Validation of Adaptive Wall Treatment for the EB-RSM

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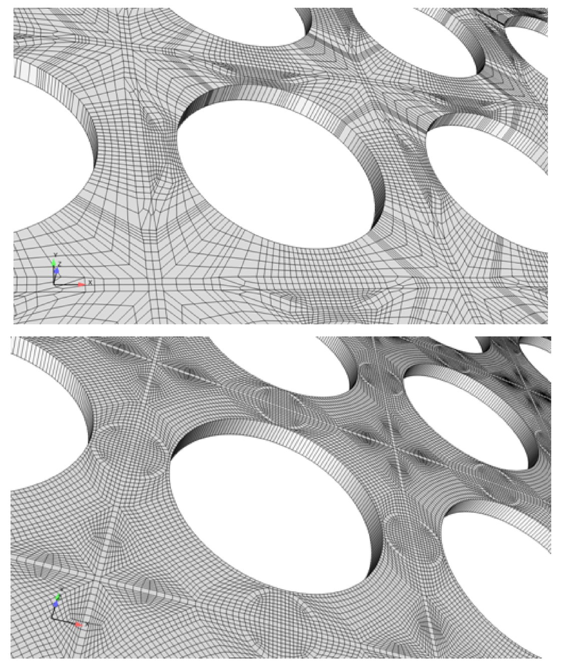
Motivations and objectives

Motivations

- Turbulence models impose constraints on the mesh.
- Industrial meshing processes make those constraints difficult to meet in the whole computational domain.
- Divergence/wrong physical behaviour.

Objectives

- A new model able to cope with all wall cell sizes.
- Convergence towards *Low-Reynolds* EB-RSM.
- Improve the *High-Reynolds* behaviour of standard wall functions.

