

Wachstums Kern Fluss-Strom Plus

Grundlastfähige Energiegewinnung durch ökologisch verträgliche Flusswasserkraftanlagen



OTTO VON GUERICKE  
UNIVERSITÄT  
MAGDEBURG

VST

FAKULTÄT FÜR VERFAHRENS-  
UND SYSTEMTECHNIK

# Numerische Untersuchungen zum „Fischfreundlichen Wehr“

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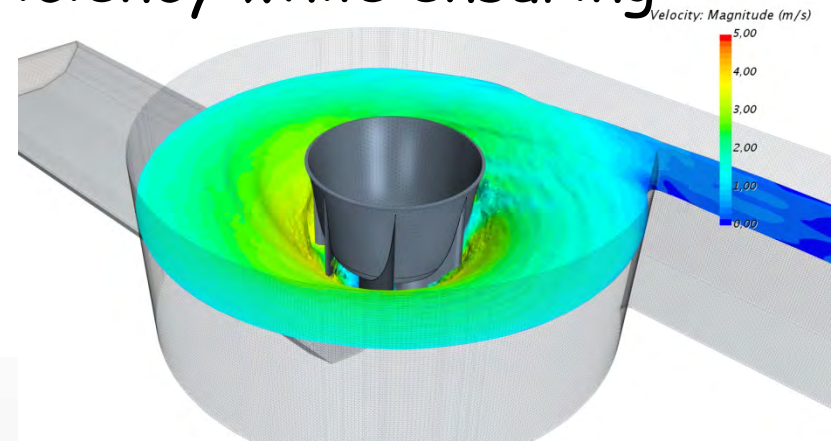


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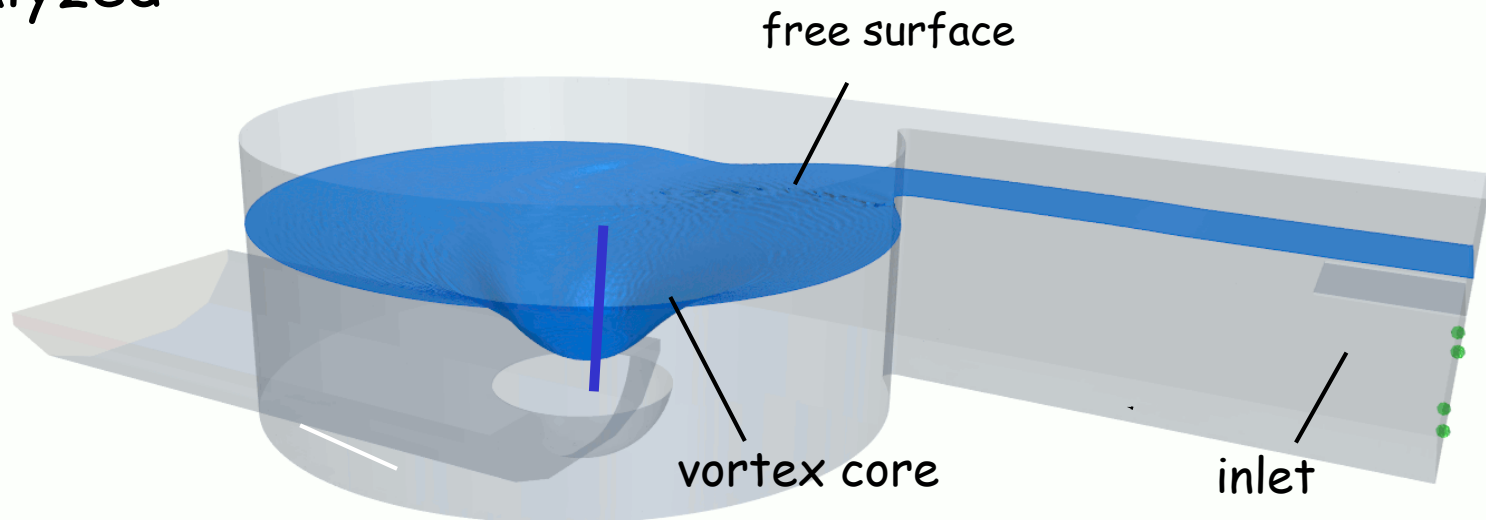
# Investigating the FFW at Univ. Magdeburg:

- **Understanding:** What does the flow structure look like in the weir?
- **Checking:** How can we assess fish-friendliness?
- **Optimizing:** Maximize turbine efficiency while ensuring fish-friendliness
- **Upgrading:** Cascading FFWs



# CFD (Computational Fluid Dynamics)

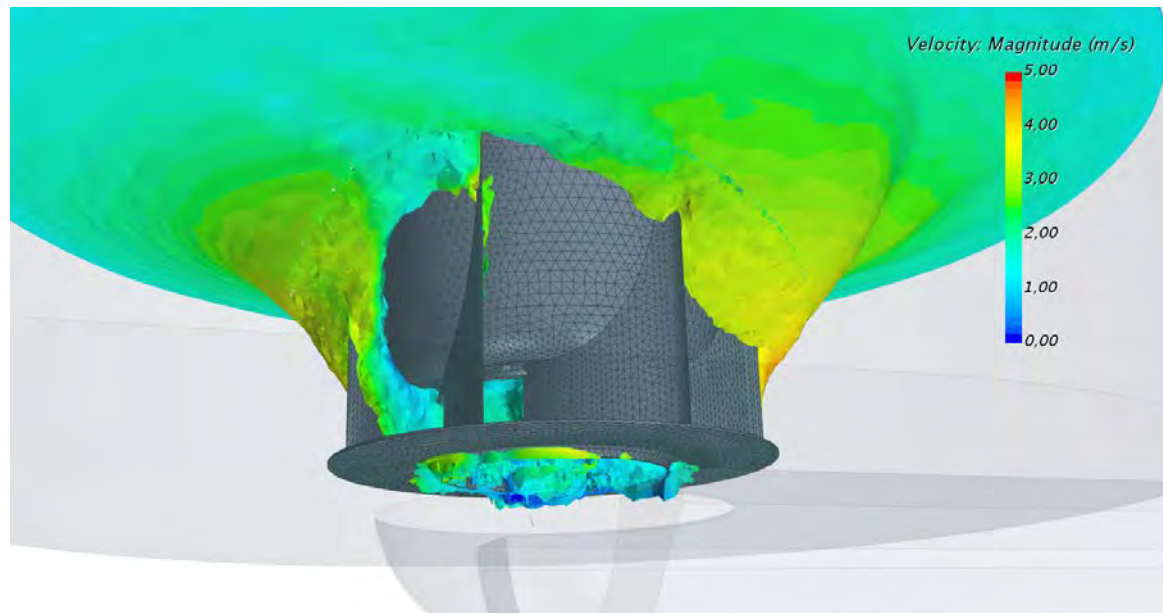
- We define geometry, walls, inflow conditions...
- The computer then **calculates the hydrodynamics** based on **conservation equations for mass, momentum, energy**
- Once completed (it can take weeks!), every detail of the flow (velocity, pressure, turbulence...) can be analyzed



# How does the turbine affect the flow?

Up to now, turbine geometry from the Bühlau prototype:

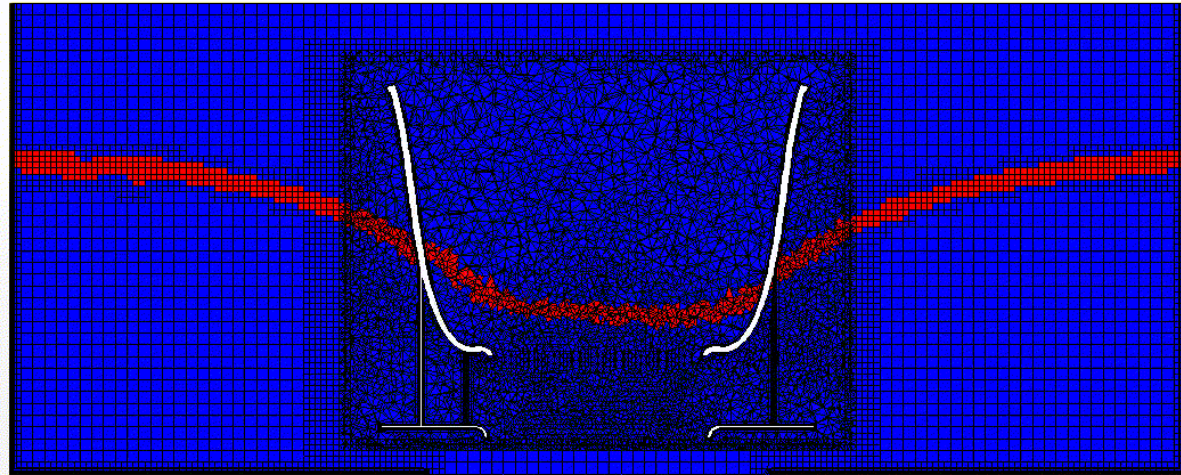
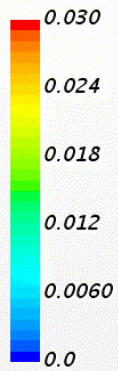
- Rotating mesh with overset technique; grid refined dynamically
- Forces, torque, and velocity measured numerically
- Time-dependent solution obtained
- Total cost for one full simulation:  
>10 000 CPU-hrs





