Brake wear particle emissions of a passenger car measured on a chassis dynamometer

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Agenda

- Vehicle measurement procedure
- Chassis Dynamometer measurements

LOW BRA SYS

- Grant agreement no. 636592
  www.lowbrasys.eu

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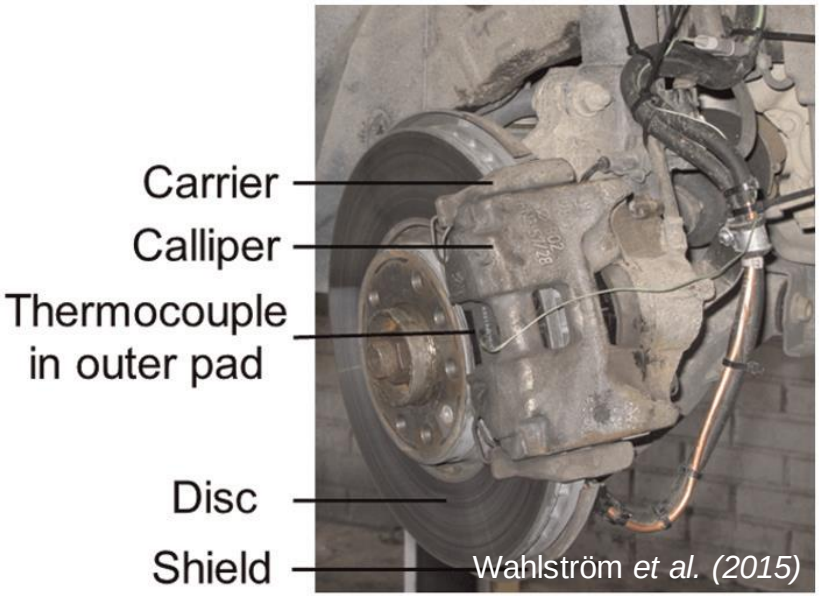
VEHICLE BASED BRAKE PARTICLE MEASUREMENT APPROACH – STATE OF THE ART

Sanders *et al. (2003)*

Mathissen *et al. (2011)*



Wahlström *et al. (2015)*

- Traditionally: Sampling inlet near particle source

Issues:

- Low Signal-to-Noise ratio.
- Contamination from other sources.
- Quantification difficult.

