CFturbo®

Several Examples of Turbomachinery Design and CFD-Simulation using **CFturbo® and STAR CCM+**

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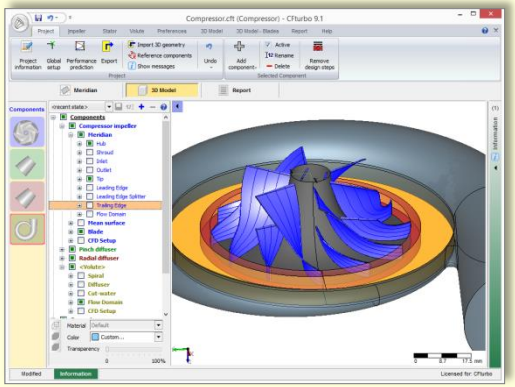
Company

CFturbo® Software & Engineering GmbH

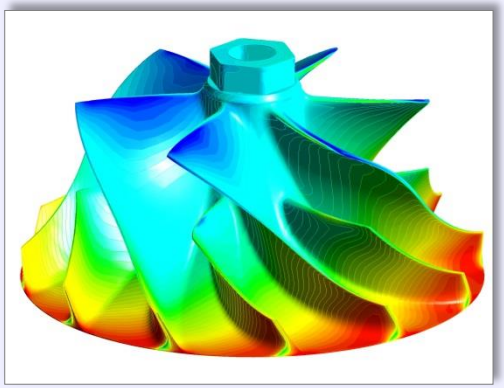
CFturbo® Software

- Turbomachinery Design Software
- Automated Workflows



Engineering

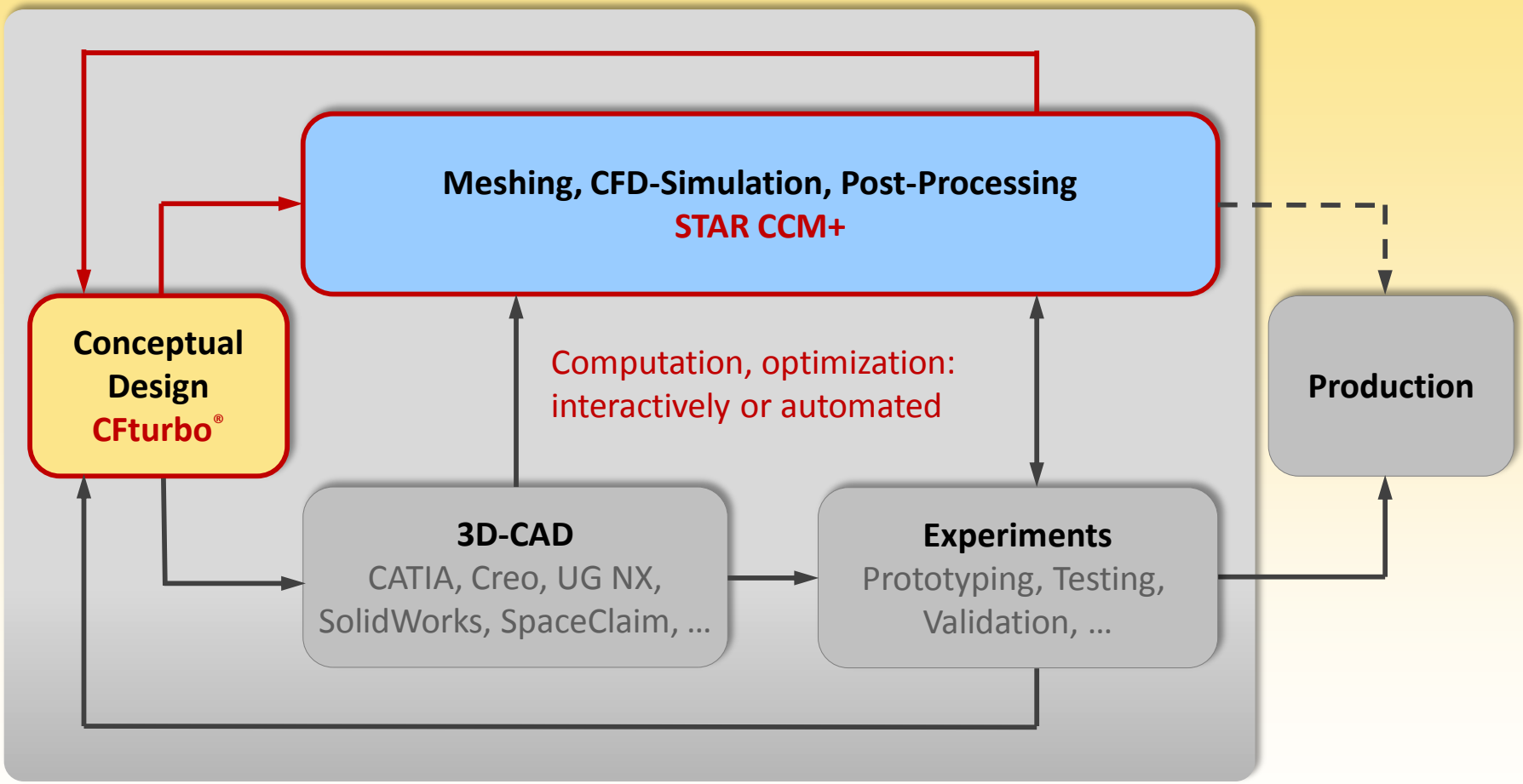
- Turbomachinery Conceptual Design
- CFD/FEA Simulation
- Optimization



CAD & Prototyping

- 3D-CAD Modeling
- Prototyping
- Testing, Validation

Turbomachinery Design Process



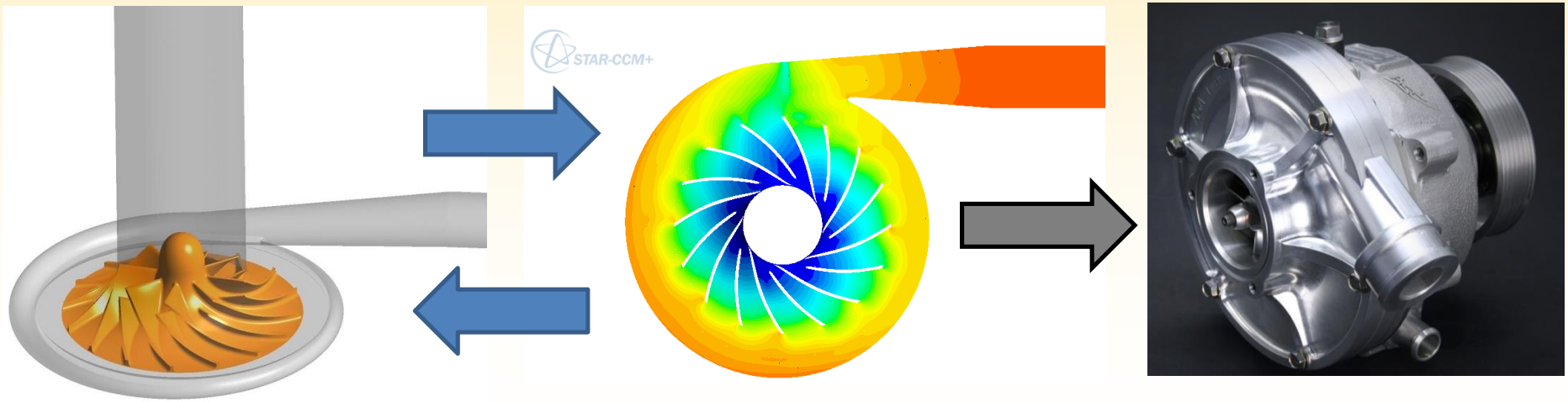
Manual „Optimization“ Workflow

Transsonic Radial Compressor
Traditional common workflow: 5 … 25 model variations, 1 to 4 weeks,

Design point (BEP)

Total pressure ratio:	$\Pi_{tt} = 4$
Mass flow rate:	$\dot{m} = 0.11$ kg/s
Speed:	$n = 90.000\ min^{-1}$
Power (limitation):	$P_m < 30$ kW

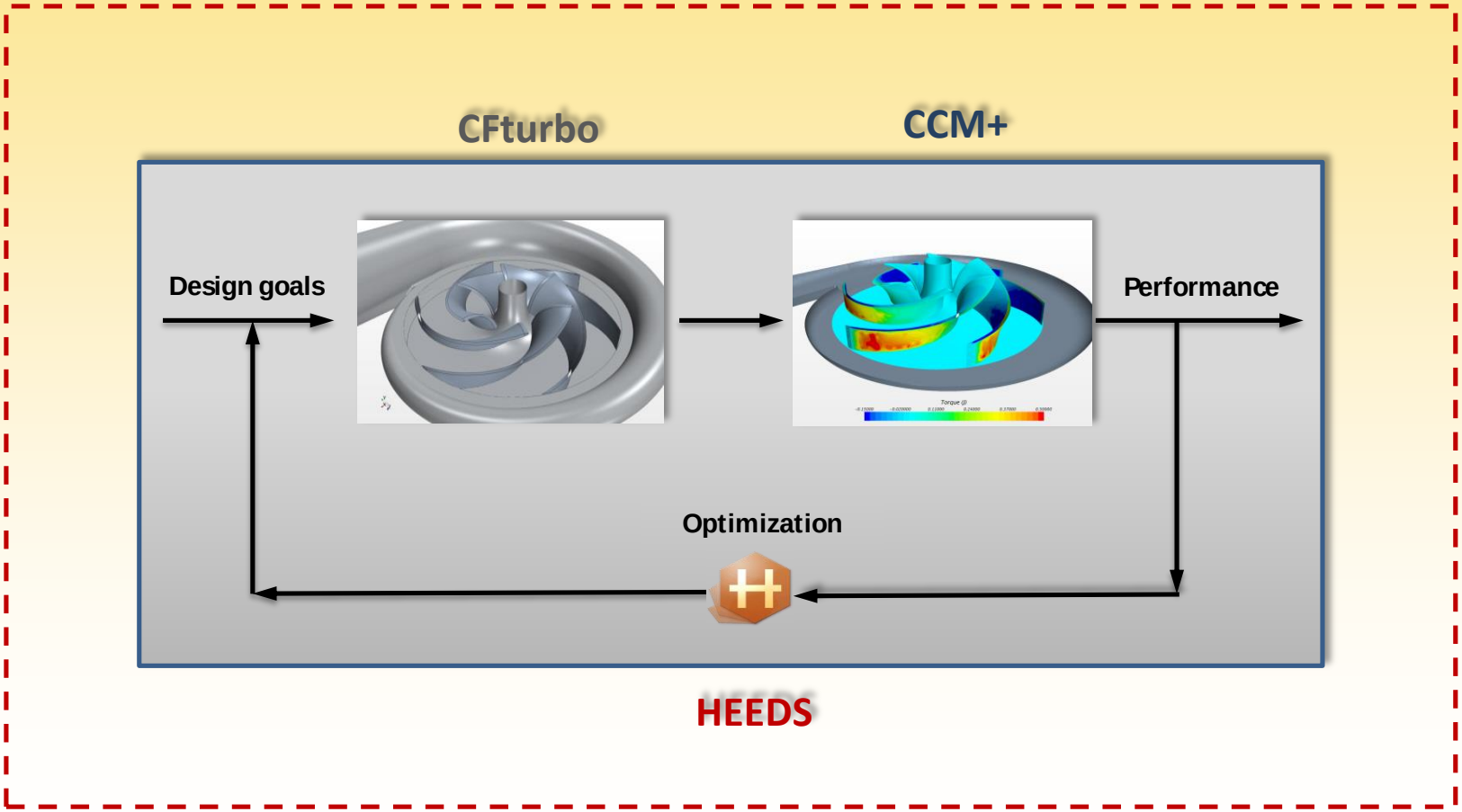
20 Designs **20 Performance Curves** **1 Prototype**



