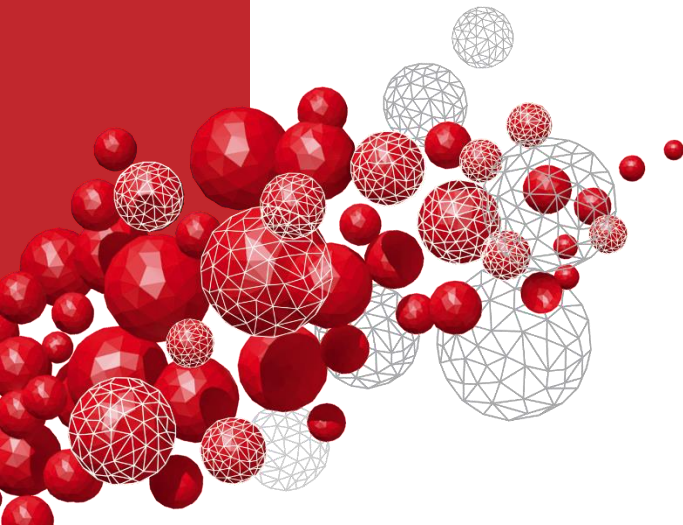


# Dekati Solutions for Automotive Particle Measurements

Peter Lambaerts

Oskari Vainio





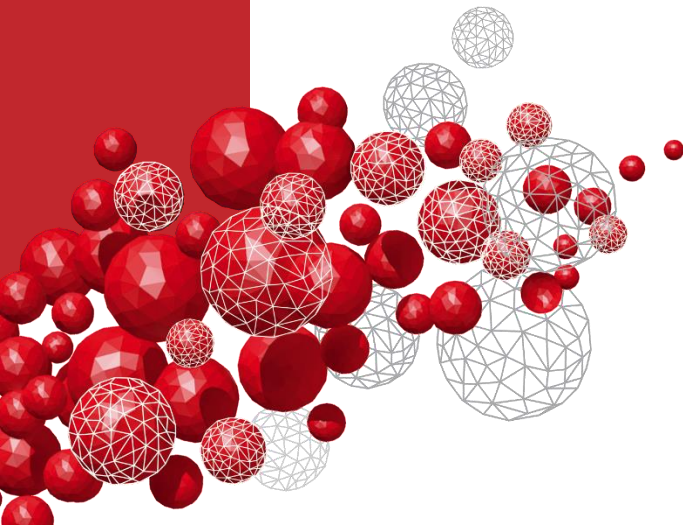
# Dekati – 25 years of fine particle measurements

- Sales, manufacturing and development of fine particle measurement solutions
- Core competence: Real-time fine particle size & concentration measurement and sample conditioning technologies
- Privately owned technology spin-off company from TUT Aerosol Physics Lab
- Located in Kangasala Finland
- Exports ~ 95 % of sales, Distributors in ~35 countries worldwide
- >20 high-know-how employees
- Since 1993 over 500 ELPI's and over 1000 other instruments sold





# Engine Exhaust Emissions



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[www.dekati.com](http://www.dekati.com)

# Non-compliance setups for engine exhaust measurements

- Types of engine emission studies
  - Pre-aftertreatment direct from tailpipe
  - Post-aftertreatment direct from tailpipe
  - CVS or partial flow dilution with volatiles
  - CVS or partial flow dilution without volatiles
  - On-board – PEMS



# Vehicle exhaust measurements

- HT(HR)-ELPI<sup>®</sup>+ only real-time instrument capable to measure size distribution from tailpipe
- Particle size measurement
  - Becomes more interesting as regulation goes from 23nm to 10nm
- Fuel and lubricating oil effects
- Aftertreatment effects

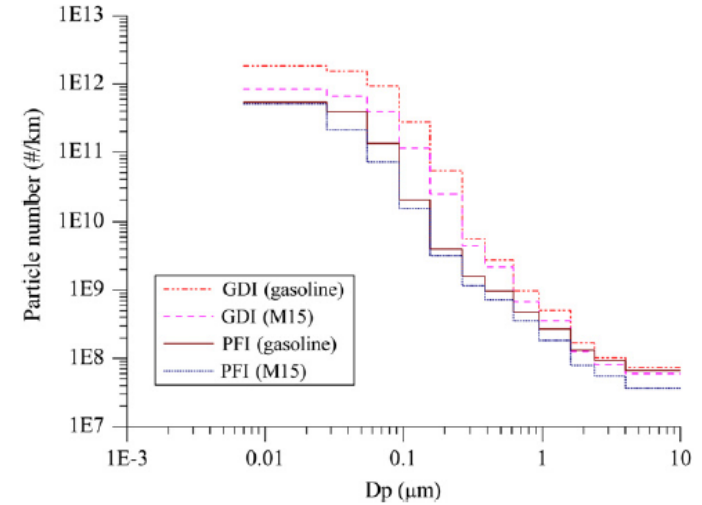
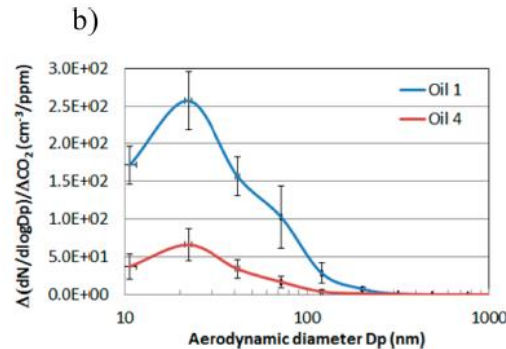
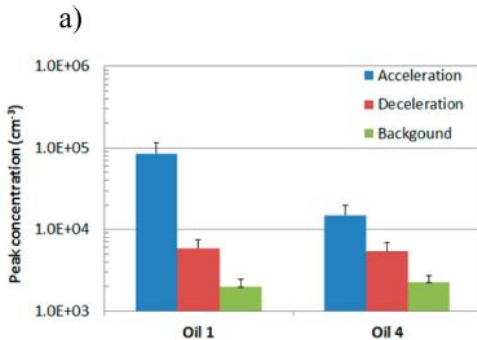


