

# **Update on the UN-ECE Particle Measurement Programme (PMP)**

Chris Parkin – UK Department for Transport

# Background to PMP

- Inter-governmental research programme under the auspices of UN-ECE GRPE to develop new vehicle exhaust particle measurement procedures for regulatory use
- Set up due to health concerns over nano-particles and concerns over capability of current PM measurement to force adoption of technology which effectively controls these emissions
- Mandate was to develop techniques to replace or complement particulate mass measurement. Techniques must be applicable to Light Duty Vehicle & Heavy Duty Engine type approval testing
- PMP also to provide data on the performance of different vehicle technologies according to the new measurement procedures

# PMP Phases

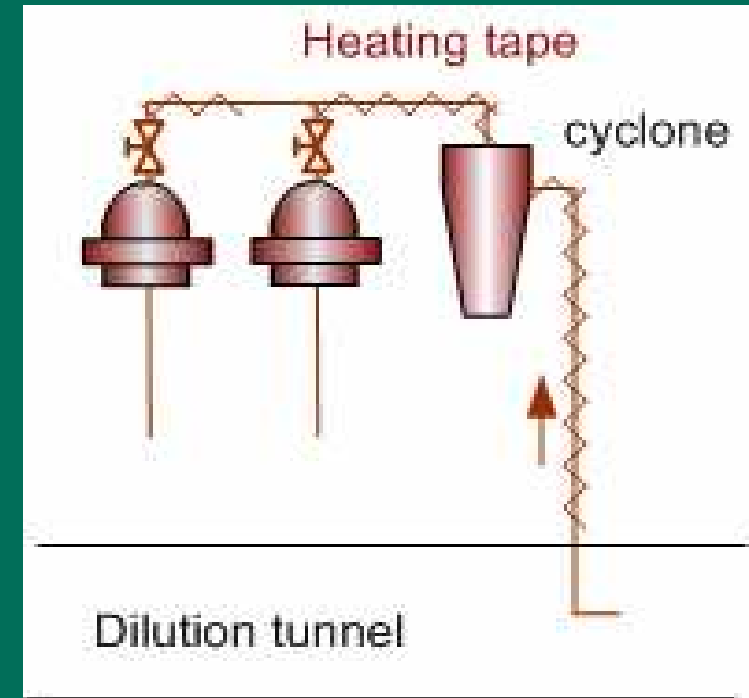
- Phase I (2001-2) developed protocols for examining different candidate measurement systems.
- Phase II (2002-3) evaluated a range of measurement techniques and sample conditioning systems.
- Phase III (2004-) is validating the recommended measurement techniques via inter-laboratory test programmes.
- Validation for light duty testing completed in 2006 and reported in 2007.

