

**French Institute
of Science and Technology
for Transport, Development
and Networks**

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Primary particle emissions and atmospheric ageing from road traffic

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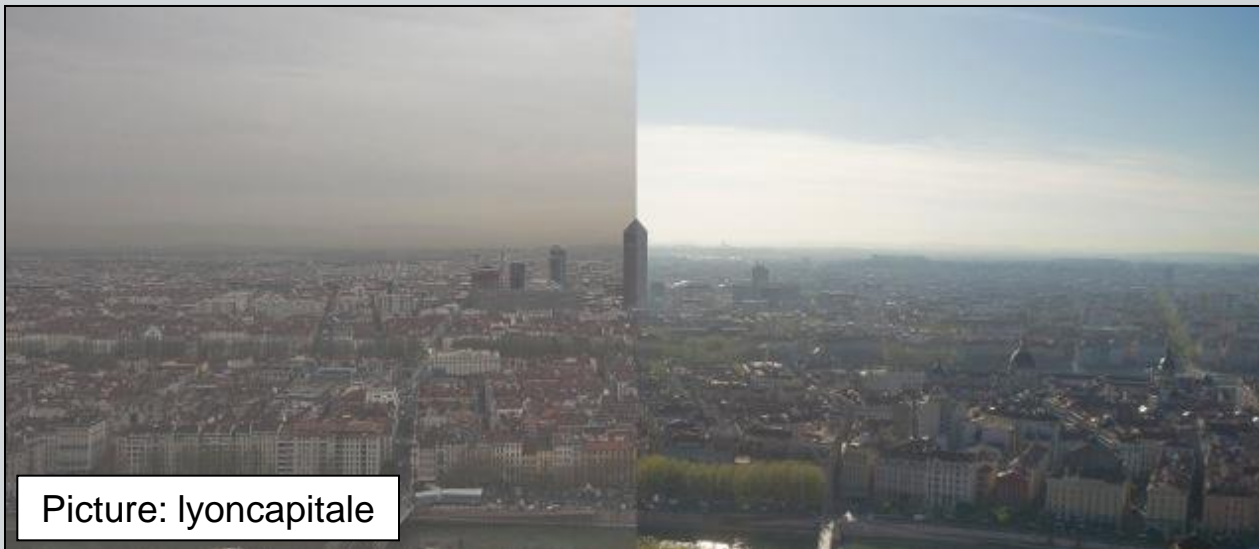


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becomes université
Gustave Eiffel



Introduction

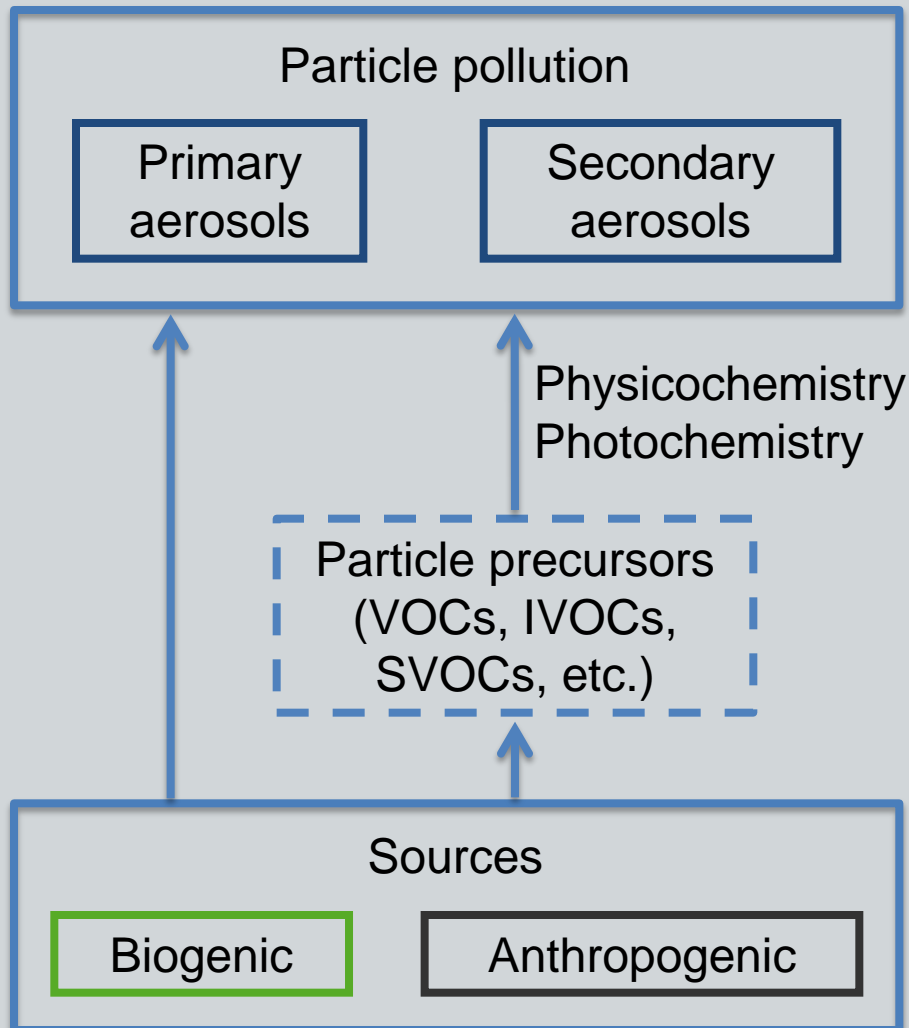
- 600 000 prematured deaths / year in Europe ⁽¹⁾
- US\$ 1.5 trillion / year in Europe ⁽¹⁾
- Road traffic contribution
 - 54% of NO_x ⁽²⁾
 - 46% of BC ⁽²⁾
 - 30% of PM_{2.5} in Lyon ⁽³⁾



- (1) Economic cost of the health impact of air pollution in Europe, WHO, 2015.
- (2) Rapport national d'inventaire, CITEPA, 2015.
- (3) Bilan de la qualité de l'air en 2017, Atmo AURA, 2018.



