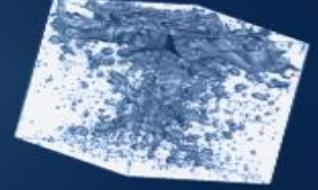




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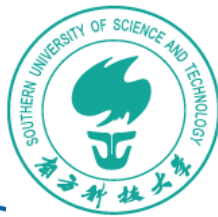
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Particle laden turbulent flow: comparison of fully resolved approaches

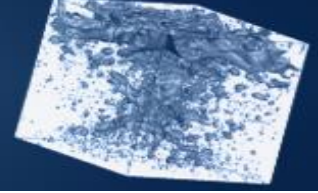
J. C. Brändle de Motta, P. Costa, J. J. Derksen, C. Peng,
L.-P. Wang, W.-P. Breugem, J. L. Estivalezes, S. Vincent,
E. Climent, P. Fede, P. Barbaresco, N. Renon

Based on a collaborative paper submitted for publication in **Computers & Fluids 2018**



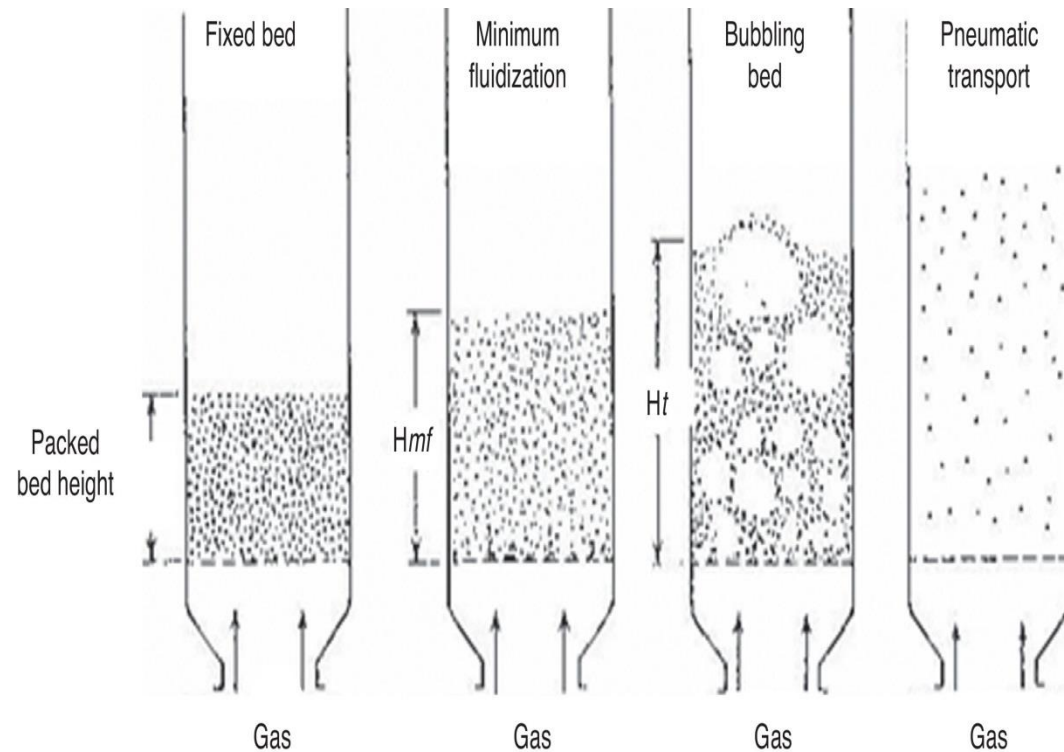
SUSTech
Southern University
of Science and Technology

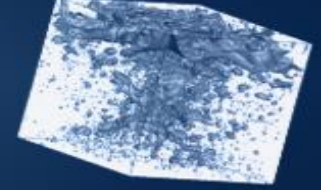




Particulate flows / turbulence

- Environmental as well as industrial applications (sand storm, fluidized beds, fluid catalytic cracking, sediments in rivers, ...)





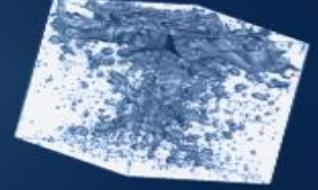
A benchmark for turbulent particulate flows with resolved-scale particles

	VoF-Lag	IBM	LBM-BB
Laboratory	MSME/CORIA/IMFT	TU Delft	U Delaware
Navier-Stokes	Augmented Lagrangian	Time splitting projection	Lattice-Boltzman BGK
Particles behavior	Viscous Penalty	Immersed boundary	Bounce back scheme
Particles tracking	No equation solved	Newton-Euler equation	Newton-Euler equation
Reference	Vincent et al. – JCP (2014)	Breugem – JCP (2012)	Wang et al. Comp. & Maths (2014)

To ensure reliability :

- No turbulence forcing
- Elastic collisions
- Same initial condition and positions are shared

A 4th code was considered for some comparisons : LBM-IBM, based on Derksen – PoF (2011)