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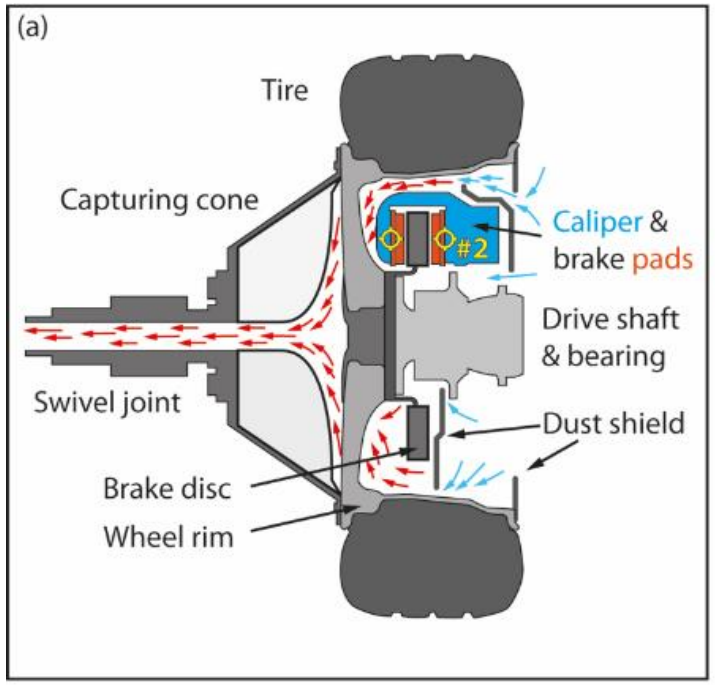
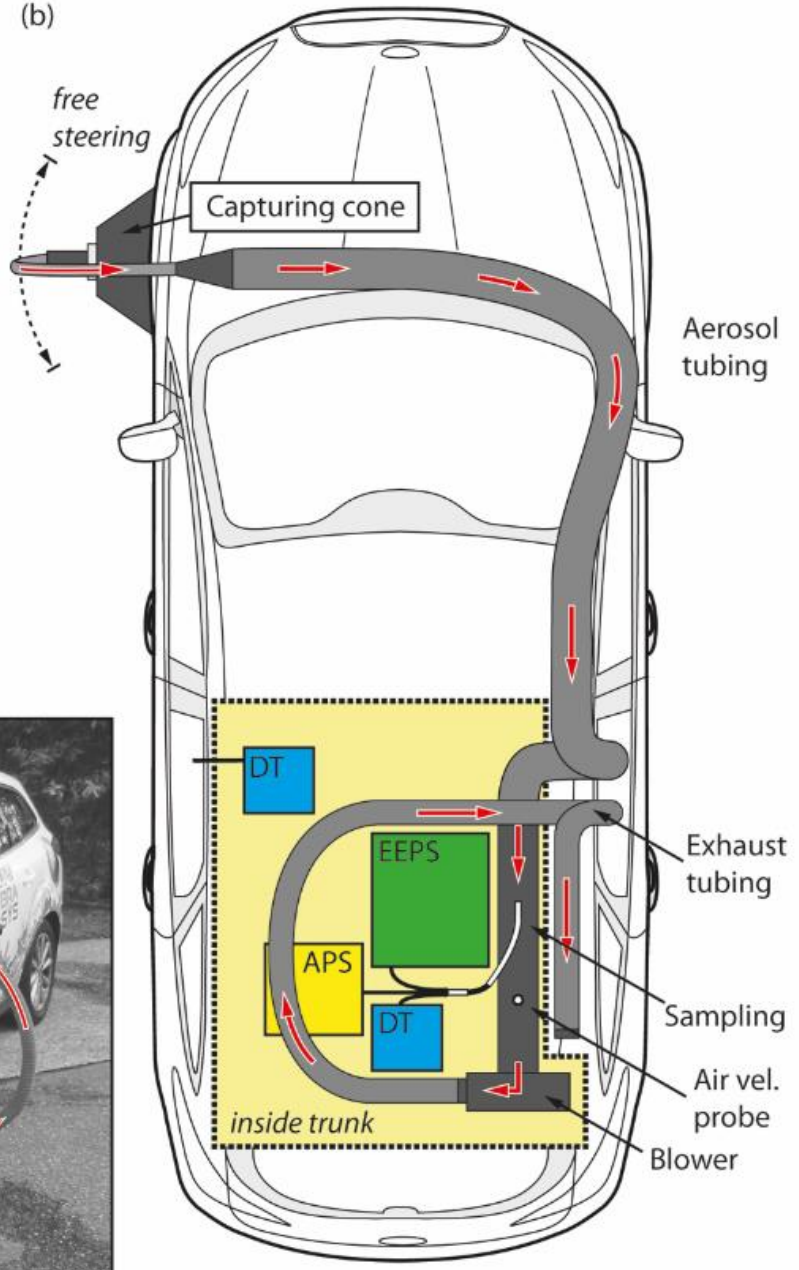
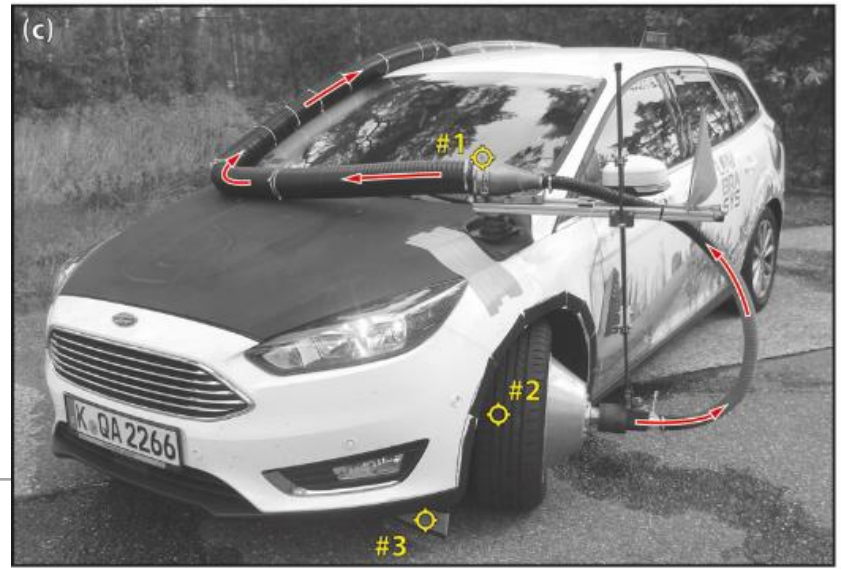
NEW MEASUREMENT APPROACH

- Semi-enclosed brake housing. Design optimized with CFD simulations.
- Constant volume flow approach
- Conserving natural air flow direction.
- Captures wheel induced particle losses
- Very good signal-to-noise ratio but artificially increased brake temperatures due to housing

Farwick zum Hagen *et al.*, On-road Driving Measurements of Brake Wear Particle Emissions, Atmos.Env., *2019*

