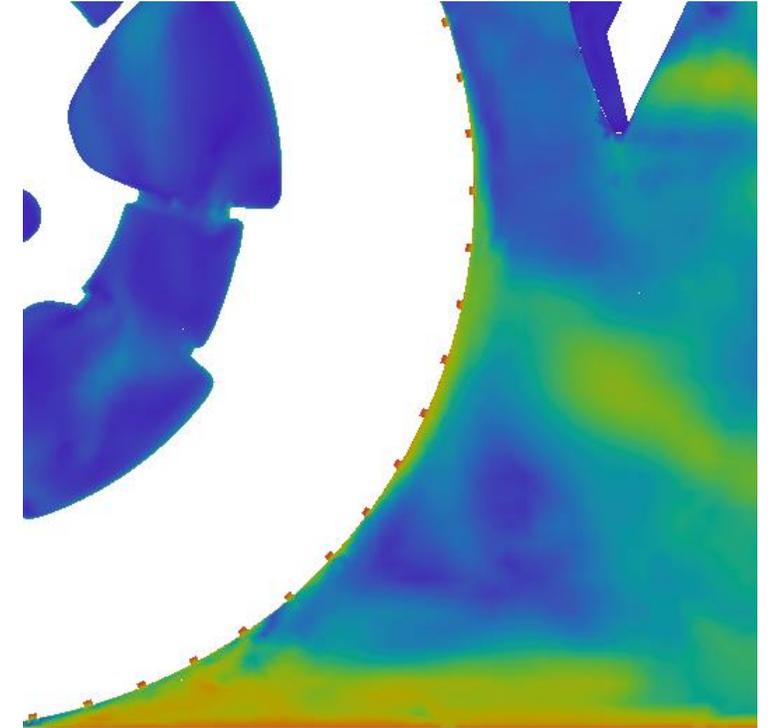


# AN AUTOMATED METHOD FOR THE AERODYNAMIC MODELLING OF GROOVED TIRES

An efficient solution for the modelling of  
complex motion in vehicle applications

Thomas Schumacher, Pavlos Alexias  
Gothenburg Region OpenFOAM User Group Meeting  
20/11/2019



# About ENGYS

- › Global providers of CFD products and services
- › Founded in the UK (2009)
- › Main focus on leveraging open-source software
  - FOAM/OpenFOAM developers since 1999
- › 200+ customers worldwide
- › 7 local offices
  - UK, Germany, Italy, USA, Australia, RSA, Brazil
- › Well established resellers network
  - Japan, South Korea, China, USA, France, Spain

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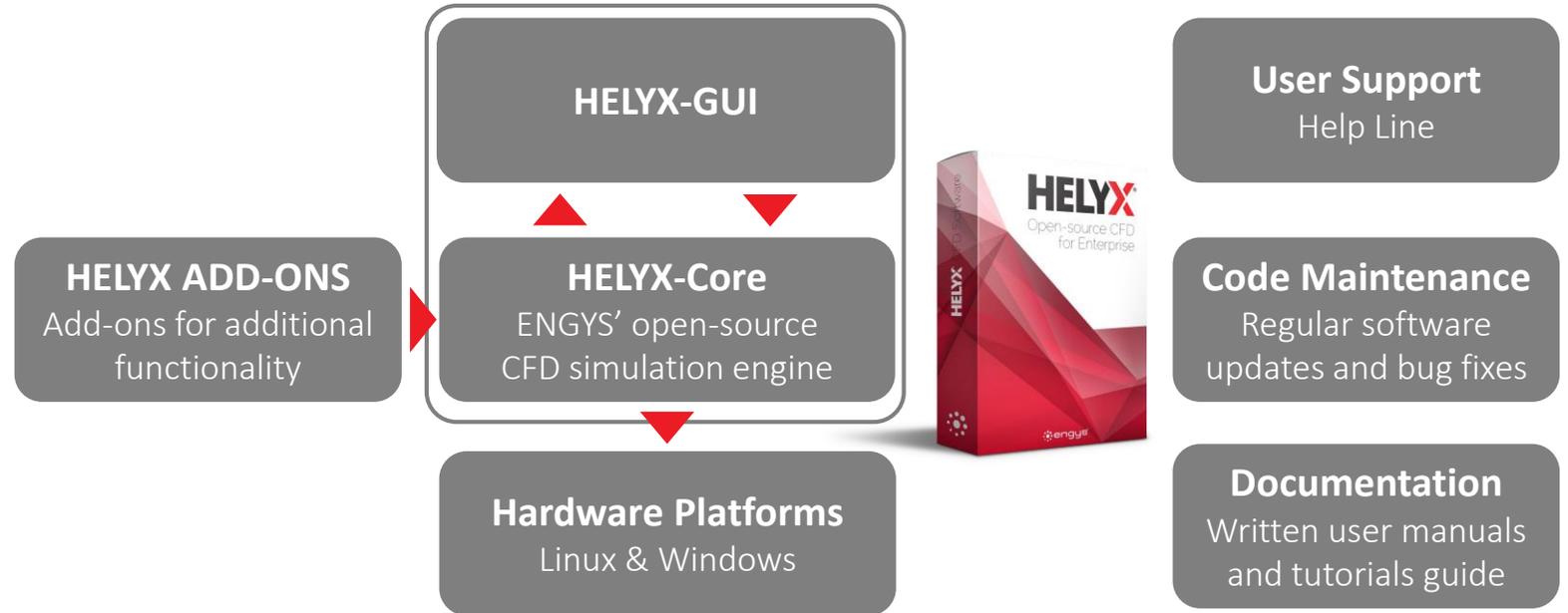


# Engys Worldwide



# What is HELYX?

- › CFD software suite
- › General purpose
- › Enterprise product
- › Highly scalable
- › Cost effective
- › Cloud ready
- › Multi-platform
- › Extendable
- › In production since 2010



# CONTENTS

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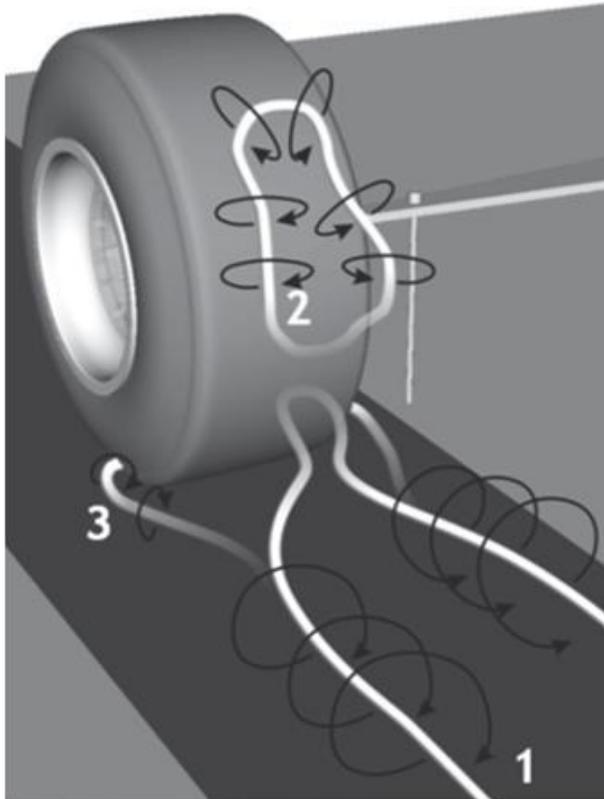
1. Introduction
2. GRF Methodology
3. Tire Modelling Results
4. Extended Reference Frames
5. Conclusions

# Introduction

- › Moving Reference Frames (MRF)
  - Rotation Approximation
  - Only rotationally symmetric zones
  - Convergence Slowdown
- › Refactoring + Extended Functionality
- › Two main features
  1. More Accurate + Easier Tire Modelling
  2. Vehicle Cornering

