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Numerical Study on Effects of Swirler Core Blockage Ratios of a Low-Swirl Model Combustor

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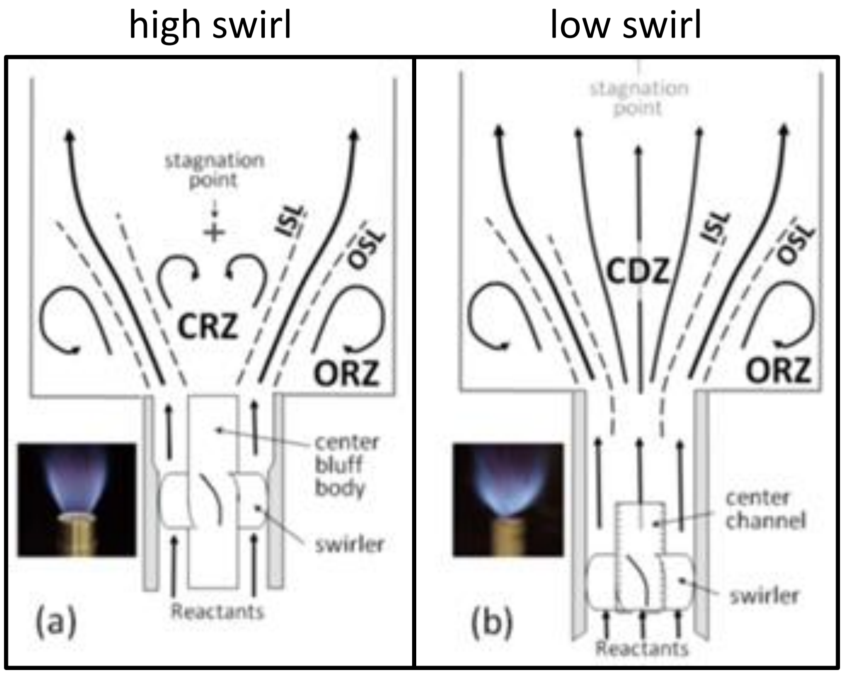
Introduction : Low-Swirl Combustion

- A swirler of low swirl combustion, unlike general high swirl, consists of vanes and perforated plate.
- A lifted flame is created by the combination of the center jet flow and the outer swirling stream.



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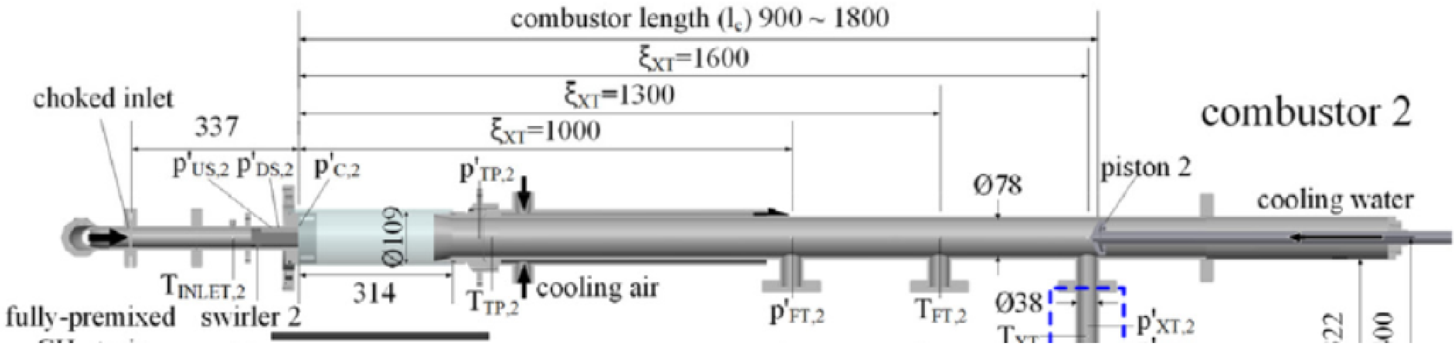
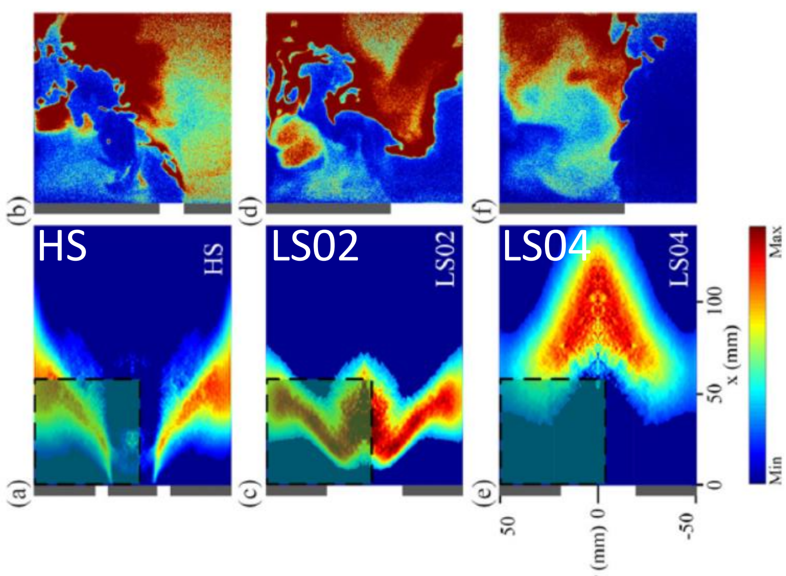
Introduction : Previous Research

