2015 *Code_Saturne* User Meeting

EDF – R&D
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RENUDA

Modelling complex industrial flows with *Code_Saturne*

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Contents

1. Introduction

Introduction

- *Code_Saturne* has been extensively used by Renuda over the course of the last 12 months

- **Applications**
  - Industrial R&D projects
  - Verification and validation
  - Code development

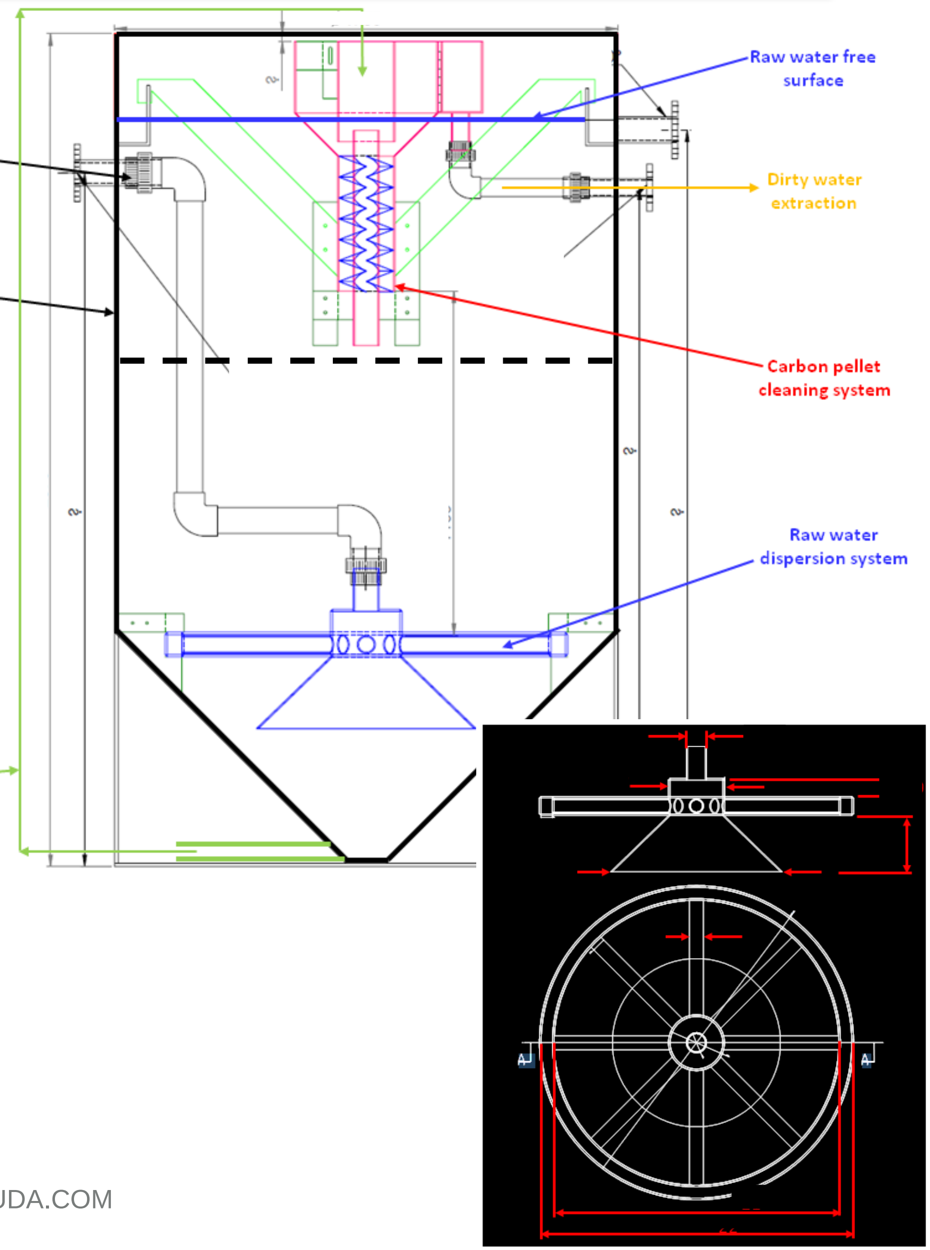
- **Used as part of an open source calculation chain**
  - SALOME for CAD and volume meshing
  - SYRTHES for conjugate heat transfer
  - ParaView for results analysis

- This presentation presents a summary of three challenging industrial R&D projects

2. Optimisation of a water filtering system

Optimisation of a water filtering system

- Veolia has designed and patented a water filtering system, ***Filtraflo® Carb***, which uses pellets to filter raw water
- A pilot unit has been built and tested but observations have indicated that the unit is not operating as desired
- The pellet bed is seen to be moving at a given point on its surface indicating the presence of excessive velocities inside the pellet bed

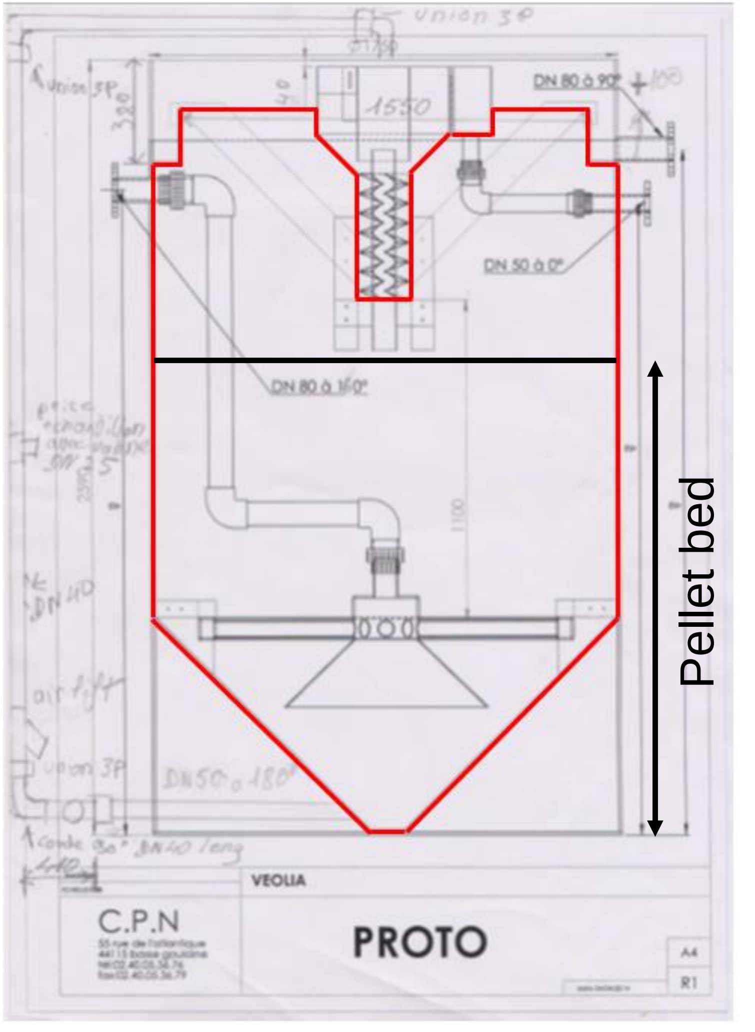


Optimisation of a water filtering system

- Objective is to **homogenise the velocity field in the main tank** in improve the efficiency of the filtering system

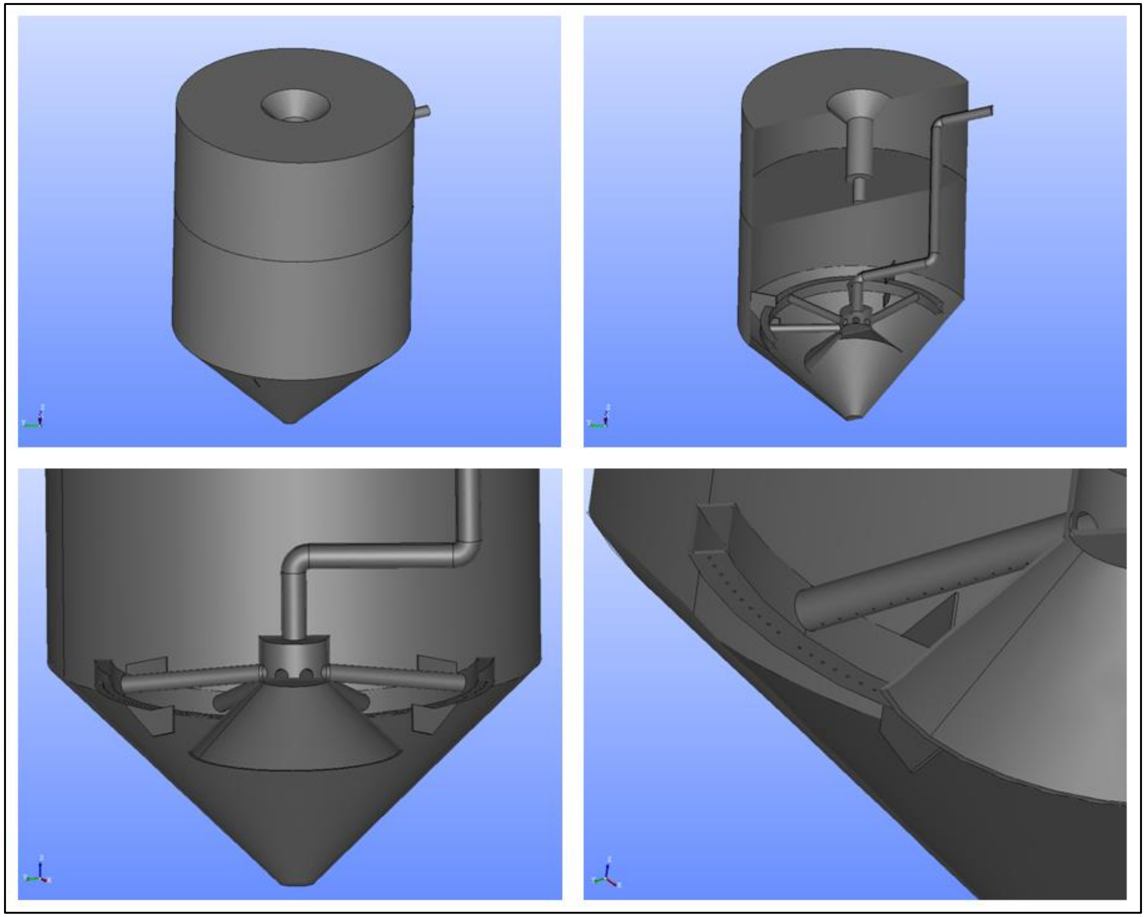
- Geometry simplified to simulate the zone shown in red plus delivery pipe and dispersion system

