Aerospace Engineering
Seoul National University

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FGM을 적용한 저선회 연소기의 코어 막힘률에 관한 수치적 연구

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- Numerical method
- Results & discussion
- Conclusion

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 core jet flow and the outer swirling stream.

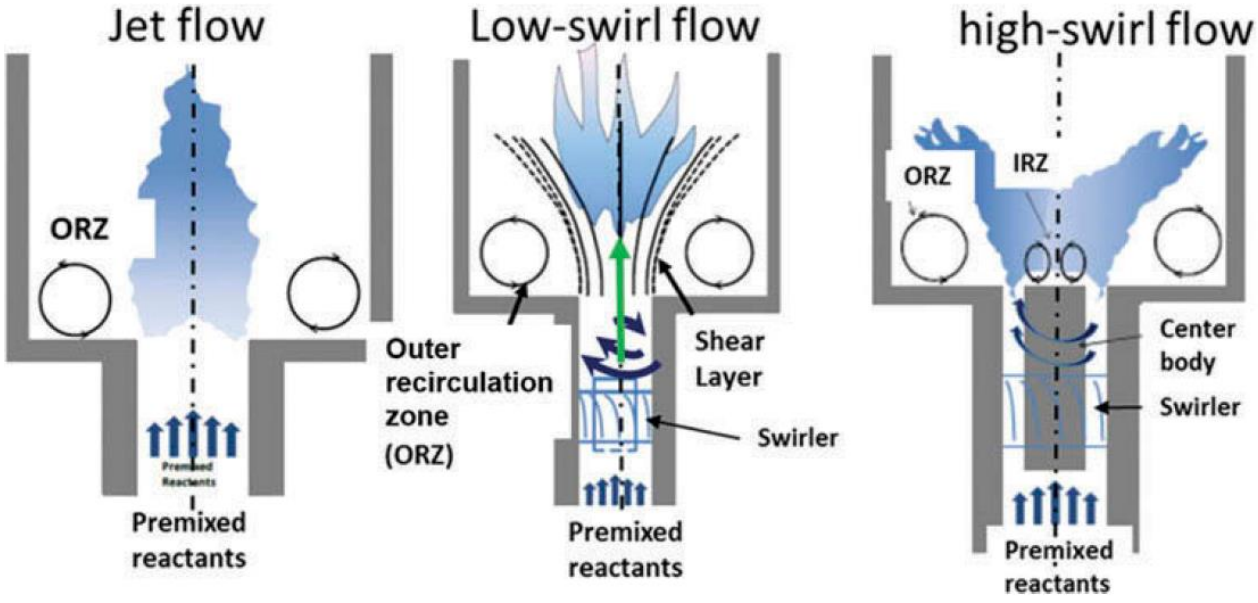
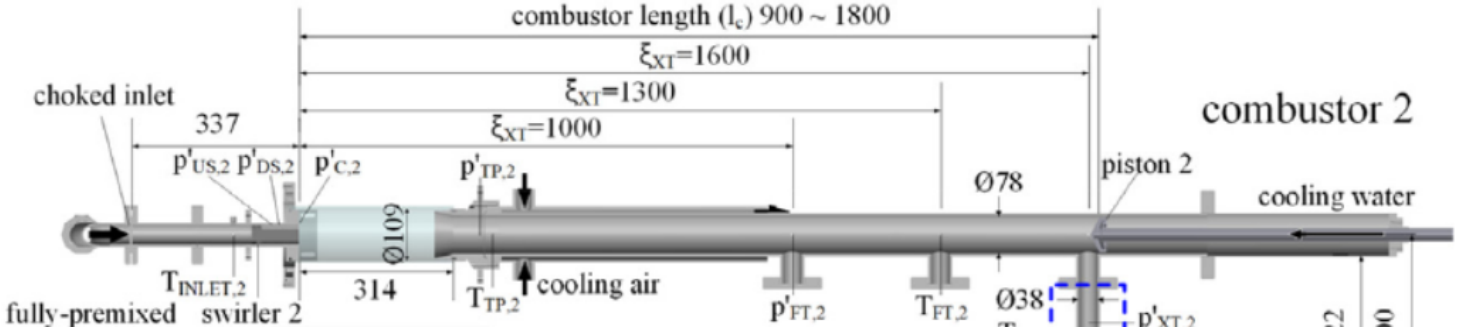
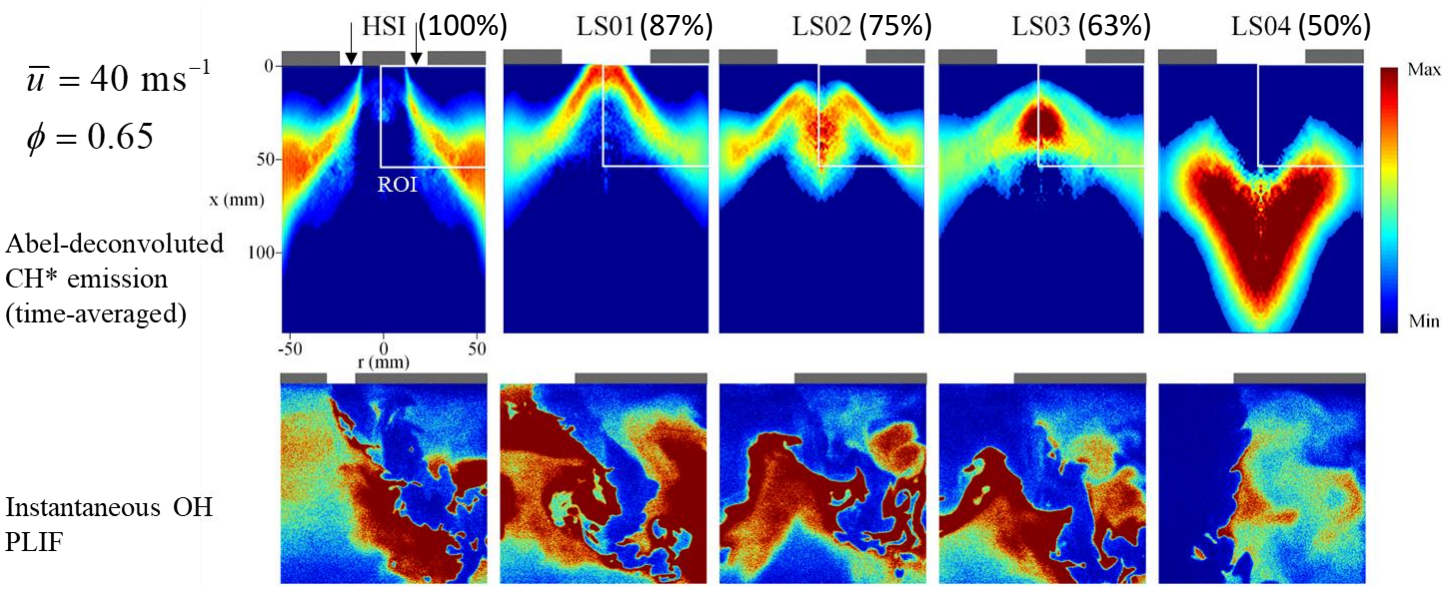


