Results of the European PN-PEMS Measurement Program for the Type A Approval of Light-Duty Vehicles in Europe

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Center for Environmental Research & Technology

UC Riverside, USA

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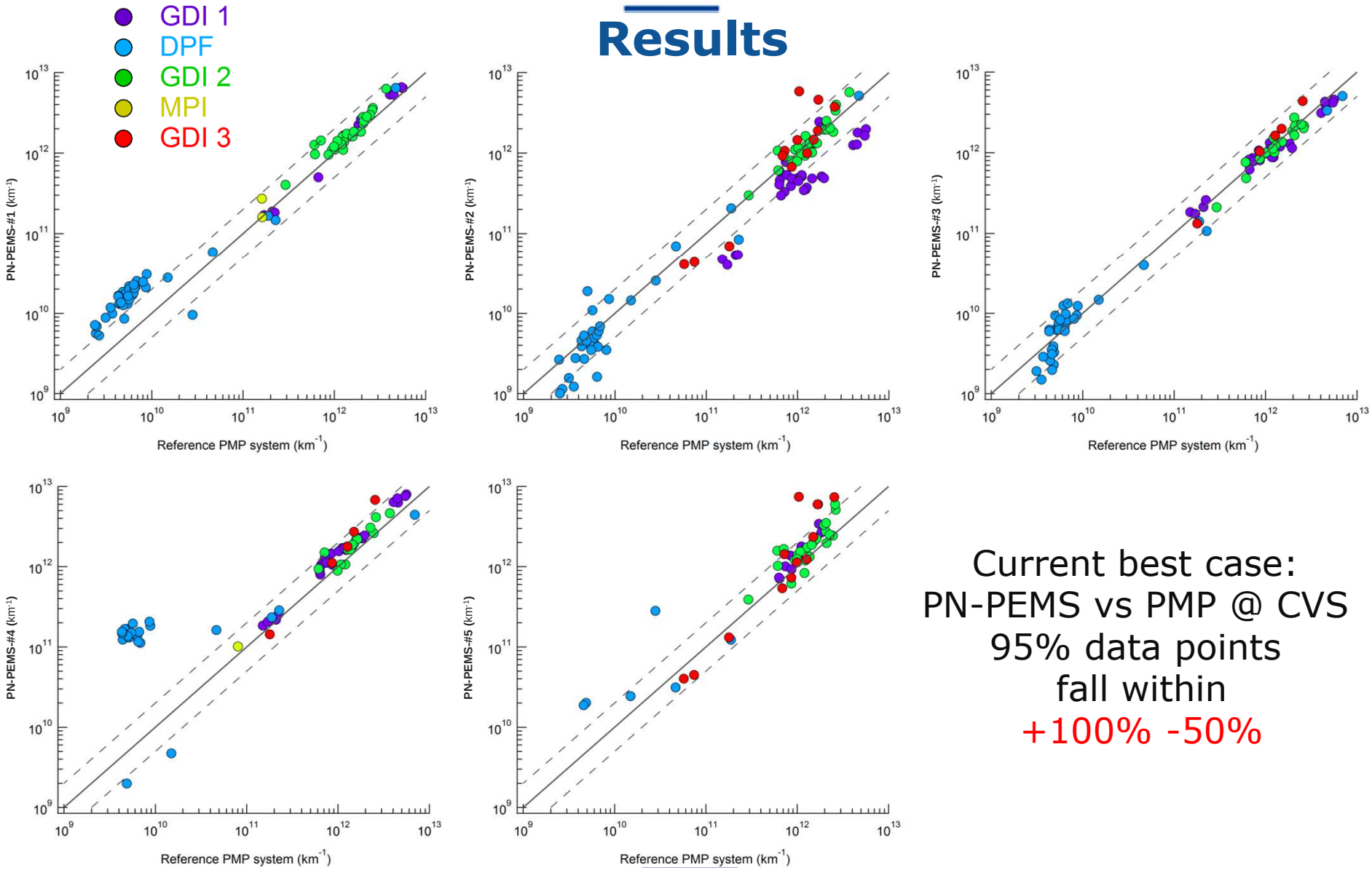
European Commission DG - Joint Research Centre (JRC)

IET - Institute for Energy and Transport

Results

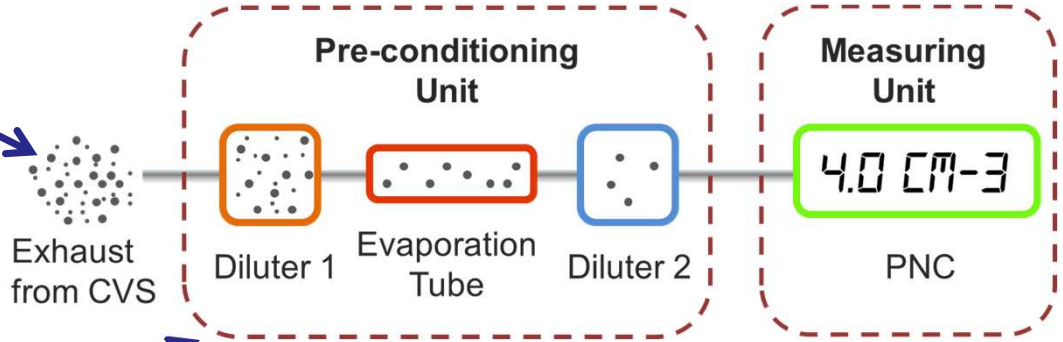
European Commission

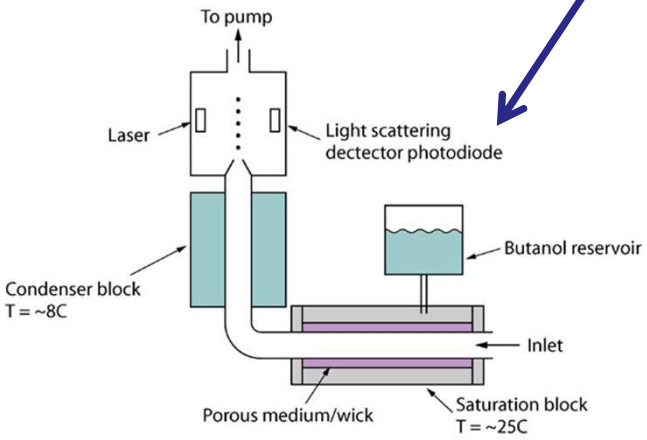
Results



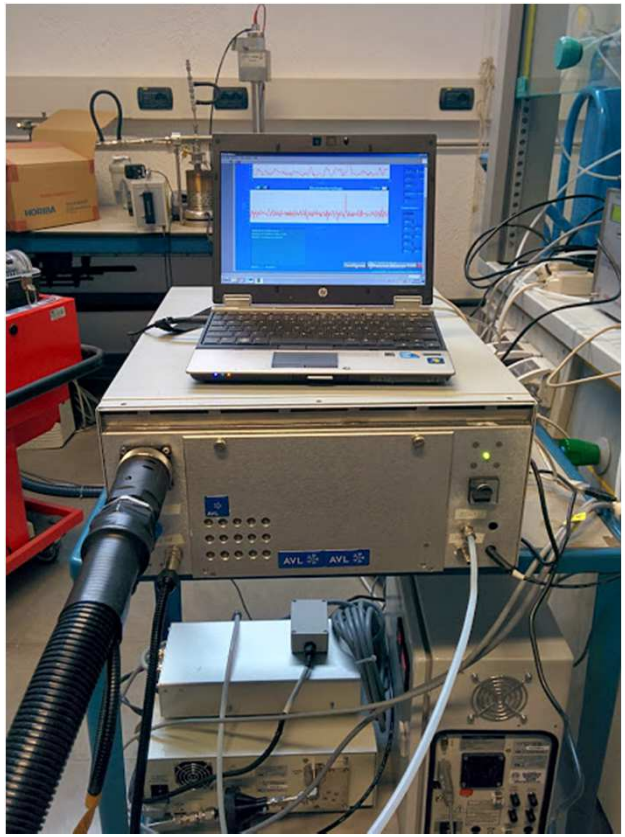
Current best case:
PN-PEMS vs PMP @ CVS
95% data points
fall within
+100% -50%

