KTH ROYAL INSTITUTE
OF TECHNOLOGY

Control of particle agglomeration with relevance to after-treatment gas processes

Ghulam Mustafa Majal

11.10.2018, CCGEx – Research Day

Energimyndigheten SCANIA VOLVO VOLVO BorgWarner

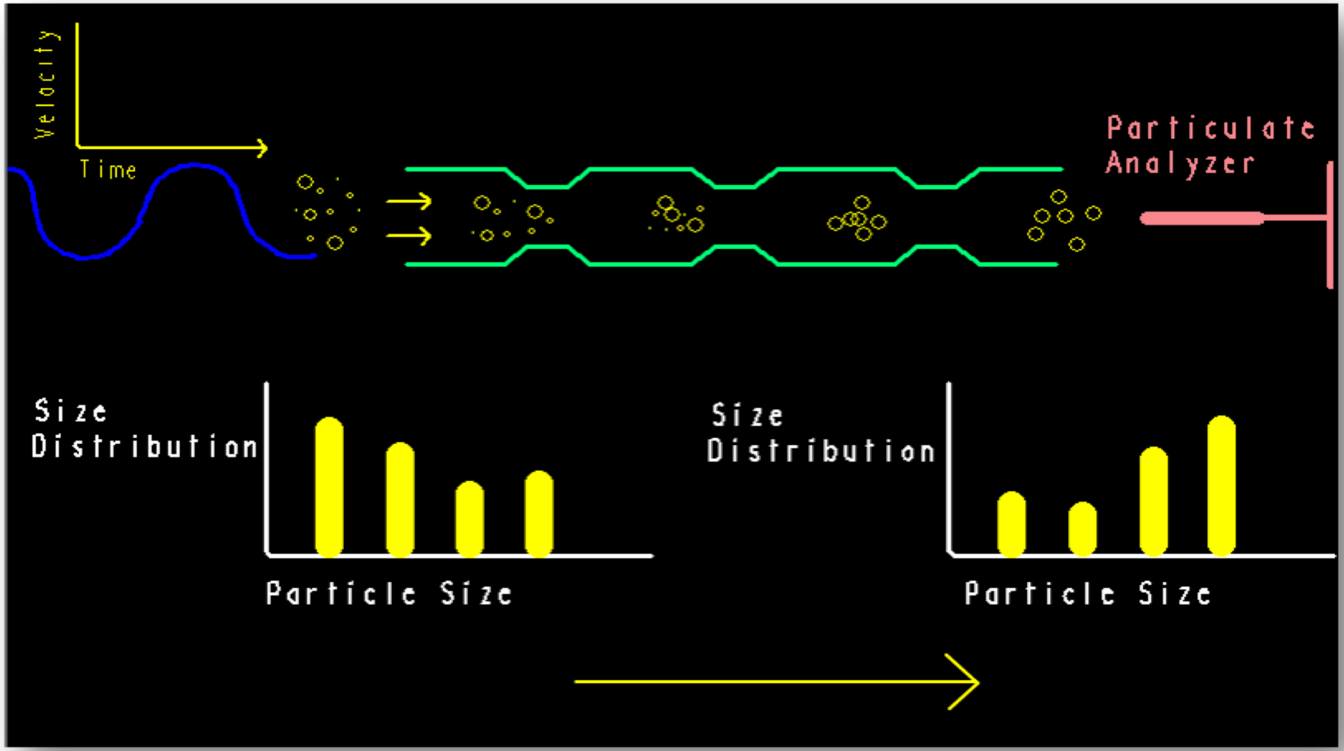
Outline

- Scope
- Highlights of the CFD study
- Future plans

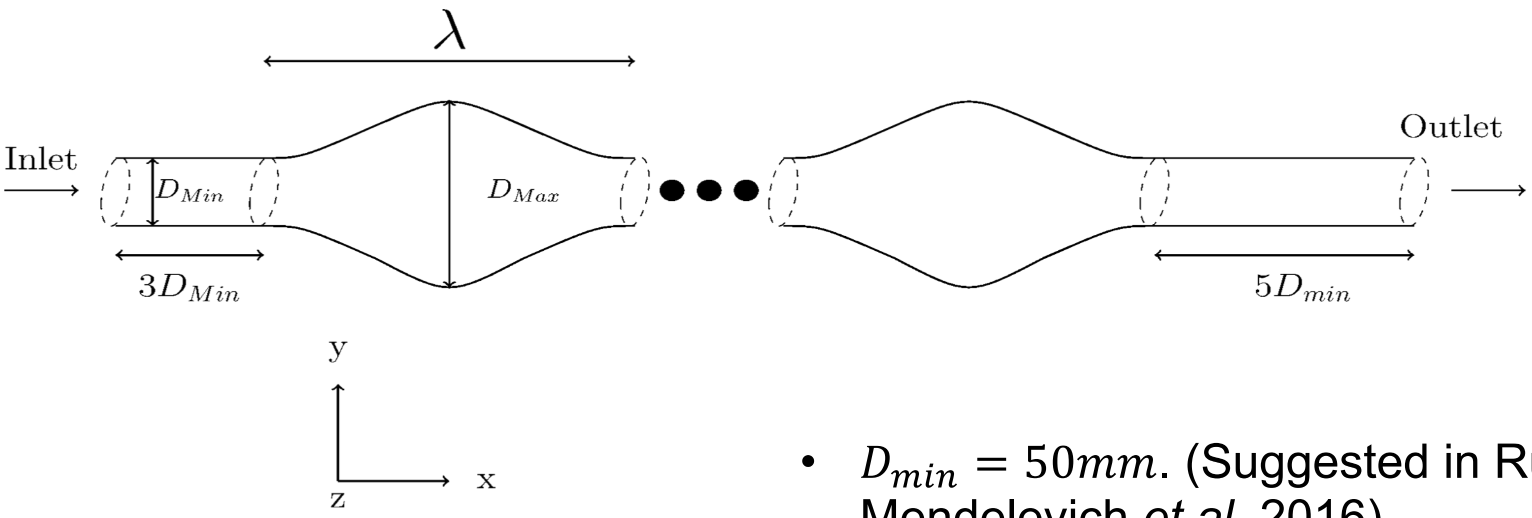
Scope of the study

- (**Why?**)Reduce the number of particles in the internal combustion engine(ICE) exhaust gases.
- (**How?**)Using flow and acoustic forcing to enhance particle agglomeration.