Fig. 5. Particle number distributions for the four tests measured by ELPI.



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DEED-300



eDiluter™ / eDiluter™ Pro



HR-ELPI®+

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HT-ELPI®+



eDiluter™ / eDiluter™ Pro



HR-ELPI®+

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HR-ELPI®+



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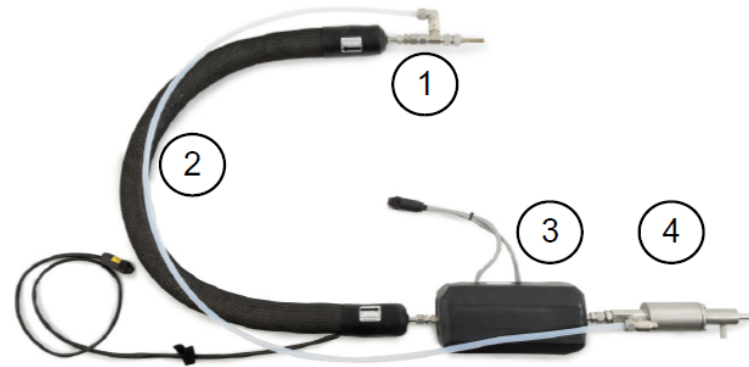
HT-ELPI®+

## Dekati® Sample Conditioning Set-up for Standardized RDE Particle Number Measurement according EU Commission Regulations 2017/1151 and 2017/1154

The Dekati® sample conditioning set-up for standardized on-board measurements consists of

1. Sampling probe connected to the vehicle tailpipe, with an integrated primary (axial) diluter
2. Heated sampling line with temperature controller
3. Catalytic stripper as volatile particle remover (VPR)
4. Dekati® Diluter as the secondary (ejector) diluter

The secondary diluter used in this setup is the widely used and robust Dekati® Diluter with stainless steel construction. The diluter exhaust from the system can be fed directly into a particle number counter or other particle measurement instrument for detection. This set-up requires power for the heated sampling line and the VPR, and pressurised dilution air for dilution. As such, no air heater is required, making the set-up ideal for on-board measurements.



# Volatile particle remover

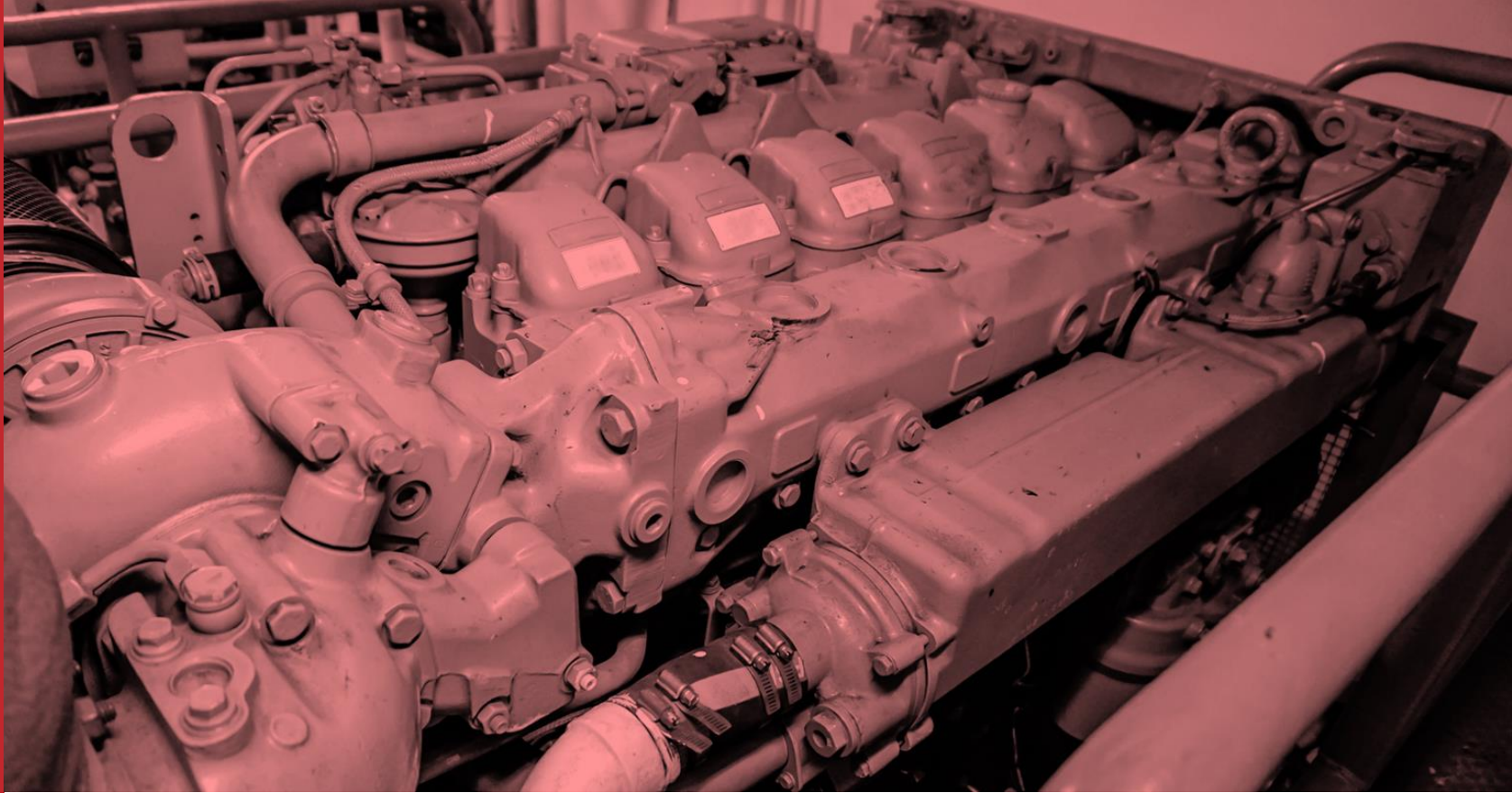
- UN/ECE R83 & R49, ISO 8178 (PN determination)
  - eDiluter™ Pro
  - Dekati® Engine Exhaust Diluter DEED



