CERFACS

CENTRE EUROPÉEN DE RECHERCHE ET DE FORMATION AVANCÉE EN CALCUL SCIENTIFIQUE

Code of the Month
AVBP

Gabriel STAFFELBACH

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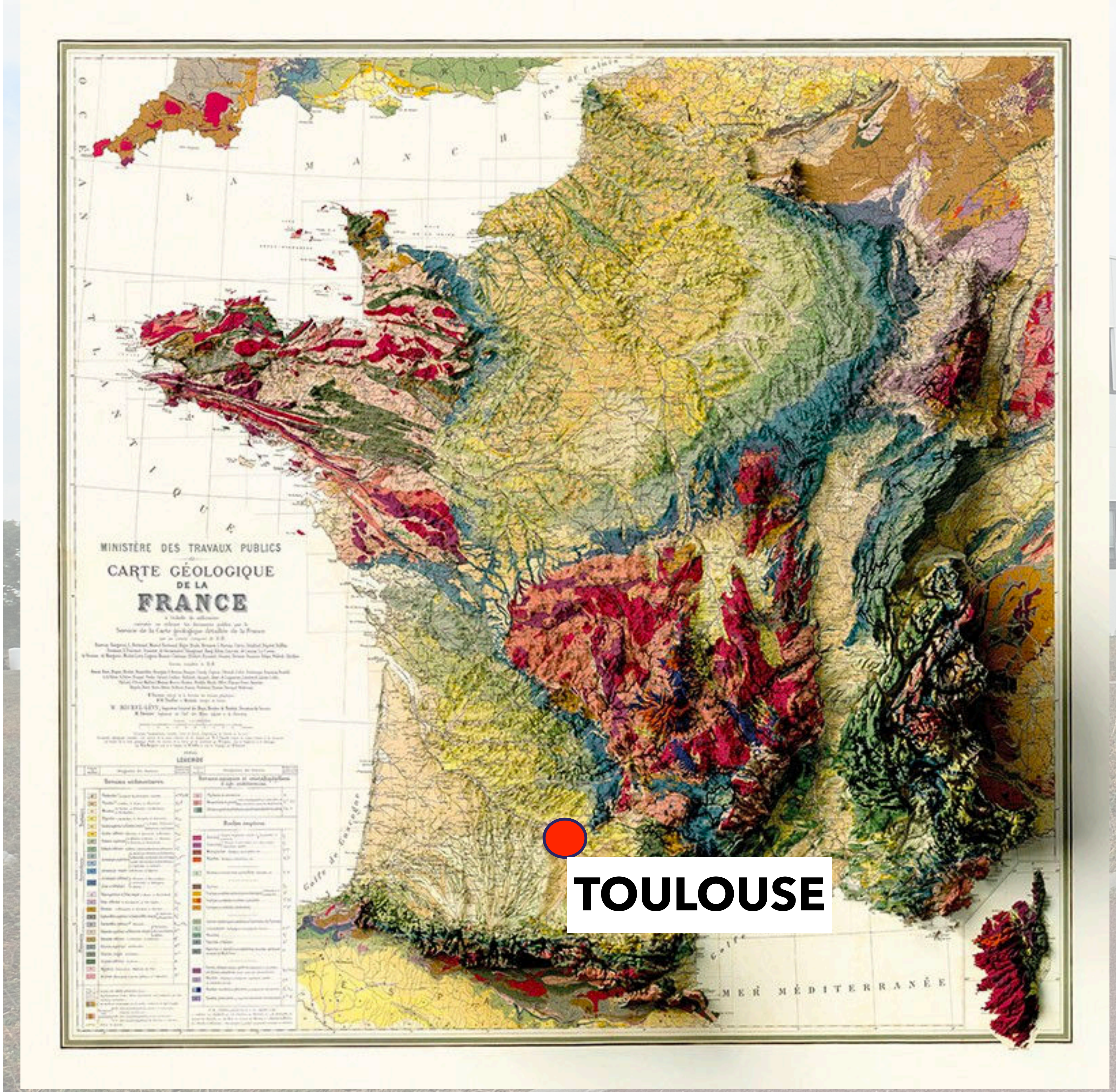


Research center focused on training and technology transfer using High performance computing

Concentrate competences in HPC, numerical methods, modelling to tackle scientific problems

3 scientific teams

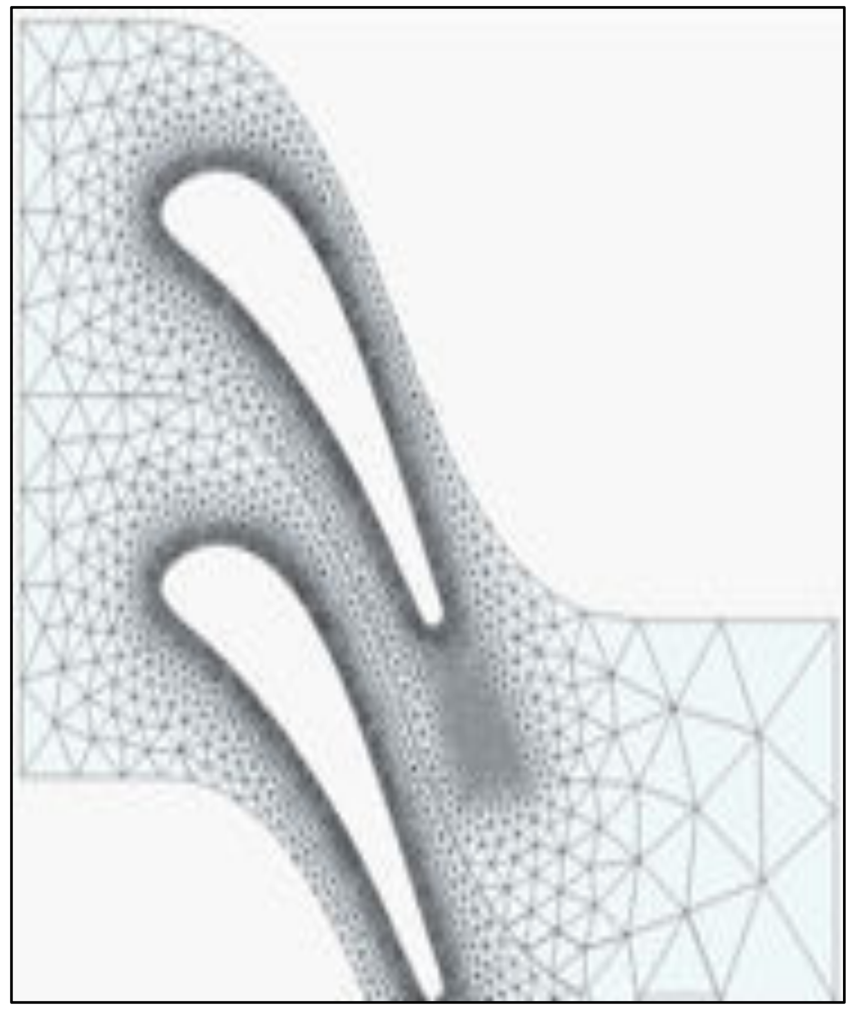
GLOBAL CHANGE **ALGO-COOP** **CFD**

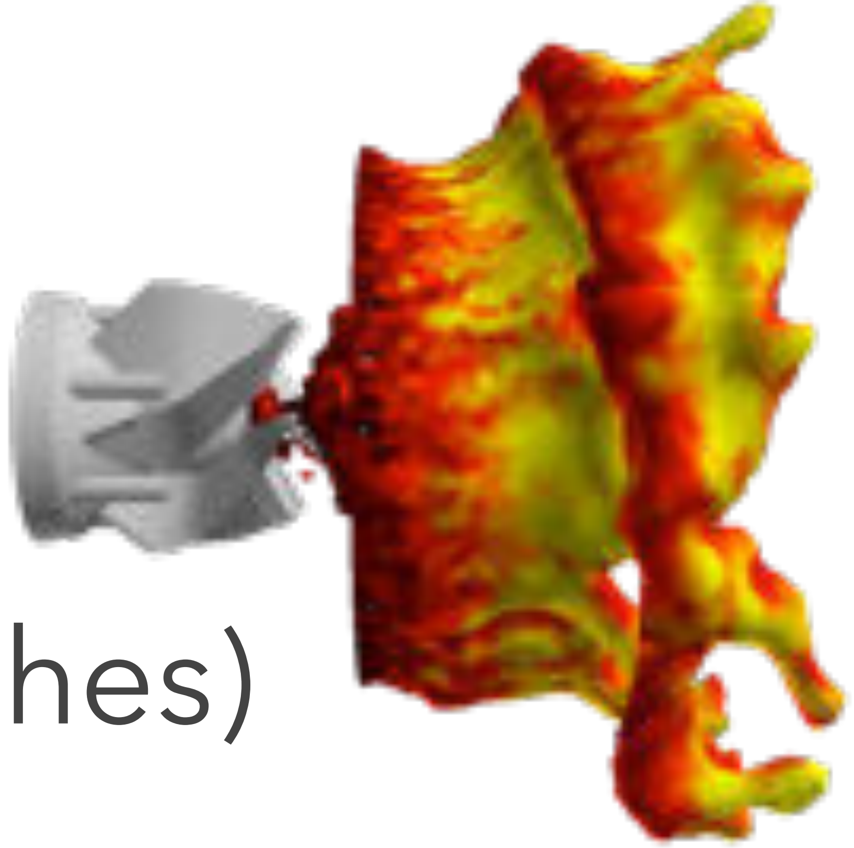
Partners

TOTAL, cnes, ONERA THE FRENCH AEROSPACE LAB, eDF, SAFRAN AEROSPACE · DEFENCE · SECURITY, AIRBUS, METEO FRANCE

The AVBP Code

- Compressible Navier-Stokes Finite Element Solver
- Unstructured multi-element grids
  - Arbitrary Lagrangian-Eulerian Method for moving grids
  - Automatic Mesh adaptation
- Large Eddy Simulation
- Up to 3rd order space and time numerical scheme
- Reduce and Analytically Reduce chemistry
- Two-phase flow modelling (Eulerian and Lagrangian approaches)
- Perfect and Real Gas Thermodynamics
- Characteristic Boundary conditions





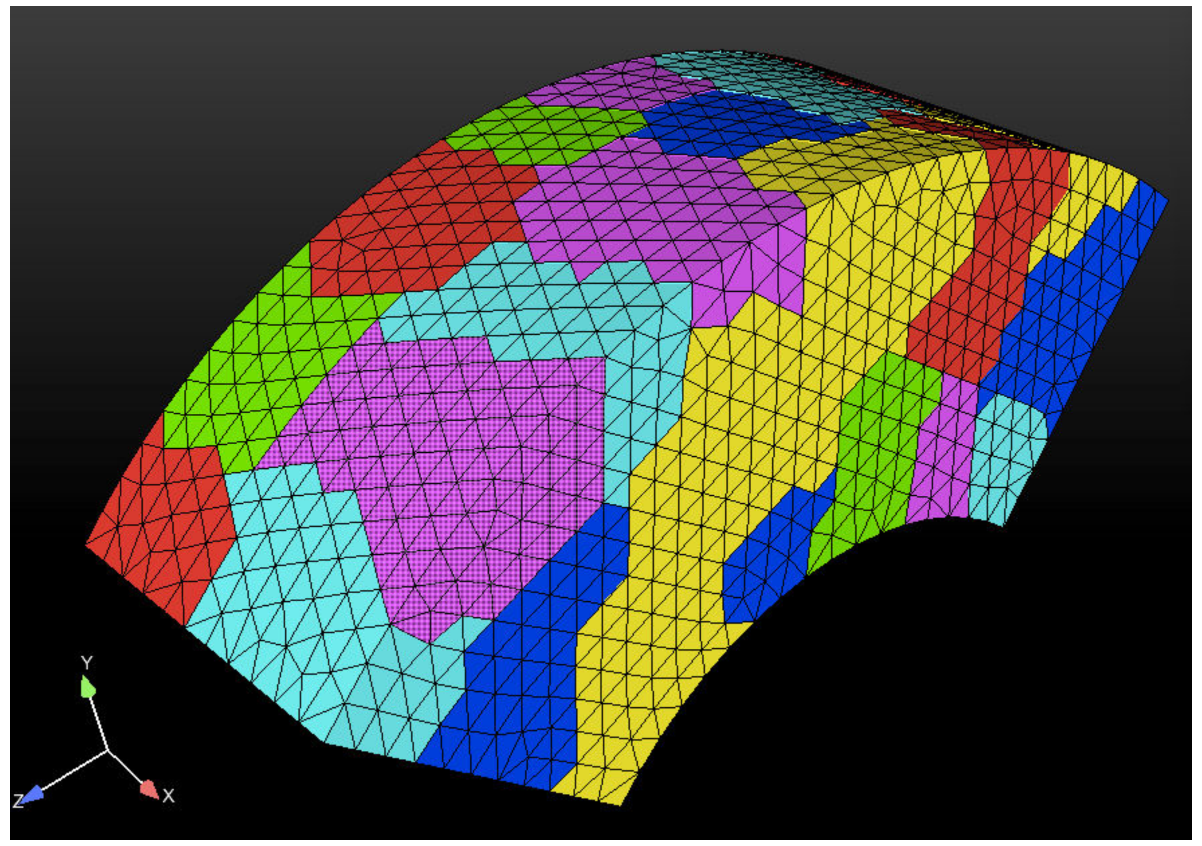
The AVBP Community

- An Open Science Code :
  - access for research and non-compete activities
    - TU Munich, TU Berlin, ETHZ, University of Sherbrooke, VKI, CNRS (CORIA, IMFT, EM2C, LMFA)
  - Industrial own usage upon bilateral agreements:
    - GRTgaz, Total Energies, CNES, SAFRAN, AIRBUS

