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On Low Reynolds Modelling Robustness for Industrial Flows and Feedback to L.E.S.

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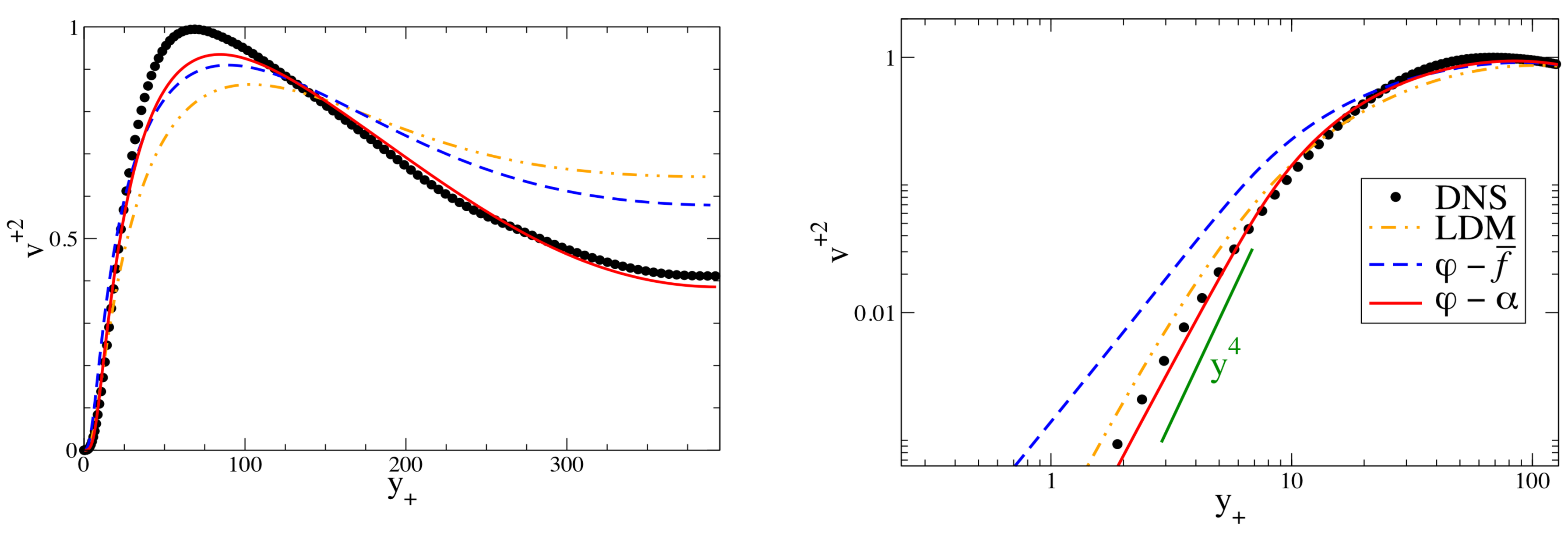
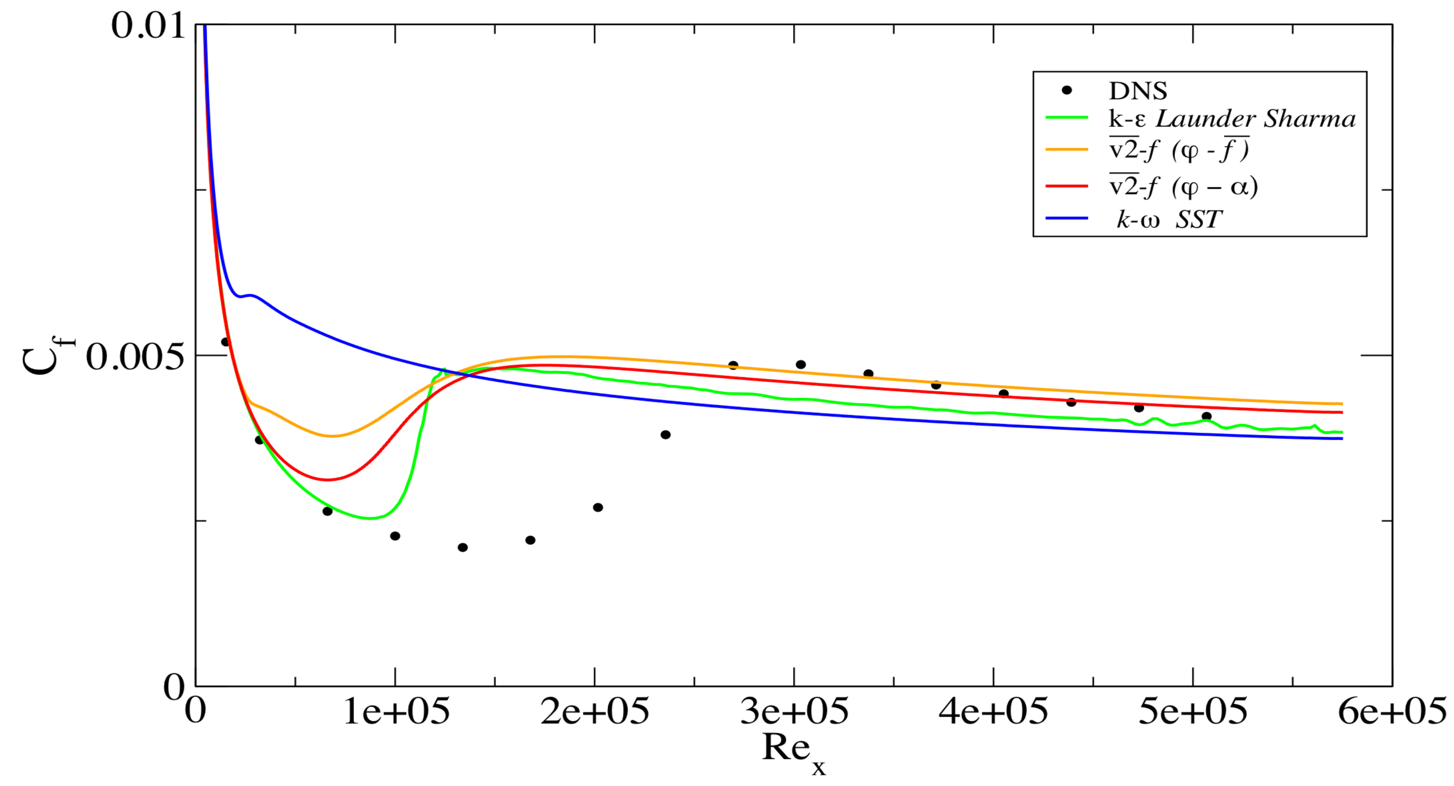
The φ-α model