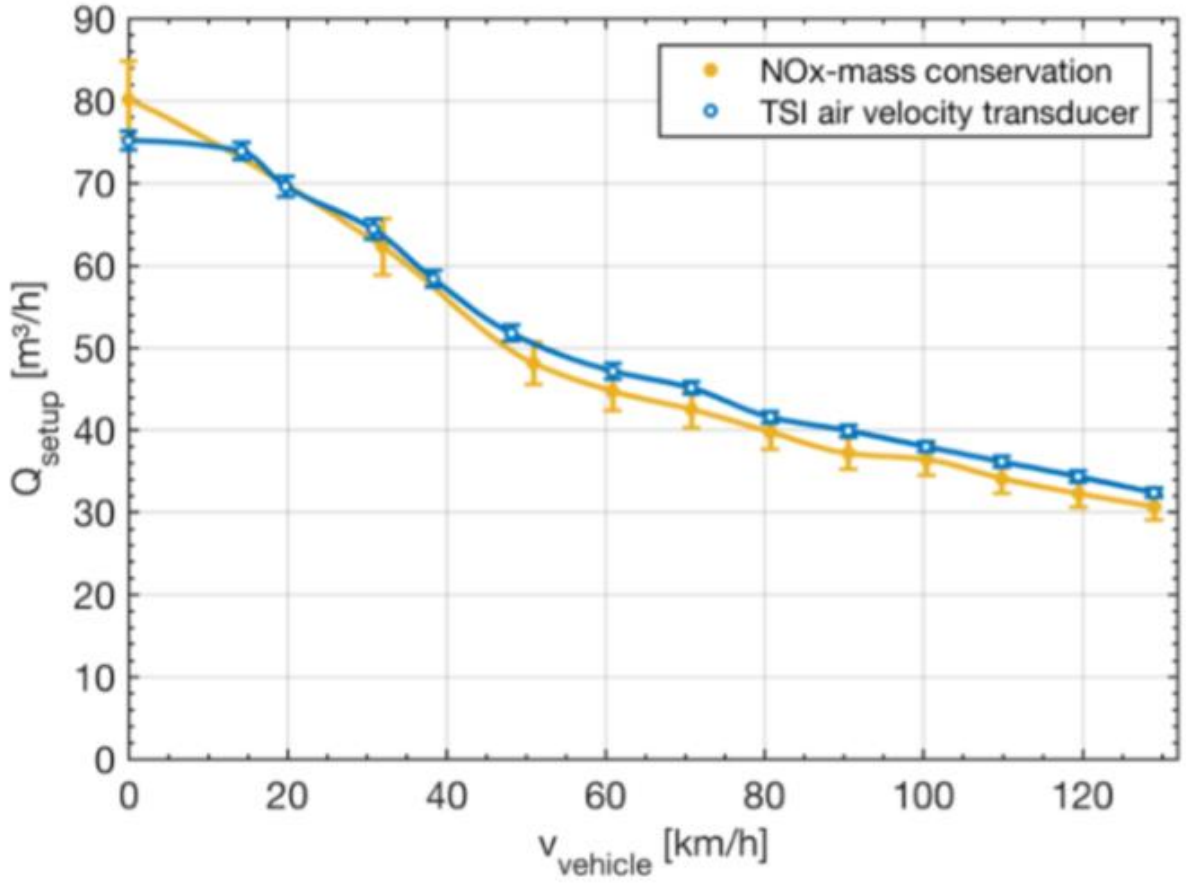






VEHICLE MEASUREMENT APPROACH – CONSTANT VOLUME SAMPLING?

- Setup flow is vehicle velocity dependent
- Decreasing flow rate with increasing speed
- More powerful blower needed to achieve CVS but power restrictions in the vehicle.



