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Prediction of self-excited combustion instabilities in gas turbines using compressible large eddy simulation

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Introduction

I. Objectives
- ❑ Develop compressible LES method for predicting combustion instabilities
- ❑ Accurately capture self-sustained thermo-acoustic coupling in gas turbines
- ❑ Identify and study underlying feedback mechanisms

II. BOFFIN-LESc solver
- ✓ Eulerian stochastic fields method (*Jones et al. 2007*)
- ✓ 15 step / 19 species CH_4 mechanism (*Lu et al. 2008*)
- ✓ Non-reflective outflow boundary conditions (*Poinsot & Lele 1992)*

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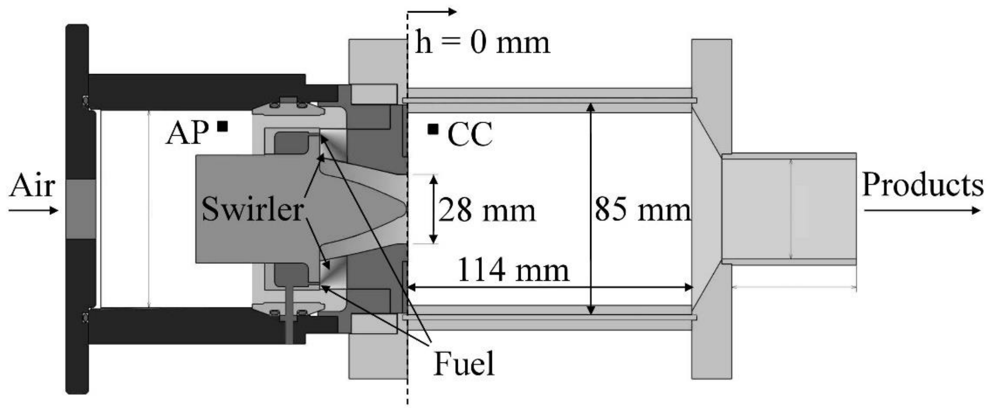
Test case

I. Computational set-up

- ✓ Ambient inflow conditions, equivalence ratio of 0.7 *(Meier et al. 2007)*
- ✓ Isothermal wall temperatures in combustion chamber (*Fredrich et al. 2019)*
- ✓ Pressure probes in air plenum (AP) and combustion chamber (CC)



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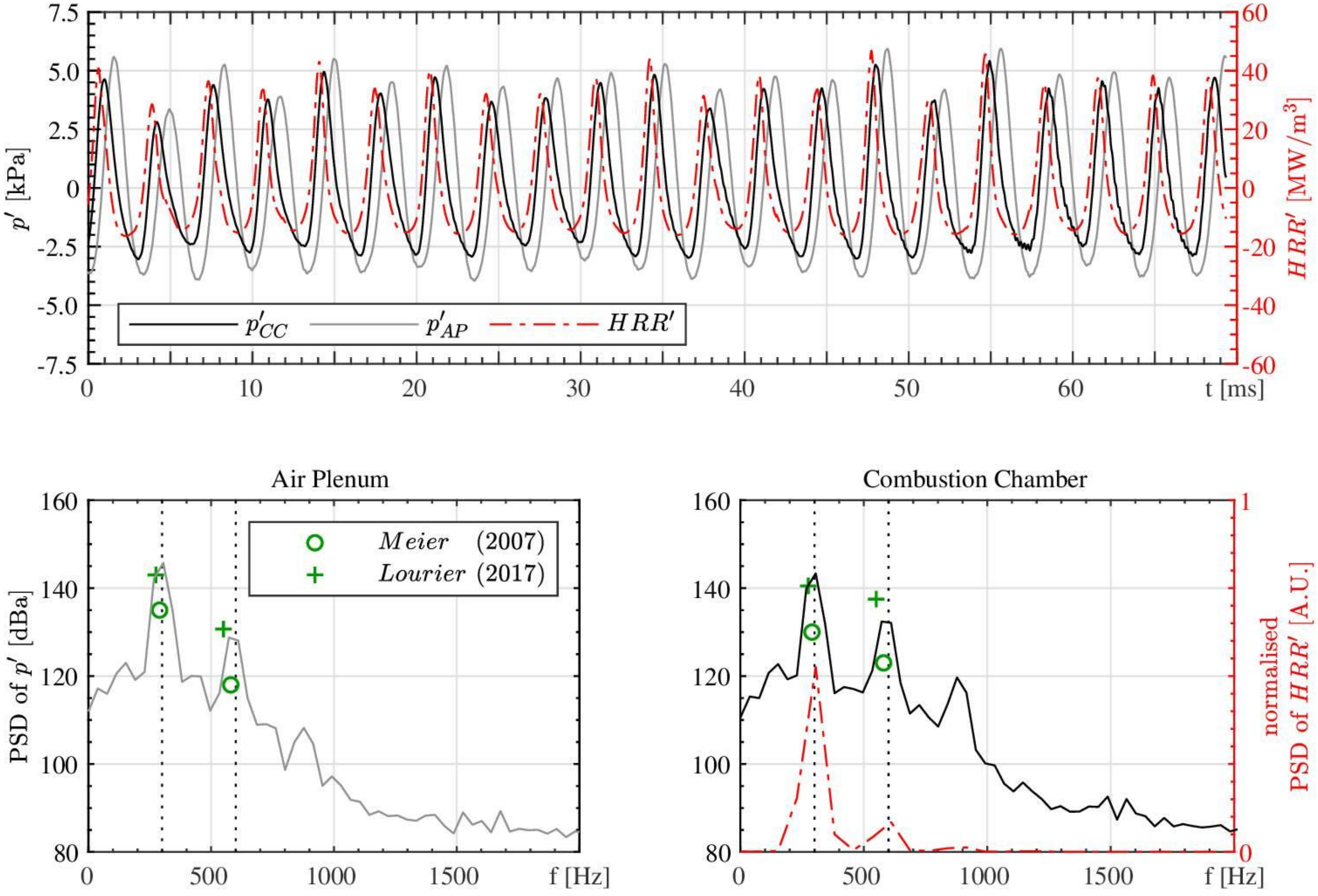
Limit-cycle oscillation



