Aerodynamik

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Future demands – Higher speeds and high capacity

- Wide body trains with max speed > 250 km/h
- Aerodynamic challenges specific for wide body trains:

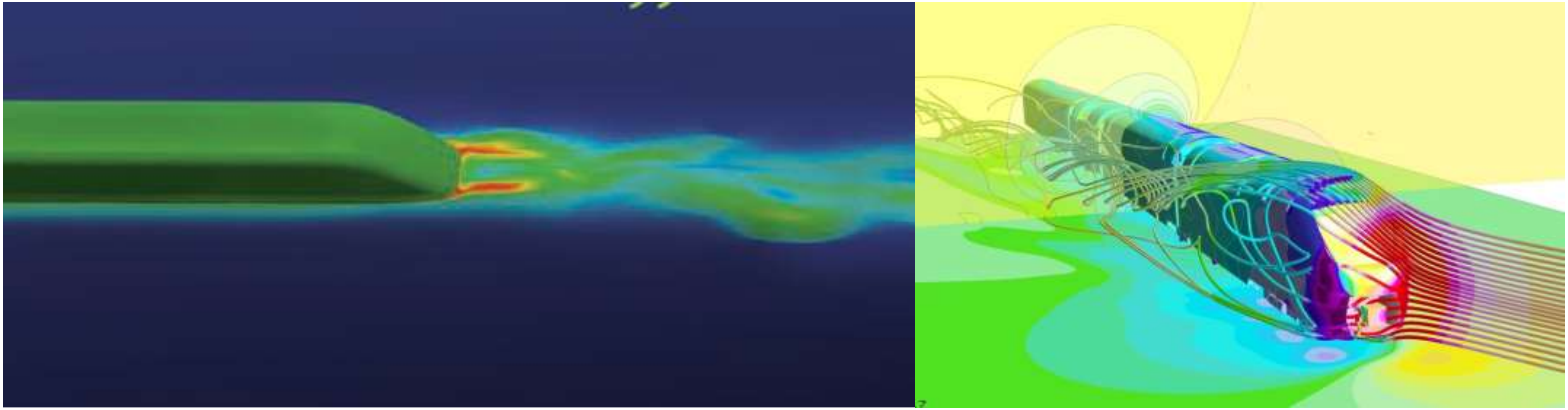
  head pressure pulse & slipstream

Slipstream

- Safety issue for passengers on platform and trackside workers
- Measures on operation & train design

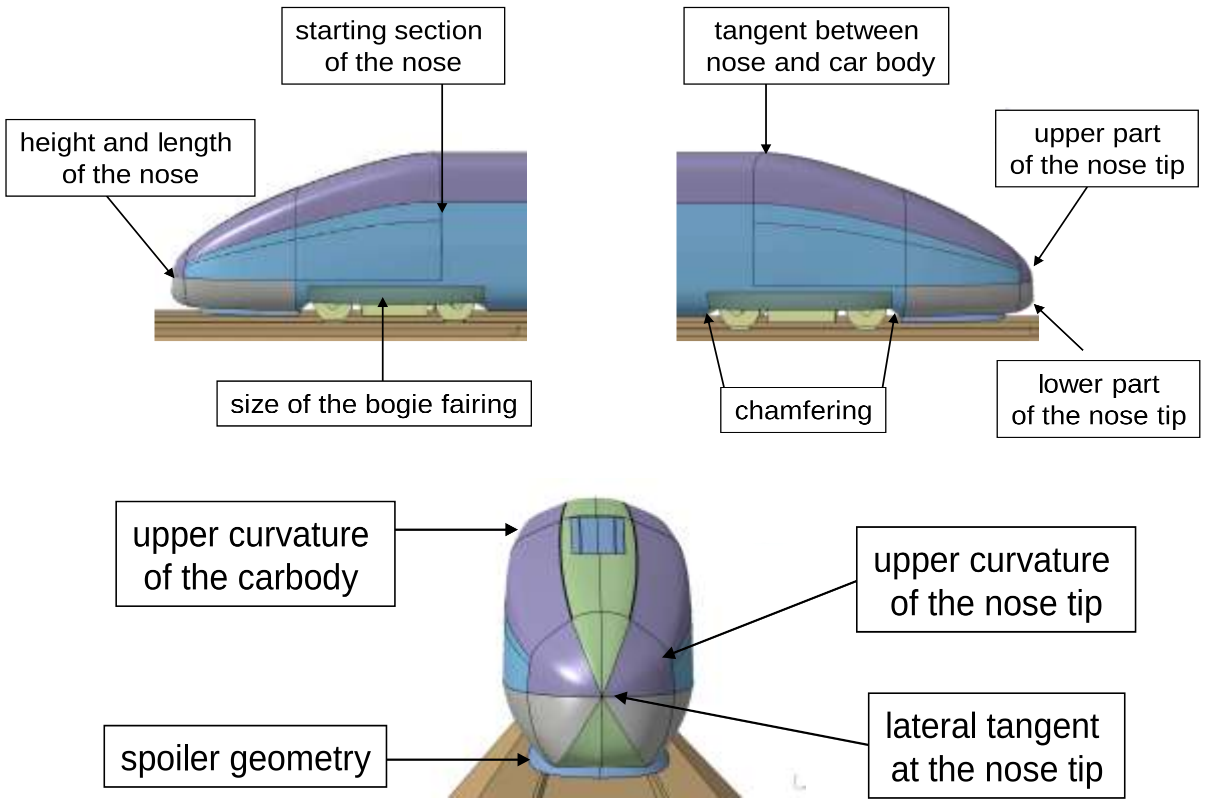
More value for environment and performance: Aerodynamic optimisation

