Application of DualSPHysics in assessment and design of a wave absorbing caisson

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OUTLINE

1- NUMANTIA PROJECT. HARBOUR IN PUNTA LANGOSTEIRA

2- NUMERICAL MODELLING OF THE ANTI-REFLECTIVE CAISSON

3- SPH MODELLING WITH DUALSPHYSICS. MULTIGPU

4- RESULTS WITH DUALSPHYSICS: VALIDATION AND ANALYSIS

5- CONCLUSIONS

1 - NUMANTIA Project

Universida de Vigo

UNIVERSIDADE DA CORUÑA

OBJECTIVE: Numerical design of low-wave-reflective quay wall **caissons** in the new harbour of Punta Langosteira.

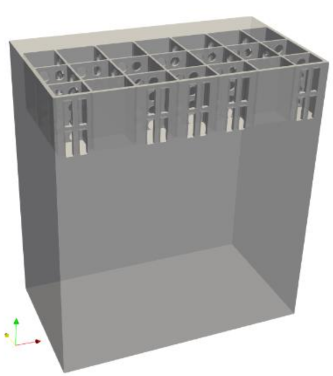
Punta Langosteira is in A Coruña, Northwest of SPAIN

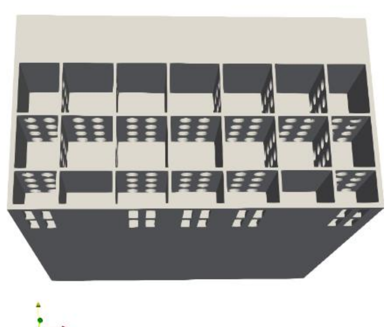
1 - Harbour in Punta Langosteira

- Main function of harbours is to provide sheltered waters for the moorage of ships.

- Quay walls are usually built with vertical paraments, but they almost entirely reflect the incident wave.

- A frequent solution is to equippe the parament with a **casson-type wave-energy absorbing**.





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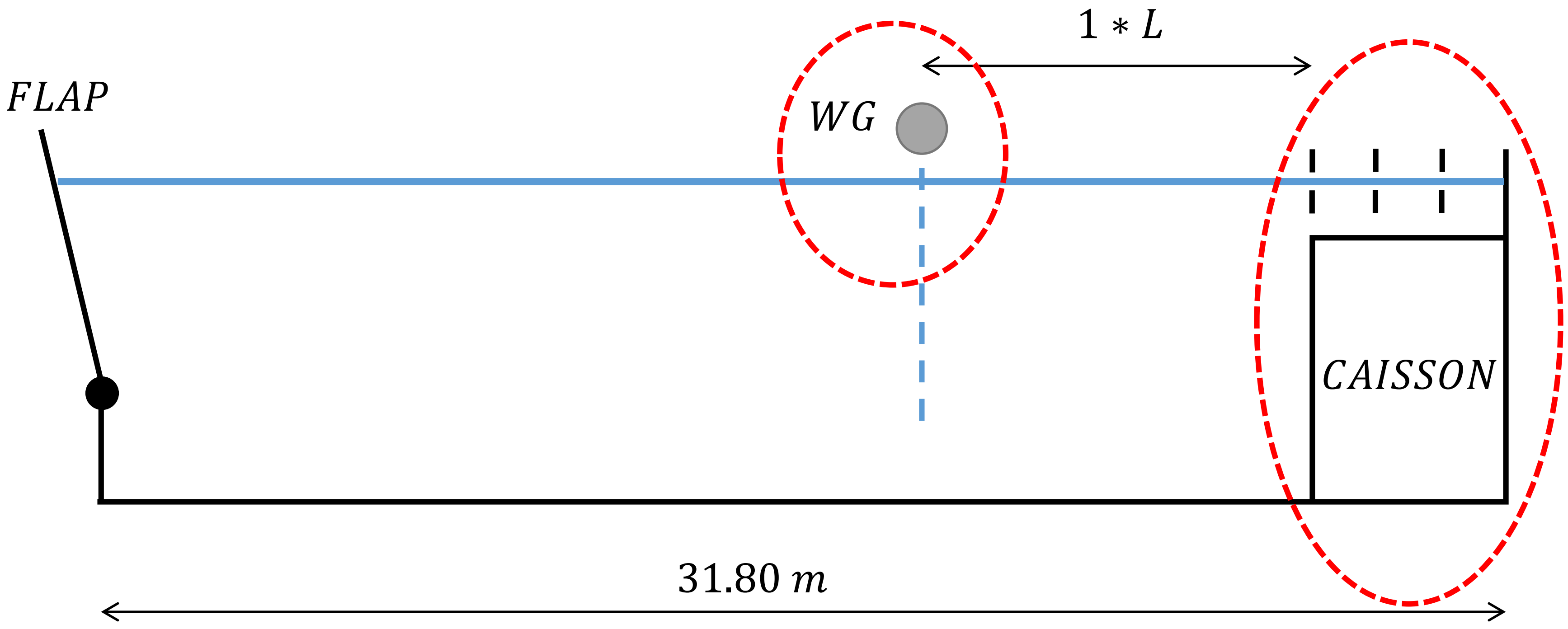
2 - Numerical modelling of the caisson

Grupo de Enxeñaría da Auga e do Medio Ambiente

- OBJECTIVE: Performance of the CAISSON
- PARAMETER: WAVE REFLECTION COEFFICIENT (at $1 * L$)

