UNECE GRPE

Particle Measurement Programme

UPDATE ON THE PMP PHASE 3 LIGHT-DUTY INTER-LABORATORY CORRELATION EXERCISE: SUMMER 2006

10th ETH-Conference on Combustion Generated Nanoparticles
21st –23rd August 2006

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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 late 2006 / early 2007

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Overview of light-duty inter-laboratory exercise

- Repeated measurements 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:
  - ‘Golden Measurement System’ for particle numbers
  - Pre-specified modified mass measurement system
  - Additional vehicles of various types
  - Alternative systems for particle numbers (constructed to PMP spec)

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Outline

- Test Vehicles
- Alternative systems
- Mass results
- Number results
- Regeneration effects
- Preliminary conclusions
- Next steps

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Vehicles tested

- 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

DPF DIESELS * 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
- RENAULT Megane, 1.5 dCi, 1500 cc (Euro 3)

Conventional DIESELS * 7

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

Lean DISI * 3

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

MPI

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Mass systems tested

- Pallflex TX40 mandated; single batch for all tests
- Inertial collection for protection of filter (2.5µm to 10µm cut-point)
- No back-up filter
- Single filter for entire NEDC for DPF equipped and gasoline vehicles
- Urban and extra-urban filters for conventional Diesels
- Modified filter holders for even deposition of material
- Lab modified systems with external heating tapes and mantles (most labs)
  - Sample passes through zone held at 47°C +/- 5°C for >0.2s
  - Temperatures recorded
- HORIBA HFU-4770 (Heated Particulate Filter Module) (2 labs)
  - Heated enclosure containing cyclone, transfer tubing and filter holders
    - Sample controlled to 47°C +/- 5°C for >0.2s

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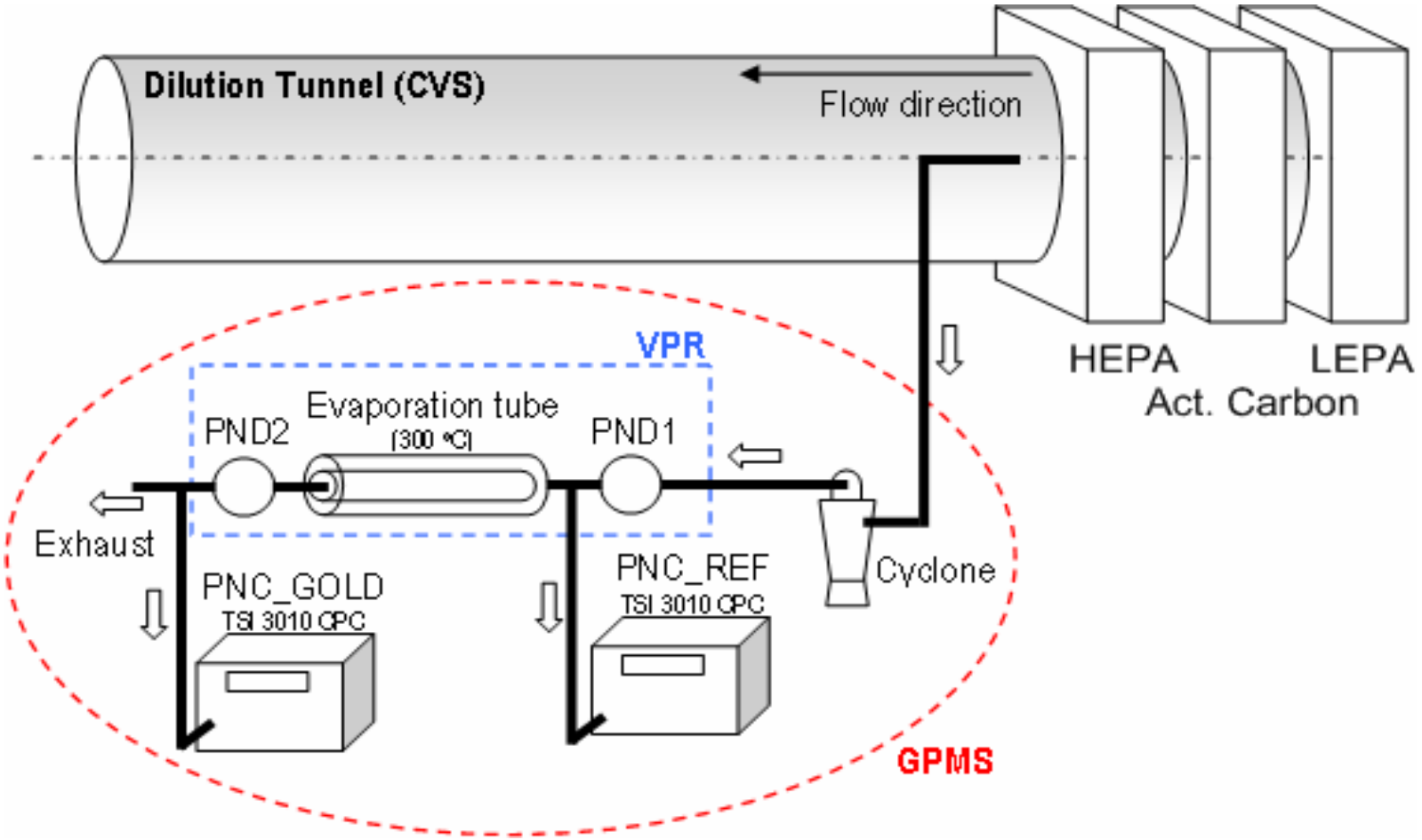
Particle Number System



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

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Alternative number systems tested

- Clone GPMS: Rotating Disc + Evaporation Tube + Ejector Dilutor (2 lab)
- EJ: Dual Ejector dilutor-TSI CPC 3010 lab modified (1 lab)
- FPS: DEKATI FPS (modified) - GRIMM modified CPC 5.403 (3 labs) or TSI CPC 3010 lab modified (1 lab)
- EJ+TD: Ejector dilutor or FPS + Thermodenuder -TSI CPC 3010 lab modified (1 lab)
- SPCS: HORIBA Solid particle counting system (2 labs)

