Automated Validation and Calibration of Solid Particle Counters: Tackling the Accuracy Challenge

Florian Hüwe & Thomas Maier

HORIBA Europe GmbH, Hans-Mess-Straße 6, 61440 Oberursel, Germany, florian.huewe@horiba.com

22nd ETH-Conference on Combustion Generated Nanoparticles, June 18th – 21st 2018 at ETH Zürich, Switzerland

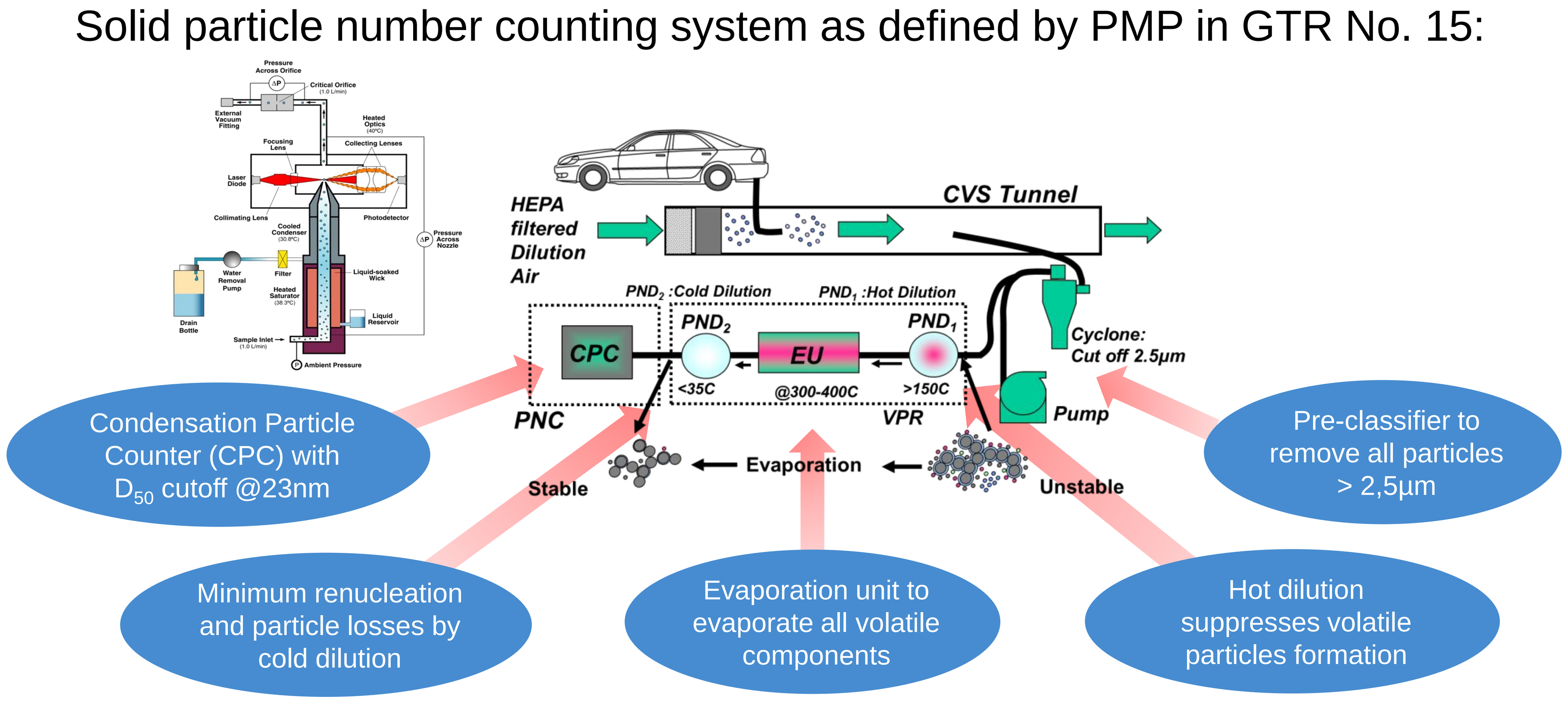
Abstract

Since its regulation in Euro 5b automotive emissions introduced in 2011[1], determining particle number (PN) emissions from internal combustions engines has always been far more prone to measurement variation than any other regulated exhaust gas component. On the one hand, this is due to intrinsic nature of nanoparticles. Compared to gaseous emissions they consist of different materials, sizes and shapes, all affecting their physical and chemical properties.

