2026 AIChE ANNUAL MEETING

NOVEMBER 8 - 12, 2026

MINNEAPOLIS, MN

CHEMICAL ENGINEERING REIMAGINED

Resolved Translational and Rotational Dynamics of Settling Non-Spherical Particles

Experiments and Simulations

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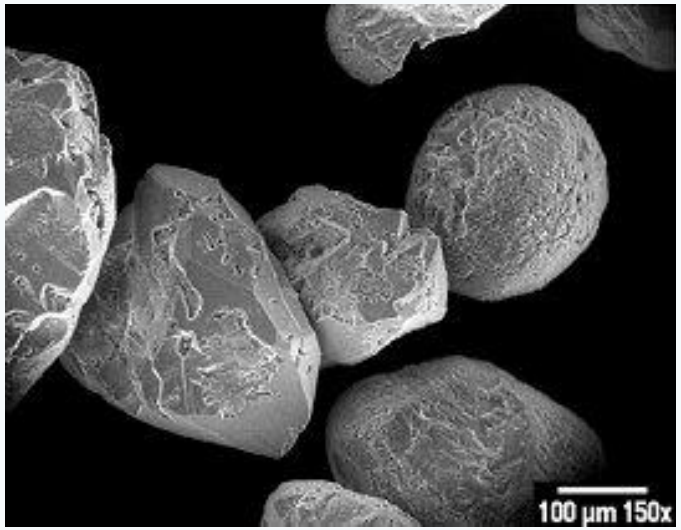
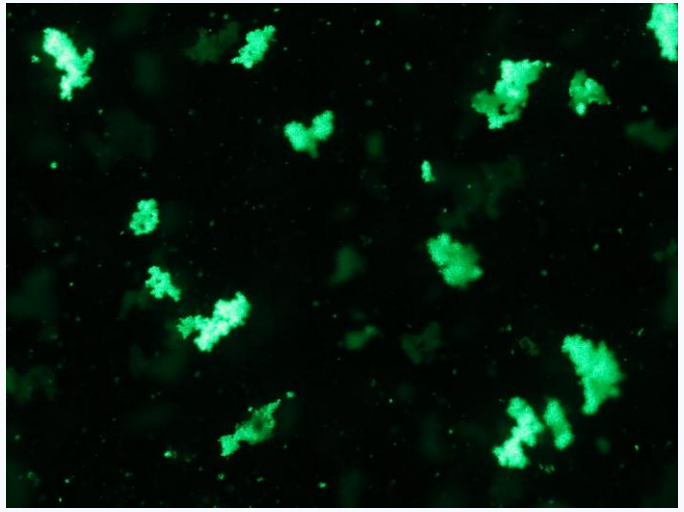
Real suspensions are not made of identical spheres

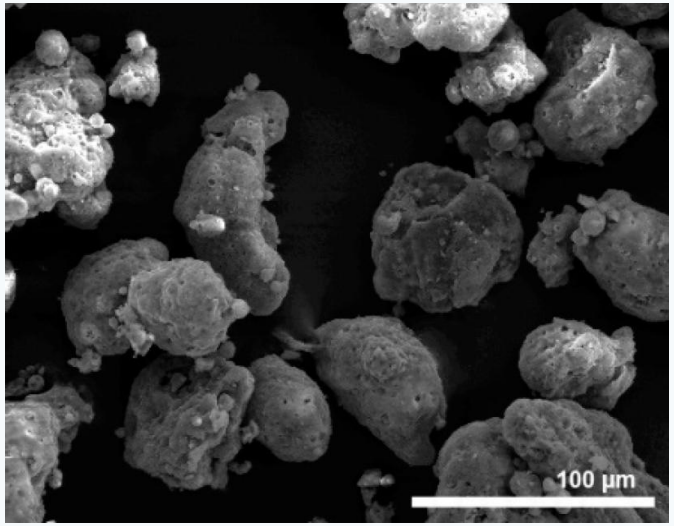
Shape, size, and concentration vary across natural and industrial processes



Sand grains



Flocs in water treatment



Fluidized bed catalyst

- **Engineering-scale flows contain far too many and diverse particles to resolve individually.**
- **Flow simplification is required to allow for predictive modeling**

Flow simplification by a Two-Fluid model approximation

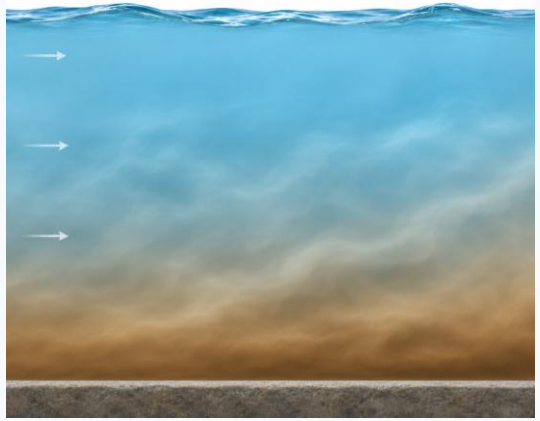
Representing the suspension as a fictitious fluid of prescribed physical properties.

