



Wind Energy Institute

Grand Opening Event TWEET-IE

LES simulations for wind tunnel validation

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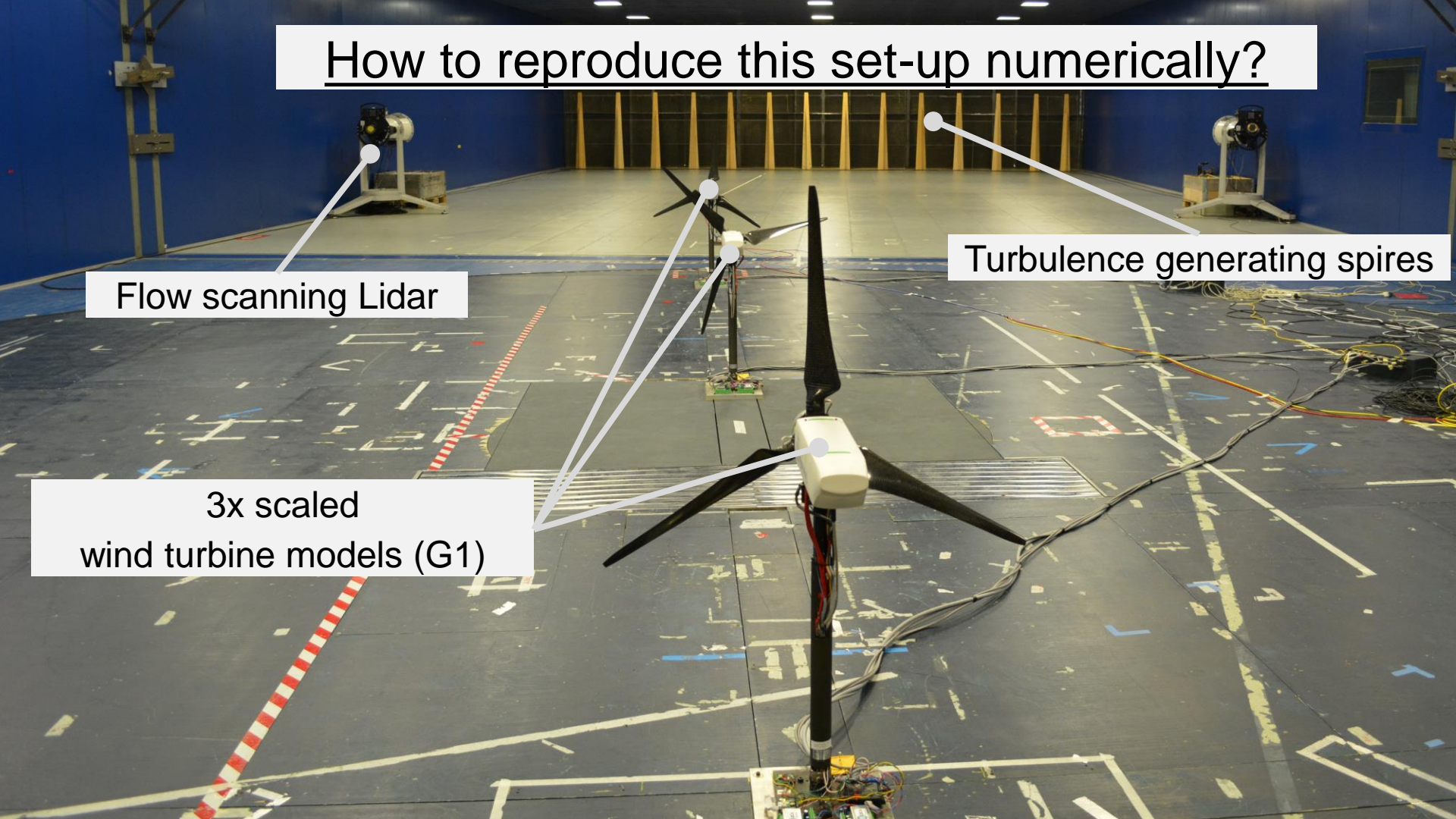


How to reproduce this set-up numerically?

Flow scanning Lidar

Turbulence generating spires

3x scaled
wind turbine models (G1)



Outline



1. Introduction to the software
 - Actuator line method
 - Computational set-up
 - Controller framework
2. Important steps for modeling wind tunnel experiments
 - Identification of blade airfoil polars
 - Modeling of tower and nacelle
 - Turbulent inflow generation
3. Example of a wake steering wind farm control experiment

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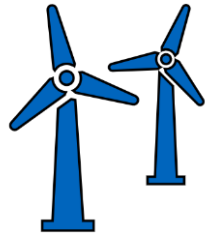
LES framework