Primary and secondary particles



- **Precursor emissions**
 - Sampling methodology (dilution & temperature)
 - Unspeciated organics
 - **Particle formation**
 - Complex processes
 - Lab conditions \neq atmospheric
- **Road traffic contribution to particle pollution not accurately described in air quality models**



Objectives

- **Investigate emissions of several pollutants in different sampling conditions**



Methodology

In situ		Laboratory
<p>Tunnel de la Défense (Paris)</p> <p>→ Representative driving conditions</p> <p>→ Avoid external pollution sources</p>	<p>Near-road urban area (Lyon)</p> <p>→ Representative driving conditions</p> <p>→ Real atmospheric conditions</p>	<p>Chassis dynamometer</p> <p>→ Specific vehicles and technologies</p> <p>→ Repeatability</p>

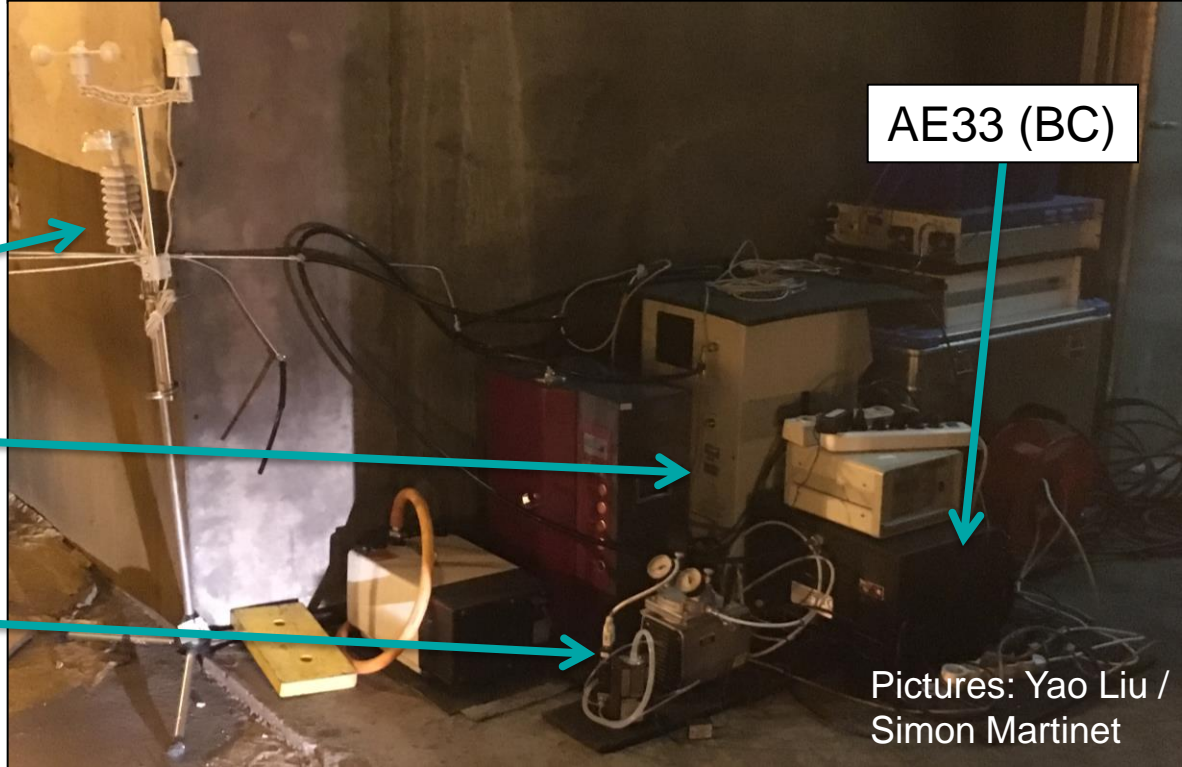
Emission factors (EFs) of:

- Particle number (PN)
- Black Carbon (BC)
- Intermediate-Volatility Organic Compounds (IVOCs)



