Introducing New Experimental Facilities to Study Lagrangian Interfacial Dynamics of Turbulent Multiphase Flow

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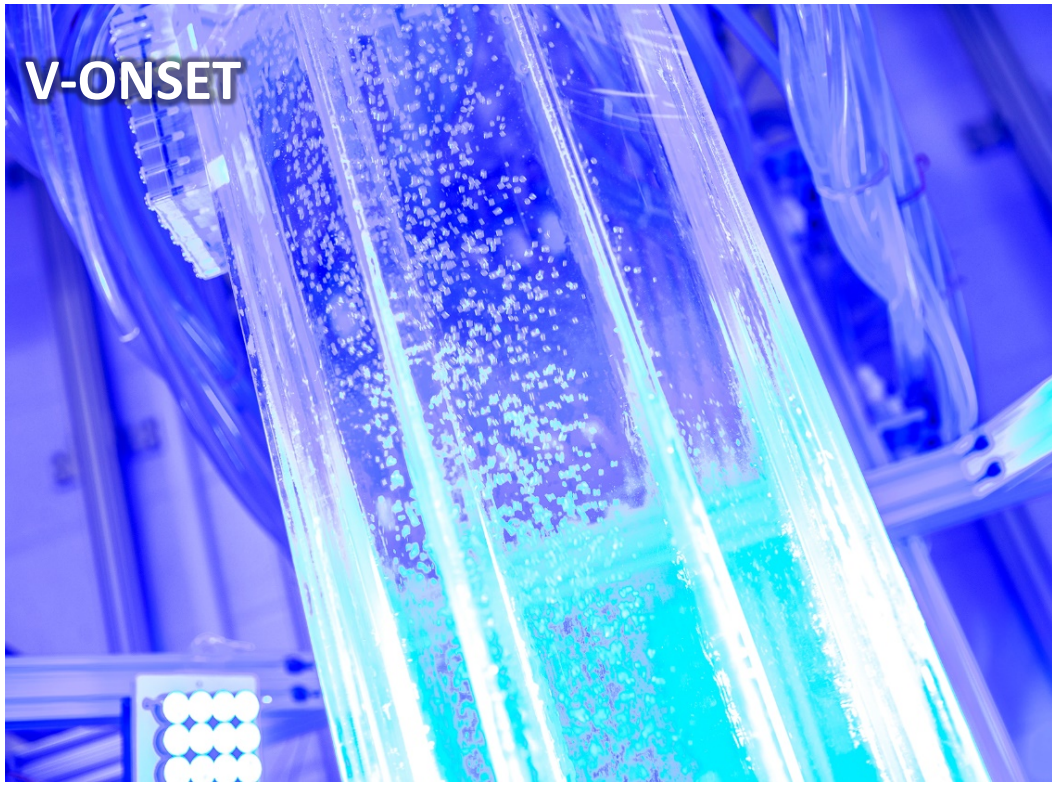

