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Experimental Study of flow and Scalar Mixing in Swirl-stabilised burners

Imperial College London

Experimental study of flow and scalar mixing in swirl-stabilised burners

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Current Research in Combustion

A Forum for Research Students and Early Career Researchers

24 September 2013, Loughborough University, Loughborough, UK

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Contents

Introduction

Swirling flows are used: (Syred & Beer, Comb. and Flame 23, 1974)

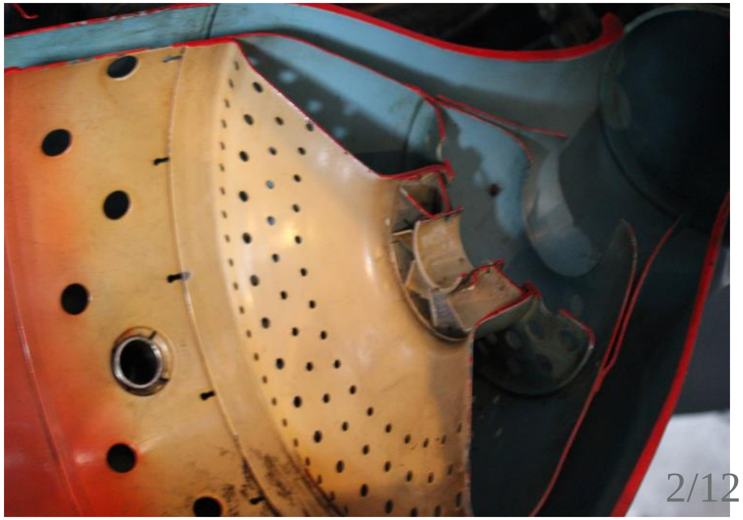
1. To reduce combustion length by producing higher rates of mixing.