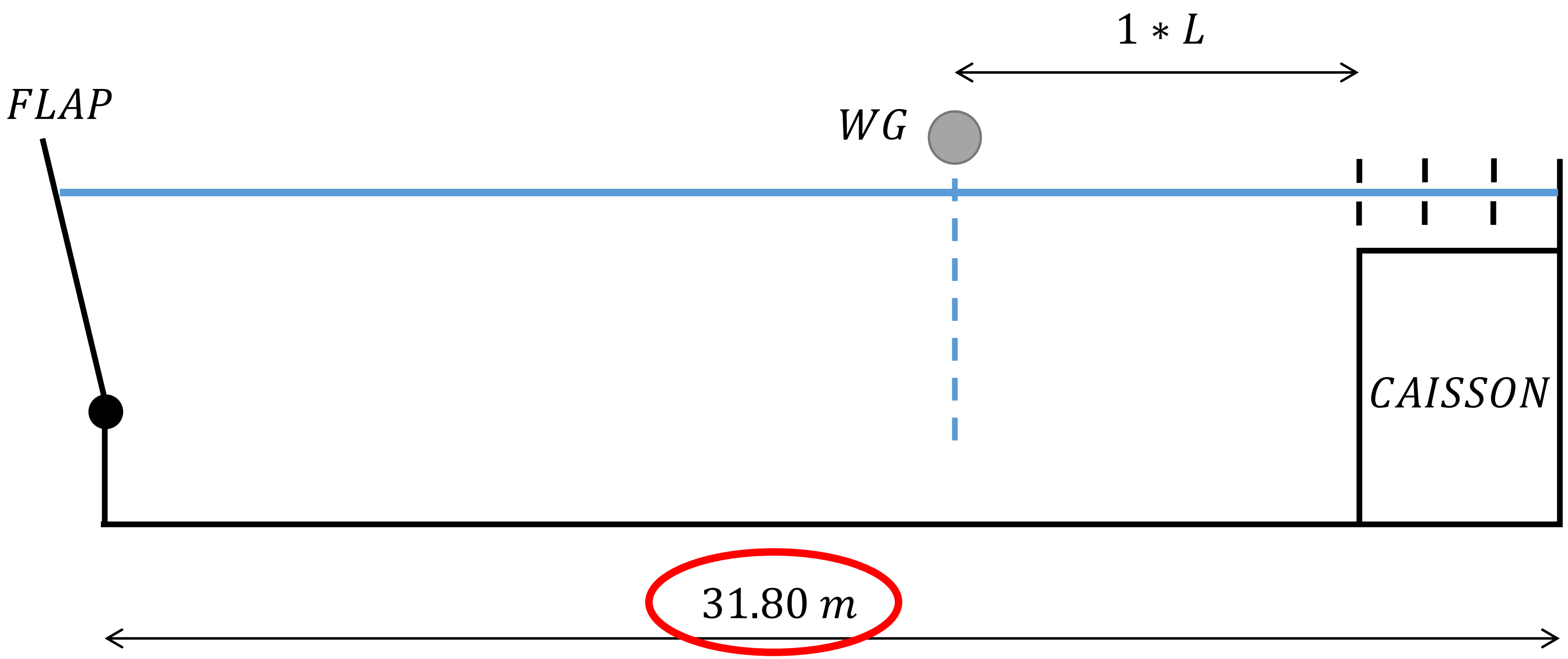


SCHEME OF THE WAVE FLUME

2 - Numerical modelling of the caisson

Experimental campaign at CITEEC (Universidad da Coruña) with a prototype of the actual caisson and real wave conditions

Wave conditions (Regular waves)			
H [m]	T [s]	d [m]	L [m]
0.025 – 0.05	1.5 – 2.8	1.36, 1.51	3.5 - 10



SCHEME OF THE WAVE FLUME

2 - Numerical modelling of the caisson

Grupo de Enxeñaría da Auga e do Medio Ambiente

Experimental campaign at CITEEC (Universidad da Coruña) with a prototype of the actual CAISSON

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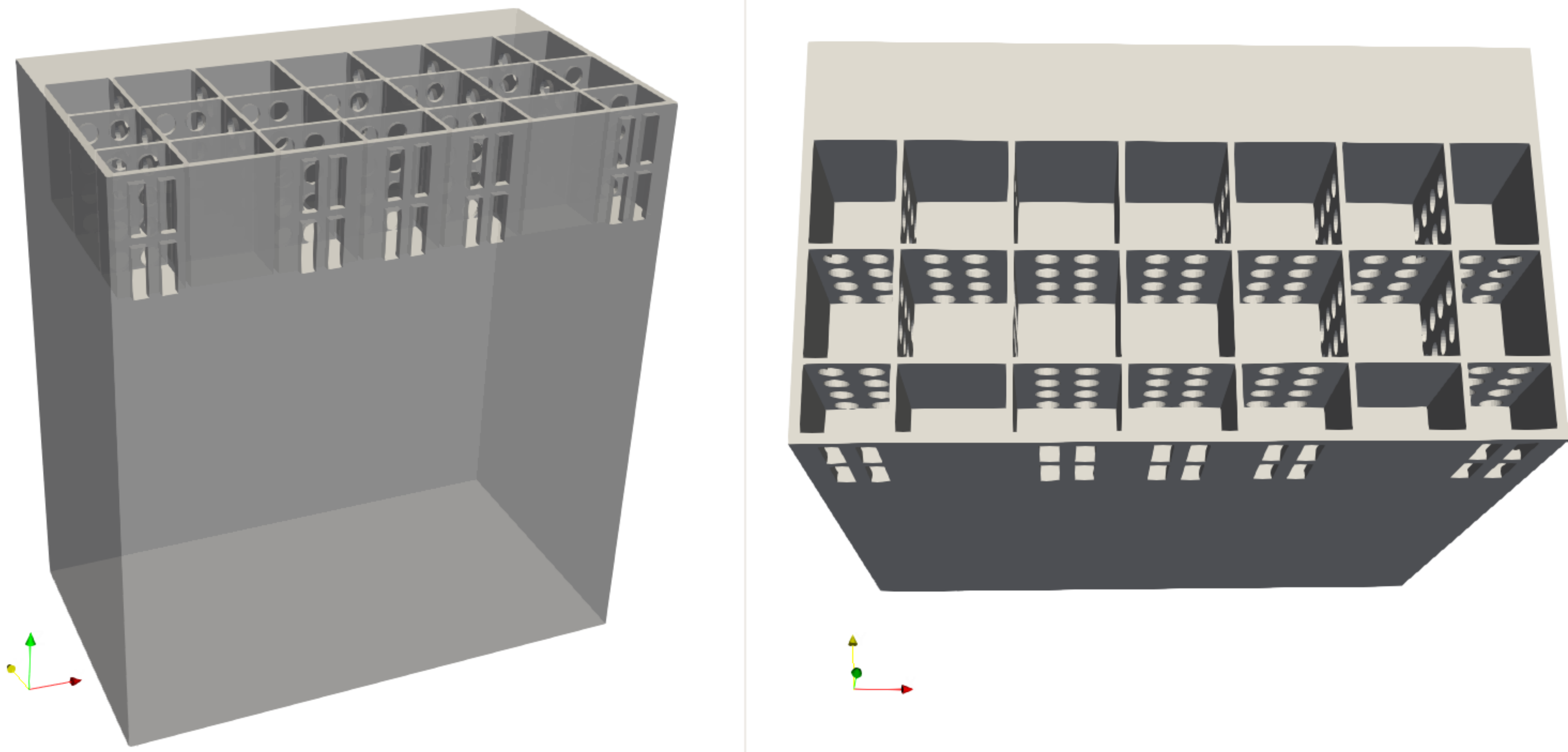
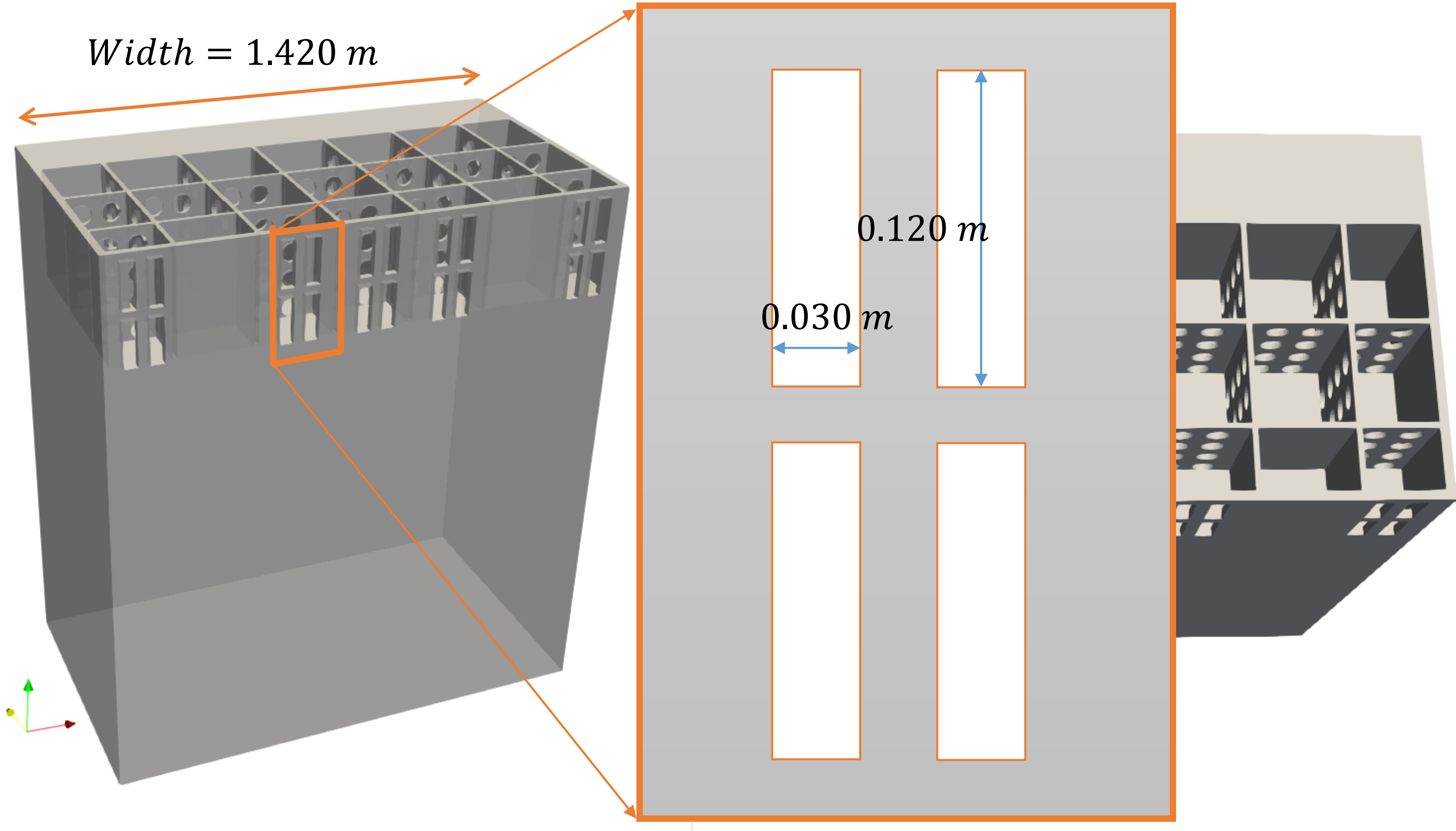


