



LABORATORY OF APPLIED THERMODYNAMICS

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ARISTOTLE UNIVERSITY THESSALONIKI
SCHOOL OF ENGINEERING
DEPT. OF MECHANICAL ENGINEERING



Evaluation of a miniaturized exhaust emission measuring system for L-Category Vehicle Measurements in Real-World Driving Conditions

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Objective

- Evaluate the performance of a miniaturized exhaust emissions measurement system in lab with reference instruments

- Assess its applicability for real-world emissions testing



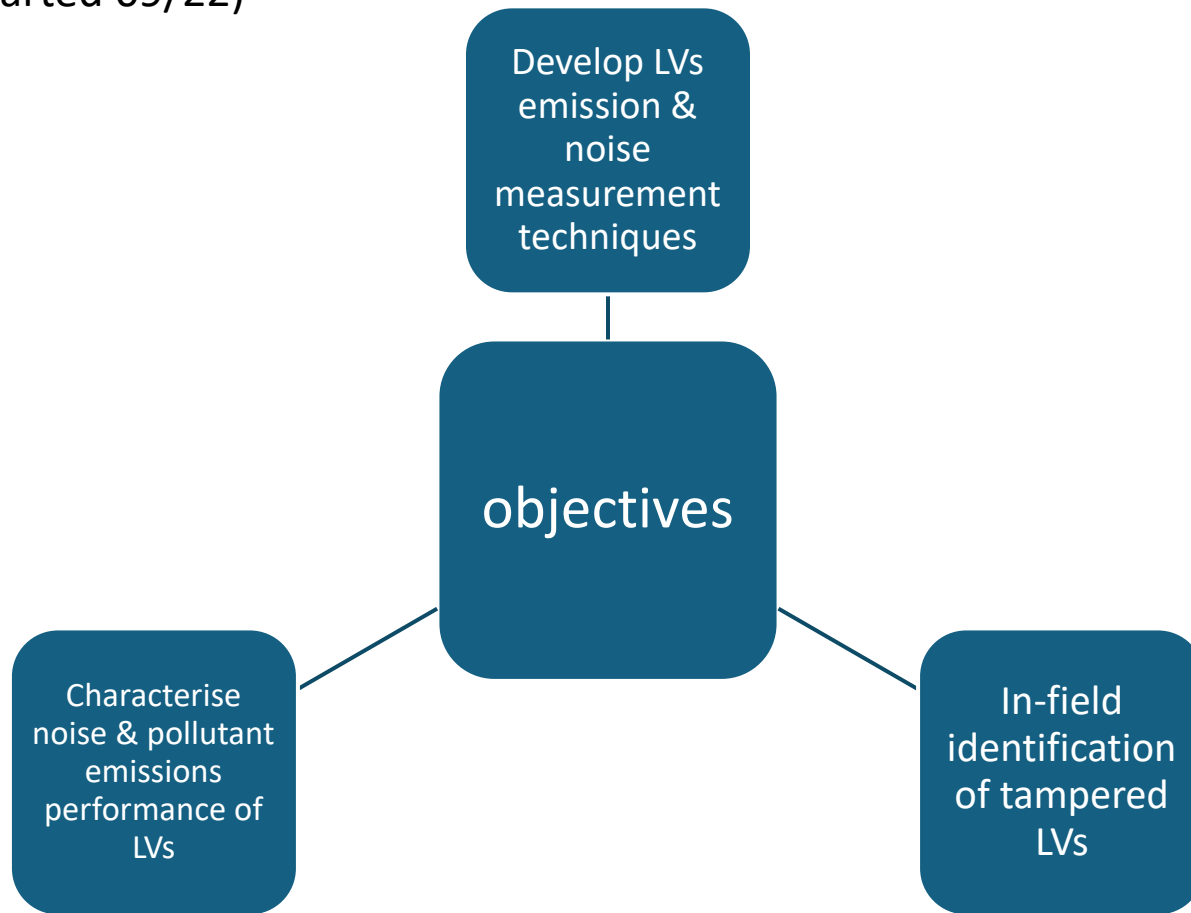
Background – L-Vehicle emissions

- **PEMS** devices are being used for type approval of light duty vehicles but are **impossible** to implement for most **L-vehicles** due to **size** and **weight** limitations
- Currently, legislation for L-vehicles is less strict than that of passenger cars, mainly due to **lack of standardized measurement equipment**
- Although PM emissions were introduced in the Euro 4 and became stricter in the Euro 5 regulations for L-vehicles, very few studies have assessed **Black Carbon (BC)** emissions of **L-category vehicles**.
- Studies of real-world emissions are very recent with the use of miniaturized PEMS devices. Development of such systems is crucial to evaluate the actual contribution of L-vehicles in air-pollution.



LENS Project

L-vehicles Emissions and Noise mitigation Solutions (Horizon Europe, started 09/22)

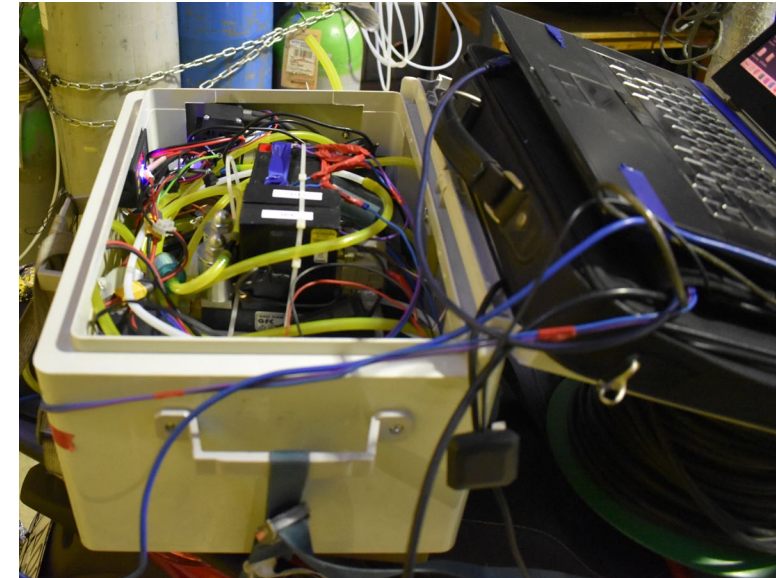


LENS website: <https://www.lens-horizoneurope.eu/>

Real Time Emissions Measurement System (ReTEMS)

