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Simulation, Consulting and Programming

Simulation of a complete triple turbo molecular pumping stage using DSMC in 3D

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Introduction

DSMC
www.pi-dsmc.com

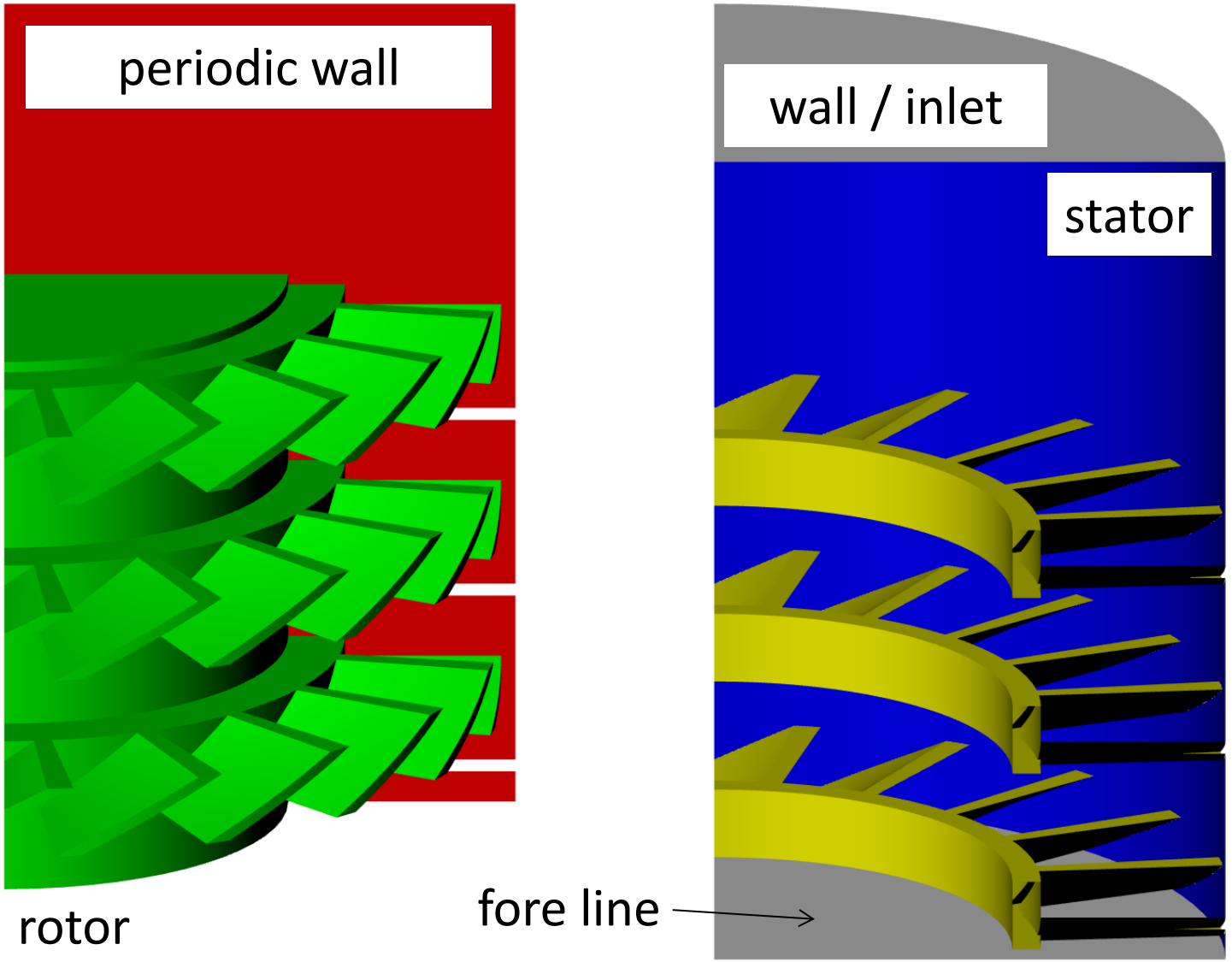
Motivation:

- Replace experiments by simulations to speed up development
- Study the 3D flow field to generate ideas for improvement

Sate of the art: (will be more detailed in the paper)

- 2D approaches → insufficient due to complex geometry
- 3D Single blade / stages → over simplified boundary conditions

Method – geometry



Method – geometry

A geometry was generated based on educated guessing.

- 3 turbo stages – each with rotor and stator
- diameter of stator: 72 mm
- radial spacing between rotor and stator: 1 mm
- height of rotor and stator blade: 5 mm
- rotor and stator blade angle: 45 °
- blades per rotor and per stator: 40
- frequency of rotation: 1000 Hz

A 90° sector of the complete geometry is simulated.

In a real pump there might be no symmetry at all! → 360°

The 3D geometry is described with 26.044 triangles.

Method – DSMC modifications

DSMC
www.pi-dsmc.com

Mesh generation:

Divide the geometry in resting and moving slices normal to rotating axis. Make sure that cells do not cross a slice boundary.

Moving molecules:

Take pseudo forces into account in moving slice: integrate curved path in gas-wall collision detection.

Evaluation of results:

Determine pressure ratio from flow field. Count number of entering and leaving molecules to determine the pumping speed.

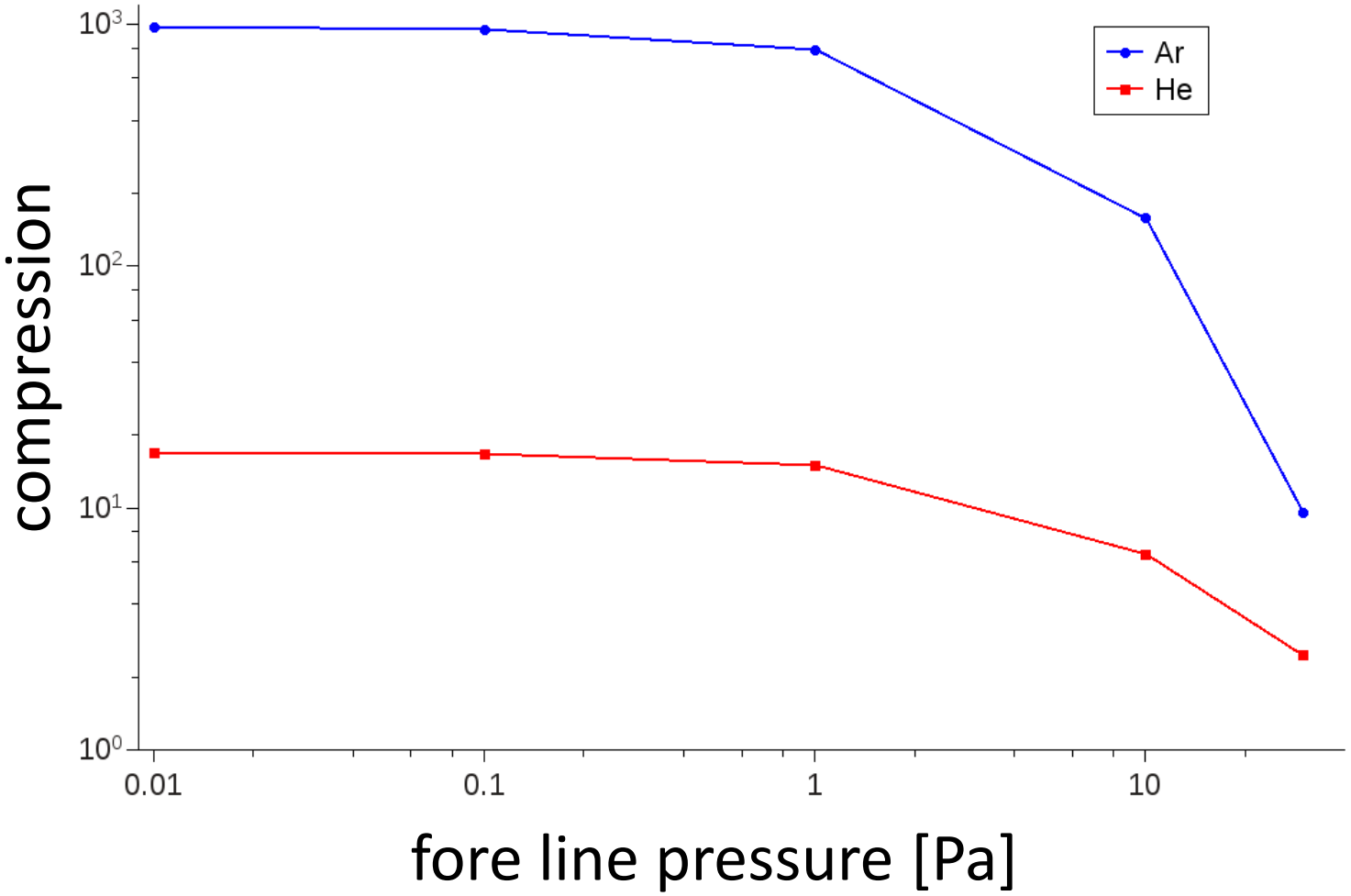
Method – boundaries

The following boundary conditions were used:

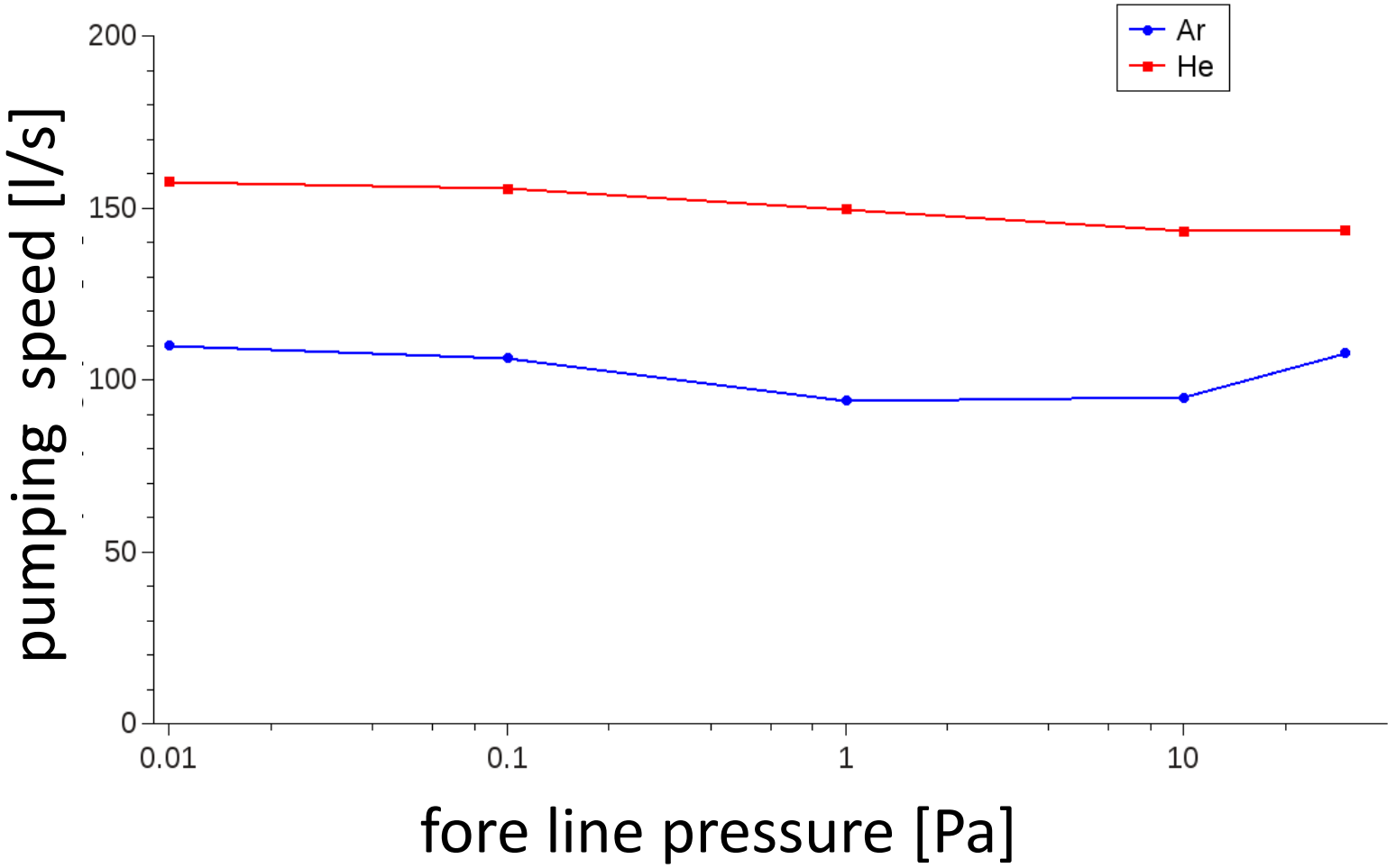
- initial state: vacuum
- temperature of rotor and stator: 298 K

1. Molecules are generated with a Maxwell-Boltzmann distribution on the side of the fore line.
2. For the simulation of compression, the side of the inlet (low pressure) is a solid wall.
3. For the simulation of pumping speed , molecules are also generated at the inlet so that P (inlet) = P (fore line).