3D MODEL OF THE CAISSON

2 - Numerical modelling of the caisson

Grupo de Enxeñaría da Auga e do Medio Ambiente

Experimental campaign at CITEEC (Universidad da Coruña) with a prototype of the actual CAISSON



3D MODEL OF THE CAISSON

2 - Numerical modelling of the caisson

The problem under study is ideal to be solved using a mesh-based model
For NUMANTIA project, OpenFOAM is used for numerical modelling

Open∇FOAM

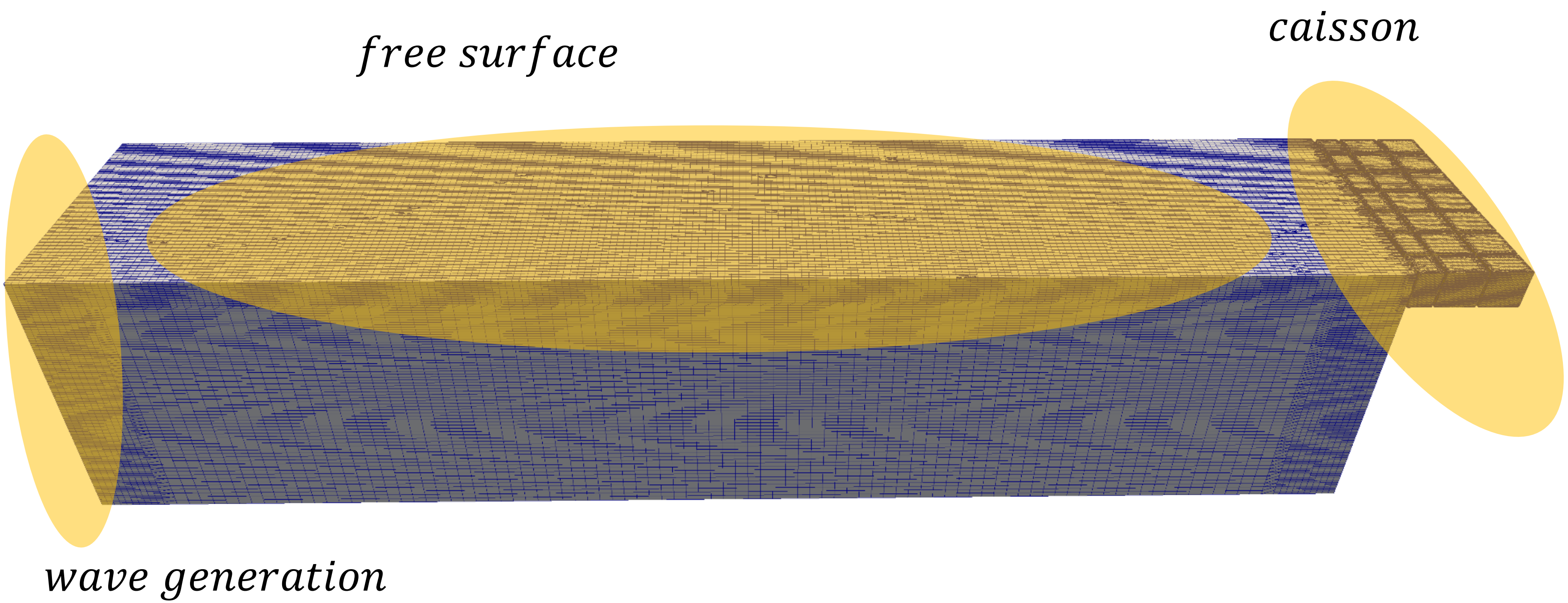
- No moving boundary condition
- Low Reynolds number
- No use of **Turbulence model**
- Geometrical multi-scale

WHY OPENFOAM?

