



**HAL**  
open science

## Effects of Exhaust Gas on CH<sub>4</sub>-AIR-O<sub>2</sub> Turbulent Swirling Flames

Hajar Zaidaoui, Toufik Boushaki, Jean-Charles Sautet, Christian Chauveau

► **To cite this version:**

Hajar Zaidaoui, Toufik Boushaki, Jean-Charles Sautet, Christian Chauveau. Effects of Exhaust Gas on CH<sub>4</sub>-AIR-O<sub>2</sub> Turbulent Swirling Flames. 37th international symposium on combustion, Jul 2018, Dublin, Ireland. 10.13140/RG.2.2.13729.04965 . hal-01848555

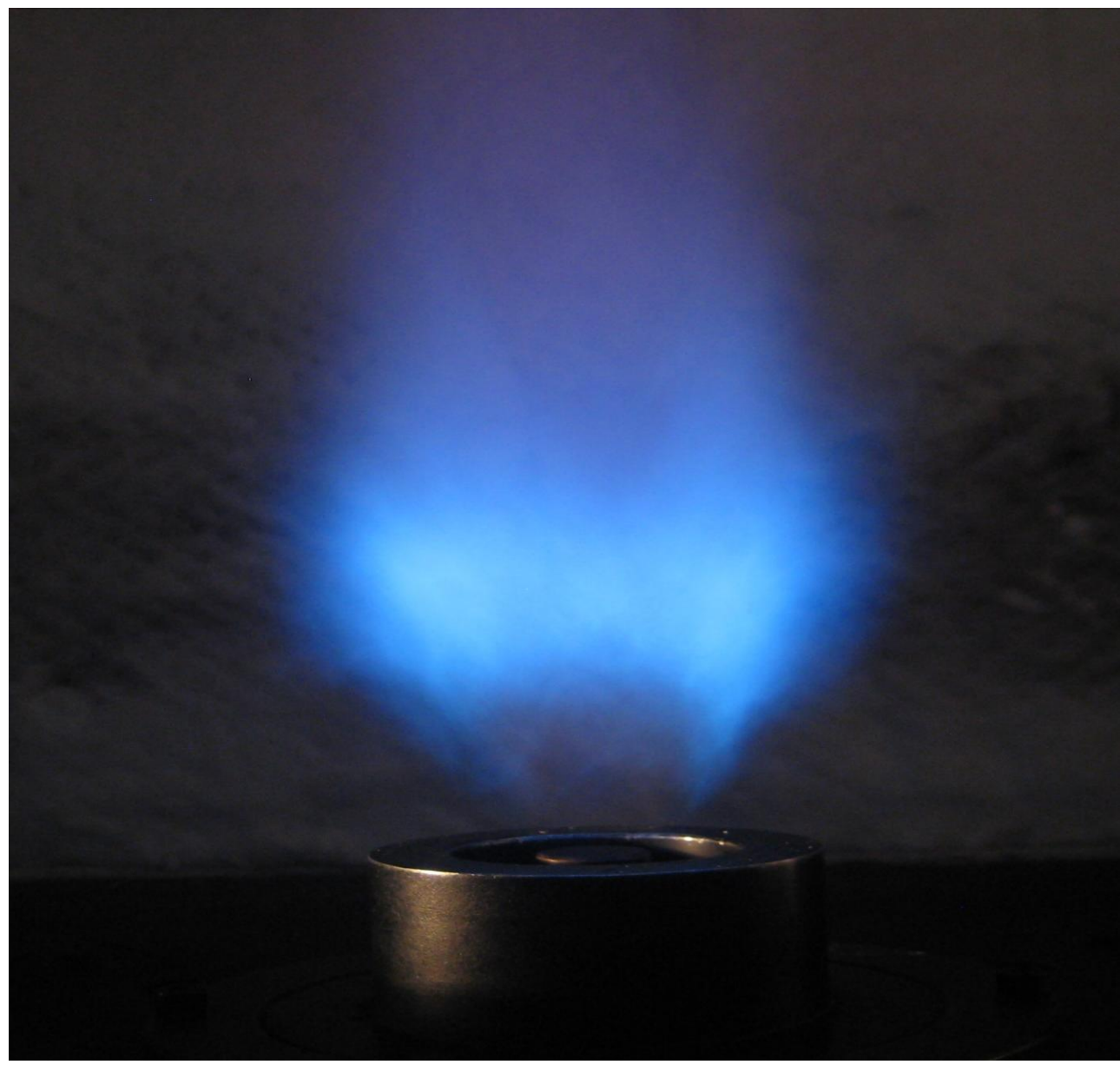