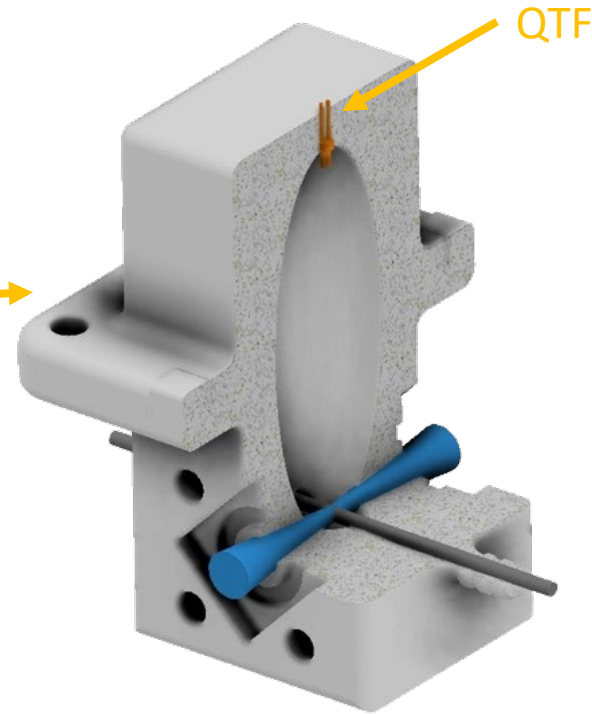
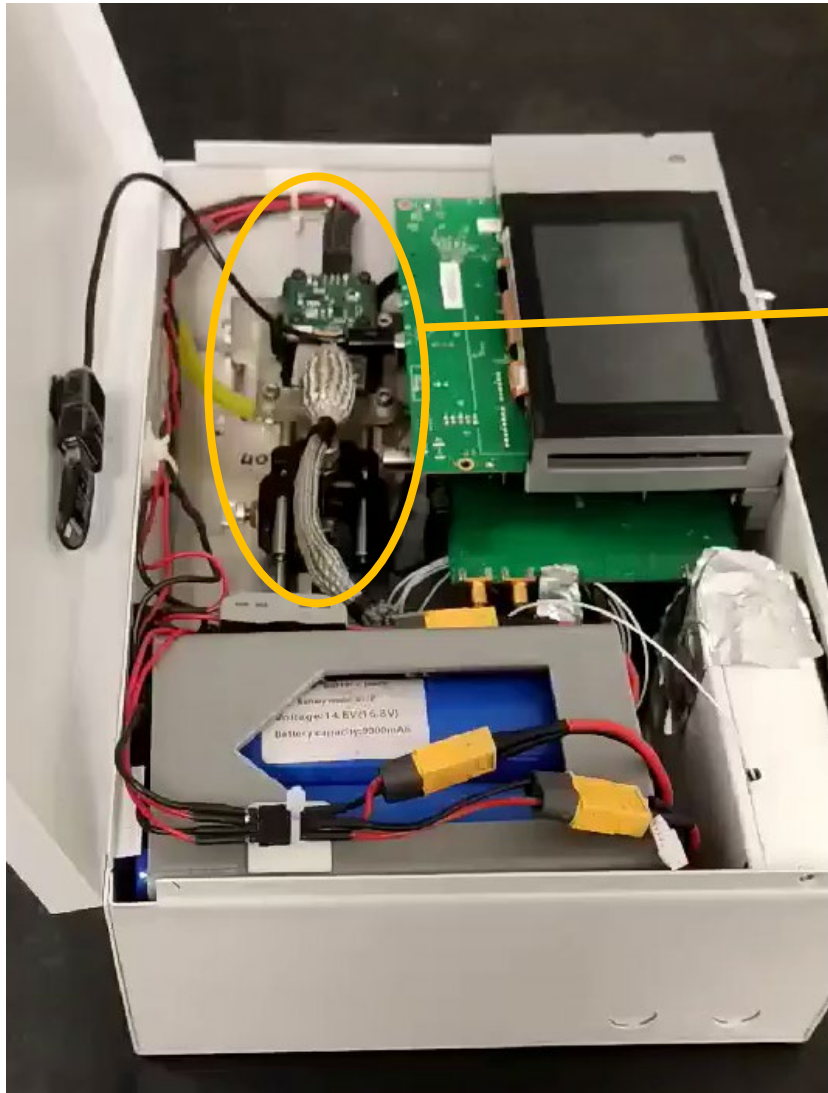


- Custom sampling system with heated line and stable flows
- Commercial ambient gas sensors
- Novel Optoacoustic Sensor for Black Carbon
- RH and T measurement



Detection Pollutant	Technology Used	Measurement Range	T ₀₋₉₀ (s)	Resolution (ppm)
CO ₂	NDIR	0-20 %	2-3	<70
CO	Electrochemical	0-5000 ppm	20-30	<0.5
NO	Electrochemical	0-500 ppm	5-10	<0.3
BC	Optoacoustic	5-10000 µg/m ³	<1	5 (µg/m ³)

