

Direct evidence of frictionless behaviour in shear thickening suspensions

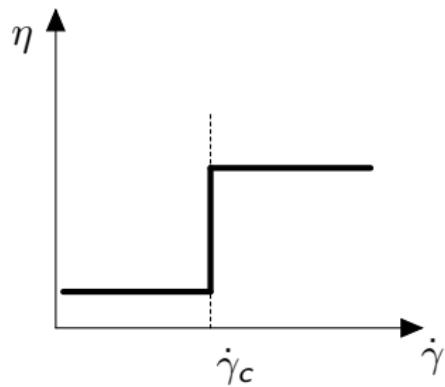
Cécile Clavaud, Antoine Bérut, Bloen Metzger, Yoël Forterre

IUSTI CNRS Marseille, France



What is shear-thickening?

Shear-thickening: brutal increase in viscosity at a critical shear rate.

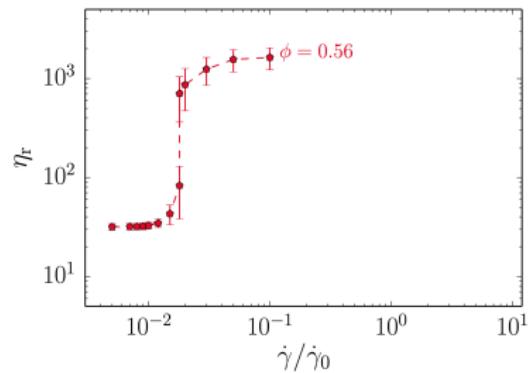
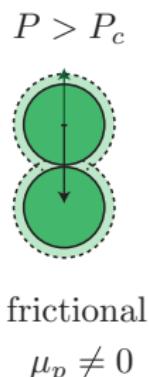
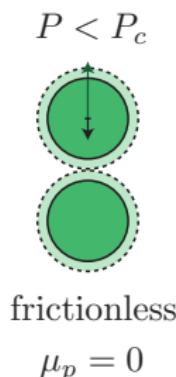


People running on a pool filled with a corn-starch suspension.

A promising scenario: frictional transition

Idea: frictional grains with short-range repulsion

Seto et al. PRL 2013, Wyart and Cates PRL 2014.



Adapted from Mari et al. J. Rheol. 2014.

Recent experimental support:

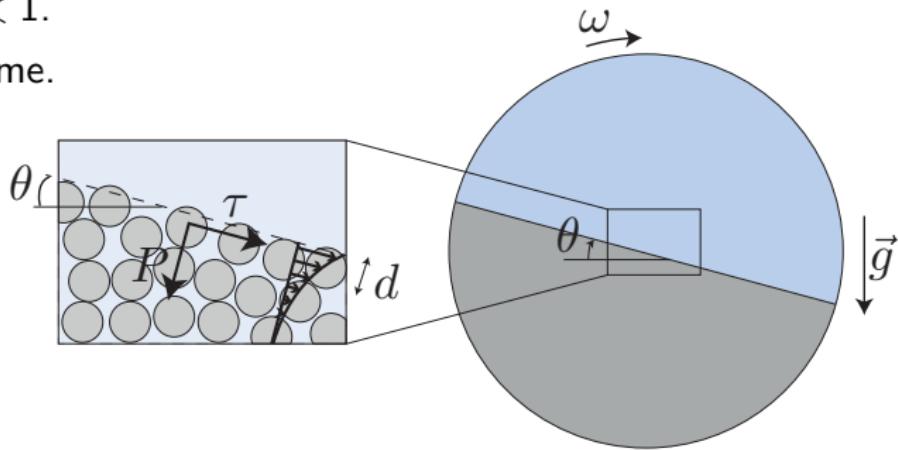
Lin et al. PRL 2015, Guy et al. PRL 2016, Royer et al. PRL 2016.

Access to η but not to μ_p .

Probing μ : steady avalanche angle

- Rotating drum.
- Non buoyant suspensions.
- No inertia: $St \ll 1$.
- Quasi-static regime.