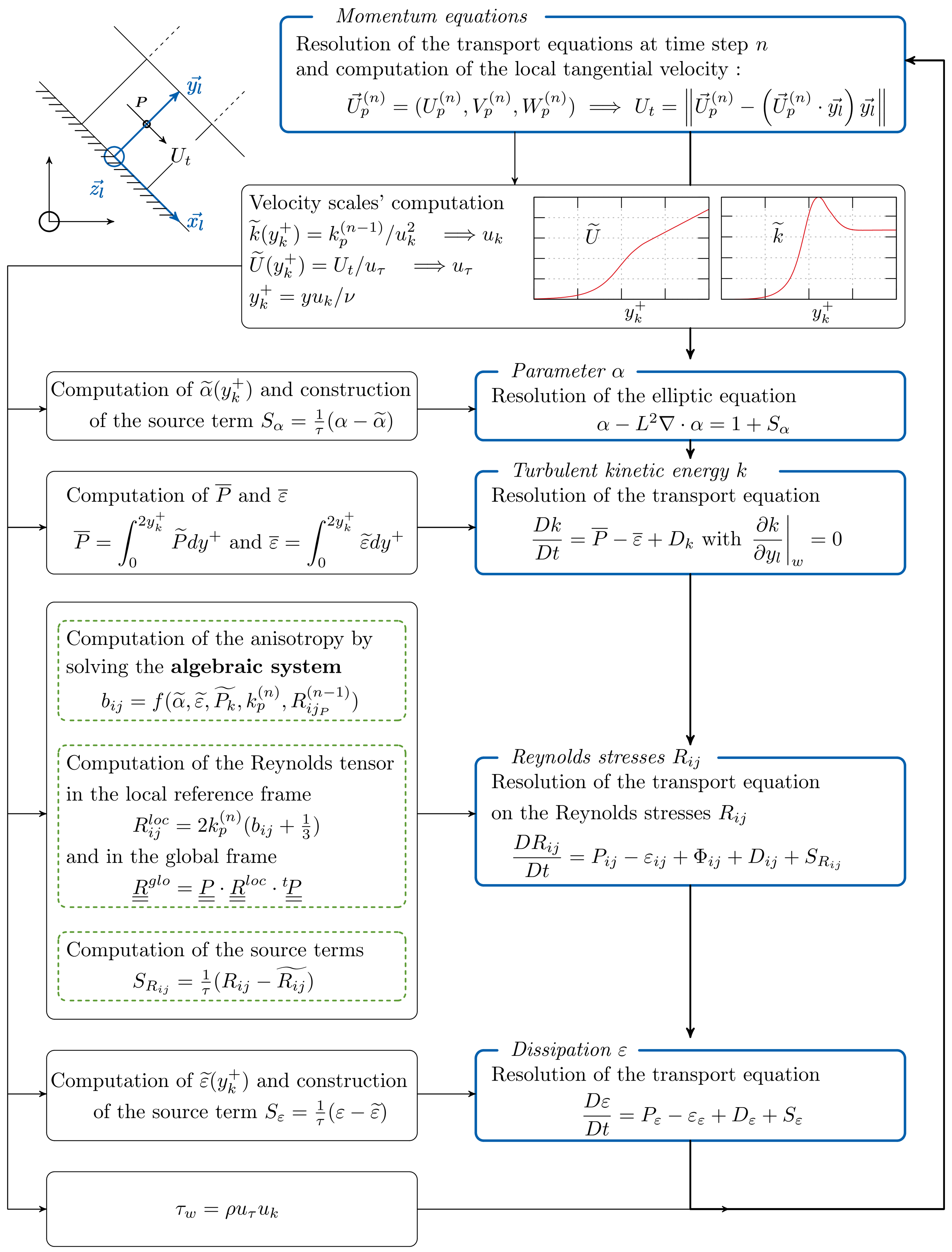


Mesh after 2 grids in a 5×5 fuel assembly

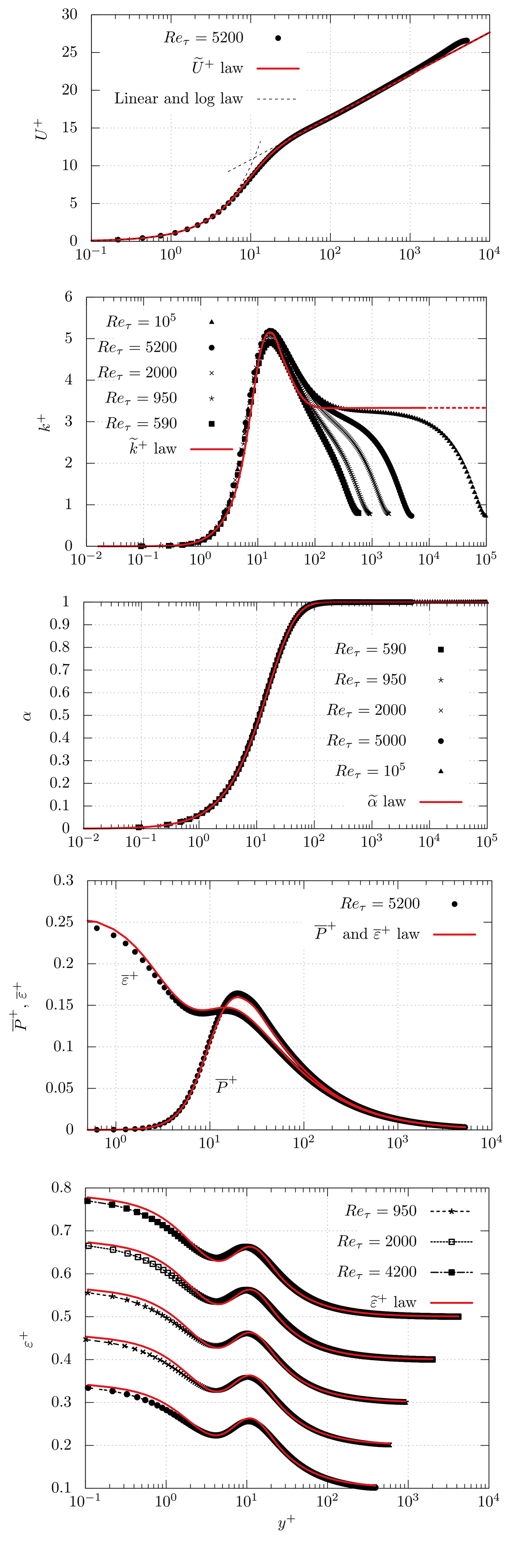
Adaptive Algebraic Wall Functions

Adaptive Algebraic Wall Functions (*AAWF*) are based on analytical laws $\widetilde{\phi} = \widetilde{\phi}(y^+)$ for the variables U, k, ε and α and the resolution of an **algebraic system of equation for the Reynolds Stresses** R_{ij}. At each time step the laws for U and k are used to prescribe the wall shear stress τ_w and compute the dimensionless distance