

CAPCAP

Controlling **A**dhesion between **P**articles for a better understanding of **C**ompaction, **A**eration and flow of **P**owders.



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Research Institute



The long term project :

Understanding the behaviour of powders under low stress conditions:

Rheology, flow, aeration, compaction.

The strategy :

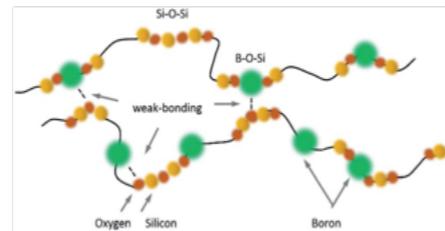
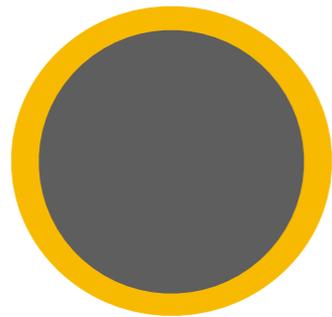
- 1) to develop Model materials with controlled cohesion
- 2) to design appropriate tools to measure rheology
- 3) to study simple flow configurations
- 4) to understand the role of air

materials with control cohesion

the most studied system: capillary bridges..
=> migration of liquid, complex dynamics...

Scheel et al Nature material 2008, Badetti et al EPJE 2018....

Polymer Coated particles

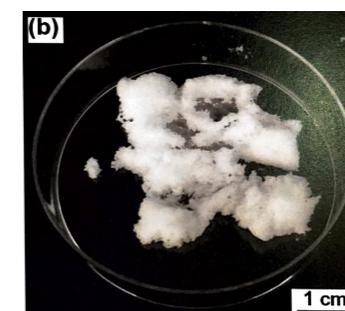
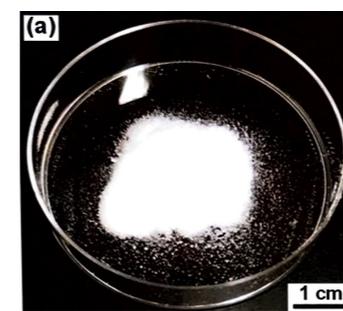
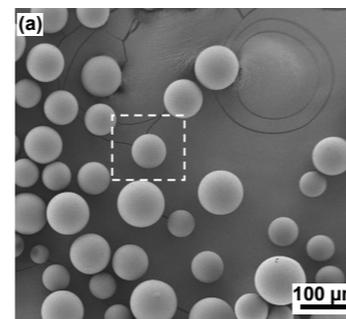
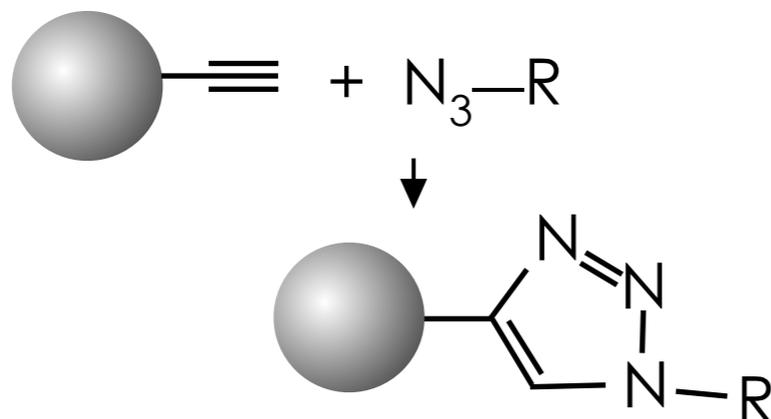


Silica Microbeads
+PDMS-OH,
+Boric Acid (H_3BO_3)



Tailored polymer micro-particles using the click chemistry

(collaboration, E. Druckenmuller, N. Sintès, LPM Univ. Lyon)



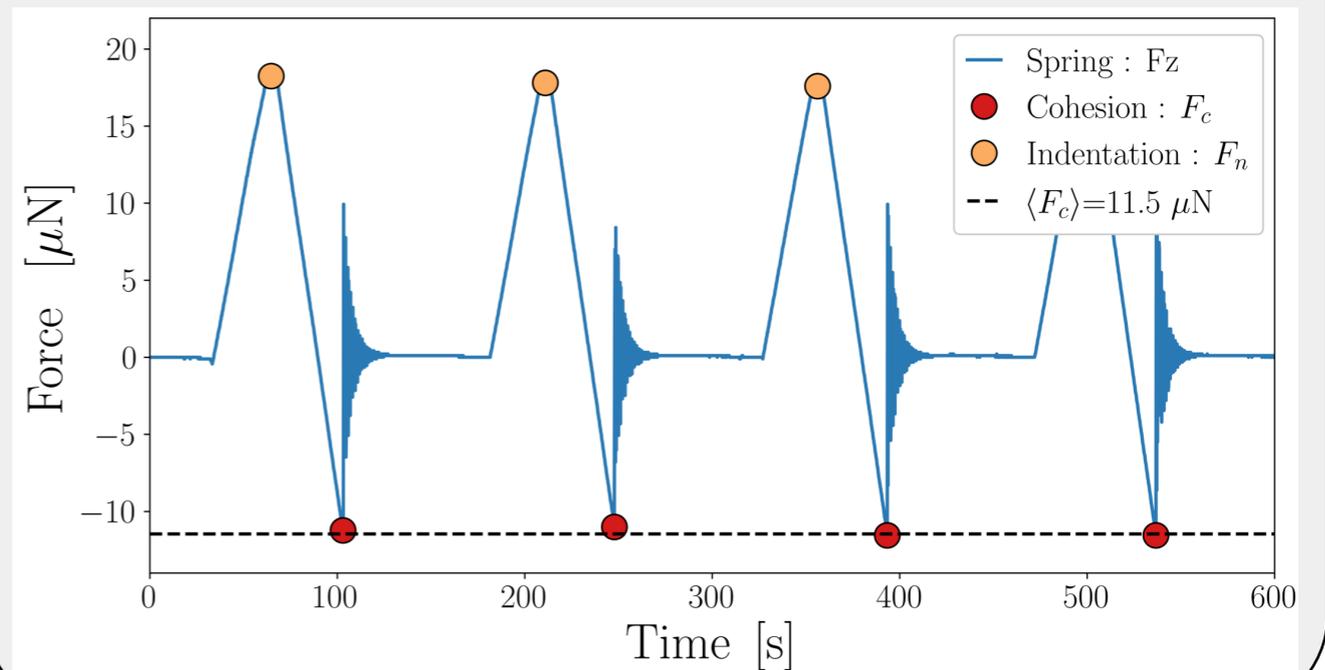
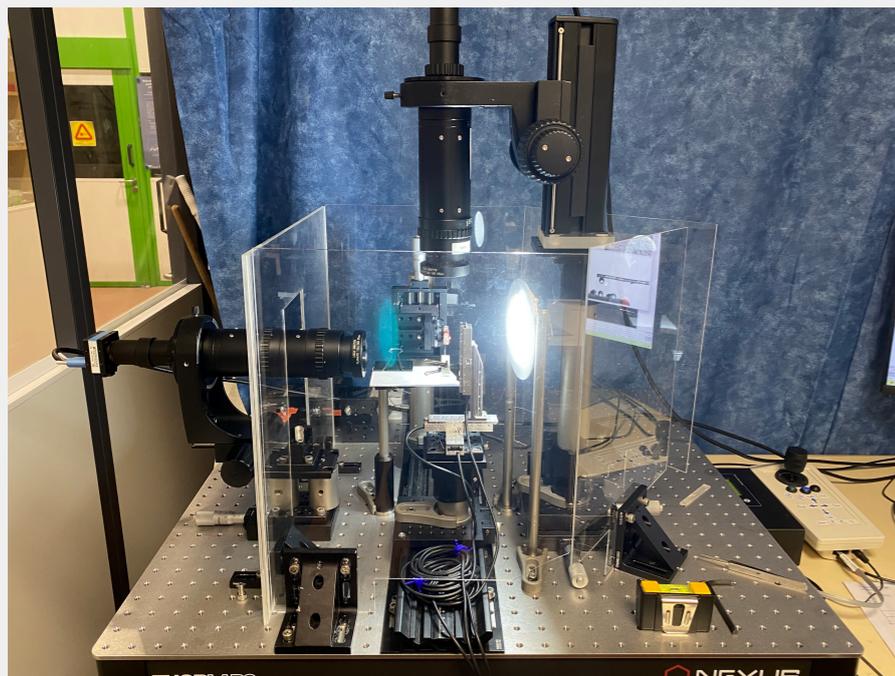
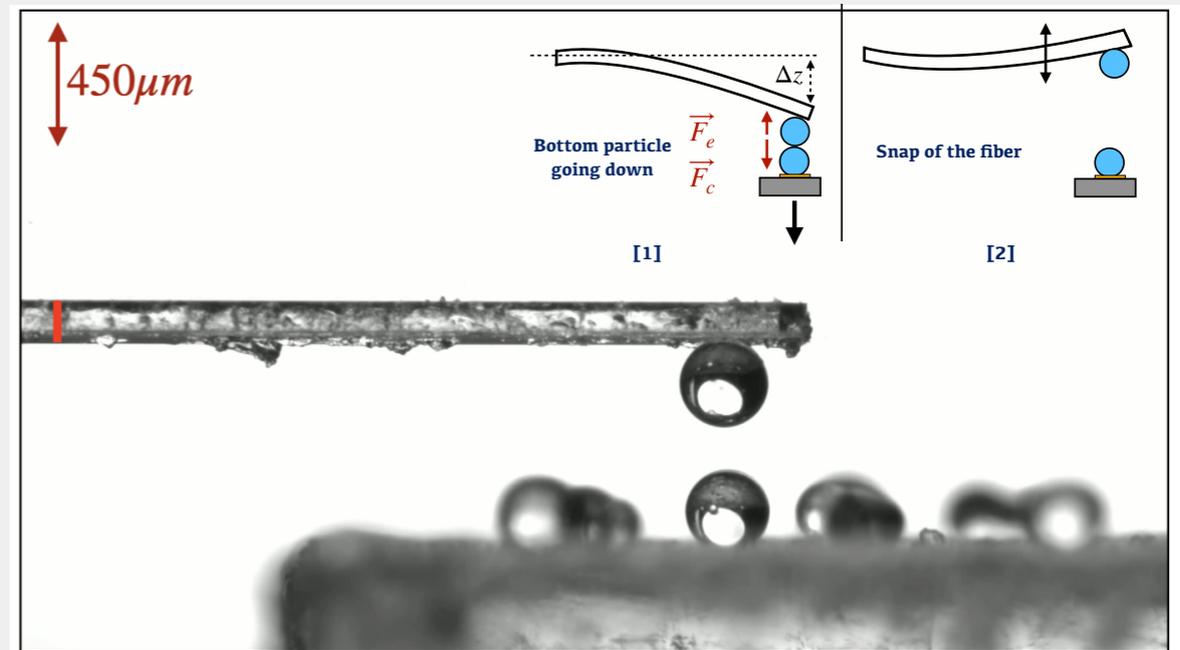
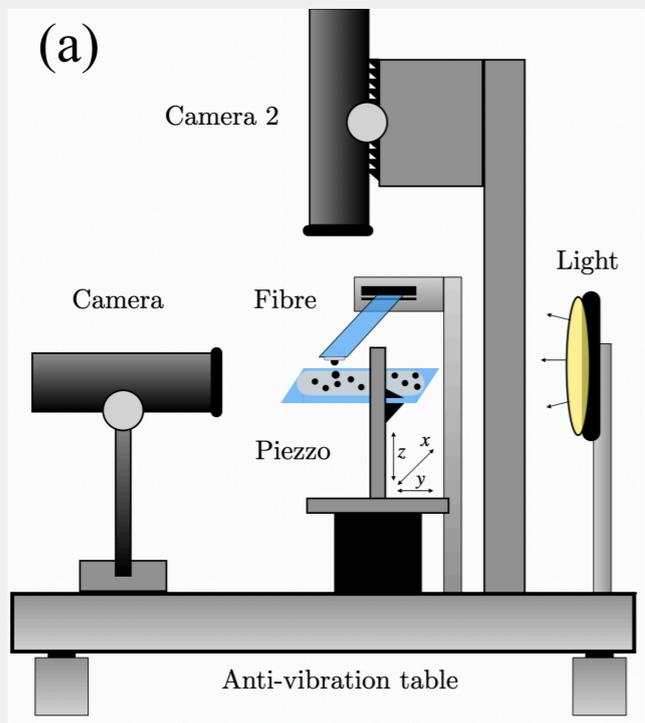
Moratille et al, J. Coll. Int. Sci. 2022