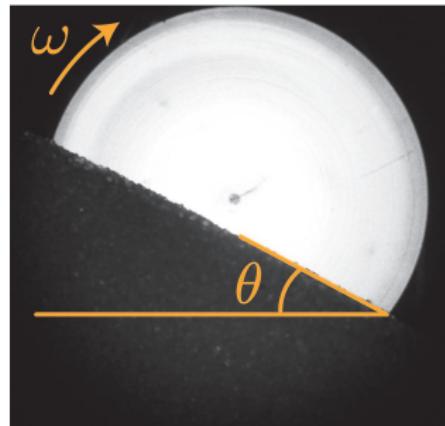
$$\mu = \frac{\tau}{P} = \tan \theta$$



Surface flow: measure of μ at low confining pressure.

Steady avalanche angle

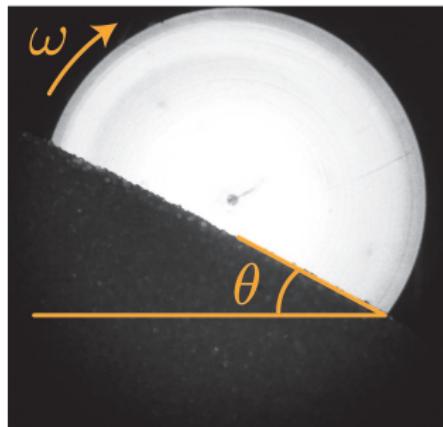
Classical suspension:
glass beads 500 μm in oil.



$$\theta \simeq 25^\circ, \mu \simeq 0.47$$

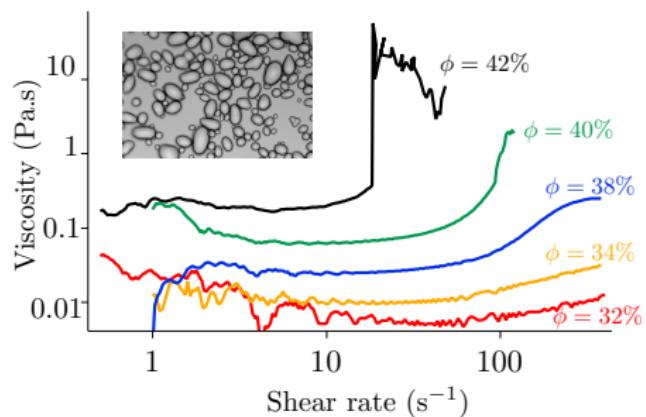
Steady avalanche angle

Classical suspension:
glass beads 500 μm in oil.



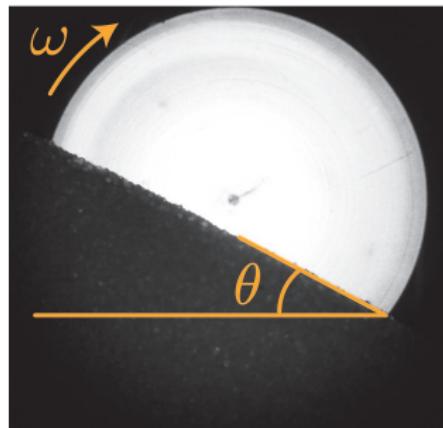
$$\theta \simeq 25^\circ, \mu \simeq 0.47$$

Shear thickening suspension:
potato starch 25 μm in water.



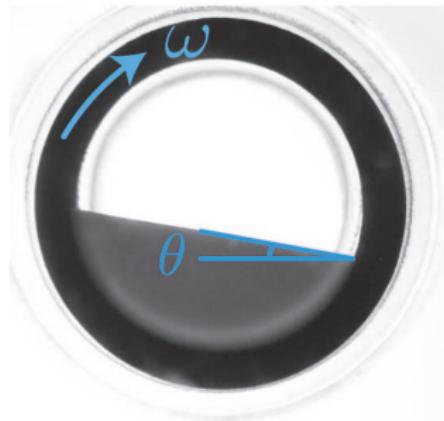
Steady avalanche angle

Classical suspension:
glass beads 500 μm in oil.



$$\theta \simeq 25^\circ, \mu \simeq 0.47$$

Shear thickening suspension:
potato starch 25 μm in water.



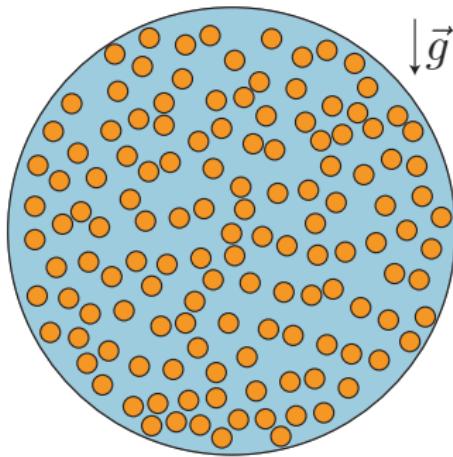
$$\theta \simeq 8.5^\circ, \mu \simeq 0.15$$

suggests that $\mu_p \simeq 0$.

