

Study of Particle Number Emissions from a Turbocharged GDI Engine Including Data from a Fast Response Particle Size Spectrometer

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Turbocharged GDI

Turbocharged Gasoline Direct Injection (GDI) is becoming more common:

- improvements in specific power output allowing engine down-sizing

GDI has many benefits but can have fuel preparation issues due to incomplete fuel vaporisation:

- Gaseous emissions of HC and CO
- Emissions of ultra-fine particles

Turbochargers reduce catalyst temperatures.



Introduction

Gaseous emissions are subject of existing legislation:

- Becoming progressively tighter

Particle emissions are of increasing concern:

- Historically particle mass has been legislated
- Particle number legislation has been introduced for Diesel vehicles in Europe
- Similar legislation is likely for gasoline vehicles at EU stage 6 (~2014)

If gasoline particle number limits were common with Diesel, most current-generation GDI engines would exceed the limit:

- Requiring engine hardware improvements
- ...calibration optimisation
- ...or aftertreatment



Test Set-up

Production Euro-4-compliant 1.6-litre turbocharged GDI vehicle.

Tests were carried-out on a chassis rolls with a robot driver.

- Representative passenger car road load
- Fuel : RF02-08 (E5)

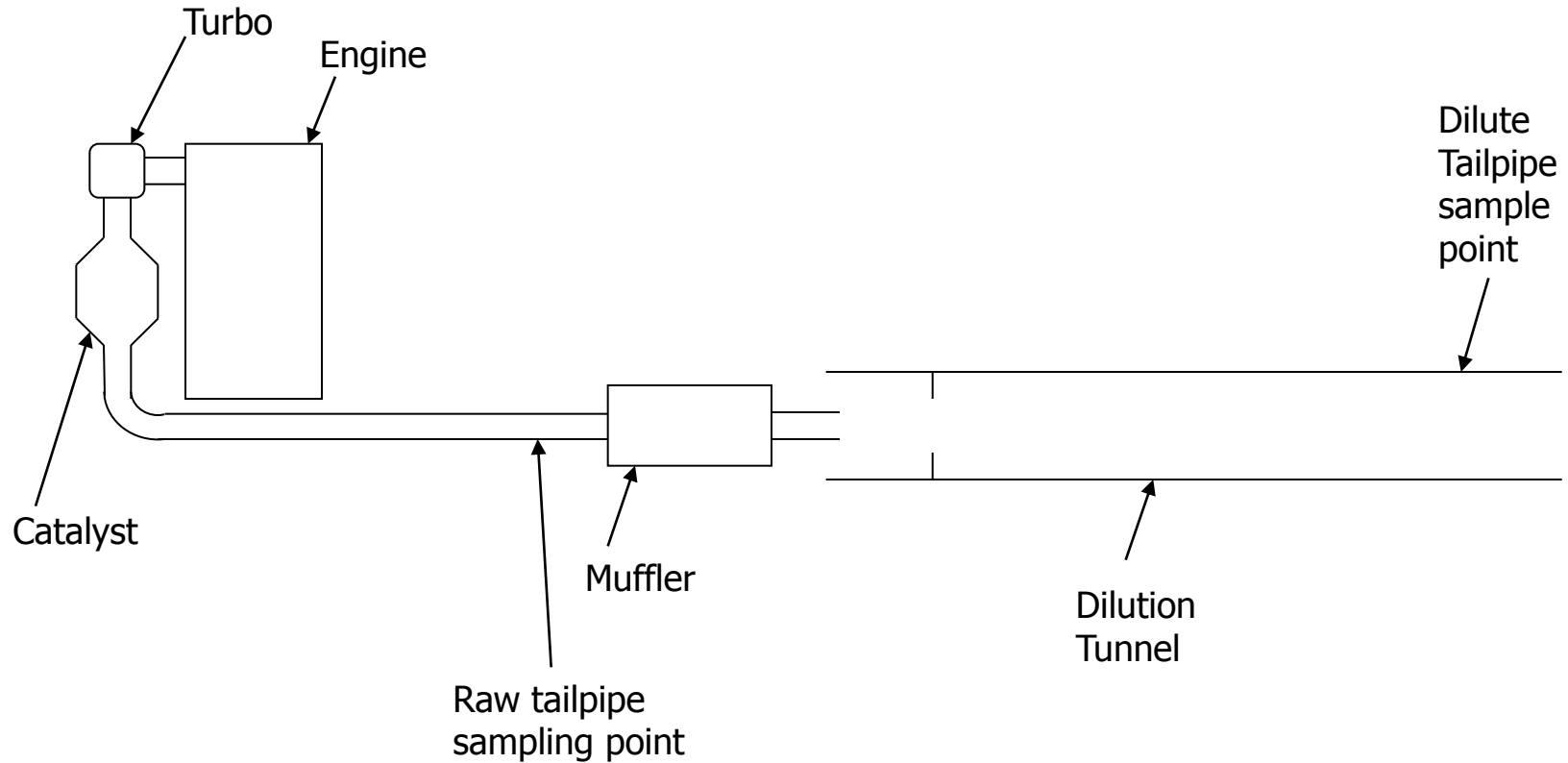
The vehicle was heavily instrumented with gas and particle emissions analysers.