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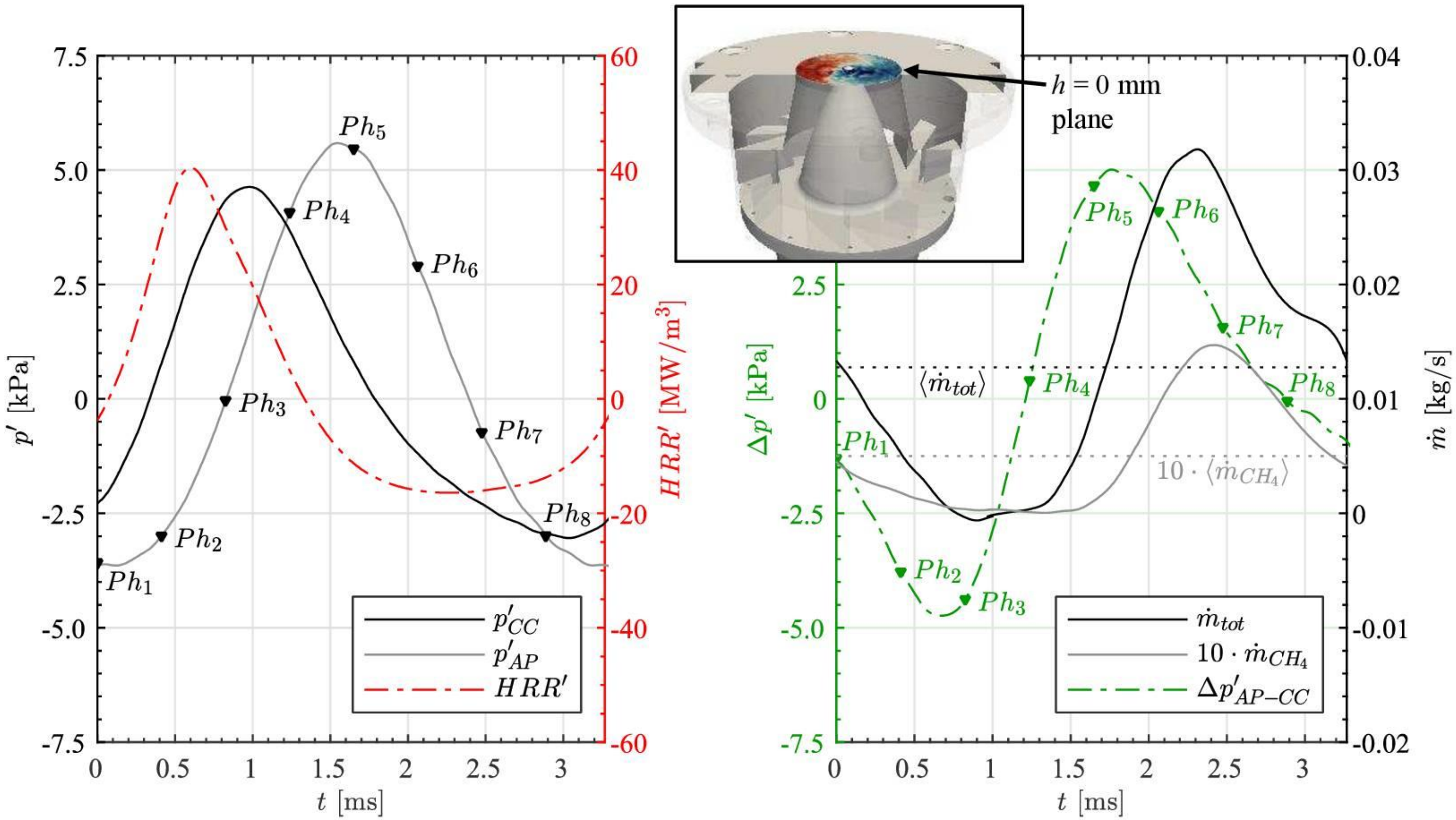
Mass flow rate and equivalence ratio oscillations