On the other hand, measurement systems defined by Global Technical Regulation (GTR) No. 15[2] are also affected by calibration uncertainties allowing for certain mismatch between different units. In this work, we present a novel aerosol and flow calibration laboratory of outstanding reproducibility to automatically validate the calibration of our solid particle counting systems (SPCS) and to decrease the mismatch between different particle counters.

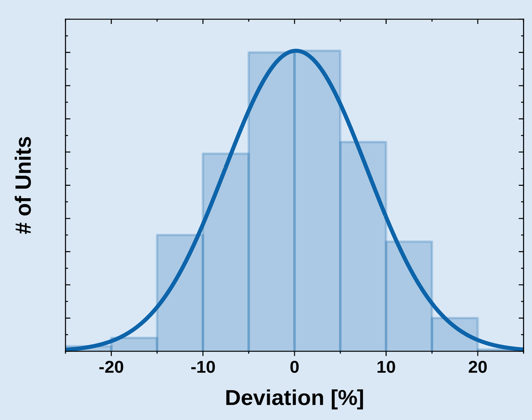
Motivation

Solid particle number counting system as defined by PMP in GTR No. 15:



$$PN\,[\#/cm^3] = \frac{\Delta N}{\Delta t}\cdot\frac{1}{q_{CPC}}\cdot k\cdot k_{Coinc}\cdot PCRF(DF)$$

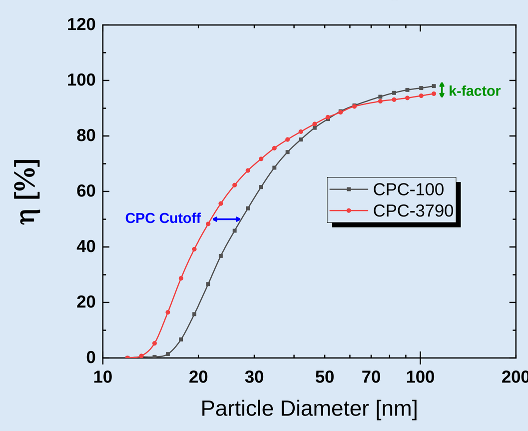
Challenge of PN Counting



Problem: **PN Comparability**

- SPCS accuracy: ±10%
- Variety of calibration parameters
- RDE legislation[3]:
  PN conformity factor = 1.5

Detection Efficiency Variation



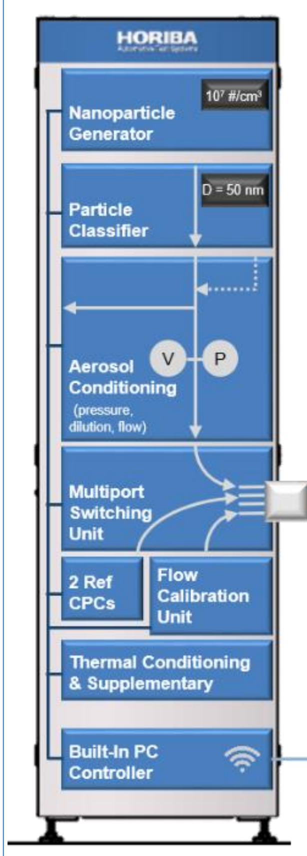
Origin: **Calibration Uncertainties**

- Flow calibration (DF, CPC flow)
- Particle Losses (PCRF)
- CPC linearity (k-factor)
- CPC cutoff curve
- Drift of reference instruments

