# Granular flow experiment designed to extract avalanche friction law parameter

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# General objectives

**St Venant Model**

Solve : h, <V>
Need : Rheology

**Bi-plan flow**

Give : h, <V>
Constrain: Rheology

**Inversion Method**

Compare : Model/Experiment

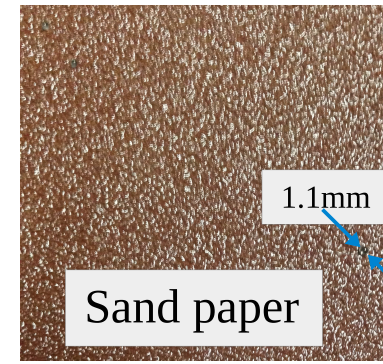
**Flow on inclane plane**

→ External and independant measurement of the rheology

# Flow on a bi-inclined plane

Granular flow on rough plane:

- Mono-disperse glass beads 1.1mm in diameter
- Roughness : Sand paper (typical roughness 250µm)

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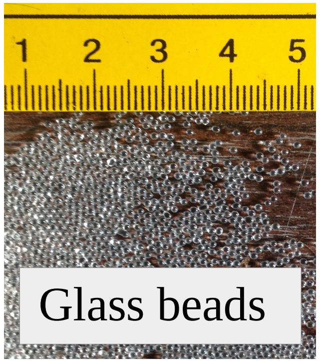
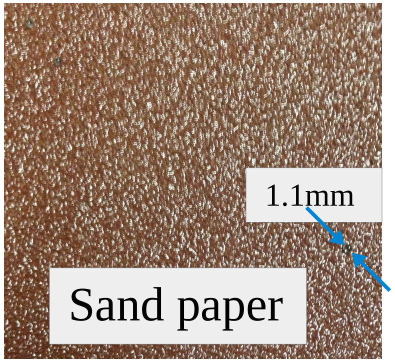
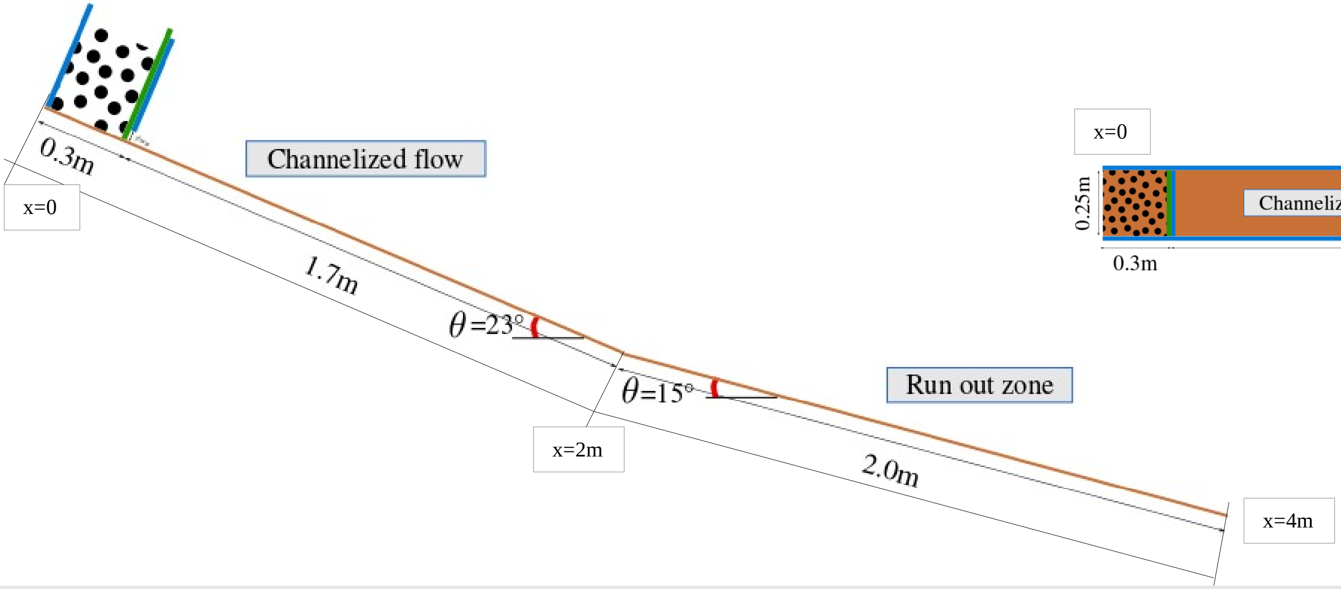
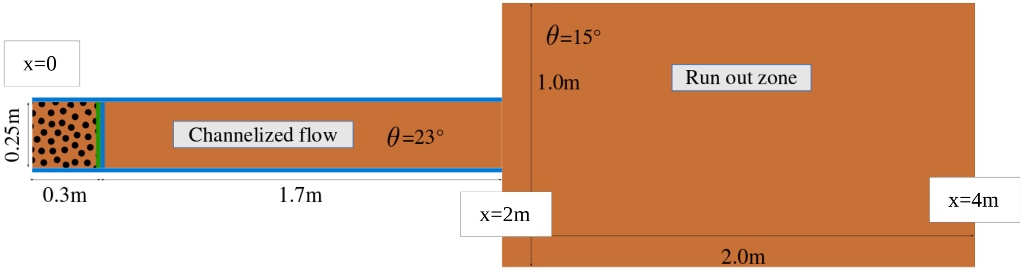