Automated Optimization Workflow Available

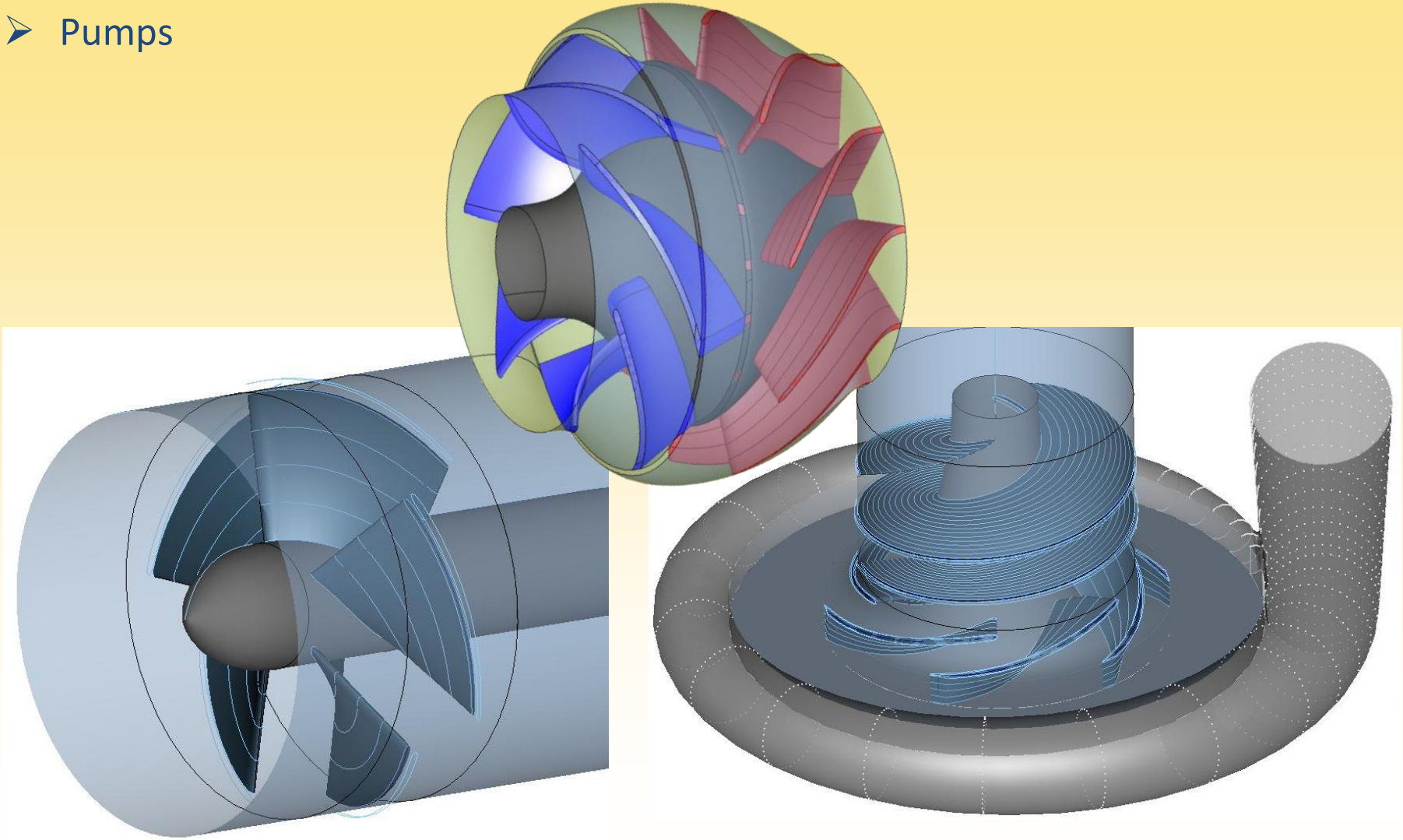
Centrifugal Pump Impeller Optimization

300 automated model variations, time & cost depending on available resources



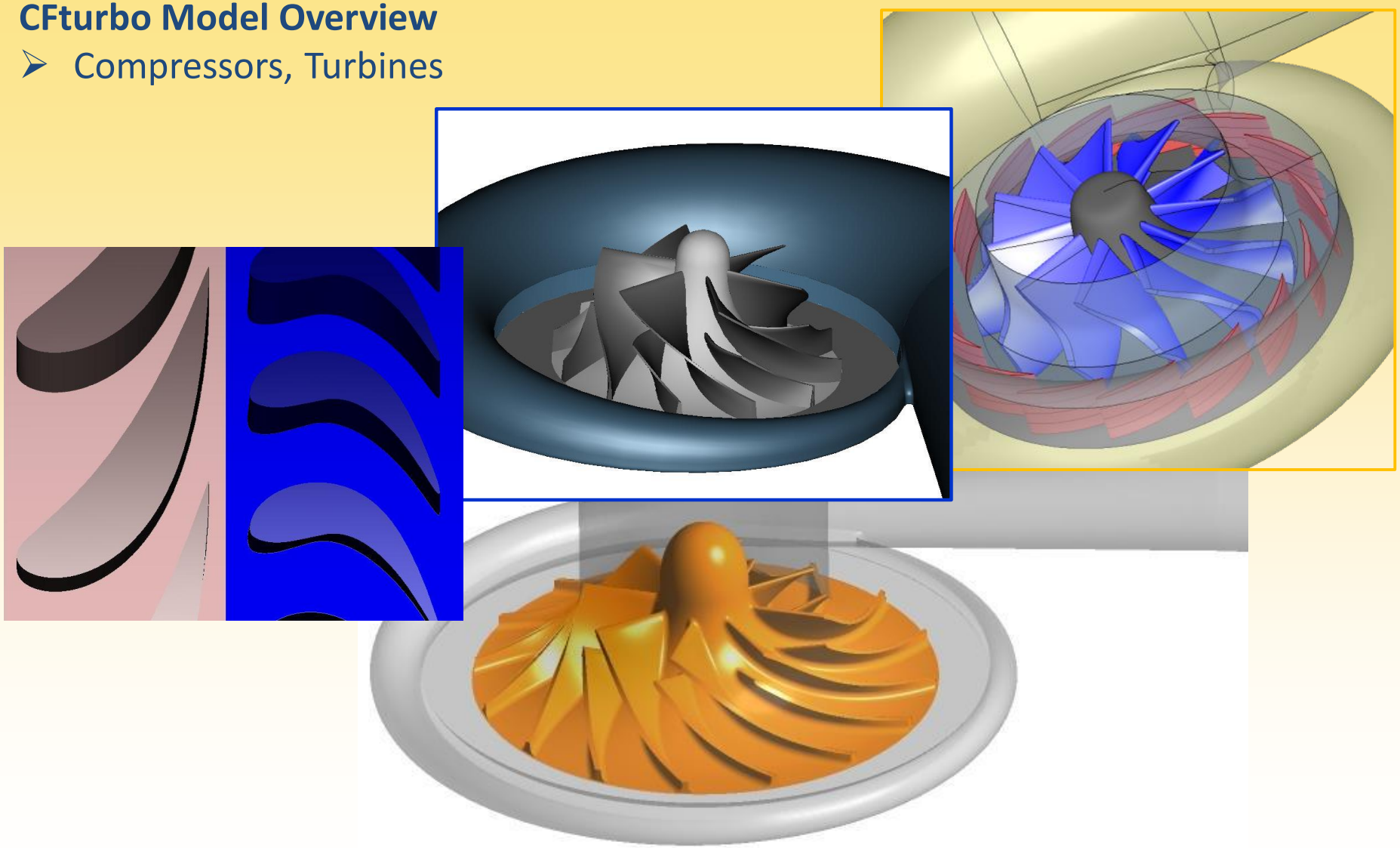
CFturbo Model Overview

- Pumps



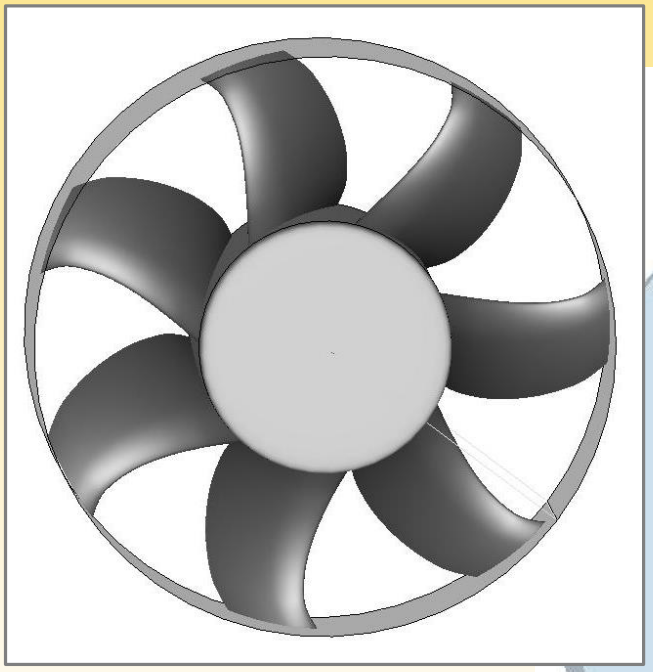
CFturbo Model Overview

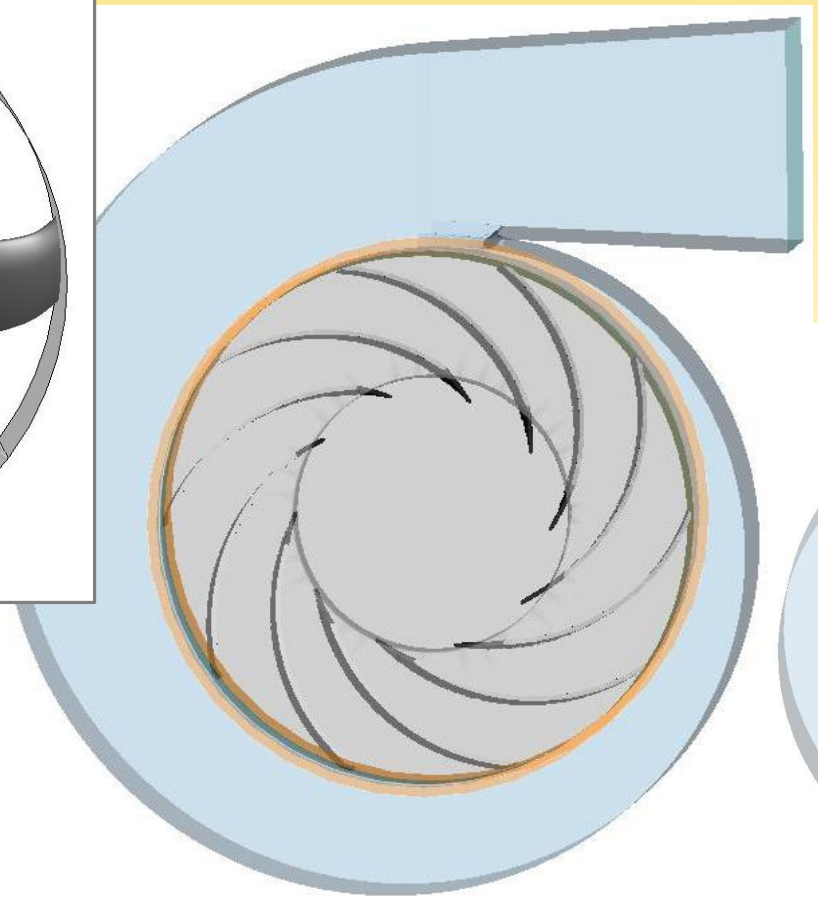
- Compressors, Turbines

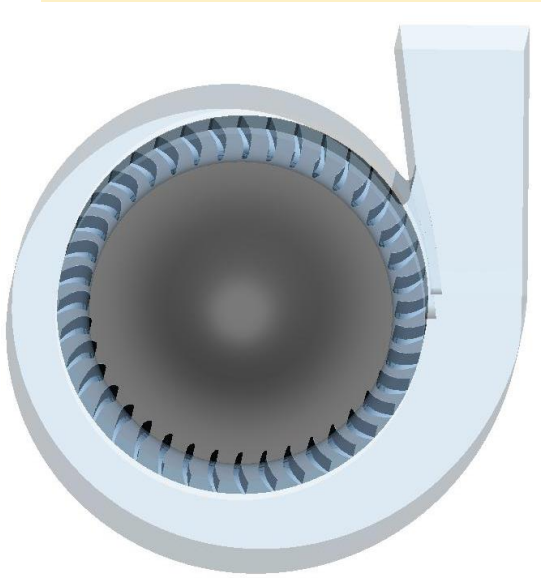


CFturbo Model Overview

- Fans, Blowers



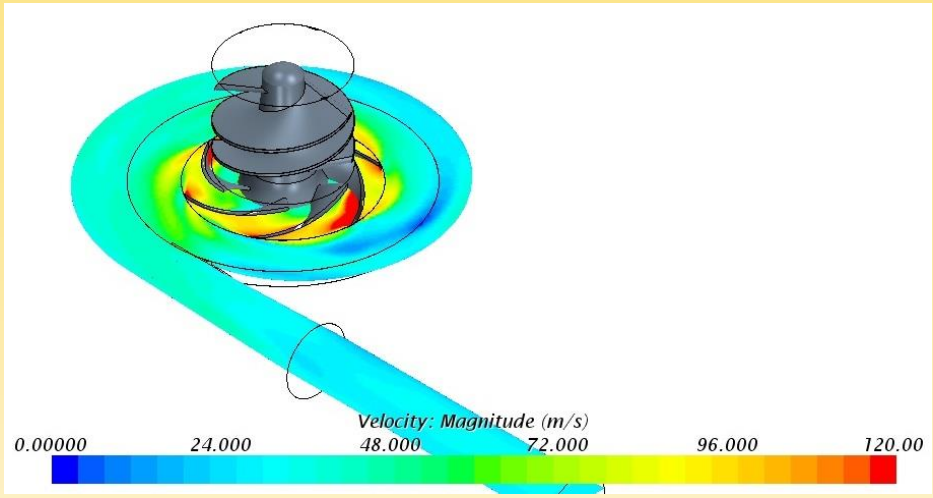


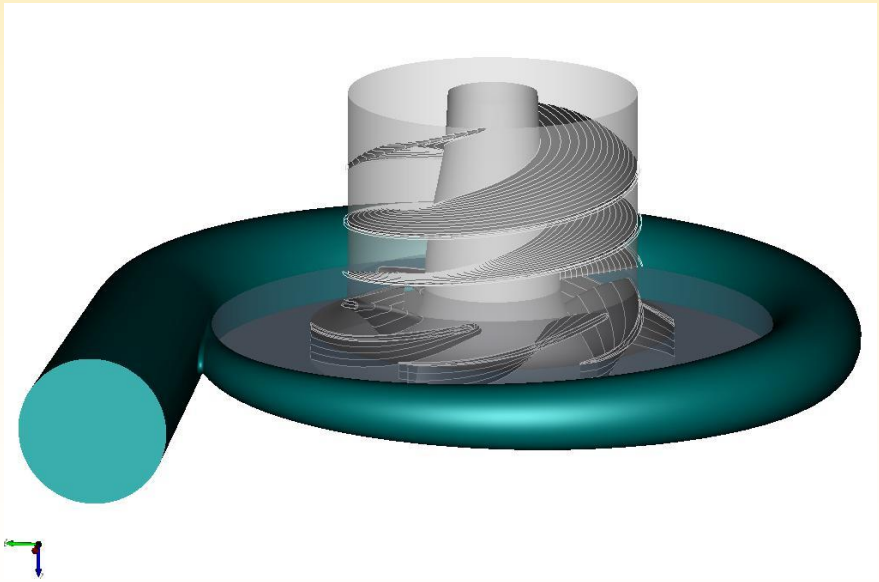


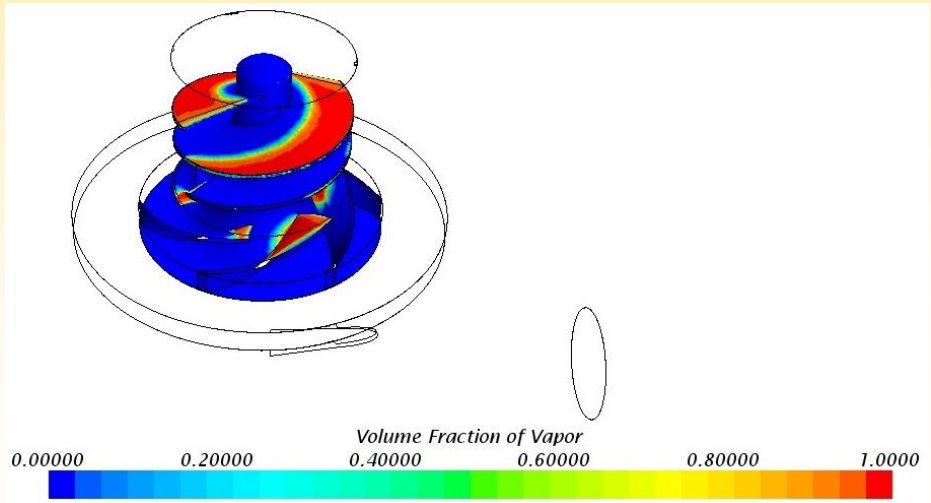