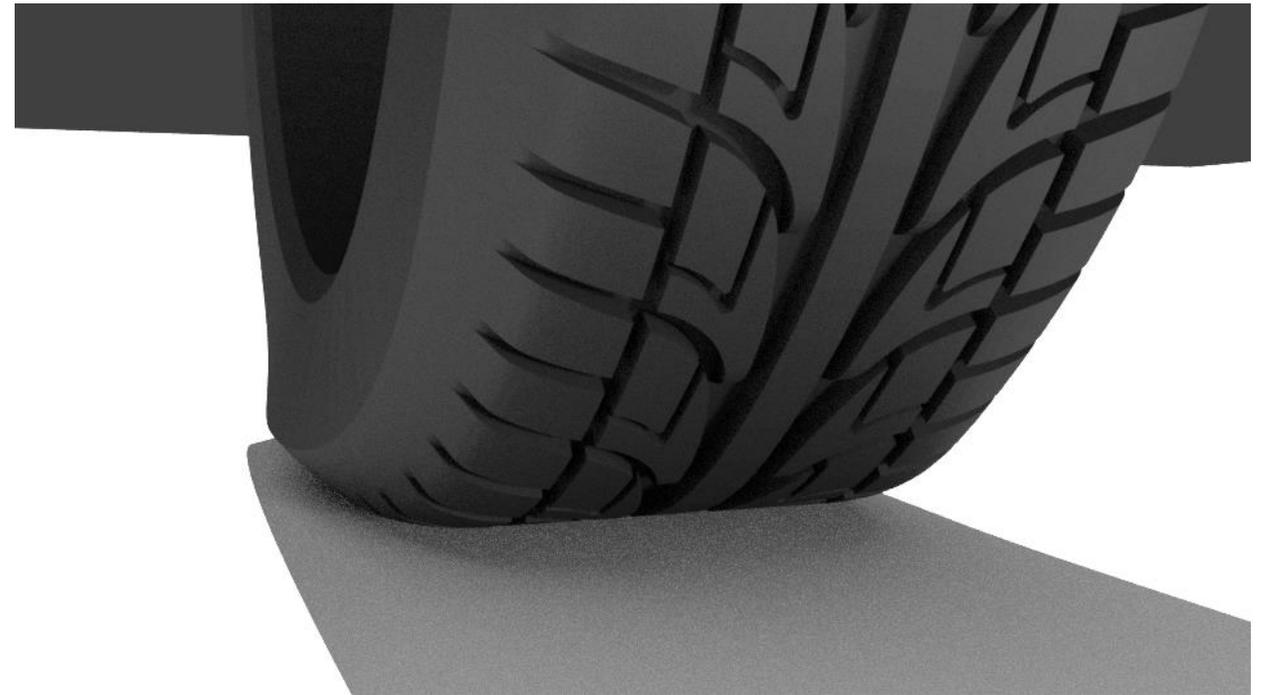
# Introduction | Tire Modelling

- 1 Radnachlauf-Hufeisenwirbel
- 2 geschlossener Nachlaufwirbel
- 3 Radlatsch-Wirbel



b) drehendes Einzelrad

Wäschle, A., "The Influence of Rotating Wheels on Vehicle Aerodynamics - Numerical and Experimental Investigations", SAE World Congress & Exhibition, (SAE International, Apr. 2007), doi: 10.4271/2007-01-0107



# Introduction | Tire Modelling

- › Existing Methods
  - Rotating Wall (RW)
    - Easy implementation
    - Too inaccurate (no wall normal velocity)
  - Moving Reference Frame (MRF)
    - Good for tire's grooves
    - Difficult to set up
  - Sliding Mesh (SM)
    - Good for accurate rim/hub simulation
    - Wheel deformation/road contact is challenging

# Introduction | Tire Modelling

## › Existing Methods

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## › Combined SM for hubs + automated MRF for treads

- MRFg (Hobeika & Sebben)

## › Generalized moving Reference Frame (GRF)

- Rotation approximation
- Good for tire's grooves
- Non circular patches
- Automated frame selection

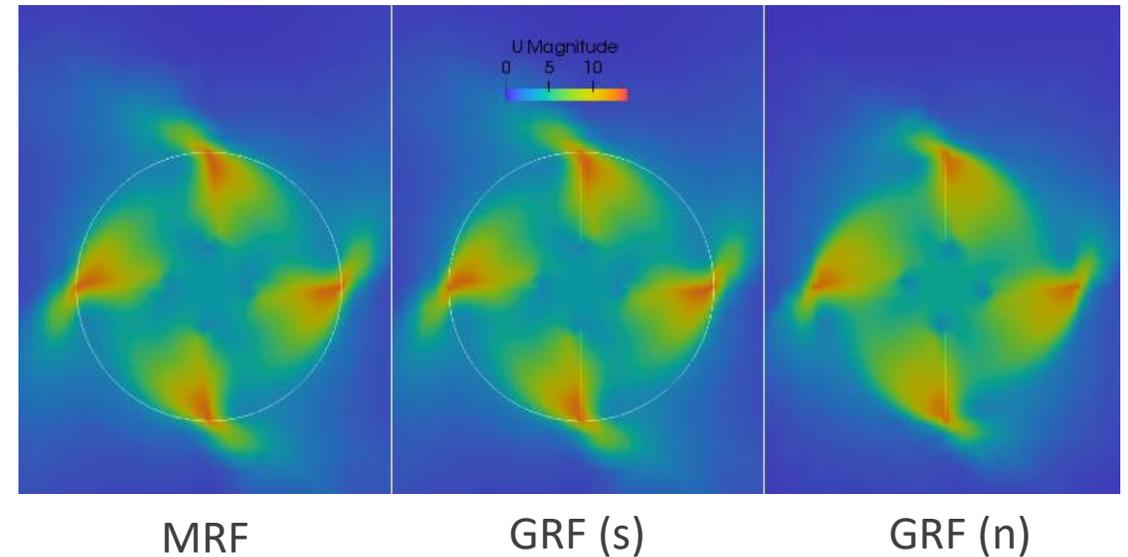
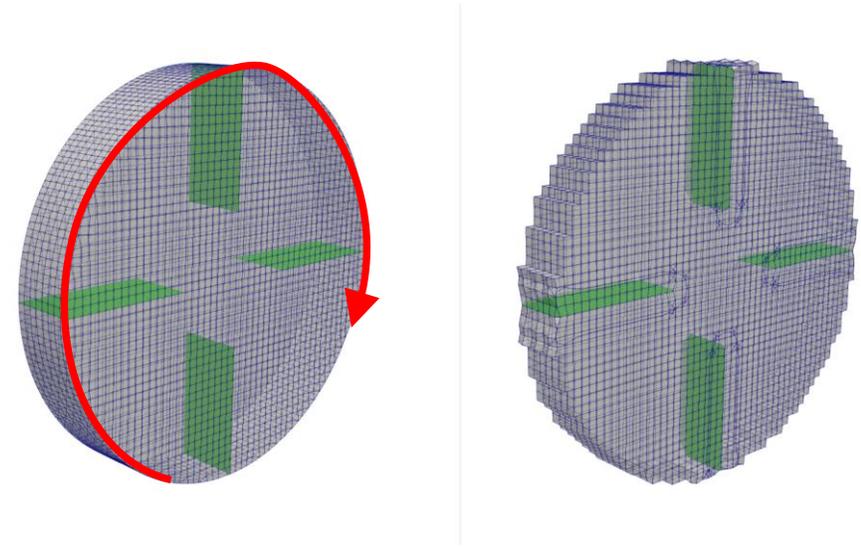
*T. Hobeika and S. Sebben, "CFD investigation on wheel rotation modelling," Journal of Wind Engineering and Industrial Aerodynamics, vol. 174, pp. 241–251, Mar. 2018.*

