Internal structures of clusters in driven granular gases

M.Noirhomme, E. Opsomer, F. Ludewig & N.Vandewalle
GRASP Lab, CESAM Research Unit, University of Liège, 4000 Liège, Belgium

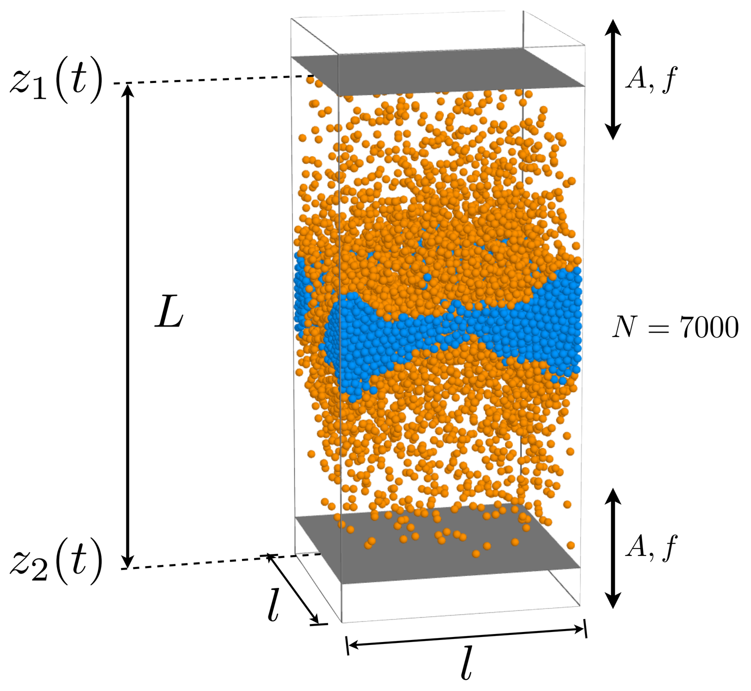
Université de Liège

Abstract

We numerically and theoretically investigate the internal structures of a driven granular gas in cuboidal cell geometries. Clustering is reported and particles can be classified as gaseous or clustered via a local density criterion based on a Voronoi tesselation. We observe that small clusters arise in the corners of the box. These aggregates have a condensation-like surface growth until a critical size is reached. At this point, a structural transition occurs and all clusters merge together, leaving a hole in the center of the cell. This hole becomes then the new capture's center of particles. Taking into account all structural modifications and defining a saturation packing fraction, we propose an empirical law for the cluster's growth and deduce packing properties such as the random loose packing of granular aggregates in microgravity environment, $\Phi_{\rm RLP} = 0.55 \pm 0.02$.

Numerical Approach

The study is based on Soft Spheres Discrete Element Method (SSDEM) simulations. Grains of radius $r = 1$ mm, restitution coefficient $\varepsilon = 0.9$ and friction's coefficient $\mu = 0.7$ are placed in cells of dimensions Ll^2.



