# An Update On The UN-ECE GRPE Particle Measurement Programme

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Department for Transport

## Inter-laboratory Correlation Exercises - Summary

- Light-duty Exercise prioritised
- Commenced late summer 2004
- Completed August 2006
- 9 labs participated (11 repetitions)
- Project managed by DG JRC (Ispra, Italy)
- Golden Engineer funded by DfT (UK)
- Heavy-duty programme planned for March 2007

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## Overview of light-duty inter-laboratory exercise

- Repeated **NEDC** tests made at several laboratories (with JRC bookends)
- Travelling '**Golden Engineer**' + **two of JRC staff** to ensure best and reproducible testing practice
- Very low PM '**Golden Vehicle**' at all labs (Repeatability/Reproducibility)
- Tests on:
  - Gaseous Pollutants
  - PMP modified mass measurement system
  - '**Golden Measurement System**' for particle numbers
  - Additional vehicles of various types
  - Alternative systems for particle numbers (constructed to PMP spec)

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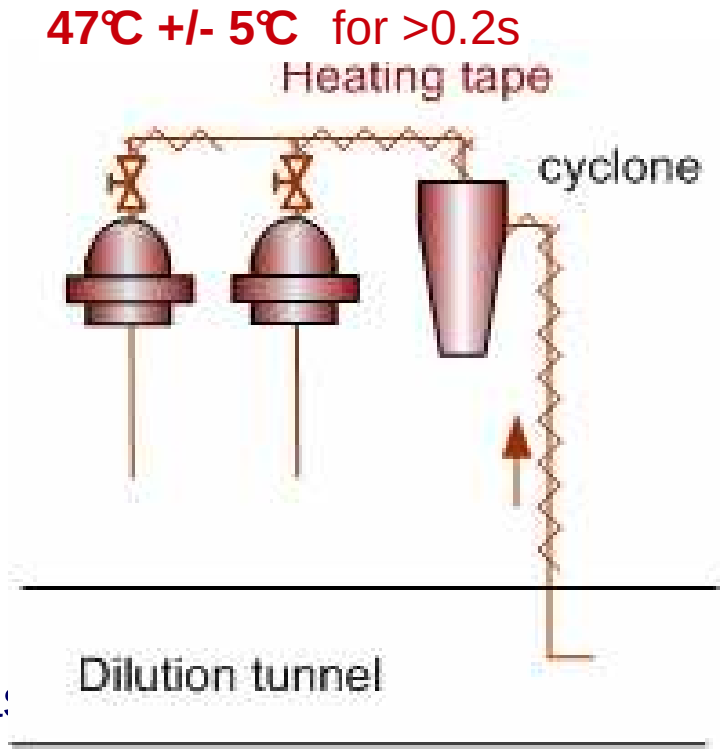
# PMP Mass system specifications

- **Cyclone** (2.5µm to 10µm cut-point)
- Lab modified systems with external heating tapes
  - Zone held at **47℃ +/- 5℃** for >0.2s
  - Filter face velocity (50cm/s to 80cm/s)
- Modified filter holders for even deposition of material
- Pallflex **TX40** mandated; single batch for all tests
- **No back-up filter**
- Single filter for entire NEDC for DPF equipped and ga
- Urban and extra-urban filters for conventional Diesels
- HORIBA HFU-4770 (Heated Particulate Filter Module) (2 labs)
  - Heated enclosure containing cyclone, transfer tubing and filter holders
    - Sample controlled to 47℃ +/- 5℃ for >0.2s

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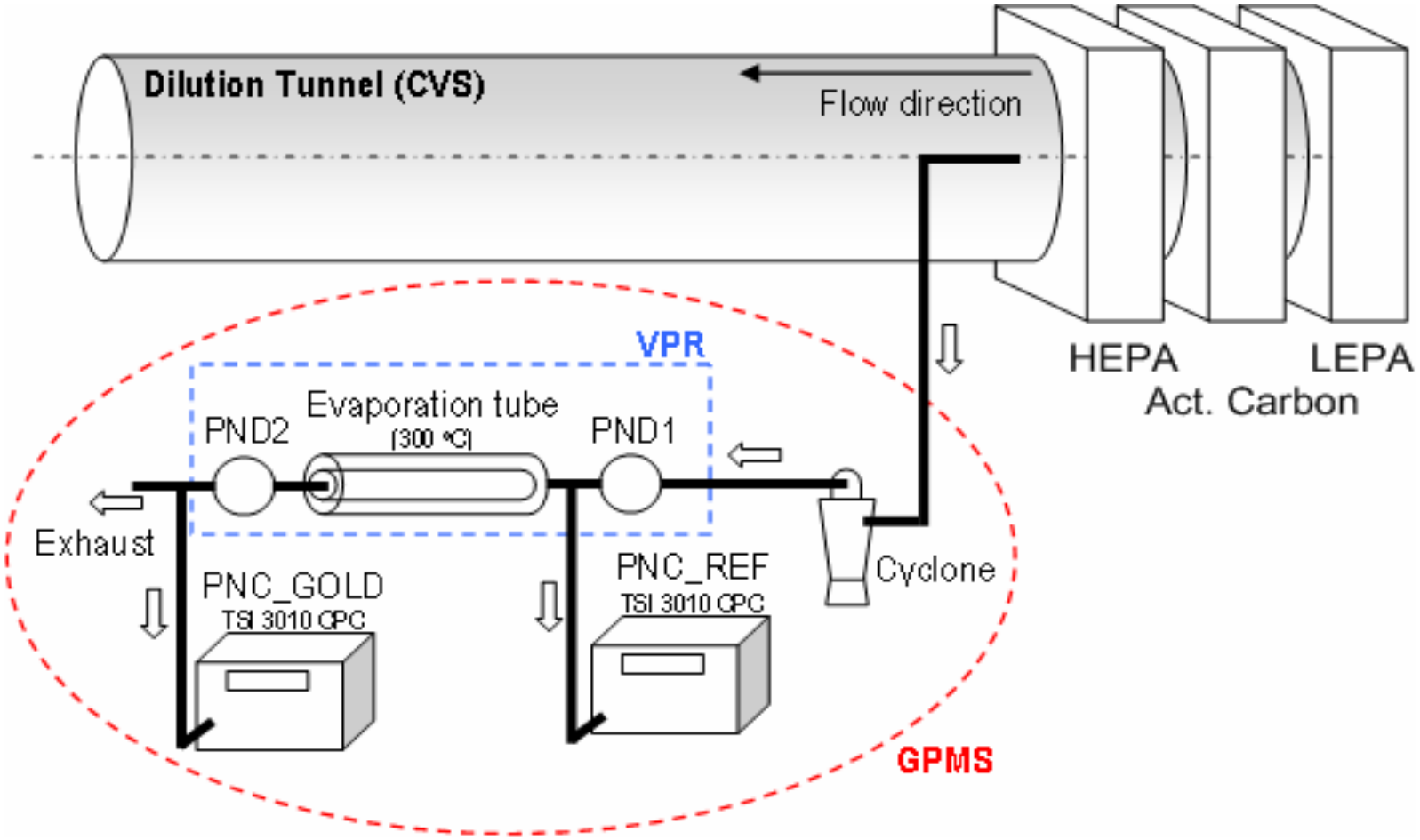
# Golden Particle Number System (GPMS)




