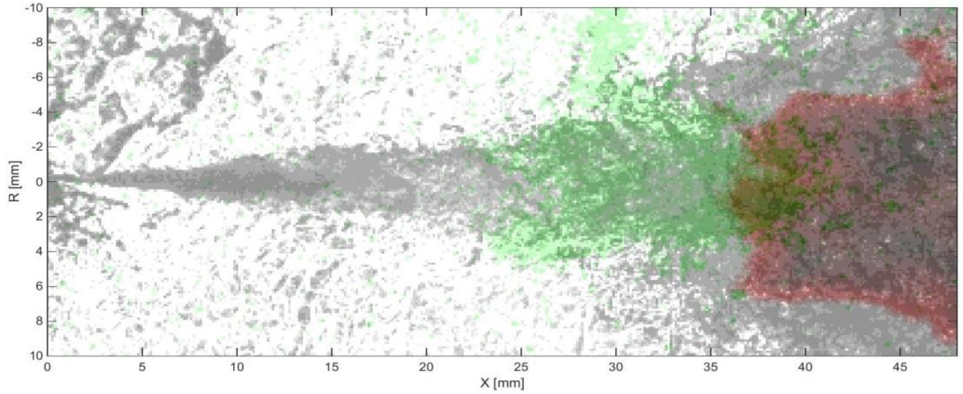
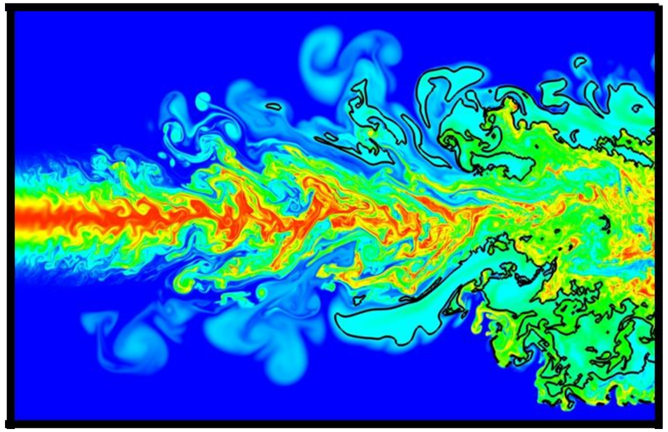
Combined study by optical diagnostics and Direct Numerical Simulation of the flame stabilization in a Diesel-type spray





Fabien Tagliante

Ph.D. started in December 2015

Thesis Director (IFPEN): **Gilles Bruneaux**
Thesis co-Director (IFPEN): **Christian Angelberger**
Supervisor (IFPEN): **Louis-Marie Malbec**
In collaboration with: **Lyle M. Pickett** (Sandia National Laboratories) & **Thierry Poinsot** (CERFACS)

IFP Energies nouvelles

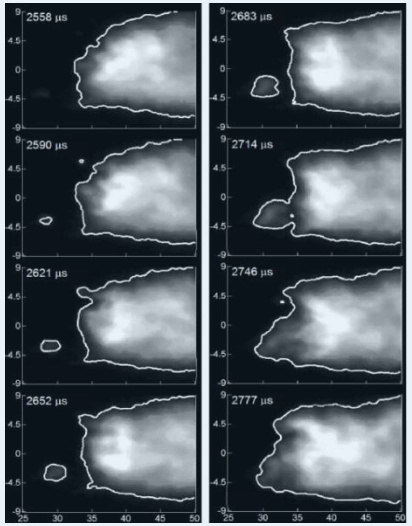
Scientific context of the flame stabilization under Diesel condition

The distance at which the flame stabilizes has a great impact on the soot production : What is the flame stabilization mechanism under Diesel condition?

CFD studies

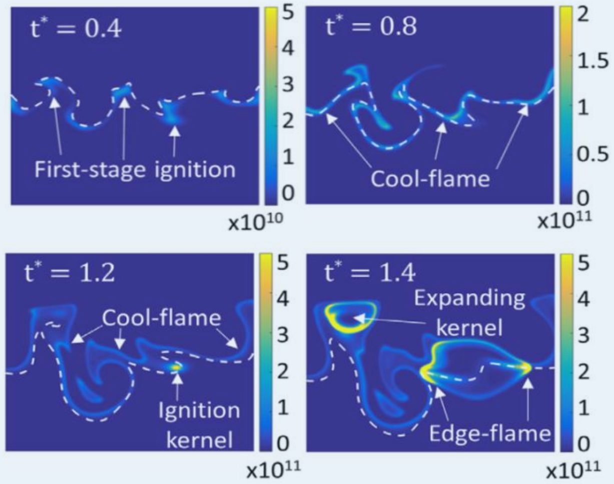
Experimental studies

Pickett et al. SAE 2005-01-3843



Flame stabilization by auto-ignition

Krisman et al. PCI 36 (2017) 3567–3575



Edge-flames are involved in the flame stabilization process

+ Real physics

−
- Temporal and spatial resolution
- Difficult to measure simultaneous quantities

+
- Access to local values
- Access to all the quantities

−
- 3D-DNS → too expensive to simulate a stabilized flame spray flame under Diesel condition
- RANS and LES→ combustion model → assumption on the combustion regime

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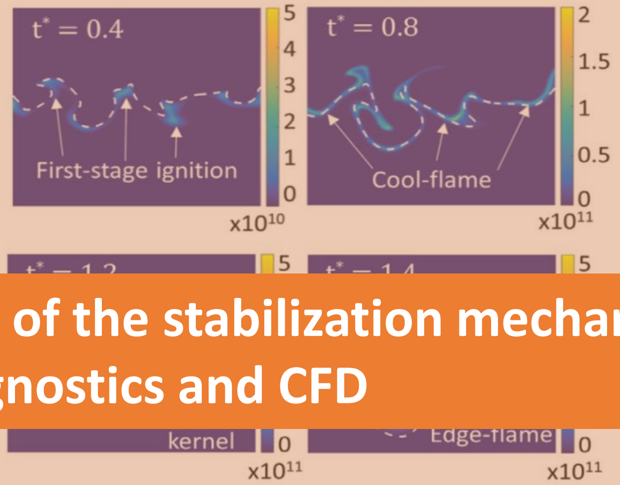

Edge-flames are involved in the flame stabilization process

Objective of my PhD: To contribute to a better understanding of the stabilization mechanisms of a Diesel-type flame combining optical diagnostics and CFD

Experimental studies:

\+ Real physics

\-
- Temporal and spatial resolution
- Difficult to measure simultaneous quantities

CFD studies:

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- Access to local values
- Access to all the quantities