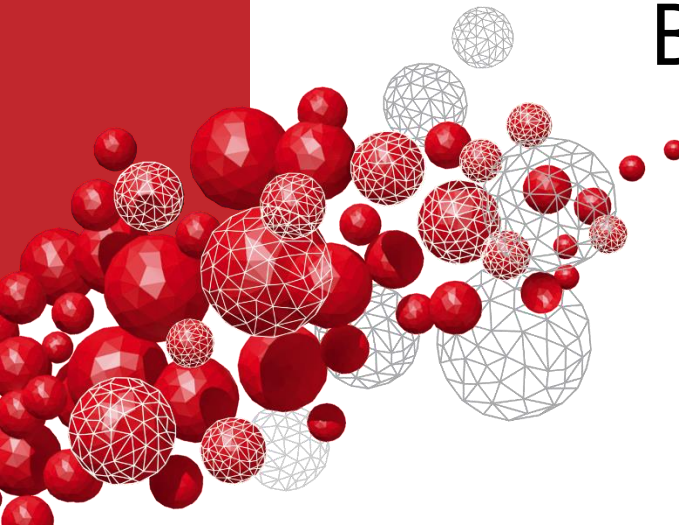
eDiluter™ Pro



DEED



## Blow-by Gas Emissions



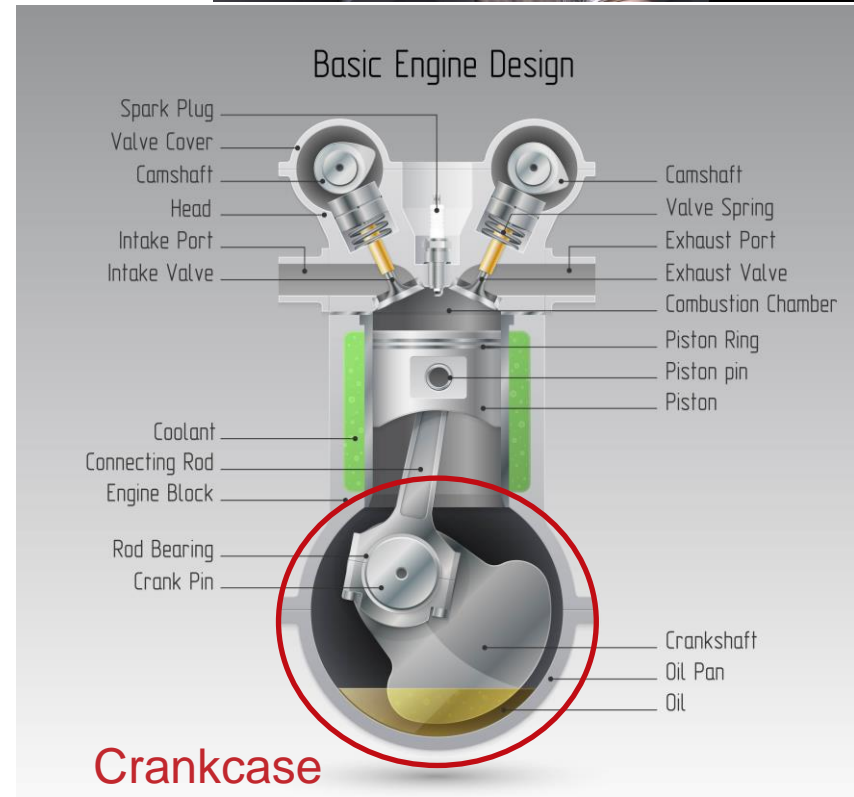
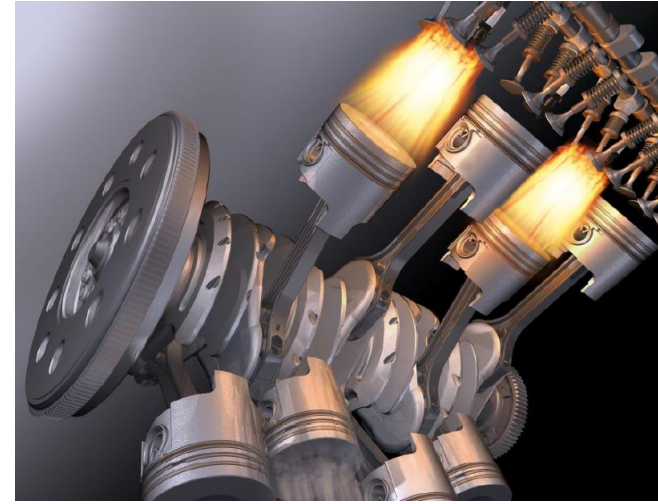
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# What is blow-by gas?