**HAL Id: hal-01848555**

**<https://hal.science/hal-01848555>**

Submitted on 24 Jul 2018

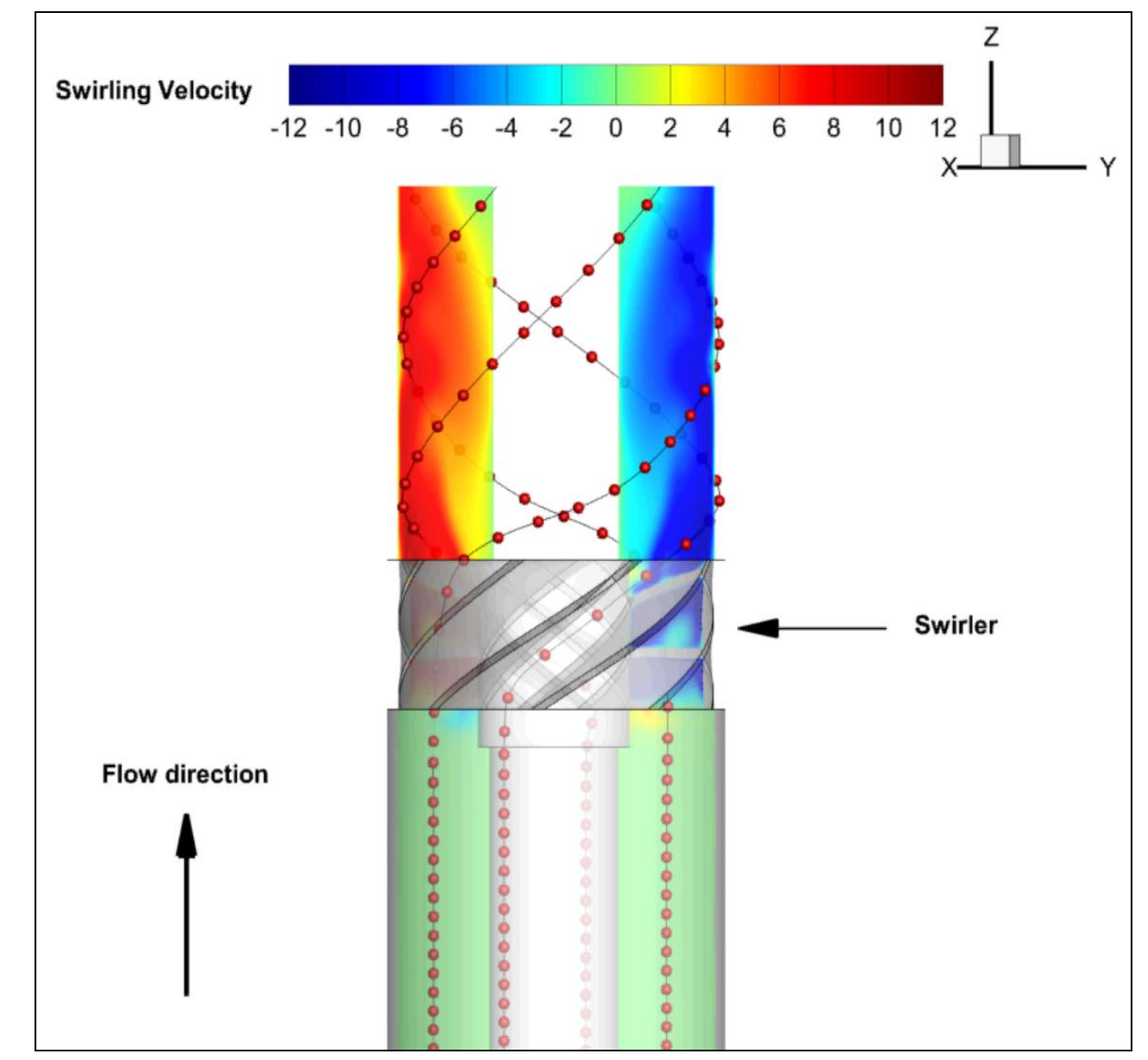
**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



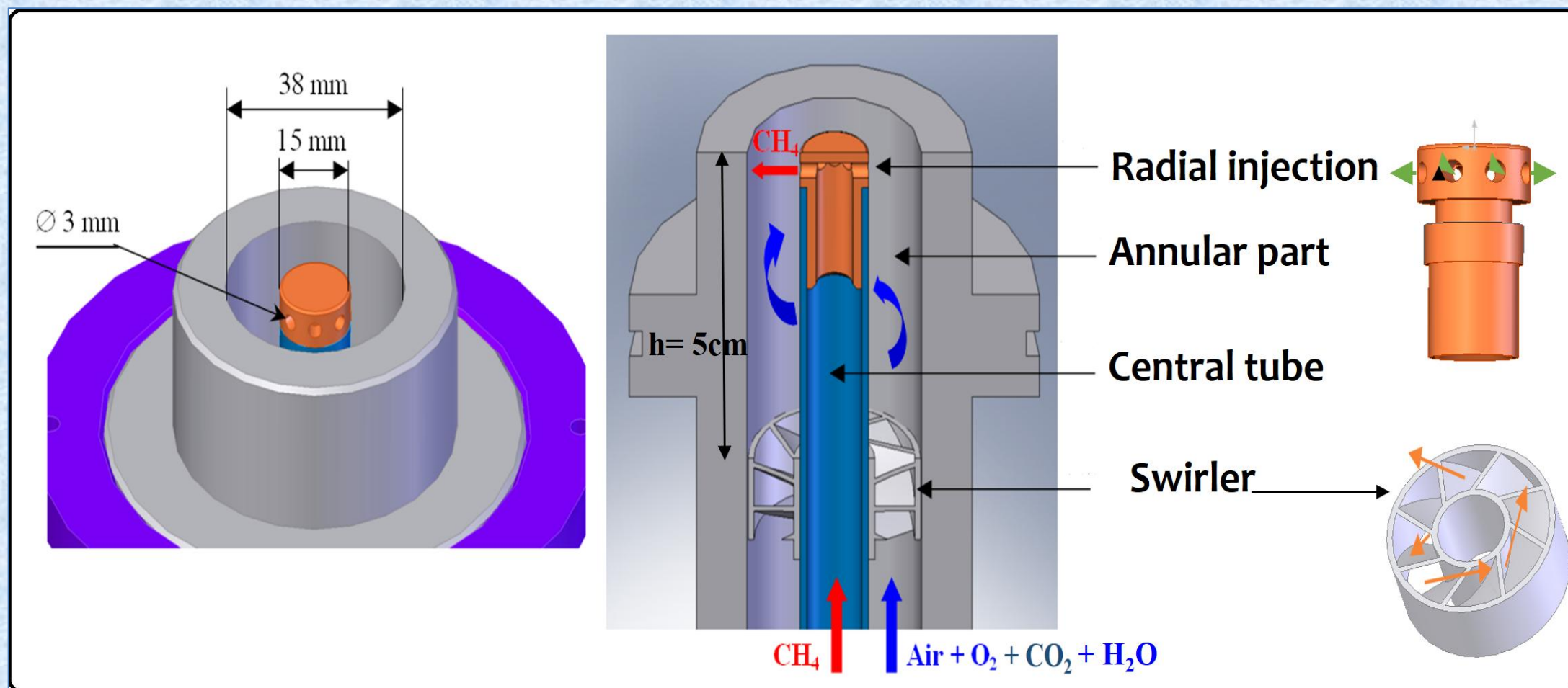
## Context and objectives

- Study of non-premixed turbulent flames stabilized by a swirler
  - Improve performances of combustion plants
  - Reduction of pollutant emissions / emissions standards
- Investigations on flame characteristics
  - Effects of oxygen enrichment
  - Effects of steam and CO<sub>2</sub> dilution
  - Effects of swirl intensity



