2013 Automotive Simulation World Congress

DrivAer - Aerodynamic Investigations for a New Realistic Generic Car Model using ANSYS CFD

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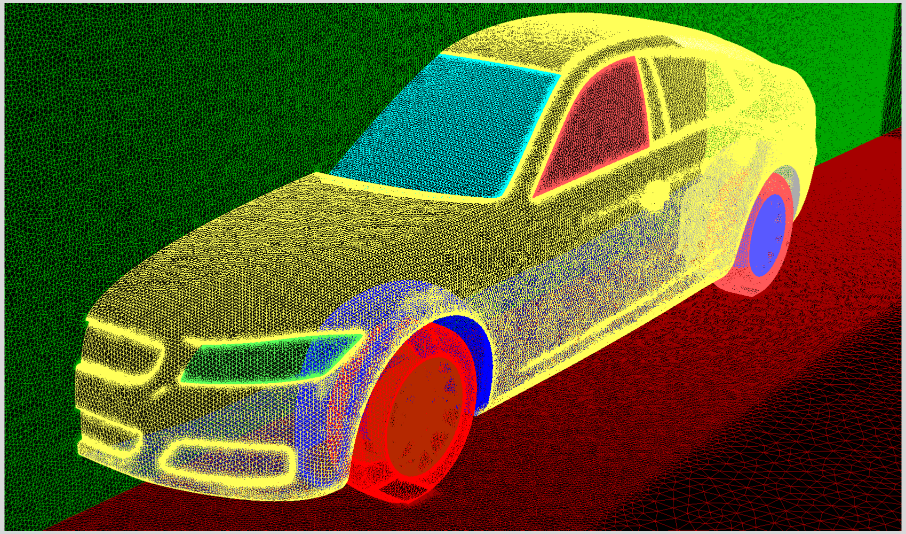
- The DrivAer Benchmark by TU Munich, Institute of Aerodynamics and Fluid Mechanics
  - Investigated DrivAer car model variants
- The meshing process
- CFD investigations for the DrivAer fastback car:
  - F_S_woM_wW
  - F_D_wM_wW
- Comparison to TU Munich wind tunnel data
- Cross-comparison of ANSYS CFX and ANSYS Fluent
- Summary & Outlook

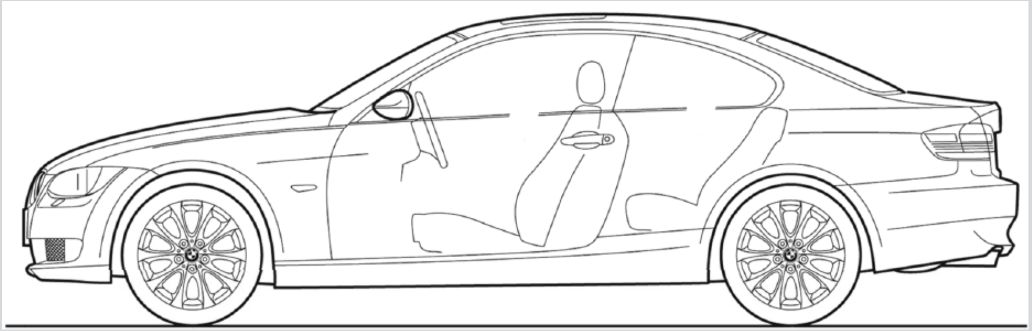
Objectives



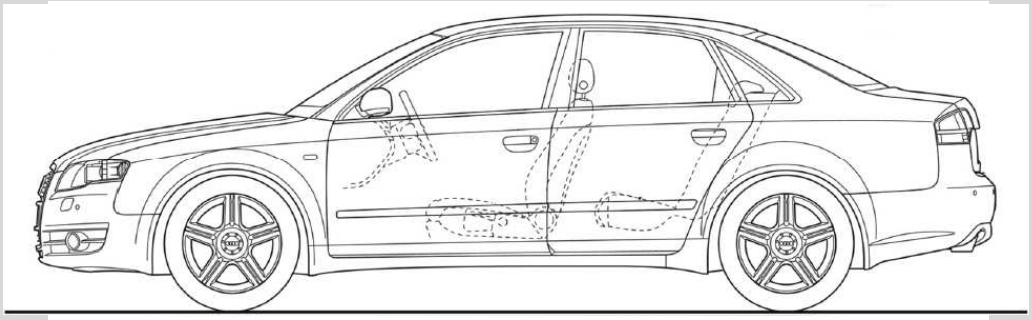
- Automotive Aerodynamics Validation of ANSYS CFD
- Generic reference model with modern car geometry
- Investigation of meshing process and technologies for contemporary and complex car body geometry
  – Including wheels
  – Including mirrors
  – Including detailed floor with exhaust system
- Validation of ANSYS CFX & ANSYS Fluent
- Comparison to TU Munich wind tunnel data
- Turbulence model validation and data comparison
  → steady/transient SST and SAS-SST

DrivAer Geometry
Development of the DrivAer model by TU Munich

BMW 3 Series
Limousine



Audi A4
Limousine



Courtesy by TU Munich, Inst. of Aerodynamics

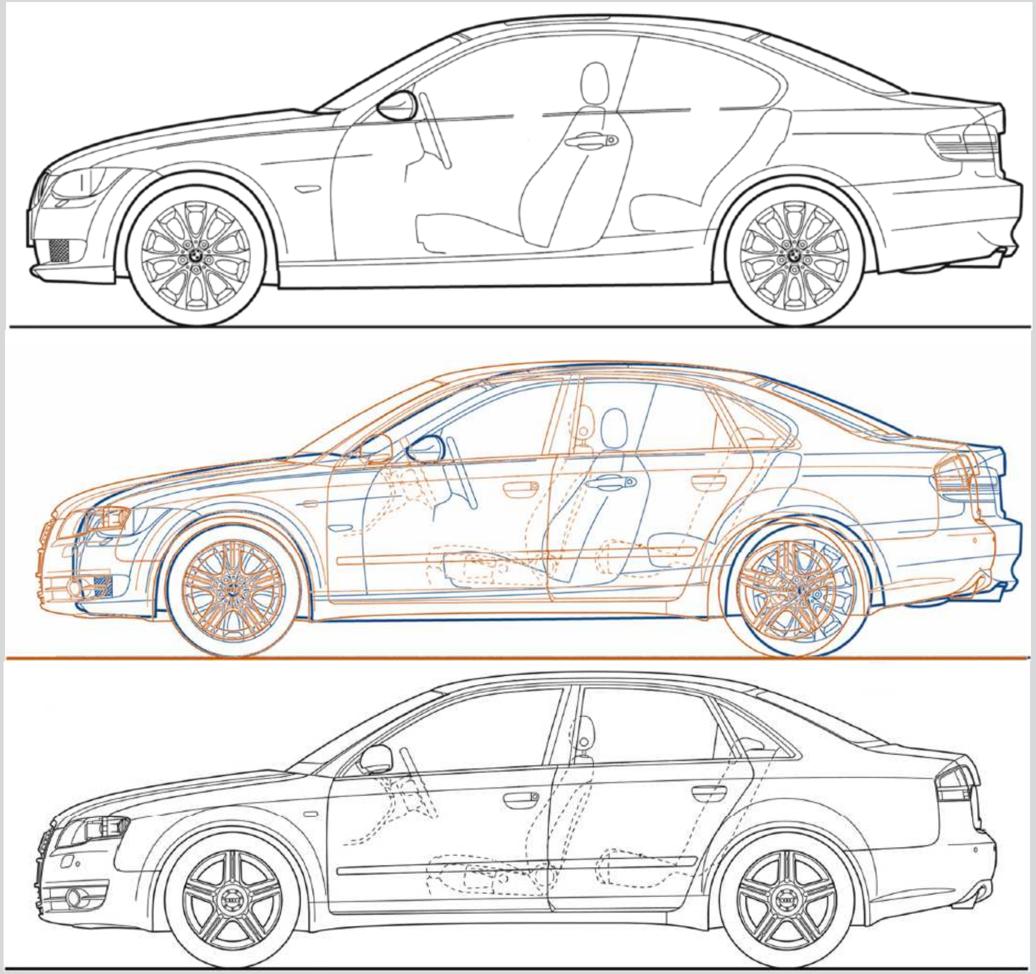
DrivAer Geometry

Development of the DrivAer model by TU Munich

BMW 3 Series Limousine

DriveAer Car Body

Audi A4 Limousine

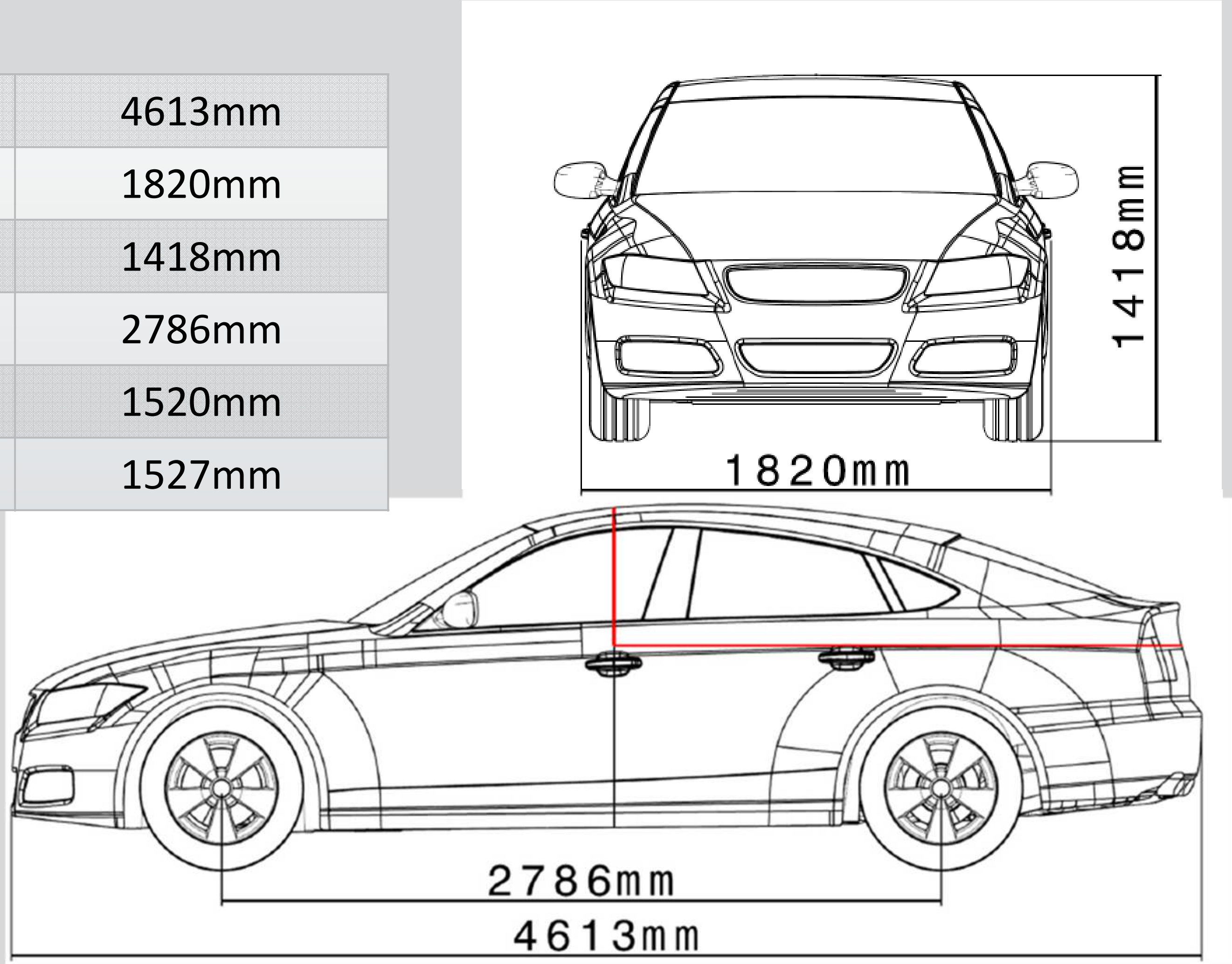


Courtesy by TU Munich, Inst. of Aerodynamics

DrivAer Geometry

Development of the DrivAer model by TU Munich

Total length	4613mm
Total width	1820mm
Total height	1418mm
Wheelbase	2786mm
Track width front	1520mm
Track width back	1527mm



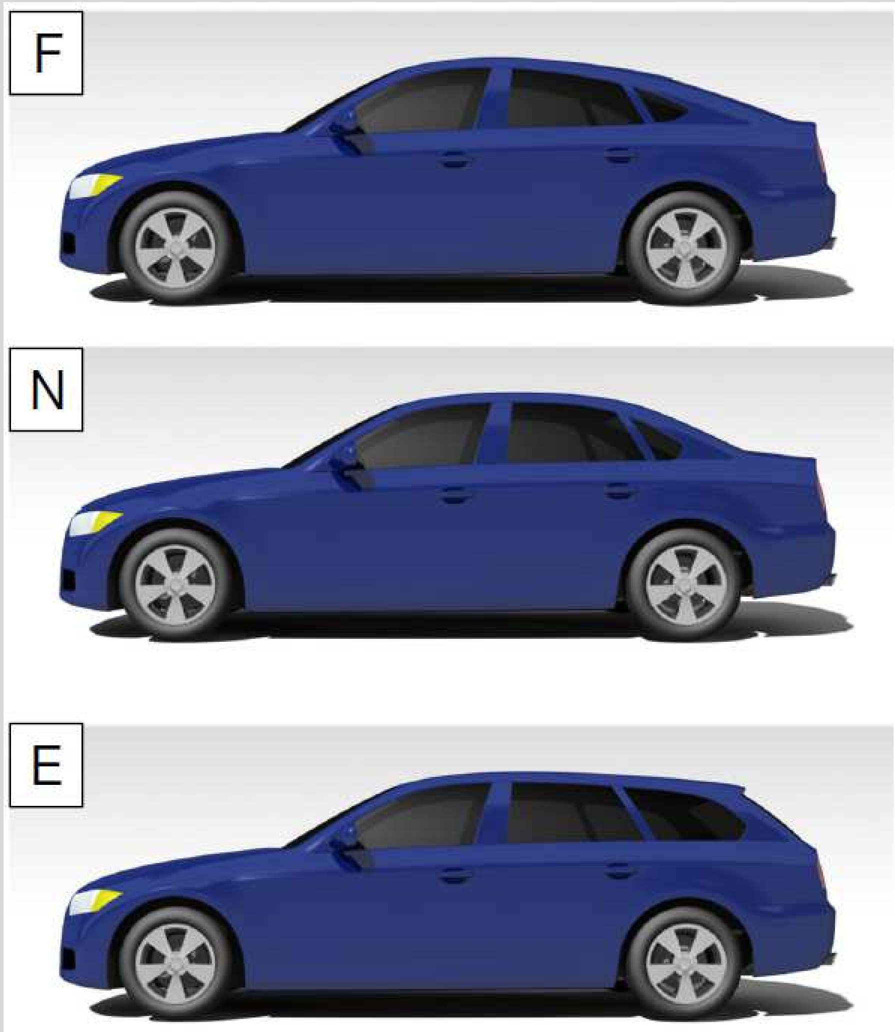
Courtesy by TU Munich, Inst. of Aerodynamics

Testcase Description - Geometry

Development of the DrivAer model by TU Munich

Naming conventions

- Rear end
- Underbody
- Mirrors
- Wheels



Courtesy by TU Munich, Inst. of Aerodynamics

Testcase Description - Geometry

Development of the DrivAer model by TU Munich

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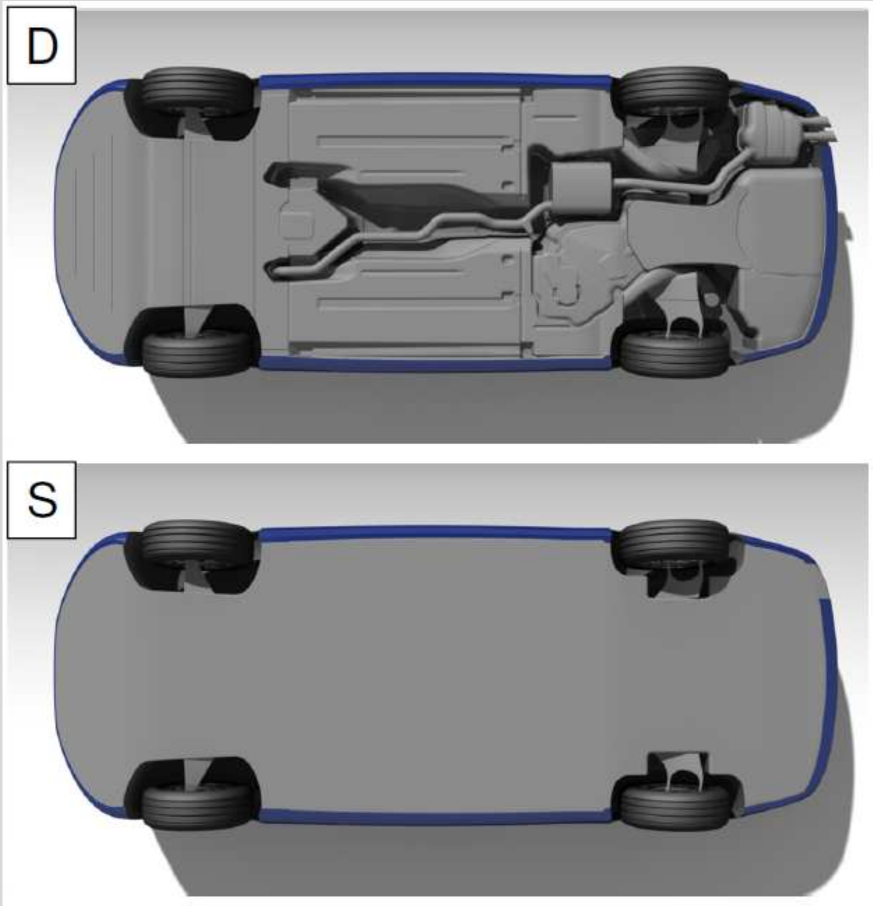

Courtesy by TU Munich, Inst. of Aerodynamics

Testcase Description - Geometry

Development of the DrivAer model by TU Munich

Naming conventions

Rear end
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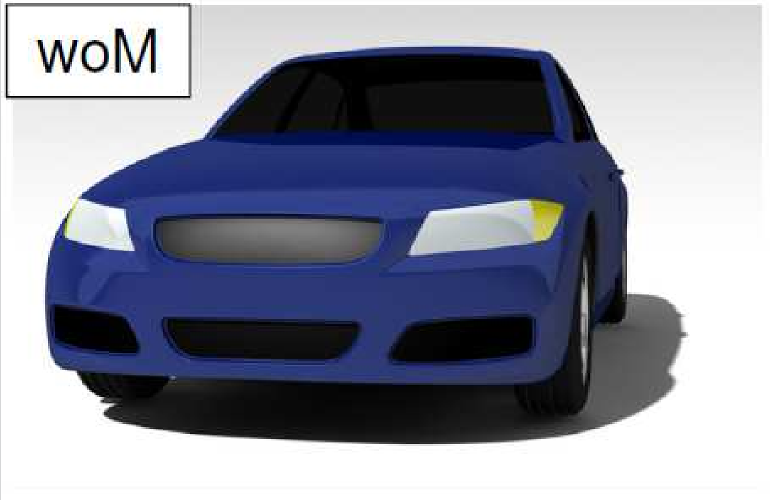


