# Activities in the Lund University High Pressure Combustion Rig and Low Swirl Flame Measurements

**30th IEA-TLM, Capri**

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LUND UNIVERSITY

# Outline

- Brief description of CECOST
- Time-resolved imaging of lean module ignition
- Studies of Swirl-Stabilized Premixed Flames
- Summary of Gas Turbine related activities in Lund

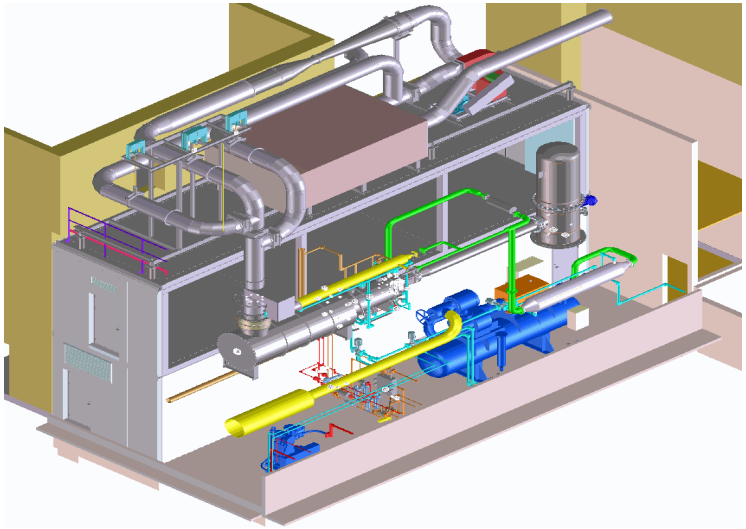
# CECOST-Centre for Combustion Science and Tecnology

- National research centre since 1998
  - Lund University
  - KTH, Stockholm
  - Chalmers, Gothenburg
- Combining generic, phenomonelogical and applied combustion research
- Funded by Swedish Energy Agency and industry (12+12MSEK/year)
- Local Strategic Research centra at Lund University 2006-2010, funded by the Swedish Foundation for Strategic Research

# CECOST: List of projects

- Gas turbine combustion
- Biofuel combustion
- Diagnostics
- Modeling and validation
- Transient sprays
- Solid/organic fuel
- Diagnostic development