- 30 contributors annually
- 30-40 papers annually

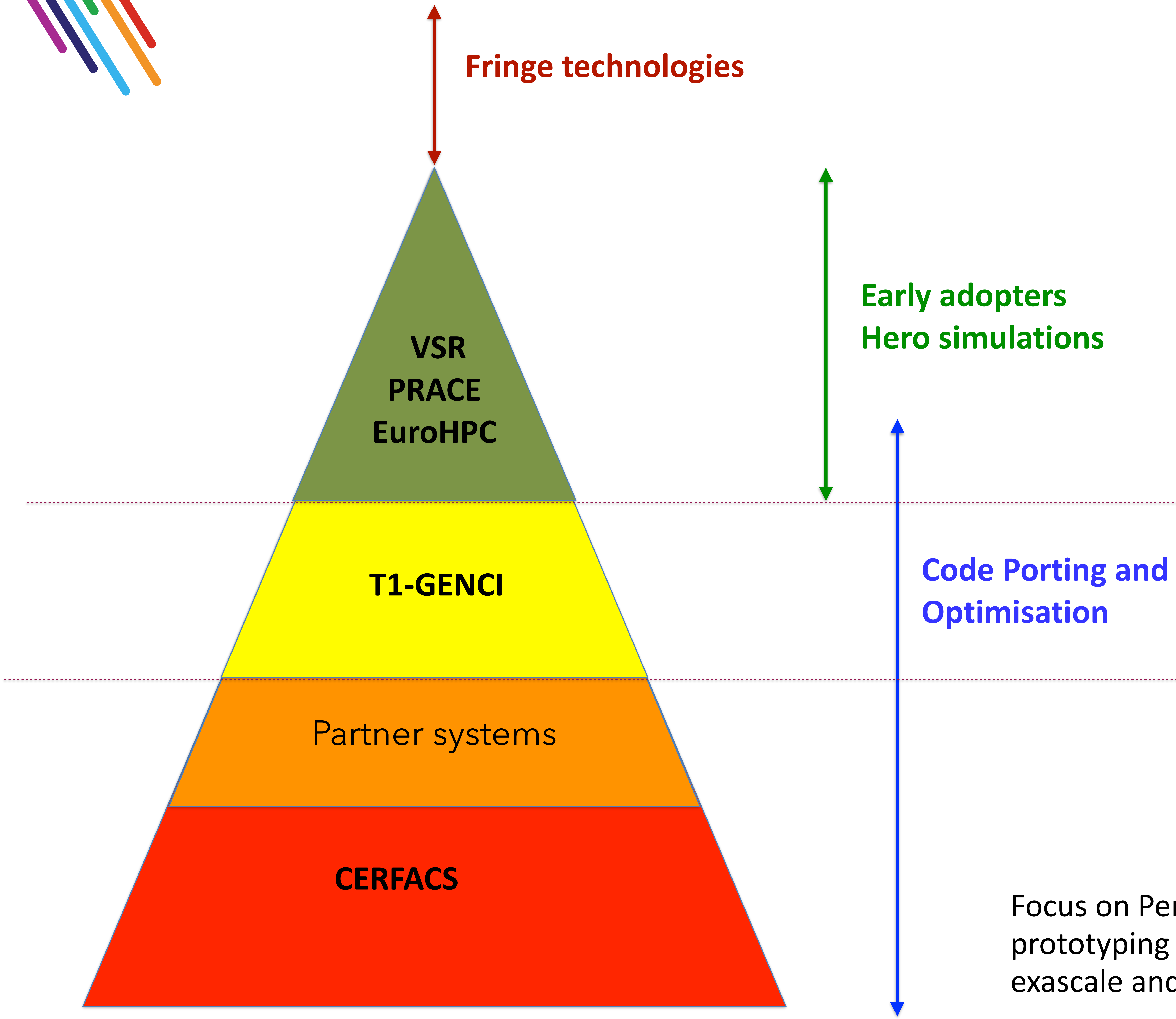
The AVBP Code

- 500k lines of code
- SPMD parallel approach / Domain decomposition method
  - Fortran 2003/C
  - MPI 1 and 3
  - Full GPU offload for Reactive gaseous - static grid case - NVIDIA and Cray AMD systems(*)
- Multi-physics coupling via CWIPI (ONERA)
  - Thermal
  - Radiative
  - Structure
- AI



* non reactive as 2023-06-15 , work in progress

High Performance computing



Graviton

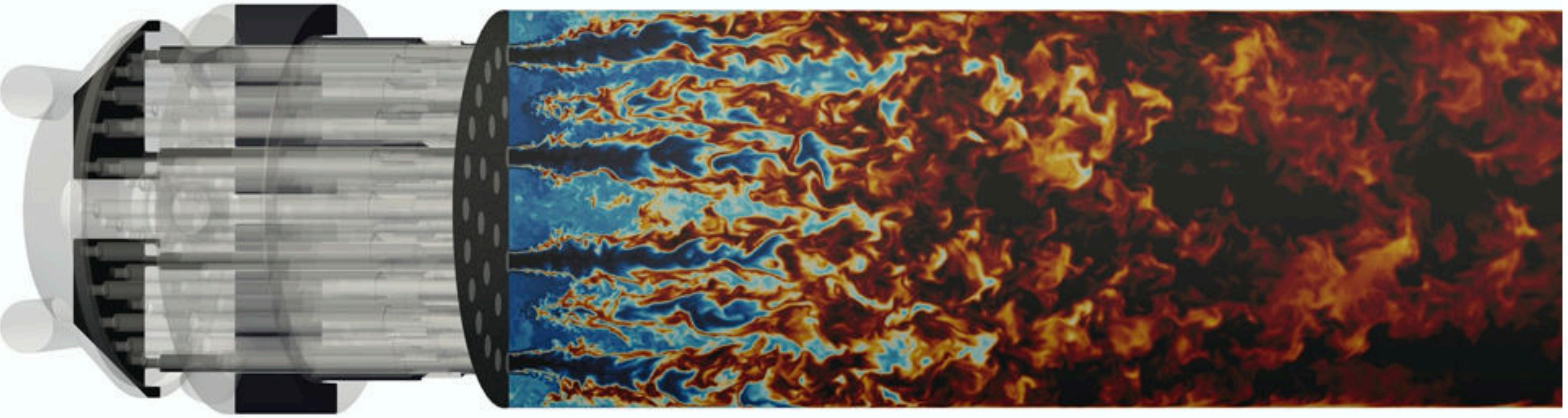
Ponte Vecchio
(Prototype)

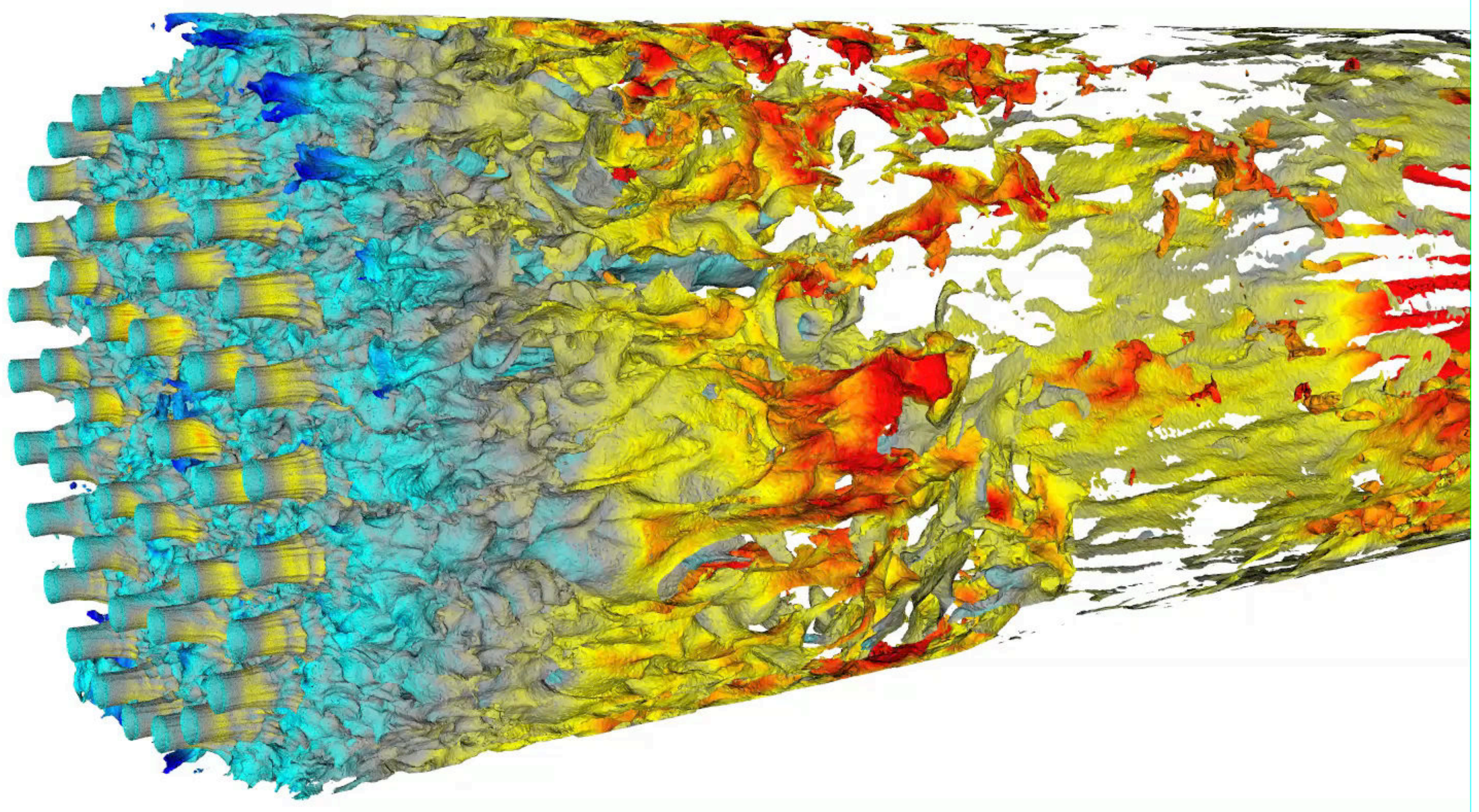
Aurora

BSC

European
Processor
Initiative

Focus on Performance of legacy codes and prototyping disruptive technologies towards exascale and beyond



