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(54th GRPE, 4-8 June 2007,

Agenda item 3.)

# UN-ECE Particle Measurement Programme Light Duty Validation Final Results

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# Light Duty Inter-laboratory Correlation Exercise - Summary

Department for  
**Transport**

- Started late summer 2004, testing completed August 2006
- 9 labs participated (11 repetitions)
- Project managed by DG JRC (Ispra, Italy)
- Golden Engineer, Golden System
- DPF equipped Golden Vehicle

# Measurements

- **Gaseous emissions** – current Regulation 83 methods
- **PMP Particulate mass** –dilution air HEPA filtered, cyclone pre-classifier, improved sample temperature & velocity control, improved filter holder & TX40 filter, deletion of back-up filter
- **PMP Particle number** –dilution air HEPA filtered, cyclone pre-classifier, volatile particle removal by heating/dilution, count of number of particles of >23nm

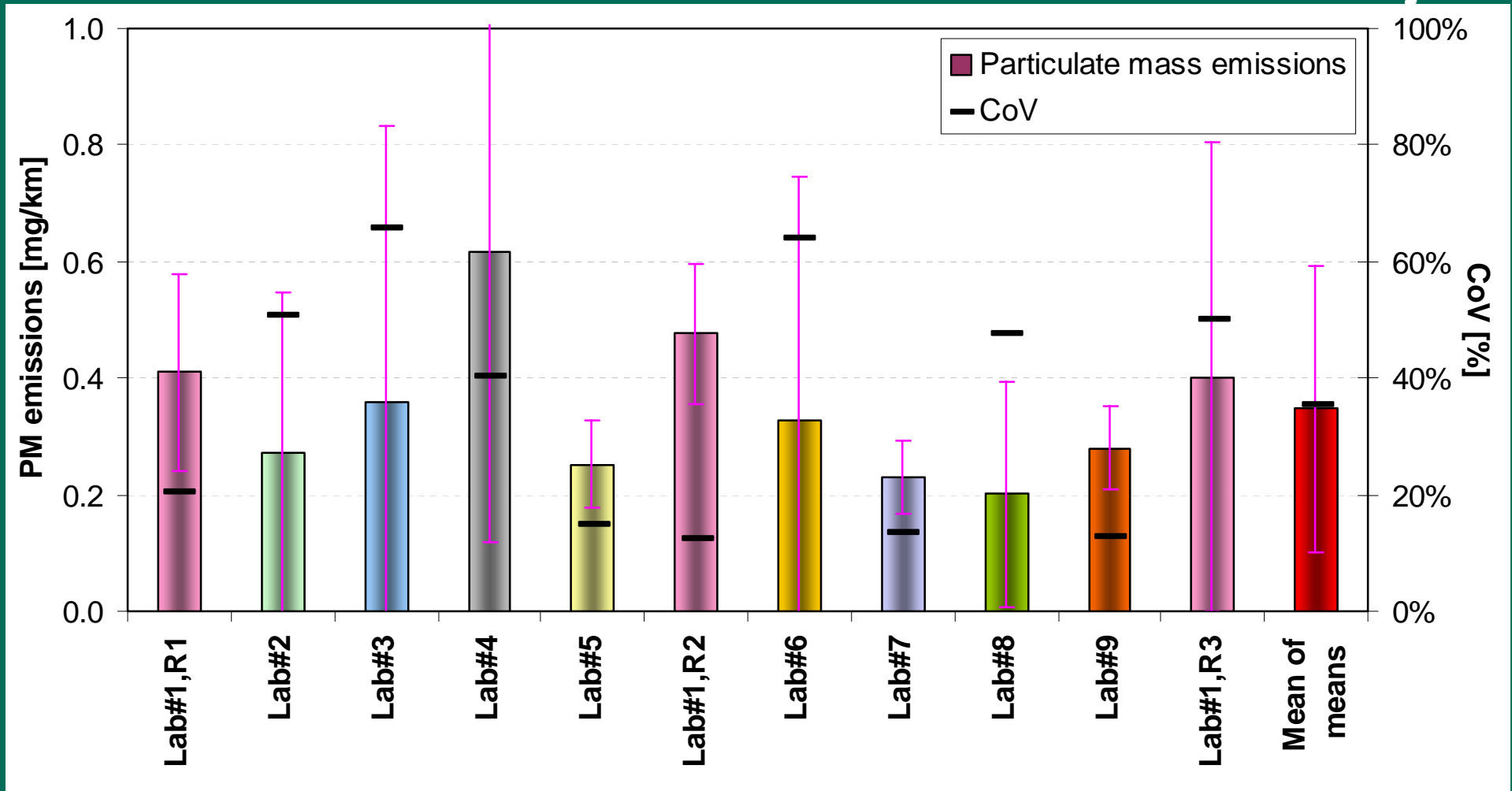
# Additional Vehicles

DPF Diesels	BMW 525d, MAZDA Bongo, TOYOTA Avensis D-CAT, MERCEDES Vito Van, PEUGEOT 206 HDi FAP
Conventional Diesels	BMW 120d AUDI A2 TDi, HONDA Accord i-CTDi, VW GOLF TDi, KIA Pride, VAUXHALL Astra CDTi
Petrol Direct Injection	mitsubishi Carisma GDI, VW GOLF FSI, TOYOTA Crown G-DI,
Conventional Petrol	FIAT Idea

# Alternative & Additional Systems

- ALTERNATIVE SYSTEMS (as per recommended system principles)
  - Clone GPMS (3 labs)
  - HORIBA Solid Particle Counting System (2 labs)
  - DEKATI FPS (modified) + GRIMM CPC (3 labs) or TSI CPC (3 labs)
- ADDITIONAL SYSTEMS (differences)
  - Dual Ejector dilutor + TSI CPC (1 lab)
  - Ejector dilutor or FPS + Thermodenuder -TSI CPC (1 lab)