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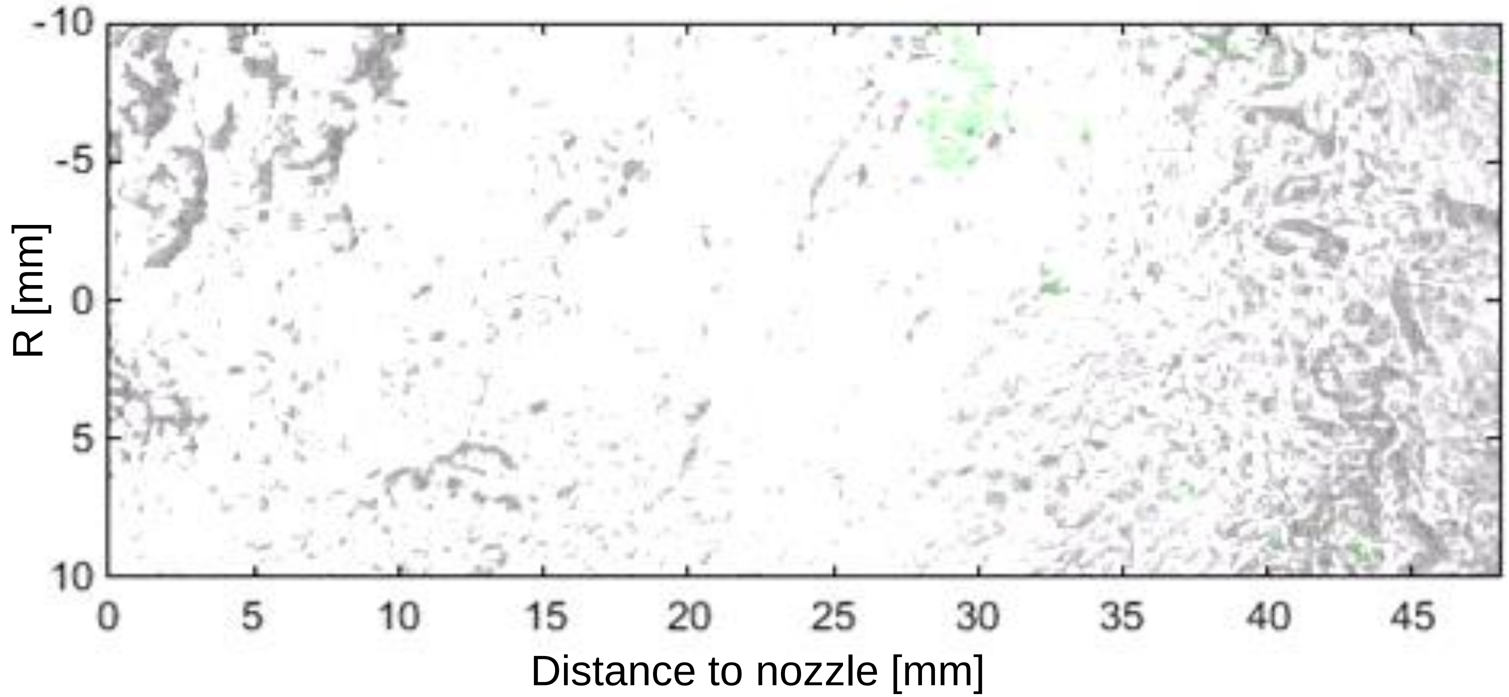
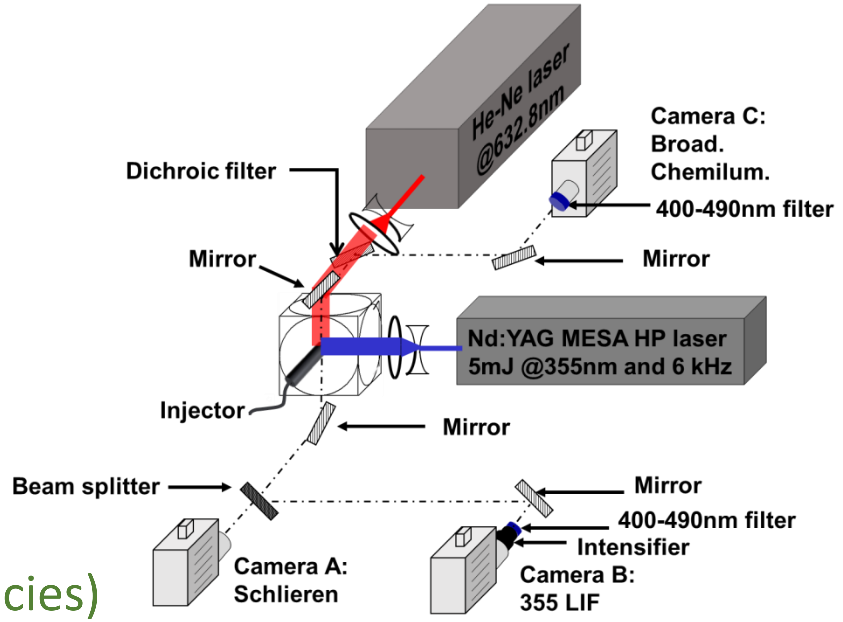
$$T_{amb} = 800K;\ \rho_{amb} = 14.8kg/m^3; P_{inj} = 150\text{MPa}$$



Test conditions name	α	α'	β	γ	δ
Ambient temperature [K]	800	**850**	800	**850**	800
Ambient density [kg/m^3]	14.8	14.8	**12**	**11**	14.8
Injection pressure [MPa]	150	150	150	150	**100**
Ambient gas oxygen (by volume) [%]			16		
Effective injection duration [ms]			10		