- (**Insight**)Perform numerical studies to study particle behavior under pulsatile flow conditions. Make comparison against measurements on an actual engine exhaust system.
- (**Goal**)Utilize the insight to help the industry develop a suitable prototype that can be used as an after treatment device.

Agglomeration Concept



3D CFD Setup

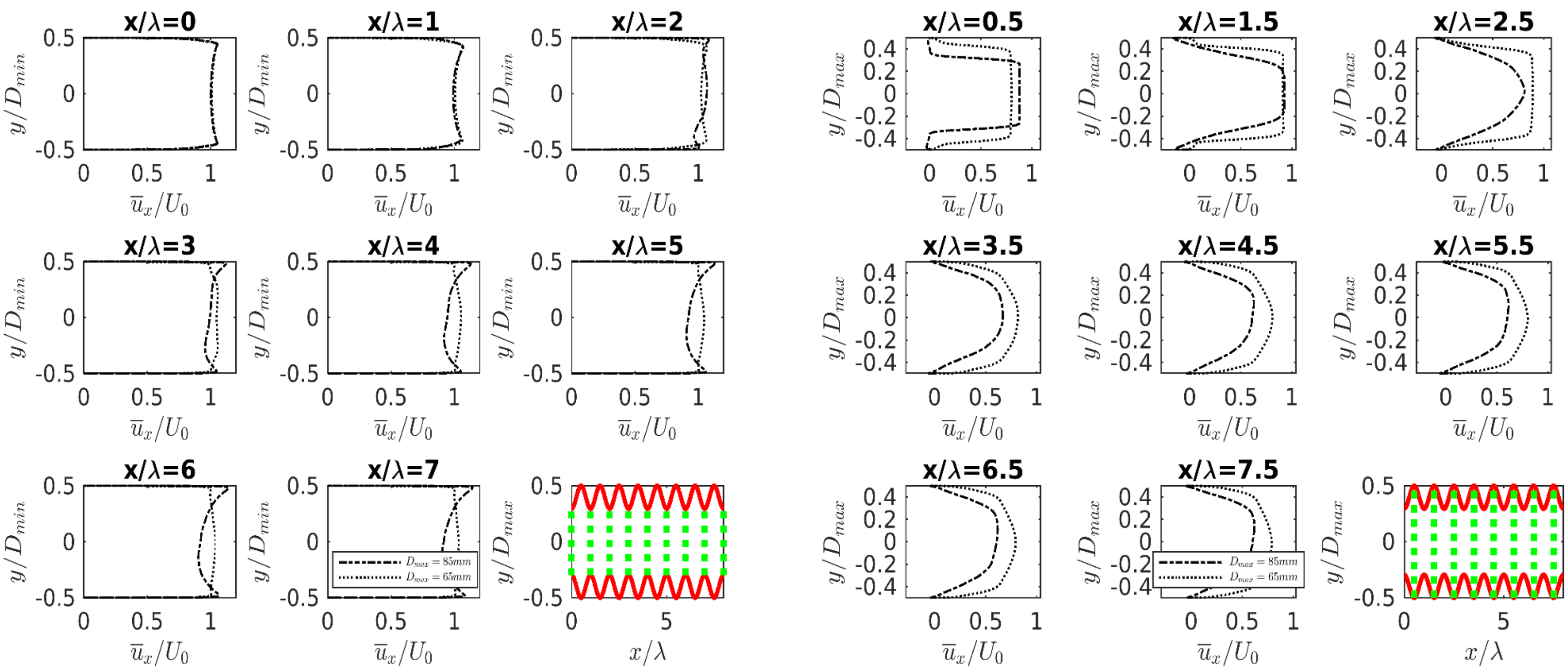


Region	Boundary Condition
Inlet	Velocity Inlet ($U_0 = 80m/s$)
Outlet	Pressure Outlet($0\ Pa$)
Walls	NoSlip