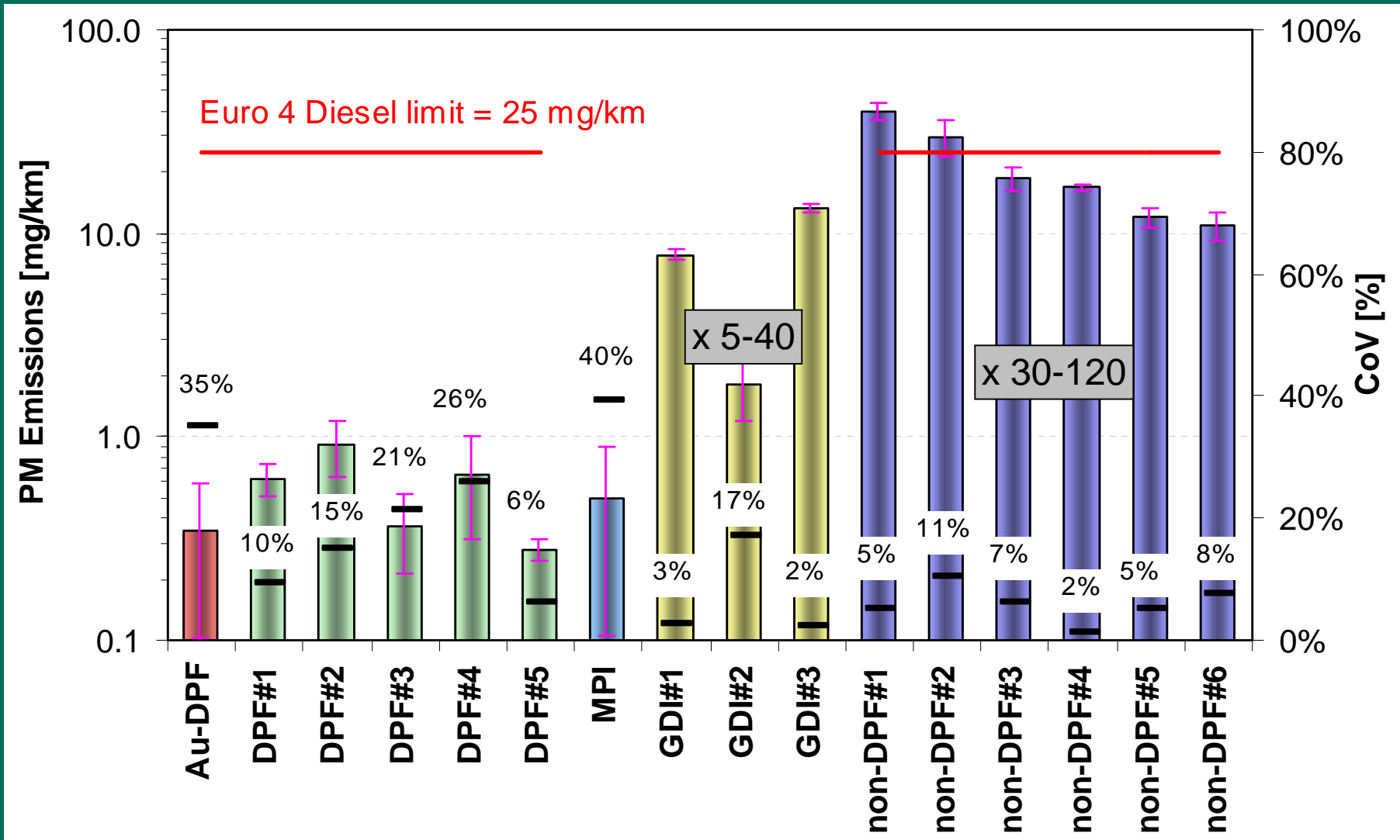
# Particulate Mass – Golden Vehicle



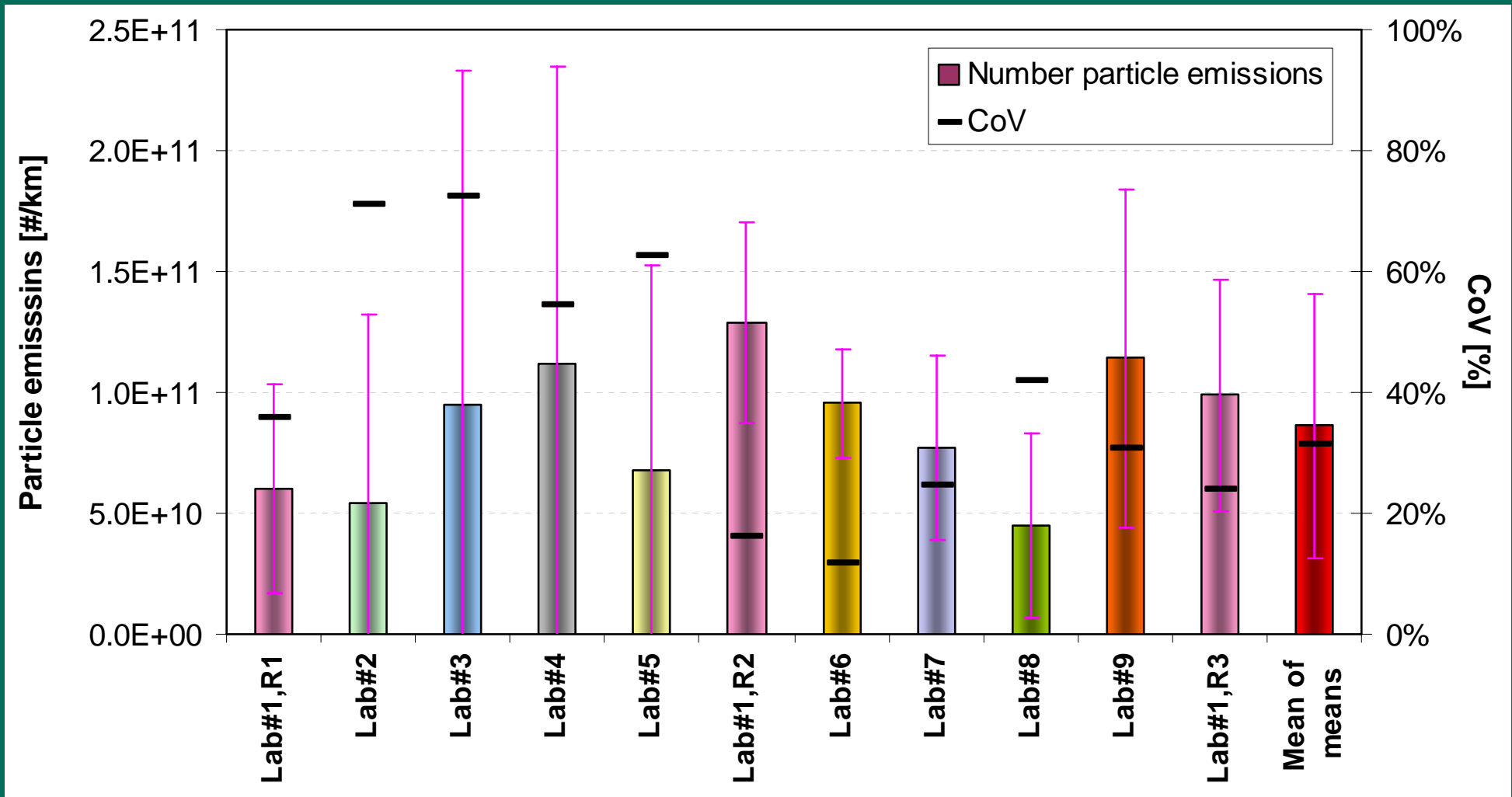
Repeatability 12-66%

Reproducibility 35%

