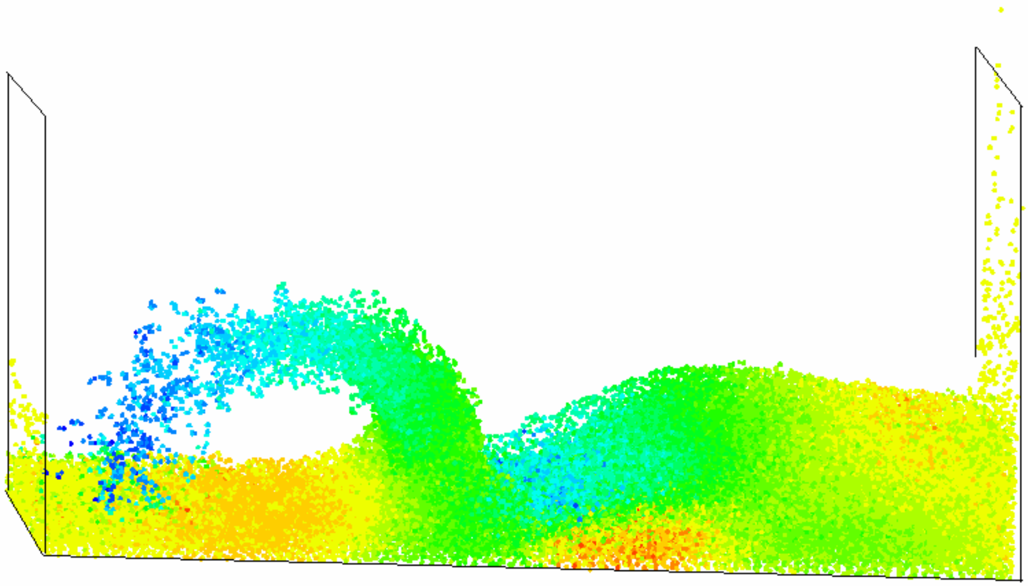
Modelling turbulent flows through Large Eddy Simulation in SPH



10th May 2006 – 1st SPHERIC workshop, Rome

Réza ISSA – Bendiks Jan BOERSMA – Damien VIOLEAU – Dominique LAURENCE

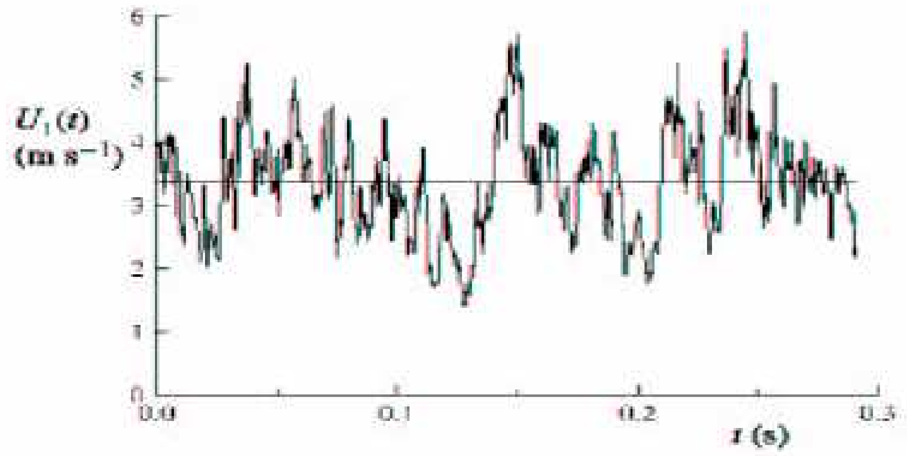
EDF – TU Delft – EDF – Univ. Manch. / EDF

Modelling turbulent flows through Large Eddy Simulation in SPH

1. *Introduction to turbulence modelling*
2. *Large Eddy Simulation in SPH*
3. *Applications*

Introduction to turbulence modelling

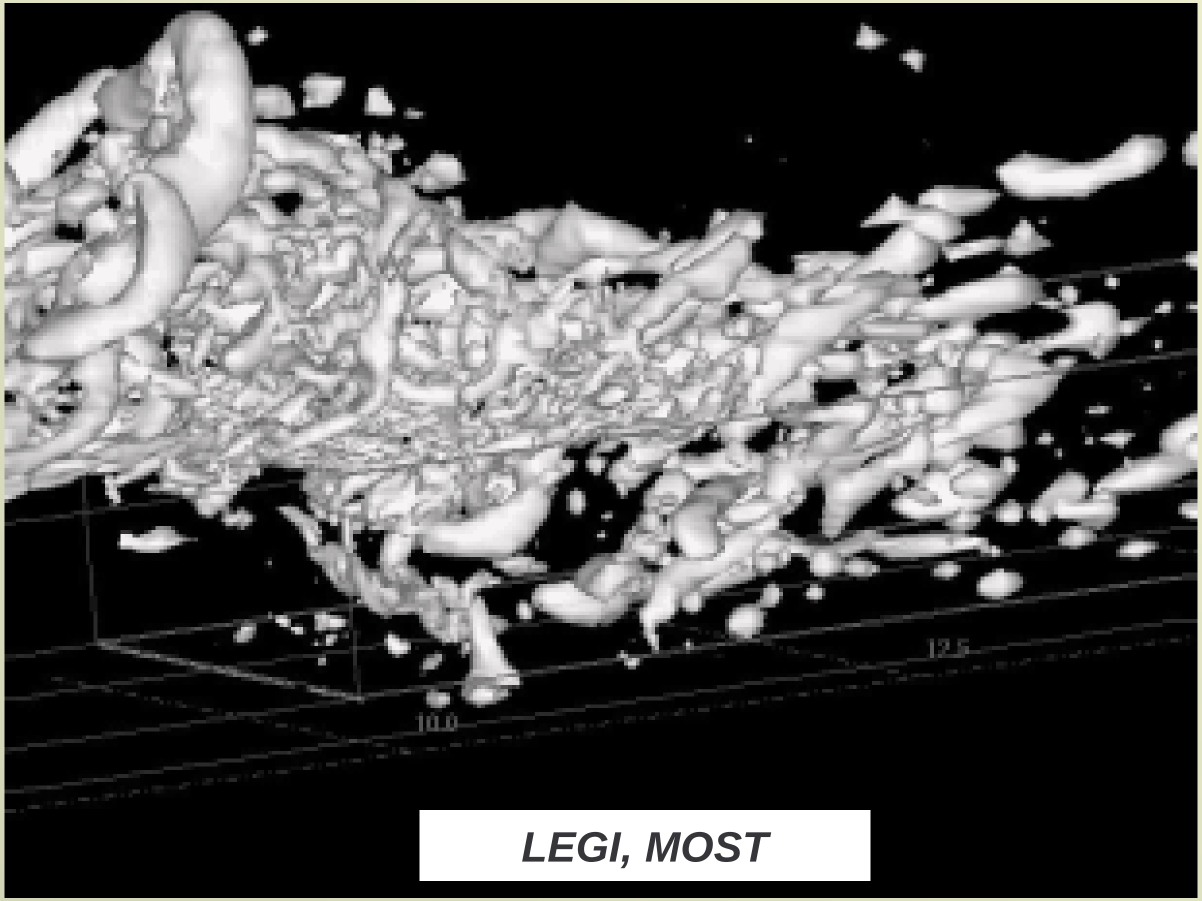
Characteristics of turbulent flows (1)



Tong et al, 1995

à Unsteady and unpredictable

Characteristics of turbulent flows (2)



