# Research Activities of LVK

ClassNK
R & D PROJECT

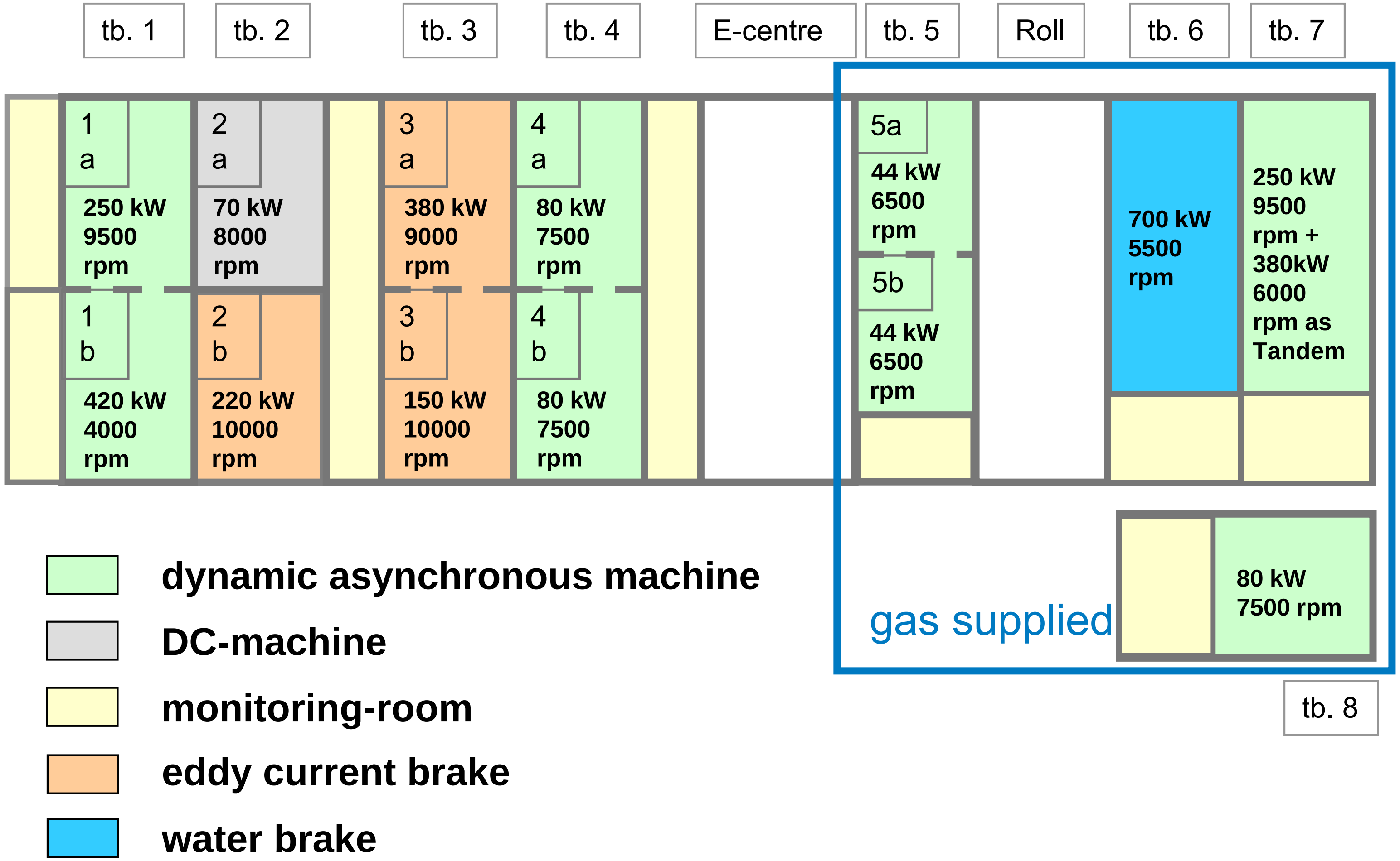
NANYANG
TECHNOLOGICAL
UNIVERSITY

# Engine Laboratory

# Personnel

| | |
|---|---|
| **Head:** | **Prof. Dr.-Ing. G. Wachtmeister** |
| **Administration / organization:** | 2 secretaries |
| **Research and teaching:** | 2 senior engineer |
| | 29 scientific engineers |
| | 2 plant engineers |
| | test bed technician |
| | electronic engineer |
| | electronic technician |
| | foreman |
| | 5 workshop-employees |
| | 2 apprentices |
| | research students |

# Testbeds


tb. 1
tb. 2
tb. 3
tb. 4
E-centre
tb. 5
Roll
tb. 6
tb. 7
1 a
250 kW 9500 rpm
2 a
70 kW 8000 rpm
3 a
380 kW 9000 rpm
4 a
80 kW 7500 rpm
5a
44 kW 6500 rpm
700 kW 5500 rpm
250 kW 9500 rpm + 380kW 6000 rpm as Tandem
1 b
420 kW 4000 rpm
2 b
220 kW 10000 rpm
3 b
150 kW 10000 rpm
4 b
80 kW 7500 rpm
5b
44 kW 6500 rpm
gas supplied
80 kW 7500 rpm
tb. 8
dynamic asynchronous machine
DC-machine
monitoring-room
eddy current brake
water brake

# Agenda

- Overview of Project Acitivities
- Influence of H2 admission in lean burn gas engines
- Unburned Hydrocarbons of Gas Engines
- Oil Flow and Distribution at Piston/Piston Rings

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# Field of Activities 1/4

## Combustion prozess development

- Diesel
- Otto
- Gas

**Experimental**

Injection

Spray Chamber

Thermodynamic engines

Engines with optical access

**Simulation**

0D / 1D Simulation

CFD-Simulation

Combined CFD-FEM Calculation

**Tools development**

Phenomenological combustion models

# Field of Activities 2/4

**Tribology of Piston / Piston Rings / Liner**

Friction Measurements

Floating Liner

Oil Flow/Distribution at Piston and Liner

Experiment

- Movements of Rings and Piston
  - Axial
  - Radial
  - Circumferential
- Pressure distribution within ring package
- Oil film thickness
- Oil condition

Simulation

CFD-calculation

- Blow By resp. Reverse Blow By
- Oil flow from combustion chamber to crankcase

# Field of Activities 3/4

## Gas Engines

- Mini Combined and Power Unit
- Lean burn Passenger Car Engine
- Combustion Process Development
  - Spark ignition
  - Prechamber
  - Pilot fuel
- Unburned Hydrocarbons
- BMEP 30bar
- Formaldehyde Emission
- Dual Fual Combustion

# Field of Activities 4/4

## Alternative Fuels

- Hydrogen
- Biogas
- Vegetable oil
- Oxygenated Fuels

# Partners

- FVV: Forschungsvereinigung Verbrennungskraftmaschinen (FVV-Eigenmittel, Aif), German association of combustion engines manufacturer and supplier
- BFS: Bayerische Forschungsstiftung (Bavarian research association)
- DFG: Deutsche Forschungsgesellschaft (German research foundation)
- Different research foundations (z.B. Projektträger Jülich, Fachagentur Nachwachsende Rohstoffe)
- Industrial research i.e. ClassNK R&D PROJECT

# Agenda

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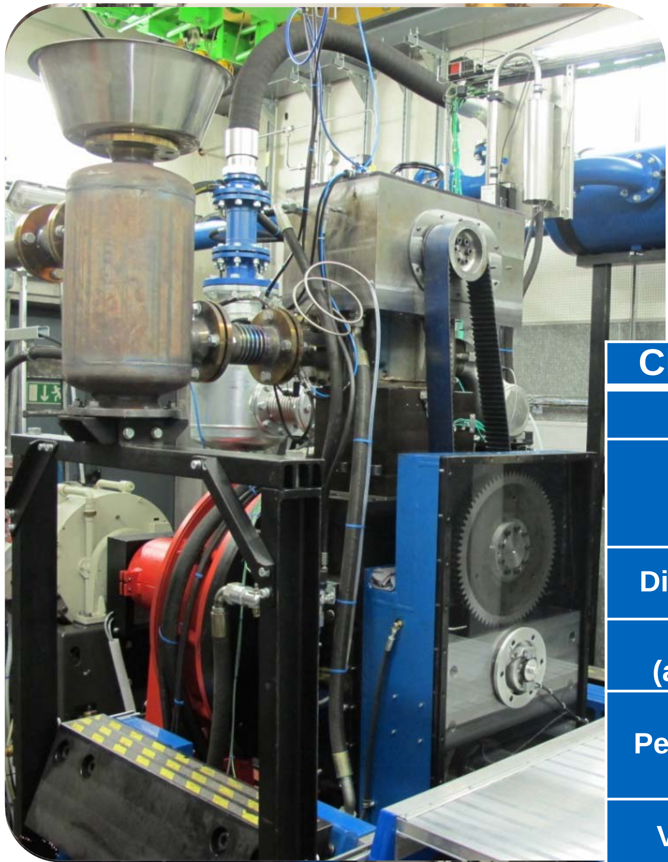
# Singe Cylinder Gas Engine Industrial Size



**Characteristics of LVK – single cylinder gas engine**

| | | | |
|---|---|---|---|
| **Bore** | 170 mm | **Mass Balancing** | 1. & 2. Order (Lancaster) |
| **Stroke** | 210 mm | **Ignition System** | Woodward IC922 (360mJ / 30++kV) / Pilot-Injection / LVK-Multisparc |
| **Displacement** | 4,77 l | **Charge Air Supply** | Screw Compressor (6 bar abs. / 8 bar abs.) |
| **Epsilon (adjustable)** | 12,7 | **Emission Measurement System** | Anysco FT-IR / O2-Analystor / FID |
| **Peak Pressure** | 300 bar | **Turbocharger Emulation** | Exhaust Throttle and Feedback Control of Tubocharger Efficiency |
| **Valve Train** | 4 Valves / 2 Camshafts | **Engine Speed** | Max. 2000 1/min / Standard 1500 1/min |
| **Variable Valve Timing** | Miller / Atkinson | **Variable Mixture of Fuel Gas** | Propan, CO2, H2, N2 in Natural Gas (Analysis with Gas Chromatograph) |

# Test Boundary Condition

- Natural gas composition (Munich city gas)

