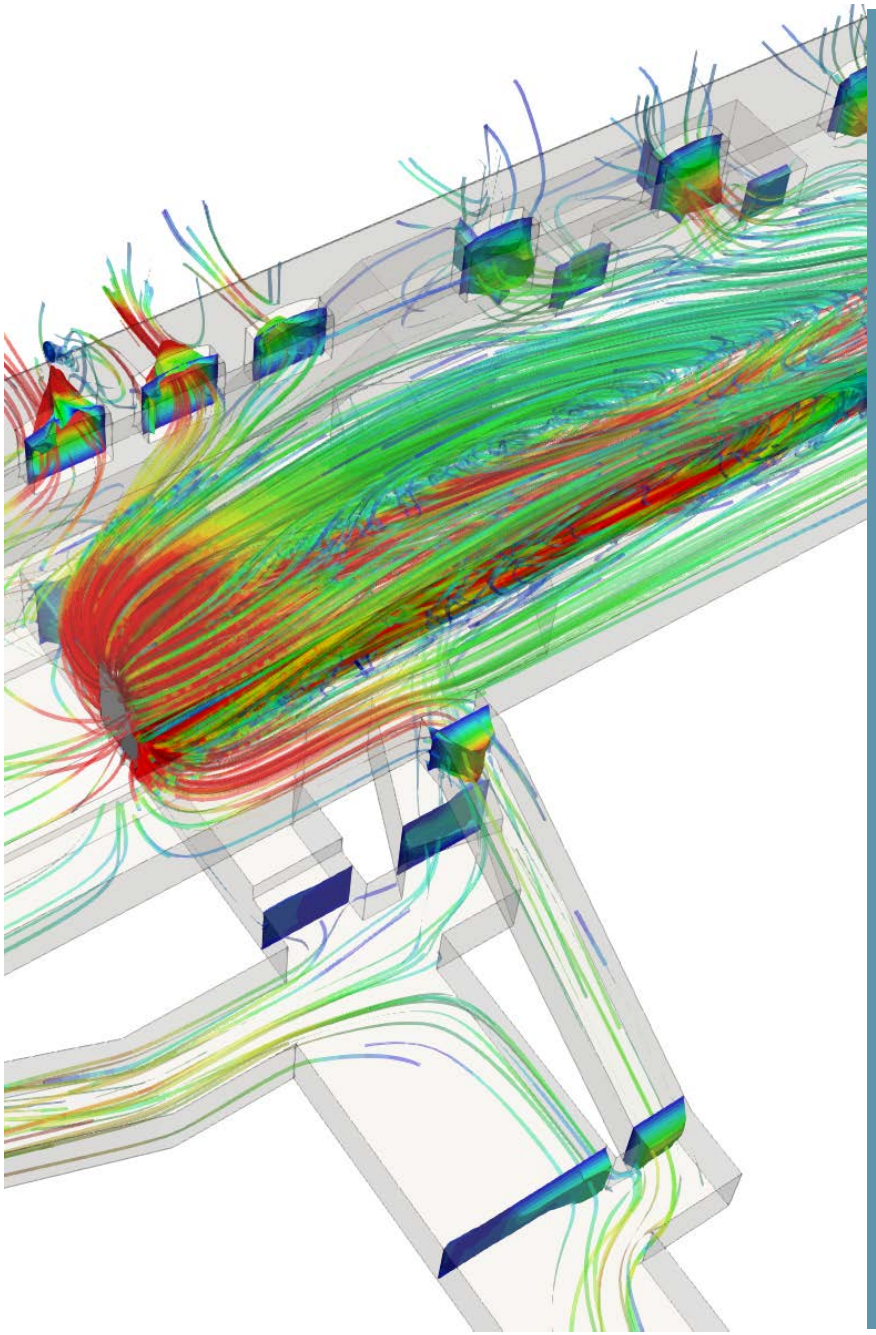

Simulation of the piston effect of a train entering or leaving an underground station

Joint Franco/Belgian OpenFOAM users conference

25/05/2018 – Sylvain AGUINAGA,
Mateusz BOGDAN,
Alexis SAUVAGEON

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Aim & Objectives of the study

Why? What for? How?

Air management inside train stations

WHY MODELLING AIR FLOW INSIDE TRAIN STATIONS?

> Pollutant dispersion
> Pedestrian comfort
> Thermal management

WHAT IS DRIVING AIR MOVEMENT INSIDE THE STATION?

> Wind blowing outside
> HVAC systems
> **Train movement**

WHAT WE ARE FOCUSING ON HERE?

> Subway train, low speed, max 70kph
> Compressibility neglected: we are not modeling the pressure wave propagation of high speed trains inside the tunnels
> Not interested into the aerodynamic of the train itself (slipstream)

>To be able to quantify the amount of air movement inside/outside the station due to the train displacement

Developing a Design Tool

USING OPENFOAM AS A SIMULATION TOOL TO DESIGN TRAIN STATIONS

> Easy to setup

> Easy to transpose to different train station geometries

> Easy to run : industrial grade solution

> Part of a wider simulation tool to model air flow management inside train stations

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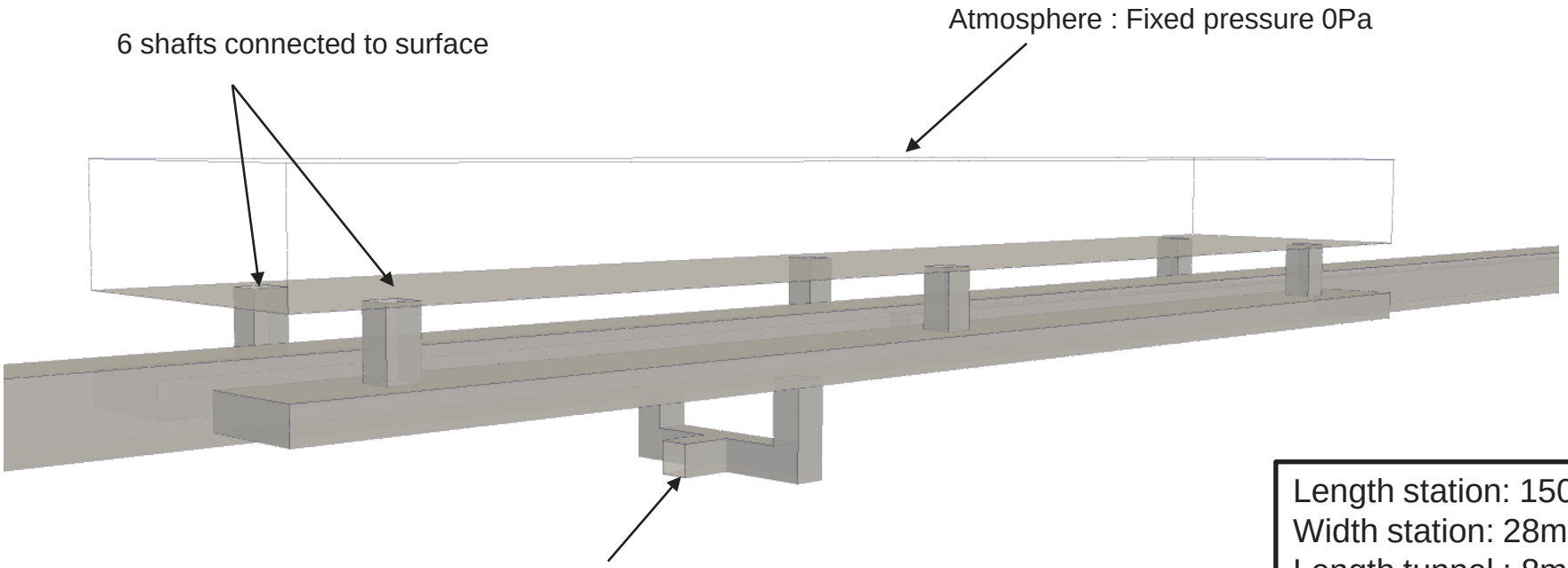
Methodology

A Simplified Train Station

Methodology

The simplified station

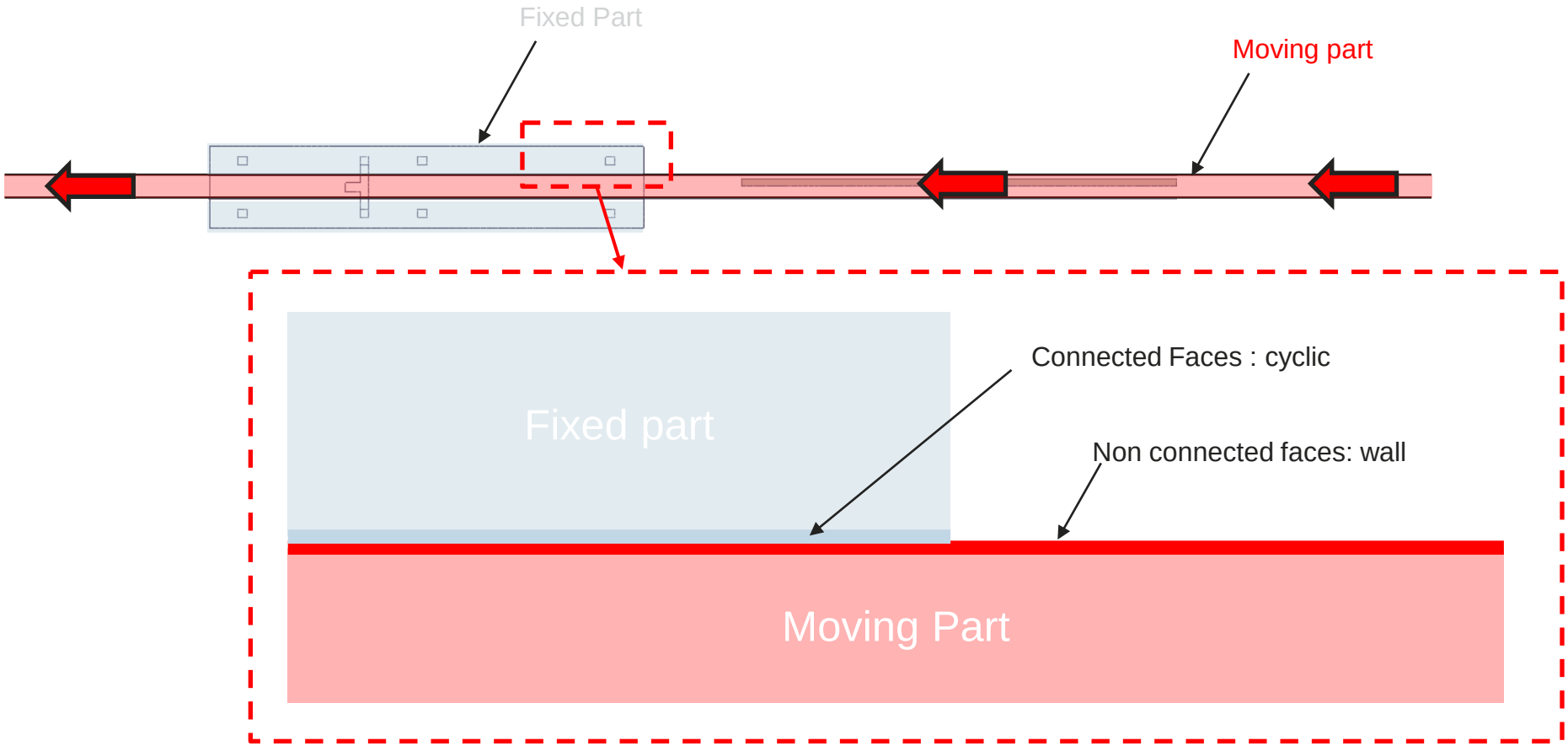
> Very simple geometry to setup the methodology



