

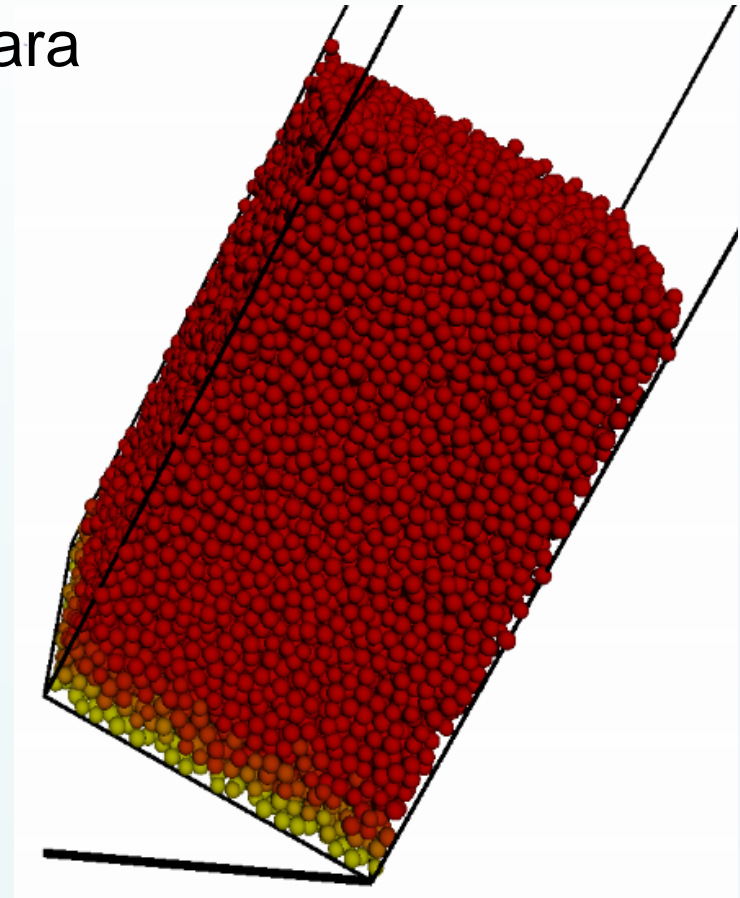
Simulations of granular flows close to the angle of repose

GDR, Transnat
16-17 mai 2011

Patrick Richard and Sean McNamara

Patrick.Richard@univ-rennes1.fr

*Institut de Physique de Rennes (IPR)
Université de Rennes 1
UMR CNRS 6251
Rennes
France*



Granular flows on a bumpy bottom

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PHYSICS OF FLUIDS

VOLUME 11, NUMBER 3

MARCH 1999

Scaling laws in granular flows down rough inclined planes

O. Pouliquen^{a)}

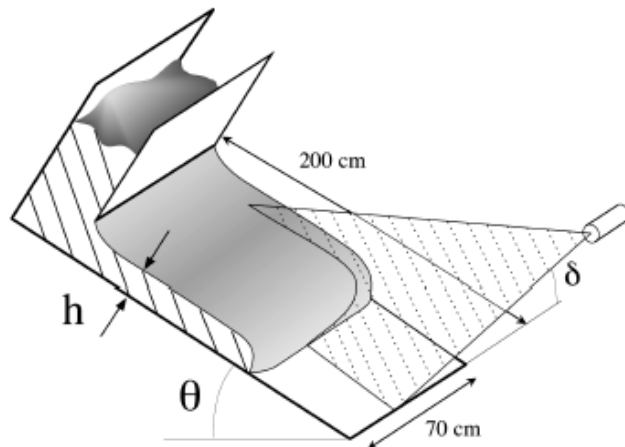
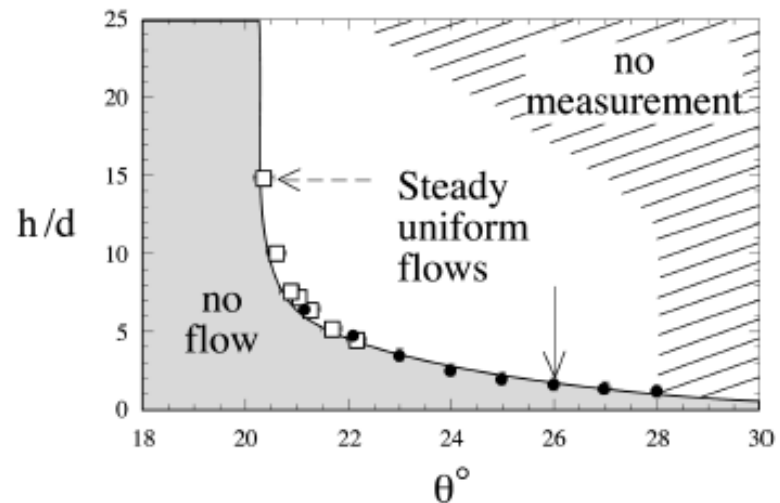