# PMP Phase II Recommendations – Improved Particulate Mass Measurement

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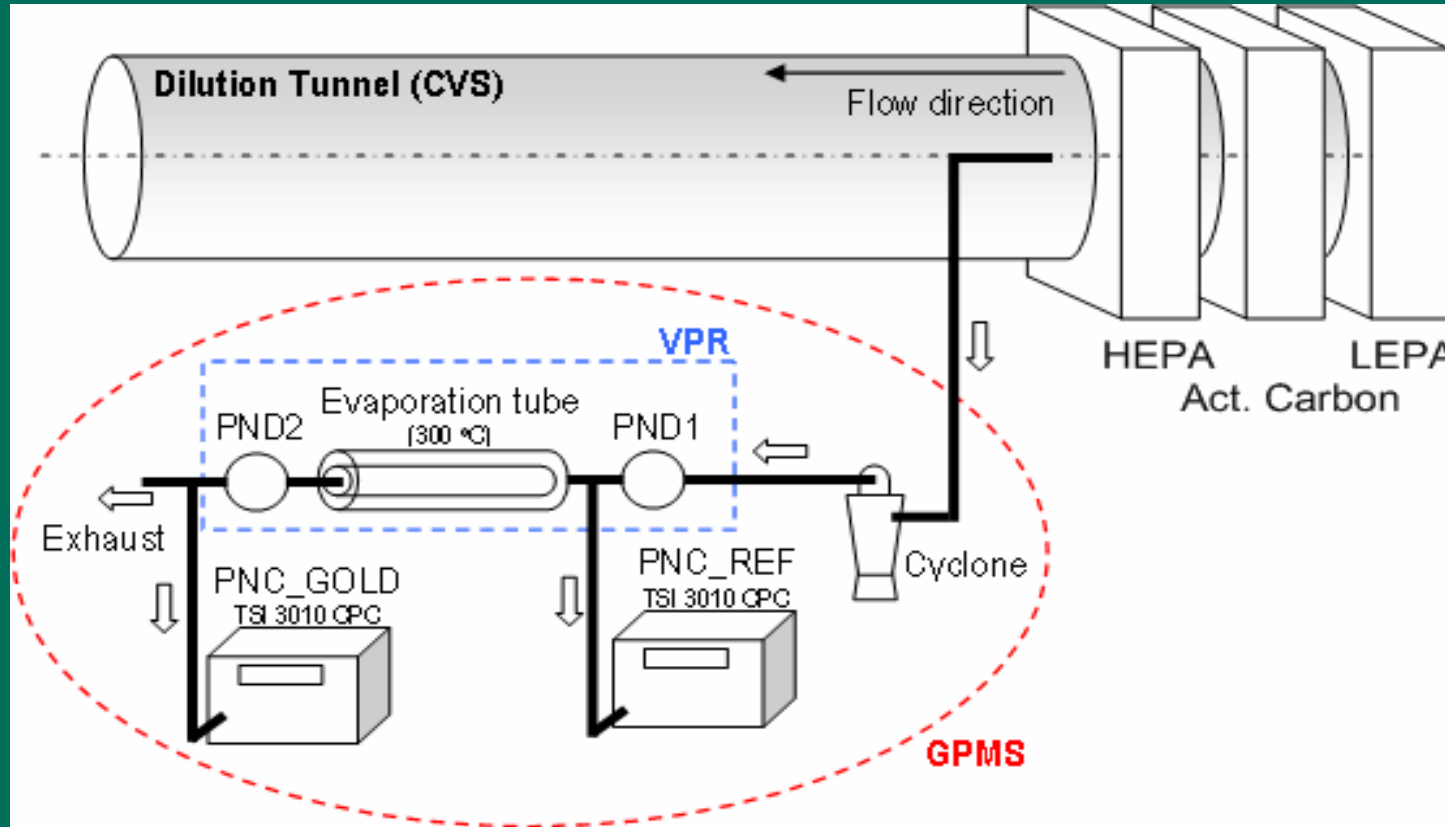
- Cyclone (2.5 $\mu\text{m}$  to 10 $\mu\text{m}$  cut-point)
- Sample to be held at **47°C +/- 5°C** for >0.2s
- Filter face velocity (50cm/s to 80cm/s)
- Pallflex **TX40** filters with no backup