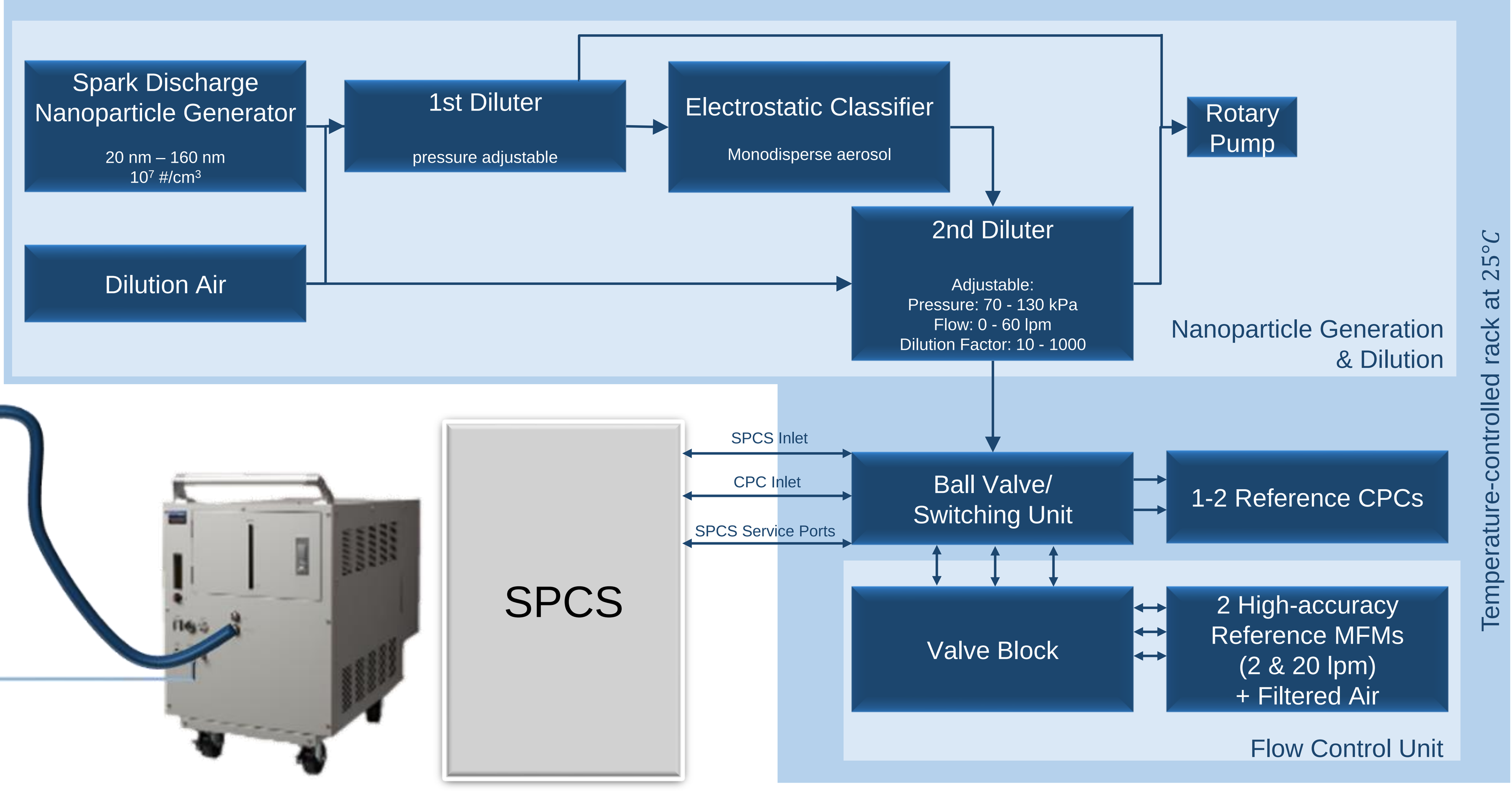
Goal:

Mobile particle aerosol and flow calibration laboratory with full automation!

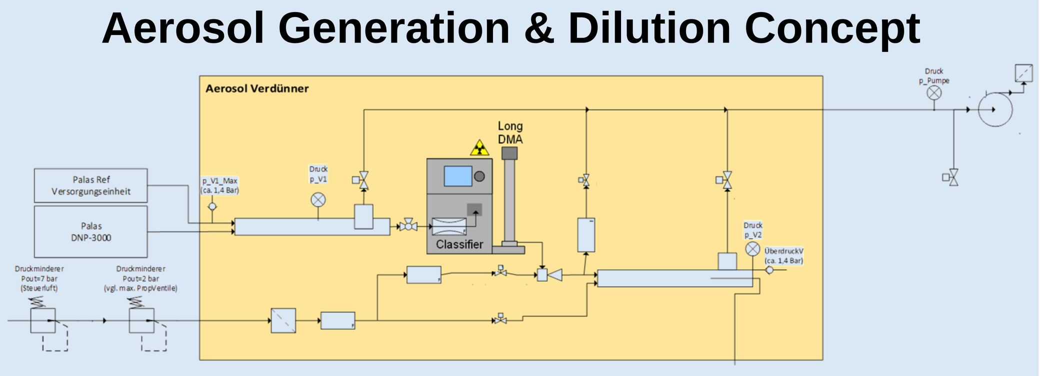
Automated Validation & Calibration System (SPCS-AVACS)