CAREER-1653389, CBET-1705246

Fluid Transport

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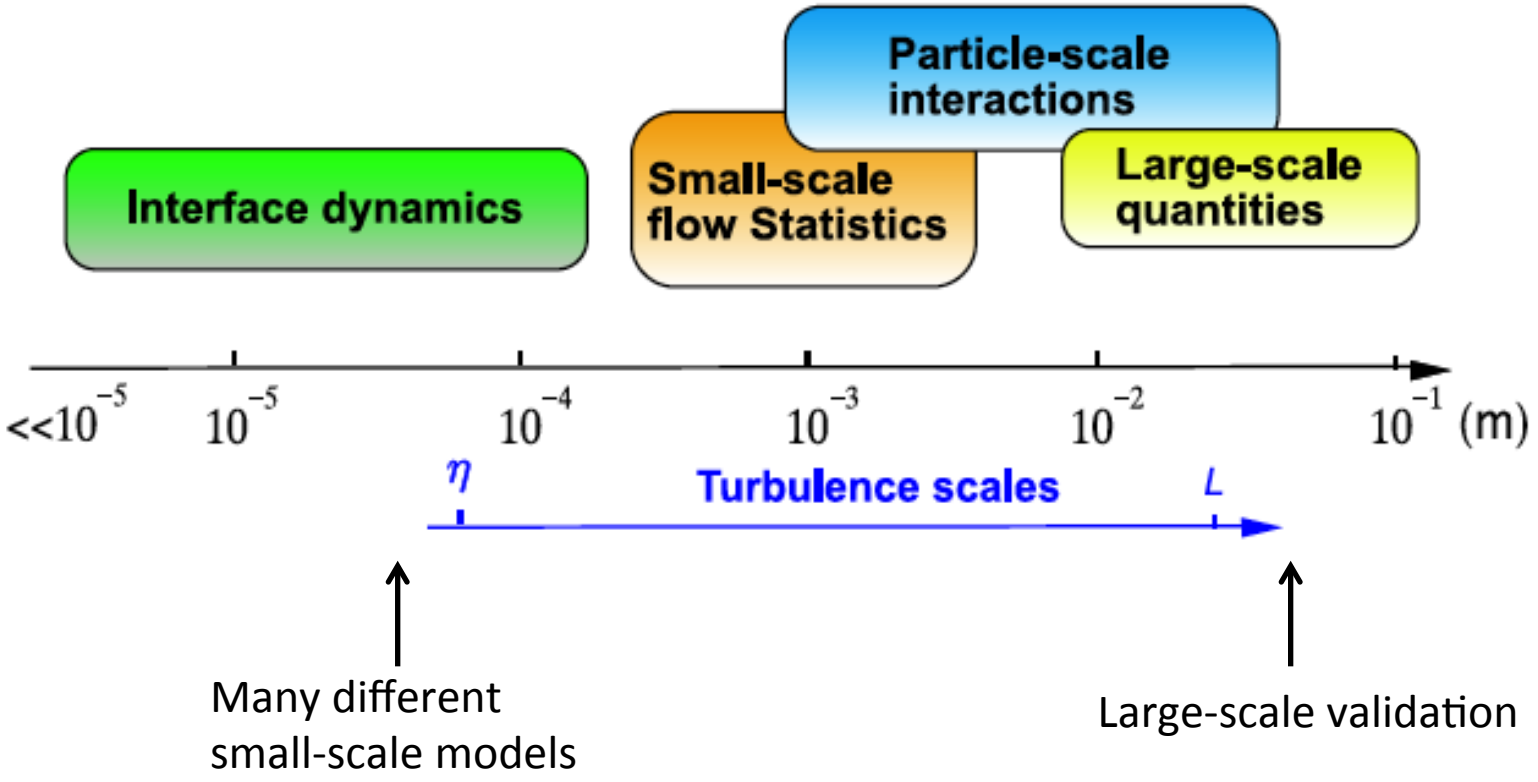
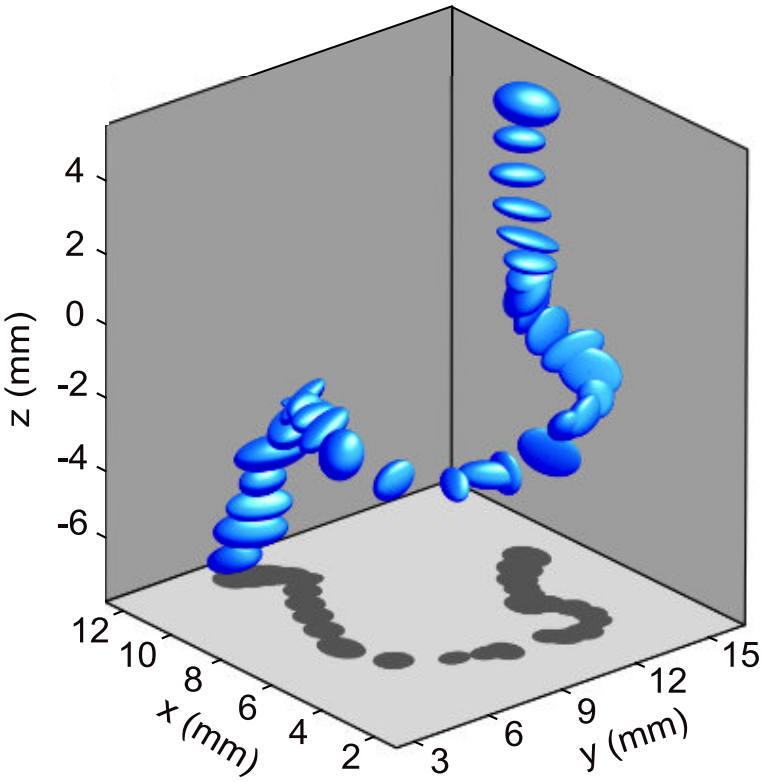
Motivation—Validation at small scales

