CERFACS

CENTRE EUROPÉEN DE RECHERCHE ET DE FORMATION AVANCÉE EN CALCUL SCIENTIFIQUE

# Remaillage dynamique pour la combustion turbulente prémélangée

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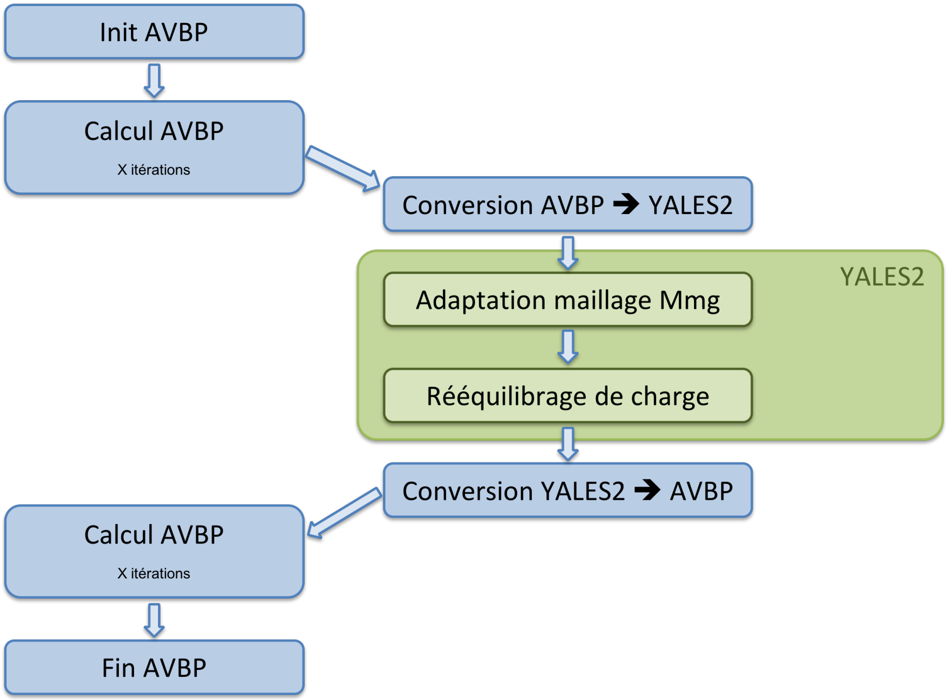
O. Vermorel, V. Moureau

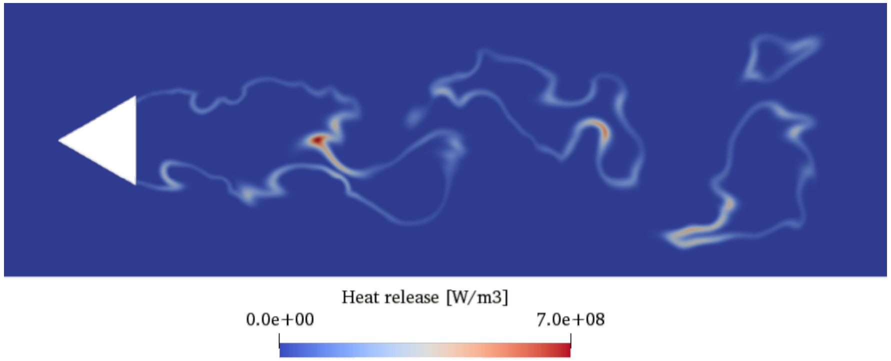
# Context

- Adaptvie mesh refinement using MMG via YALES2

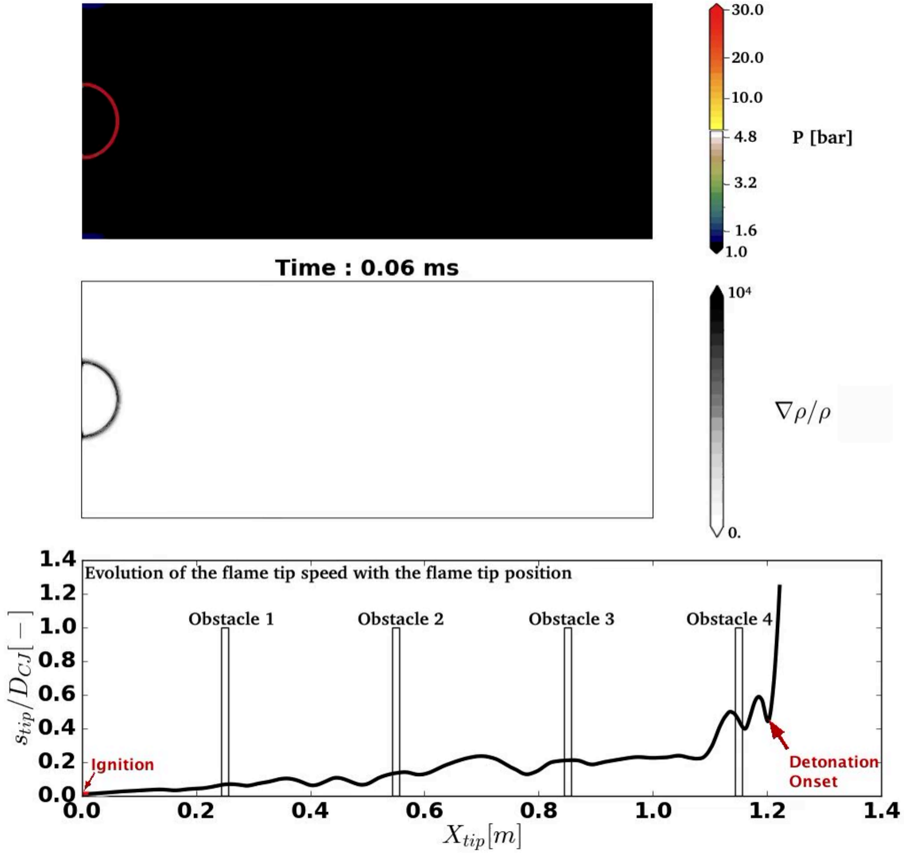


# Objective of the workshop

- Validate the current AMR strategies on « more complex » configurations:




2D volvo test case: combustion instabilities




2D Confined explosions

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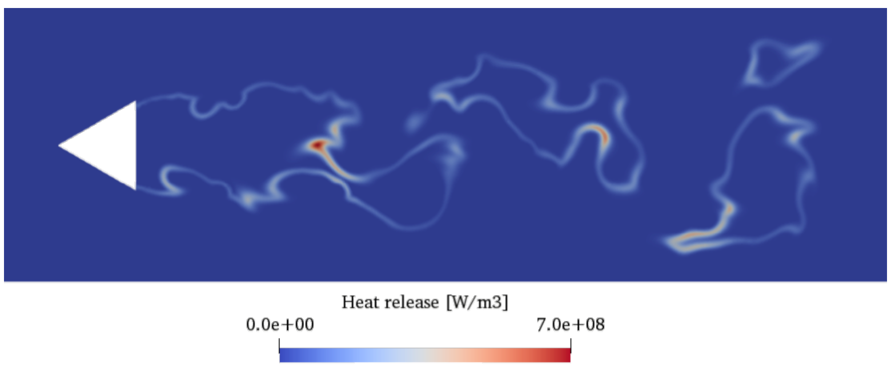