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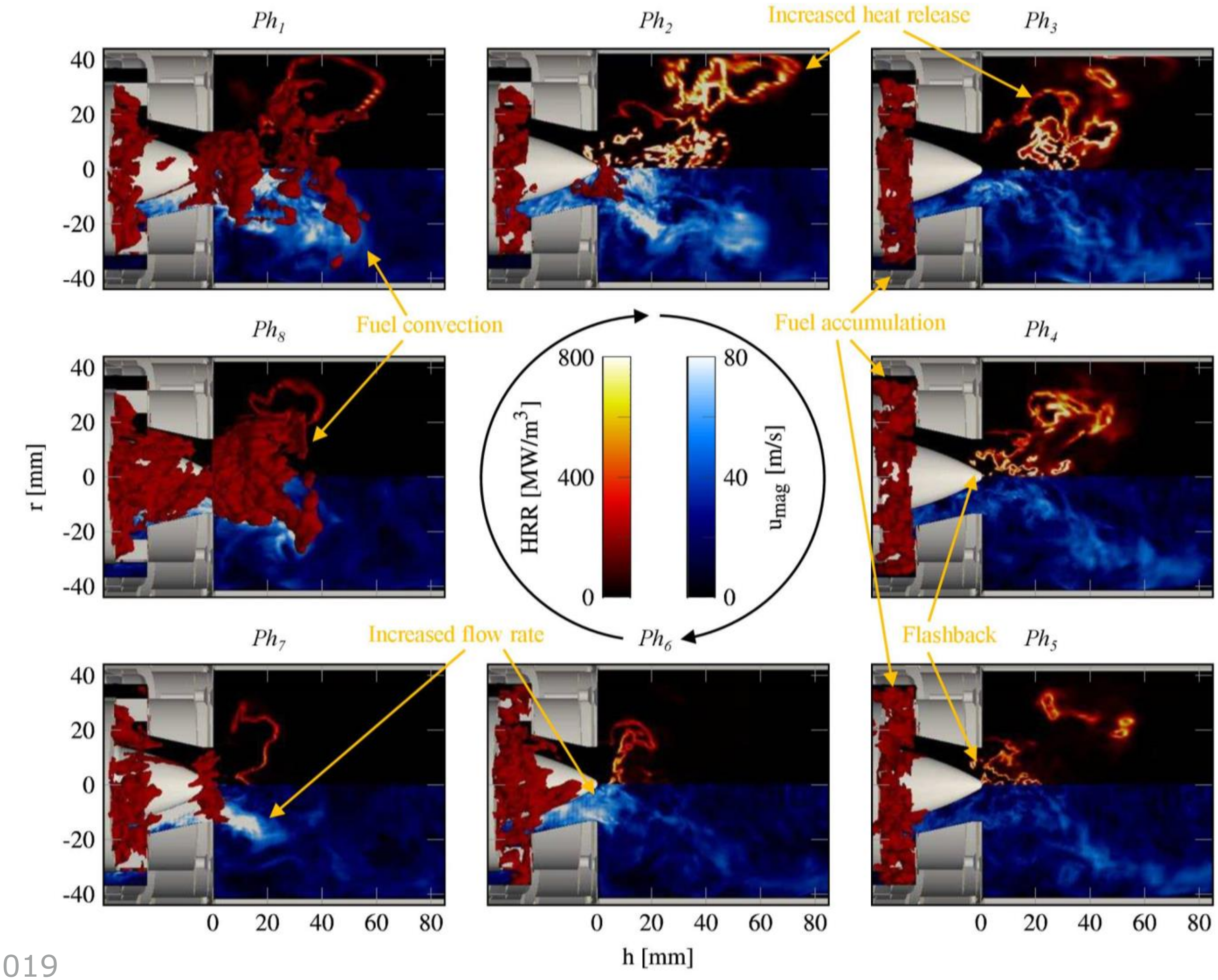
Governing feedback loop



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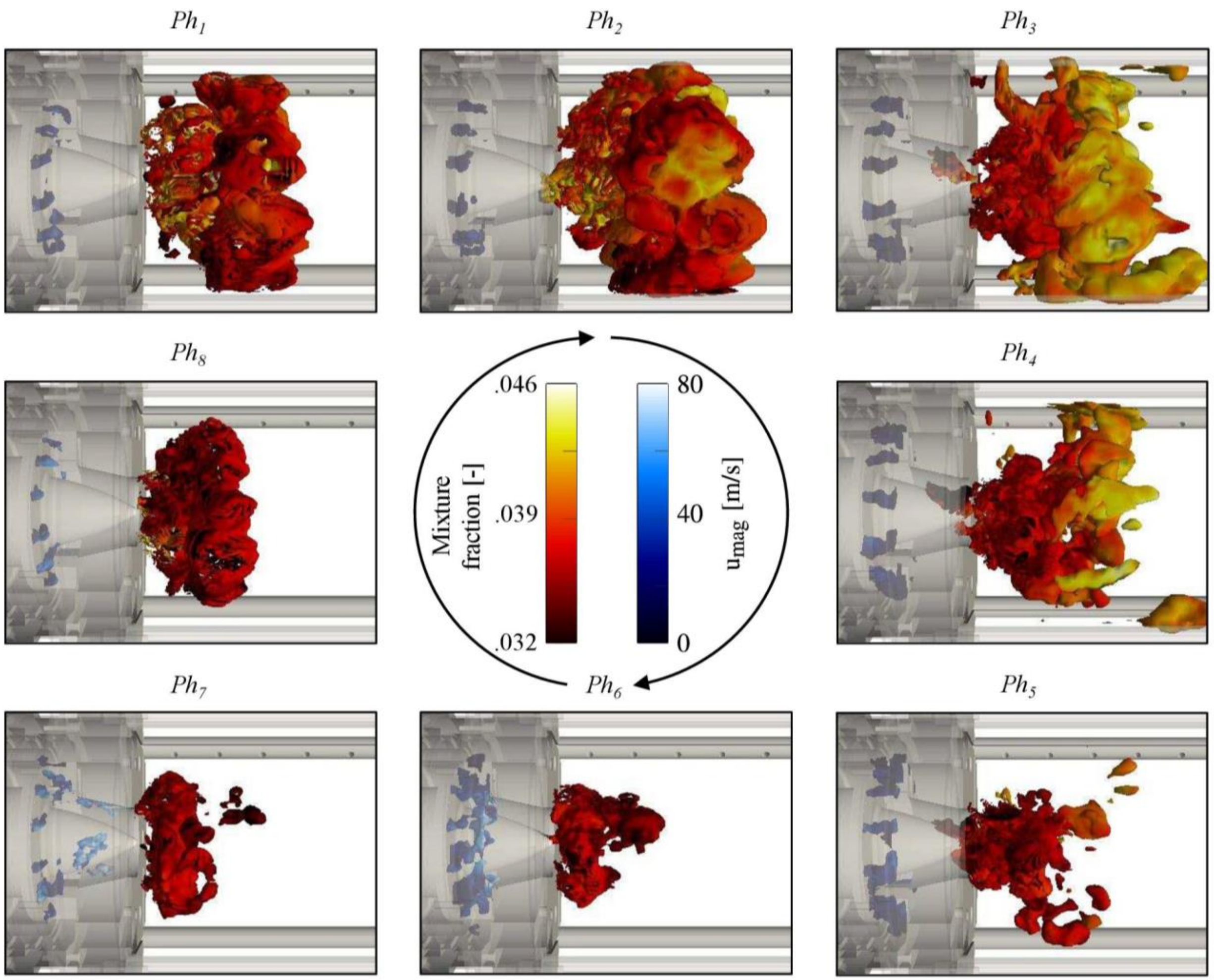
Heat release rate oscillation