# Particulate Mass – All Vehicles



# Particle Number – Golden Vehicle

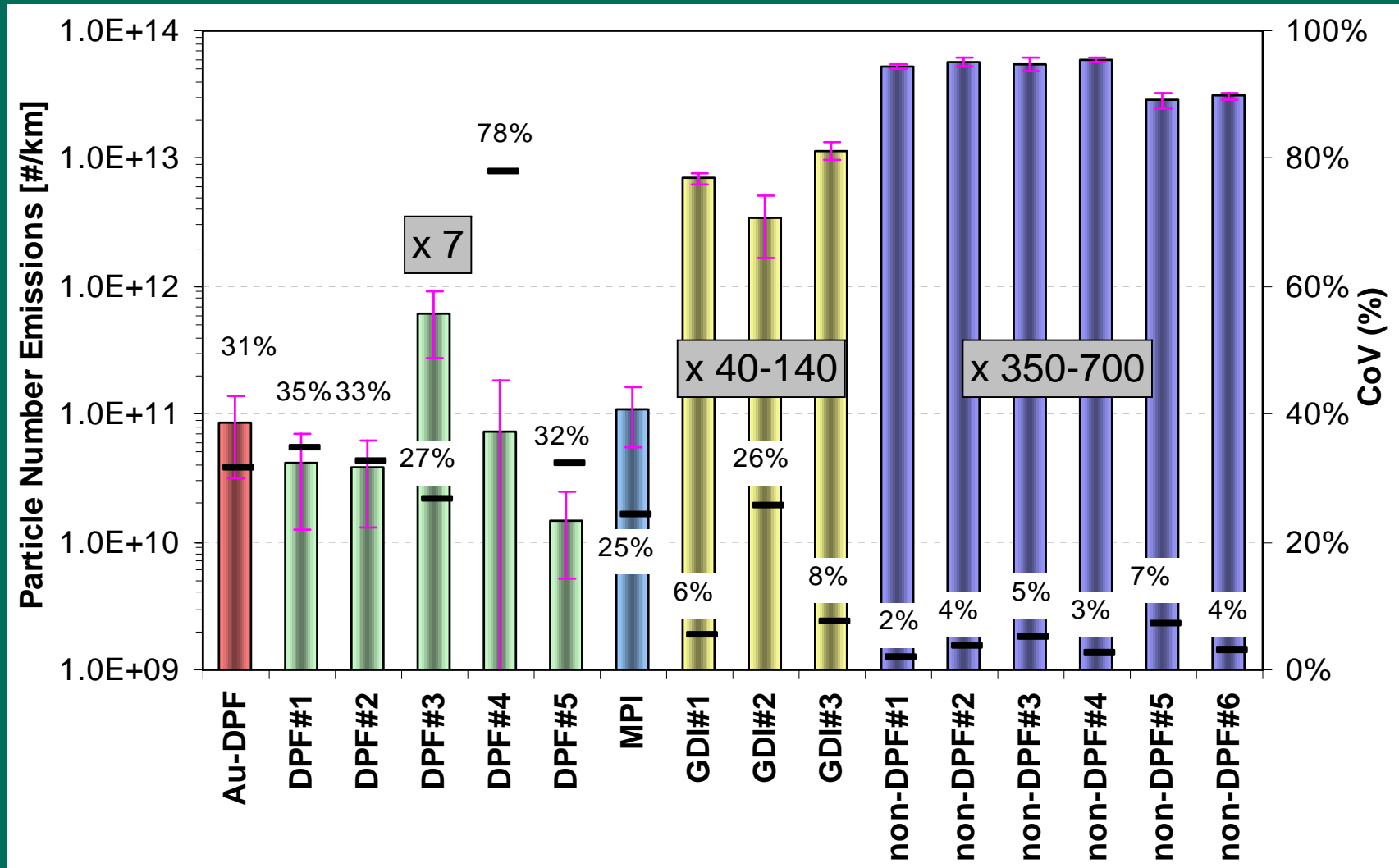


Repeatability 12-72%

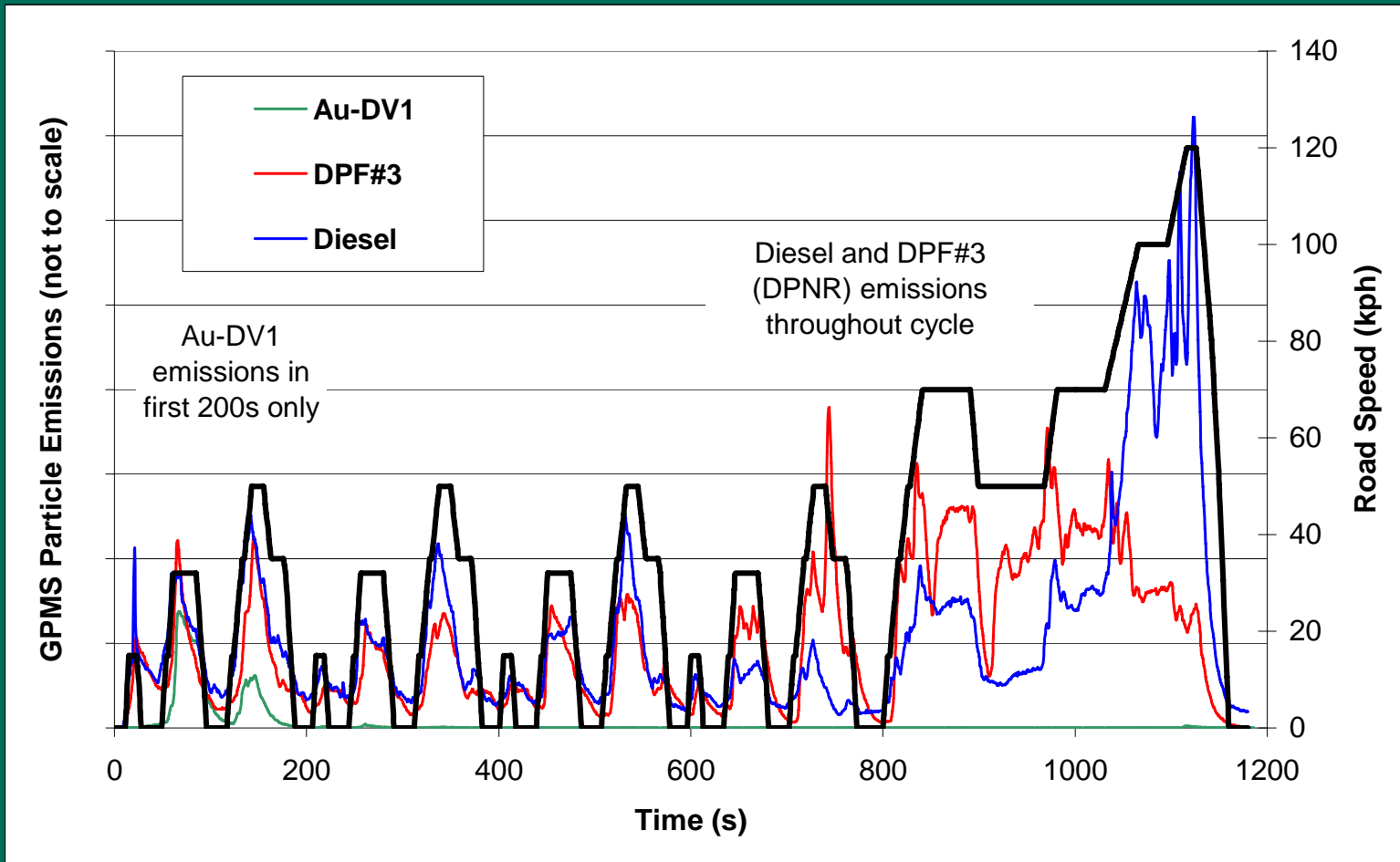
Reproducibility 31%