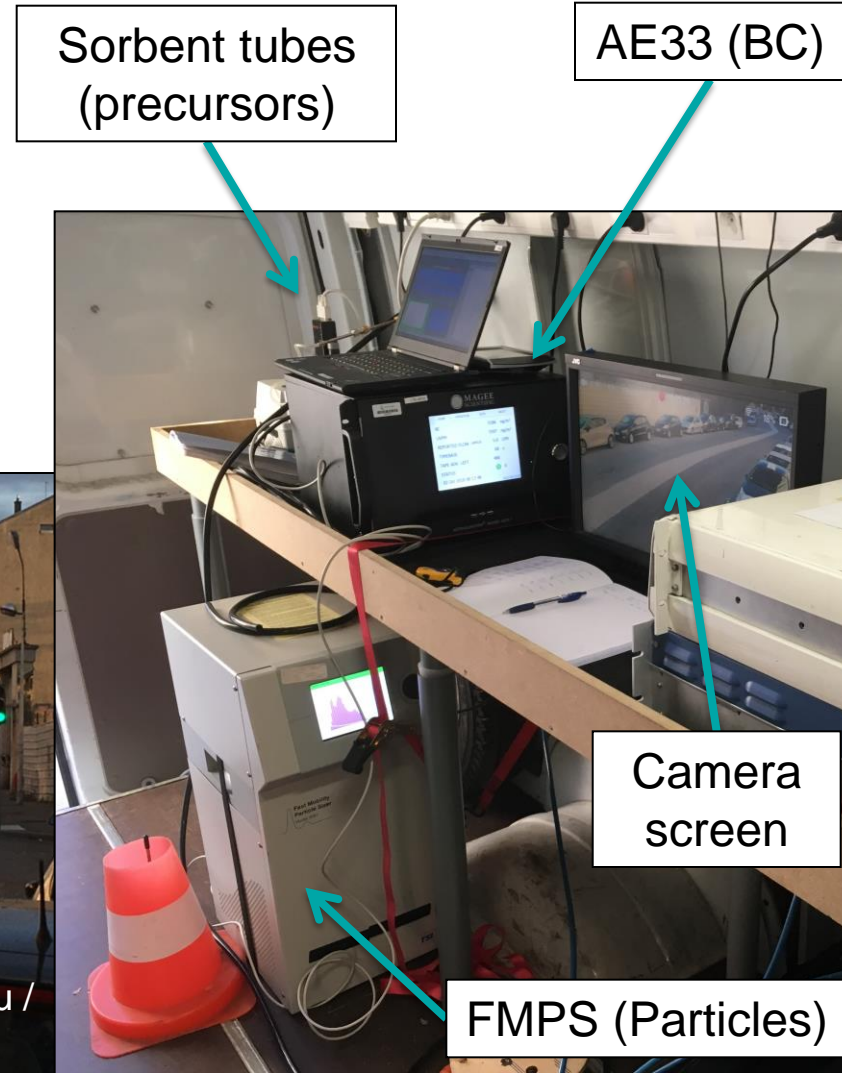
Tunnel experiment

- 70 km/h (43 miles/h)
- June
- 25° celsius (77° F)
- 7 am – 9 pm



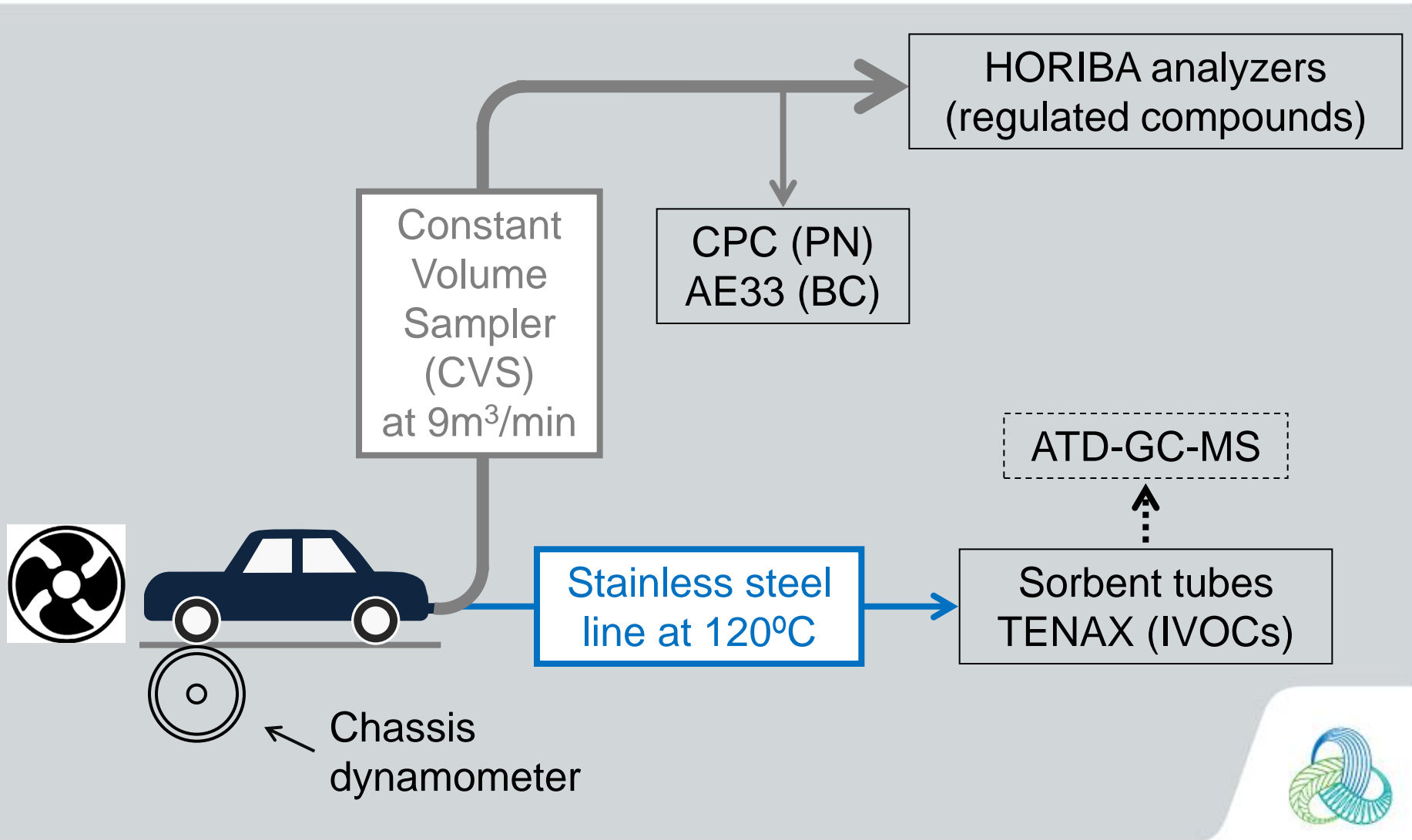
Near-road experiment

- 50 km/h (31 miles/h)
- October
- 15° celsius (59° F)
- 8 am – 10 am



Pictures: Yao Liu /
Simon Martinet

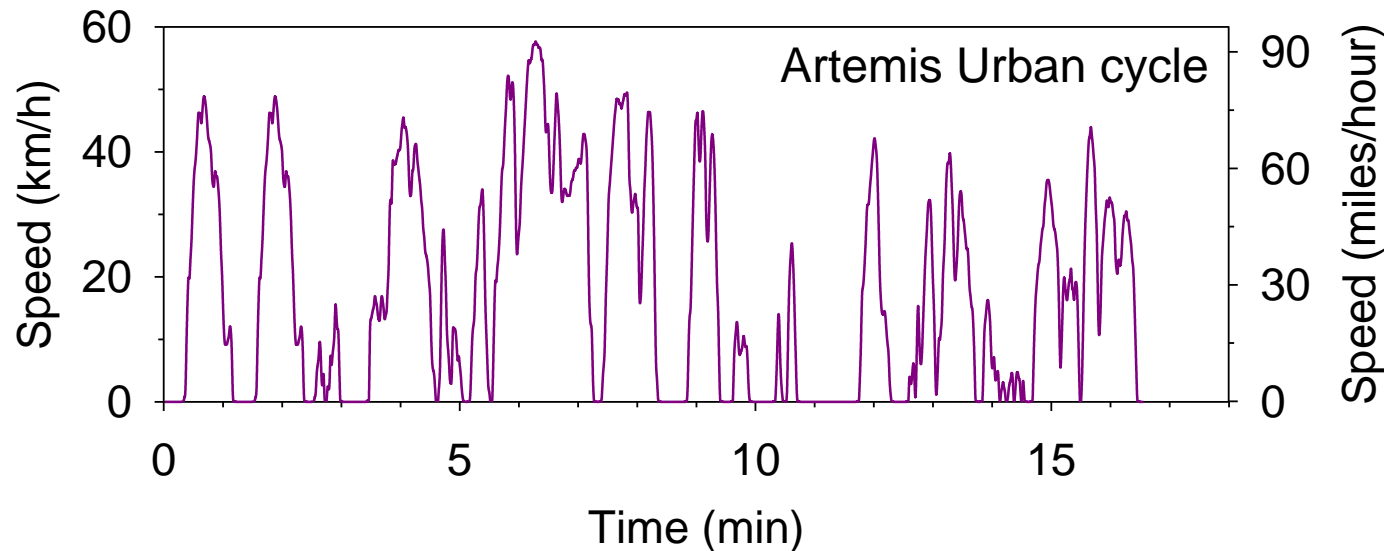
Dynamometer experiments



Dynamometer experiments

	Diesel	Gasoline
Euro 1 & 2	2 (litterature) (*)	
Euro 3	2	1
Euro 4	1 cat. DPF	1
Euro 5	2 add. DPF + 2 cat. DPF	1 + 1 DI
Euro 6	1 cat. DPF	1 DI