2. To improve flame stability as a result of the formation of recirculation zones.

3. To minimize flame impingement on the burner.

RR Trent

RR Derwent



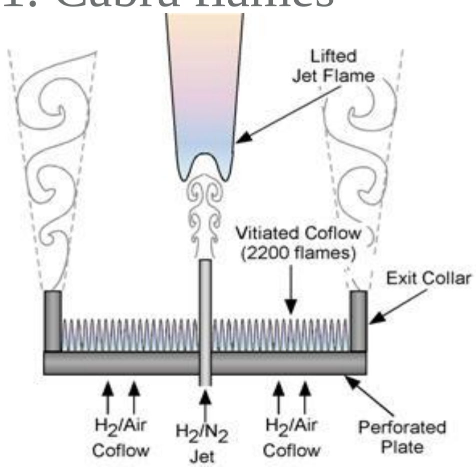
Objectives

1. To further understand the flow dynamics in reacting and non-reacting swirling flows in practical configurations.

2. To gather complete experimental data from practical configurations (velocity, temperature, scalar distribution).

Typical test cases → 1. Cabra flames, 2. Sandia flames, 3. Rod-stabilized flames

1. Cabra flames

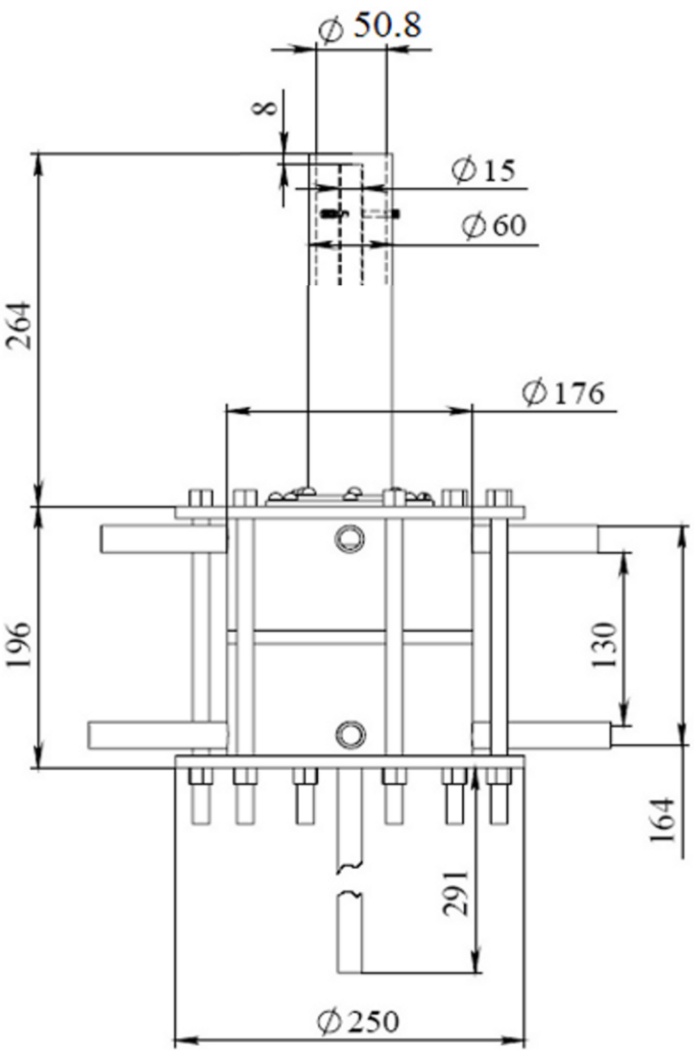


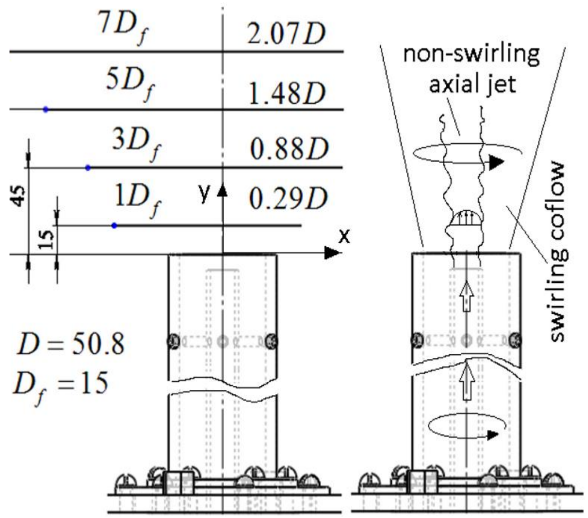
2. Sandia flames

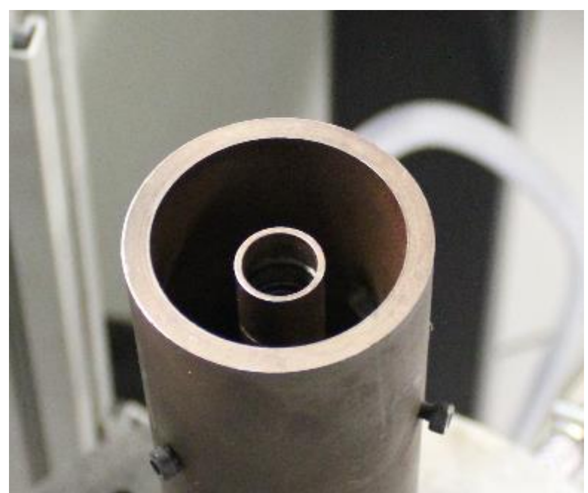
3. Rod-stabilized flames

1. http://www.me.berkeley.edu/cal/vcb/data/VCHNData.html
2. http://www.sandia.gov/TNF/DataArch/FlameD.html
3. https://ccse.lbl.gov/Research/Combustion/V-flames.html

Swirl-Stabilised Burner







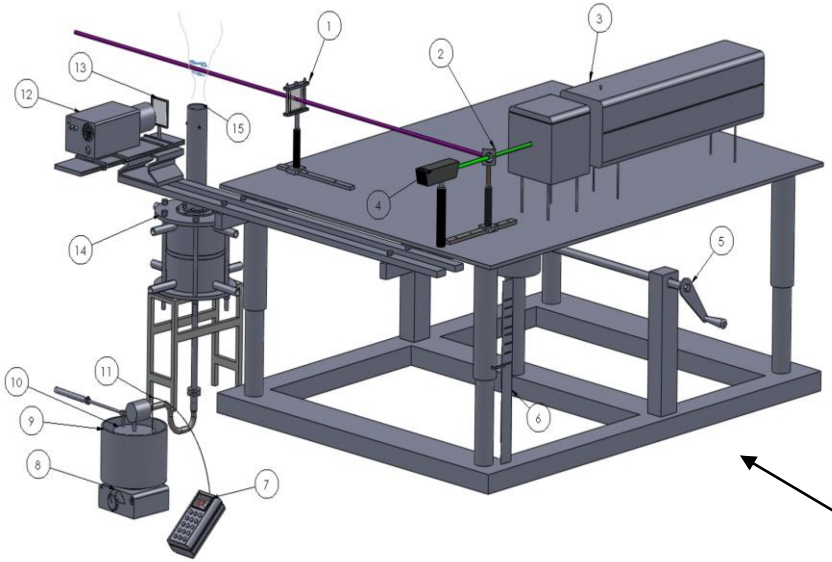
S=0.3, 0.58, 1.07
Re = 29000
V = 8.46 (m/s)
λ_β = 0.3 (mm)

