Methanol Engine Research at Lund University

2016-06-15

Martin Tunér

Division of Combustion Engines
Department of Energy Sciences
Lund University

GreenPilot kick off seminar, 15-16th of June in Gothenburg

Outline

- Engine Research at Lund University
- Benchmarking of Alternative Fuels and Engine Concepts
- Theoretical Emissions Potential for Methanol Combustion
- Methanol Engine Combustion Concepts Under Investigation
- Conclusions and Research Opportunities

Lund University

- Founded in 1666
- 46 000 students
- 2 800 doctoral students
- 6 000 employees
- 562 professors (18 % women)
- Eight faculties
- Several campuses
- EUR 750 million turnover
- 2/3 Research – 1/3 Education

LUND UNIVERSITY

Lund University
46000 students

Faculty of Engineering
(Lund Institute of Technology)
9600 students

Department of Energy Sciences
(former Heat and Power Engineering)
(Staff 90 persons)

Department of Engineering Physics

Department of Automatic Control

Prof.
Anders Rantzer
(staff 35 persons)

Division of **Energy economics and planning**
Prof.
J. Pyrko

Division of **Thermal Power Engineering**
Prof.
Jens Klingmann

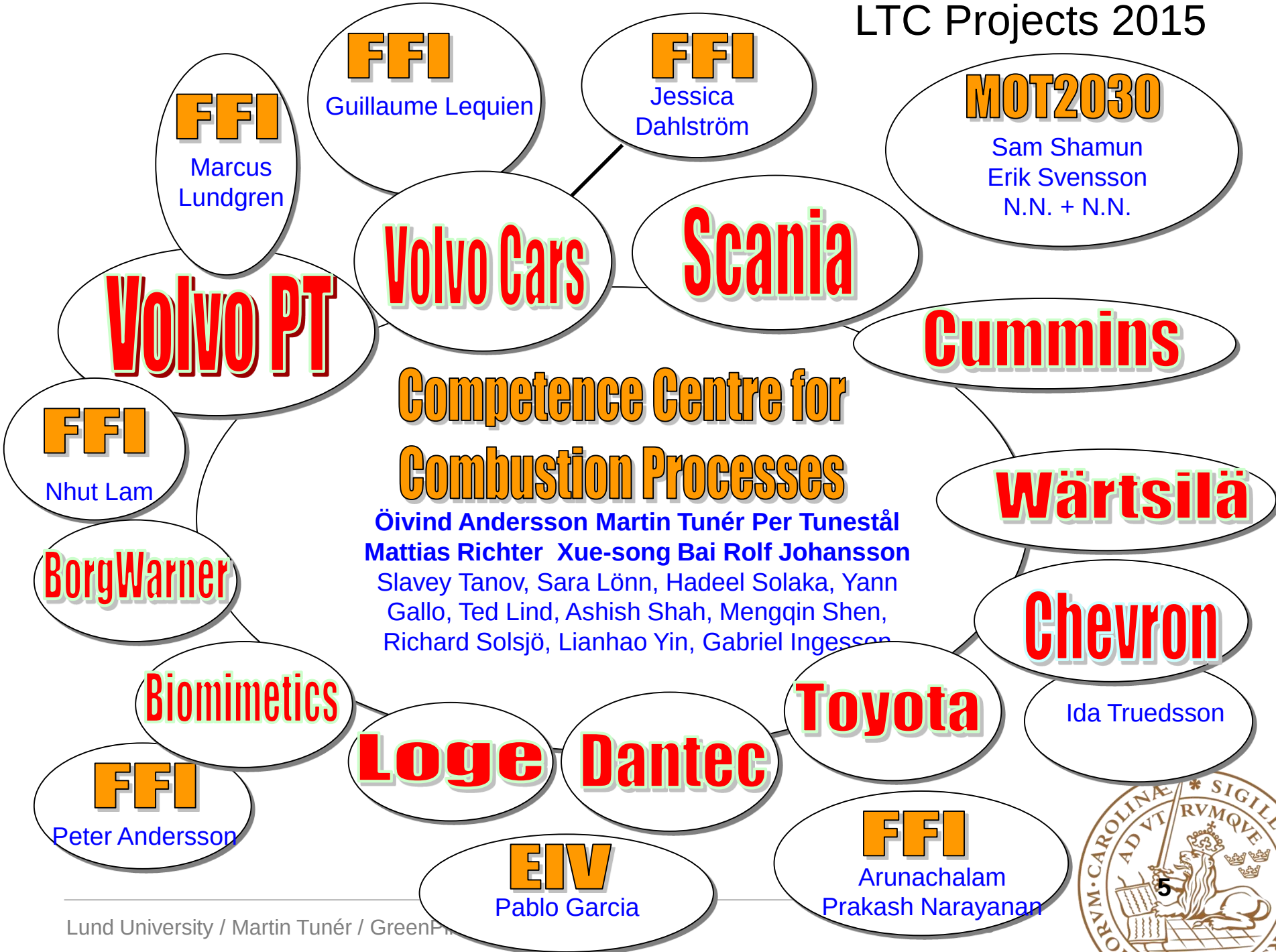
Division of **Heat transfer**
Prof.
Bengt Sundén

Division of **Fluid dynamics**
Prof.
Johan Revstedt

Division of **Combustion Engines**
Prof.
Öivind Andersson
(staff 32 persons)

Division of **Combustion Physics**
Prof.
Marcus Aldén
(staff 40 persons)

LTC Projects 2015



Lund Engine Labs

Light duty engines

1. Volvo D5 optical engine for PPC
2. Volvo D5 optical engine for diesel
3. Volvo VEA multi cylinder for PPC
4. Volvo VEA multi cylinder for LTC
5. CFR engine for fuel testing
6. Volvo VEP for education/projects

Heavy duty engines

1. Scania D13 optical engine for PPC
2. Scania D13 optical engine for diesel
3. Volvo D13 optical engine for PPC
4. Scania D13 single cylinder engine for PPC
5. Volvo D13 six-cylinder for PPC
6. Volvo D13 six-cylinder for dual fuel/HAM
7. Scania D13 six-cylinder for PPC

Medium speed engine

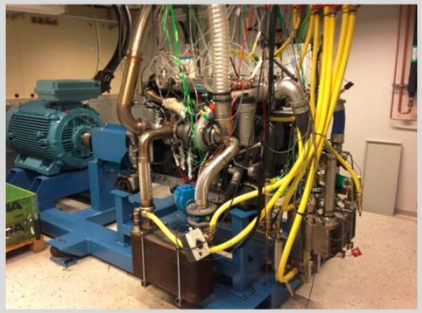
1. Wärtsilä 20 optical engine

– KCFP
– Other projects

MOT-2030

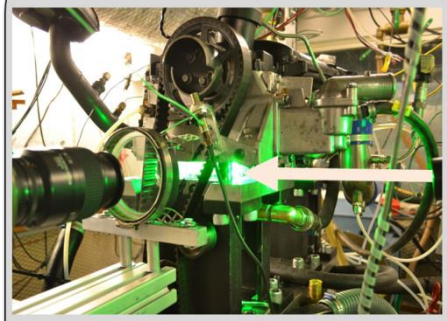
Highly Efficient Methanol Engine Systems for Fossil Free Transportation 2030

Engine experiments



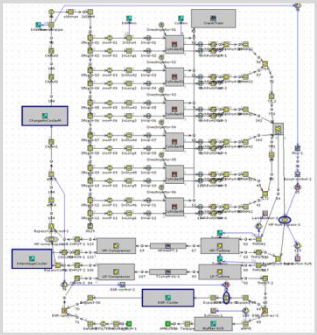
Investigate/explain emissions and efficiency performance of methanol in PPC engines

Optical diagnostics



Investigate/explain various phenomenon of methanol combustion inside the PPC engine

System analysis

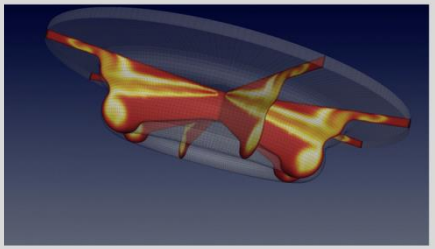


Investigate/explain overall Well-To-Wheel PPC engine performance with methanol

Supporting companies

In-house tests and other experience of methanol fuel in engines

Advanced modeling

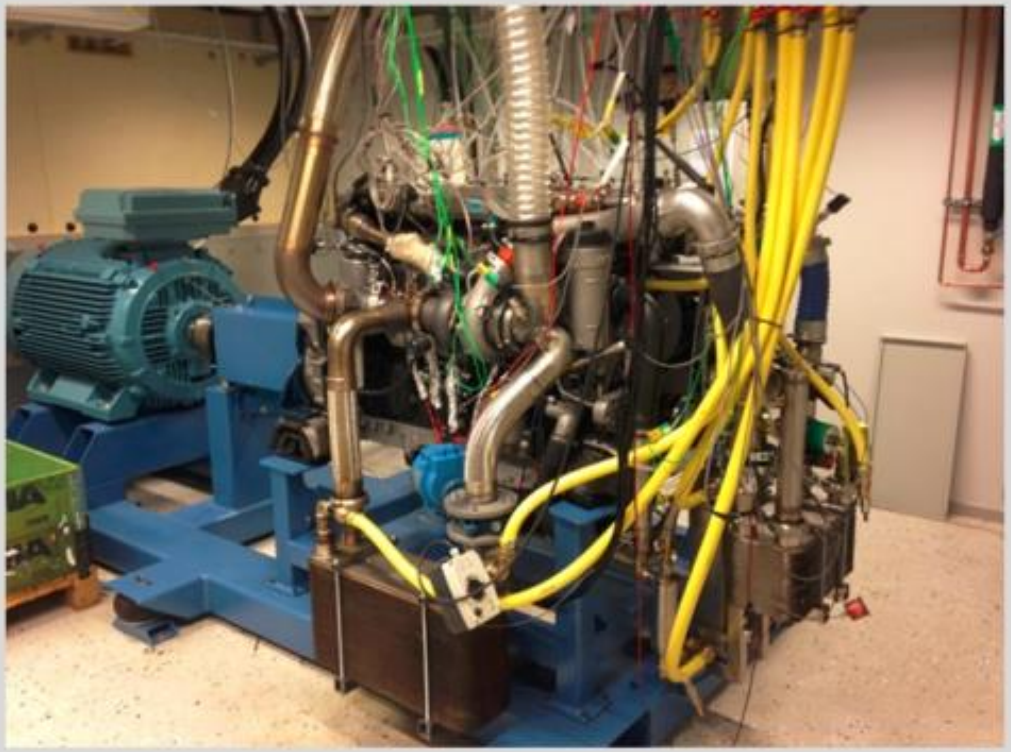


Investigate/explain relations between chemistry, heat release, heat transfer and engine physical parameters for methanol PPC

MOT-20

Highly Efficient Methanol
for Fossil Free Transp

Engine experiments



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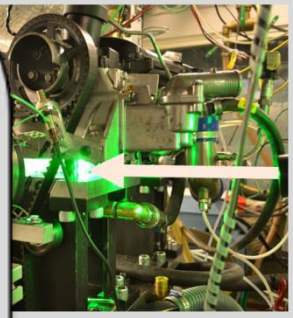

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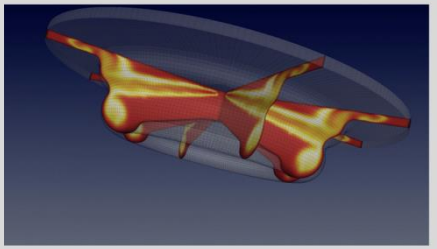