# High Pressure Rig

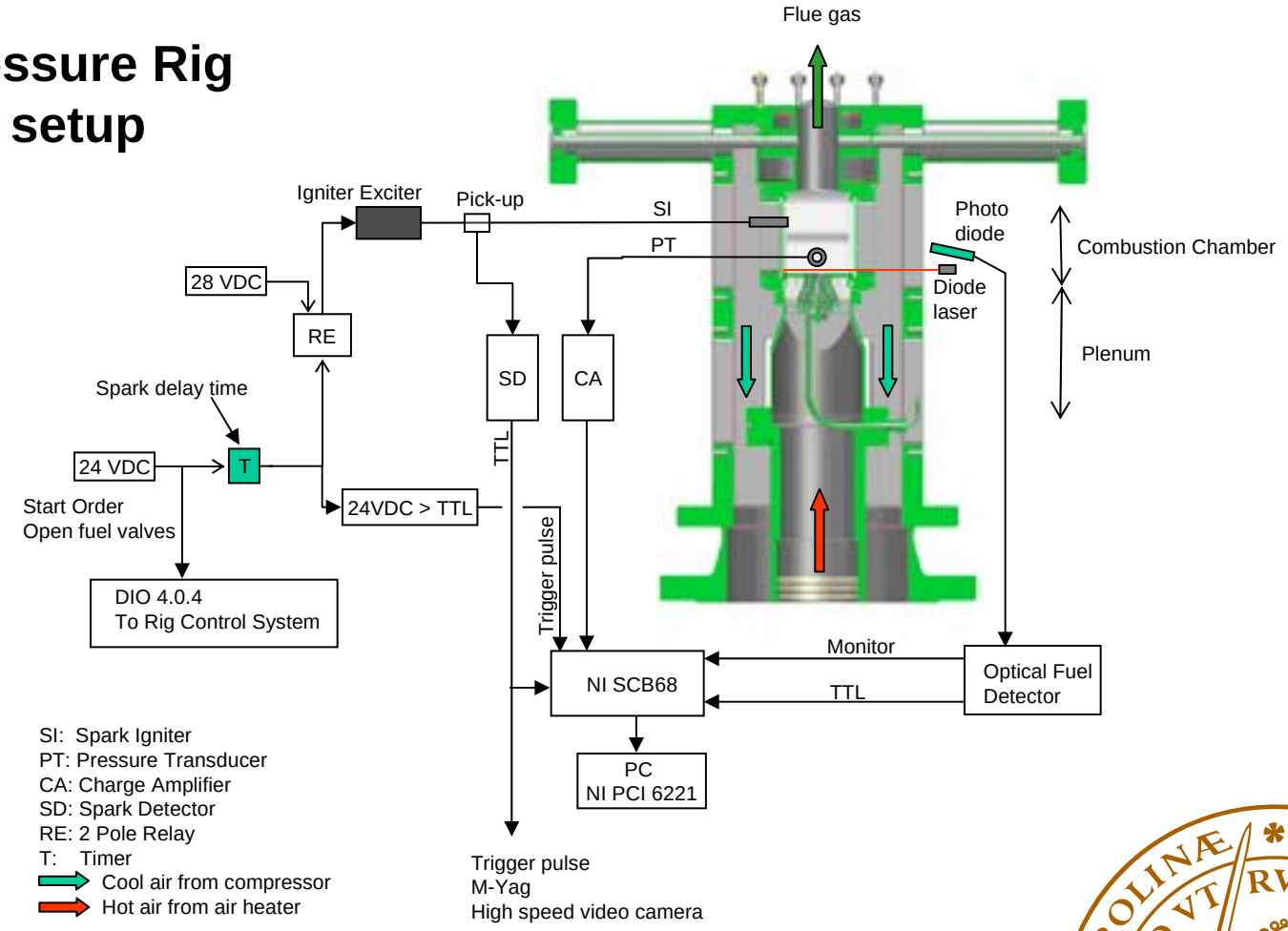


- Air flow: up to 1.3 kg/s
- Preheated 650 K
- Up to 16 bar
- Liquid and gaseous fuels
- Combustion parameter evaluation
- Vaporisation studies
- Mixing studies
- Laser diagnostic measurements (CARS, LIF/MIE, LDV, PIV)

# Time resolved imaging of a single-sector ignition on LPP(X)

- The second part of the test performed at the high pressure test facility in Lund
- Two different ignition points have been tested
- Two fuels have been studied previously:
  - **Synthetic Jet Fuel developed by Oroboros AB, Sweden**
  - **Jet A1**
- For this study only the Synthetic Jet Fuel have been used due to it's suitability for optical measurements

# LTH High-Pressure Rig
# Experimental setup



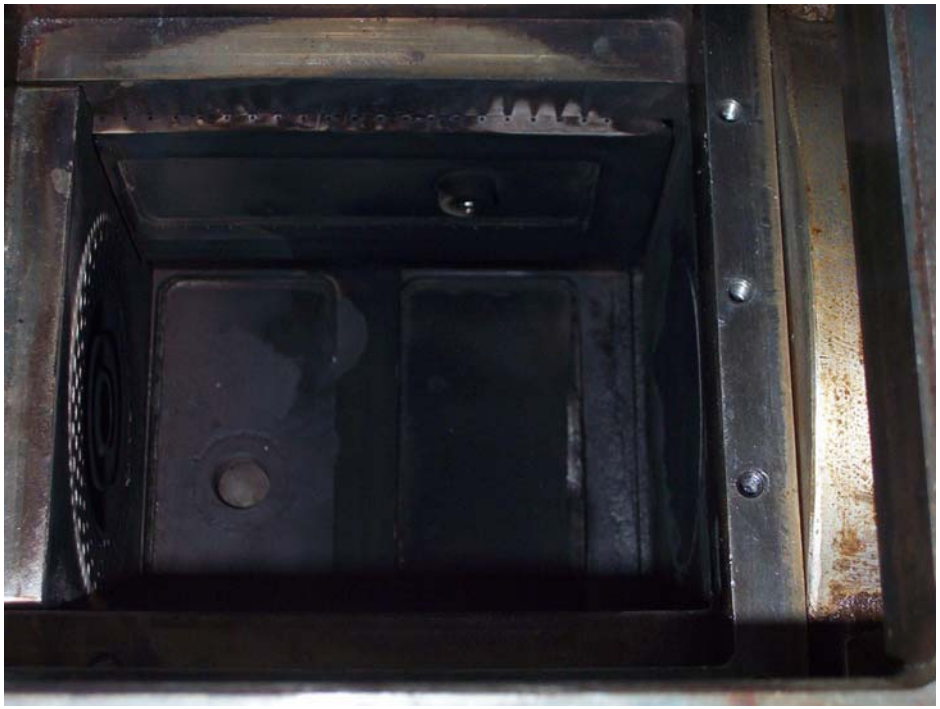
# Diagnostics

- **Kistler 7061 pressure transducer**
- **Phantom V 7.1 image intensified high speed camera (up to 15,000 frames per second)**
- **High energy laser for ignition**

Combustion Chamber after ~ 100 ignition attempts

**Ignition in LP(P)4:**

- Synthetic Jet Fuel developed by Oroboros AB, Sweden
- pilot-only
- P30=3.2 bara
- $AFR_{total}$ = 22
- T30 = 479 K
- airflow = 165 g/s