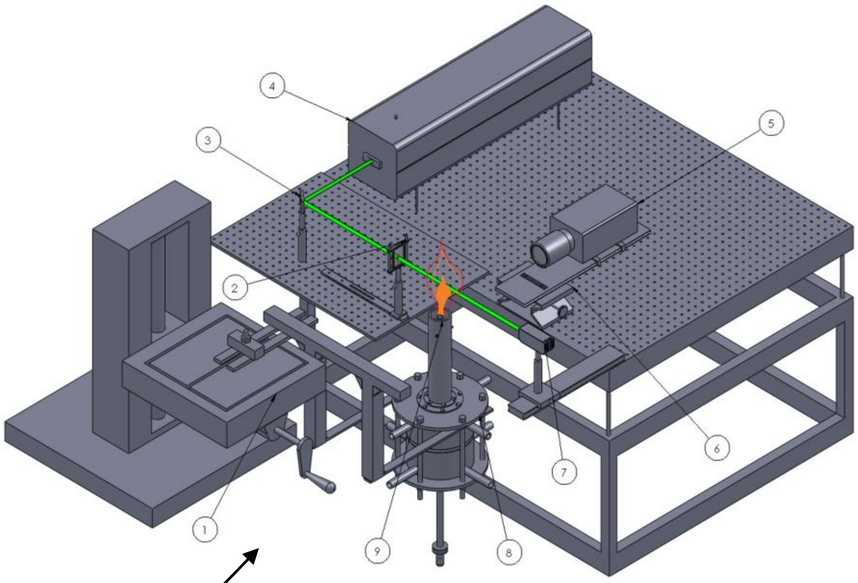
Methods used:

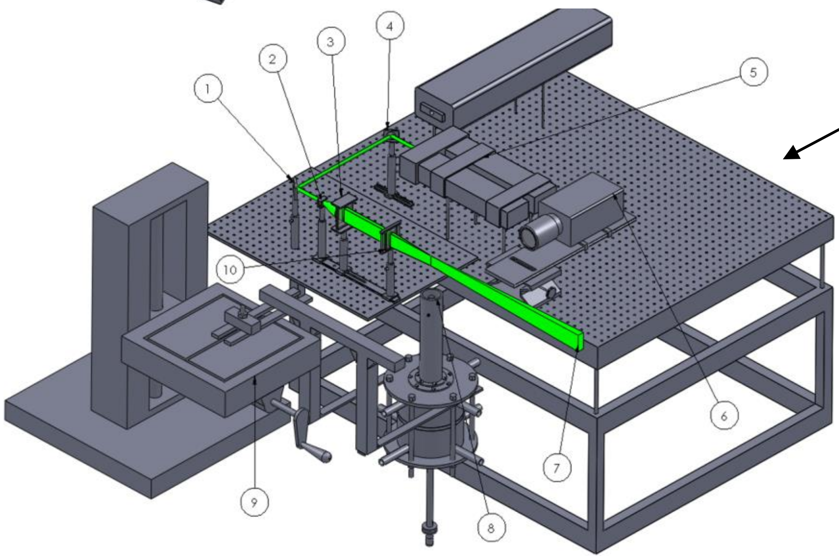
a) non-reacting case
1. LIF (acetone)
2. PIV

