The European Commission's science and knowledge service

Joint Research Centre

Stakeholder event 24 October 2018: Preparing for the future European Emission Standards for Light and Heavy Duty Vehicles

European Commission

Scientific evidence on vehicle’s emissions

G. Martini

Workshop:

24 Oct 2018, Brussels

Overview

- Emissions outside RDE boundary conditions
- Remote sensing
- Exhaust particle emissions: Sub-23 nm particles
- Non-exhaust particle emissions
- Additional pollutants

Emissions outside RDE boundary conditions

Effectiveness of RDE legislation

- RDE legislation appears effective in reducing real world emissions in new vehicle models
- Latest diesel models tested at the JRC show on-road NOx emissions well below the limit
- Investigation on emissions outside boundary conditions on-going.

Question: Is there any disproportional increase of emissions outside the boundary conditions?

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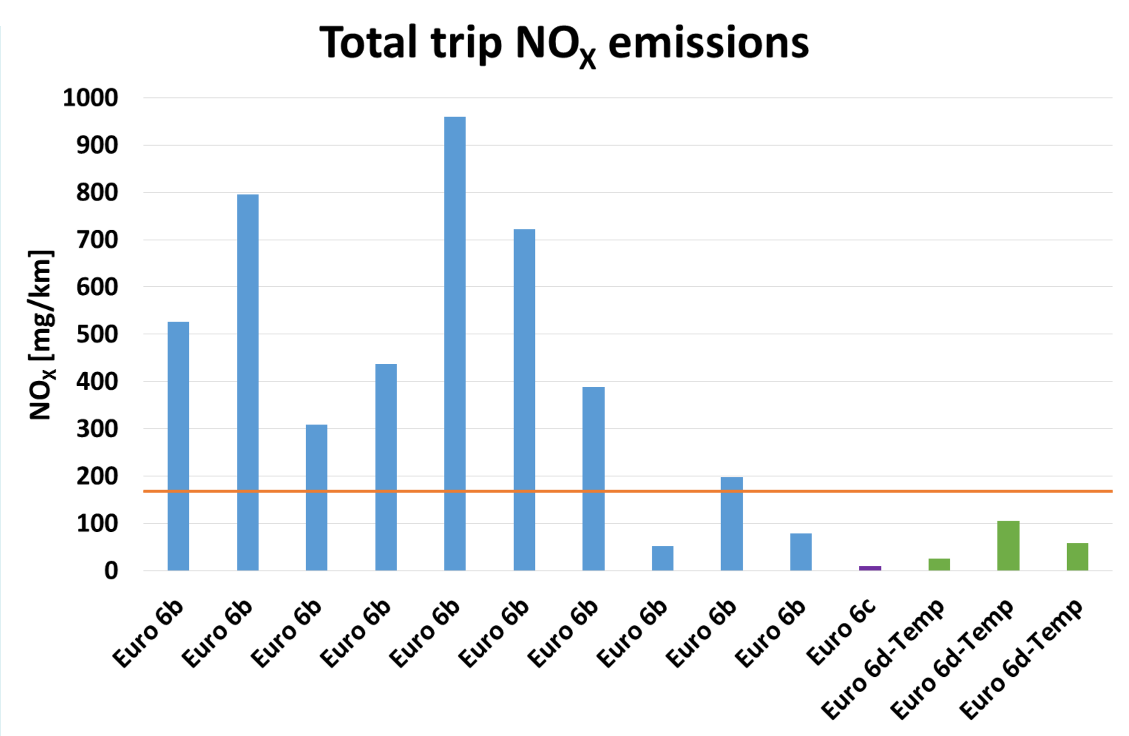
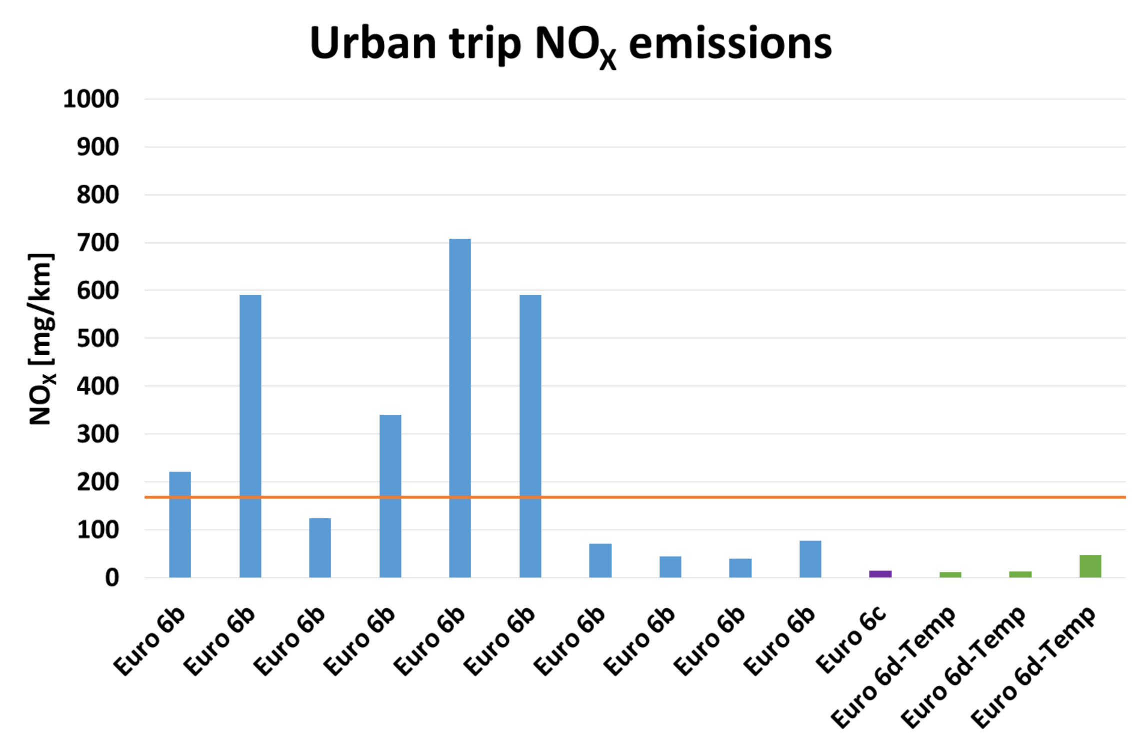
Overview of 2017/2018 JRC testing on diesel vehicles