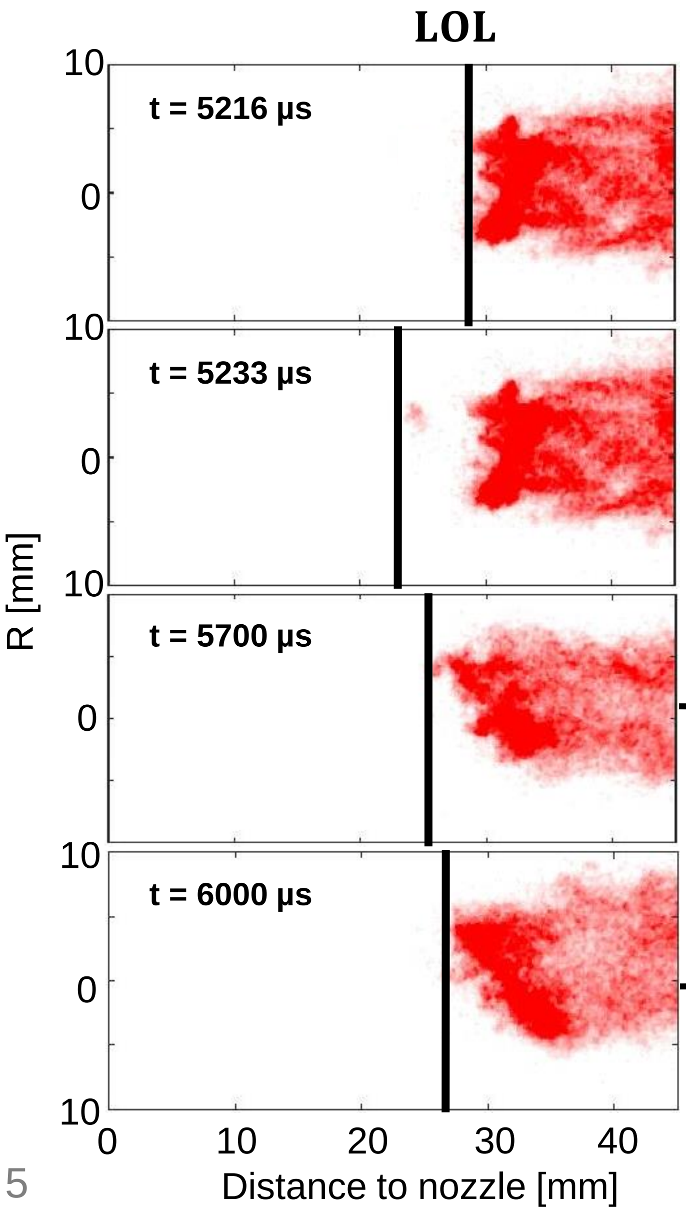


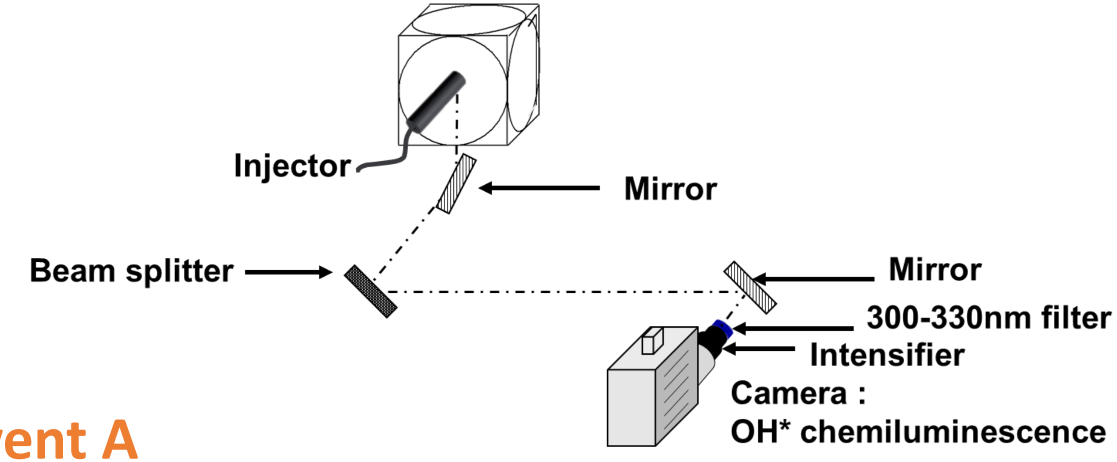
- Broadband chemiluminescence (30 kHz) → LOL detection
- 355 LIF (6 kHz) → detection of cool flame areas (formaldehyde species)
- Schlieren images (30 kHz) → Evolution of the gaseous jet envelope