- A particle number method employing a condensation nucleus counter, but using sample pre-conditioning to eliminate the most volatile particles which may contribute significantly to variability.

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# Other particle number systems tested

- **ALTERNATIVE SYSTEMS (same specifications)**
  - Clone GPMS: Rotating Disc (MATTER Eng.) + Evaporation Tube + Dilutor (3 lab)
  - SPCS: HORIBA Solid particle counting system (2 labs)
  - FPS: DEKATI FPS (modified) - GRIMM modified CPC 5.403 (3 labs) or TSI CPC 3010 lab modified (3 labs)
- **ADDITIONAL SYSTEMS (differences)**
  - EJ: Dual Ejector dilutor-TSI CPC 3010 lab modified (1 lab)
  - FPS/EJ+TD: Ejector dilutor or FPS + Thermodenuder -TSI CPC 3010 lab modified (1 lab)

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# Vehicles tested

## DPF DIESELS x 6

- **PEUGEOT 407 HDi FAP 2000 cc (in all labs)**
- BMW 525d catalysed DPF equipped, 2500 cc
- MAZDA Bongo catalysed DPF, 2000 cc
- TOYOTA Avensis D-CAT 2000 cc
- MERCEDES Vito Van DPF 3000 cc
- PEUGEOT 206 HDi FAP

## Conventional DIESELS x 6

- BMW 120d PMFC 2000 cc
- AUDI A2, TDi, EURO-4, Oxicat, 1500 cc
- HONDA Accord i-CTDi, Euro 4, Oxicat/deNOx, 2200 cc
- VW, GOLF TDi, non-DPF, 1800 cc
- KIA Pride, non-DPF, 1500 cc
- VAUXHALL Astra, CDTi, 1700 cc

## GDI x 3

- MITSUBISHI Carisma, GDI, TWC/deNOx 1800 cc
- VW, GOLF FSI, TWC/deNOx 1600 cc
- TOYOTA Crown G-DI, 3000 cc