- Fast-response gas analysers – Cambustion CO/ CO₂/ HC/ NO
- Conventional gas analysers – Horiba MEXA7000
- Fast-response particle analyser – Cambustion DMS500 particle spectrometer
- PMP-type particle number counting analyser – VPR and TSI 3790 CPC

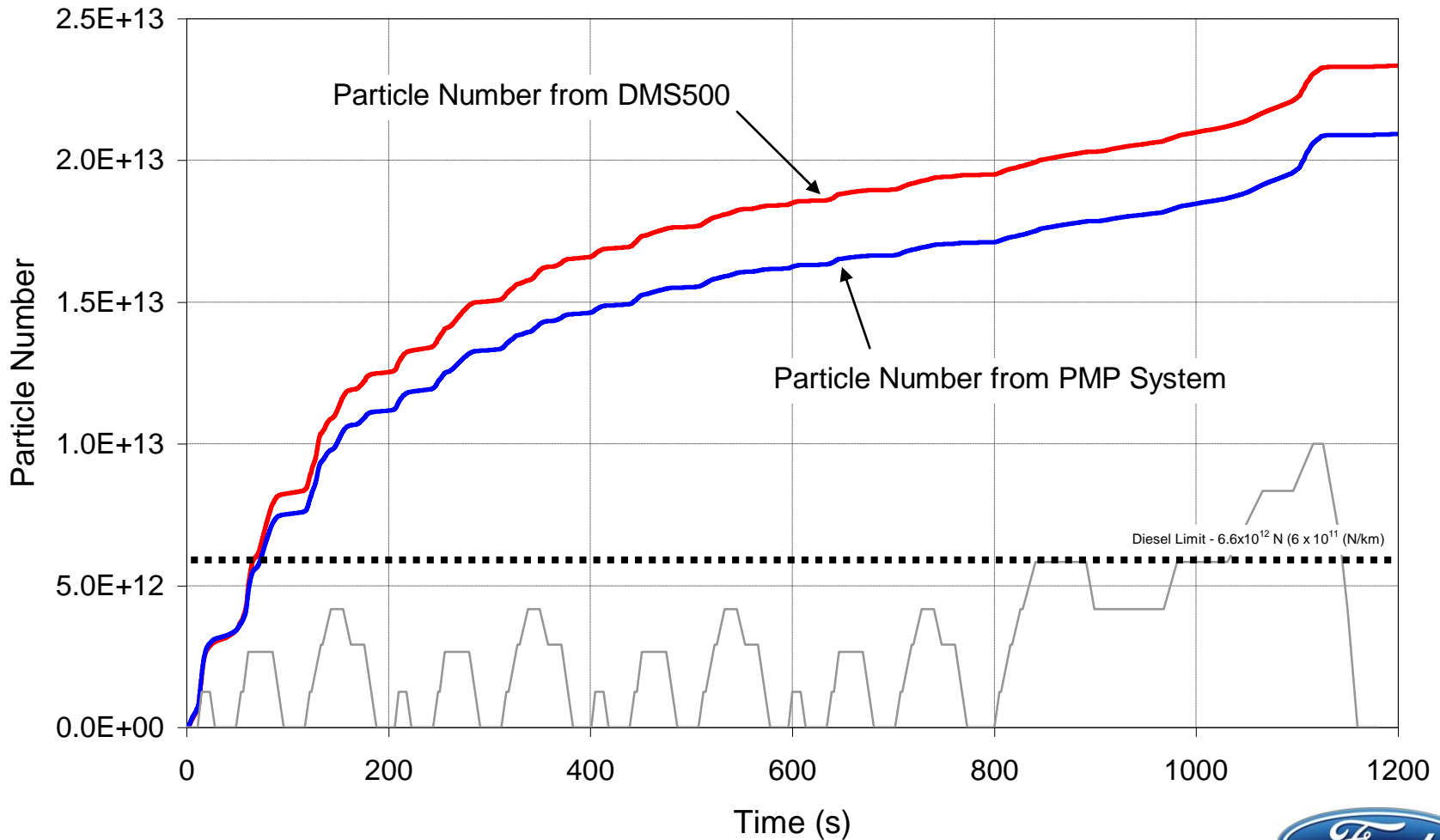
Data were also logged from the OBD port and via various sensors on the vehicle.