High-fidelity digital model (CFD)
of wind tunnel
and experimental setup

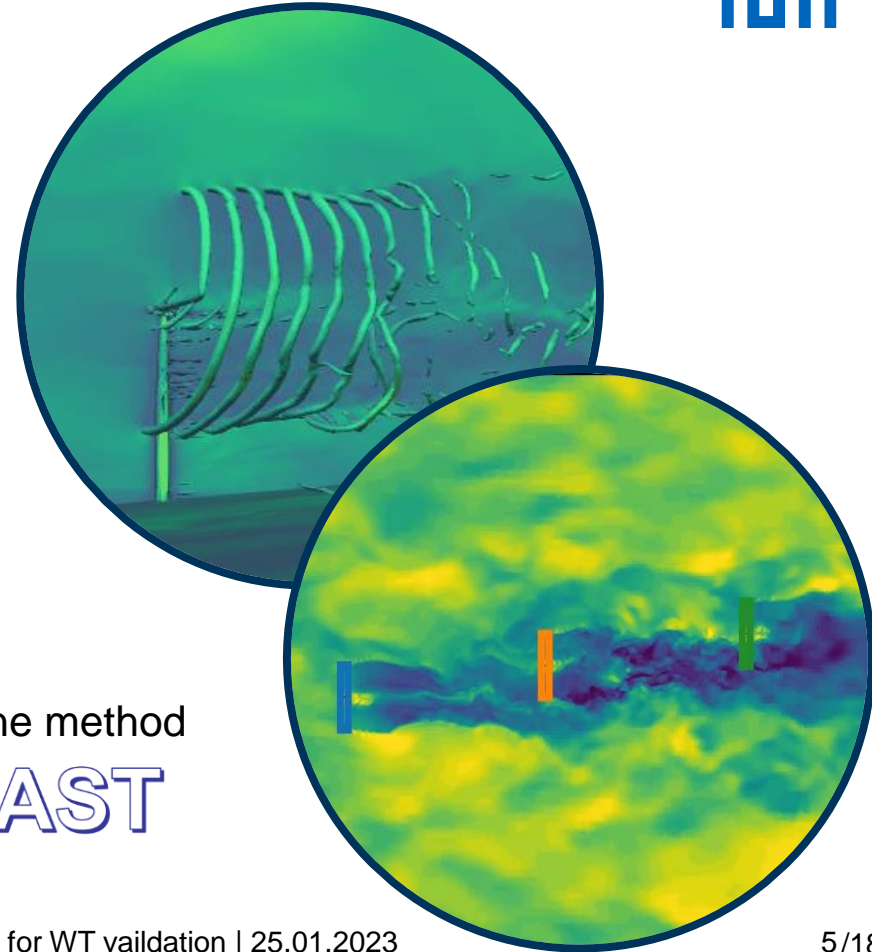


Turbulence is modeled with LES
using Smagorinsky
eddy viscosity model



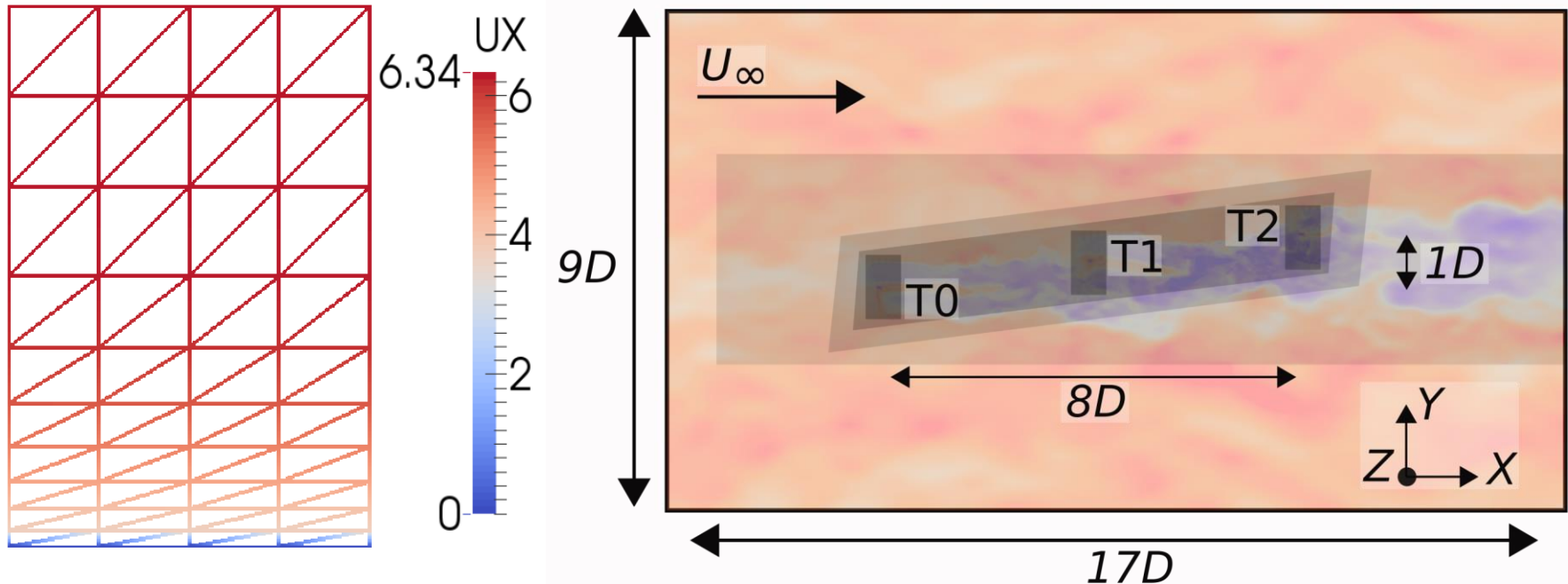
Blades are modelled with actuator line method