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www.lth.s

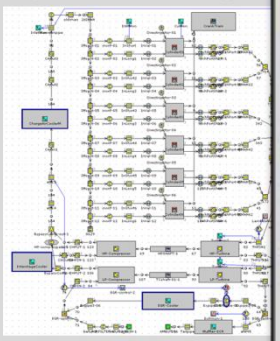
MOT-2030

Highly Efficient Methanol Engine Systems for Fossil Free Transportation 2030

Engine ex

Investiga
efficiency

System analysi



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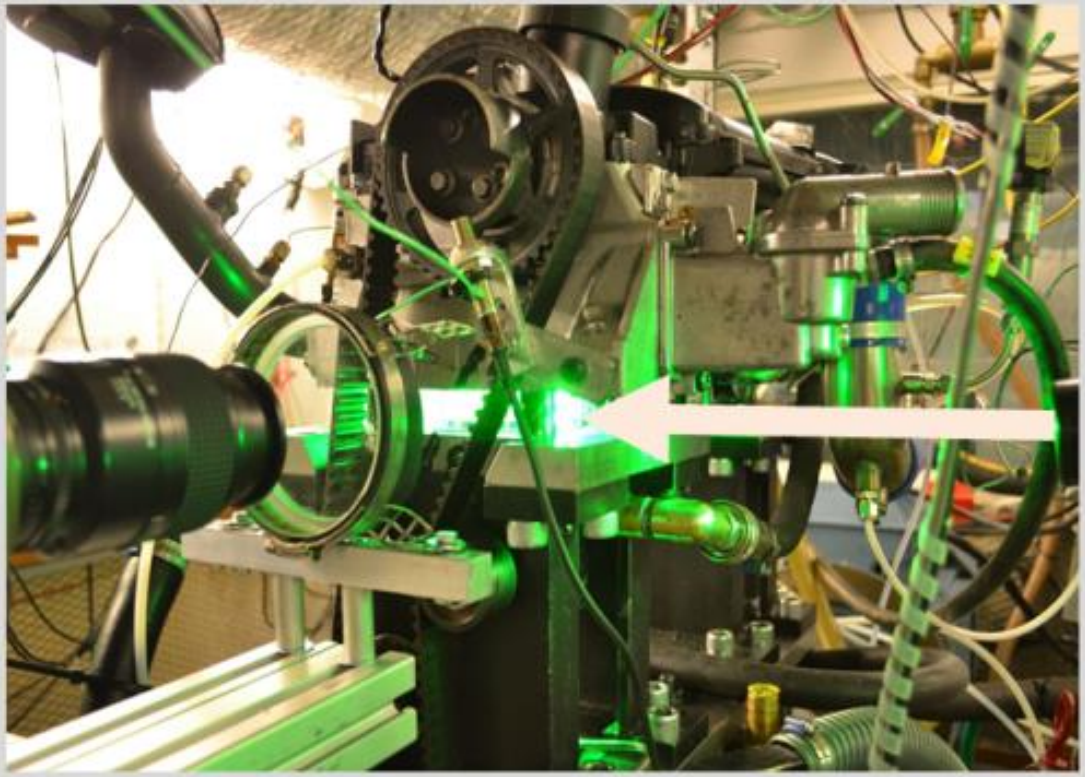

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www.lth.se/mot2030

MOT-2030

Highly Efficient Methanol Engine Systems for Fossil Free Transportation 2030

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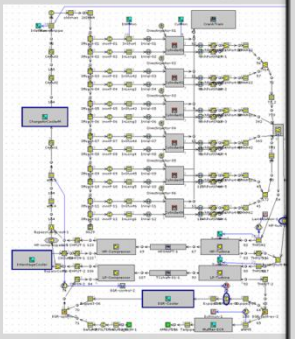
System analysis



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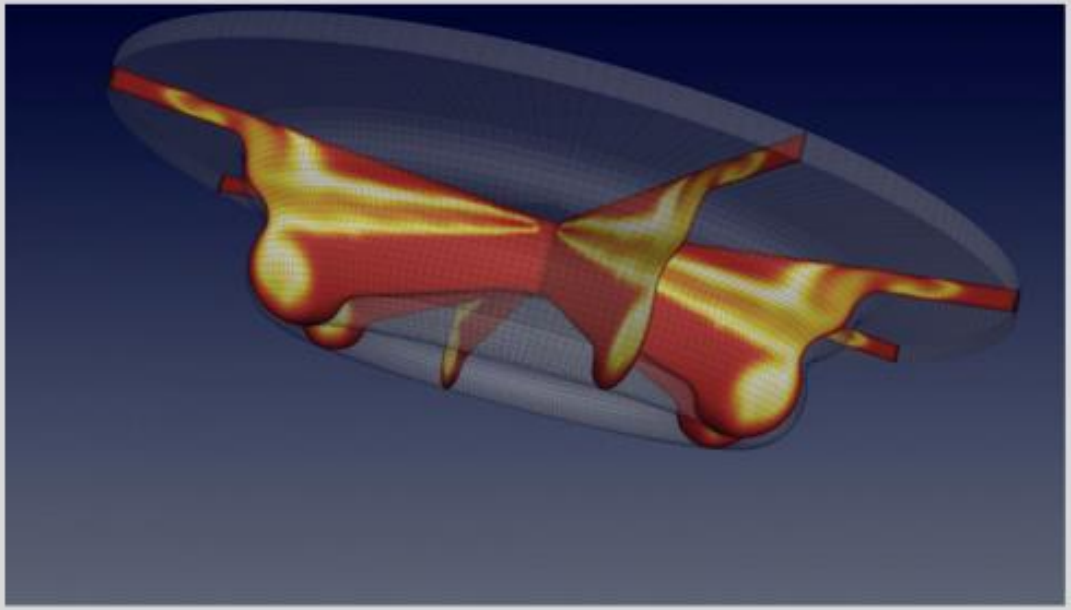

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Highly Efficient Me
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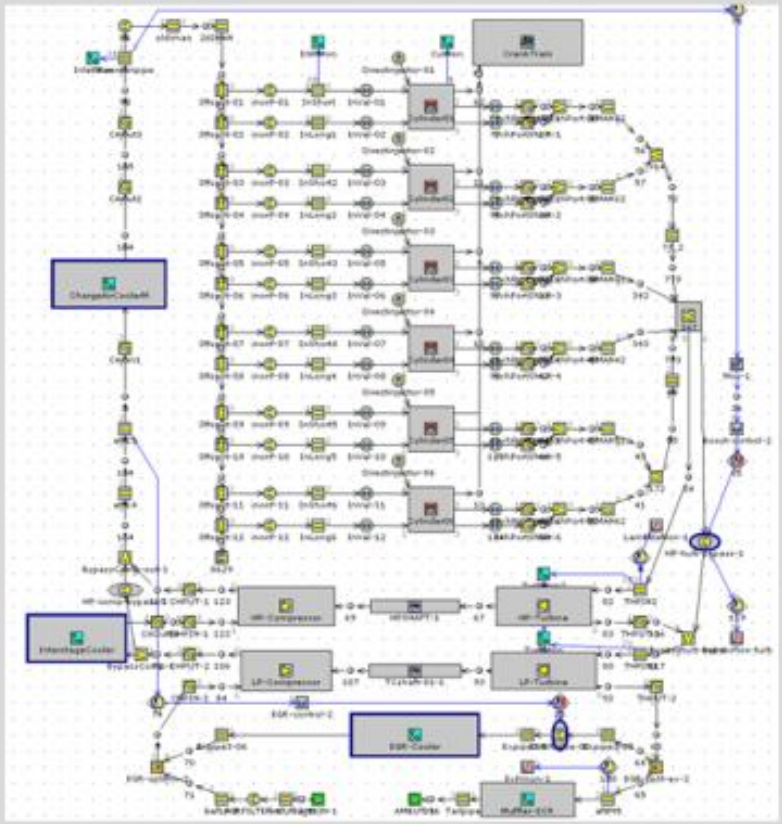

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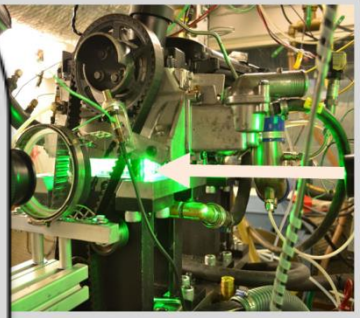

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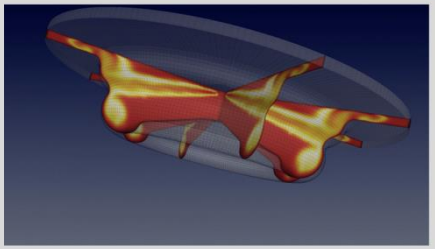

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MOT-2030

Highly Efficient Methanol Engine Systems
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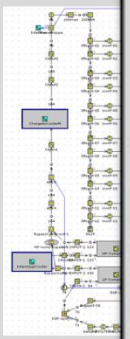
Supporting companies