Another way to probe μ : compaction and dilatancy

Compaction

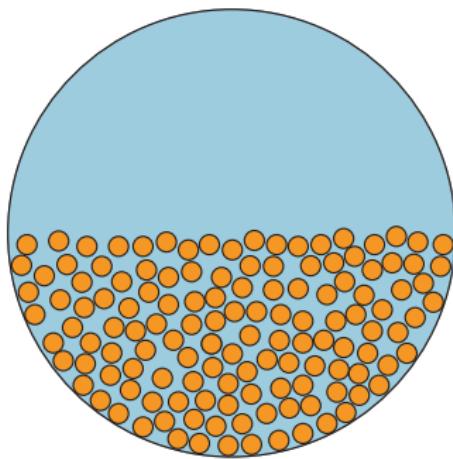
Frictional grains:



Another way to probe μ : compaction and dilatancy

Compaction

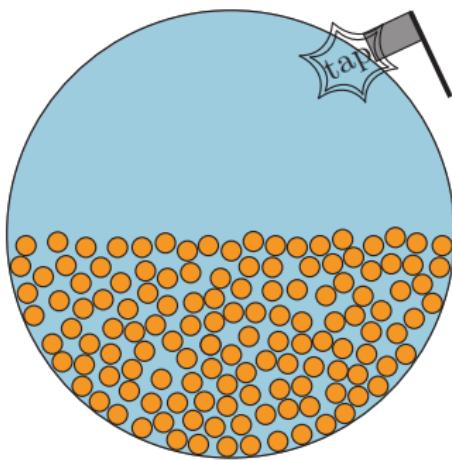
Frictional grains:



Another way to probe μ : compaction and dilatancy

Compaction

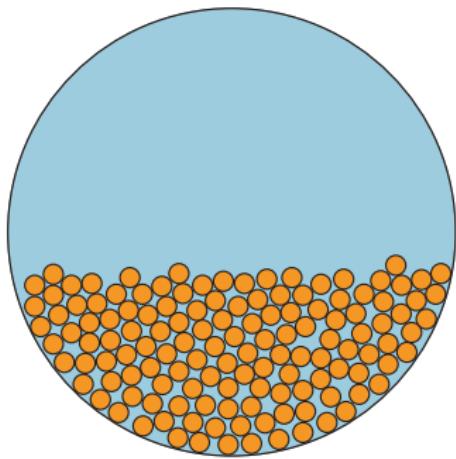
Frictional grains:



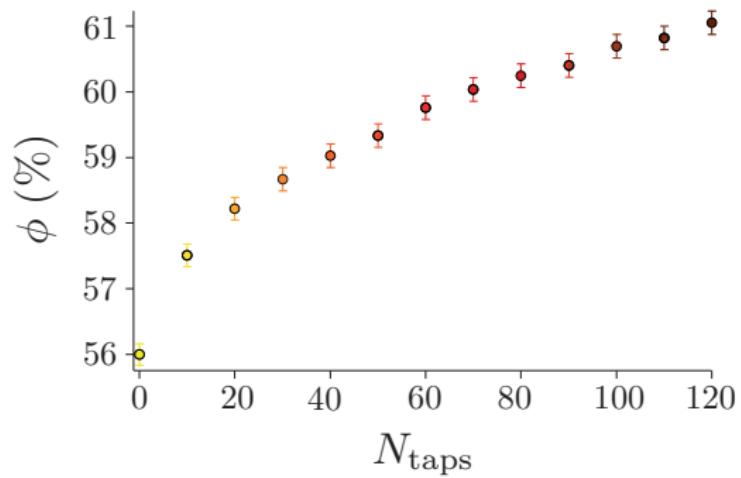
Another way to probe μ : compaction and dilatancy

Compaction

Frictional grains:



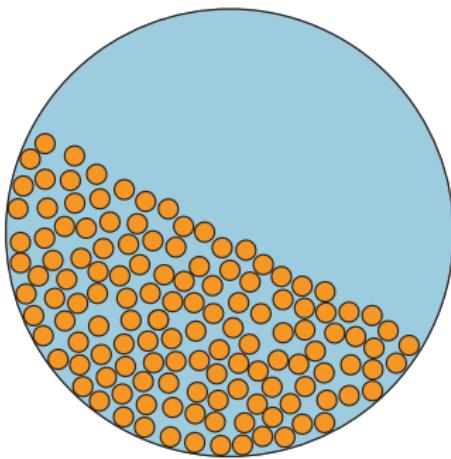
Large glass beads in oil.