# GRF Methodology

## GRF Verification

- › MRF vs GRF
- ›  $\omega = 90 \text{ rad/s}$
- › circular vs non-circular zone boundary

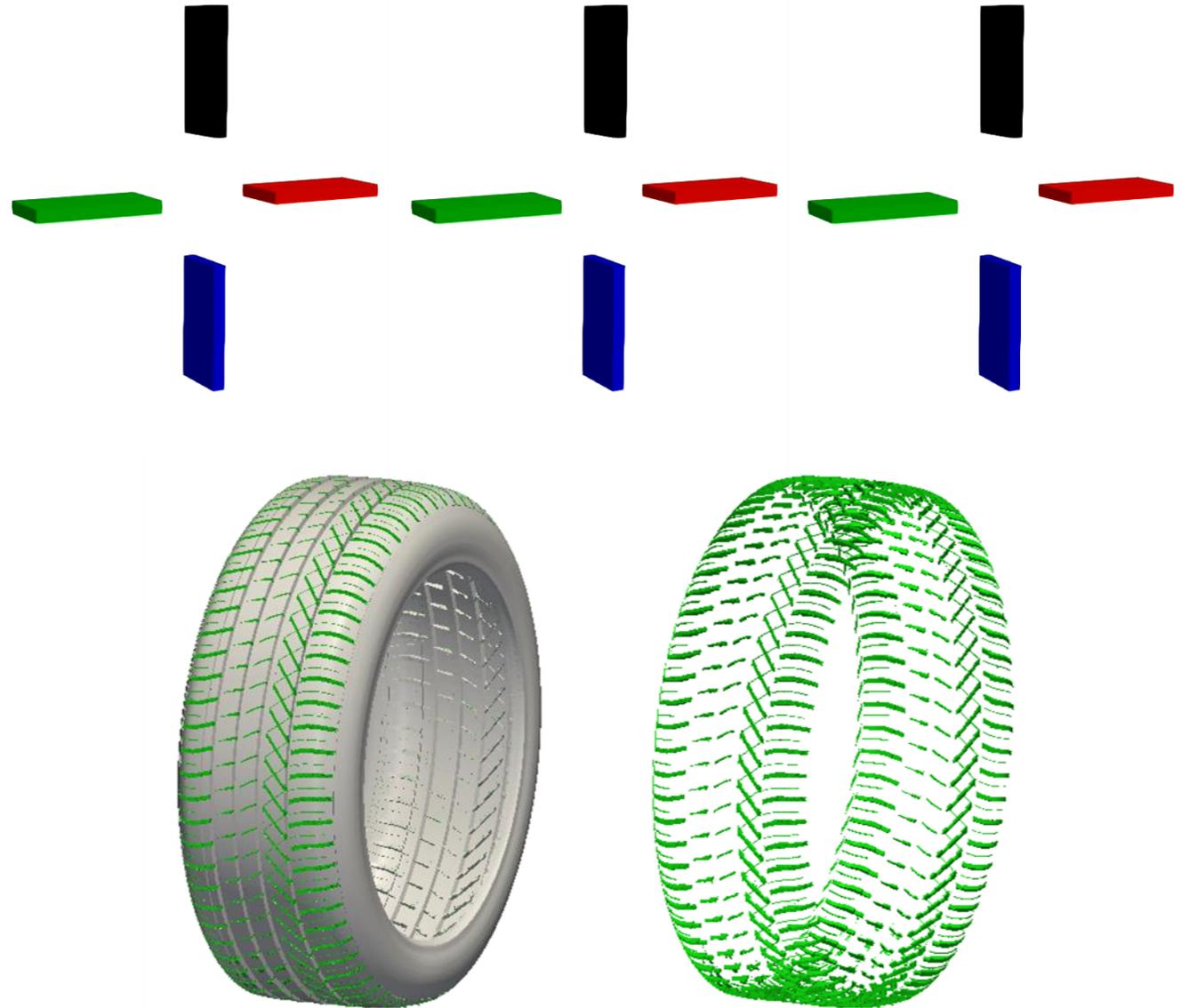
Method	Ventilation Moment (Nm)	Iterations
MRF	0.167	1866
GRF (s)	0.166	1761
GRF non-circular (n)	0.163	1243



# GRF Methodology

## Swept Cell Method

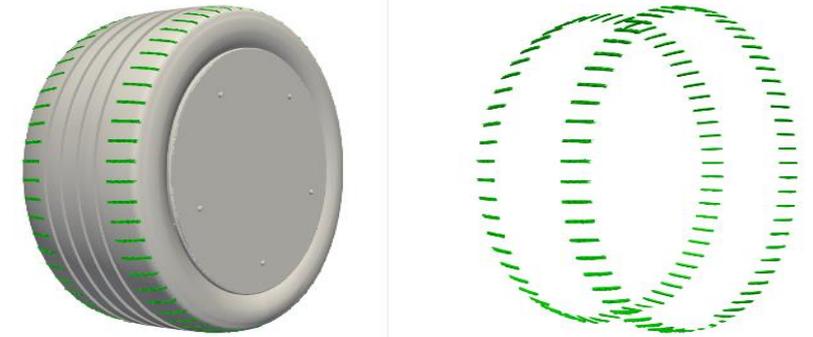
- › Complex geometries make frame definitions difficult
- › Automated detection
  - Convection equation is solved
  - $\nabla \cdot (\Phi_{\Omega} \tau) = 0$
  - Tracer field indicates zone
- › Enabled by GRF support for non-circular frame boundaries
- › Remove need for mesh-zone



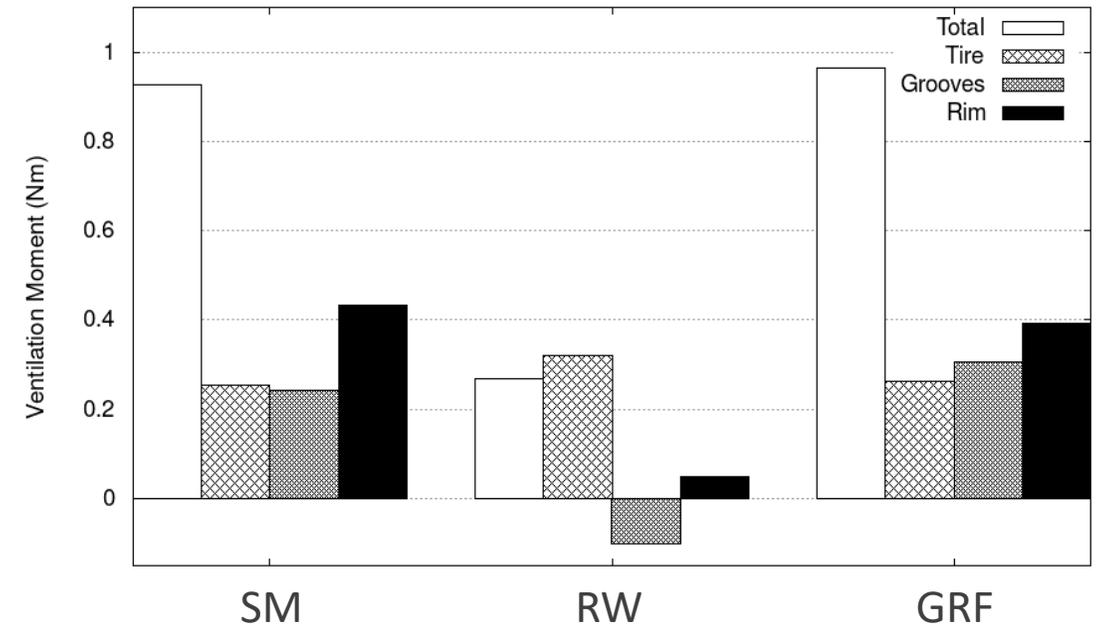
# Tire Modelling Results

## Stand-alone wheel validation

- > uRANS with k-OmegaSST
- > ~7 million cells, 2mm surface face size
- > 3 Configurations:
  - SM on the whole wheel
  - RW on the whole wheel
  - GRF on the grooves + SM for on the rim
- > Similar ventilation moment prediction between SM and GRF



