

High-Load Partially Premixed Combustion in a Heavy-Duty Diesel Engine

Prof. Bengt Johansson
Div. of Combustion Engines,
Dept. of Heat and Power Engineering,



LUND INSTITUTE
OF TECHNOLOGY
Lund University

Outline

- What is a clean engine?
- Homogeneous Charge Compression Ignition, HCCI
- Partially premixed Combustion, PPC
- Optical diagnostics
- Summary

Clean locally or globally?



Local emissions:

NO_x

HC

CO

PM

Global emission
(Greenhouse
effect):

CO₂ i.e. fuel
consumption

Environmentally friendly \equiv no CO₂?

A CO₂-neutral alternative?



But, some emission statistics from New York by the turn of the century...

- 200 m³ liquid emissions per day
- 1000 ton solid emissions per day
- An army of tenths of thousands worked with transporting the emissions out from the city

Diesel engine emissions?

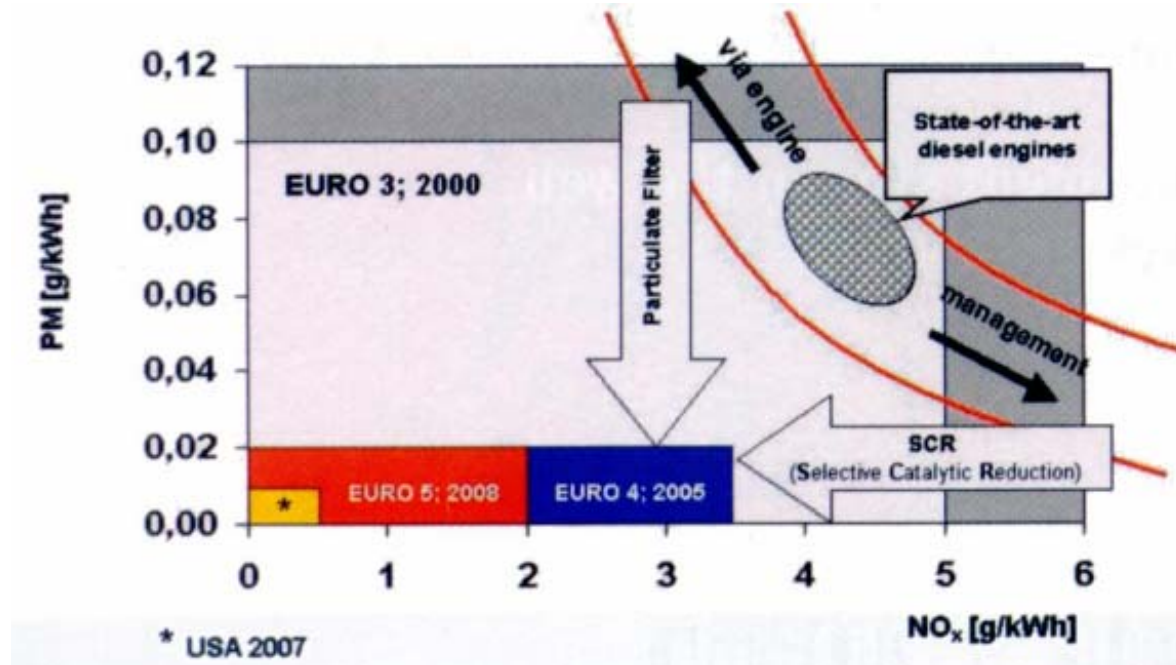
Diesel emissions



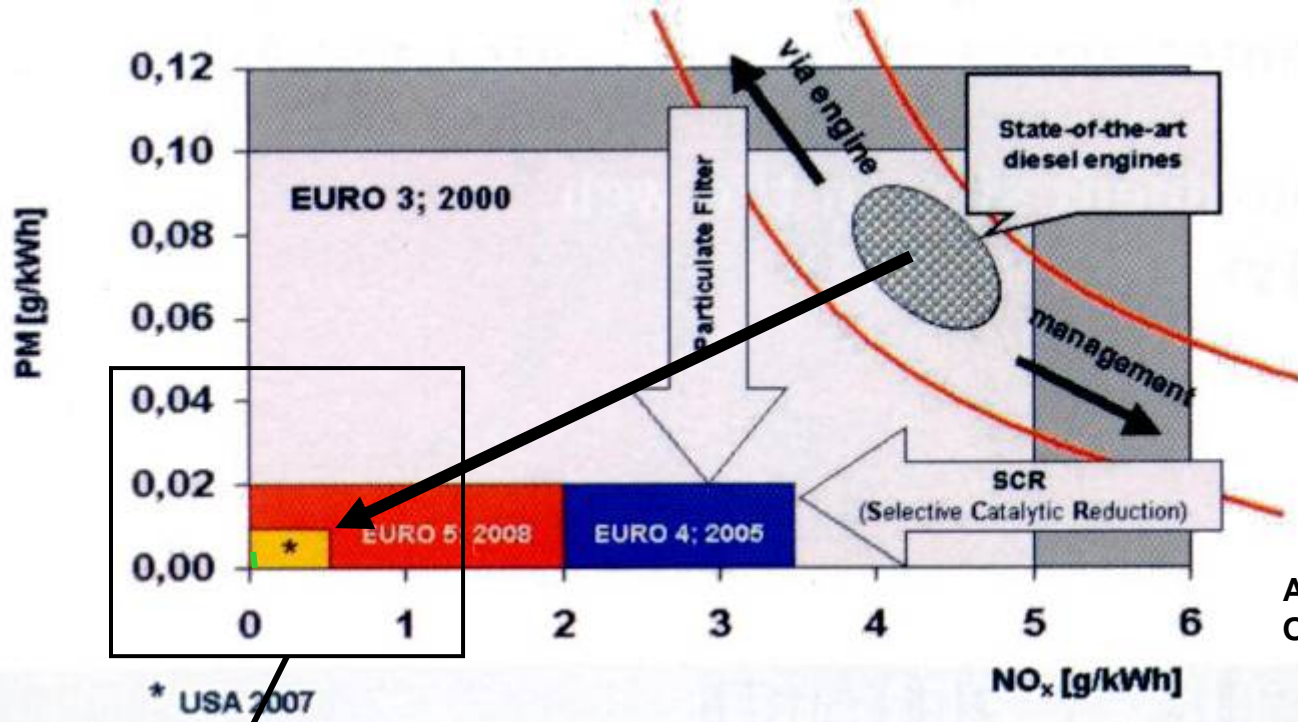
Diesel engine emissions

- Emissions depends on load
- Transient behavior
- Post cylinder oxidation important
- The engine is not the only source of emissions
 - Some PM experts claim tire wear generates 10 times more than the engine