47°C +/- 5°C for >0.2s



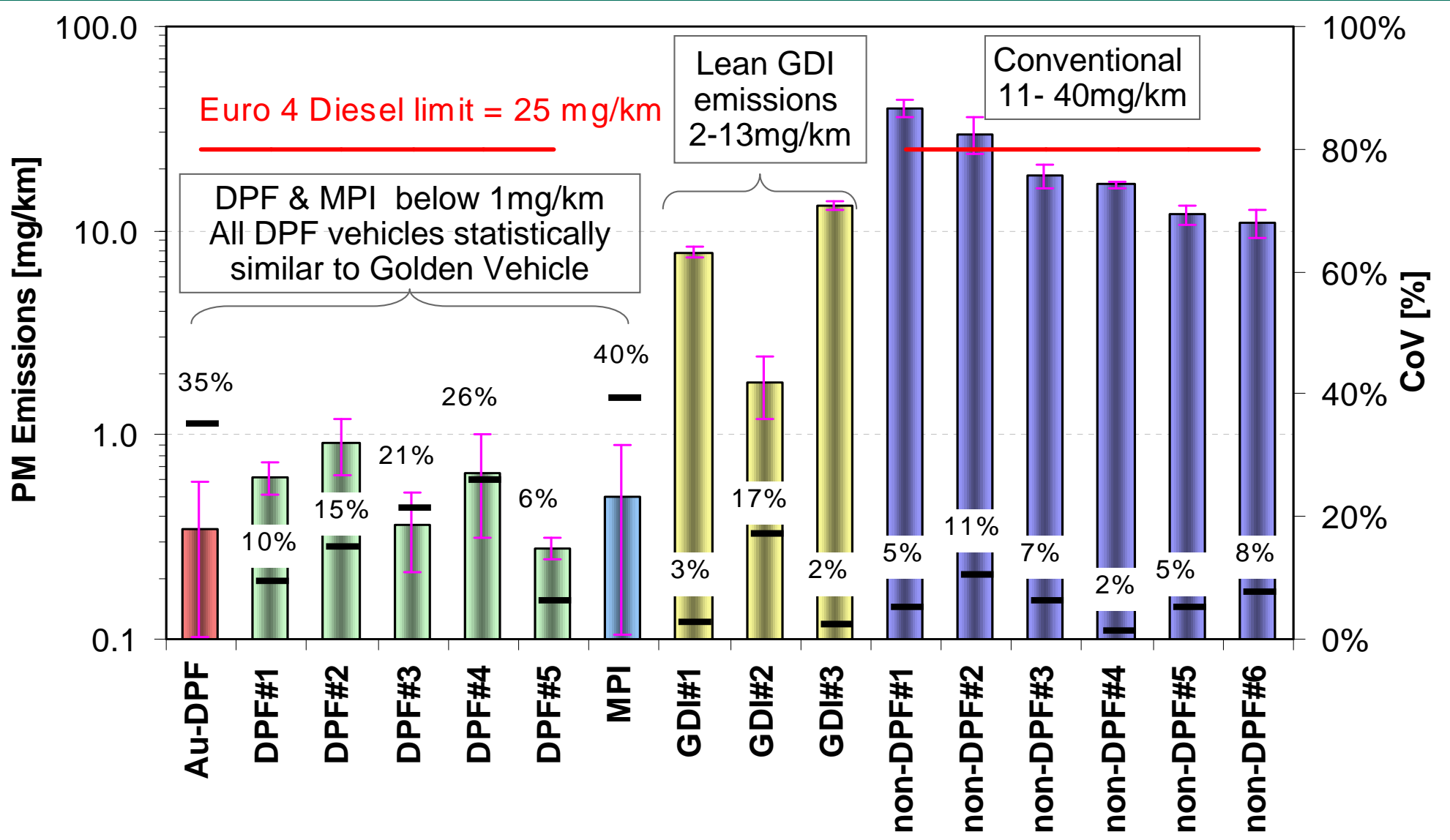
# PMP Phase II Recommendations – Solid Particle Number Count