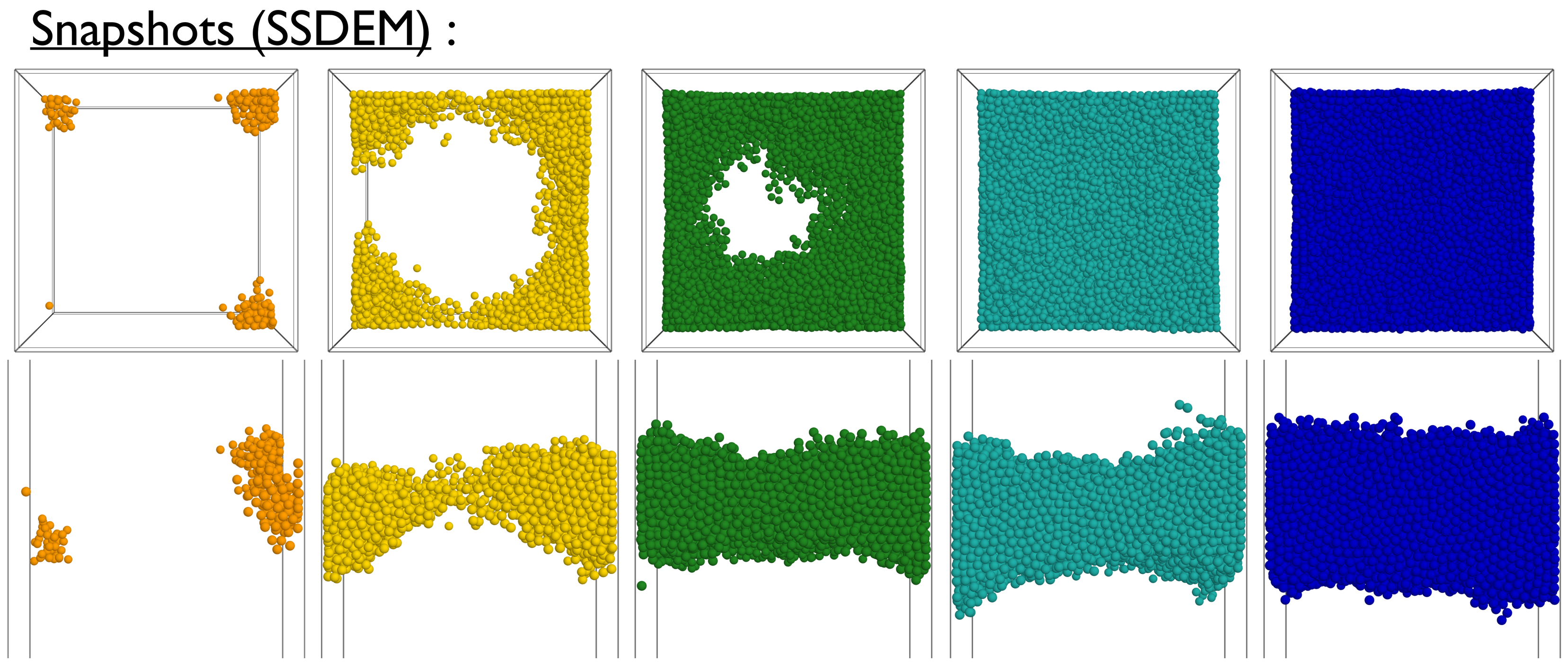
#	L(mm)	l(mm)	f(Hz)	N	
1	40	15	20	[500; 6500]	□
2	40	15	40	[600; 5000]	□
3	40	25	20	[3000; 15000]	▽
4	50	15	20	[1000; 6000]	○
5	**60**	**30**	**20**	**[1000; 30000]**	△
6	90	15	20	[1000; 10000]	◇
7	150	15	20	[1000; 19000]	⬠

Structure of the clusters

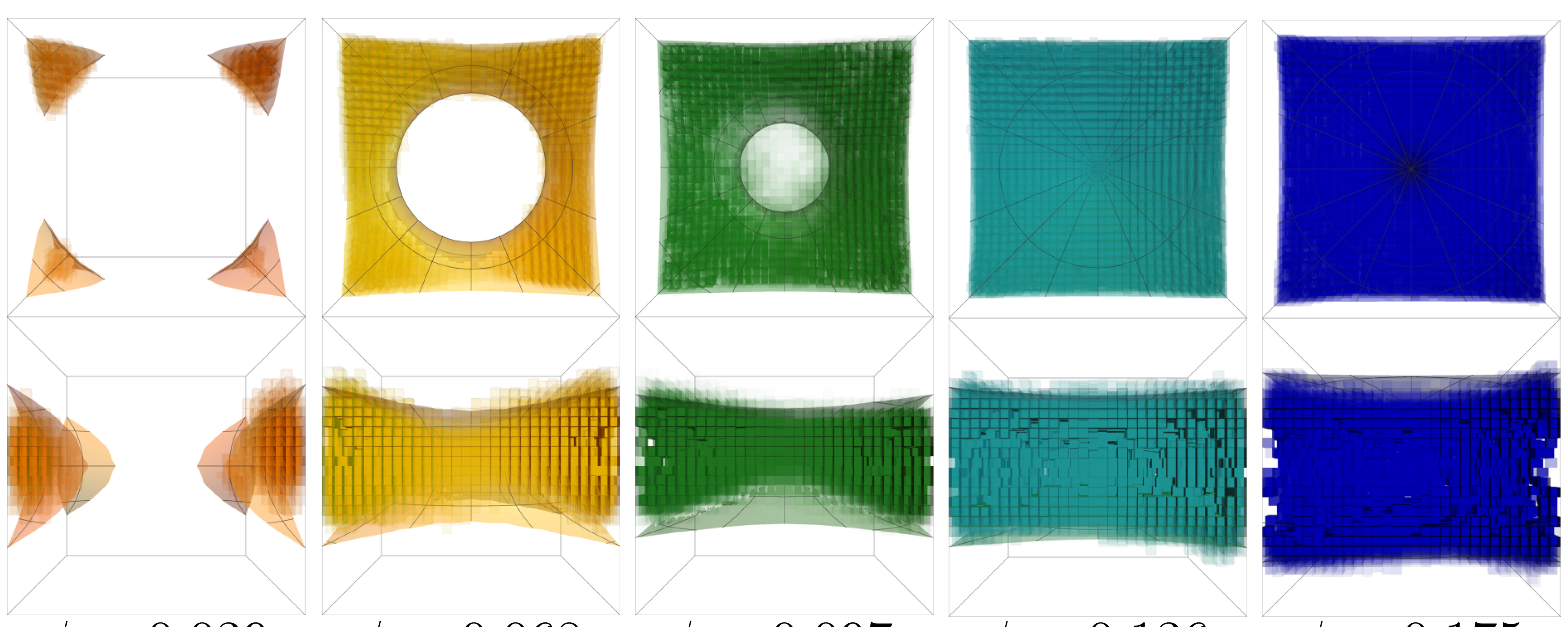
A Voronoi tesselation gives the volumes occupied by each particle. Dividing the volume of the grain by its Voronoi cell's volume gives the local packing fraction of the particle $\varphi_{\rm loc}$.