a set up to precisely measure of adhesive force

an AFM-like approach

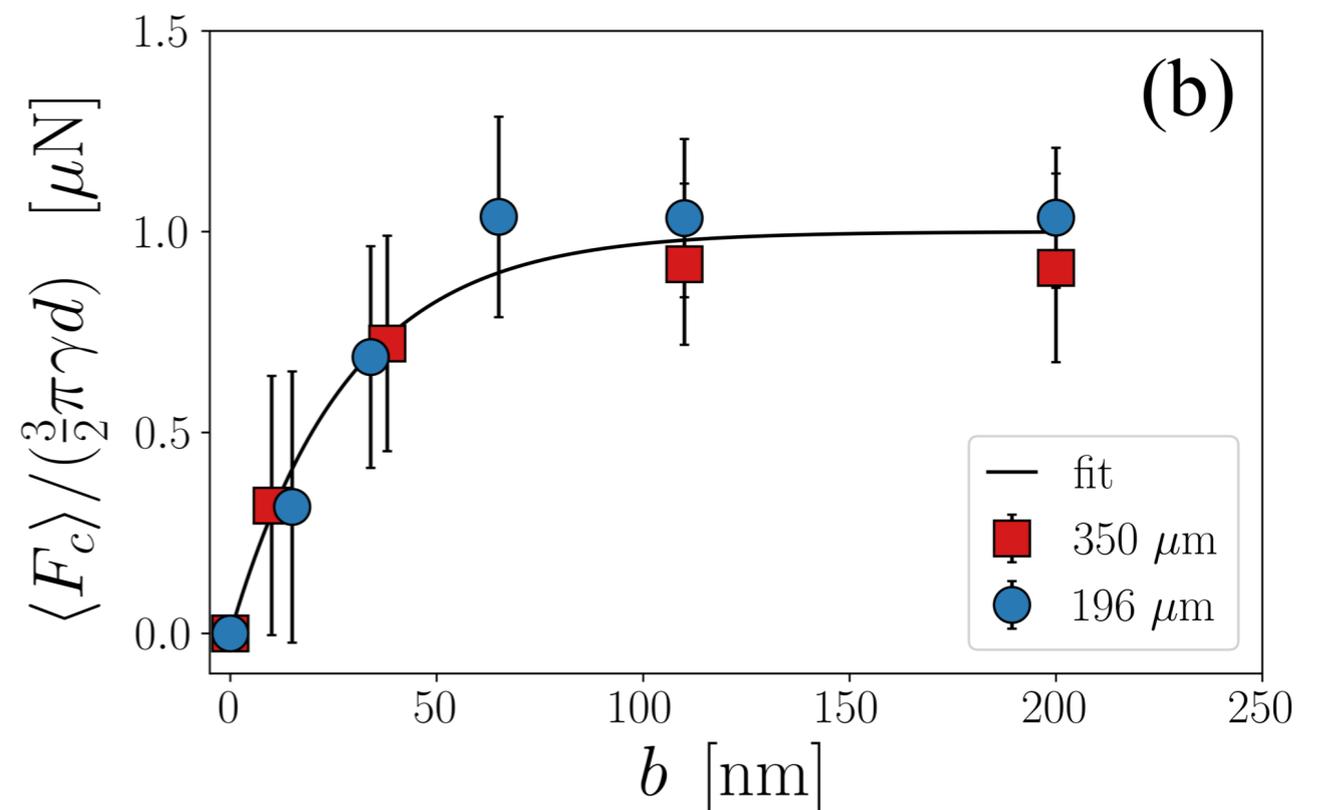
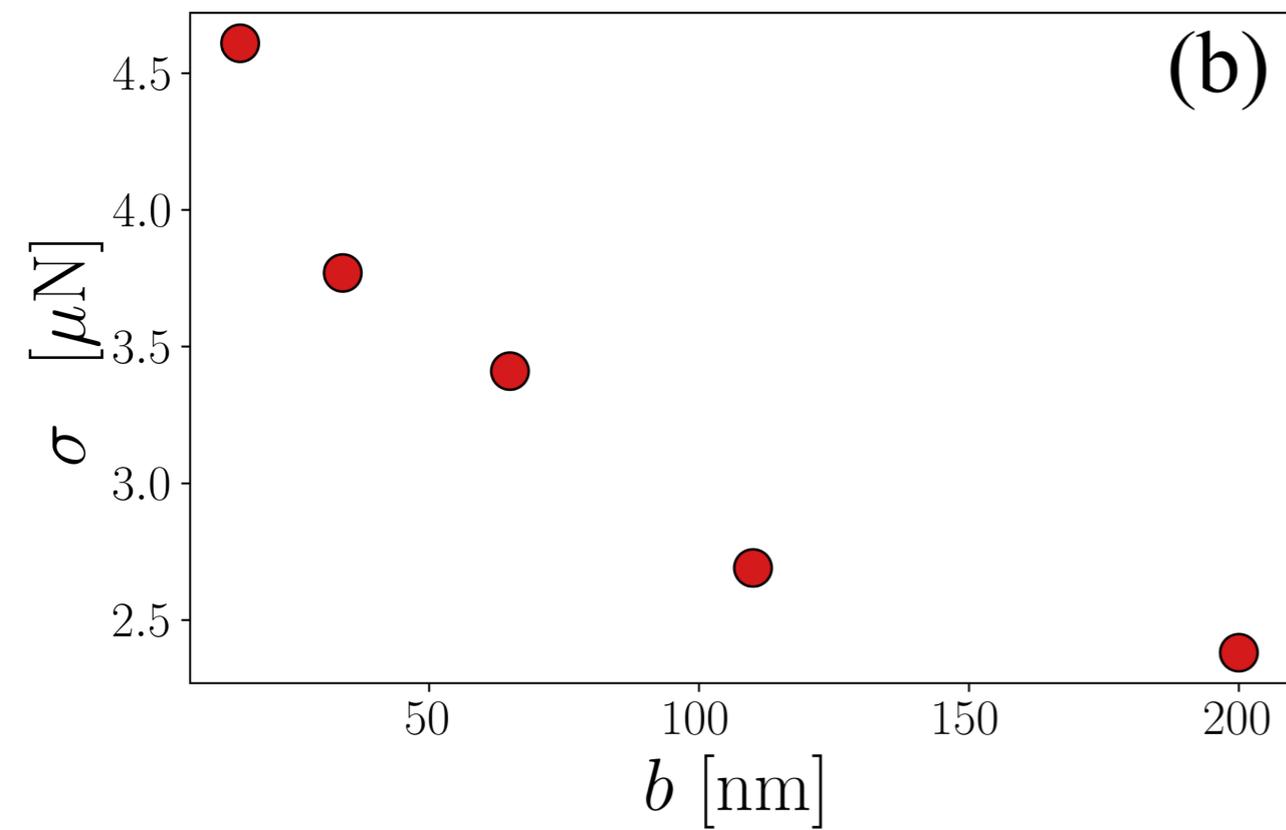
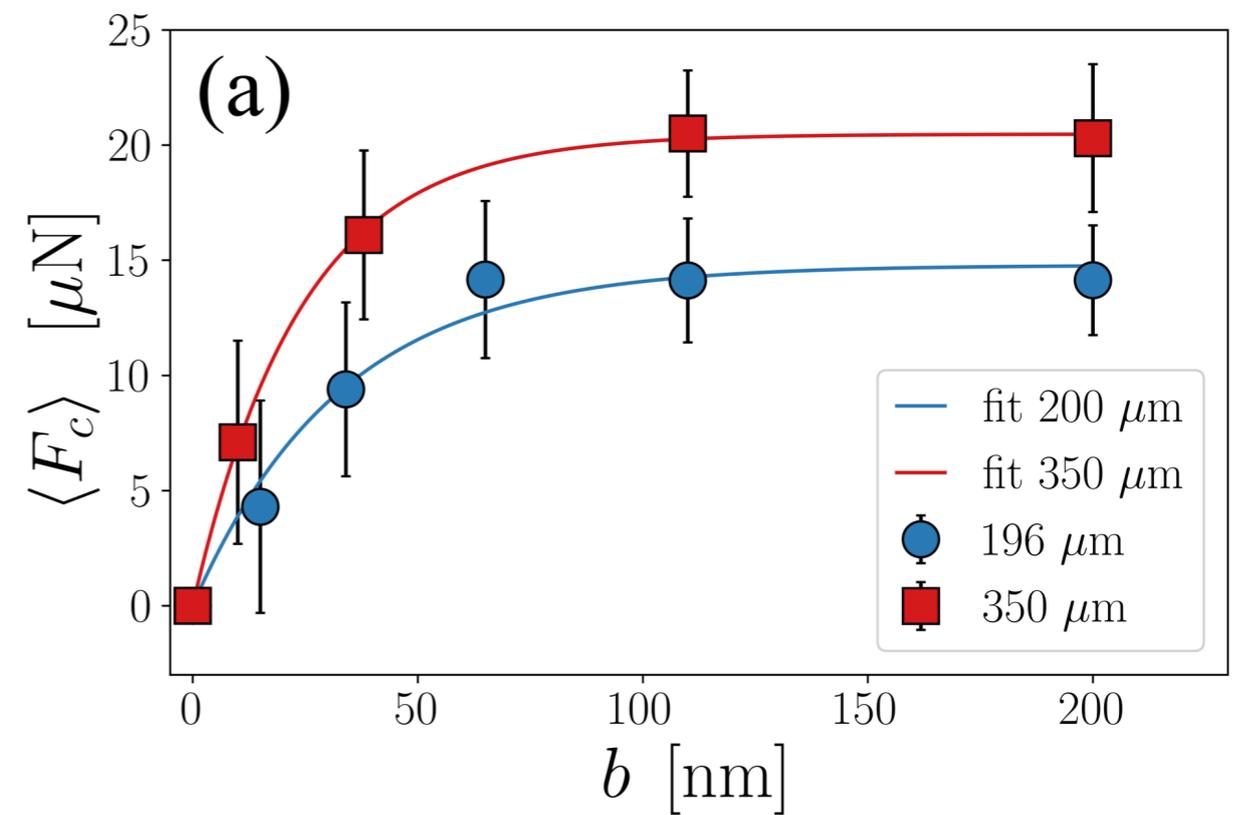
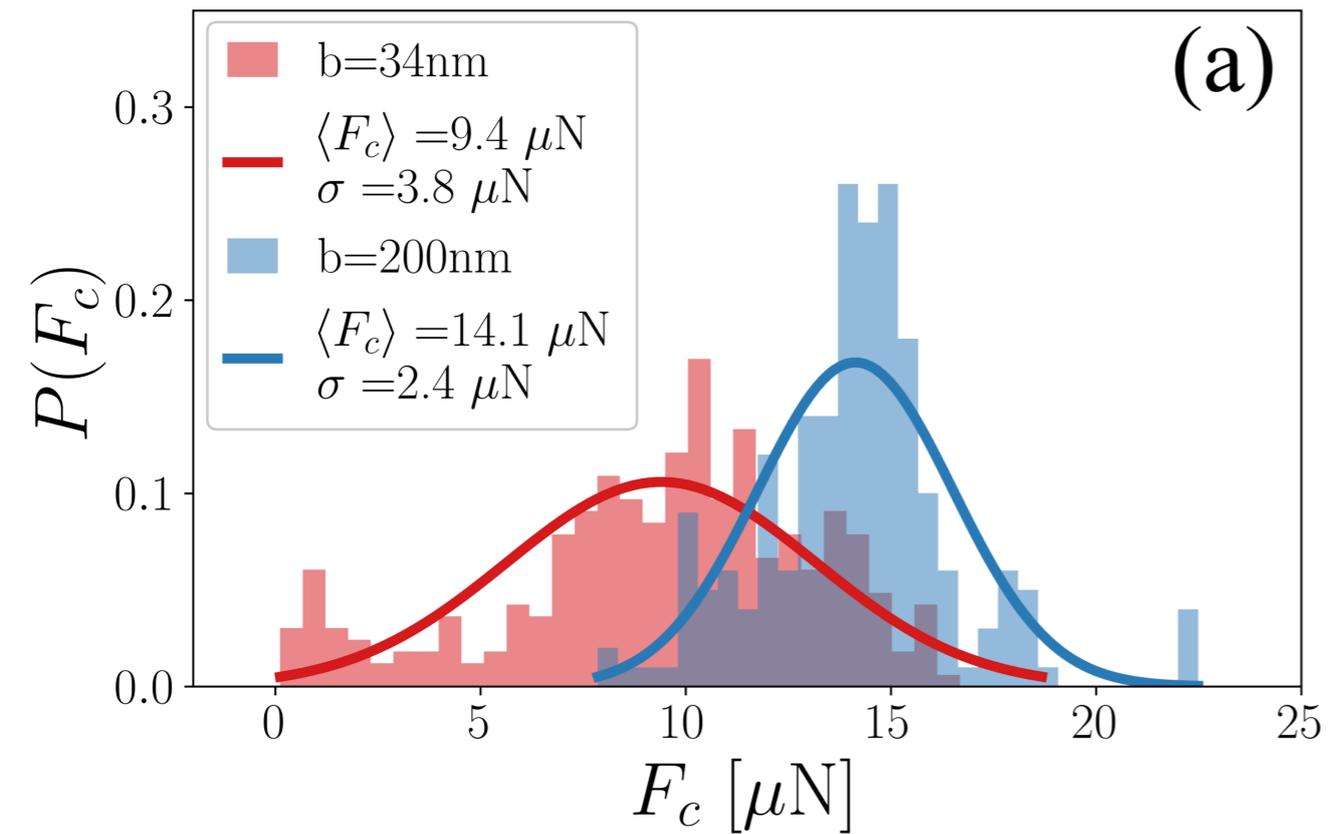