2 - Numerical modelling of the caisson

The problem under study is ideal to be solved using a mesh-based model
For NUMANTIA project, OpenFOAM is used for numerical modelling

OpenFOAM



3D VIEW OF THE MESH

2 - Numerical modelling of the caisson

The problem under study is ideal to be solved using a mesh-based model
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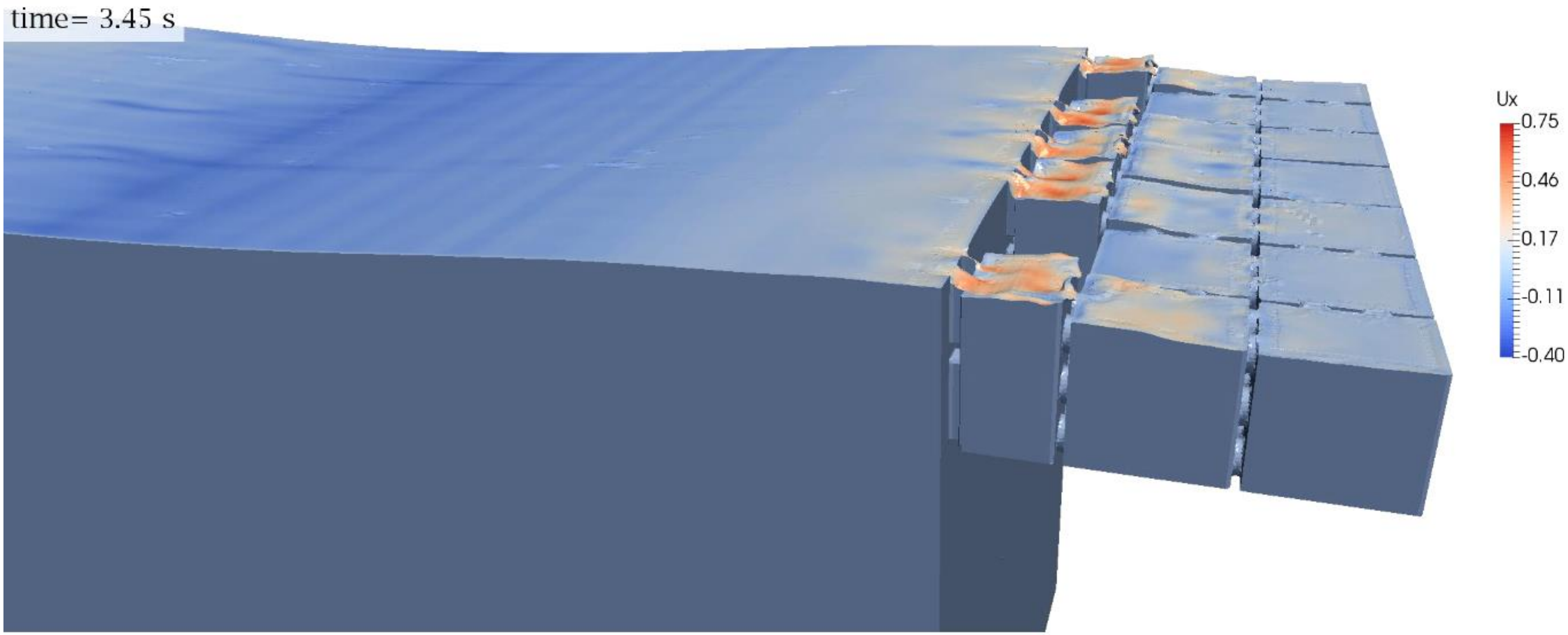

3D ANIMATION WITH OPENFOAM

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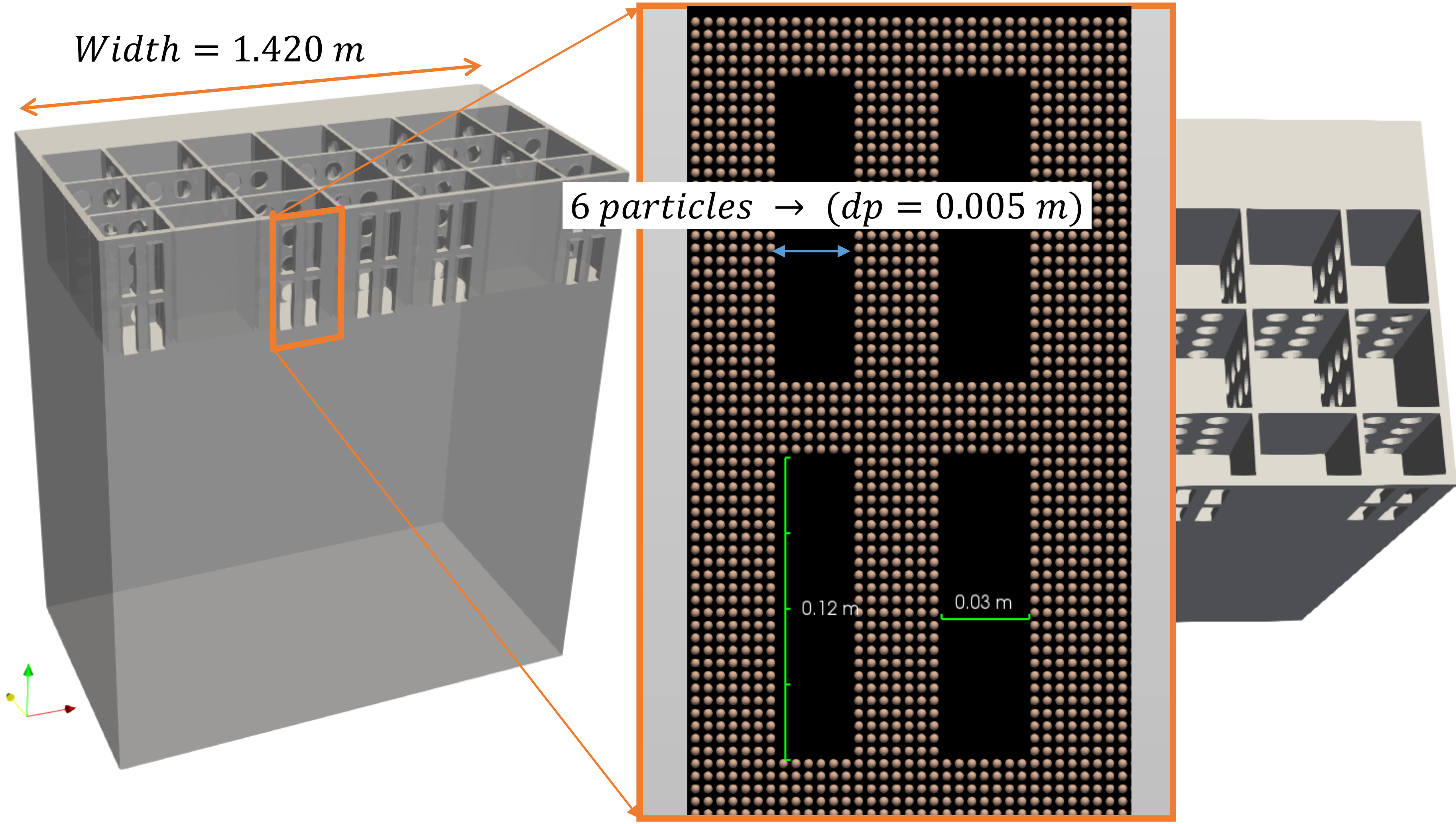
3 - SPH modelling with DualSPHysics

- ULTIMATE PURPOSE: design of new, efficient internal geometries of the CAISSON

3 - SPH modelling with DualSPHysics

How many particles can we simulate?



3D MODEL OF THE CAISSON

3 - SPH modelling with DualSPHysics

How many particles can we simulate?