b) reacting case
1. Rayleigh
2. PIV

Optical Arrangements



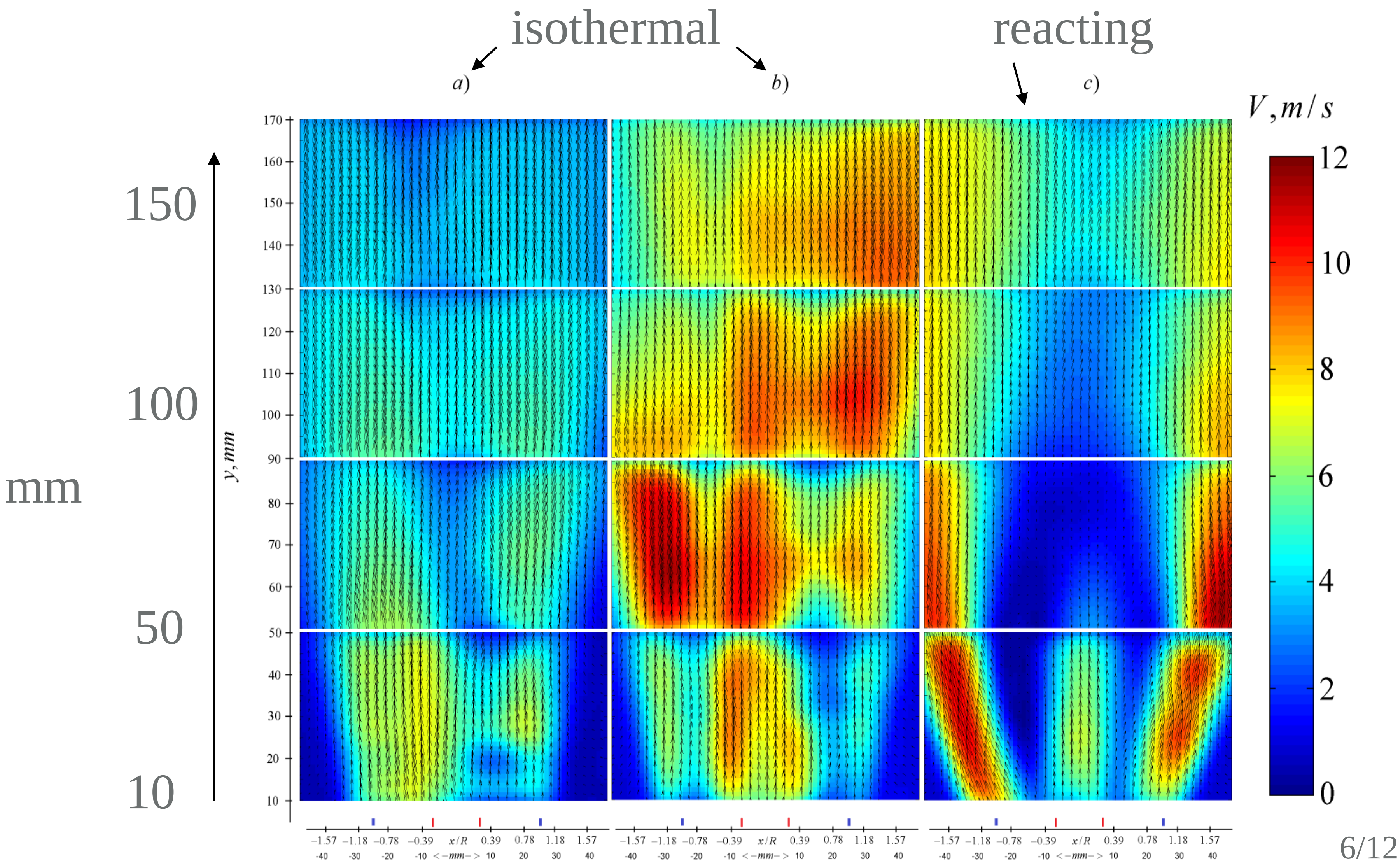




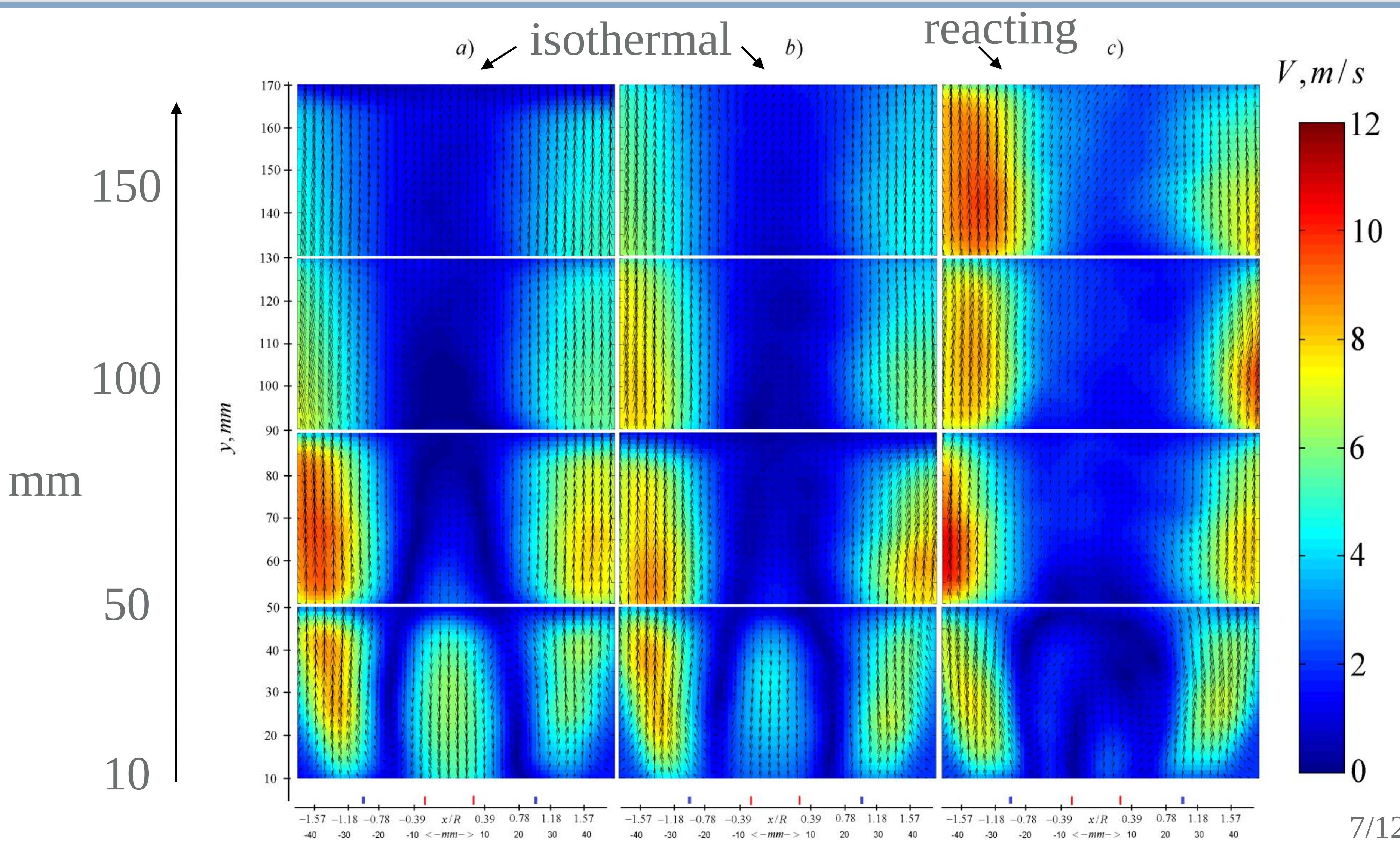
PIV, LIF, Rayleigh

Typical energy at laser exit:
- LIF: ≈ 120 (mJ/pulse)
- Rayleigh: ≈ 960 (mJ/pulse)

Flow Structure (Mean velocity; S=0.3)



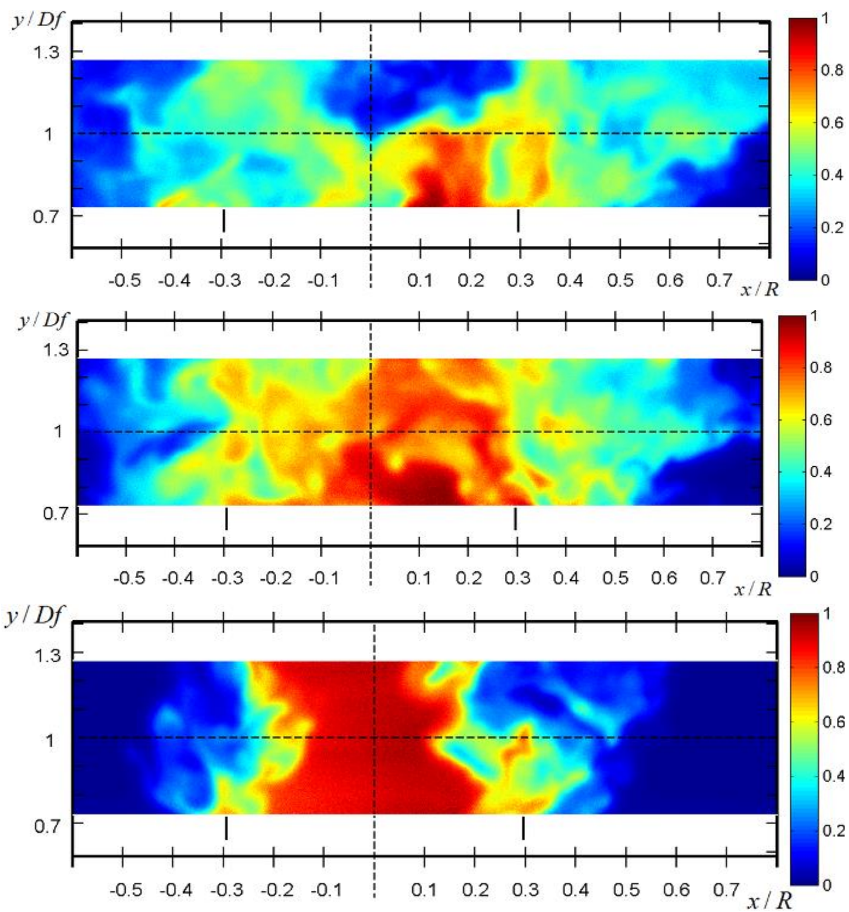
Flow structure (Mean velocity; S=1.07)



