LUND UNIVERSITY

Similarities between soot properties from low temperature combustion in a heavy duty diesel engine and miniCAST flame soot

JOAKIM PAGELS – ERGONOMICS & AEROSOL TECHNOLOGY, LUND UNIVERSITY, SWEDEN

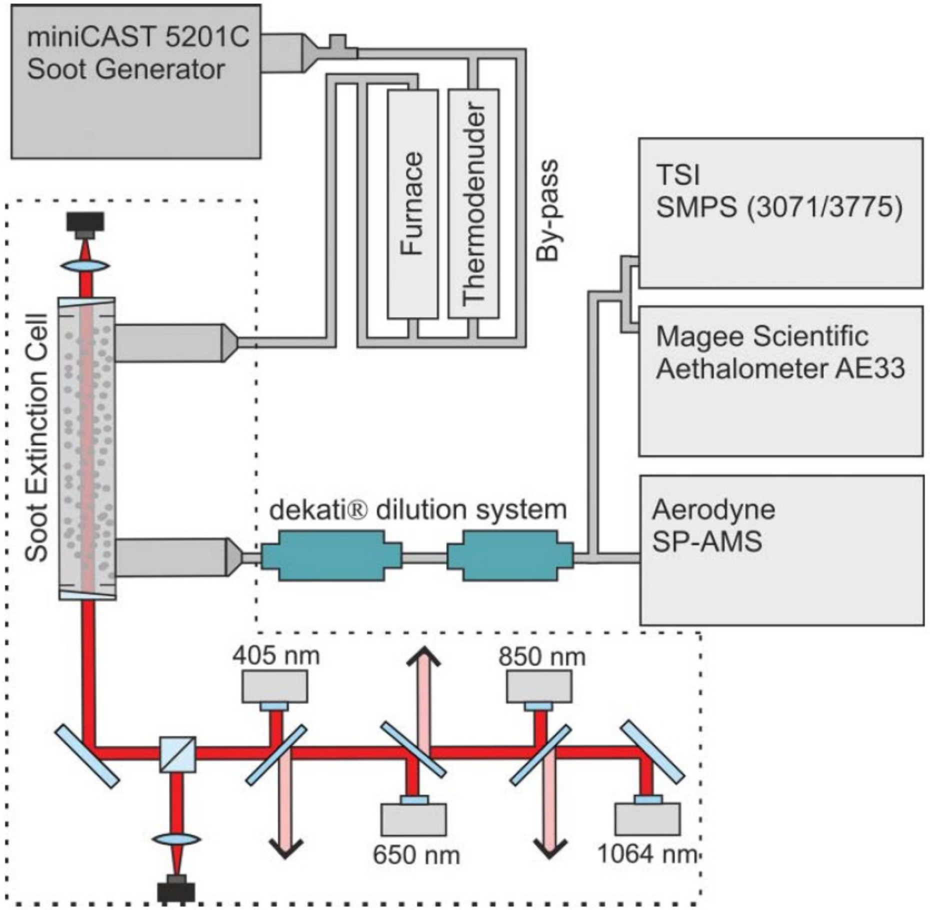
Background

- In-situ optical diagnosis in flames: Immature (young) soot with high Absorption Angstrom Exponent (AAE) early in the flame (e.g. Michelsen et al. 2017)
- Soot generators based on quenched flames can result in ”soot rich in organic carbon” (e.g. Maricq et al. 2014, AS&T)
- High AAE in biomass combustion emissions is caused by: ”extremely low volatility organic aerosol” (Saleh et al. 2014, Science)
- Ship emissions from heavy fuel oil consist of insoluble tar components with high AAE (Corbin et al. 2018 JGR)

Aims:

- Investigate optical, chemical and structural properties of emissions from:
  - Paricle emissions from a quenched diffusion flames (mini-CAST)
    - Varied N_2 dilution of fuel flow and air to fuel ratio
  - Low temperature combustion in HD diesel engine
    - From no to very high EGR)
  - Particles extracted from inside the cylinder during the diesel combustion process
    - Variations from soot formation to soot oxidation phase