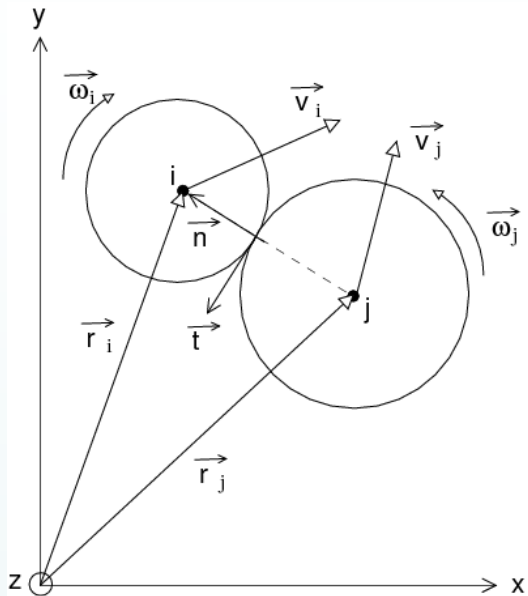
FIG. 1. Experimental setup.



No Coulomb-like friction

Simulations

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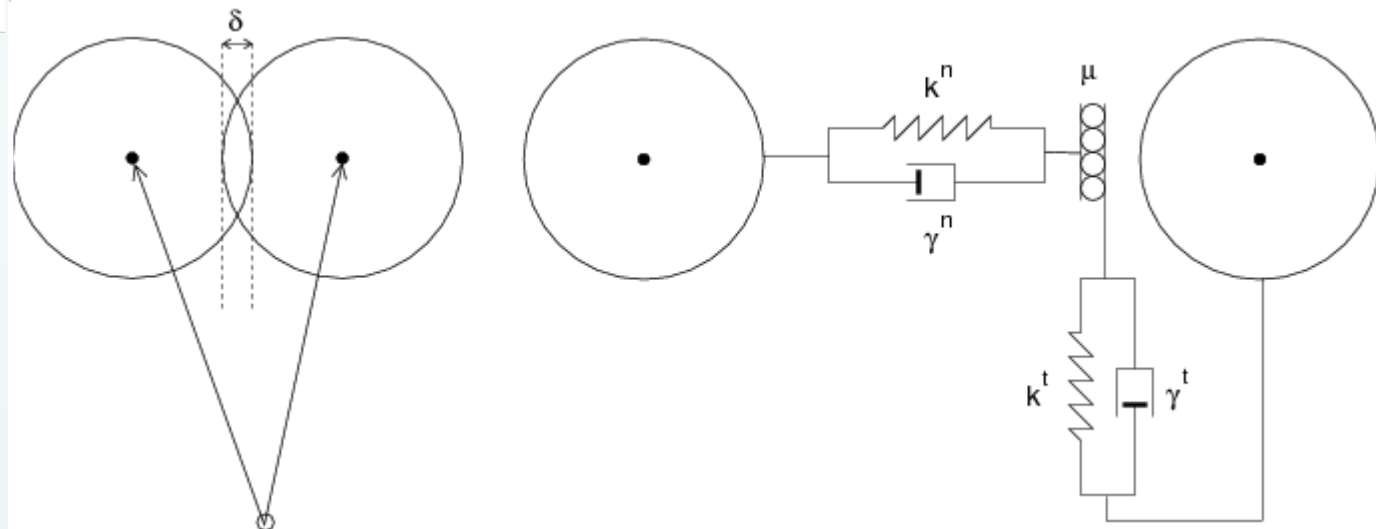
Solve equations of motion for N spheres flowing down a bumpy incline \Rightarrow forces?