- $D_{min} = 50mm$. (Suggested in Ruzal-Mendelevich *et al*. 2016).
- $D_{max} \in \{65mm, 85mm\}$. (Motivated by Steady State RANS).
- $\lambda = 120mm$. (Motivated by 1D model).
- $Re_{Dmin} = 2.55\times1\boldsymbol{e}5$

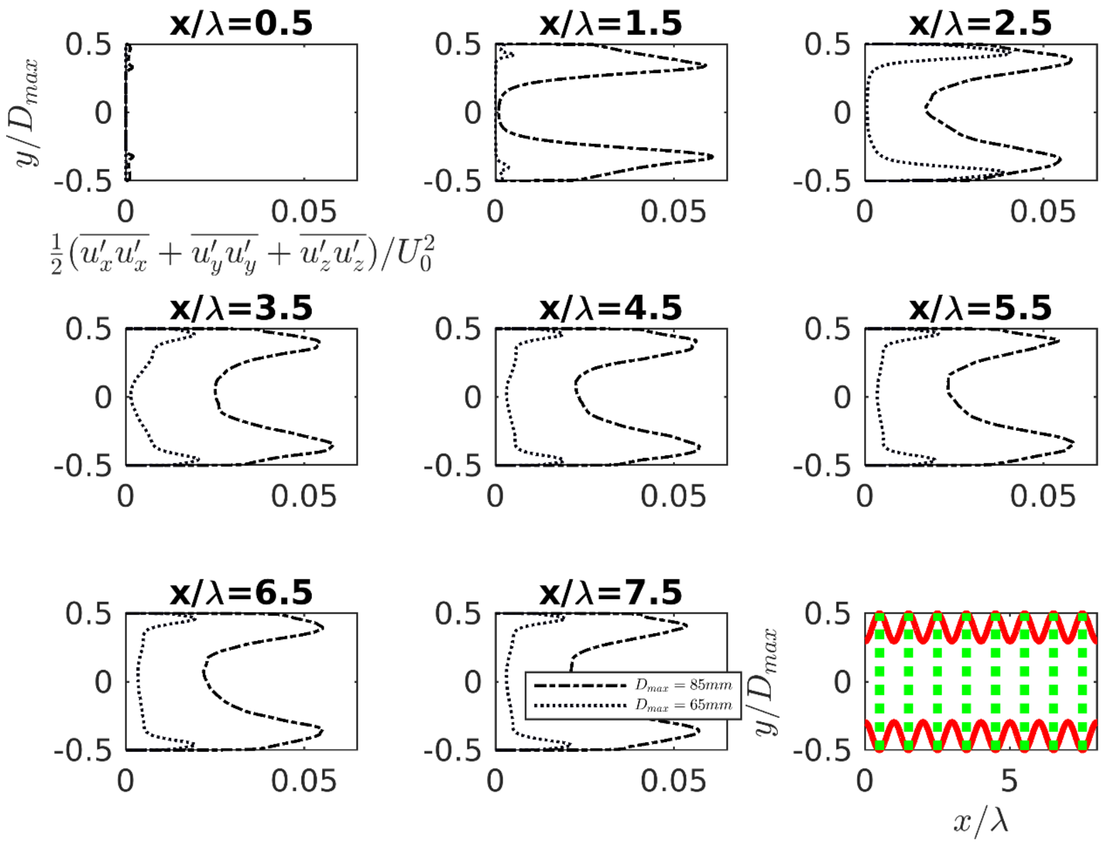
- Methodology being utilized is DES: RANS(SST $\mathrm{k} - \omega$) and SGS (Smagorinsky).
- Third Order MUSCL convection scheme.
- Second Order Implicit temporal scheme.
- Max time step $1\boldsymbol{e} - 6s$ ($Co < 1$).

Normalized time averaged streamwise velocity



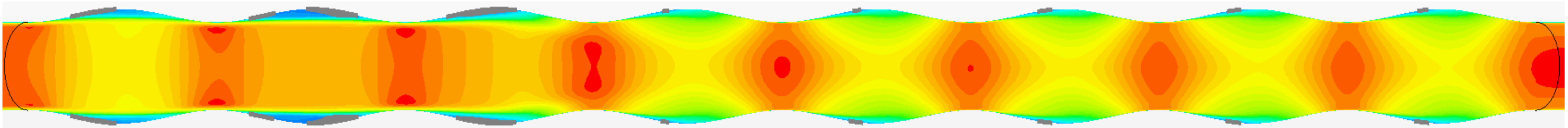
- Assymmetry in the profiles for $D_{max} = 85mm$ found across planes of maximum cross sectional area.