LEGI, MOST

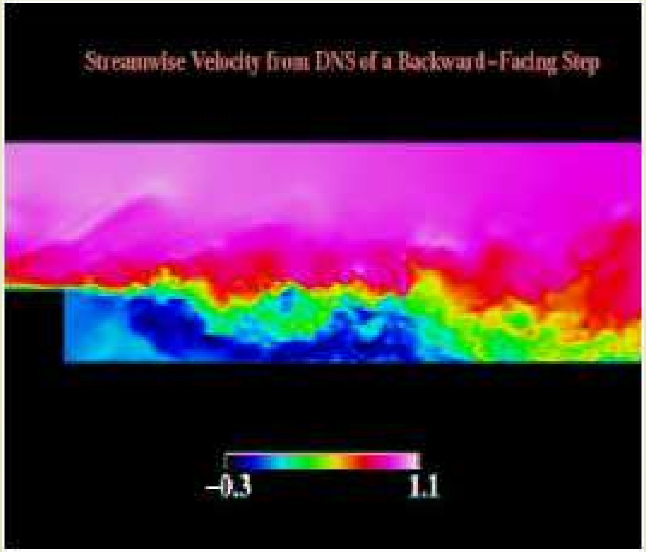
à Wide range of eddies

Direct Numerical Simulation (DNS)

à **ALL turbulence scales are SIMULATED**

à **Reference method, but :**

- Very fine grid is required
- Very small time step
- Restricted to low Reynolds number flows

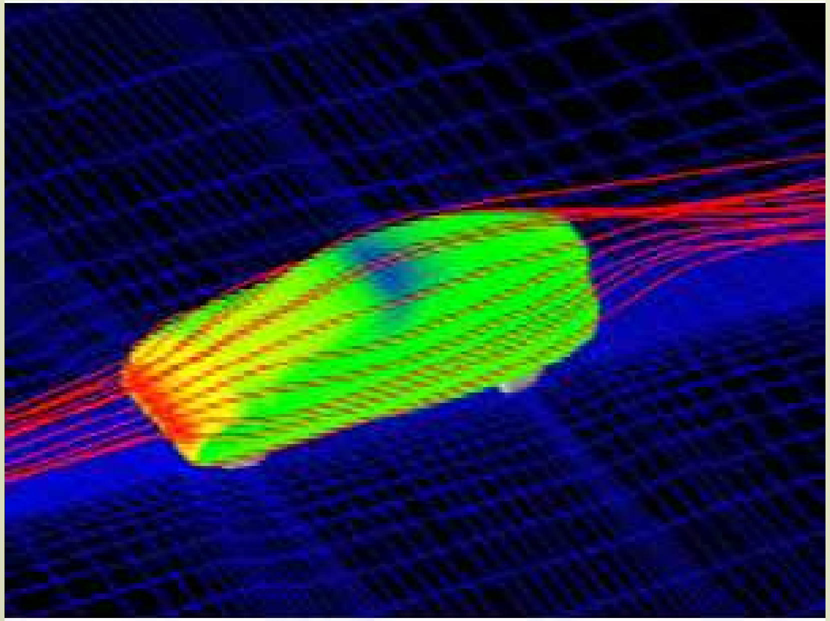


Le and Moin, Stanford Uni.

à ***Impossible in practice with SPH***

Statistical modelling (RANS)

à *ALL turbulence scales are MODELLED*



Luo et al, 1996

à *Only averaged values are considered*

à *Widespread in industrial codes*

Large Eddy Simulation (LES)

à Large scales are simulated ~ DNS

à The influence of small scales is modelled ~ RANS

- Velocity fluctuations are known
- Enables high Reynolds number flow simulation

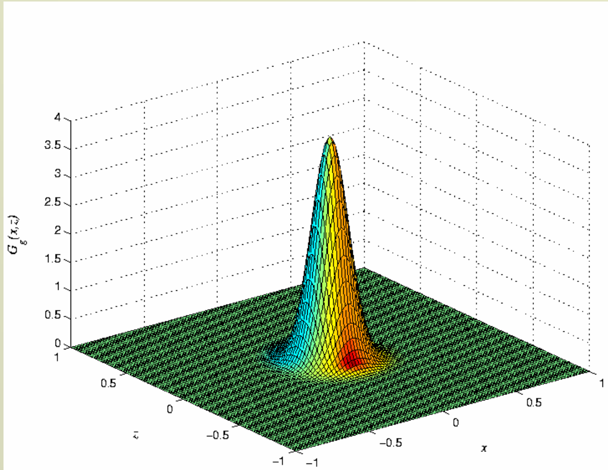
à More and more used in industry

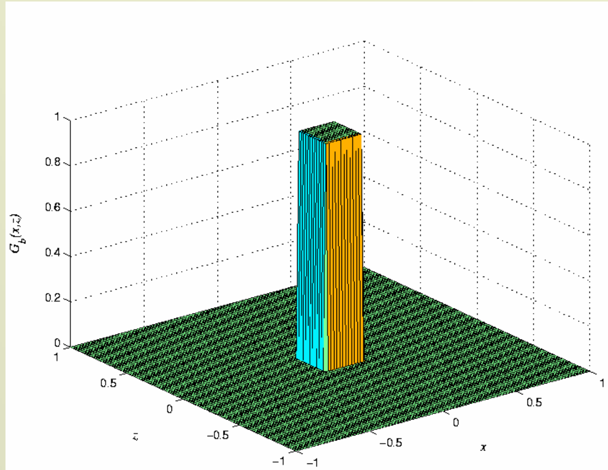
Filtered field computation

à ***Definition of filtered fields that only contain the large scale contribution***

à ***Spatial filter function characterized by a width*** Δ **:**

- Gaussian
- Box function
- Computation grid





$$\tilde{u}_i(x) = \int u_i(x')G(x,x')dx'$$

$$A(\underline{r}) = \int_\Omega A(\underline{r}')w_h(|\underline{r}-\underline{r}'|)d\underline{r}'$$

Filtered Navier-Stokes equations in SPH formalism

à **_Filtered momentum equation_**

$$\frac{D\underline{\tilde{u}}_a}{Dt} = -\sum_b m_b \left(\frac{\tilde{p}_a}{\tilde{\rho}_a^2} + \frac{\tilde{p}_b}{\tilde{\rho}_b^2} - \frac{8\left(\nu_{T,a} + \nu_{T,b}\right)}{\tilde{\rho}_a + \tilde{\rho}_b} \frac{\underline{\tilde{u}}_{ab} . \underline{r}_{ab}}{r_{ab}^2} \right) \dot{w}_h\left(r_{ab}\right) \frac{\underline{r}_{ab}}{r_{ab}} + \underline{F}_a^e$$

à **_Filtered continuity equation_**

$$\frac{D\tilde{\rho}_a}{Dt} = \sum_b m_b \underline{\tilde{u}}_{ab} \dot{w}_h\left(r_{ab}\right) \frac{\underline{r}_{ab}}{r_{ab}}$$

