EPSC2012-566

The dependence of mantle thermal conductivity on particle shape and size

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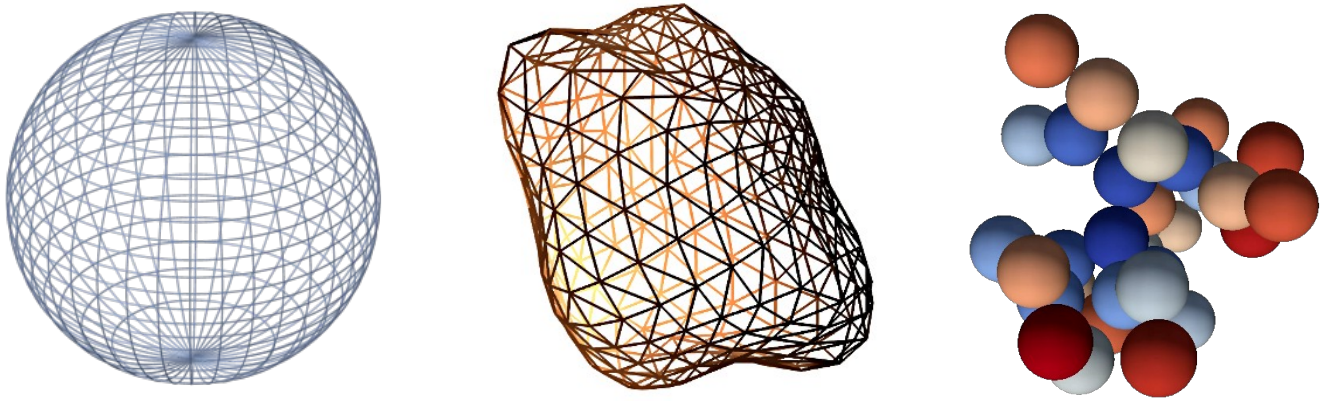
A multi-scale problem



	Global	Local	Microscopic
Scale	kilometre	metre	< centimetre
Input	bulk properties	local topography high res. images	grain properties
Output	gas and dust production rates	e.g. jet production	local bulk properties
Technique	1D, 2.5D finite difference, DSMC	3D FEM	DEM

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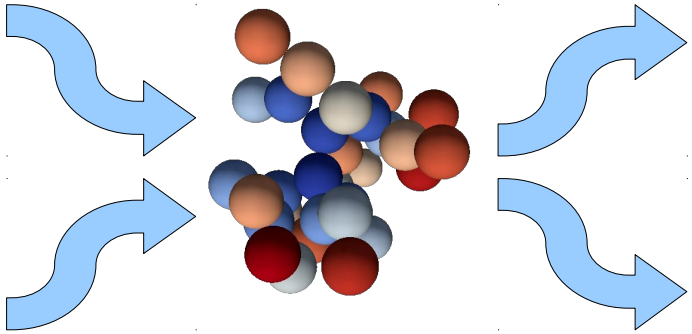
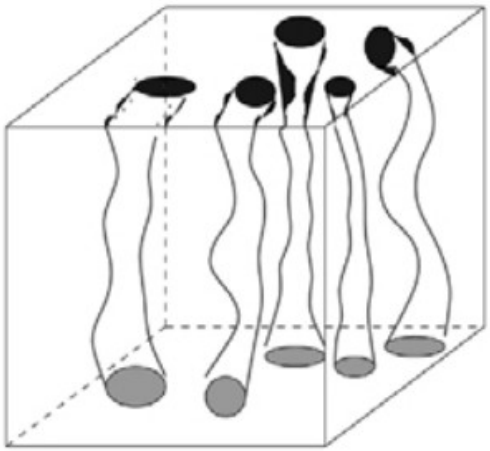
Anatomy of a particle

Young's modulus
Surface energy
Shape
Size
Porosity
Surface roughness
Coef. of restitution



Cohesion & flowability
Tensile strength
Shear strength
Bulk porosity
Angle of repose
Gas permeability
Thermal conductivity

Example: porosity Prialnik (2002)



tortuous capillaries

rubble pile

porous aggregates

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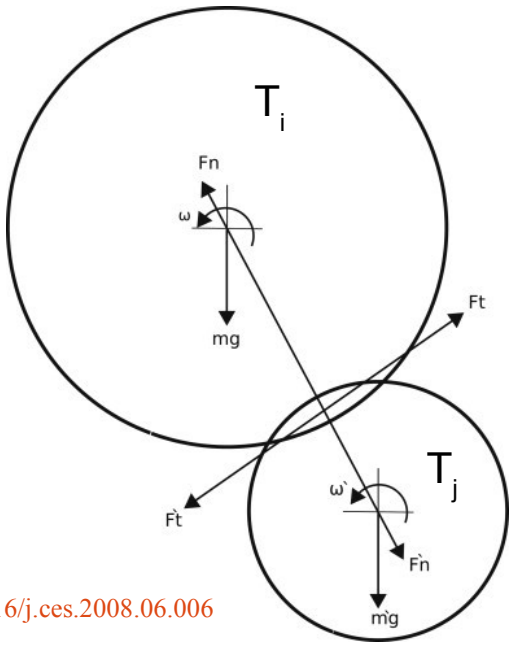
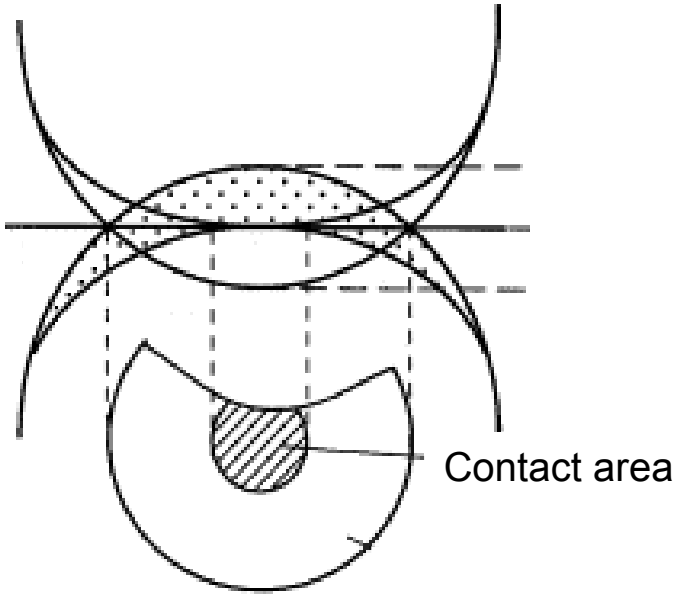
Discrete Element Modelling