STAR-CCM+

Meshrefinement



*Physical Time: 0.050 (s)*





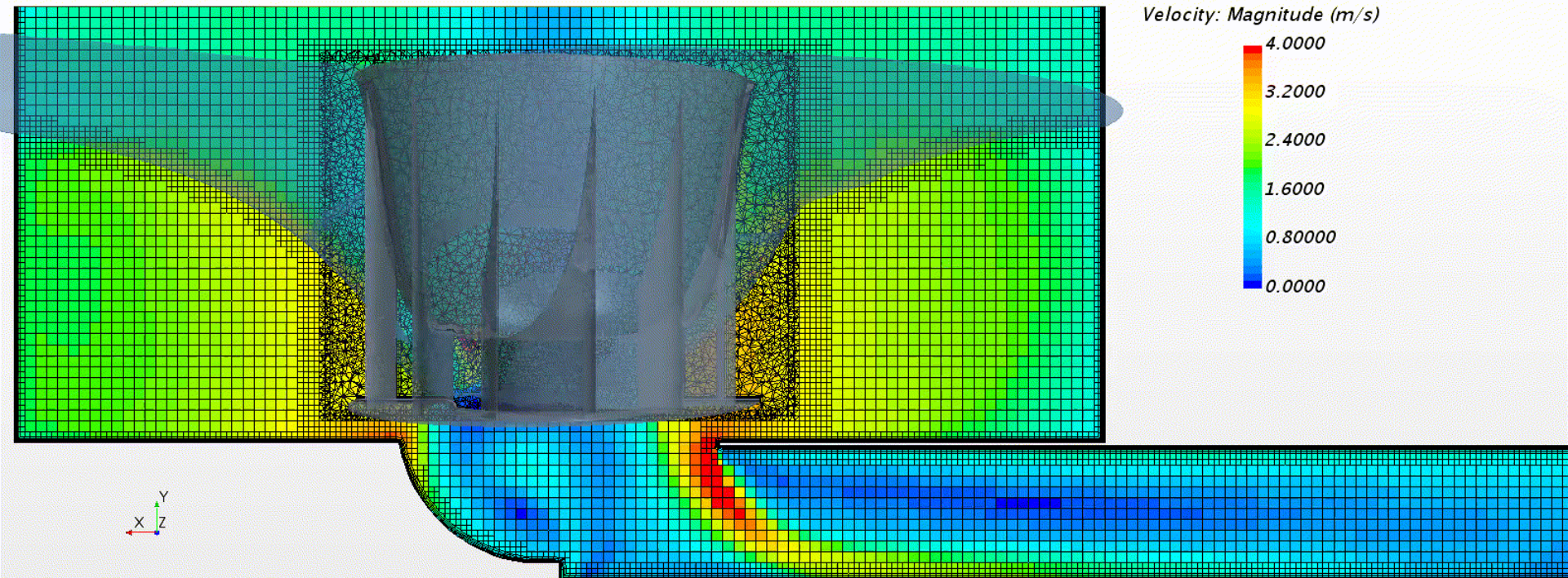
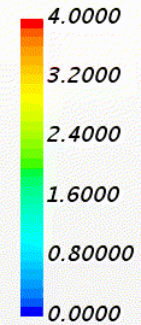
# Turbine rotation speed: 0.52 rot./s



STAR-CCM+

*Physical Time: 0.050 (s)*

Velocity: Magnitude (m/s)

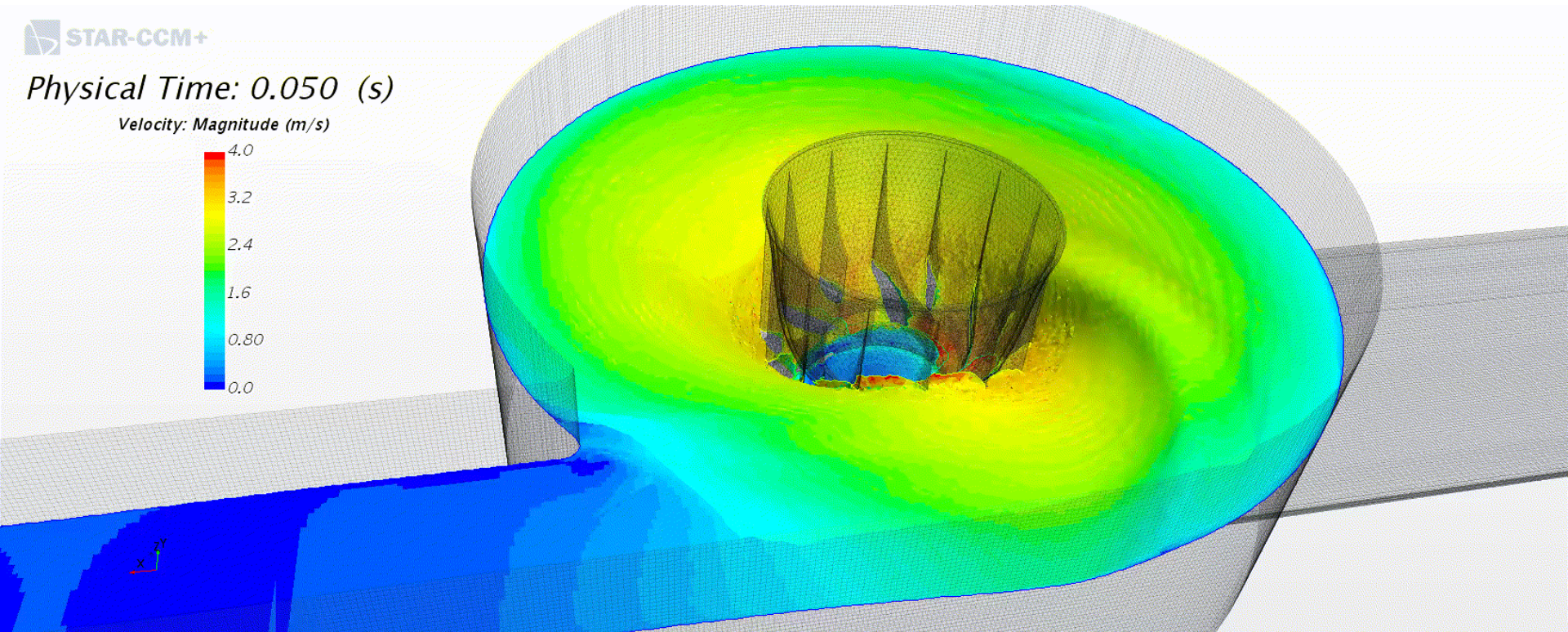
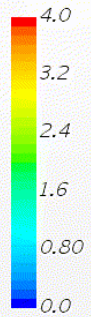




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Physical Time: 0.050 (s)