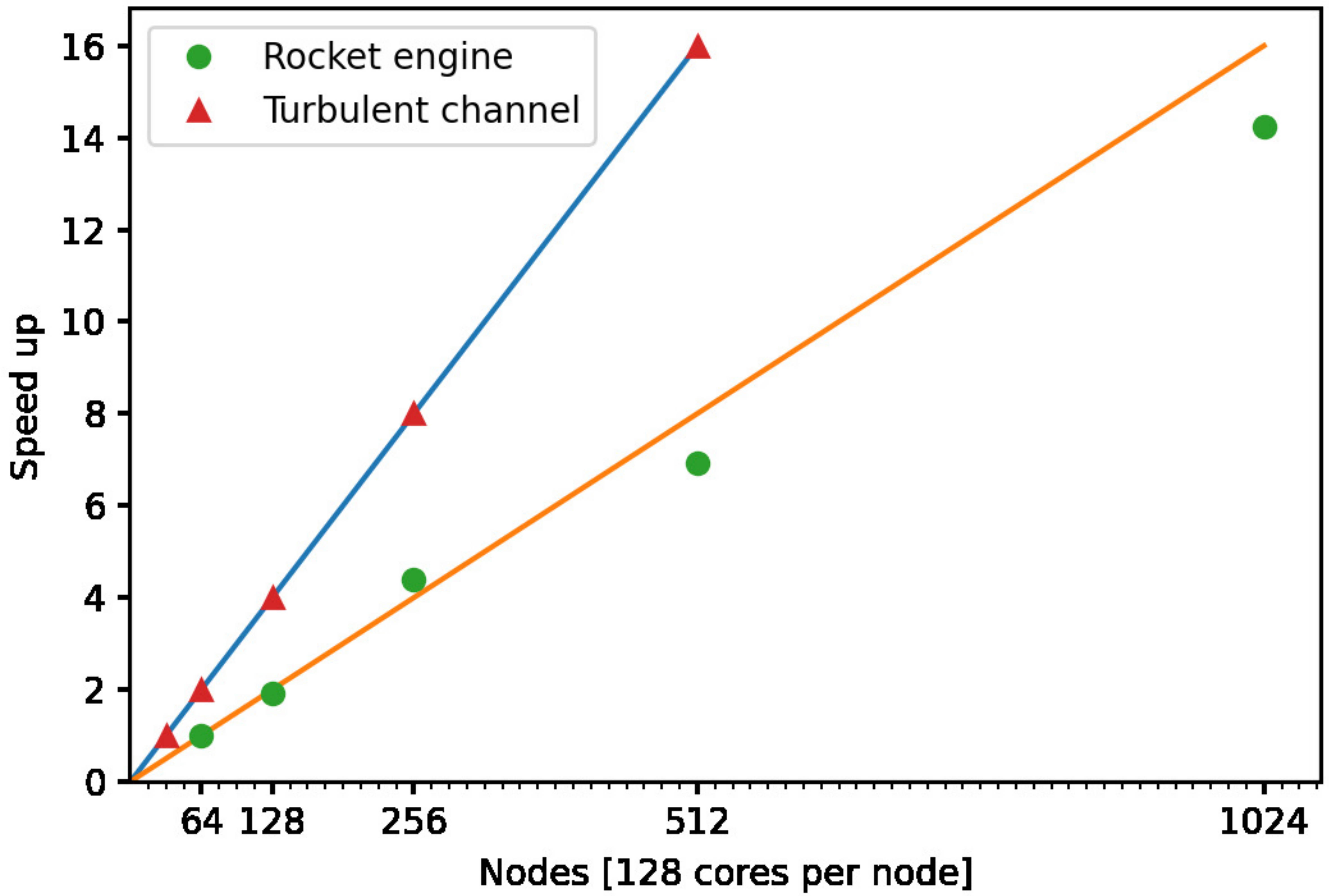


1.4B elements simulation on 132k Rome EPYC 2 cores

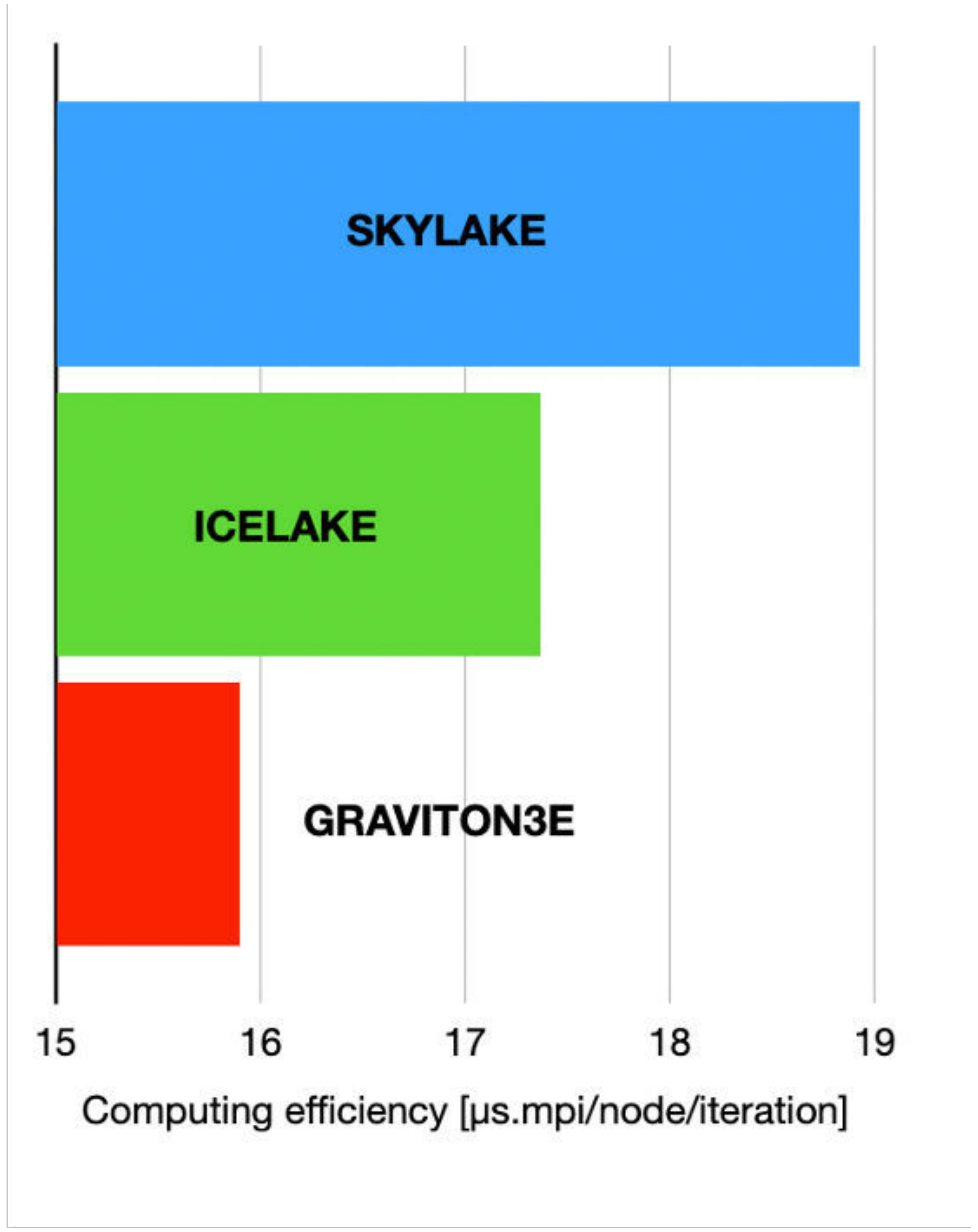
Schmitt & Staffelbach

Stefan Gröning, Justin S Hardi, Dmitry Suslov, Michael Oschwald, "Injector-driven combustion instabilities in a hydrogen/oxygen rocket combustor", *Journal of Propulsion and Power, Volume 32 [560-573] 2016*