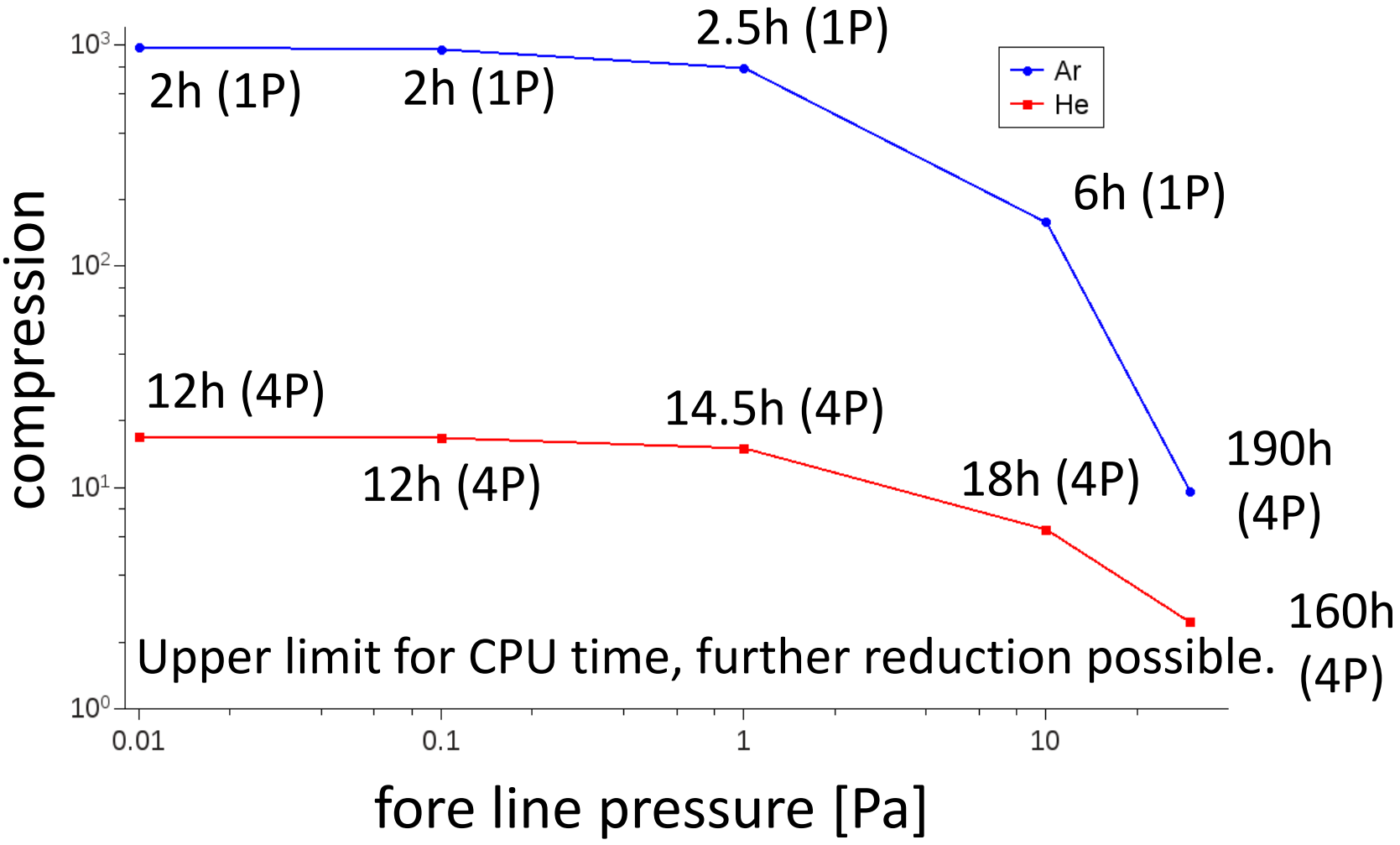
Results – compression



Results – pumping speed

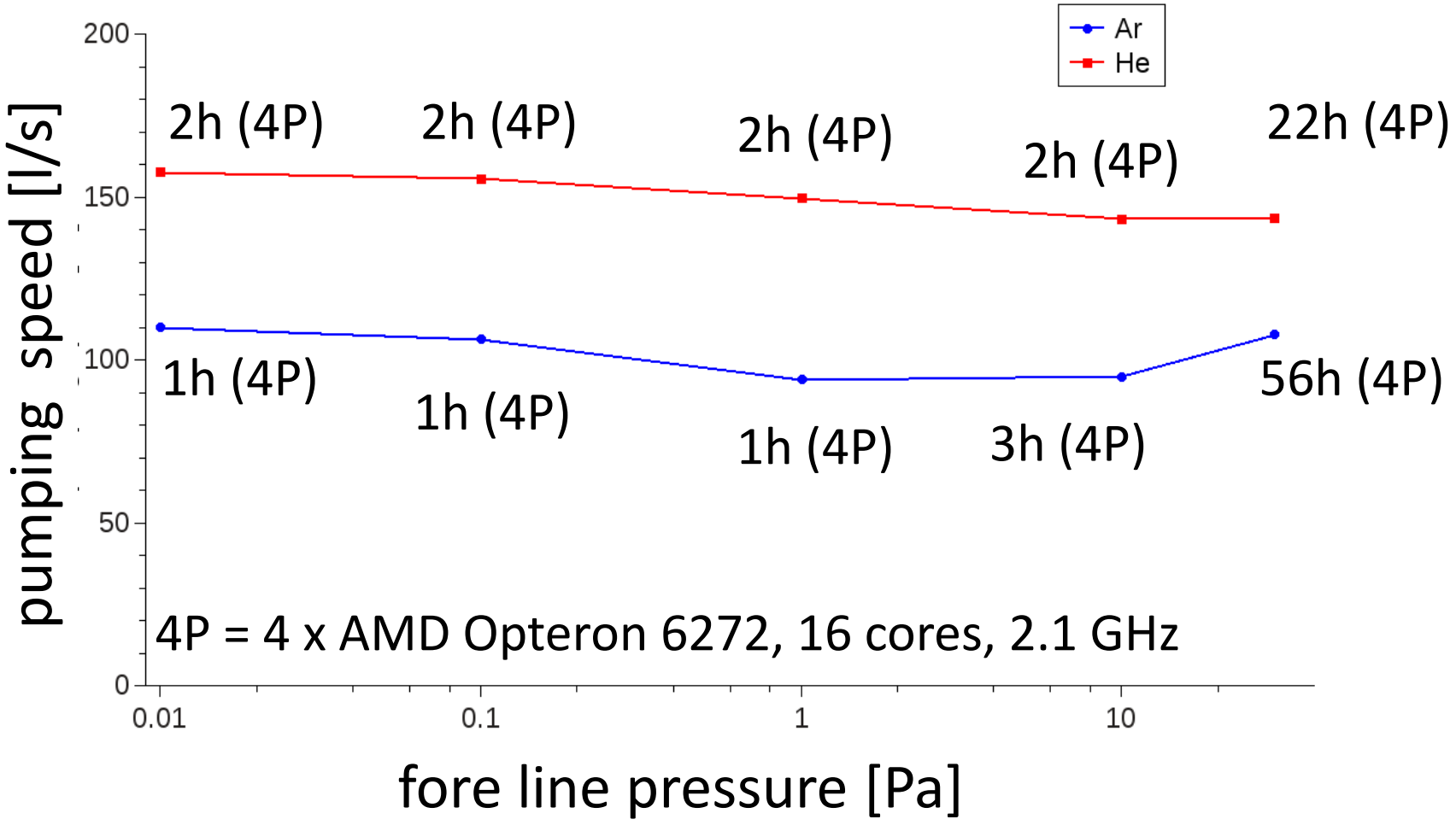


Results – computation time



4P = 4 x AMD Opteron 6272, 16 cores, 2.1 GHz

Results – computation time



Results – flow field

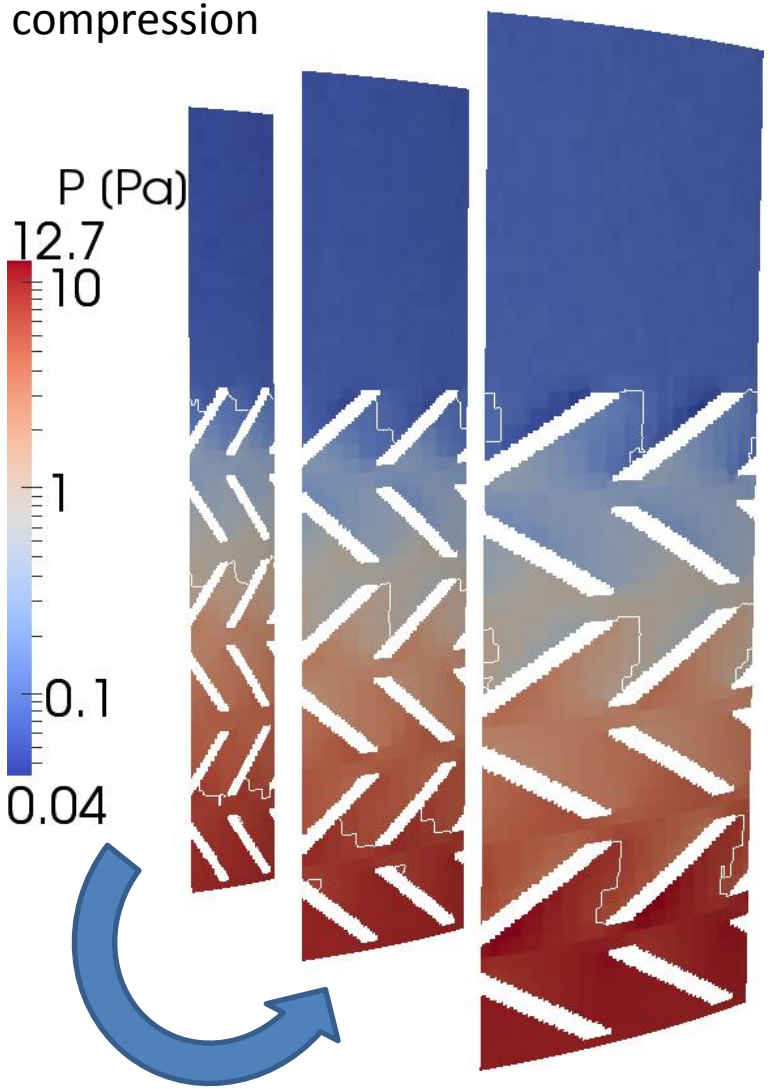
Why is it necessary to perform 3D simulations?

→ The flow field is highly inhomogeneous in the radial direction.

