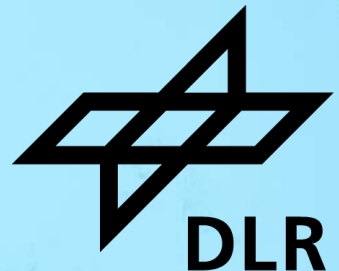


SIMULATION OF TONAL NOISE OF A FAN STAGE FOR UAM APPLICATIONS WITH INFLOW DISTORTIONS USING TRACE-HB

TRACE user conference 2025, Cologne

Tobias Blaschke, Sébastien Guérin, Antoine Moreau, Robert Jaron



1 TRACE in DLR Department of Engine Acoustics

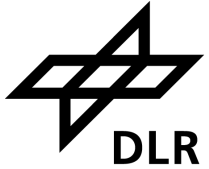
2 Problem Description

3 Numerical Setup

4 Preliminary Results

5 Summary

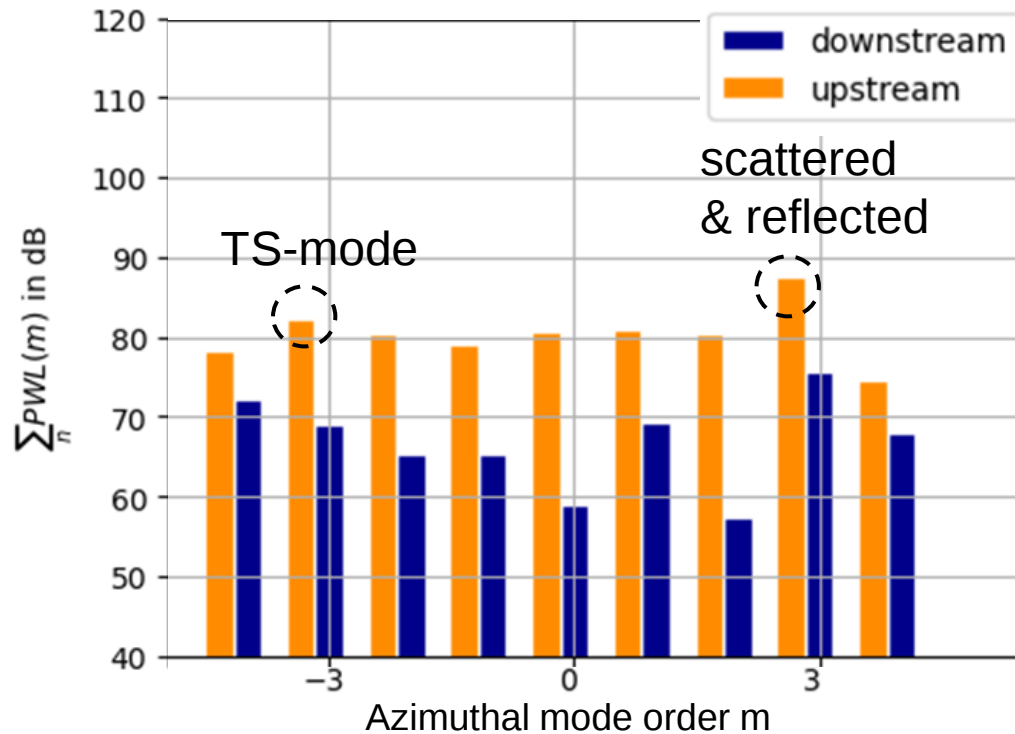
Importance of TRACE in Engine Acoustics



- **RANS** → optimization, input for PropNoise
 - **URANS** with phase shift
 - **Harmonic Balance**
 - **LES/DES**
- } → tonal noise prediction
- postprocessing

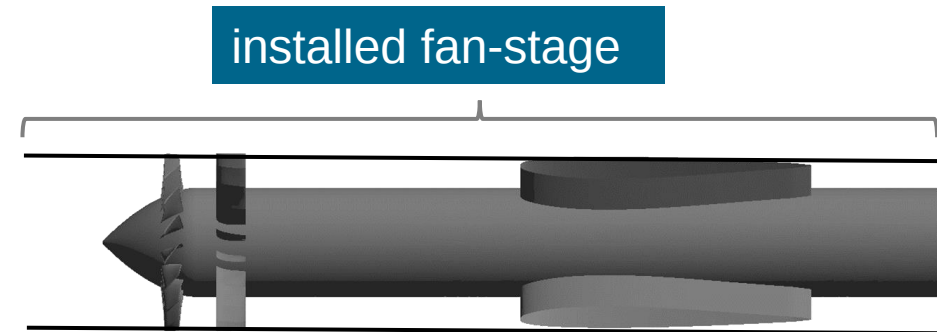
Example of application (1/2)