Combustion Chamber after ~ 20 ignition attempts

**Ignition in LP(P)4:**

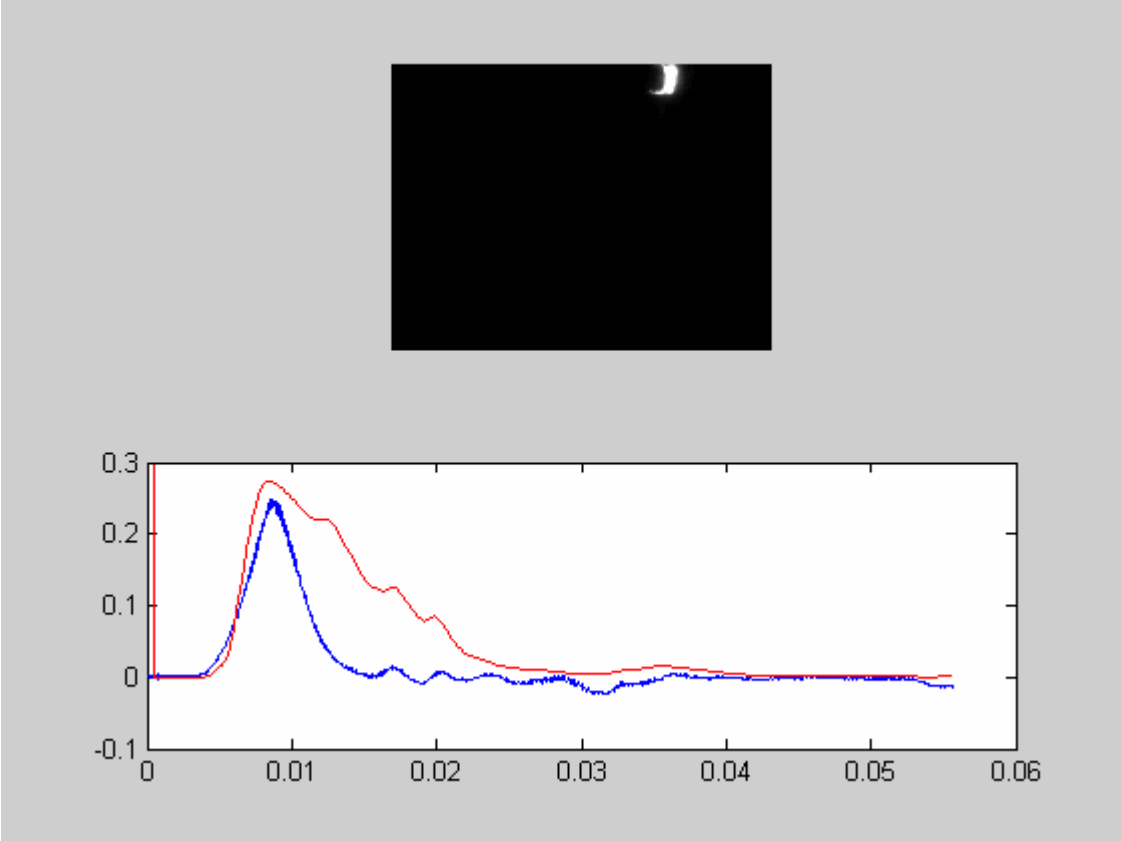
- Jet A1
- pilot-only
- P30=3.2 bara
- $AFR_{total}$ = 22,
- T30 = 479 K
- airflow = 165 g/s

Combustion Chamber before tests

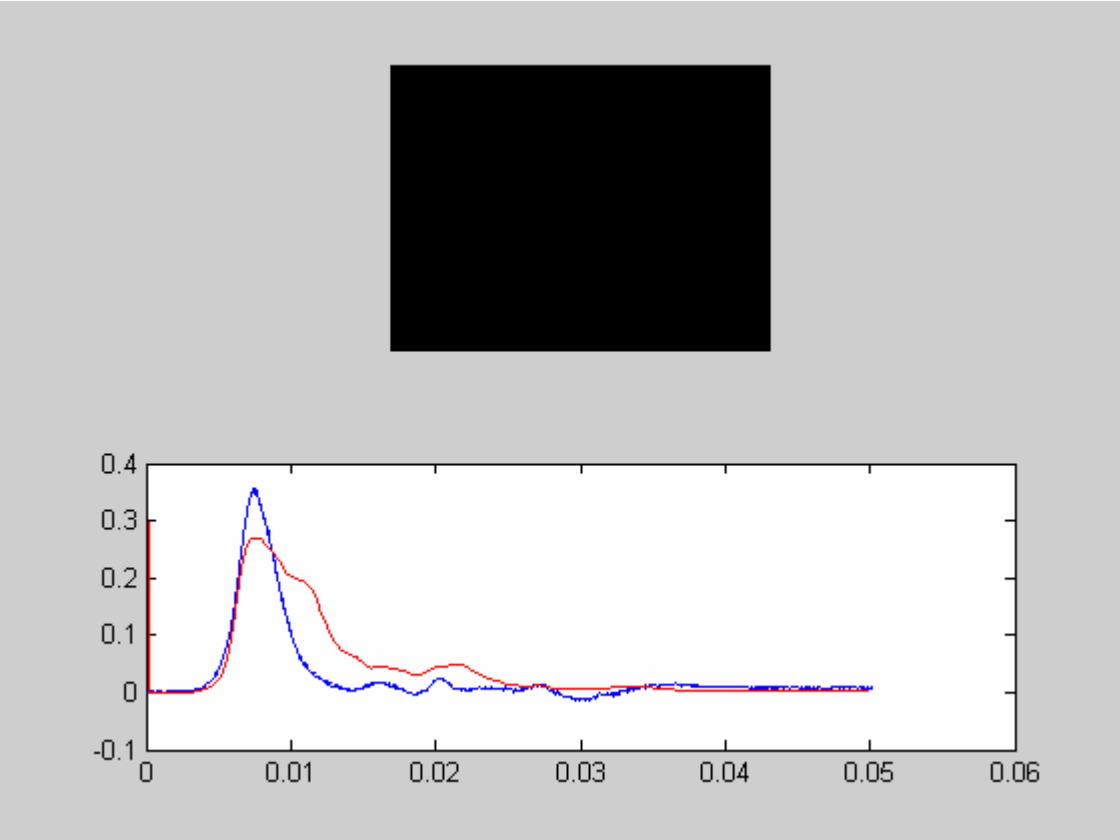
**Ignition in LPP(X):**

- Synthetic Jet Fuel developed by Oroboros AB, Sweden
- pilot-only
- P30=3.2 bara
- $AFR_{total}$ =14
- T30 = 479 K
- airflow = 145 g/s