Example 1. Radial Pump with Inducer

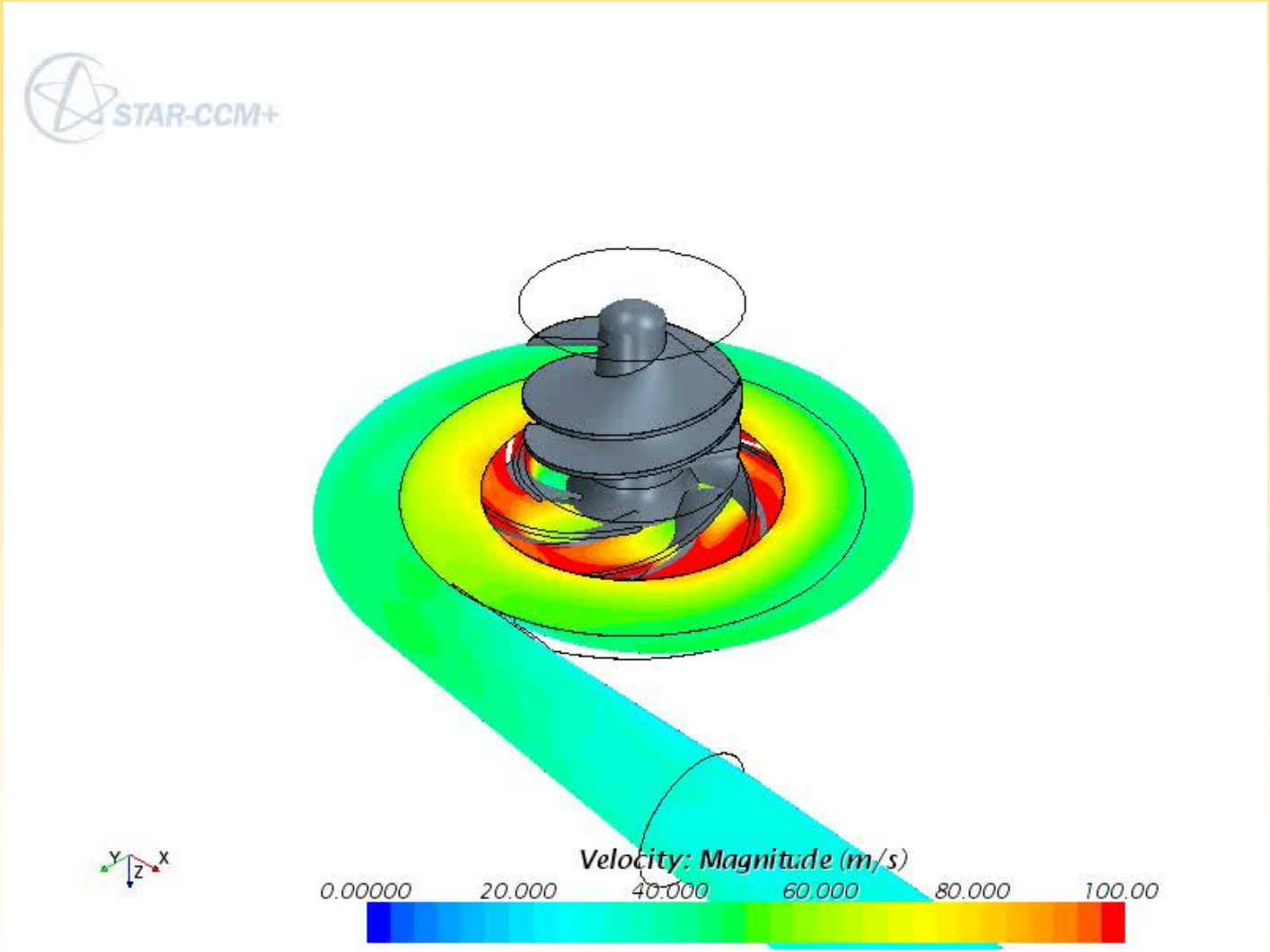
Comments

- Generic CFturbo design, 5 design variations
- Q=600 m³/h, Π=120 bar, n=12000 rpm
- Compare CFD-simulation
  - Steady State, no cavitation
  - Transient flow, no cavitation
  - Transient flow, with cavitation
- No experimental are data available

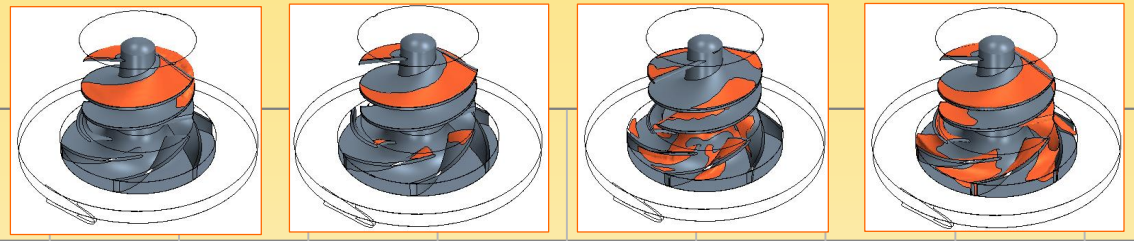







STAR-CCM+
Velocity: Magnitude (m/s)
0.00000
20.000
40.000
60.000
80.000
100.00

Example 1. Radial Pump with Inducer



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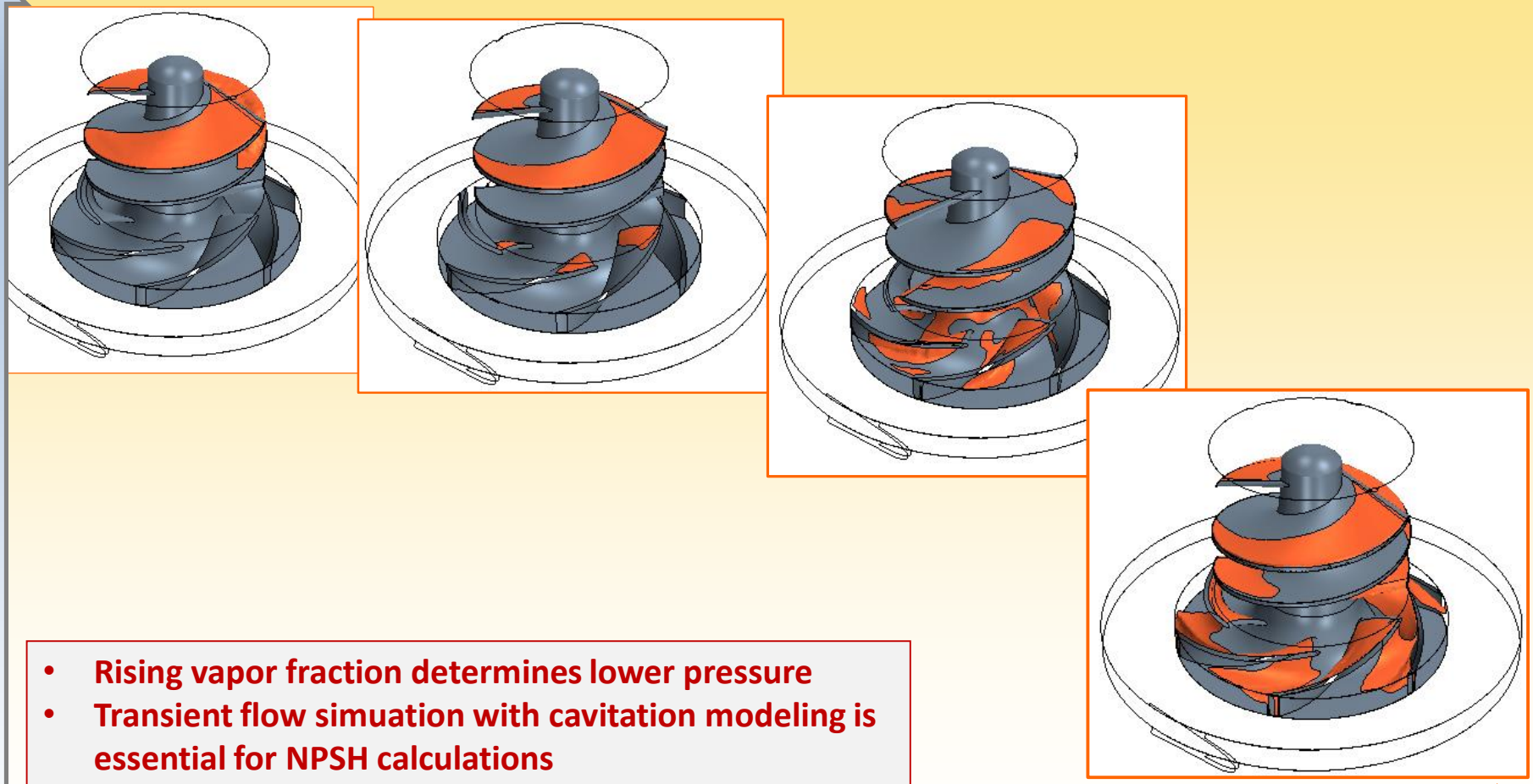
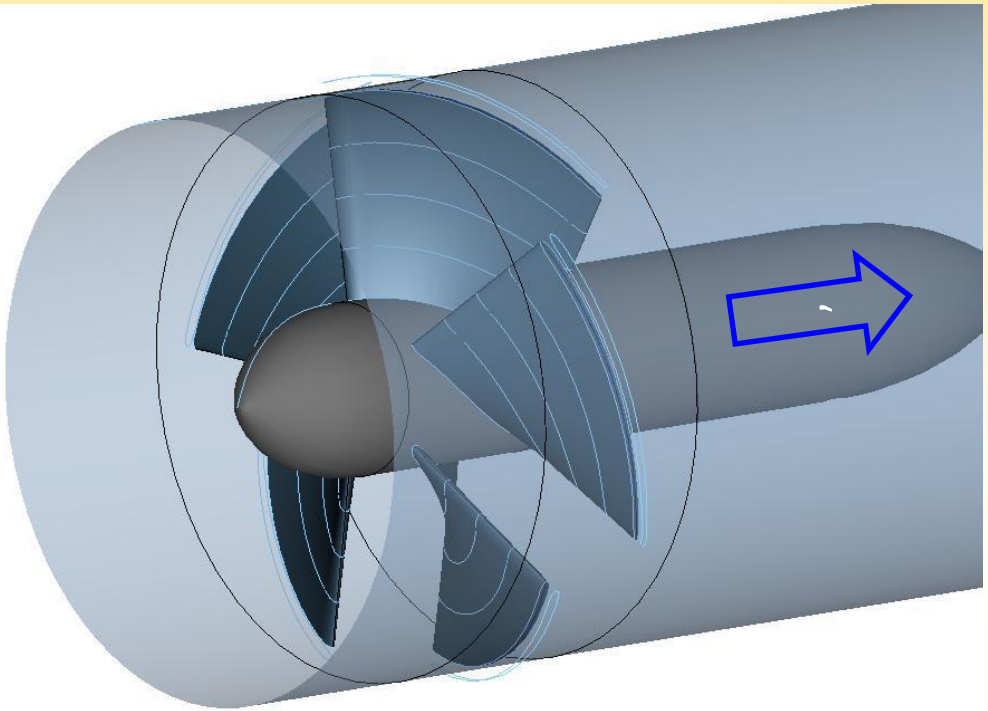