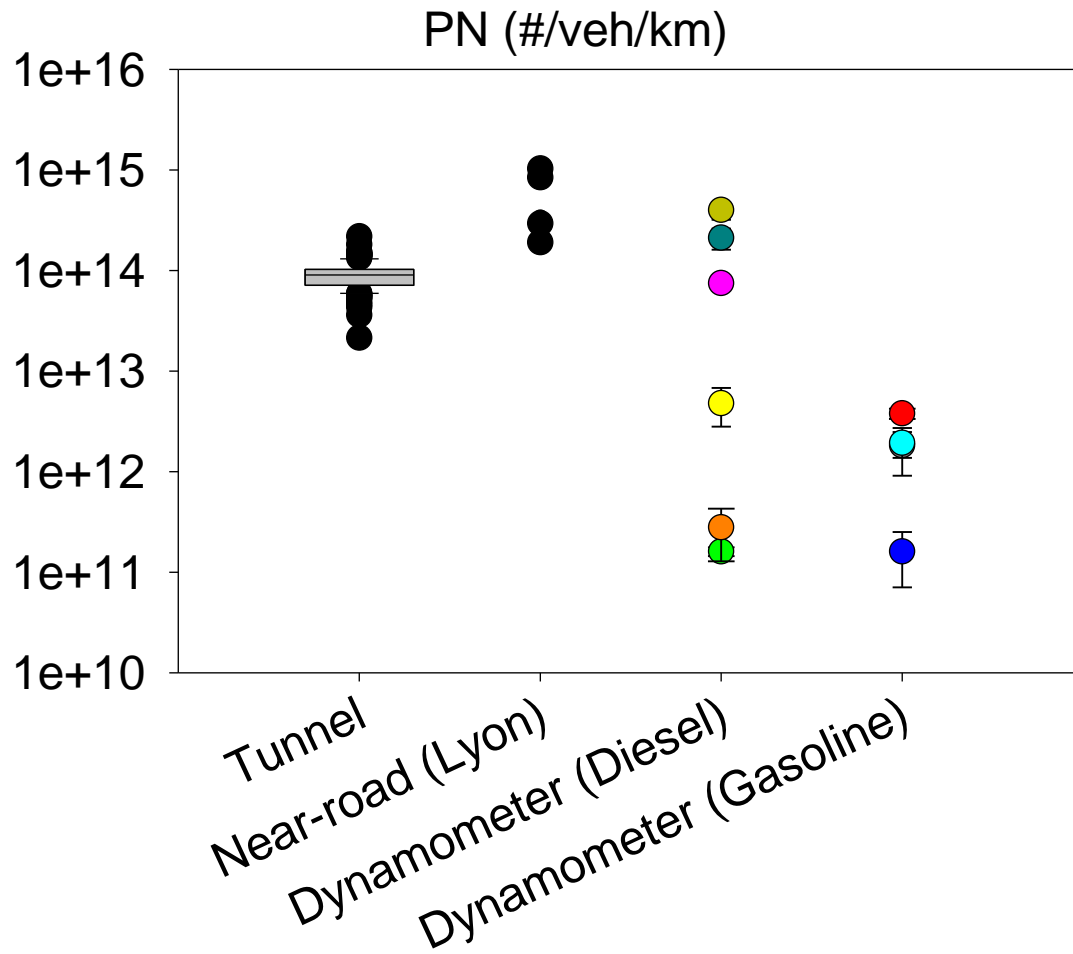
Dilution ratio	
CVS	Heated line
34	8.4



* EMEP/EEA (2016). URL <https://www.eea.europa.eu/publication/s/emep-eea-guidebook-2016>



