

Instruments and sensors for Periodic Technical Inspection (PTI) with DPF-equipped vehicles and Kerbside Control

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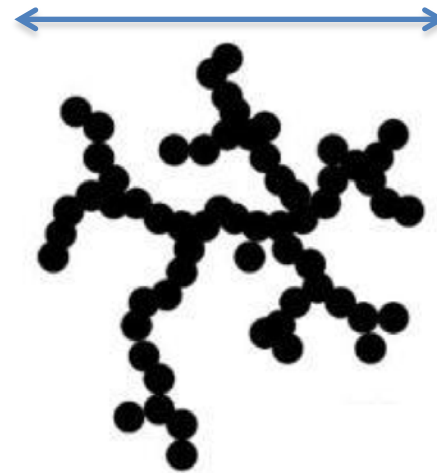
Contents

- How perform PTI with DPF diesel
- Then opacity no longer useful
- Type approval Euro 6 - particle number
- Current PTI legislation Switzerland 🇨🇭
- New sensors and instruments for PTI and kerbside control
- Conclusions



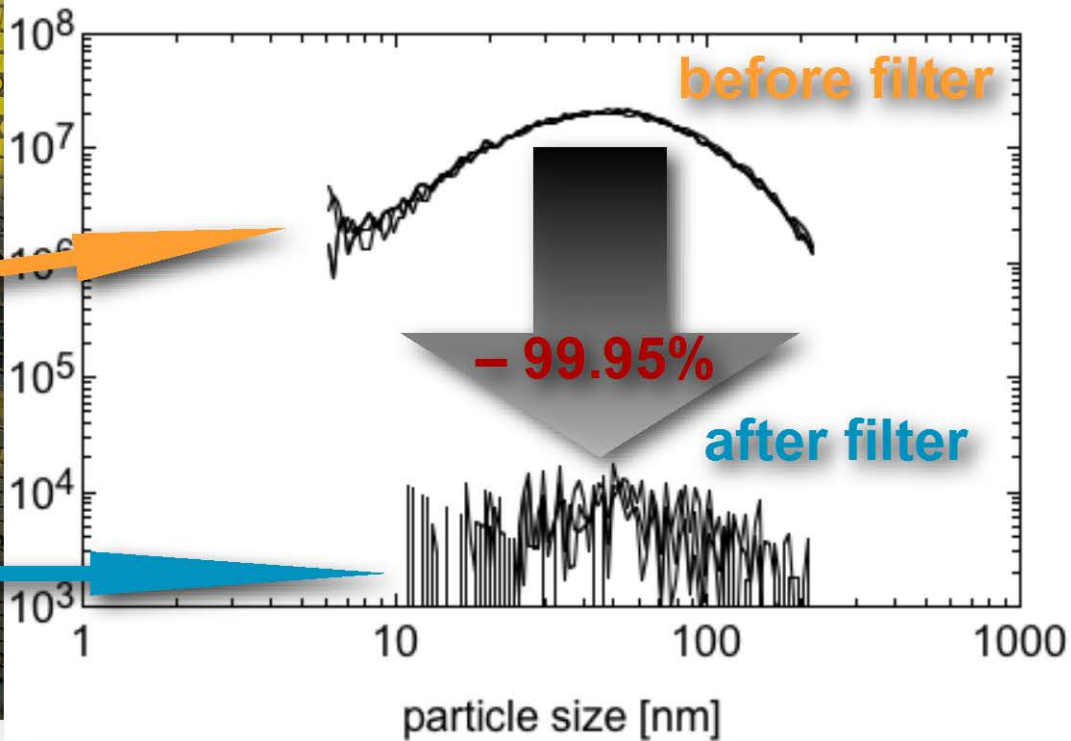
What do we need to measure?

- 70 nm soot particles (0.0000070 mm)

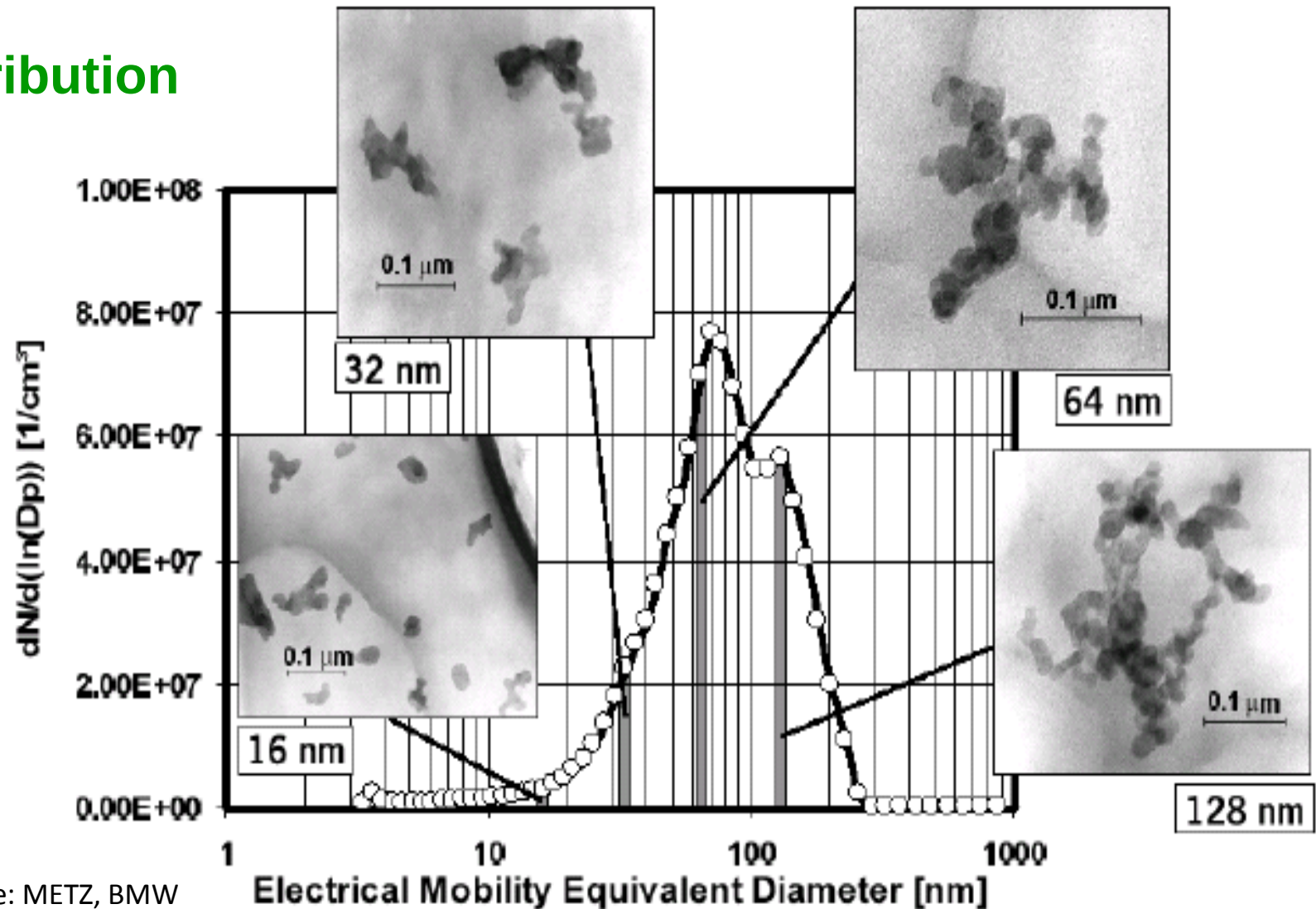


- Upstream DPF 1'000'000 per cm^3
- Downstream as low as 1000 per cm^3
- Small failures: concentration in between