SPCS-AVACS System Overview



Aerosol Generation & Dilution Concept



- Venturi mixer to decouple pressures between 2 dilution stages

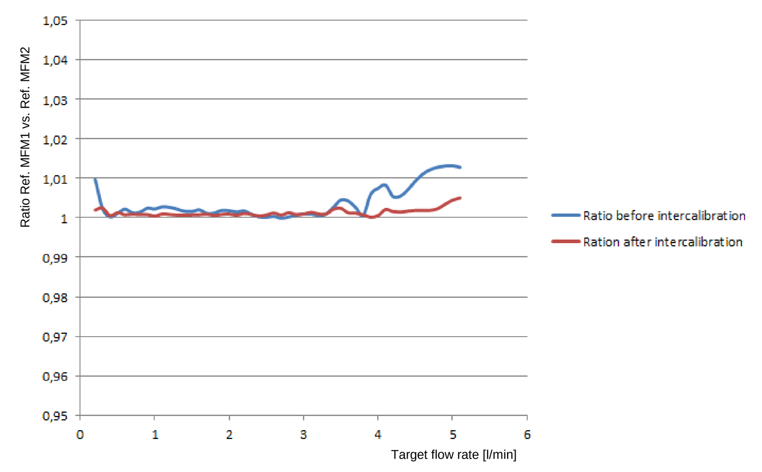
System Features

- Fully automated tests
- Defined test aerosol (pressure, concentration, flow)
- Access to test all flow elements inside SPCS
- References held @ 25 °C
- Mobile, single rack with uninterruptible power supply