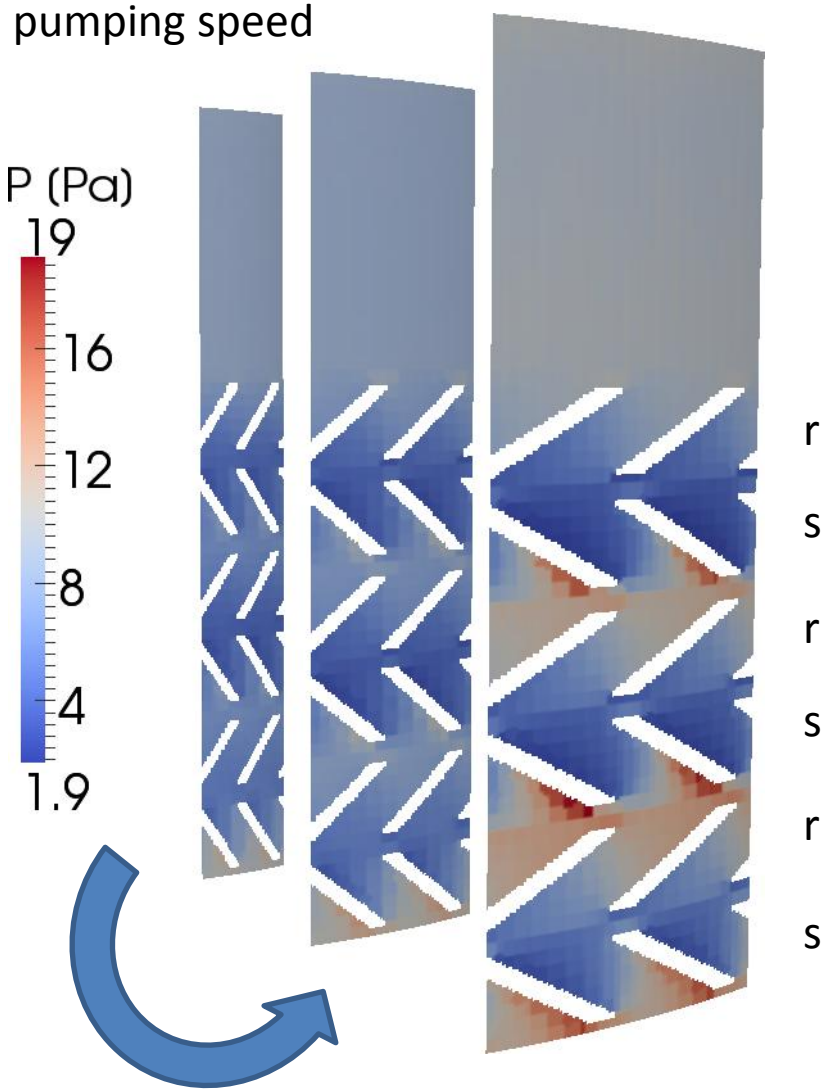
Let’s investigate the flow field!

