Calibration of Fast Electrical Mobility Spectrometers for Engine Particulate Measurement

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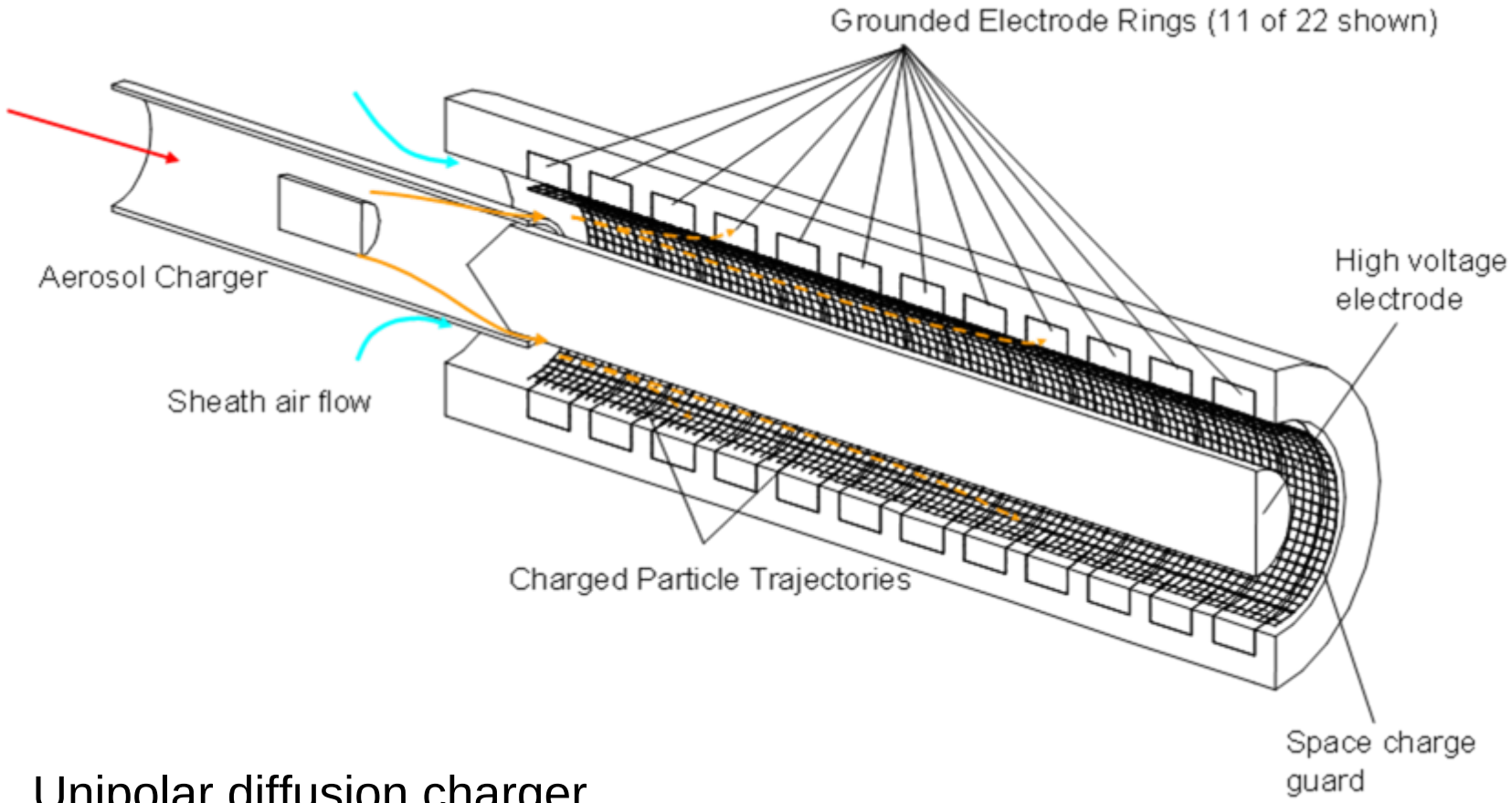
Content of Talk

- Principle of DMS type Fast Particulate Size Spectrometer
- Calibration Procedure
  - Gain (concentration)
  - Size
- Relative charging of simple & agglomerate particles
- Effect on DMS calibration
- Application of dual agglomerate : spherical calibrations with automatic mode identification
- Comparison of mode identification with proposed PMP R83 volatile particle remover + particle counter
- Conclusions

DMS Principle of Operation



- Unipolar diffusion charger
- Electrometer detection
- Sizing by charge : drag ratio - electrical mobility

'Fast Response Classification of Fine Aerosols with a Differential Mobility Spectrometer'; Reavell, K. Proc. AGM Aerosol Soc. UK. 2002

DMS Calibration Procedure

Gain Calibration

- Comparison with aerosol electrometer
- Single-charged particles of desired size selected in DMA
  - Requires small aerosol – renucleated H_2SO_4 and NaCl
- Traceable to calibration of electrometer & flowmeter
- Better than CPC standard
  - only reliable in count mode, ∴ differential dilution required, with uncertainty

Size Calibration

- Small sizes – calibration against DMA (mobility standard)
- Larger sizes (prone to multiple charging issues in DMA) – certified PSL spheres
  - requires good size resolution

- Information incorporated into transfer function used in deconvolution of electrometer currents

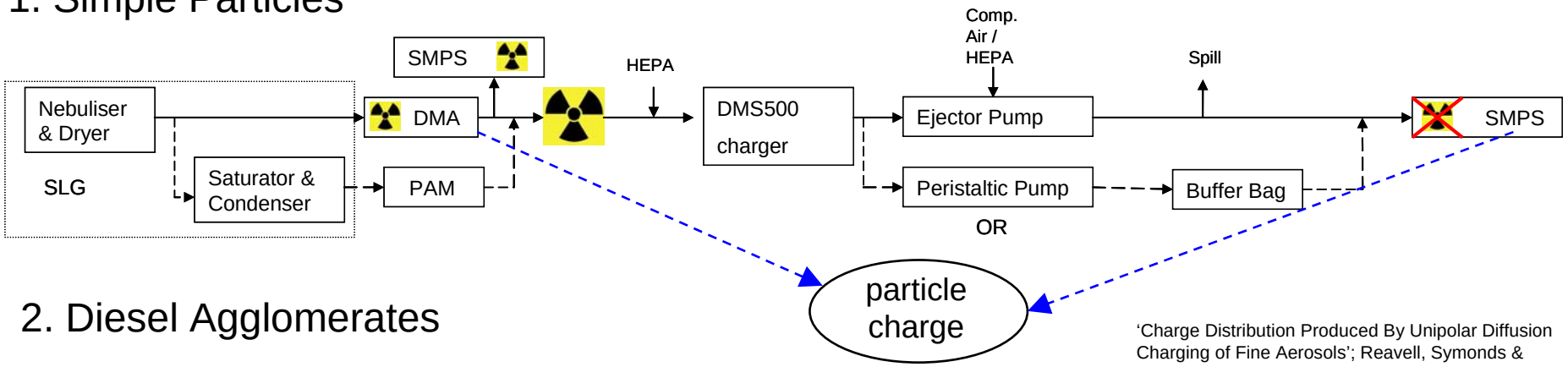
Charging of Agglomerate Particles

- Size classification by charge : drag ratio
- Concentration measurement by electrical current

- Measurement sensitive to charge distribution of particles.

