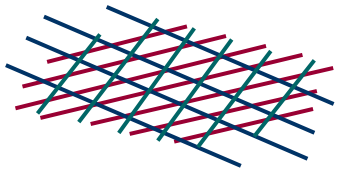
Simulations of the flows over round cylinder at different Reynolds' numbers

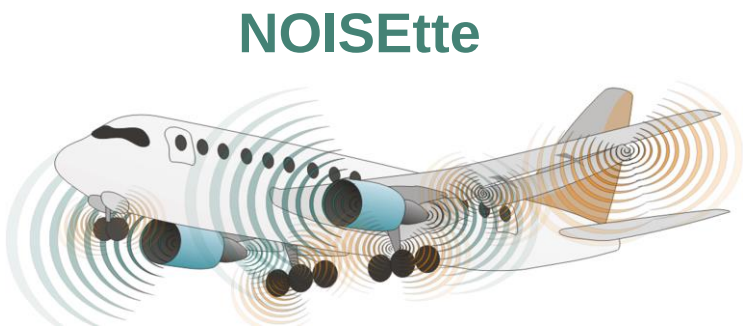
NOISEtte

- Scale resolving hybrid RANS-LES **DDES** approach (recent formulation)
  - shear layer adapted Δ_{SLA} [Shur et al., 2015] is used
  - based on SA turbulence model

- **Vertex-centered higher accuracy EBR scheme**
  - not higher than 2nd order on arbitrary unstructured meshes (control-volume method)
  - EBR6 CD + EBR5 upwinding
  - **adapting hybrid CD-Upwind-WENO scheme** which depends on local flow characteristics [Guseva et al., 2017], σ_{min}=0.3, σ_{max}=1



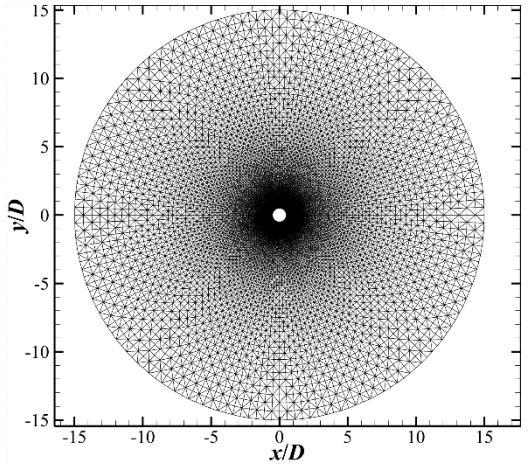
- **Time integration**
  - implicit scheme, based on Newton iterations
  - BiCGStab solver
  - ILU0 preconditioner
  - CFL_{max}=50

