



# Characterizing a Real-Driving Brake Emissions Sampling System in Different Test Environments



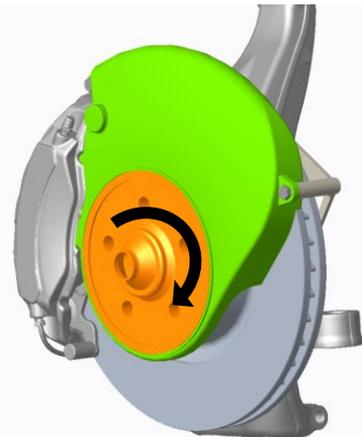
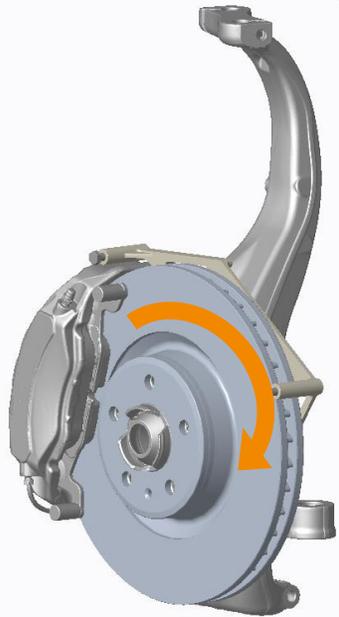
Michael Peter Huber