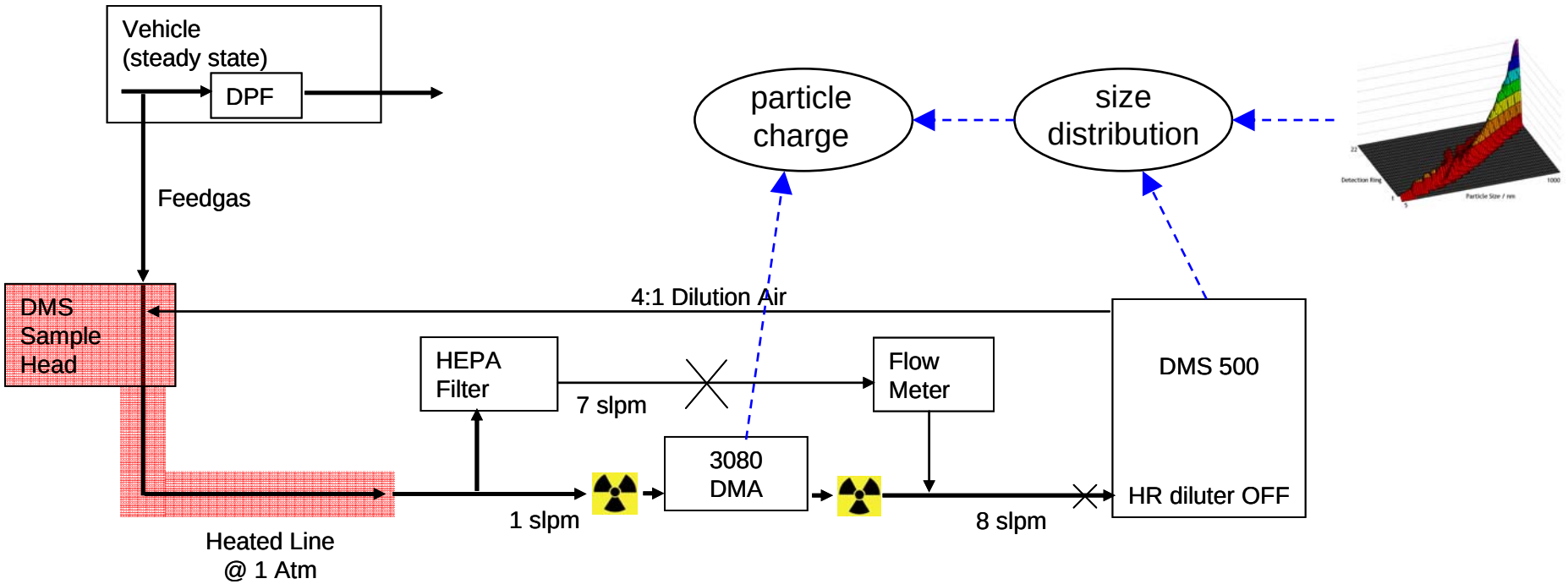
Charge & Size Measurement

1. Simple Particles



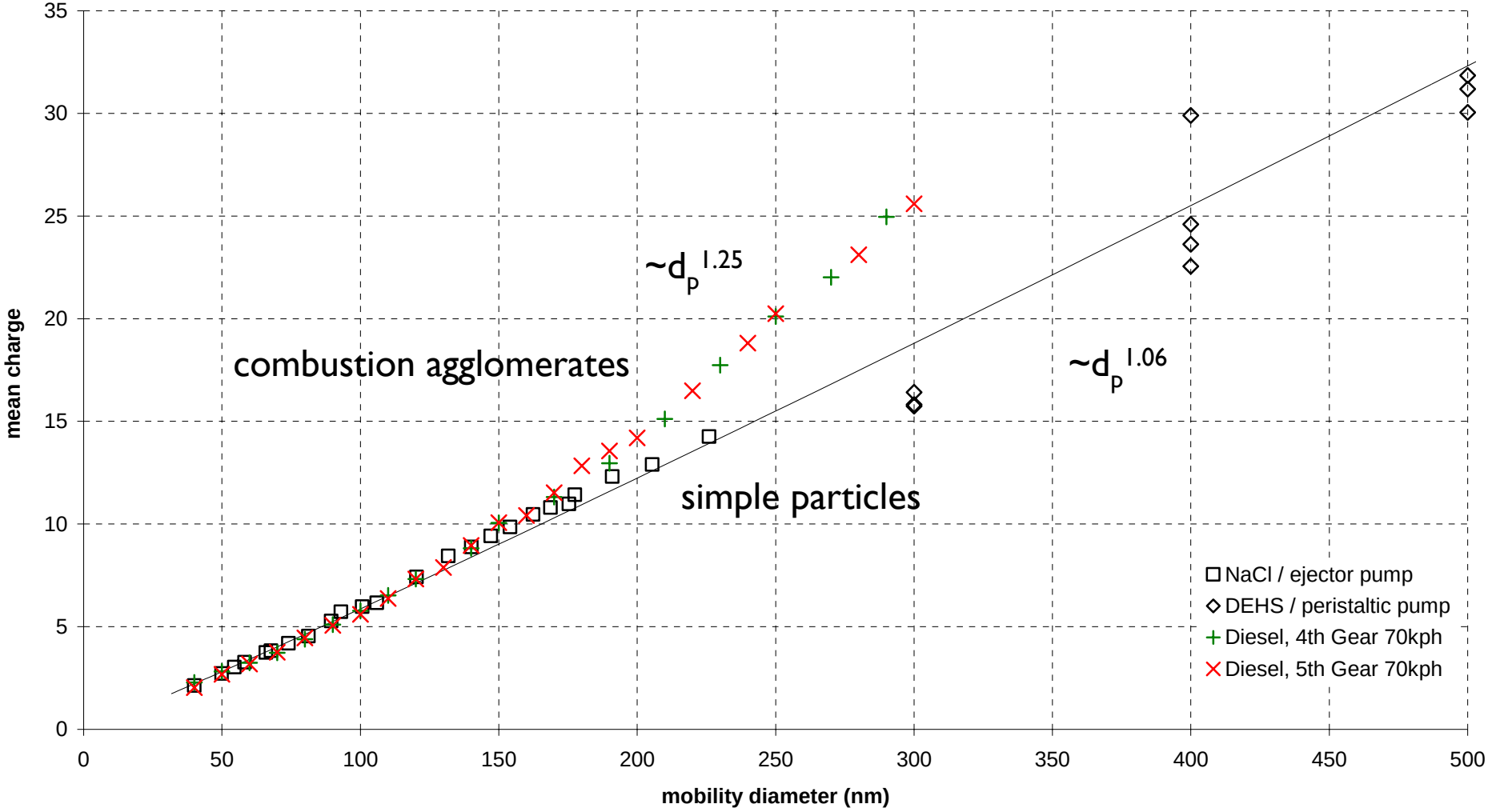
2. Diesel Agglomerates

'Charge Distribution Produced By Unipolar Diffusion Charging of Fine Aerosols'; Reavell, Symonds & Biskos. Conf. AAAR 2004