Reactors (nuclear and bio) are large ⟶ High Reynolds number **turbulent** flow

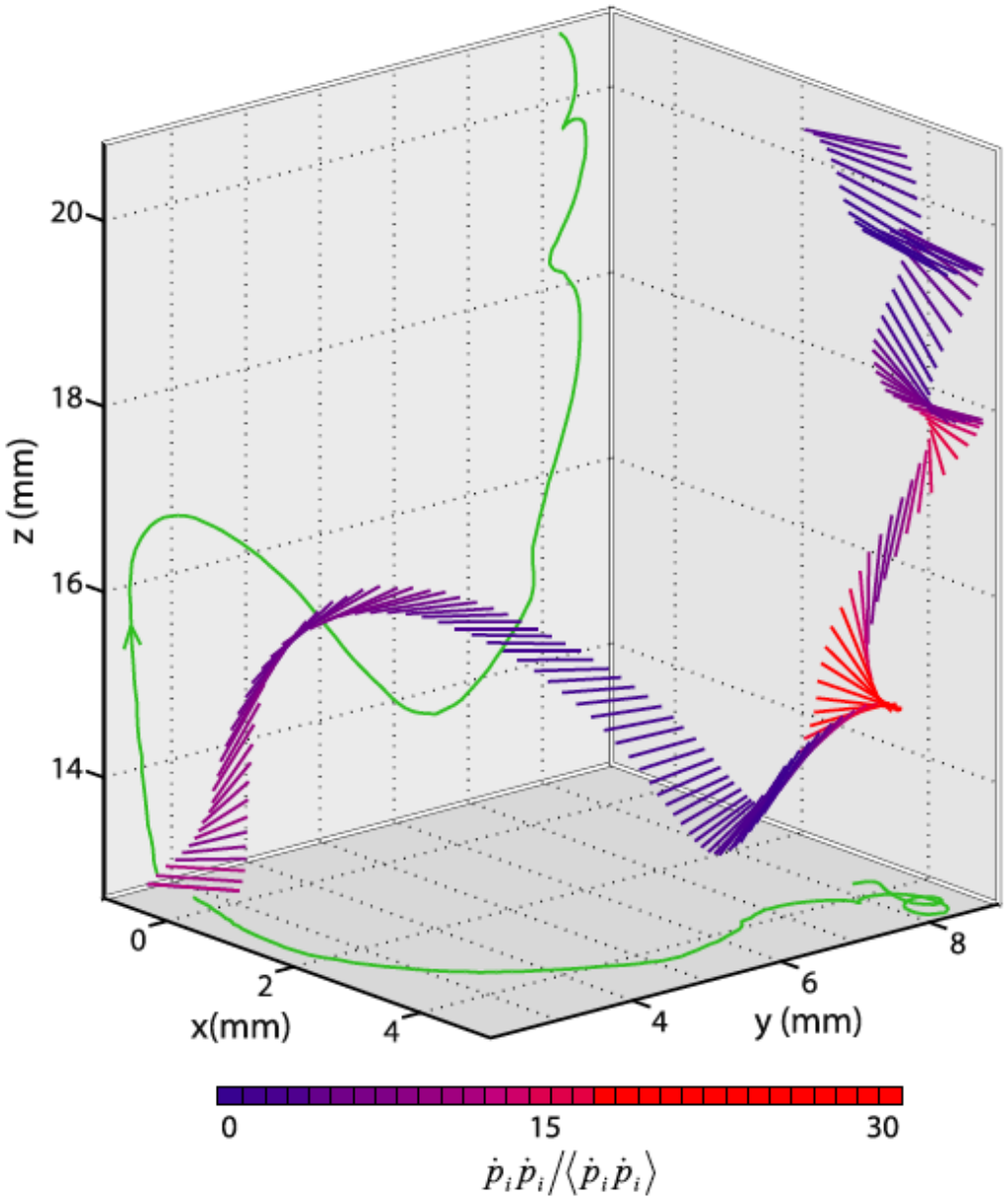


Eulerian-Lagrangian method



Challenges in small-scale dynamics

- Non-spherical (rigid and deformable) particles
- Particle-flow interaction
- Particle-particle interaction



Rod dynamics

Trajectory of a 1mm rod at R_λ=210 spans 280 ms.