Linear spring - dashpot

$$\bullet F_n = k_n \delta + \gamma_n d\delta/dt$$

$$\bullet F_t = \text{MIN}(\mu F_n, k_t u + \gamma_t du/dt)$$

$$k_n d/mg \approx 10^5 \text{ (to save time...)}$$



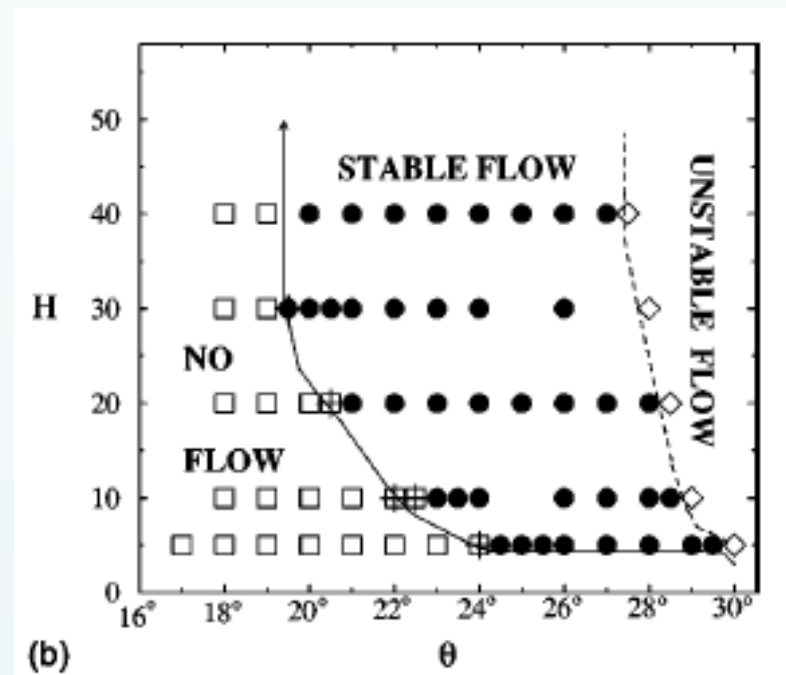
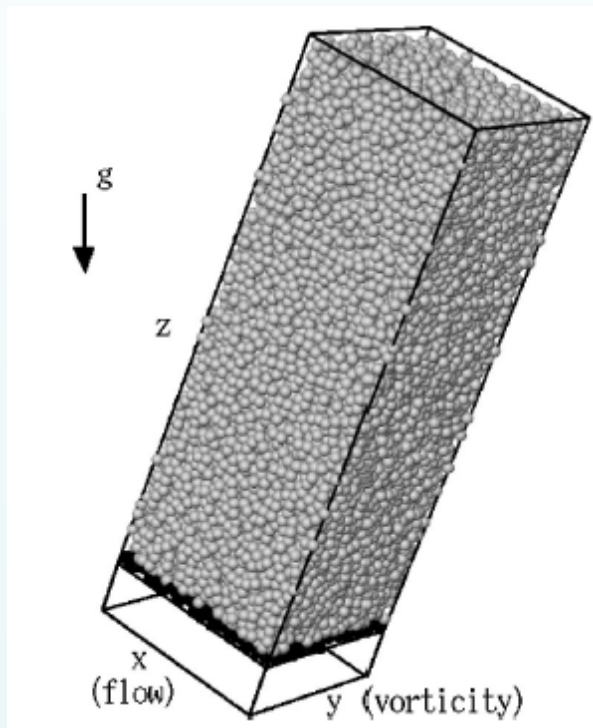
Simulations

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PHYSICAL REVIEW E, VOLUME 64, 051302

Granular flow down an inclined plane: Bagnold scaling and rheology

Leonardo E. Silbert,¹ Deniz Ertas,² Gary S. Grest,¹ Thomas C. Halsey,² Dov Levine,³ and Steven J. Plimpton¹



Oscillations close to the angle of repose?

