

# Shear Flows of Dense Suspensions

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Department: Mechanical Engineering

Funding: Gorman Program

# Surrounded by Fluids

- Fluids play a crucial role in our lives
- Still do not understand many of their properties
  - Effect when shear force is applied to dense suspension

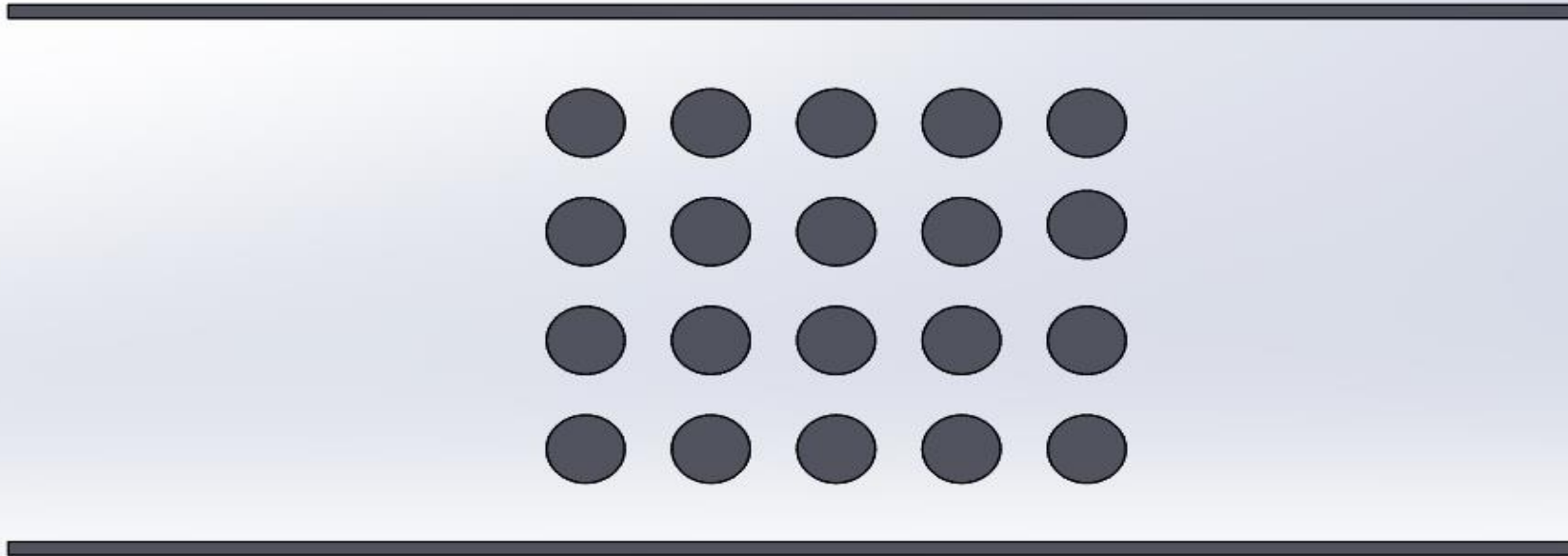


# Fundamental Fluid Flow Research

- Many possible applications
- Predict and control debris flows and mudslides