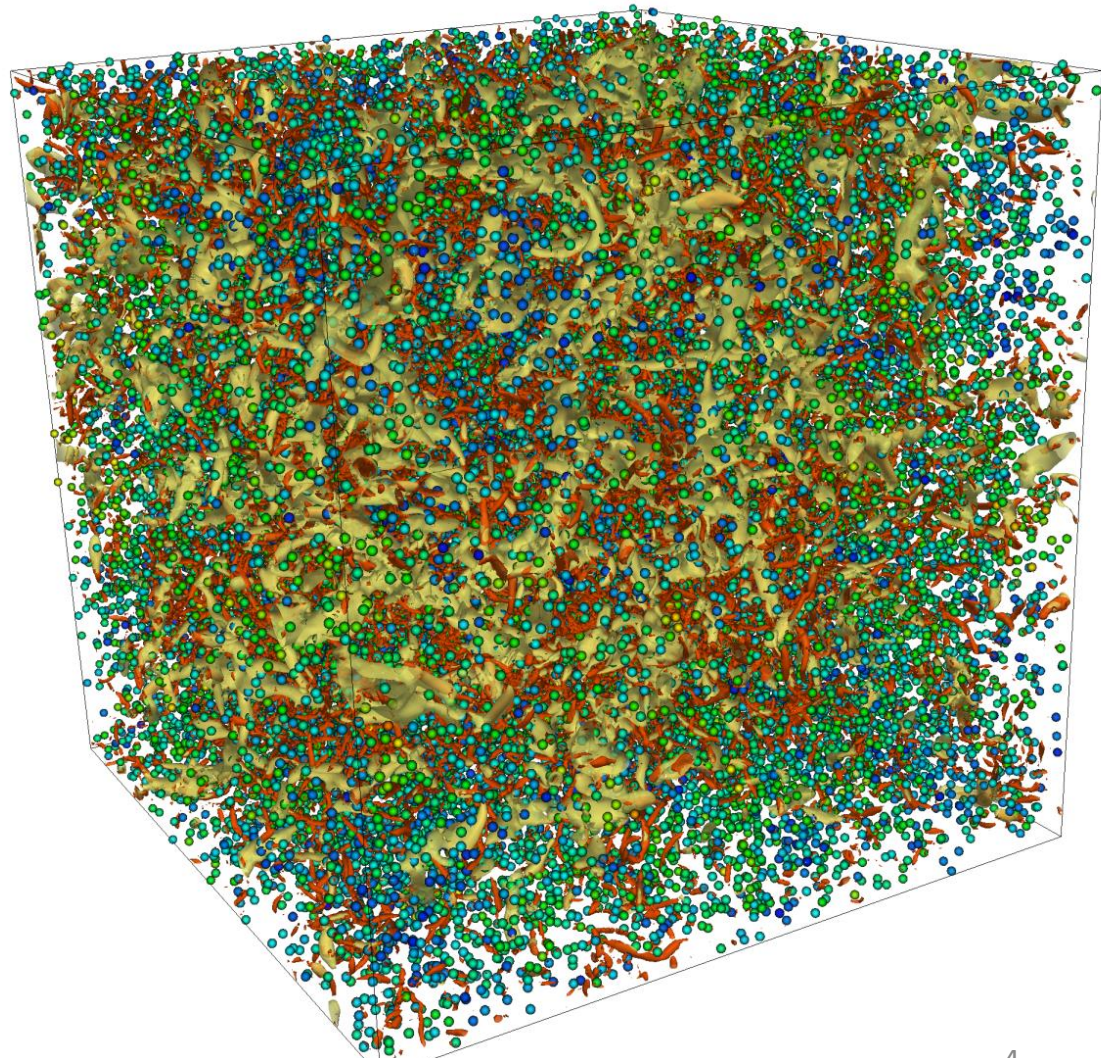


Initial condition

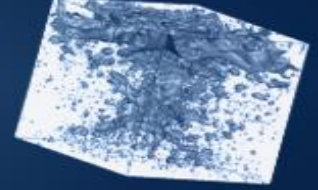
- $Re_\lambda = 87$
- $N_p = 4450$
- $\alpha_v = 3\%$
- $\frac{D}{\eta} = 19.8$