- **Rising vapor fraction determines lower pressure**
- **Transient flow simuation with cavitation modeling is essential for NPSH calculations**

Example 2. Initial Design Axial Pump

- Typical design point for axial pump defined
- First initial conceptual design by CFturbo
- No diffuser or inlet guide vane. Rotor in pipe.
  - n = 780 rpm
  - H = 15.6 feet
  - Q = 23,400 gpm
  - NPSHr = 27 feet
  - Tip diameter = 23 inches
  - Shroud diameter = 23.25 inches
  - 0.3 hub/tip ratio
- Steady state & transient Simulation,
- Cavitation



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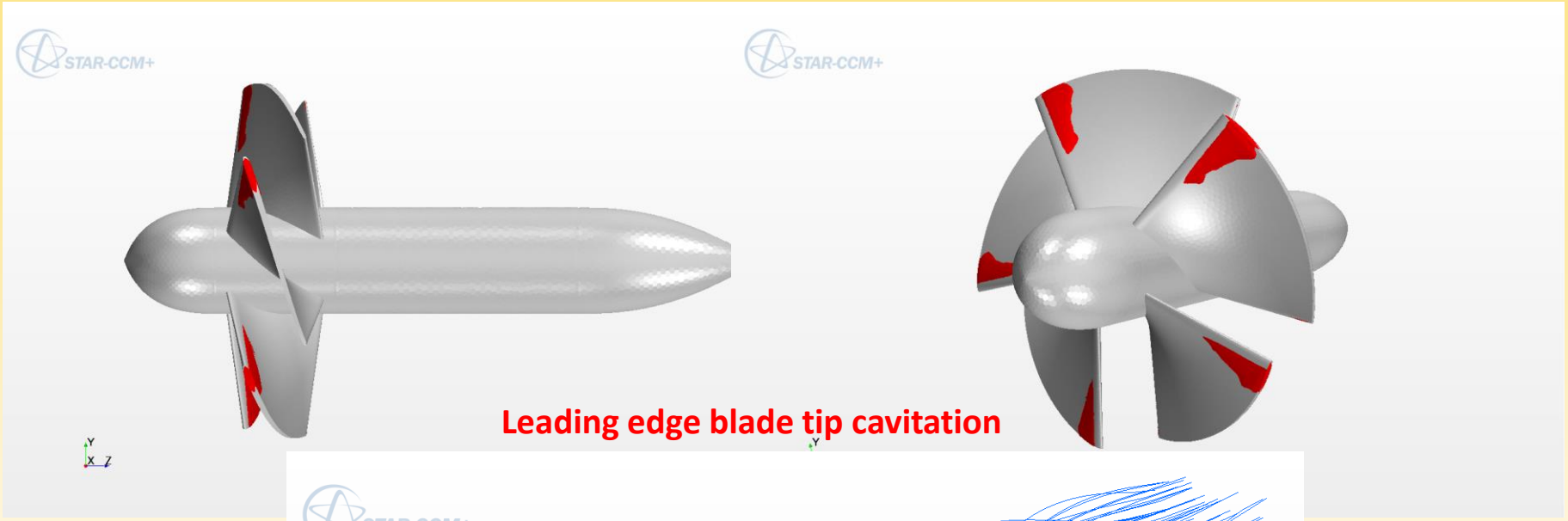
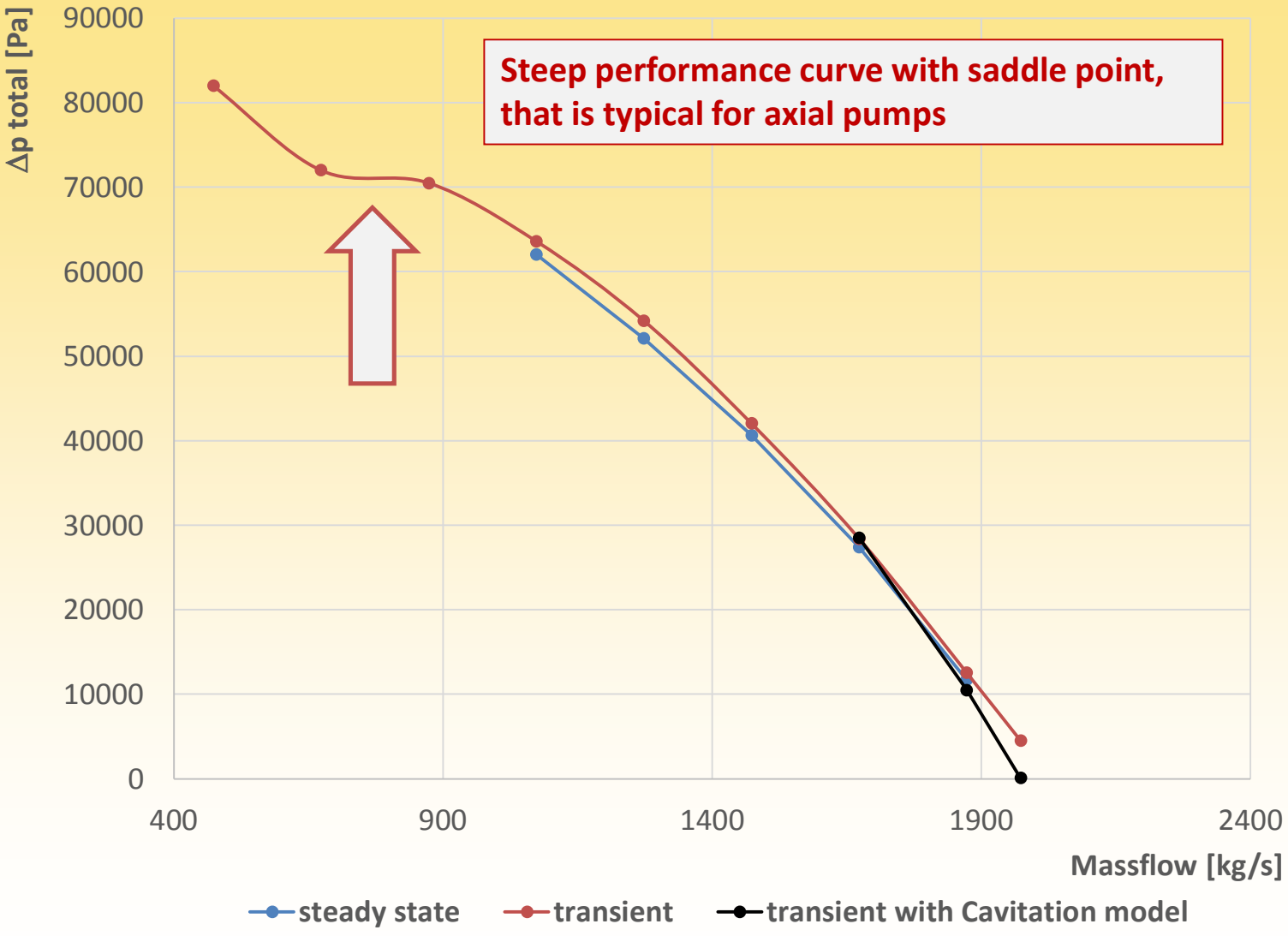
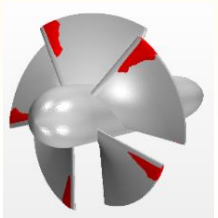



Δp total [Pa]
90000
80000
70000
60000
50000
40000
30000
20000
10000
0
400
900
1400
1900
2400
Massflow [kg/s]
Steep performance curve with saddle point, that is typical for axial pumps
steady state
transient
transient with Cavitation model



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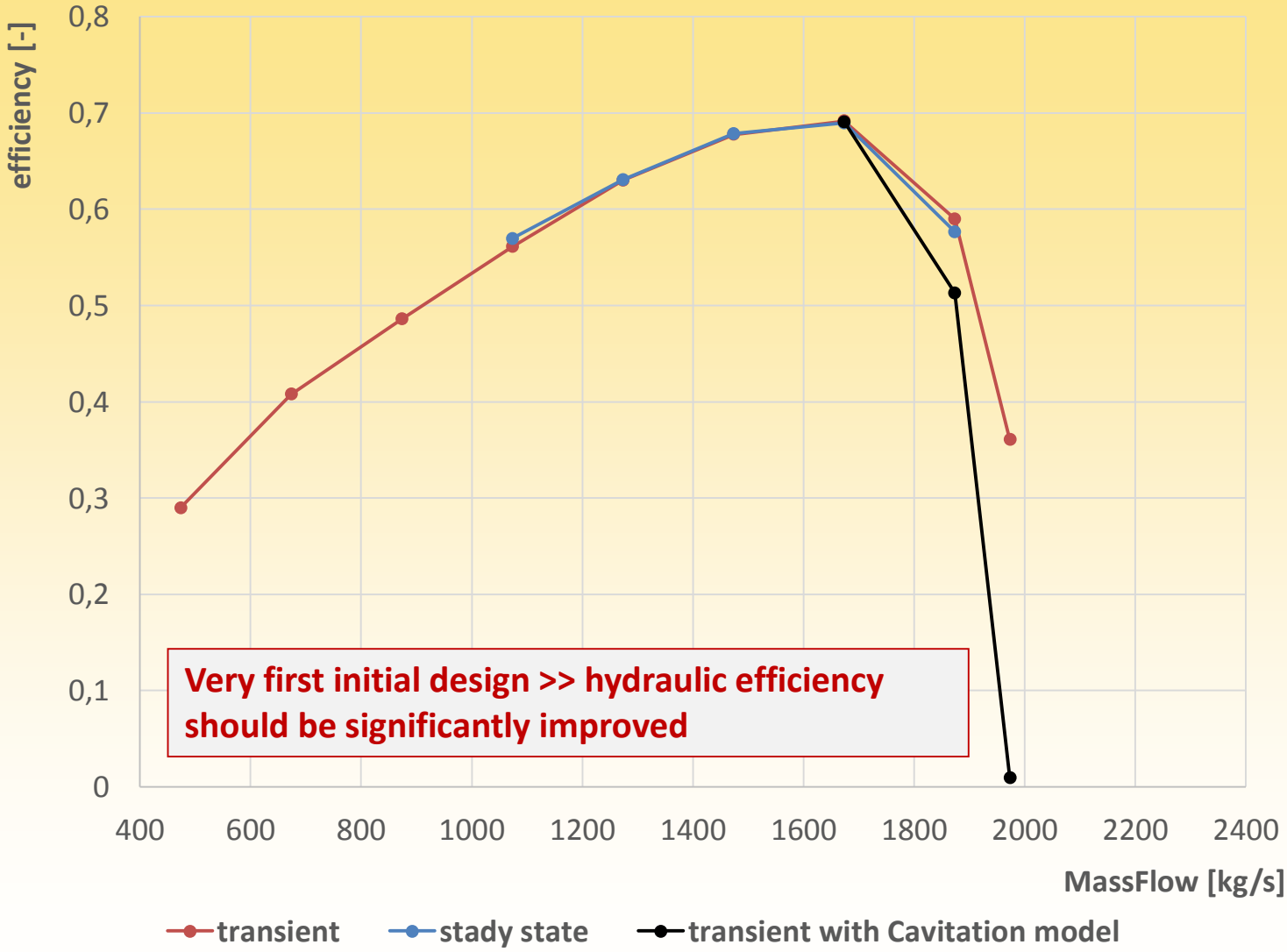
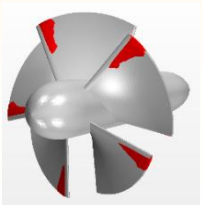
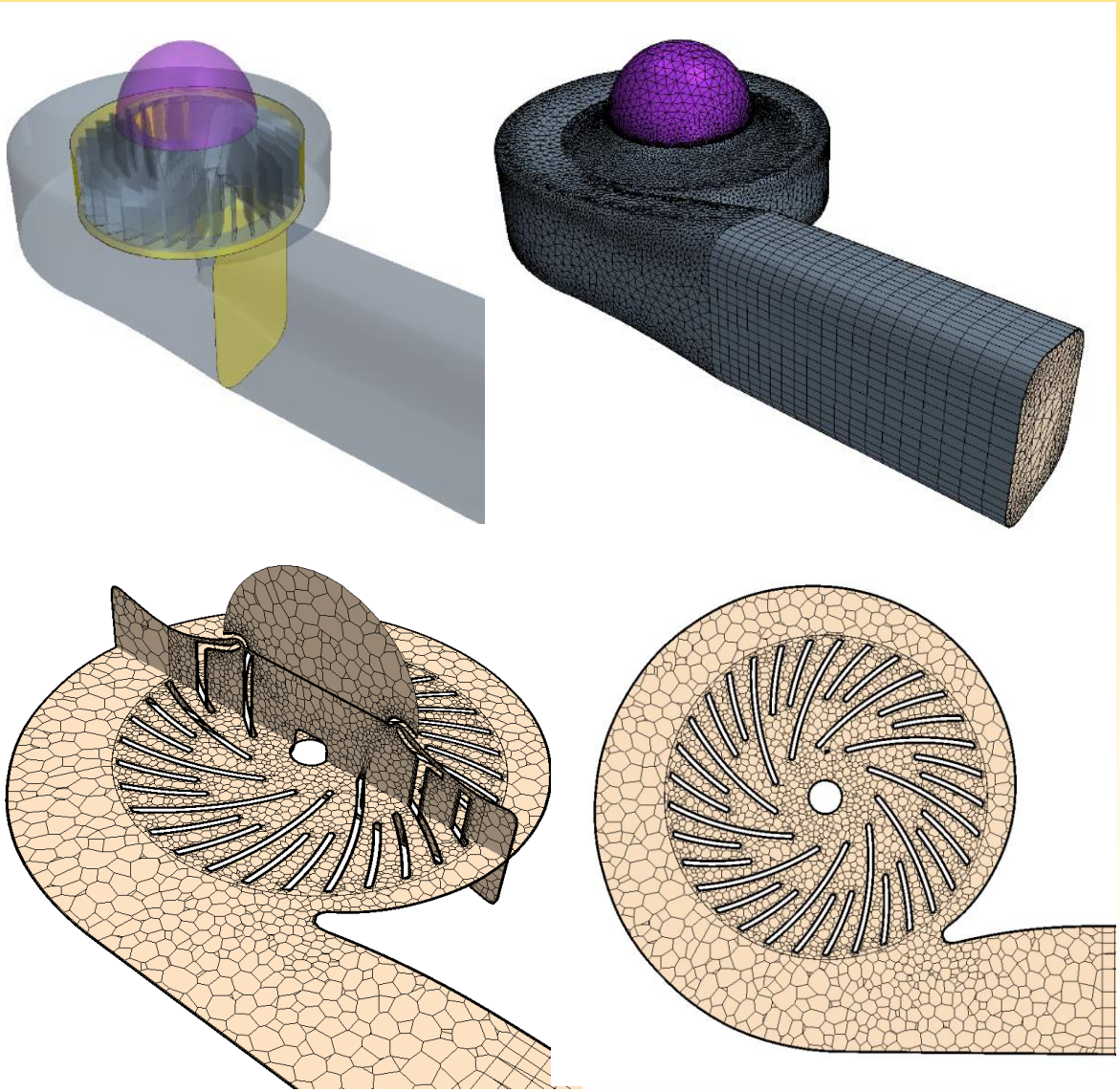