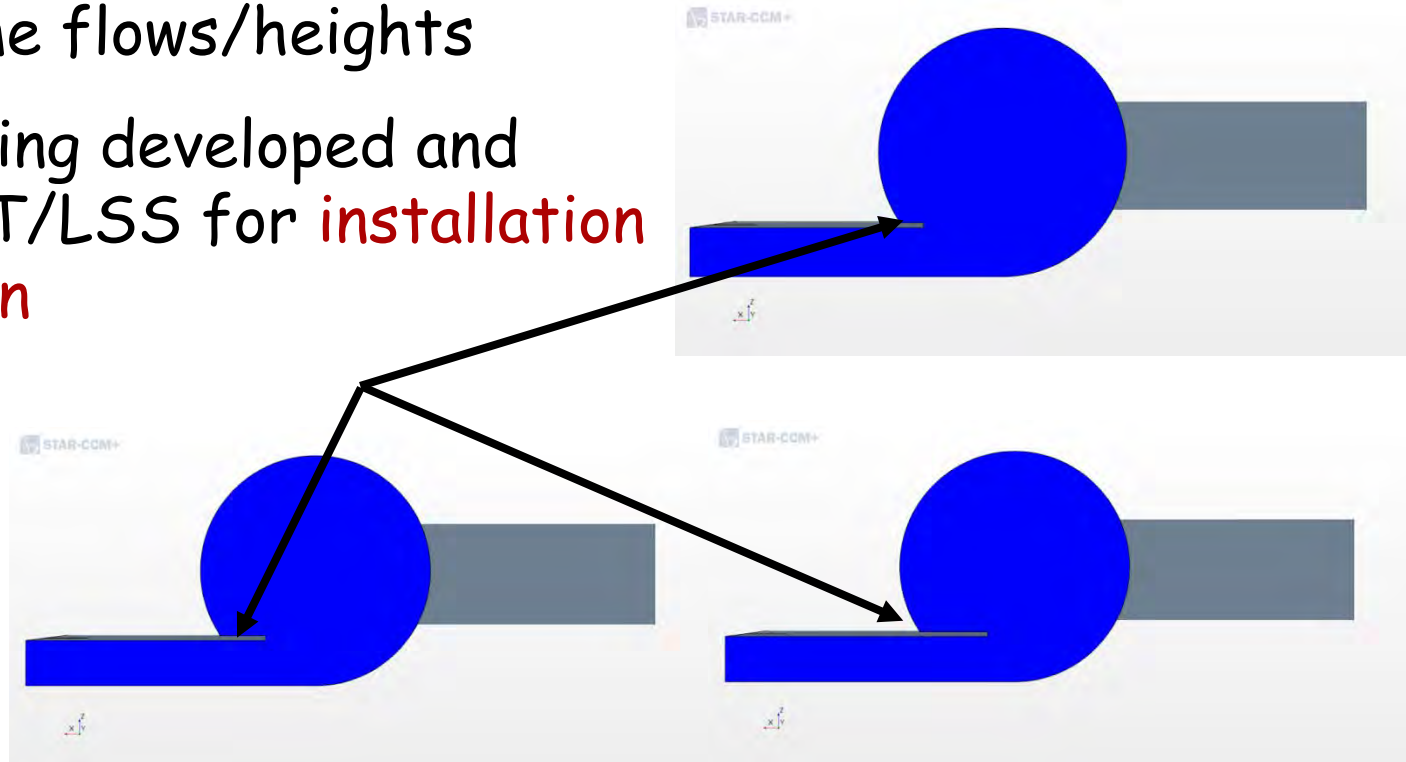
Velocity: Magnitude (m/s)



# Can we adapt the weir to varying flow conditions?

Development of a **control and regulation plate**

- Adapted from "old" scientific literature
- Concept: a moving plate to control vortex strength under varying volume flows/heights
- Prototype being developed and built by ISUT/LSS for **installation at TU Dresden**

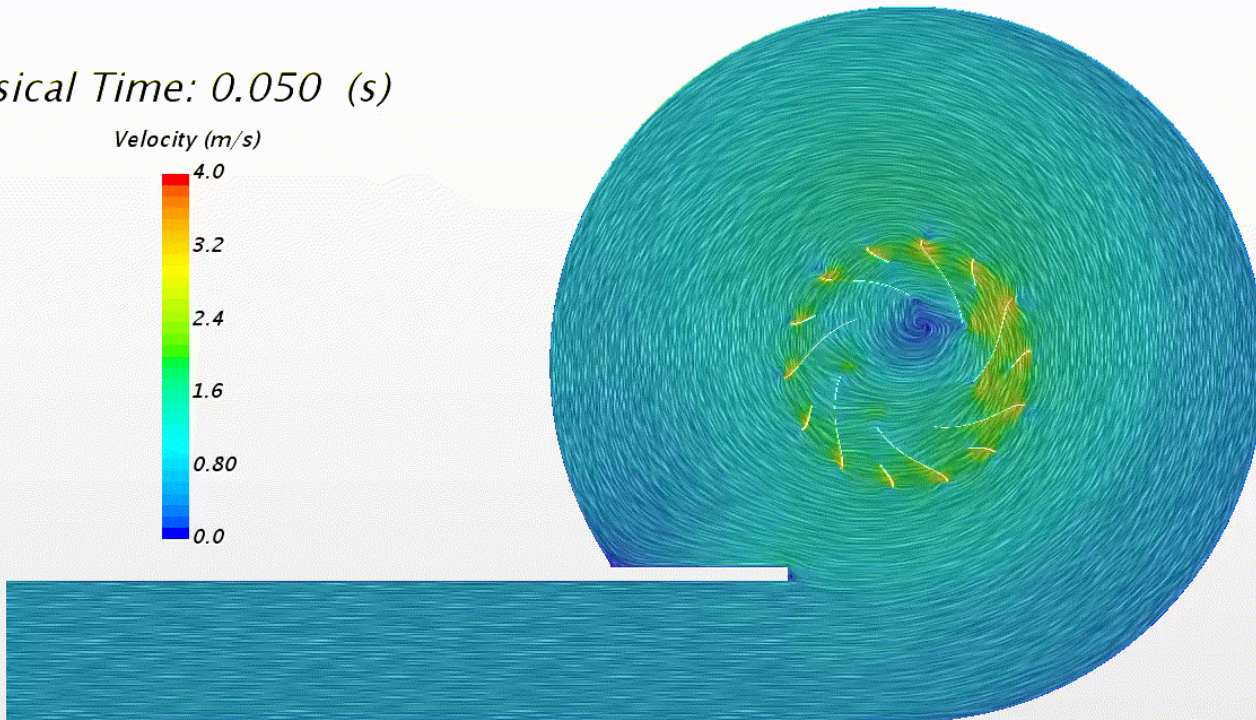






Physical Time: 0.050 (s)

Velocity (m/s)



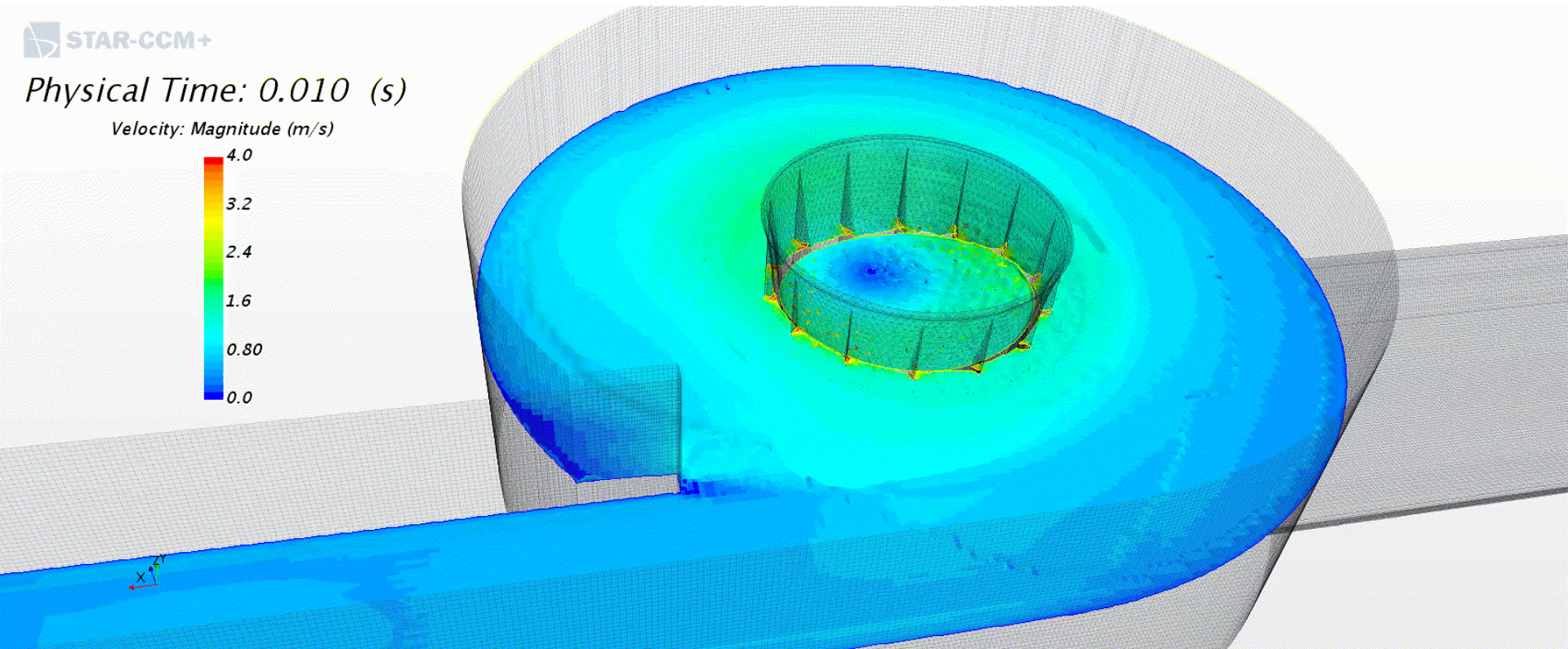
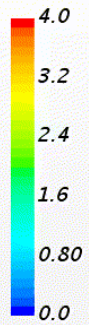
Müller, S., Cleynen, O. and Thévenin, D.: Numerical investigation of the influence of a guide wall in a fish-friendly weir. Presented at *International Conference on Engineering and Ecohydrology for Fish Passage*, Corvallis, Oregon, June 2017.