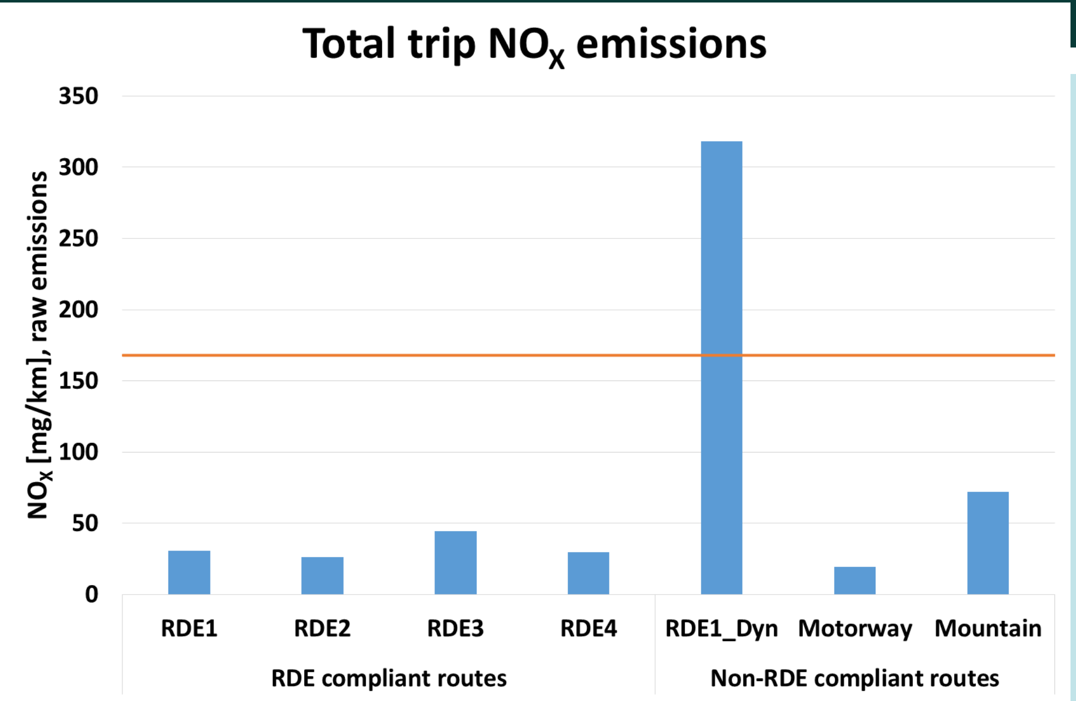


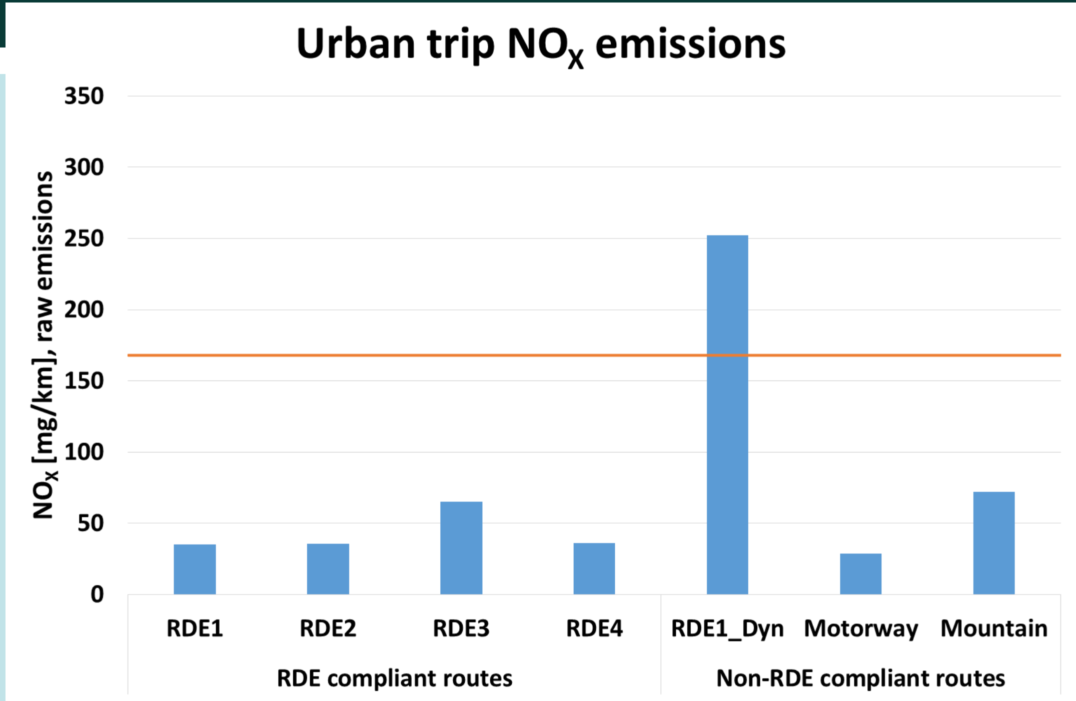
- The 3 Euro 6d-Temp vehicles tested so far show compliance with RDE NOX NTE limits
- Euro 6d-Temp show a clear reduction of NOx emissions on the road compared to an average Euro 6b diesel vehicle, although some late Euro 6b show low NOX emissions (vehicles equipped with SCR).

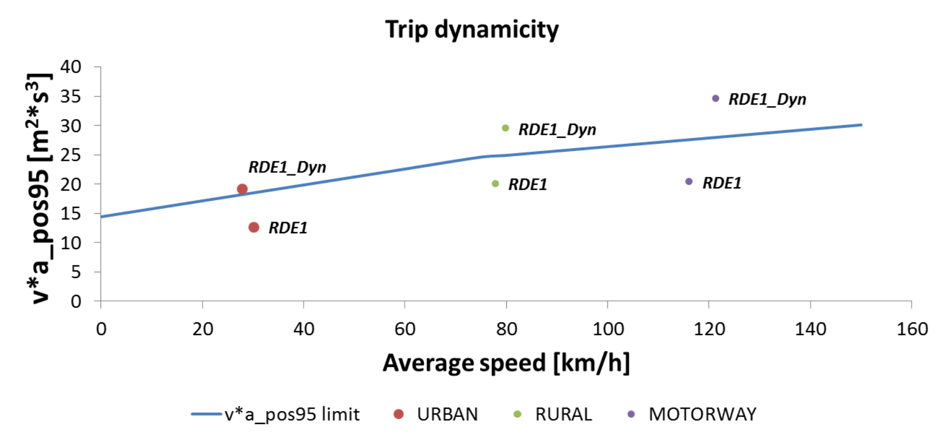
Current boundary conditions

- **Payload:** ≤90% of maximum vehicle weight
- **Temperature:** (0÷30 ºC ; extended -7 ÷35 ºC)
- **Altitude** (Moderate 0÷700 m; extended 700÷1300 m
- **Dynamicity** – Velocity times positive acceleration distribution (no excess, sufficiency)
- **Cumulative altitude gain:** 1200 m/100 km
- **Start/end test elevation difference**: 100 m
- **Stop percentage:** Between 6% and 30% of urban time
- **Maximum speed:** 145 km/h (160 km/h for 3% of motorway driving time)

Euro 6dTemp : Emissions over different RDE trips







- **Euro 6d-Temp vehicle**
- **EGR+DOC+SCR+DPF**
- **1.5 litres, 96 kW**

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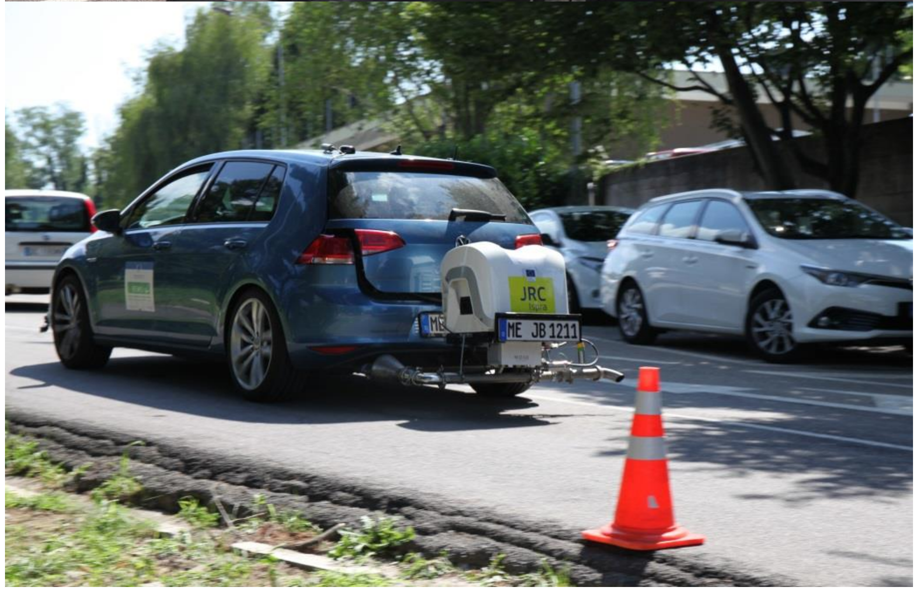
Remote Sensing Devices (RSD) for vehicle emissions

Why RSD are important

- Remote sensing may represent an extremely useful tool to :
    - Identify models that have higher emissions than average and that could be further investigated in market surveillance activity
    - Identify vehicles that have major problems (mechanical failures, not functioning emission control devices,…)
    - Identify tampered vehicles

JRC 2017 RSD Program: Overview

- 2017 Remote Sensing Devices (RSD) program: RSD Measurement performance assessment
- Electric vehicles equipped with gas bottles to simulate the vehicle exhaust i.e. realistic concentrations of CO2 and gaseous pollutants (NO, CO).
- Conventional vehicles of various emissions standards and equipped with a PEMS were also used to assess the ability of the RSD systems beyond the pollutants and the ranges simulated with the electric vehicle.