Results: particle EFs

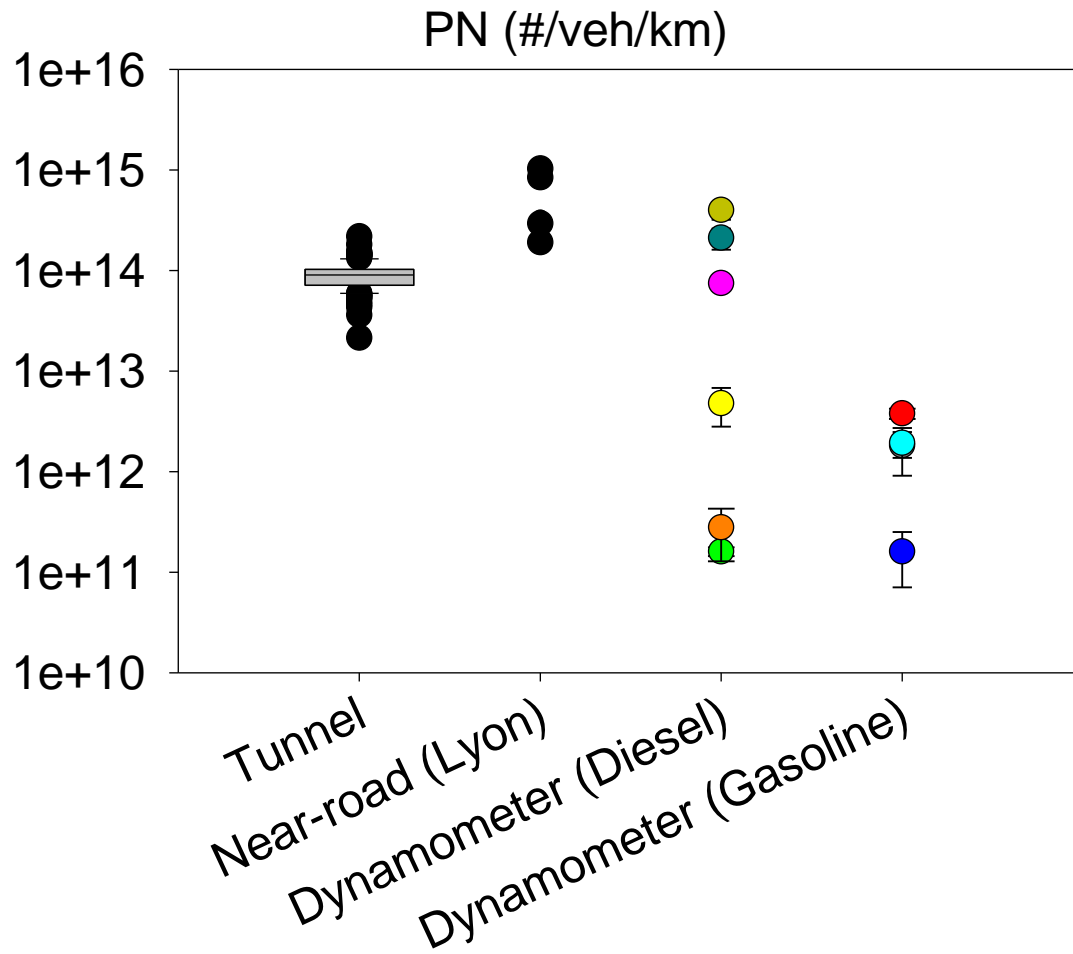


- **New diesel: PN ↓**
- **New gasoline: PN ↑**

- Euro 6 Diesel
- Euro 5 Diesel
- Euro 4 Diesel
- Euro 3 Diesel
- Euro 2 Diesel
- Euro 1 Diesel
- Euro 6 Gasoline
- Euro 5 Gasoline
- Euro 4 Gasoline
- Euro 3 Gasoline



Results: particle EFs

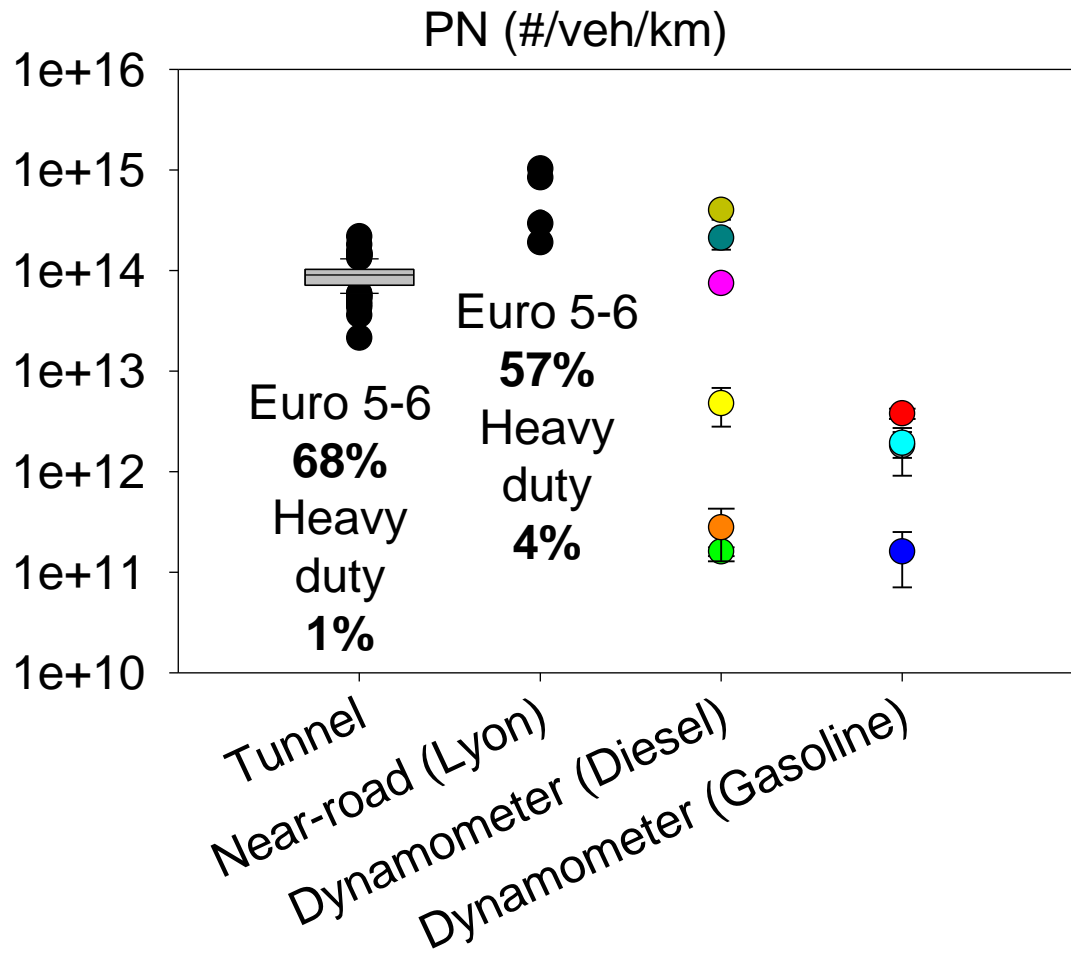


- **New diesel: PN ↓**
- **New gasoline: PN ↑**
- **Lyon: cold start effect**

- Euro 6 Diesel
- Euro 5 Diesel
- Euro 4 Diesel
- Euro 3 Diesel
- Euro 2 Diesel
- Euro 1 Diesel
- Euro 6 Gasoline
- Euro 5 Gasoline
- Euro 4 Gasoline
- Euro 3 Gasoline