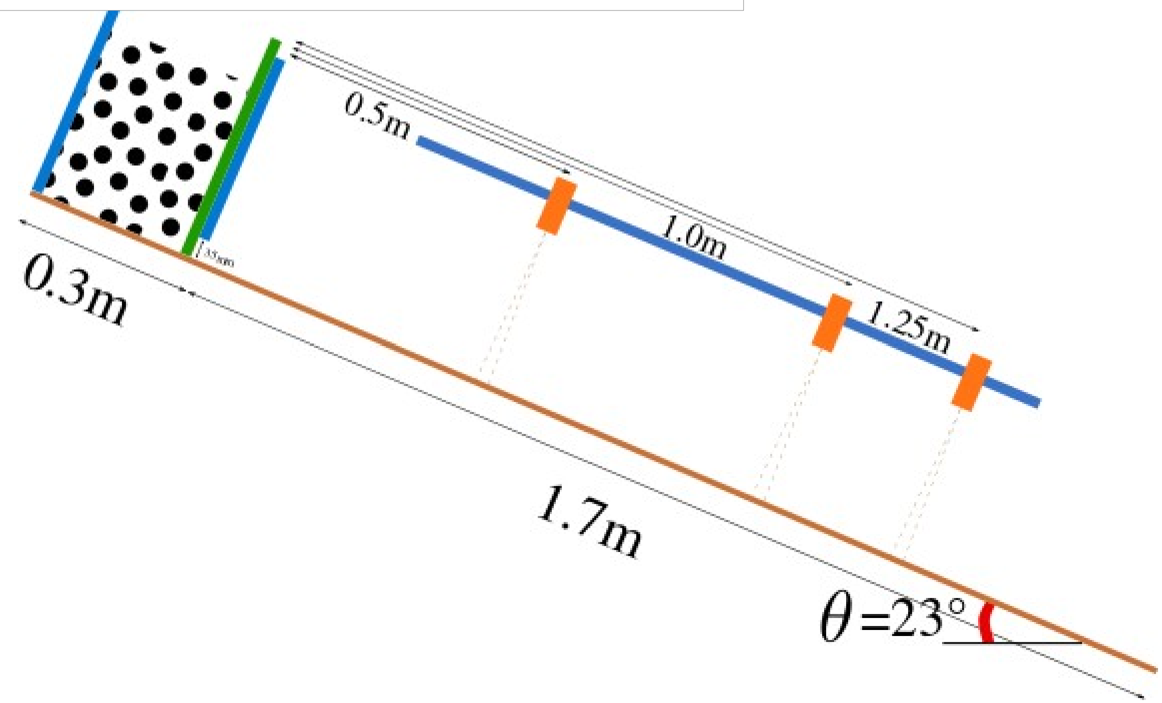



# Measurement

Upper channel:

→ Thickness: 3 optical sensors.

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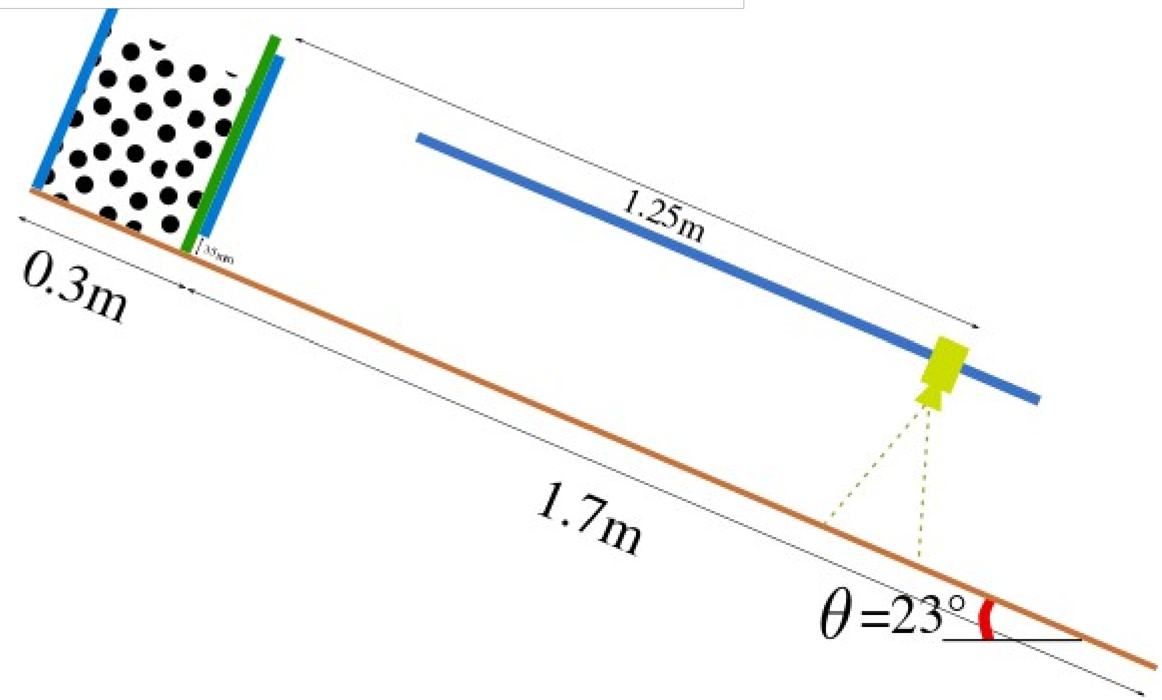
# Measurement

Upper channel:

→ Thickness: 3 optical sensors.