PARTICLE SCALE

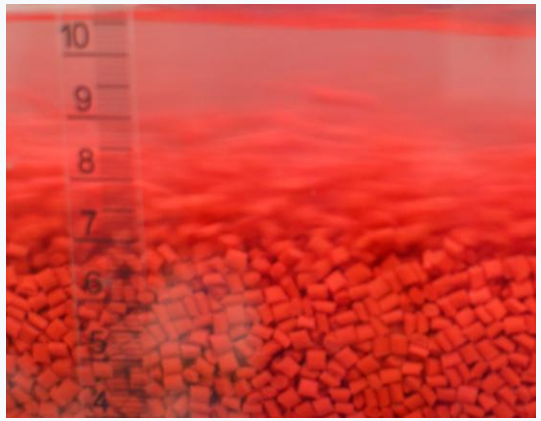


suspension approximation model

PHASE-AVERAGED FIELDS



EXPERIMENTAL DATA REALITY

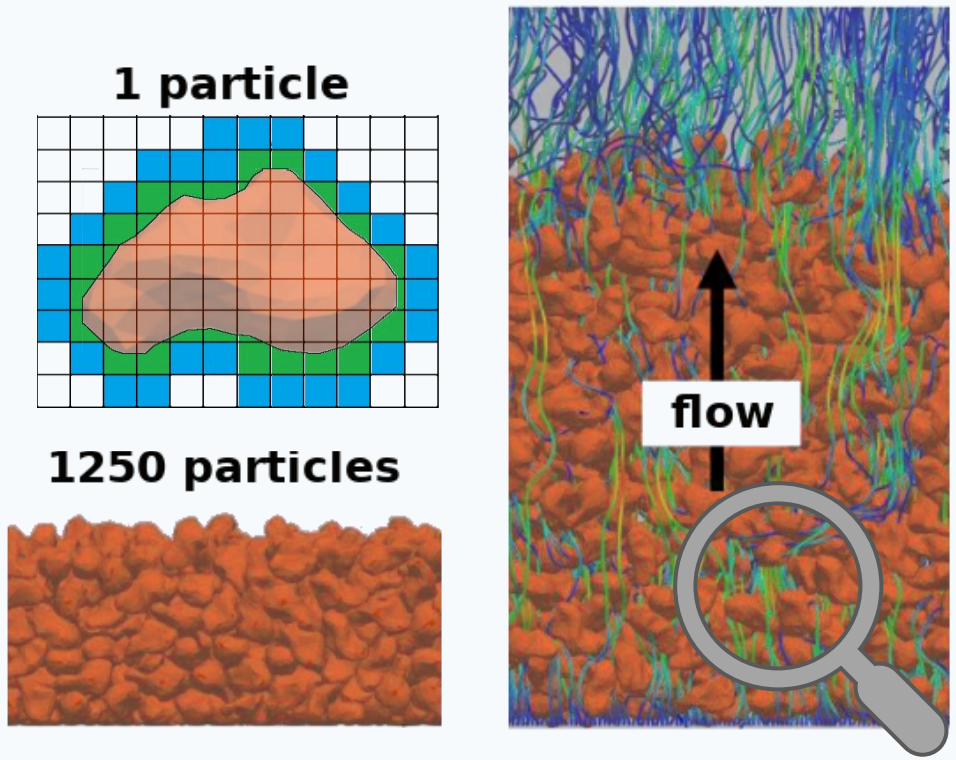


- The approximation model calibration requires sufficiently detailed and reliable data
- Experiments are usually restricted to ~2D / small scales / focused on the integral quantities
- Deeper insight requires demanding / non-existent experimental techniques

DEM simulations to extend the experimental data

Developing and using fully coupled CFD-DEM simulations to inspect the system at the local scales

OpenHFDIB-DEM solver



- **Developed on top of the OpenFOAM library**
- **Particles represented as STL meshes**
- **Immersed Boundary for particle-fluid interactions**
- **Four-way coupling, Soft DEM**
- **Up to ~10,000 particles of arbitrary shape**
- **Up to a Reynolds number of 5,000**

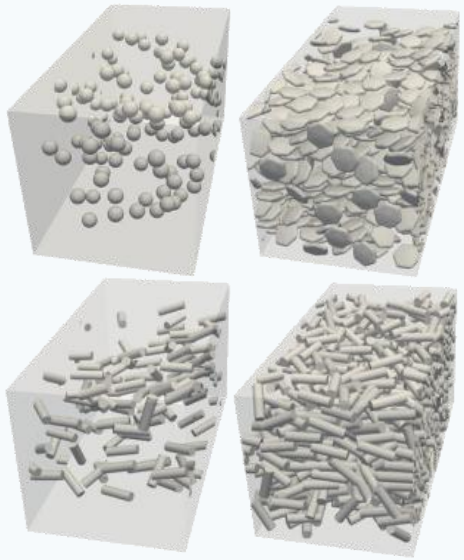
Isoz M. et al. *Computers & Fluids 2022*, vol. 244