- Reduction of drag saves energy and traction power
- Drag and Cross-Wind Optimisation



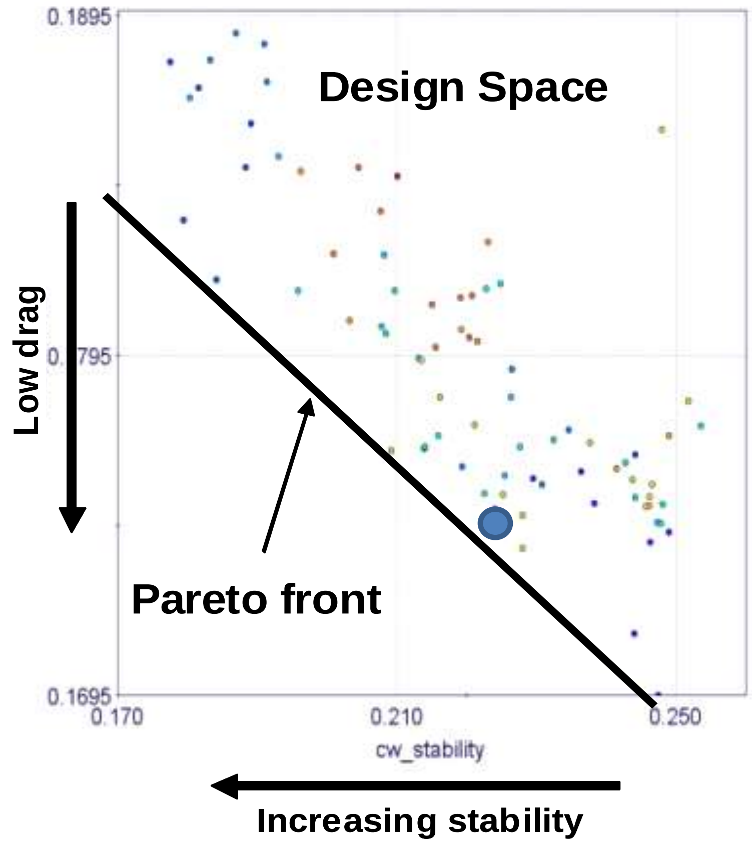
More value for environment and performance:
Aerodynamic optimisation

- Parameterized model defines the variables and boundary conditions
- Computer optimisation by using the parameterized model
- Goal function is reduce drag while keeping the cross wind safety

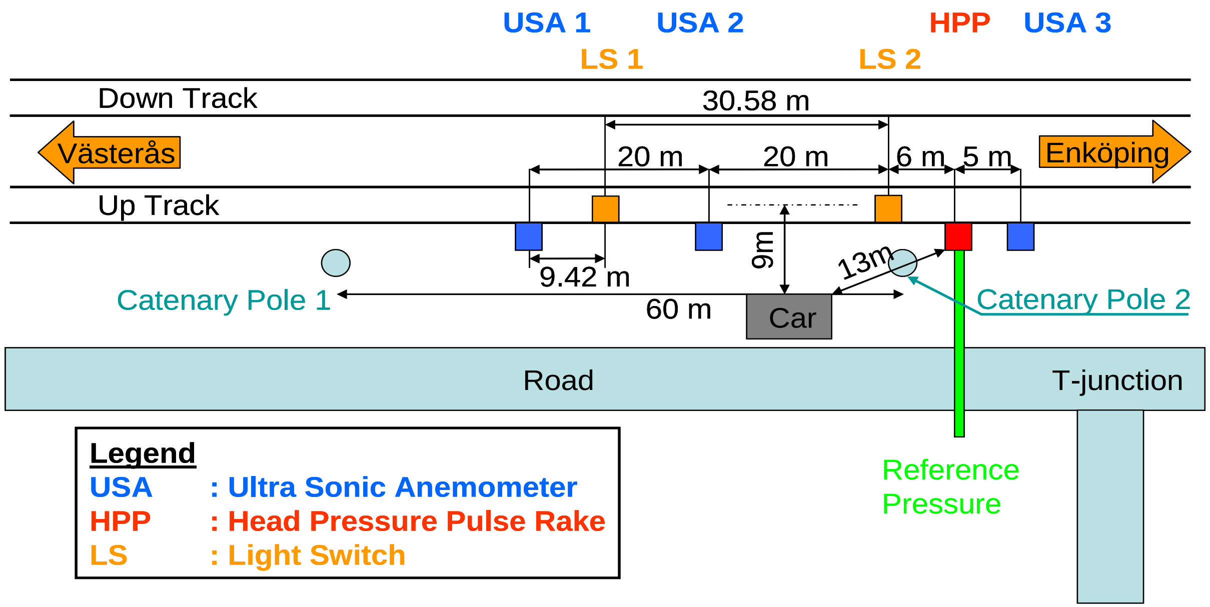


More value for environment and performance: Aerodynamic optimization

- Thousands of “virtual wind tunnel tests” in the computer used to find the very best shape
- Main result shows 20 – 30 % lower drag and 10 – 15 % lower energy consumption
- Installed power can be reduced with lower cost
- Lower energy cost for operators

