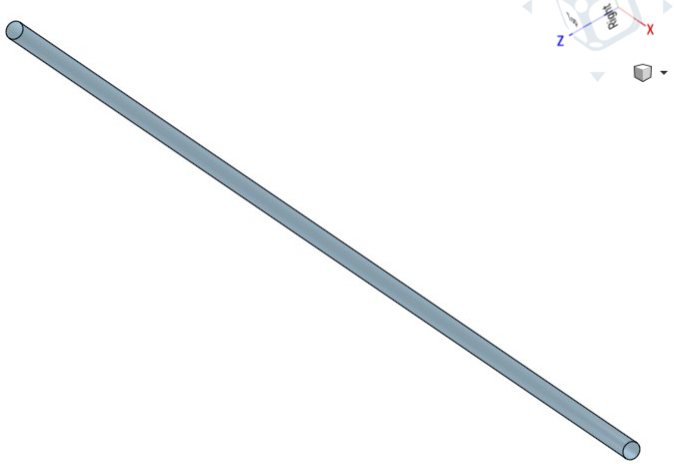
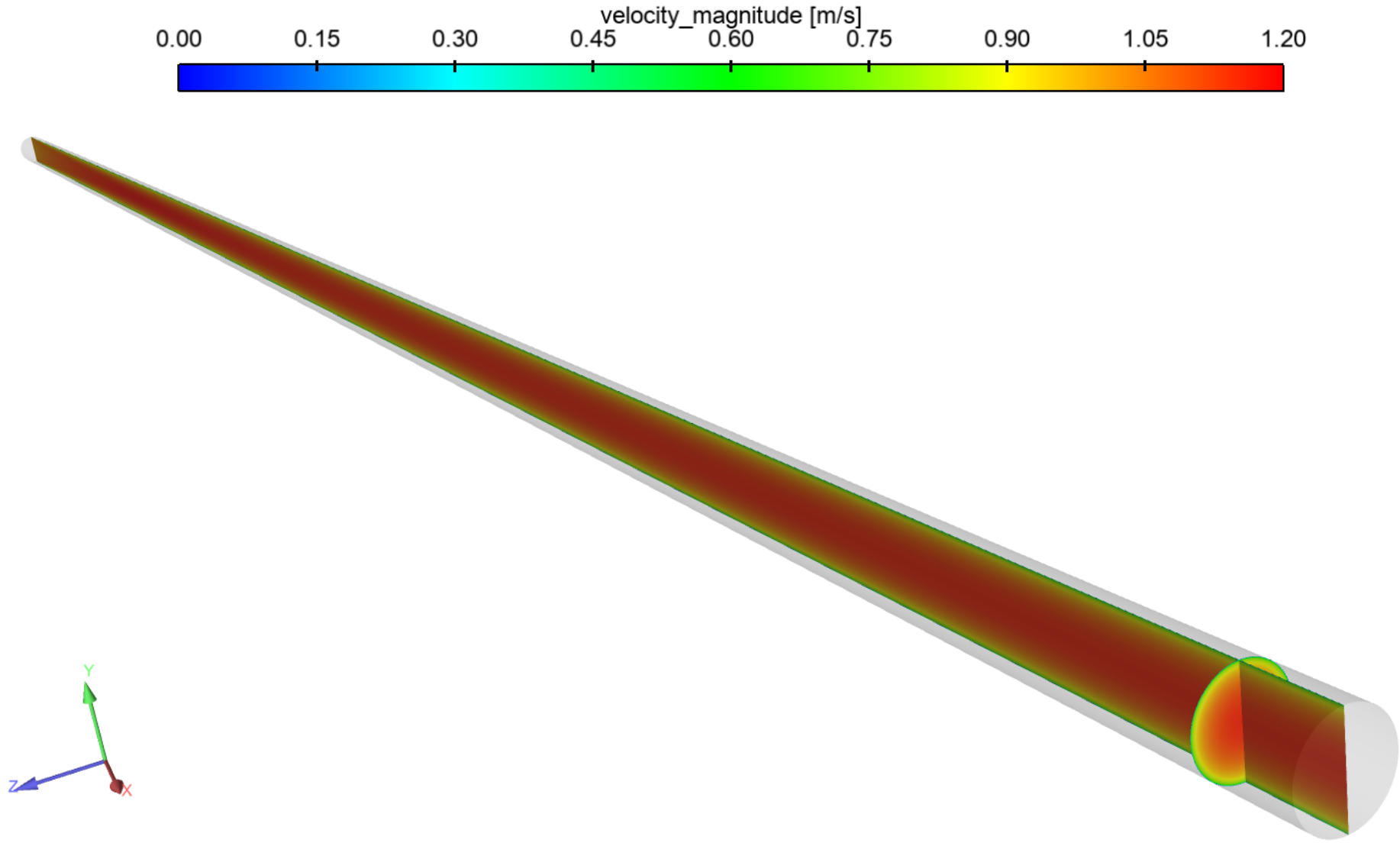
# Problem definition

