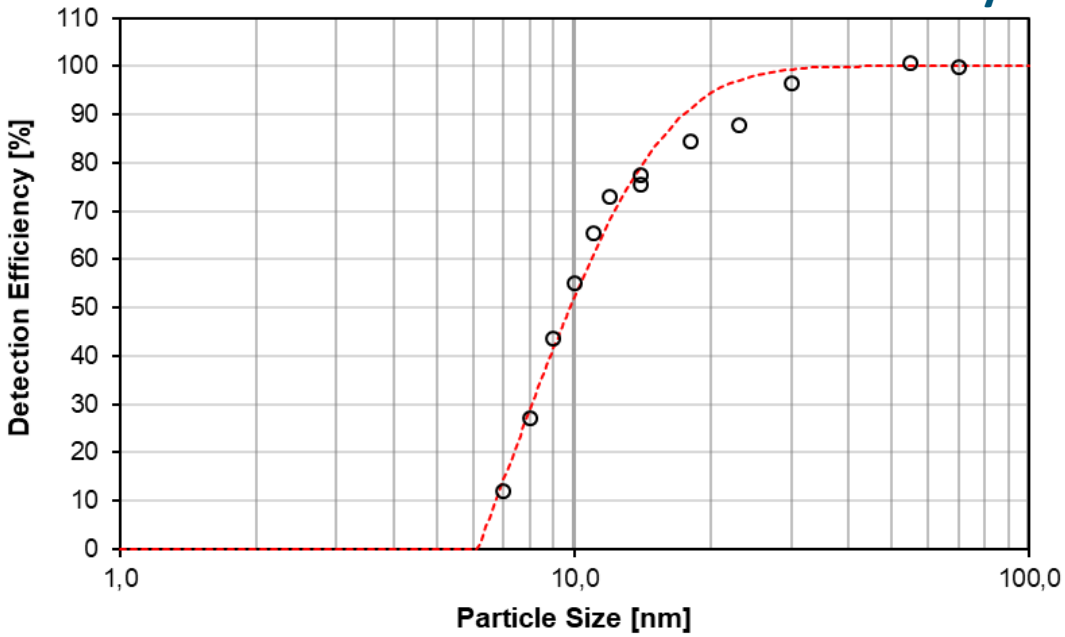
- Gas phase HC (toluene) removal efficiency > 98-99% (concentration of 1000 ppm)



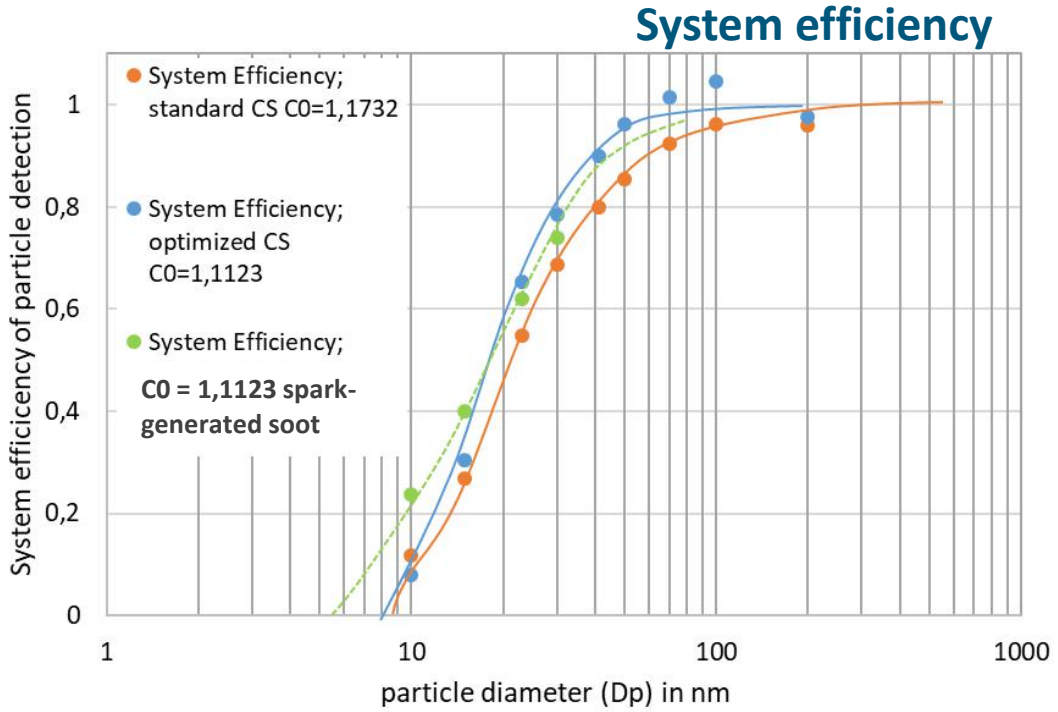
CPC and System Efficiency (PEMS)