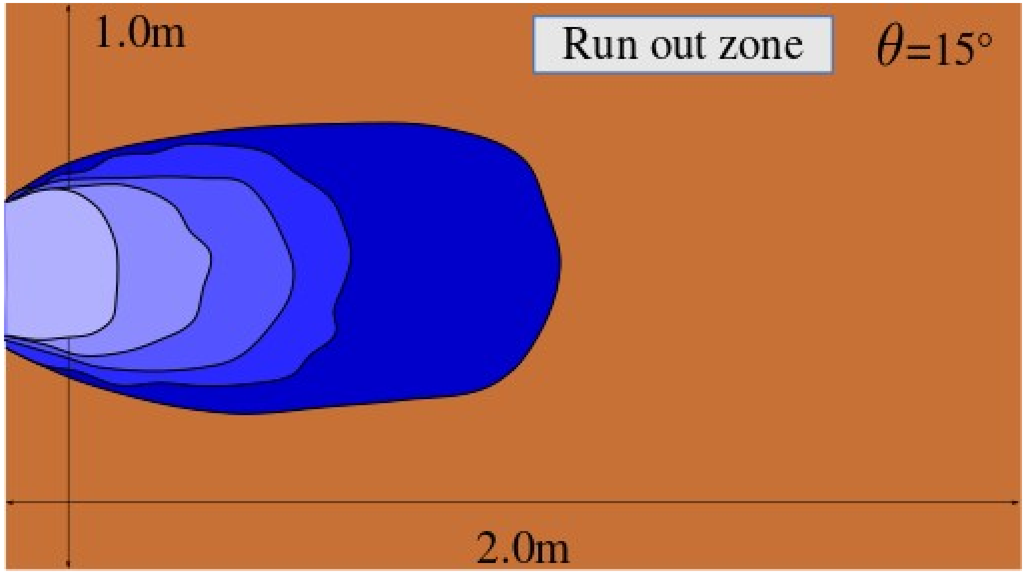
→ Velocity: Granular PIV (High speed camera)



# Measurement

Run out zone:

→ Front velocity: Image processing

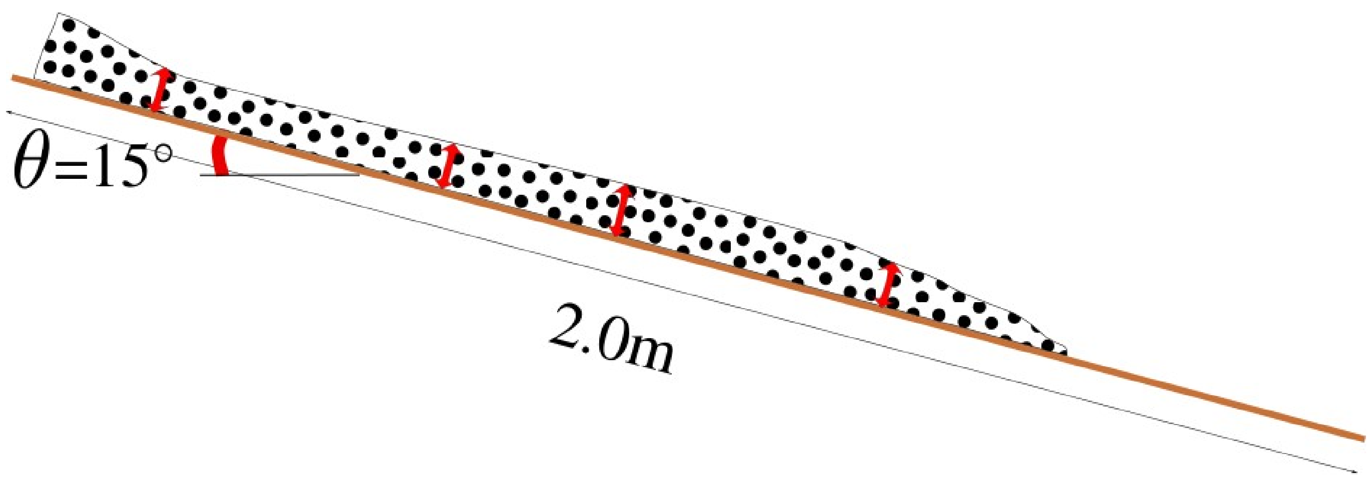


# Measurement

Run out zone:

→ Front velocity: Image processing

→ Thickness of the deposit: Fringe projection measurement



# 24 flows in the same condition

Repeat the same test in the same condition:

→ d = 1.1mm and constant roughness

→ Initial mass: 12kg of glass beads

→ Constant slope of the 2 plane (23°-15°)

→ Constant temperature and humidity

→ Static electricity control

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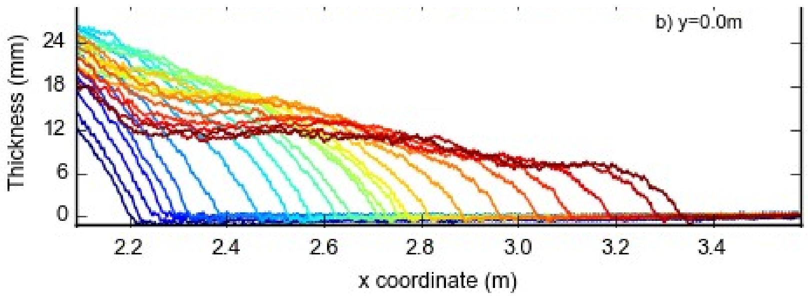
**Drastic evolution of the flow**