Another way to probe μ : compaction and dilatancy

Transient avalanches: dilatancy

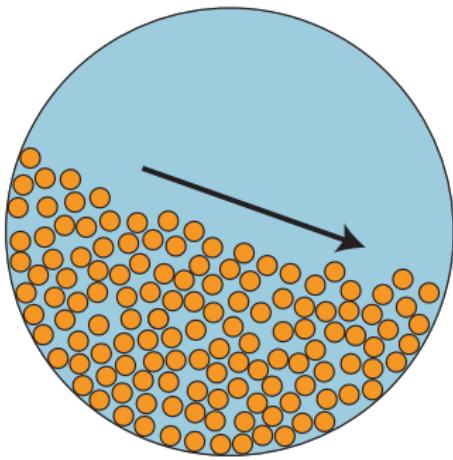
Frictional grains.



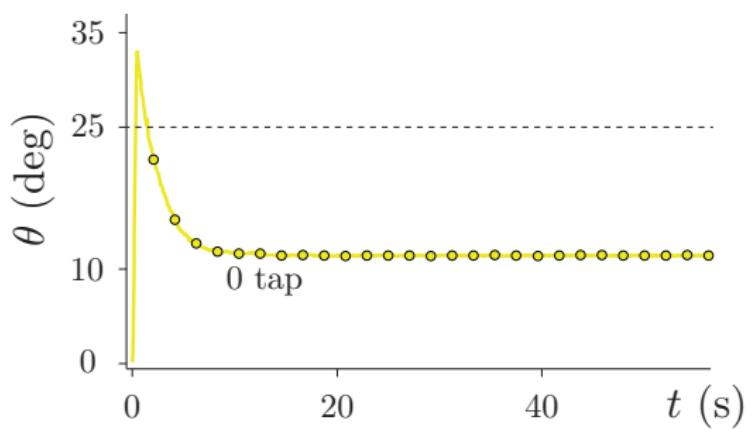
Another way to probe μ : compaction and dilatancy

Transient avalanches: dilatancy

Frictional grains.



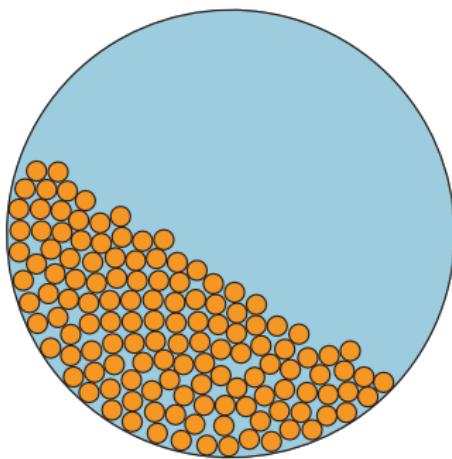
Large glass beads in oil.



Another way to probe μ : compaction and dilatancy

Transient avalanches: dilatancy

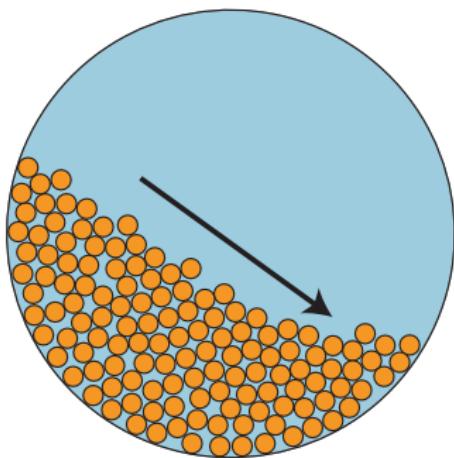
Frictional grains.