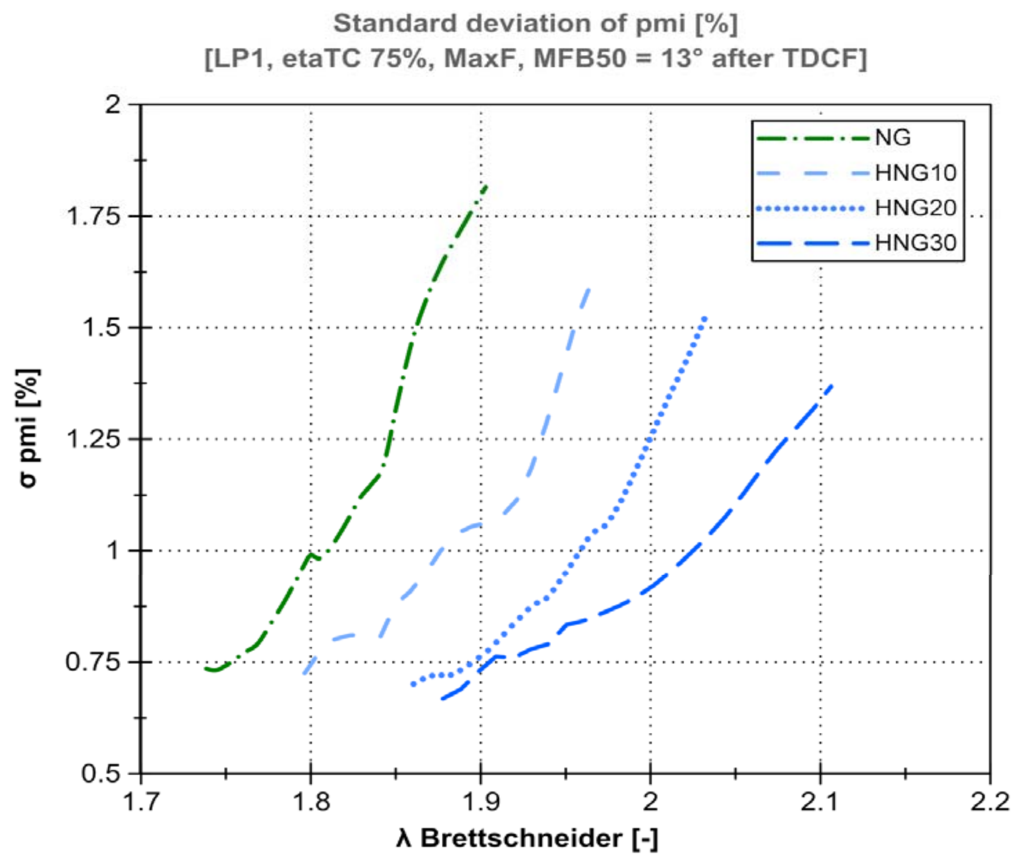
| Species | mol.% | Species | mol.% |
|---|---|---|---|
| $CH_4$ | 94.87 | $CO_2$ | 0.79 |
| $C_2H_4$ | 3.31 | $N_2$ | 0.53 |
| $C_3H_8$ | 0.34 | Others | 0.16 |