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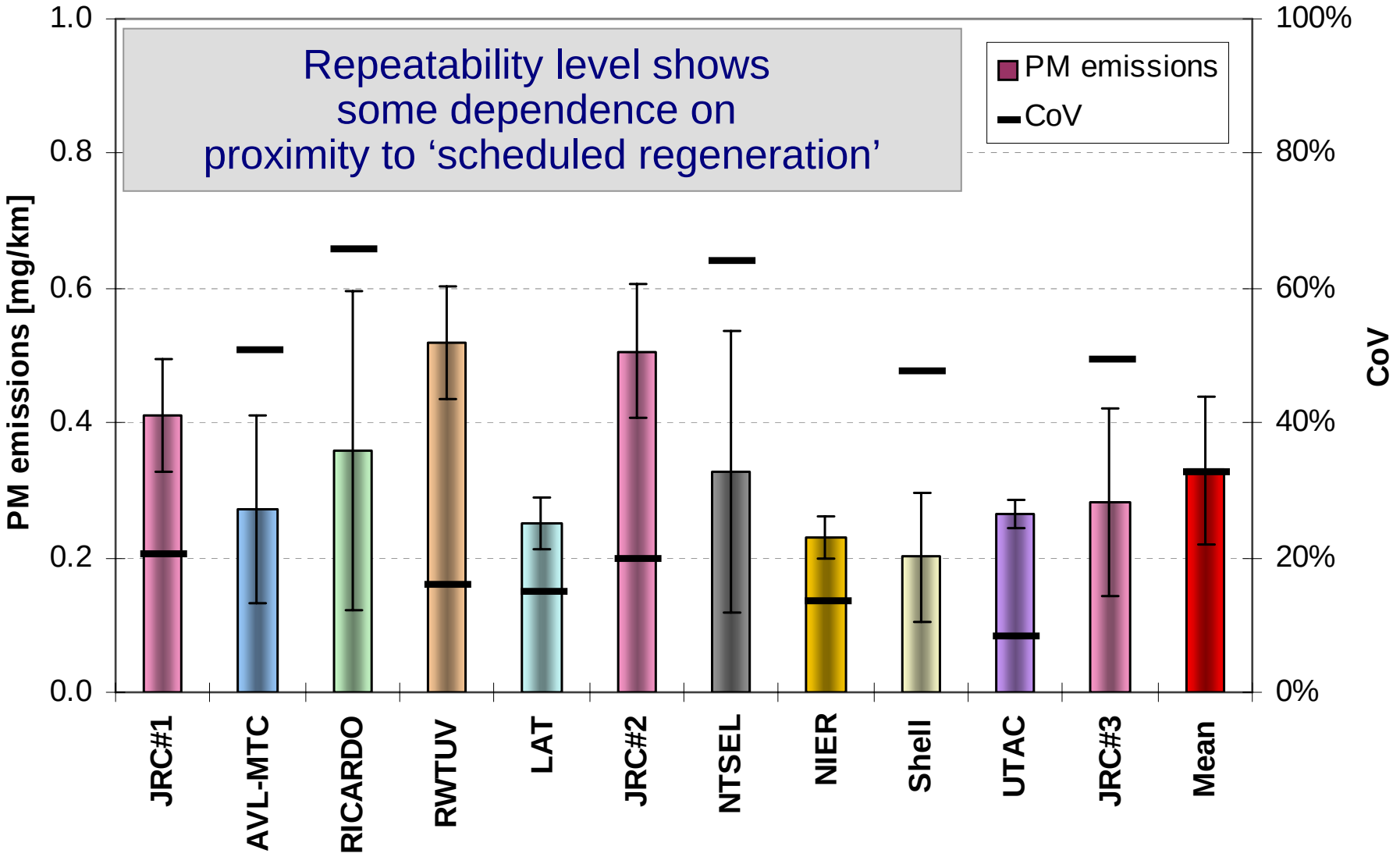
Particulate Mass Emissions From Golden Vehicle Below 1mg/km



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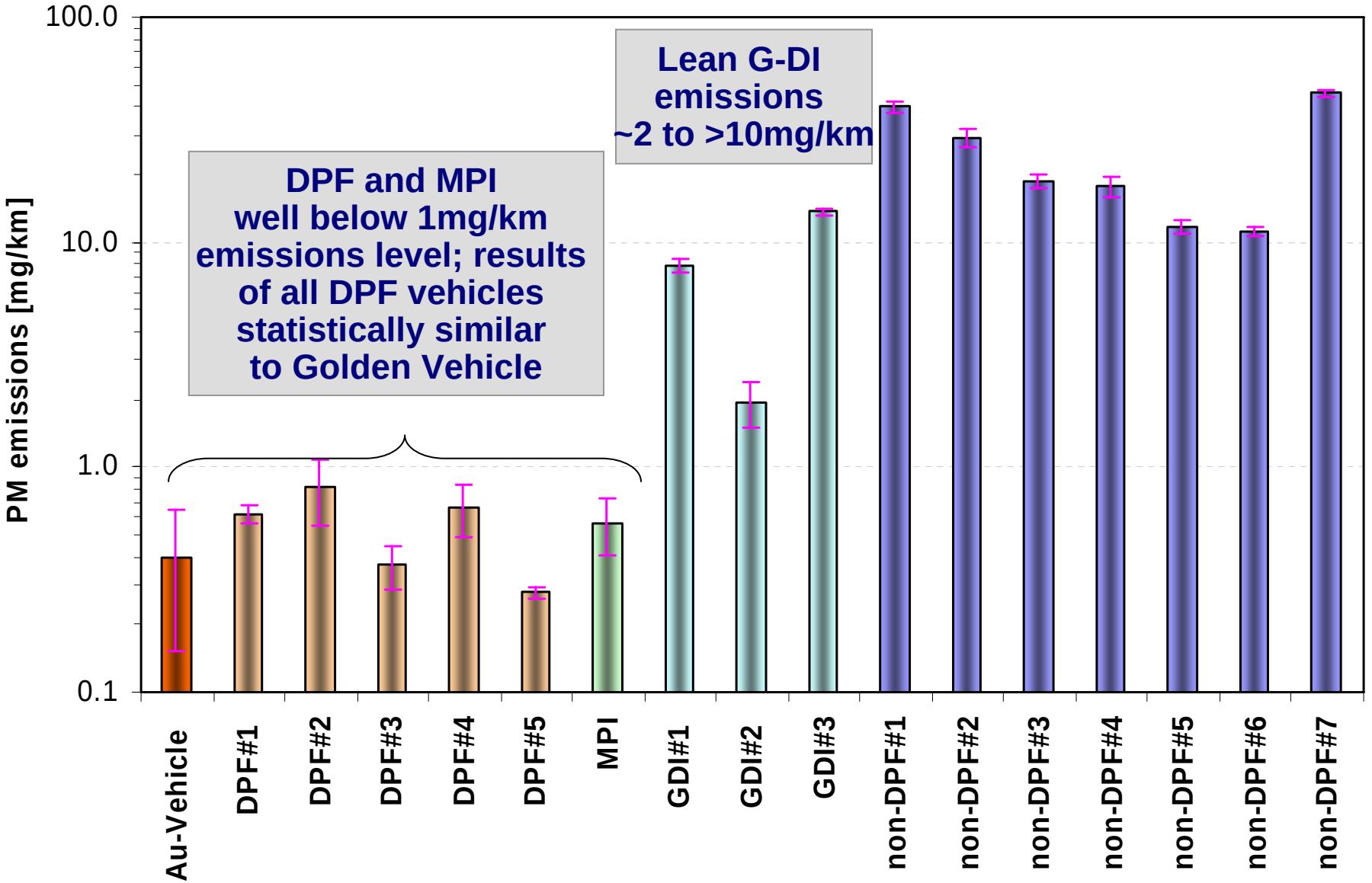
Particulate Mass Emissions (mg/km)