Open  FOAM® \longleftrightarrow FAST



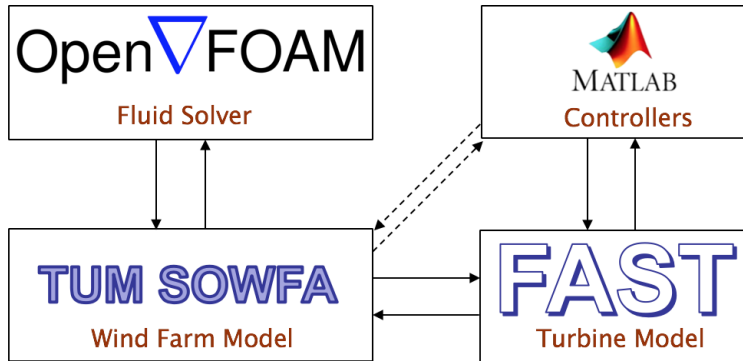
Computational set-up – spatial discretization

- Cartesian mesh, minimum 50 grid cells across rotor to well resolve tip/root vortex structure
- Multiple refinement levels are employed to reduce computational cost, and achieve enough accuracy
- Stretching ratio is set to 1.27 for boundary layer mesh ($y_+ < 55$)

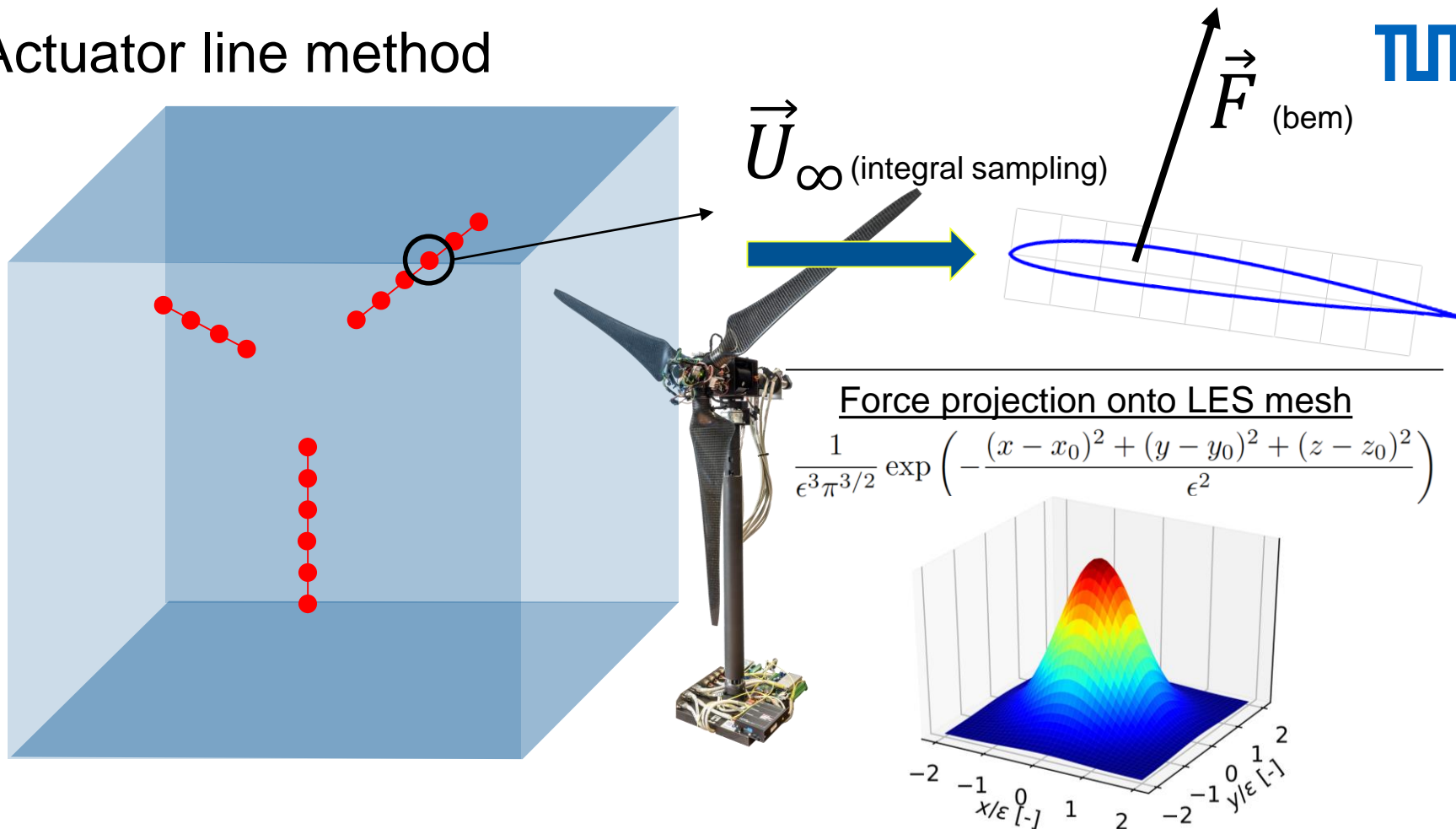


Controller framework

- Turbine controllers are synthesized with SIMULINK, converted to C-code and successively compiled into a bladed-style DLL .
- The exact same controller can be run on the scaled WT model (Bachmann)