Length station: 150m
Width station: 28m
Length tunnel : 8m
Width train : 3m
Height tunnel: 6m
Height train : 3m

Methodology

The main trick : DynamicMesh + Moving Wall + ACMI



ACMI + DYNAMIC MESH

> Arbitrary Cyclic Mesh Interface

> Moving mesh: both train and tunnel are moving inside the fixed station

Methodology

About boundary conditions

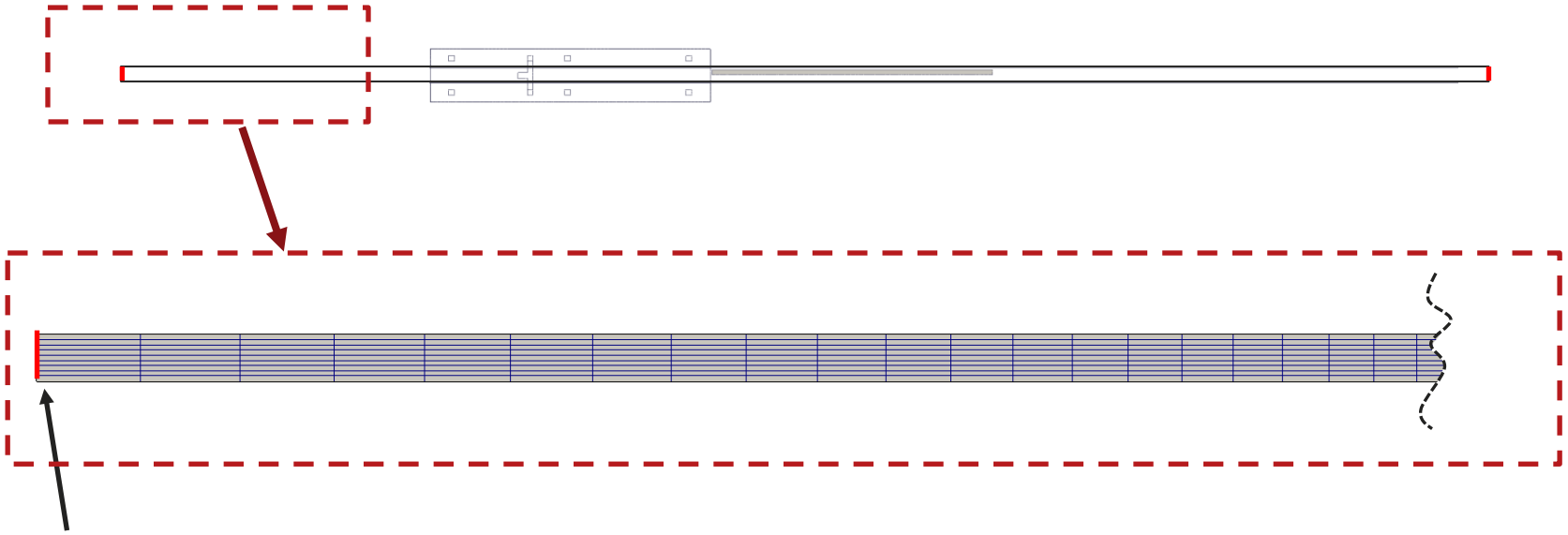
ON THE WALLS?

> On the train : moving wall, velocity equal to domain displacement
> On the tunnel: fixed zero velocity

→ Works just fine!

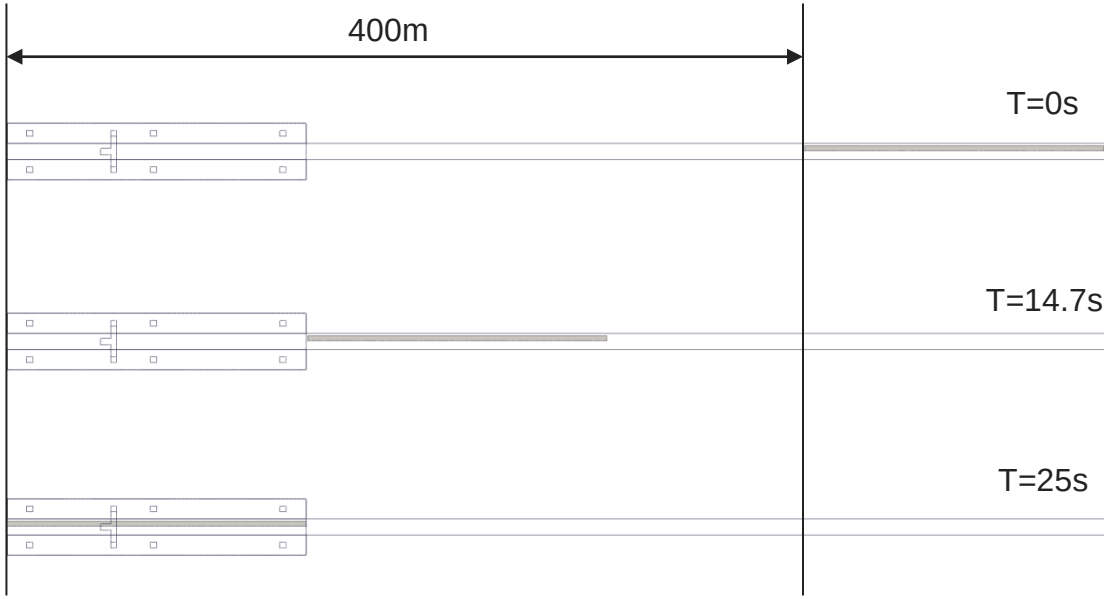
WHICH BC AT THE END OF TUNNEL?

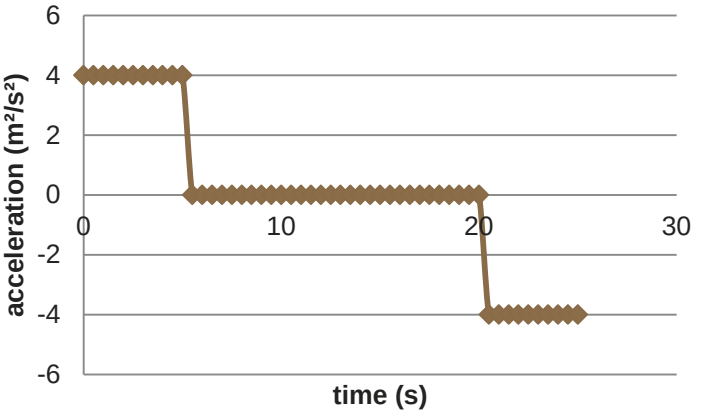
> Wall ➔ neither realistic nor stable
> Cyclic ➔ works OK but increases the flow rate in the tunnel
> Fixed pressure ➔ works fine, realistic (there must be a ventilation shaft somewhere)