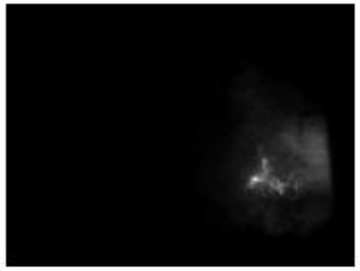
# 2008-05-21: Spark ignition

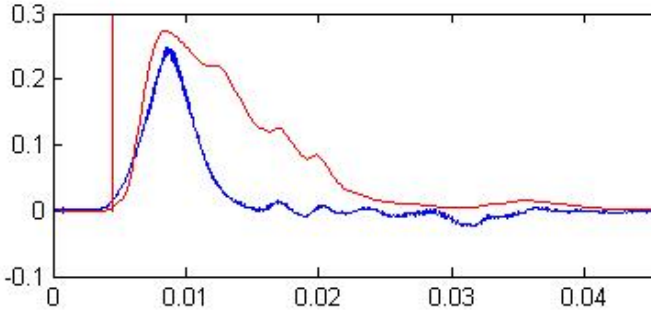


# 2008-05-27: Laser ignition

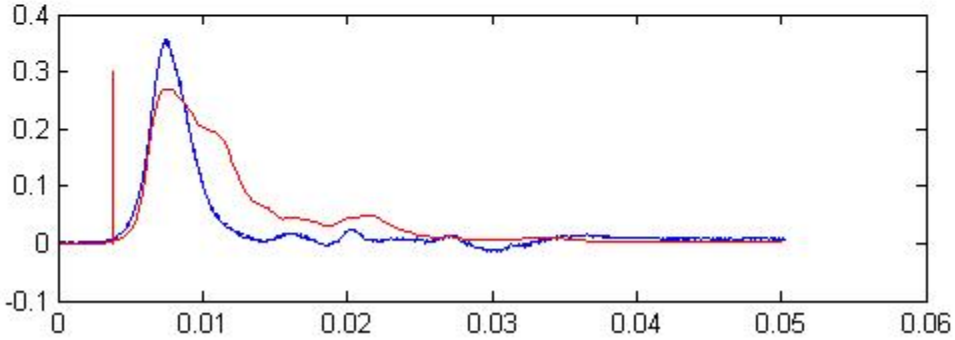


Spark ignition






Laser ignition



# Main observations of fuel influence on ignition in LP(P)4:

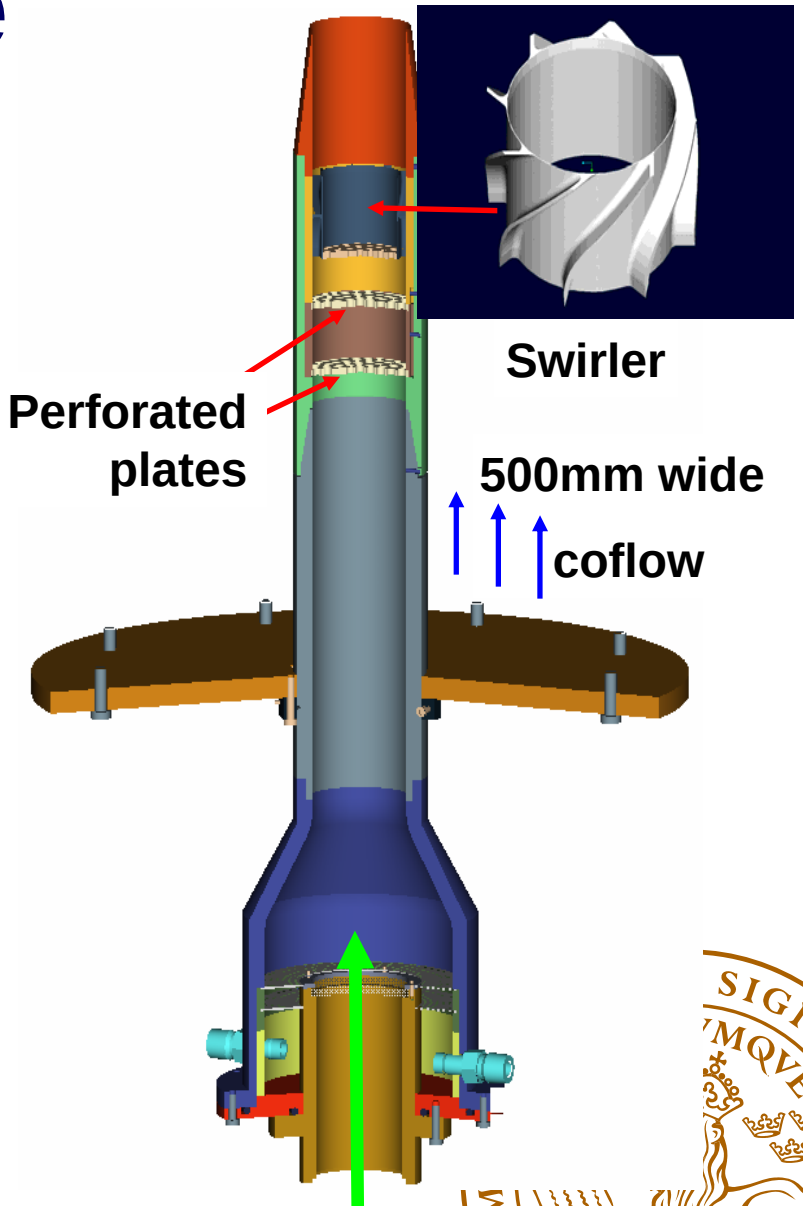
| Fuel | Reliable ignition | Ignition delay after Initiation | Soot and deposits | Suitability for optical measurements |
|---|---|---|---|---|
| **Synth. Jet** | **Yes** | **10.5-12.5 seconds** | **Small amounts** | **Very good** |
| **Jet A1** | **Yes** | **6-7 seconds** | **Large amounts** | **Not so good** |