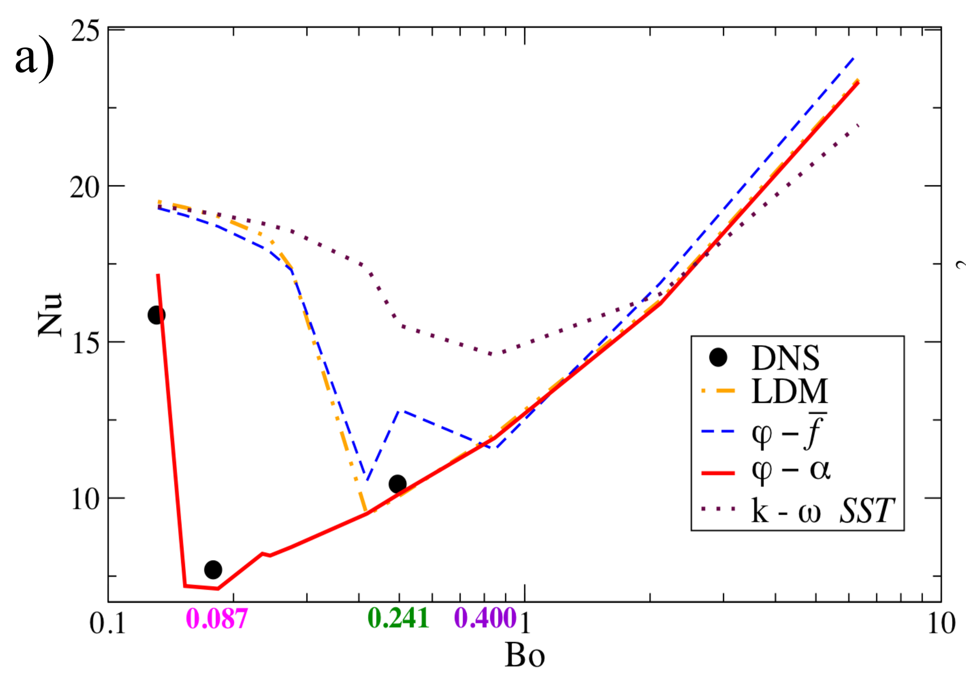
The aim of this work is to develop a RANS model as simple as eddy viscosity models, with good predictive capabilities to correctly reproduce near-wall effects, with emphasis on robustness when used in an industrial code such as Code_Saturne. It stems from a v^2-f based model (Durbin (1991)) (thus not requiring any ad-hoc damping function, distance to the wall dependent), and combines code-friendly modifications of Lien & Durbin (1996) and Laurence *et. al* (2004). The output, the φ-α is a model both robust (code-friendly boundary conditions) and accurate (no neglected terms). It replaces the elliptic relaxation of Durbin (1991) by the elliptic blending (Manceau (2002)) to enhance its robustness.

