24th International Young Physicists' Tournament

10. Faraday heaping

When a container filled with small spheres (e.g. mustard seeds) is vibrated vertically with a frequency between 1 – 10 Hz, so called Faraday heaping occurs. Explore this phenomenon.

Presentation plan

- The required experimental setup
- Heap formation and merging processes
- The influence of acceleration, grain size and the number of layers
- Final conclusions

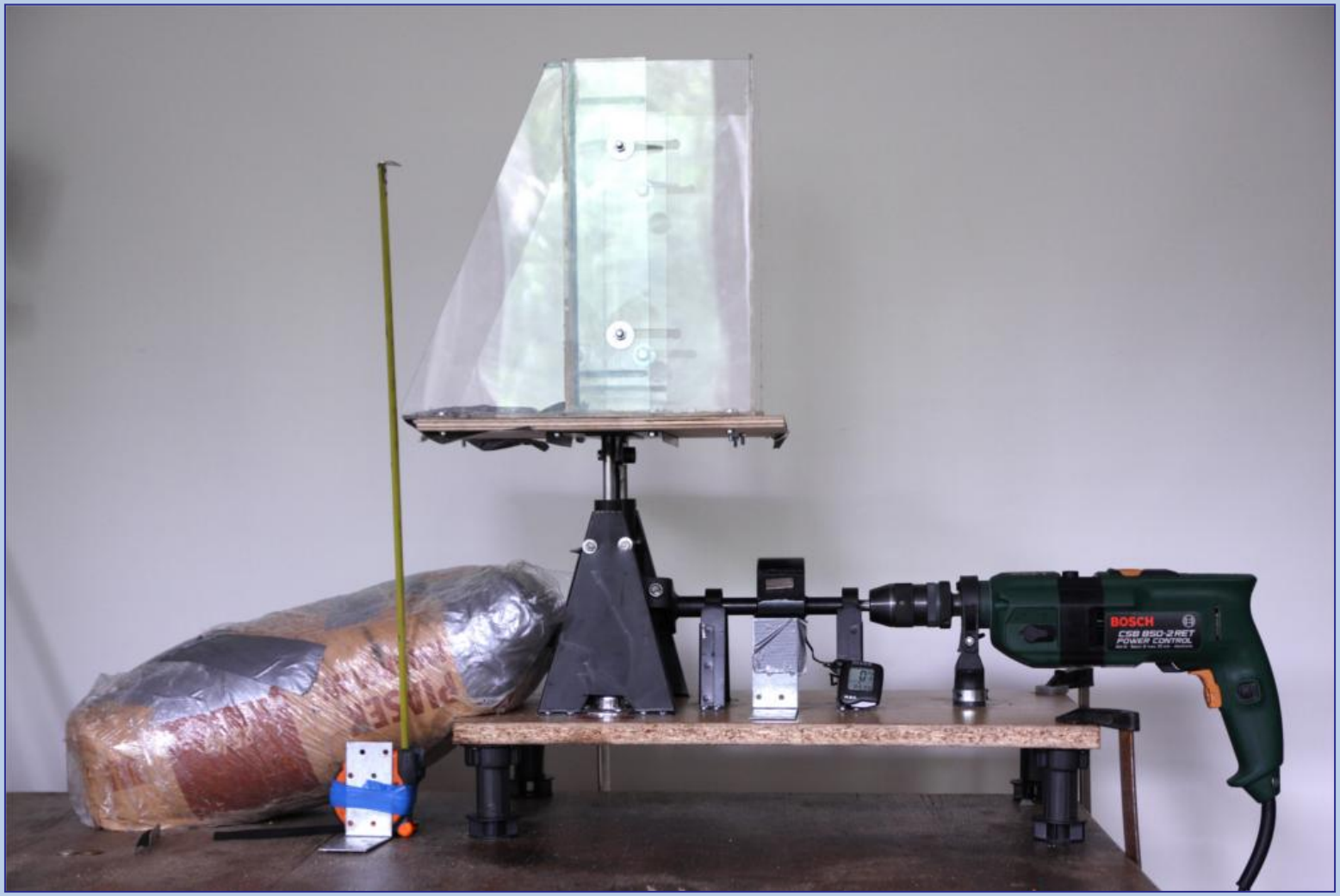
Experimental setup

In order to examine Faraday heaping we built an experimental setup

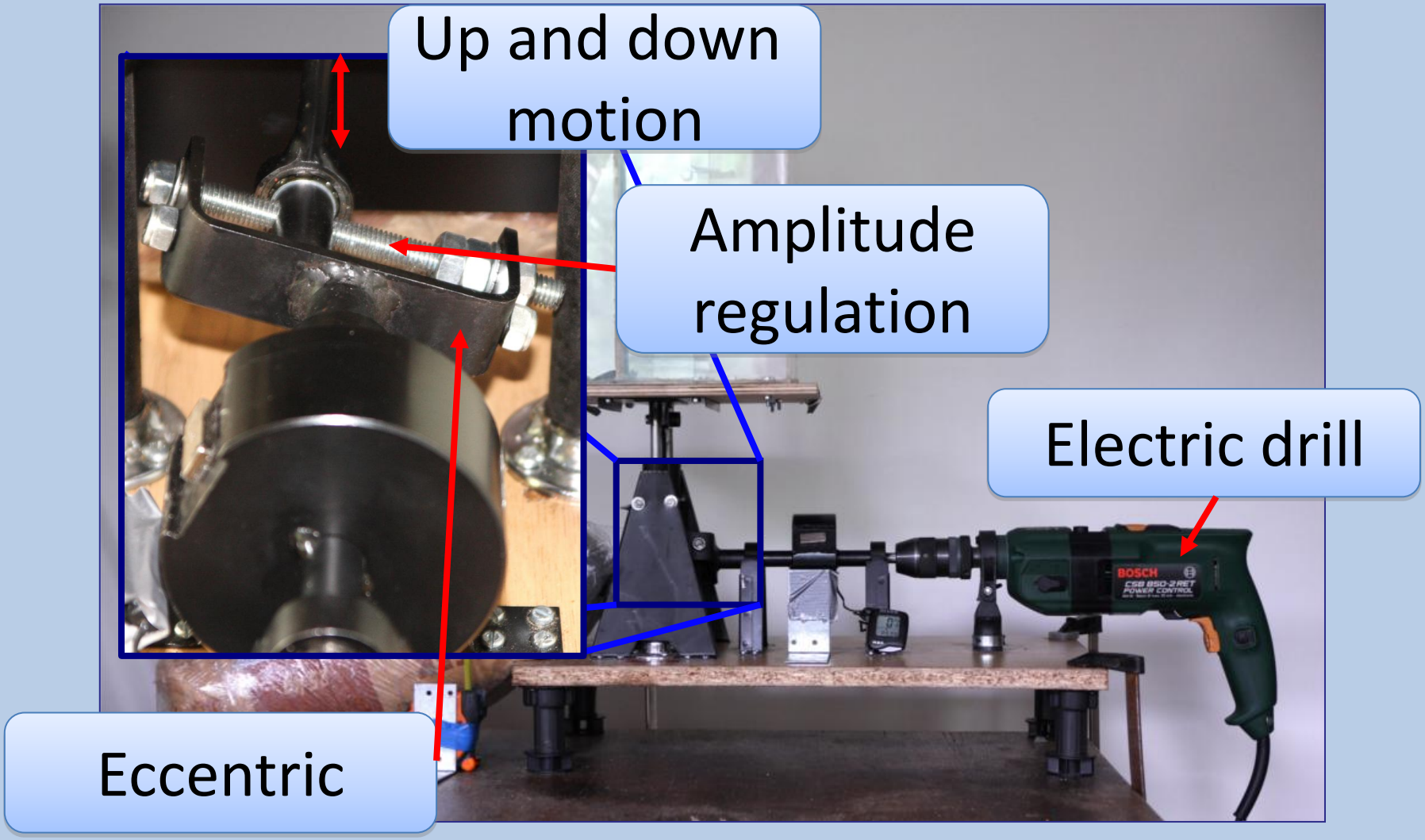
Our requirements for a good experimental setup:

- **Stable amplitude** of motion
- Surface should perform **sinusoidal oscilations**
- **Adjustable frequency** and **amplitude** of oscilations
- **Horizontal orientation** of the moving suface during motion