# Particle Number – All Vehicles

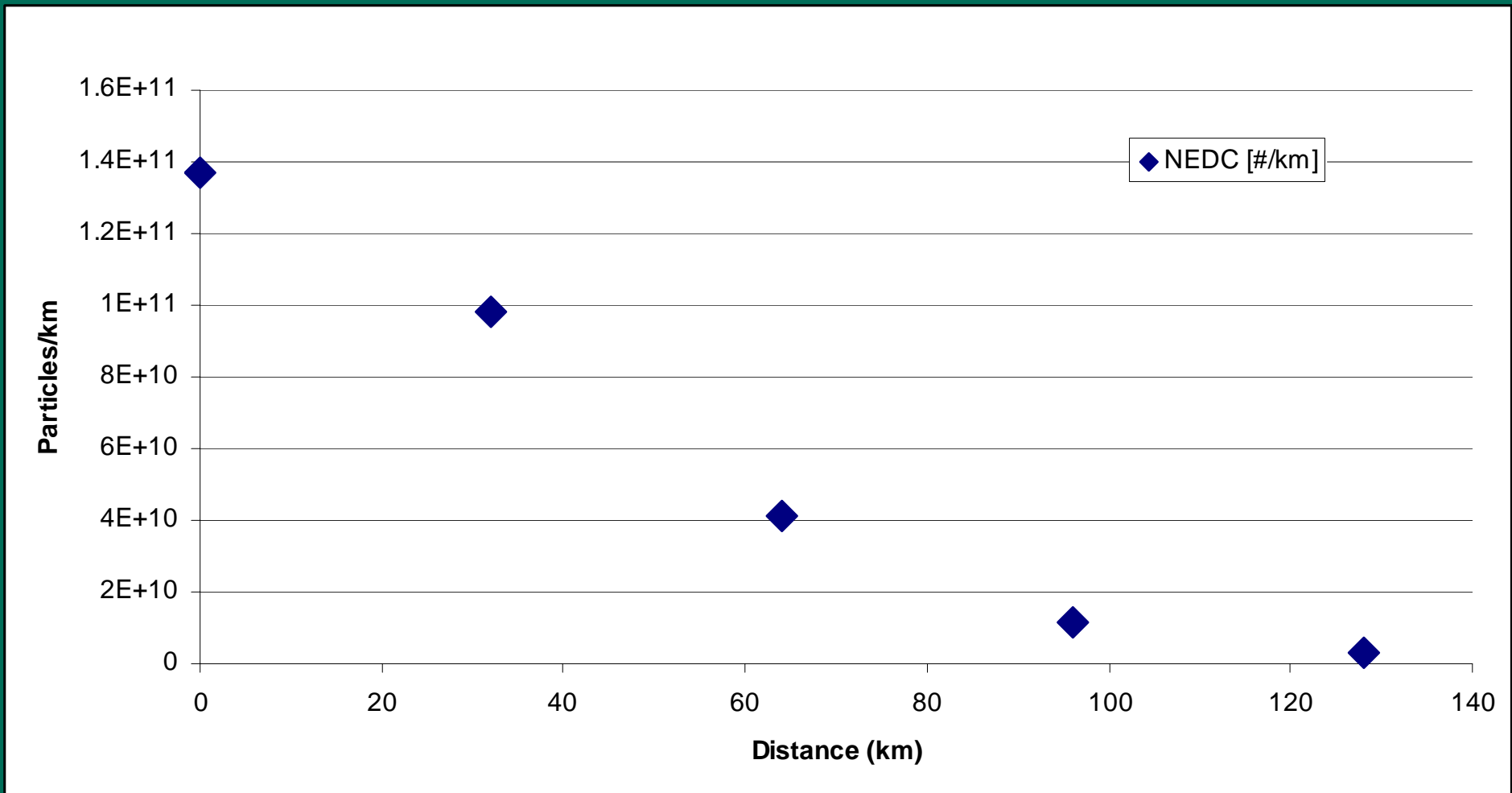


# DPF#3 More Porous DPF



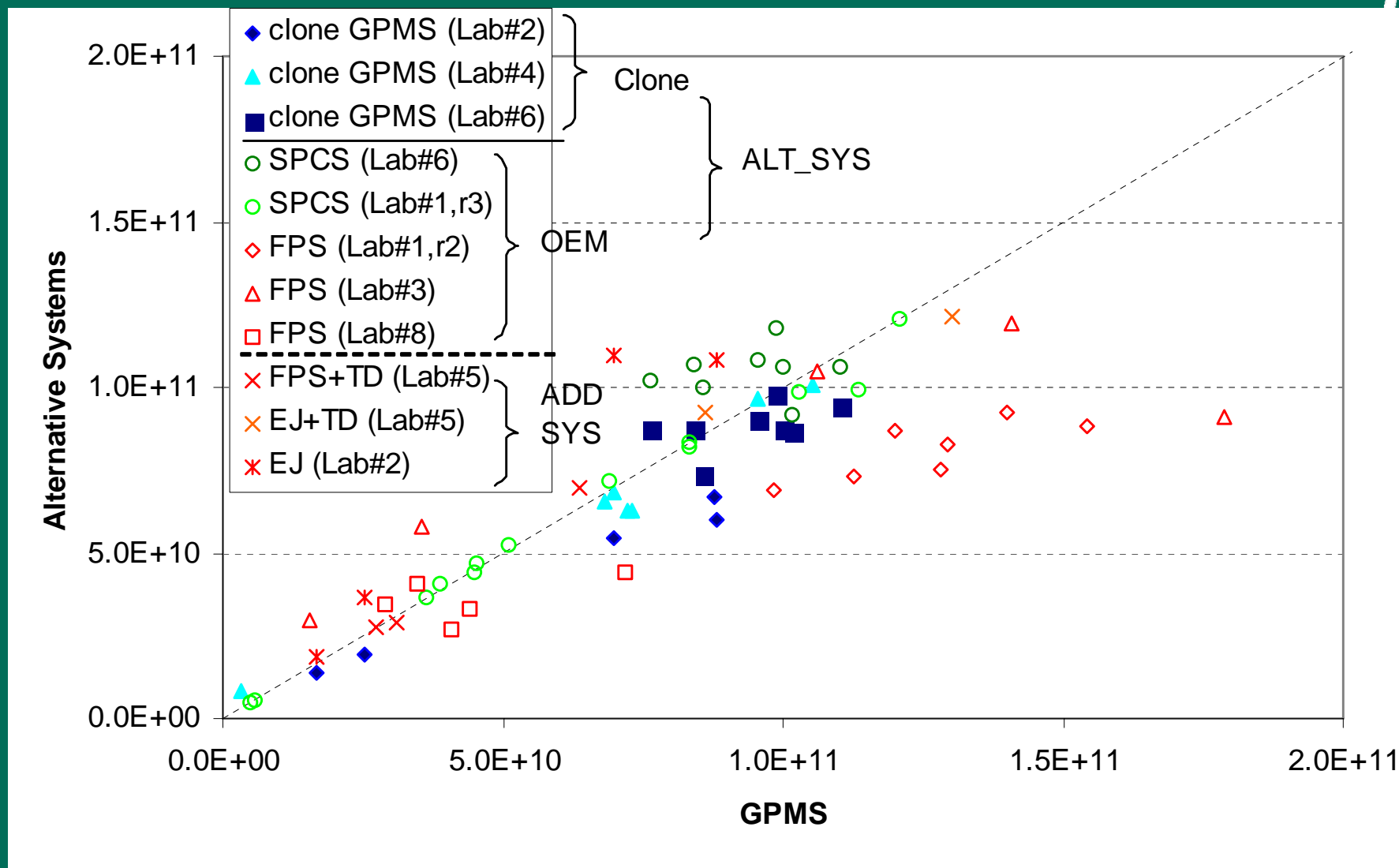
- Golden (and other) DPF vehicle particle emissions fall to near background levels after first elementary cycle
- DPF#3 particle emissions track the test cycle like a non-DPF vehicle showing particles penetrate through this DPF