Wave conditions (Regular waves)			
H [m]	T [s]	d [m]	L [m]
0.025 – 0.05	1.5 – 2.8	1.36, 1.51	3.5 - 10

Following **Altomare et al., 2015** it is recommended that $\frac{H}{dp} > 10$

Hence, we should use $\boldsymbol{dp \approx 0.004\, m}$

The therefore number of particles will be

$$N_p = \frac{\text{length} * \text{depth} * \text{width}}{dp^3} \approx 550{,}000{,}000$$

3 - SPH modelling with DualSPHysics

Available implementation in DualSPHysics to reduce the domain size:

- Inlet/Outlet (not fully tested to absorb waves) ✗
- Coupling with other model (e.g. SWASH) ✗
- Relaxation Zone (Altomare et al., 2018) ✗
- Piston with AWAS (wave conditions at a certain point) ✓

Available implementation in DualSPHysics to optimize the number of particles:

- Combining different *dp* using variable resolution:

  Vacondio et al., SPHERIC 2015: Not efficient ✗

  Leonardi et al., SPHERIC 2018: Only for 2D cases ✗

Hardware acceleration with DualSPHysics:

- SingleGPU: Limited by memory space ($\approx 30M$) ✗
- MultiGPU of 2013 (MPI version): NO double precision ✓

3 - SPH modelling with DualSPHysics

How many particles can we simulate?

- PISTON with AWAS at 2L from the caisson
- Execution with MultiGPU 2013 (MPI version)

$$N_p \approx 200{,}000{,}000$$

3 - SPH modelling with DualSPHysics

How many particles can we simulate?

WE WILL CREATE A REDUCED NUMERICAL DOMAIN FOR THIS WORK:

- T is reduced, L is reduced, domain length is reduced
- Width of the tank is reduced
- Depth is reduced (1/3)
- With same dp, the total number of particles is **12M**
- **There is no issue with precision now**

THAT NEW REDUCED DOMAIN CAN BE SIMULATED WITH:

- **One GPU (memory space enough)**
- **MultiGPU 2013 (only single precision)**

WE WILL VALIDATE SPH RESULTS vs OPENFOAM

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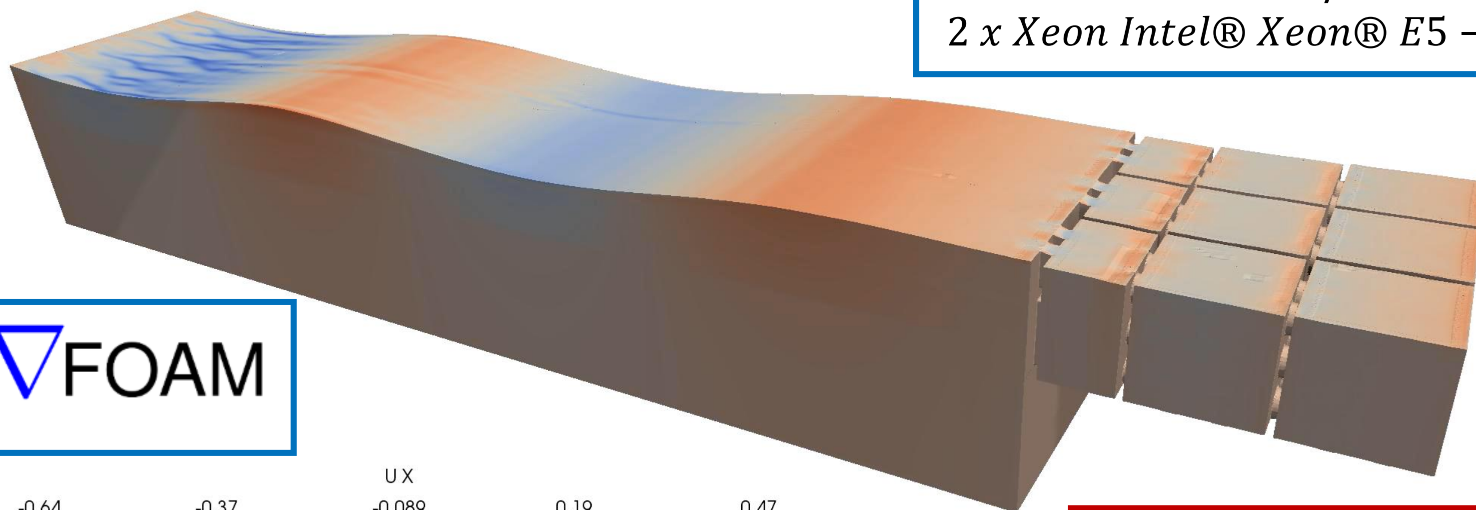
4 - SPH modelling with DualSPHysics

VALIDATION

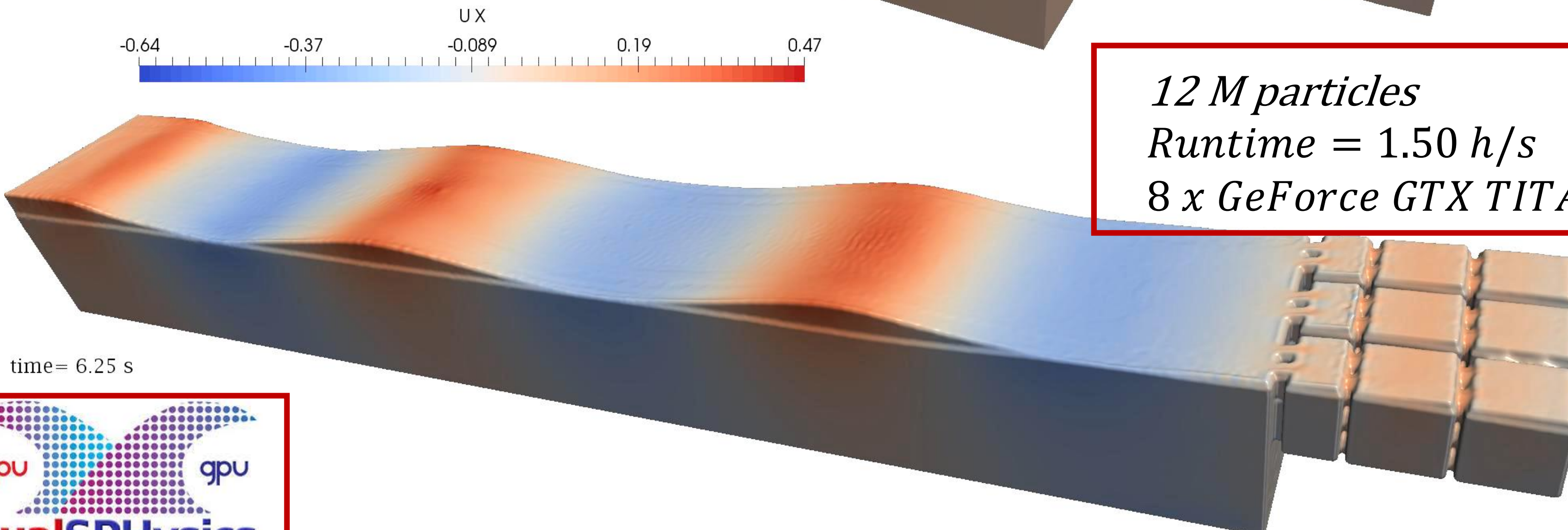
Wave condition: $T = 1.00m, \; H = 0.05m, \; d = 1.36m$