L_{rod}=4.7 η , t_{travel}= 11 τ_η

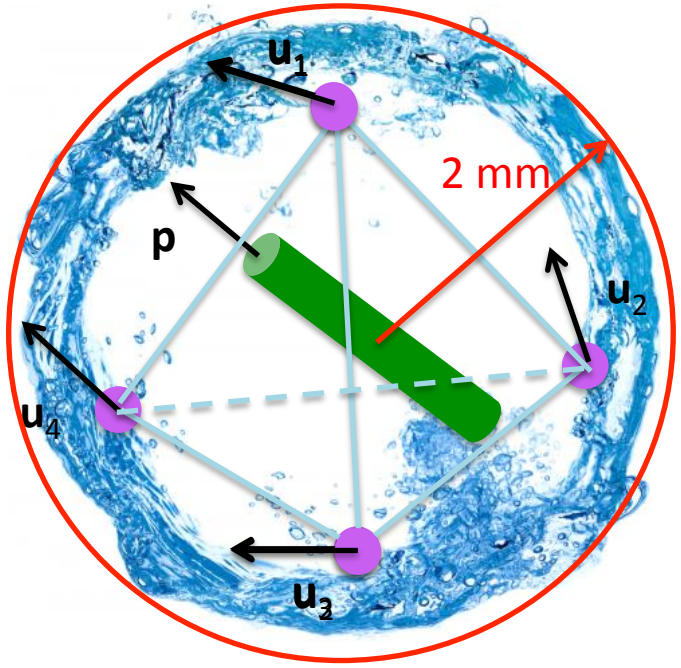
Colormap represent the magnitude of the rotation rate.

Parsa et al PRL 109,134501(2012)

Coupling between rods and flow

$$\dot{p}_i = \Omega_{ij} p_j + \frac{\alpha^2 - 1}{\alpha^2 + 1}(S_{ij} p_j - p_i p_k S_{kl} p_l)$$ Jeffery's equation

- How to validate the coupling?
  - We need to measure the fluid motion around rods



Rods (fluorescent)
- 700 μm long and 30 μm thick rods

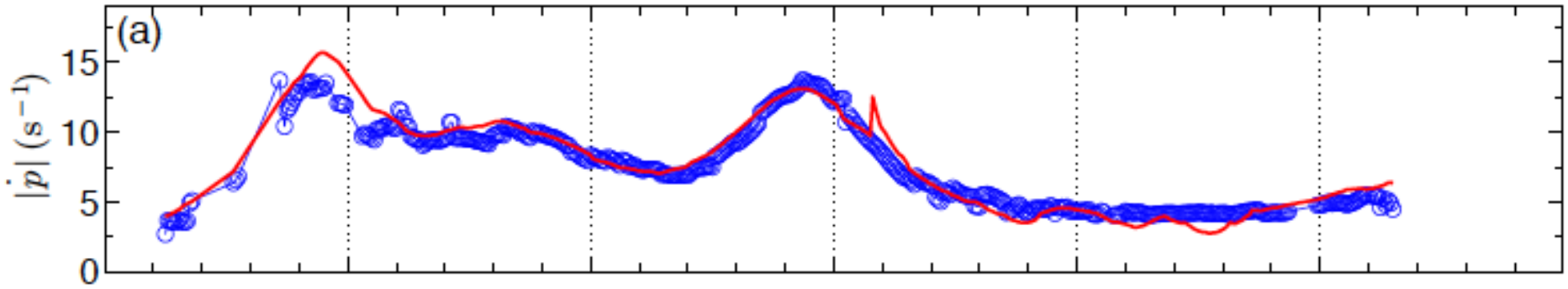
Tracers (fluorescent) 30 μm

Fluid motion can be characterized by velocity gradient tensor A_{ij}

Velocity gradient tensor A_{ij} could be determined by at least 4 particles.

In practice, we use 6~10 particles to least-square fit the results A_{ij}

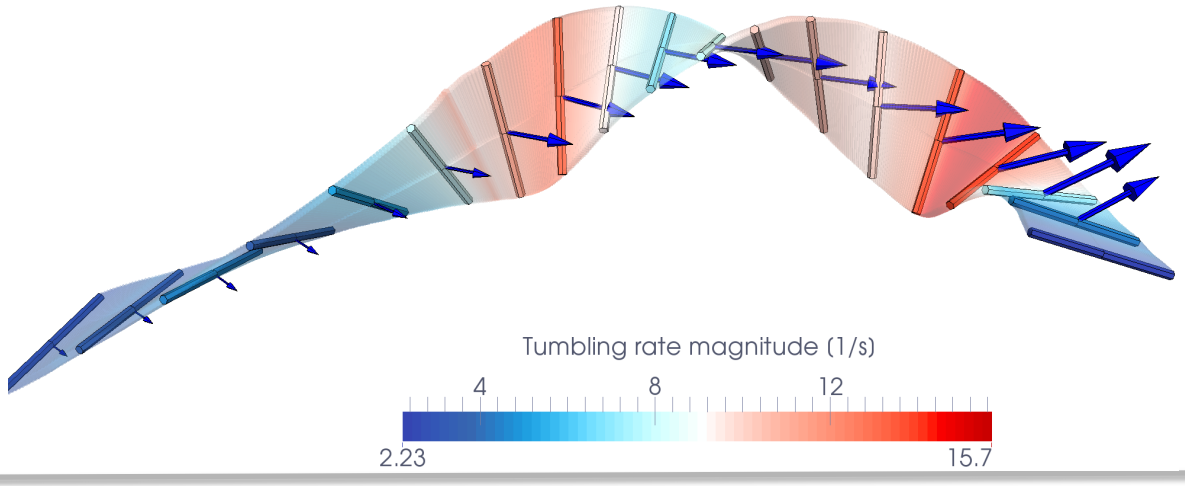
Particles has to be close enough, so velocity gradient doesn't change across it