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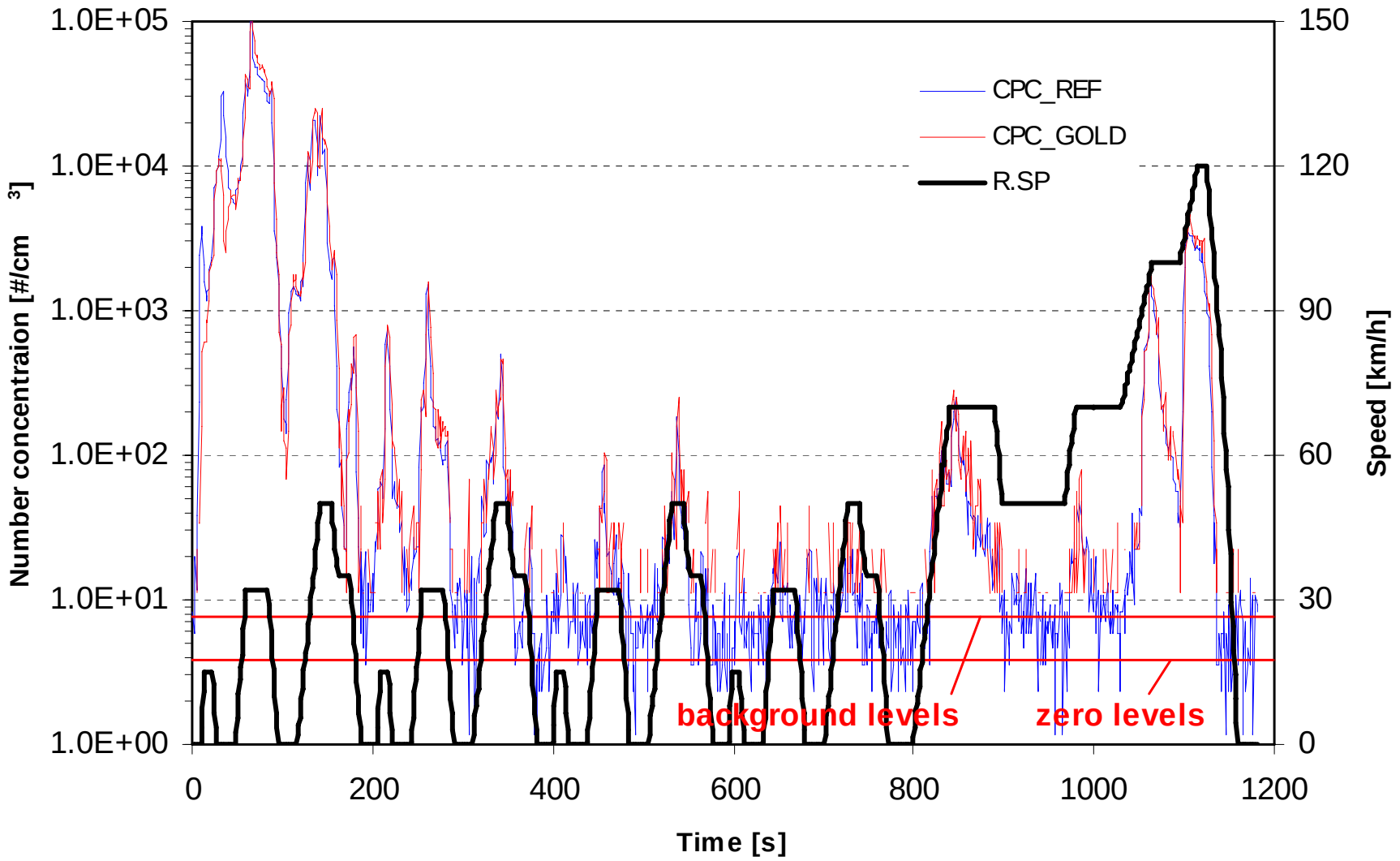
Majority of Particle Numbers Emitted During Cold-Start Testing
Emissions dominated by Urban Phase/cold start