10.1016/j.ces.2008.06.006

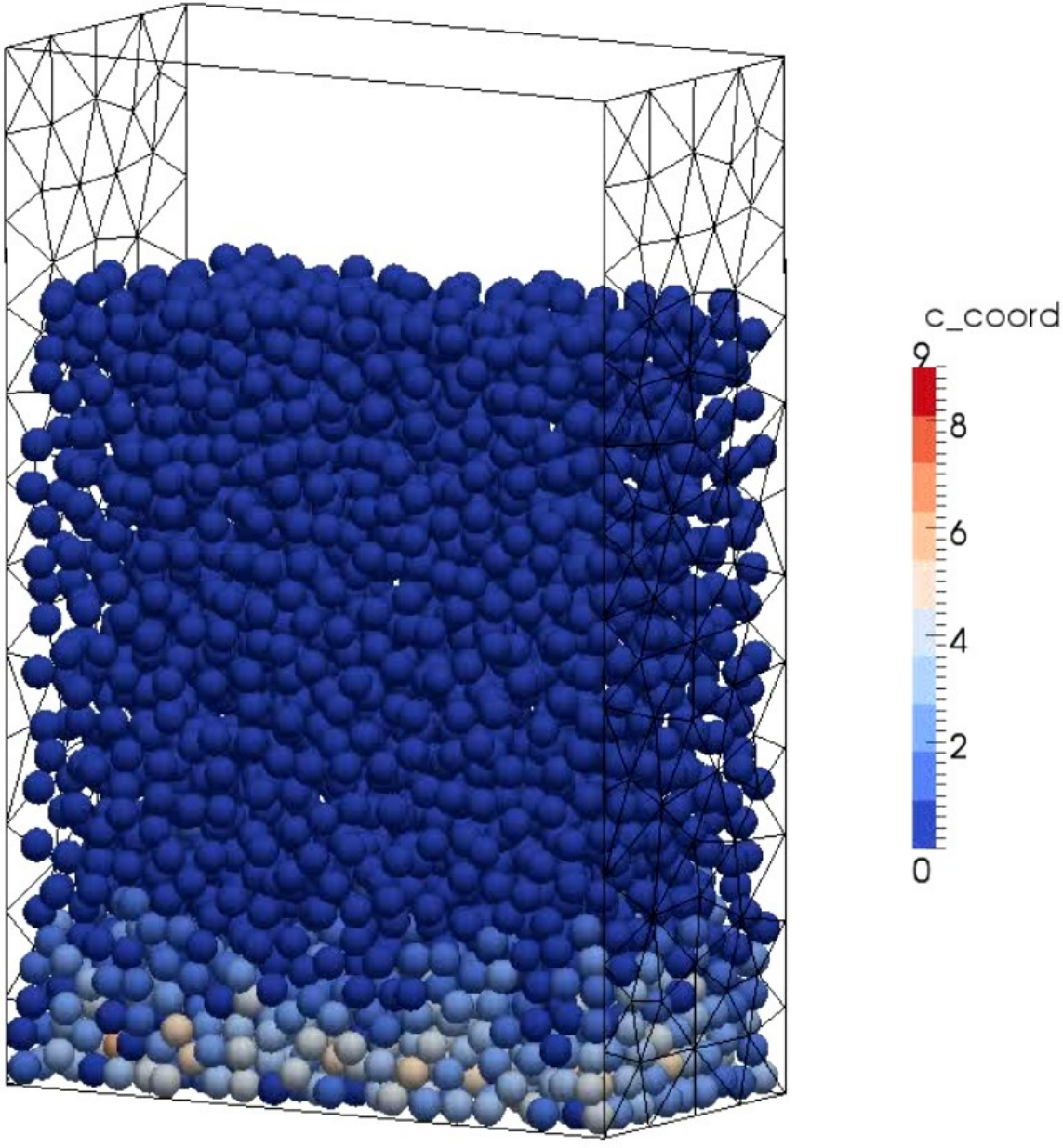
$$\mathbf{f}_{j \to i}$$

$$m\ddot{\mathbf{x}}_i = \sum_{j \neq i} \mathbf{f}_{j \to i}$$



Parameter	Value	Unit
Particle diameter	200	µm
Coefficient of restitution	0.6	
Young's modulus	5	MPa
Friction coefficient	0.2	
Poisson's ratio	0.45	
Solid conductivity	5	W m^{-1} K^{-1}

Generic simulation



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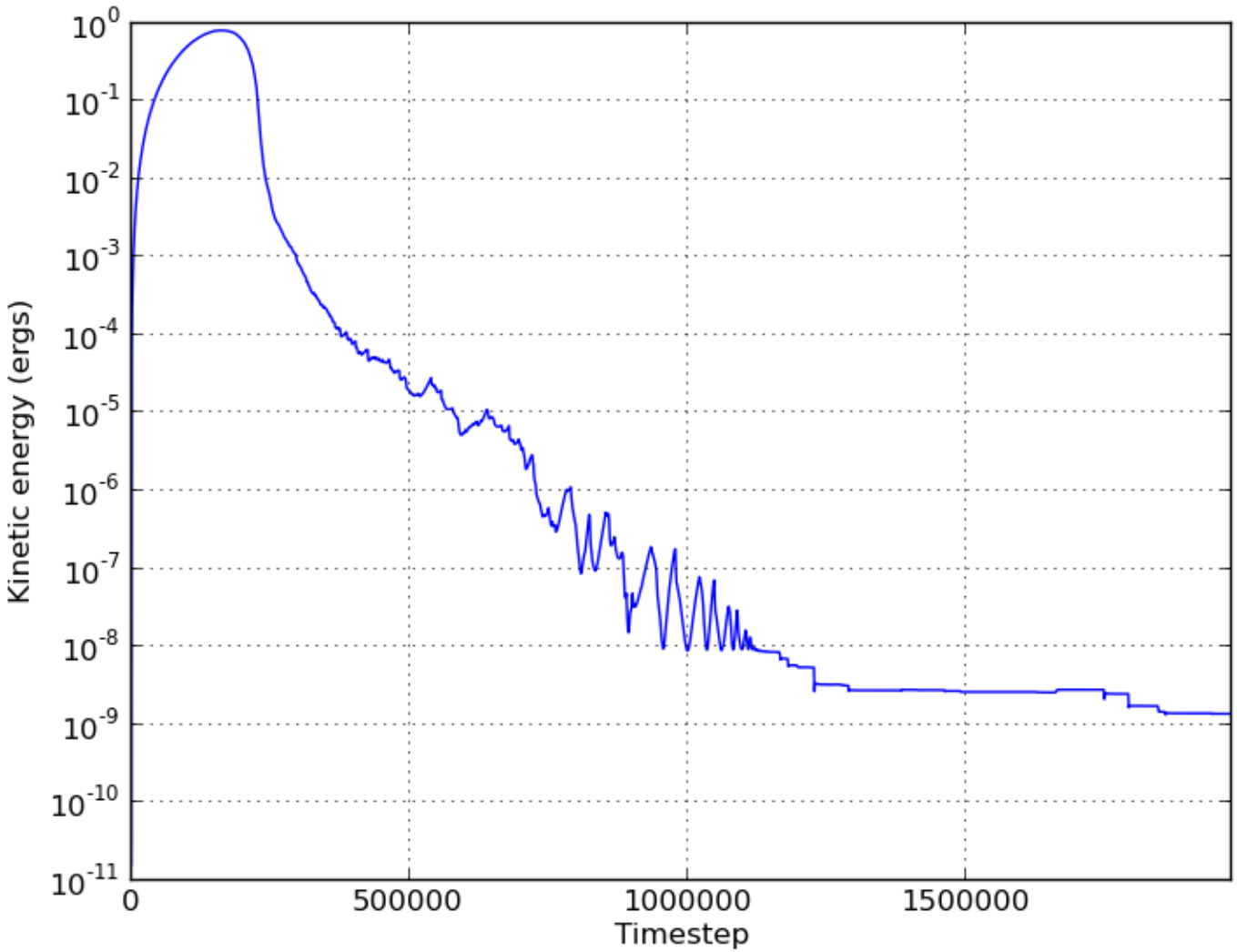
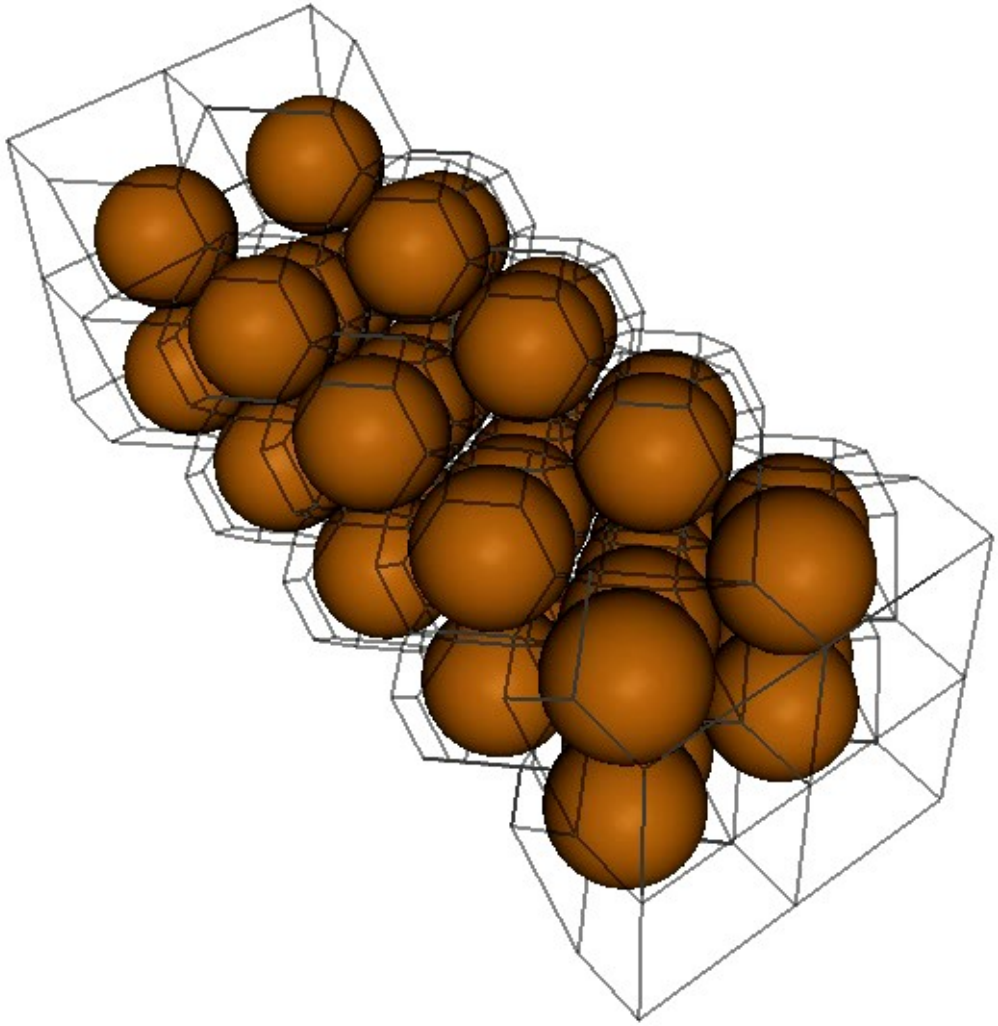
Generic simulation