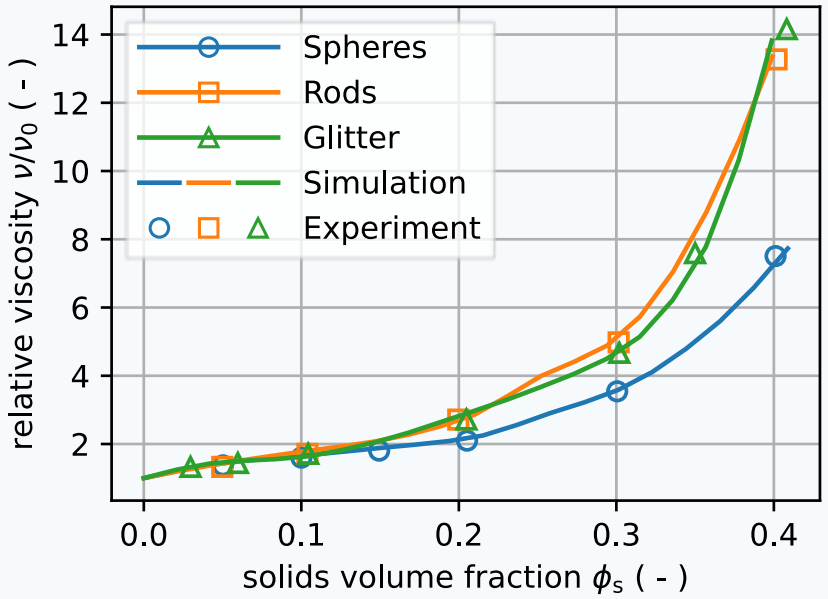
https://github.com/techMathGroup/openHFDIB-DEM

OpenHFDIB-DEM solver validation

OpenHFDIB-DEM solver needs to be validated before generating the two-fluid calibration data

DENSE SUSPENSION VISCOSITY





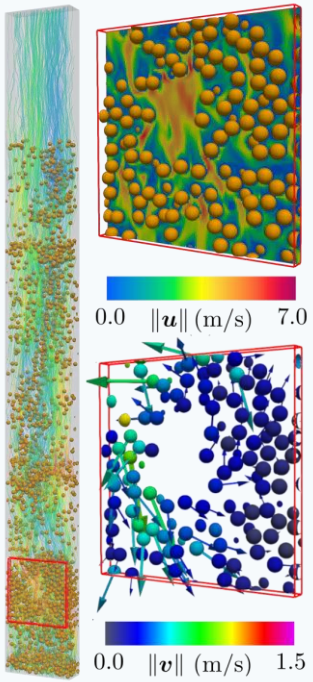
- **Flow of three suspension types spheres / rods / glitters**
- **Solid volume fractions to 40 %**
- **Good agreement between simulations and experiments**

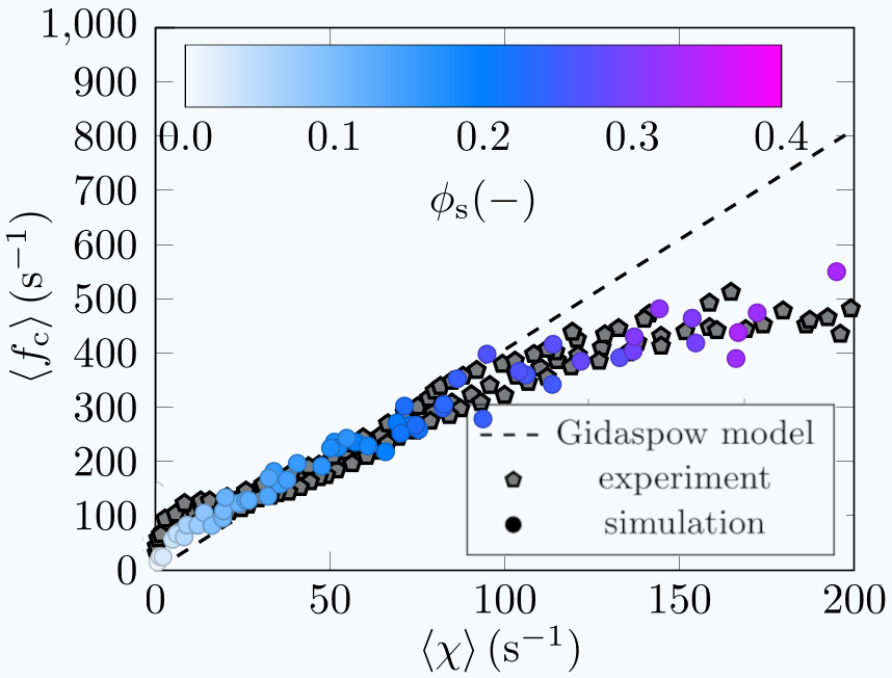
Šourek M. et al. *Powder Tech. 2024*, vol. 444

OpenHFDIB-DEM solver validation

OpenHFDIB-DEM solver needs to be validated before generating the two-fluid calibration data

2.5D FLUIDIZATION OF SPHERES





- Fluidization of spheres in the air
- Low-depth flow field
- Sampling near-wall particles
- Comparison of granular collision frequencies