Maxime Lajeunesse



a set up to precisely measure of adhesive force

Maxime Lajeunesse

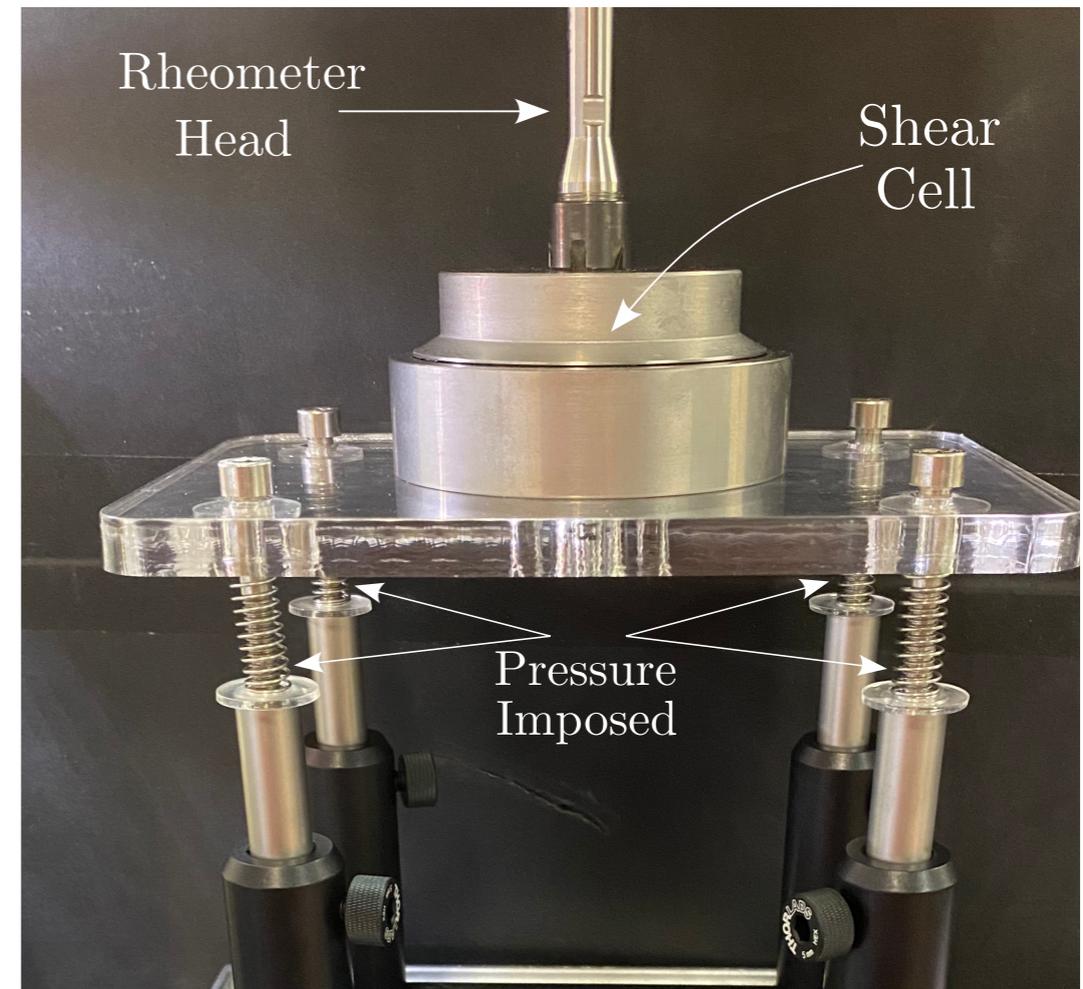
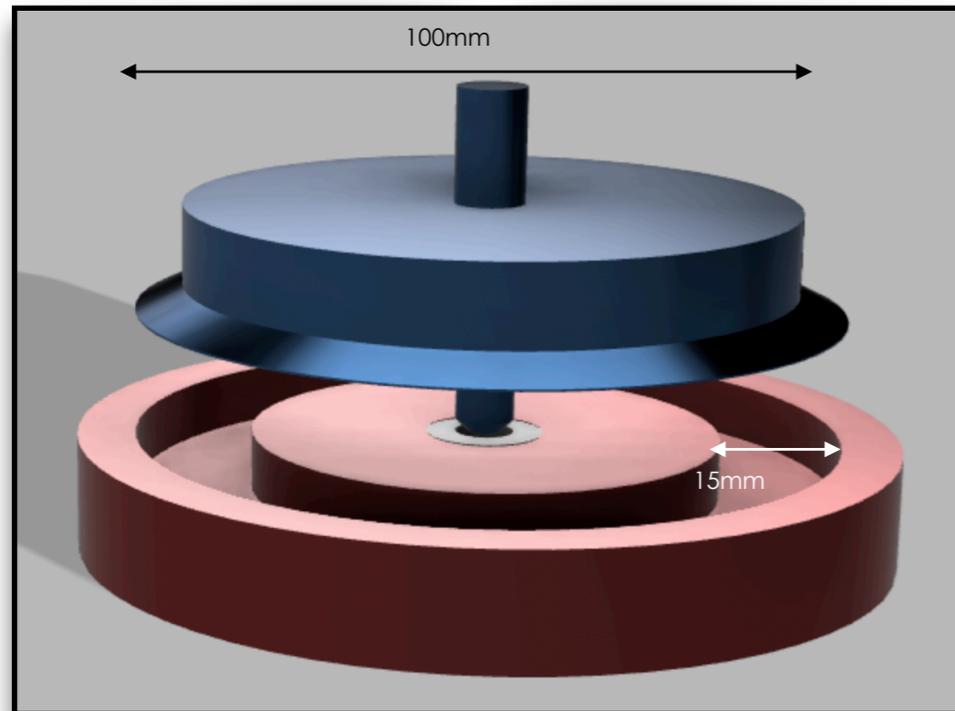


Rheology of fine particles: challenges



Chico Rocha Maxime Lajeunesse

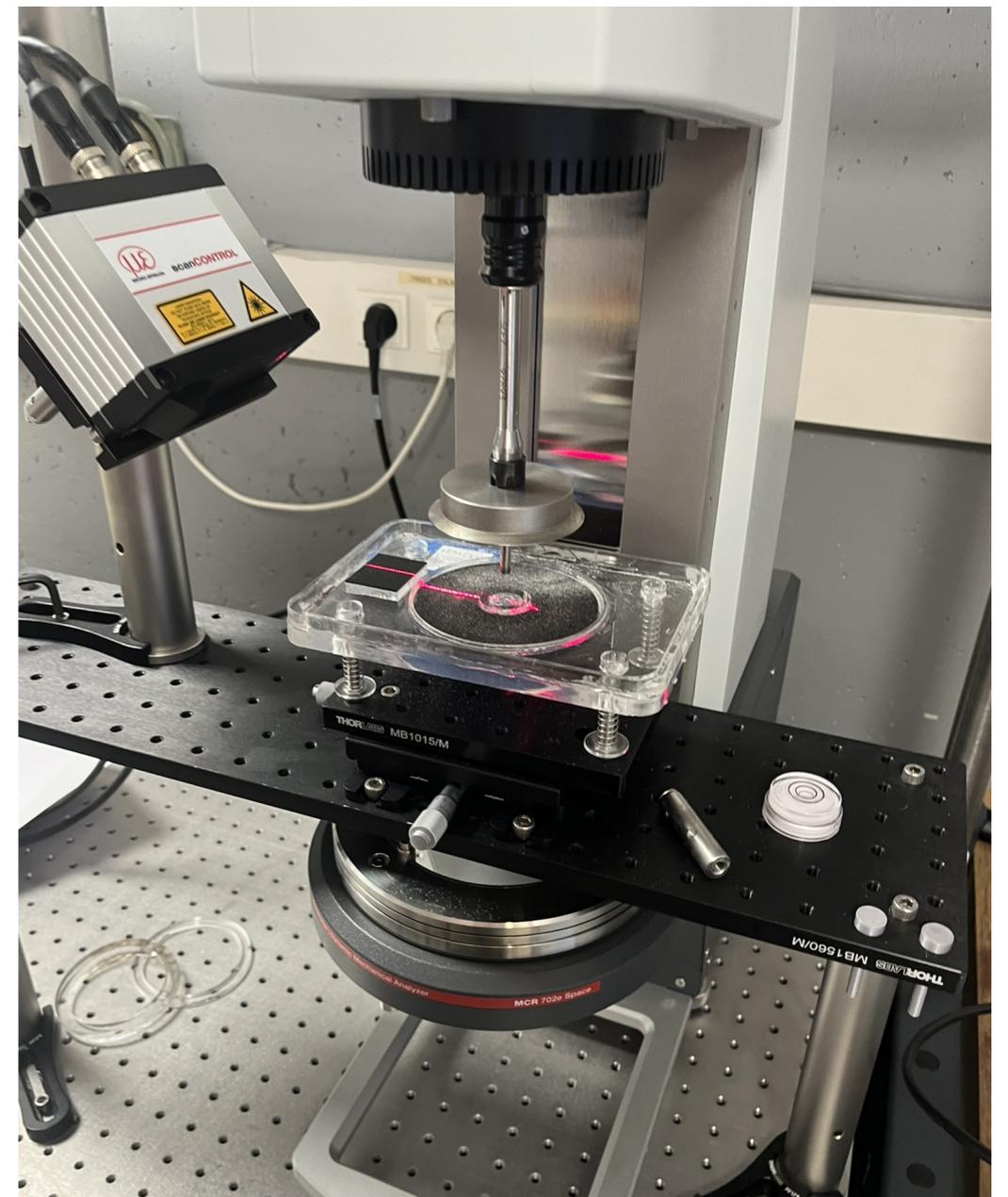
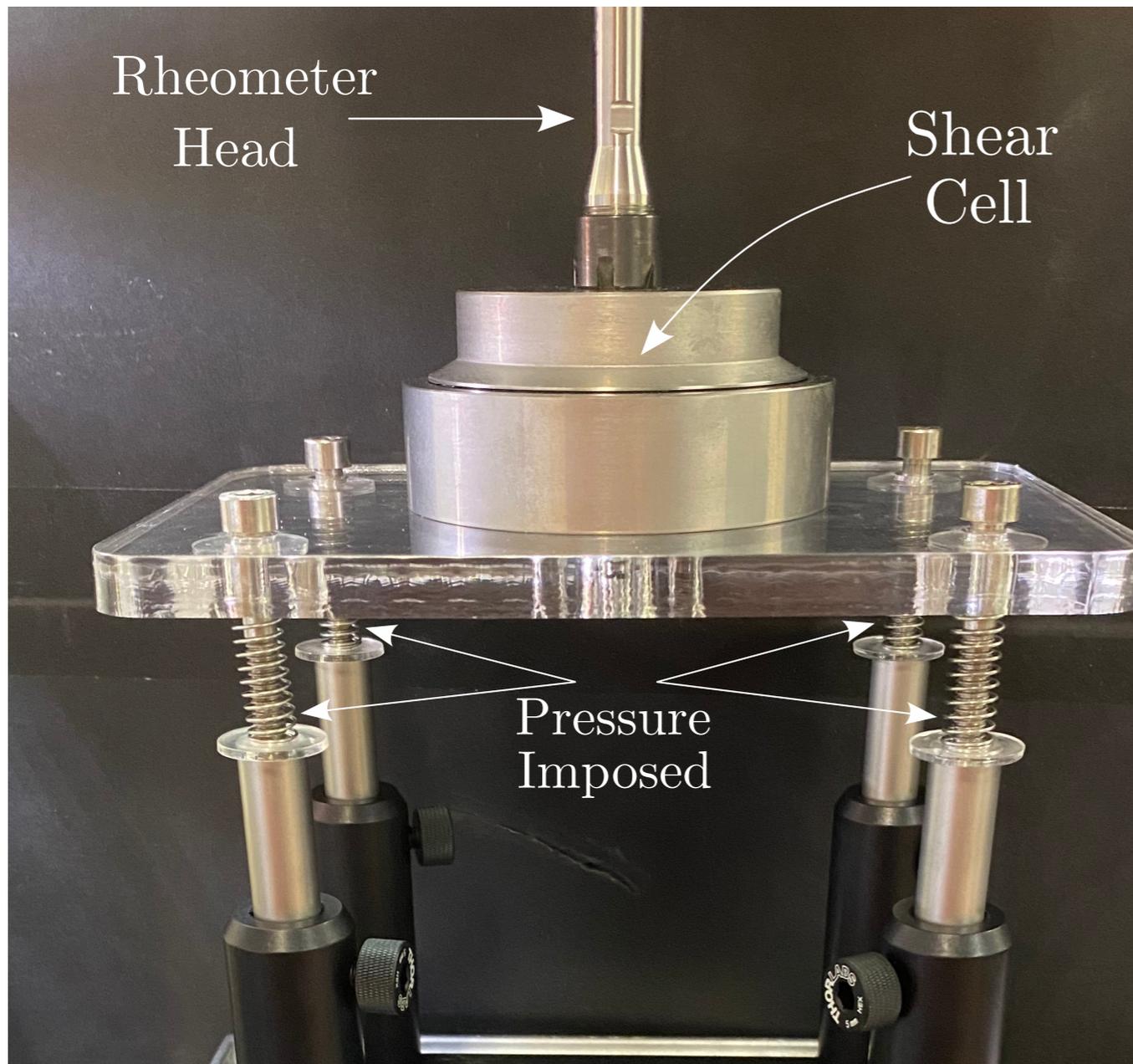
Micro shear cell