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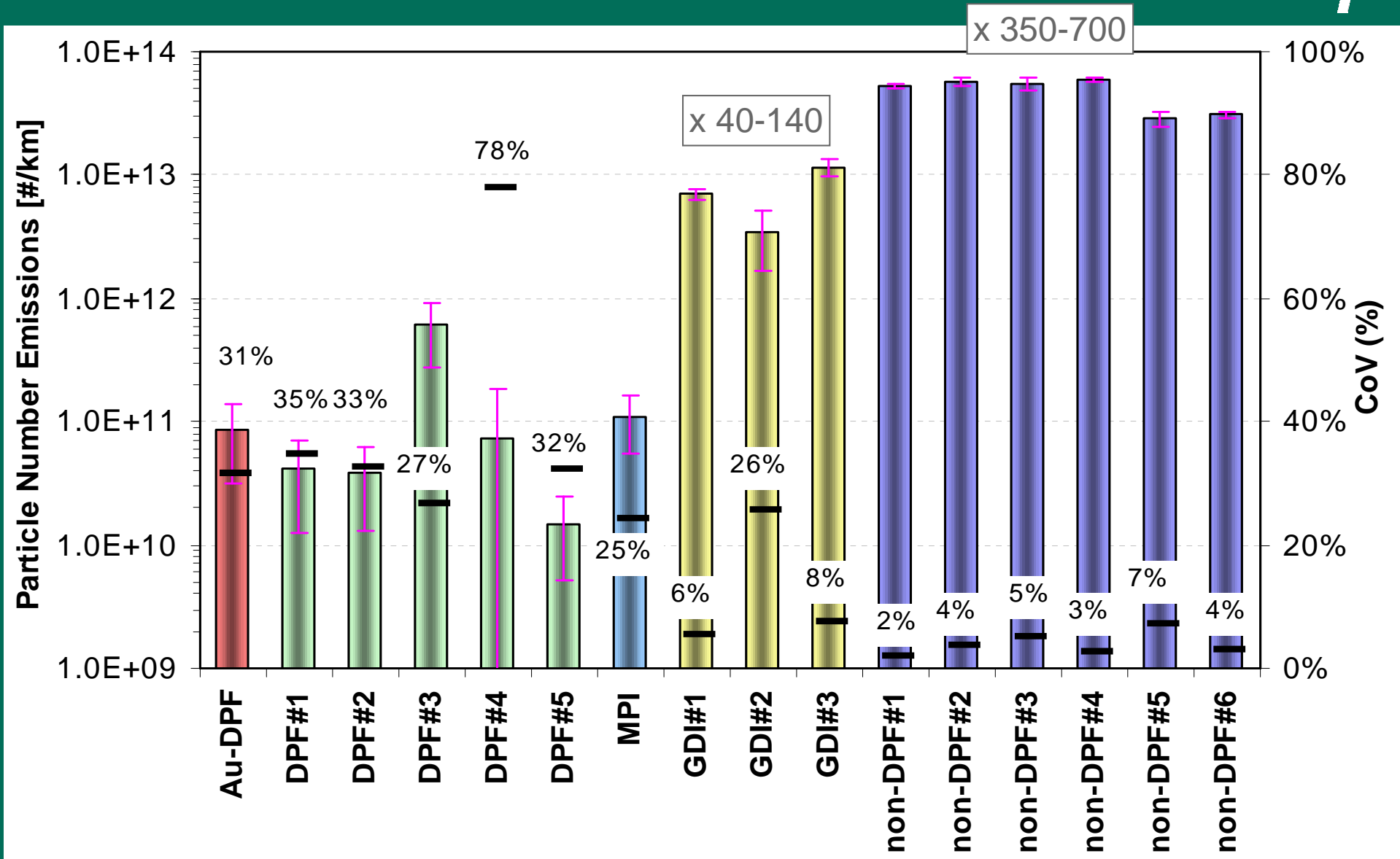
- LEPA, charcoal + HEPA filtration of dilution air
- Sample pre-conditioning by heated dilution, heating, second stage dilution to eliminate volatile particles.
- Particle number count by condensation nucleus counter with 23nm low size cut-off.

# PMP Phase III – Light Duty Validation Results, Department for Particulate Mass *Transport*



# PMP Phase III – Light Duty Validation Results, Department for Particle Number

*Department for  
Transport*



# UK Proposal To GRPE in June 2007

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- Proposed inclusion of particle number and revised particulate mass procedures in UN-ECE Regulation 83 as an unreferenced Annex for future use
- Proposal included;
  - Mandatory LEPA, charcoal & HEPA filtration of dilution air
  - Background correction permitted for PM (max 1mg/km) and PN for CoP but not type approval
  - PN logged for 20s after end of cycle to capture offset
  - Max permissible Volatile Particle Remover solid particle losses 40%, 30% and 20% at 30nm, 50nm and 100nm respectively.
  - VPR volatile removal efficiency  $\geq 99\%$  (upstream v downstream or cold v hot measurements)
  - Gas calibration of VPR for dilution across range, losses & volatile removal efficiency validated (upstream v downstream concentration measurements)
  - VPR leak check ( $<1 \text{ cm}^{-3}$ ) prior to each test



## UK Proposal To GRPE in June 2007 (cont)

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- PNC 0-10,000cm<sup>-3</sup> in single particle count mode
- PNC counting efficiency validated against reference PNC or electrometer (+/-10%)
- No periodic validation requirement of PNC low size cut-off characteristic
- PNC Checks: Monthly linearity check, daily zero (<1cm<sup>-3</sup>) and high (>100cm<sup>-3</sup> with ambient air) response check prior to each test, daily flow check,