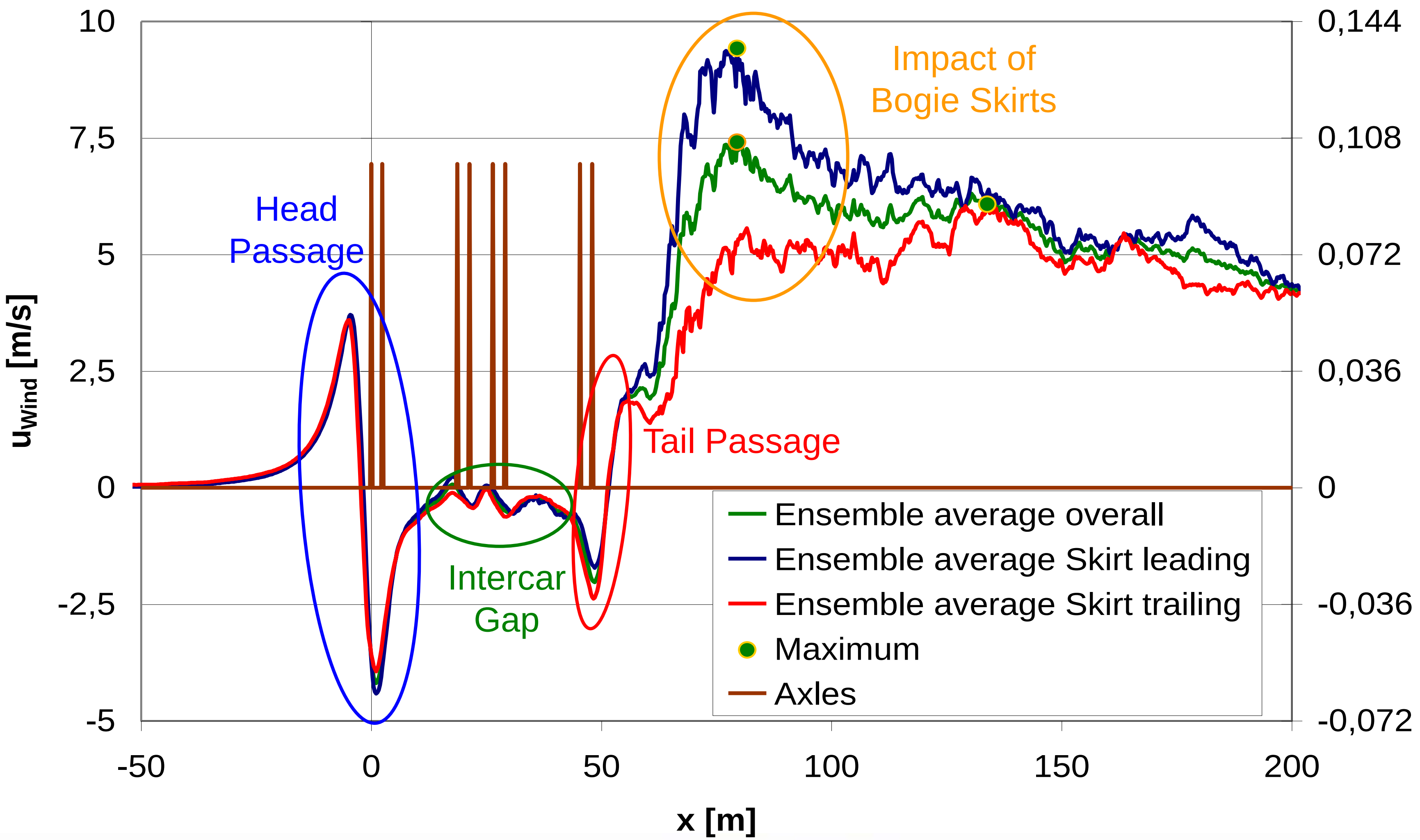


Slipstream Test Setup



- Measurements with fast 3D-ultrasonic anemometers (USA)
- Train speed and positions measured with light switch
- Light switch mounted to detect single rail passages

Measurement results



Numerical simulations of slipstream performed at KTH

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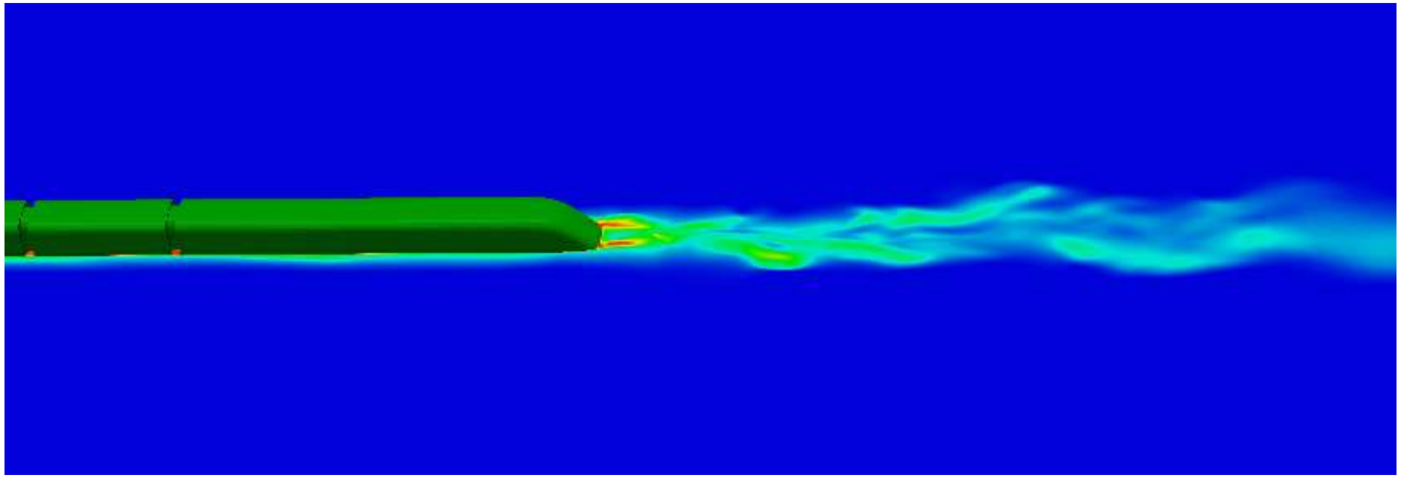


