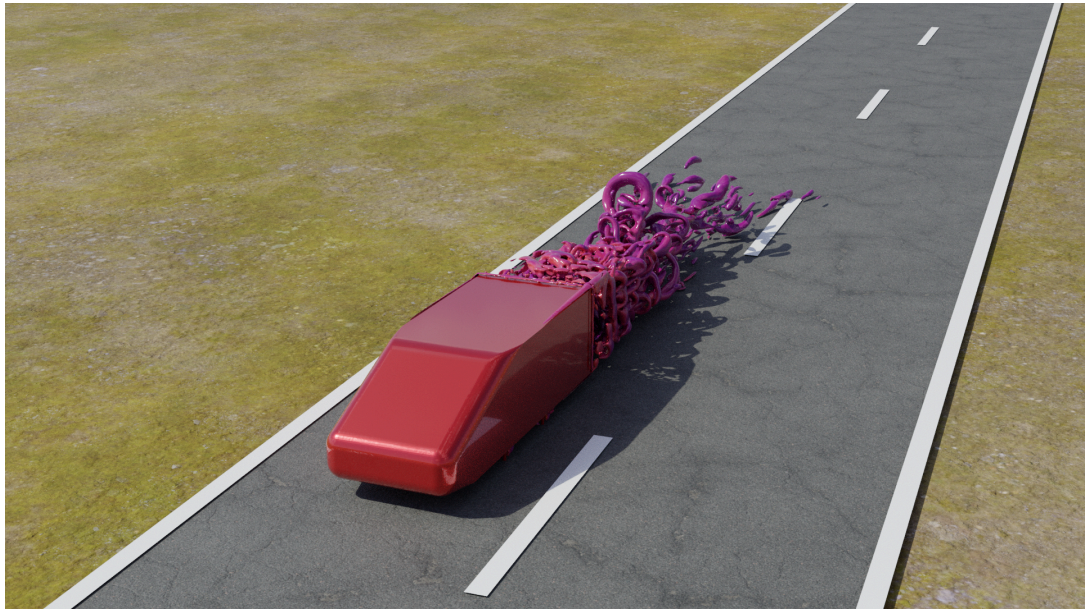
Assessment of code_saturne

Case 1: Windsor squareback at 2.5° yaw

From steady RANS to hybrid RANS-LES

Florian Hermet, Maxime Gueguin
Simvia, EDF Group

5th Automotive CFD Prediction Workshop,
Bologna, 8-9 October 2026

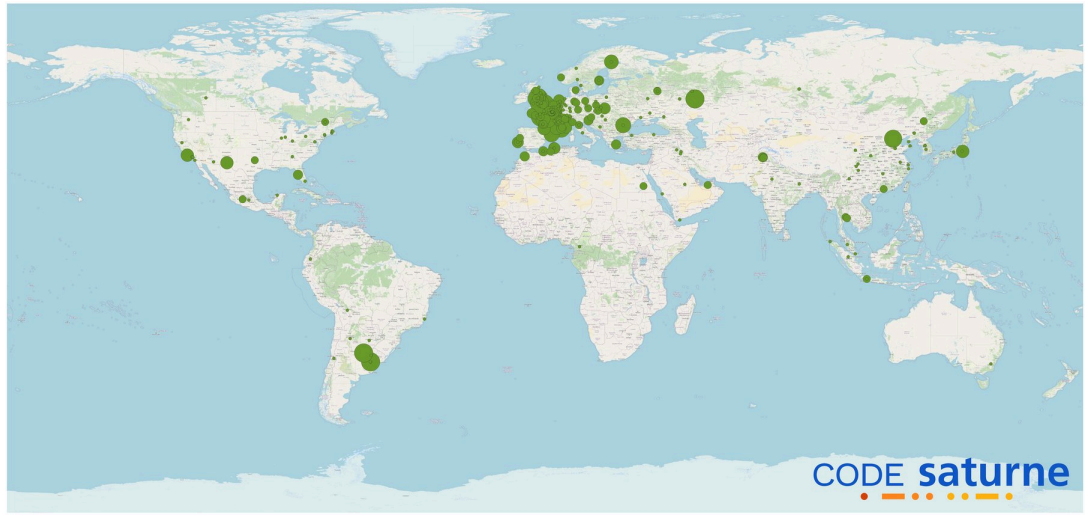


Q-criterion, SST-DDES, code_saturne

code_saturne

What it is

- General-purpose CFD code developed by EDF R&D
- Open source (GPL) since 2007
- Finite volume, co-located, arbitrary polyhedral meshes
- Massively parallel MPI / OpenMP
- Advanced multiphysics: combustion, radiation, particles, compressible & multiphase flows, MHD, atmospheric flows, ALE/FSI...
- Industrial-grade, validated for EDF nuclear safety applications
- Industrial support: Simvia - EDF Group



code_saturne users worldwide

Turbulence portfolio

- RANS: k-ϵ, k-ω SST, EB-RSM
- LES: Smagorinsky, WALE
- Hybrid RANS-LES: DES, DDES, SAS, HTLES