# GRPE June 2007 Outcome

- Several nations expressed a view that proposal was premature with remaining issues to be resolved in particular regarding;
  - calibration procedures
  - VPR & PNC specifications
  - Potential system to system offsets
- Proposal not adopted by GRPE
- However GRPE endorsed a 'Road Map' of activities to allow a revised proposal to be considered by GRPE 55 in Jan 2008

# PMP Road Map

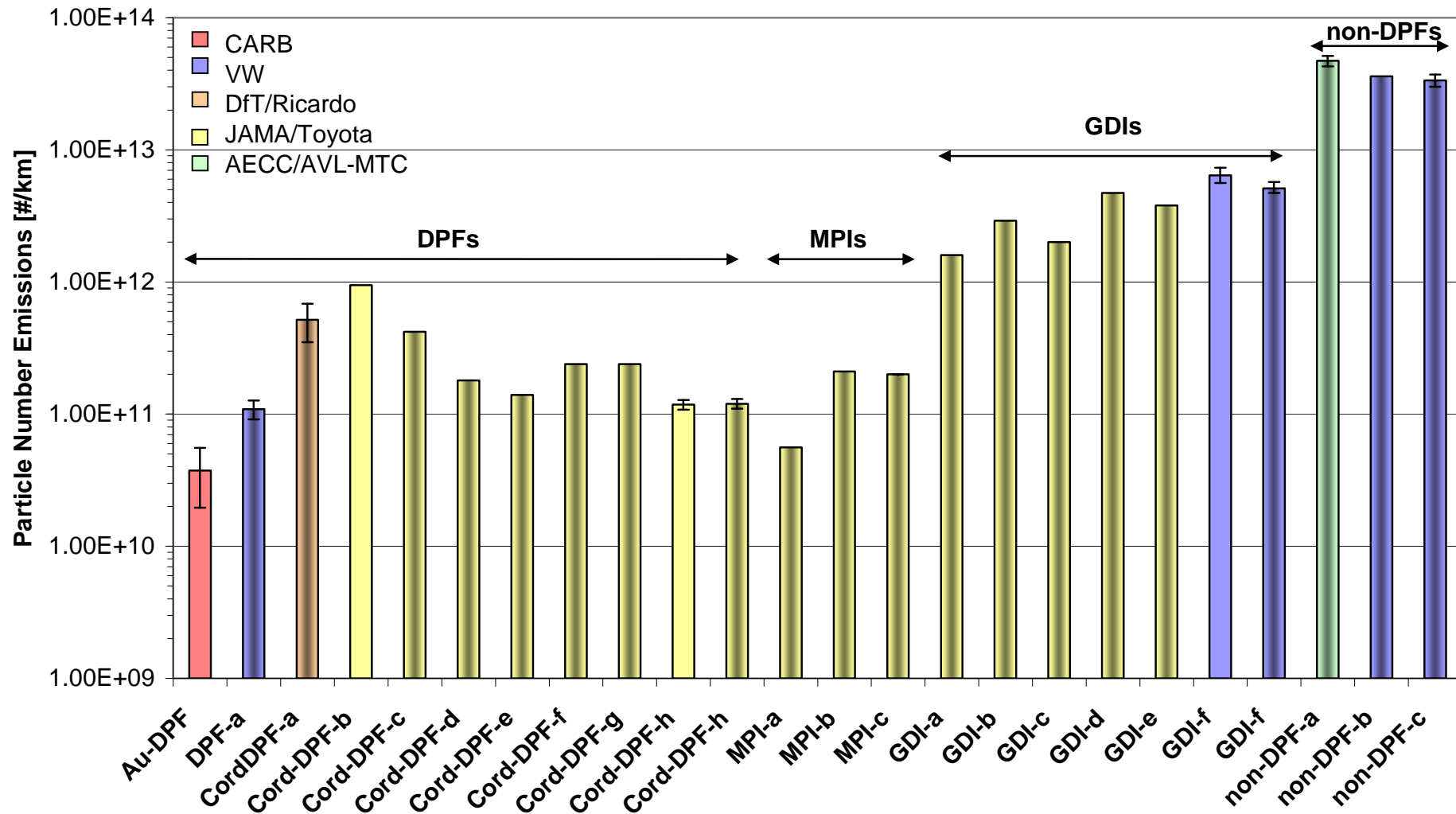
- Compile additional existing PN results from outside validation exercise
- Improve calibration procedures
- Analyse accumulation of errors/system tolerances to assess potential differences between systems
- Demonstrate improved calibration procedures