- **Operating point**
  - Water at 4°C
  - Raw water flow = 20m^3/h
  - Cleaning system flow = 0.3m^3/h
  - Air lift flow = 0.3m^3/h



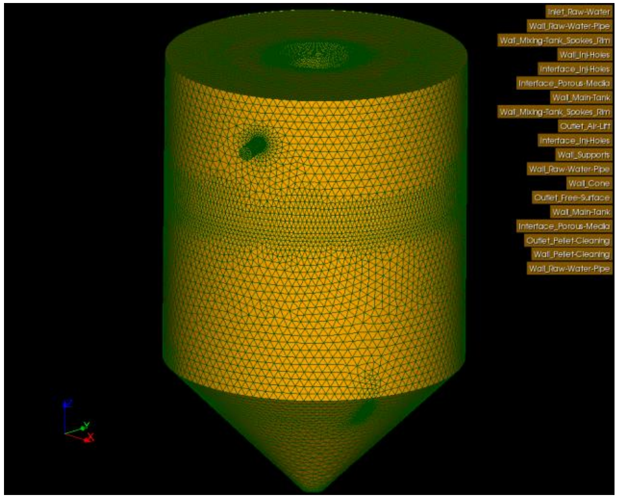
Optimisation of a water filtering system

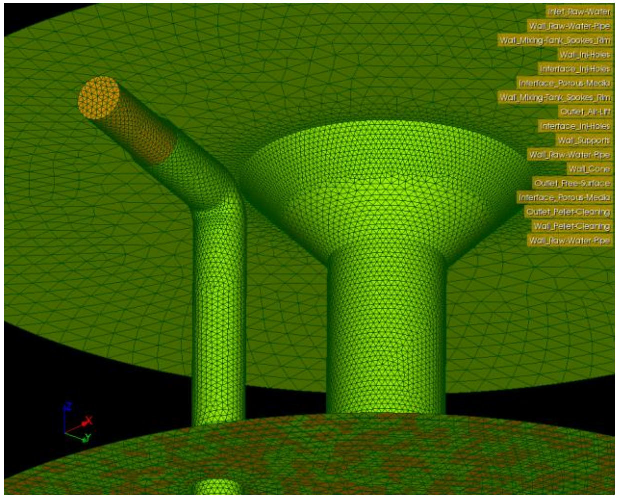
- **Geometry and volume mesh generated using SALOME**
  - Volume mesh has 4.75 million cells

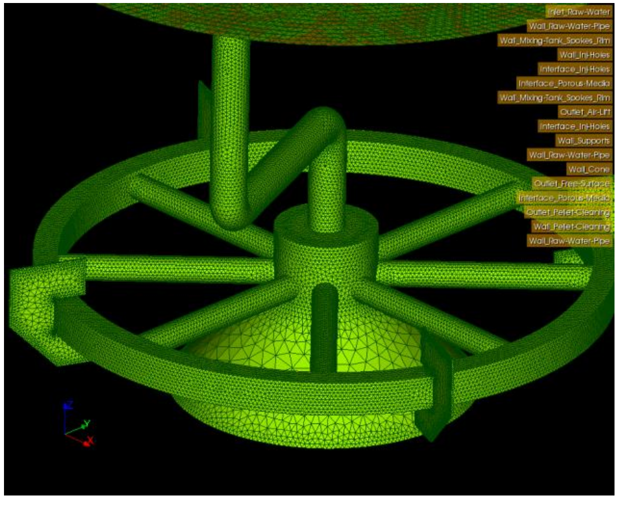


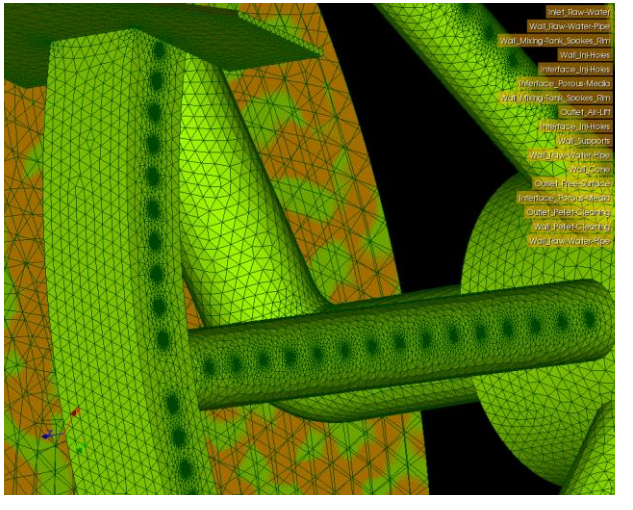
Optimisation of a water filtering system