Studeník O. et al. *Topical Problems of Fluid Mechanics 2026, Prague.*

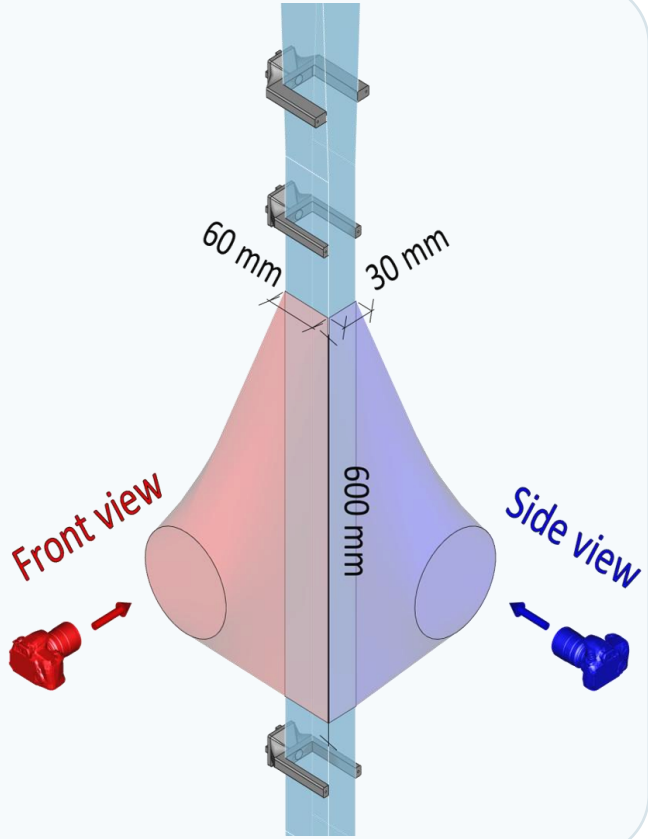
Single particle

Extend validation data by pure particle-fluid interaction

- Measurement of settling trajectories of spheres + cylinders (1:1 – 3:1) + Platonic polyhedra
- Rectangular column 30 x 60 x 2000 mm
- Water-PG solutions
- High-speed, high-resolution imaging

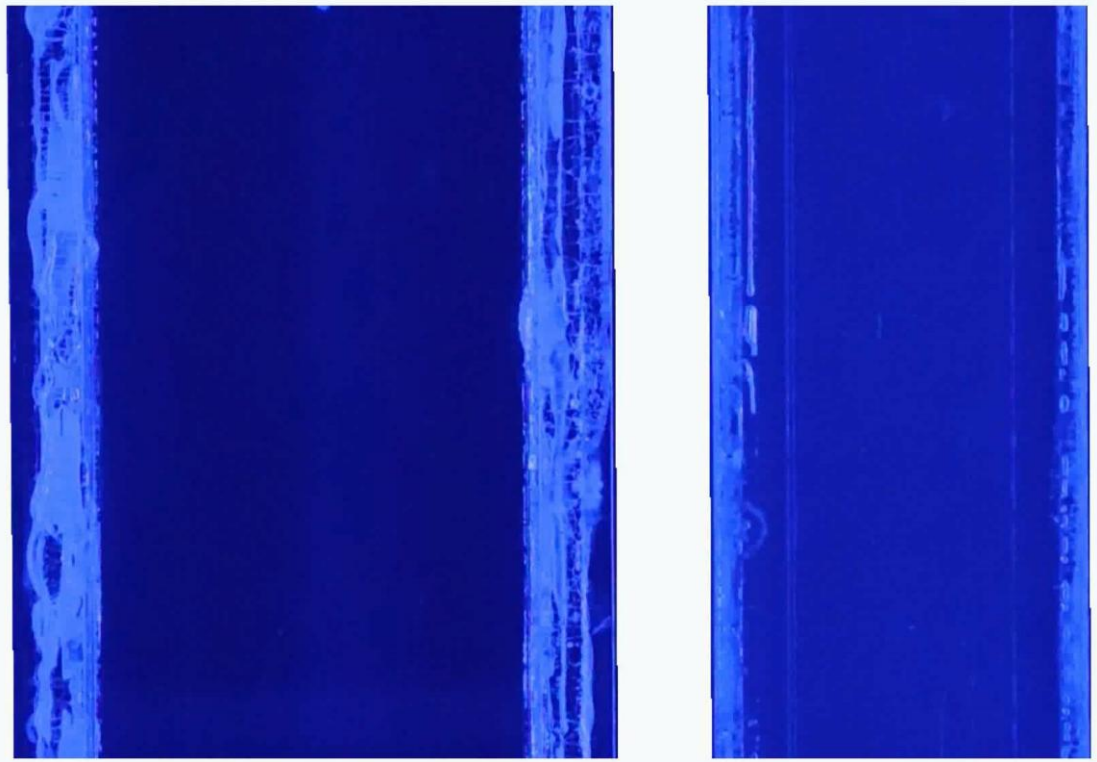
- Fully resolved translation and rotation for selected cases