Courtesy by TU Munich, Inst. of Aerodynamics

Testcase Description - Geometry
Development of the DrivAer model by TU Munich

Naming conventions

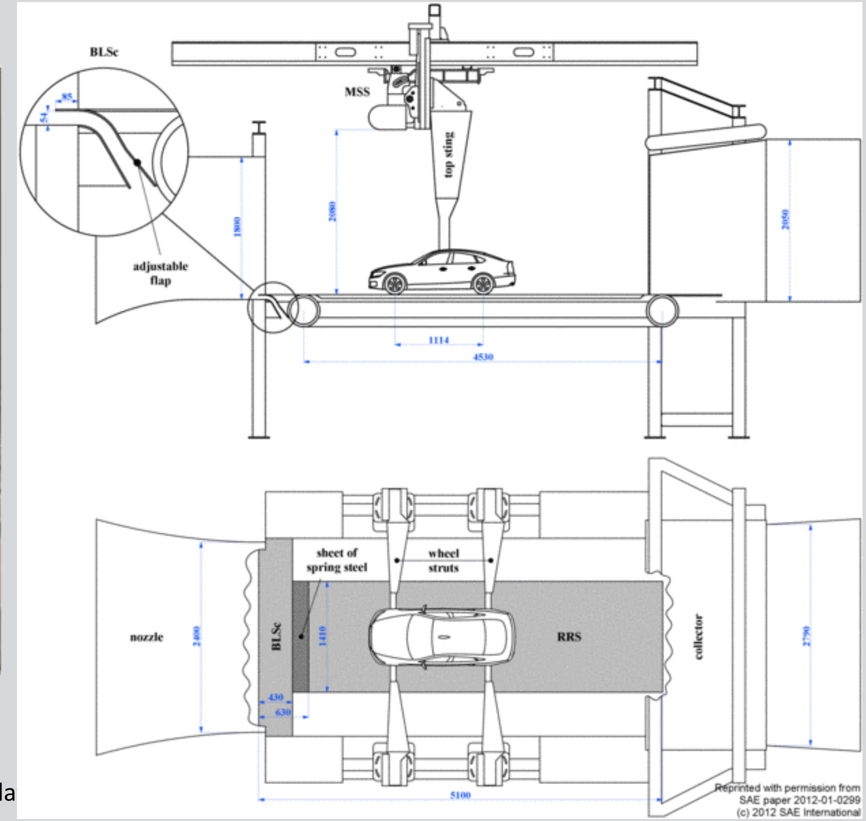
Rear end
Underbody
Mirrors
Wheels

Courtesy by TU Munich, Inst. of Aerodynamics

Experimental Facility and Data

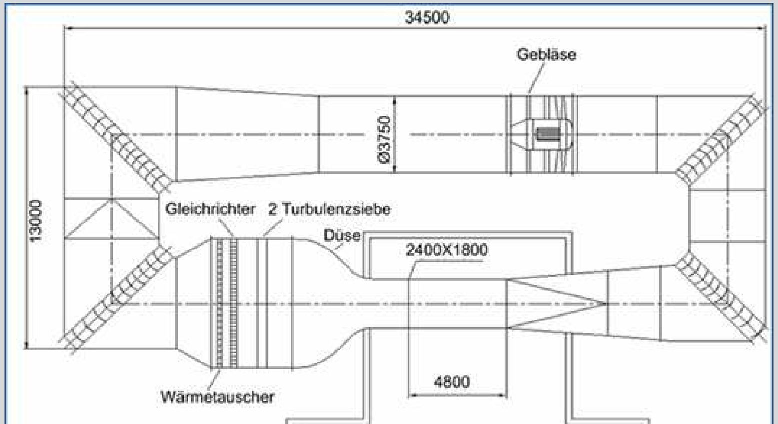
- The experimental data is provided by the Institute of Aerodynamics and Fluid Mechanics, TU Munich
- Experiments are performed in a wind tunnel including a moving belt @ 1:2.5 model scale

Courtesy by TU Munich, Inst. of Aerodynamics

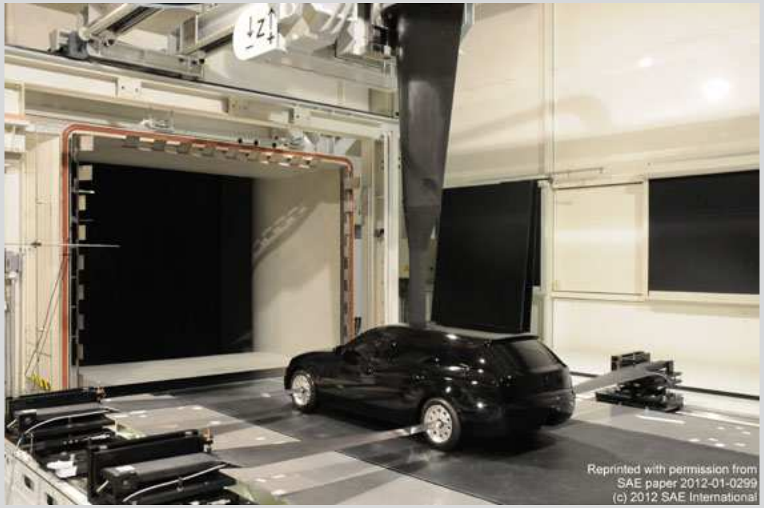


Test Case Conditions

Model Scale	**1:2.5**
Inlet velocity	40 m/s
Air Temperature	20°C
Air Pressure	1.013 bar
Air Density	1.2047 kg/m^3
Reference Length (Length of car model)	1.84 m
Resulting Reynolds number	$4.87*10^6$
Ground velocity	**40 m/s**



Courtesy by TU Munich, Inst. of Aerodynamics



Experimental Uncertainties

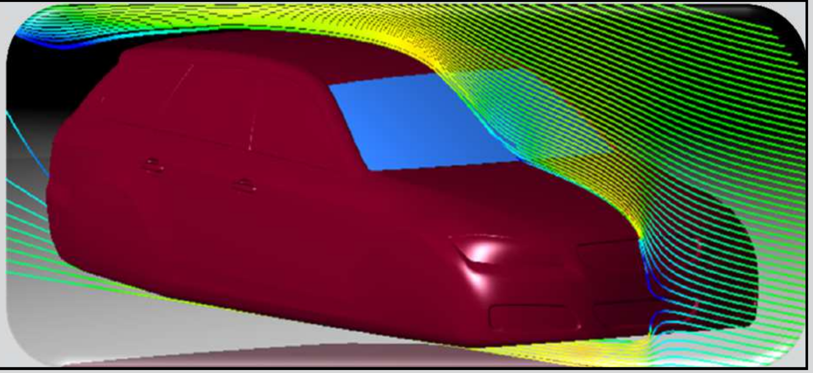
Also DrivAer experiments are carried out with care, the data are subject to the following uncertainties:

- **Blockage of the TUM wind tunnel cross sectional area is rather high for the car model**
- **Existent pressure gradient over the length of the measurement section of the wind tunnel**
- **Efficiency of boundary layer scoop**
- **Necessity to take into account rolling friction and aerodynamic effects from rotating wheels and tire rim design; but tires are not connected to the weights (i.e. C_D and C_L measurement system)**
- **Disturbance from model support system (MSS) and wheel supports on car aerodynamics**
- **Influence from interaction of the rolling road system (RSS) with not moving side floor of the wind tunnel**
- **General measurement errors of applied measurement technologies (weights, pressure transducers)**

Investigated DrivAer Car Models

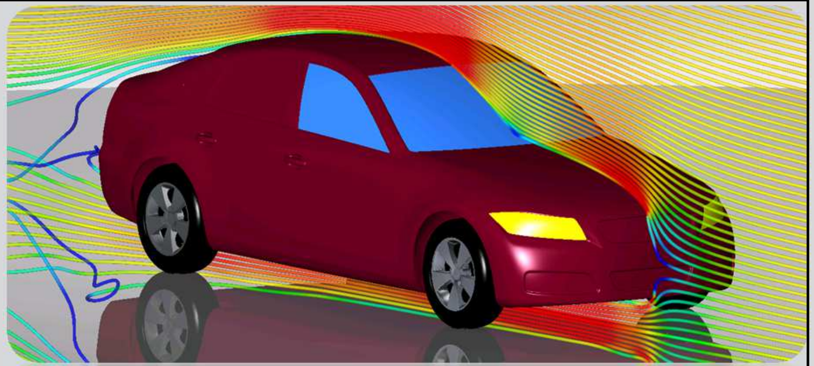
E_S_woM_woW

Estate_
Smooth underbody_
without Mirrors_
without Wheels



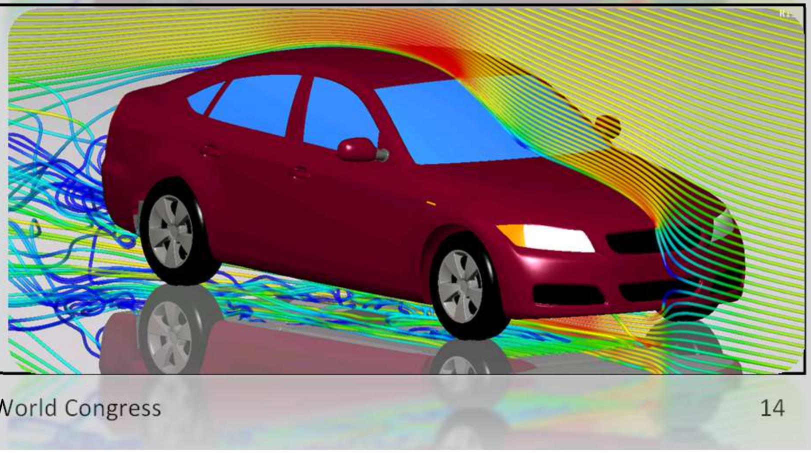
F_S_woM_wW

Fastback_
Smooth underbody_
without Mirrors_
with Wheels



F_D_wM_wW

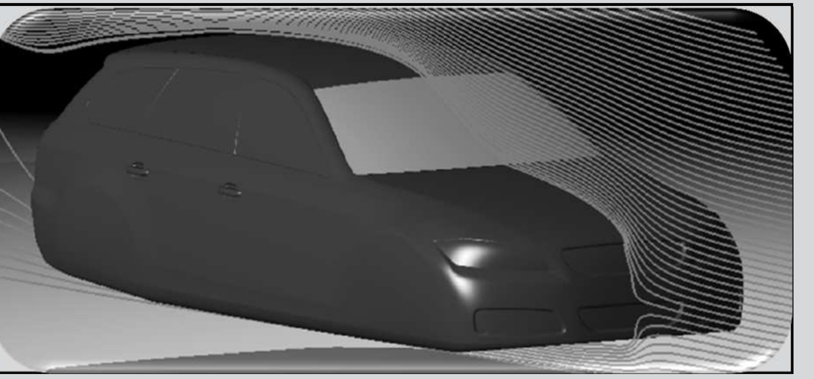
Fastback_
Detailed underbody_
with Mirrors_
with Wheels



Investigated DrivAer Car Models

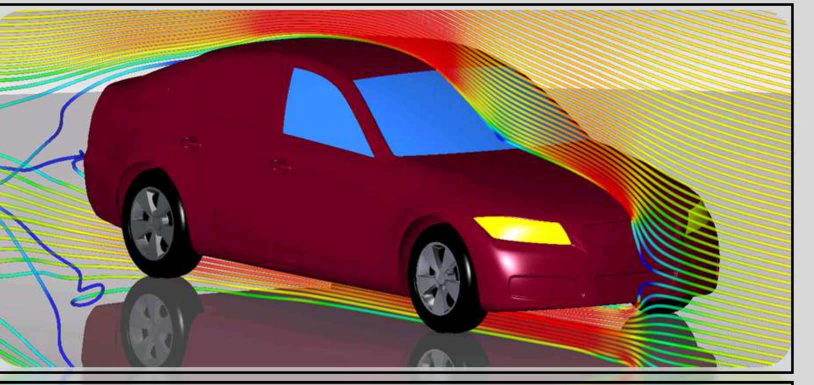
E_S_woM_woW

Estate_
Smooth underbody_
without Mirrors_
without Wheels



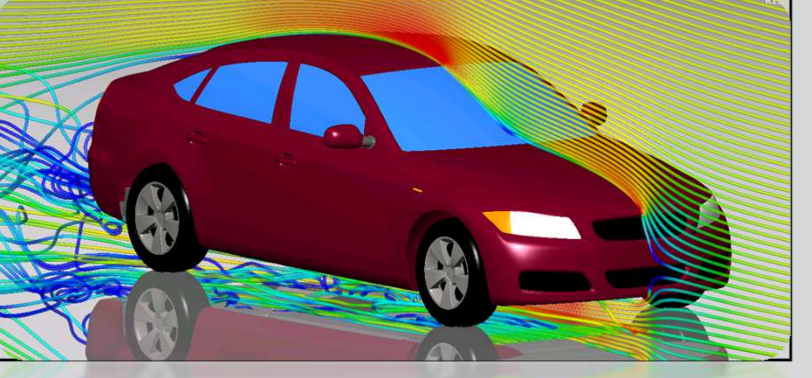
F_S_woM_wW

Fastback_
Smooth underbody_
without Mirrors_
with Wheels



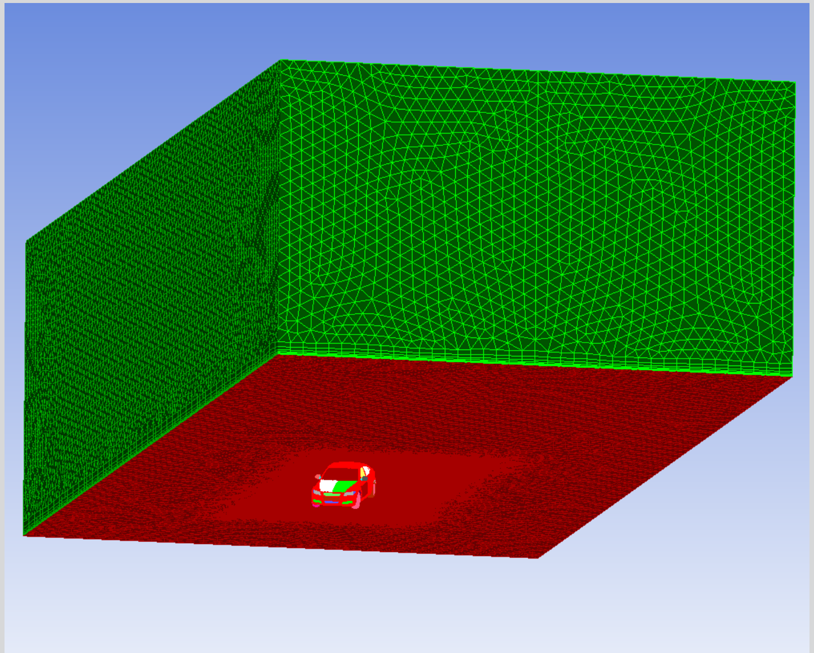
F_D_wM_wW

Fastback_
Detailed underbody_
with Mirrors_
with Wheels



Geometry & Computational Domain

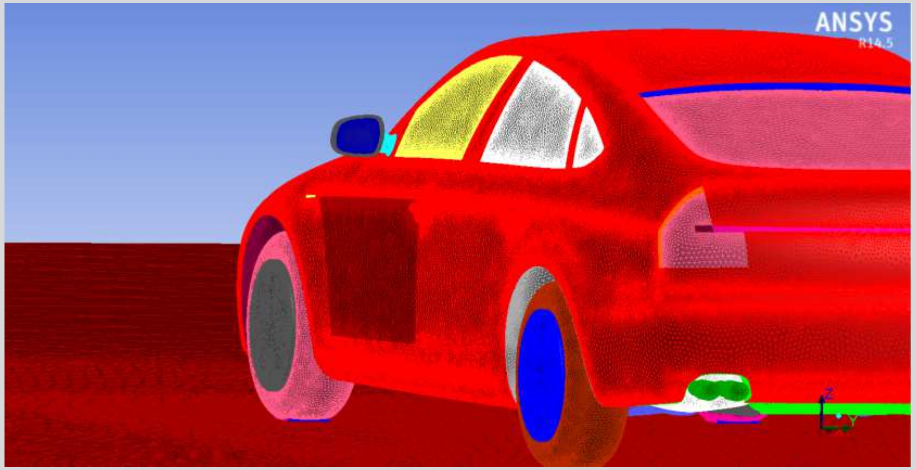
Model Scale to Car Size	**1:1**
Inlet velocity	**16 m/s**
Air Temperature	20°C
Air Pressure	1.013 bar
Air Density	1.2047 kg/m^3
Reference Length (Car Length)	4.6
Resulting Reynolds number	4.87*10^6
Ground velocity	**16 m/s**

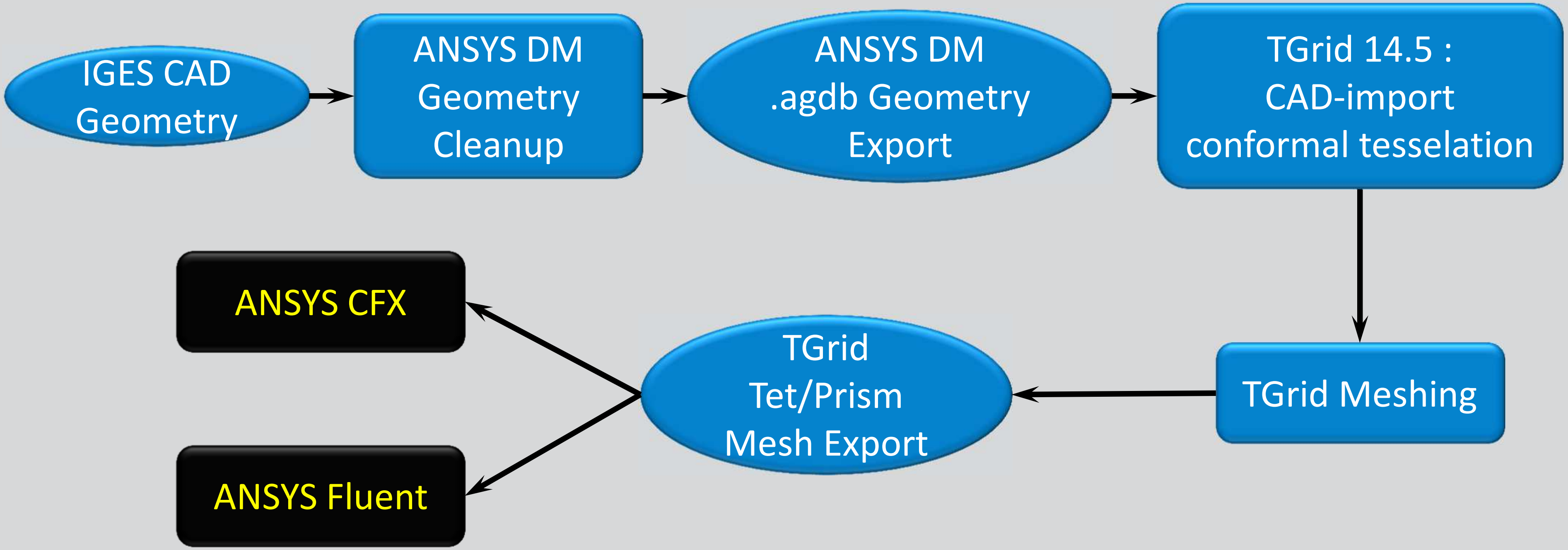


Dimensions of the Bounding Box		
Model scale	1 : 1	1 : 1
Total length	10L	46.13 m
Total width	11B	20.02 m
Total height	8H	11.34 m