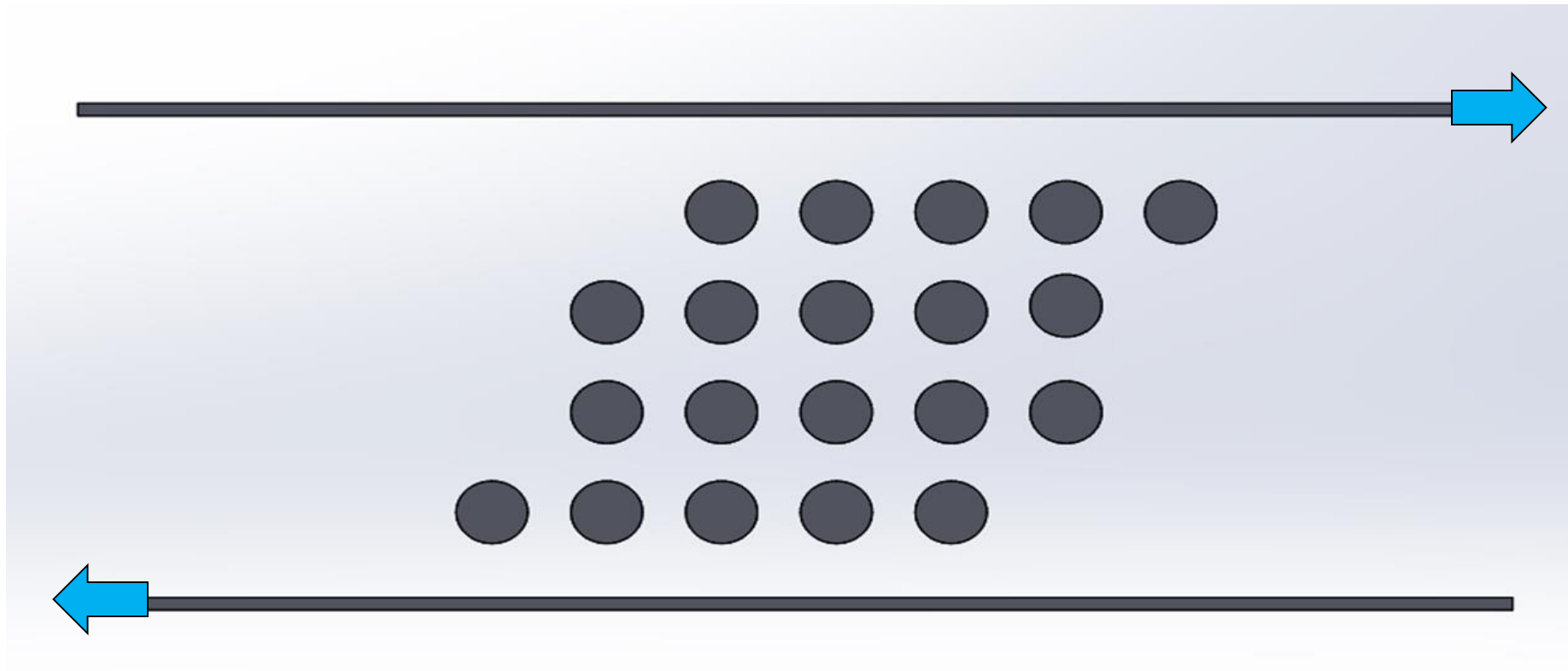
# Suspended Particles in a Channel





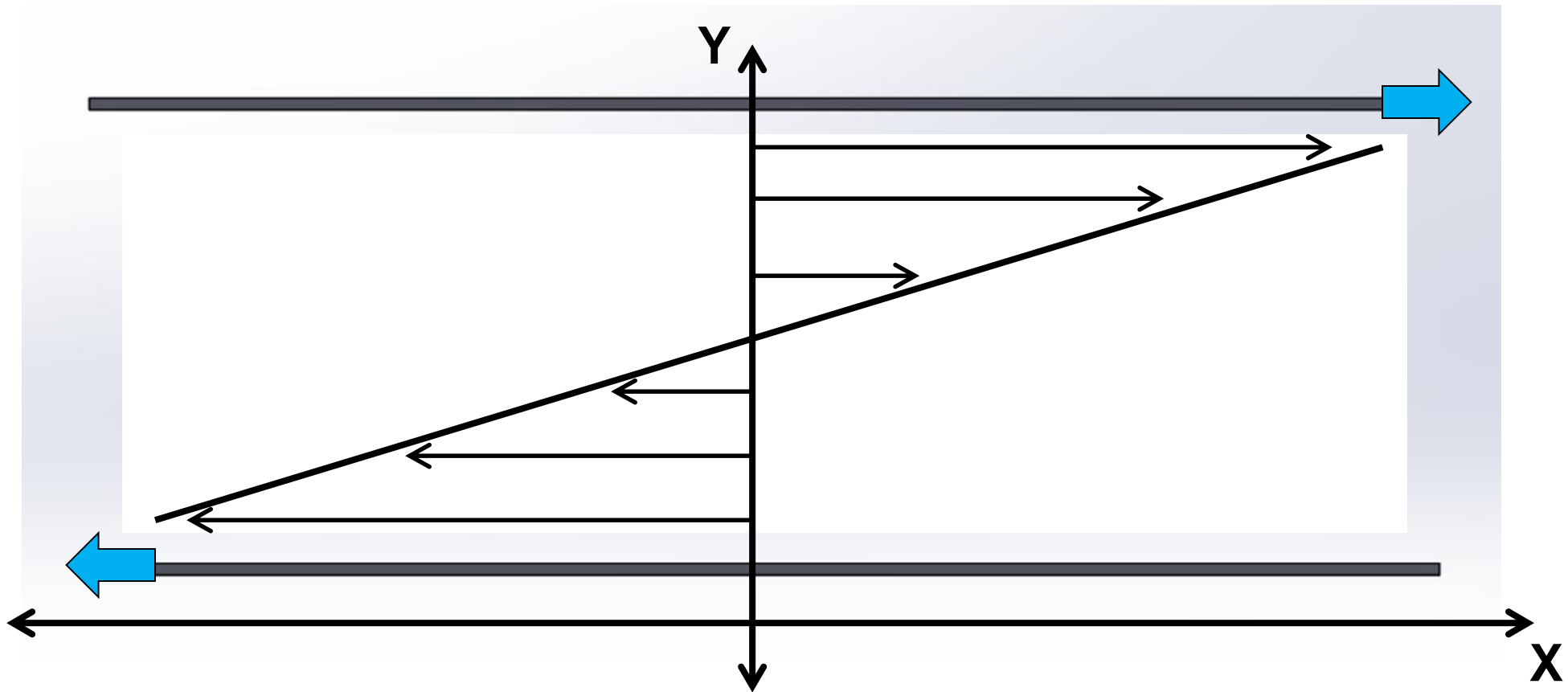
# Suspended Particles in a Channel

Shear suspension by moving channel walls



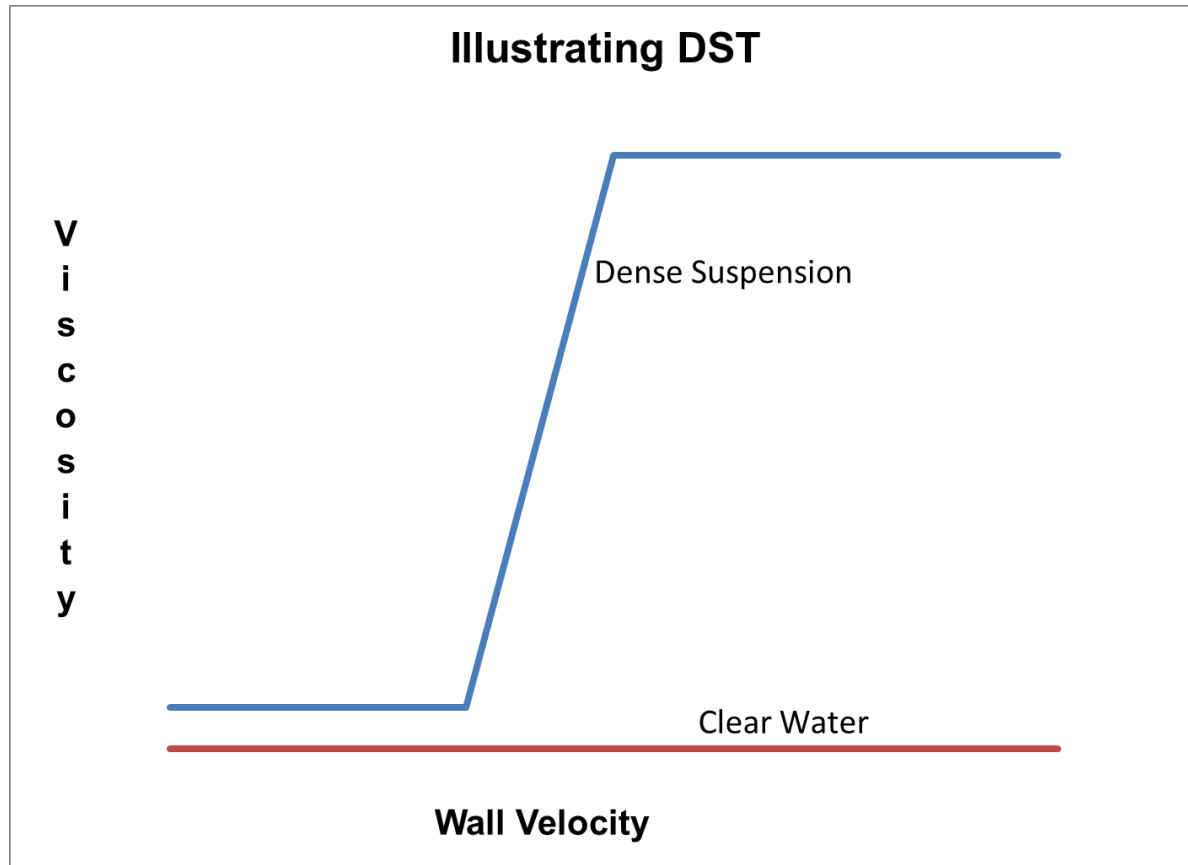
# Suspended Particles in a Channel

Velocity vectors



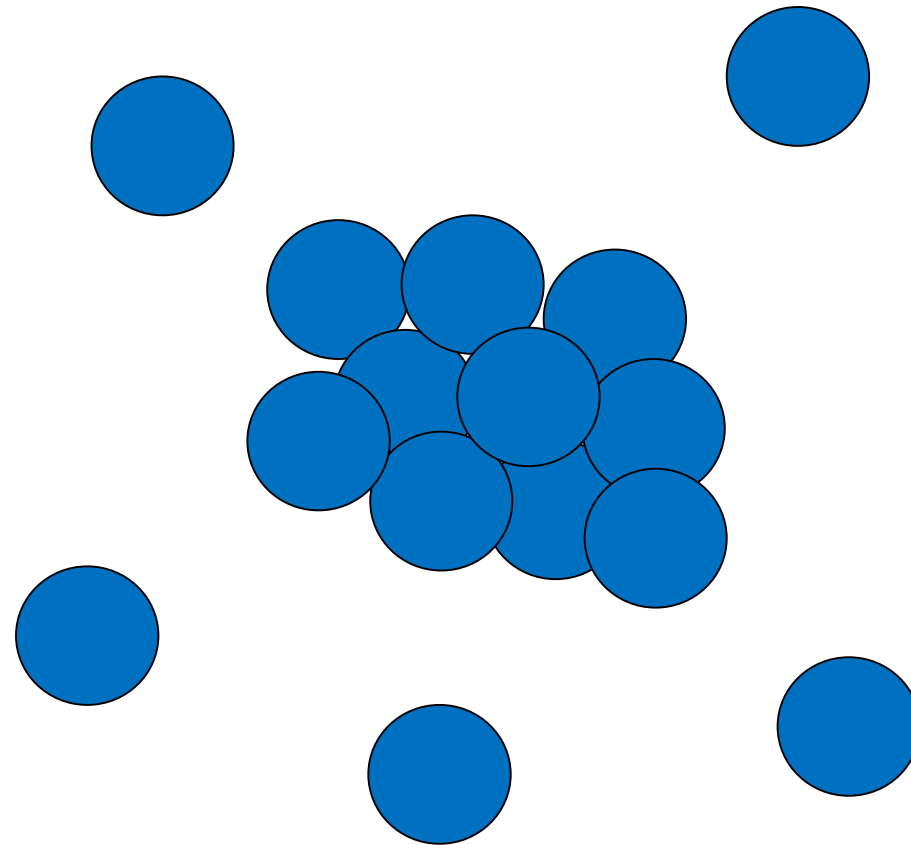
# Discontinuous Shear Thickening

A very small increase in speed of the channel walls causes an abrupt increase in viscosity → Discontinuous Shear Thickening (DST)