- Formed when gases from the combustion chamber partially leak past the piston rings into the crankcase.
- Mainly oil droplets after combining with the oil vapor in the crankcase
- Ventilation systems are used to
  - Lead the gas back to the engine air intake (closed crankcase ventilation, CCV)
  - or**
  - To the atmosphere through a filter (open crankcase ventilation, OCV)
- To avoid excess oil loss there is always a filter, impactor or cyclone in the breather tube





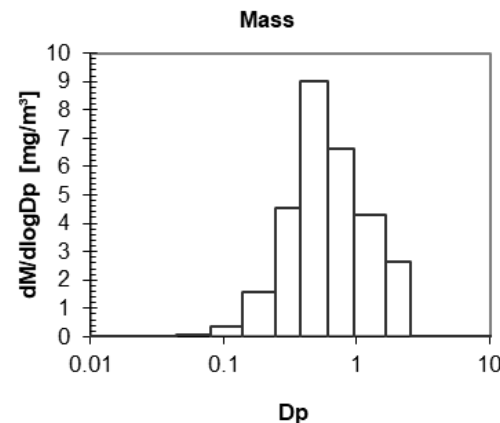
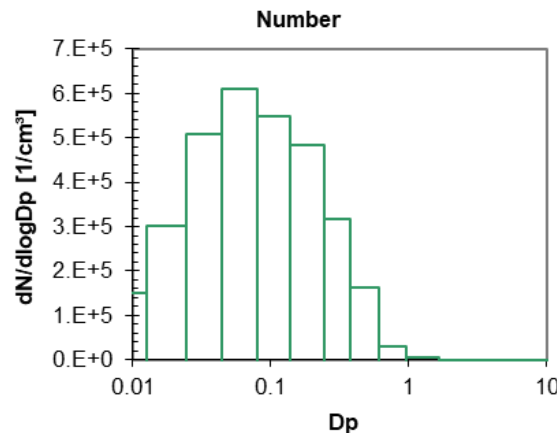
# Blow-by gas properties

- Oil droplets, wide particle size range
- High concentration (milligrams / m<sup>3</sup>)
- High temperature (~80 - 100°C)
- Slightly elevated pressure
- Wide concentration range (measurements before and after filtration)
- **Perfect application for High Temperature ELPI<sup>®</sup>+ with sintered collection plates!**

Blow-by is a mixture of several distinct components. Some are gaseous, some are liquid, and some are particulate matter. Most of the components of blow-by are:

- Oil Aerosol Particles; 0.1 to 10+  $\mu\text{m}$
- Soot Particles; 0.3 to 0.5  $\mu\text{m}$
- Gasses; CO, CO<sub>2</sub>, NO<sub>x</sub>, O<sub>2</sub>, H<sub>2</sub>O
- Gaseous Hydro-Carbons (HC)
- Water Vapor (H<sub>2</sub>O)
- Aldehydes

Source: Parker.com



ELPI<sup>®</sup>+ data, blow-by measurements



# ISO 17536-1

## Road vehicles — Aerosol separator performance test for internal combustion engines

- By working group ISO/TC 22/SC 34/WG 11, *Filtration performance of closed crankcase ventilation systems*
- “Recommended particle counters are optical particle counters (in accordance with ISO 21501-1) or **other counters demonstrating good correlation in measuring particle sizes such as aerodynamic particle counters.**”
- “The airborne particle counter shall be capable of counting particles in the 0,35  $\mu\text{m}$  to 55  $\mu\text{m}$  optical size range and **0,5  $\mu\text{m}$  to 10,0  $\mu\text{m}$  aerodynamic size range.... Most laboratories currently use optical particle counters, however the technical advantages of using aerodynamic particle counters is also well recognized.**”

### HT-ELPI<sup>®</sup>+ instrument has major benefits

- Aerodynamic sizing
- Capability to measure down to much smaller particle sizes compared to optical instruments
- Can measure directly from high sample temperature