Filter Efficiency Measurement



Diesel Soot Size Distribution

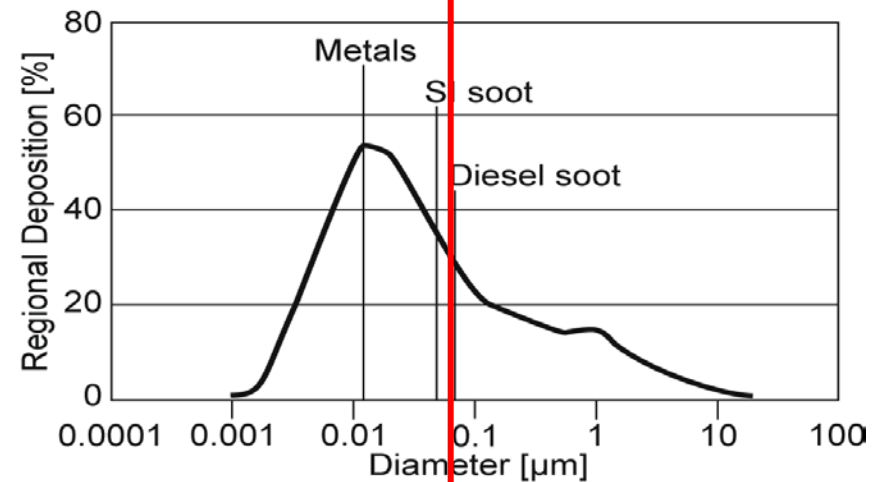
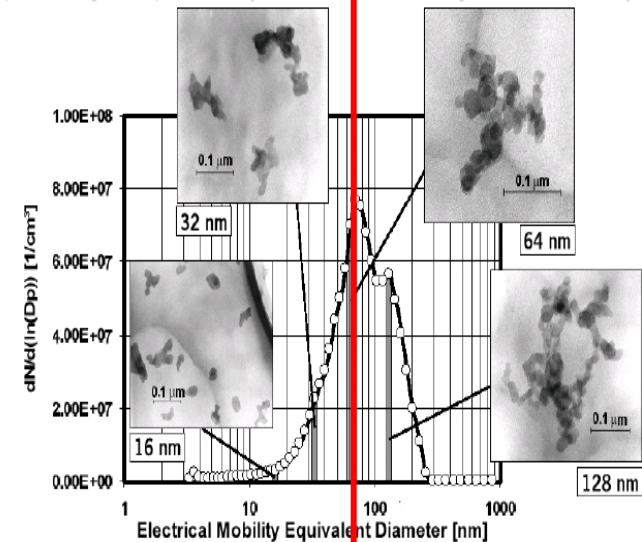


Source: METZ, BMW

A very strange coincidence

The most sensitive size range of the Lungs is the most intensive emission range of the Engines

The Lung is an open door for engine emitted particles



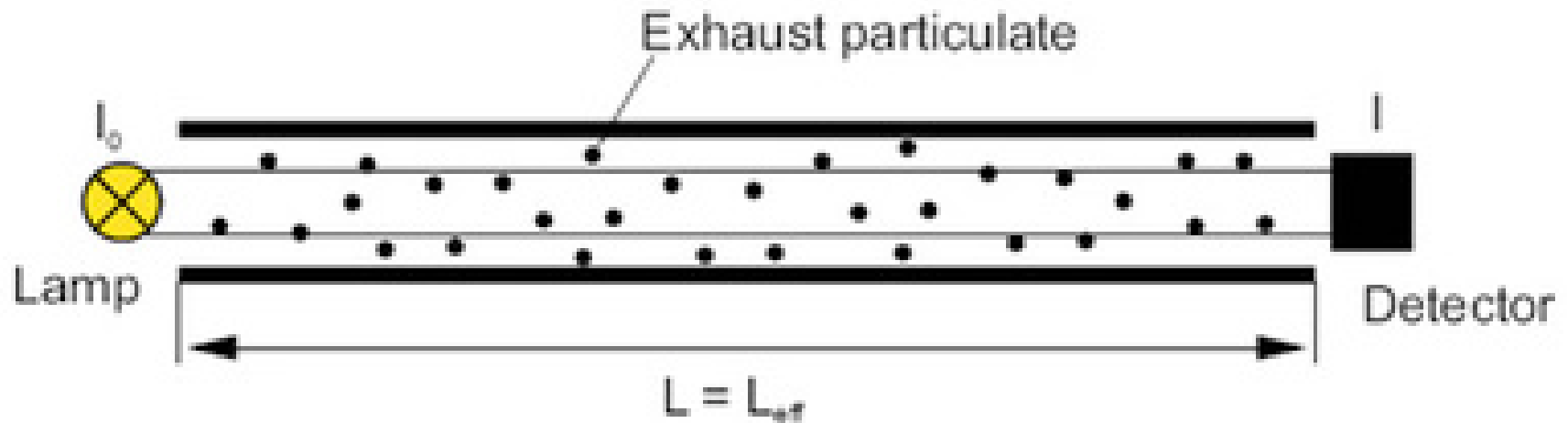
Opacimeter

- Typical LOD 0.3 m^{-1}
- Accuracy $\pm 0.3 \text{ m}^{-1}$

ACTIA ATAL
Vehicle Electronics & Diagnostics



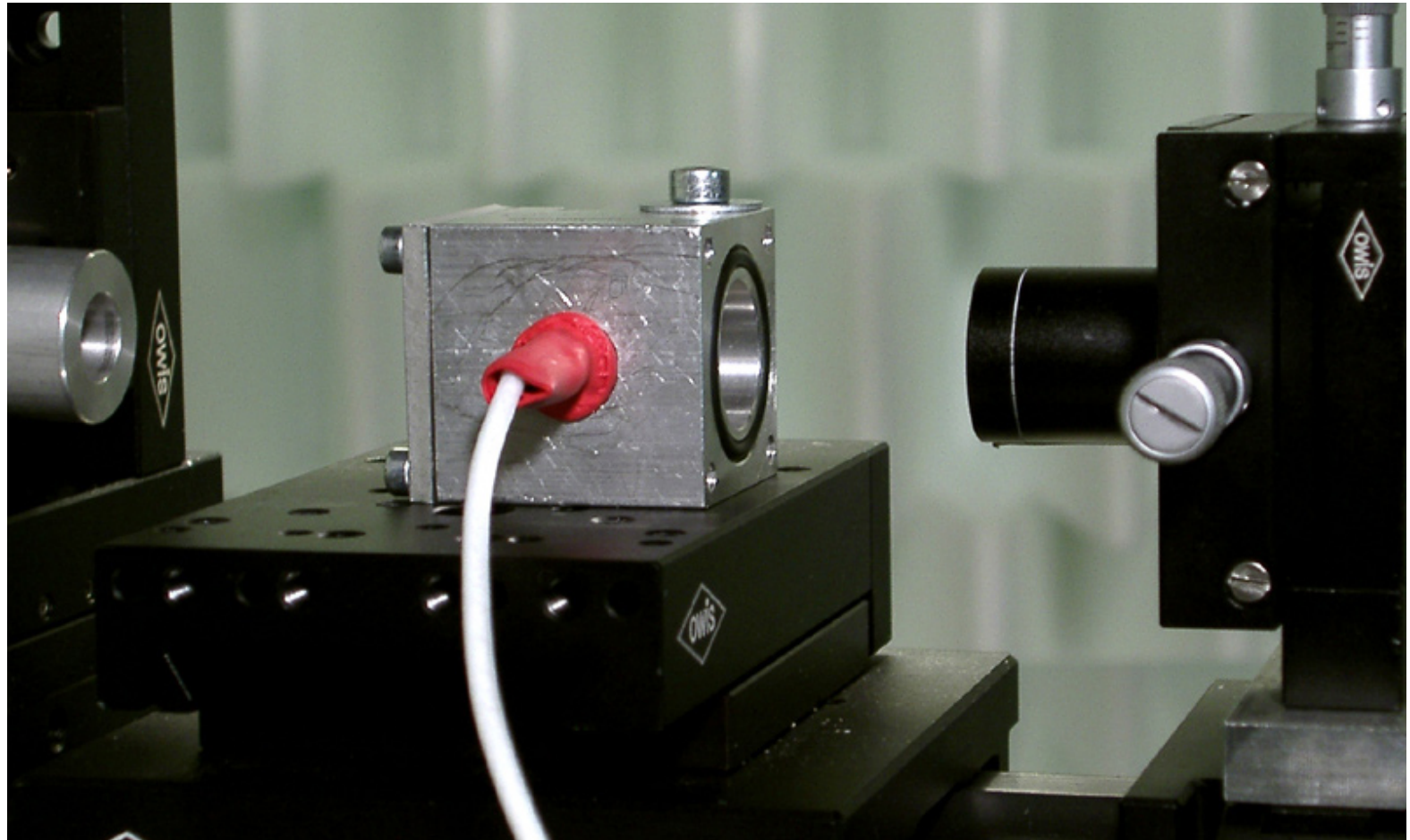
Opacimeter module AT605
(for diesel engines)