Methods – Mini CAST emissions

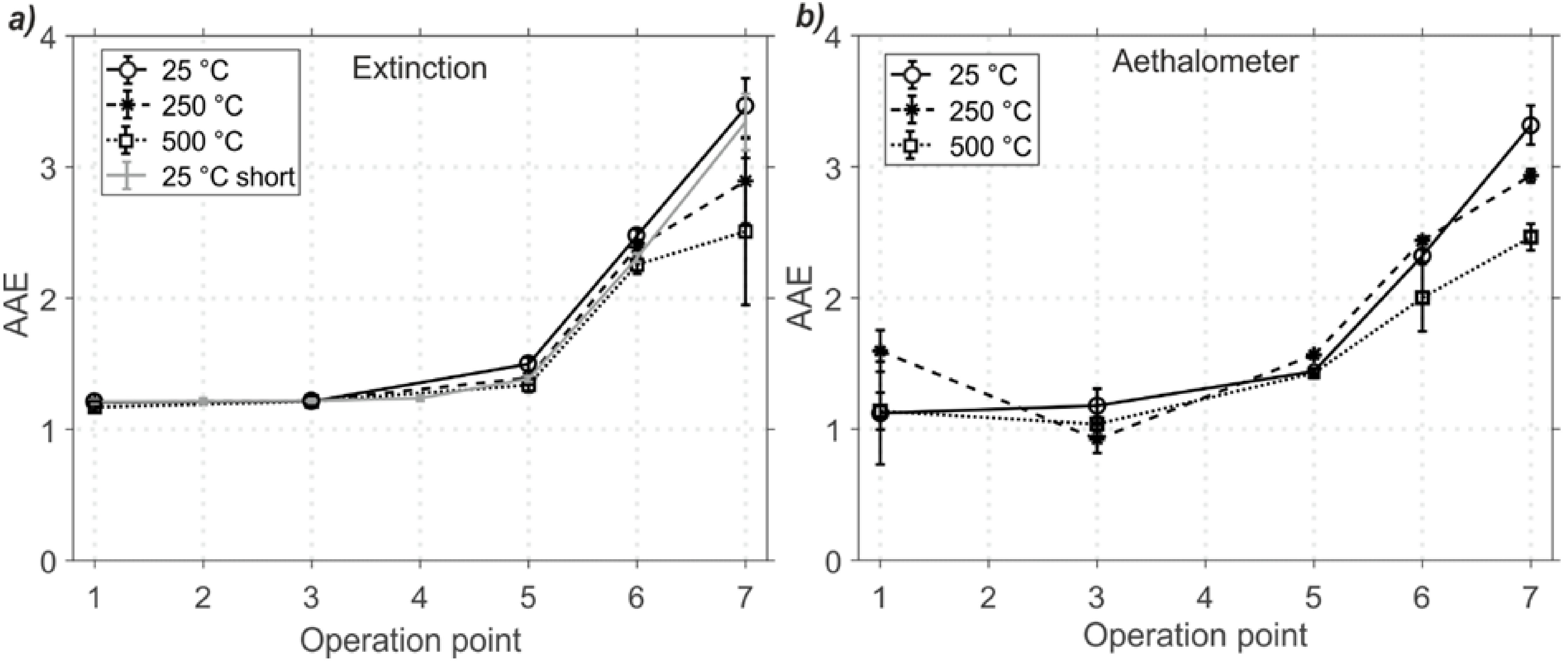


- Thermal optical analysis (OC/EC) using EUSAAR_2 protocol
- AAE and eBC from Aethalometer and in-situ Extinction cell
- Aerodyne SP-AMS (1064 nm IR Vaporisation)
  - Laser off: Quantification of particulate PAHs (202 - 302 Th, Malmborg et al. 2017)
  - Laser on: Carbon cluster distribution from soot cores

OP	Propane (L min^{-1})	Air-oxid (L min^{-1})	N_2-mix (L min^{-1})	N_2-quench (L min^{-1})	Air-dil (L min^{-1})
1	0.06	1.55	0	7	0
3	0.06	1.52	0.100	7	0
5	0.06	1.47	0.200	7	0
6	0.06	1.42	0.250	7	0
7	0.06	1.36	0.300	7	0