The reference: PMP system





Candidate PN-PEMS systems



5 instruments (3 on market + 2 prototype)

All based on diffusion charging principle

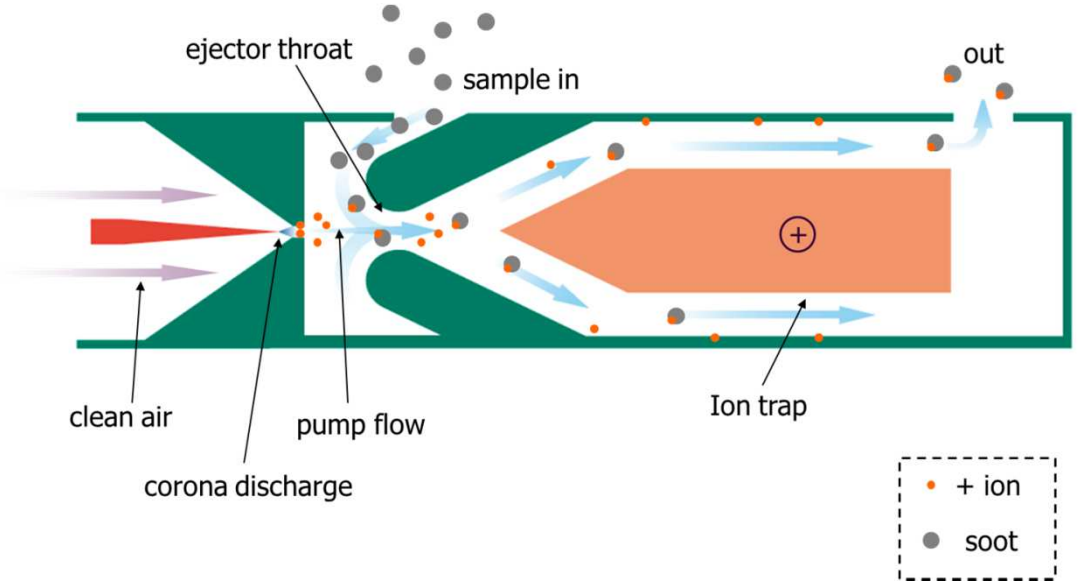
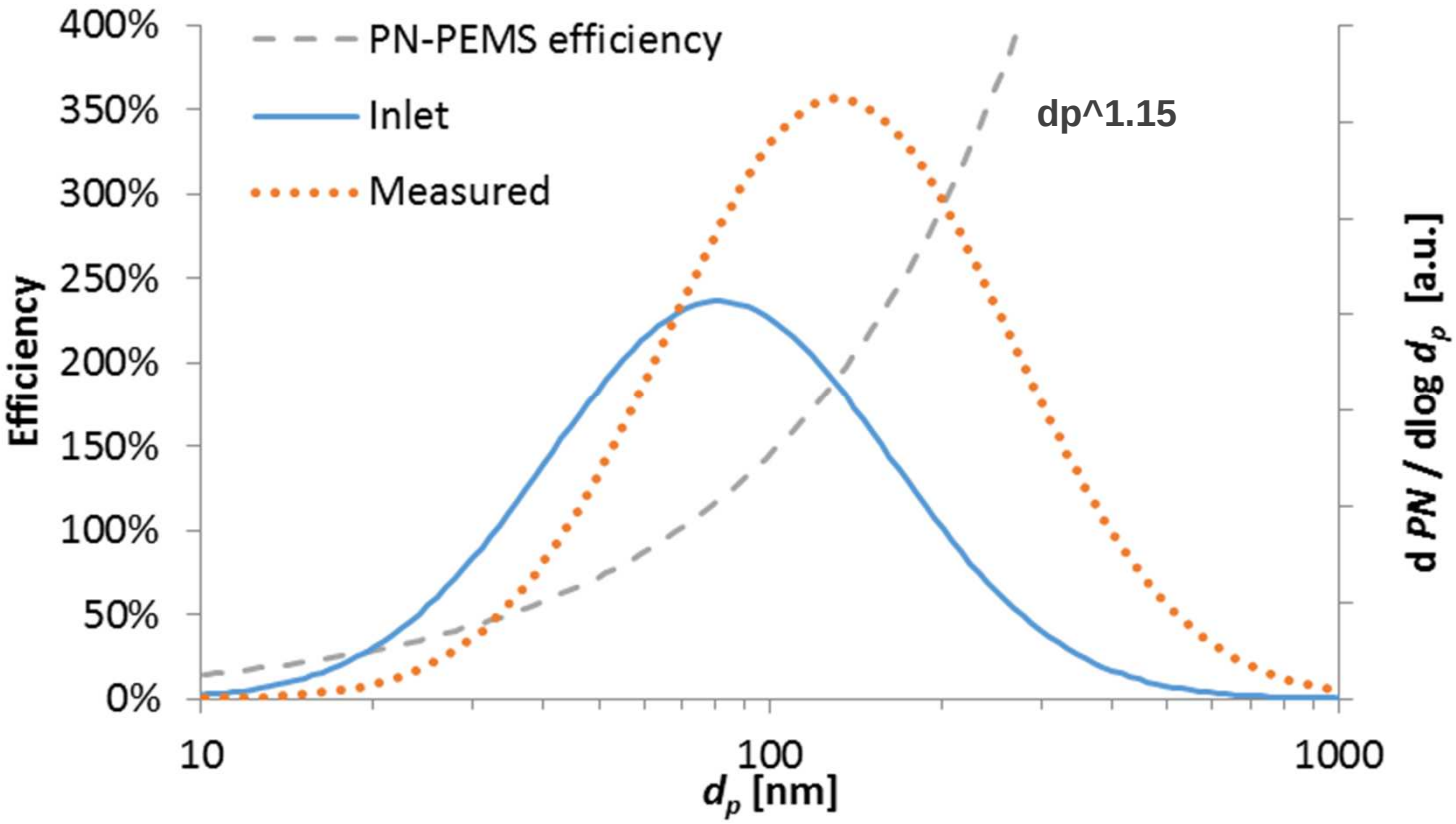