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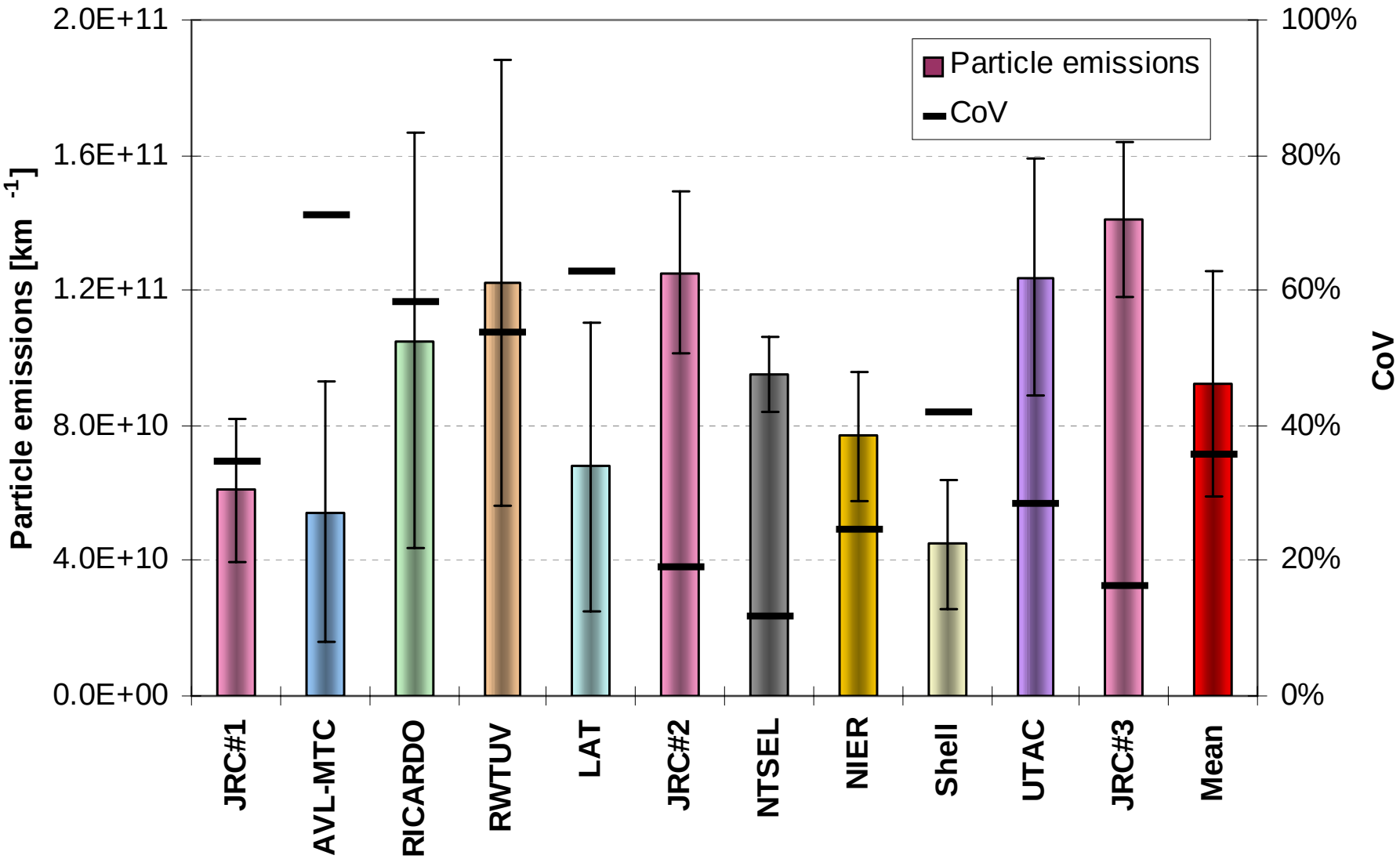
Particle Numbers from NEDC ~10^{11}/km

Apparent poor repeatability is manifestation of DPF fill effects



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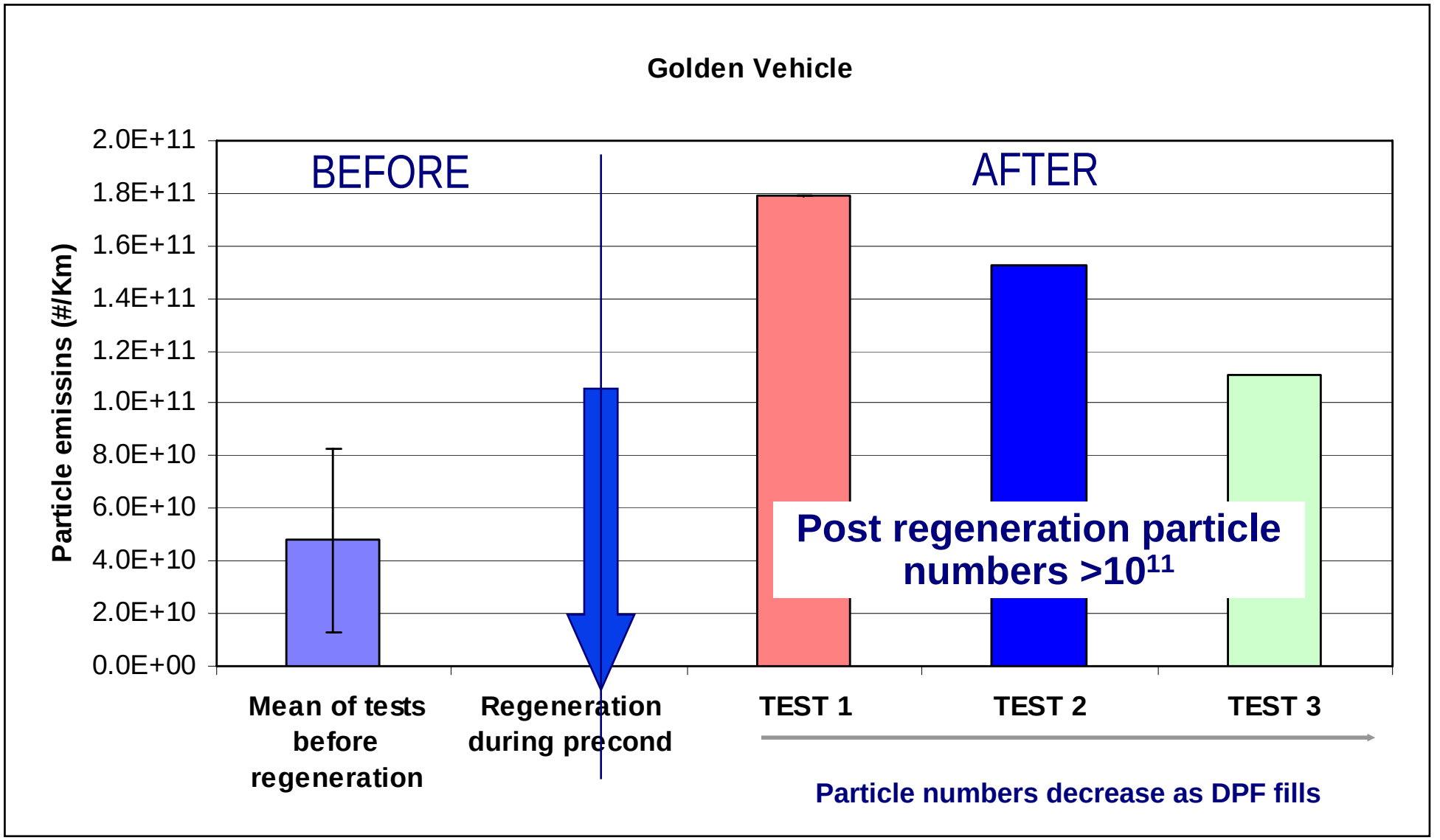
DPF fill state influences particle numbers – and repeatability!