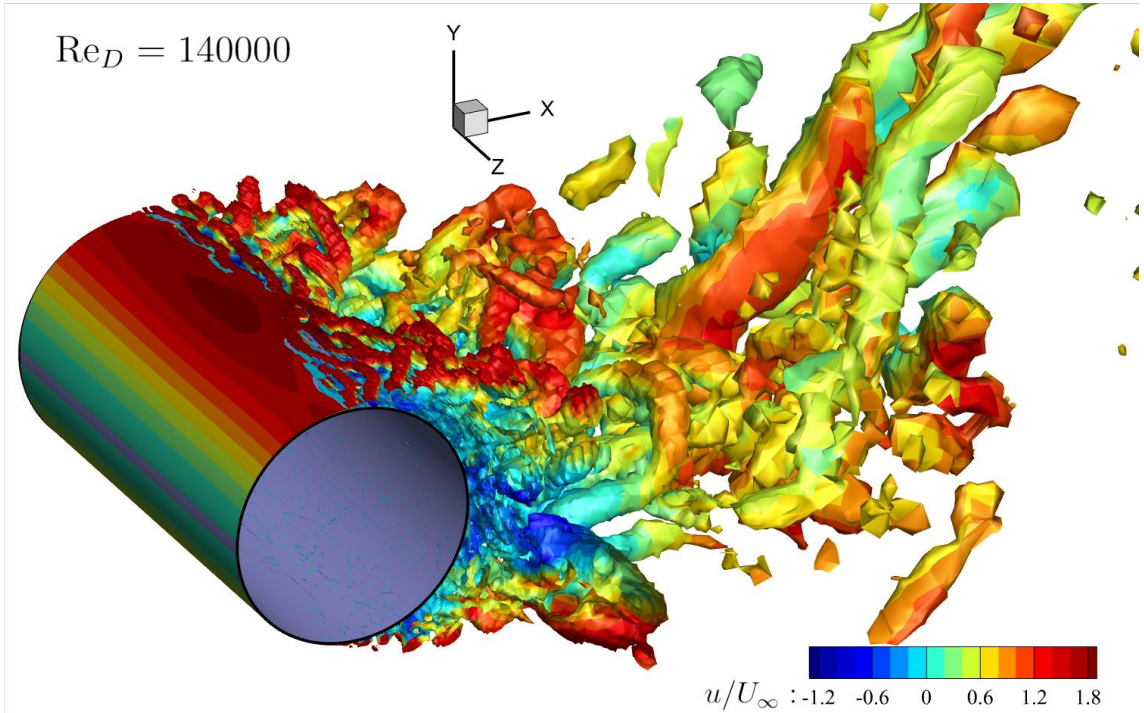


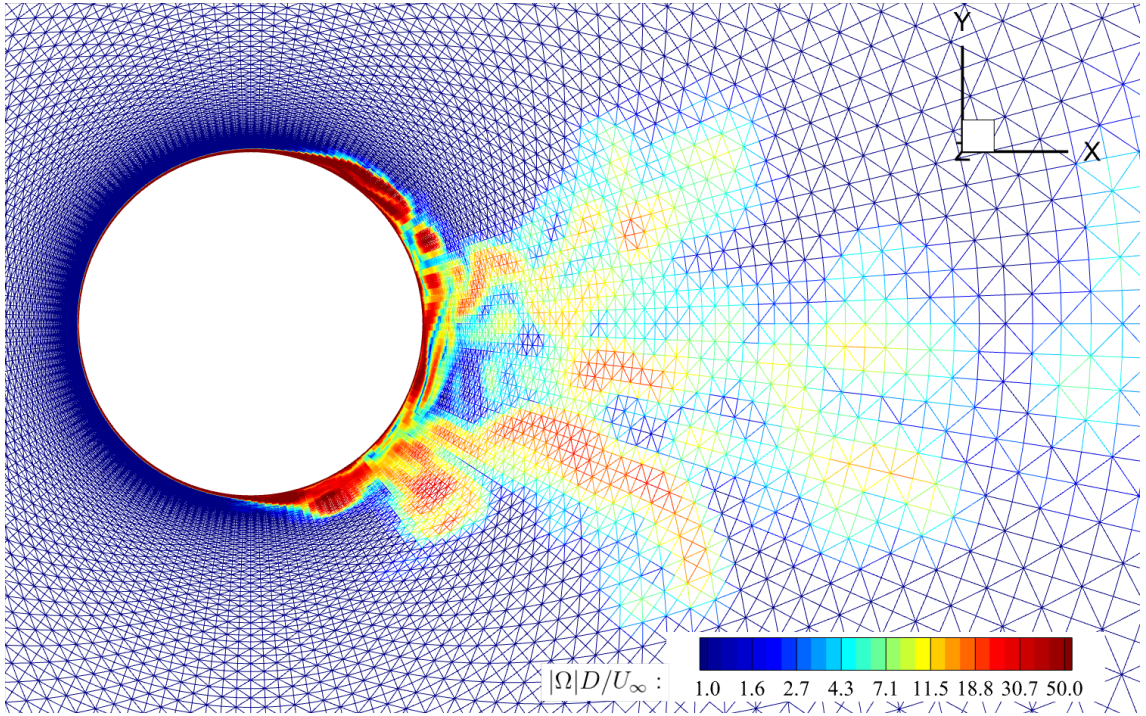
Re_D=140k: setup

- Flow parameters:
  - $Re_D=1.4 \cdot 10^6$
  - $M_\infty=0.1$
- Cylinder surface: noslip BC

- Mesh:
  - 1.76M nodes
  - 10.3M tetrahedrons
  - 27060 nodes in 2D mesh
  - 64 cells in the spanwise direction (L_z=2D)
  - $\Delta_z=D/32$