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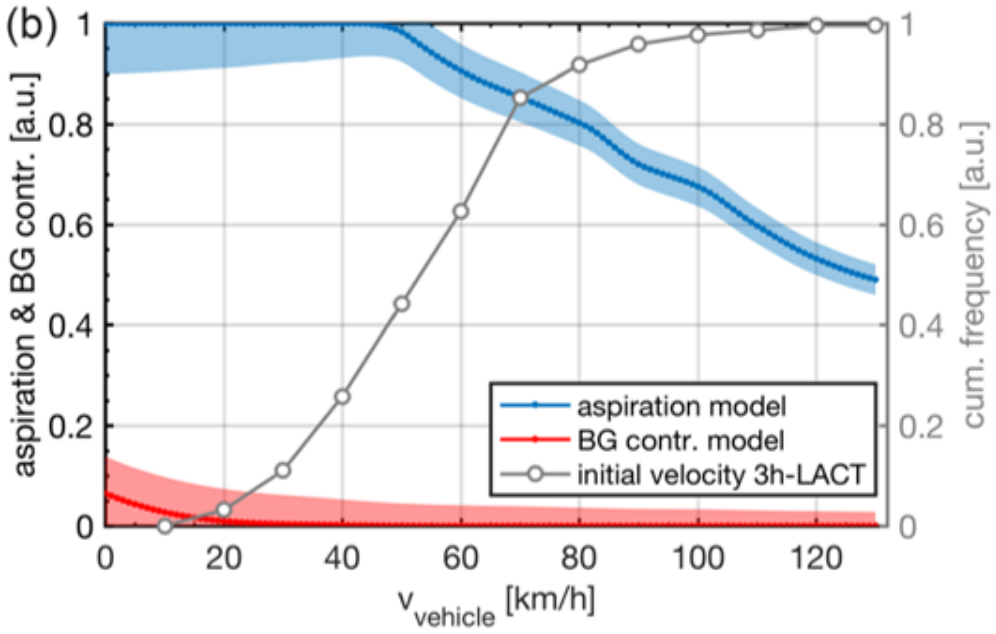
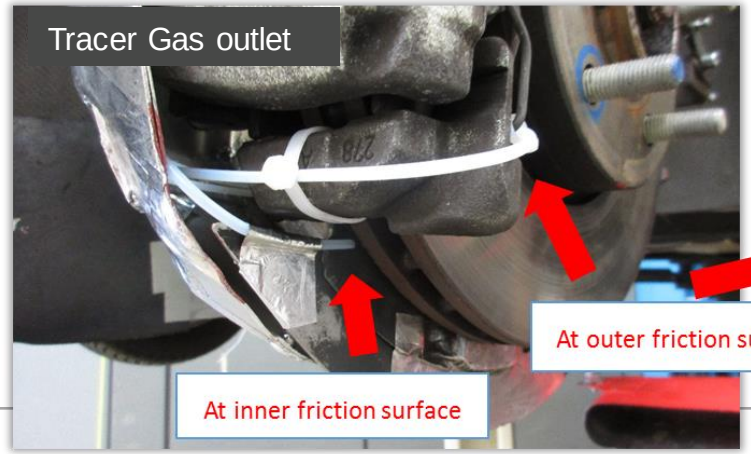
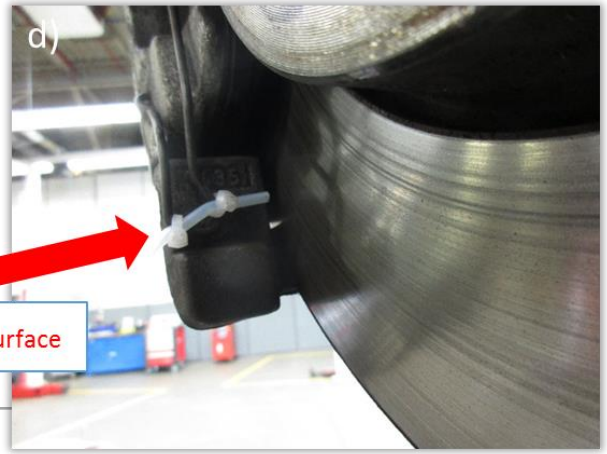
VEHICLE MEASUREMENT APPROACH – CHARACTERIZATION WITH TRACER GAS



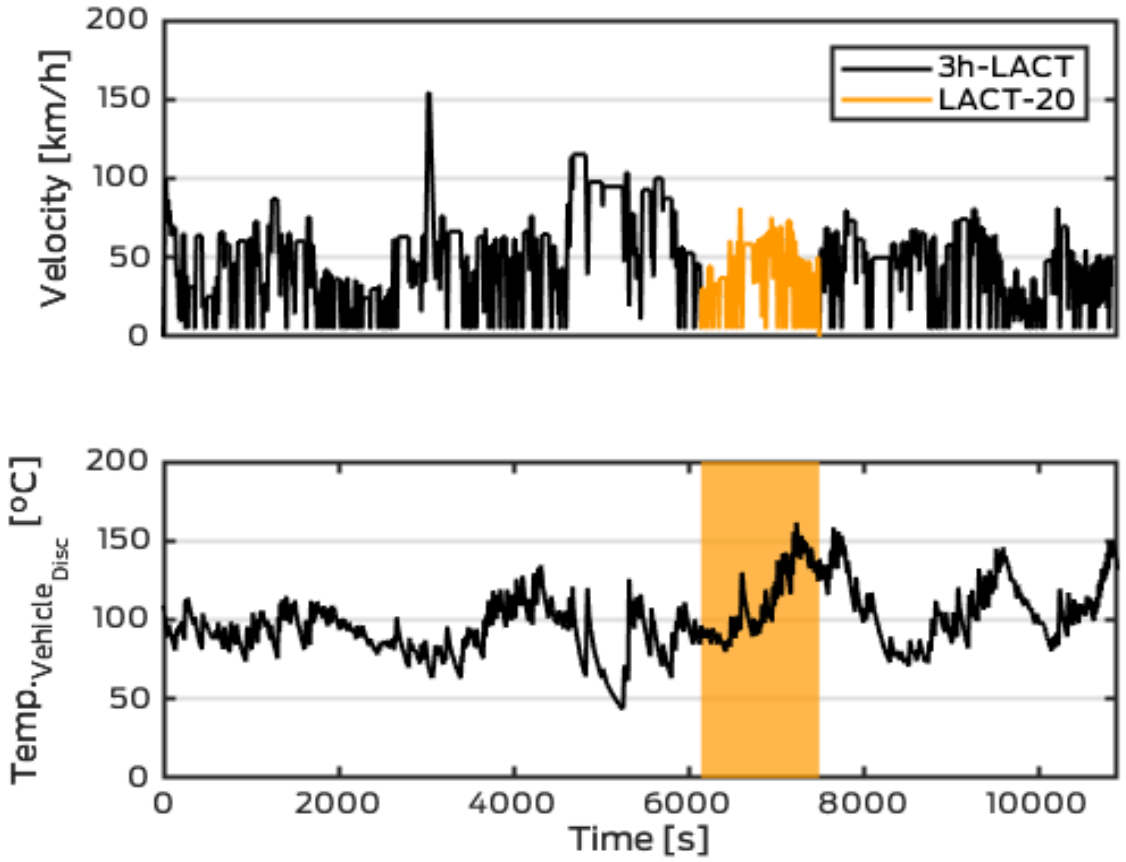
- In-depth tracer gas characterization campaign for measurement approach:
  - Aspiration efficiency of 93 % for 3h-LACT
  - Low contribution from particle sources near tire/road (<8% and no influence above 30 km/h)