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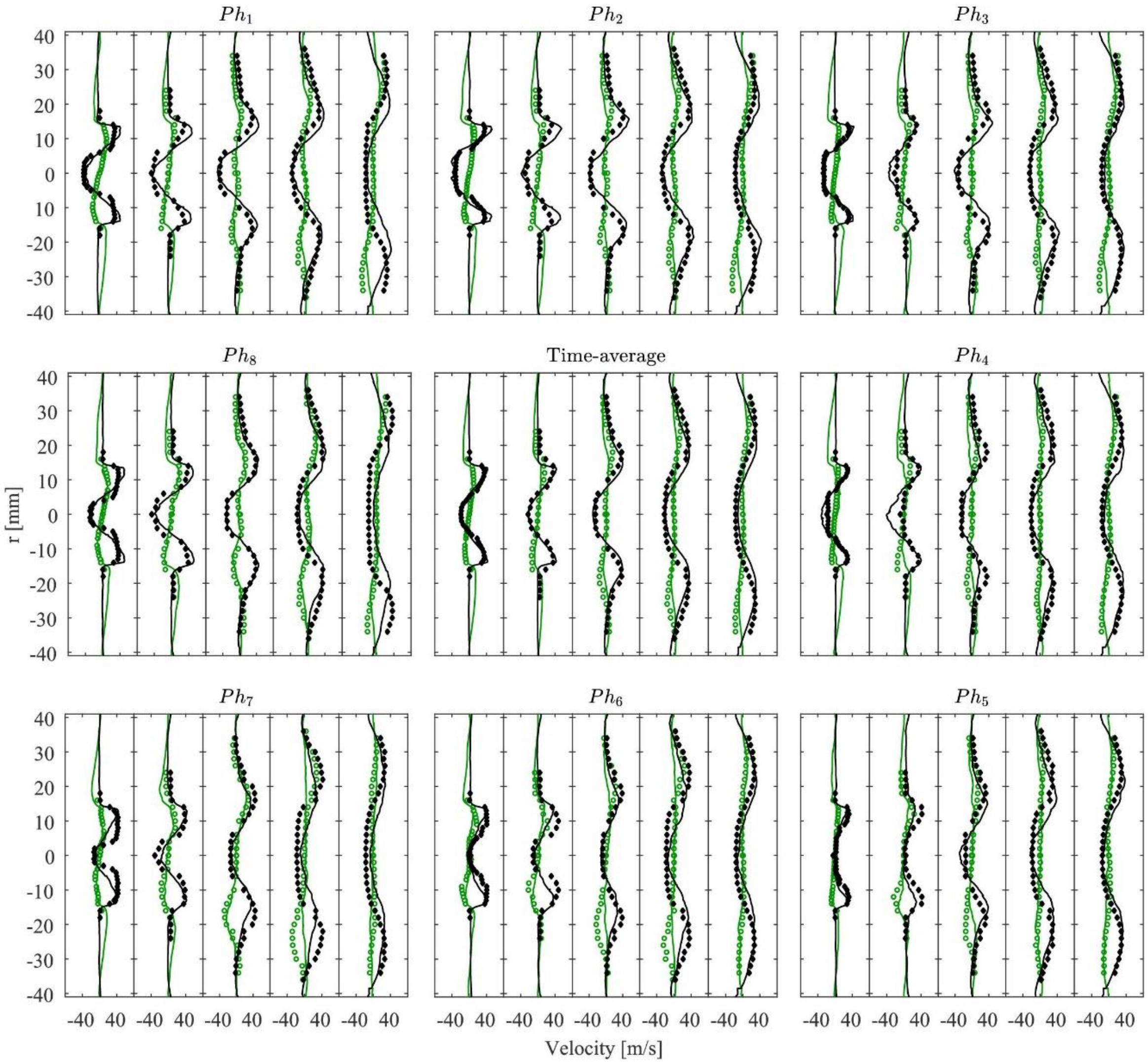
Phase-averaged velocity profiles