Image: A. Colorado and V. McDonell, *CST*, Vol 189, 2017

Introduction : Previous Research

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



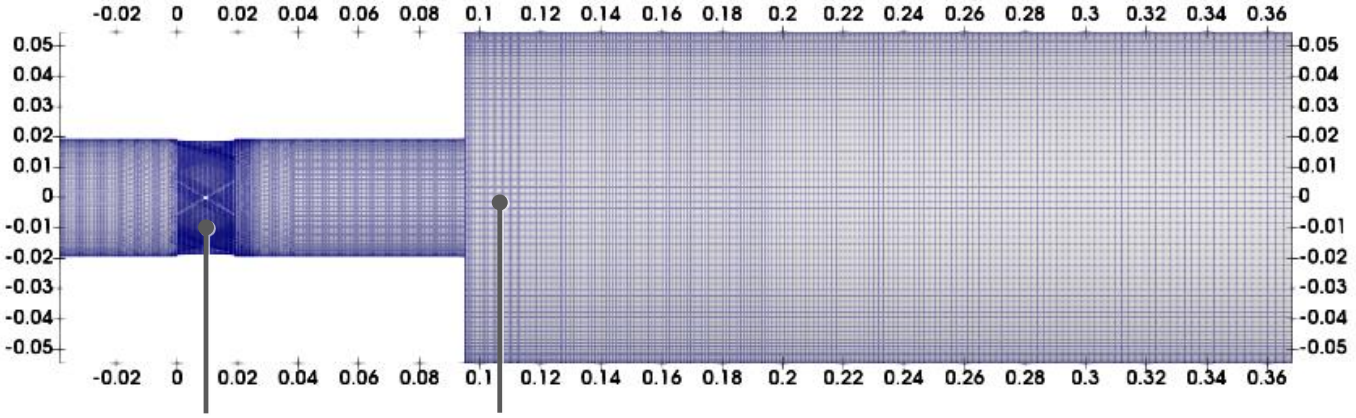


Introduction : Objective

- **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**



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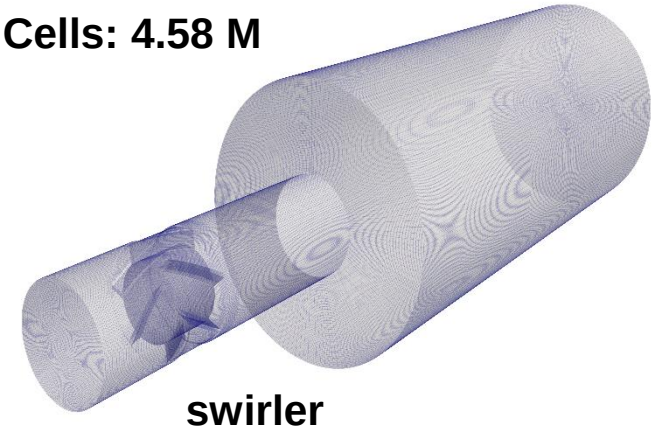
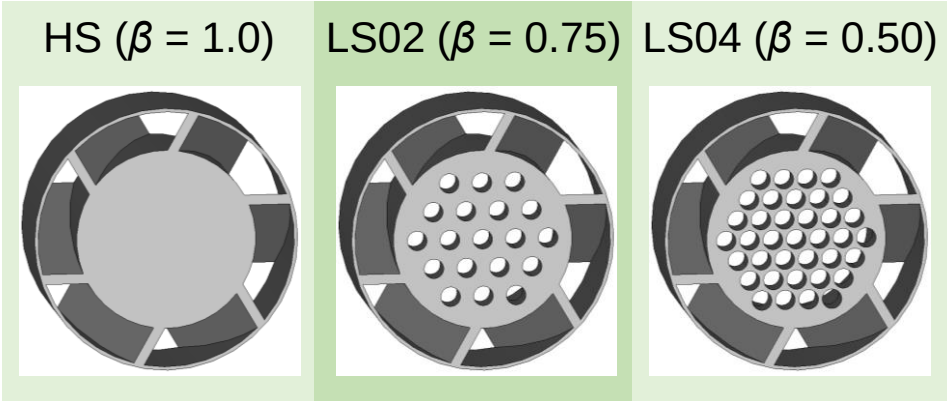
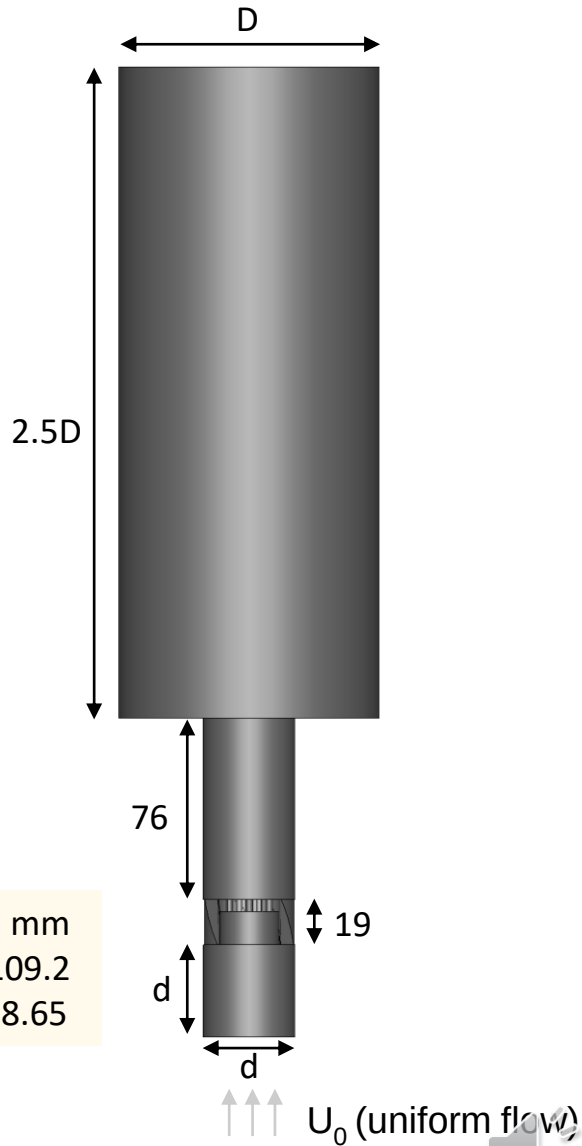