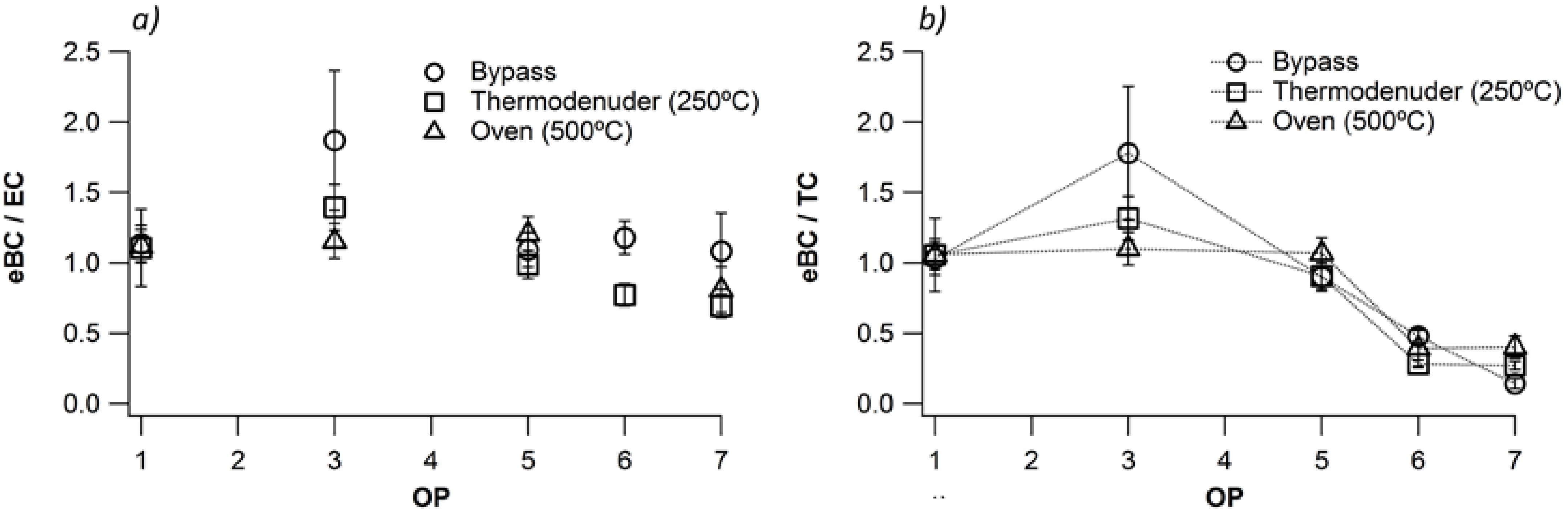
Török et al. 2018 AS&T

Wavelength dependent absorption



Török et al. 2018 AS&T

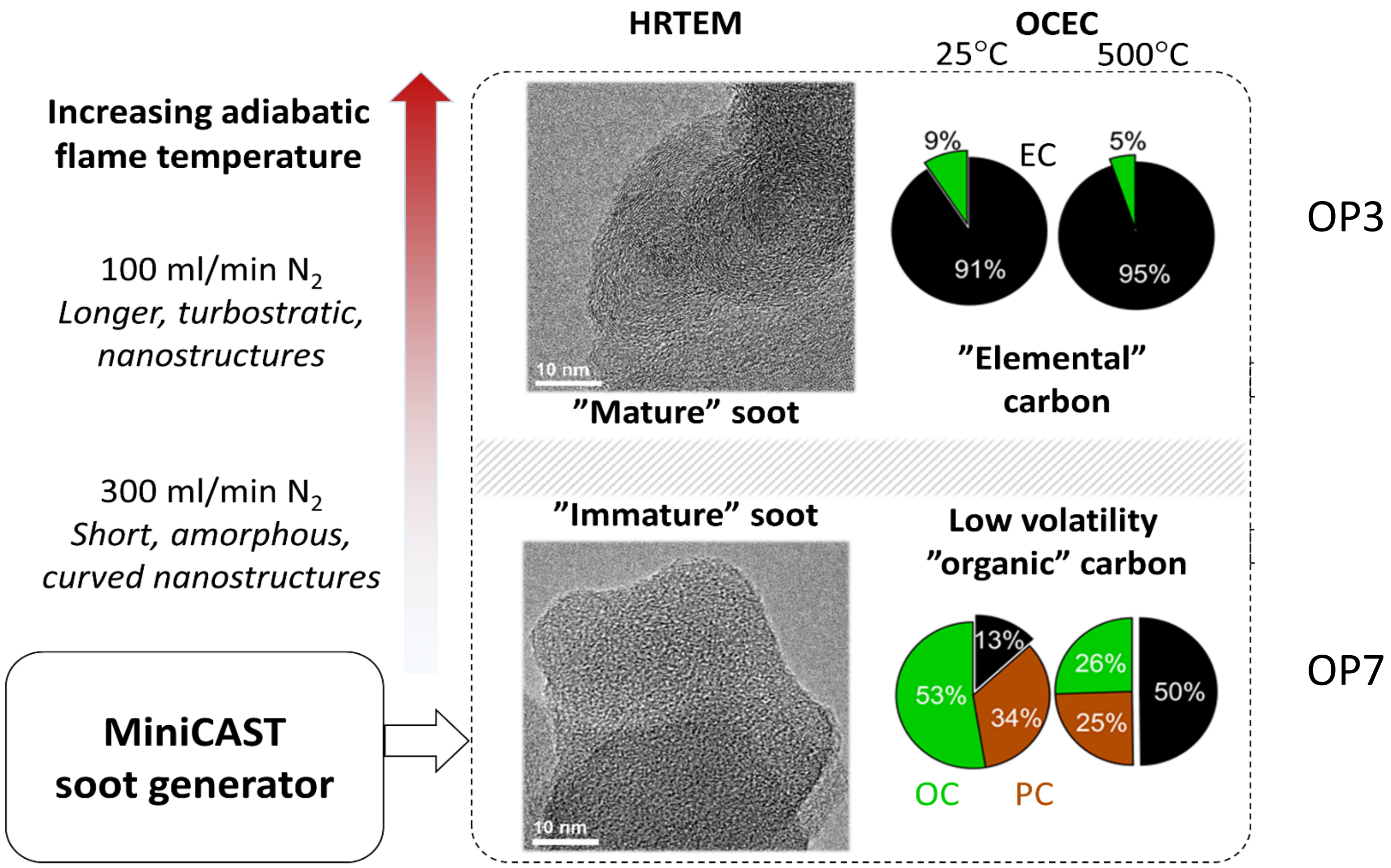
BC fractions depends on what reference mass is chosen