Gröna Tåget

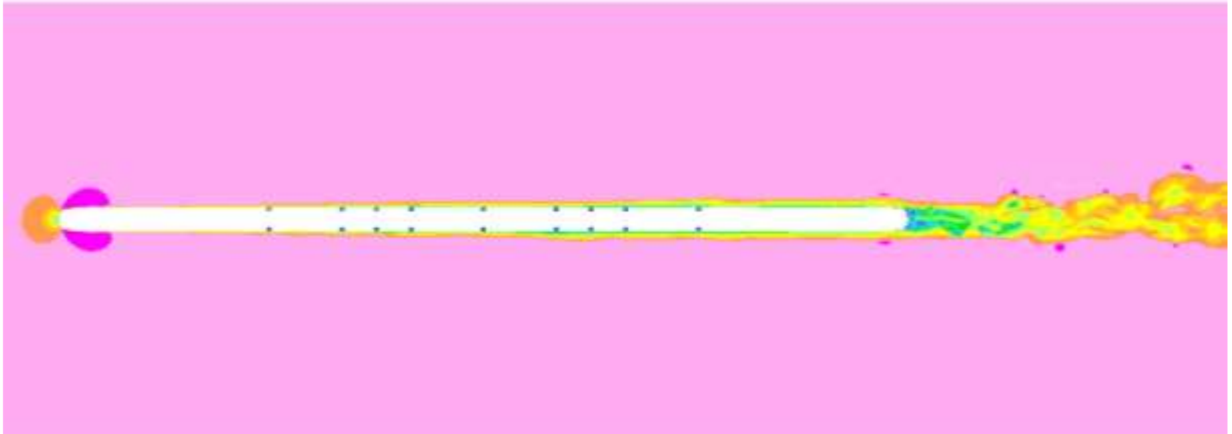
Trains for tomorrow's travellers

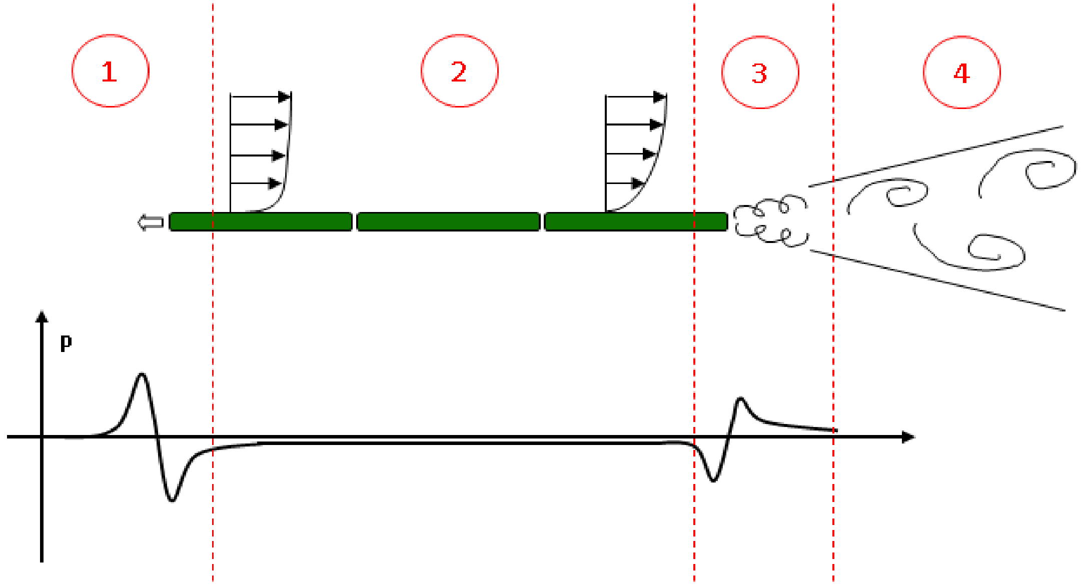
Slipstream

- Slipstream= Induced velocity by the train

- Regions

1) Head pressure pulse
2) Boundary Layer (Freight Trains)
3) Near wake (High-speed Train)
4) Far Wake





Train models

Aerodynamic Train Model (ATM)

Regina (CRH1)