→ Example: Run out distance




Solution to get stabilise flow:
→ Pre-flow in a rotating drum

# Measurement: Thickness

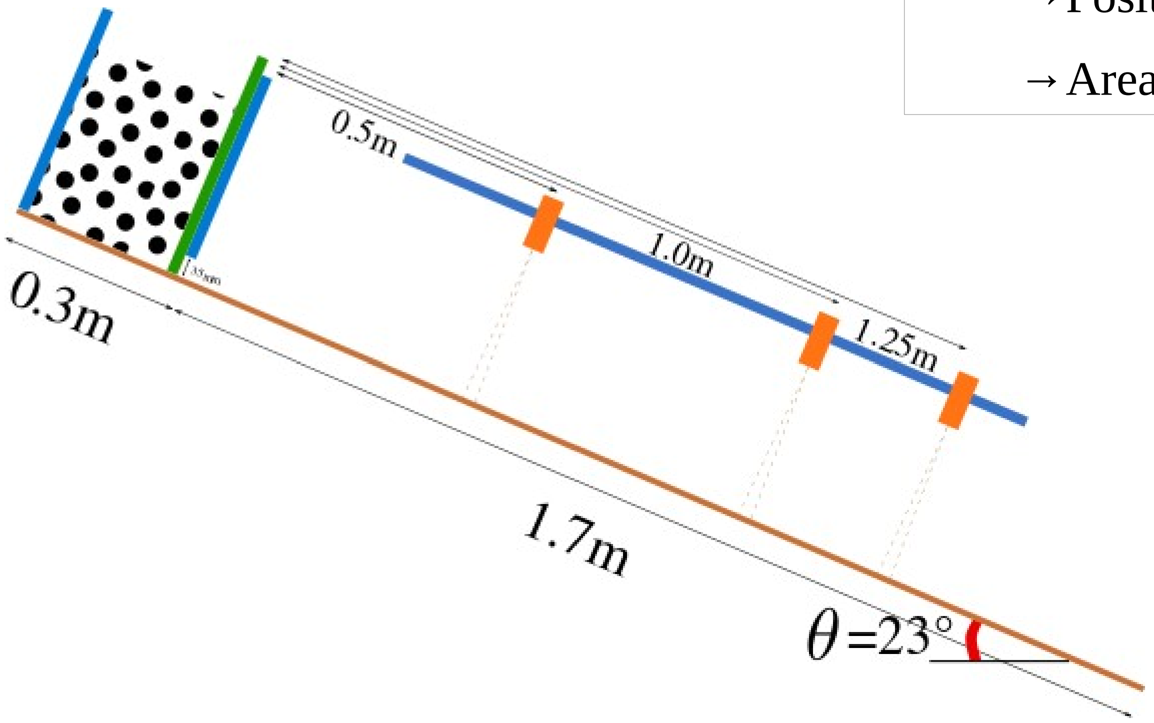
3 Optical distance sensors: ODS 96B M/V6-600-S12

→ f = 100Hz

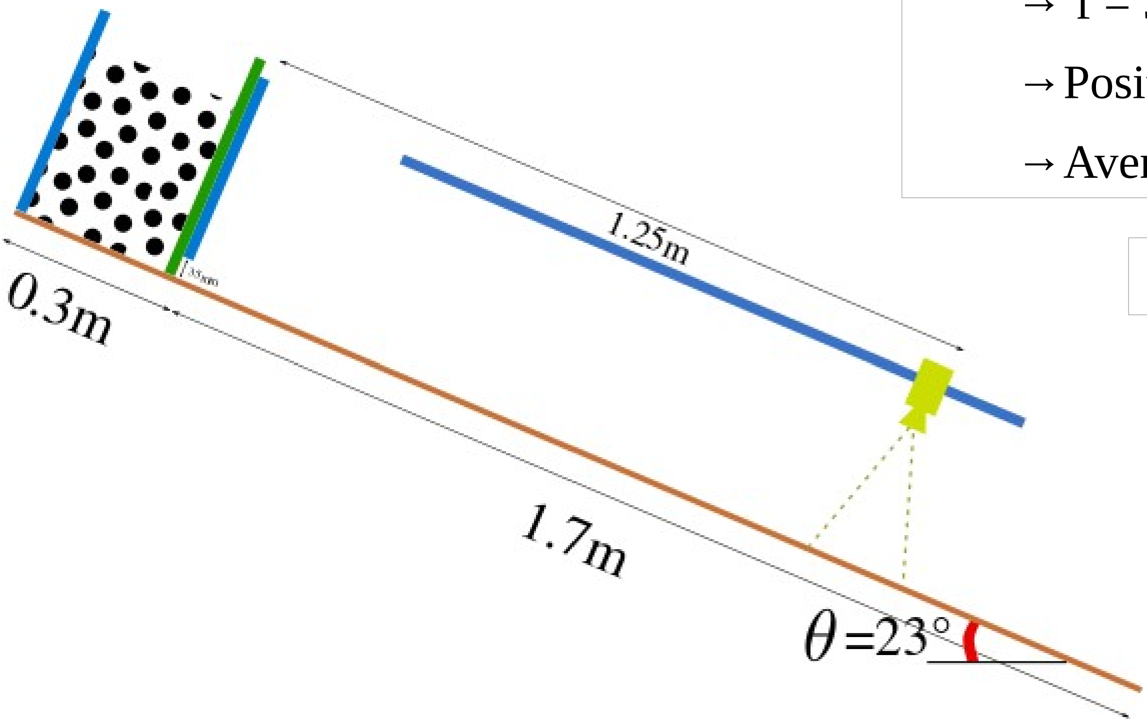
→ Special calibration for glass beads (transparent)

→ Position in the channel: x = 0.5m – 1.0m – 1,25m

→ Area of measurement: 1-4cm$^2$




# Measurement: Velocity




Granular Particule Image Velocimetry (PIV):

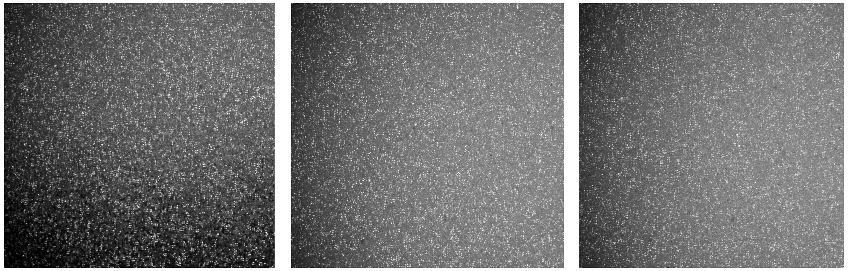
→Acquisition of image: High speed Camera (Baumer HXC13) + 35mm f2.8 lens (Nikon Nikkor)

→ f = 300Hz

→Position: x= 1.25m.

