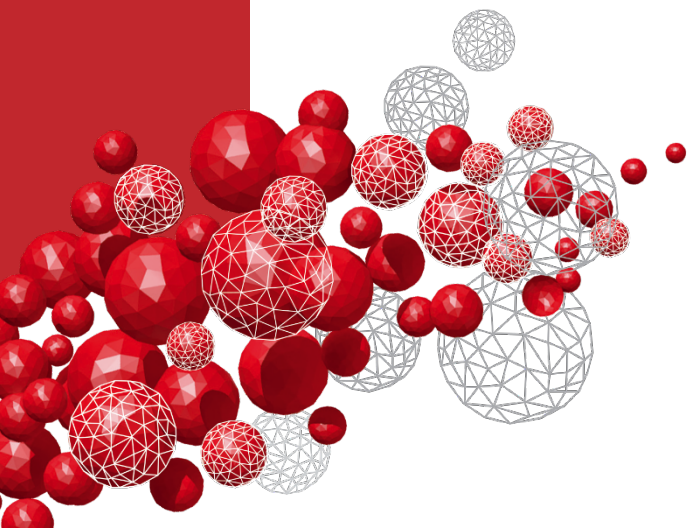
Brake emission measurement -what we can mesure?

Dekati Ltd



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Introduction

- “Road transport is one of the most important sources of urban pollutant emissions”
- “Given the more stringent legislation foreseen for exhaust emissions, brake and tyre emissions have been estimated to become the main contributor to PM road transport sector emissions”
  - Brakes = 10x tailpipe emissions
- “At present, airborne PM generated from different brake systems is currently not regulated *mainly owing to the lack of a standardized sampling procedure and measurement techniques.”*

Towards the ranking of airborne particle emissions from car brakes – a system approach. Perricone et al. Proc IMechE Part D: J Automobile Engineering 1–17, 2016

PMP – Particle Measurement Program
UNECE Informal Group Non-exhaust particle emissions

- PMP group is working on the development of a suggested common test procedure for sampling and assessing brake wear particles:
  - The selection/development of a braking test cycle appropriate for the investigation of particle emissions from brake wear
  - selection of an appropriate methodology for particles generation and sampling
  - selection of the appropriate instrumentation for the measurement and characterization of brake wear particles

- JRC has established a Task Force focusing on the particle measurement related aspects comprising the experts in this specific field

What can we measure?

What we would like to measure?

What we should measure?

Why we are measuring?

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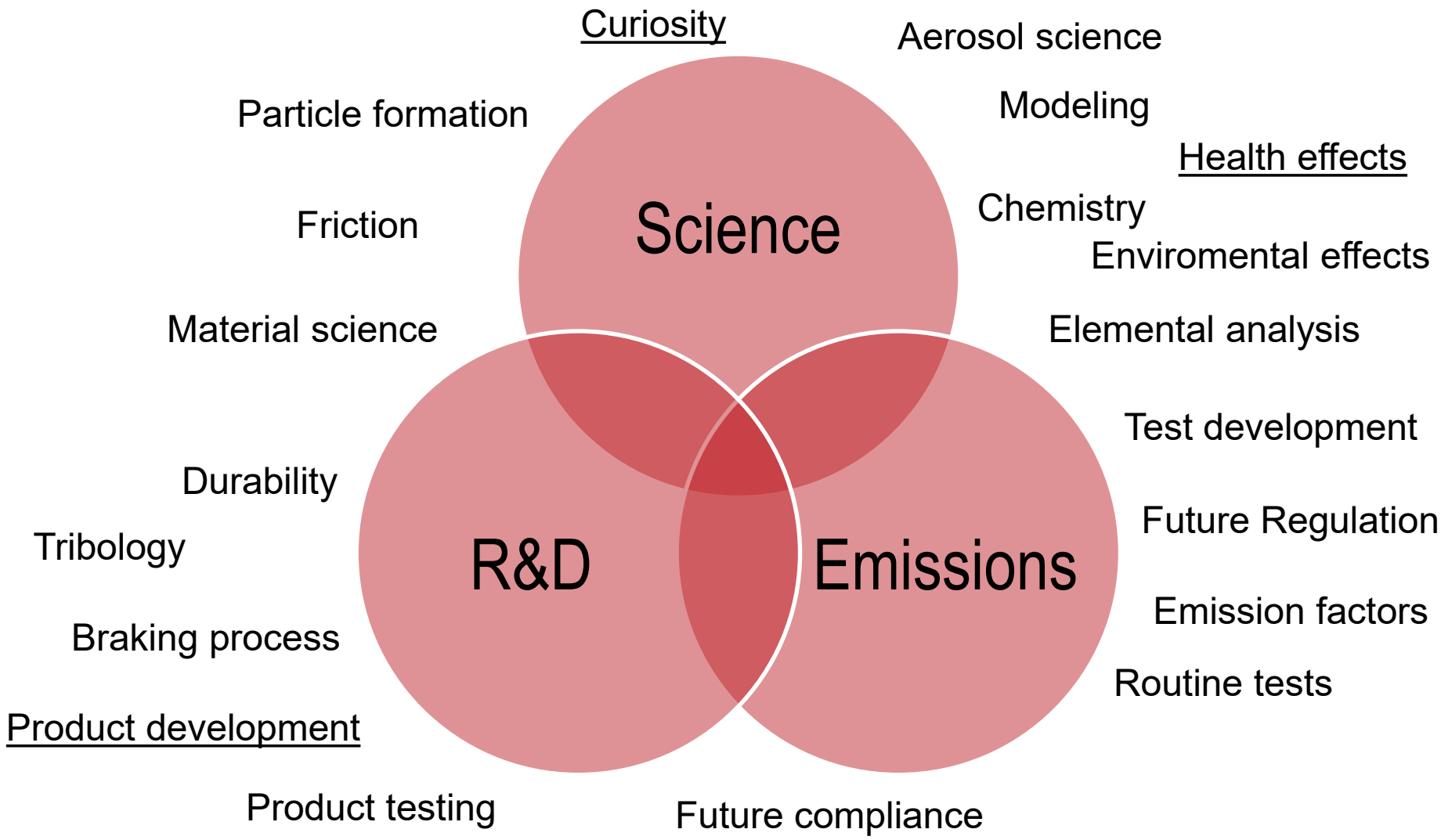
Why? Oh Why?