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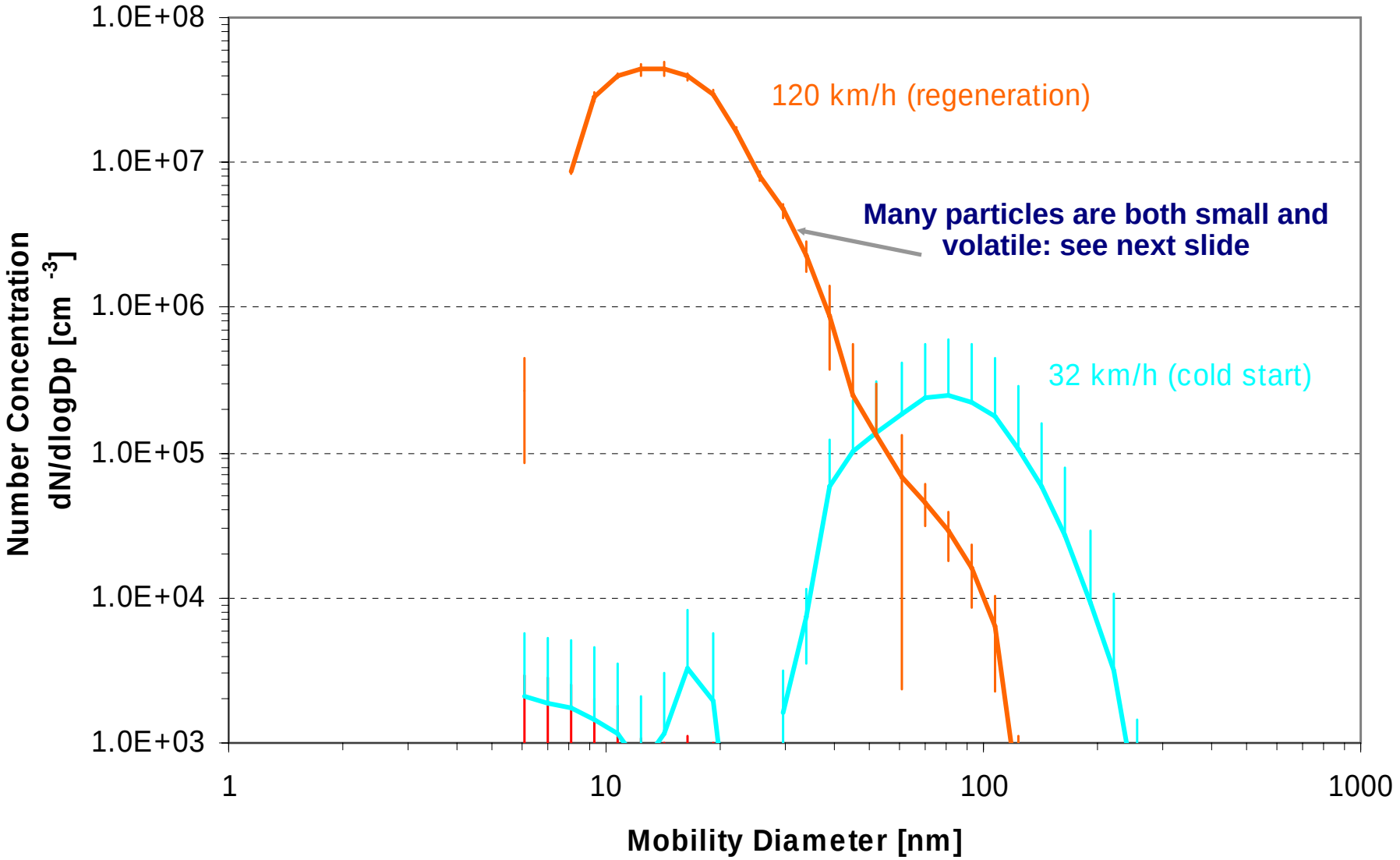
EEPS measurements show that large numbers of <30nm particles are released during regenerations, but usually almost all particles are >30nm



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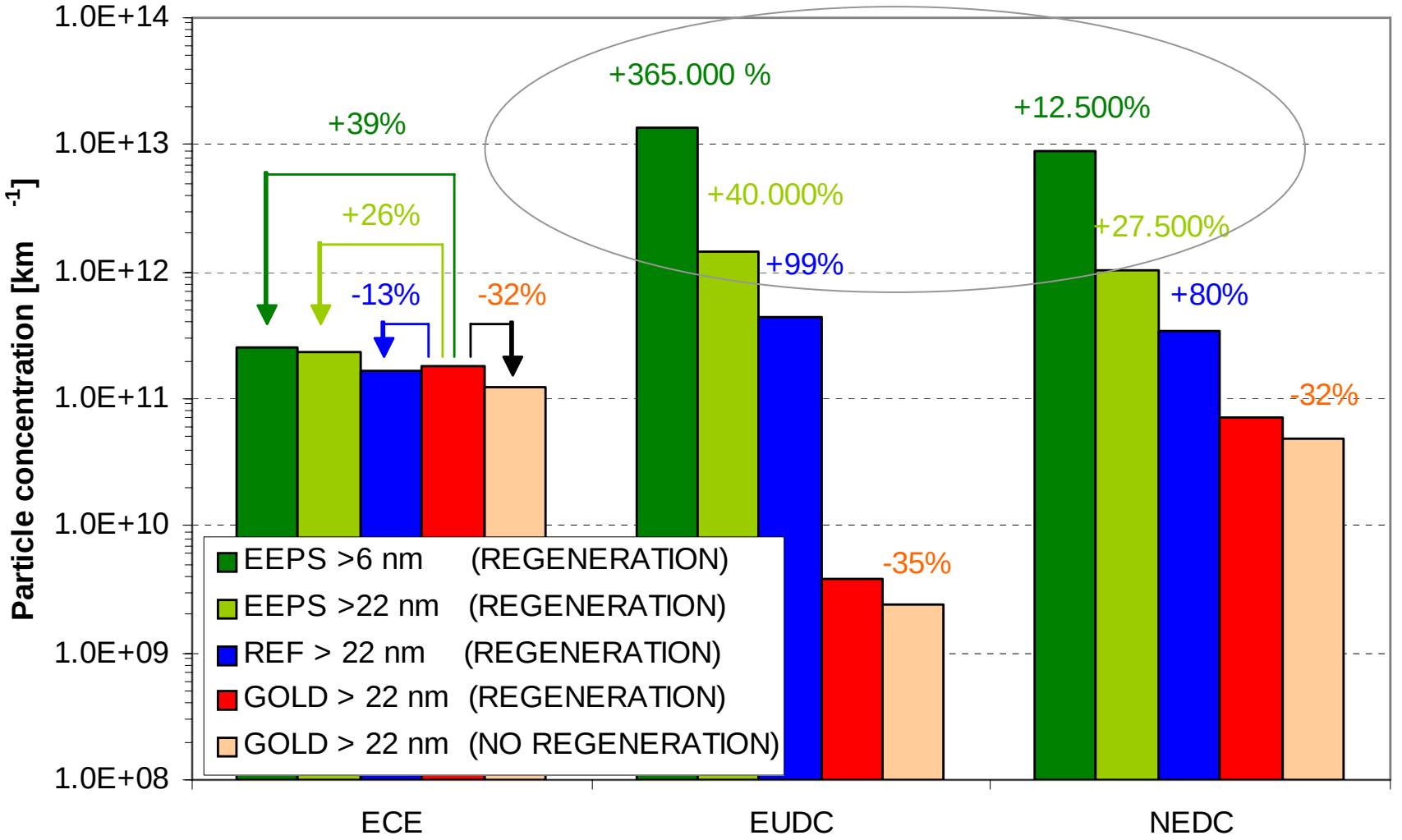
Solid Particle number emissions increased by 50% max during NEDC regeneration, but small and volatile particles increased by ~125x