# Consolidation of Particle Number Data

- Compilation of Existing Particle Number Test Data from PMP compliant equipment used outside of the PMP ILCE
  - Data was received from AECC, CARB, JAMA, Sweden, Concawe, UK, Toyota and Volkswagen
  - PMP compliant measurement systems used were the Horiba SPCS and Matter MD19+TSI PNC. Results were submitted on other measurement systems but no data was available to demonstrate that these systems met PMP solid particle penetration and volatile particle removal efficiency requirements.
- Analysis of accumulation of errors by NPL suggested potential 15% offset. The most significant factors were the PNC calibration and the allowable tolerance on VPR pcrf validation checks

# Consolidation of Particle Number Data

Matter/TSI results shown shaded, Horiba SPCS results shown unshaded



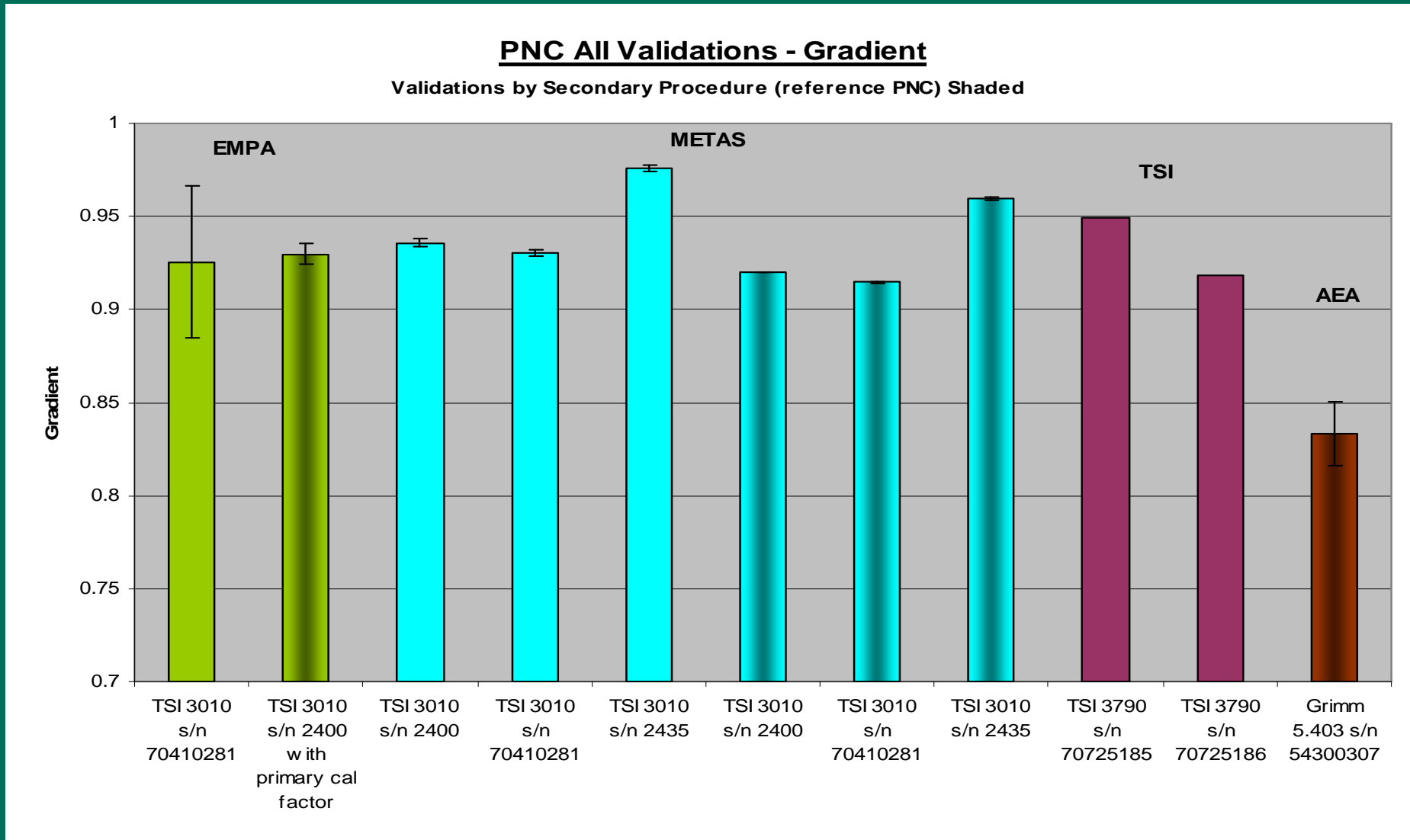
# Improved Calibration Procedures

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- The following key revisions to the procedures were agreed over 2 meetings in August & October
  - VPR will be calibrated for particle concentration reduction factor (a combination of particle losses and dilution) which must not be excessively size dependent
  - PNC will be calibrated to reference electrometer level
- This substantially reduces potential offset between systems by correcting out differences in particle losses and PNC counting efficiency
- EMPA, METAS, TSI & AEA undertook measurements during August-September demonstrating the procedures and their repeatability

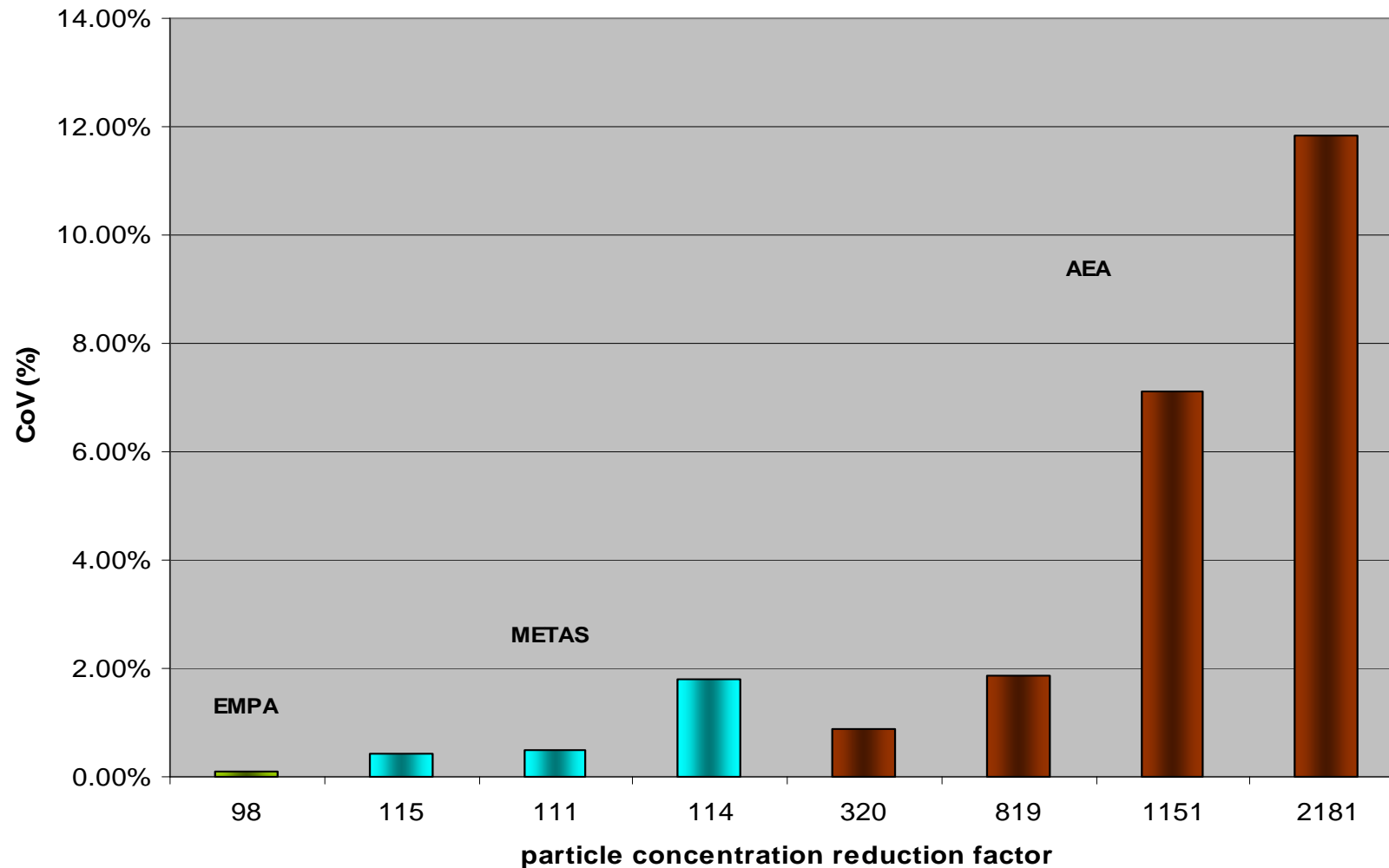
# PNC Primary & Secondary Validation Gradients