swirler



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

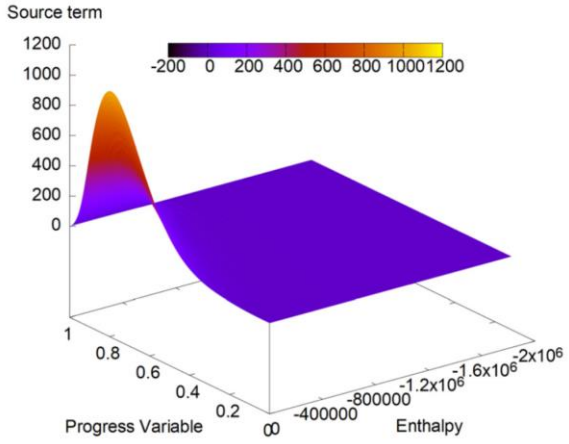
Presumed PDF

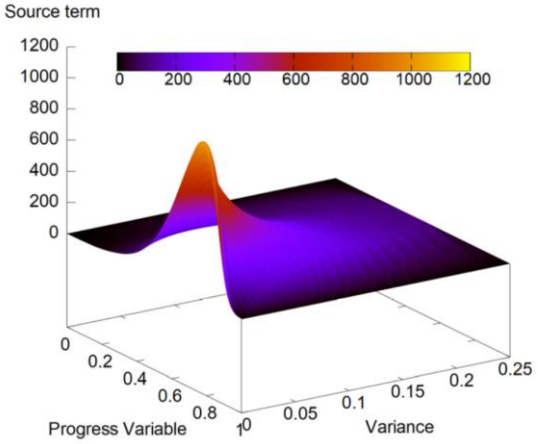
- β-PDF approach

convolution

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

3D Flamelet-Generated Manifold





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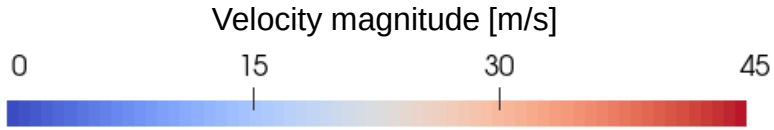
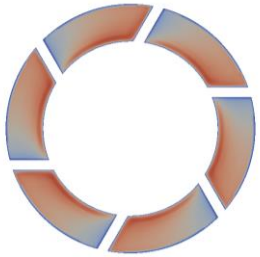
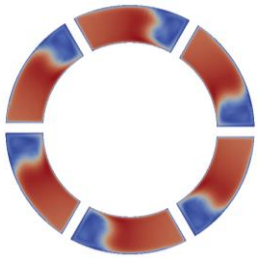
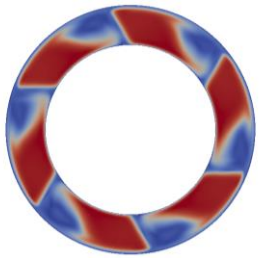
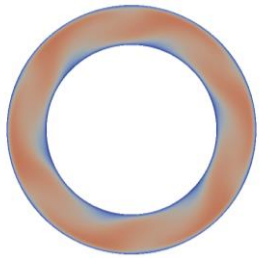
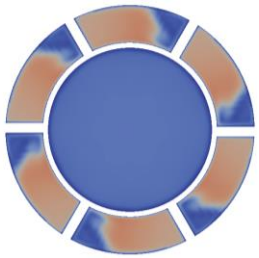
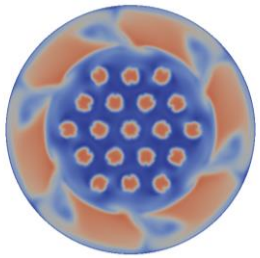
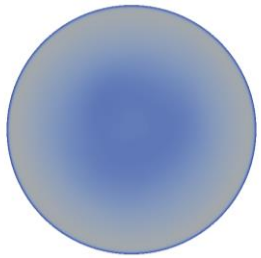
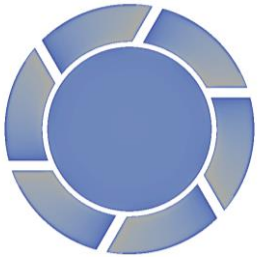
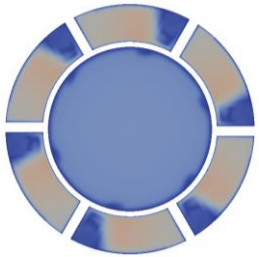
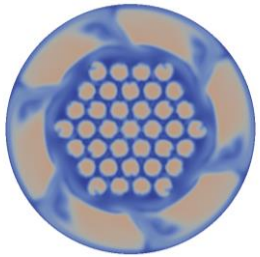
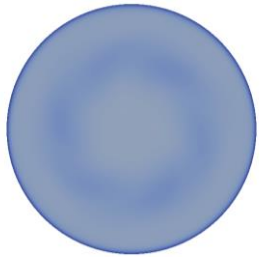
Results