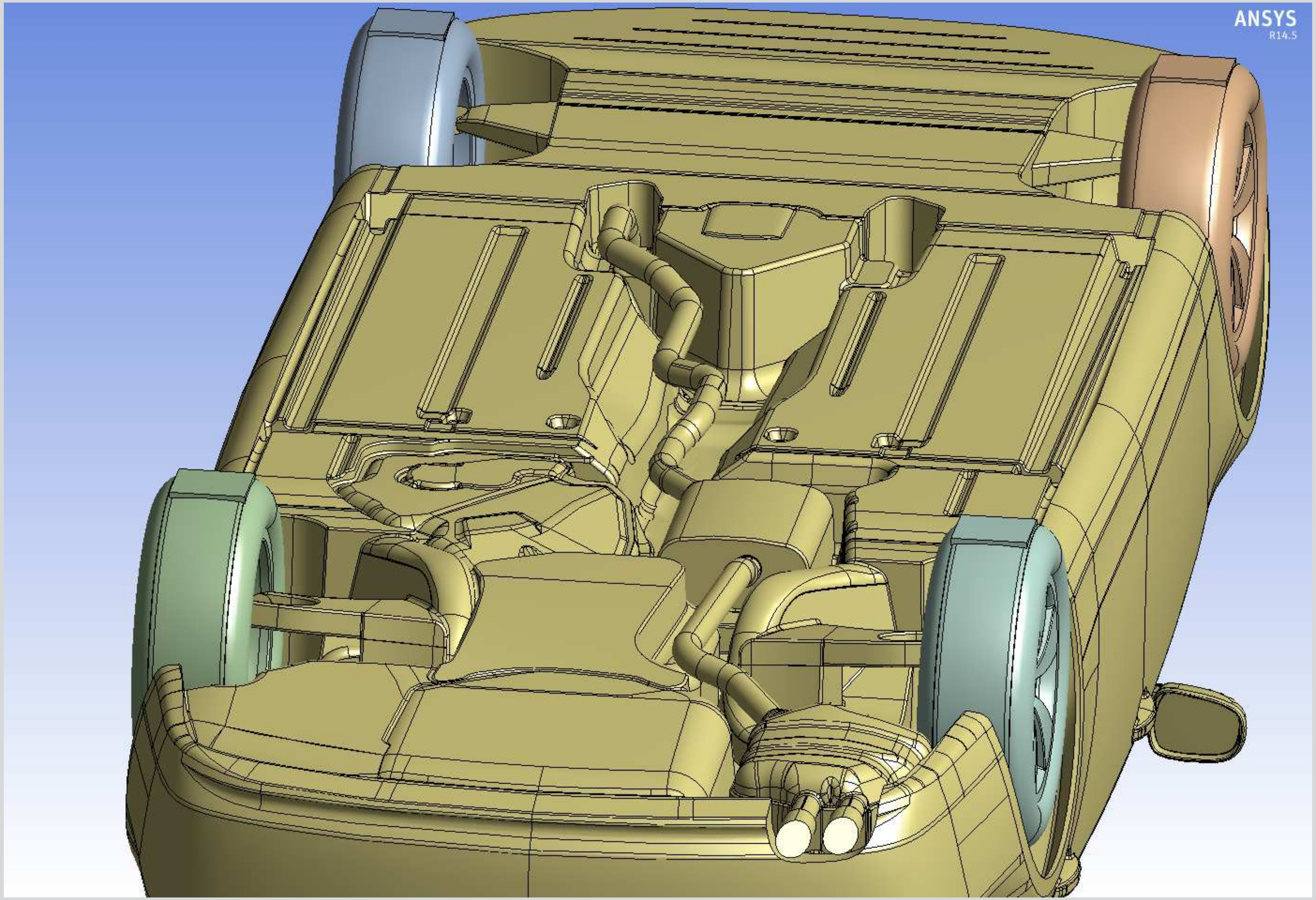
Meshing Process

- **Meshing process using:**
  - ANSYS DesignModeler 14.5
  - ANSYS TGrid in Fluent 14.5



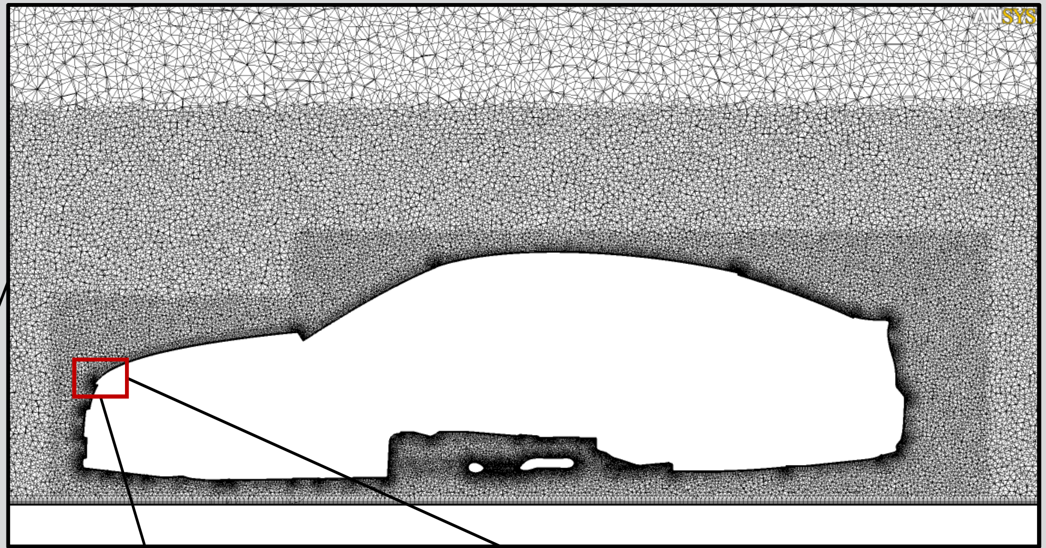


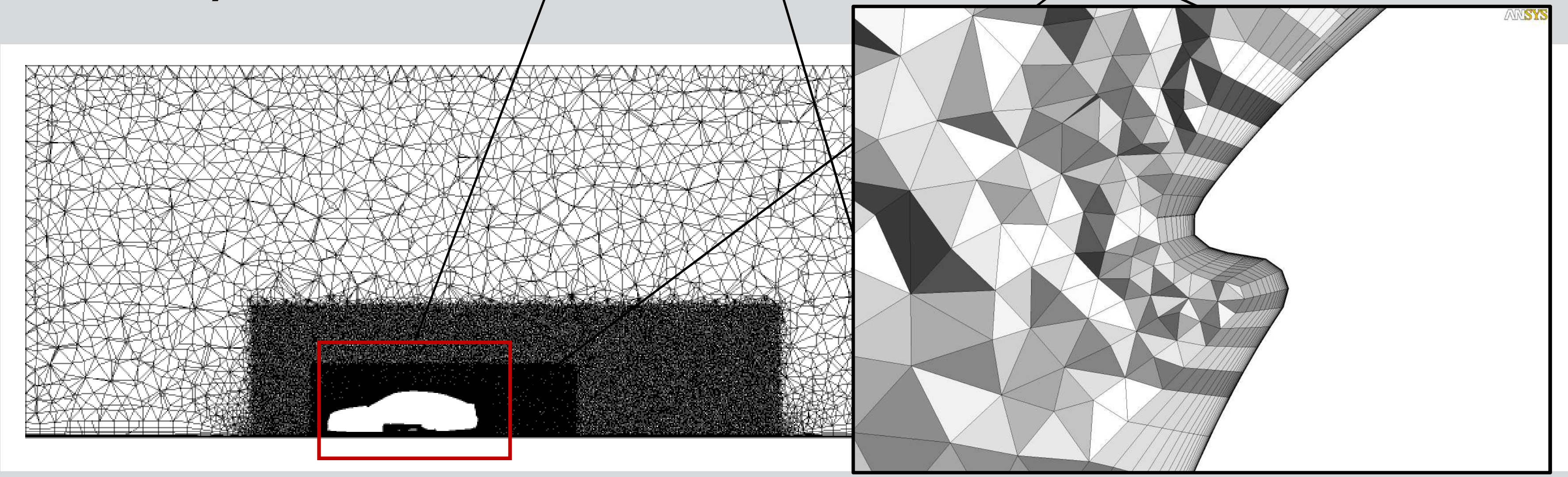
Geometry Clean-up



F_D_wM_wW: Computational Mesh2

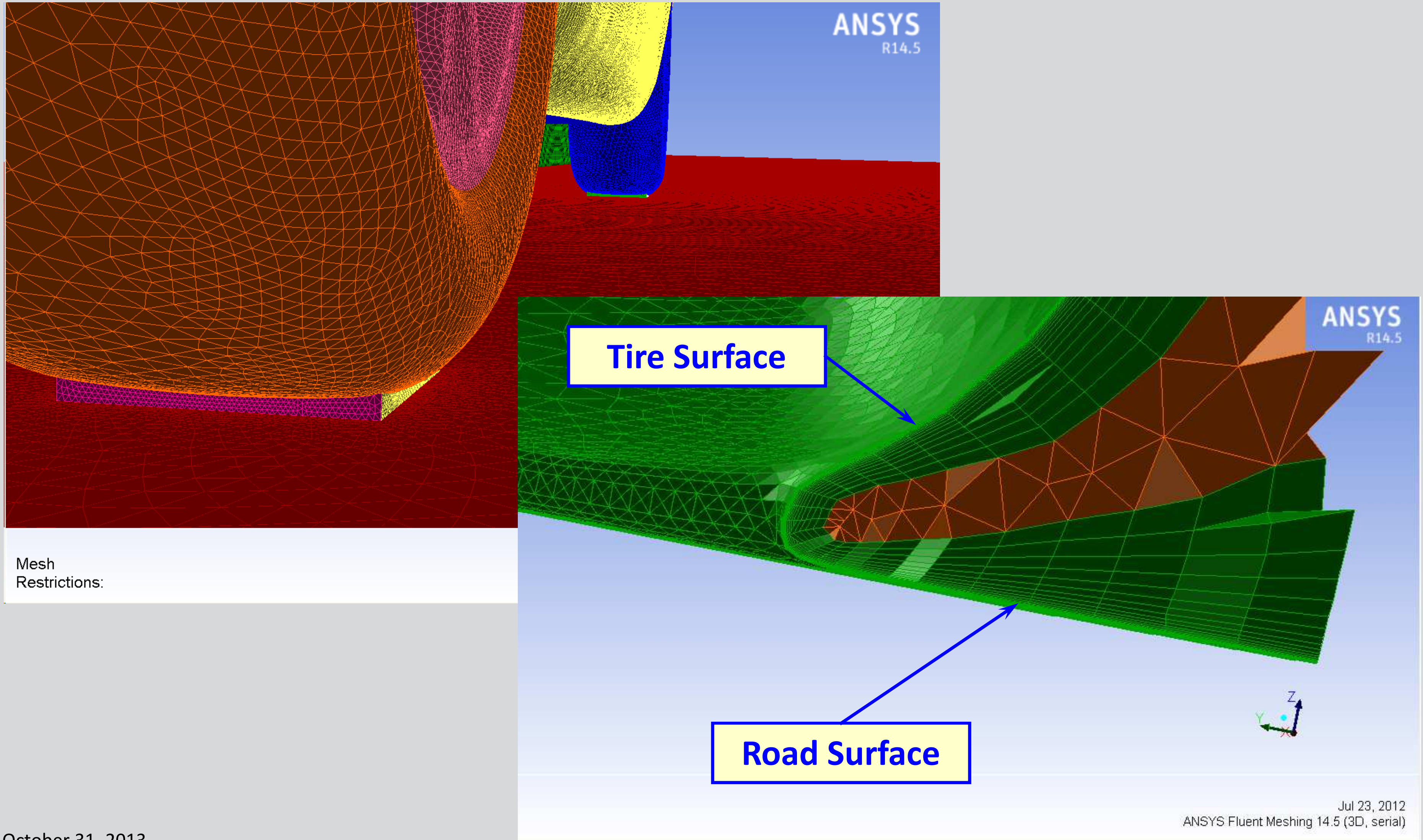
- Full 3d model → SAS-SST
- ~110 Mill. Cells
- Four refinement zones
- 20 Inflations on the car
- 15 Inflations on the road
- $y^+<1$ on the car body
- MRF-Zones for the rims (MRF=Moving Reference Frame)





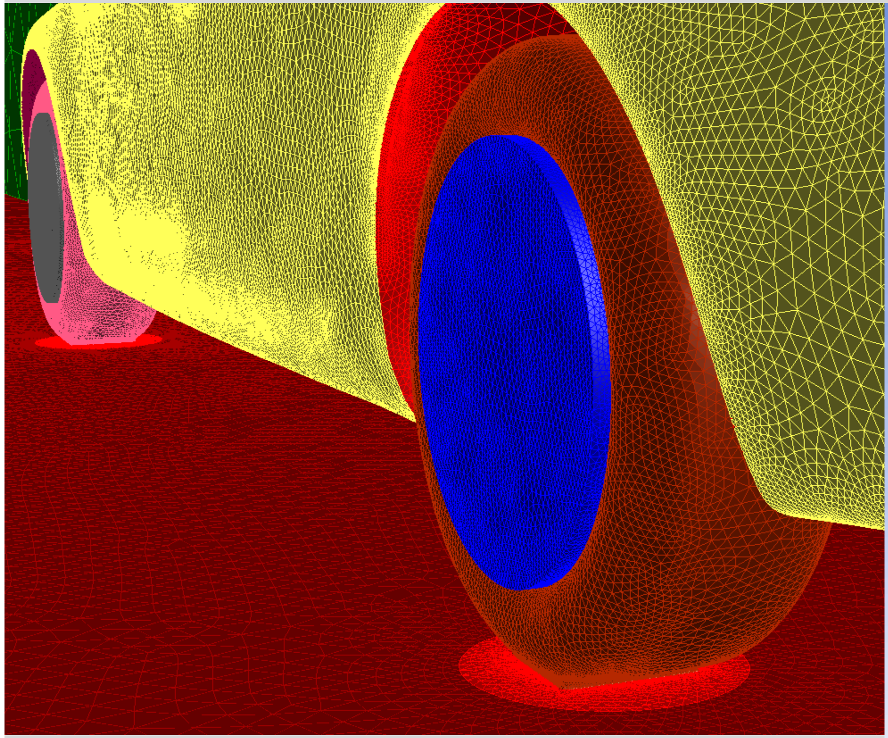
Mesh Generation

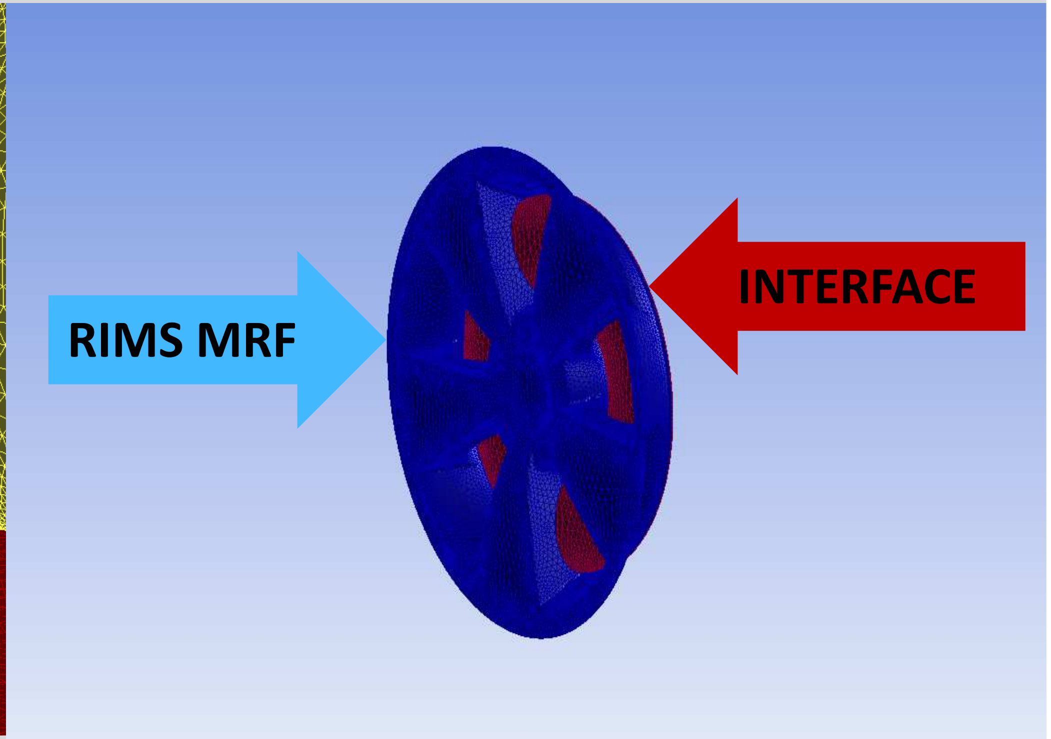
Connection between road and wheels



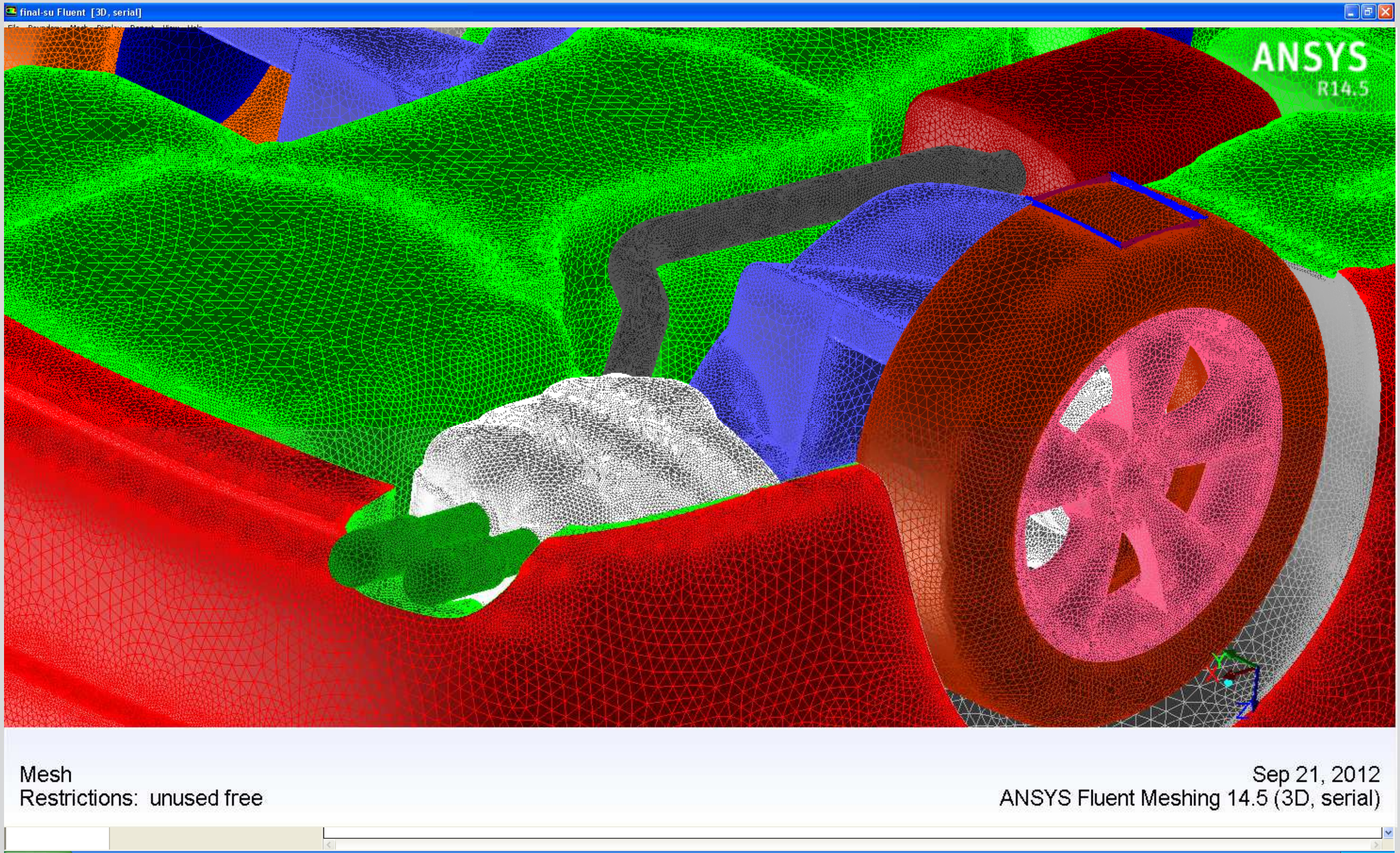
Setup for Road & Wheels

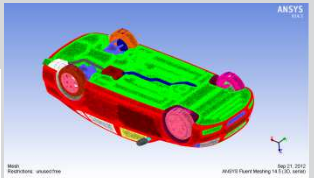
- Road = Moving wall
- Rotational boundary condition on tire
- MRF-Zones at the rims (Moving Reference Frame)