à **_Filtered state equation_**

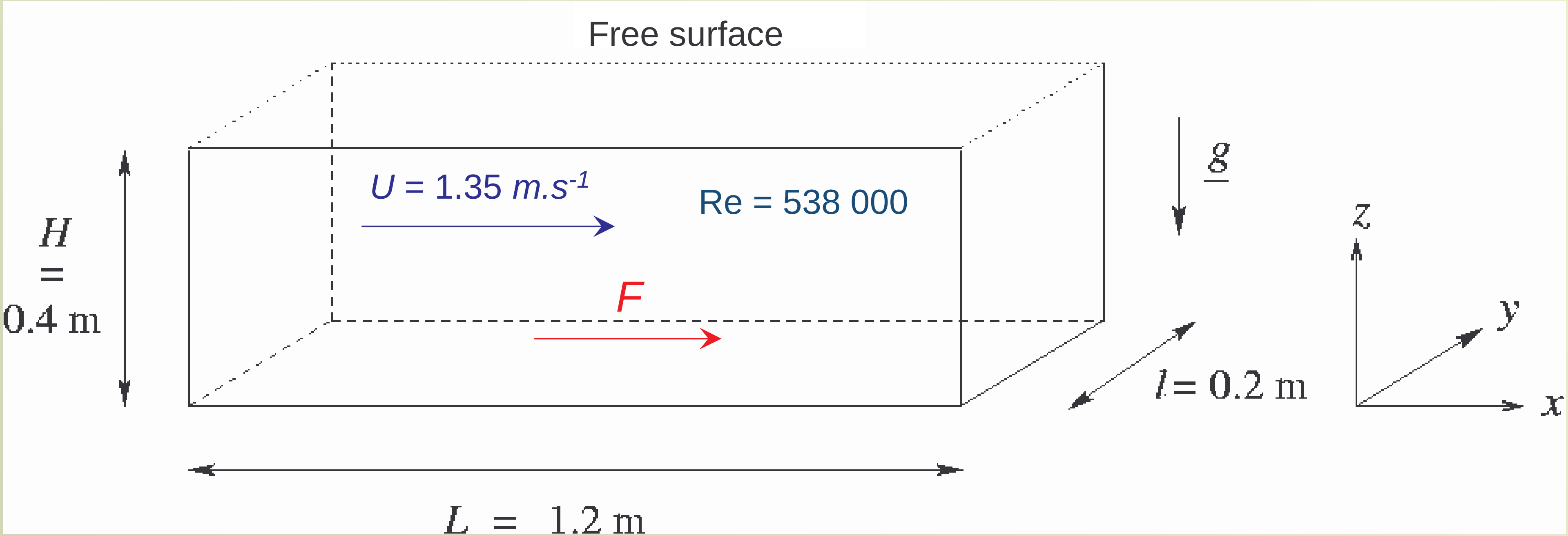
$$\tilde{p}_a = \frac{\rho_0 c_0^2}{\gamma} \left[\left(\frac{\tilde{\rho}_a}{\rho_0} \right)^{\gamma} - 1 \right]$$