Blue symbol: calculated rotation rate from Jeffery's equation

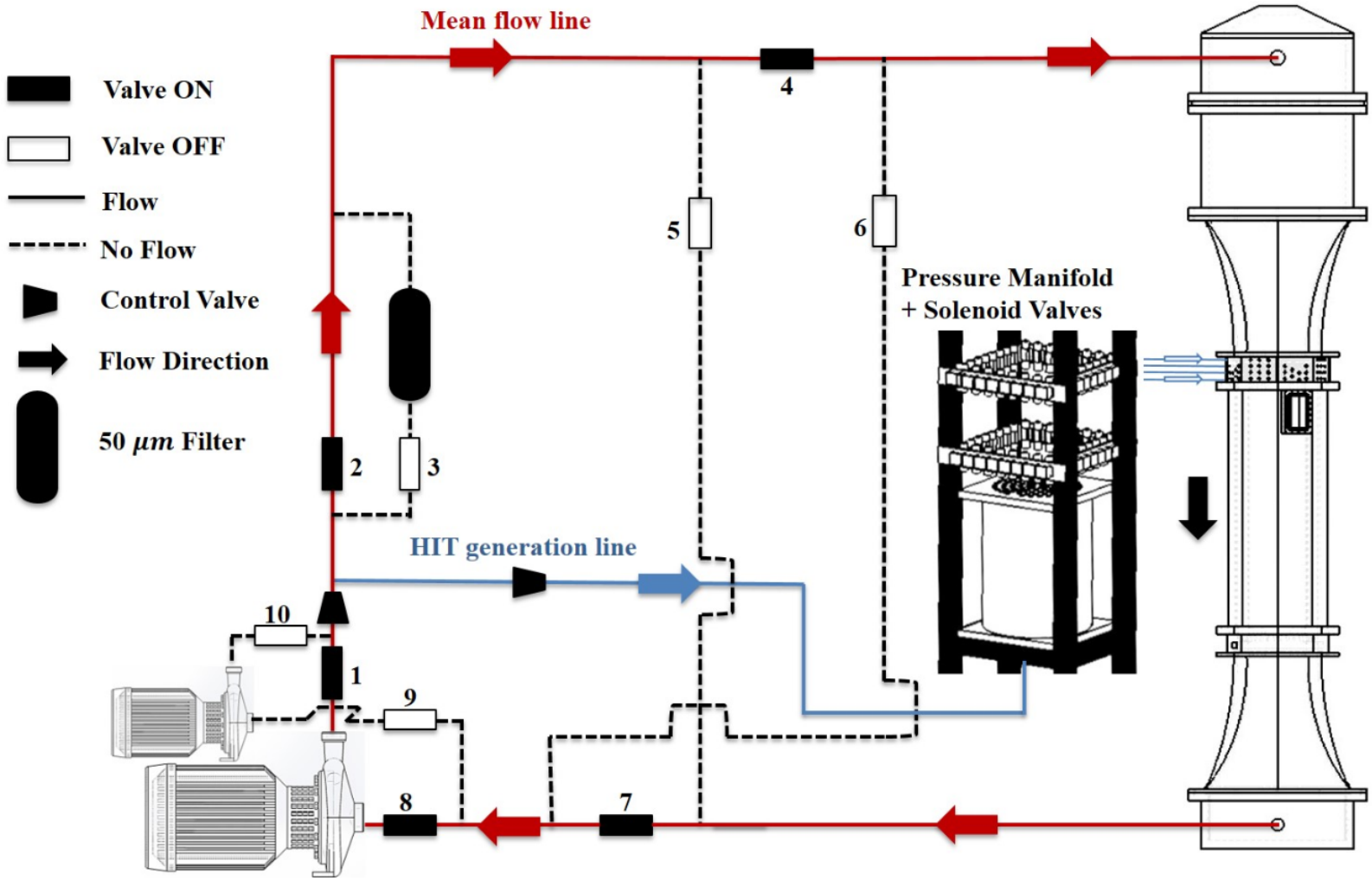
$$\dot{p}_i = \Omega_{ij}p_j + \frac{\alpha^2 - 1}{\alpha^2 + 1}(S_{ij}p_j - p_i p_k S_{kl} p_l)$$

Red line: directly measured from rod Lagrangian trajectory p(t+1)-p(t)



What about deformable particles (bubbles/ droplets)?