3 simultaneous and time-resolved optical diagnostics

Focus on the high-temperature flame

- OH* chemiluminescence at 60 kfps to track the high-temperature flame





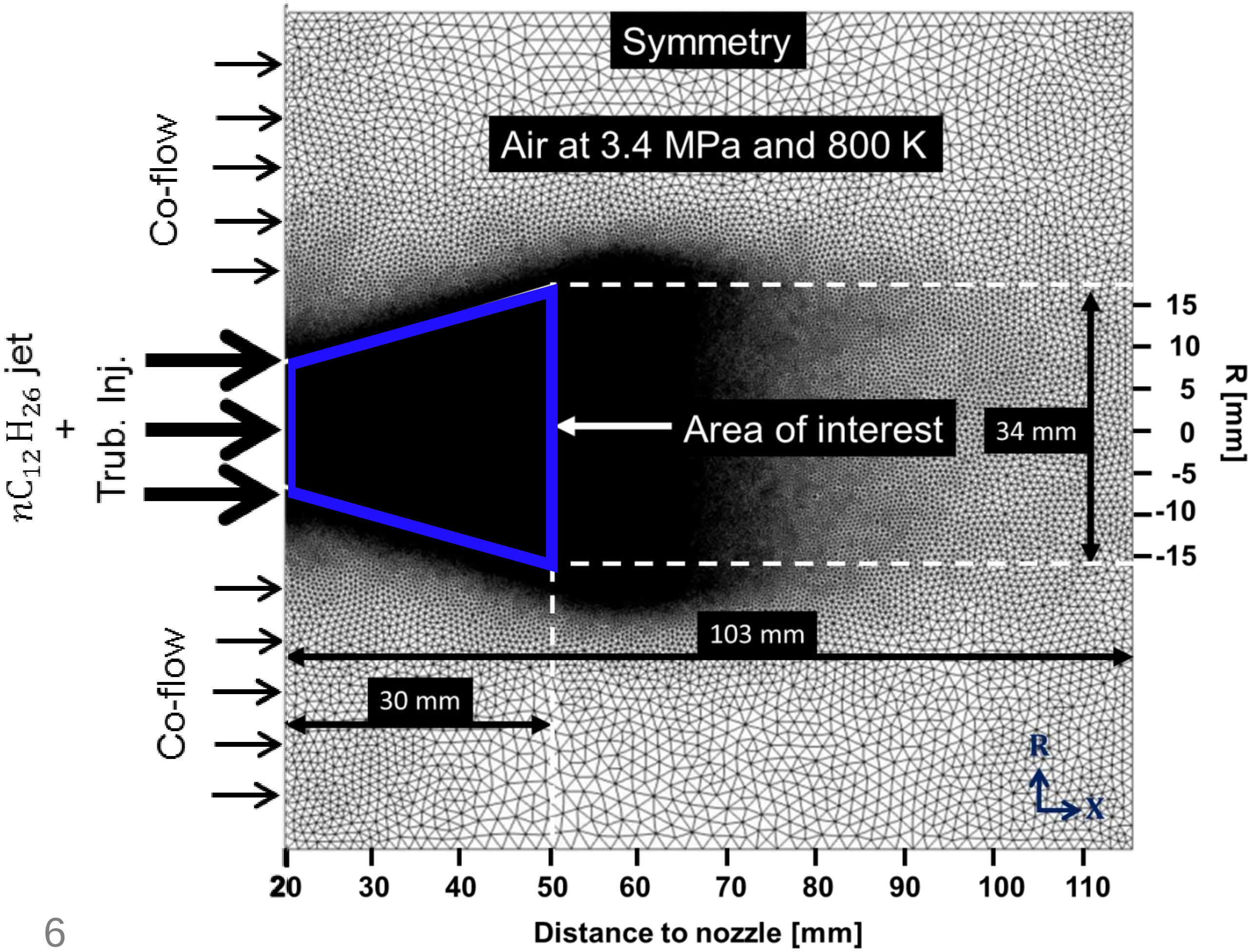
Auto-ignition → Event A

Downstream evolution of the LOL → Evolution B

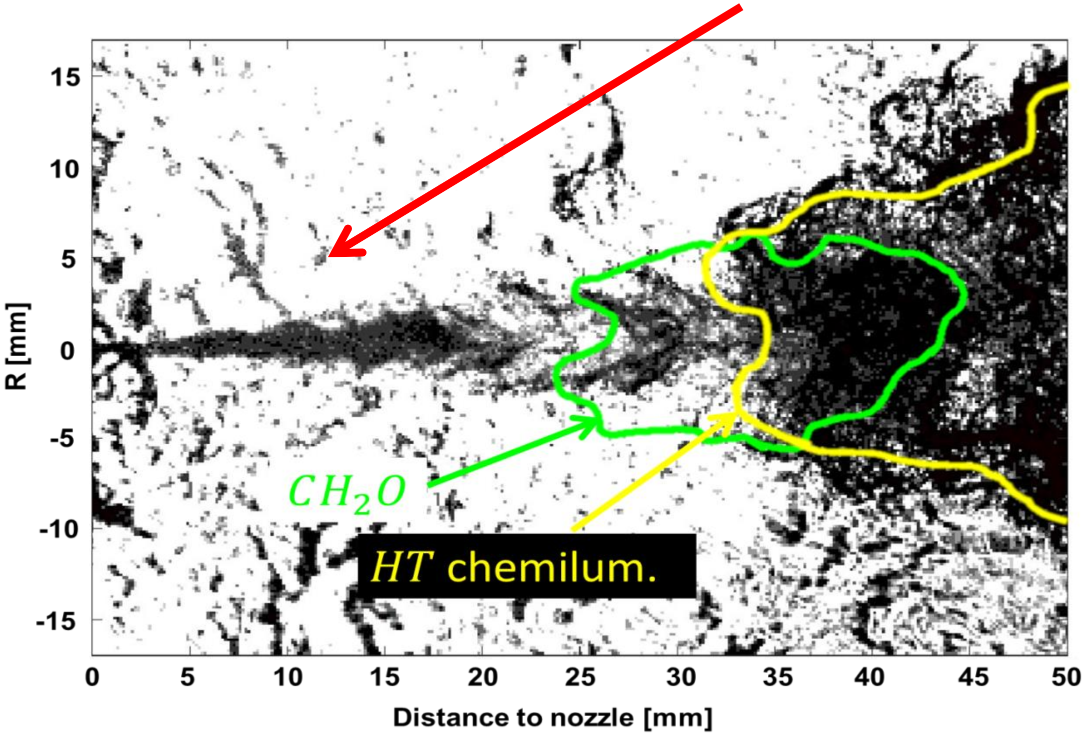
F. Tagliante, L-M. Malbec, G. Bruneaux, L.M Pickett, C. Angelber, Experimental study of the stabilization mechanism of a lifted Diesel-type flame using combined optical diagnostics and laser-induced plasma ignition, Combustion and Flame 197 (2018) 215-226.

- Objective: To reproduce the α test conditions to distinguish the stabilization mechanisms thanks to local values

- 2D-DNS
- Gaseous injection + Synthetic turbulence
- Chemistry: 28 species transported



Non-simulated area due to:
- Very high Reynolds number
- Two phase flow



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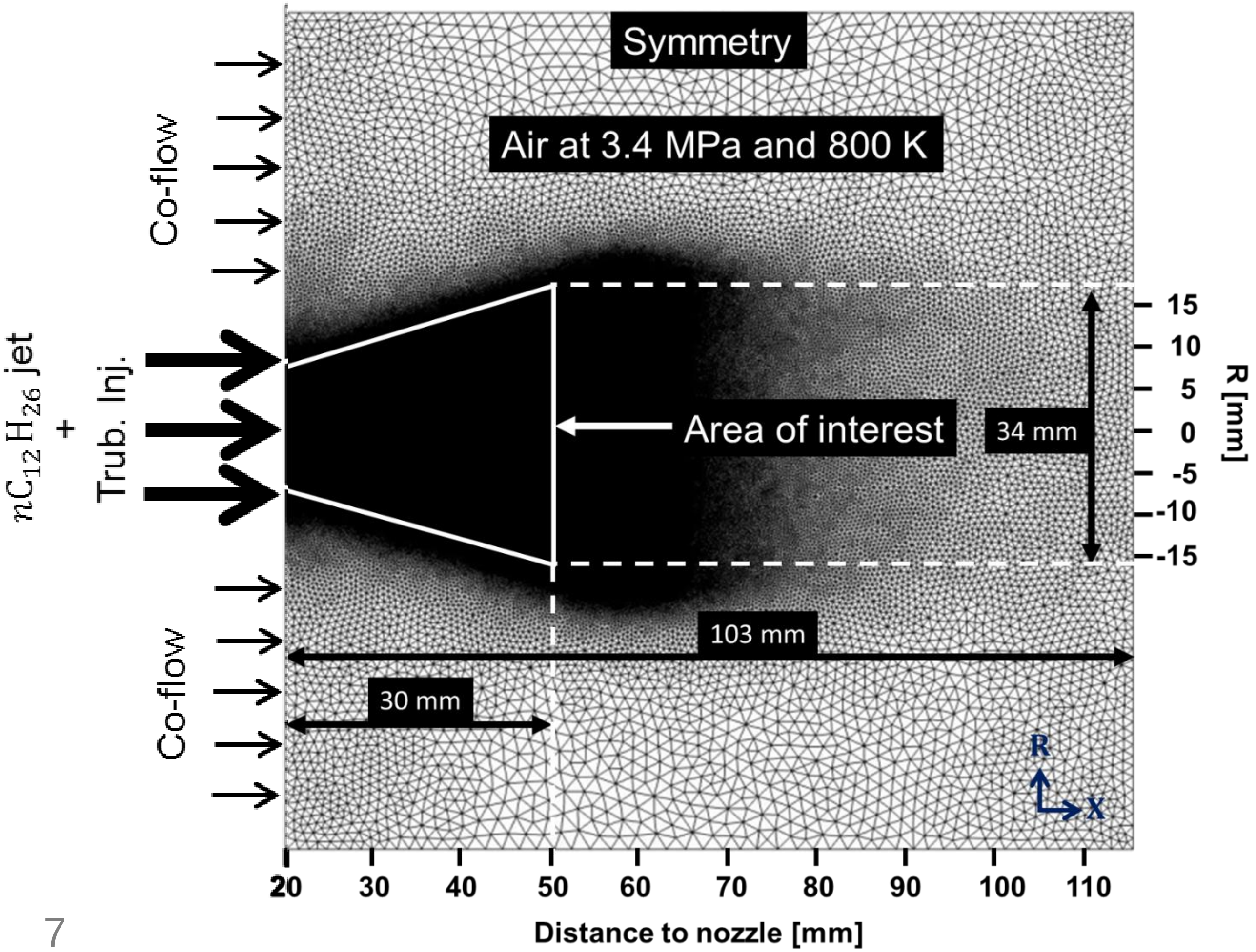