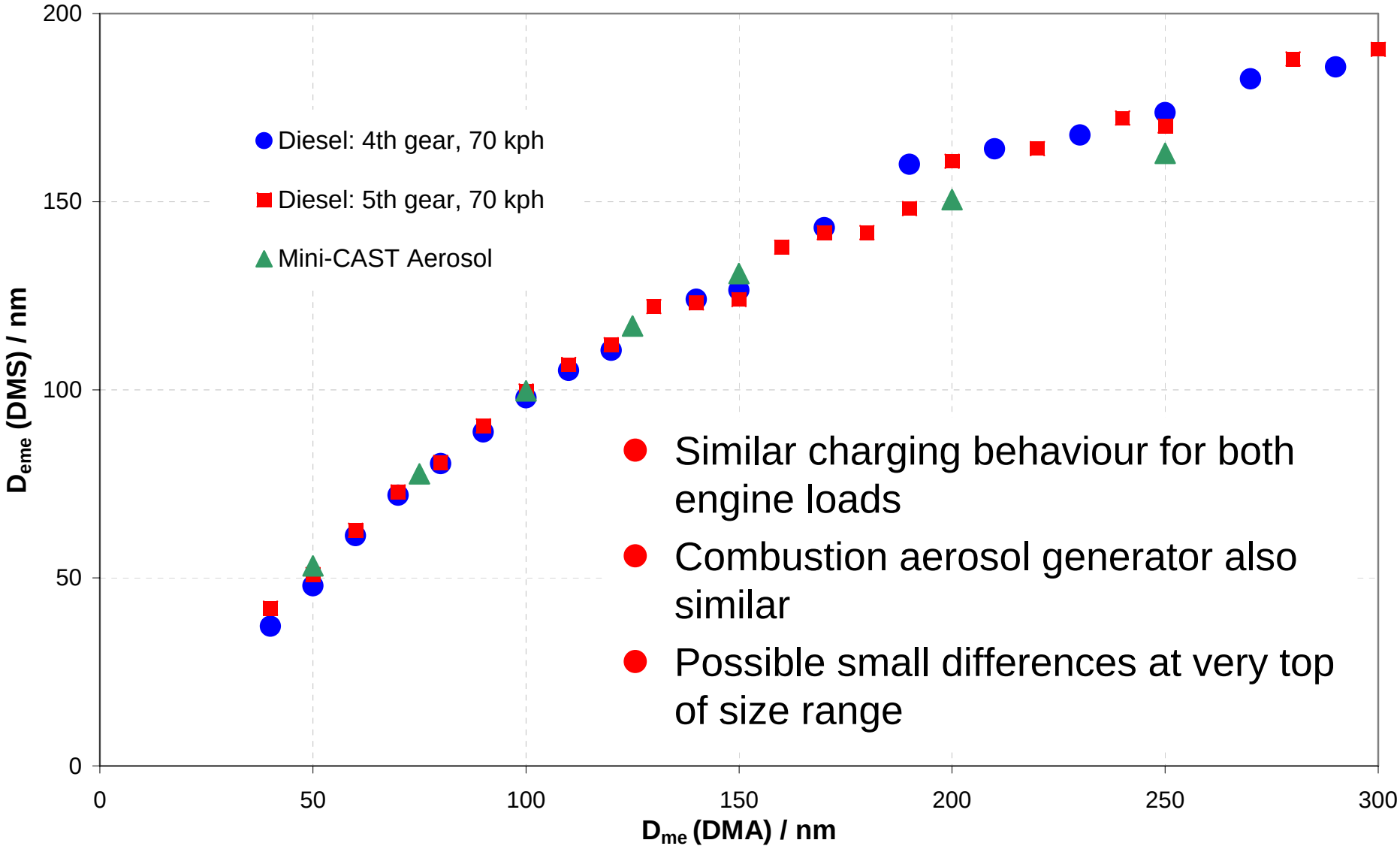


Unipolar Diffusion Charging Comparison - simple particles vs. agglomerates

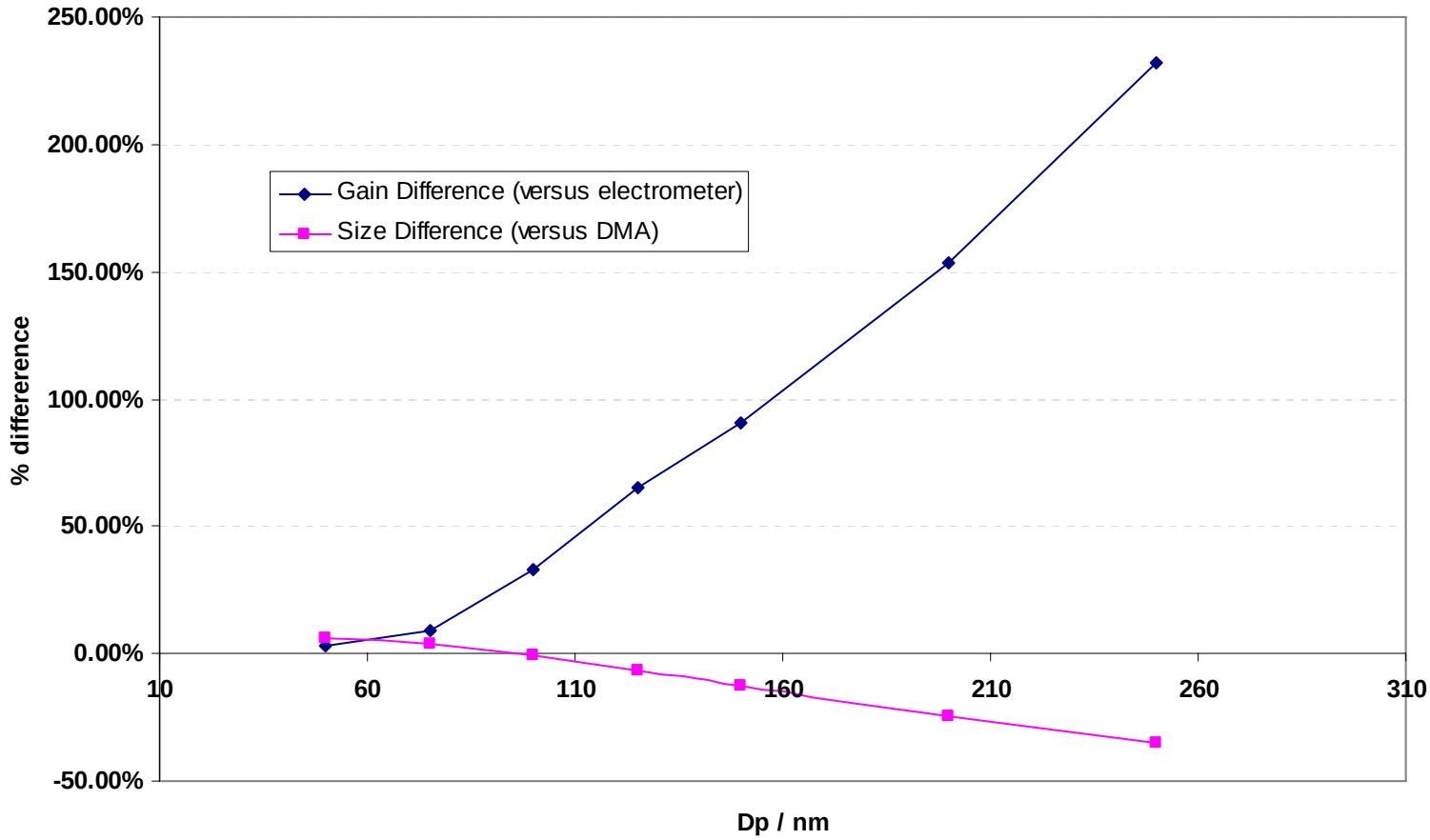
DMS500 Mean Particle Charge



DMS:DMA sizing comparison



Effect of Agglomerate Charging on Instrument Calibration



Difference between spherical & agglomerate particles causes errors in measurements