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

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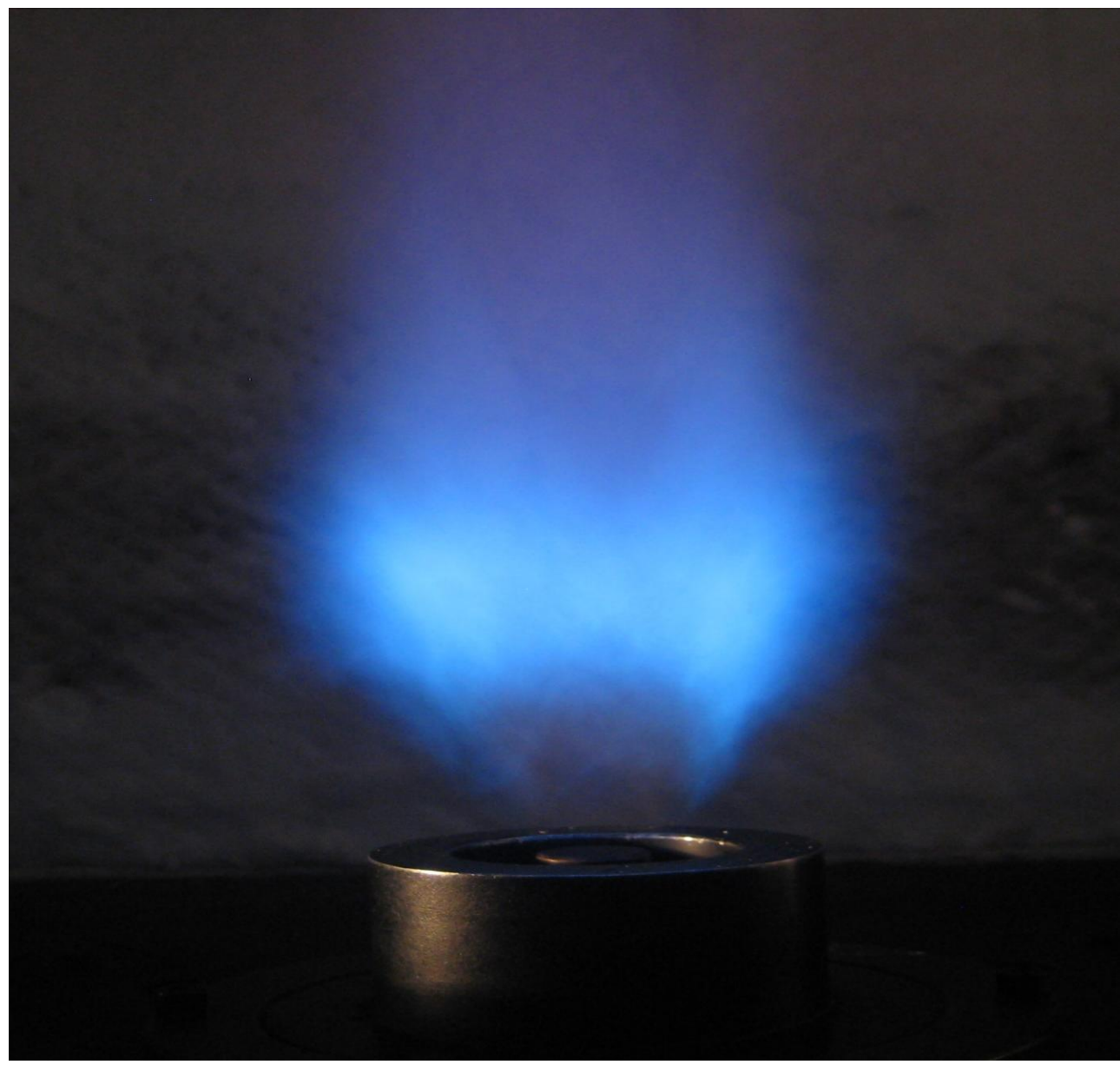
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