Turbulent Kinetic Energy

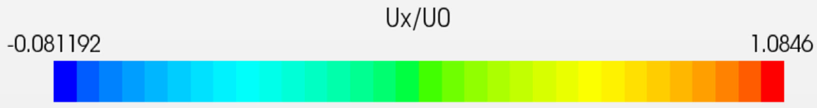


- Higher TKE found for $D_{max} = 85mm$

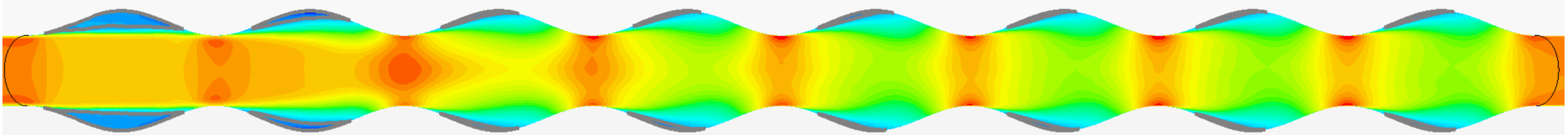
Recirculation Regions



Grayed outlines represent isosurfaces of time averaged streamwise velocity corresponding to $\bar{u}_x = -1e-4m/s$



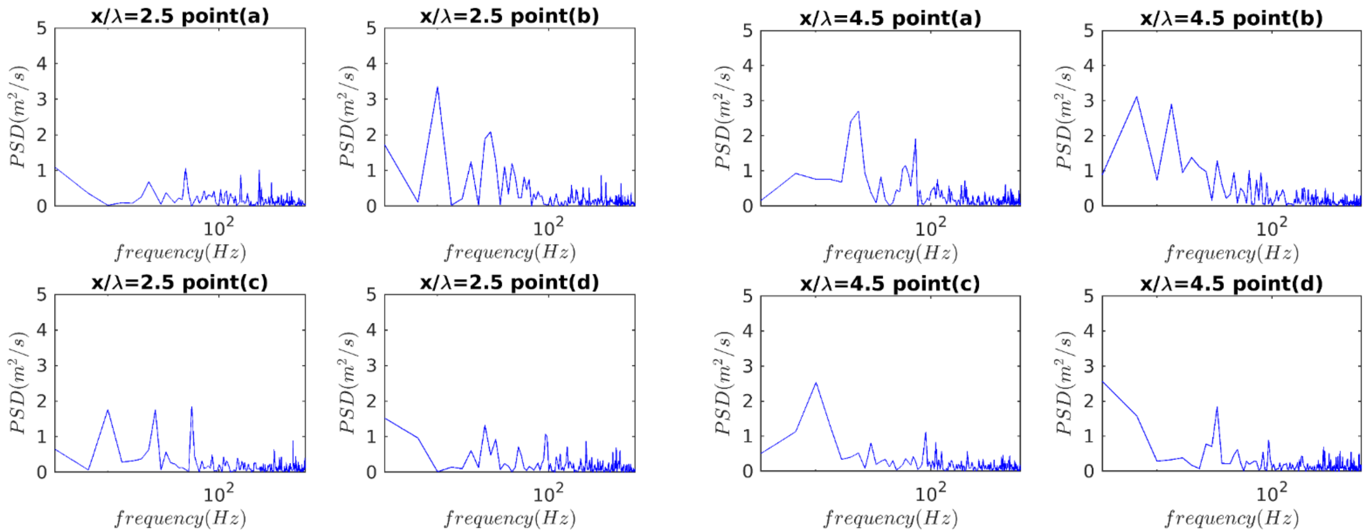
Contours of normalized time averaged streamwise velocity for $D_{max} = 65mm$ across the xyPlane: $z = 0$

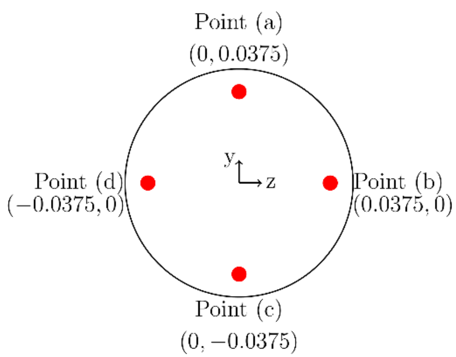


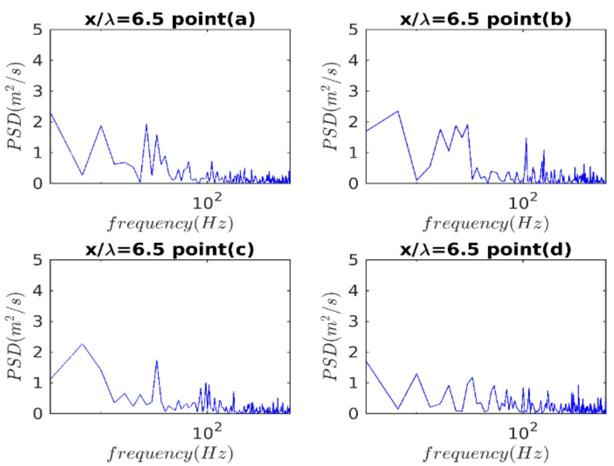
Contours of normalized time averaged streamwise velocity for $D_{max} = 85mm$ across the xyPlane: $z = 0$

