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Particulate Matter Emissions from a Highly Boosted GDI engine

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Outline

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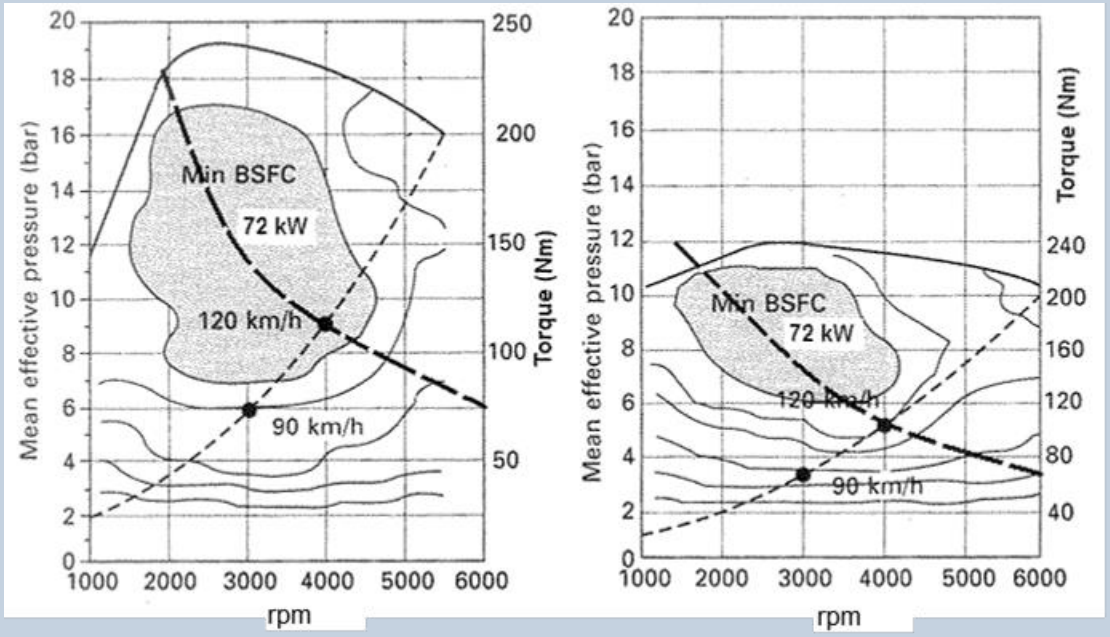
- DMS – PN measurement
- Results
  - Load
  - Fuel injection pressure
  - EGR
  - Inlet air temperature
  - Exhaust back pressure
  - Lambda
  - Fuel injection timing
- Conclusions

Boosted engines

Stone, Introduction to Internal Combustion Engines, 4th Ed. 2012



Boosted 1.6L NA 2.5L

- Highly boosted engines move road load operating points to a more efficient part of the engine map

Boosted engines

- Bugatti Chiron
- 8.0L engine
- quad-turbocharged (2x parallel sequential)

- Mercedes-AMG A45
- Mercedes M133 AMG 2.0 L
- Single turbocharger

Boosted engines

- Bugatti Chiron
- 8.0L engine
- quad-turbocharged (2x parallel sequential)
- 25.1 bar BMEP

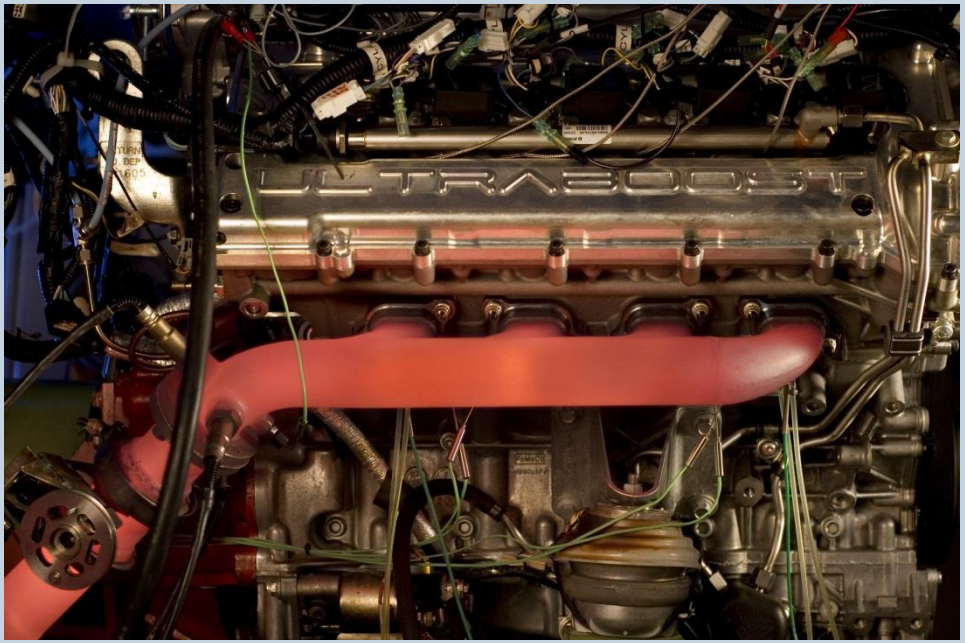
- Mercedes-AMG A45
- Mercedes M133 AMG 2.0 L
- Single turbocharger
- 28.3 bar BMEP

PN from boosted engines

- Higher cylinder Ts & Ps
  - Greater post-flame oxidation?
- Higher exhaust backpressures
  - Higher residuals? Better mixture formation
- Higher exhaust temperatures
  - Greater post-flame oxidation?