Results – pressure

compression

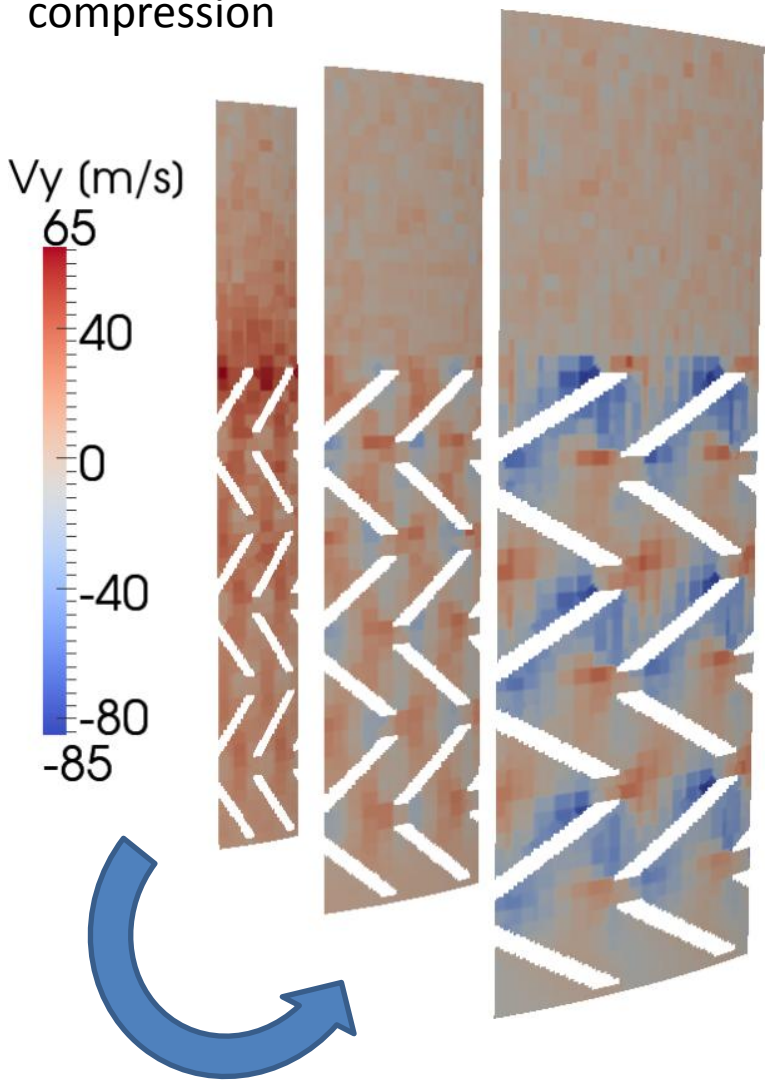


pumping speed

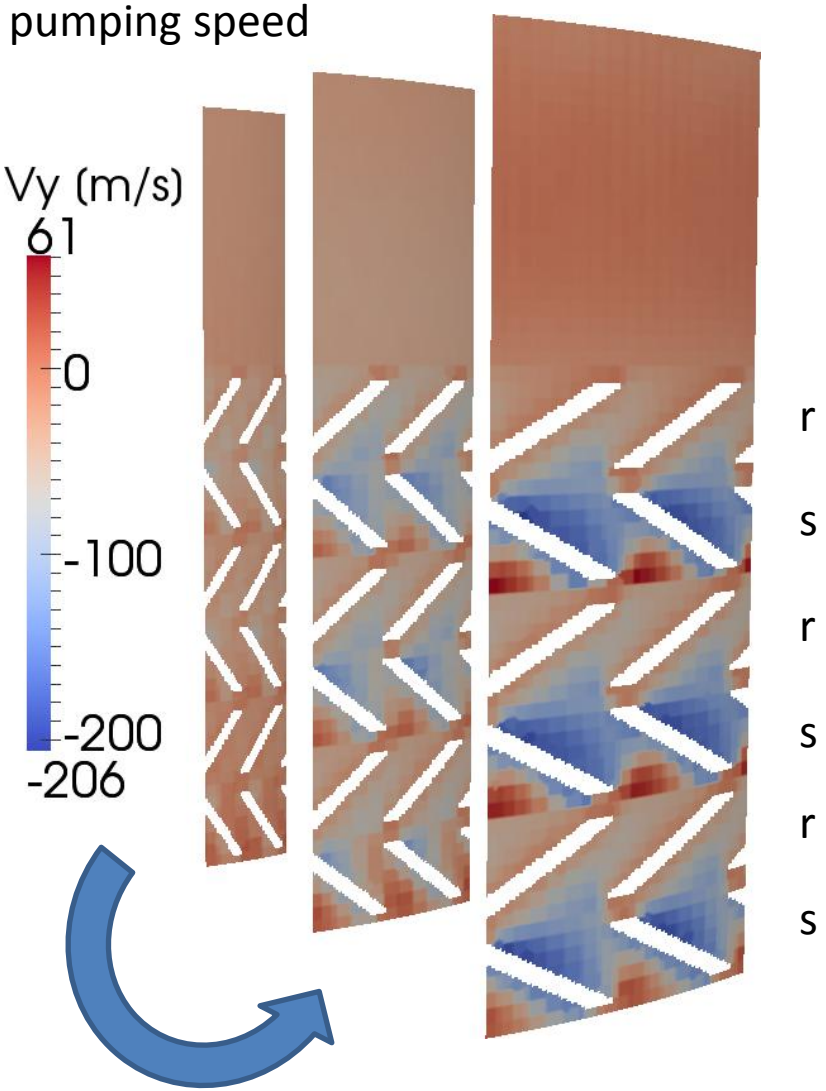


Results – axial velocity

compression

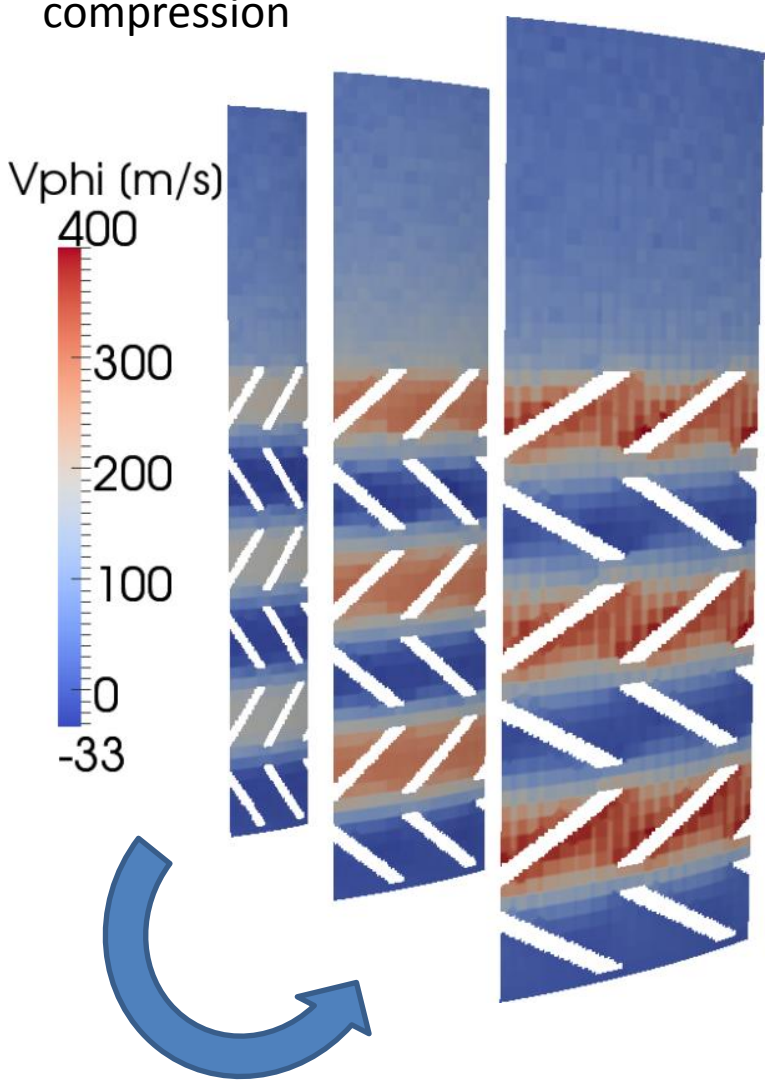


pumping speed

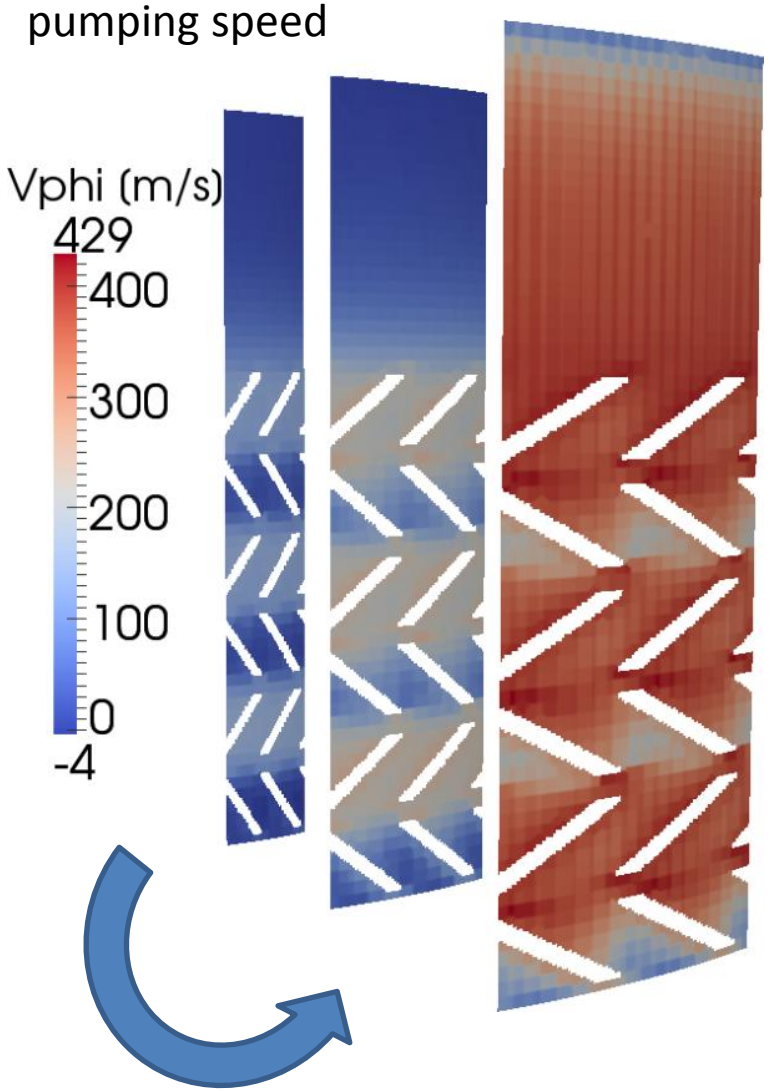


Results – angular velocity

compression



pumping speed



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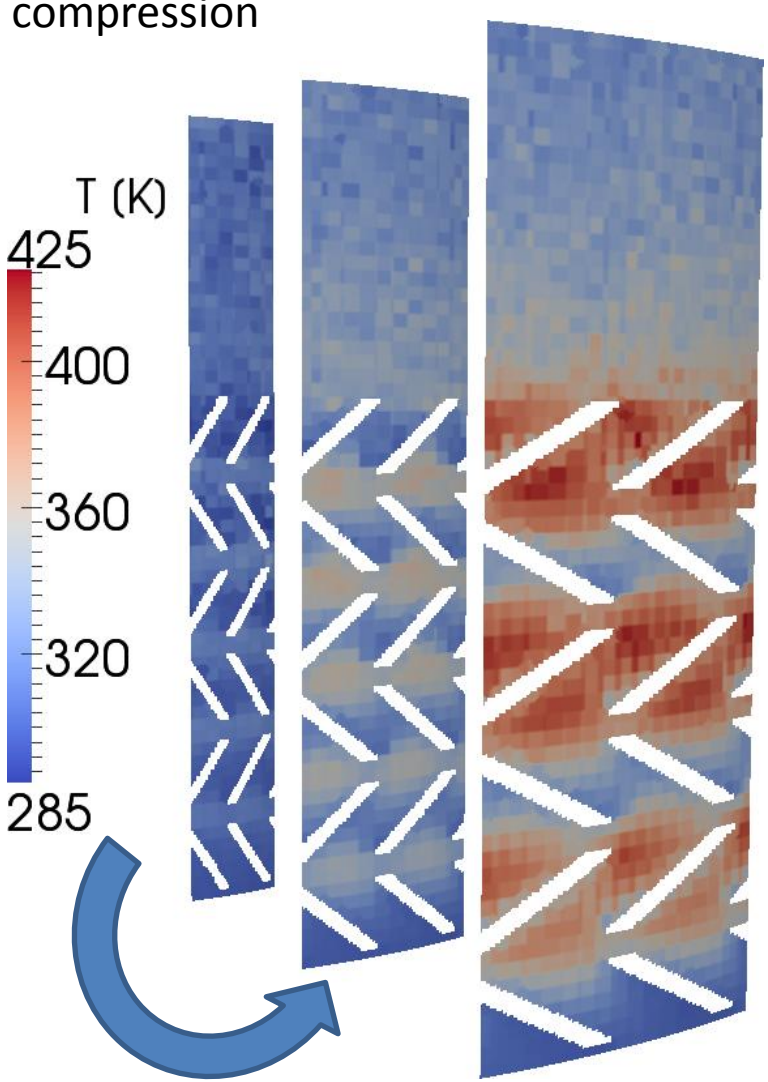