Results: particle EFs

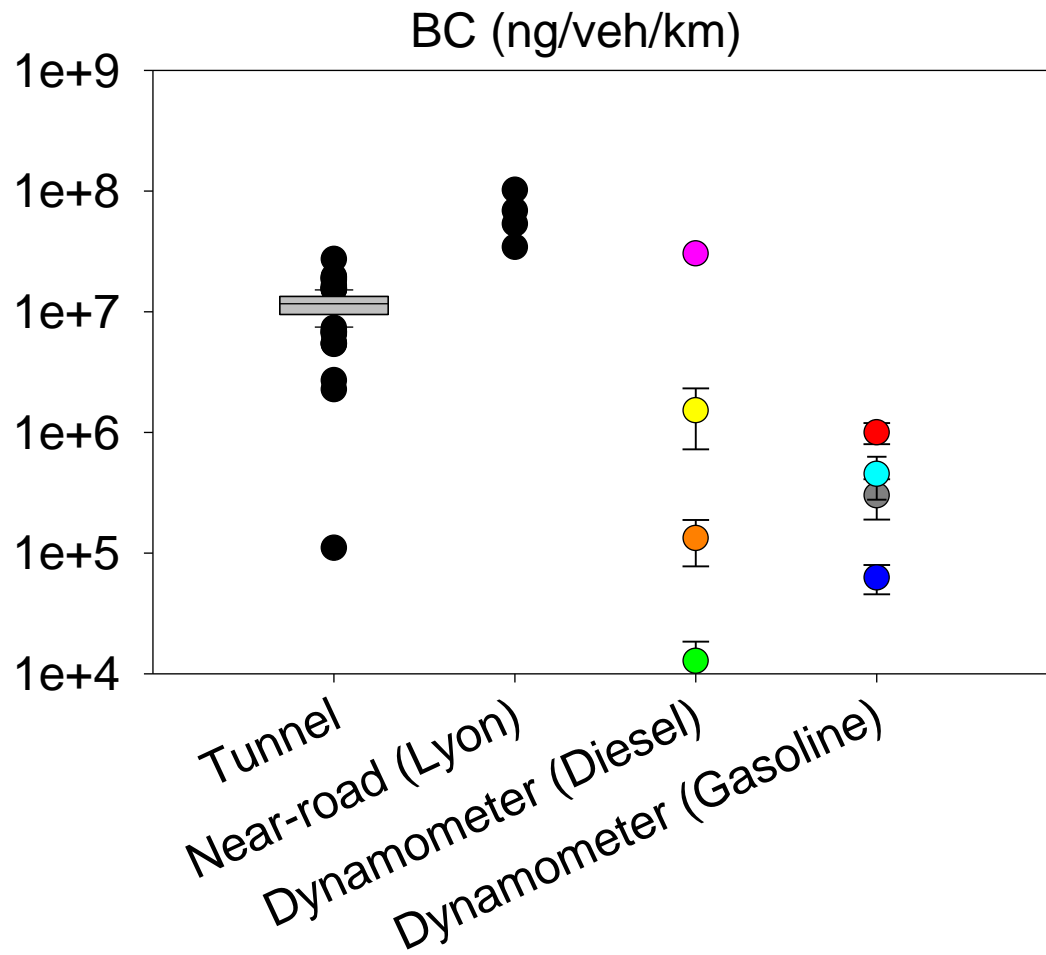


- **New diesel: PN ↓**
- **New gasoline: PN ↑**
- **Lyon: cold start effect**
- **Impact of the fleet**
 - Tunnel: more recent
 - Lyon: heavy duty

- Euro 6 Diesel
- Euro 5 Diesel
- Euro 4 Diesel
- Euro 3 Diesel
- Euro 2 Diesel
- Euro 1 Diesel
- Euro 6 Gasoline
- Euro 5 Gasoline
- Euro 4 Gasoline
- Euro 3 Gasoline



Results: BC EFs

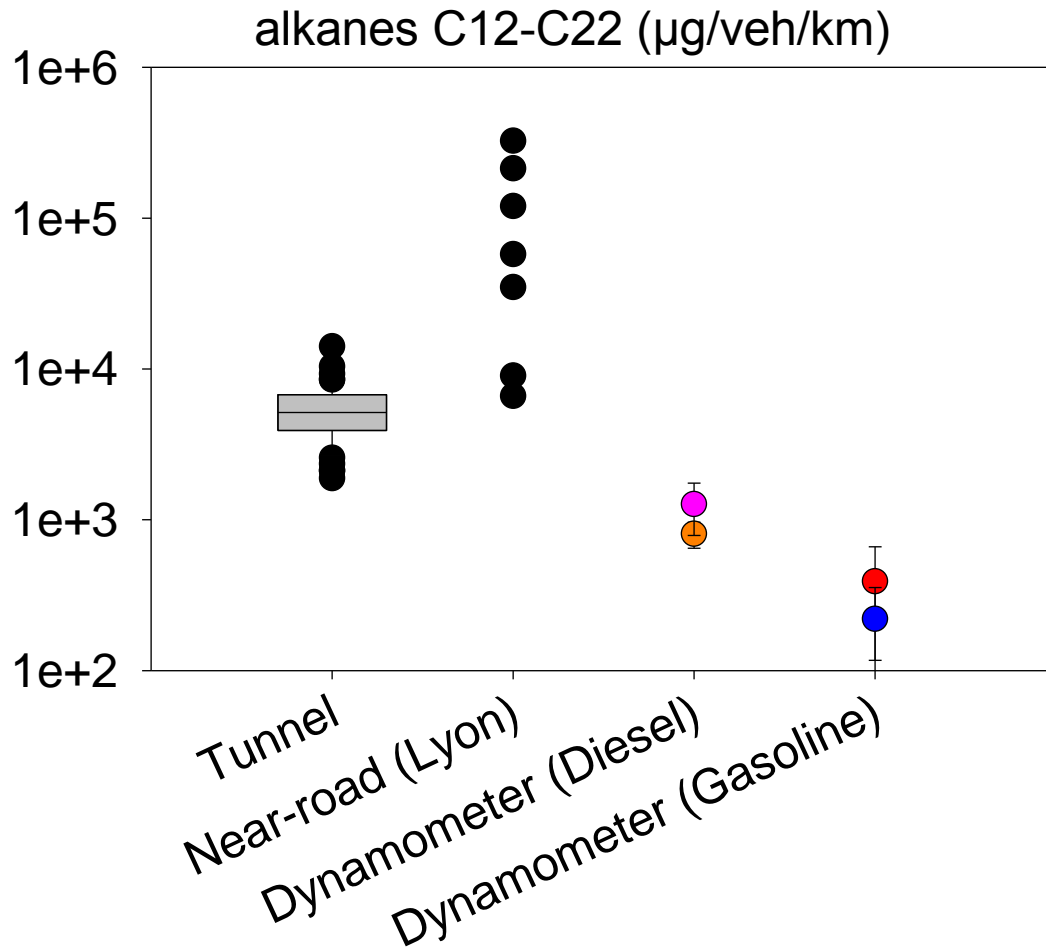


- **Great dependence on motorization and Euro norm**
- **Lyon: cold start effect**
- **Impact of the fleet**

- Euro 6 Diesel
- Euro 5 Diesel
- Euro 4 Diesel
- Euro 3 Diesel
- Euro 2 Diesel
- Euro 1 Diesel
- Euro 6 Gasoline
- Euro 5 Gasoline
- Euro 4 Gasoline
- Euro 3 Gasoline