- Volume mesh



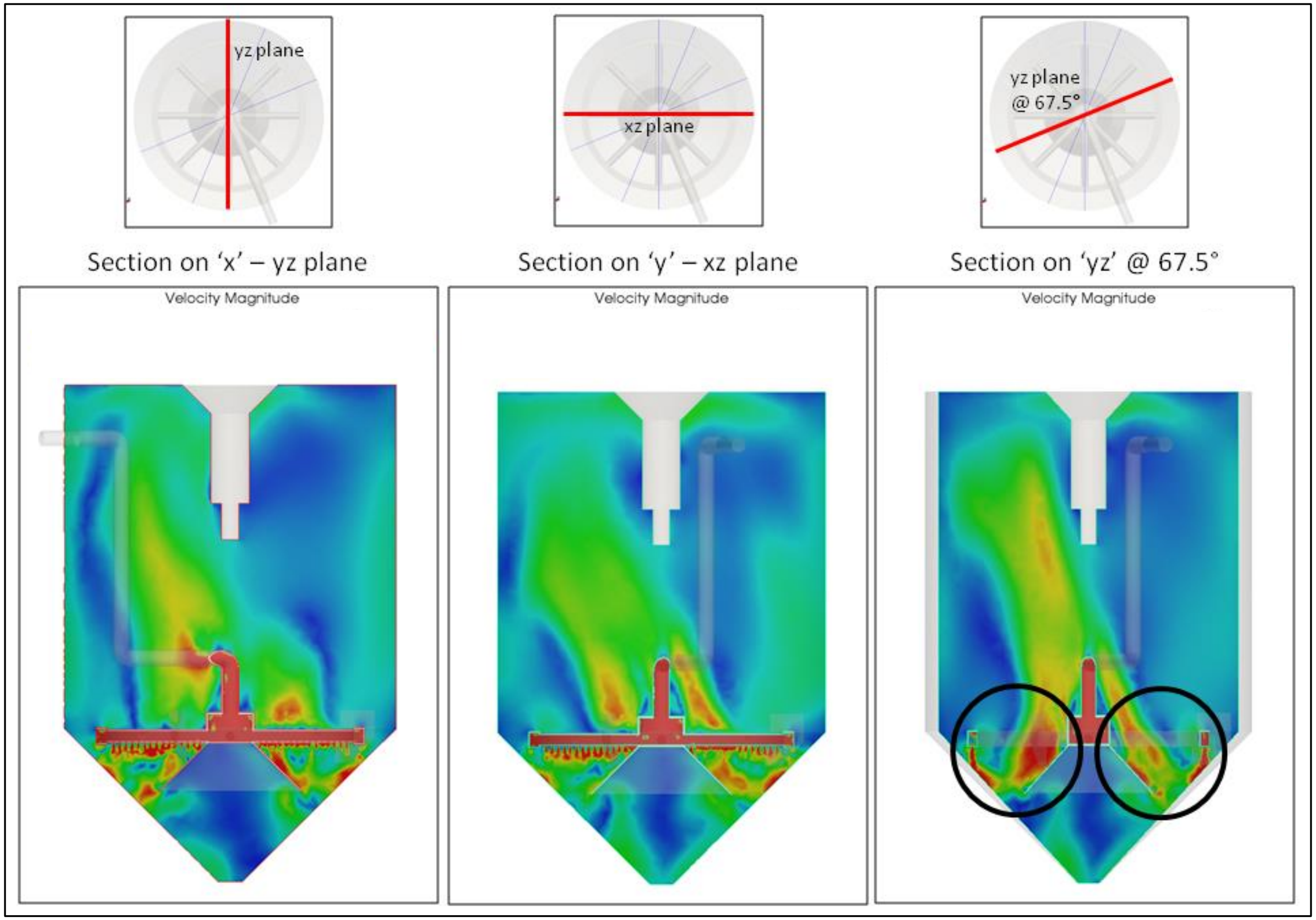






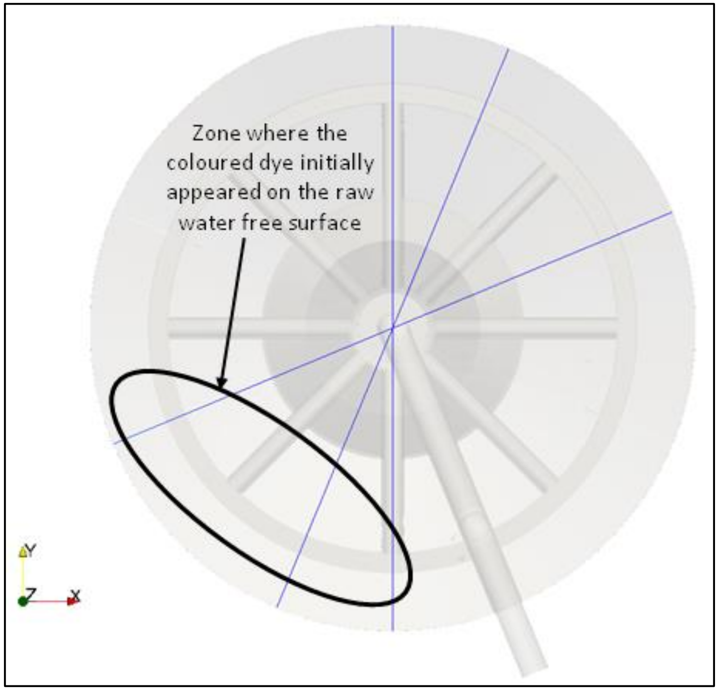
Optimisation of a water filtering system

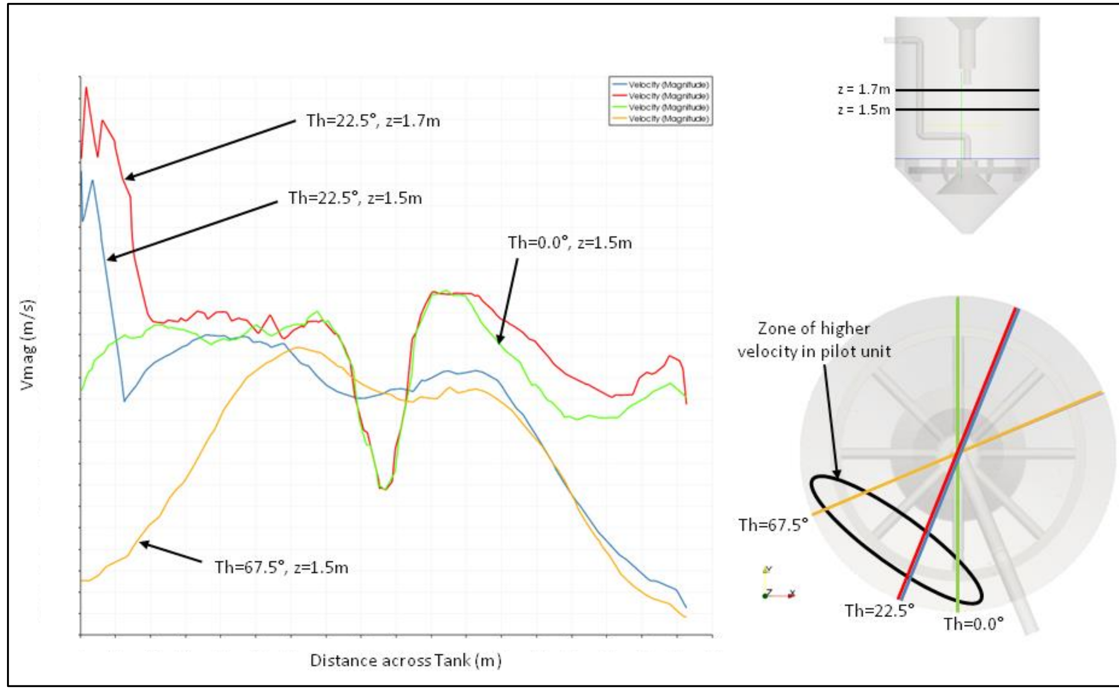
- Results – **no porous media**



Optimisation of a water filtering system

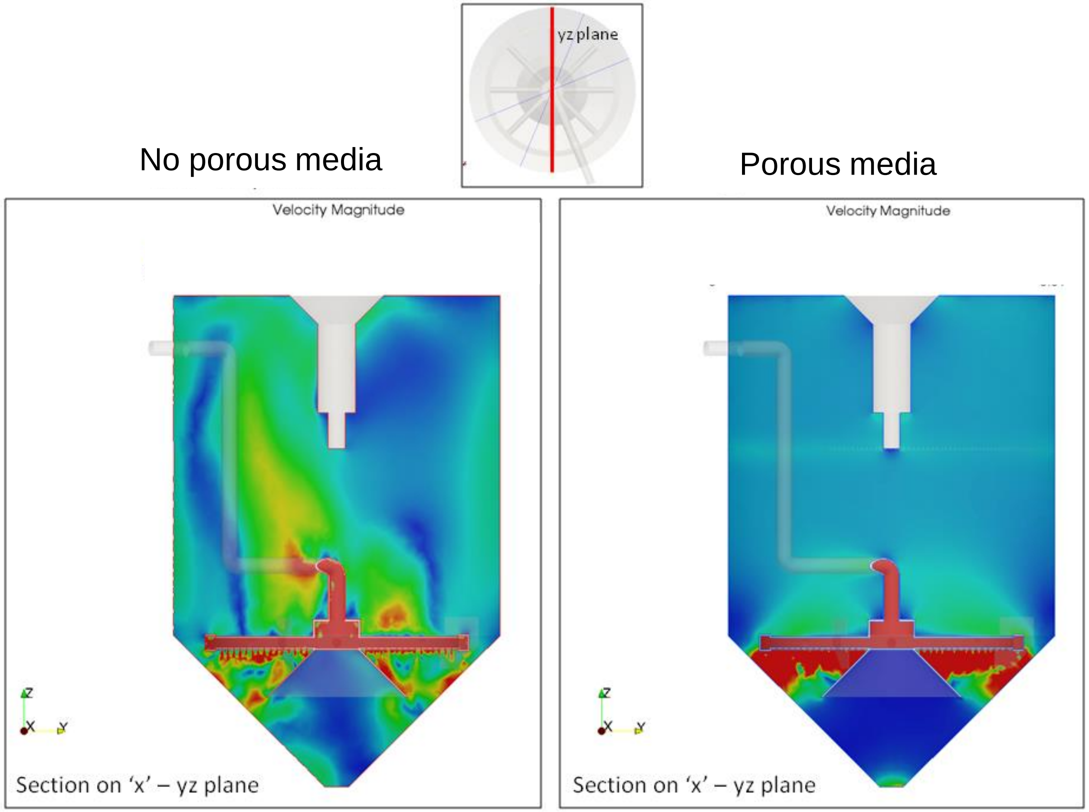
- Results – **no porous media**





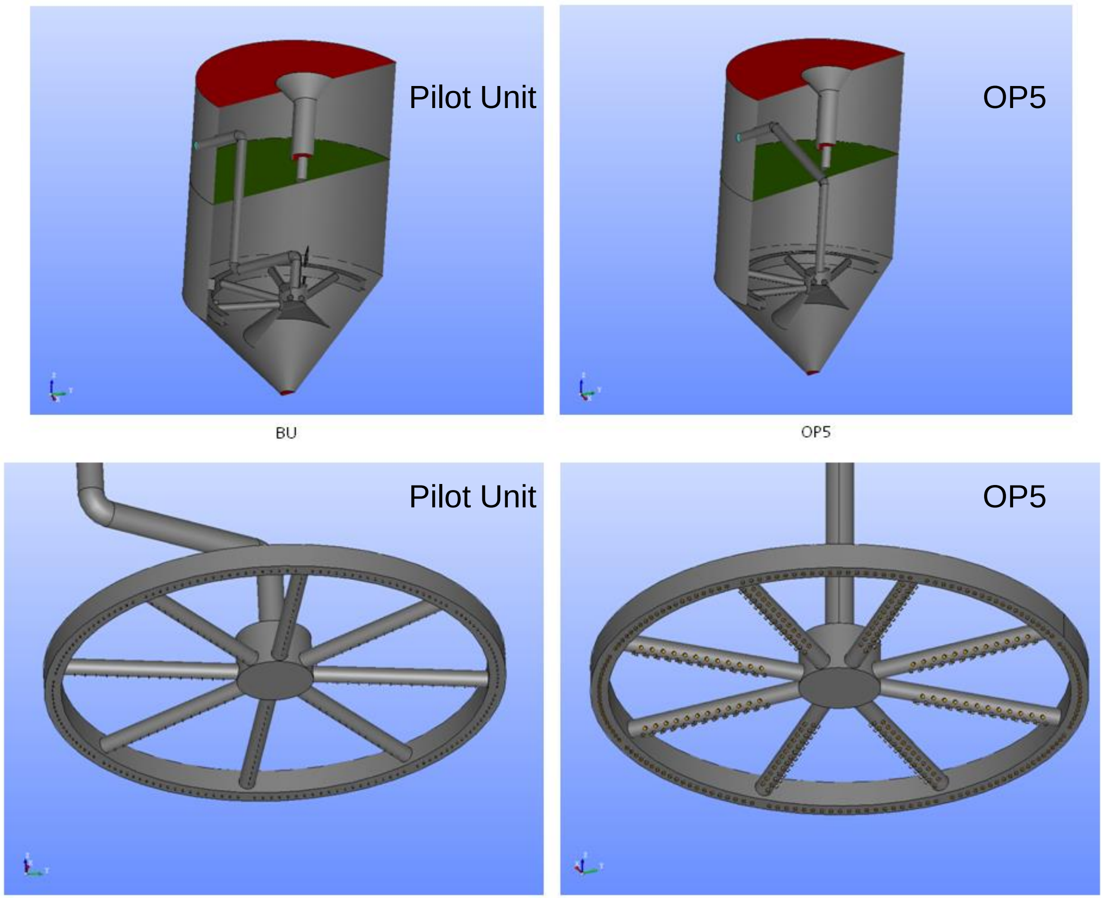
Optimisation of a water filtering system