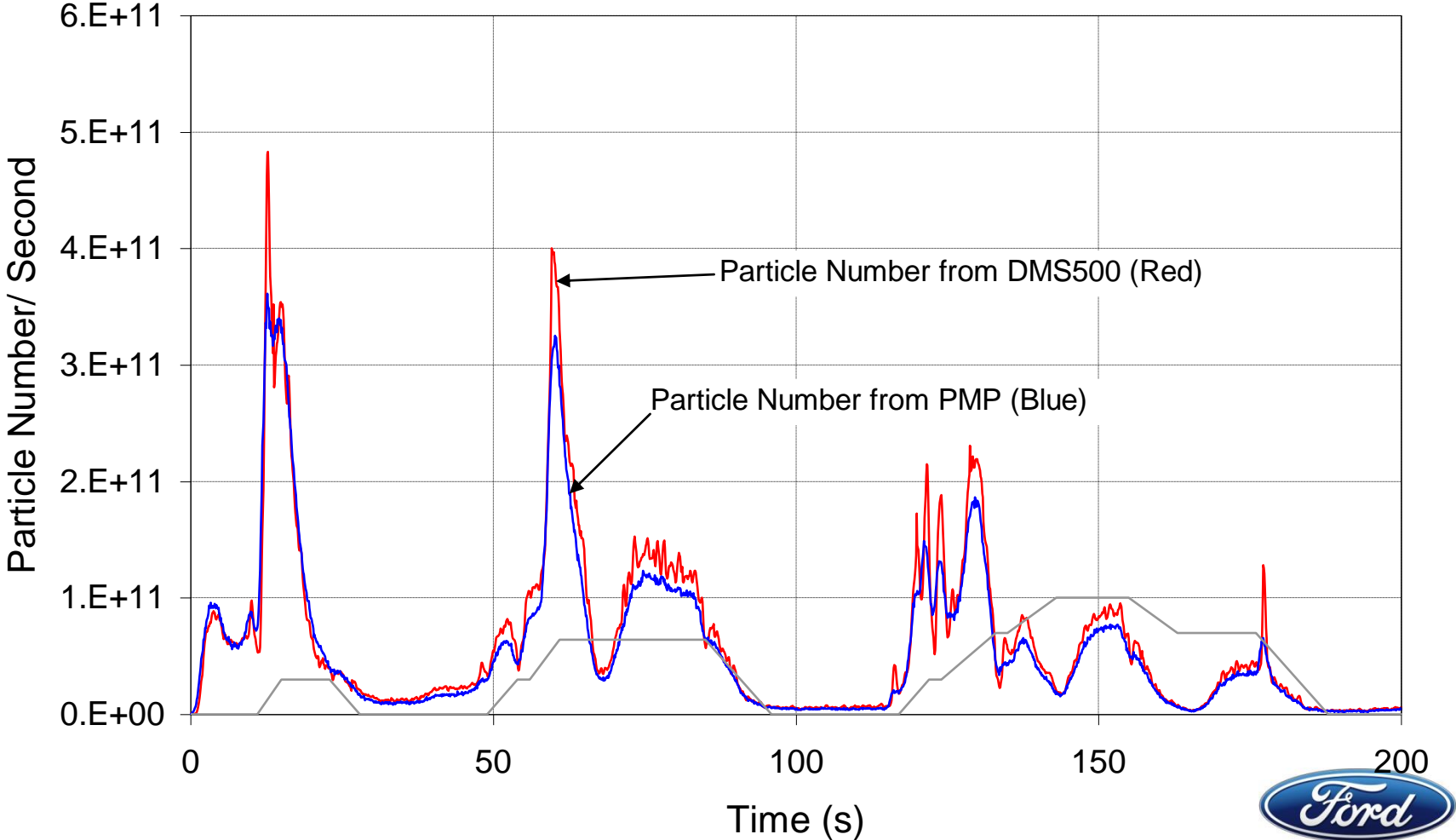
Schematic of Test Set-up



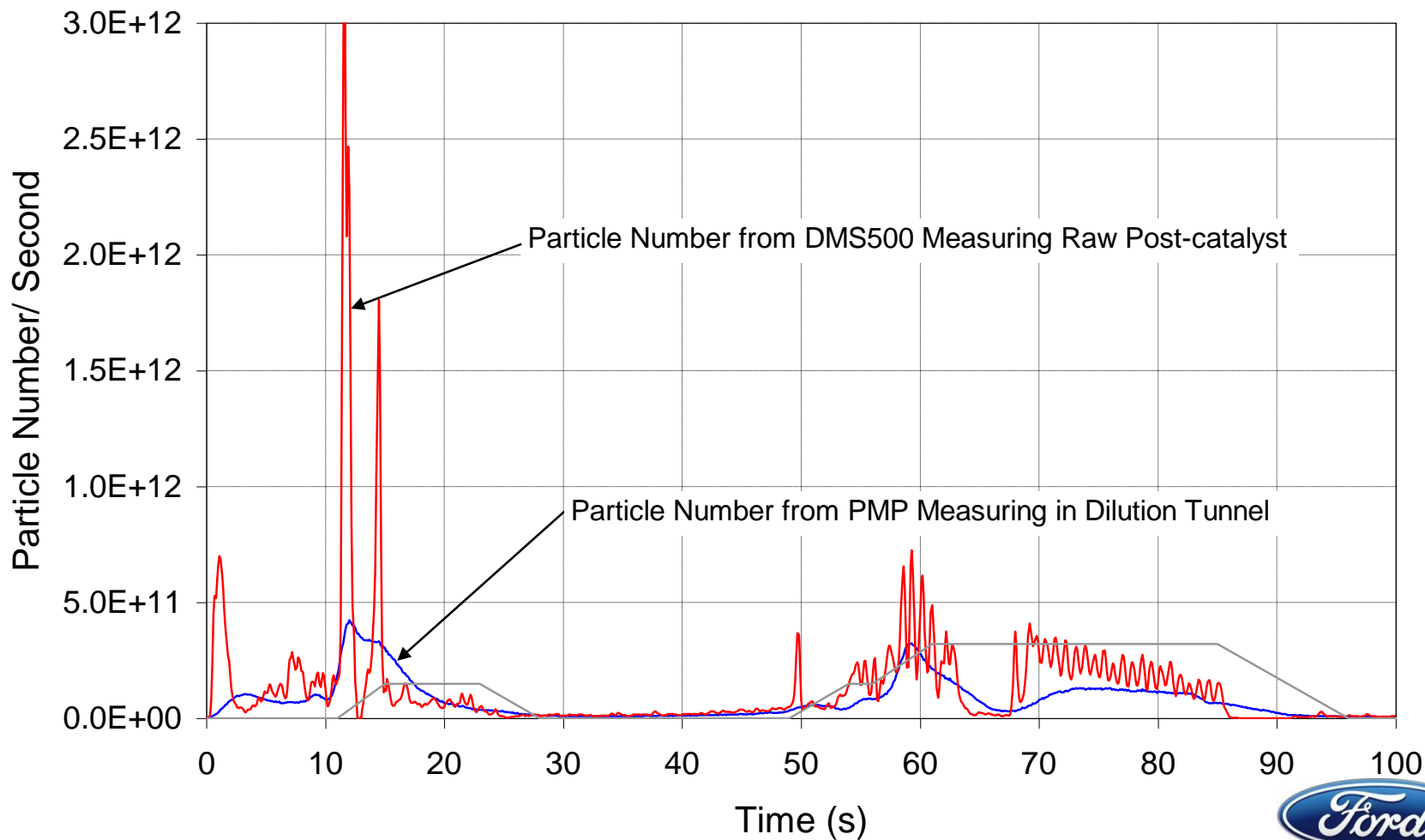
GDI Particle Number Measurements from Dilution Tunnel