- **Contributors**
  - **M. Aldén, A, Lindholm** Combustion Physics, Lund University
- **Financial support:**
  - **European union (INTELLECT)**
  - **Swedish Energy Agency**

# Low swirl burner

# Low Swirl Flame

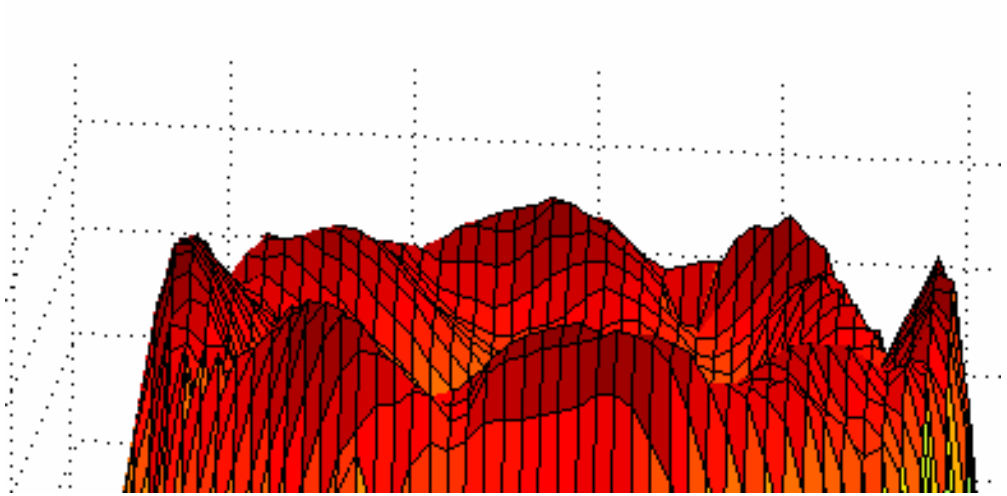
- Original design by R.K. Cheng
- Nozzle diameter 50mm
- Access for laser beam along burner axis → no beam steering
- Operating conditions
  - premixed $CH_4$ /air
  - $\Phi$=0.62, Re=20080, 27 kW (LSF1)
  - $\Phi$=0.62, Re=30125, 40 kW (LSF3)
  - classified in the thin reaction zone based on LDV auto-correlation measurements
  - Swirl number S=0.63 based on LDV velocity profiles at nozzle exit (2mm)