Example 3. Radial Blower

Comments

- Customer design
- CFD-Solver-Benchmark
- Steady state (MFR) and transient flow
- Coarse mesh (approx. 1 Mio. nodes)
- Experimental data available



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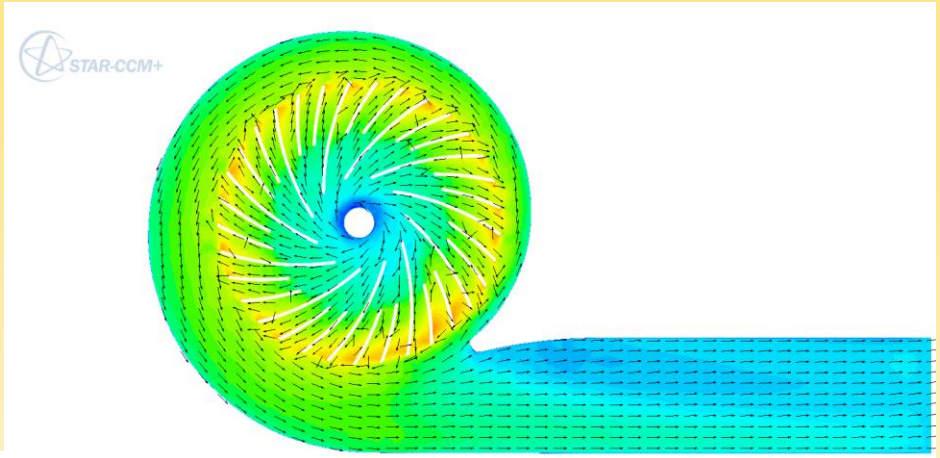

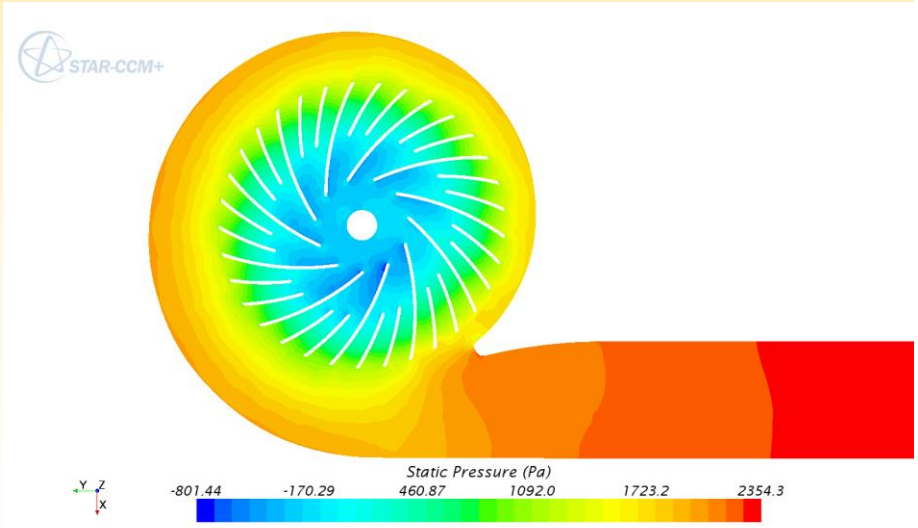

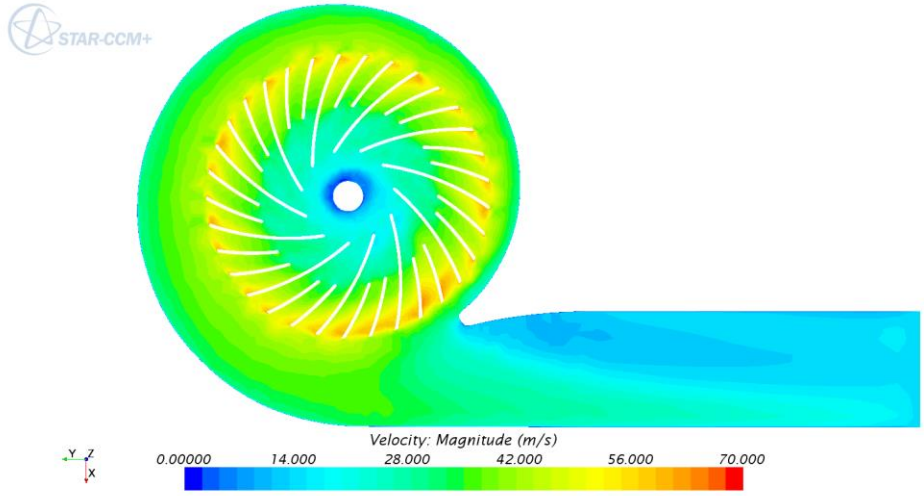

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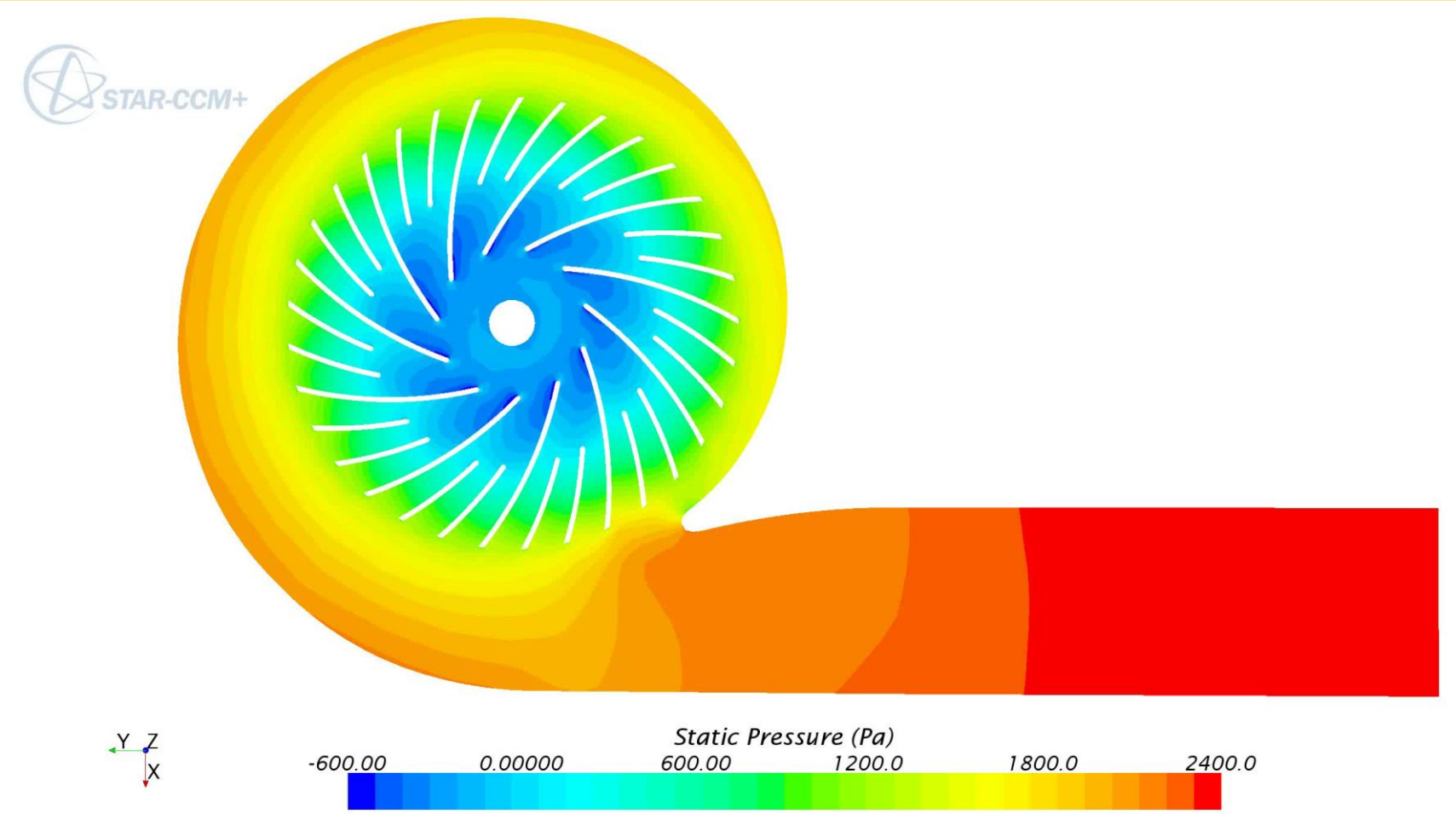

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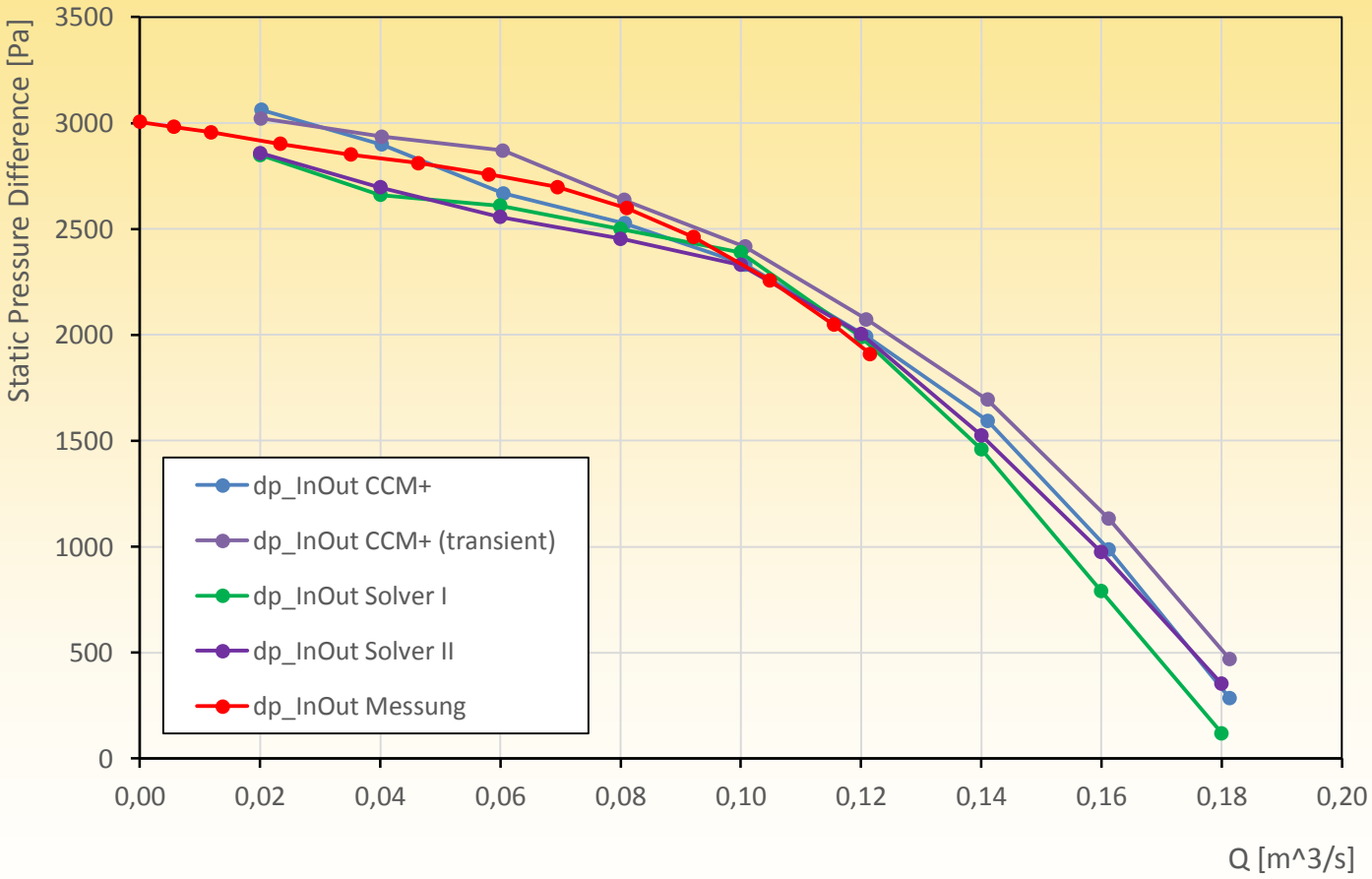