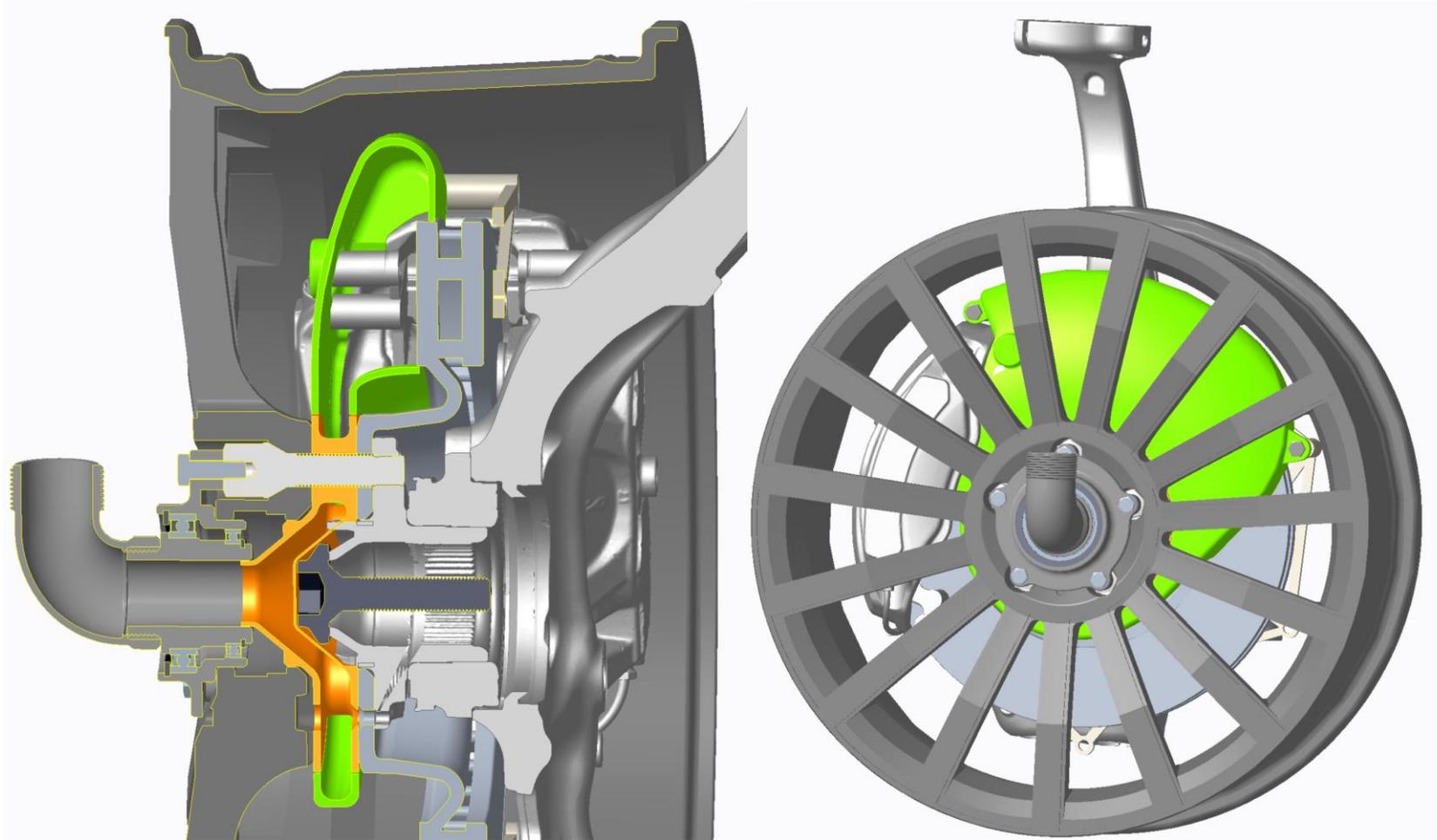


Bitte drücken  
Push for green

# RDE Brake Wear Sampling System

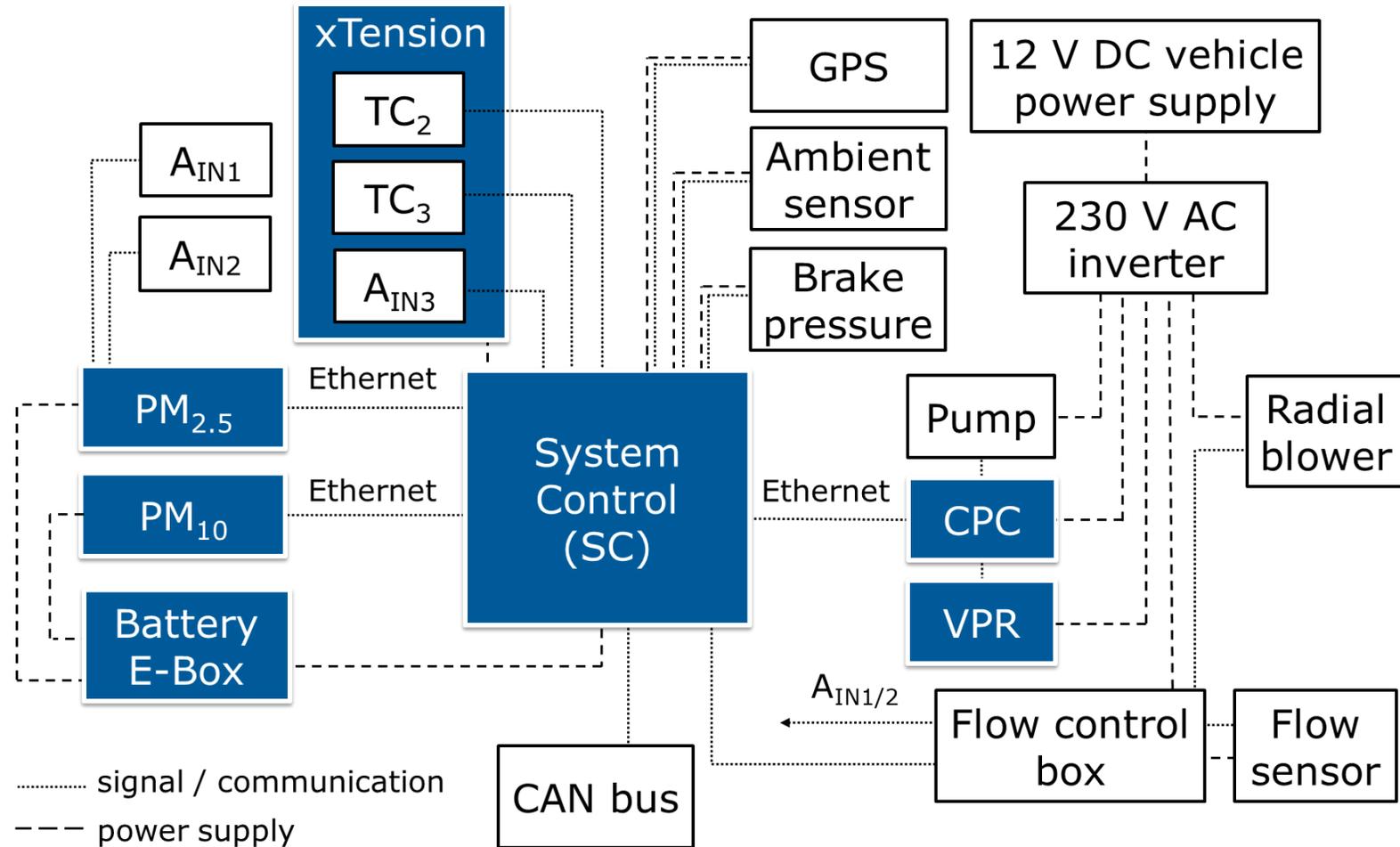
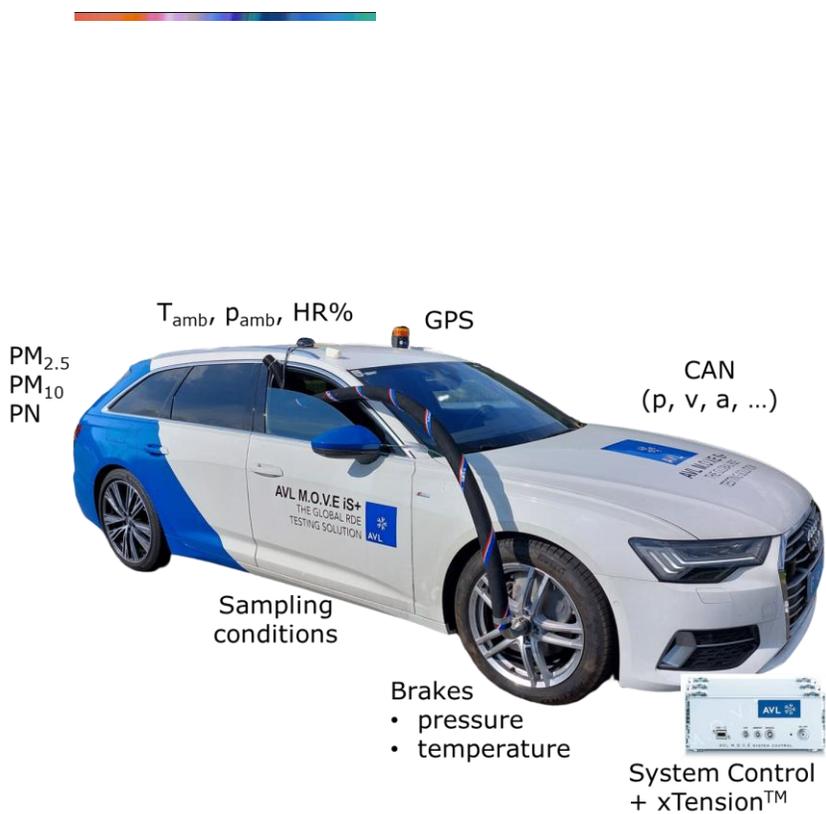


# RDE Brake Wear Sampling System

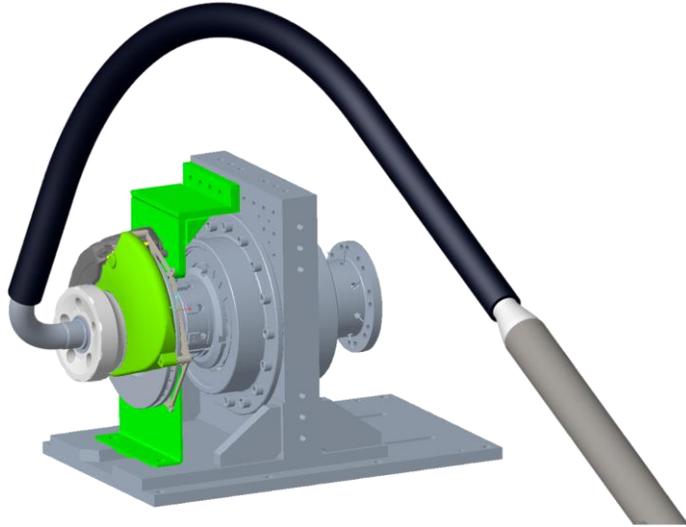


- Symmetric release of particles  
→ emission result doubled
- Sufficient natural cooling
- No influence on brake temperature