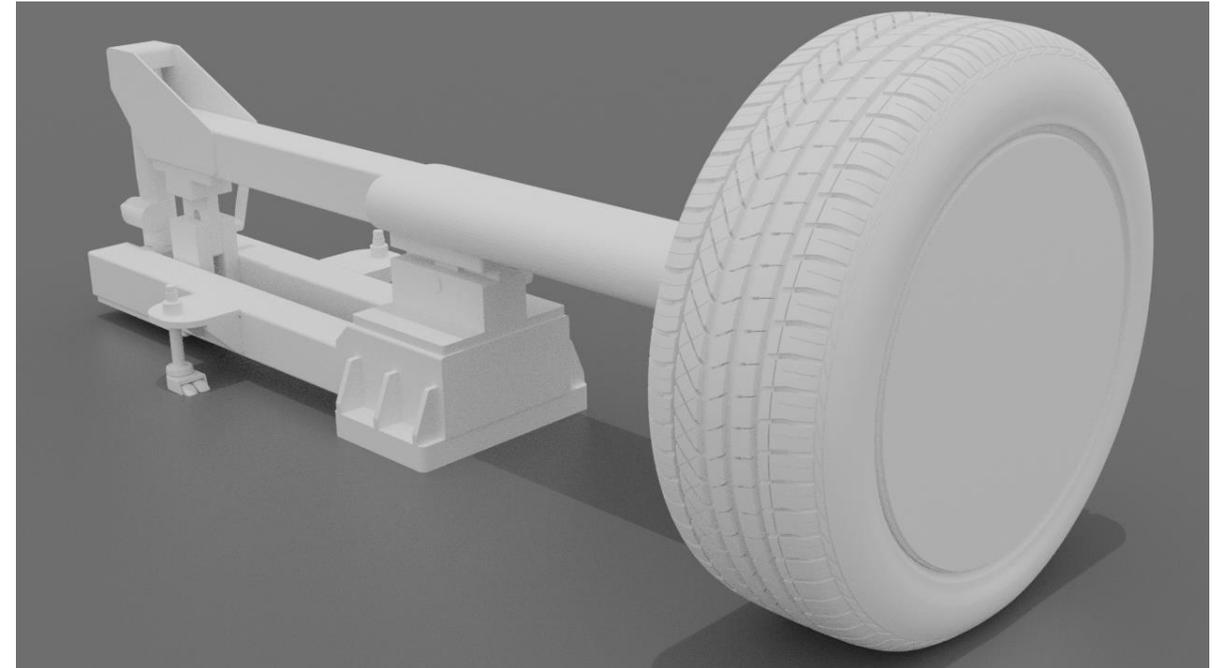
GRF zone automatically created with swept cell method



Ventilation moments for three different configurations.

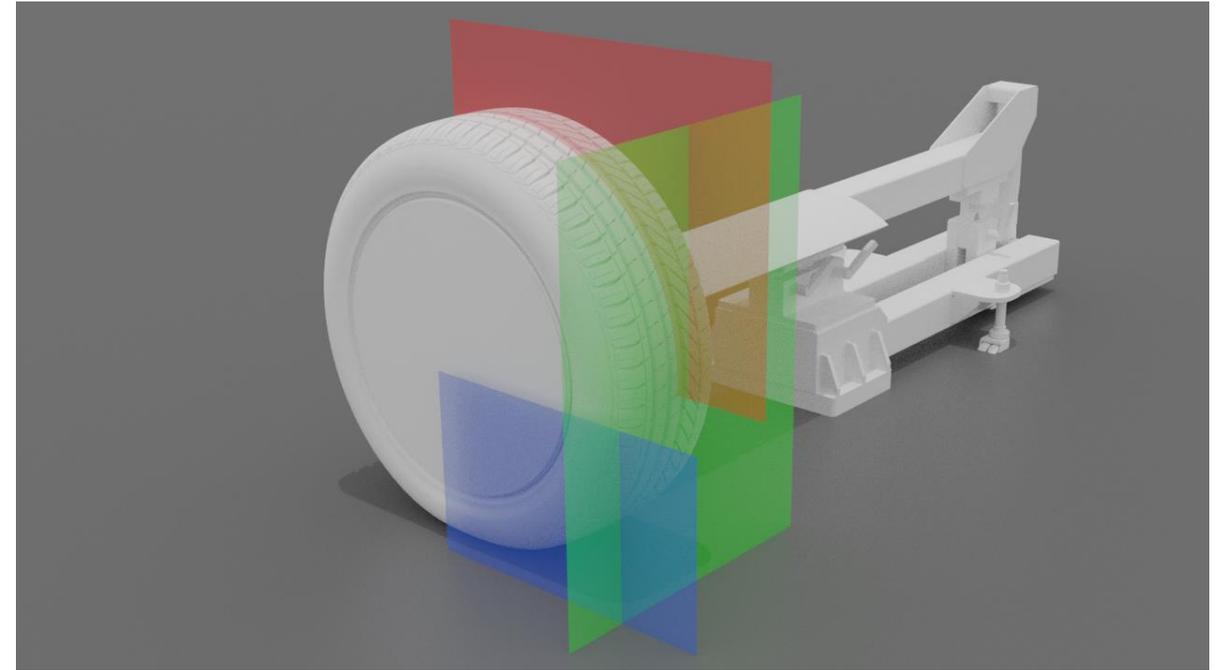
# Tire Modelling Results

- › With kind permission of BMW AG
- › PhD thesis
  - Schnepf, B., „Untersuchung von Einflussfaktoren auf die Umströmung eines Pkw-Rades in Simulation und Experiment“, Dissertation, Technische Universität München, 2016
- › Windtunnel campaign with moving ground at 140 km/h.
- › Deformed tire



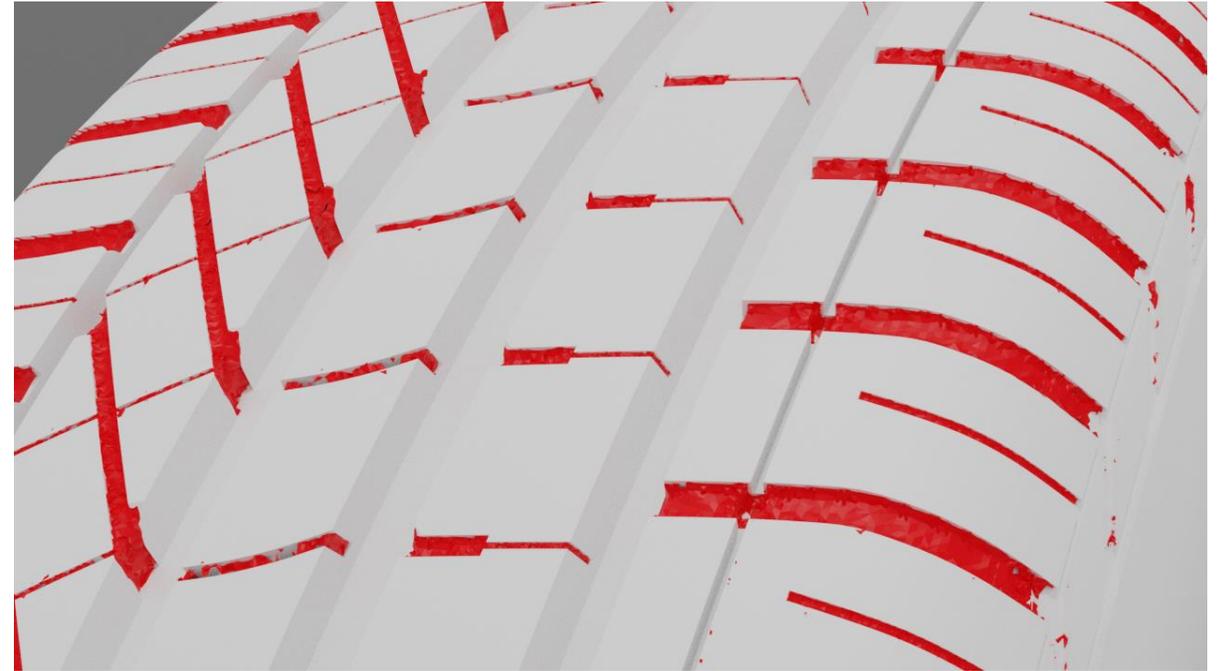
# Tire Modelling Results

- › Experimental data available
- › Pressure and velocity measurements in various planes