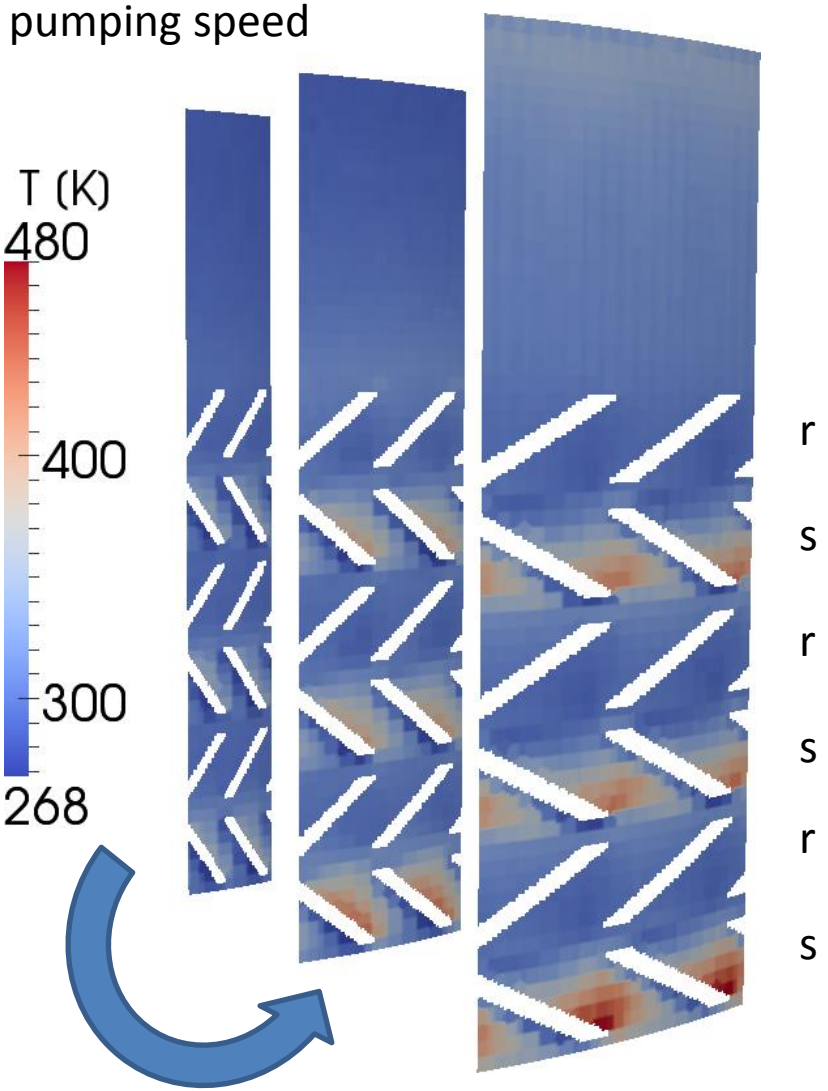
Results – temperature

compression



pumping speed



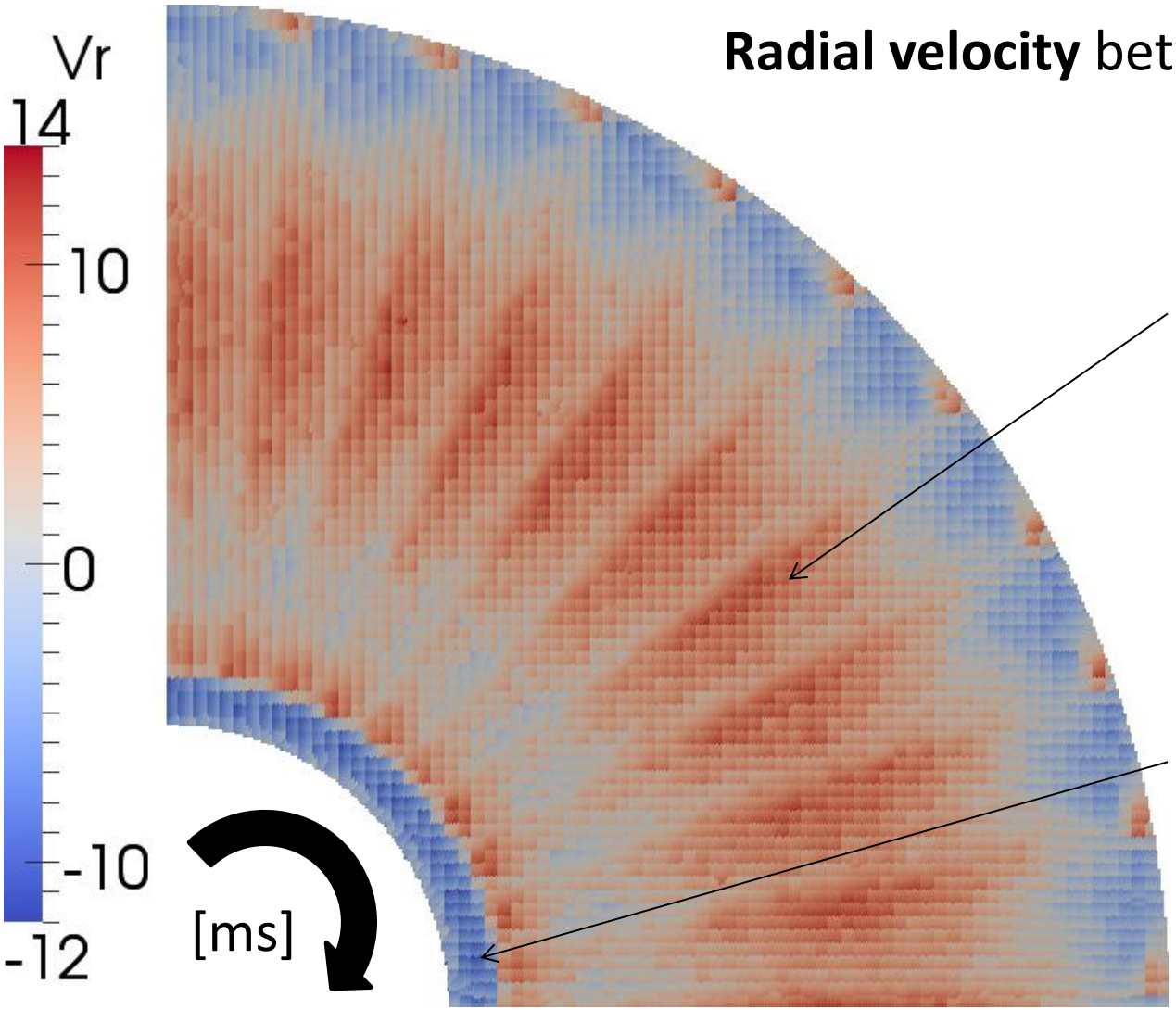
Results – flow field

Why is it necessary to perform multi stage simulations?

→ Very complex boundary conditions would be required for single stage simulations.

Let’s investigate the flow field!