2.4 M cells
$Runtime = 0.65\ h/s$
$2\ x\ Xeon\ Intel®\ Xeon®\ E5-2650\ v3$

time= 4.13 s



OpenFOAM



12 M particles
$Runtime = 1.50\ h/s$
$8\ x\ GeForce\ GTX\ TITAN$

time= 6.25 s

cpu gpu DualSPHysics

4 - SPH modelling with DualSPHysics

VALIDATION Wave condition: $T = 1.00m,\ H = 0.05m,\ \ d = 1.36m$

The validation has been carried out by means of the **WAVE REFLECTION COEFFICIENT**

$$K_r = \frac{H_r}{H_i}$$

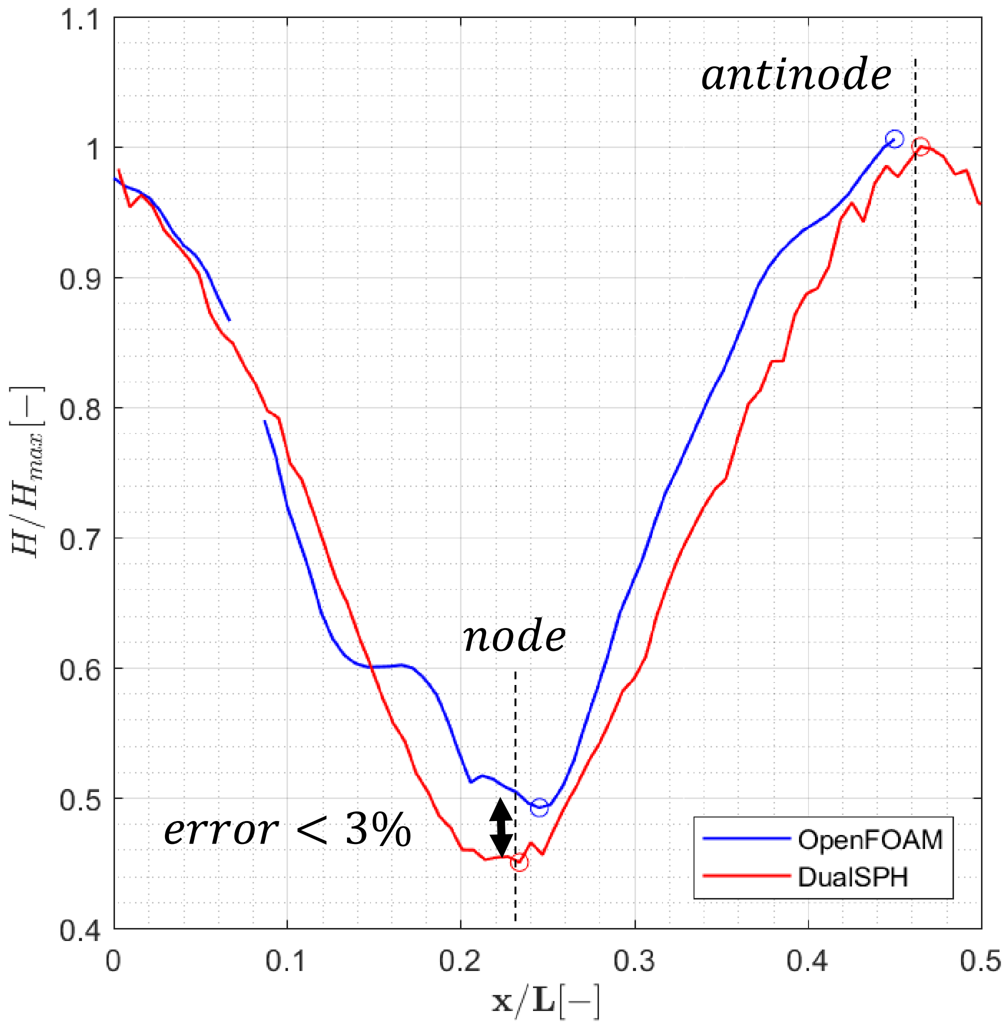
HEALY's method, for regular waves, leads to

$$K_r = \frac{H_{antinode} - H_{node}}{H_{antinode} + H_{node}}$$

4 - SPH modelling with DualSPHysics

VALIDATION Wave condition: $T = 1.00m,\ H = 0.05m,\ \ d = 1.36m$

REFLECTION COEFFICIENT of the caisson is computed either for OPENFOAM and SPH results



