Experimental study of the discharge of granular quasi-2D silo in a uniform magnetic field

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TGF Lyon 2024

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How magnetic cohesion influence silo flows ?

- General context
- Methodological framework
- Results

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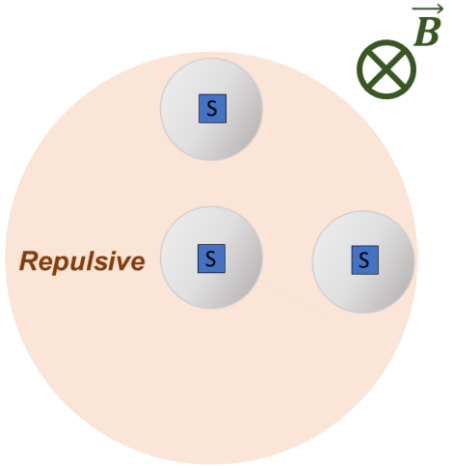
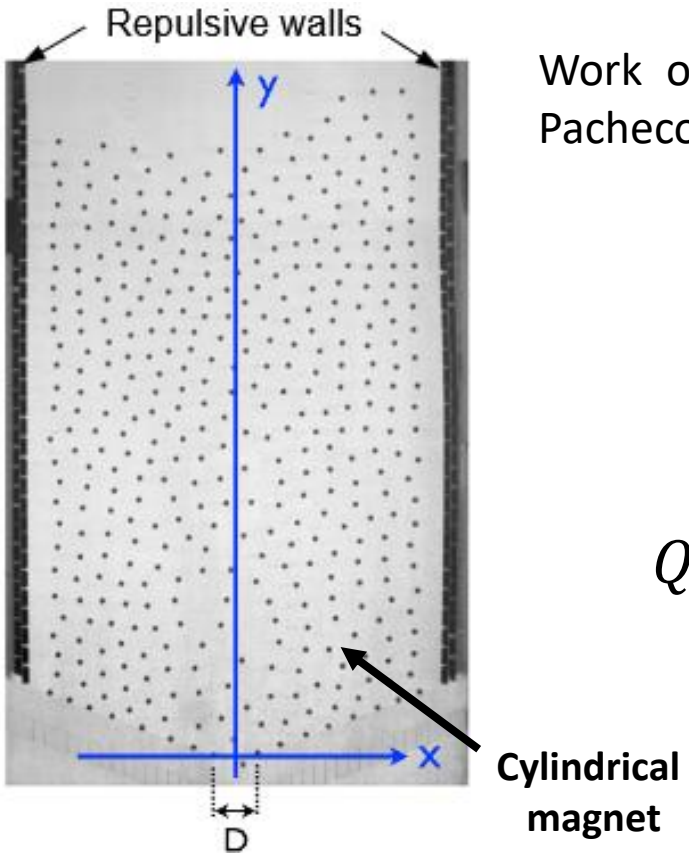
How magnetic cohesion influence silo flows ?

General context of 2D silo :

*Granular media → **frictional** interaction between particles*

*Magnetic cohesion → add a **magnetic interaction** between particles*

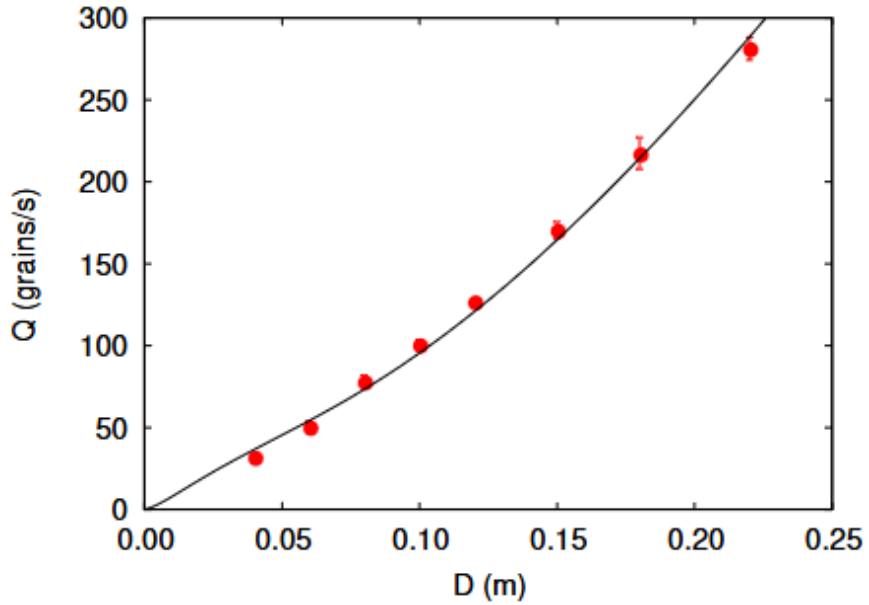




Work of G. Lumay, J. Schockmel, D. Henández-Enríquez, S. Dorbolo, N. Vandewalle, F. Pacheco-Vázquez in **"Flow of magnetic repelling grains in a 2D silo",** Papers in Physics (2015)

Modified version of the Beverloo law
(in cohesionless case :

$$Q = C\rho\phi_b\sqrt{g}W(D - kd)^{3/2})$$



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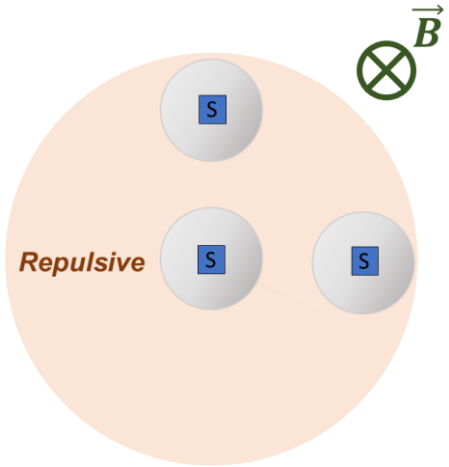
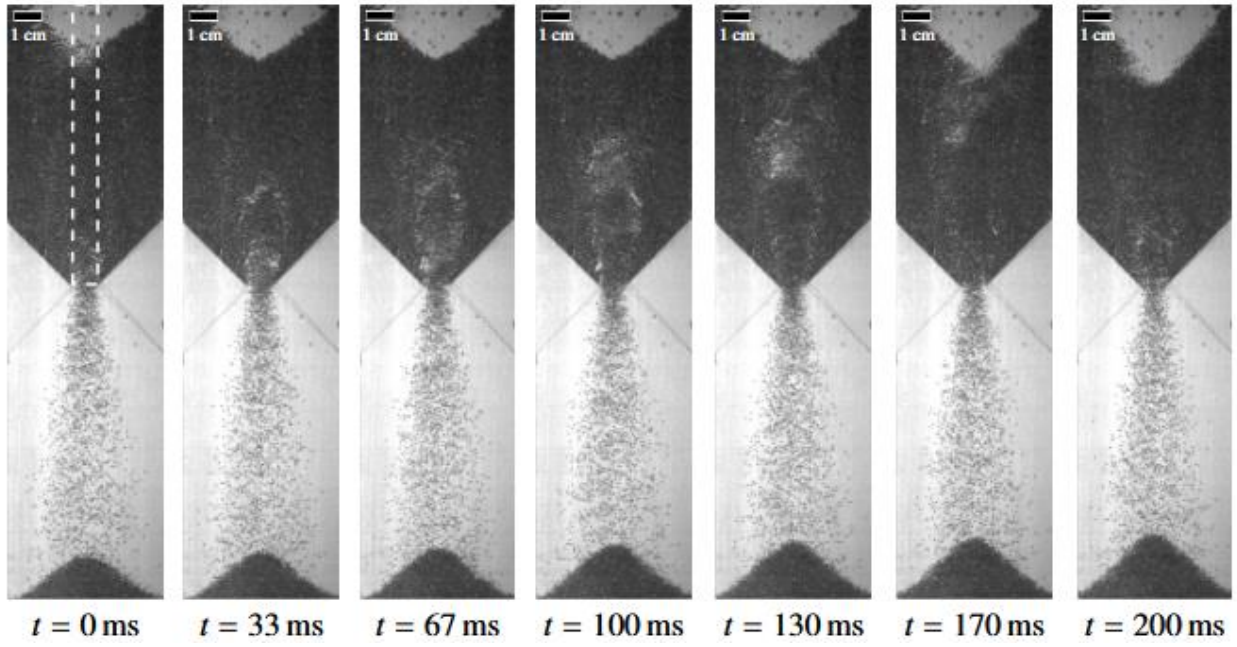
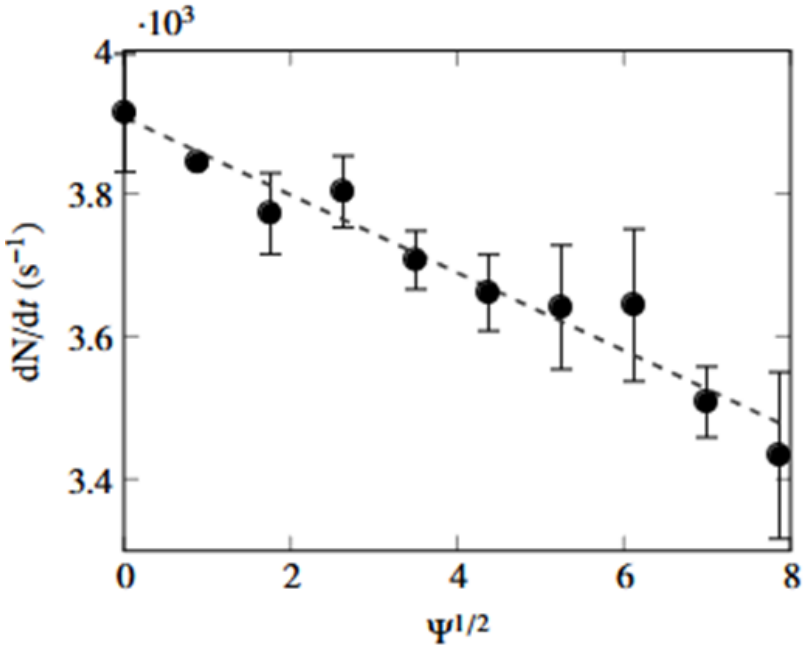


