New Euro 6 Legislation on RDE: Overview and Technical Challenges

Theodoros G. Vlachos, Pierre Bonnel, Martin Weiss, Barouch Giechaskiel, Francesco Riccobono

European Commission - Joint Research Centre (JRC)
IET - Institute for Energy and Transport

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Overview

- **RDE-LDV general principles**
- **RDE-LDV boundary conditions**
- **RDE-LDV technical elements**
  - Testing protocol
  - Testing instrumentation
  - Ex-post evaluation
- **RDE-LDV PEMS-PN**
- **Remarks**

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RDE-LDV general principles

- Test vehicles on the road
- Use accurate and advanced portable instruments
- Ex-ante trip selection
  - urban, rural, motorway shares and their sequence
  - road profile
  - requirements for urban driving (idling)…
- Ex-post data evaluation
  - check of dynamic conditions by composite indicators
    - Moving Averaging Window (MAW) method => CO_2
    - Power Binning (PB) method => power at the wheels
  - check of vehicle dynamics (additional indicators)

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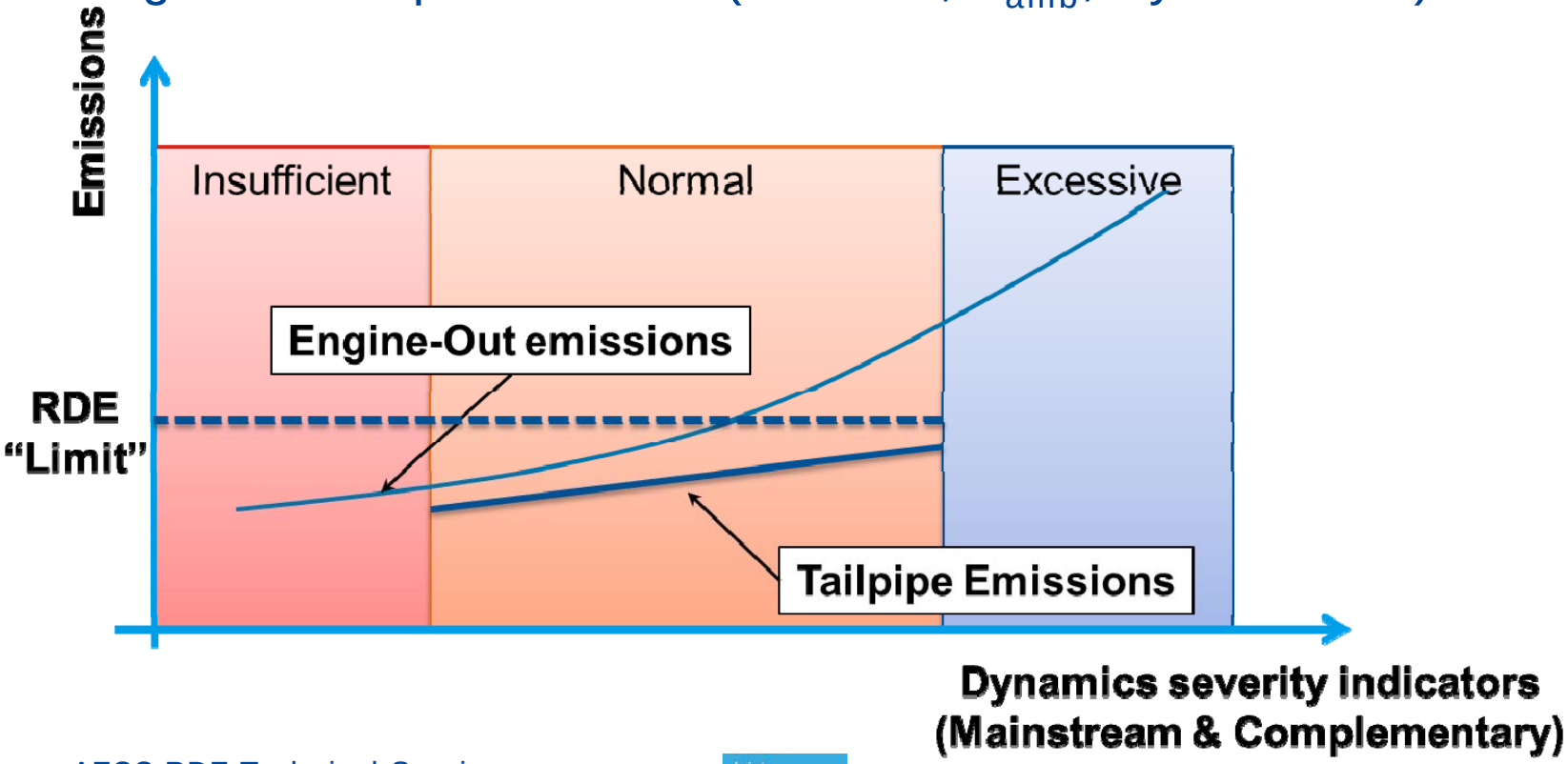
RDE-LDV boundary conditions

- Ranges for all parameters (altitude, T_{amb}, dynamics…)



RDE-LDV boundary conditions

- Ranges for all parameters (altitude, T_{amb}, dynamics…)
- A <u>single</u> RDE test does <u>not</u> cover all the possible situations
- RDE limits <u>shall be met</u> for <u>any</u> parameters combination
- Risk with ex-post data evaluation
  - invalidation of tests (insufficient coverage…)
- Wider ranges improve the practicality
  - increased ability to realize a valid RDE trip

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Testing protocol

- Trip selection and operational requirements
- PEMS installation
- Specifications of PEMS equipment
- Pre-tests and post-tests PEMS calibration

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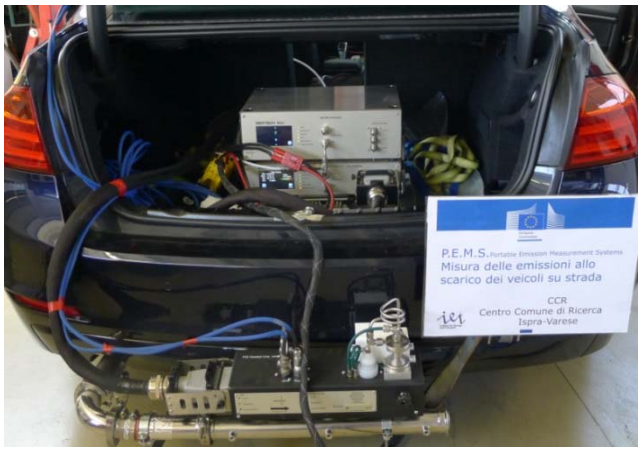
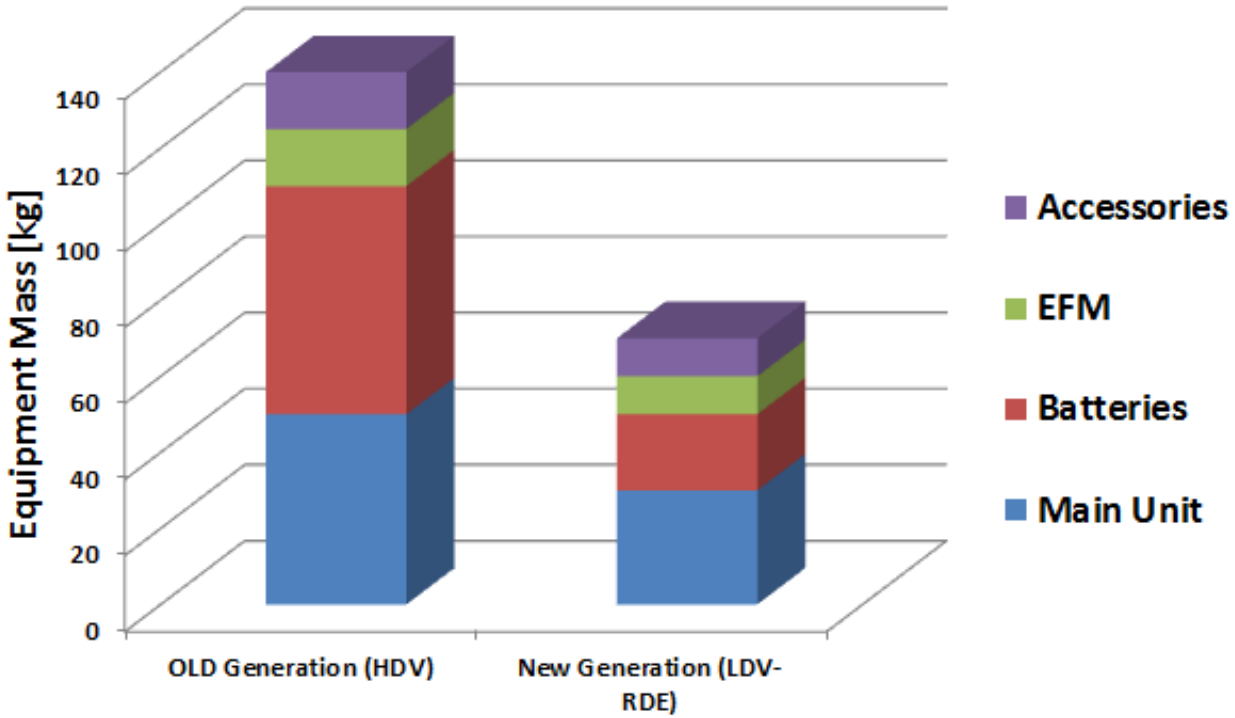
Testing Equipment

