Simulation of a super-critical bathtub vortex: comparison with experimental data

Gaspard Fourestier, Timothée Santagostini, Marc Le Boulluec, Philippe Magaldi , Yves-Marie Scolan

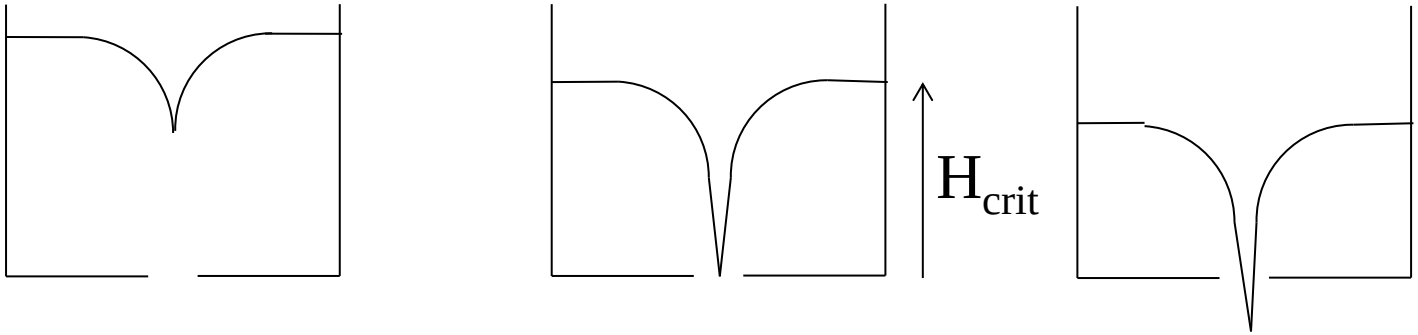
Context

- One solution for low head hydropower
  - Bathtub vortex
  - Turbine placed at the center of the vortex
- Experimental and numerical study of the vortex

ZOTLÖTERER - worldwide first Gravitation Water Vortex Power Plant
https://www.youtube.com/watch?v=oo_mP18IXMo

Bathtub vortex : Classification and analytical models

- Bathtub vortex classification



Subcritical vortex

Critical vortex

Supercritical vortex: Air entrainment

- Analytical model (Rankin)
  - Doesn't work very well for **supercritical vortices**
  - **Walls and injection's** influence not taken into account
  - **Turbine** effect