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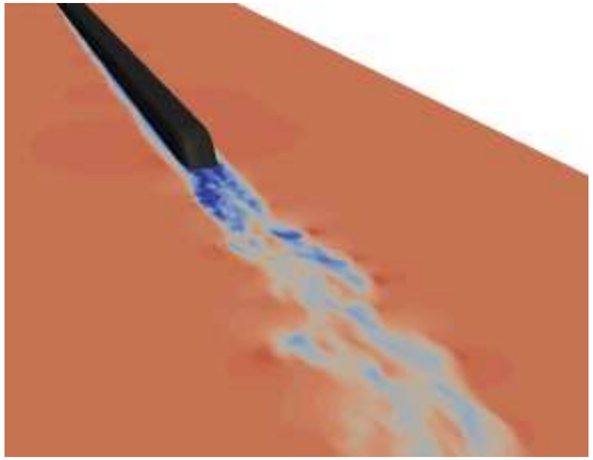
Decomposition models

Full flow field



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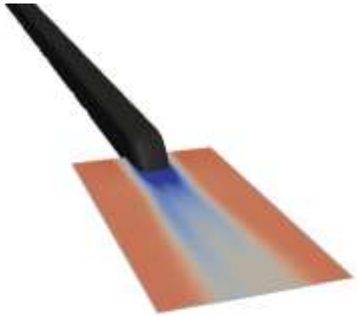
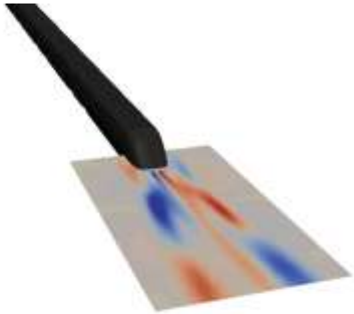
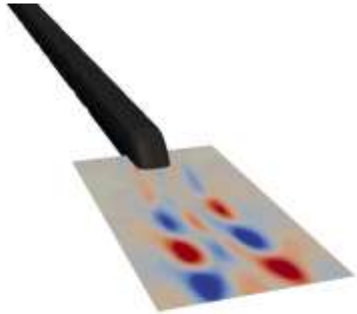
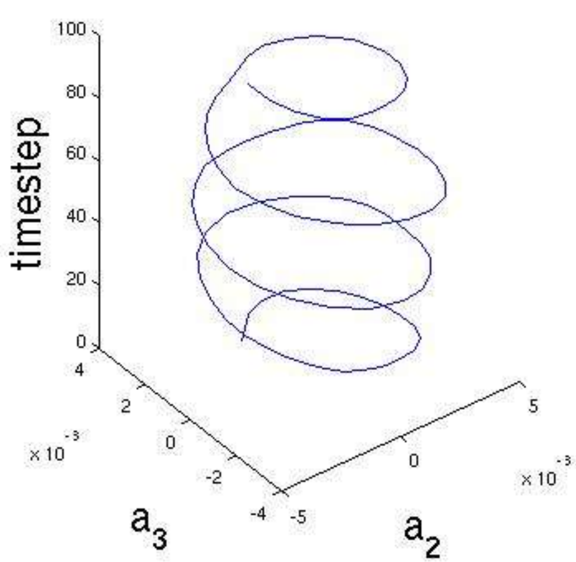
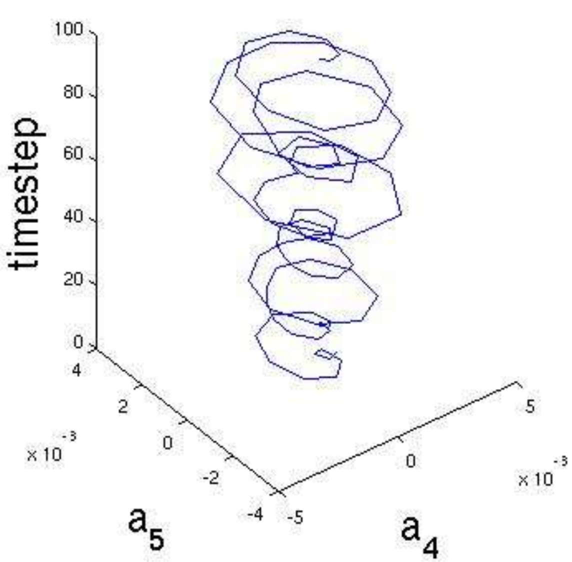
=  +  +  +…

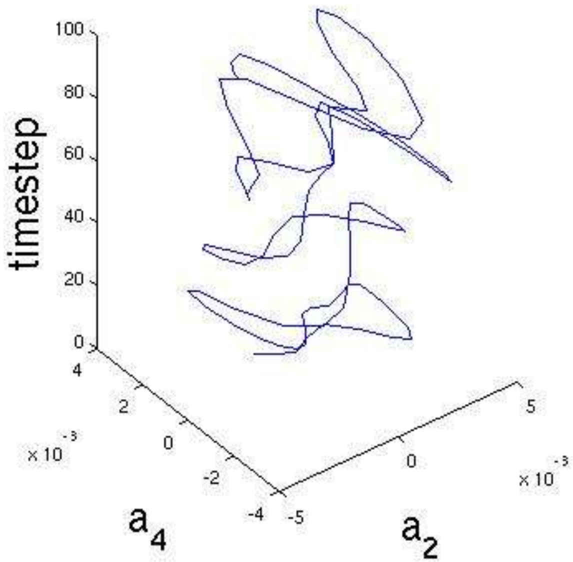
Mode 1 **Mode 2,3** **Mode 4,5** **Mode 6+**

Connection between modes

- Phase portrait
  - Spiraling circles when the modes are connected
  - Random patterns when not