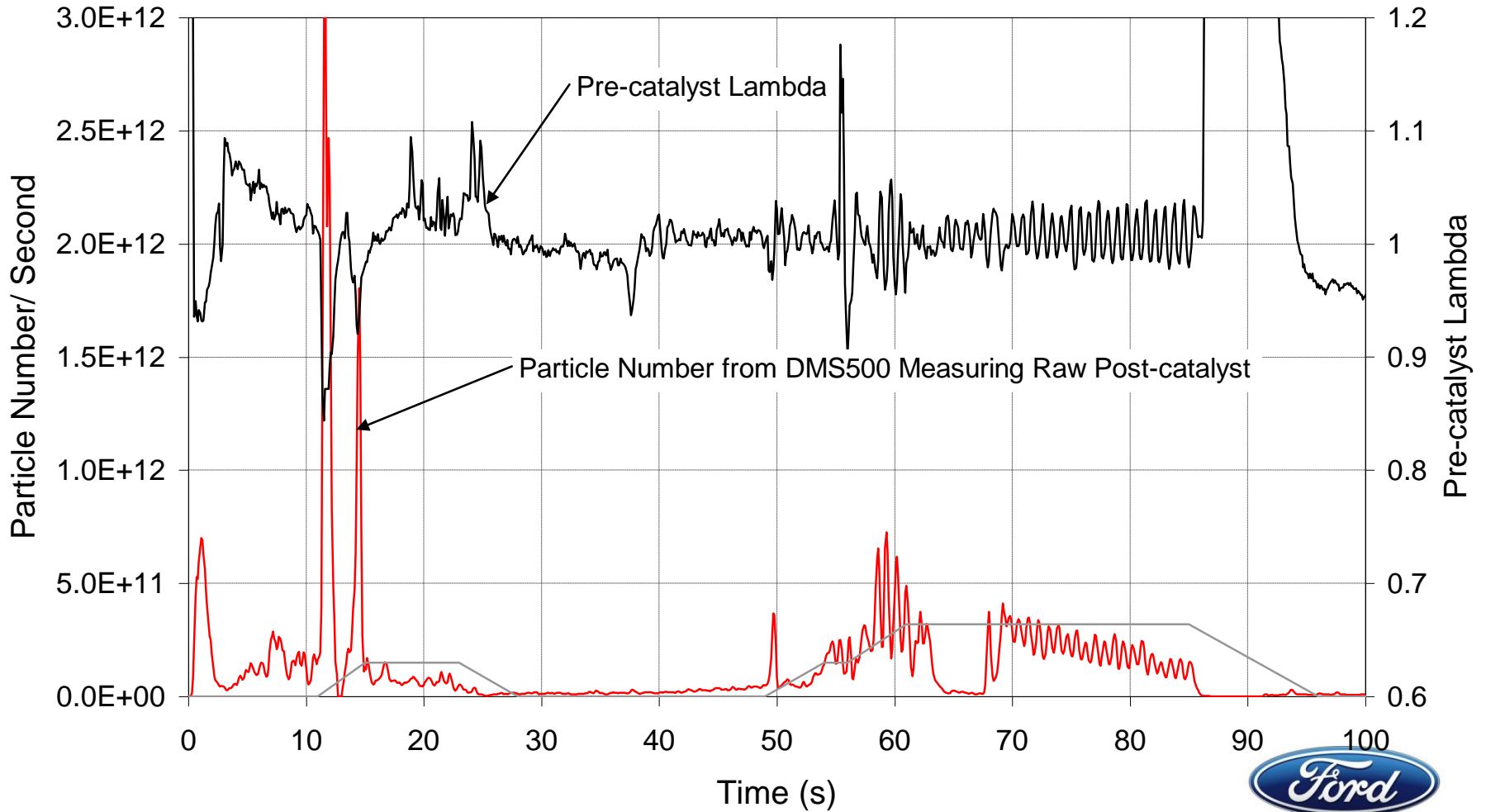
Cold-Start GDI Particles – Measurements in Dilution Tunnel



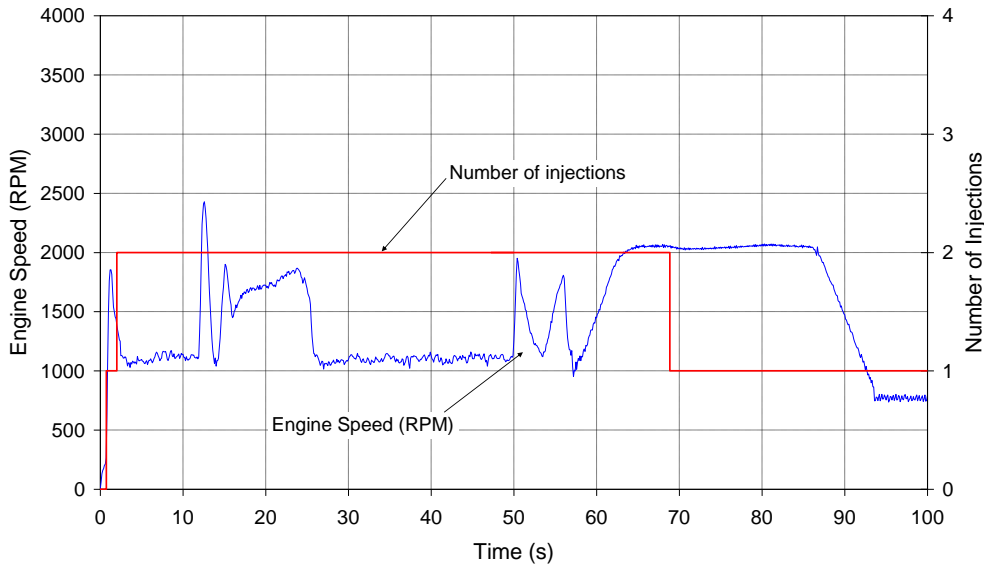
Cold-Start GDI Particles – Raw DMS500 and Dilute PMP Measurements