challenges:

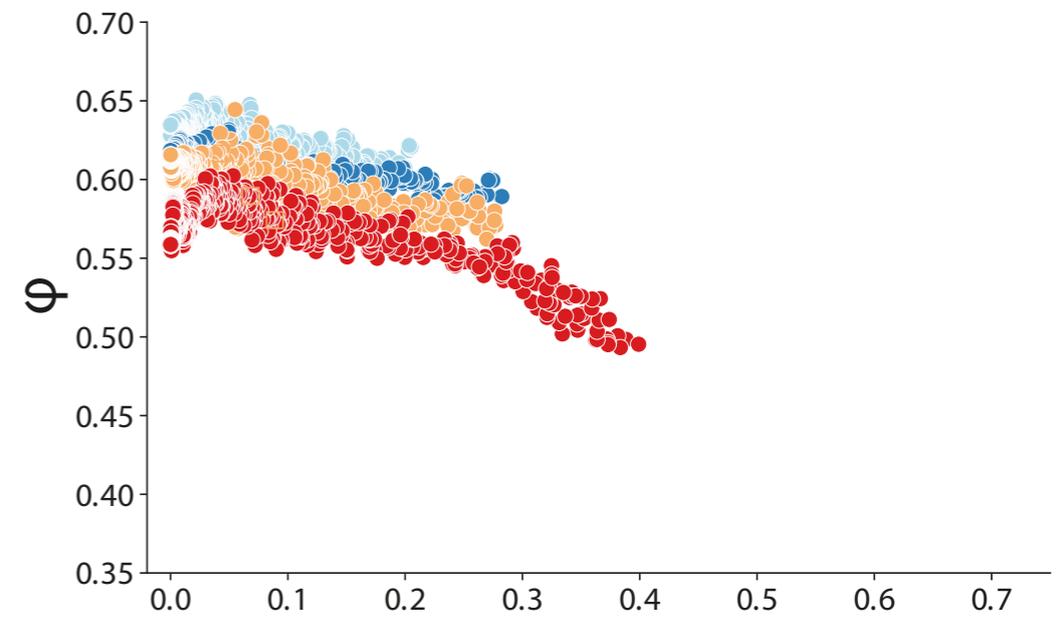
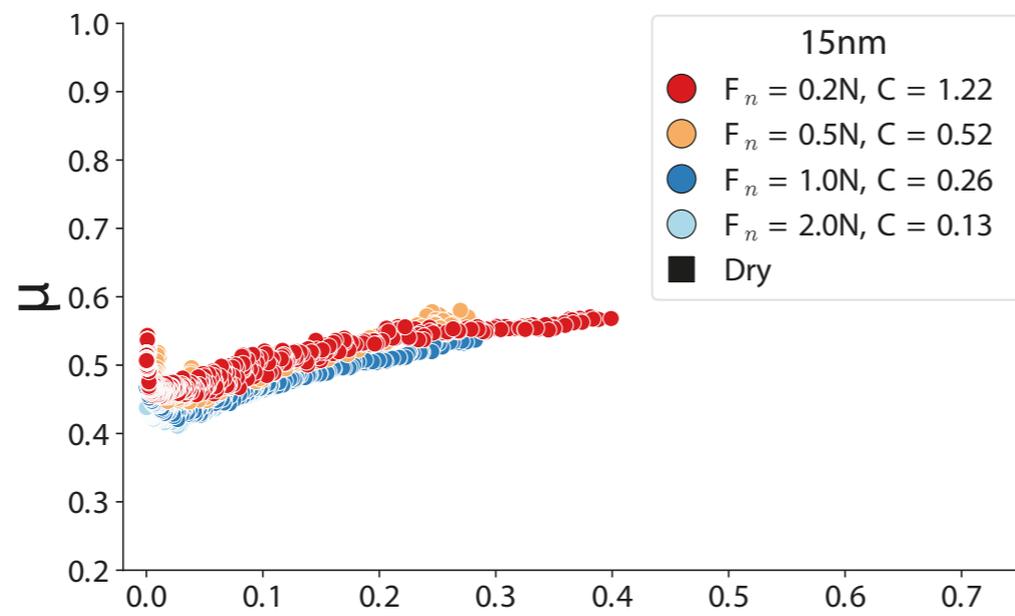
- imposing and measuring low normal stresses (100Pa)
- measuring volume fraction
- prevent leaks between top and bottom parts.

Rheology of fine particles: (for the moment $200\mu\text{m}$)

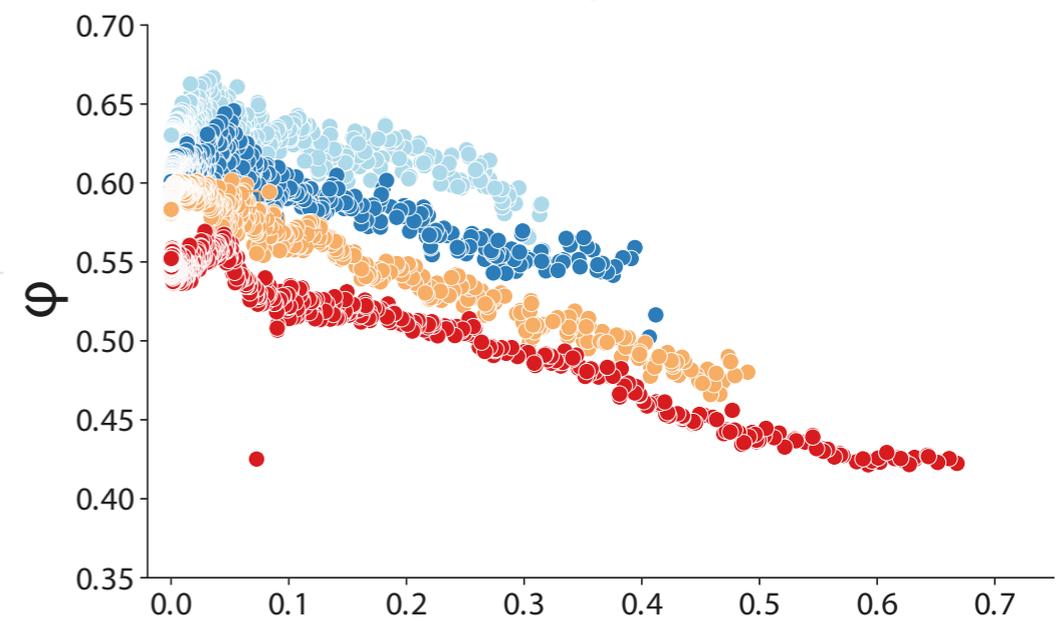
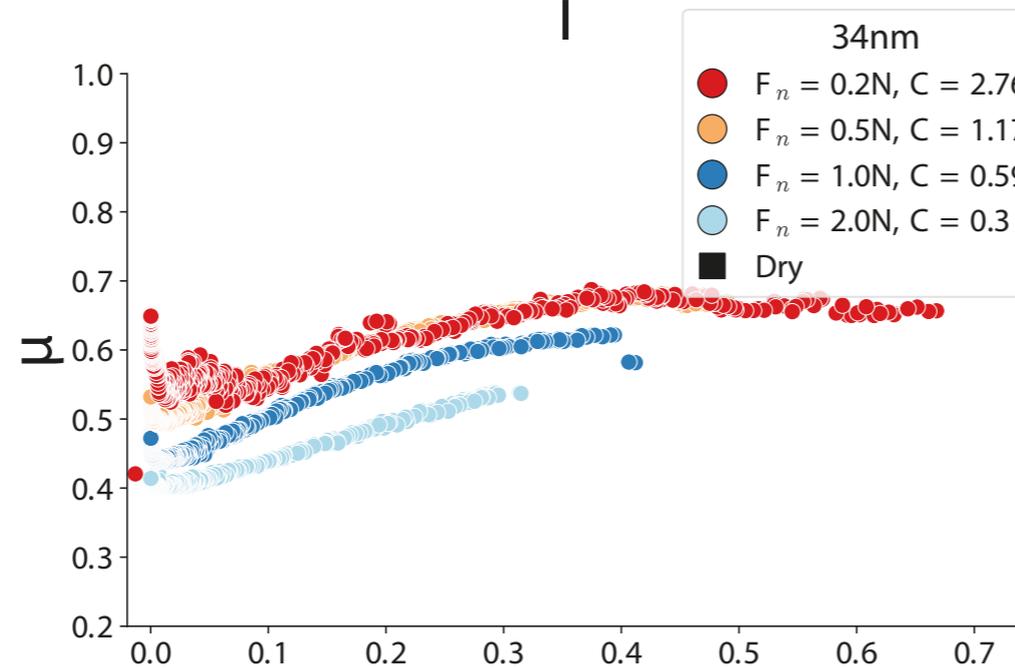