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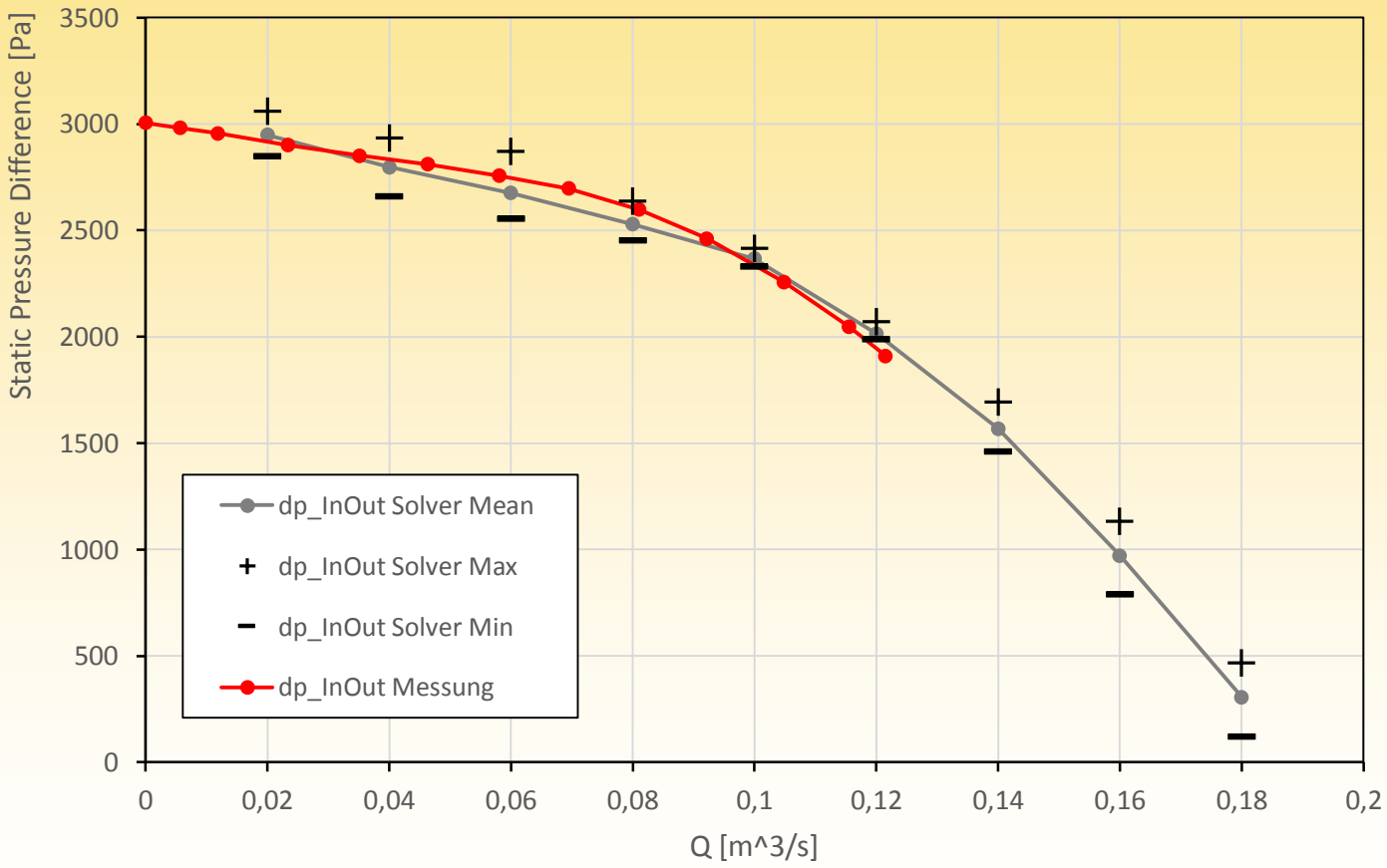

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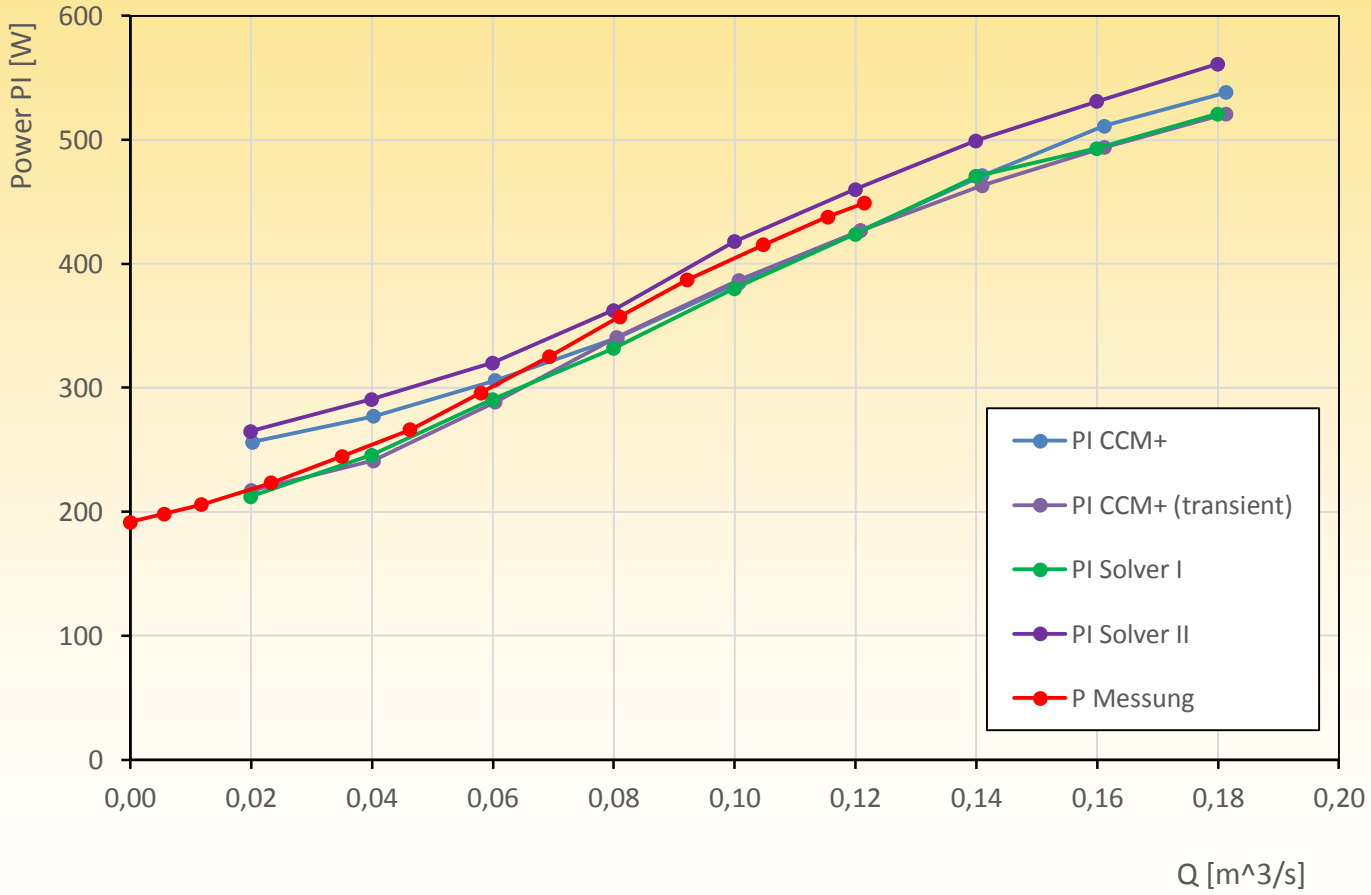

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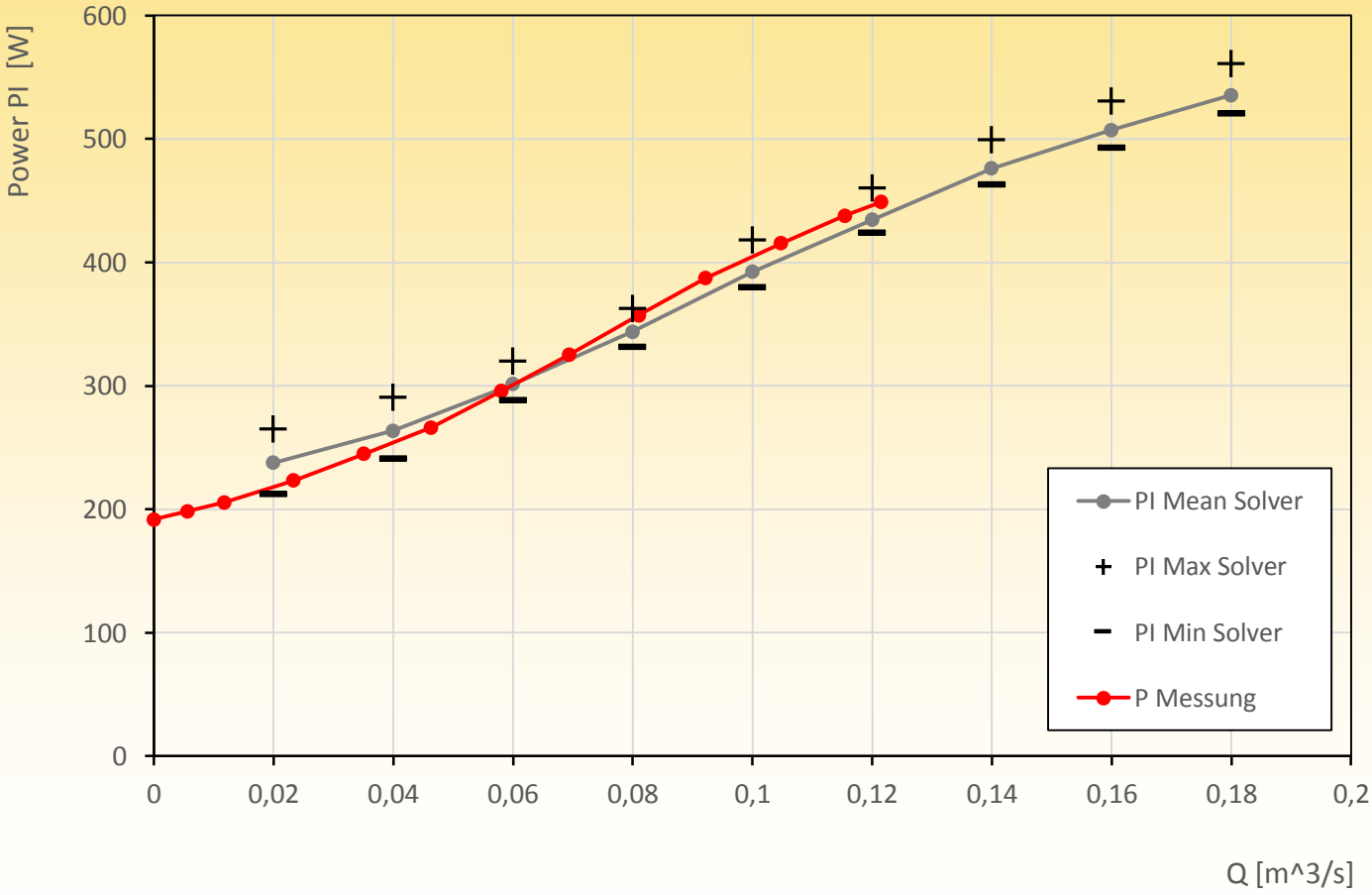