Actuator line method



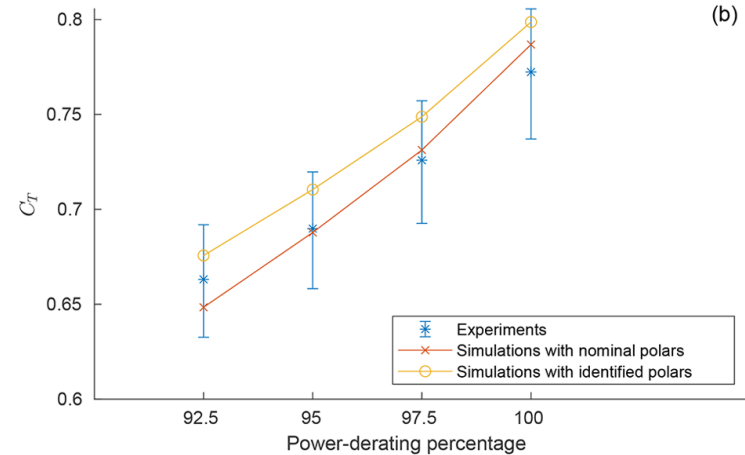
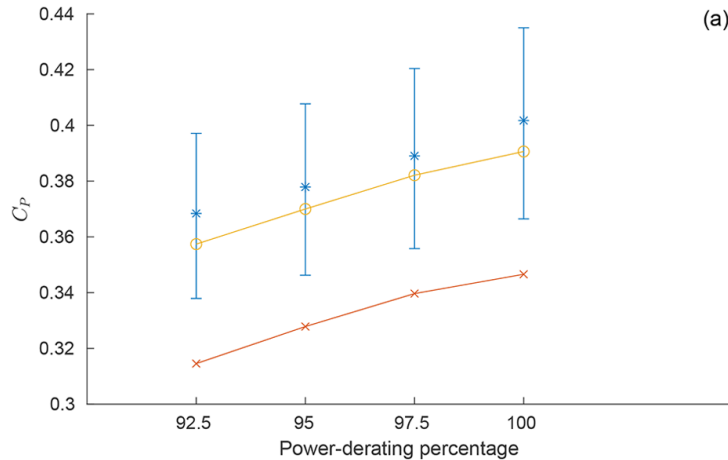
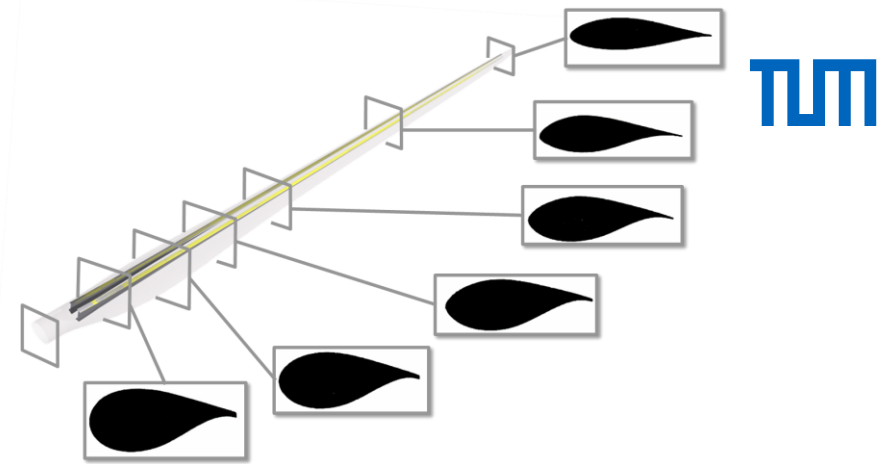
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Identification of polars