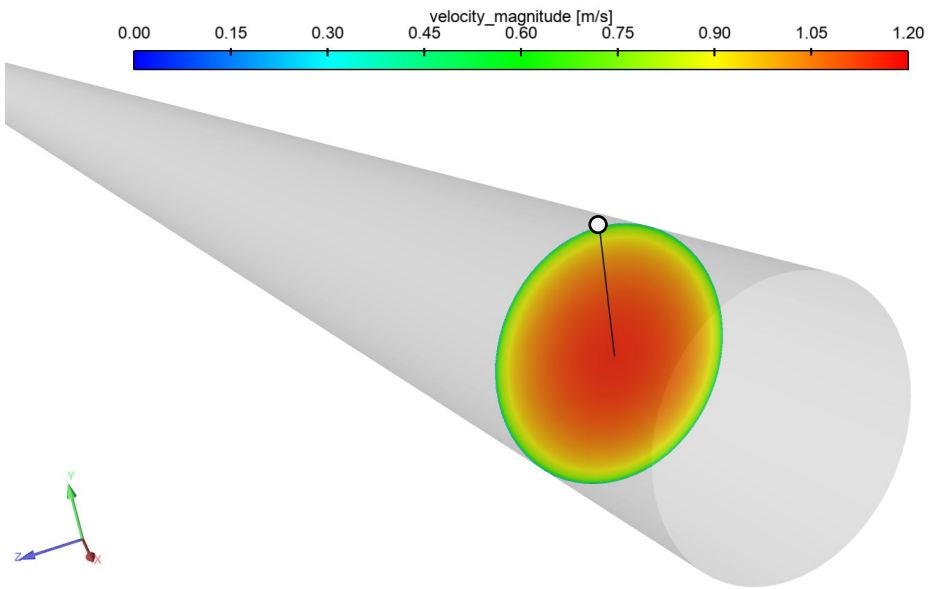



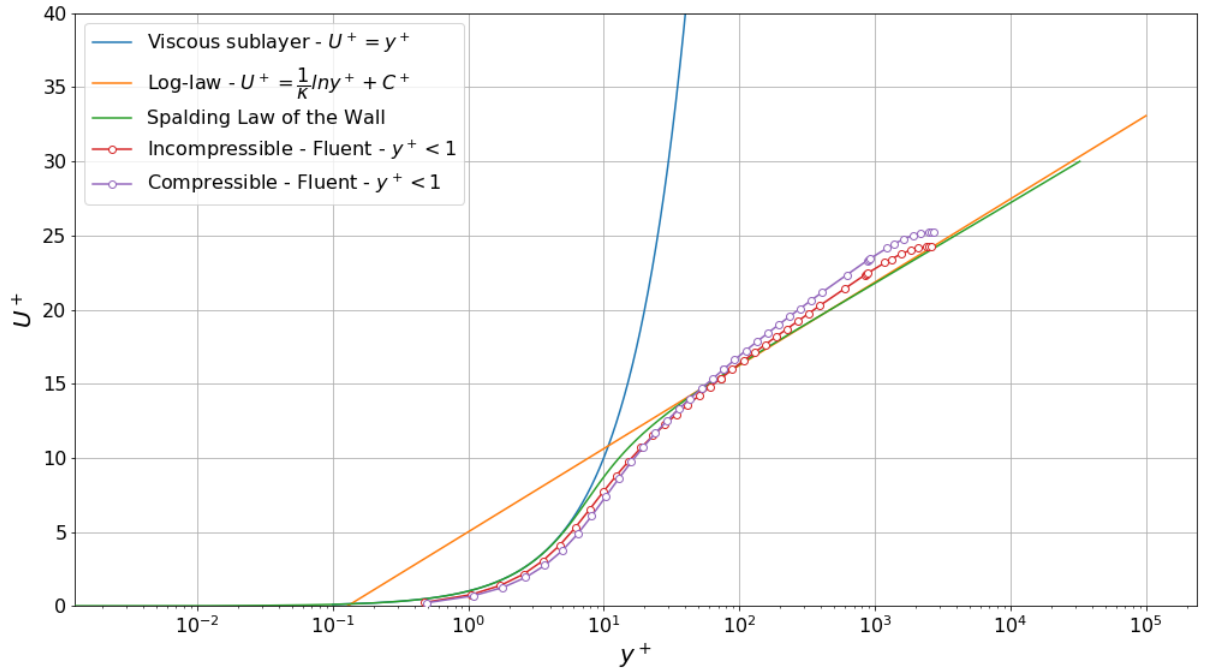
- Pipe diameter = 0.1 m
- Pipe length = 7.0 m
- Run the case in laminar regime and turbulent regime.
  - $Re_{laminar}$ = 500
  - $Re_{turbulent}$ = 100000
- Working fluid – Incompressible flow.
  - Set density equal to 1 $kg/m^3$ and inlet velocity equal to 1 m/s
- Run the case in 2D and 3D.

# Post-processing



# Post-processing



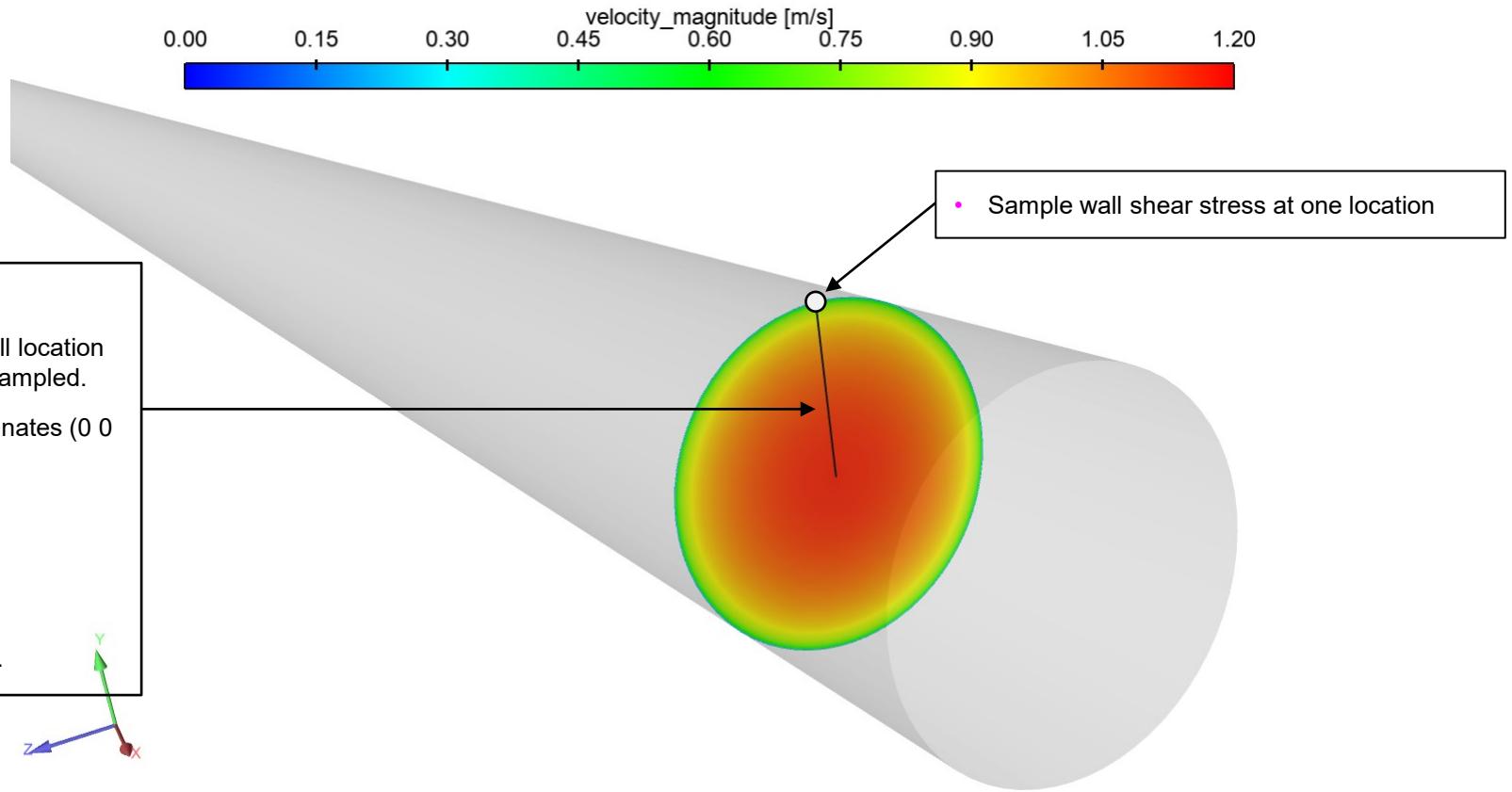

$$y^+ = \frac{\rho \times U_\tau \times y}{\mu} = \frac{U_\tau \times y}{\nu}$$

$$U_\tau = \sqrt{\frac{\tau_w}{\rho}}$$

$$u^+ = \frac{U}{U_\tau}$$

- To do the plot of $u^+$ vs. $y^+$, you will need to sample wall shear stress and velocity in a location where the flow is fully developed and there is no separation.