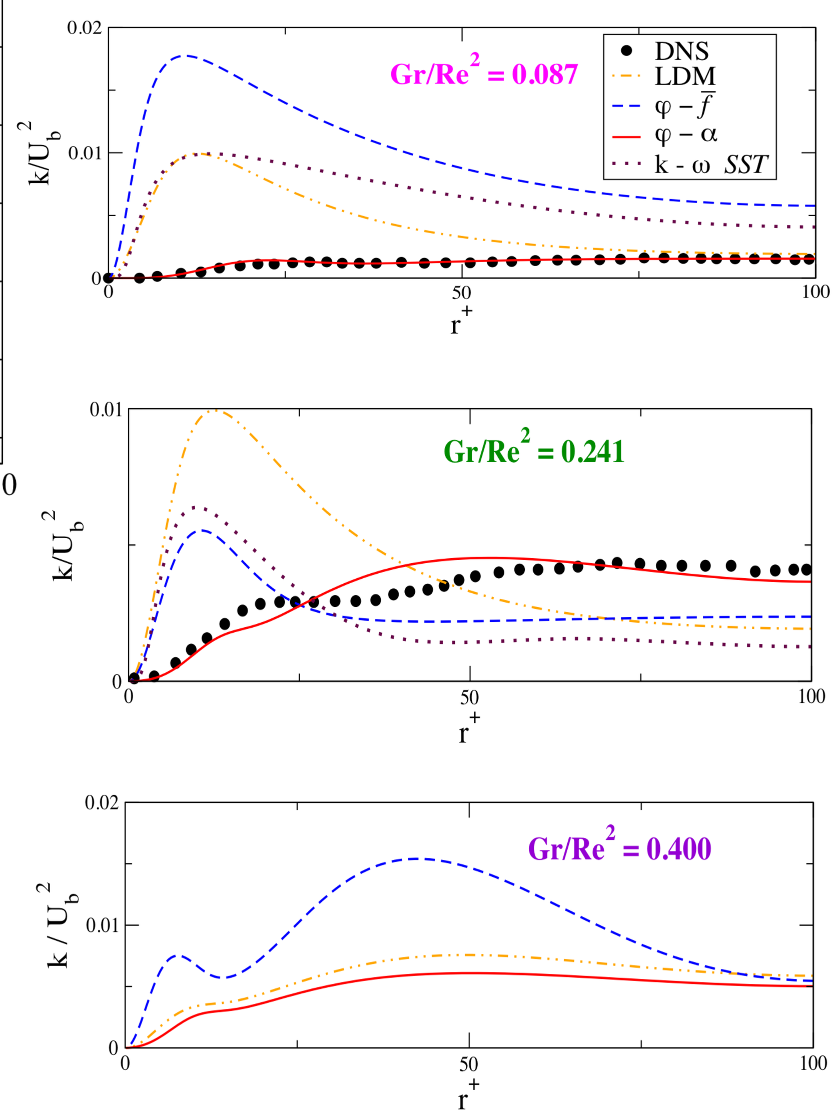


Prediction of v^2 in a channel flow (Re*=395) for the Lien & Durbin (LDM), the Laurence *et al.* (φ-f) and the Billard *et al.*(φ-α). The main difference between code-friendly versions of the v^2-f model is the way they handle the boundary condition given to the redistributive term f to give the correct near wall asymptotic behaviour (y^4) of v^2