Why?

- There are multiple good reasons/needs
- We need harmonisation
- We cannot accommodate all needs
- We should think as extensively as possible

  (but only as much as is needed)

What can we measure?

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What we can?

- Estimate, measure and model the losses and representativeness of sampling
- Minimize losses from 10 nm to 10 um
- Measure total number (PN) in real time
- Measure total cumulative mass (PM10/PM2.5/PM1)
- Measure number size distribution 10 nm to 10 um in real time
- Measure mass size distribution from 10 nm to 10 um
- Collect particles for analysis (size fractionated)
- Measure density of particles as function of particle size
- Measure volatile particles (within limits)

What we cannot (or is too impractical)

- Measure above 10-15 um
- Measure/handle all volatiles accurately
- Measure all particles below 10 nm -> nucleation mode
- Measure mass size distribution in real time
- Avoid losses completely
- Simulate the real world emission conditions

What should we measure?

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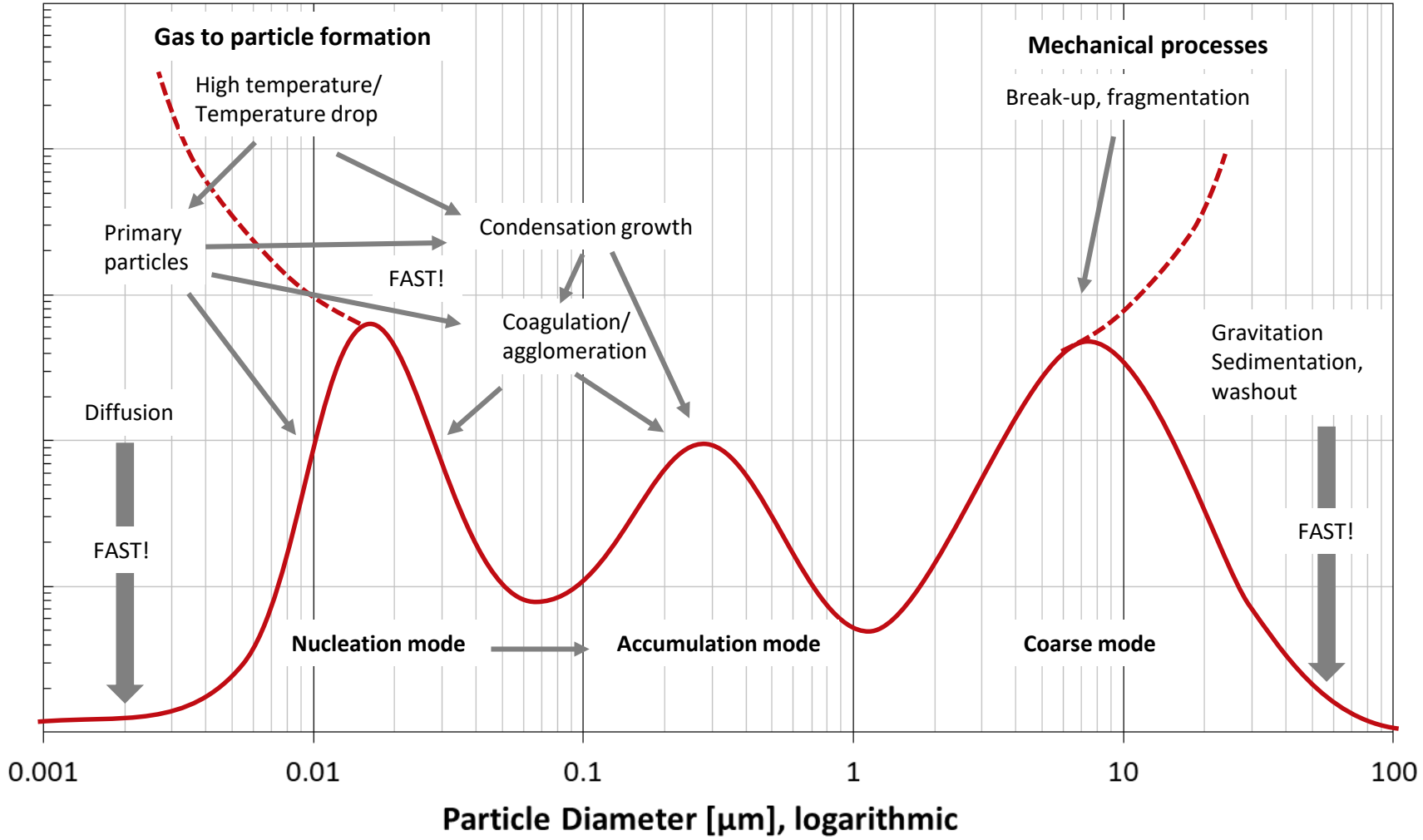
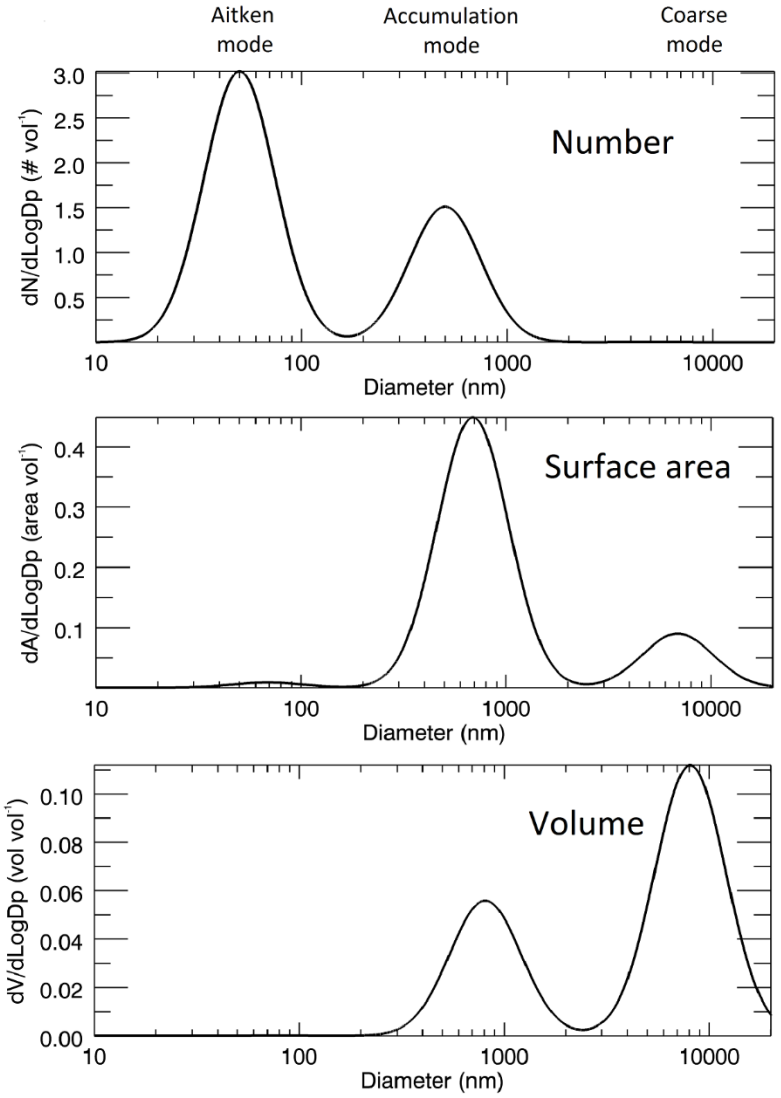
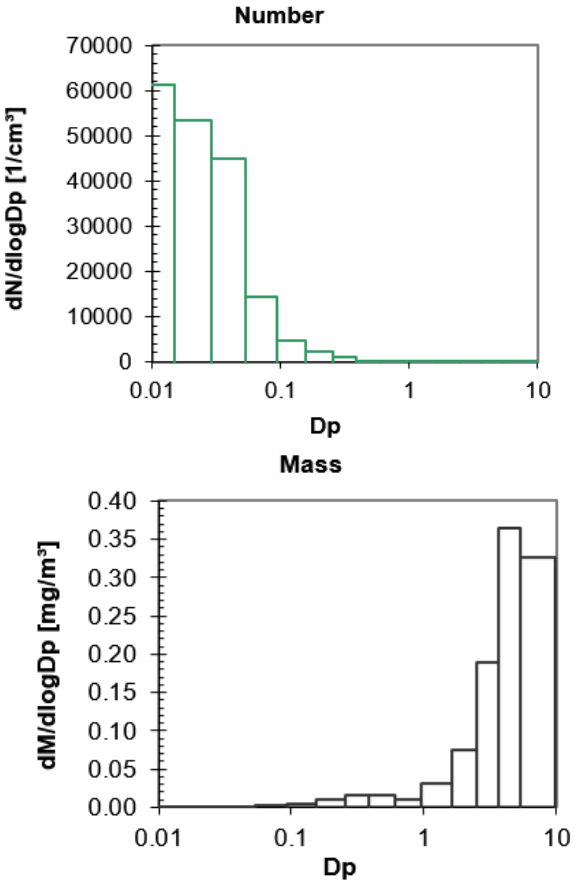
Aerosol Physics: particle formation