CRAFT-rig*:
experimental data



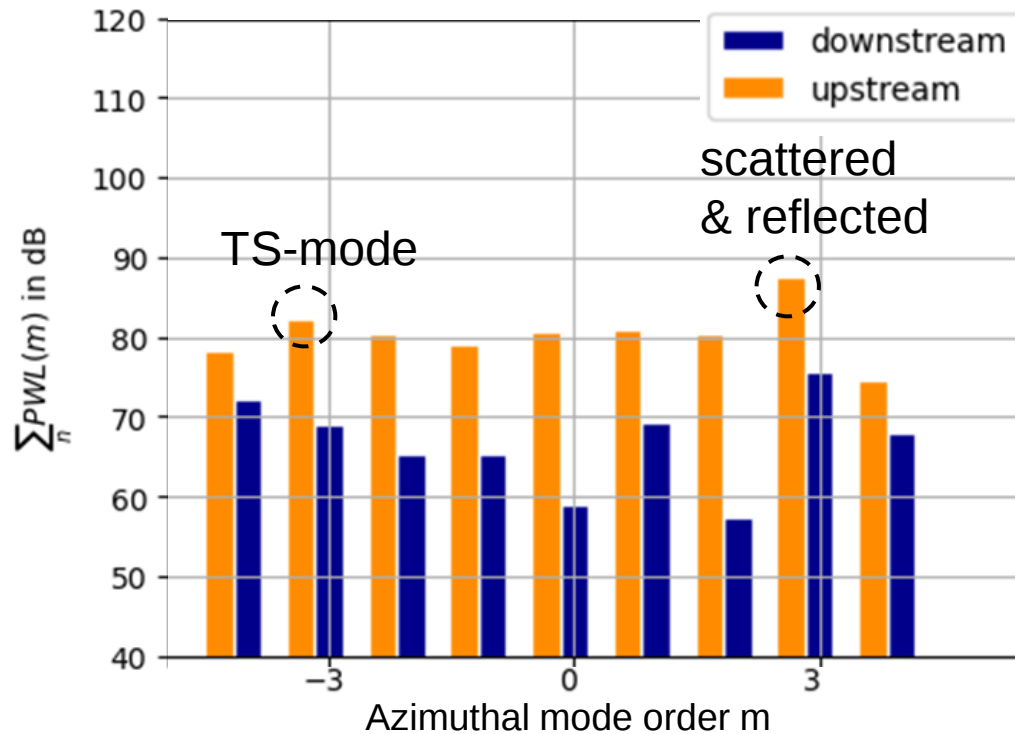
CRAFT: measurement data at the inlet
(1BPF, DP, baseline fan-stage)

TRACE:
HB-method



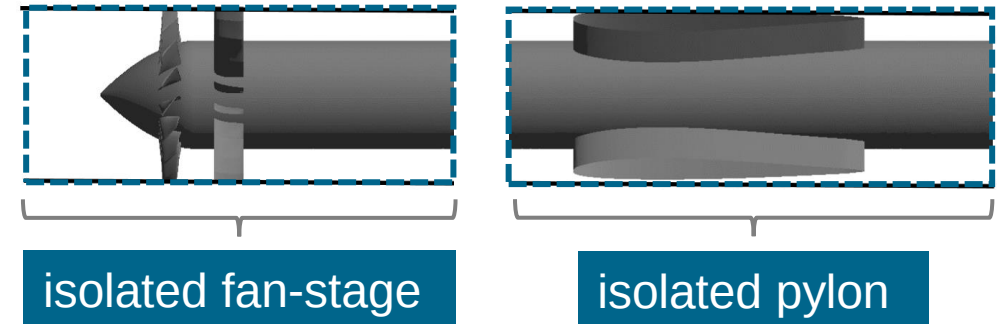
Example of application (1/2)

CRAFT-rig*:
experimental data



CRAFT: measurement data at the inlet
(1BPF, DP, baseline fan-stage)

TRACE:
HB-method

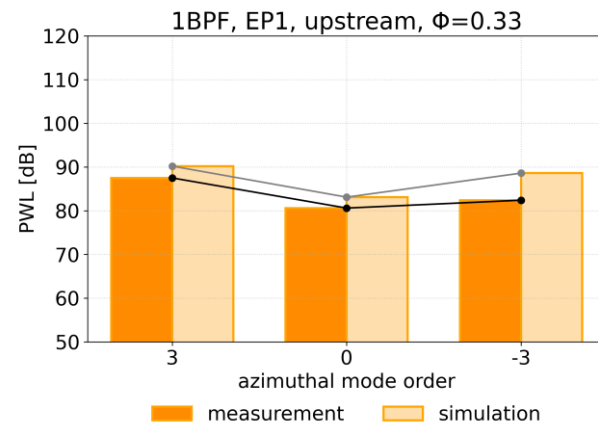


→ assessment of mode reflections at the pylons

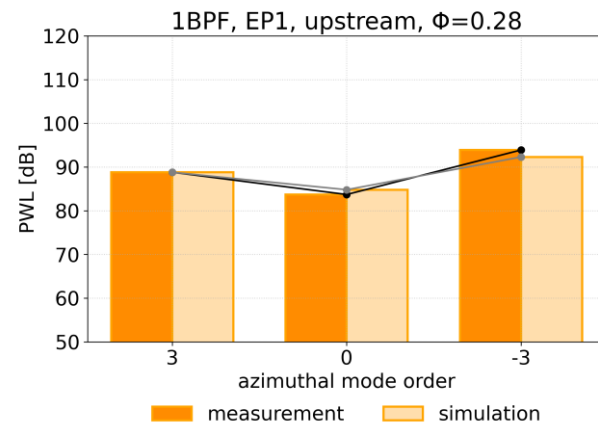
Example of application (2/2)