## MPI x 1

- FIAT, Idea, MPI, EURO-4, TWC, 1400cc

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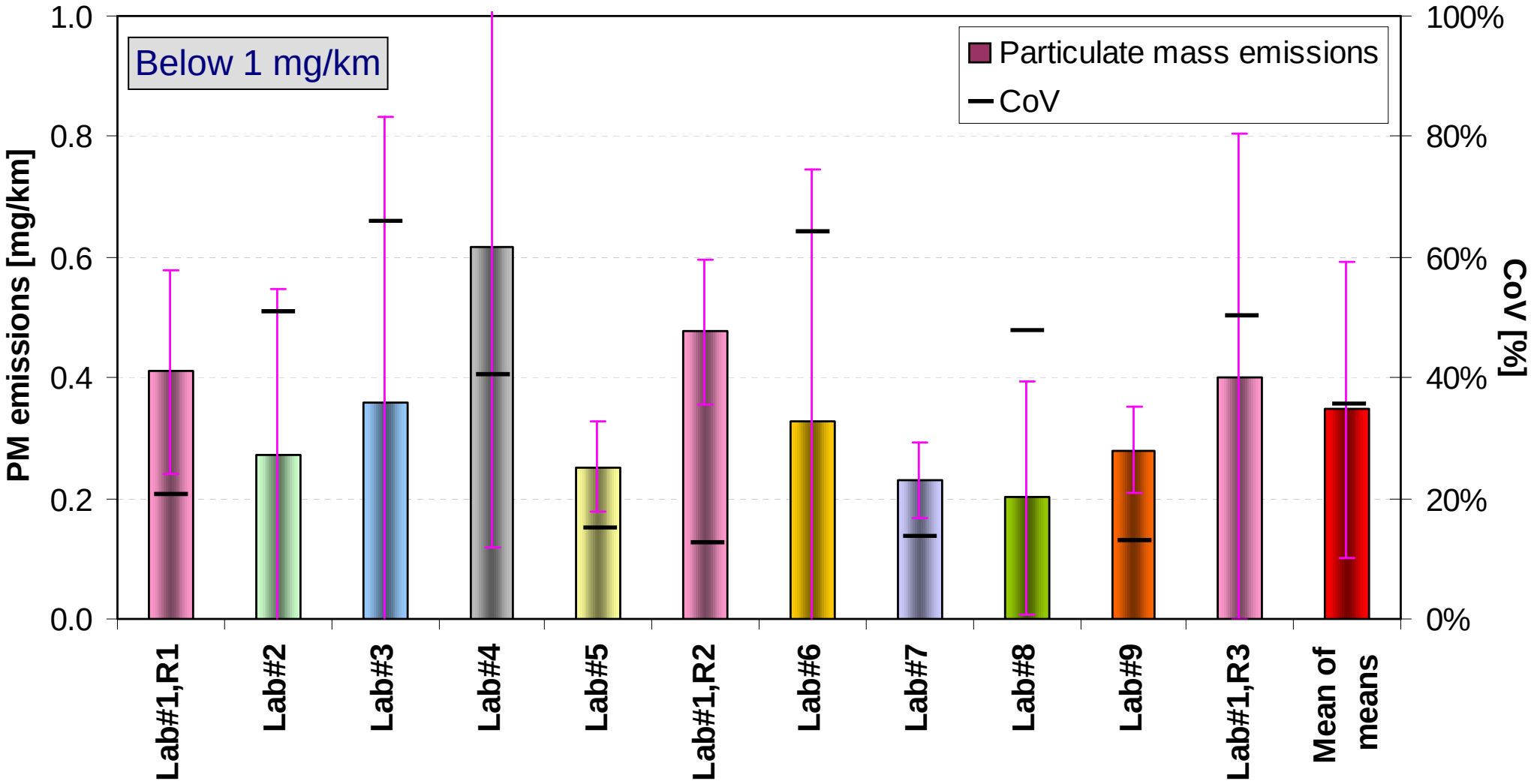
# Particulate Mass Emissions NEDC - Golden Vehicle




Emissions: 0.2-0.6mg/km
Repeatability: 12-66%

Emissions: 0.34mg/km
Reproducibility: 35%

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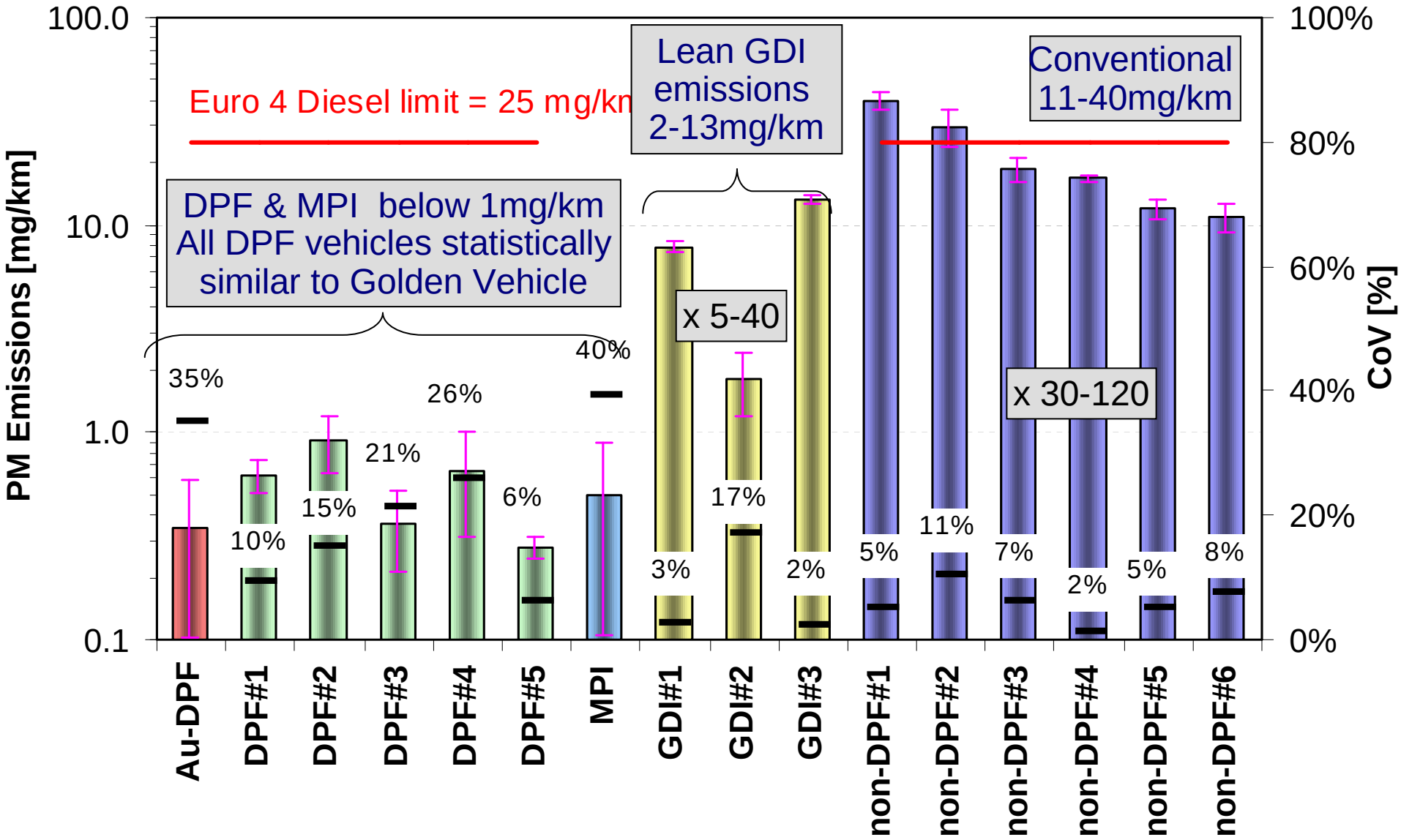
# Particulate Mass Emissions NEDC – all vehicles