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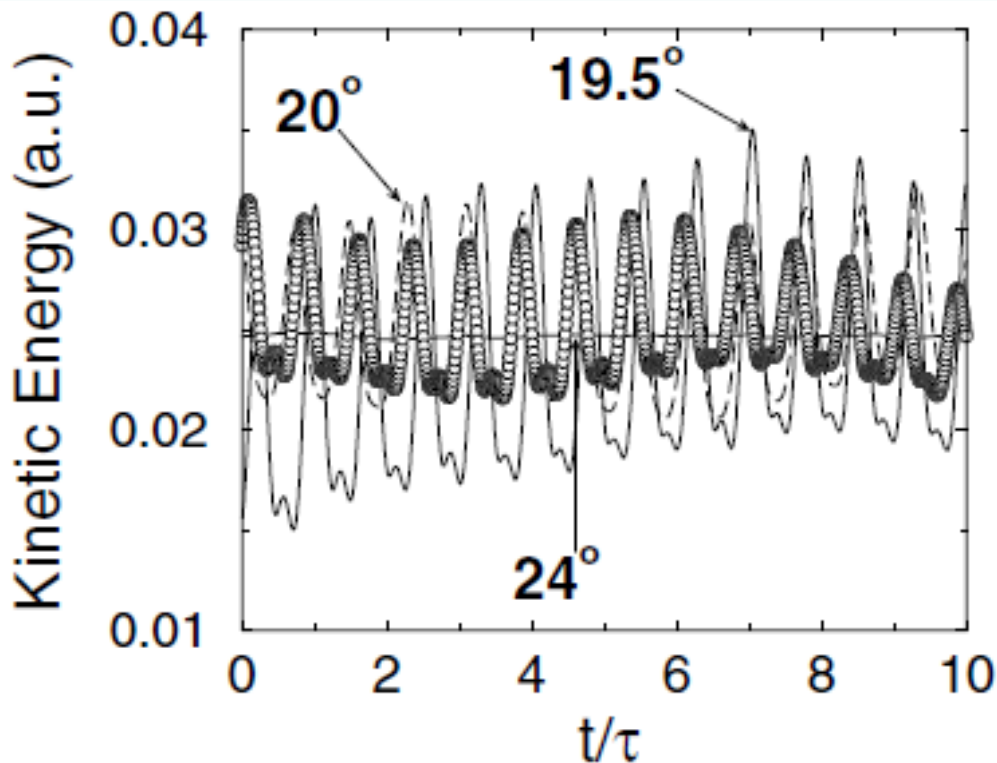
PRL 94, 098002 (2005)

PHYSICAL REVIEW LETTERS

week ending
11 MARCH 2005

Temporally Heterogeneous Dynamics in Granular Flows

Leonardo E. Silbert*



- Learn something about jamming?
- Explain « booming » sand?

Oscillations close to the angle of repose?

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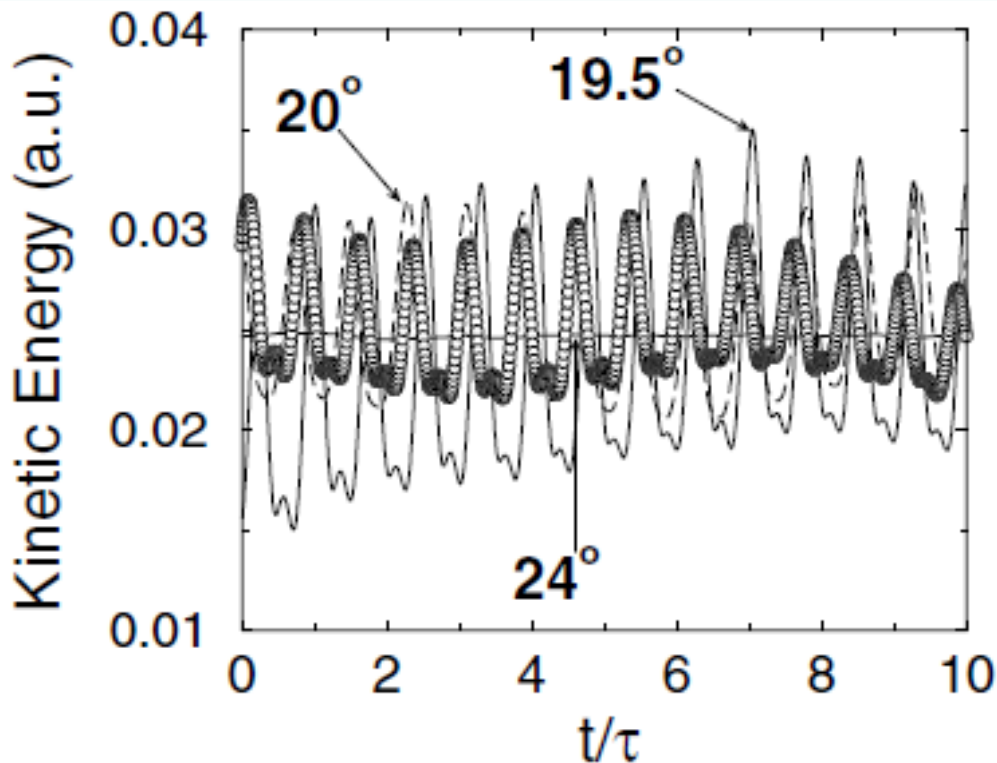
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Temporally Heterogeneous Dynamics in Granular Flows