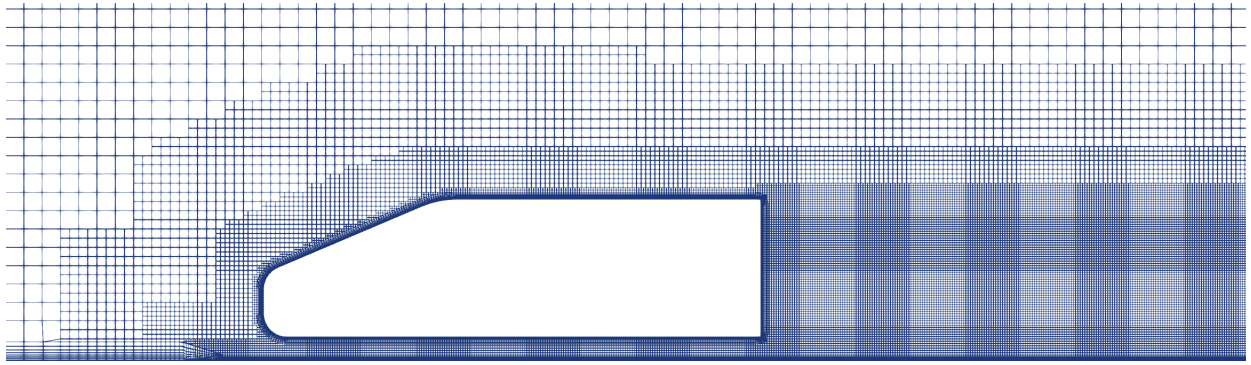
Scan to download code_saturne

Case and numerical setup

Scan to download this study

Numerics

- k-ω SST, two-scale log-law wall function
- SIMPLEC, 2nd-order centred schemes
- Forces integrated over the body zones in a user routine

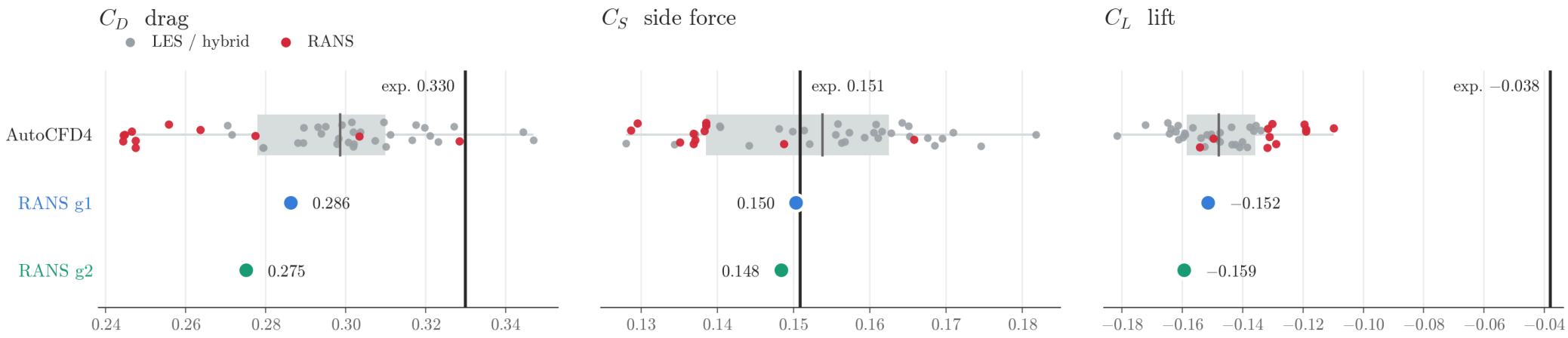


g1 and g2: near-uniform refinement, both $y^+ \approx 30$ with wall functions.