Results: Calibrated solid particle counting system for PEMS use

CPC efficiency



System efficiency



- PEMS CPC calibrated with 350°C conditioned flame soot aerosol, optimized for 50% detection efficiency at 10 nm
- This leads to a system efficiency of > 20 % at 10nm (with spark generated soot)

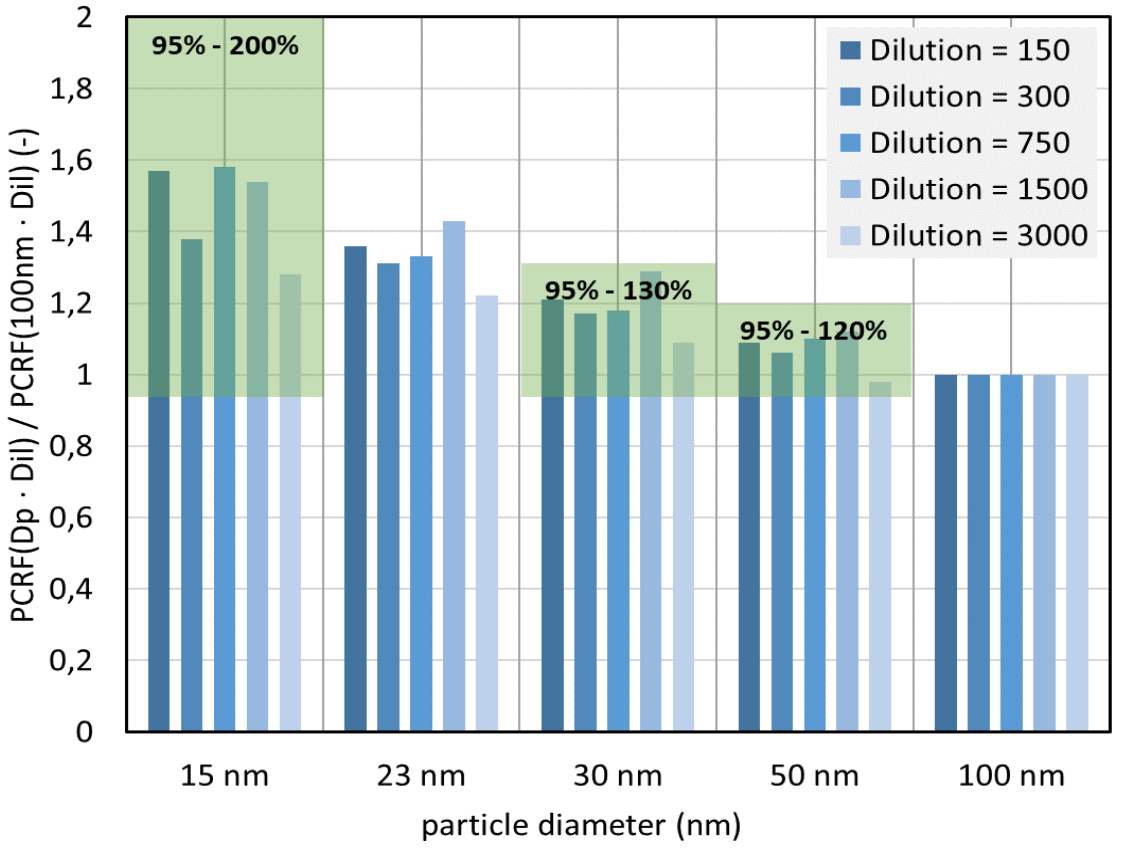
Calibration of SPCS PCRF

PCRF (Particle Concentration Reduction Factor)

- PCRF-factor describes the ratio of particle number concentrations before ($N_{in}(D_p)$) and after ($N_{out}(D_p)$) the passage through the VPR at different particle diameters (D_p)

$$PCRF\ (D_P) = \frac{N_{in}(D_P)}{N_{out}(D_P)}$$

- PCRF at 15nm; 23nm; 30nm; 50nm and 100nm has been measured for the PEMs4Nano Laboratory System



After the Project SPCS (laboratory)

- New products and upgrade of existing products will be available
- Upgrade strategy
  - Sampling: Application of the hot catalytic stripper instead of the evaporation tube and re-calibration
  - Counter: Re-calibration by changing internal temperature settings of the saturator and the condenser
- Delivery term (from order to delivery)
  - Upgrade: 3 weeks
  - New product: 4 months

After the Project PEMS (mobile)

- A new OBS-ONE-PN device will be available soon
- Upgrade availability of existing products will be taken into account

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Thank you

Any questions?

These projects have received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement no. 723954 (PaREGEn) and no. 724145 (PEMs4Nano)