 STAR-CCM+

Physical Time: 0.010 (s)

Velocity: Magnitude (m/s)





# Can we assess "fish-friendliness"?

Ultimately, **fish experiments absolutely necessary!**

As a preliminary step, autonomous probe measurements in  
Dresden

To support measurements, **development of a set of monitors for  
a systematic analysis from computations:**

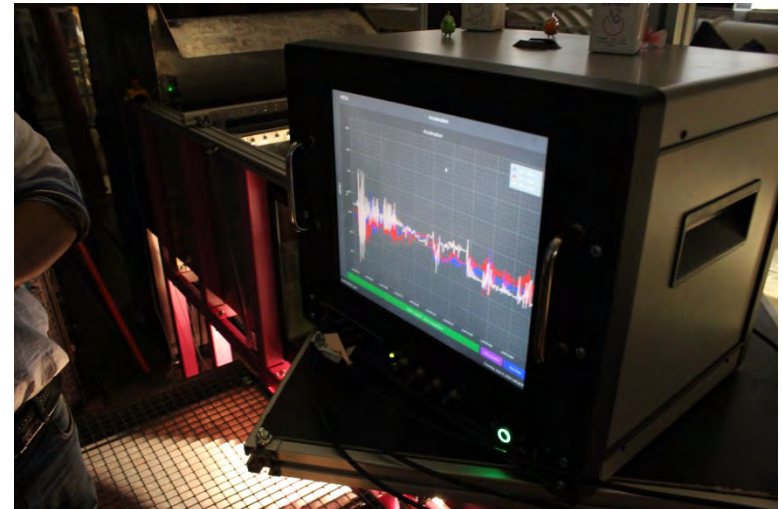
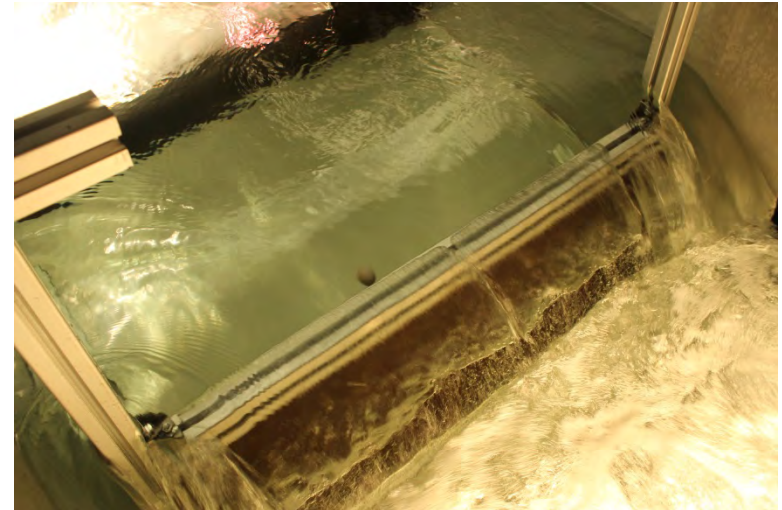
- Simple: minimum water heights in inlet/outlet
- More advanced: min/max velocities, distribution of velocity magnitudes and directions...
- Analytical model to predict probability of impact with blades?

Experimental investigations in TU Dresden starting soon: a  
**unique opportunity for rigorous, scientific comparison with  
experiments!**

# Autonomous measurement probes

Live data acquisition:

- Radiotransmission with 10 Hz acquisition frequency
- Measurement of temperature, acceleration ( $\Leftrightarrow$  forces, shocks), pressure ( $\Leftrightarrow$  depth)

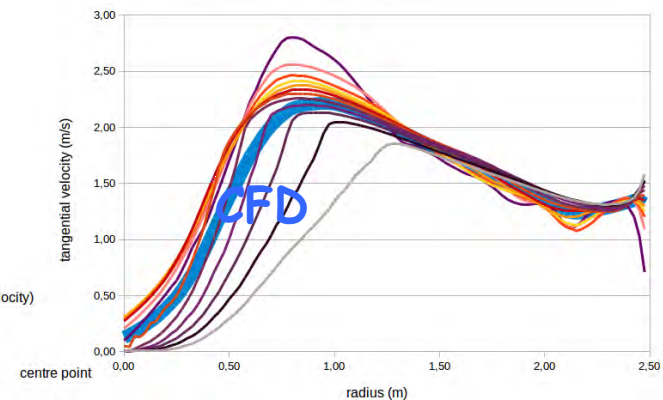
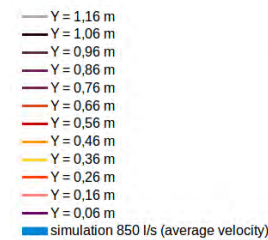
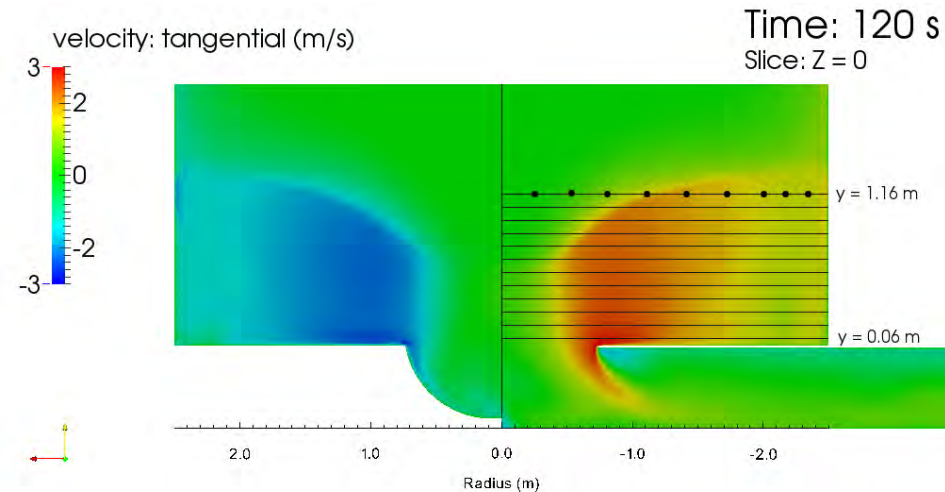




# Validation by comparison with measurements

Unfortunately, only one short set of low-quality measurements in FFW published so far:

P. Lippitsch: Funktionskontrolle des „Fischfreundlichen Wehrs“ im Bezug auf die Fischdurchgängigkeit, Studentische Arbeit, University of Görlitz/Zittau, 2013