Syste



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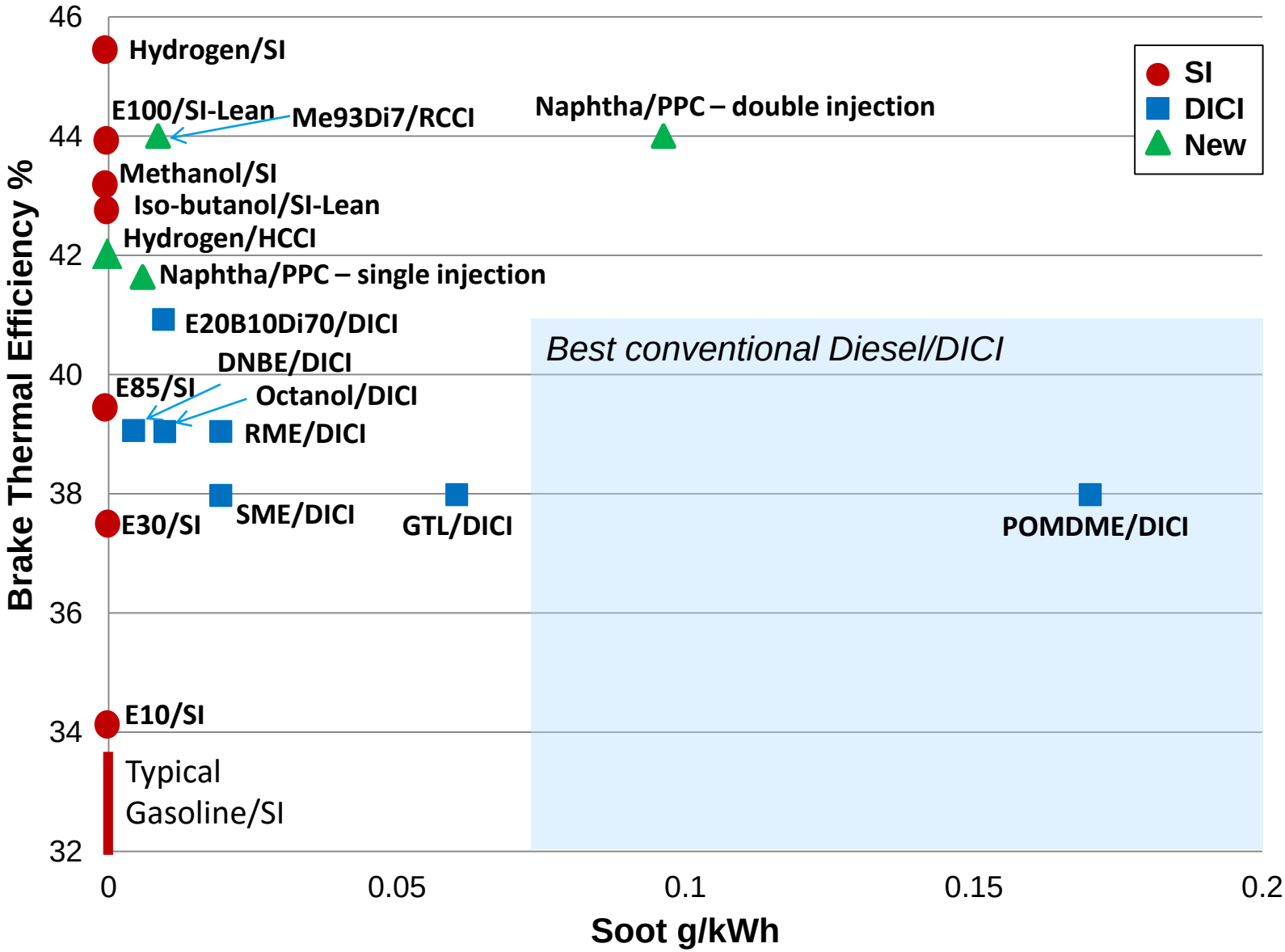
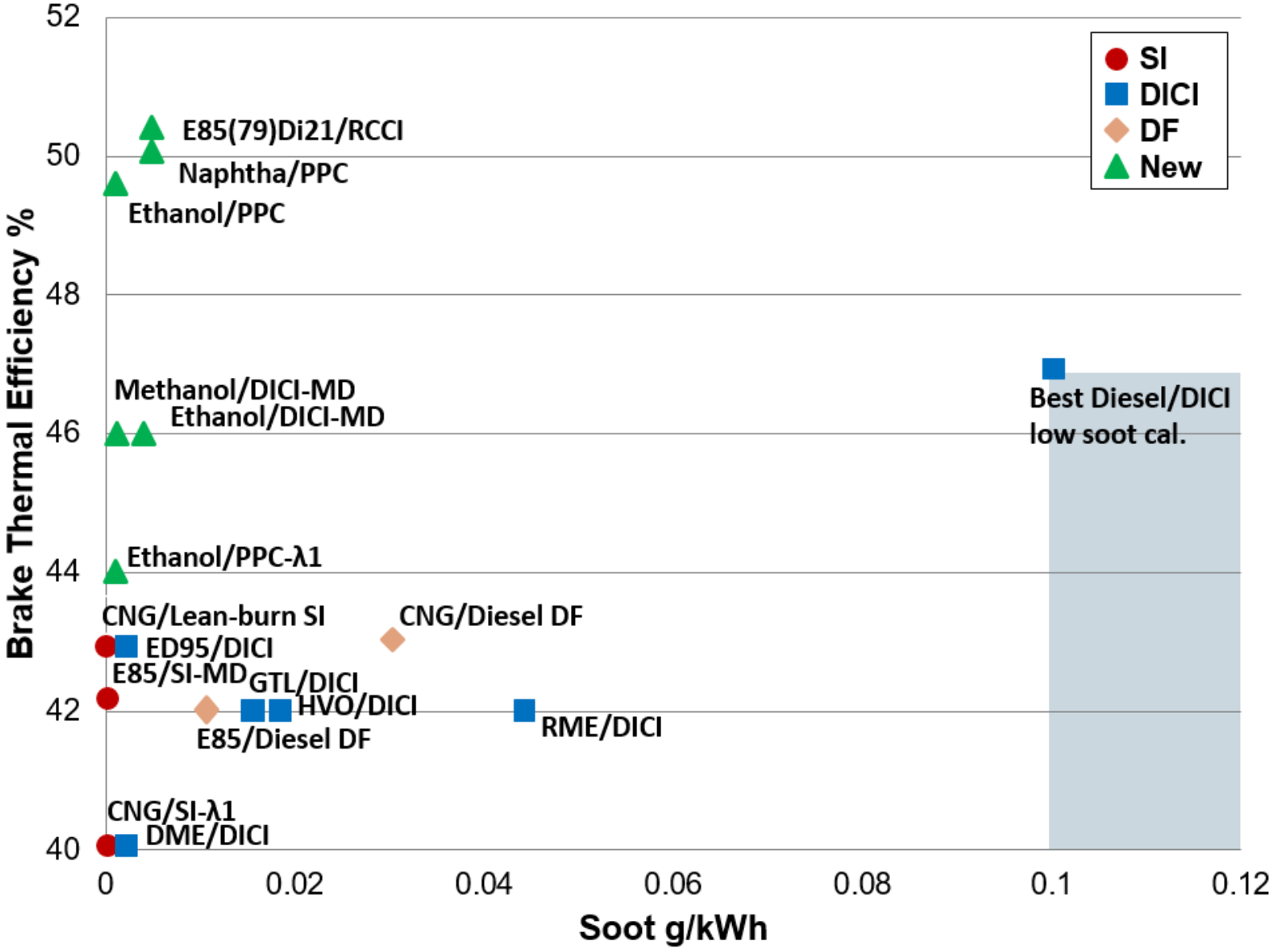
In-house tests and other experience of methanol fuel in engines