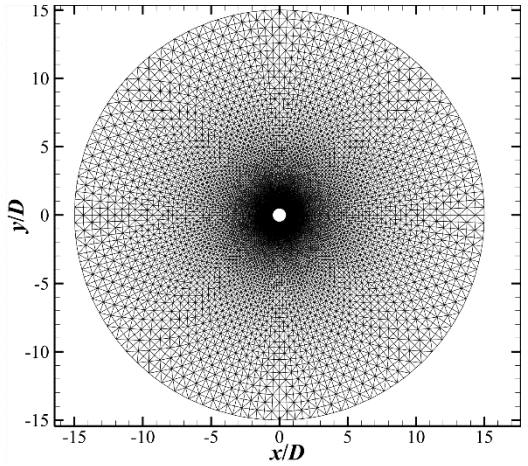


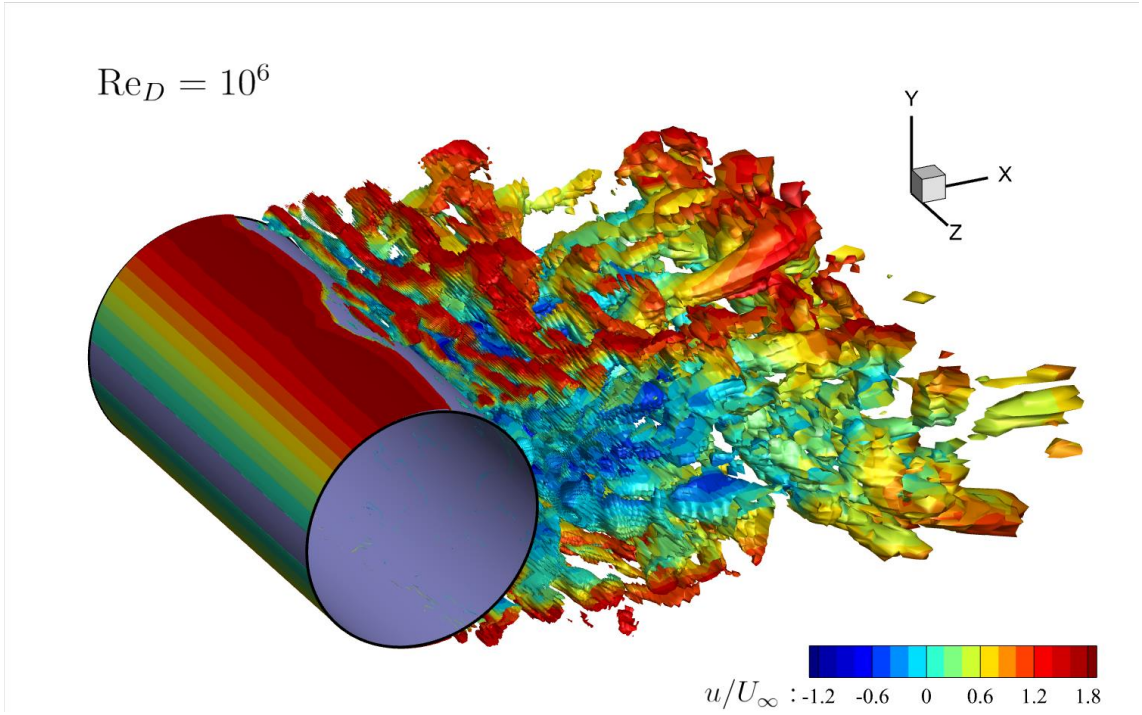


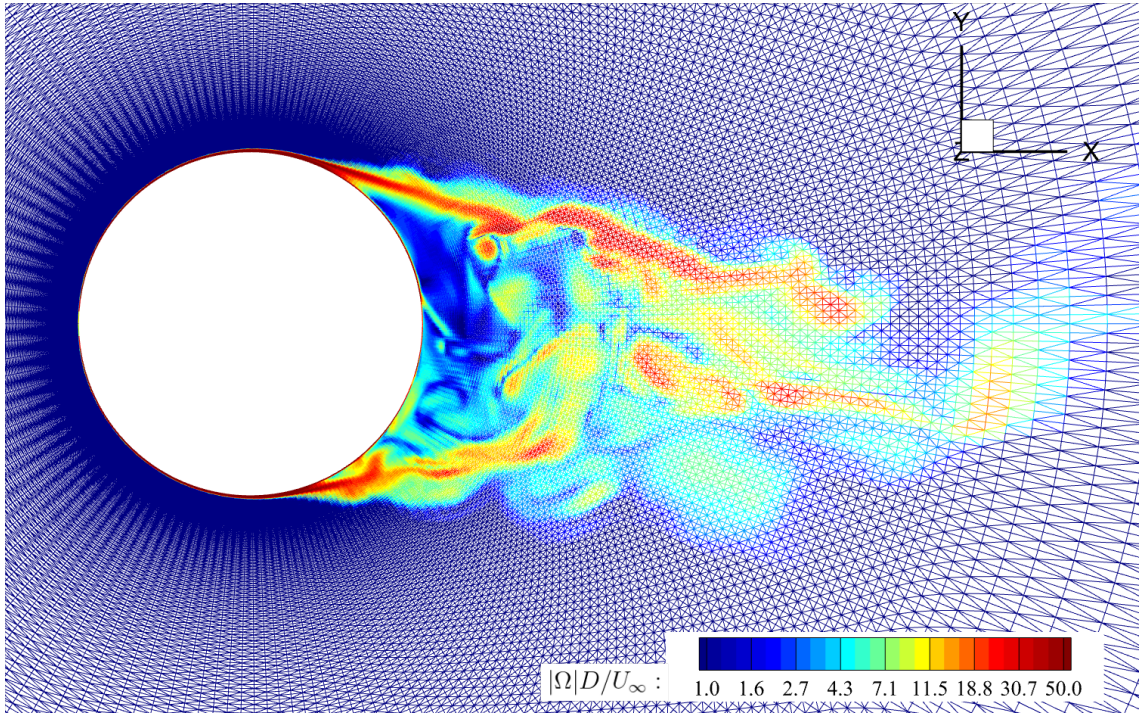
Re_D=1M: setup

- Flow parameters:
  - $Re_D=10^6$
  - $M_\infty=0.1$
- Cylinder surface: wall functions (Reichardt law)