If $\varphi_{\rm loc} \geq 0.285$, the grain can not leave the cage formed by its neighboring and is considered as clustered.

Snapshots (SSDEM) :



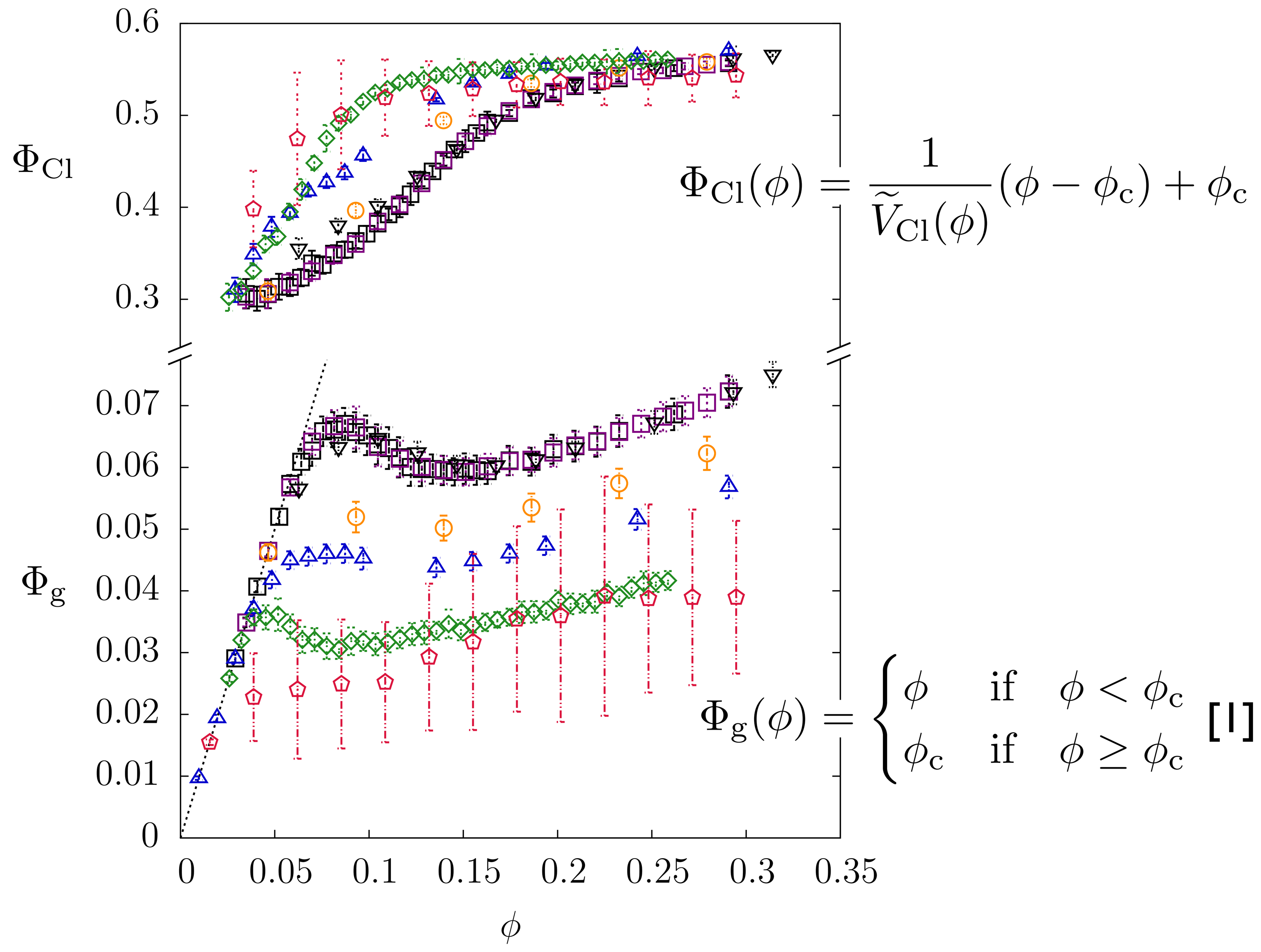
Simulations vs model :