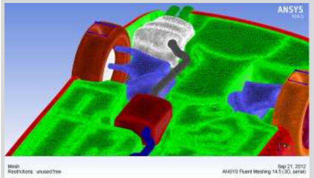


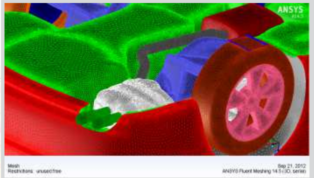


ANSYS TGrid Meshing Details









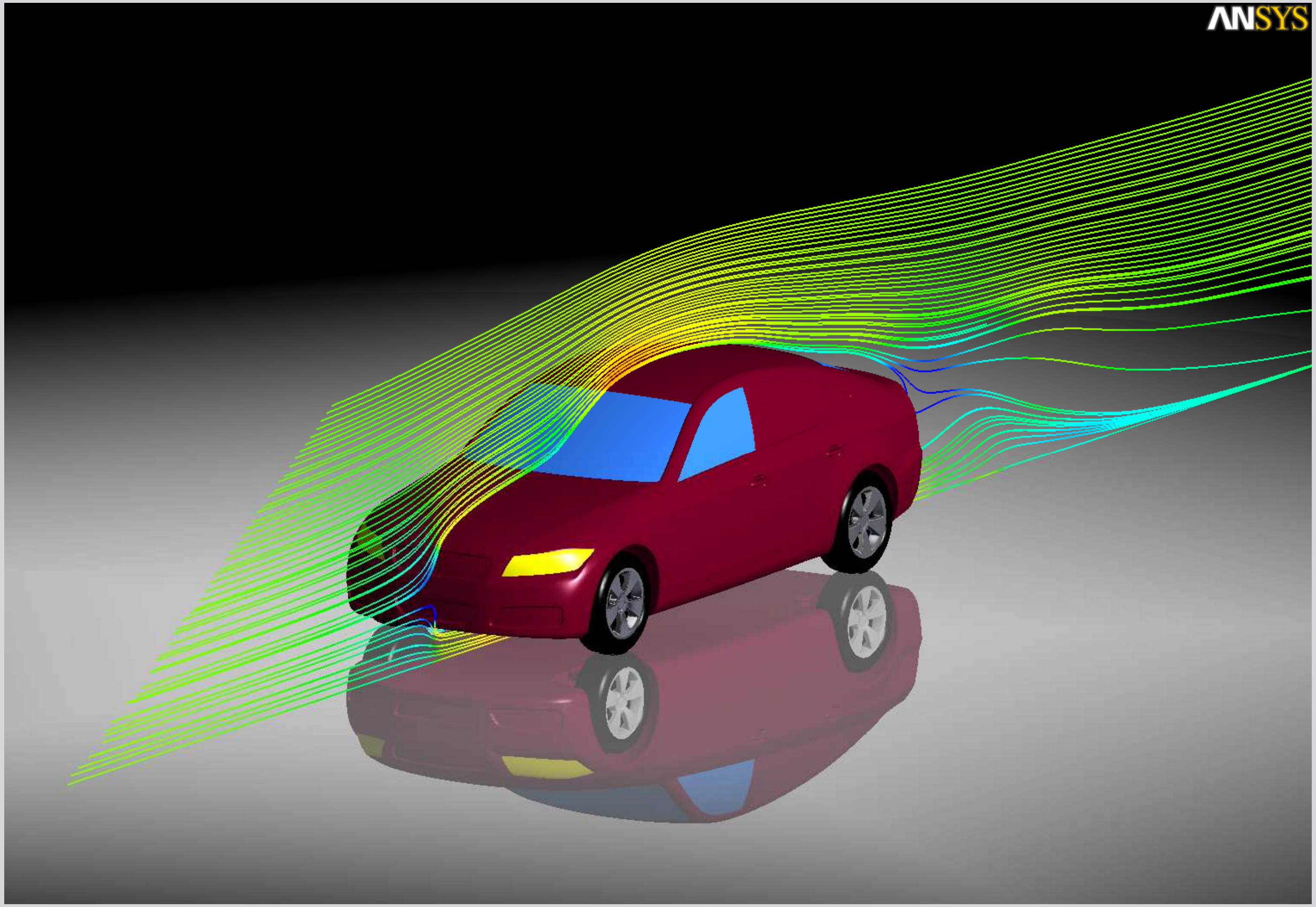
Simulation Matrix

Timestep		Mesh 1	Mesh 2	Mesh 2 Full Domain
Steady SST	Δt = 0.1ms	X		
Steady SST	Δt = 1 ms	X	X X	X X
Steady SST	Δt = 10 ms	X		
Transient SST	Δt = 1 ms	X		X X
Transient SAS-SST	Δt = 1 ms			X X
Transient SAS-SST	Δt = 0.2 ms			X X

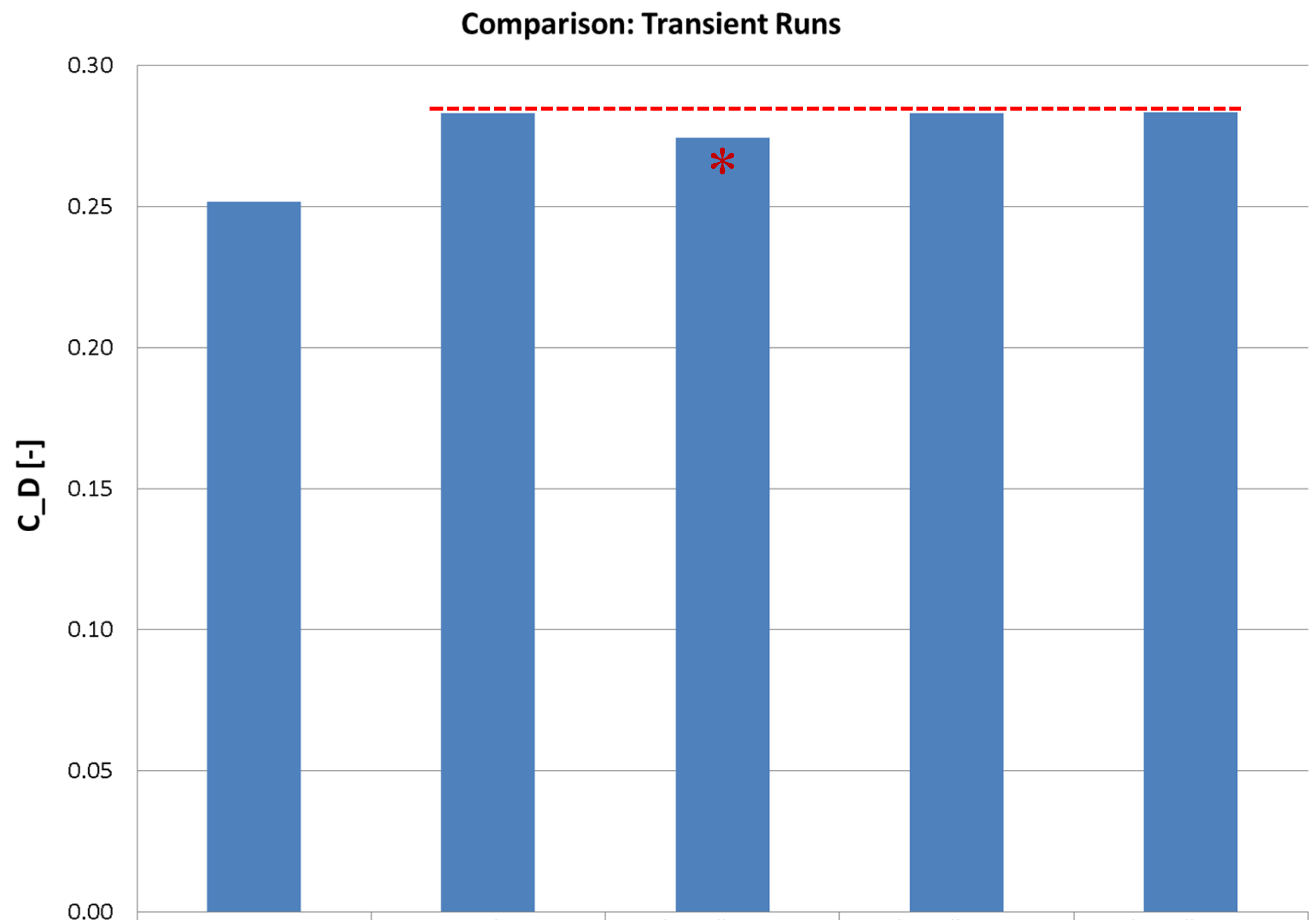
X – ANSYS CFX investigation
X – ANSYS Fluent investigation

Investigation Results F_S_woM_wW

F_S_woM_wW - Fastback_Smooth underbody_without Mirrors_with Wheels



F_S_woM_wW: Comparison of Drag

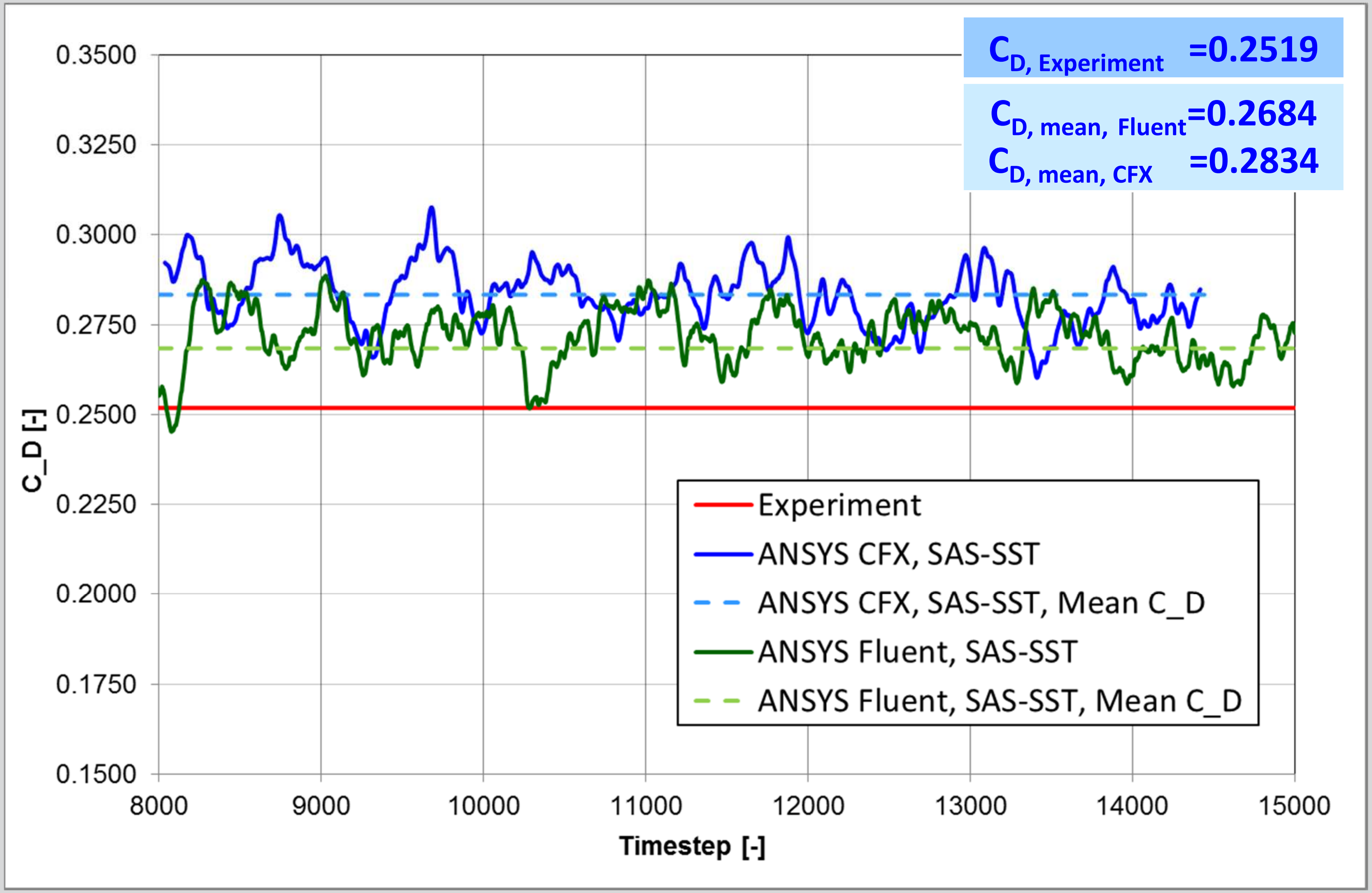


	Exp Results	Mesh 1 Transient 1ms	Mesh 2 Full Geometry Transient 1ms	Mesh 2 Full Geometry SAS-SST 1ms	Mesh 2 Full Geometry SAS-SST 0.2ms
Drag Coeff	0.2519	0.2831	0.2745	0.2830	0.2834
Averaged over	60s	1500 time steps	1440 time steps	2000 time steps	6382 time steps

*** - Simulation did not totally converge within the given coefficient loops**

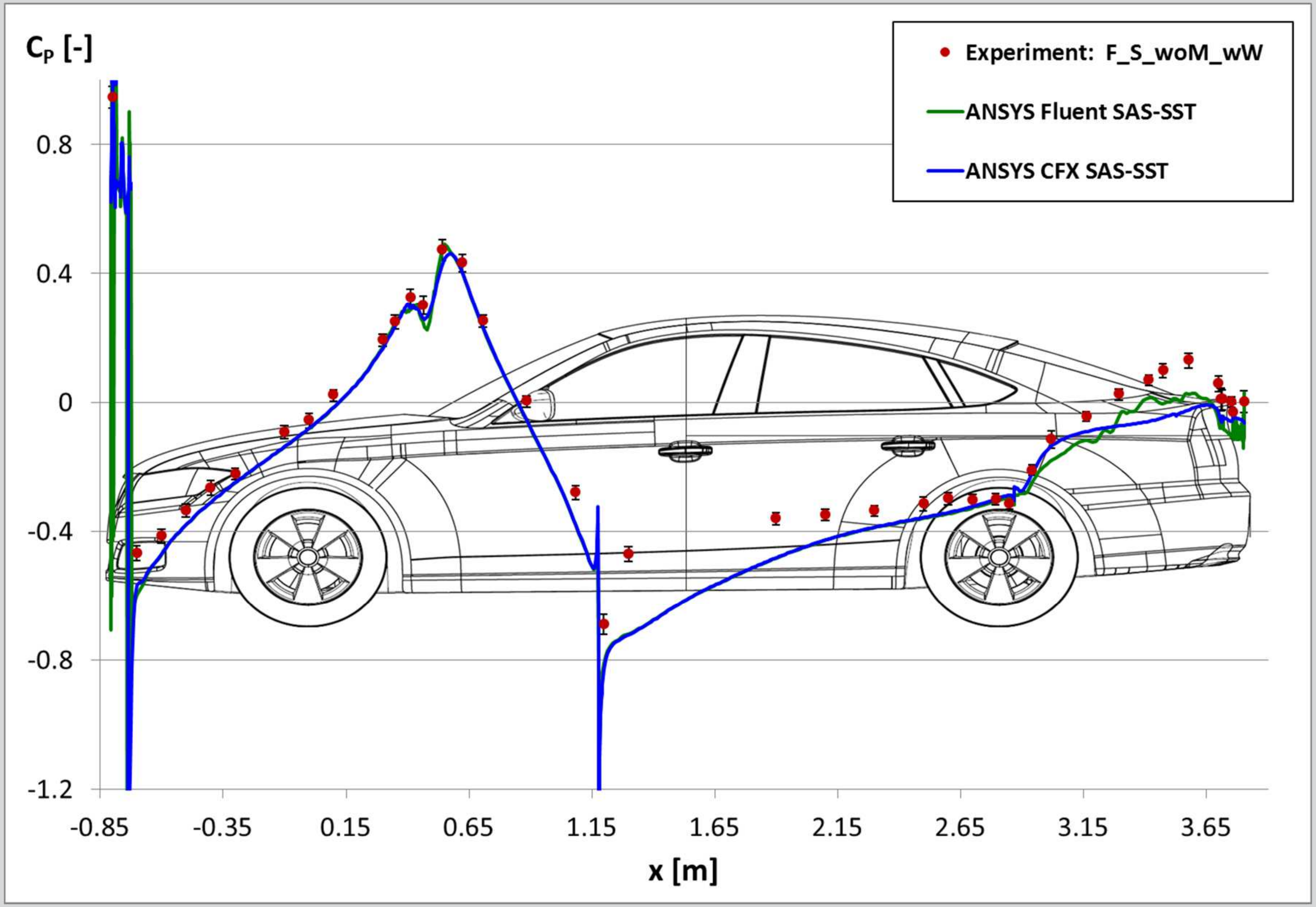
ANSYS CFD, SAS-SST – C_D Histories

Experimental data by courtesy of TU Munich, Inst. of Aerodynamics



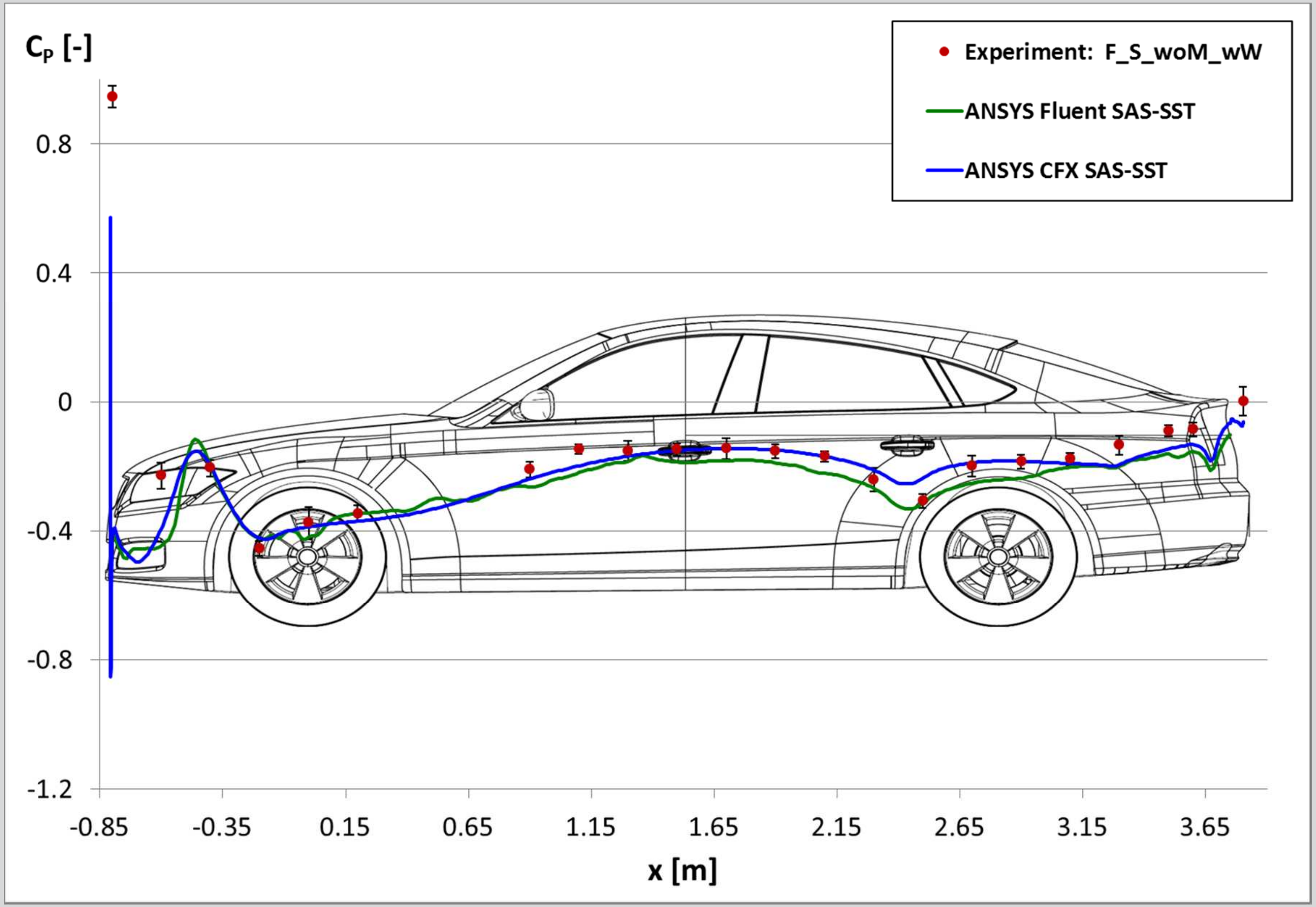
ANSYS CFD, SAS-SST – C_p at Symmetry Plane y=0mm (top)