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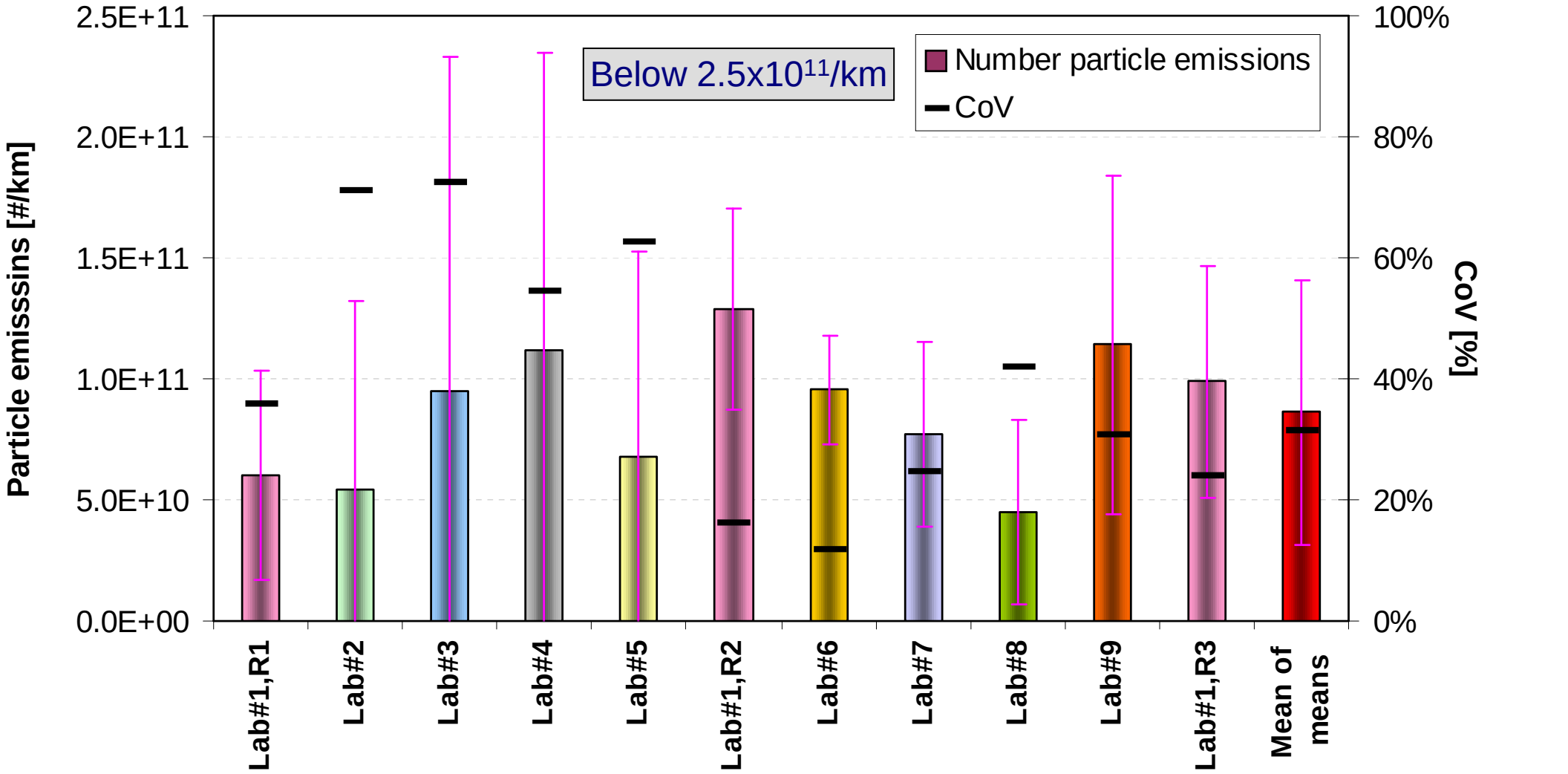
# Particle Numbers from NEDC - Golden Vehicle