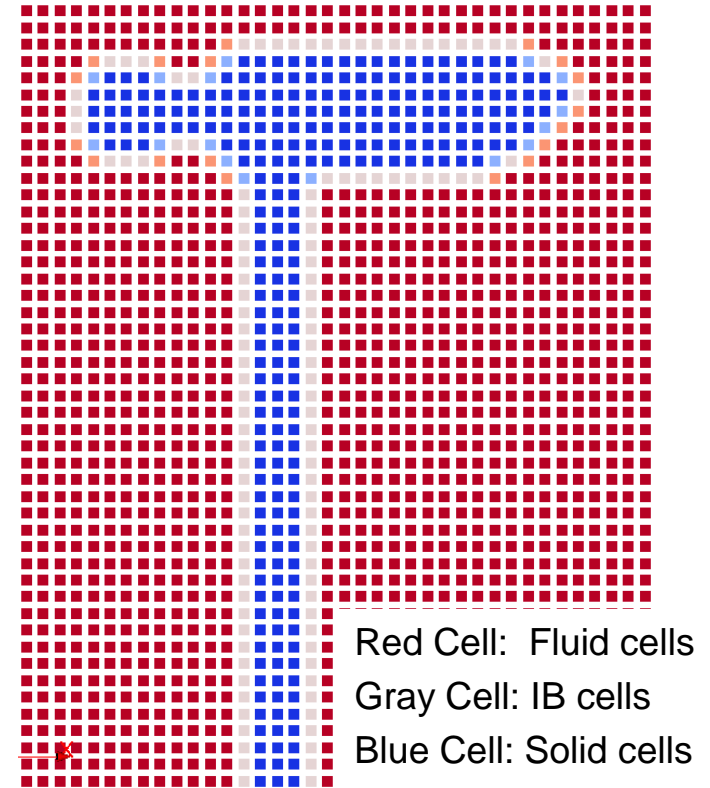
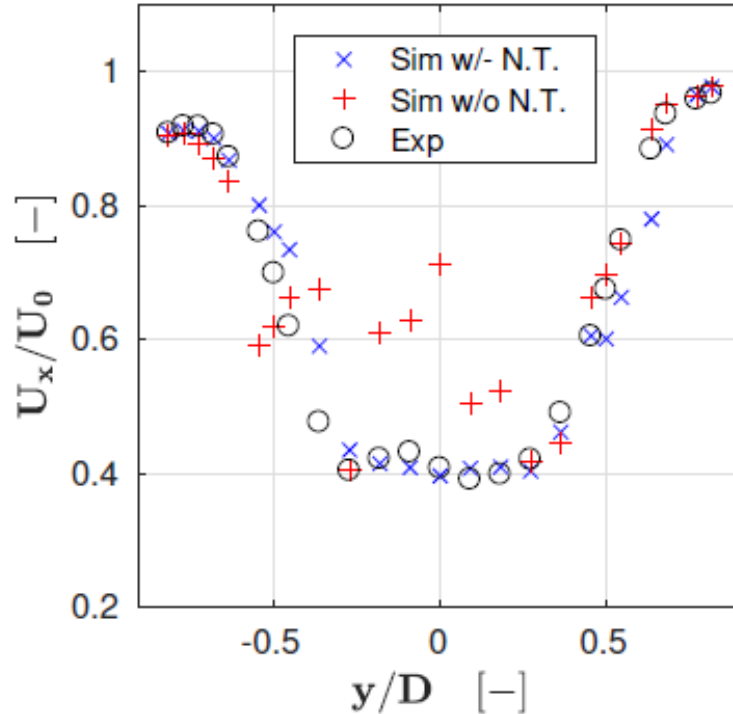
- Sources for uncertainty:
 - Low Reynolds regime
 - Small changes in operating conditions cause significant changes in aerodynamics
 - Standard blade wear
 - Modest manufacturing imperfections



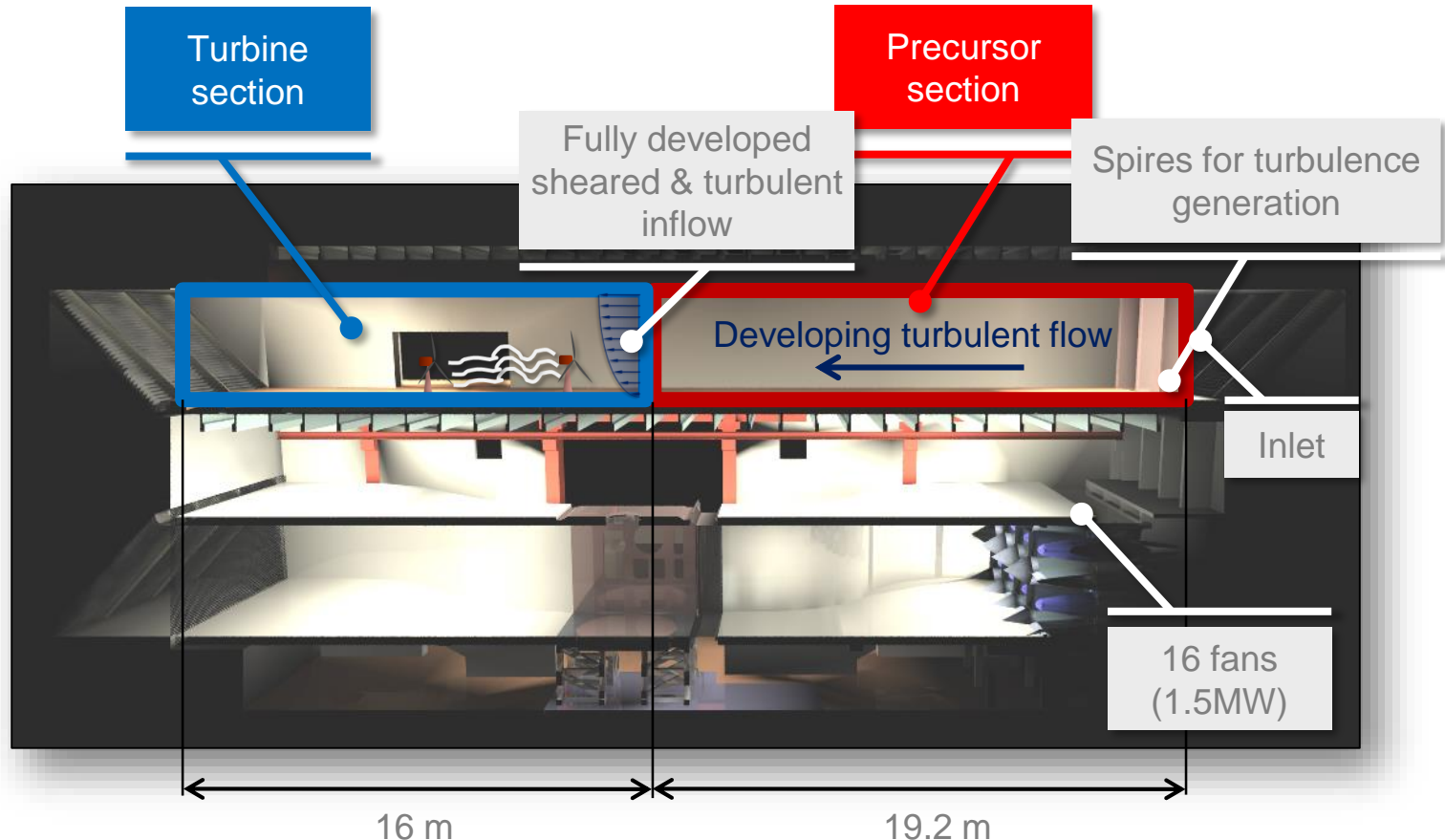
Wang, C., Campagnolo, F., and Bottasso, C. L.: Identification of airfoil polars from uncertain experimental measurements, *Wind Energy. Sci.*, 5, 1537–1550, <https://doi.org/10.5194/wes-5-1537-2020>, 2020.