Four computations, covering both modelling families available in the code:

Computation	Mesh	Cells	Model	Time step	Purpose
RANS g1	g1	6.3 M	k-ω SST	steady, local	baseline
RANS g2	g2	37.4 M	k-ω SST	steady, local	mesh sensitivity
SST-DDES g1	g1	6.3 M	SST-DDES	8×10^{-5} s	hybrid RANS-LES
SST-DDES g1 refined	g1 + local	15.8 M	SST-DDES	8×10^{-5} s	wake resolution

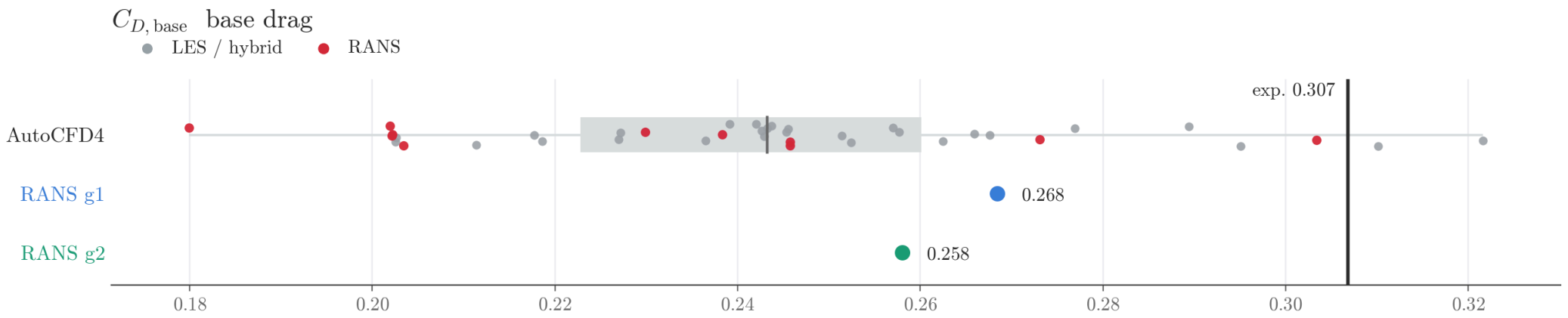
Integrated forces vs the AutoCFD4 submissions



- C_D *top of the RANS group (red), closer to the measurement than most of it*
- C_S *on the measured value, above the RANS group*
- C_L *low edge of the cloud, but every submission misses the measurement*
- *g1 → g2 a sixfold refinement changes little, and not towards the measurement*

On integrated forces, code_saturne is at the level of the commercial solvers

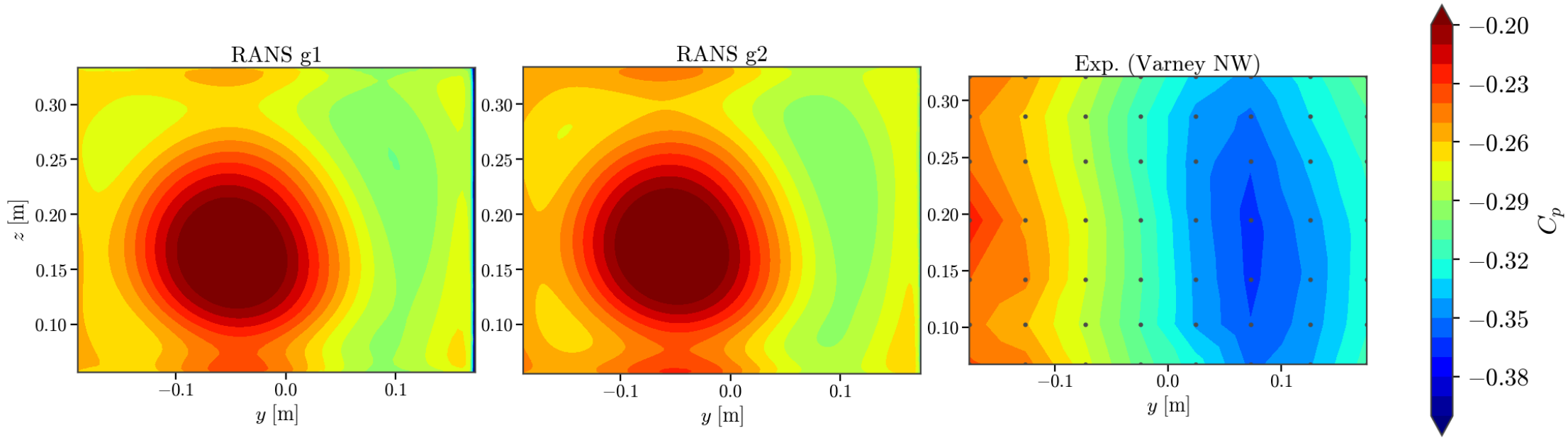
Base drag drives the C_D deficit



- *Base drag is recovered by integrating the 56 base pressure taps, which cover exactly the reference area*
- *g1 → g2 lowers base drag, so refinement again moves away from the measurement*
- *Base suction is still under-predicted*