# Blow-by emission measurement setup

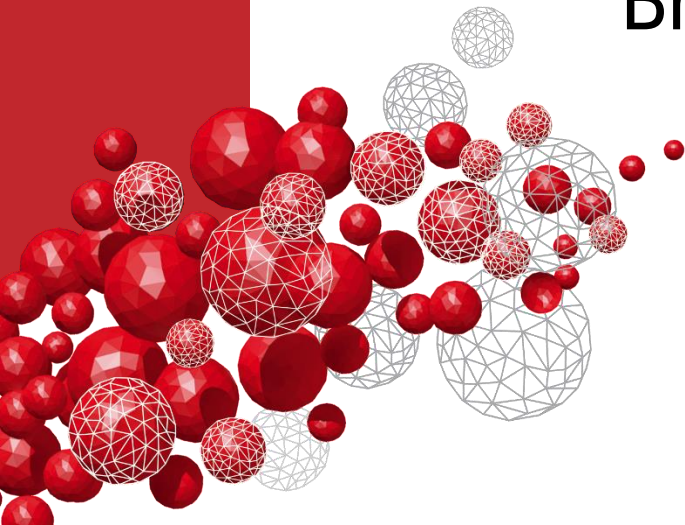
- HR-HT-ELPI<sup>®</sup>+ with one heated Dekati<sup>®</sup> Diluter (DI-1000)
  - Customers prefer to keep the sample temperature at ~80 °C
  - Sintered plates







## Brake Wear Emissions



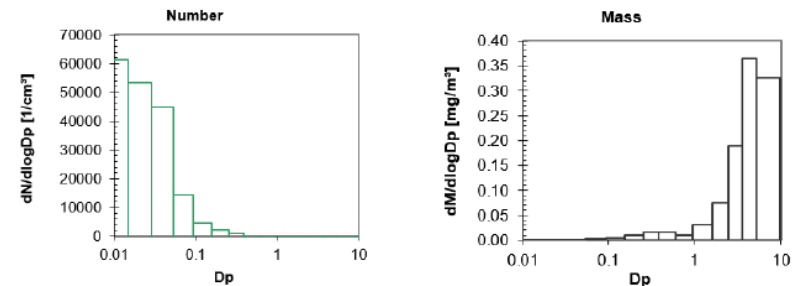
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# Brake Wear Measurements

- First emission regulations are being prepared
  - Brake wear emission PM correspond to ~10 times tailpipe emission PM
- Complex process with multiple variables
  - Materials, test conditions, aging of brakes etc.
- Dekati ELPI<sup>®</sup>+ instrument family is ideal for these measurements
  - Wide size range with single operation principle
  - Real time measurement
  - Possibility to analyze volatility
  - Possibility to collect samples with analysis plates



Particle number size (left) and mass size (right) distribution of brake wear emission measurements using ELPI<sup>®</sup>+

# Brake Wear Measurements: Example setup & Data

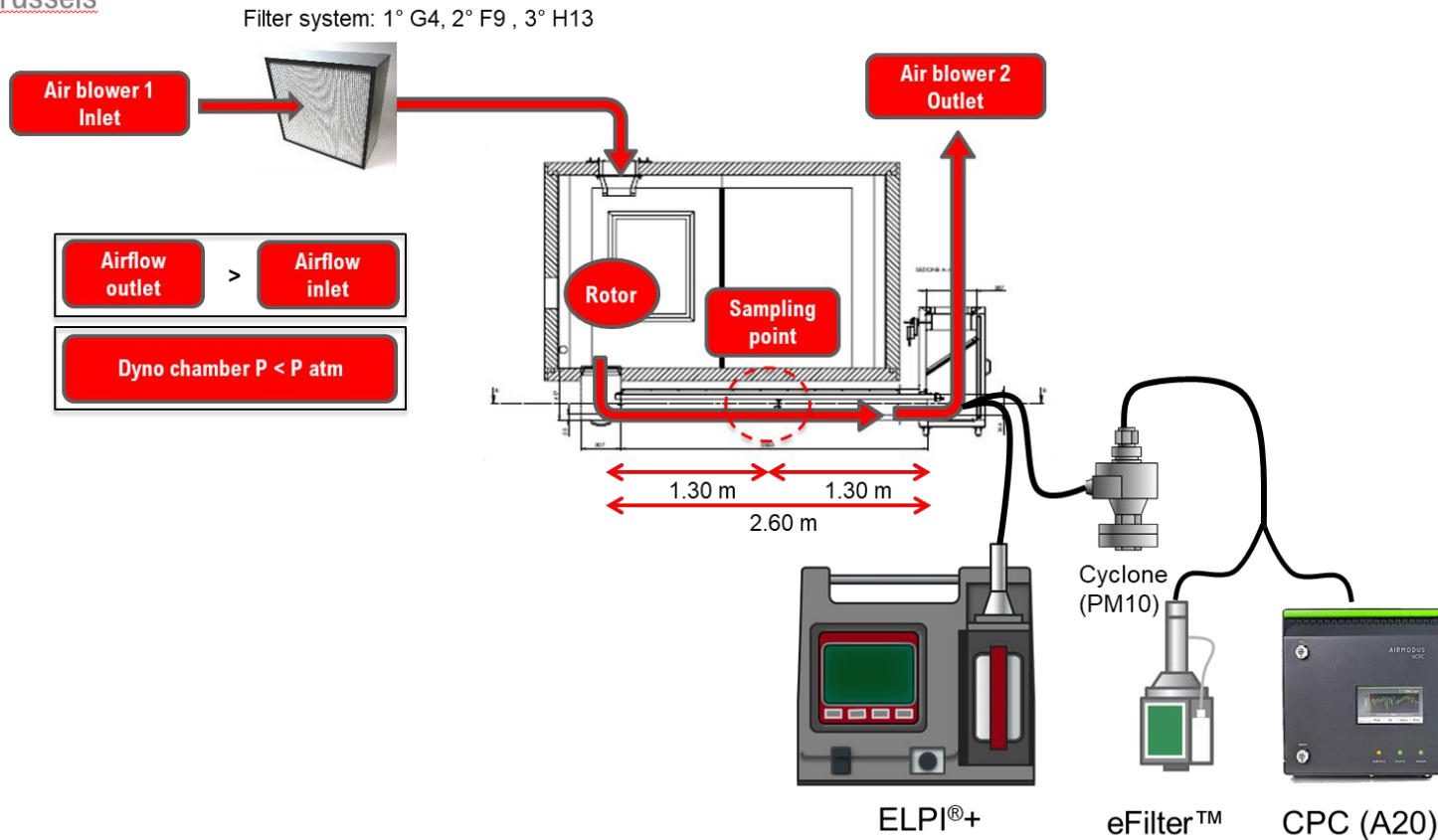
*Preliminary Results for Brake Wear Particle Emission PN and PM Concentration and Size Distribution Measurements*