Run until stable packing achieved

Output parameters



Voronoï tessellation

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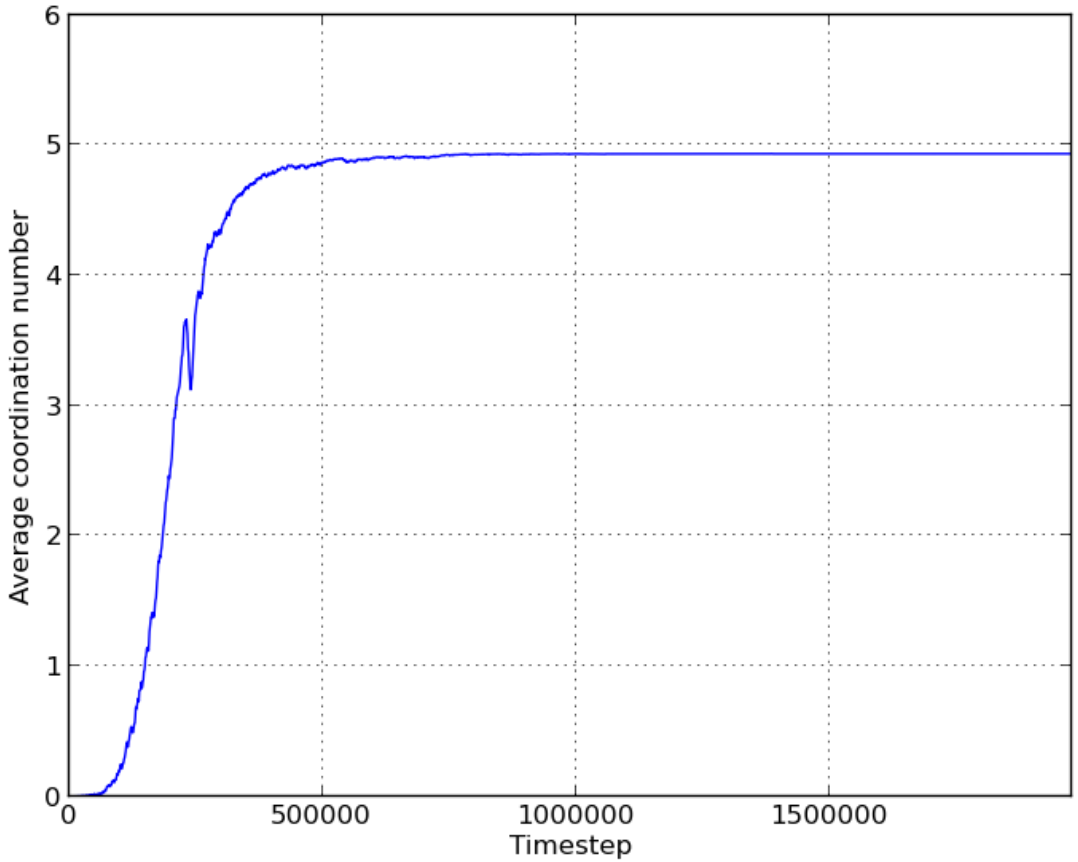
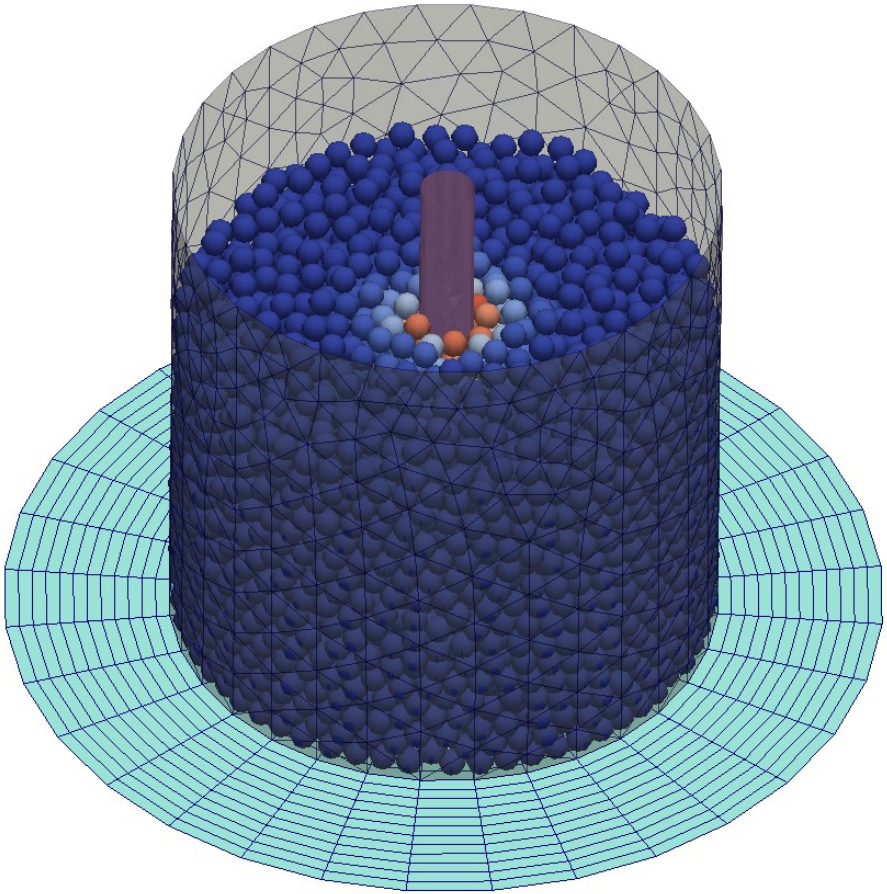
Output parameters