Diesel

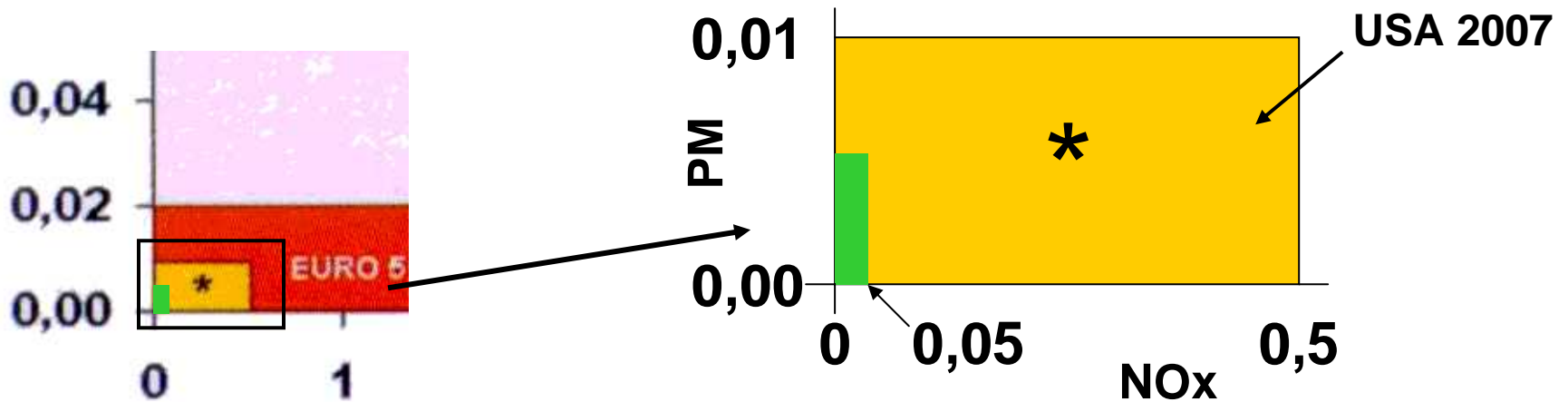


HCCI Emissions vs. diesel



AutoTechnology
Oct. 2002, p 54

HCCI



HCCI with diesel fuel

1. Port fuel injected (classical HCCI)
2. Direct fuel injection (HCCI or PPC)

1. HCCI with port fuel injection

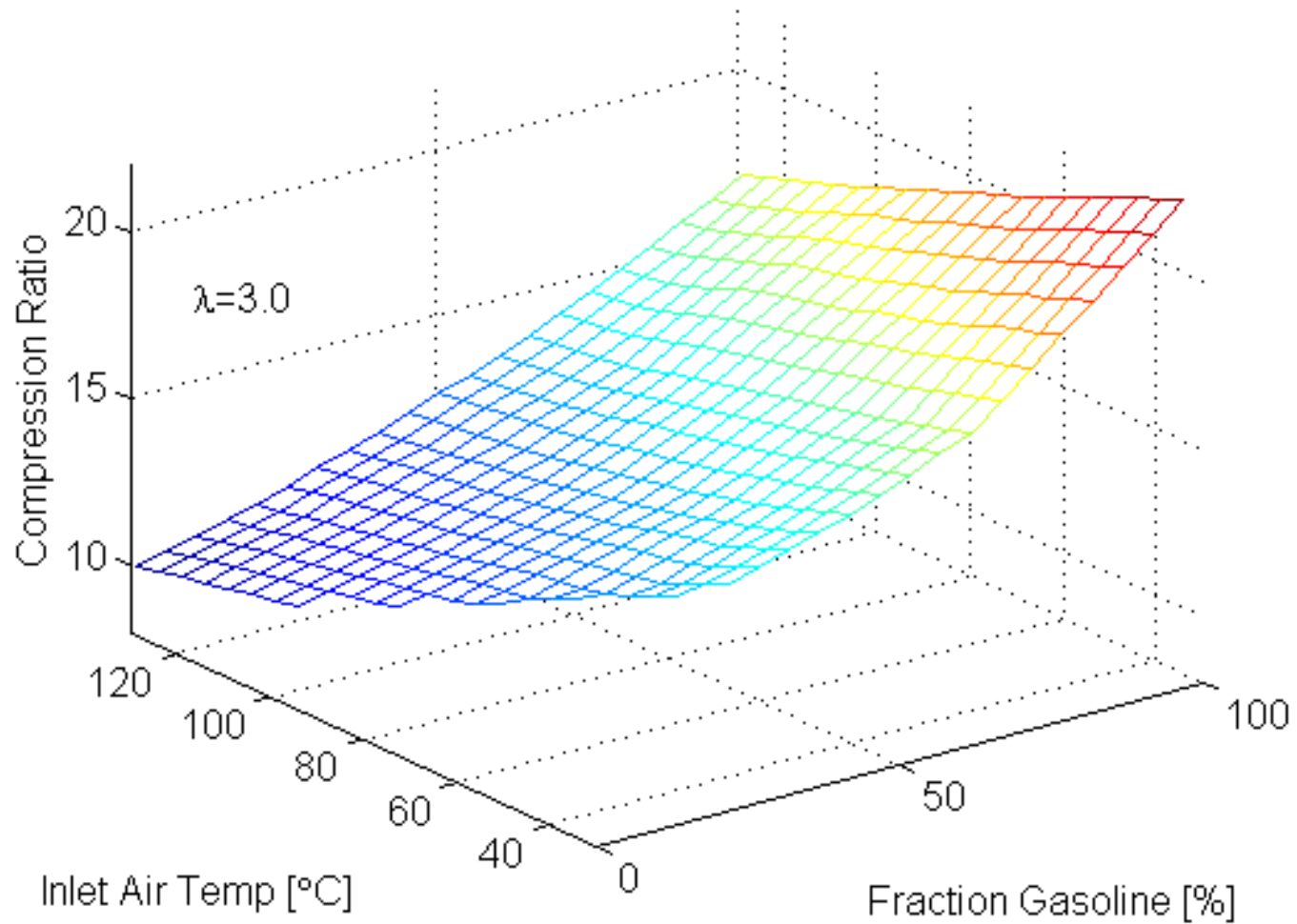




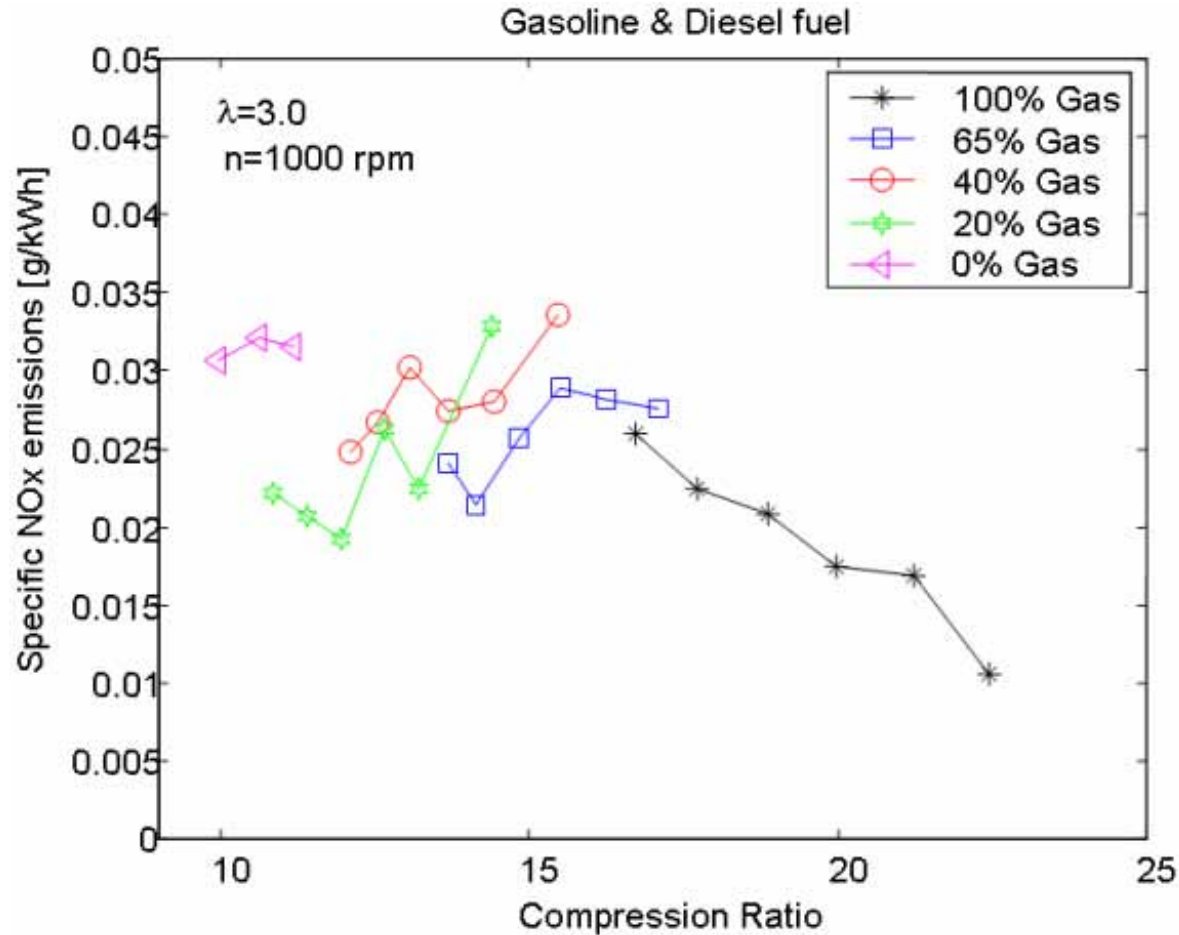
**First VCR
system**

Multifuel capability

Gasoline & Diesel fuel

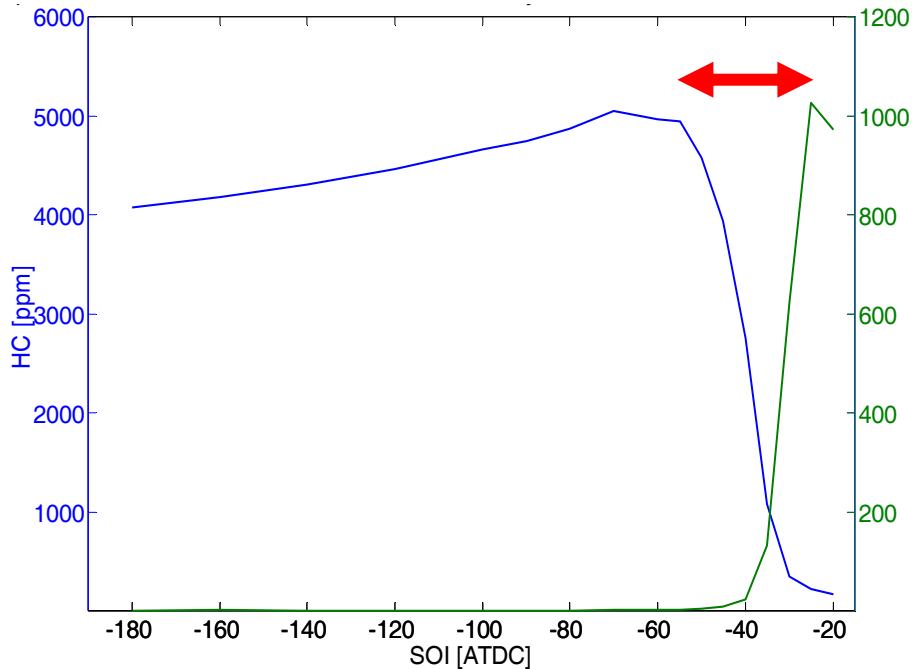


Low NOx from HCCI mode



2. Direct fuel injection HCCI

Partially premixed combustion, PPC



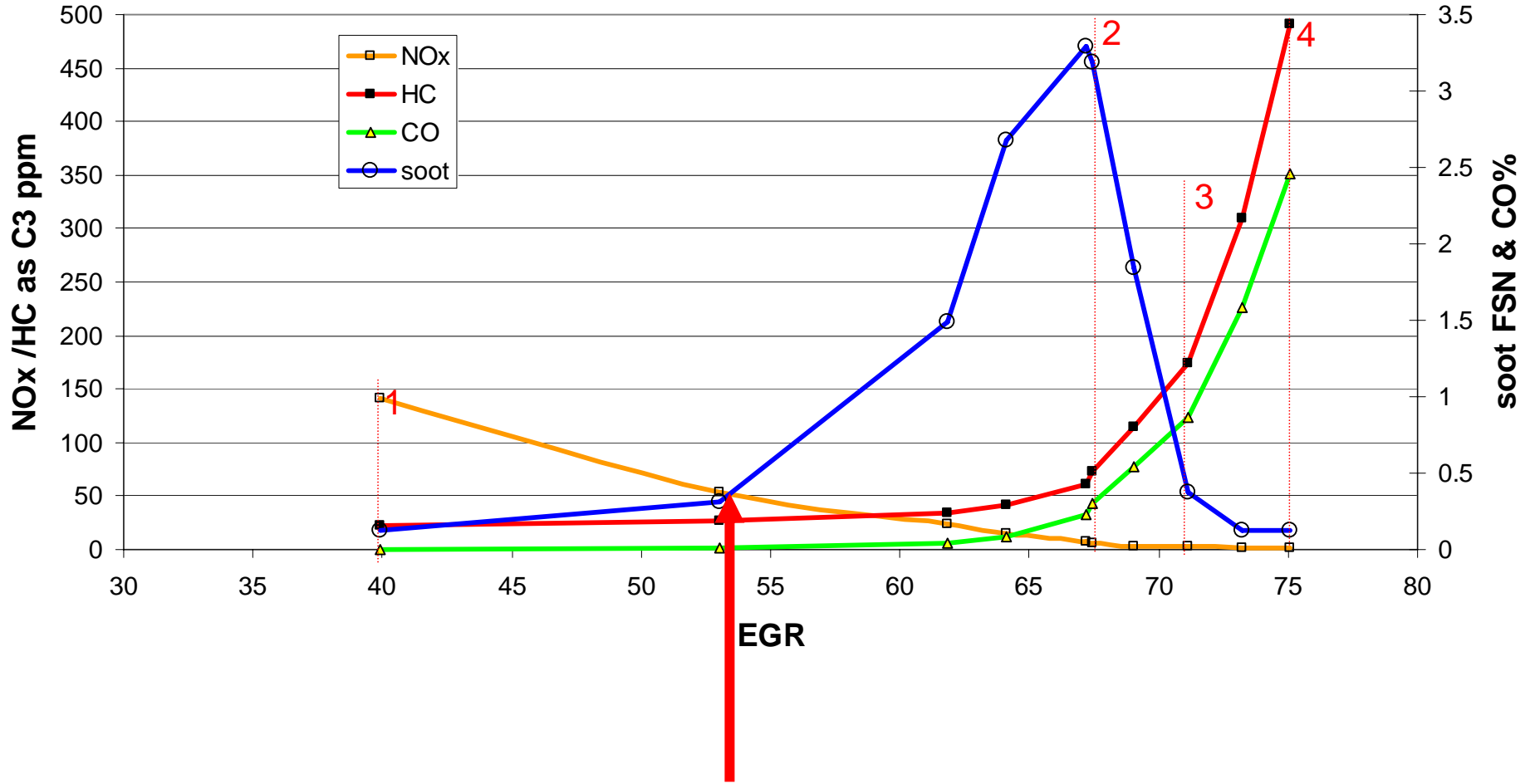
- Def: region between truly homogeneous combustion, HCCI, and diffusion controlled combustion, diesel
- Trade-off between NOx and HC, soot typical
- Combustion process not well known
- Soot the key feature

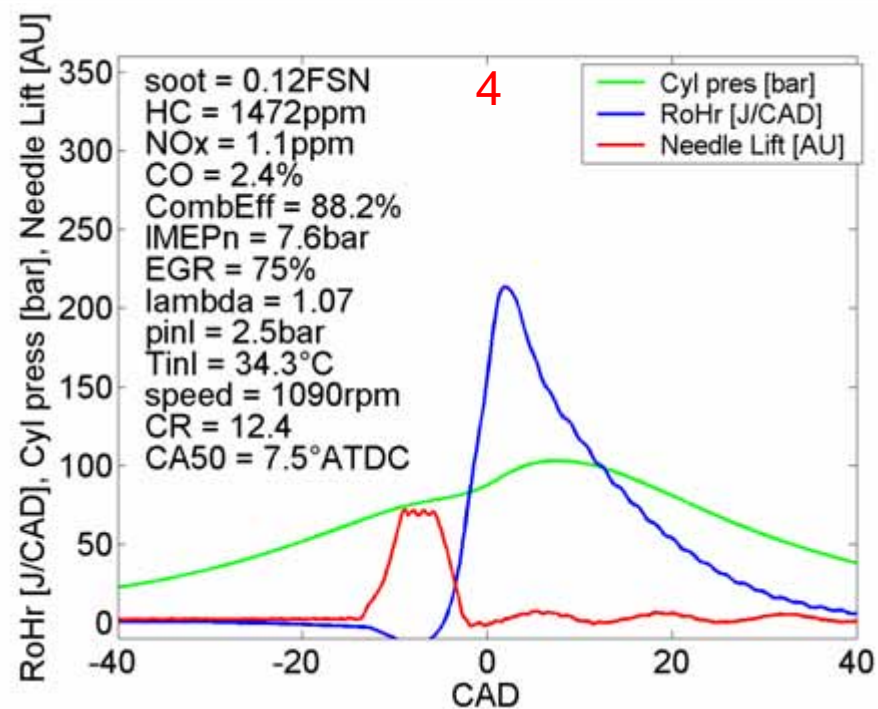
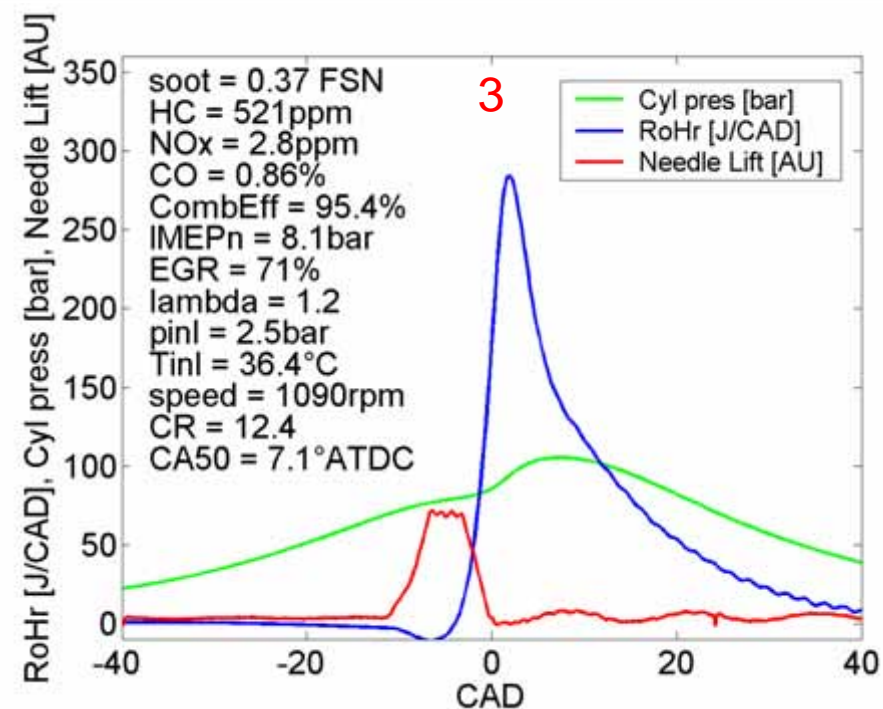
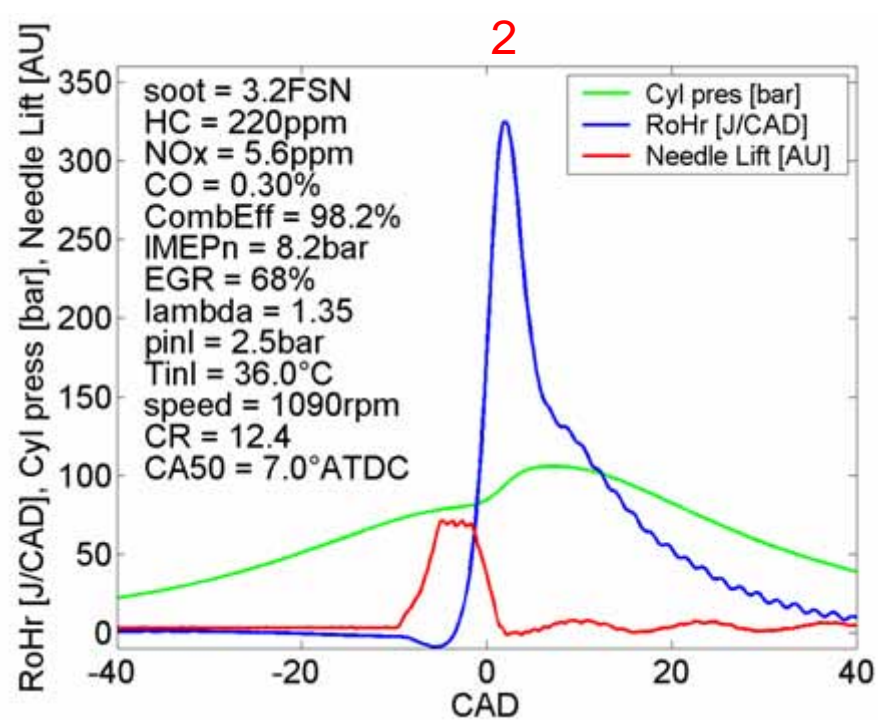
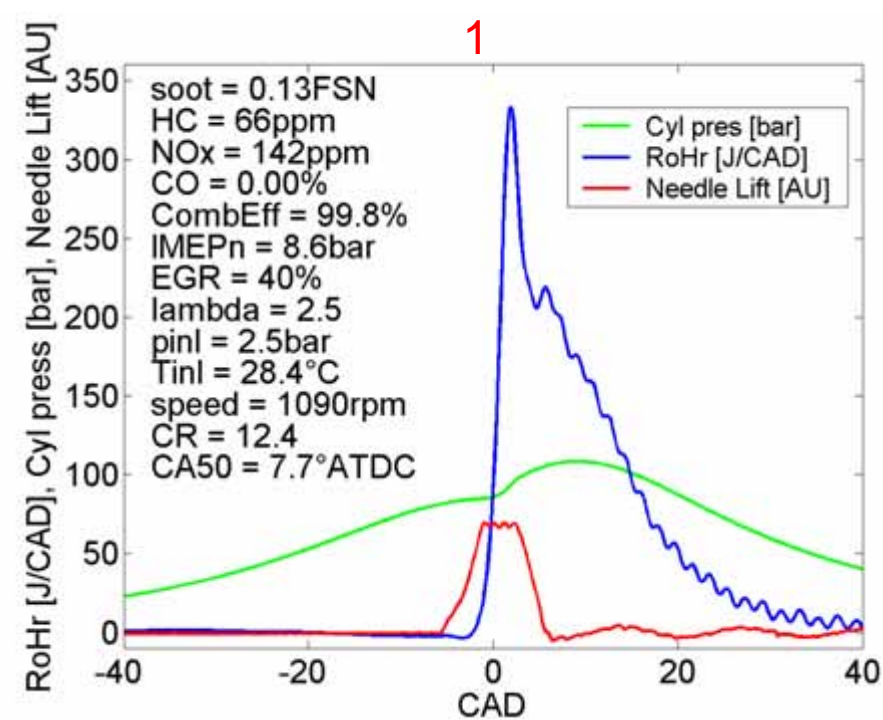
Some experimental results

- Scania single cylinder engine
- 1.95 liter displacement
- Lowered compression ratio, 12.4:1
- Common Rail fuel injection
- Fuel injection pressure 1600 bar
- 8, 12 and 15 bar IMEP presented
- EGR sweep at constant fuel flow rate
- Swedish MK1 diesel fuel