Emissions: 5-13x10^10/km
Repeatability: 12-72%

Emissions: 8x10^10/km
Reproducibility: 31%

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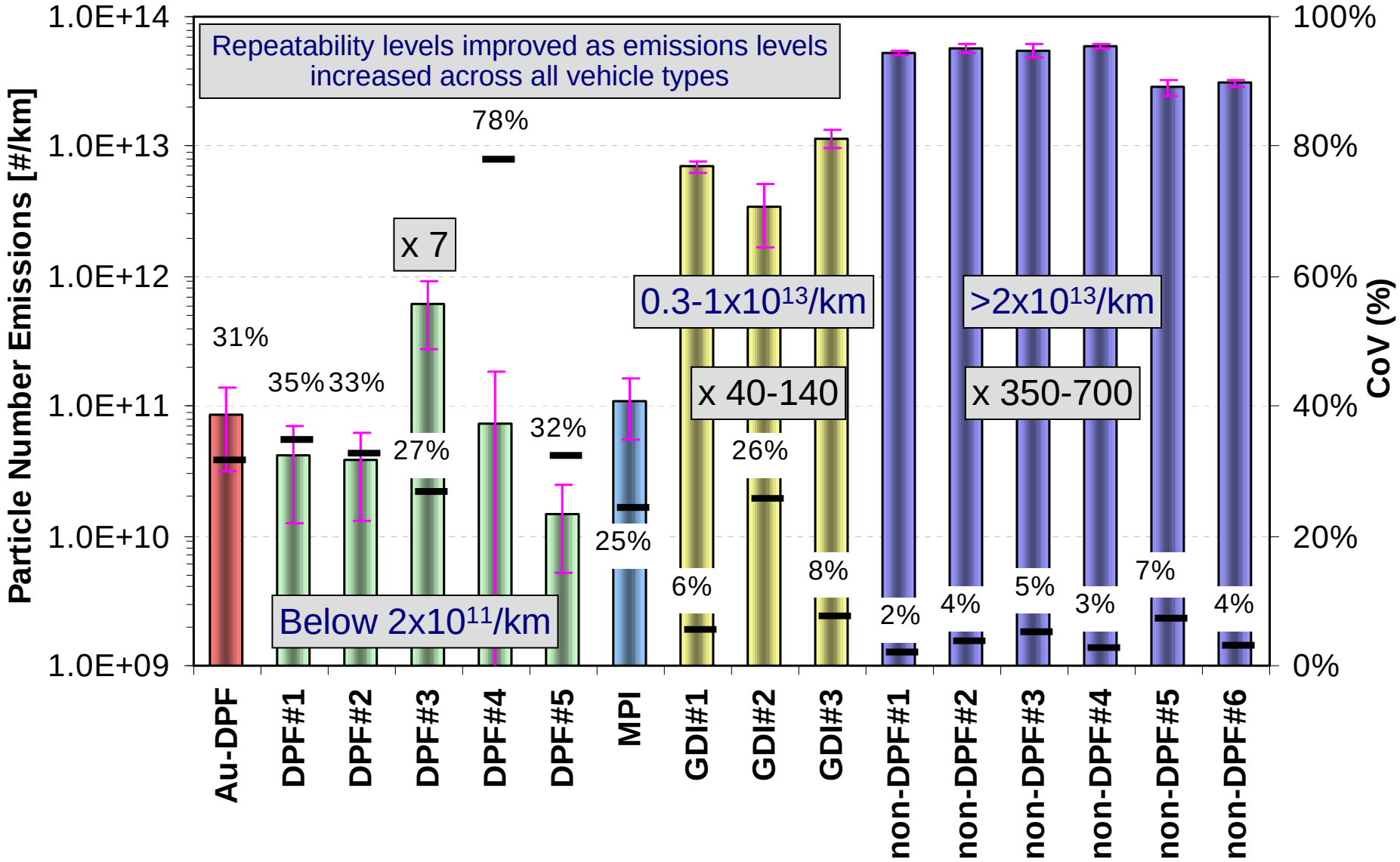
# NEDC Particle Numbers (#/km) – All vehicles

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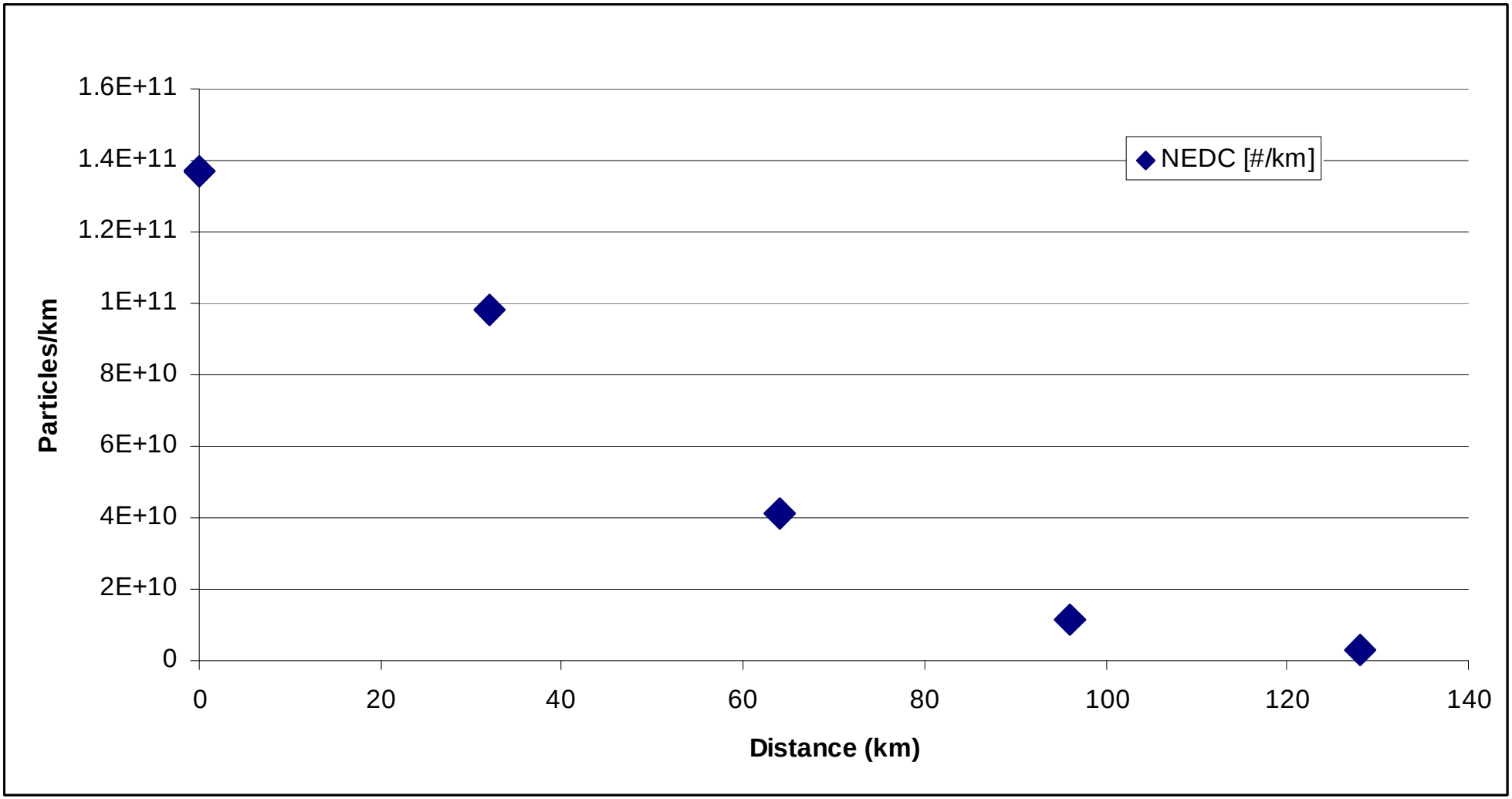
# Repeatability of DPF#4