# Repeatability of DPF#4

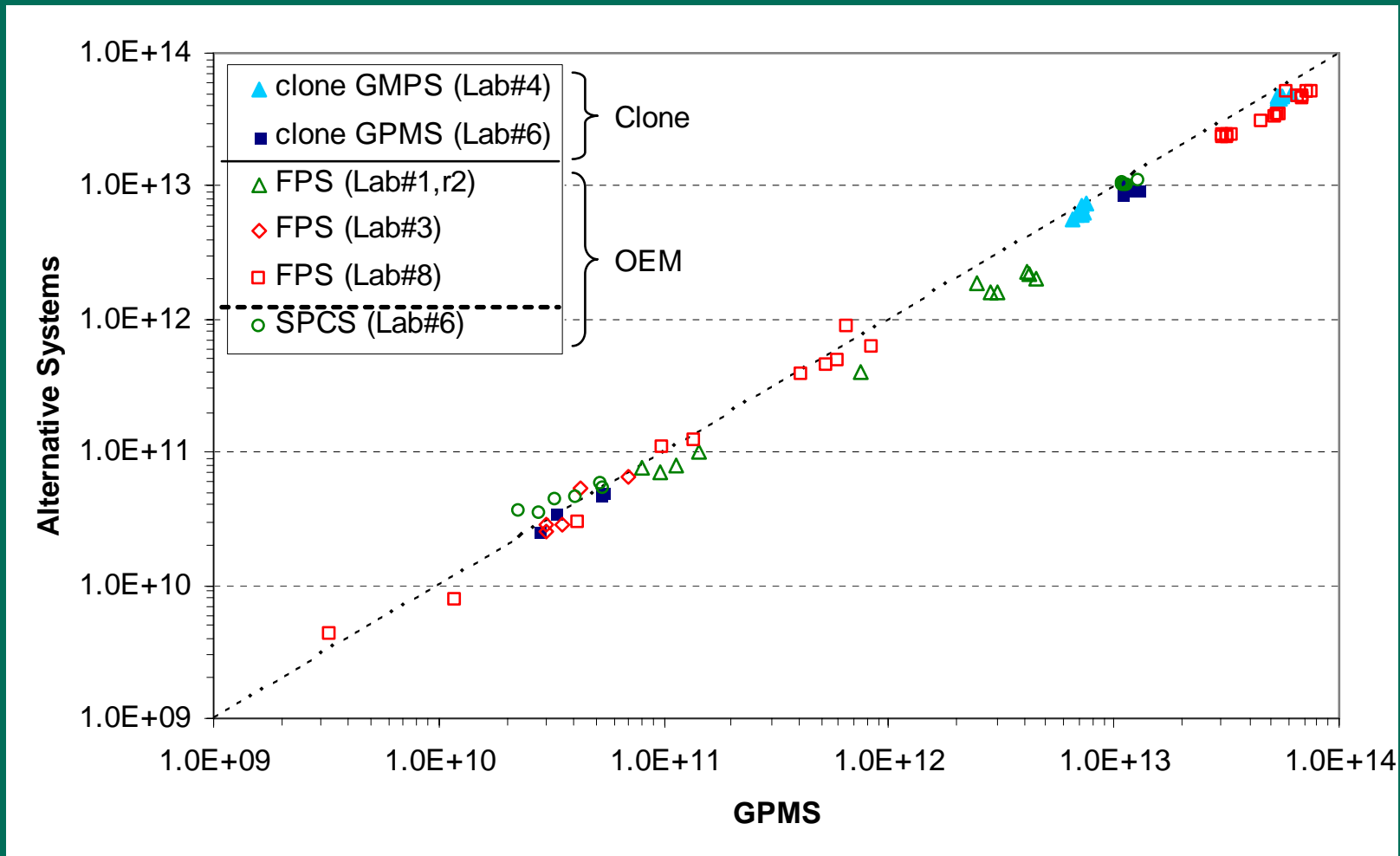


- Regeneration occurred prior to first test
- PN decreased from test to test as DPF filled increasing filtration efficiency