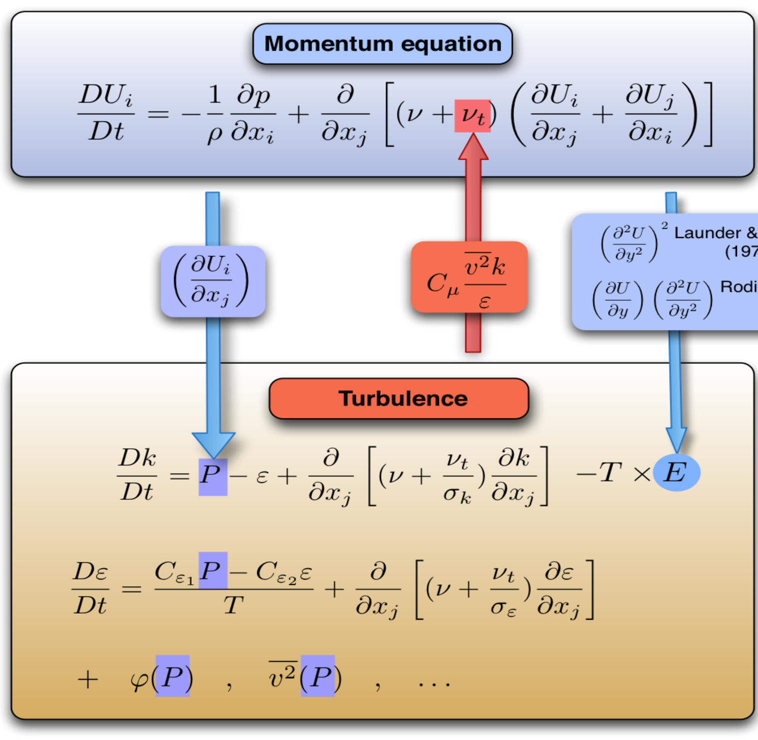


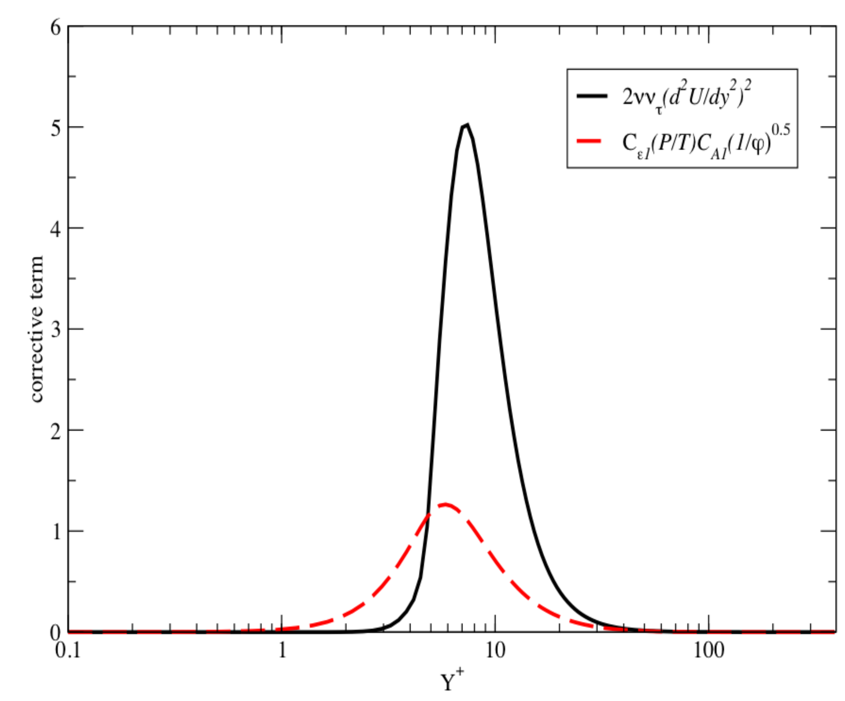
Low Reynolds number modelling of bypass transition flow. Prediction of the skin friction coefficient for T3A Flat plate test case. Comparison of different low-Re RANS models.