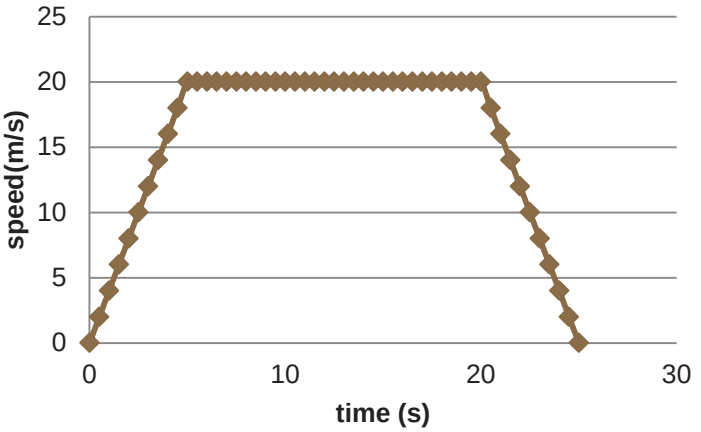


Methodology

Train movement



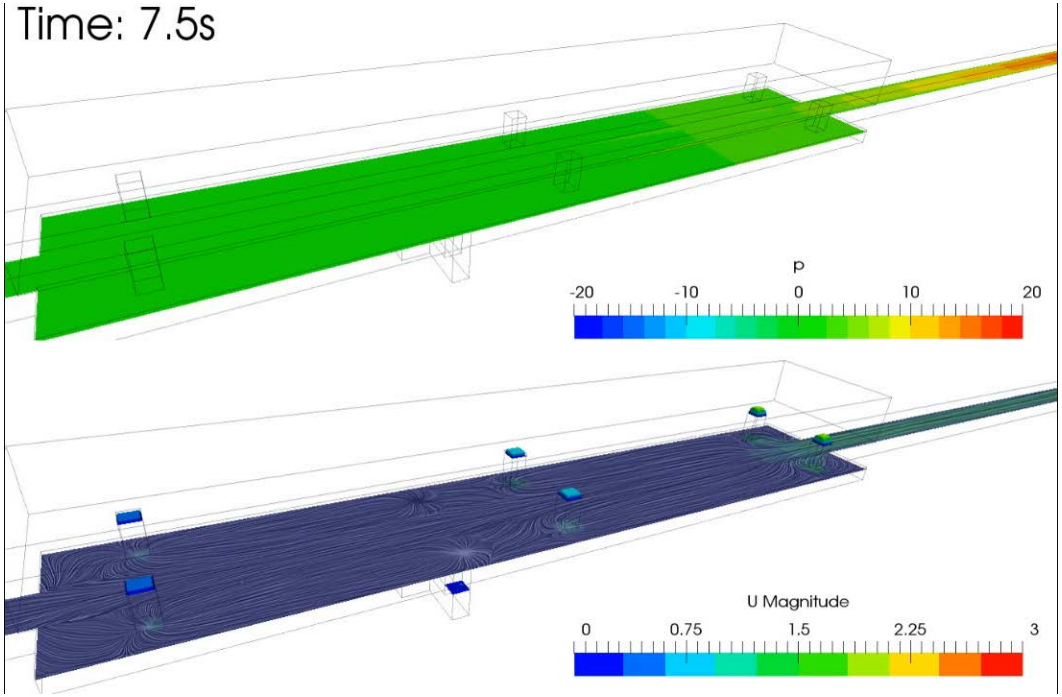




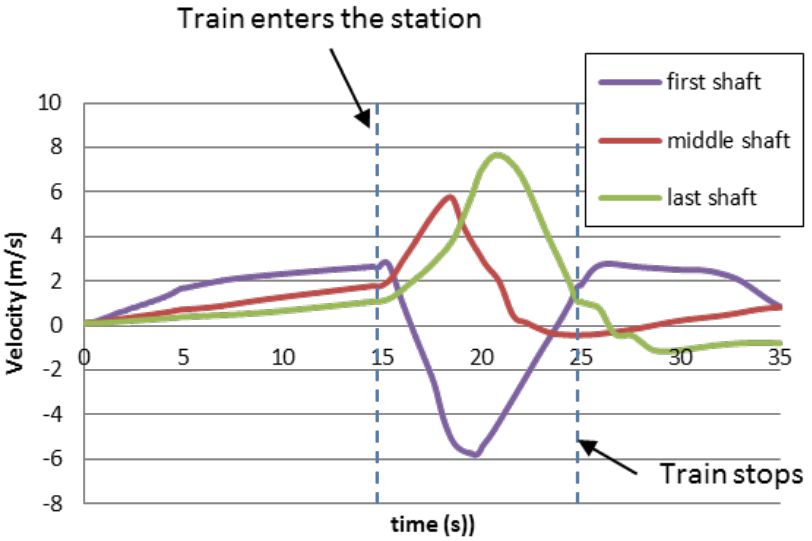
> Solver: pimpleDyMFoam (Openfoam 3.0.1)
>Turbulence: k-eps Realizable

Methodology

Results



> Air flow velocity in the shafts



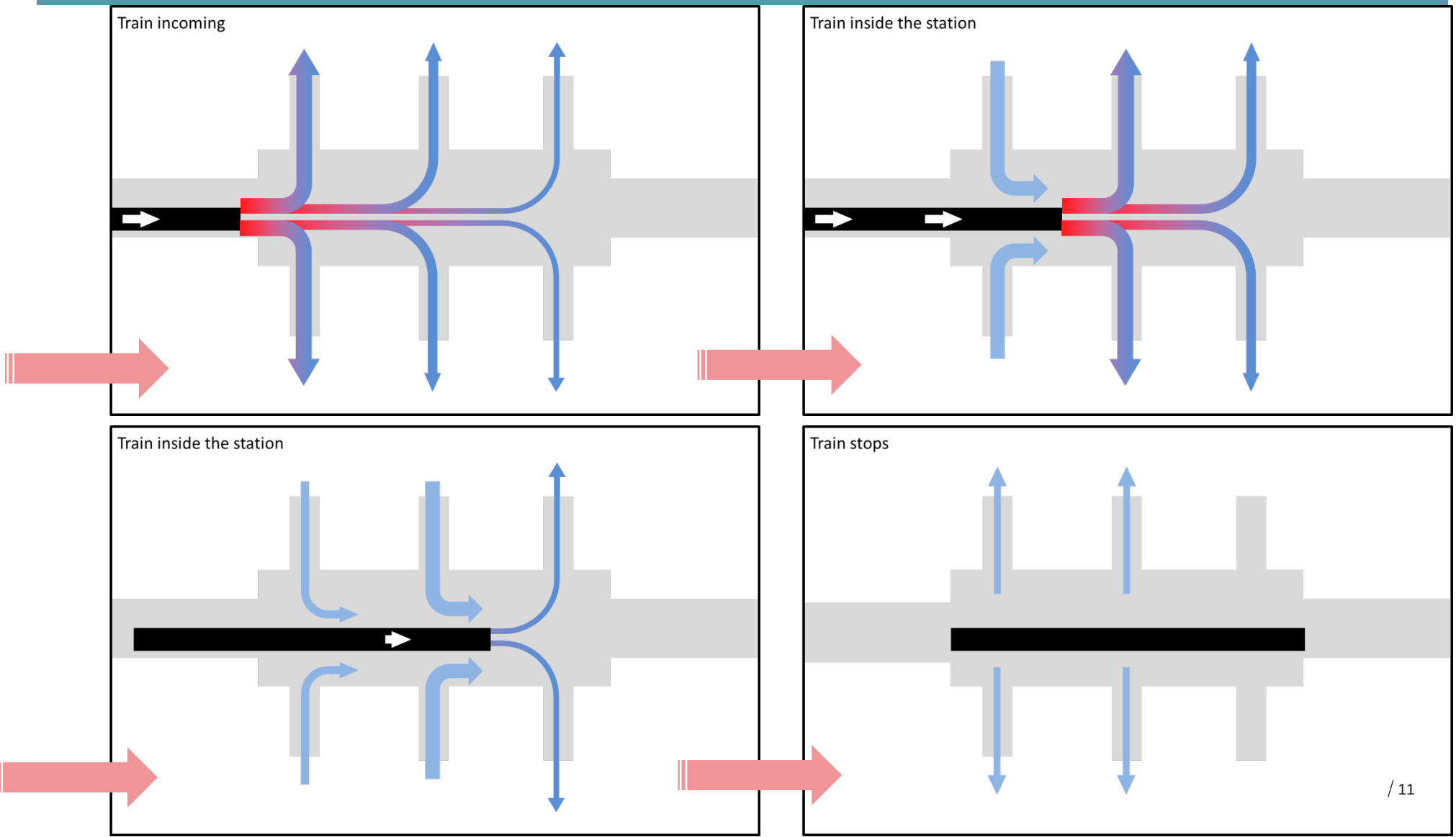
COMPLEX BEHAVIOR

> Wind speeds look realistic

> Transient behavior into the shafts is interesting to analyze

Methodology

Analysis



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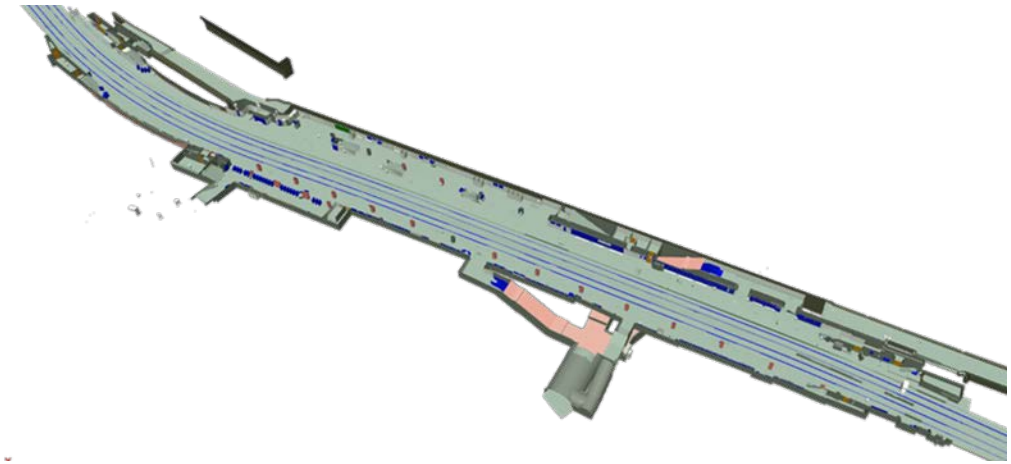
Application to a real train station

The train station

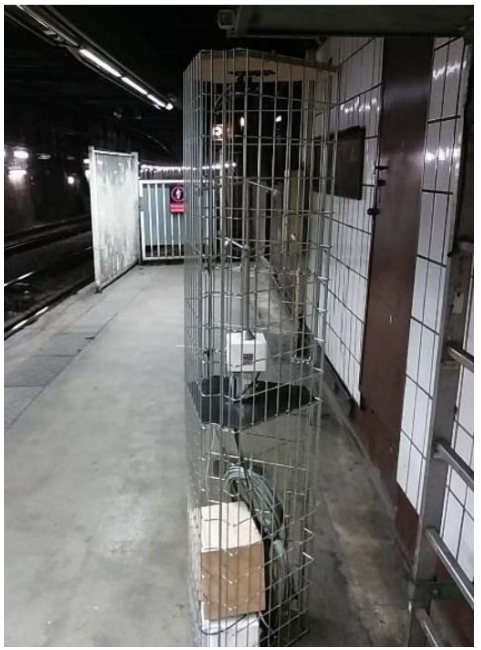
HIGHLY DETAILED BIM MODEL

> Open IFC format
> All the tunnels to surface and the connections to underground network are modelled

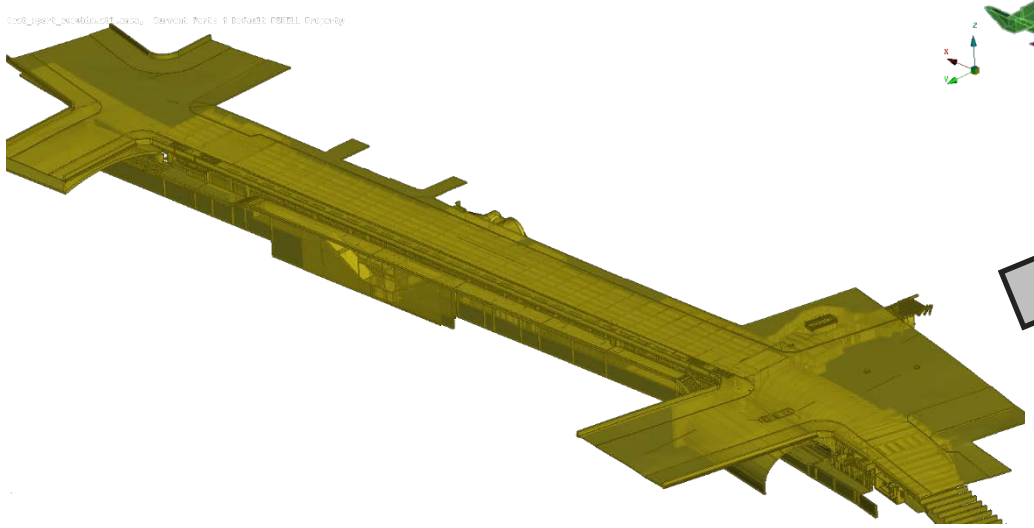


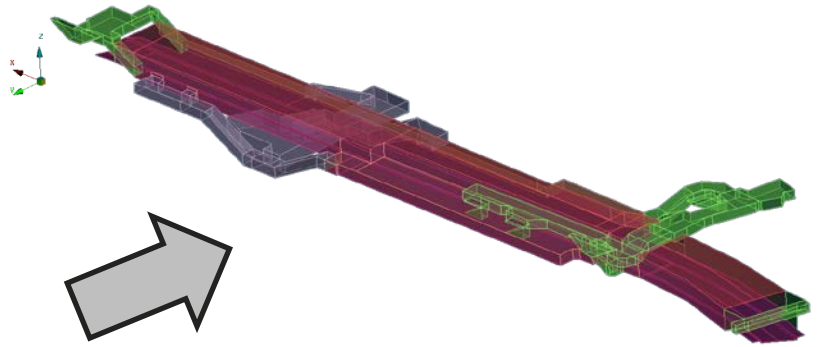
MEASUREMENTS

> Sonic anemometers
> Dozen of points in the station
> Difficult to identify an isolated event (arrival/departure)