ULTRABOOST

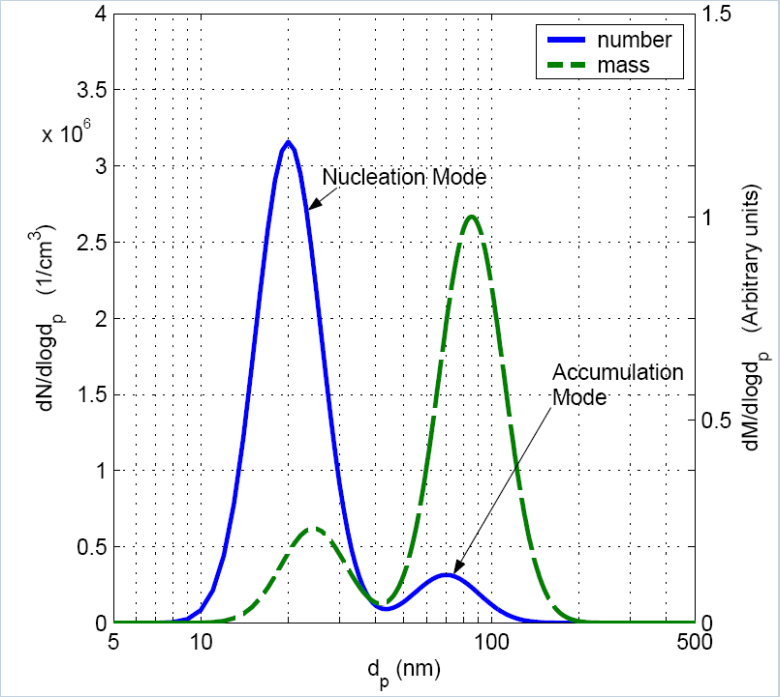
- Highly-boosted, heavily-downsized engine
  - torque curve and power output of the NA Jaguar Land Rover AJ133 5.0 L V8 engine
- 35% improvement in fuel economy / CO_2 target
- 60% downsizing (2.0 litre i4)
- Driveability of the original V8 to be maintained
- Operation on 95 RON pump gasoline

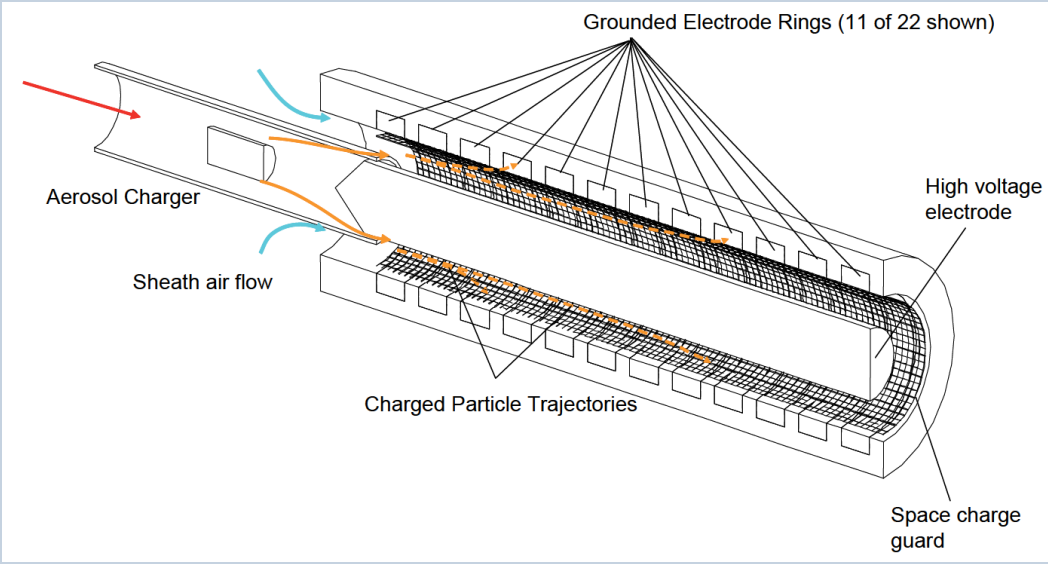


Type	**Inline 4 cylinder**
Bore × Stroke	**83 × 92 mm**
Displacement	**1991 cm^3**
Valves per cylinder	**2 intake, 2 exhaust**
Compression ratio	**9:1**
Maximum fuel pressure	**200 bar**
Peak BMEP	**35 bar**
Peak cylinder pressure	**150 bar**