RSD Systems

RSD system 1

RSD system 2

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Test Site


Via Periferica Nord
Via Lussemburgo
Via Gran Bretagna
Via Francia
Via Germania
Via Olanda
Via Italia
Via E. Fermi
JRC Ispra
900,71 m
500,00 m
Mesurer une distance
Cliquez sur la carte pour ajouter la ligne au trajet.
Distance totale : 900,71 m (2 955,08 ft)
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Campaign description

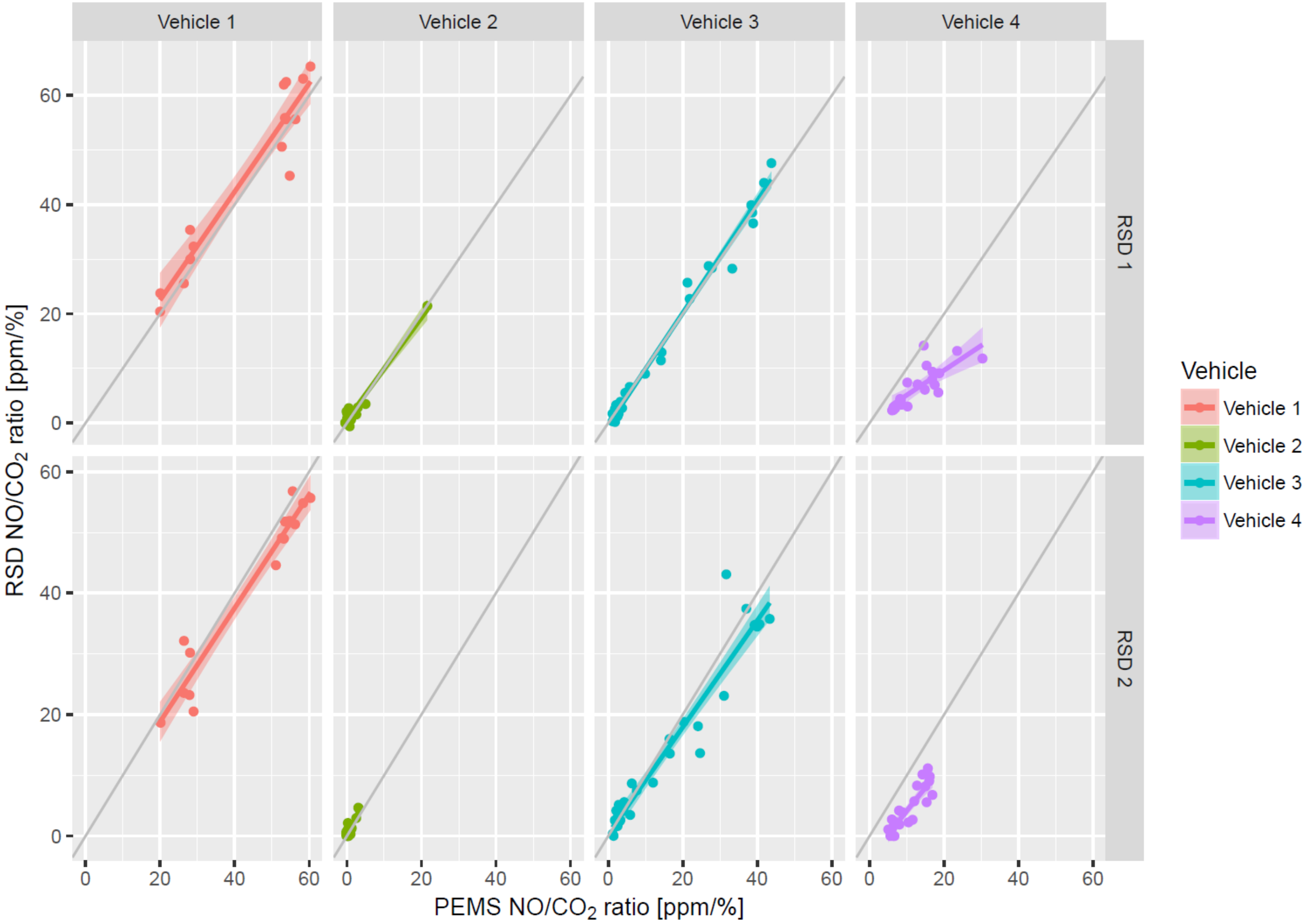
<u>Method</u> – Reference Vehicles Characteristics (with PEMS)

	Engine	Euro standard	Engine capacity [cm^3]	Power [kW]
Vehicle 1	Electric	-	-	-
Vehicle 2	Gasoline	Euro4	1368	57
Vehicle 3	Diesel	Euro6b	1968	110
Vehicle 4	Diesel	Euro6b	2967	184