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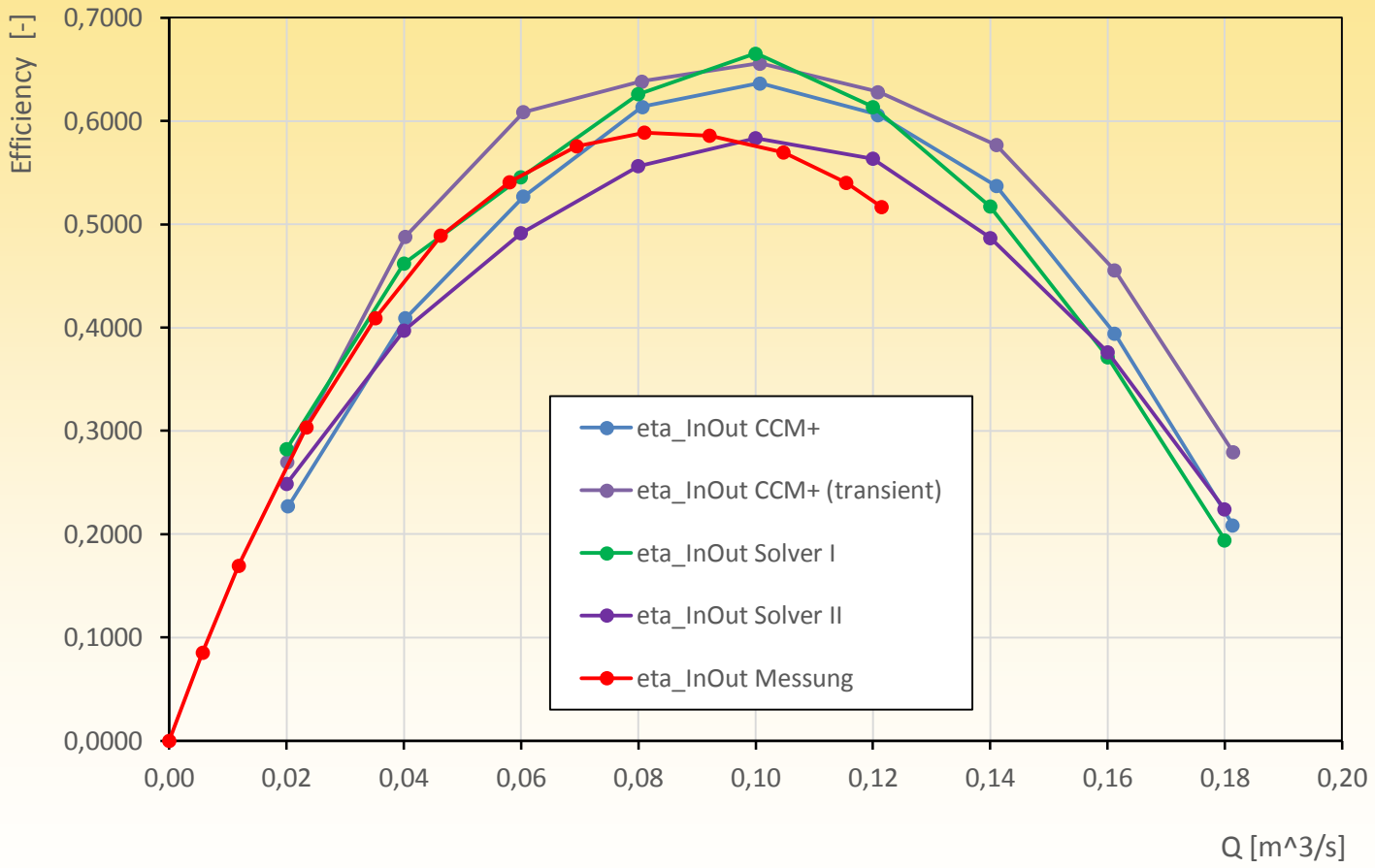
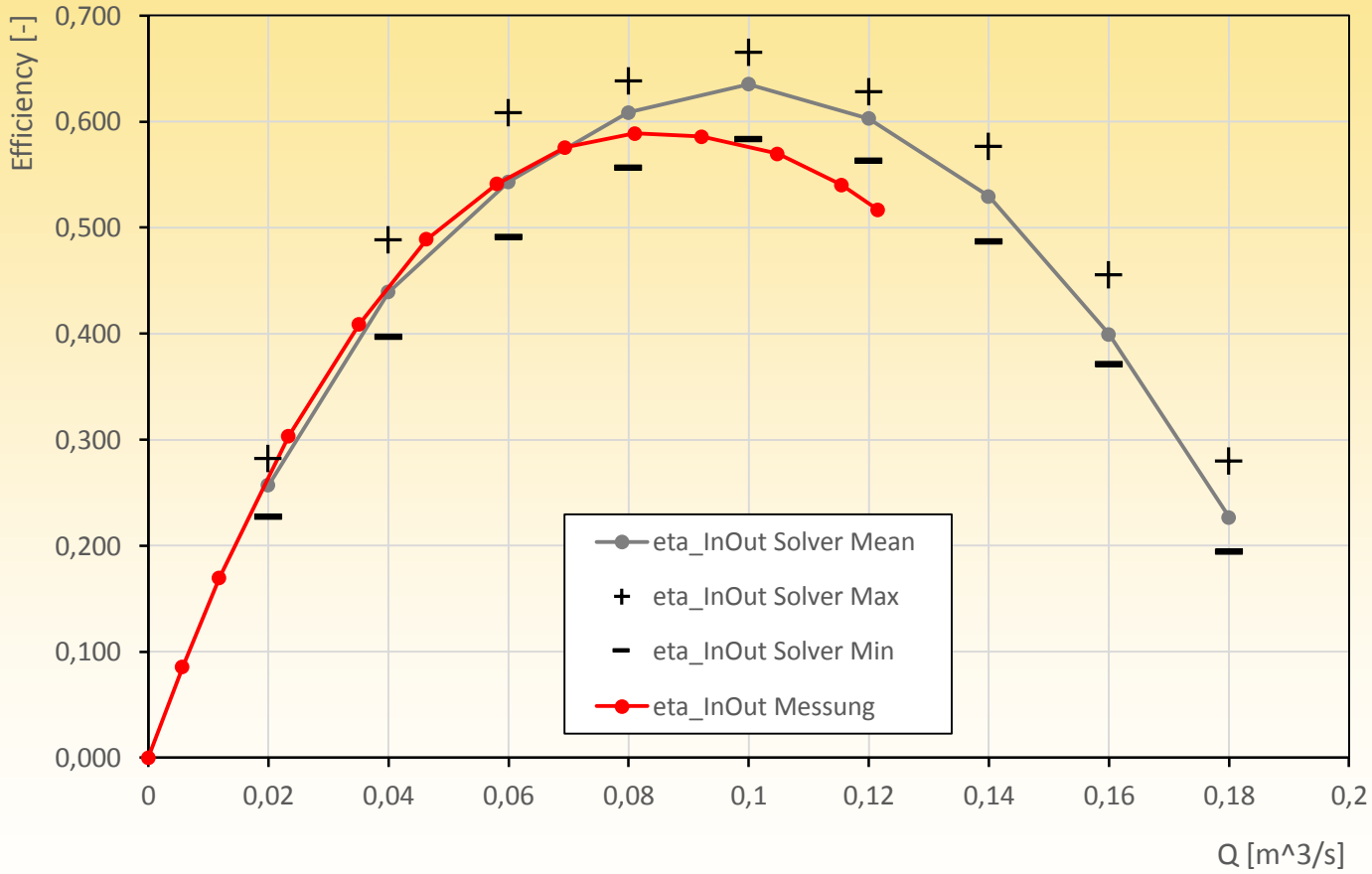
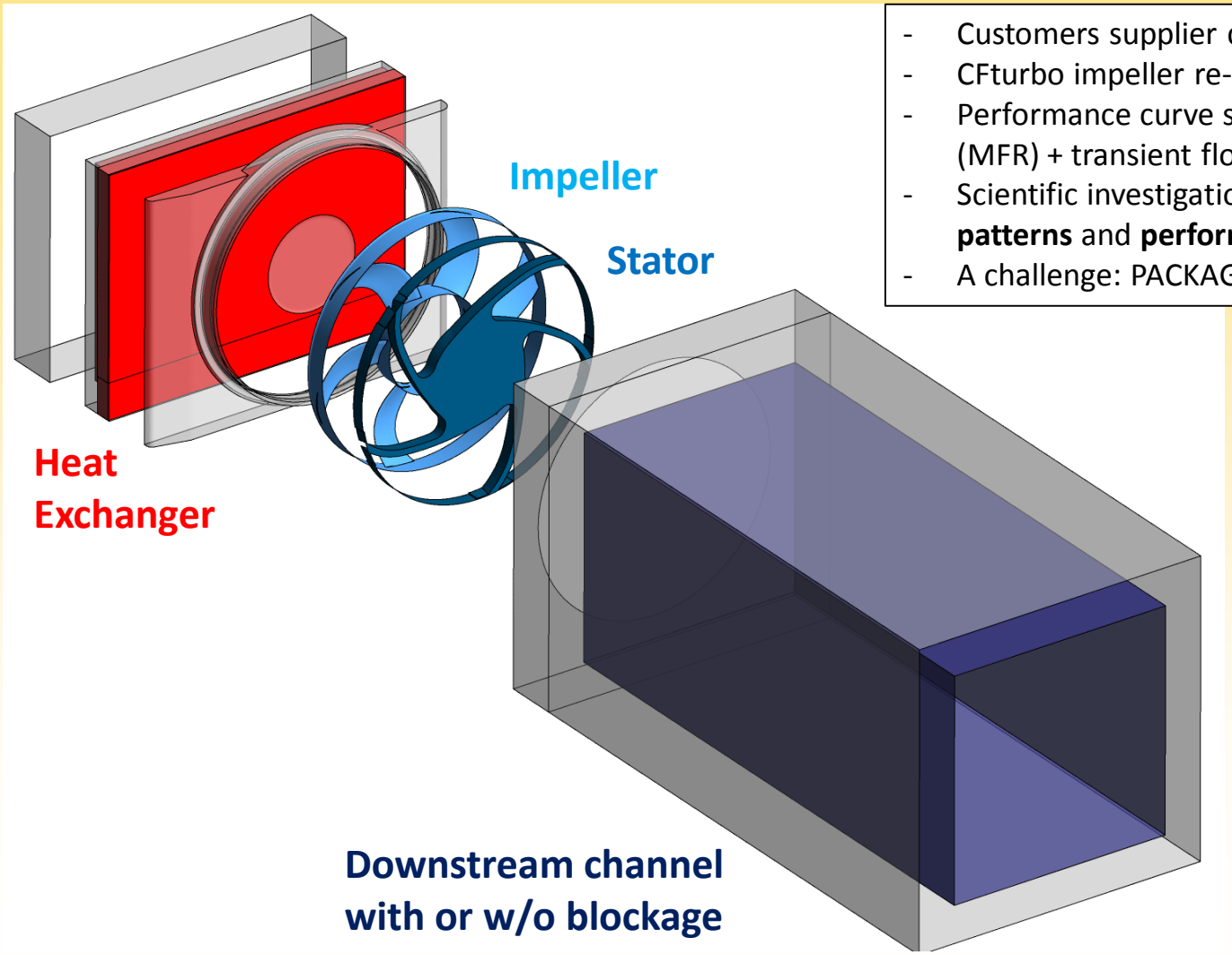


Example 3.
Radial Blower

Reasons of discrepancy between simulation and measurement should be investigated - mesh, time step, turbulence models,…
- check experimental set-up



Example 4. Virtual Automotive Cooling Fan Test Rig



- Customers supplier design
- CFturbo impeller re-design
- Performance curve simulations, Steady state (MFR) + transient flow on a virtual testbench
- Scientific investigation on **downstream flow patterns** and **performance curves**
- A challenge: PACKAGING

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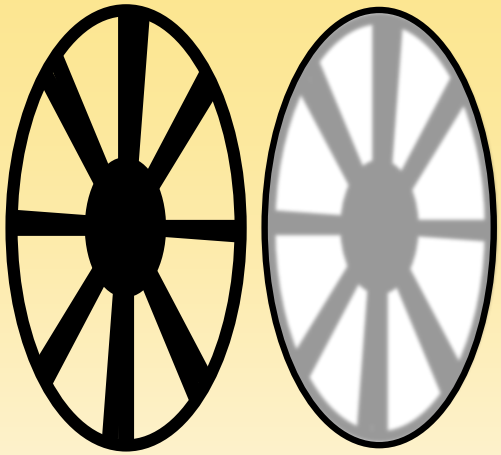
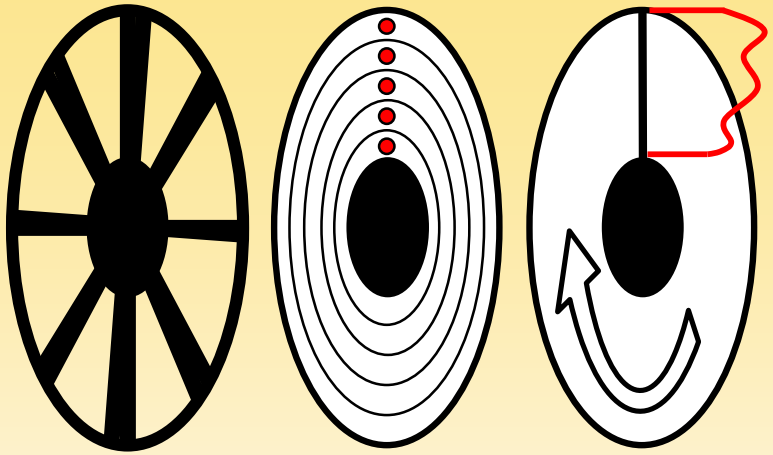