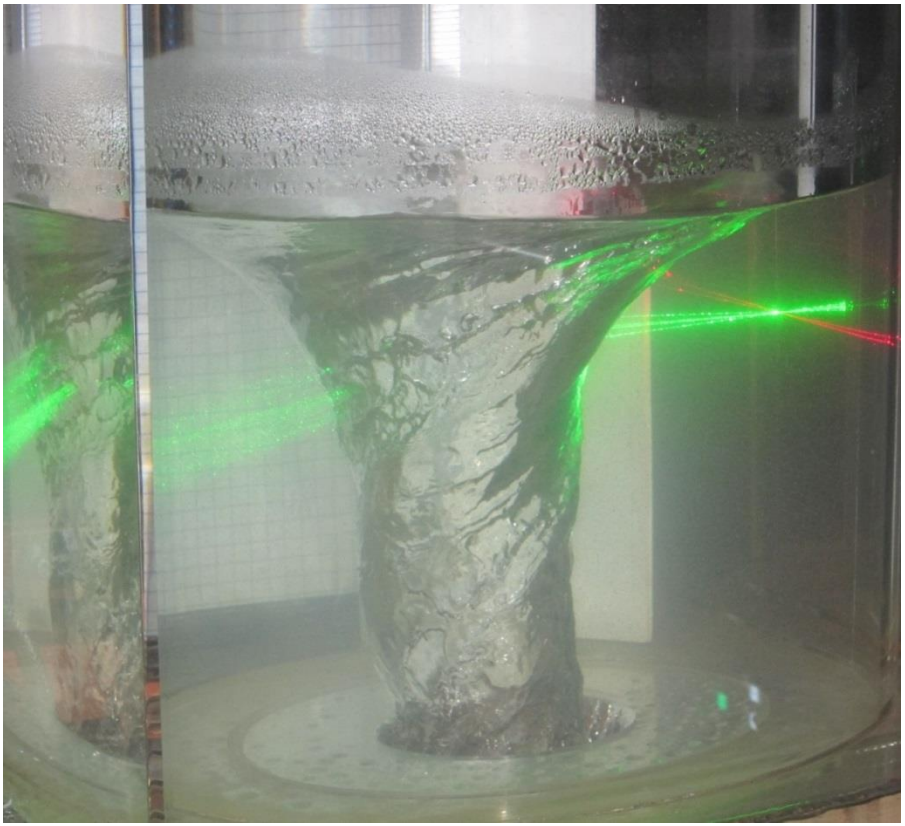
Summary

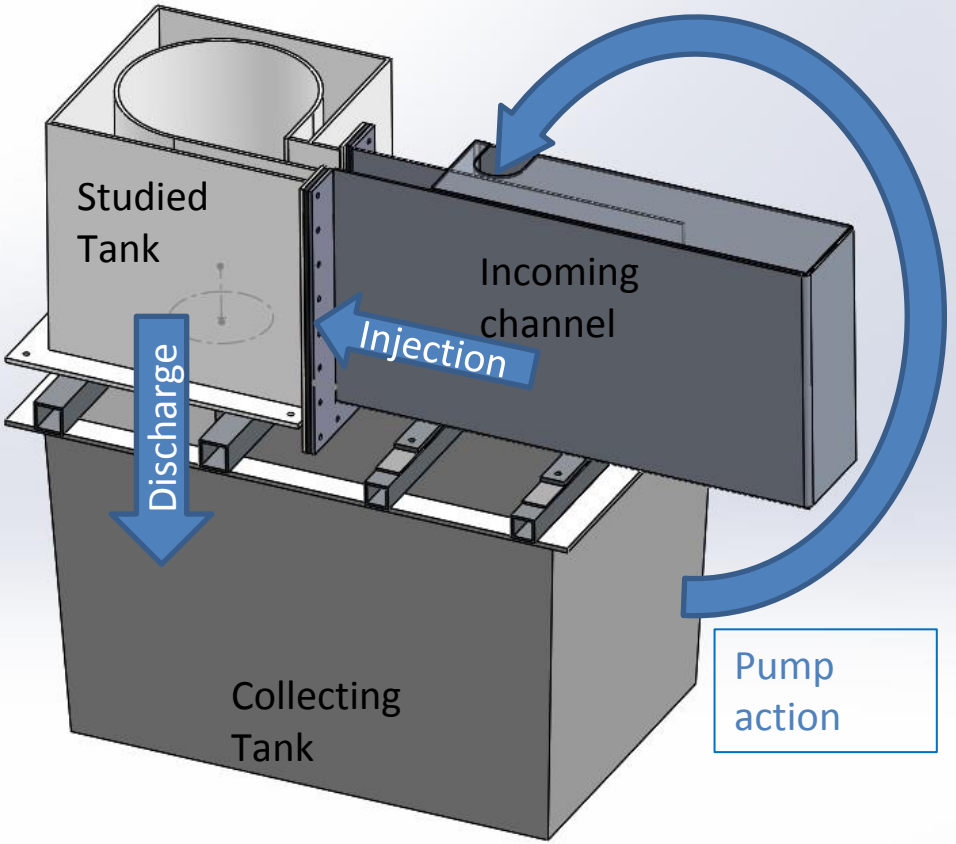
1. Experimental device
   1. Experimental setup
   2. Tested configurations
   3. Measurement