Single particle: experimental

Settling trajectories: settling velocity + sideways motion

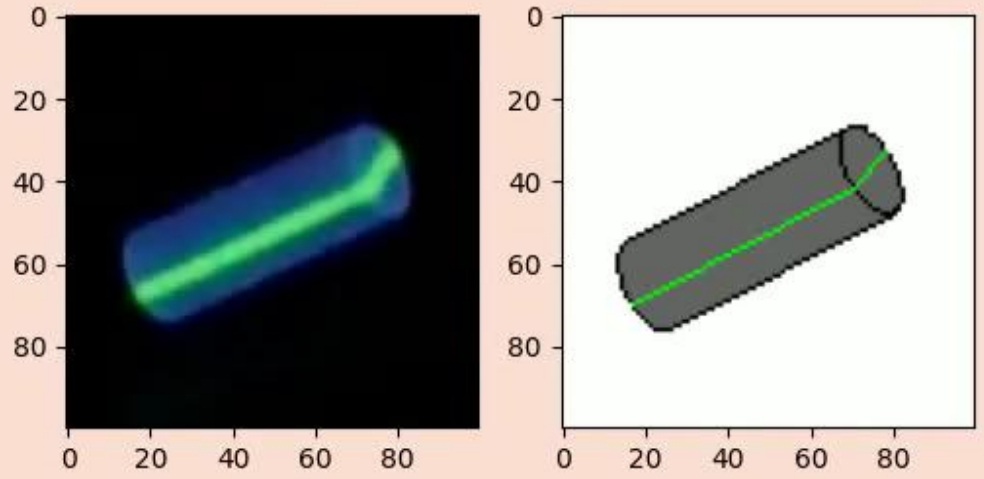


- Particles released from the submerged injector at the column head
- ~ 1.4 m developing zone
- 1000 mm imaged height: front + side view, 2MPx @ 180 fps
- Image masking and enhancement
- Customized PTV SW TracTrac*

*Heyman J. *Computers & Geosciences 2019*, vol. 128

Single particle: experimental

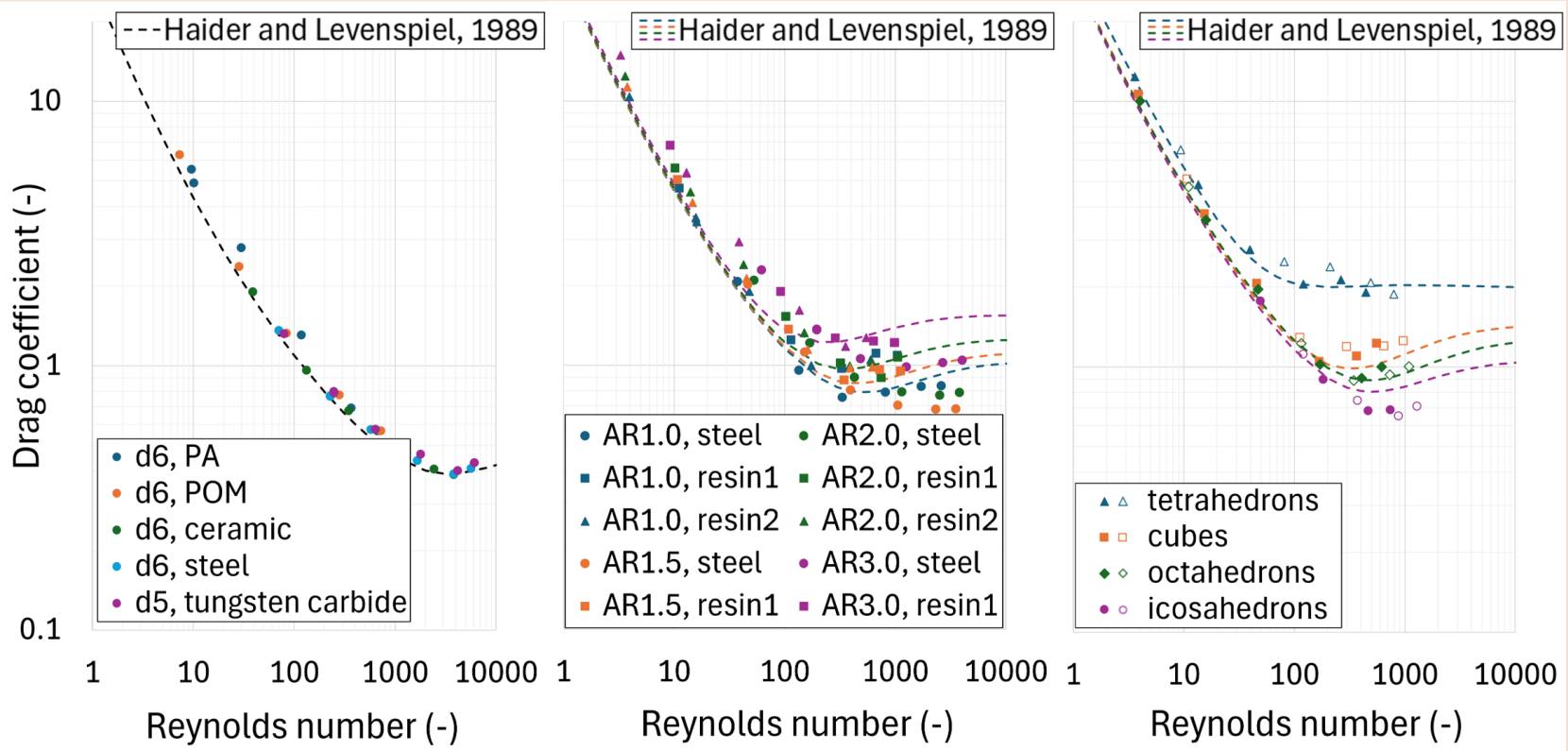
Resolved trajectories: translational and rotational motion