Optical access for “bottom-top” diagnostics

# Inlet conditions 3D PIV, LDV

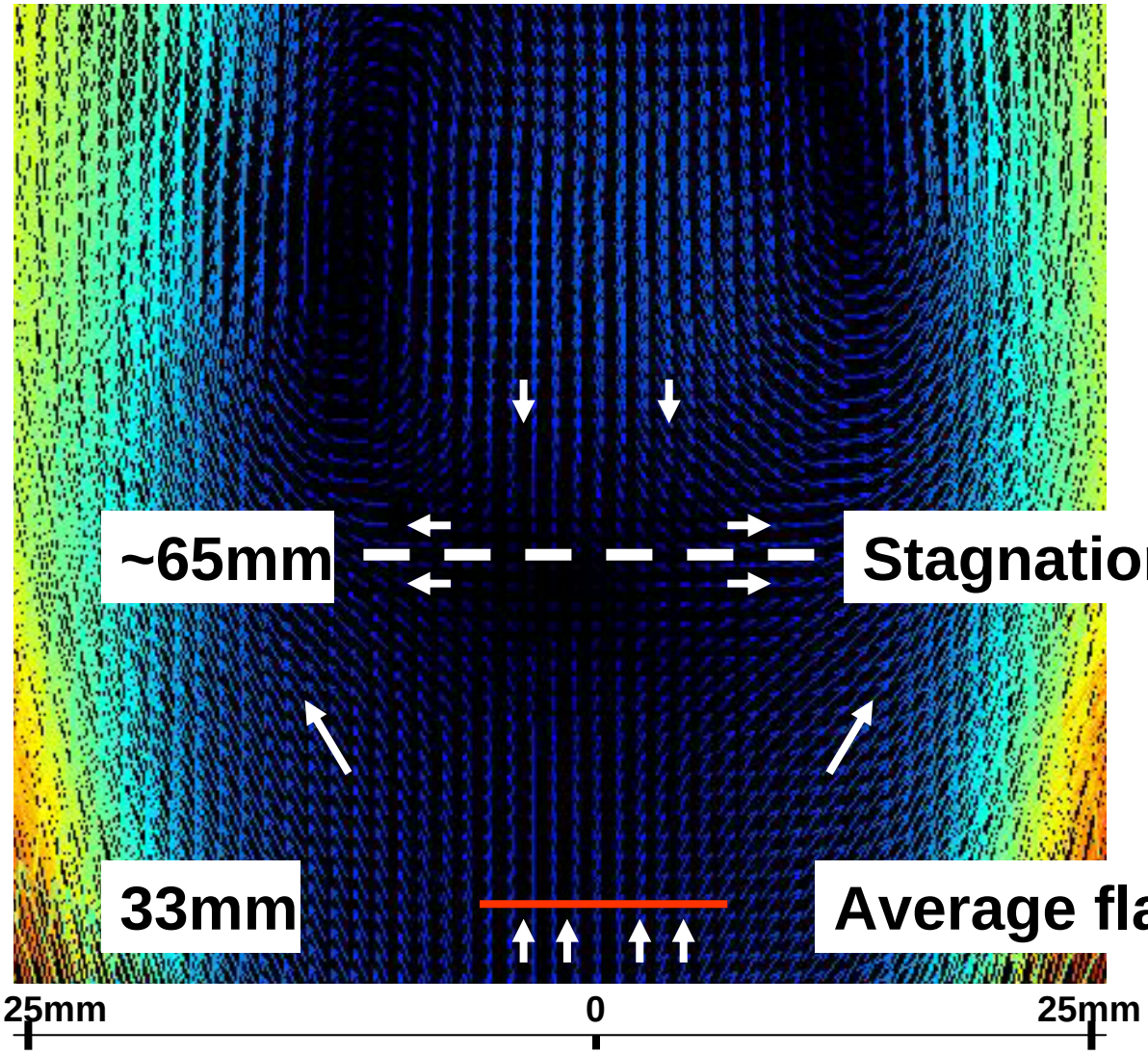
**3-D PIV data 2mm above nozzle**



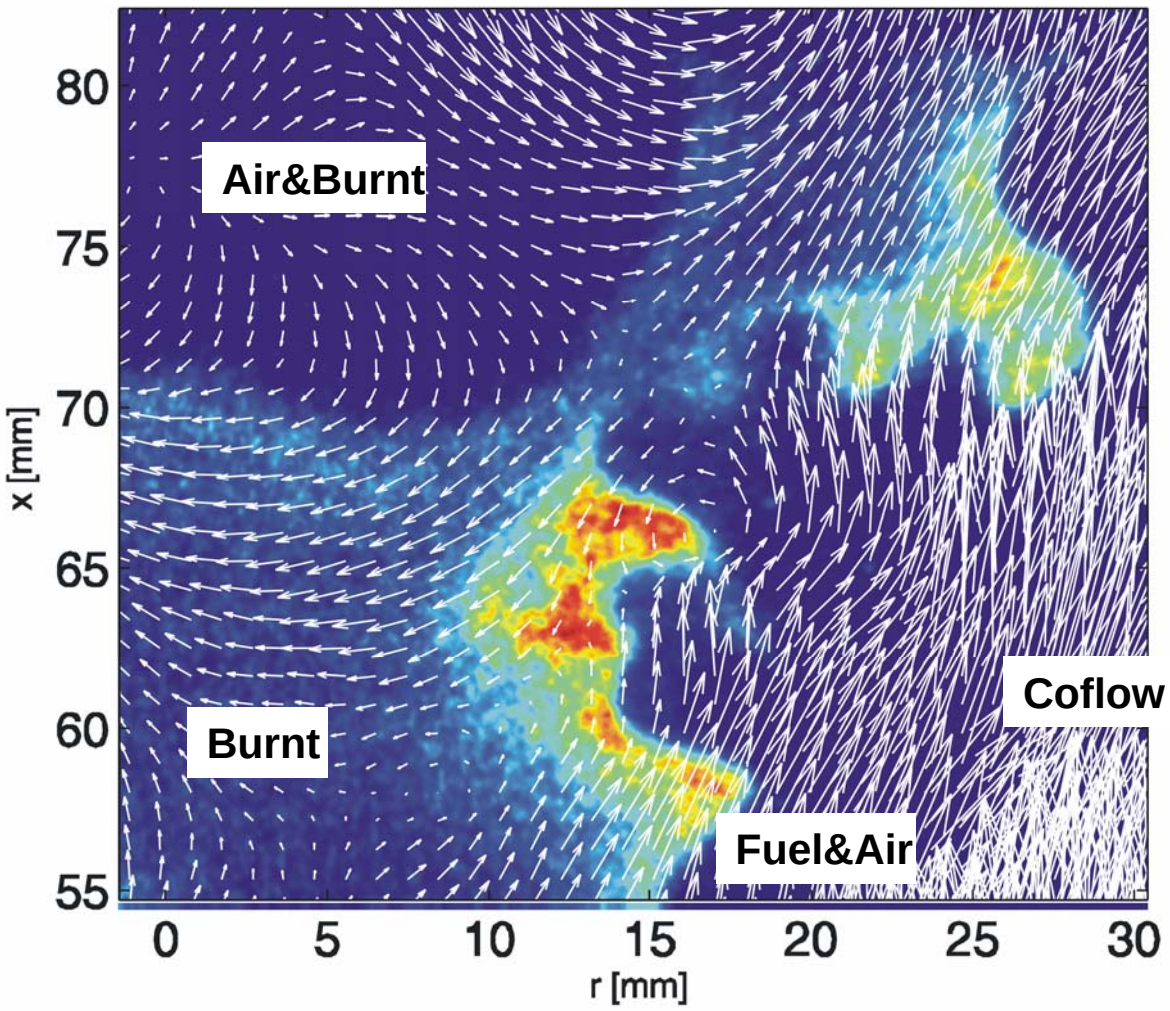
**Mass flow split:**
- **swirler ~60%**
- **center ~40%**