LOWBRASYS BRAKE CYCLE

- 3h-Los Angeles City Traffic (3h-LACT)
- Developed as a first step towards a commonly accepted test procedure in Lowbrasys.
- 217 stops, decelerations up to 0.3 g
- A 20 minutes subset was used for vehicle repeatability measurements (LACT-20).



Mathissen & Evans, (2019), “Lowbrasys brake wear cycle - 3h LACT”, Mendeley Data

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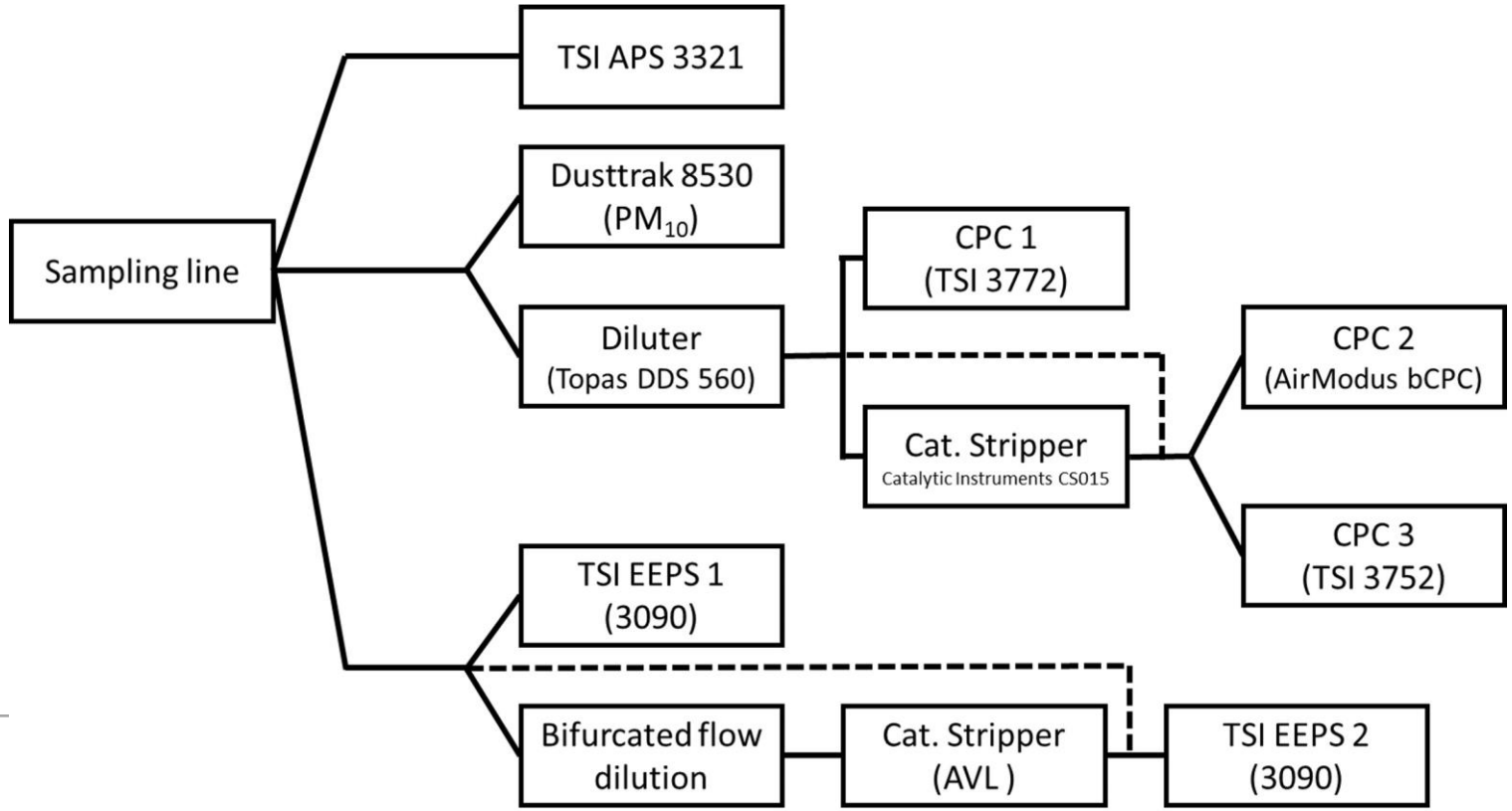
CHASSIS DYNO SETUP

- Extended particle instrumentation with focus on ultrafine particle emissions.
- Applied on-road estimated correction factors for aspiration efficiency. Airflow differs at chassis dynamometer. Influence expected to be small.