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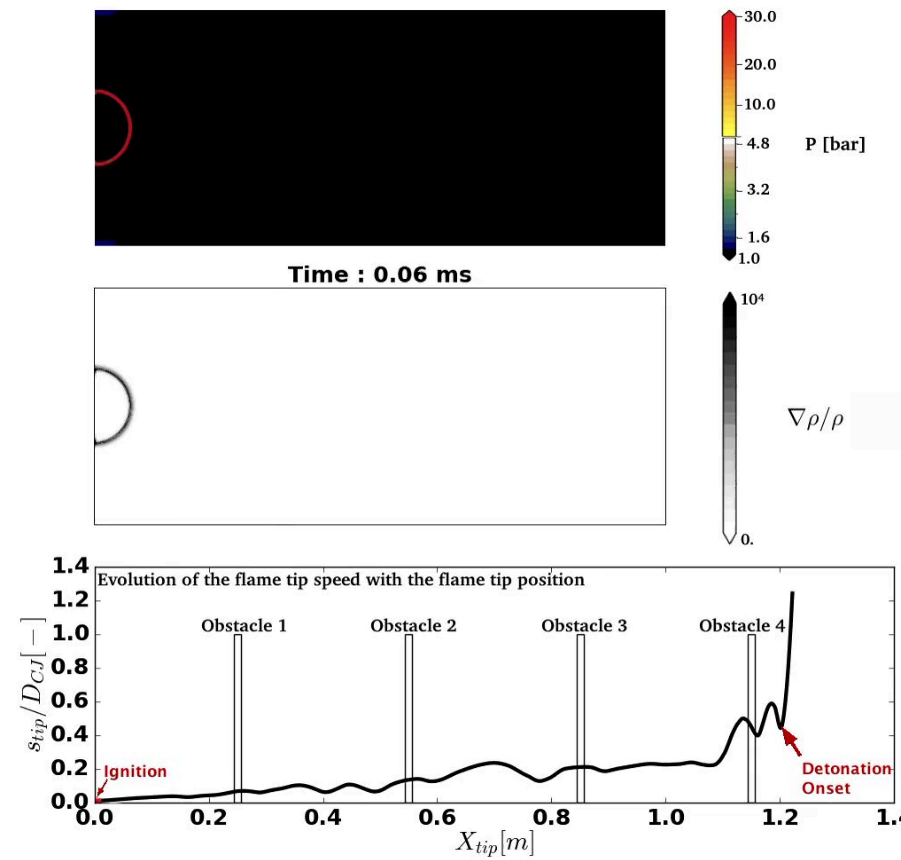


2D Confined explosions

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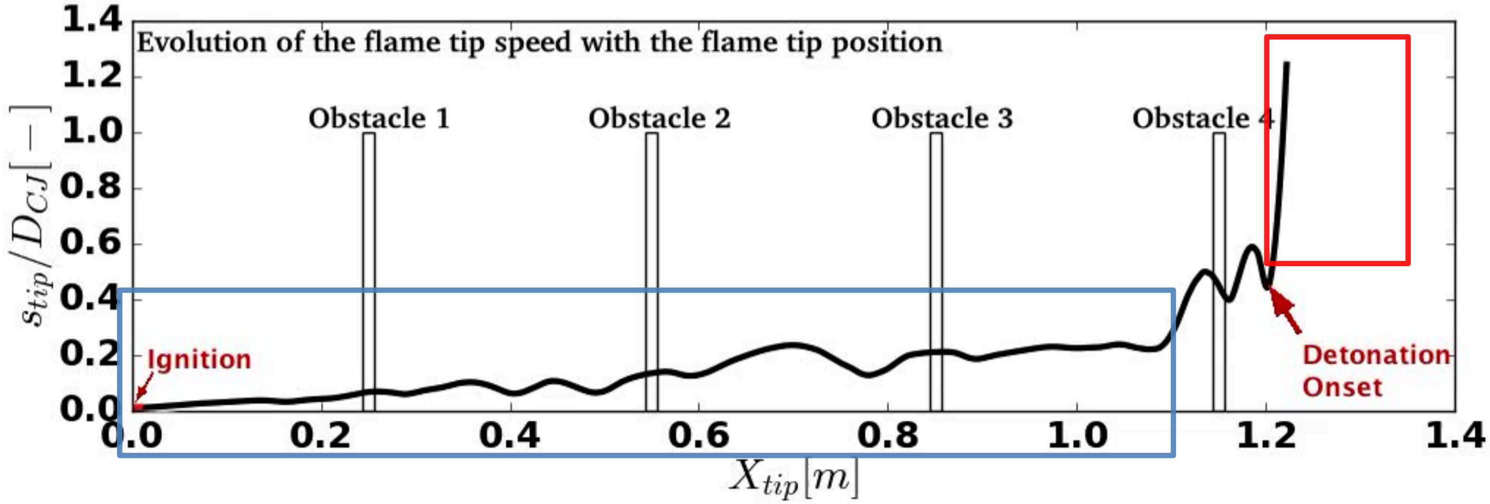


Focus on two stages:

Flame acceleration

Detonation propagation

# First stages of flame acceleration

Available online at www.sciencedirect.com
ScienceDirect
Proceedings of the Combustion Institute 000 (2016) 1–8
Proceedings of the Combustion Institute
www.elsevier.com/locate/proci

## Flame propagation across an obstacle: OH-PLIF and 2-D simulations with detailed chemistry

L.R. Boeck [a,*], S. Lapointe [a], J. Melguizo-Gavilanes [a], G. Ciccarelli [b]

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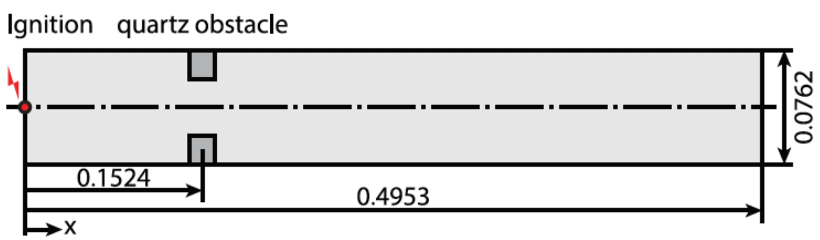
[b] *Department of Mechanical and Materials Engineering, Queen's University, Kingston ON K7L 3N6, Canada*