- Measurement performance
- Safety
- Size and installation



Testing Equipment

- Comparison of PEMS equipment mass



- Significant decrease of mass for new PEMS generation

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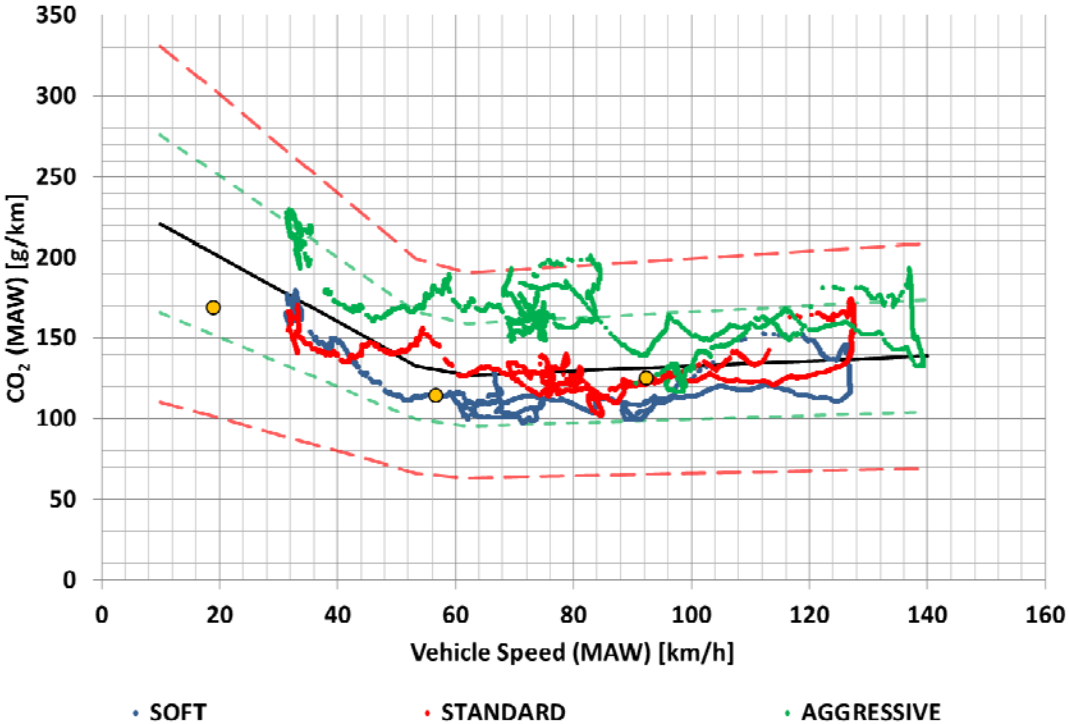
Ex-post evaluation

- MAW method
  - CO_2 to check driving dynamics vs. reference WLTP CO_2 values
- Power binning method
  - P_{wheels} to check driving dynamics vs. reference $P_{distribution}$

Ex-post evaluation

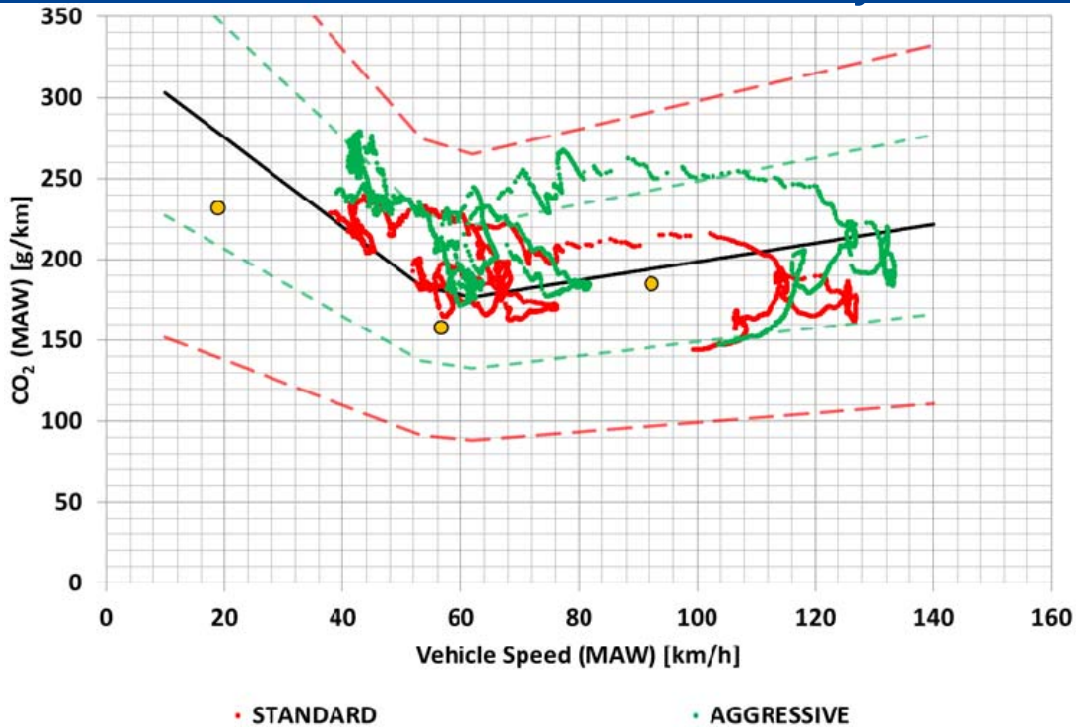
- MAW method



- CO_2 can be used as trip severity indicator

Ex-post evaluation

- Complement the verification of vehicle dynamics



- Additional vehicle dynamics indicators (under discussion)

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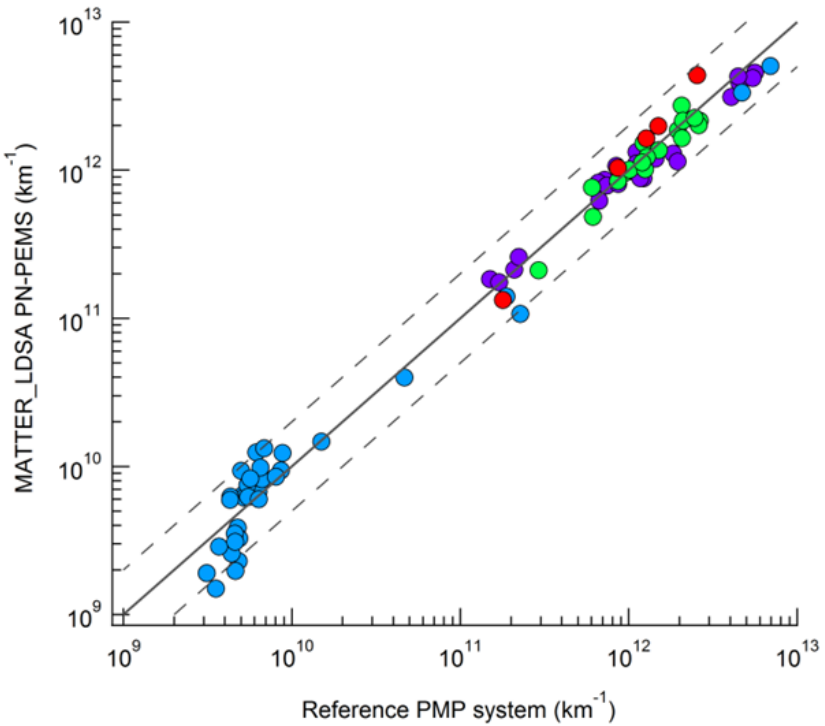
PEMS-PN: Project Overview

- Phase I (2012) – Feasibility study
  - application & performance of PEMS-PN vs PN reference (PMP)
- Intermediate step – Update of specifications
  - Volatile Particle Remover (VPR)
  - efficiency of diffusion chargers (DC)
- Phase II (2014)
  - confirmation of Phase I
  - calibration procedures
  - more accurate estimation of uncertainty
- Finalization of PEMS-PN technical specifications
  - next steps under discussion