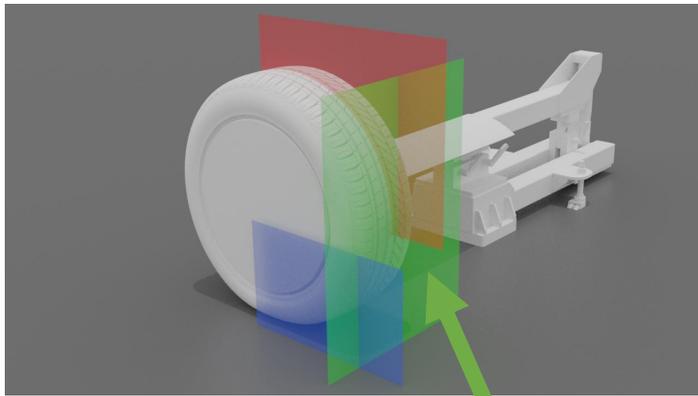


# Tire Modelling Results

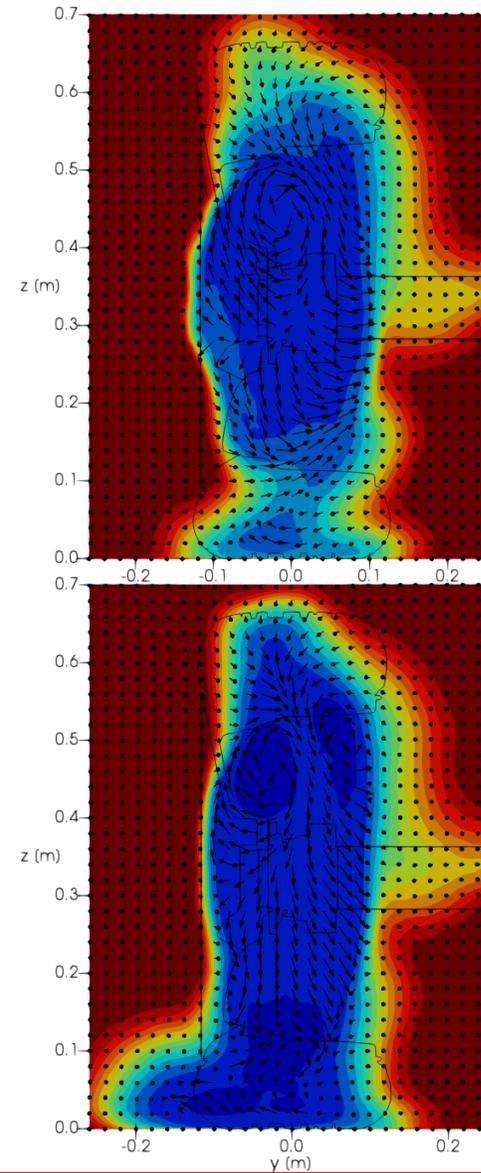
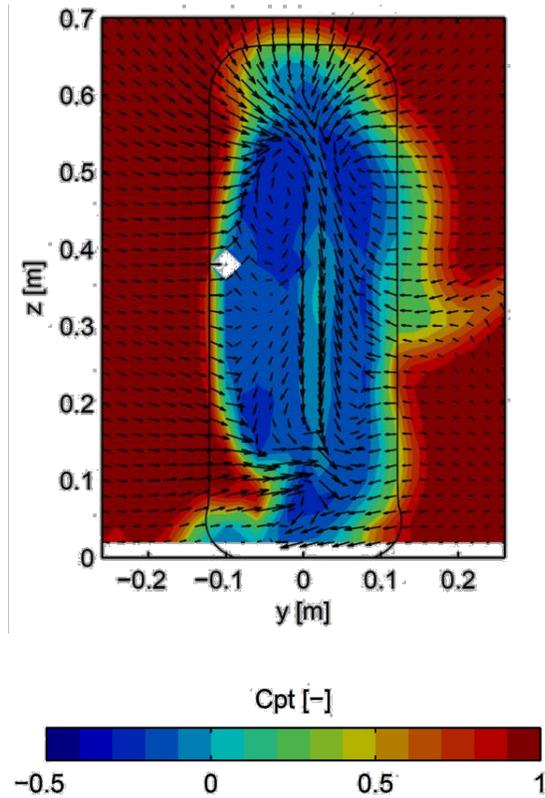
- › Automatic GRF cells selection with sweep method