Novel Optoacoustic Black Carbon sensor - RSENSE

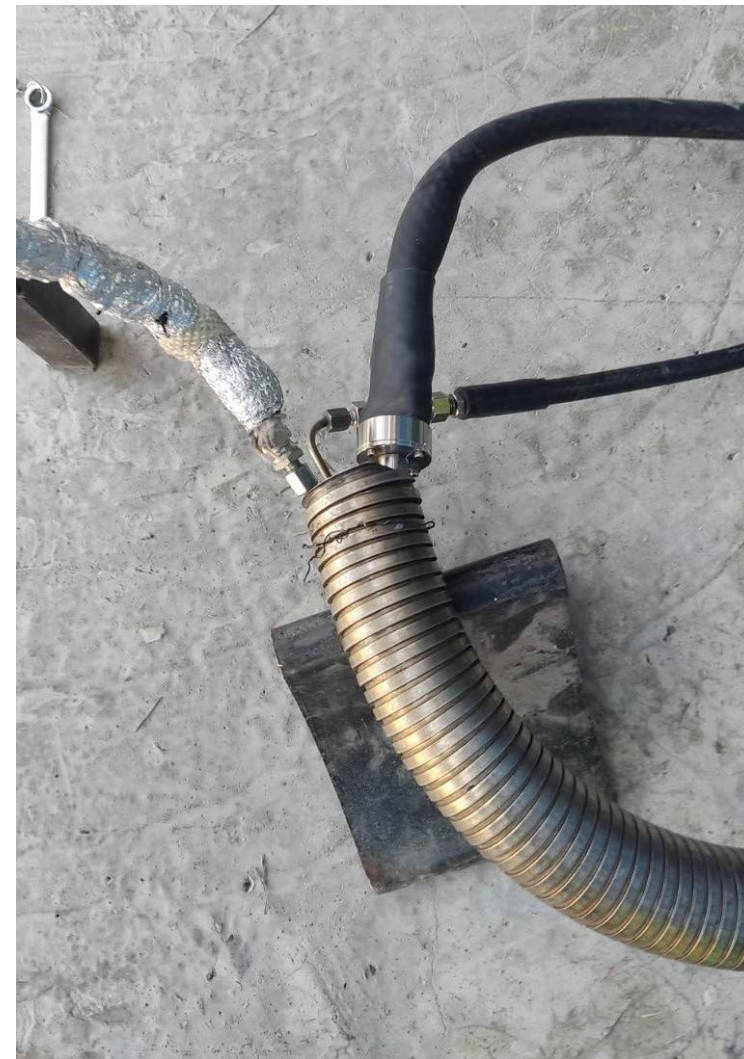


- Optoacoustic principle
- 808 nm LD for BC detection
- Ellipsoid chamber for sound refocusing
- QTF for highly sensitive sound detection

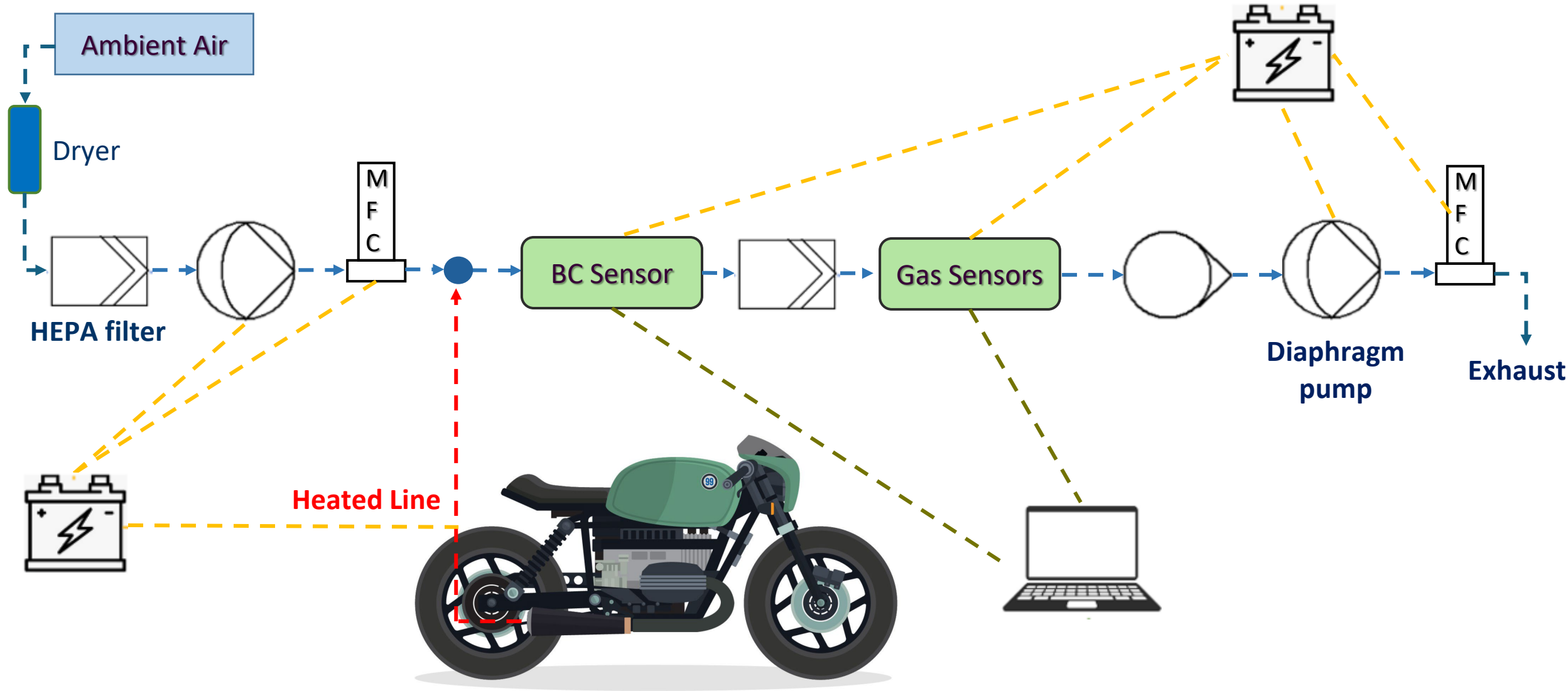
	Current version	Potential
Weight	4 kg	2 kg
Dimensions	33 x 22 x 12 cm	20 x 20 x 10 cm
Cost	4k €	1.5k €