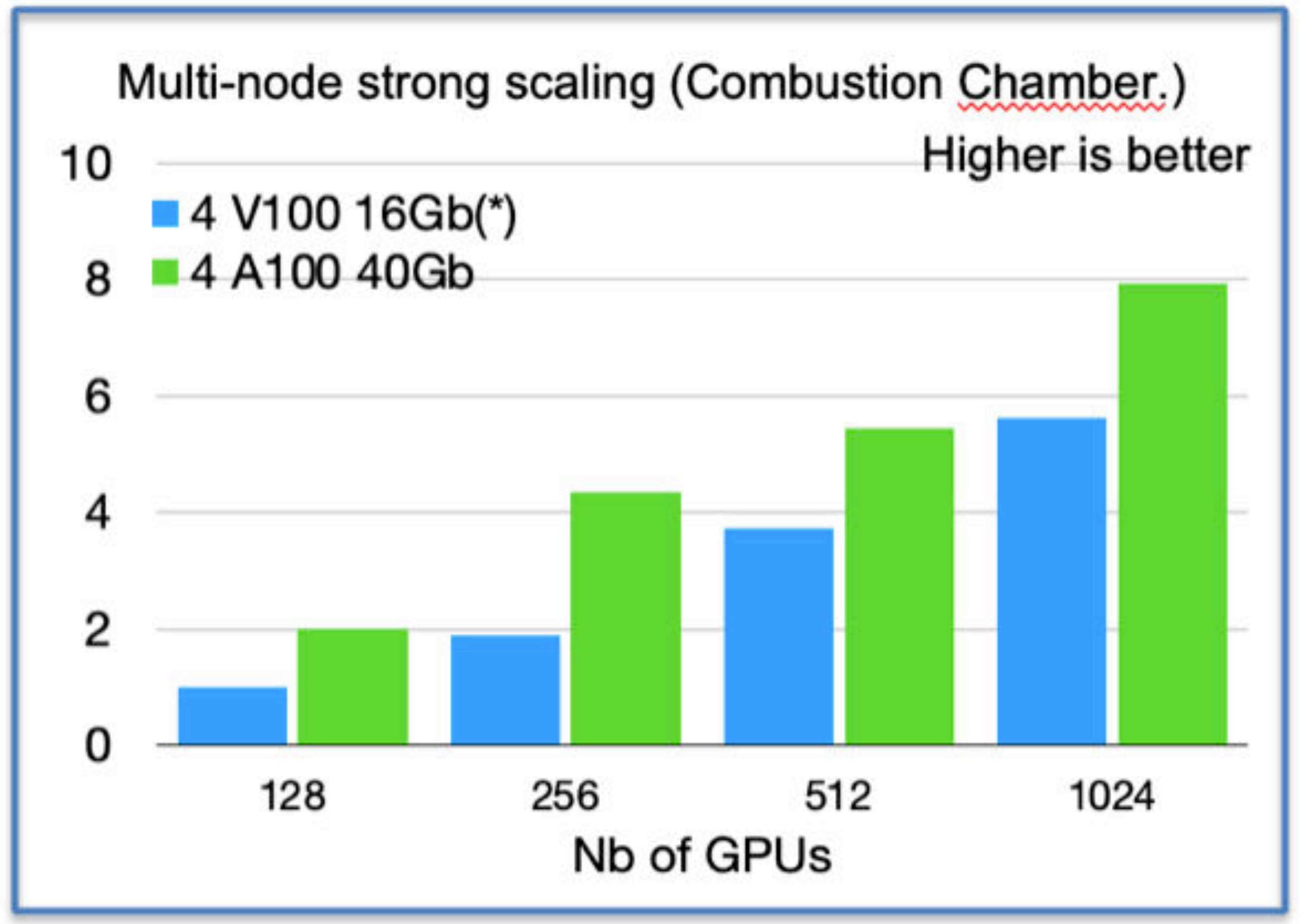
Strong scaling and portability



Single node performance

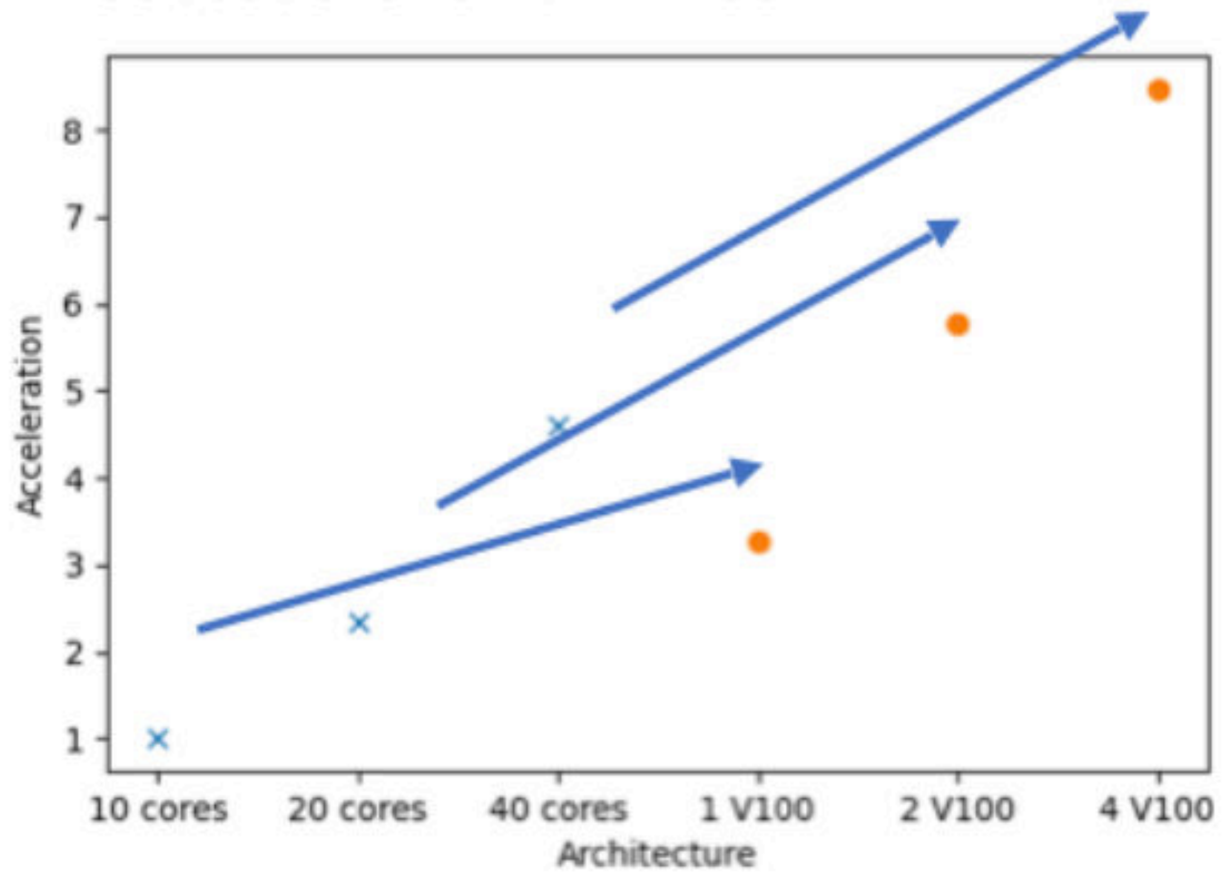


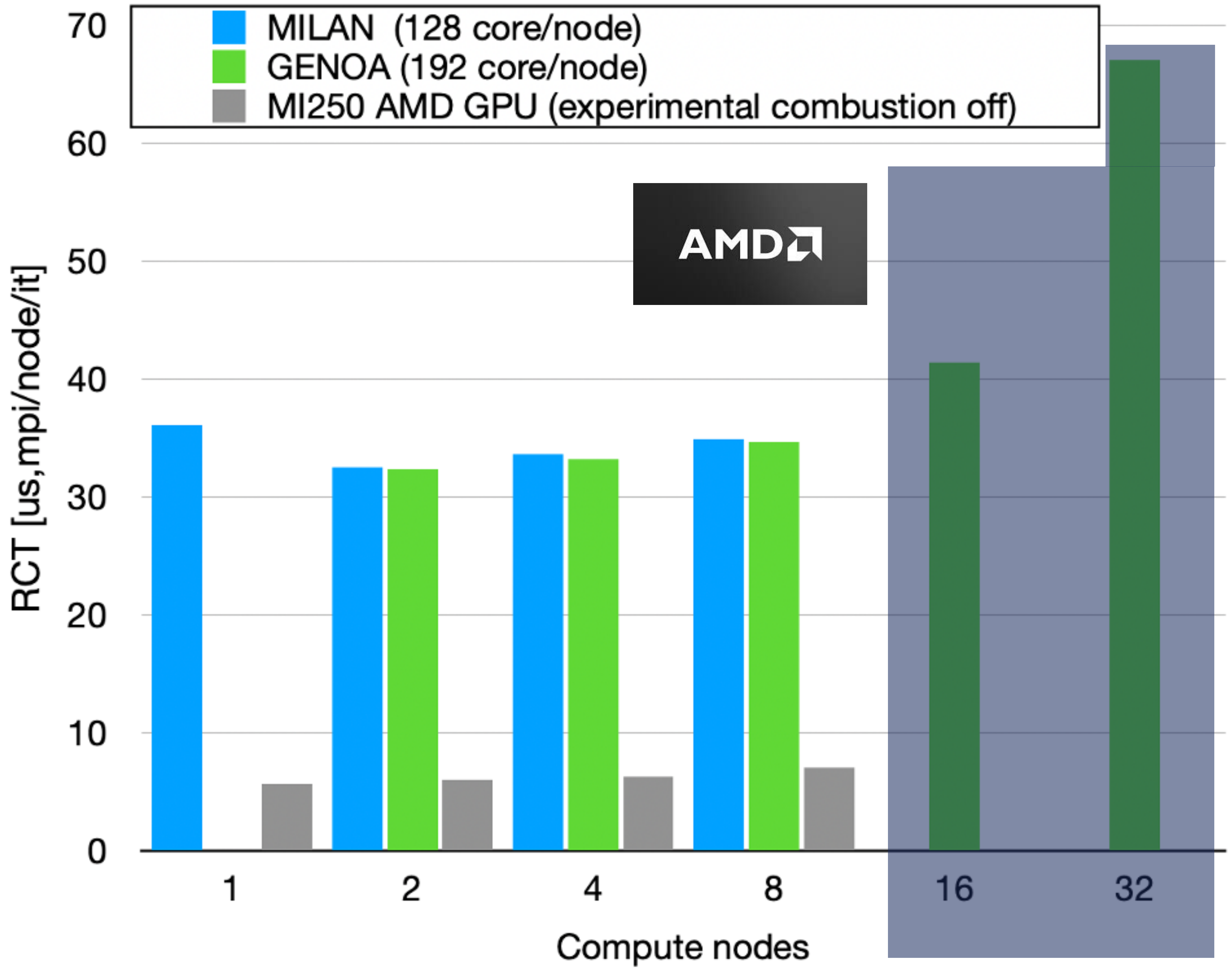
Parallel GPU support (OpenACC)



NVIDIA

GPU Acceleration vs CPU : 40 core Cascade lake vs 4 V100

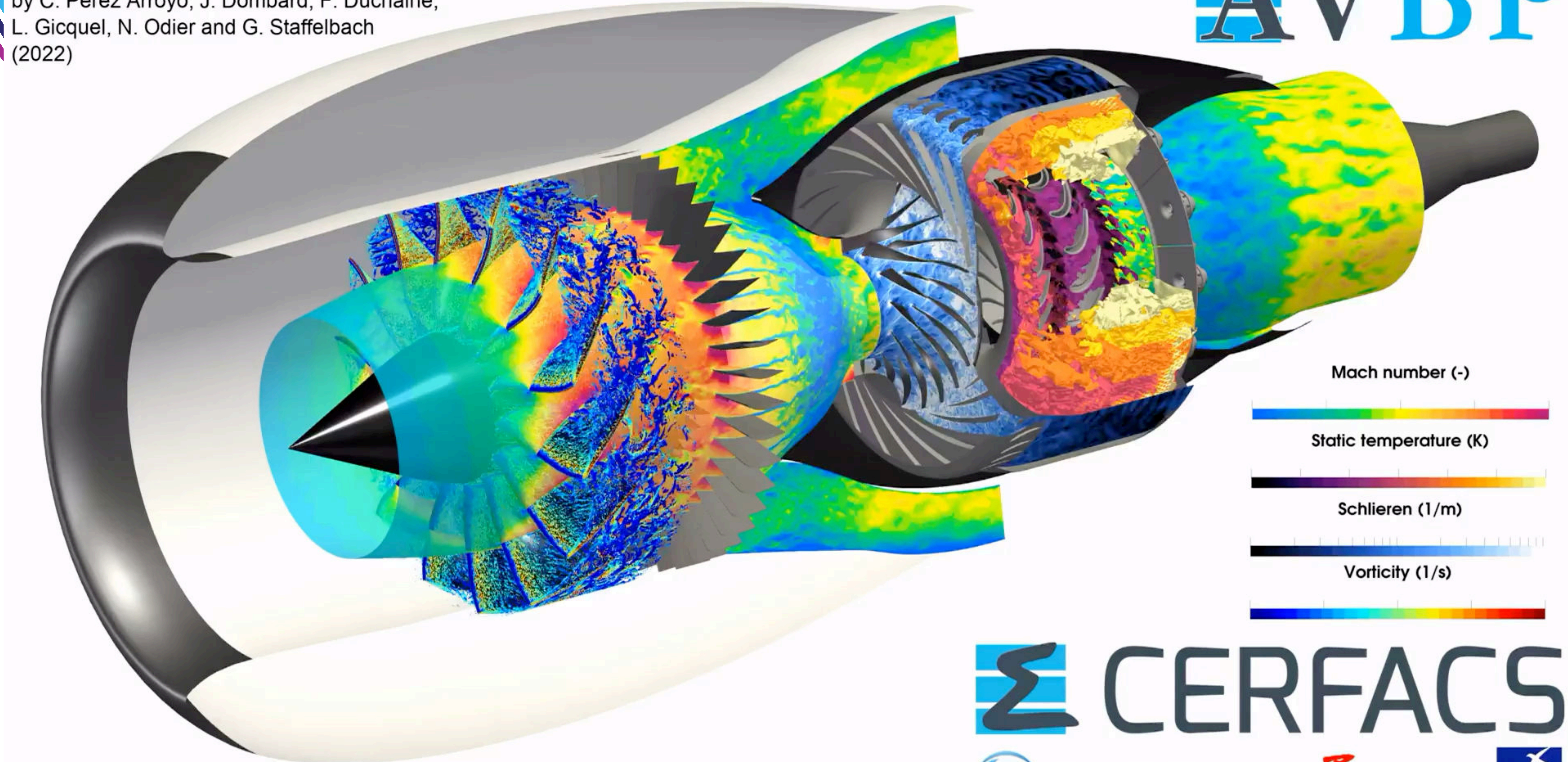




EXCELLERAT

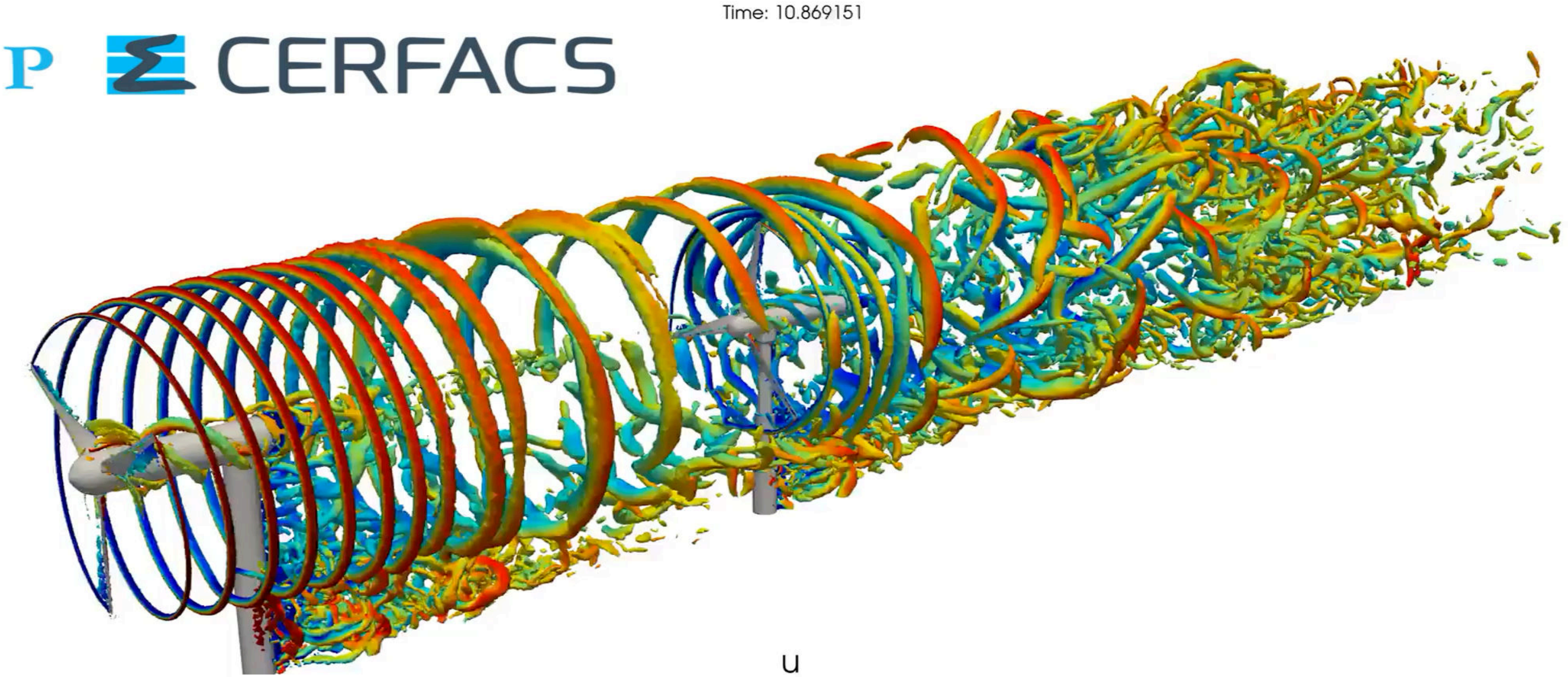
DGEN-380 engine Large Eddy Simulation at take-off conditions

by C. Pérez Arroyo, J. Dombard, F. Duchaine,
L. Gicquel, N. Odier and G. Staffelbach
(2022)



These results benefitted of funding or developments from:
project ATOM (DGAC/SafranTech No 2018-39), PRACE (20th Call Project Access FULLEST), EXCELLERAT (H2020 823691), EPEEC (H2020 801051) and GENCI (A0122A06074).