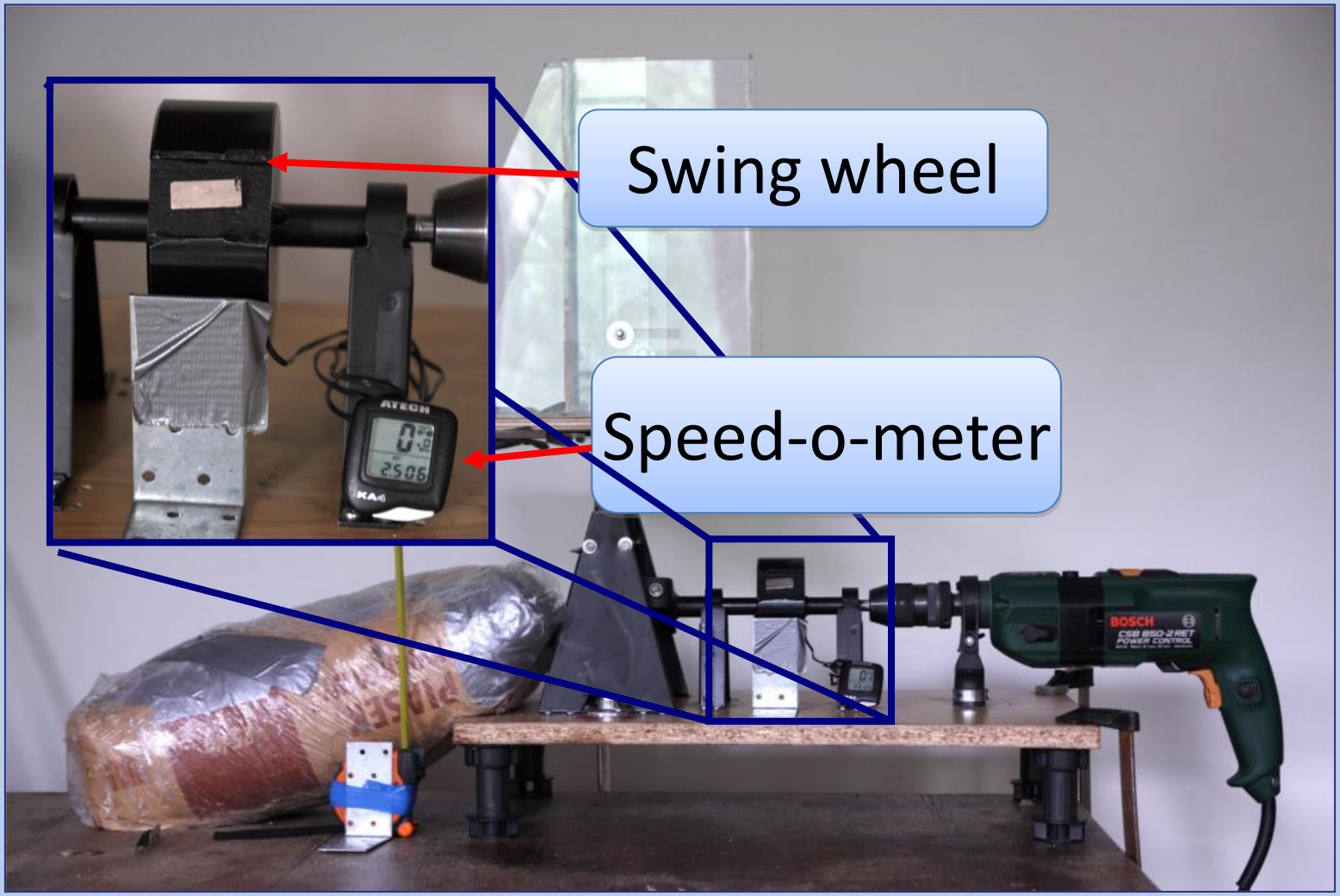
Experimental setup



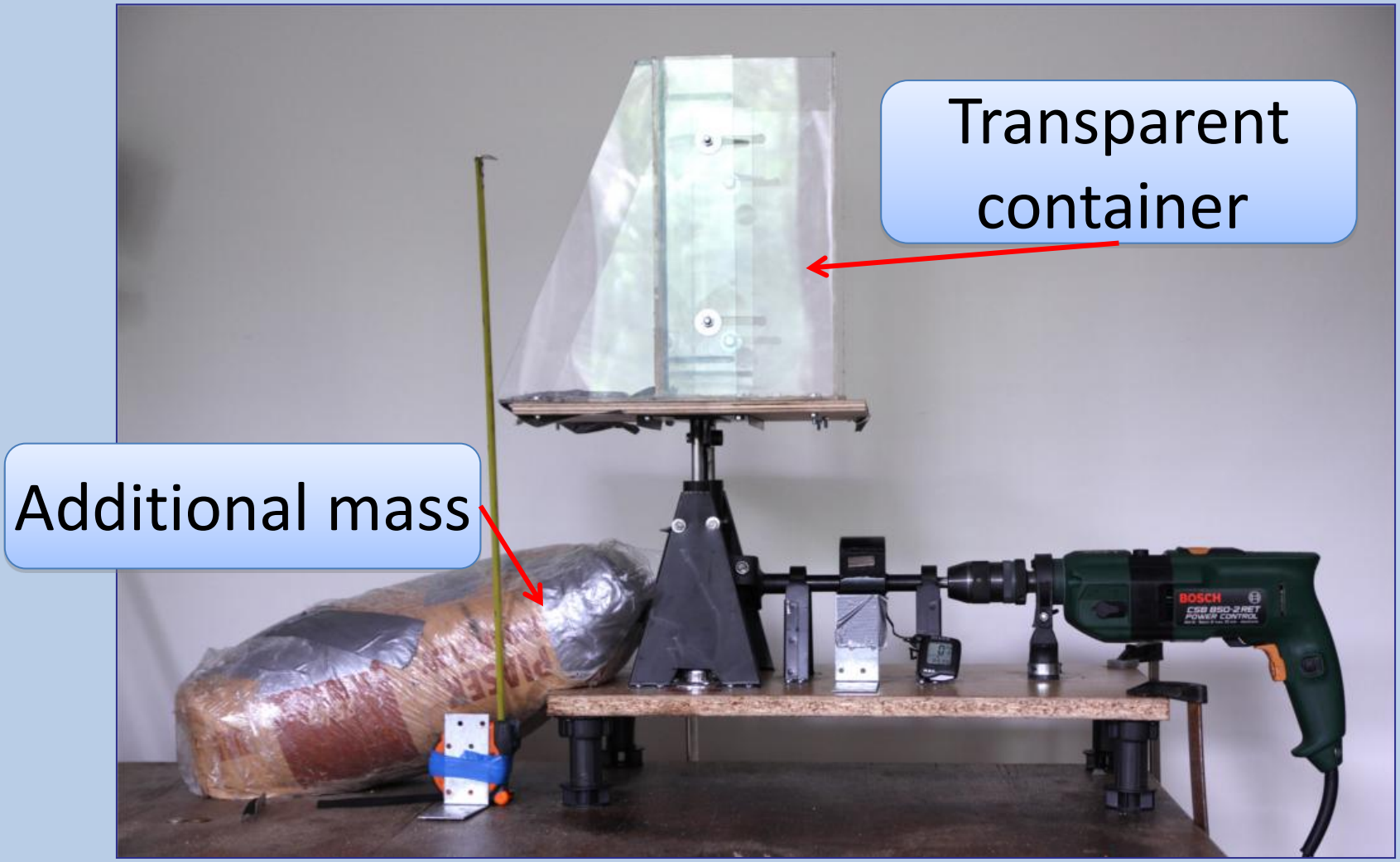
Experimental setup



Experimental setup



Experimental setup

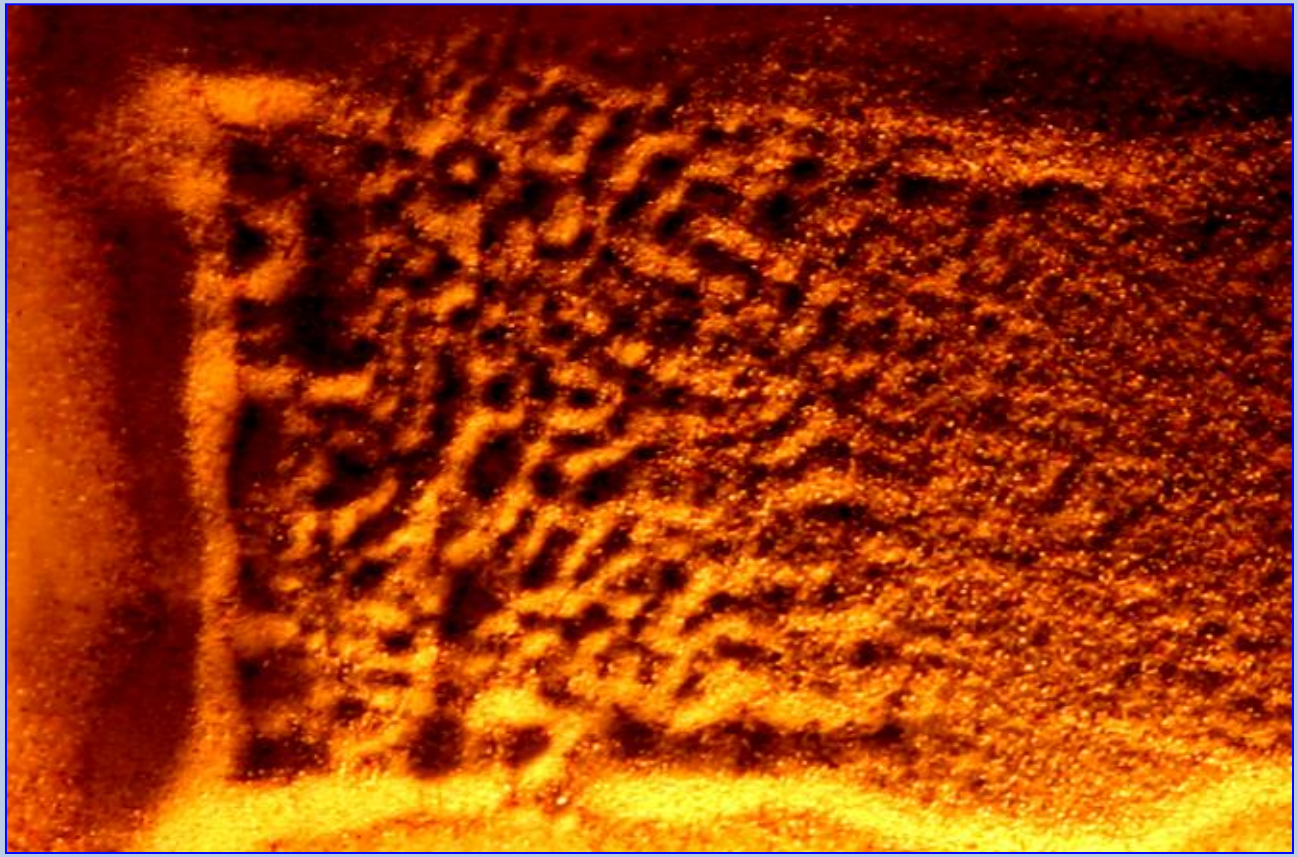


Phenomenon presentation

Evolution of the surface

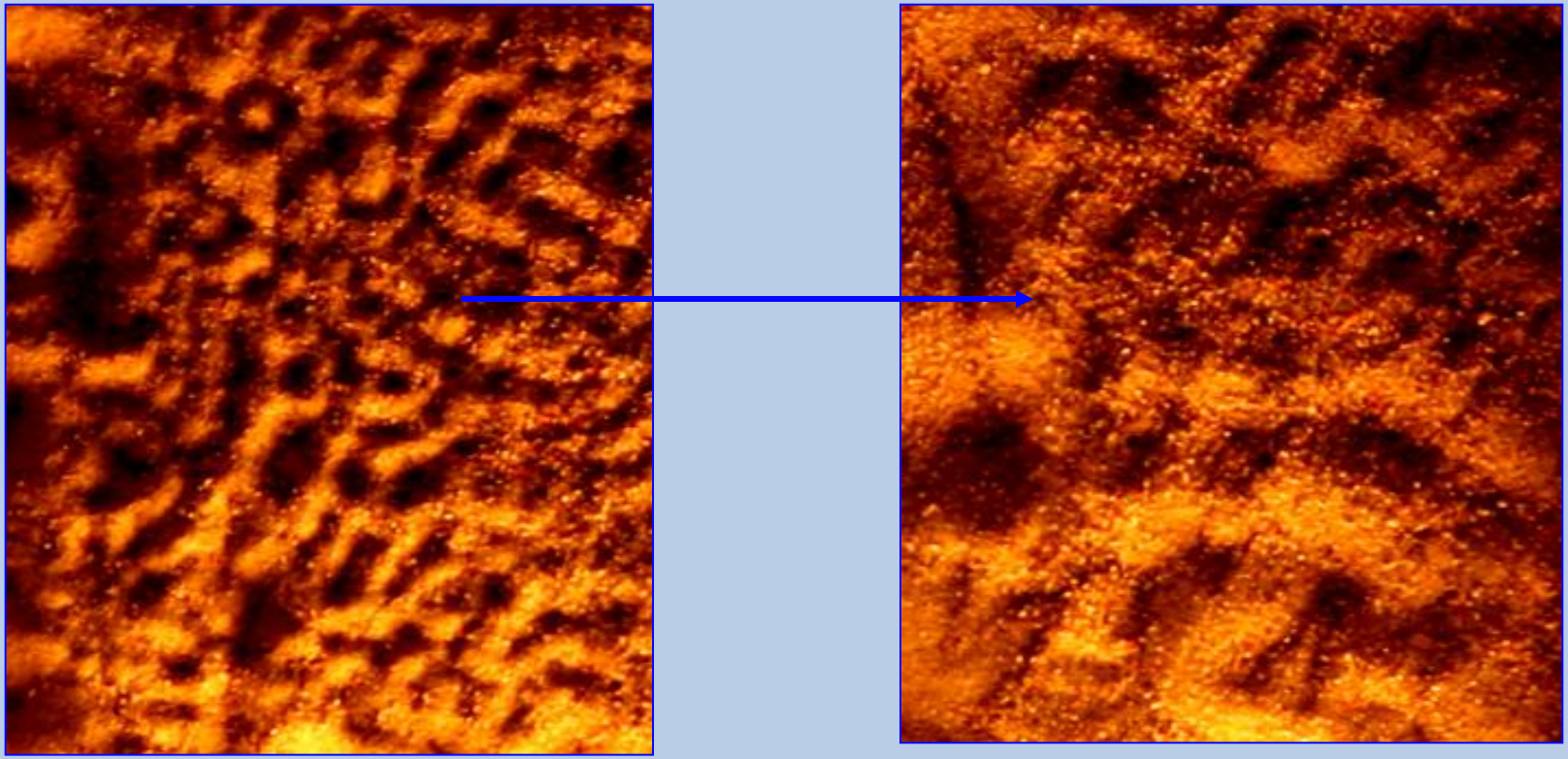
The surface is initially flat.