www.lth.se/mot2030

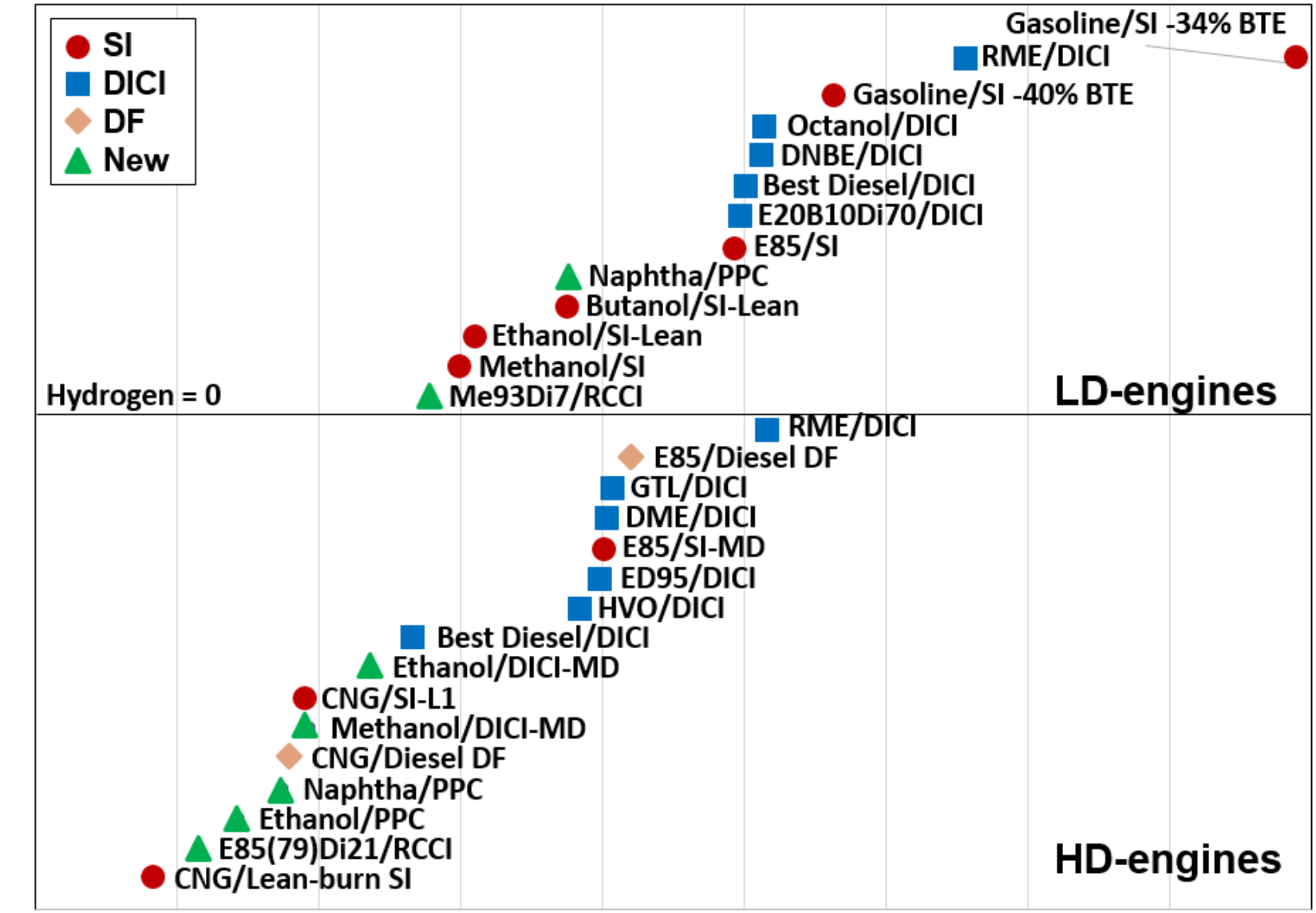
BTE and engine-out soot - LD engines



BTE and engine-out soot - HD engines

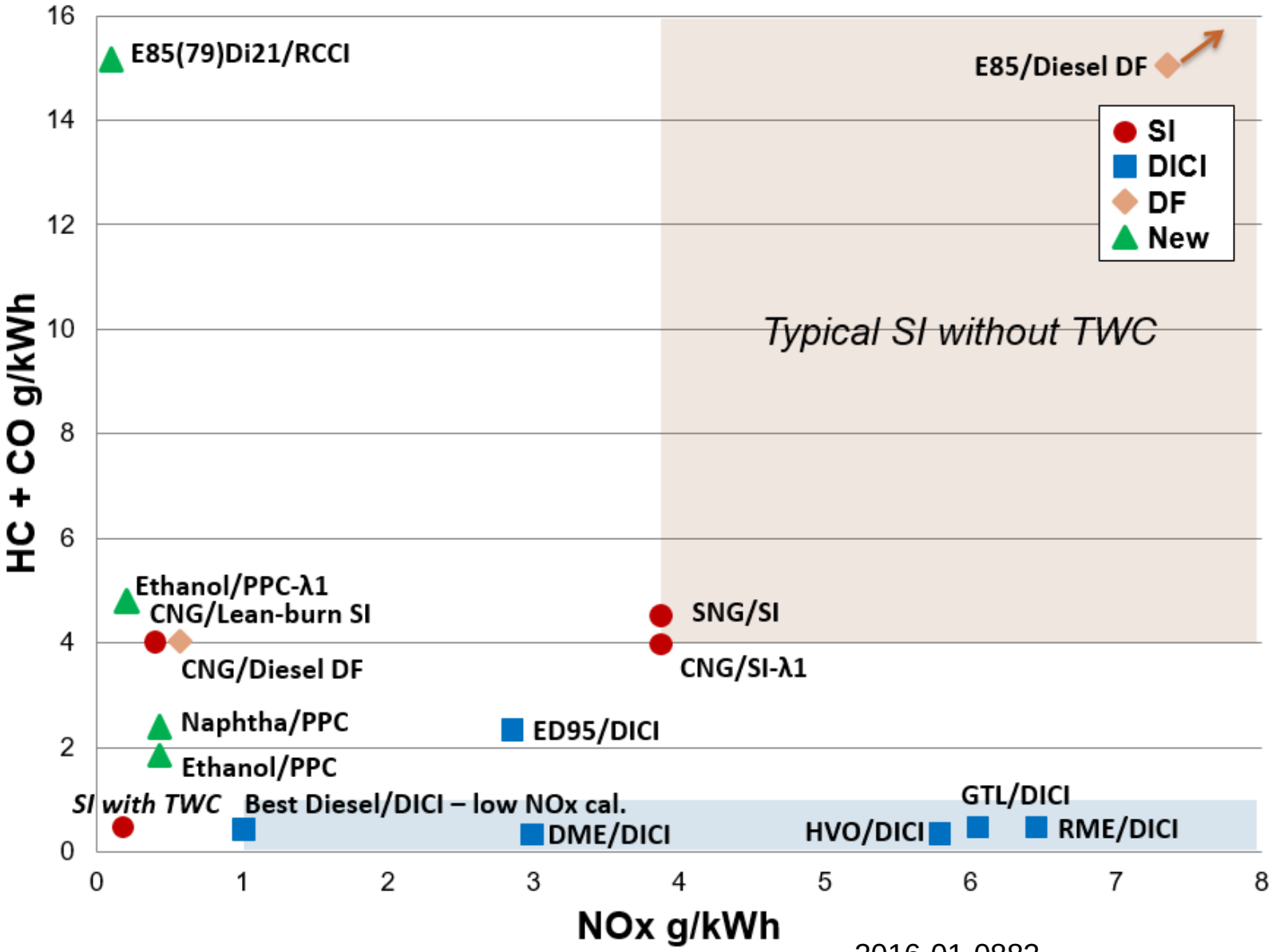


CO_2 tailpipe emissions, Tank-To-Engine output shaft



Paper 2016-01-0882

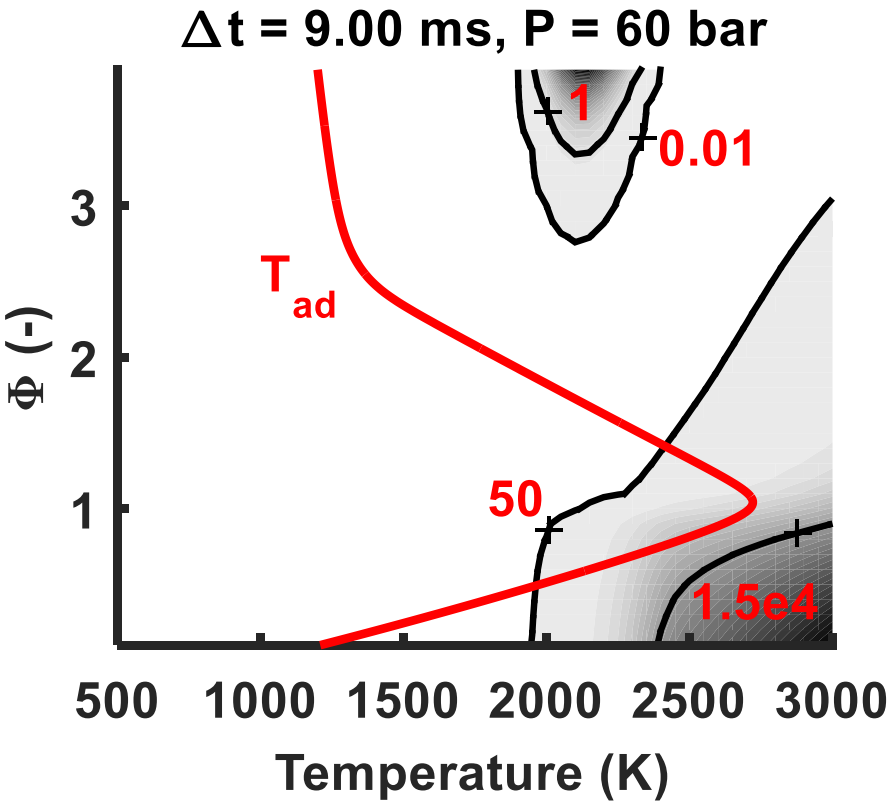
Engine-out emissions - HD engines



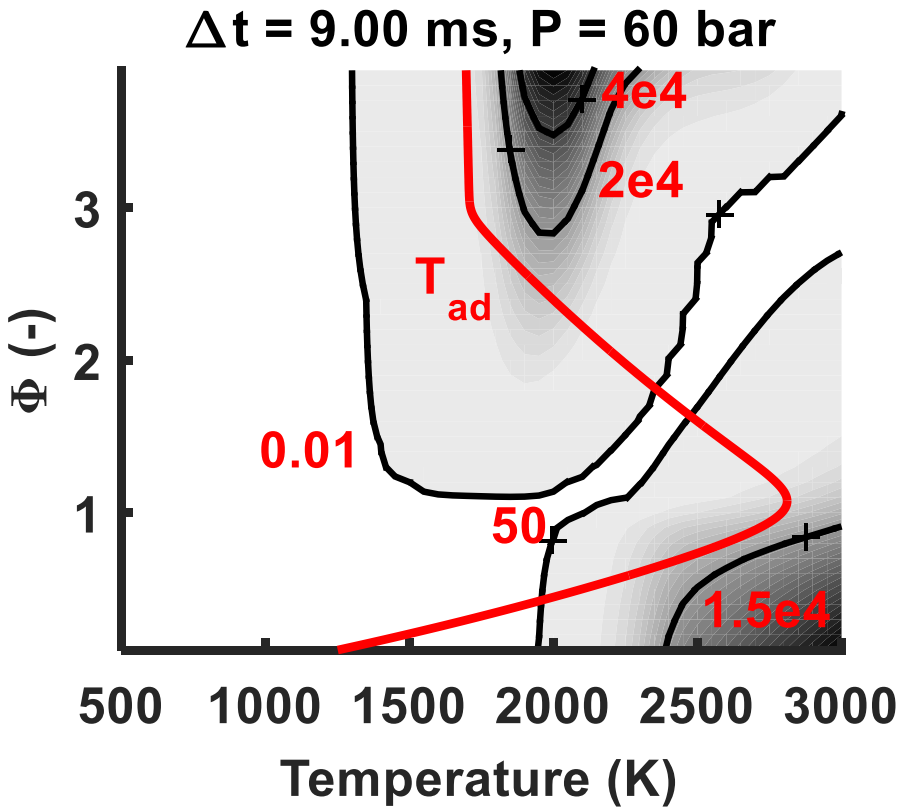
Theoretical Emissions Potential for Methanol Combustion

Theoretical NOx and Soot emissions

Methanol



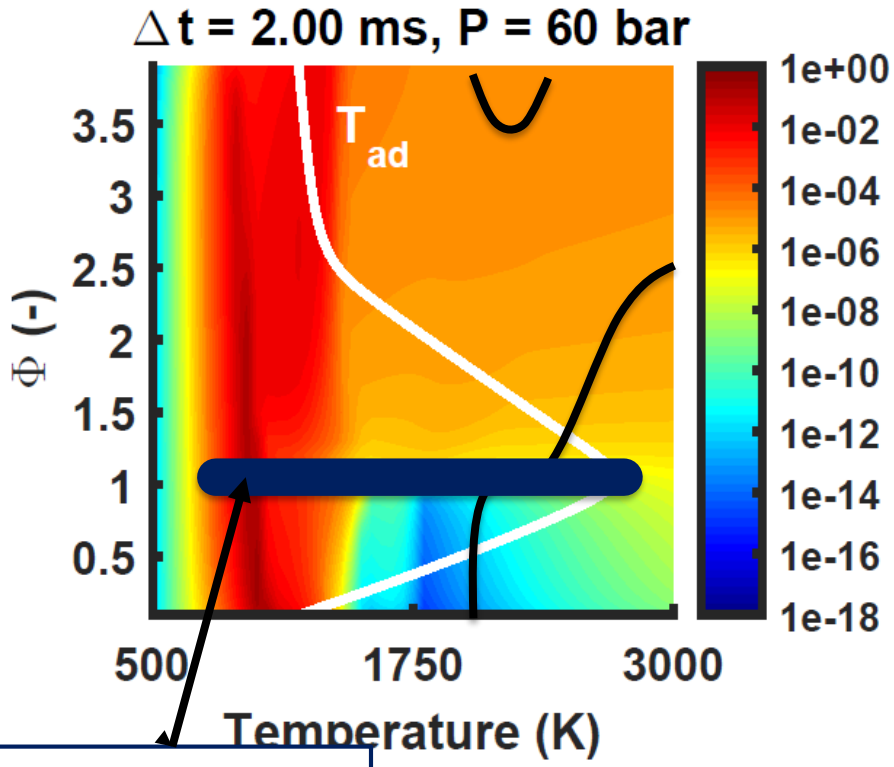
Diesel



Svensson et al. Potential Emission Levels of Soot, NOx, HC and CO in the T-Phi Plane for Methanol, SAE 2016-01-0887

Why methanol engines have been associated with high formaldehyde emissions and formation of formic acid

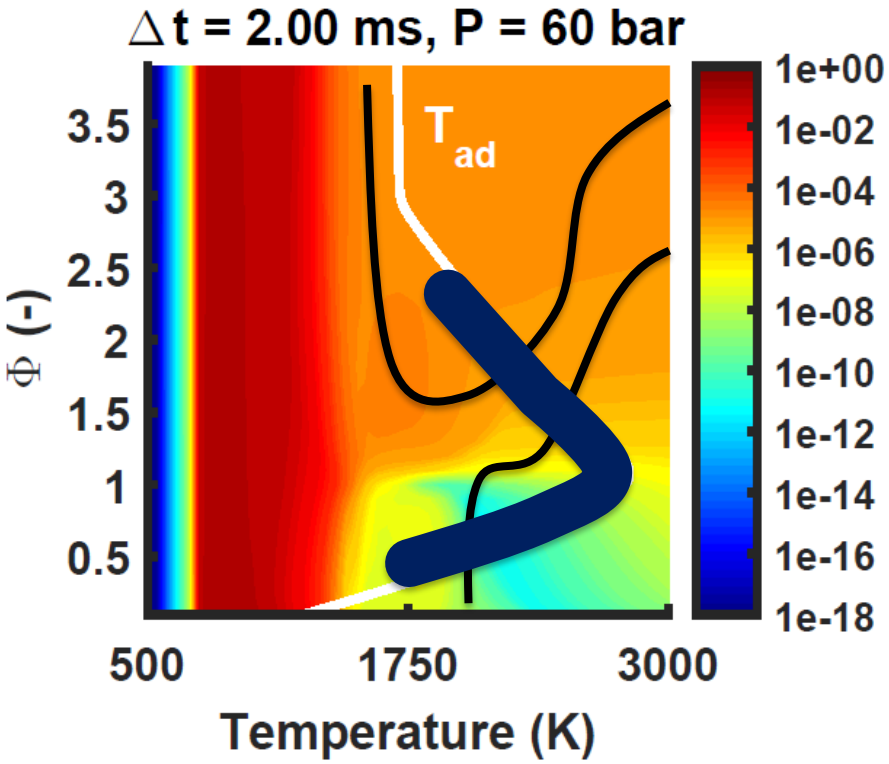
Conventional MeOH premixed SI combustion