PEMS-PN: Phase I

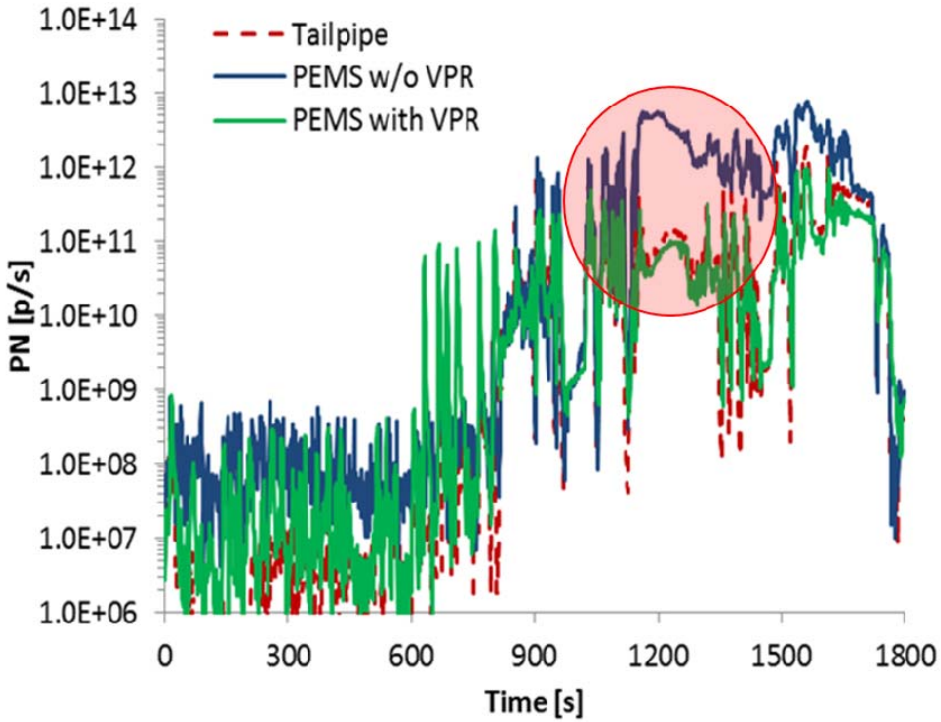
- Results



- Diffusion charger based systems: good linearity with PMP

PEMS-PN: Phase I

- Results



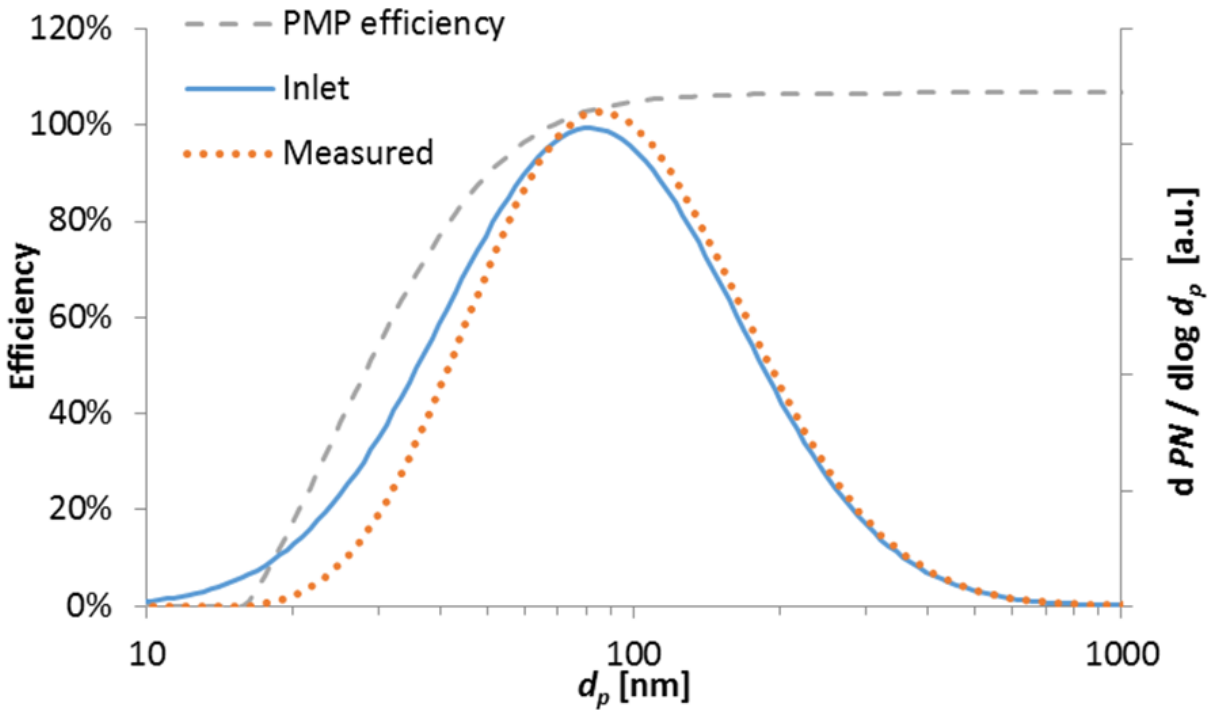
- Volatile Particles Removers (VPR) recommended

PEMS-PN: Phase II, Topics

- Calibration in the laboratory
- Comparison with PMP systems
- Dependency on particle size
- Regeneration
- Volatile removal efficiency (moped 2-stroke)
- Ambient temperature effect
- Calibration at the CVS
- Bias and precision
- PASS or FAIL success rate
- Challenge aerosol (solid sub 23 nm)

PEMS-PN: Calibration

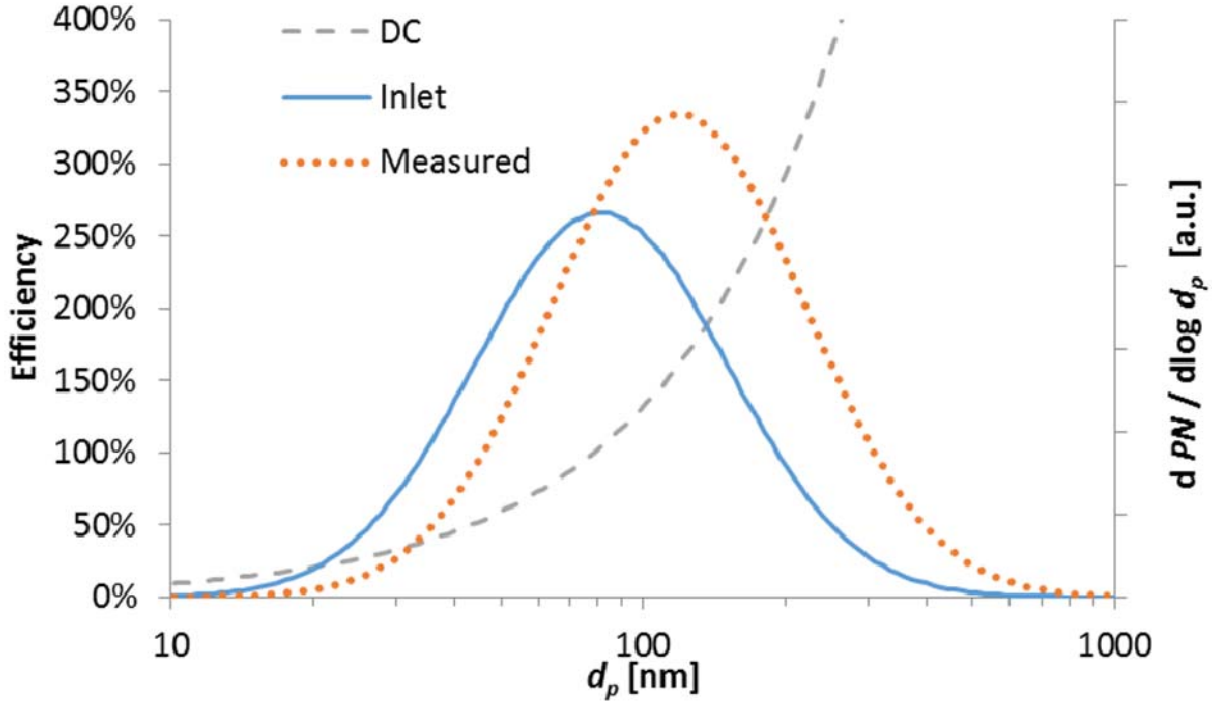
- PMP



- Significant errors for particles <30nm

PEMS-PN: Calibration

- Diffusion Charger



- Increasing response with increasing particles size

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Remarks

- RDE-LDV trade-off

Ex-ante

Boundary testing conditions ranges & testing requirements

=>

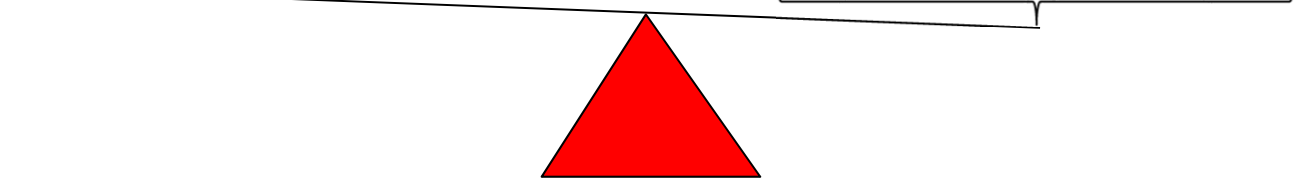
Impacts on testing representativeness

Ex-post

Check of dynamic conditions & vehicle dynamics

=>

Impacts on vehicle performance judgement



Remarks

- PEMS-PN preliminary results
  - diffusion charging seems a promising alternative to CPCs
  - DCs, if adopted, will require more attention during
    - calibration (low levels)
    - instantaneous particles emissions

Acknowledgments

We thank the participants of the RDE working group and the RDE data evaluation task force for their contribution to the development of the data evaluation methods. The staff of the Vehicle Emissions Laboratory (VELA) of the Joint research Centre (JRC): Andrea Bonamin, Mauro Cadario, Massimo Carriero, Rinaldo Colombo, Fausto Forni, Gaston Lanappe, Philippe Le Lijour, Dominique Lesueur, Francois Montigny, Marcos Otura Garcia and Mirco Sculati, is acknowledged for executing the vehicle emissions testing on the road and in the laboratory.