- Results – **with and without porous media**
  - The porous media model smooths the flow field in the main tank
  - This model is not appropriate for modelling the carbon pellet bed
  - A more sophisticated model is required for that purpose



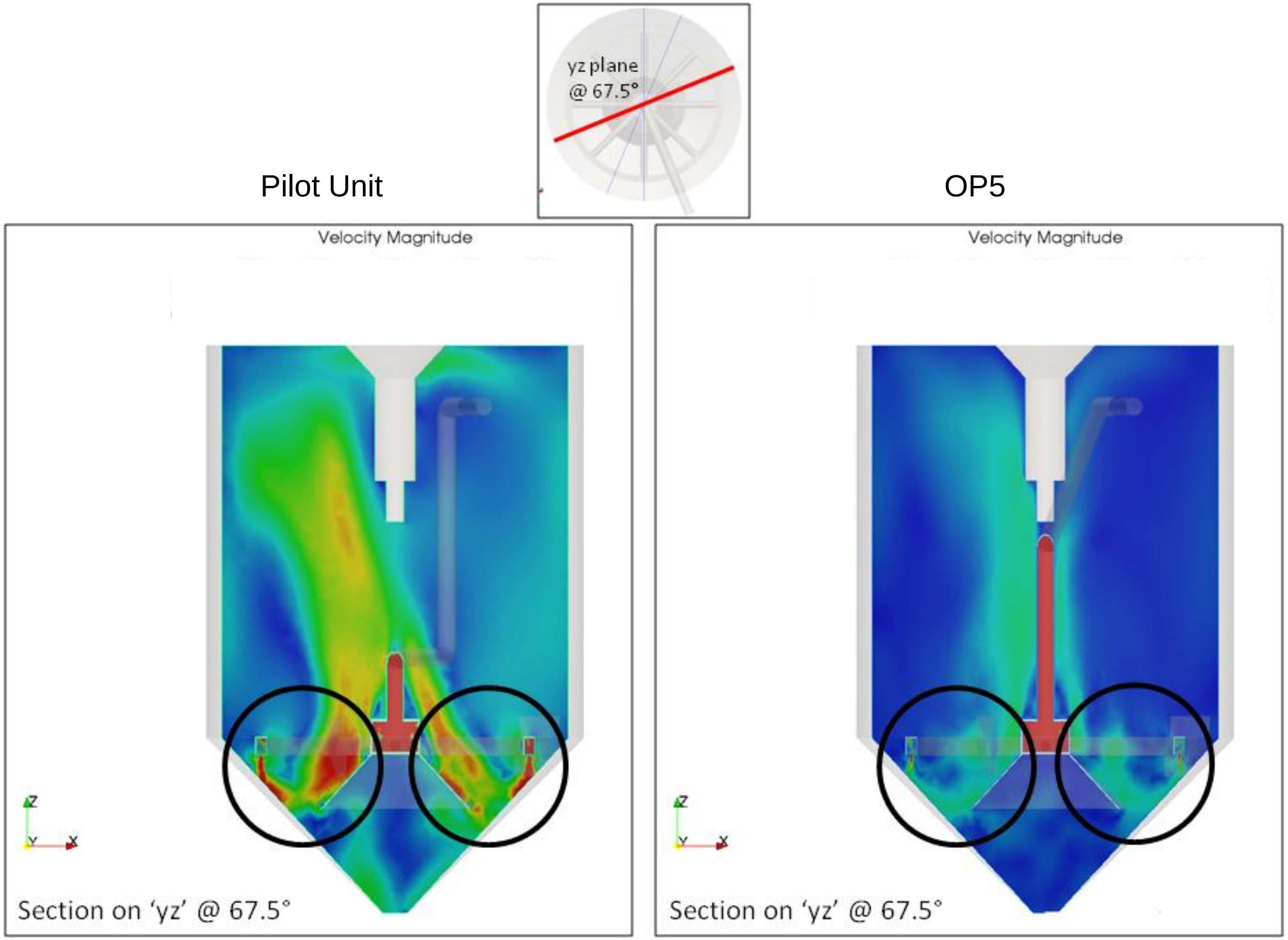
Optimisation of a water filtering system

- **Optimisation**
  - Numerous geometric optimisations tested – OP5 best optimisation



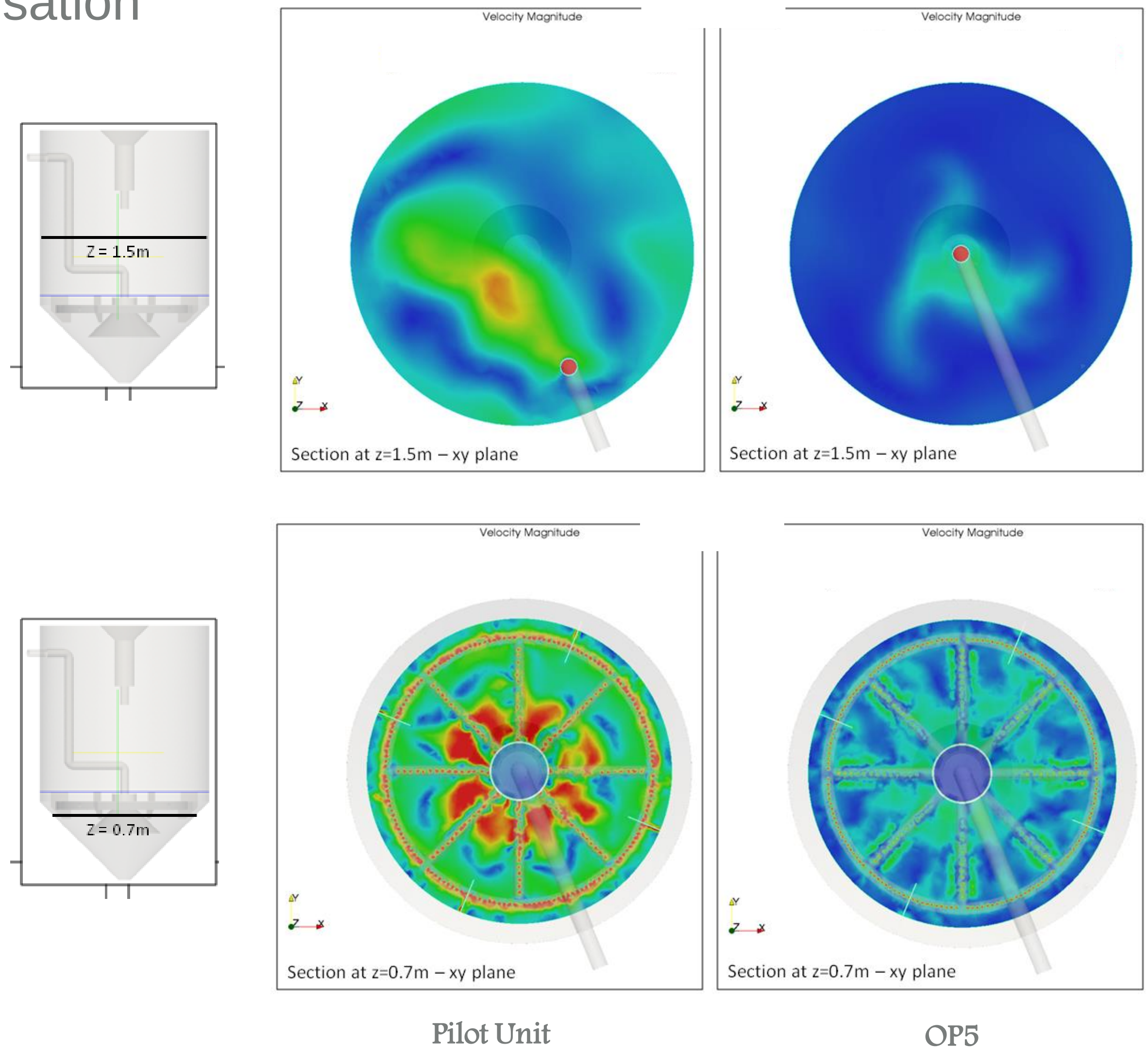
Optimisation of a water filtering system

- Optimisation



Optimisation of a water filtering system

- Optimisation



Optimisation of a water filtering system

- **Summary**
  - *Code_Saturne* has been used to simulate a pilot water filtering system and its optimised versions
  - The *Code_Saturne* results for the pilot unit have been shown to agree with experimental observations
    - No porous media used to represent the carbon pellet bed
  - Optimised versions of the pilot unit indicate that it is possible to achieve a homogeneous flow in the main tank
    - No porous media used to represent the carbon pellet bed
  - The assumption that a porous media model can be used to model the carbon pellet bed was not correct
    - Indicates that the carbon pellet bed is not acting in a way that will enable it to be modelled as a porous media
    - A more sophisticated method will be required to model such a bed

3. Combustion for Power Generation

Combustion for power generation

- **Version 4** of *Code_Saturne* has been used to carry out combined coal and biomass power plant simulations