Validation against PEMS measurement

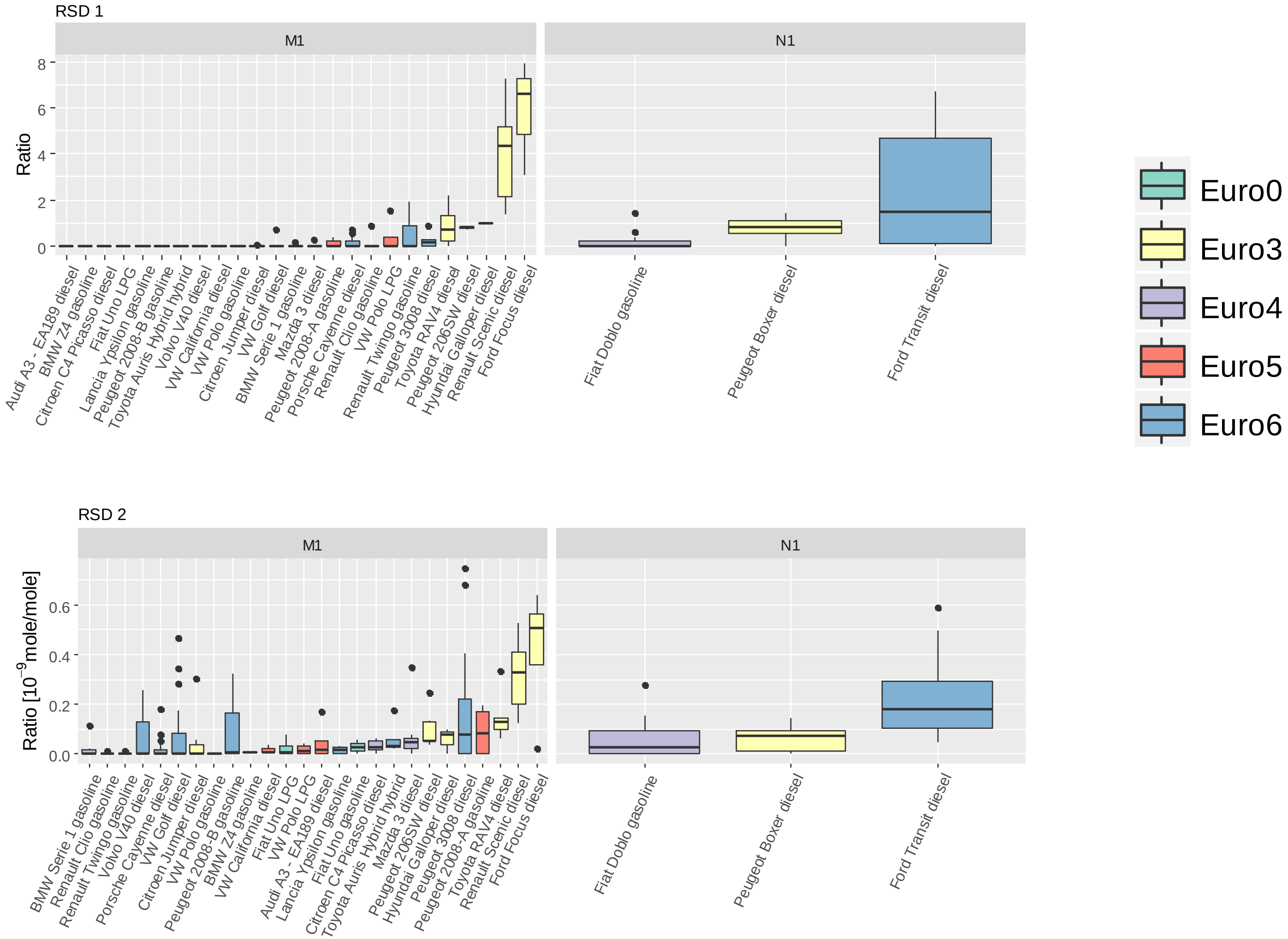
Validation

PEMS vs RSD



Application for monitoring

Results – Euro 6 Diesel with tampered DPF



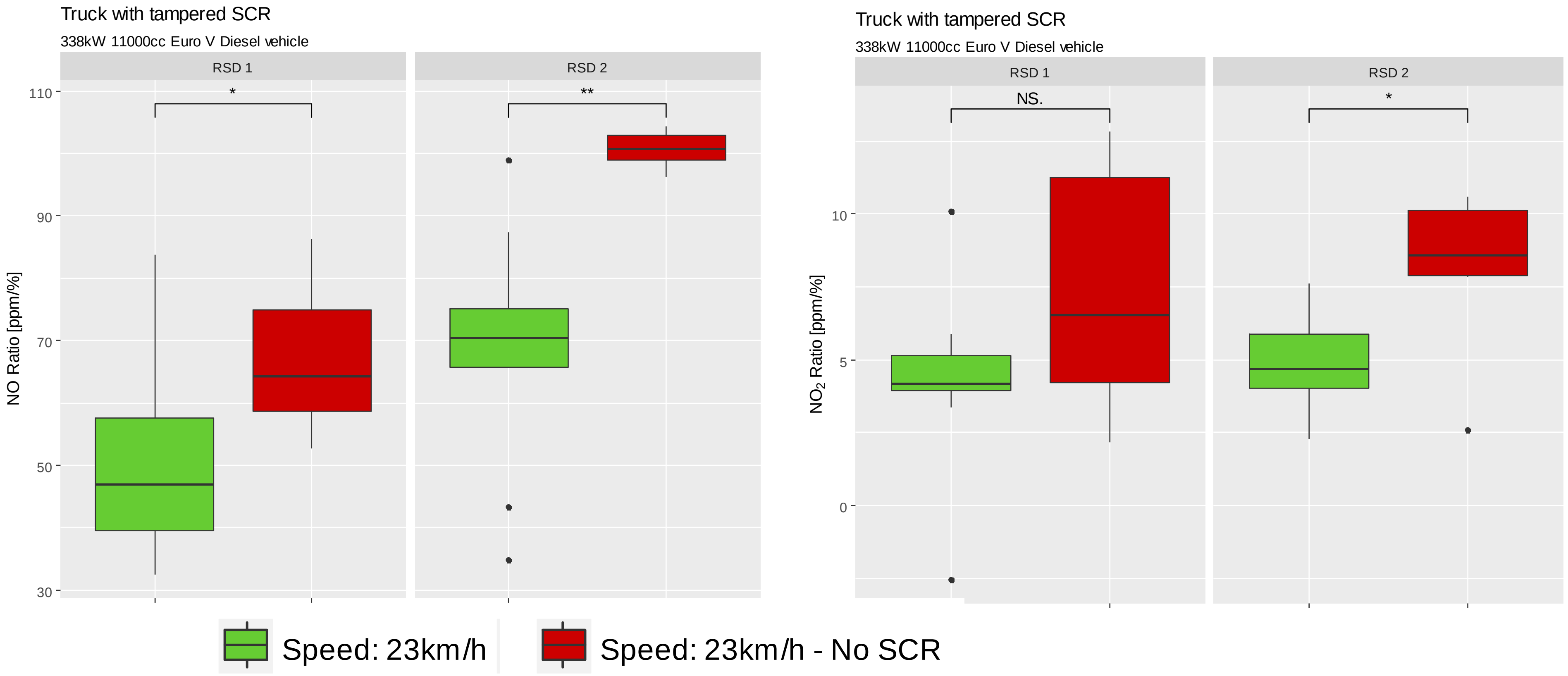
The emissions results of the vehicles are relative to each other and do not represent a judgment on their compliance with the emissions standards.

The tested vehicles are single and private vehicles. Their emissions behaviour does not necessarily reflect the emissions behaviour of the brand and model considered.

Some vehicles were tampered for the need of the project only.

Application for monitoring

Results – Euro VI Diesel Truck with tampered SCR



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Conclusions from JRC 2017 Program

- RSD Instrumentation measurement performance verified under real-world conditions
- Ability to discriminate emissions standards (Euro 0/Euro 6) within a given vehicle technology (diesel, gasoline, LPG, with and without DPF)
- Ability to detect tampered or poorly performing vehicles (e.g. due to ageing effects), relative to the functioning ones
- RSD provides **relative** emissions information and is only **complementary** to detailed RDE/PEMS testing

Next Steps

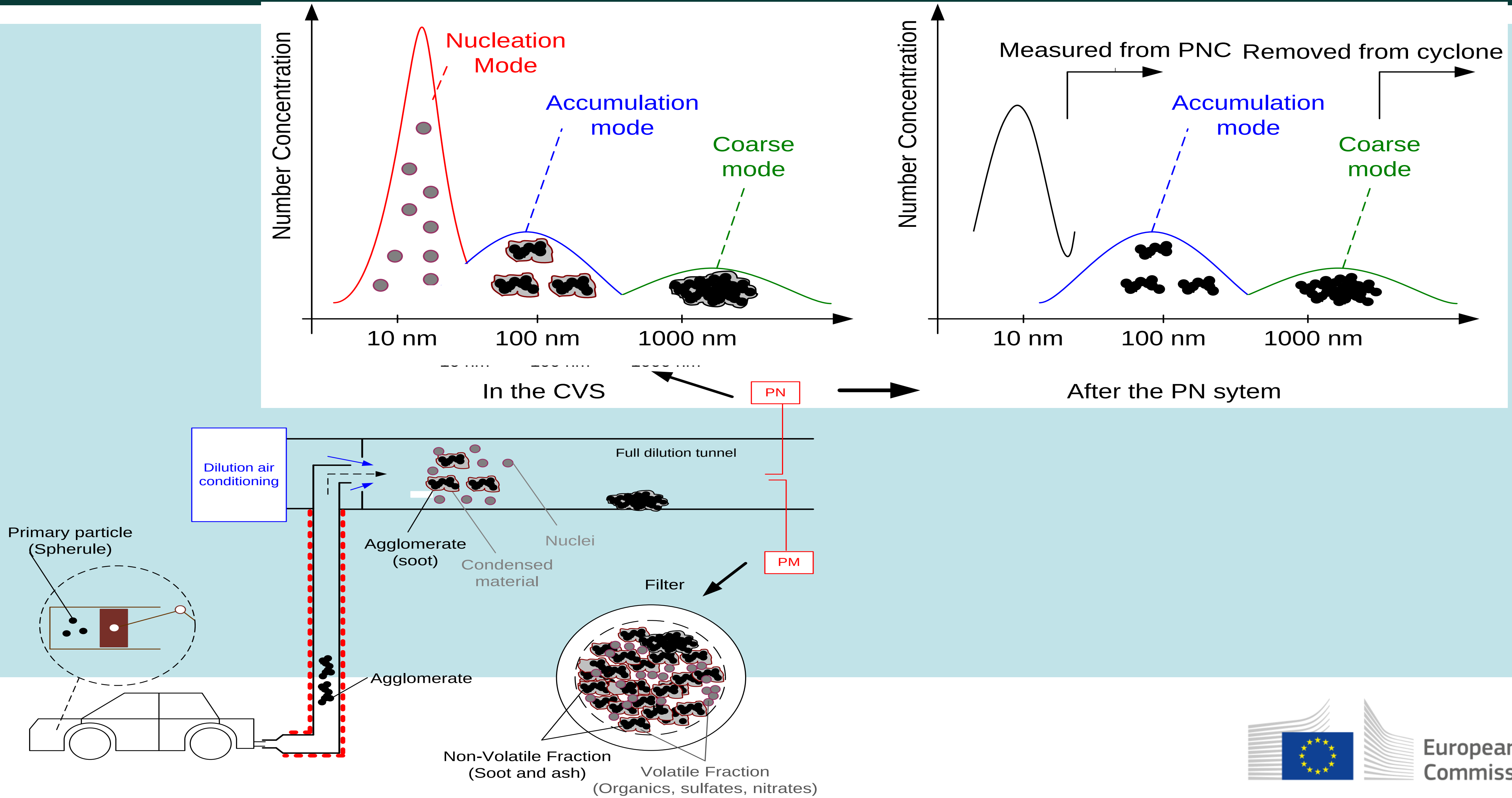
- Publication of JRC report
- To accompany a potential RSD deployment for ISC, development of technical recommendations for equipment installation and data processing

EXHAUST PARTICLE EMISSIONS: Sub-23 nm particles

What is measured by the PMP method

- Solid particles defined by the measurement equipment :
  - Particles with a size from ~23nm to 2.5µm and surviving evaporation in the range 300 ºC to 400 º C
  - Particles are counted by means of a condensation particle counter, but the sample is pre-conditioned to eliminate most volatile particles which may contribute significantly to variability
- Why measuring from 23 nm only?
  - Nuclei mode very sensitive to sampling conditions – maximizing repeatability/reproducibility
- How was the PN limit set?
  - Based on the BAT emissions (DPF) + uncertainty + engineering margin