Image source: Juha Tikkanen

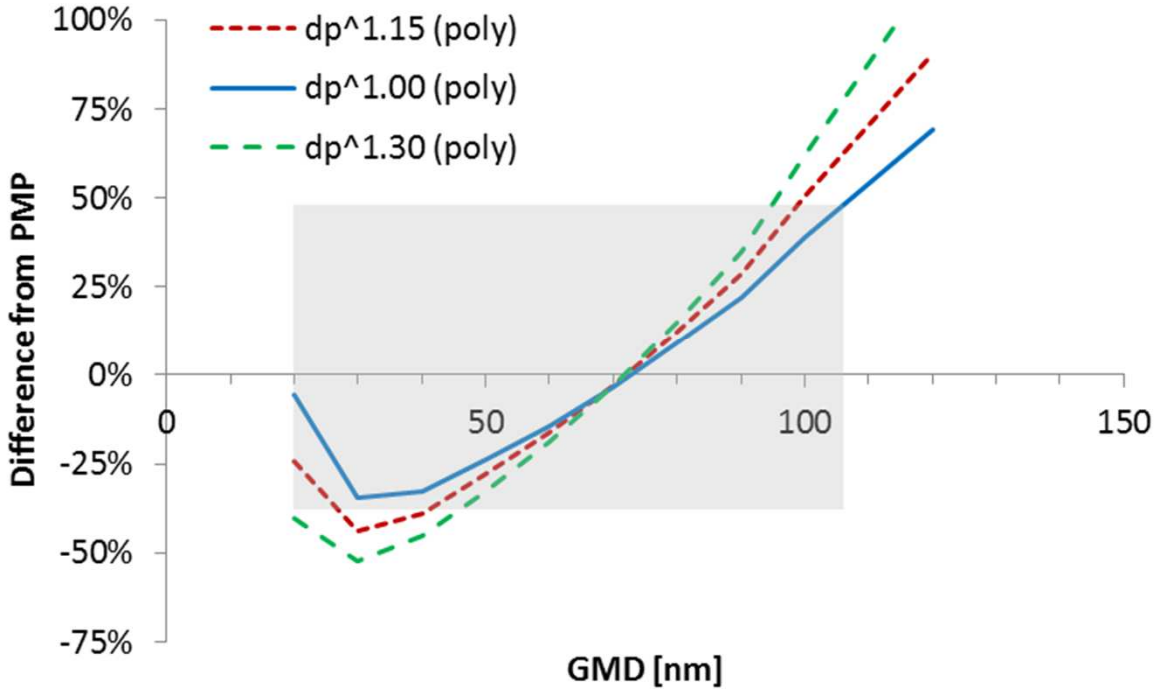
PN-PEMS influencing parameters

- *Temperature: Affects ion mobility*
- *Pressure: Affects ion mobility*
- *Morphology: Fractal particles acquire more charges*
- *Pre-existing charge: With the same polarity of ions*
- *Particle concentration: Due to ion depletion*
- ***Particle size**: Counting efficiency proportional to particle diameter to the power of 1.1–1.3*

PN-PEMS efficiency



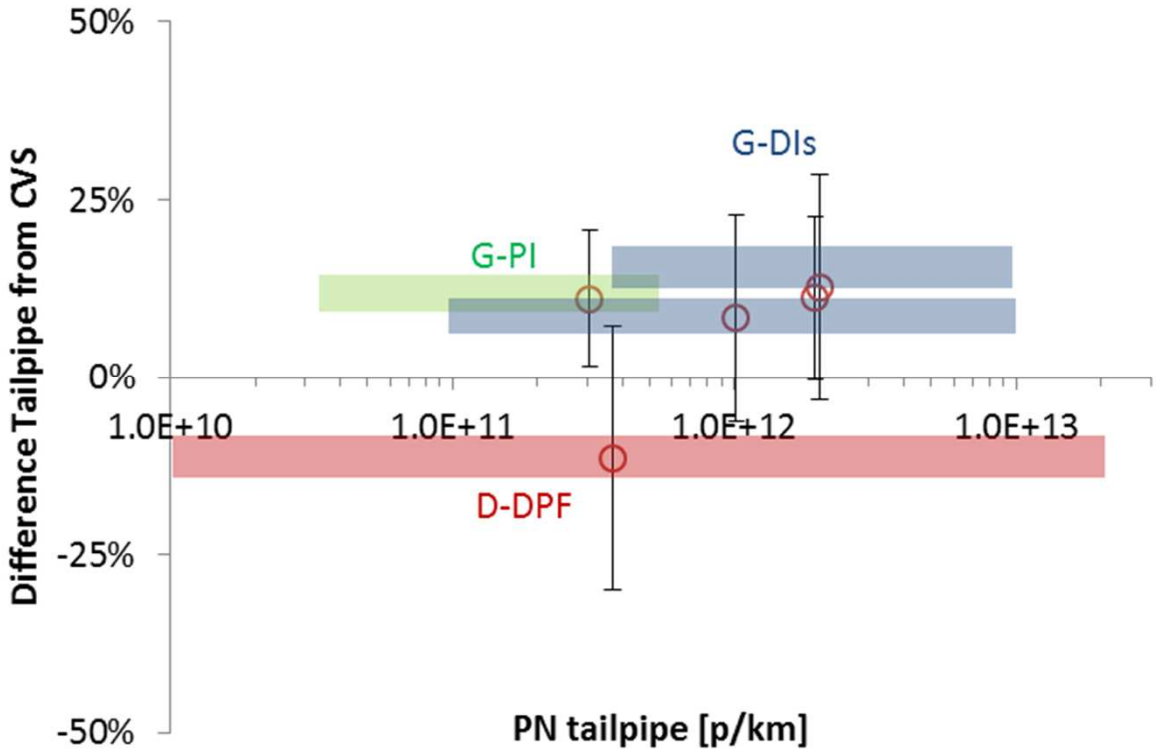
Difference PN-PEMS & PMP



Theoretical differences: -43% to +50% (GMD=40-90nn)

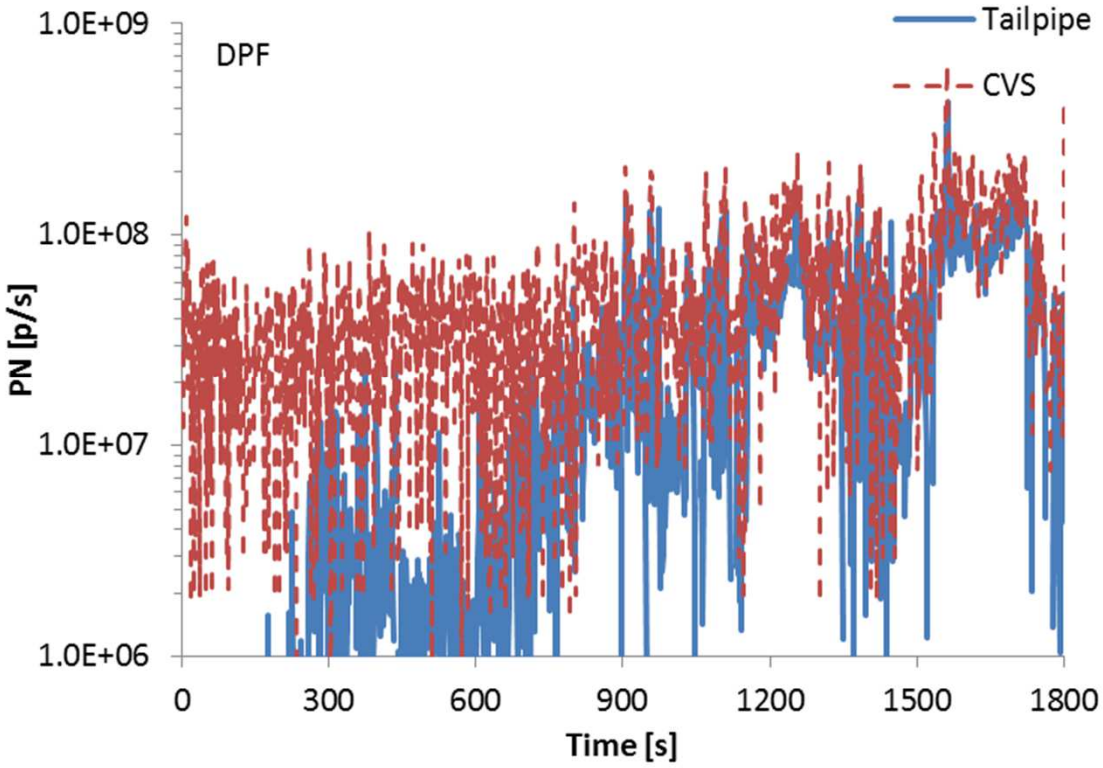
Additional PMP and sampling position uncertainty