- H2 volume : 0, 10, 20, 30 vol.%

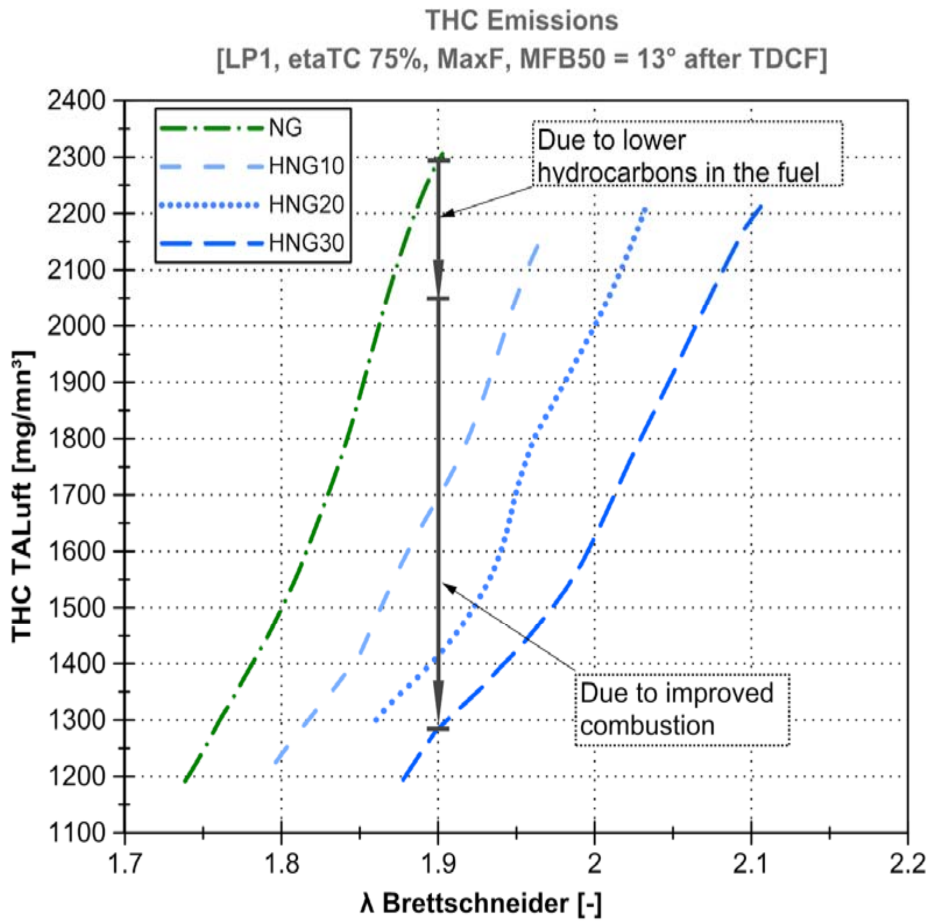
Operating conditions

- Air mass flow constant
- IMEP : 18 - 20 bar
- Turbocharger efficiency : 75%

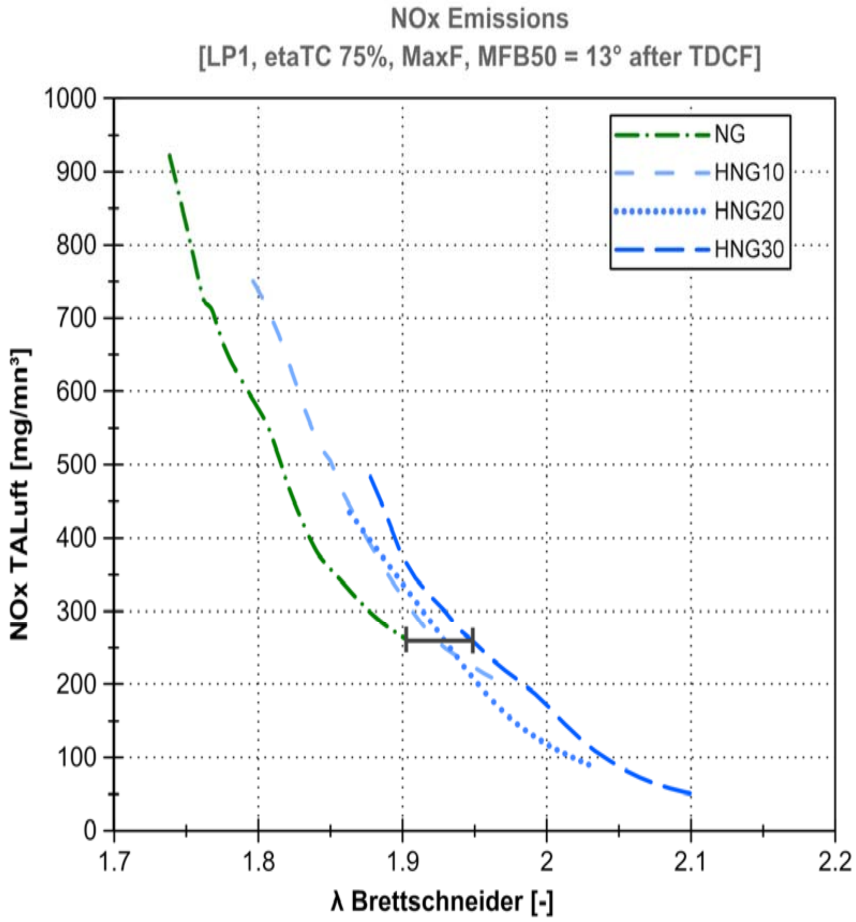
# Combustion Stability



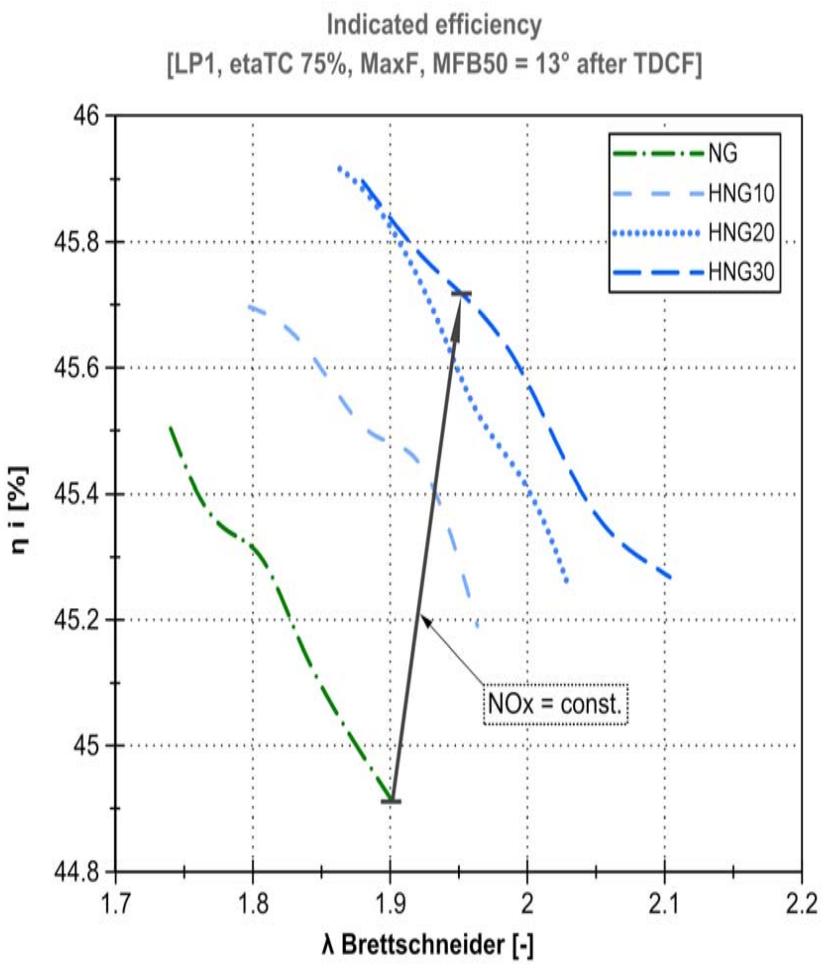
# THC-Emission



# NOx-Emission



# Indicated Efficiency



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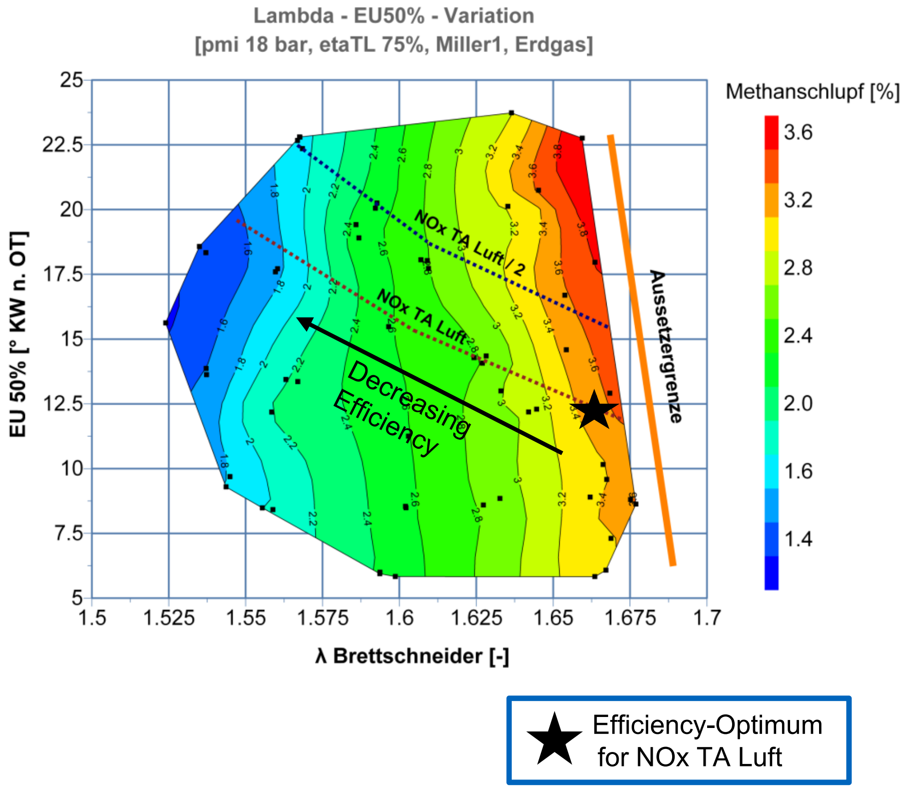
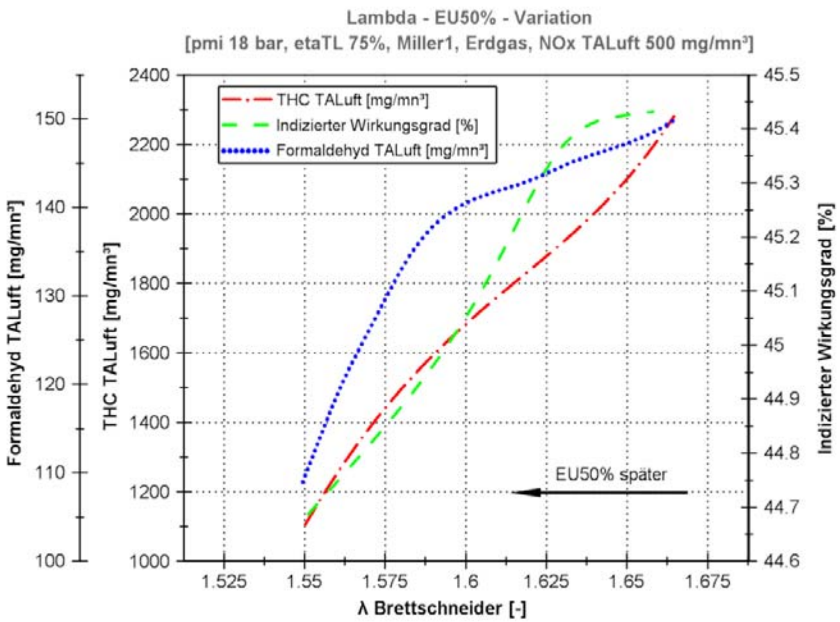
# Influence of Equivalence Ratio and Combustion Phasing




Efficiency-THC trade-off at MFB50%-variation

Insufficient compensation of burning efficiency losses (later MFB50%) by higher fuel conversion rate

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FNR Fachagentur Nachwachsende Rohstoffe e.V.
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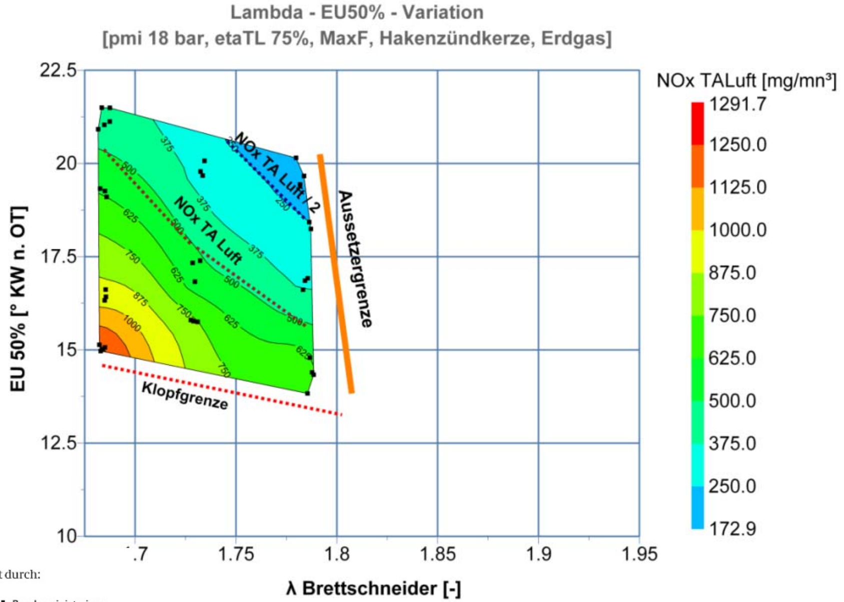
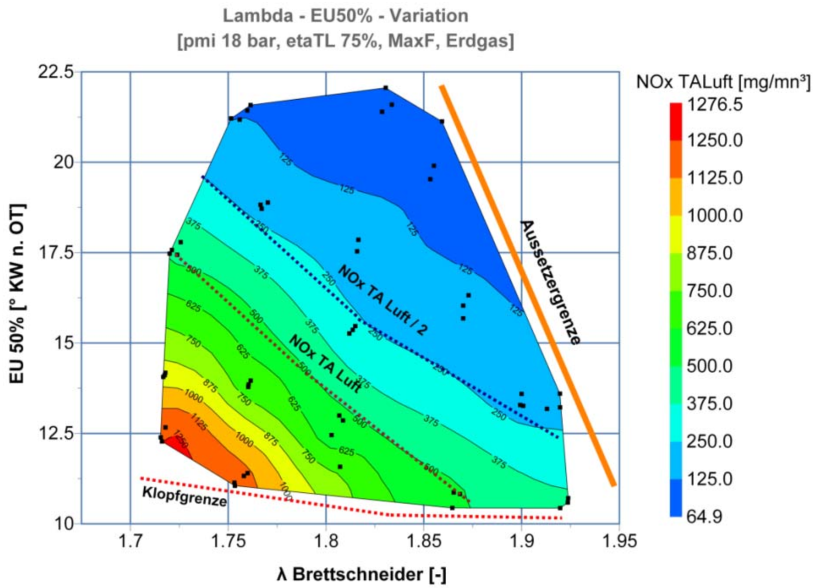
# Ignition System

- Extended operating range (lean and knock limit) with prechamber
- Lower NOx levels reachable
- Earlier COC at constant NOx attainable

## Spark-Plug




## Prechamber (unscavenged)

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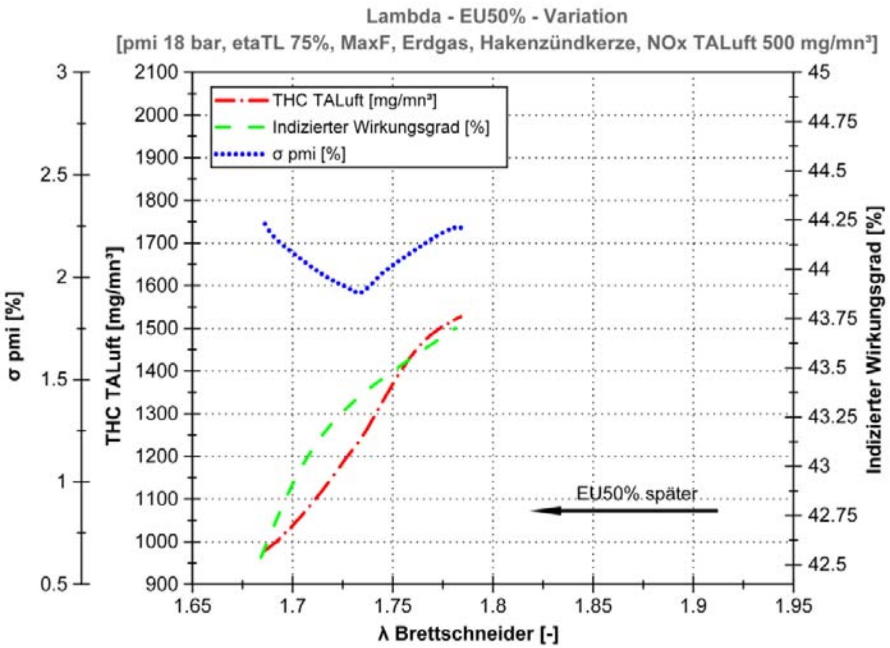
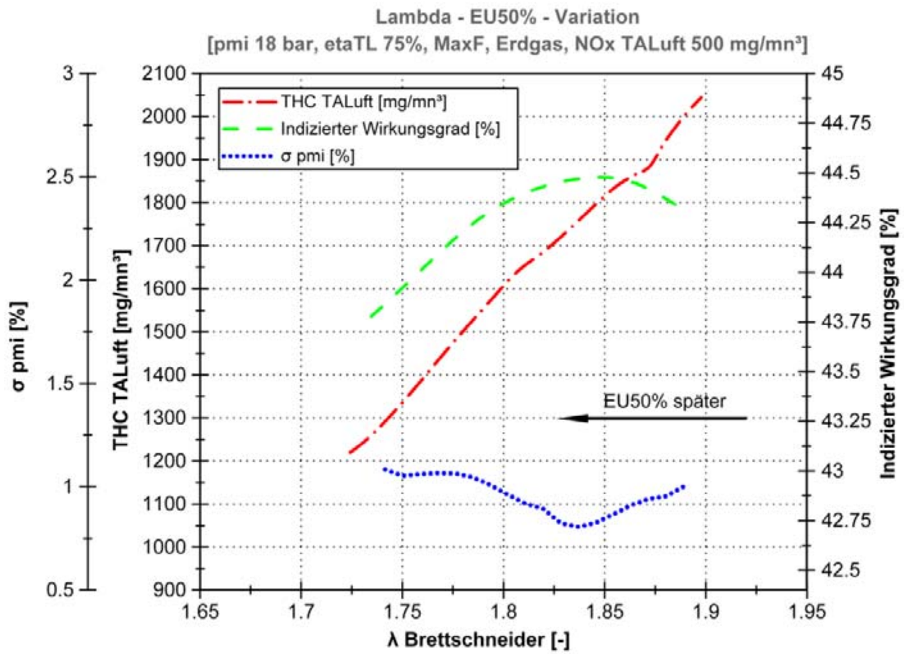
# Ignition System

Spark-Plug




Prechamber (unscavanged)




Operation with prechamber:

⇨ Same level of efficiency at lower THC (lines)