The drag deficit is a base-pressure problem, not a forebody or friction one

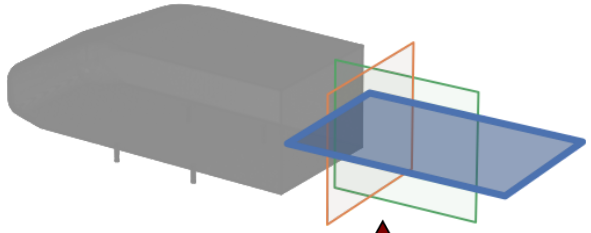
Pressure distribution on the base

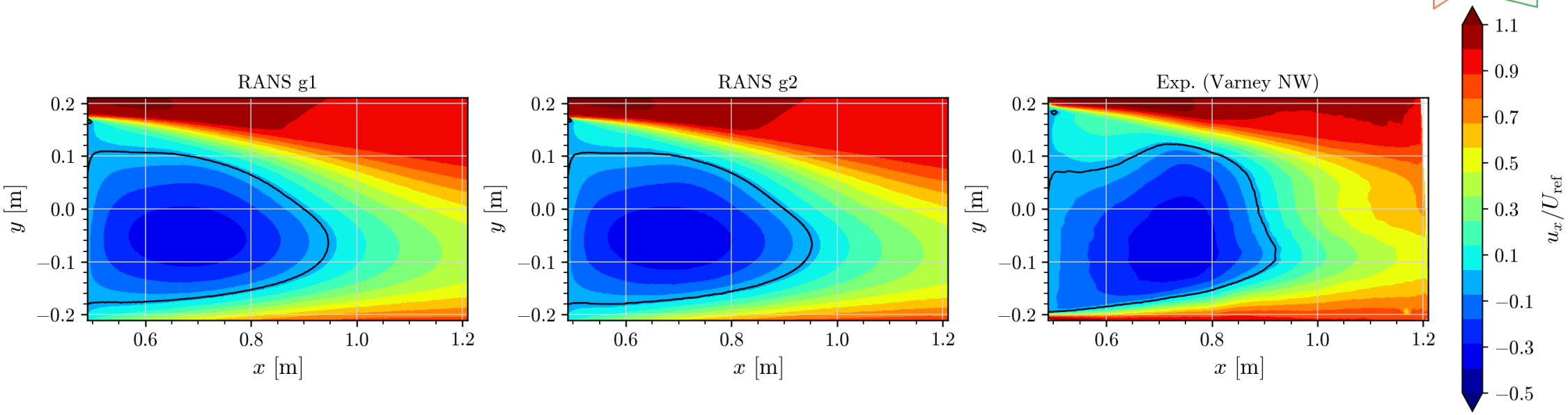


- *Measured: a lateral gradient across the base, set by the yaw*
- *RANS: a concentrated central core, and the measured suction is never reached*
- *g1 → g2 leaves the central core unchanged, the grids differ only near the edges*