Wall quenching

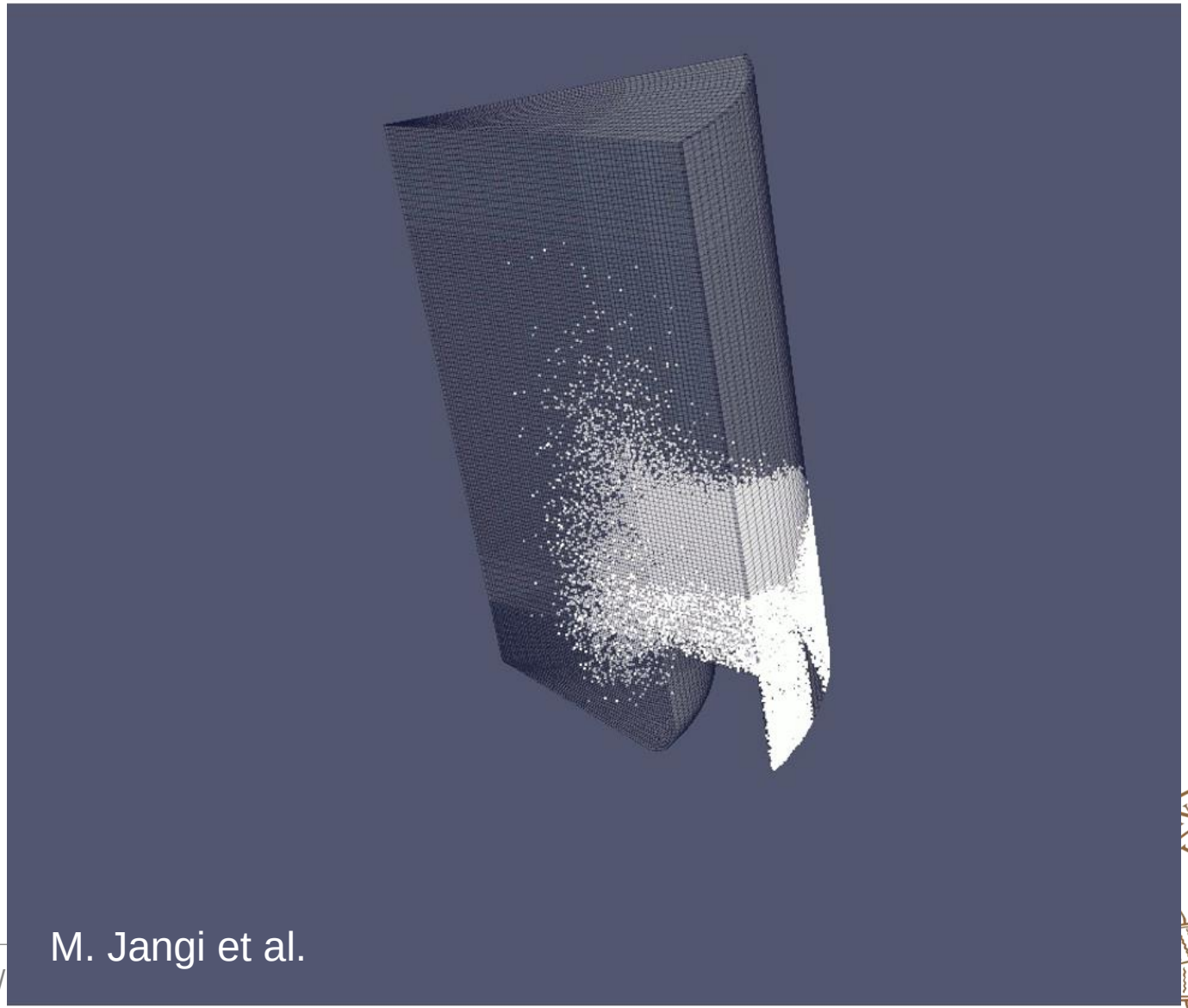
$_2$O - Methanol

Conventional Diesel combustion



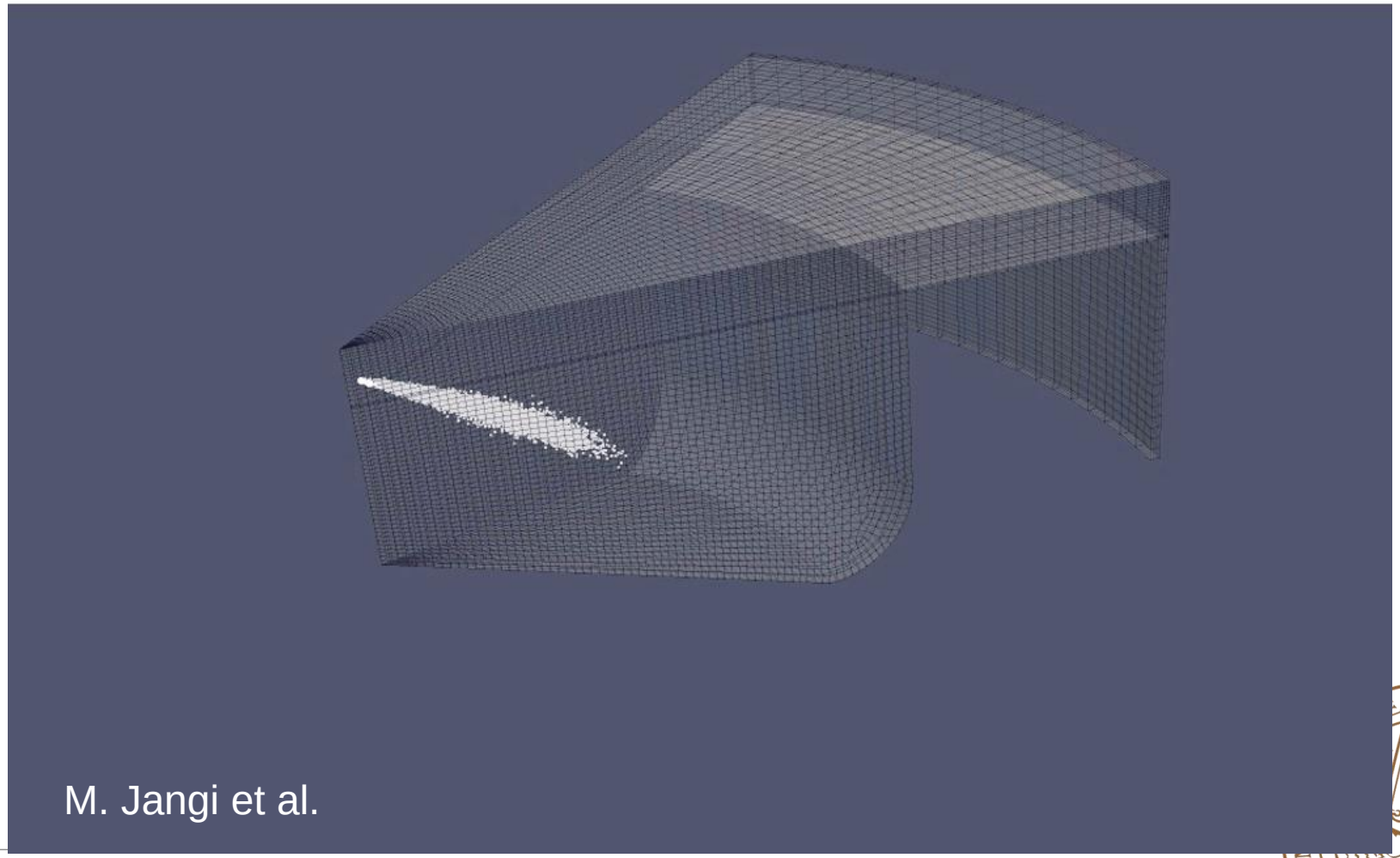
b) CH_2O - Diesel

Early injection – premixed SI



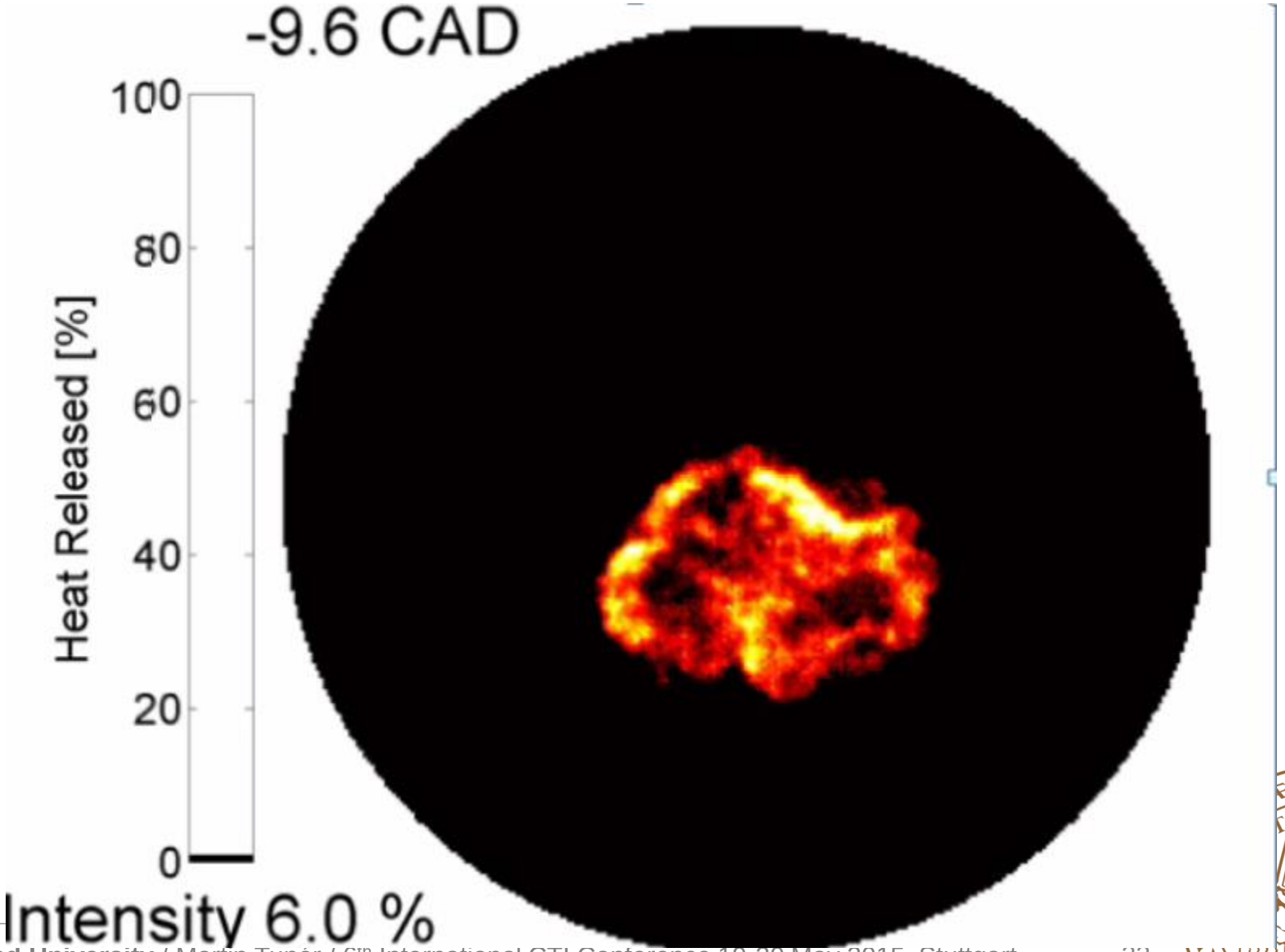
M. Jangi et al.