# Particles Modify Flow Behavior

## Clustering

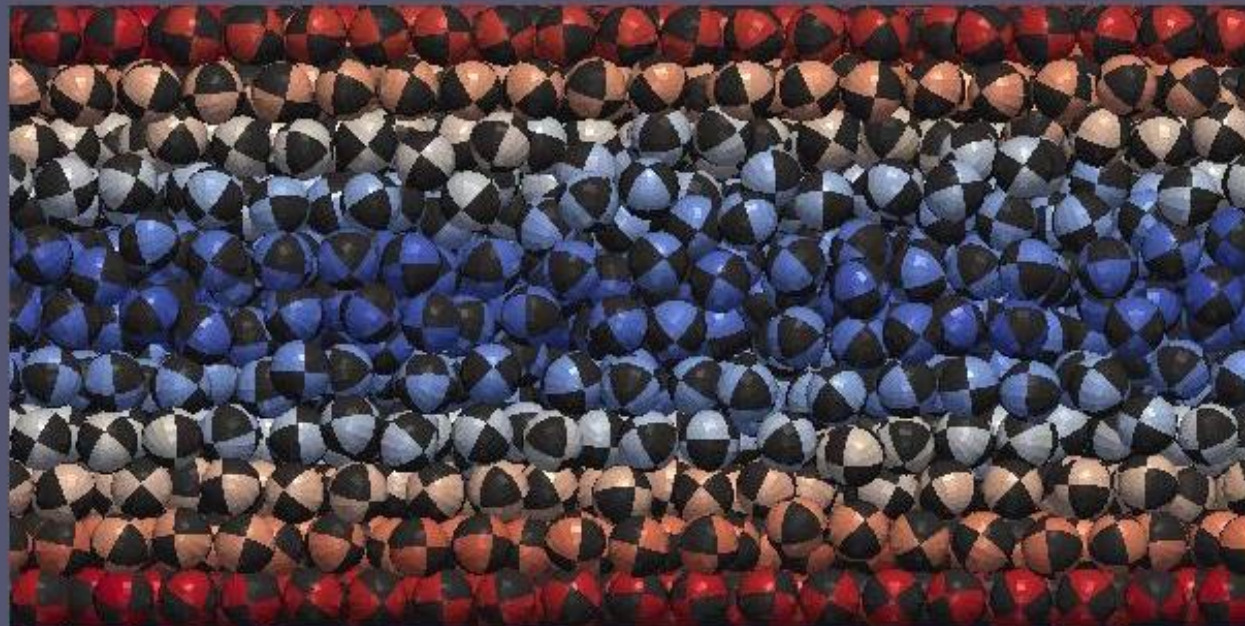




# Computer Simulation of Particle Flow

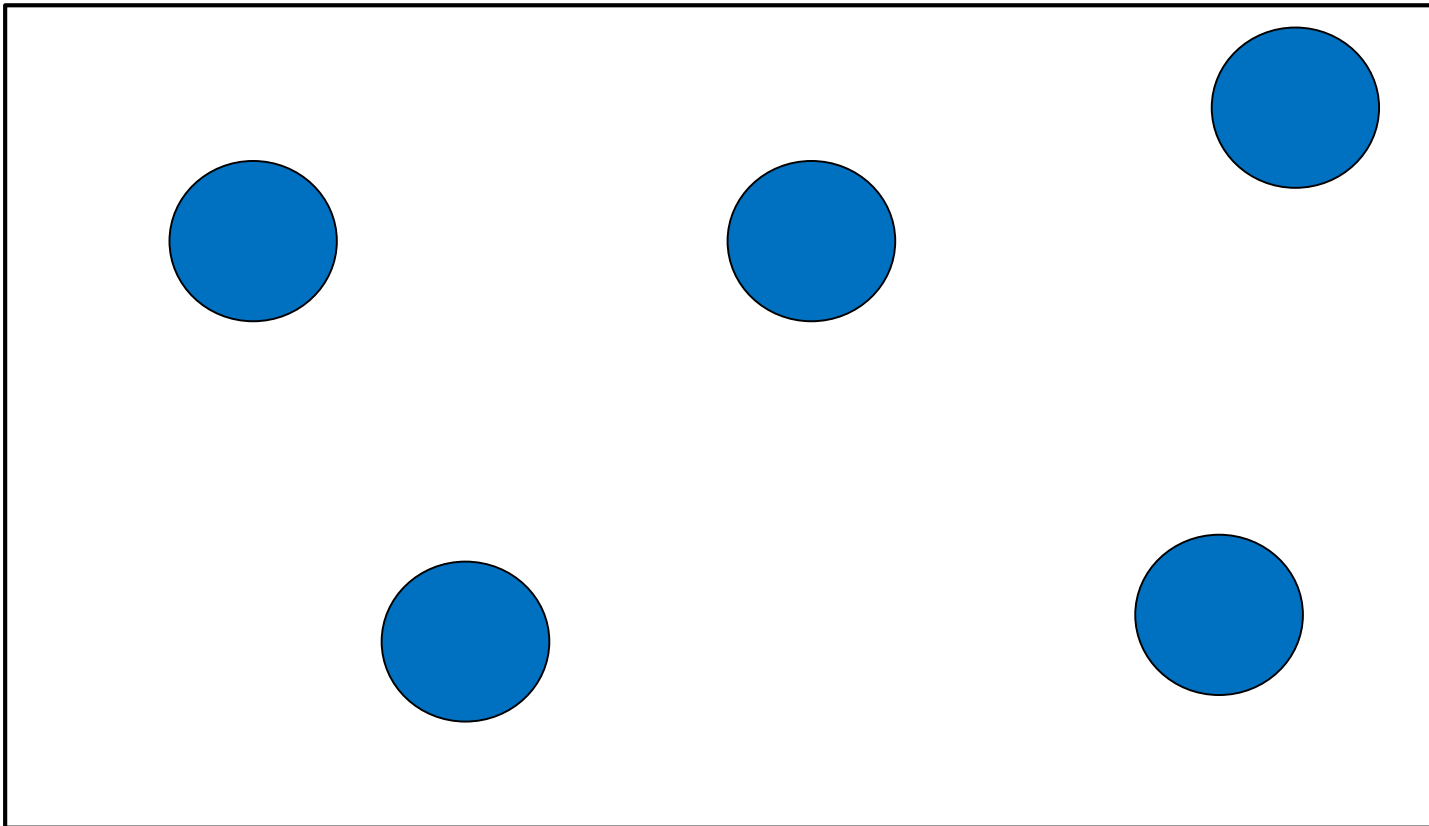
# Computer Simulation of Particle Flow

Linear Velocity Magnitude



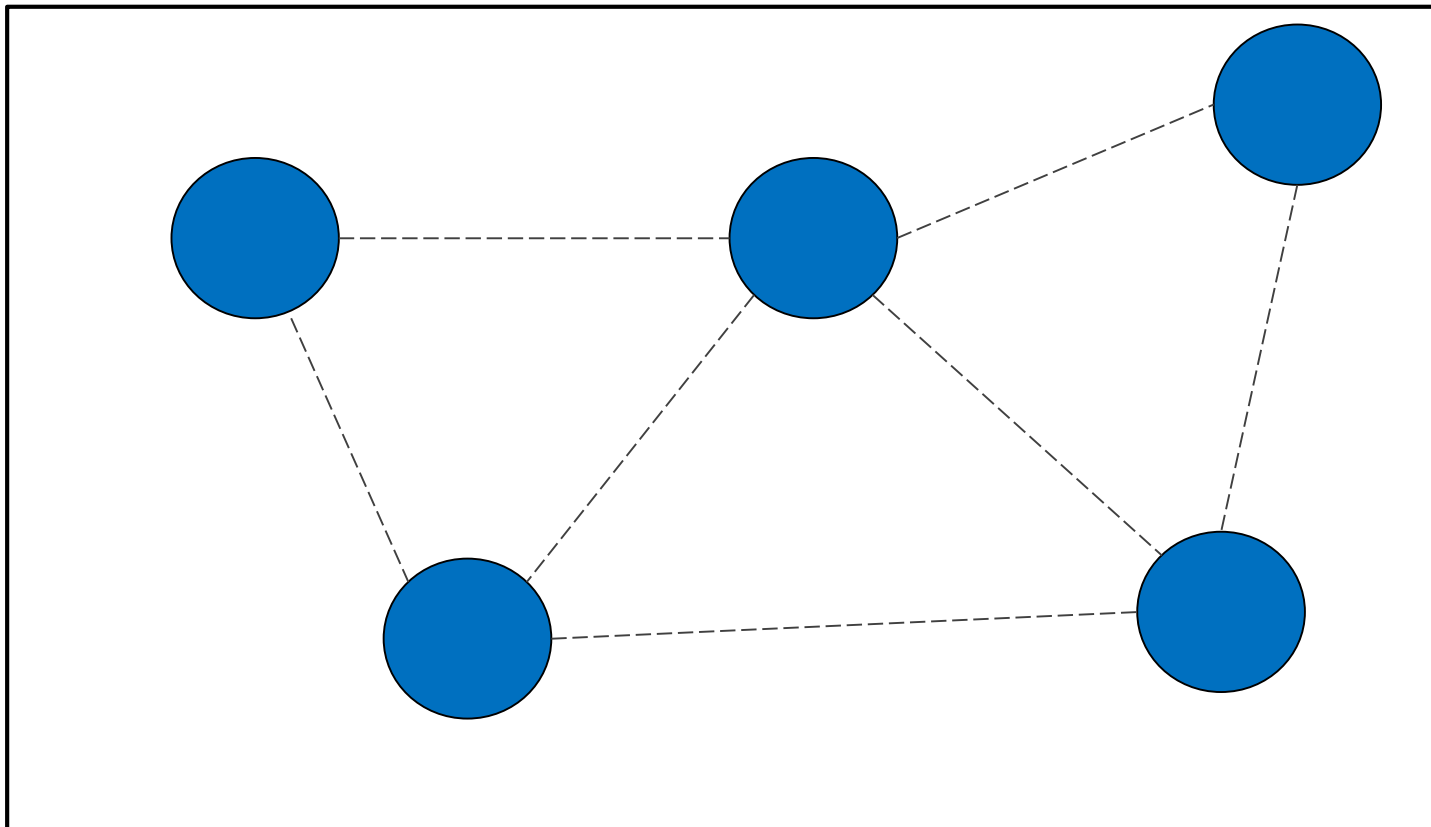
# Voronoi Diagram

Collection of boundaries drawn around the volume/area closer to each particle than to any other