- The model, mesh, calculations and post-processing have all been carried carried out with the previously mentioned OSS chain

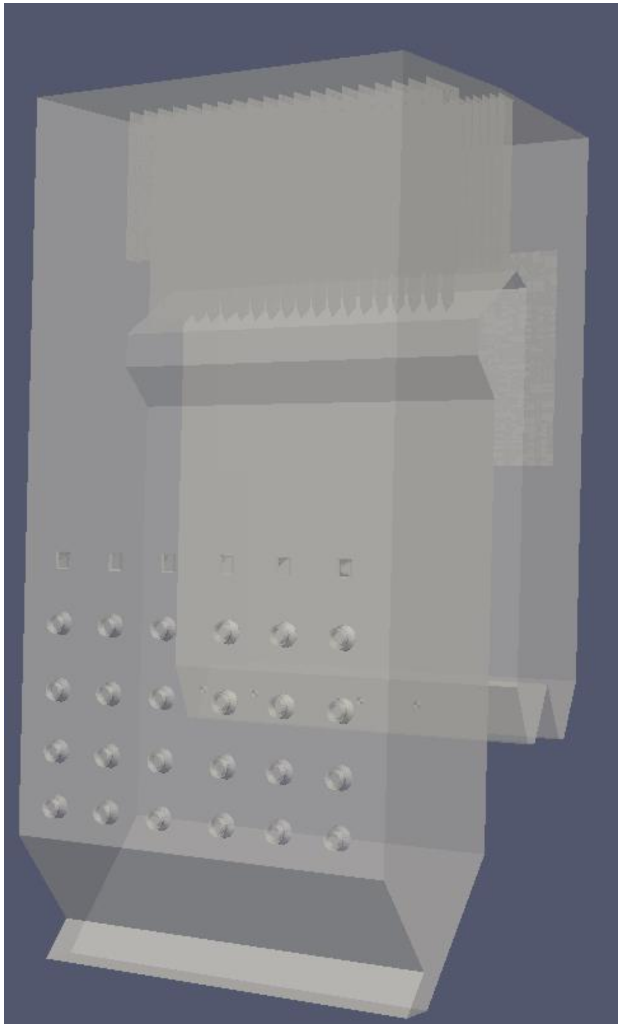
- **Objectives:** verify v4 and assess the impact of biomass for three models: Eulerian, Lagrangian, and Eulerian with slip

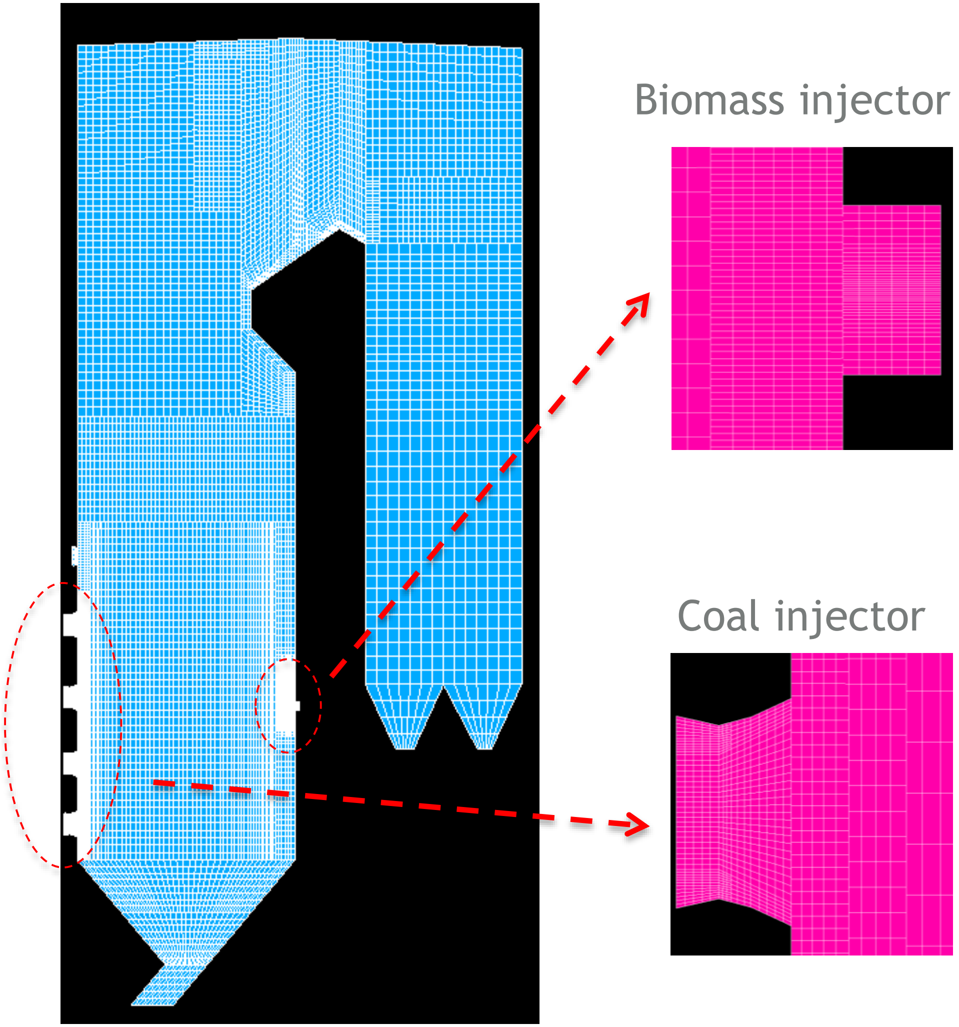
Combustion for power generation

- 5 classes of coal particles with given coal compositions
  - 34, 44, 63, 99.8 and 182 μm in diameter
- 1 class of biomass (wood chips) particles with given composition
  - 800 μm in diameter
- Injectors with different swirl velocities and direction of rotation
- Rows of active and inactive injectors. Inactive injectors inject cooling air
- Two outlets with a fixed mass flow ratio