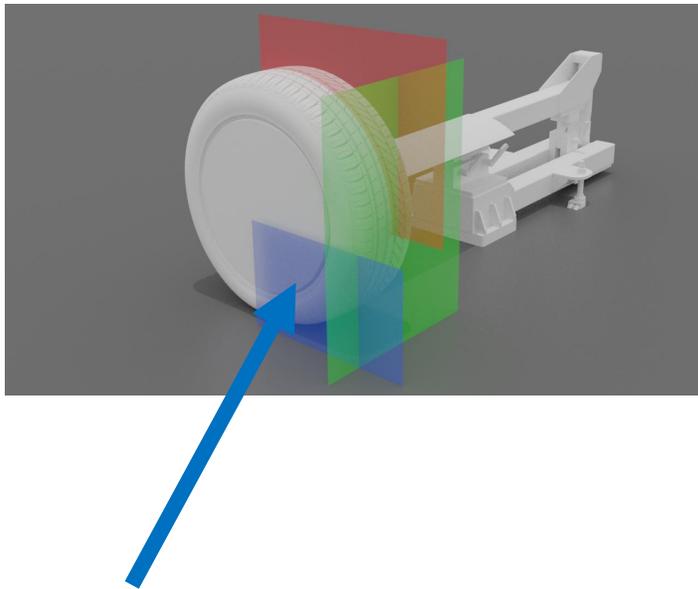
# Tire Modelling Results



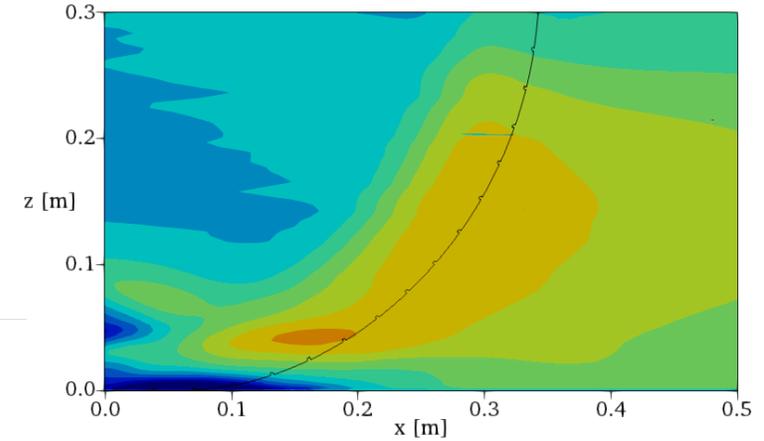
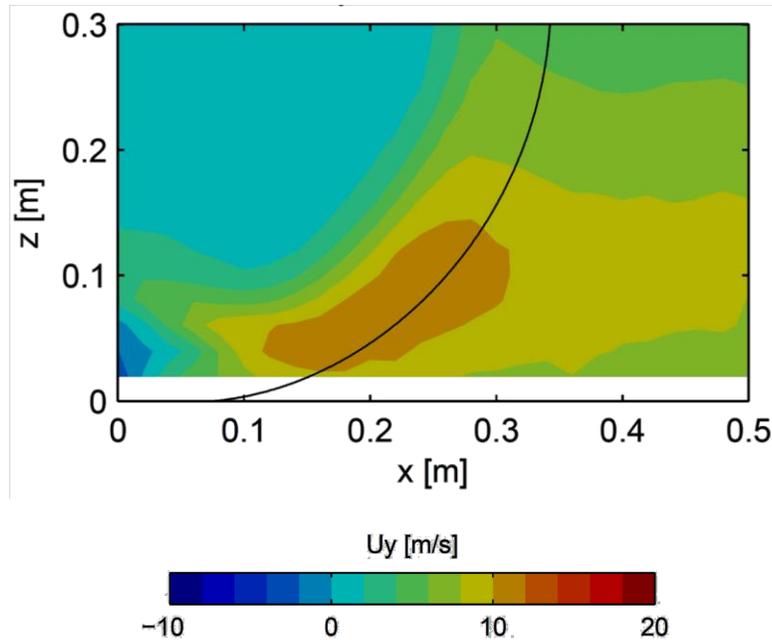
Experiment



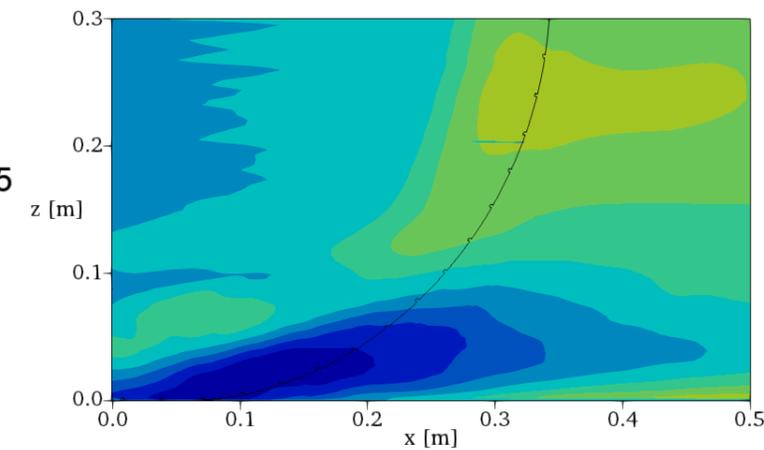
# Tire Modelling Results



Experiment



GRF



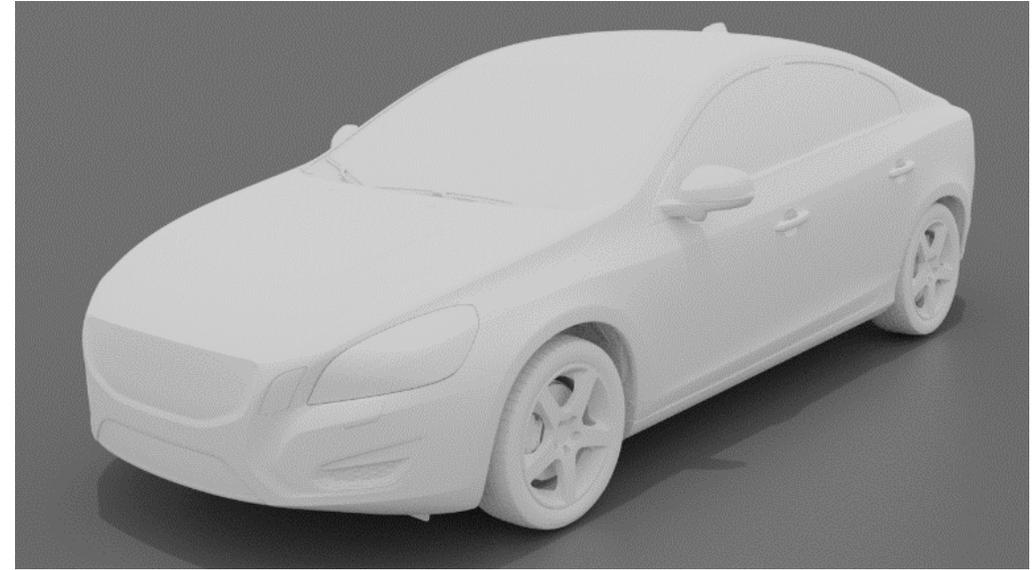
Rot Wall

# Tire Modelling Results

## Full car simulation

- › With kind permission of Volvo Cars
- › Volvo S60
- › Open and Closed Rim configurations
  - SM used for Open Rim
- › Difference in drag coefficient between slick and detailed tires
- › Compare with experimental values for

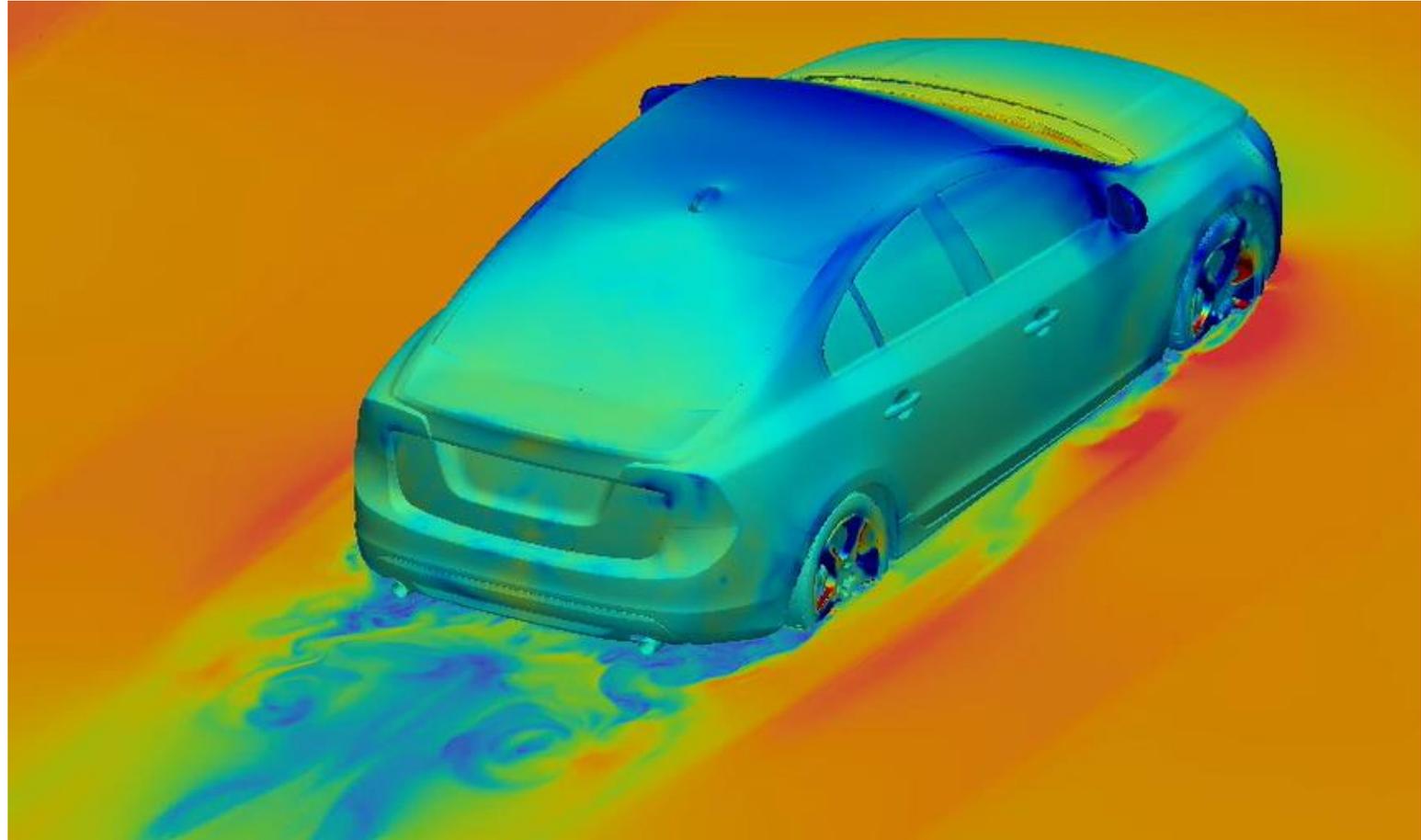
$$\Delta C_D = C_{D \text{ Detail}} - C_{D \text{ Slick}}$$