What is measured by the PMP method



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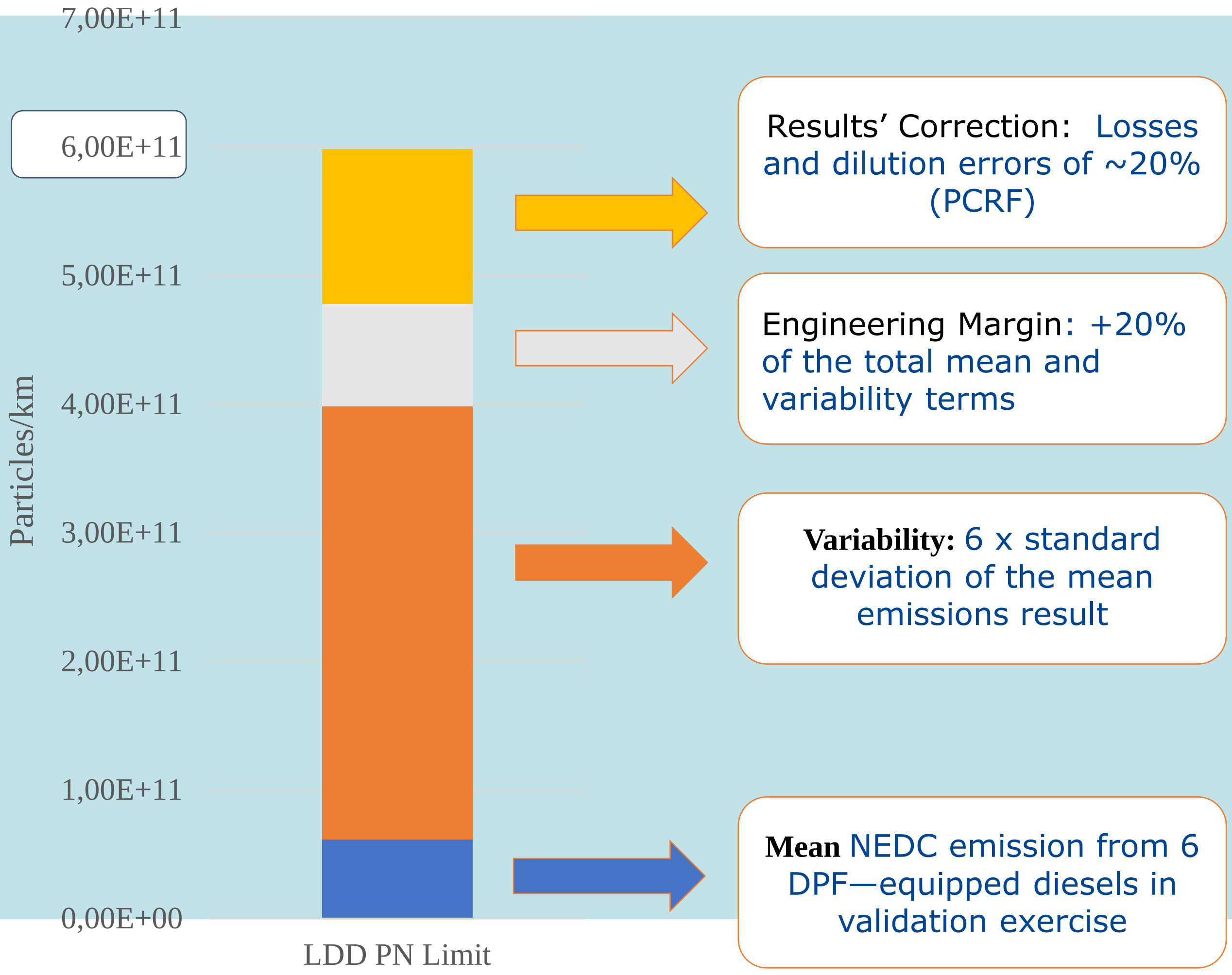
How was the PN limit set?



- Limit value constructed from several factors
- Aim to be easily complied with by DPF diesel, but not with partial / open filters (efficiencies ~60%)
- Typical non-DPF PN emissions value was 5×10^{13} /km
- Filtration efficiency required > 98%

Slide from Jon Andersson - Ricardo

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UNECE PMP IWG current scope

- Calibration procedures update (and <23nm if necessary)
- Regeneration (PMP >23nm).
- Measurement of particles <23 nm
- Engine dyno tailpipe PN measurements for HD at Type Approval
- NRMM (only guidance document)
- Low Temperature testing (only feedback)

Is there a need to regulate <23 nm?

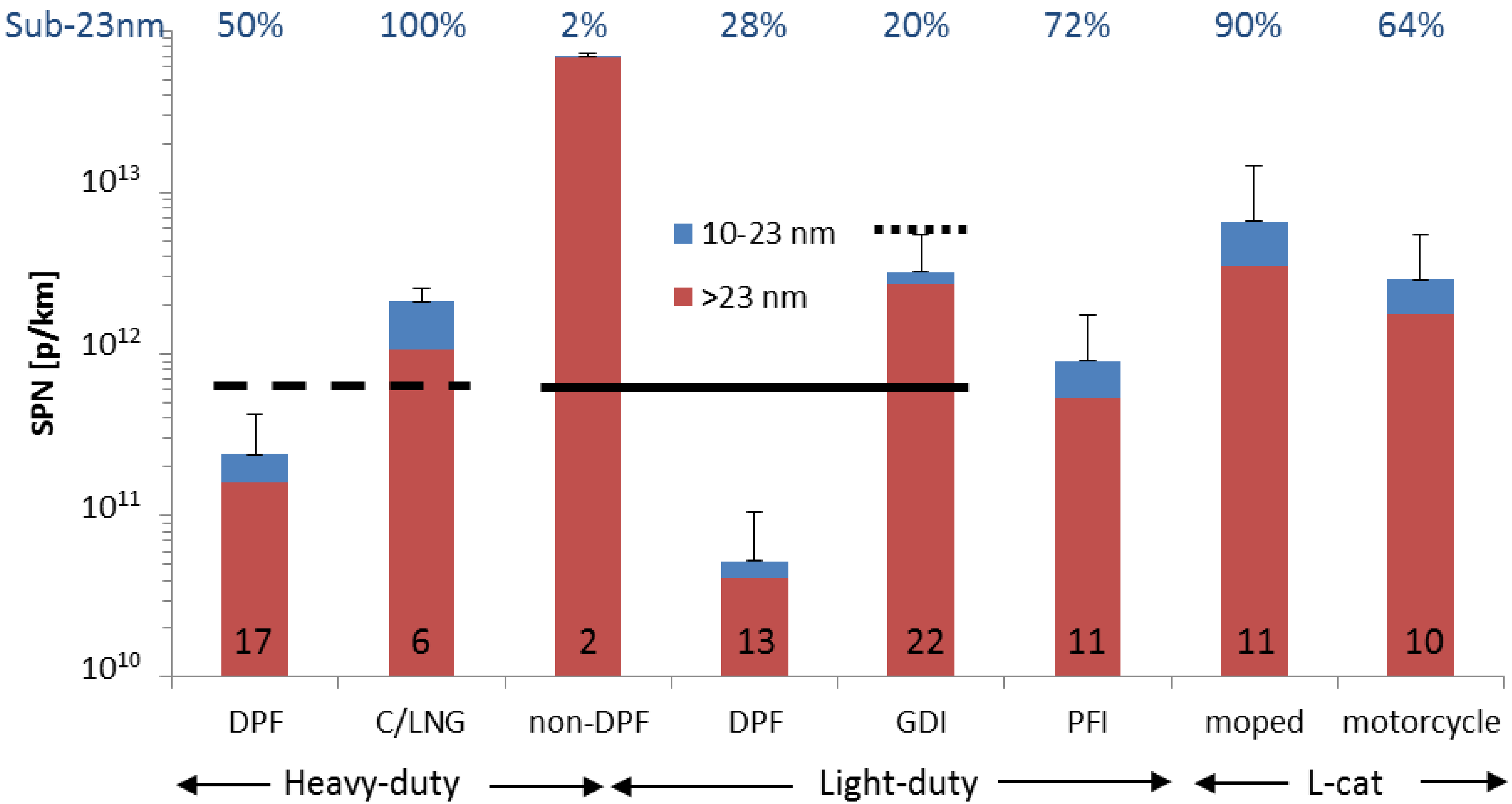
- Literature review: Emission levels of sub23nm
  - There are particles <23nm

- Experimental investigation at JRC
  - There are particles <23nm
  - Sometimes they are an artefact
  - "Real particles" are on average 30-40% on average over a test cycle (GDI)