Evolution of the surface



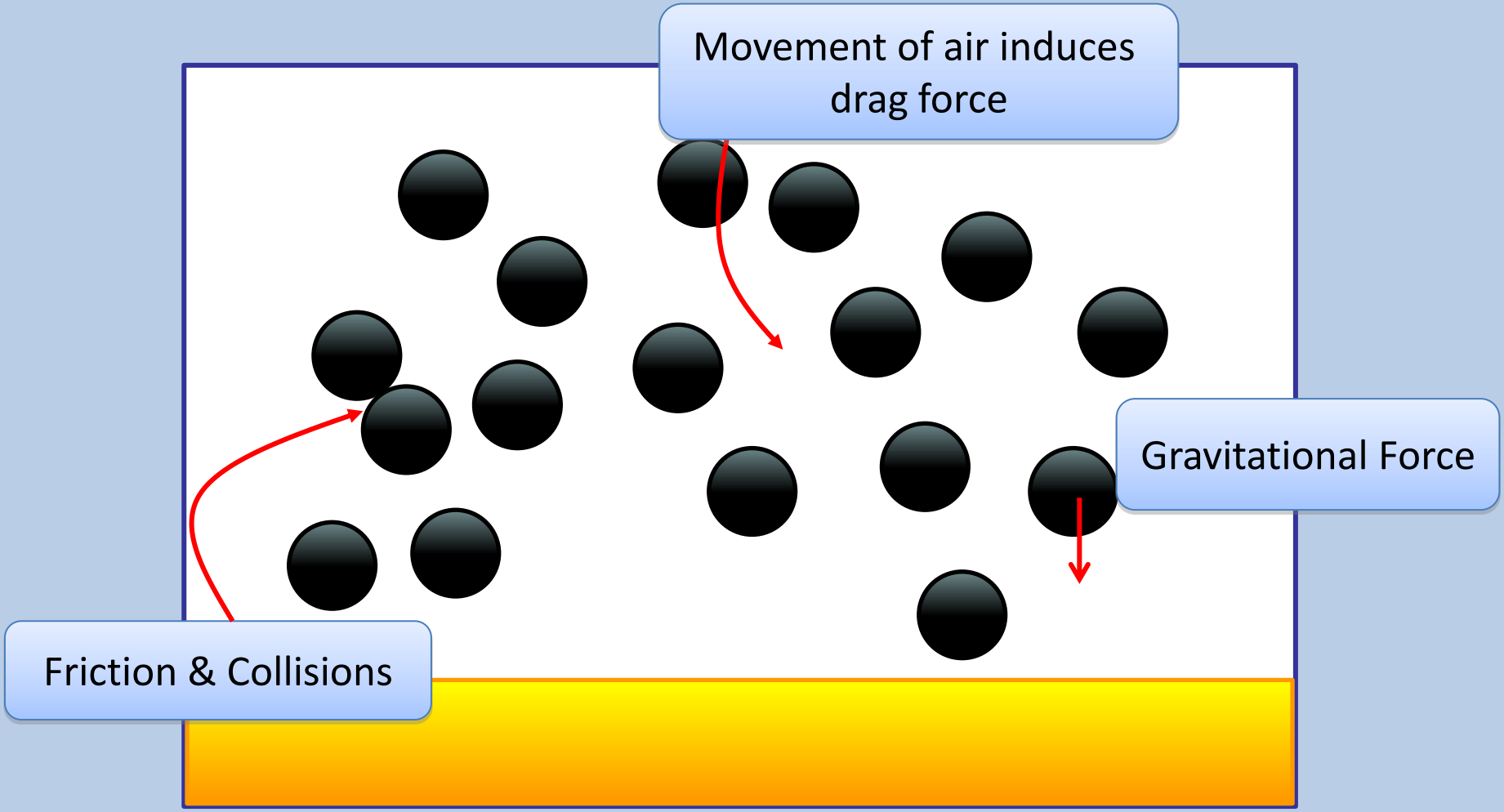
Several little heaps form.

Evolution of the surface



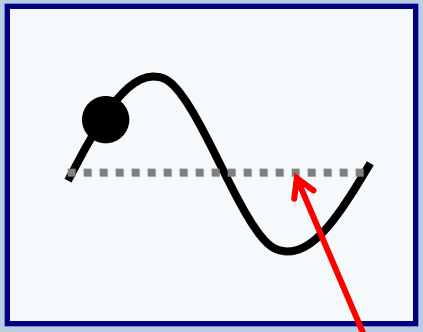
The little heaps merge into larger heaps.

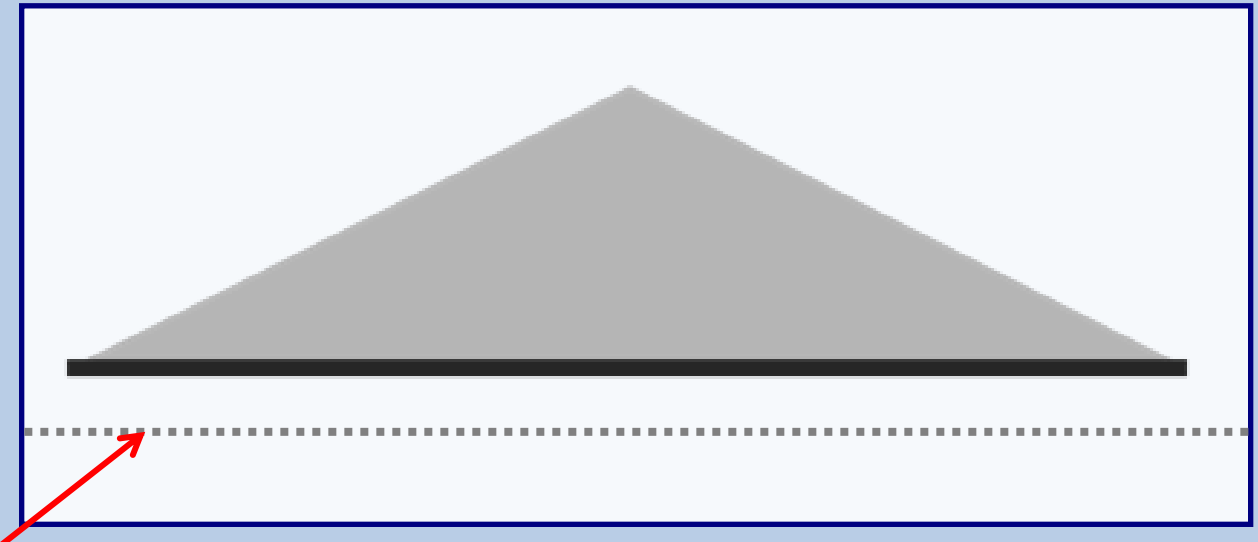
Processes relevant for the phenomenon



Single heap stability

Plate is going up



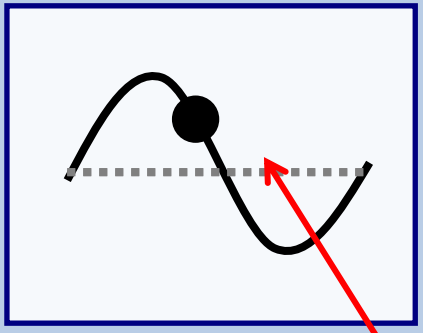


Zero level

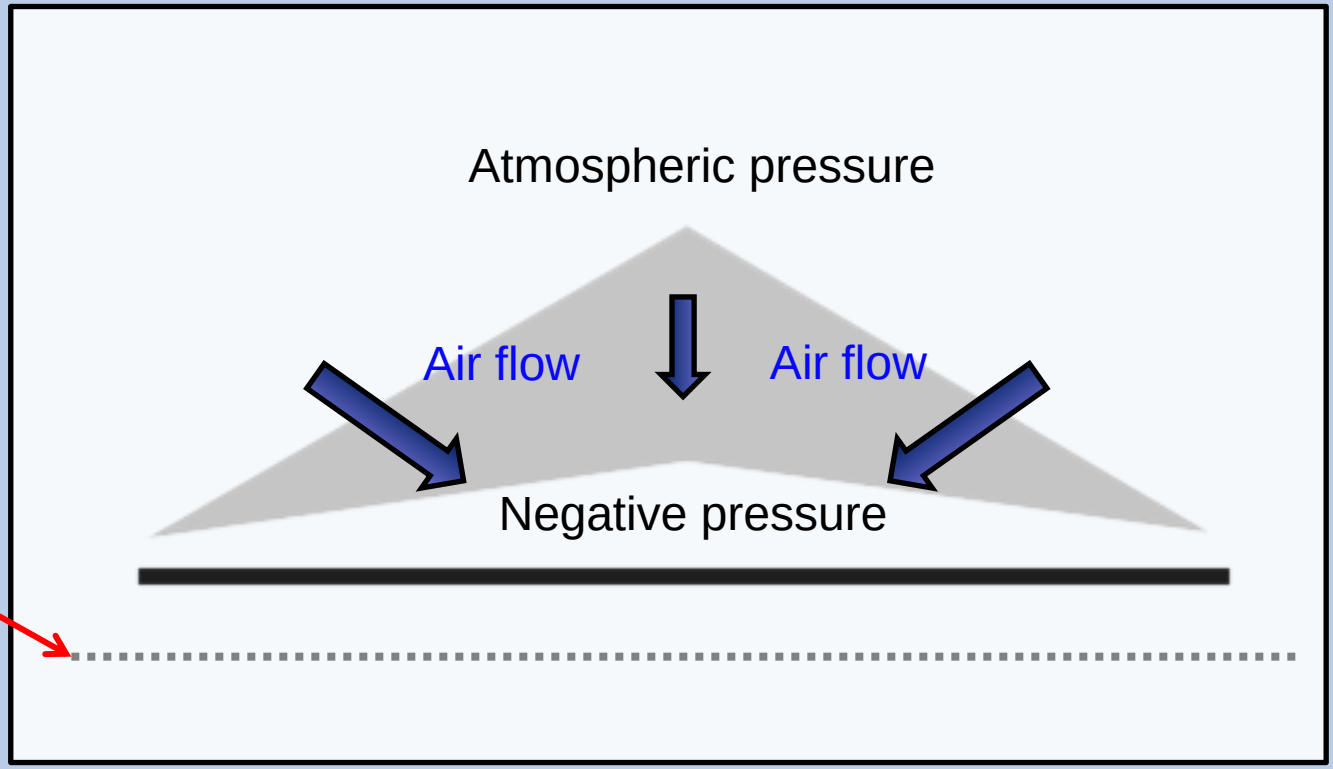
Heap is ascended by the horizontal plate