Numerical conditions

- $N = 512^3$
- $\frac{D}{\Delta x} = 12$



Green particles have high velocities and blue particles have low



Initial condition

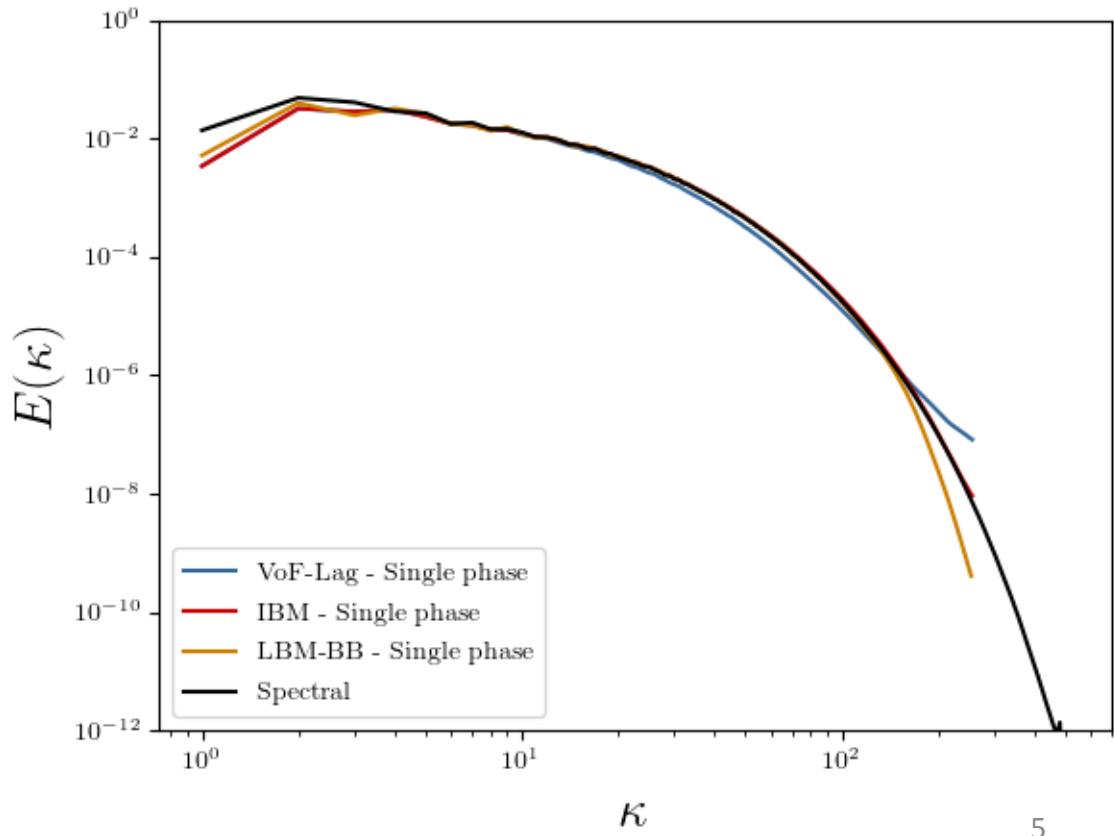
Initial turbulent field => spectral code with 1024^3 modes

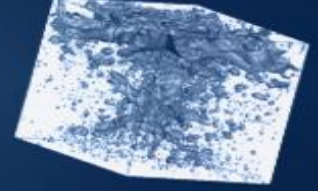
A forcing scheme of [Eswaran & Pope CAF 1988] was used to obtain a statistically steady flow by adding a stochastic force on the spectral modes.

- $Re_\lambda = 87$
- $N_p = 4450$
- $\alpha_v = 3\%$
- $\frac{D}{\eta} = 19.8$

Numerical conditions

- $N = 512^3$
- $\frac{D}{\Delta x} = 12$





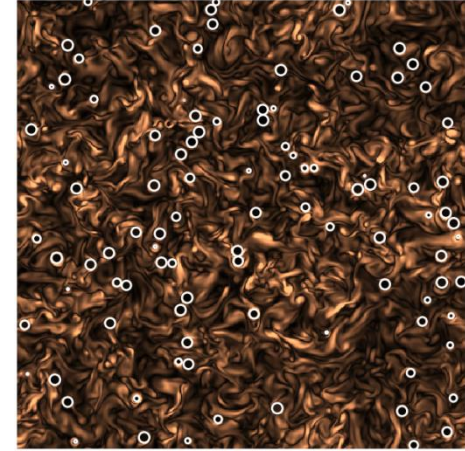
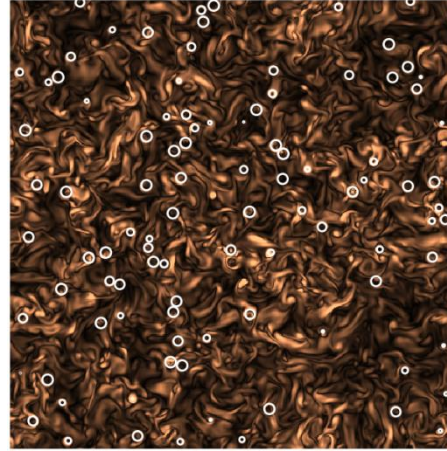
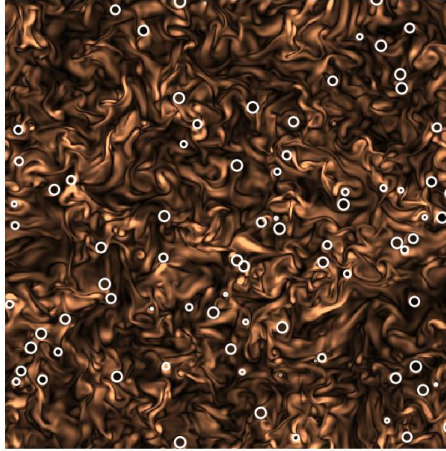
Qualitative results