- Mesh:
  - 1.76M nodes
  - 10.3M tetrahedrons
  - 57600 nodes in 2D mesh
  - 20 cells in the spanwise direction (L_z=2D)
  - $\Delta_z=D/10$

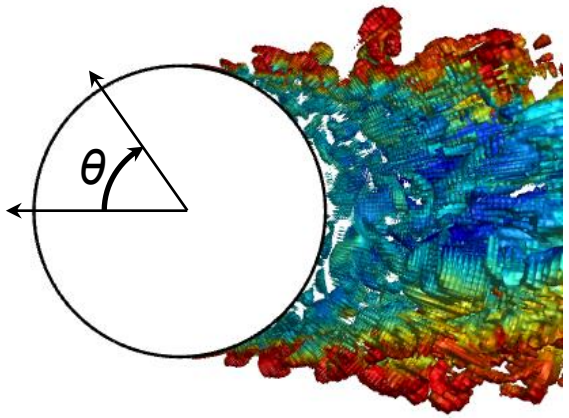


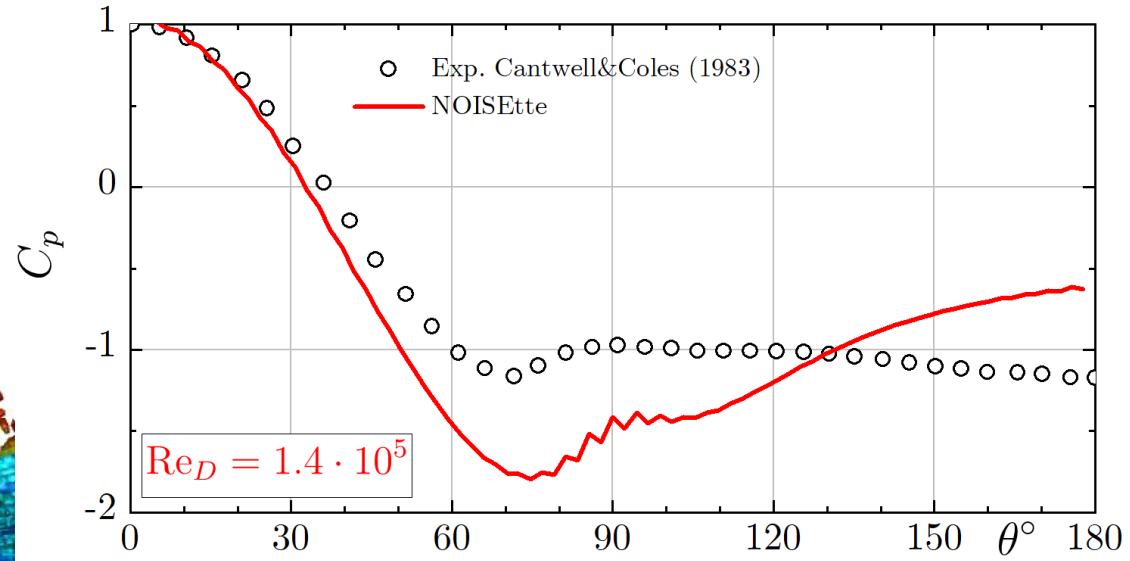


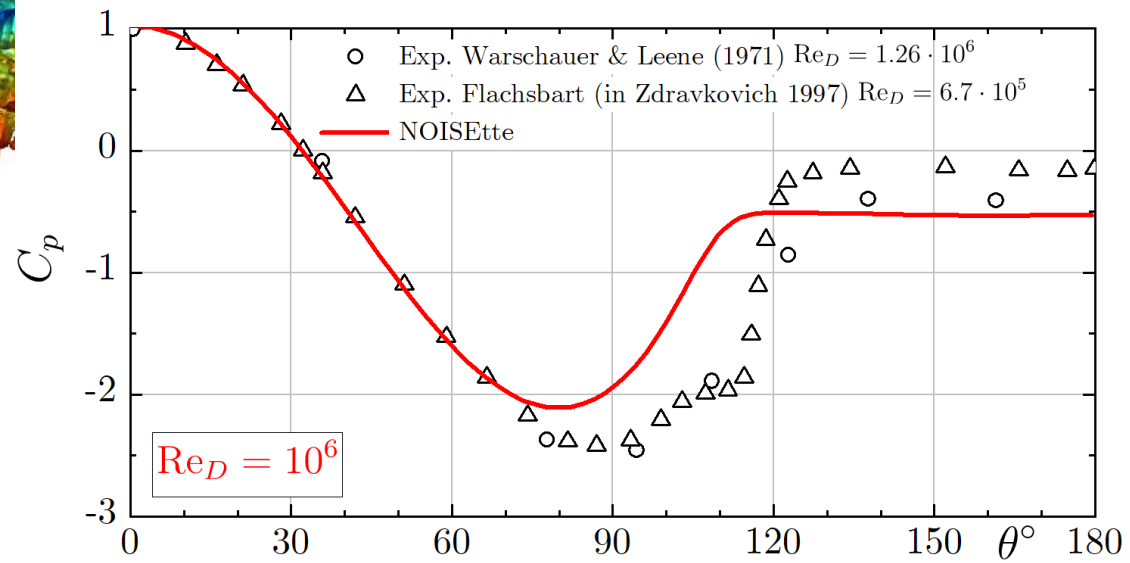