à **_Smagorinsky model_**

$$\nu_{T,a} = \left(C_S h\right)^2 \sqrt{2 \tilde{S}_{ij,a} \tilde{S}_{ij,a}}$$

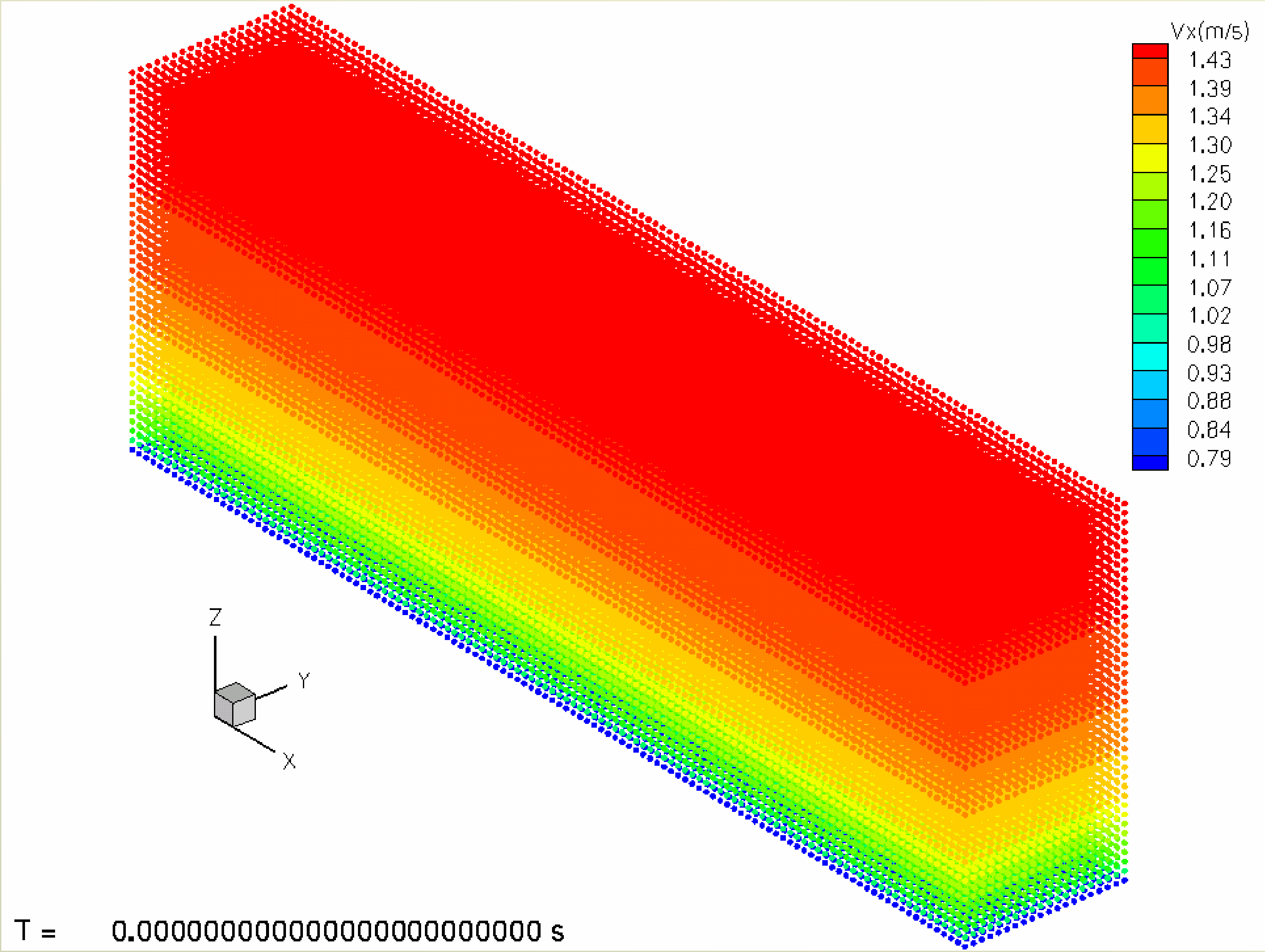
3D turbulent free surface channel

3D turbulent free surface channel

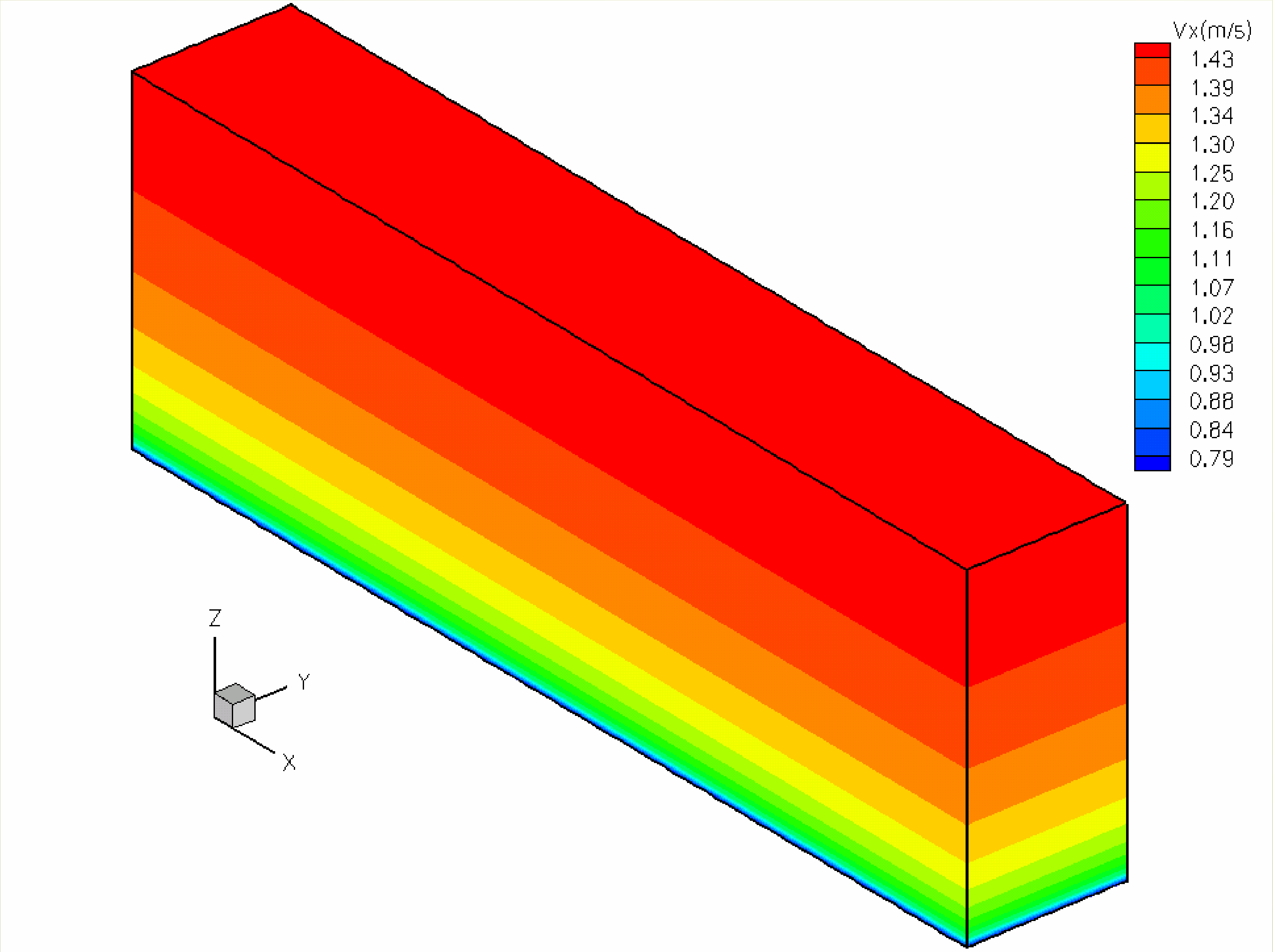


105 000 particles