VoF-Lag

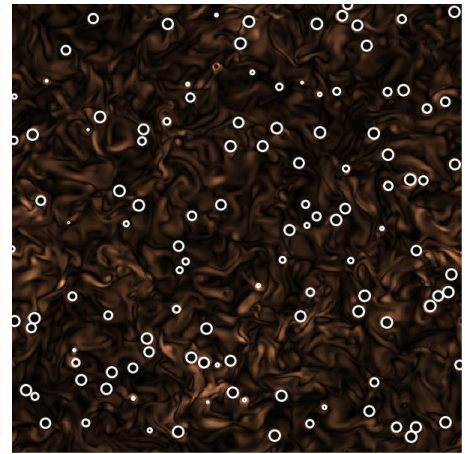
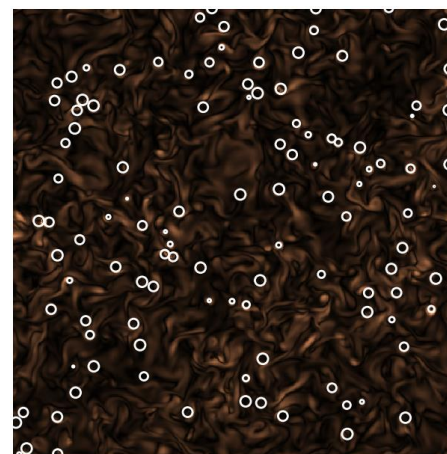
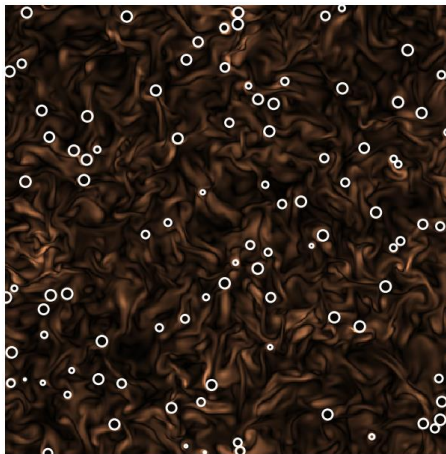
IBM

LBM-BB

1.25 Te



3.75 Te



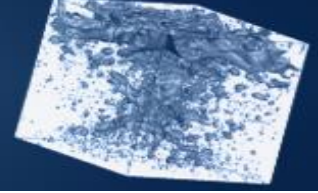
- Same type of turbulent structures
- Different positions for VoF-Lag



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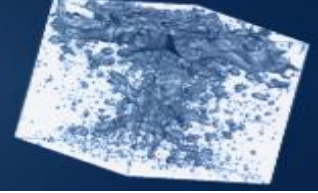
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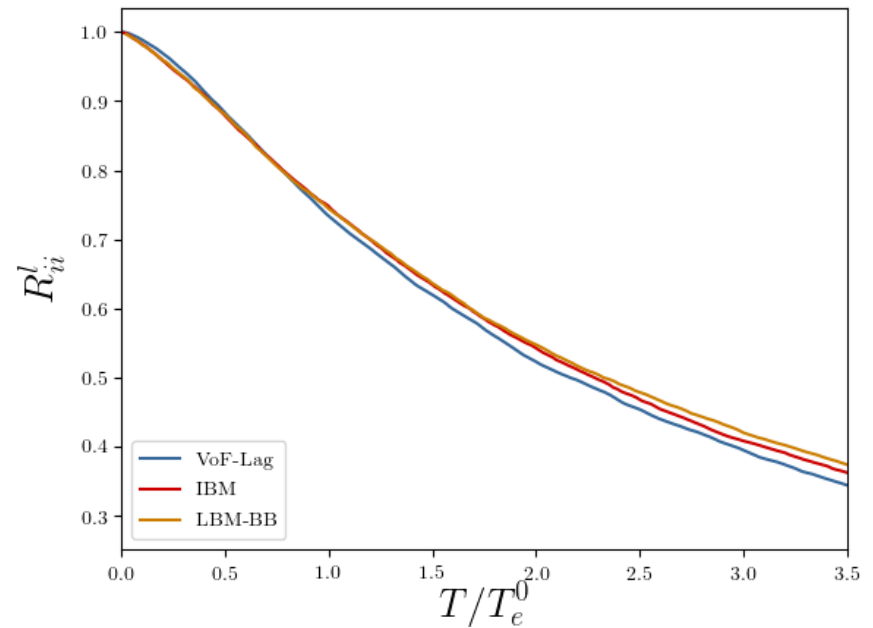
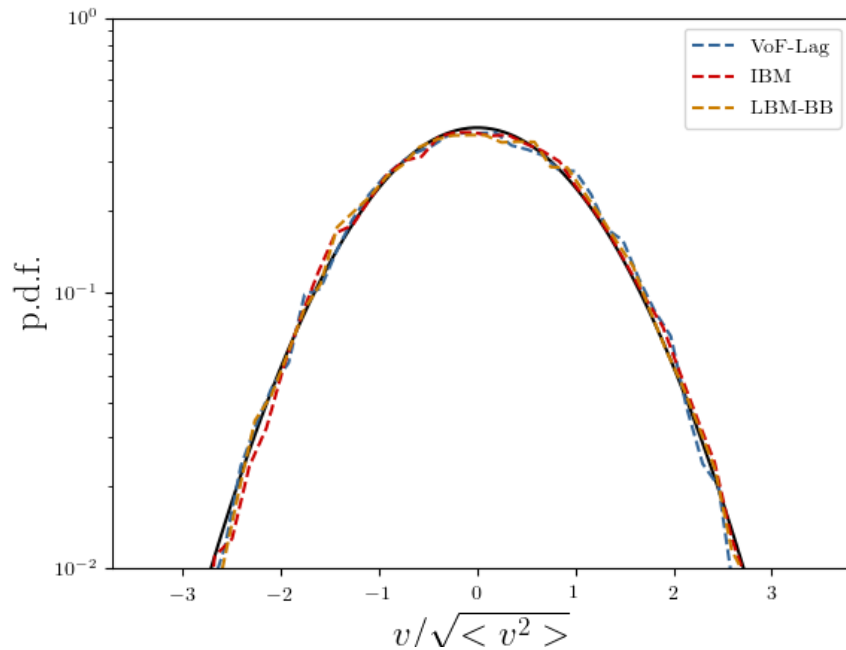
Particle trajectories