Importance of correct tower/nacelle modeling

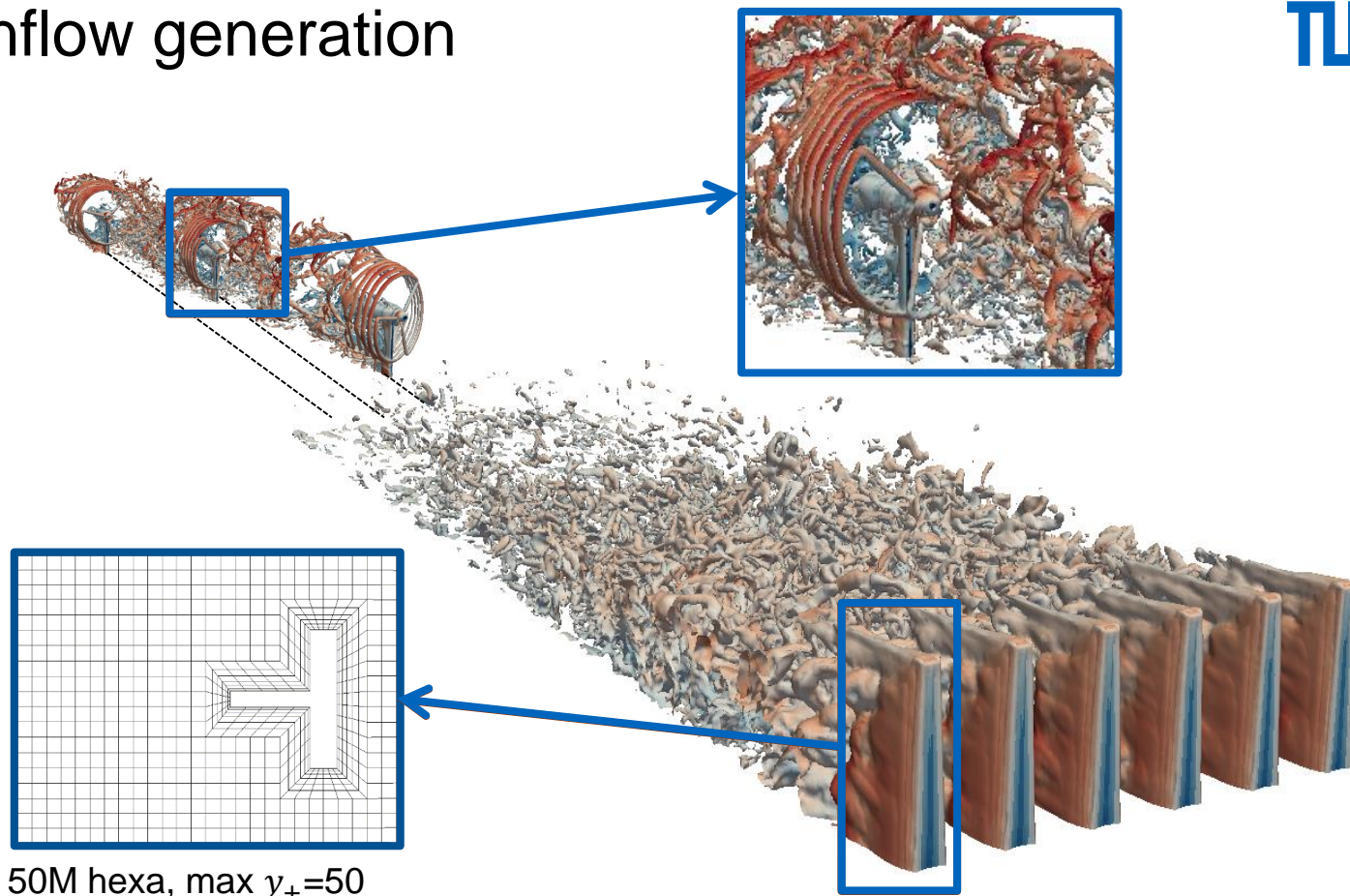
Immersed boundary method



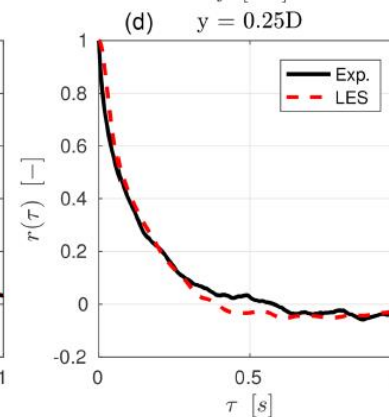
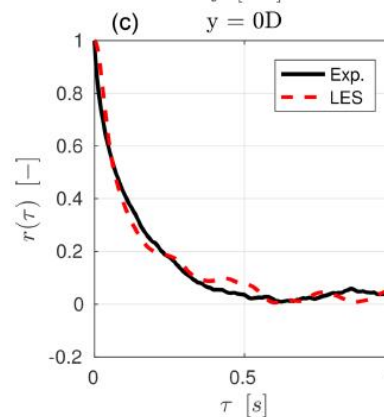
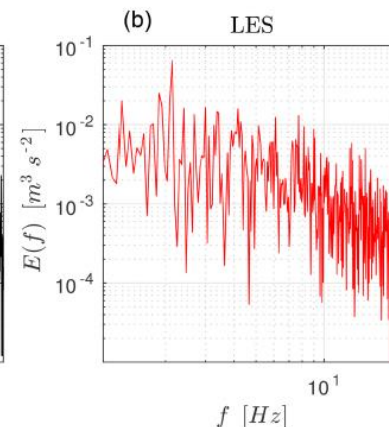