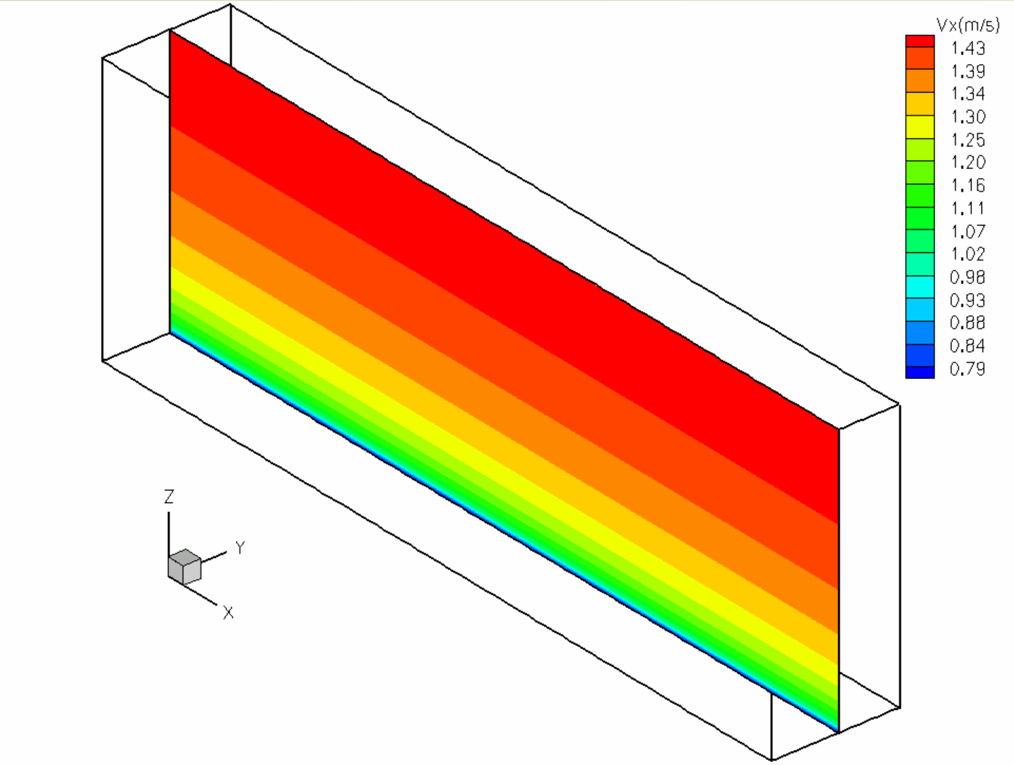
Instantaneous axial velocity field

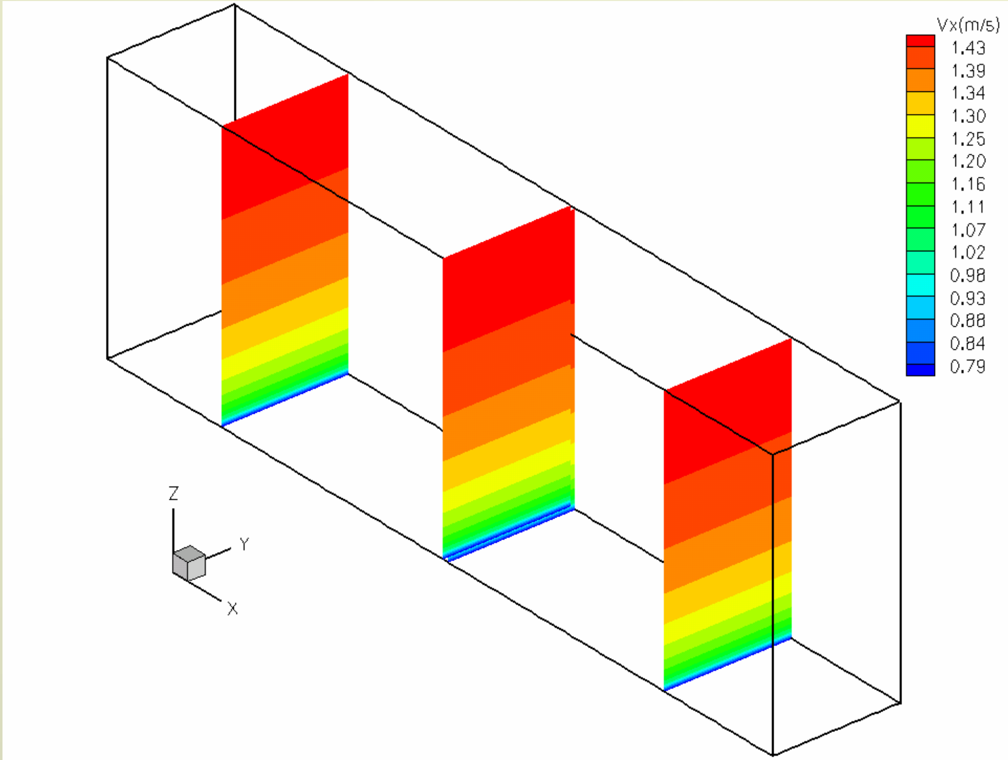


Interpolated instantaneous axial velocity field

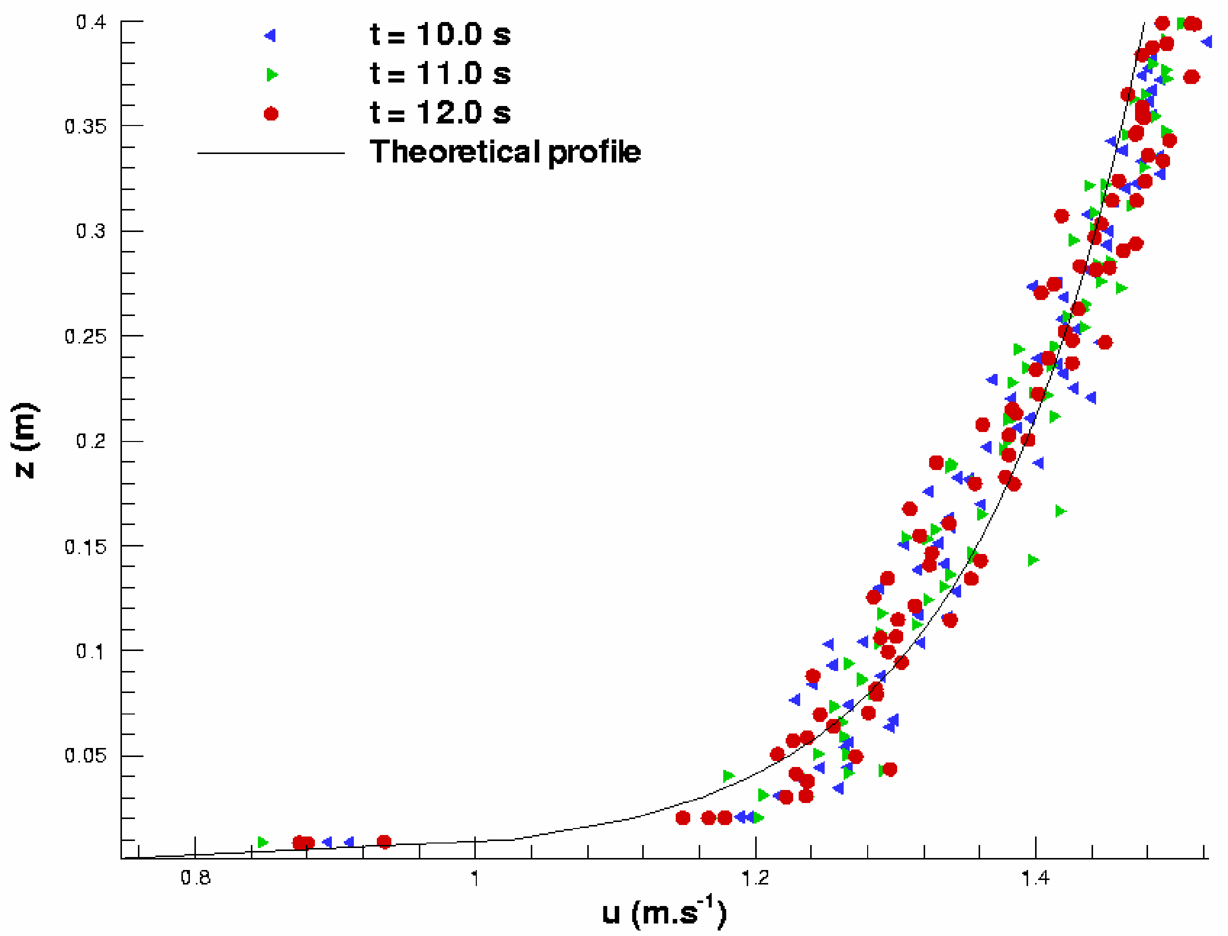


Instantaneous axial velocity slices

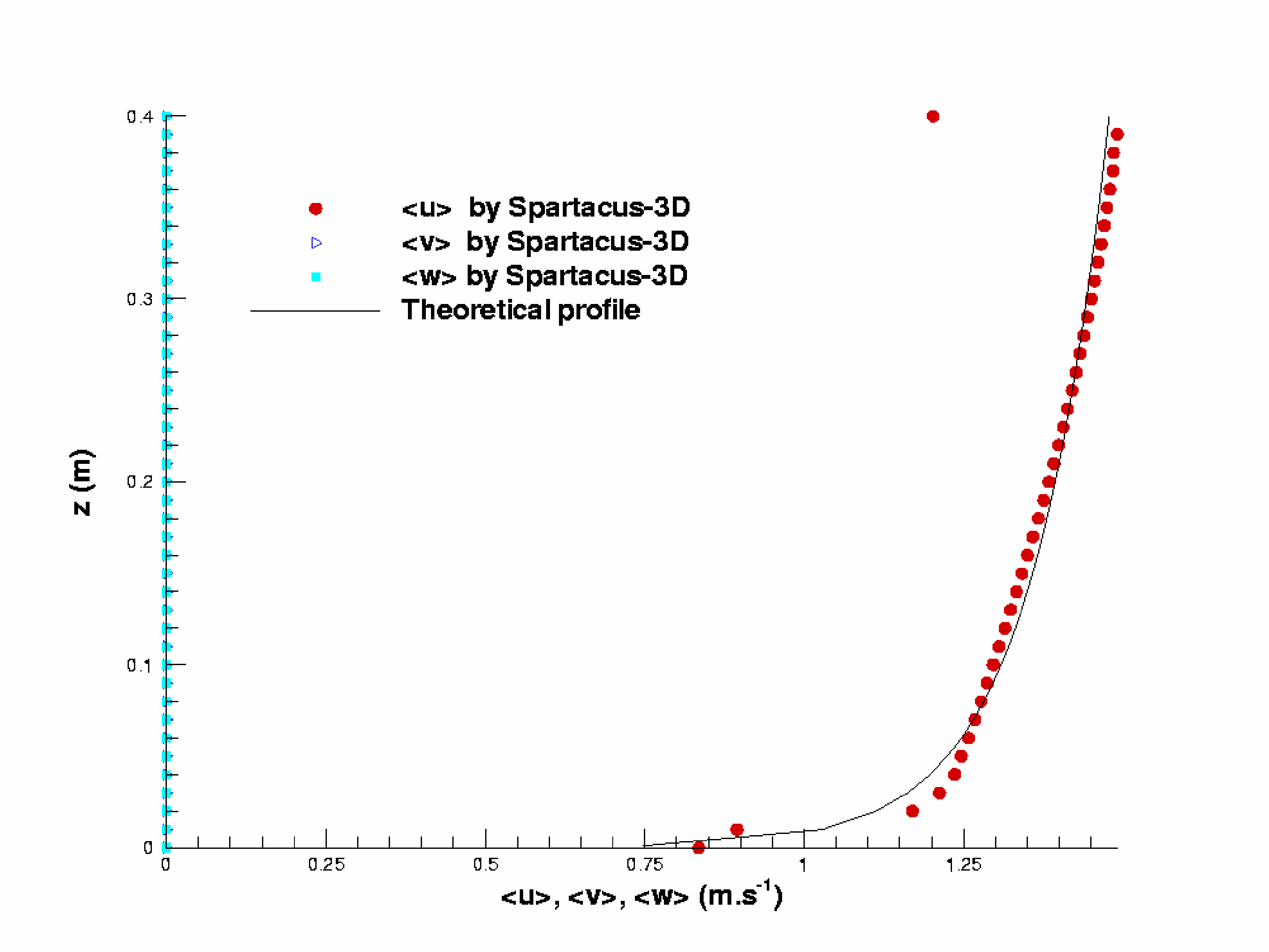