RANS misses the structure of the base pressure, not only its level

Shape of the recirculation

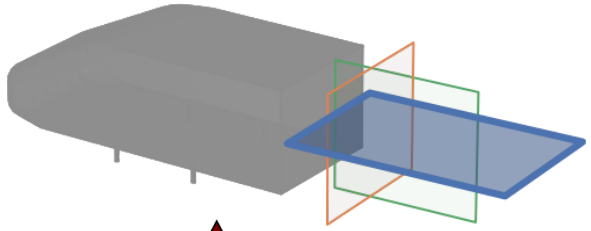


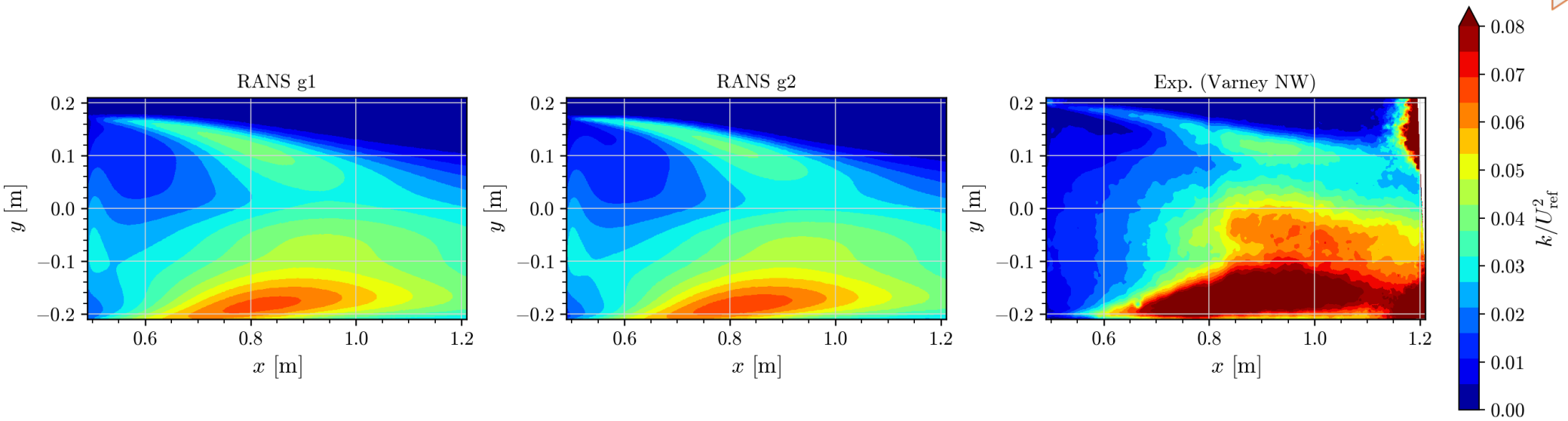


- *The yaw-induced asymmetry is reproduced*
- *The bubble is too long and too narrow, its length-to-width ratio too high*
- *Yet the reversed-flow area and the reverse-flow strength both match: the two shape errors compensate*

The mean wake differs in shape, not in strength

Turbulent kinetic energy



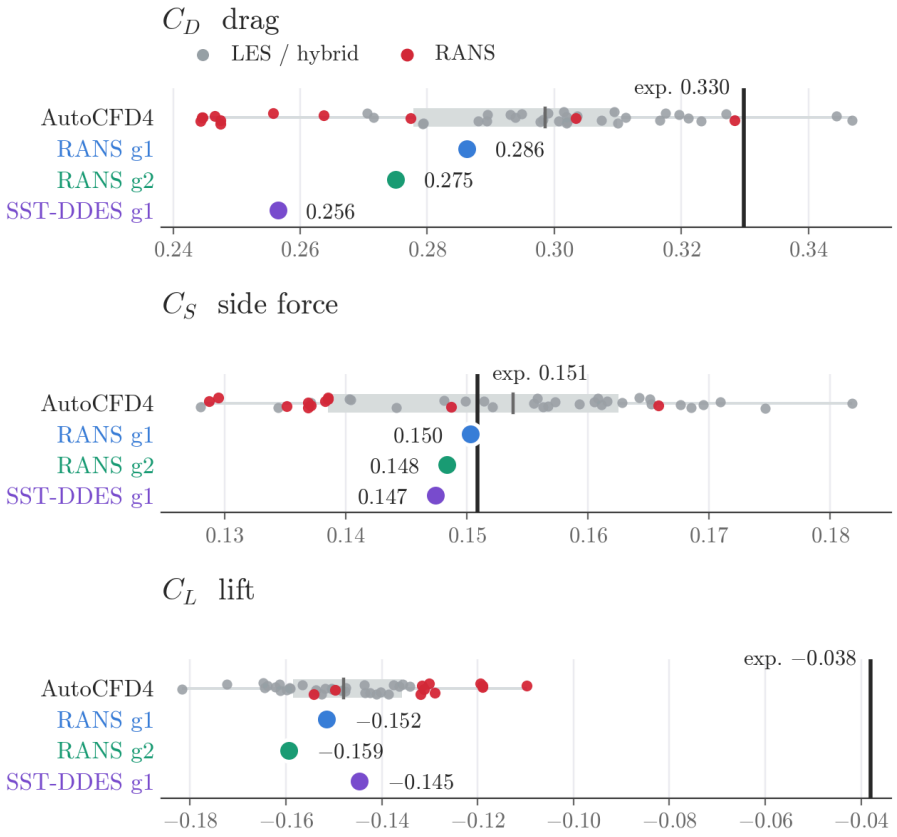


- *Modelled k stays in a thin band along the shear layer, at most two thirds of the measured level*
- *The PIV shows a much broader region, filling the recirculation itself, where the mean shear is weak*
- *g1 → g2 changes neither the level nor the distribution*