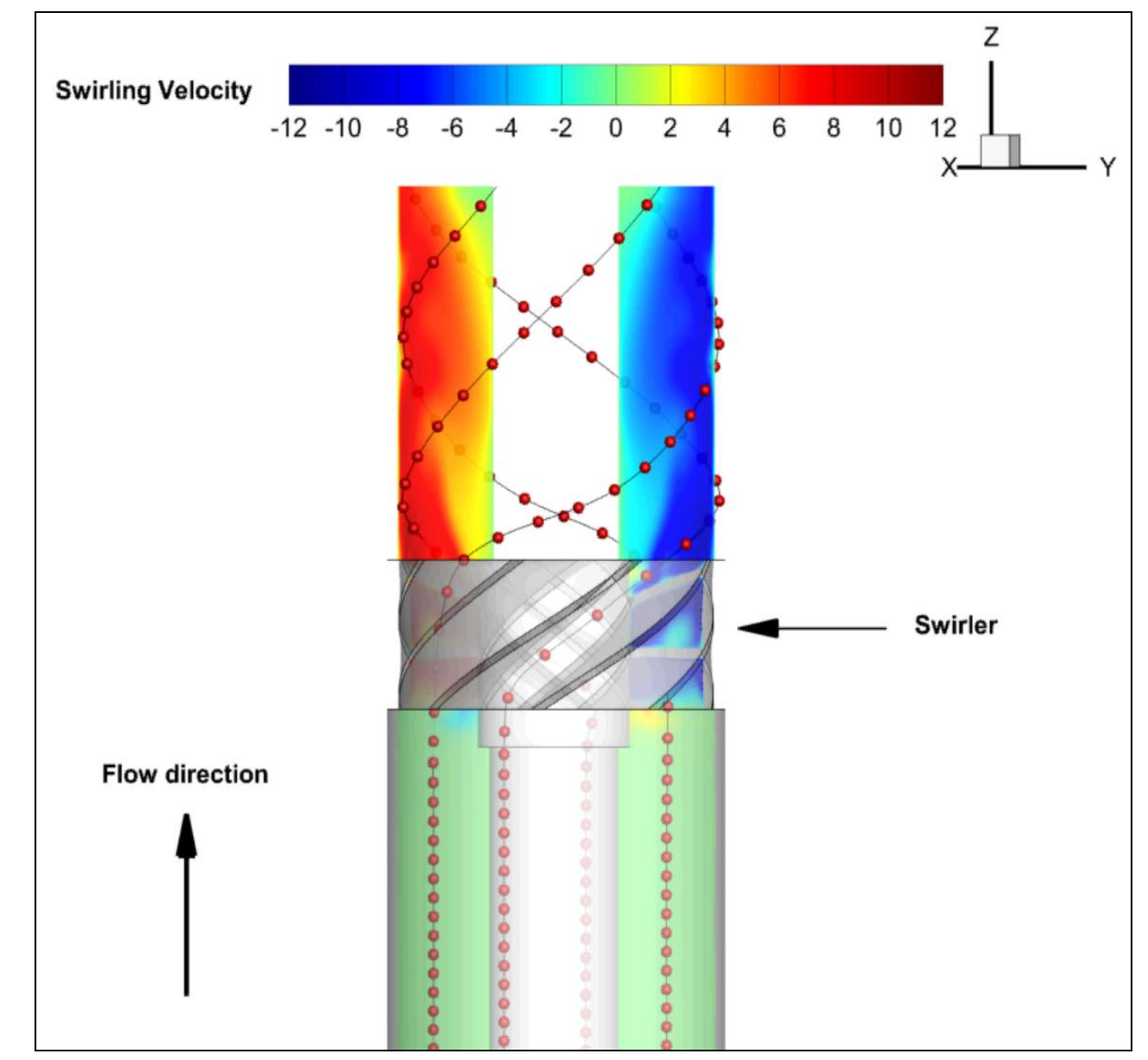
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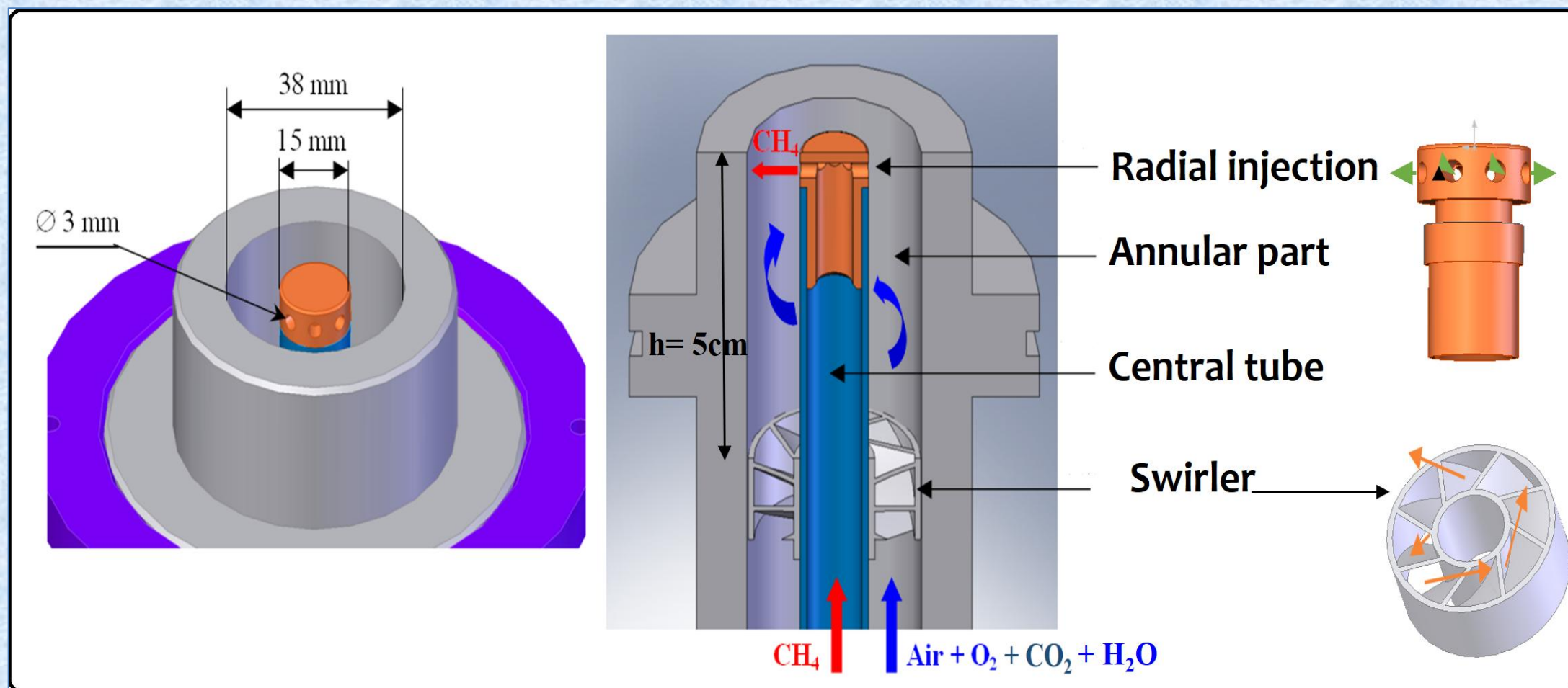
## Context and objectives