Work of L. Thorens, M. Viallet, K.J. Måløy, M. Bourgoin, S. Santucci, in **"Discharge of a 2D magnetic"**, EPJ Web of Conferences (2021)

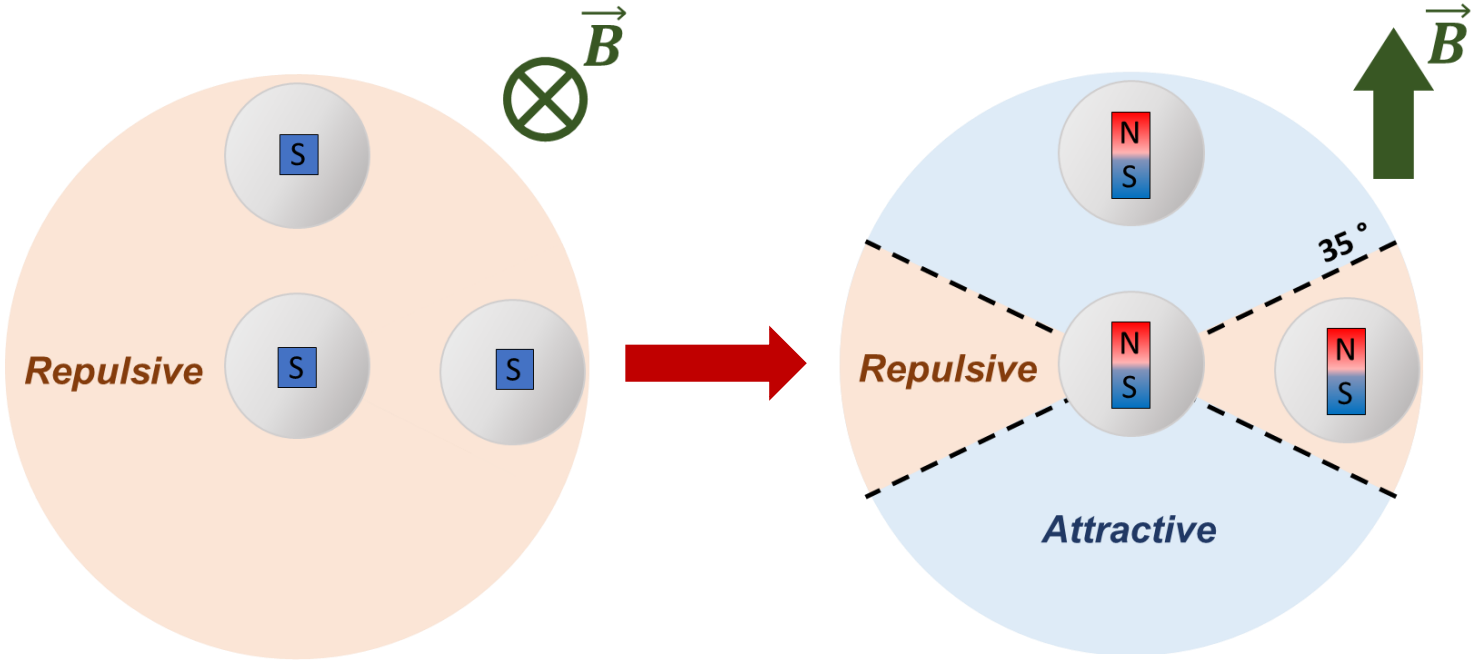


Decrease of the flow rate versus the magnetic field intensity



How magnetic cohesion influence silo flows ?

The idea :



How can vertical magnetic cohesion modify the 2D silo flow ?

Quantifying cohesion = ***The Bond number***

$$Bo = \frac{Cohesive\ force\ magnitude}{Weight\ of\ a\ grain}$$

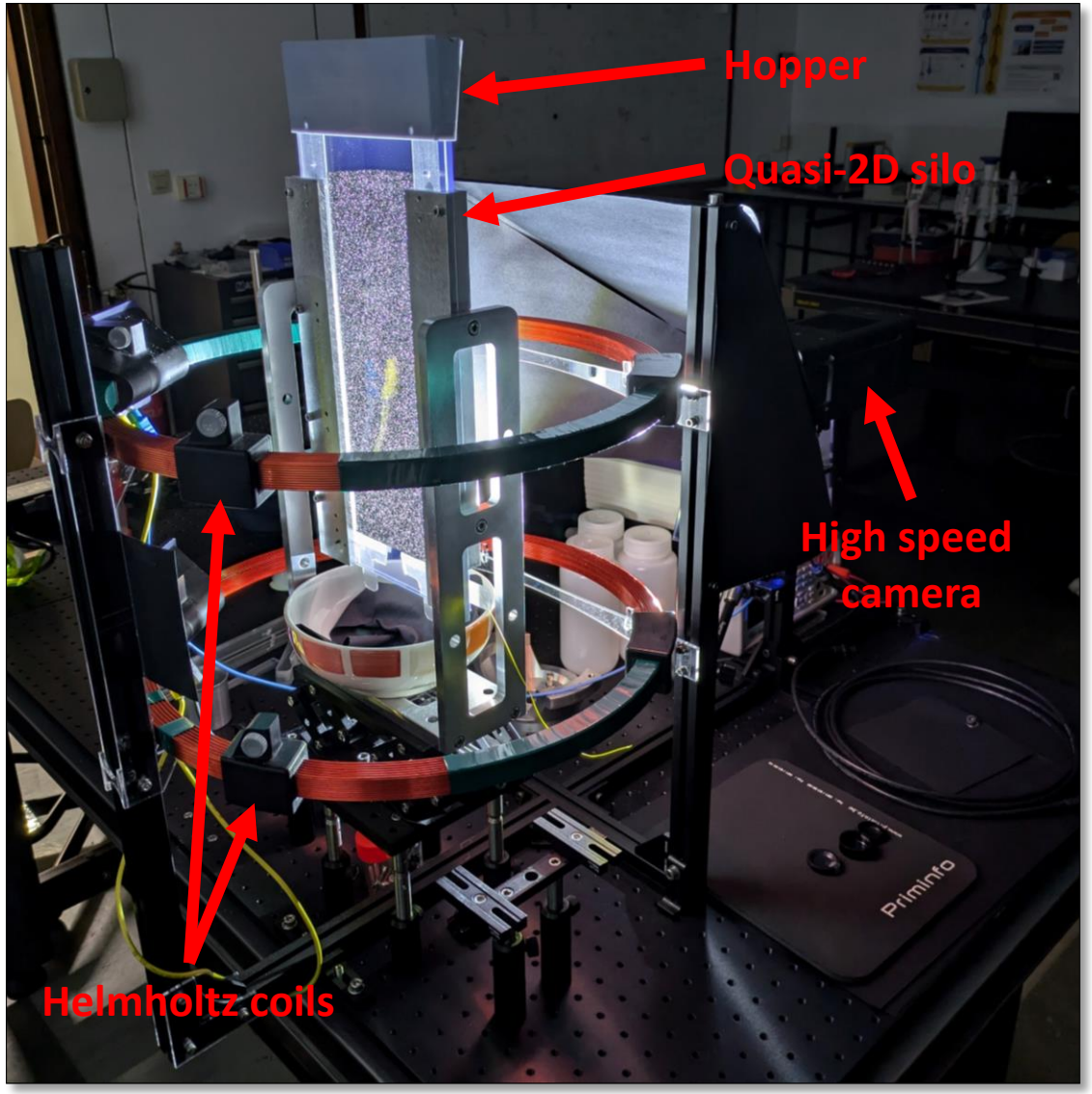
$Bo \geq 1$: one grain can hold another one