## Experimental setup

### Coaxial swirl burner



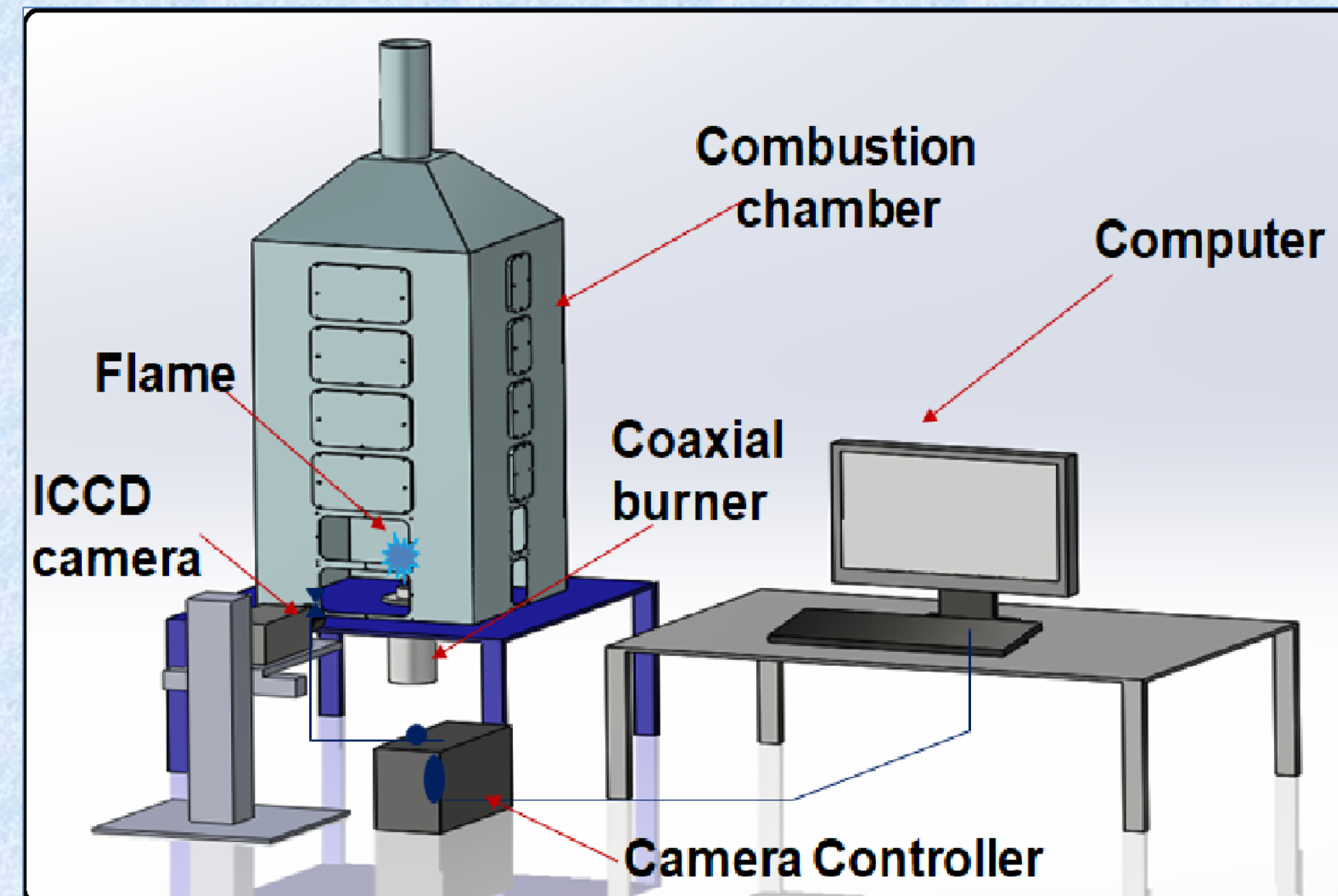
- Two concentric tubes with a **swirler** in the annular part
- Combustion chamber : 25 kW, dimensions 0.5x0.5x1 m<sup>3</sup>