# Tire Modelling Results

## Full car simulation

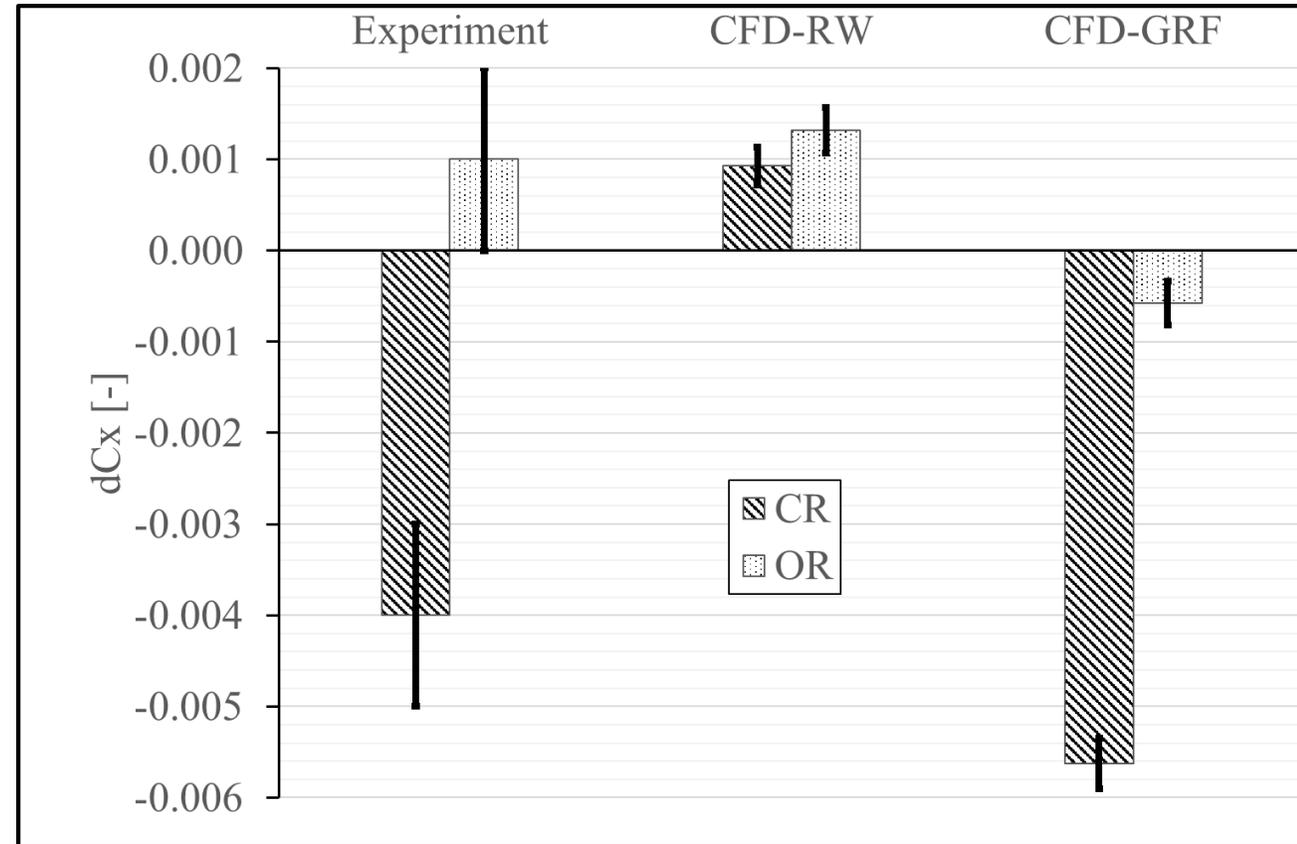
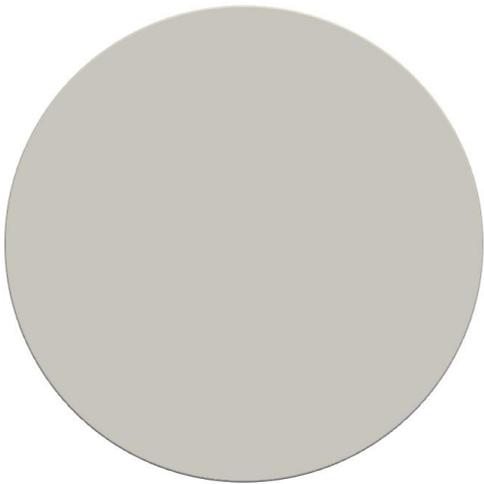
- › Delayed Detached Eddy Simulation (DDES)  
Spalart-Allmaras  
turbulence model
- › ~100 million cells
- › Inlet velocity: 100 Km/h
- › Average over 1 second



# Tire Modelling Results

## Full car simulation

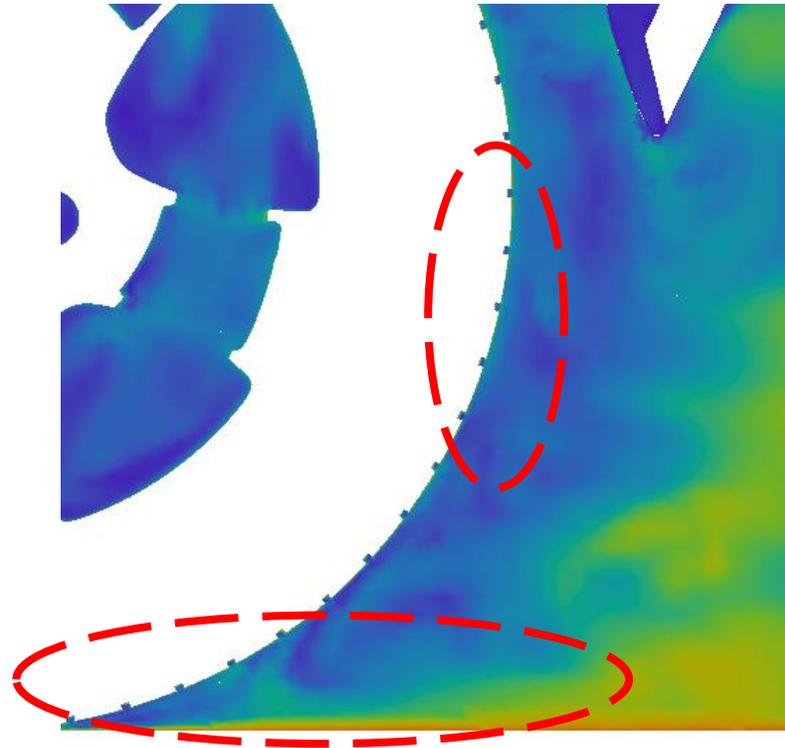
- › Comparison of  $\Delta C_D$
- › Good prediction for closed rims
- › Ambiguous results for open rims