High fidelity simulation of a wind turbine



Wall-modelled Large Eddy Simulation of two inline wind turbines, Dabas et al 2022

[1] Pierella, F., Krogstad, P.-Å. et Sætran, L. (2014). Blind test 2 calculations for two in-line model wind turbines where the downstream turbine operates at various rotational speeds. Renewable Energy, 70:62–77.

Dabas et al

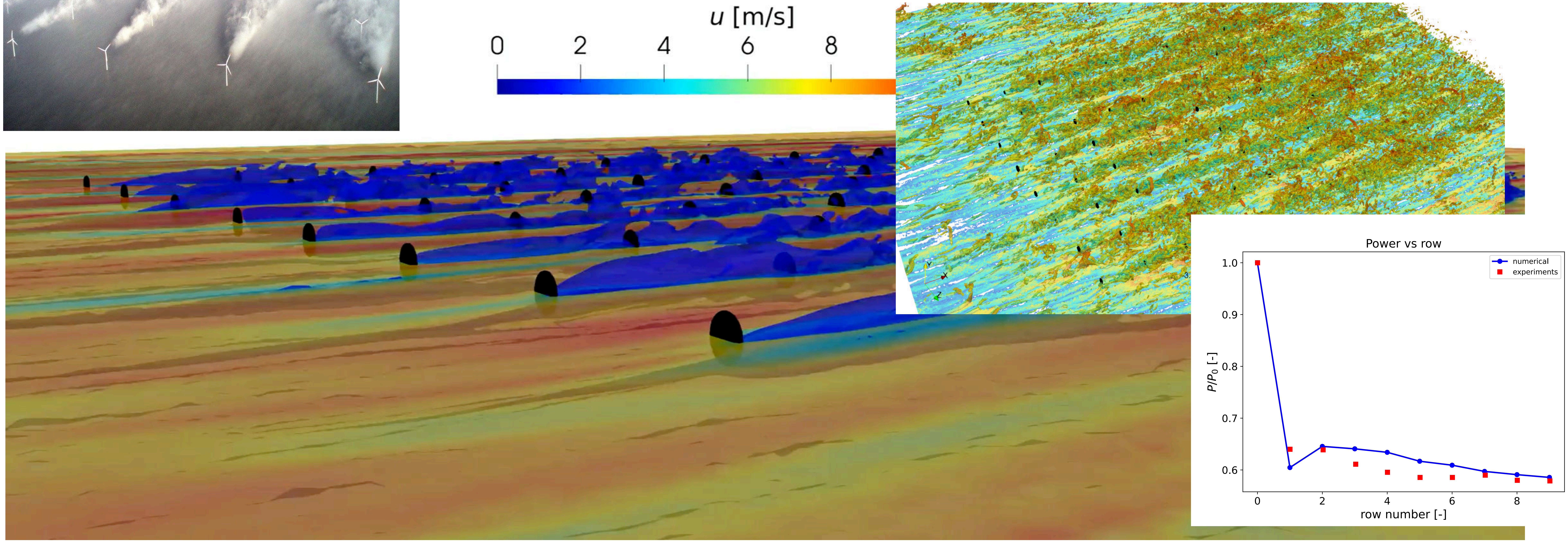
80 windturbine farm demonstrator

ADASTRA

Dabas et al

Time: 1795 s

X30 gain in time to solution using AMD GPUs

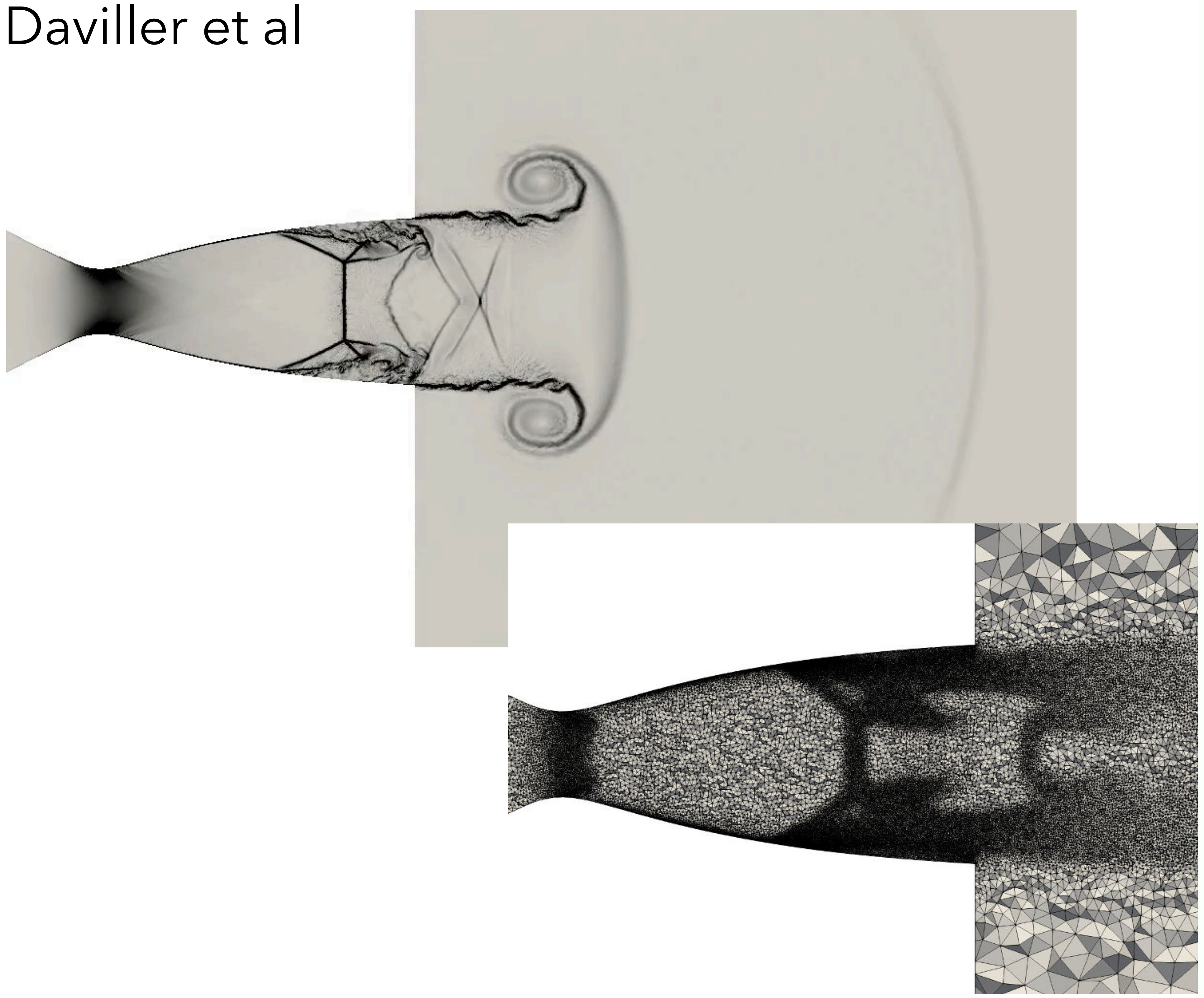


Adaptative Mesh

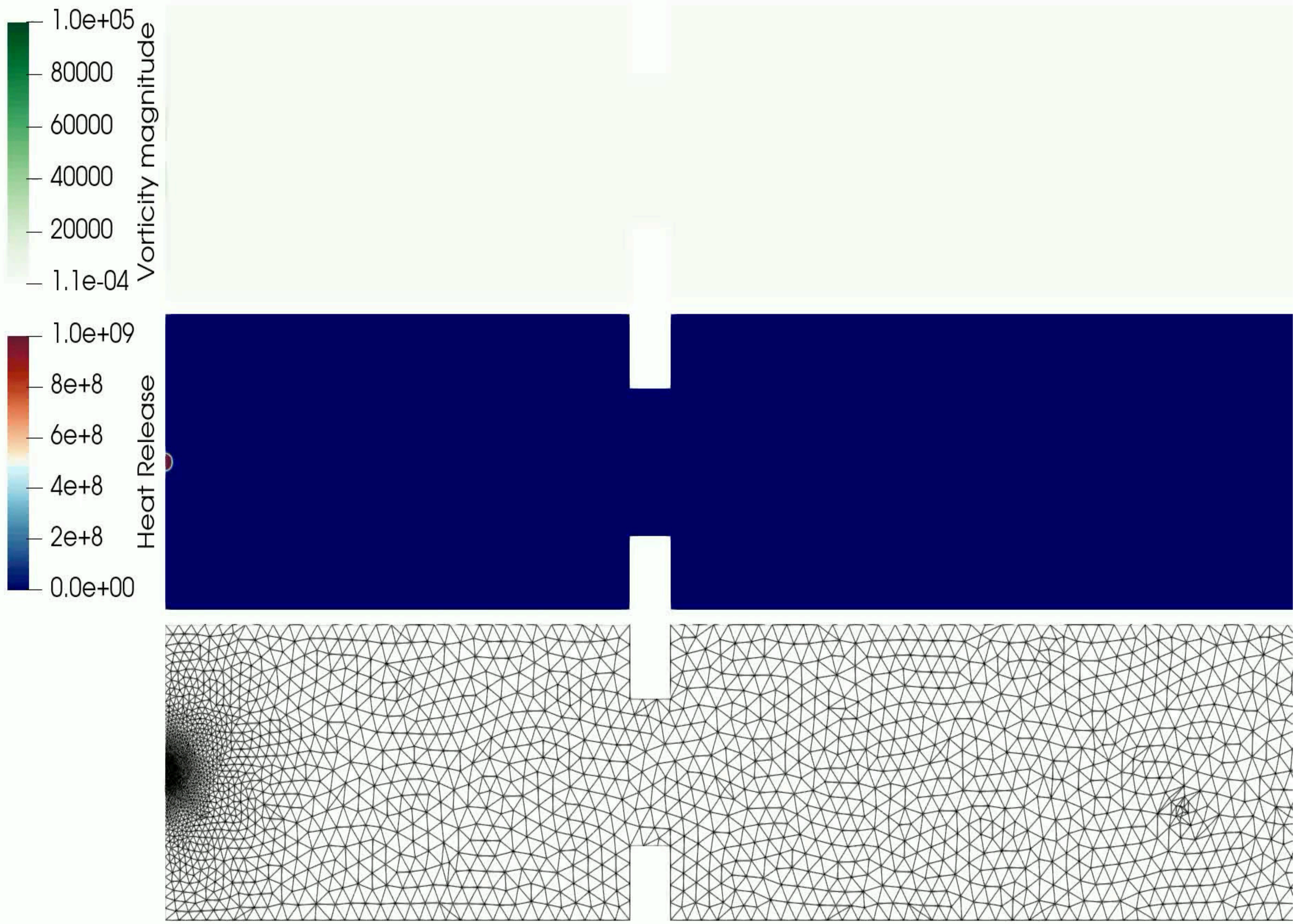
EXCELLERAT

Physics informed Static mesh generation: TIC Nozzle

Daviller et al



Automatic Mesh adaptation : Safety simulations



Meziat et al

[6] Daviller G., Dombard J., Staffelbach G., Herpe J. & Saucereau D. « Prediction of Flow Separation and Side-Loads in Rocket Nozzle Using Large-Eddy Simulation ». Int. J. Comp. Fluid Dyn. 2020.