of larger agglomerate particles made with a calibration for spherical ones

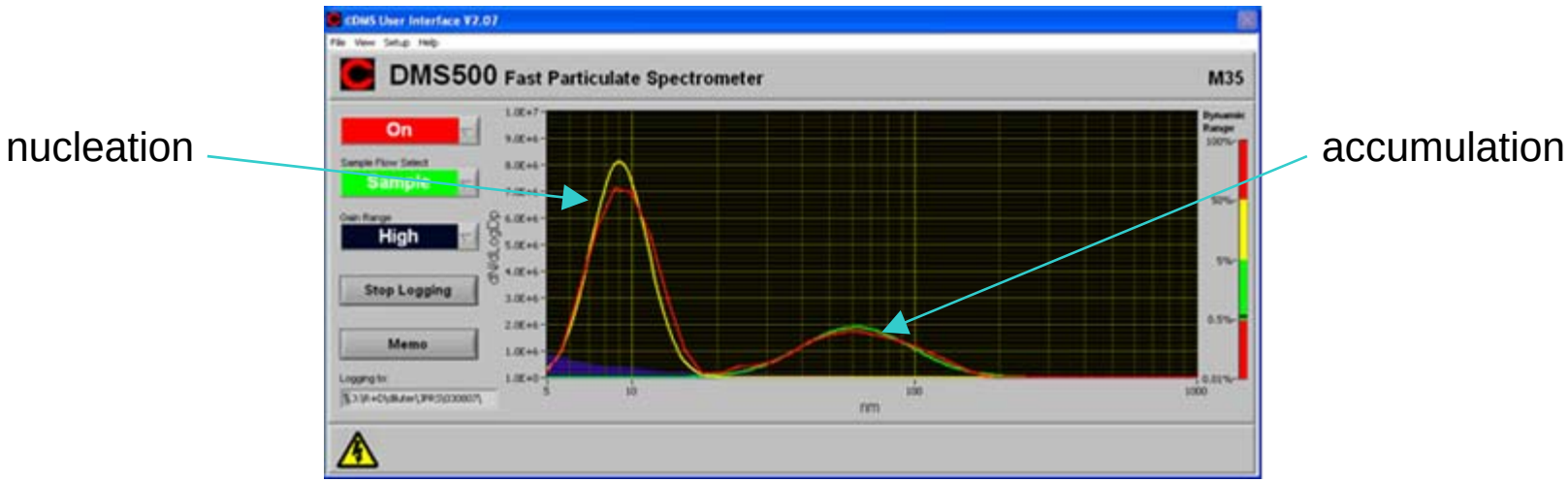
- due to coupling of size & concentration measurements

New Data Processing Facility - Automatic Lognormal Mode Identification

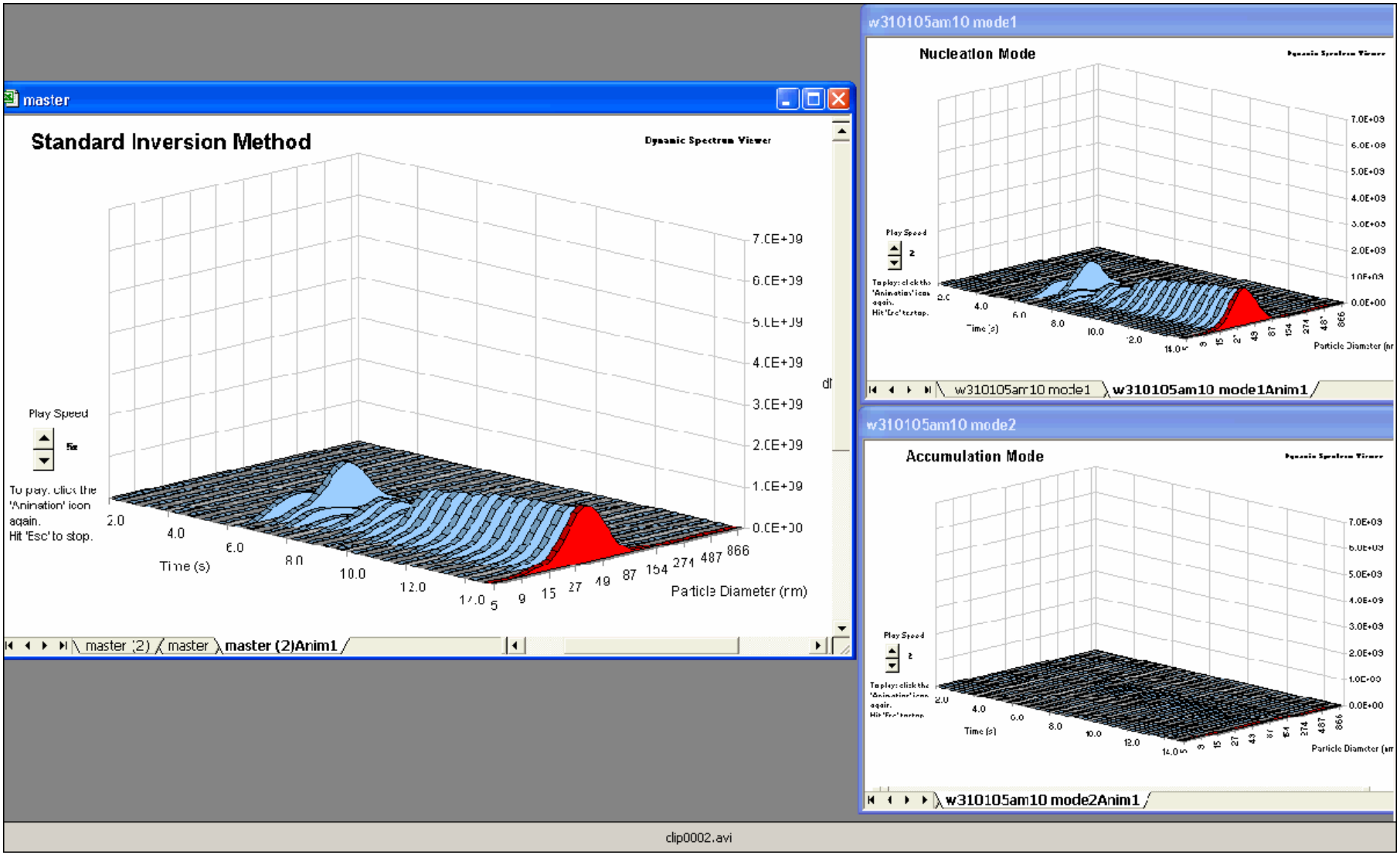
- Mode identification software replaces continuous spectrum with 6 parameters:

Nucleation			Accumulation		
GMD	GSD	N/cc	GMD	GSD	conc

- Bayesian algorithm identifies modes significantly above noise base of instrument, and identifies whether accumulation or nucleation mode.
- Reduces noise in measurements by increasing data redundancy (6 vs 38 DoF)
- Removes cross sensitivity introduced by crude size cut-off methods
- Improves spectral resolution – also improves calibration accuracy with PSL spheres
- Algorithm operates directly on electrometer current data:
  - **Different transfer functions can be used for the two modes**



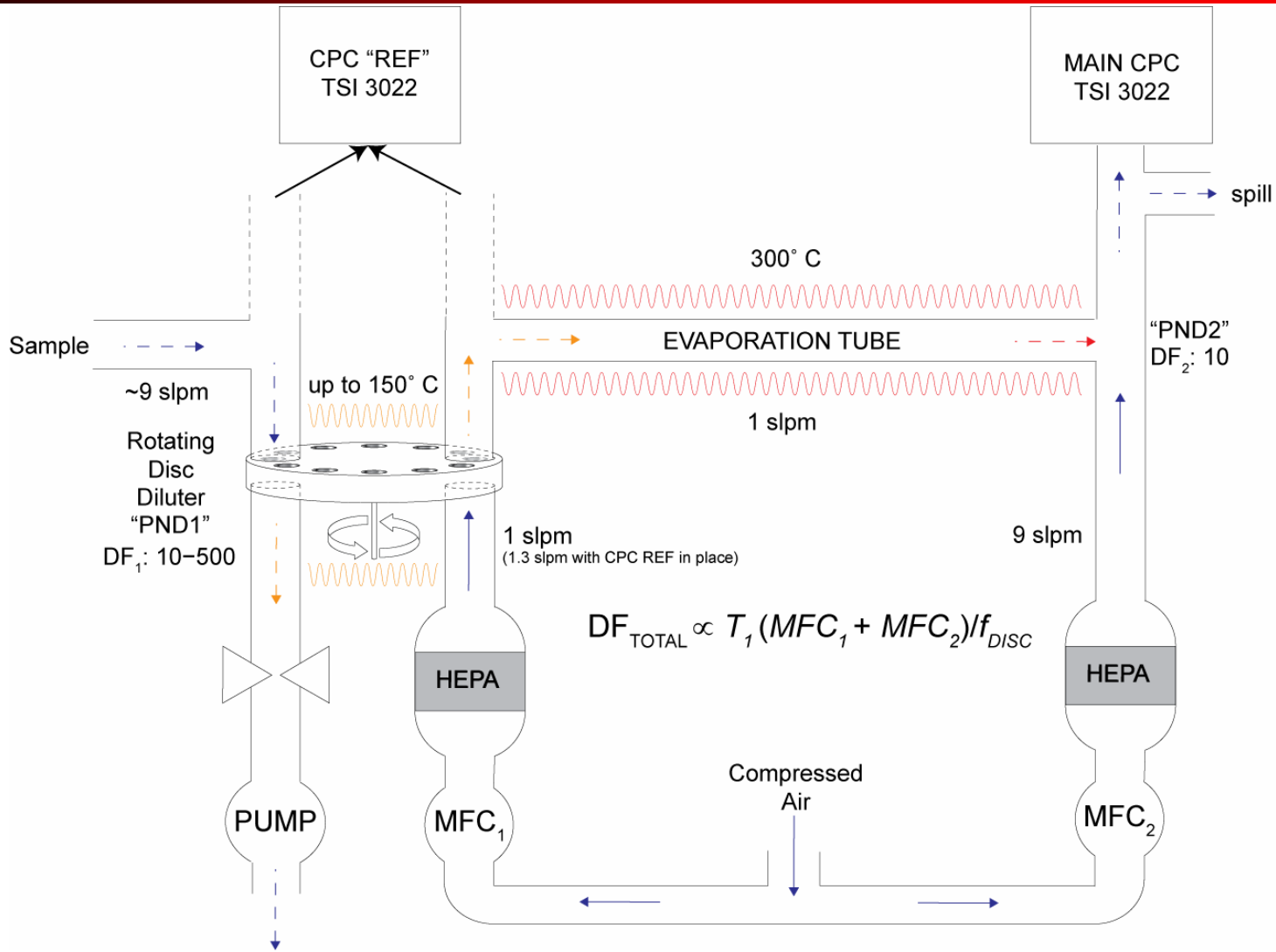
Real-time Mode Identification - transient vehicle test



Validation of Accumulation Particle Number Measurement

- Peugeot 406 HDi 2.2l common rail diesel vehicle (no DPF, with DOC).
- Compare DMS500 accumulation mode number concentration with output from PMP-like CPC + VPR system
  - CPC + VPR equivalent system measurements corrected with true solid particle penetration measured with NaCl (not in proposed standard)
  - CPC TSI 3022 (ie. non PMP-compliant lower size threshold)
- DMS500 accumulation mode calibrated with miniCAST aerosol, (DMA & Electrometer)
- Tests under no load:
  - Ejector diluter in tailpipe, DF ~ 4.7
  - Idle, fast idle, transient and high-rev (U.K. “MOT test”) conditions
  - CPC “REF” used post PND1 to measure nucleation mode concentration
- Tests under load:
  - Chassis dynamometer
  - CVS tunnel used
  - New European Drive Cycles