### Measurement and analysis of flue gases

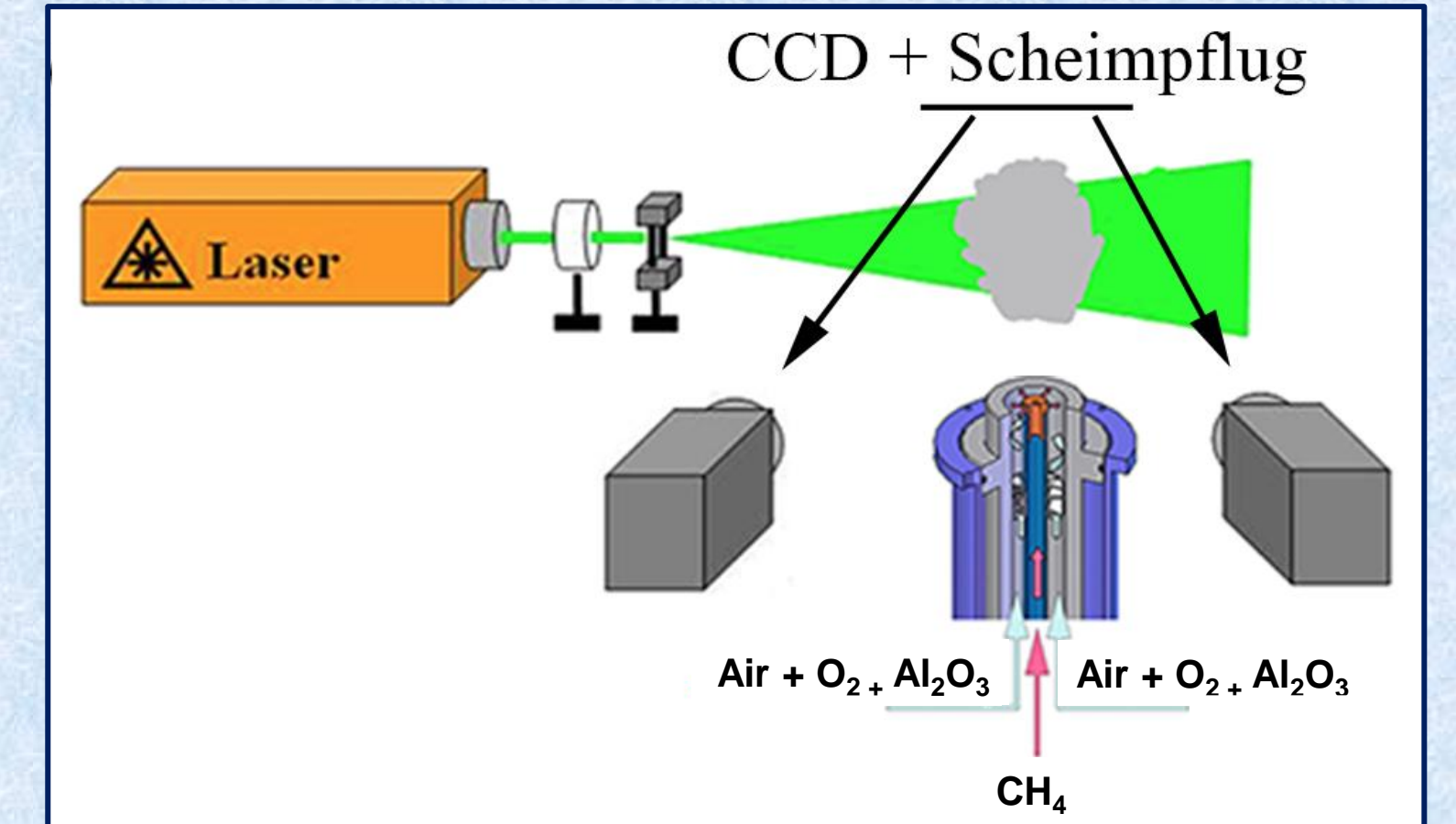
- Concentrations of NO<sub>x</sub>, CO, CO<sub>2</sub>, O<sub>2</sub> and SO<sub>2</sub> in the flue gases are measured.
- ABB 220 and HORIBA PG250 multi-gas analyzers.

### OH\* chemiluminescence technique

- Apparatus** : ICCD camera, a 105 mm UV lens, a 306 nm filter, an acquisition card with a computer.
- OH\*** : Spontaneous emission on the band (0-0) at 306.4 nm
- Visualization of flame front** : stability, lift-off heights, flame lengths.