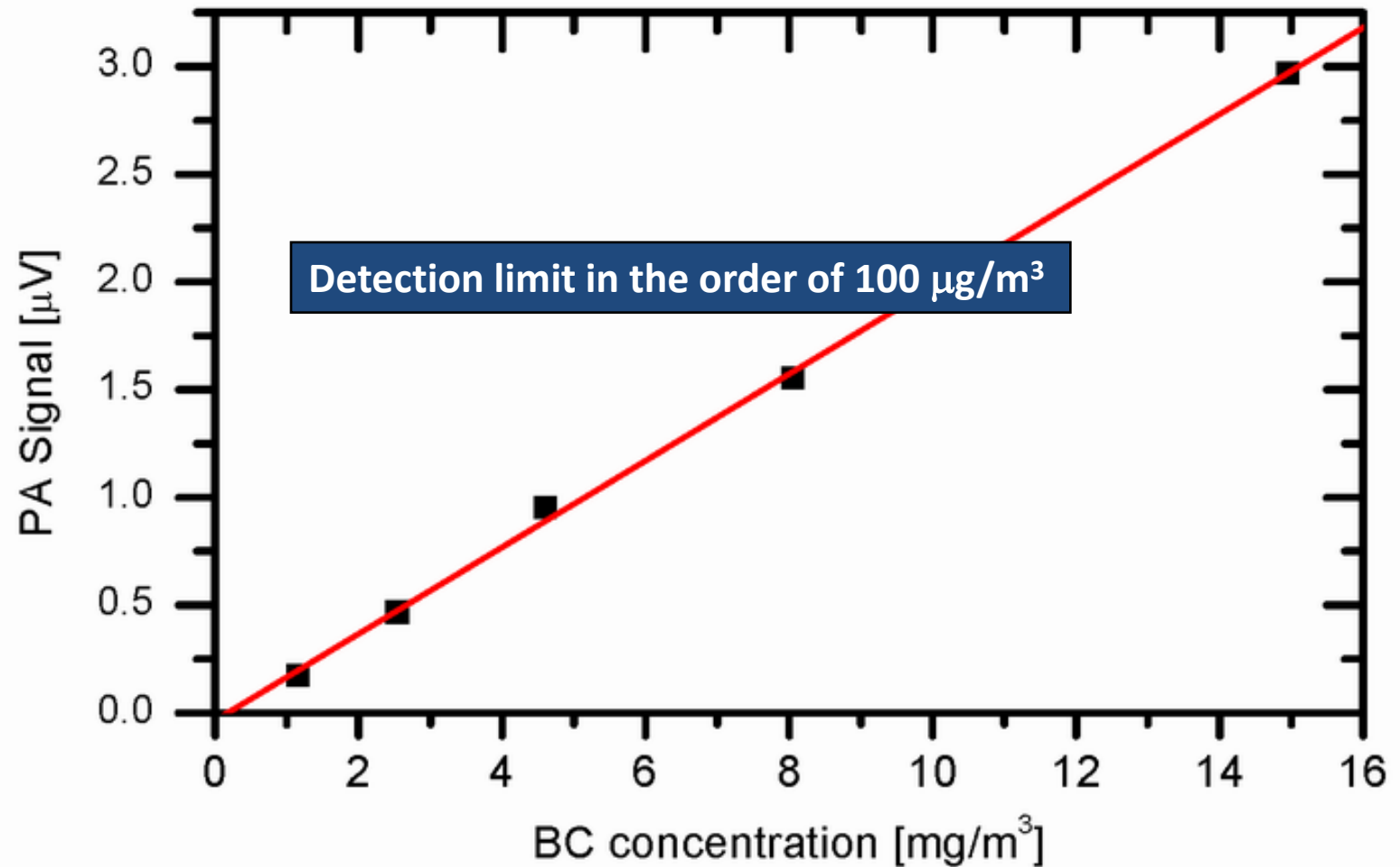
"Good" instruments for DPF

- Condensation Particle Counter (CPC)
- Diffusion Chargers (DC)
- Soot sensors
- Photoacoustic sensor