Sampling position uncertainty

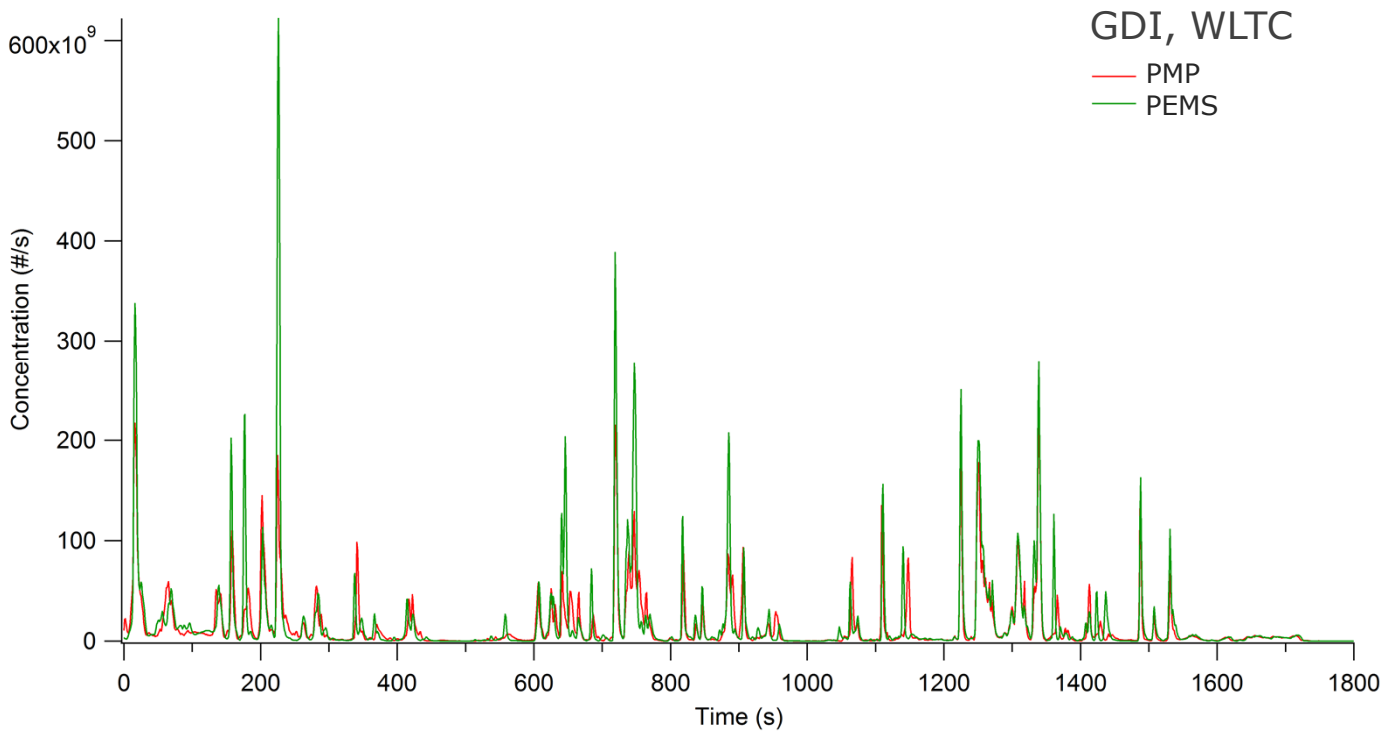


Differences ± 25%

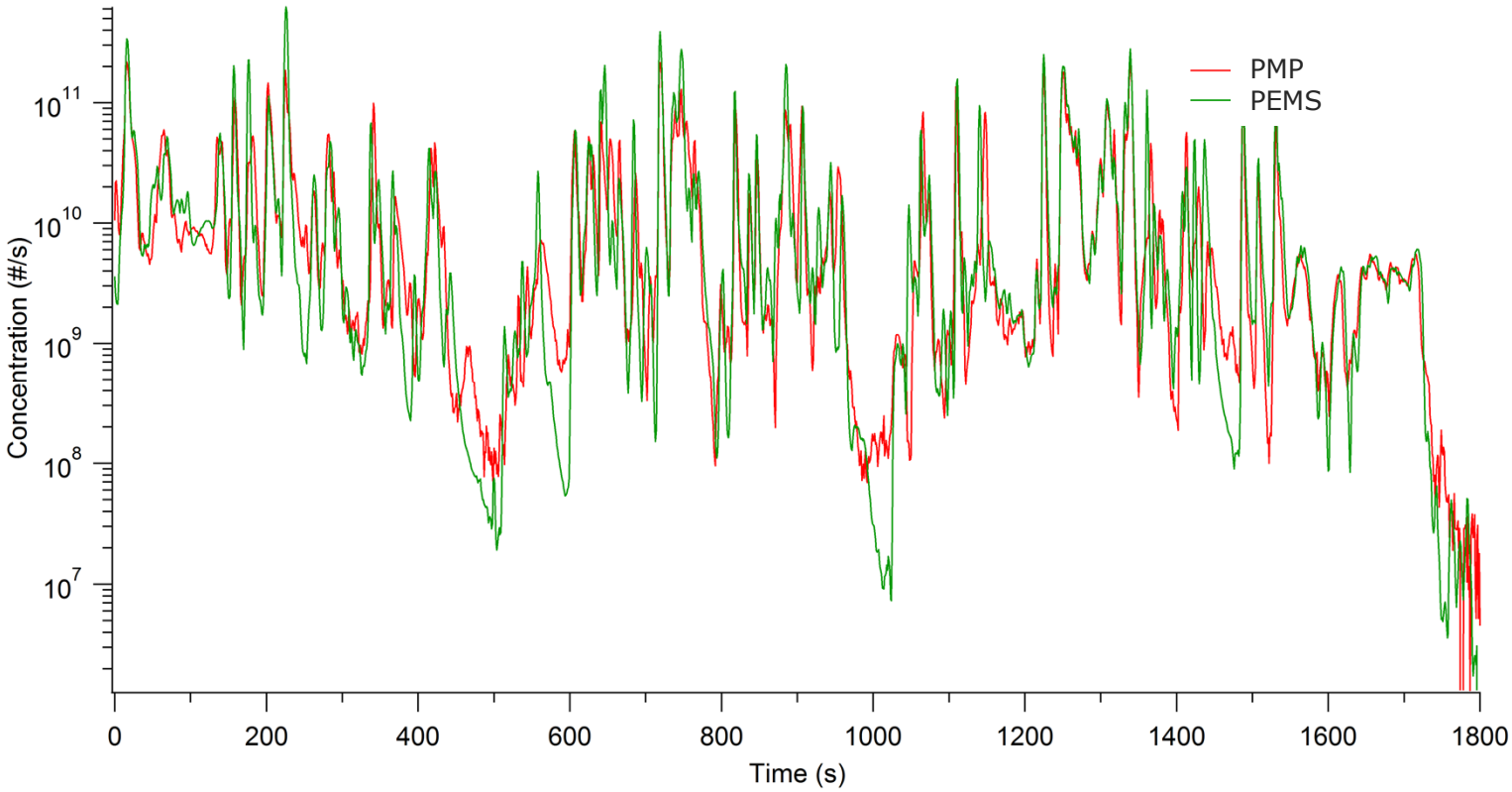
PMP detection limit



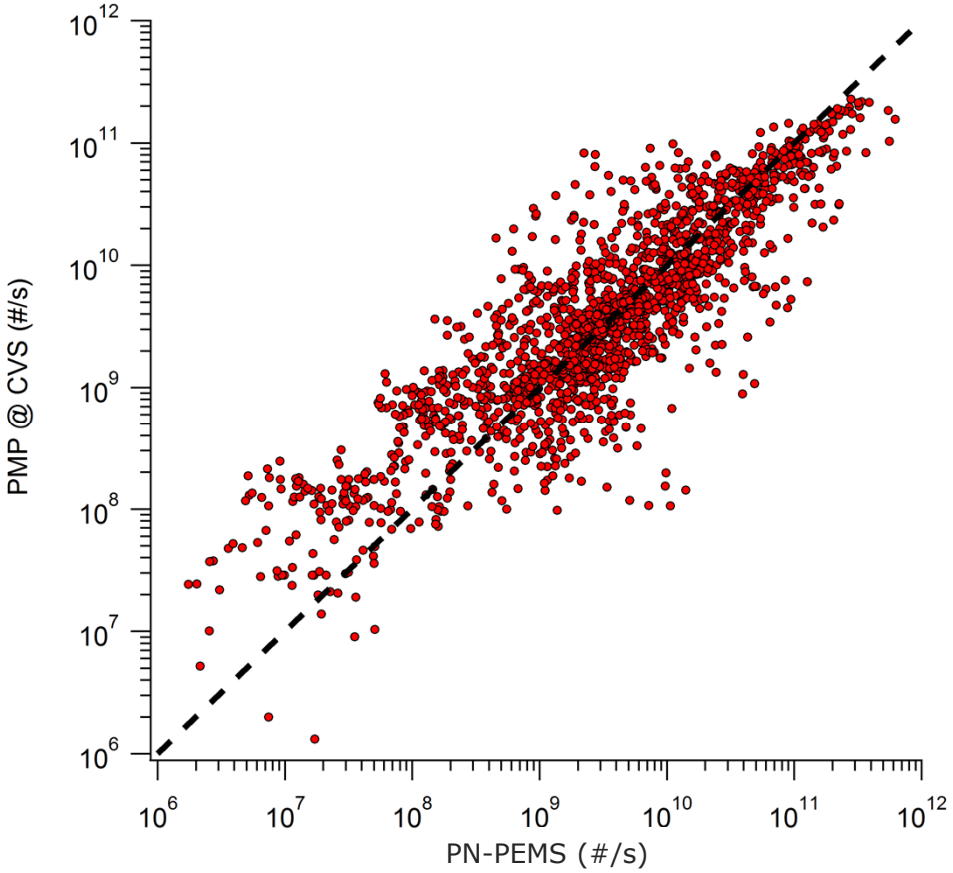
PMP vs PN-PEMS times series



PMP vs PN-PEMS times series (zoom in)