Contacts

- Light-Duty Vehicles:
  - **Martin Weiss**: martin.weiss@jrc.ec.europa.eu
  - **Pierre Bonnel**: pierre.bonnel@jrc.ec.europa.eu
  - **Theodoros G. Vlachos**: theodoros.vlachos@jrc.ec.europa.eu
- PEMS-PN:
  - **Barouch Giechaskiel**: barouch.giechaskiel@jrc.ec.europa.eu
  - **Francesco Riccobono**: franscesco.riccobono@jrc.ec.europa.eu
- Heavy-Duty Vehicles & Non-Road Mobile Machinery:
  - **Adolfo Perujo**: adolfo.perujo@jrc.ec.europa.eu
  - **Pablo Mendoza**: pablo.mendoza-villafuerte@jrc.ec.europa.eu

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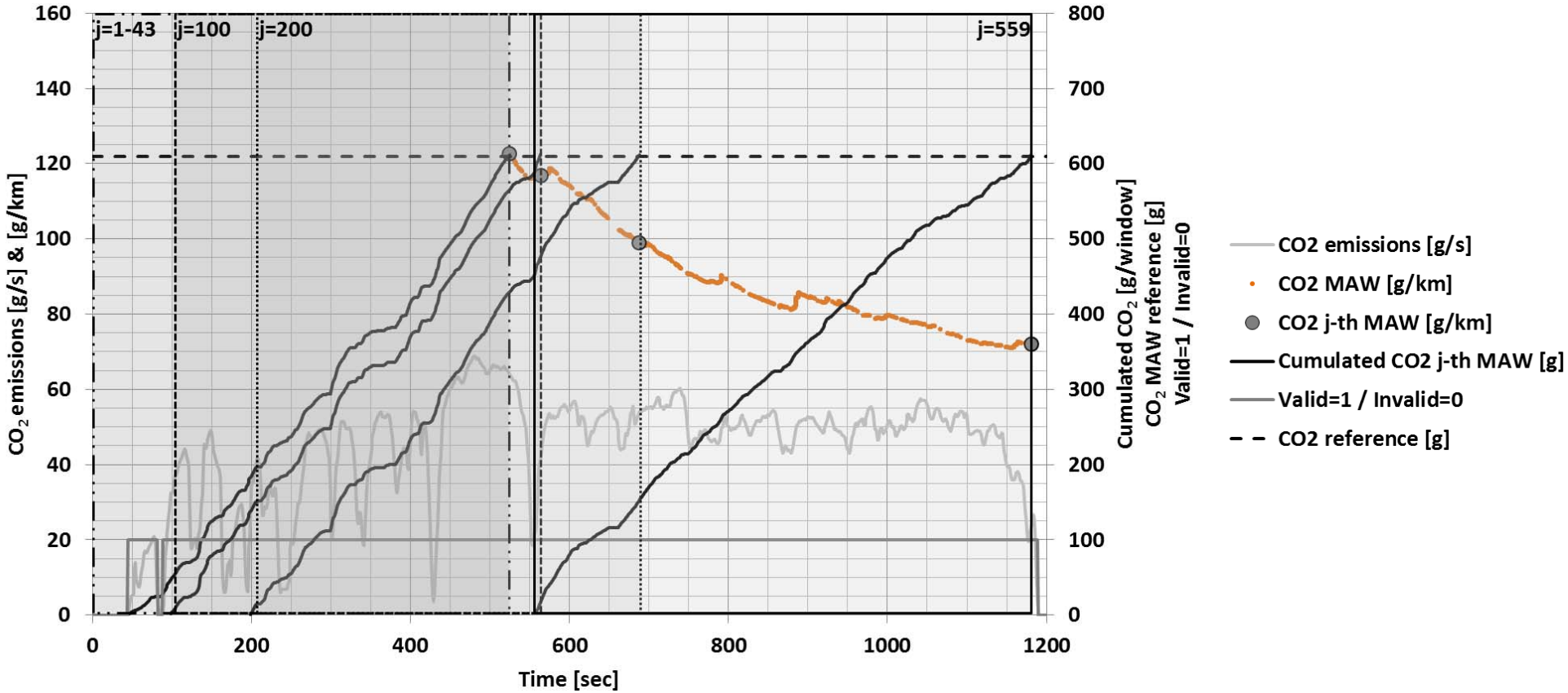
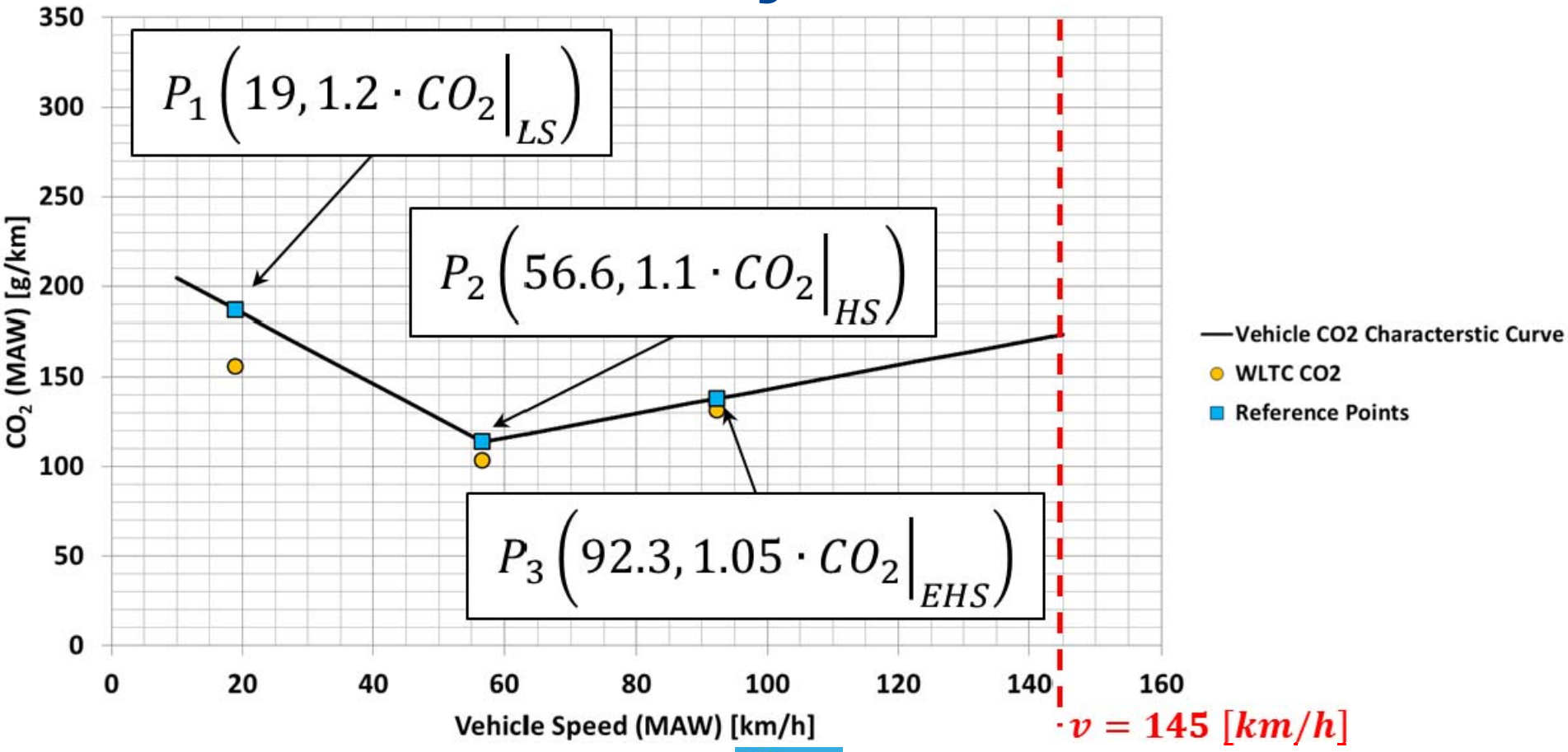
Towards RDE: RCG vs. PEMS