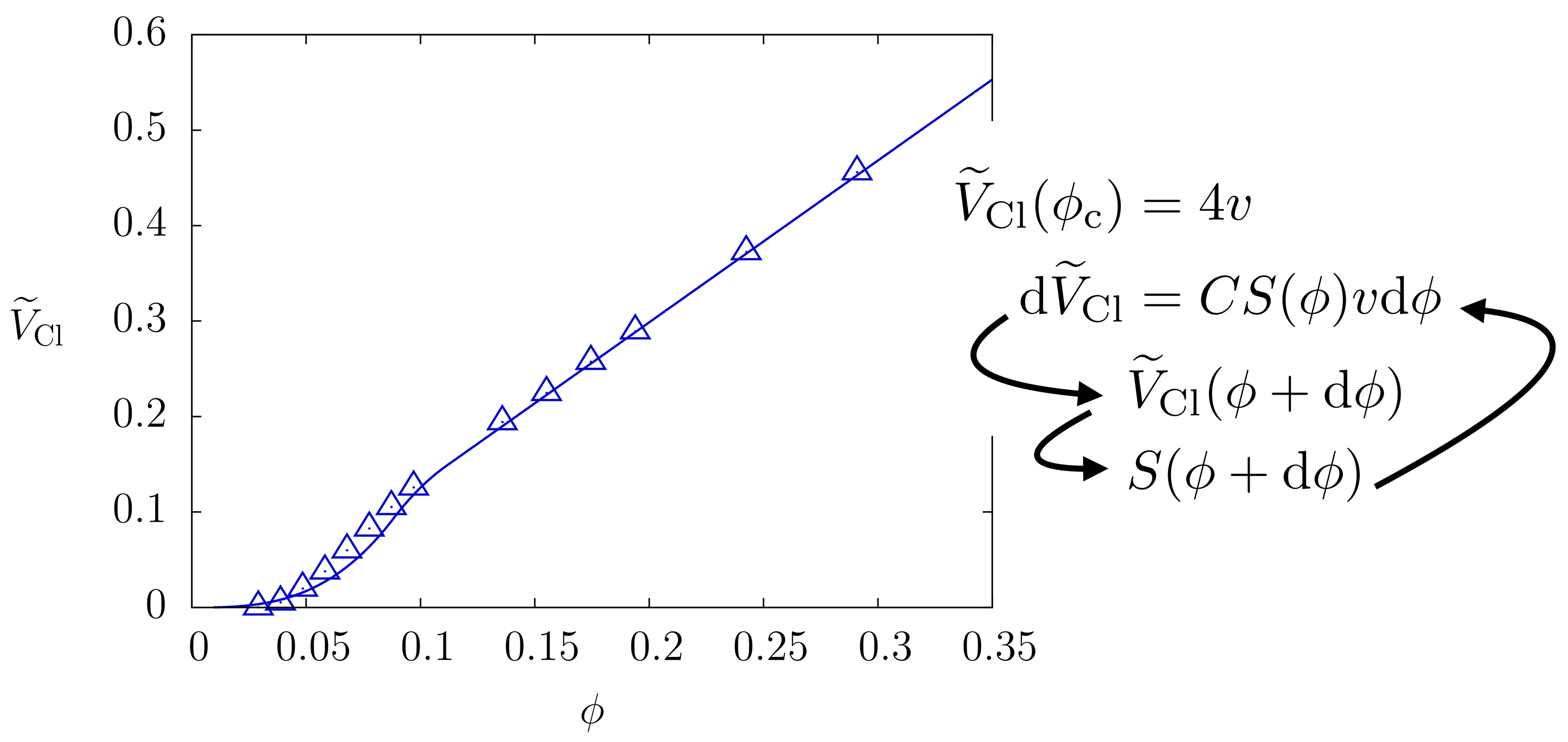
$\phi = 0.039$ $\phi = 0.068$ $\phi = 0.097$ $\phi = 0.136$ $\phi = 0.175$