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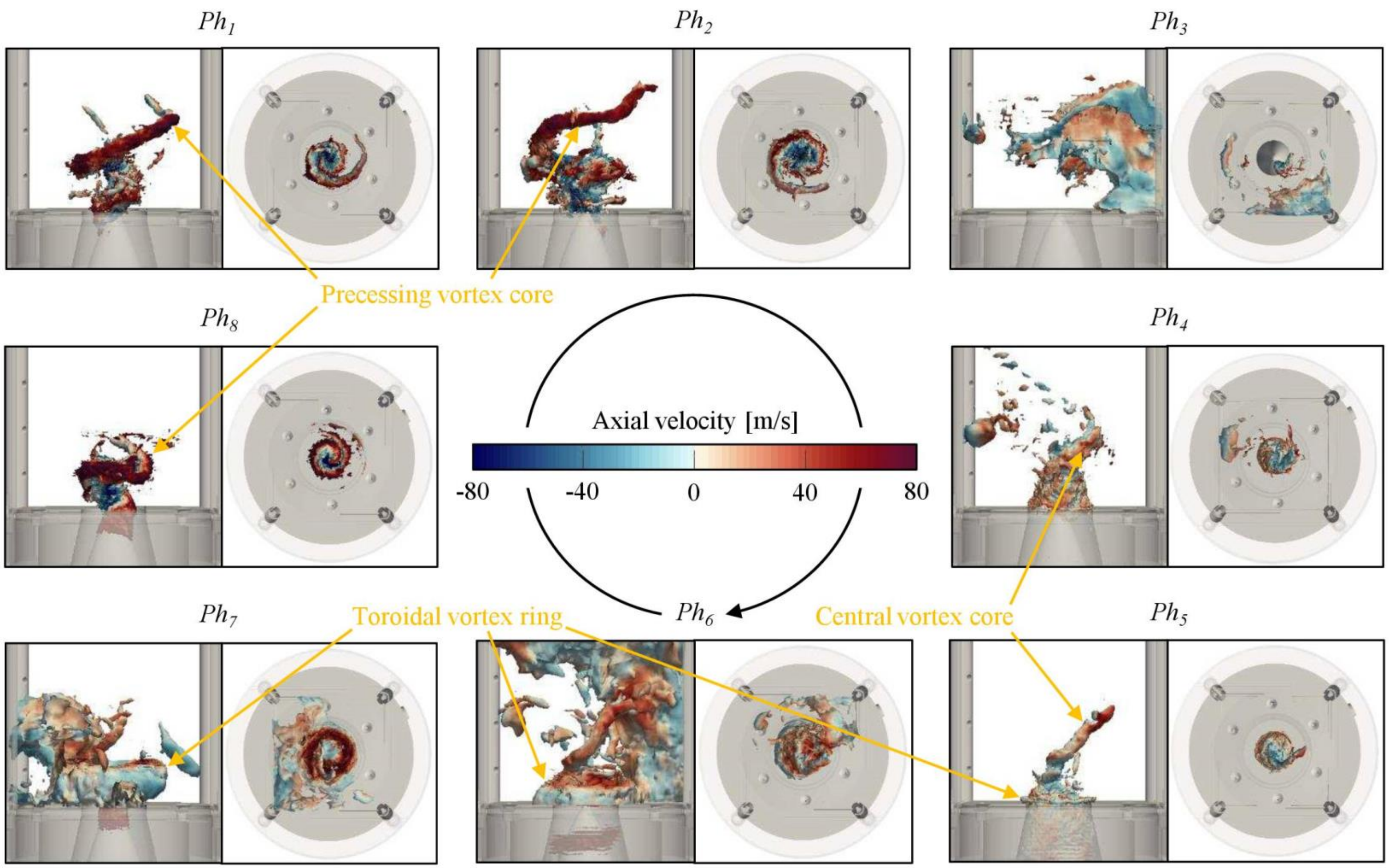
Large-scale vortical structures