# Post-processing

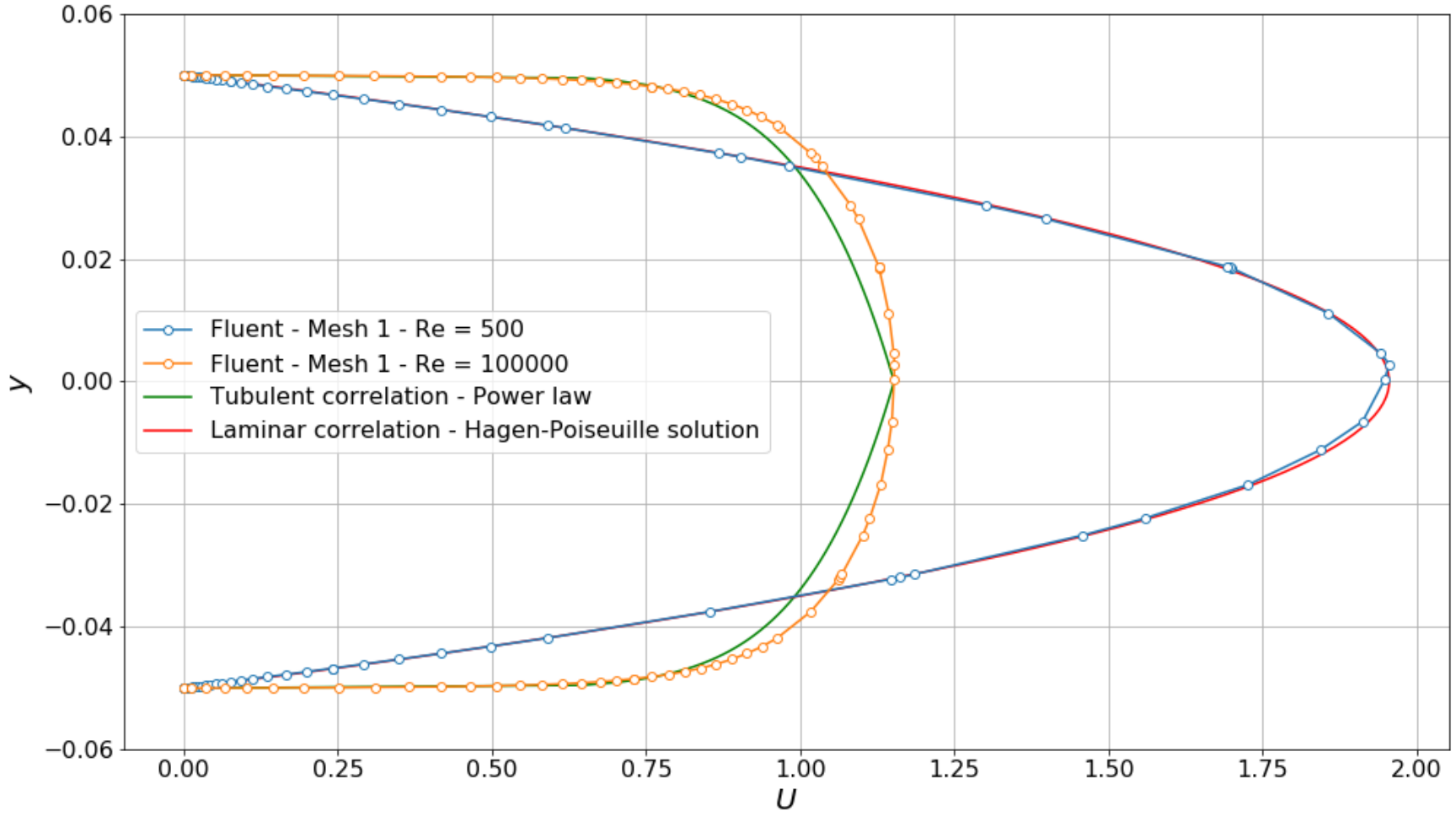



- Sample wall shear stress at one location

- Sample velocity along a line.
- The line must be normal to the wall location where the wall shear stress was sampled.
- This location is the origin of coordinates (0 0 0).
- Compute $y^+$ along the line.
- Compute $u^+$.
- Plot $u^+$ in function of $y^+$.
- Set the x-axis to logarithmic scale.

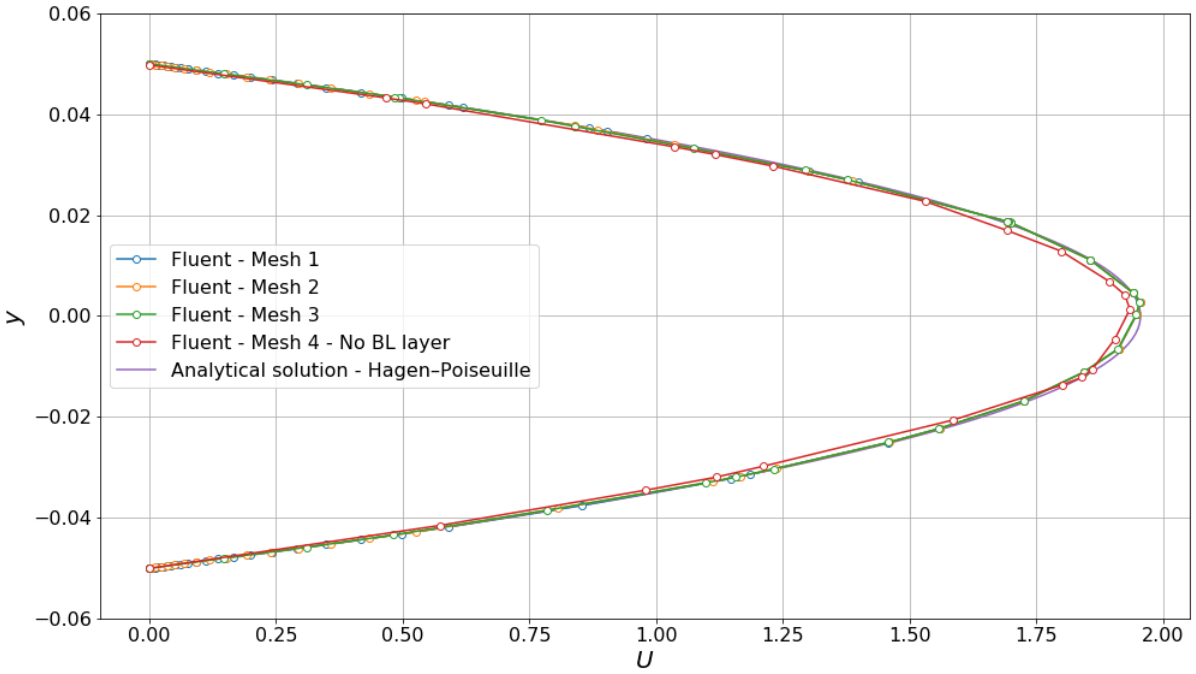
- To do the plot of $u^+$ vs. $y^+$, you will need to sample wall shear stress and velocity in a location where the flow is fully developed and there is no separation.