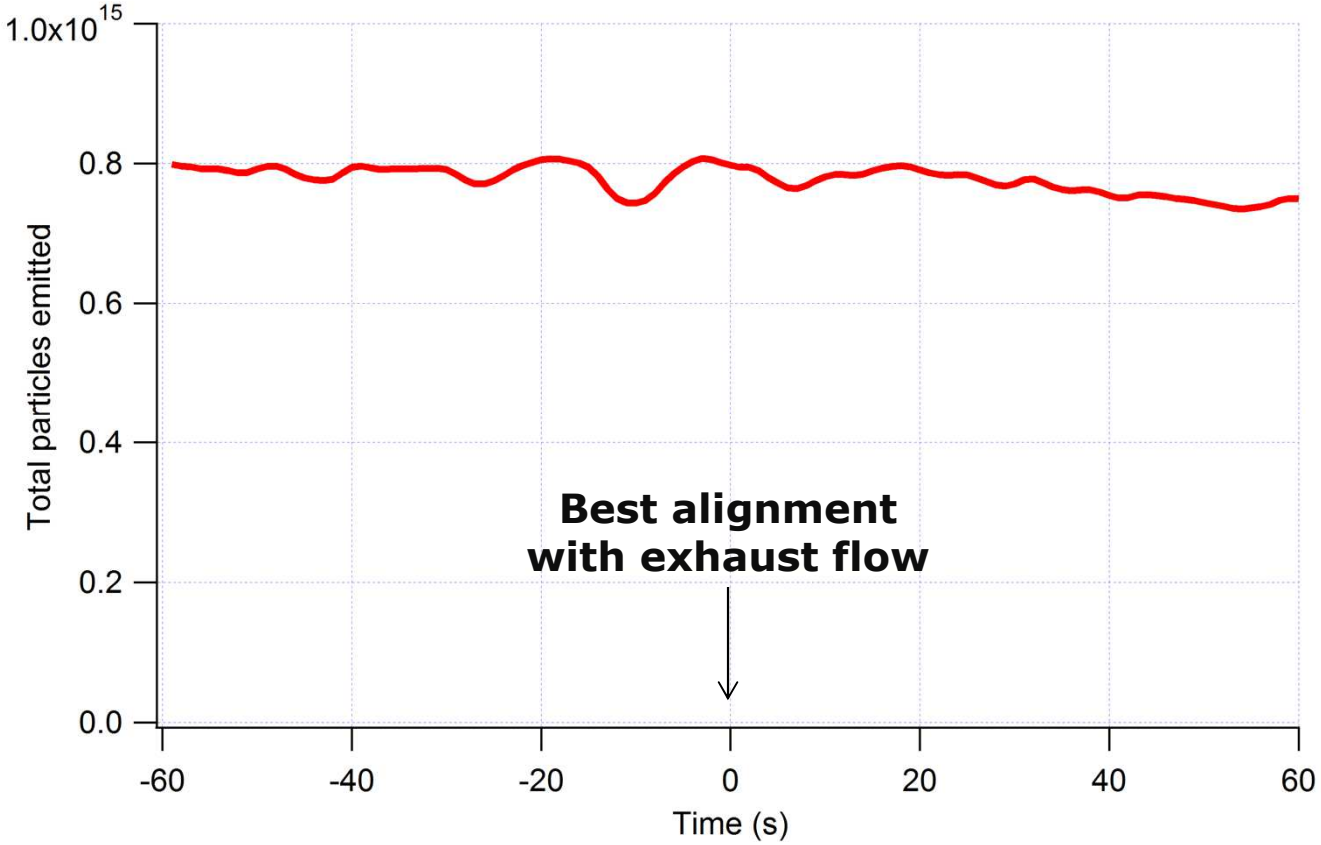
PMP vs PN-PEMS 1Hz



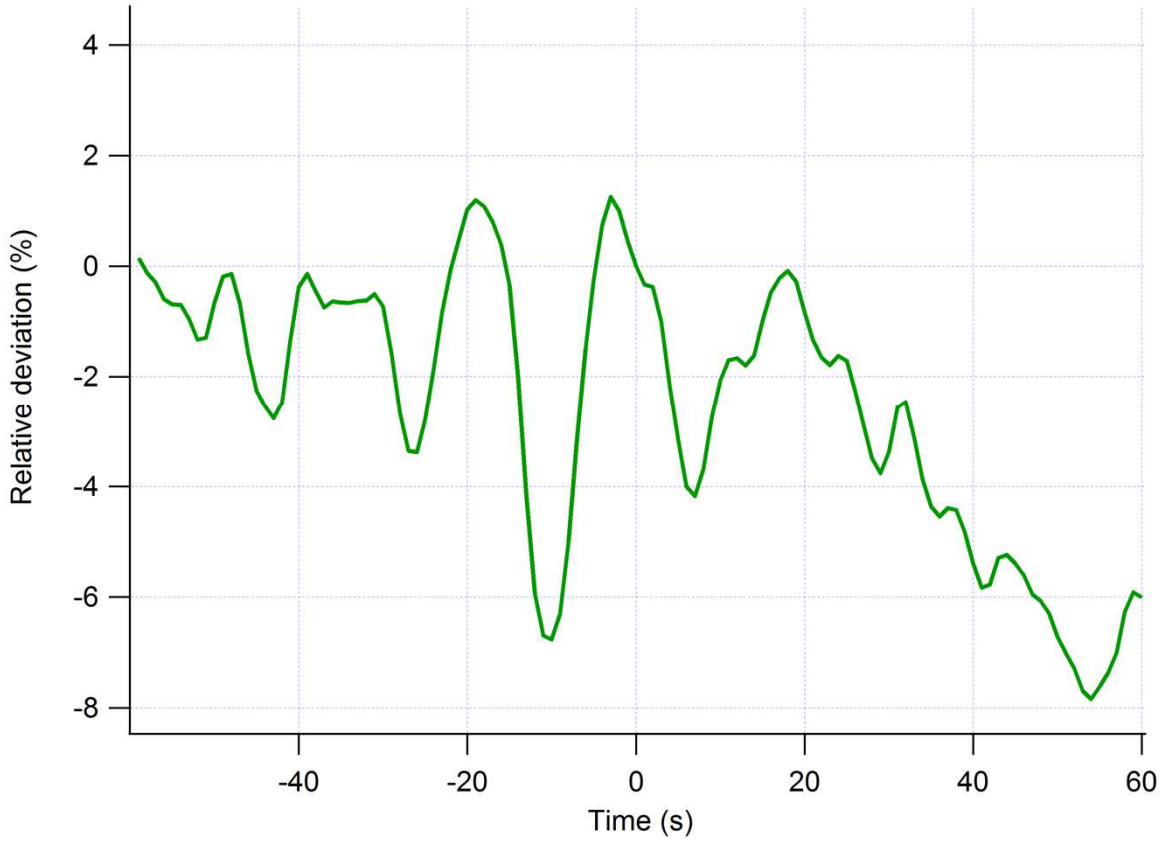
Unavoidable time misalignment due to different response time of the systems and time delay between tailpipe and CVS