- **H. Jegal et al., Proc. Combust. Inst. (2020)**



OH_PLIF

CH* chemiluminescence

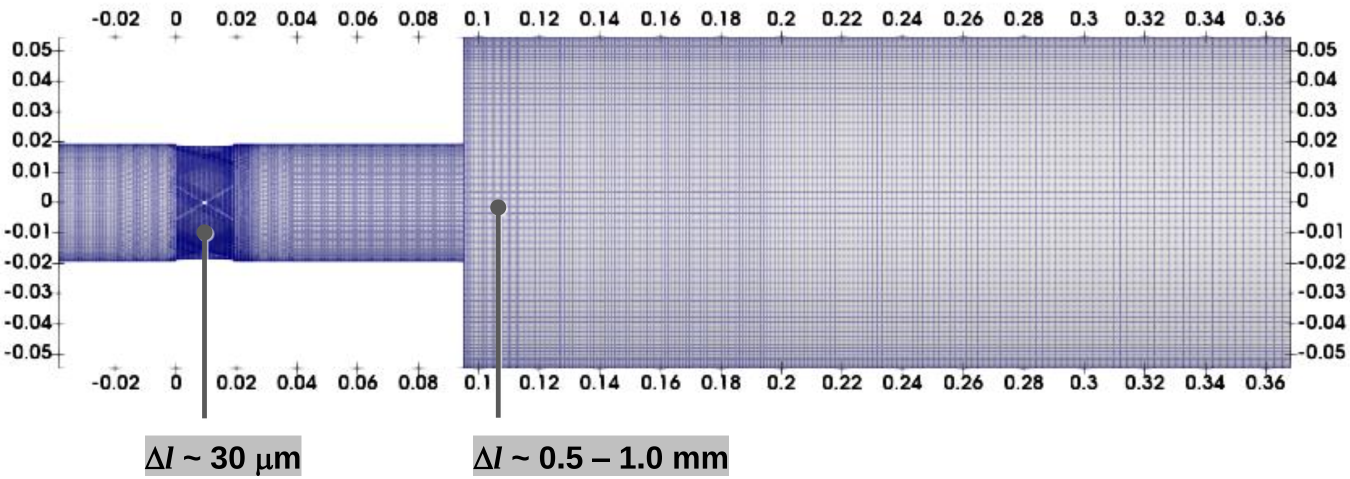


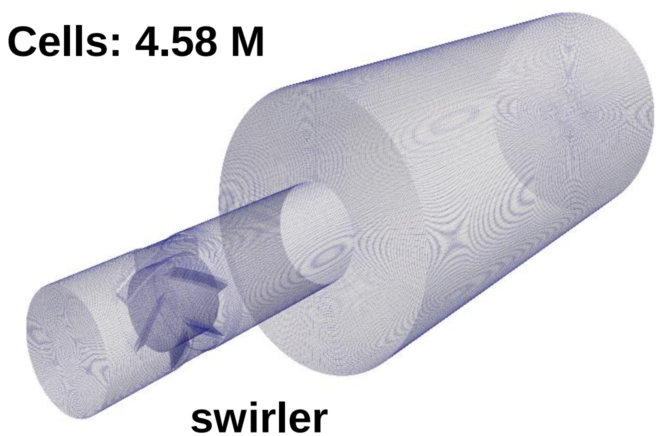
Introduction : Objective

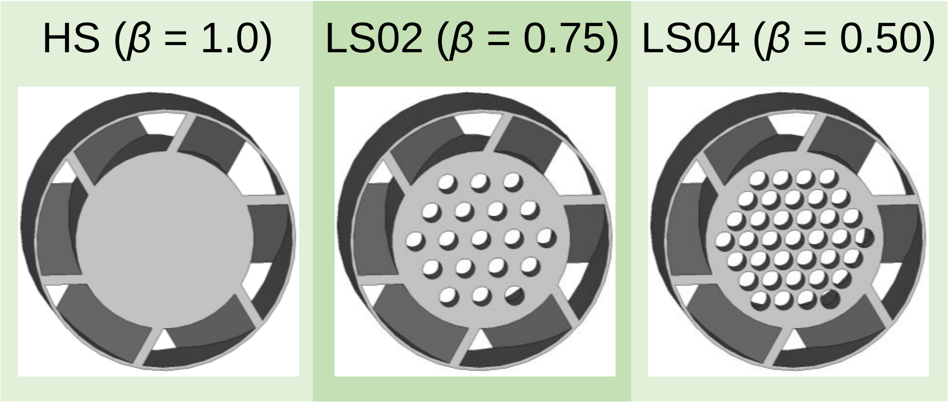
- **LES** analysis applying **FGM** technique to low swirl model combustor according to the swirler core blockage ratios.
  - Comparison of the flow fields
  - Flame structure comparison
  - Emission performance comparison