Open Photoacoustic Detector



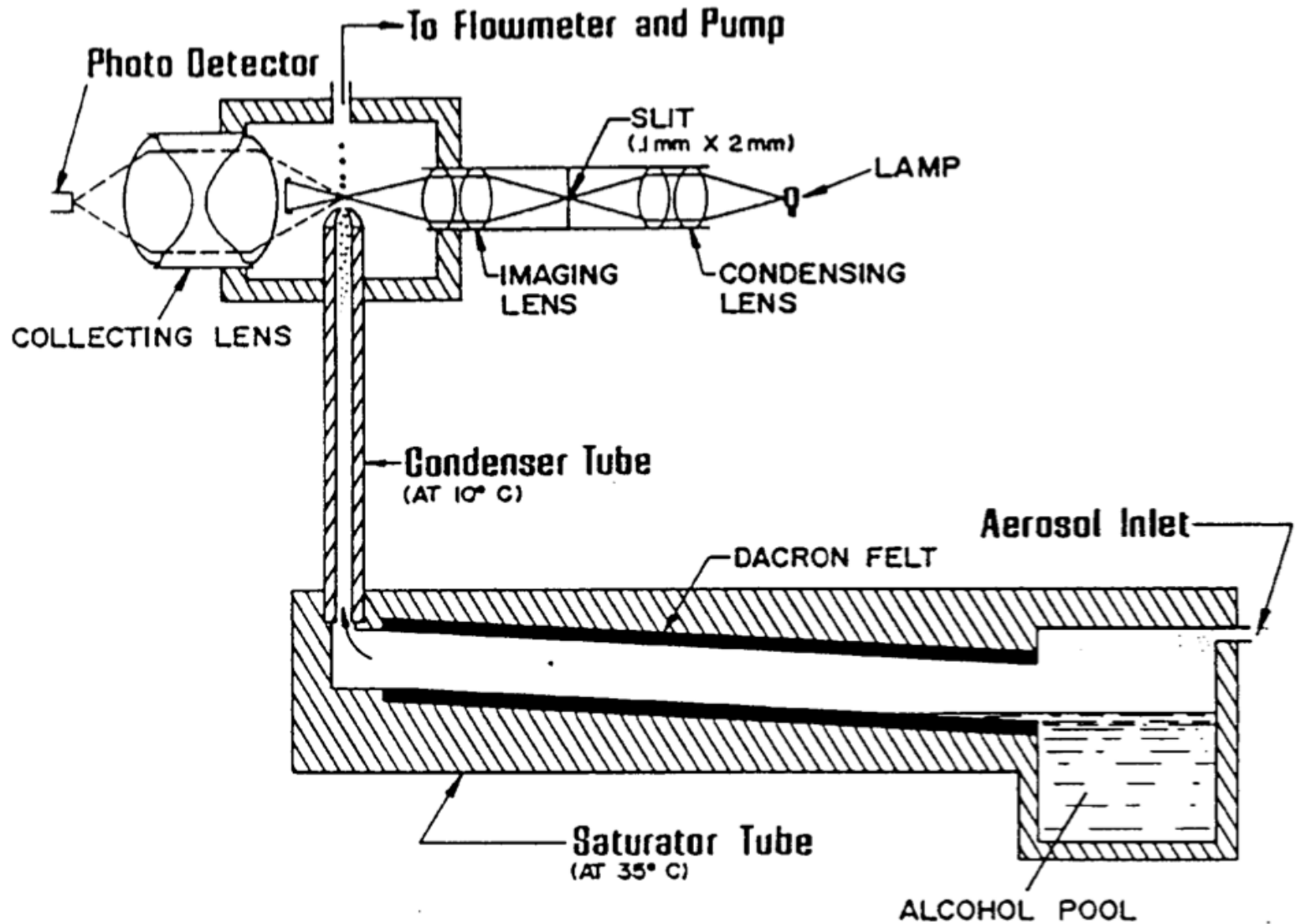
PA signal vs. BC concentration



AVL Micro Soot Sensor Generation MSS^{plus}



CPC



Field Data - NPET vs. Opacity

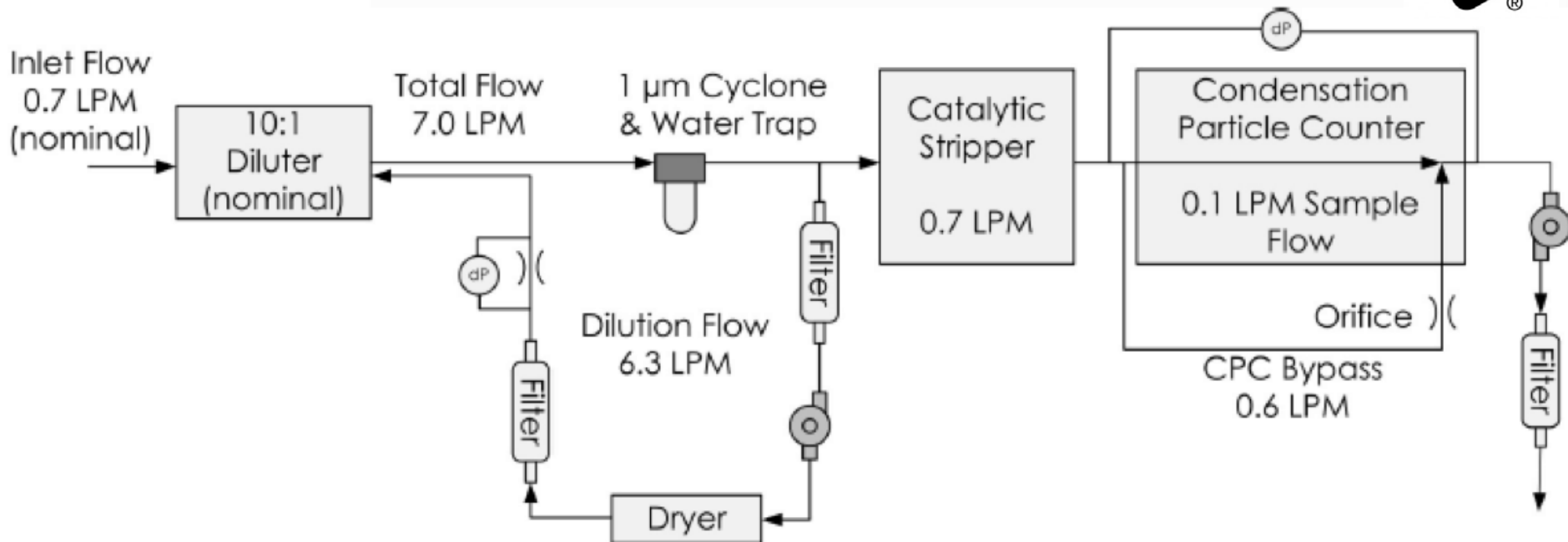
courtesy of Aliosha Reinoso (Geasur), VERT Forum 2016 and TSI inc.



- TSI NPET 3795



How does NPET 3795 work?