EEPS data measured directly from the CVS

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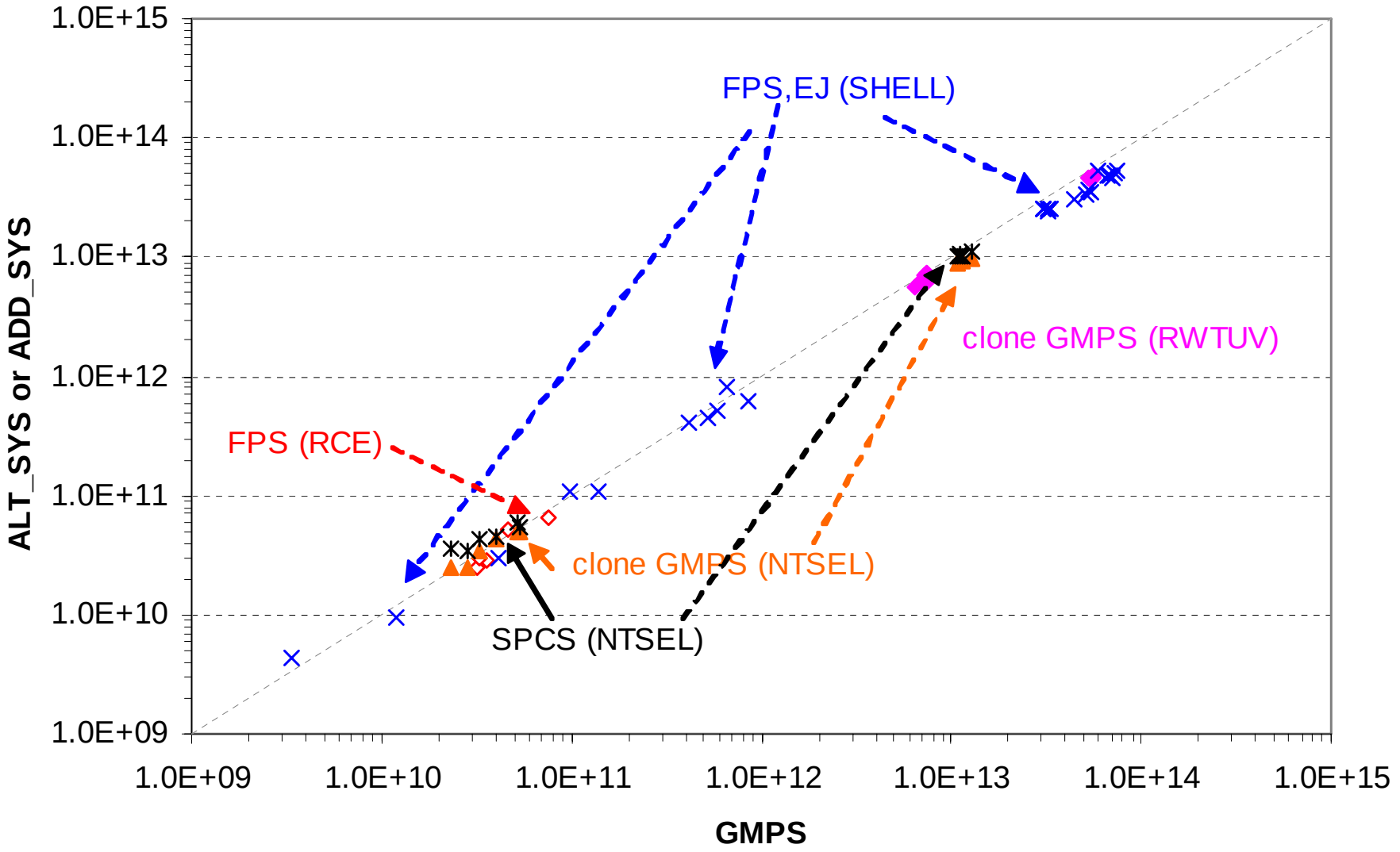
Strong similarity between GPMS and Alternative particle measurement systems: DPF and non-DPF vehicles