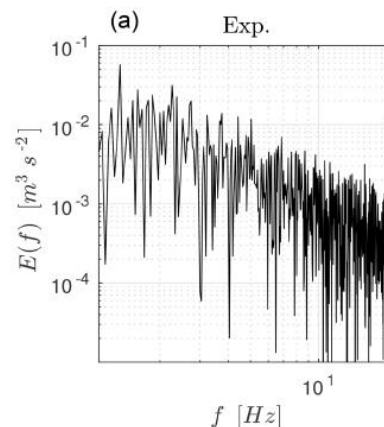
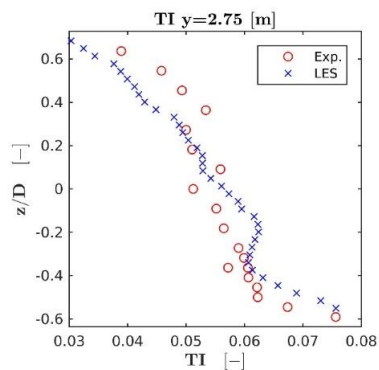
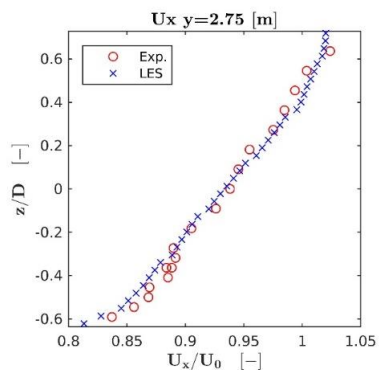
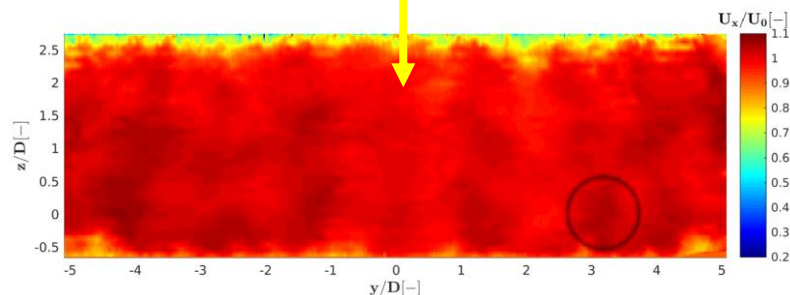
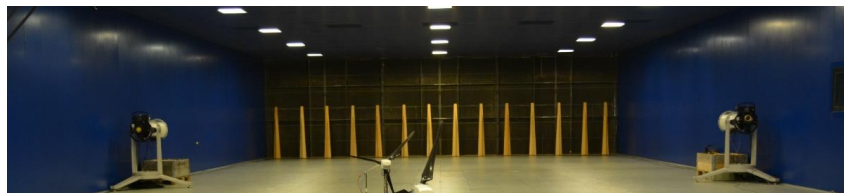
Turbulent inflow generation