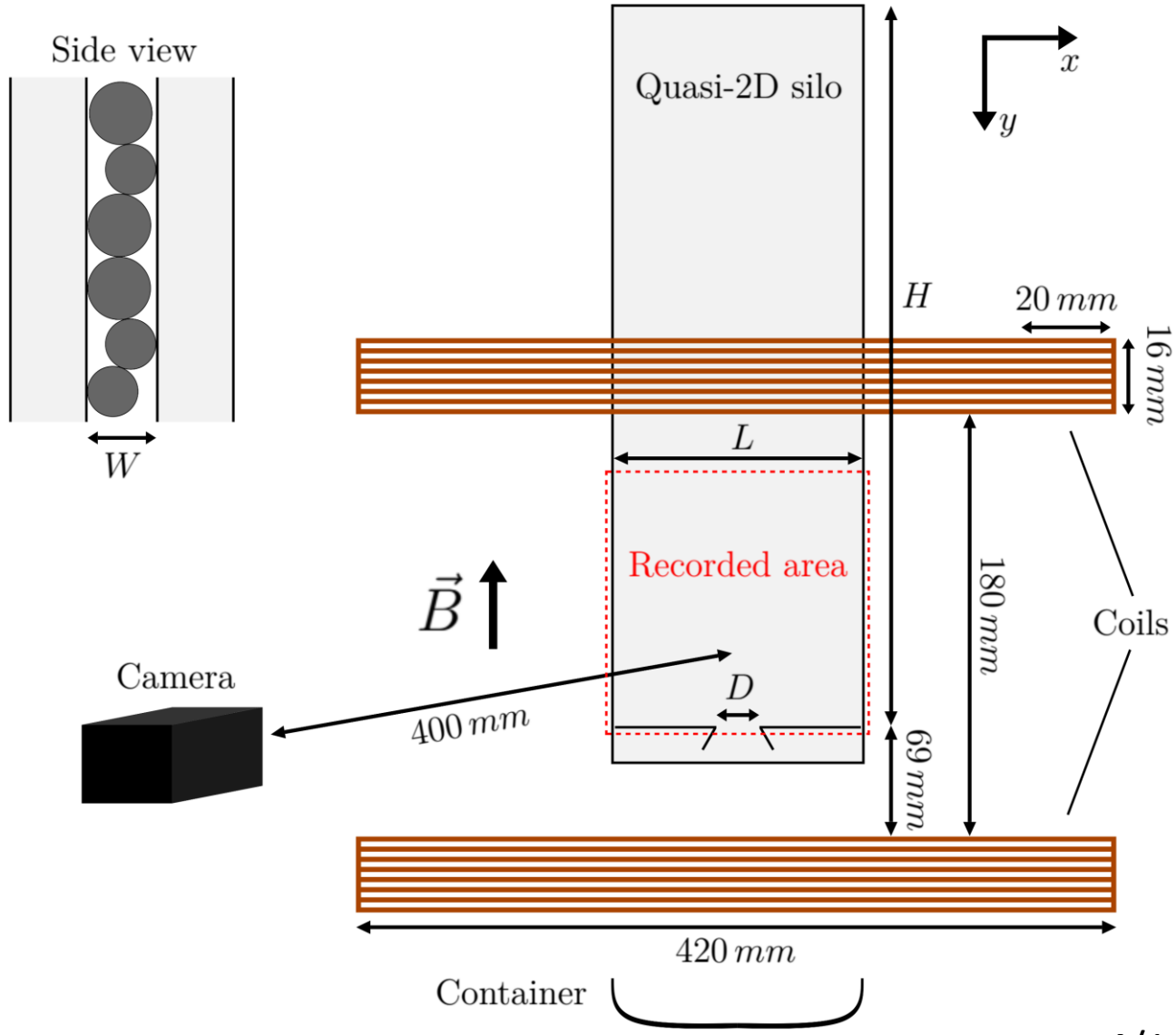
How magnetic cohesion influence silo flows ?

- General context
- **Methodological framework**
- Results

How magnetic cohesion influence silo flows ?

Methodological framework :

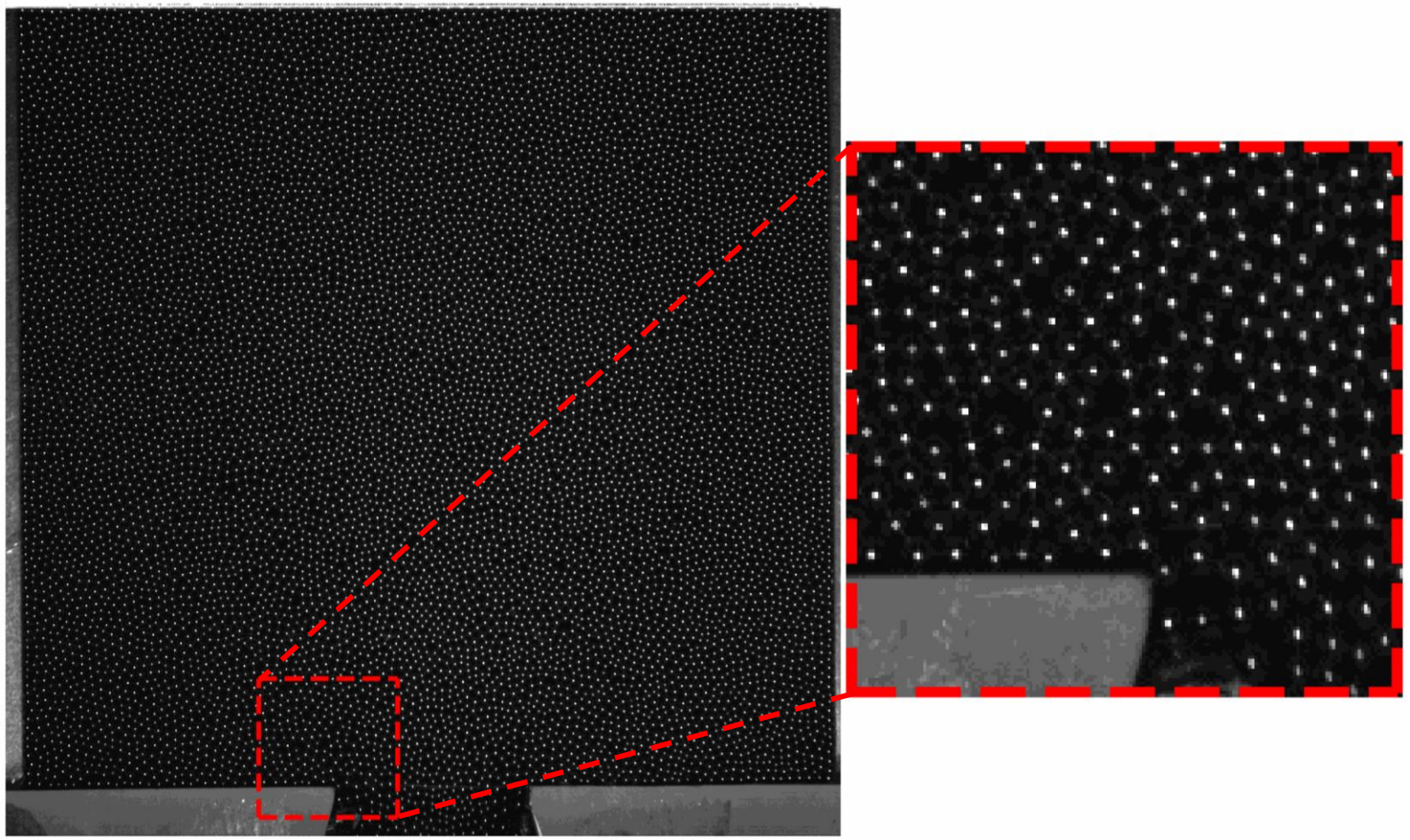




How magnetic cohesion influence silo flows ?

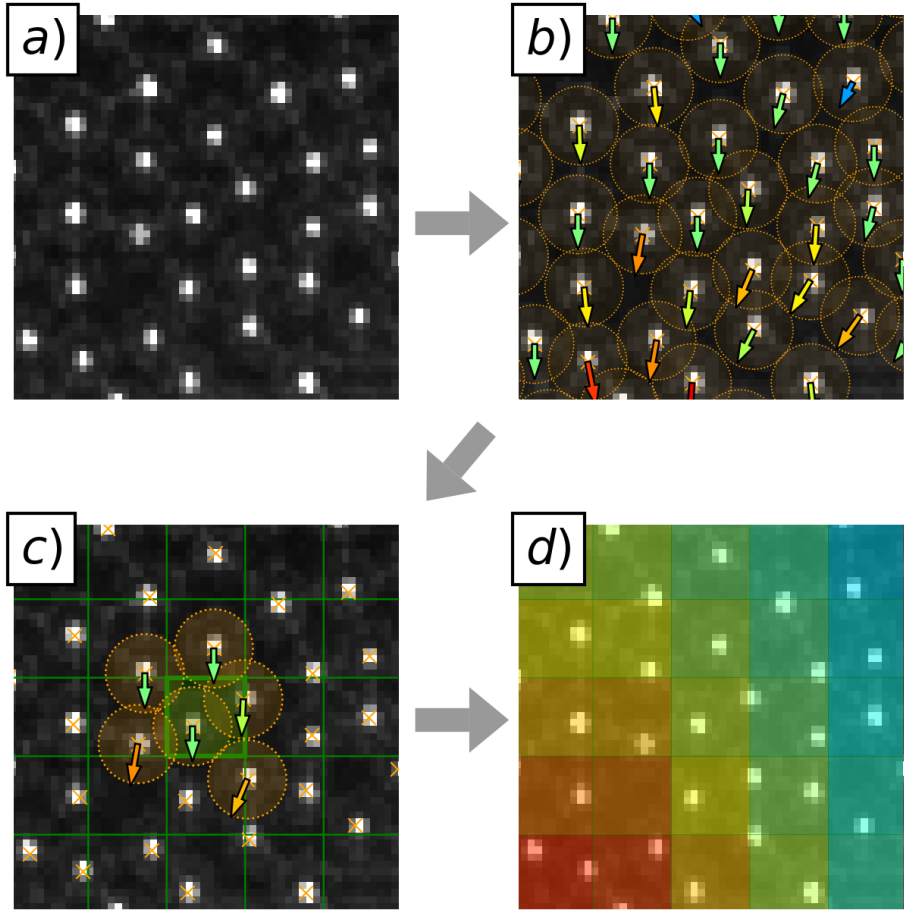
Methodological framework :

Raw frame (1024 x 1024 at 2000 Hz)



Analysis Method in 4 steps :

a) Raw frame recording
b) Detection and tracking of grains
c) Eulerian instantaneous projection
d) Temporal and realization average



How magnetic cohesion influence silo flows ?