V-ONSET (Vertical Octagonal Noncorrosive Stirred Energetic Turbulence)



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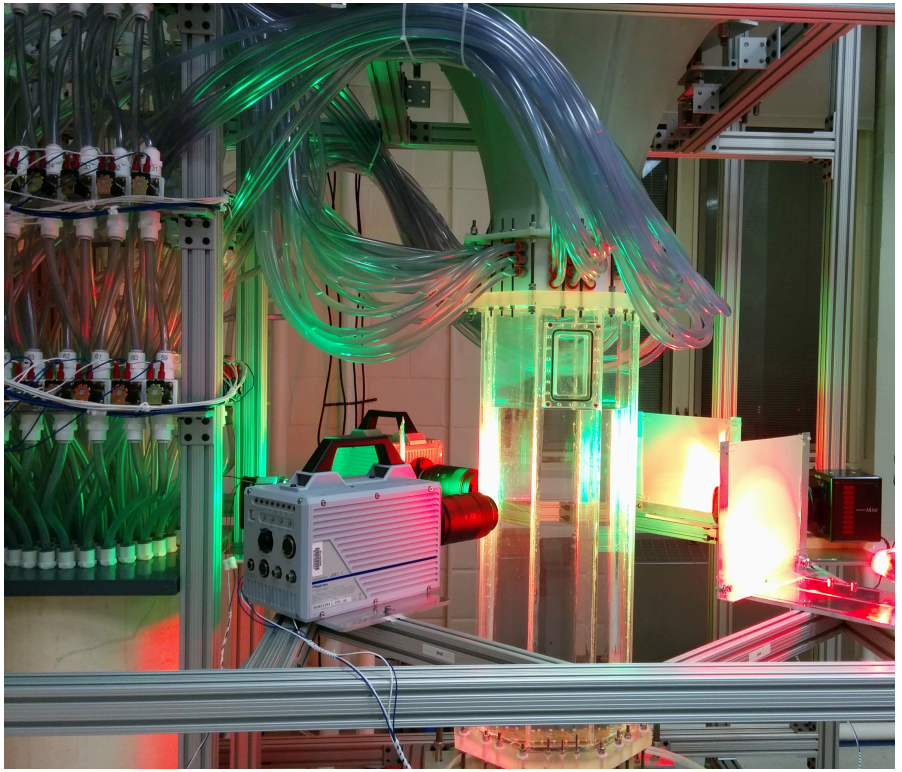
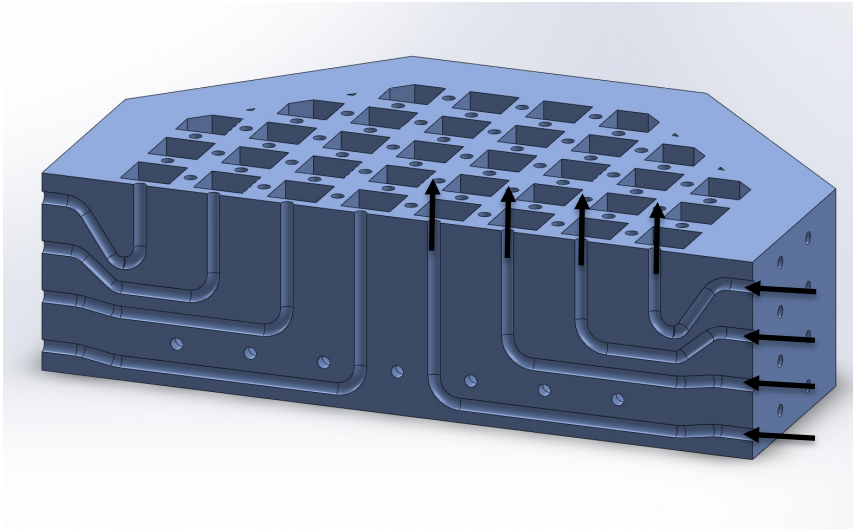
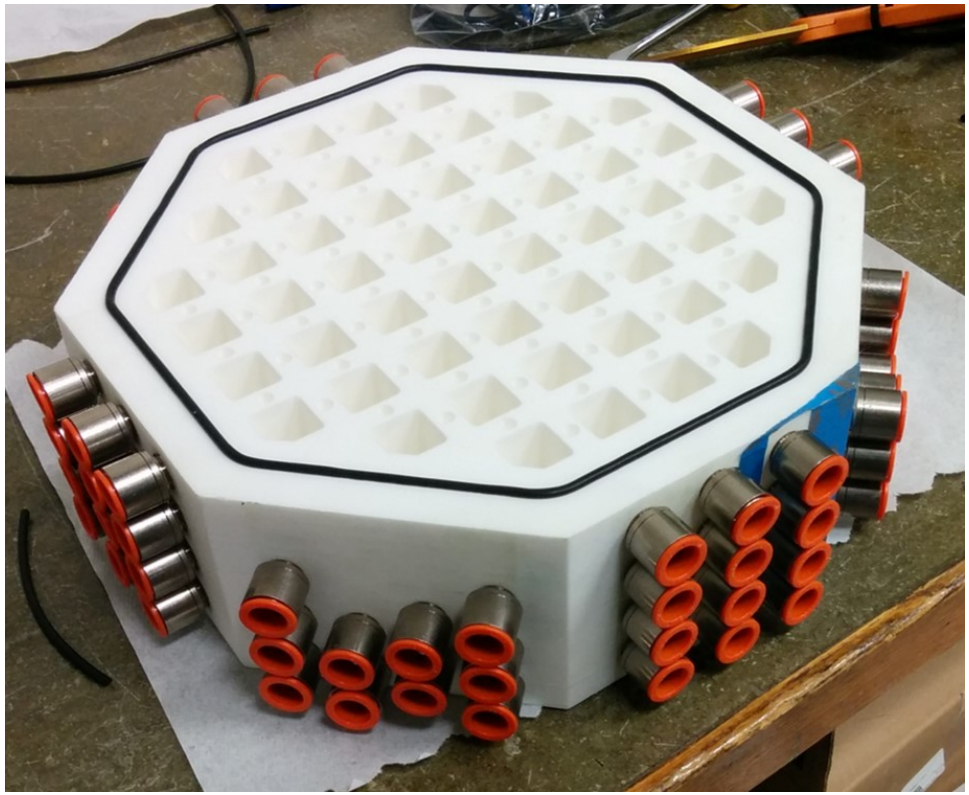