Inertial regime

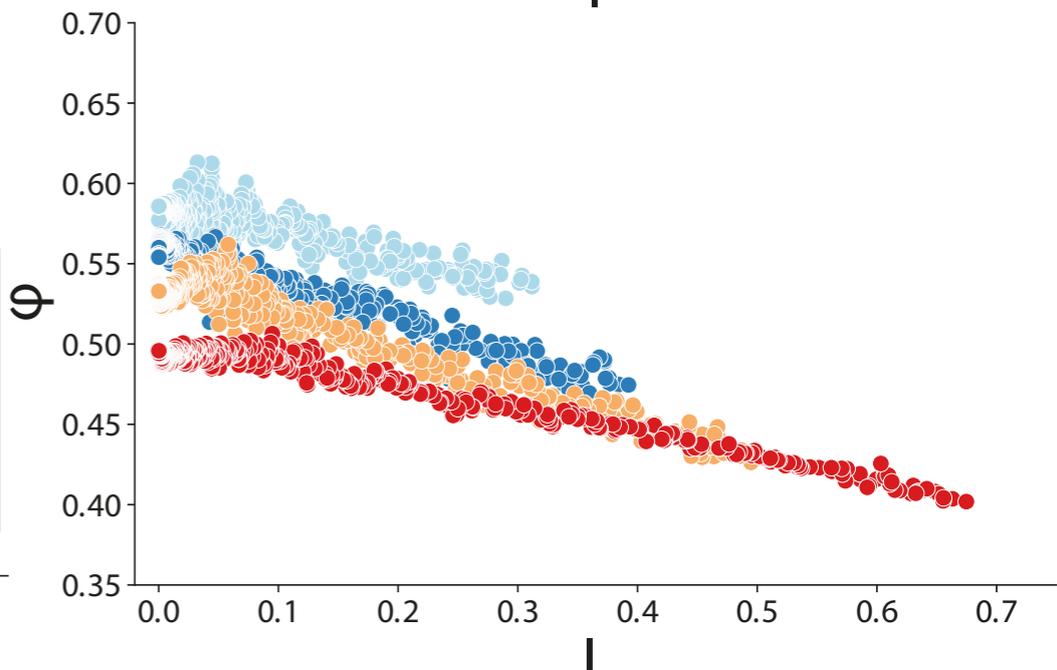
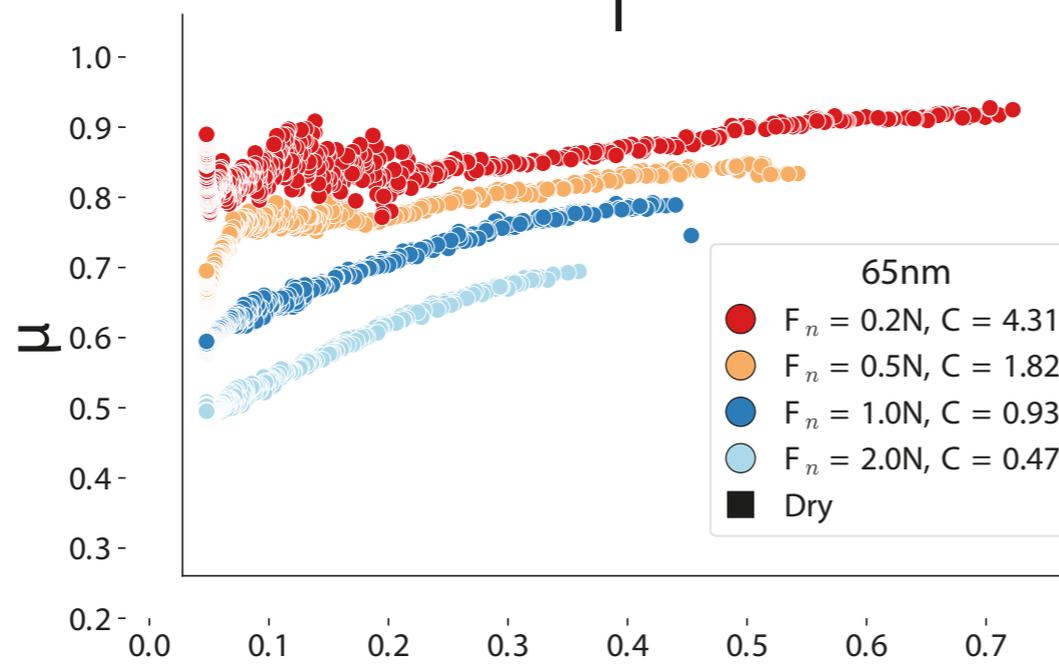
low
adhesion



intermediate
adhesion



high
adhesion



What controls the rheology ?

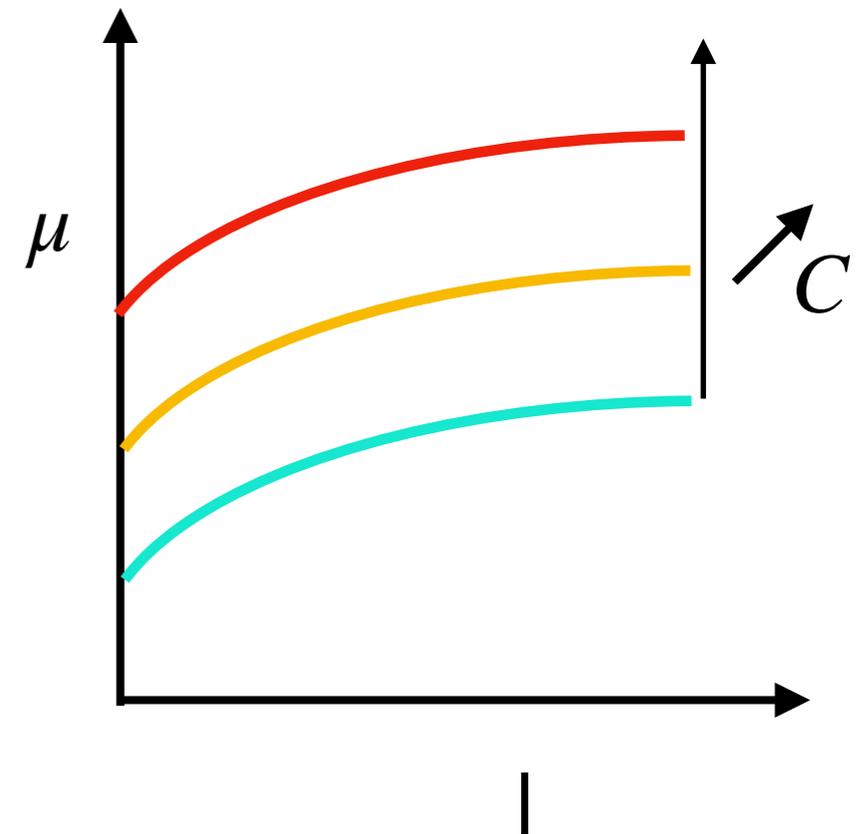
$$I = \frac{\dot{\gamma}d}{\sqrt{P/\rho}} \quad C = \frac{F_c}{Pd^2} \quad \dots?$$

The basic description:

$$\tau = \tau_c + \mu(I)P$$

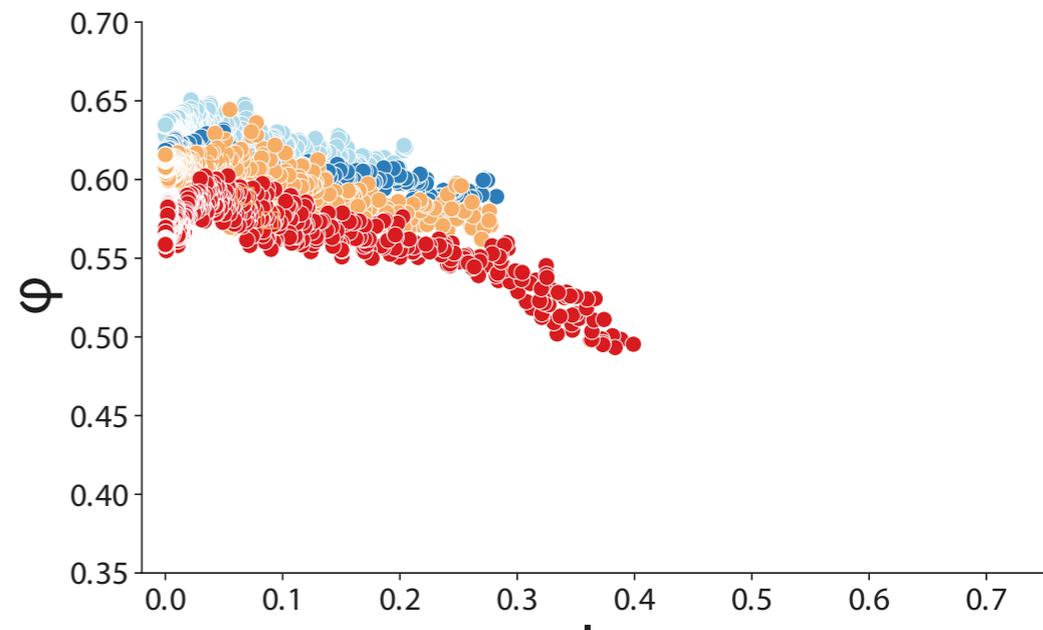
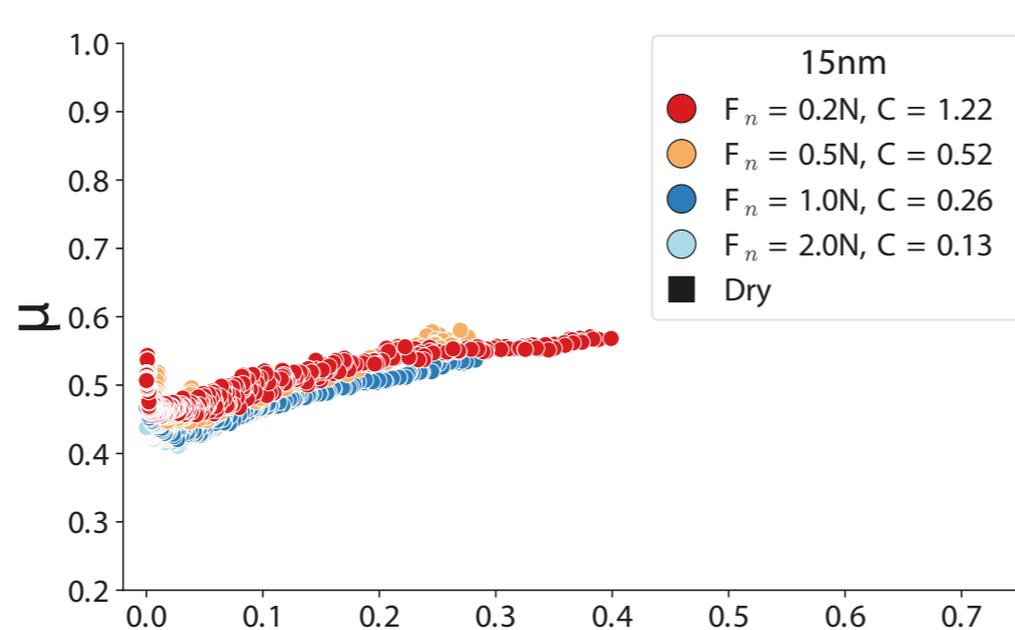
 ↑ ↑
cohesion inertia

$$\mu(I, C) = \alpha C + \mu(I)$$

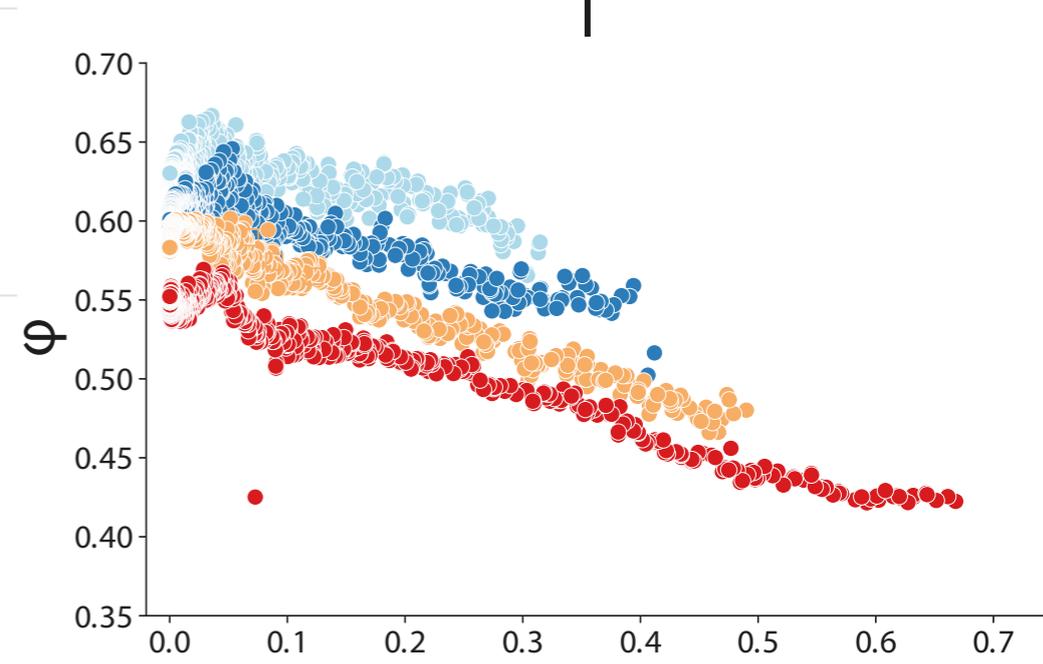
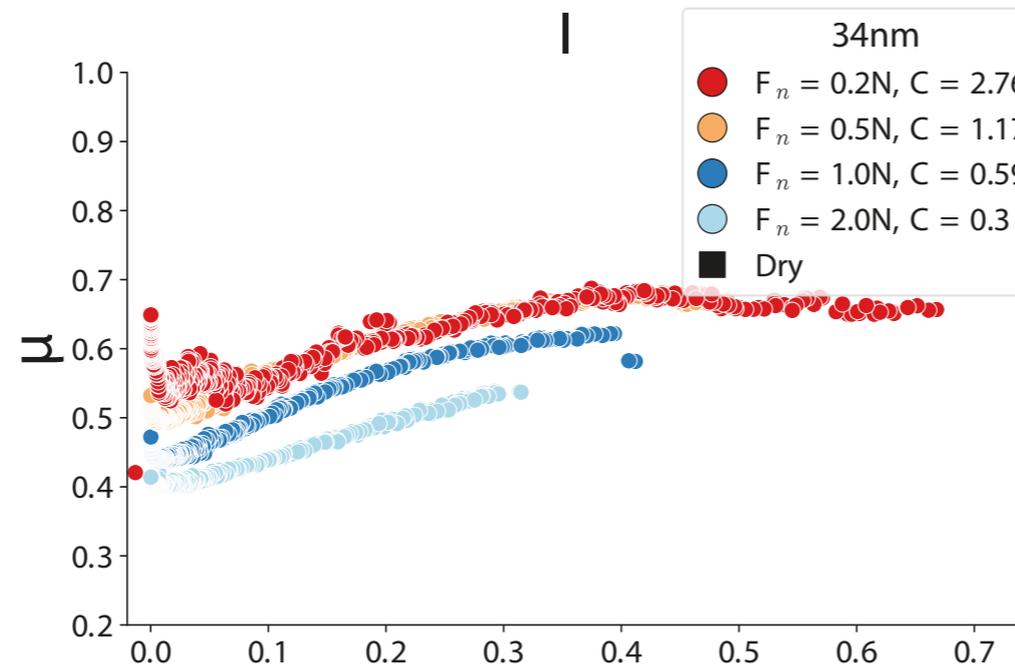