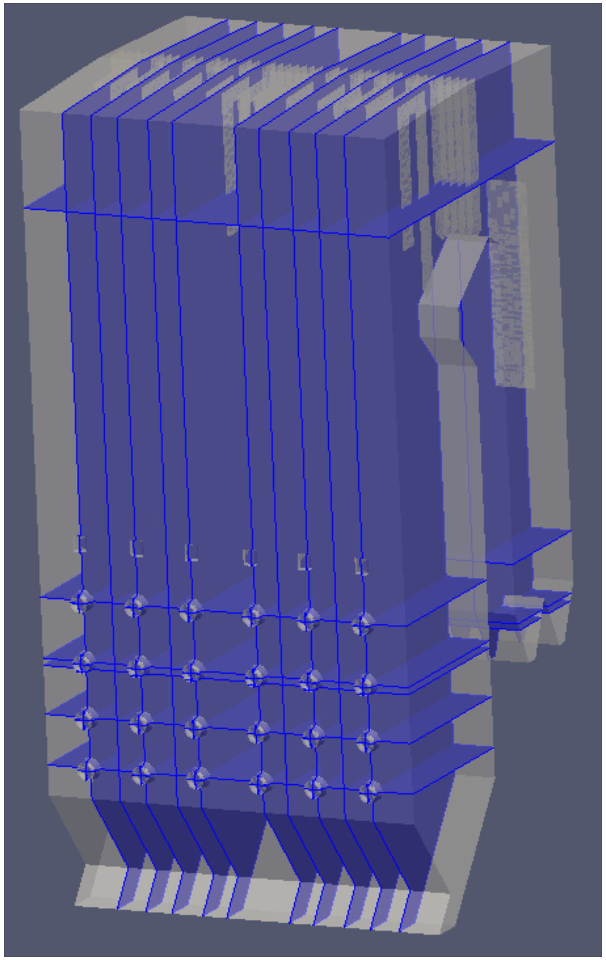
Combustion for power generation

- Computational domain, mesh and detail of injectors





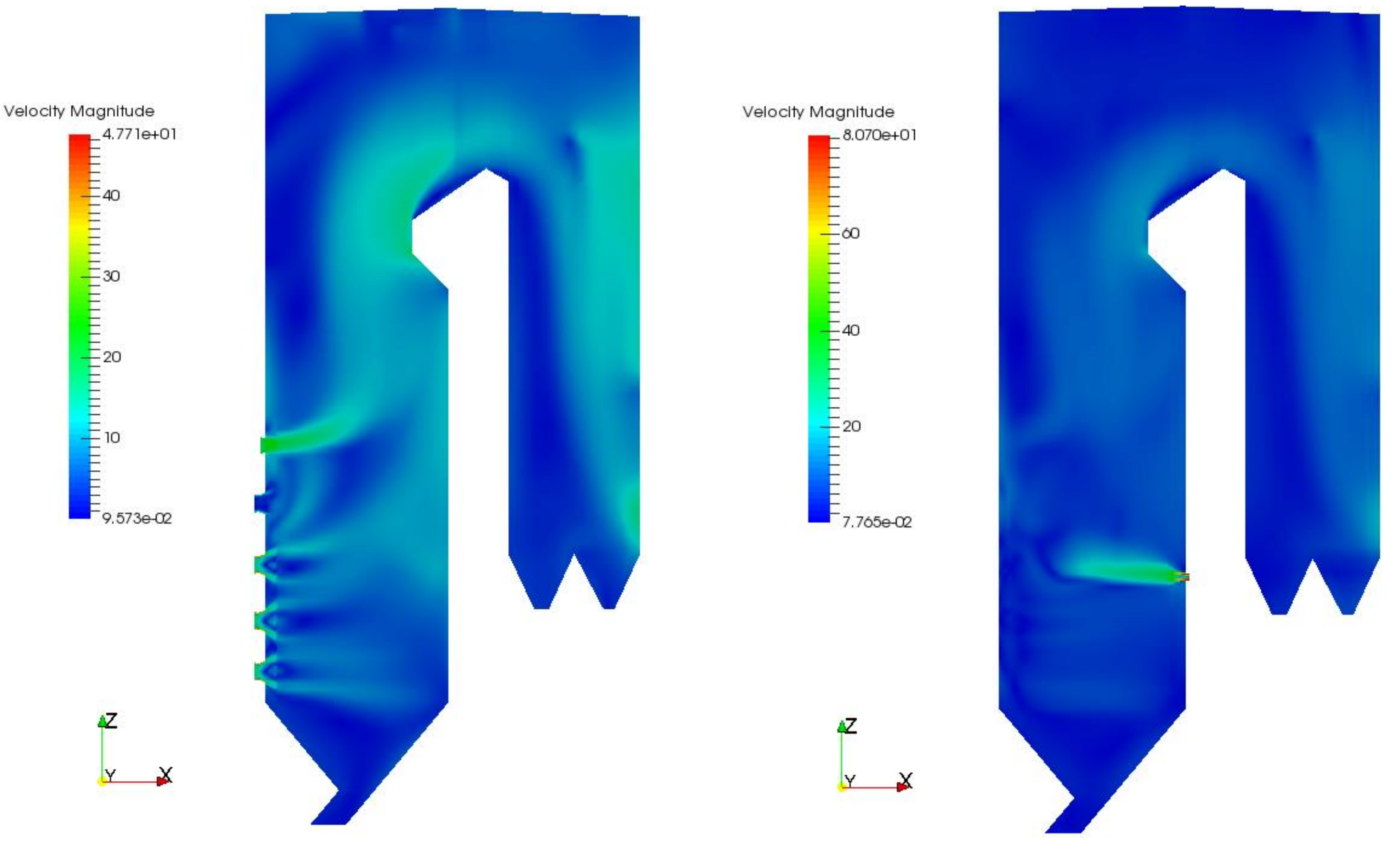
- Preparation for analysis



- Instrumented with 92 probes and 14 cutting planes to analyse:
    - the calculation,
    - the flow field,
    - the efficiency of the combustion process: particles burn, unburnt, volatiles, etc.