Turbulent inflow generation



Turbulent inflow generation



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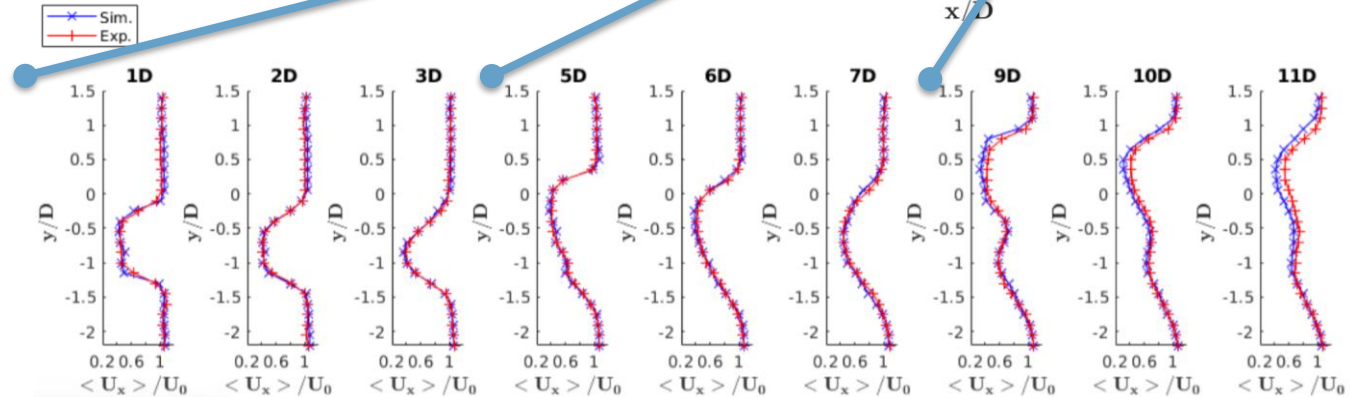
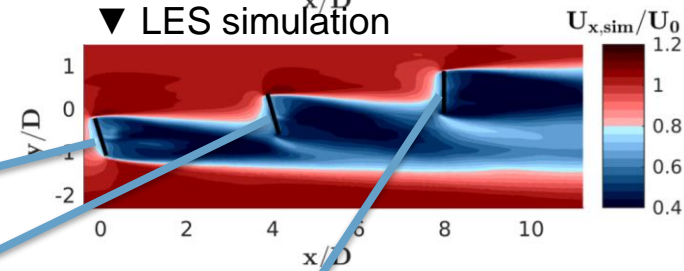
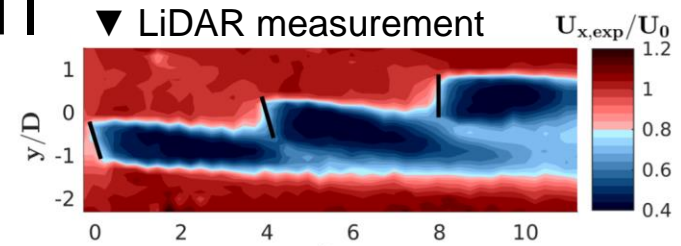
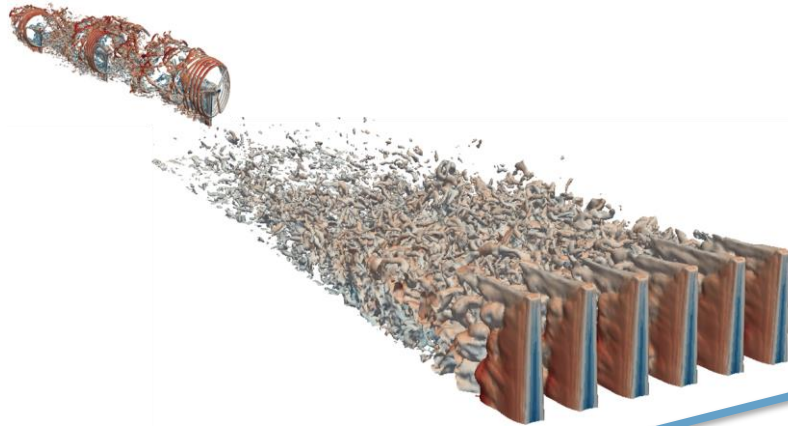


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Experimental set-up



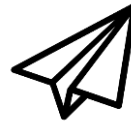
Example: Yawed Turbines, 6% TI



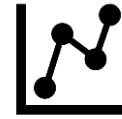
Conclusions



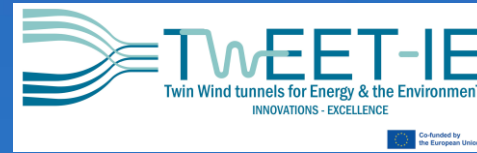
LES simulations are extensively used at the Wind Energy Institute @TUM for exploration of ideas and preparation of experiments



The numerical set-up requires some special steps to deal with low Reynolds number aerodynamics and scaled dimensions



The LES methodology allows to obtain an accurate match with experimental results



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Thank you for your attention!