- Also has implications when calculating Mass Absorption Cross Sections

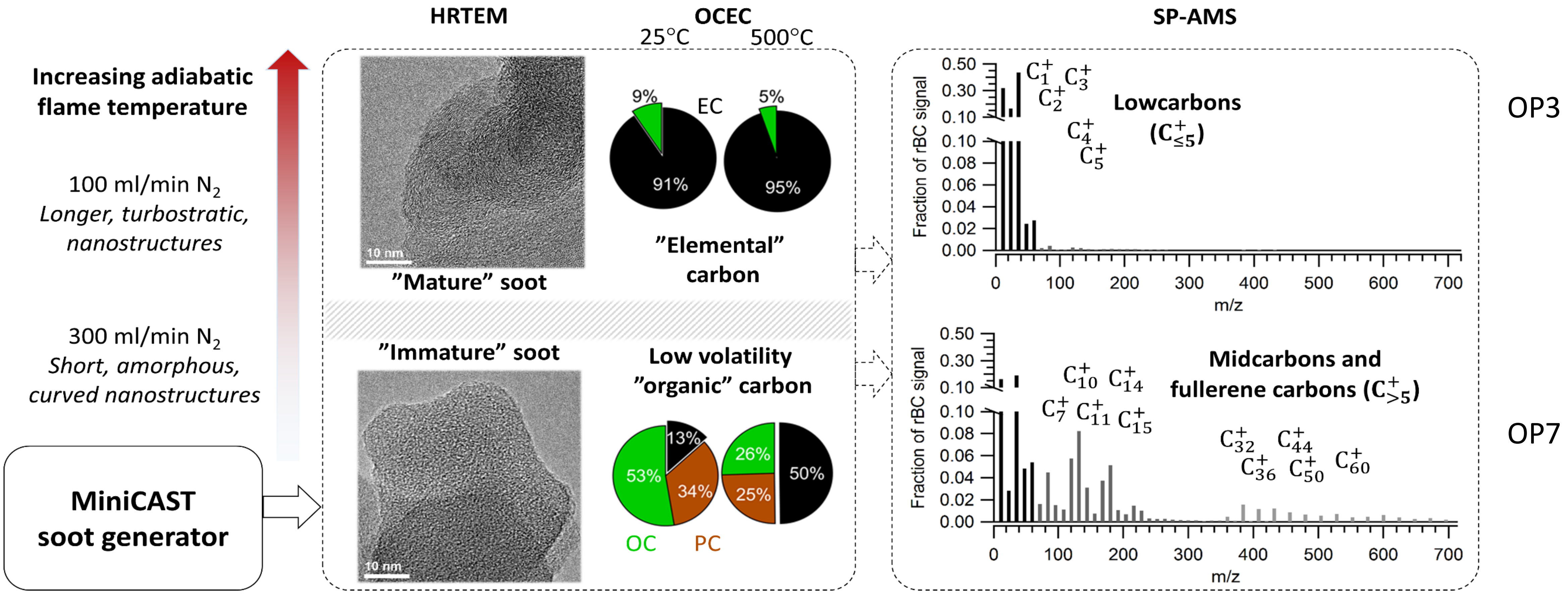
Török et al. 2018 AS&T

Changes in Particle Composition



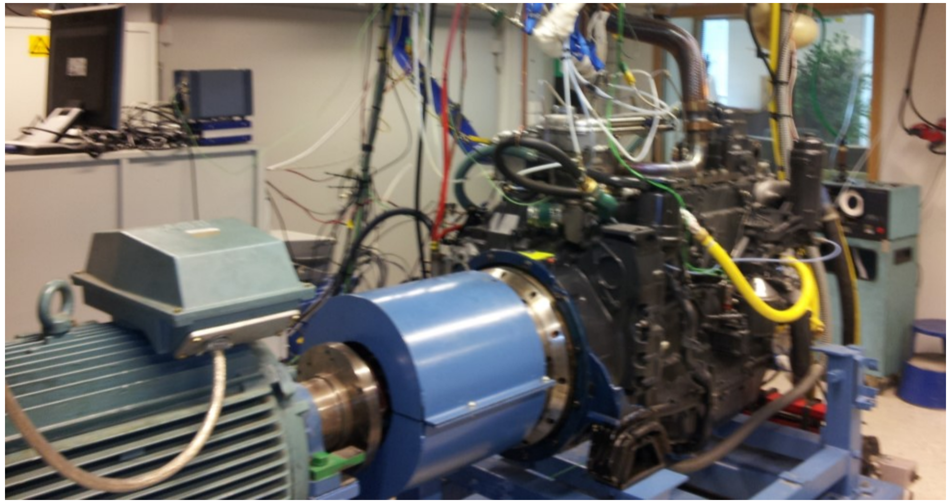
Malmborg et al. 2018 Submitted

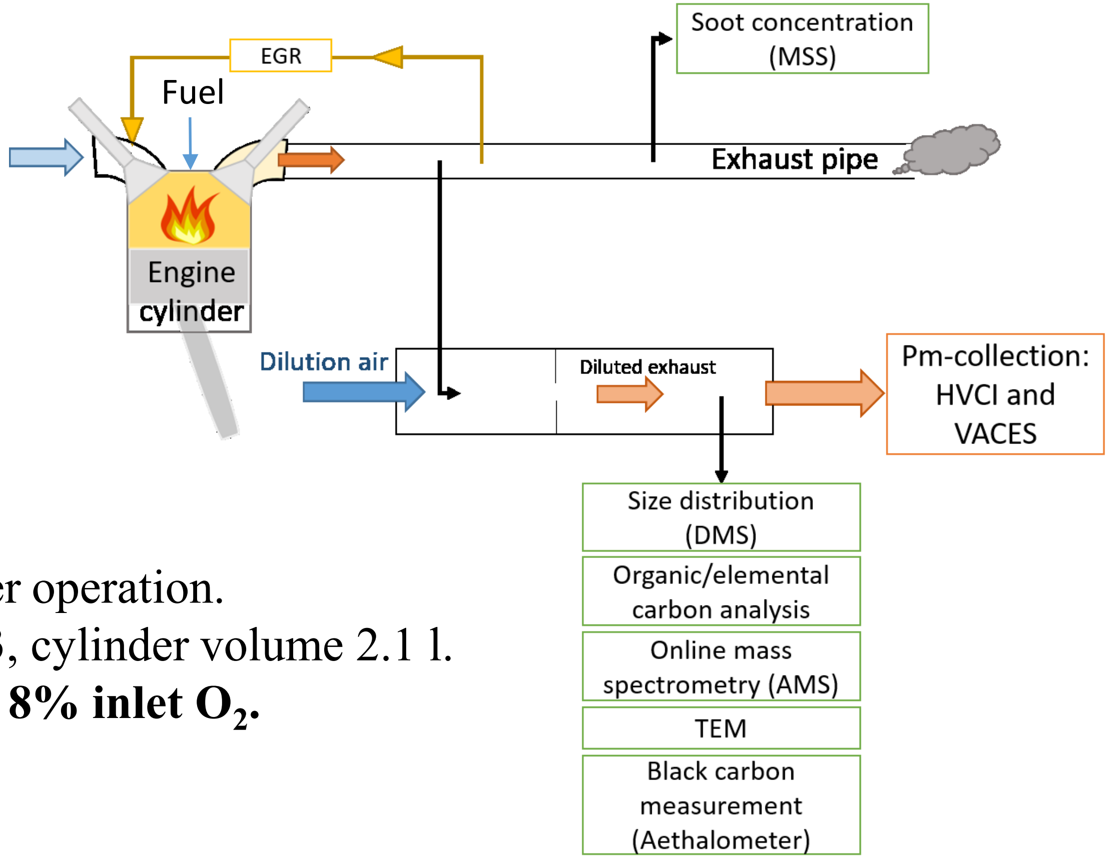
Changes in Particle Composition



Malmborg et al. 2018 Submitted

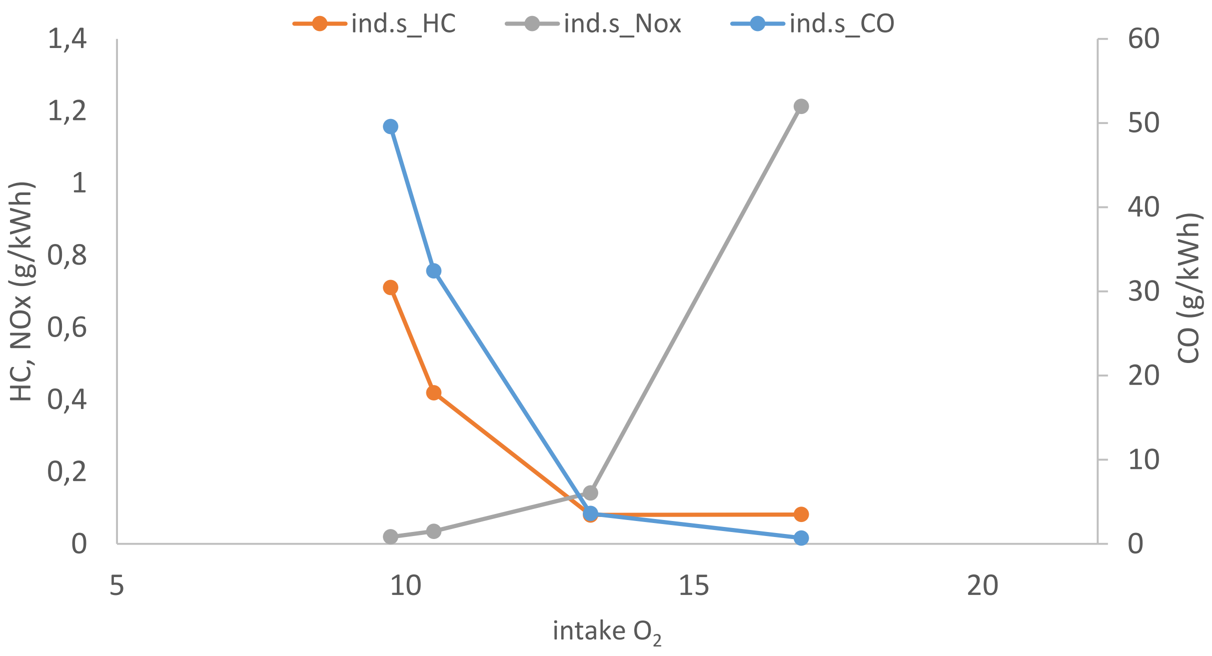
Low Temperature Combustion in HD Diesel Engine - Methods