Particulate Matter measurements

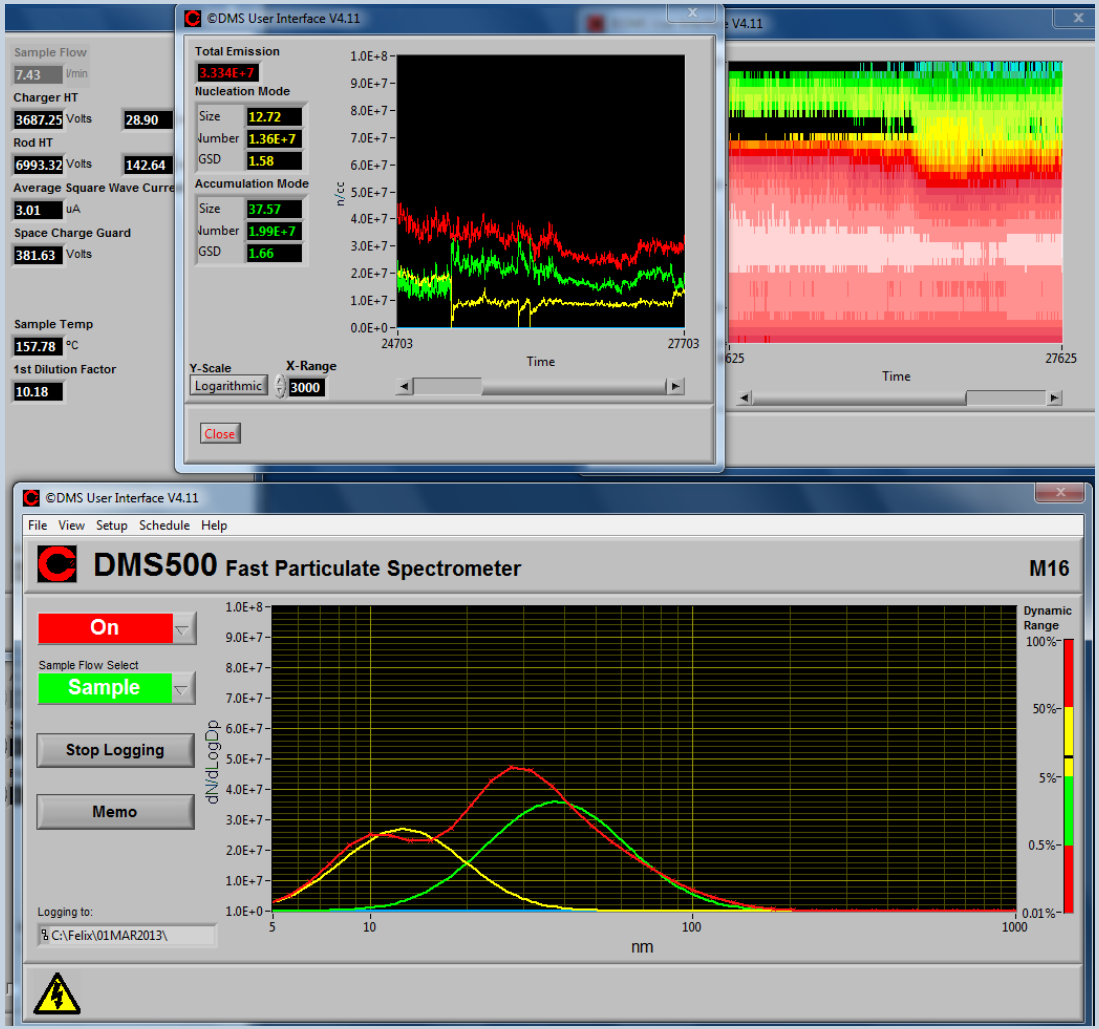
Cambustion DMS500





Reavell et al. SAE 2002-01-2714

DMS mode fitting

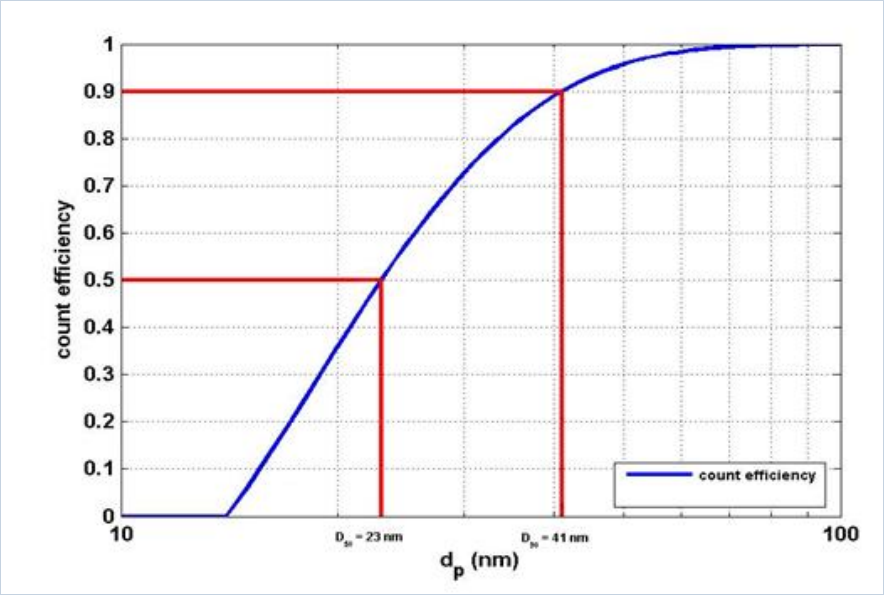


Digital filtering of low diameter PN

To replicate PMP measurement protocol

50% count efficiency: D50 = 23 nm

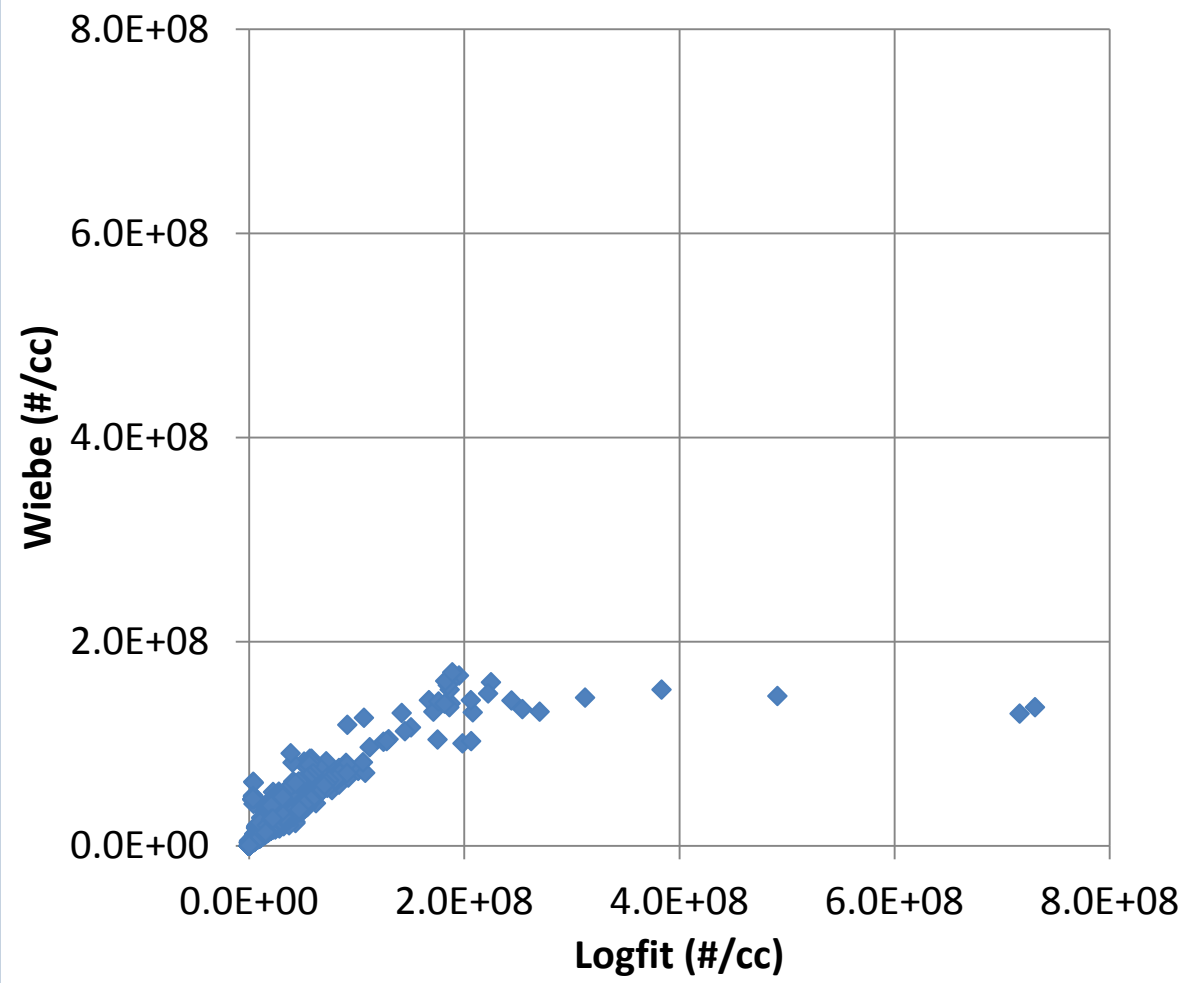
>90% count efficiency: D90 = 41 nm



Wiebe function: $f = 1 - \exp\left[-3.54\left(\frac{d_p - 14}{40}\right)^{1.09}\right]$