Numerical Method

- **Computational domain**

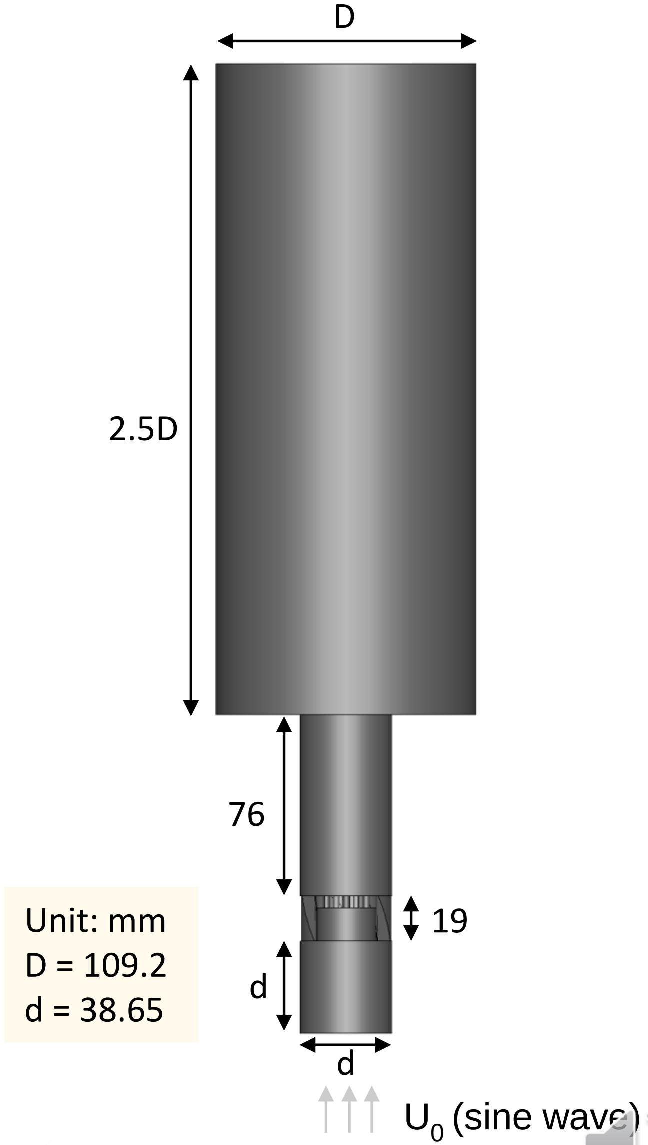






Numerical Method

- Reactant: **premixed methane/air**
- Equivalence ratio: **0.65**
- Outlet pressure: **1 atm**
- Inlet temperature: **473 K**
- Inlet mean velocity: **11.48 m/s**



Numerical Method

- **FGM (Flamelet Generated Manifold)**

Turbulent flow

- LES (Large Eddy Simulation)
- Dynamic One-equation model
- Mesh generation
  - snappyHex w/ Salome

Turbulent combustion modeling

3D manifold

- Detailed Chemistry (GRI30) w/ Cantera
- Heat loss
- PV(Progress Variable)
- Variance of PV

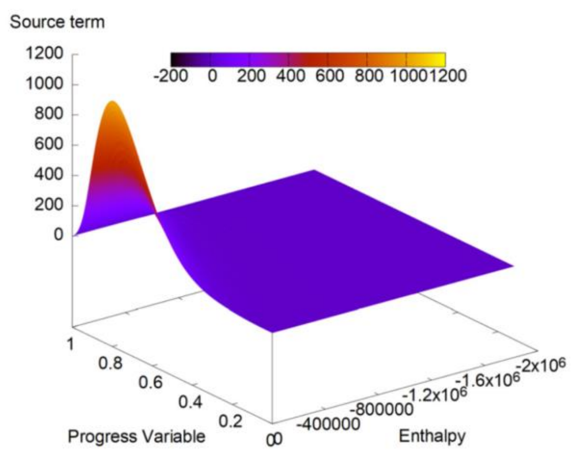
Presumed PDF

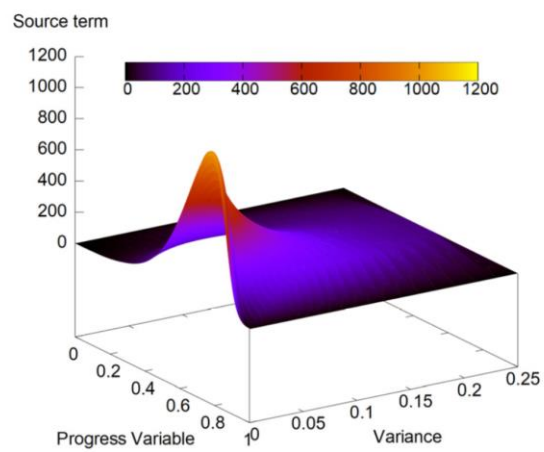
- β-PDF approach

convolution

3D Flamelet-Generated Manifold

$$\overline{\dot{\omega}}_Y = \int_0^1 \overline{\dot{\omega}_Y(Y)}\, P(Y)\, dY$$





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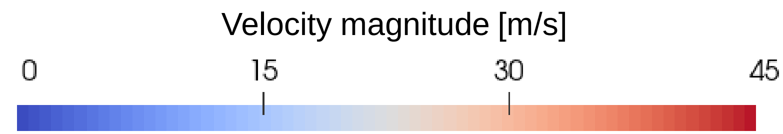
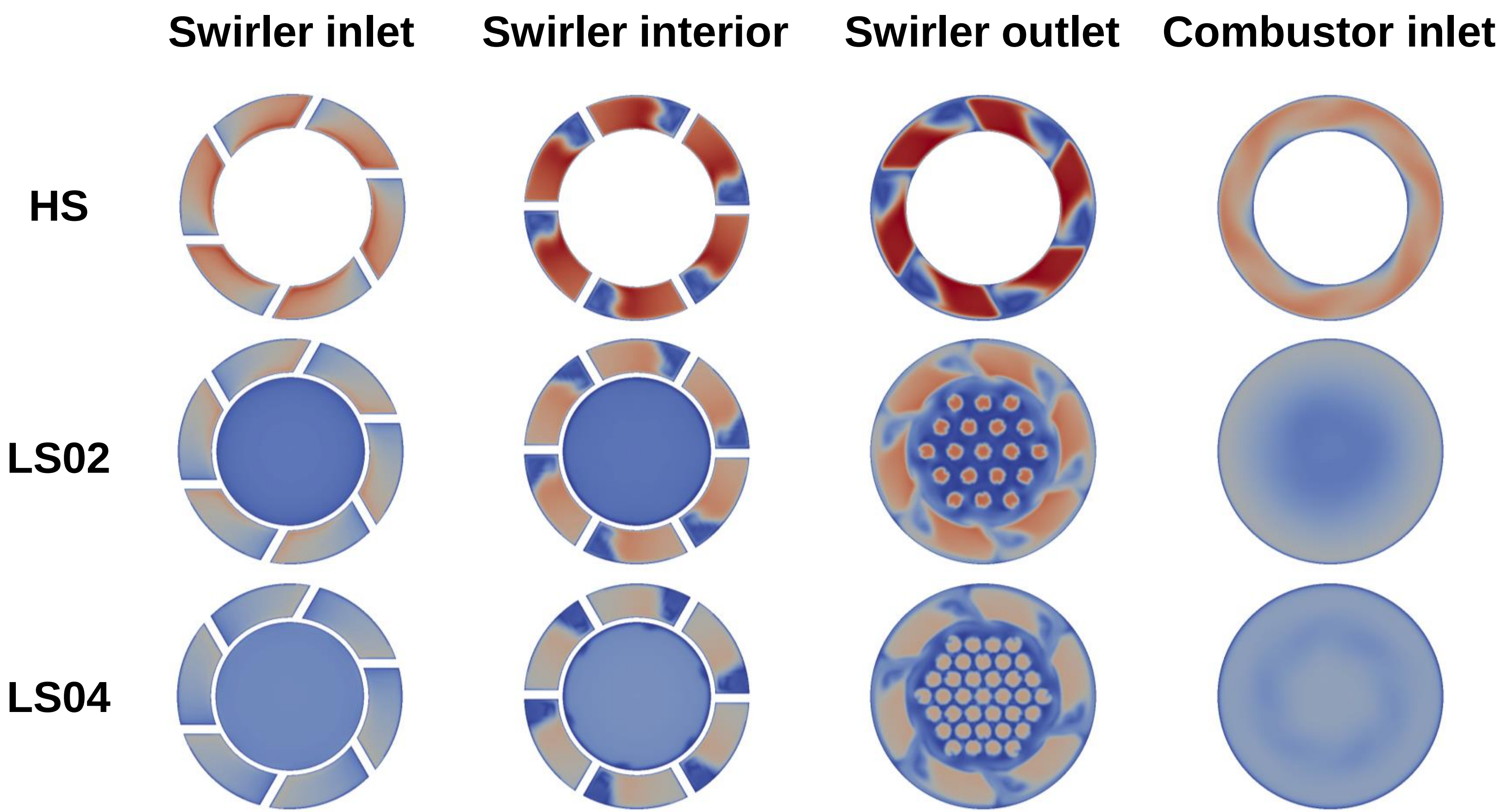
Results