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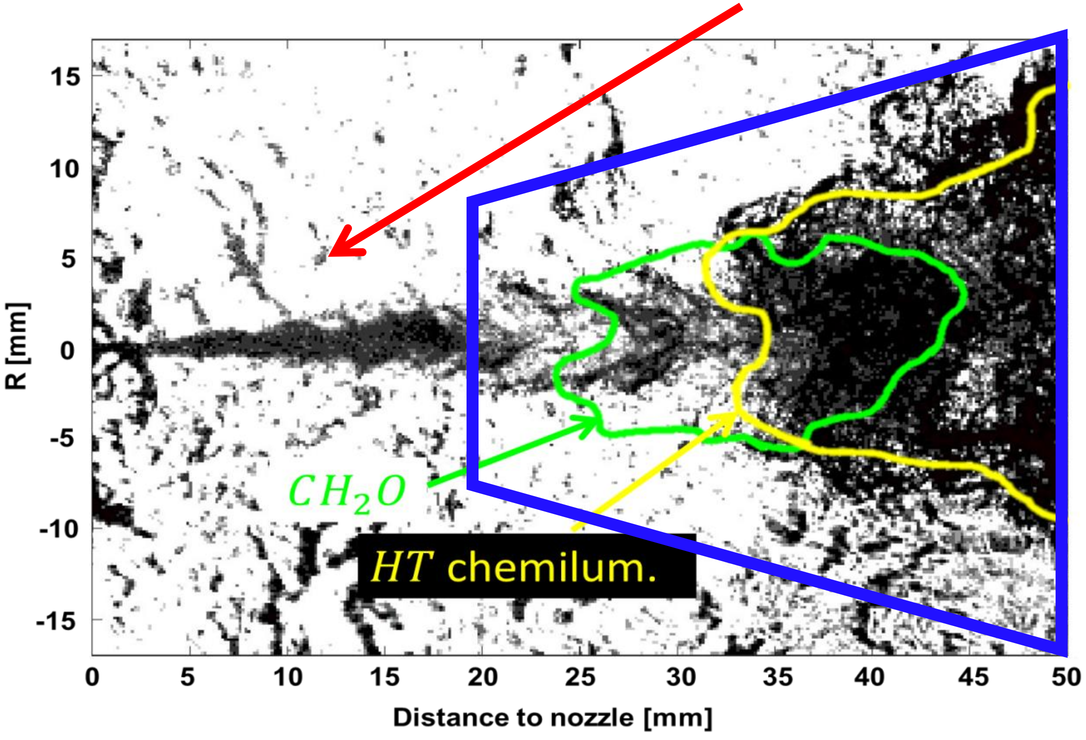
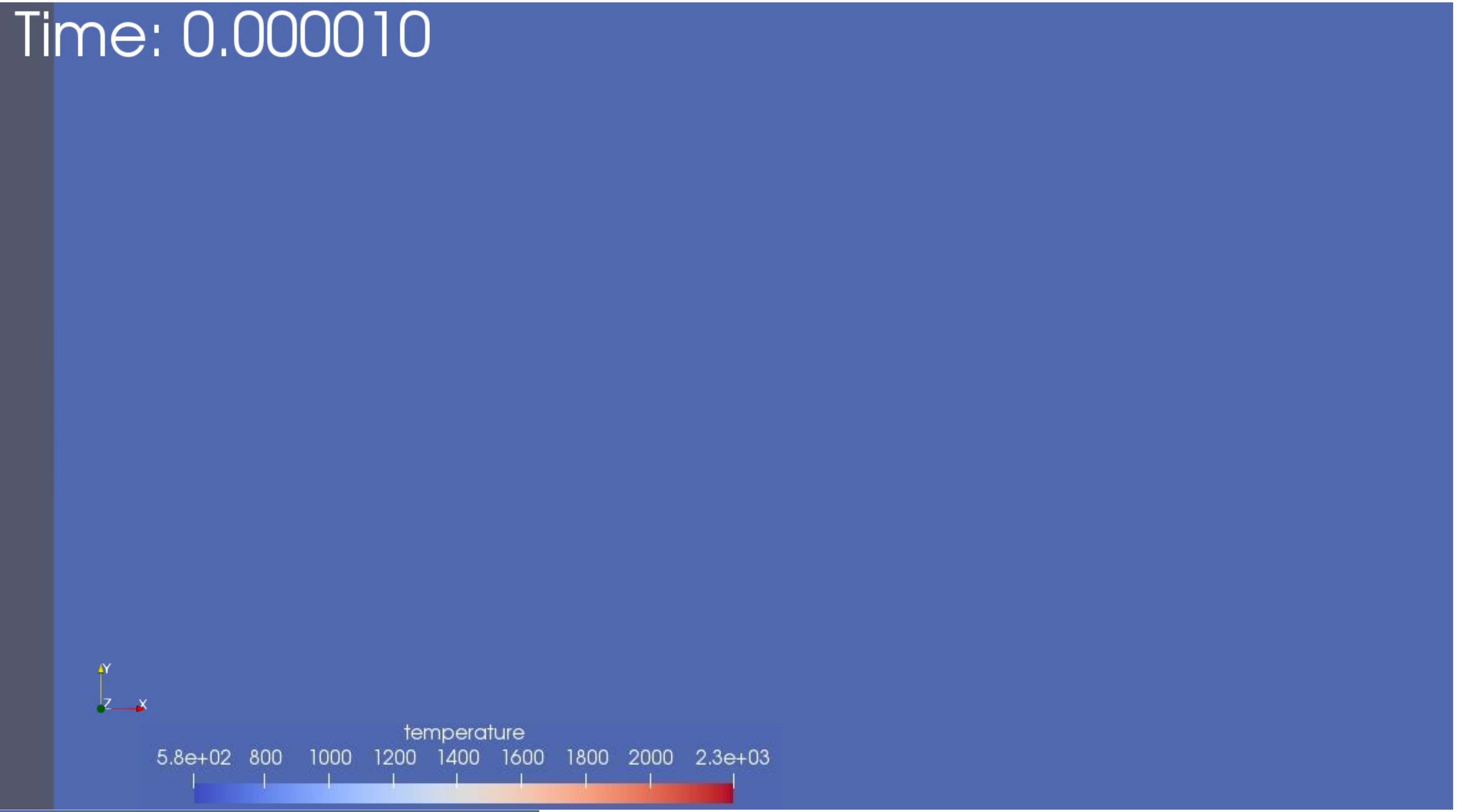


2D DNS



$z_{st} = 0.048$

$Heat\ Release = 4e11\ W/m^3$

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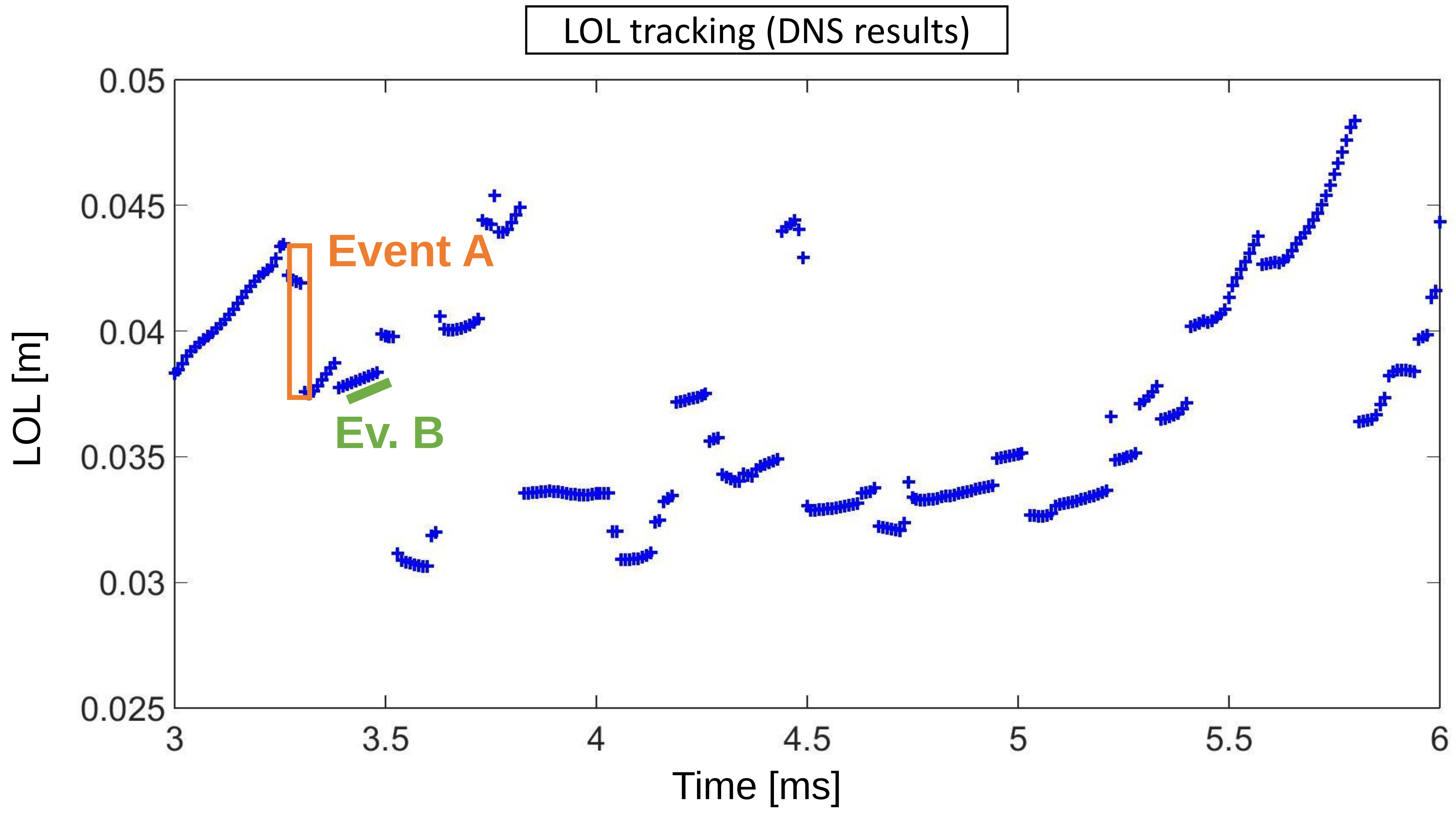
LOL tracking with the reaction zone topologies identification