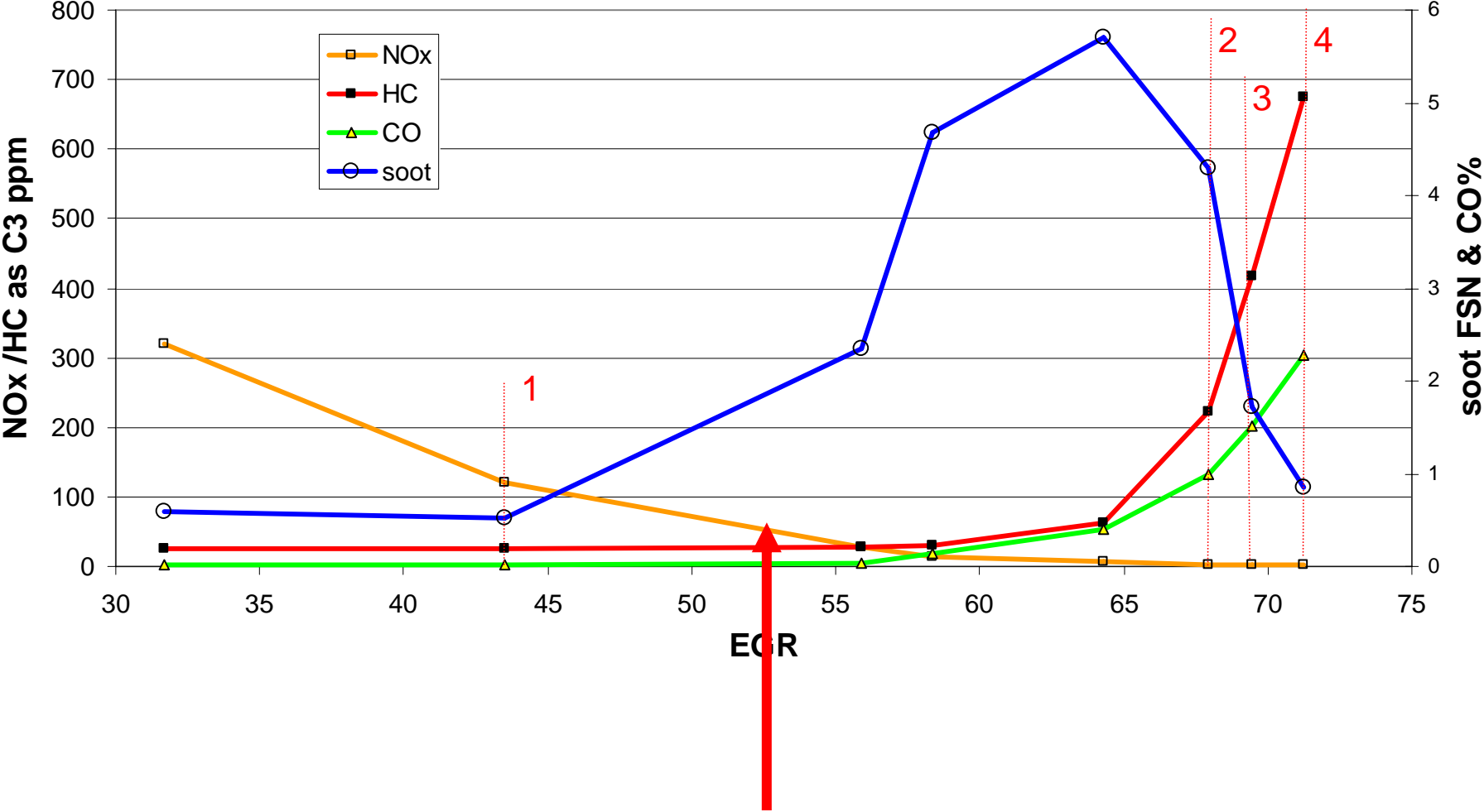


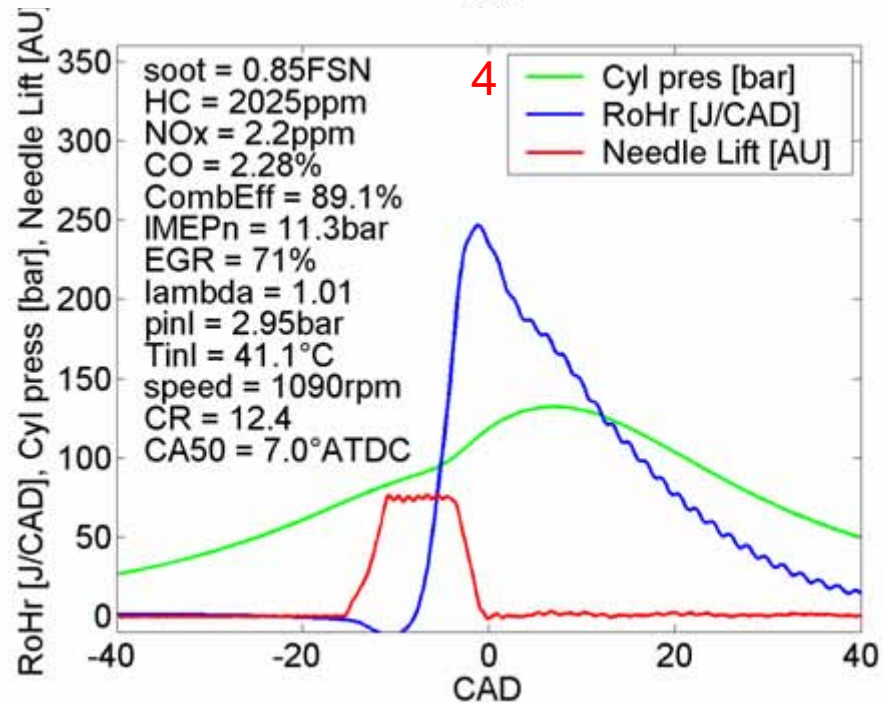
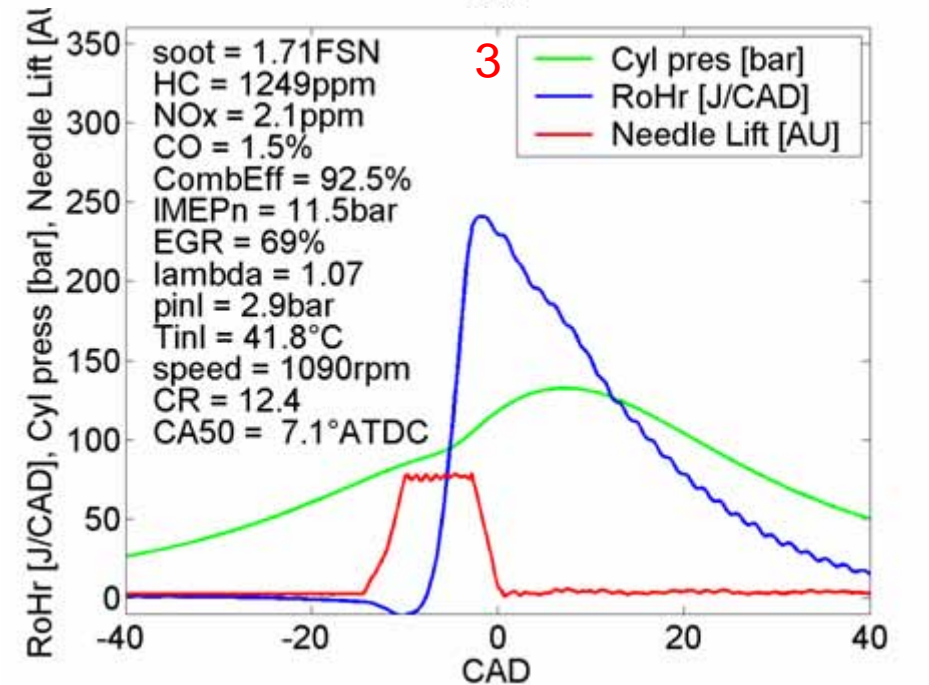
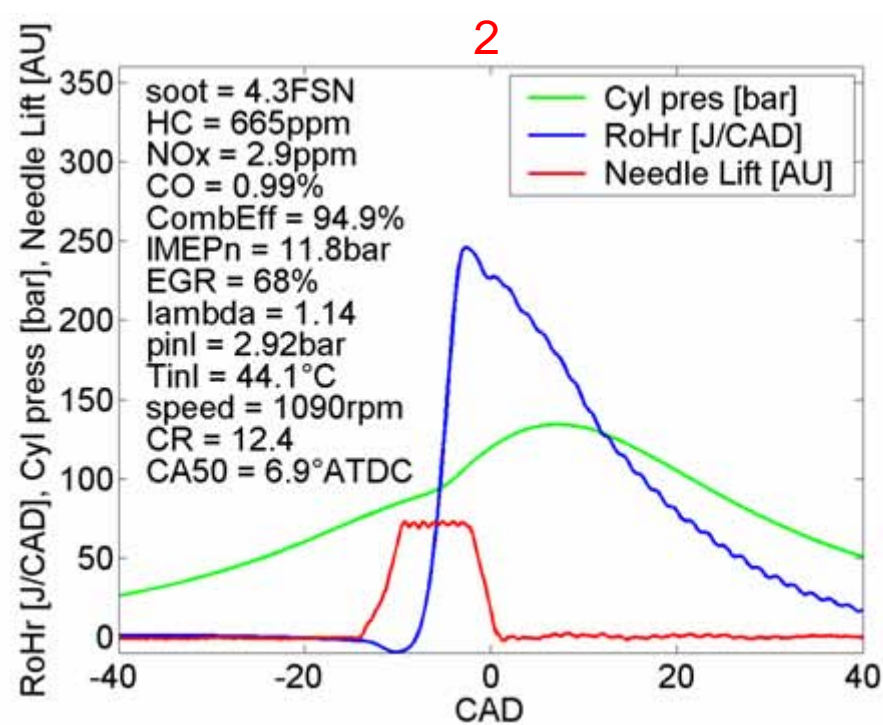
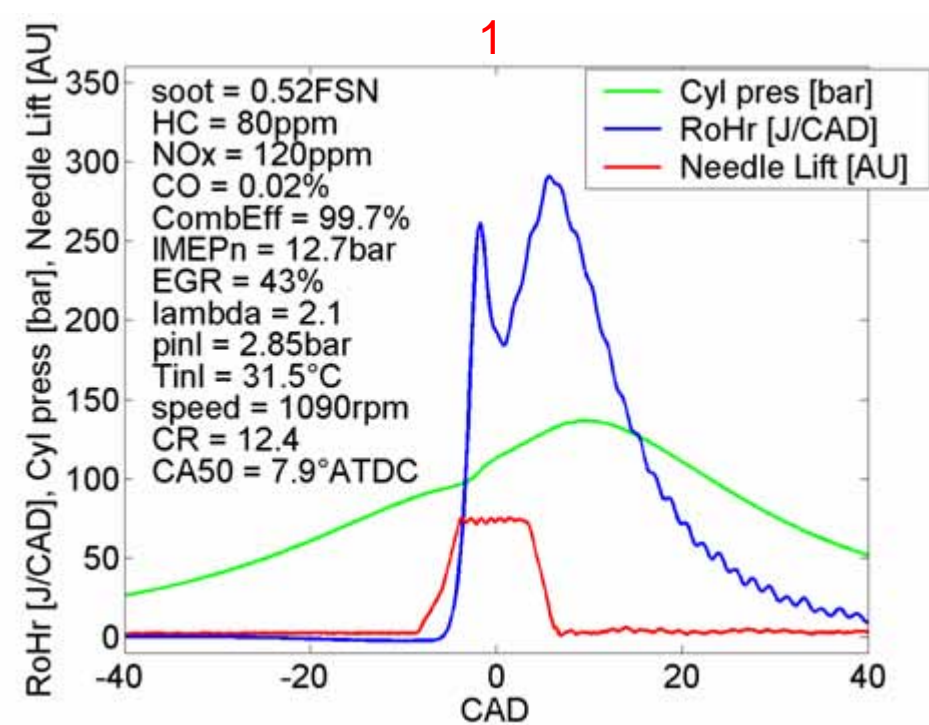
8bar IMEP