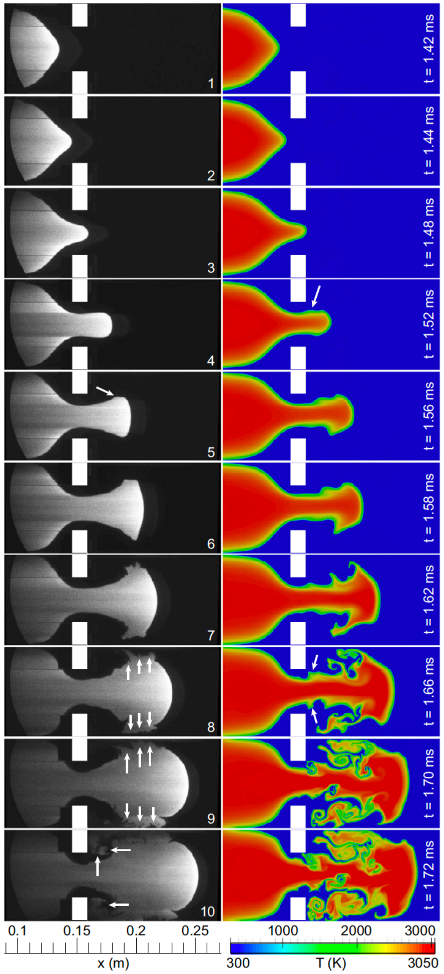
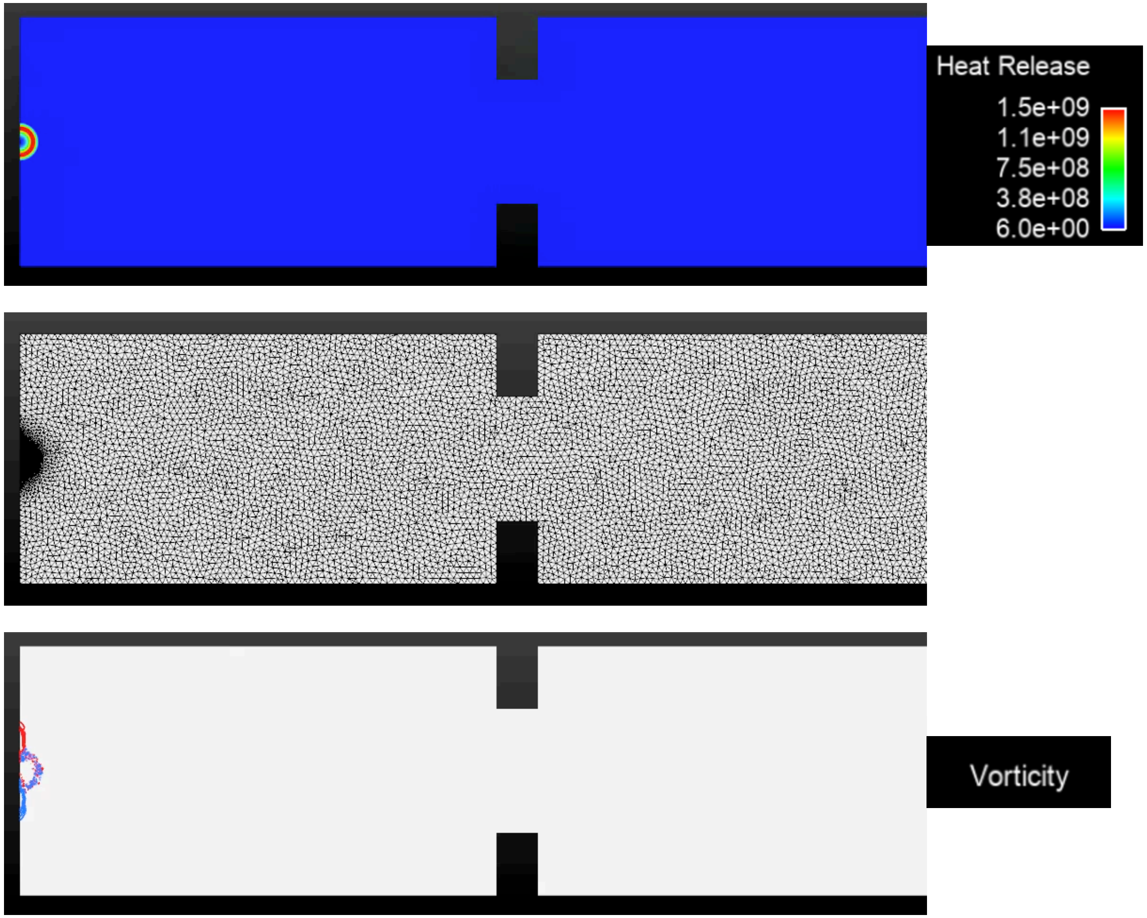



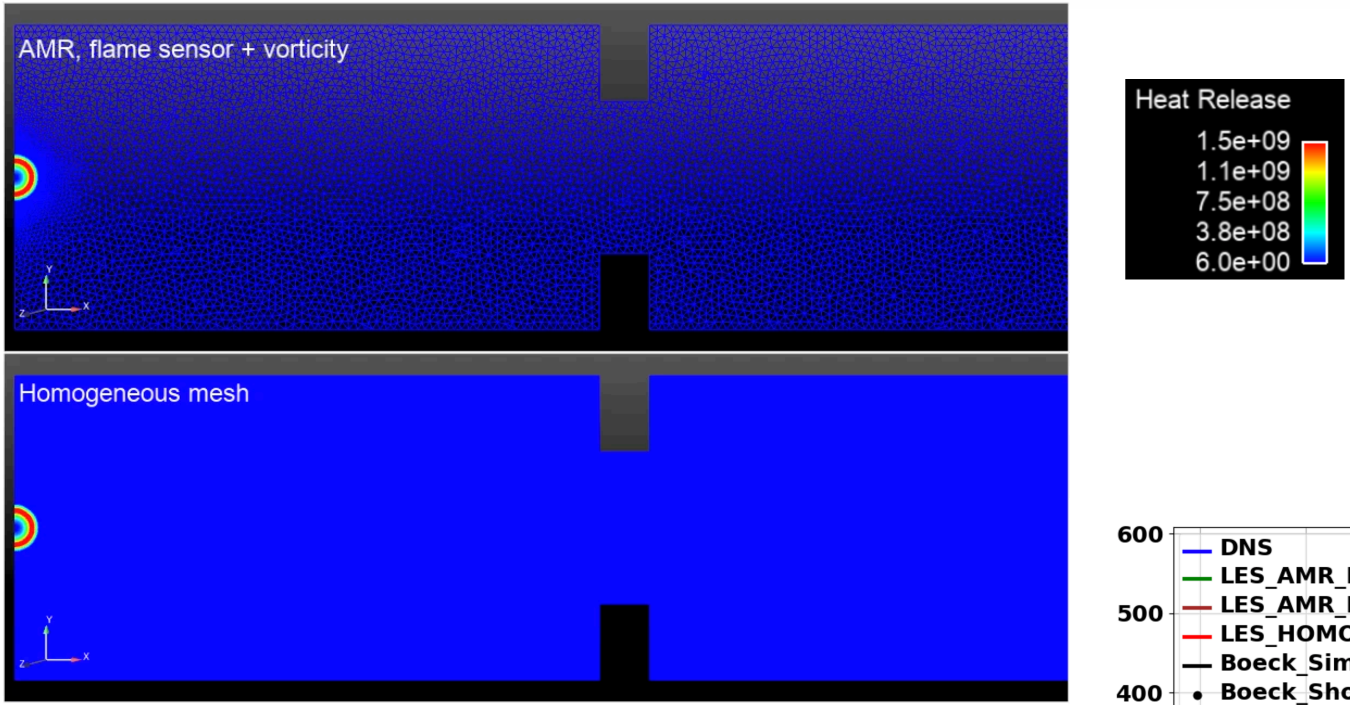

Fig. 4. Left: experimental OH-PLIF images from ten experiments. Right: temperature fields from simulations.