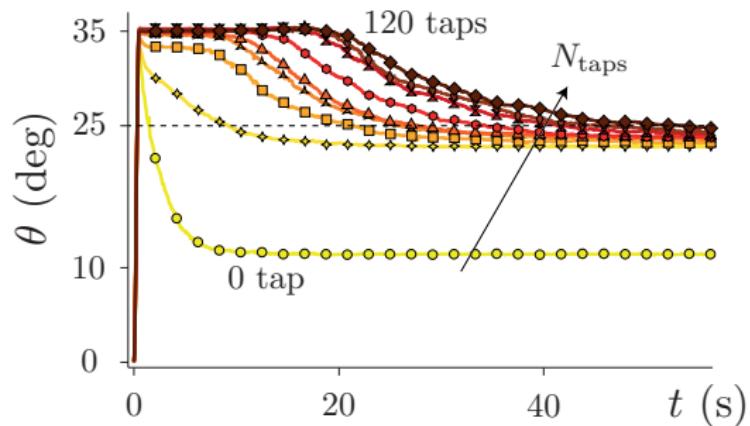
Another way to probe μ : compaction and dilatancy

Transient avalanches: dilatancy

Frictional grains.

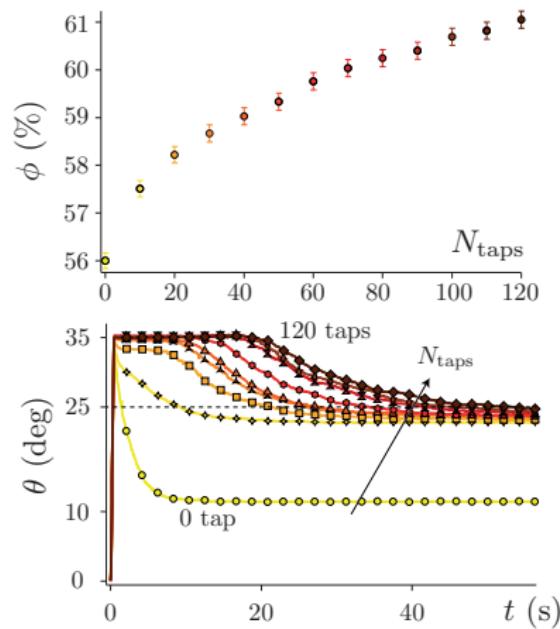


Large glass beads in oil.



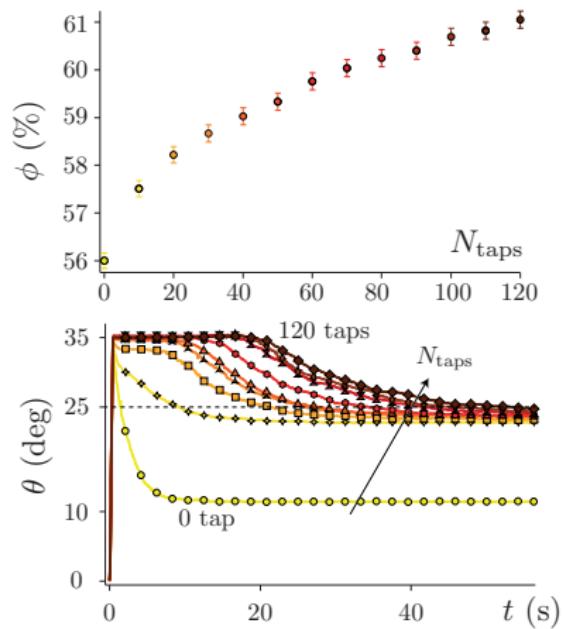
Compaction and dilatancy

Classical suspension:
large glass beads in oil.

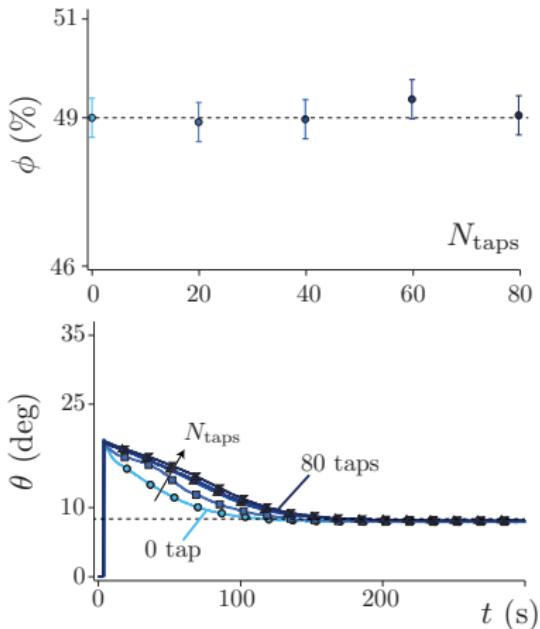


Compaction and dilatancy

Classical suspension:
large glass beads in oil.