	Random Cycle testing	On-road testing with PEMS
Established procedures and equipment	++	+
Reproducibility and repeatability of test	+	-
Wide range of operating conditions coverage (real-world conditions)	-	++
Effectiveness in limiting "cycle-beating' strategies (high level of randomness)	- -	++
Control over test severity	(designing driving dynamics of the test cycle)	(boundary conditions, severity indicators)

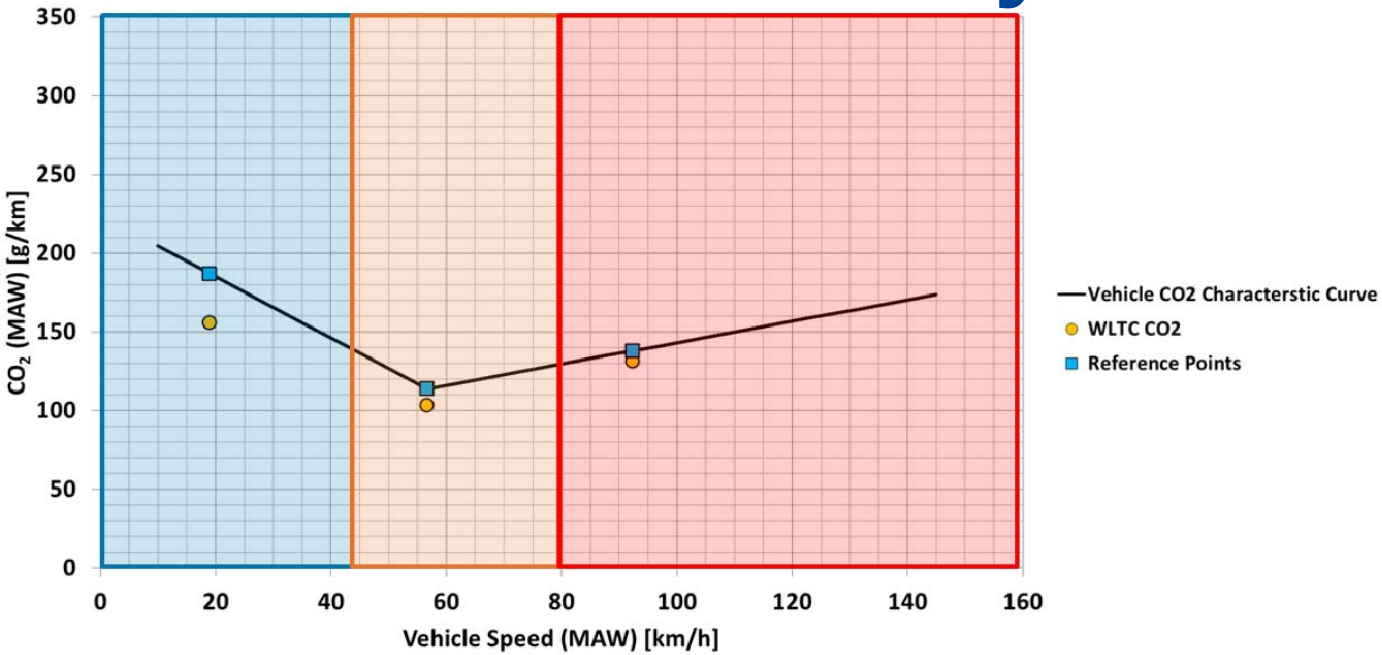
Moving Averaging Windows



Reference of dynamic conditions

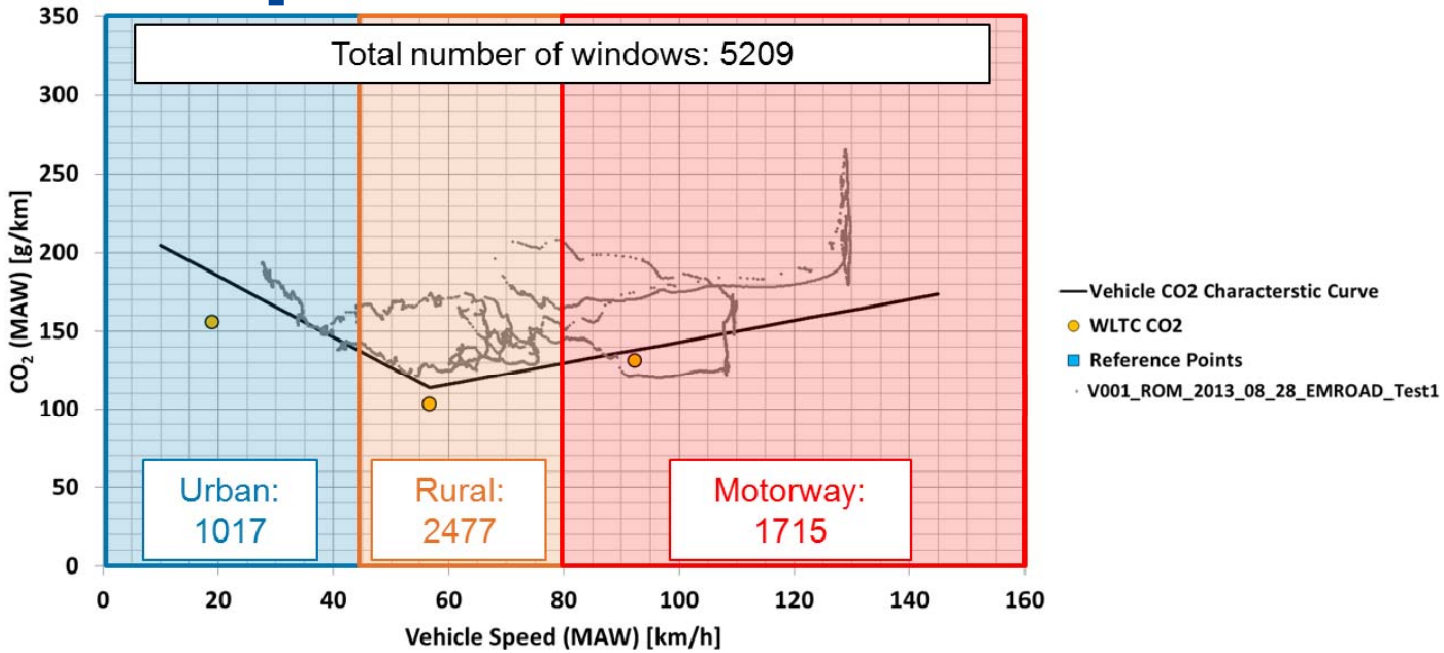


Urban / Rural / Motorway MAWs



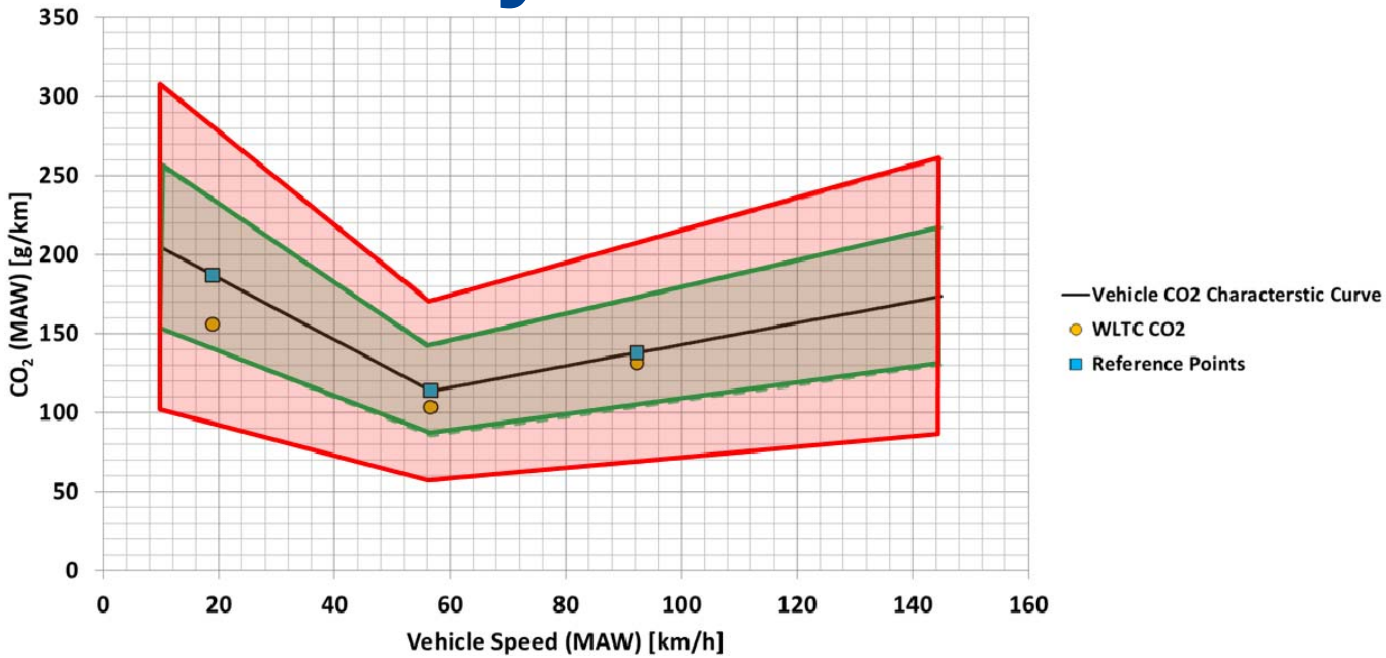
- **Urban**: $\bar{v}_{MAW} < 45\ [km/h]$
- **Rural**: $45\ [km/h] \leq \bar{v}_{MAW} < 80\ [km/h]$
- **Motorway**: $\bar{v}_{MAW} \geq 80\ [km/h]$