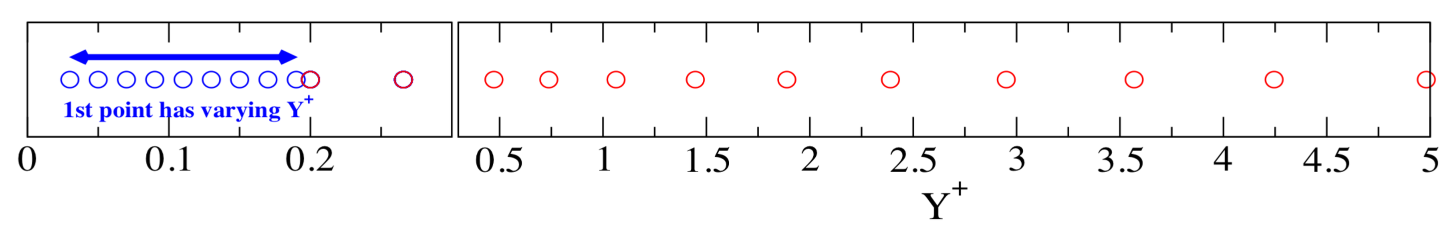
Predictions of the buoyancy-induced relaminarisation of an upward flow inside a heated pipe (DNS of You *et al.* (2003)). The φ-α is the only model able to correctly predict the low levels of k for the heat tranfer regime associated with relaminarization. On the other hand, the k-ω SST model predicts a turbulent flow regardless of the heat flux.
a) Nusselt number as a function of the buoyancy parameter. b) turbulent energy profiles for the 3 regimes.





Ongoing work: a) improvement of the φ-α model using ingredients coming from other models such as Launder & Sharma model (1974) in order to strengthen the coupling between turbulence and mean velocity. b) The ε equation needs additional terms when used down to the wall. Comparison of the term used by the model of Laurence *et al.* (2004) (dashed red line) and by the one of Launder & Sharma (1974)(black).

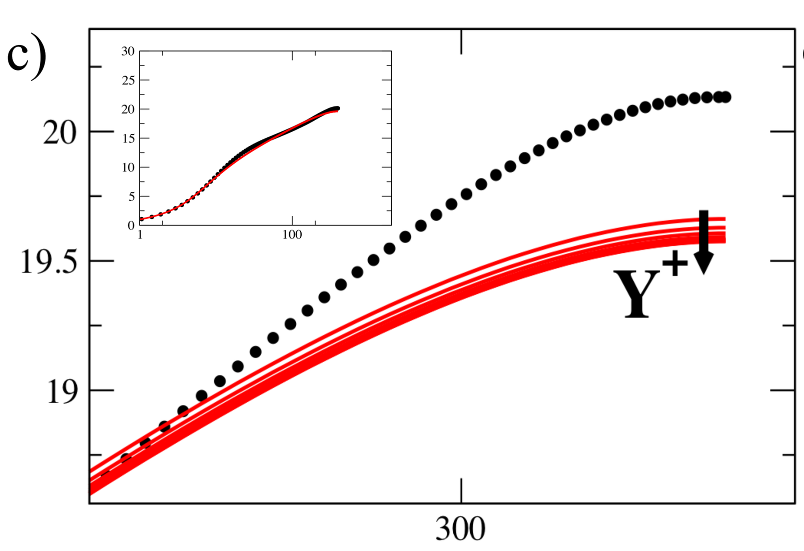
a)



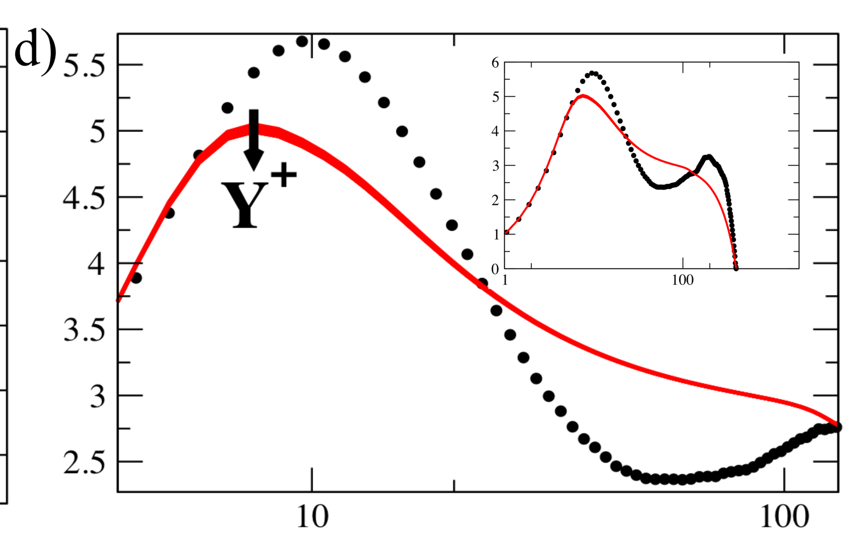
b)