Results – flow field

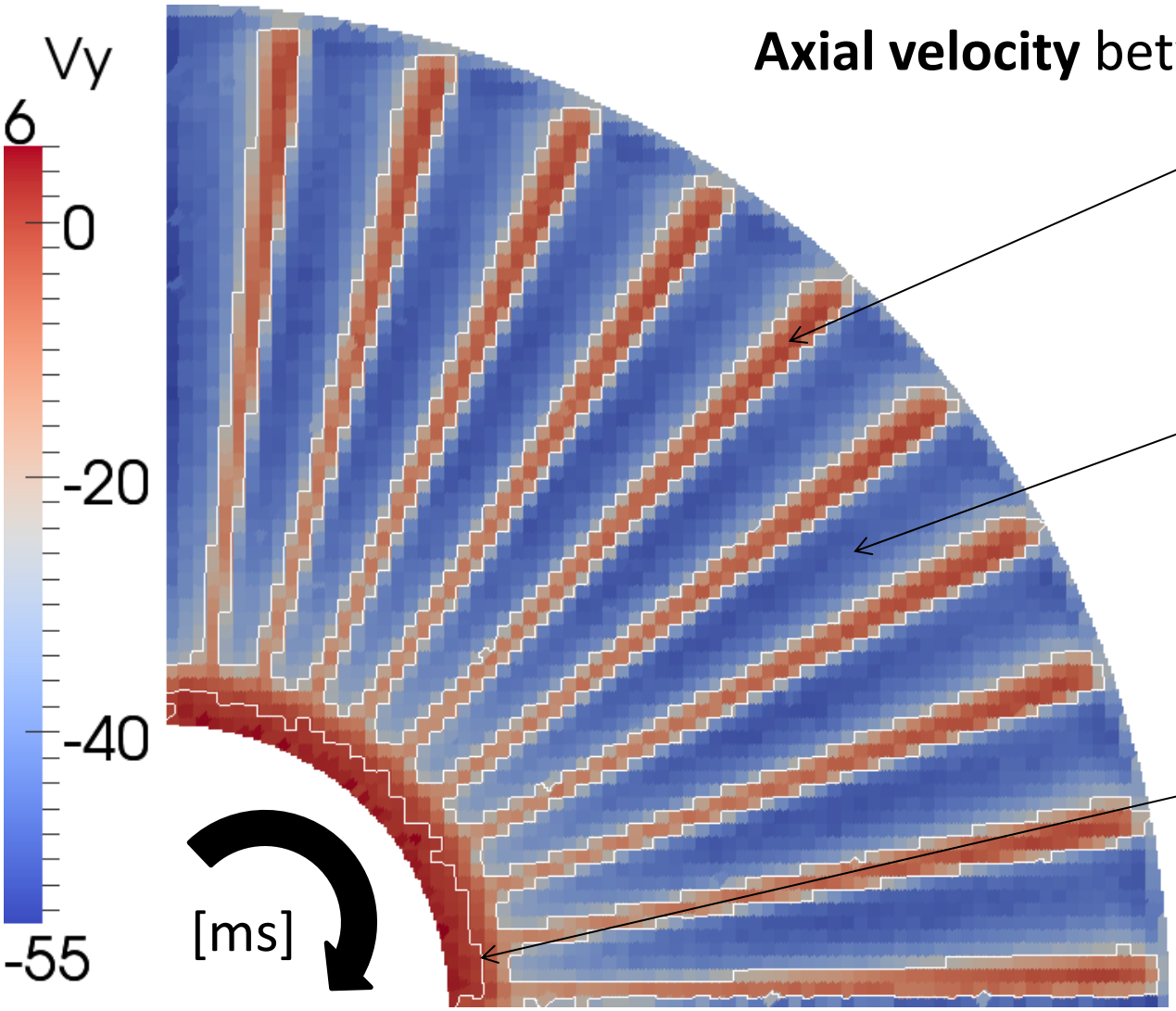


Radial velocity between stage 2 & 3.

Gas is driven outwards by the blades.

Note the flow towards the rotor.

Results – flow field



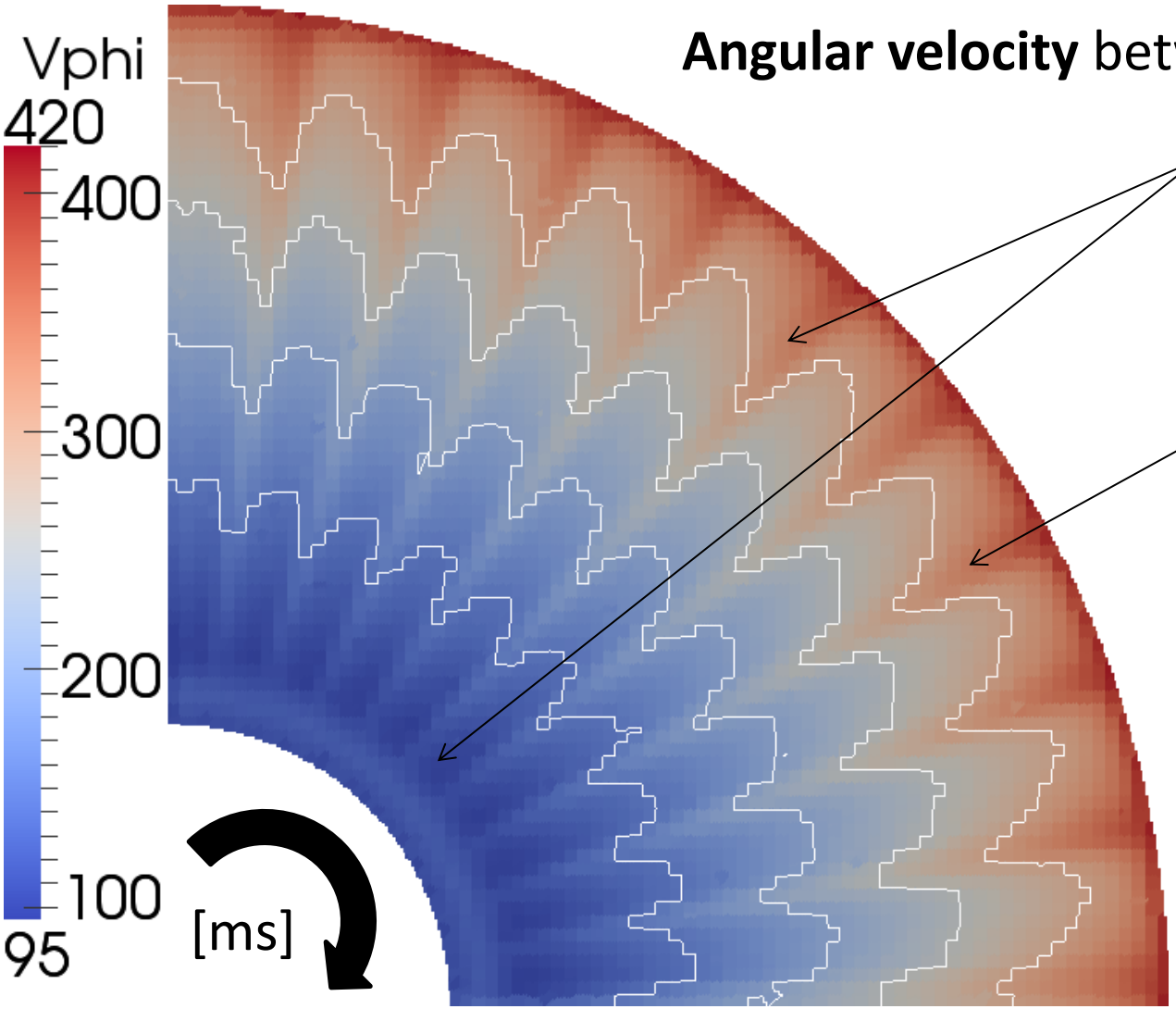
Axial velocity between stage 2 & 3.

Gas flows to the low pressure side (inlet) between blades.

Gas is driven to the high pressure side (fore line) by the blades.

Gas flows to the low pressure side (inlet) at the rotor.