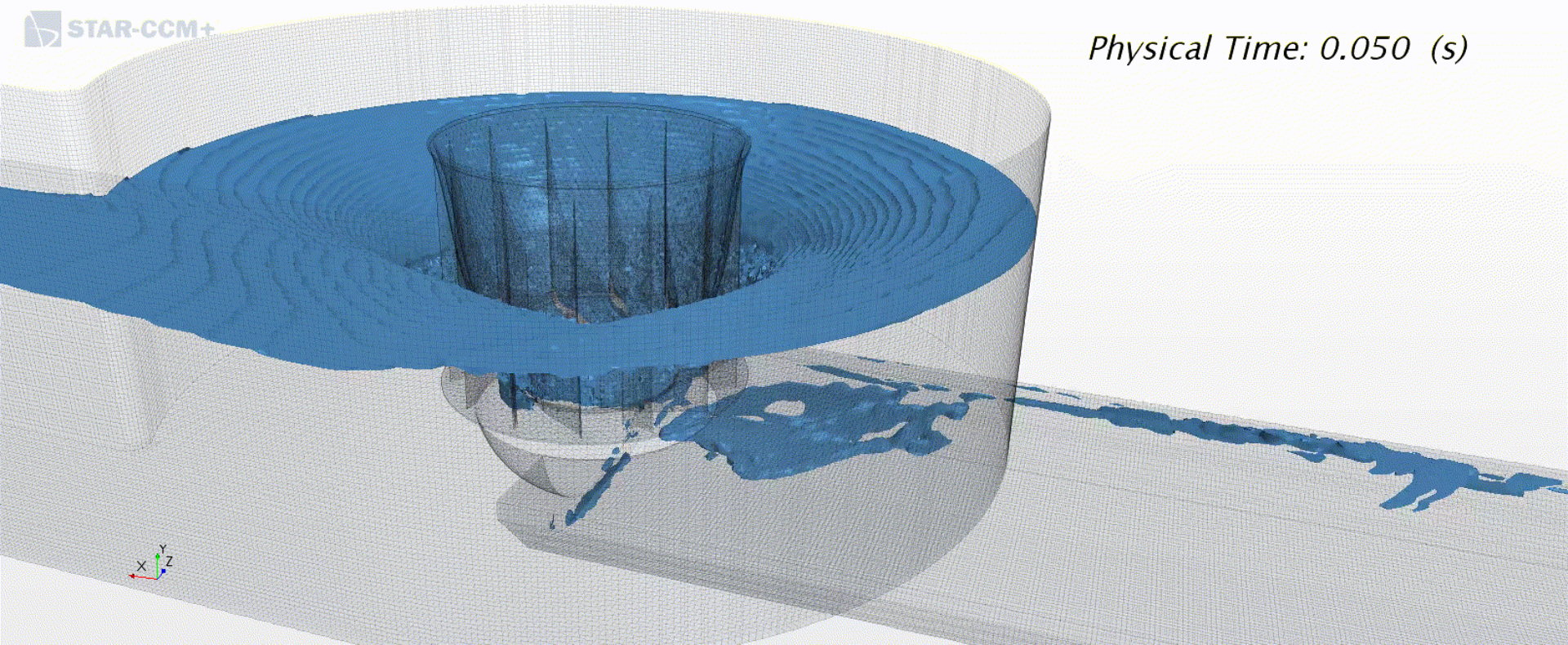
# Validation by comparison with measurements

Much richer and more precise experimental data sets are absolutely needed! Will soon take place in the Lab of TU Dresden:

- Reproducible experiments & controlled inflow conditions
- Optical access provided (clear water)
- Test of **guiding plates for control and regulation**
- **Autonomous measurement probes** to measure data "from the fishes' perspective"
- **Hydrodynamic characterization**
- Live tests involving different fish species, under control of biologists



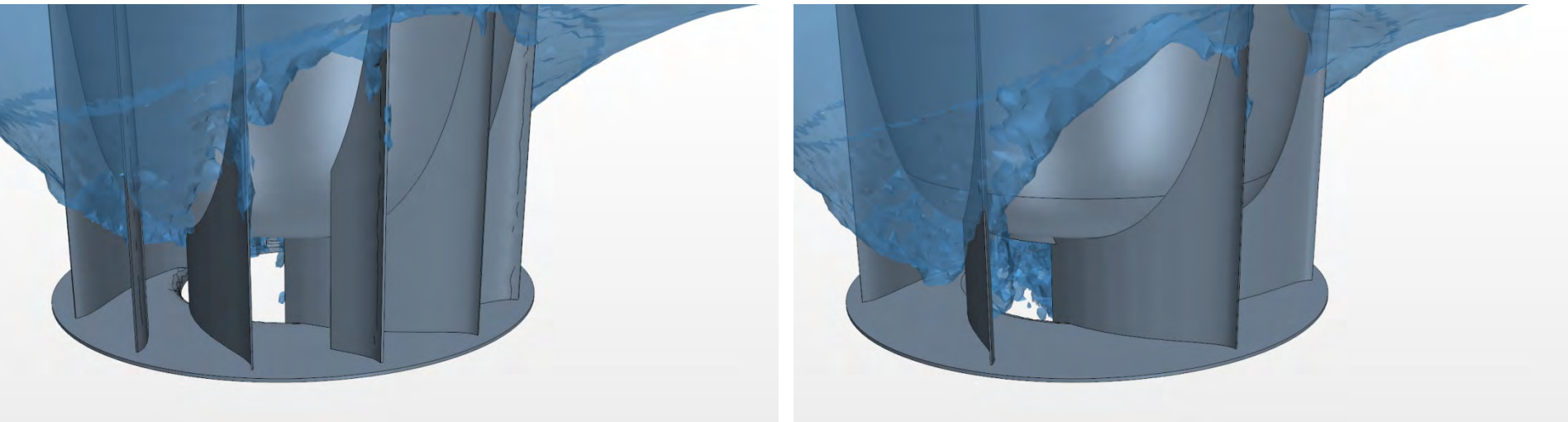
STAR-CCM+



*Physical Time: 0.050 (s)*

# Systematic parameter variation

- Reducing the number of blades: how much more “fish-friendliness” for how much reduction in power?

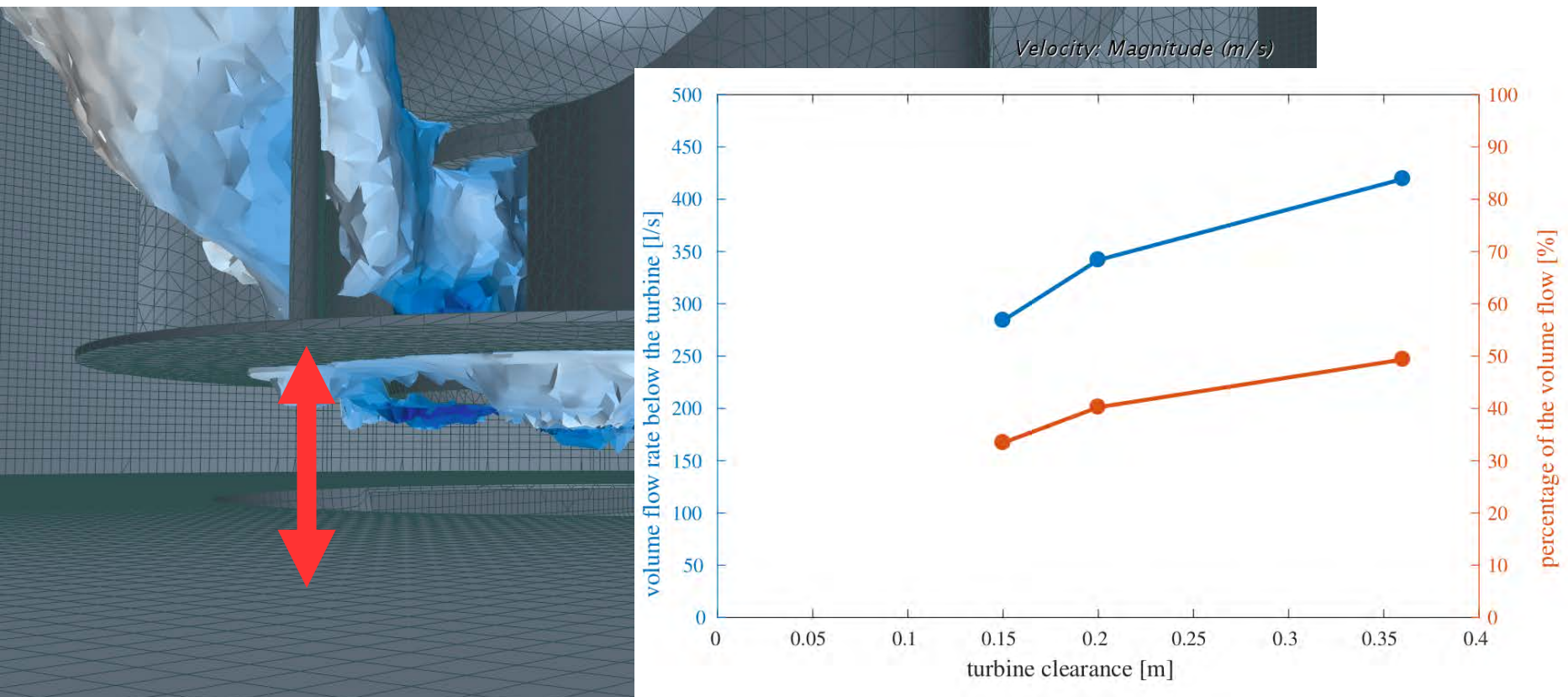


S. Müller: Numerical Investigation of the flow in a vortex power plant in consideration of the river continuity. Master's Thesis, Otto-von-Guericke-Universität Magdeburg, ISUT/LSS (2017)