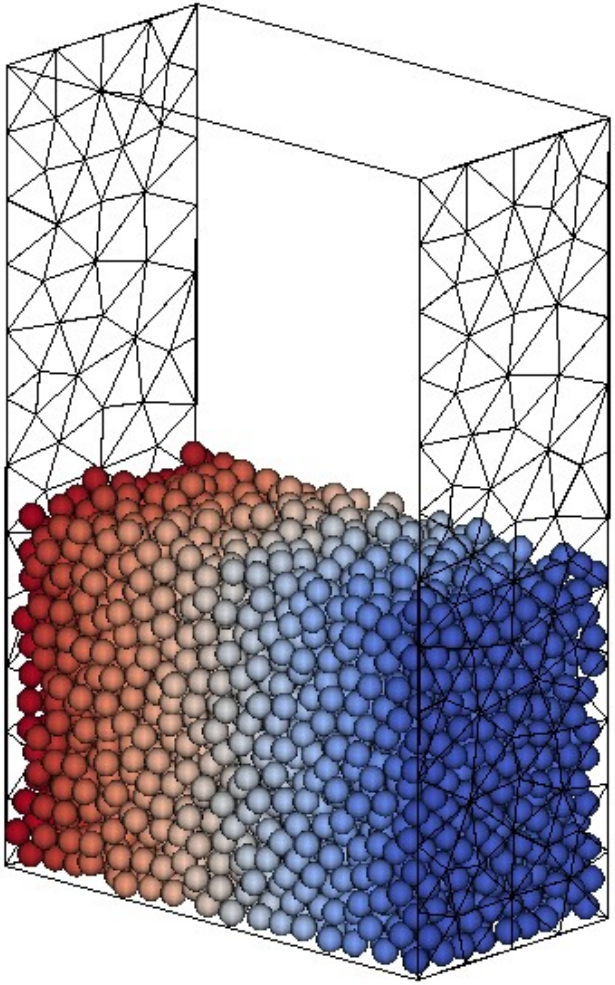


Several other things *could* be calculated

- gas permeability, surface-volume ratio, radiative transport etc.
  - using pore structure

Measuring thermal conductivity





$$k_{eff} = \frac{Q \ln\left(R_2 / R_1\right)}{2 \pi H \Delta T}$$

$$k_{eff} = \frac{Q L}{W H \Delta T}$$

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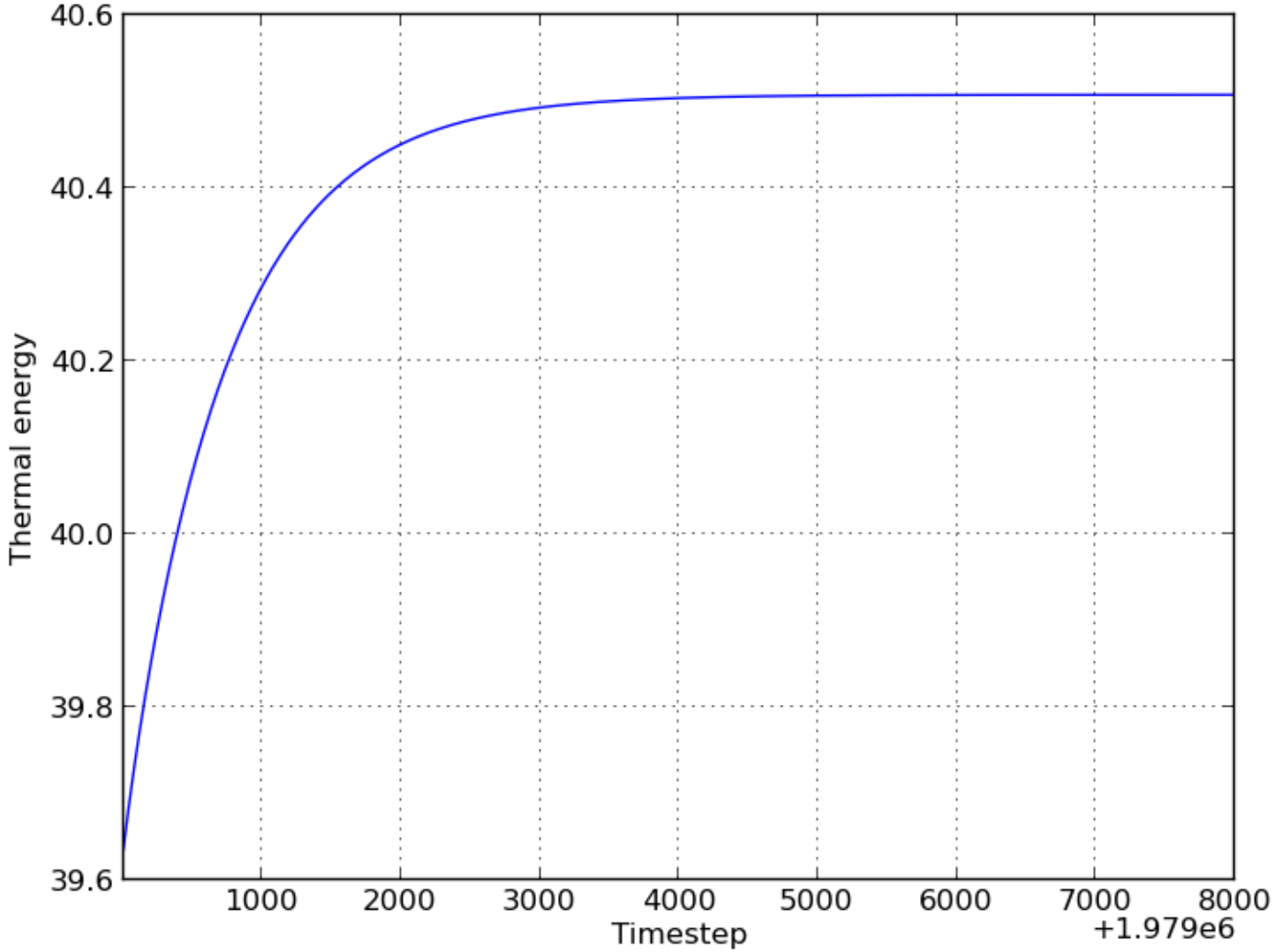
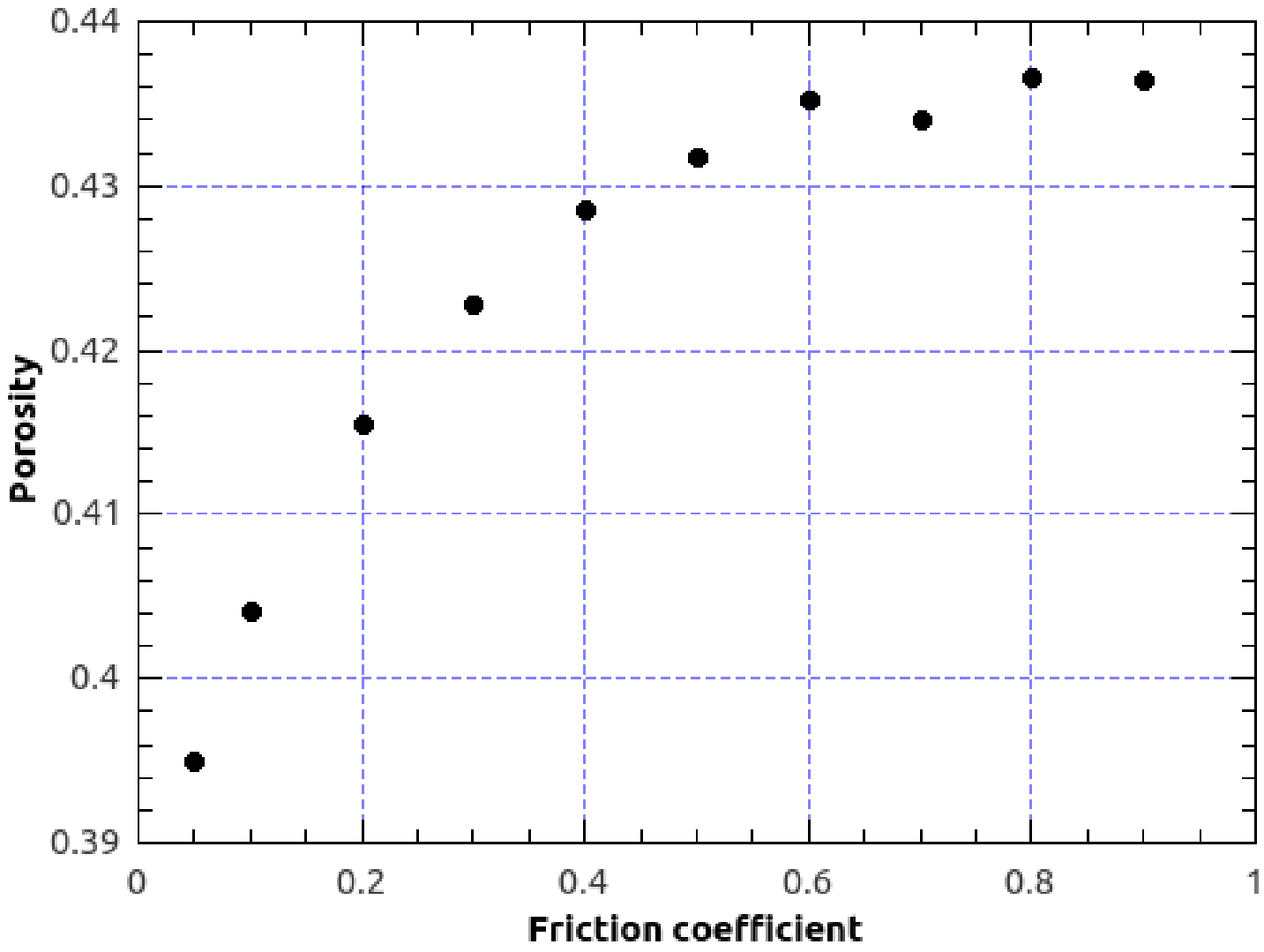
Measuring thermal conductivity