$d_p > 14$

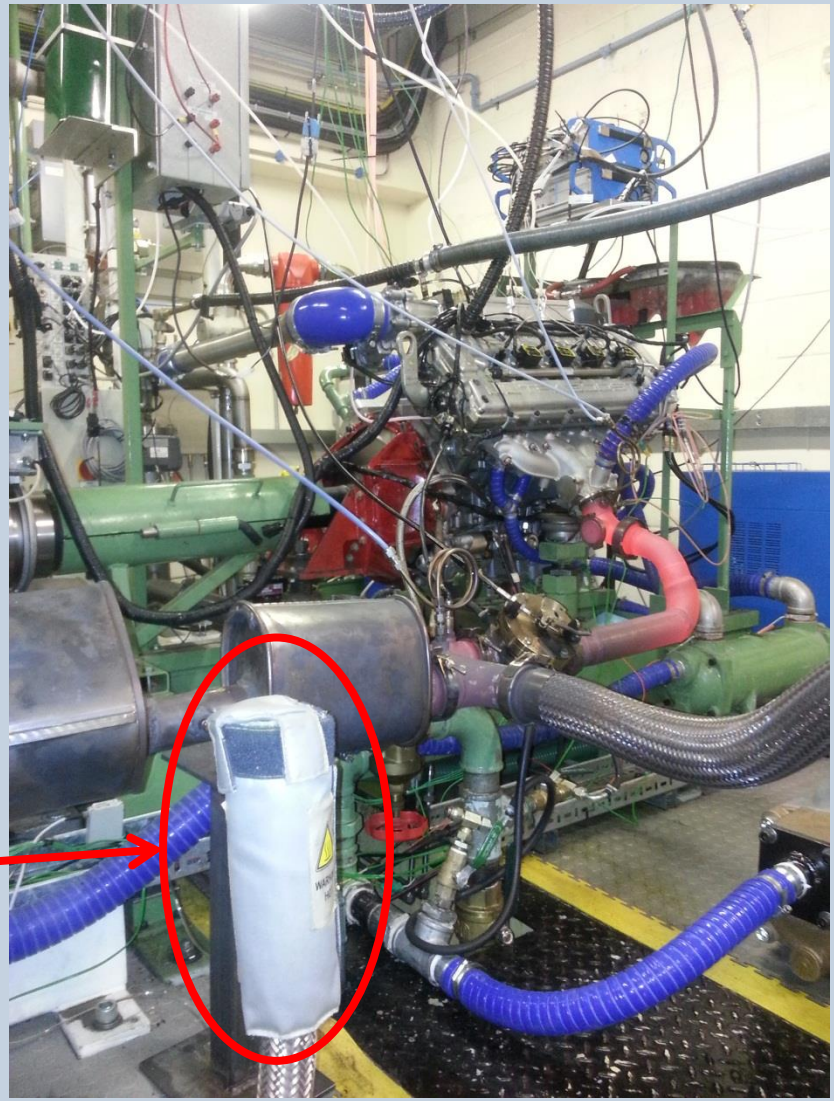
Effect of Wiebe filtering



Sampling location

- Approx 3m downstream of exhaust manifold
- Water cooled exhaust manifold
- Downstream of backpressure throttle and one silencer
- No catalyst