# RDE Vehicle Setup

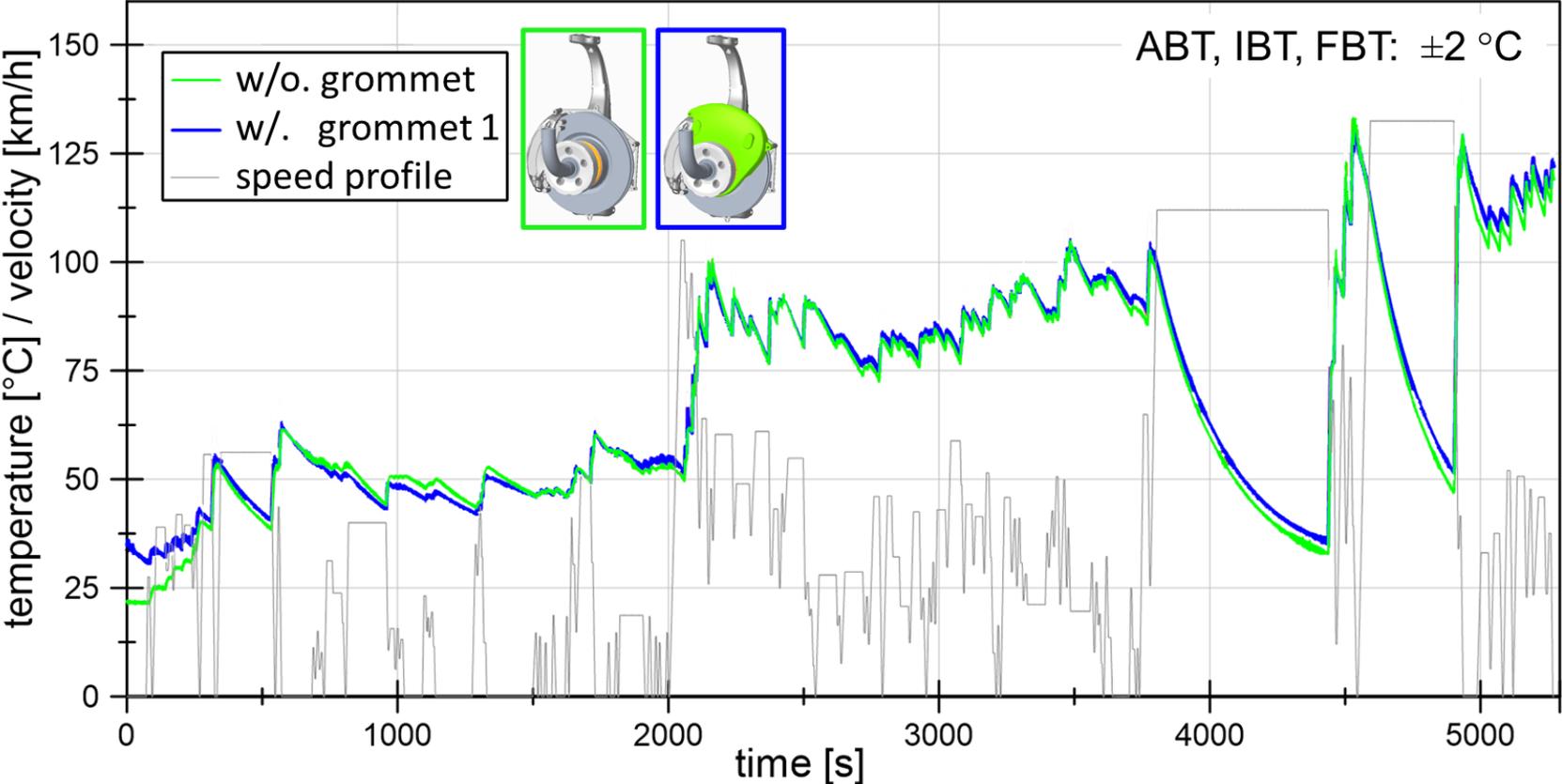
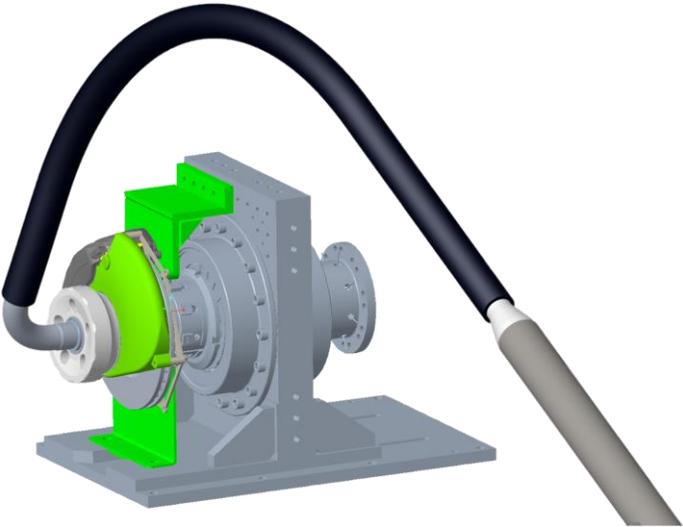


# Test Environments – Brake Dyno – Emission Test Bed – RDE



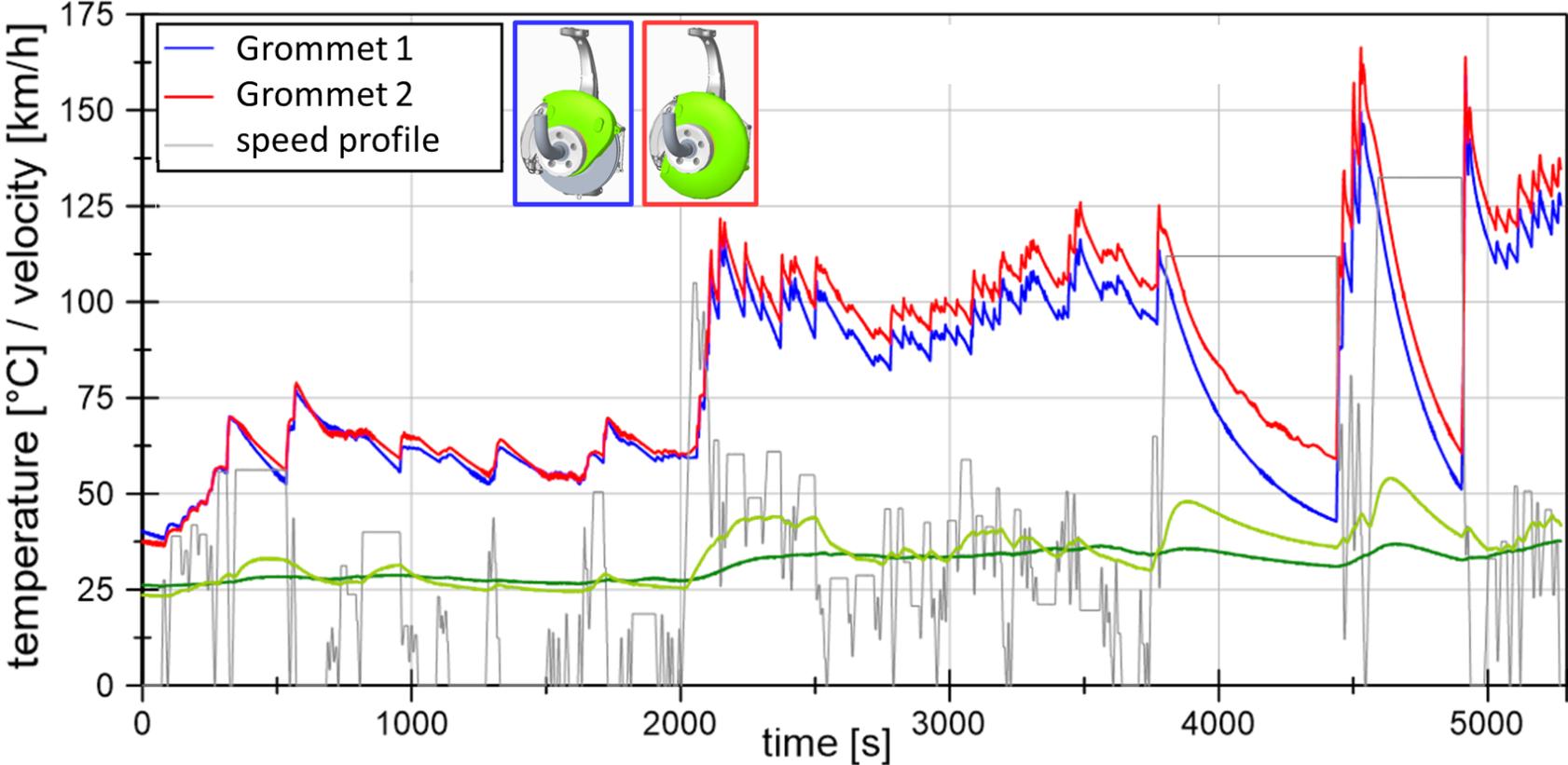
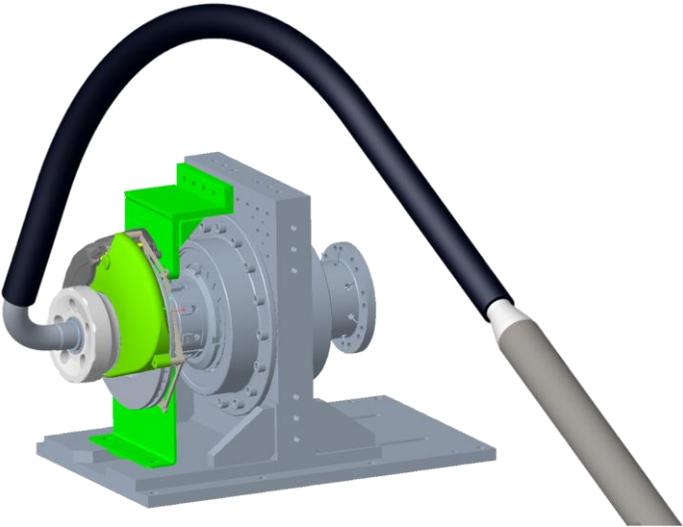
# Temperature Impact