Monitoring of sub-23 nm particles

- Diesel: <50%
- GDIs: 20%
- CNG: 100%
- Motorcycles: >60%

- Fractions are important only if emissions are close to the SPN limit



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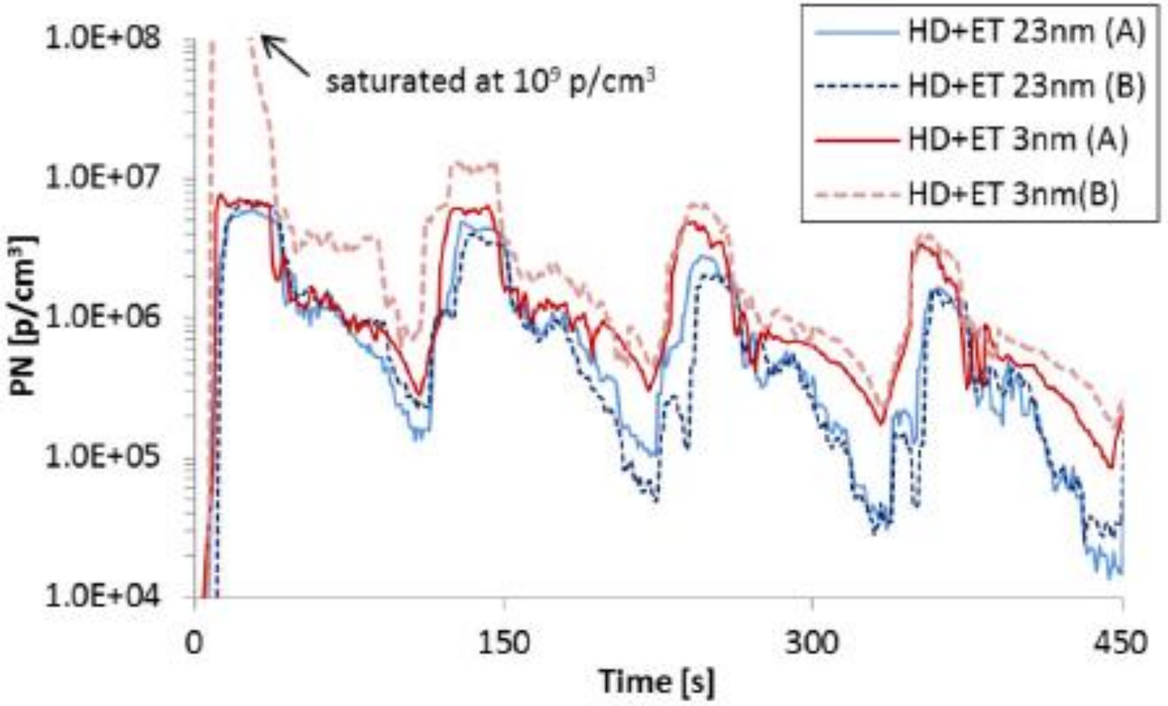
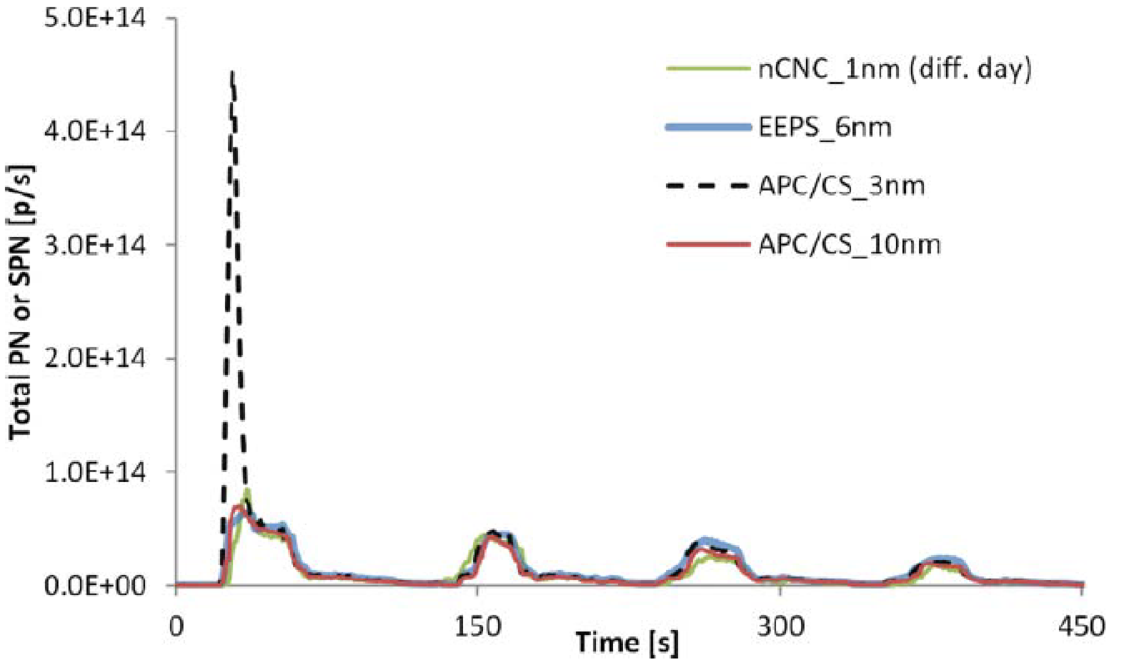
(Volatile) artefact

- Volatile artefact:
  - Renucleation of volatiles after the evaporation tube or the catalytic stripper results in volatile particles being counted as solid
- Typically at cold start (high amount of volatiles)
- Quite often with DPF equipped vehicles (low soot)
- Even with catalytic stripper volatile artifact at the 3 nm range can appear





Measuring Sub23 nm particles

- Development of a sub23nm (cut-off size:~ 10 nm) particle number measurement procedure based on the existing PMP methodology conveniently adapted.

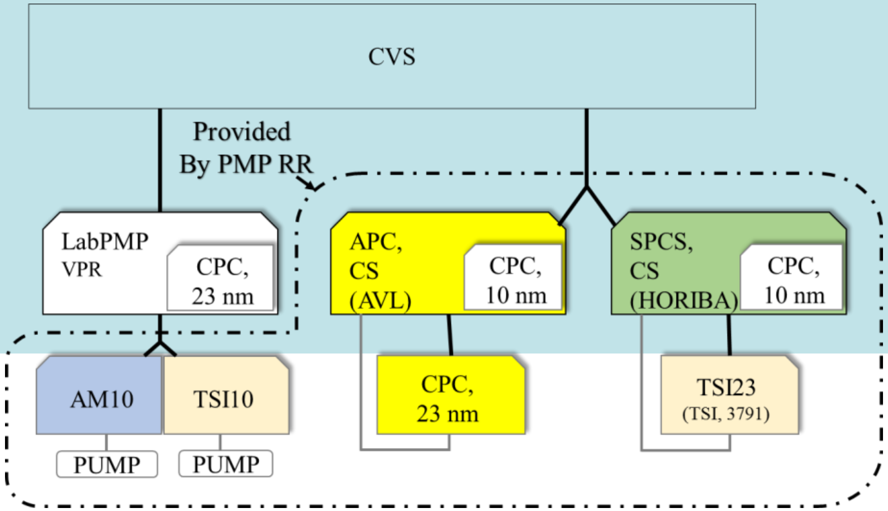
- Main purpose: Monitoring particle emissions of new engine/after-treatment technologies.

- Assessment of the repeatability/reproducibility of the proposed particle counting methodology by means of a “round robin”.

About the exercise

- Measurement of a LD GDI vehicle in 8 laboratories
- 3 cold WLTC, 5 hot WLTC, 1 steady speed test
- Objectives of the exercise is to
    - uncertainties PMP-23nm and PMP-10nm, the need of a catalytic stripper (CS) and data for sub23nm
- Two systems with CS and 10nm CPC to circulate

APC	10 and , 23 nm cut-off, CS
SPCS	10 nm cut-off, CS
AM10	10 nm cut-off LabPMP
TSI23	23 nm cut-off, SPCS
TSI10	10 nm cut-off LabPMP



About the exercise

- Measurements so far conducted in 7 different laboratories
- Japan (perhaps China and US) to be done
- PN10 and PN23 Data with Heated Evaporation Tube and Catalytic Stripper (CS) from all of the laboratories (CS1 or CS2)
- Until now only results from PMP vehicle (gasoline DI without GPF)
- The data shown is about variability between the laboratories

Summary

Measurement variability between laboratories over WLTC-cycle. The variability between PN-emissions – 6 labs					
	CO2	PN23, VPR	PN23, CS	PN10, VPR	PN10,CS
HOT	2%	19%	16%	19%	18%
COLD	1%	12%	12%	16%	8%

Summary

- The measurement data shows acceptable variability between the laboratories
  - CO_2 emission variability below 1 % between the laboratories (only one laboratory deviates from average)
  - The PN23 (particle diameter>23nm) data shows that the variability of current PMP-method (VPR) is at the same level as that of Catalytic Stripper-method
  - Similarly PN10 measurement variabilities are at the same level for both CS and for VPR
  - Next Steps - robustness : longer term durability of CS / efficiency checks and challenging the method also on HD engines Q4 2018

HORIZON 2020 projects

- The group is monitoring the progress of the three projects funded by EU under the H2020 scheme
  - DownToTen
  - PEMS4nano
  - SUREAL-23
- These projects have the objective of investigating (nature, composition,…) sub23 nm emissions and to develop new test procedures to measure these particles
- Representative of the consortia provide regular updates to PMP group – Presentations available on the PMP website