- 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



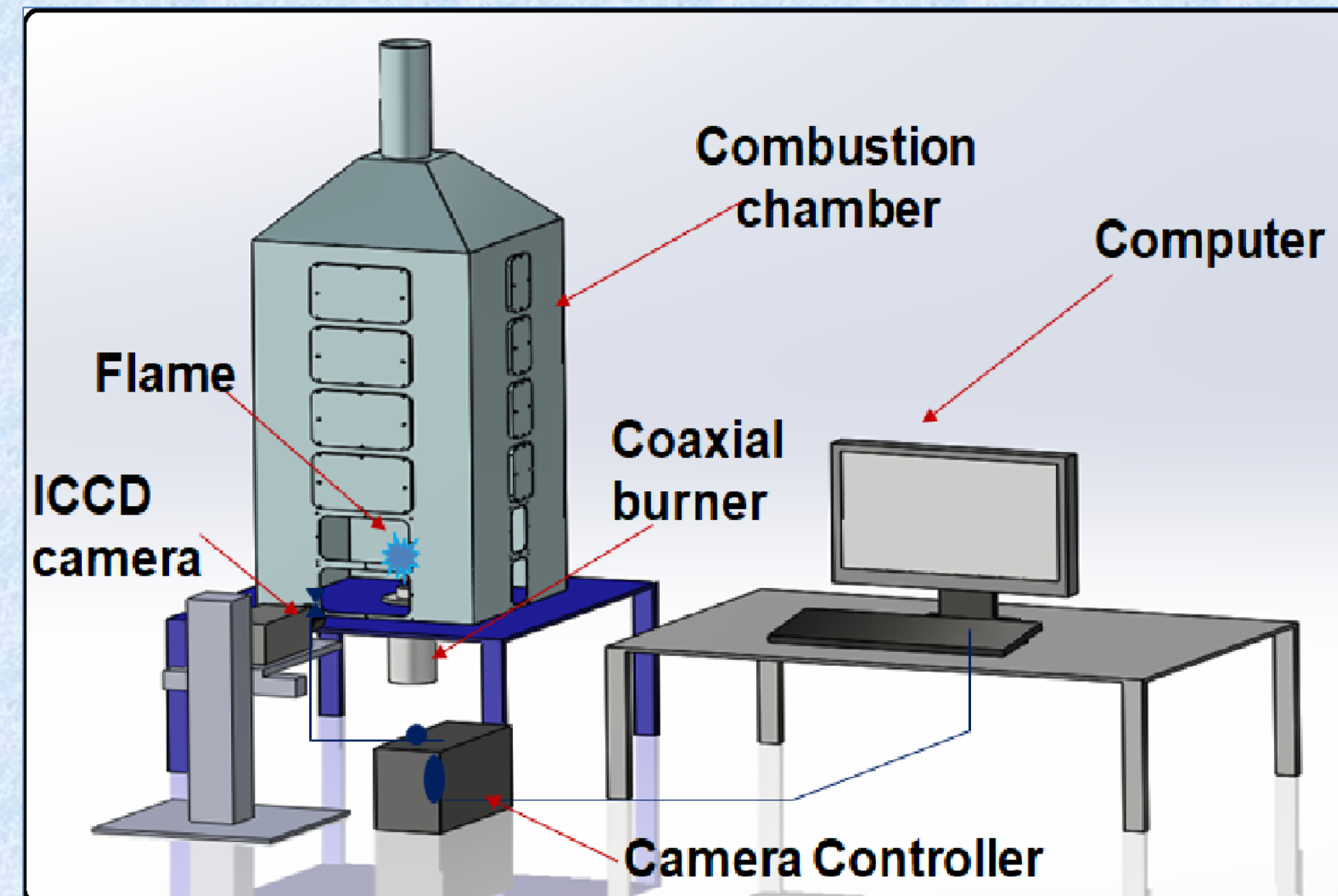
- Two concentric tubes with a **swirler** in the annular part
- Combustion chamber : 25 kW, dimensions 0.5x0.5x1 m<sup>3</sup>