M. Moisio, O. Vainio Dekati Ltd., A. Sin, S. Ansaloni, ITT, J. Vanhanen, Airmodus Ltd.

50<sup>th</sup> PMP meeting 3-4 April 2019  
Brussels



AIRMODUS







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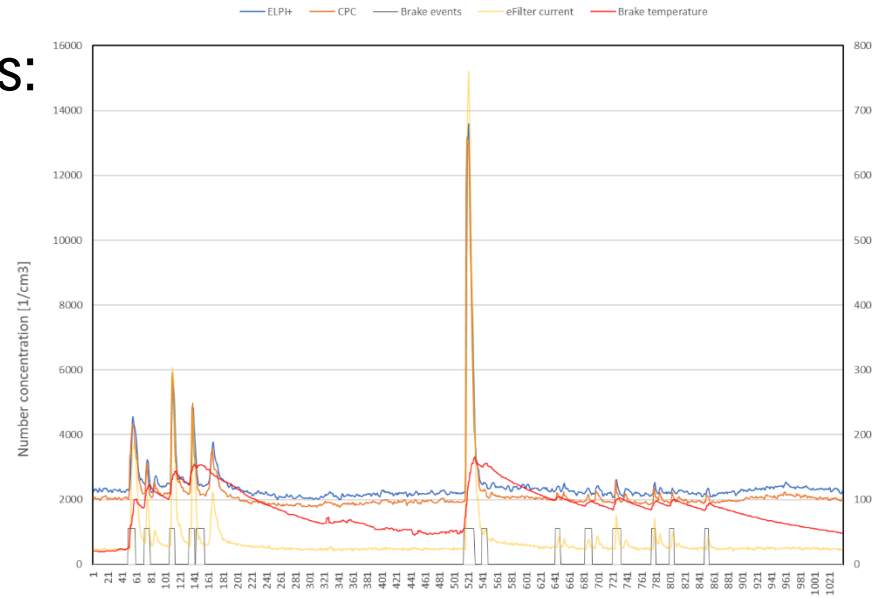
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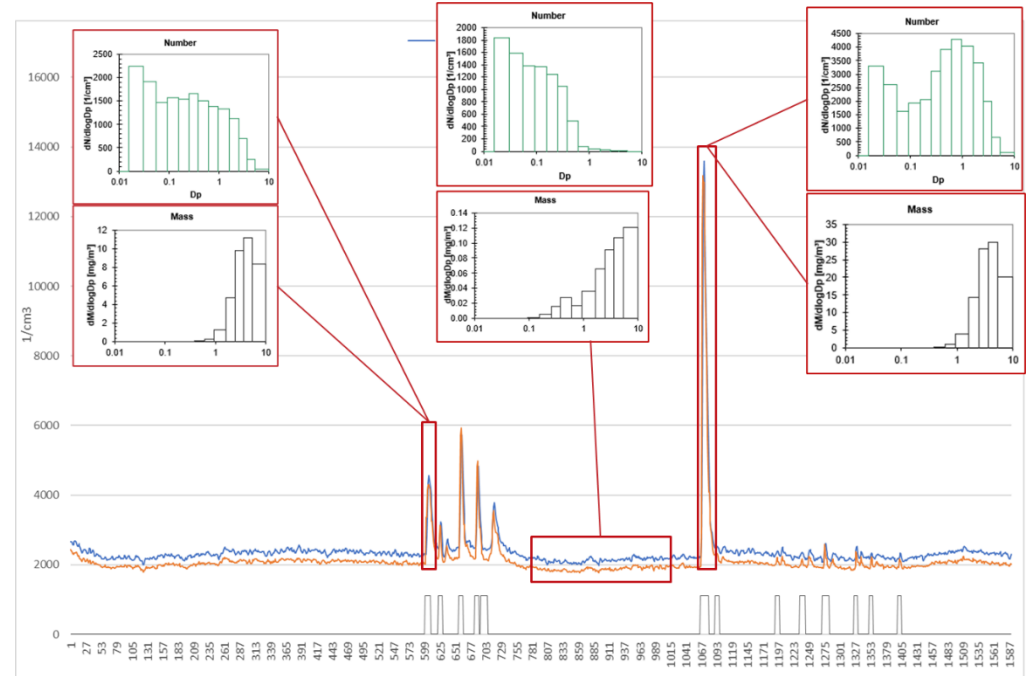
50<sup>th</sup> PMP meeting 3-4 April 2019  
Brussels