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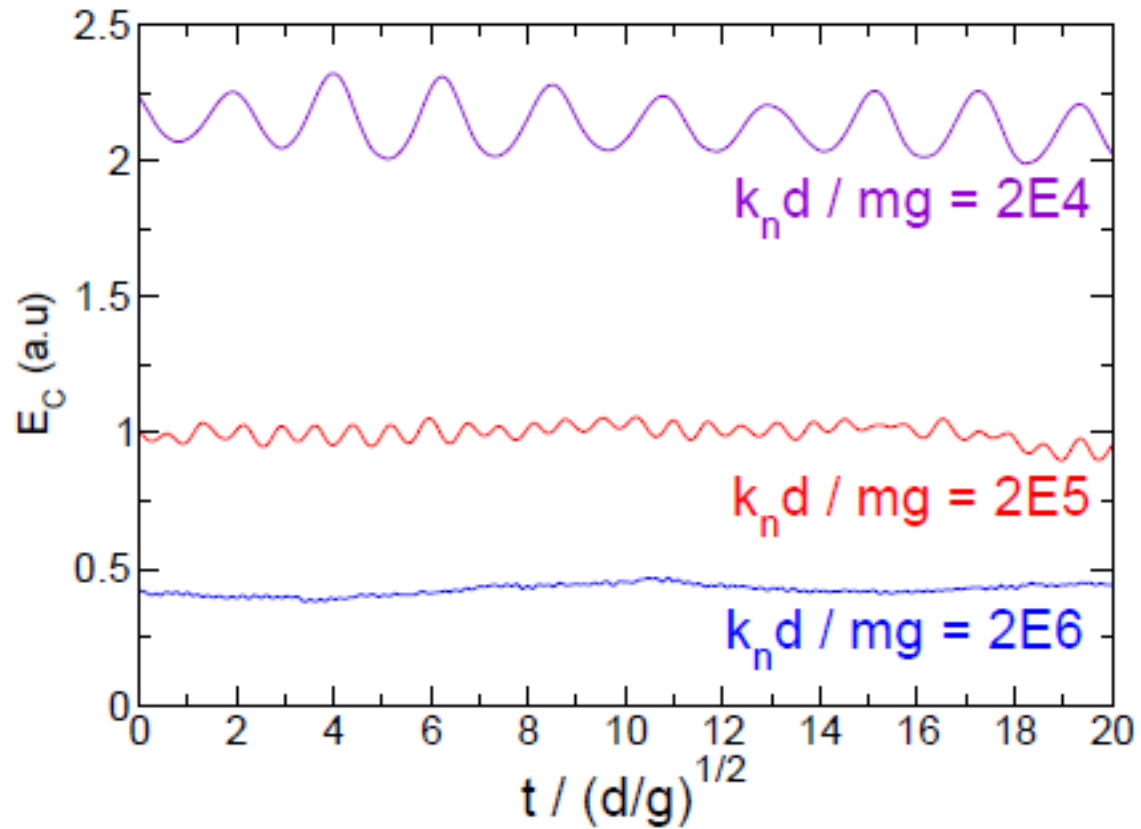
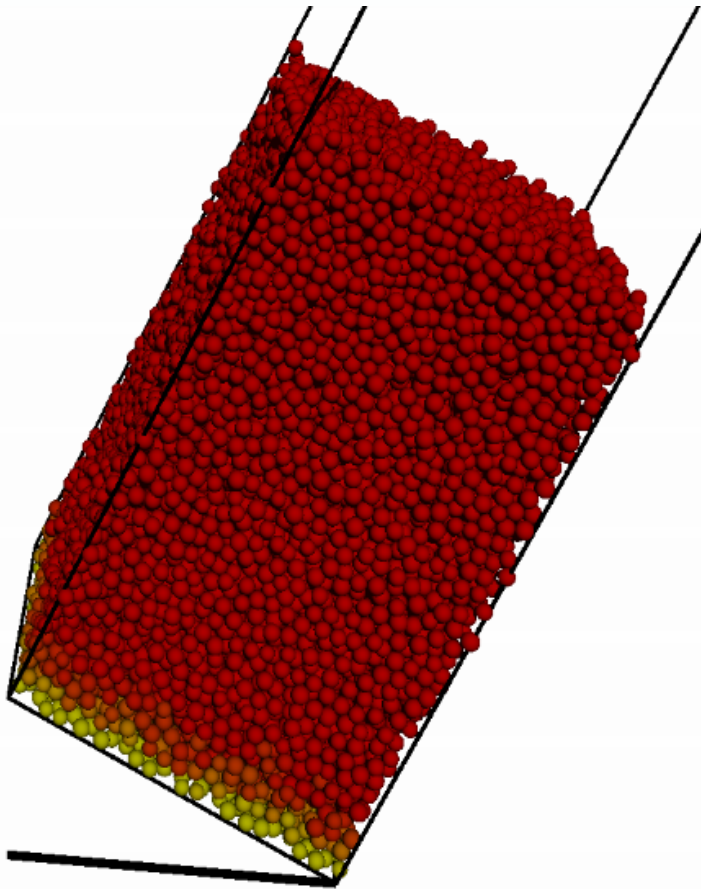