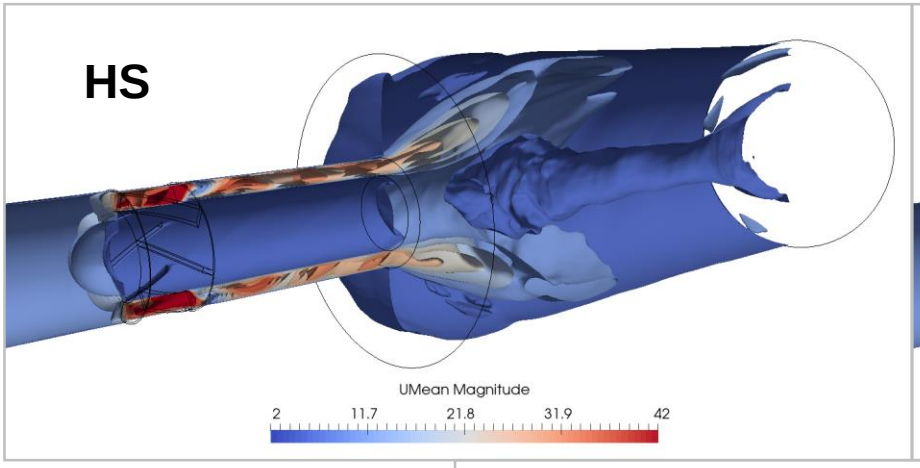
- **Velocity at swirler**

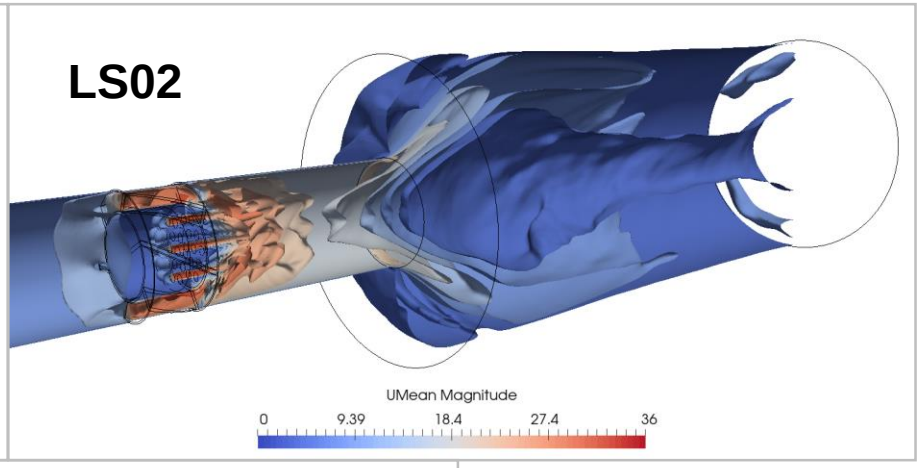


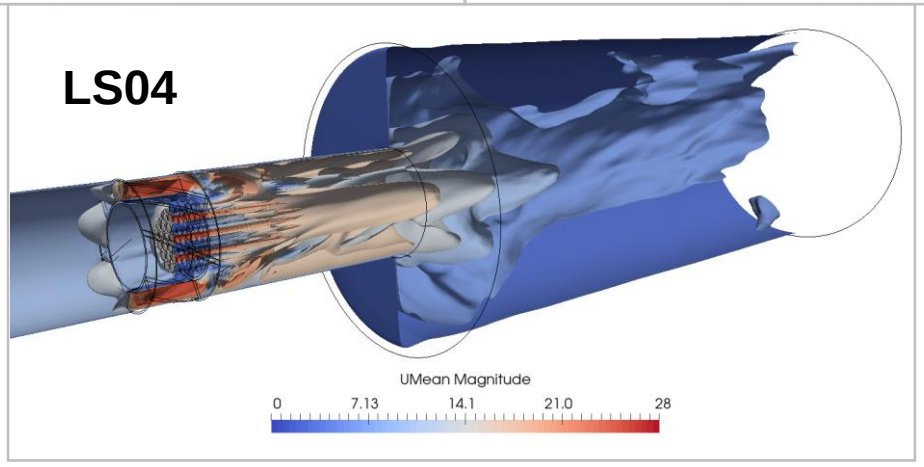
	Swirler inlet	Swirler interior	Swirler outlet	Combustor inlet
HS				
LS02				
LS04				