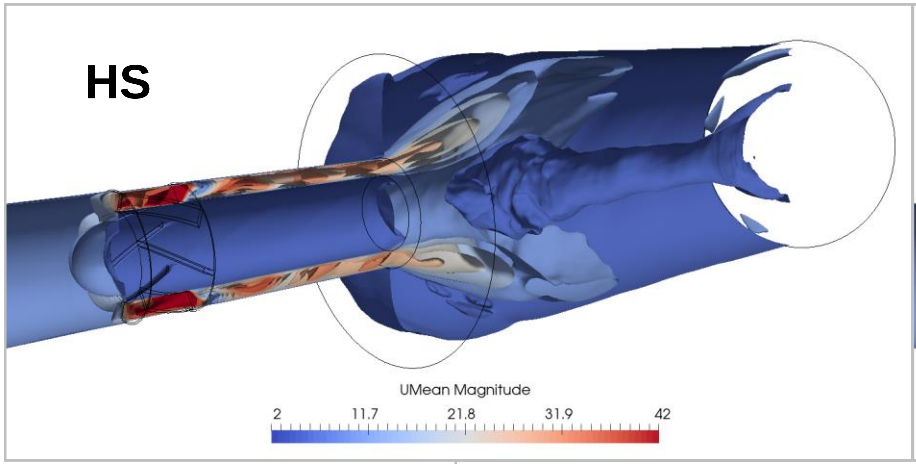
- **Velocity at swirler**

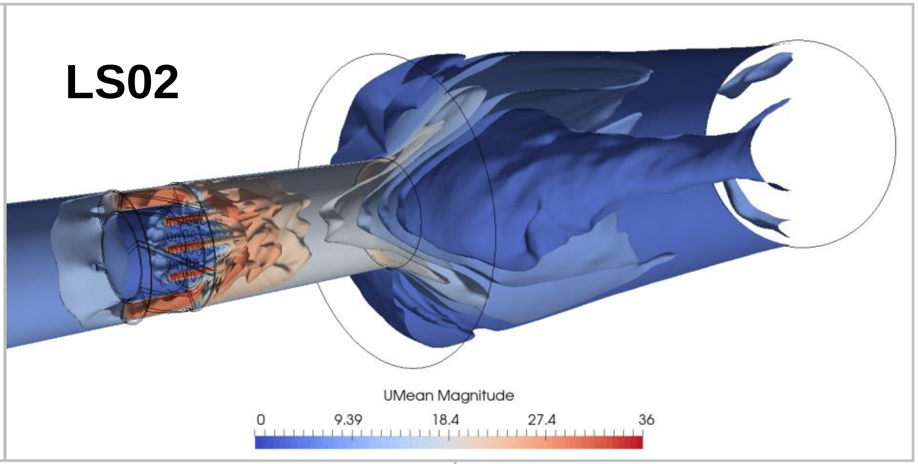


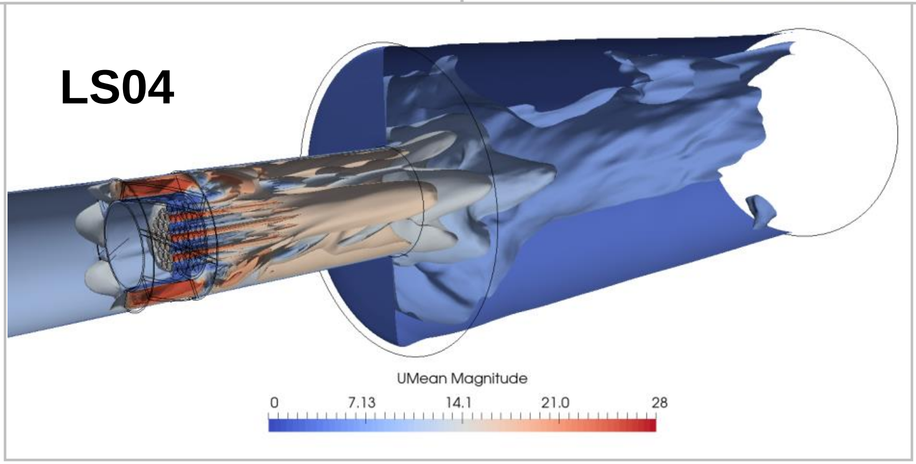


Results

- **Velocity contour**



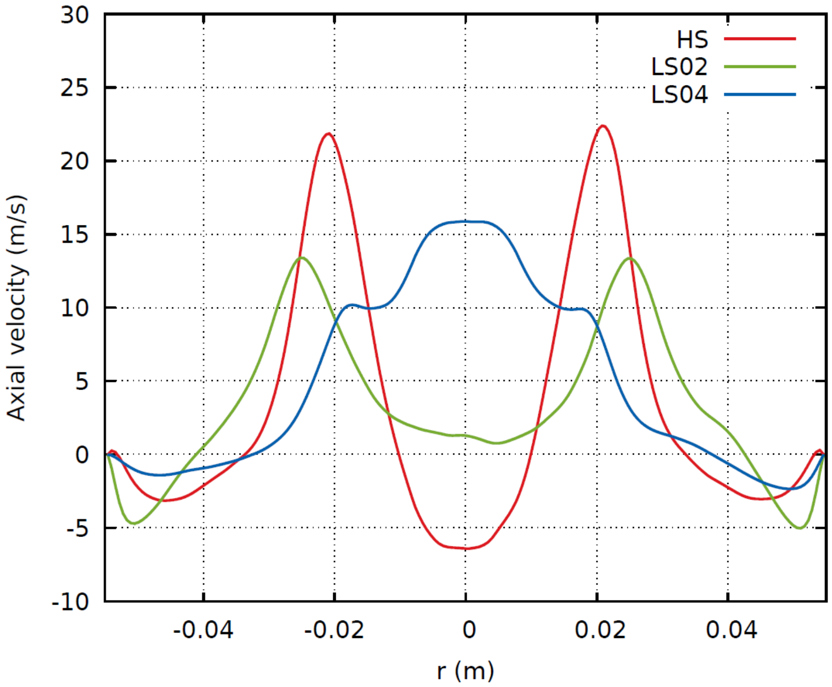