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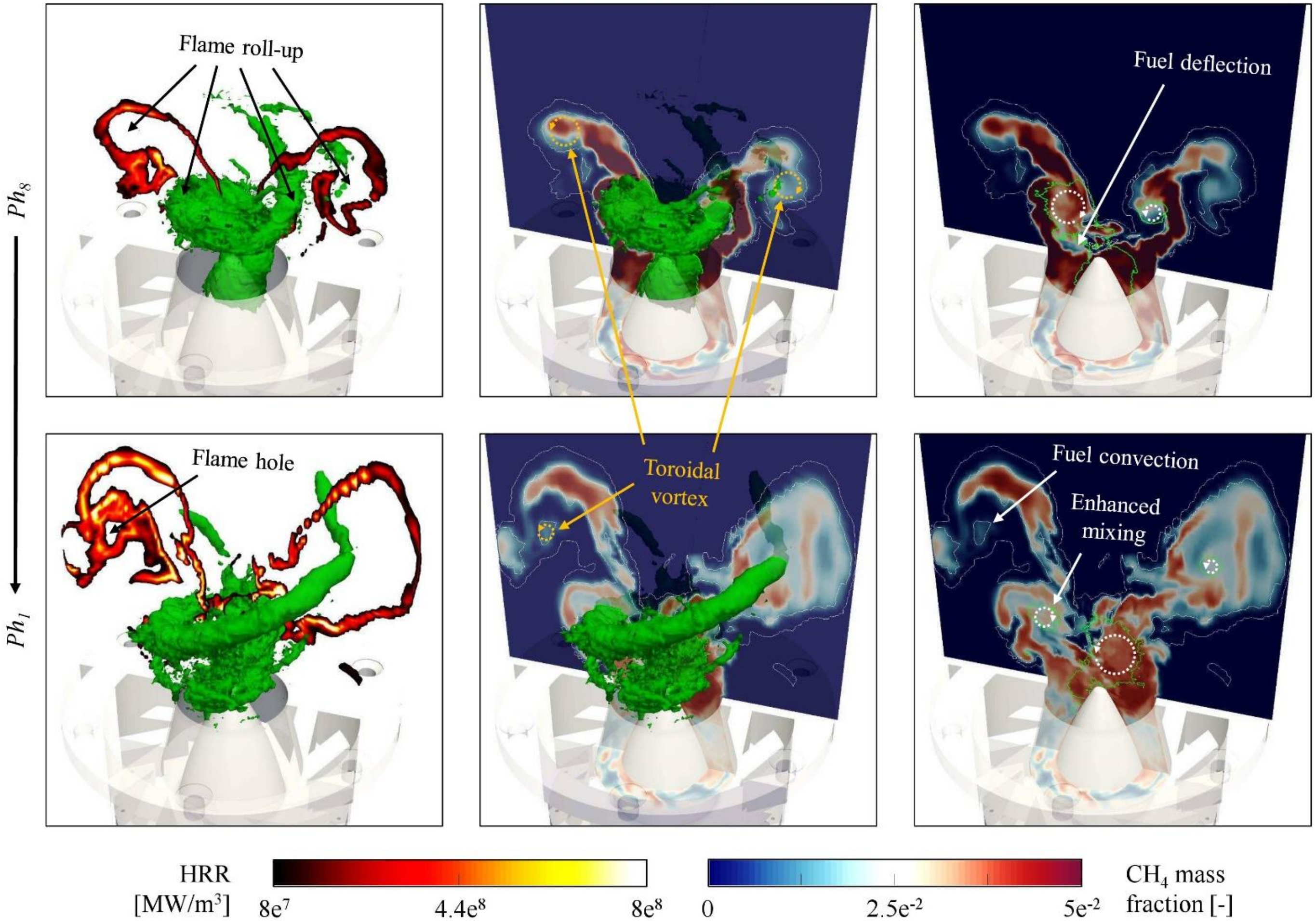
Flame-vortex interaction



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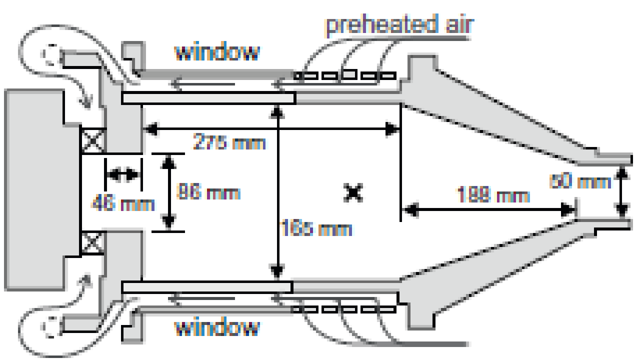
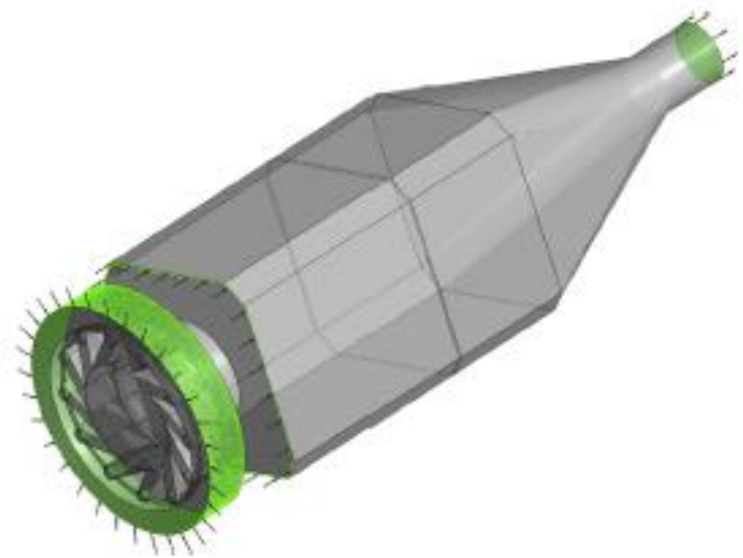
SGT-100

Test case

I. Computational set-up
   - ✓ Elevated pressure, lean equivalence ratio *(Stopper et al. 2013)*
   - ✓ Isothermal wall temperatures in combustion chamber
   - ✓ Additional exhaust pipe (not shown here)





(Bulat et al. 2014)