⇨ Vice versa: same level of THC at higher efficiency

⇨ Higher THC-Level at max. efficiency due to leaner mixture

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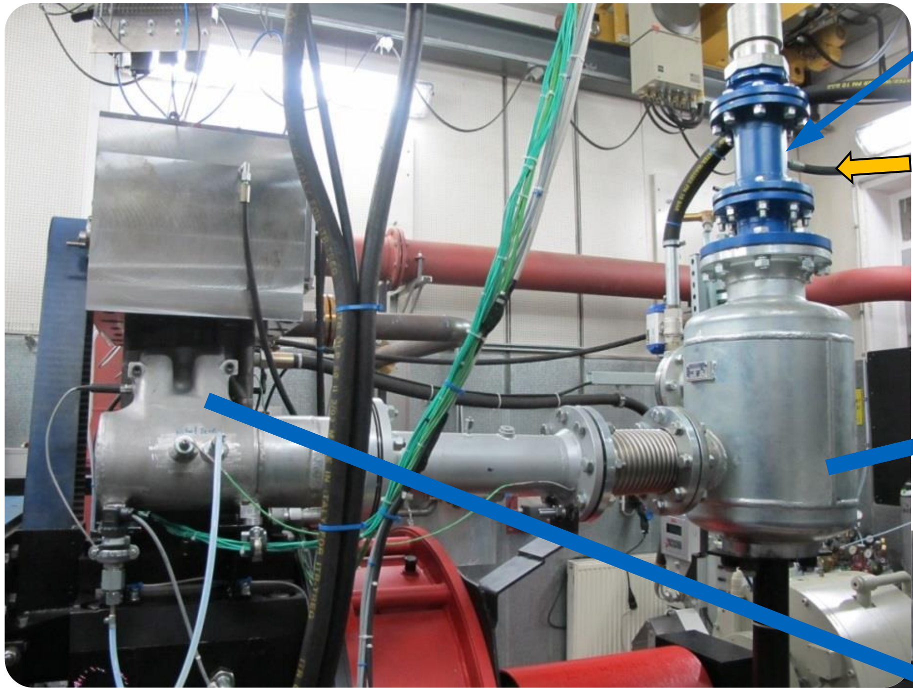
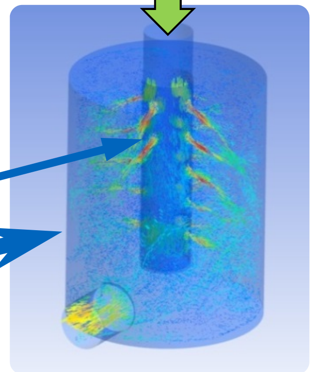
# Mixture Formation



Venturi mixer with crankangle-synchronic gasinjection

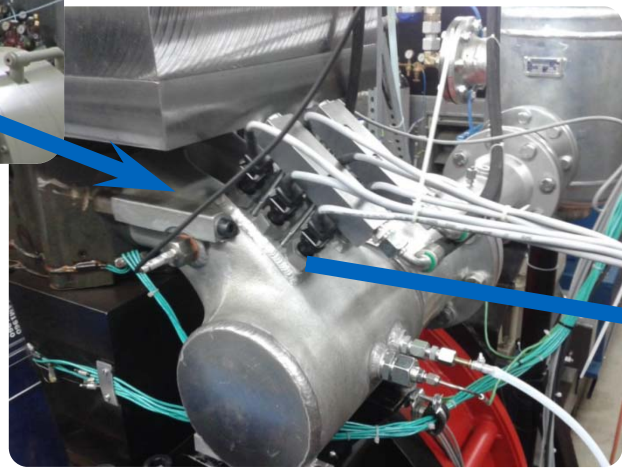
Gas supply

Gas-Air-Mixture

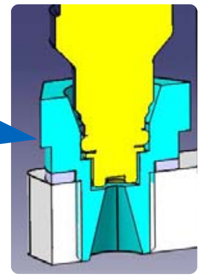


Perforated downpipe

Modified reciever-pipe for PFI-Mode



PFI-Duct-Geometry



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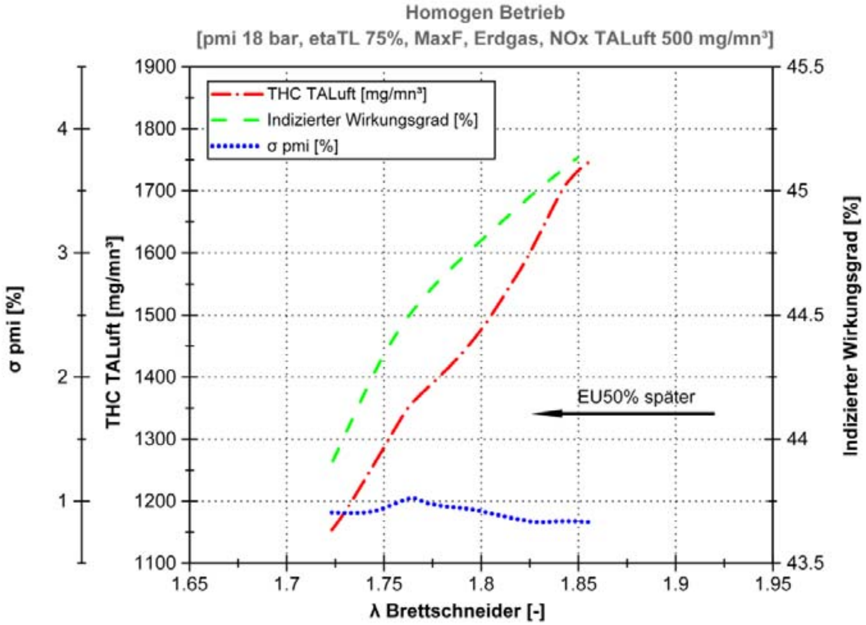
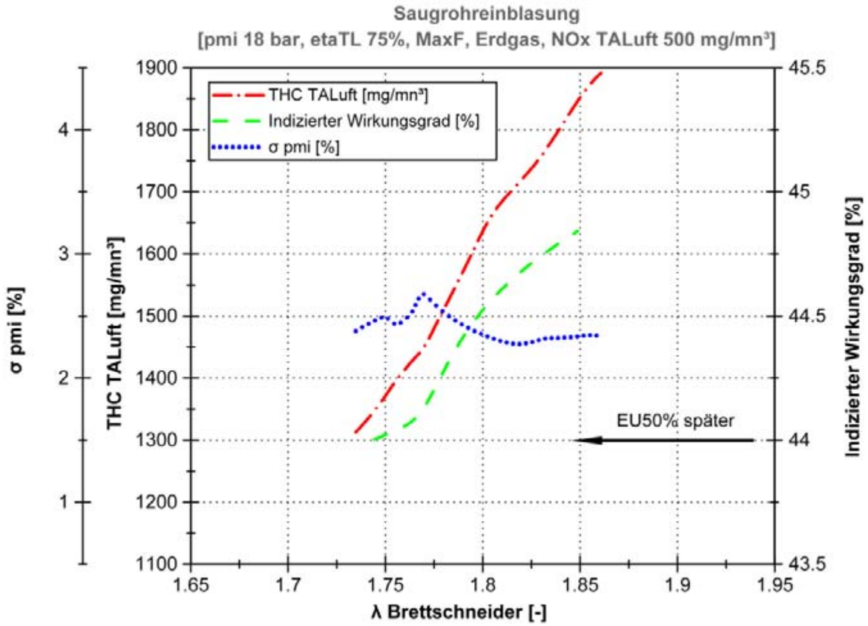
# Mixture Formation

Mixture formation via homogenizer




Port-Fuel-Injection




⇨ Additional Info.: Operating range comparable; COC slightly later due to knock limit with PFI-Mode

⇨ Increased THC (and CO) due to local too lean and rich mixture with PFI-Mode

⇨ Homogeneos mixture should be intended

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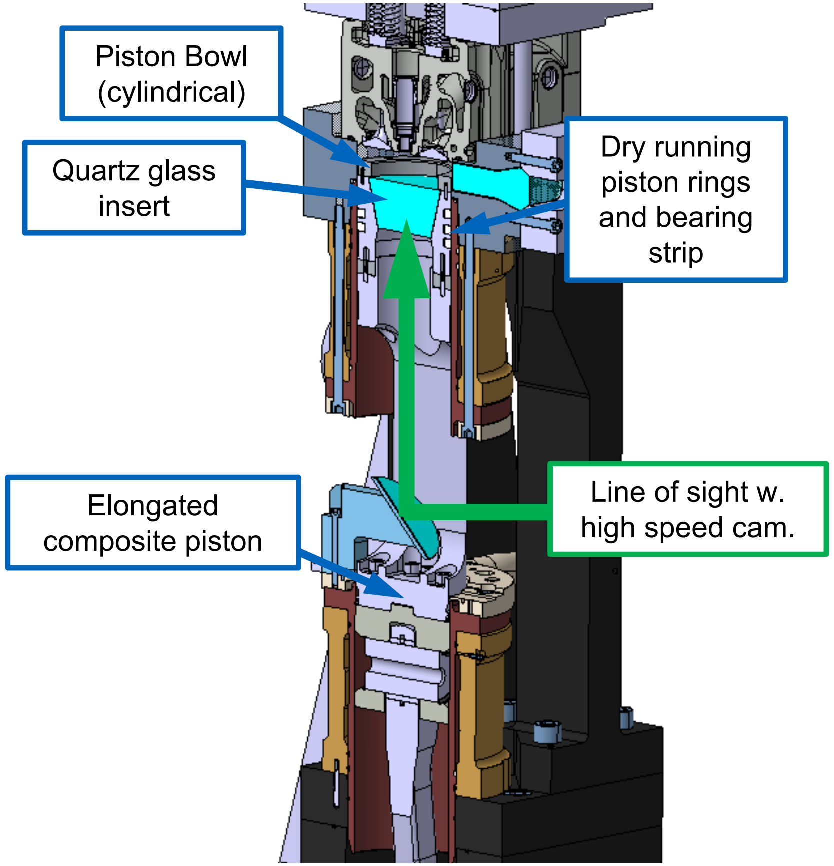
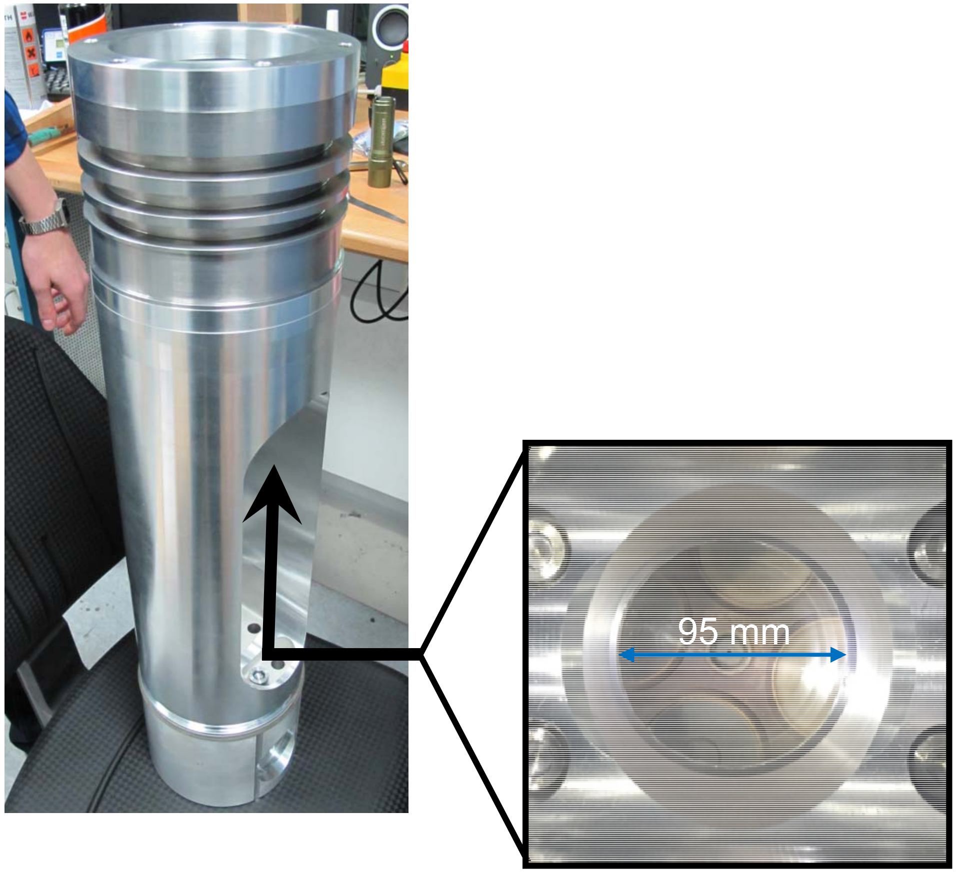
# Optical Set-up