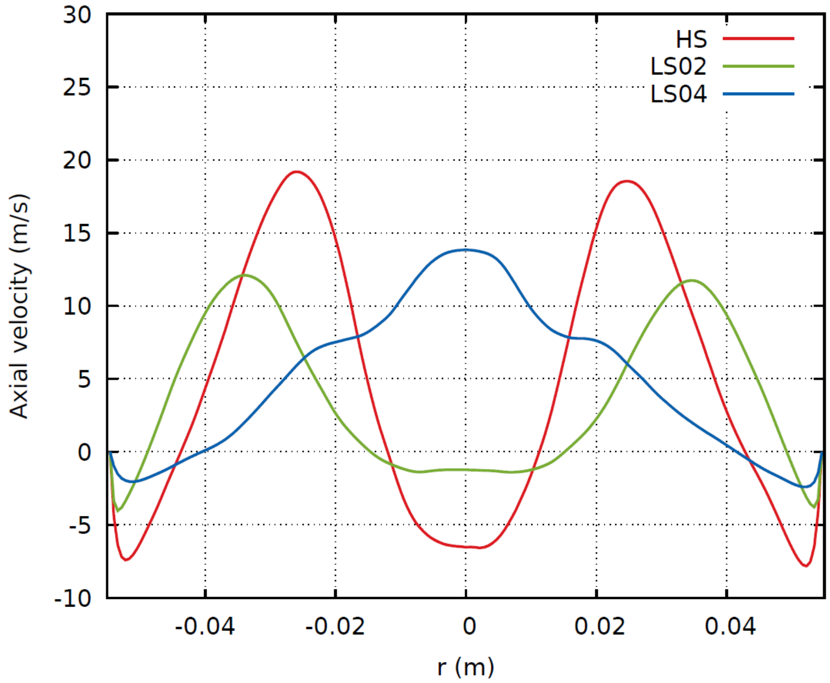
Results

- **Velocity profile**

+0.5 d from nozzle



+1 d from nozzle



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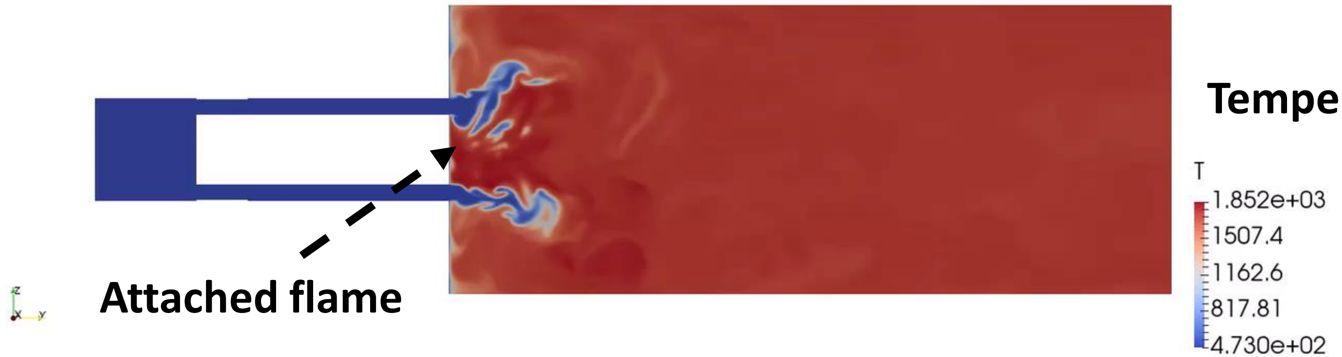
Results