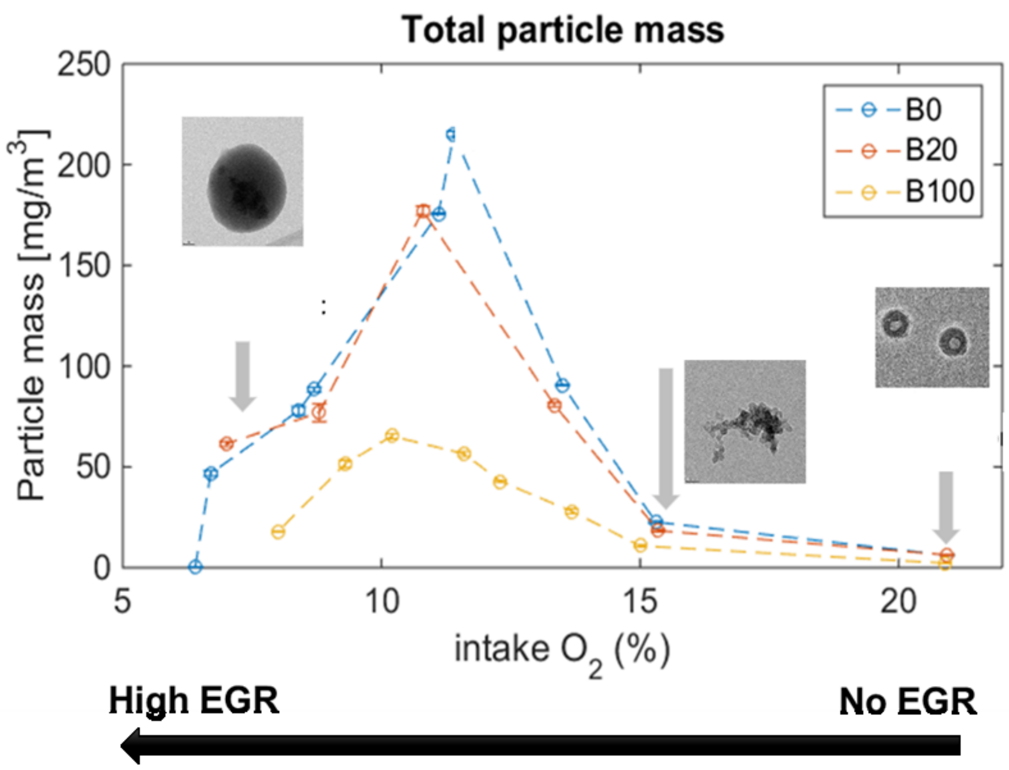




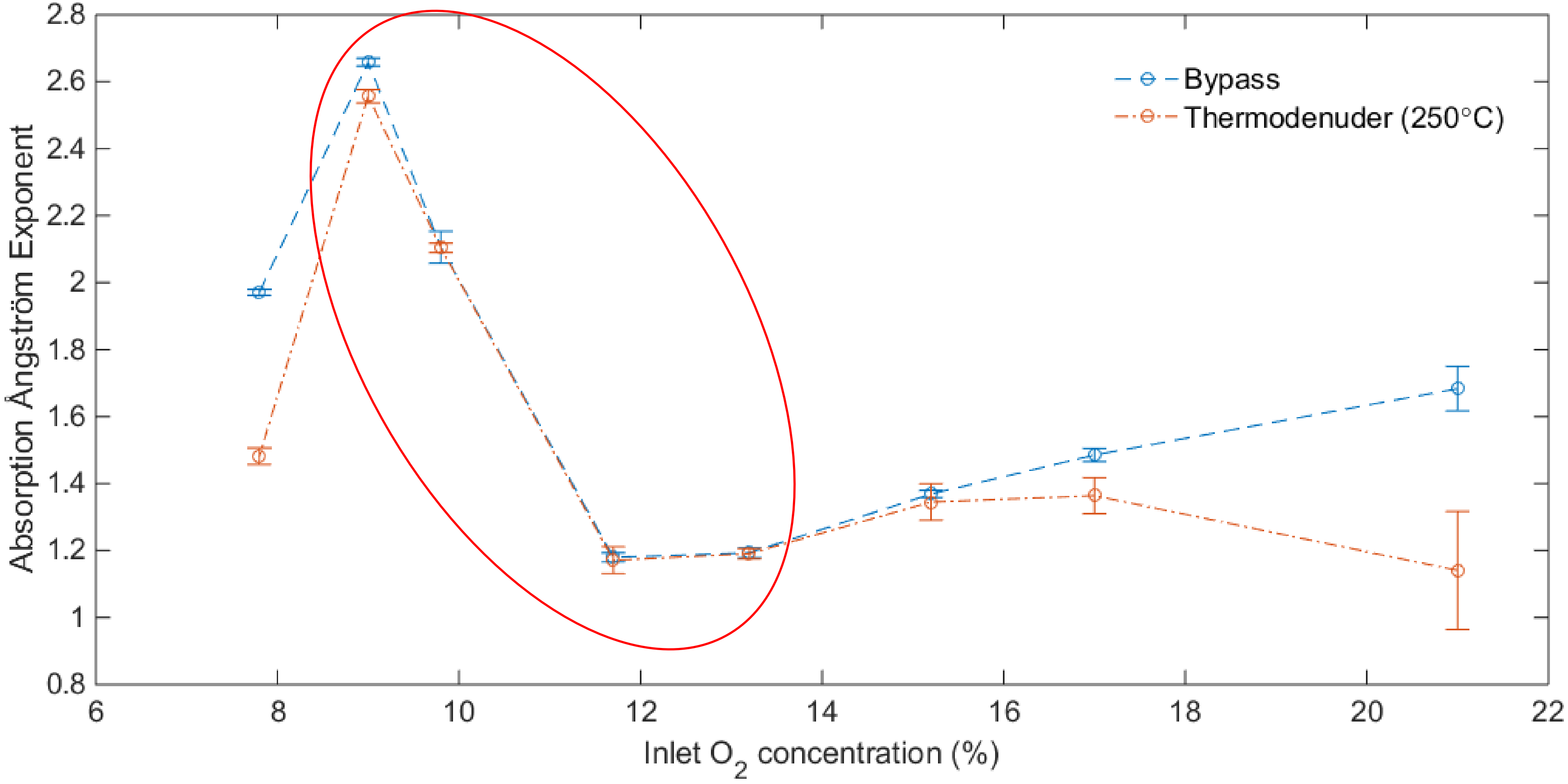
- Scania Heavy-Duty D13 engine modified to 1 cylinder operation.
- Bore 130 mm, stroke 160 mm, compression ratio 17.3, cylinder volume 2.1 l.
- **Exhaust gas recirculation (EGR) sweep from 21 to 8% inlet O_2.**
- Fuels: MK1 Diesel, HVO, RME
- No after treatment
- Low load: 6 Bar IMEP (~20%)