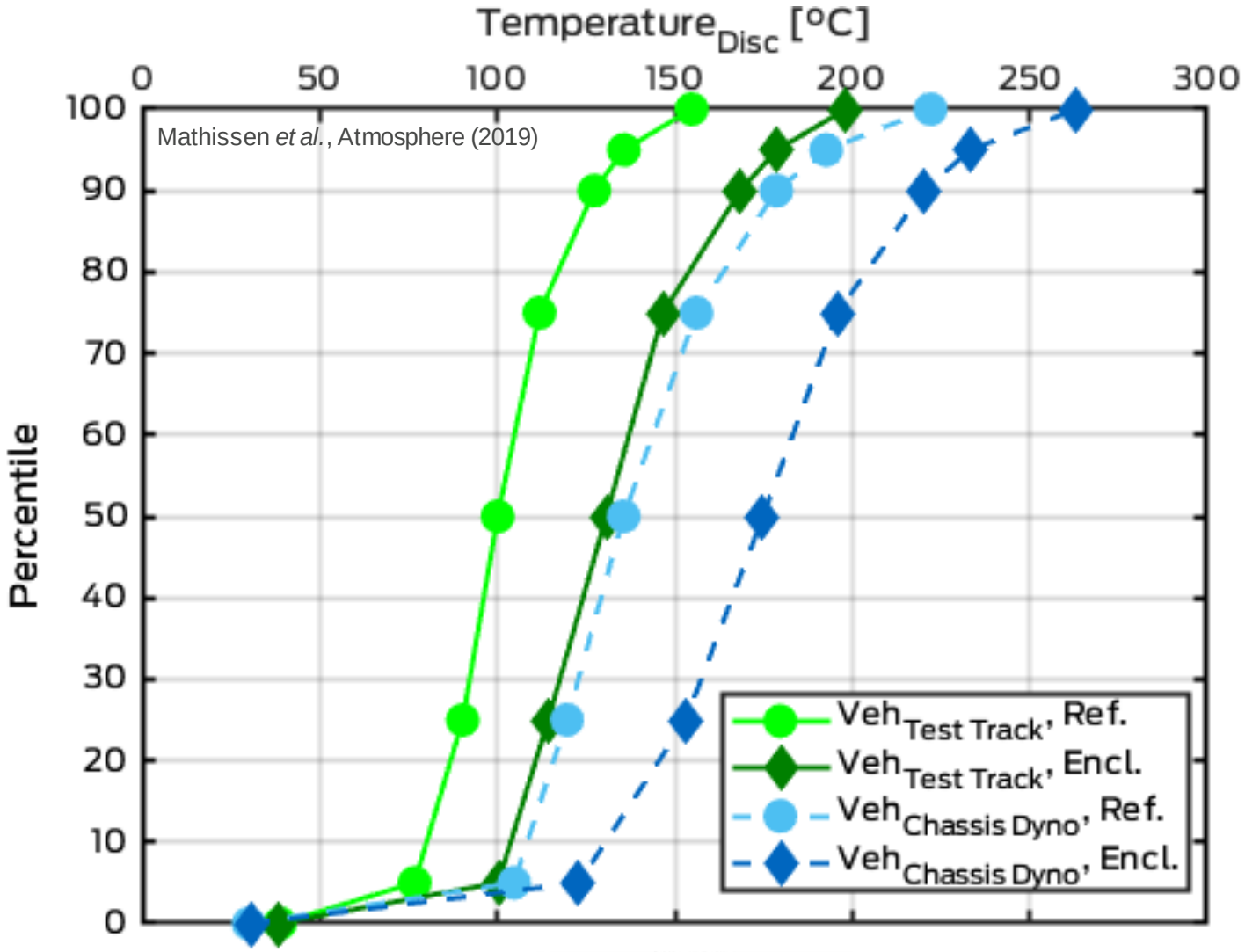


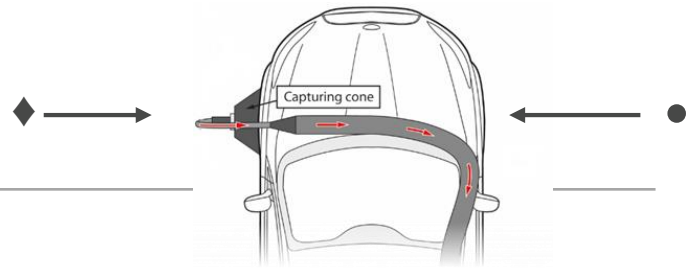
CHASSIS DYNO TEMPERATURES

- Vehicle measurement procedure leads to artificial increase of brake disc temperatures.