comparison with measurement data

TRACE:
HB-method

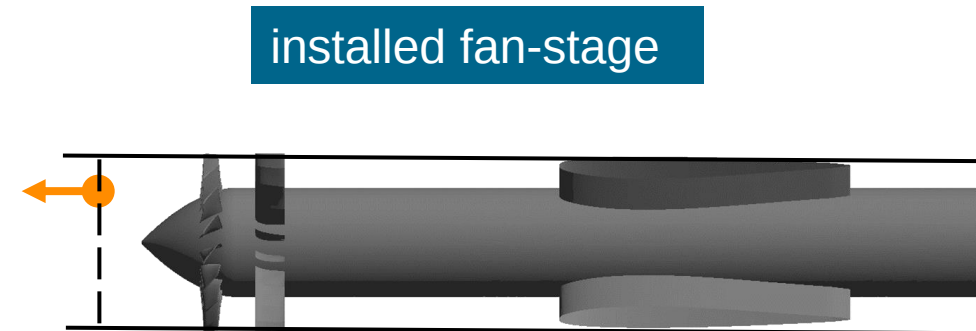


scattered &
reflected mode
is dominant



TS-mode
dominant

→ improved understanding of experimental data



1 TRACE in DLR Department of Engine Acoustics

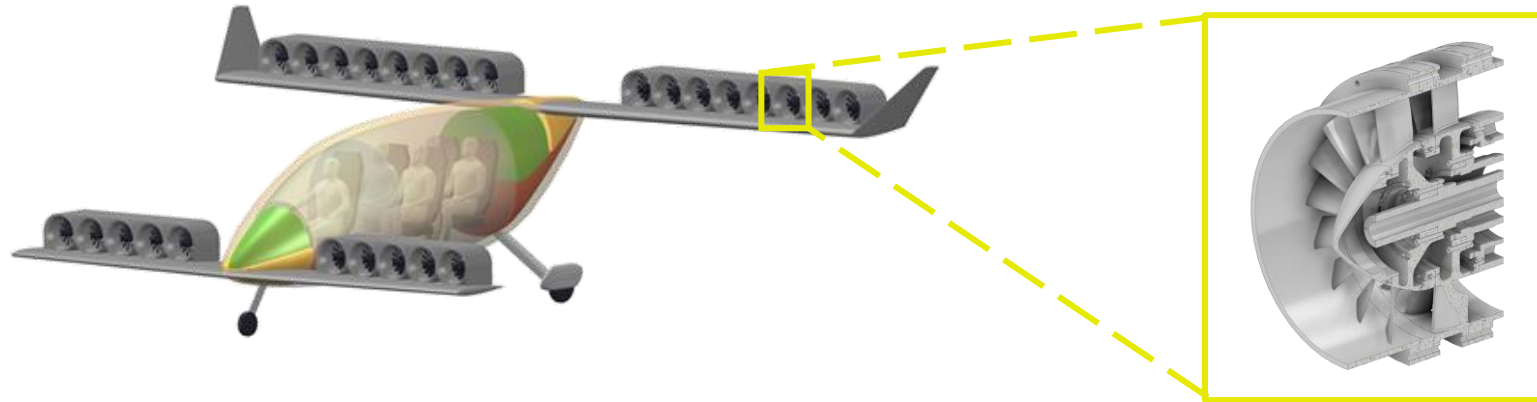
2 **Problem Description**

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5 Summary

Problem Description - Motivation



CRAFT baseline
fan-stage
DLR VIRLWINT
project

© DLR project VIRLWINT

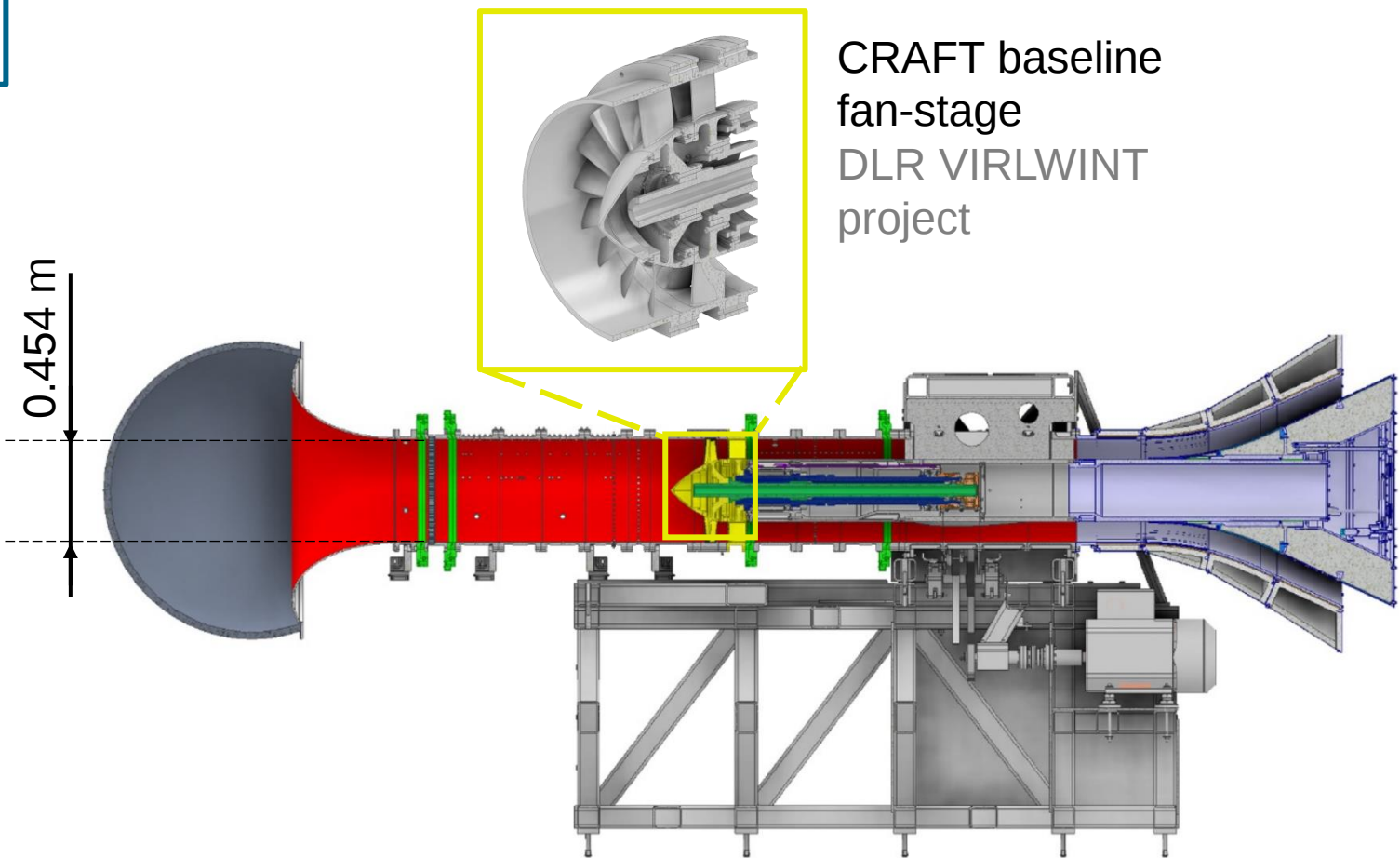
sketch of tilt duct vehicle configuration with simplified fan housings contour
(Credits: P. Ratei, SL-AES)

→ Inflow distortions in transition phase

Co/Counter Rotating Acoustic Fan Test Rig

CRAFT-rig:
experimental data

variable	Value (@DP)
$\phi = \frac{U_x}{U_{tip}}$	0.33
Ma_{tip}	0.31
$Ma_{x,outlet}$	0.17
Q_c	6.98 kg/s
PR	1.038
N_c	4500 rpm



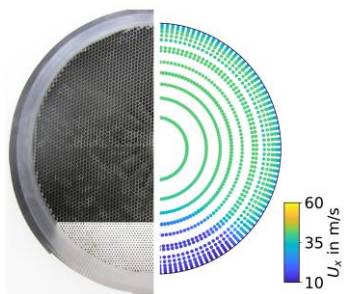
CRAFT-rig of the DLR Institute of Propulsion Technology [3]

[3] Tapken, U., Caldas, L., Meyer, R., Behn, M., Klähn, L., Jaron, R., Moreau, A., Enghardt, L. (2021). New test facility to investigate the noise generated by shrouded fans for small aircraft applications. DICUAM 2021 - Delft International Conference on Urban Air-Mobility, 15.-17. March 2021, Delft, Netherlands.

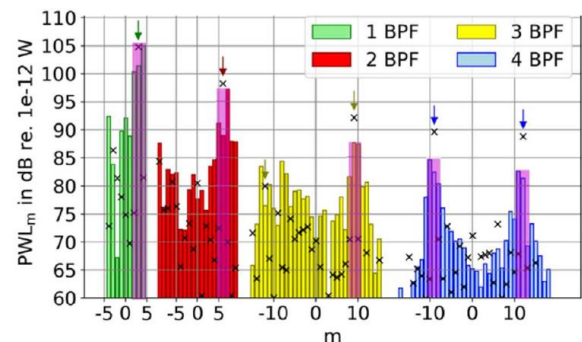
Co/Counter Rotating Acoustic Fan Test Rig