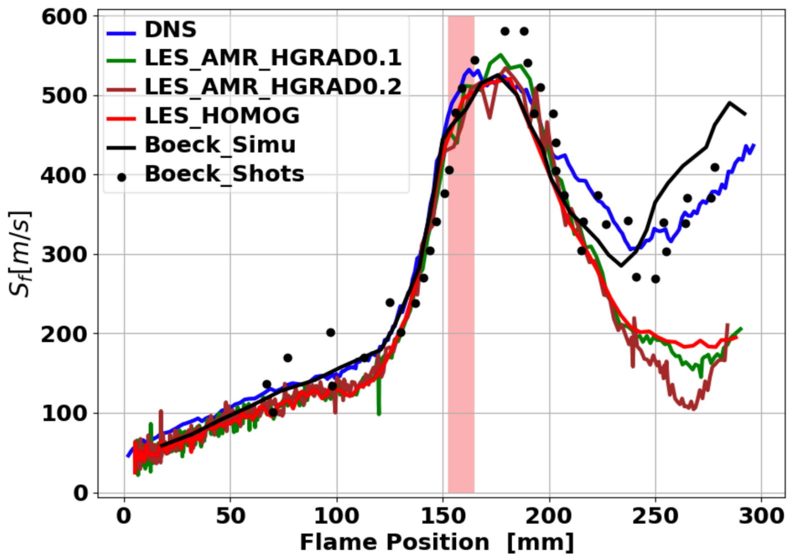
# Flame propagation across an obstacle

Remeshing criteria: flame sensor & vorticity



# Flame propagation across an obstacle
# AMR vs homogeneous mesh




$\triangle$x min AMR = 0.3mm = $\triangle$x homogeneous mesh

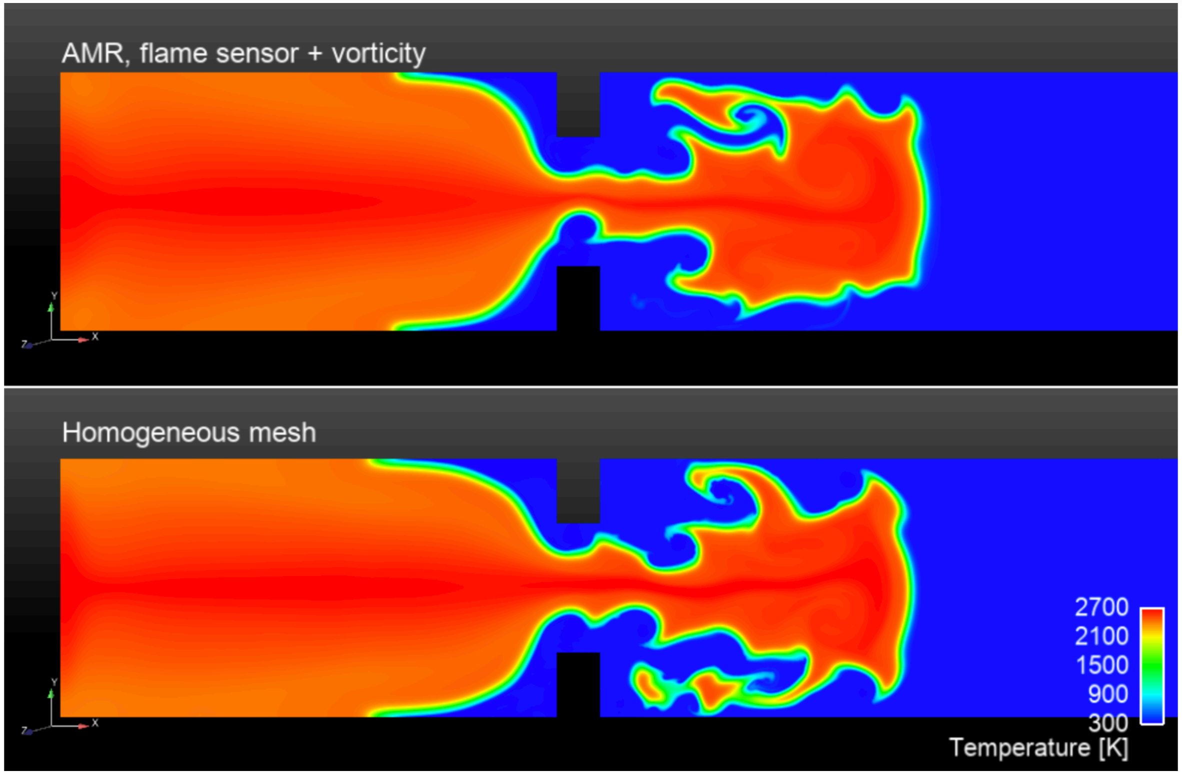
$\triangle$x max AMR = 2.0mm

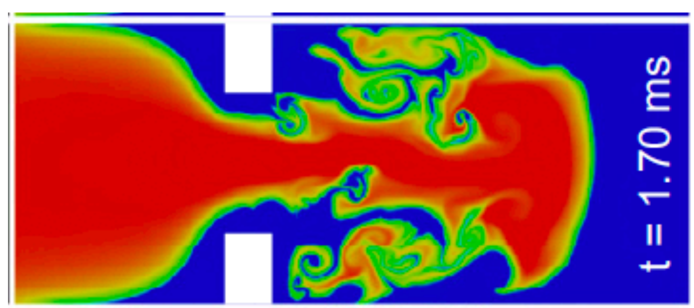
$\triangle$x max DNS = 0.07mm

Cost homogeneous run: 110 CPU h

Cost AMR run: 33 CPU h (remeshing: 1.7 CPU h)

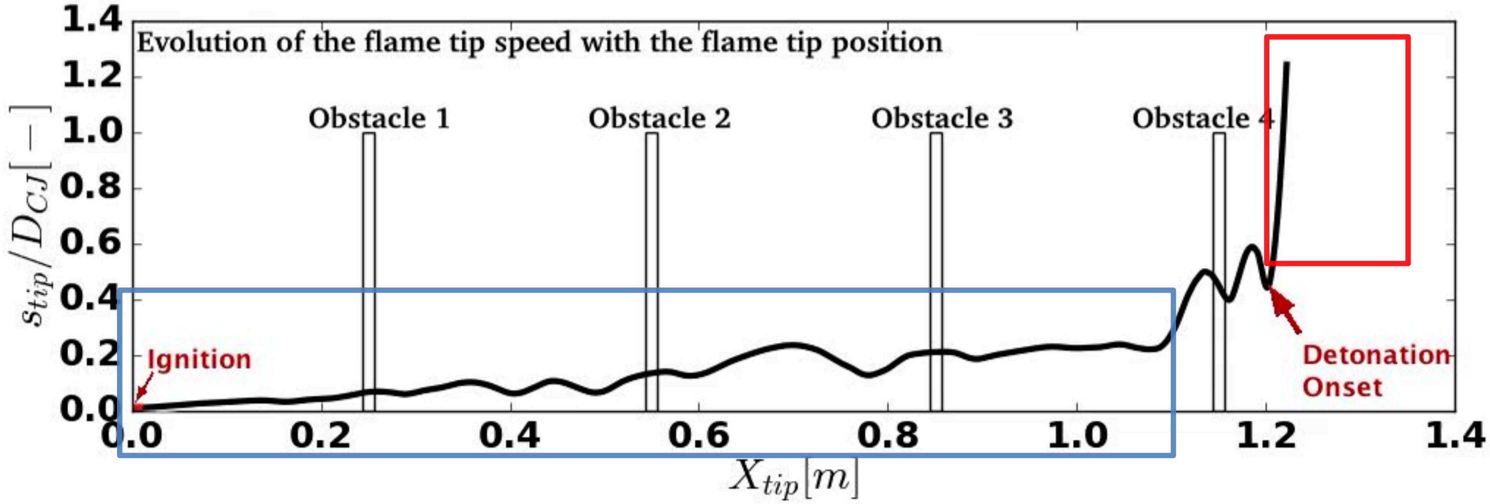
# Flame propagation across an obstacle
# AMR vs homogeneous mesh