Late injection – PPC

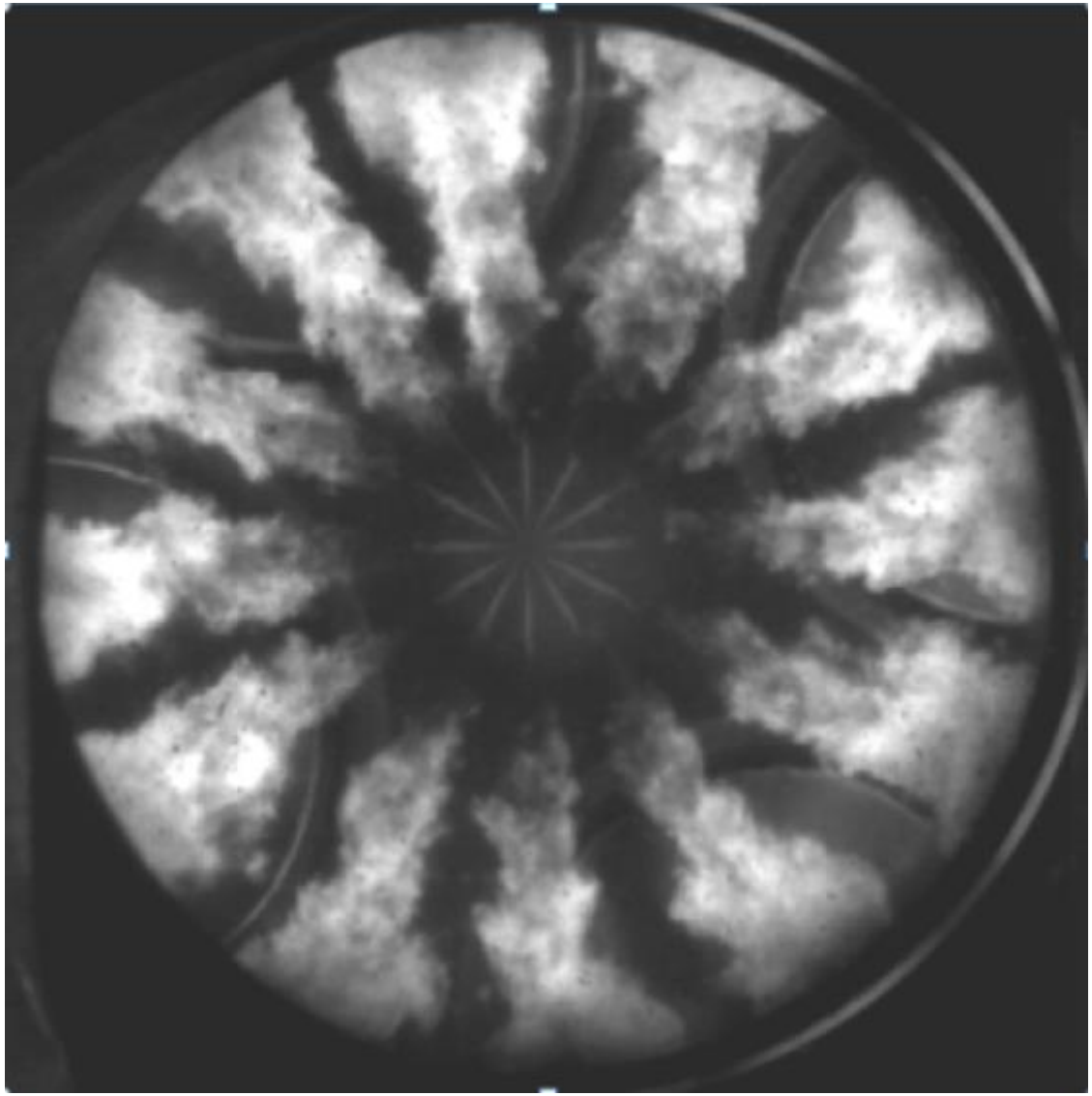


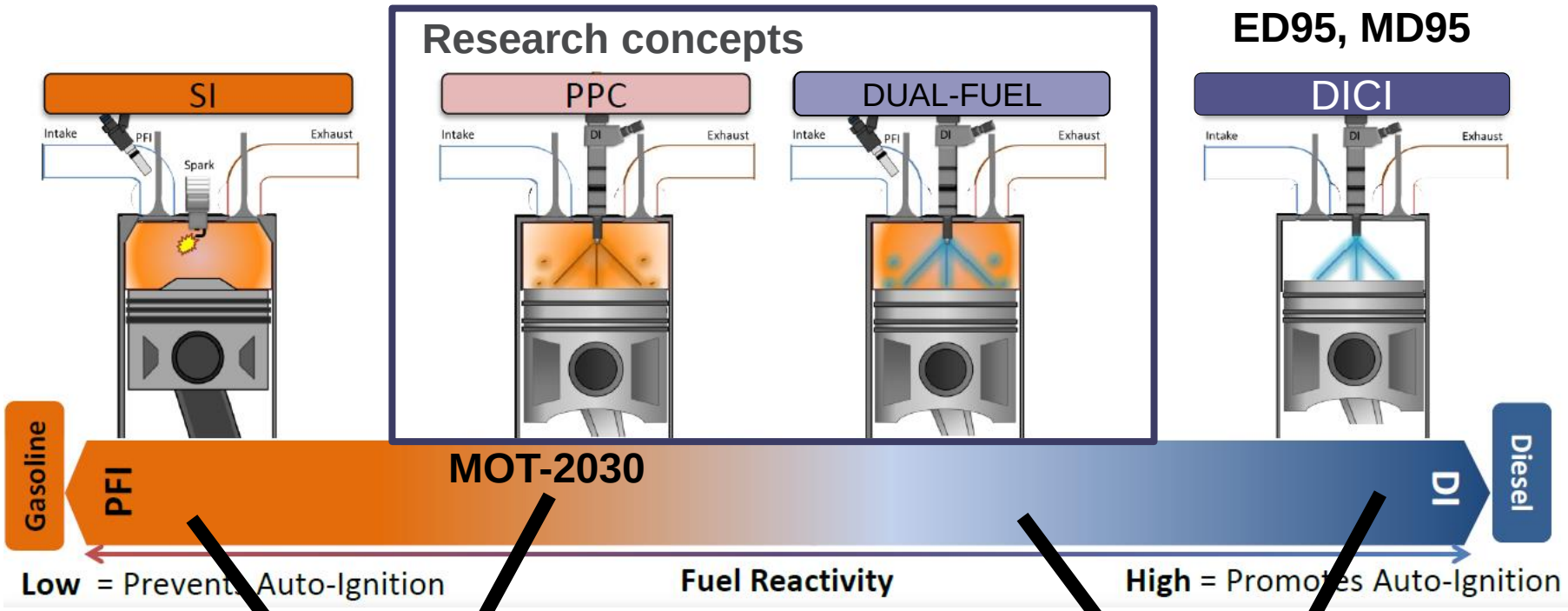
Methanol Engine Combustion Concepts Under Investigation

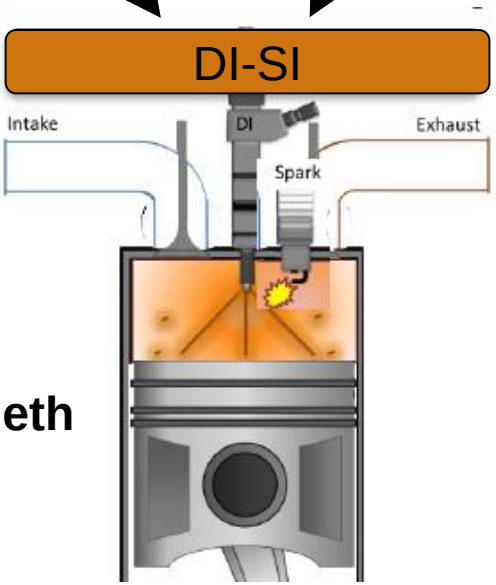
SI combustion – flame propagation



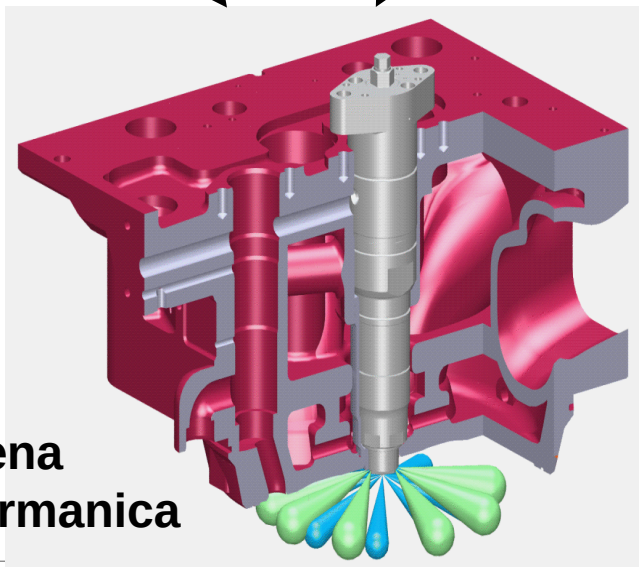
DI combustion – diffusion flame







Summeth



Stena Germanica

Conclusions

Methanol

- One of the most promising candidates for low cost, high efficiency and low emissions operation
- Neat methanol combustion is soot-free

Direct Injection and Compression Ignition MeOH op.

- Dual fuel with direct injected diesel and port injected alcohols is established but lead to high emissions
- Wärtsiläs concept with double late direct injected dual fuel is functional and associated with reduced emissions

PPC

- High efficiency, low emissions and high load op. Fuel flexible.
- Still some immaturities as research concept: Low load - cold start issues, high combustion noise
- PPC-MeOH is possible

Observations & Research opportunities

- Late direct injection reduces formaldehyde and formic acid emissions – Something to pursue further in SI, DICI and PPC

- SI-MeOH will work. How well is the question!

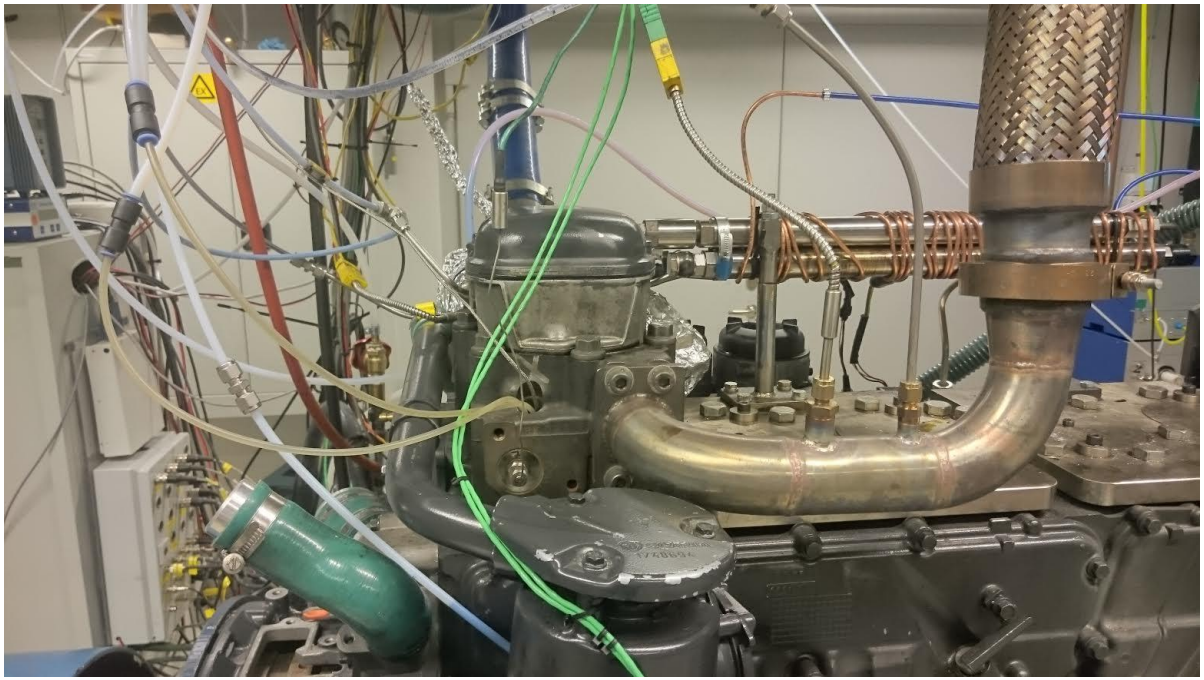
- Is 60% gross efficiency within reach for HD-MeOH engines?