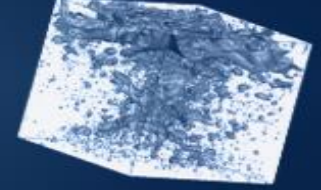
see movie



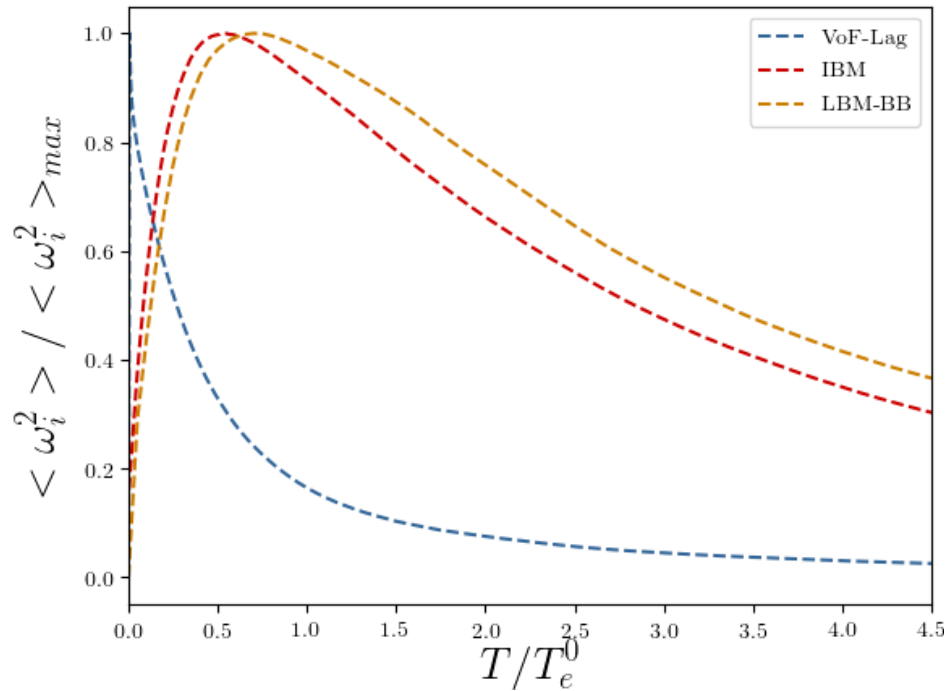
Particle statistics

- Gaussian velocity distribution is respected
- Classical autocorrelation is observed for all codes