DNS Boeck *et al.*

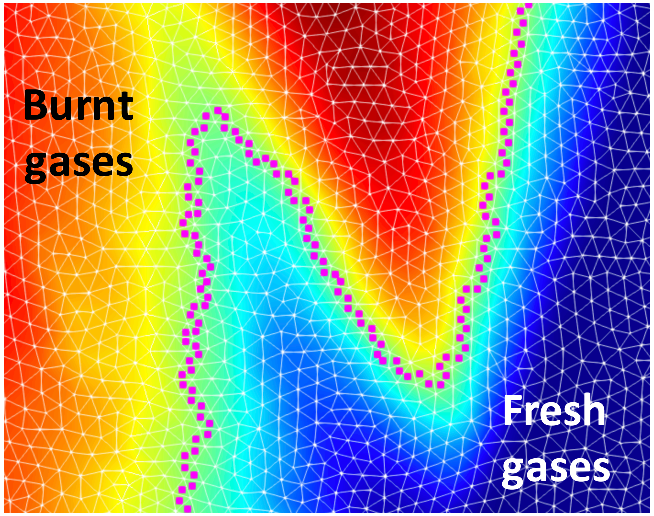
# Objective of the workshop

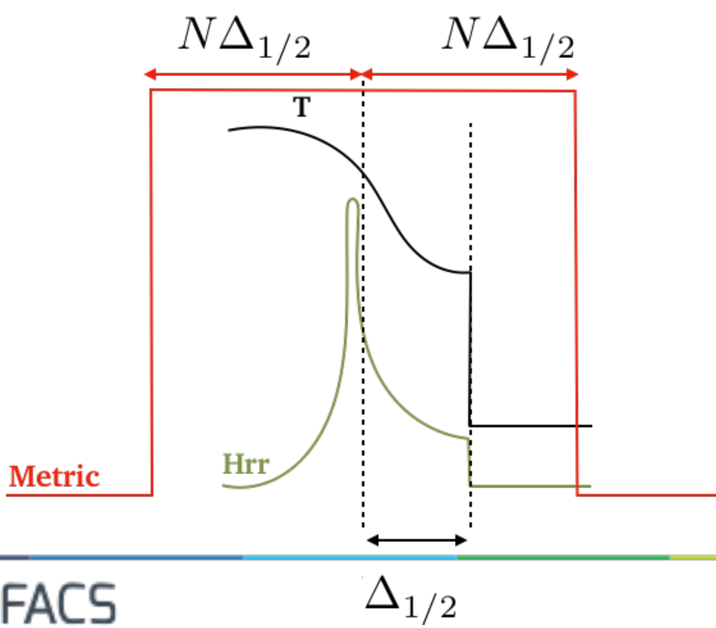



Focus on two stages:

Flame acceleration

Detonation propagation



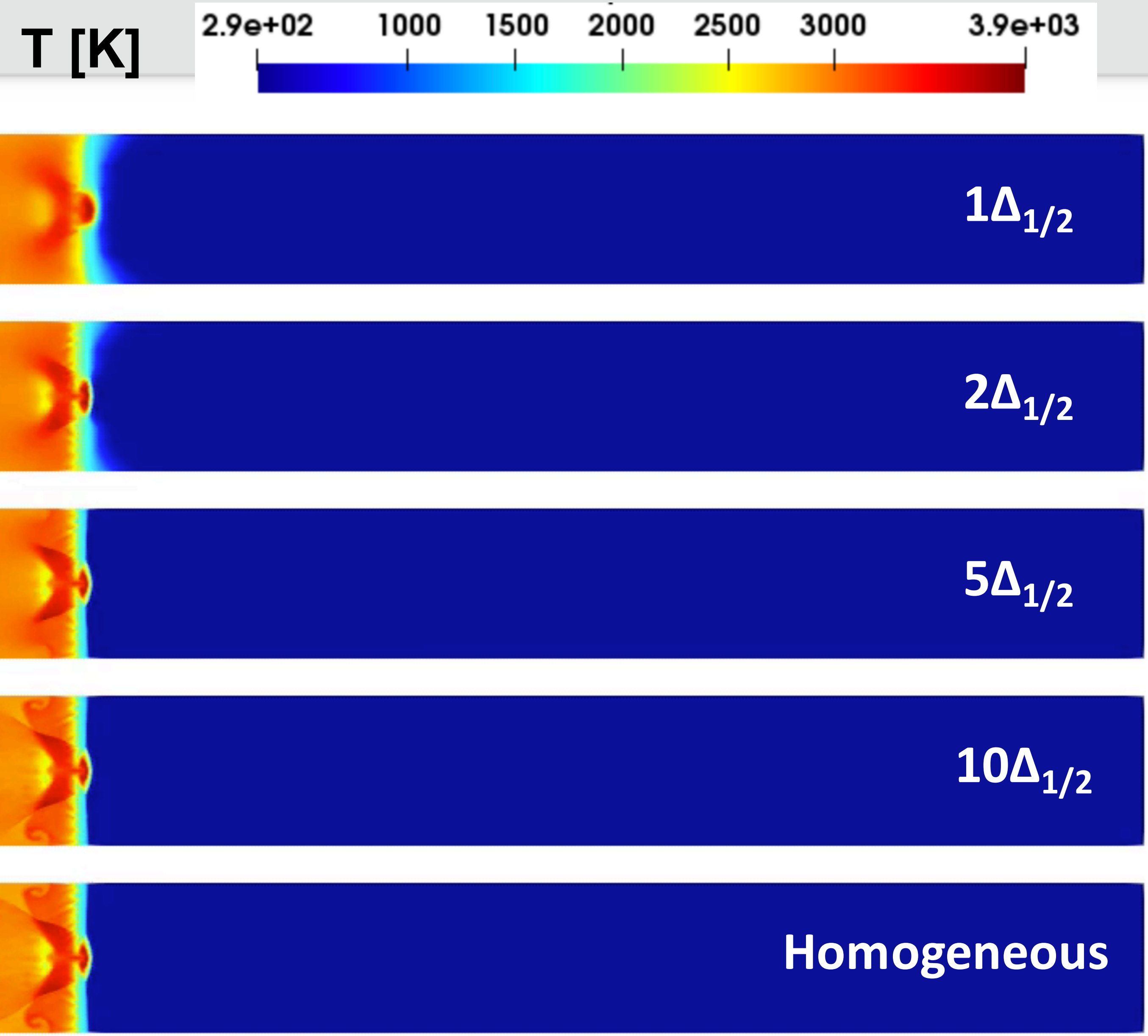




- Target mesh size
  - Fine region: 10 µm
  - Corse region: 100 µm
- Detection criterion: iso-surface of progress variable (C = 0.5)
- Lagrangian markers + propagation on $N\Delta_{1/2}$ distance in both direction