### Measurement and analysis of flue gases

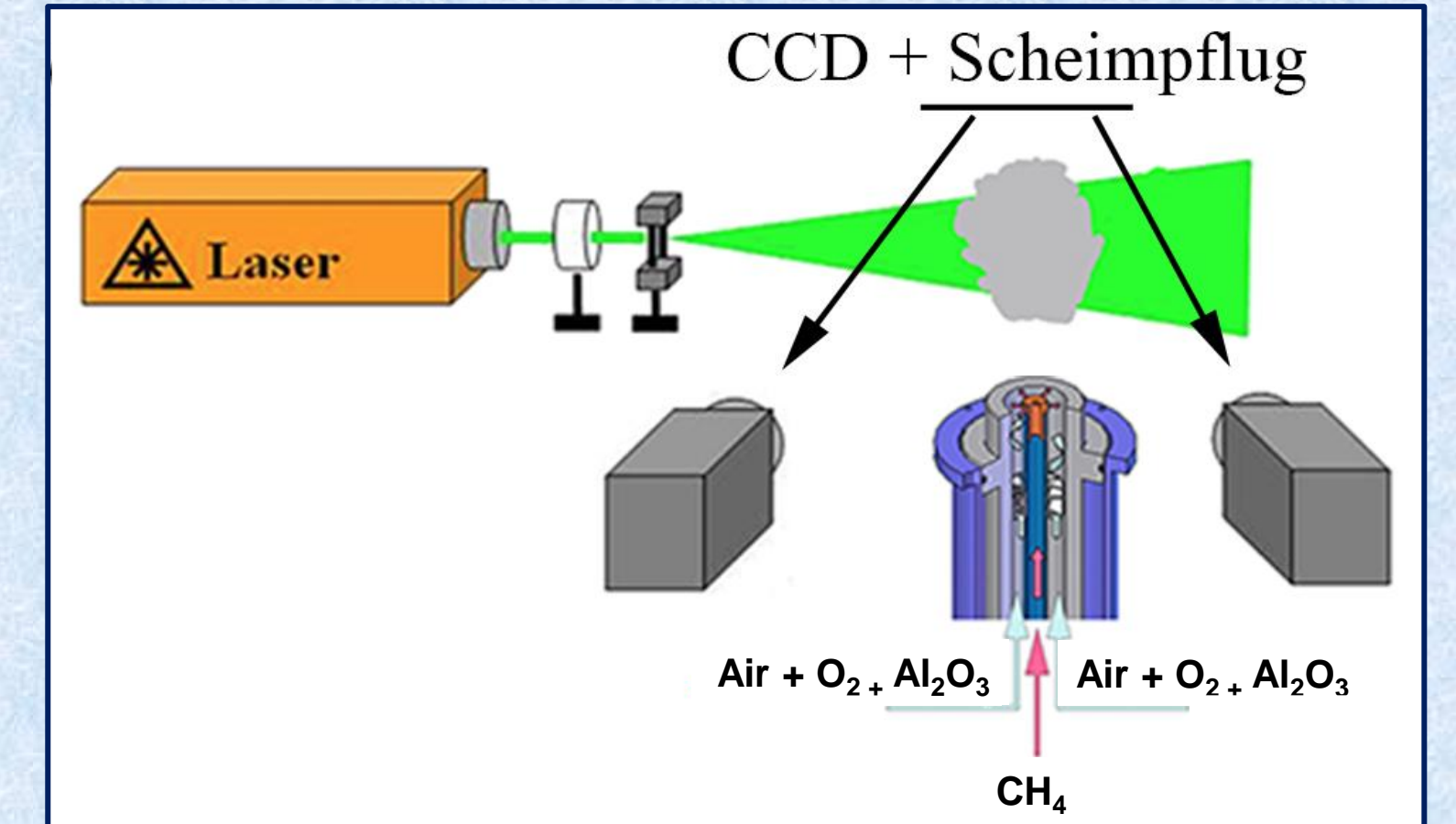
- Concentrations of NO<sub>x</sub>, CO, CO<sub>2</sub>, O<sub>2</sub> and SO<sub>2</sub> in the flue gases are measured.
- ABB 220 and HORIBA PG250 multi-gas analyzers.