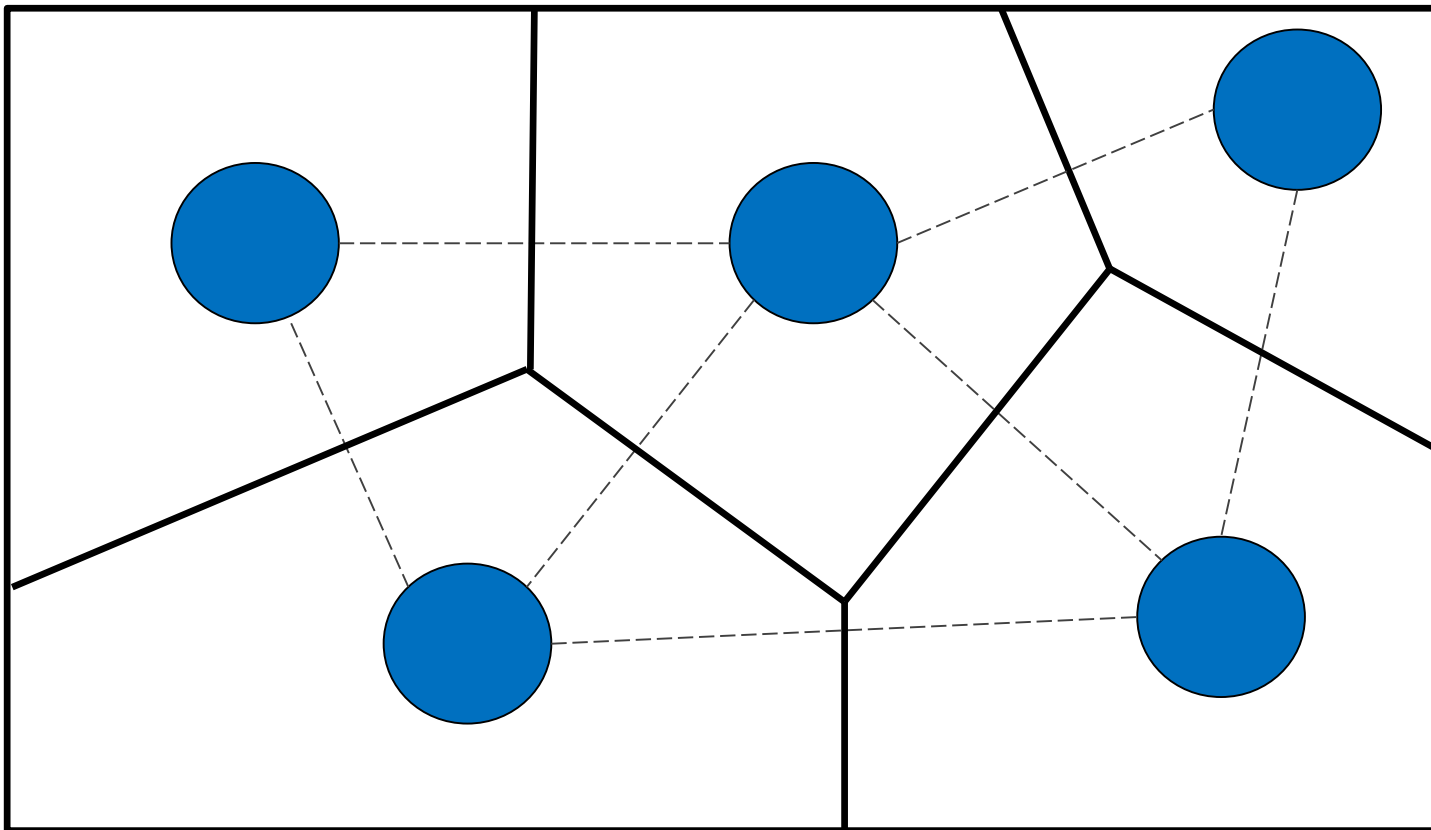
# Voronoi Diagram

Draw lines connecting the particles



# Voronoi Diagram

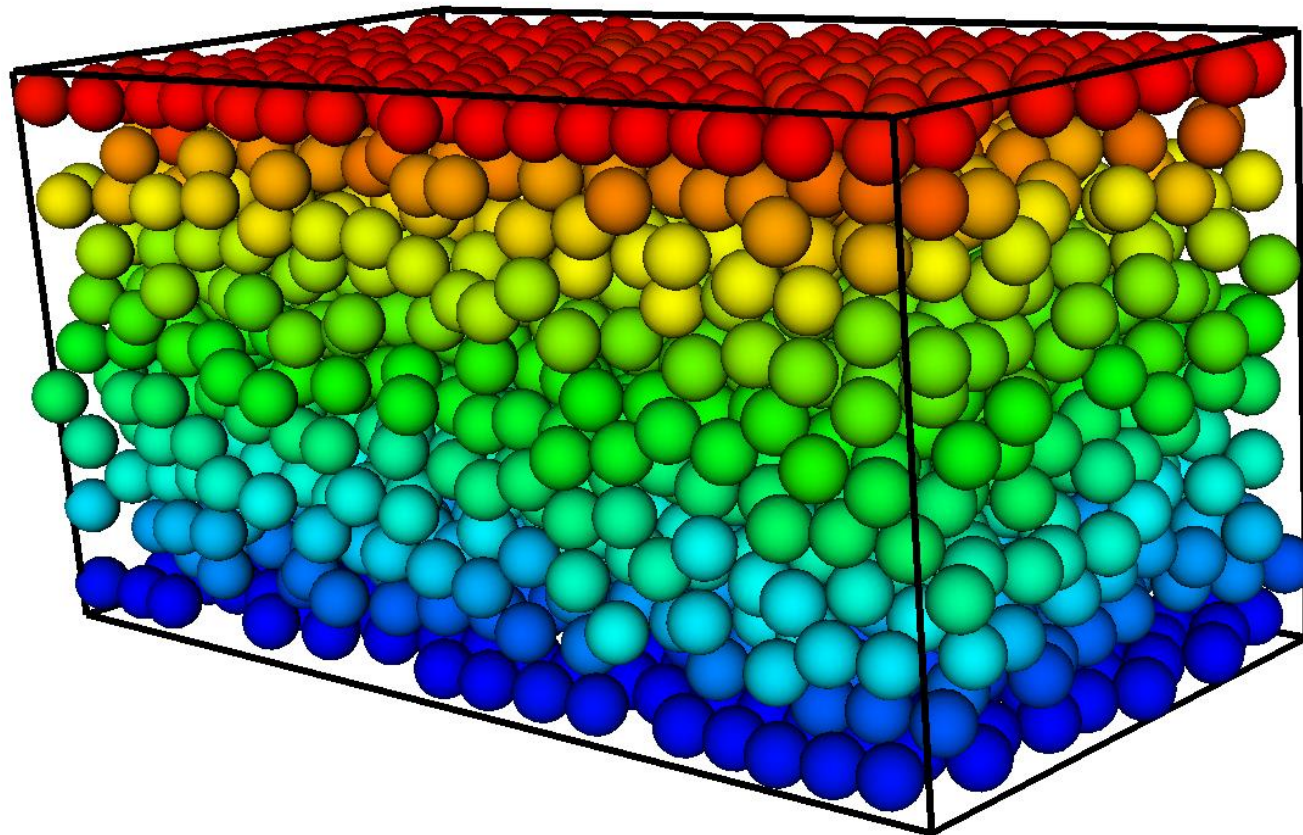
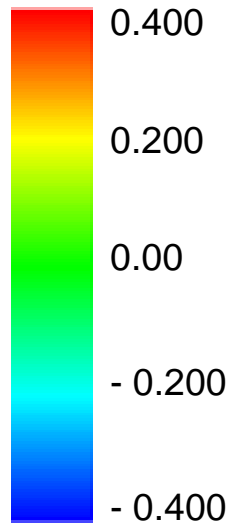
Draw perpendicular bisector of each line  $\rightarrow$  boundaries of Voronoi cells



# Voronoi Diagram

Collection of boundaries drawn around the volume closer to each point than to any other