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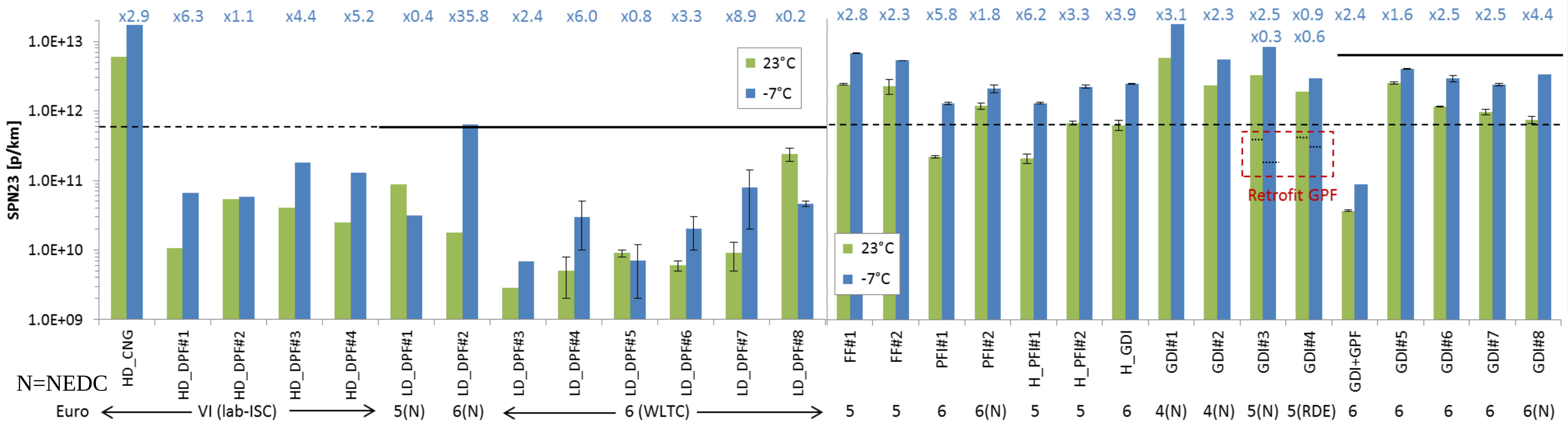
Low Temperature (-7°C)

- Low temperature testing (-7°C) was not including SPN
- PMP confirmed the possibility to include it
- JRC has tested many vehicles



Conclusions

- For some technologies there is a significant fraction of particles below 23 nm.
- Decreasing the lower size to 10 nm seems possible with minimum risks: definition of PCRF (losses), volatile artifacts, equipment investment (PMP and PEMS)
- But decreasing the lower size below 10 nm has high risk of artefacts with today's instruments

Further questions

- Ultrafine particles might be more dangerous than PM2.5. Are sub-23nm particles more dangerous than >23 nm?

- The $6x10^{11}$ p/km(kWh) limit was based on best available technologies. What is the health and air quality relevance?

- There are health concerns for the (semi)volatile part of particles. Should it be included in the regulations?

NON-EXHAUST PARTICLE EMISSIONS

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The importance of non-exhaust particle emissions

- Today it is estimated that about 50% of the traffic generated particles come from non-exhaust sources

- The relative contribution of non-exhaust sources is expected to increase in the forthcoming years due to the decrease of exhaust emissions

Contributions of specific sources to non-exhaust traffic-related PM_{10} emissions

Source	PM_{10} (%)
Brake Wear	16-55*
Tyre Wear	5-30**
Resuspension	28-59

* Significantly lower contributions have been reported in freeways (~ 3%)

** Many studies don't distinguish from road wear particles

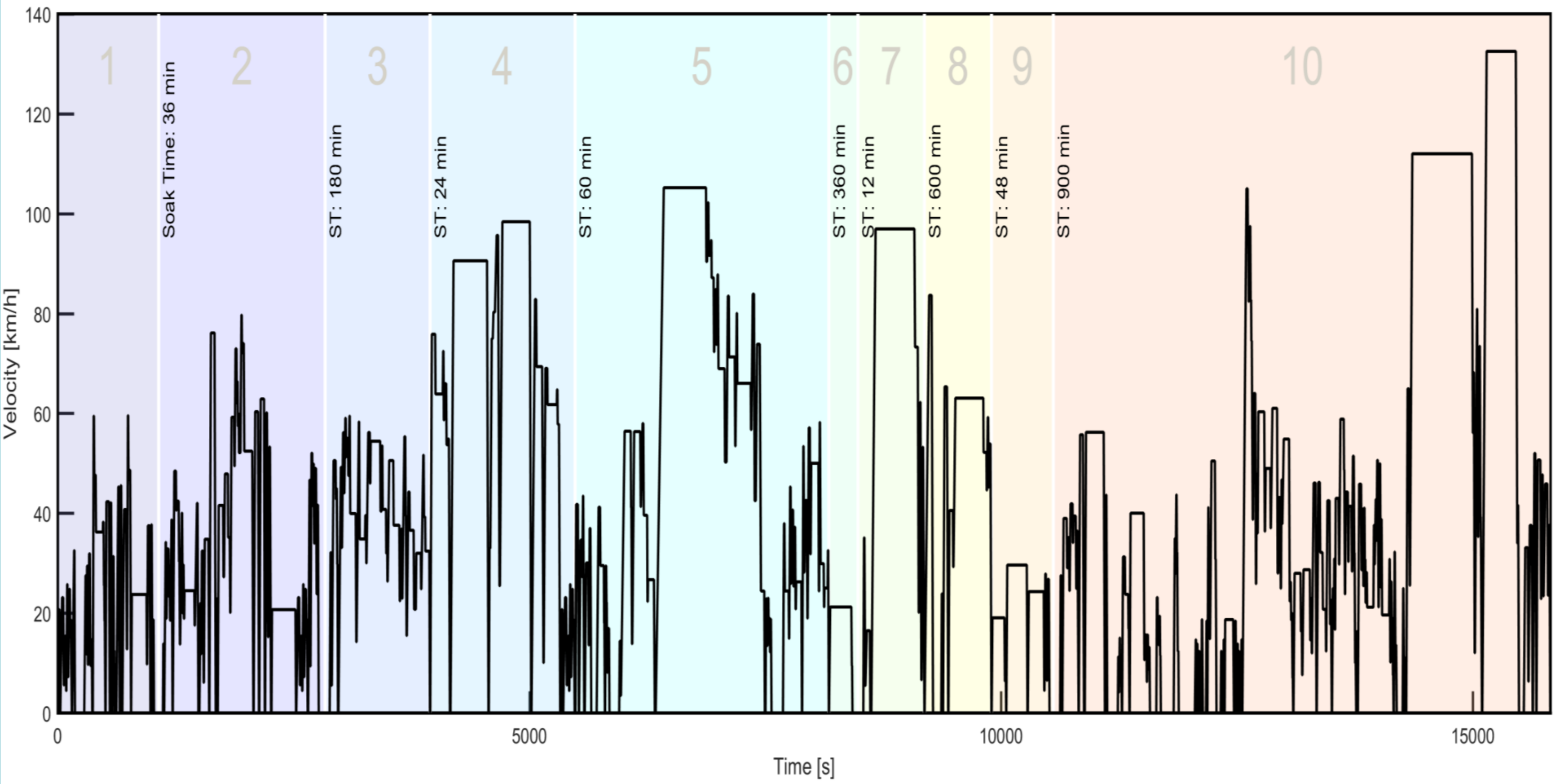
NON-EXHAUST PARTICLE EMISSIONS

DEVELOPMENT OF A NEW REAL-WORLD BRAKING CYCLE FOR STUDYING BRAKE PARTICLE EMISSIONS

- WLTP Database Analysis (Concluded)
- Comparison of WLTP data with Existing Industrial Cycles (Concluded)
- Development of a first version of the new (WLTP based) and backup (LACT based) braking schedule (Concluded)
- Validation of the cycles - Round robin (reproducibility assessment on different dynos) (Deadline: December 2018)

DEVELOPMENT OF A NEW REAL-WORLD BRAKING CYCLE FOR STUDYING BRAKE PARTICLE EMISSIONS

NOVEL CYCLE



IN BRIEF

- 10 individual trips
- 303 stops over 192 km
- Duration of 4h 24min
- Average speed of 44 km/h and maximum speed of 133 km/h
- Brake phase deceleration range of 0.5 – 2.5 m/s² (mean of 0.97 m/s²)