# Correlation of Alternative Systems – Golden Vehicle Results

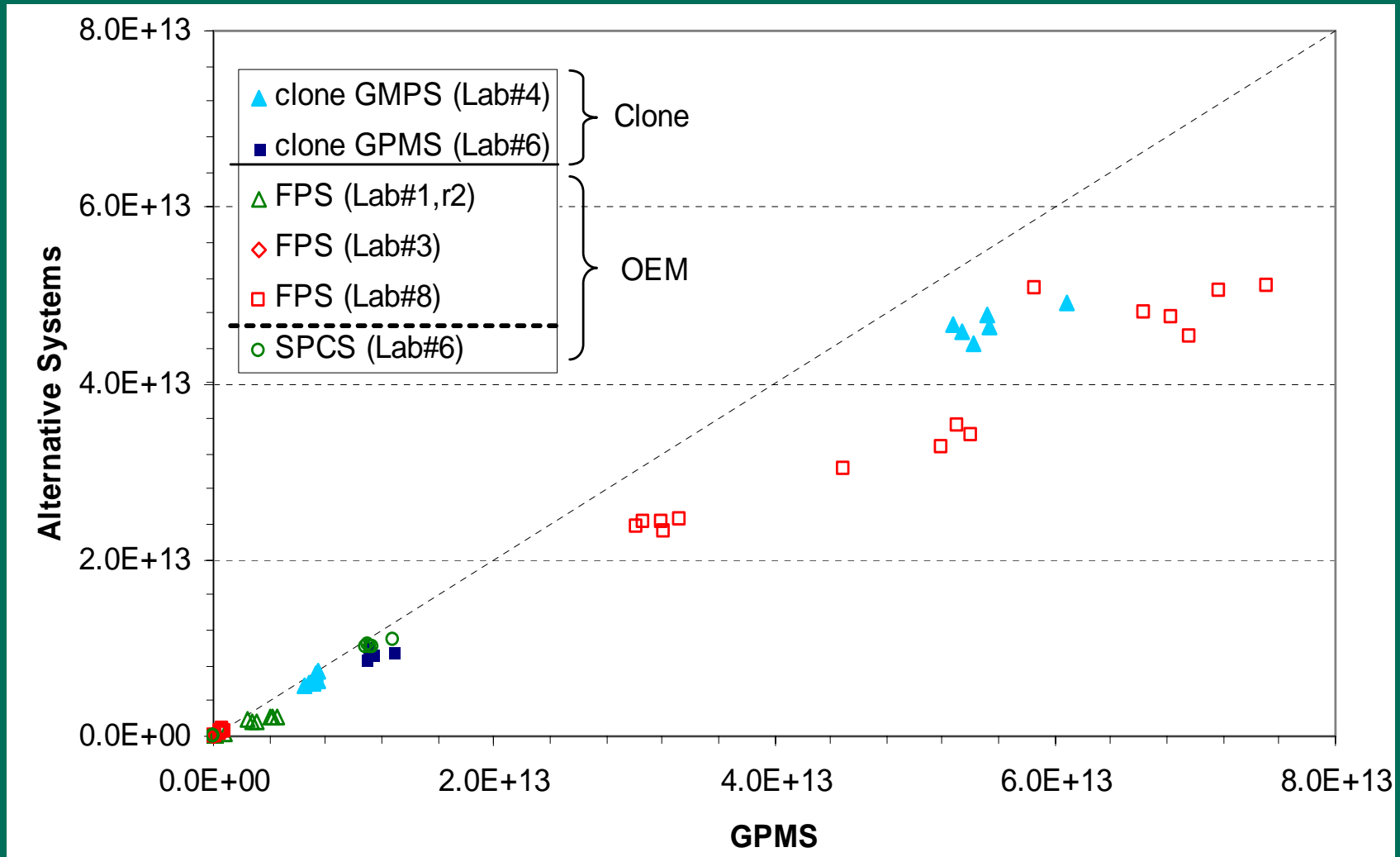


# Correlation of Alternative Systems – All Vehicle Results (Log-Log)



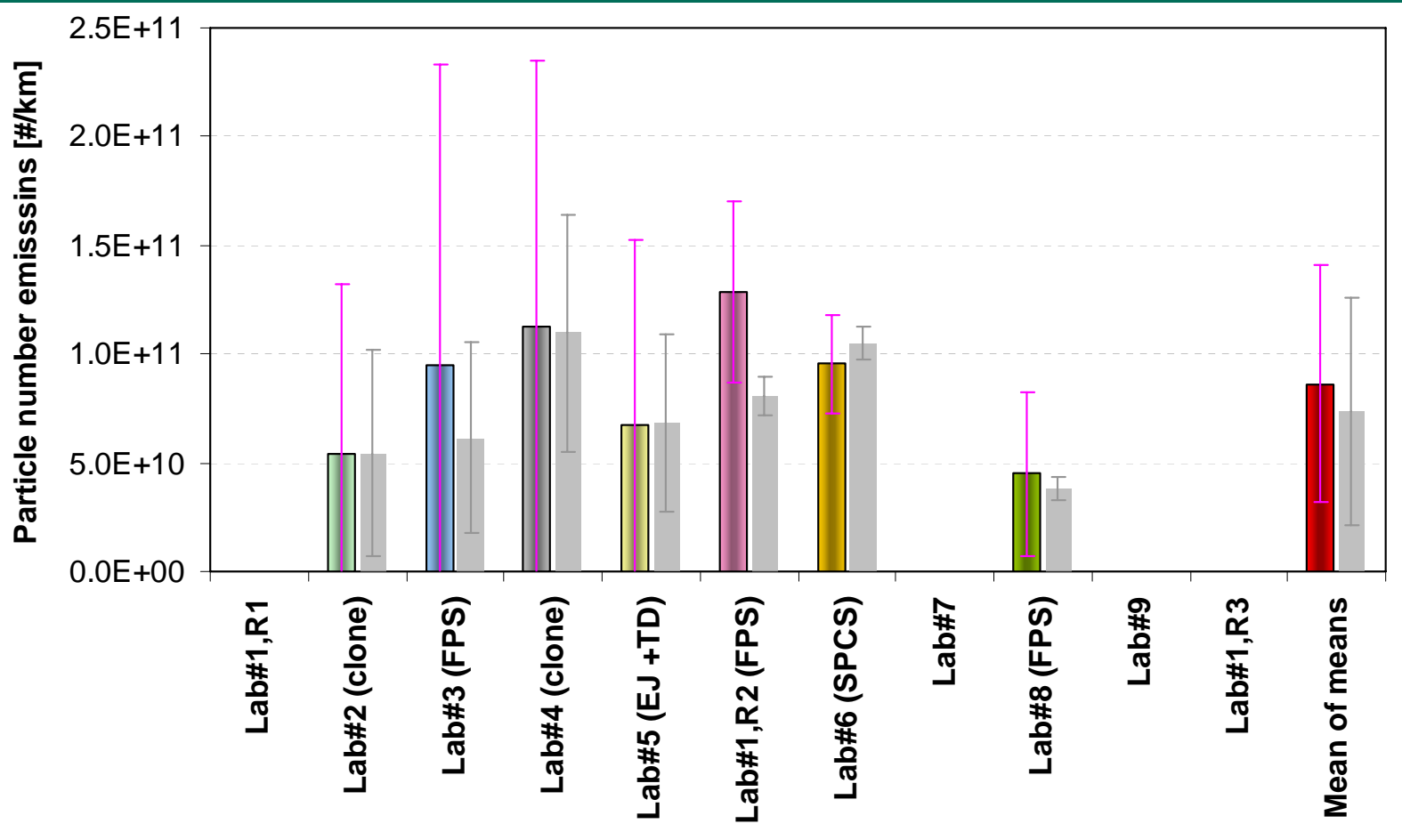
Linear relationship across 4 orders of magnitude

# Correlation of Alternative Systems – All Vehicle Results (Linear-Linear)



- SPCS & GPMS clones similar ~15% lower
- FPS significantly lower - not optimised to meet PMP specs

# Round Robin Simulation



GPMS:  $8.5 \times 10^{10} / \text{km} \pm 36\%$   
 ALTS:  $7.5 \times 10^{10} / \text{km} \pm 35\%$