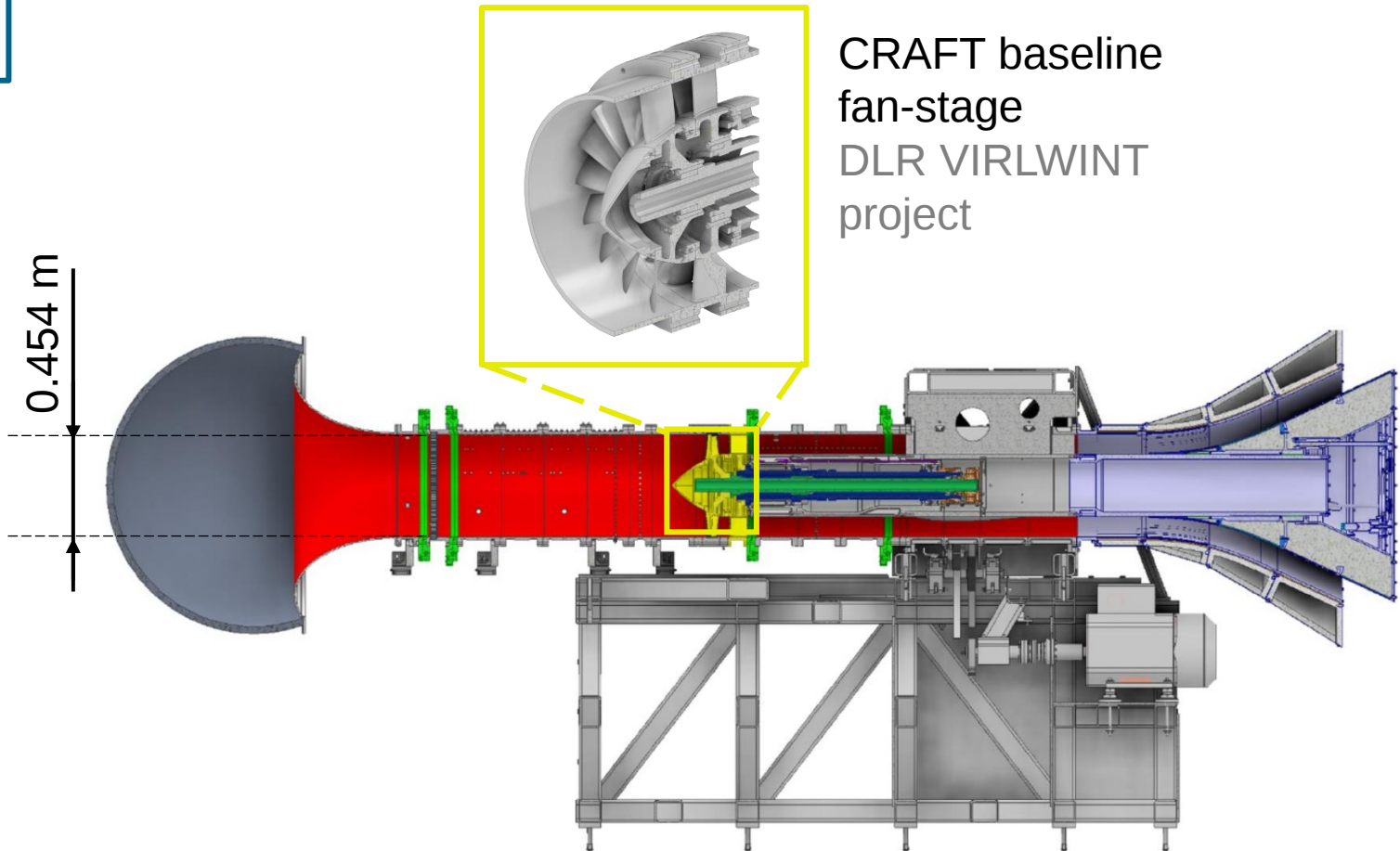
CRAFT-rig:
experimental data



Aerodynamic
measurements [1]



Acoustic
measurements [2]