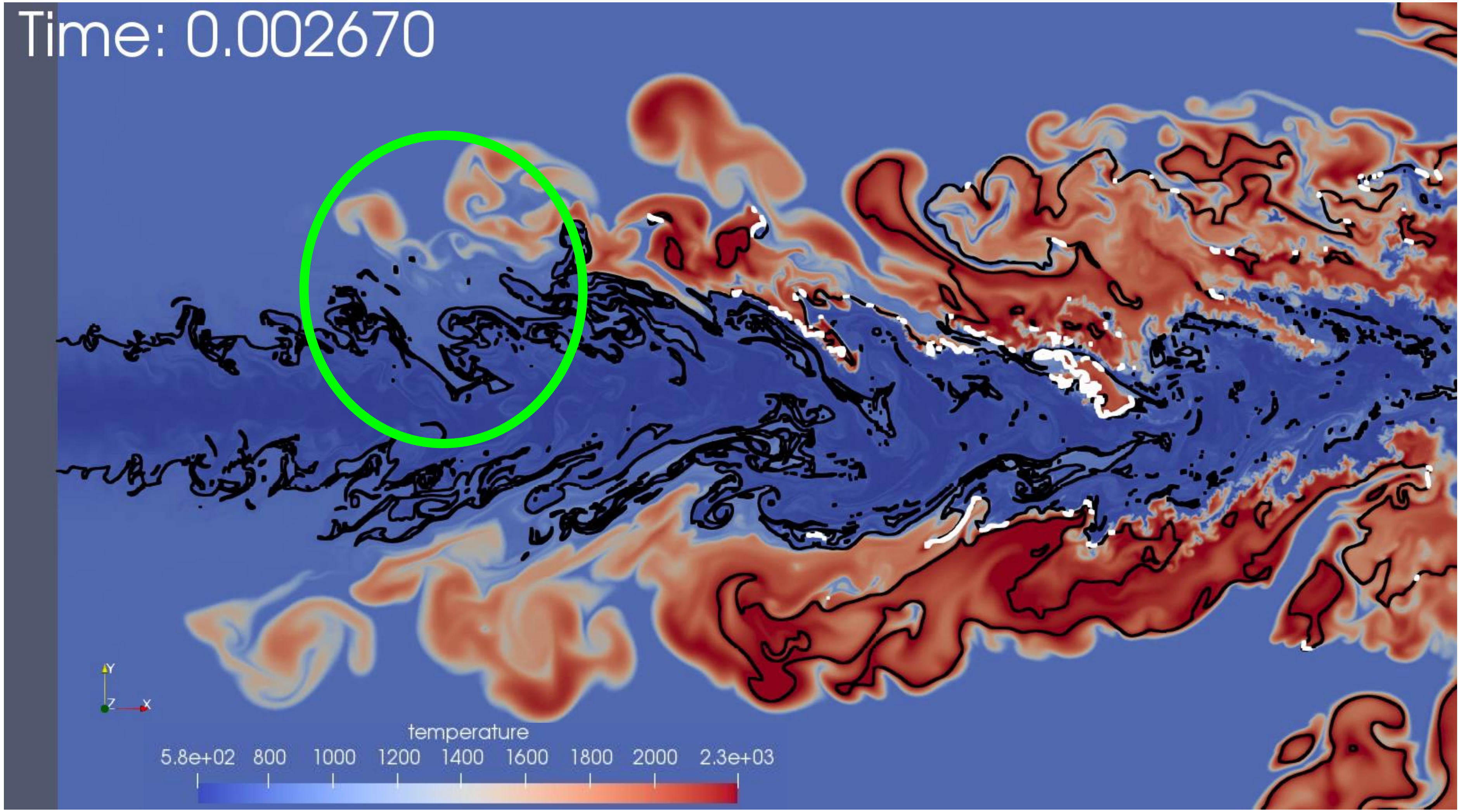


The DNS allows to:

- Isolate local reaction zone topologies identified at the lift-off

→ Focus on auto-ignition: **Event A**

- **Isolated auto-ignition (AI-I)**



$z_{st} = 0.048$

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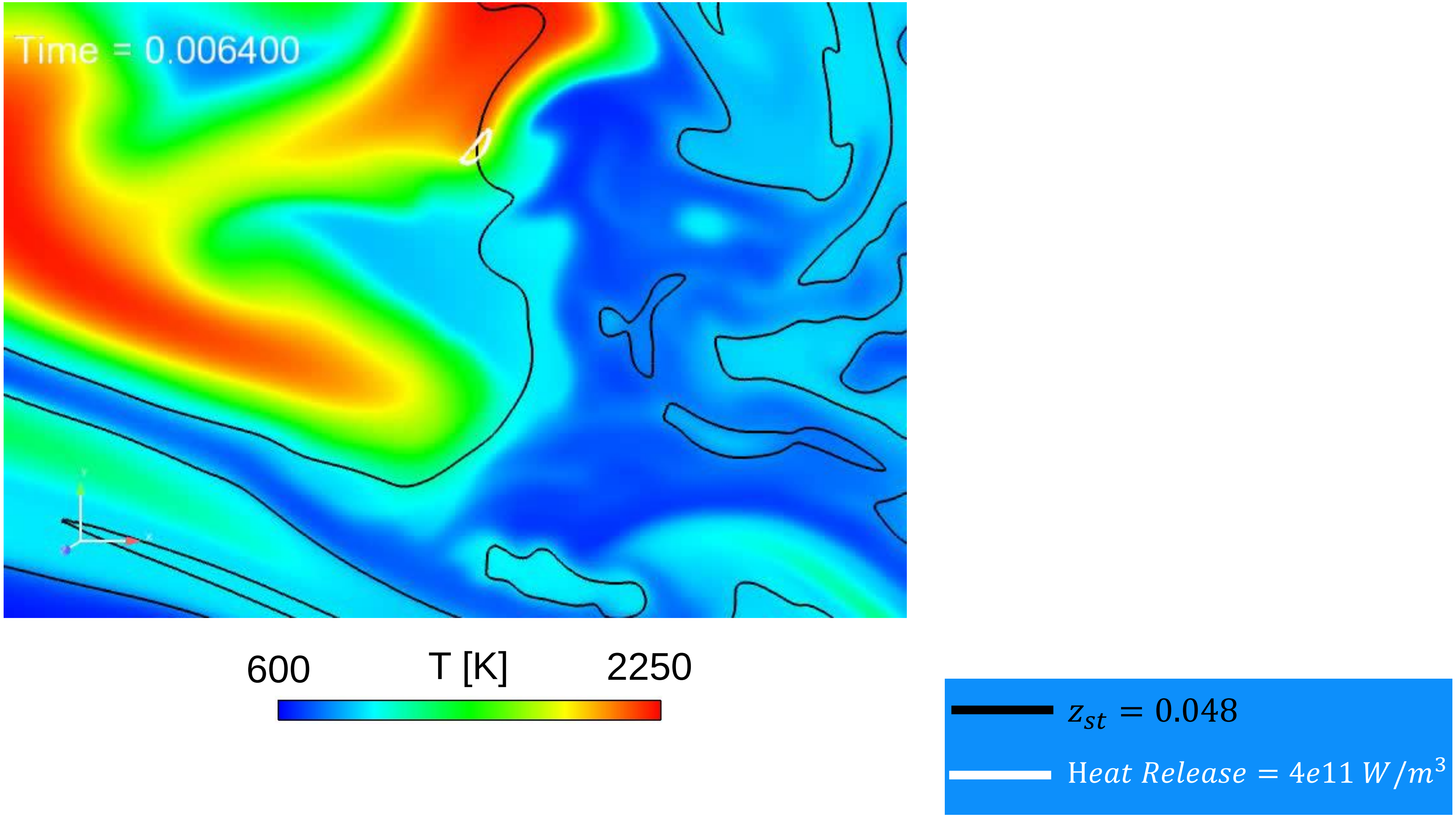
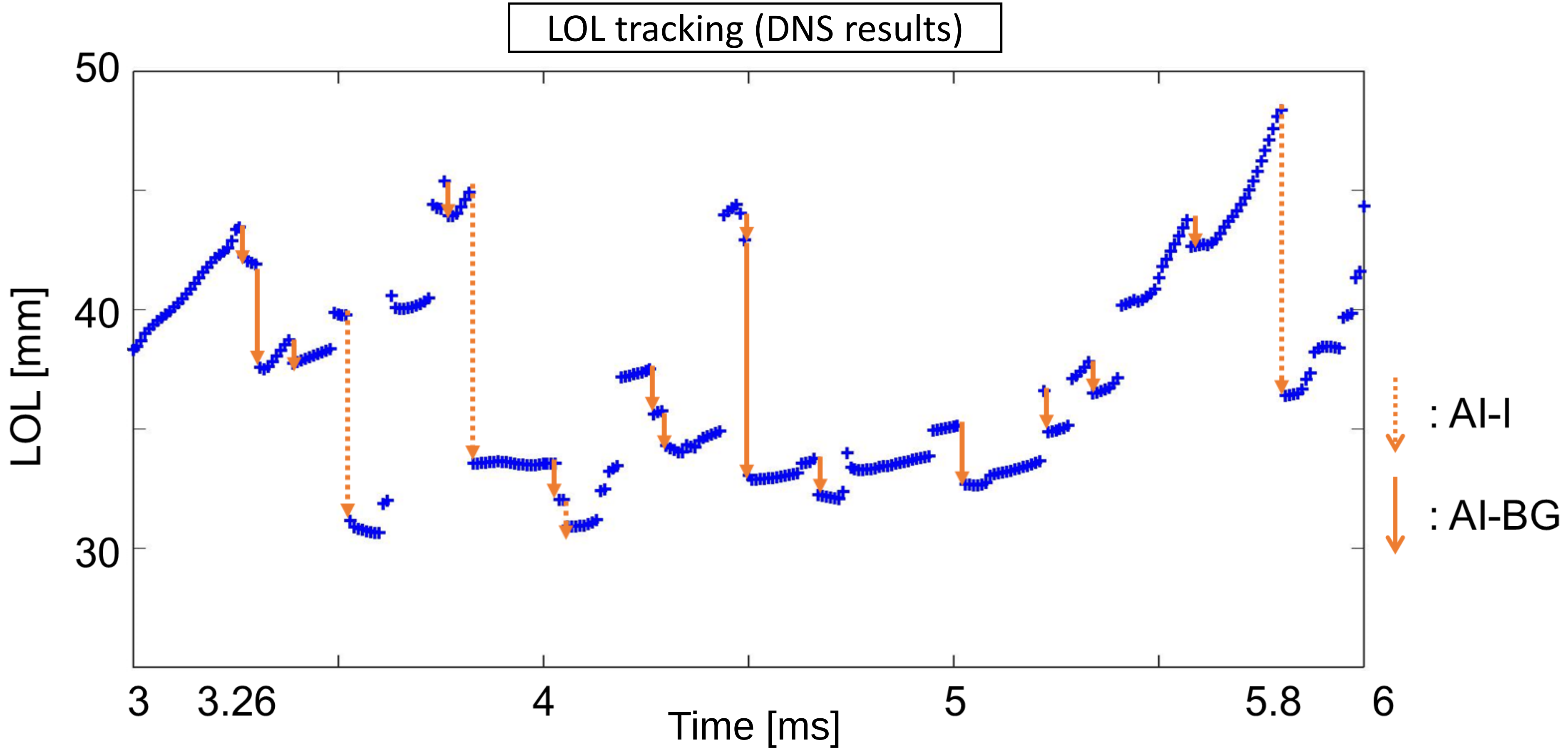
Reaction zone topologies: auto-ignition assisted by burnt gases