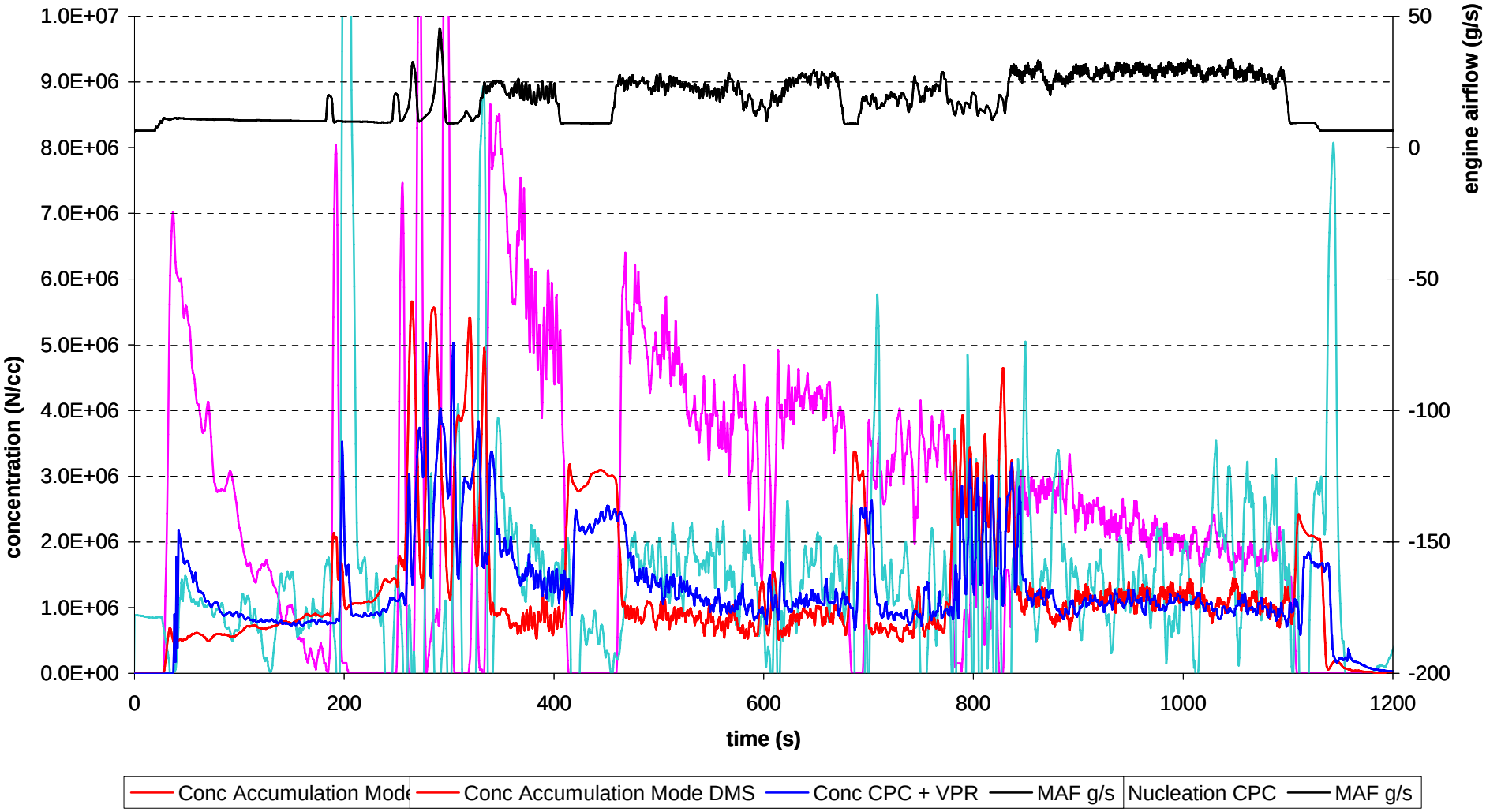
PMP equivalent dilution system



ET effectiveness measured at 99.7% with H_2SO_4 with T_1 = 50°C

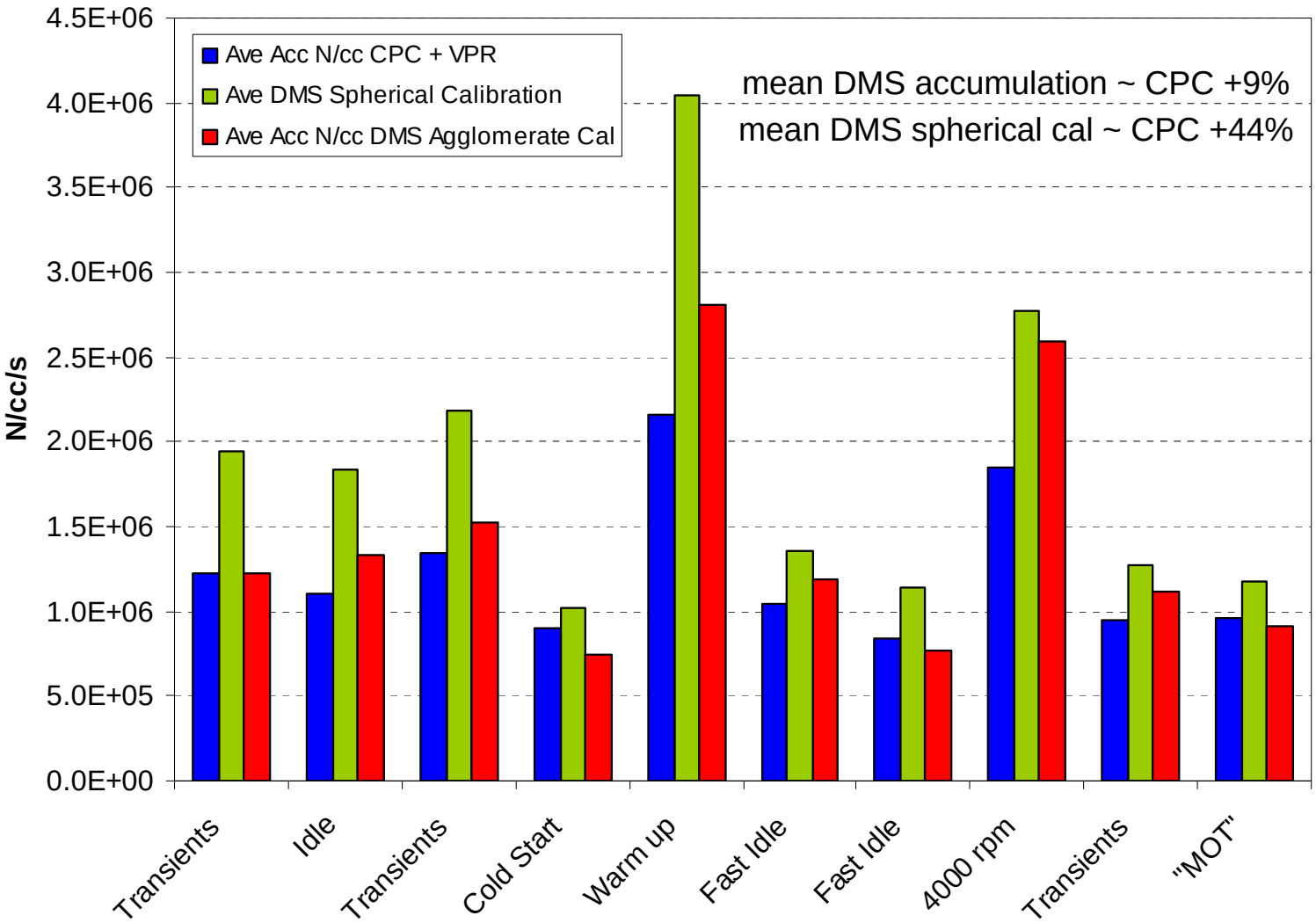
No Load Transient Cycle: Real-time comparison DMS vs CPC + VPR