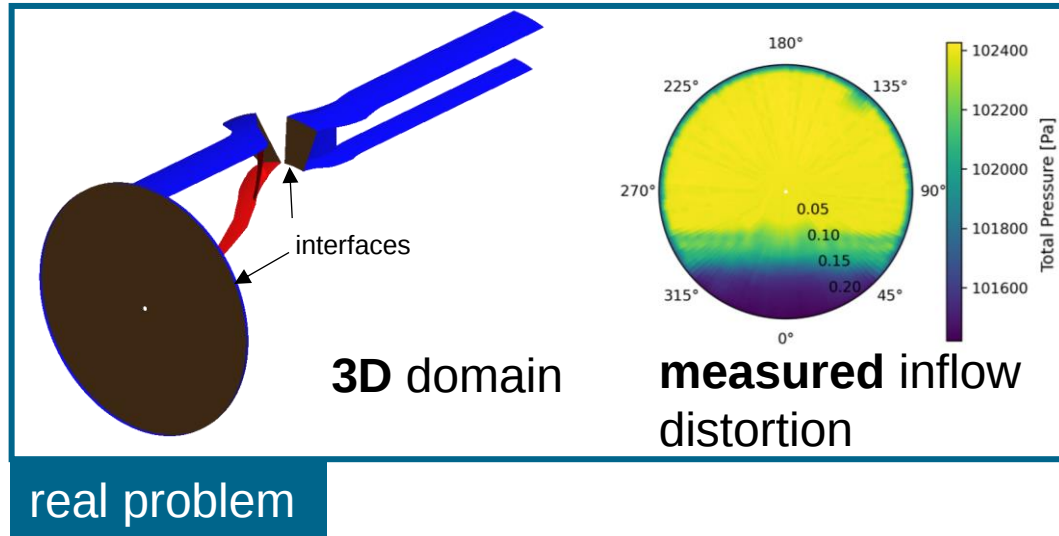


CRAFT baseline
fan-stage
DLR VIRLWINT
project

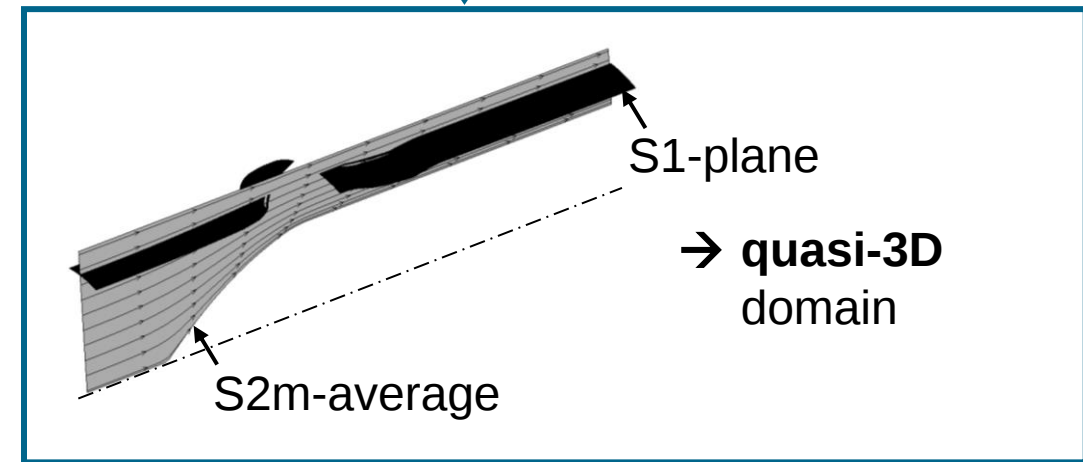
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Methodology – Simulation of fan tones due to inflow distortions