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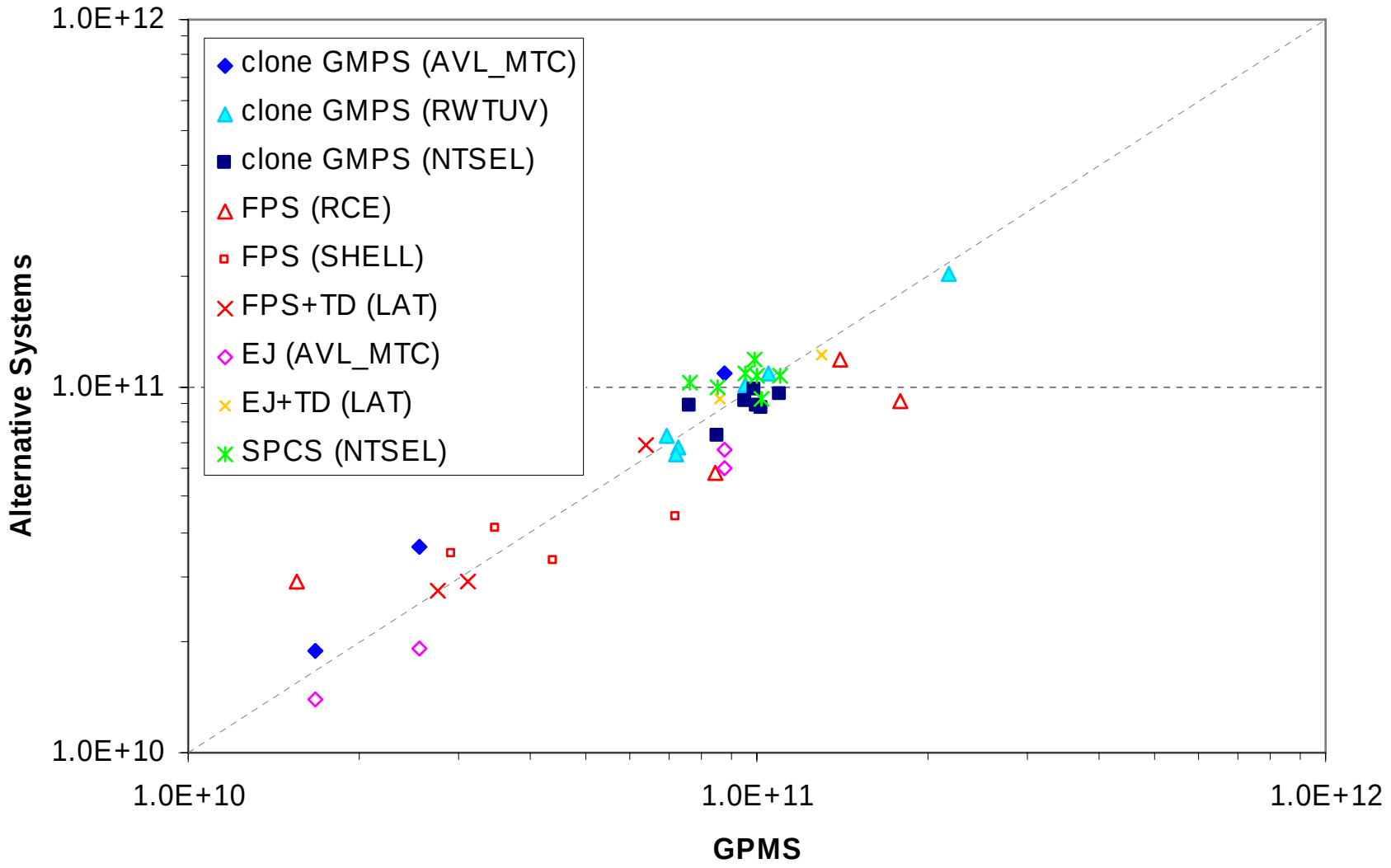
Alternative systems for Au-Vehicle



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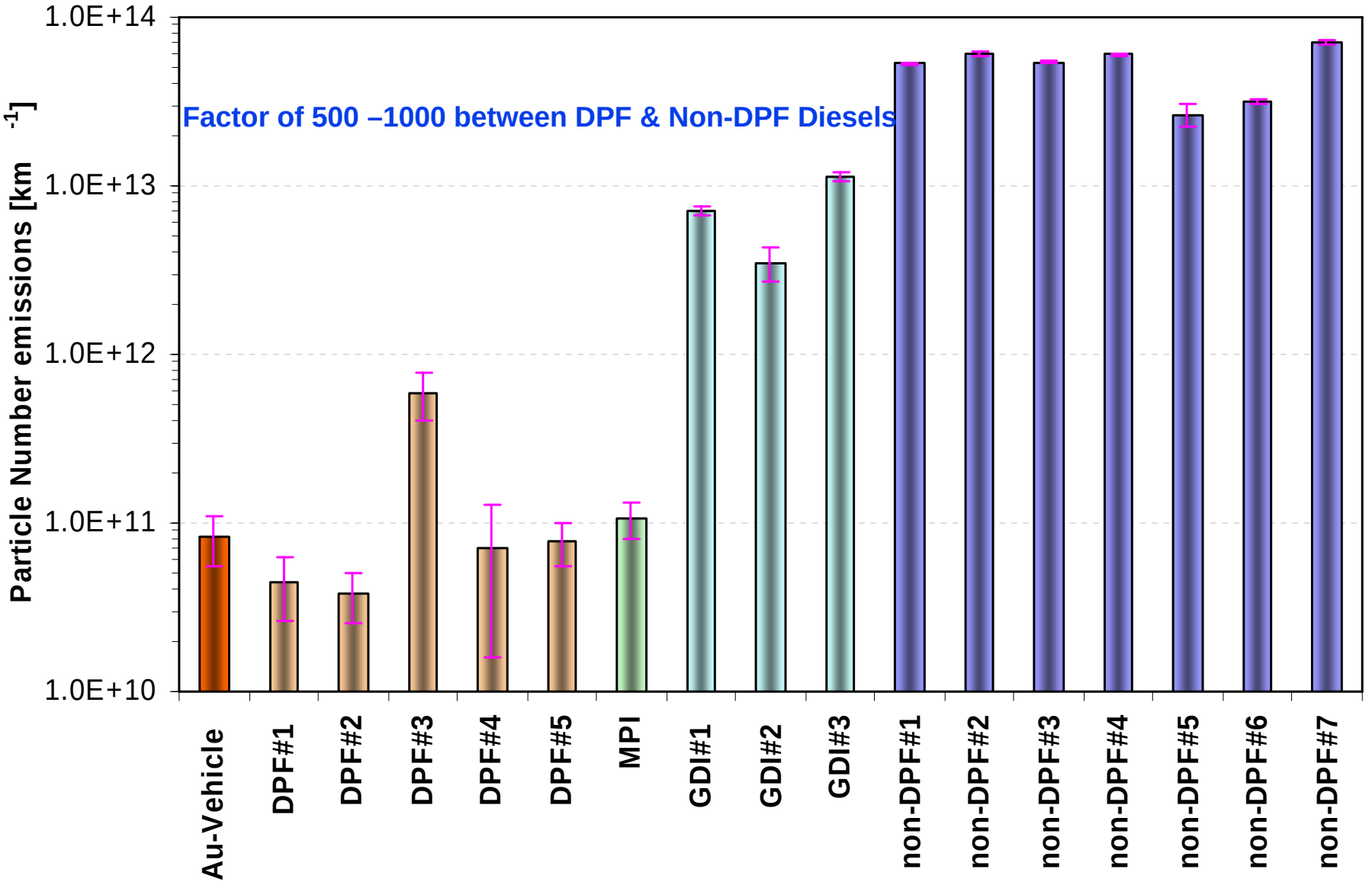
NEDC Particle Numbers (#/km)