Remeshing time-scale

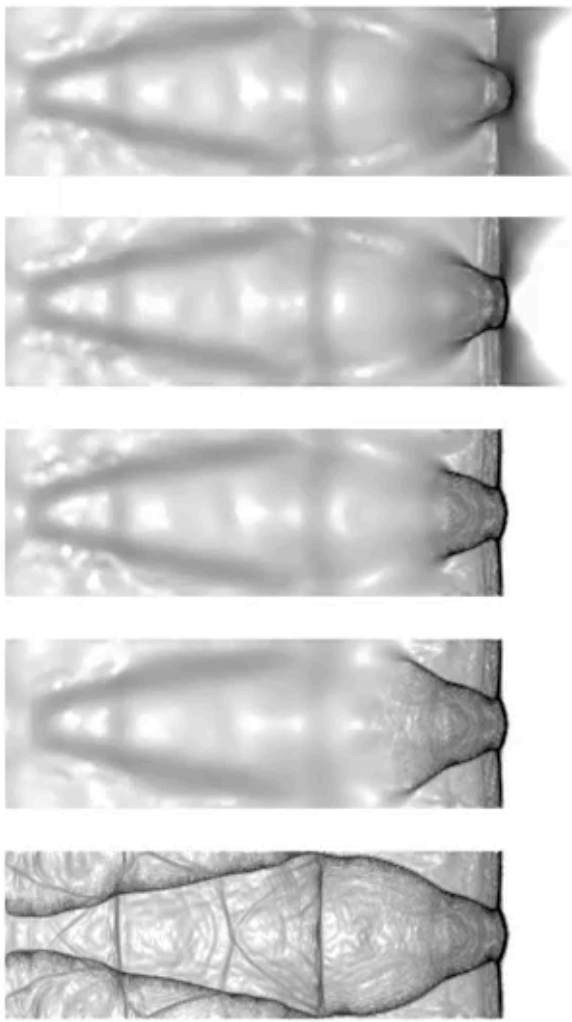
$$\tau = (N\Delta_{1/2}/U_{wave})/2$$

# *Stable detonation*



# *Stable detonation*, $5\Delta_{1/2}$ protection zone

$\nabla P$ [N/m$^3$]