Results: IVOC (alkanes) EFs

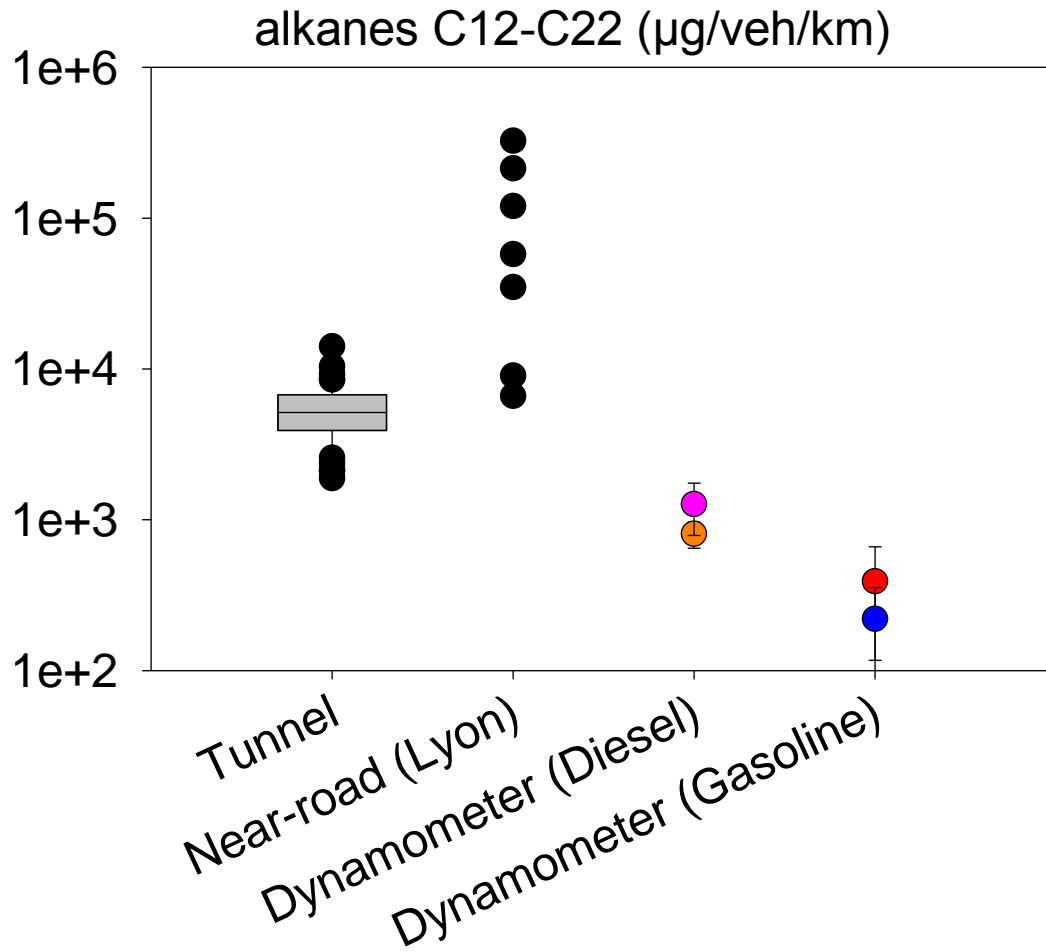


- Lyon: high variability

- Euro 6 Diesel
- Euro 5 Diesel
- Euro 4 Diesel
- Euro 3 Diesel
- Euro 2 Diesel
- Euro 1 Diesel
- Euro 6 Gasoline
- Euro 5 Gasoline
- Euro 4 Gasoline
- Euro 3 Gasoline



Results: IVOC (alkanes) EFs

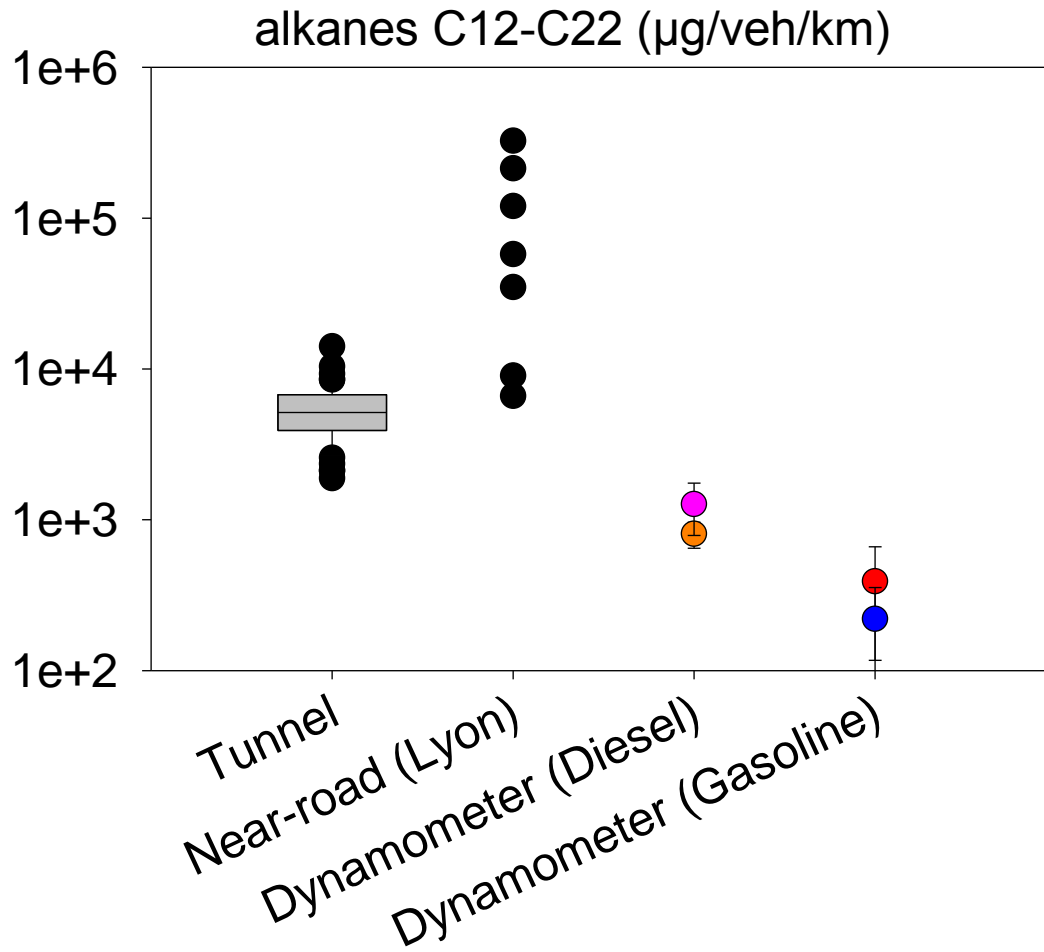


- Lyon: high variability
- $EF_{\text{in situ}} > EF_{\text{dynamo}}$

- Euro 6 Diesel
- Euro 5 Diesel
- Euro 4 Diesel
- Euro 3 Diesel
- Euro 2 Diesel
- Euro 1 Diesel
- Euro 6 Gasoline
- Euro 5 Gasoline
- Euro 4 Gasoline
- Euro 3 Gasoline