ABT, IBT, FBT  $\pm 2$  °C

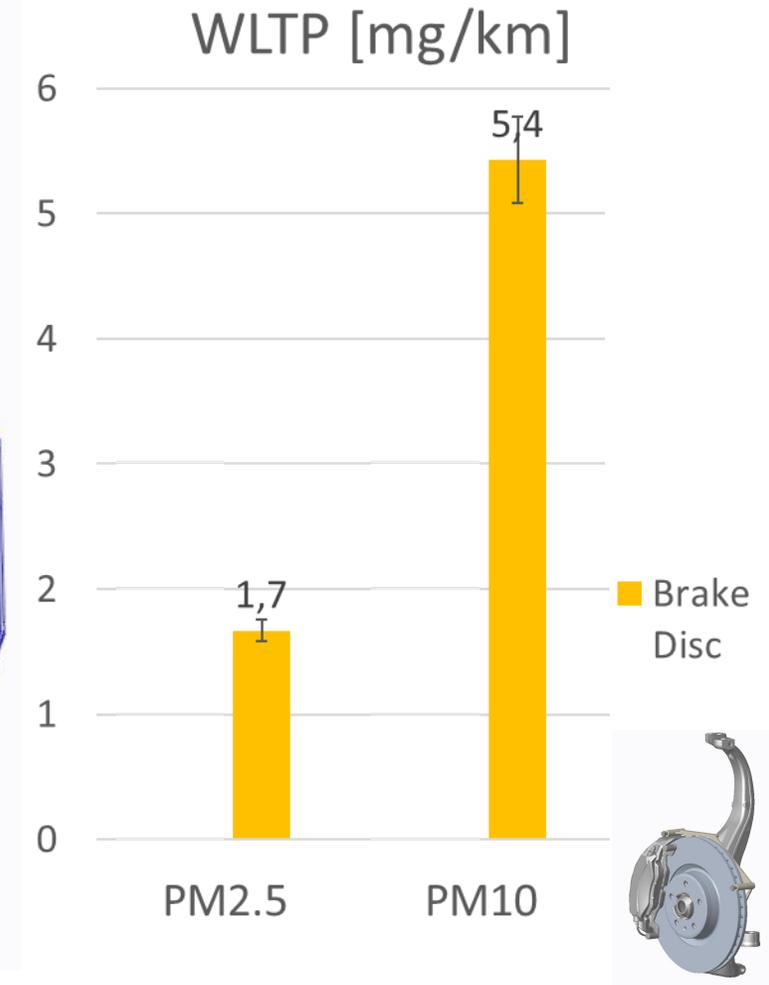
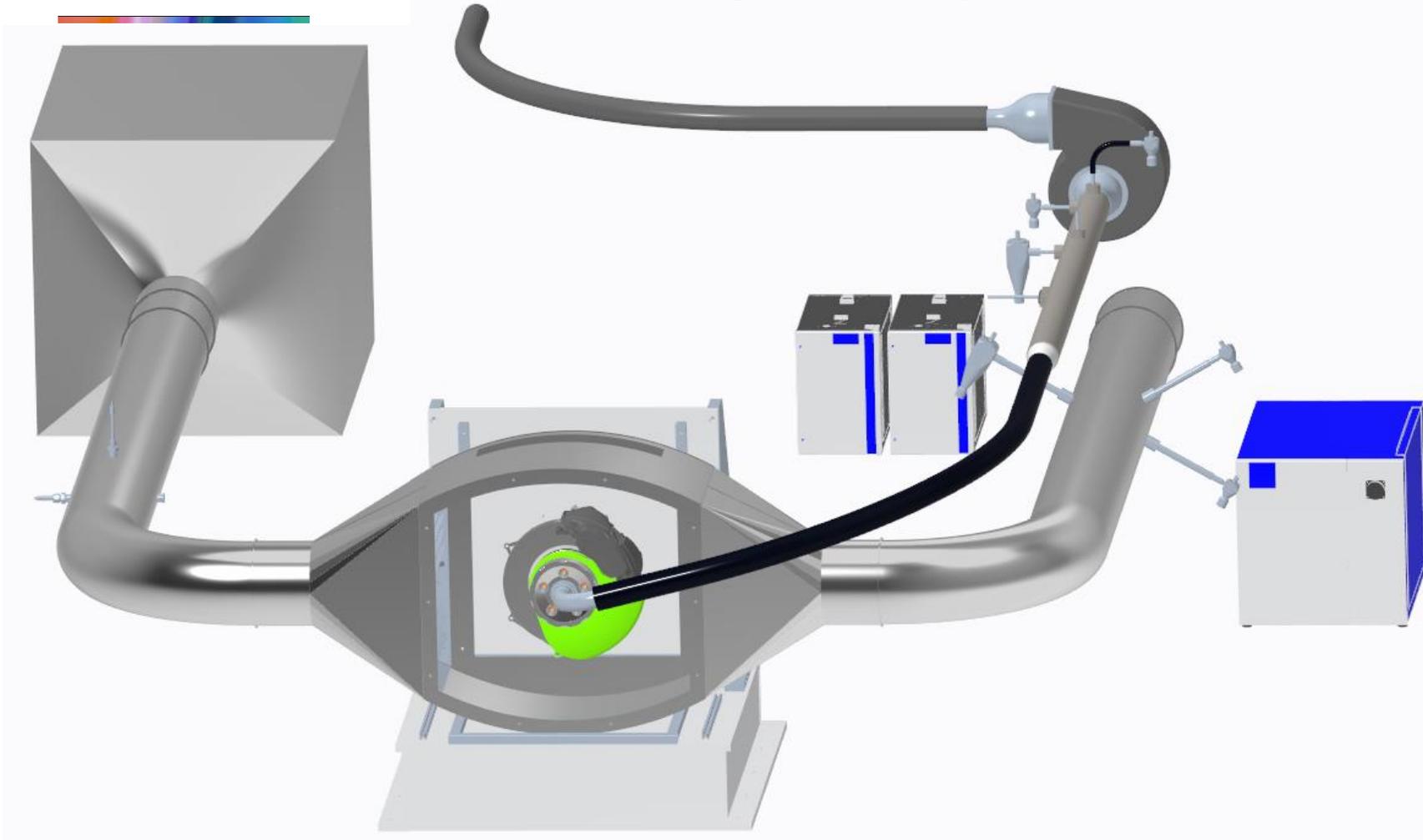