- Methanol has high sensitivity and high heat of vaporization – Is this combination a key feature in managing both high and low loads in compression ignition of neat methanol (for instance PPC)?

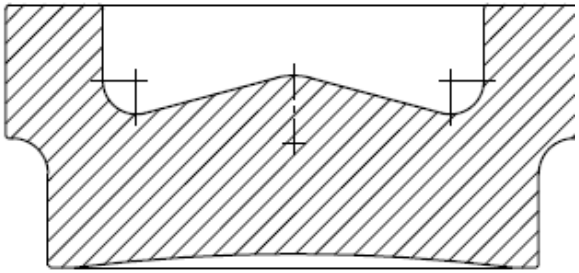
Extra slides

Test Rig

- Single cylinder Scania D13 Engine
- XPI injection system
- 10 hole injector with bigger holes for higher flow rate, 148^0 umbrella angle

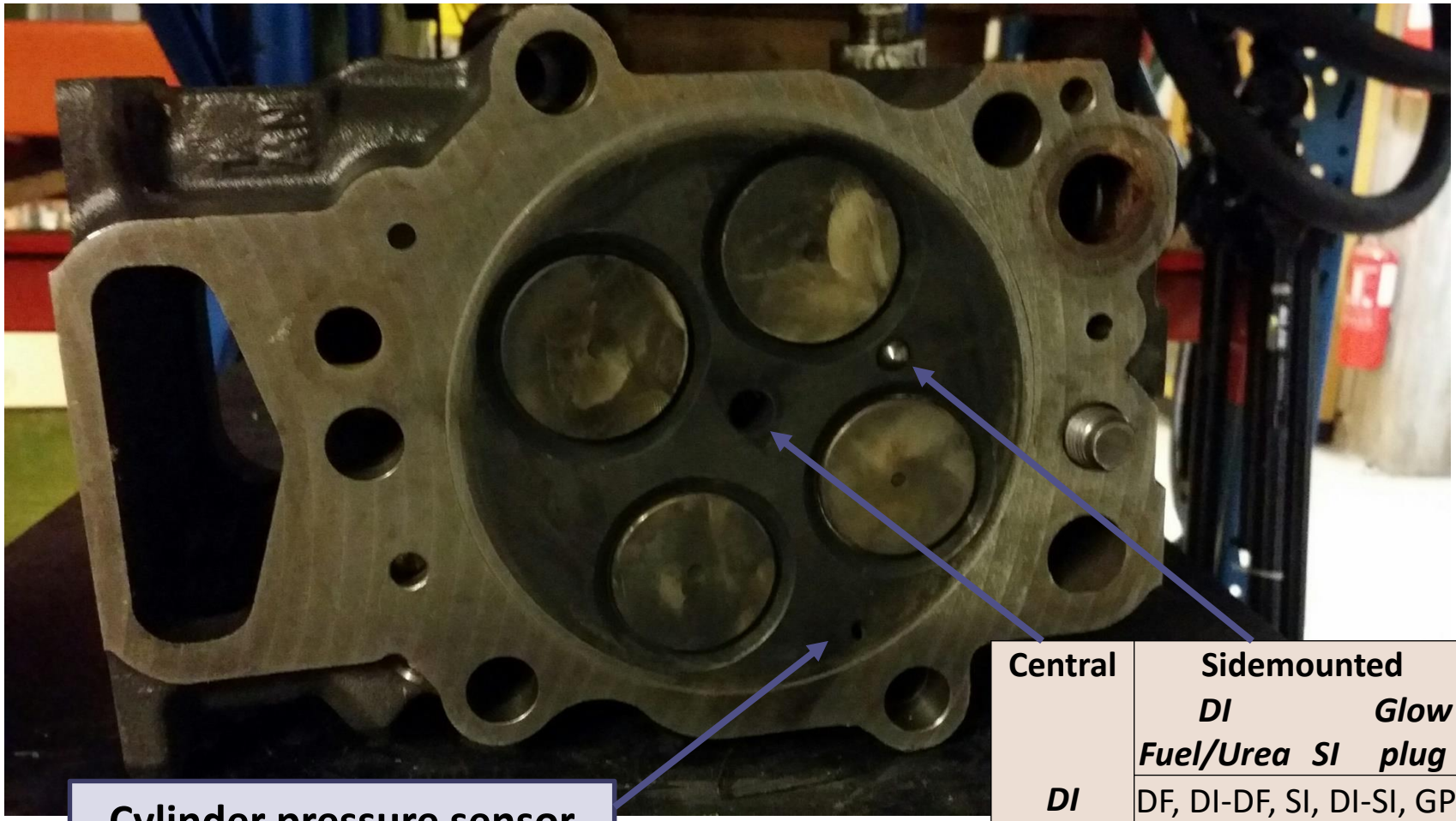


V_d	2124 cm^2
Stroke	160 mm
Bore	130 mm
r_c	15:1 nominal
Swirl ratio	2.1
IVC	-141 CAD ATDC
EVO	137 CAD ATDC



Piston Geometry

Multi-mode cylinder head



Central	Sidemounted			Port
	DI		*Glow*	
	Fuel/Urea	*SI*	*plug*	*PFI*
DI	DF, DI-DF, SI, DI-SI, GP ass DI, DI-			
SI	Urea etc etc			

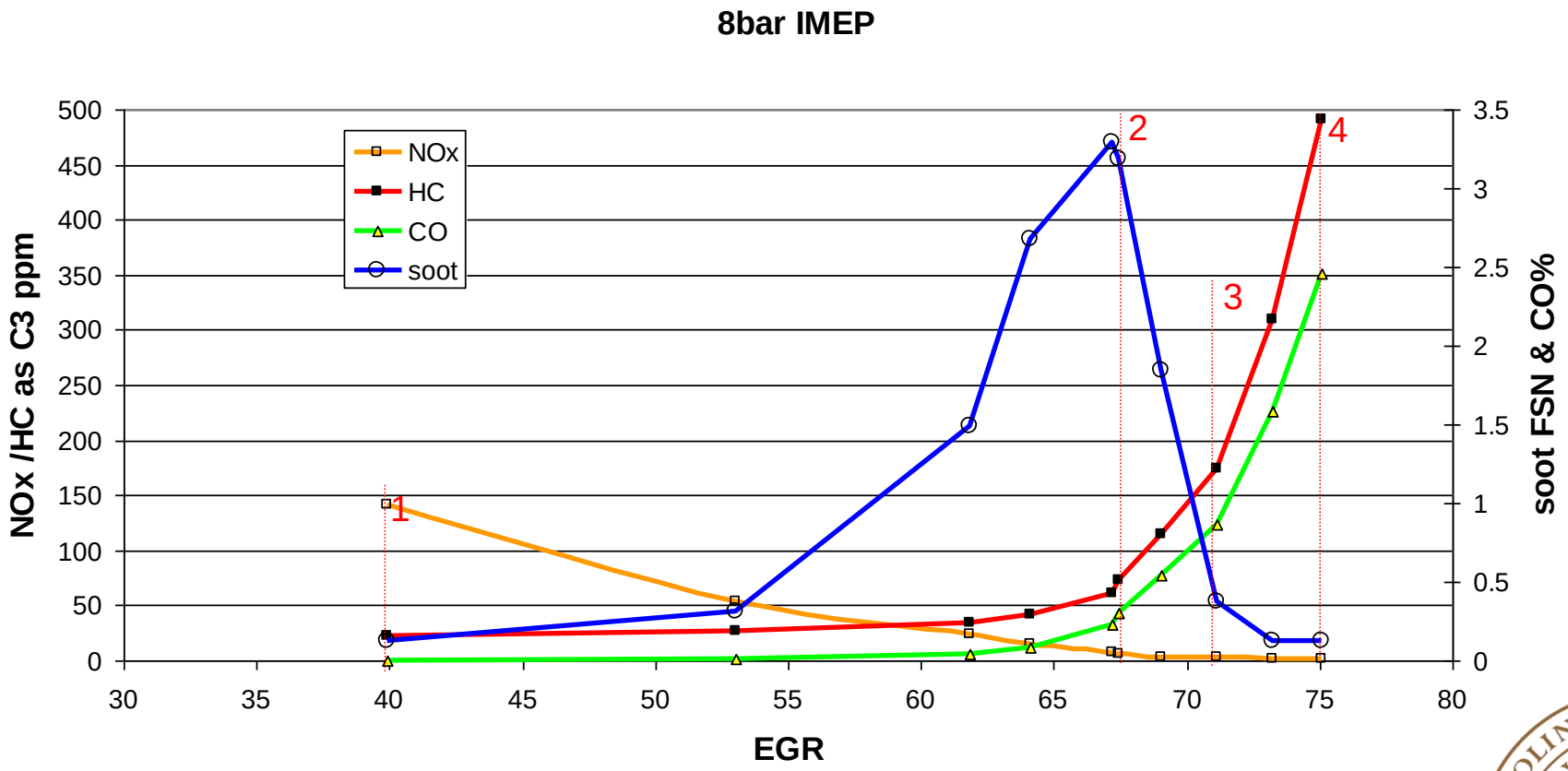
What is PPC?

Partially Premixed Combustion

”The best fuel for a diesel engine is gasoline!”