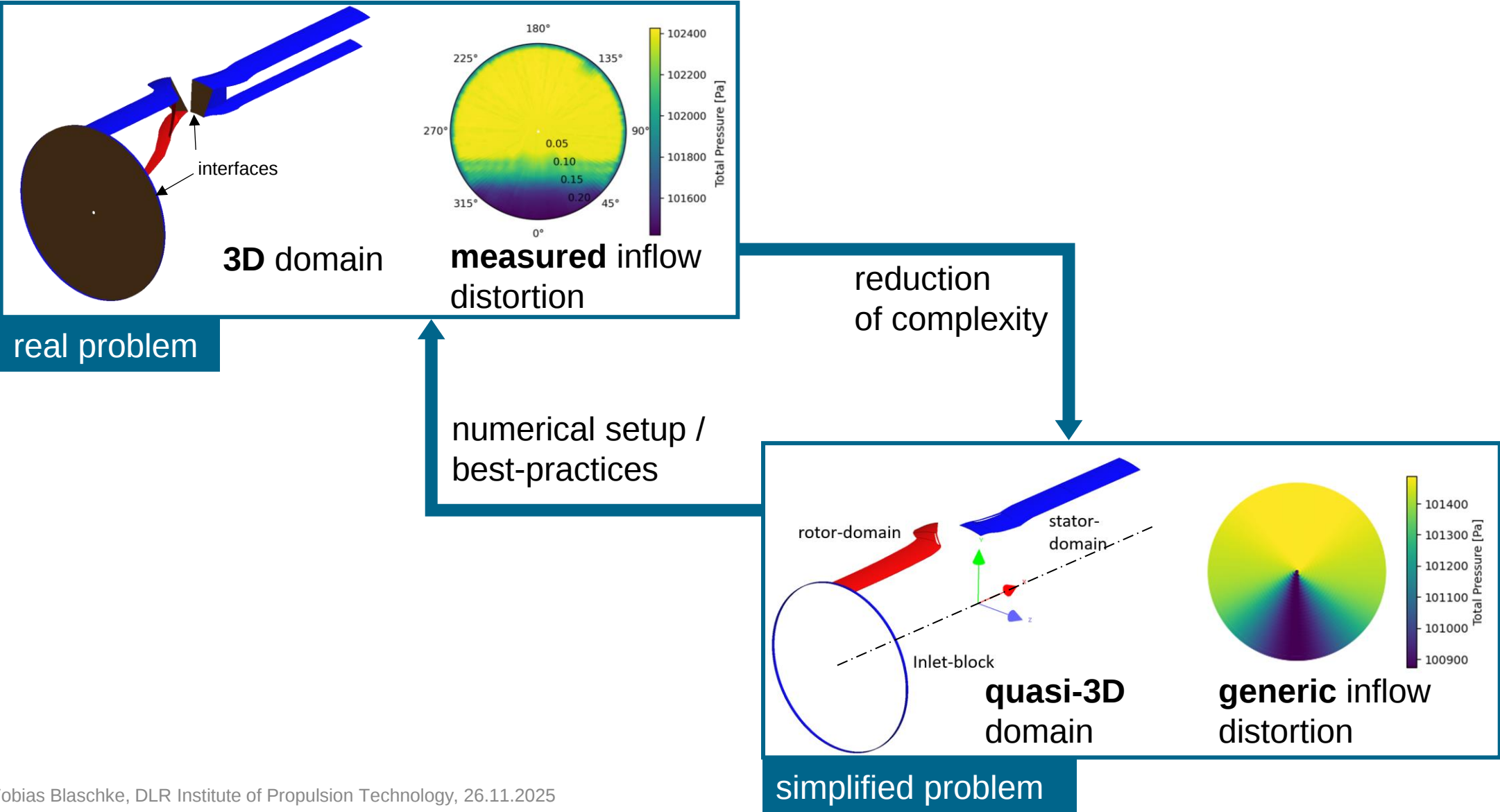


reduction
of complexity



simplified problem

Methodology – Simulation of fan tones due to inflow distortions



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- 4 Preliminary Results
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Numerical setup

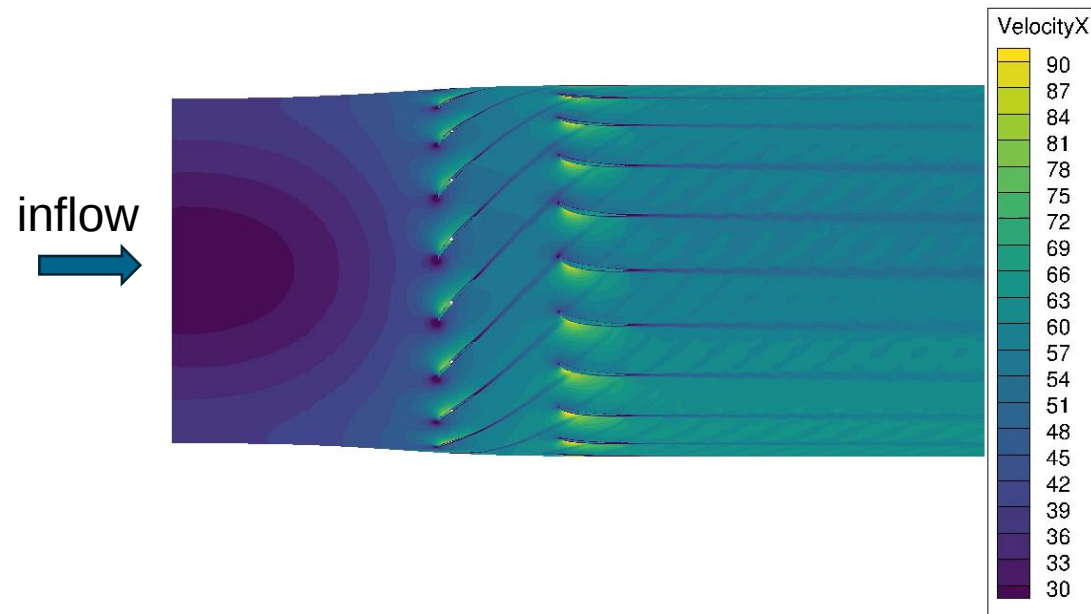


- Harmonic Balance method