$1\Delta_{1/2}$

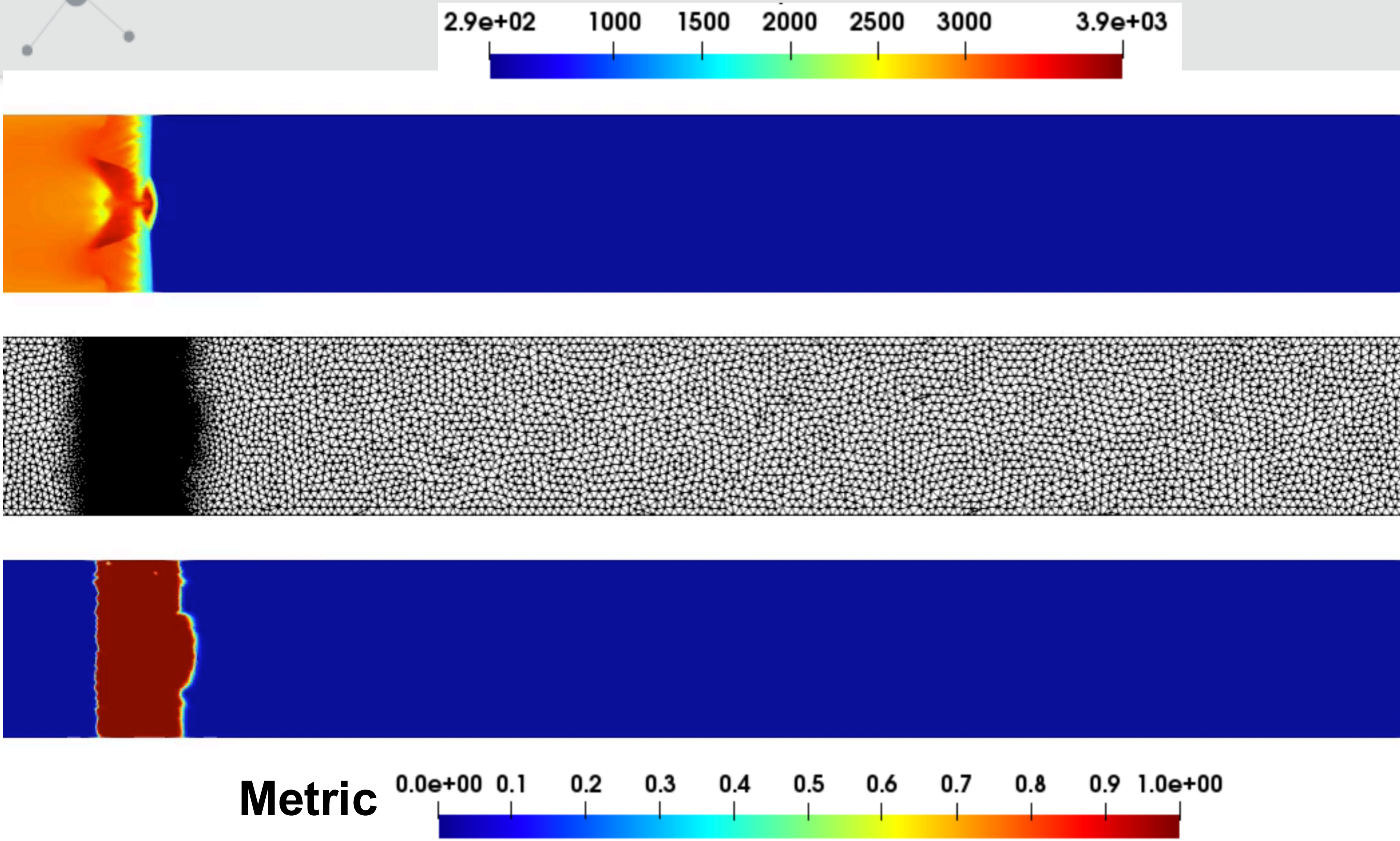
$2\Delta_{1/2}$

$5\Delta_{1/2}$

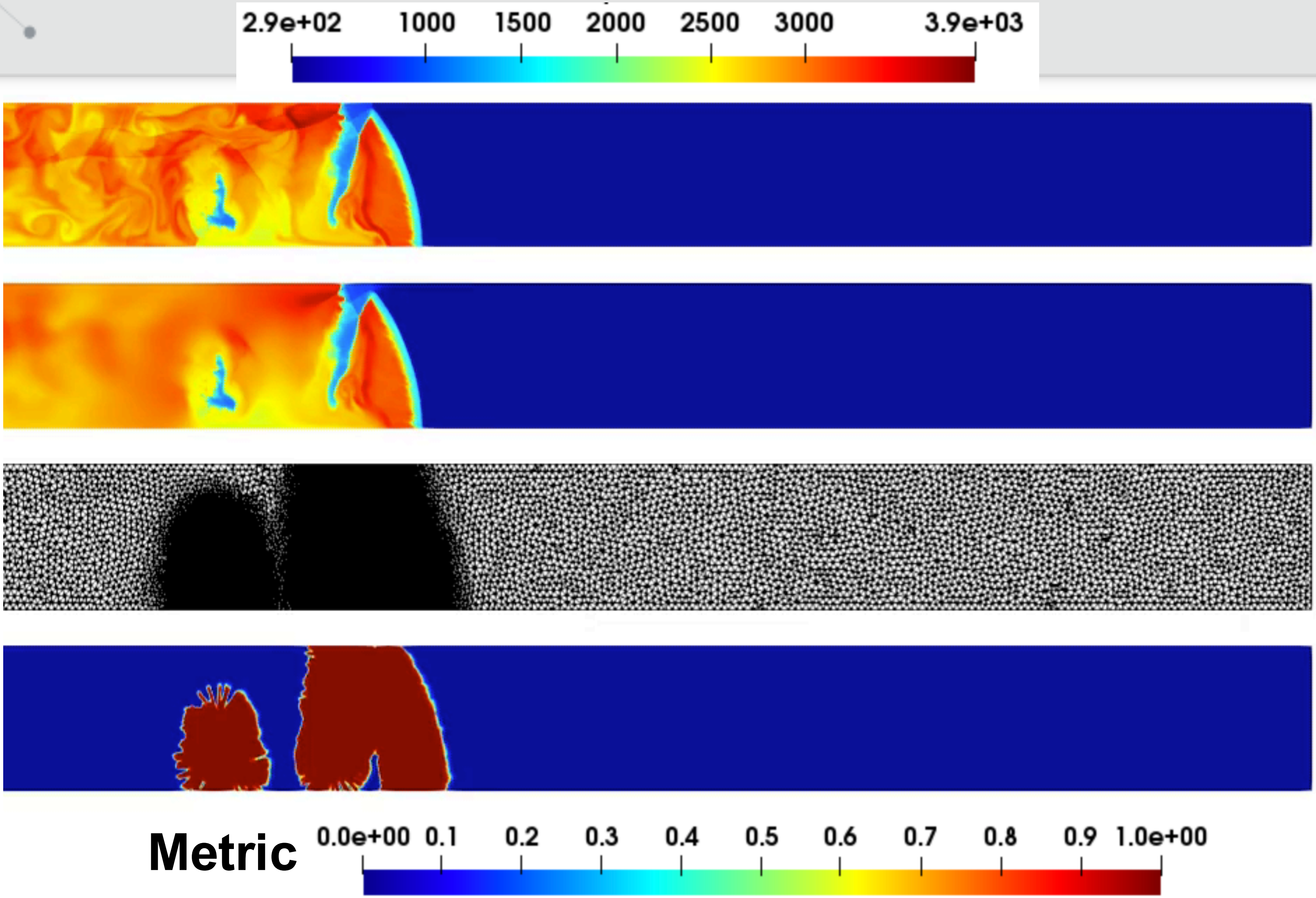
$10\Delta_{1/2}$

**Homogeneous**

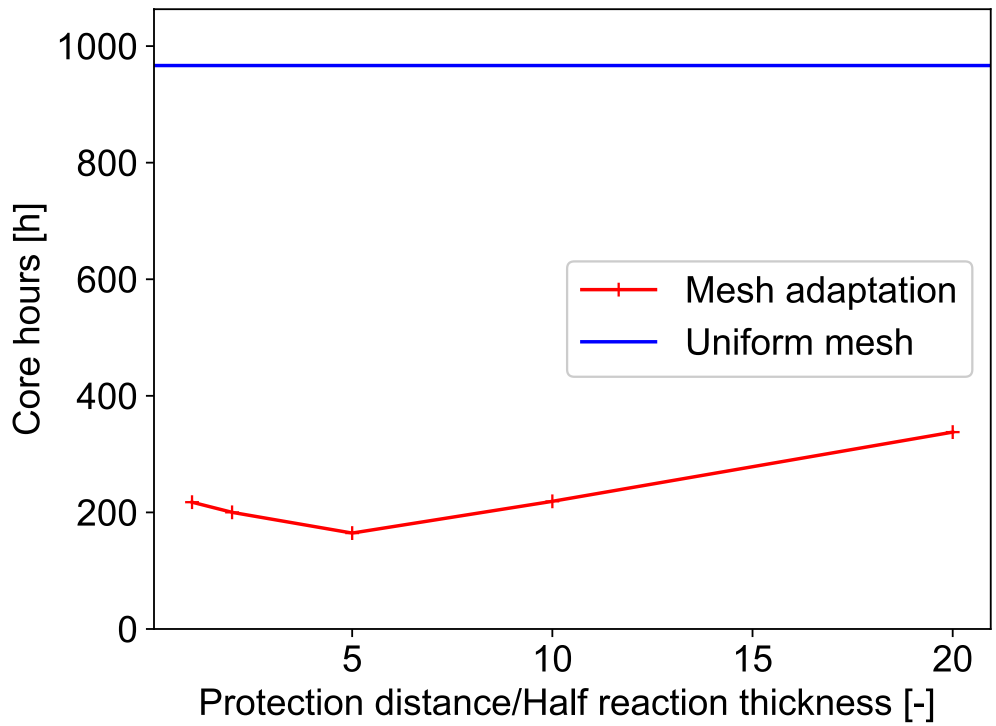
# *Stable detonation,* $5\Delta_{1/2}$ protection zone



# *Unstable* *detonation,* $5\Delta_{1/2}$ protection zone

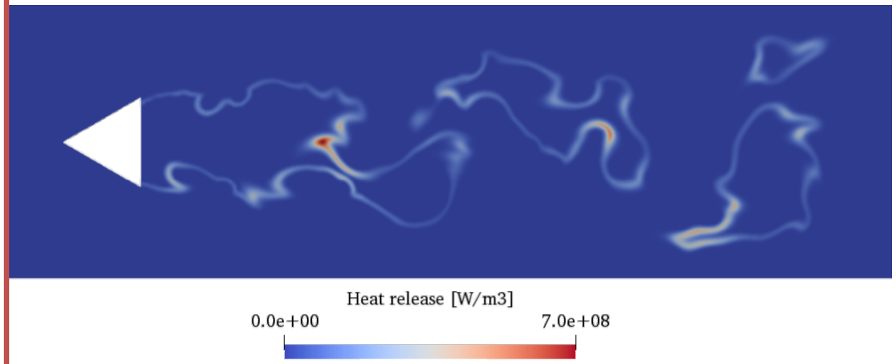


# *CPU cost vs. protection distance*




- Compromise to find for the size of the refined zone
  - Small protection distance: high remeshing frequency
  - High protection distance: larger mesh

- Validate the current AMR strategies on « complex » configurations:

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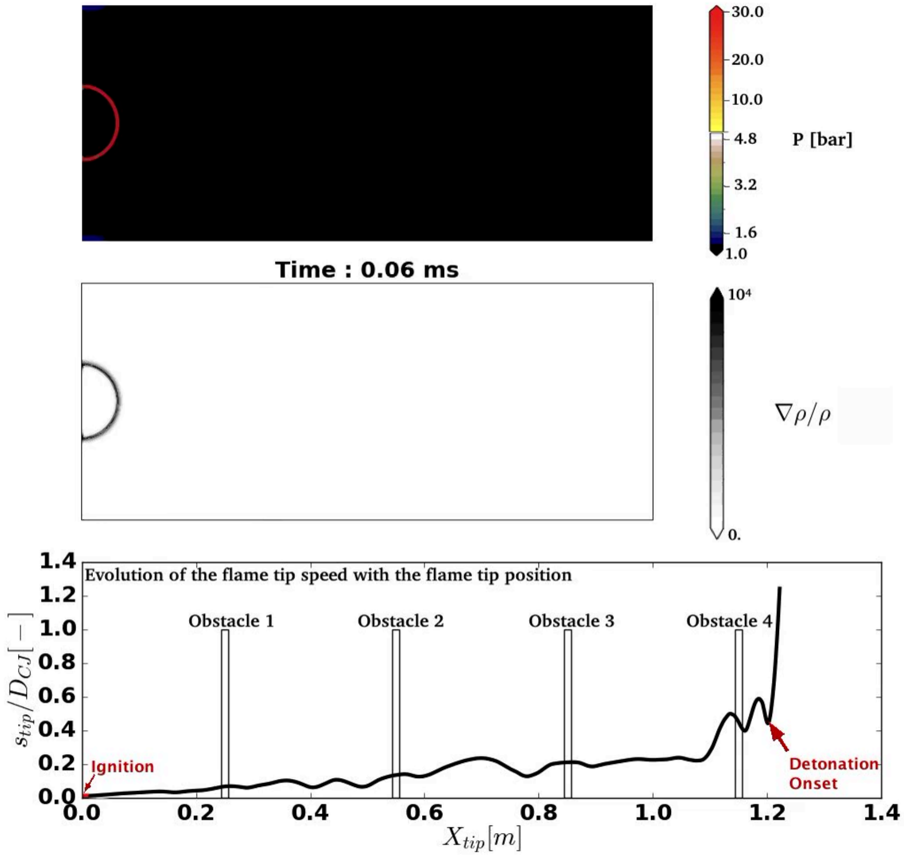
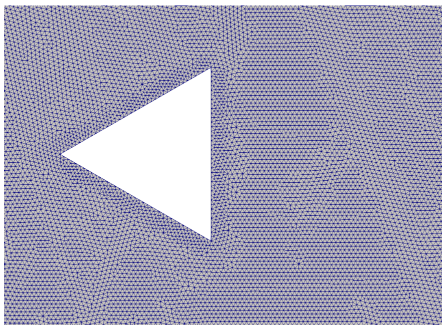
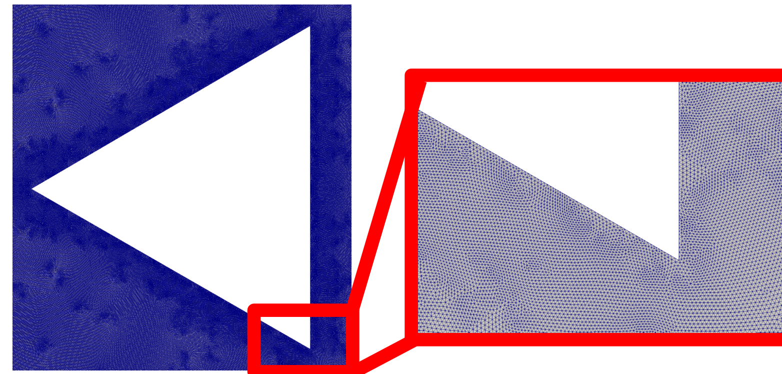