Sampling system

- Custom heated line at 70 °C
- MFCs for flow stabilization and dilution control (exhaust pulsations)
- Dilution ratio is 10:1
- Dilution ratio setting using the CO₂ sensor and a reference CO₂ span gas



ReTEMS Experimental Layout



Vehicle and test specifications

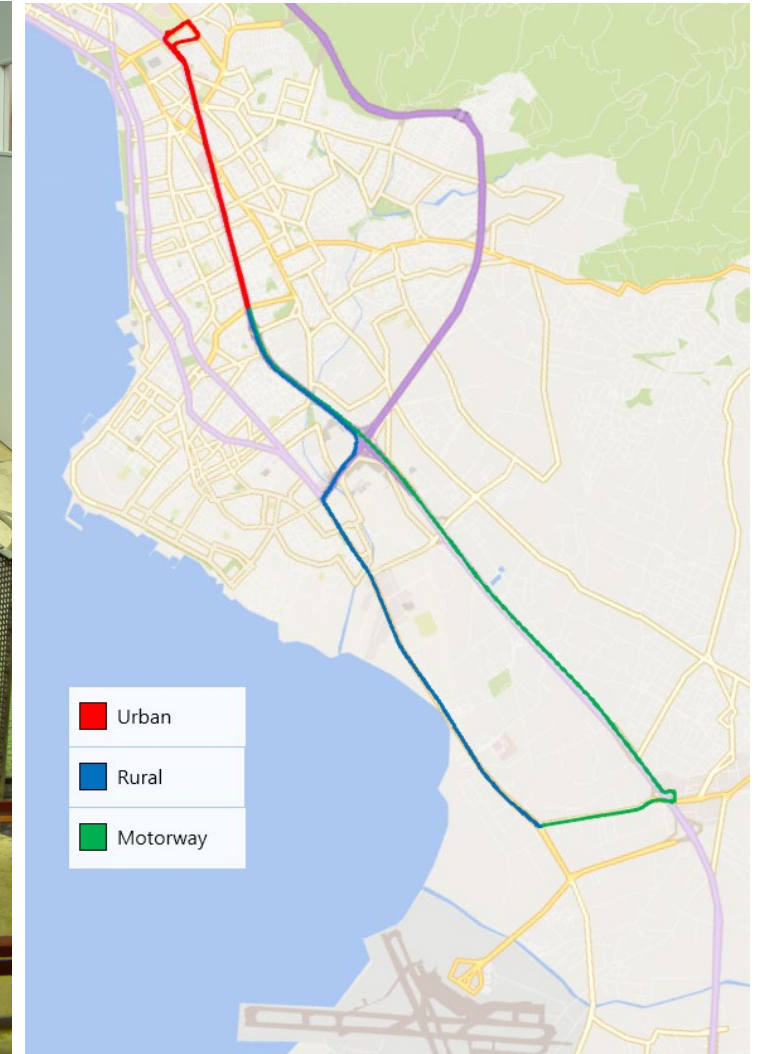
Vehicle characteristics:
150 cc / gasoline / 4-stroke