Single heap stability

Plate descends



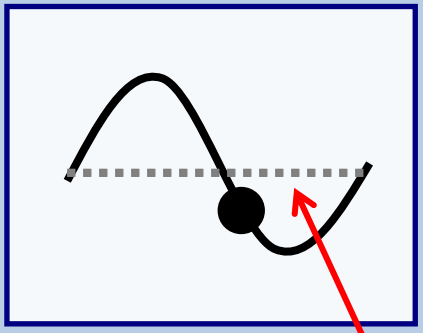
Zero level



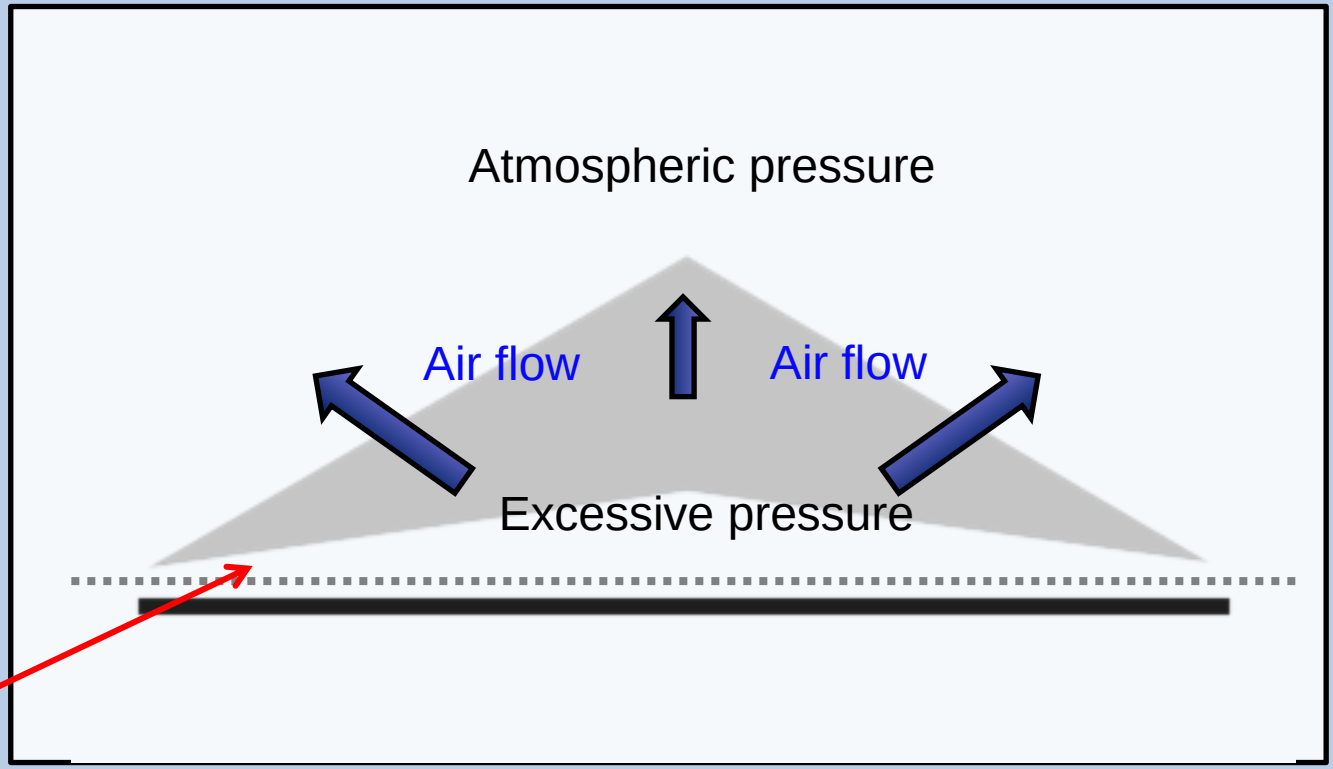
Air flows faster through the thinner parts of the heap. The flow of air induces the particle inward motion.

Single heap stability

Heap comes closer to the plate

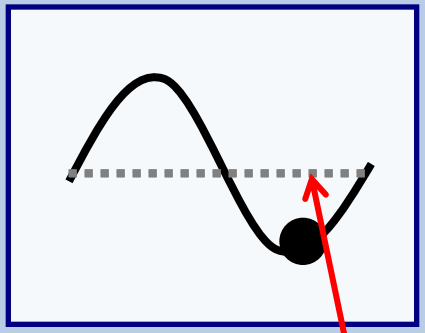


Zero level



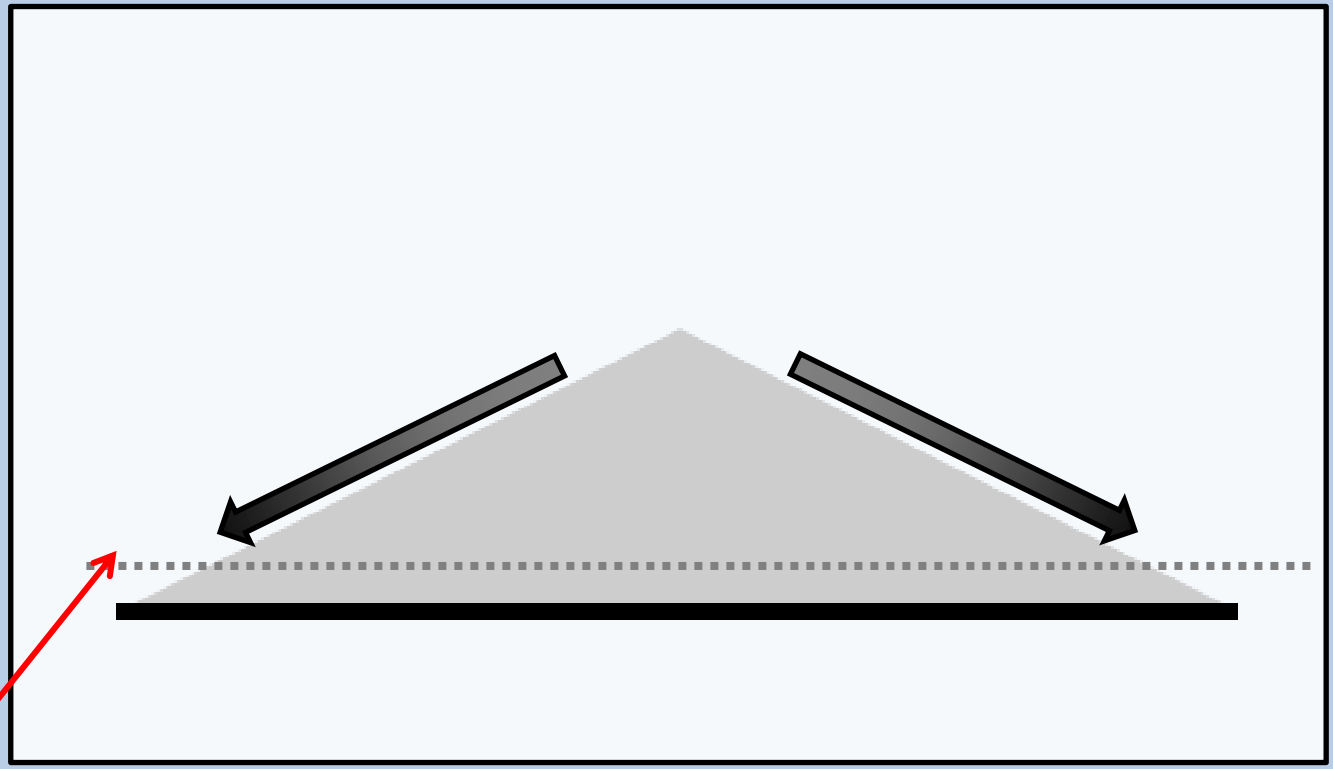
The escaping air decelerates the particles. In result of this and the latter phenomenon, particles are moved towards the center of the heap.

Single heap stability



Granular matter hits the plate

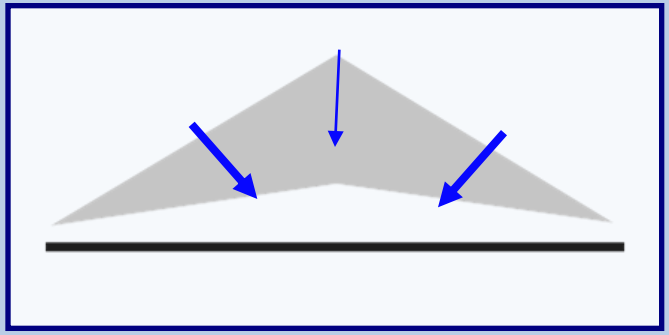
Zero level



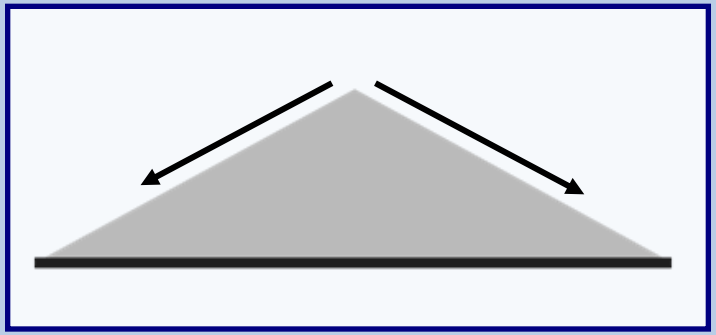
In result of the impact, the particles of heap are scattered along the edges of the heap.

Single heap stability

The motion of air causes the heap to „squeeze”

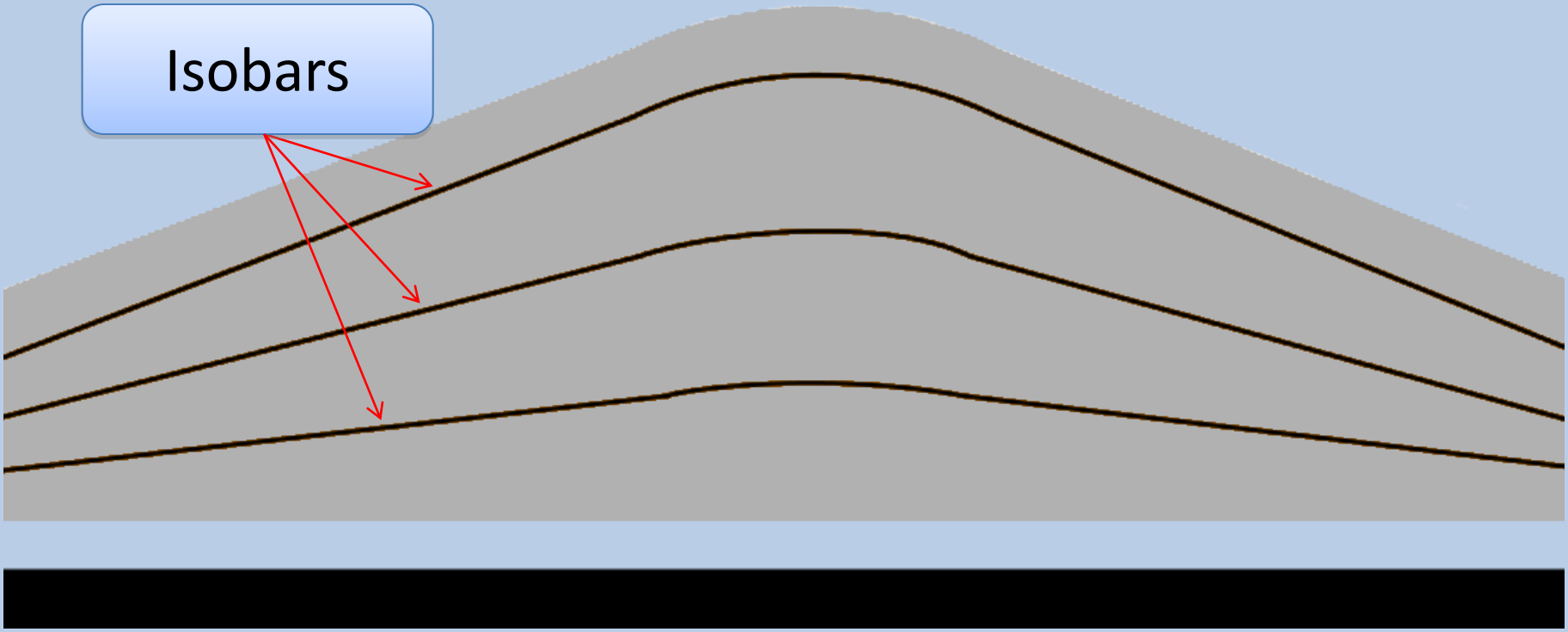


The impact causes the boundary particles to scatter



The theory presented is widely accepted. (among others : van Gerner et al. ”Interplay of air and sand: Faraday heaping unravelled”)