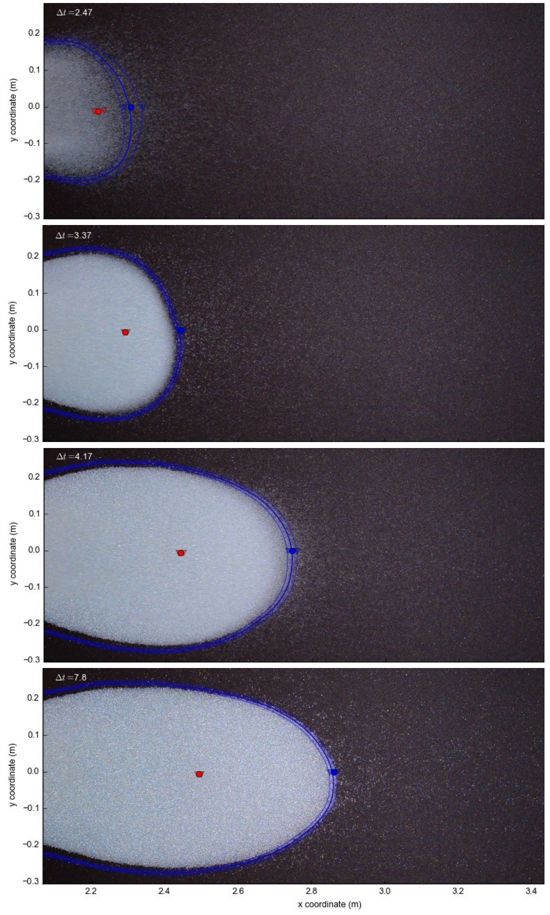
→Average velocity in the field of view (10x10cm)

Typical images:



# Measurement: Front position

Typical images:




Acquisition of video at 30fps → Extract images

Image processing (colour threshold):
→ glass beads (white), rough bed (black).
→ threshold: optimised value.
3 different values use and compare
(threshold sensitive for dilute flow).

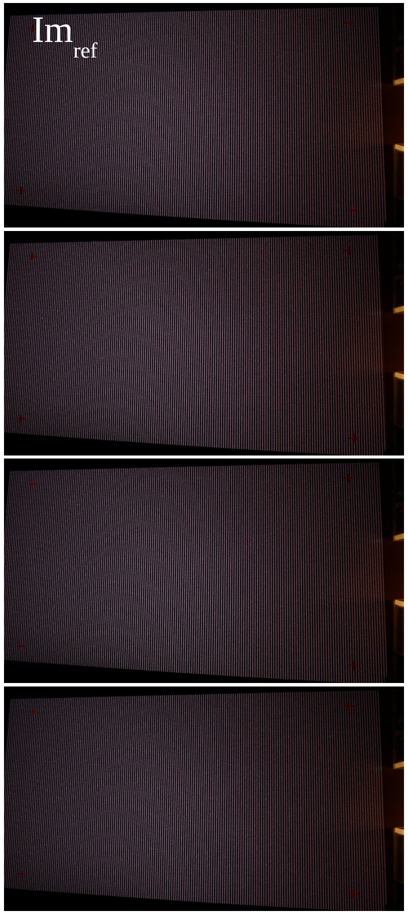
Track 2 special points:
→ Maximum position (blue point)
→ Centroid of the contour line (red point)

# Measurement: Thickness of the deposit

3D measurement of all the run out area (2m x 1m)
→ Fringe projection or Moiré technics
How it works:
→ Project on the plane 4 phase-shifted fringes (black and white fringe varies sinusoidally)

Step 1/4:
→ Acquisition of the reference images

Typical images:



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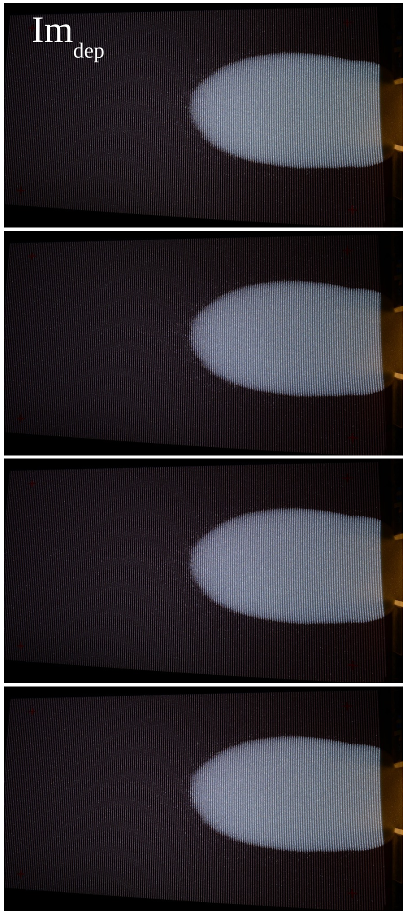
Step 2/4:
→ Image with the deposit