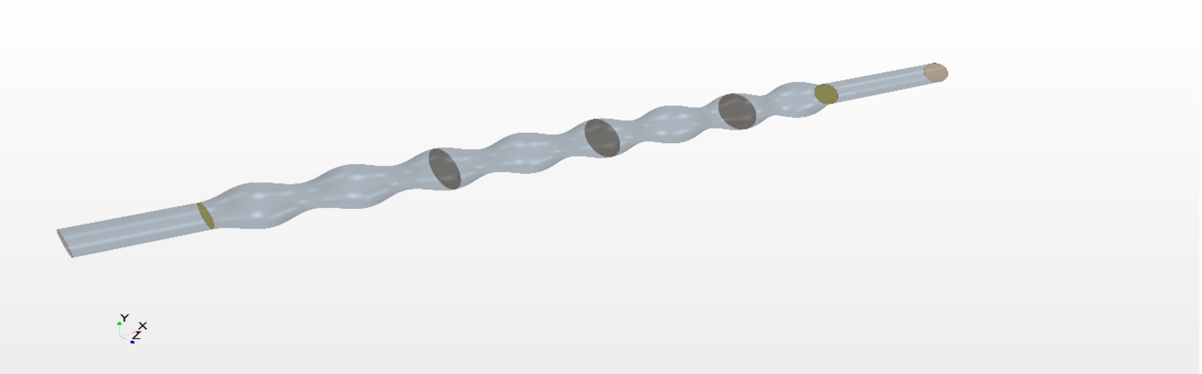
- ❑Larger recirculation regions found for $D_{max} = 85mm$