The missing turbulence comes from the model, not from the mesh

Does supplying it also restore the base suction? → SST-DDES

SST-DDES on g1: setup and integrated forces

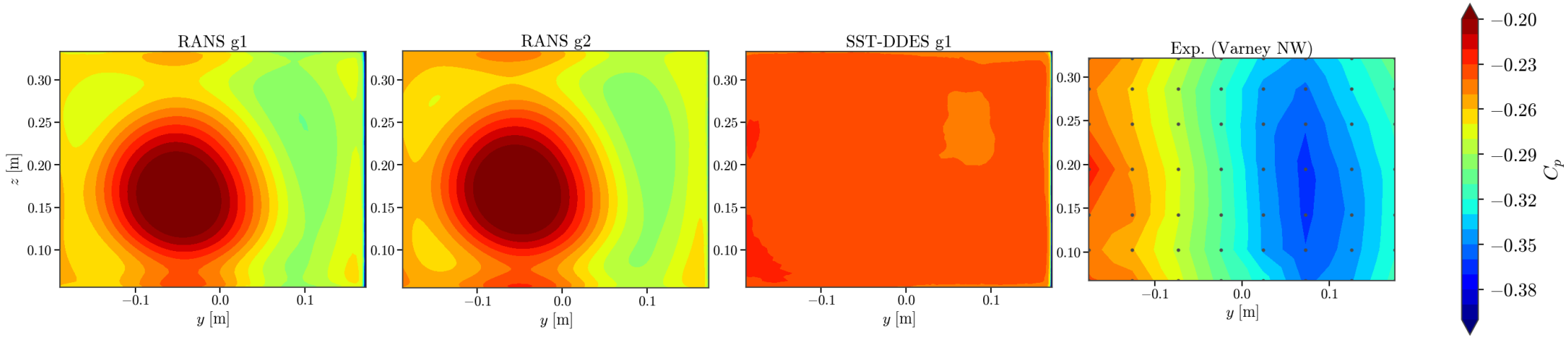


Setup

- Shielded SST-DDES
- Same g1 mesh, same boundary conditions
- Started from the converged RANS solution
- Averaging window 4.0 s, near 150 convective times L/U_{ref}

- *Side force and lift remain in line with the RANS results*
- *C_D is now worse than on either RANS grid, with most of the discrepancy coming from the base, where the pressure distribution is poorly reproduced*

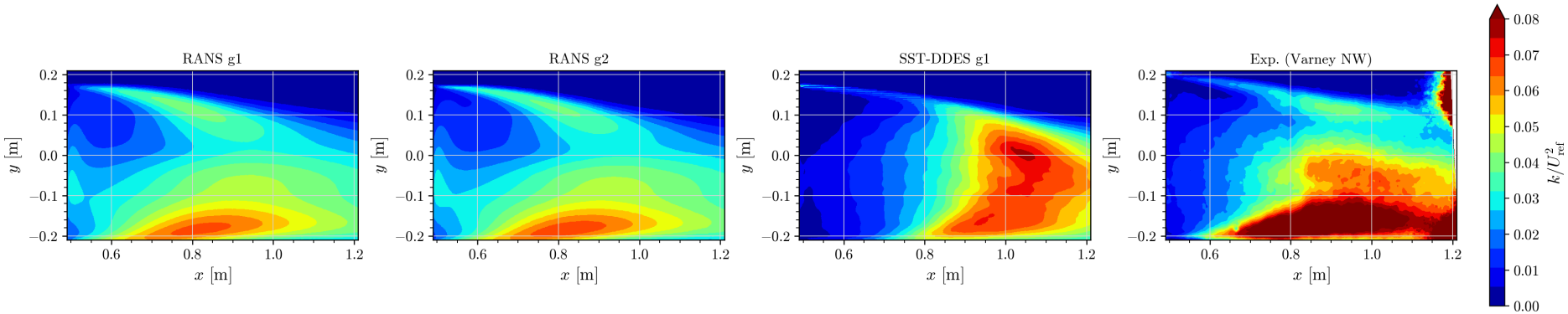
SST-DDES on g1: pressure on the base



- *The SST-DDES base carries no structure at all: it is nearly uniform, and the yaw gradient has disappeared*
- *It is also the weakest mean suction of the three computations, which is where the drag deficit of the previous slide comes from*

The hybrid model loses the base pressure structure that RANS still had

SST-DDES on g1: where the turbulence develops



What improves?

- *SST-DDES reaches the experimental TKE level.*

What is still wrong?

- *Turbulence develops too far downstream.*
- *The near wake remains too quiet.*
- *The recirculation closes too late.*

Why?