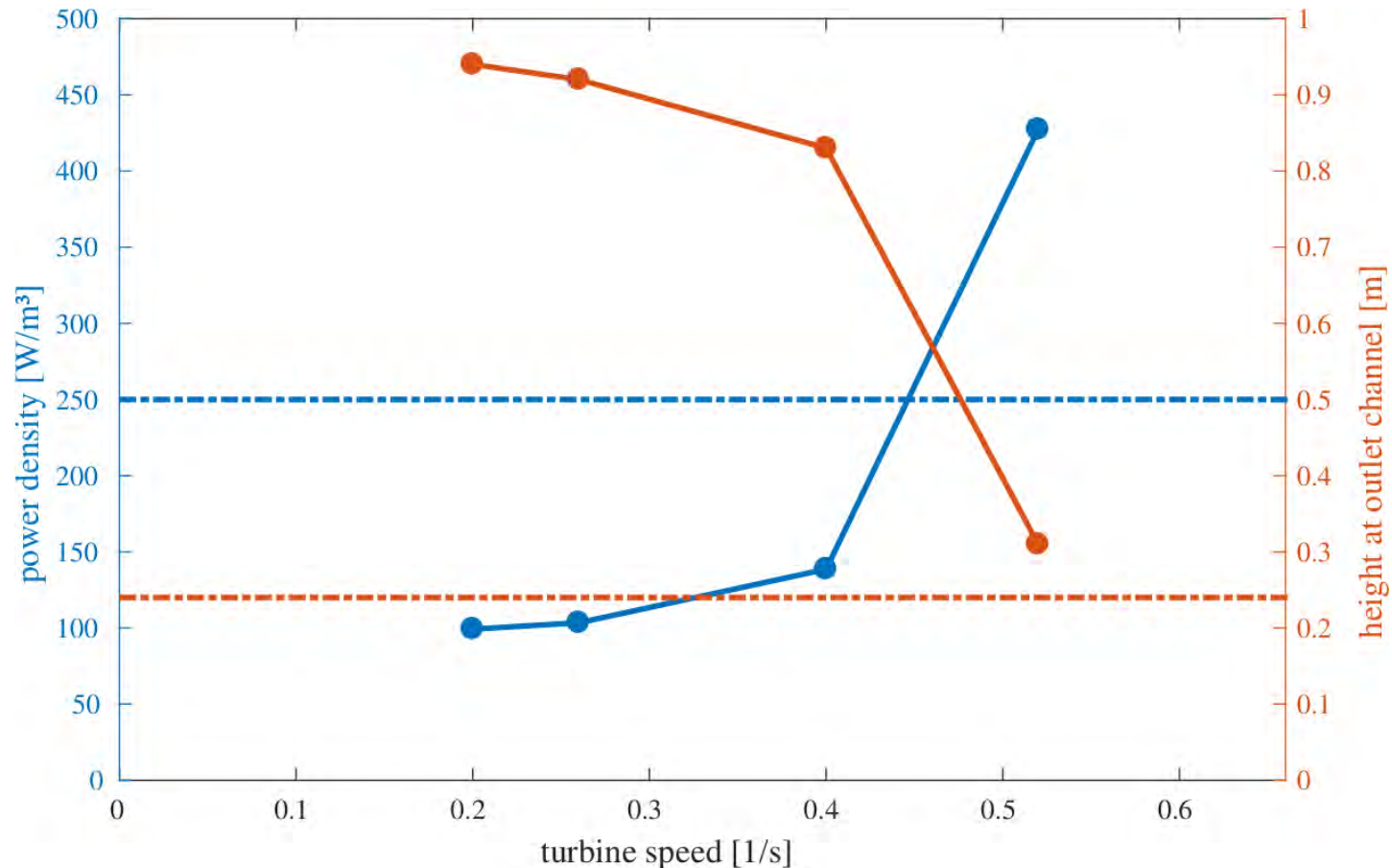
# Systematic parameter variation

- Varying the turbine bottom clearance: how much flow passes below the turbine?



# Systematic parameter variation

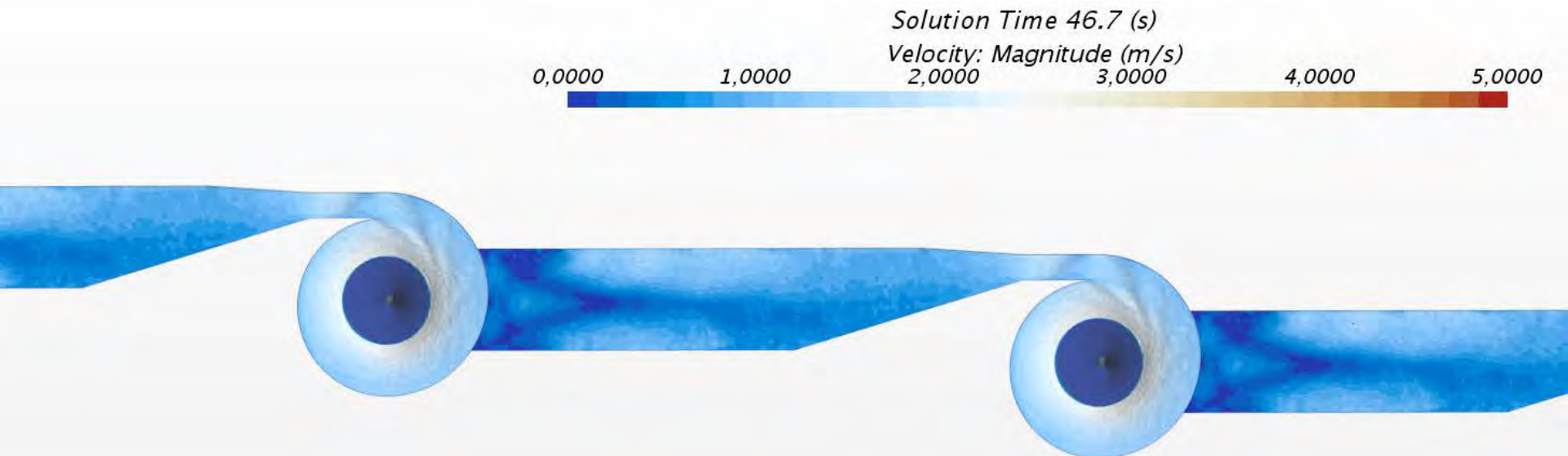
- Increasing the turbine rotation speed: how do the power density and the outlet height vary?