model	$U^+max(Y^+=0.03)$	$U^+max(Y^+=0.19)$	Difference (%)
φ-α	20.40	20.40	10^{-5} %
Launder Sharma	21.16	21.16	10^{-5} %
k-ω SST	19.66	19.58	0.4%

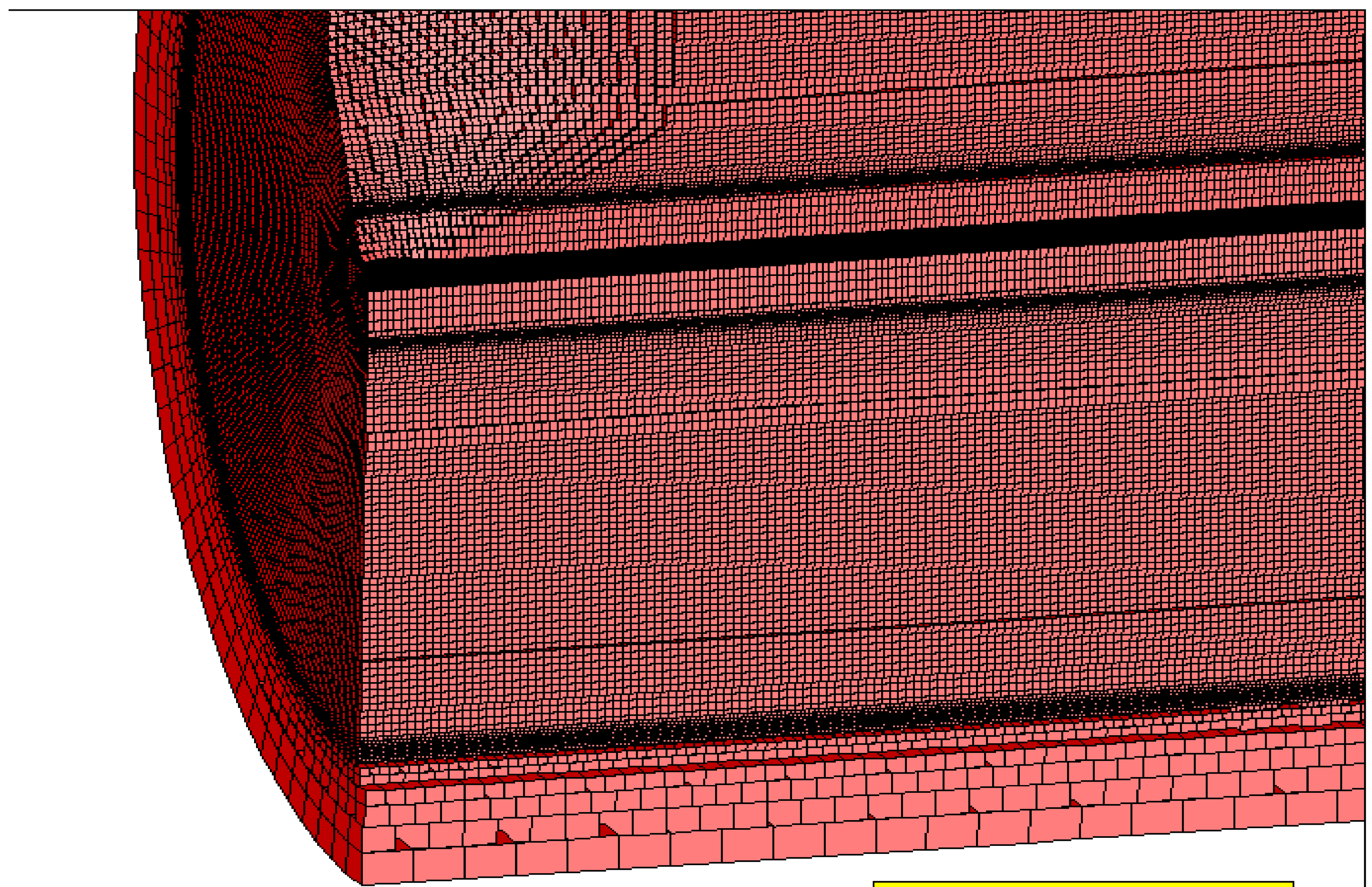
c)