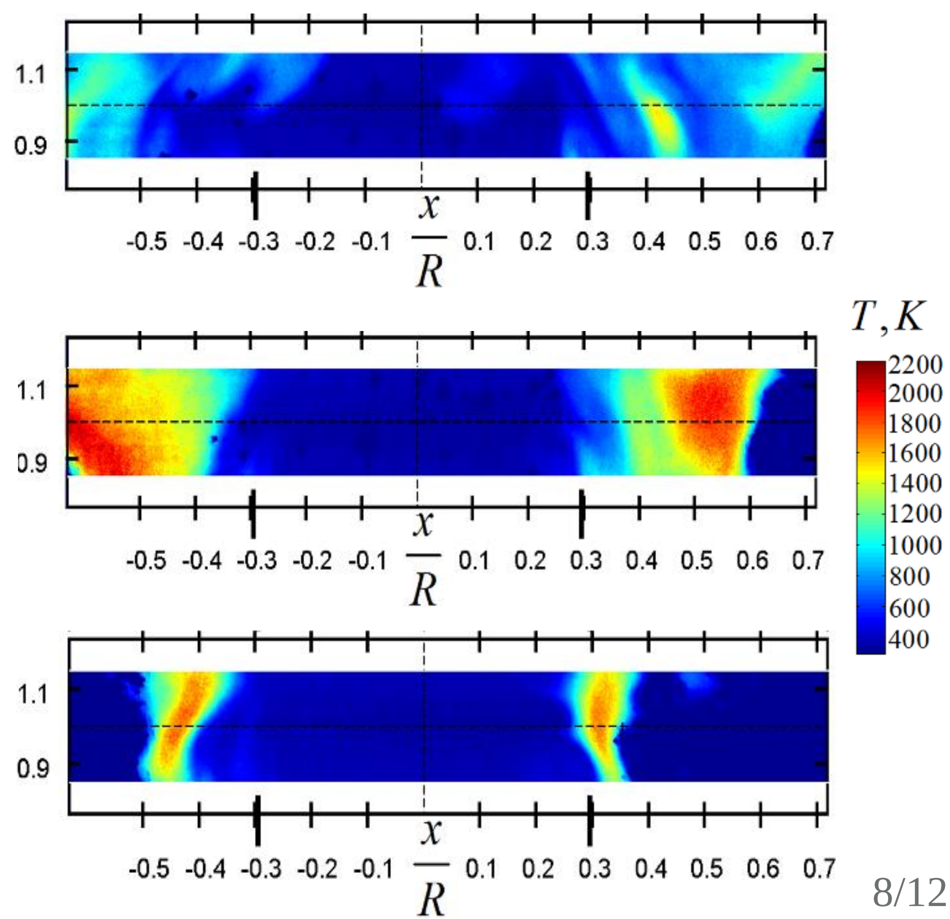
Scalar mixing and Combustion (S=0.3-1.07)

Instantaneous distribution at y=15mm of {top to bottom: S=1.07, 0.58, 0.3}:

Mixture fraction



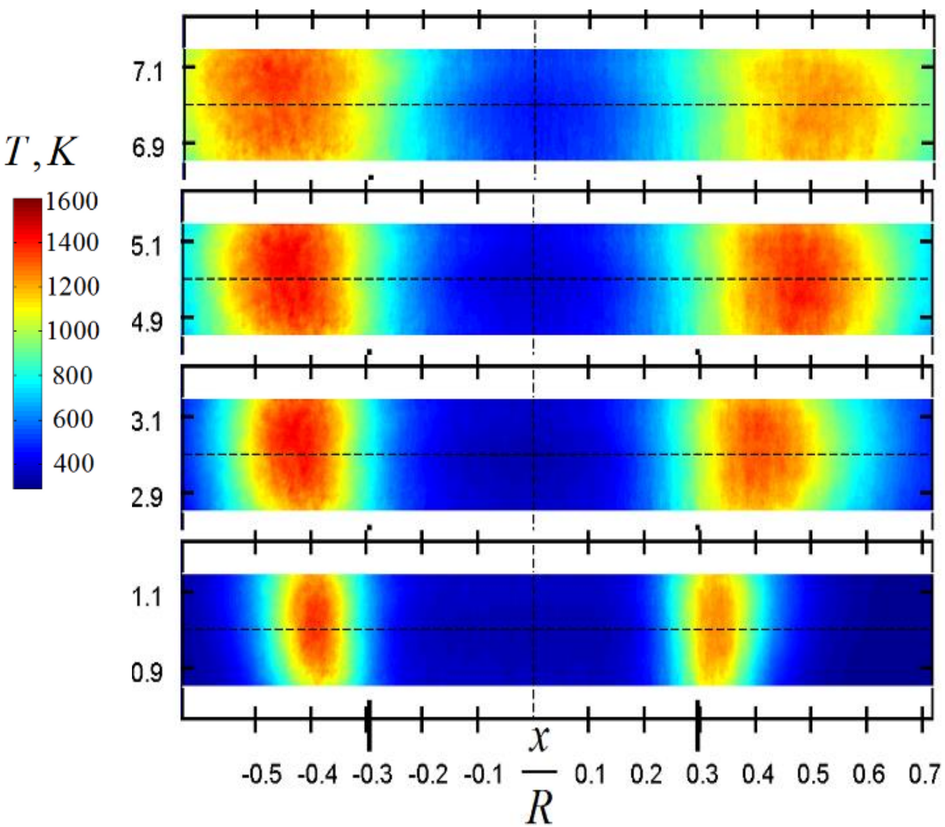
Temperature

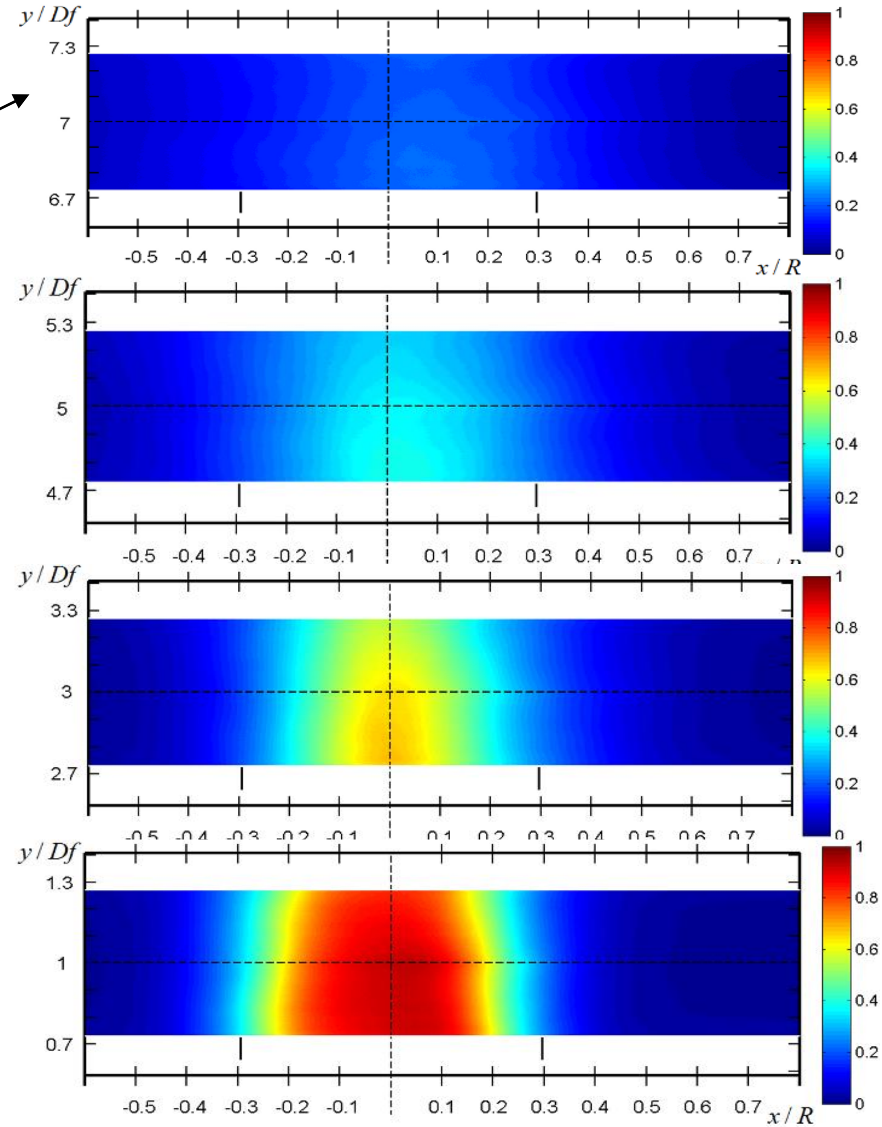


Scalar mixing and Combustion (S=0.3)

Distribution of mean:

Temperature, Mixture fraction

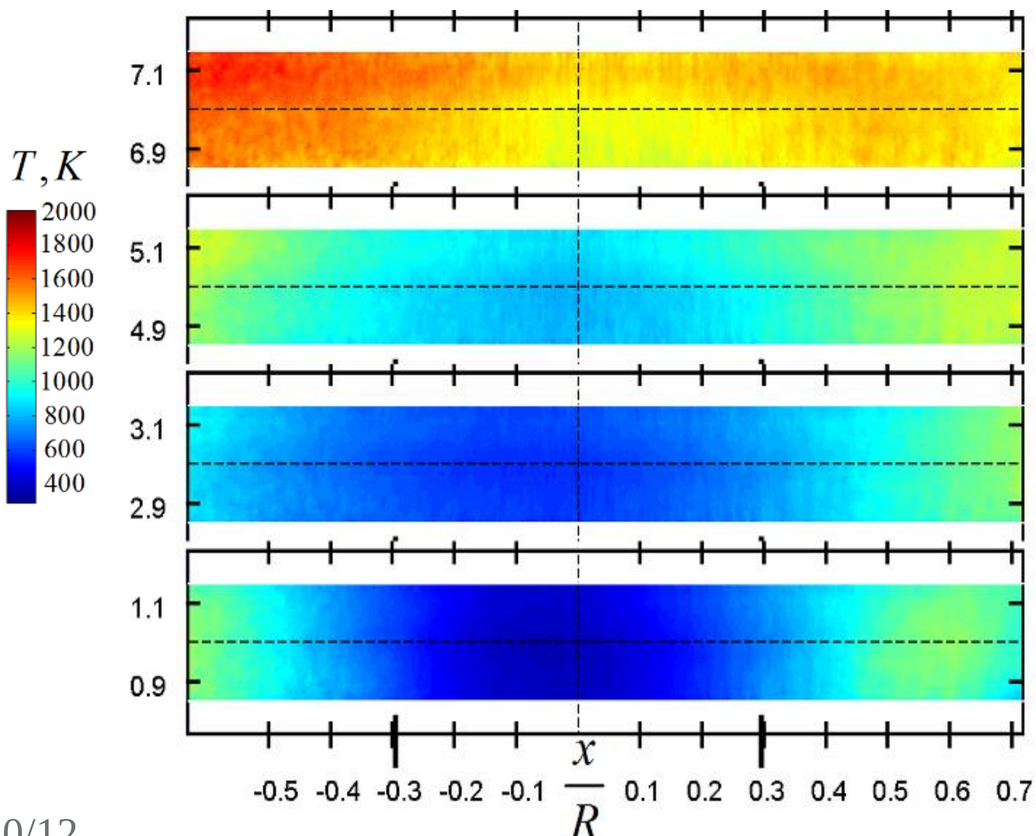


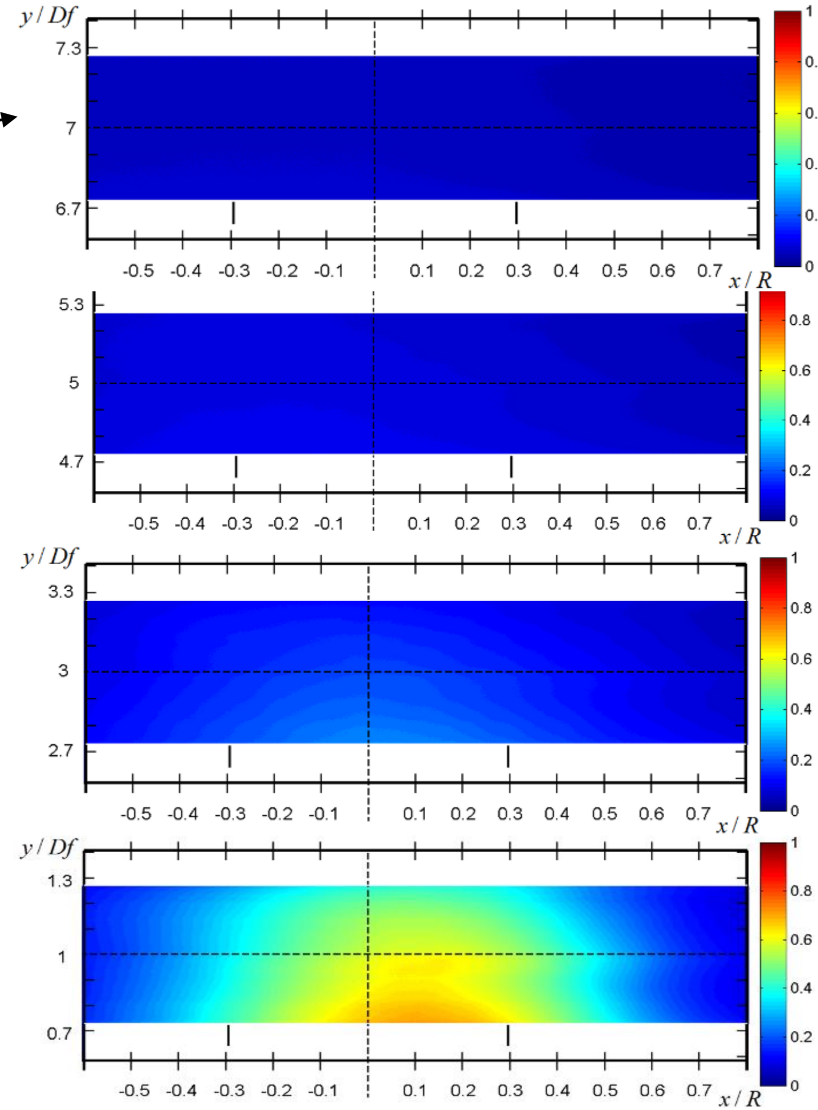


Scalar mixing and Combustion (S=1.07)

Distribution of mean:

Temperature, Mixture fraction





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Parameters evaluated (as a function of 'S')

Isothermal case:

- ✓ Mixture fraction statistics.
- ✓ Scalar dissipation rate (instantaneous, mean, fluctuations, conditional).
- ✓ Filtered density functions (in the context of LES).
- ✓ Velocity statistics.
- ✓ Vorticity and flow structure (proper orthogonal decomposition).

Reacting case:

- ✓ Temperature statistics.
- ✓ Thermal dissipation rate.
- ✓ Velocity statistics.
- ✓ Vorticity and flow structure.

General Conclusions

1. Isothermal and reacting swirling flows produced by a 'real' burner were investigated.

2. Statistics were obtained and relevant quantities were assessed.

- ✓ S=0.3 flame was not stabilised by the recirculation zone.
- ✓ S = 0.58 and S=1.07 flame was stabilised by the recirculation zone.
- ✓ Highly inhomogeneous instantaneous scalar and temperature distributions near the burner exit.
- ✓ High scalar and temperature fluctuations near the burner exit.

Specific conclusions (on scalar dissipation rate, temperature statistics etc.) are not presented here.

Thank you

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