Test cycles:
WMTC / RDC / RDE

Reference instruments:
BC → *MSS* / *Gases* → *PEMS*

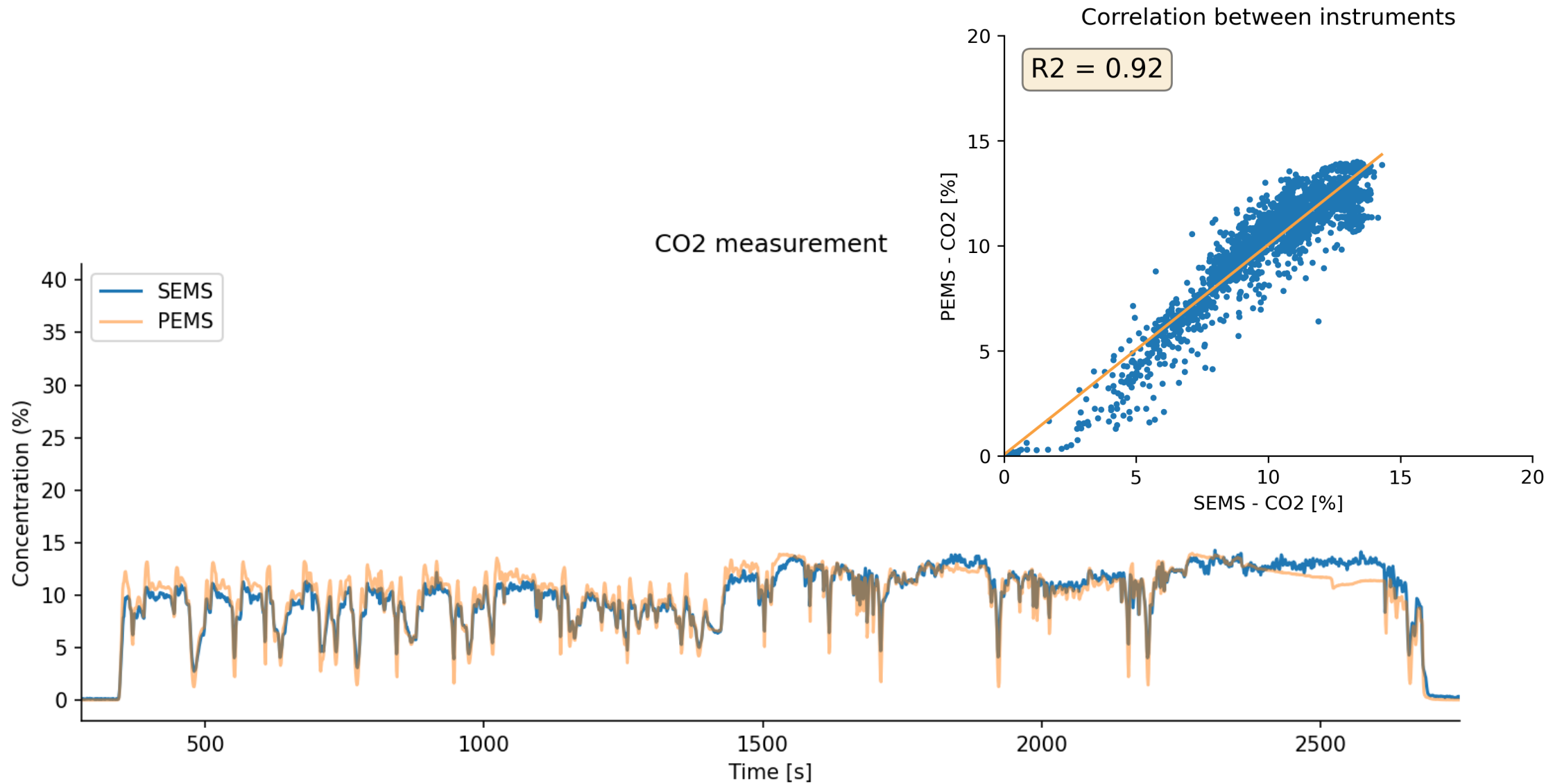


Chassis dyno setup

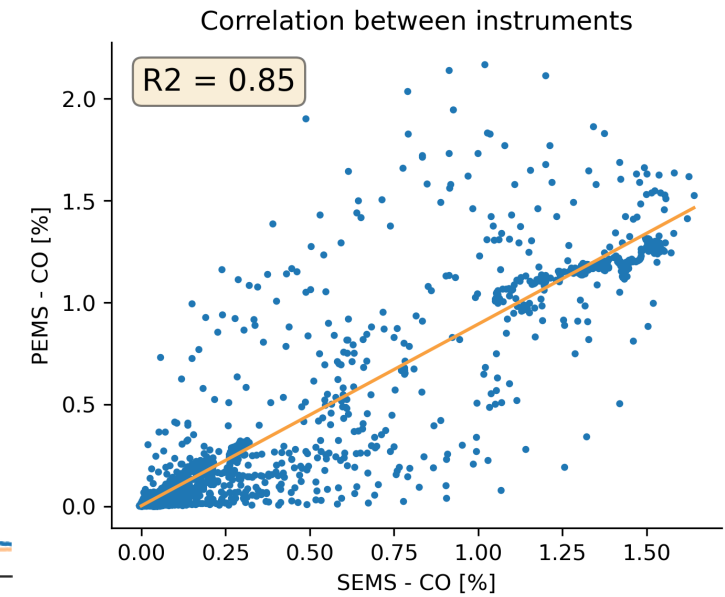
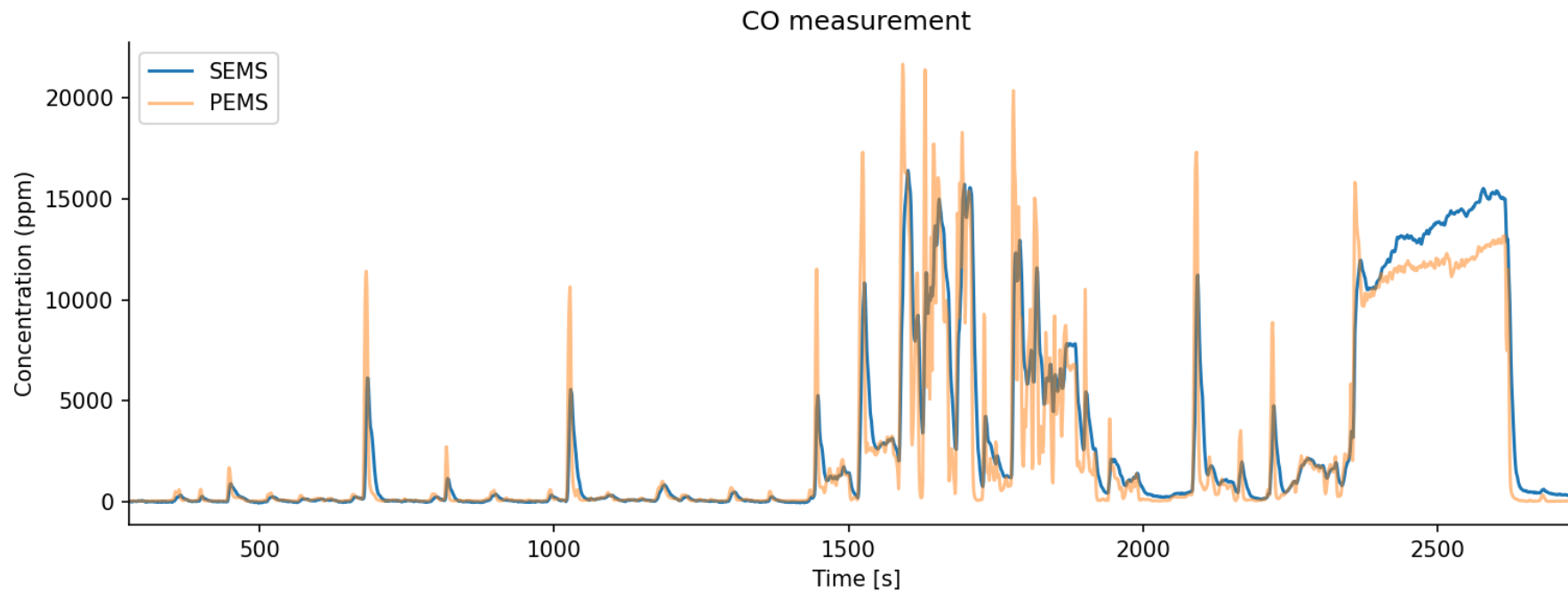