Frequency spectrum for tangential components of velocity at probe points









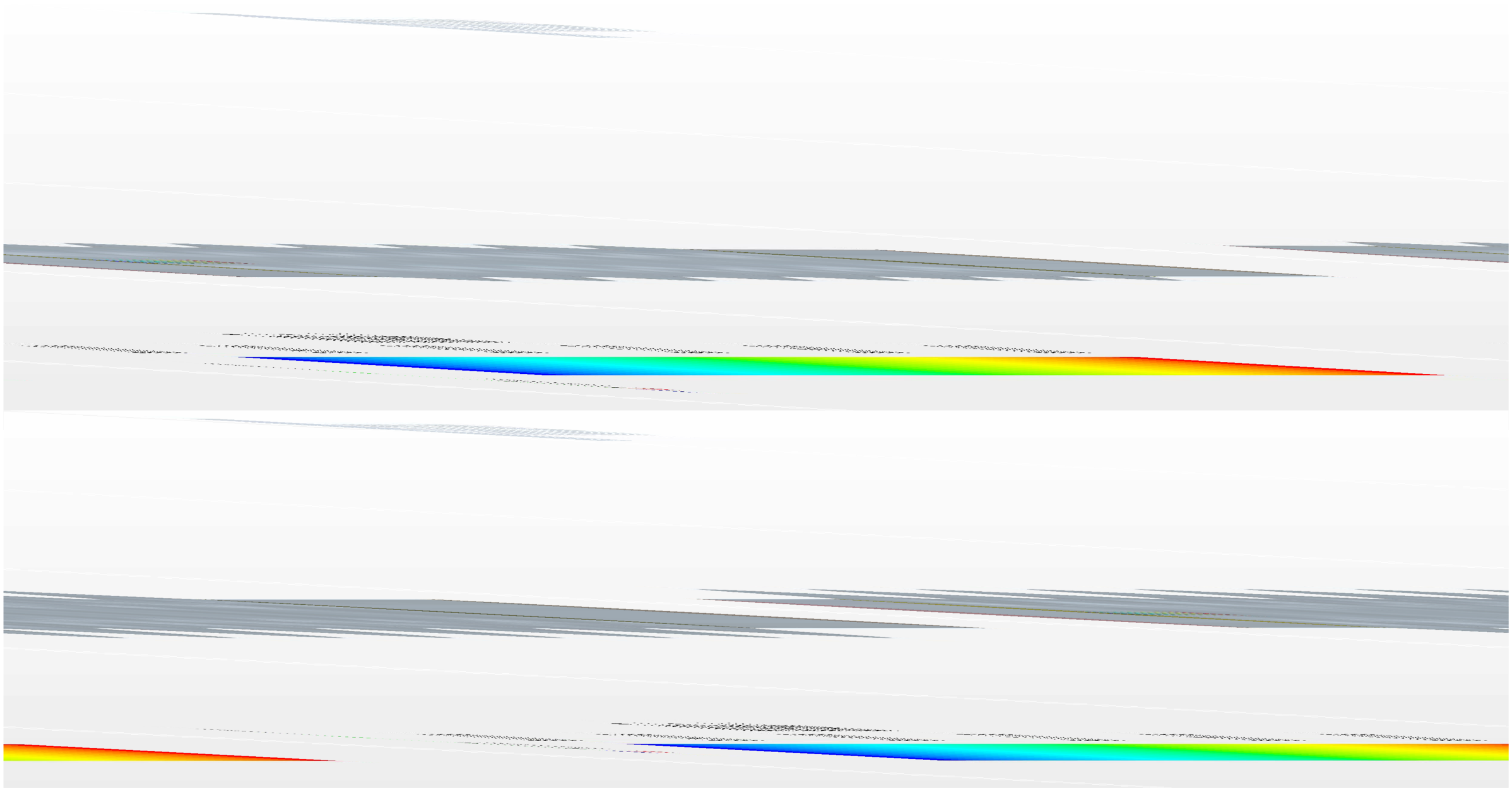
Length and Velocity Scales

- Four frequencies identified: (3.3Hz, 10.02Hz, 13.3Hz and 16.7Hz).
- Corresponding length scales ($l_1 = 0.12m$), ($l_2 = 1m$) and ($l_2 = 0.05m$).
- Corresponding velocity scales ($u_1 = 0.3m/s$), ($u_2 = 9m/s$) and ($u_3 = 0.64m/s$).

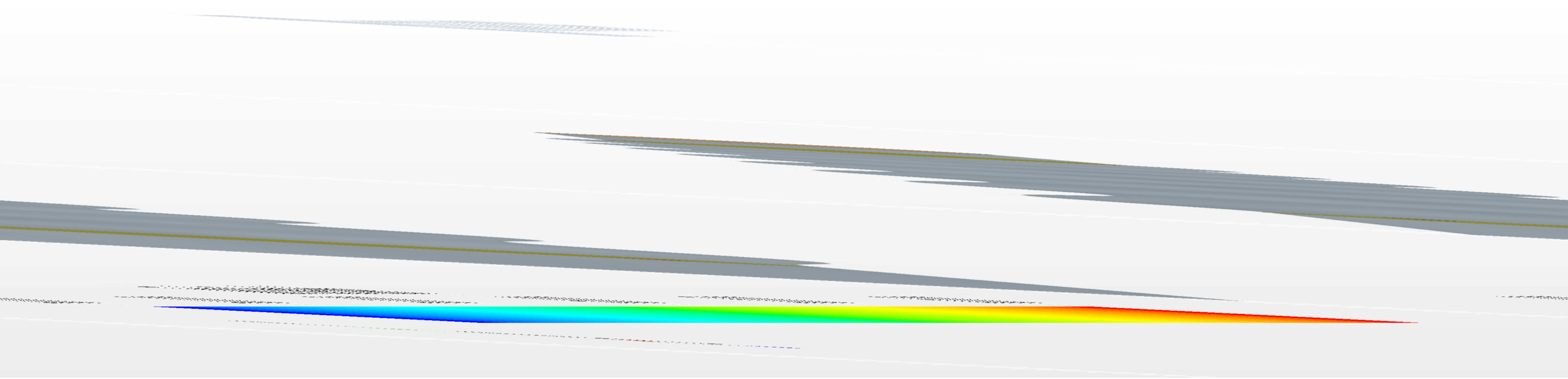
Particle Injection

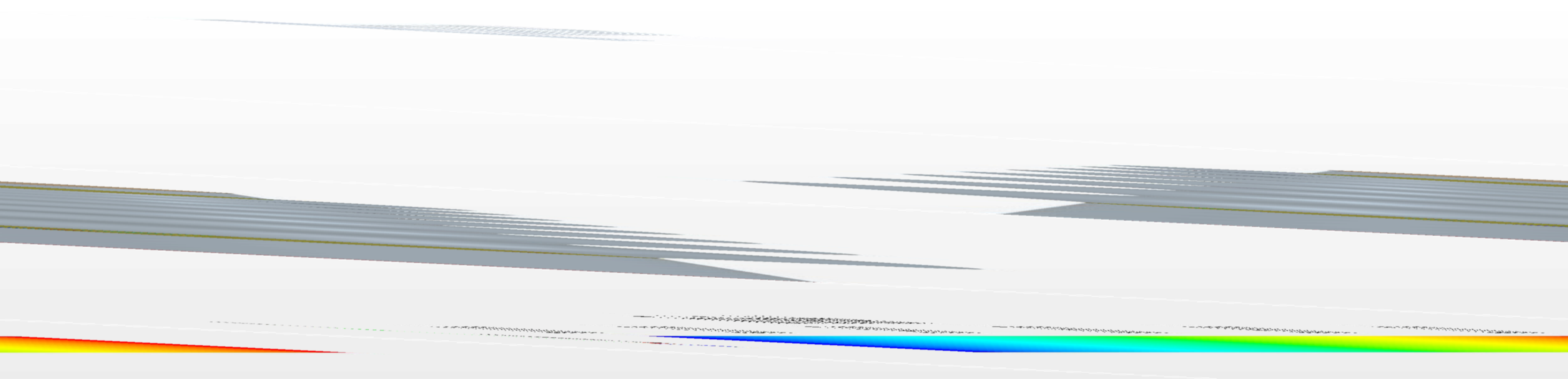
- Simple test case of monodisperse particles with $D_p = 900nm$. Stokes number $\sim O(10^{-4})$
- One way coupling with no particle-particle interaction using a Lagrangian approach.
- Three different injection locations are tested.
- Particles injected in the first time step only in these test cases.
- Drag force and Pressure gradient force are included.