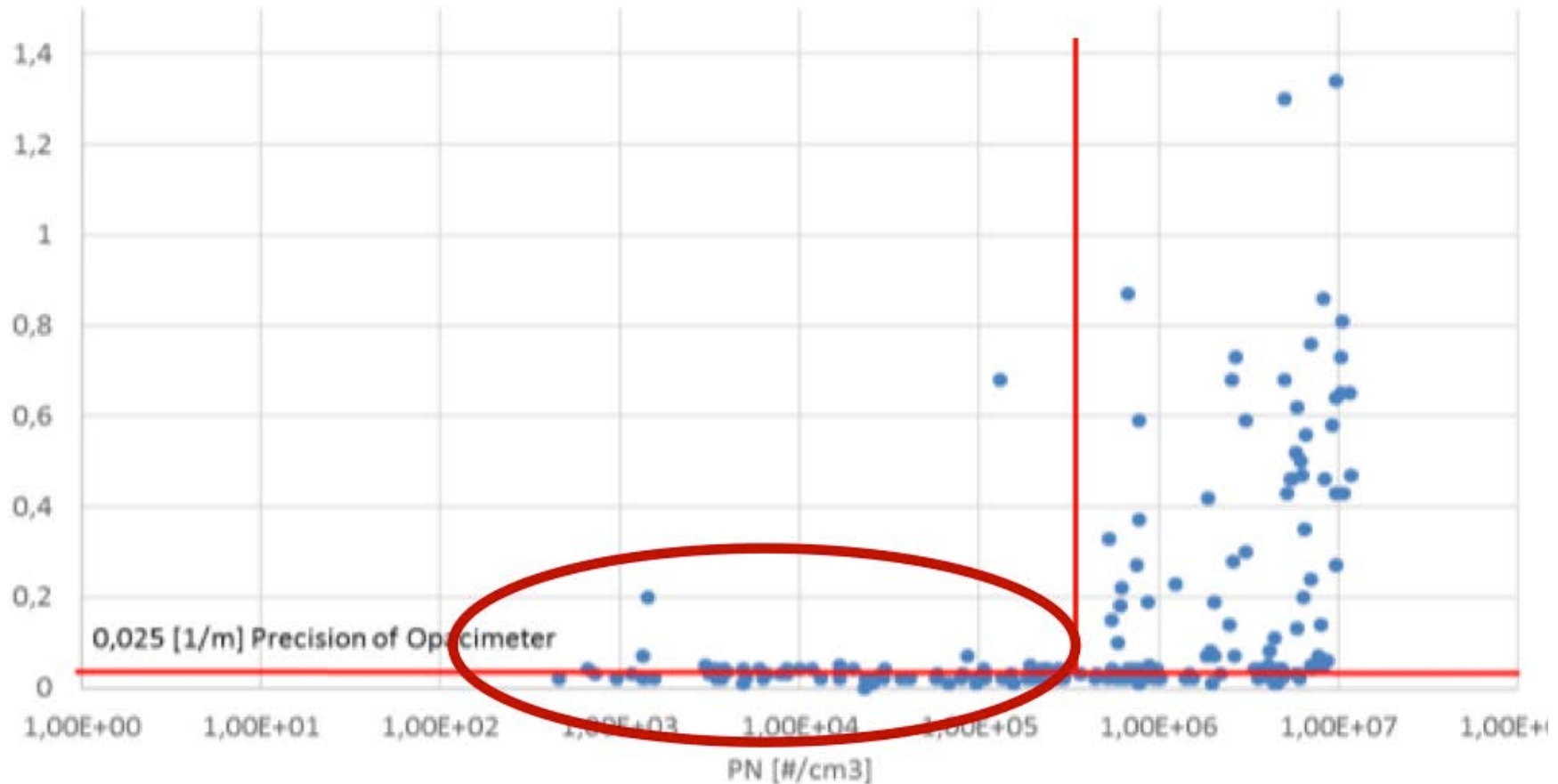
Testing of Santiago buses, Chile



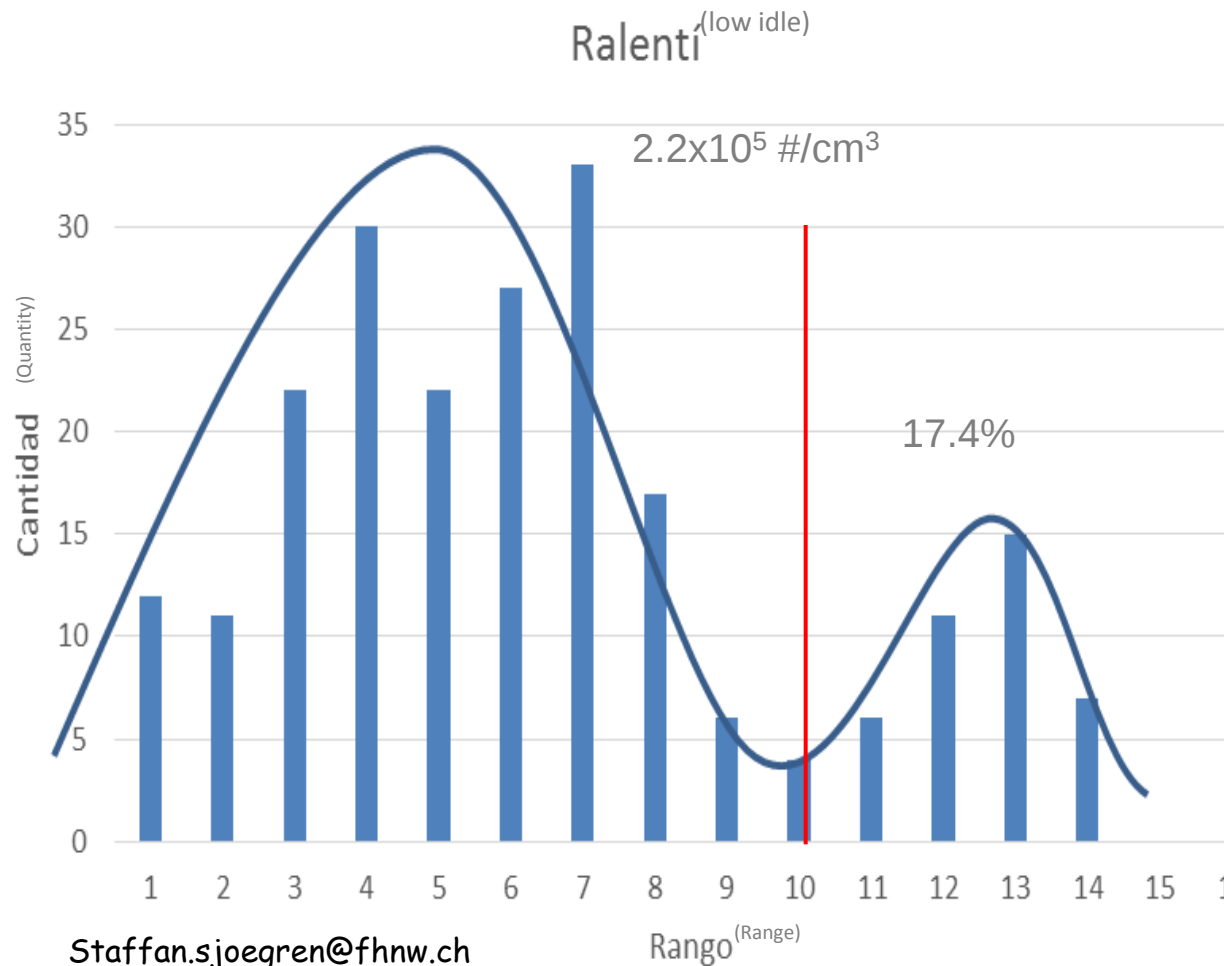
Aliosha Reinoso (Geasur), VERT Forum 2016 and TSI inc.



Testing of Santiago buses, Chile



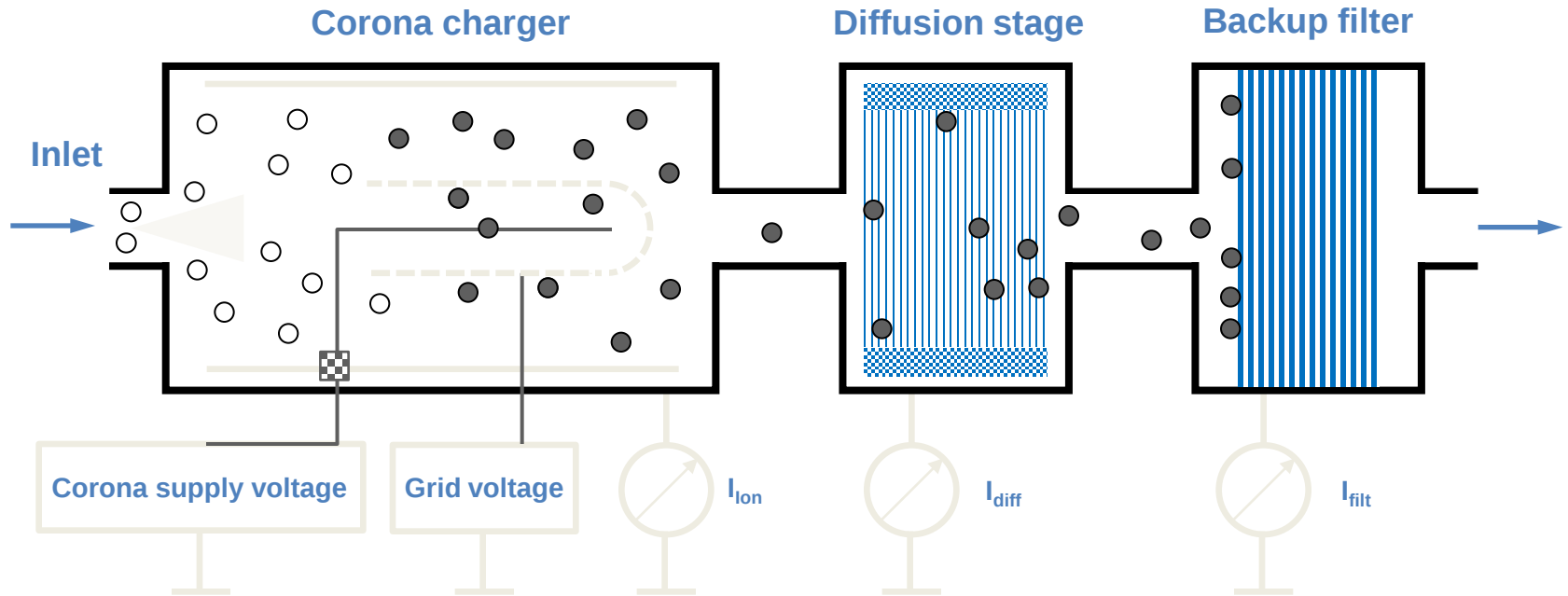
End of pipe PN Limit to detect Abnormal Emissions