2. Numerical model

3. Comparisons

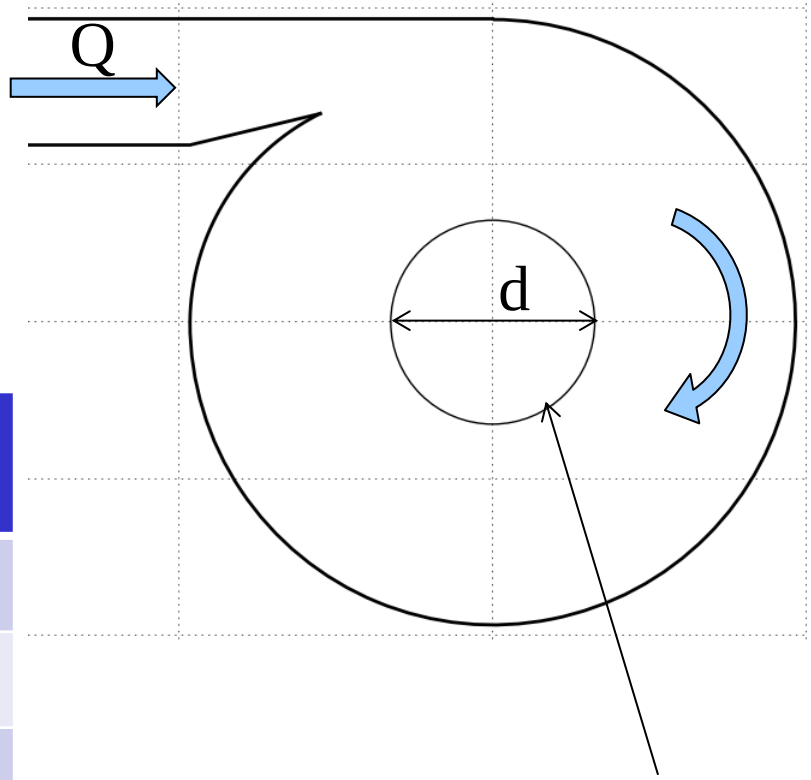
The experimental setup



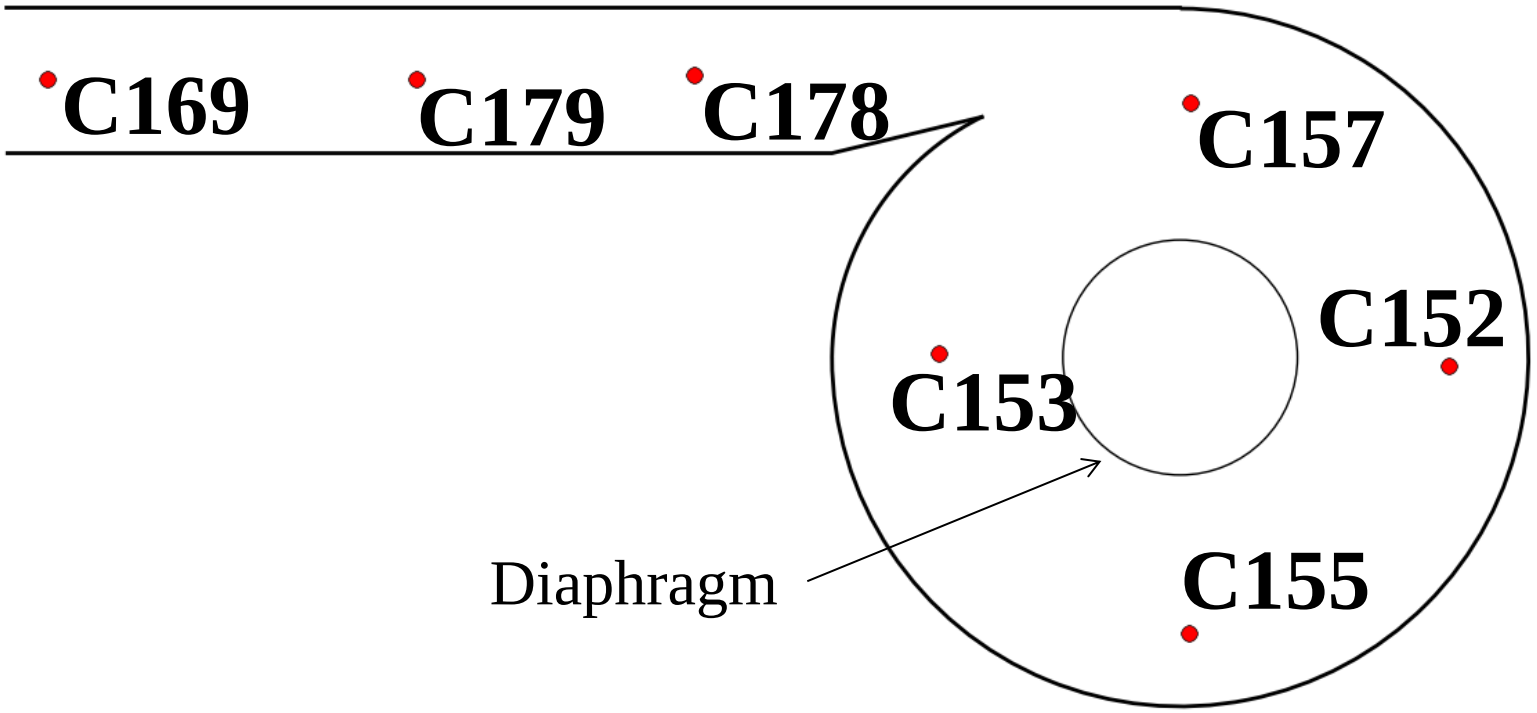


Tested configurations

Configuration number	d (mm)	Q (l/s)	h (cm)
1	130	3.5	16.4
2	100	5.5	28.6
3	200	14.0	28.7
4	130	9.4	32.9
5	130	7.2	26.3