Sampling location

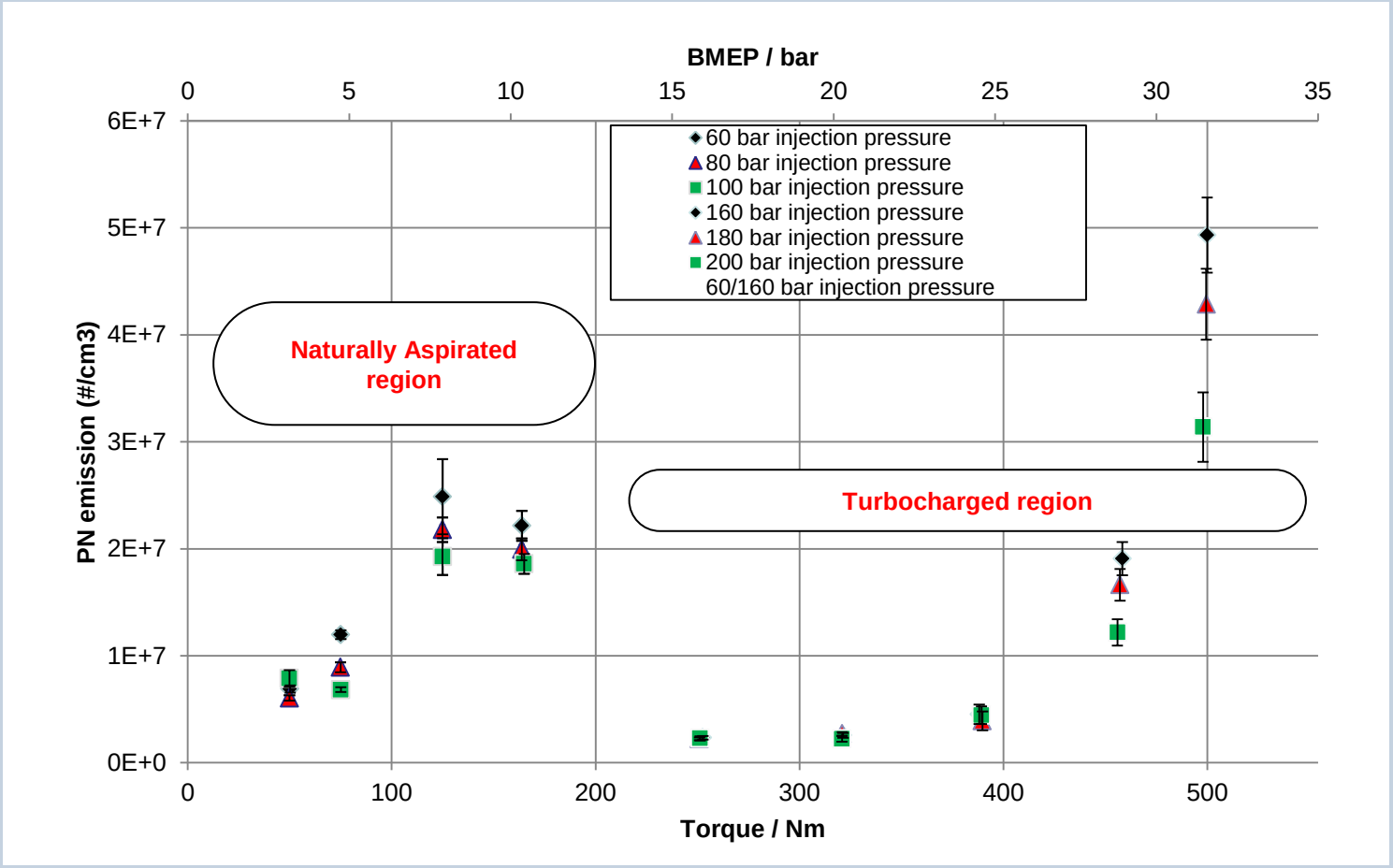


Results – load ramp

- PN measured from ~50 – 500 Nm load (~3 - 32 bar BMEP)
  - Fixed engine speed (2000 rpm)
  - 9 steps
  - 3 injection pressures
- Naturally aspirated and turbocharged regions
- Change in calibration between two regions
- All tests conducted on a baseline gasoline (97 RON, EN228)