Range	≥	<	N	Condition
1	1,00E+02	2,20E+02	12	Normal
2	2,20E+02	4,70E+02	11	Normal
3	4,70E+02	1,00E+03	22	Normal
4	1,00E+03	2,20E+03	30	Normal
5	2,20E+03	4,70E+03	22	Normal
6	4,70E+03	1,00E+04	27	Normal
7	1,00E+04	2,20E+04	33	Normal
8	2,20E+04	4,70E+04	17	Normal
9	4,70E+04	1,00E+05	6	Normal
				Indifferen
10	1,00E+05	2,20E+05	4	t
11	2,20E+05	4,70E+05	6	Abnormal
12	4,70E+05	1,00E+06	11	Abnormal
13	1,00E+06	2,20E+06	15	Abnormal
14	2,20E+06	4,70E+06	7	Abnormal
15	4,70E+06	1,00E+07	0	Abnormal
16	1,00E+07	2,20E+07	0	Abnormal
TOTAL			223	

Diffusion charger

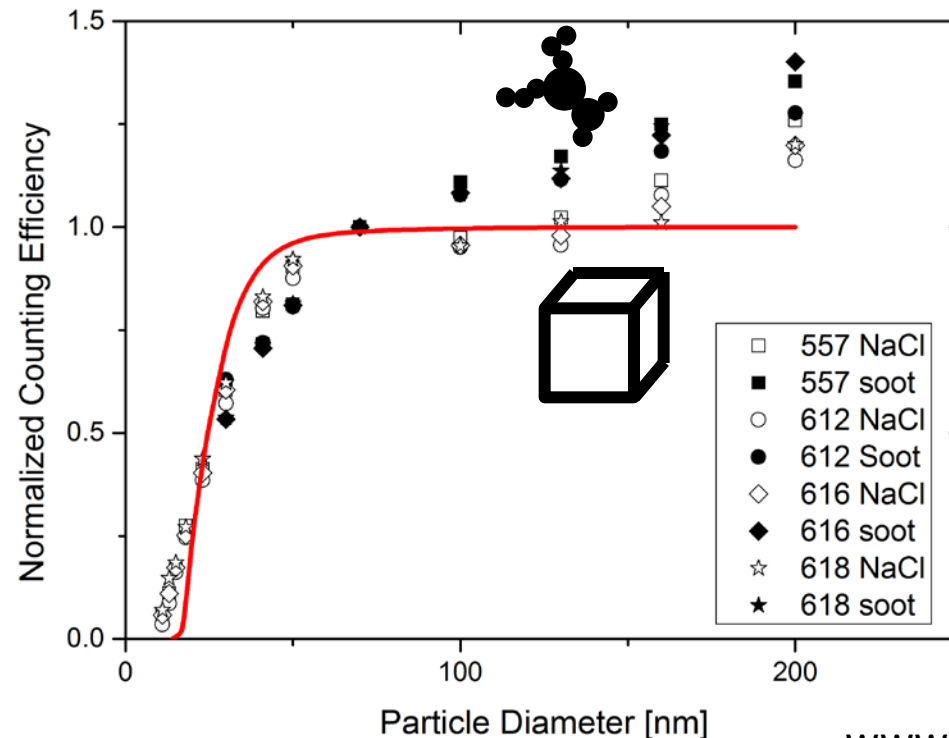
Operating principle



- Particles are labeled with positive charges in a unipolar charger, so that they can later be detected by the current they induce
- Particles are deposited by diffusion in a "diffusion stage" and detected as an electrical current $D = I_{diff}$; Diffusion stage penetration is size-selective
- Remaining particles end up in a filter stage and also produce an electrical current $F = I_{filt}$
- DiSC Sensor measures both currents D and F simultaneously, with 1s time resolution

Counting efficiency

- Devices based on charging can only **mimic** but not completely **reproduce** CPC counting efficiency curve



Add here again same size distribution to show it is measurable

Swiss Regulation on PN for construction machinery

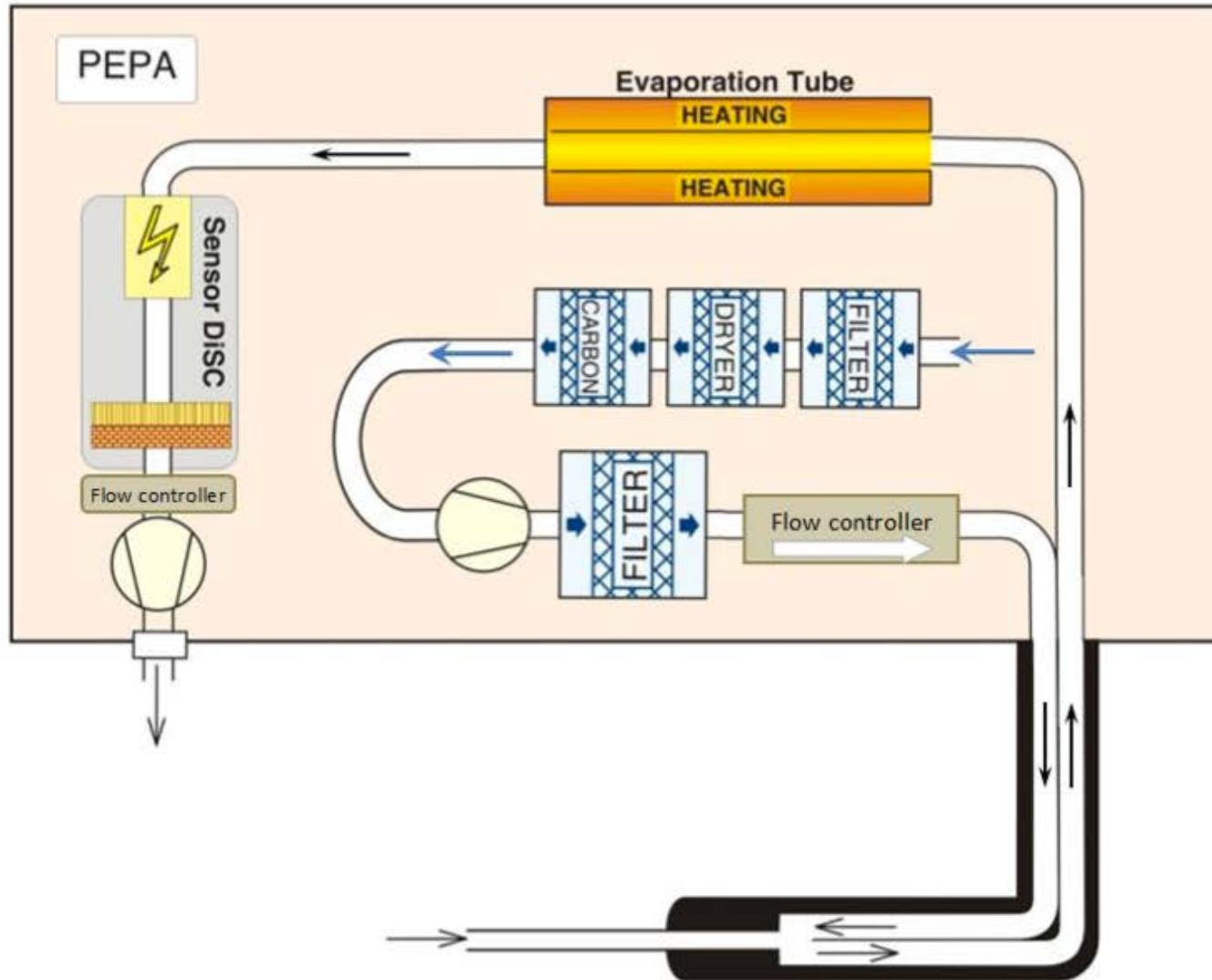


PEPA – Portable Emissions Particle Analyzer



ViPR Thermo-Dilution

Wir messen es.