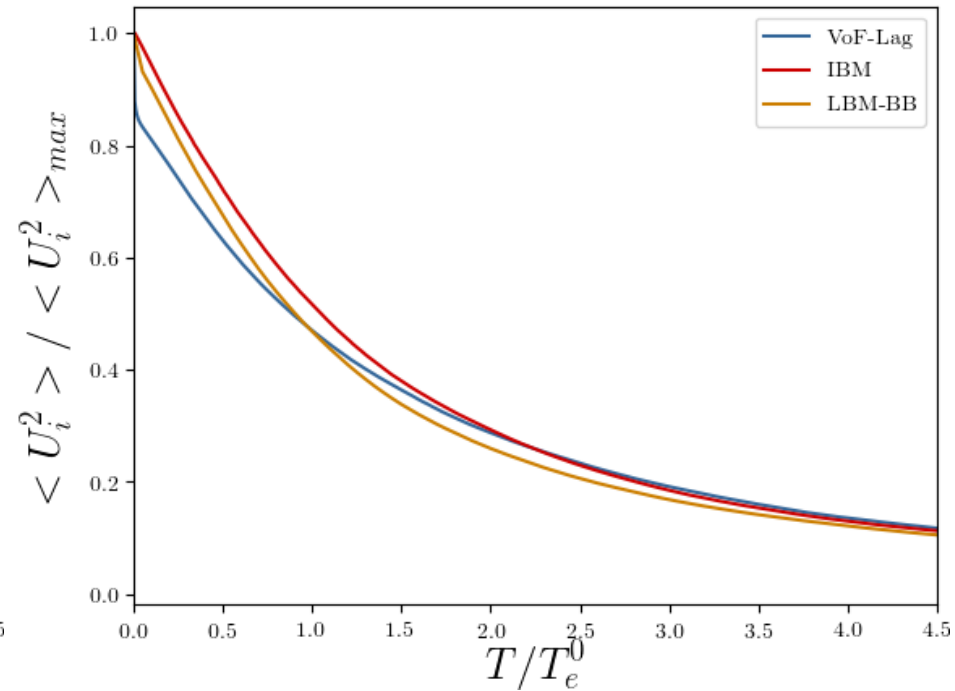




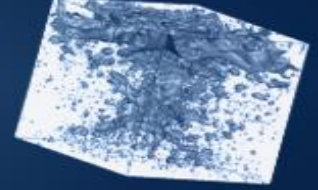
Particle Kinetic Energy



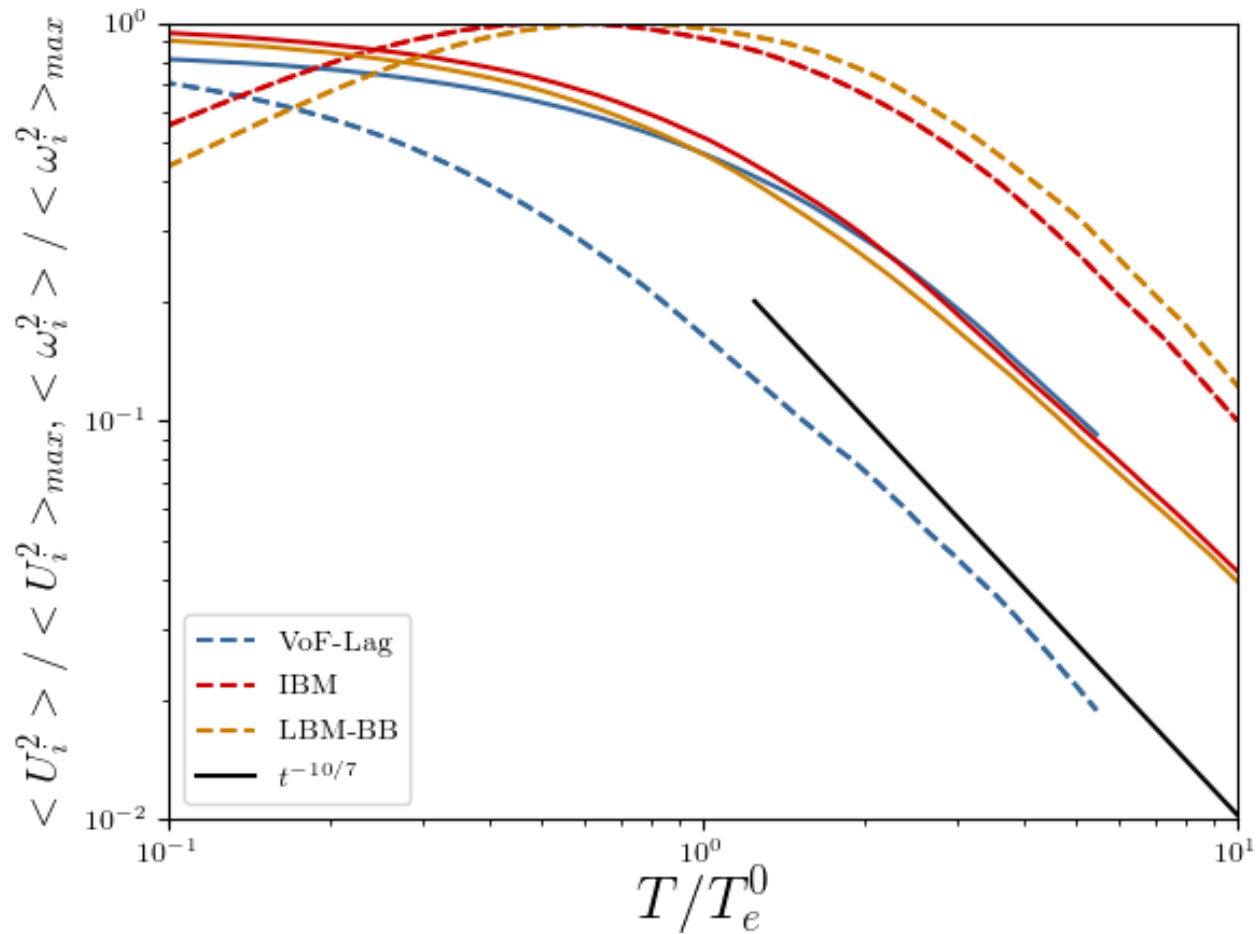
Rotational velocity

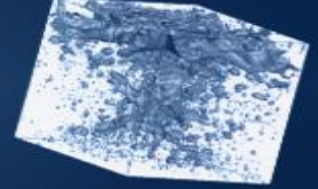