Results

- Velocity contour



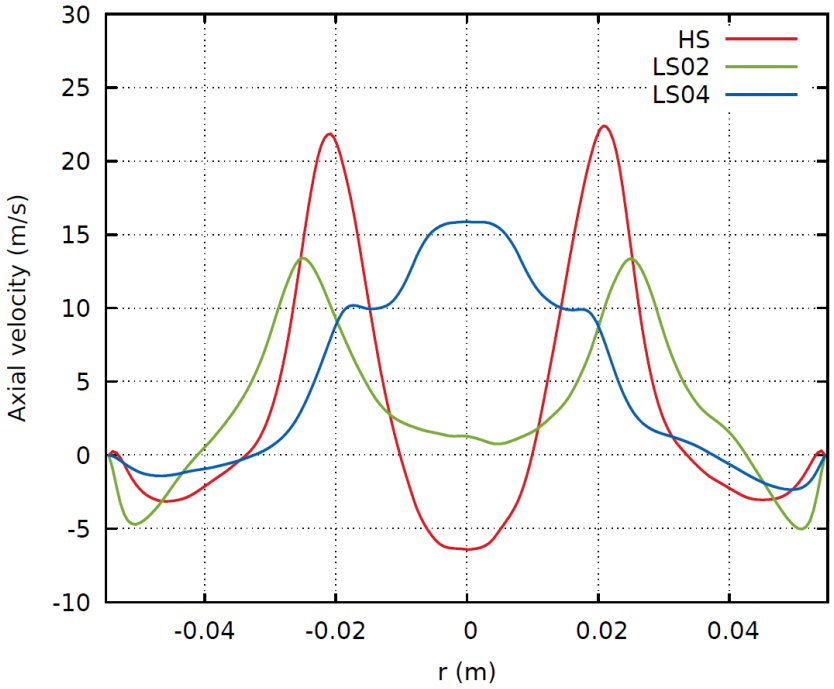




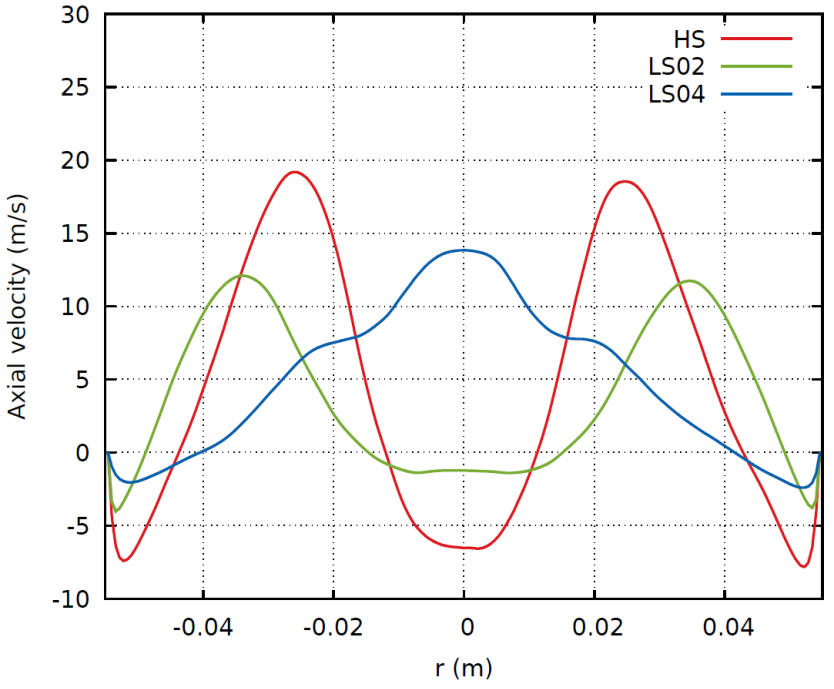
Results

- **Velocity profile**

+0.5 d from nozzle



+1 d from nozzle



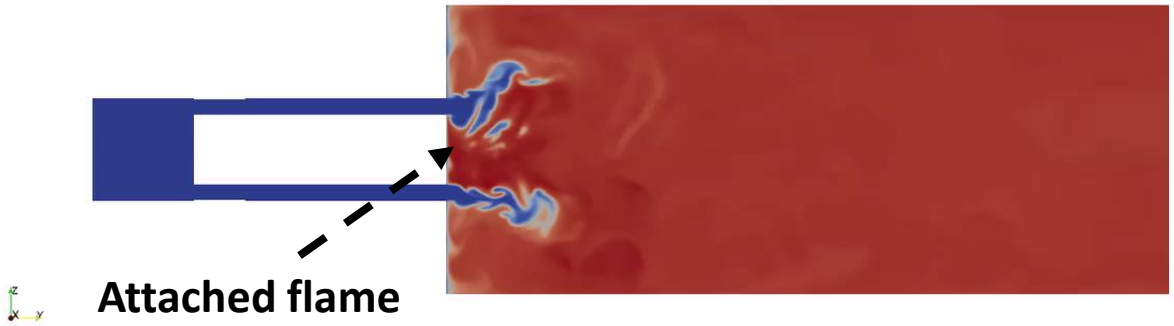
Results

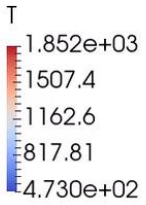
- **Comparison injector**

HS vs LS

Time: 0.2000 s

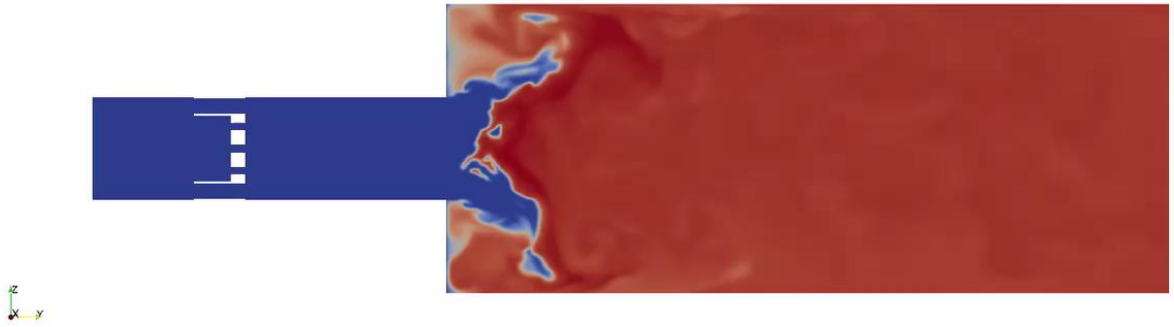
HS

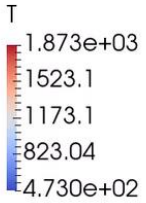