Instantaneous axial velocity profiles

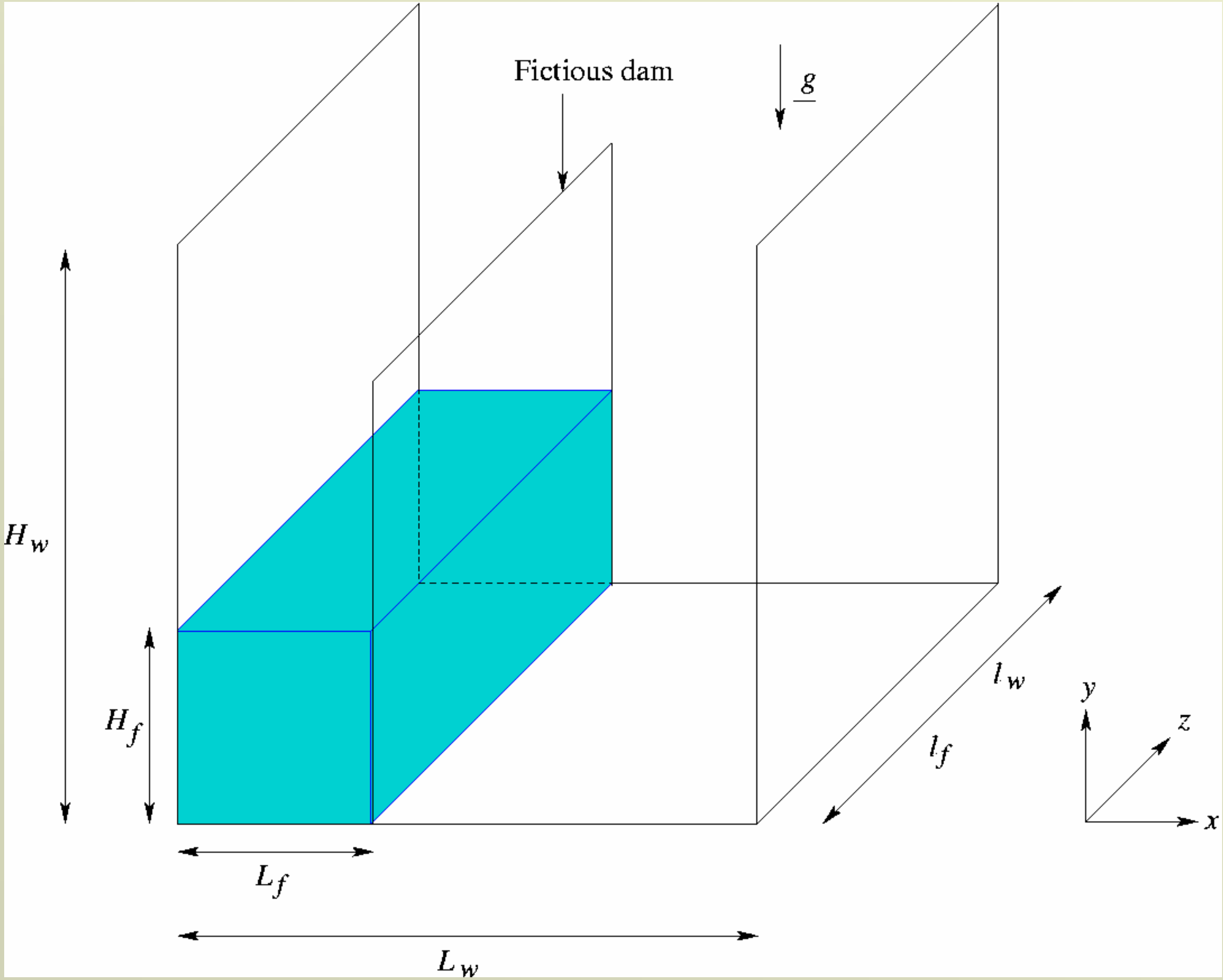


Averaged axial velocity profile



3D dam breaking

System modelling

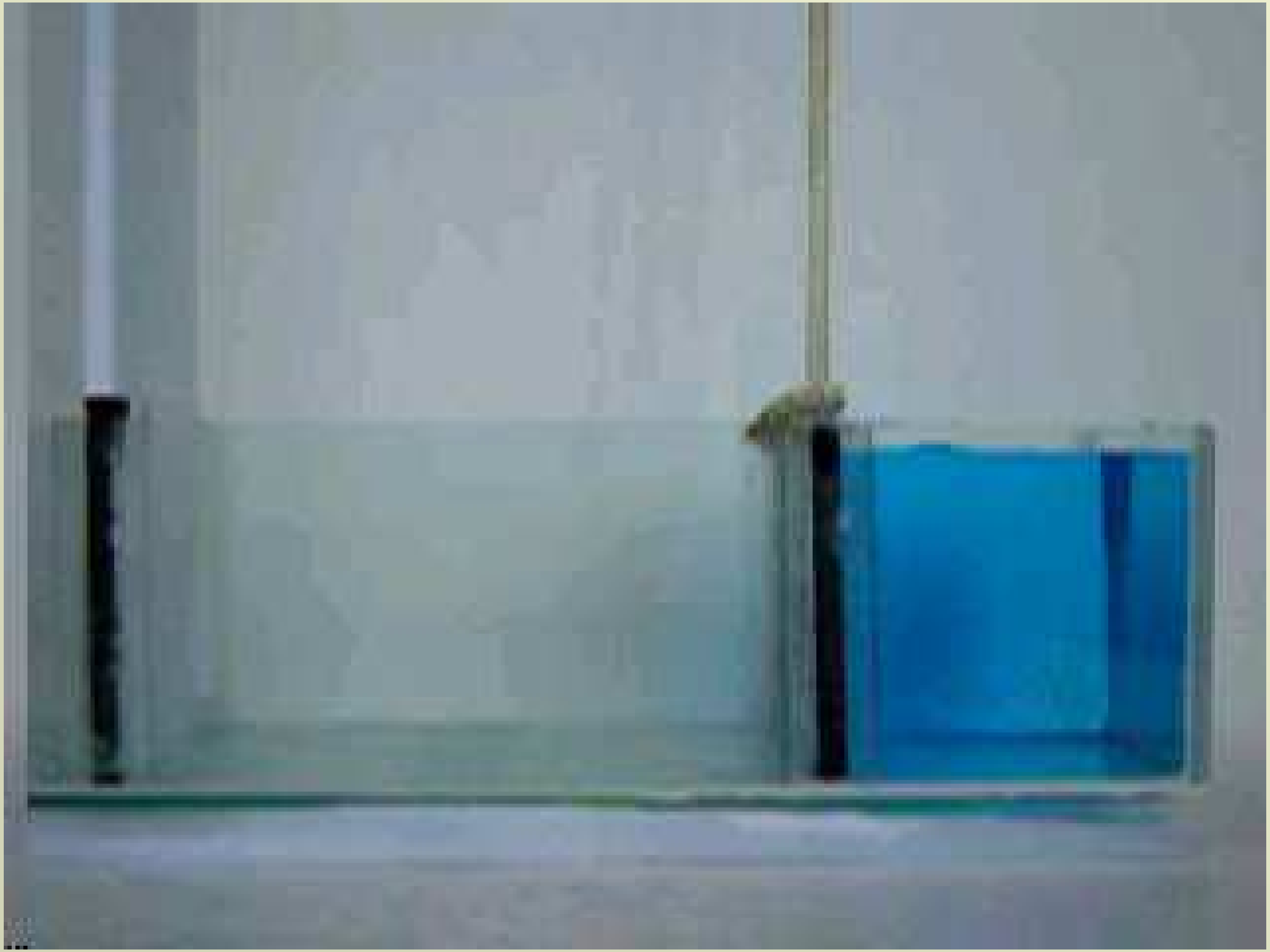


Dimensions in m

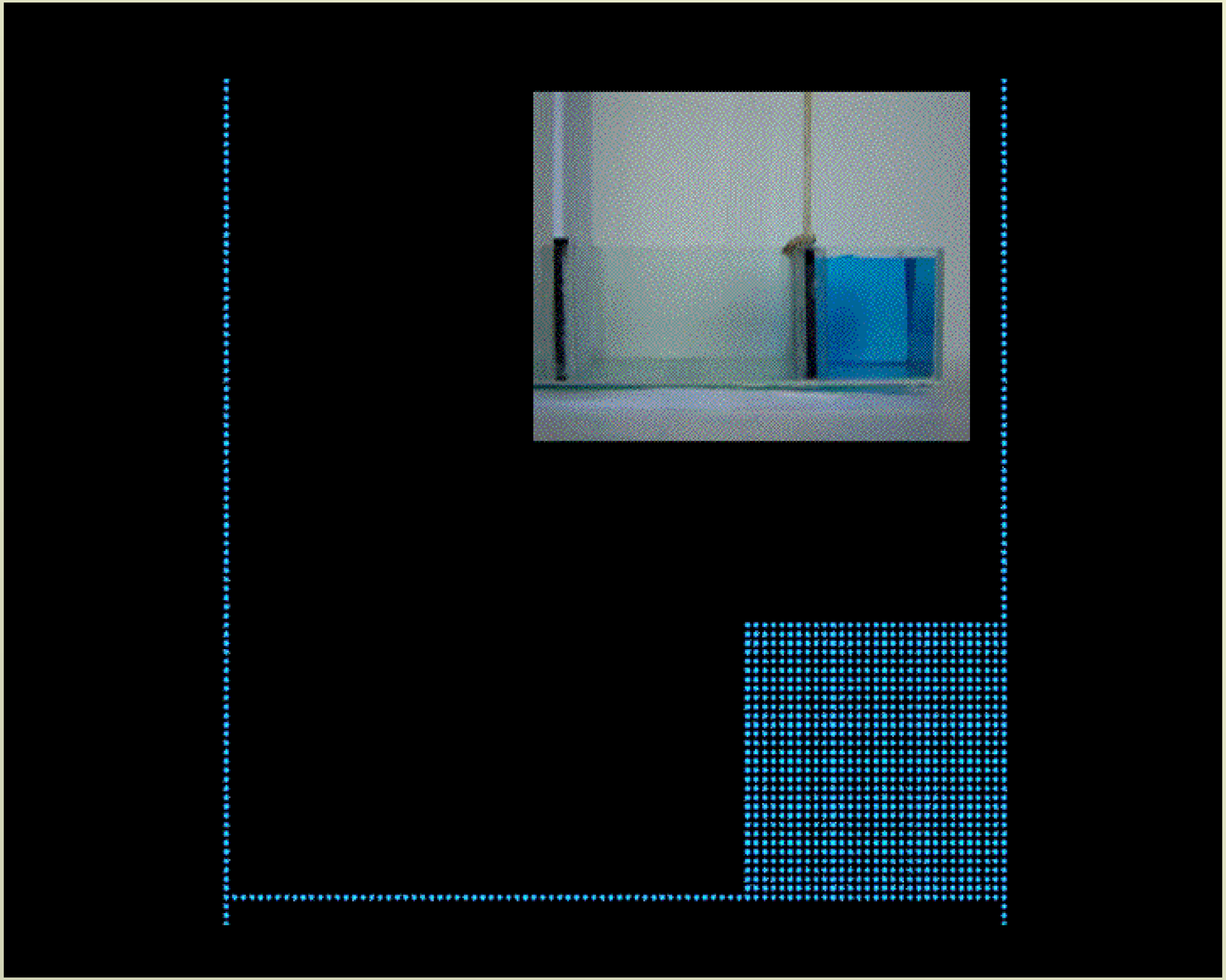
H_w	0.9
H_f	0.3
L_w	0.9