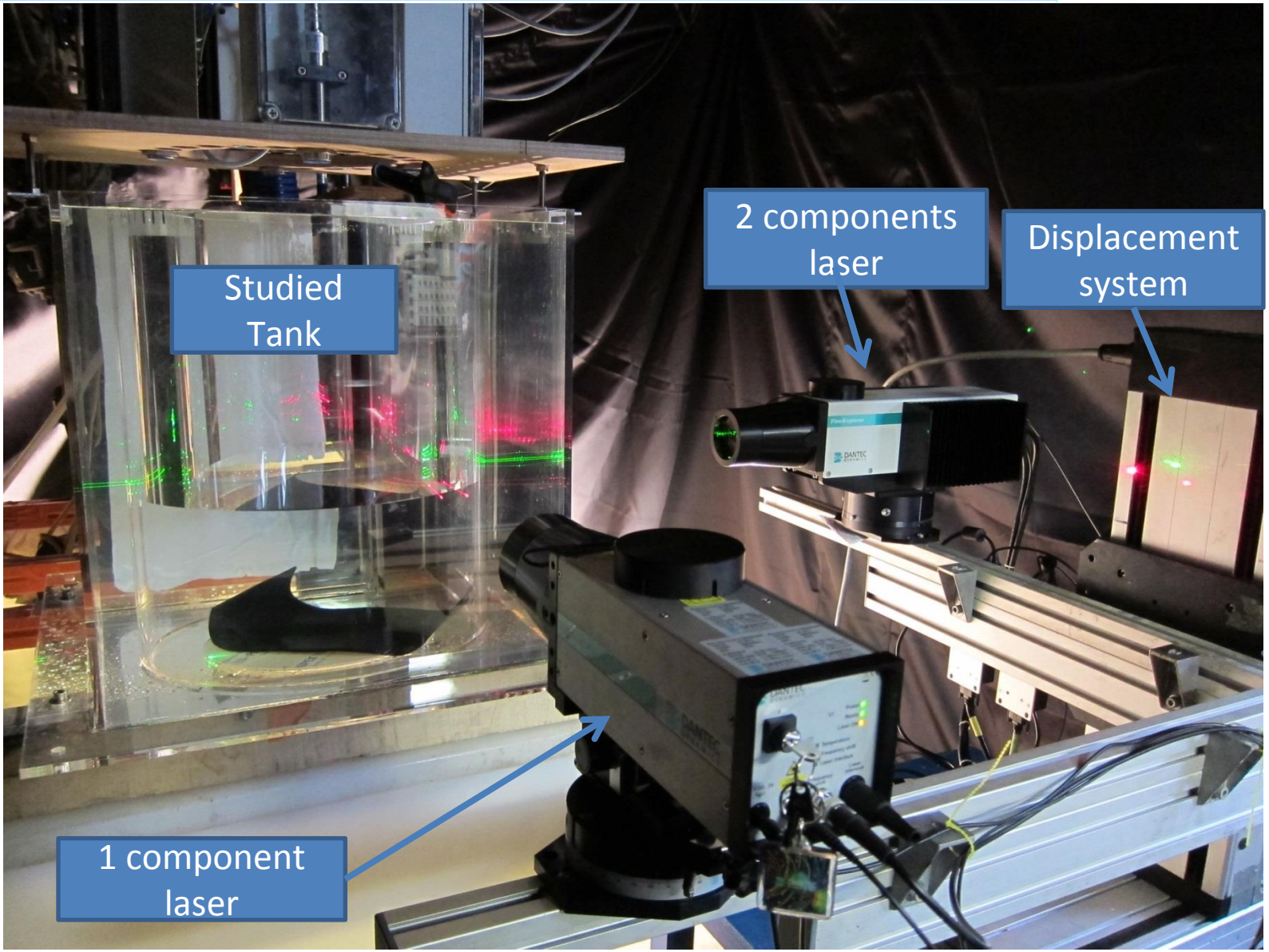


Measures : Water height



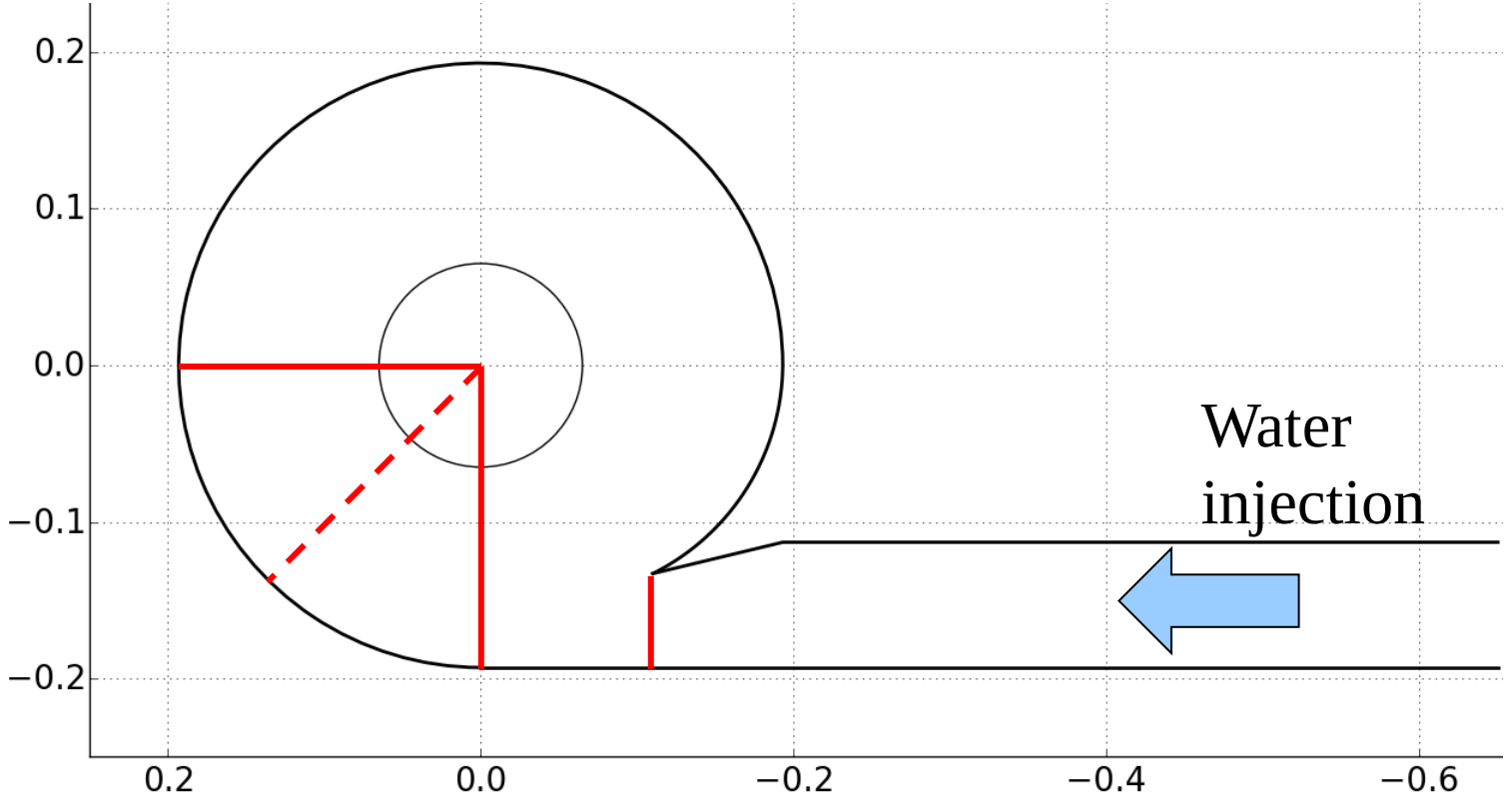
Water levels measured in **7 points** using acoustic sensors

Measures: Velocities
LDV (Laser Doppler Velocimetry)



Measures: Velocities
LDV (Laser Doppler Velocimetry)

- Velocities are measured in one point
- Planes where the velocity is measured:



- Optical difficulties because of the shape of the studied tank

Summary

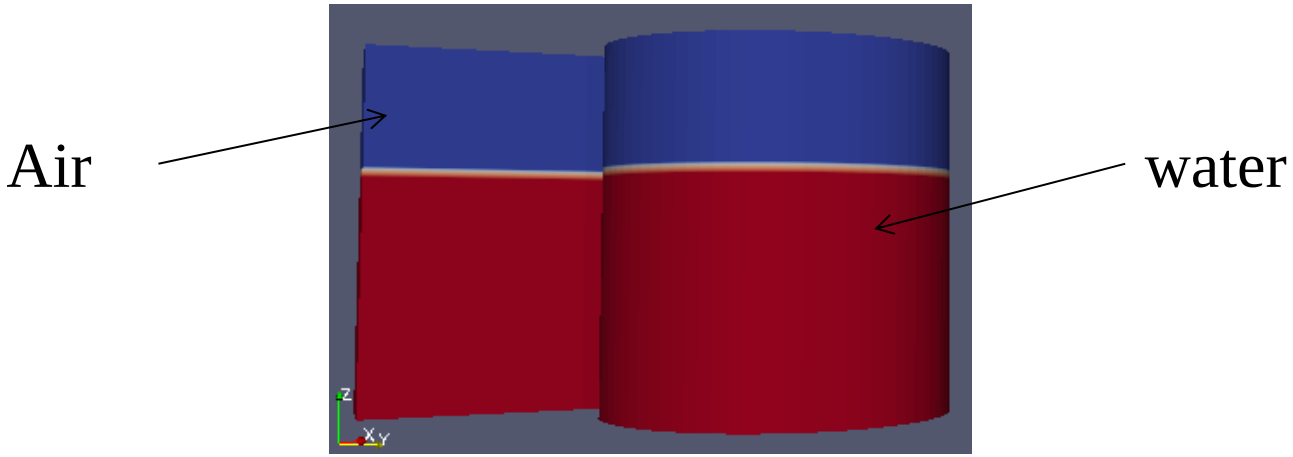
1. Experimental device

2. Numerical model
   1. General approach and solver
   2. Mesh
   3. Boundary conditions

3. Comparisons

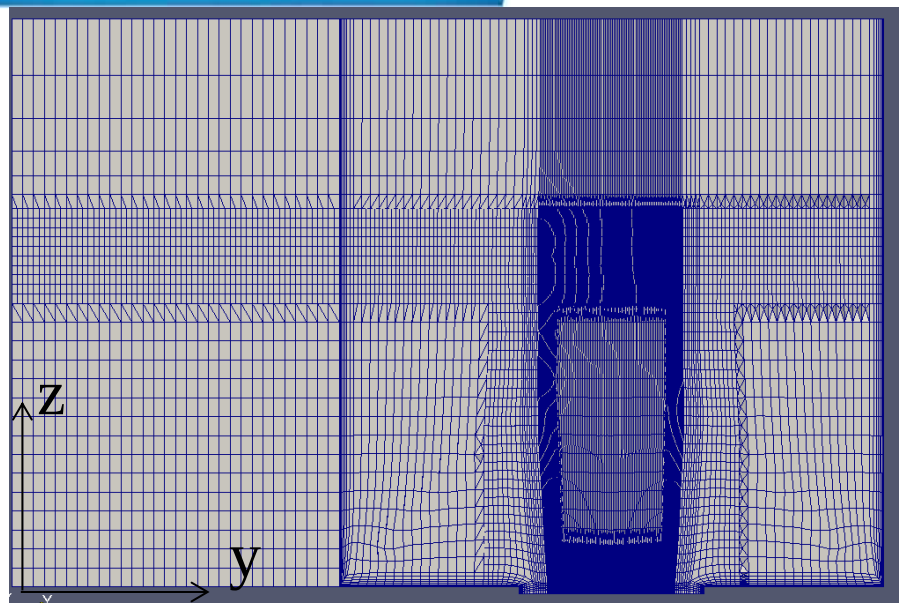
Equation solved: interFoam solver

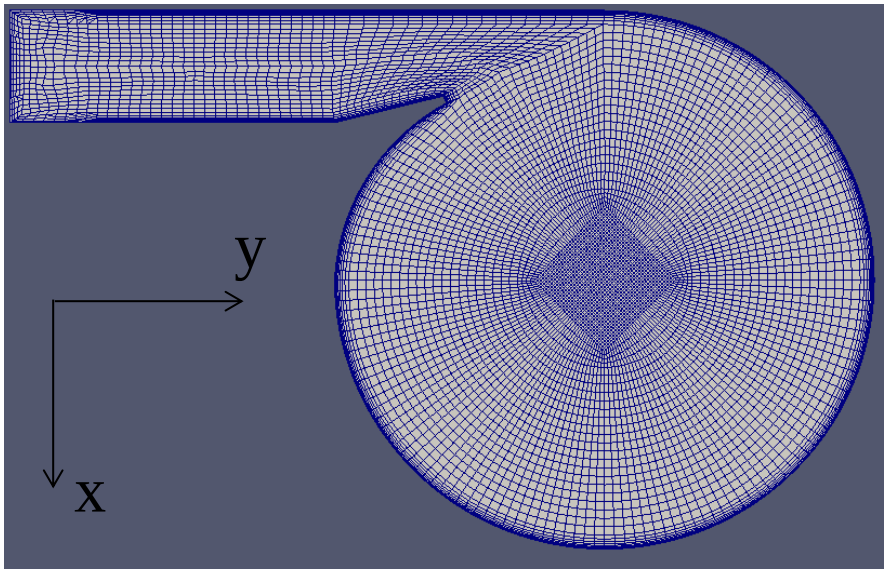
- Mass equation
- Momentum equation
- 2 phases distinction: Volume of Fluid (VoF)
  - Another variable: fraction of fluid



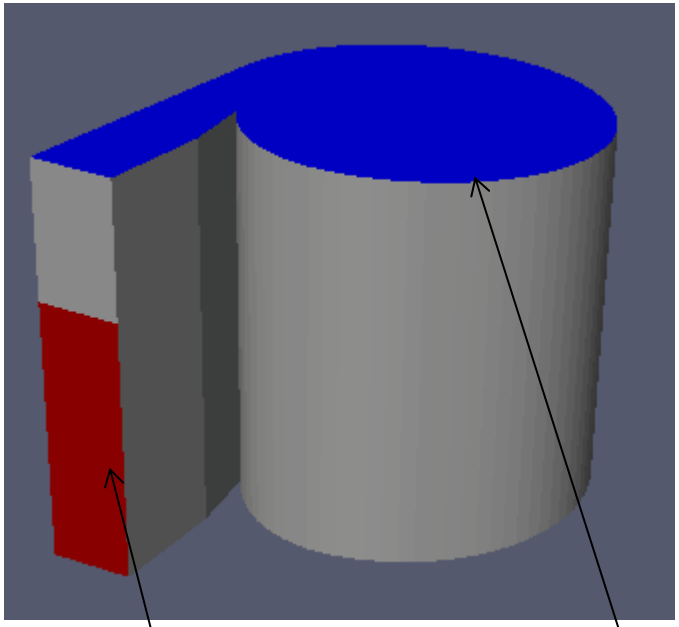
Mesh

- Initial mesh made with **blockMesh**
- boundary layers and refinement zones added with **snappyHexMesh**



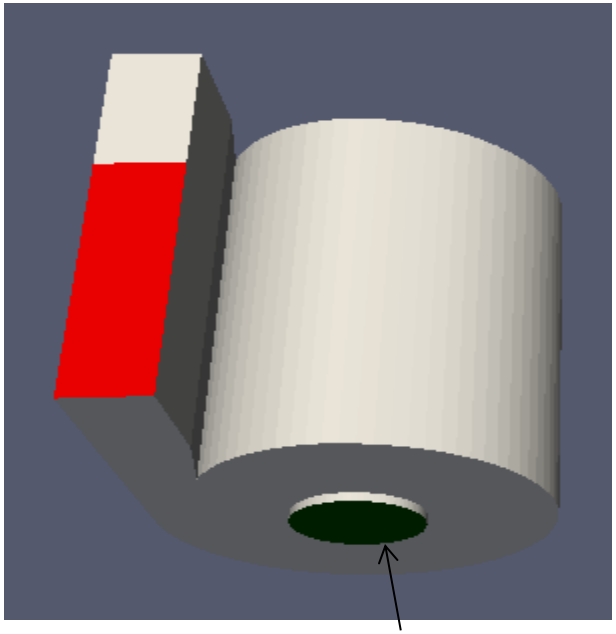


Boundary conditions



Injection

Atmosphere



Diaphragm

Boundary conditions	Velocities	Pressure	Volume fraction
Injection	fixedValue	fixedfluxPressure	inletOutlet
walls	fixedValue	fixedfluxPressure	zeroGradient
Diaphragm	pressureInletOutletVelocity	totalPressure	inletOutlet
Atmosphere	pressureInletOutletVelocity	totalPressure	inletOutlet

