

Dynamic mesh adaptation for moving fronts and interfaces: application to the modeling of premixed flames and primary atomization

V. Moureau, P. Bénard, G. Lartigue

CORIA, CNRS UMR6614, Normandie Univ, UNIROUEN, INSA Rouen, France

R. Mercier, M. Cailler – SAFRAN Tech, France

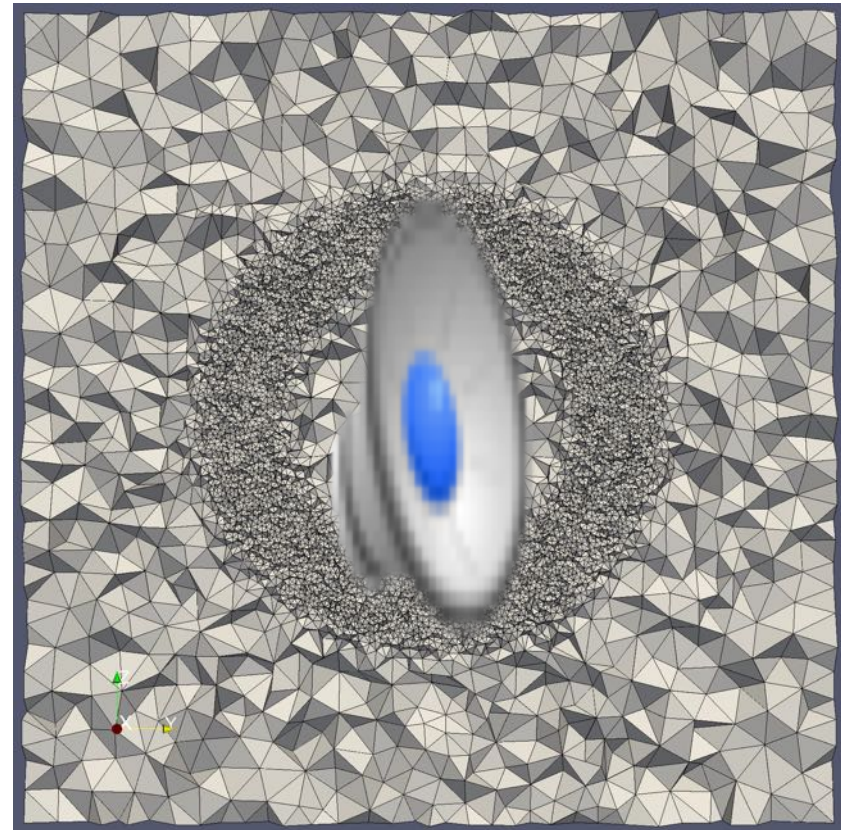
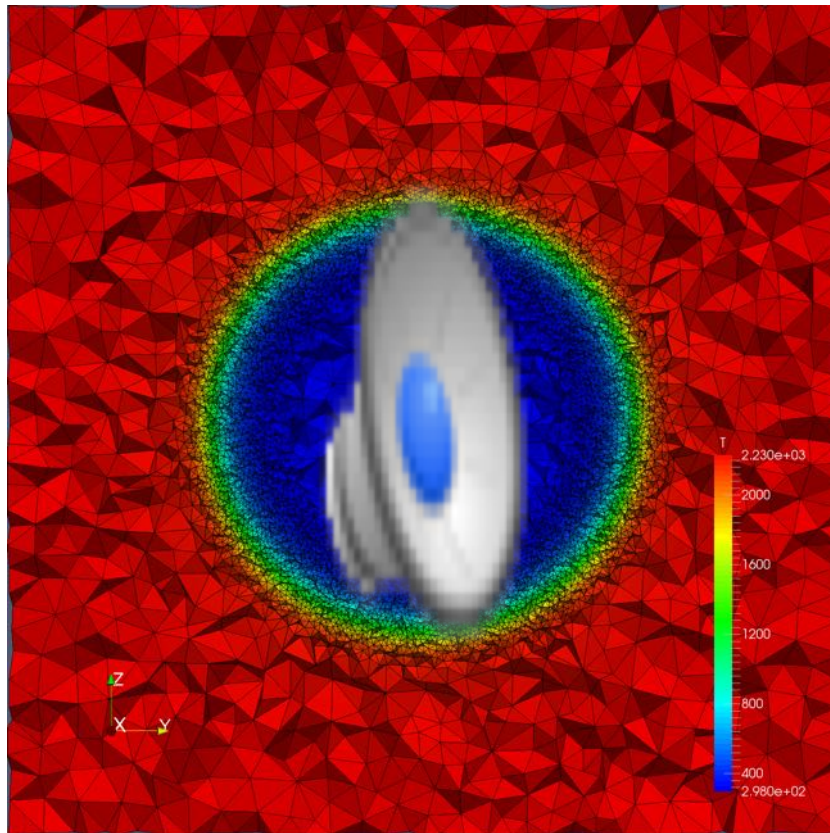
A. Froehly – LMB/INRIA Bordeaux, France

In memoriam **C. Dobrzynski** – LMB/INRIA Bordeaux, France

APS DFD meeting, November 25th 2019, Seattle, WA, USA

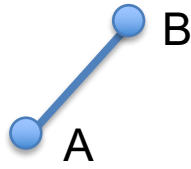
Motivation

- Isotropic and dynamic h-adaptation of tetrahedral-based meshes has a great potential for material interfaces