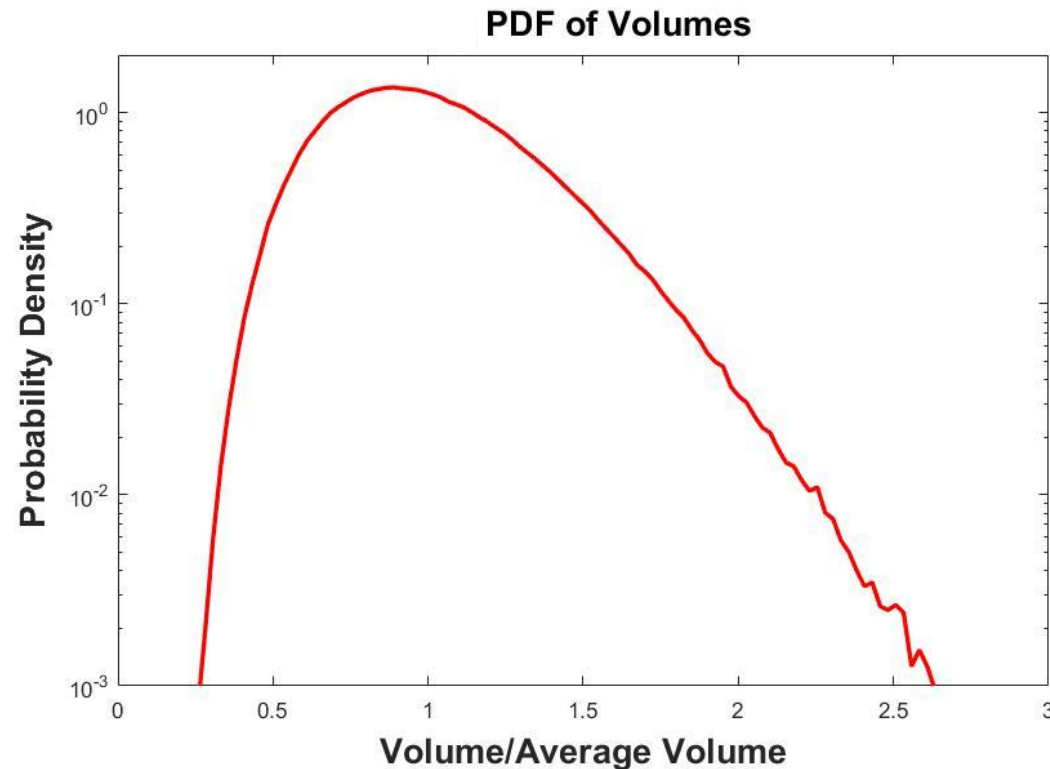
Particle velocity



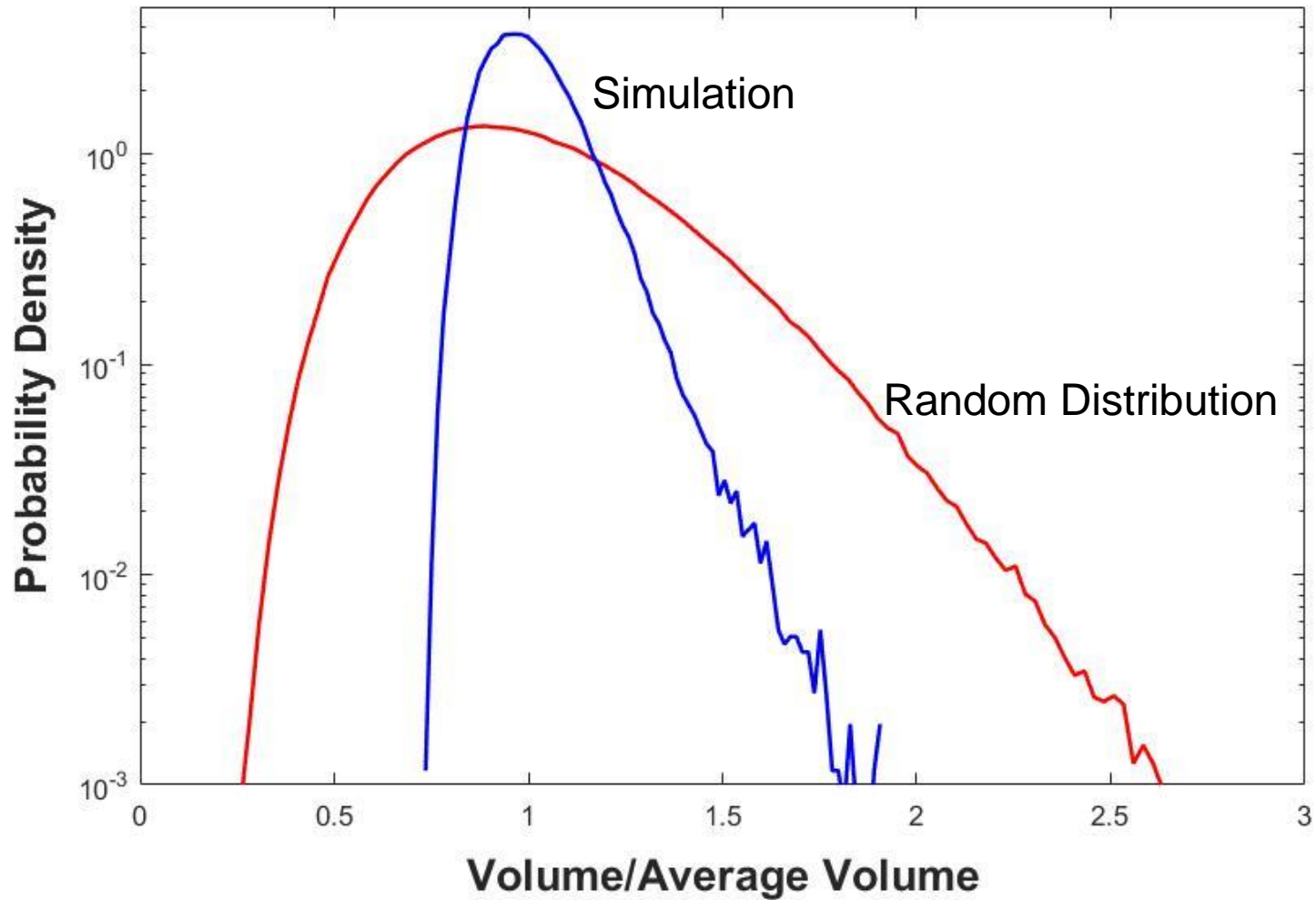


# Volumes of Voronoi Cells

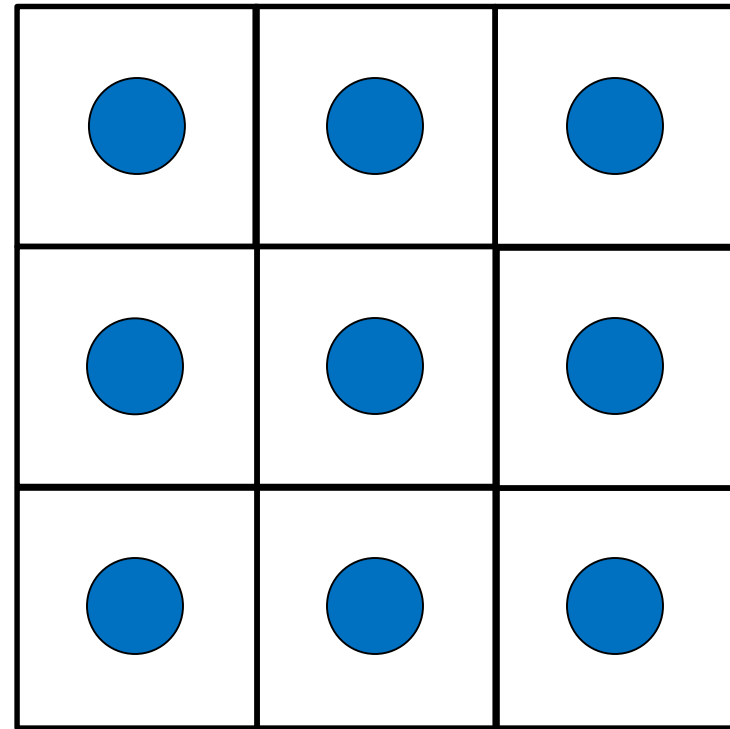
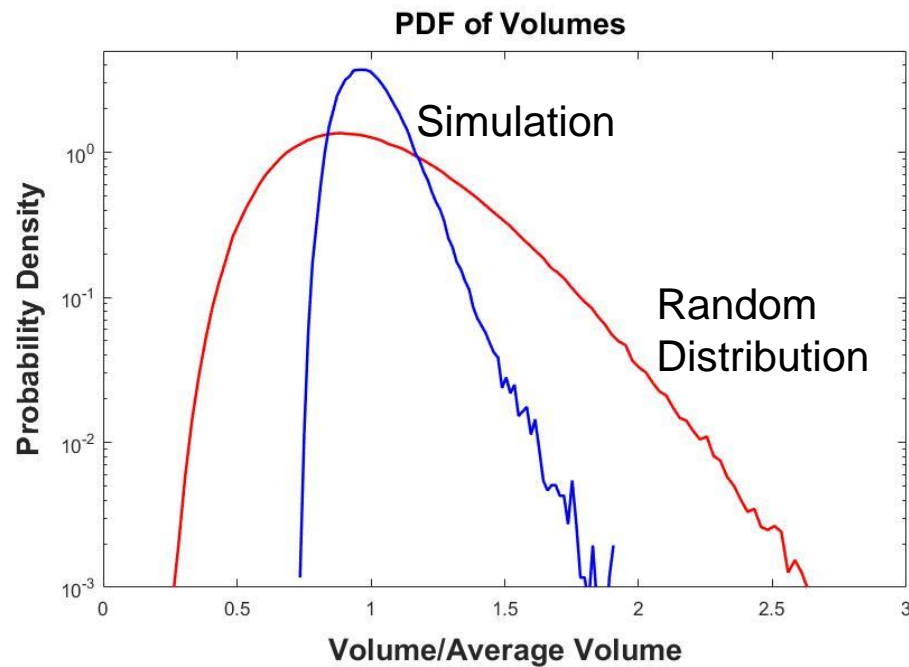
- Volume of Voronoi cells  $\rightarrow$  measures clustering of particles
  - Small volumes  $\rightarrow$  particles are tightly clustered
  - Large volumes  $\rightarrow$  particles are spaced farther apart