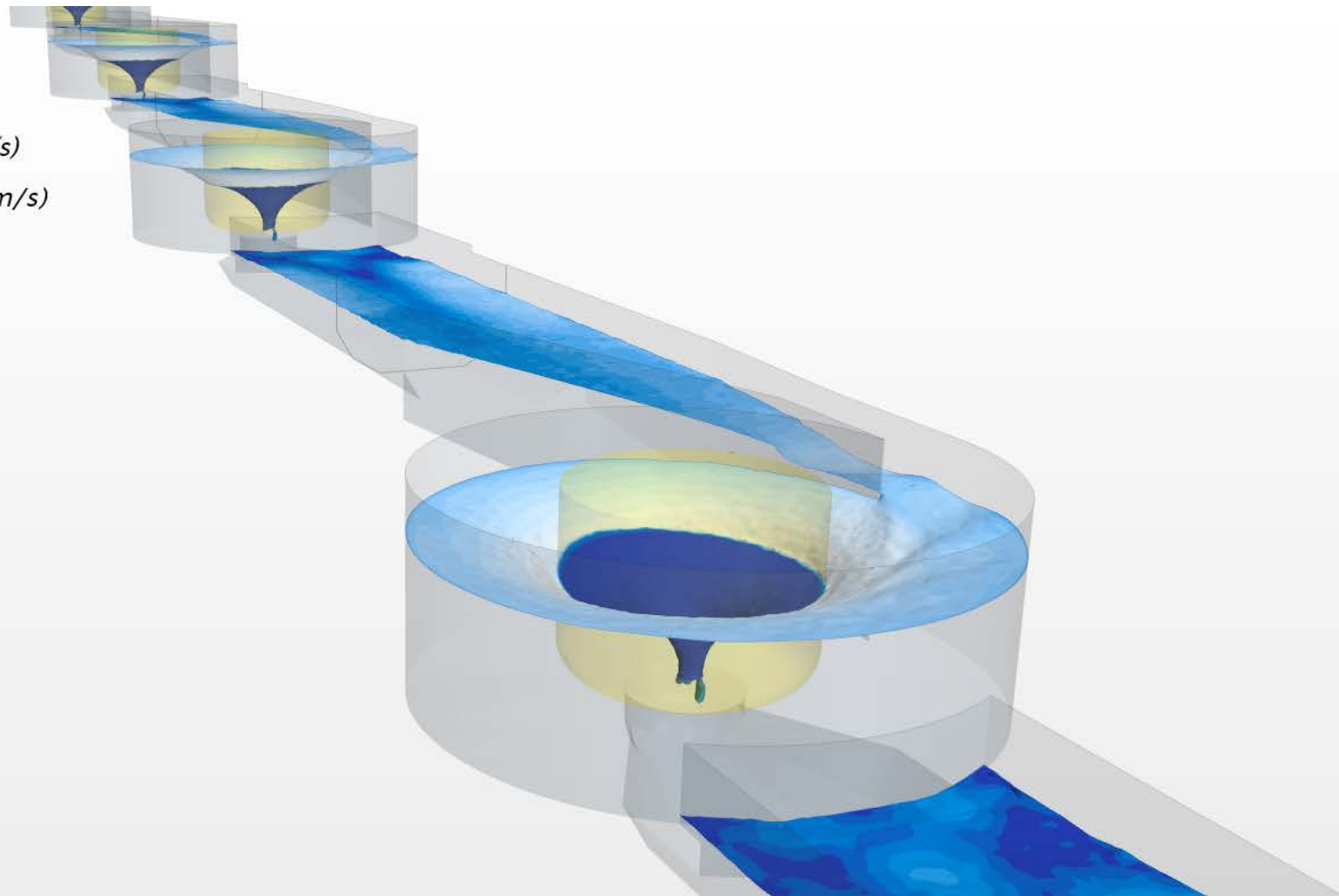
# Optimal setup for a cascade?

- The outlet is fed back into the inlet
- Question: for a given installation, what is the optimal arrangement of weirs, as function of the volume flow?
- Optimization of the cascade currently running, using a simplified model for the turbine



*Solution Time 46.7 (s)*

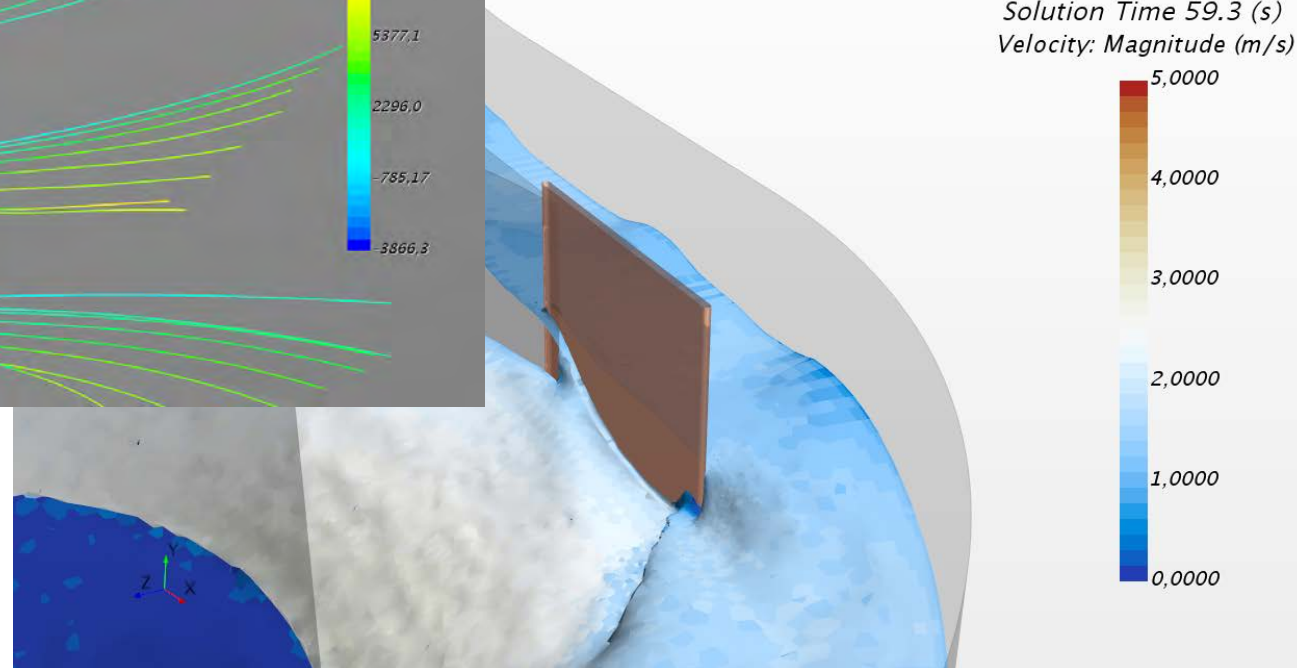
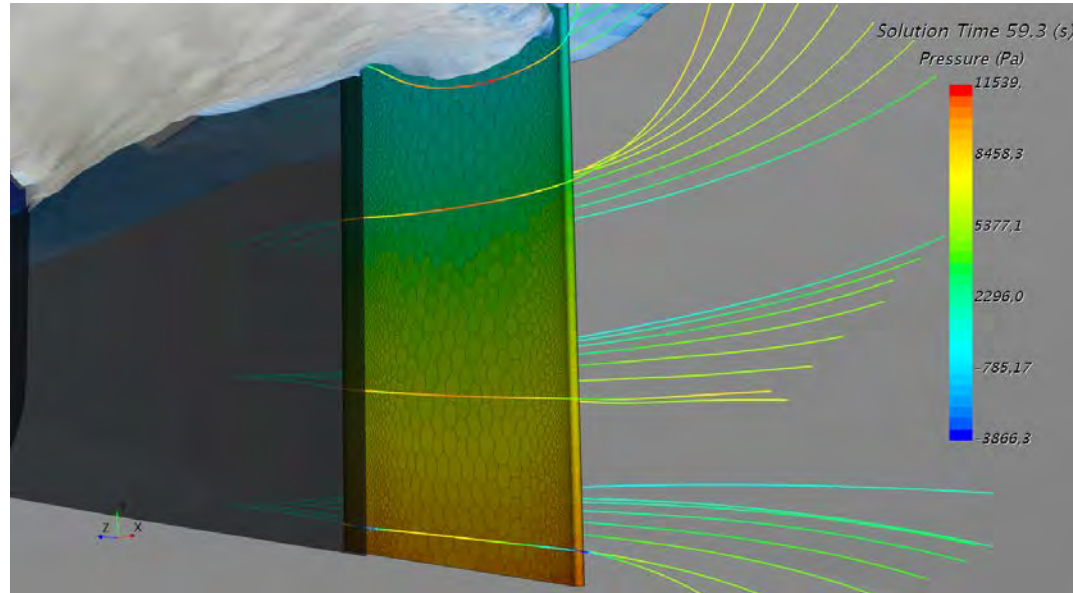
*Velocity: Magnitude (m/s)*