### Stereo-PIV system



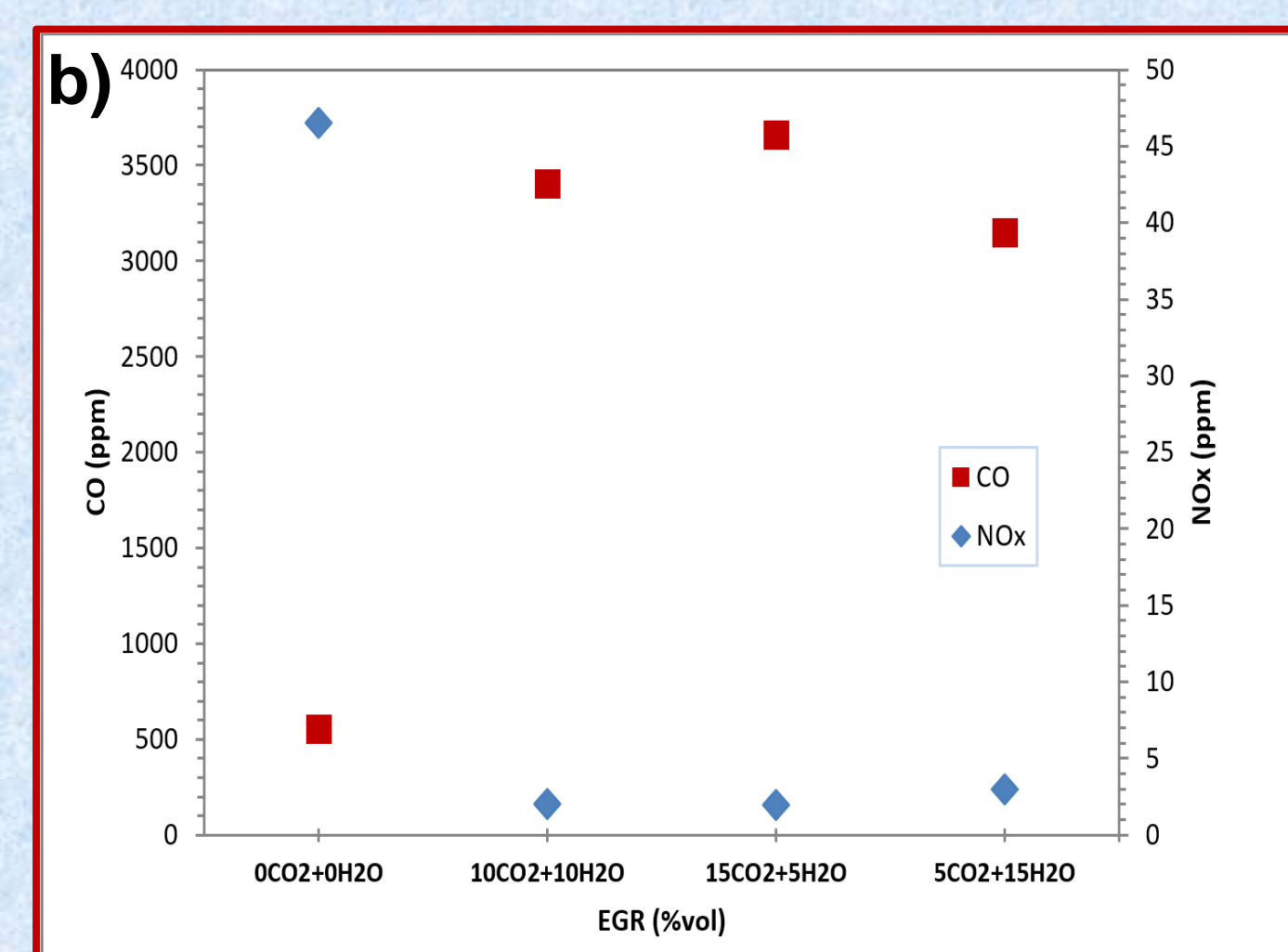
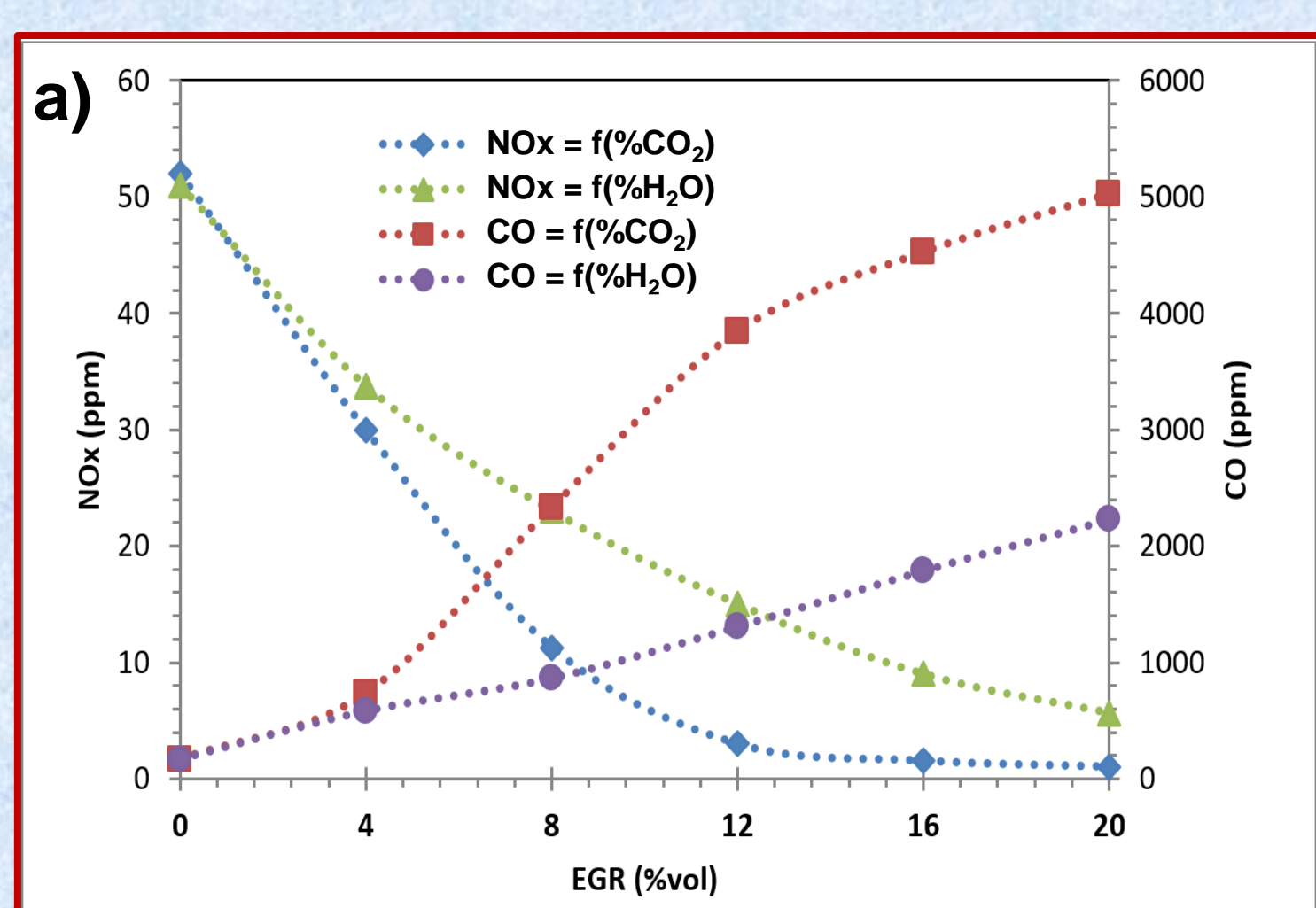
- 2 Planes of velocity measurements
- 3 Positions in the transverse plane

**Apparatus**: a double-pulsed Nd:YAG laser (25 mJ/pulse) at 532 nm, 10 Hz. 2 cameras TSI Powerview Plus 4MP CCDs, 12-bit output and 2048 x 2048 px<sup>2</sup>. Scheimpflug adapters. Seeding : Al<sub>2</sub>O<sub>3</sub> 0.5-1 μm.