L_f	0.3
L_w	0.6
l_f	0.6

120 000 particles

Experiment visualization



Comparison with SPH



Conclusions and future work

• *First results relative to LES in SPH*

• ***Development of a fully incompressible algorithm***

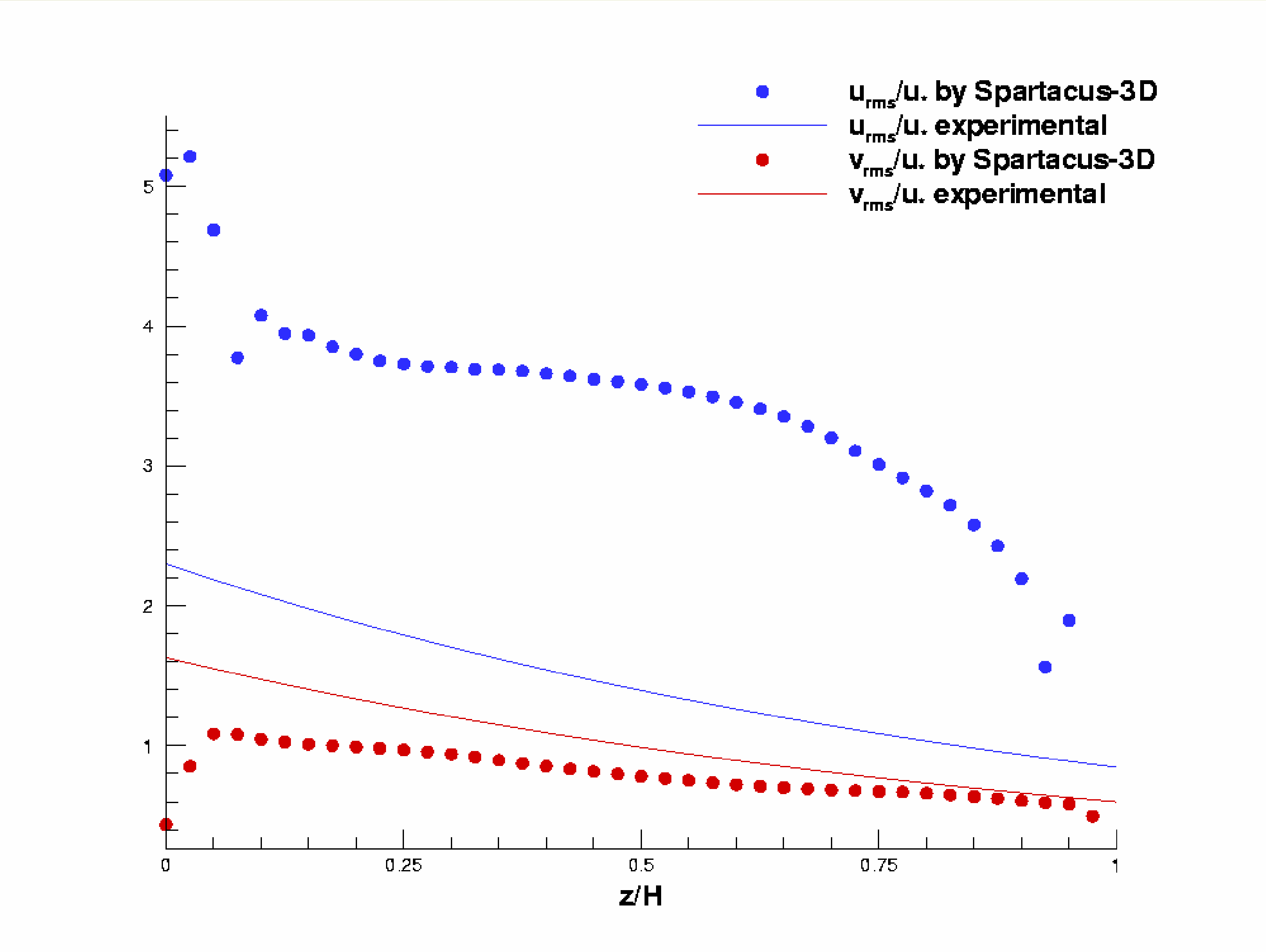
(E.S Lee, Univ. Man)