y^+. Then all the variables are scaled and prescribed through source terms *via* the ana--lytical laws or the algebraic system.

Algorithmic view of AAWF

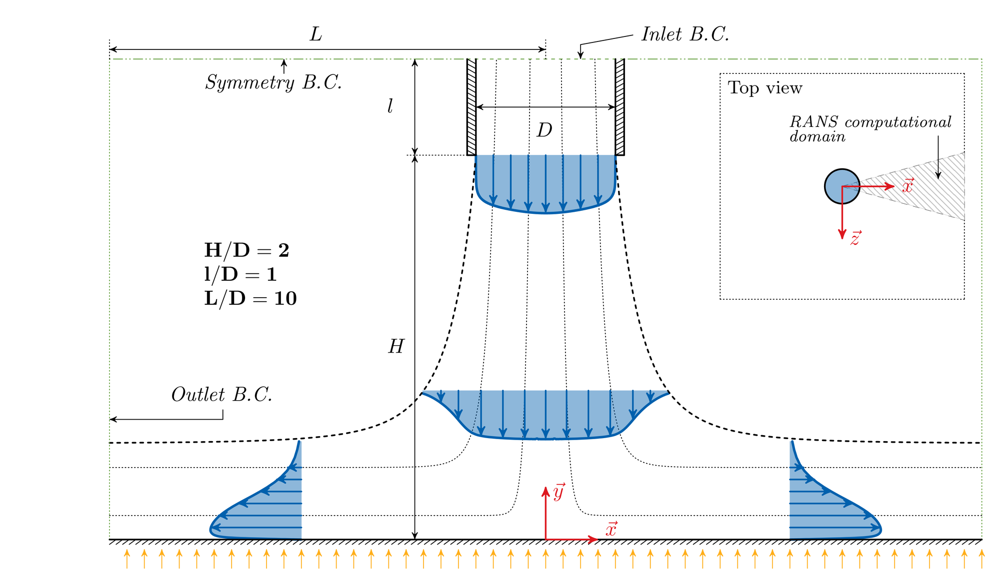


Profiles of associated laws



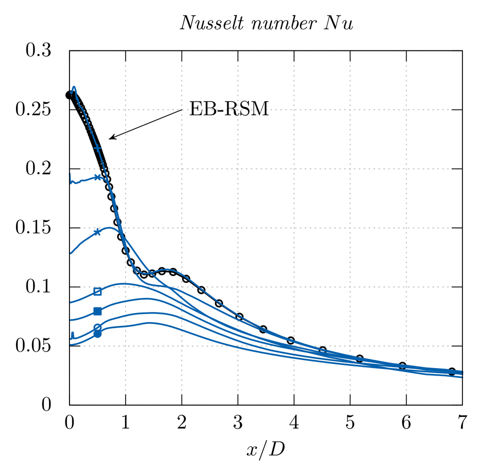
Impinging jet

Fully developepd pipe flow impacting a heated wall



▷ Computation on 7 meshes, $y_p^+ \in [0.05, 100]$, *GGDH* for $\overline{u'T'}$

Type	Mesh	y^+_{max}	Symbol
Low-Reynolds	A	0.05	
	B	1	
Buffer	C	5	
	D	10	
High-Reynolds	E	20	
	F	40	
	G	80	
	H	100	