Centerline Injection



Cross stream and spanwise injection





Summary

- Assymetry observed for the case of $D_{max} = 85mm$.
- Larger Recirculation regions and turbulent kinetic energy observed for this case as well.

Future plans

- Analyze instability mechanisms for the flow.
- Include particle-particle interaction inside a polydisperse scenario.
- Consider pulsatile flow.

Thank you for your attention!

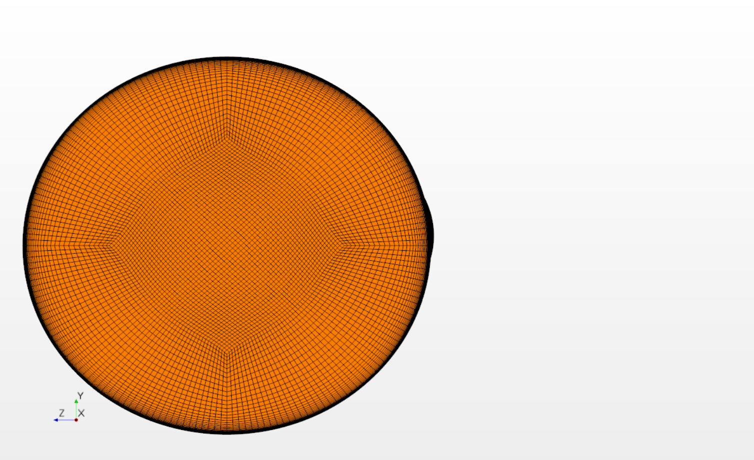
Competence Center for Gas Exchange

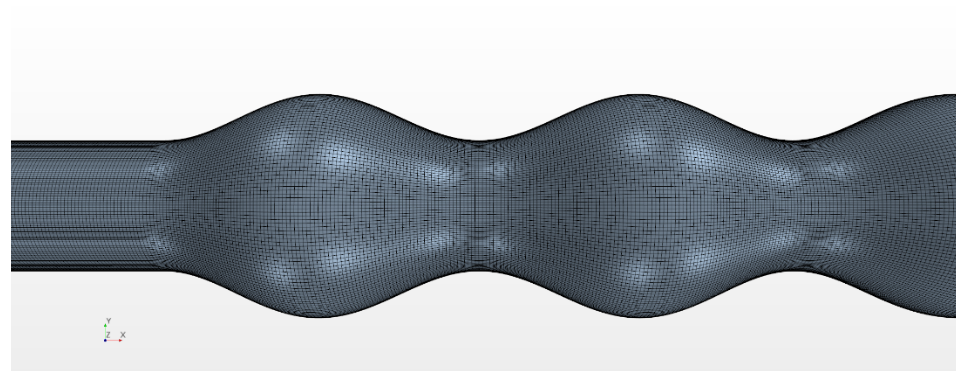
CCGEx

”Charging for the future”

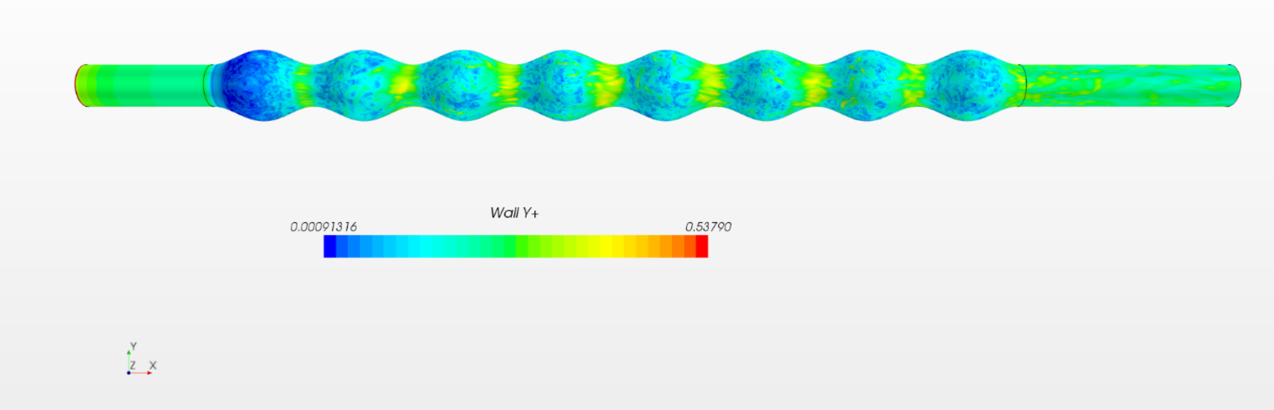
Energimyndigheten SCANIA VOLVO VOLVO BorgWarner