Others characteristics

- Time step adjusted with maxCo = 0.5
- Pressure-velocity coupling: Pimple algorithm
- Numerical schemes:

		Scheme
time		Euler
Gradient		Gauss linear
Convection	div(rho*phi,U)	Gauss limitedLinearV 1
	div(phi,alpha)	Gauss vanLeer
	div(phirb,alpha)	Gauss interfaceCompression
	div((muEff*dev(T(grad(U)))))	Gauss linear

- Turbulence not represented: laminar flow

Summary

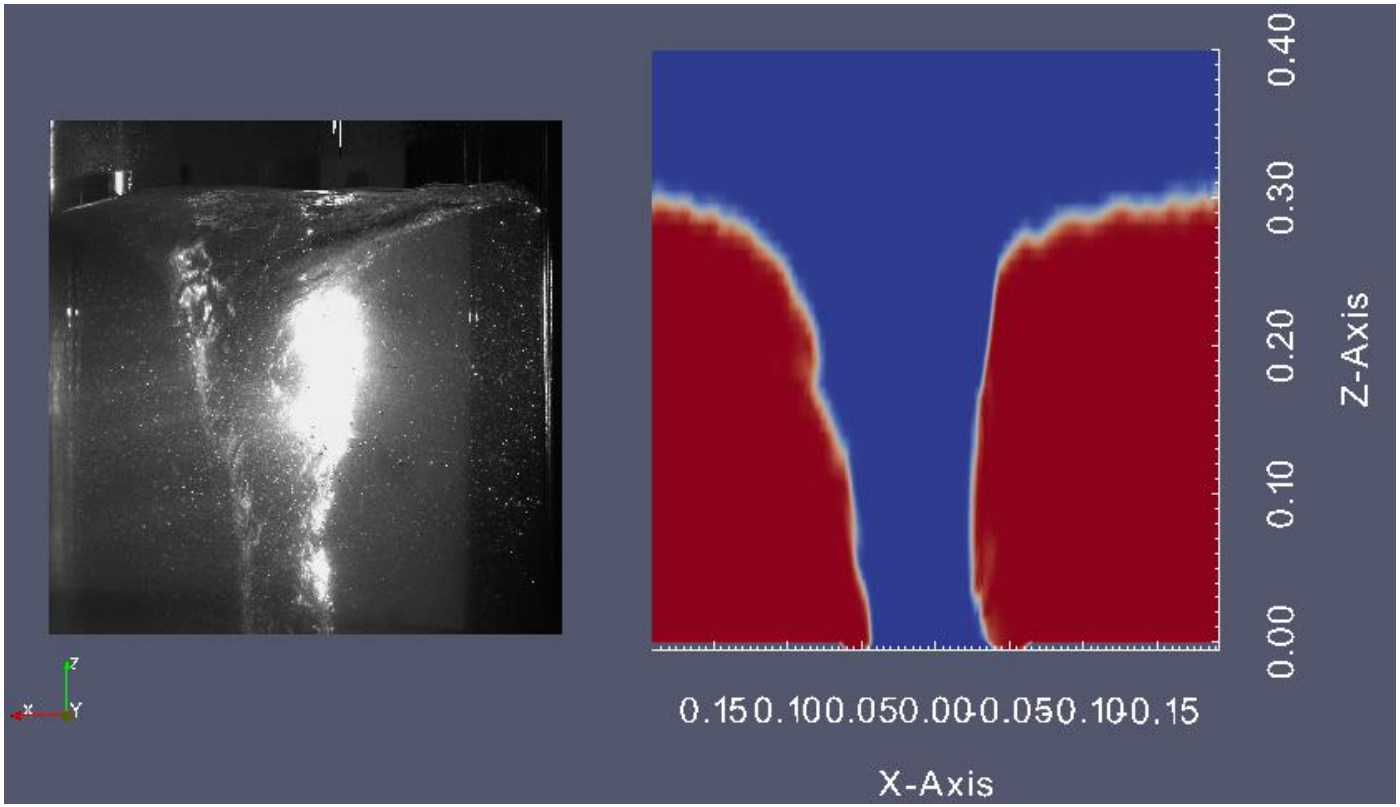
1. Experimental device

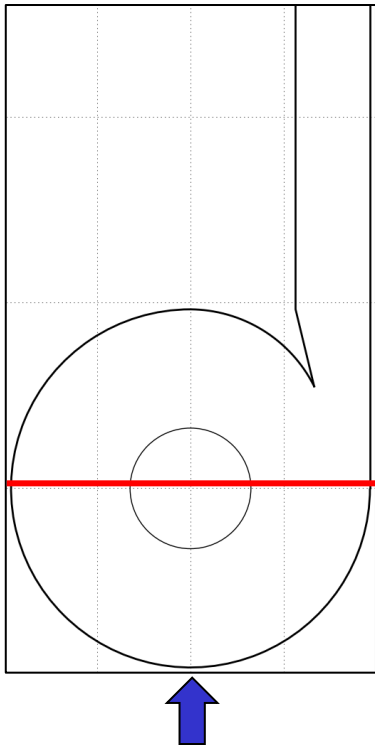
2. Numerical model

3. Comparisons
   1. Qualitative comparison
   2. Water height
   3. Velocities

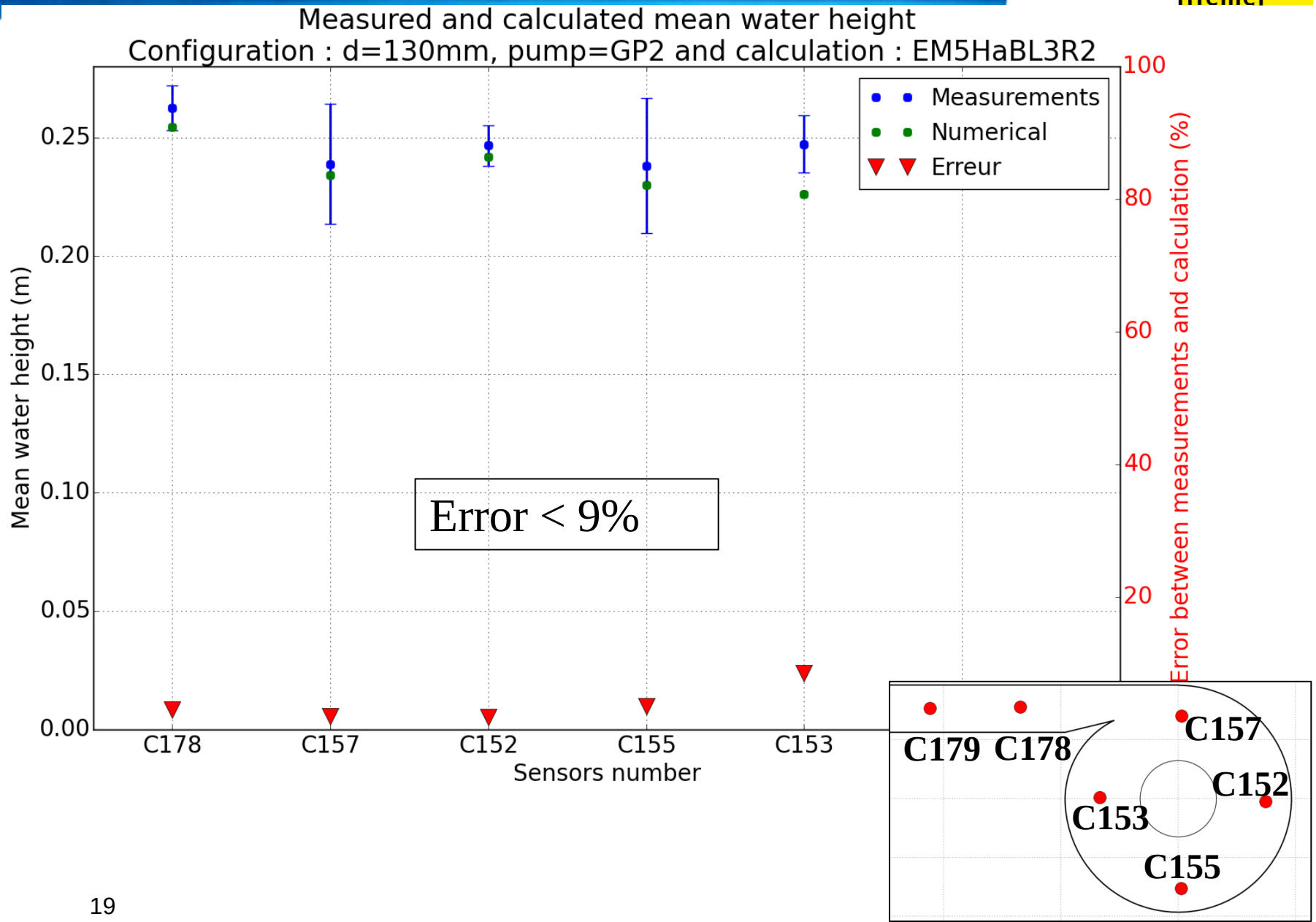
Qualitative comparison

interFoam represents well the physical phenomenon

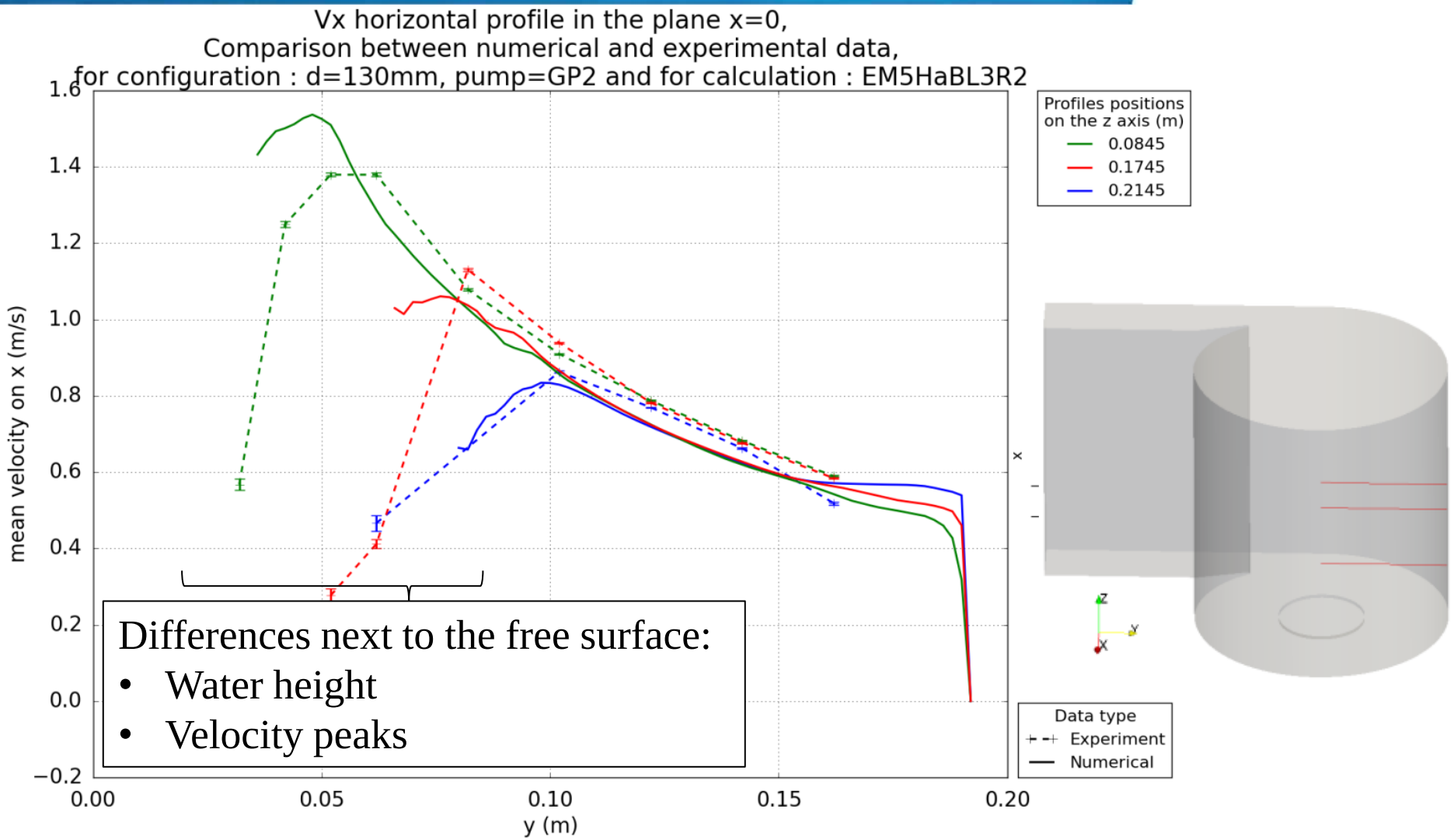