Inertial regime

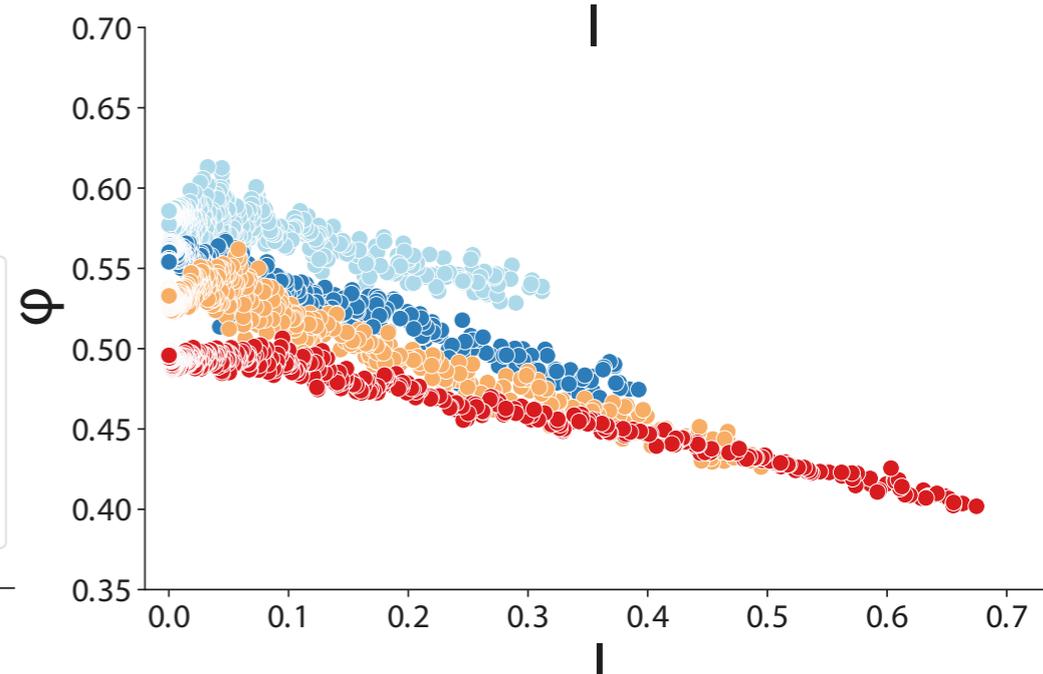
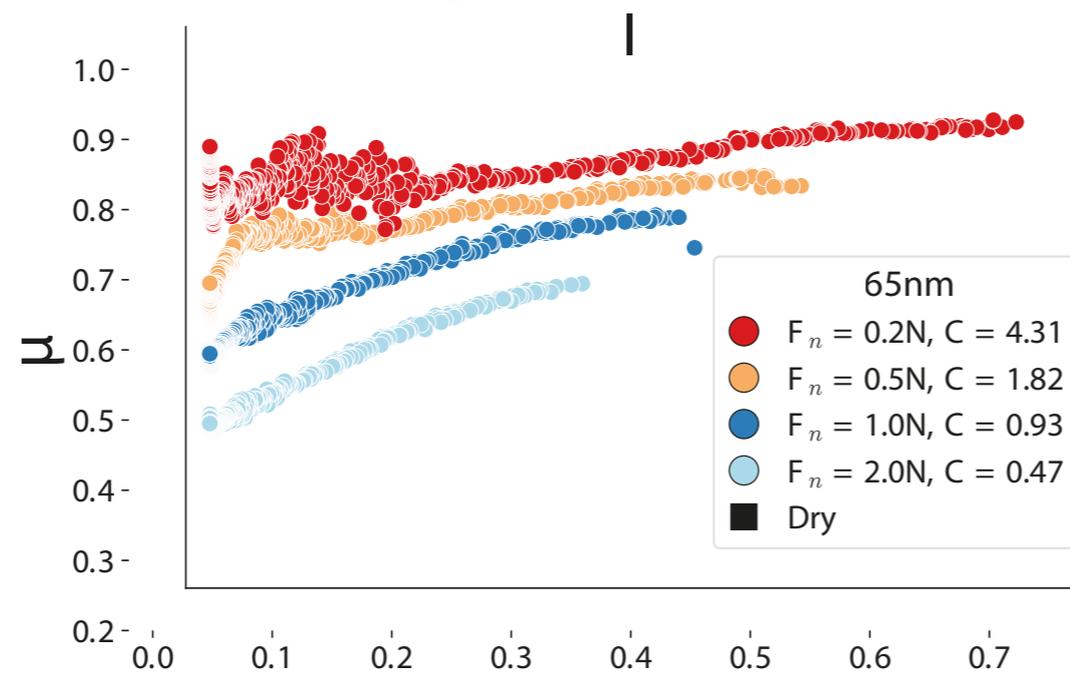
low
adhesion



intermediate
adhesion

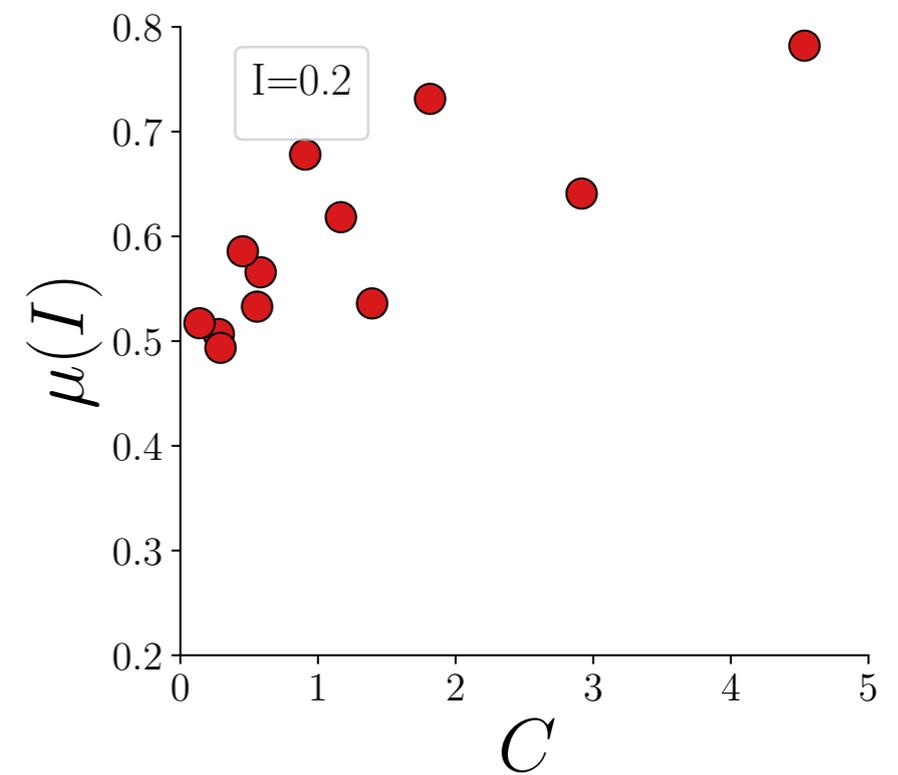
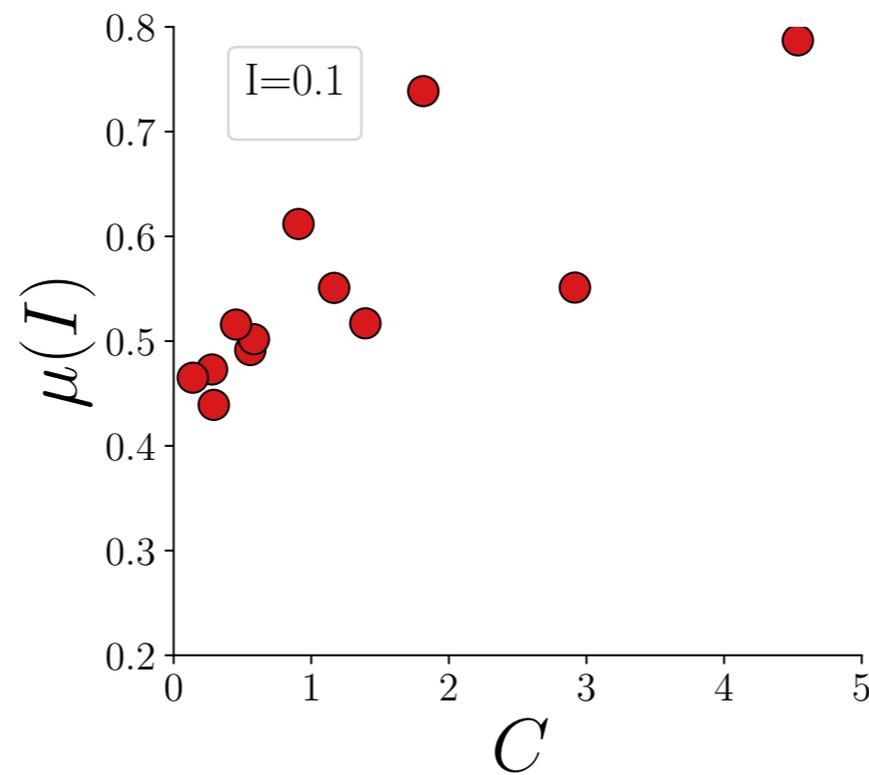
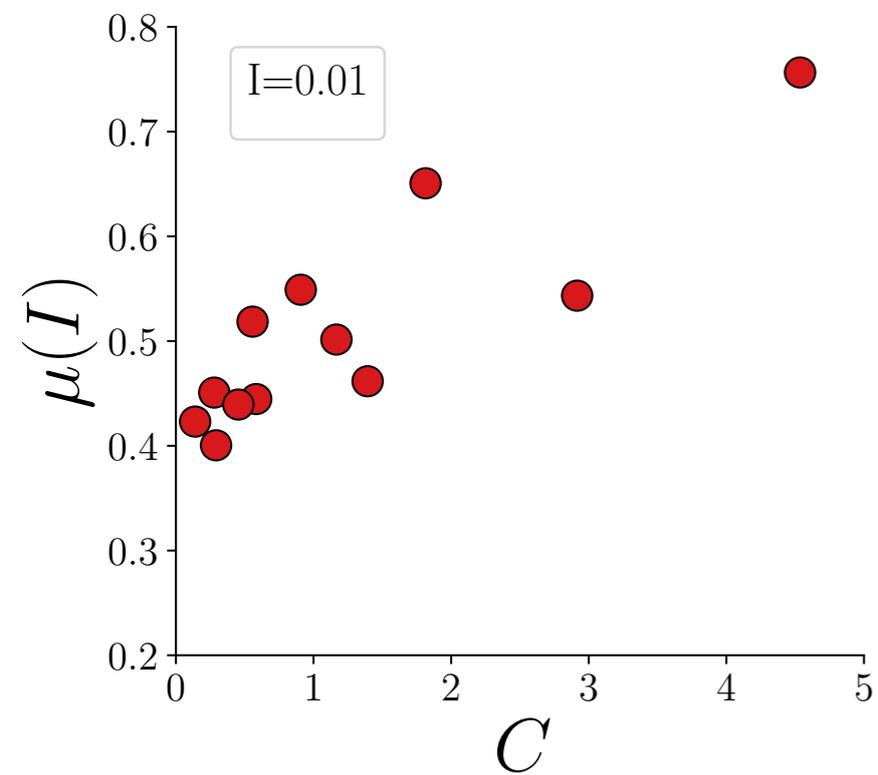
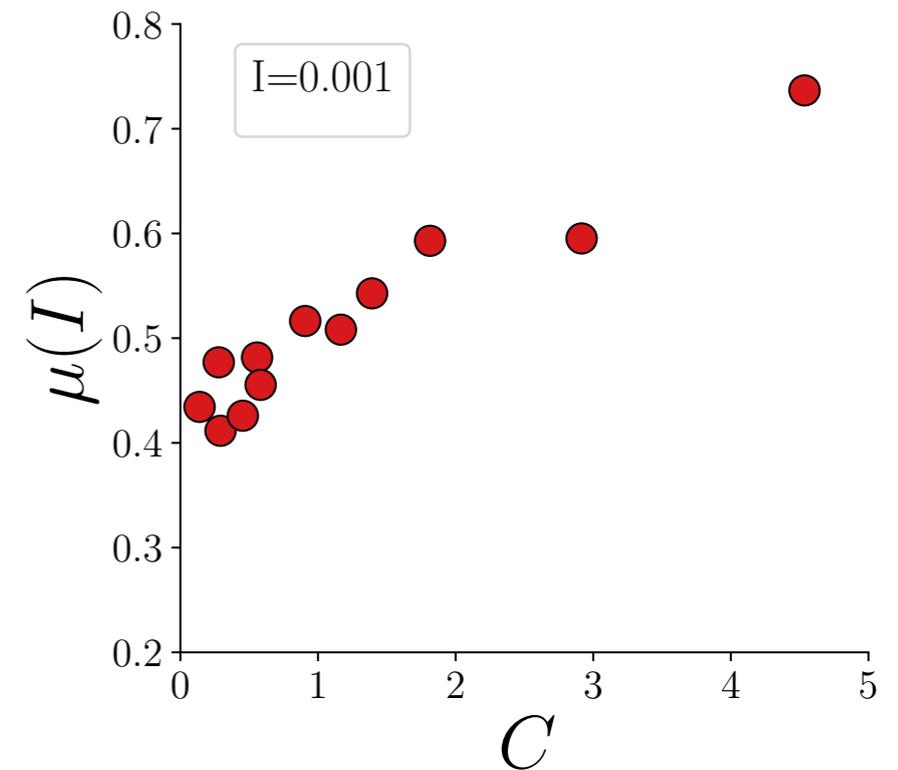
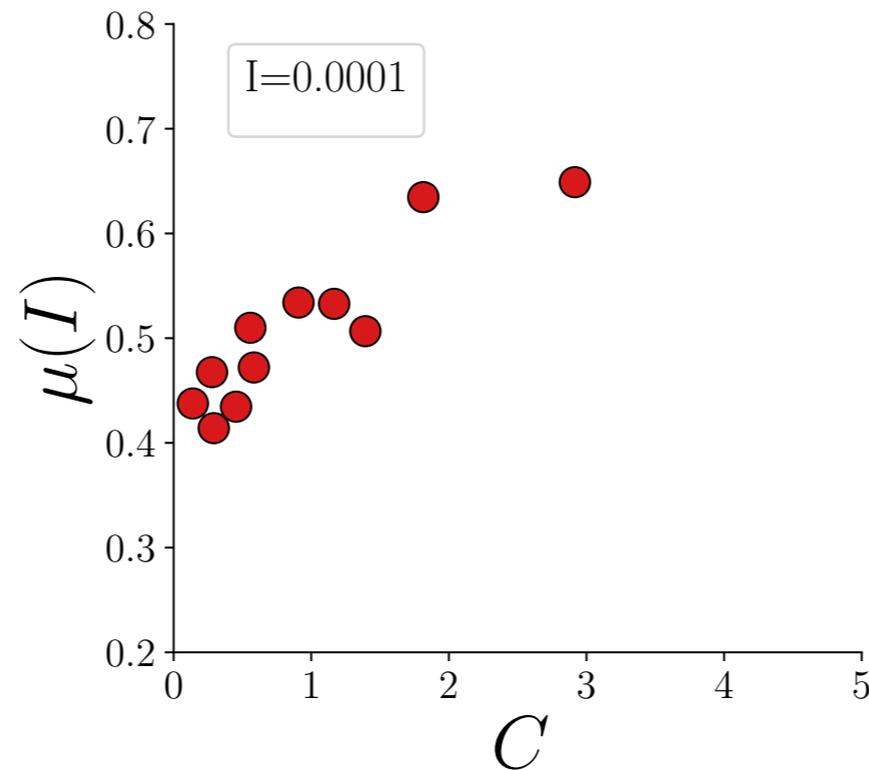