- Same arrangement as in the settling velocity measurement
- ~240 mm imaged height: front + side view, 2MPx @ 180 fps
- In-house SW for position and orientation evaluation
- Particles stored as positional and rotational vectors

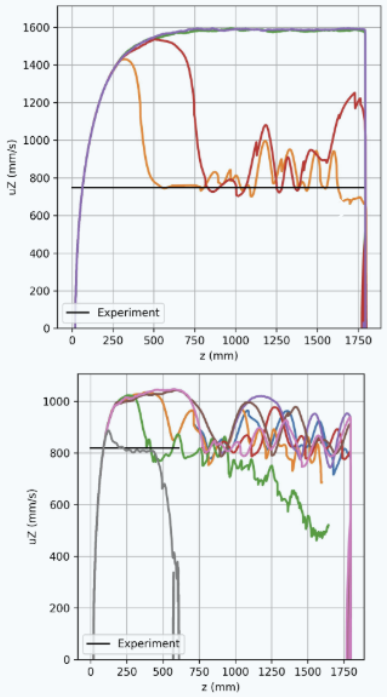
Single particle: Settling velocity

Comparison with the widely accepted correlations

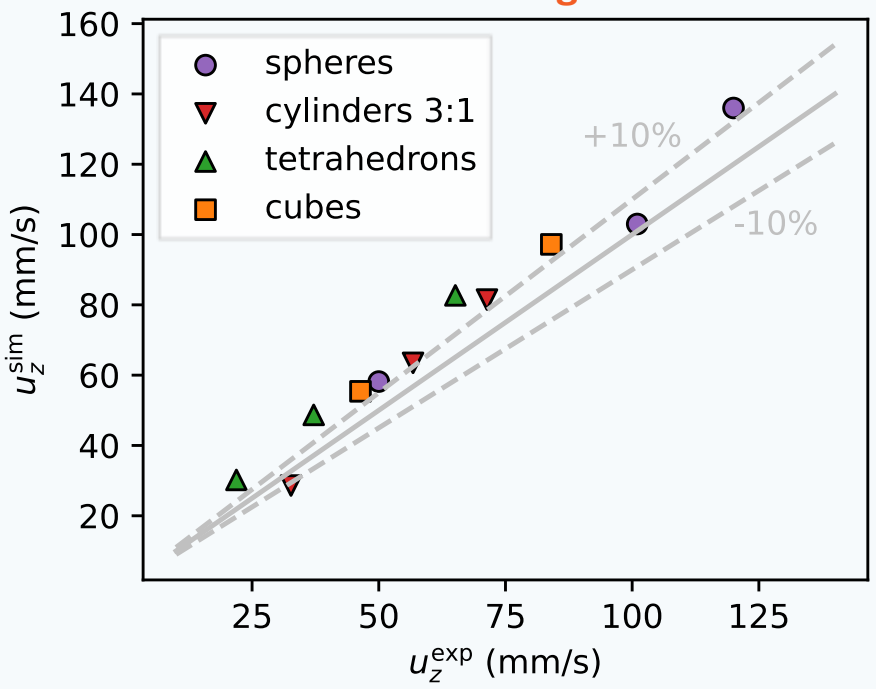


Single particle: Settling velocity

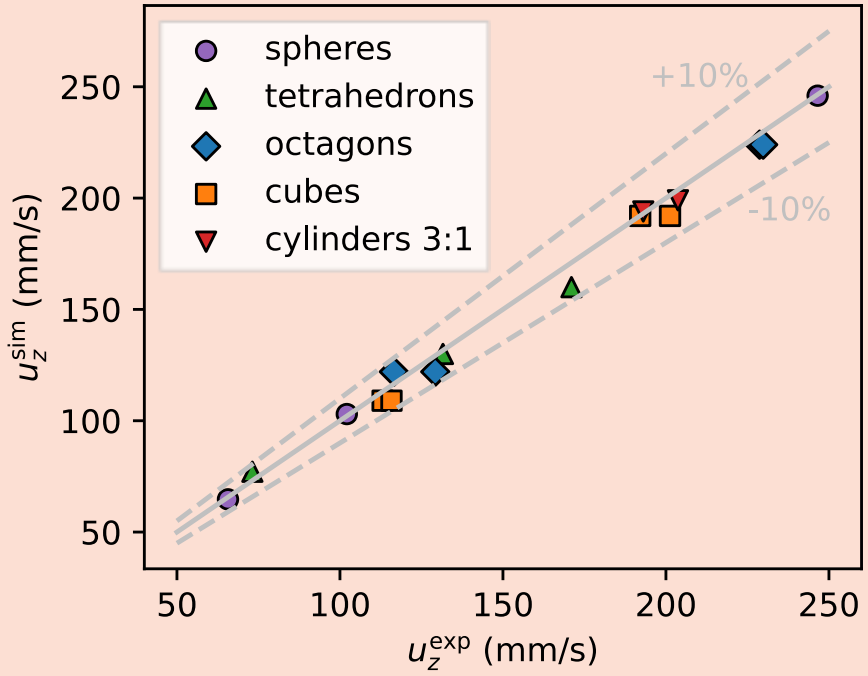
Comparison with the simulations - imperfections at both low and high Reynolds numbers