Aitken mode
Accumulation mode
Coarse mode
Number
dN/dLogDp (# vol⁻¹)
Diameter (nm)
Surface area
dA/dLogDp (area vol⁻¹)
Diameter (nm)
Volume
dV/dLogDp (vol vol⁻¹)
Diameter (nm)


Number
dN/dlogDp [1/cm³]
Dp
Mass
dM/dlogDp [mg/m³]
Dp

What should we?

Questions	Notes
Size range of interest	
Above 10 um	Difficulties sampling (losses), environmental effects
Below 23 nm?	Difficulties sampling (losses), volatiles/nucleation
Size Distribution	Distribution vs. total
Measurand	
Particle Number (PN)	Dominated by ultrafines
Particle Mass (PM)	Dominated by coarse fraction
Surface area (LDSA)	Health effect related
Size definition	Aerodynamic or electrical mobility diameter?
Volatile fraction	Need to characterize? Sample conditioning
Time resolution	1 Hz? Actual time response of system?

What should we?

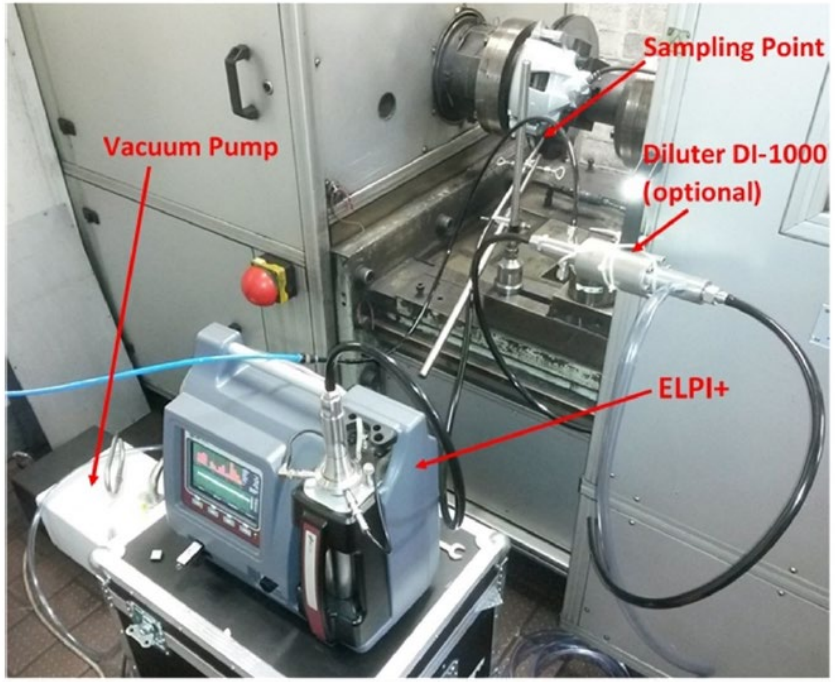
Questions	Notes
Size range of interest	
Diffusion	Flow rate vs. sampling line diameter
Inertial losses	Isokinetic sampling, length of sampling line
Thermophoretic/electric	Conductive measurement lines
Sample collection	
Full flow/partial	Flow control, sample extraction
Sample analysis	What analysis methods are used? Requirements
Dilution	Concentration range
Conditioning	Removal of the volatiles, thermodenuder?
Flow and enclosures	Physical construction, representativeness
Volume of sampling system	Time constant, memory effect

Beware: here be Dragons:

- Brake emission is not tailpipe emission
  - There are lot of coarse particles (by mass)
  - Nucleation mode has solid particles
- Underestimation of importance of isokinetics or diffusional losses
- PM10/PM2.5 = Aerodynamical diameter
- Electrical mobility to aerodynamical to optical particle size calculations or transformations (or between any different size definitions)
- Number size distribution to mass size distribution calculation
- Instrument calibrations which are dependent on particle properties or size distribution
- ”Black box” calculations
- Concept of volatiles is tricky
- Mass above 10 um is tricky too
- Nucleation mode PN is very tricky below 23 nm (accuracy and sharpness of cut-off or detection of instruments)