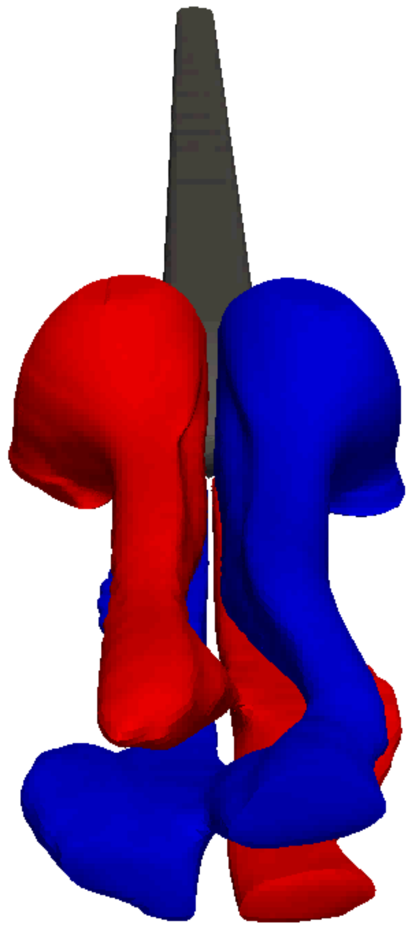






Example of flow structure

Isosurface of V-velocity Mode 1+4+5



Decomposition models

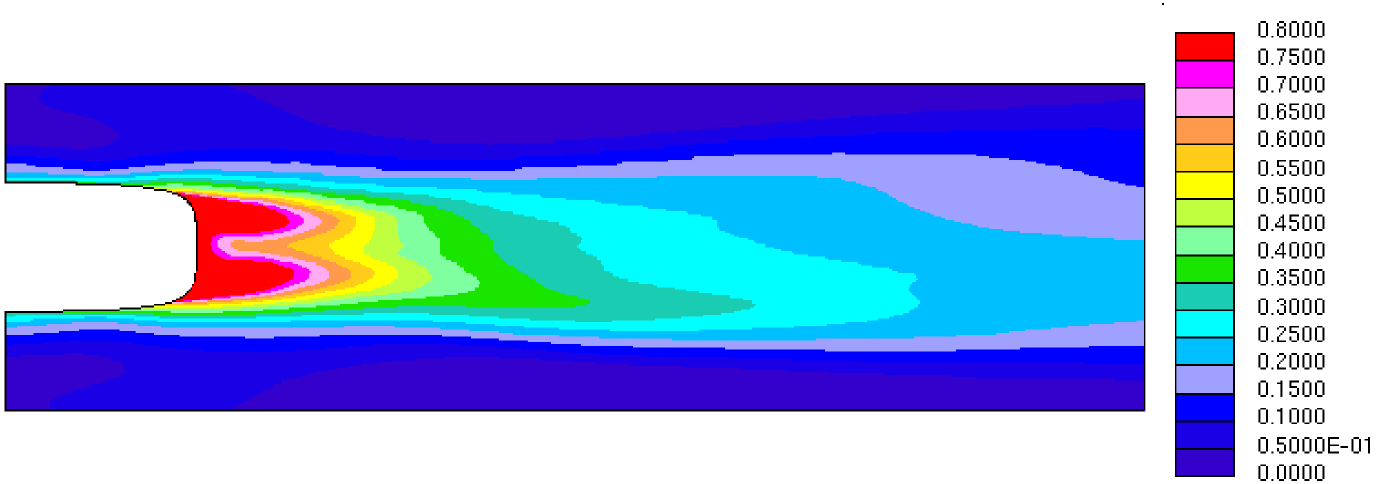
- Challenges
  - Long computation times
  - Accurate results

- Understanding of dominant energetic structures

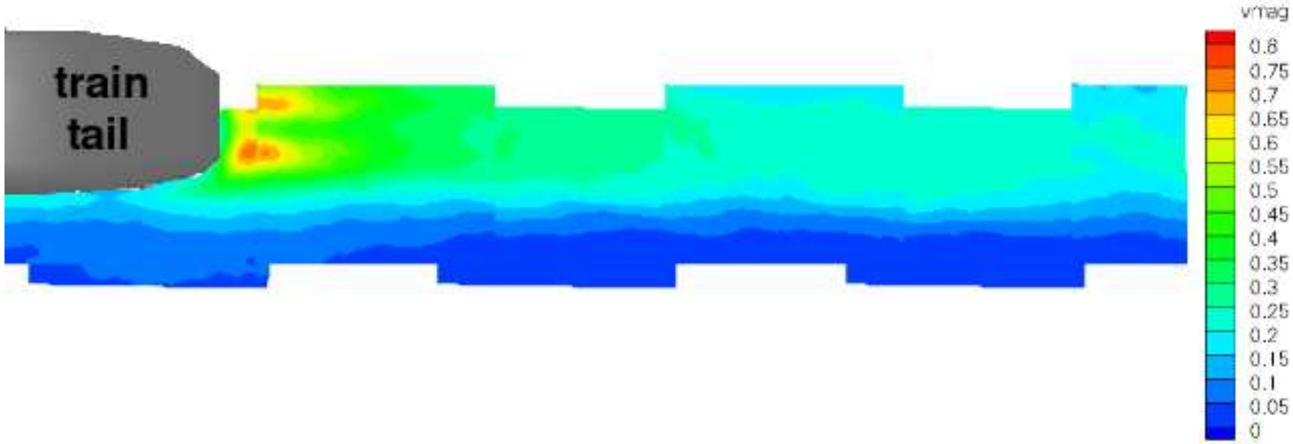
- Two methods
  - Proper Orthogonal Decomposition (POD)
  - Dynamic Mode Decomposition (DMD)