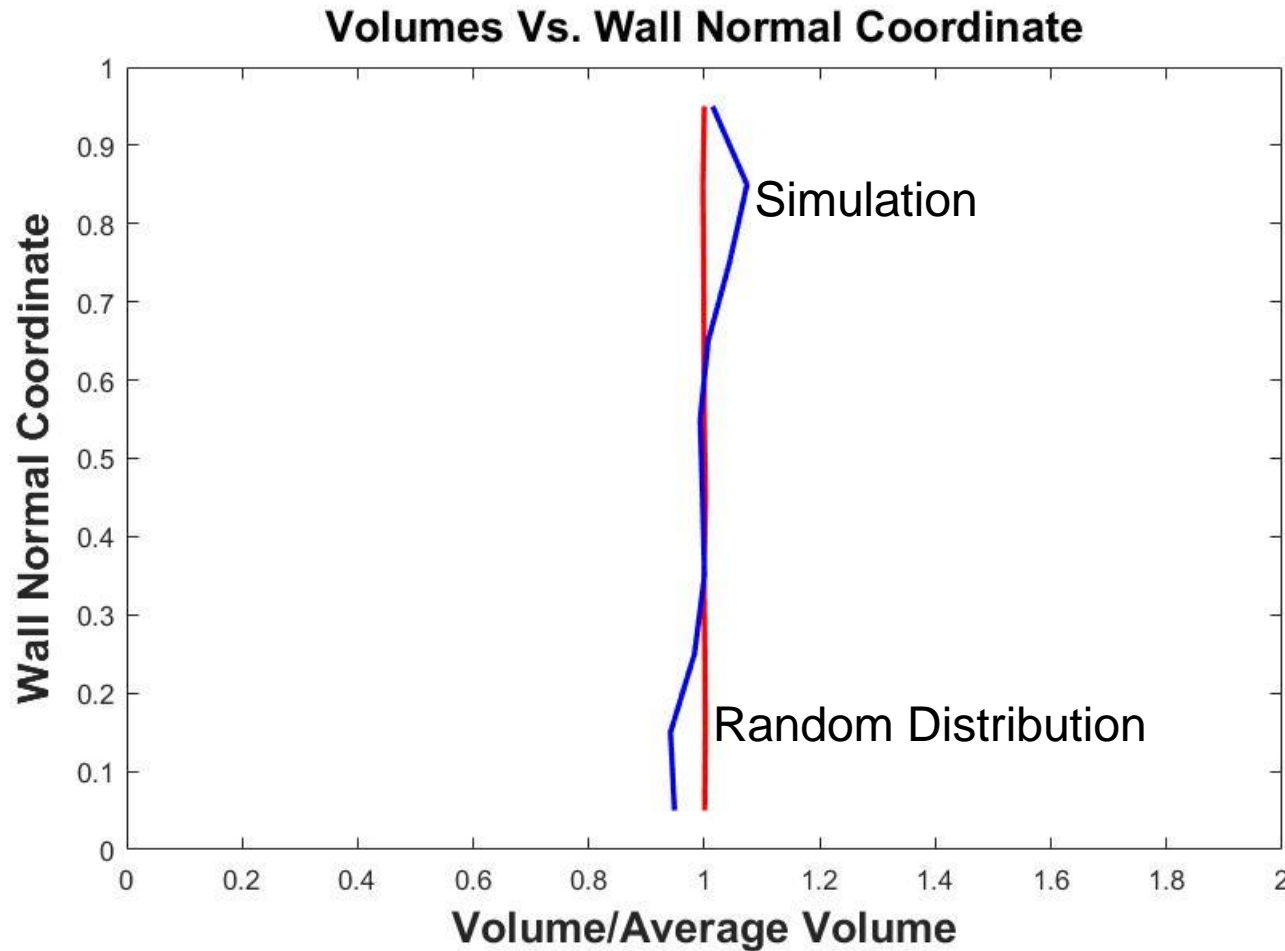
# PDF of Volumes



# Particles in the Simulation are Evenly Dispersed



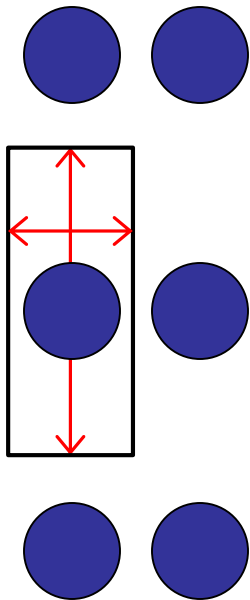
# Volume Vertically Throughout the Channel



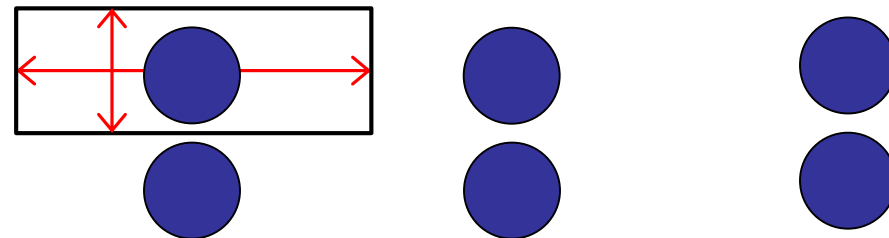
# Aspect Ratios of Voronoi Cells

- Aspect ratio  $\rightarrow$  ratio of the largest horizontal dimension to the largest vertical dimension of the Voronoi cell
- Measures the shape of the particle clusters