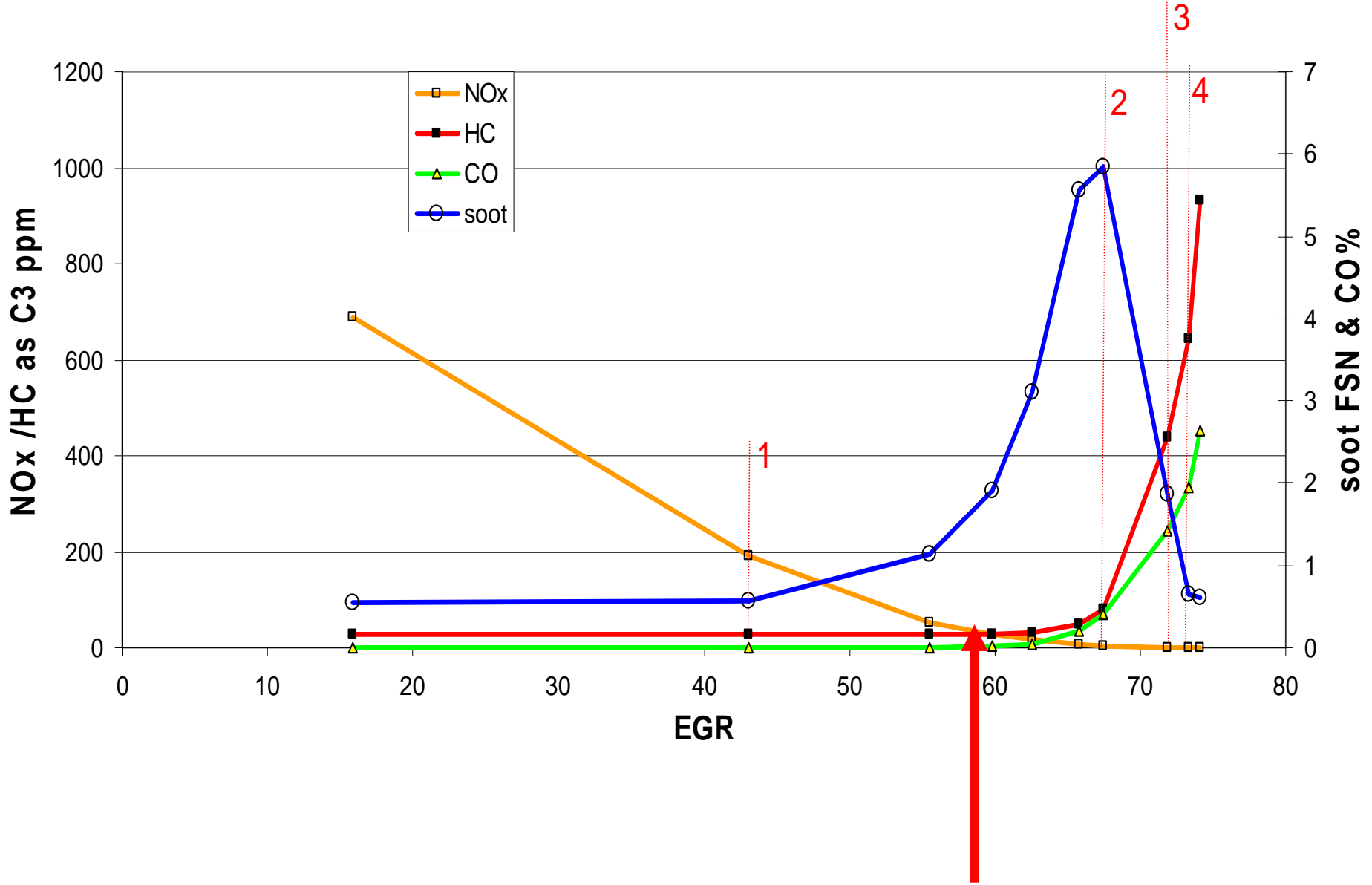


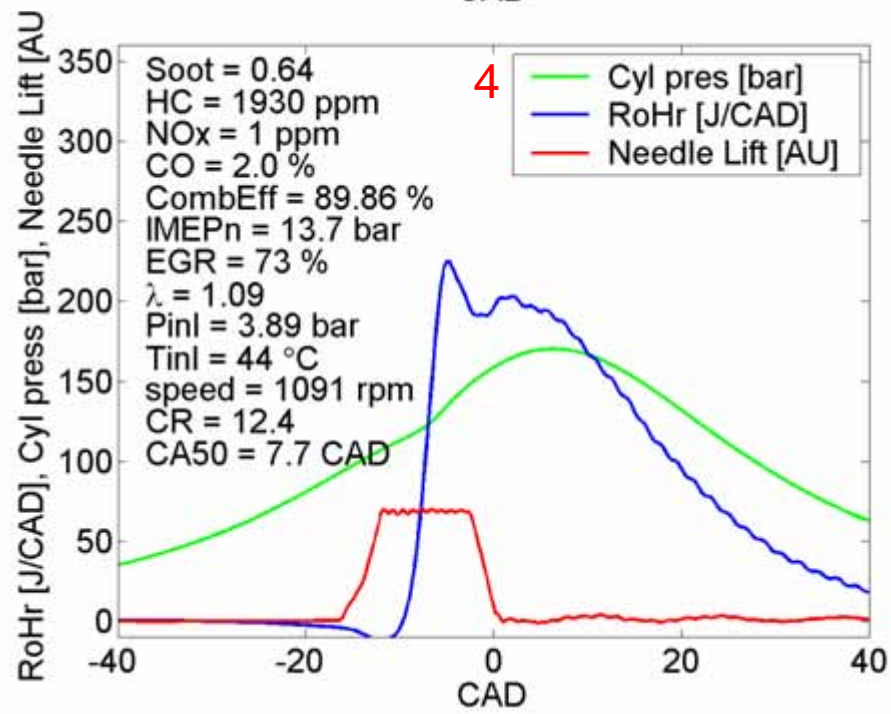
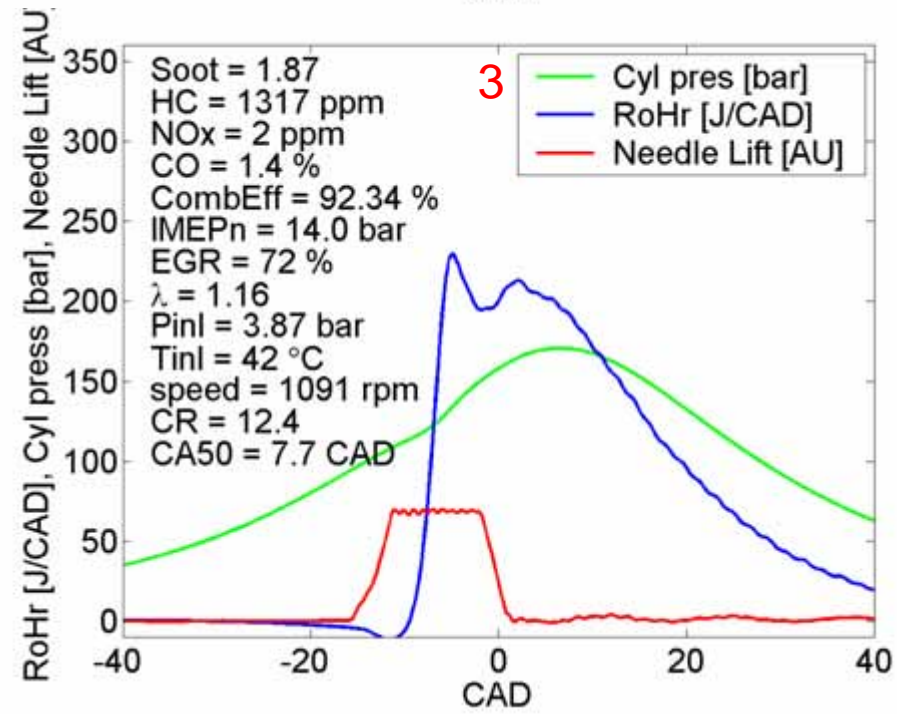
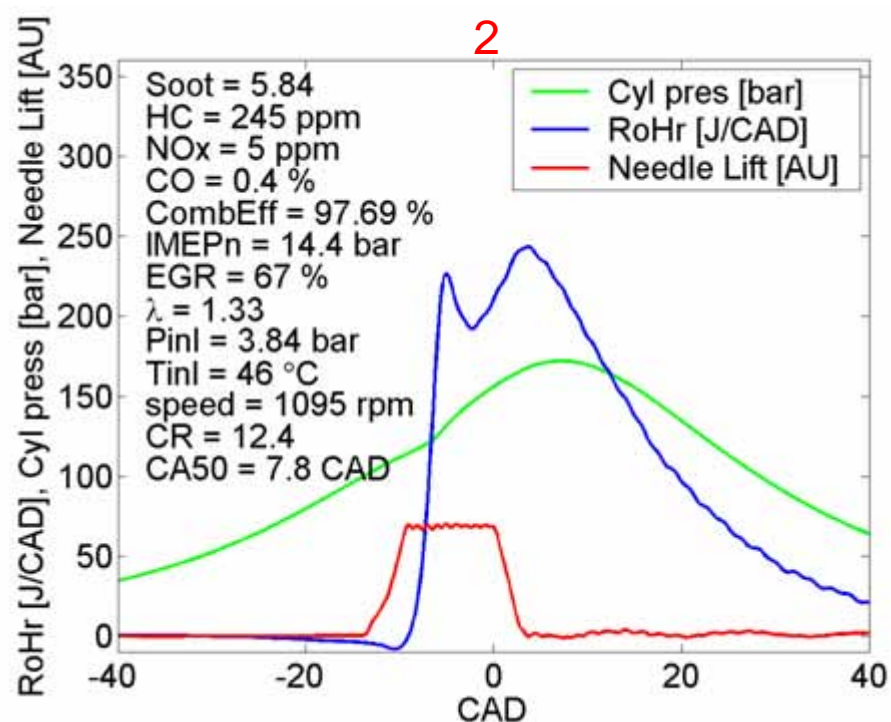
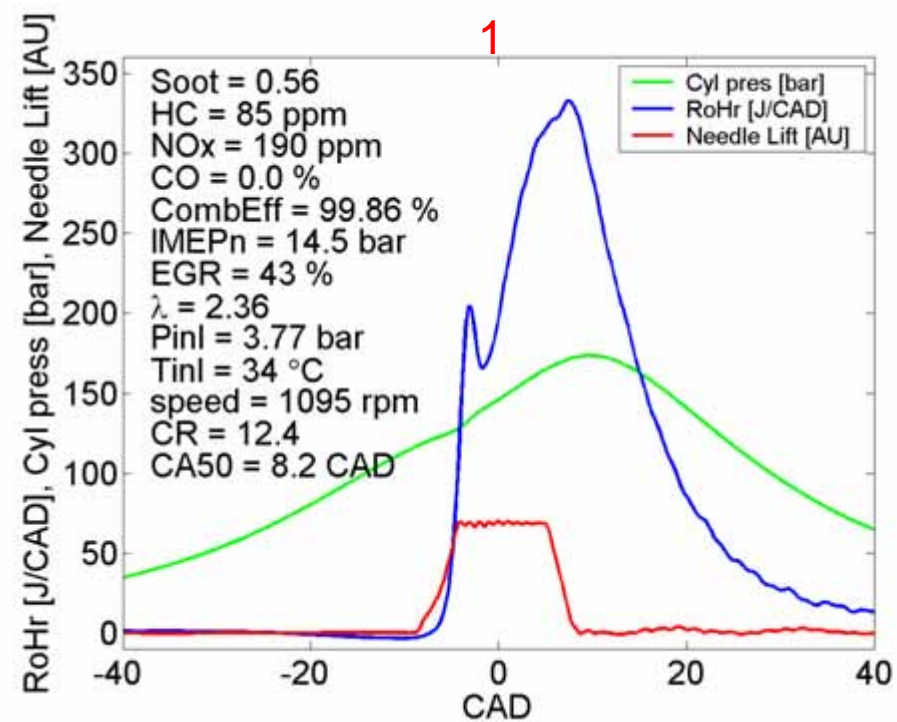
12bar IMEP