Co-simulation learning

RAISE
Center of Excellence

AVBP Fortran

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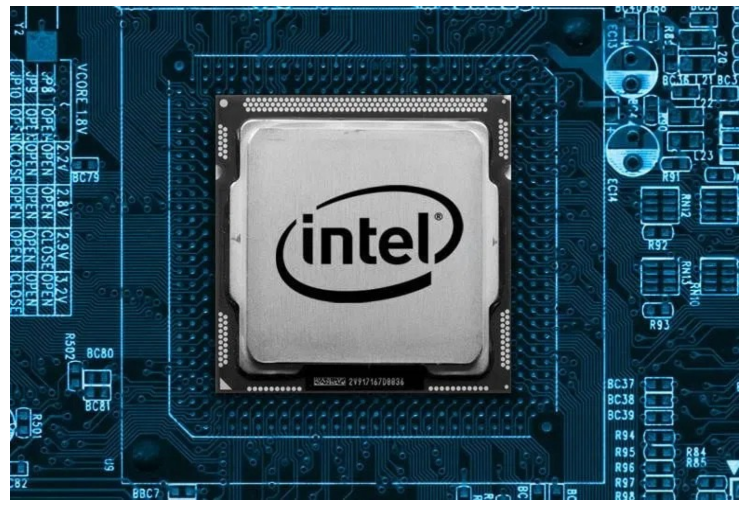
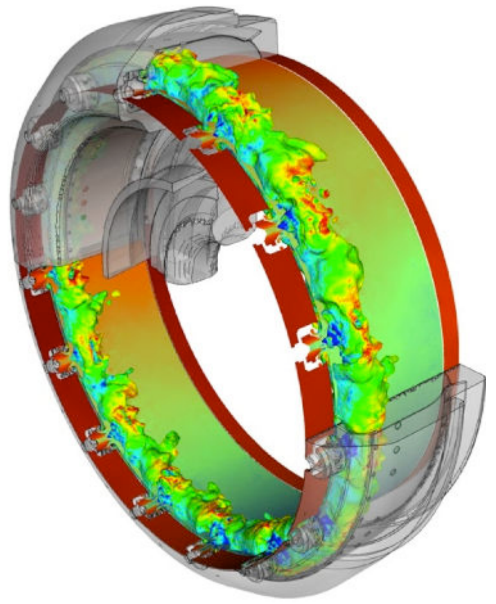
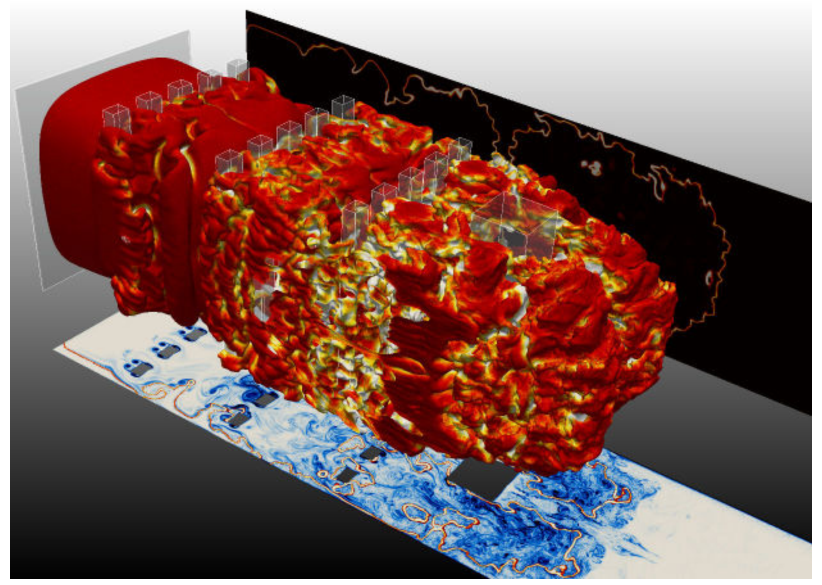






AVBP+PhyDLL

MPMD (Multiple Program Multiple Data)

```
mpirun –n 16 EXECAVBP : –n 2 python dl.py
```