High-speed visualization systems

Water jets

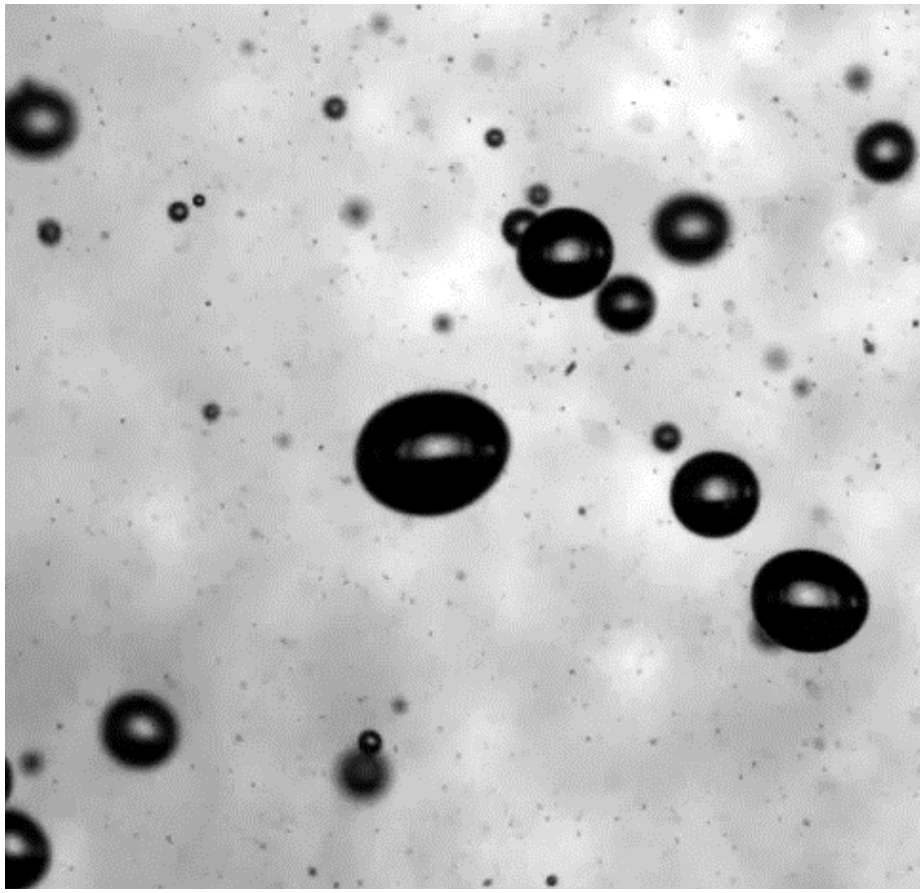
- Turbulent flow fields of high Reynolds Number are created by shooting water jet into the test section of the facility.