- Temp. controlled dynamometer testing was performed at higher temperatures than what is observed on a vehicle in the field.

- Brake disc temperatures need to match the temperature level of a vehicle in the field to avoid any bias on the measurements.





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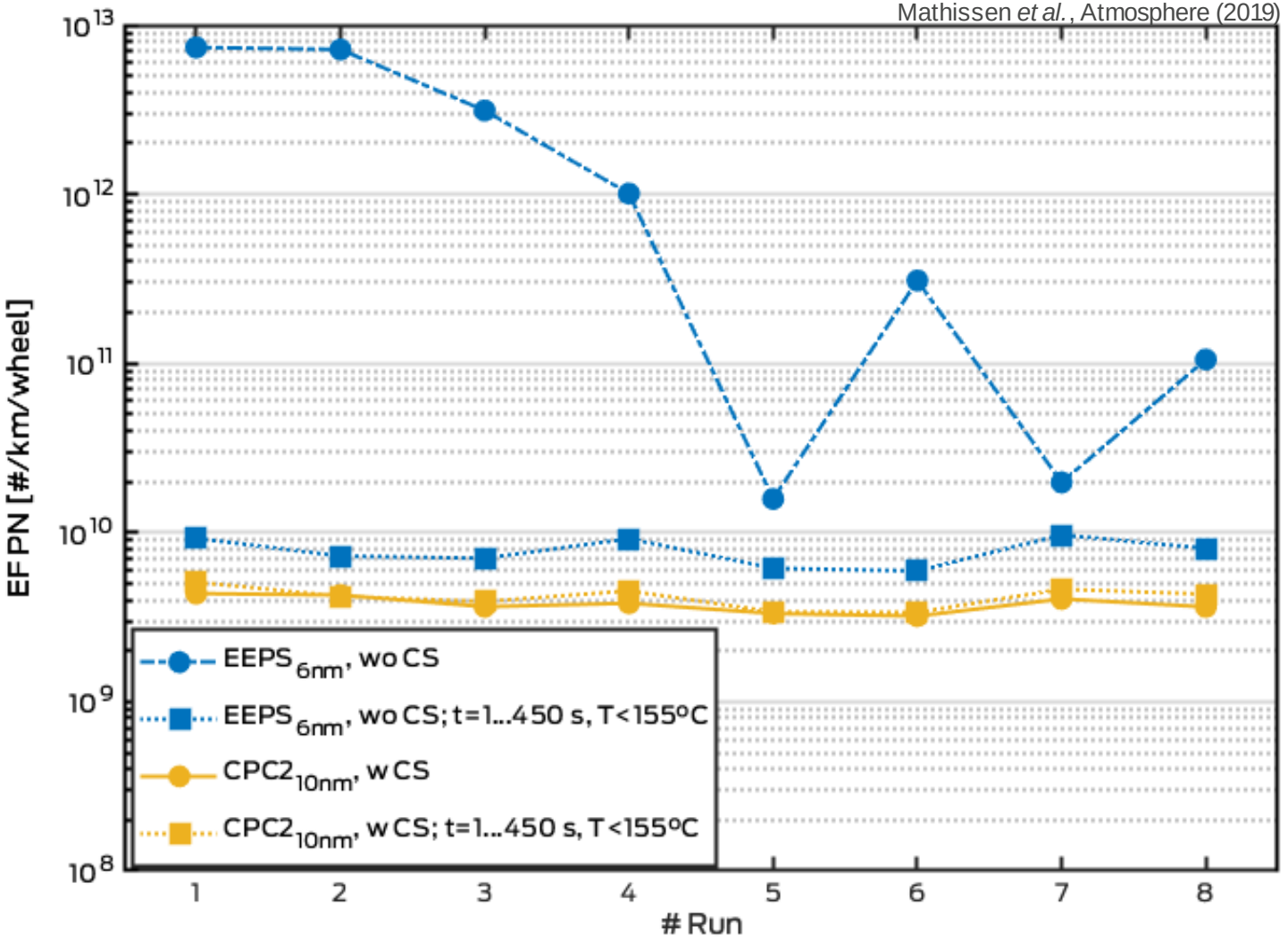
CHASSIS DYNAMOMETER MEASUREMENTS

- In excess of realistic temperature, PN emission factors of more than $7 \cdot 10^{12}$ #/km were found (LACT-20).
- The vast majority of PN was found to be volatiles. Sampling through a catalytic stripper resulted in $4 \cdot 10^{9}$ #/km solid particles.
- High measurement variability without removal of volatile particles

Mathissen *et al.*, Atmosphere (2019)