Typical images:



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Step 3/4:
→ Calculation of the phase φ on each point:

$$\varphi = \mathrm{Atan}((Im_3 - Im_1)/(Im_4 - Im_2))$$

Where $Im_i = Im_{dep} - Im_{ref}$

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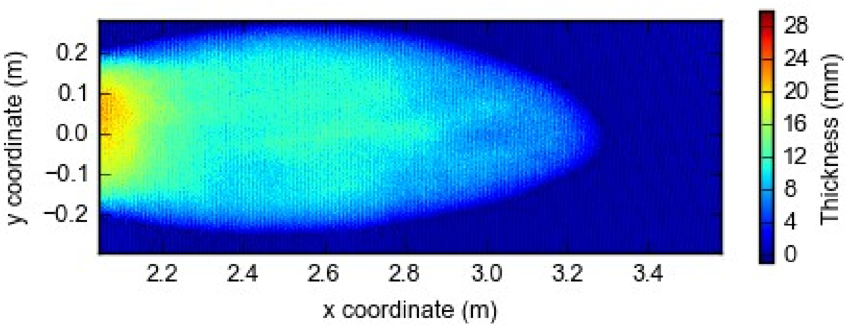
→ Project on the plane 4 phase-shifted fringes (black and white fringe varies sinusoidally)

Step 4/4:
→ Compute the thickness: **t = φ x C**
C = calibration parameter
Obtain by the measurement of 13 plate assemblies

$$C = tc/\varphi$$

where tc = [5,10,...,60,65]mm (13 different thickness)



# 24 flows in the same conditions

The experiments were realised the same day (2015/04/01) within 6 hours

Repeat the same test in the same condition:

→ d = 1.1mm and constant roughness.

→ Initial mass: 12000g (±10g) of glass beads.

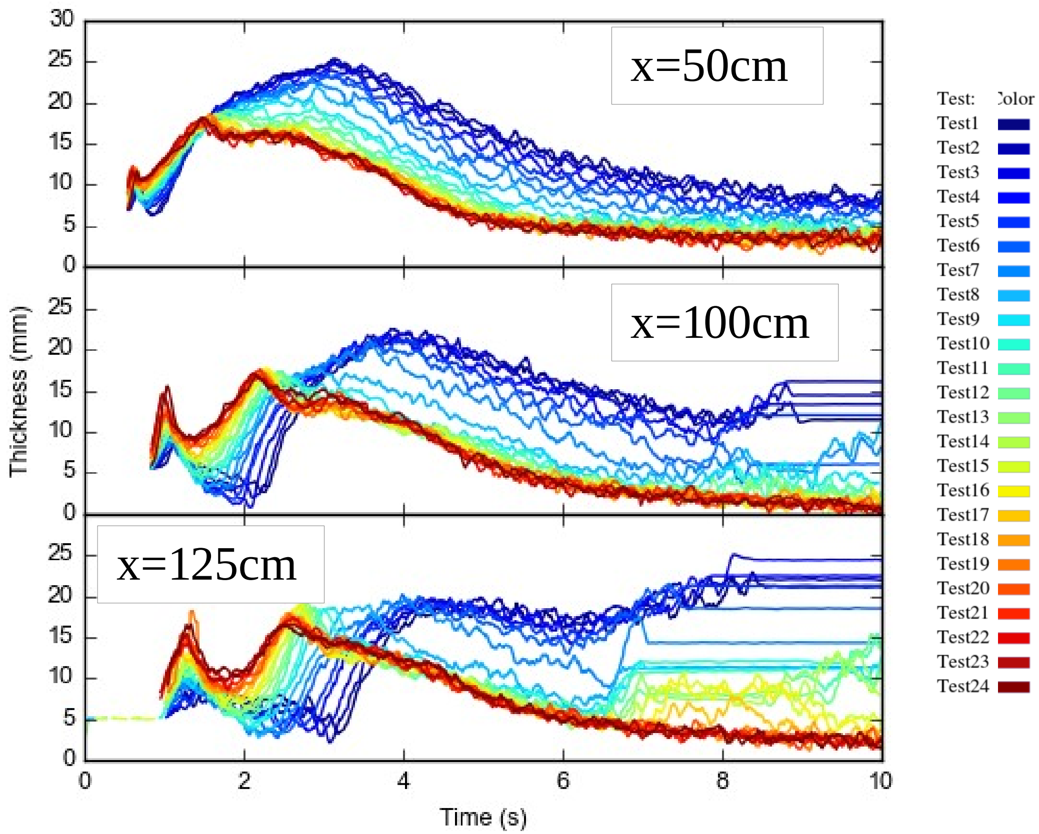
→ Constant slope of the 2 plane (23°-15°)

→ Constant temperature (18°C) and constant relative humidity (30%) in the experimental area.