Cold-Start GDI Particles – Effect of Lambda

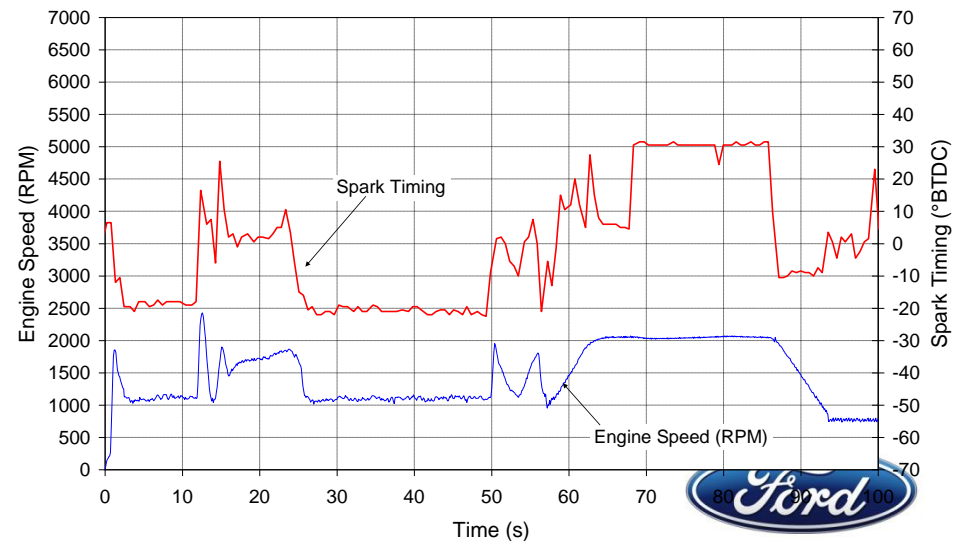


Cold-Start GDI Particles – Effect of Changes in Operating Conditions

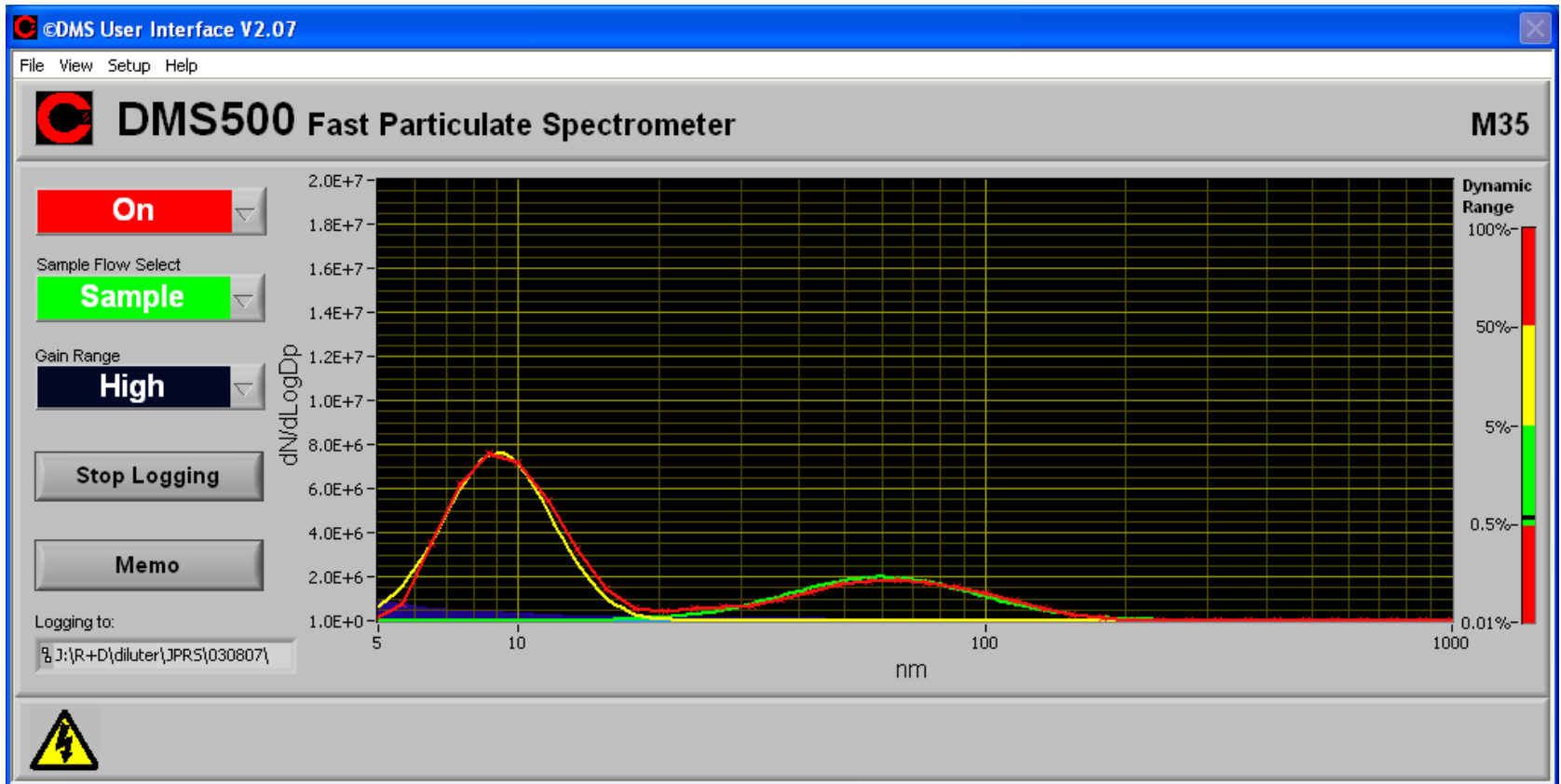


← Number of fuel injection events per cycle and engine speed

Spark timing and engine speed →
(logged from OBD port)