Model

Assumption :
- The gas has to keep its constant packing fraction [1].
- Only the cluster is compacting



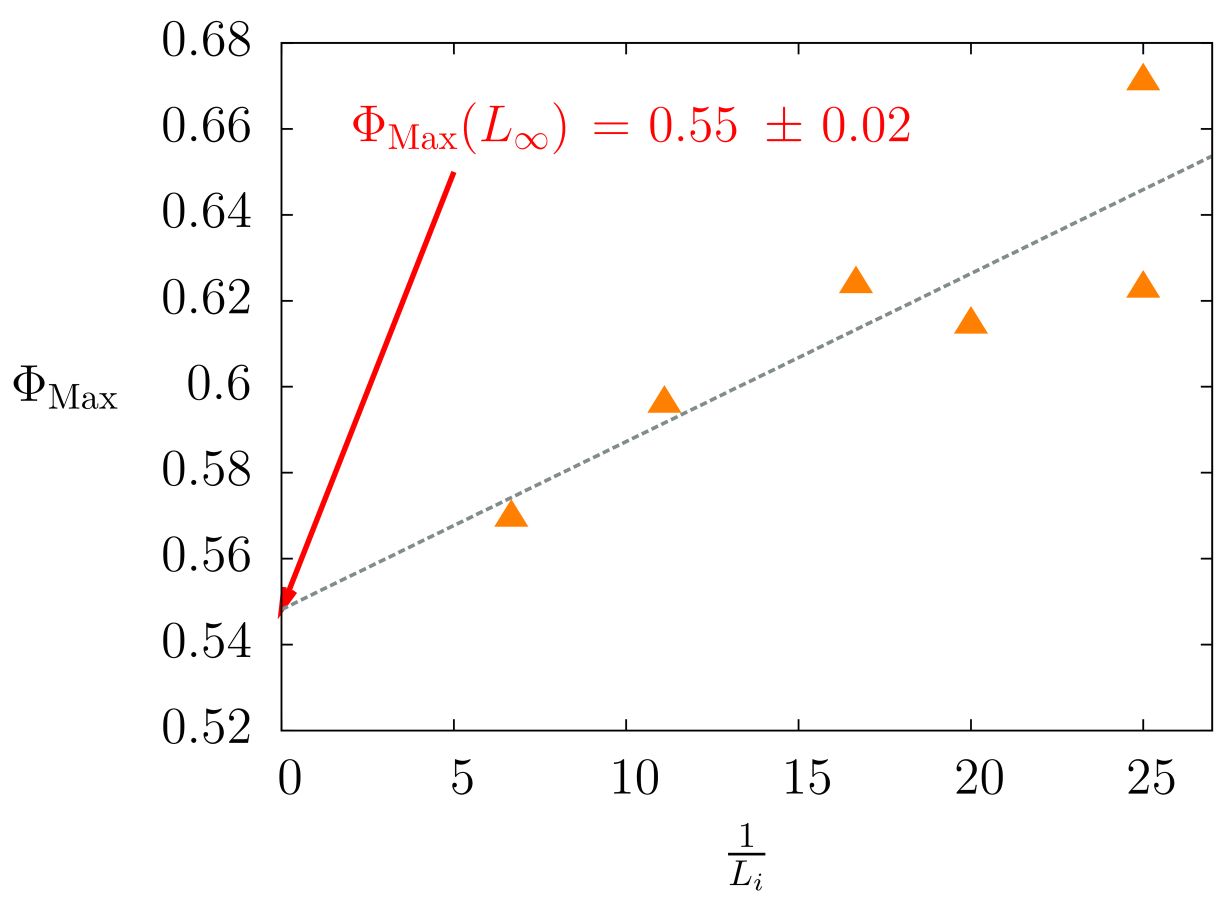
- The nucleation arises in the corners of the box at $\phi = \phi_c$.
- The cluster cages grains on its surface only.
- The cluster surface has the form of a truncated elliptical torus.



The RLP in microgravity conditions

Extrapolation of the maximal packing fraction reached in each cell at

$$\widetilde{V}_{\rm Cl}(\phi_{\rm Max}) = 1.$$



Given the independence on l, this result is universal.
Similar values of RLP can bet found in literature [2,3].
Can a granular surface tension be deduced ?

[1] E. Opsomer *et al.*, Eur. Phys. Lett. **99**, 40001 (2012).
[2] M. Jerkins *et al.*, Phys. Rev. Lett., **101**, 018301 (2008).
[3] C. S. O'Hern *et al.*, Phys. Rev. Lett., **88**, 075507 (2002).

CESAM GRASP