Existing setup for brake measurement

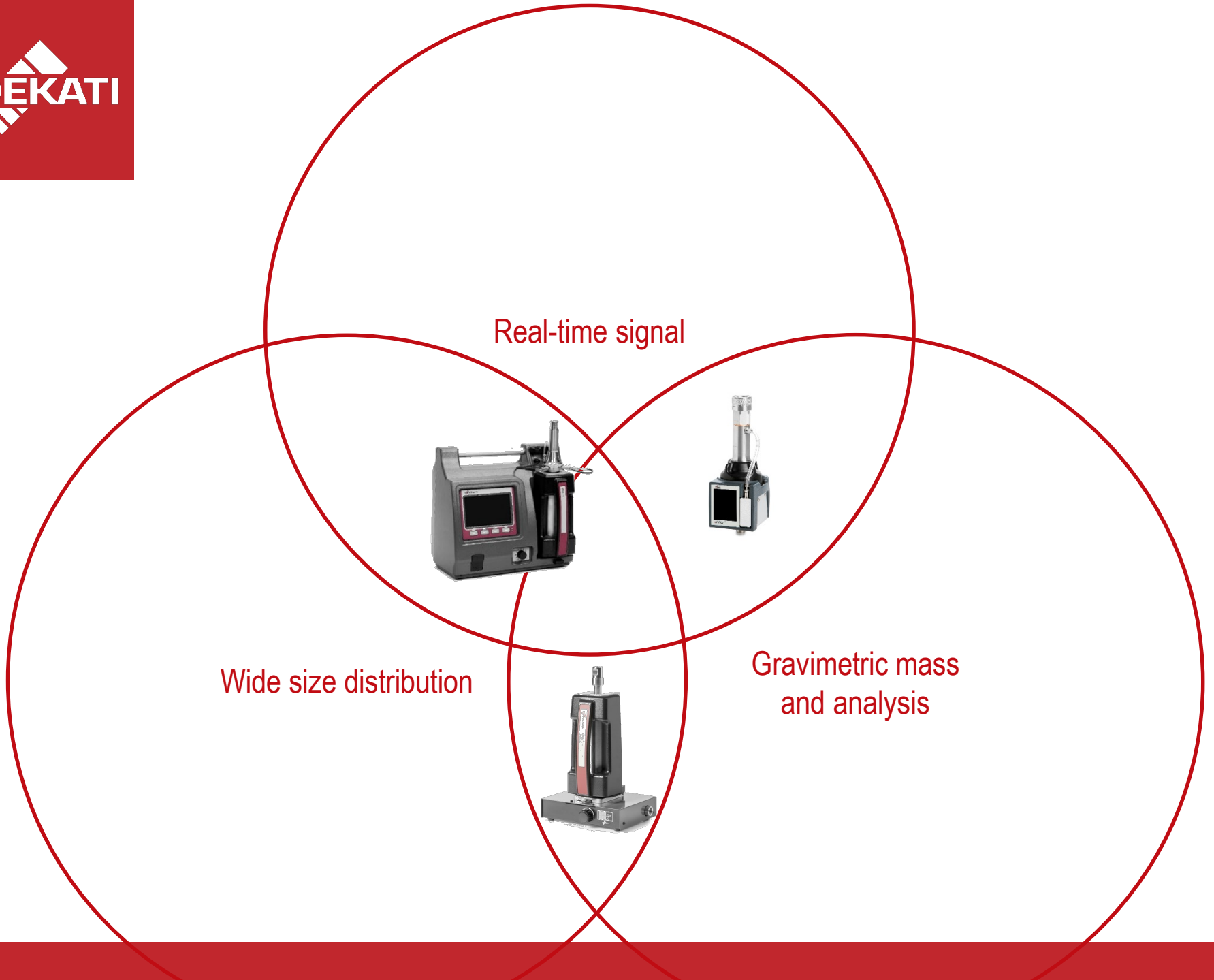
- ELPI+
  - High Resolution or High Temperature options
- DLPI
  - Gravimetric & analysis
- Dilution or conditioning
  - Optional dilution/thermodenuder
- eFilter
  - Total cumulative mass concentration, mass correlation together with ELPI+
  - Routine measurements (future)



Real time particle size and mass concentration measurement setup using ELPI®+ and optional Dekati® ejection Diluter (DI-1000)

Measurement solutions

- ELPI+ (HT/HR)
  - Real-time PN/LDSA/PM
  - Distribution
- DLPI+
  - Gravimetric mass
  - Distribution
  - Analysis
- eFilter
  - Real-time LDSA
  - Total mass