OpenFOAM

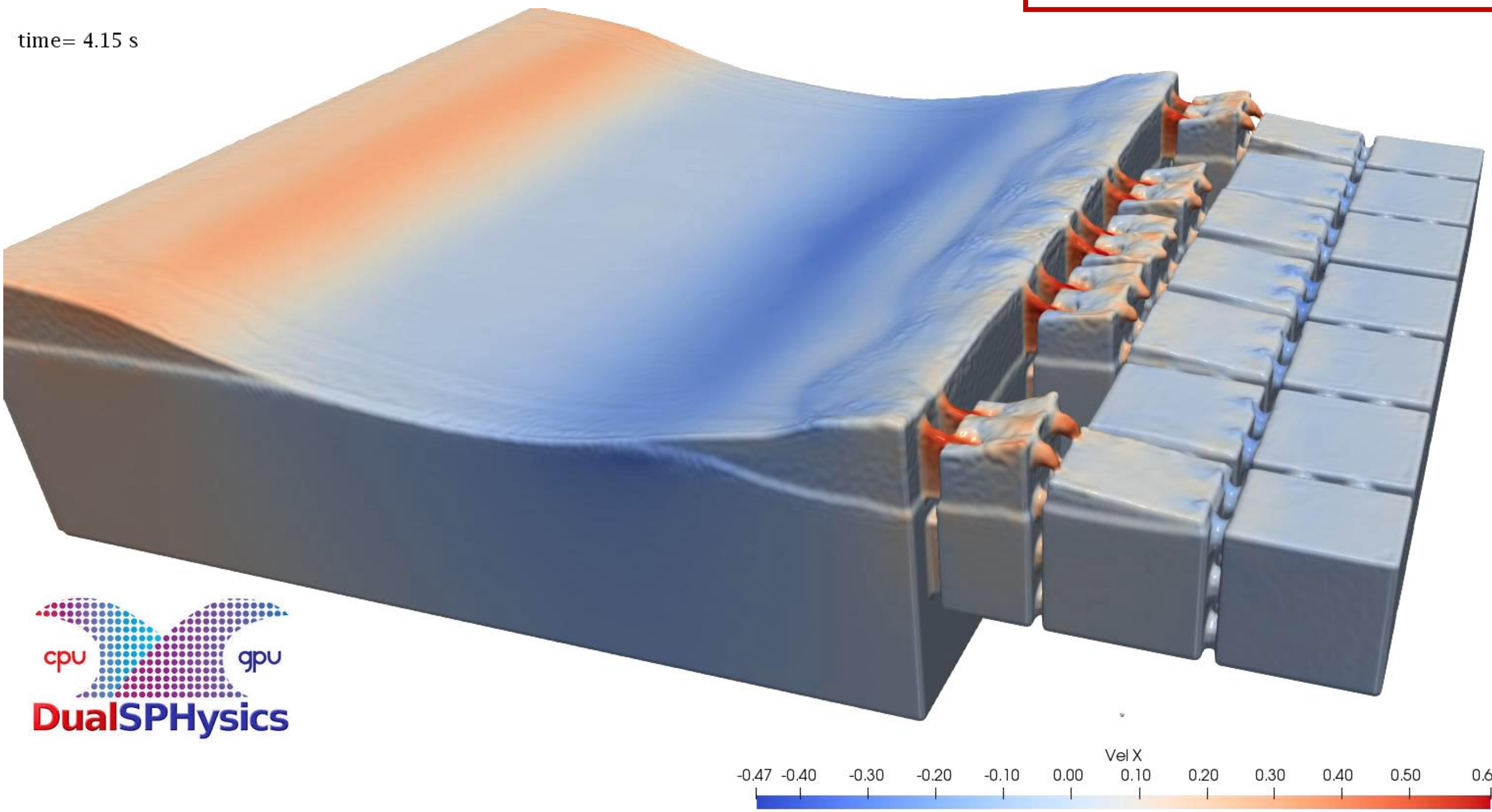
DualSPHysics

4 - SPH modelling with DualSPHysics

ANALYSIS Wave condition: $T = 1.00m,\ H = 0.05m,\ \ d = 1.36m$

ANIMATION $dp = 0.0035\ m$;