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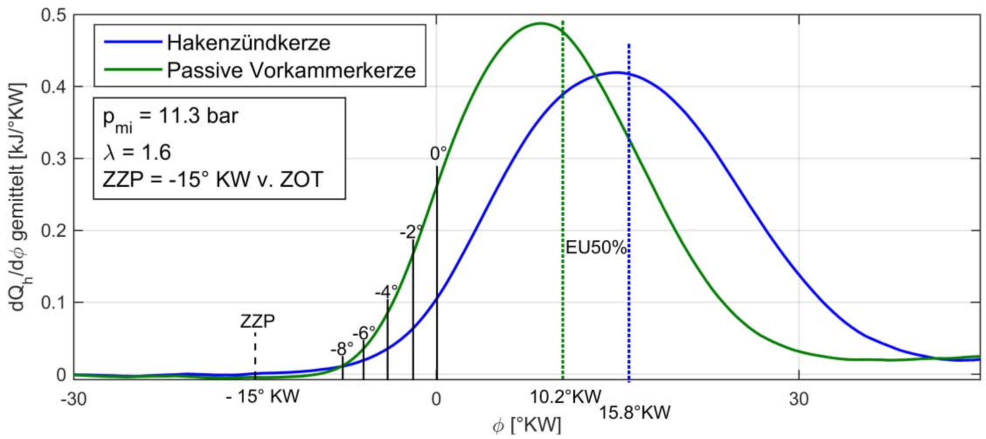
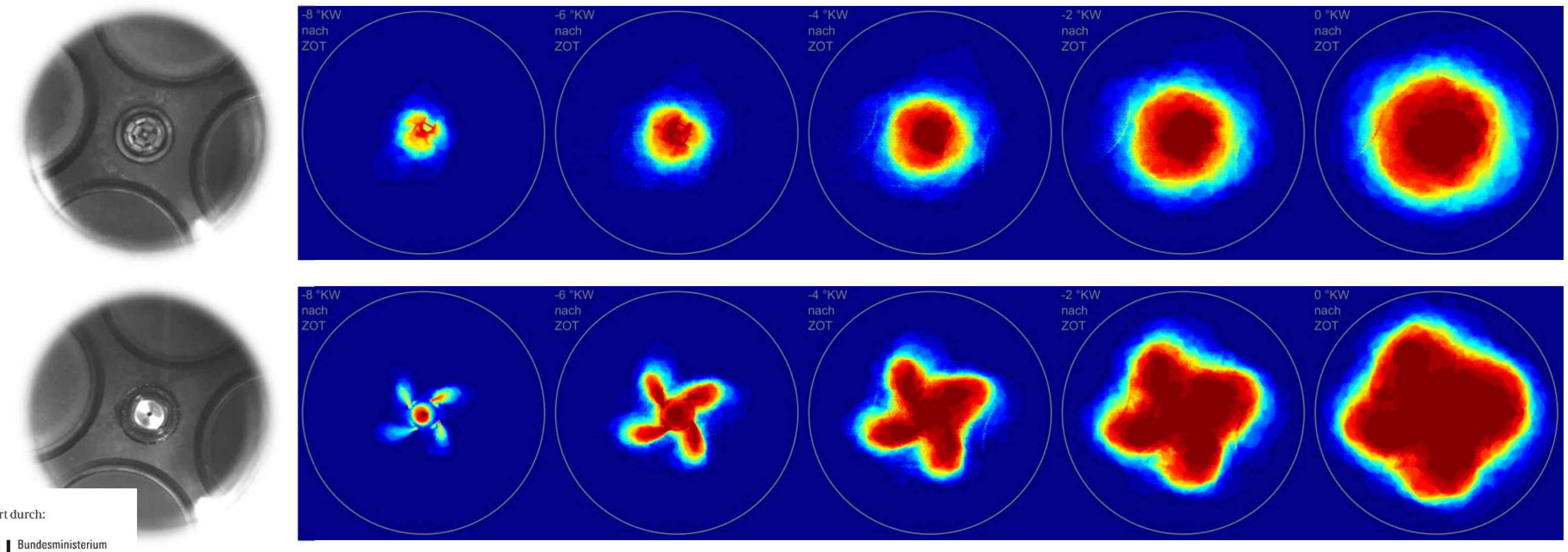
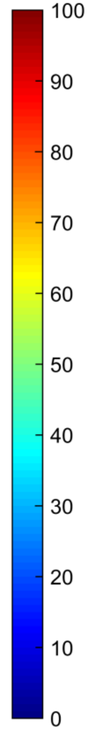
# Optical Investigations of the First Flame Propagation




**Dark red means that the flame is present in 100 % of the cycles at the shown crank angle*

Average Flame Probability Distribution* [% of cycles]

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# Project Overview

- Design of measurement techniques for tribological studies in the piston ring area

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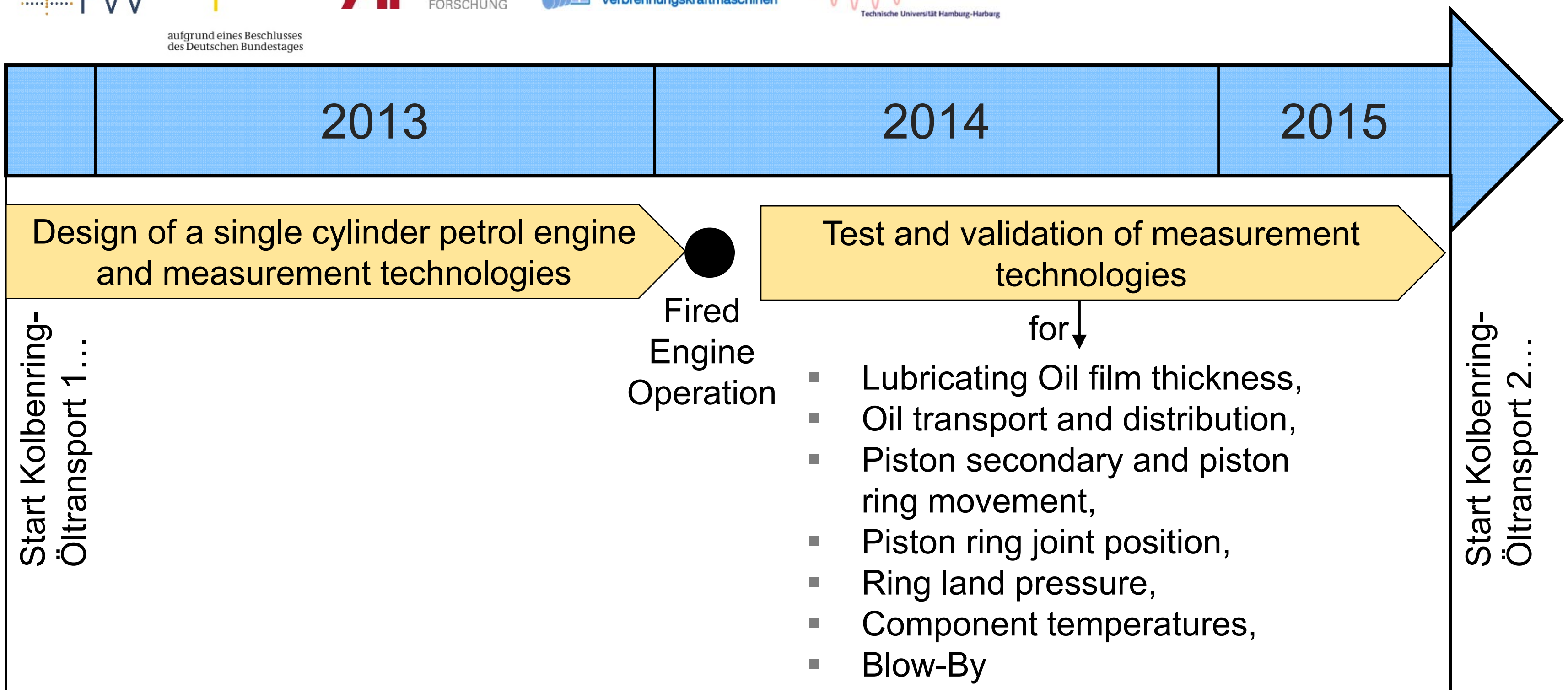
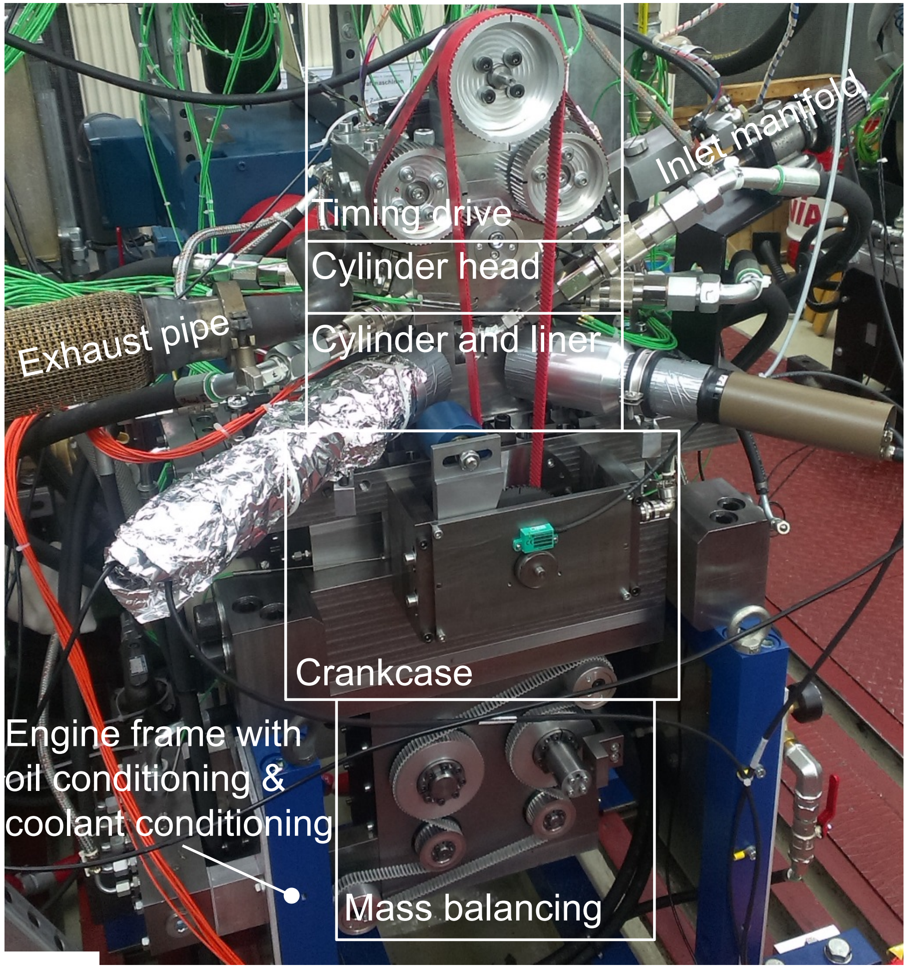
AiF ALLIANZ INDUSTRIE FORSCHUNG