C_p distributions over the cylinder surface

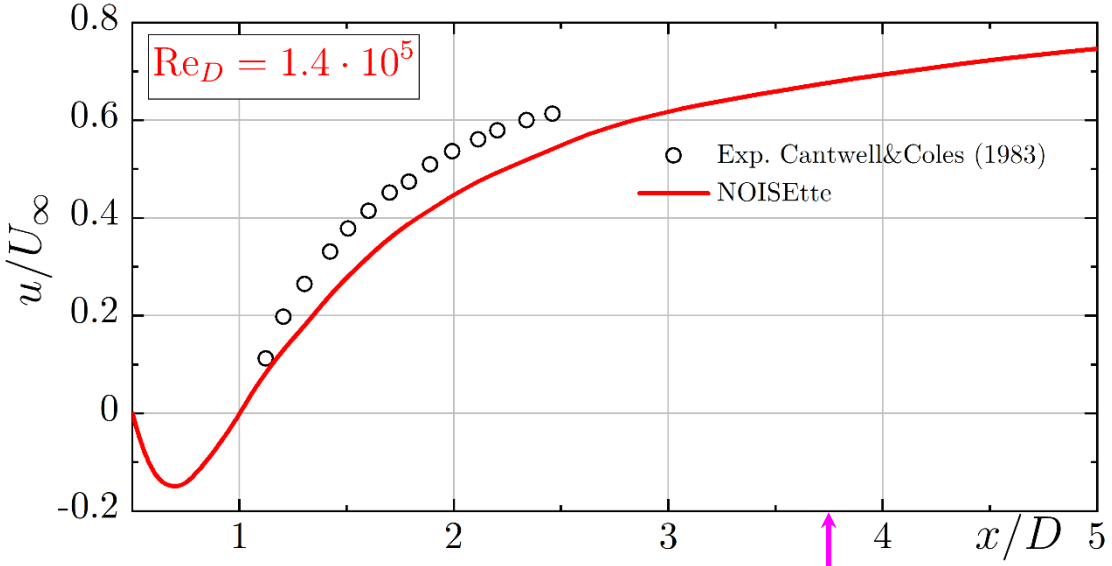
- Integral characteristics are not predicted correctly
- Strouhal number could not be detected certainly
  - wake region is not resolved correctly