AIRMODUS



PN Concentration, eFilter™, brake events and temperature

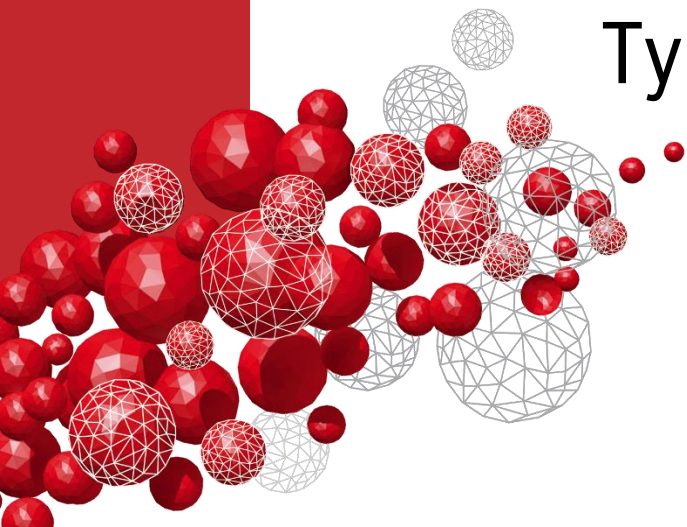


ELPH+ Size distributions





## Tyre Wear Emissions



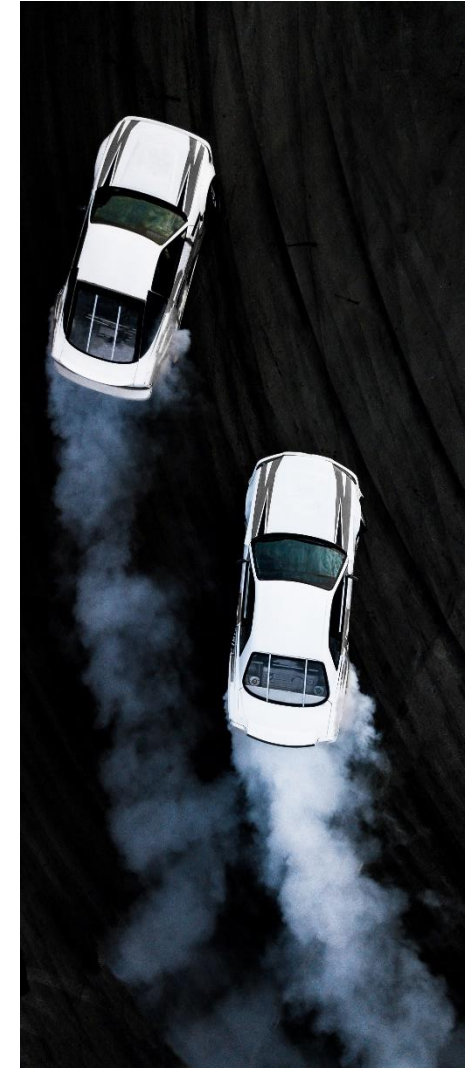
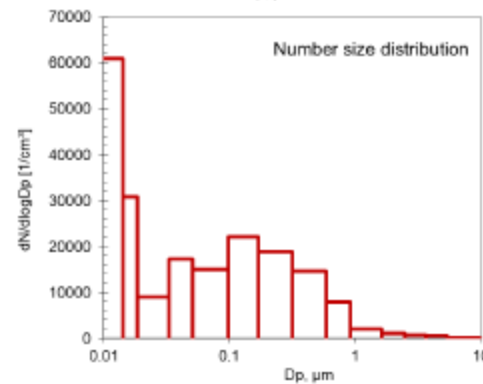
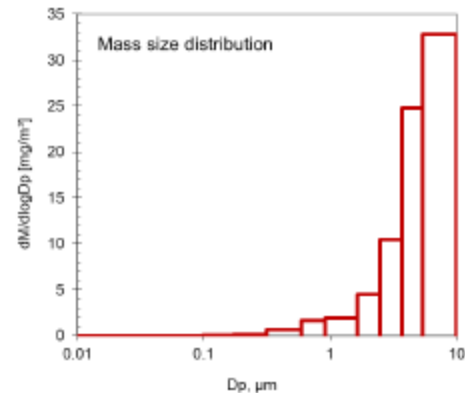
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# Tyre wear measurements