Prototype

- Demonstrator built at FHNW: a handheld DPF filter tester
 - Handheld
- Battery powered



Instrument specs

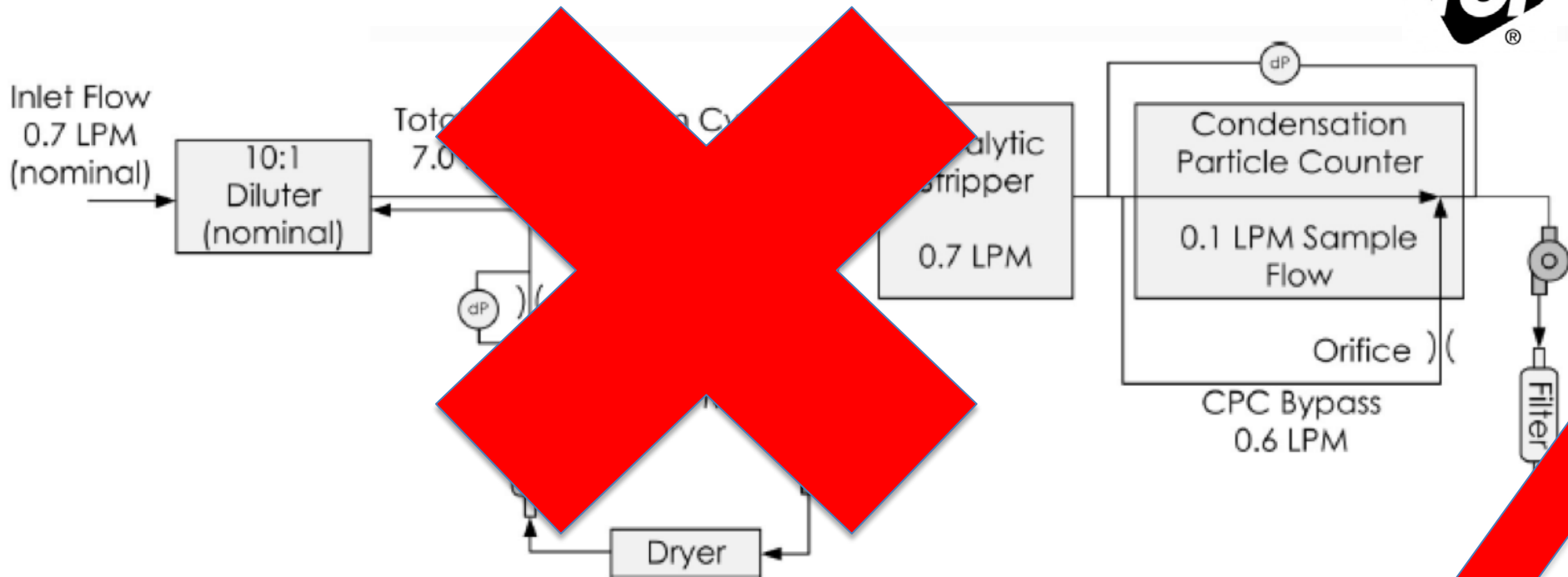
- Handheld
- 1.5kg
- battery powered
- 10-fold dilution @ 200° C
- Concentration range
 $10^4 - 10^8$ pt/ccm
- A prototype, not a finished instrument



Requirements, Improvements & Solutions

- Workshop deployable and useable
- Measurements at idle
- 250'000 particles per cm^3
- So cheap(er) and simpler and robust
- Police and kerbside controls
- Can the instruments (still) do the job?

Simplifications possible



We need to answer a simple question

DPF ok?

Yes/no

Simple question

Simple answer!

- We need a simple way of answering this question

Automotive partector

Sensor specs:

- Miniature 174x88x33mm
- Lightweight 500g
- Low power 2W
- Comparatively low-cost (to CPC)



AVL PN-PEMS

- Market leader AVL has chosen the automotive partector for its PN-PEMS system instead of a CPC
- ~100 devices in the field already



Partector

Particle counting: Diffusion Size Classifier

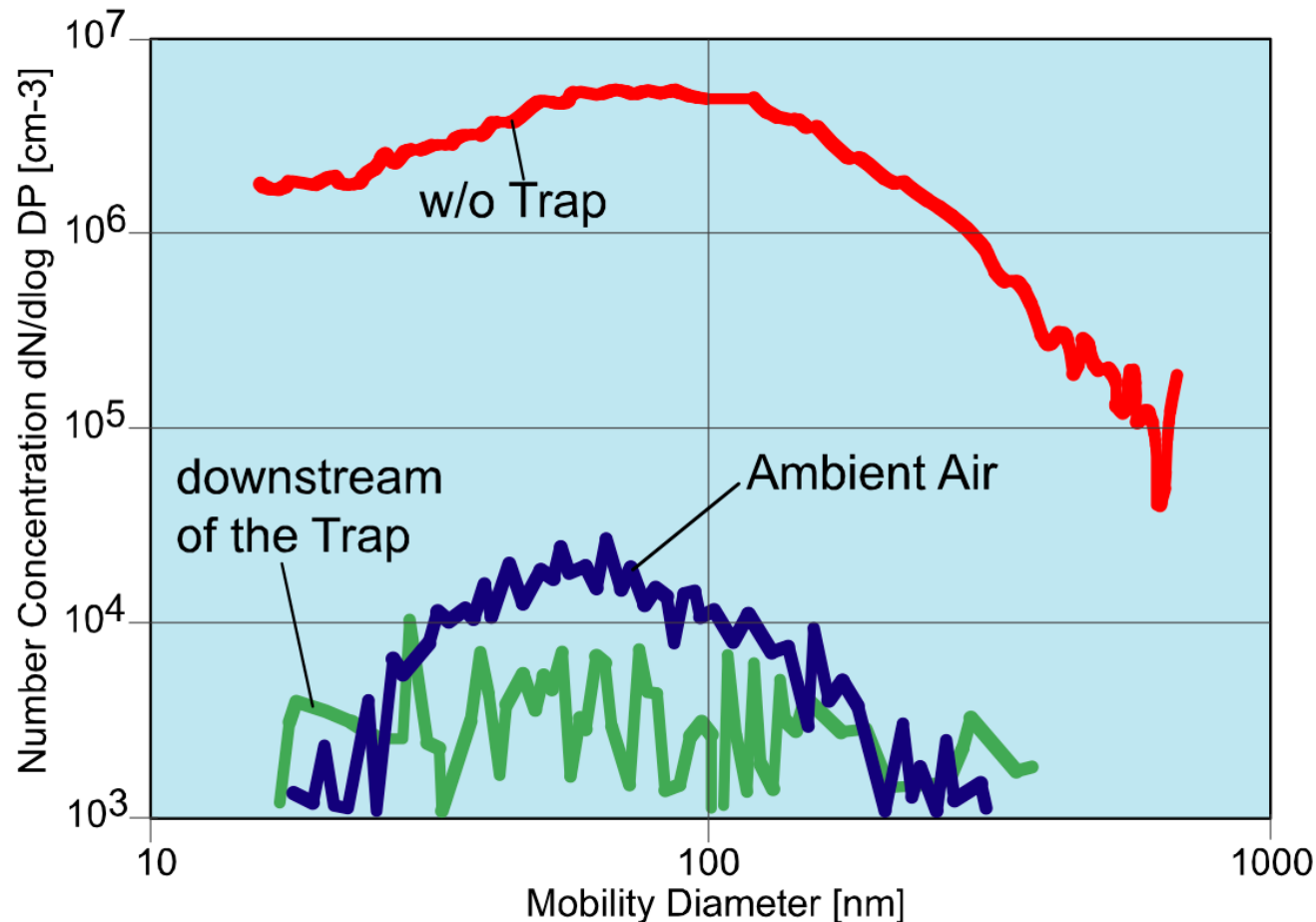
Wir messen es.