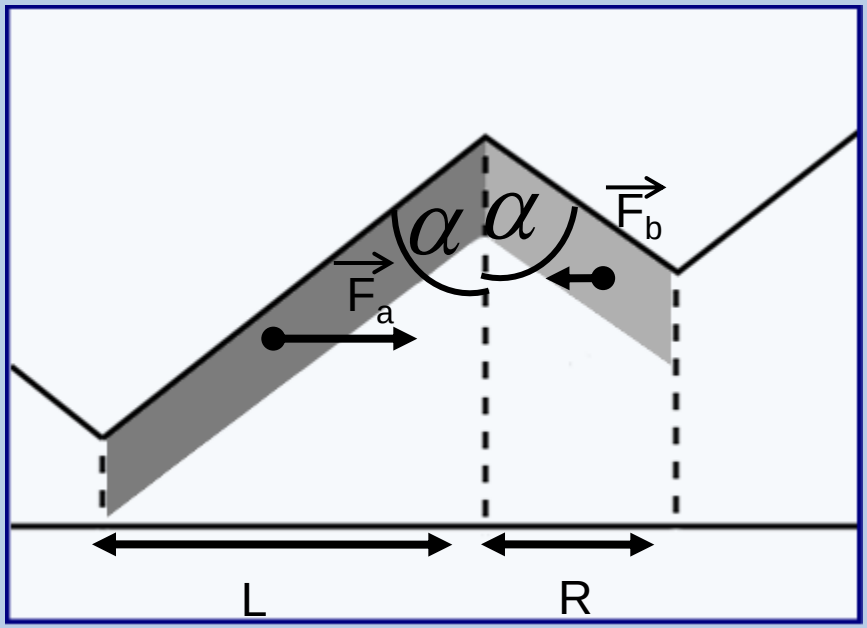
Pressure distribution within heap

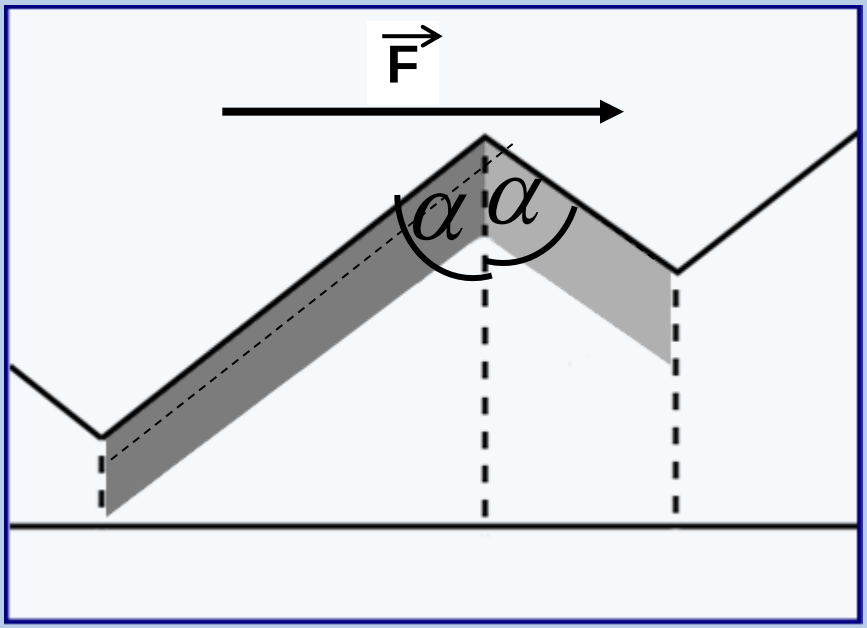


Experimental observation of Thomas and Squires (1998)

Merging of the heaps

ven Gerner et al. ”Coarsening of Faraday Heaps:Experiment, Simulation, Theory”.

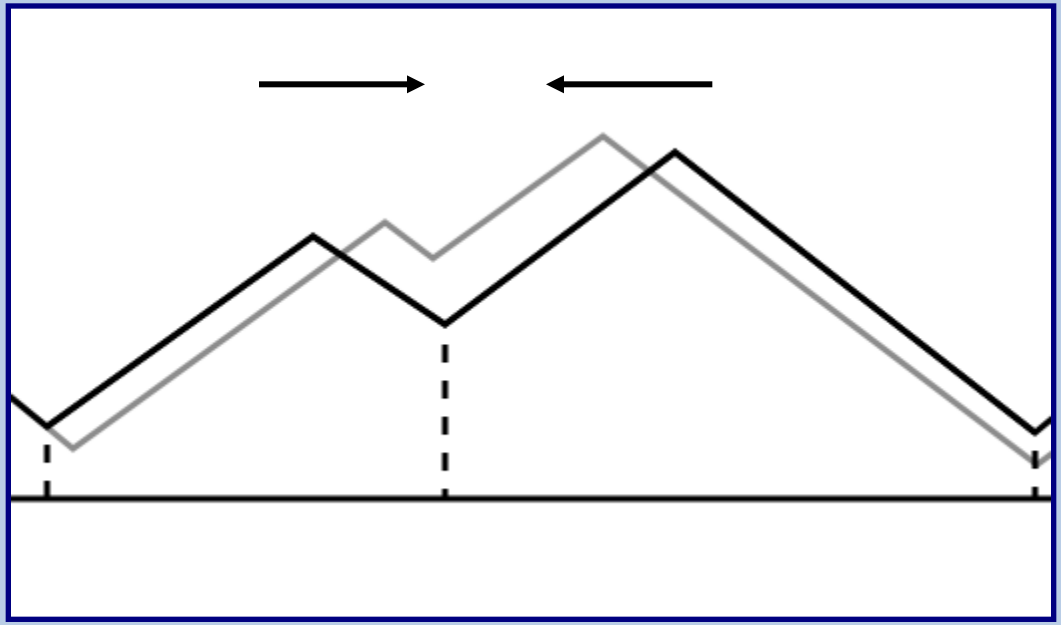




$$F_a \propto L \qquad F_b \propto R$$

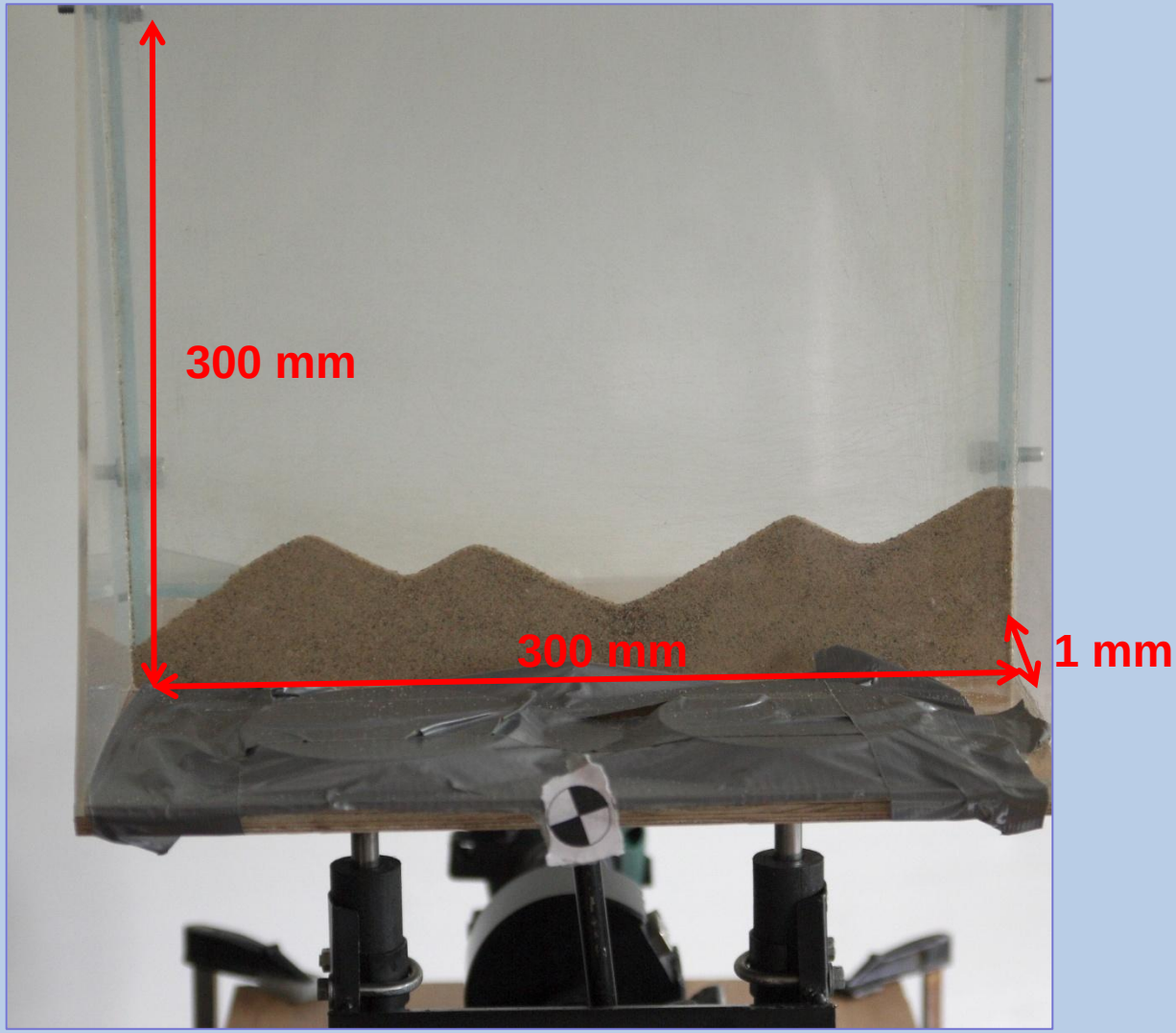
$$F = F_a - F_b \propto L - R$$

Merging of the heaps



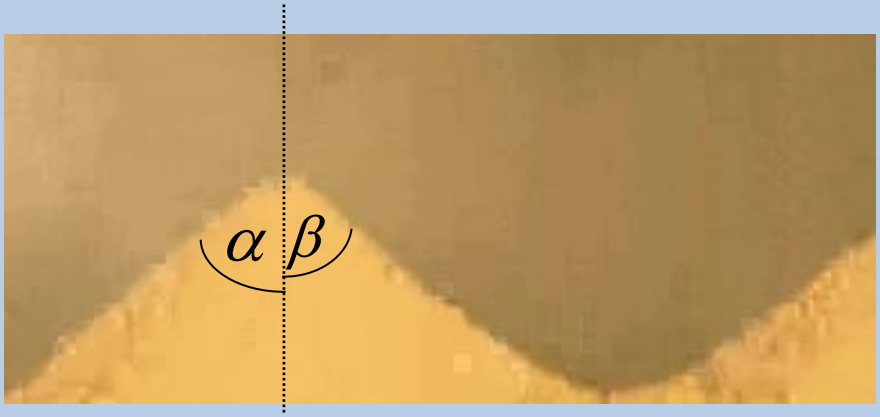
The unsymmetrical shape of the heap causes it to move. This effect is responsible for heap-merging.