Real-time signal
Wide size distribution
Gravimetric mass
and analysis

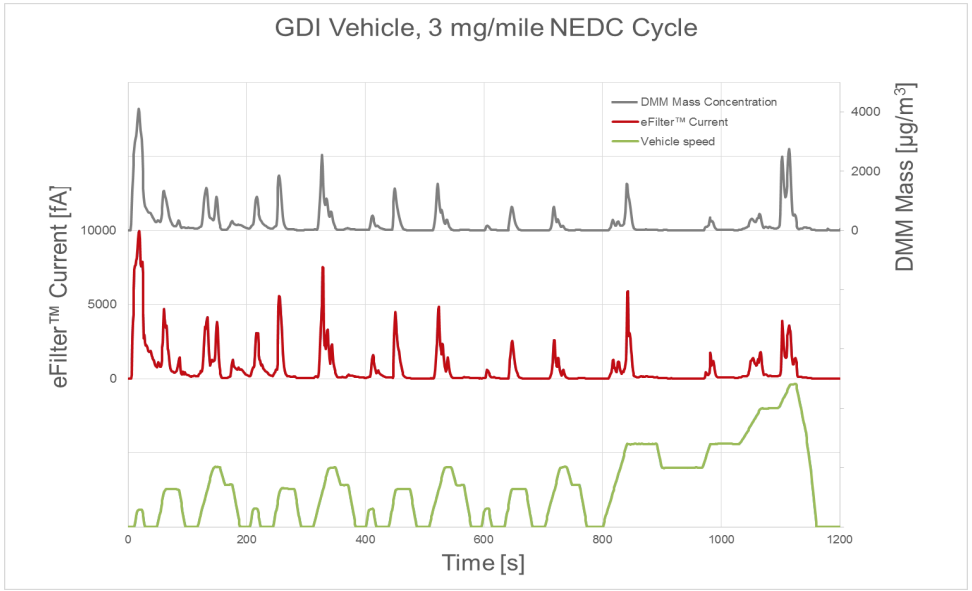
DLPI+ for gravimetric and analysis

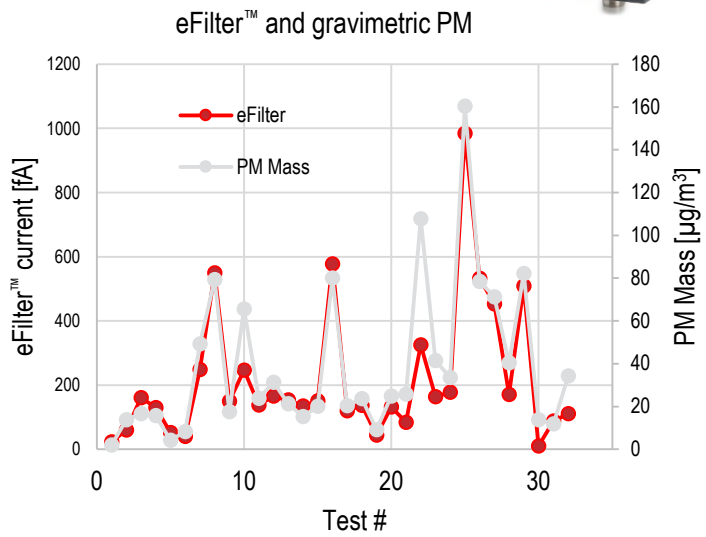
Particles in 14 size fractions can be analysed after the real-time measurement

- Cascade low-pressure impactor
- 14 size fractions
- 16 nm – 10 µm
- Ø25 mm
- No filter stage
- 10 lpm flow rate
- 40 mbar low pressure
- Max 50 °C
- Can be upgraded into an ELPI+™

eFilter™ mass comparison, diesel exhaust

- Standard gravimetric filter measurement
- Real-time signal throughout the filter sampling
- Real-time PM accumulation during different stages of the measurement