 - phase shift: one passage
 - harmonic set
- inlet: 2D inflow distortion
- 2D NRBC (f-domain)
- Menter SST 2003 k-w
- quasi-3D domain: setup studies

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Quasi-3D simulation results

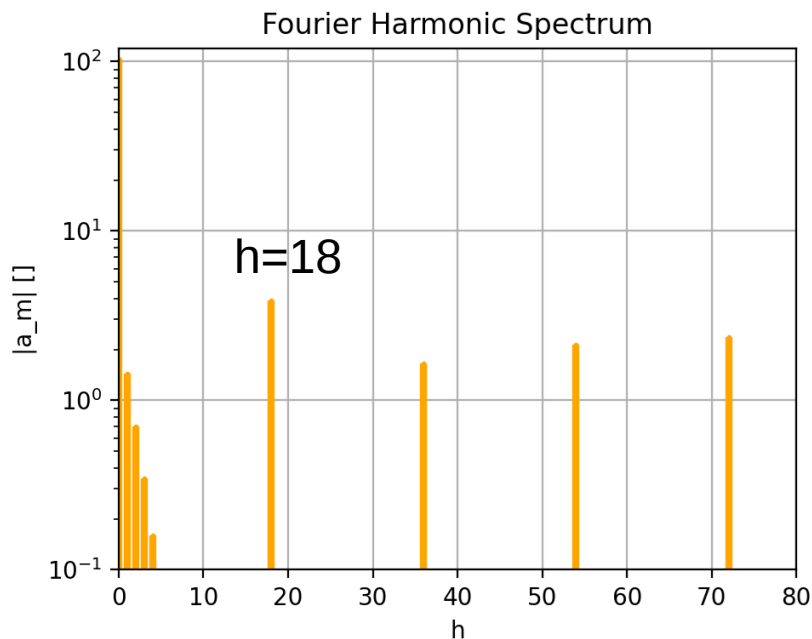
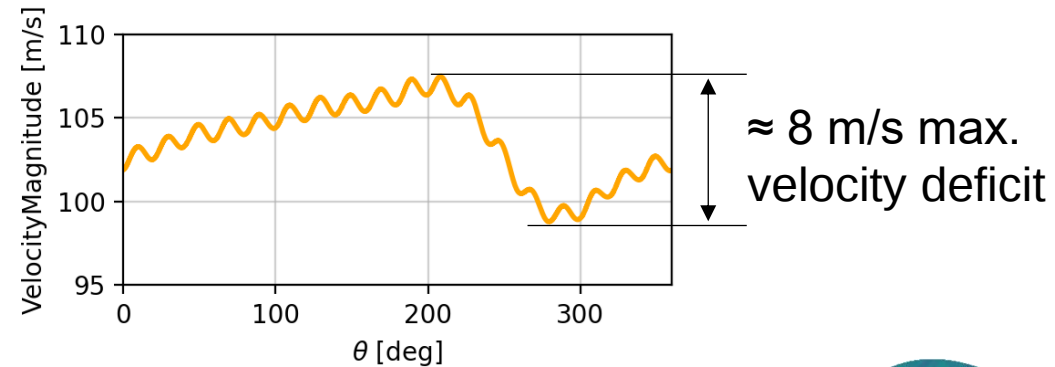
- Postprocessing:
Connect3D with XTPP*