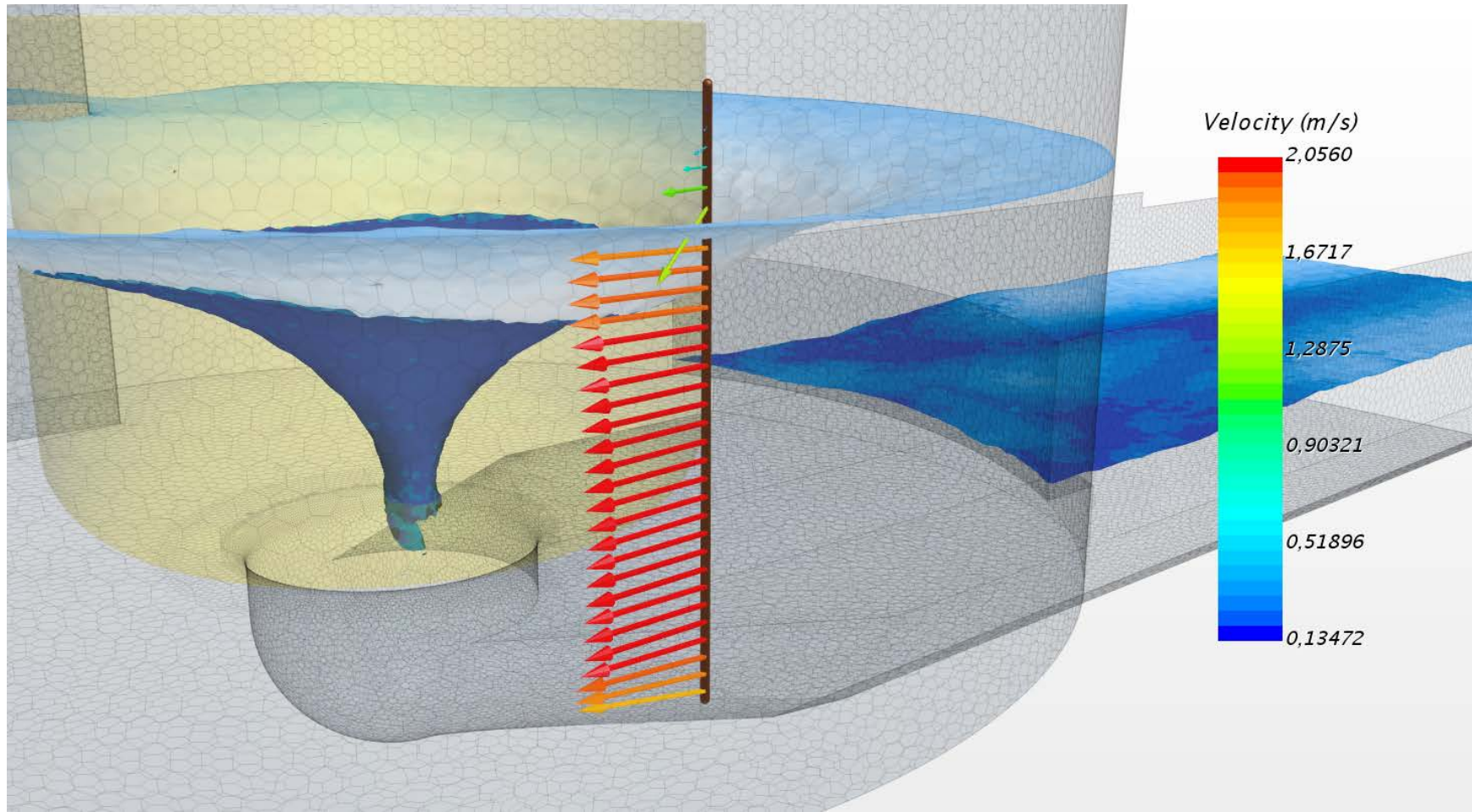
# Preparing for Dresden experiments

- Computation of hydrodynamic forces on guide wall
- Final design decisions, construction started



# Preparing for Dresden experiments

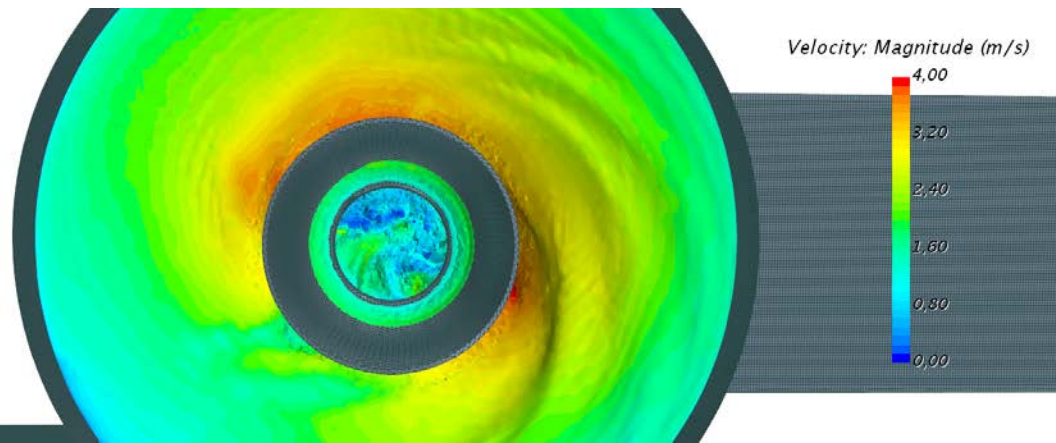
- Comparison with laser-Doppler velocity measurements soon possible





# Conclusions

- Fluid simulations are a complex, but very powerful tool
- Reliable CFD simulations require high-quality experimental measurements for validation
- Help supporting assessment of fish-friendliness based on hydrodynamic criteria
- Opens the door for systematic parameter studies of possible variations: different turbine designs, range of volume flows, etc.
- Finally guiding process control and optimization

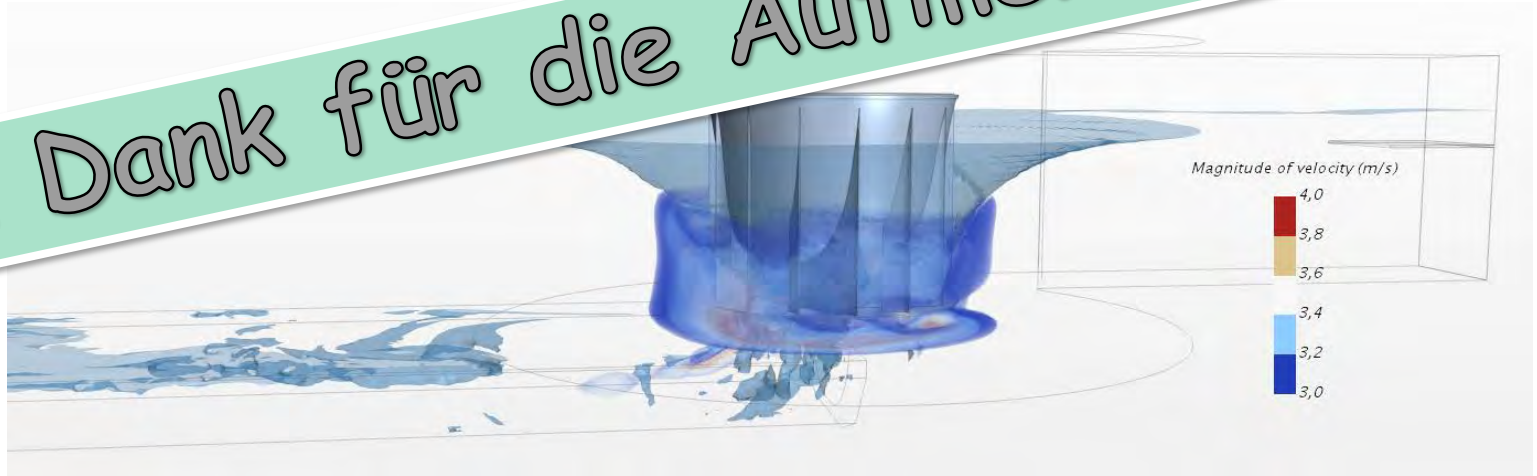


## Lehrstuhl für Strömungsmechanik und Strömungstechnik (LSS)

<http://www.lss.ovgu.de/>

Prof. Dr-Ing. Dominique Thévenin

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# Assessing blade impact probability

- Analysis of near-turbine flow: what is the probability that a fish passively drifting down hits a blade?