Frozen Rotor

1:1 direct transfer of all physical values to the other side of the interface

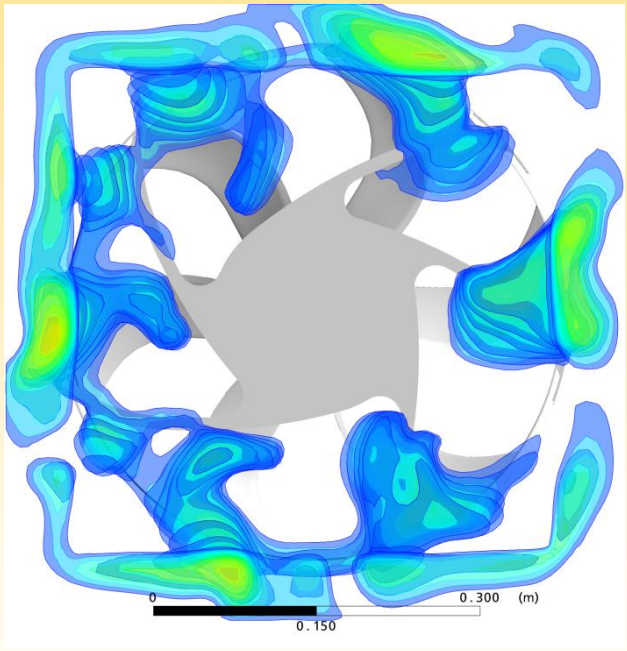
Mixing Plane (Stage Inteface)

Mean values of pressure and momentum are used to provide radial distribution

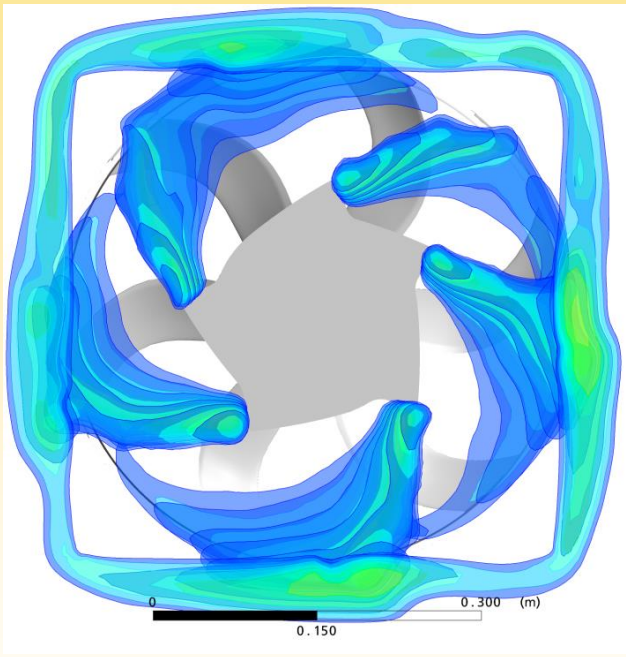
- Are these steady state models a good alternatives compared to transient simulation of axial automotive cooling fans?

Example 4. Virtual Automotive Cooling Fan Test Rig

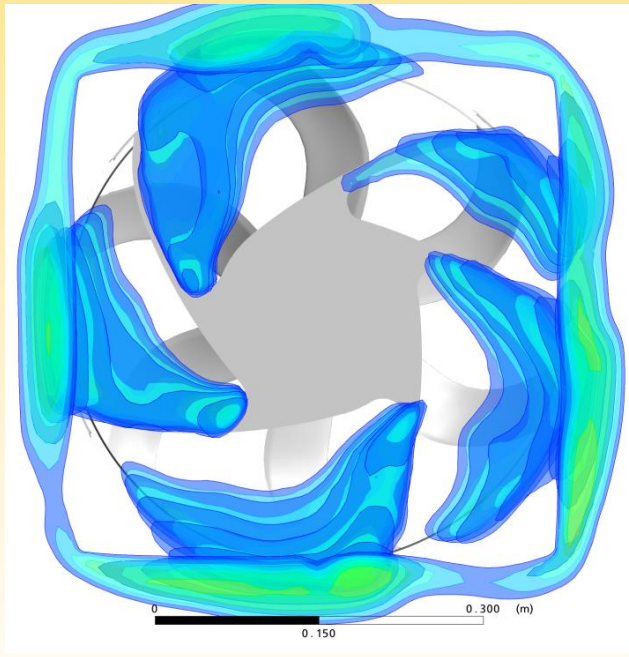
Downstream flow patterns



Frozen Rotor



Mixing Plane



Transient

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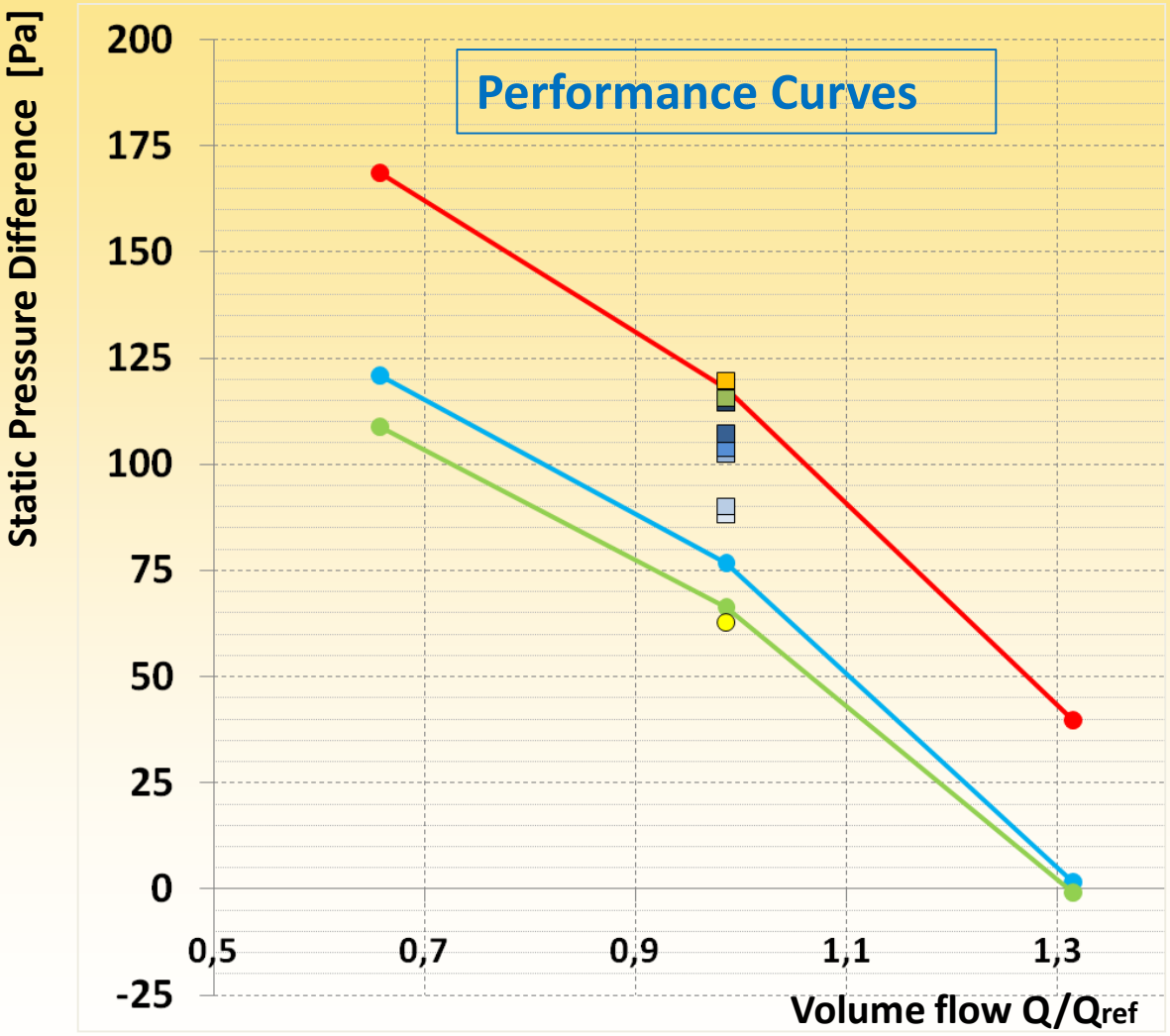
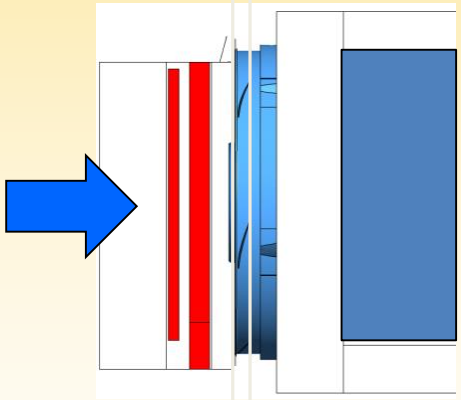


Steady state CFD-solutions are dependent on the position of the Rotor-Stator-Interfaces!

>> Computation of energy transmission within the impeller is affected!



Transient

Mixing Plane (MP)

Frozen Rotor (FR)

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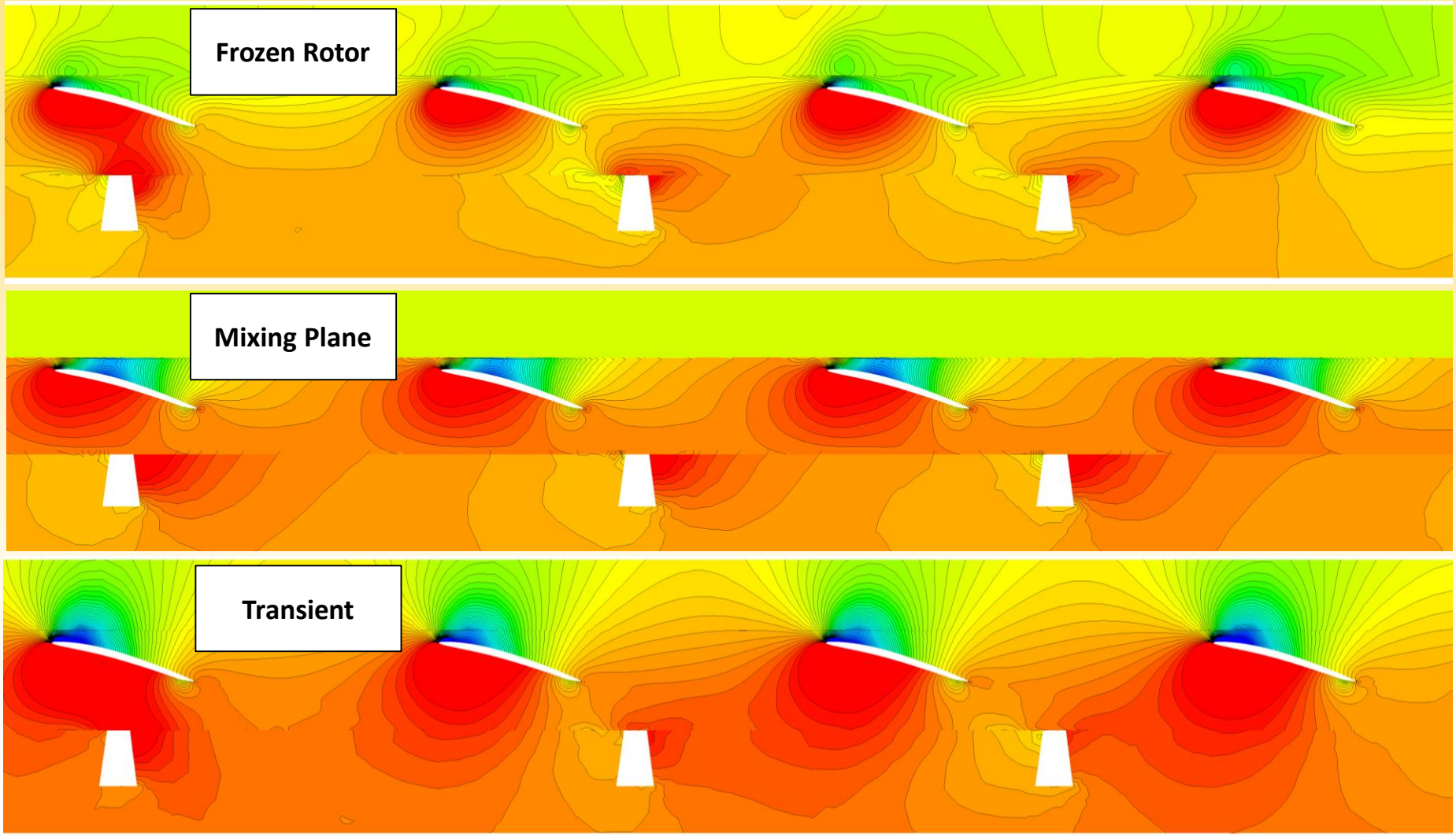

Summary

- CFturbo® and STAR CCM+ is a powerful combination for conceptual Turbomachinery design and 3D-CFD-simulation
- For different Turbomachinery applications different methodologies may be necessary
- Transient simulations do provide more accurate results im most cases
- Automated workflows and multi-objective optimization processes are available by additional application of OPTIMATE™ and HEEDS™
- Various types of Turbomachinery can be designed and investigated effectively
  - pumps, blowers, compressors, turbines
  - radial, mixed-flow and axial type
  - incompressible and compressible flow
  - without and with cavitation