Example Results

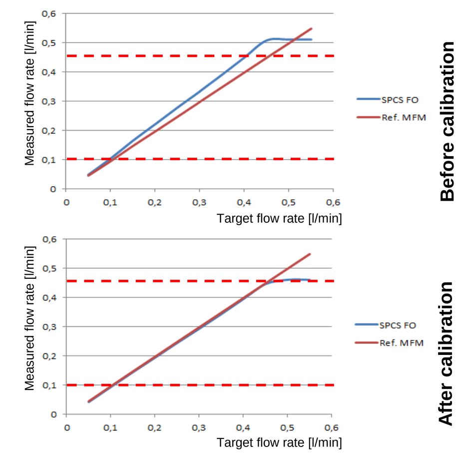
SPCS Flow Calibration

Intercalibration of Mass Flow Meters



- Relative accuracy: better than 1%

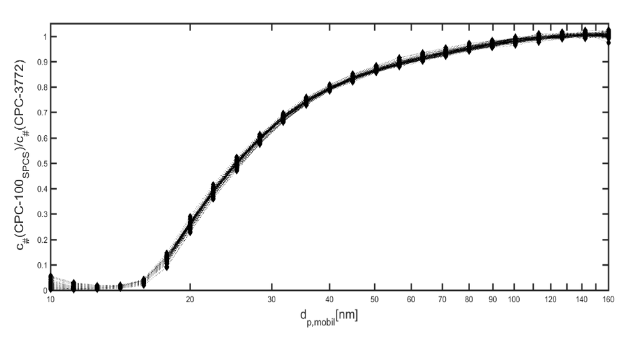
Correction of Flow Calibration Errors



- Improvement of flow accuracy

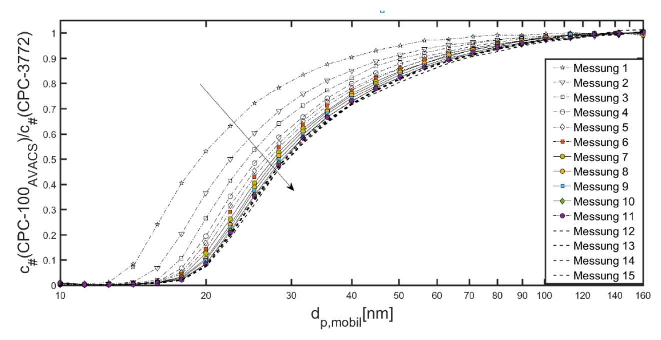
Particle Detection Efficiencies

Golden Reference for CPC Efficiency



- 152 curves @ 25 datapoints measured with very high reproducibility

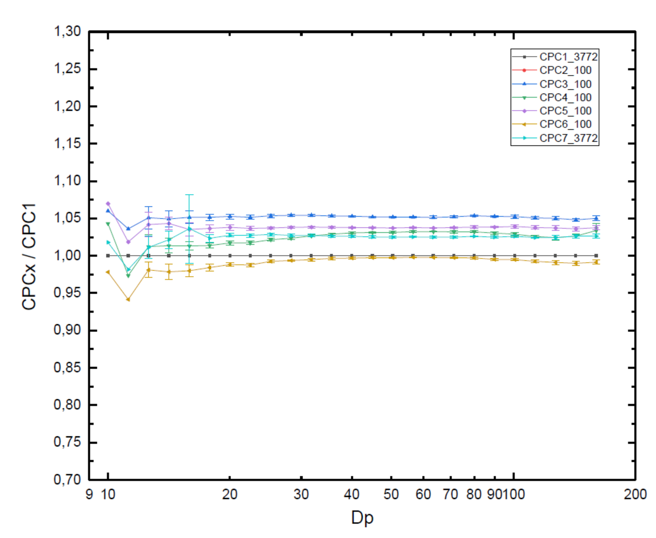
Ambient Temperature Drift of CPC



- Ambient temperature of one CPC varied

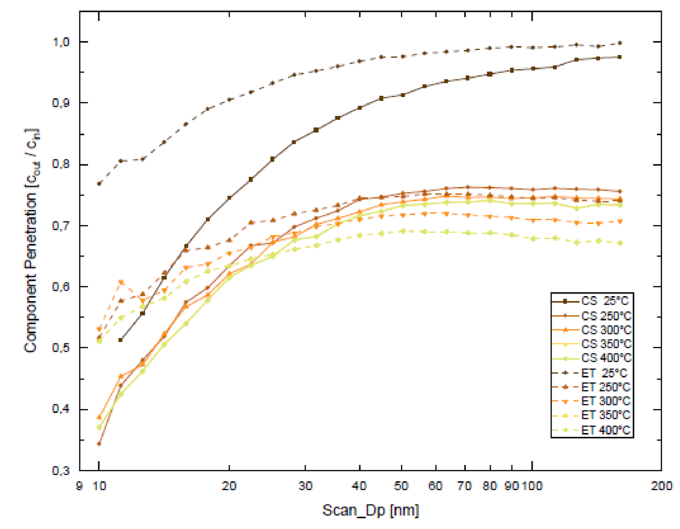
Sub-23nm SPCS Component Testing

Relative CPC Detection Efficiencies



- All measured in parallel with same saturator and condenser temperatures
- Deviation w/o linearity correction < 10%

Particle Losses in Evaporation Units



- Particle losses rise with temperature
- Smaller D_p: particle losses CS > ET
  Larger D_p: particle losses ET > CS

Benefits from SPCS-AVACS

Comparability	Usability	Troubleshoot	Mobility
"Golden instrument" to check all particle counters on site	Automated checks of a SPCS with minimum user interference	Root cause of errors (such as flow errors, clogging, drift,…)	Easy installation & transfer between laboratories
R&D	**Quality**	**PEMS**	**GTR 15**
Complete statistics of SPCS calibration characteristics & component testing	Easy quality checks to enhance measurement reliability	Simulation of external environment & PN conformity factor	CPC checker for the verification required after every 6-month

References & Acknowledgements

[1] COMMISSION REGULATION (EC) No 692/2008 of 18 July 2008 implementing and amending Regulation (EC) No 715/2007 of the European Parliament and of the Council

[2] UN Global Technical Regulation No. 15

[3] COMMISSION REGULATION (EU) 2017/1154 of 7 June 2017 amending Regulation (EU) 2017/1151 supplementing Regulation (EC) No 715/2007 of the European Parliament and of the Council

Funding: PEMs4Nano has received funding from the European Union's Horizon2020 Programme under Grant Agreement no. 724145 (H2020-GV-2016)

European Commission | Horizon 2020 European Union funding for Research & Innovation