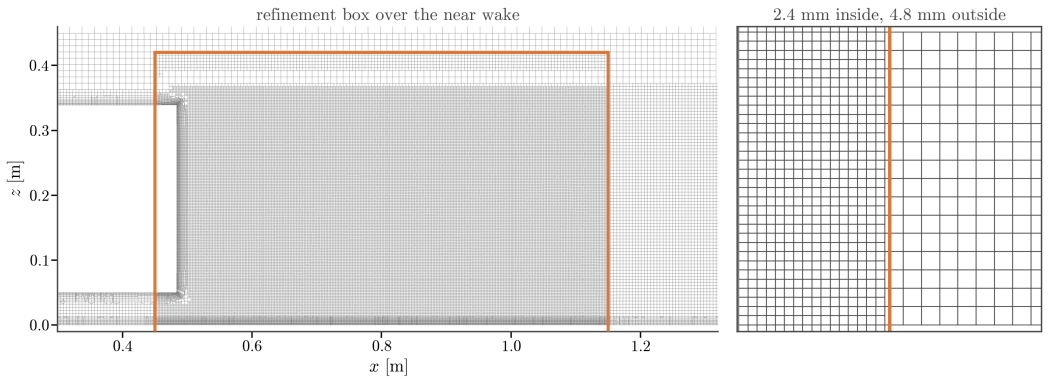
Resolved vs modelled turbulence is not the main issue

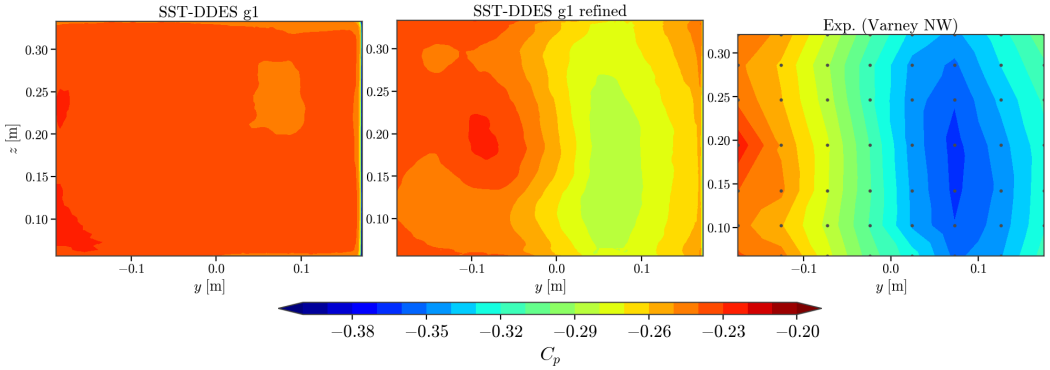
- *The resolved energy fraction satisfies Pope's criterion in the developed wake.*
- *But g1 is a RANS-designed mesh, with insufficient resolution across the separated shear layer.*

→ The shear-layer instability develops too late.

The issue is not the turbulence level, but where the turbulence develops.

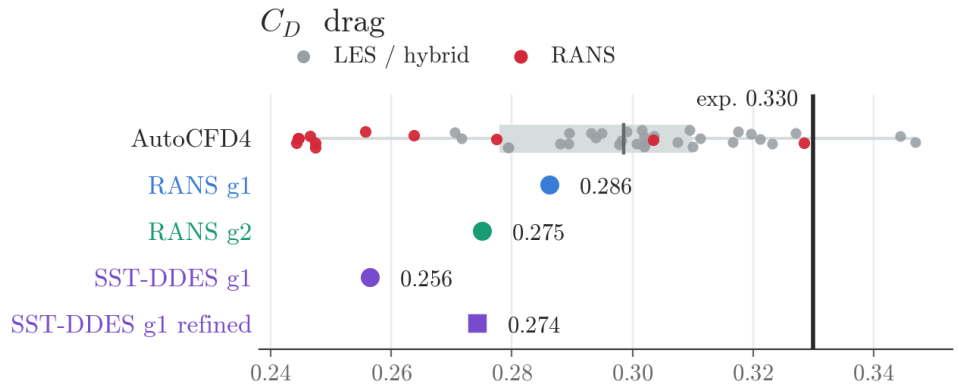
Refining the wake, without redoing the mesh





How to improve the SST-DDES results?