Translational velocity

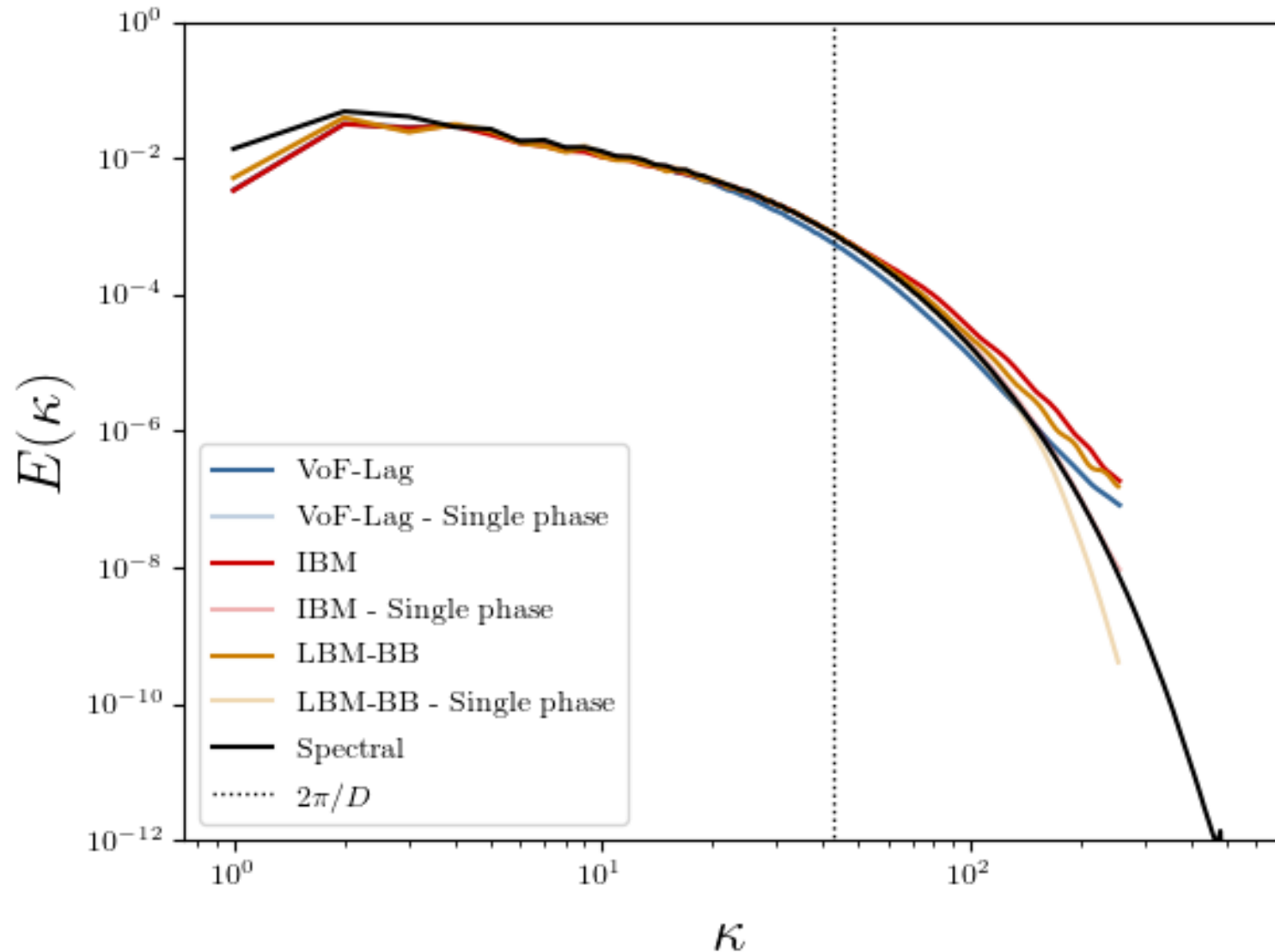


Particle Kinetic Energy in log-log scale

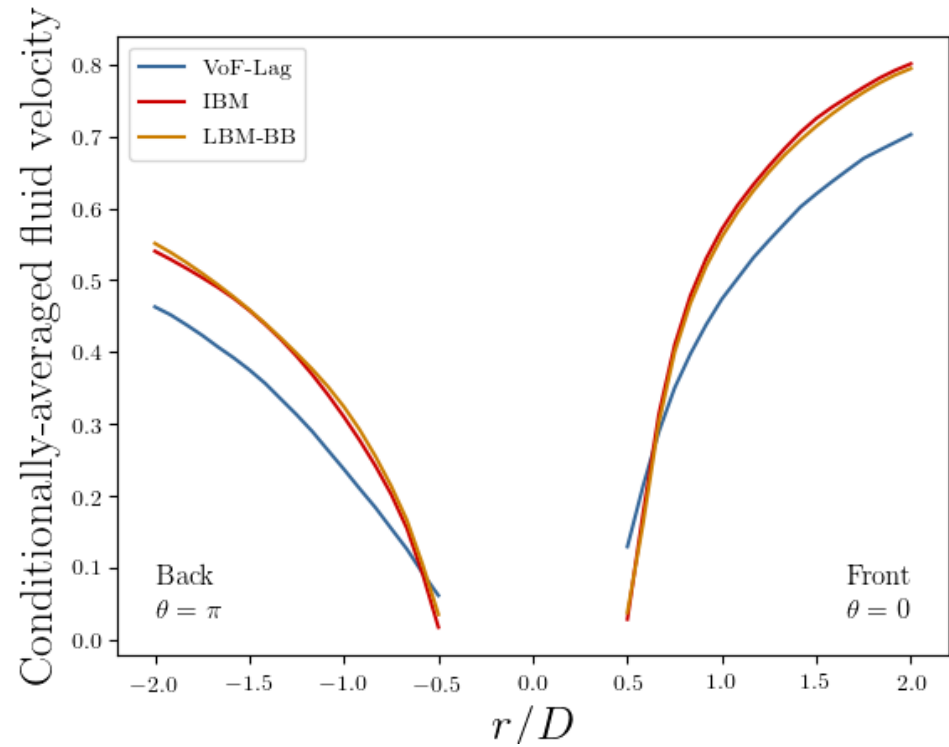
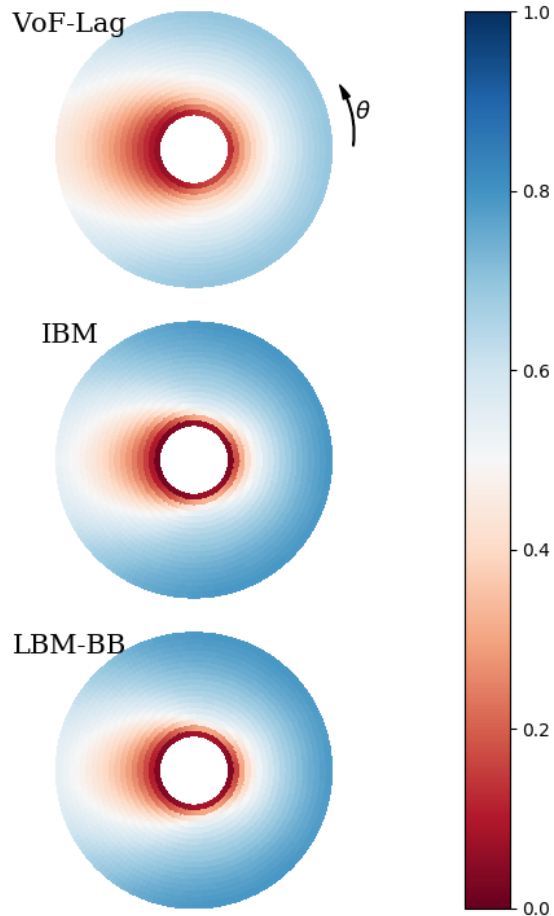
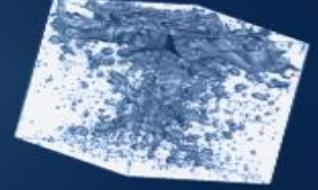