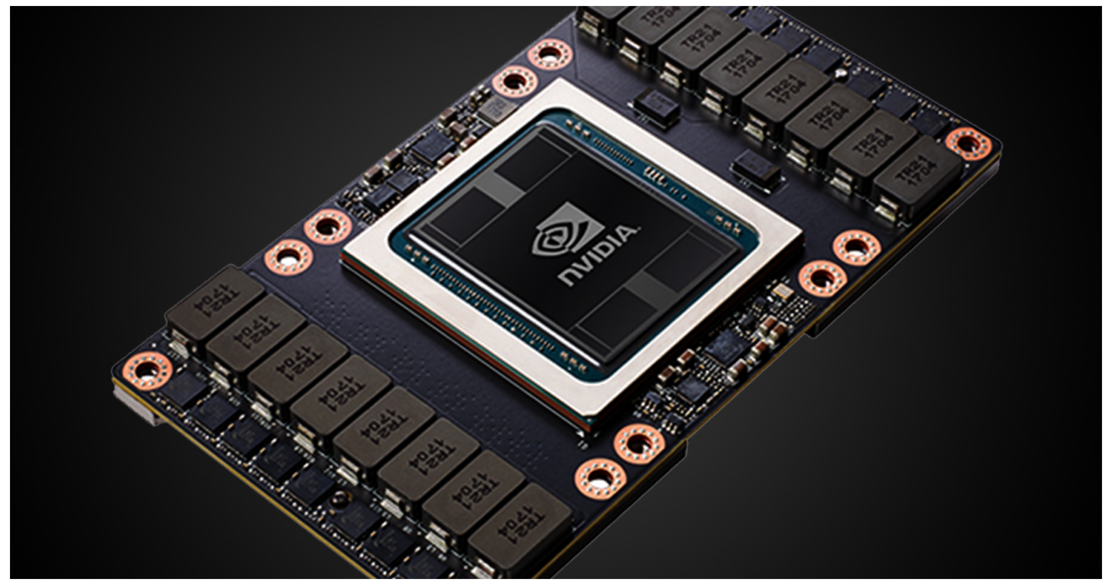
COUPLING Interface

- CWIPI
- MPI

ONERA
THE FRENCH AEROSPACE LAB

MPI

python™ TensorFlow PyTorch

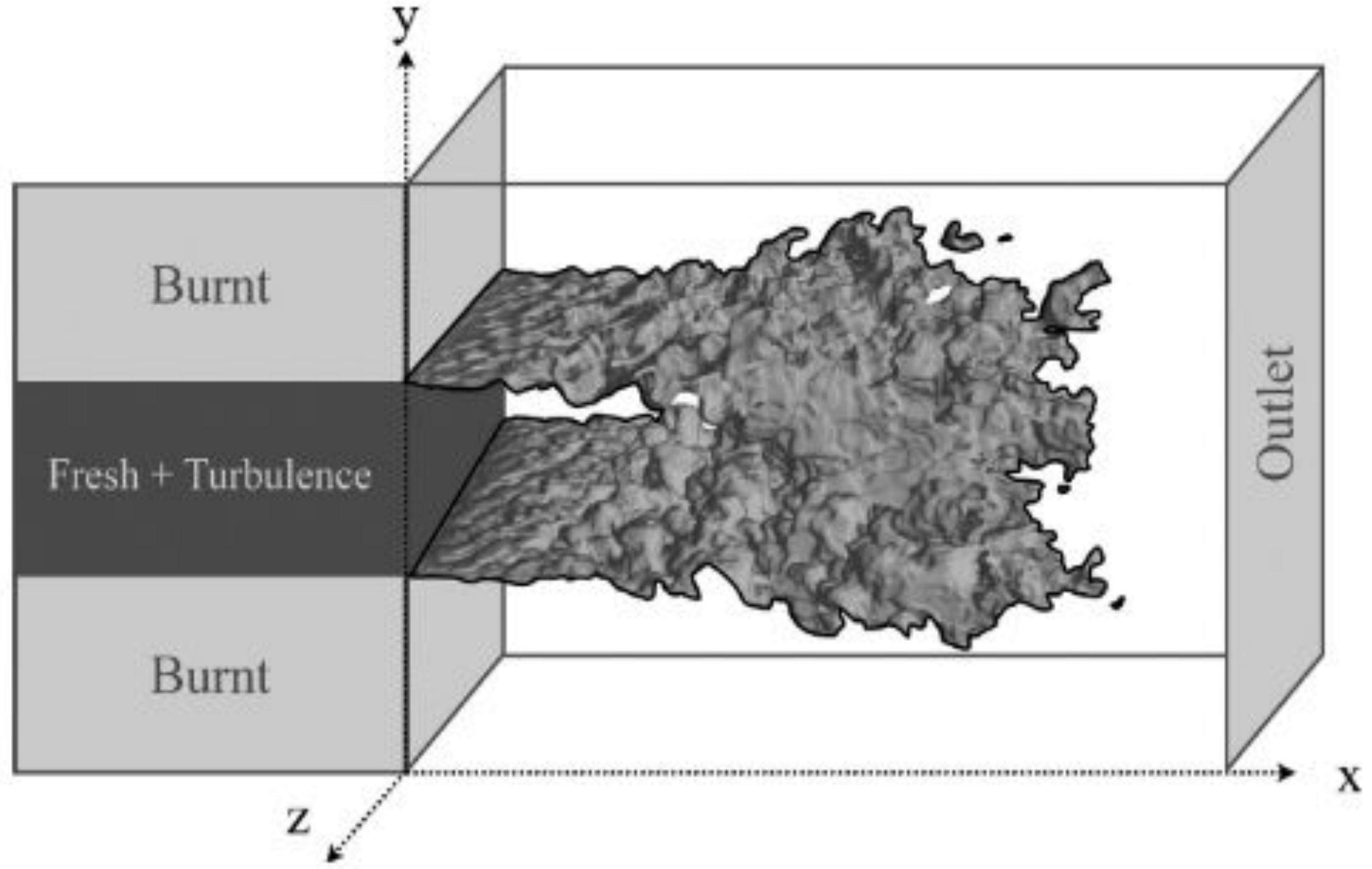


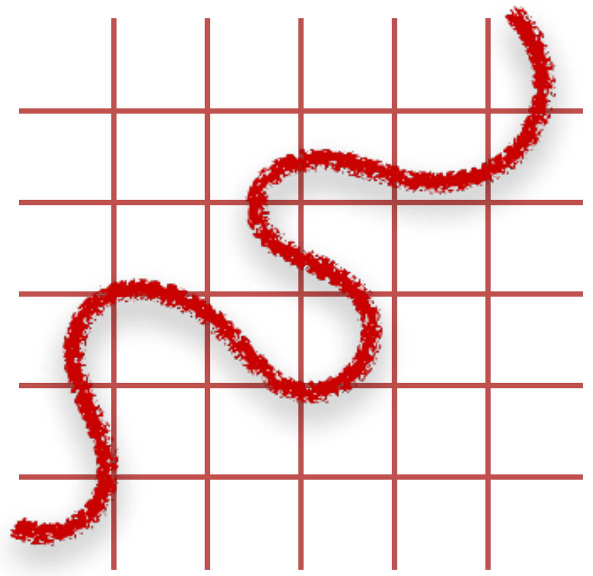
DL CNN/GNN inference

[1] https://www.cerfacs.fr/avbp7x/

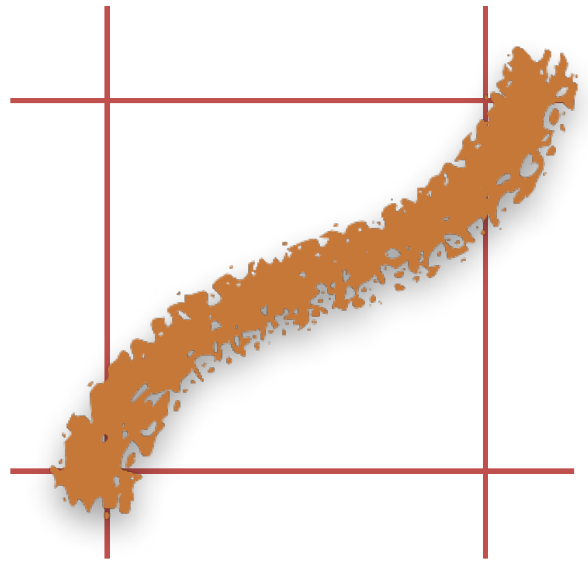
AI and simulation

- Replace sub grid-scale combustion model with AI





DNS : resolved flame front



LES : missing wrinkling

SGS slot-burner

$(\ldots, \quad \bar{c} \quad , \ldots)$

Progress-variable

Classical computations

~~Charlette model~~

Reaction-rate

$(\ldots, \quad \bar{\dot{\omega}} \quad , \ldots)$

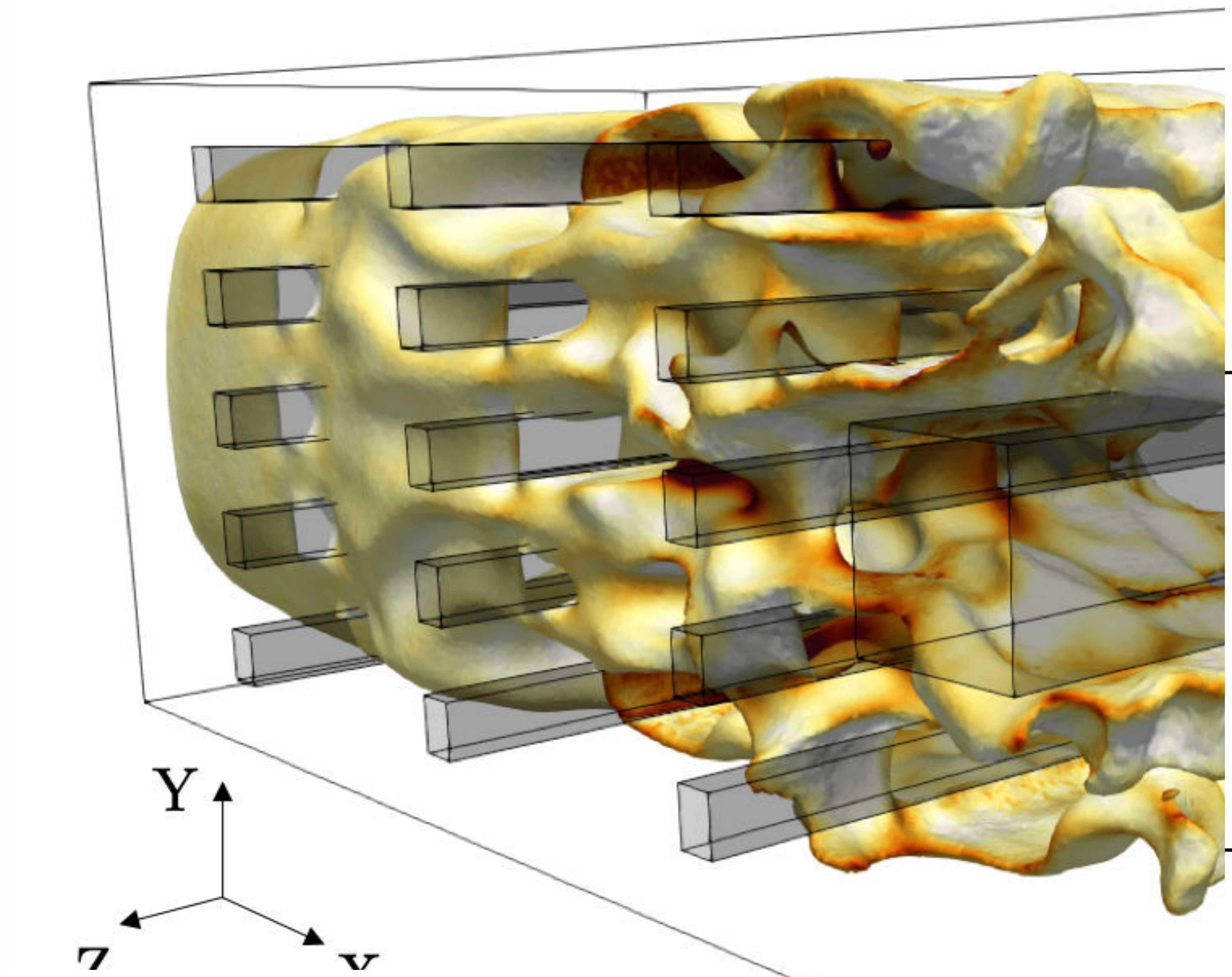
Update $\bar{\dot{\omega}} = \bar{\Xi}\, \dot{\omega}(\bar{c})$

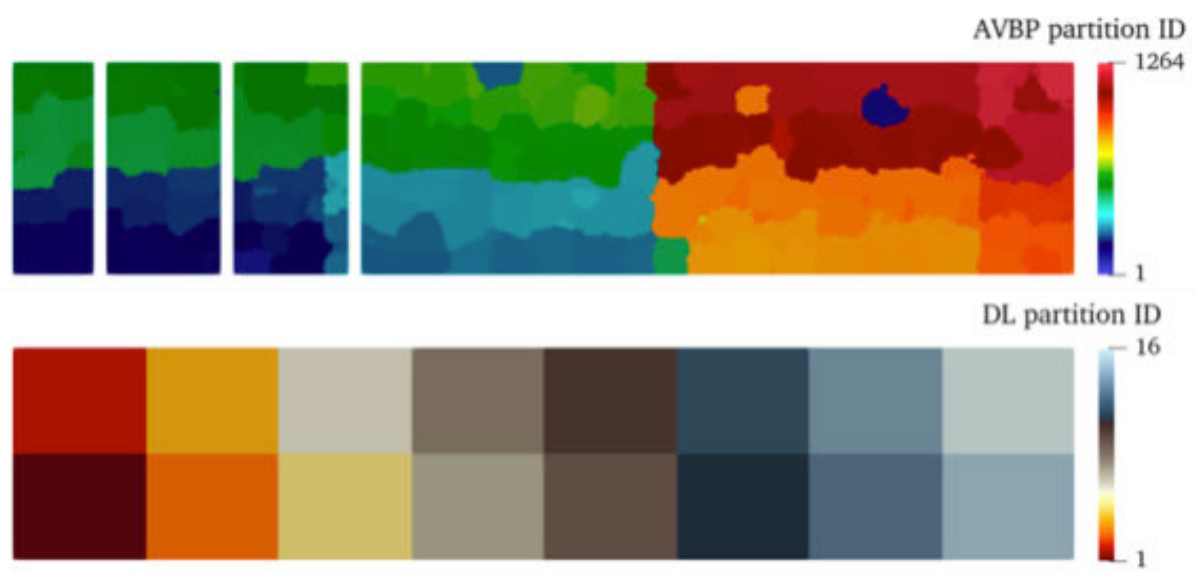
input $\bar{c}$ → **Convolutional Neural Net (CNN)** → output Ξ SGS flame wrinkling

C. Lapeyre et al., *Training convolutional neural networks to estimate turbulent sub-grid scale reaction rates*, Combustion and Flame, Volume 203, 2019, Pages 255-264.

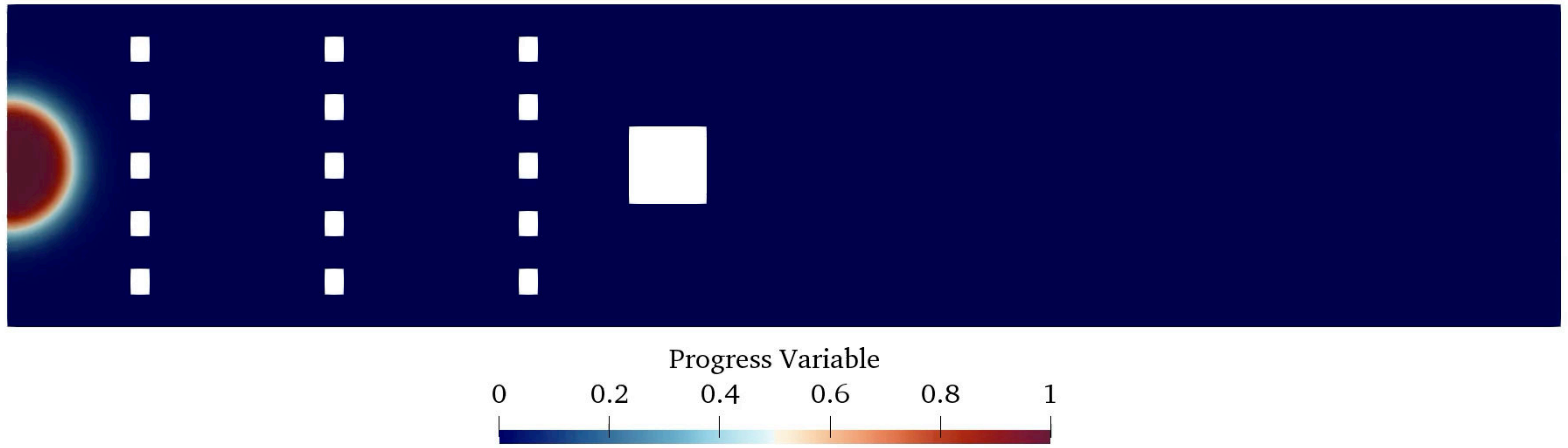
[2] V. Xing et al., Generalization capability of convolutional neural networks for variable variance and reaction rate subgrid-scale modeling, Energies, 14(16), 2021.