Standard RDE trip in Thessaloniki

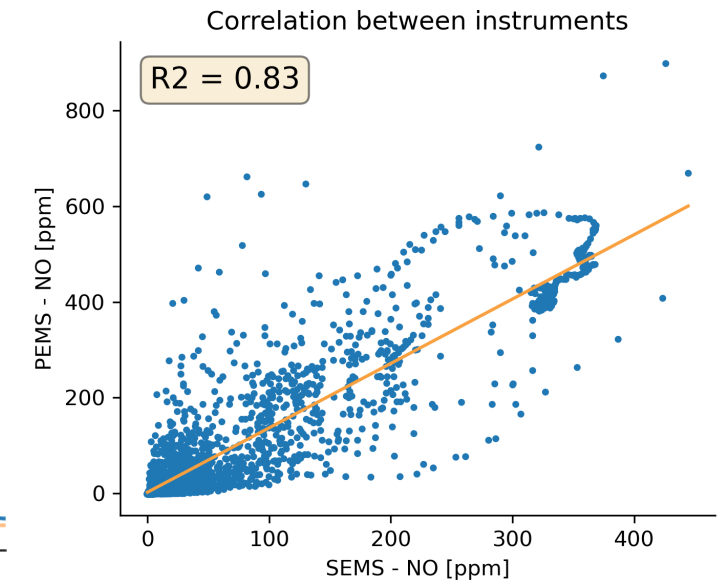
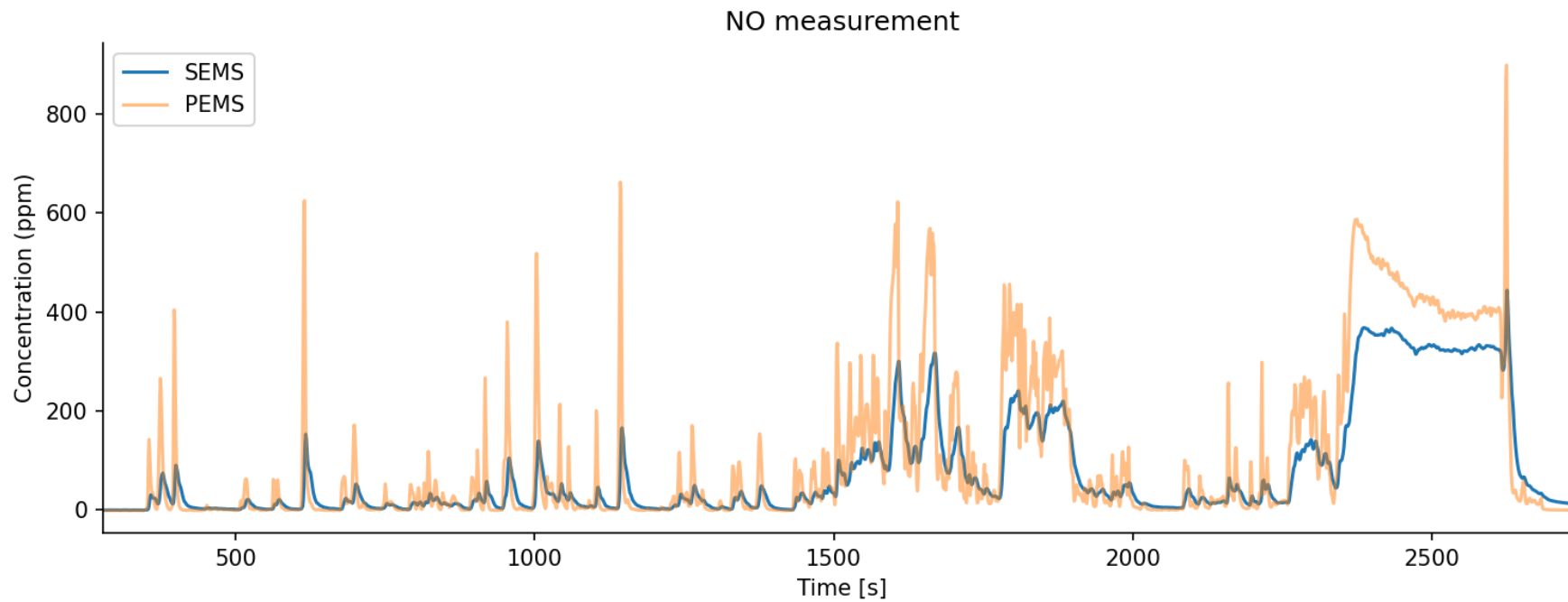
CO2 Sensor Evaluation