- Regeneration occurred prior to first test
- PN decreased from test to test as DPF filled giving high variability

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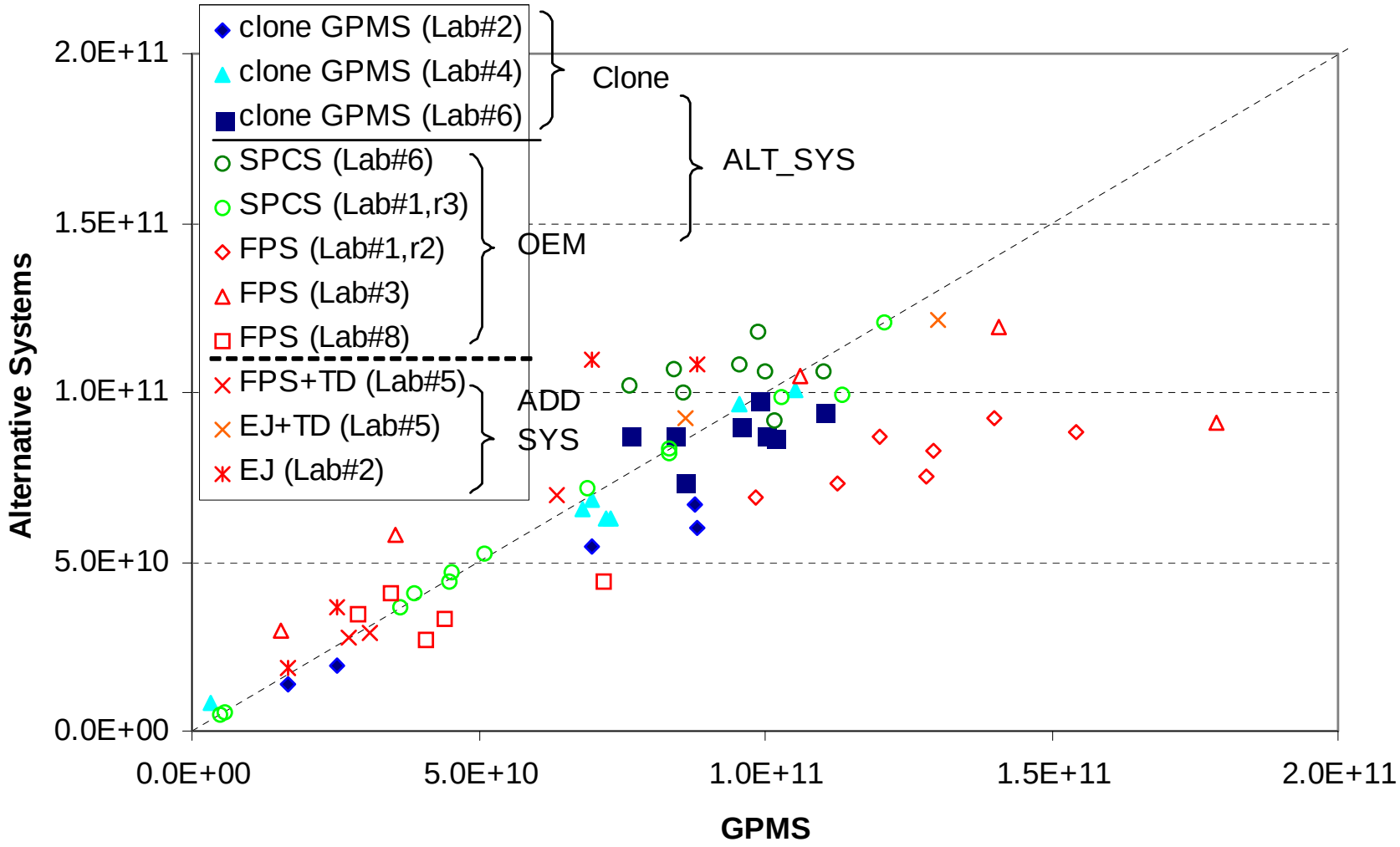
# Alternative systems – Golden vehicle