high
adhesion



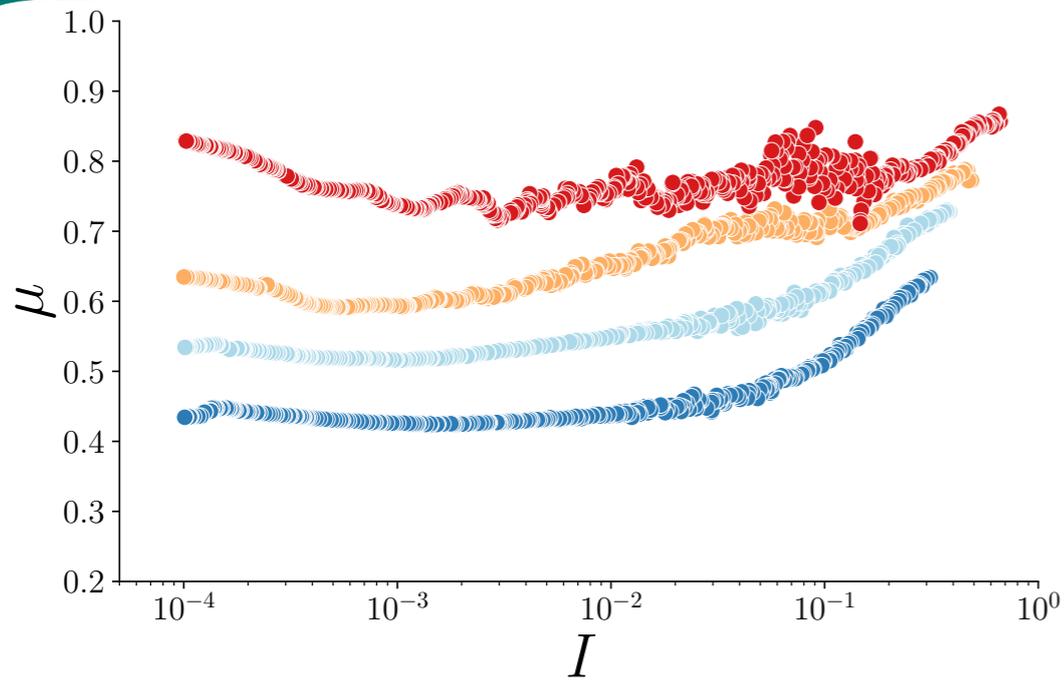
scaling with Cohesive number $\mu(I, C)$?

Not so clear !!!
(especially in the
inertial regime)

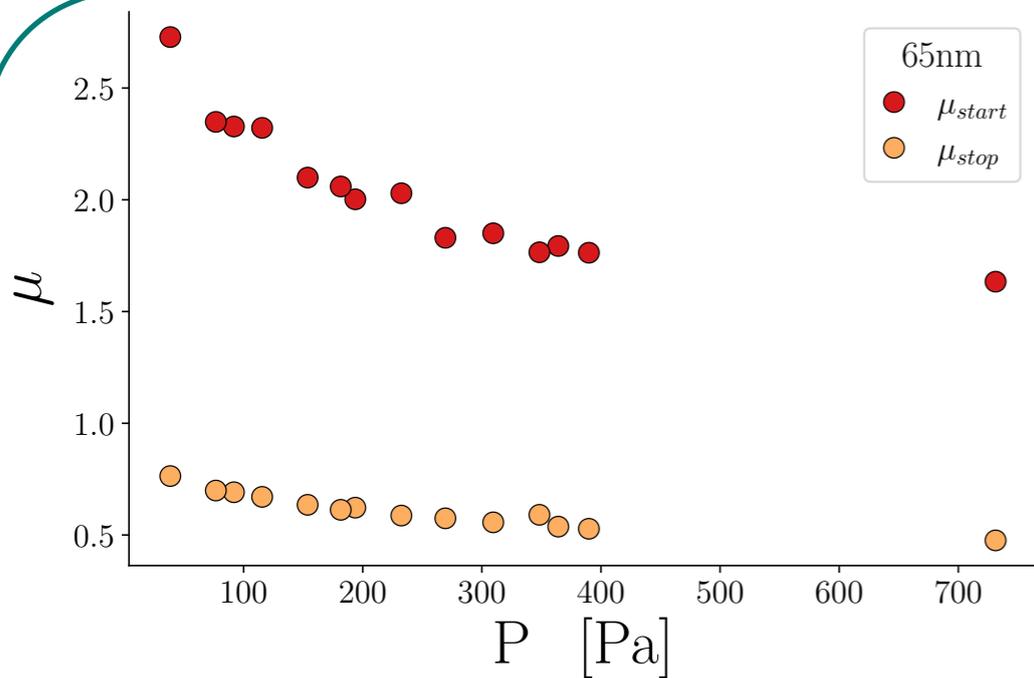


other parameters ?

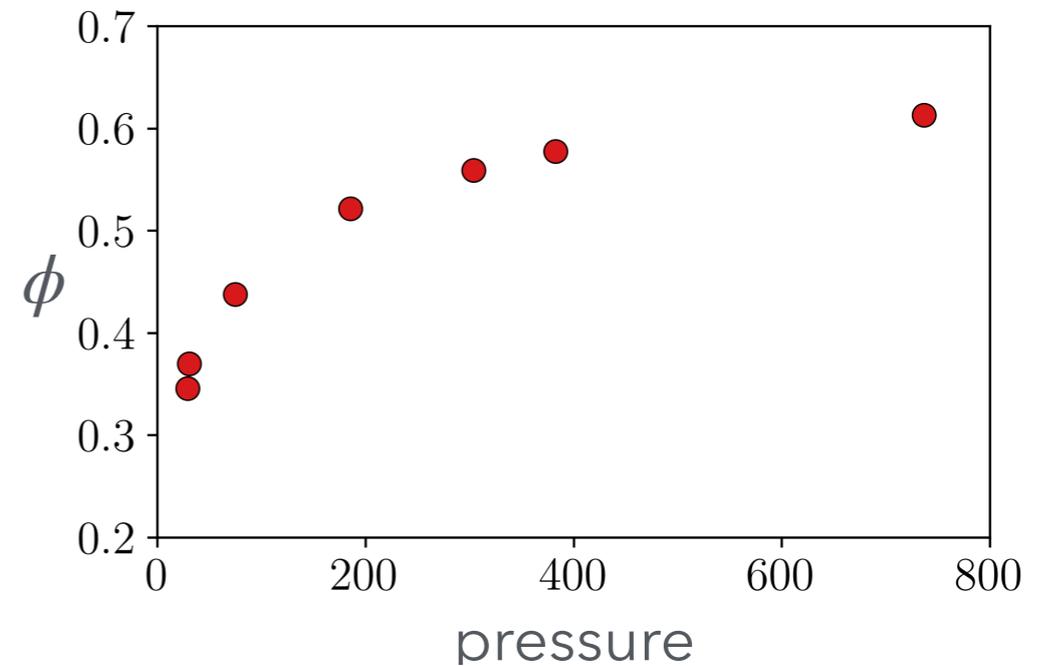
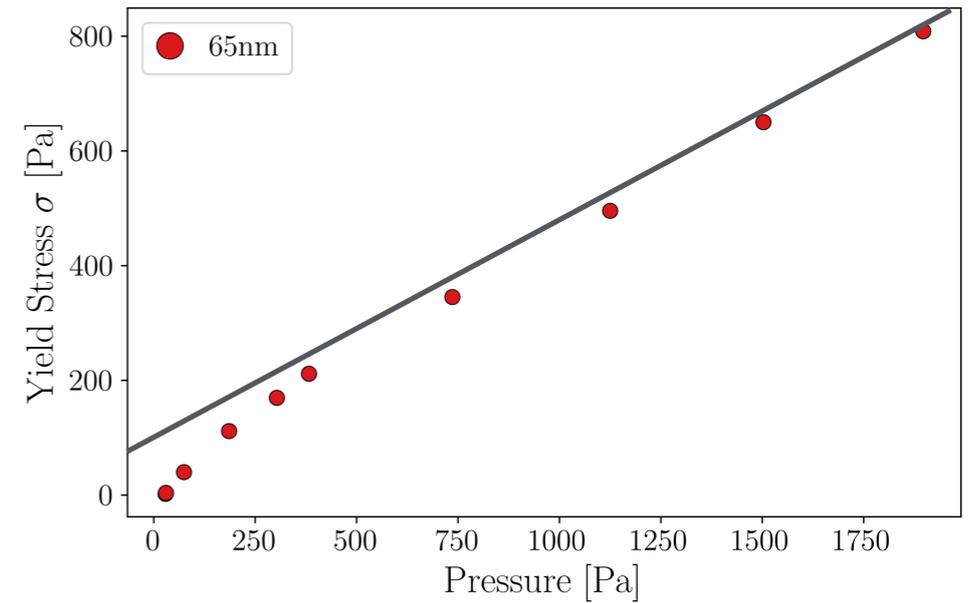
Information about the quasi-static regime...