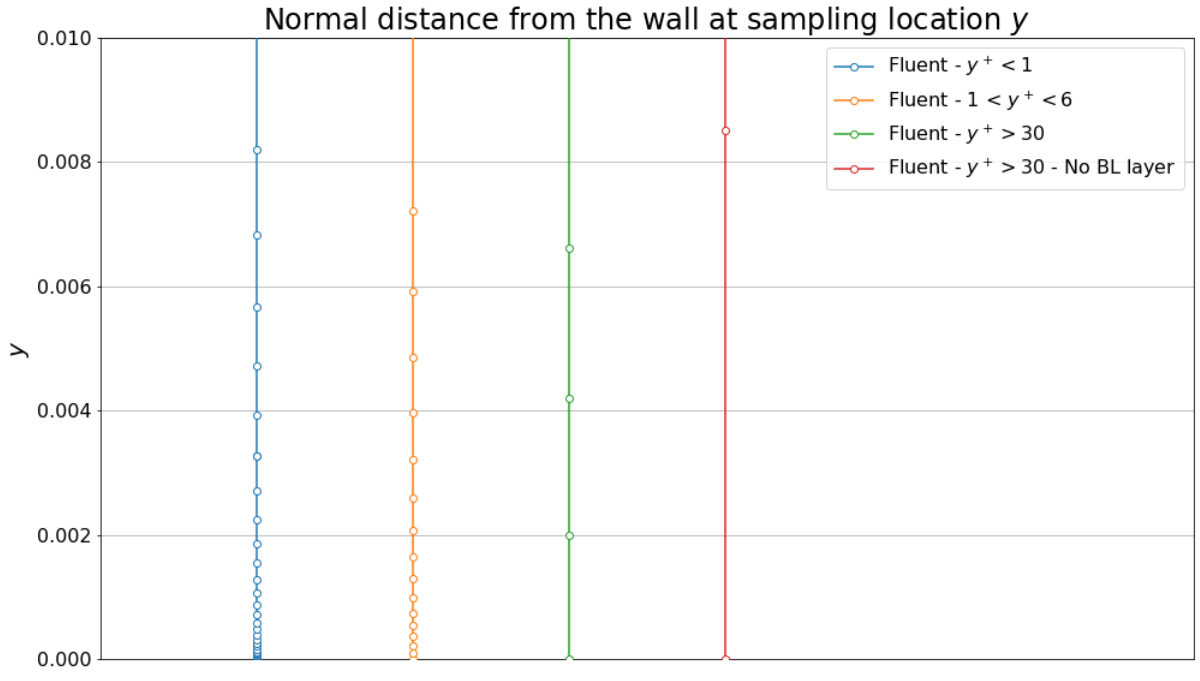
# Post-processing




- Comparison of the velocity profiles in laminar and turbulent regimes.
- All sampling is done where the flow is fully developed.