• ***Expensive computational coast à Parallelization***

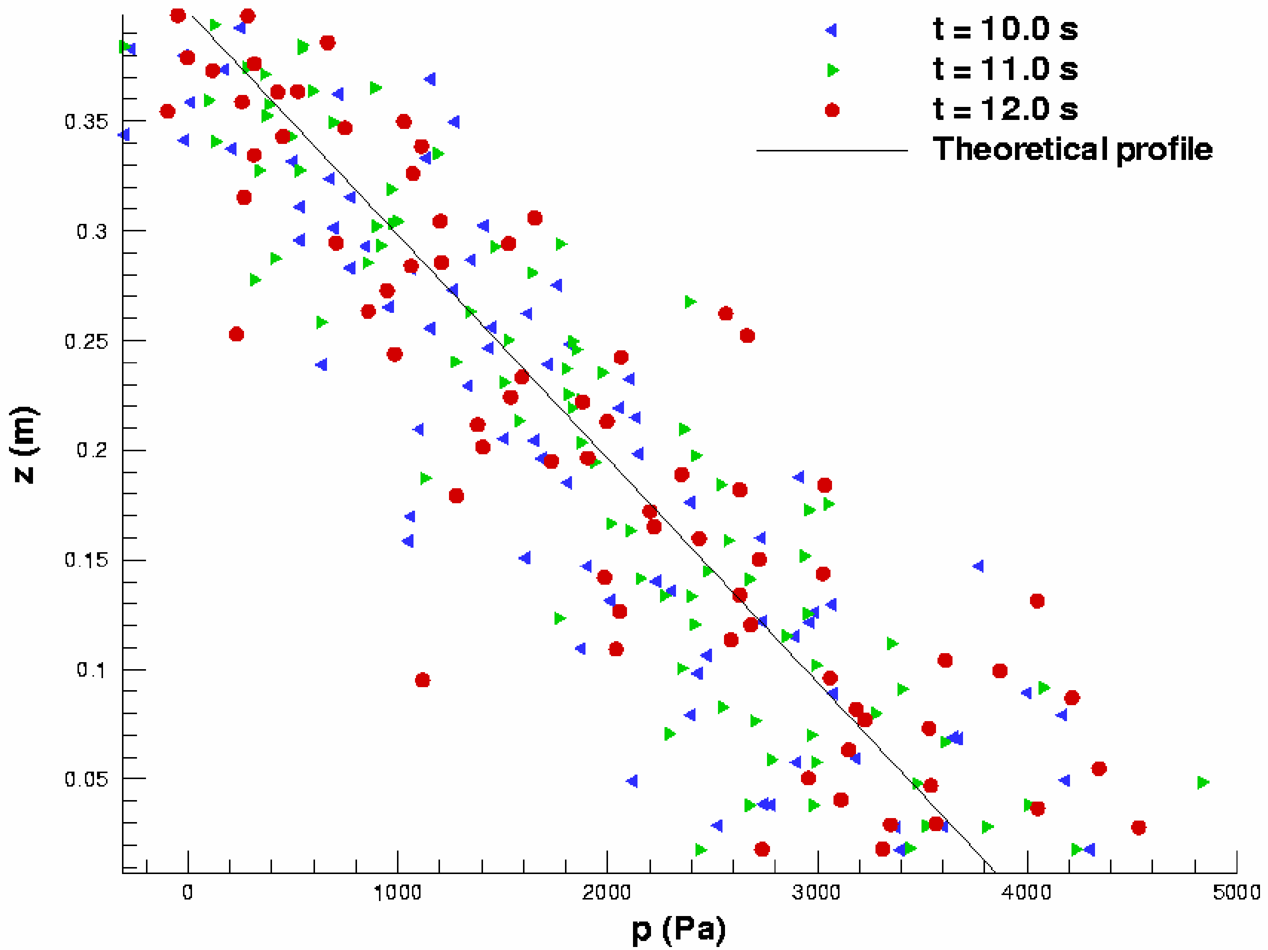
(J.C Marongiu, ECL)

Thank you for your attention…

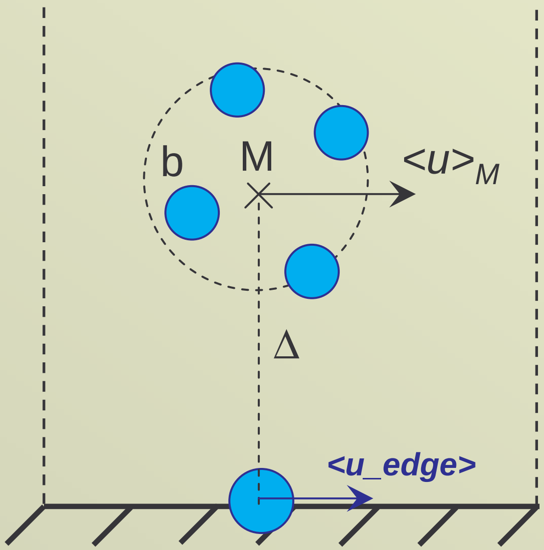
Intensité turbulente



Profils de pression instantanée



Friction velocity estimation



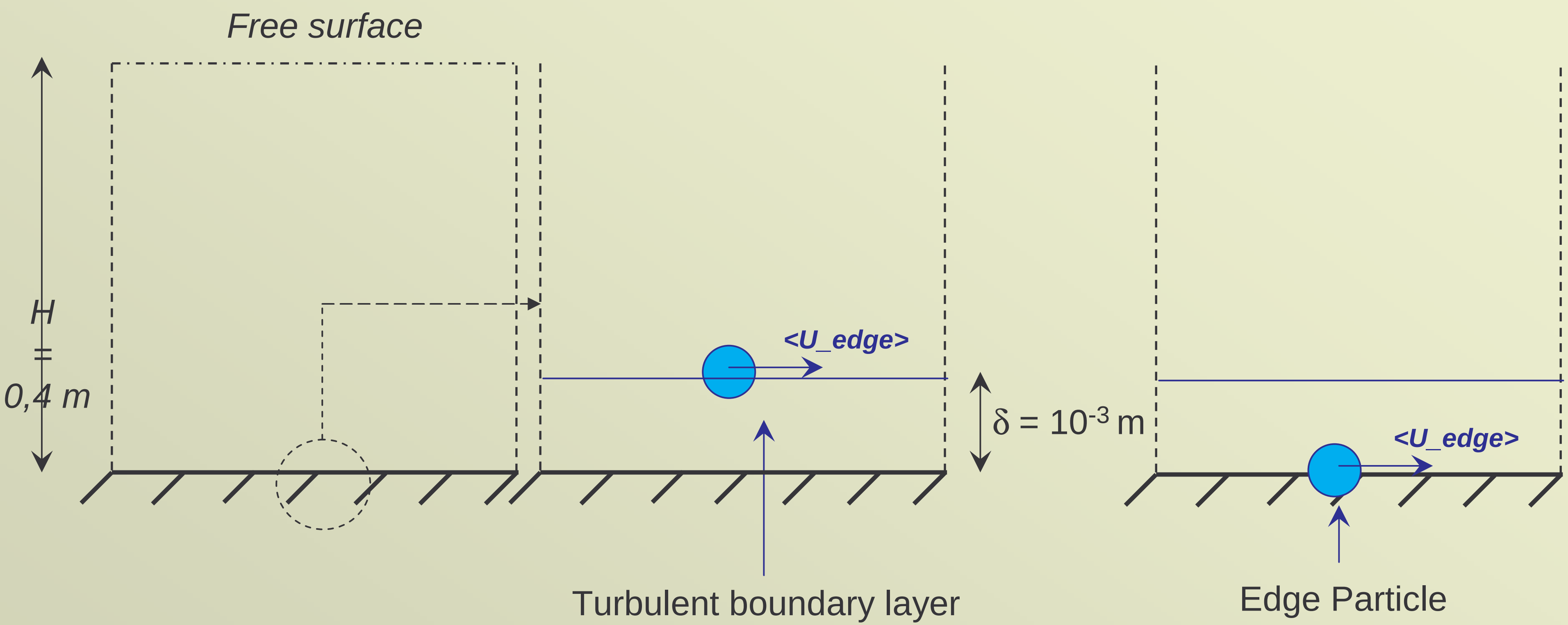
$$< u >_M = \sum_b \frac{m_b}{\rho_b} u_b w_h \left(\left| \underline{r}_{Mb} \right| \right)$$

$$< u >_M = \frac{1}{\kappa} \ln\left(\frac{(\Delta + \delta) u_\tau}{\nu} \right) + C$$

à u_τ obtained by iteration

$$< u\_edge > = \frac{1}{\kappa} \ln\left(\frac{\delta u_\tau}{\nu} \right) + C$$

Boundary and initial conditions



$$\langle u\_edge \rangle = \frac{1}{\kappa} \ln\left(\frac{\delta u_\tau}{\nu} \right) + C$$

- ***Initial conditions***

  Averaged velocity profile ***<u>without perturbation</u>***