Dimensions of 2D container



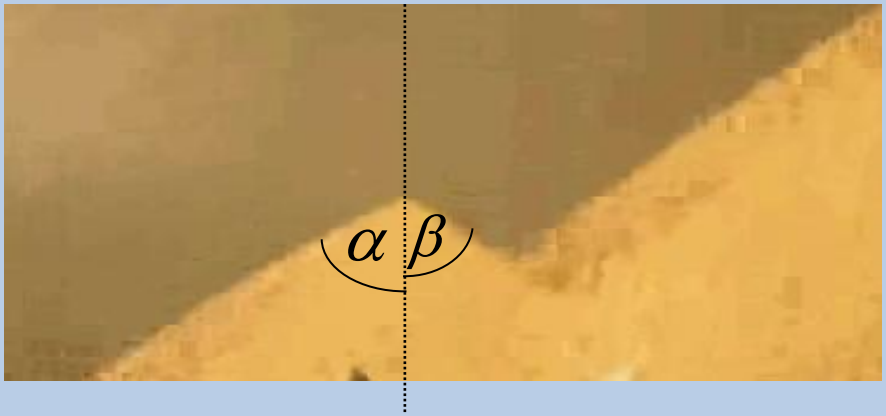
What can we achieve using 2D setup?

Checking the assumption of the theoretical model



Merging heap

$$\alpha = \beta$$



Nearly merged heap

$$\alpha < \beta$$

Further observations

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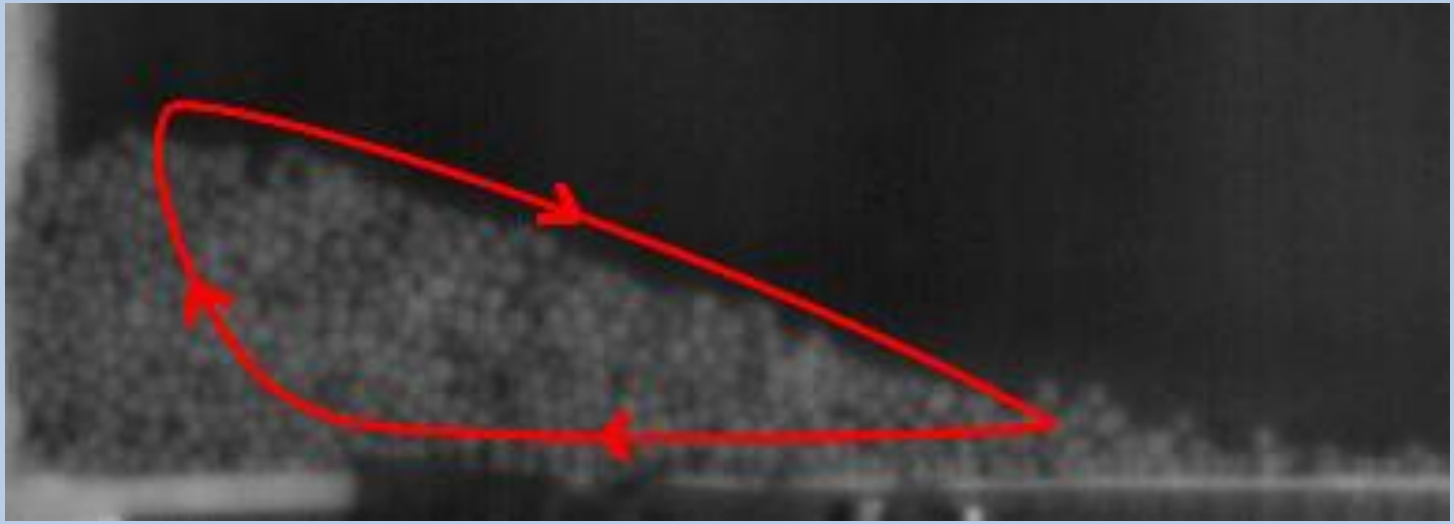
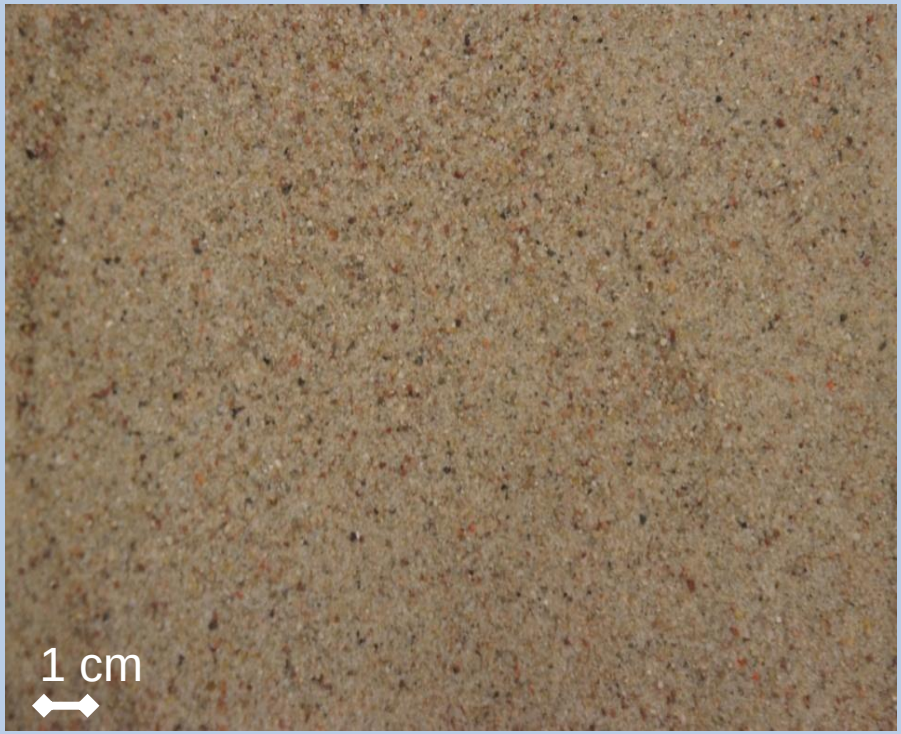
“Convection” in a heap

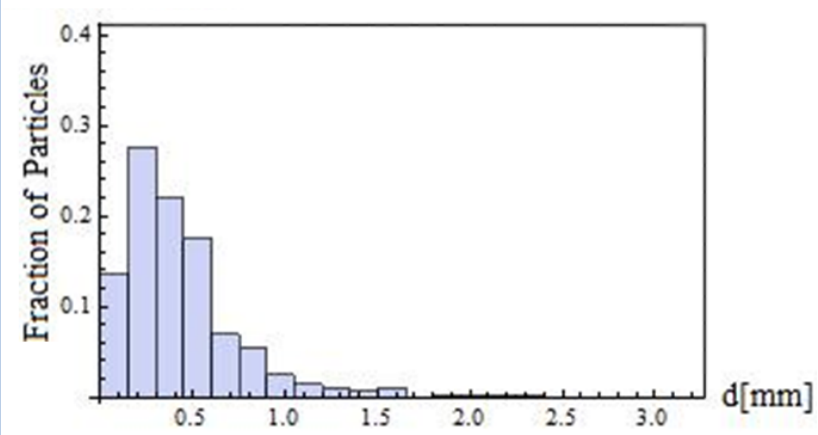


The trajectory of granular particles resembles the shape of convection roll

Diameter of particles - ordinary sand



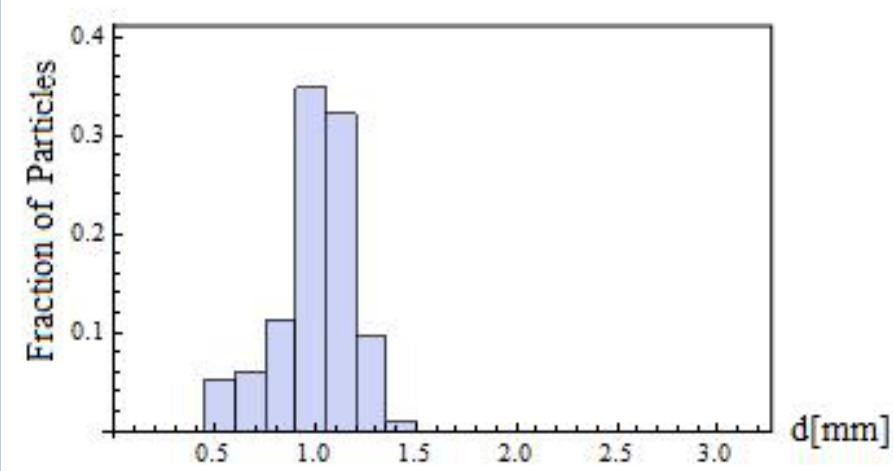
Average particle size: 0.5mm



The values were obtained on basis of image analisys using **Fiji** program. The amount of grains studies was about **2000** in each case.

Diameter of particles - aquarium sand

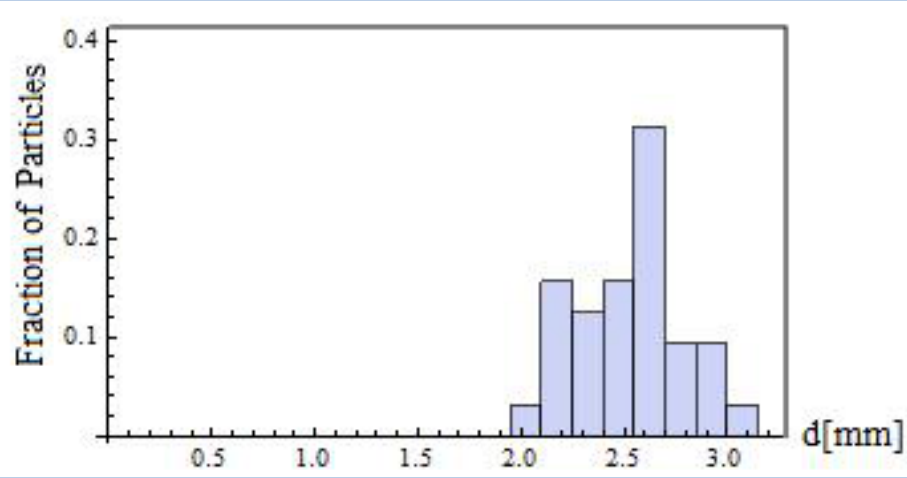
Average particle size: 1.0mm



The values were obtained on basis of image analisys using **Fiji** program. The amount of grains studies was about **2000** in each case.