# Temperature Impact

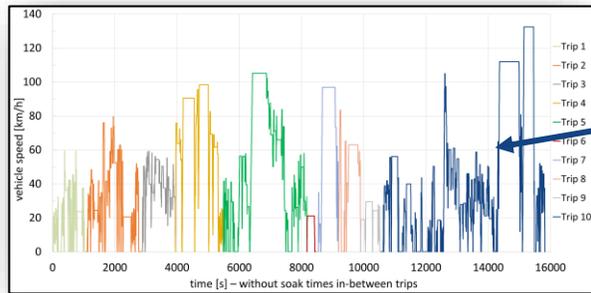
ABT +7, IBT +10, FBT +14 °C



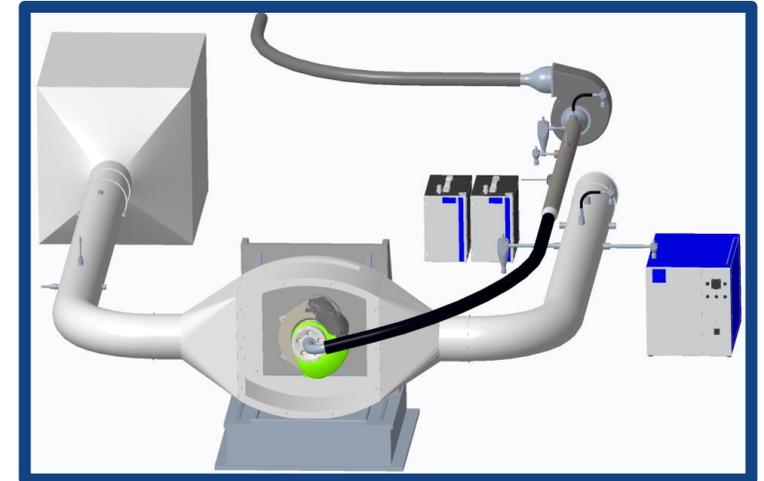
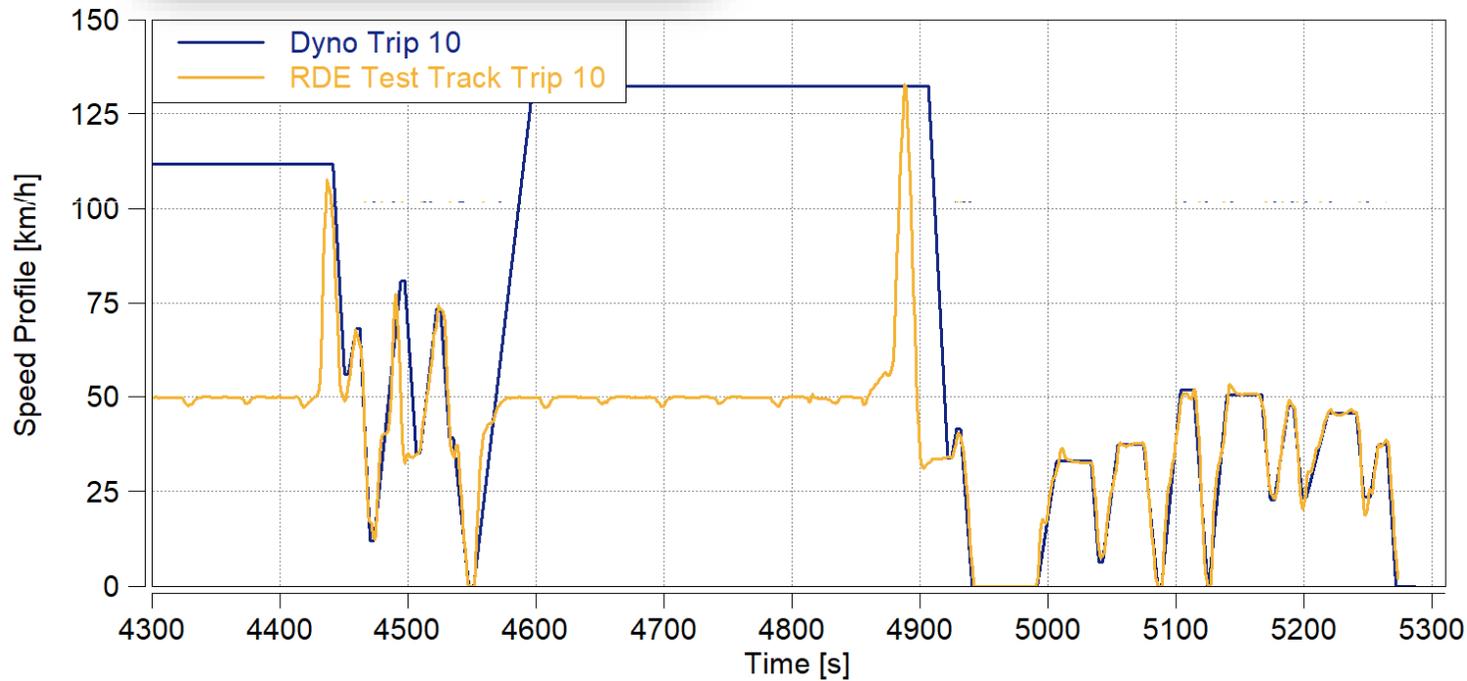
# Characterization on dyno – symmetrical release of emissions



# WLTP Trip10 – Dyno vs. Test Track



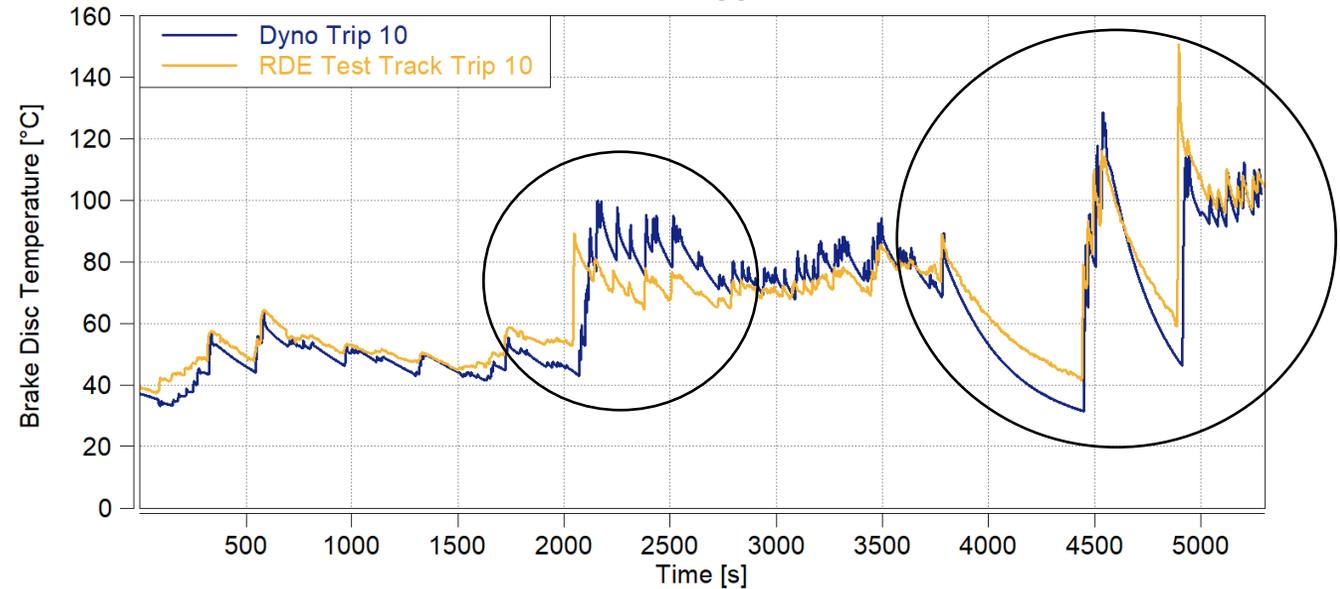
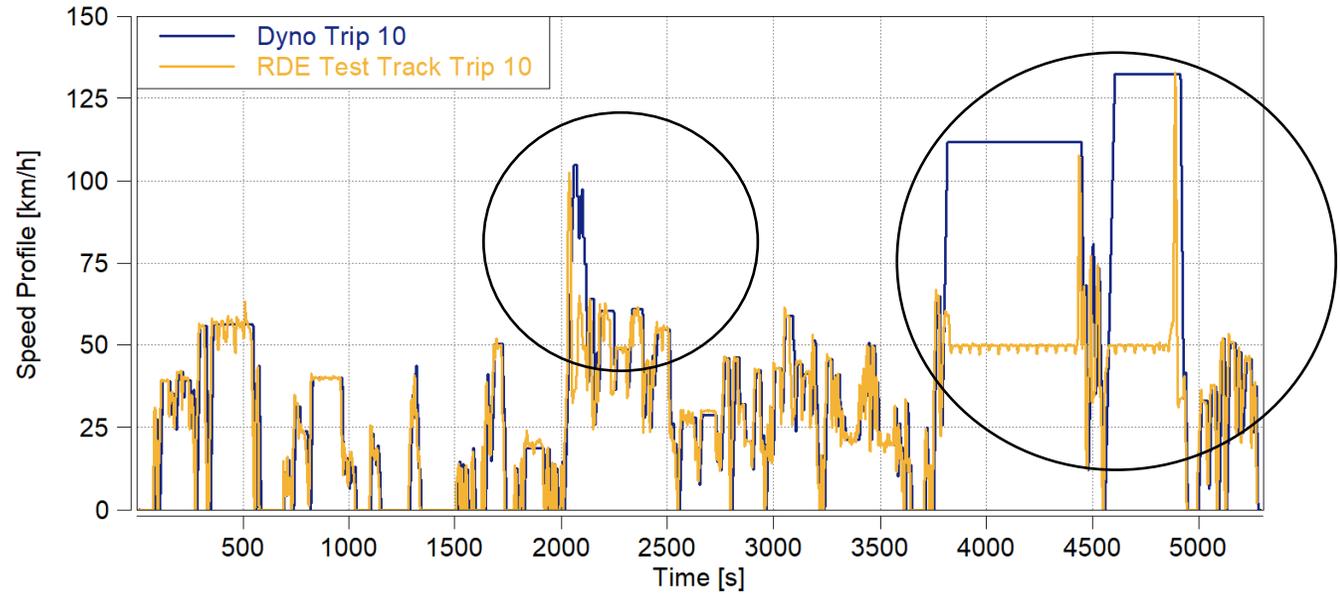
WLTP Trip10