Experimental data by courtesy of TU Munich, Inst. of Aerodynamics



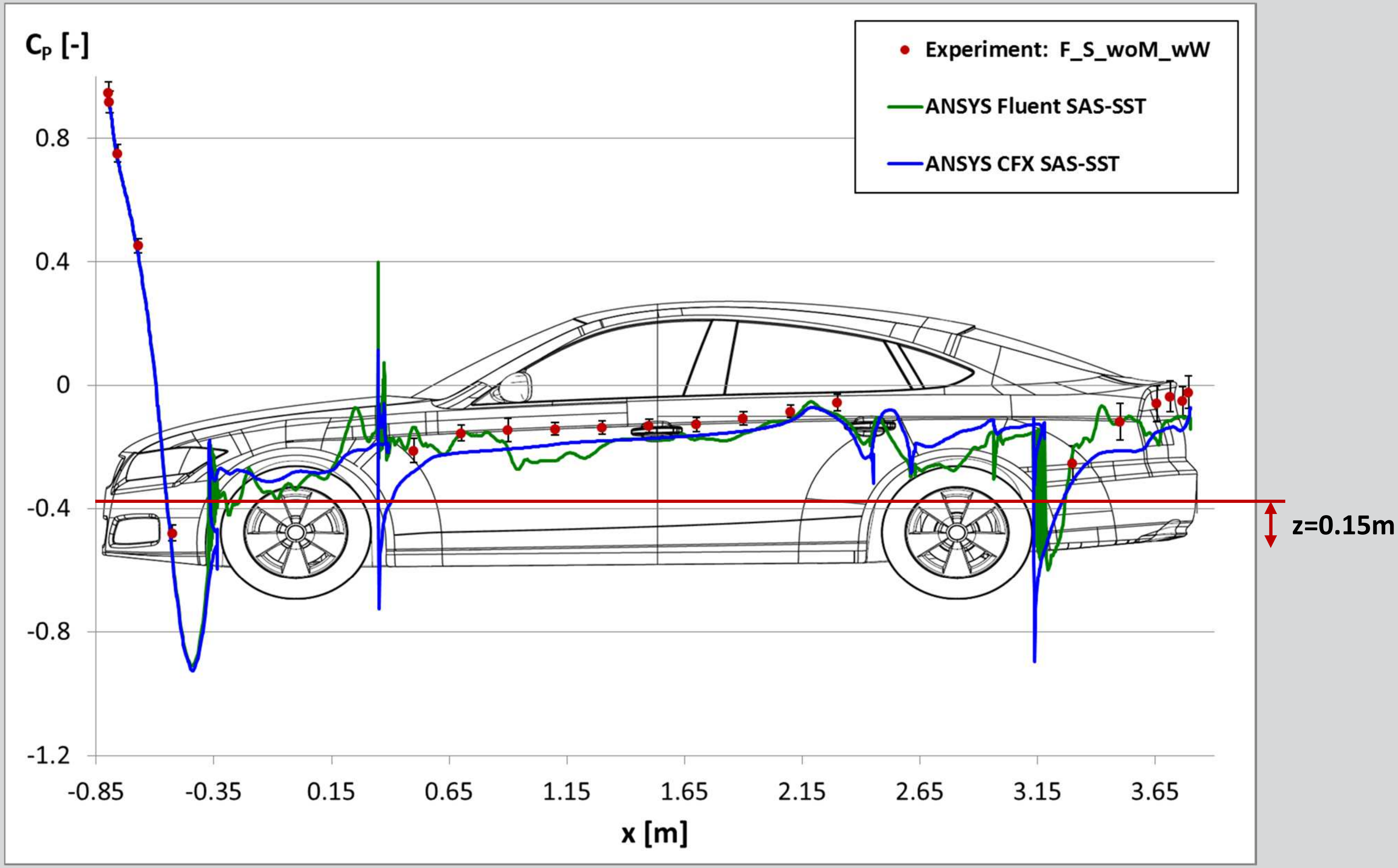
ANSYS CFD, SAS-SST – C_p at Symmetry Plane y=0mm (bottom)

Experimental data by courtesy of TU Munich, Inst. of Aerodynamics

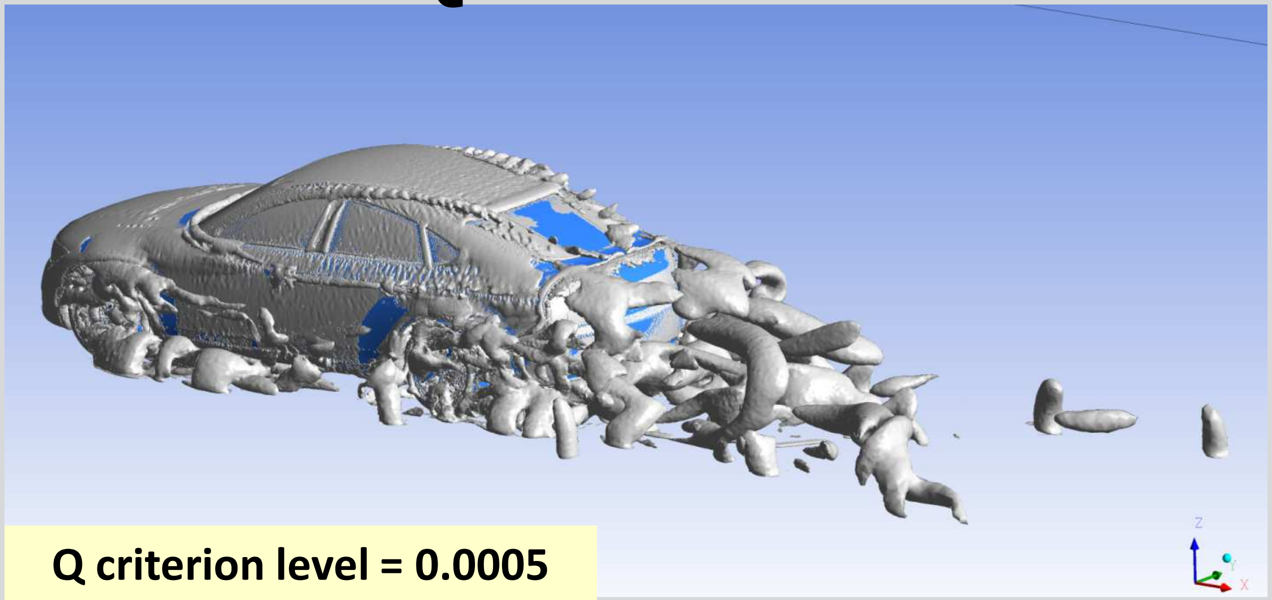


ANSYS CFD, SAS-SST – C_p at z=0.15m

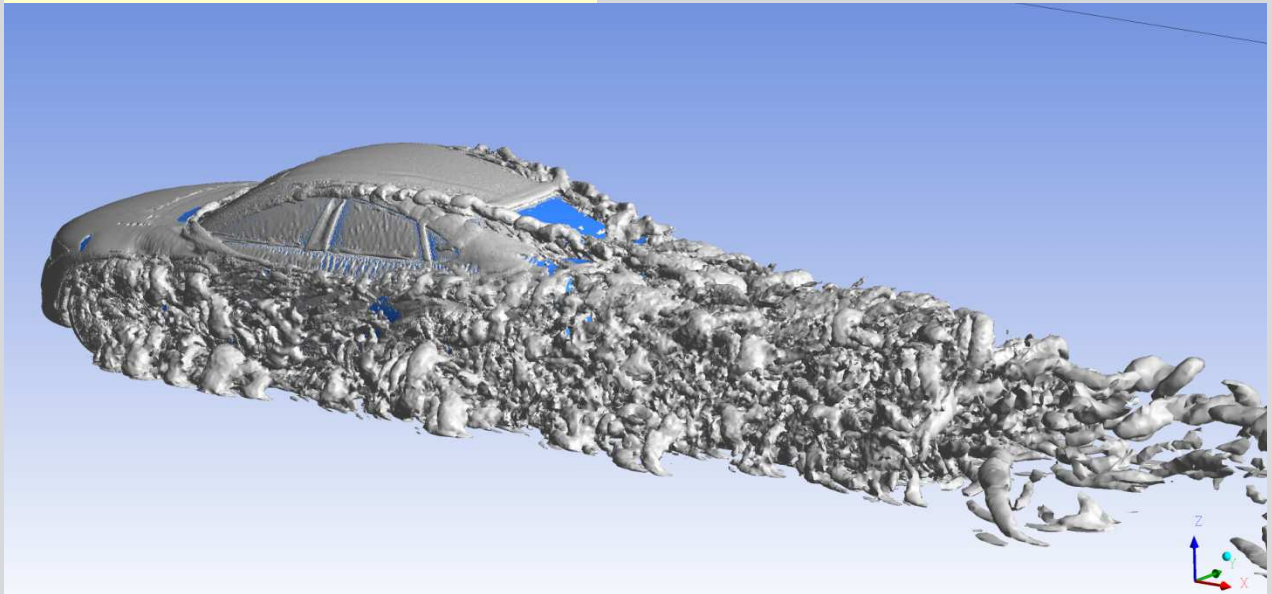
Experimental data by courtesy of TU Munich, Inst. of Aerodynamics



Comparison of Q-Criterion



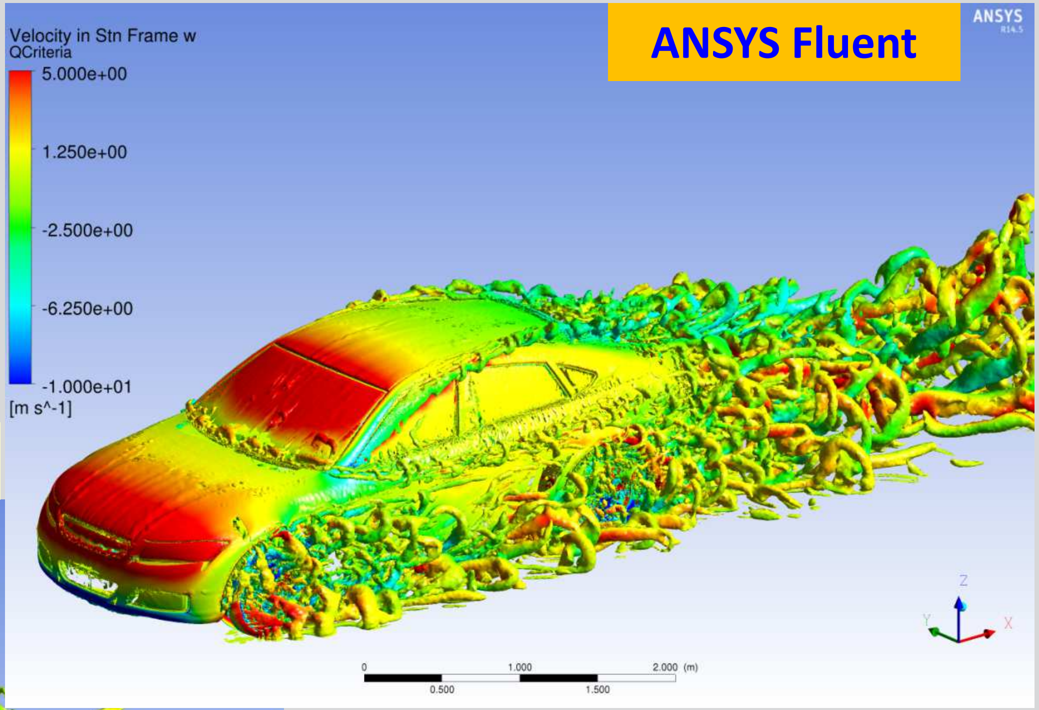
URANS SST
Δ t=0.001s
2,942 Timesteps
=> 2.942s



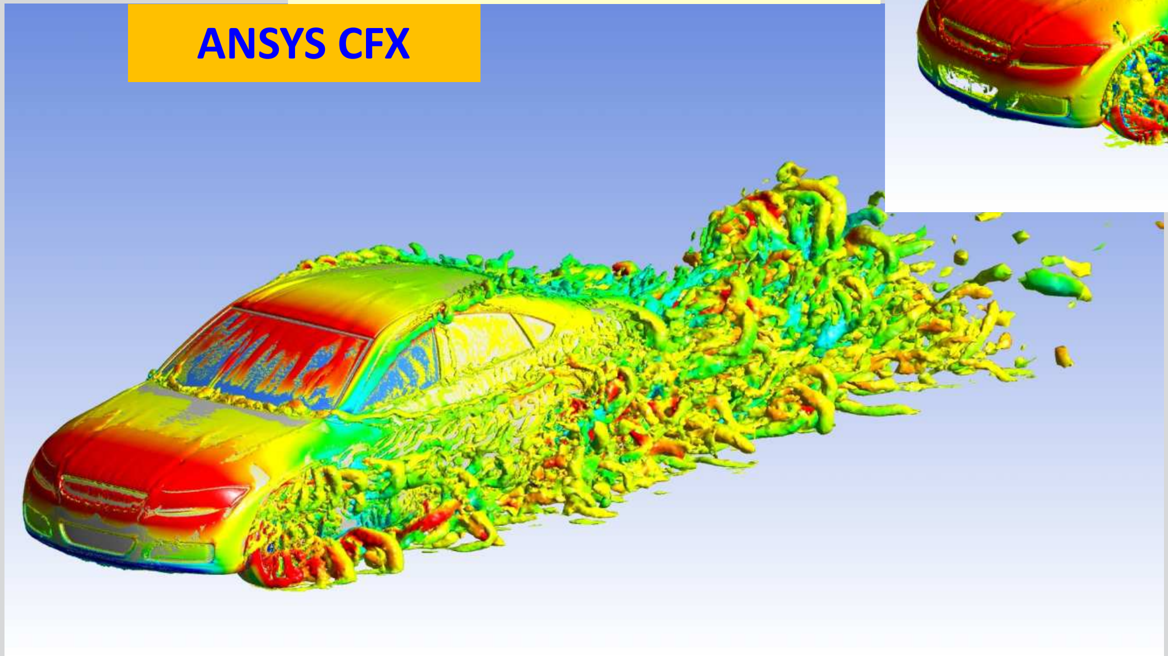
SAS-SST
Δ t=0.001s
High Resolution
1,000 Timesteps
=> 1s