Time: 0.2000 s

LS02

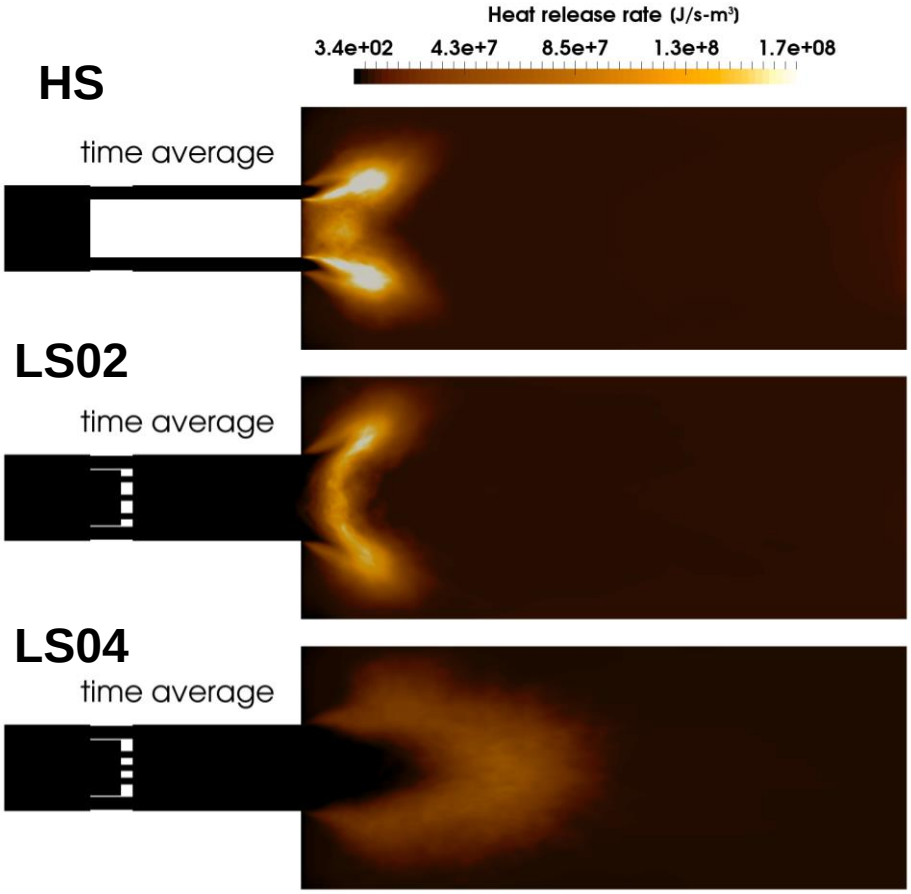




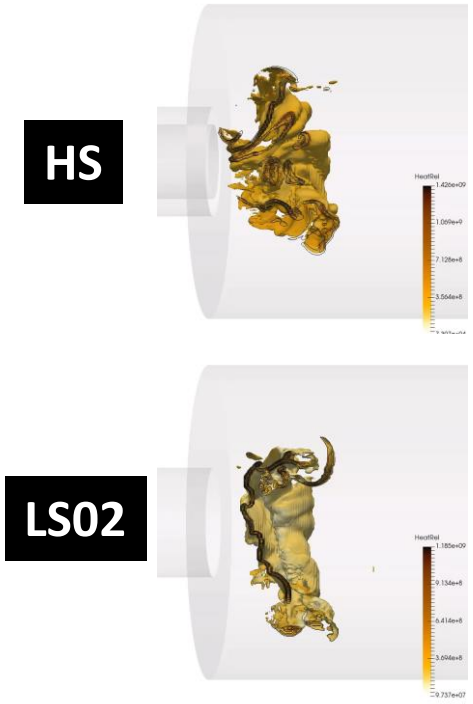
Results

- **Comparison injector**

Equivalence ratio = 0.65

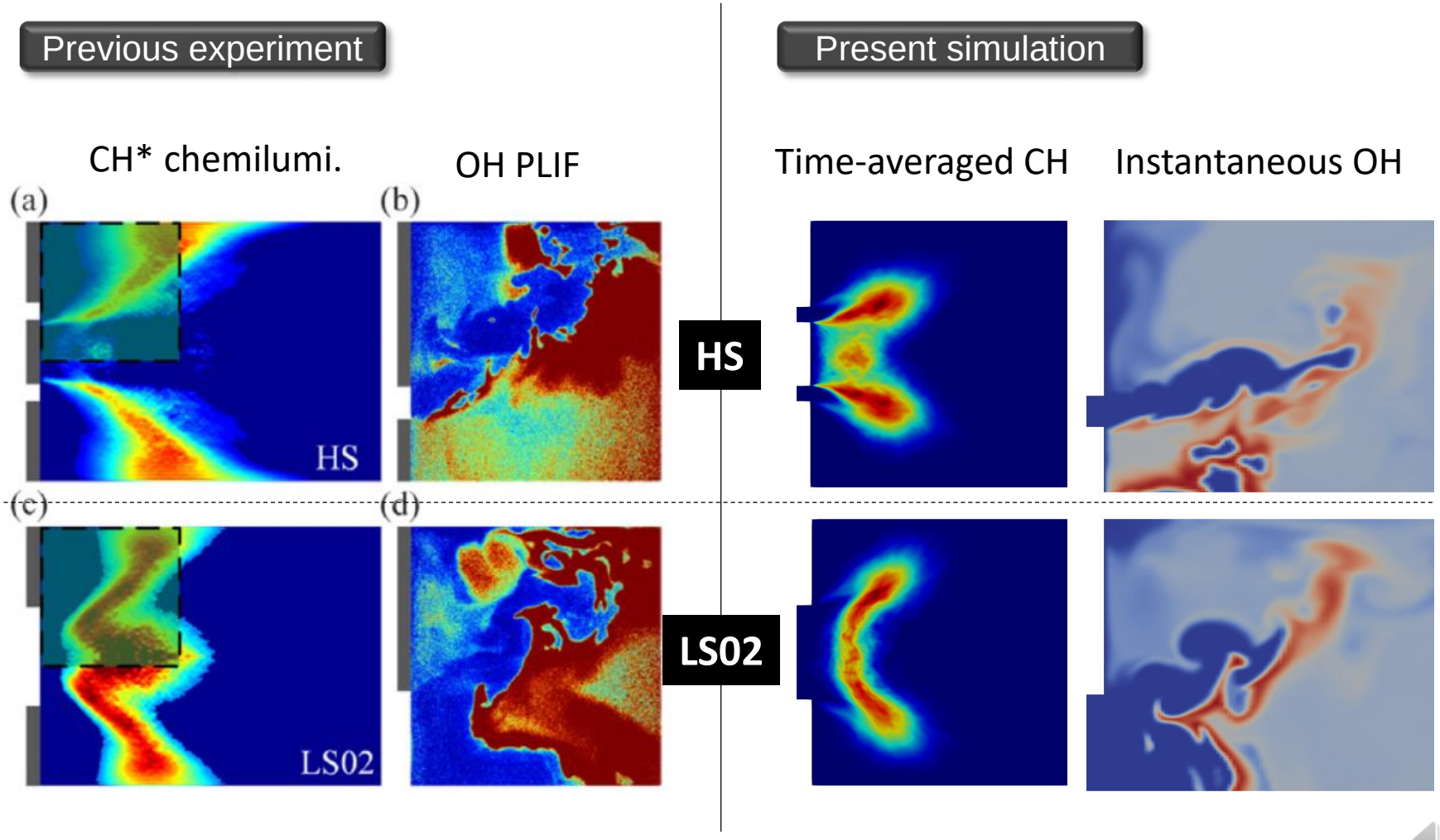


Heat release rate



Results

- **Comparison of experiment and simulation**



Results

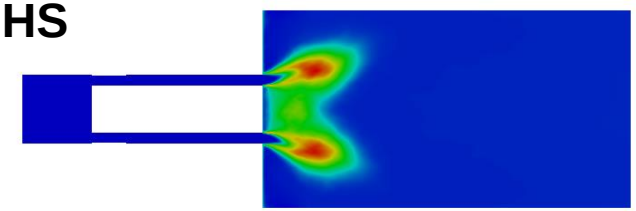
- **Emission performence**

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