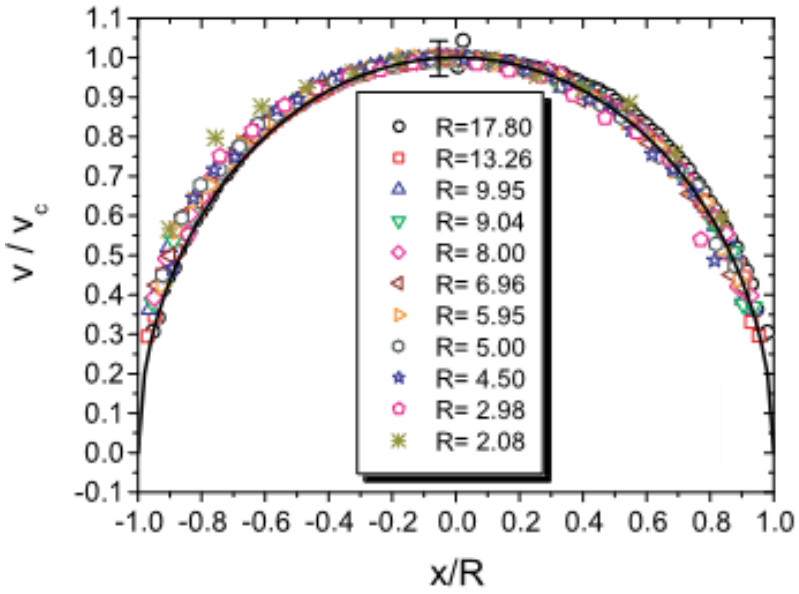
- General context
- Methodological framework
- **Results**

How magnetic cohesion influence silo flows ?

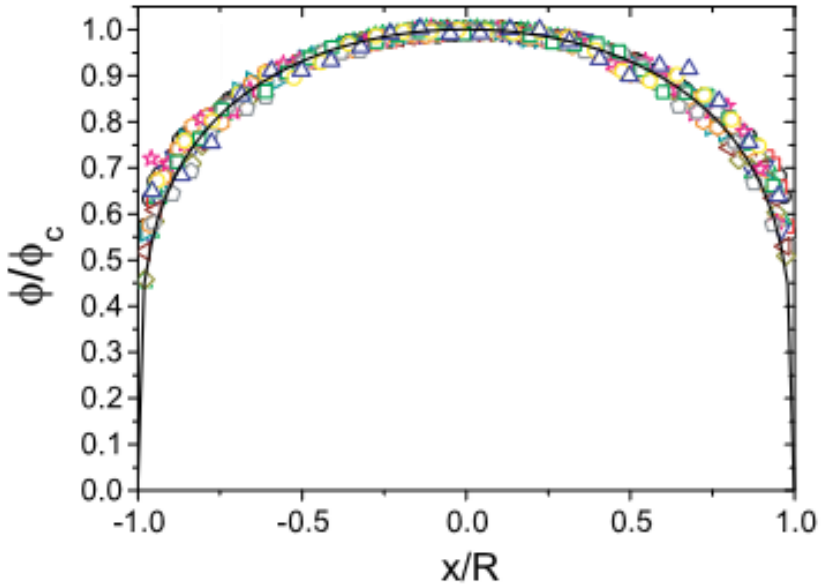
Results : focus on the outlet flow

Work of A. Janda, I. Zuriguel and D. Maza, in **"Flow rate of particles through apertures obtaines from self-similar density and velocity profiles"**, PRL, (2012)

Velocity profiles

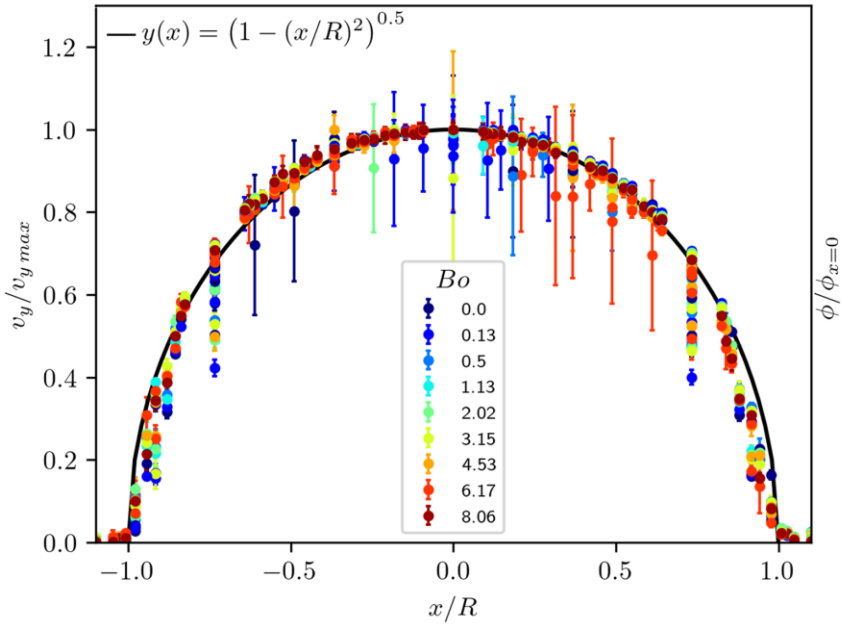


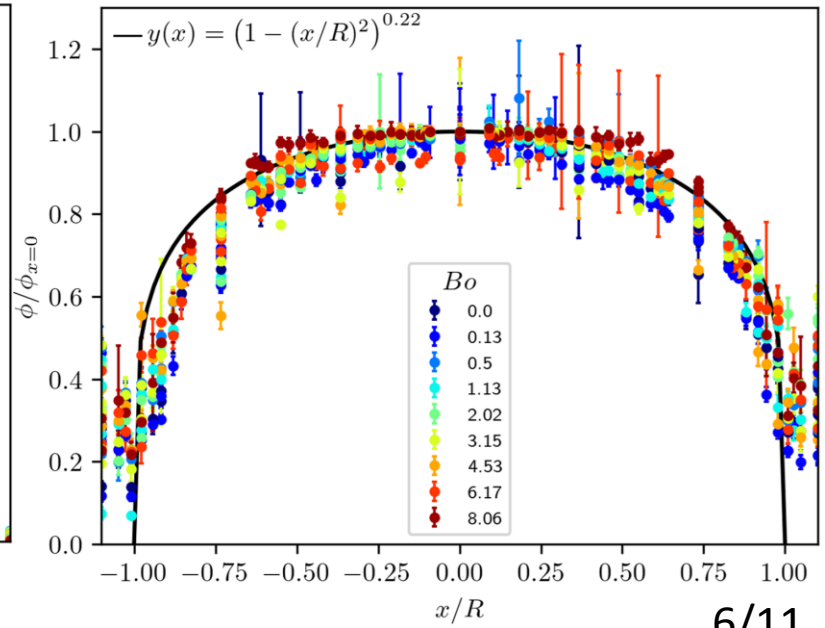
Density profiles



Vertical magnetic cohesion
does not change
the self-similar profiles !