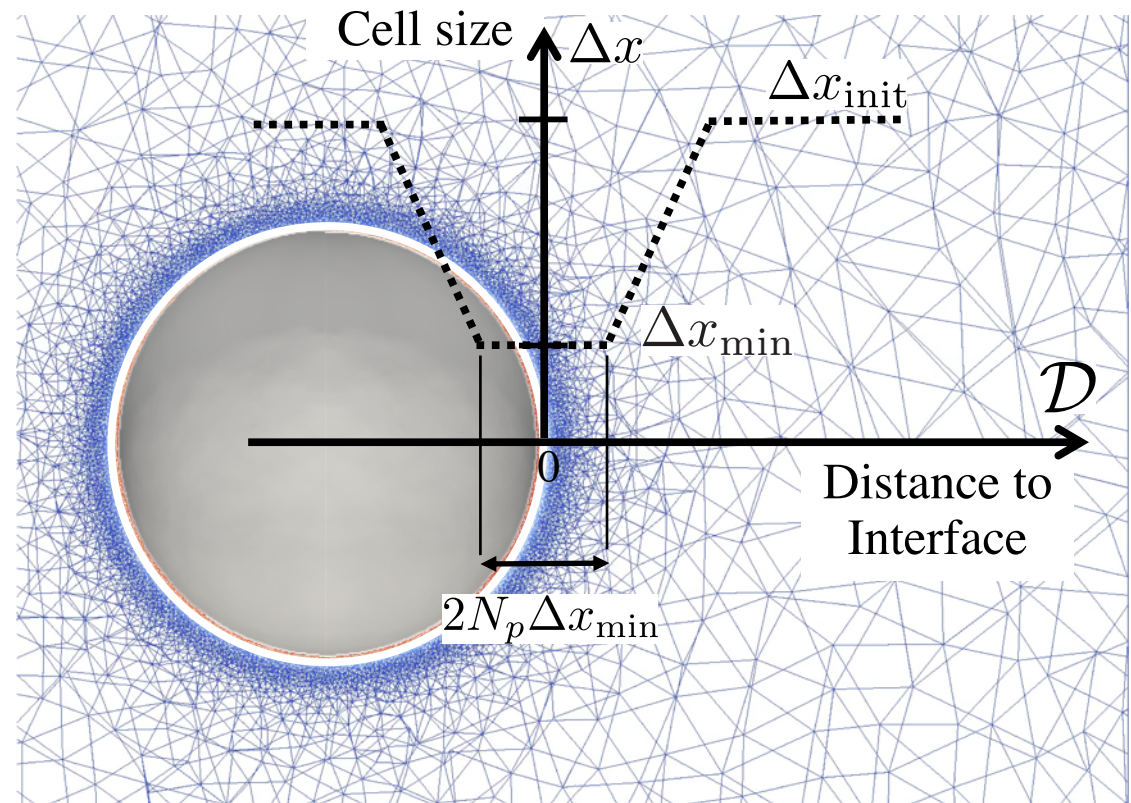


- Massive parallelism is the main challenge
 - Frequent mesh topology changes in distributed memory
 - Mesh load balancing

A prerequisite to h-adaptation: Mesh metric definition

- A continuous metric is defined [1,2] $L_{\mathcal{M}}(AB) = \int_A^B \sqrt{\mathcal{M}(s)} ds$ 
- The isotropic metric is linked to the local cell size $\mathcal{M}(x_i) = \Delta x_i^2$

- To avoid interpolation errors, the mesh is kept constant and fine at the interface
- Cell size gradient is prescribed
- Remeshing is controlled by a CFL-like condition

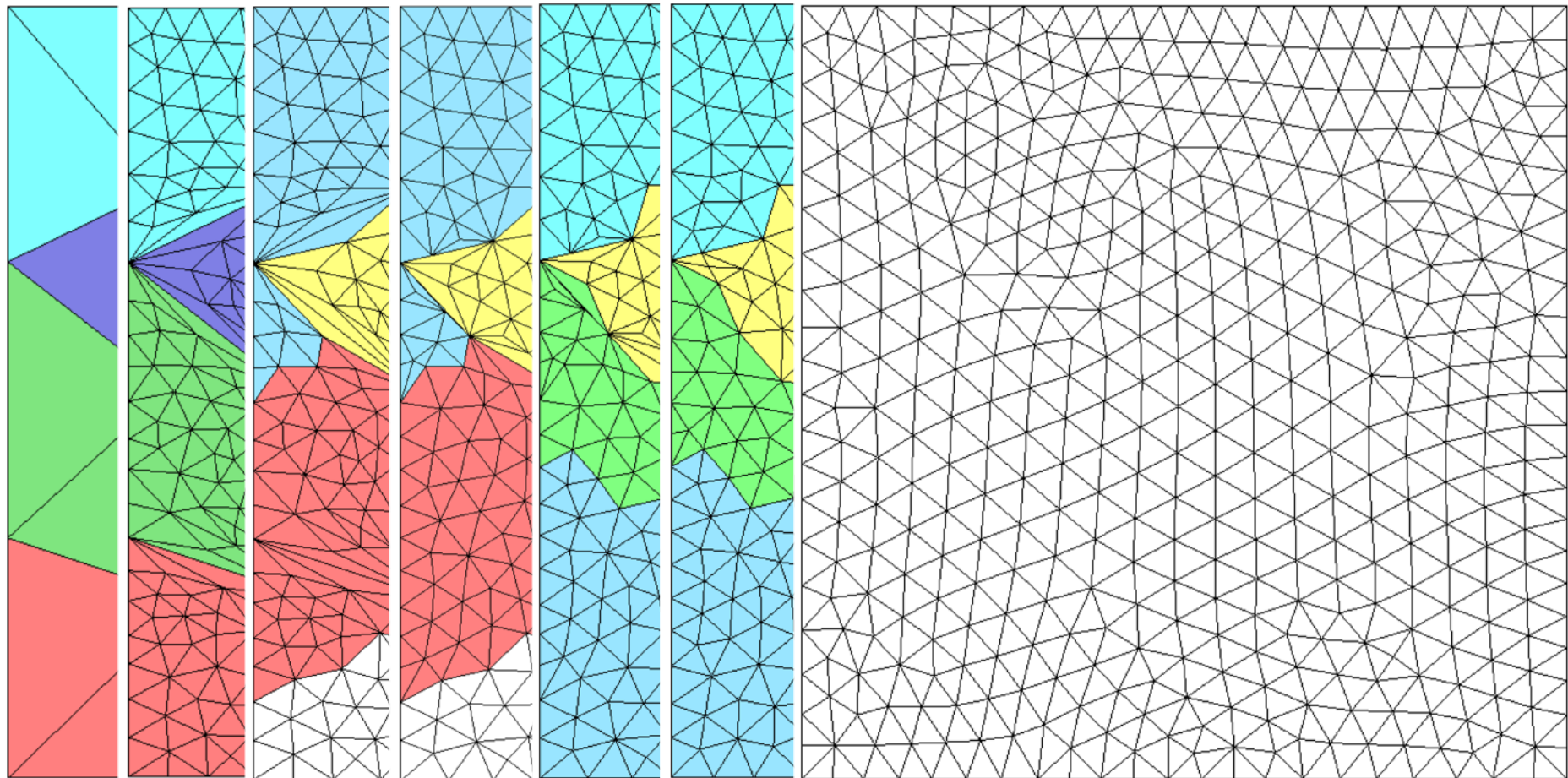


Moving interface method for parallel h-adaptation

- Principle with a standard memory distribution of the mesh [1]