LVK Lehrstuhl für Verbrennungskraftmaschinen

Messtechnik
Technische Universität Hamburg-Harburg



# Research Engine




| Engine data | Value |
|---|---|
| Bore x stroke | 82,5 mm x 92,8 mm |
| Standard components | Piston, conrod |
| Timing drive | 2 inlet valves, 2 exhaust valves |
| Maximum peak pressure | 110 bar |
| Compression ratio | 9,5 : 1 |
| Maximum engine speed | 6500 rpm (with measurement link 4000 rpm) |
| Flywheel mass | 1,5 kgm² |
| Mass balancing | 1. and 2. engine order |

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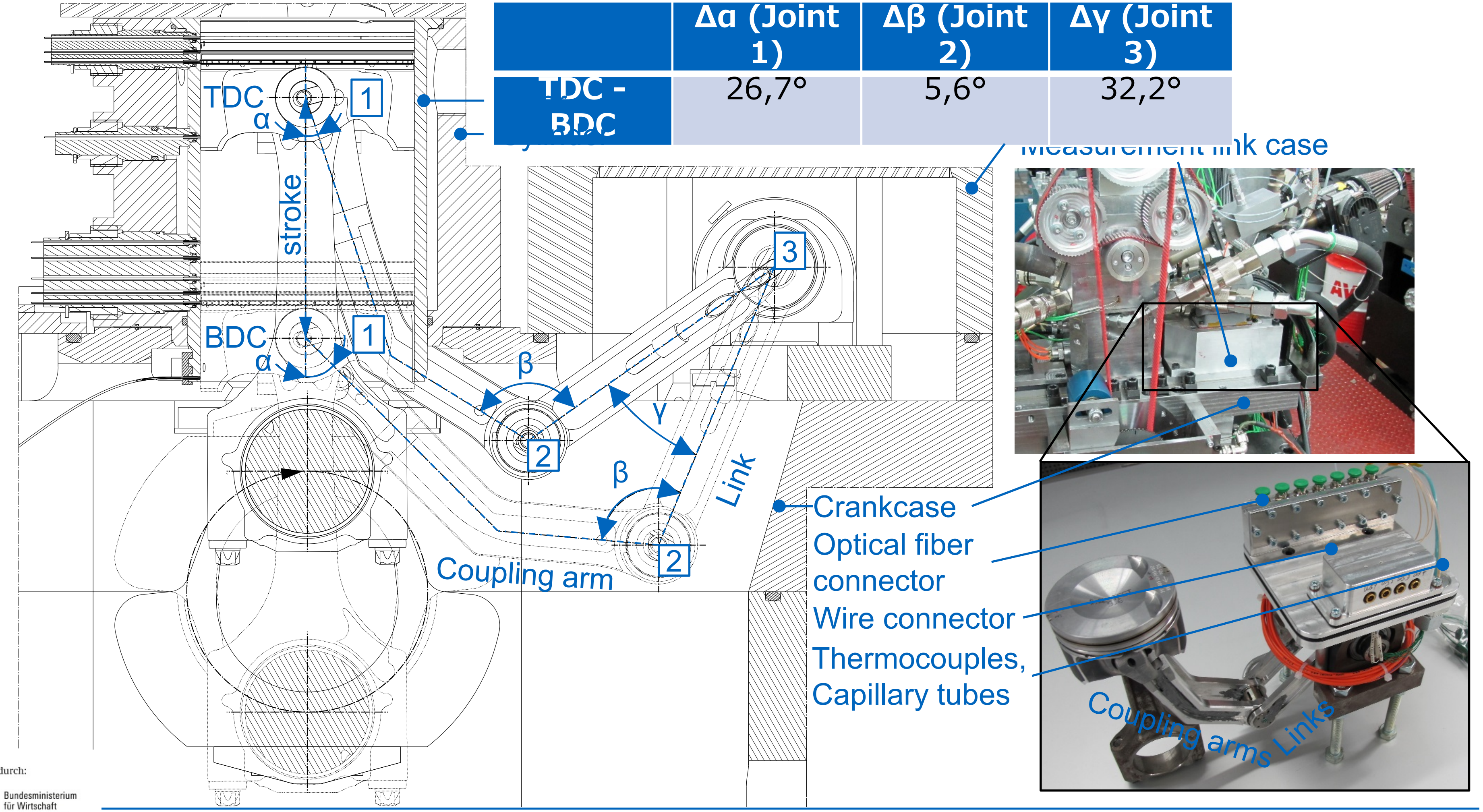
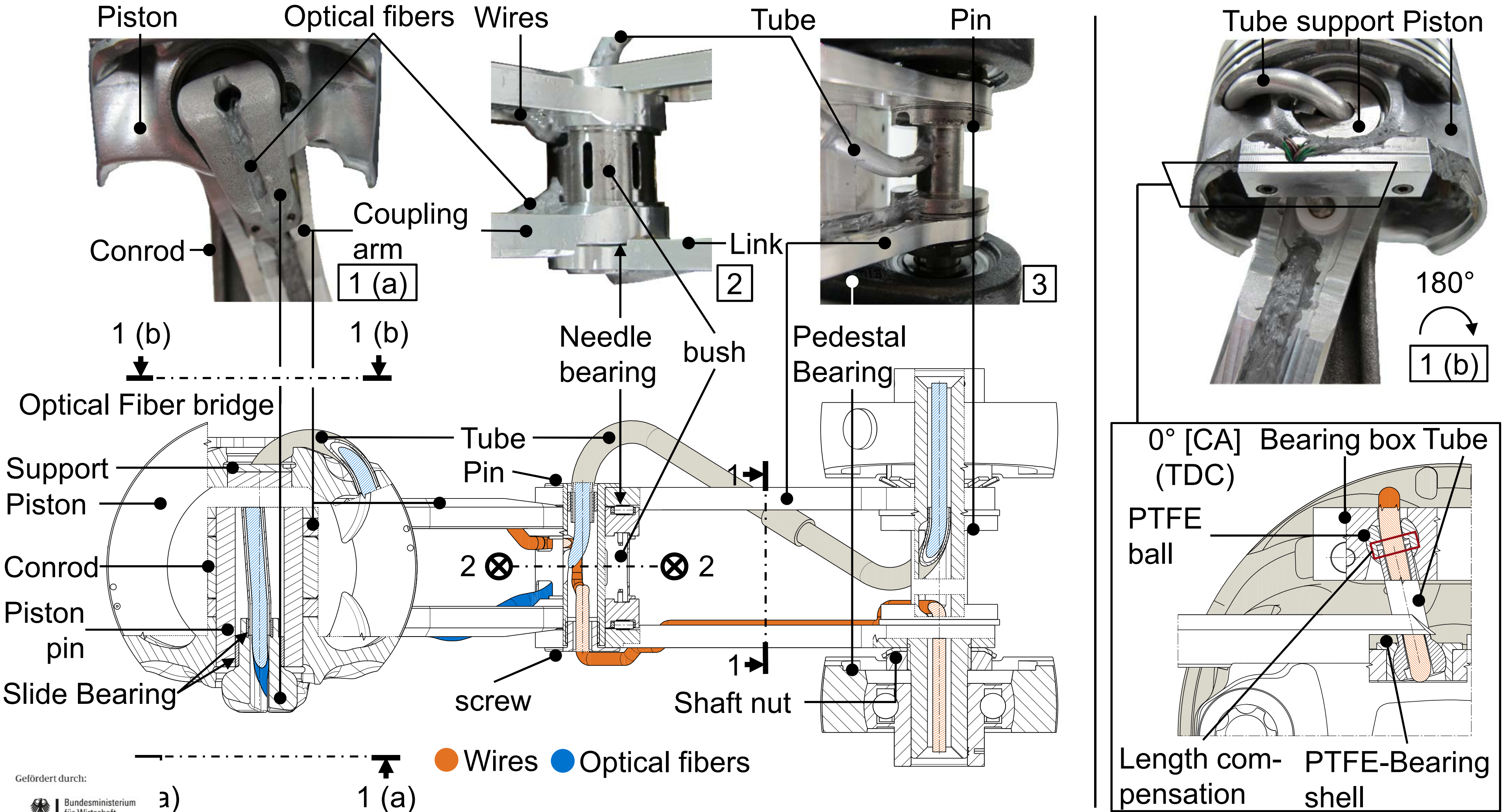
# Data Transfer via Grashopper Link

| | Δα (Joint 1) | Δβ (Joint 2) | Δγ (Joint 3) |
|---|---|---|---|
| TDC - BDC | 26,7° | 5,6° | 32,2° |