$$\textit{Flow rate : } Q = \rho \int_{-D/2}^{+D/2} \phi(x) v_y(x)\, dx$$



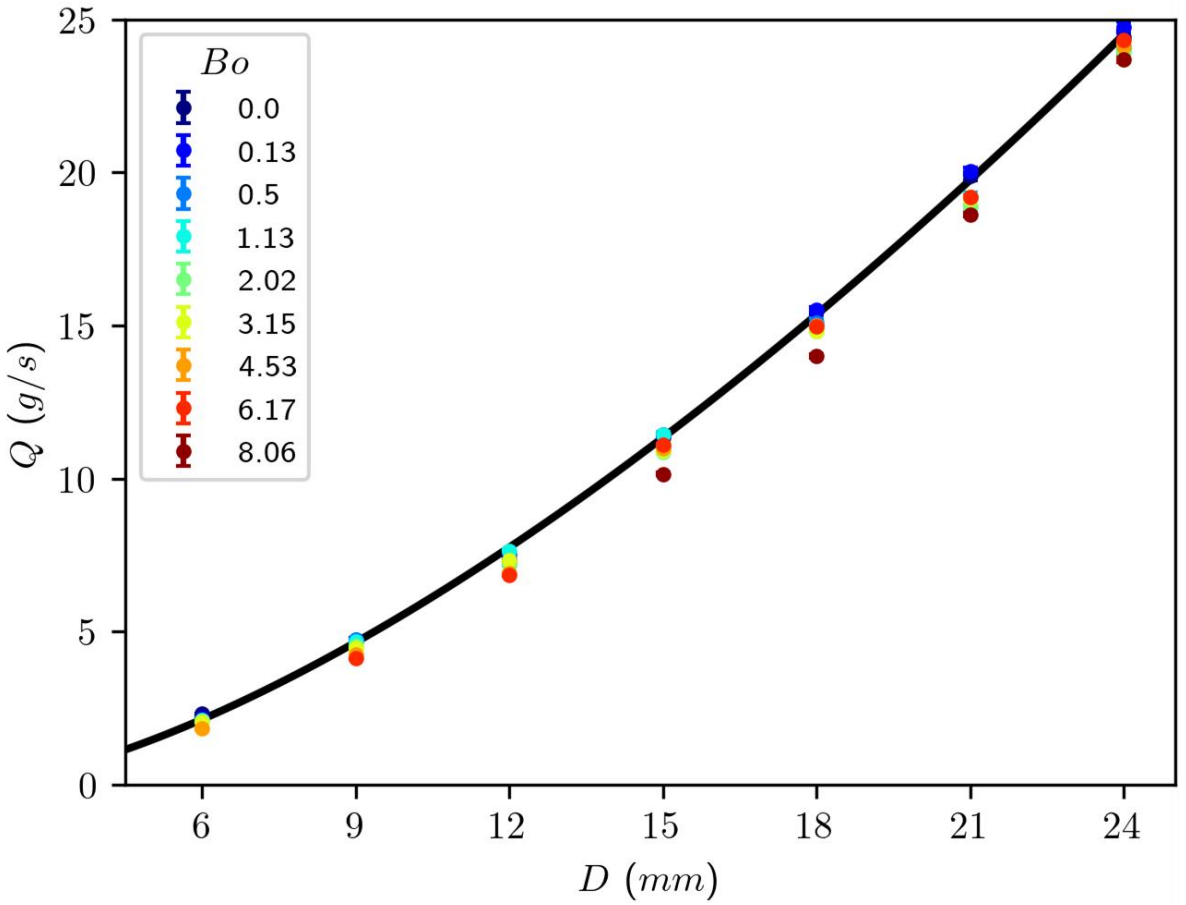


How magnetic cohesion influence silo flows ?

Results : focus on the outlet flow

The Beverloo law
capture globally
the flow rate behaviour

How vertical magnetic cohesion modify the flow rate in more details ?



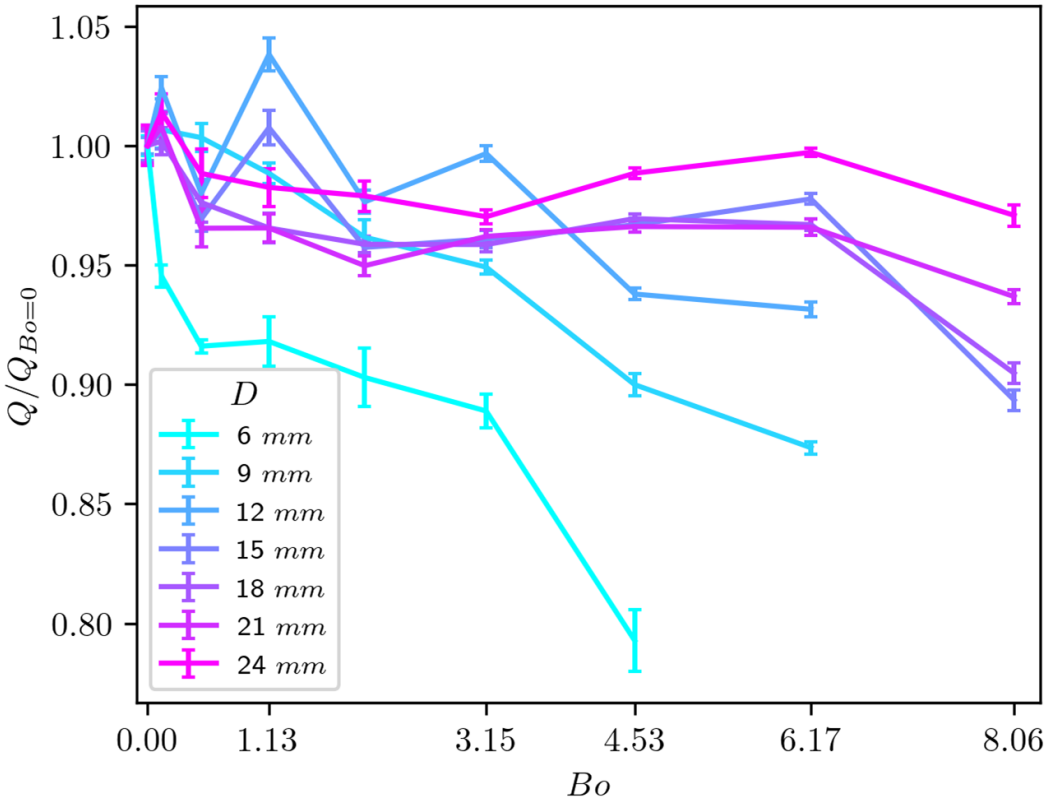
Beverloo law [1] : $Q = C\rho\phi_b\sqrt{g}W(D - kd)^{3/2}$

[1] Reference to W. A. Beverloo, H. A. Leniger, and J. van de Velde, **"The flow of granular solids through orifices"**, Chem. Eng. Sci. 15, 260–269 (1961)

How magnetic cohesion influence silo flows ?

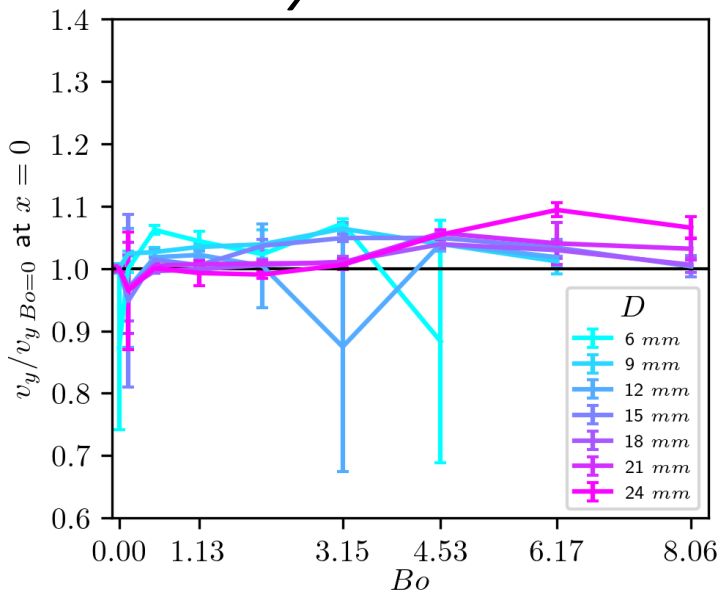
Results : focus on the outlet flow

*Normalized flow rate versus **cohesion***



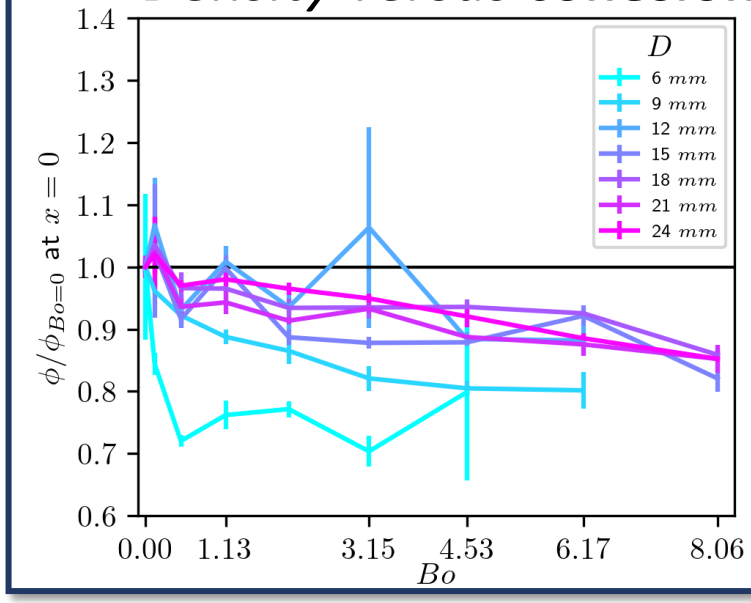
What are the contribution of the velocity ? of the density ?