CO emission

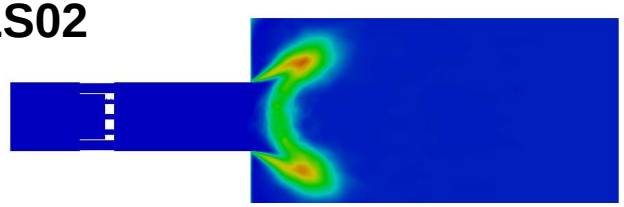
NO emission

HS



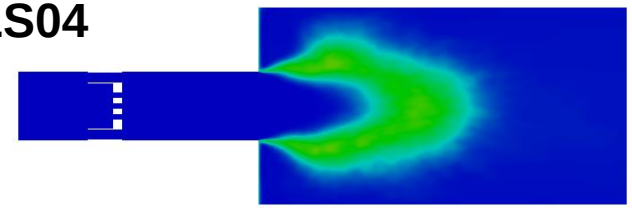
Exit NO emission rate
3.86 ppm

LS02

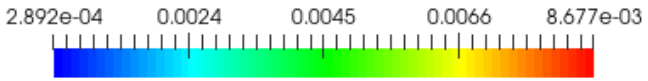


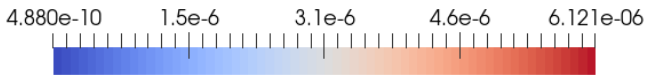
3.97 ppm

LS04



2.56 ppm





Conclusion

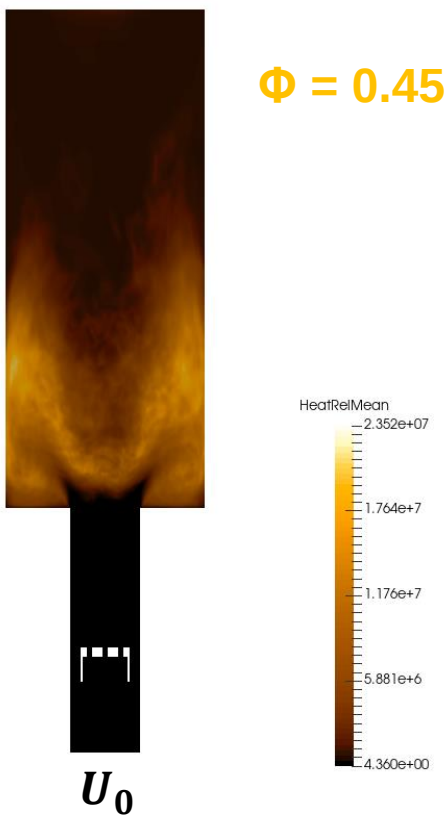
- LES results using FGM showed similarly to the experimental results at reference research.