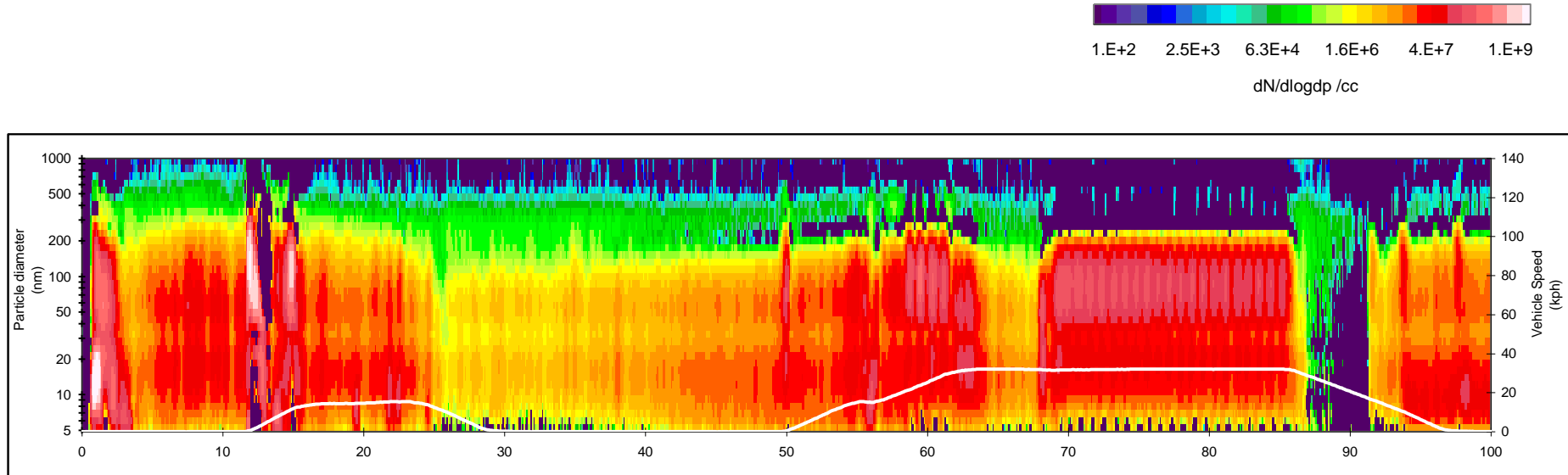
Particle Size Spectra



Nucleation mode – condensation of volatile material
Accumulation mode – solid particles – mainly carbon



Particle Size Distribution – First 100 Seconds of NEDC



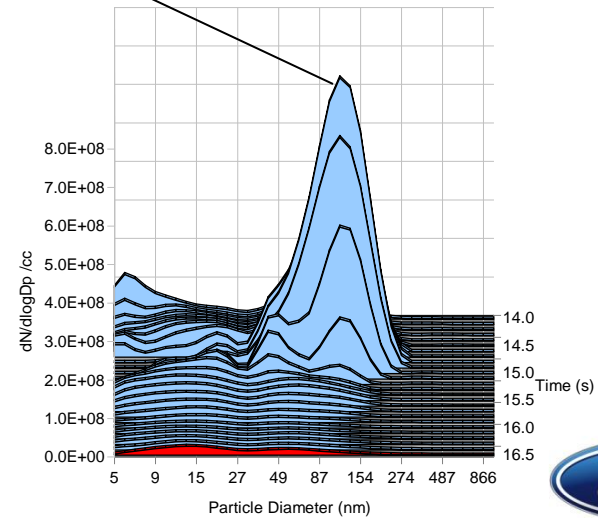
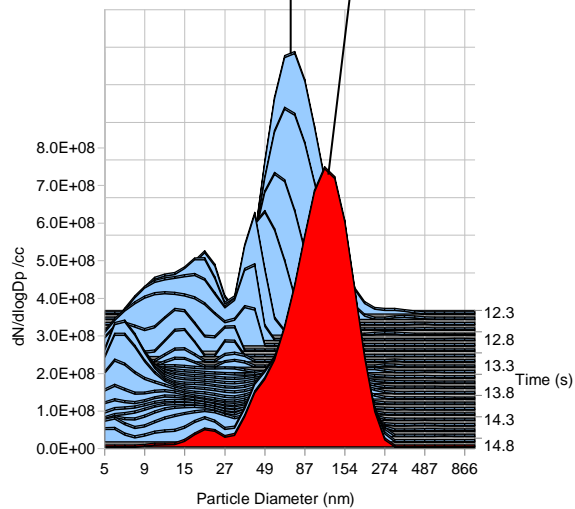
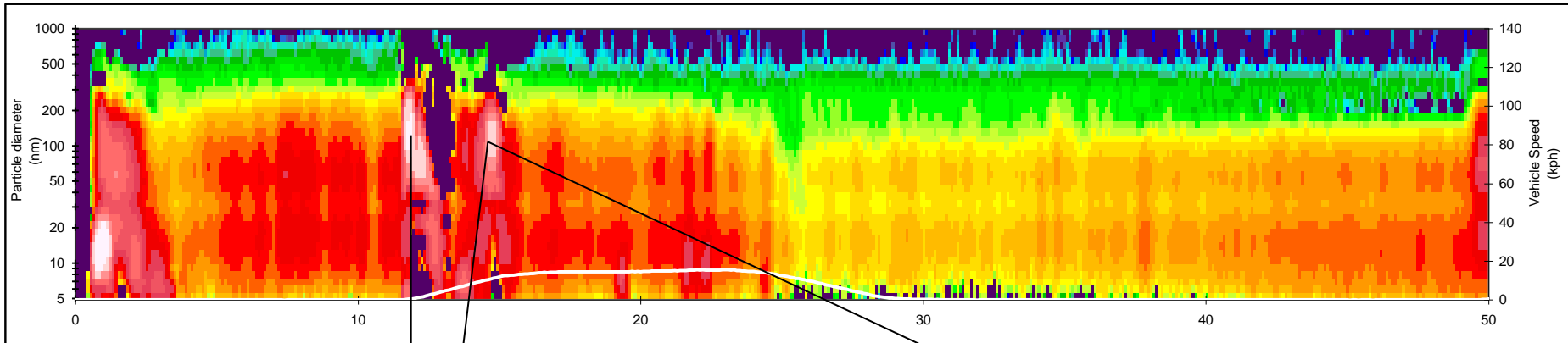
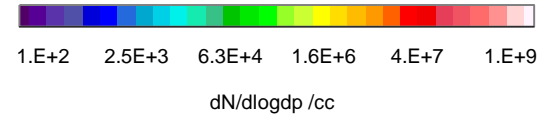
Wide range of particle sizes