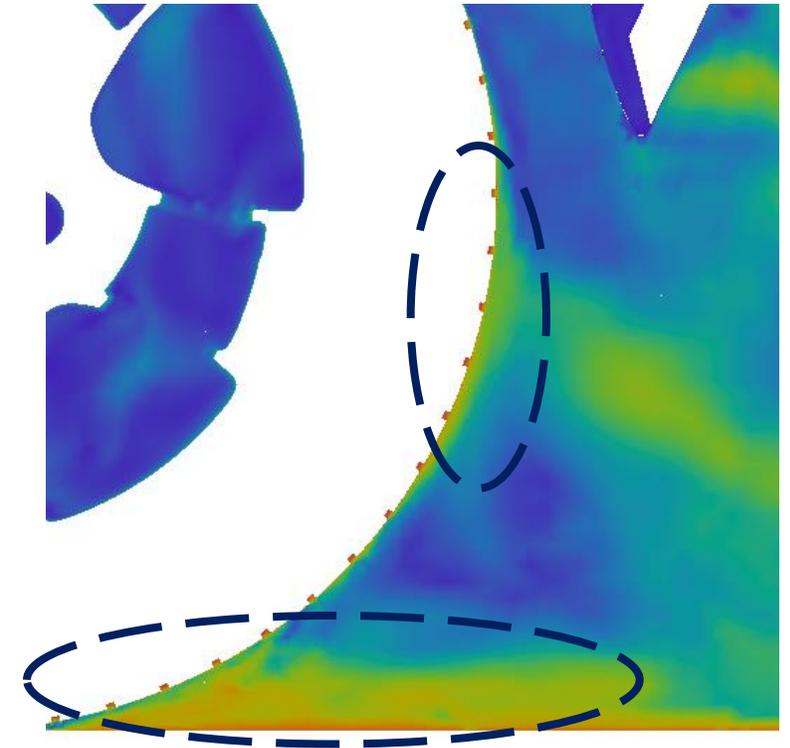
# Tire Modelling Results

## Full car simulation

- › Slice across the wheel plane
- › Difference in the velocity field in the vicinity of the grooves



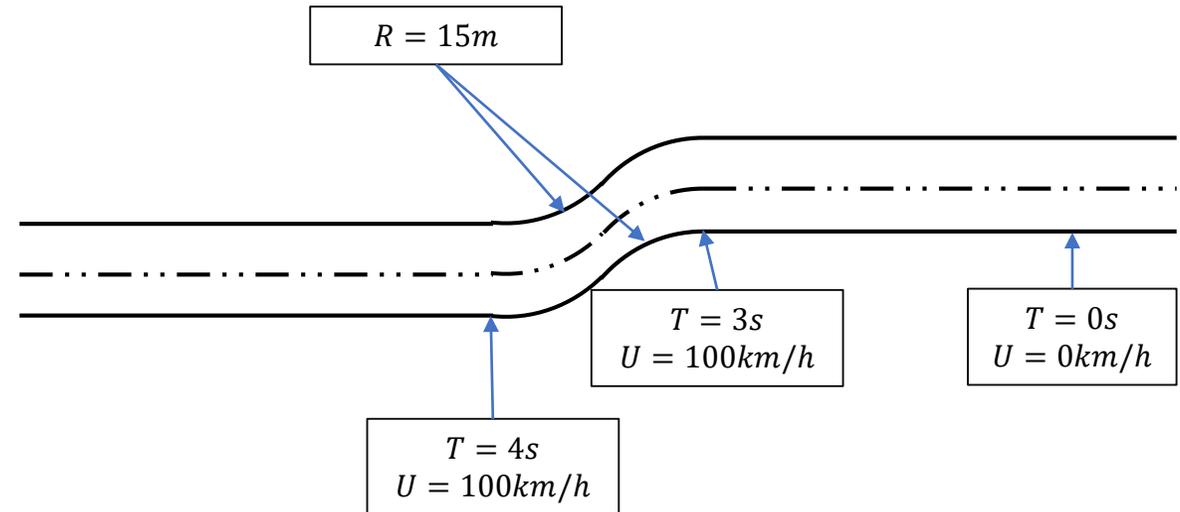
Rotating Wall



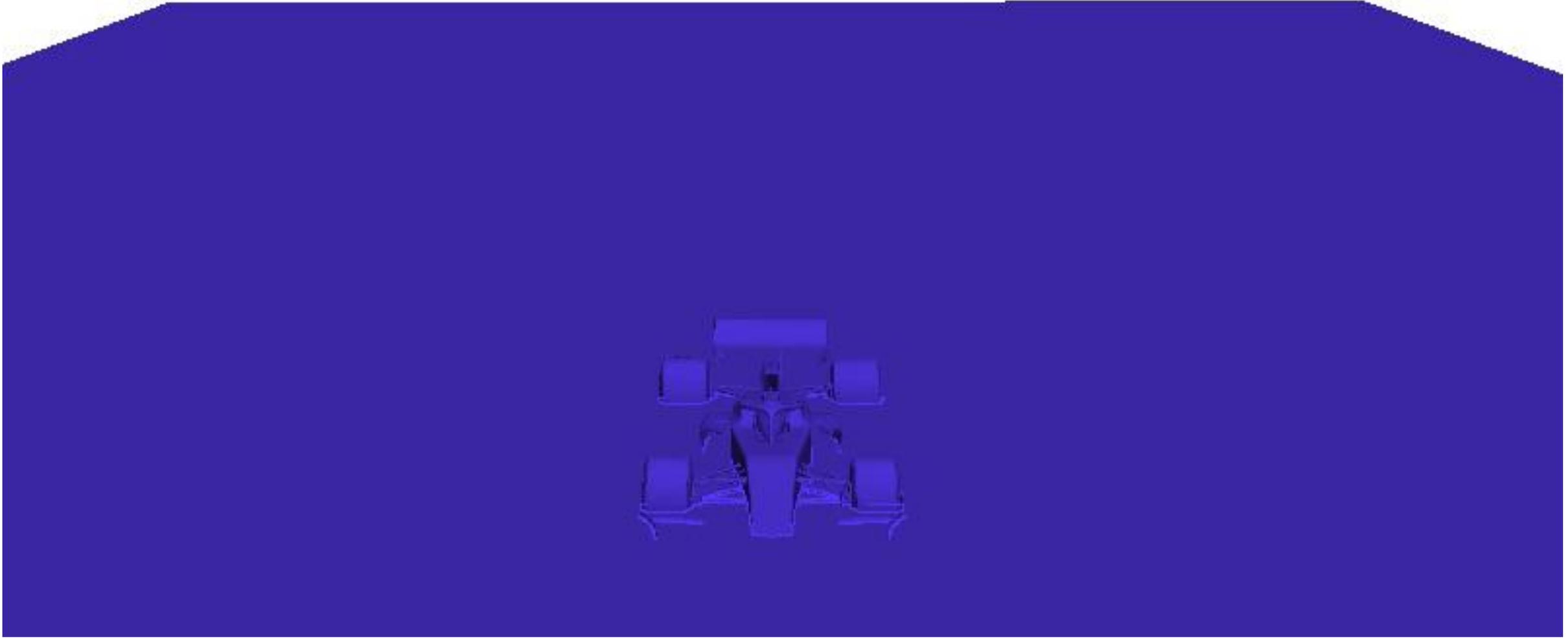
GRF

# Extended Reference Frames | Application

- › Vehicle cornering through a chicane
- › Vehicle max speed 100km/h



# Extended Reference Frames | Application



# Conclusions

- › For wheel modelling
  - Easy to set up and use
  - Accurate
  - GRF can support any shape and any motion
- › For vehicle cornering
  - Globalized definition of reference frames
  - Nested frames support
- › Future work:
  - sliding mesh interface automation
  - performance optimization
  - Extended reference frames for dynamic meshes
  - GUI support