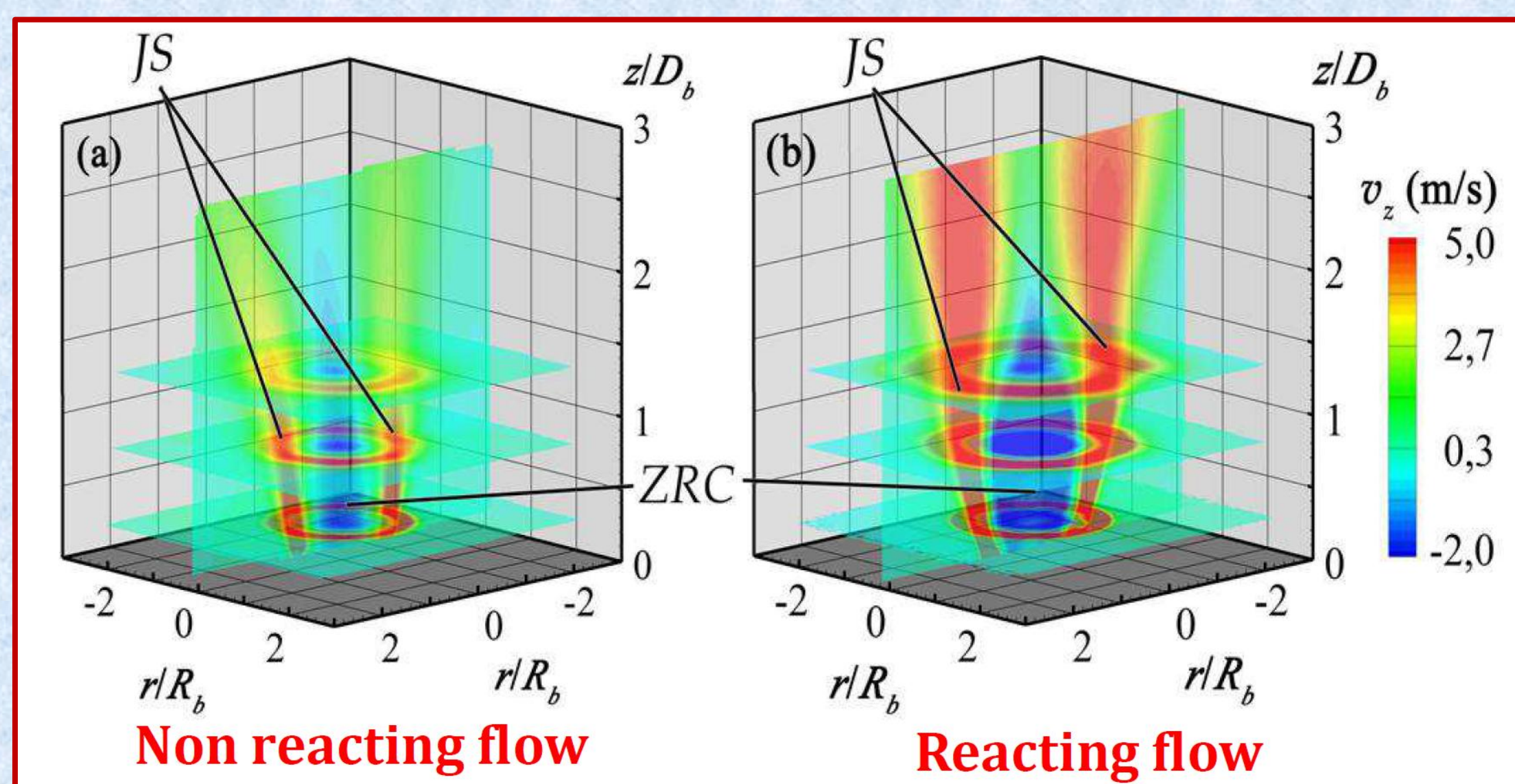
## Results and discussions

### Pollutant emissions

NO<sub>x</sub> and CO emissions are reported for  $\phi=0.8$ ,  $\Omega = 25\%O_2$ ,  $Sn = 1.4$  in the case of diluting with CO<sub>2</sub> and H<sub>2</sub>O separately (Fig.a) and for  $Sn=0.8$  in the case of EGR (H<sub>2</sub>O+CO<sub>2</sub>) (Fig.b).



### Velocity mean fields of non reacting and reacting flows

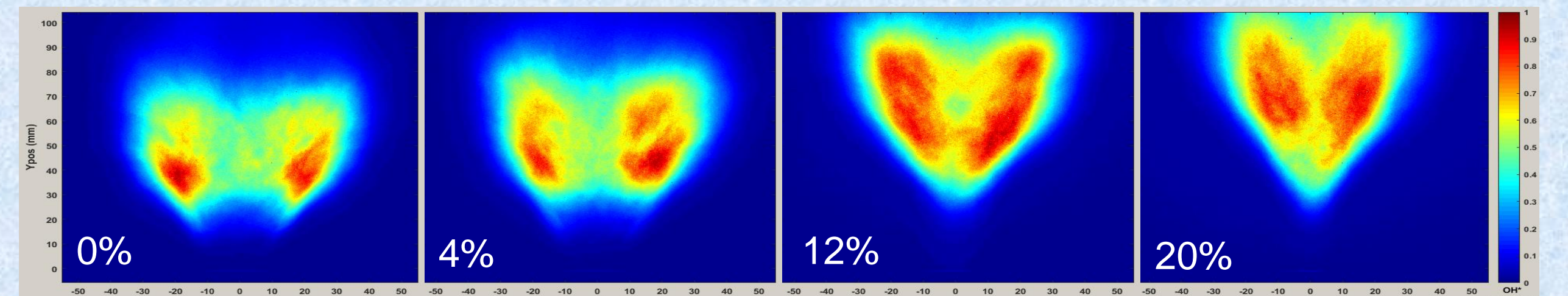


- Recirculation zone at the flow center, and the swirling jet in the peripheral flow.
- Reacting flow: - greater radial expansion + larger recirculation zone. - higher velocities