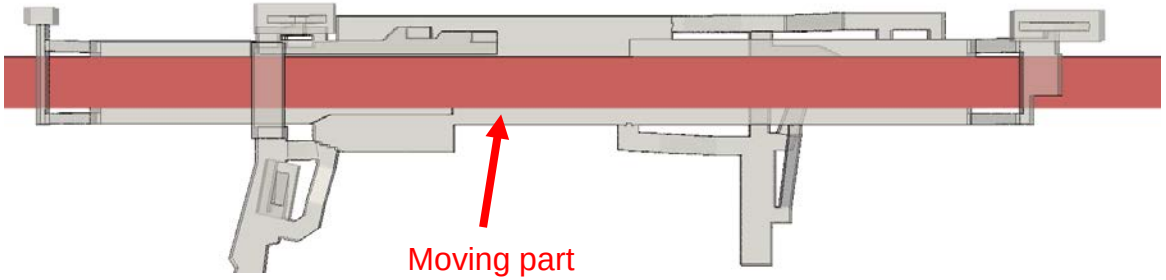
The train station
Simplification

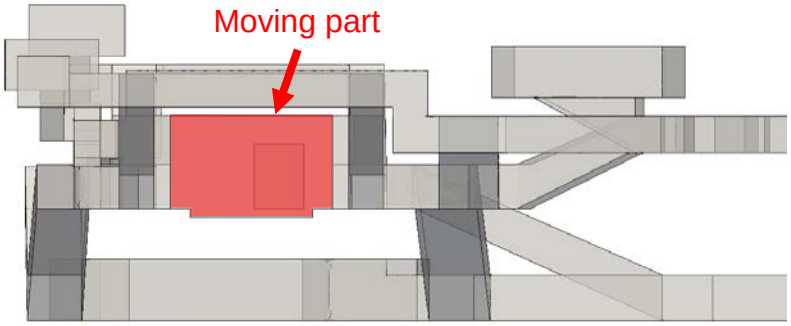




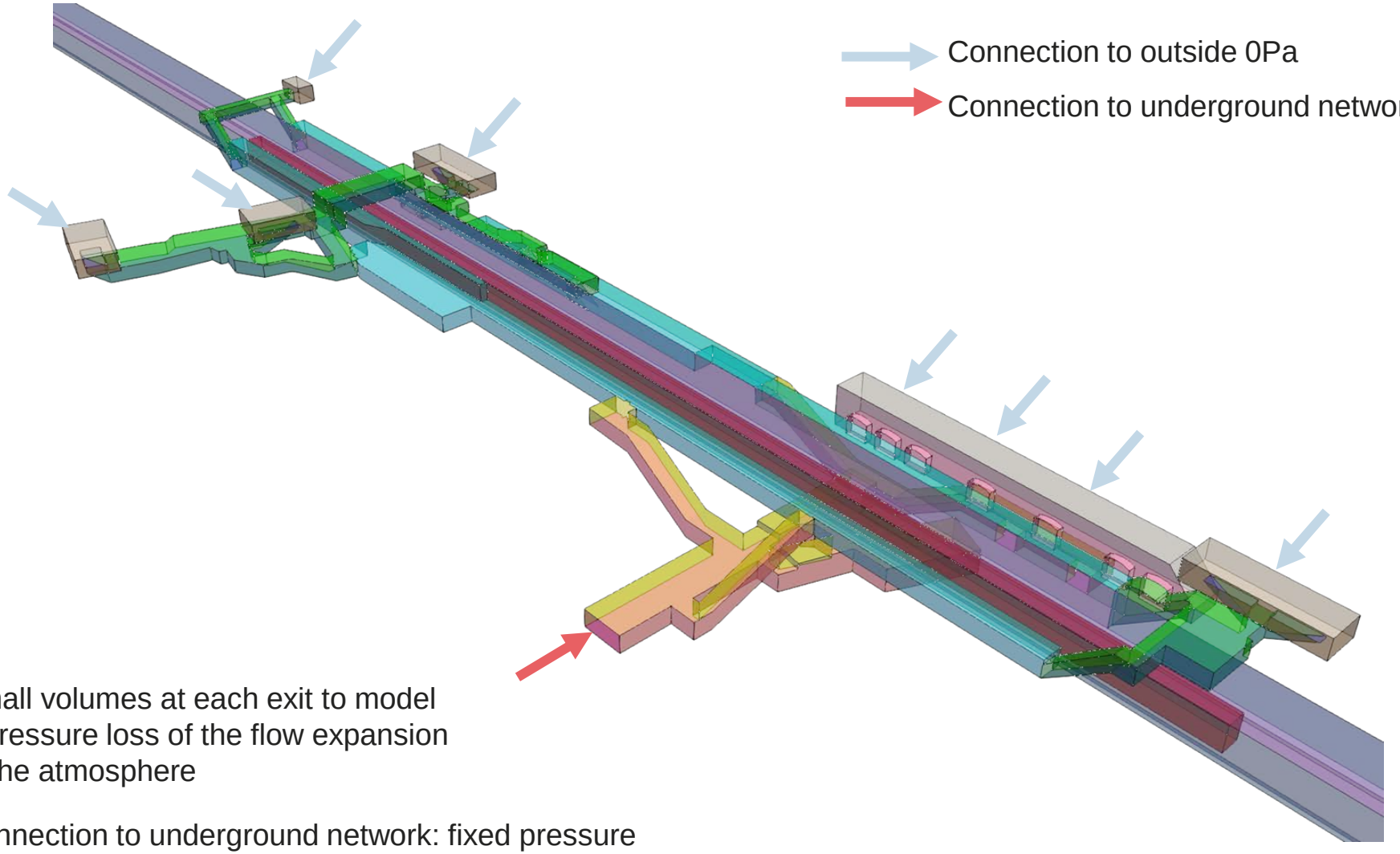
> Volume extraction from the BIM model
> First simplification

> Moving mesh requires further simplification :
→To straighten the curb
→To keep the tunnel height constant





The train station
Simplified model

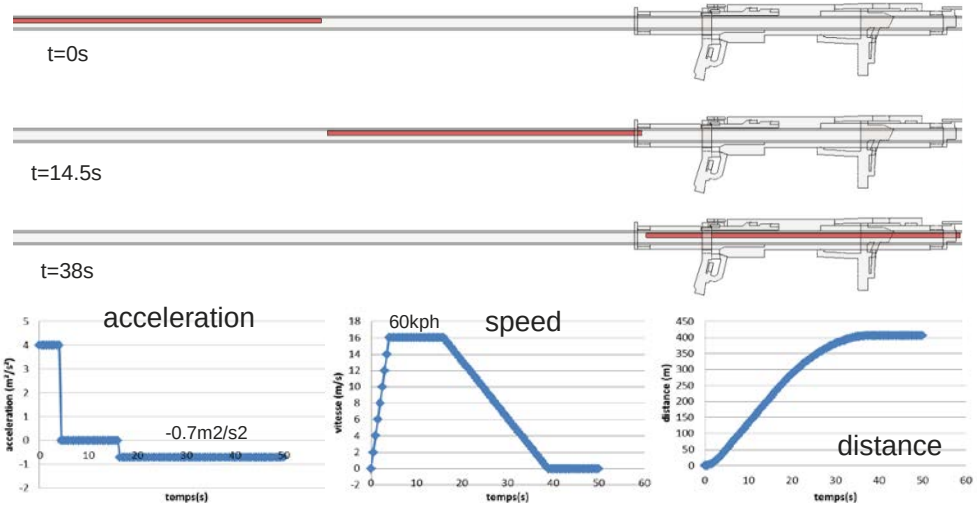


> Small volumes at each exit to model the pressure loss of the flow expansion into the atmosphere

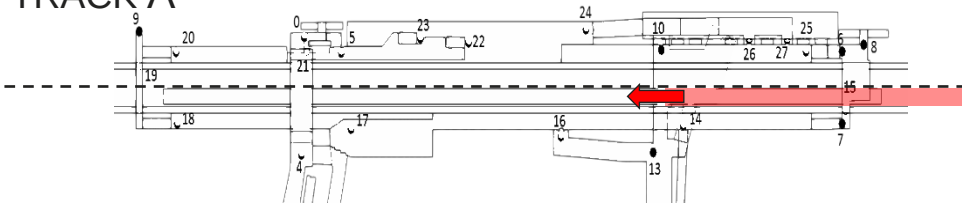
> Connection to underground network: fixed pressure calculated from the measurements (1m/s in the tunnel)