15bar IMEP

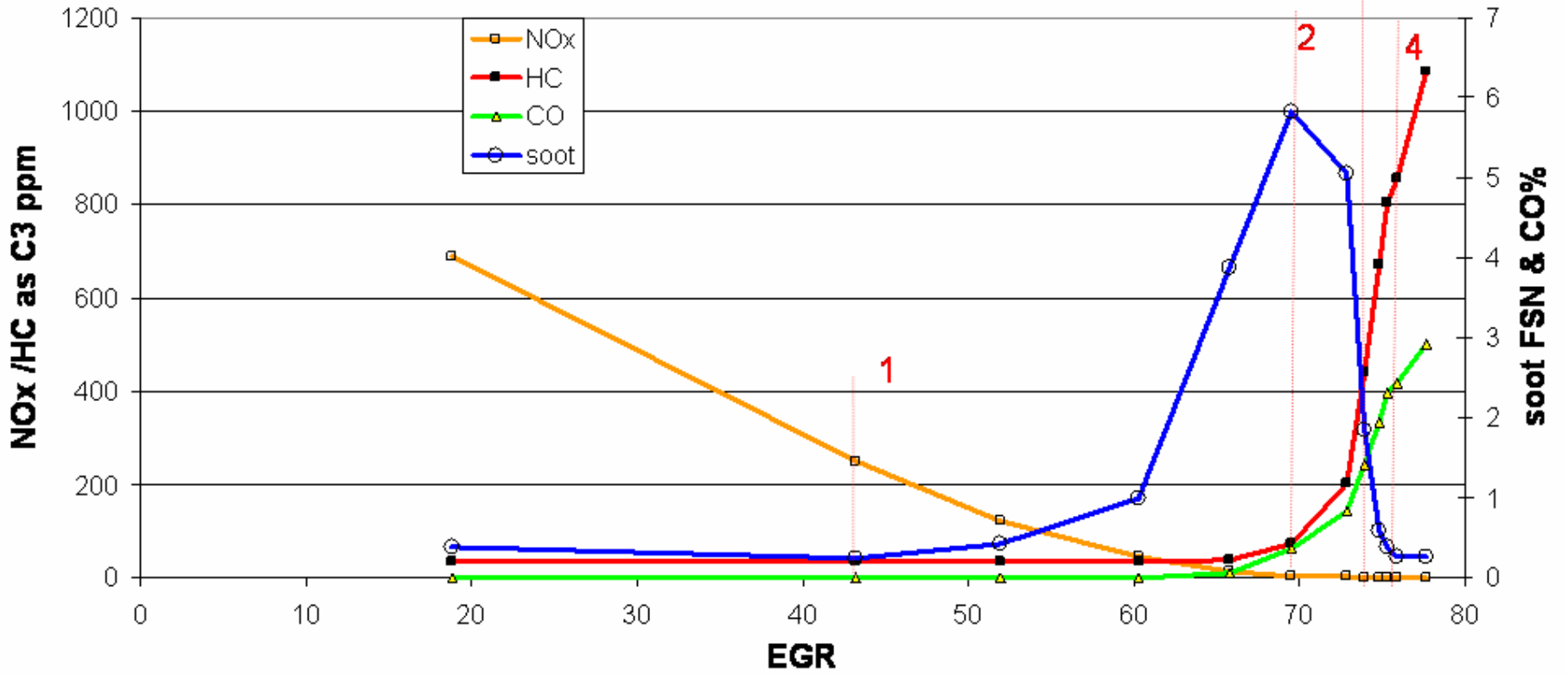


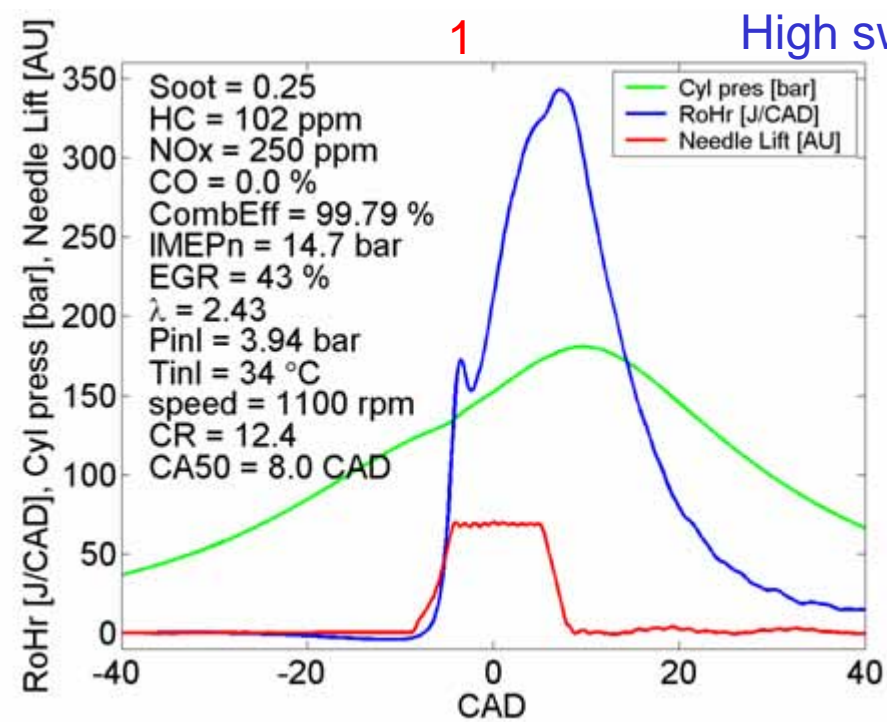
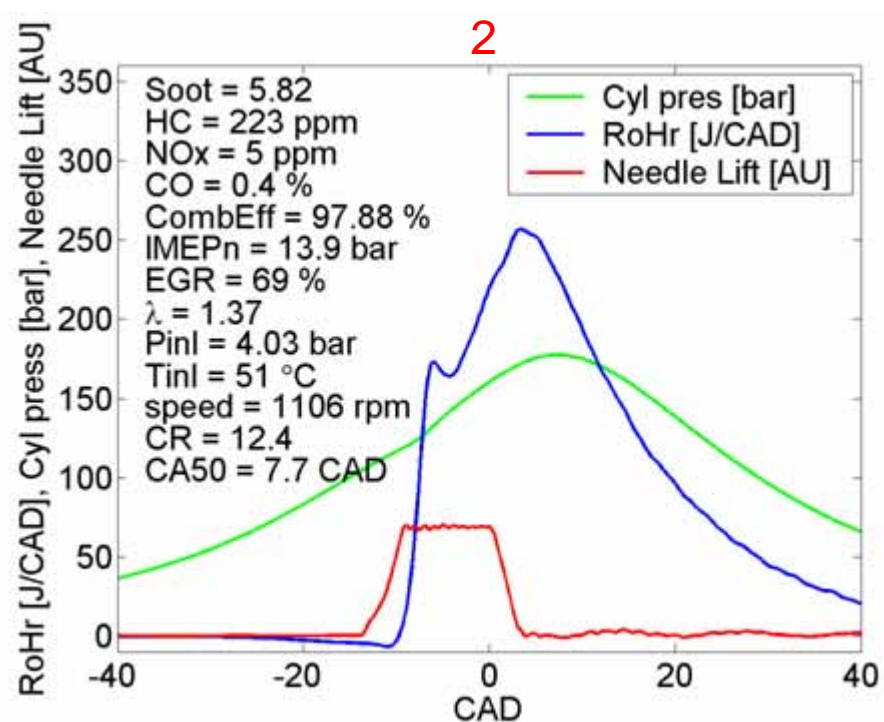
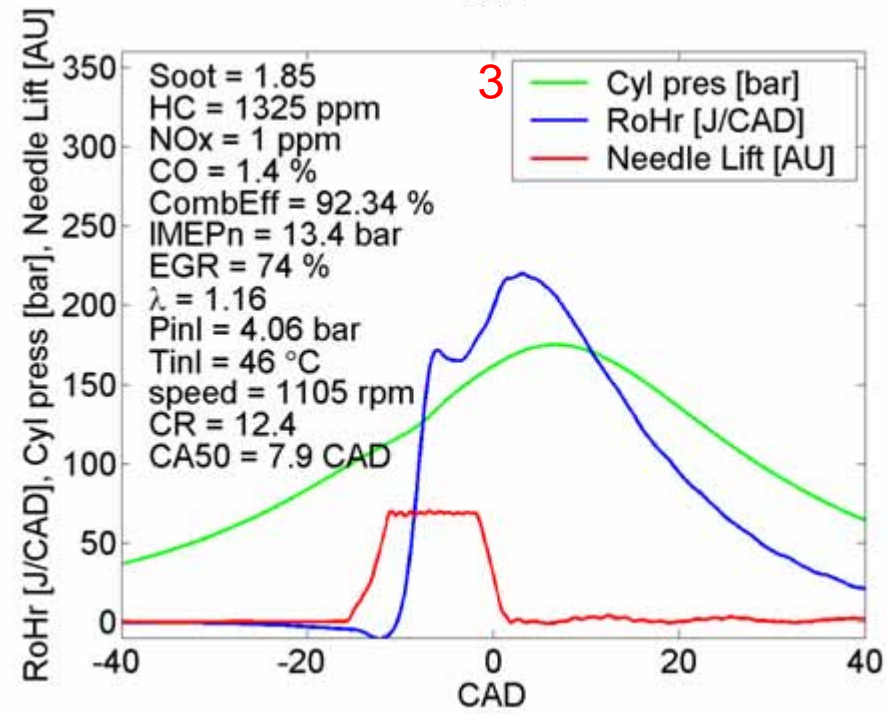
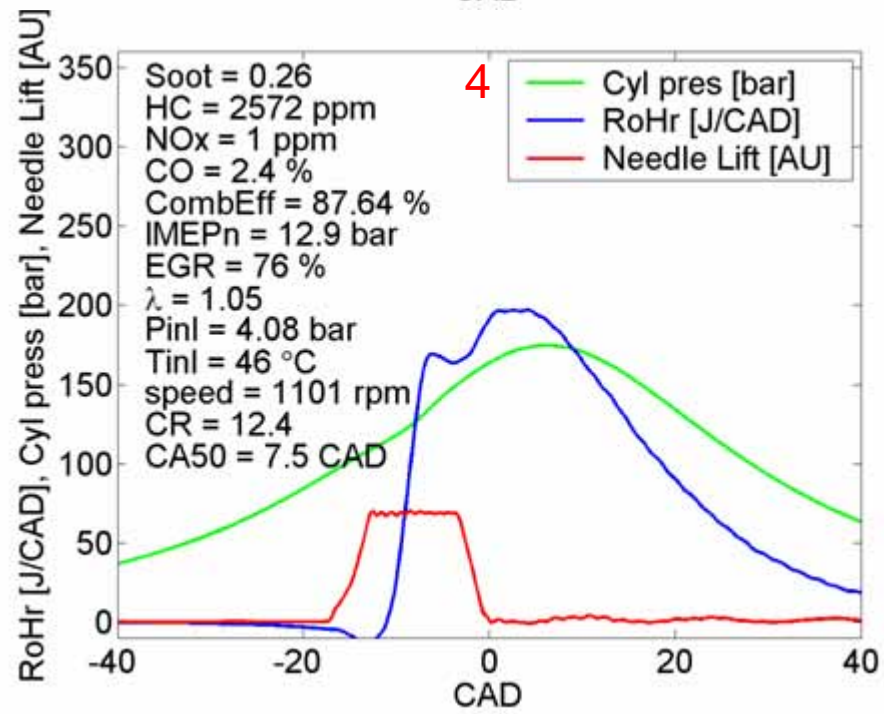


The effect of swirl

- One inlet port deactivated gives twice the swirl

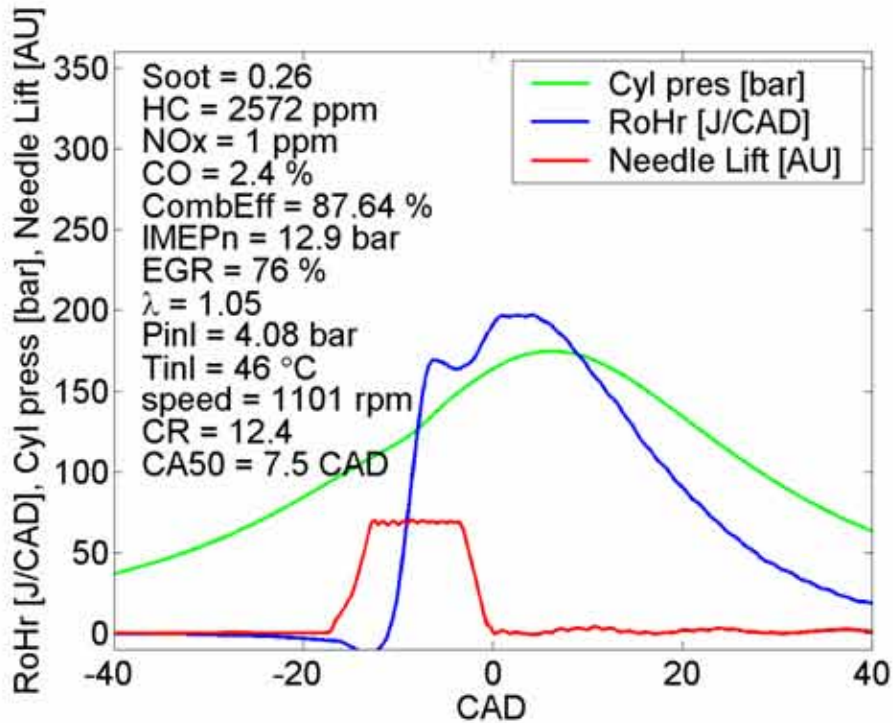
15bar IMEP swirl



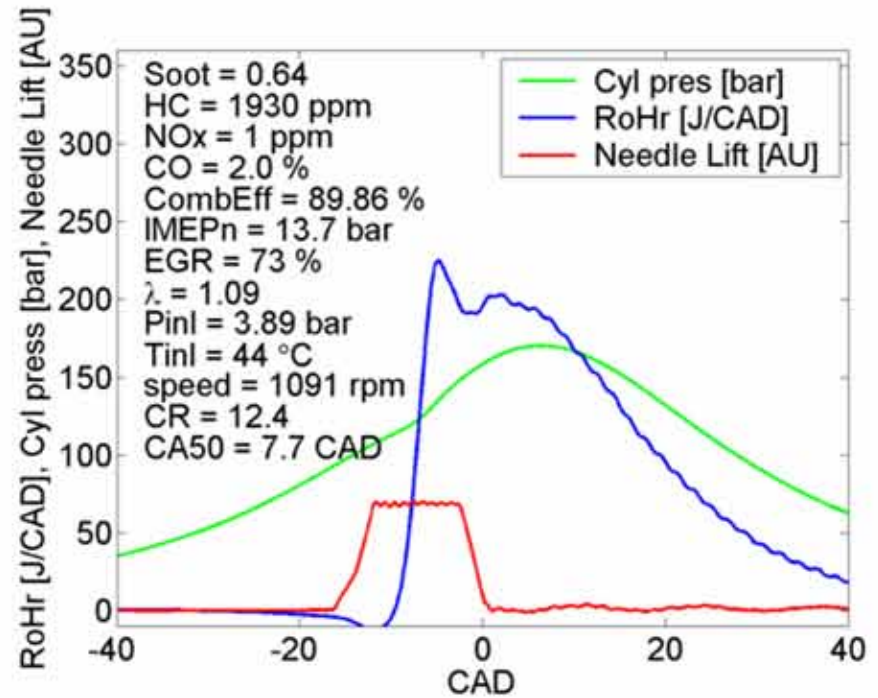
1**High swirl****2****3****4**

Swirl effect

Higher Swirl

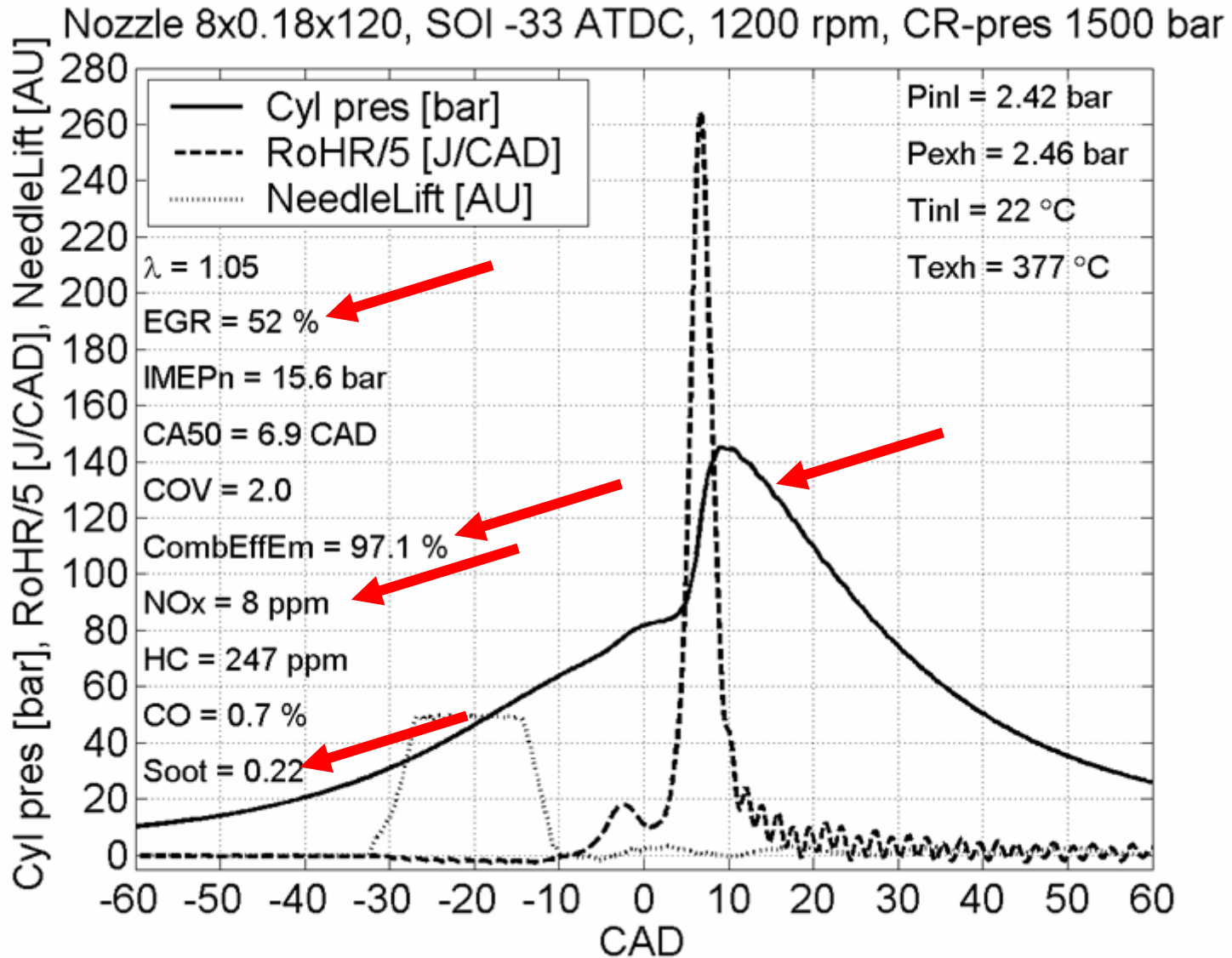


Standard Swirl



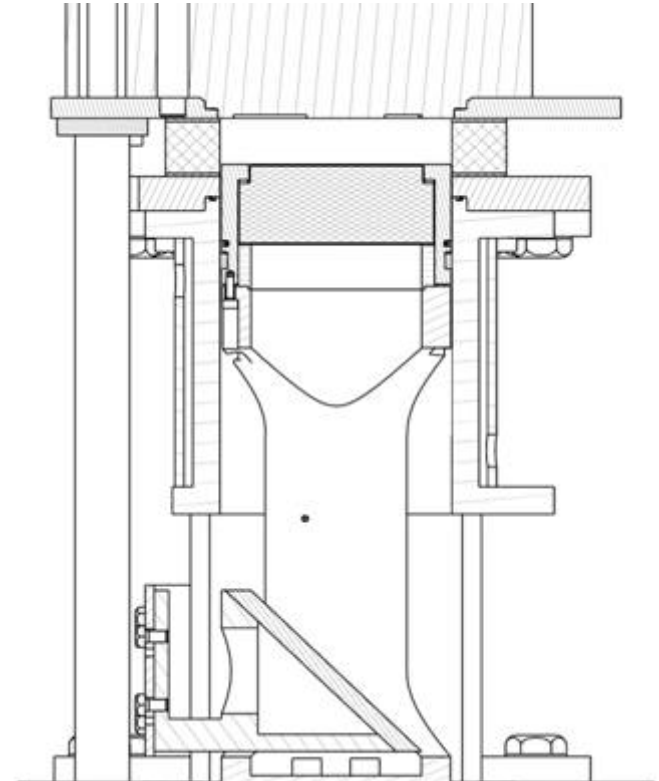
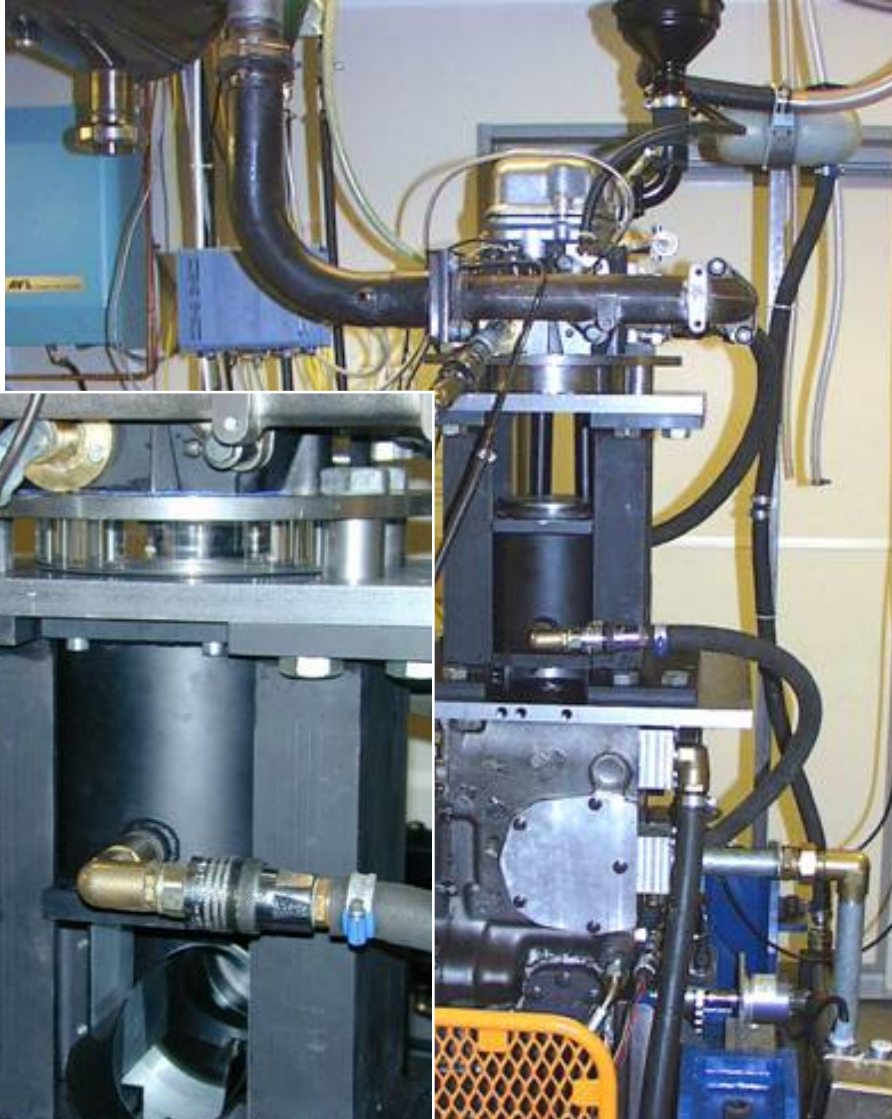
Lower cetane fuel (CN 21)