DMS & CPC Measurement of Nucleation & Accumulation Modes

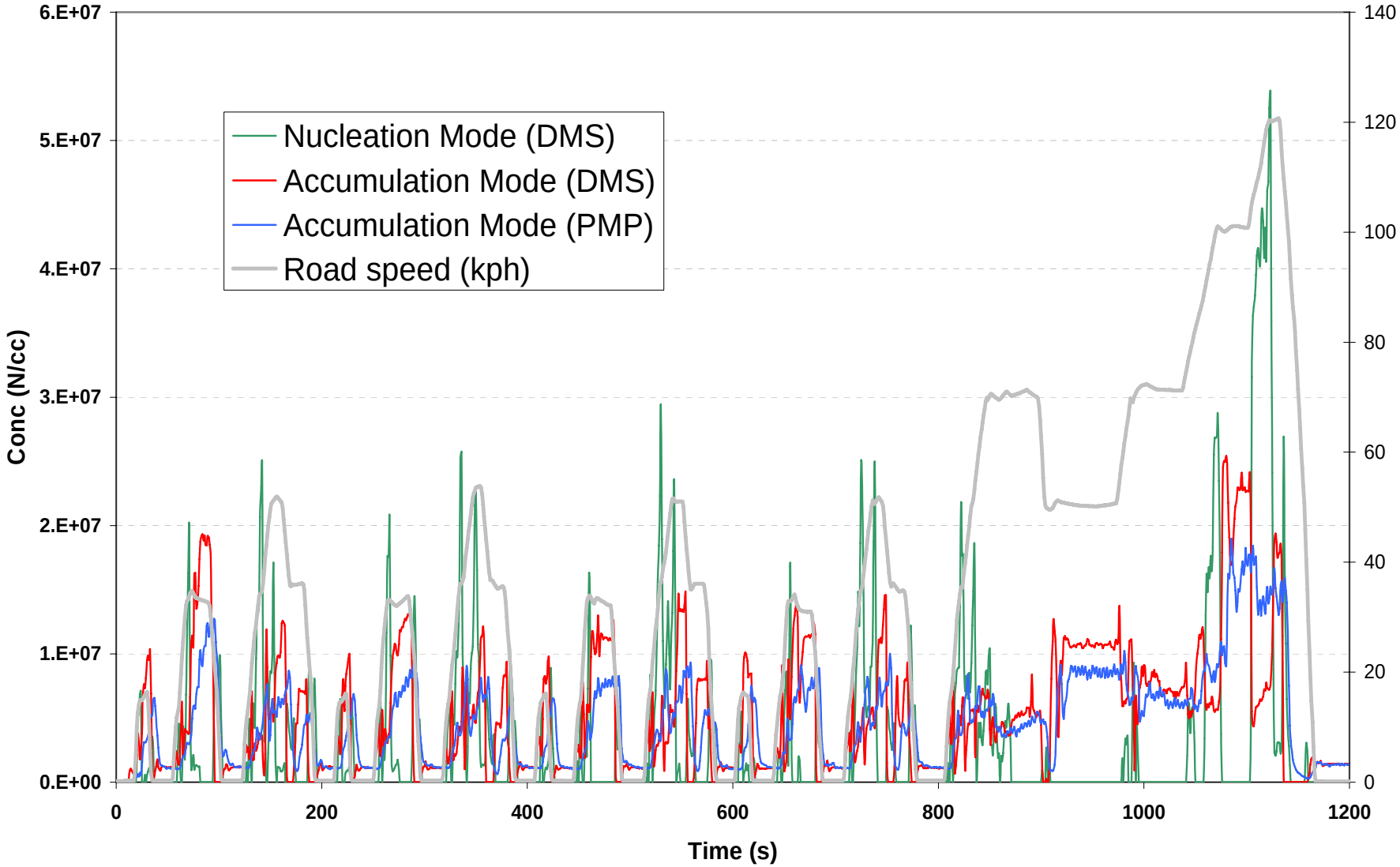


No Load Total Emissions Comparison: DMS Accumulation Mode vs. CPC + VPR

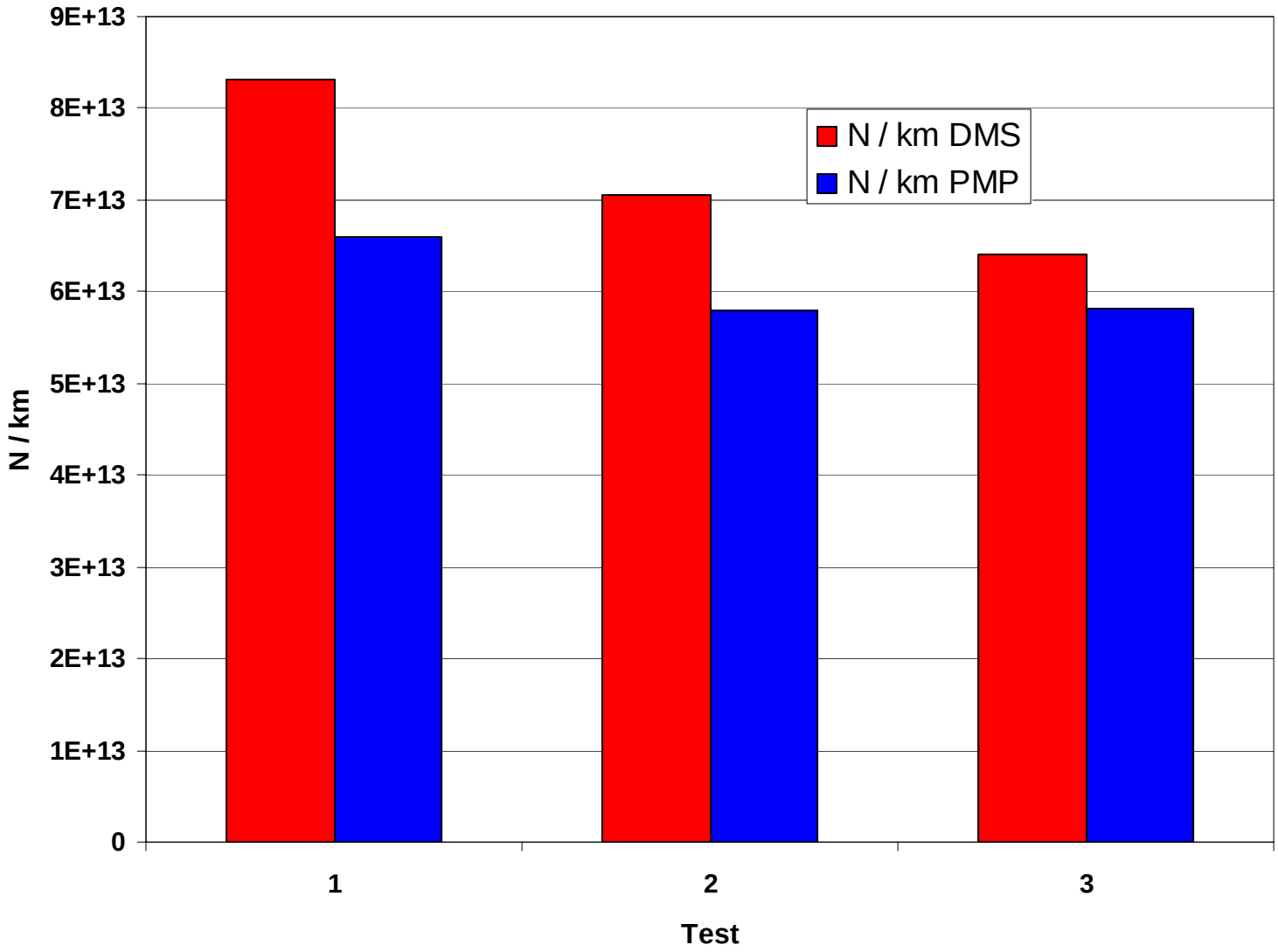
Solid particle number data corrected to **pre**-PND1 and averaged per second.



Loaded Transient Tests: NEDC on Dynamometer (1)

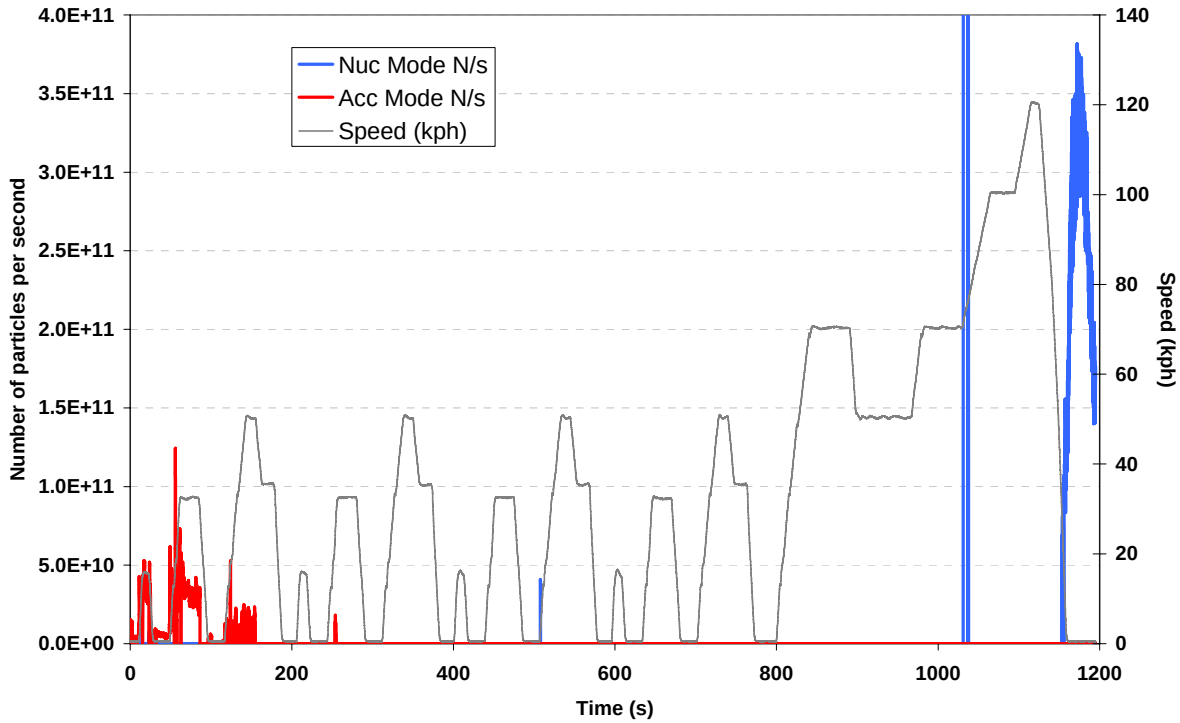


NEDC on dynamometer: Repeats



NEDC with DPF Fitted

- Same vehicle with DPF fitted
- Direct sampling post-DPF with DMS500
- Newly regenerated DPF
- Total particle number from DMS would fail proposed standard
- With automatic mode identification, accumulation mode emissions correctly resolved below limit.



Acc Mode N / km	Nuc Mode N / km	Total N / km	Proposed PMP limit N / km
1.9×10^{11}	1.4×10^{12}	1.6×10^{12}	5.0×10^{11}

Conclusions

- A traceable calibration procedure based on comparison with an aerosol electrometer for gain and PSL spheres for size calibration is described for DMS type instruments.
- Combustion agglomerates are more highly charged in the DMS unipolar charger (~ $d_p^{1.25}$) than simple particles (~ $d_p^{1.06}$).
- This affects both the size, and particularly, concentration measurement of agglomerate particles in electrical mobility based sizing instruments.
- A calibration for agglomerate particles which can be automatically applied to just the accumulation mode of an exhaust aerosol is demonstrated and compared with a PMP-like CPC + VPR measurement system.
- The average difference between the CPC+VPR measurement and agglomerate calibrated DMS is ~9% on engine exhaust aerosols.
- The automatic mode identification allows the DMS to measure accumulation mode levels in the presence of significant nucleation concentrations.
- There are significant differences between nucleation concentrations measured with the DMS and by differencing two CPCs.

Acknowledgements

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And to the organising committee of the conference.

Questions?