Reported results are cycle average emission factor #/km

Time alignment uncertainty



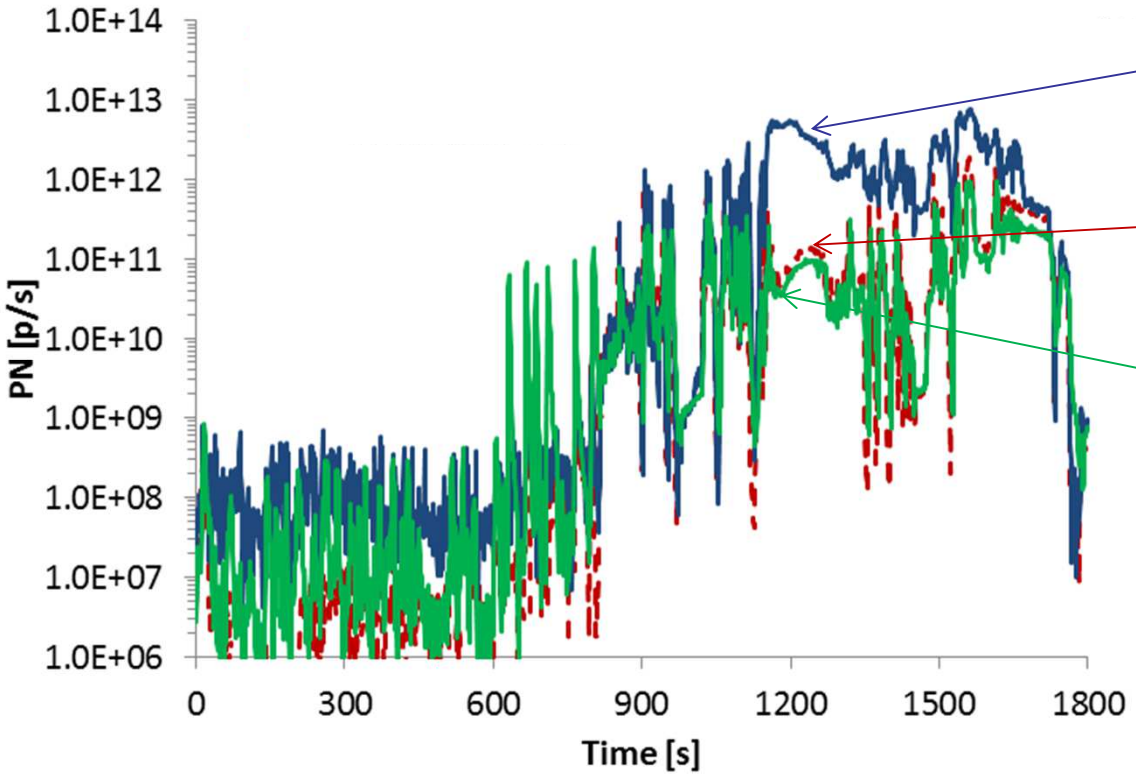
Time alignment uncertainty



Logging exhaust flow would minimize the uncertainty

Max deviation from mean ±4%

Extreme condition: Regeneration



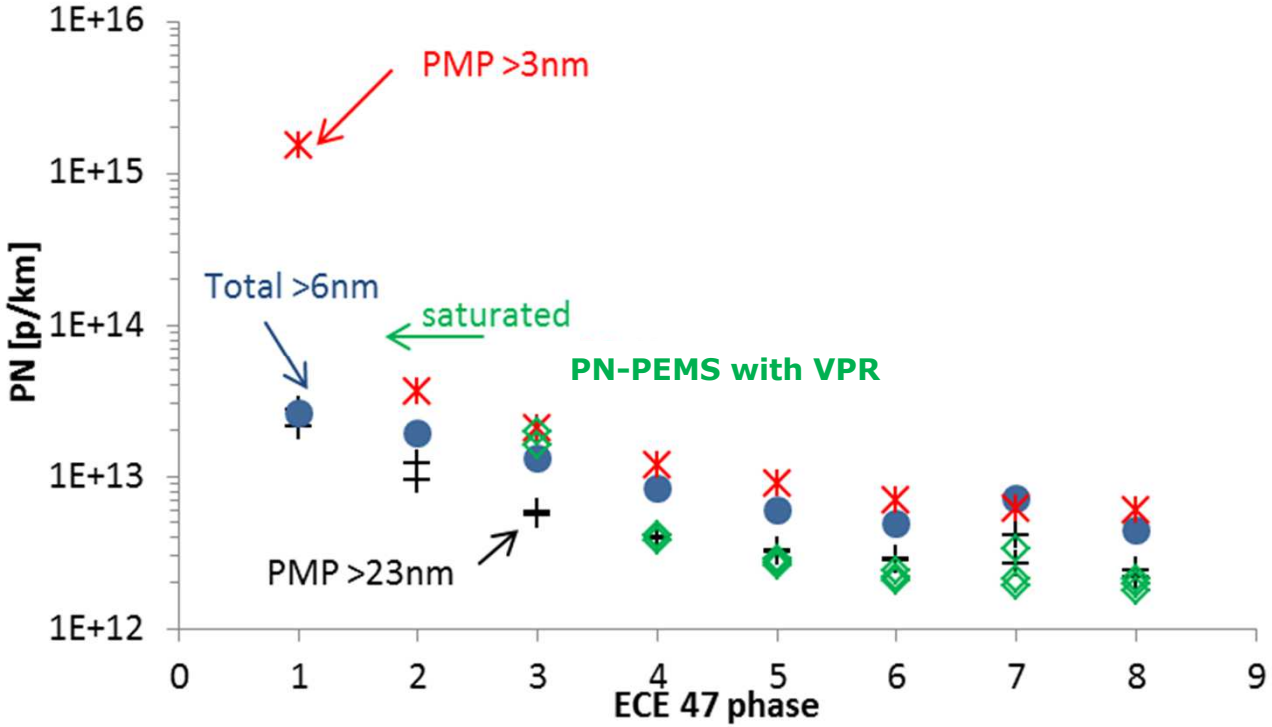
PEMS w/o VPR

PMP

PEMS w/ VPR

Thermal treatment is needed

Very extreme condition: Moped



Calibration of the cut-off curve is needed

Requirements for next generation of PN-PEMS instruments

- *Thermal treatment to remove volatile particles*
- *Calibration cut-off d_{50} at 23 nm*
- *Definition of daily functionality checks (draft):*
  - Status check: corona current and voltage, ion trap voltage, leak check.
  - Dilution ratio check: trace gas or particle generator.