Some very large accumulation mode particles

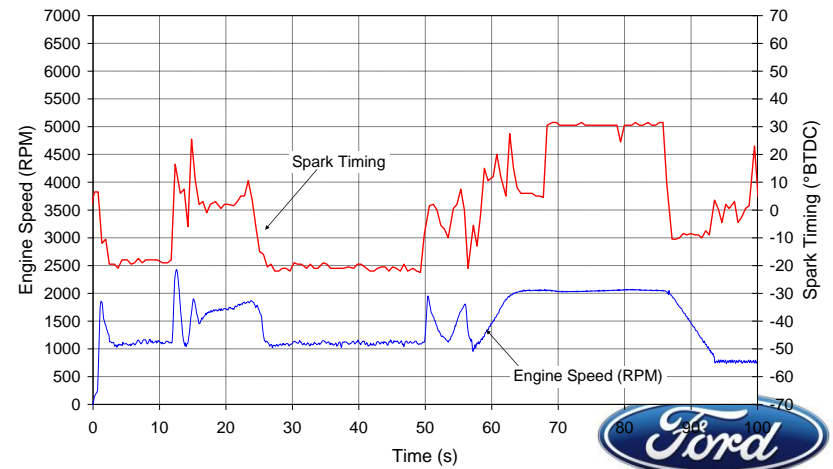
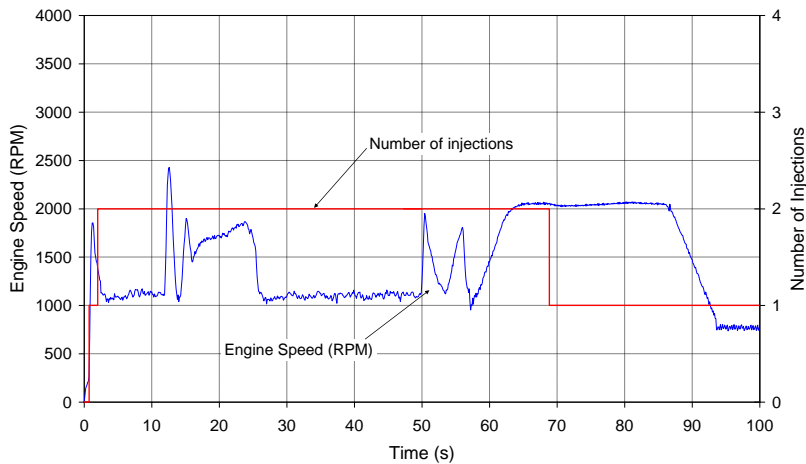
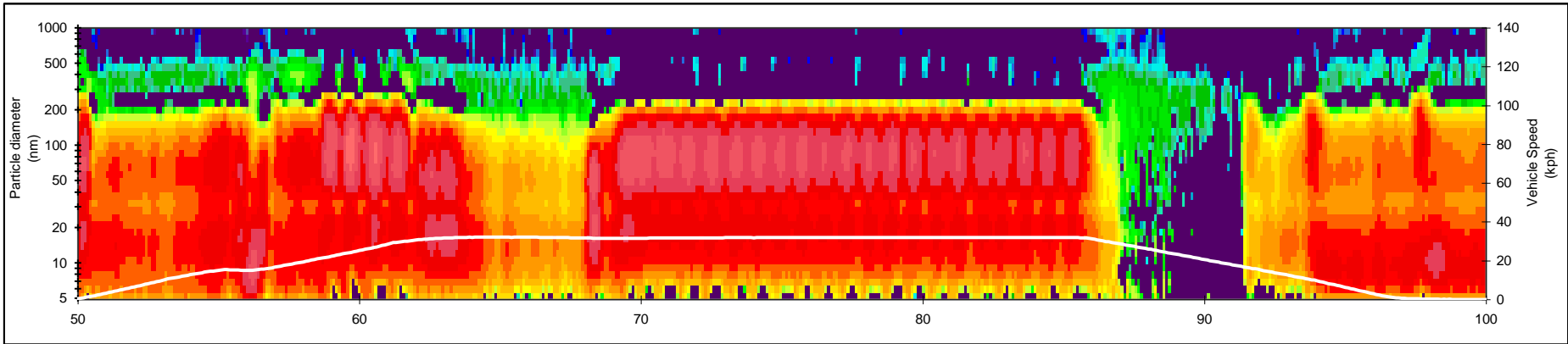
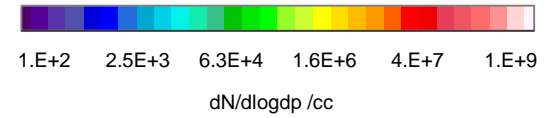
Lots of nucleation mode particles