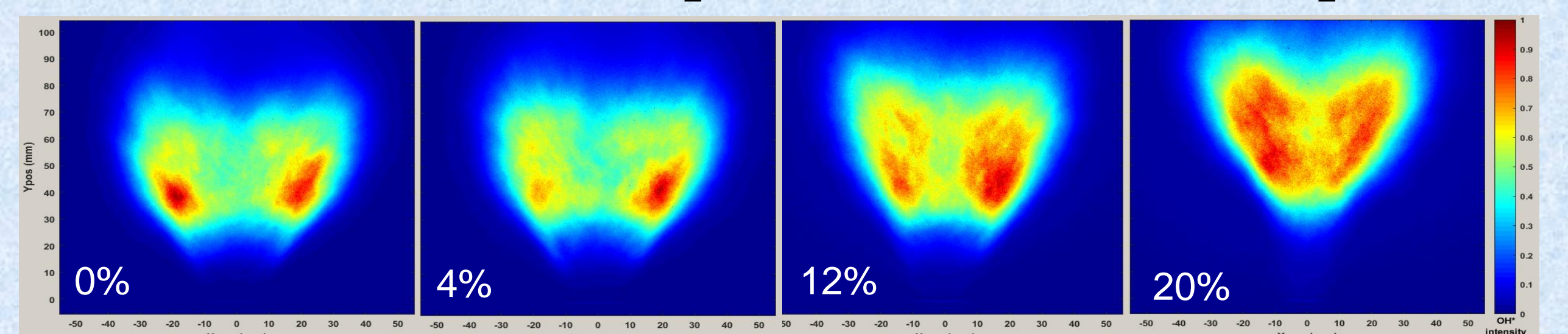
Axial velocity ( $V_z$ ) :  $Sn = 1.4$ ,  $\phi = 0.8$  and 21% of O<sub>2</sub>

### Flame structures

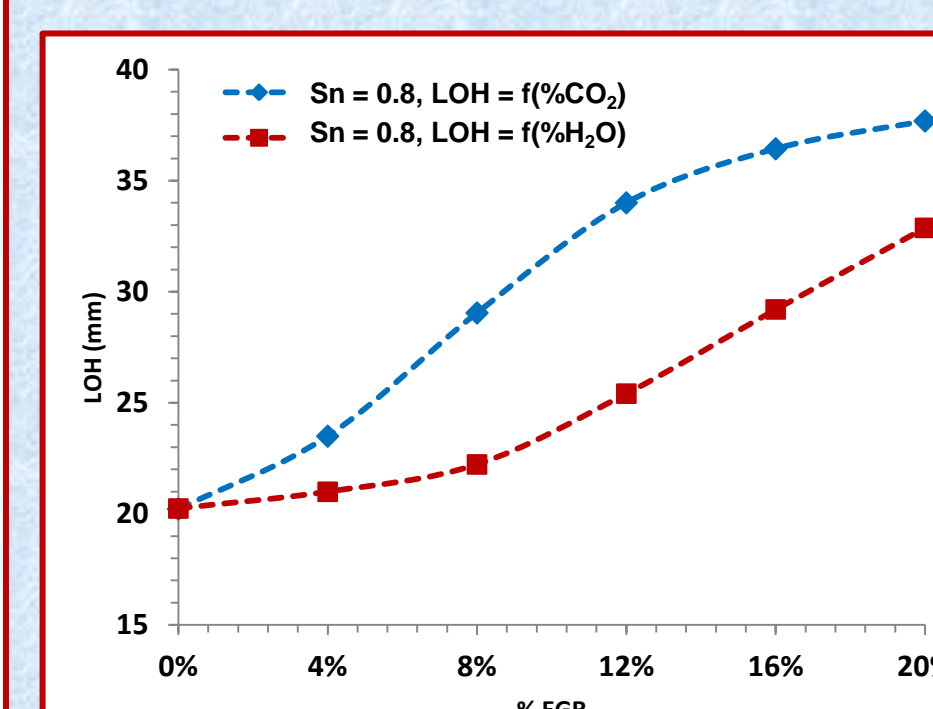
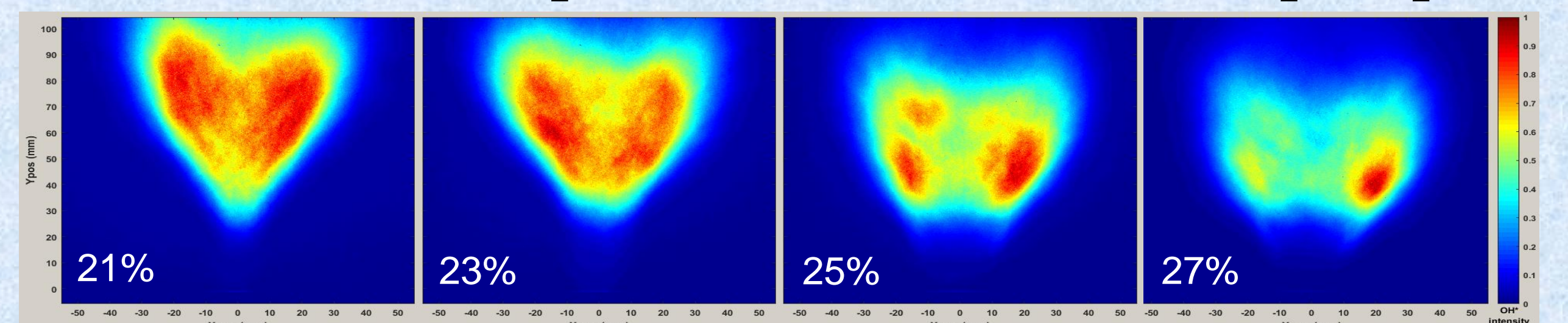
Lift-off height =  $f(\%CO_2)$ ,  $Sn=0.8$ ,  $\phi=0.8$ , 21%O<sub>2</sub>