Influence of EGR on Emission Levels

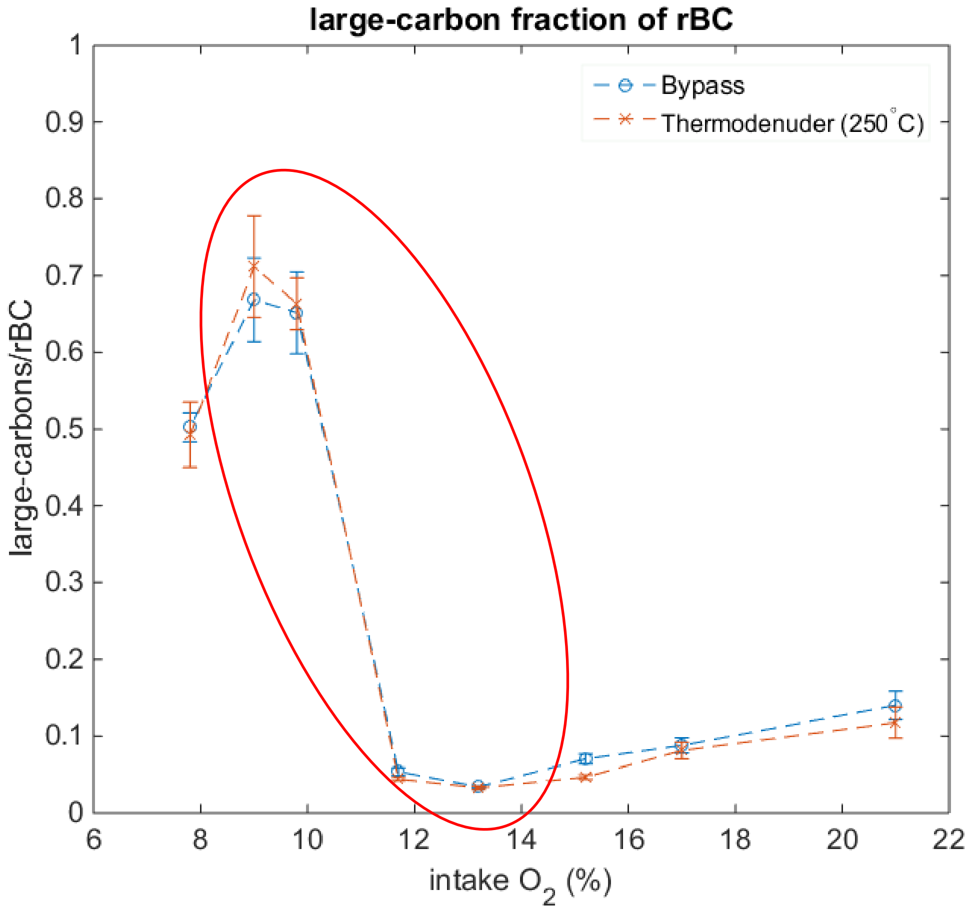


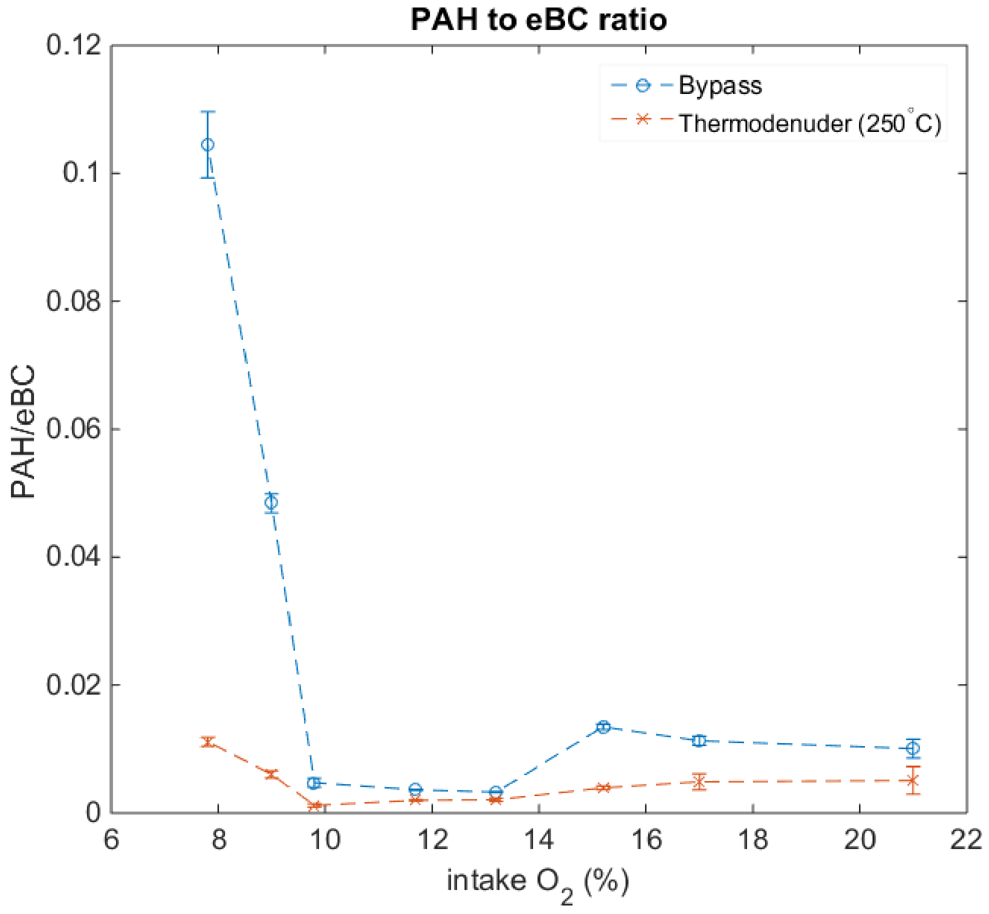


Absorption Angstrom Exponent vs EGR level (HVO)