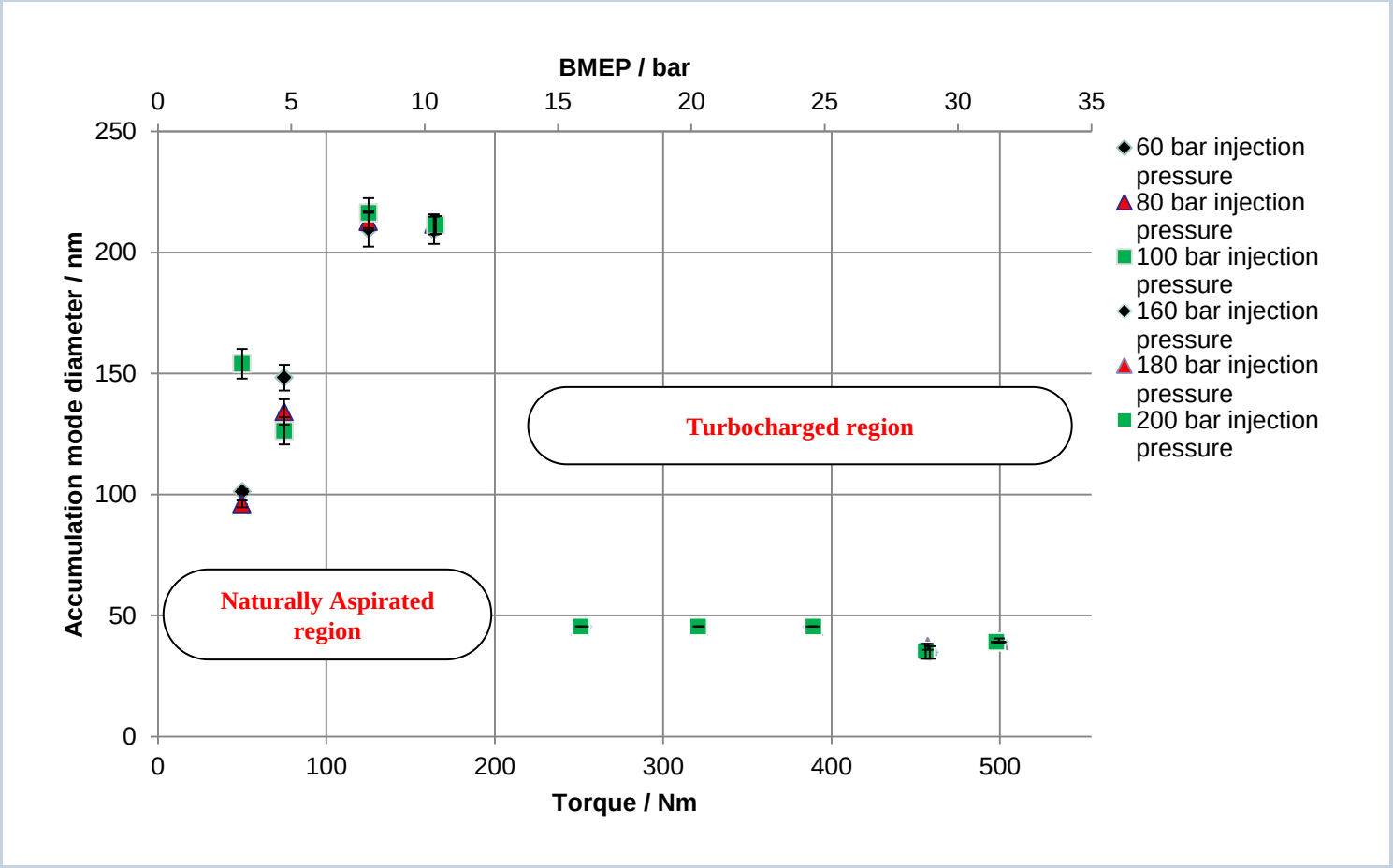
Results – load ramp

- Particle Number

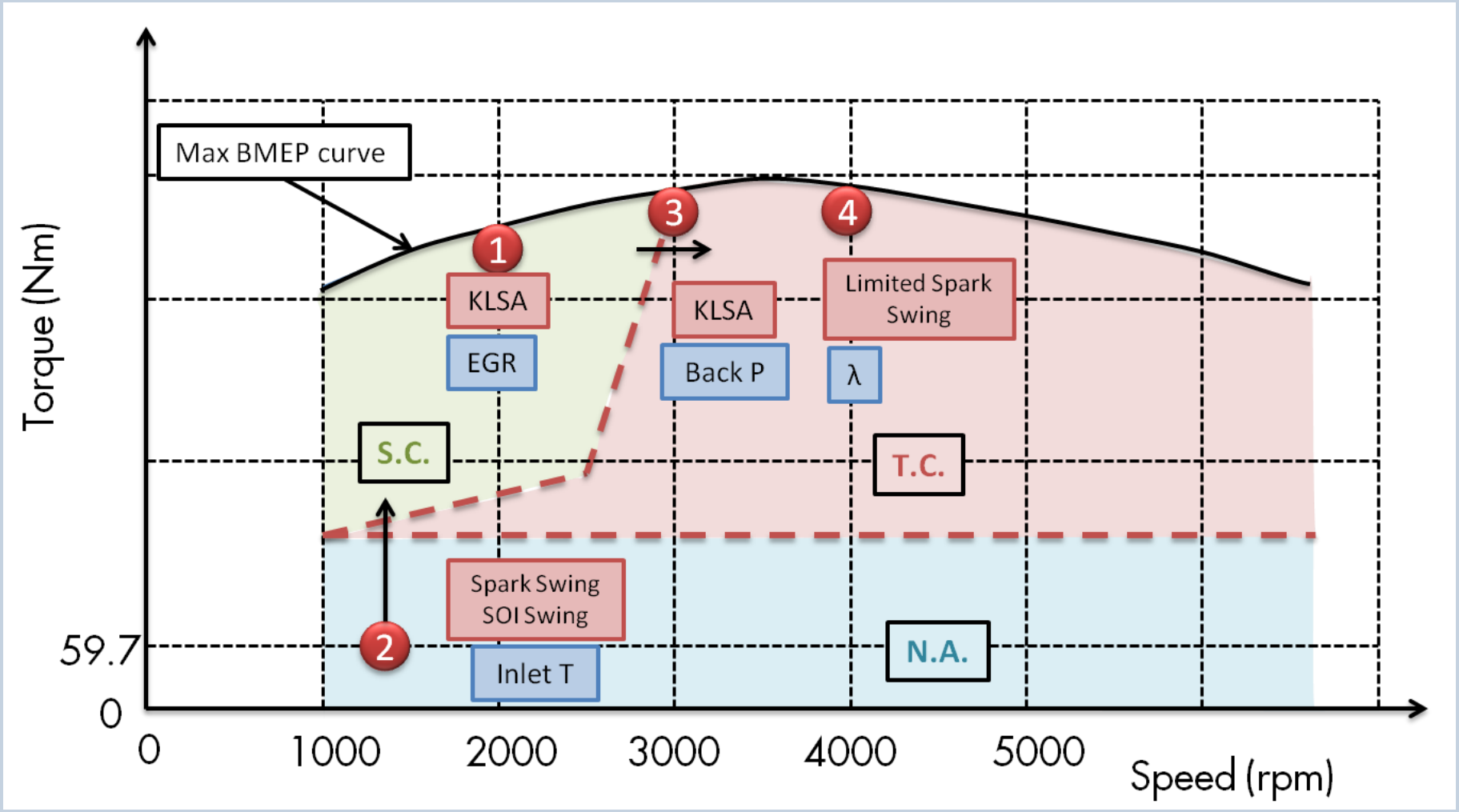


Results – load ramp

- Particle size

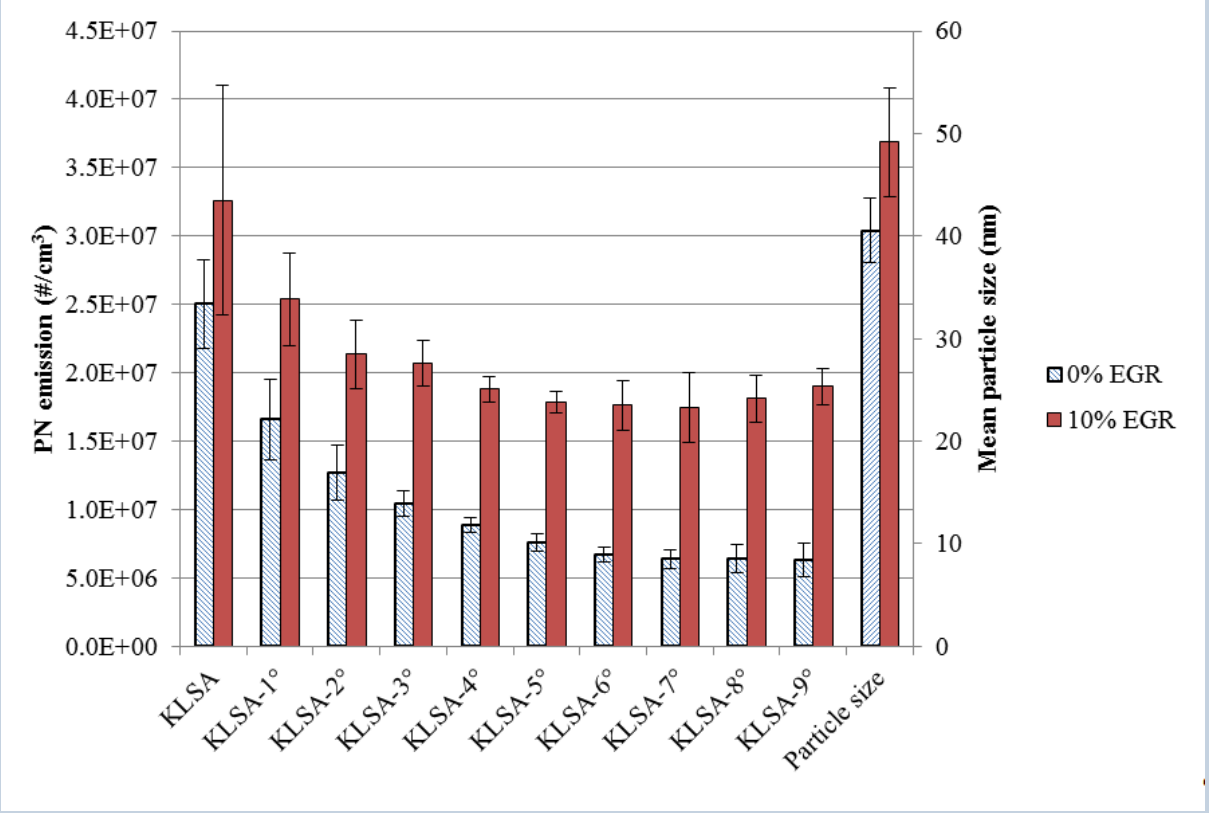


Test points


Max BMEP curve
1
KLSA
EGR
2
S.C.
Spark Swing
SOI Swing
Inlet T
3
KLSA
Back P
4
Limited Spark
Swing
λ
T.C.
N.A.
Torque (Nm)
59.7
0
0
1000
2000
3000
4000
5000
Speed (rpm)