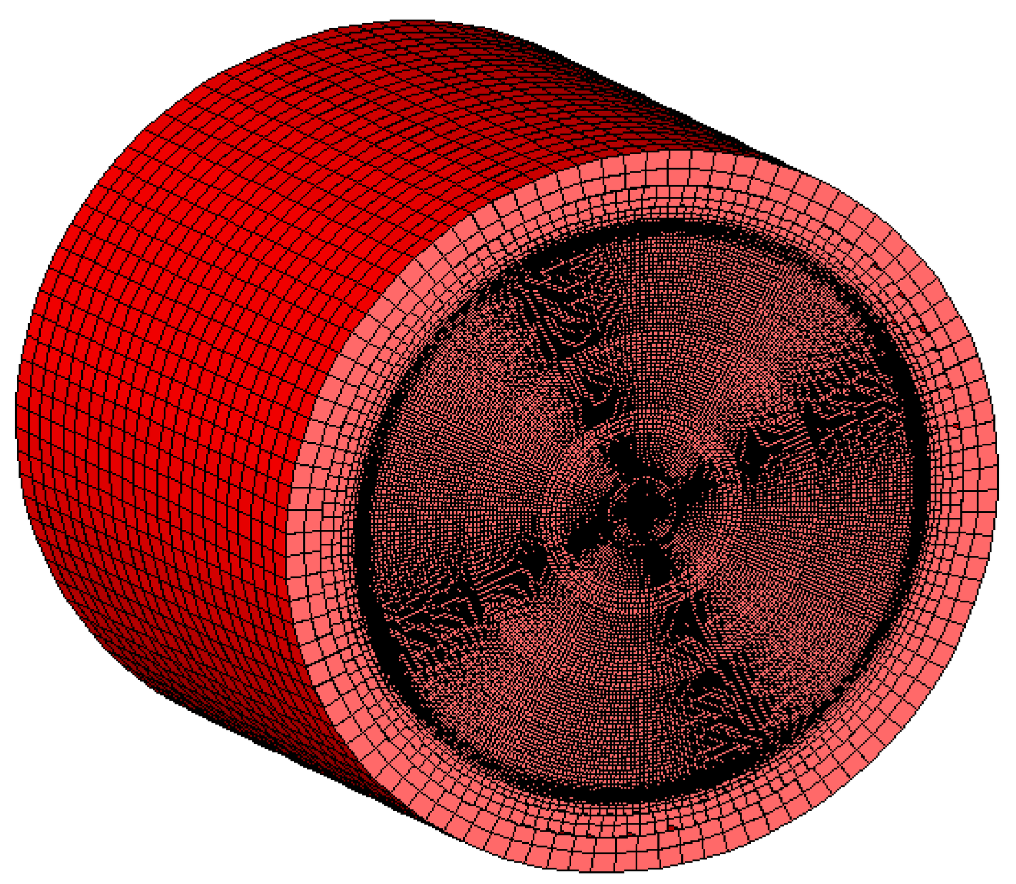
d)



Mesh dependancy of the k-ω SST model, in a 1D channel flow (1D code). a) Viscous sub-layer distribution of the grid nodes. b) Comparison of the 3 models. c&d) Velocity profiles computed with the k-ω SST model, using 130 nodes, all identical, except for the first point (Y^+ = 0.03, 0.05, 0.07, 0.09, 0.11, 0.13, 0.15, 0.17, 0.19) Re*=395. k-ω SST (red solid line). DNS (symbols) c) velocity, d) y^+dU^+/dy^+.



3D view with a cut on the centre of the computational domain



3D view of the grid near the inlet jet zone

Coaxial free jet meshing for L.E.S

The grid is generated using integral scales computed from a RANS model predictions.
Here it is important for RANS models to be able to predict the correct levels of k and ε which can be then used for the input turbulent length scale in the automatic, python based, grid generator.

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