# Optical Acess with Fiber Wires

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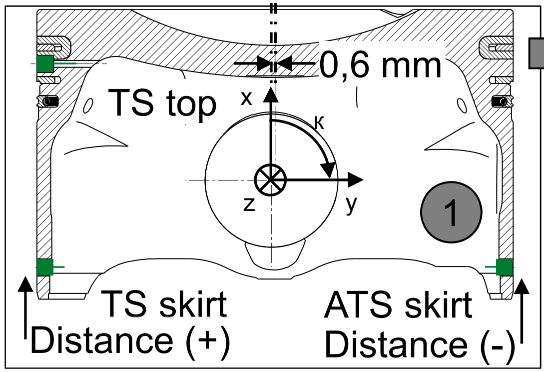
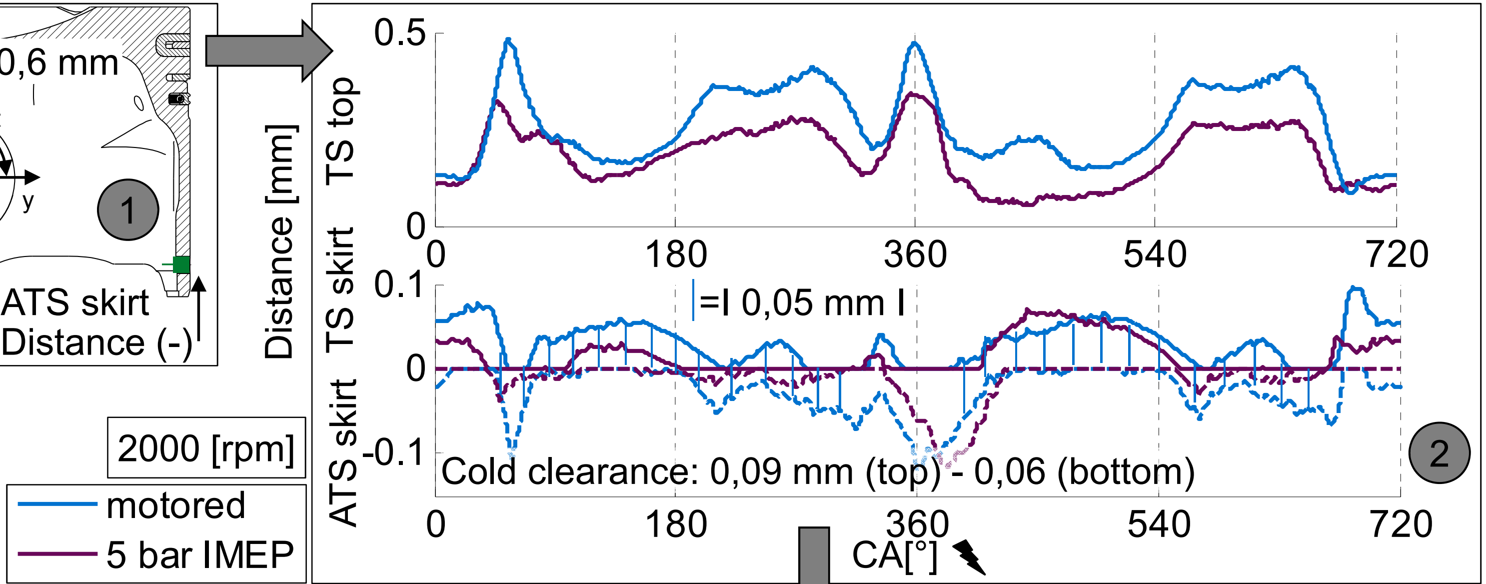
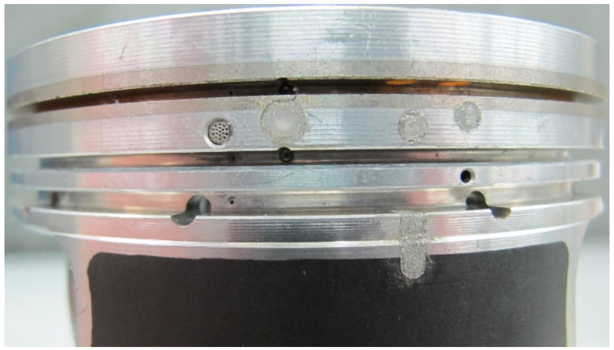
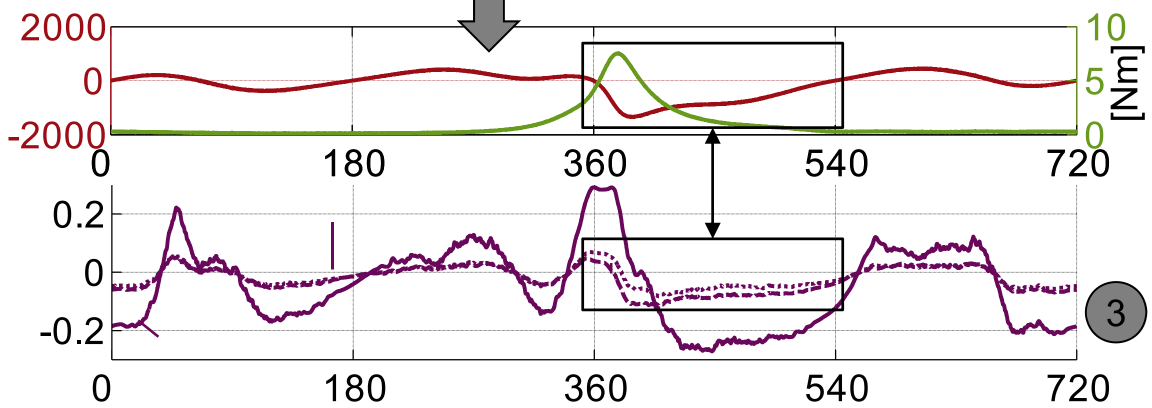
# x<

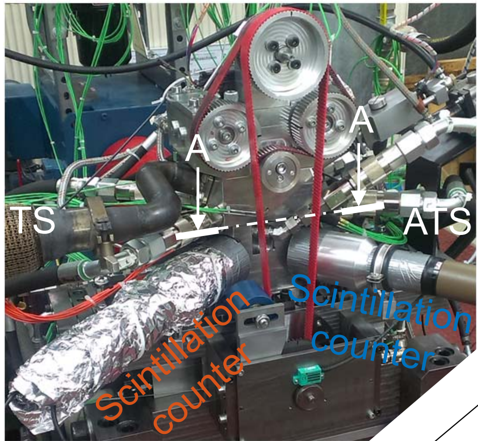

0,6 mm
TS top
x
κ
z
y
1
TS skirt
Distance (+)
ATS skirt
Distance (-)

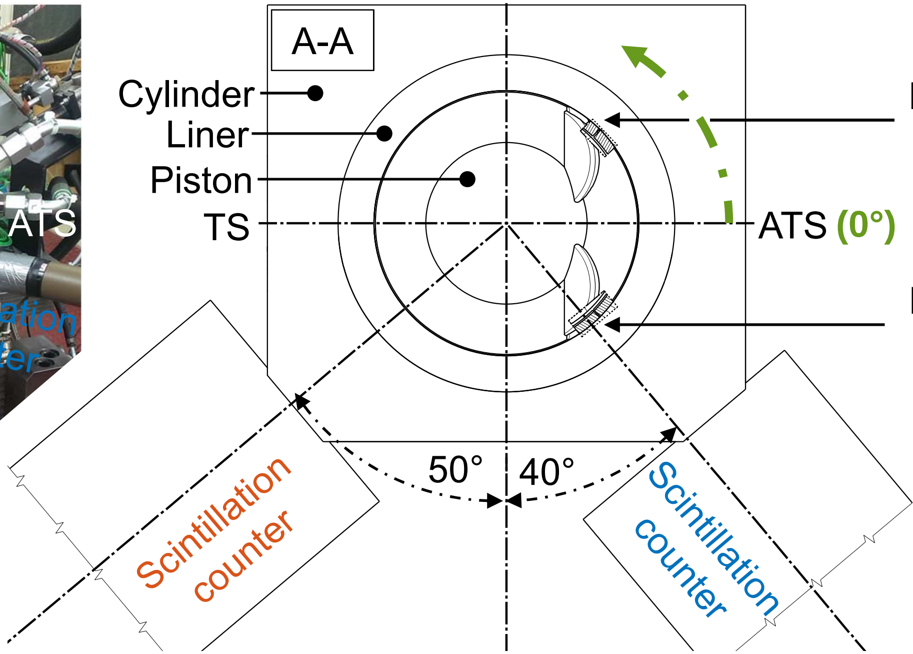

0.5
0
TS top
Distance [mm]
0
180
360
540
720
0.1
0
-0.1
TS skirt
ATS skirt
=I 0,05 mm I
Cold clearance: 0,09 mm (top) - 0,06 (bottom)
2
CA[°]
2000 [rpm]
motored
5 bar IMEP