- Learn something about jamming?
- Explain « booming » sand?

Artifact of the force model ?

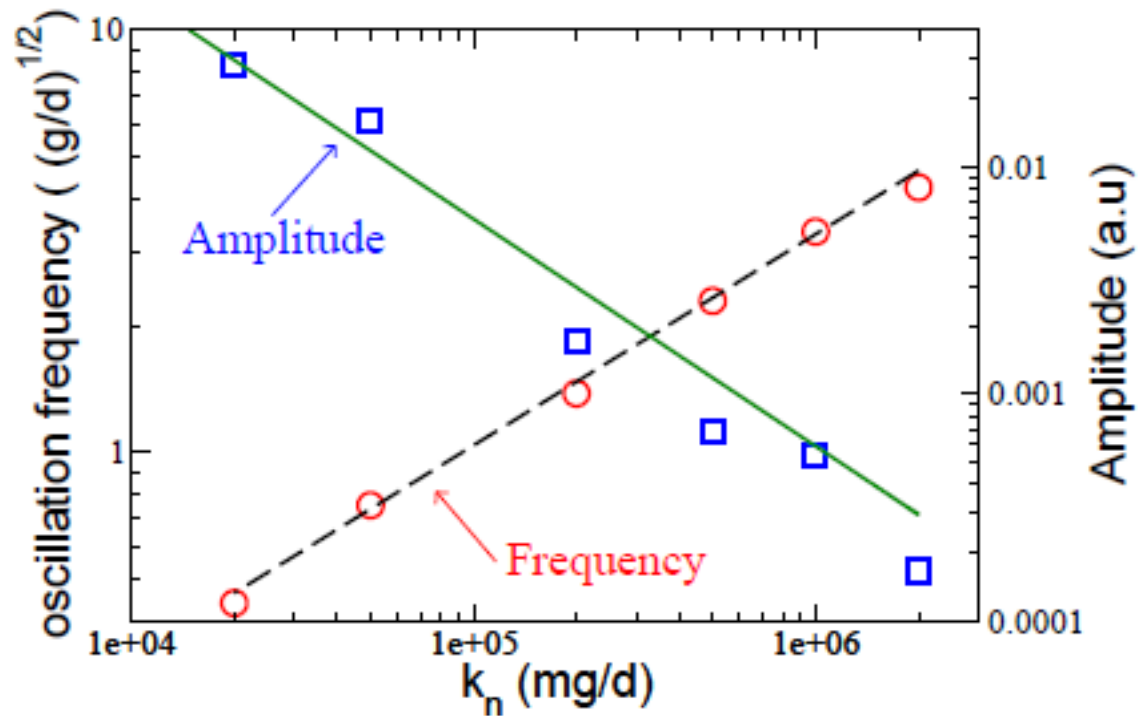
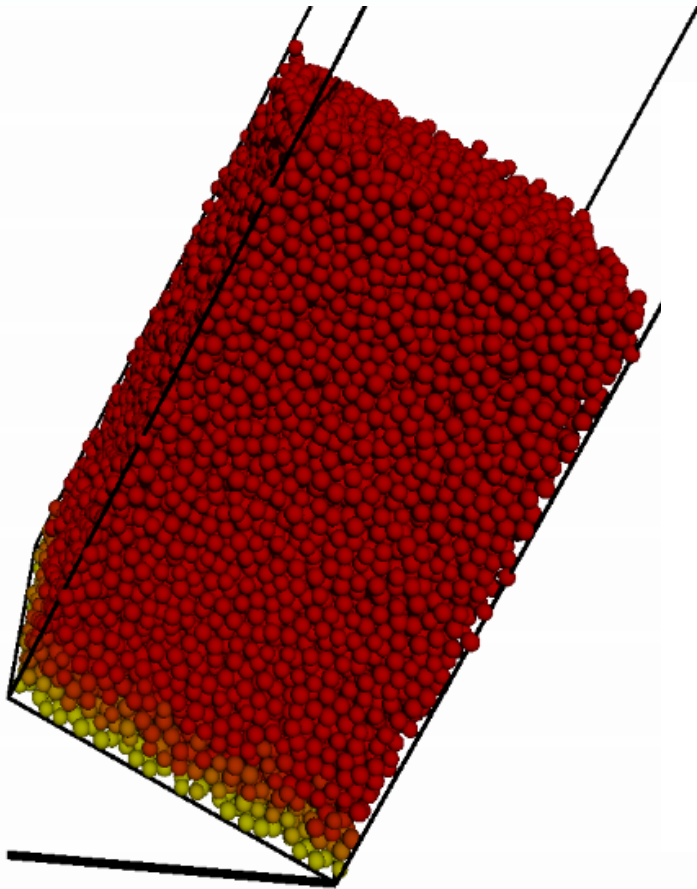
Effect of k_n ?