Run to thermal equilibrium

The effect of friction



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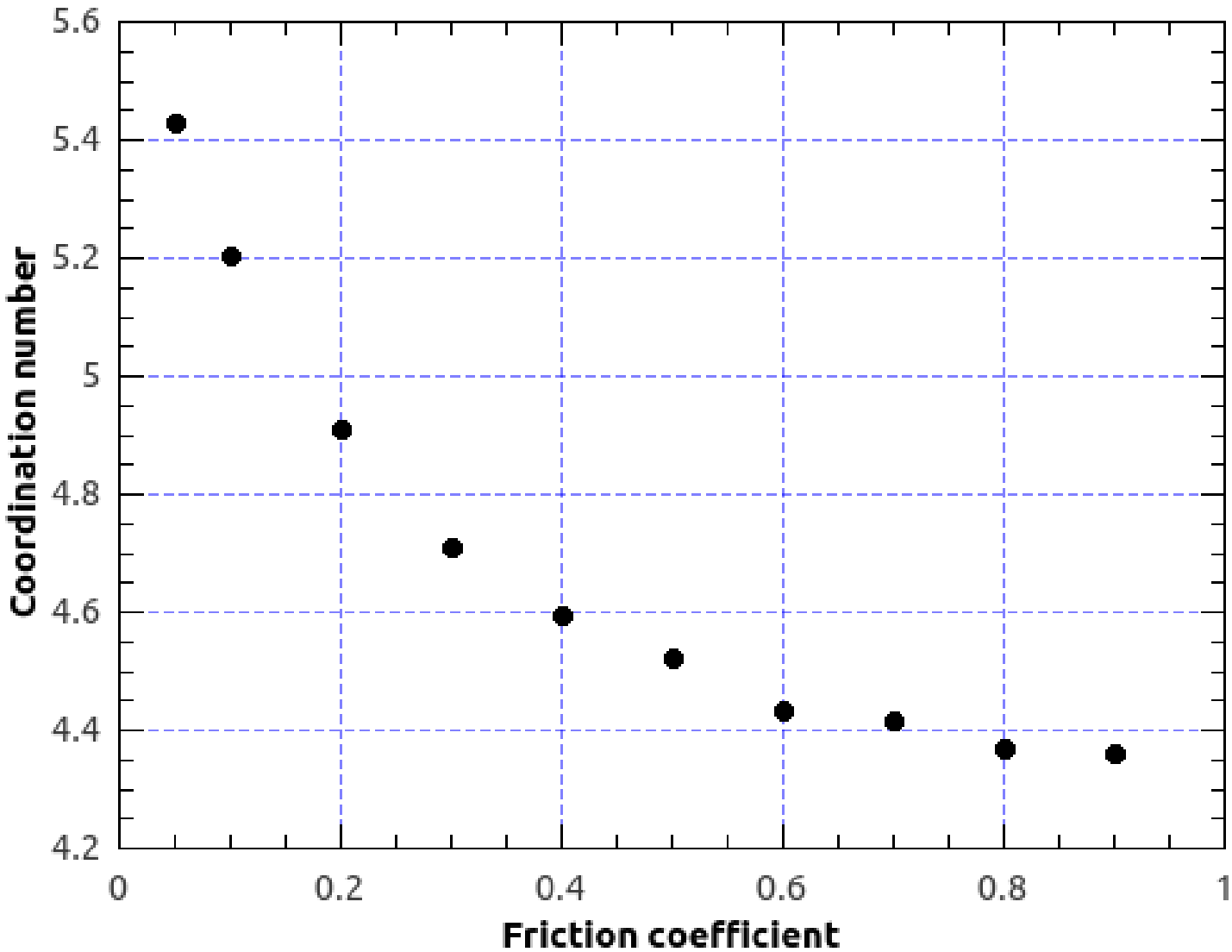
The effect of friction



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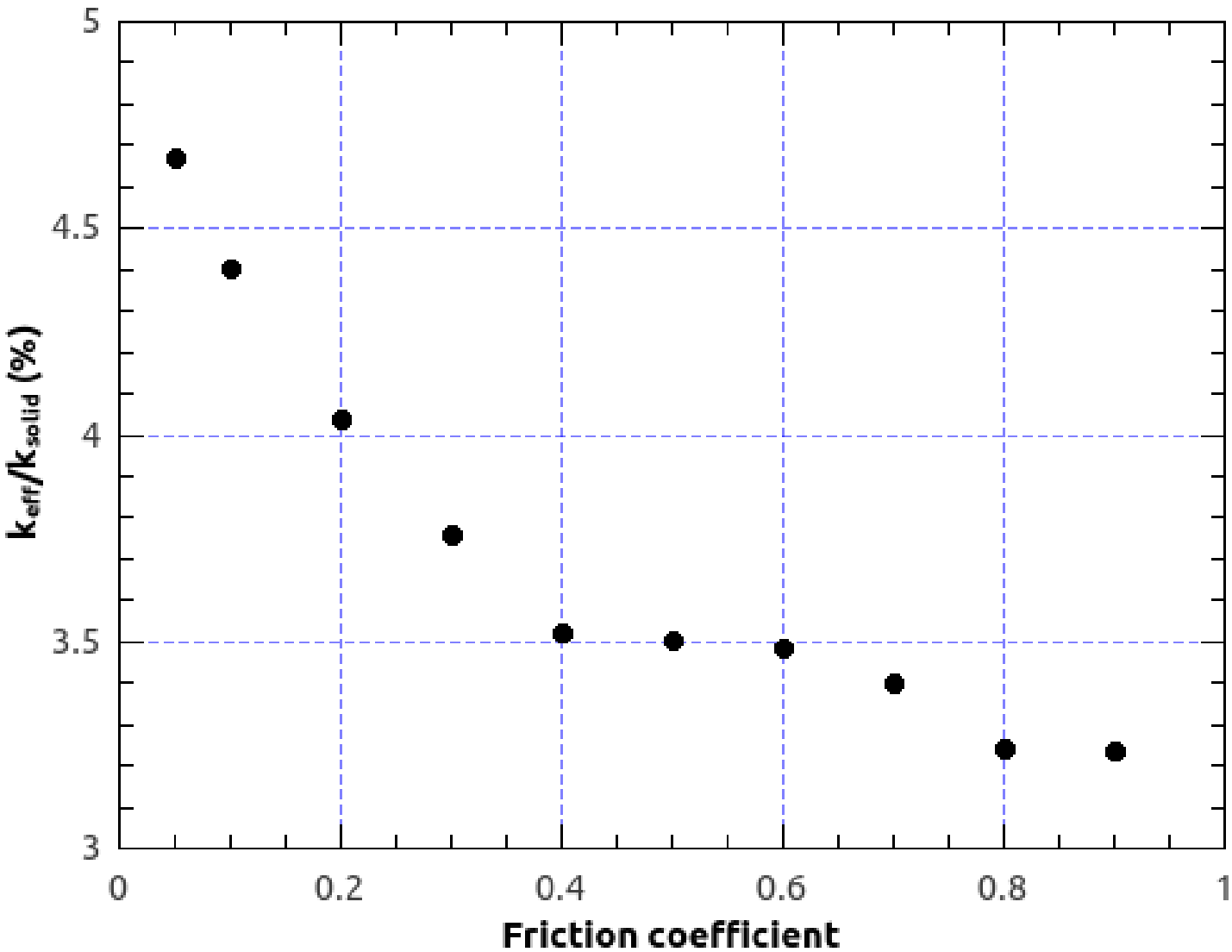
The effect of friction