### 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



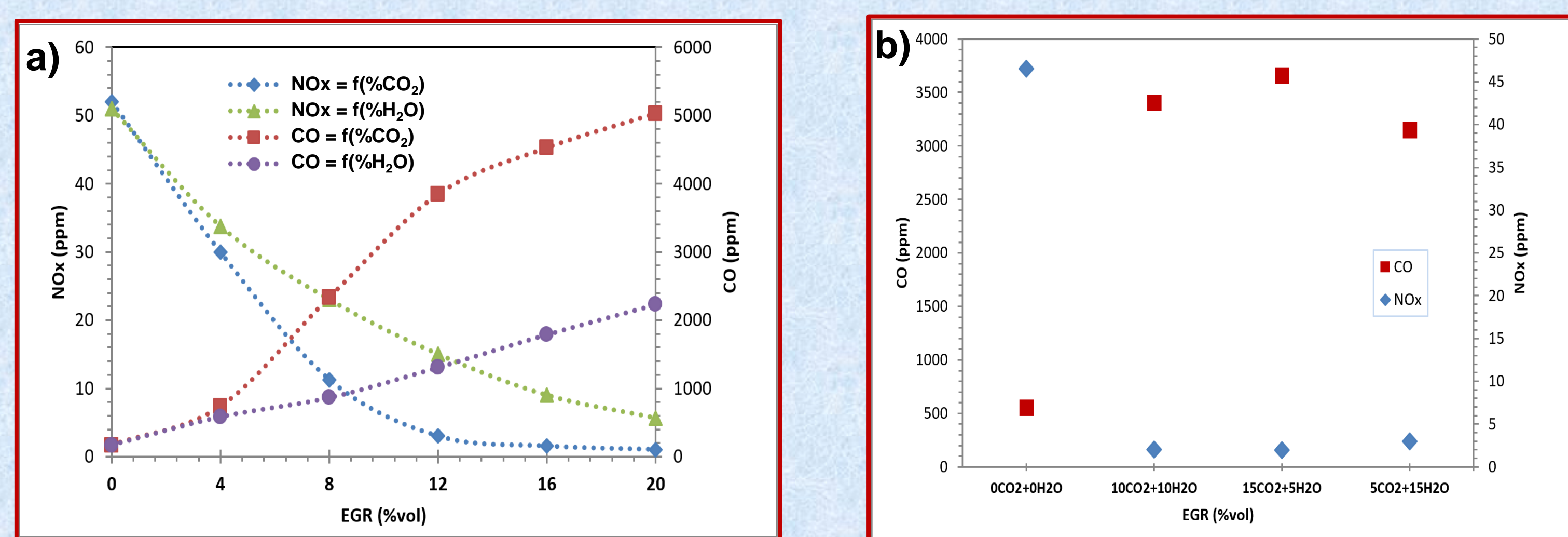
- 2 Planes of velocity measurements
- 3 Positions in the transverse plane

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.