→ Static electricity control (the grain flow over a grid link to the earth before each test).

| Test: | Time | Color |
|---|---|---|
| Test1 | 2:24pm | dark navy |
| Test2 | 2:50pm | dark blue |
| Test3 | 3:11pm | blue |
| Test4 | 3:28pm | blue |
| Test5 | 3:40pm | blue |
| Test6 | 3:52pm | medium blue |
| Test7 | 4:06pm | light blue |
| Test8 | 4:24pm | sky blue |
| Test9 | 4:35pm | cyan |
| Test10 | 4:52pm | turquoise |
| Test11 | 5:02pm | aquamarine |
| Test12 | 5:14pm | light green |
| Test13 | 5:27pm | light green |
| Test14 | 5:40pm | yellow-green |
| Test15 | 5:51pm | yellow-green |
| Test16 | 6:04pm | yellow |
| Test17 | 6:25pm | amber |
| Test18 | 6:42pm | orange |
| Test19 | 6:56pm | orange |
| Test20 | 7:07pm | red-orange |
| Test21 | 7:19pm | red |
| Test22 | 7:32pm | red |
| Test23 | 7:45pm | dark red |
| Test24 | 7:56pm | maroon |

# Result: Thickness (upper channel)

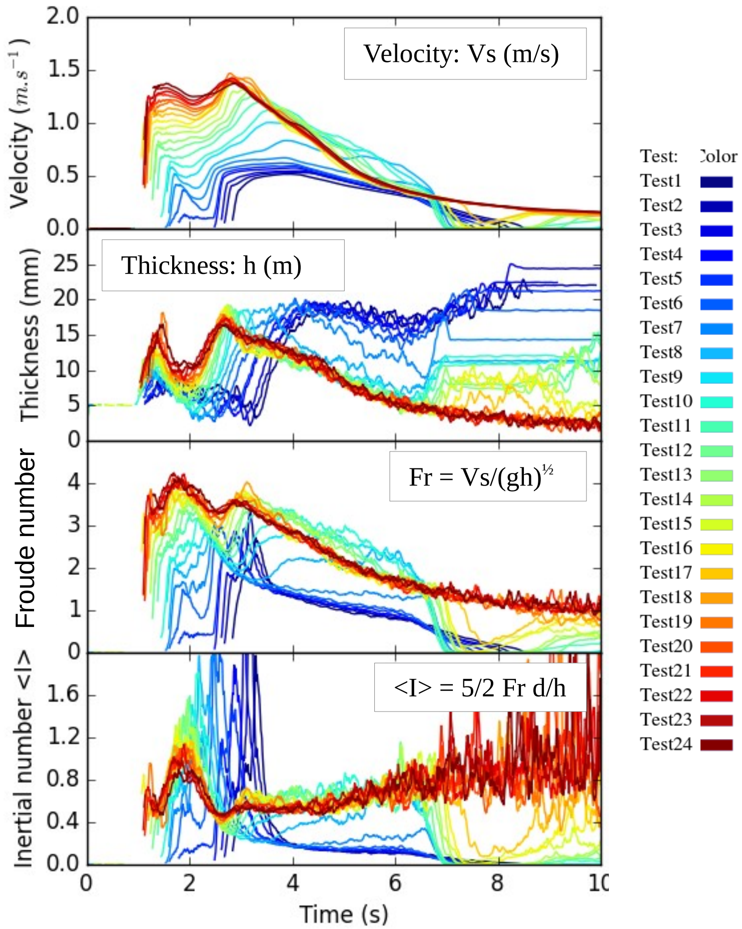



Sensor 1 (x=50cm) show an analogous behavior for the head flow. But for the first tests (1-5) the tail front form a deposit in the channel while for the latter (18-24) there is no more beads.

The lower sensors capture the deposit formed in the run out area for the first tests (1-10).

For the last tests we measure 2 fronts then the thickness decreases until the emptying of the channel.

# Result: Velocity




The maximum velocity increases for all the tests. For the first tests (1-5) there is only one front velocity measure then for the other tests two front are detected with two peaks.

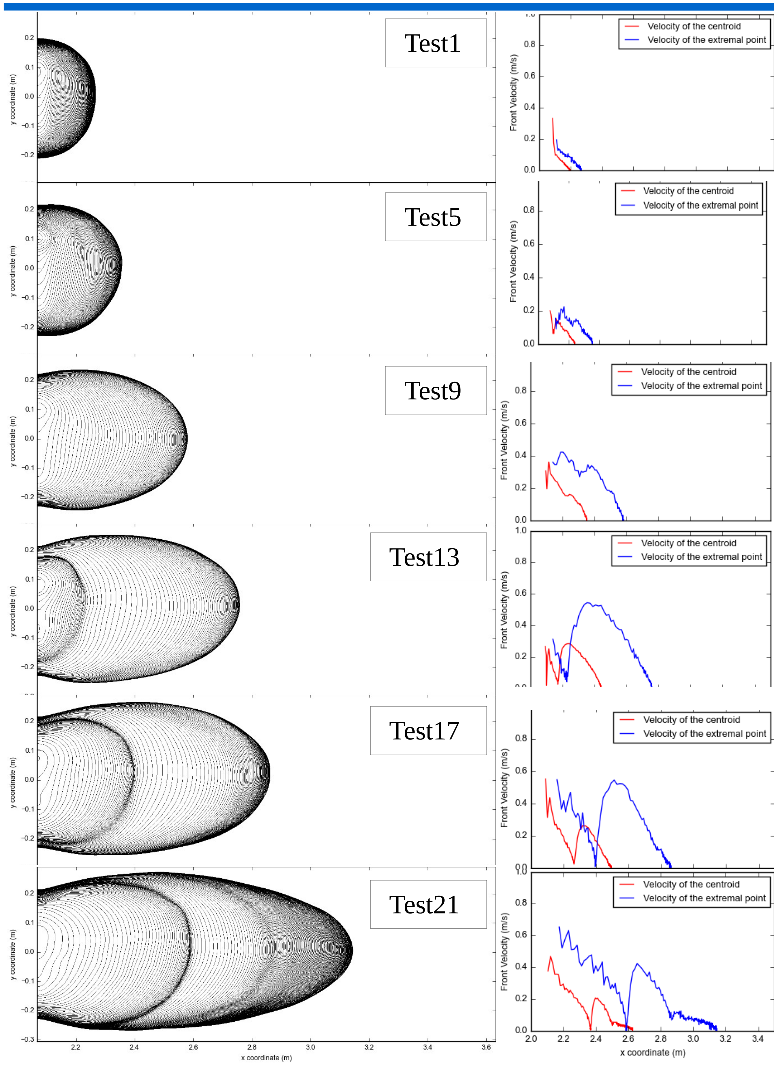
The Froude number (Fr) and the Inertial number (<I>) show two different regime:

→ For the tests (1-7), Fr ≈ 1 and I ≈ 0.2.