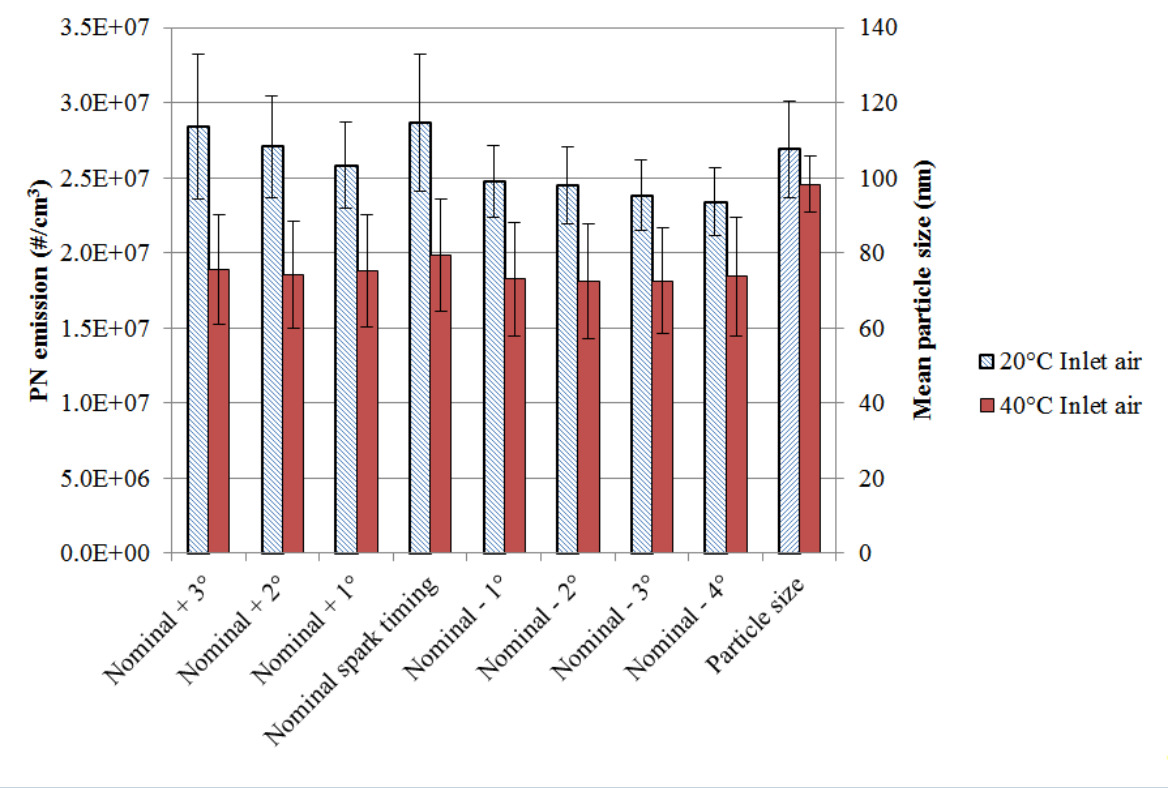
Results - EGR

- 2000rpm – full load



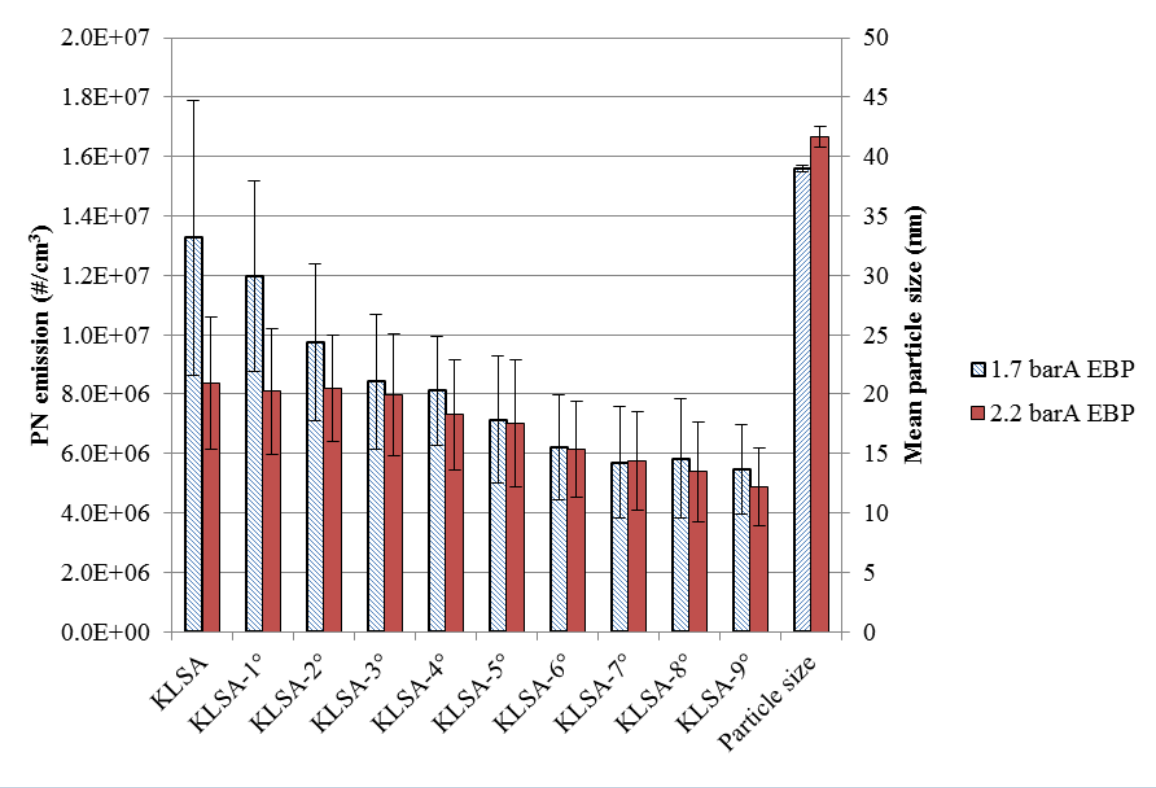
Results – Inlet air T

- 1250rpm / 3.77 bar BMEP



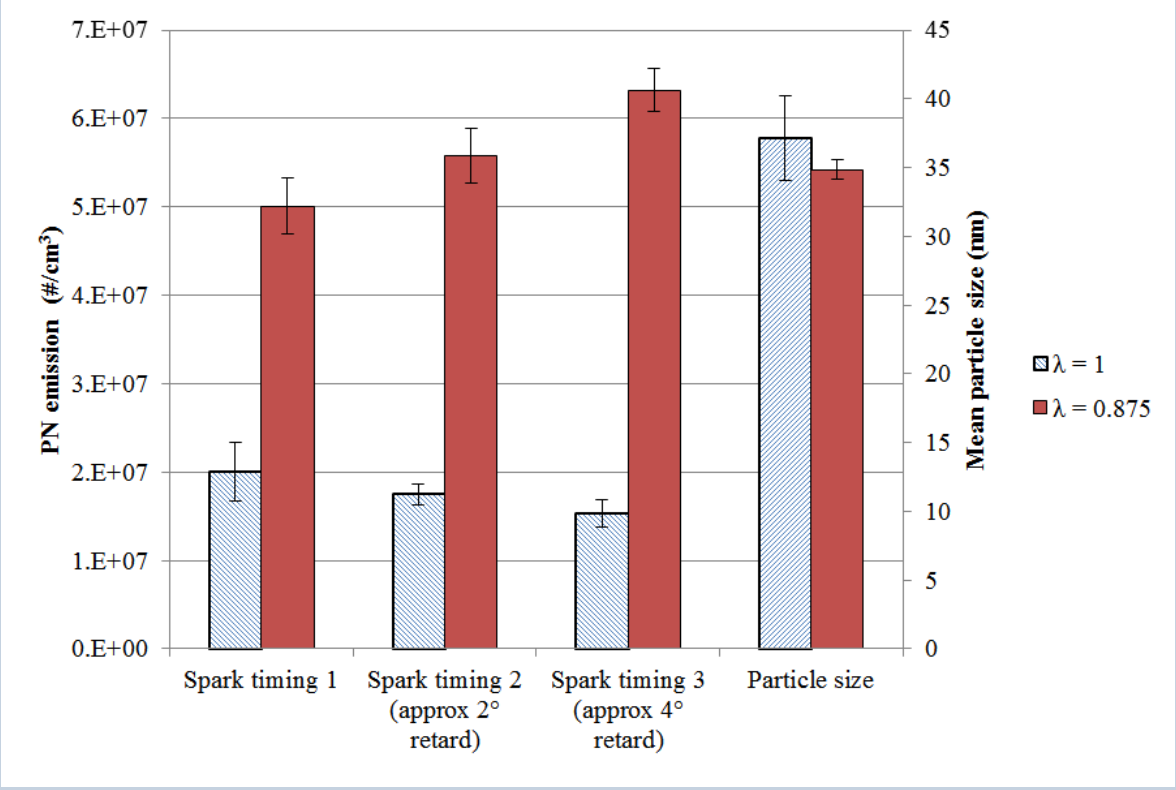
Results – Exhaust Back Pressure

- 3000rpm – full load



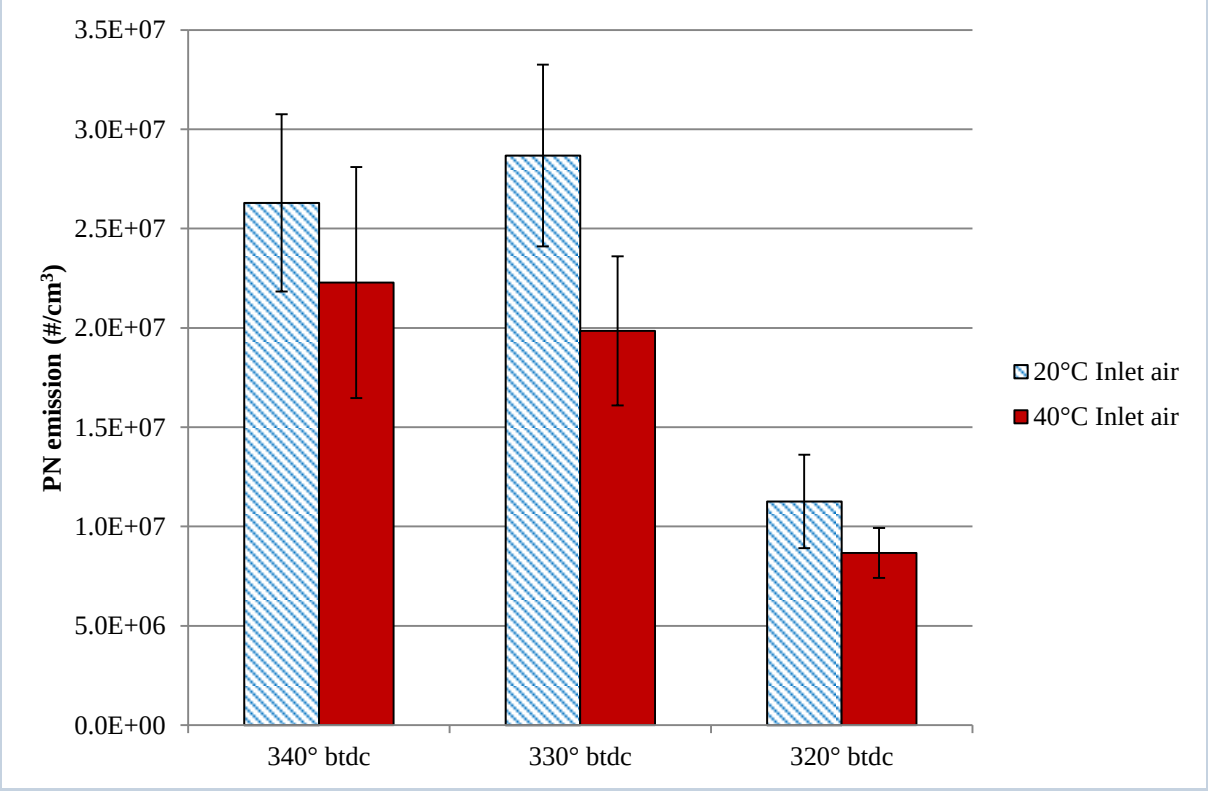
Results – Lambda

- 4000rpm – full load



Results – Fuel injection timing

- 1250rpm / 3.77 bar BMEP



Conclusions

Variable	Effect on PN emissions
Engine load	Load ↑ Particulates ↑
Fuel injection pressure	P ↑ Particulates ↓
EGR	EGR ↑ Particulates ↑
Inlet air temperature	T ↑ Particulates ↓
Exhaust back pressure	Back pressure ↑ Particulates ↓
λ (AFR)	λ ↓ Particulates ↑
Spark timing	Ignition ← Particulates ↓
Fuel injection timing	Injection → Particulates ↓

Reference:

Leach *et al*. “Particulate emissions from a highly boosted GDI engine” International Journal of Engine Research 2017

ULTRABOOST consortium

ULTRABOOST

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Any questions?