Comparing with Experiments

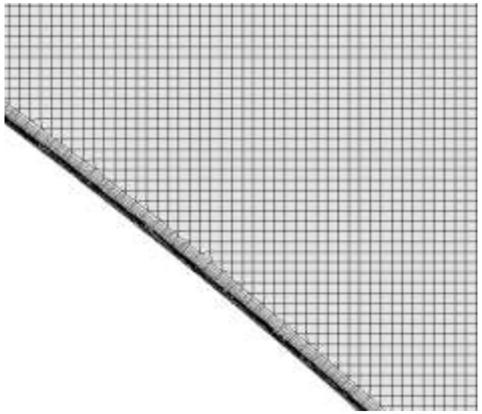
CFD
by KTH

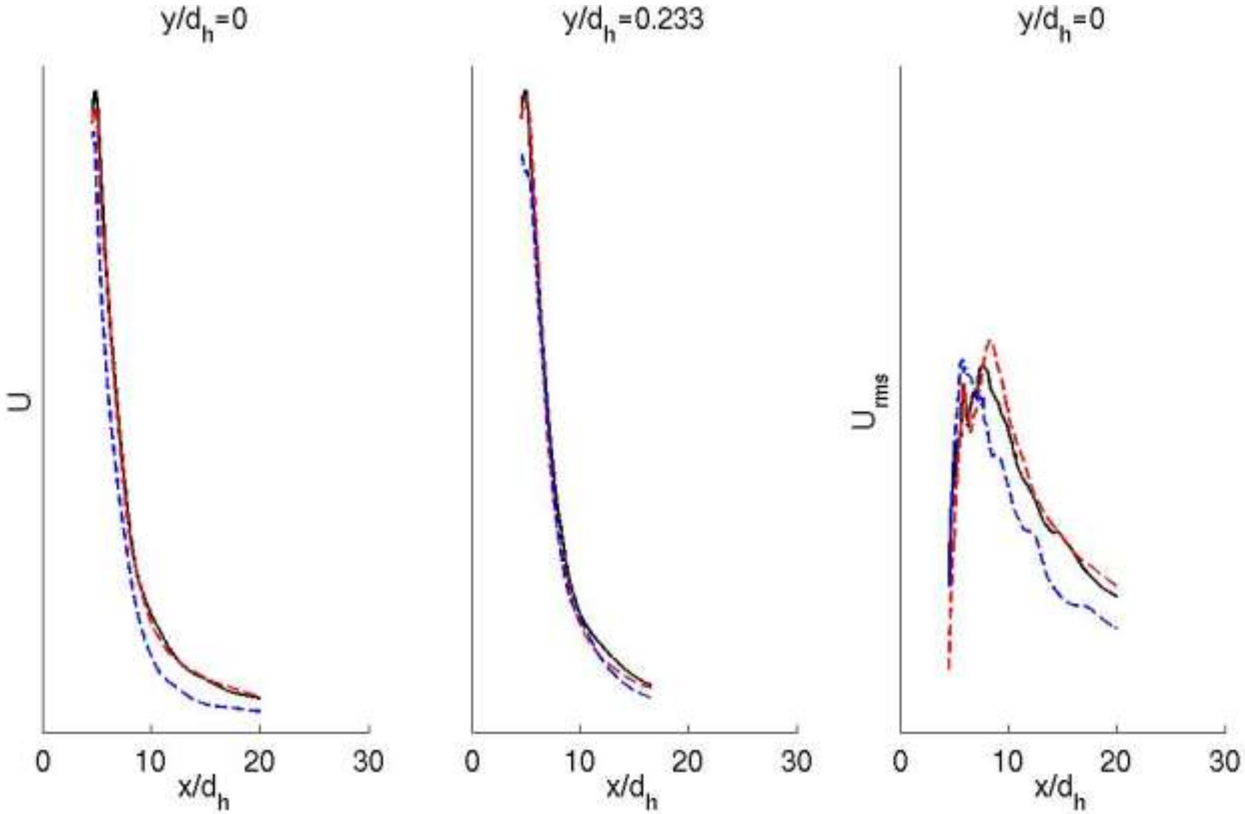


Water
Towing Tank
from
Bombardier
performed at
DLR



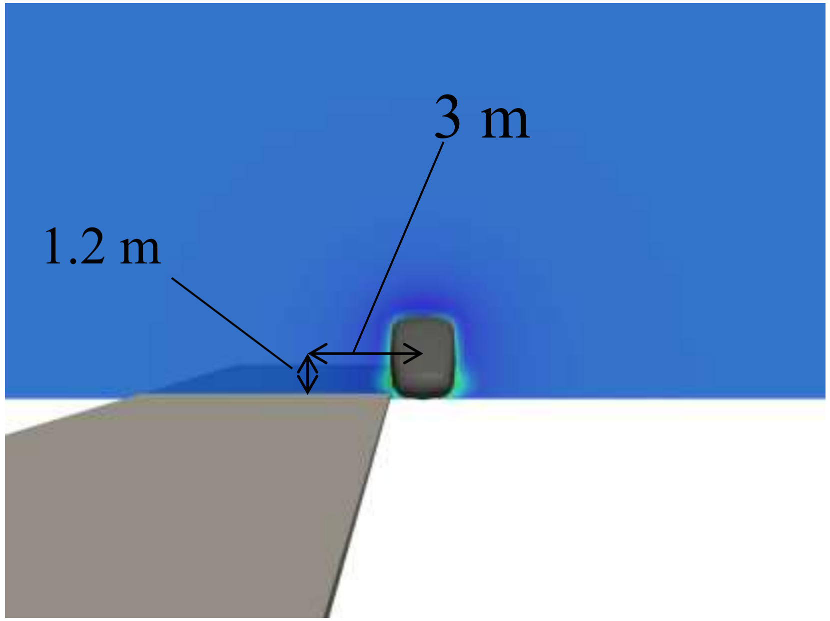
Grid study

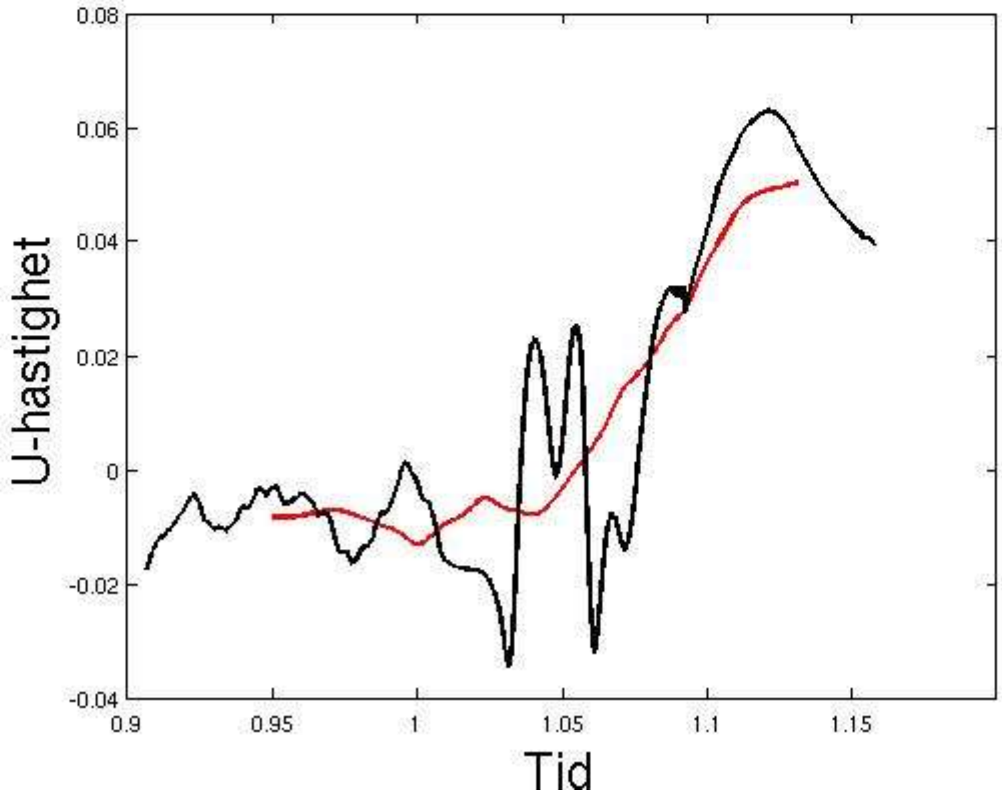




Small cells
Medium cells
Large cells

TSI-measurements





Velocity for an observer standing on platform

0.07s (1s) time averaged velocity

Achievements

- Showed that POD and DMD can be used with Detached Eddy Simulation flow fields.
- Identified dominant flow structures for two different trains.
- Used advanced models on applied geometries.
- Cooperation and exchange of knowledge with Bombardier.
- Fundament for efficient prediction to connect train geometry and slipstream.

Publications

- Muld, T.W, Analysis of Flow Structures in Wake Flows for Train Aerodynamics, Licentiate Thesis in Mechanics, KTH Stockholm, ISBN 978-91-7415-651-5, 2010

- Muld T.W, Efraimsson G., Henningson D. S, Flow structures around a high-speed train extracted using Proper Orthogonal Decomposition and Dynamic Mode Decomposition, Computer & Fluids, DOI: 10.1016/j.compfluid.2011.12.012 , 2012

- Muld T.W, Efraimsson G., Henningson D. S, Mode decomposition on surface mounted cube, Flow, Turbulence and Combustion, DOI: 10.1007/s10494-011-9355-y, 2011

- Muld T.W, Efraimsson G., Henningson D. S, Mode Decomposition of Flow Structures in the wake of Two High-Speed Trains, The First International Conference on Railway Technology: Research, Development and Maintaince, April 16-18, Gran Canaria, Spain, 2012

- Muld T. W., Efraimsson G., Henningson D. S., Herbst A. H. and Orellano A., Analysis of Flow Structures in the Wake of a High-Speed Train, Aerodynamics of Heavy Vehicles III: Trucks, Buses and Trains, September 12-17, 2010, Potsdam, Germany

- Muld T. W., Efraimsson G., Henningson D. S., Herbst A. H., Orellano A., Detached Eddy Simulation and Validation on the Aerodynamic Train Model, Euromech Colloquim 509, Vehicle Aerodynamics, Berlin Germany, March 24-25 2009

- Muld T. W., Efraimsson G., Henningson D. S., Proper Orthogonal Decomposition of Flow Structures around a Surface-mounted Cube Computed with Detached-Eddy Simulation, SAE paper 09B-0170, 200915