Results: IVOC (alkanes) EFs



- **Lyon: high variability**
- **$EF_{\text{in situ}} > EF_{\text{dynamo}}$**
- **Effect of sampling conditions and dilution:**
 - ~ 8 (dynamometer)
 - > 1000 (ambient)

- Euro 6 Diesel
- Euro 5 Diesel
- Euro 4 Diesel
- Euro 3 Diesel
- Euro 2 Diesel
- Euro 1 Diesel
- Euro 6 Gasoline
- Euro 5 Gasoline
- Euro 4 Gasoline
- Euro 3 Gasoline



Conclusions and prospects

- **PN and BC emissions** ↘ for newer diesel vehicles but ↗ for newer gasoline vehicles
- **Major effects of dilution on IVOC measurements**
 - Low dilutions underestimate IVOC emissions
- **Investigate IVOC emissions in more conditions (driving, atmospheric, sampling methodology)**
- **IVOCs = important contribution to secondary particles: in situ studies to link with particle evolution**



Thank you for your attention

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Thanks to:



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Appendix 1: In situ measurements

Tunnel (Paris)

- 3 lanes – unidirection
- 70 km/h (43 miles/h)
- No heavy duty vehicles
- Avoid external pollution sources
- 7 days in June
- 25° celsius (77° F)
- 7am to 9pm + 1 night

Near-road (Lyon)

- 1 lane - bidirection
- 50 km/h (31 miles/h)
- All vehicles
- Representative conditions
- 3 days in October
- 15° celsius (59° F)
- 8am to 10am



Appendix 2: In situ EF determination

- **Traffic characterization**

- Recorded by camera
- Categorized by type, motorization, Euro norm

- **Background concentrations**

- Lyon: away from traffic
- Tunnel: closed 1 night

- **NO_x EFs from COPERT 5**

- $$EF_p = \Delta[P] \times \frac{EF_{NO_x}}{\Delta[NO_x]}$$

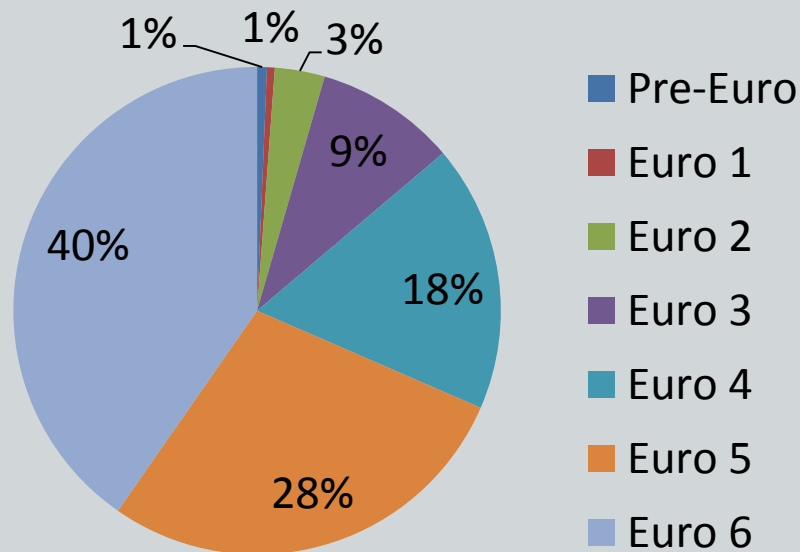
Euro 1	Jan 1 st 1993
Euro 2	Jully 1 st 1996
Euro 3	Jan 1 st 2001
Euro 4	Jan 1 st 2006
Euro 5	Jan 1 st 2011
Euro 6b	Sept 1 st 2018
Euro 6c	Sept 1 st 2019

European pollutant regulation norms



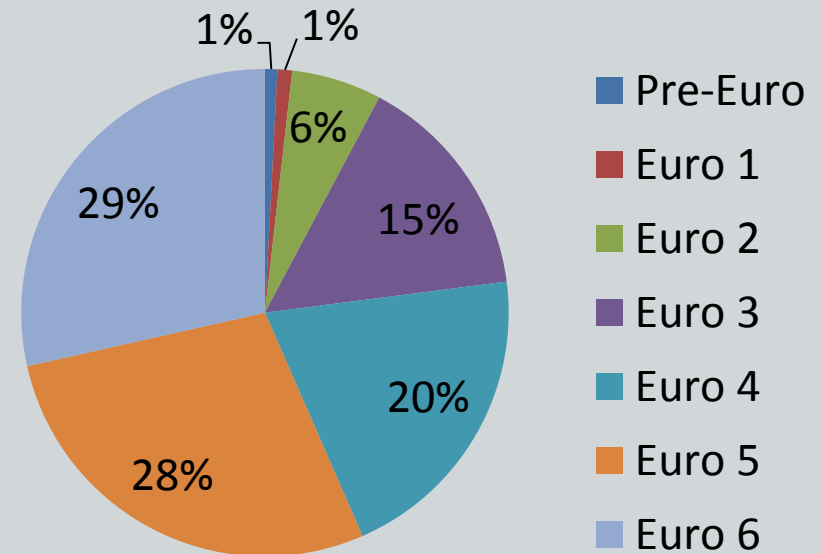
Appendix 3: In situ fleets

Tunnel



- **Passenger cars: 87%**
- **Heavy-duty: ~ 1%**
- **Diesel ~ 65%**
- **Gasoline ~ 30%**

Lyon



- **Passenger cars: 75%**
- **Heavy-duty: ~ 4%**
- **Diesel ~ 65%**
- **Gasoline ~ 30%**



Appendix 4: IVOC potential on particle formation

- IVOCs can play an important role in particle formation
 - Nucleation
 - Condensation
- Particle mass (PM) ↗ in dark prototype chamber

	Dilution ratios	PM ↗	
Diesel (Euro 3-5)	19-387	3-51%	→ PM ↗ for both diesel and gasoline
Gasoline (Euro 3-5)	19-97	4-27%	→ PM ↗ for all Euro norms
			→ PM ↗ up to 50%