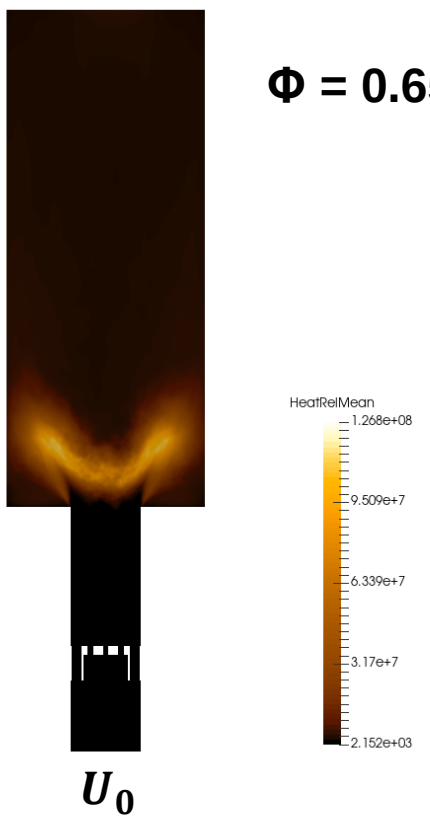
- The flame structure is as follows:
  - HS: a general anchored flame
  - LS02: a stable lifted flame
  - LS04: a large triangular distribution flame

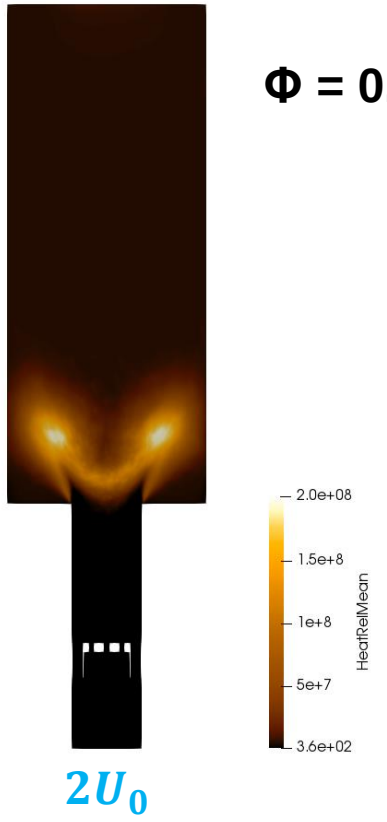
- CO emission: HS > LS NO emission: HS ≈ LS

Future work

- Flame behavior near the lean flammable limit
- Flame liftoff height with inlet velocity







Thank you for your attention.