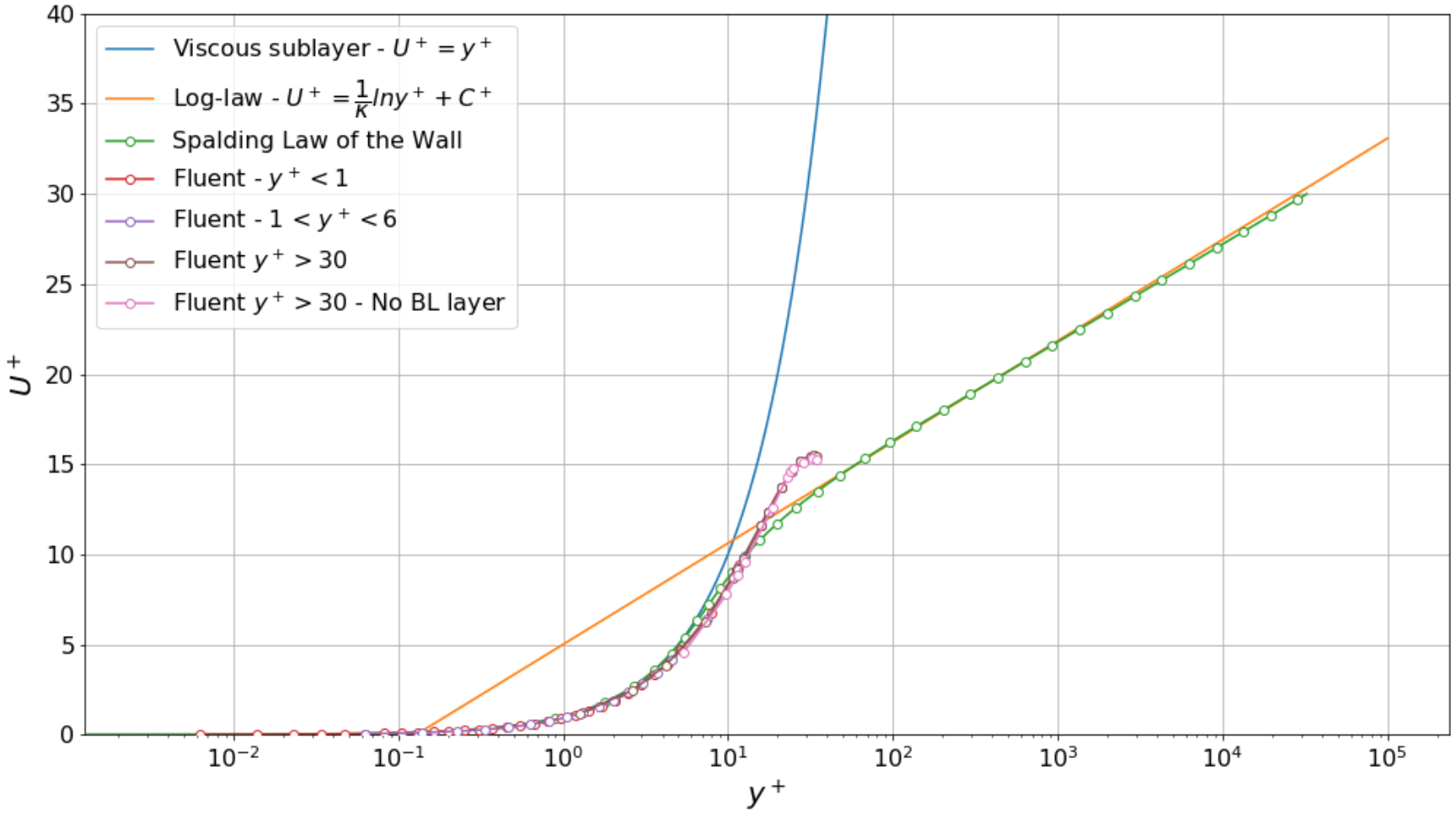
# Post-processing



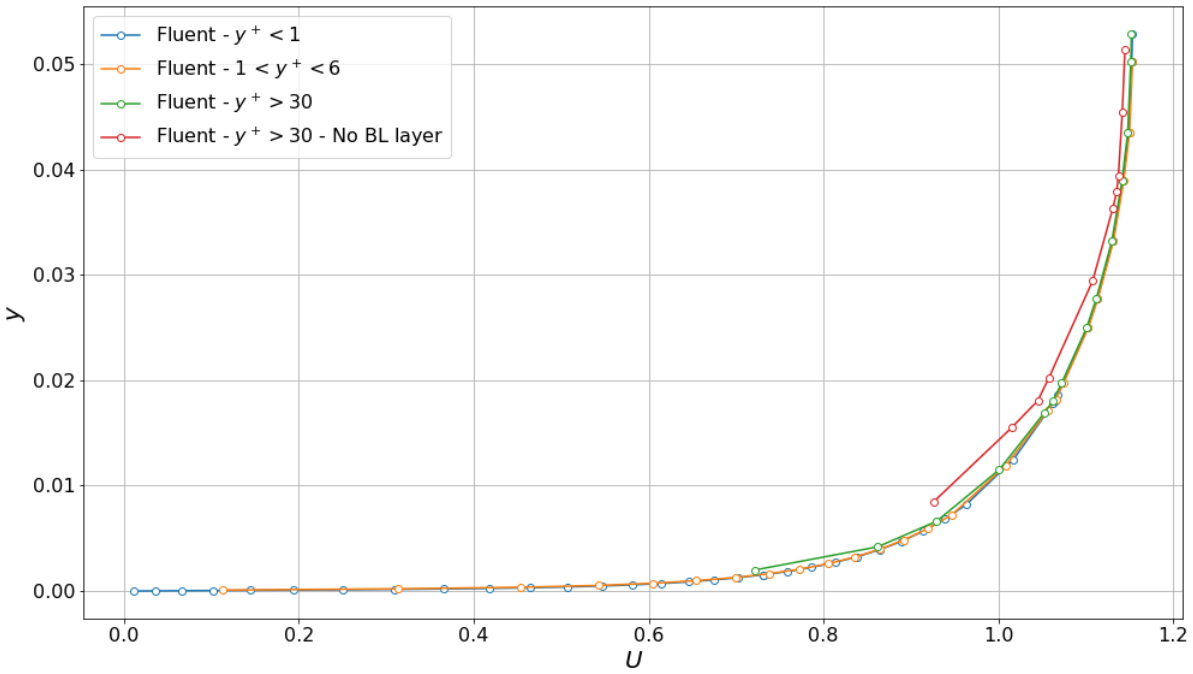

- Comparison of the velocity profiles using different meshes – Laminar regime.
- All sampling is done where the flow is fully developed.

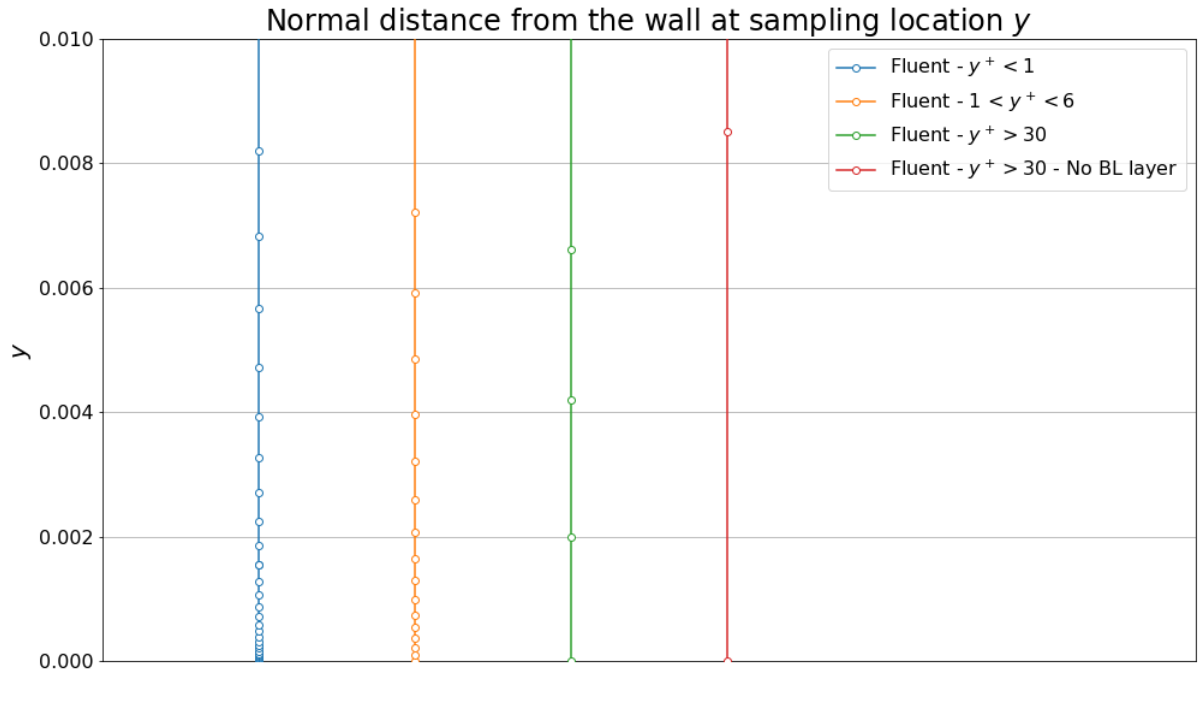
# Post-processing




- $u^+$ vs. $y^+$ plot – Laminar regime
- All sampling is done where the flow is fully developed.