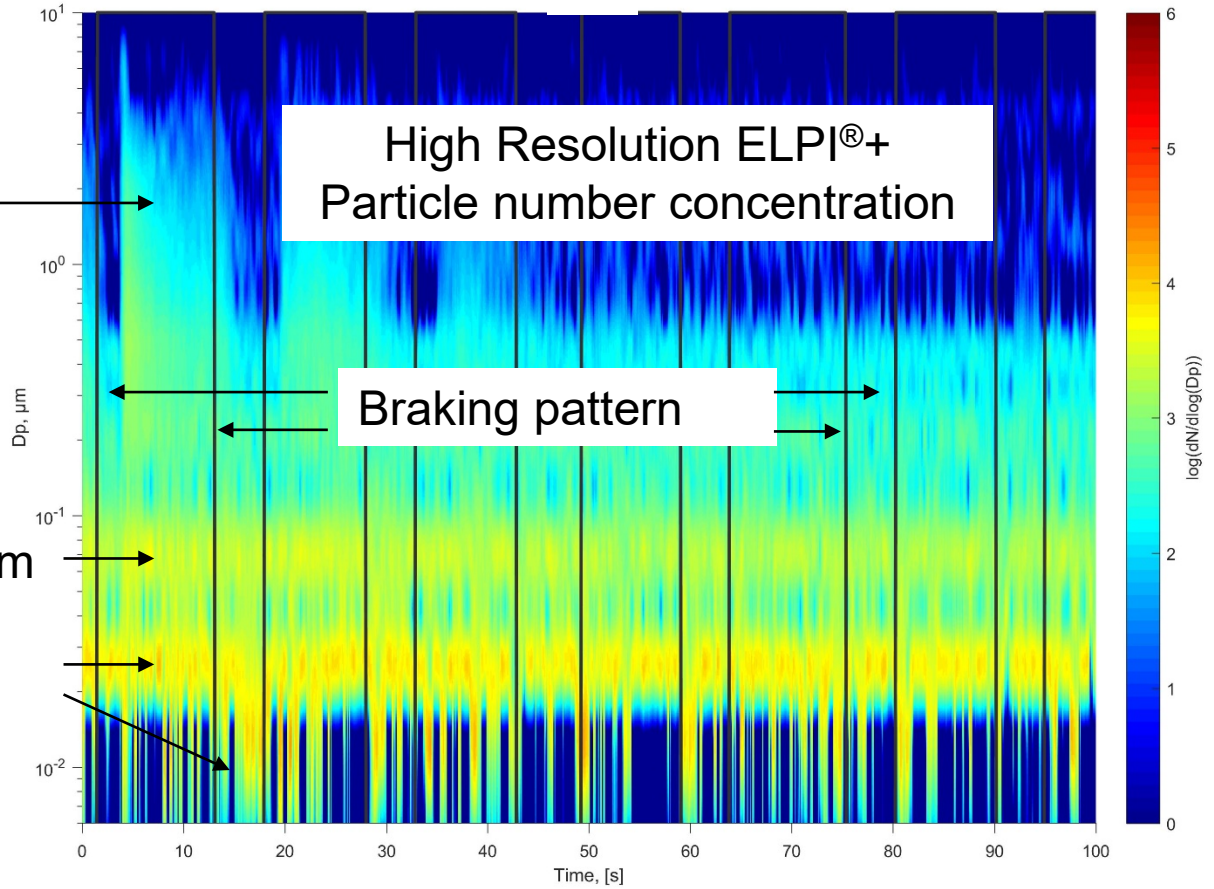


Niemelä et al. 26th CRC Real World Emissions Workshop
Data courtesy by Ford Motor Company

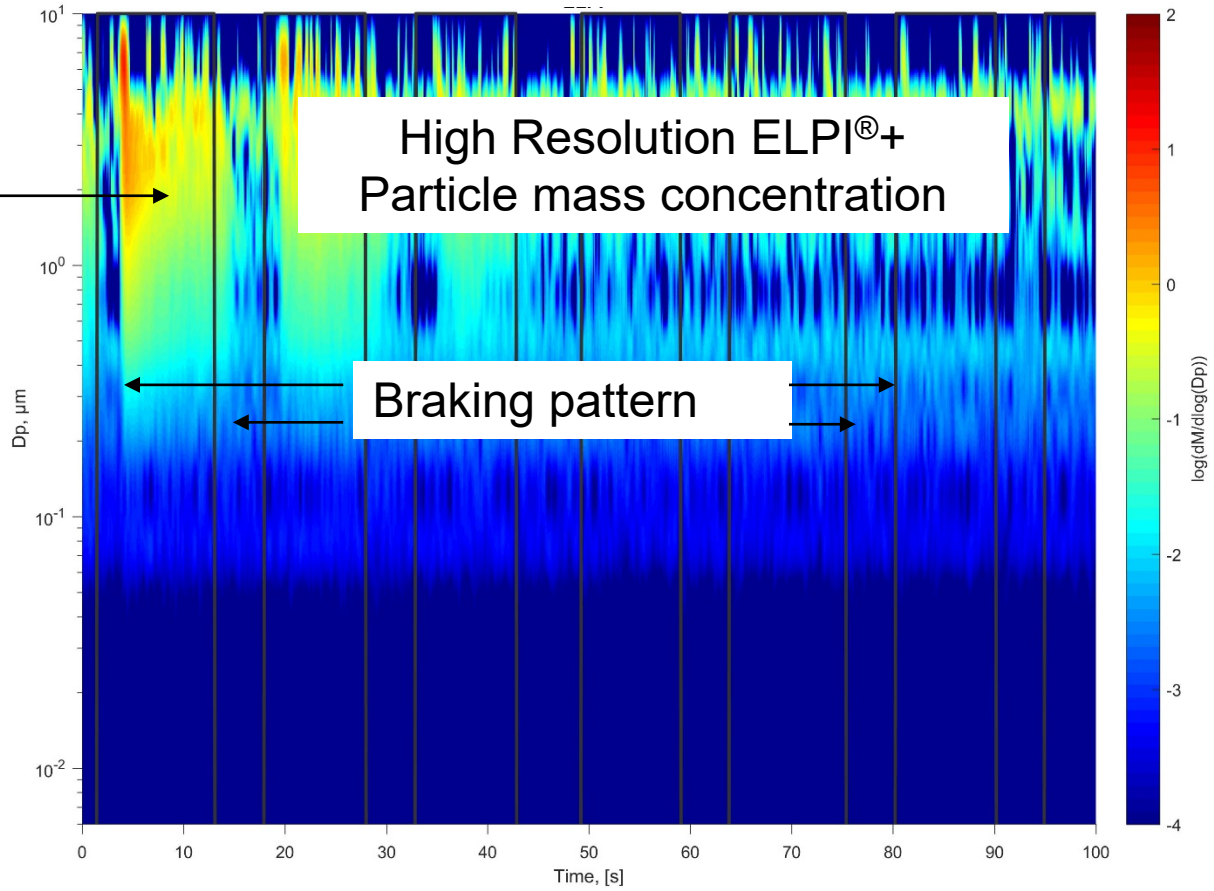
Brake Emission Measurements: Dekati® ELPI®+