\mathcal{M}_{init}

\mathcal{M}_{target}

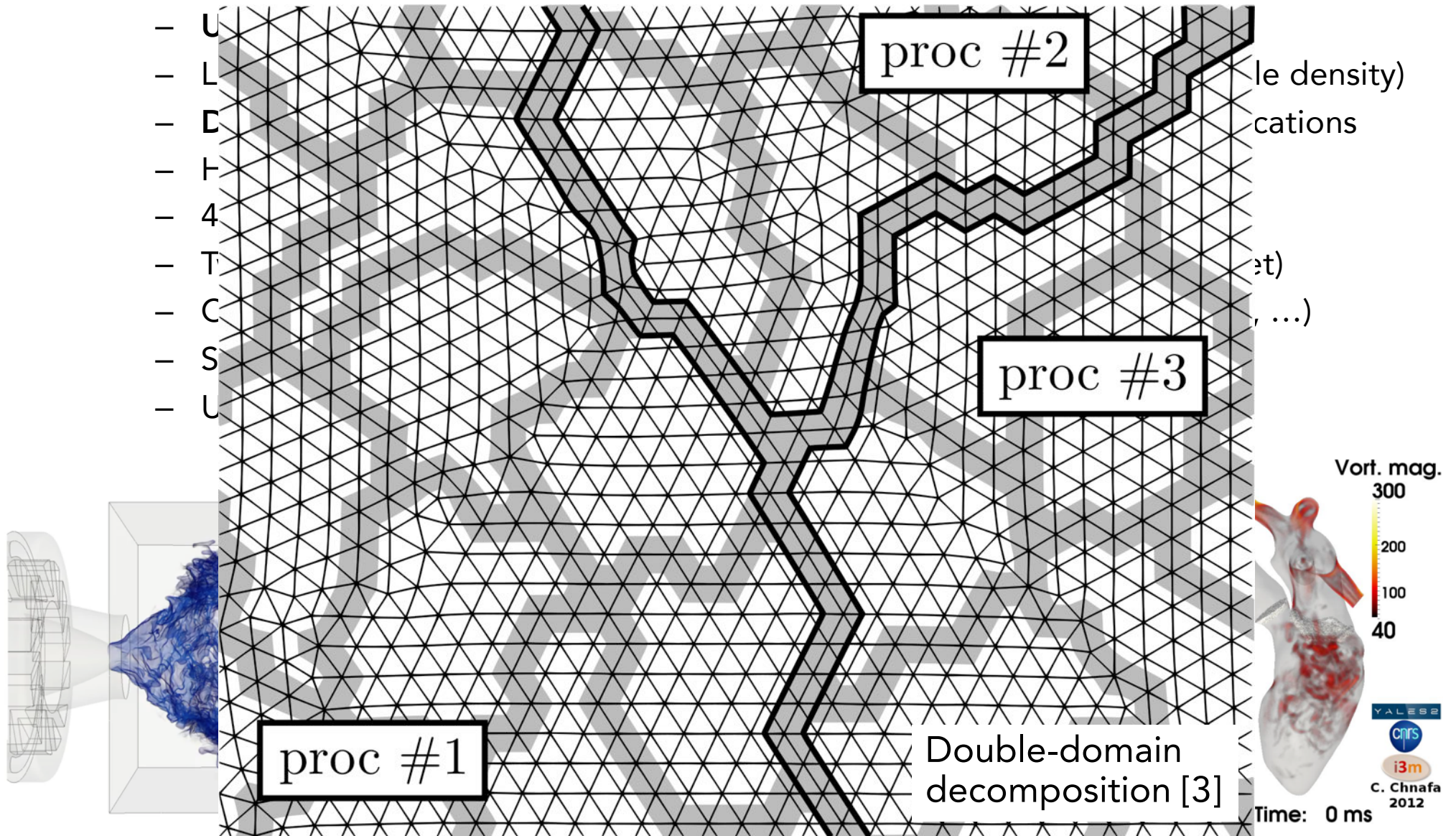


Final mesh

- Interpolation and load balancing remain two important bottlenecks

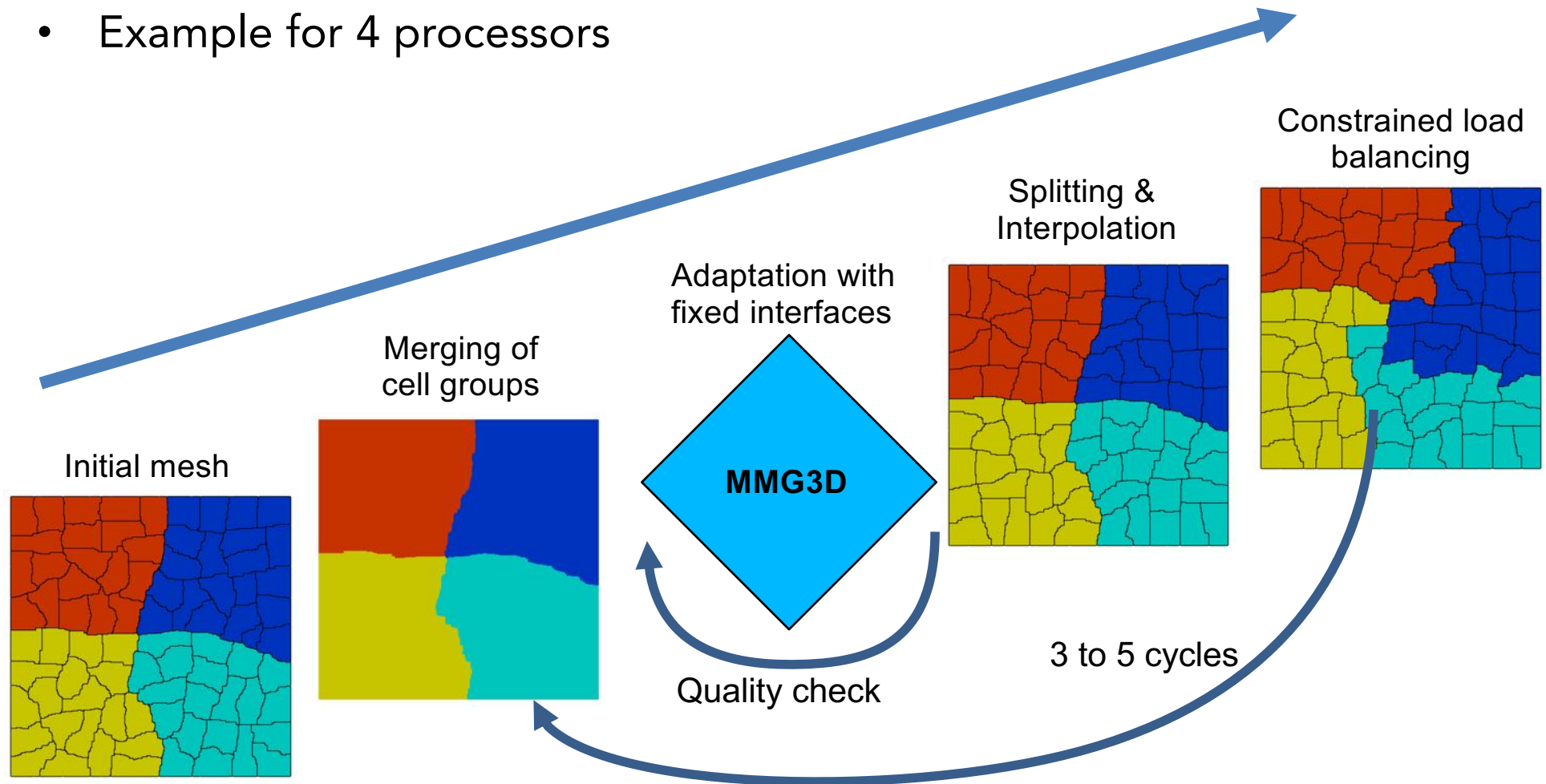