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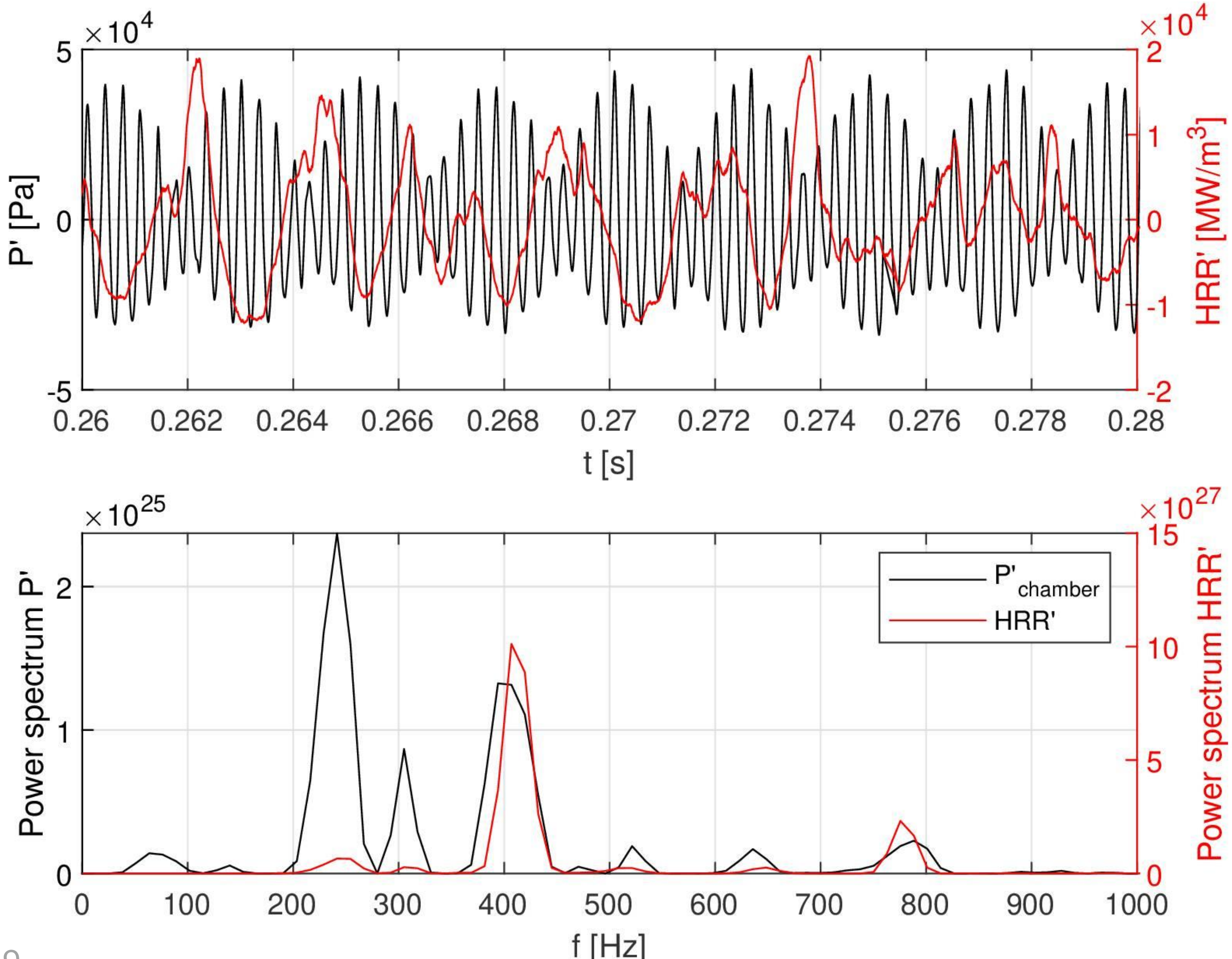
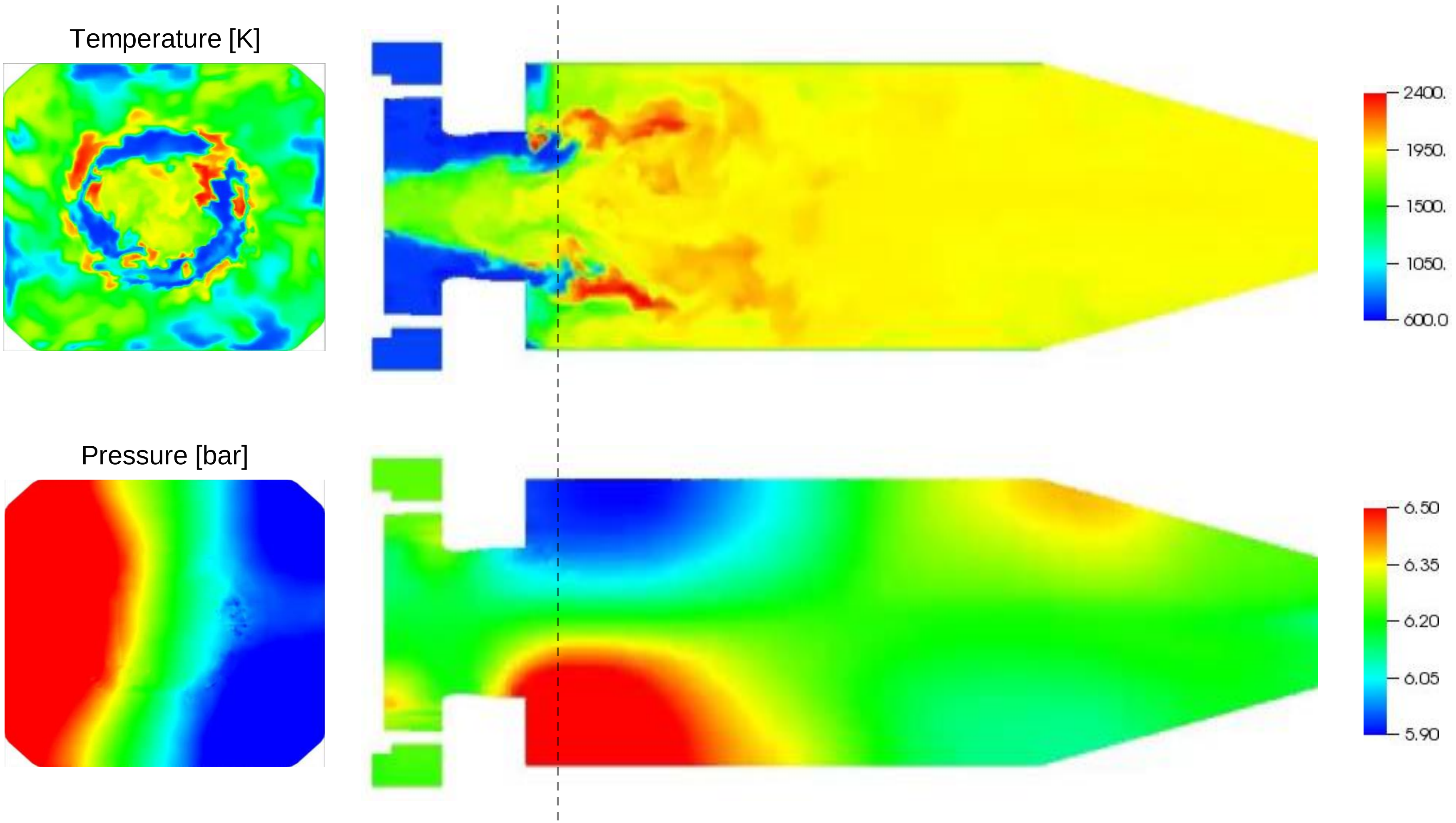
Thermo-acoustic coupling