INITIAL STATE
some tweaking needed

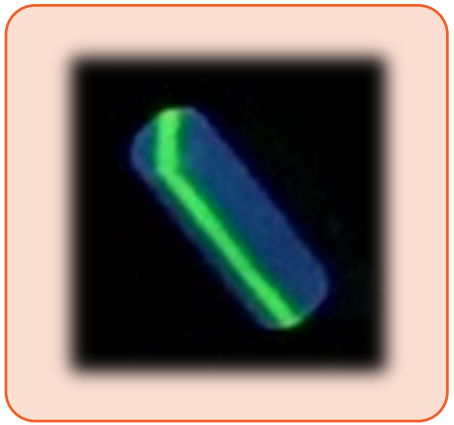


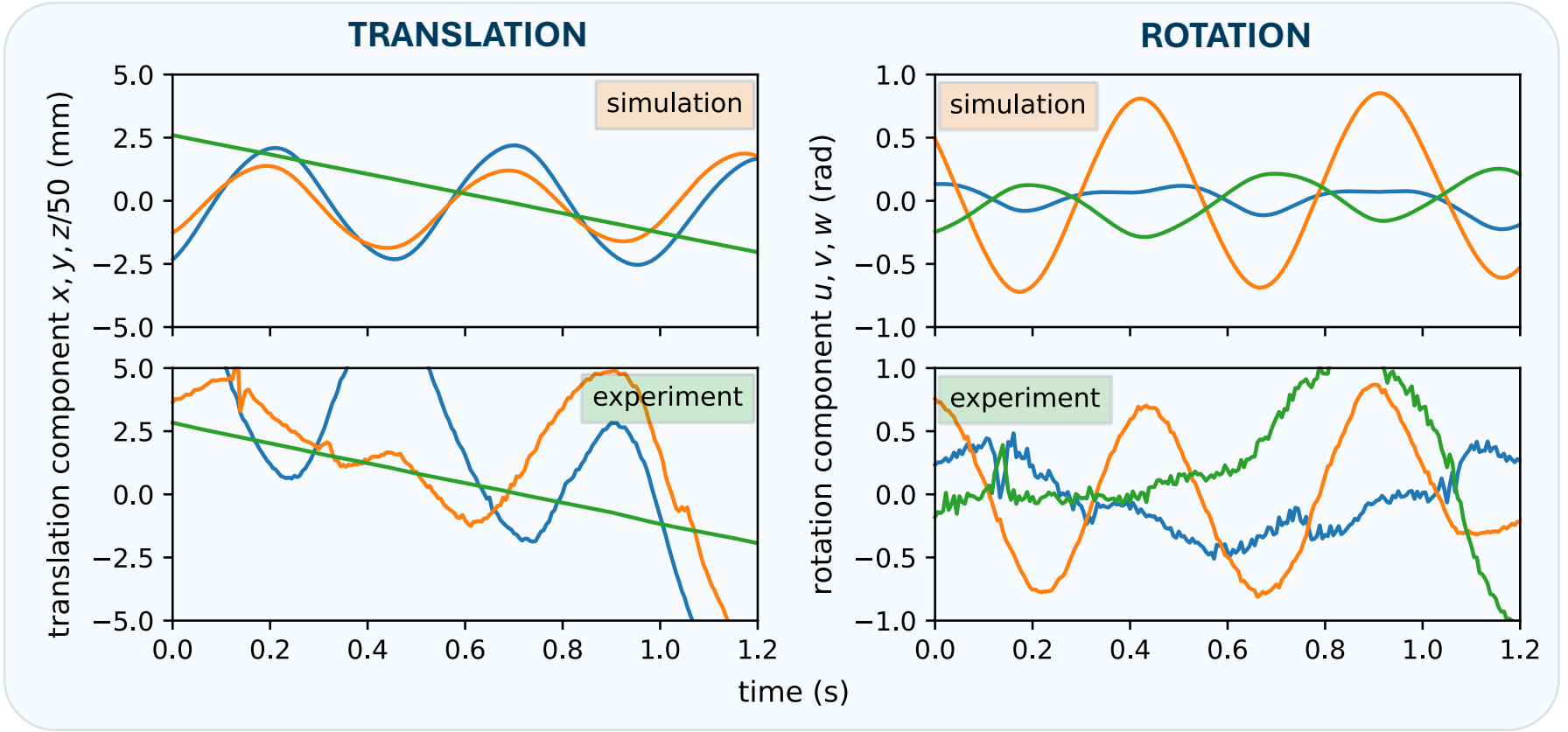
FINAL RESULTS



Single particle: resolved settling dynamics

Comparison with the modified simulations





Single particle: resolved settling dynamics

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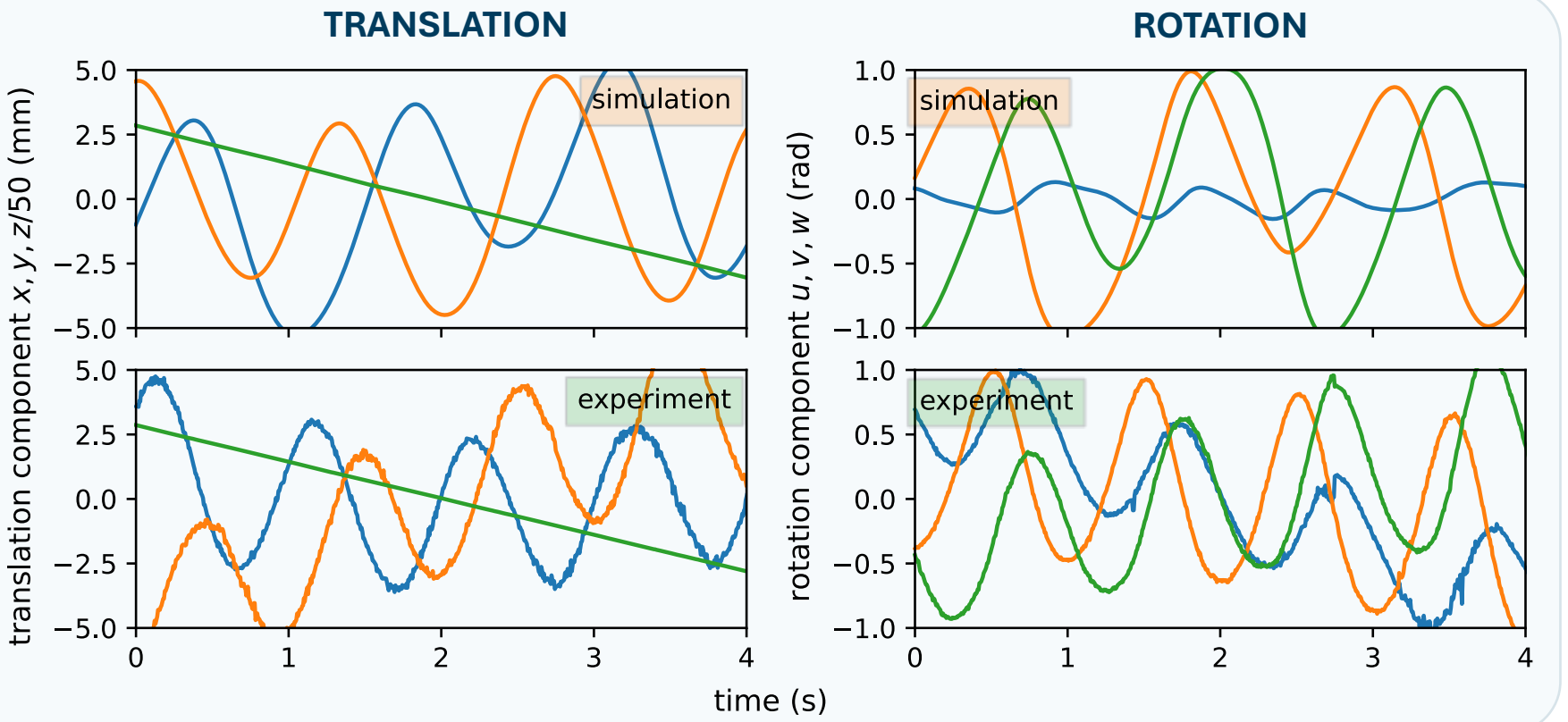
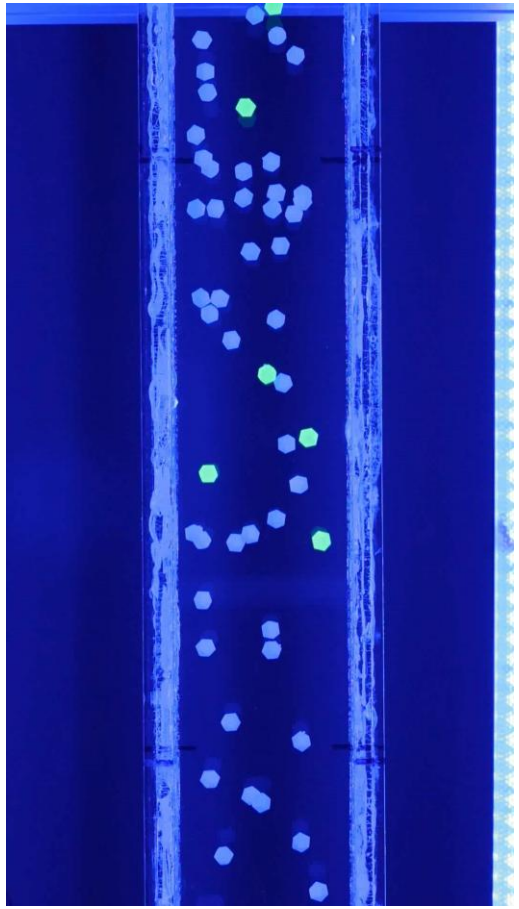


Final conclusions & Future outlook



- Settling trajectories & fully resolved settling dynamics measured for a variety of similarly sized particles.
- OpenHFDIB-DEM solver deficiencies corrected based on the measured data.
- Solver validation cases successfully extended to particle-fluid interactions

- Validation extension to non-spherical fluidization
- Eulerian model development & calibration on generated data