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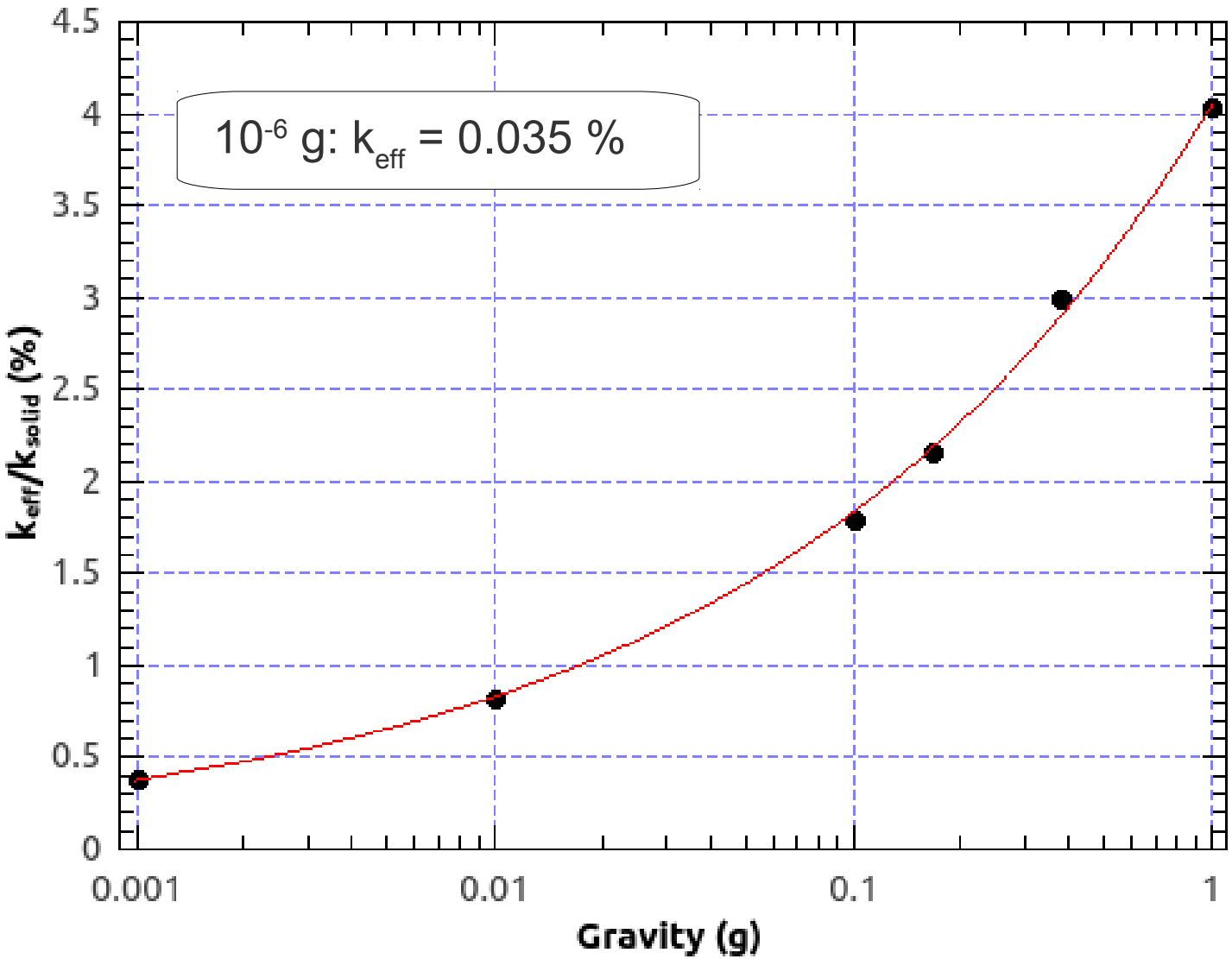
The effect of gravity



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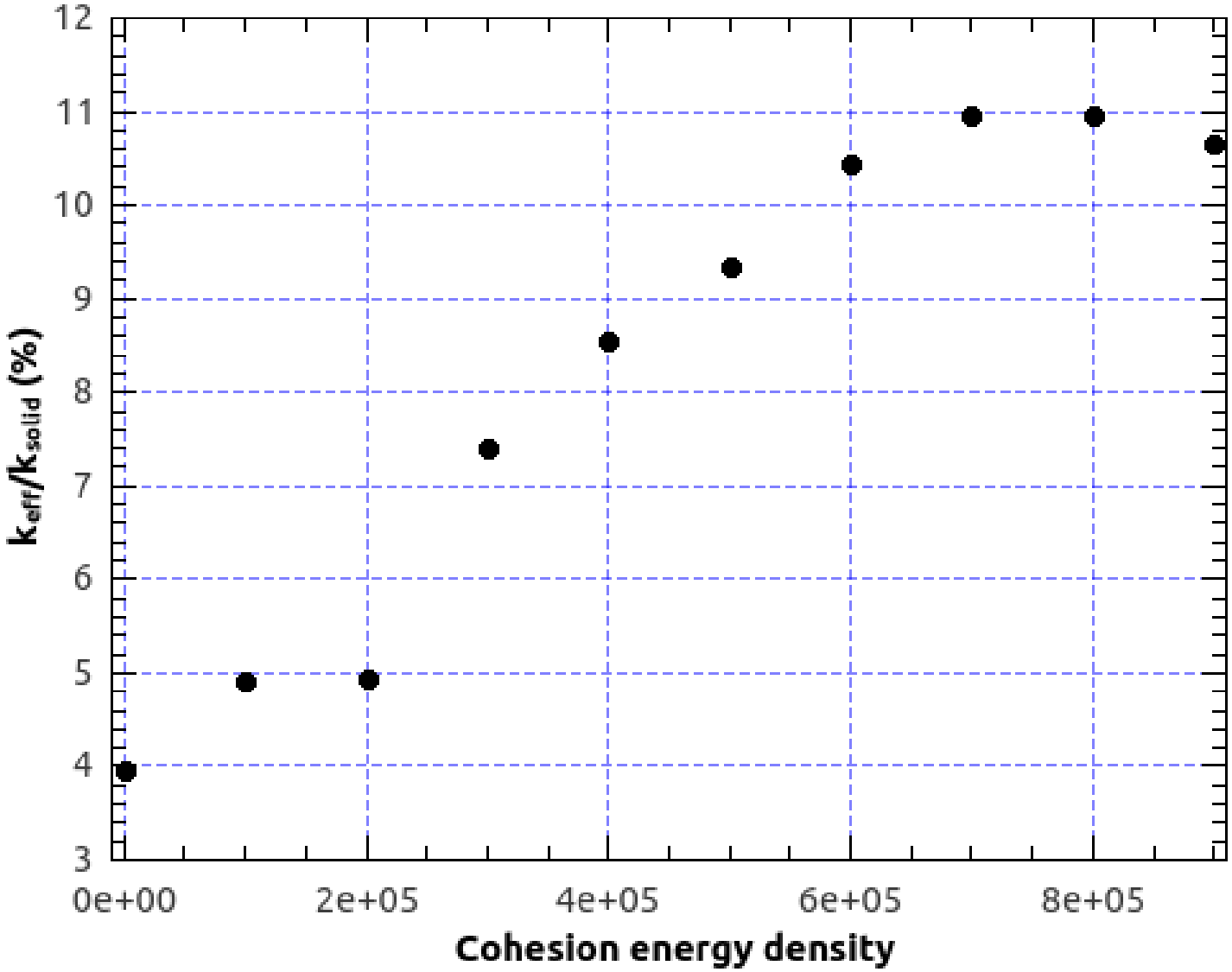
The effect of cohesion