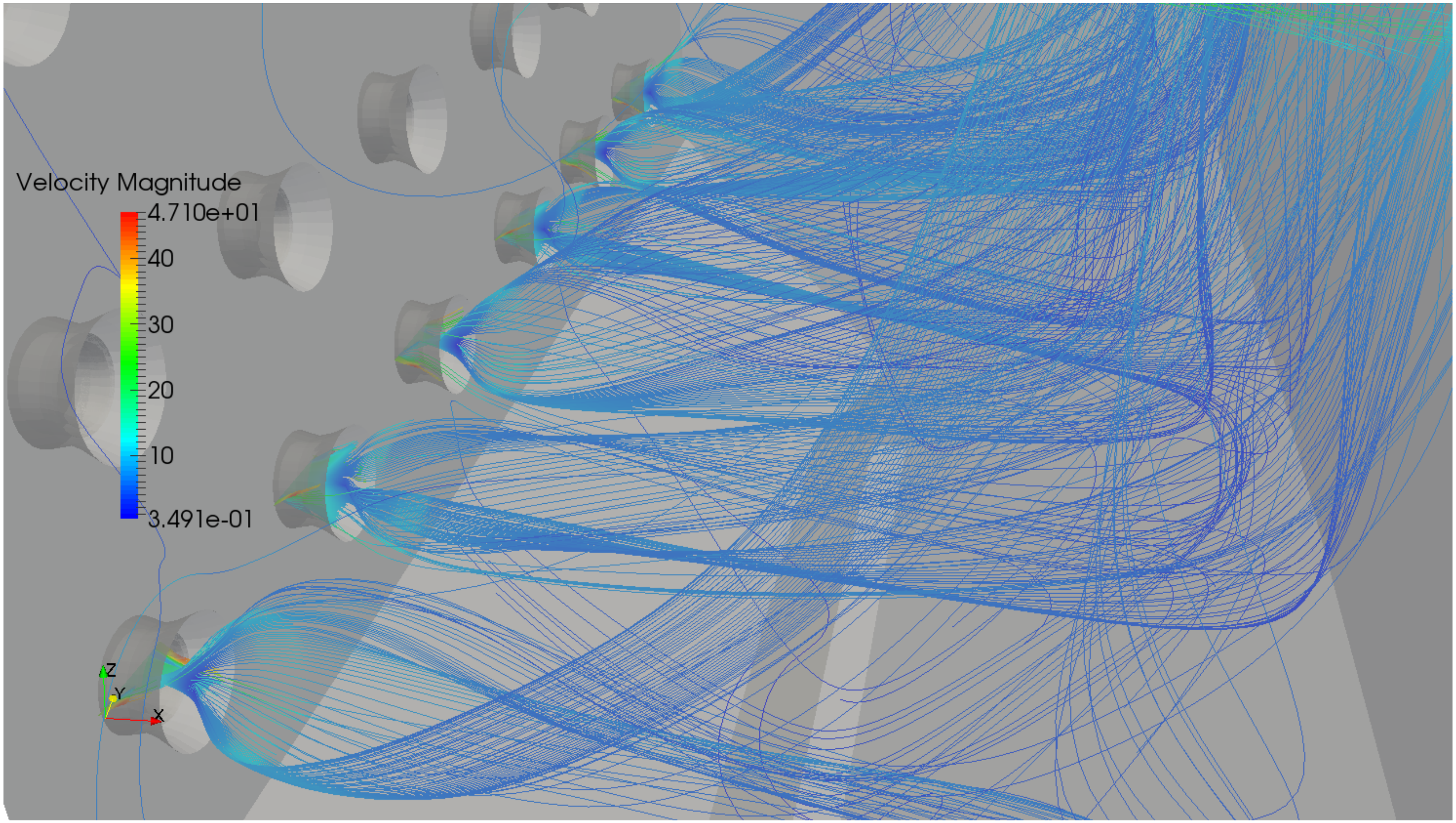
Combustion for power generation

- Velocity field in the vicinity of the coal and biomass injectors



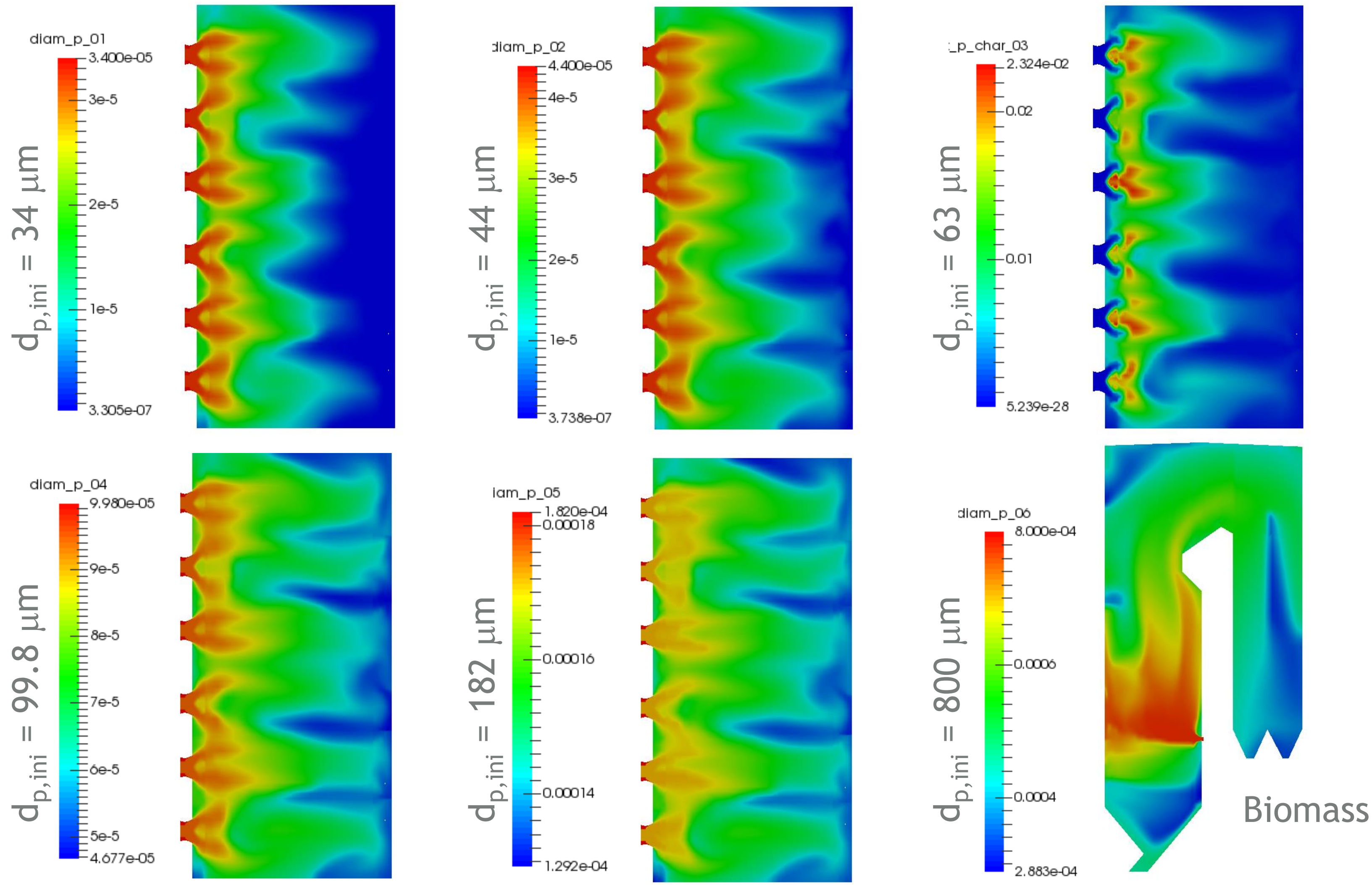
Combustion for power generation

- Flow field in the vicinity of the coal injectors



Combustion for power generation

- Coal particle diameters at z=17.85 m, biomass at y = 6.63m



Combustion for power generation

- **Lagrangian simulations**

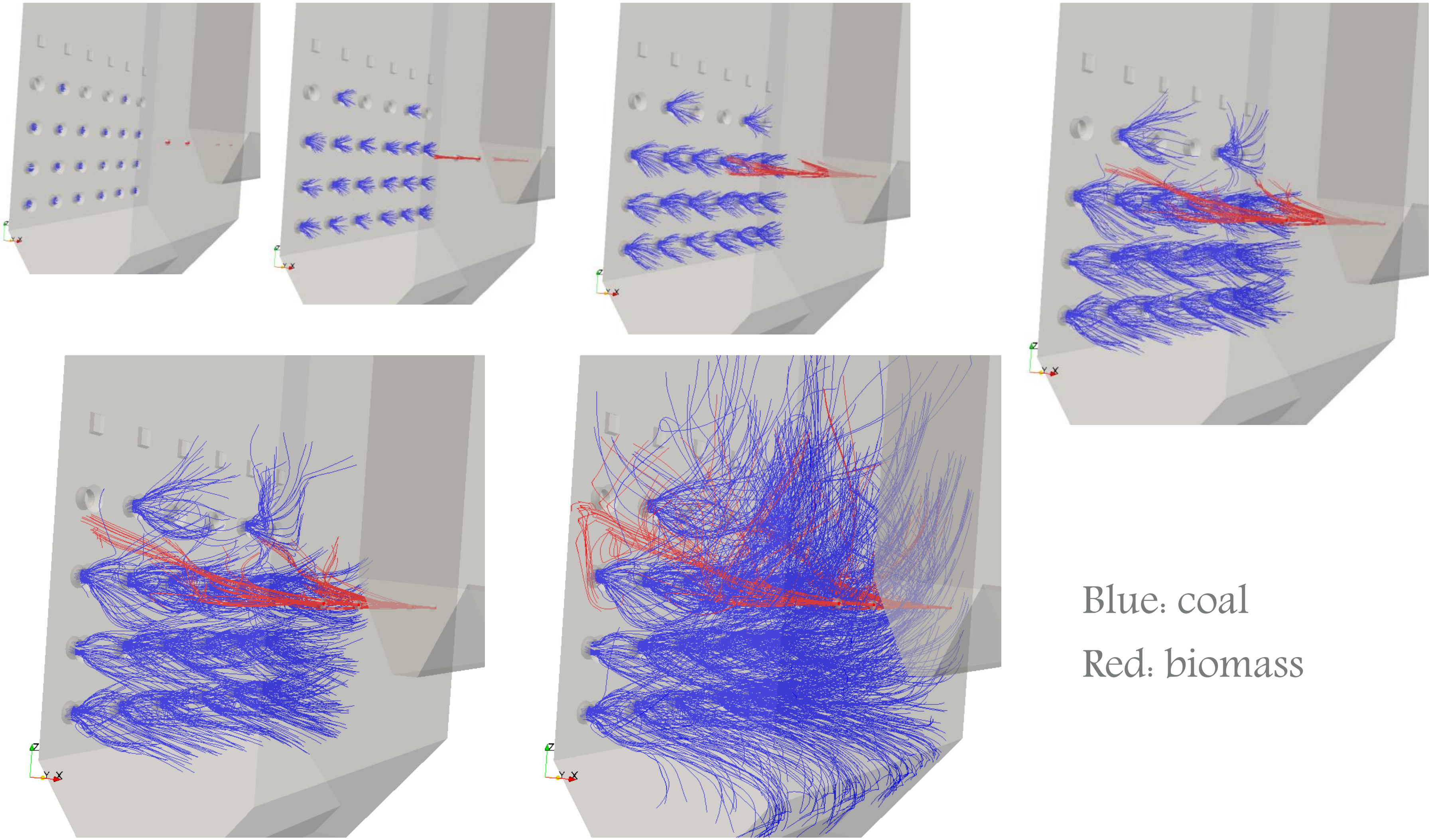
  - Averaged, frozen field obtained from the Eulerian, combustion results results
    - Mix of GUI and user coding to calculate the averaged fields, and to restart restart from them

  - Particles injected from both the coal and the biomass injectors
    - Coal: 34, 44, 63, 99.8 and 182 μm in diameter
    - Biomass: 800 μm in diameter