# Trip-10 Results

- Kin. Energy +1.2 %
- Decelerations +14.0 %
- Brake temperature +1.5 °C
- Temperature peaks +35.0 °C

	<b>PM<sub>2.5</sub>*</b> [mg/km]	<b>PM<sub>10</sub>*</b> [mg/km]
Dyno	2.1	7.3
Dyno	2.2	7.6
Test track	2.3	8.8
Test track	2.0	8.1
	+2.7%	+13.1%



\*normalized for kinetic energy

# RDE On-road Tests



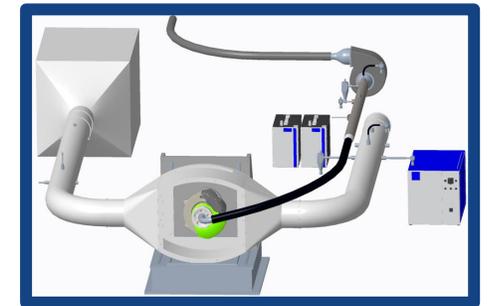
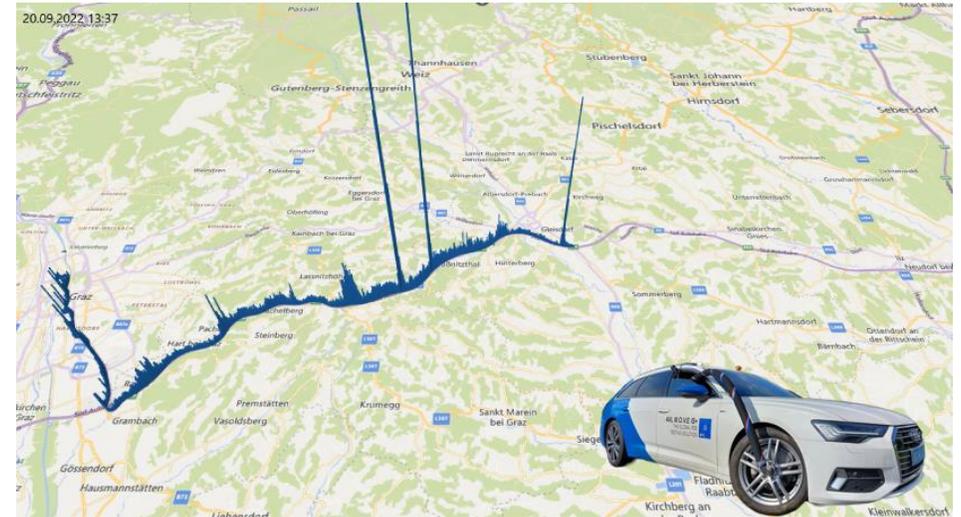
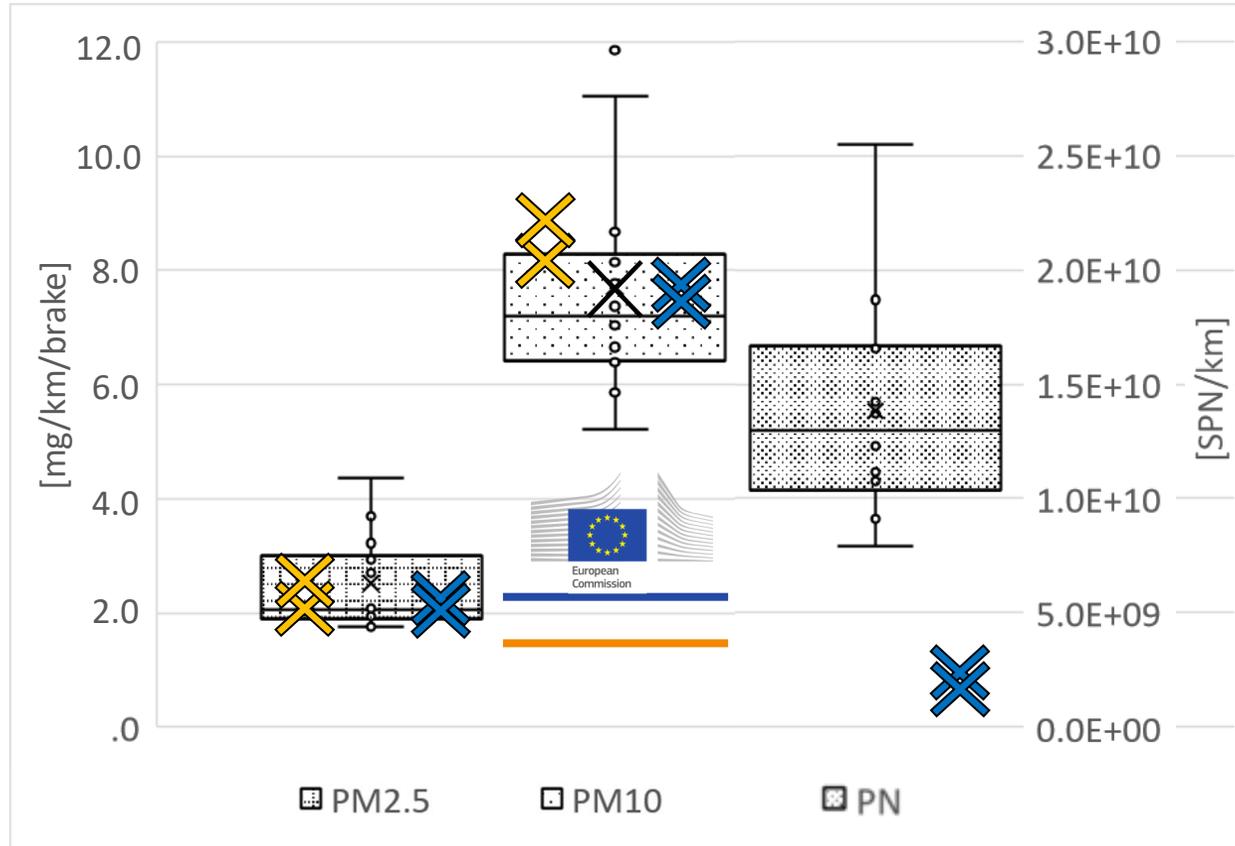
- A – B Urban
- B – C Motorway
- C – D – E Rural / Urban
- E – F Hills
- F – A Urban