2D Confined explosions

# *VOLVO 2D premixed test case*

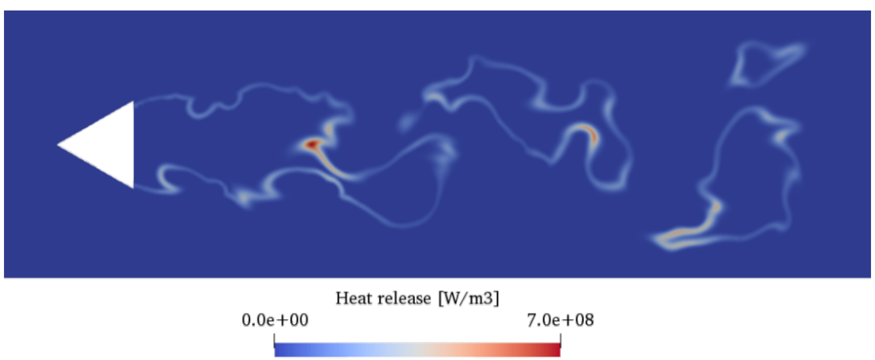


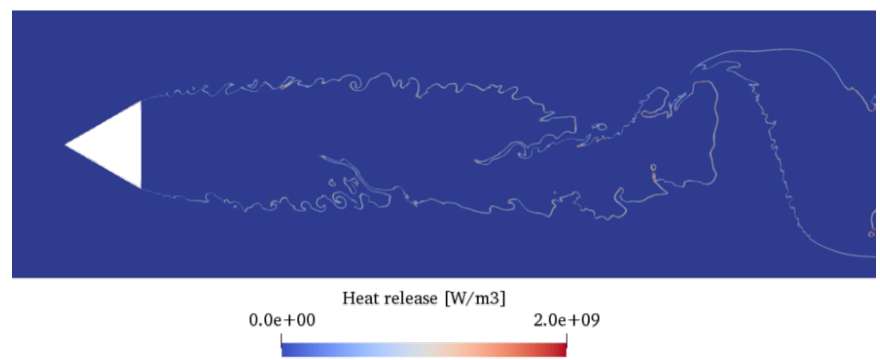
- Dynamic Smagorinsky model [Germano et al. 1991].
- C3H8-AIR 2 steps



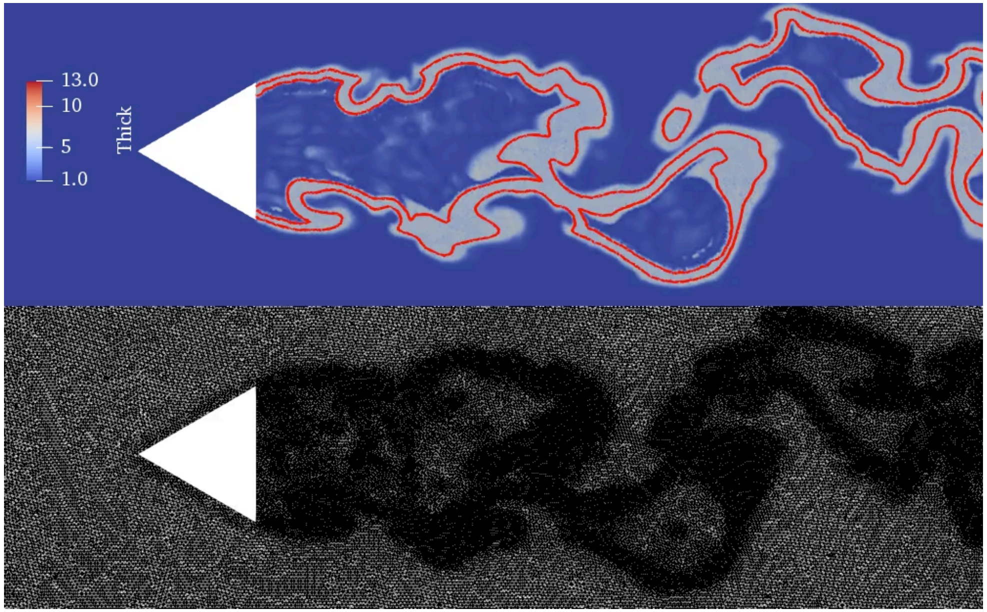
- **0.126M coarse mesh** ($\Delta x$ = *1 mm)*
- TFLES: Thickening value of 10 (7 points in the flame)

- **8M DNS mesh** ($\Delta x$ = *0.1 mm)*
- No TFLES needed



| *Mesh* | *Cells [M]* | *$\Delta t$ [$10^{-6}$ s]* | *Cost [ ]* |
|---|---|---|---|
| Coarse | 0.126 | 0.33 | 1 |
| DNS | 8.45 | 0.022 | 386 |
| AMR (10%) | 1.1 - 1.2 | 0.022 - 0.226 | 148 |
| Static MR | 4.17 | 0.022 | 386 |




Simulation costs is reduced by a **factor of 3** by using Adaptive Mesh Refinement strategy

Remesh metric variation threshold of 10% has been found to be the optimum for flame front remeshing. In this case low thickening value is applied everywhere in the flame.

# Main takeaways and perspectives

- Adaptative mesh refinement is well-suited to track traveling reaction fronts (deflagrations and detonations)
  - Significant speed-up with AMR
  - Robust

- Lagrangian tracking allows to build flexible metric to identify the wave propagation region

- Some problems:
  - Control of the skewness (in 2D, 3D?)

- Perspectives:
  - AMR in configurations involving both detonations and flames
  - Towards DDT
  - Move towards 2D simulations