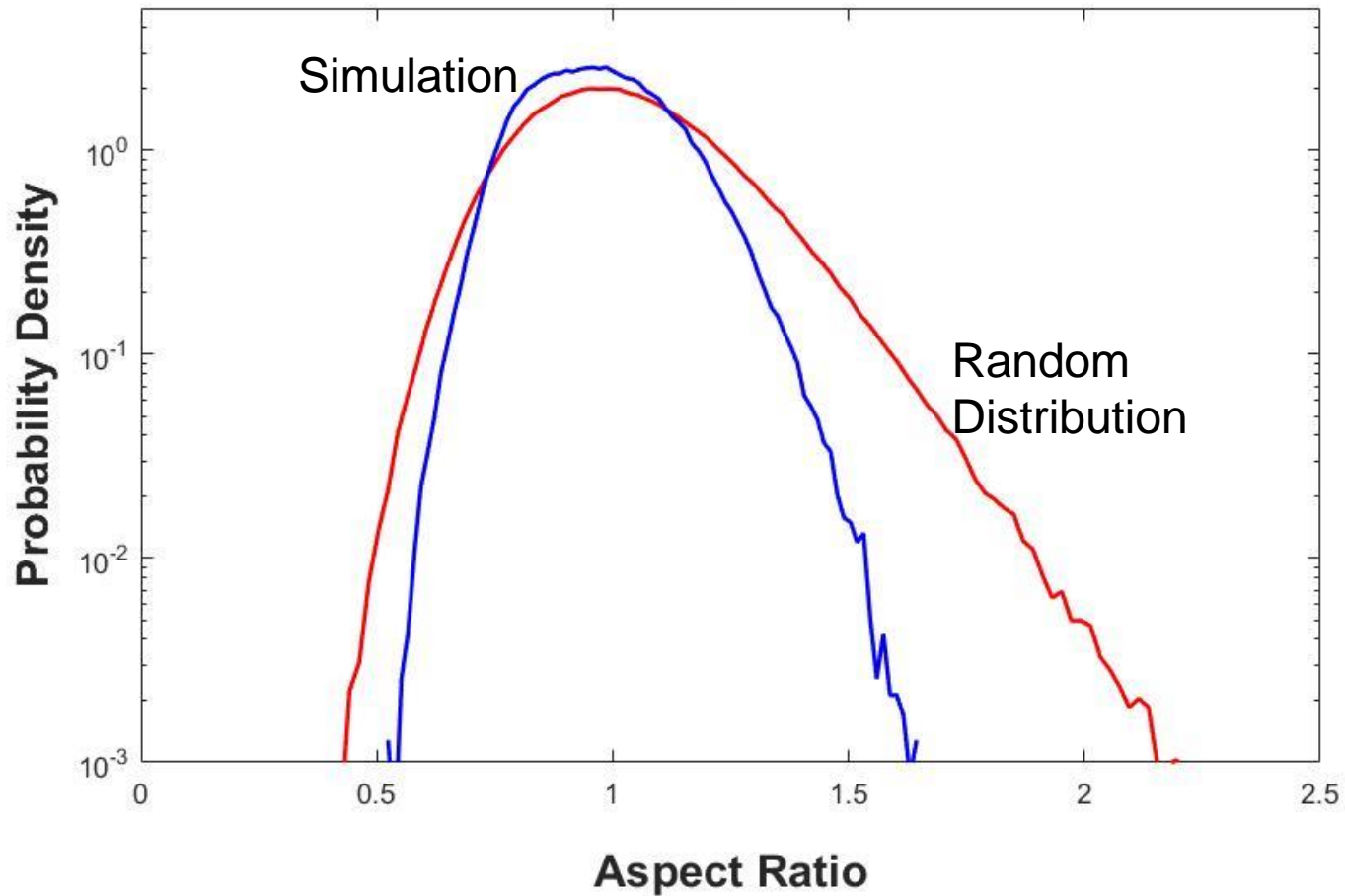
Vertical cluster  $\rightarrow$  small aspect ratio



Horizontal cluster  $\rightarrow$  large aspect ratio

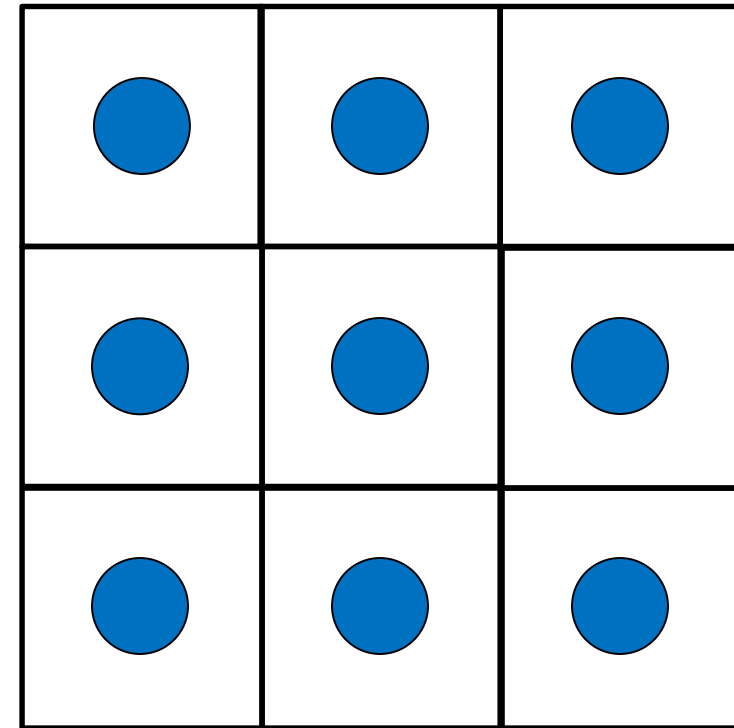
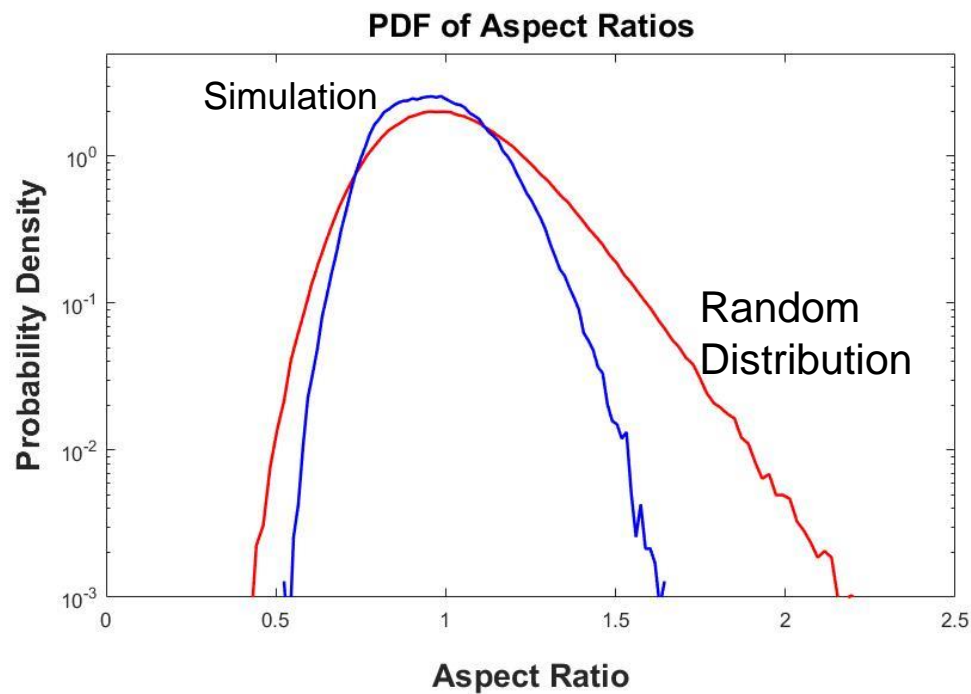