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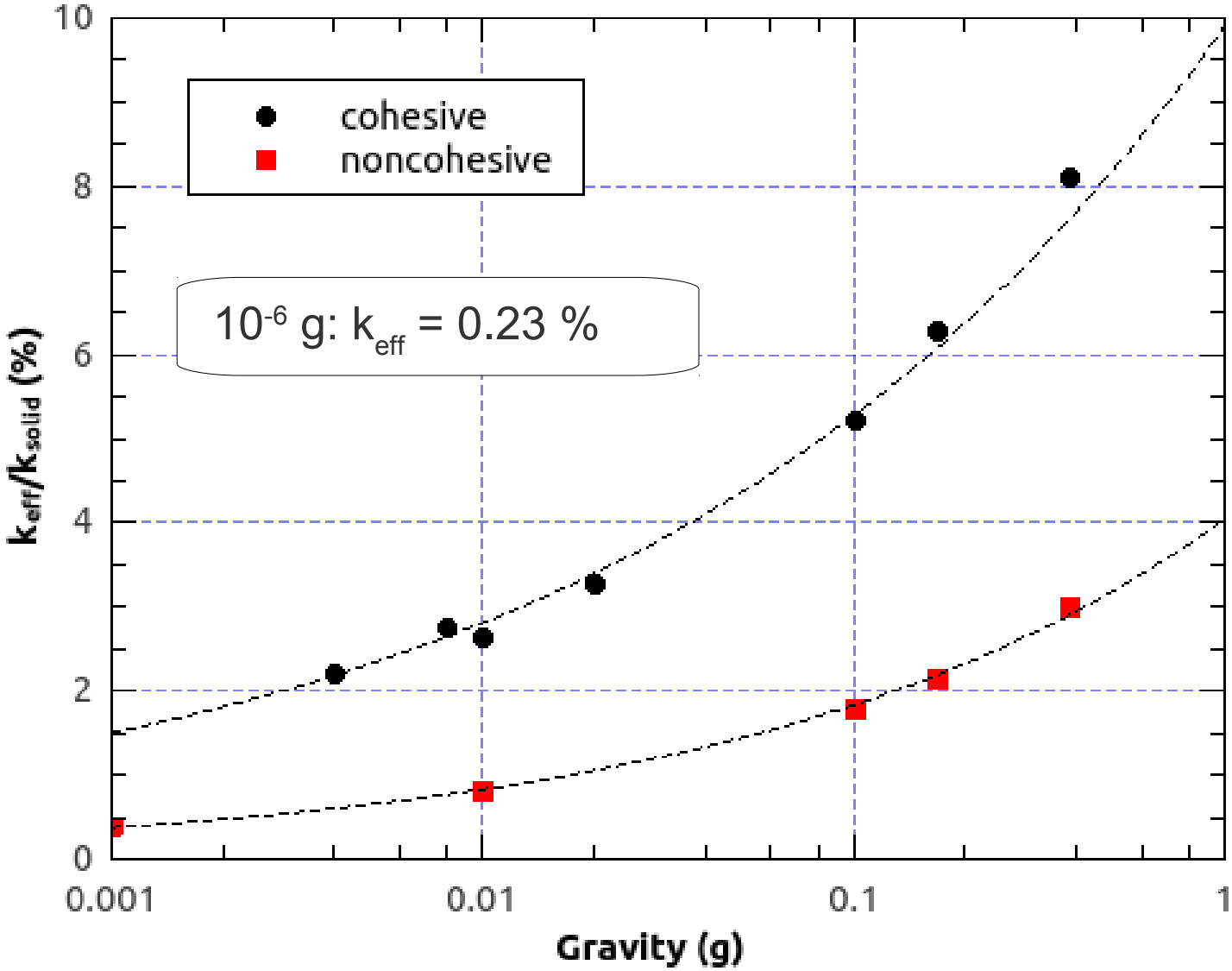
Cohesion + gravity