PPC potential

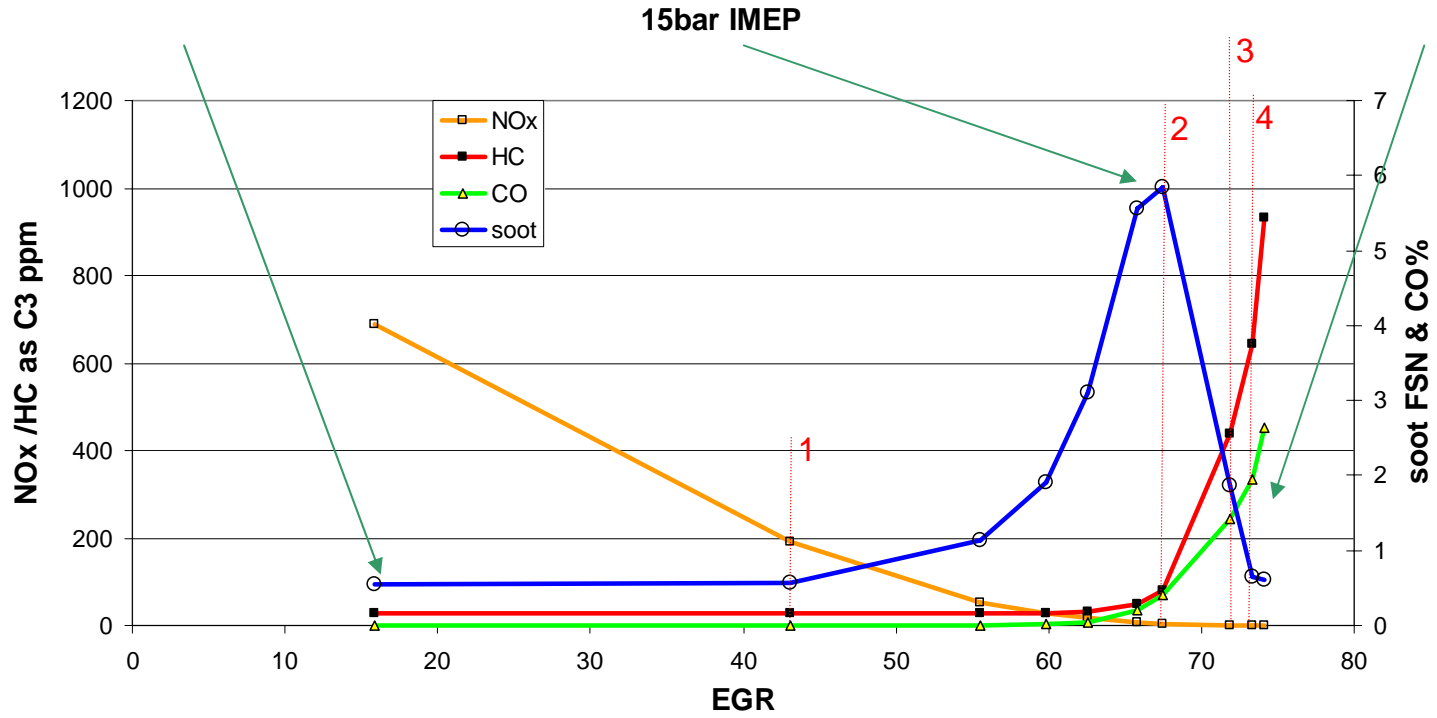


Optical diagnostics to better understand the process

1. Direct imaging of soot
2. Laser induced fluorescence of formaldehyde and OH

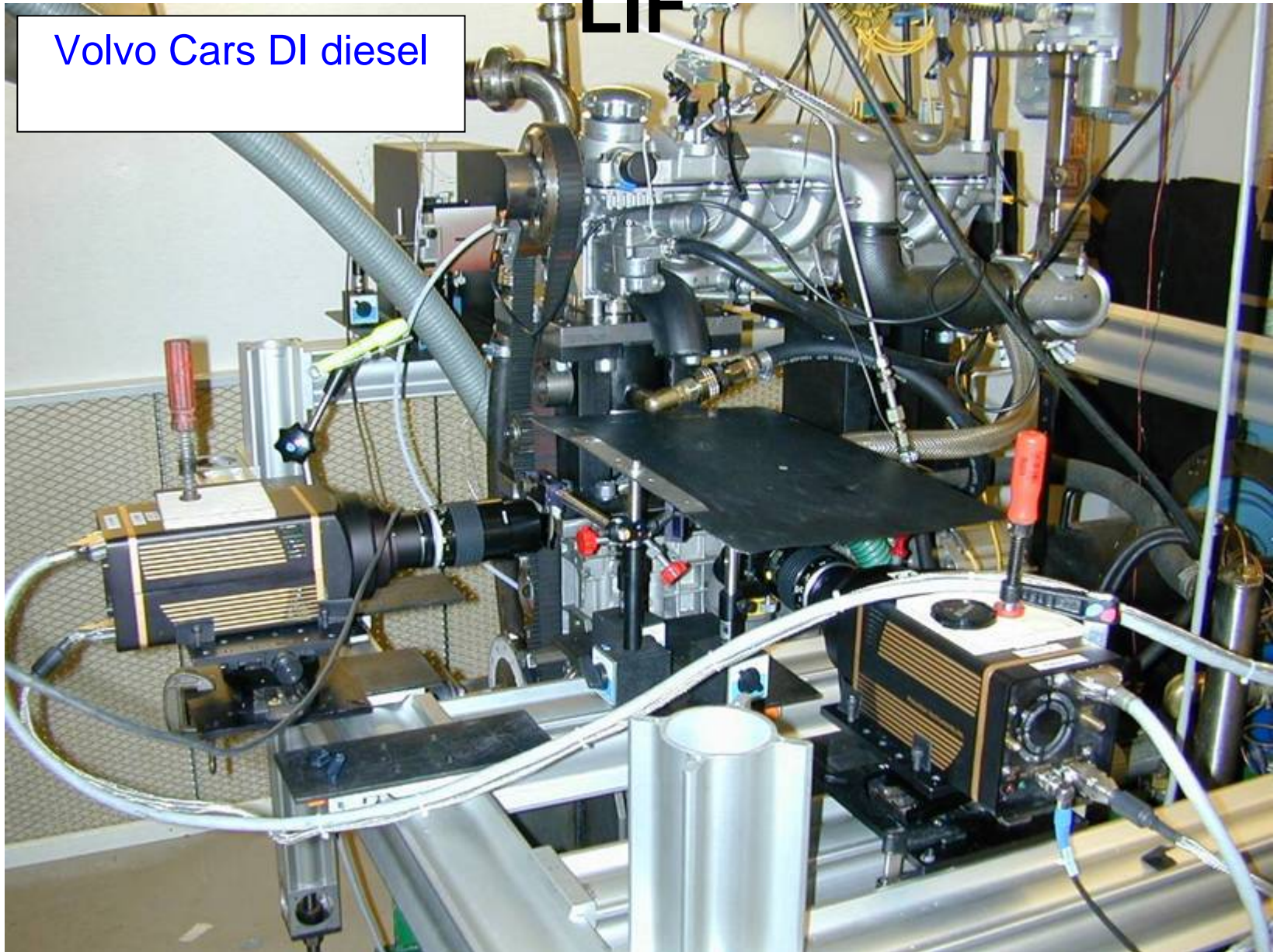


Optical diagnostics to better understand the process (Soot)

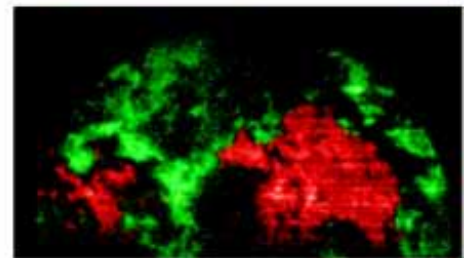
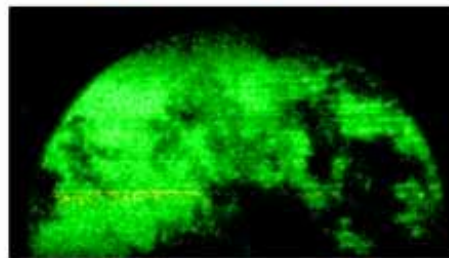
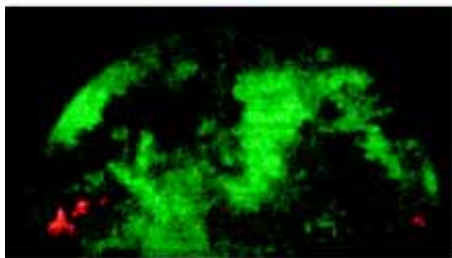
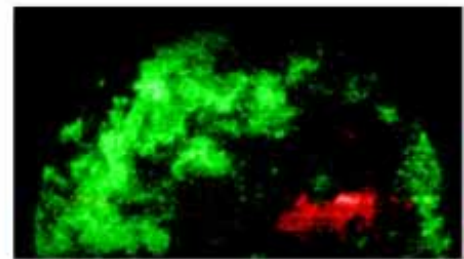
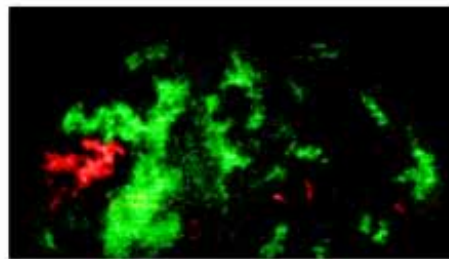
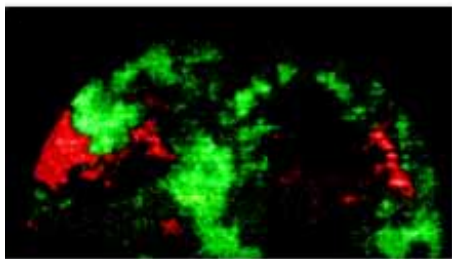
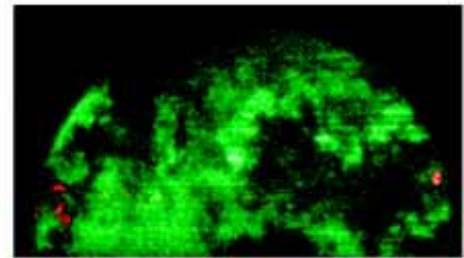
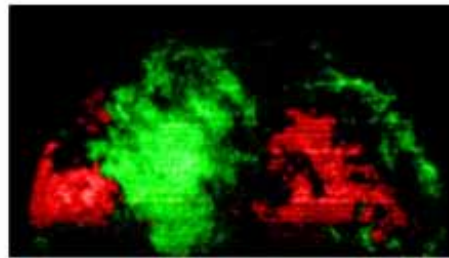
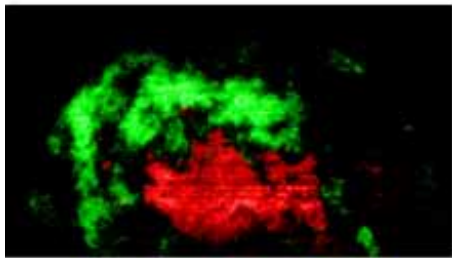
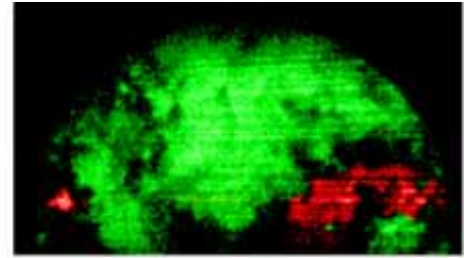
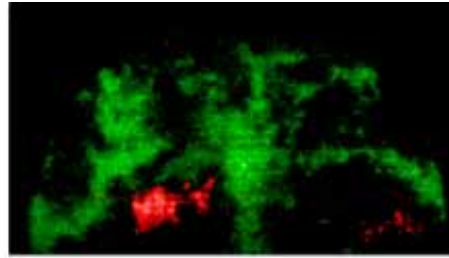
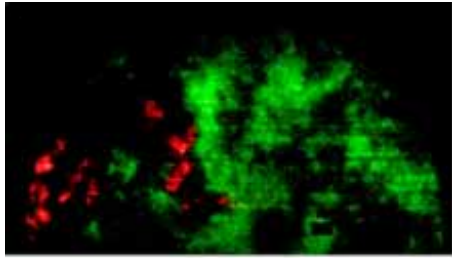