Conclusions - take home message

- **Instruments are available:**
Testo PEPA, TSI 3795, Nanocos partector
- In workshop and kerb-side control, **at idle**
- Can evaluate **diesel particle filters** and diesel particle emissions
- Suitable **concentration** range:
10'000 - 1'000'000 particles cm⁻³

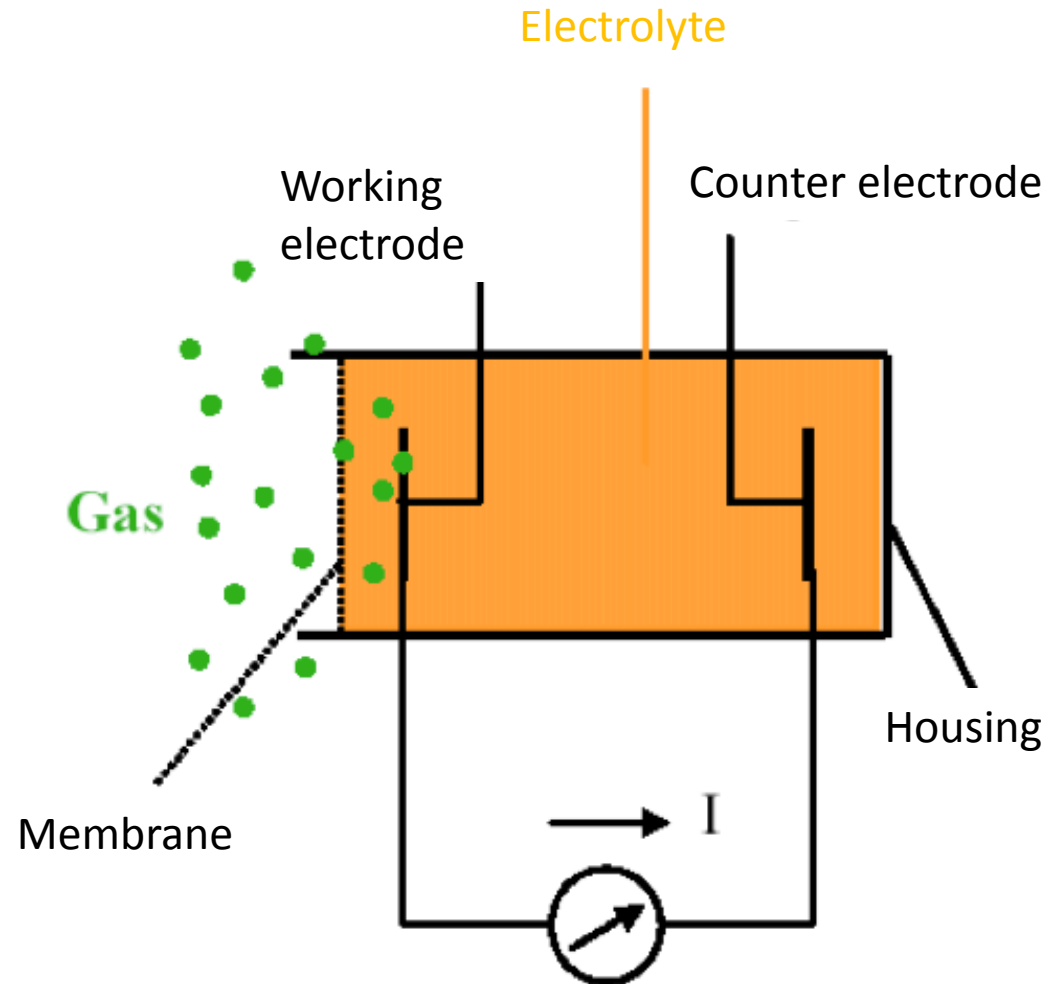
Exhaust Gas downstream of the
Filter is cleaner than Ambient Air !



2. Gases

- Sensors
- Instrument example

Electrochemical sensors



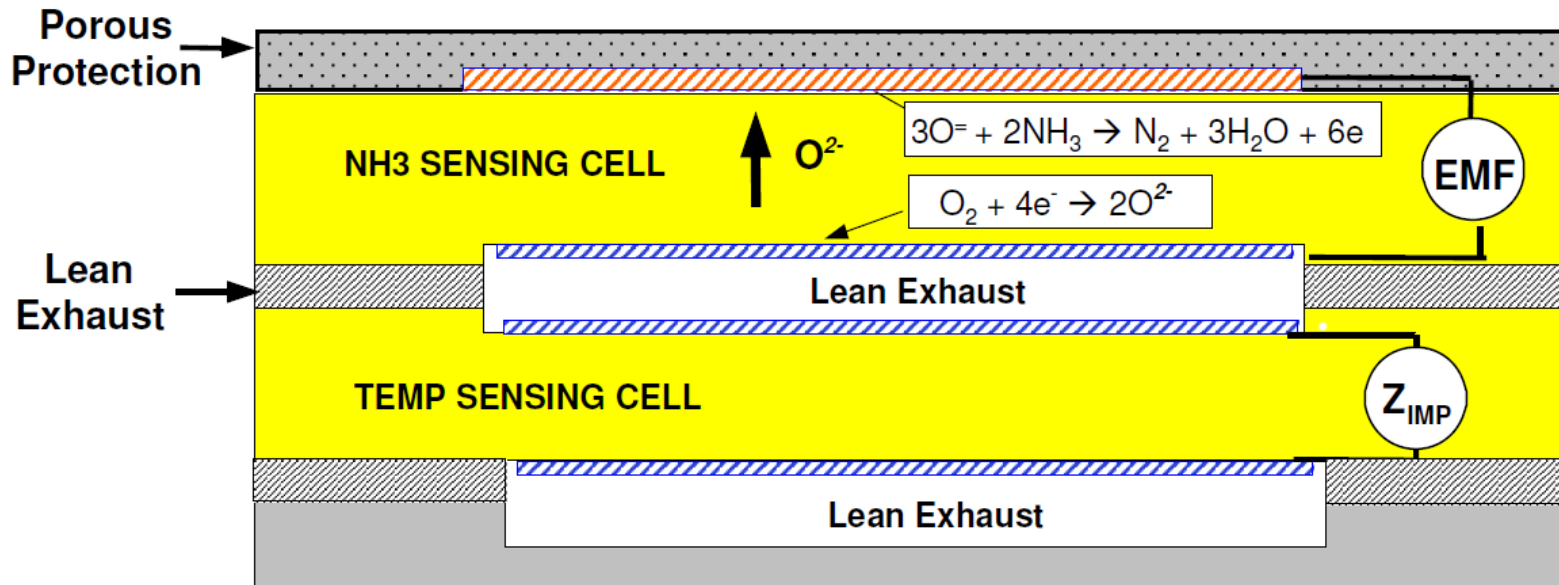
SCR Ammonia Sensor

- 0 to 100 ppm
- durability in hostile high temperature exhaust



testo 350 – The **NEW** testo 350

Delphi - nonequilibrium electrochemical principle



Soot scattering and absorption