→ For the tests (12-24), Fr ≈ 3 and I ≈ 0.7.

The other test correspond to the transition between the 2 regime.

# Result: Front positions




The length of the deposit is even longer from flow to flow. It is link to the increasing velocity in the channel.

We can also see that the front velocity increase for each test.

We also see some evolution on the front dynamics for the different tests:

→ For the first Test 1-10 there is only one surge on the run out area.

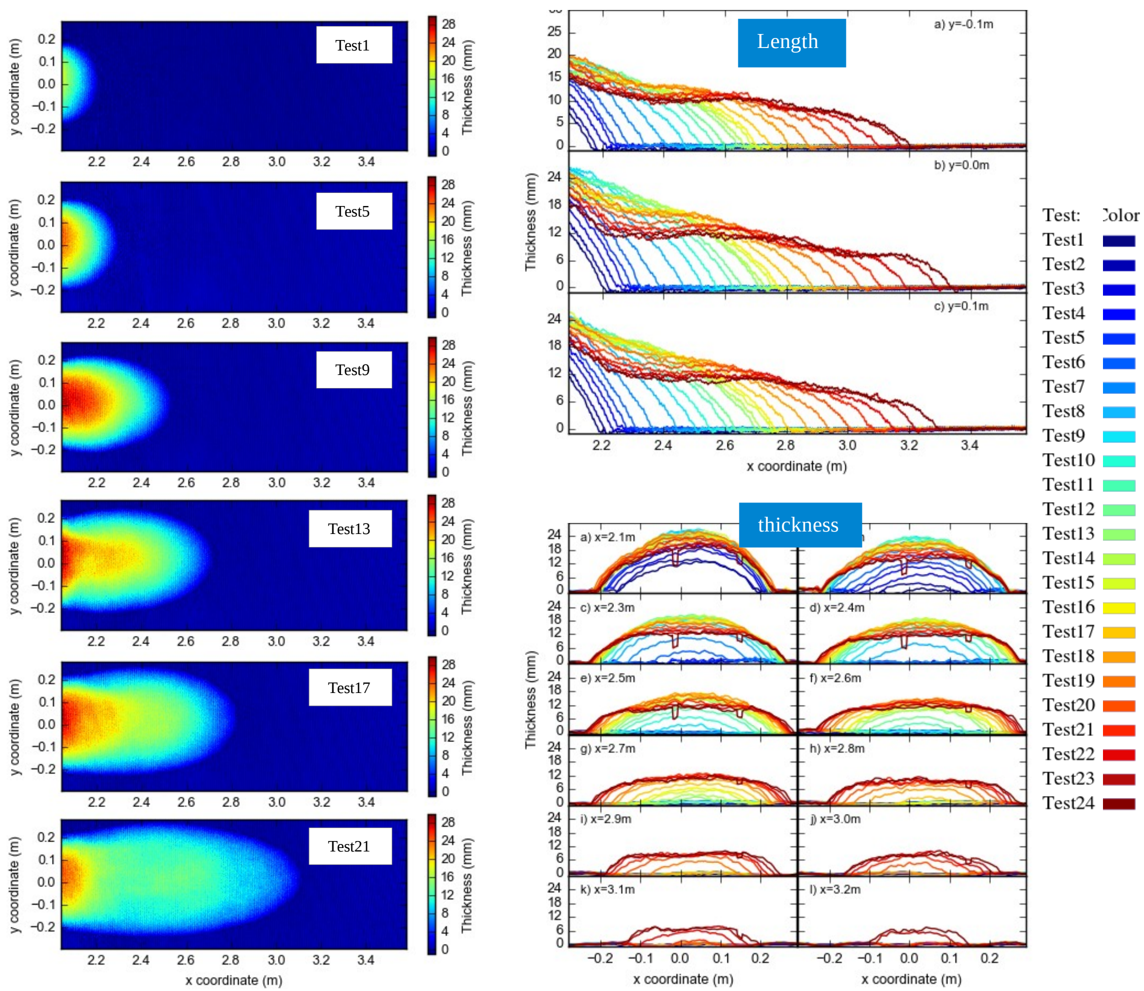
But for the next tests there are multiple surges on the second plane:

→ For the intermediate experiments (Test 11-20) we measure 2 different surges and

→ For the last Test (21-24) 3 different surges.

This different front show some evolution in the dynamics for each specific test but also for the different test.

# Result: deposits




Length: The measured thicknesses of the deposit clearly show the increase of the run-out distance from test to test.

Thickness: There is also some evolution on the shape of the deposit:

→ For tests 1-10 the deposit have a cambered shape.

→ For the last tests the deposit become flatter. There is an area in the deposit where the thickness is constant.

# Conclusion

We have develop an experiment of bi-inclined plane in order to retrieve the rheology of granular material. The configuration mesurement is similar to the one we can reproduce in the field.

The measurement show some important evolution of the flow characteristic during the experiment event if the initial condition are the same.

Interesting data set to identify the reological evolution with the history of the material.

Mandatory:
In order to understand better the rheology we would like to measure some reproducible experiment. From preliminary tests we found a way to stabilise the material by pre-flow in a rotating drum.

Thank you for your attention.