## Validation Exerc.

### Reproducibility

N:	31%
PM:	35%
CO <sub>2</sub> :	4%
NO <sub>x</sub> :	10%
HC:	35%
CO:	44%

## RR simulation.

### Reproducibility

GPMS:	36%
PM:	40%
CO <sub>2</sub> :	4%
NO <sub>x</sub> :	12%
HC:	45%
CO:	49%

# Conclusions

- Reproducibility: PM 35%, PN 31% (but includes variability of vehicle)
  - Similar to HC & CO
- Mass and number systems presented no significant functional or maintenance challenges
- 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, post DPF measurements similar to tunnel background
  - Post DPF mass results are a 'Repeatable zero'



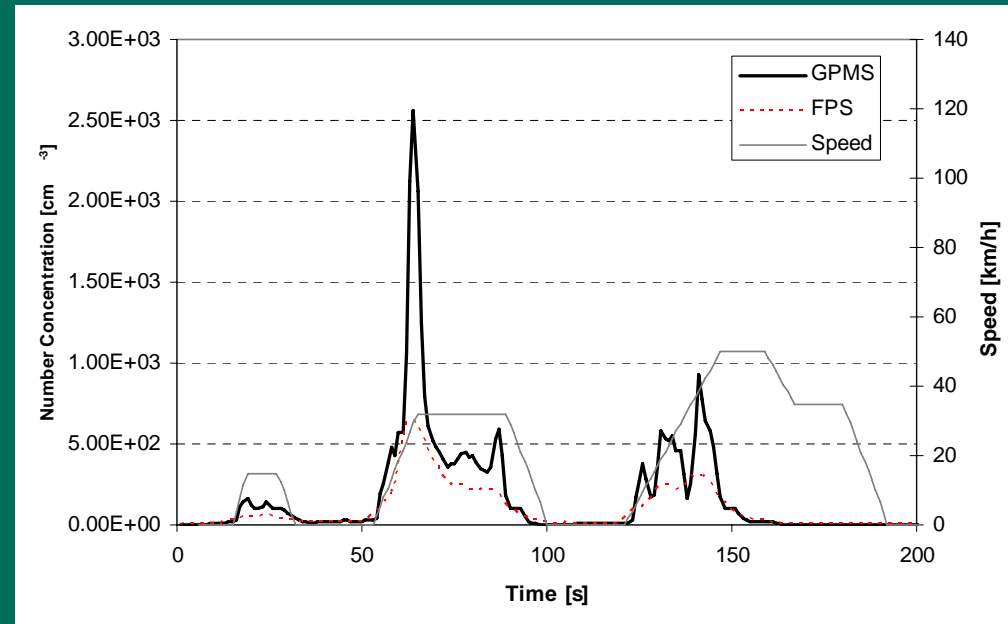
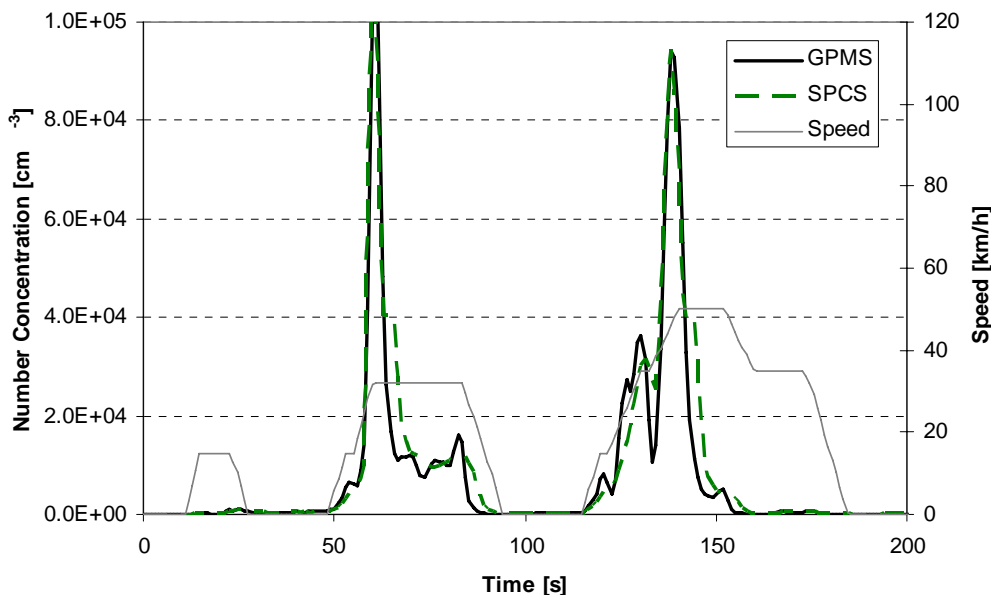
## Conclusions (continued)

- Number provides best sensitivity, being able to identify variations in DPF fill state, preconditioning and DPF porosity. Lowest number measurements ~55 times higher than background levels
- Both mass and number sufficiently sensitive to discriminate between a DPF equipped Diesel and current non-DPF equipped Diesels
- Alternative number measurement systems meeting PMP performance requirements agree closely with Golden System (within 15%)
- Variability in DPF emissions implies the importance of pre-conditioning vehicle to a stable DPF fill state

# Alternative – Golden System Correlation Data

Alternative System	Linear relation to GPMS + intercept	R <sup>2</sup>
clone GPMS (Lab#4)	$y = 0.8352x + 32605$	R2 = 0.9864
clone GPMS (Lab#6)	$y = 0.826x$	R2 = 0.9897
FPS (Lab#1)	$y = 0.5266x + 2794$	R2 = 0.8076
FPS (Lab#3)	$y = 0.8609x + 4$	R2 = 0.8776
FPS (Lab#8)	$y = 0.5760x + 244135$	R2 = 0.8889
SPCS (Lab#6)	$y = 0.8742x + 2330$	R2 = 0.9323

# Correlation of Realtime Data



- SPCS correlates extremely well
- FPS appears to smooth particle trace – due to 4x longer residence in evaporation tube, uncertainties in ejector diluter dilution ratios at high temperatures?
- Manufacturer has subsequently developed FPS for PMP