Comparison of Q-Criterion

Fluent, SAS-SST
Δt=0.2 ms
15000 time steps
3.0 s total time

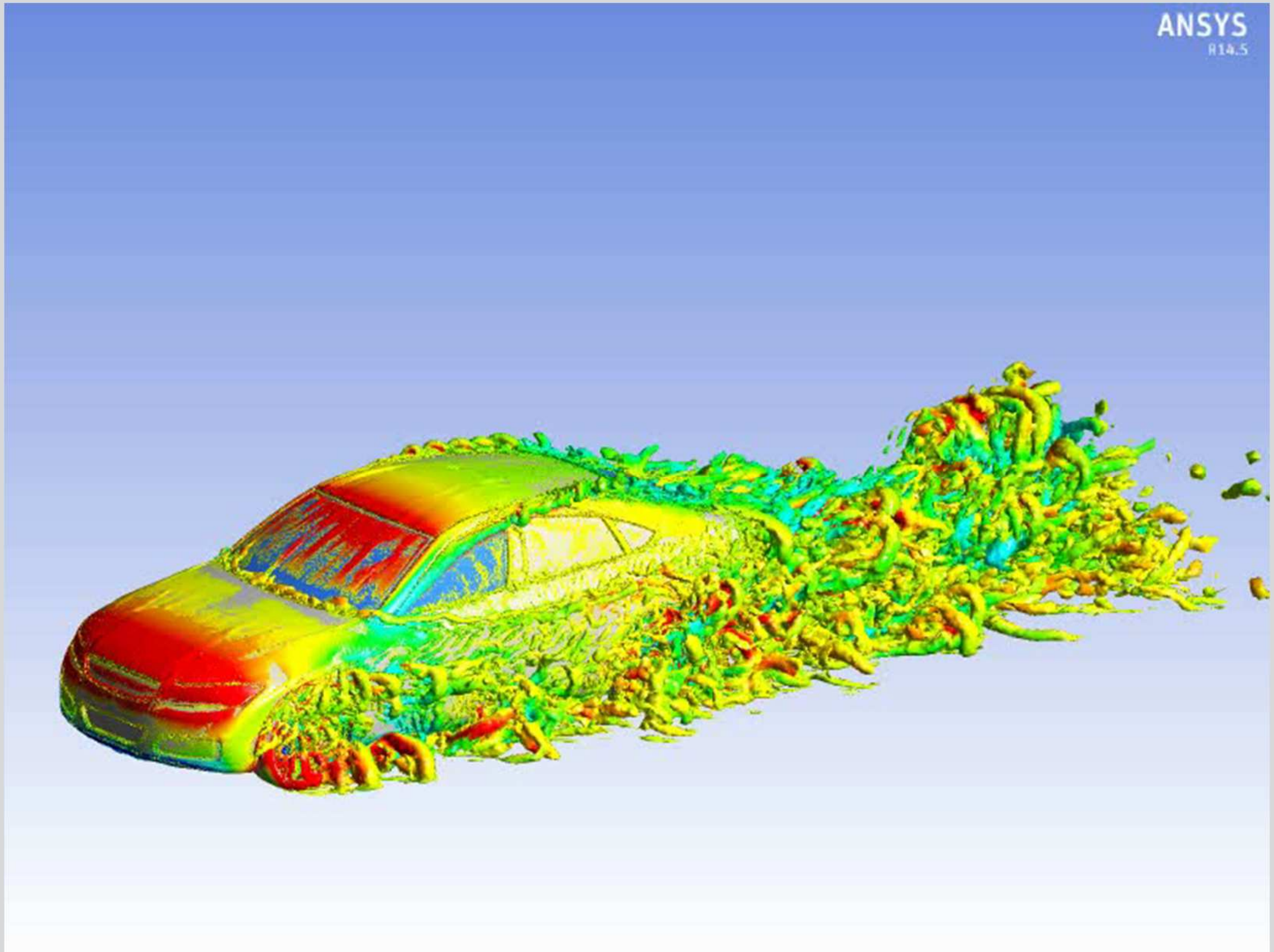


Q criterion level = 0.0005

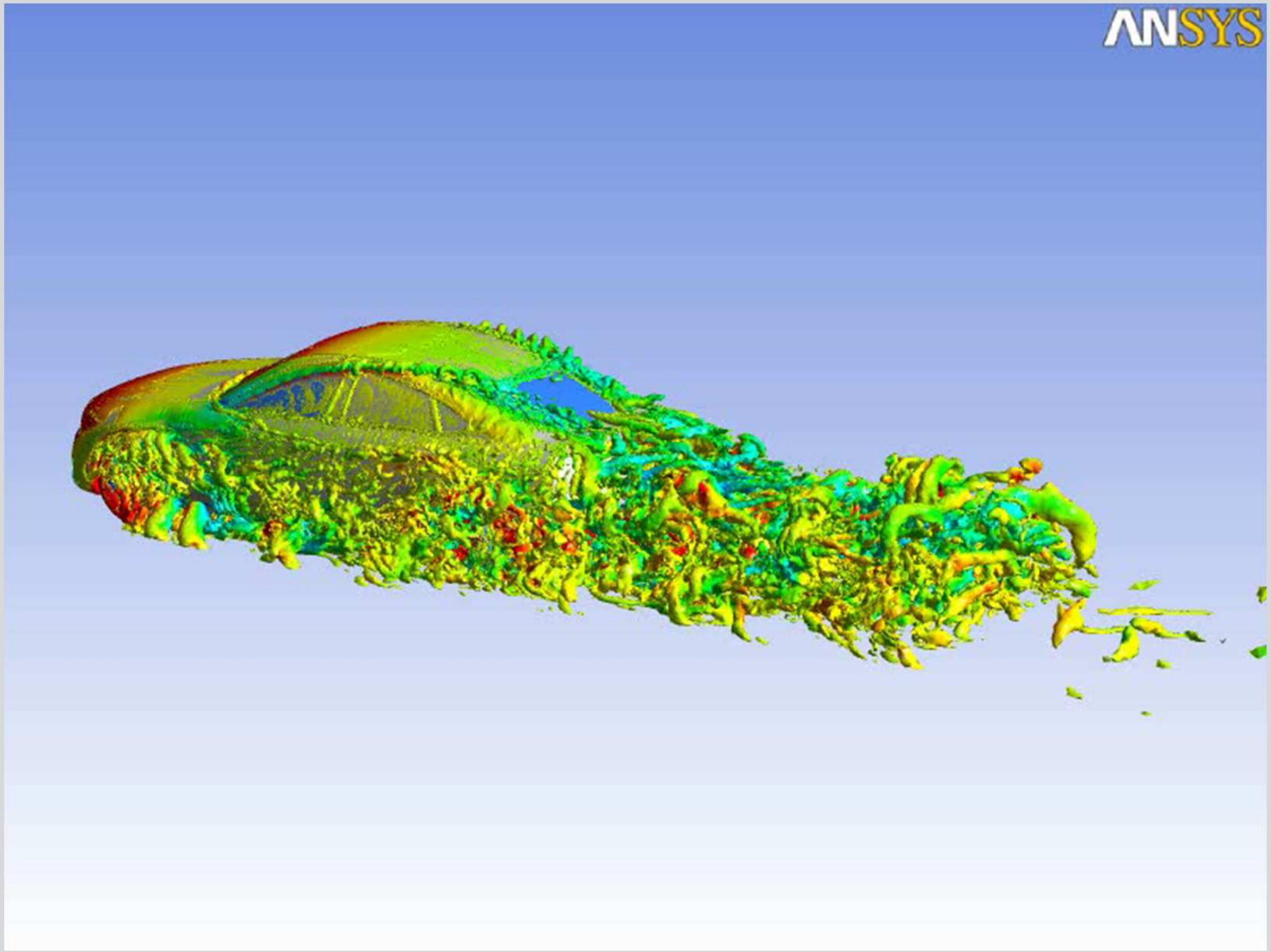


CFX, SAS-SST
Δt=0.2 ms
14419 time steps
2.884s total time

Vortex Structure from Transient Simulation, SAS-SST, Δt=0.2ms

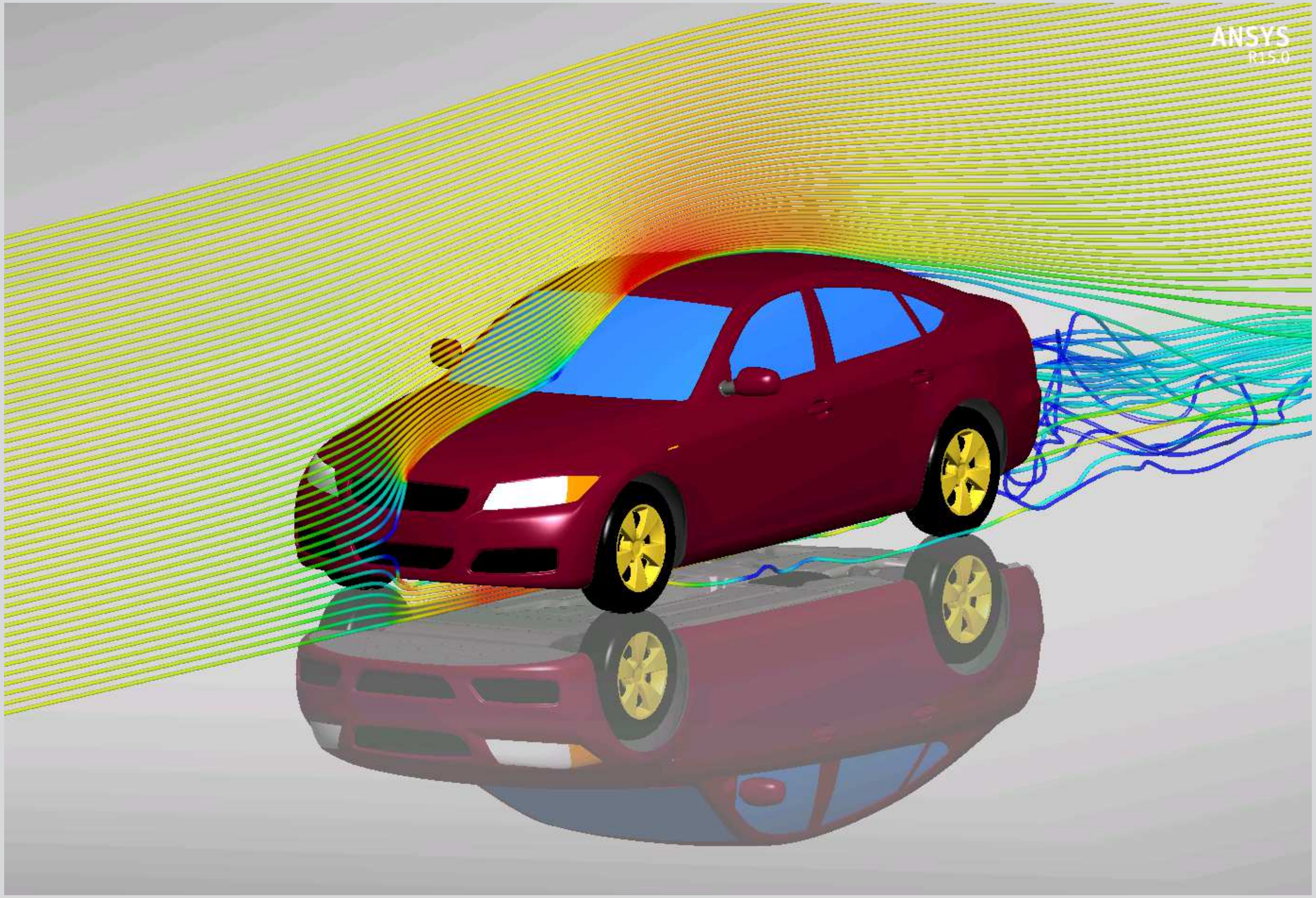


Vortex Structure from Transient Simulation, SAS-SST, Δt=0.2ms



Investigation Results F_D_wM_wW

F_D_wM_wW - Fastback_Detailed underbody_with Mirrors_with Wheels

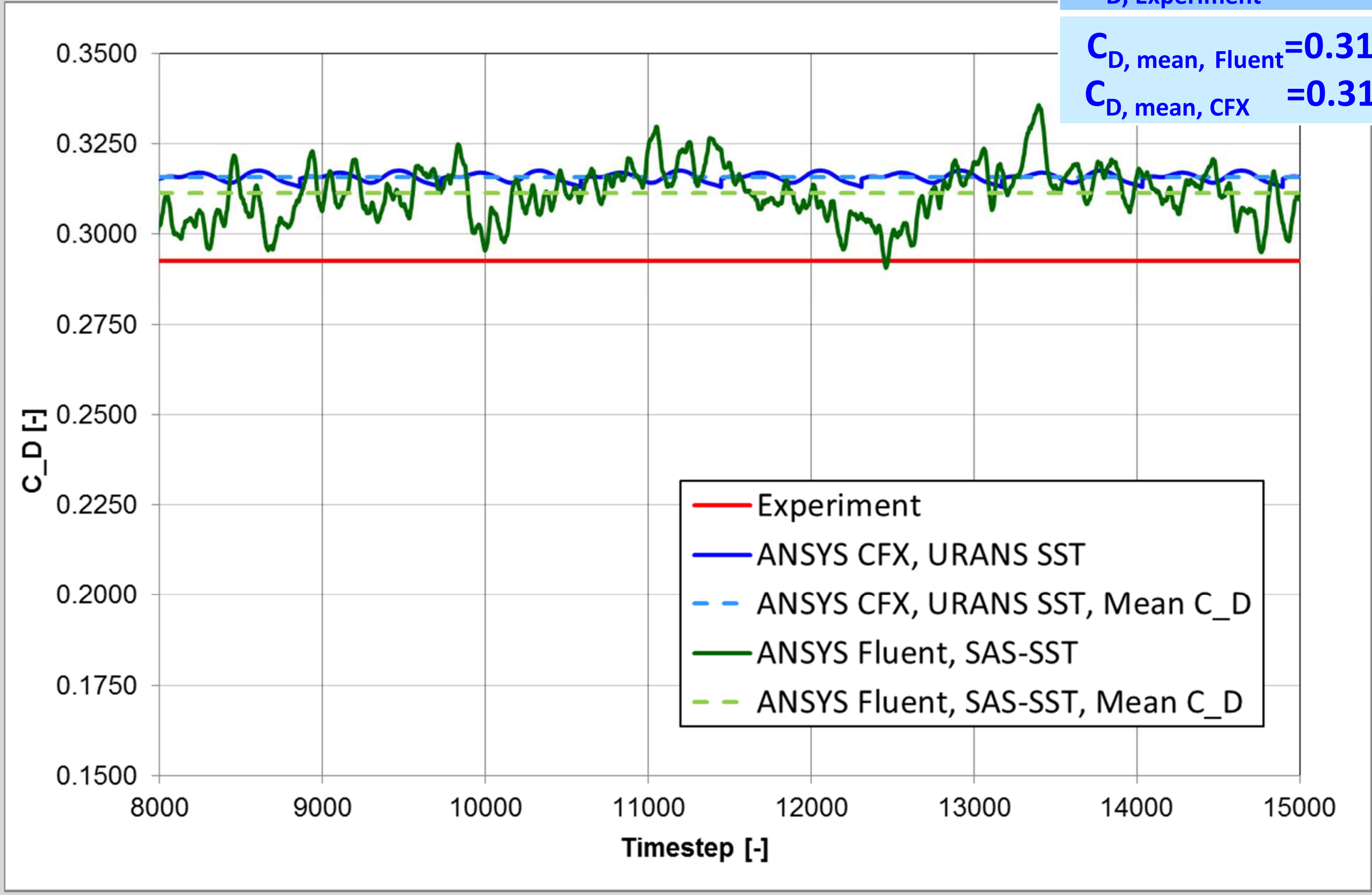


ANSYS CFD, URANS SST & SAS-SST – C_D Histories –

Experimental data by courtesy of TU Munich, Inst. of Aerodynamics

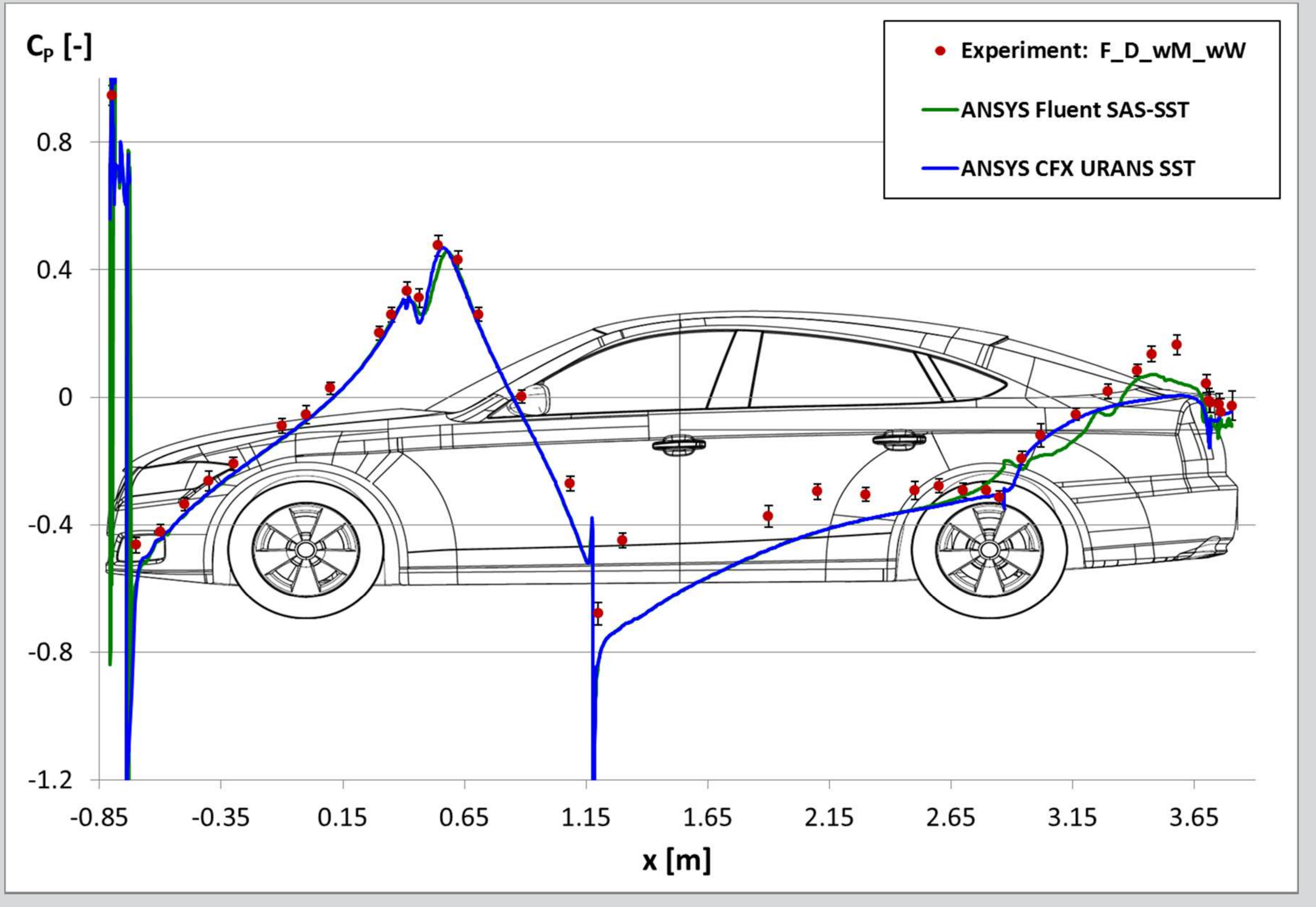
$C_{D, Experiment}$ =0.2927

$C_{D, mean, Fluent}$=0.3114
$C_{D, mean, CFX}$ =0.3158



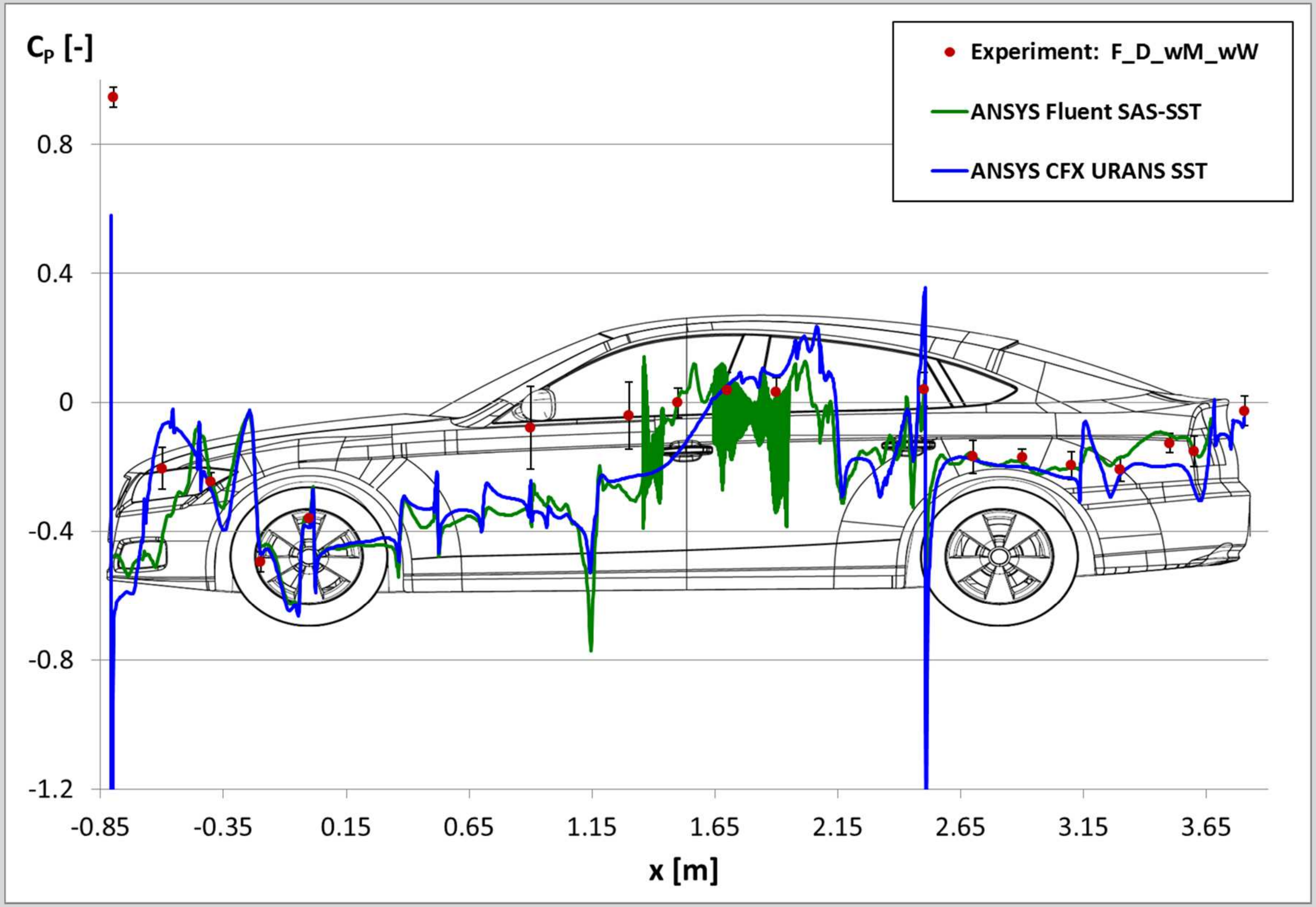
ANSYS CFD, SAS-SST – C_p at Symmetry Plane (top)