Simultaneous OH- and Formaldehyde-LIF

Volvo Cars DI diesel

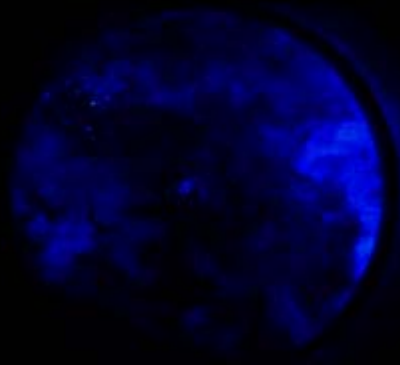


Cycle to cycle variations: 12 image-pairs with homogeneous charge

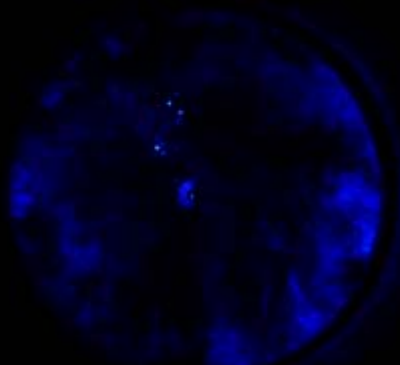


The difference between single shot and average image

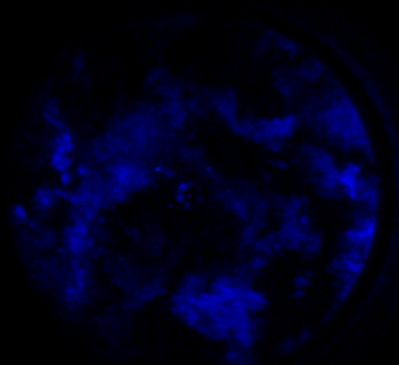
Single



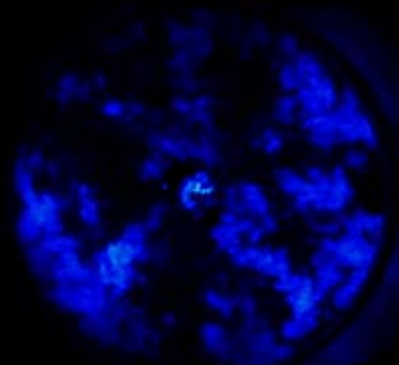
SOI -60ATDC



SOI -50ATDC

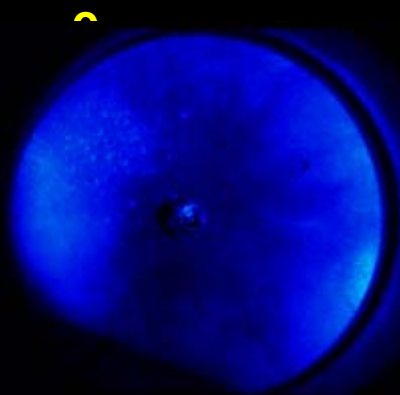


SOI -40ATDC

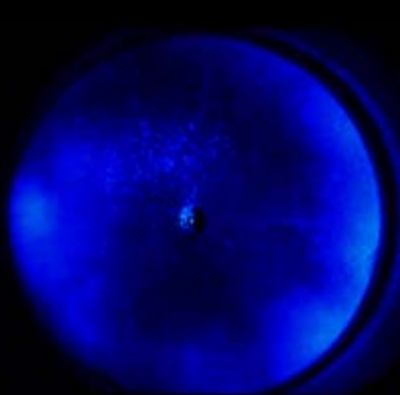


SOI -30ATDC

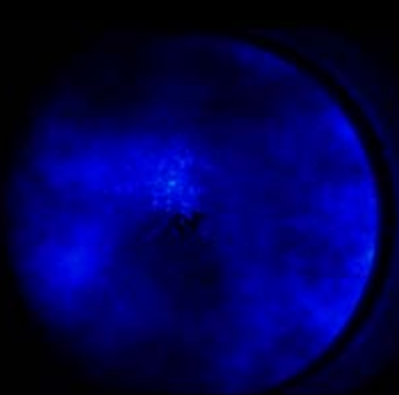
Averag



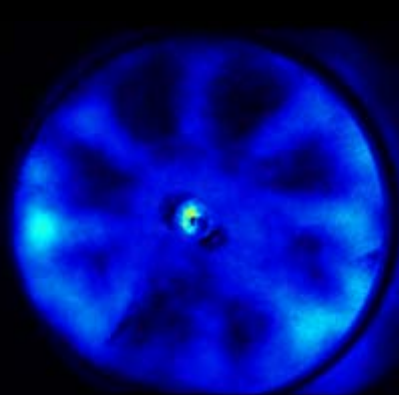
SOI -60ATDC



SOI -50ATDC



SOI -40ATDC



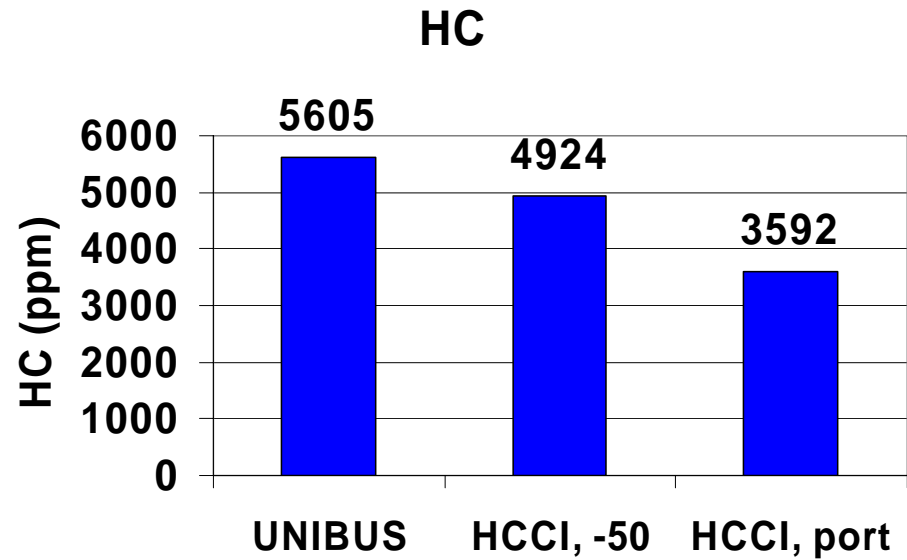
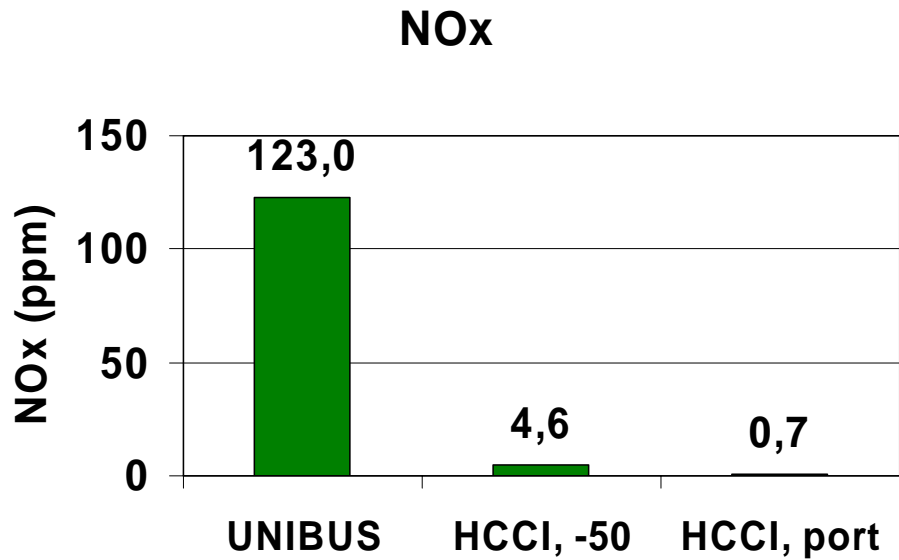
SOI -30ATDC

Injection strategies

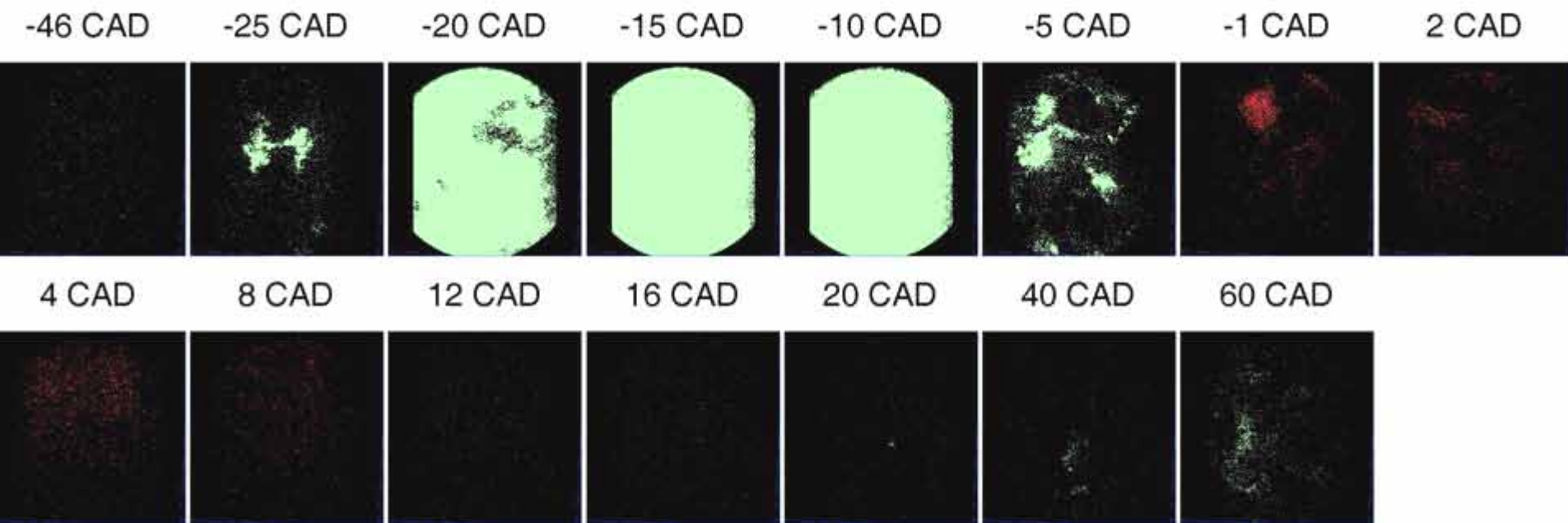
1. **HCCI. Port injection**
2. **HCCI. Injection at 50 CAD BTDC**
3. **UNIBUS. Injection at 50 CAD BTDC and 3 CAD BTDC**