The CFD platform: YALES2

- Features



A moving interface method with 2-level decomposition [1]

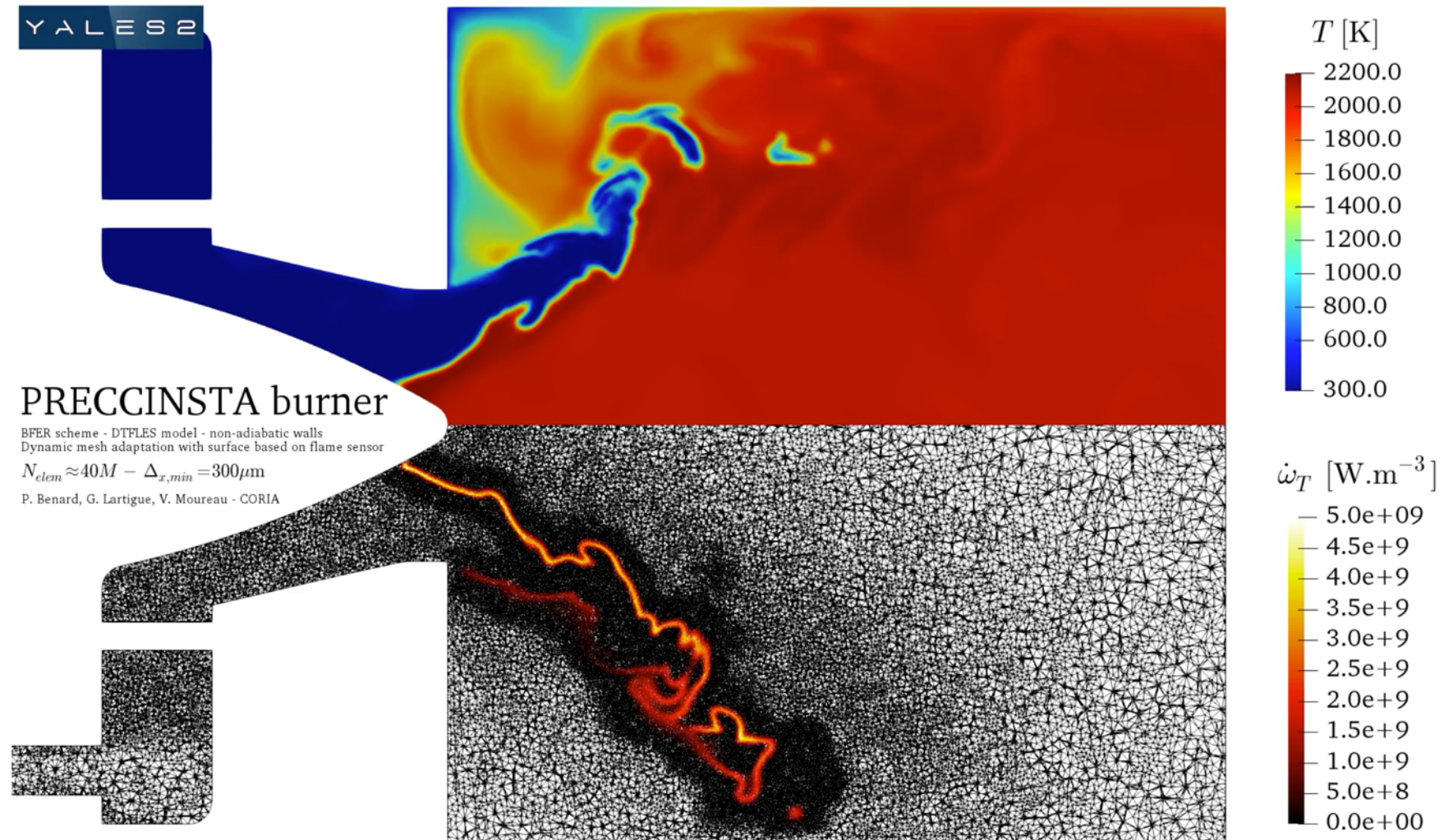
- MMG library [2] from INRIA/IMB adapts the mesh on each rank
- Example for 4 processors