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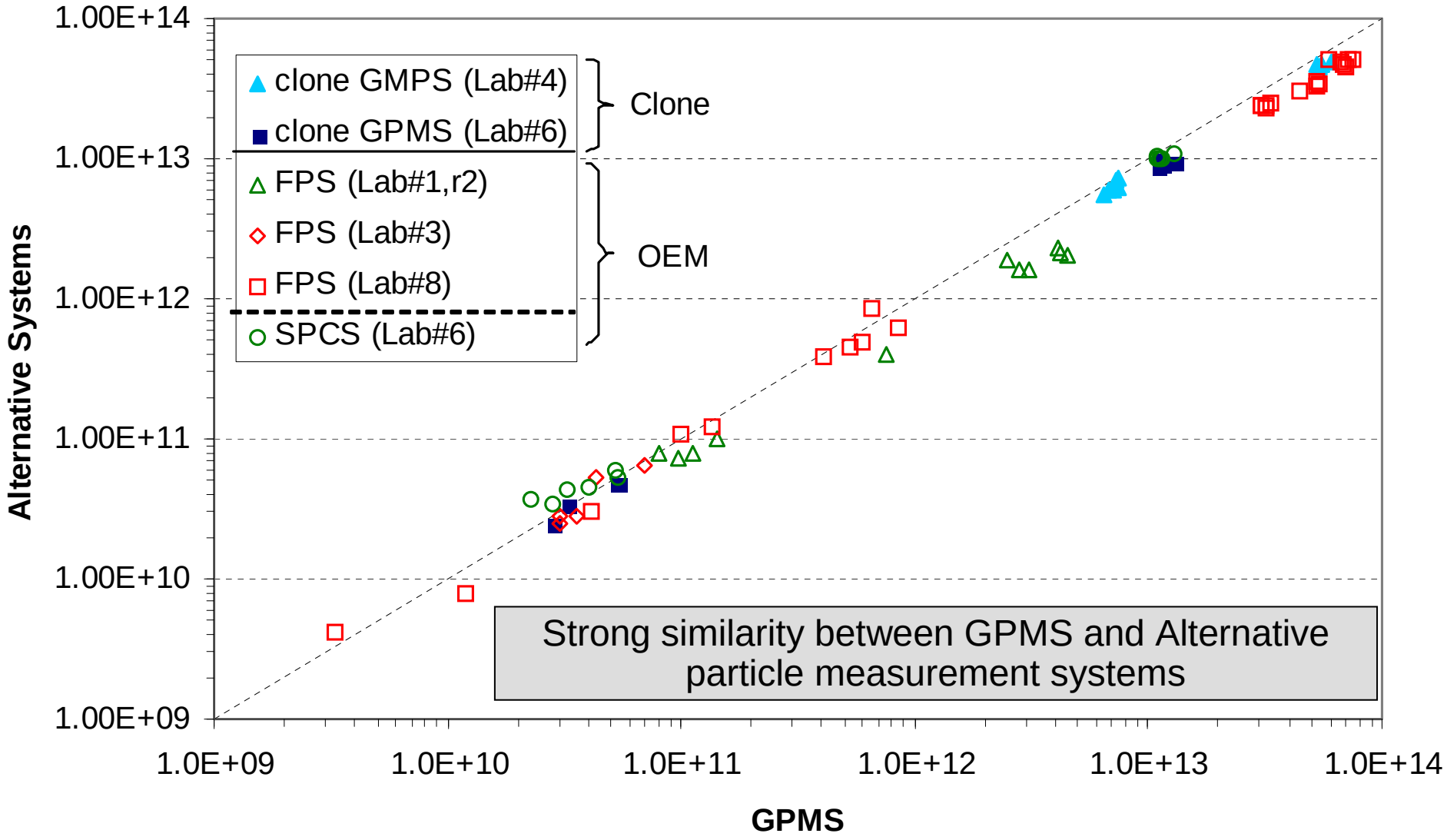
# Alternative systems – Rest vehicles