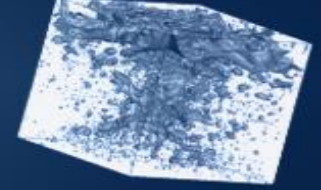


Turbulence modulation

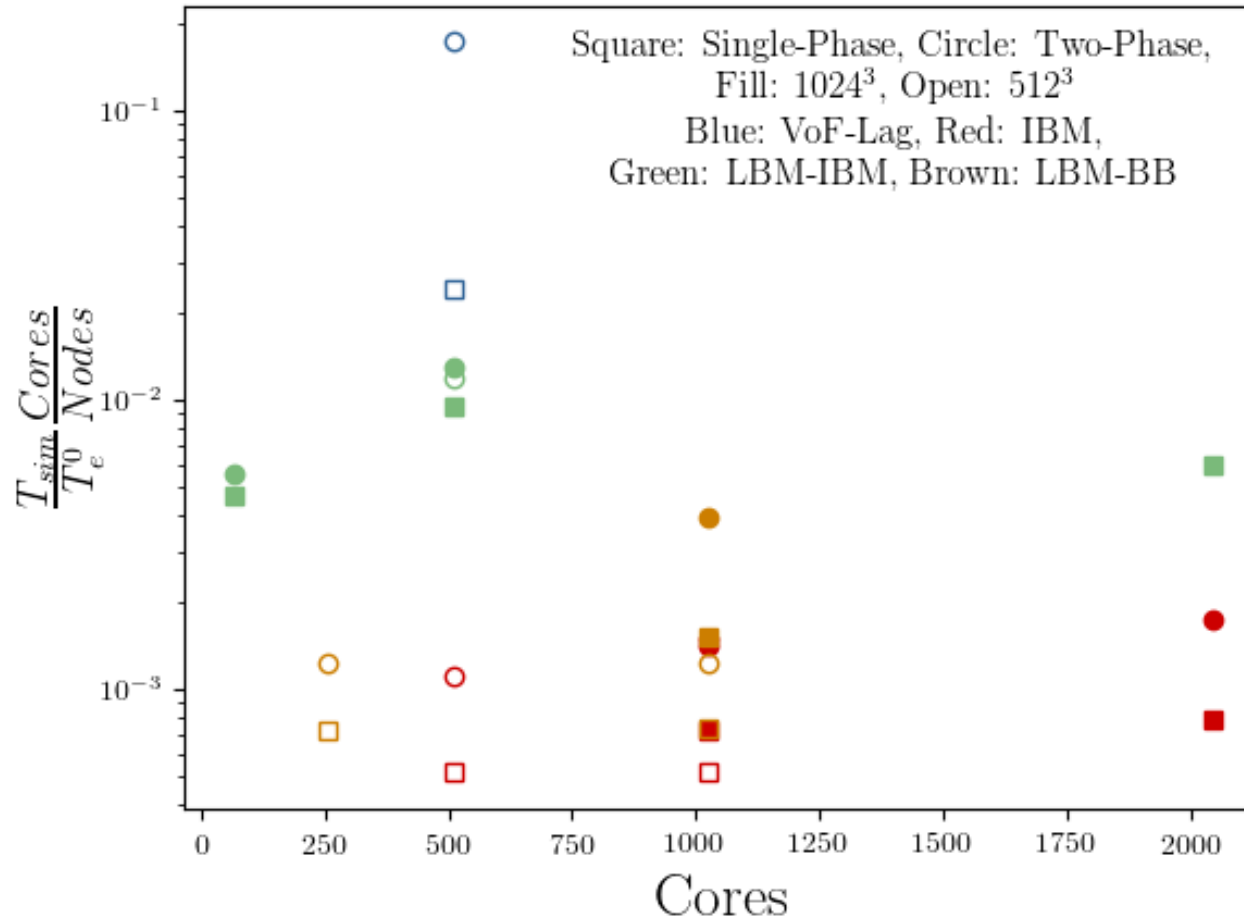


Averaged slip velocity





CPU Statistics



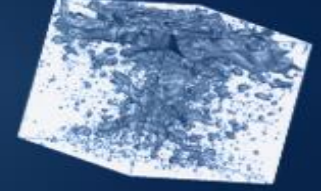
LBM-BB simulations were done on different supercomputer



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Thank you for your attention