Investigated Scenarios

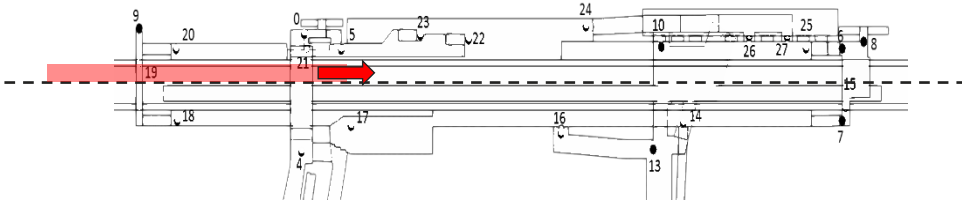
ARRIVAL



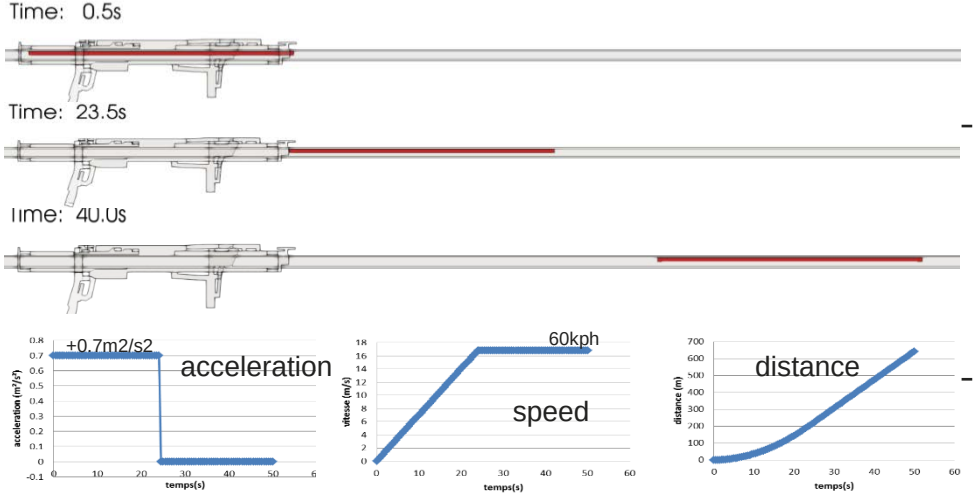
TRACK A



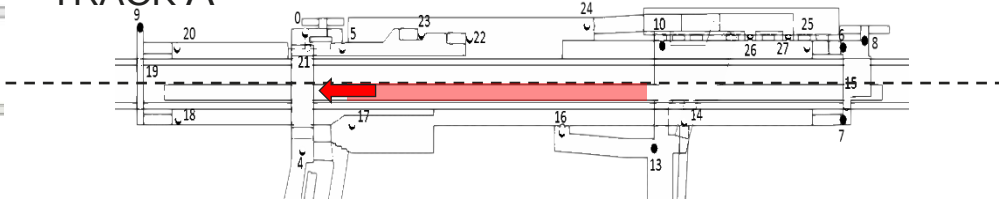
TRACK B



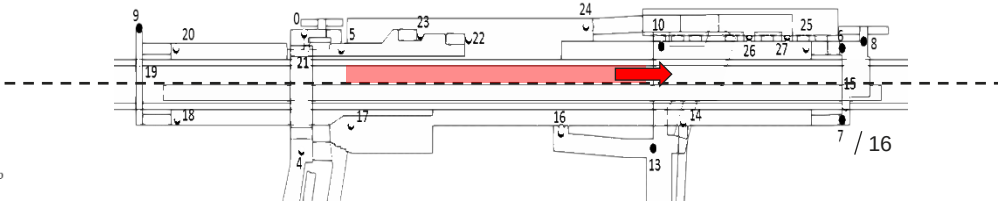
DEPARTURE



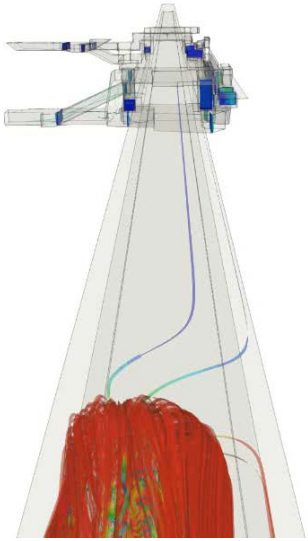
TRACK A

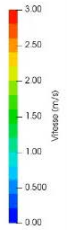


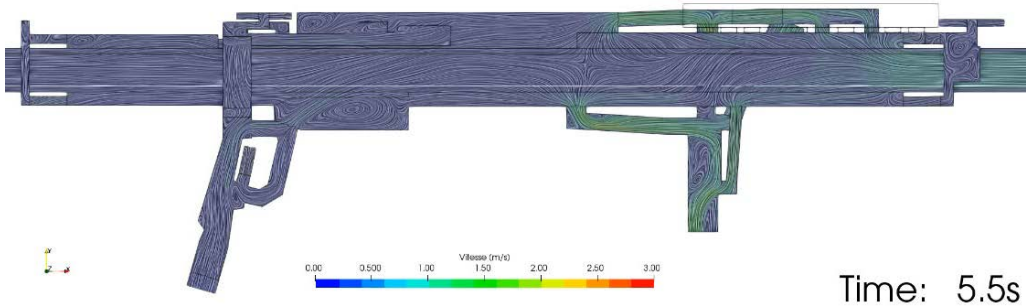
TRACK B



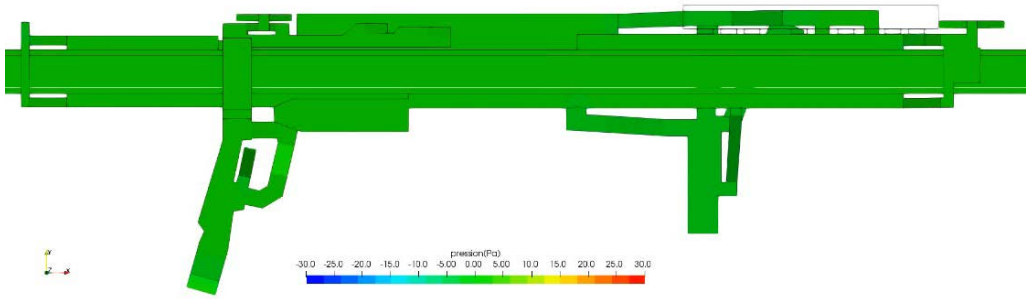
Time: 5.5s



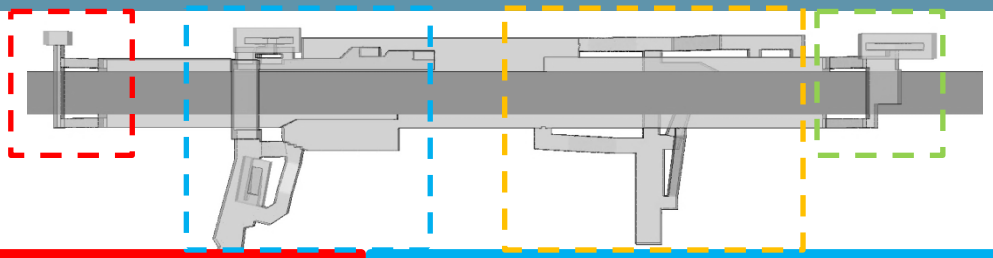


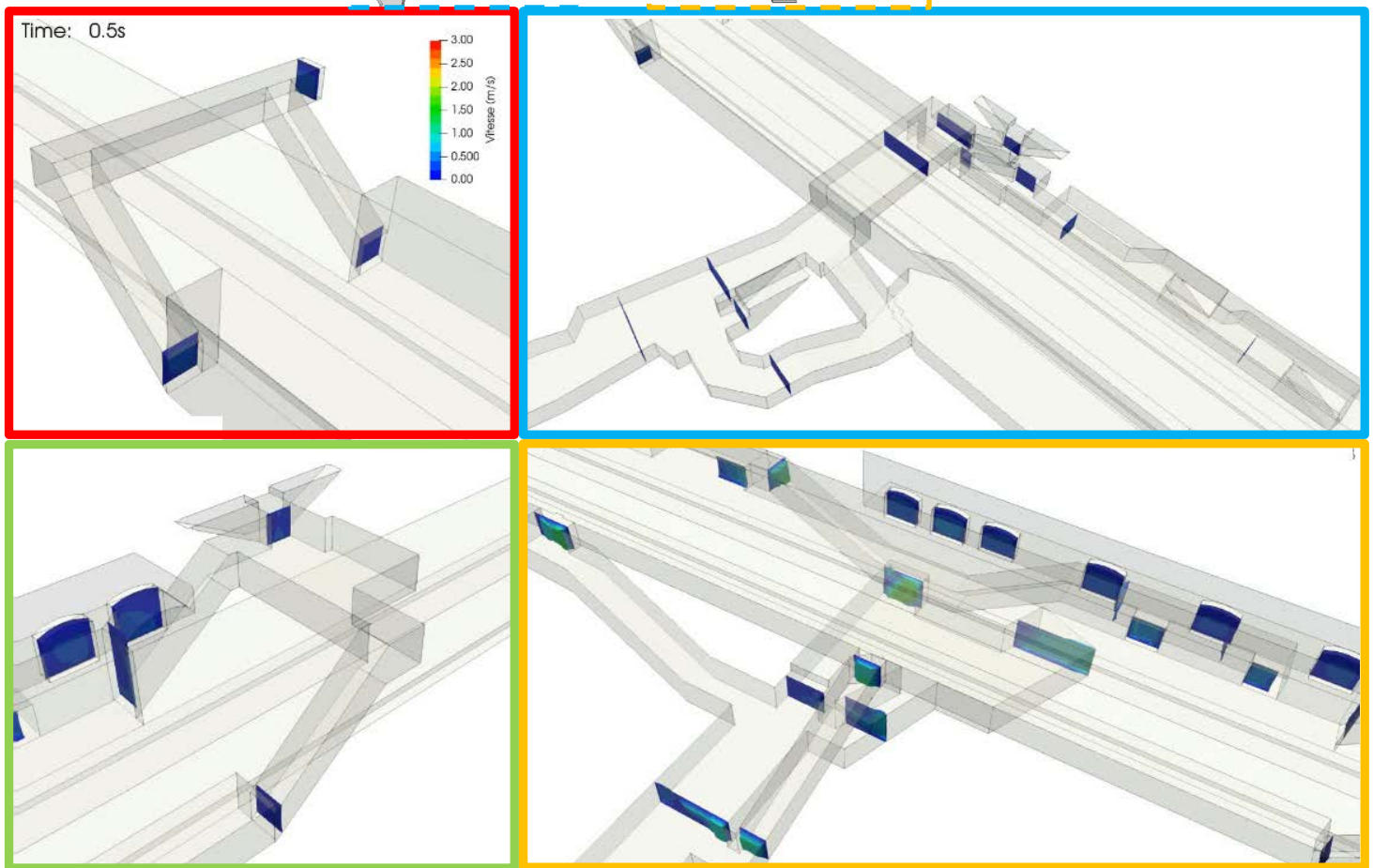


Time: 5.5s

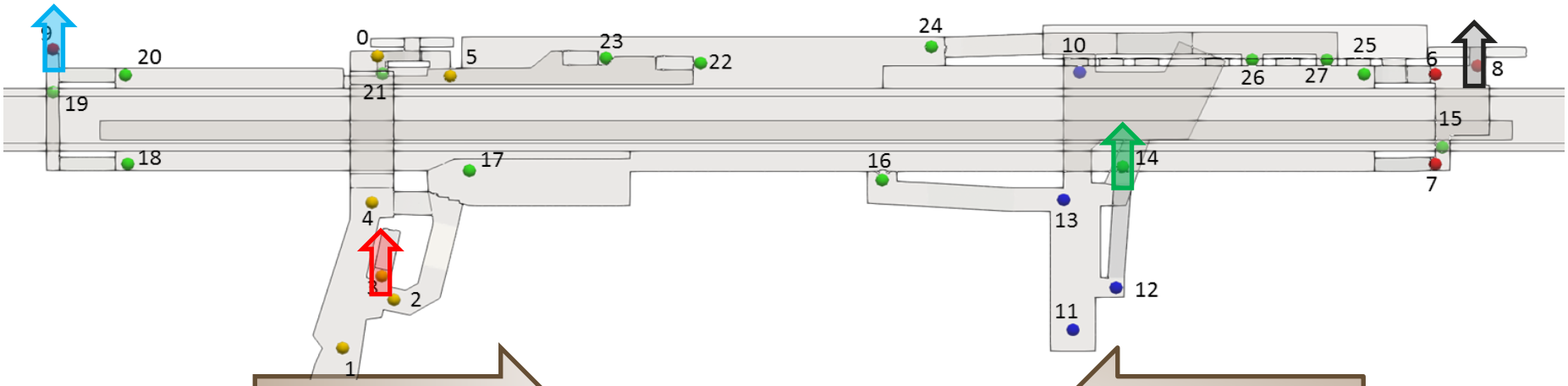


Simulations