- Primary & Secondary methods show similar results
- Repeatability generally good



# VPR pcrf Repeatability

- Repeatability very good at pcrf settings used for DPFs (typically ~150) and GDIs (typically ~600)





# Amendments To Reg 83 Proposal

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Based on the results of the Roadmap activities a revised proposal to amend Regulation 83 was submitted to GRPE. Key changes;

- Charcoal scrubbing of dilution air is now optional
- PM sample minimum residence time at 47°C deleted, Teflo filters allowed
- Additional 20s PN sampling deleted
- VPR must be calibrated for mean particle concentration reduction factor (pcrf) (mean of 30nm, 50nm and 100nm results) across its range of dilution settings
- VPR pcrf for 30nm and 50nm particles must be no more than 30% and 20% respectively higher than for 100nm particles
- VPR must have a minimum dilution factor upstream of the ET of 10
- PNC must be calibrated to reference electrometer reading
- Upper limit of PNC range no longer restricted to 10,000cm<sup>-3</sup>
- Validation check of PNC cut-off performance introduced as part of calibration
- Monthly PNC linearity check deleted, PNC flow check changed from daily to monthly
- PNC zero and leak check tolerances tightened

# Outcome of GRPE in January 2008

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- Proposal adopted by GRPE for transmission to WP29
- Now awaiting i) agreement of EU position via TCMV meeting on 26<sup>th</sup> May and ii) formal vote in June WP29
- Amendment enters into force 9 months after vote

Meanwhile;

- Particle Number limits agreed for inclusion in Euro 5 & 6
- Diesel:  $6 \times 10^{11}$  particles/km & 4.5g/km
- From 1<sup>st</sup> September 2011 (new types), 1<sup>st</sup> Jan 2013 (all types)
- GDI: TBD for Euro 6 & 4.5g/km

# Heavy Duty Validation & Round Robin

- Validation programme featuring Golden Systems (partial & full flow sampling), Golden Engine and Golden Engineer

JRC	To end of February 2008
AVL-MTC	March-April 2008
JRC	May - June 2008
Ricardo	July - August 2008
UTAC	September - October 2008
Review of data accumulated	November 2008
EMPA	December - January 2009
JRC	February - March 2009

# Heavy Duty Validation & Round Robin

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plus...

- Round Robin with (different) Golden Engine, labs own systems, no Golden Engineer

TUV	April-May 2008
Ricardo	June-August 2008
Volvo	September-October 2008
Japan & Korea	November 2008 - June 2009
JRC	July-August 2009
UTAC	September-October 2009
TNO	November-December 2009
VTT	January-February 2010
Scania	March-April 2010
Environment Canada	June-August 2010
Daimler Chrysler	September 2010