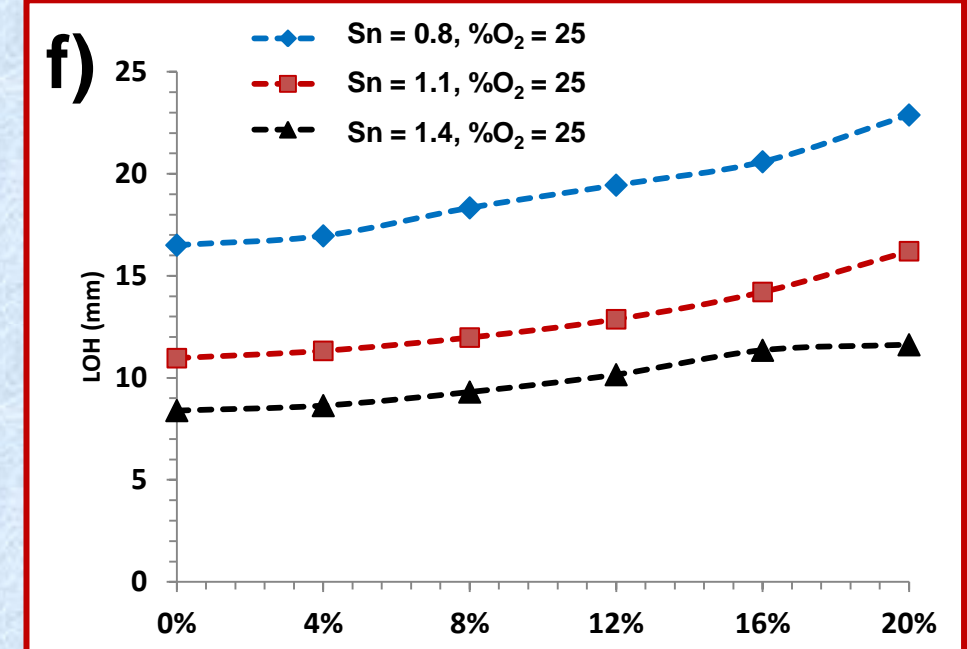
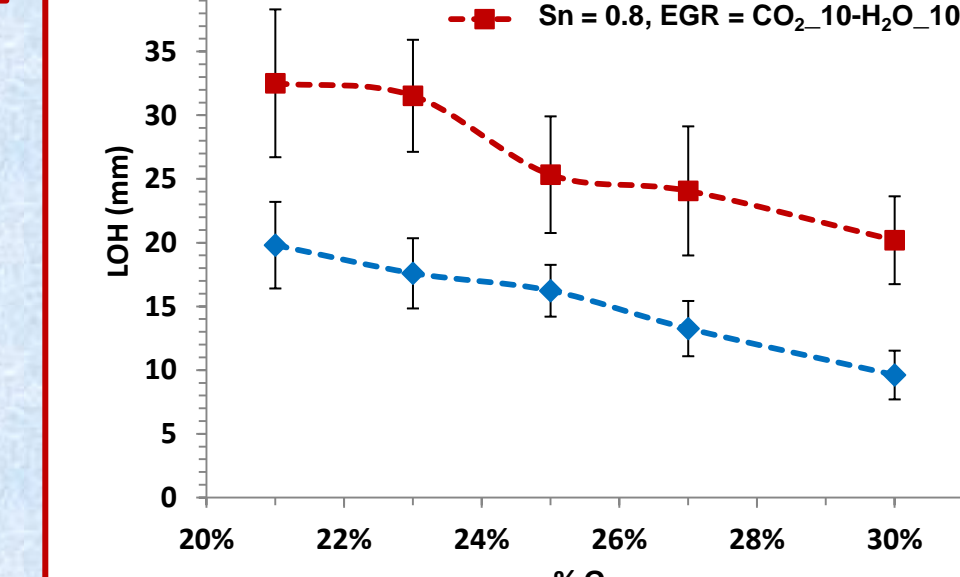
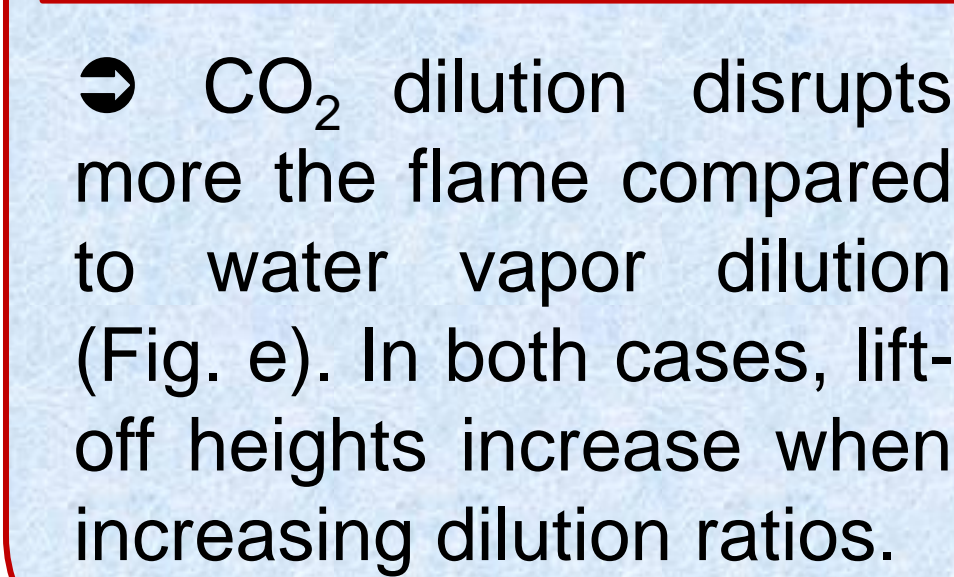
Lift-off height =  $f(\%H_2O)$ ,  $Sn=0.8$ ,  $\phi=0.8$ , 21%O<sub>2</sub>



Lift-off height =  $f(\%O_2)$ ,  $Sn=0.8$ ,  $\phi=0.8$ , EGR (10CO<sub>2</sub>-10H<sub>2</sub>O)



EGR dilution promotes flame fluctuations and increases the lift-off heights about 60% compared to the case without EGR (Fig. g).



In the case of H<sub>2</sub>O dilution (Fig. f), the flame becomes leaner, appears more lifted and remains compact.

## Conclusion

- Better stabilization is obtained with O<sub>2</sub> enrichment. The dilution with EGR destabilizes slightly the flame without blowout (up to 20%).
- Dilution with CO<sub>2</sub>, H<sub>2</sub>O and EGR decreases highly NO<sub>x</sub> emissions and increases CO emissions.
- Swirling part of the flow and the central recirculation zone are clearly identified by Stereo-PIV measurements.

## Acknowledgments

The authors are grateful for the financial support of this work provided by the French Government's Investissement d'Avenir program: LABEX CAPRYSSES, under Grant ANR-11-LABX-0006-01.