- **Auto-ignition assisted by burnt gases (AI-BG)**

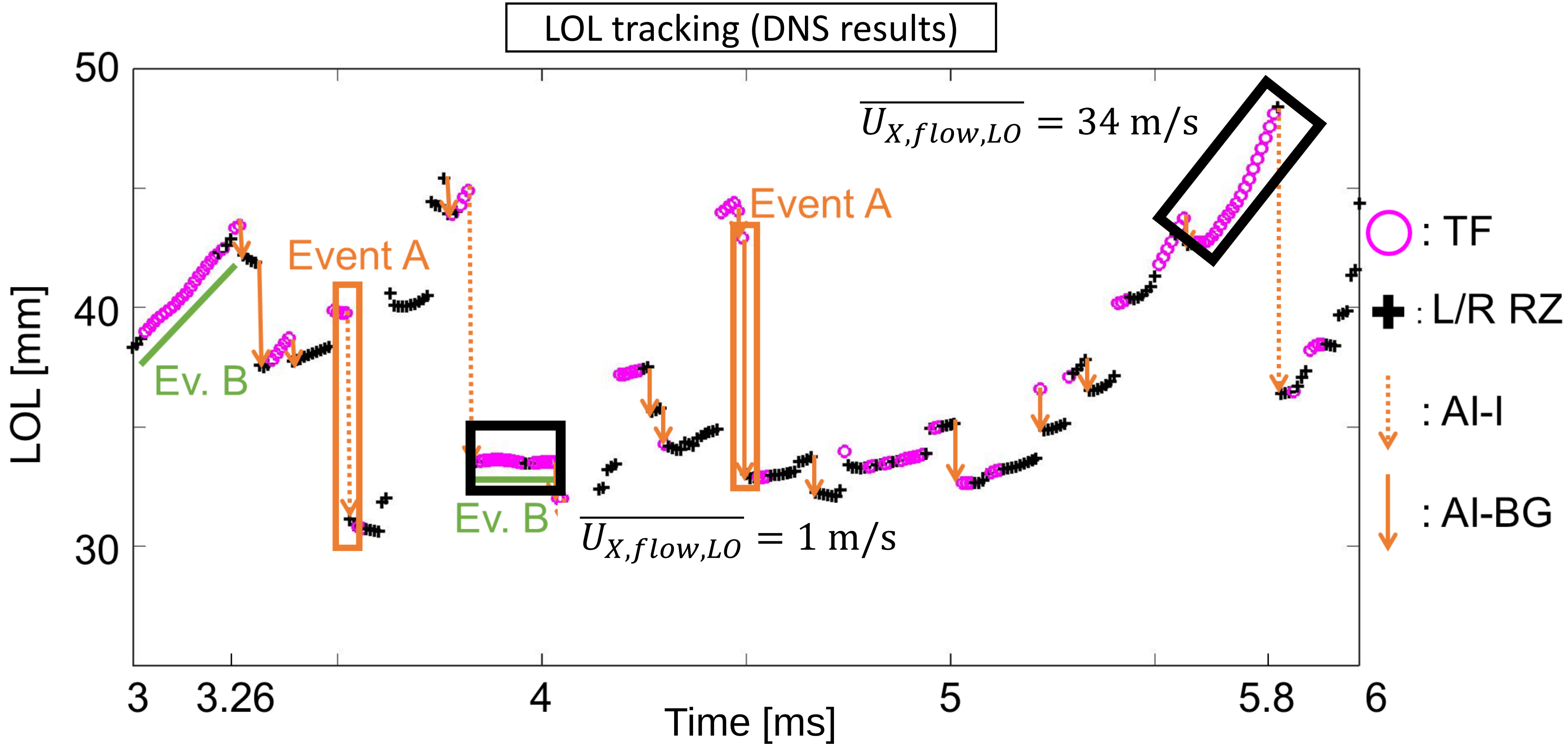


LOL tracking with the reaction zone topologies identification



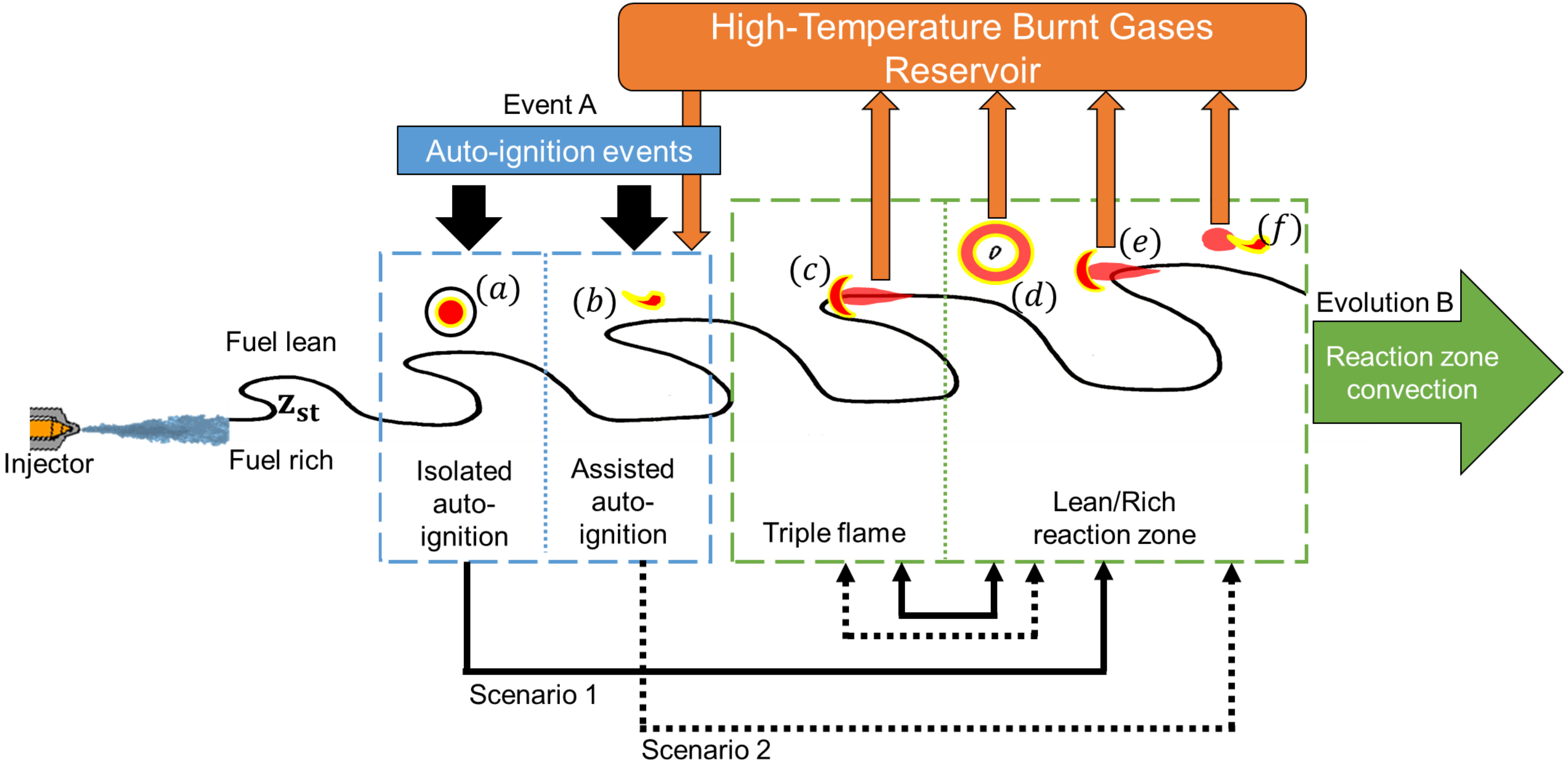
- Like in the experimental study, two main stages are observed, stage A and B:
    - Event A is attributed to isolated auto-ignition (AI-I) or auto-ignition assisted by burnt gases (AI-BG)

LOL tracking with the reaction zone topologies identification



- Like in the experimental study, two main stages are observed, stage A and B:
  - Event A: isolated auto-ignition (AI-I) or auto-ignition assisted by brunt gases (AI-BG)
  - Evolution B: triple flame (TF) or lean/rich reaction zone (L/R RZ) → **governed by the flow velocity**

Conceptual model of flame stabilization



F. Tagliante, T. Poinsot, L. M. Pickett, P. Pepiot, L-M. Malbec, G. Bruneaux, C. Angelberger, *A conceptual model of flame stabilization mechanisms for a lifted Diesel-type flame based on Direct Numerical Simulation and experiments* . Submitted to Combustion and Flame in October 2018.

Thank you for your attention