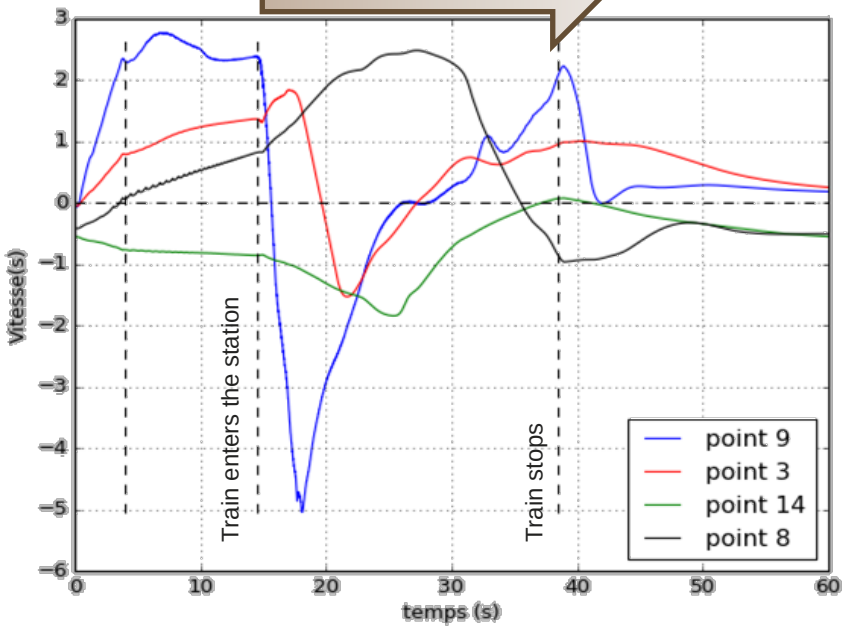




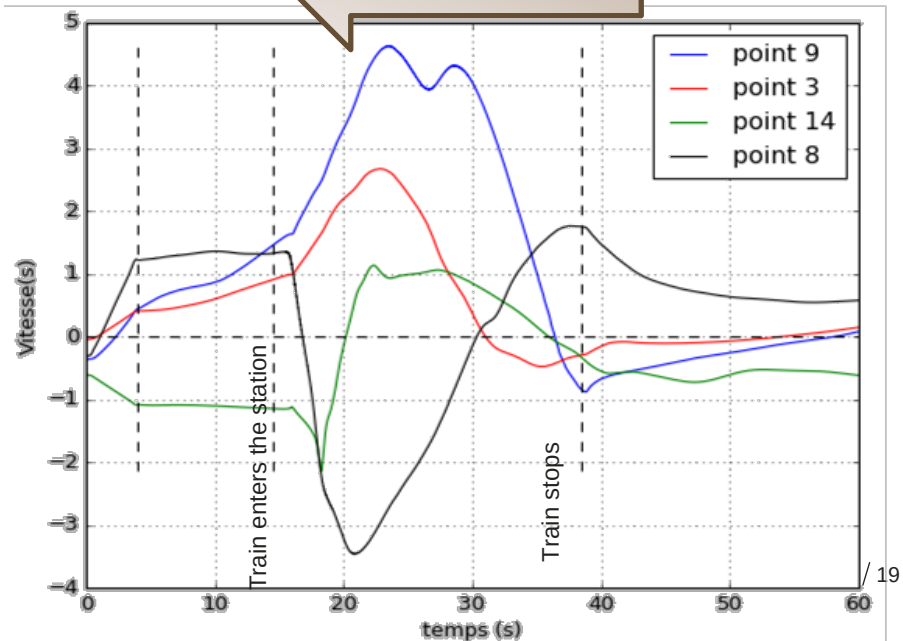
Simulations



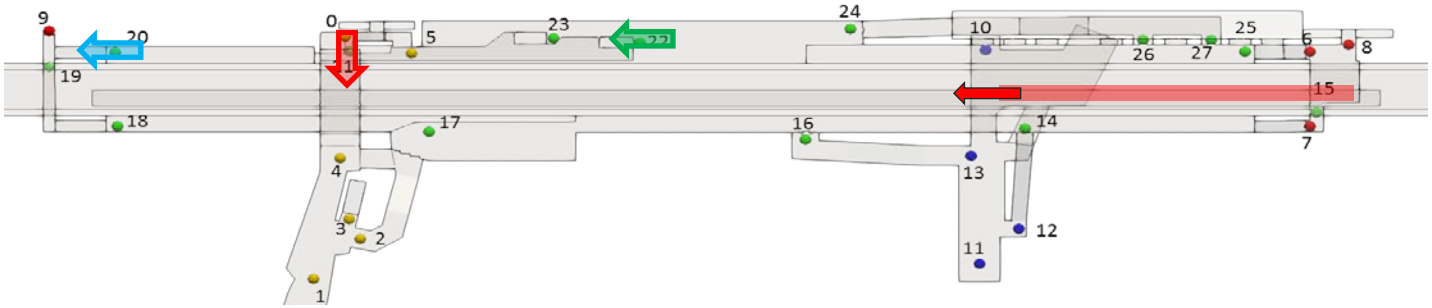
Arrival track B



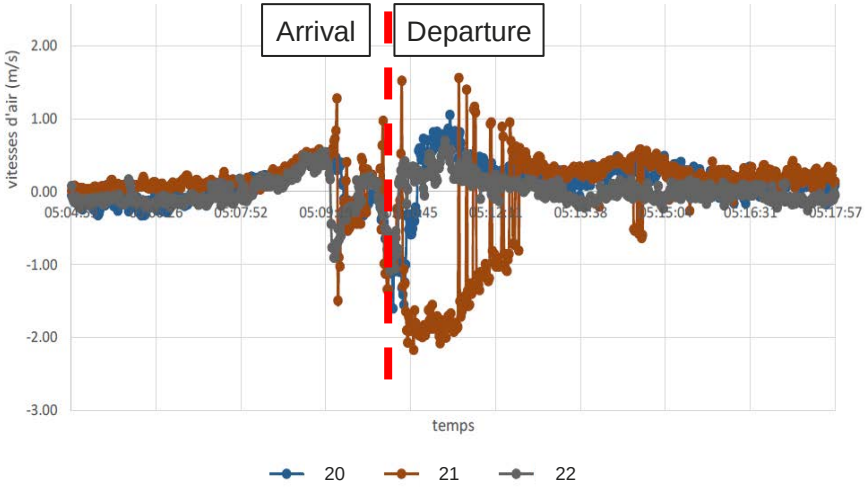
Arrival track A



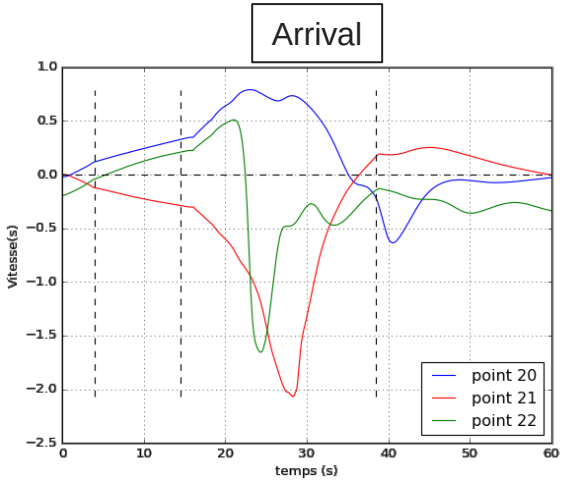
Comparison to measurements

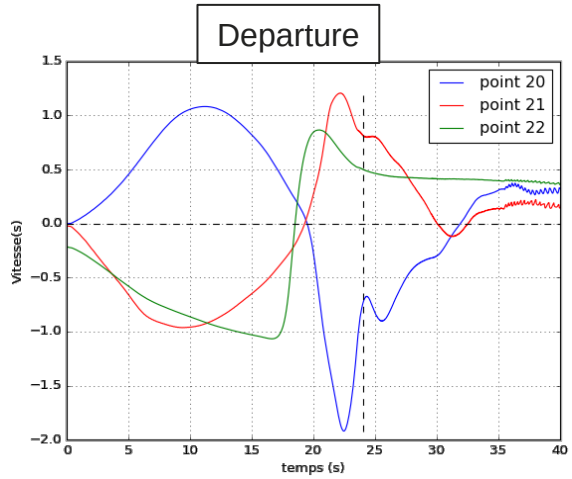


MEASUREMENTS



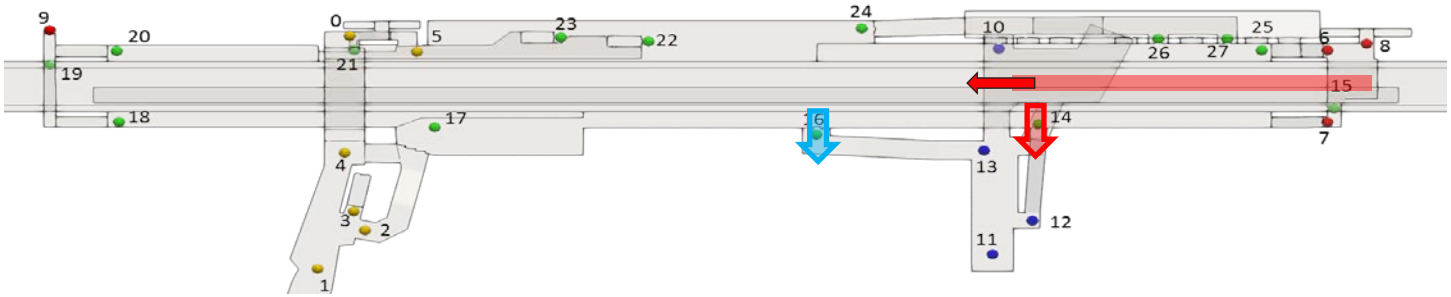
SIMULATIONS



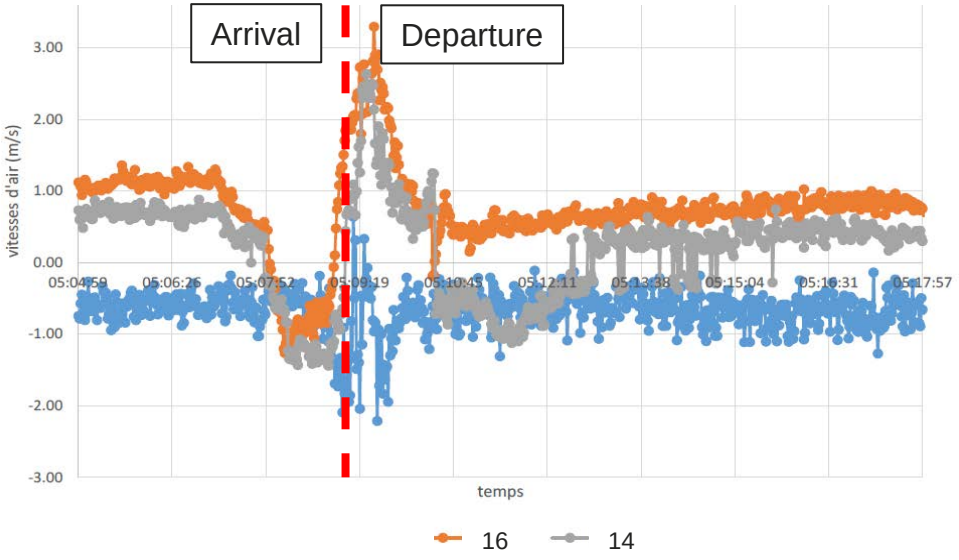


> Comparison to measurements difficult to achieve (sensor position, train direction, combination arrival/departure)
> Order of magnitude is good, both in time and velocity