# PDF of Aspect Ratios

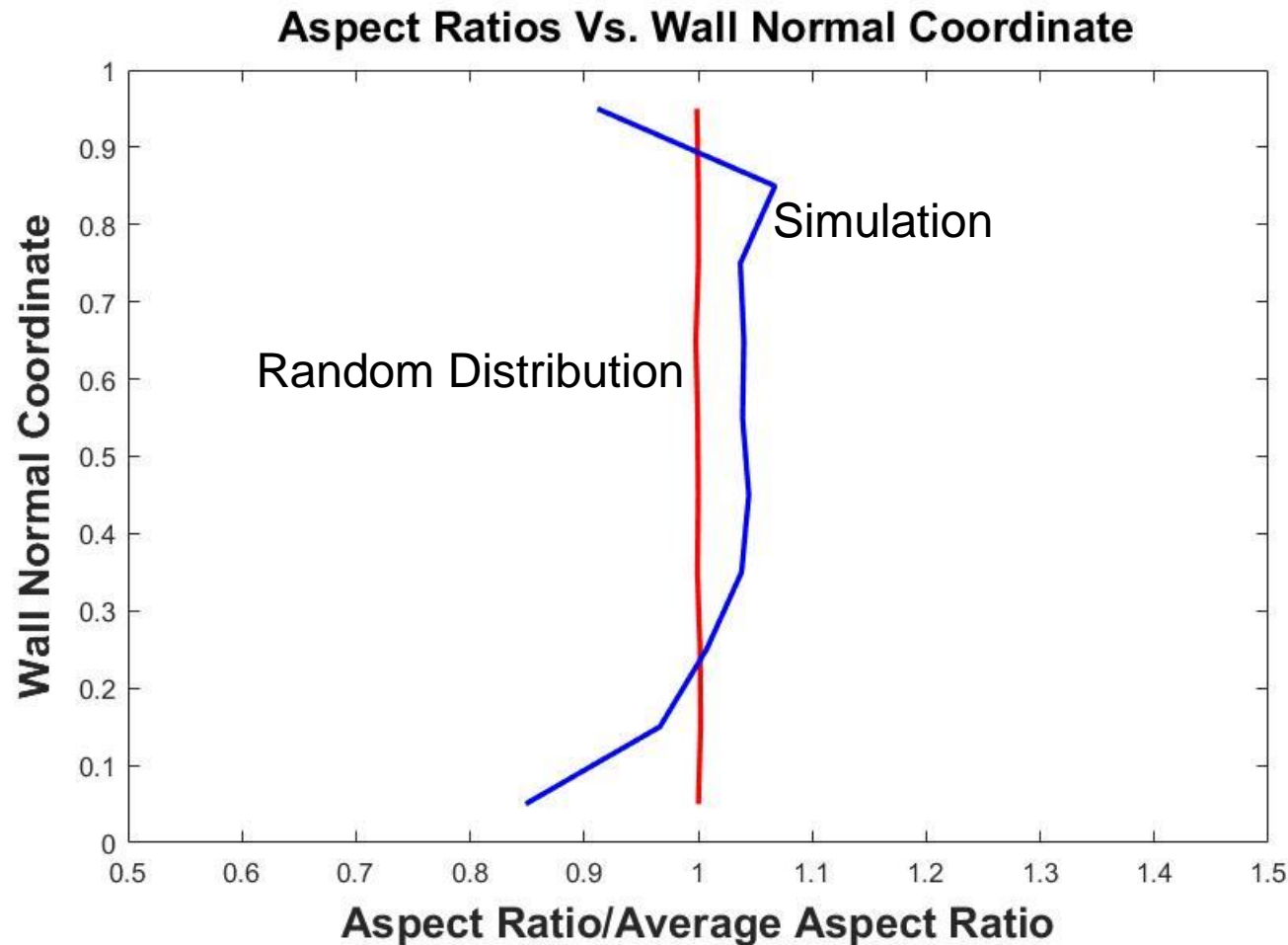




# Particles in the Simulation are Evenly Dispersed

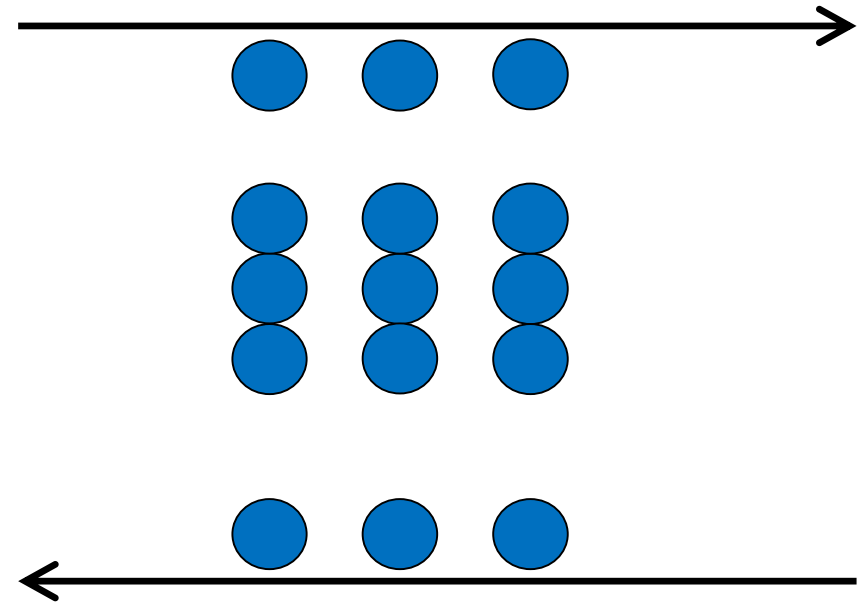
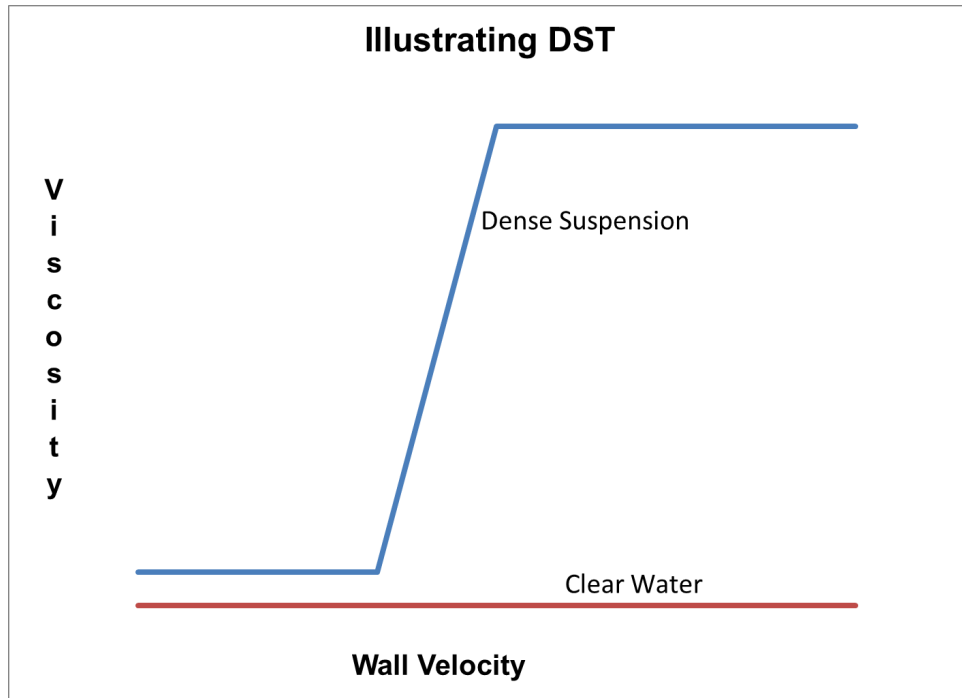


# Aspect Ratios Vertically Throughout the Channel



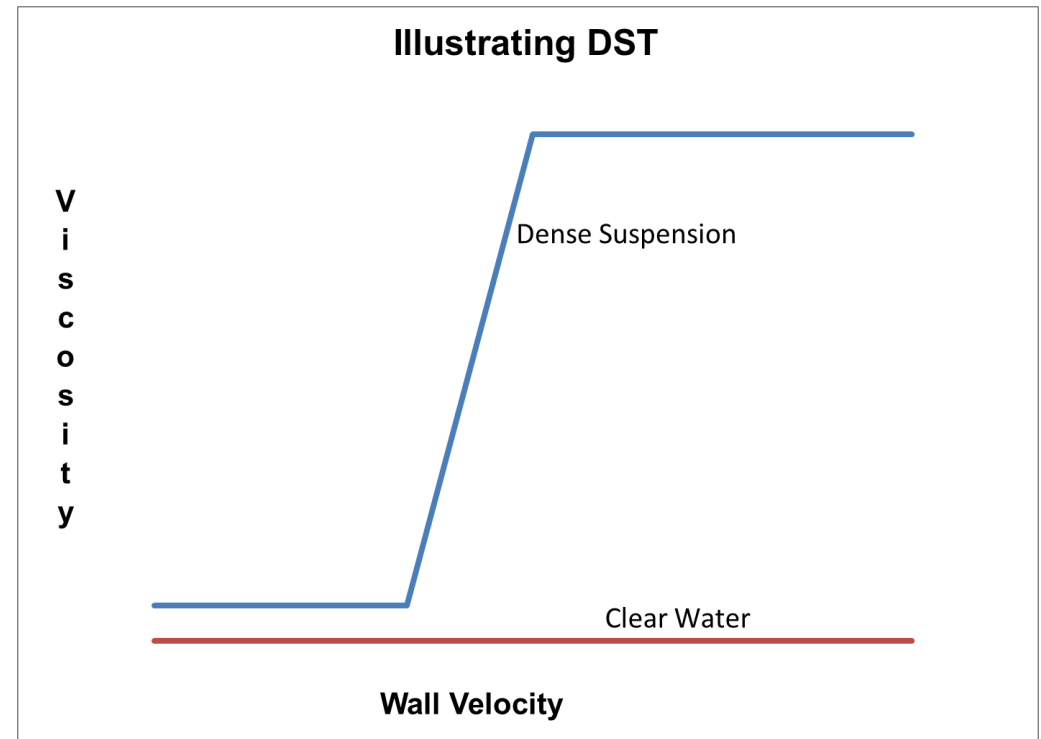
# Particles Cluster in the Center of the Channel

Clear fluid flows quickly near the channel walls and a high concentration of particles flows slowly in the center



# Discovering the Origin of DST

- Perform calculations to measure particle mixing
- Run more simulations to find the threshold where DST occurs
- Compare the clustering and mixing of the particles on either side of this threshold



# Acknowledgements



Gorman  
Scholar  
Program



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# Picture References

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