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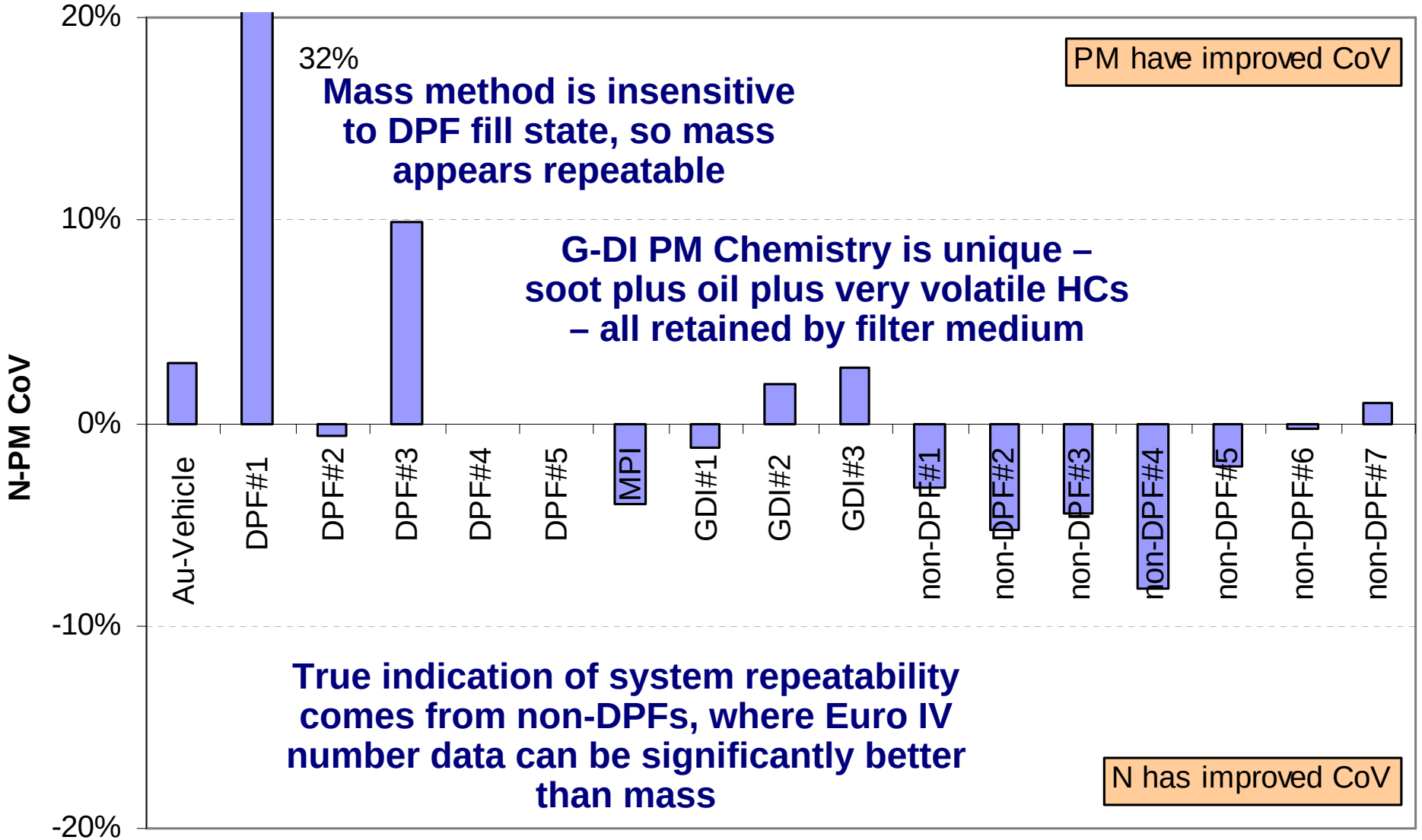
Mass shows better apparent repeatability than number for DPF Diesels!



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Outline

- Revised timetable
- Vehicles tested
- Alternative systems tested
- Mass results
- Number results
- Regeneration effects
- Preliminary conclusions

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Preliminary Conclusions

- Mass method sufficiently sensitive to permit repeatable measurements at well below 2.5 mg/km level
  - Significant questions remain regarding sampling and retention of volatiles by filter media in absence of carbon
- Number method ~20 times more sensitive than mass
  - Emissions of ~10^{11}/km achievable with DPF Diesels, similar as modern MPI
  - GDIs between 10^{12} and 10^{13}/km
  - Conventional Diesels ~ 500 times higher (5 x 10^{13}/km) than DPF equipped ones
- PMP Solid Particle Number method less variable than mass for EURO-4 non-DPF diesel cars
- Mass method insensitive to DPF fill state, 'true repeatability' masked

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Preliminary Conclusions-2

- Mass and number measurement equipment presented no significant functional or maintenance challenges during the programme
- Both mass and number sufficiently sensitive to discriminate between a DPF equipped Diesel and non-DPF equipped Diesel
  - Number metric provides best sensitivity and avoids uncertainties with volatile components
- Current technology GDI emissions fall between DPF Diesel and non-DPF Diesel both in mass and number

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Next Steps

- Compile full PMP results including Alternative Systems
- Analyse all data and prepare final reports for PMP WG
- Further revision of draft regulatory documents
  - Fine tuning
  - Integration of necessary validation and calibration procedures for number measurement equipment
- Submission of drafts to EC in Brussels as protocols in regulation format for consideration as part of Euro V
- Heavy Duty Inter-lab exercise – Kick-off meeting late in 2006

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Thank you for your attention

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