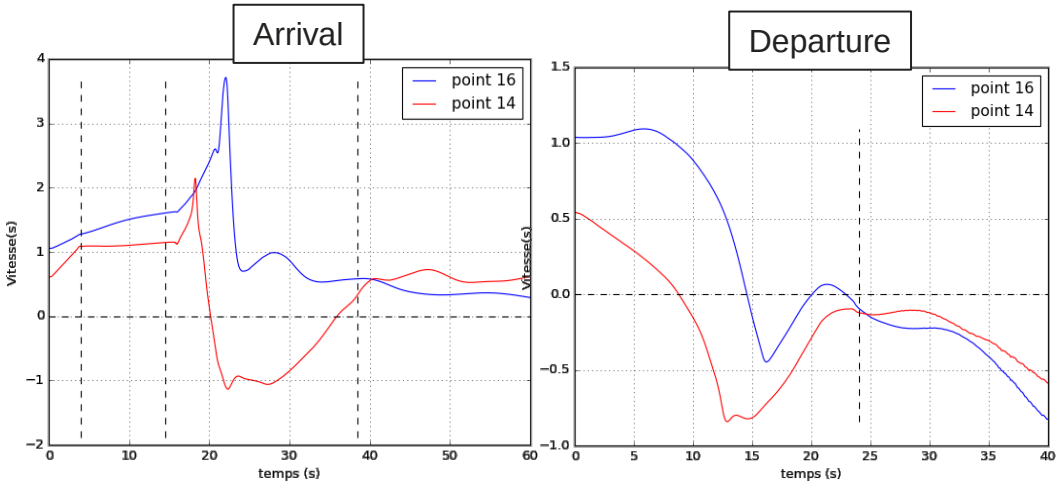
Comparison to measurements



MEASUREMENTS



SIMULATIONS



> Comparison to measurements difficult to achieve (sensor position, train direction, combination arrival/departure)
> Order of magnitude is good, both in time and velocity

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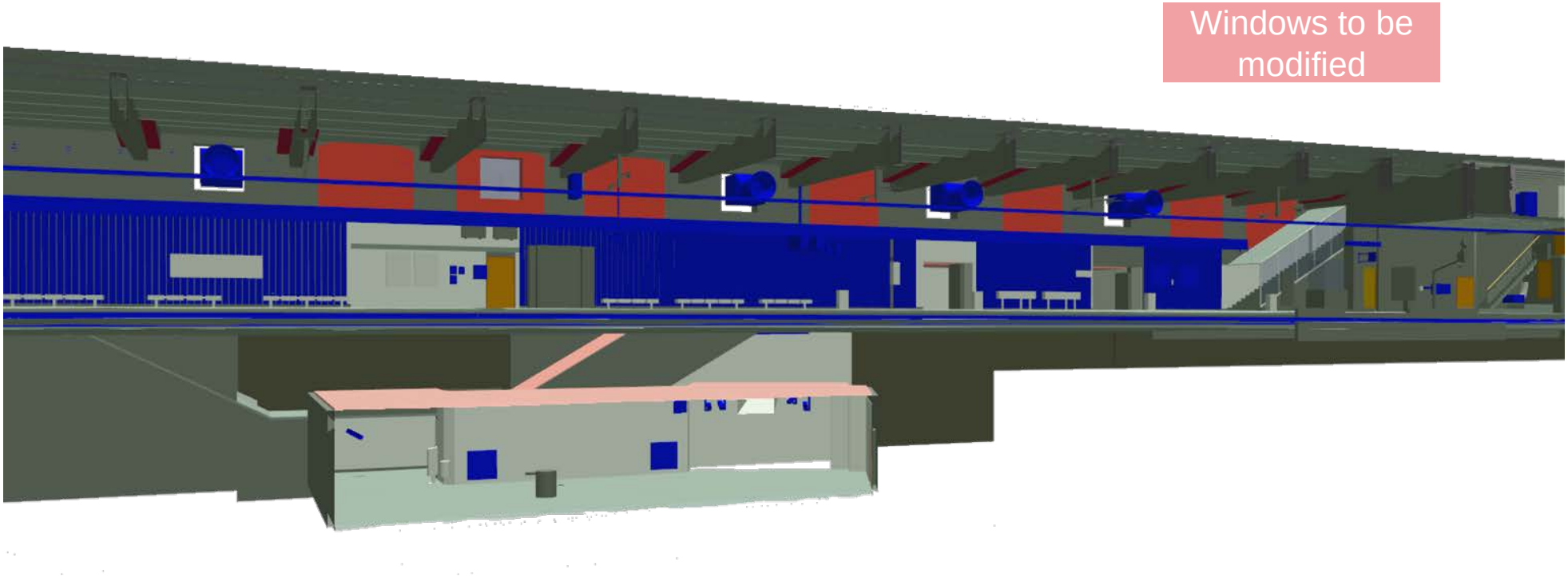
A designing tool

Prediction of the impact of modifications in the train station

A designing tool

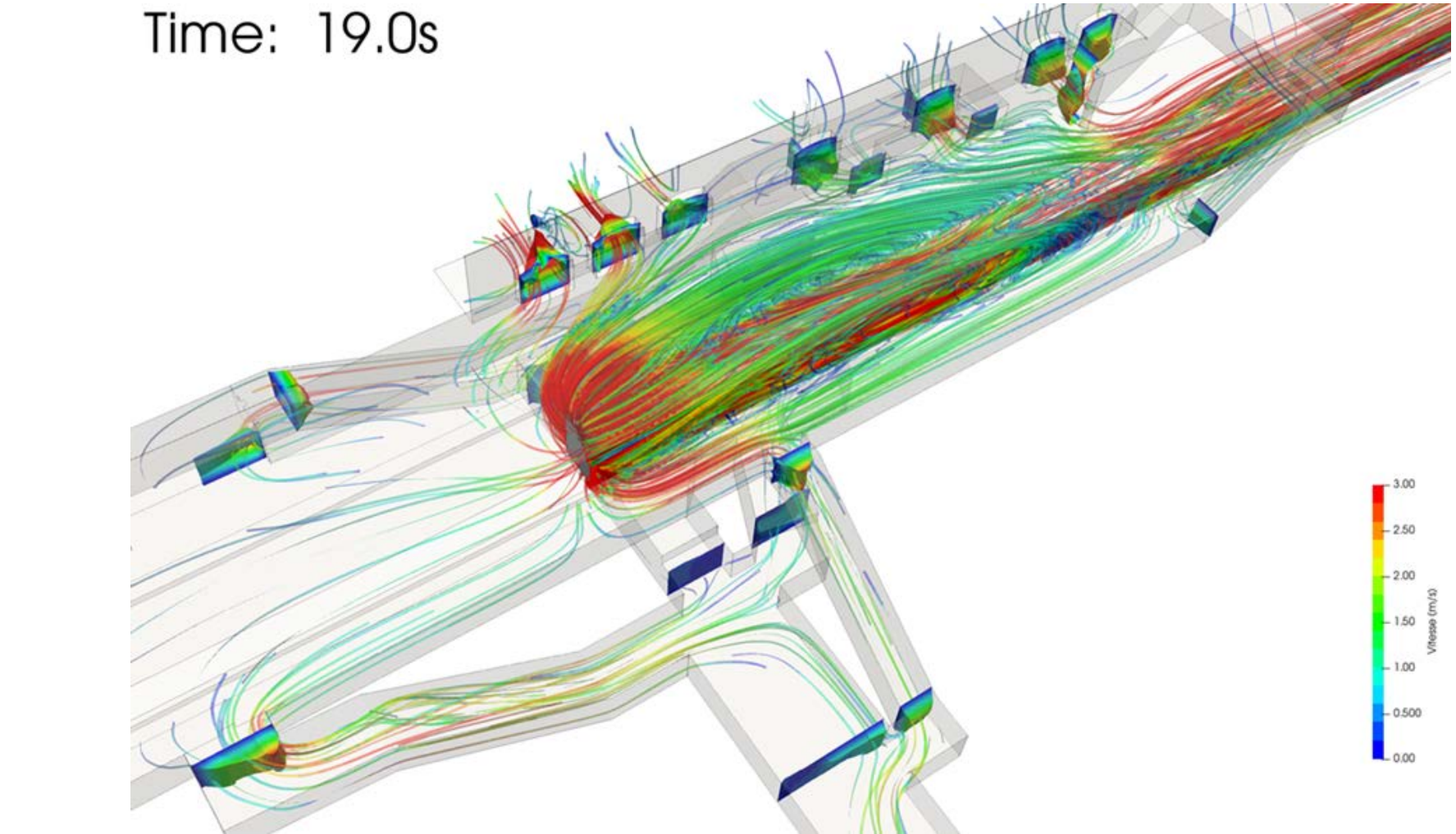
APPLICATION

> Modification of 7 windows ➔ what impact on the air velocity inside the station?