1st Acceleration



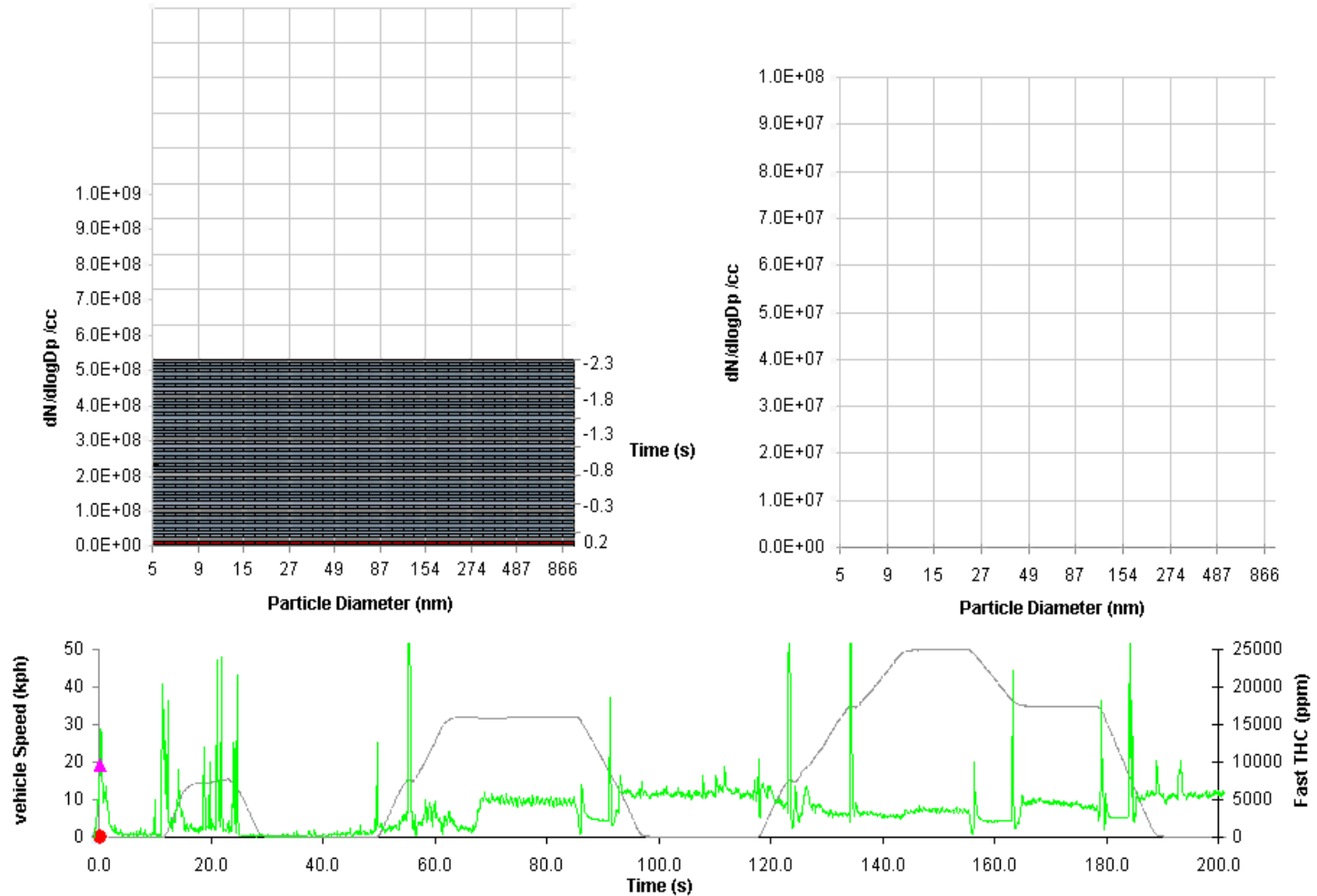
2nd Acceleration



Animation of the Particle Spectra over the 1st 200 Seconds

Note: animation plays in separate media file which is not available to download

DMS Dynamic Particle Spectrum



Summary

Overall particle number emissions from this GDI vehicle are $\sim 2 \times 10^{12}$ particles/km on the New European Driving Cycle.

There is a strong impact of the cold start on particle number:

- There may be some impact of the catalyst heating strategy on particle number – positive or negative.
- There is evidence of a longer term effect – probably related to engine temperatures.

There are very abrupt short-lived transients in particle emissions:

- These transients contribute significantly to overall particle numbers.
- It is not clear what causes these, some correlation with Lambda is clear, but there are interactions with other parameters (# of fuel injections/cycle, spark timing etc).

There are a wide range of particle sizes seen during the cold-start period – excluding the nucleation mode:

- Some very large particles are seen during transients – circa 150nm CMD.
- Often smaller particles are seen – circa 50nm CMD.
- At times both of these “modes” are seen simultaneously.



Thank you for listening

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