- Interpolation and load balancing are highly optimized

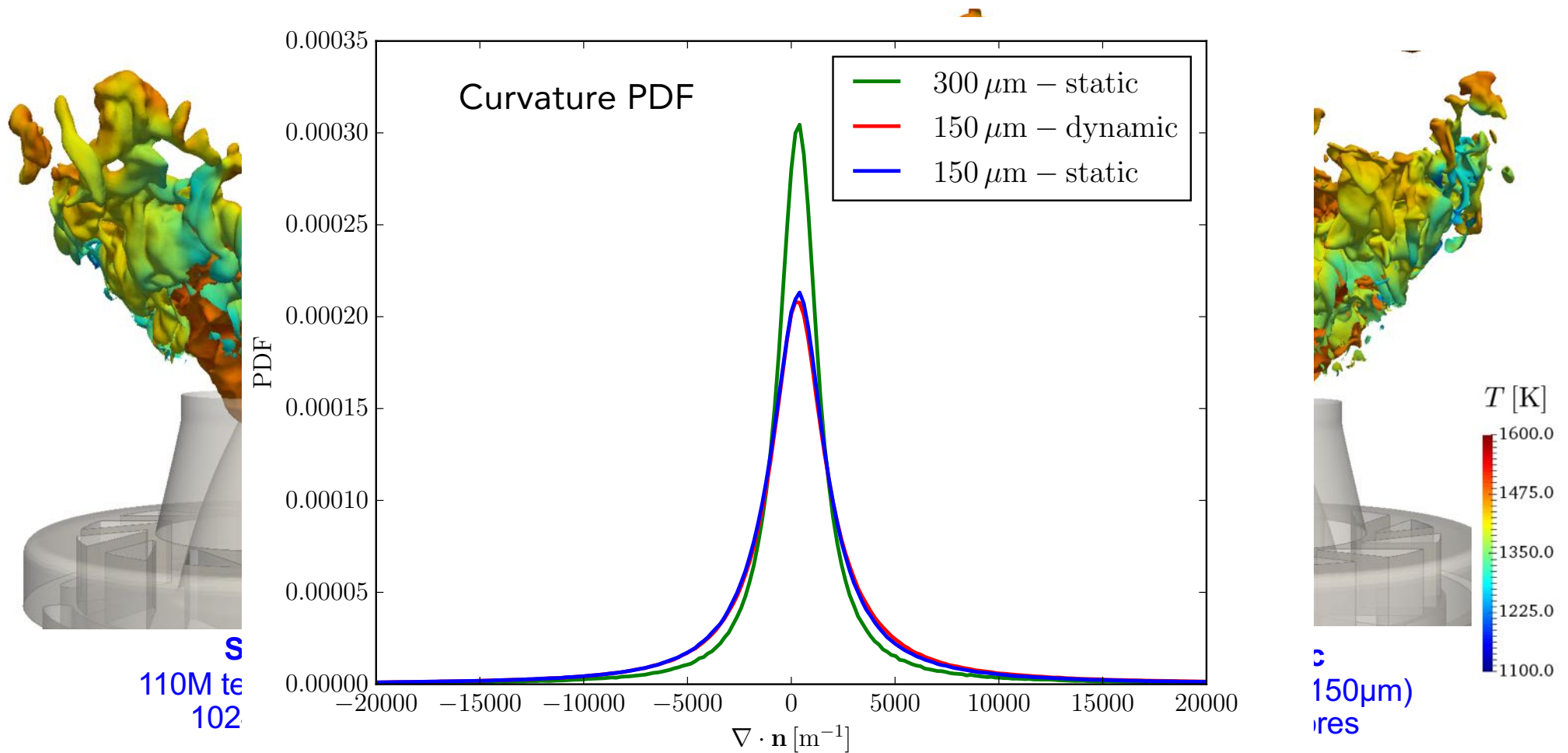
Application to a lean-premixed flame

- ▶ Methane/air, Sankaran scheme (17 species, 73 reactions) [1], wall heat loss [2]
- ▶ Interface location given by the gradient of the progress variable
- ▶ Volume/surface adaptation, refinement rate at interface = 2