Same IMEP for all conditions, about 1.6 bar
20% EGR

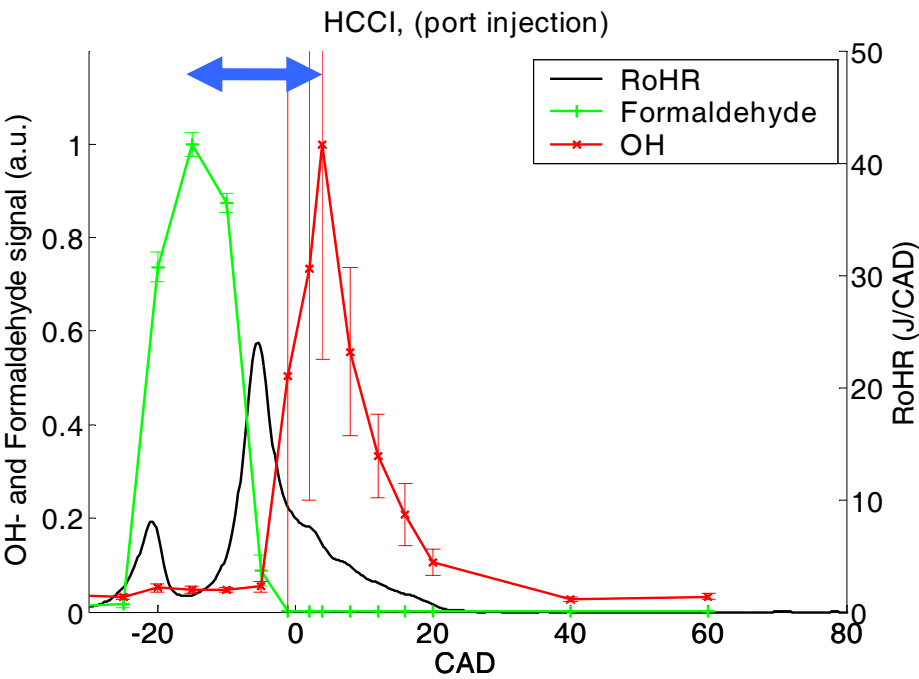
Emissions



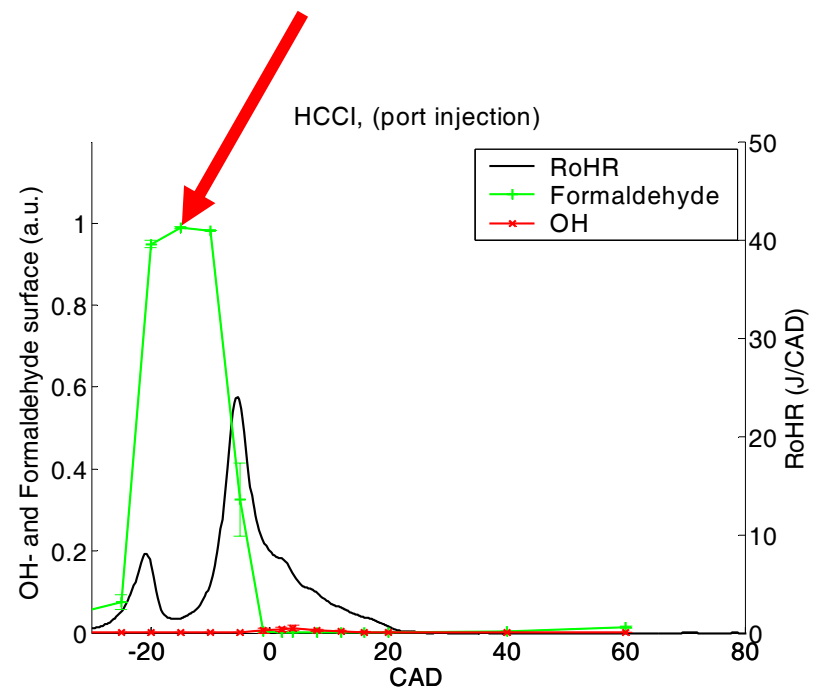
Port inj. HCCI, individual images



Port inj. HCCI, signal and surface

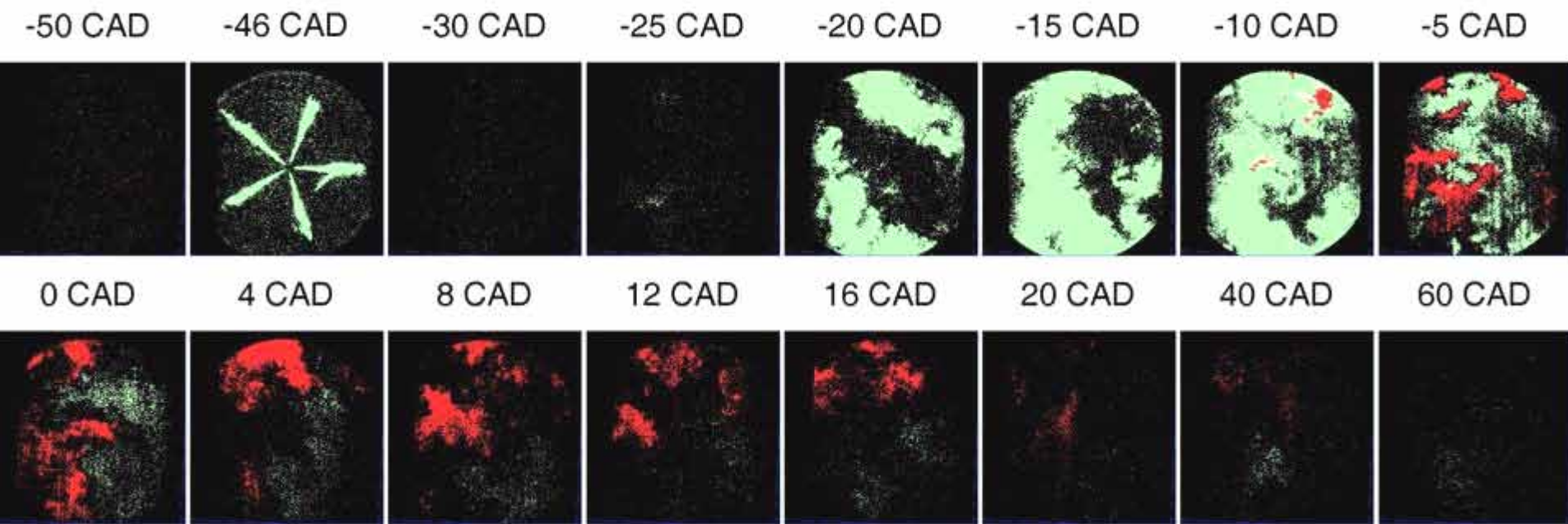


Signal

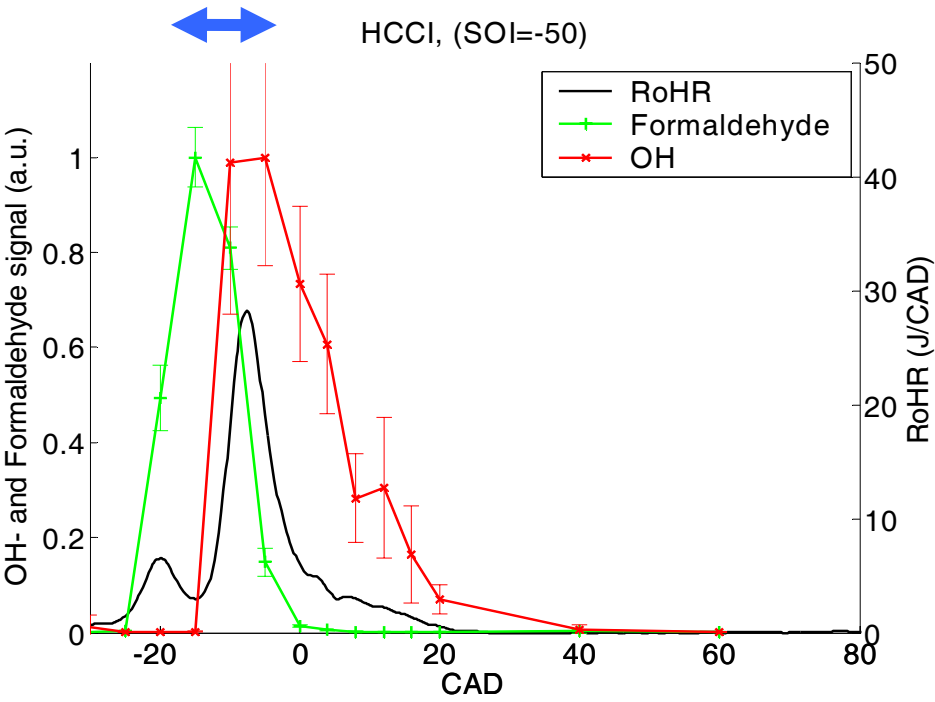


Surface fraction

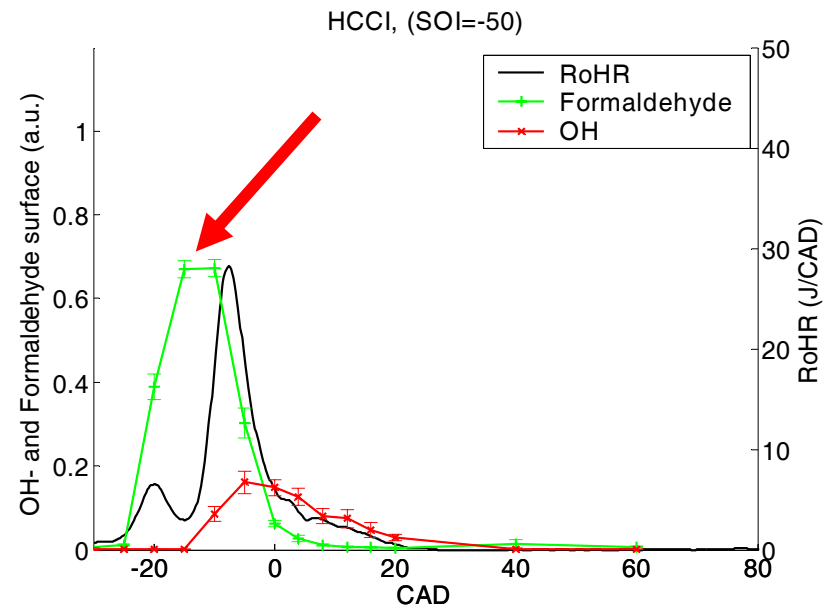
Direct inj. HCCI, individual images



Direct inj. HCCI, signal and surface

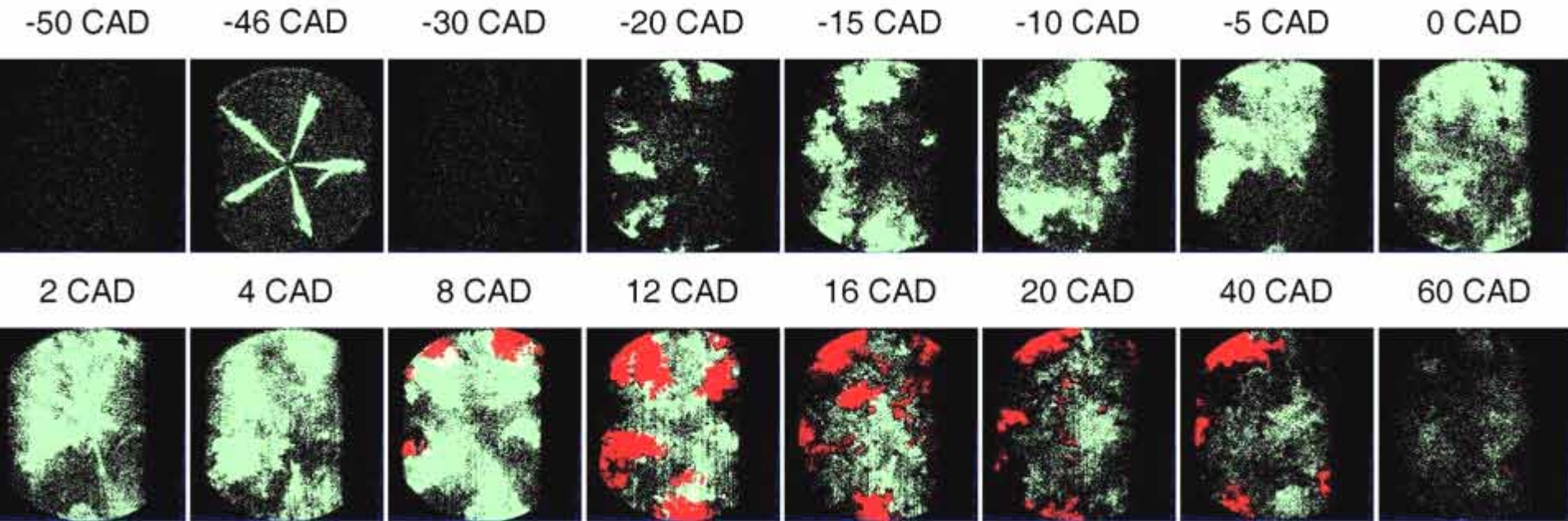


Signal

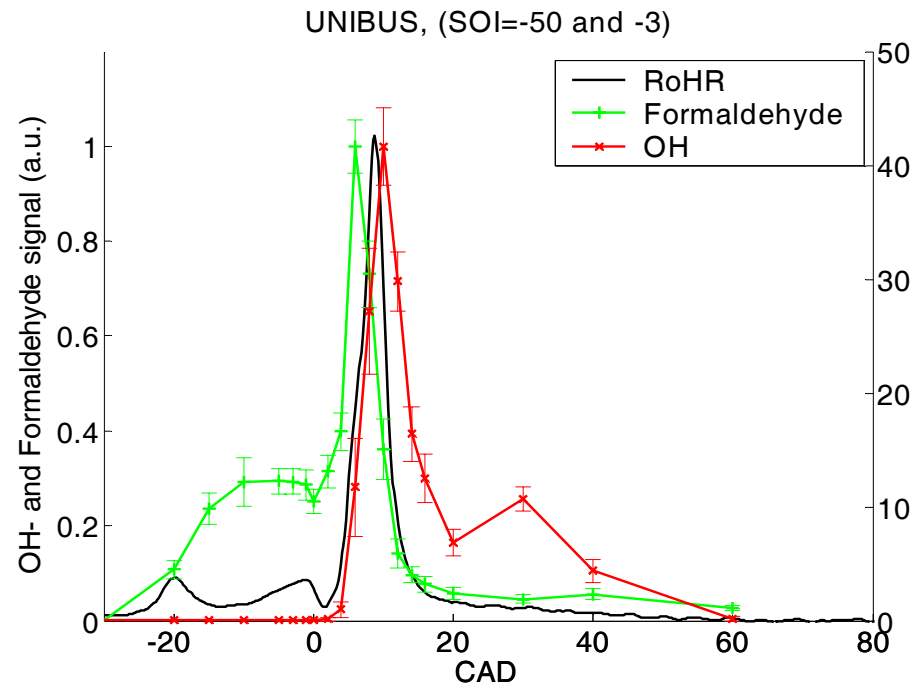


Surface fraction

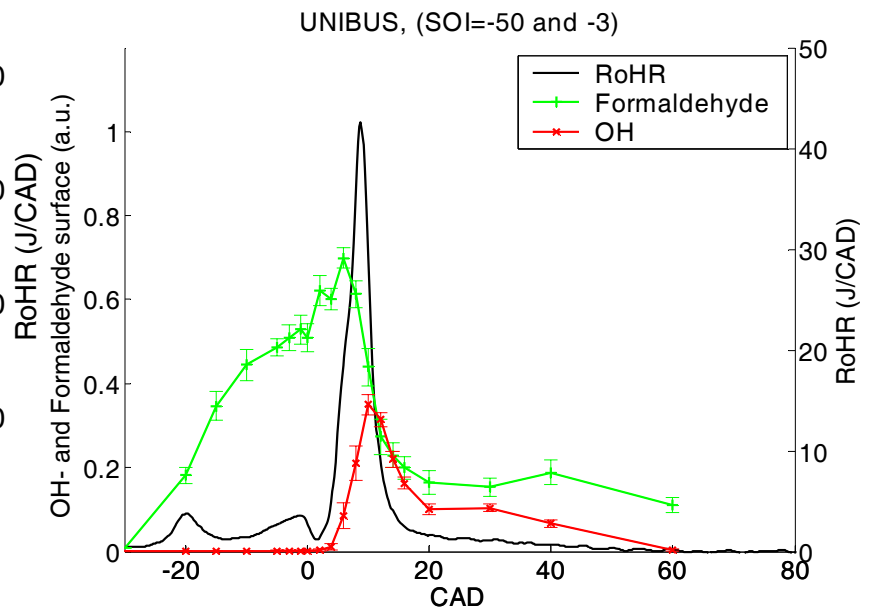
UNIBUS, individual images



UNIBUS, signal and surface



Signal



Surface fraction

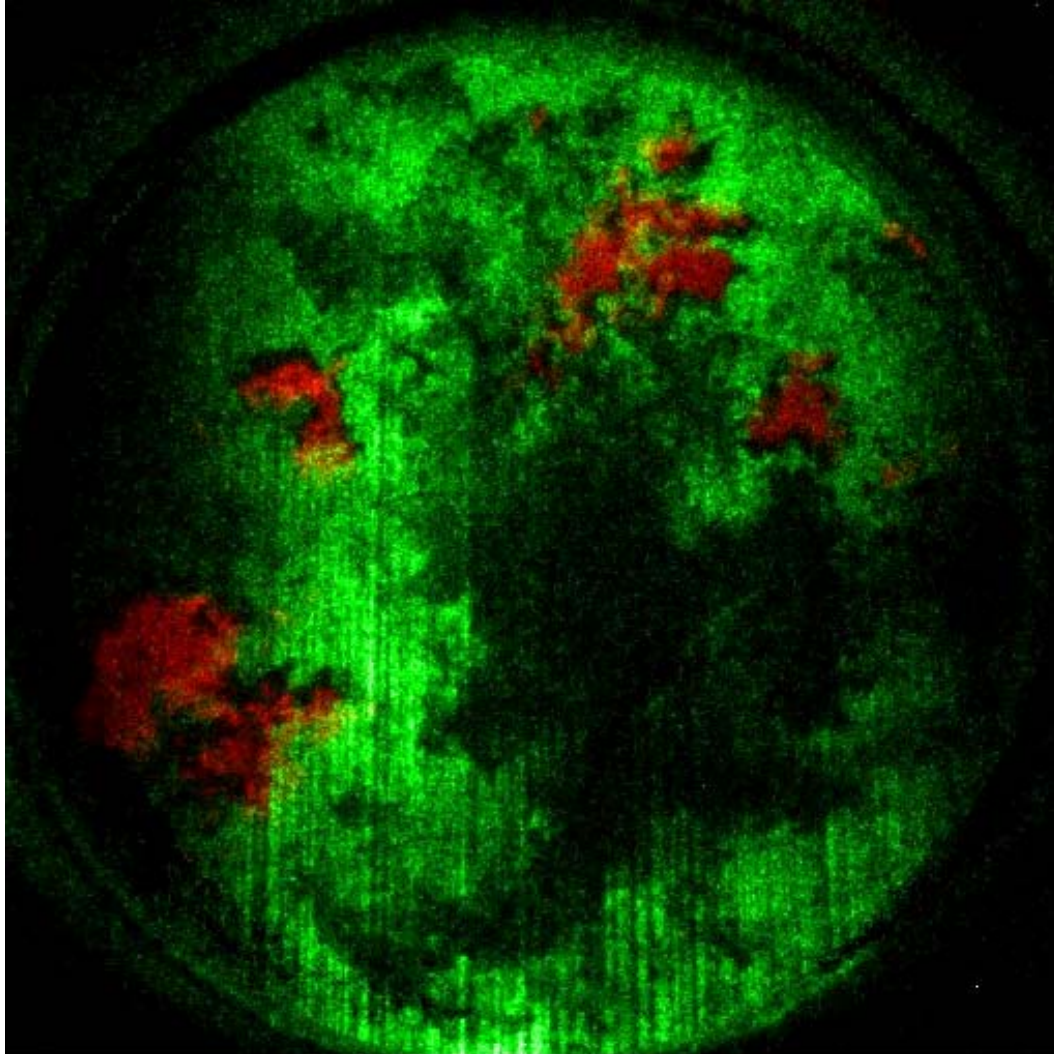
Summary

- The classical diesel diffusion controlled combustion will be complemented with premixed or partially premixed combustion, PPC, in the near future
- PPC will enable low enough NO_x without aftertreatment
- PM is still an issue
- PPC is very sensitive to in-cylinder mixing
- Laser diagnostics can be used to give new insights to the combustion processes in diesel engines

SAE HCCL symposium in Lund

- September 19-20, 2005
- Invited speakers from US, Japan and Europe
- More info at www.sae.org

Thank You!



Acknowledgements

- The work presented has been sponsored by STEM and Vinnova through the Centre of competence combustion processes, KCFP, CeCOST, Green Car (GIHR) and by Swedish and foreign engine companies
- The collaboration with the laser diagnostics group of combustion physics is greatly appreciated.