Large particles >1µm
from brake wear

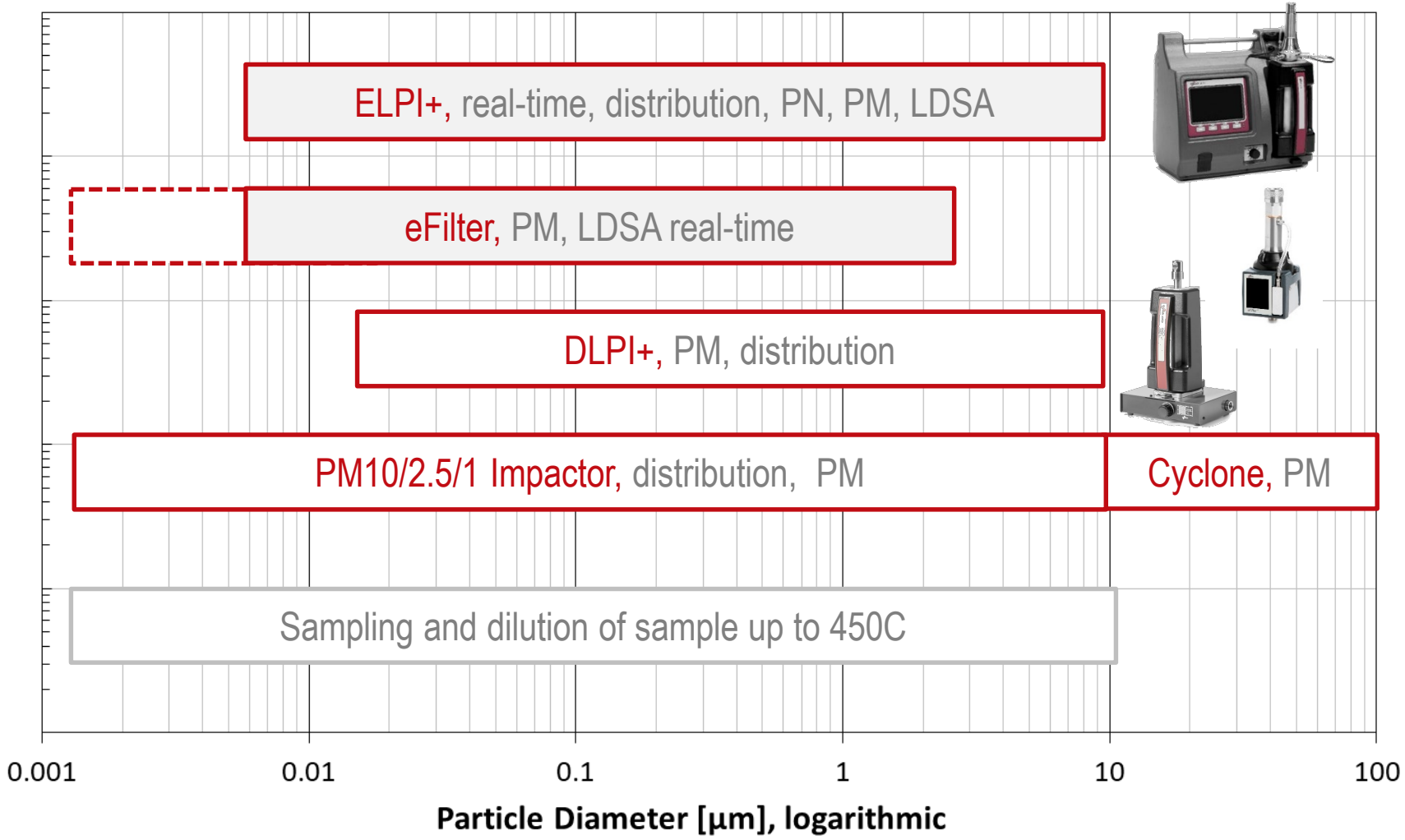
Small particles < 300nm
from brake wear



Large particles >1µm
from brake wear



Dekati measurement solutions




Thank you for your attention!
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