Diameter of particles – mustard seeds

Average particle size: 2.0mm



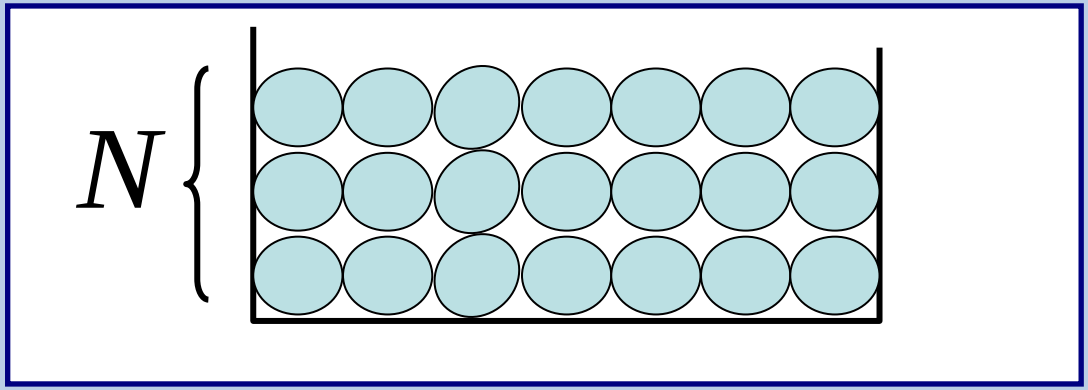
The values were obtained on basis of image analisys using **Fiji** program. The amount of grains studies was about **2000** in each case.

Parameters decisive to the problem

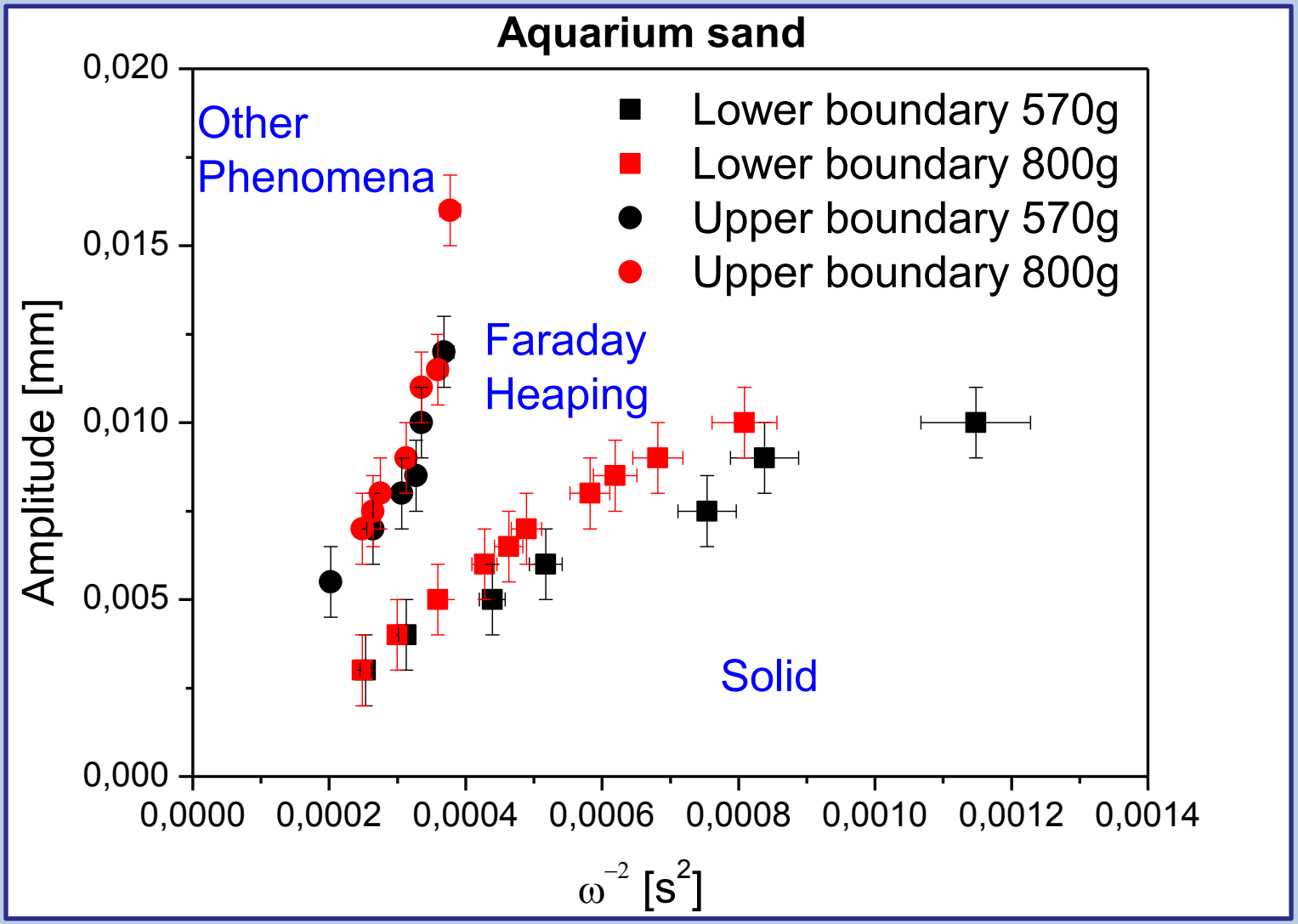
Maximal non-dimensional acceleraton: $$\Gamma = \frac{A\omega^2}{g}$$

A – amplitude of oscillation, ω-frequency of oscillations,
g –gravitational acceleration