Serhani et al

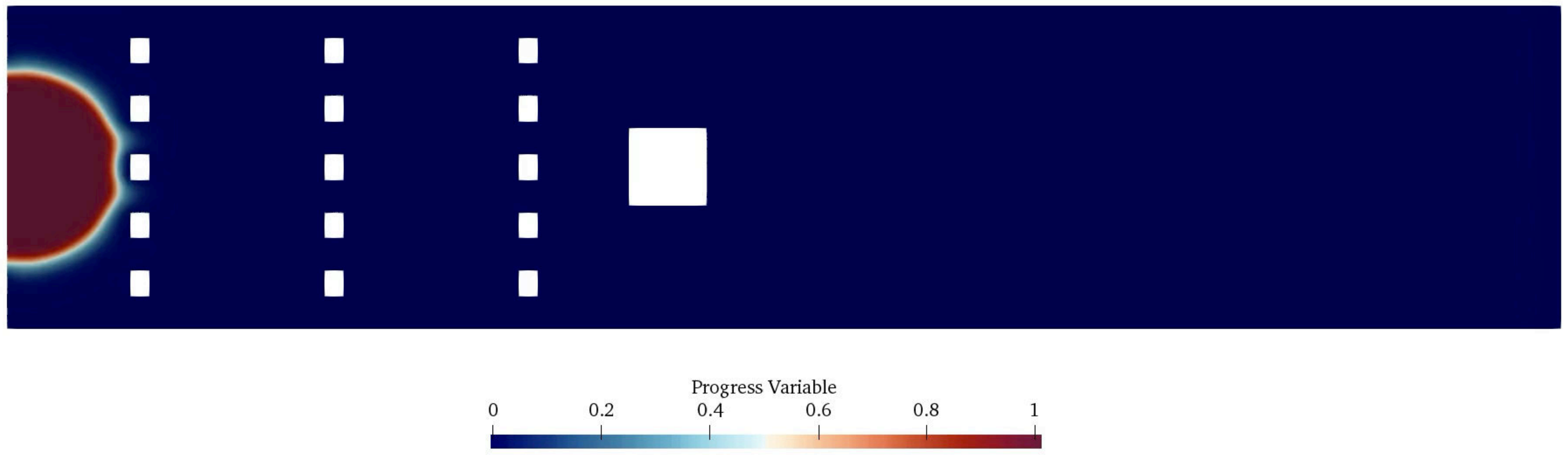


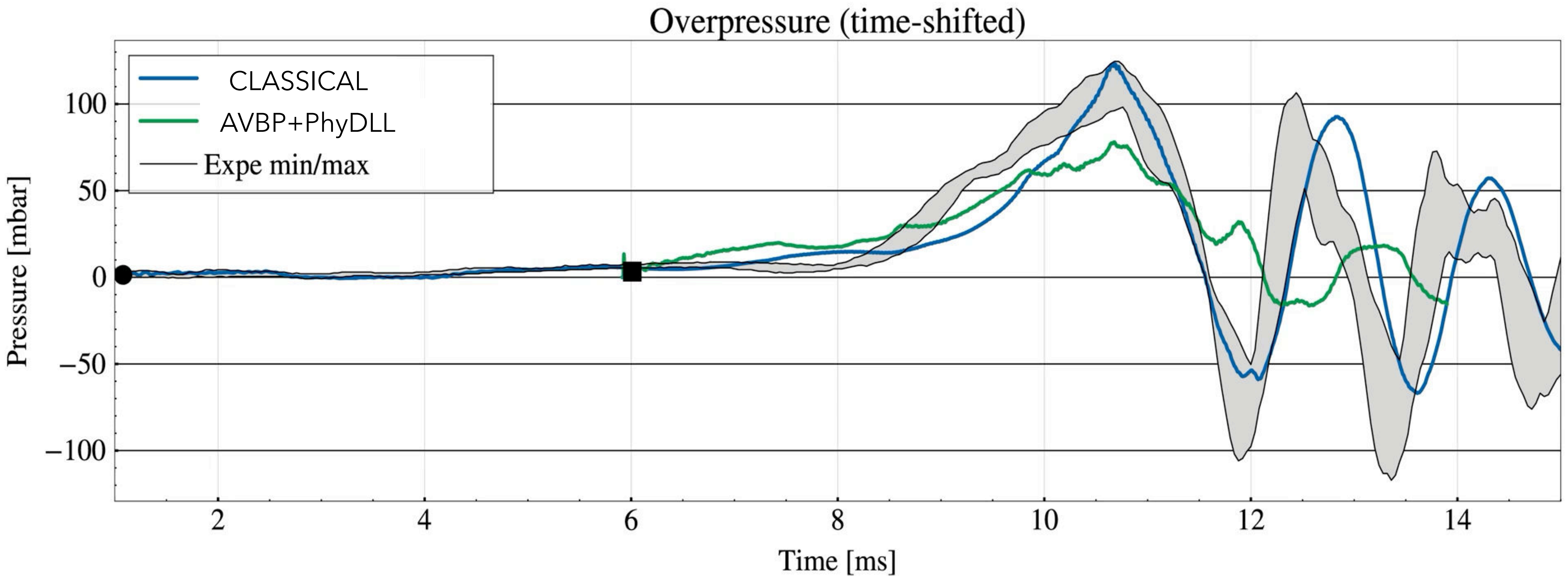


Time: 0.1 ms CLASSICAL

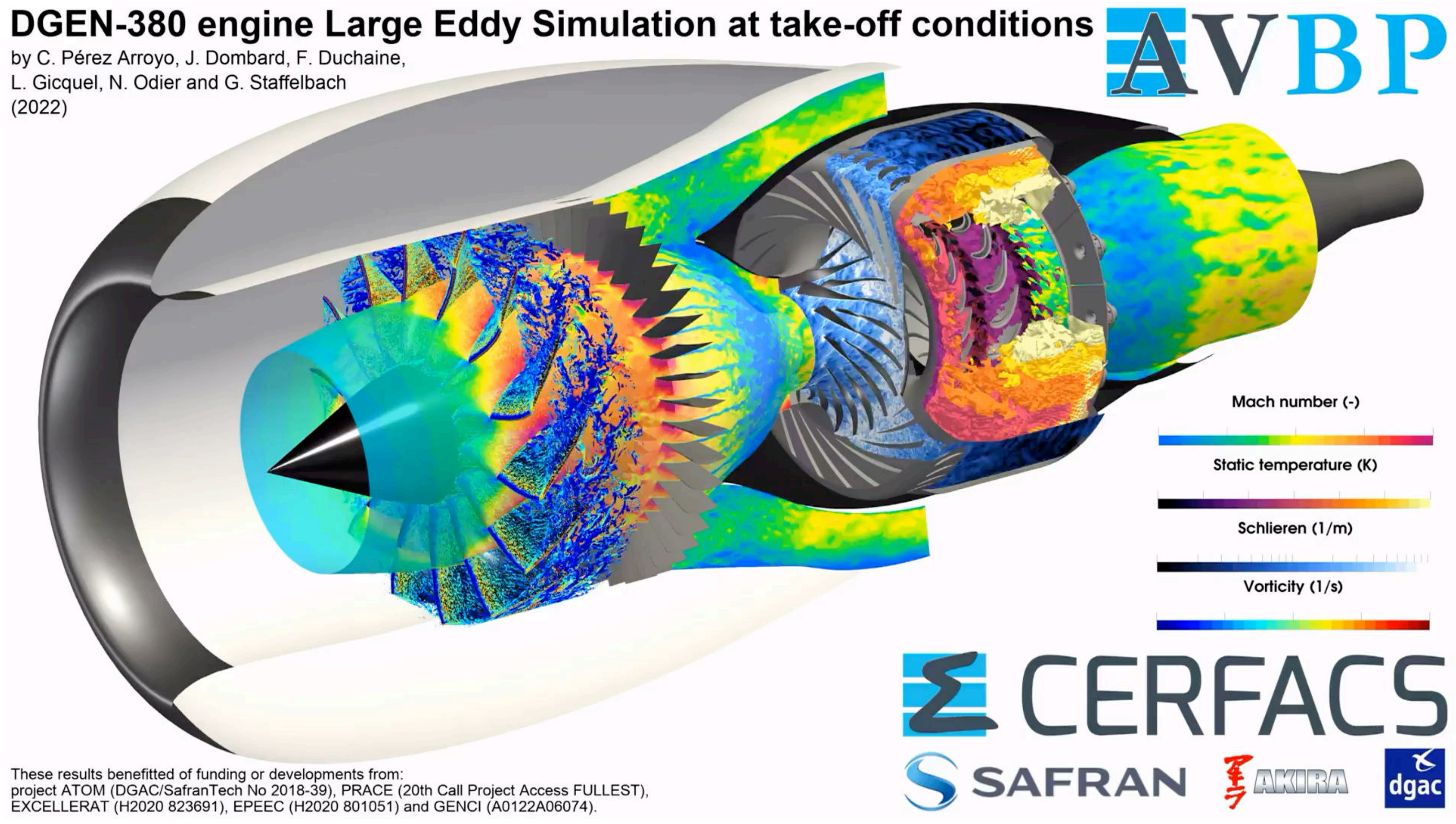


Time: 3.1 ms AVBP+PhyDLL

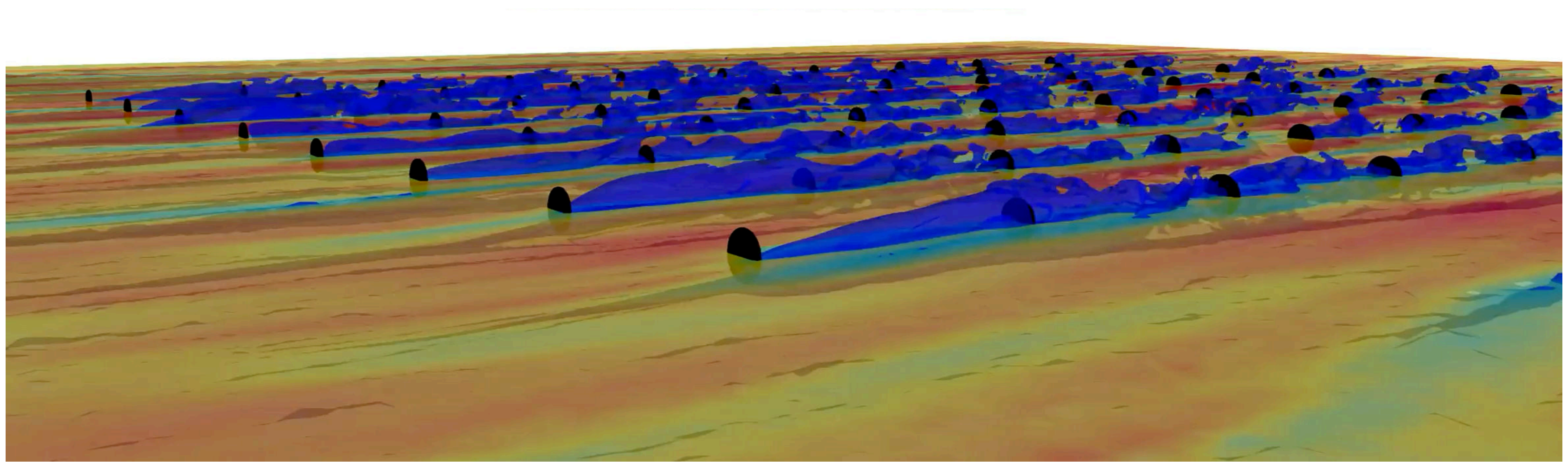


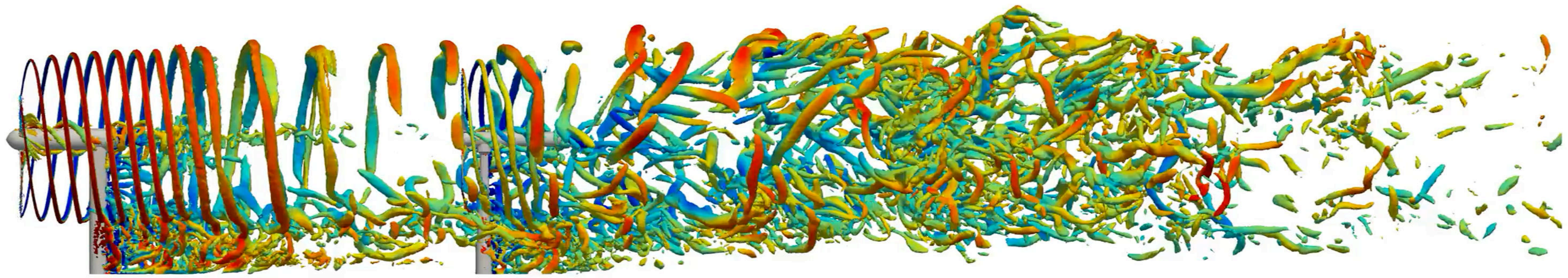


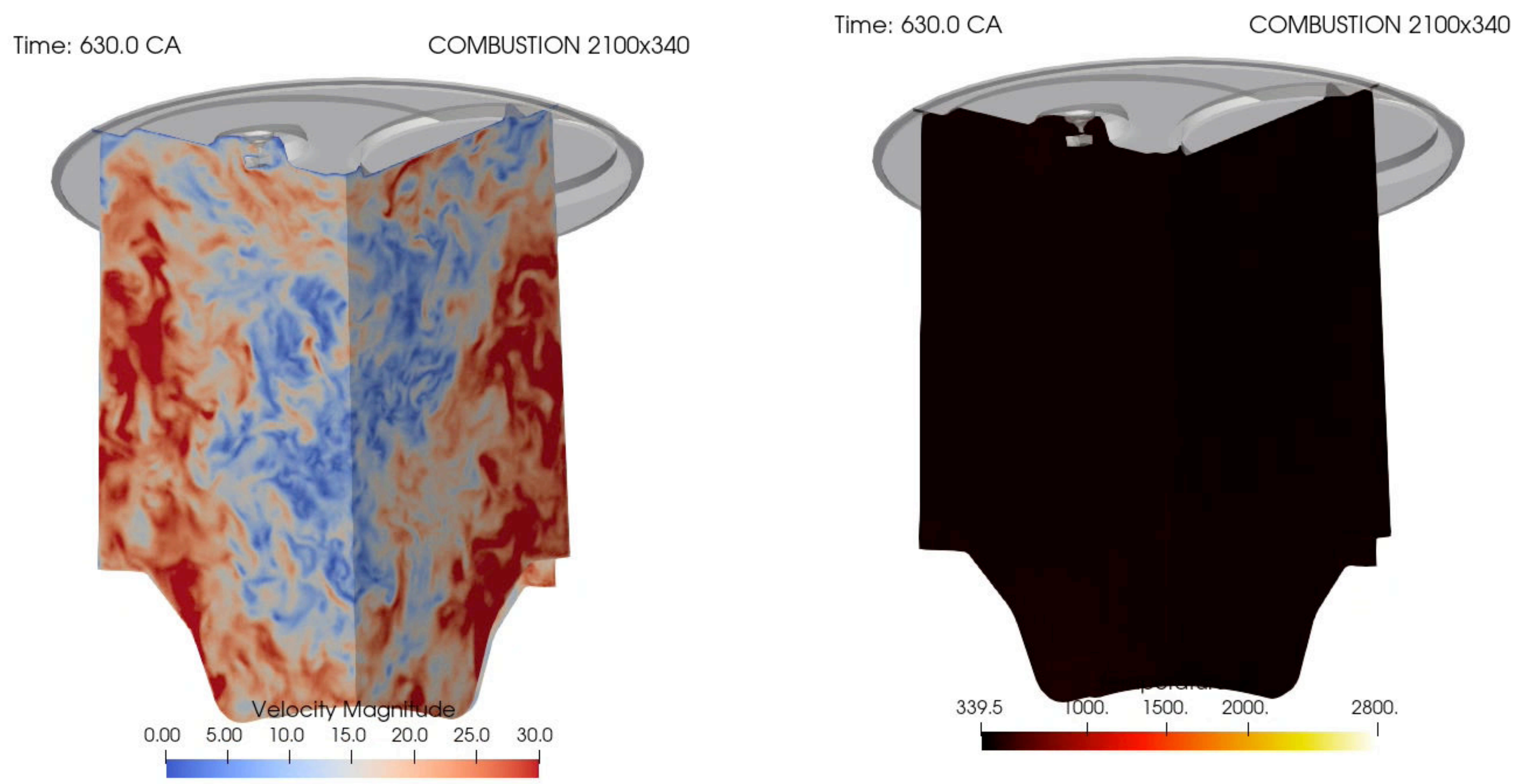
Thank you for your attention



Dabas et al







Dabas et al

Potier et al