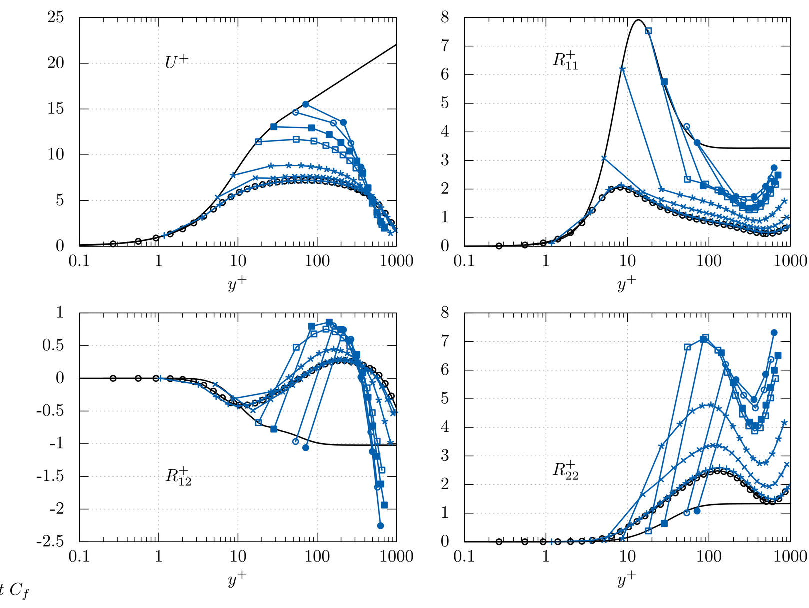


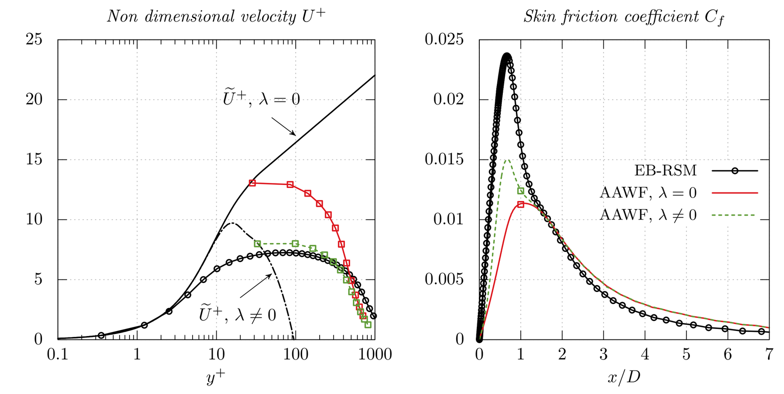
Non dimensional profiles at $x/D = 0.5$

▷ Wall functions force first points but are far from *Low-Reynolds* EB-RSM.

▷ Good asymptotic behaviours ensure convergence towards EB-RSM when the mesh is refined.

▷ *High-Reynolds* behaviour is improved *via* source terms in the $\widetilde{U}^+$ law





▷ Modification of the logarithmic law

$$\widetilde{U}^+_{log} = \frac{1}{\kappa}\left(\ln(y^+) + \lambda y^+\right) + B$$

λ may include pressure gradient, convection or even thermal effects in the future