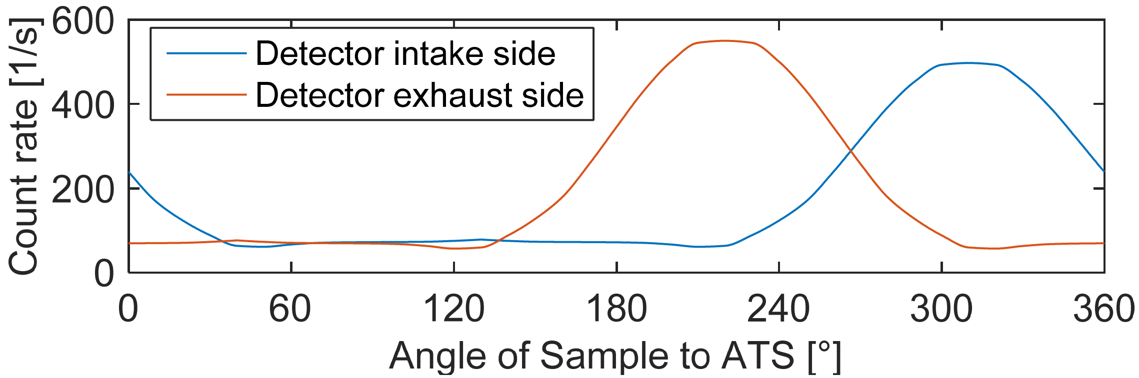



2000
0
-2000
10
5
0
[Nm]
0
180
360
540
720
0.2
0
-0.2
3

# Circumferential Piston Ring Motion

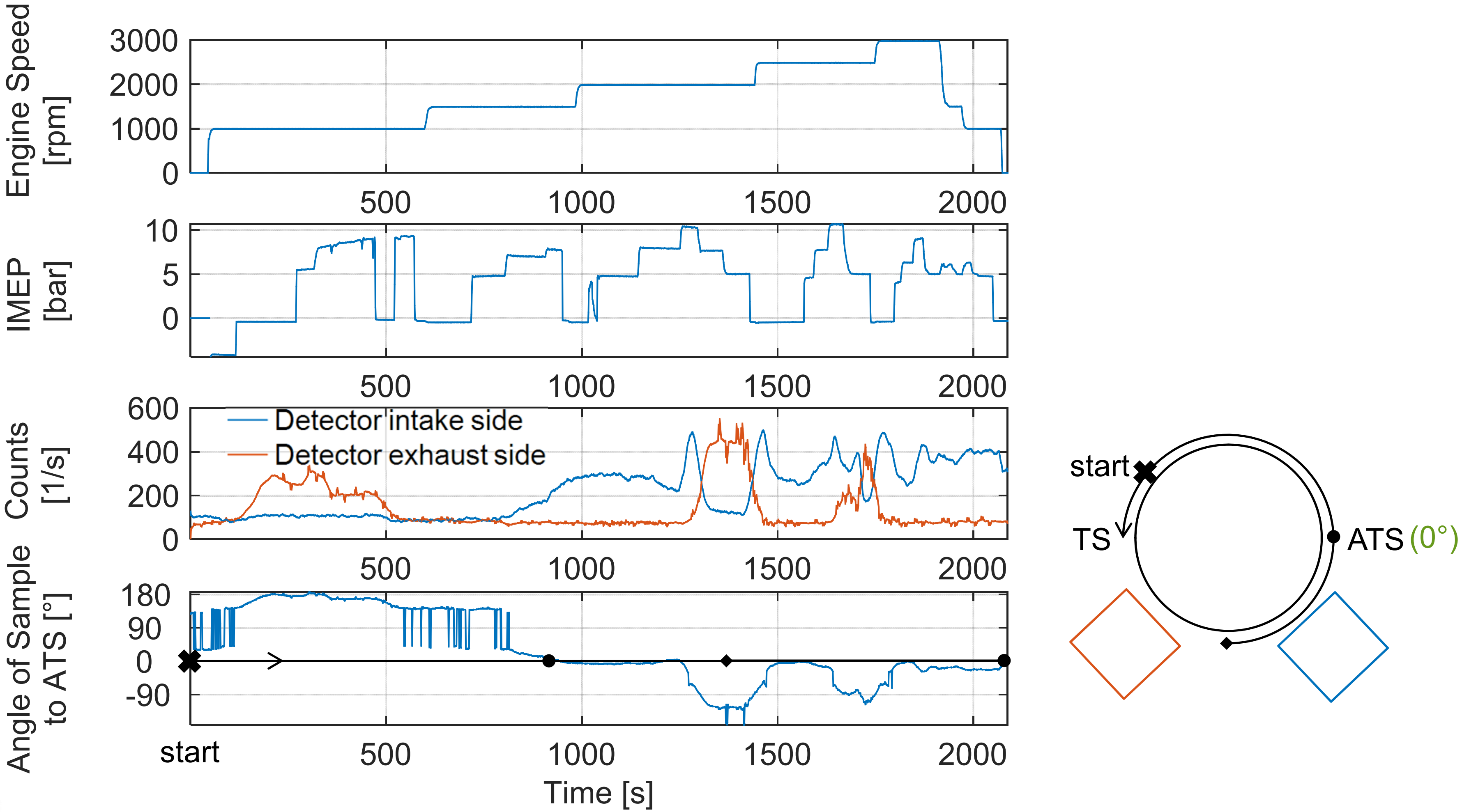



Measured with $Co^{60}$ sample with 69 kBq in piston ring 2

# Circumferential Piston Ring Motion

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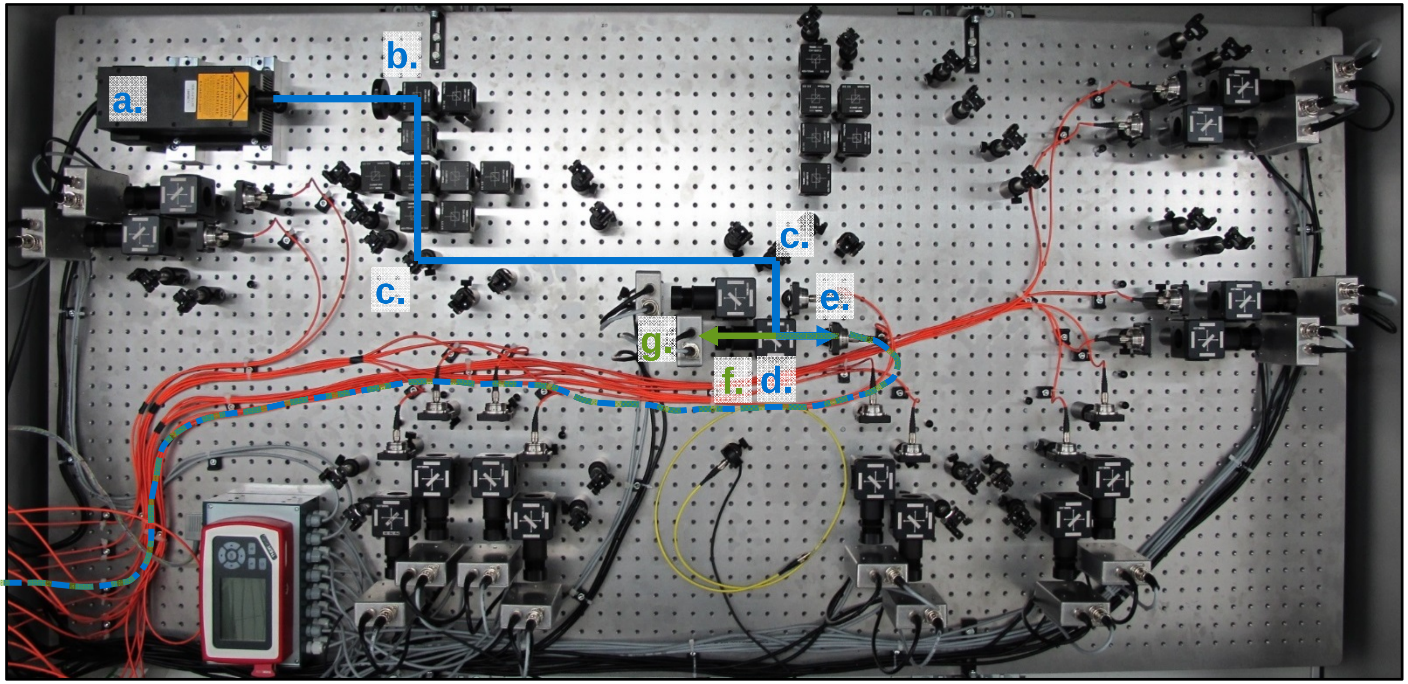
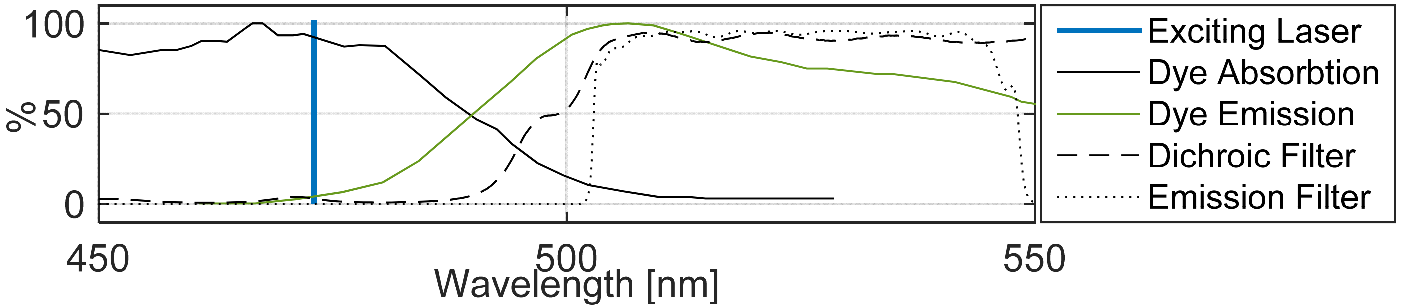
# Oil Film Thickness with LiF

a. Laser (1,5 W)
b. 50/50 Beam splitter (15)
c. Mirror (32)
d. Dichroic Mirror (16)
e. Fiber Coupling (16)
f. Filter & Convex Lens (16)
g. Photodiode (16)

To engine…
From engine…

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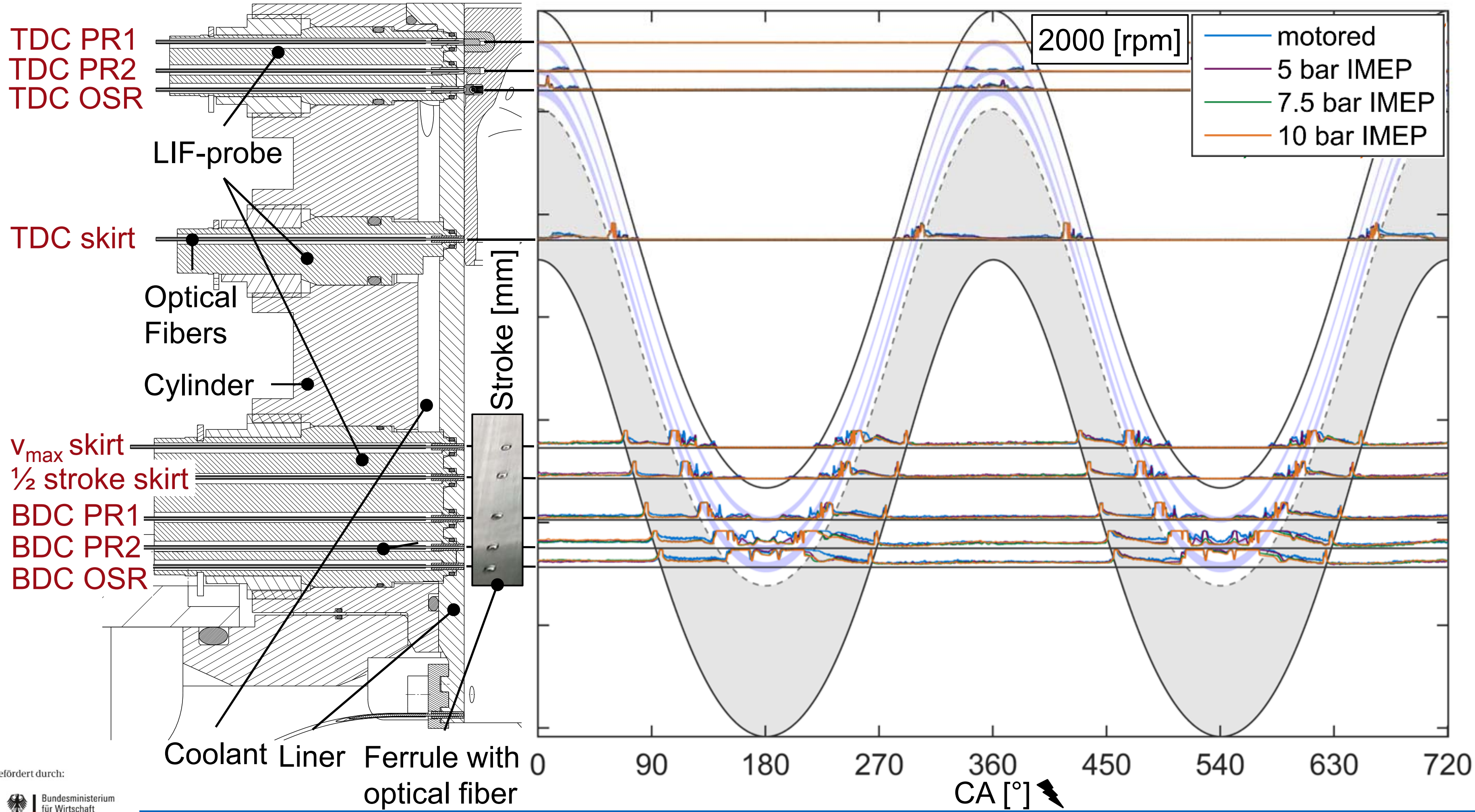
# Measured Oil Film Thickness

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We have already achieved a high level insight into the individual mechanisms of a combustion engine

We have pushed the combustion engine to a high mature level

**But we still have a lot to do!**

# Many thanks for your kind attention

Particular thanks to ClassNK R&D PROJECT

for the very fruitful cooperation

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