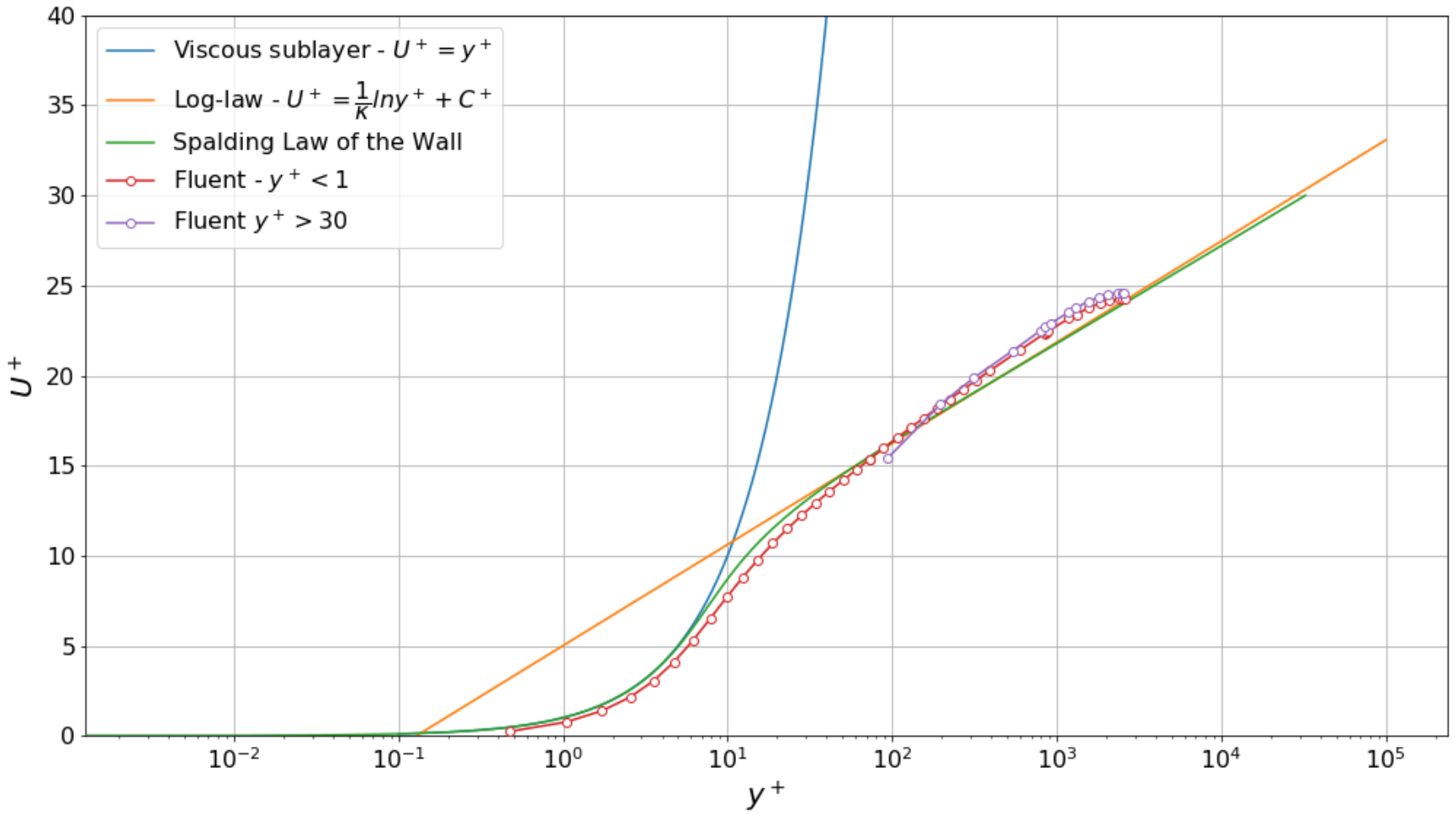
# Post-processing



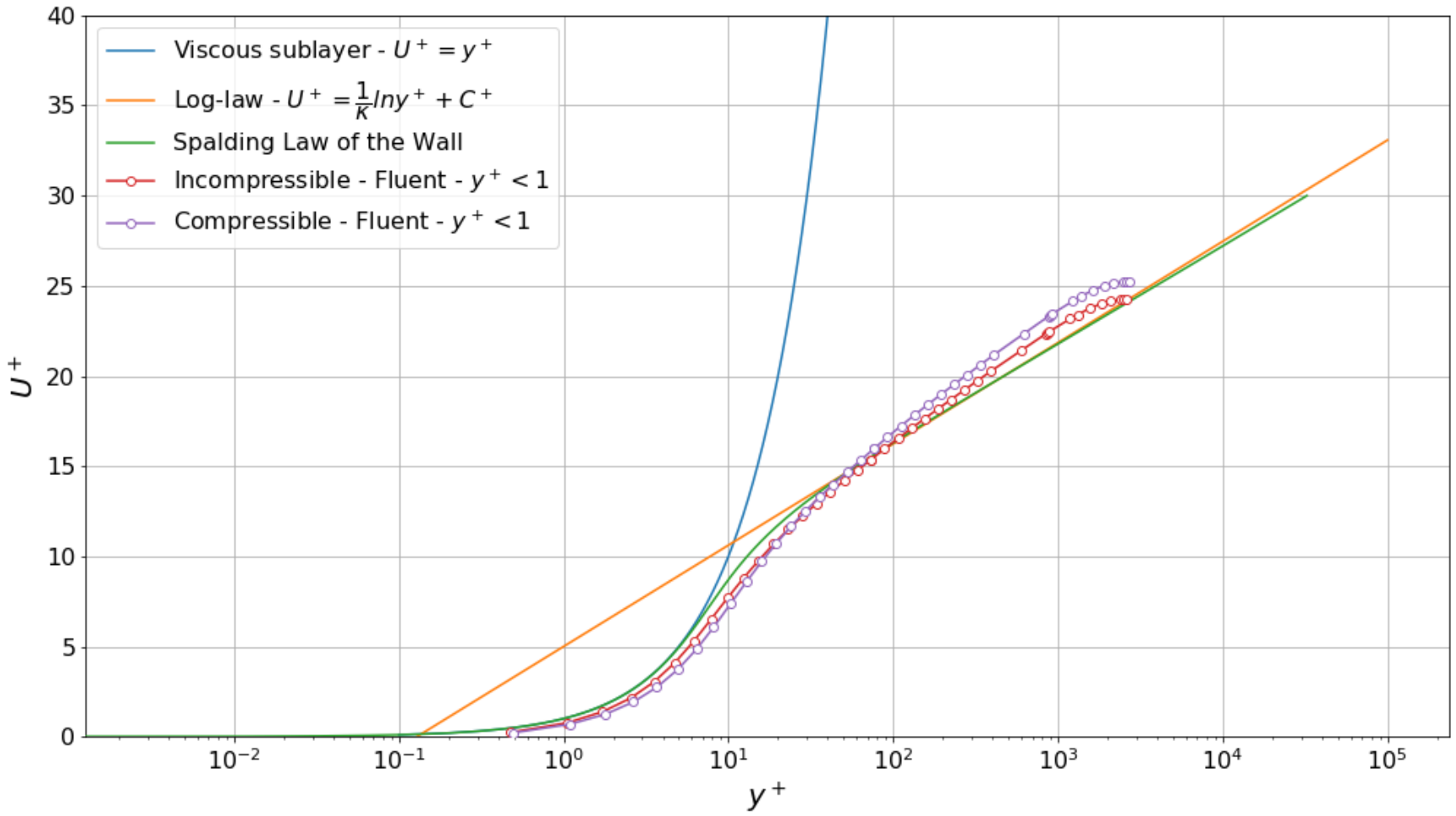

- Comparison of the velocity profiles using different meshes – Turbulent regime.
- All sampling is done where the flow is fully developed.

# Post-processing



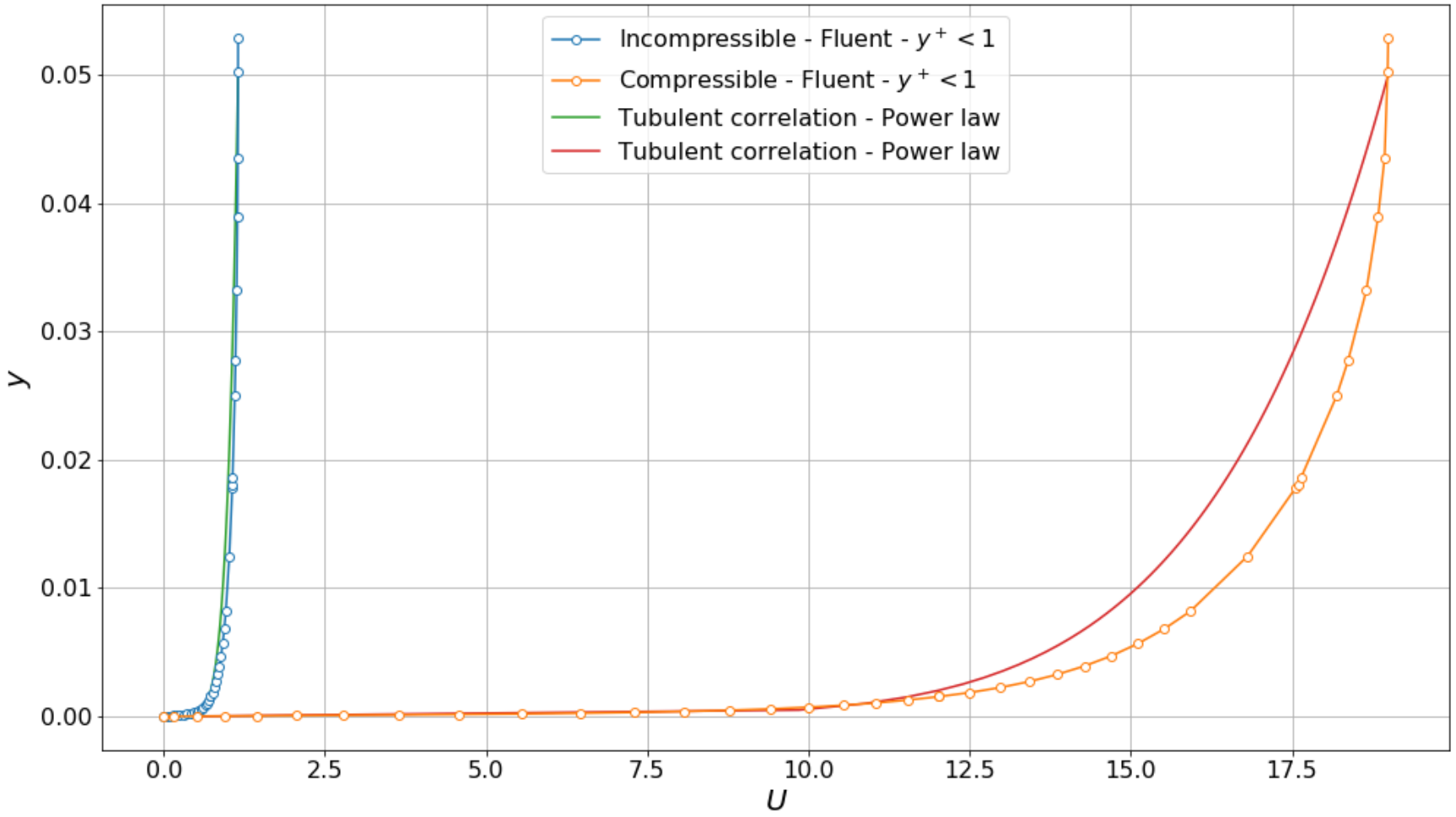

- $u^+$ vs. $y^+$ plot – Turbulent regime
- All sampling is done where the flow is fully developed.

# Post-processing




- $u^+$ vs. $y^+$ plot – Turbulent regime – Comparison of incompressible and compressible case.
- All sampling is done where the flow is fully developed.