Application to a lean-premixed flame

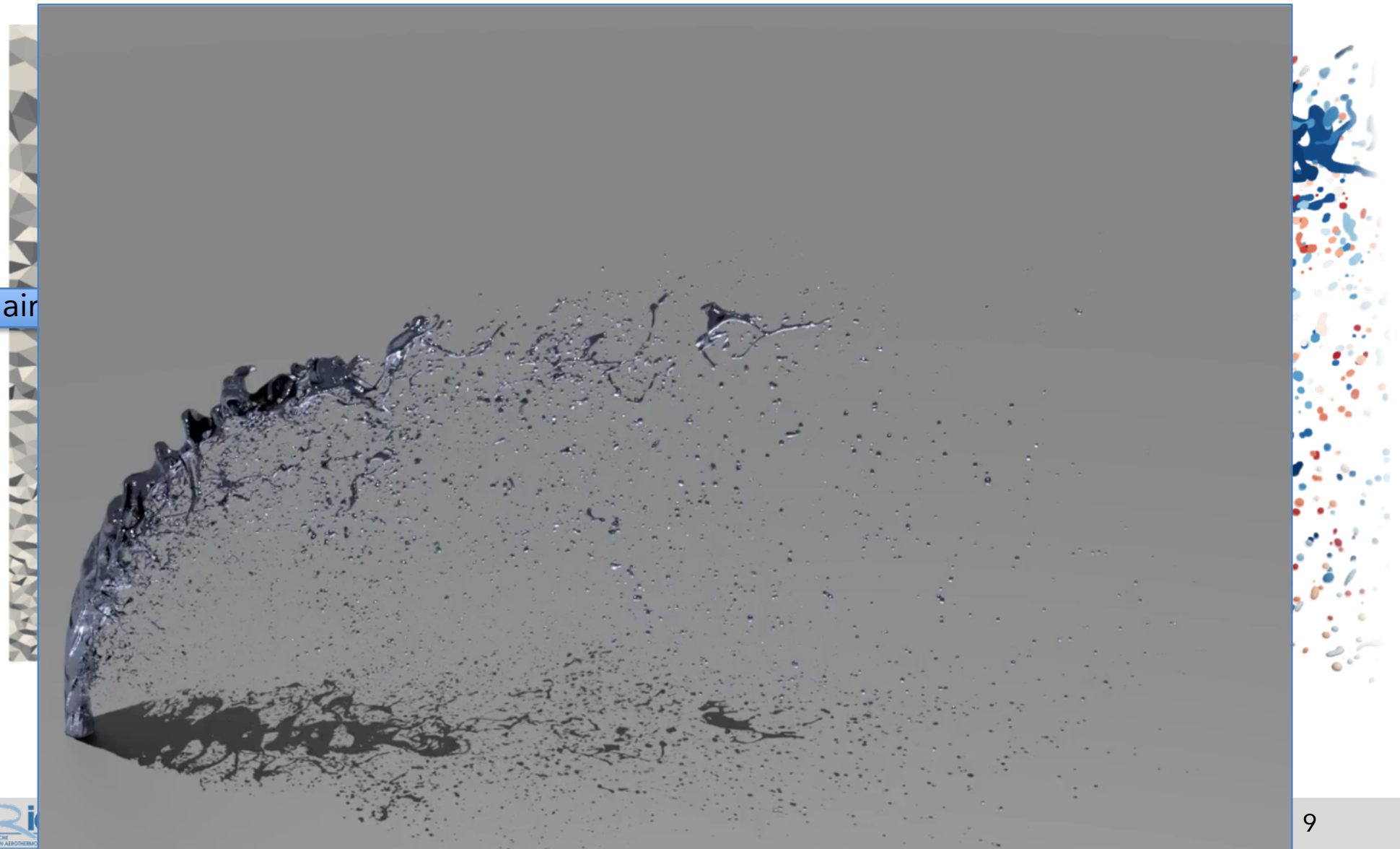
- Comparison of the dynamic mesh results to static cases [1]
- Progress variable iso-contour:



- The small-scale wrinkling depends only on the finest cell size

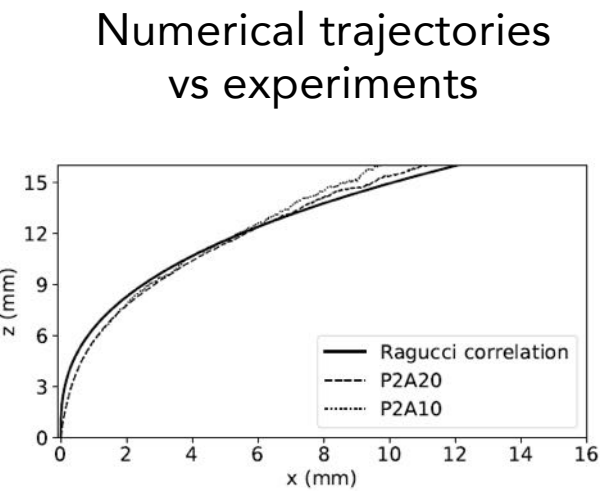
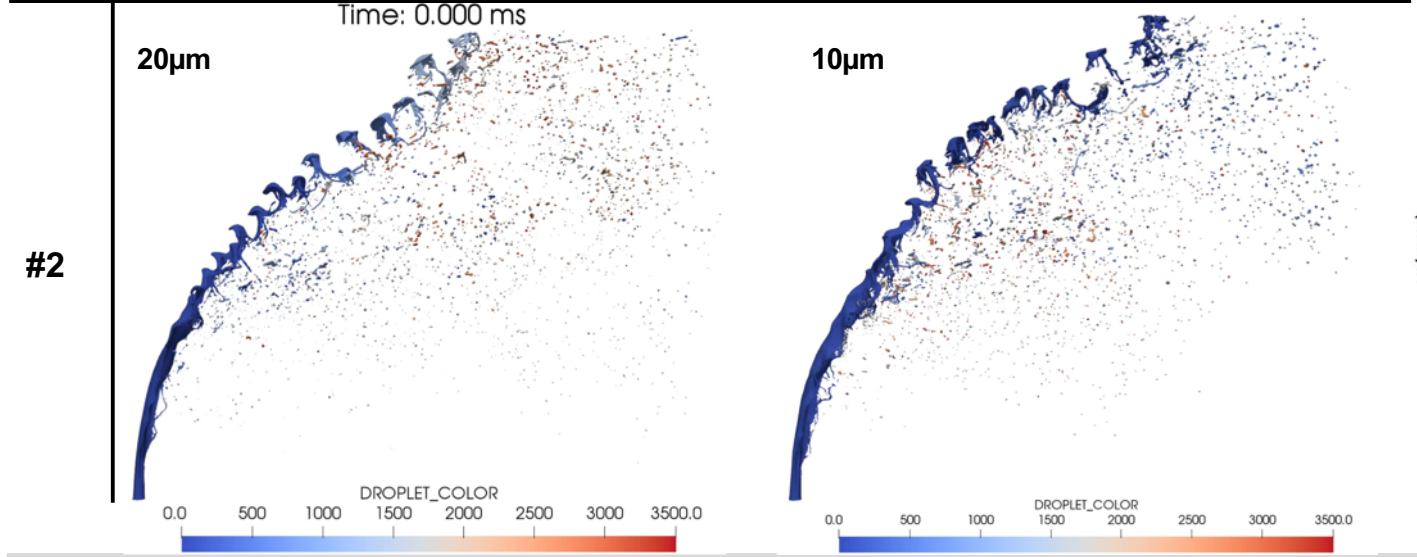
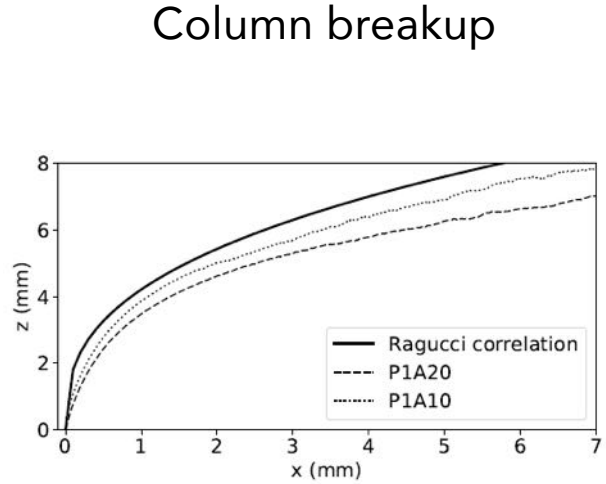
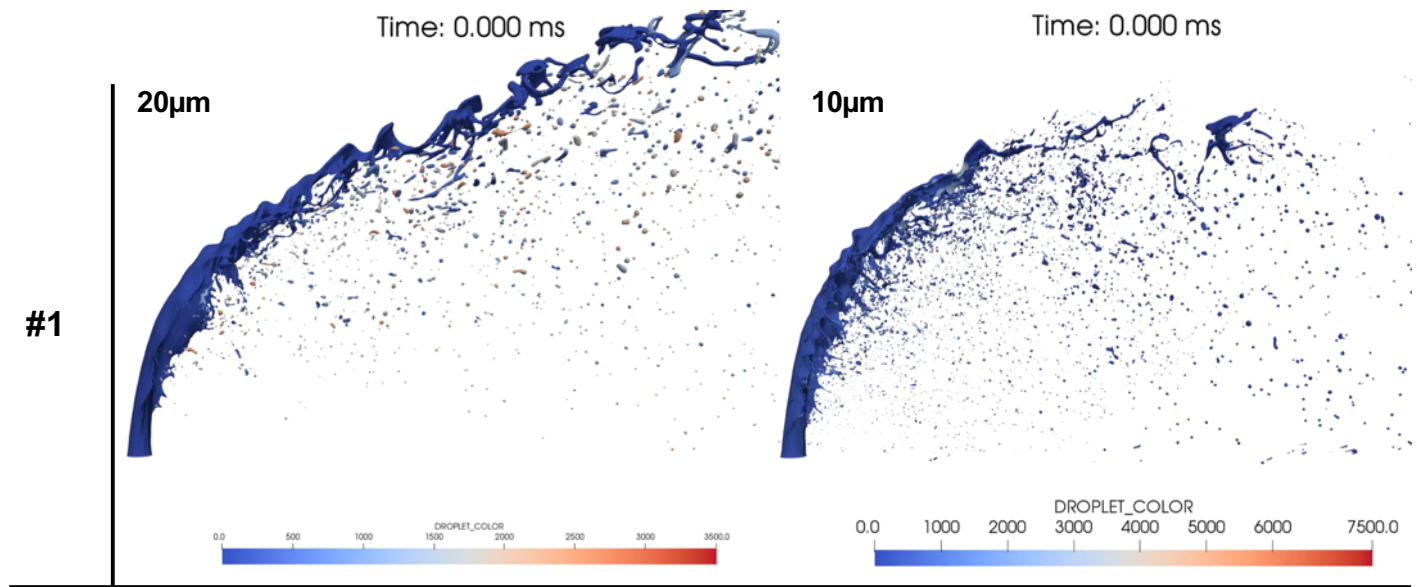
Application to gas/liquid interfaces

- Kerosene jet-in-cross flow at 10 bar, $We_{aero} = 60$ to 400 [1]
- Accurate Conservative Levelset [2], up to 1.6 billion tets on 8192 cores [3]