Experimental data by courtesy of TU Munich, Inst. of Aerodynamics



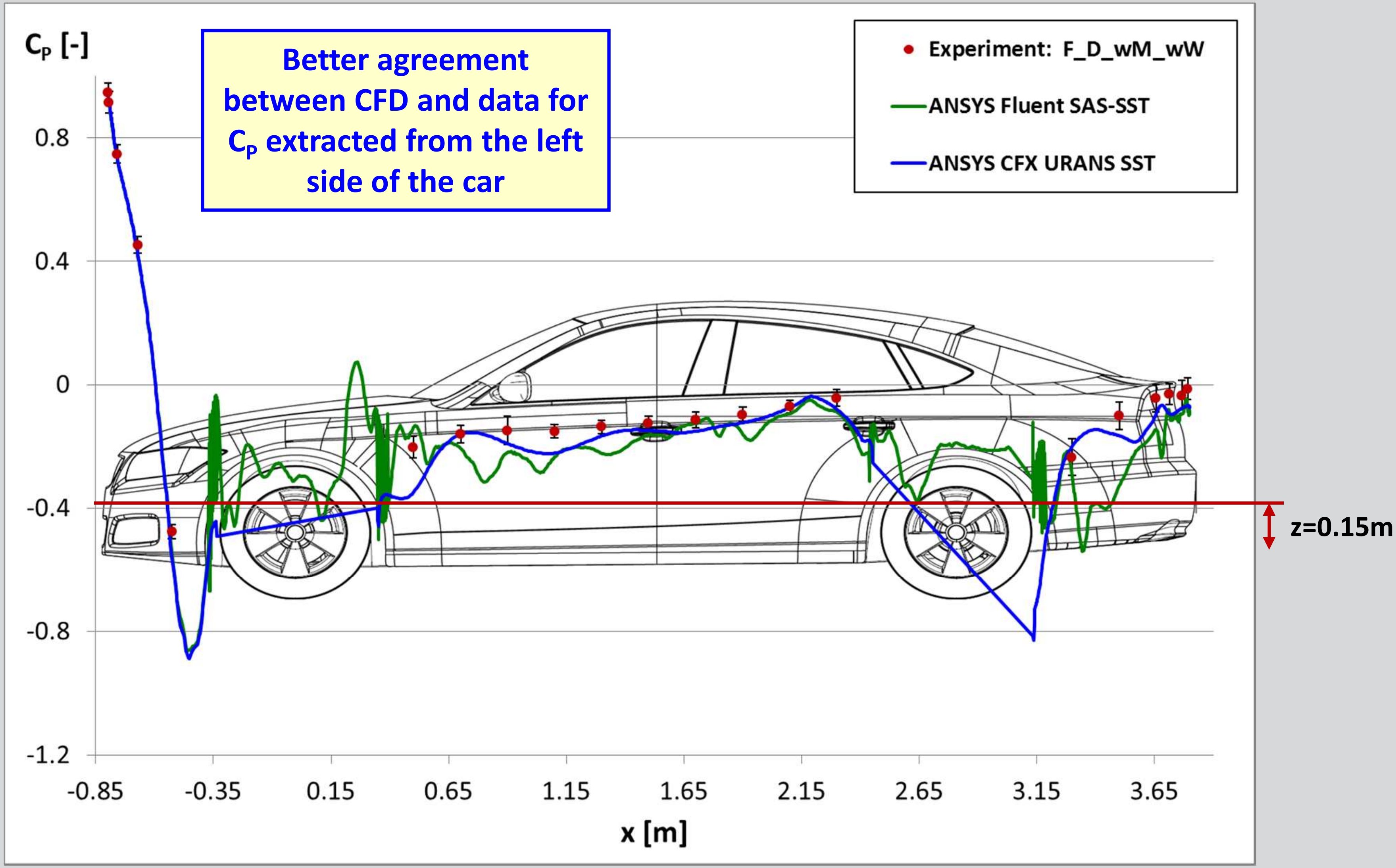
ANSYS CFD, SAS-SST – C_p at Symmetry Plane (bottom)

Experimental data by courtesy of TU Munich, Inst. of Aerodynamics



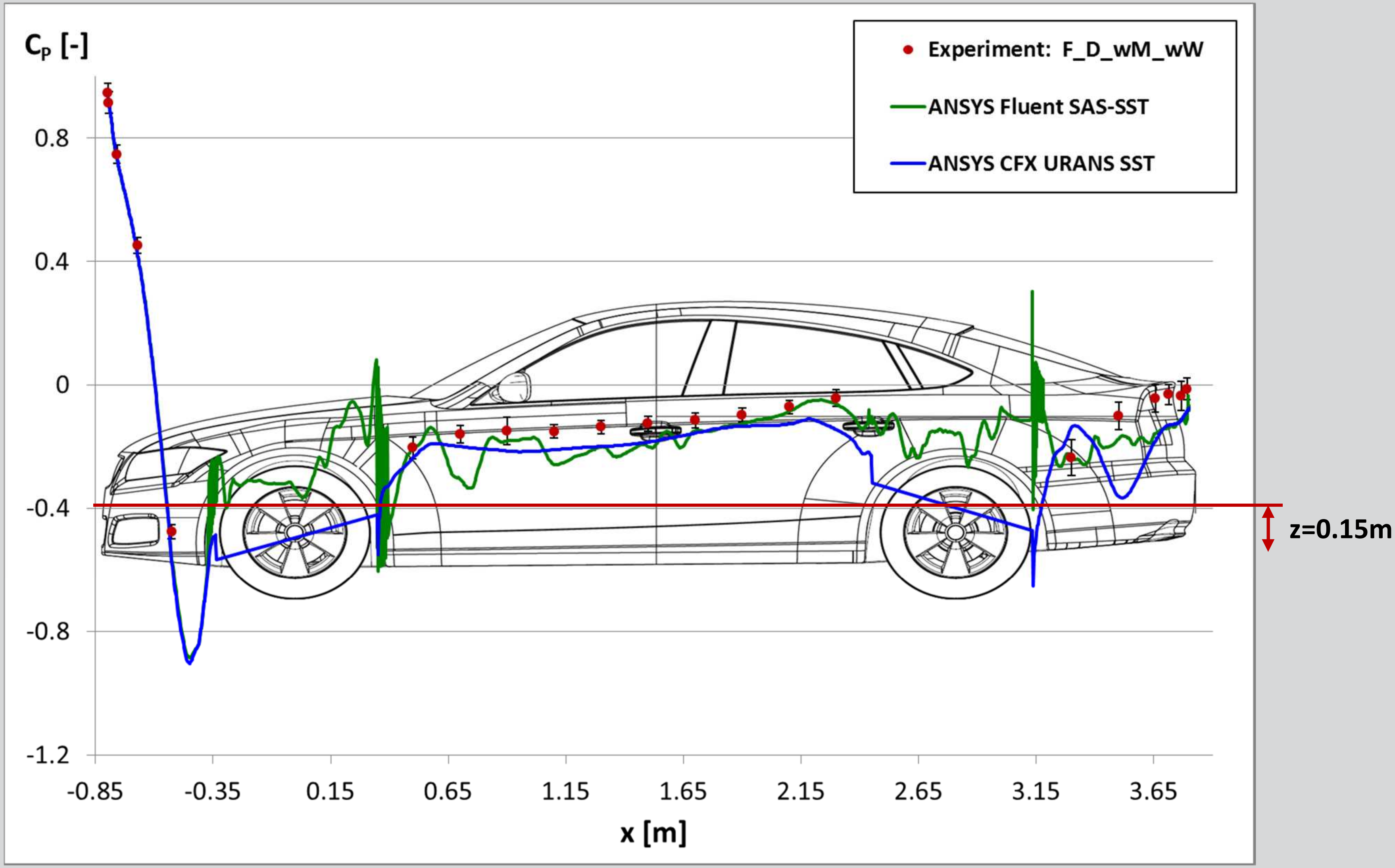
ANSYS CFD, SAS-SST – C_p at z=0.15m (left)

Experimental data by courtesy of TU Munich, Inst. of Aerodynamics

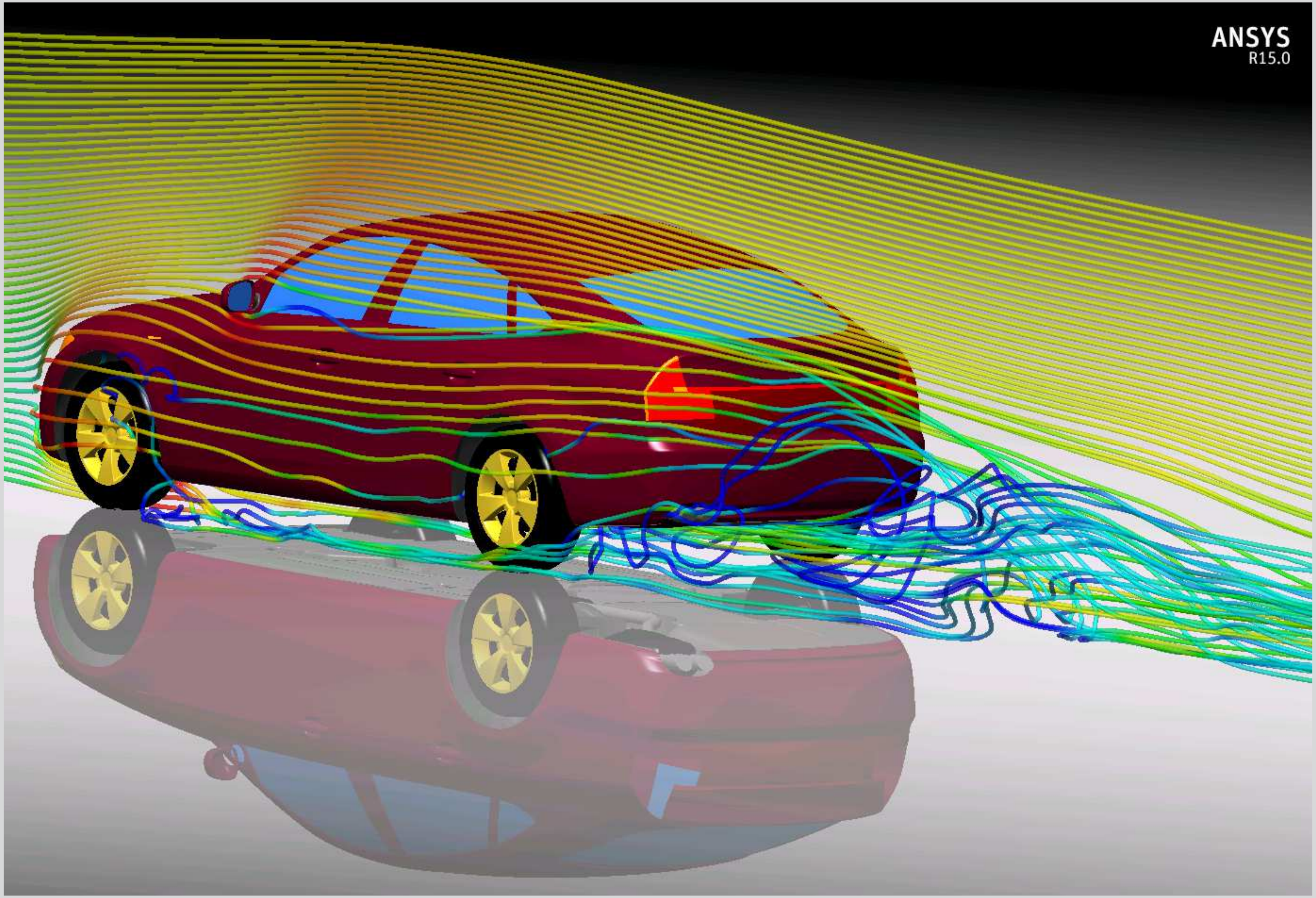


ANSYS CFD, SAS-SST – C_p at z=0.15m (right)

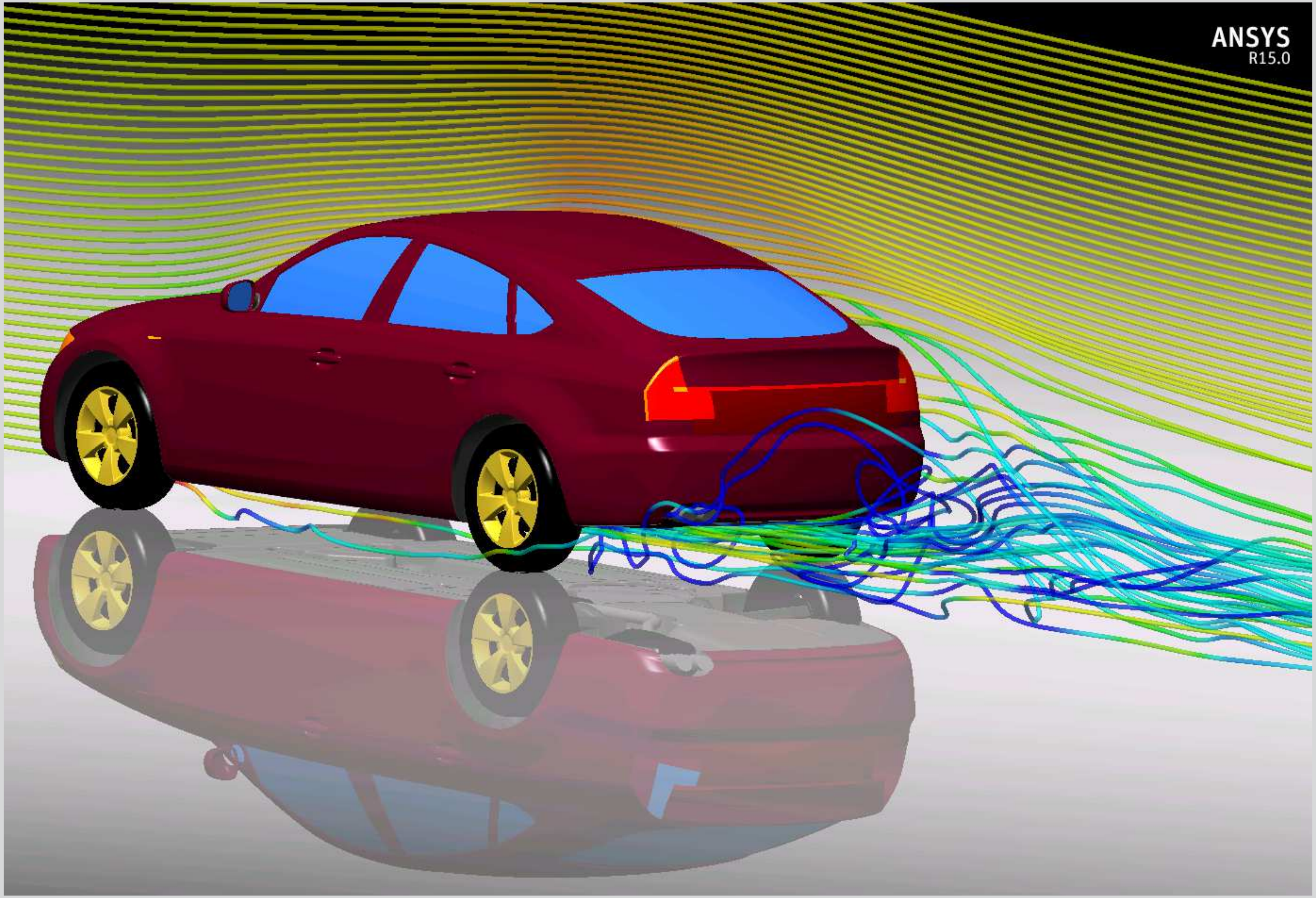
Experimental data by courtesy of TU Munich, Inst. of Aerodynamics



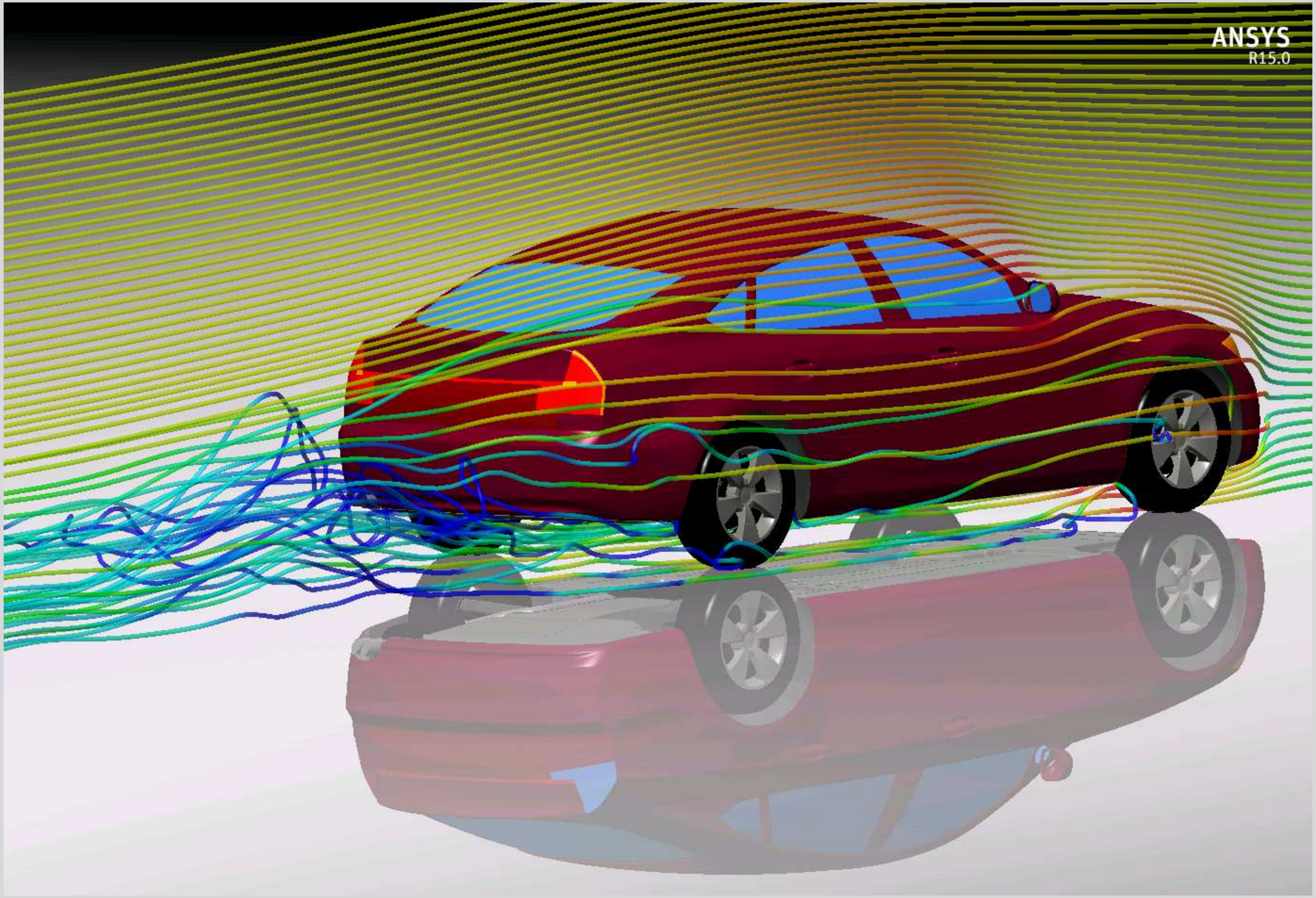
ANSYS CFX, URANS SST, Δt=0.2ms – Asymmetric wake –