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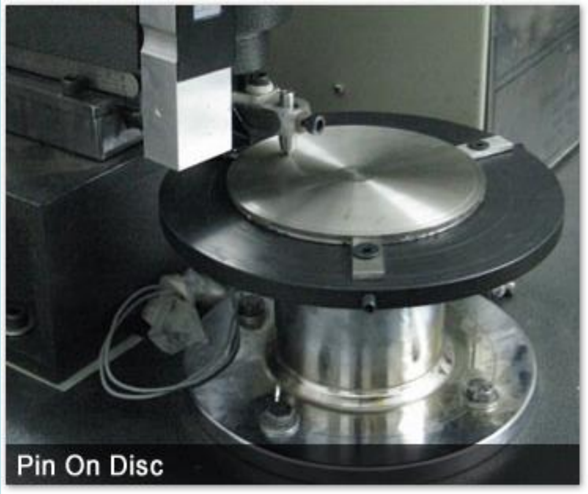
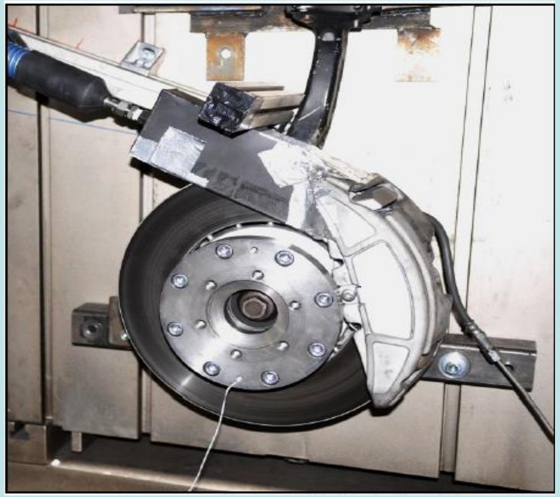
BRAKE DUST SAMPLING AND MEASUREMENT

SELECTION OF THE TESTING METHODOLOGY

What were the available options to start with?

✓ The method would be either laboratory based – with options being pin-on-disc, brake dyno rig and full chassis dyno – or it would be real driving with a dedicated on-road test

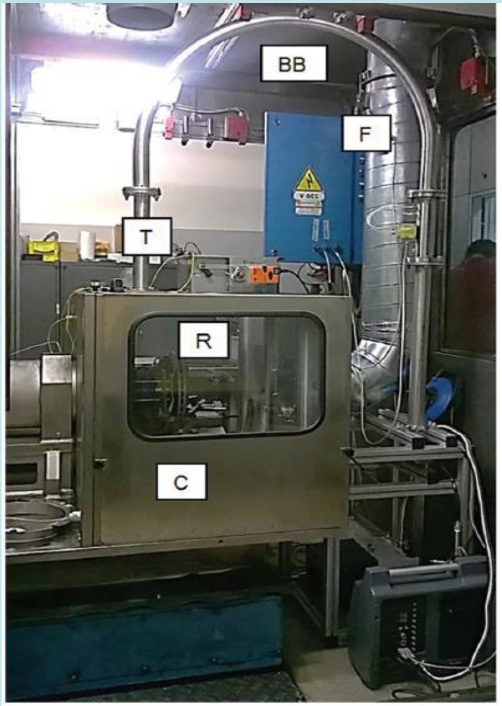


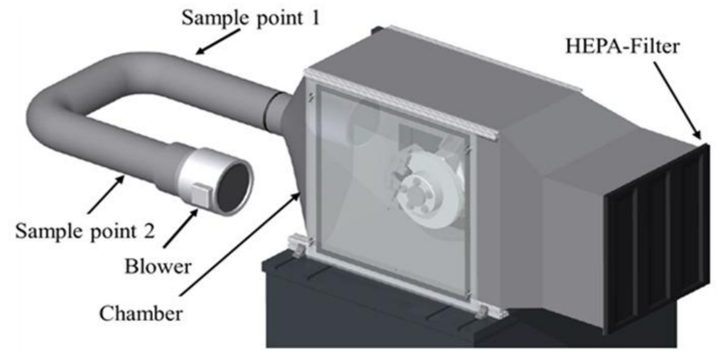


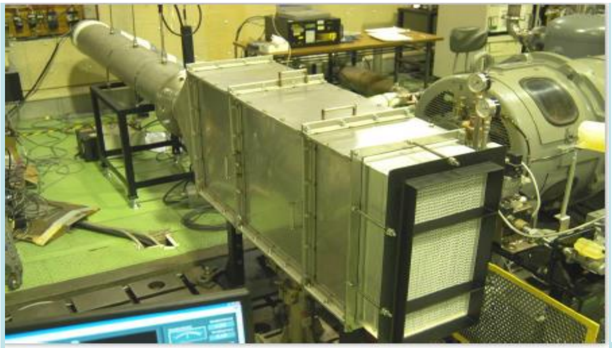
BRAKE DUST SAMPLING AND MEASUREMENT
COMPARISON OF EXISTING TEST RIG CONFIGURATIONS

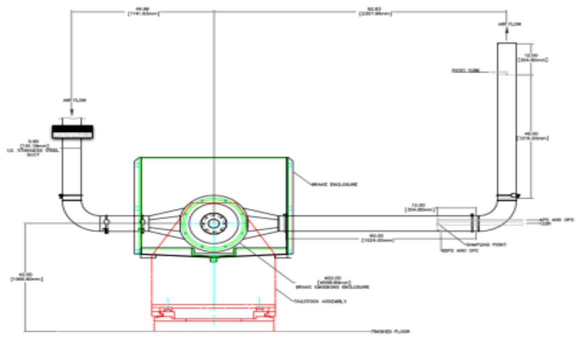
What was the main outcome of this step?

- ✓ 11 labs presented their setups. Completely different configurations with different dimensions, geometries and functional parameters were presented. In fact, there were not two single setups that looked like to each other









- ✓ A decision to define a set of minimum requirements to be followed by all labs and run preliminary tests with the same brake system in order to collect data was taken

PARTICLES FROM TYRE AND ROAD WEAR

- In the 47th PMP meeting a session was dedicated to this subject. More presentations will be given in November
- No major developments in the field
- JRC presented the results of a small study investigating the influence of the treadwear rating on PM/PN emissions
- The development of a standardized methodology to measure the abrasion rate is currently an option under discussion

Additional pollutants

Additional Pollutants – NH_3

- NH_3 is a major precursors of PM2.5 (secondary PM)
- At concentration levels above 25 ppm in air, NH_3 is reported to be hazardous, causing headaches, nausea, and severe burning (nose, throat, and skin)
- NH_3 emission limit is included for HDV regulation (≤ 10 ppm weighted average over the WHTC and WHSC for C.I. & P.I. engines).
- NH_3 emissions are not regulated for LDV
- Sources of NH_3 emissions:
  - In C.I. engines: Ammonia slip from SCR
  - In P.I. engines: ammonia may be formed as a secondary pollutant during the NOx reduction process over the three-way catalyst .

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Additional Pollutants – NH_3

- C.I. vehicles with the best available technology (i.e. AMOX*) have emission values well below the present limit (≈1.5 ppm).
- A NH_3 for limit LDV needs to be defined.
- The NH_3 emission limit should be expressed as emission factor i.e. g/kWh for HDV or g/km for LDV, and not as a concentration.
- As the legislation should be technology neutral, then the same limit needs to be applicable to P.I which will also force the use of the best available technology for the abatement of NH_3.

*AMOX: Ammonia Oxidation catalyst

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Additional Pollutants – N_2O

- High global warming potential (GWP100 years 1 g N_2O ≈ 298 g CO_2)

- Represent more up to 4% of CO_2eq in Euro 5/V and Euro 6/VI diesel vehicles.

- N_2O emissions increased with some after-treatment devices.

- Also present in positive ignition vehicles but lower emissions than diesel.

Additional Pollutants – Aldehydes

- Emissions of aldehydes are related to fuel blends (methanol, ethanol, etc) and additives.
- Alcohols and aldehydes are measured in USA to correct THC emissions which could be underestimated by up to 98%.
- Note: Formaldehyde is a Type I carcinogenic

Additional Pollutants – Isocyanic acid (HNCO)

- HNCO is linked to atherosclerosis, cataracts, and rheumatoid arthritis
- Currently present in higher concentrations in positive ignition than diesel

Additional Pollutants – General considerations

The procedure to measure:

- N_2O
- NH_3
- Aldehydes

Is already developed and included in the Global Technical Regulation - 15 (WLTP)

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Conclusions

- JRC is already investigating several of the issues relevant for post-EURO 6/VI regulations
- Some of the issues (sub/23 nm particles, non-regulated pollutants) are very advanced, others still need to be completed, or start.
- JRC will collaborate with DG-GROW and the external contractors in the post-EURO 6/VI study

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Thank you for your attention!

Any questions?

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