Application to gas/liquid interfaces

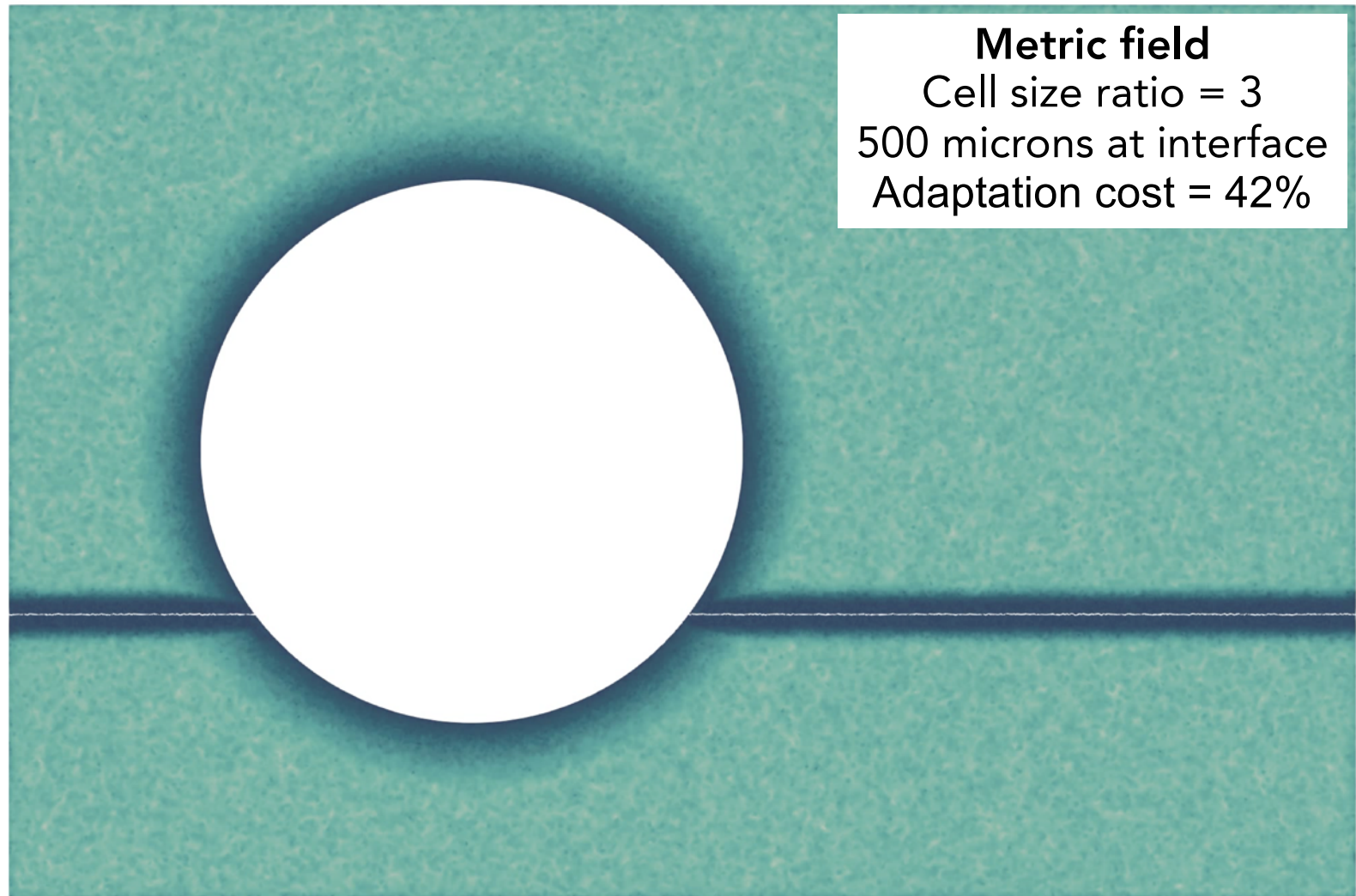
- Parametric study of the kerosene jet-in-cross flow [1,2]



Surface breakup

Application to gas/liquid interfaces

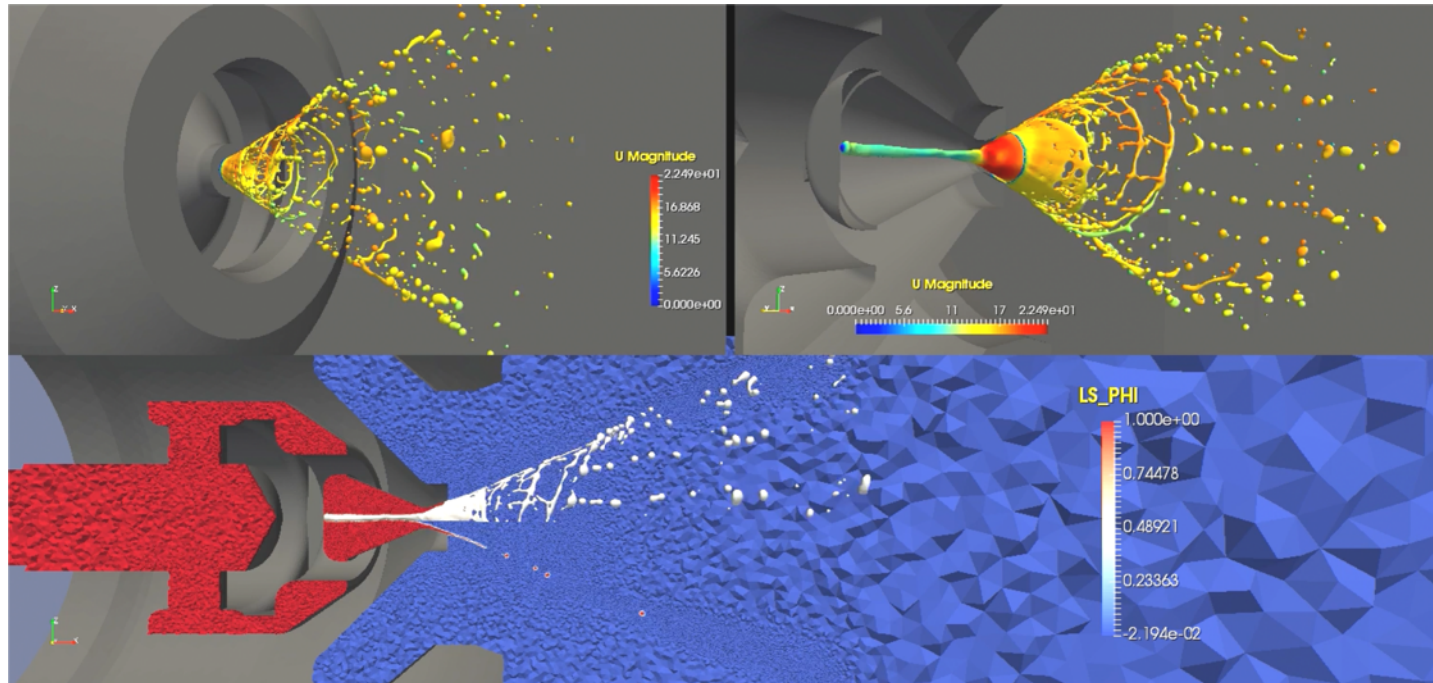
- Simulation of oil churning by M. Cailler, SAFRAN TECH [1,2]
- Real fluid properties, 206 million tets on 1250 cores (Cobalt, CEA)



Metric field
Cell size ratio = 3
500 microns at interface
Adaptation cost = 42%

Conclusions and prospects

- Parallel dynamic mesh adaptation of massive grids is feasible



- Many theoretical and numerical developments are still required
 - Modeling of space/time commutation errors in LES
 - Better load balancing algorithms

Acknowledgements

- A. Pushkarev, G. Balarac – LEGI, Grenoble
- CPU hours from PRACE, GENCI and CRIANN