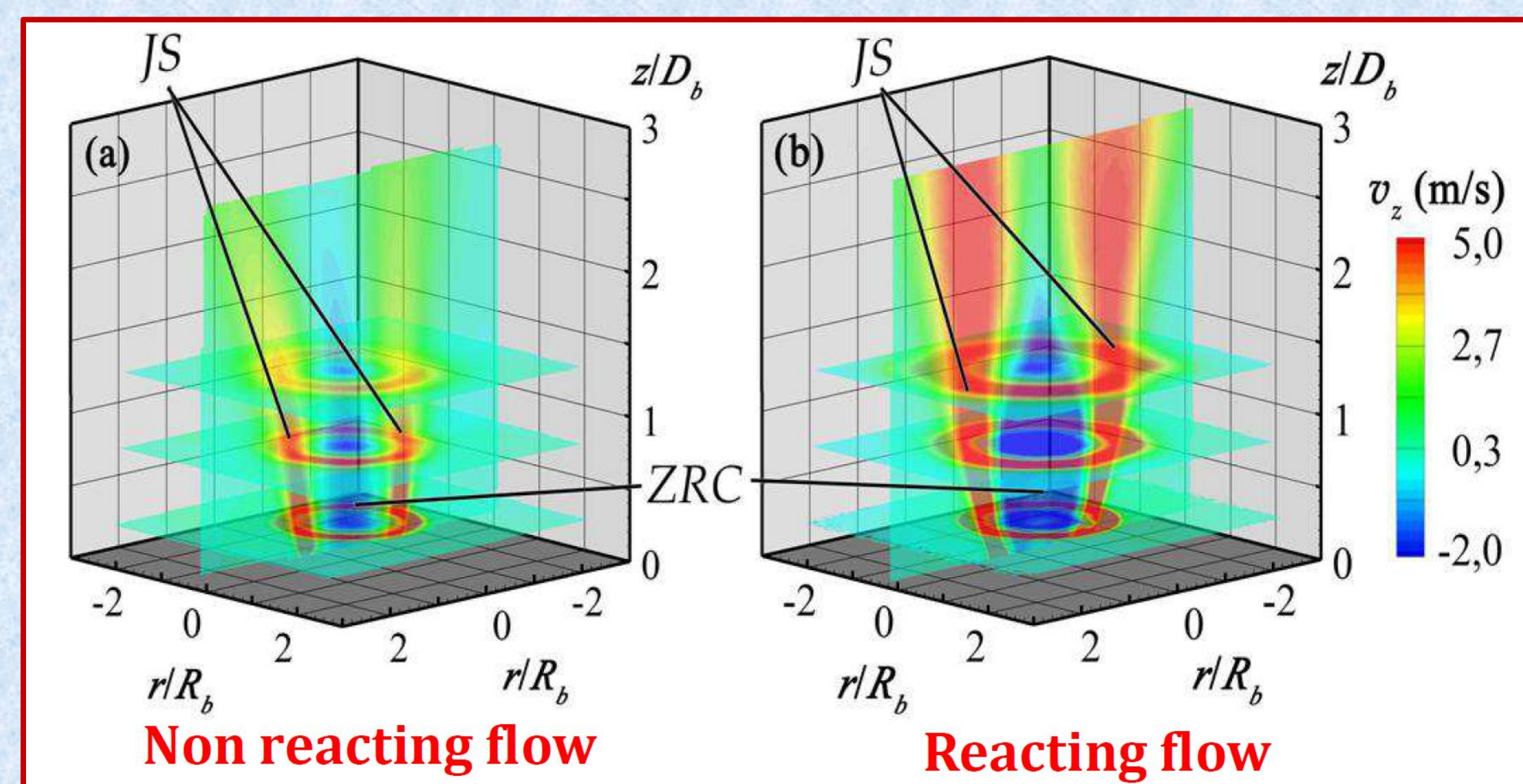
## Results and discussions

### 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

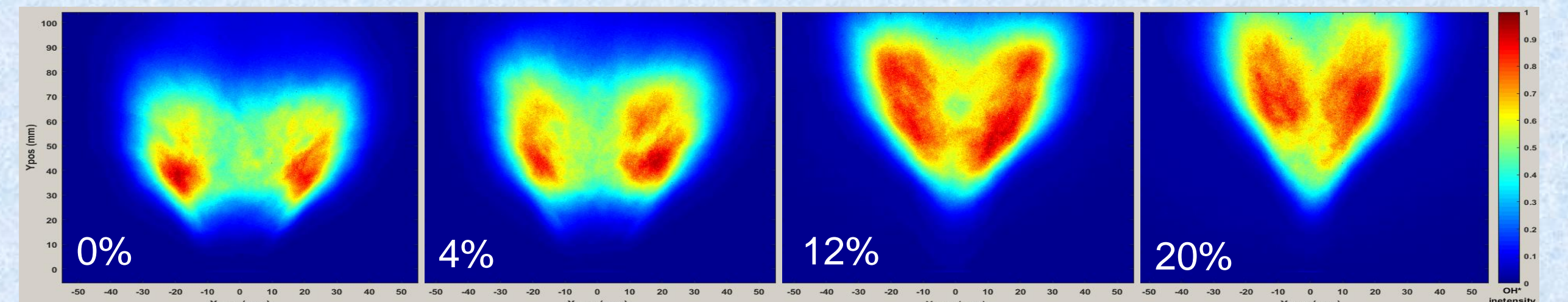


- Recirculation zone at the flow center, and the swirling jet in the peripheral flow.
- Reacting flow: - greater radial expansion + larger recirculation zone. - higher velocities

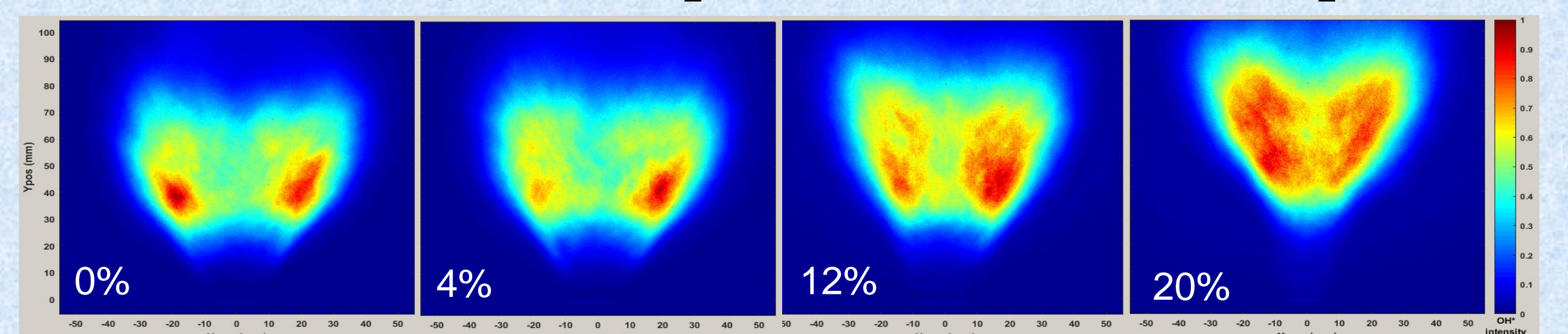
Axial velocity ( $V_z$ ) :  $Sn = 1.4$ ,  $\phi = 0.8$  and 21% of O<sub>2</sub>