*Velocity versus **cohesion** at the center*



Slight increase in velocity

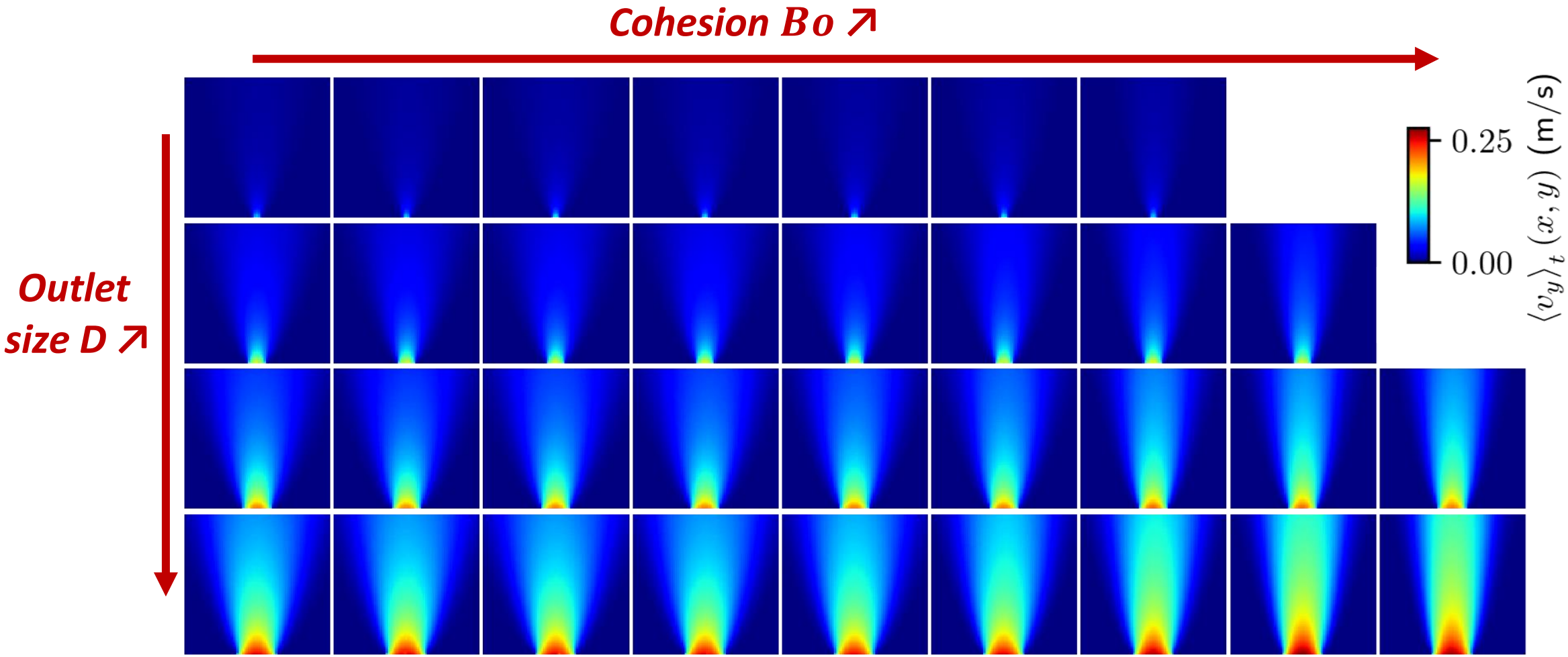
*Density versus **cohesion** at the center*



Clear decrease in density

How magnetic cohesion influence silo flows ?

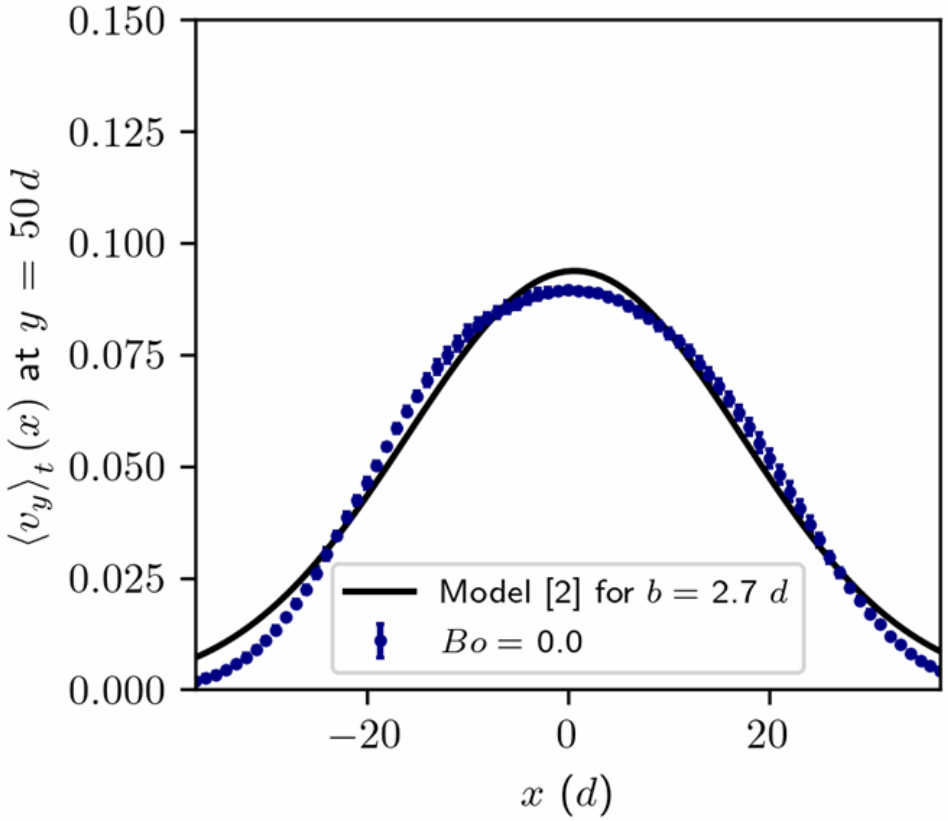
Results : focus on the bulk flow

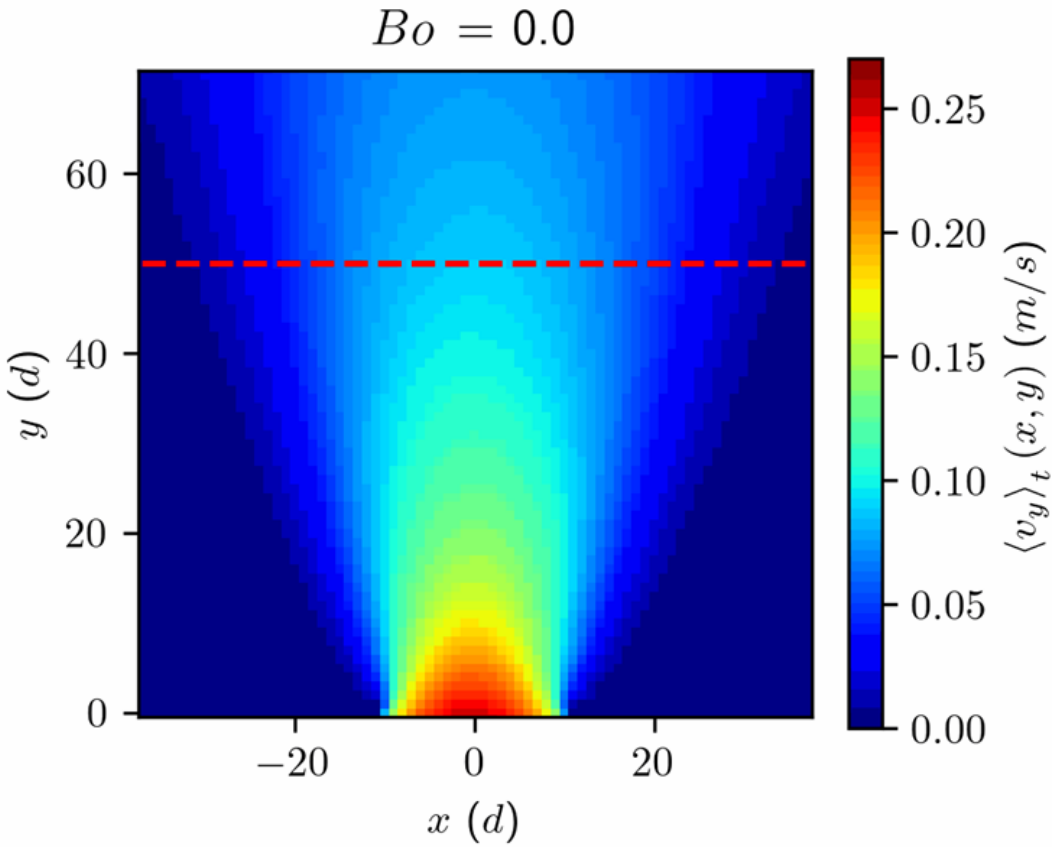


The magnetic vertical cohesion channels silo flows …
How can this phenomenon be modeled ?

How magnetic cohesion influence silo flows ?

Results : focus on the bulk flow





$$\textit{Kinematic model [2] : } v_y(x,y) = \frac{Q}{\sqrt{4\pi b y}}\ exp\left(\frac{-x^2}{4by}\right)$$

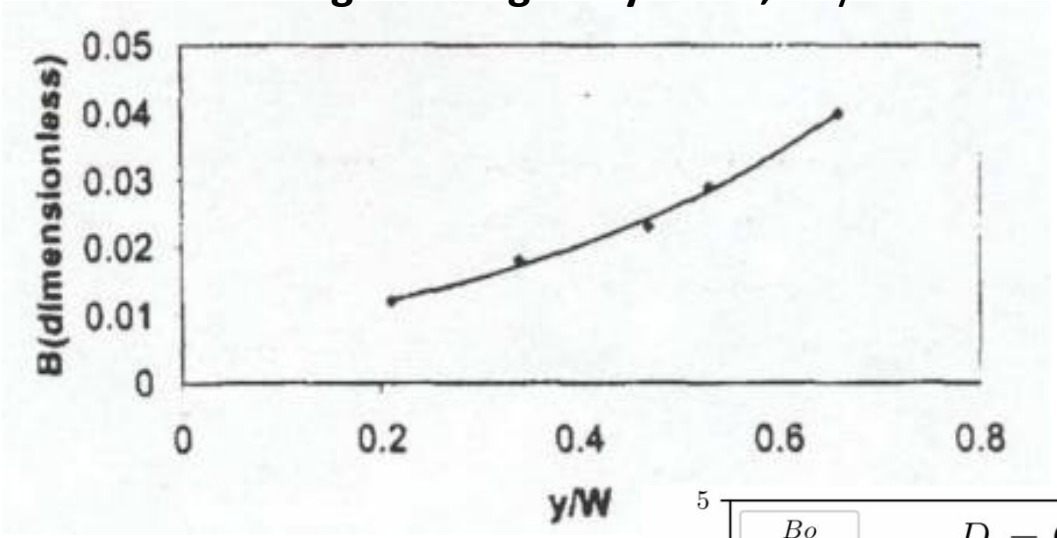
The length b can be interpreted as a diffusion length