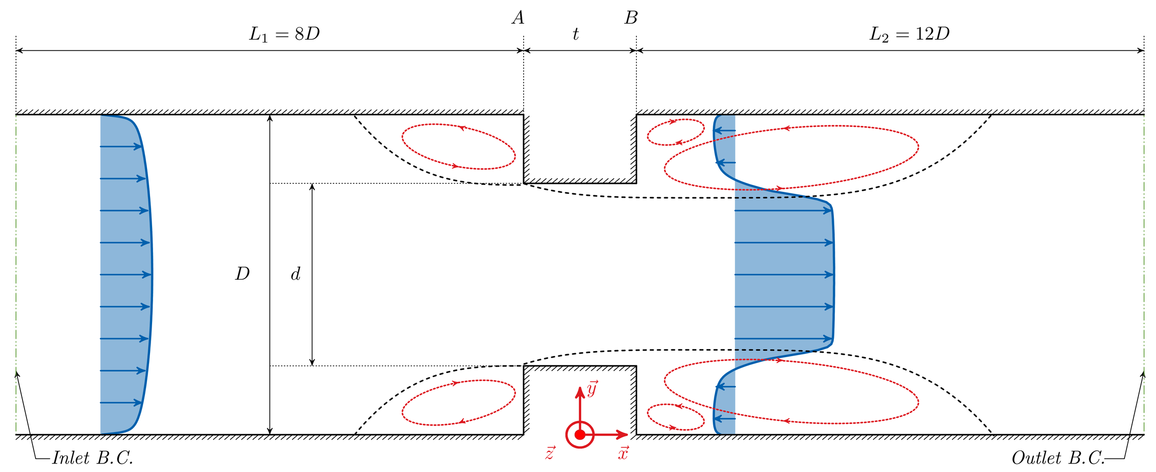
▷ No miracles : only little improvment

Conclusions

- Adaptivity / Convergence towards EB-RSM
- Source terms slightly improve C_f predictions in the present case
- Wall functions don't make any mircales: precision has a cost and *Low-Reynolds* meshes are unavoidable (Nusselt number's peak for EB-RSM not caught even at $y^+ = 5$)

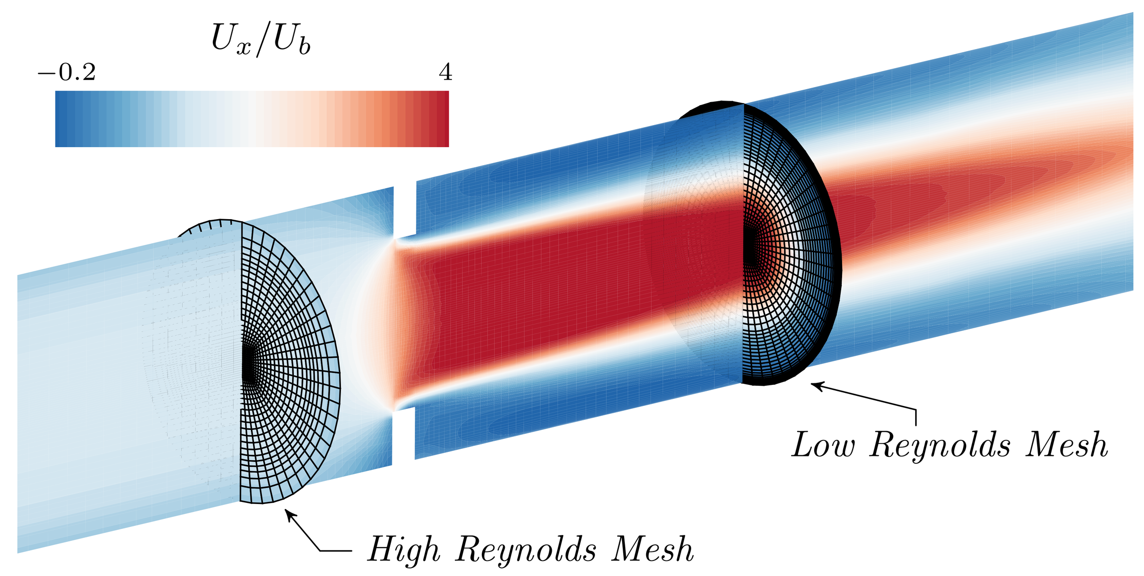
Orifice Flowmeter

The flow is accelarated through a square-edged orifice, creating recirculation zones