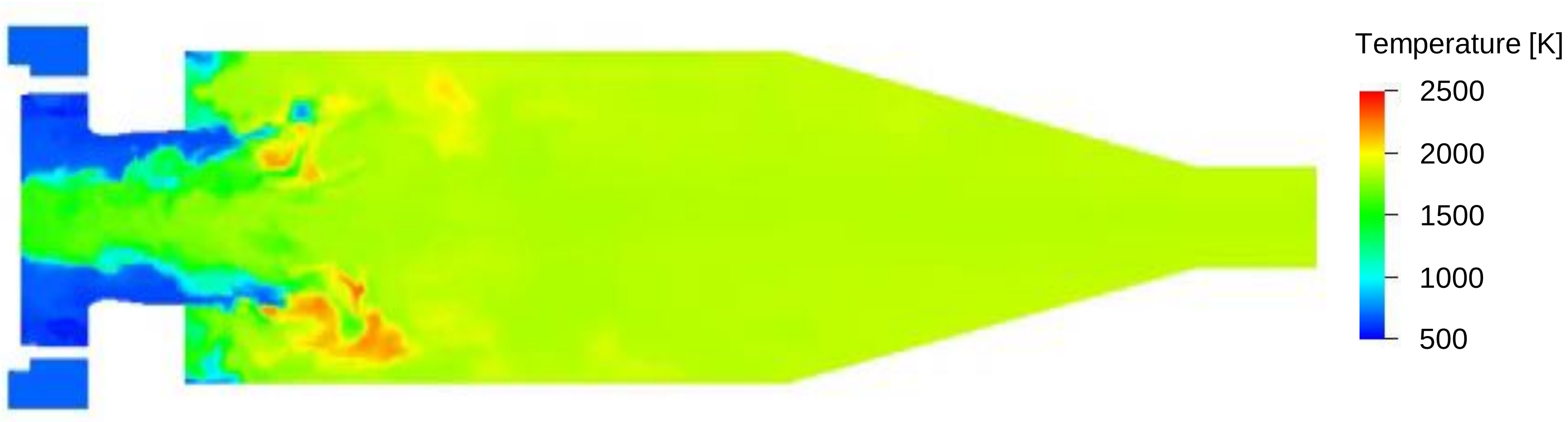
SGT-100

Longitudinal and azimuthal modes



SGT-100

Hydrogen-induced flame flashback



Concluding remarks

I. Summary
- ✓ Self-excited combustion instabilities captured using BOFFIN-LESc
- ✓ Successful identification and description of various oscillation drivers
- ✓ Longitudinal and azimuthal modes predicted in industrial combustor

II. Future work (SGT-100)
- ❑ Locally quantify fluctuations of pressure, heat release rate and fuel concentration
- ❑ Validate time-averaged results against available experimental data
- ❑ Apply non-reflective boundary condition to air inflow

Acknowledgements / References

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- *Meier et al. (2007)*, Combustion and Flame 150, pp. 2-26.
- *Poinsot & Lele (1992)*, Journal of Computational Physics 101, pp. 104-129.
- *Stopper et al. (2013)*, Combustion and Flame 160, pp. 2103-2118.

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Underlying driving mechanisms