- **Comparison injector**

HS vs LS

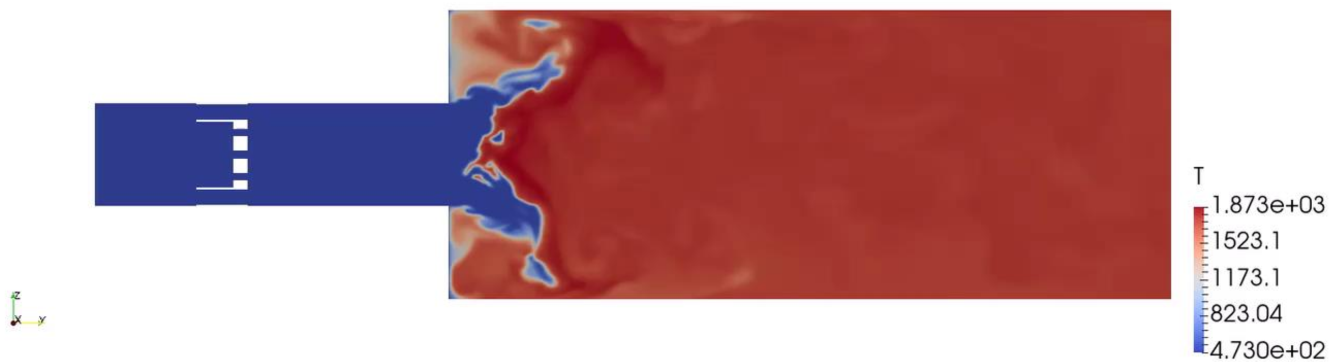
Time: 0.2000 s

HS



Time: 0.2000 s

LS02



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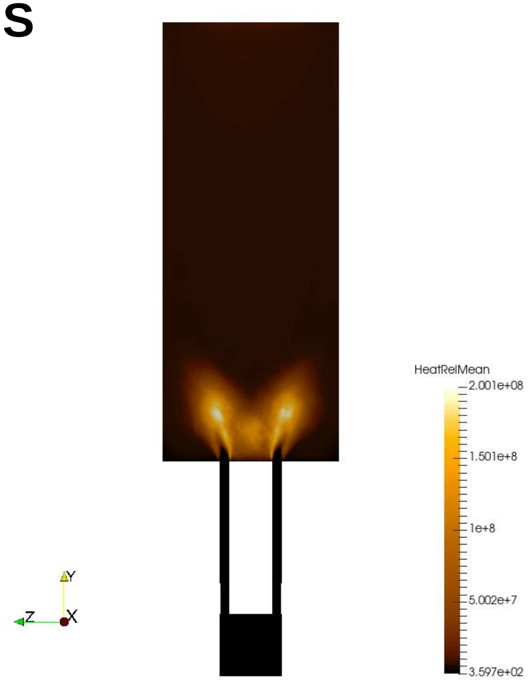
Results