Results – flow field

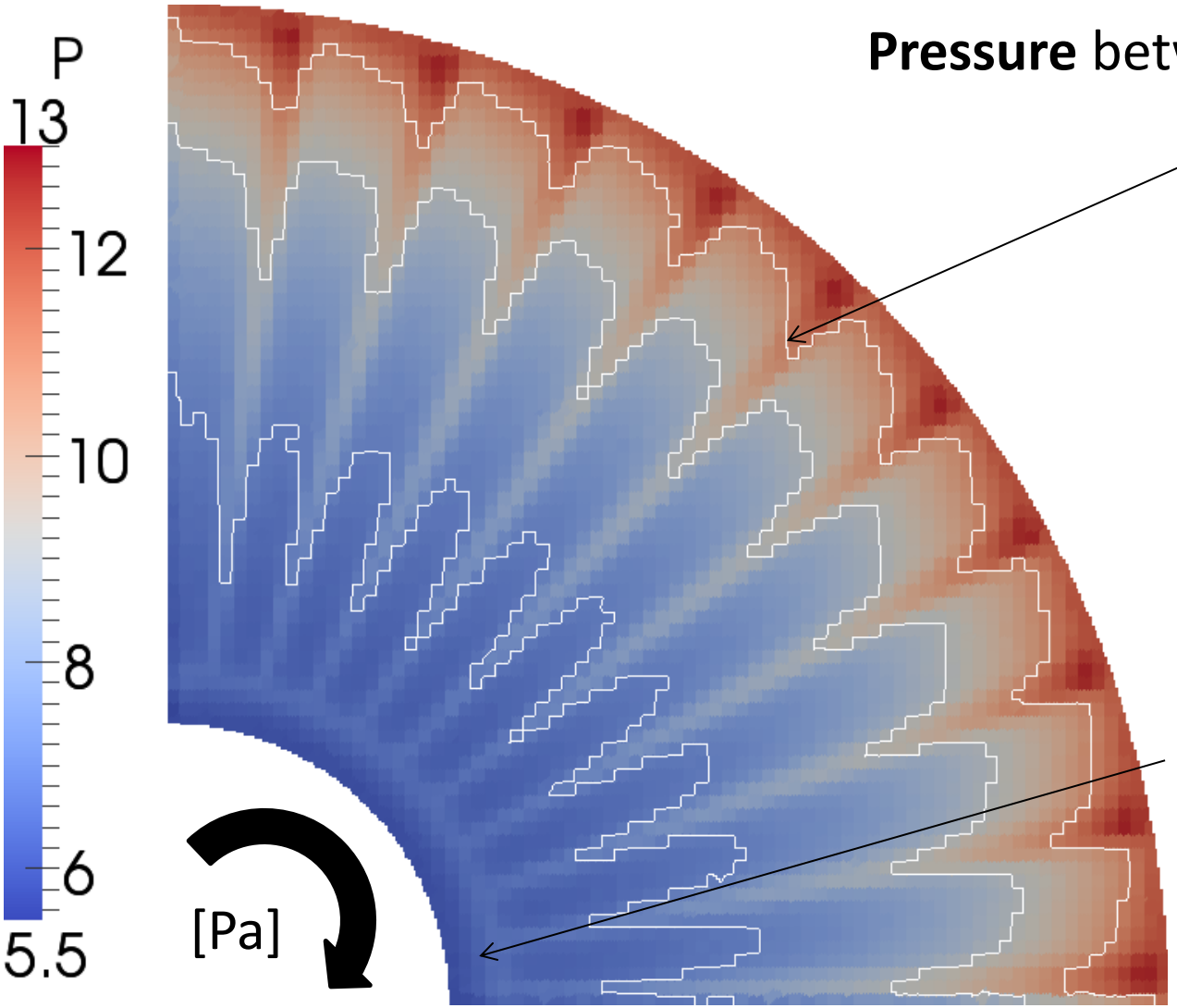


Angular velocity between stage 2 & 3.

Angular velocity increases with radius.

For constant radius the velocity increases in front of blades.

Results – flow field

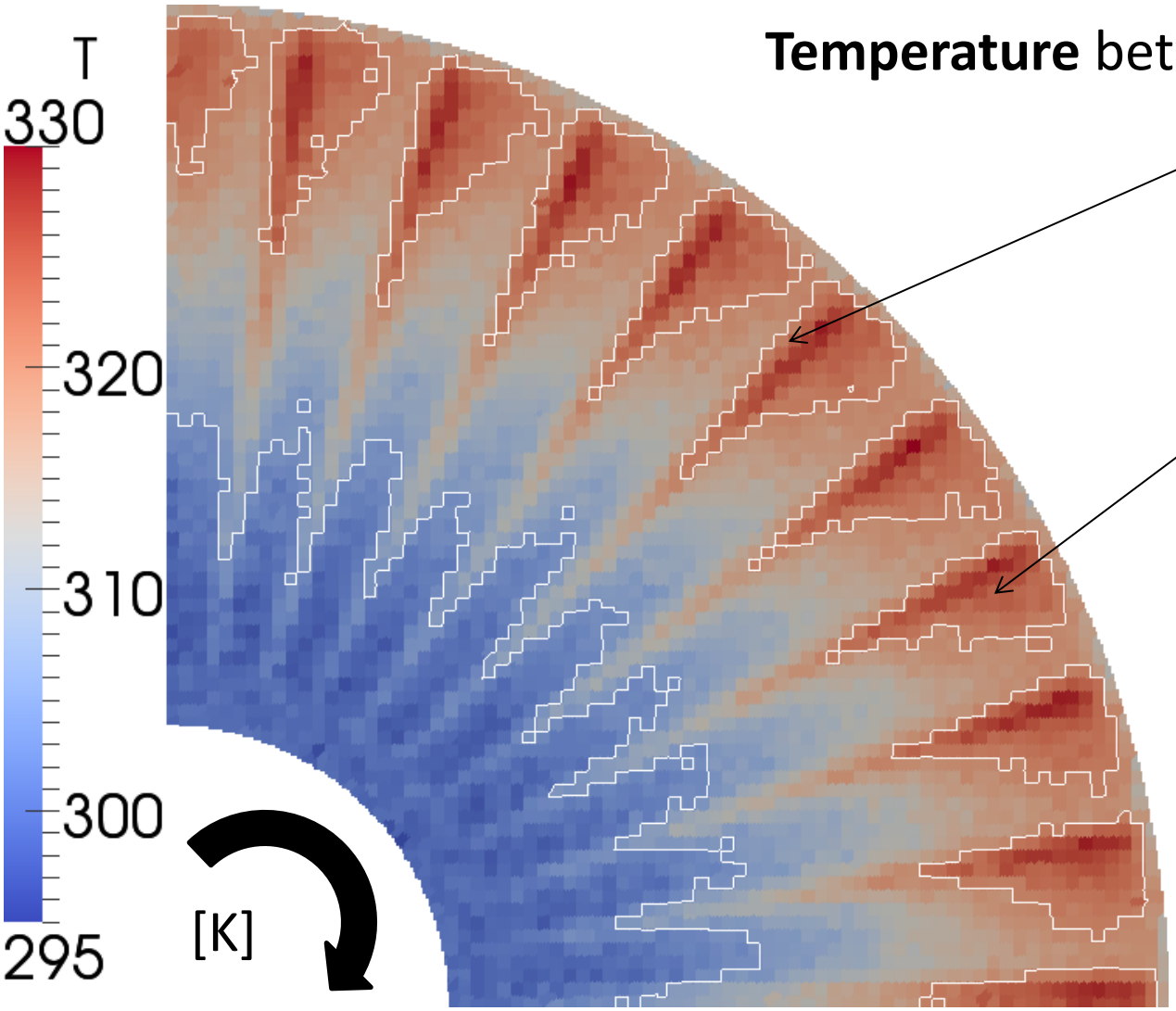


Pressure between stage 2 & 3.

Pressure increases with radius due to centrifugal force.

Pressure increases in front of blades due to motion of blades.

Results – flow field



Temperature between stage 2 & 3.

Temperature increases with radius.

Temperature increases in front of blades due to the motion of blades.

Summary & Conclusions

- A simulation of compression and pumping speed is possible in 3D. Realistic trends have been observed.

- The flow field for both modes of operation was investigated and differences were pointed out.
  This information can be used to optimize the TMP.

- The flow field between stages was analyzed. The complexity thereof indicates that multi stage simulations are necessary.

- The required CPU time to simulate a realistic geometry was determined.

End

Thank you very much for your attention!