Trip Completeness



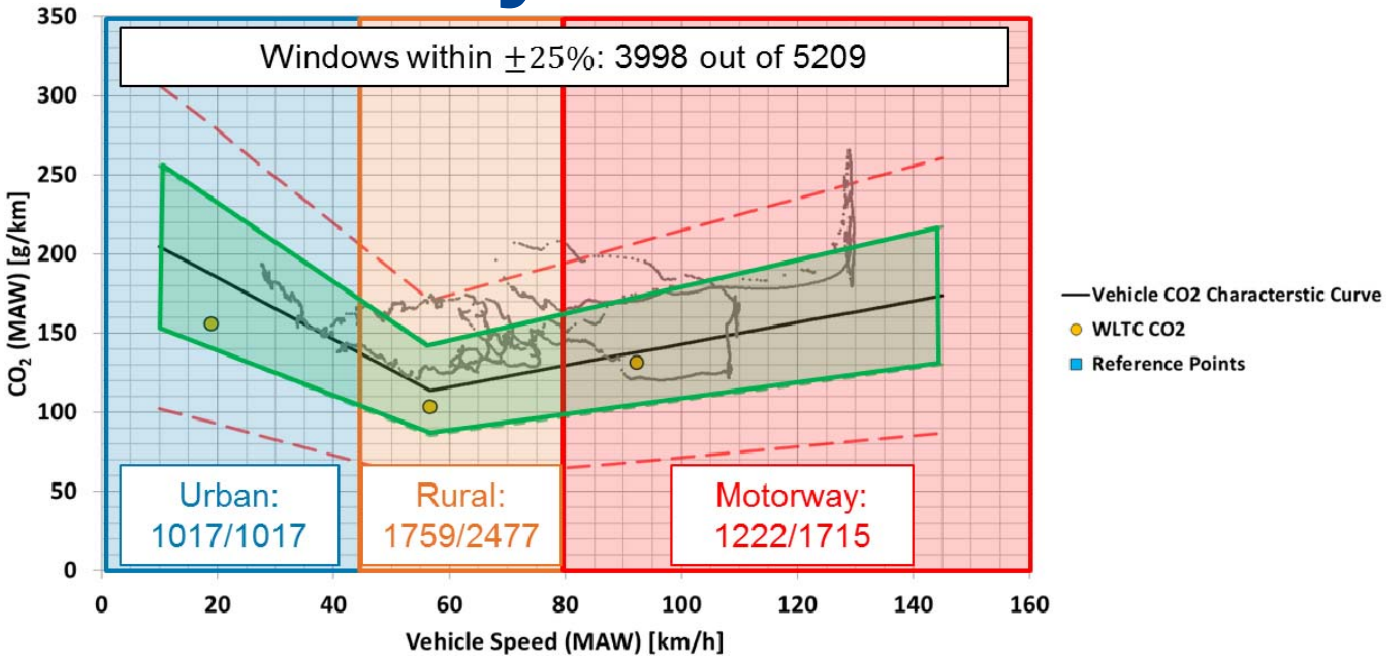
- **Urban:** $1017/5209 \cdot 100 = 19.53$
- **Rural:** $2477/5209 \cdot 100 = 47.55$
- **Motorway:** $1715/5209 \cdot 100 = 32.92$

Trip Normality



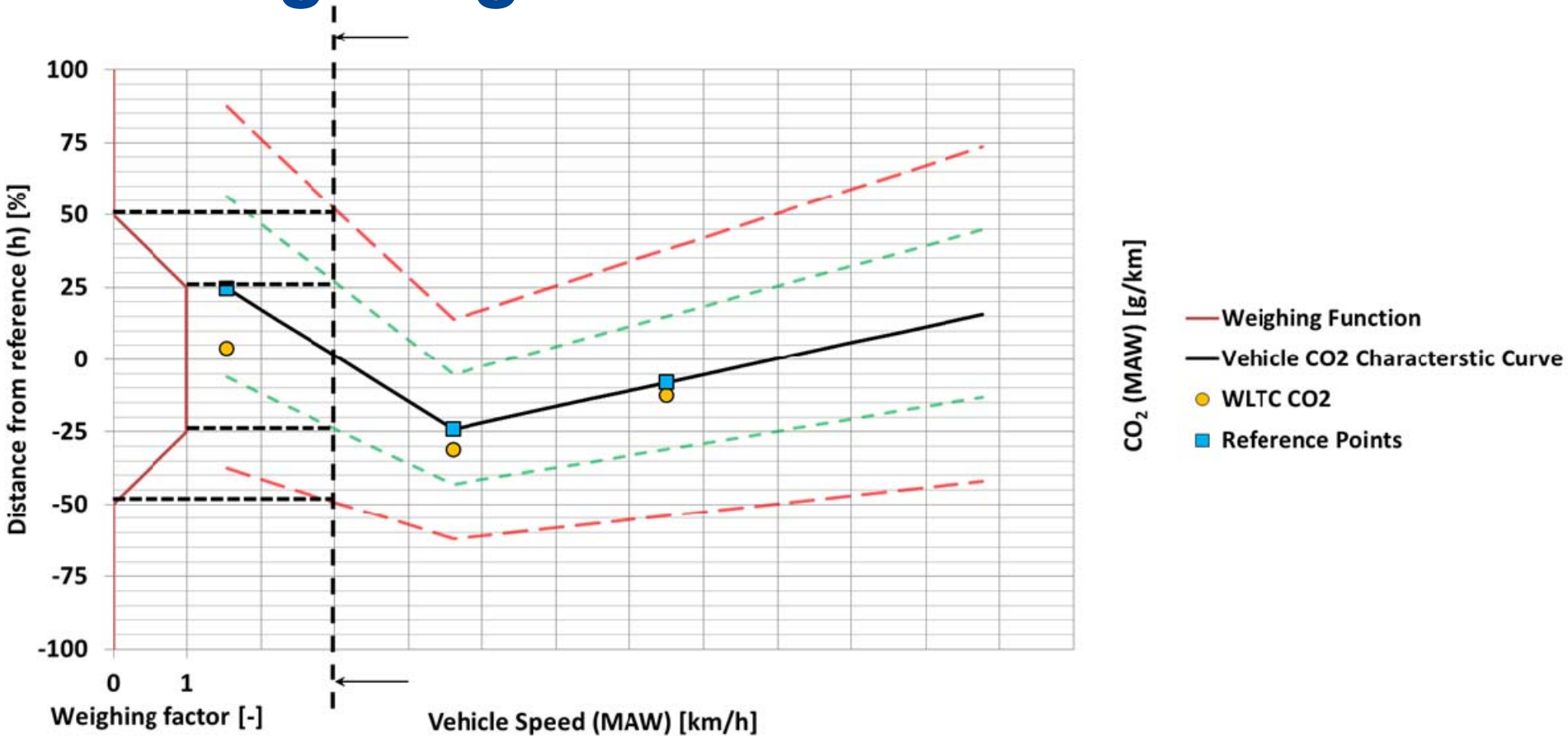
- **Primary Tolerance:** 25%
- **Secondary Tolerance:** 50%