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Effect of k_n ?

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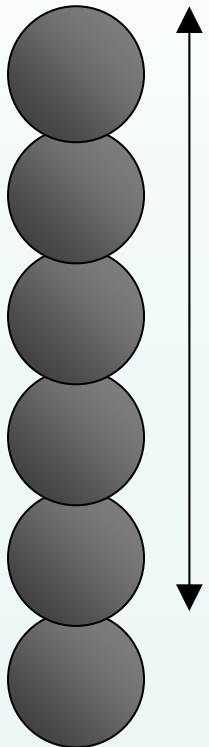
And for real grains...?

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$$F_n = \frac{2E\sqrt{R}}{3(1-\nu^2)}\delta^{3/2}$$



$$k_n = \frac{dF_n}{d\delta} = \frac{E\sqrt{R}}{(1-\nu^2)}\delta^{1/2}$$



n grains

$$F_n = \frac{2}{3}k_n\delta$$

$$F_n = nmg$$

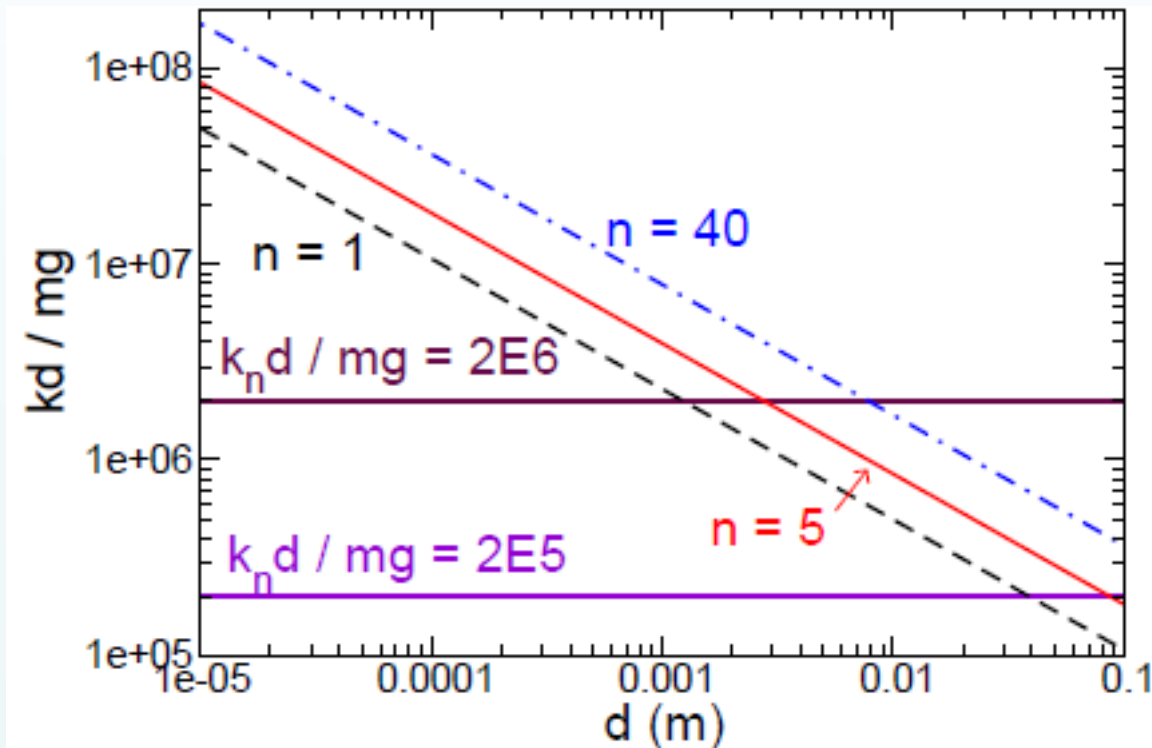
$$\left(\frac{d}{\delta}\right)^{3/2} = \frac{4E}{\pi(1-\nu^2)\sqrt{2}n\rho dg}$$