  - Diffusion charging sensor check: zero check (HEPA filter), span check (ambient air vs reference CPC, PMP?).

Next: Same challenges of gas-PEMS

- *PEMS equipment*
  - Size, installation, safety
- *Need to contain variability of parameters*
  - Non-dynamic: altitude, ambient temperature
  - Dynamic and controlled: road grade, vehicle payload
  - Dynamic and uncontrolled: wind, vehicle speed and acceleration, engine load
- *Data evaluation*
  - Excluding data outside permissible operating conditions
  - Averaging window principle

Thanks for your attention!

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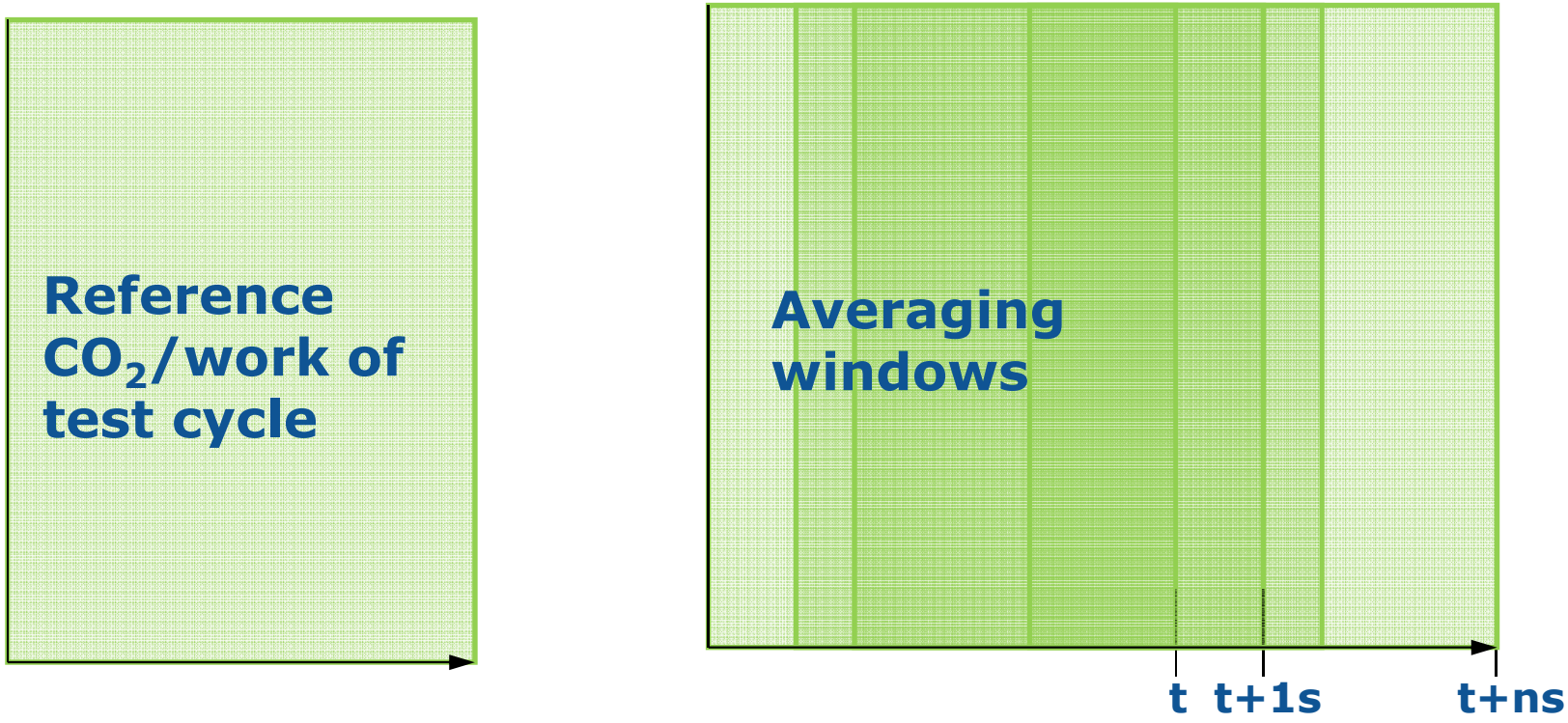
Moving averaging window approach: Averages over sub-sets of tests; duration in line with type-approval cycle