[2] A. Medina, J.A. Córdova, E. Luna, C. Treviño, "Velocity field measurements in granular gravity flow", Physics Letter A (1998)

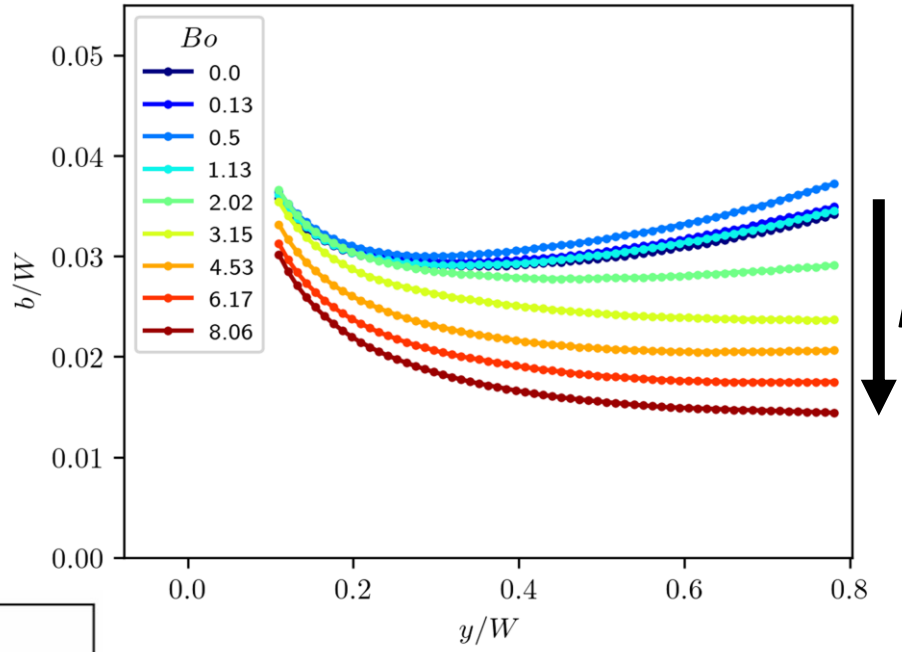
How magnetic cohesion influence silo flows ?

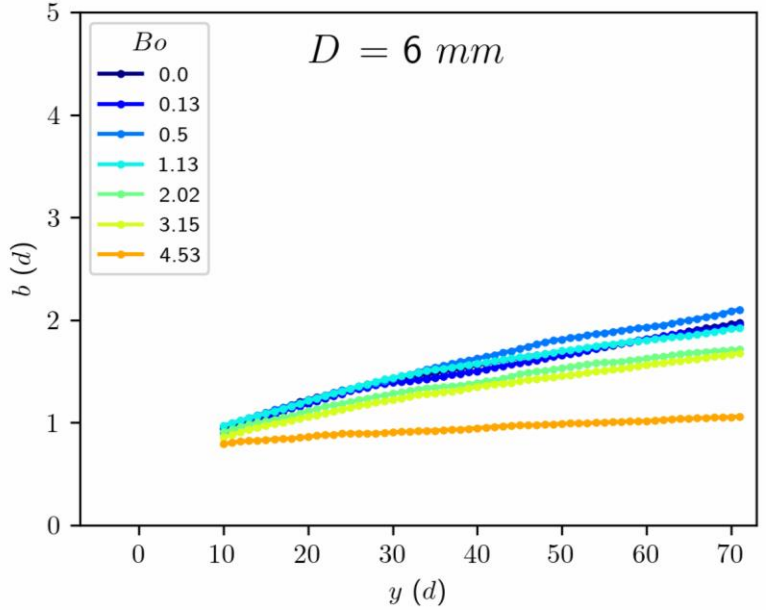
Results : focus on the bulk flow

Work of A. Medina, J.A. Córdova, E. Luna, C. Treviño, in **"Velocity field measurements in granular gravity flow",** Physics Letter A (1998)



Clear decrease in the diffusion length b



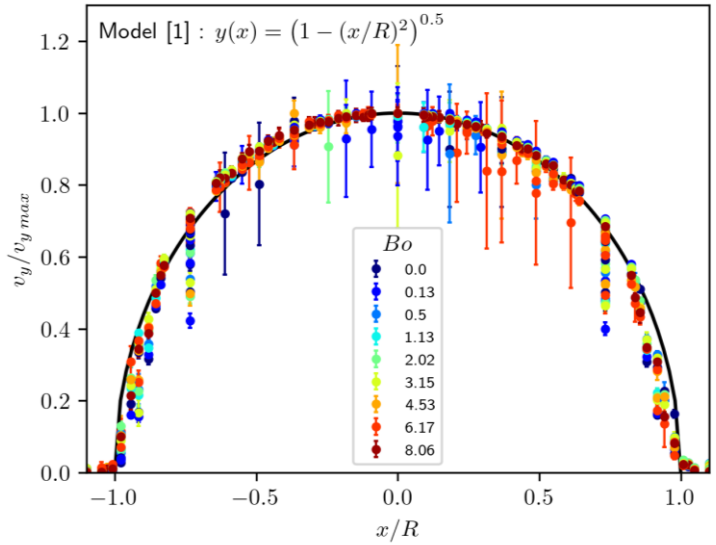


True for all outlet size !

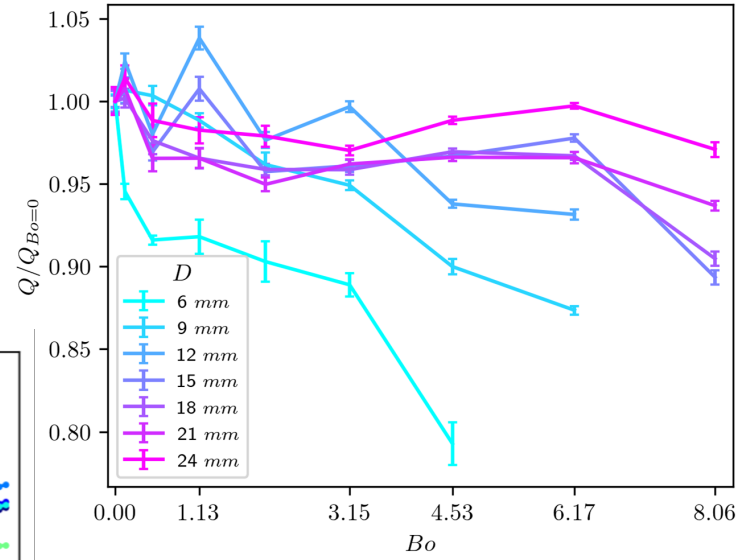
How magnetic cohesion influence silo flows ?

Conclusion :

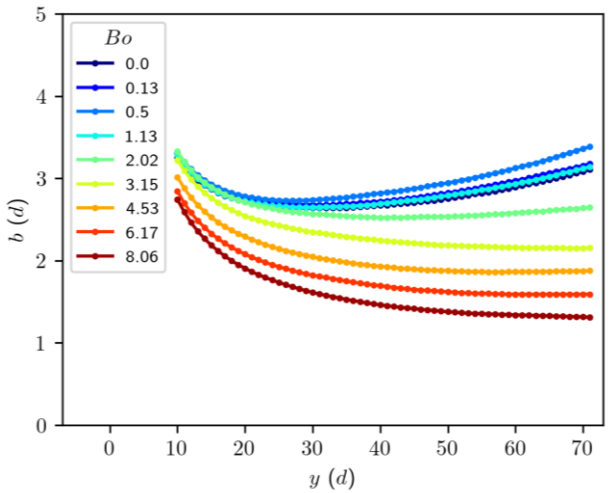
- ✓ *Vertical magnetic cohesion **does not alter** the self-similarity of velocity and density profiles*



- ✓ ***Non-monotonic effect** of cohesion on the flow rate law*



- ✓ ***Increase in the size of solid zones :** the kinematic model remains valid*



Thank you for your attention !