Mesh Details

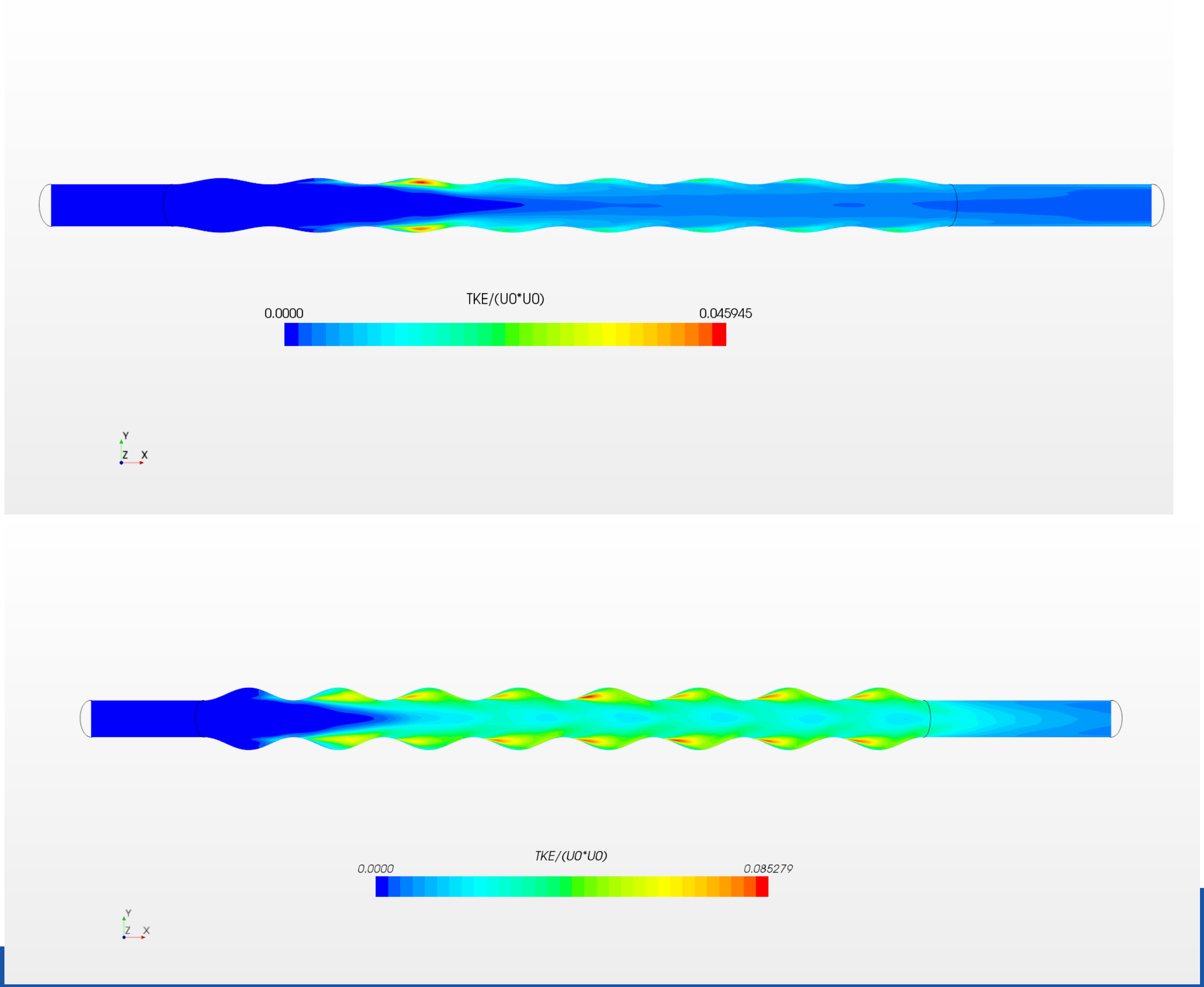




Hexahedral mesh with ~ 12.5mil cells.



Turbulent Kinetic Energy



Streamlines