Trip Normality

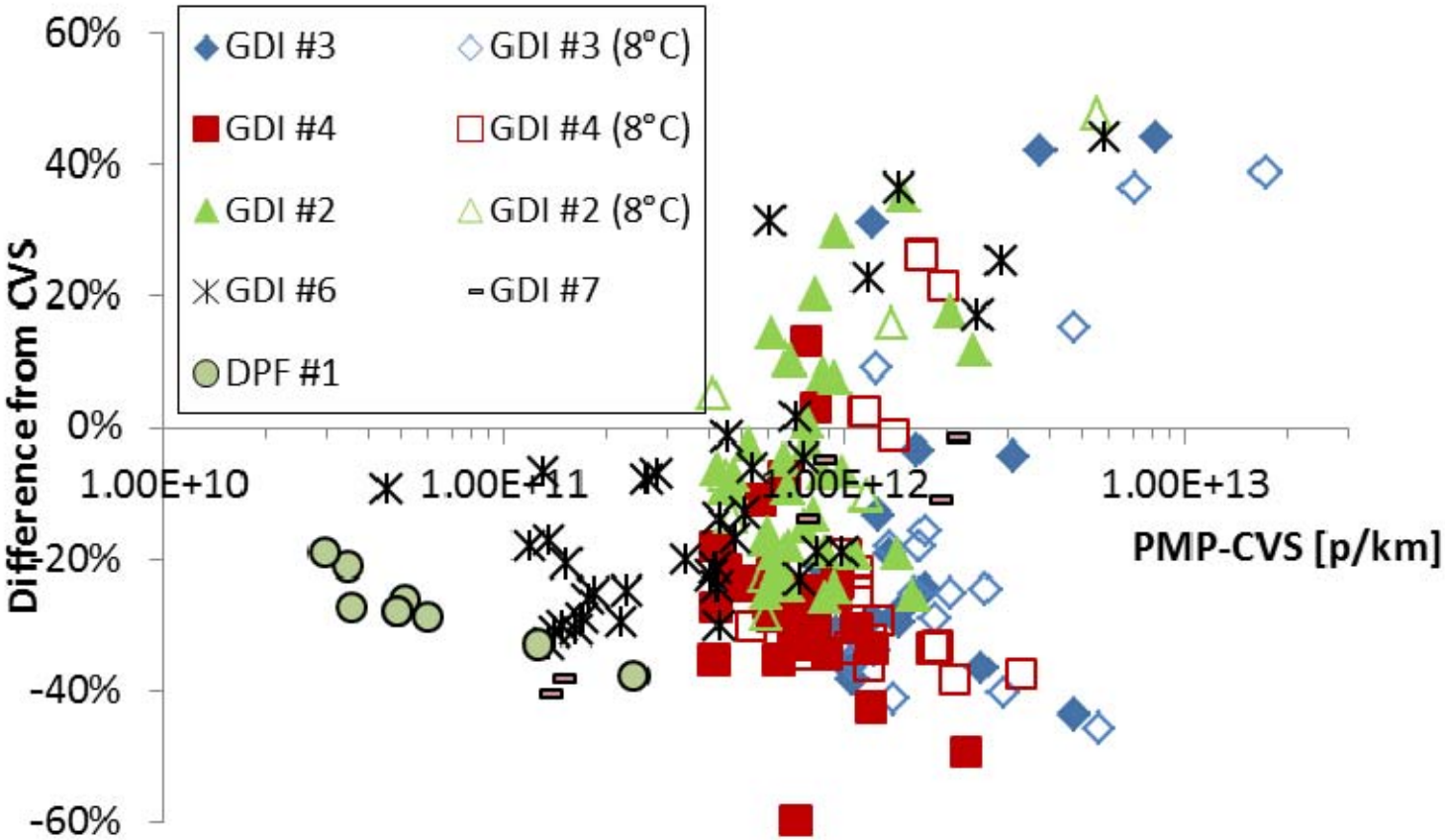


- **Urban:** $1017/1017 \cdot 100 = 100$
- **Rural:** $1759/2477 \cdot 100 = 71.01$
- **Motorway:** $1222/1715 \cdot 100 = 71.25$