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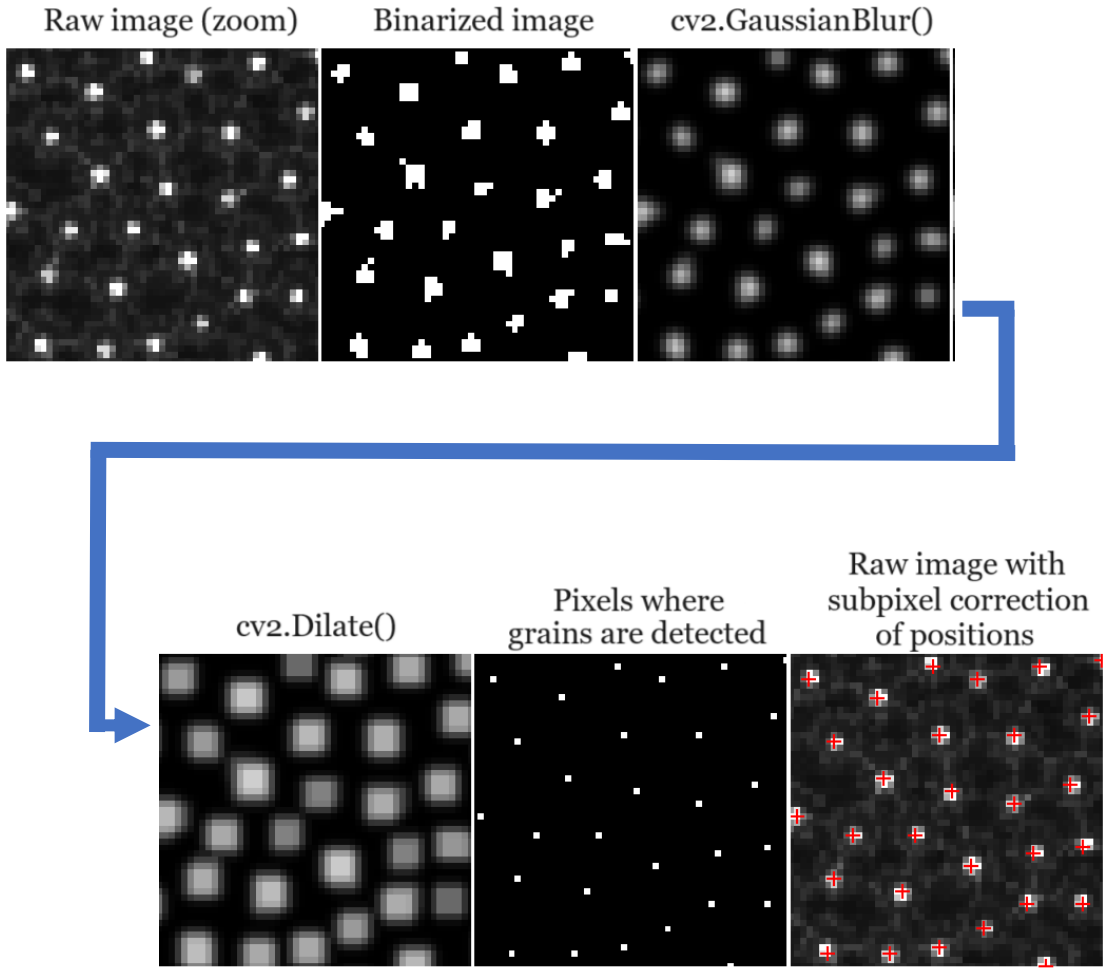
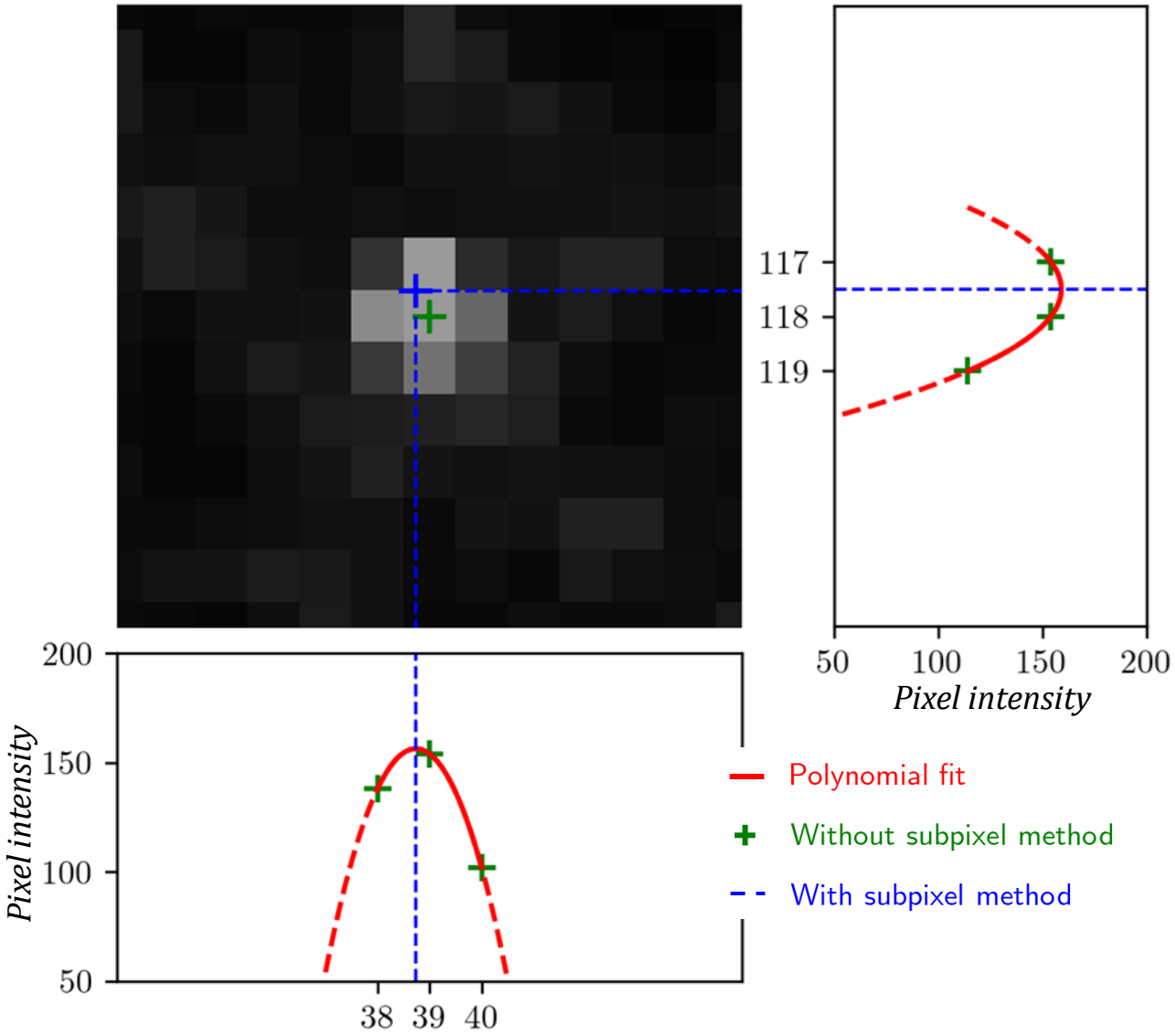
Methodological framework

The analysis sequence

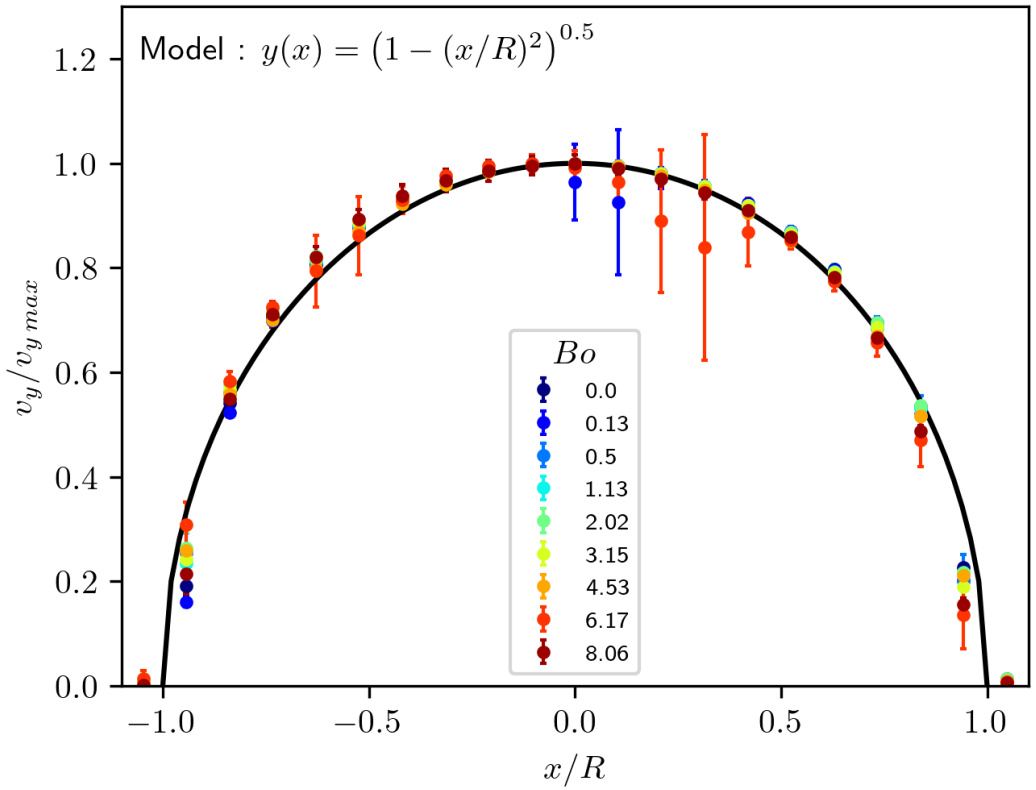


The subpixel method



Methodological framework

Explaination of errorbars :



Scratches near the outlet