### Flame structures

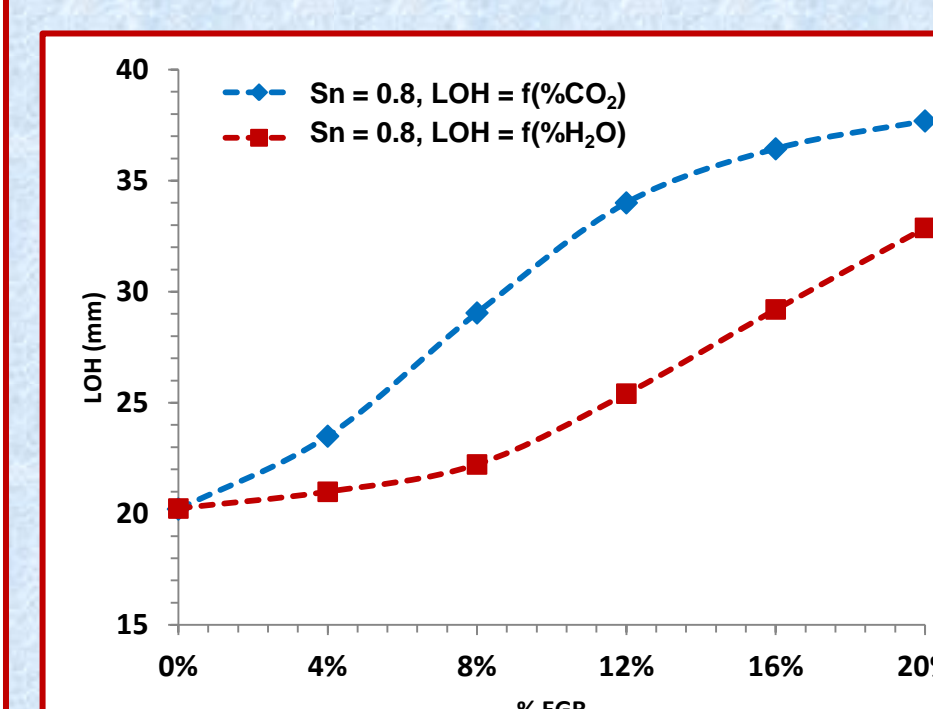
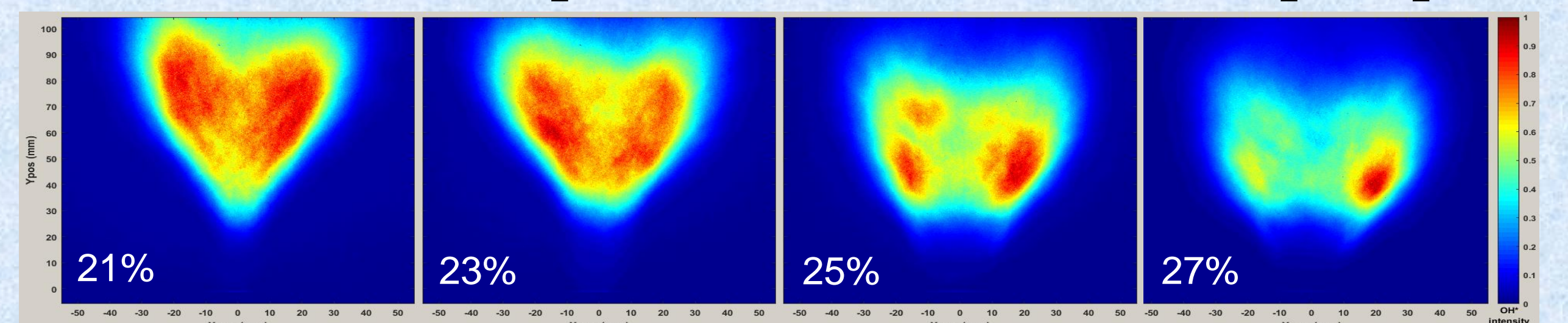
Lift-off height =  $f(\%CO_2)$ ,  $Sn=0.8$ ,  $\phi=0.8$ , 21%O<sub>2</sub>