existence of shear weakening
(to be confirmed...)



strong hysteresis between
static and quasi-static



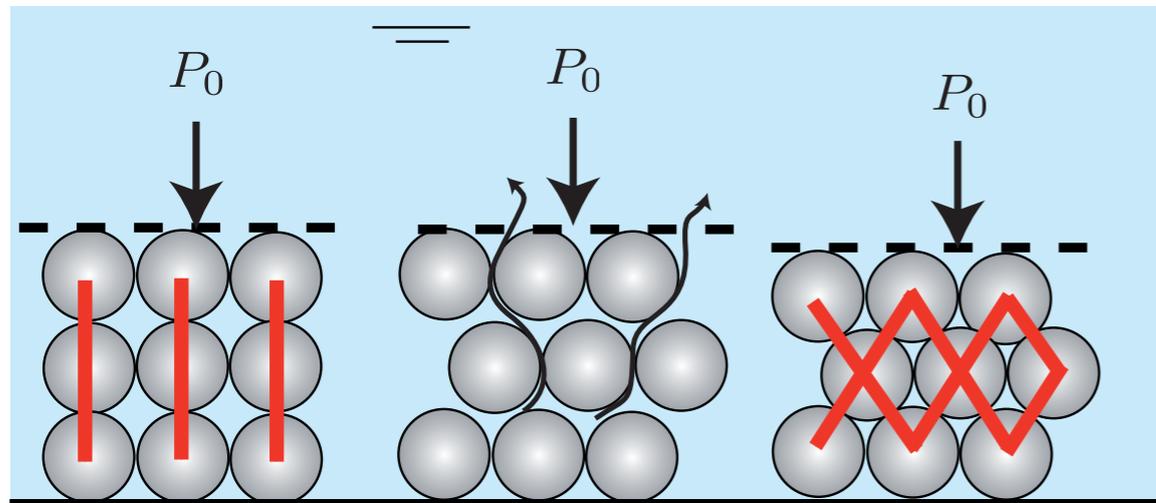
Surprising Critical state
at low pressure

- an original set up to investigate the rheology at low stress in the inertial regime.
- The rheology of low-stress cohesive materials is more more complex than originally thought !

aeration => desaeration

a link with liquefaction ?

liquefaction phenomena:



$P^p = P_0$
 $P^f = 0$

$P^p = 0$
 $P^f = P_0$

$P^p = P_0$
 $P^f = 0$

granular=> suspension=>granular



With powders in air ?

small size

=> coupling with air

help instability

cohesion:

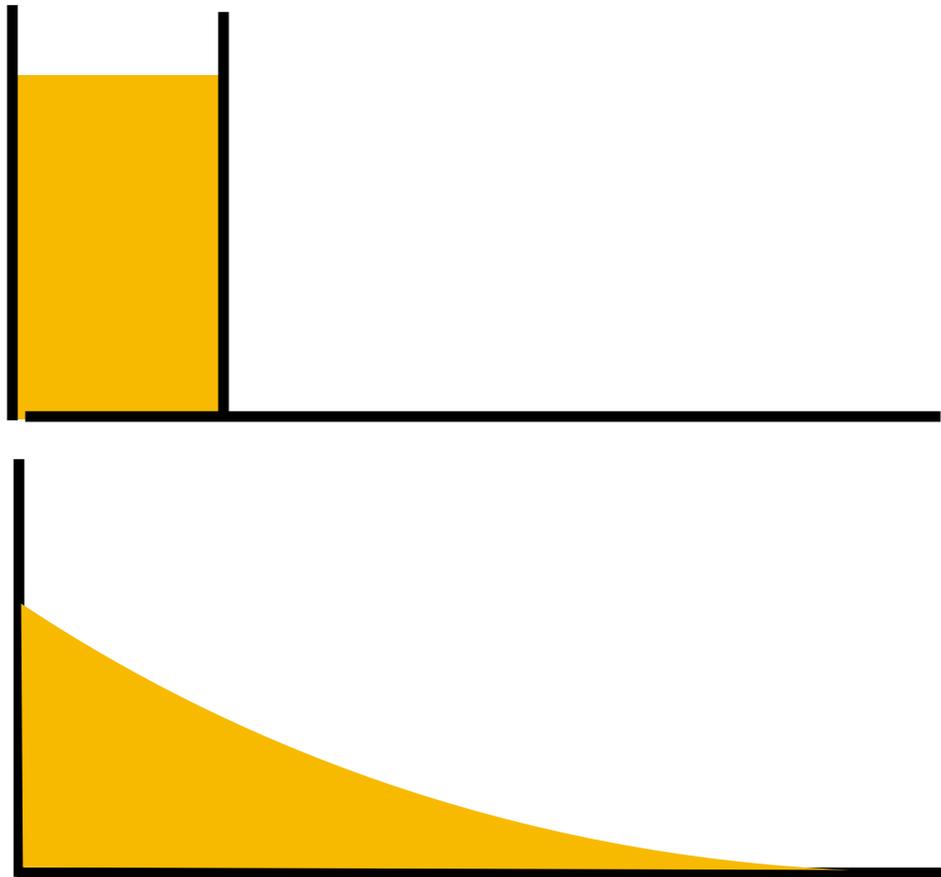
=> add strength

attenuate instability

=> loose state

help instability

a simple configuration:
Powder collapse with different initial preparations



Control parameters

$$C = \frac{\tau_c}{\rho g H}$$

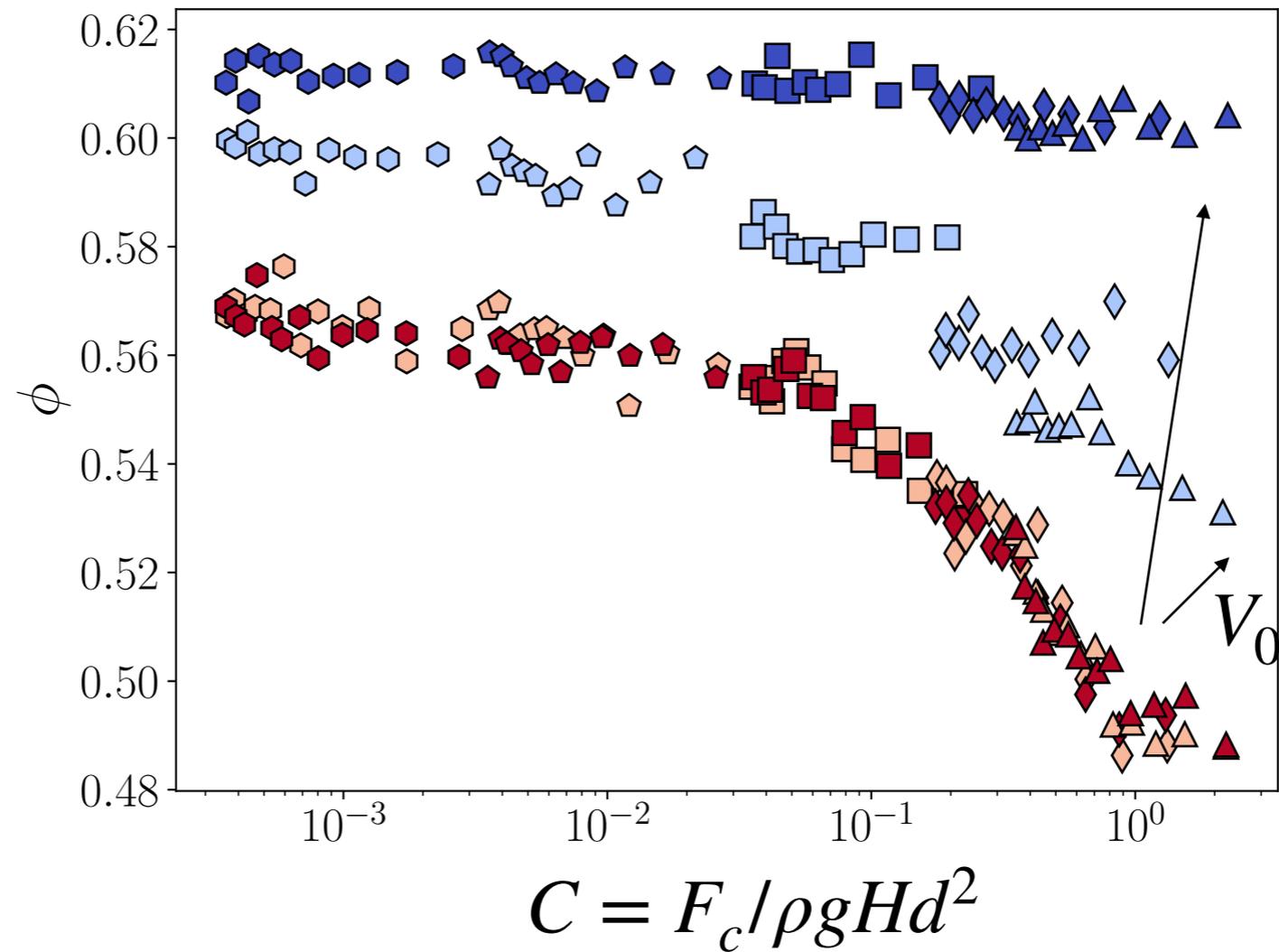
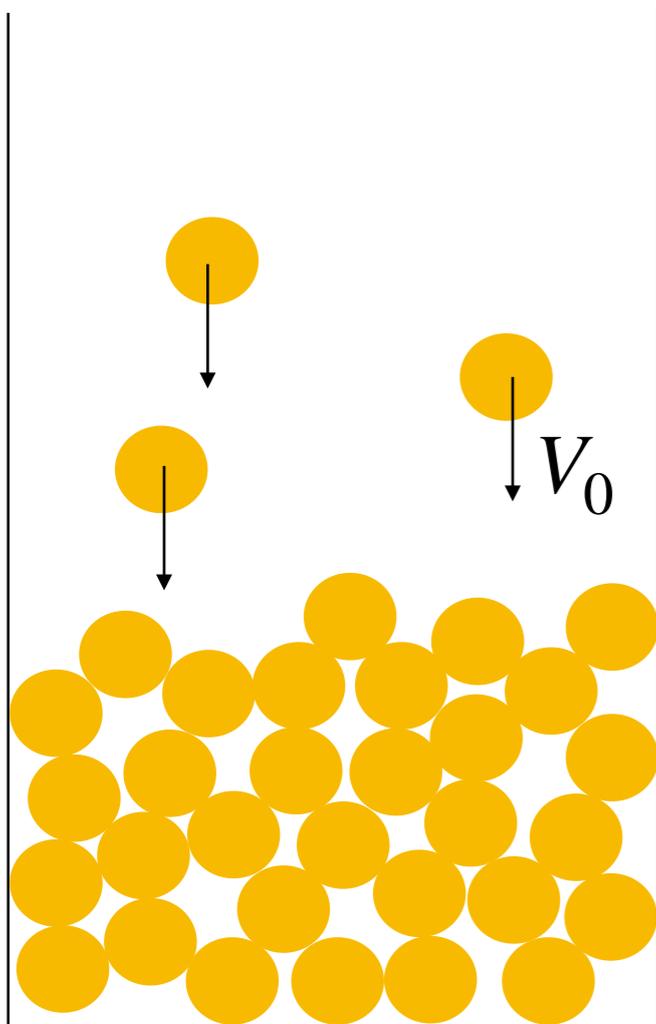
$$F = \frac{P_f}{\rho g H} = \frac{\eta_{air}}{\rho d^2} \sqrt{\frac{H}{g}} f(\Delta\phi)$$

$$\phi_{init}$$

Flow
+
compaction/dilatation
+
air coupling

Rheology?
+
volume fraction
dynamics of
cohesive materials?

a first step: understanding the preparation



-Role of cohesion

-Role of launching velocity

Liu et al Pow. Tech 2016

futur work:

rheology:

- change materials, cohesion type,
- try to understand the other control parameters (adhesion energy?)
- find a way to analyse smaller particles (Toward type C)
- understand the link with other rheometers (rotating drum, FT4,..)

aeration/desaeration :

- collapse experiments with controlled fine material to disentangle the role of auto-fluidisation and cohesion...