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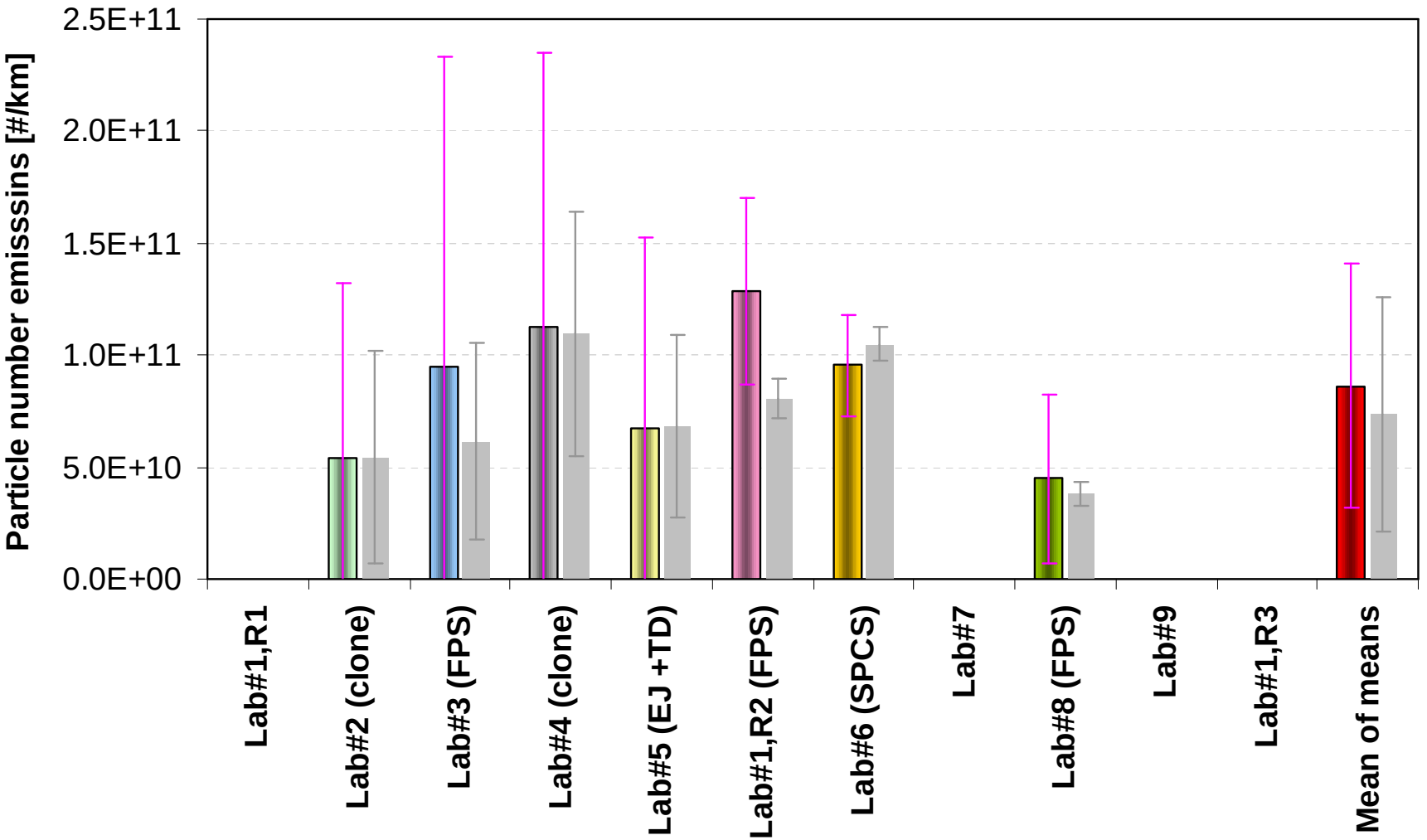
# Validation Exercise and Round Robin simulation




**Validation Exerc.**

Reproducibility

| | |
|---|---|
| N: | 31% |
| PM: | 35% |
| $CO_2$: | 4% |
| $NO_x$: | 10% |
| HC: | 35% |
| CO: | 44% |

**RR simulation.**

Reproducibility

| | |
|---|---|
| GPMS: | 36% |
| PM: | 40% |
| $CO_2$: | 4% |
| $NO_x$: | 12% |
| HC: | 45% |
| CO: | 49% |

GPMS: $8.5 \times 10^{10}$/km ±36%

ALTS: $7.5 \times 10^{10}$/km ±35%

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# Conclusions

- Golden vehicle
  - PM: ~ 0.34 mg/km ± 35%
  - PN: ~$8x10^{10}$ /km ± 31%

- Rest vehicles
  - PM: Conv. Diesels(11-40mg/km)>G-DI(2-13mg/km)>porous DPF ~ MPI ~DPF(1mg/km)
  - PN: Conv. Diesels ($5x10^{13}$)>G-DI($5x10^{12}$)>porous DPF($5x10^{11}$)>MPI ~DPF($1x10^{11}$)

- The majority of alternative systems correlated closely with the GPMS
  - The validation exercise and a simulation of a Round Robin exercise showed that number method (and mass) have reproducibility levels similar to those of HC and CO.

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# Conclusions

- Mass and number measurement equipment presented no significant functional or maintenance challenges during the programme
- Mass method less variable than number for DPF diesel cars but not for non-DPF vehicles
- Mass method insensitive to DPF fill state, preconditioning of the vehicle and DPF porosity - ‘true repeatability’ masked
- Number provides best sensitivity and avoids uncertainties with volatile components
  - The mass method collects a large gaseous volatile fraction that may be 20 times the mass of the solid particles collected
- Both mass and number sufficiently sensitive to discriminate between a DPF equipped Diesel and current non-DPF equipped Diesels

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# Next Steps – Light Duty

- Publication of final Light Duty Validation report - imminent
- Consideration of proposal to include PMP procedures in UN-ECE Regulation 83
  - GRPE 7th & 8th June 2007
  - WP29 November 2007 ?
- Adoption of Particle Number limits in EU Euro 5 & 6 Regulation
  - Draft implementing measures currently include limit for diesels from 1st September 2009 of $5x10^{11}$ particles/km
  - European Parliament & Council agreement requires particle number limits 'as soon as possible and at the latest upon entry into force of the Euro 6 stage'

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# Next Steps – Heavy Duty

- Commence Heavy Duty Validation testing at JRC – imminent
  - Golden Engine Iveco Cursor 8 + CRT
  - Golden Engineer – Jon Andersson, Ricardo
  - Golden Systems – Horiba SPCS
  - Full and partial flow sampling
  - 8 repeat tests on 6 cycles (WHTC x3, WHSC, ETC, ESC)
  - Labs: JRC x2, UTAC, EMPA, TNO?, Sweden, UK
- Update Heavy Duty test protocol on basis of results of JRC investigative experiments e.g. pre-conditioning, partial flow sampling system operation

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# Next Steps – Heavy Duty

- Commence Round Robin once updated test protocol available
  - Golden Engine - DCX 501
  - No Golden Engineer, No Golden System
  - TUV, VTT, Volvo, UTAC, NTSEL, JARI, Transport Canada, NIER
- Duration of both (parallel) exercises ~ 2 years
- Propose inclusion of PMP procedures in UN-ECE Regulation 49

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