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

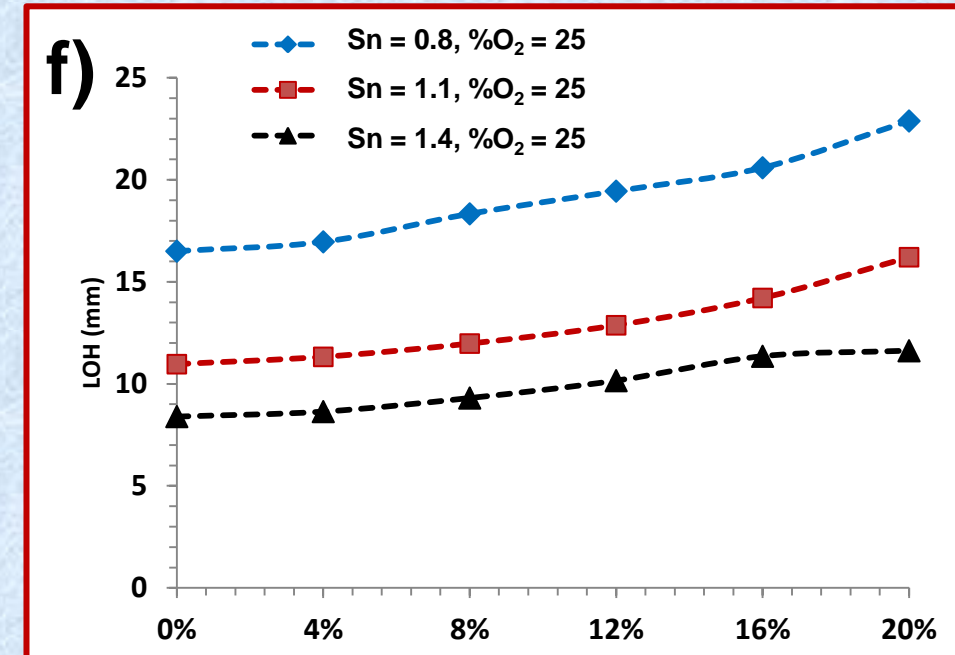
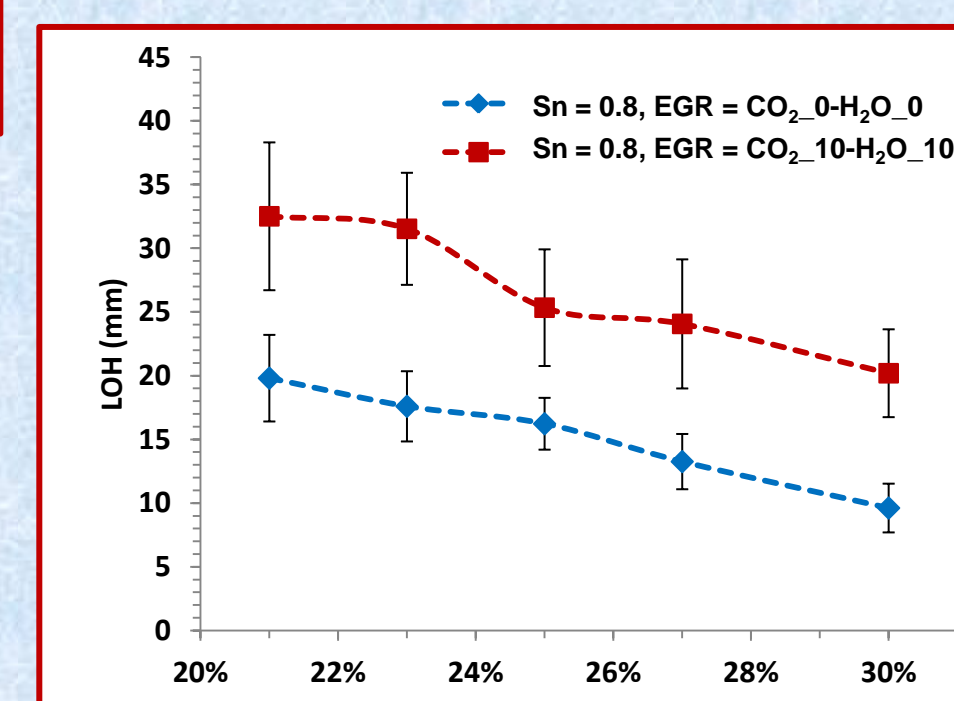


Lift-off height =  $f(\%O_2)$ ,  $Sn=0.8$ ,  $\phi=0.8$ , EGR (10CO<sub>2</sub>-10H<sub>2</sub>O)



CO<sub>2</sub> dilution disrupts more the flame compared to water vapor dilution (Fig. e). In both cases, lift-off heights increase when increasing dilution ratios.

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.

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