Shear thickening suspension:
potato starch in water.



No compaction, no dilatancy: $\mu_p = 0$ (Peyneau and Roux. PRE 2008).

Shear thickening suspension (potato starch):

- low steady avalanche angle,
- no compaction, → frictionless behavior at low P .
- no dilatancy,

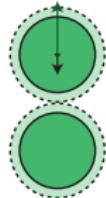
Origin of this behavior?

Shear thickening suspension (potato starch):

- low steady avalanche angle,
- no compaction, → frictionless behavior at low P .
- no dilatancy,

Origin of this behavior?

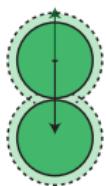
$$P < P_c$$



frictionless

$$\mu_p = 0$$

$$P > P_c$$



frictional

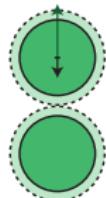
$$\mu_p \neq 0$$

Shear thickening suspension (potato starch):

- low steady avalanche angle,
- no compaction, → frictionless behavior at low P .
- no dilatancy,

Origin of this behavior?

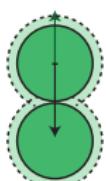
$$P < P_c$$



frictionless

$$\mu_p = 0$$

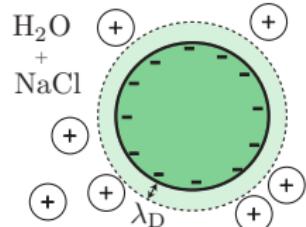
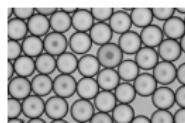
$$P > P_c$$