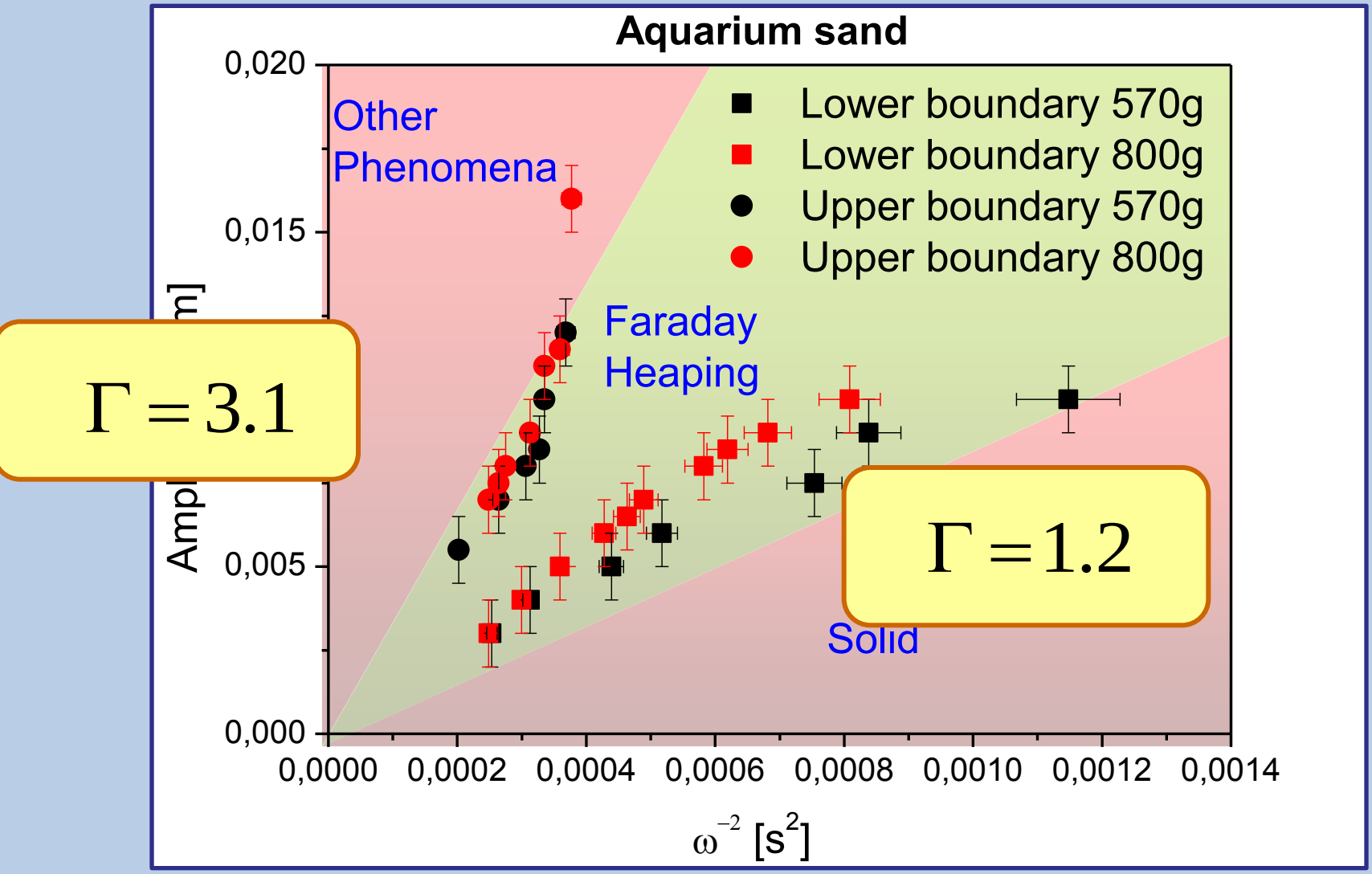
The number of layers of granular matter



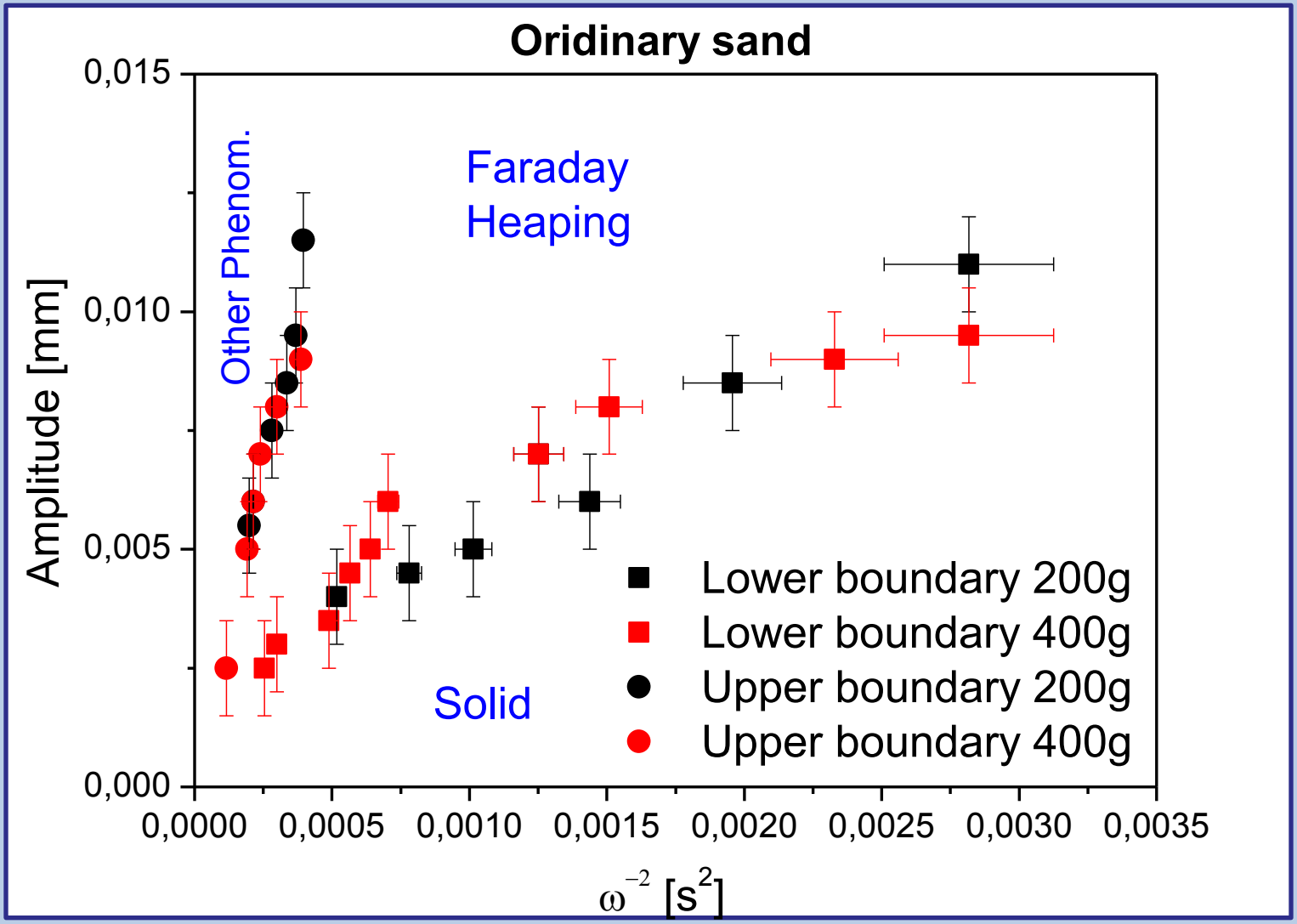
„Phase" Diagram of Faraday heaping



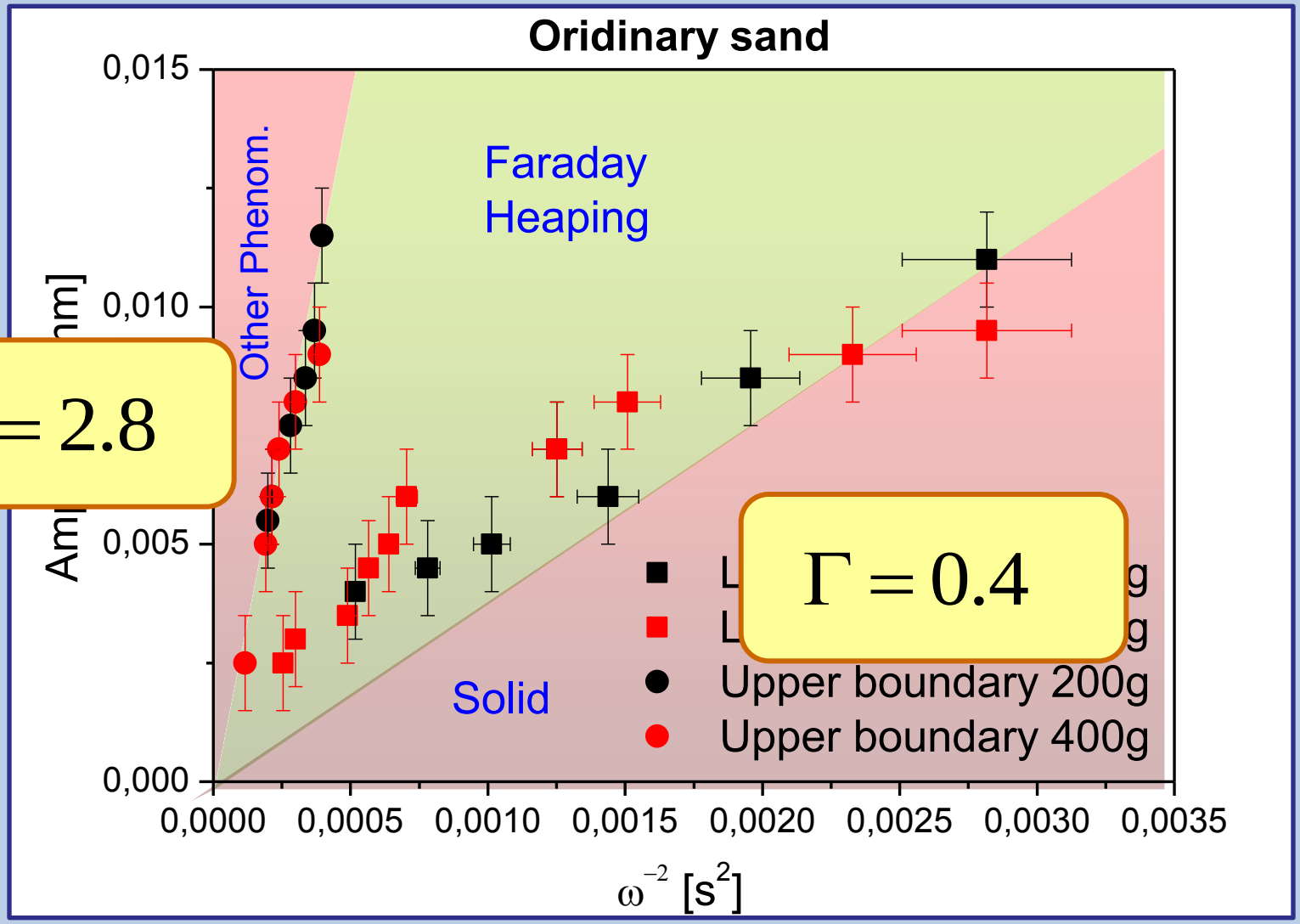
„Phase” Diagram of Faraday heaping



„Phase” Diagram of Faraday heaping



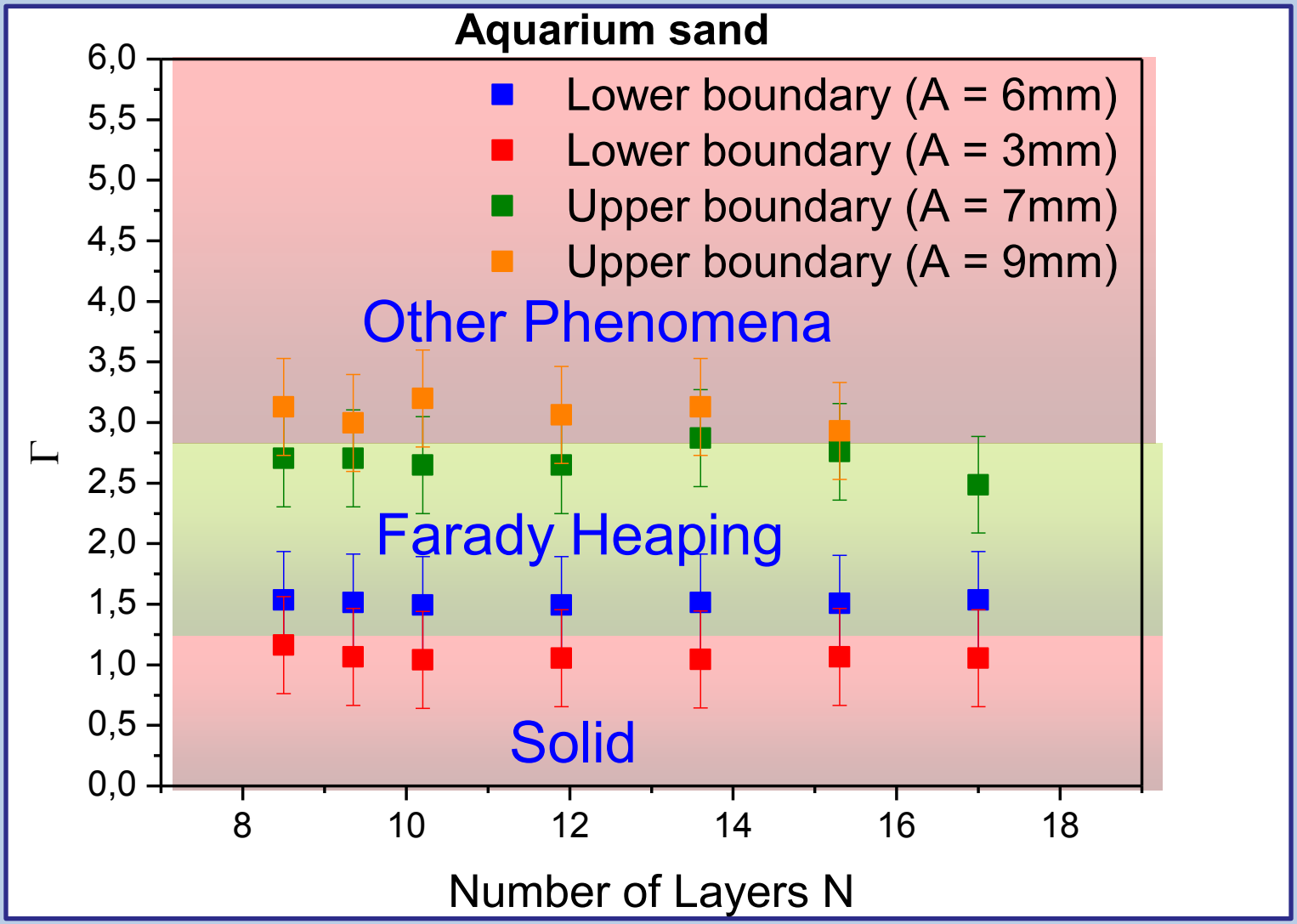
„Phase” Diagram of Faraday heaping



$\Gamma = 2.8$

$\Gamma = 0.4$

„Phase” Diagram of Faraday heaping



Summary

- If granular material is vibrated vertically, Faraday heaping may occur
- The main factors determining the Faraday heaping process are: air drag and collisions with surface
- The process of heap-merging, the formation and stable state of a heap are qualitatively understood
- The major parameters in the phenomenon are: the diameter of the particle, the acceleration, amplitude, number of layers.

Literature

- Henk Jan van Gerner et. Al.,”Coarsening of Faraday Heaps: Experiment, Simulation, Theory”, Physical Review Letters, 2009

- Henk Jan van Gerner et al., ” Interplay of air and sand: Faraday heaping unravelled”, Physical Review Letters, 2007

- Peter Eshuis et al.,”Phase diagram of vertically shaken granular matter”, Physics of Fluids, 2007

Other phenomena observable using our experimental setup

„Exploding” Faraday heaps

Other phenomena observable using our experimental setup

Undulations

Other phenomena observable using our experimental setup

Oscillons