24 M particles
$Runtime = 4.70\ h/s$
8 x GeForce GTX TITAN



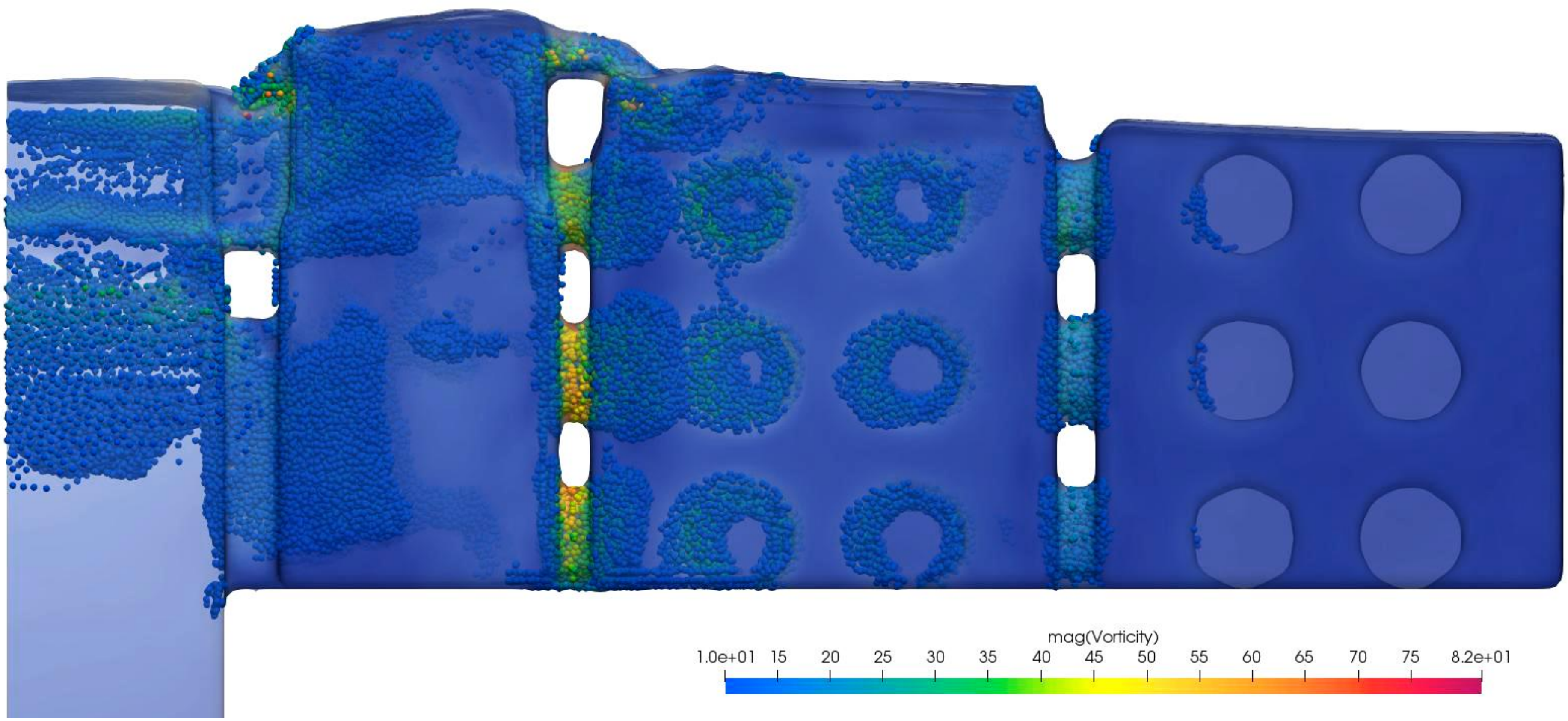
4 - SPH modelling with DualSPHysics

ANALYSIS

Wave condition: $T = 1.00m,\ H = 0.05m,\ \ d = 1.36m$

ANIMATION $dp = 0.0035\ m$

time= 4.25 s

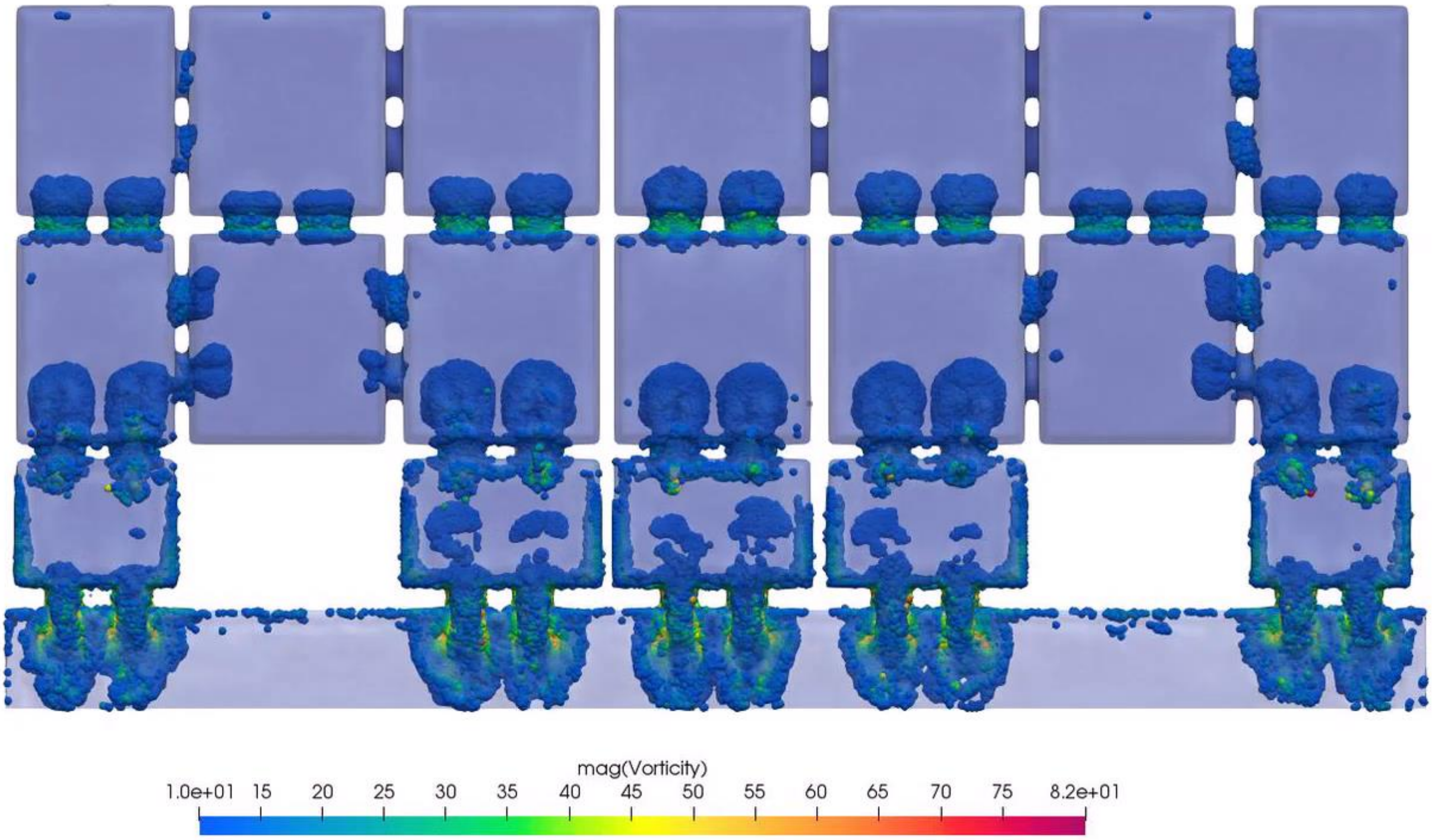


FREE SURFACE AND VORTICITY (LATERAL VIEW)

4 - SPH modelling with DualSPHysics

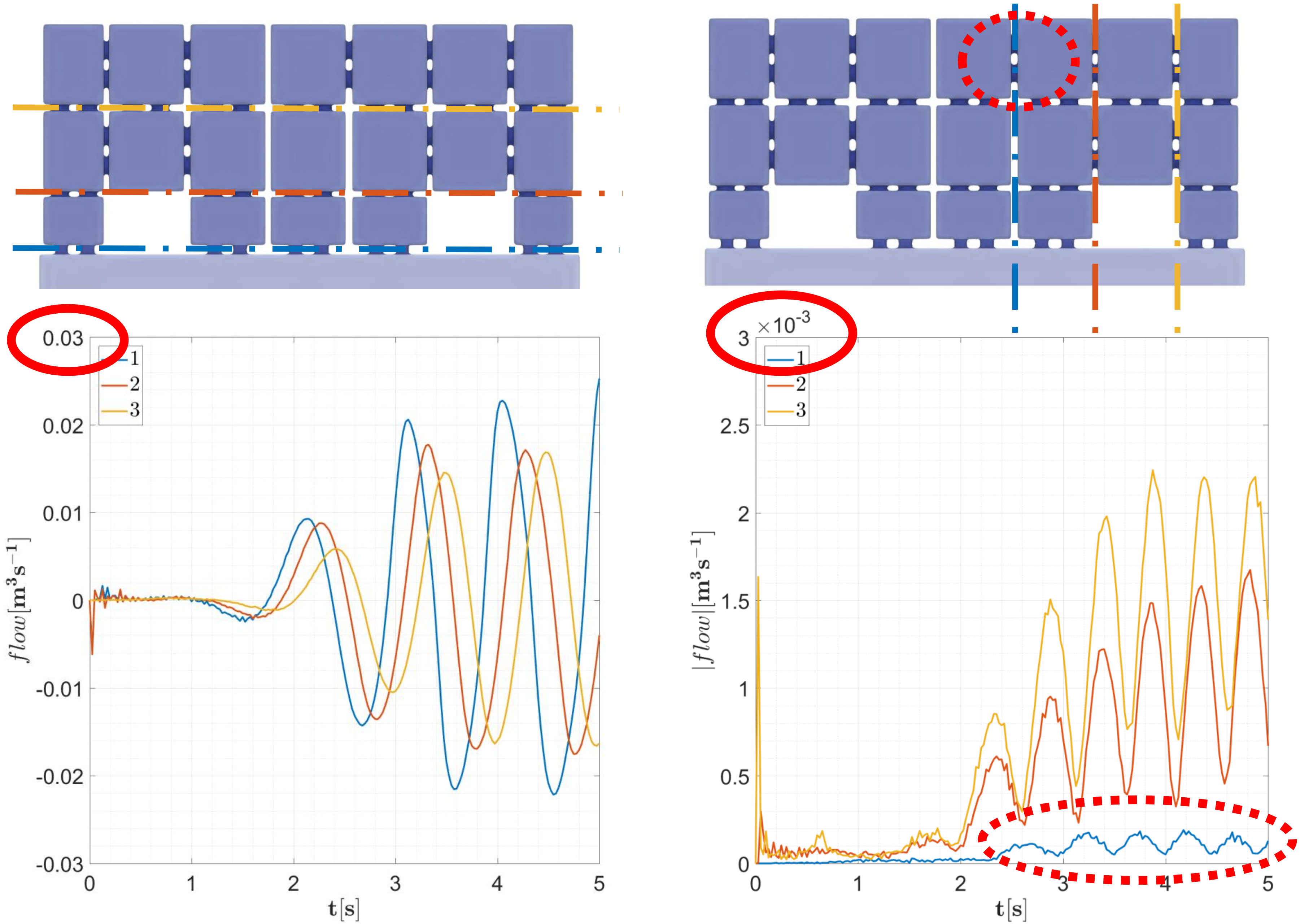
time= 3.53 s

Wave condition: $T = 1.00m,\ H = 0.05m,\ \ d = 1.36m$



FREE SURFACE AND VORTICITY (TOP VIEW)

4 - SPH modelling with DualSPHysics



FLOW RATES WITH DUALSPHYSICS

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5 - CONCLUSIONS

GOOD NEWS

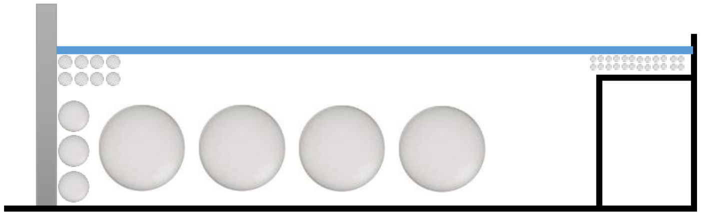
- The problem could have been solved with SPH method.

BAD NEWS

- It came up against the model limits.

We need now to improve the code:

- **Variable resolution (optimization)**
- **MultiGPU**



DualSPHysics

2011	2013	2014 – 2018	2019
DSPH	MultiGPU MPI	Double precision Multi-phase models Coupling with Chrono Relaxation zone Inlet/Outlet	MultiGPU (OpenMP)

Thanks for your attention