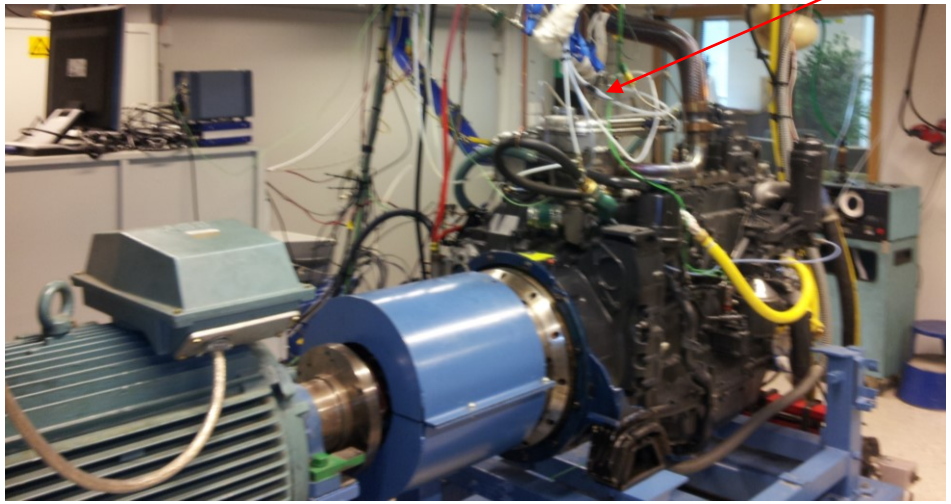
Effect of EGR on Particle Composition (HVO)



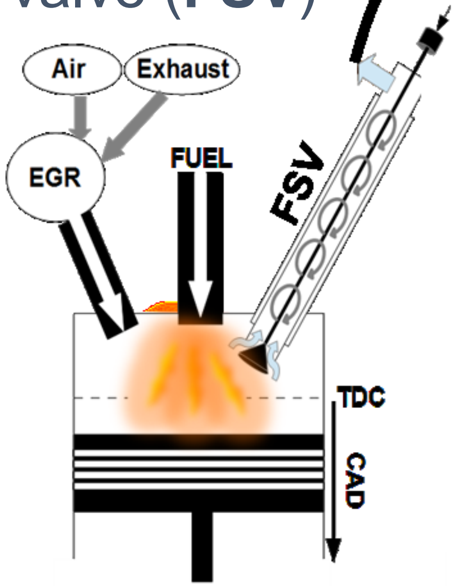


In-cylinder diesel soot characteristics investigated with on-line aerosol mass spectrometry

Single cylinder heavy duty diesel engine



Fast gas-sampling valve (**FSV**)