# RDE Results



$6 \times 10^{11}$

Exhaust limit



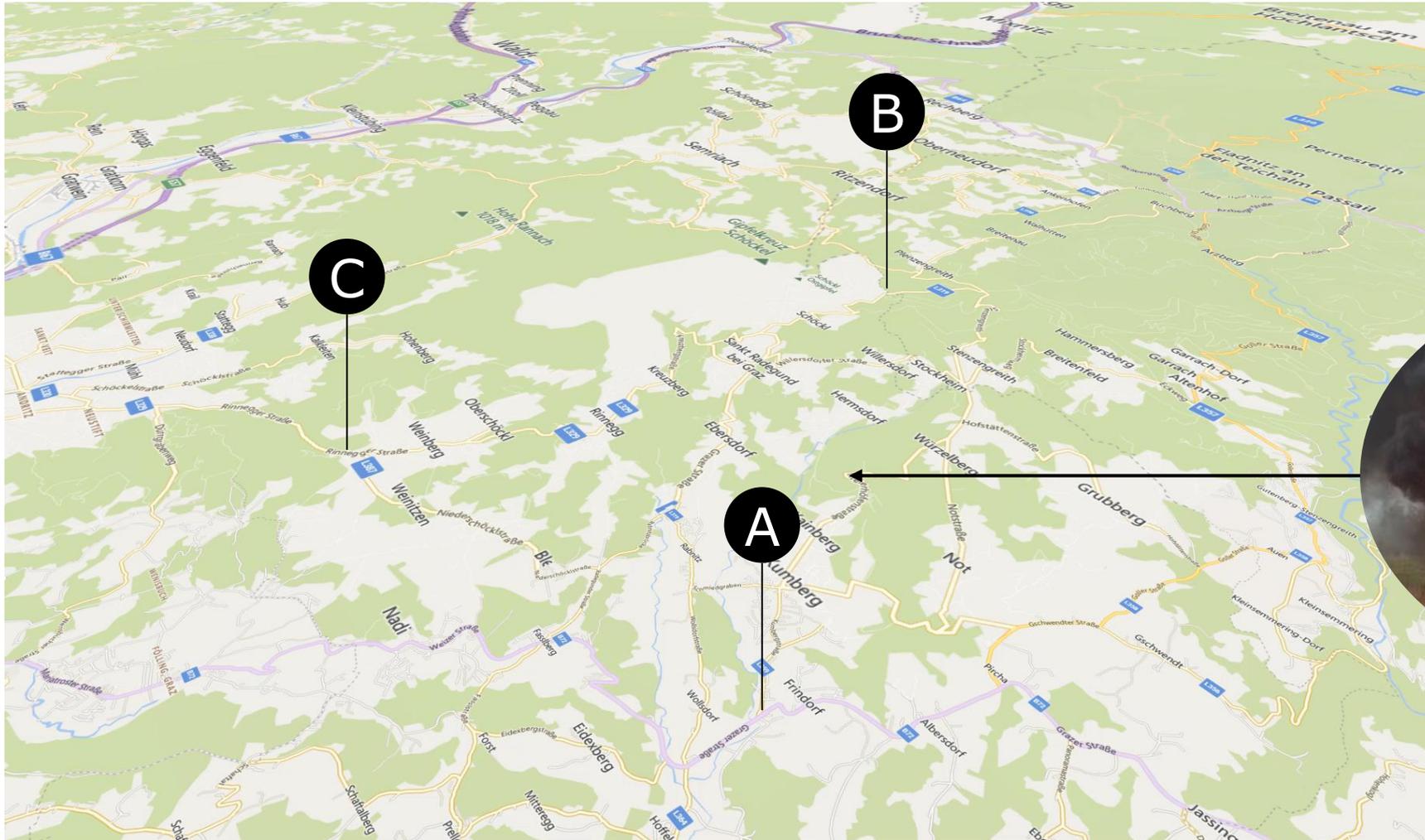
Brake PM<sub>10</sub>

RDE

**7.7 mg/km/brake**

Trip-10

# Hilly Terrain – Mountain Roads



- 82 km hilly terrain
- Brake T > 450 °C
- Brake T > 840 °F

PM<sub>10</sub>: [mg/km/brake]

- Entire route: 20
- Downhill (1/4): 42
- RDE route: 7.7

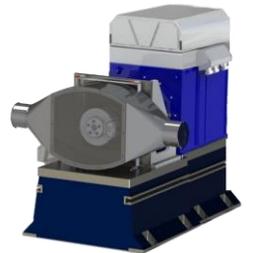


# Conclusion

- Vehicle's correct **natural temperature behavior** to assess **real-world brake emissions**
- RDE sampling system has **no impact on the brake temperature**
- Good agreement between dyno and RDE test results under same conditions
- Assessing **PN emissions** on-road proved **challenging** – especially in urban environment