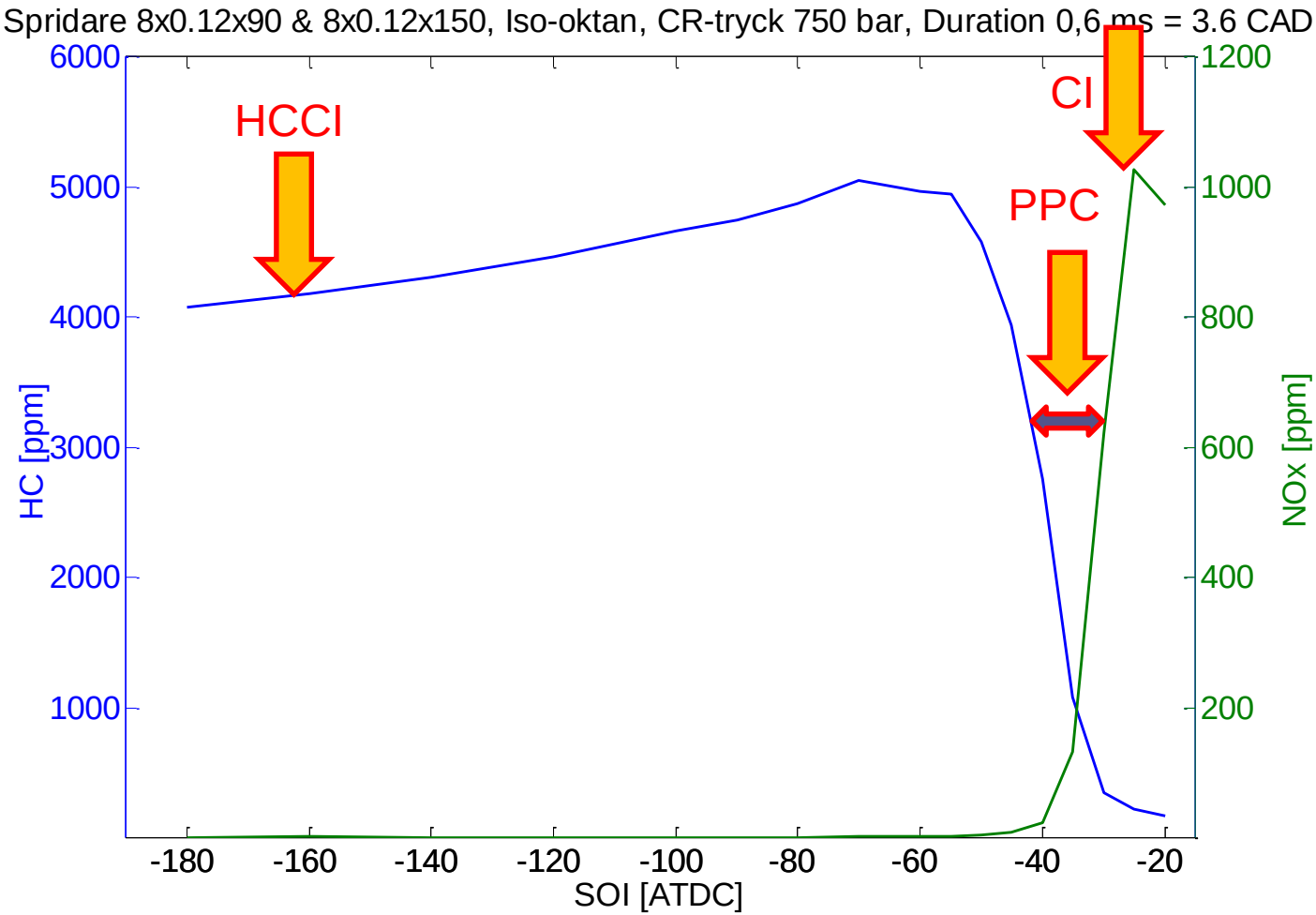
Is methanol an even better ”diesel” engine fuel?

Clue 1: EGR-sweep (diesel)



SAE 2006-01-3412

Clue 2: SOI sweep (DI)



Def: region between truly homogeneous combustion, HCCI, and diffusion controlled combustion, diesel

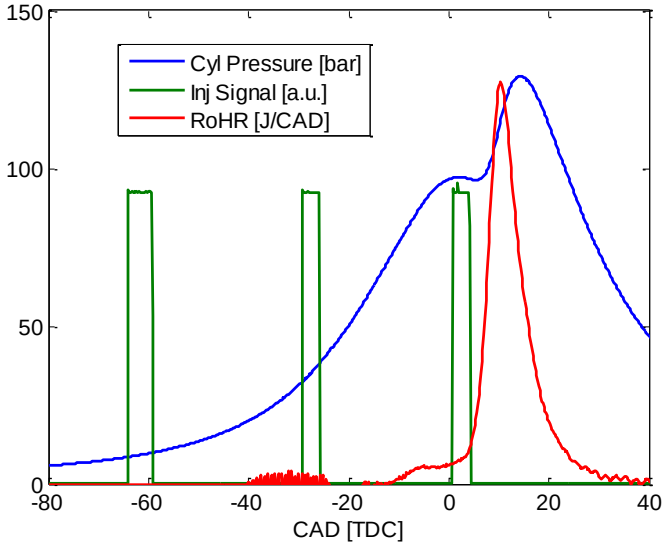
SAE 2004-01-2990

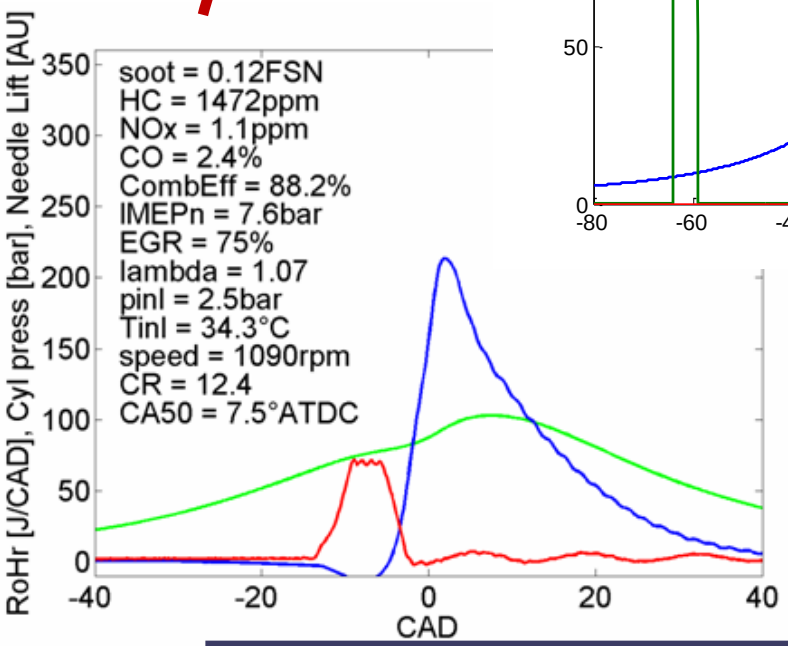
Clue 3: Burn rate and η_T

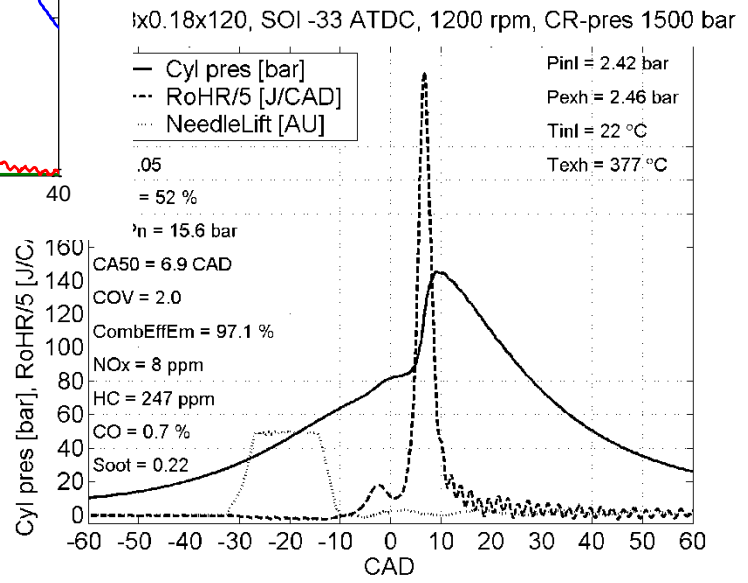
Optimum Thermodynamic efficiency

Low effective expansion ratio

High heat losses







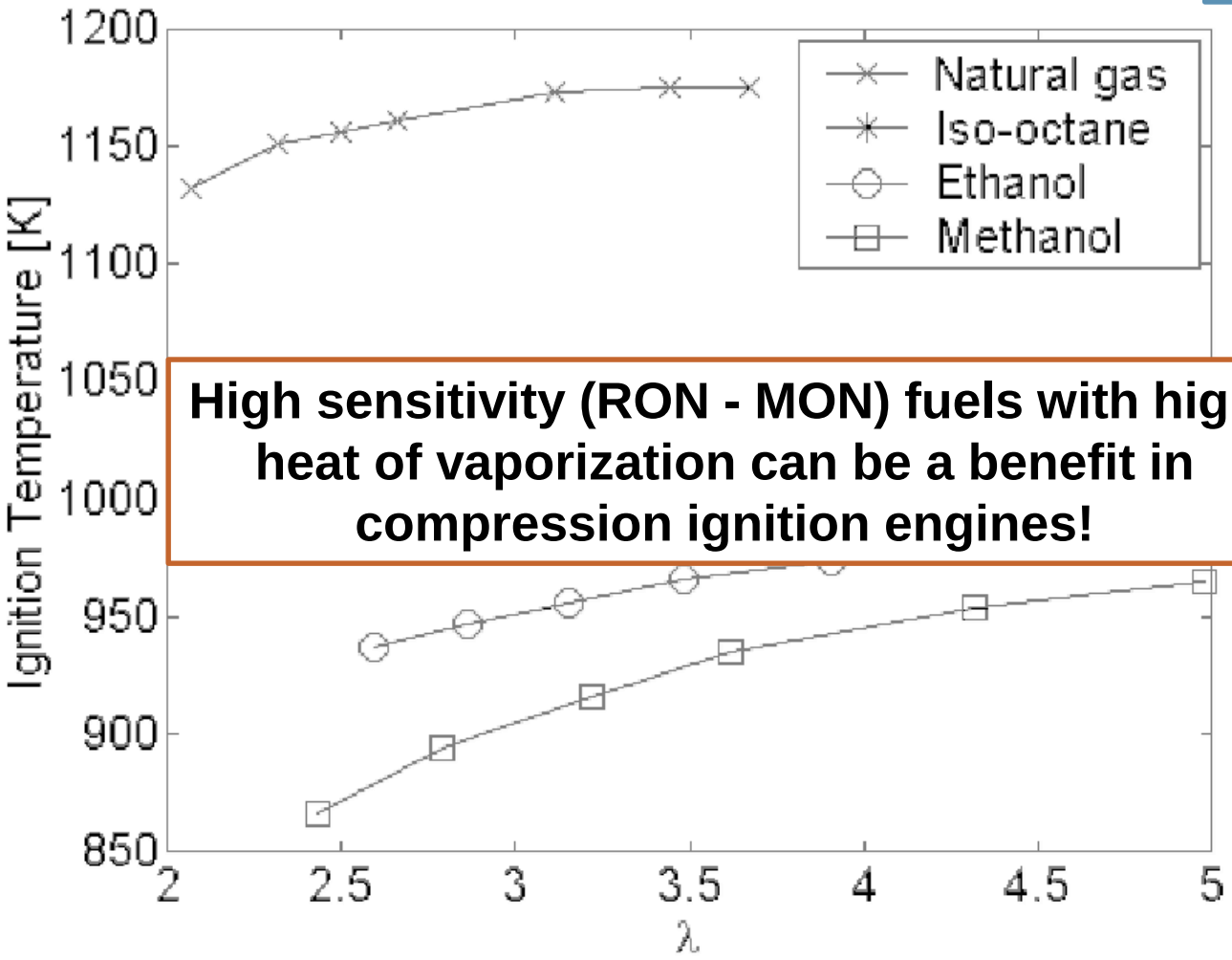
Premixedness

Lund PPC recipe

- ✓λ ≈ 1.5
- ✓EGR ≈ 50 %
- ✓RON > 60
- ✓SOI to control CA50

Ignition T of some fuels (very lean HCCI)

Premium Gasoline US
RON 92, MON 83



High sensitivity (RON - MON) fuels with high heat of vaporization can be a benefit in compression ignition engines!

Natural gas
RON 120, MON 120

Iso-octane
RON 100, MON 100

Ethanol
RON 109, MON 90

Methanol
RON 109, MON 89