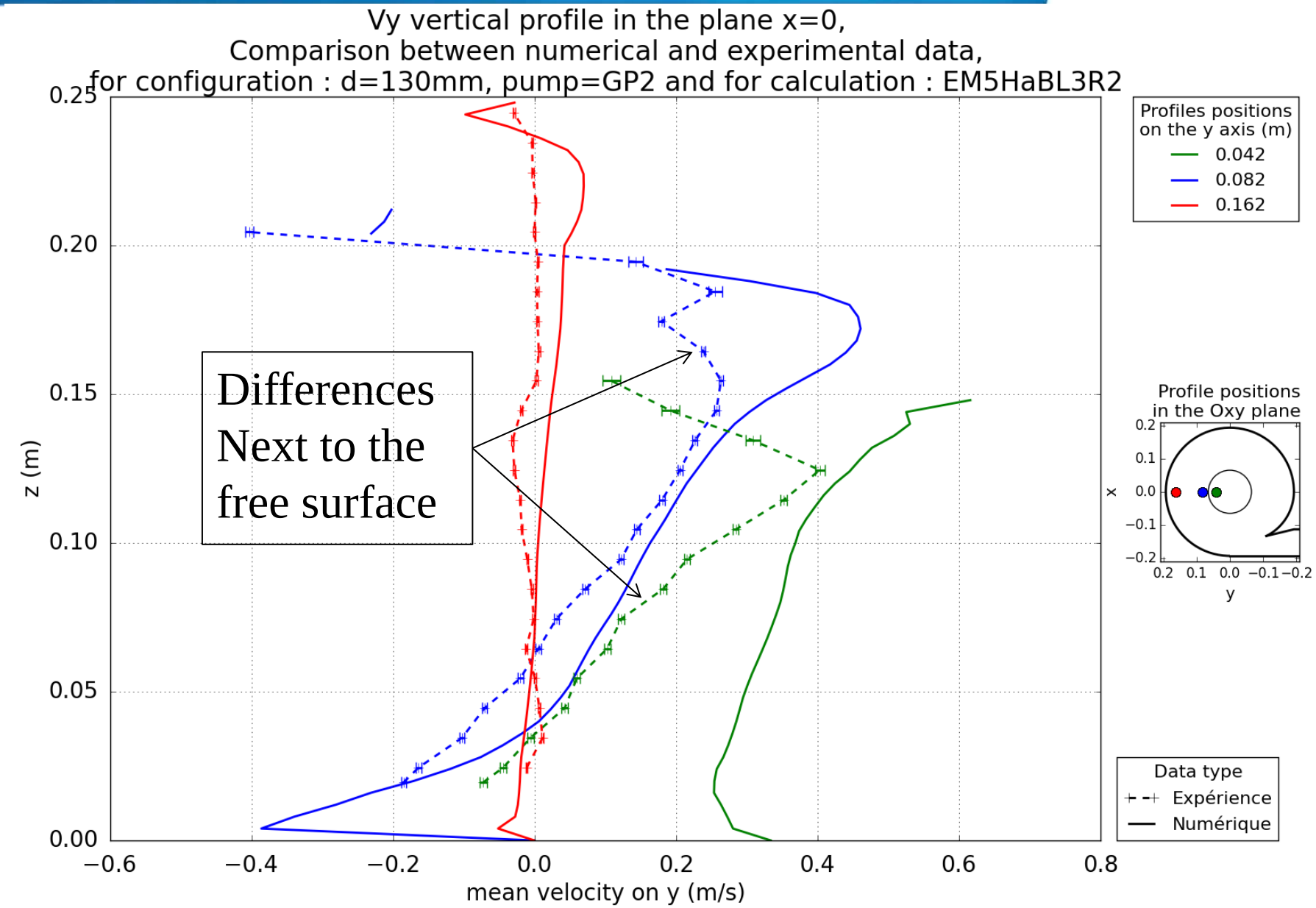
Water height



Tangential velocities



Radial Velocities



To conclude

- Complex flow
  - 3D and transient flow
  - Comparison with experimental data

- Perspectives
  - Other studies with turbulence model
  - Turbine

Thank you for your attention

Gaspard Fourestier
PhD Student at GEPS Techno, ENSTA Bretagne and IFREMER, France
gaspard.fourestier@geps-techno.com