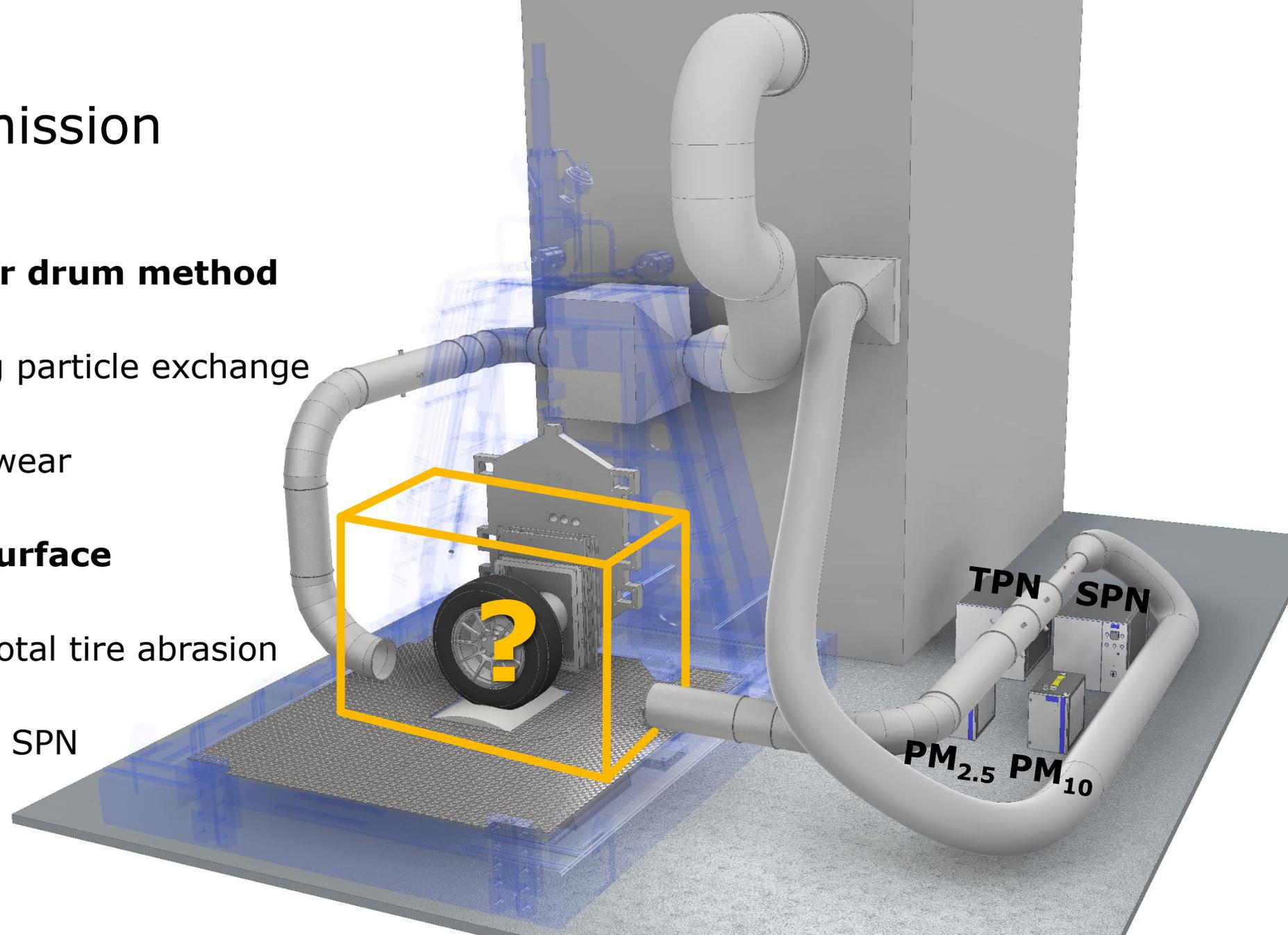


**PM<sub>10</sub> Euro7 limit 7 mg/km/vehicle**



# Outlook Tire Emission

- UNECE TF TA – **indoor drum method**
- **Enclosure** preventing particle exchange
- **Reproducible** tire wear
- Big impact of **drum surface**
- **PM<sub>10</sub>** up to **25%** of total tire abrasion
- **TPN** **10<sup>1</sup>** higher than SPN





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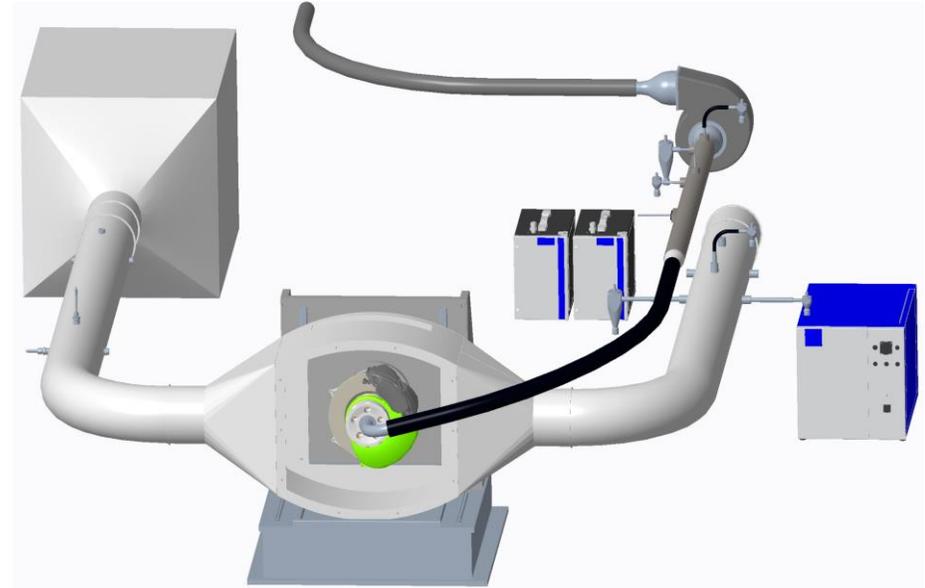


michael.huber@tugraz.at



# Outlook

- Reproducing **on-road driving profile on test bed**
- Applying to **other vehicles** with different friction materials, caliper positions, and corner designs
- Validating that multiplying the measured emissions by two is also valid for **asymmetrical brakes**

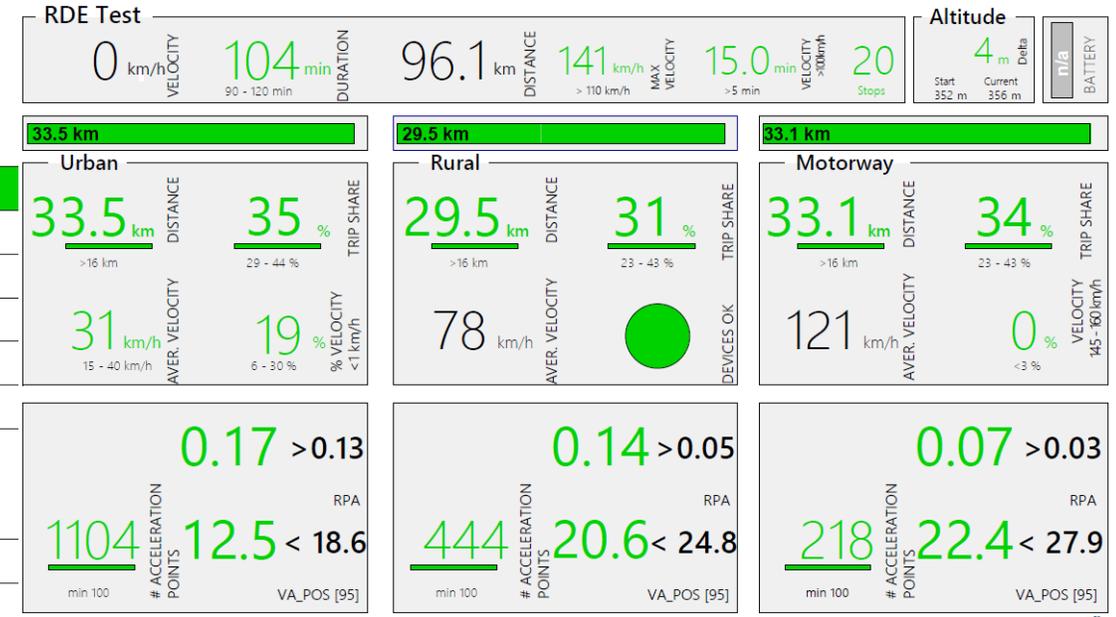


# Corrosion



# RDE Test Criteria

Criterion	Description		
Driving Profile/Route	Time	Total Duration	90 - 120 min
		Stopping time	individual stopping time: 10 - 180 s
		Duration of route sections of the total duration	Urban: 34 % (+ 10 % / - 5 %) Rural: 33 % (± 10 %) Motorway: 33 % (± 10 %)
	Speed	Urban	0 - 60 km/h Ø 15 - 40 km/h 6 to 30% of vehicle velocity < 1 km/h
		Rural	60 - 90 km/h
		Motorway	90 - 120 km/h > 5 min have to exceed 100 km/h < of 3% between 145 and 160 km/h
	Route	Minimum Distance per Section	16 km
		Start and End Point	both located in the urban section
	Acceleration	> 100 positive acceleration points > 0,1 m/s <sup>2</sup>	
	Altitude	< 700 m above sea level	
Accumulated Altitude Difference	< 1200 m / 100 km < 100 m altitude delta between start and stop		
Environmental Conditions	Outside Temperature	0 - 30 °C	
Payload	Test weight	≤ 90 % of the maximum vehicle weight	



Hesse, D. "Beitrag Zur Experimentellen Und Analytischen Beschreibung Partikelförmiger Bremsenemissionen." Dissertation. Technischen Universität Ilmenau, June 2020.  
 EUR-Lex - 32018R1832 - EN. "Commission Regulation (EU) 2018/1832." November 5th 2018. eur-lex.europa.eu/eli/reg/2018/1832/oj.