CO Sensor Evaluation

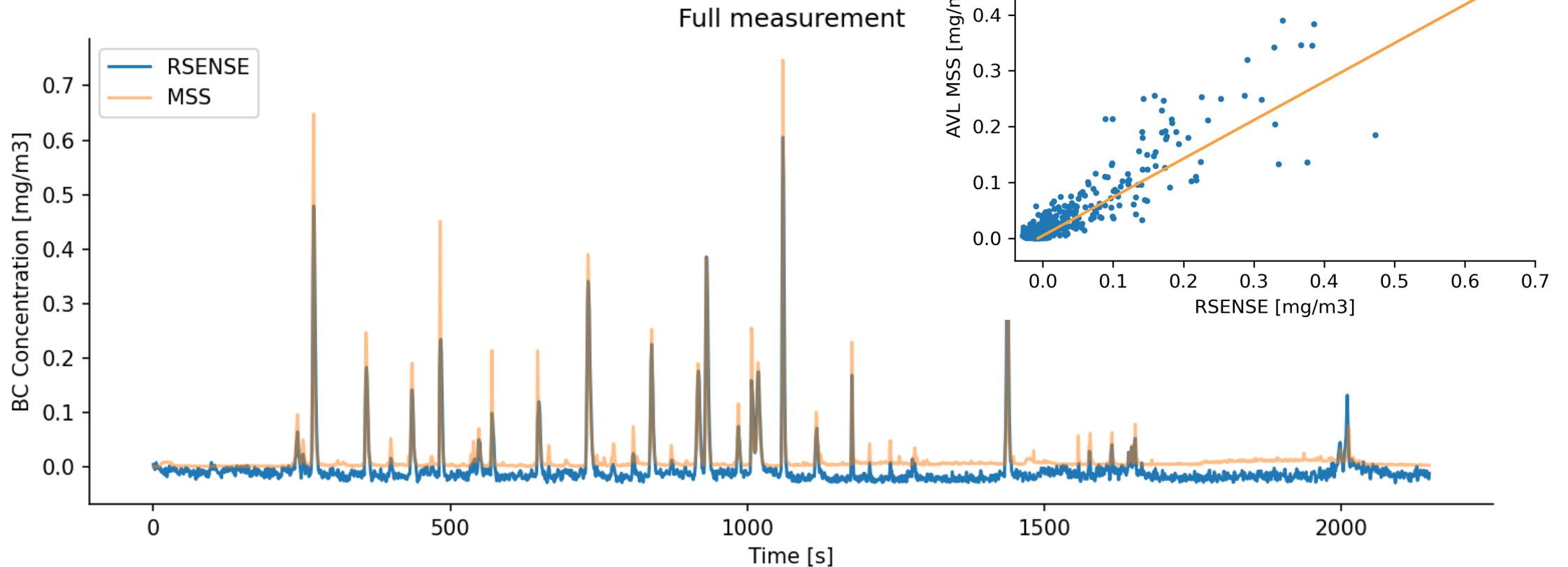


NO Sensor Evaluation

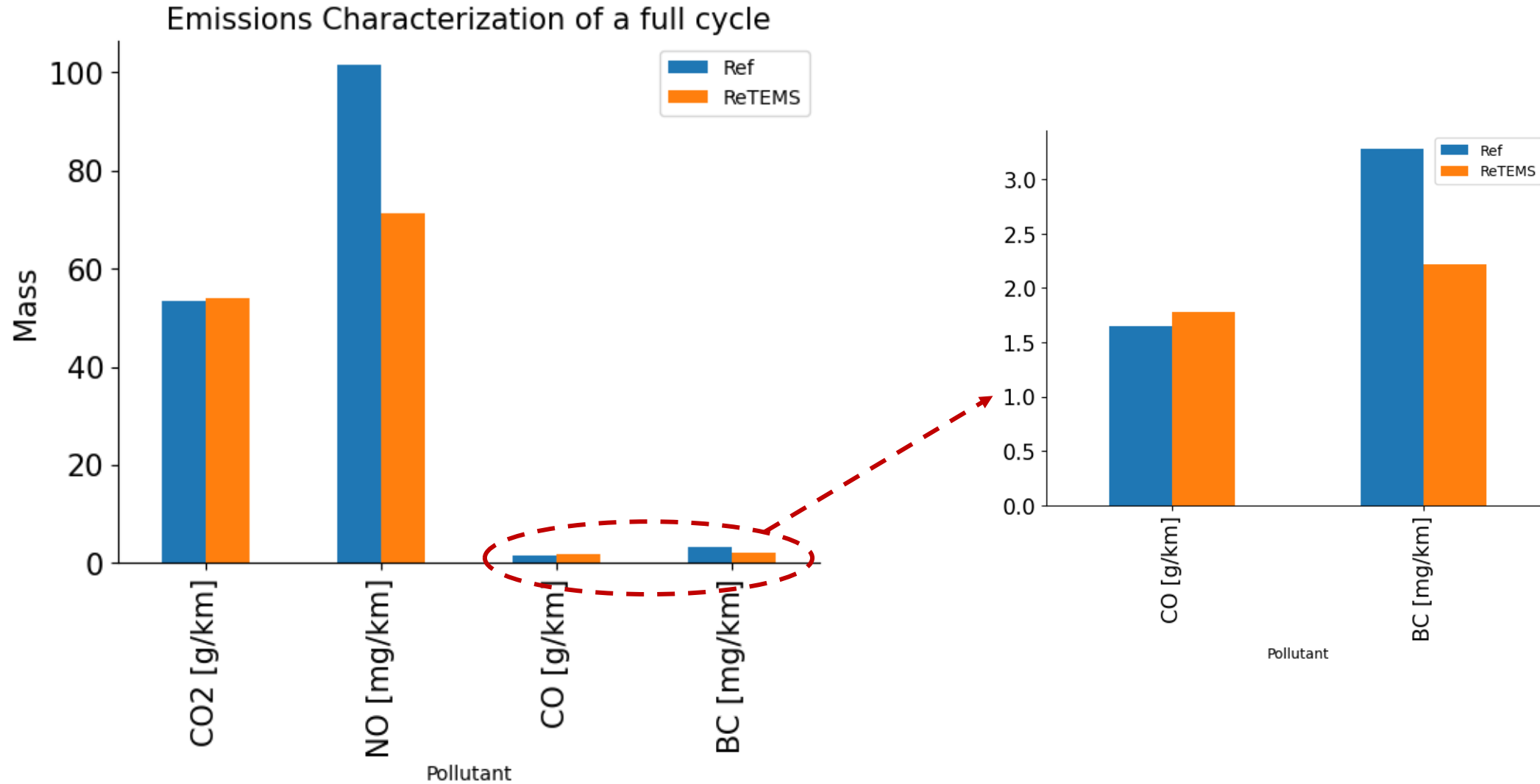


BC Sensor Evaluation

- Strong linear correlation with the MSS
- Sensitive dynamic response for “peaks” detection



Emissions characterization



Conclusions and next steps

- Good correlation of ReTEMS system with reference instruments in the lab
- Sufficient dynamic response for “peak events”
- Possibility for tampering detection
- Suitability for real-world measurements