  - Cold flow calculations, with combustion calculations to follow

Combustion for power generation

- **Lagrangian simulations** – close up on the injectors

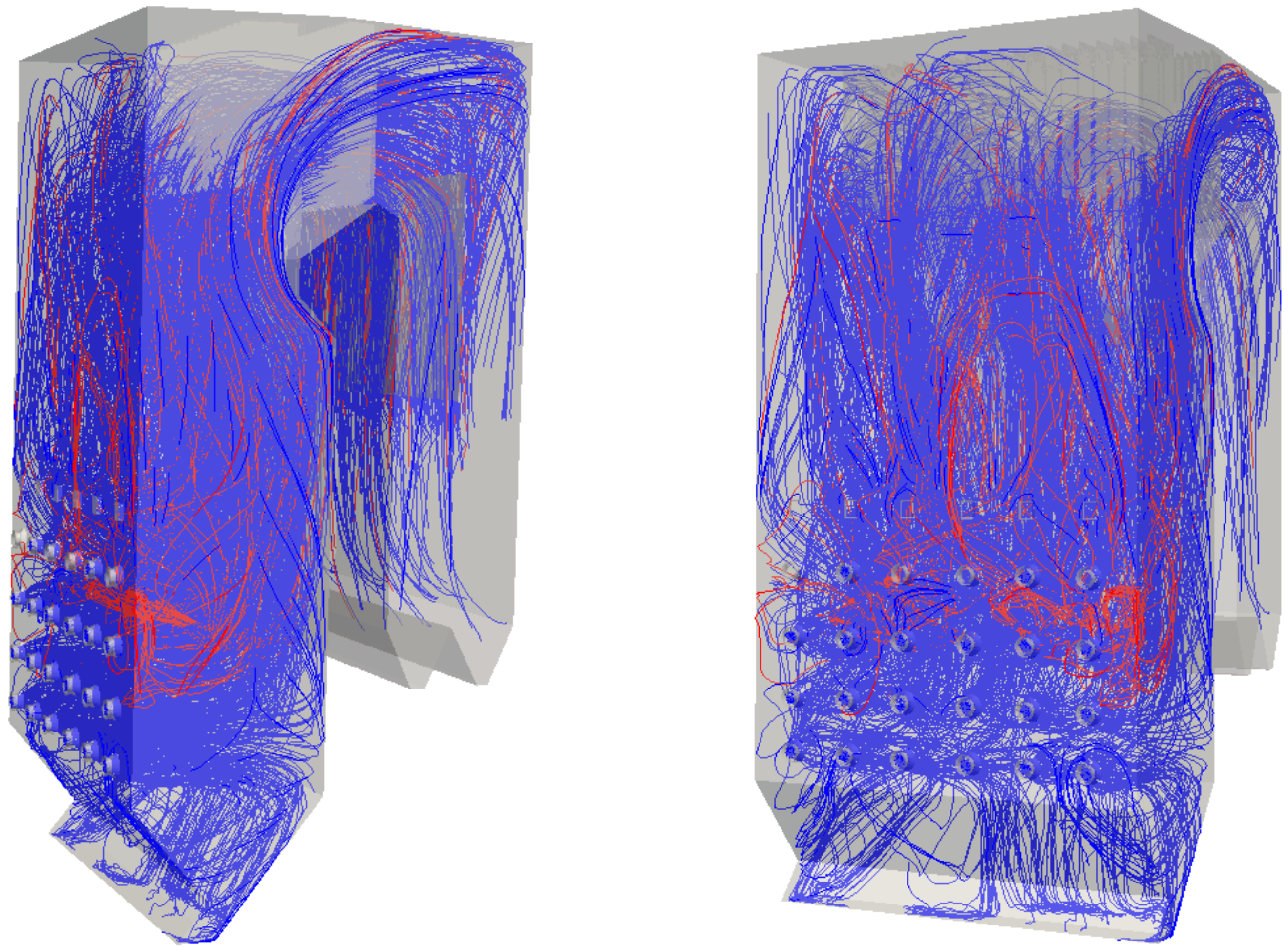


Blue: coal

Red: biomass

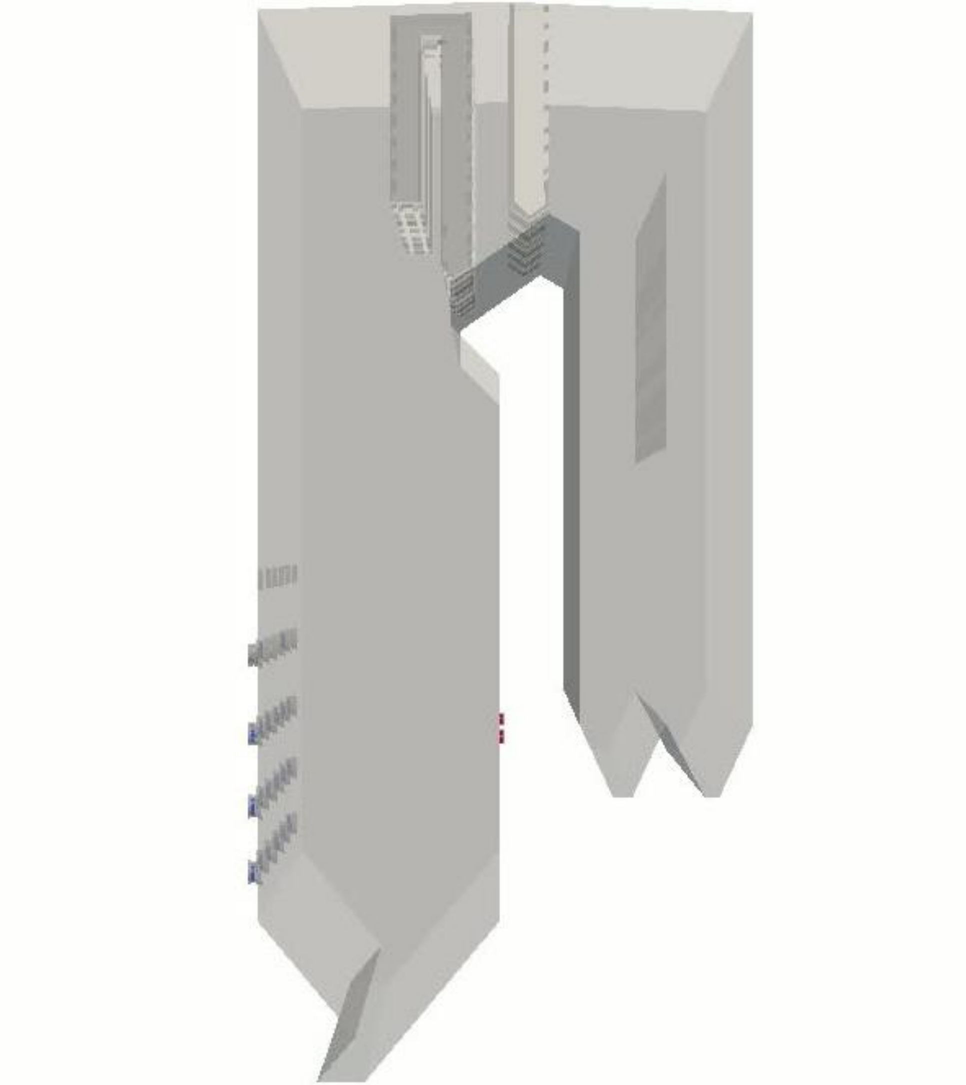
Combustion for power generation

- **Lagrangian simulations** – particle trajectories



Combustion for power generation

- **Lagrangian simulations** – animation



Combustion for power generation

- **Summary**
  - Version 4 of *Code_Saturne* has been used to simulate a combined coal and biomass power plant, including the effects of heat exchangers
  - The Eulerian simulations have made it possible to study the relative influence of coal and biomass on each other, and the impact of biomass on the completion of the combustion process
  - Lagrangian calculations will verify these findings further, taking into account temperature distribution within the particles
  - The Eulerian slip model will then be introduced, making it possible to account for the aerodynamic and inertial effects of variable particle diameters

4. Heat Recovery System

Heat recovery system

- Fives Stein has **designed and patented** a system for using exhaust gas to heat incoming air used for combustion and to entrain burnt gas into the combustion process

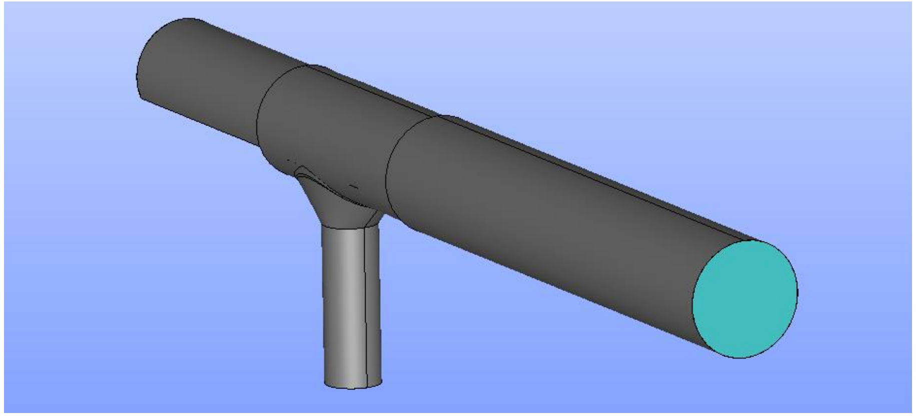
- **Three designs for the heat recovery system needed to be tested**
  - The designs differ only in the nozzle through which the air flows and subsequently entrains the burnt gas

- **In order to keep costs down Fives Stein is looking to use CFD** to which design to test experimentally
  - Compare air temperature rise, burnt gas entrainment fraction, system and nozzle pressure drops and air nozzle exit velocity

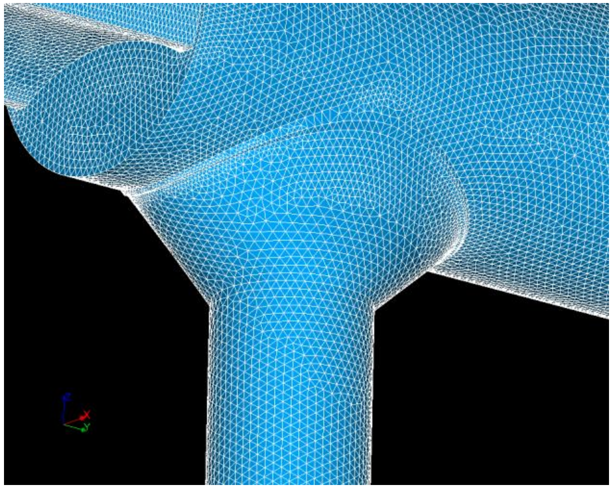
- **Software**: SALOME, *Code_Saturne* and SYRTHES

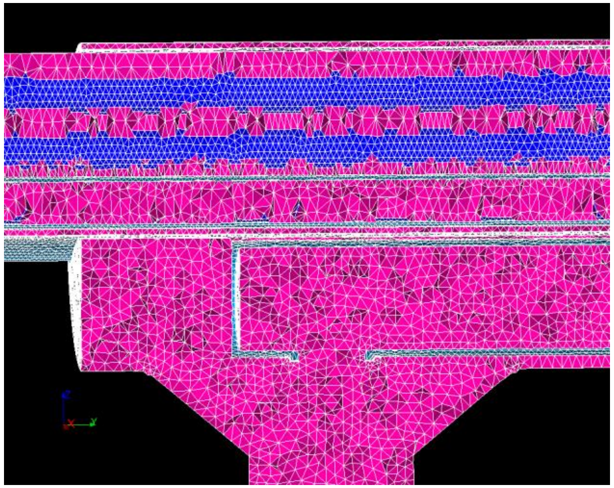
Heat recovery system

- Simplified flow domain and geometry



- Tet volume mesh – approx 2.5 million cells for fluid + solid domains





- **Numerical model**
  - 3D, steady state, turbulent flow with conjugate heat transfer
  - Polynomials as a f(T) for air and burnt gas fluid properties
  - k–ε LP model
  - First and second order discretisation
  - Inlet, outlet and wall boundaries
  - Clipping of the temperature scalar
  - Solution monitoring to check simulation stability

- **Results**
  - The air temperature and velocity at the exit of the nozzle were compared with compared with expected values and were in good agreement
  - From air inlet to just upstream of the nozzle, the air temperature increases by increases by approximately 150°C to 180°C
  - Over half the system pressure drop was shown to be due to the nozzle
  - The angle and maximum velocity of the air jet exiting the nozzle was shown to shown to be heavily dependent on nozzle geometric quantities
  - More than 35% of the burnt gas was entrained by the air
  - No nozzle was shown to give the best results for all four performance criteria criteria

Heat recovery system

- **Summary**
  - Simulations were undertaken on a burnt gas heat recovery unit in order to to assess the impact of three nozzle designs on system performance
  - Results of air nozzle exit velocity and temperature agree well with data supplied by Fives Stein
  - Over half the system pressure drop occurs in the nozzles
  - More than 35% of the burnt gas is entrained by the air and this percentage percentage appears to be independent of nozzle pressure drop but dependant dependant on air exit velocity and flow angle relative to the nozzle
  - A nozzle design will seemingly have to be a compromise with respect to the the performance criteria specified by Fives Stein

5. Summary and Perspectives

Summary

- Renuda has extensively used *Code_Saturne* over the last 12 months for a variety of industrial projects
  - Used in conjunction with SALOME, SYRTHES, and Paraview

- *Code_Saturne* has been successfully applied to a variety of challenging problems involving varied physics and fluids
  - Liquids
  - Gases
  - Multi-species
  - Multi-phase
  - Reactive flow

Perspectives

- **Open source CFD is becoming more accepted in industry** as more companies are prepared to exploit this option
  - Significant cost reductions
  - Undertake more complex simulations

- The **SALOME** – ***Code_Saturne*** – **SYRTHES** open source calculation chain chain can be considered to be a **viable alternative to commercial codes codes**

- **Improvements desired**
  - CAD
  - Volume meshing
  - Additional physics
  - Post processing