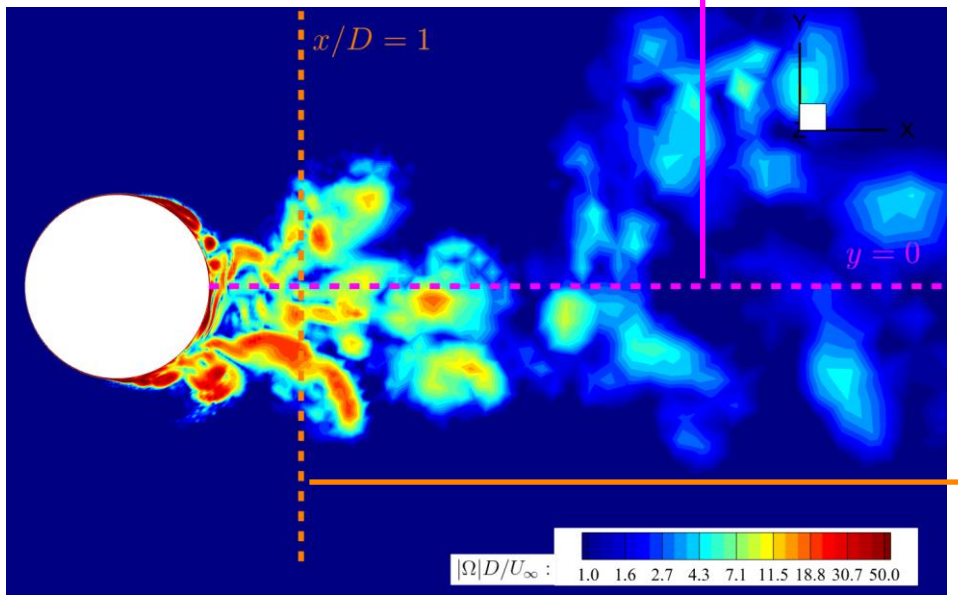


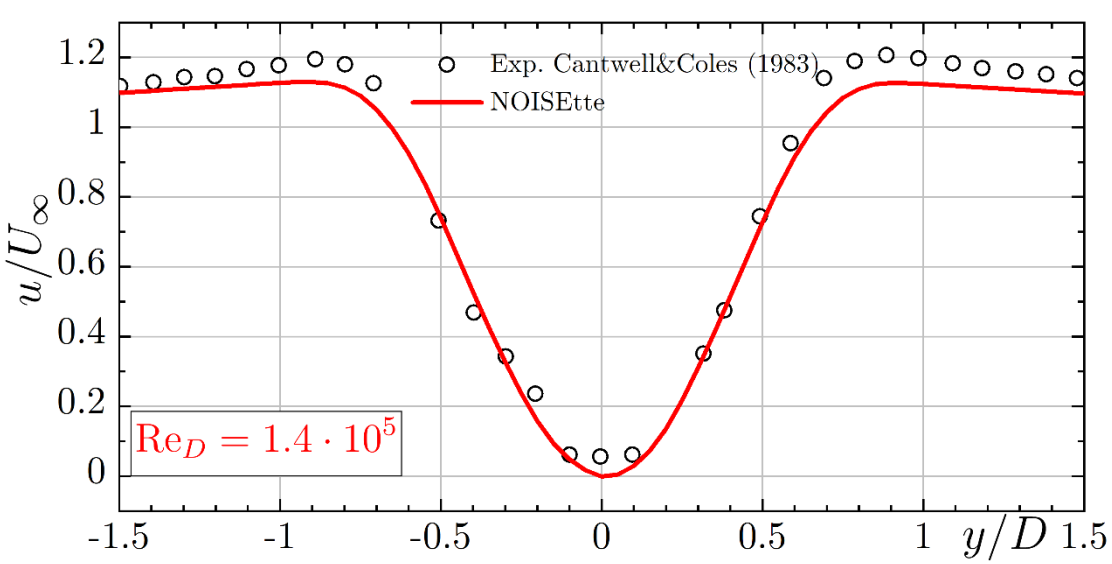


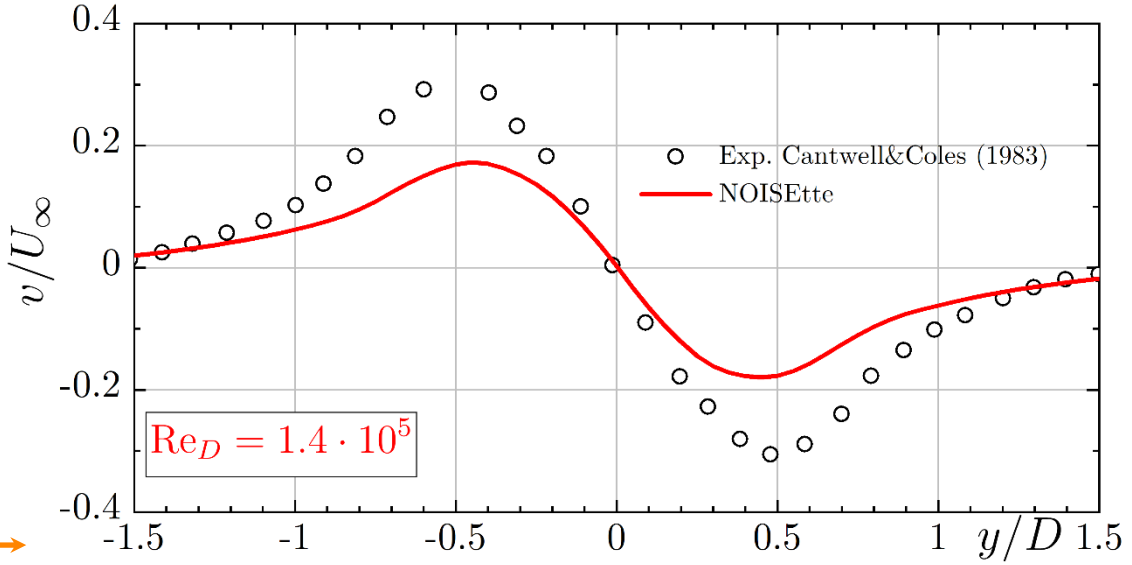


Re_D=140k: velocity profiles









Issues that prevent correct simulation and adequate evaluation

Issues:

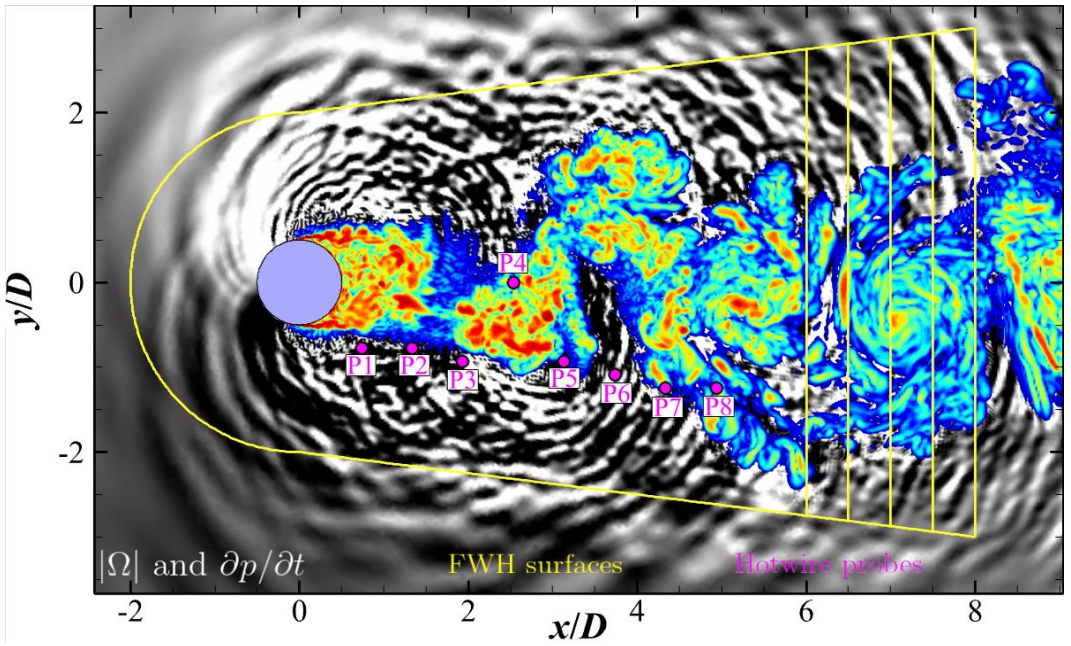
- Insufficient mesh resolution
  - spanwise resolution for the $Re_D=10^6$ ($\Delta_z=D/10$)
  - wake region downstream the cylinder
- Insufficient spanwise domain size
  - L_z=**3**D should be used at least
- Inappropriate mesh topology
  - hexahedrons mesh should be used
- Usage of wall functions
  - standard law of the wall does not consider pressure gradient that provokes separation
  - noslip BC should be used
- Suboptimal numerical dissipation

Proposition:

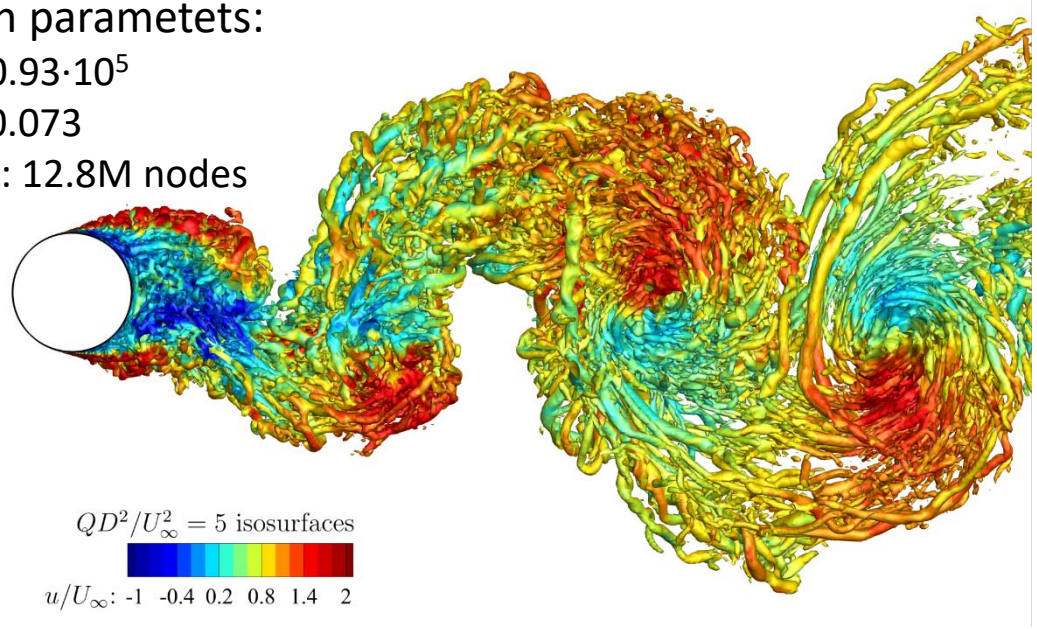
1 Reference scale-resolving simulation
- L_z=3D
- $\Delta_z=D/40$
- $\Delta<=D/40$
- Mesh size ~10-15M nodes