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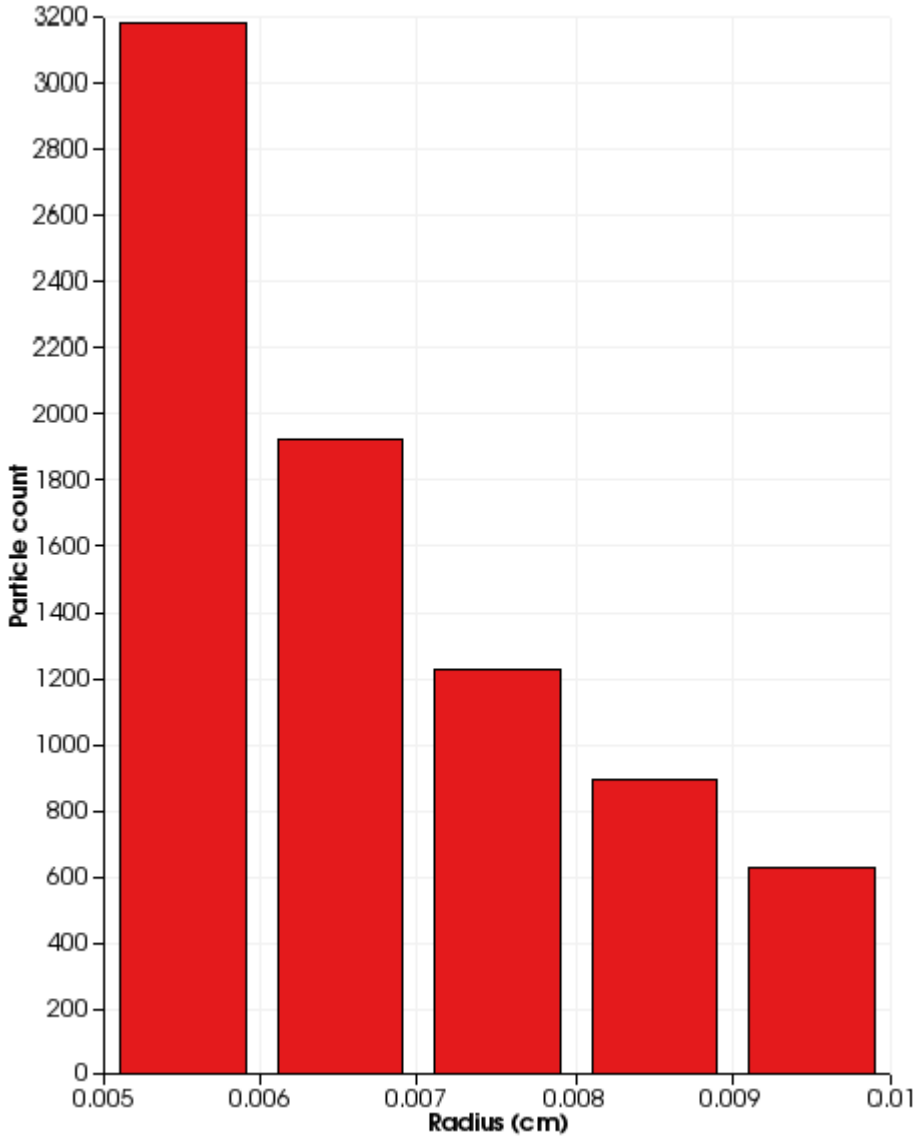
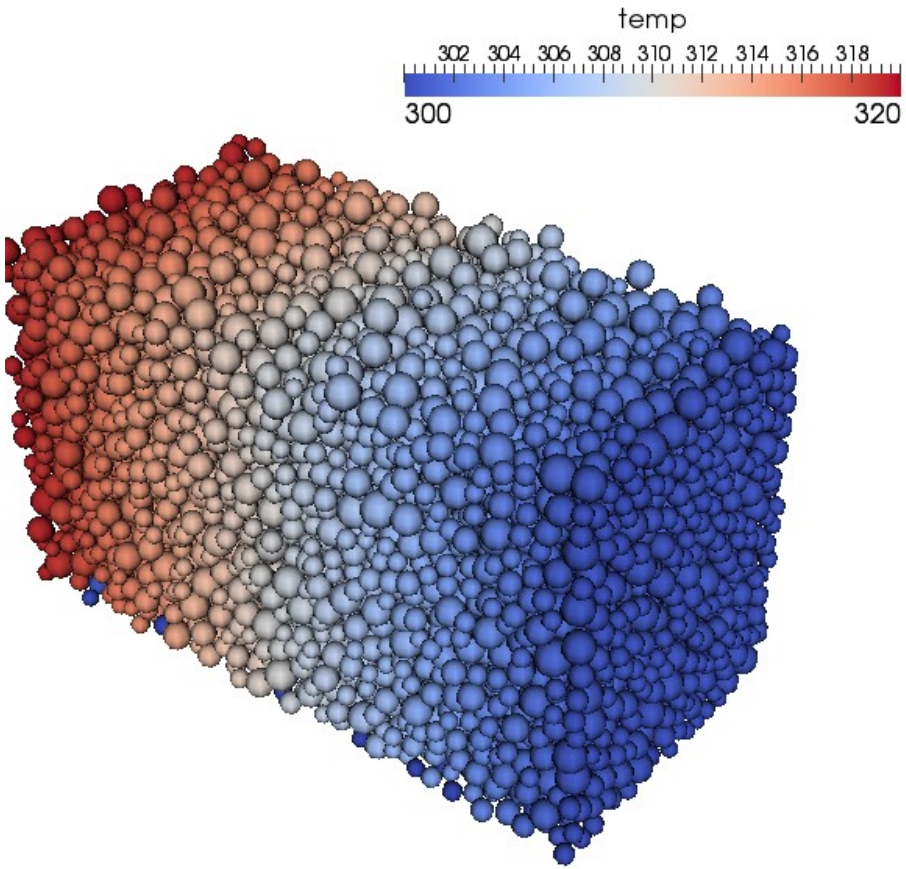
Going poly-disperse





$\varepsilon = 0.43$

$k_{eff}/k_{solid} = 4.01\%$

Small dispersion – no change

Next steps

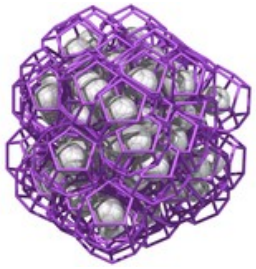
- Expand the parameter study (more runs!)
- Ensure initial particle distribution does not influence porosity
  - packing algorithm currently does this
- Include area correction for higher Young's modulus
- Add a better cohesion model
  - model VdW attraction for particles *almost* in contact
  - model JKR-type adhesion for particles in contact
- Model complex particle shapes
  - aggregates of non-overlapping spheres
  - heat transfer within aggregates may need to be considered

Summary

- Microscopic models are vital to understanding low-gravity granular surfaces
  - *in situ* measurements of these parameters are missing
  - but Rosetta will help (MIDAS, CIVA-M etc.)
- Thermal conductivity is a key parameter in understanding comet activity
  - and depends critically on the microscopic grain properties
- DEM techniques can predict conductivity from microscopic parameters
  - in a self-consistent way, with porosity, permeability etc.
- First results show conductivity is very sensitive to certain microscopic props
  - but the parameter space is large – many more runs needed!
- Updates to cohesion model planned, and move to more realistic inputs

LIGGGHTS

ParaView
Parallel Visualization Application



Voro++

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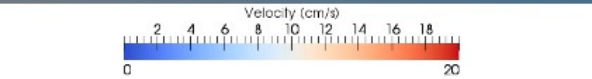
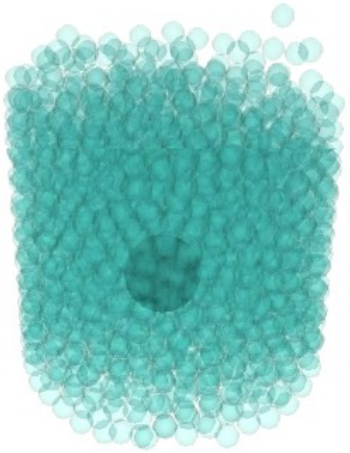
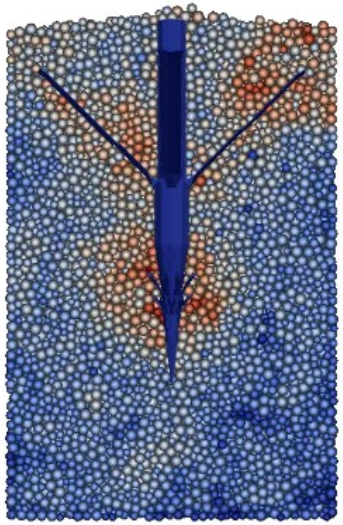
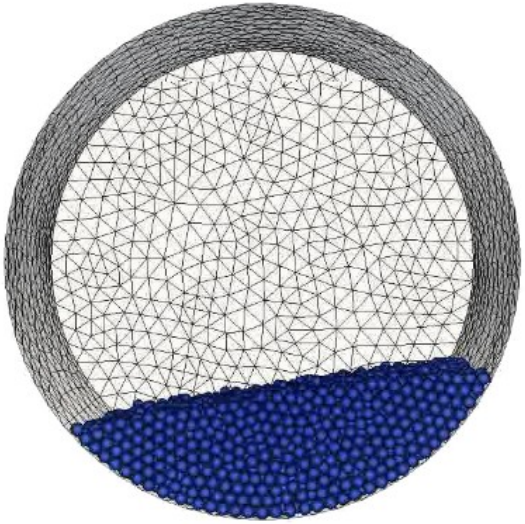
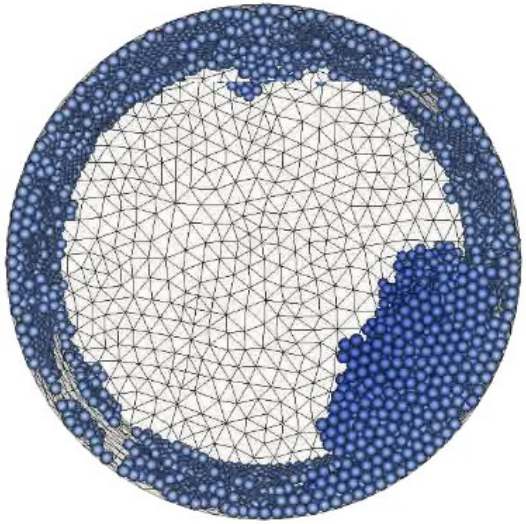
Other applications of the code…











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