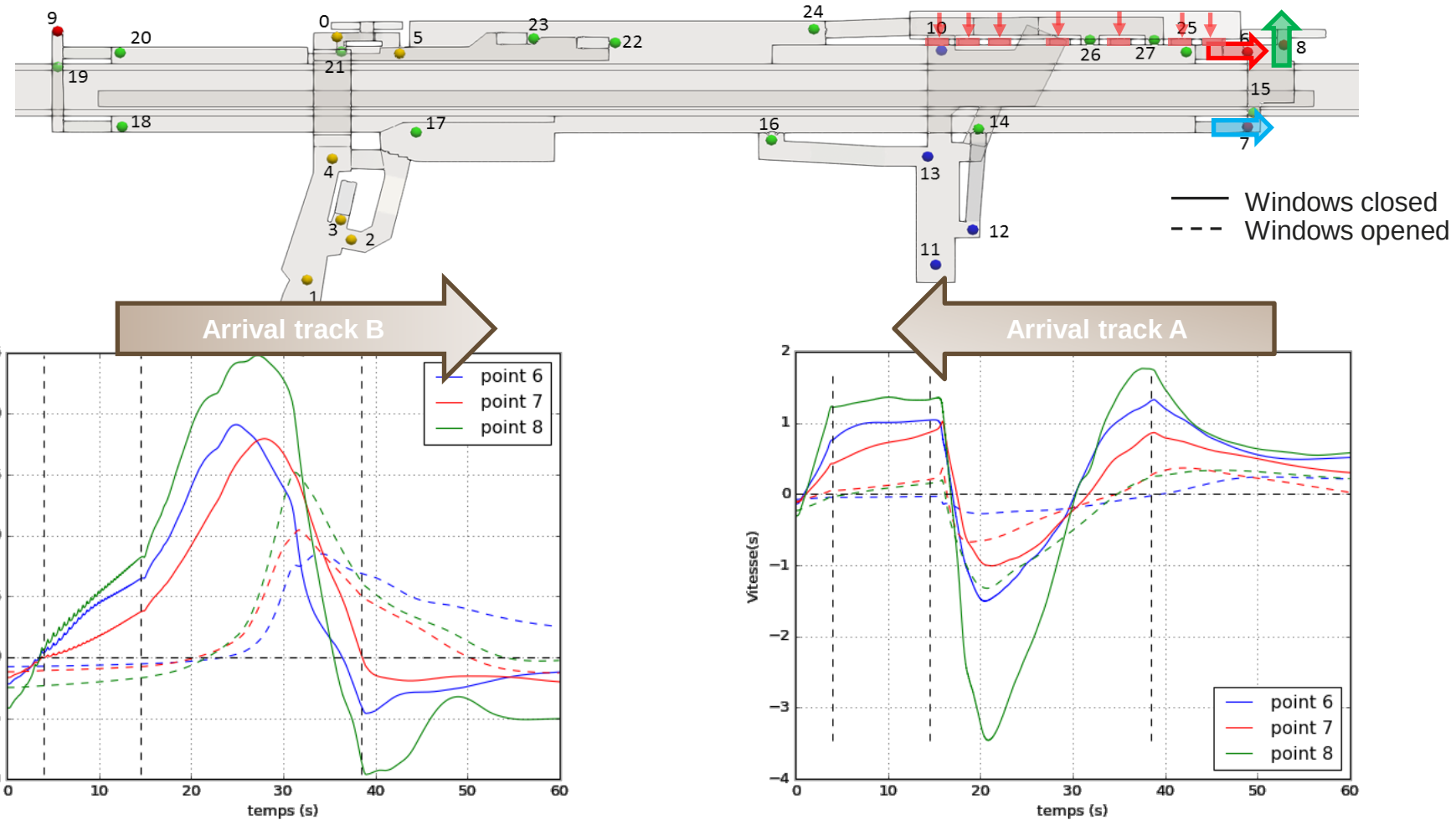


A designing tool

> A lot of air seems to go back and forth through those windows

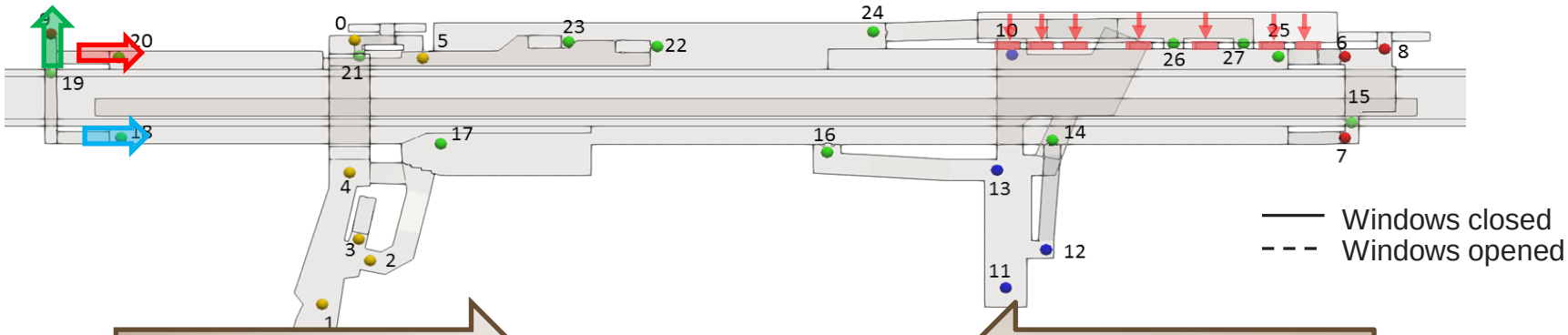


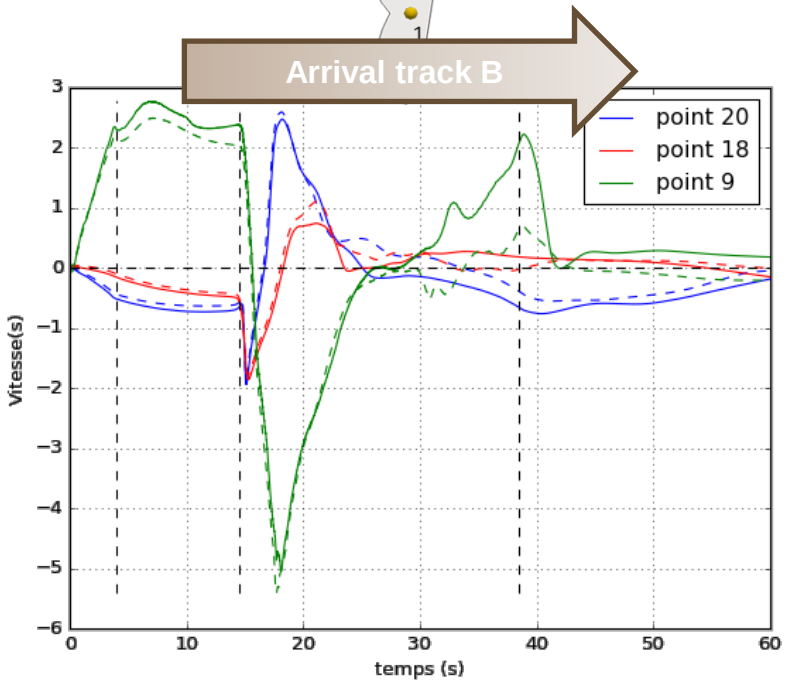
Impact of the openings

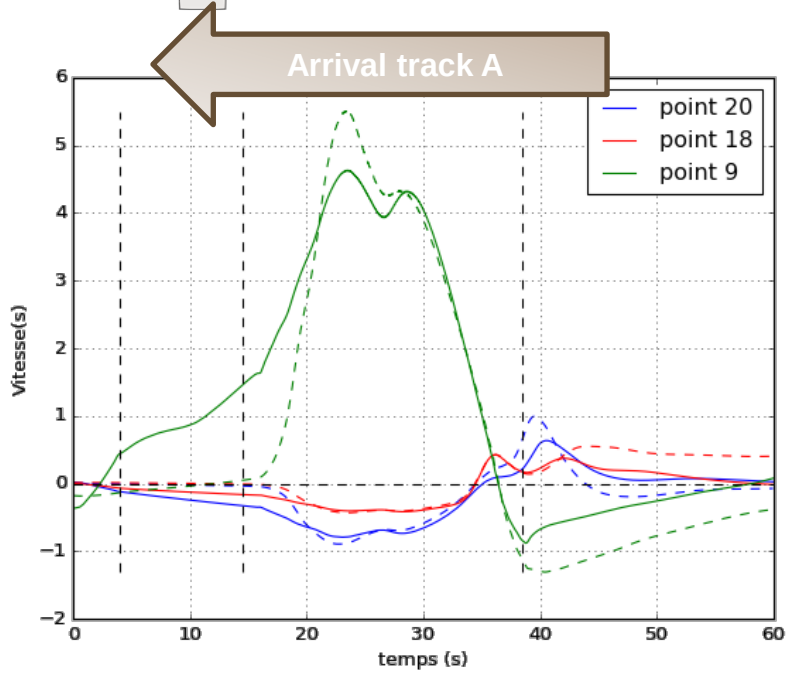


> Major impact for the exit located close from the windows

Impact of the openings







> Smaller impact for the exit located far from the windows

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Conclusions

Conclusions

> A simulation tool based on OpenFOAM to design train stations

> Allow to investigate the piston effect of trains entering and leaving the station

> Comparisons to measurements quite difficult to achieve but they show that the orders of magnitude are OK

> Application to a real train station in order to predict the impact of closing some windows.

> A designing tool : part of AREP wider simulation suite for air management inside train station.