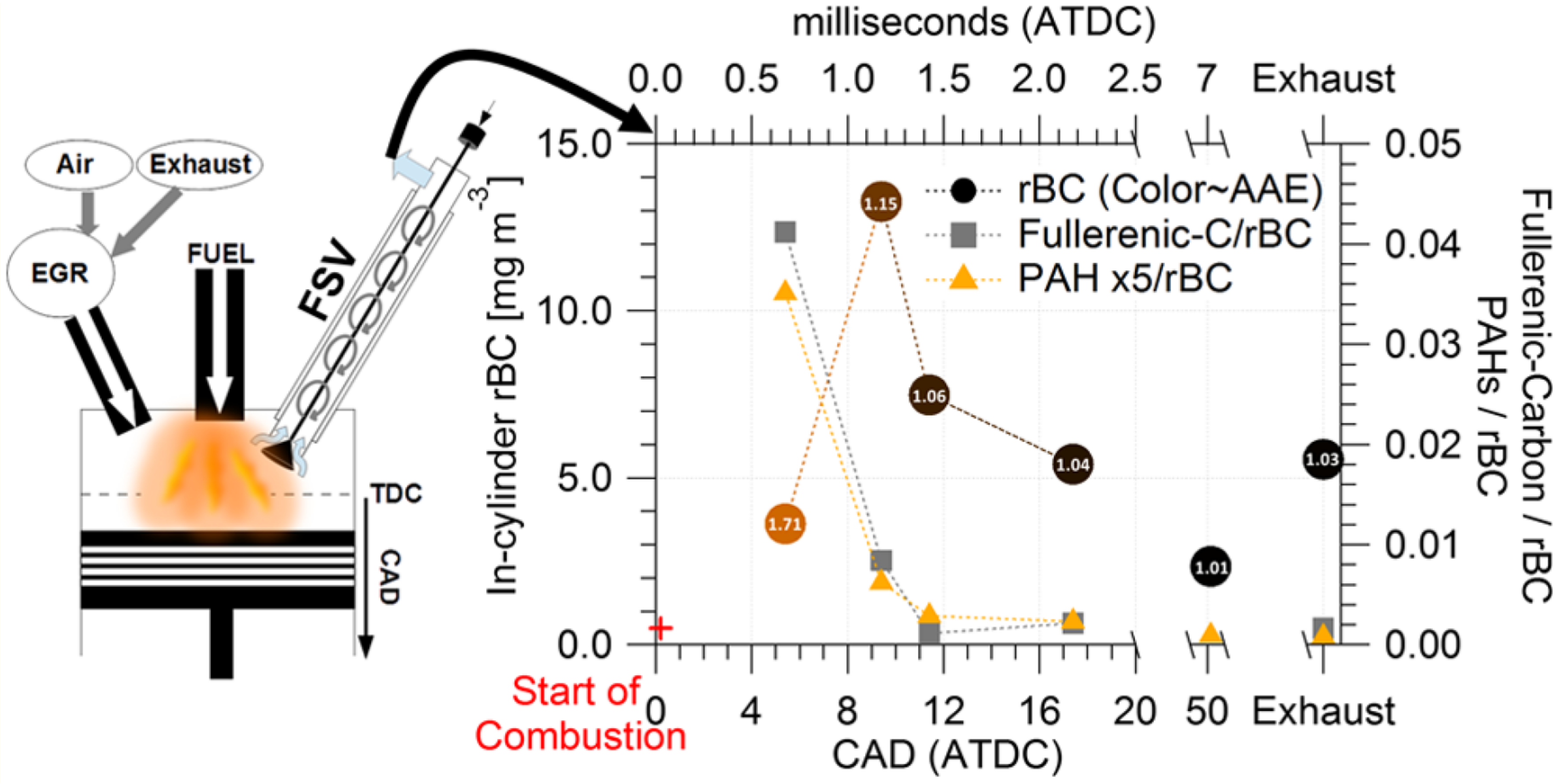


Dilution x700

- Soot Particle Aerosol Mass Spectrometer
- Aethalometer
- SMPS

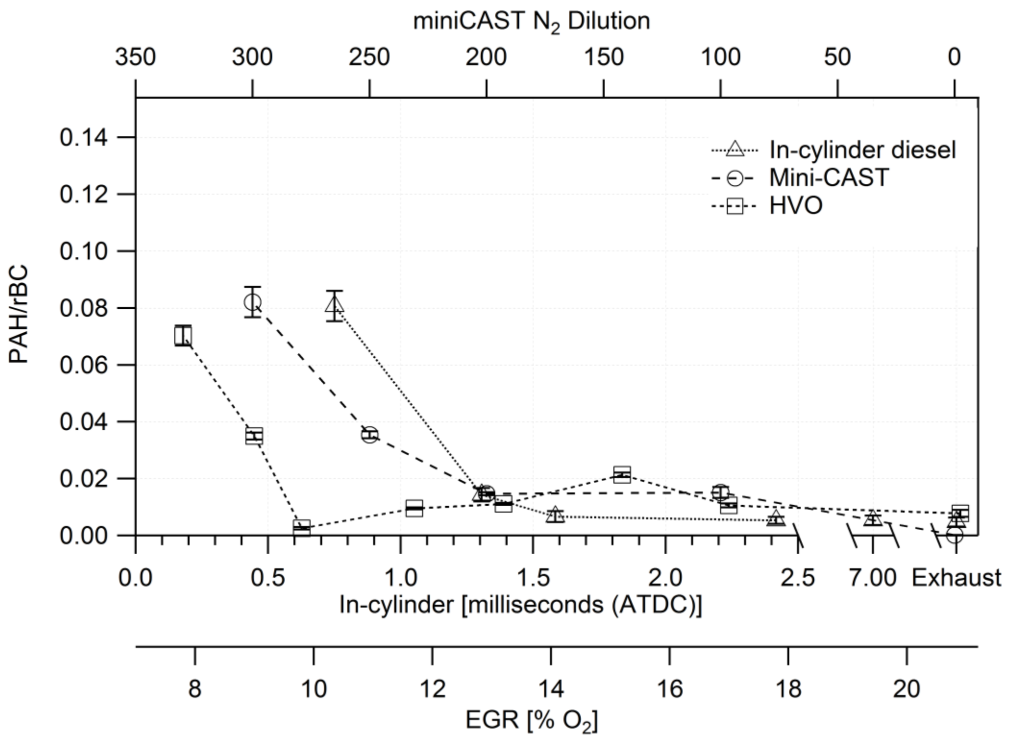
Malmborg et al., (2017) Environ. Sci. Technol.

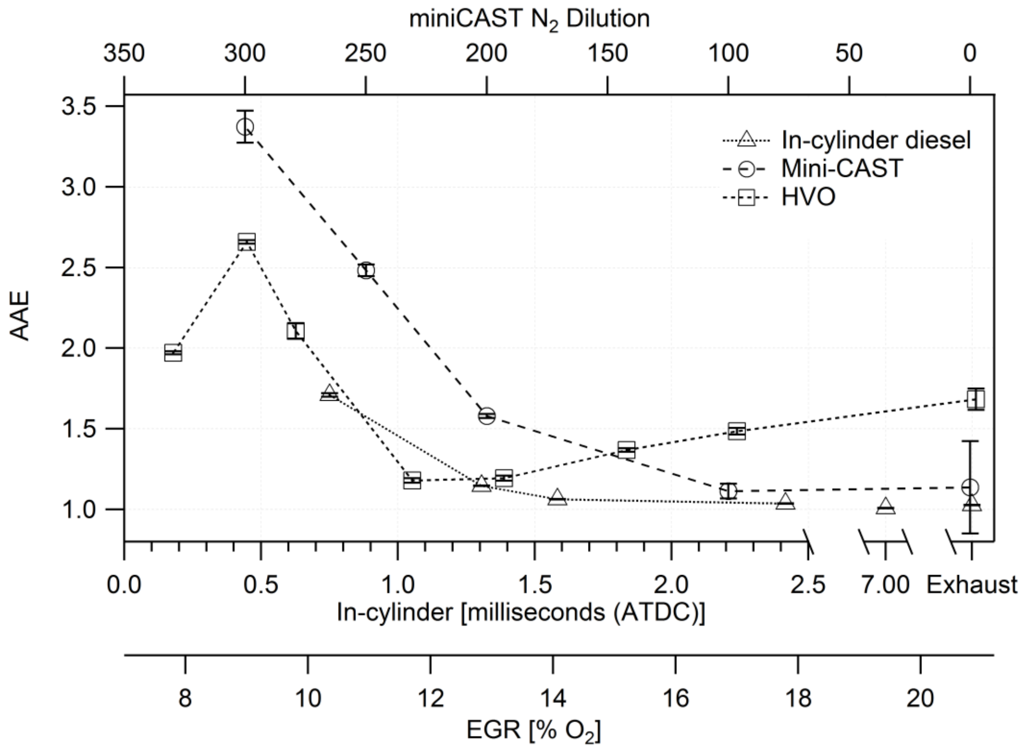
Evolution of particle properties over the combustion cycle – HD diesel engine



Malmborg et al. ES&T 2017

Similarities between miniCAST and HD diesel engine exhaust





Conclusions

- Similarities in composition and optical properties of PM from:
  - miniCAST with high N_2 fuel dilution
  - Low temperature combustion in HD diesel engine
  - Soot formation phase in HD diesel engine
- High AAE (Brown Carbon)
- Persistent ”organic” carbon that pyrolyse upon heating in inert gas
  - Linked to large carbon fragments in SP-AMS mass spectra
- Structural properties changes (reduced fringe length in TEM)
- This may be the intersection of organic carbon and immature soot!
  - We may detect Black Carbon Precursors (BPC) that has not matured to BC
- Future work
  - What are the health effects of this new class of carbon?

Acknowledgements

- Co-authors: V. B. Malmborg, S. Török, L. Gren, A. C. Eriksson, S. Shamun, P. Shukla, Y. Zhang, S. Kook, M. Tunér, Ö. Andersson, P.E. Bengtsson

- Swedish Research Councils FORMAS and VR