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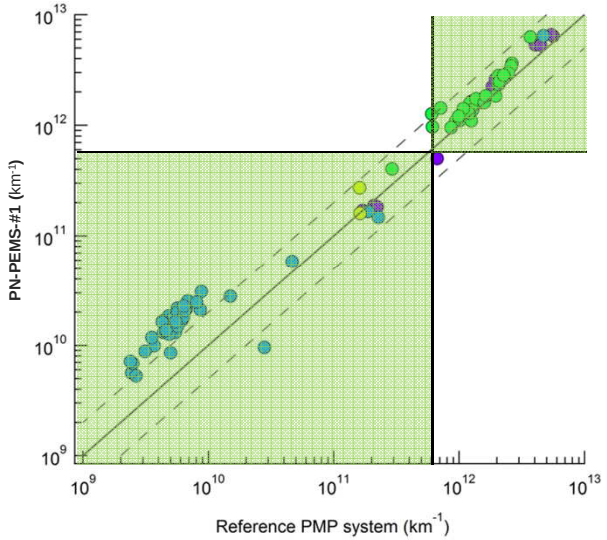
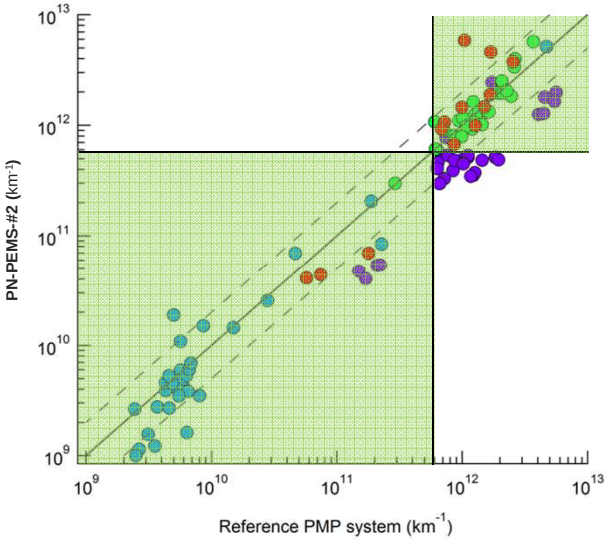
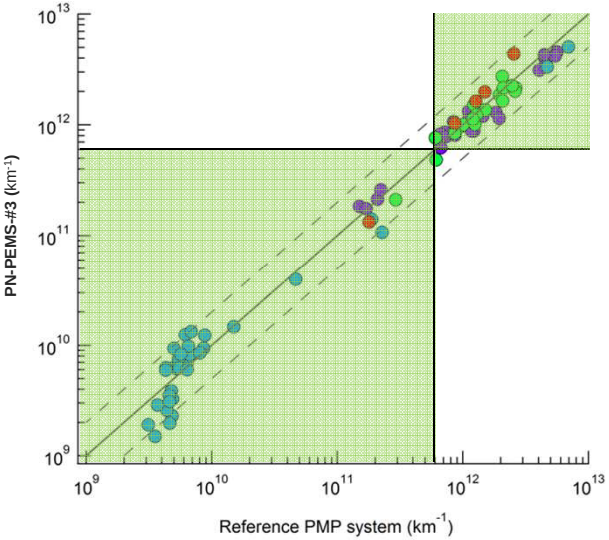
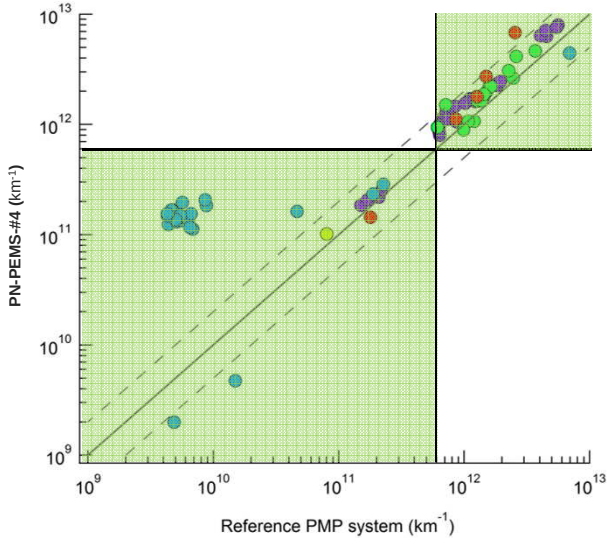
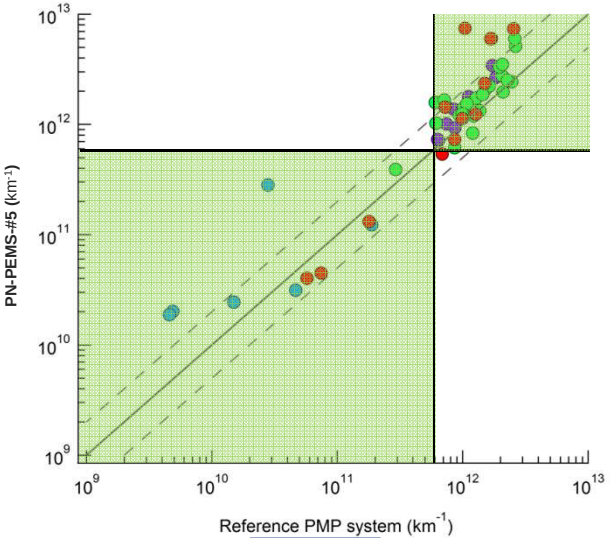
PN-PEMS vs PMP





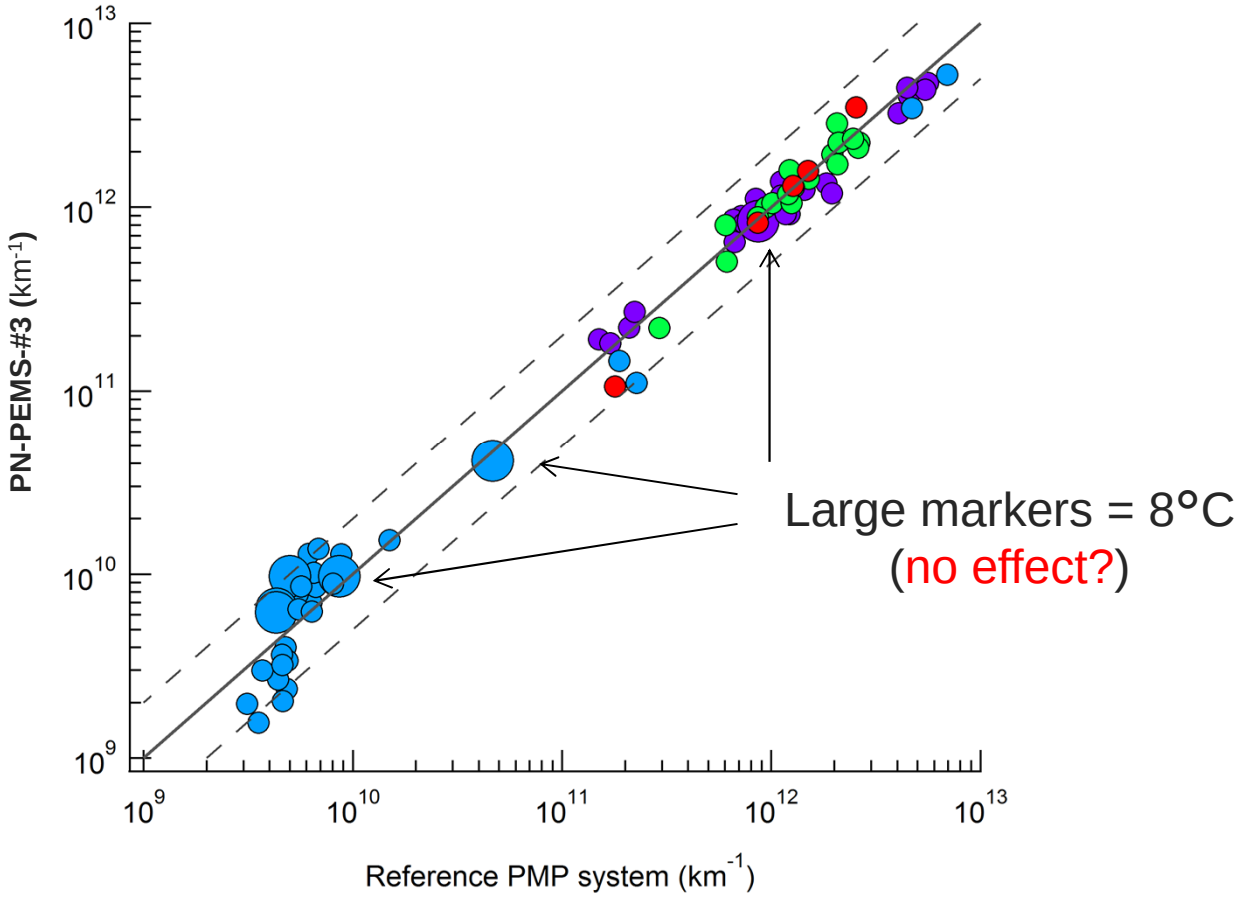






- GDI 1
- DPF
- GDI 2
- MPI
- GDI 3

Effect of ambient temperature



PMP efficiency