- Improve the mesh resolution in the near wake to allow the amplification of the shear-layer instability
- code_saturne can subdivide its own grid inside a box over the wake
- The g1 solution is interpolated onto it, nothing already computed is thrown away
- 6.3 to 15.8 M cells, 42 % of g2, for a third of the CPU cost of a full g2 DDES: 3 100 against 9 500 CPU-h per second of physical time



Conclusions

Everything this case needs is already in code_saturne

- Wall functions, steady RANS, hybrid RANS-LES
- Local mesh refinement, from inside the solver
- One open-source, industrially supported code

The RANS behaves as RANS

- Base suction under-predicted, recirculation too long, turbulence too weak
- These are offsets of the model, not of the solver

The SST-DDES behaves as a hybrid model on a RANS-grade grid

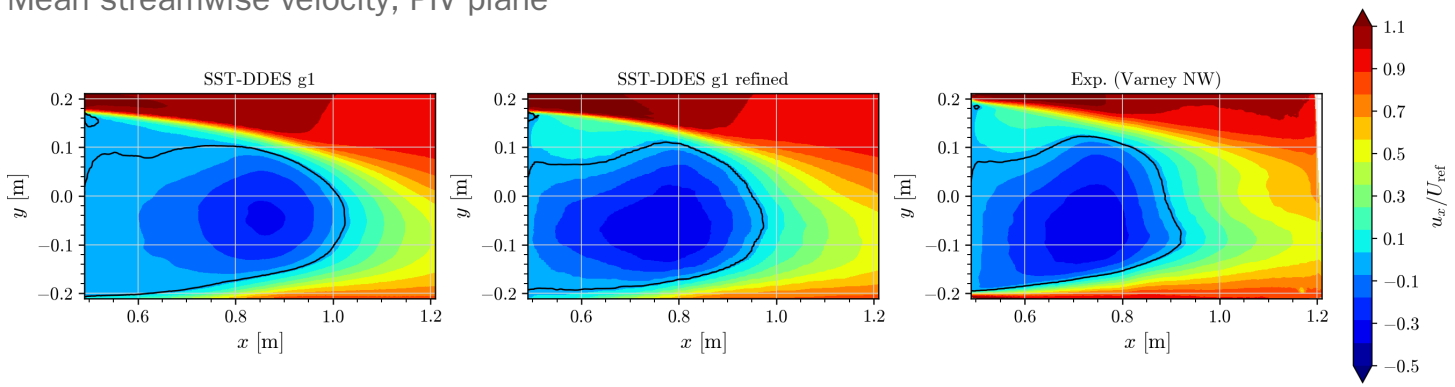
- The resolved turbulence appears, but too far downstream
- Refining the wake alone moves the turbulence back, and recovers a quarter of the drag deficit



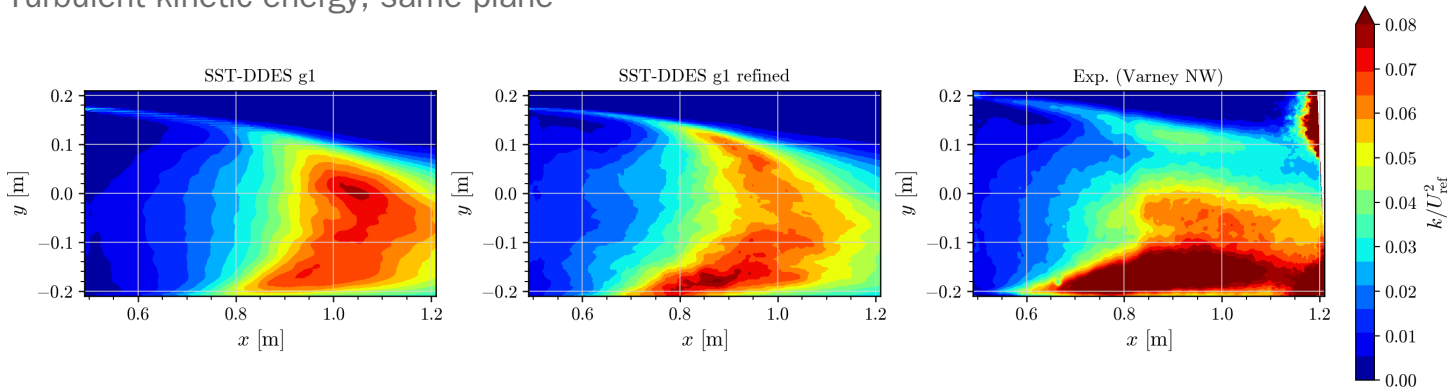
All case files, user routines and post-processing scripts are publicly available, so every result in this talk can be reproduced.

The wake, before and after refinement

Mean streamwise velocity, PIV plane



Turbulent kinetic energy, same plane



- *Recirculation closes earlier*
- *Turbulence develops further upstream, activating the shear layer sooner*
- *The main change is the location of turbulence, not its peak intensity*
- *This confirms the mechanism identified two slides earlier*