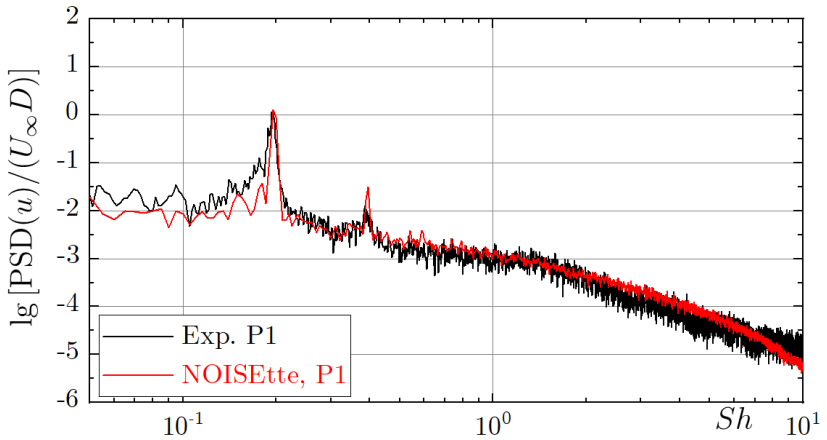
2 Simulation using coarser meshes
- noslip BC
- L_z=3D

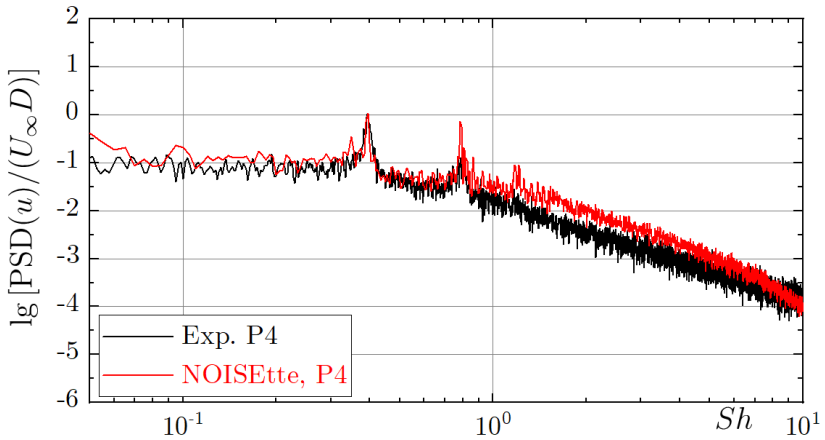
Example of accurate simulation



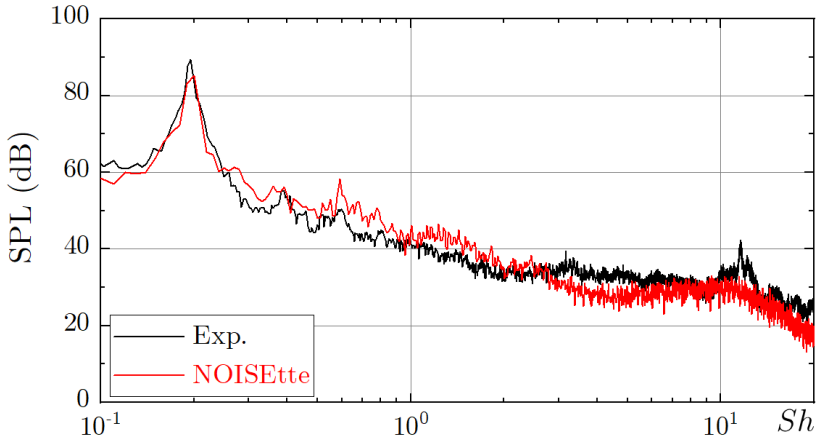
- Simulation parametets:
  - Re_D=0.93·10^5
  - M_∞=0.073
  - Mesh: 12.8M nodes







Nearfield velocity spectums



Far field spectrum at point (0; 13.3D)