**Swirl number = 0.54**

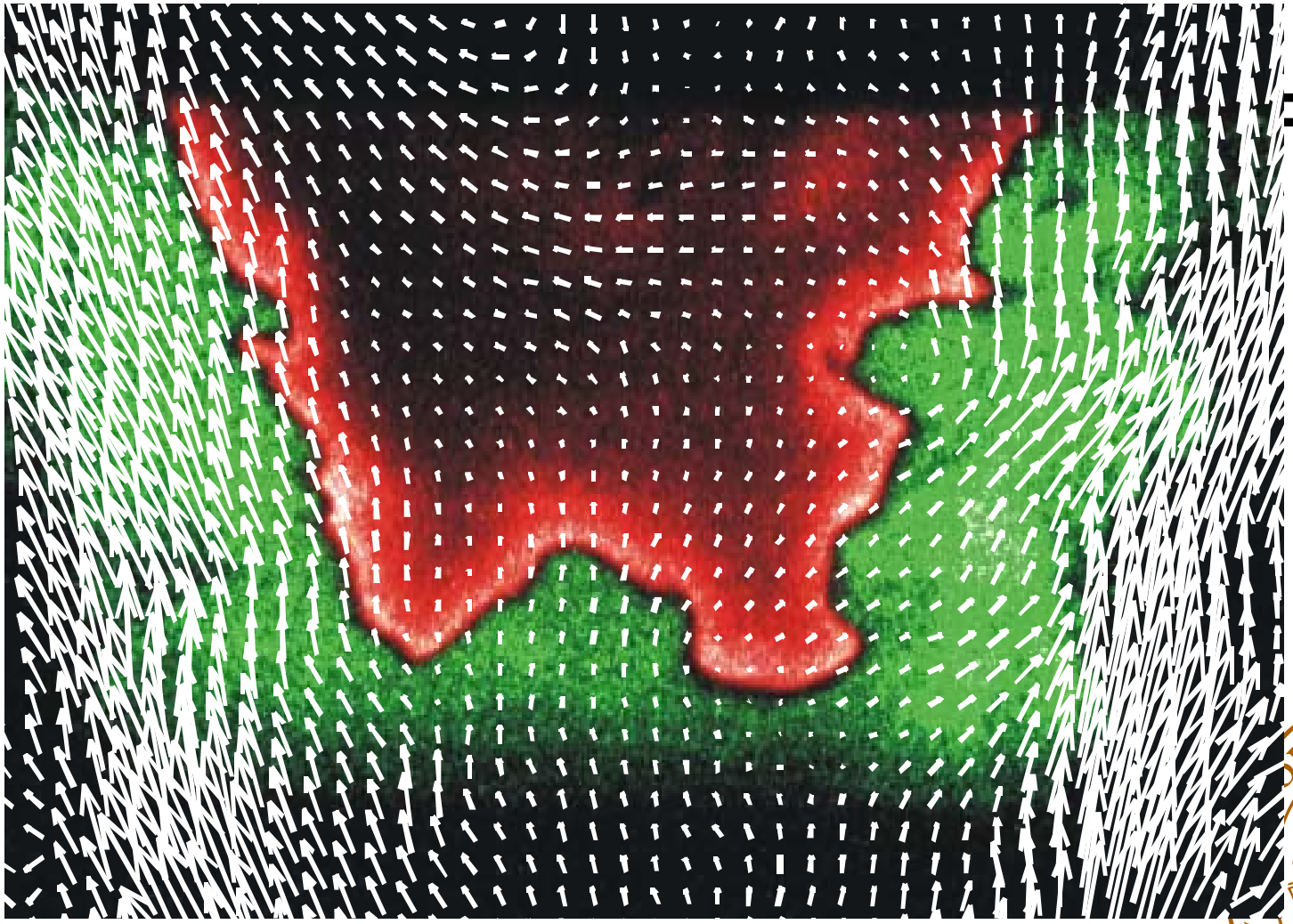
# Mean flow field in centre of flame



# Combined PIV and OH-LIF measurements in the outer stratified flame region

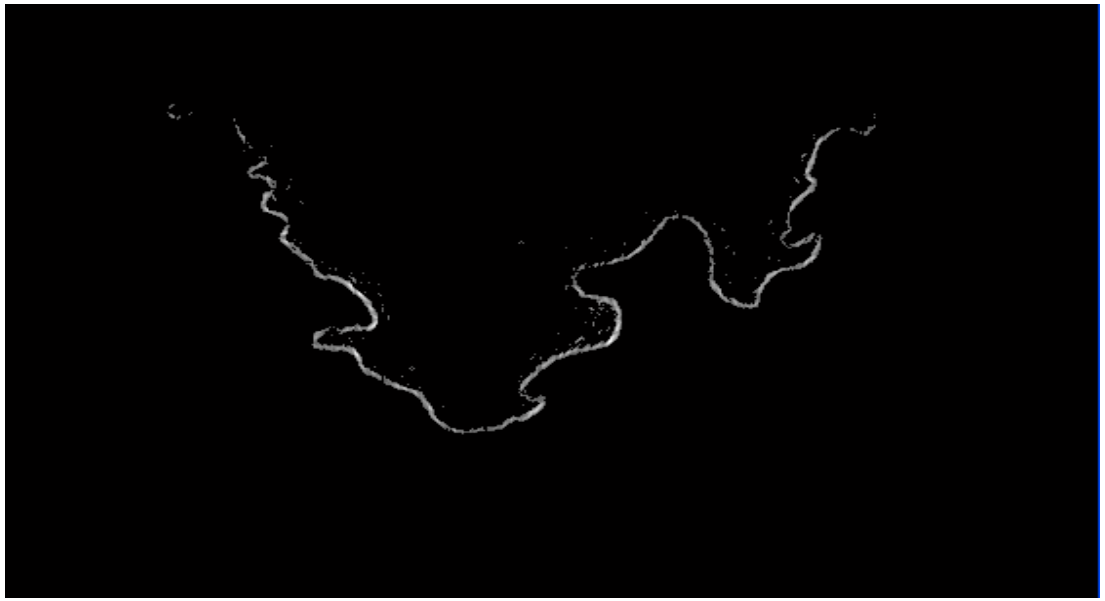


# Simultaneous OH-PLIF & Fuel-PLIF& PIV



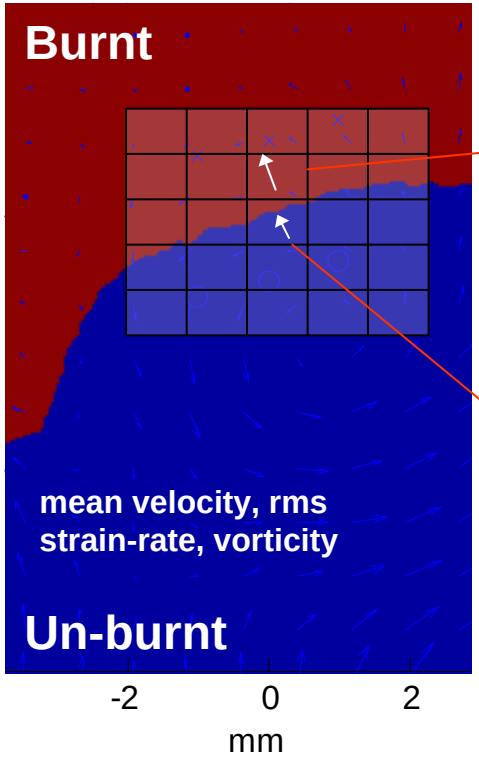
# Flame front visualization

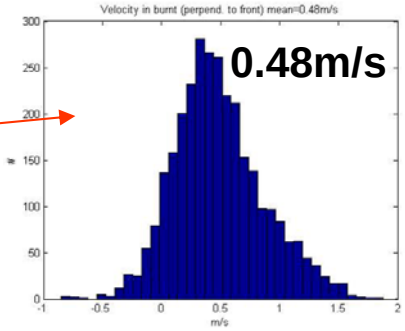
- **data set with simultaneous velocity and flame contour**

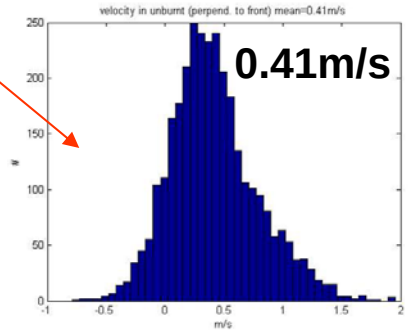


# Local flame parameters

**Mean conditional velocity**
**(component perpendicular to the flame front)**




Conditional-
•velocities,
•fluctuations

……

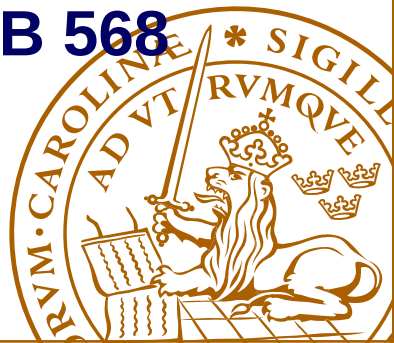
•strain-rate,
•vorticity

For characterization of flames (conditional data in burnt & un-burnt)
Detailed information about flow / flame interaction

# Summary

- **Data sets for different turbulent premixed target flames under construction**
- **Publication of database under discussion**

- **Contributors:**
  - **P. Petersson, C. Brackman, H. Seyfried, J. Olofsson, M. Aldén, M.A. Linne,** Division of Combustion Physics, Lund University
  - **A. Nauert, Andreas Dreizler,** Fachgebiet Energie- und Kraftwerkstechnik, Fachbereich Maschinenbau, TU Darmstadt
- **Financial support:**
  - **Swedish Energy Agency through CECOST and Swedish Research Council**
  - **European Union (Large Scale Facility)**