frictional

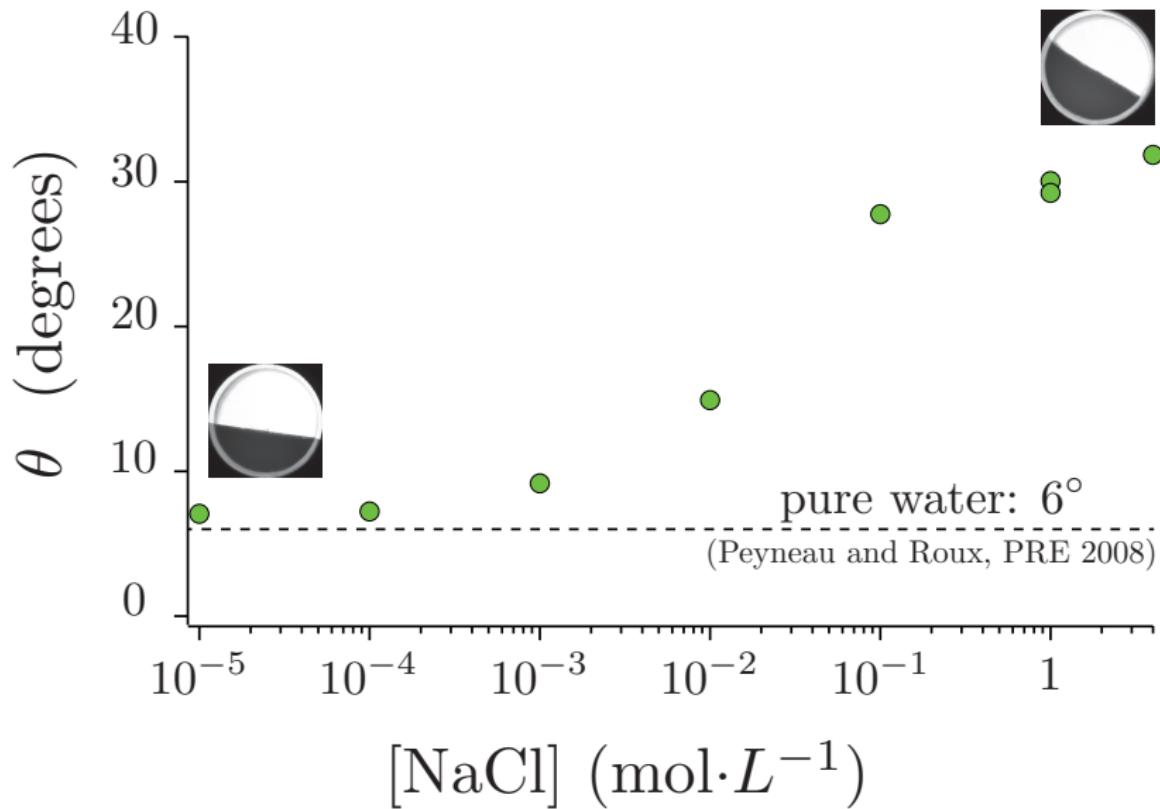
$$\mu_p \neq 0$$

Silica beads 24 μm in $\text{H}_2\text{O} + \text{NaCl}$

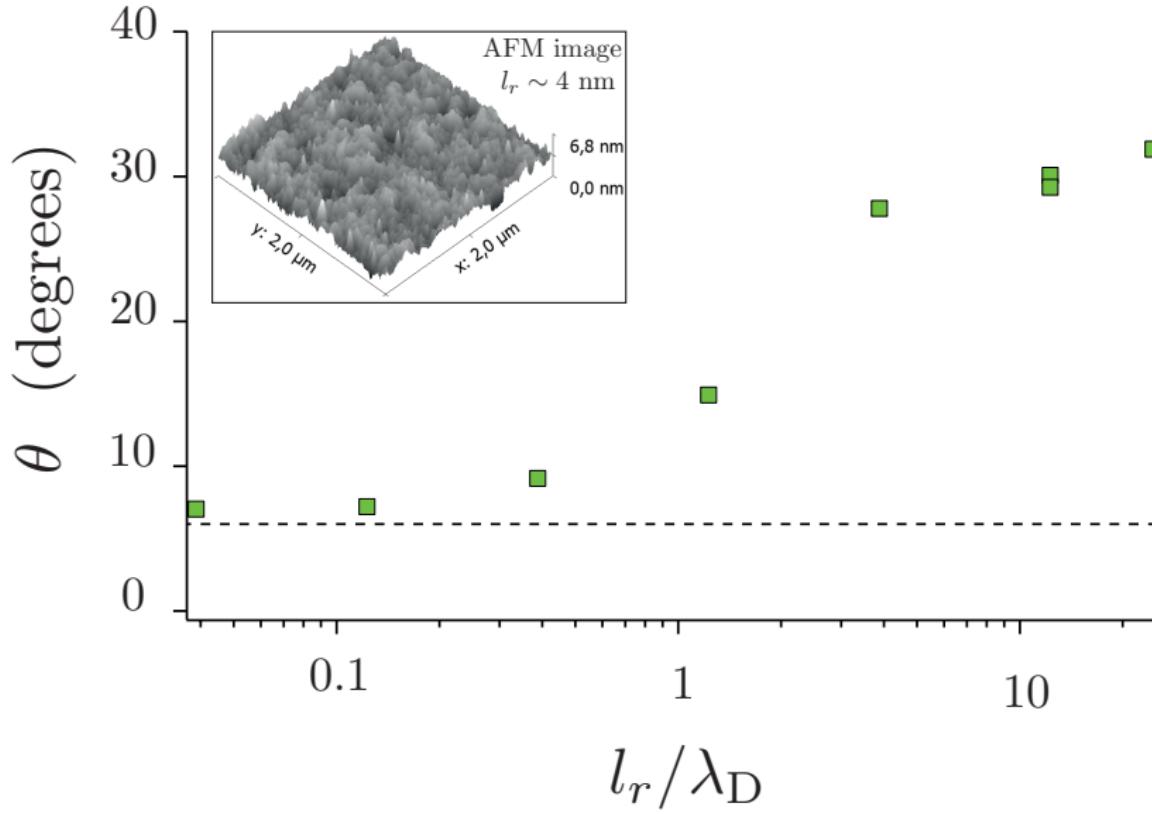


$$\lambda_D = \frac{0.304}{\sqrt{[\text{NaCl}]}} \text{ nm}$$

Frictional transition by tuning the repulsive force



Frictional transition by tuning the repulsive force



Conclusions

Shear thickening suspension:

- low steady avalanche angle,
 - no compaction, → frictionless behavior at low P .
 - no dilatancy,

Model suspension (silica beads):

Controlling the range of the repulsive force: frictional transition.

At low P , transition for $\lambda_D \sim l_r$.

Future work: measure the friction coefficient as a function of P .