$$\frac{k_n d}{mg} = \frac{3}{2}n \frac{d}{\delta} = \frac{3}{2} \left[\frac{2\sqrt{2}nE}{\pi(1-\nu^2)\rho dg} \right]^{2/3}$$

Stiffness

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$$\frac{k_n d}{mg} = \frac{3}{2} n \frac{d}{\delta} = \frac{3}{2} \left[\frac{2\sqrt{2nE}}{\pi(1-\nu^2)\rho dg} \right]^{2/3}$$

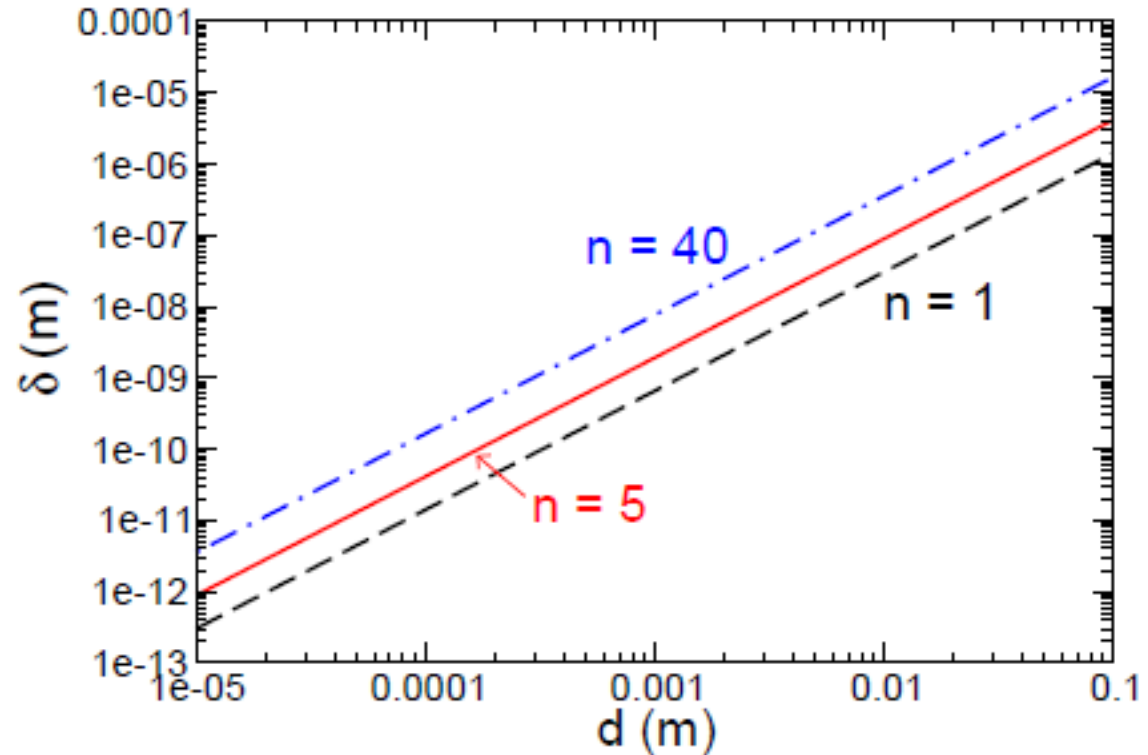


Overlap

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$$\delta = \frac{3d^{5/3}n^{2/3}}{2K}$$

$$K = \frac{3}{2} \left[\frac{2\sqrt{2}E}{\pi(1-\nu^2)\rho g} \right]^{2/3}$$



Glass Spheres $d \approx 1\text{mm} \Rightarrow d \approx 1\text{nm}$ (size of the roughness a the bead)

Thus... we are doing nanophysics!

Conclusion

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- Simulations should be used with care especially for time \approx collision time
- This work casts doubt on the Hertz for inter-grain forces which reposes on the assumption that the grains are beautiful, smooth spheres that are pushed together.
- At the nanometer scale, the grains are certainly not smooth. The force law will be governed by their asperities, of which we know almost nothing.