- **Comparison injector**

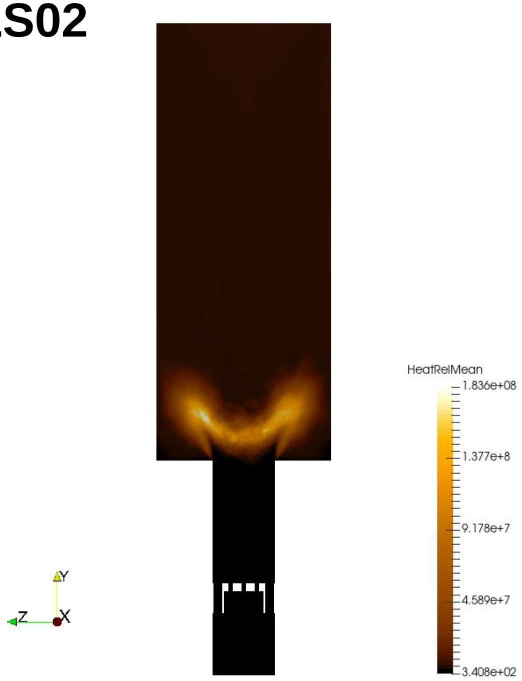
Equivalence ratio = 0.65

Heat release rate

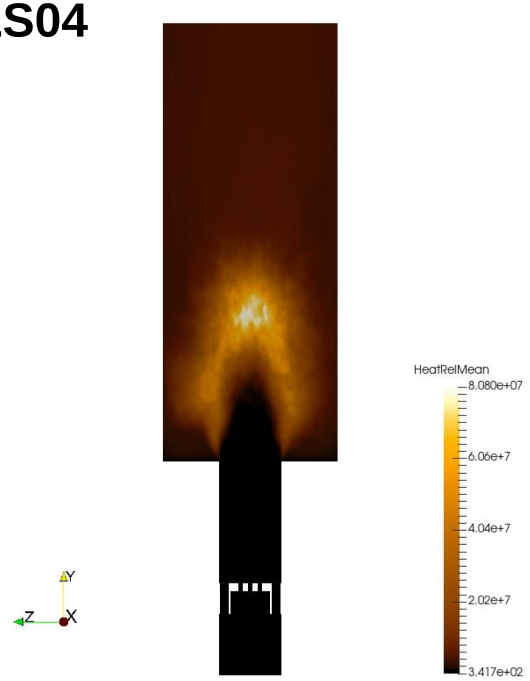
HS



LS02



LS04

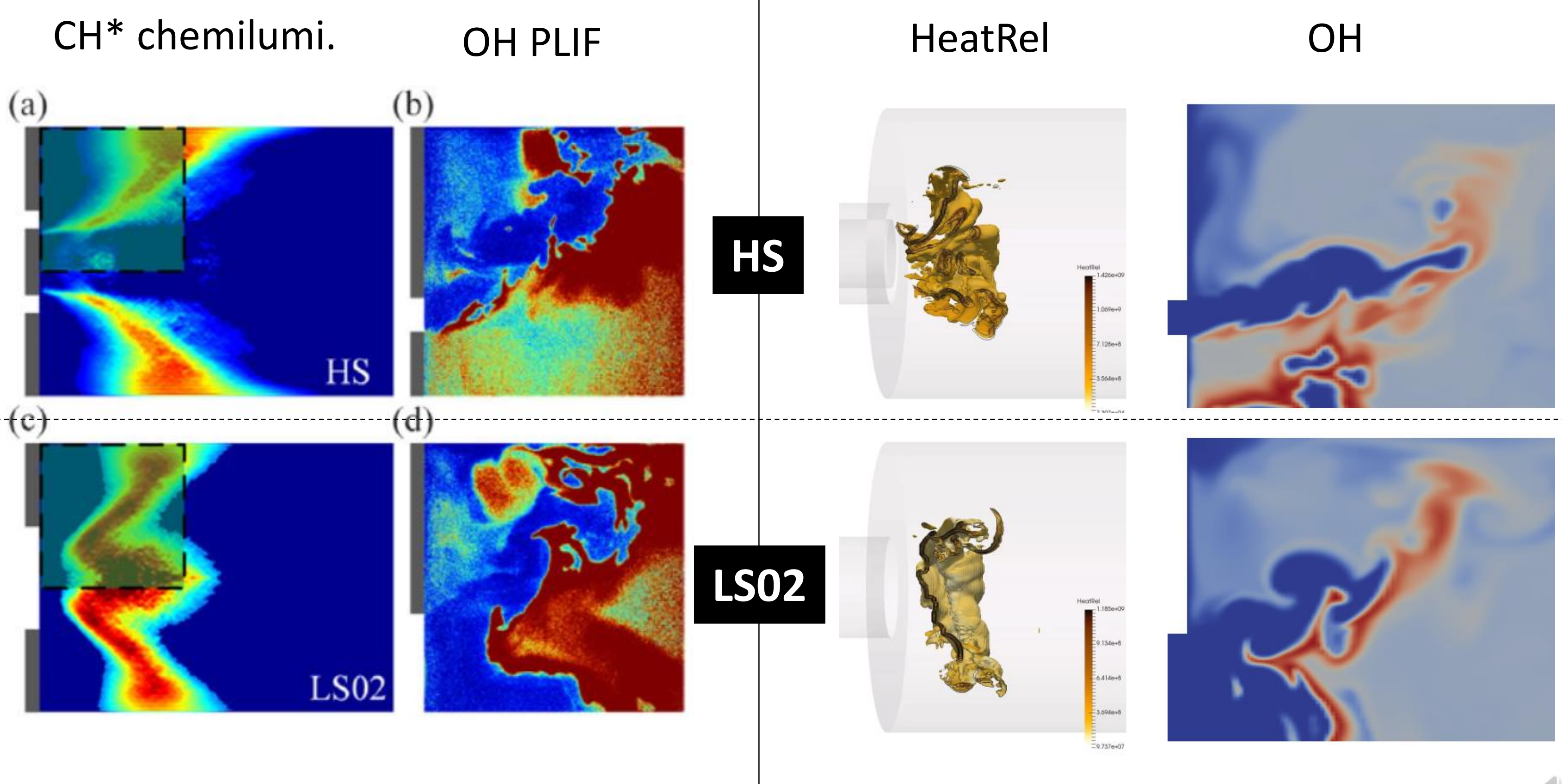


Results

- **Comparison injector**

Previous experiment

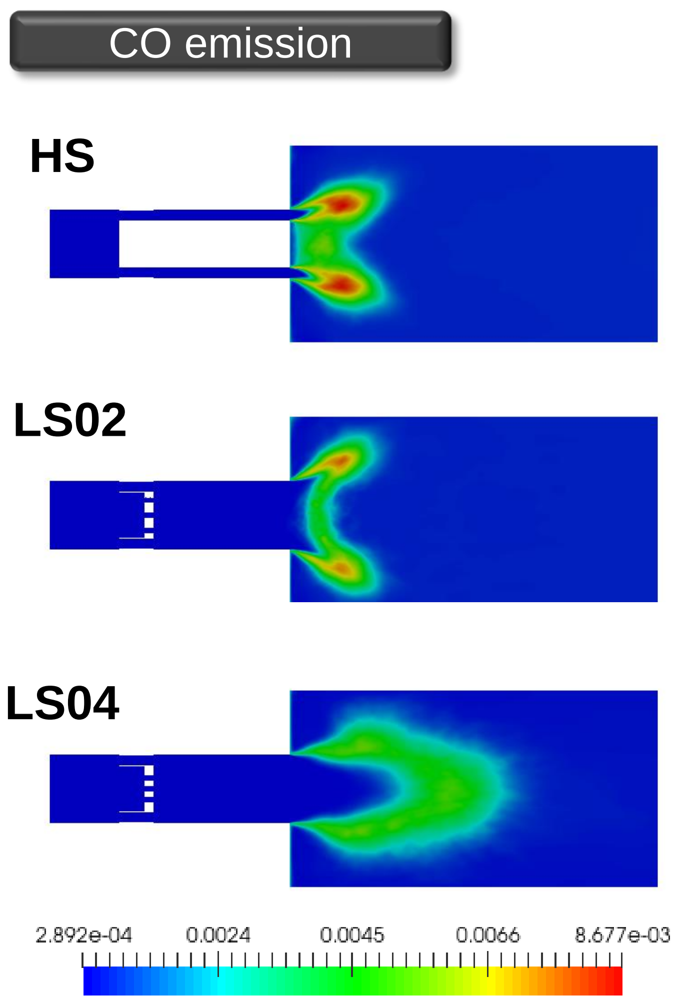
Present simulation

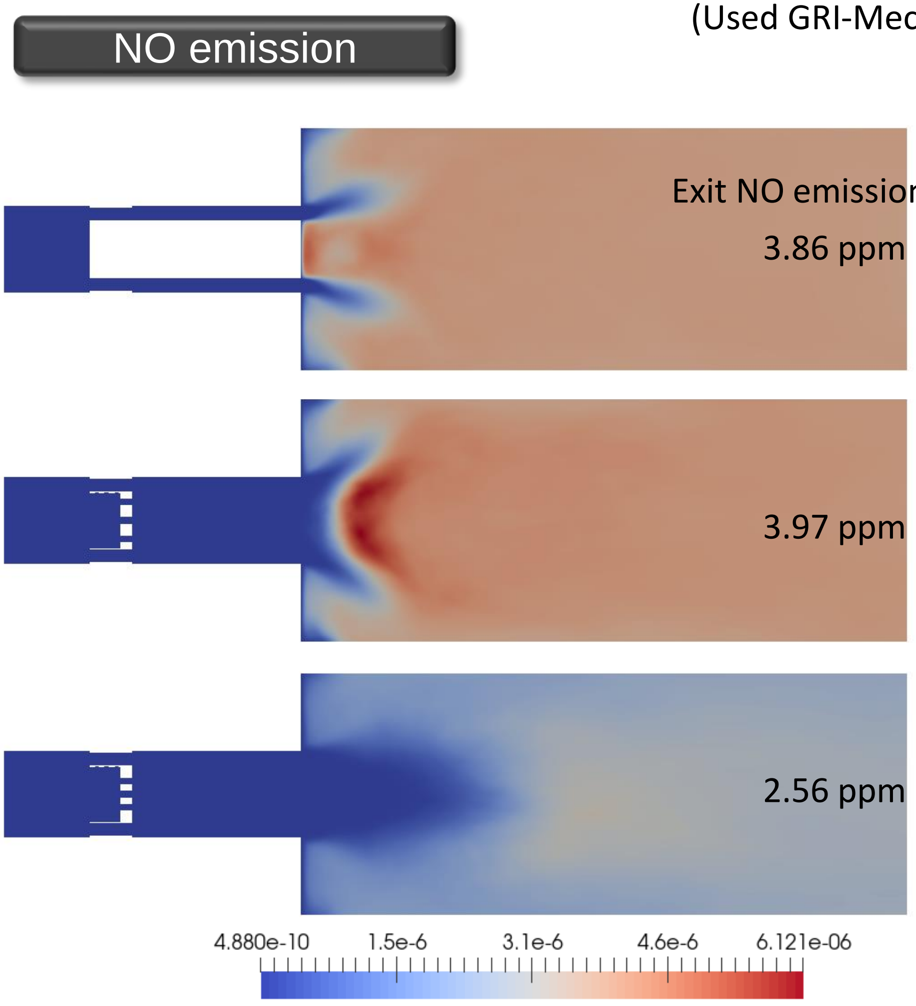


Results

- **Comparison injector**

CO emission rate at exit : HS > LS02 > LS04
NO emission rate at exit: LS02 > HS > LS04
(Used GRI-Mech 3.0)





Conclusion

- LES results using FGM showed similarly to the experimental results at reference research.

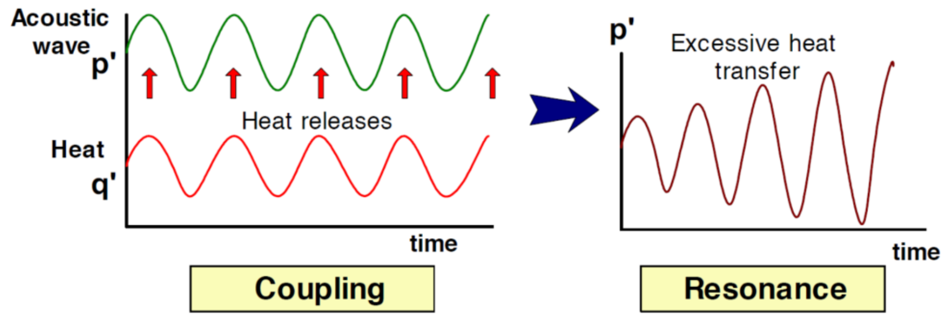
- The flame structure is as follows:
  - HS: a general anchored flame
  - LS02: a lifted W-shaped flame
  - LS04: a large triangular distribution flame

- CO emission: HS > LS   NO emission: HS ≈ LS

Future work

- **Flame Transfer Function** simulation of HS and LS will be performed.

$$FTF(f) = \frac{q'(f)/\bar{q}}{u'(f)/\bar{u}}$$



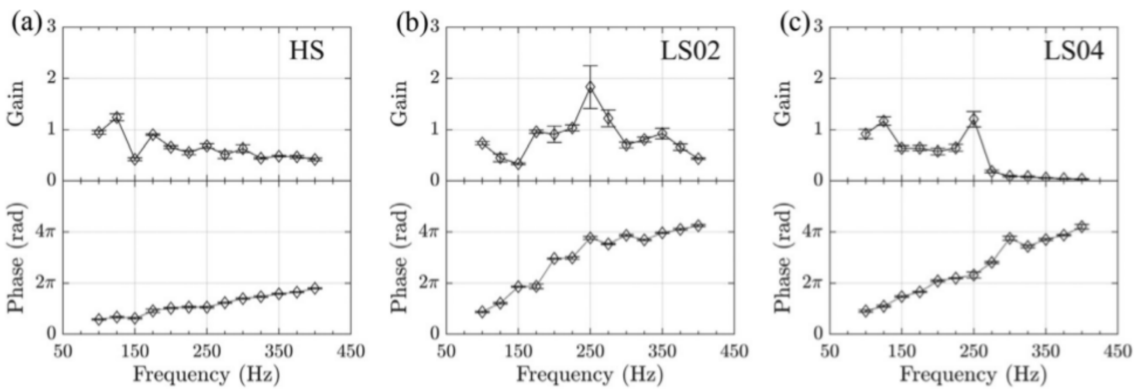


Fig. 4. Flame transfer functions (FTF) of the HS, LS02, and LS04 flames at $\phi_1 = \phi_2 = 0.65$. The FTF is defined as the ratio of the normalized heat-release-rate fluctuations ($q'/\bar{q}$) to the normalized inlet velocity fluctuations ($u'/\bar{u}$).

H. Jegal et al.,

Proc. Combust. Inst. (2020)

Thank you for your attention.