Weighing function

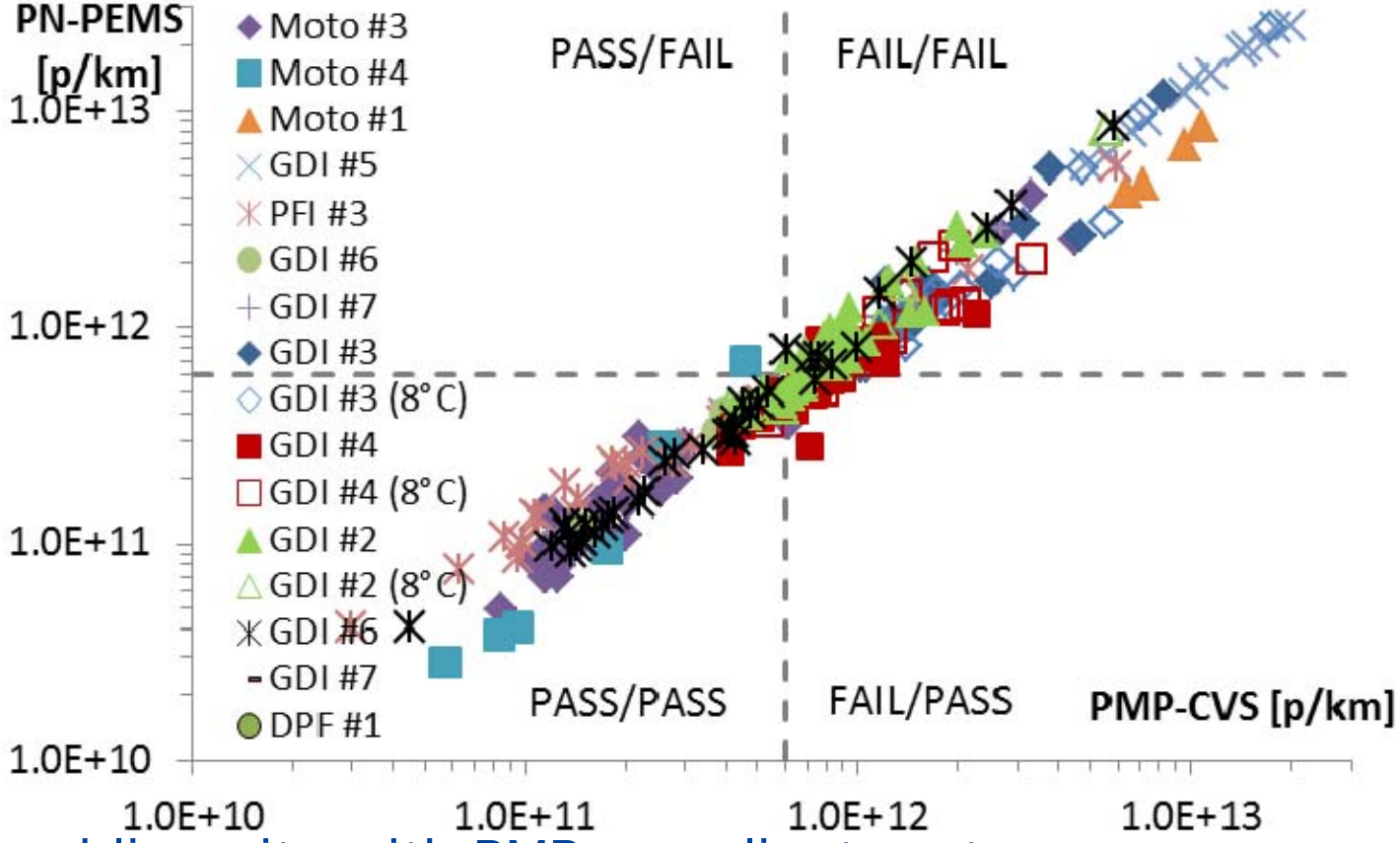


PEMS-PN: Difference from PMP



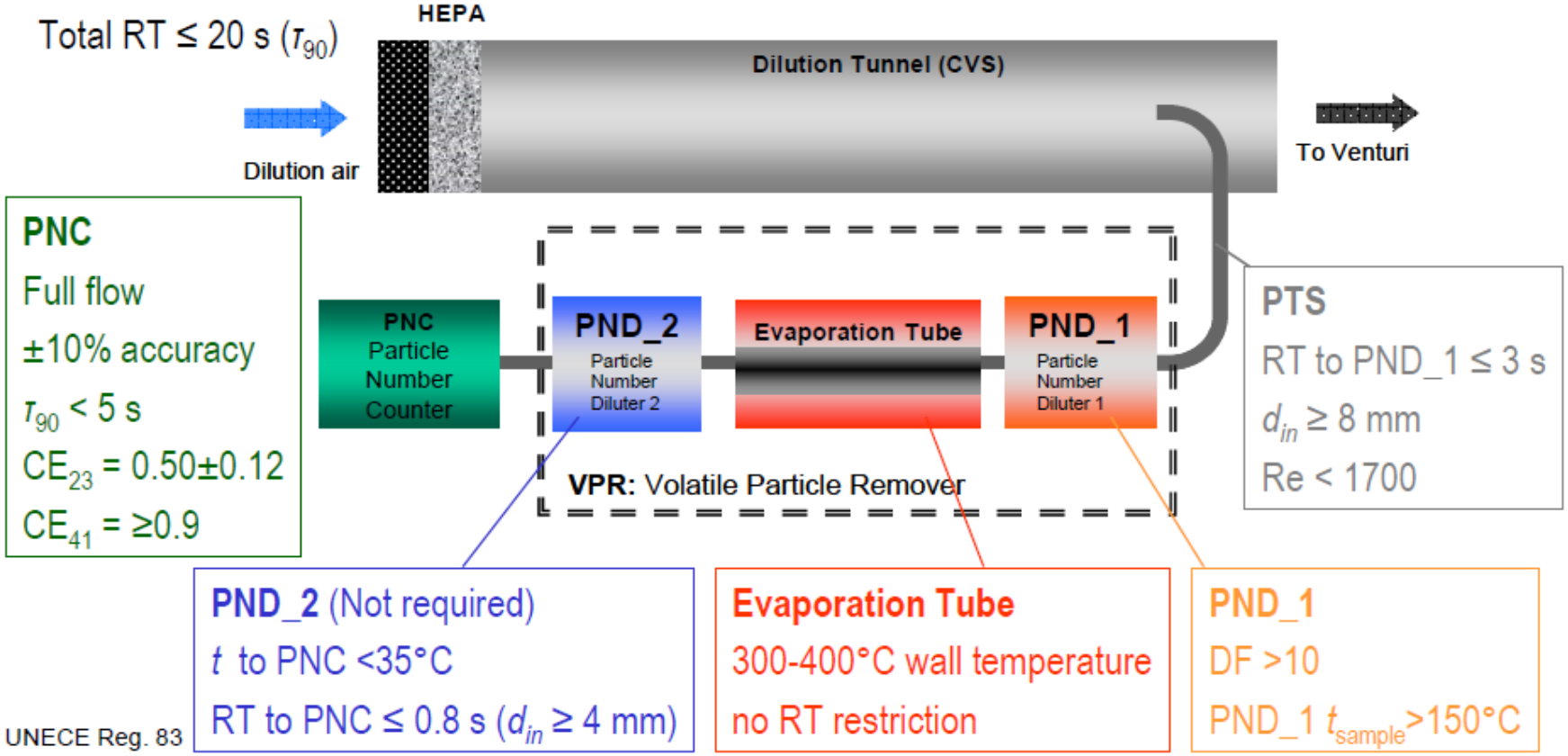
- ±60% variation respect to PMP compliant system

PEMS-PN: Phase II vs. Phase I



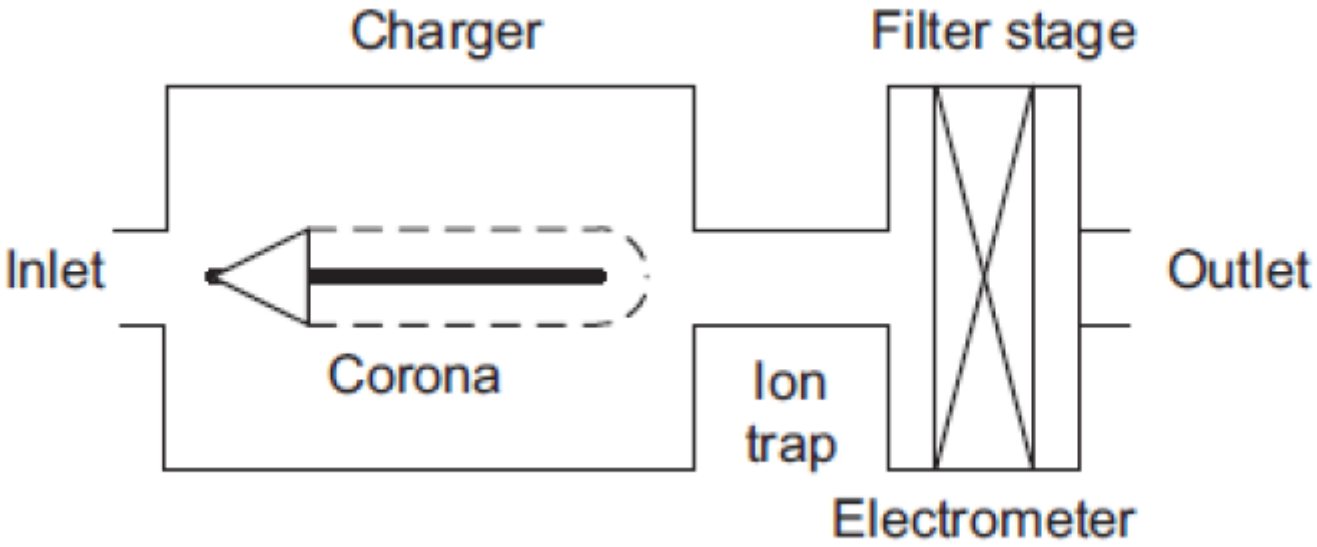
- Good linearity with PMP compliant system

Phase II: Calibration, PMP



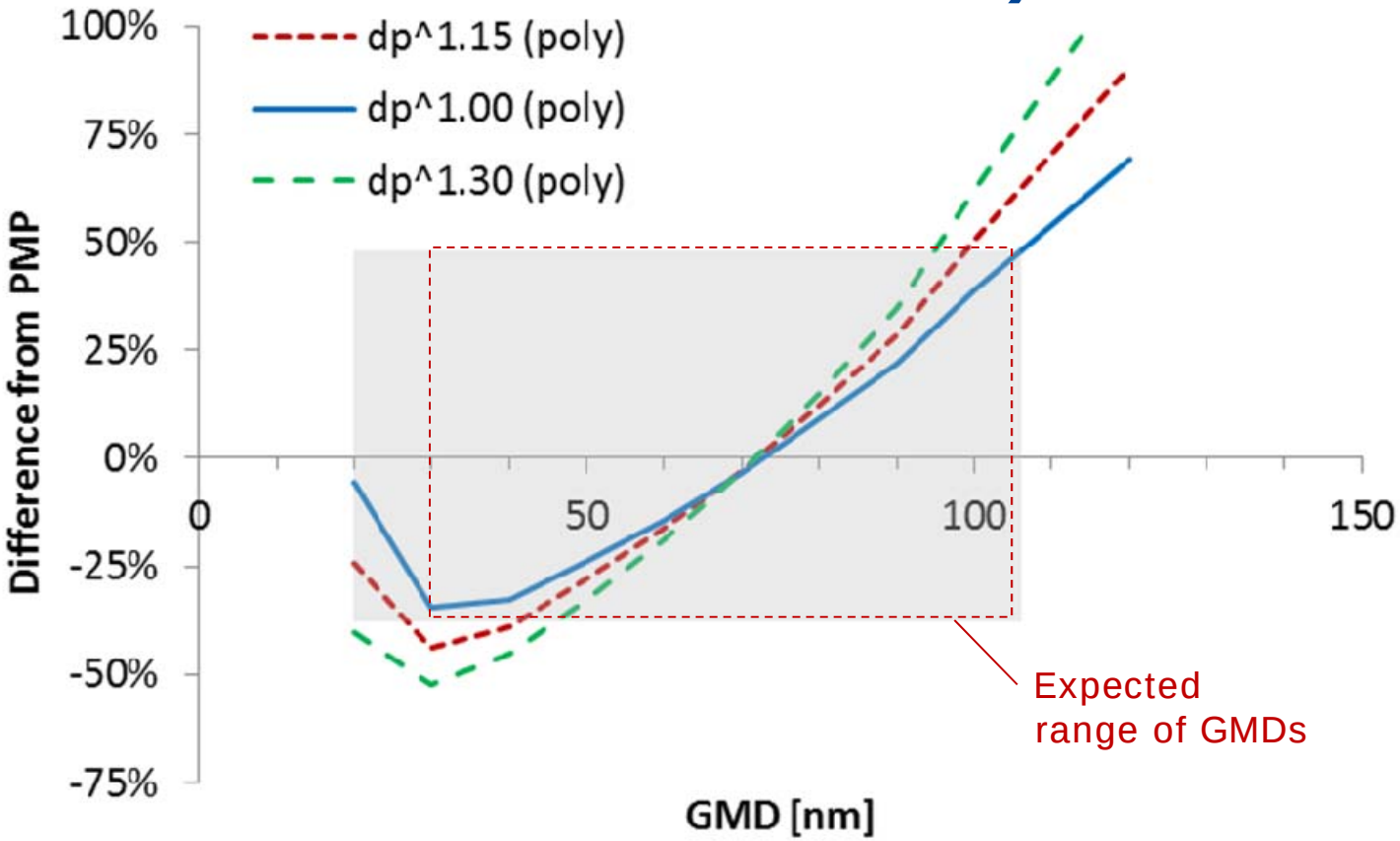
- Counting efficiency depends on efficiencies of VPR and PNC

Phase II: Calibration, DC



- Current ∝ (particles number*particle average charge)

Phase II: Calibration, DC vs PMP



- Calibrated at 100nm monodisperse => 75nm polydisperse