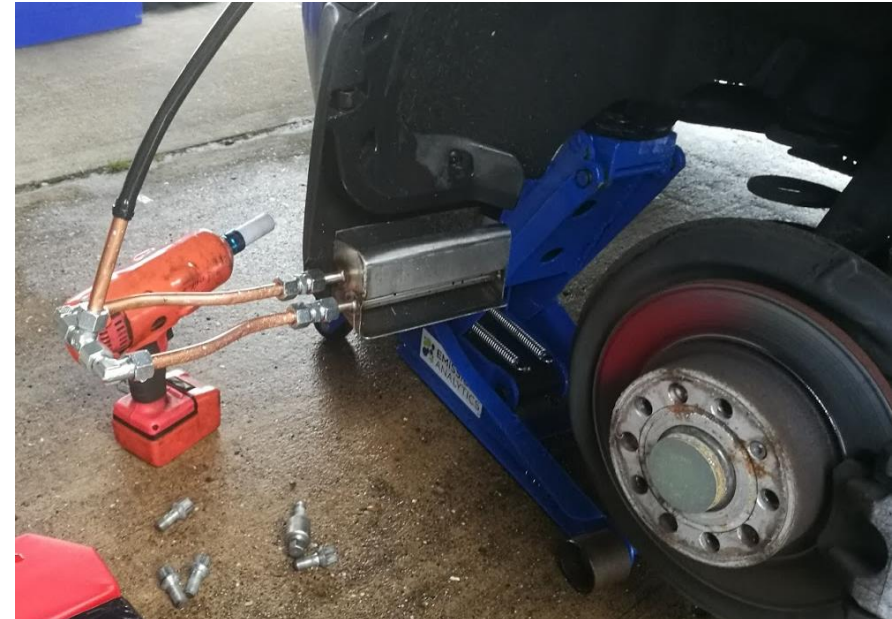
- Complex process with multiple variables
  - Tire material
  - Wear dust
  - Drive cycle and cornering aggressiveness
  - Road surface
- HR-ELPI<sup>®</sup>+ ideal for this application
  - Wide size range with single operation principle
  - Real time measurement
  - Possibility to do both test cell and on-board measurements
  - Possibility to collect samples with analysis plates





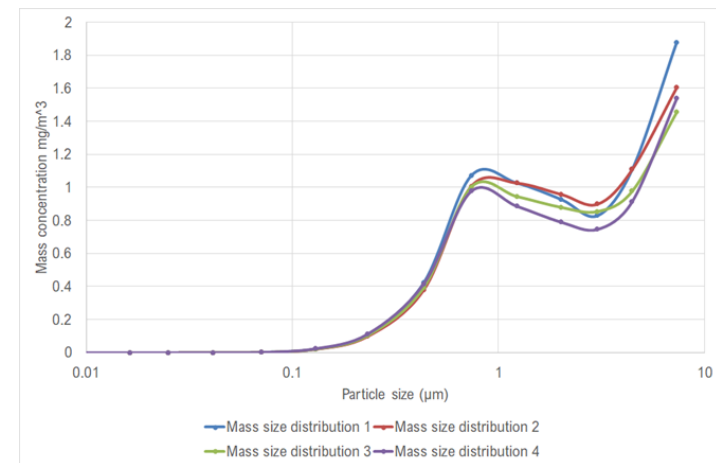
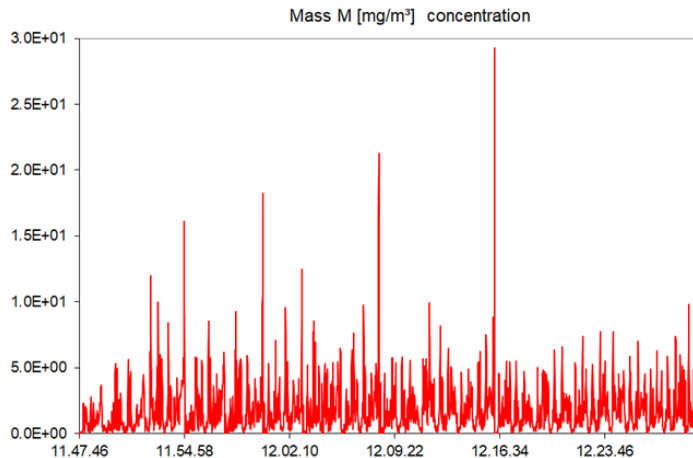
# On-board testing - is it feasible?

- With ELPI<sup>®</sup>+ - YES! Even with light duty vehicles and Sogevac SV25 pump
  - Would be easier with dry scroll pump (e.g. Edwards)
  - VW Golf passenger vehicle loaded up to 90% capacity with batteries, inverter and weights
- Direct measurement, no dilution needed, PM10 cyclone recommended



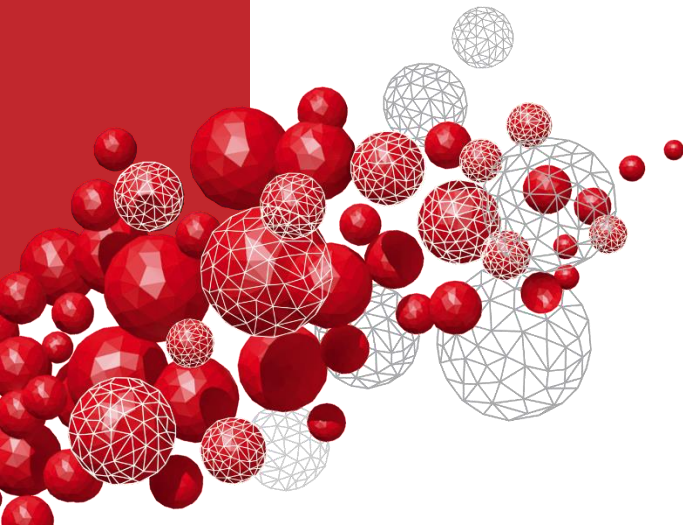
# On-board testing - is it feasible?

- Car driven by professional drivers on a closed track with the aim to cause as much tread wear as possible - two 50-minute runs ~10 laps
- Tyres weighed before and after each run
  - Weight loss 5.8 grams per km - much higher than expected
  - New data suggests that even premium tyres emit significant amount also during "peaceful" driving and especially during cornering
- Extremely repeatable data from ELPI®+
  - Unfortunately no vehicle data in this feasibility test





Thank you!



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