ANSYS CFX, URANS SST, Δt=0.2ms – Asymmetric wake –

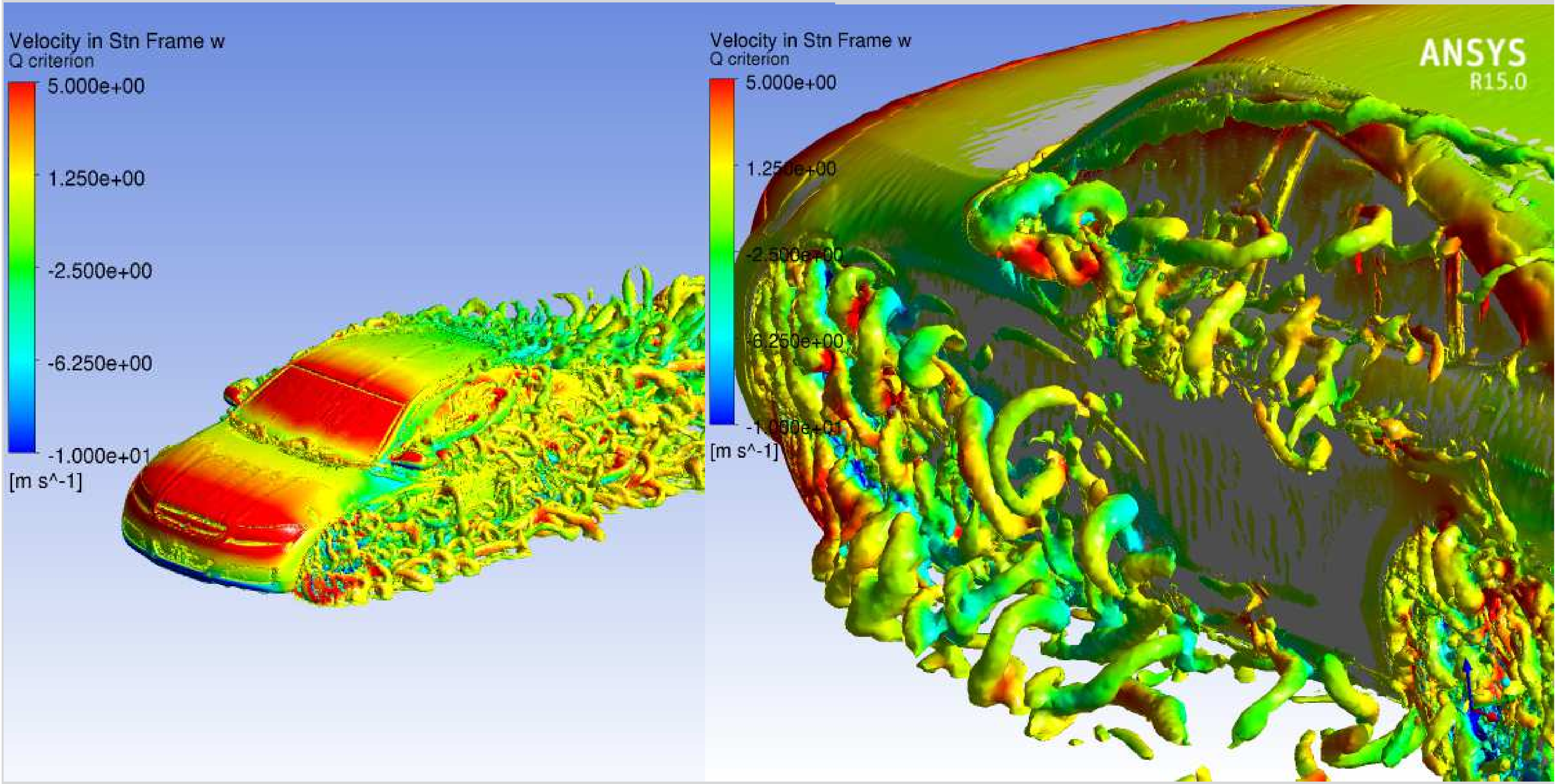


ANSYS CFX, URANS SST, Δt=0.2ms – Asymmetric wake –



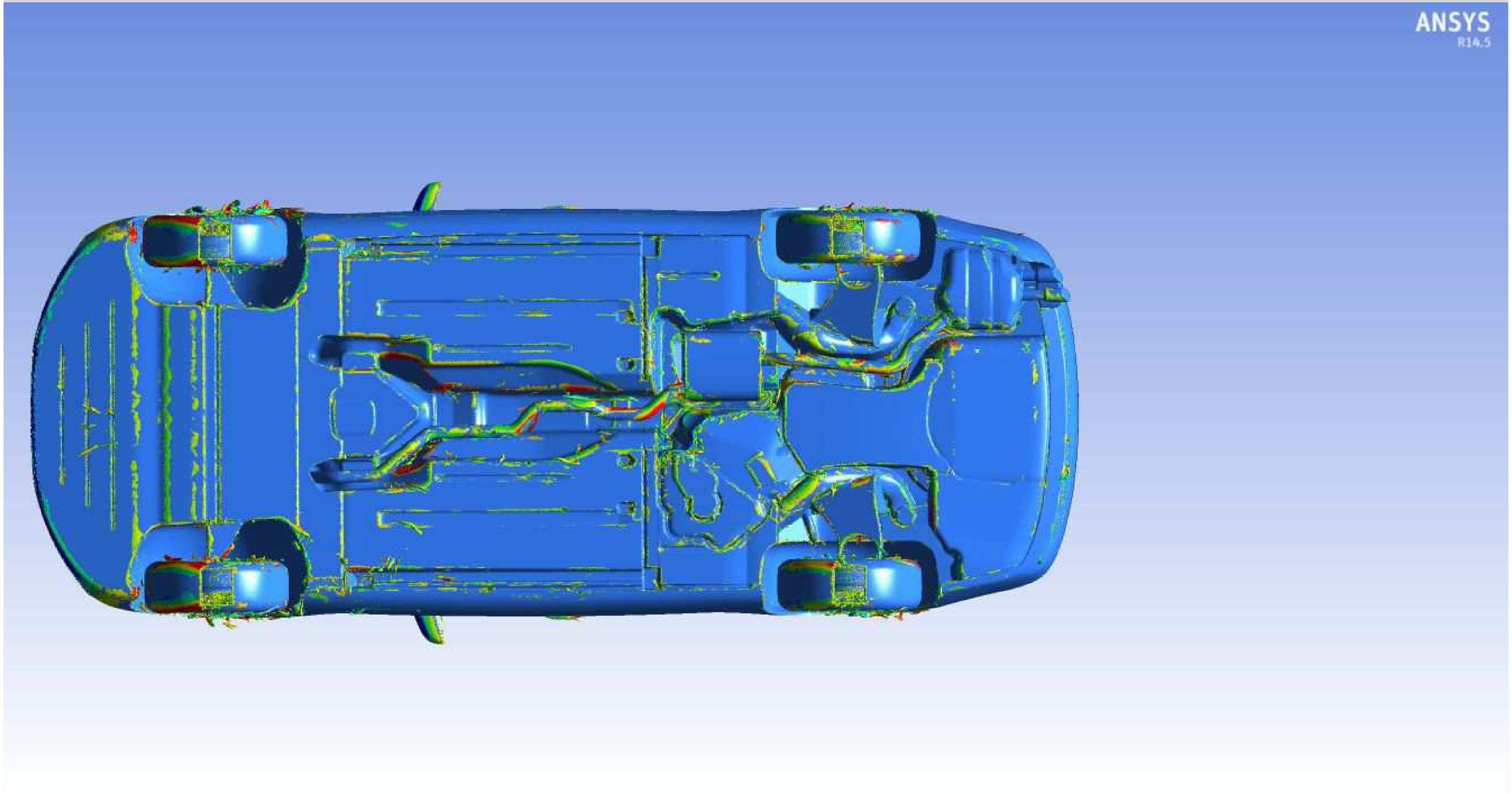
ANSYS Fluent SAS-SST, Δt=0.2ms – Q-Criterion Isosurfaces –

Q criterion level = 0.0005



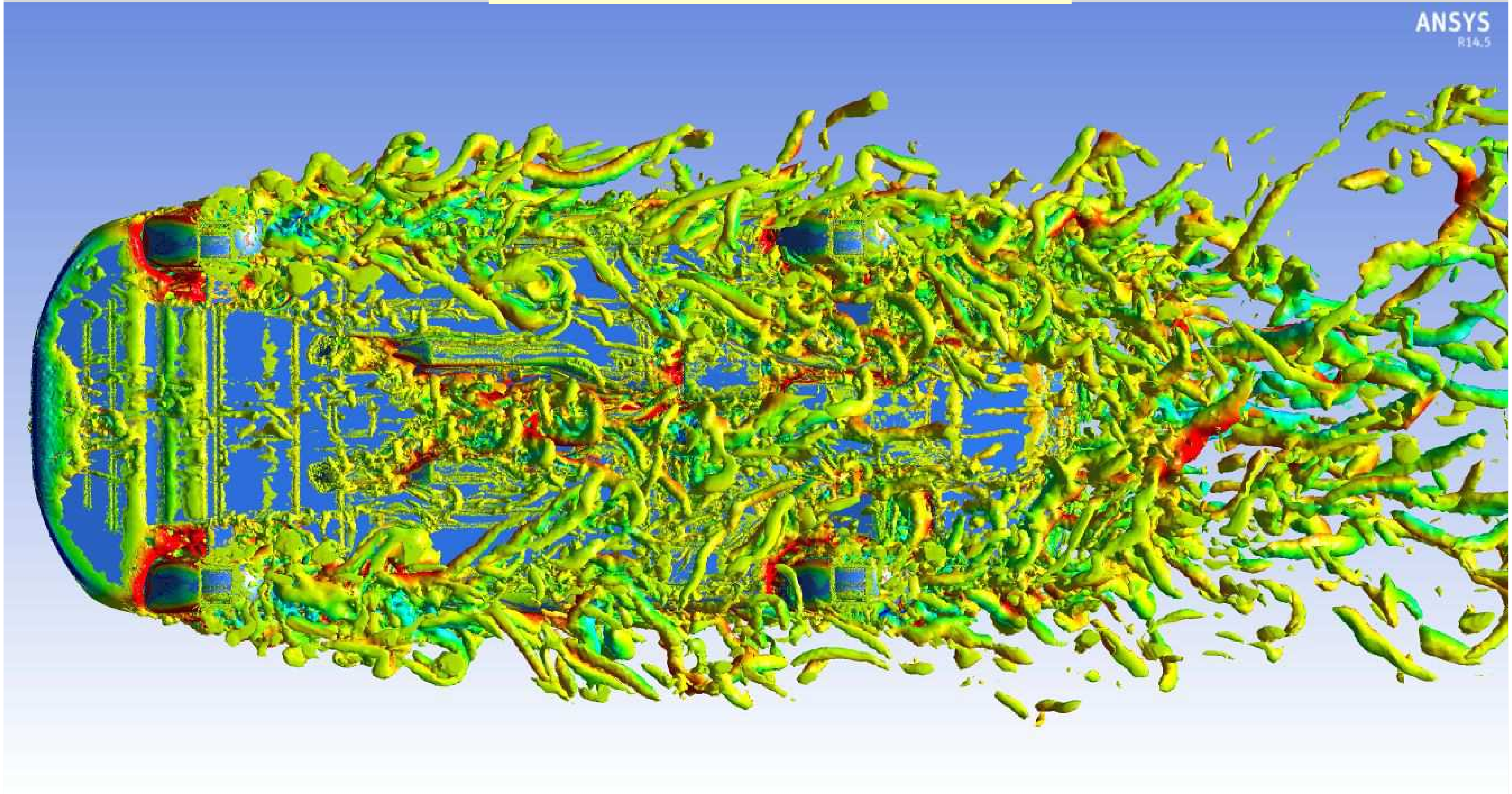
ANSYS Fluent SAS-SST, Δt=0.2ms

Lambda-2 criterion level = 0.01
Bottom view of F_D_wM_wW



ANSYS Fluent SAS-SST, Δt=0.2ms

Lambda-2 criterion level = 0.001
Bottom view of F_D_wM_wW



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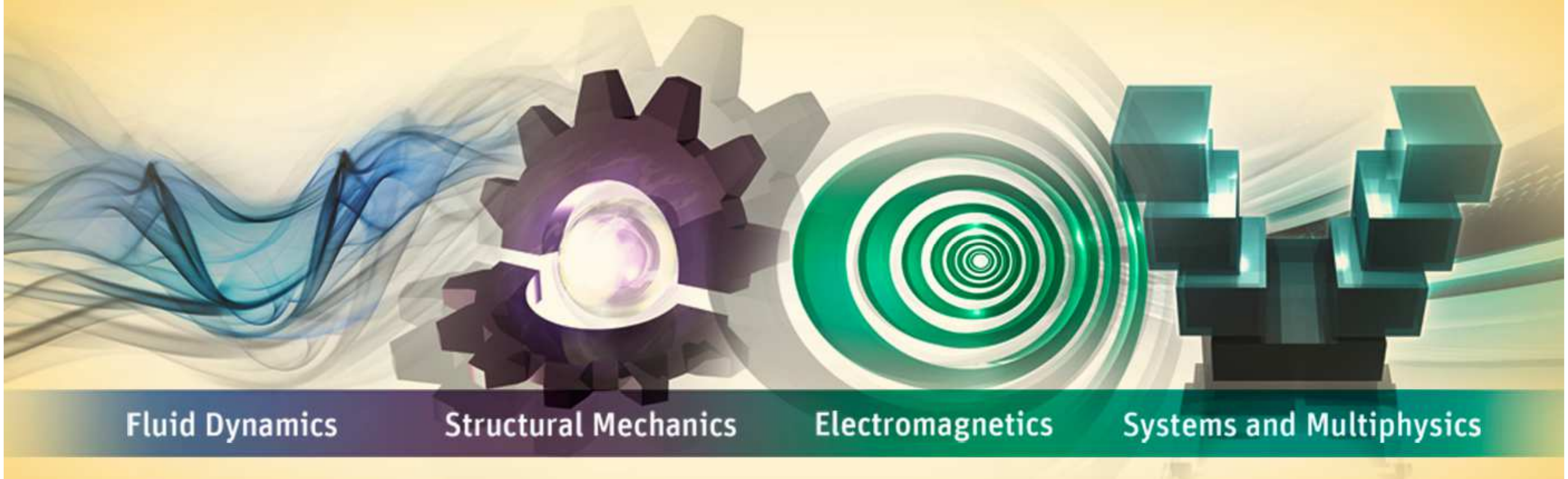
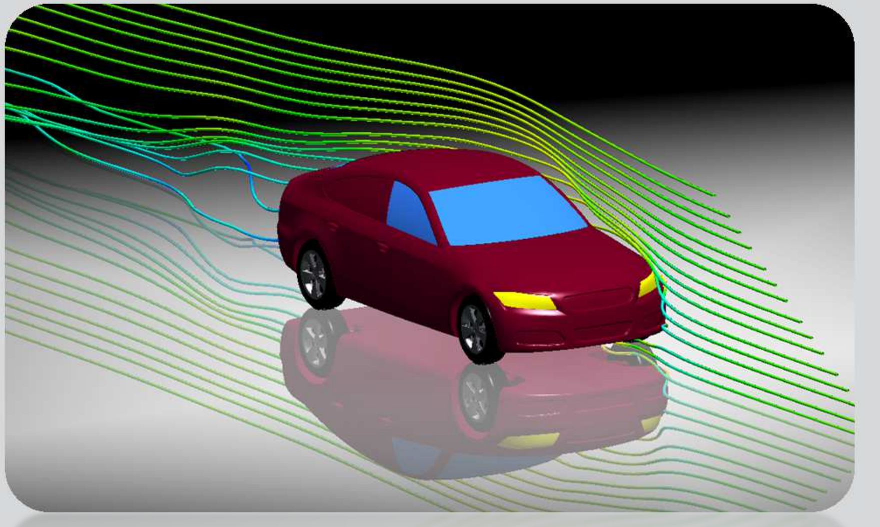
Summary & Conclusions



Summary & Outlook



- Simulating the DrivAer car is first of all a meshing challenge!
- Established a meshing process, where ANSYS TGrid in Fluent 14.5 and direct CAD model tessellation was applied
- Three different DrivAer cars meshed and simulated
  → (U)RANS SST and SAS-SST comparison
- Applied feasible amount of CFD best practice related investigations:
  - mesh and timestep dependence
  - iteration error → convergence
  - steady vs. transient
  - (U)RANS vs. scale-resolving turbulence modeling

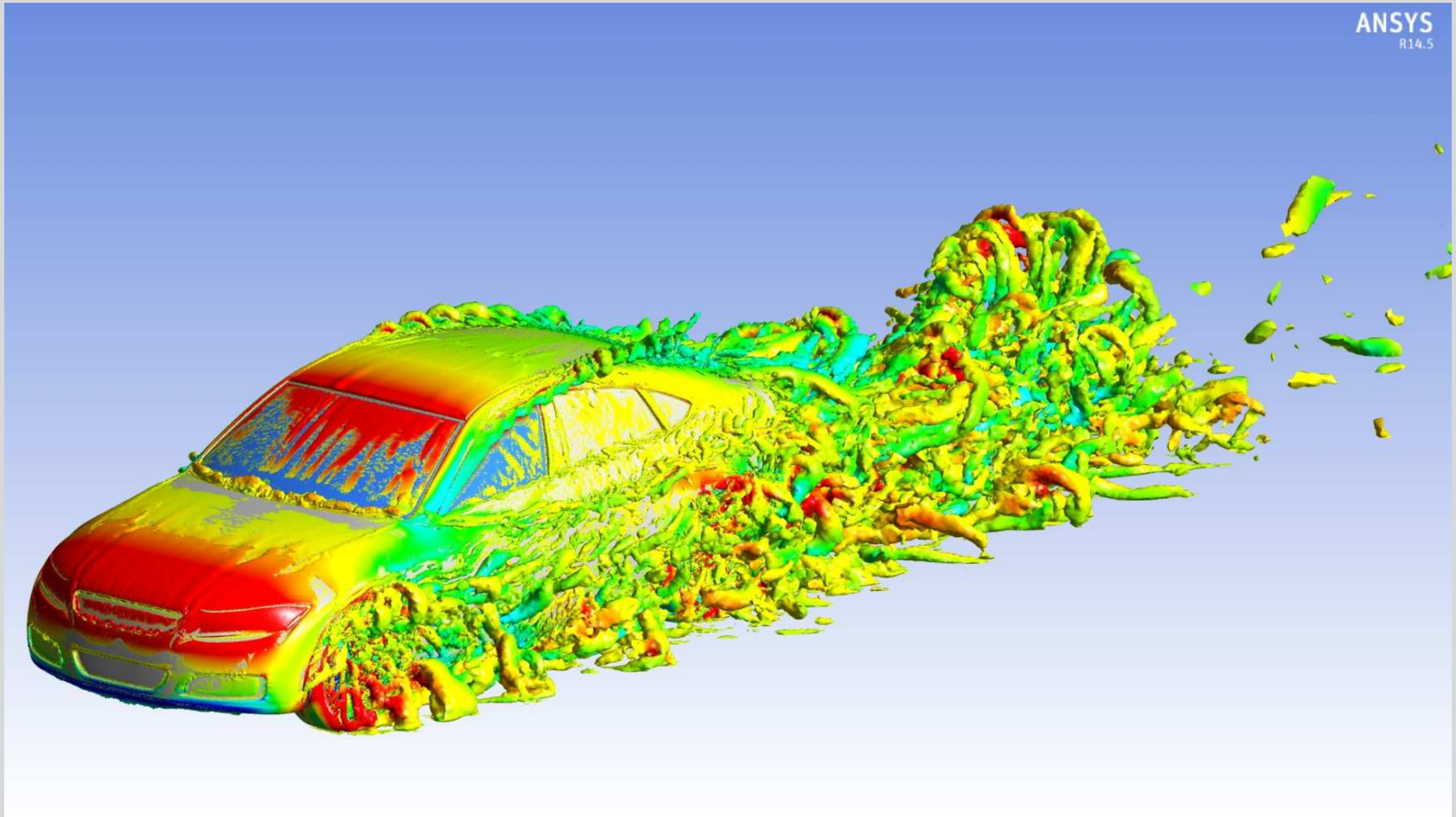
Summary & Outlook (cont.)

- Reasonable good agreement for C_P value comparison to data
- Influence from the model support system (MSS) on C_P on the top of the car roof observable
- Differences at point of vortex impingement in the rear of the car

- CFD predicted slightly higher C_D values in comparison to data
  - Influence from wind tunnel geometry
  - Quite high blocking ratio for this large model in TUM wind tunnel
  - Influence from road simulator vs. entirely moving road (CFD)

  → Desirable to have PIV data for flow field comparison
- Good and very consistent comparison between ANSYS CFX and ANSYS Fluent for investigated DrivAer car models
- Further streamlining and refinement of the ANSYS TGrid in Fluent based meshing process possible
  → e.g. longer extension of refined zones behind the car

Questions?



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