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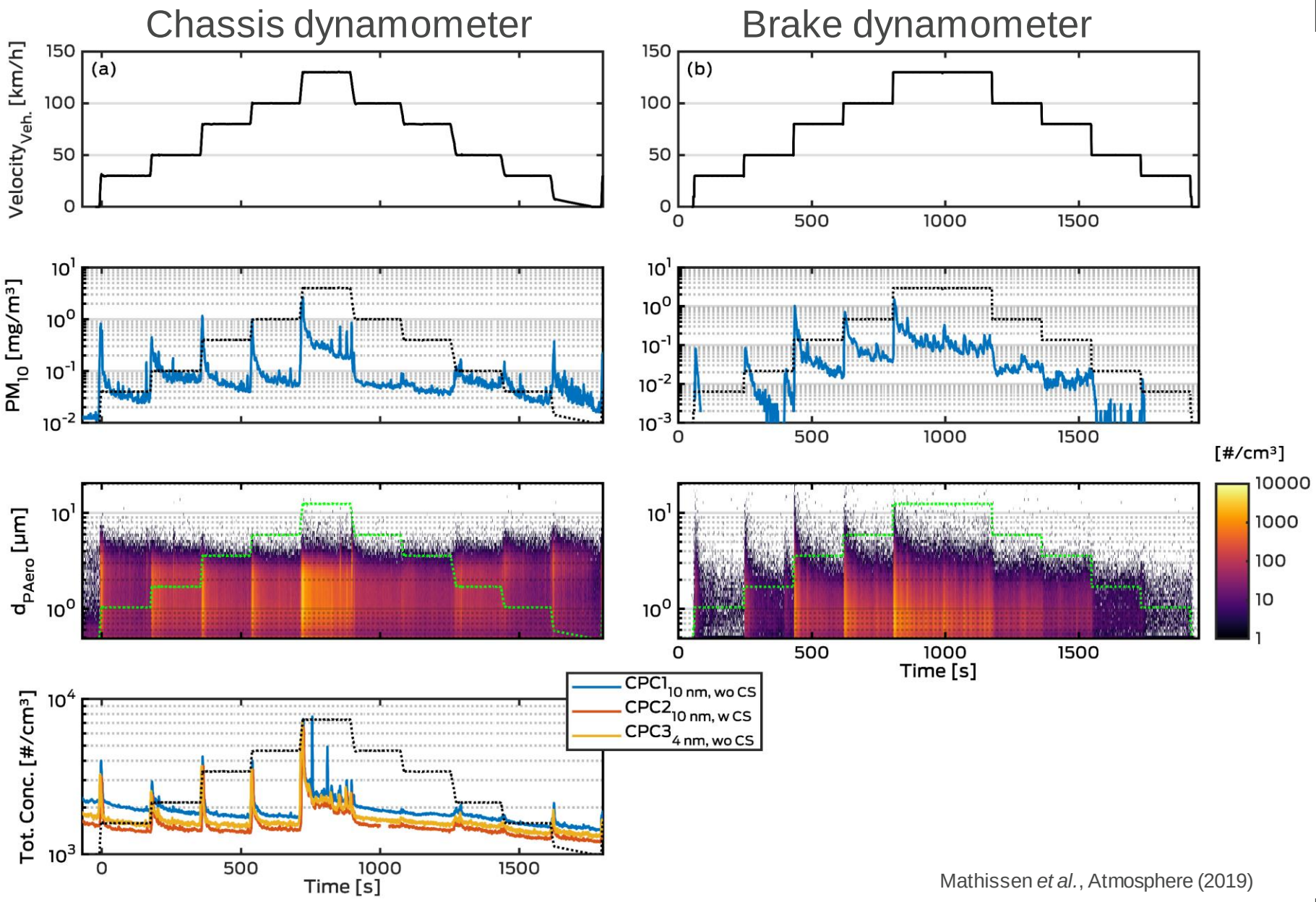
PYRAMID CYCLE - BRAKE DRAG EMISSIONS

- Pyramid cycle: No brakes applied during cycle at any time.
- Resuspension of particles as root cause is excluded.
- Brake Drag related particle emissions are found both on vehicle and brake dyno level
- App. 25% - 40% of the PM_{10} emissions during 3h-LACT are allocated to “off-braking” emissions



Mathissen *et al.*, Atmosphere (2019)

SUMMARY

- A new vehicle-based measurement approach was developed for measuring brake wear particle emissions. Method is a substantial improvement compared to state-of-the approaches art but still associated with high uncertainties.
- Semi-enclosed wheel effectively reduces contamination from other sources and captures wheel-induced particle losses but leads to increased brake temperatures due to reduced brake cooling.
- Particle emissions were investigated on the chassis dynamometer:
  - Vast majority of PN emissions were found to be volatiles.
  - Sampling through a catalytic stripper resulted in $4 \cdot 10^9$ #/km solid particles.
  - High measurement variability without removal of volatile particles.
  - Brake Drag related particle emissions are found both on vehicle and brake dyno level.

Mathissen *et al.*, Atmosphere (2019)

THANK YOU FOR YOUR KIND ATTENTION!