  - **Deutsche Forschungsgemeinschaft (SFB 568 and DR347/4-1)**



# CECOST: List of projects

- Gas turbine combustion
- Biofuel combustion
- Diagnostics
- Modeling and validation
- Transient sprays
- Solid/organic fuel
- Diagnostic development

# The Modeling & Validation Project in CECOST

- Validation: experiments and laser diagnostics (swirl burner)
  - Mark Linne, Marcus Aldén, LTH
- Modeling: Flamelet and level-set based LES model (swirl burner)
  - Xue-Song Bai, LTH
- Modeling: LES flame-capturing model (swirl burner)
  - Lars-Erik Eriksson, CTH
- Validation: experiments and laser diagnostics (plane wall jets)
  - Joakim Bood, Marcus Aldén and Mark Linne, LTH
- Modeling: DNS model development (plane wall jets)
  - Arne Johansson, KTH
- LES at FOI (swirl burner, in-kind contribution)
  - Christer Fureby, FOI

# The Gas Turbine Project in CECOST

- Stability of burners for fuel flexible gas turbines
  - Laszlo Fuchs, LTH, SIEMENS
- Alternative fuel spray modelling and validation
  - Laszlo Fuchs, LTH , SIEMENS
- Flameless oxidation burner with piloting
  - Marcus Aldén, LTH , SIEMENS
- Flame temperature measurement for syngas application
  - Marcus Aldén, LTH , SIEMENS
- Fuel profile measurement for syngas application
  - Marcus Aldén, LTH , SIEMENS
- Optical diagnostics in a jet engine afterburner
  - Marcus Aldén, LTH , Volvo Aero
- Investigation of flames from biogas
  - Jens Klingmann, LTH , E.ON Sweden