- LENS campaign until 09/2024 with various L-vehicles
- Comparison and correlation of on-road and in-lab emissions
- Emission factors for different L-vehicles



**Thank you for your
attention!**



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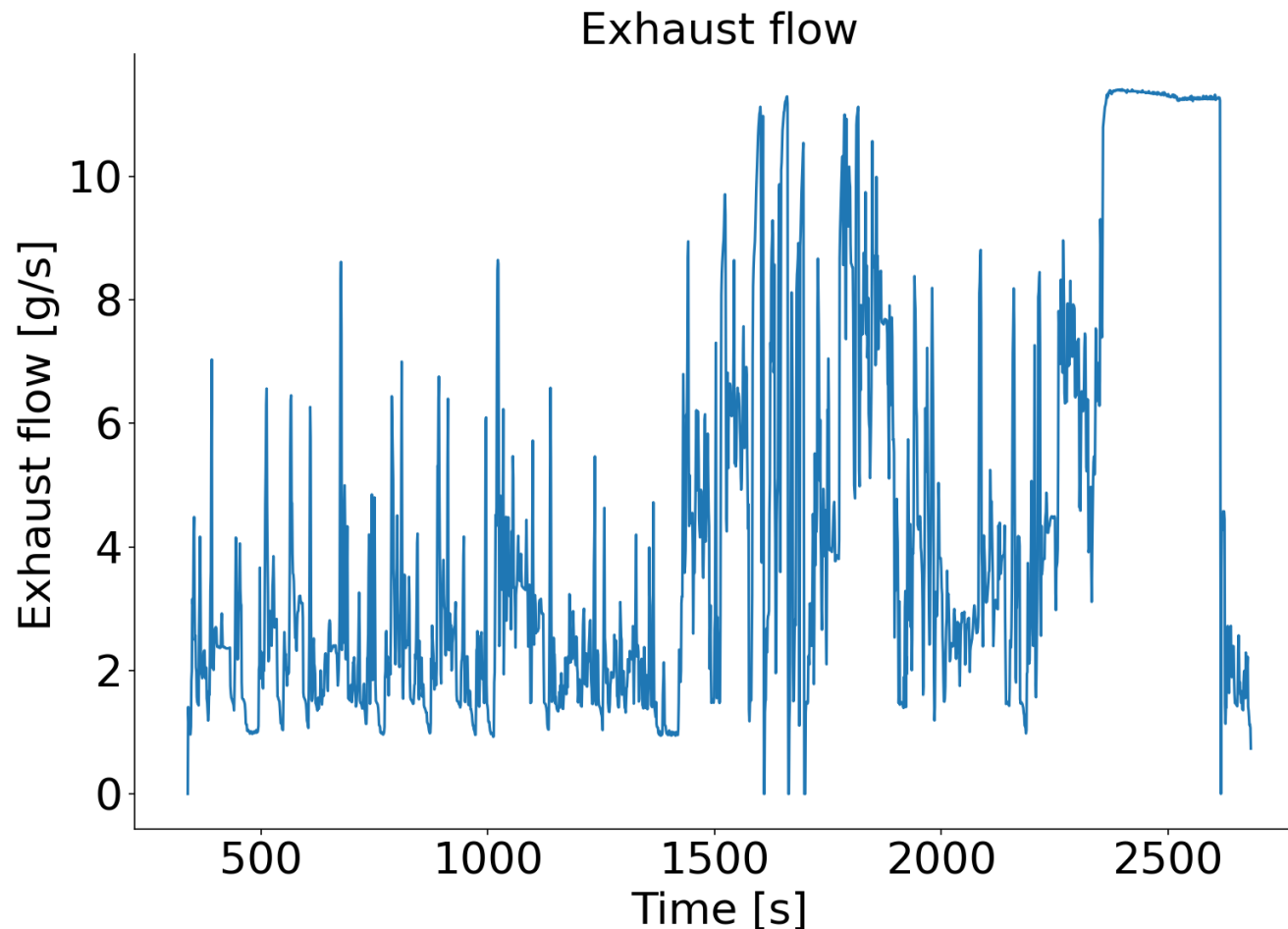
Acknowledgments

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Backup slide – Exhaust flow calculation



- Exhaust flow calculation using MAP and RPM data from the OBD
- VE calculated by performing steady state operation points on the chassis dyno and the CVS