▷ Computation on 11 meshes with $y_a^+ \in [0.7 : 50]$

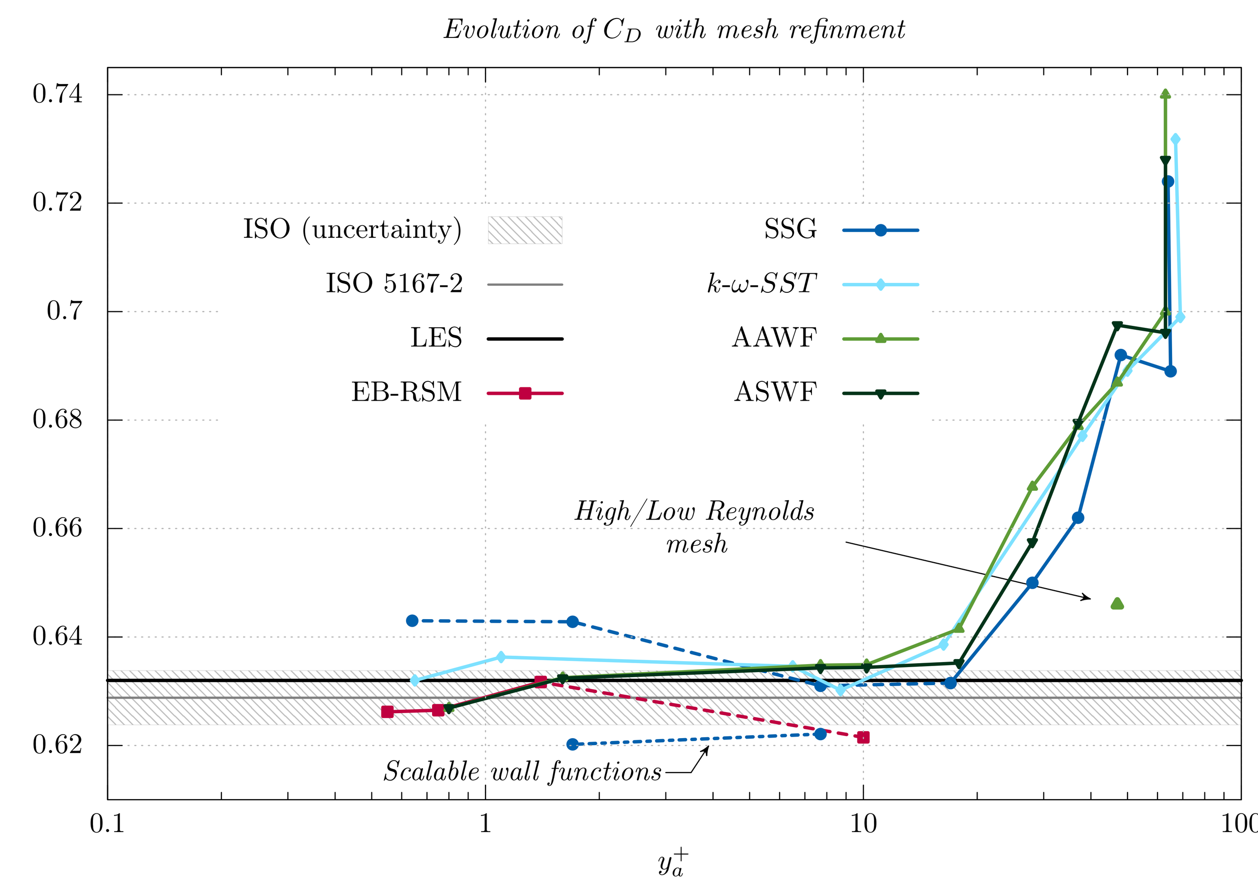
▷ 1 mesh with coexistence of *High Reynolds* cells and *Low Reynolds* cells



Computation of the discharge coefficient C_D for all the mesh refinments

$$C_D = \frac{1}{\varepsilon} U_b \sqrt{1 - \beta^4} \sqrt{\frac{\rho}{2\Delta P_D}}$$

Pressure tappings for the measurment of ΔP_D are located at $0.5D$ from A and at $2D$ from B



Conclusions

- Adaptivity
- Convergence towards EB-RSM
- Allow the coexistence of both *High* and *Low Reynolds* cells in the regions of interest (recirculations)

References :

[1] R. Manceau and K. Hanjalić, *Elliptic Blending Model : A New Near-Wall Reynolds-Stress Turbulence Closure*, 2002

[2] M. Popovac and K. Hanjalić, *Compound Wall Treatment for RANS Computation of Complex Turbulent Flows and Heat Transfer*, 2007

[3] F. Billard, D. Laurence, K. Osman and S. Utyuzhnikov, *Adaptive Wall Functions for an Elliptic Blending Eddy Viscosity Model Applicable to Any Mesh Topology*, 2015