# Post-processing

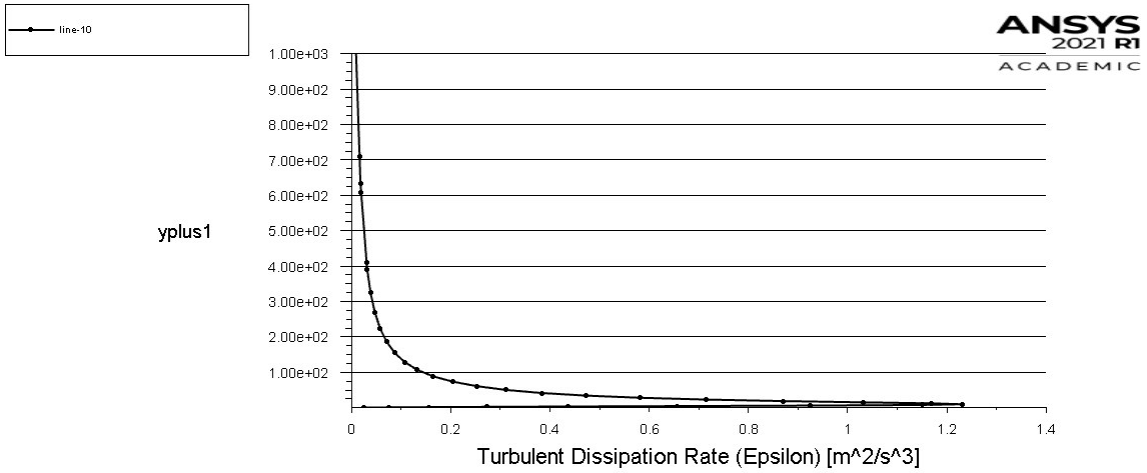


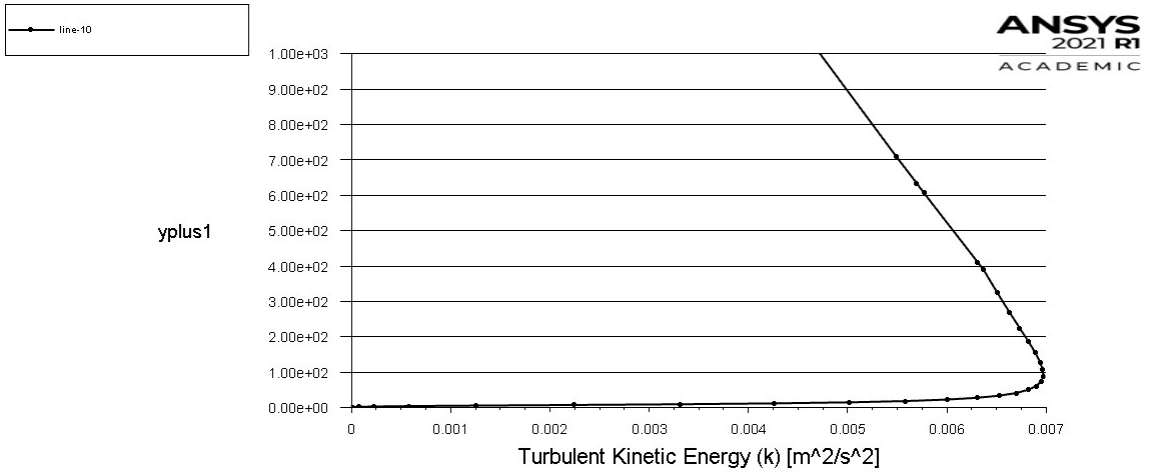

- Comparison of the velocity profiles in the turbulent regime – Comparison of incompressible and compressible case.
- All sampling is done where the flow is fully developed.

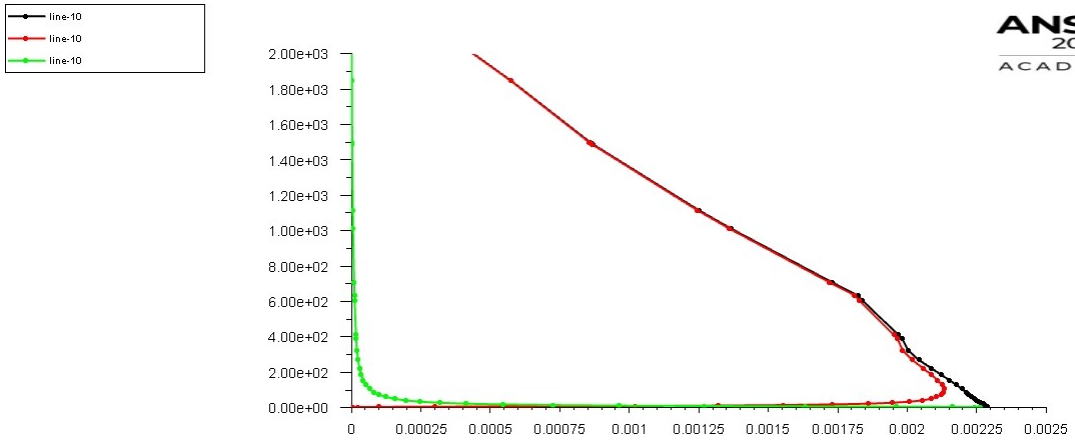
# Post-processing

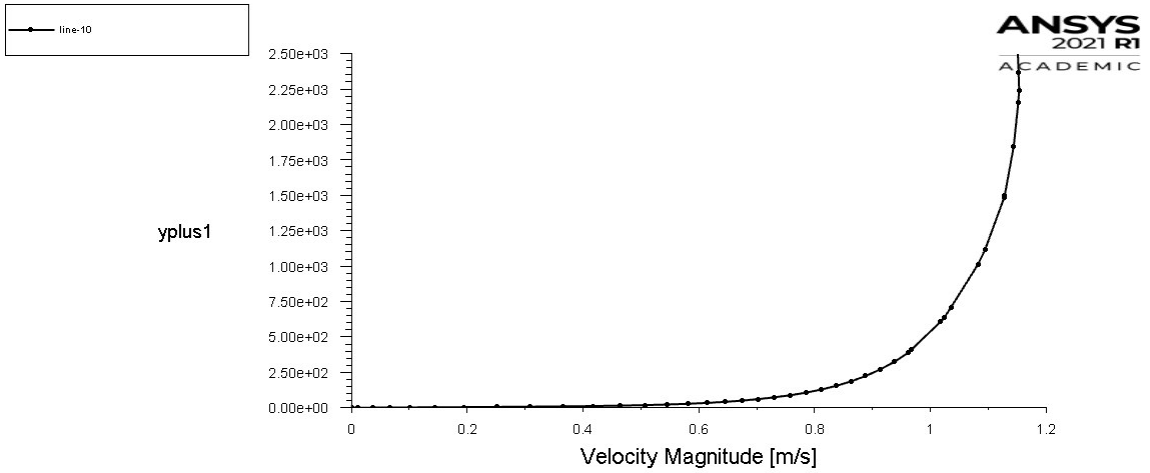
- The previous plots are classic verification in turbulence modeling.
- Independently of the geometry, flow properties, and inlet velocity, you should be able to reproduce the theoretical profiles of $u^+$ vs. $y^+$.
  - Of course, there are a few exceptions that we will study later.
- Remember, the sampling should be done where the flow is fully developed.
- Apart from these plots, you can also plot the following information (as shown in tutorial 1):
  - $y^+$ vs. turbulent kinetic energy.
  - $y^+$ vs. turbulent dissipation rate.
  - $y^+$ distribution at the walls.
    - This plot can be done along a line corresponding to a wall (in 2D), or on the wall surface (in 3D).
  - Laminar and turbulent shear stress along a line.
  - Wall shear stress and friction coefficient at the walls.

# Post-processing




- If you compare the 3D results with the 2D results you will notice that 2D flows are much more energetic.
- There is no vortex stretching.