- **Creates jets through nozzles**
- **Allows mean flow to pass through grid openings**

Bubble deformation

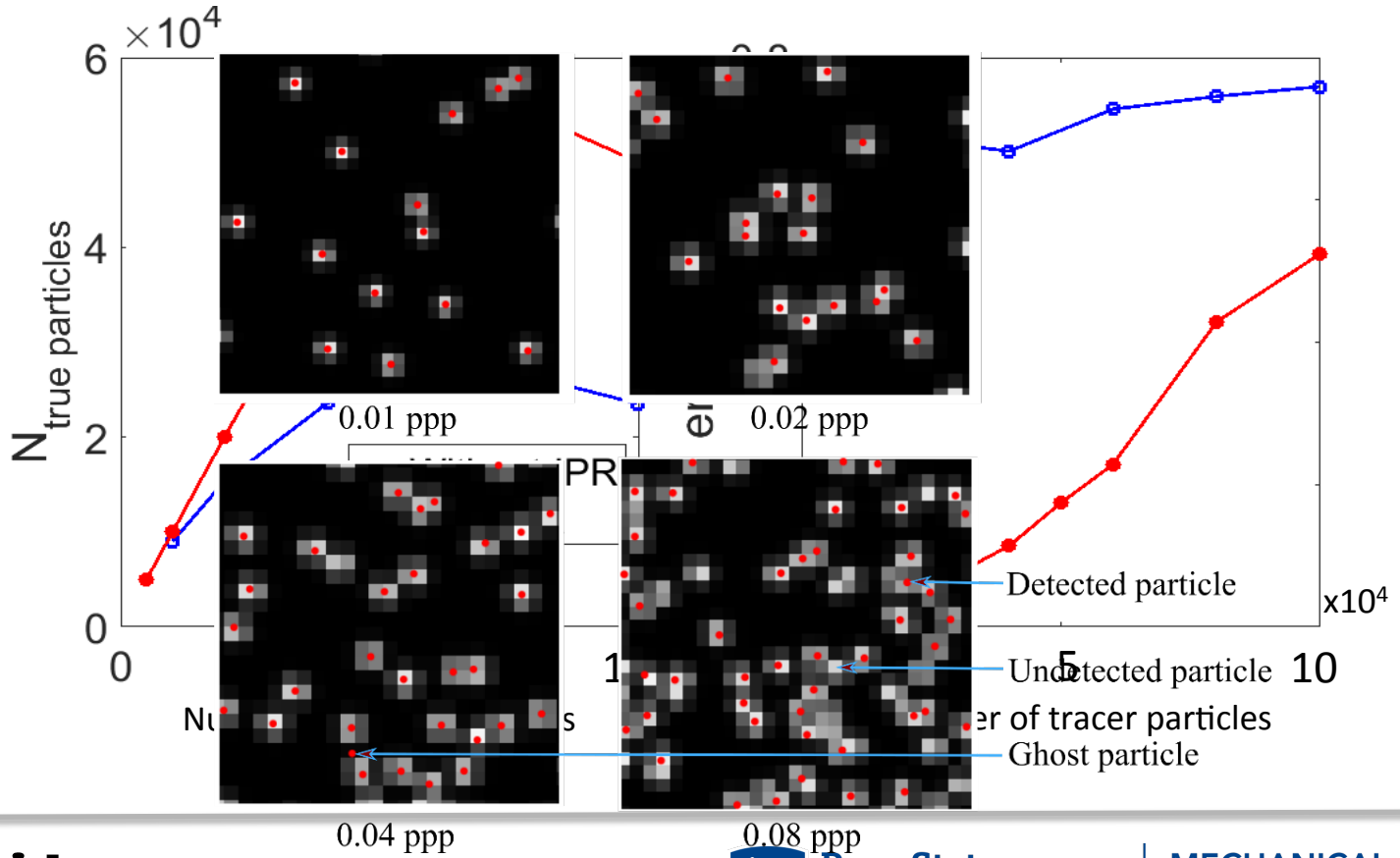


Large bubble suspends in the mean flow

Deform under turbulence

Carrier phase tracking

The in-house code can detect the center of most of the particles with high seeding density (up to 100000 particles)



Summary

Multiscale physics require multiscale validation!