*eXtended Triple Plane Pressure
mode matching technique

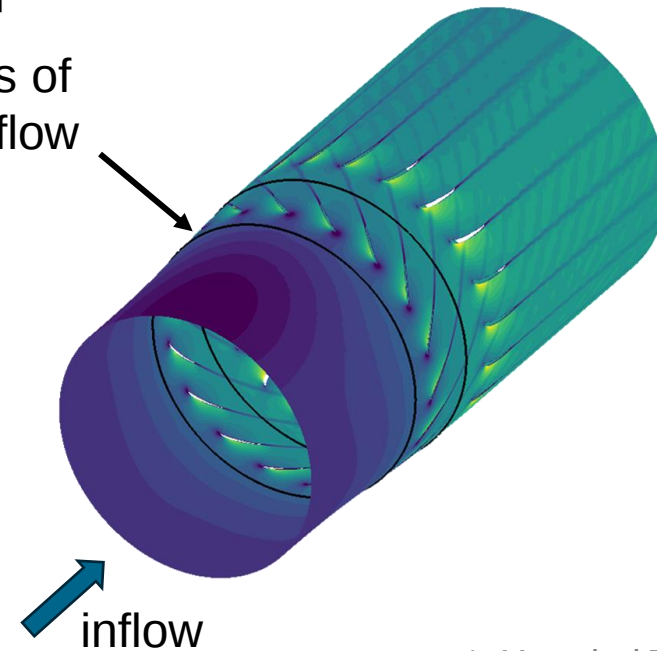
Quasi-3D simulation results

- Postprocessing:
Connect3D with XTPP*



analysis of
rotor inflow

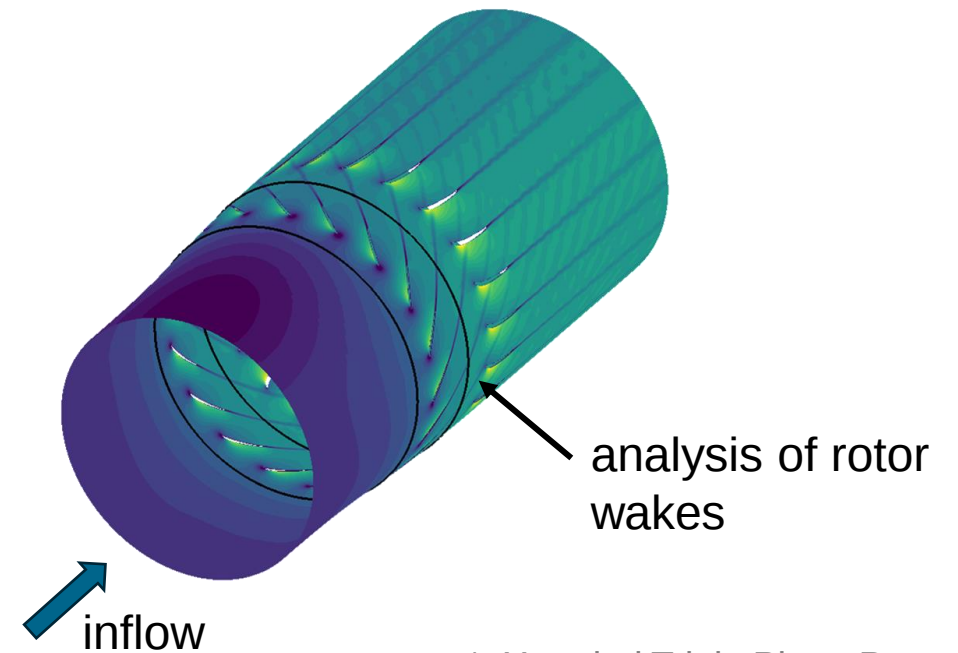
CRAFT baseline:
number of rotor
blades **B=18**



*eXtended Triple Plane Pressure
mode matching technique

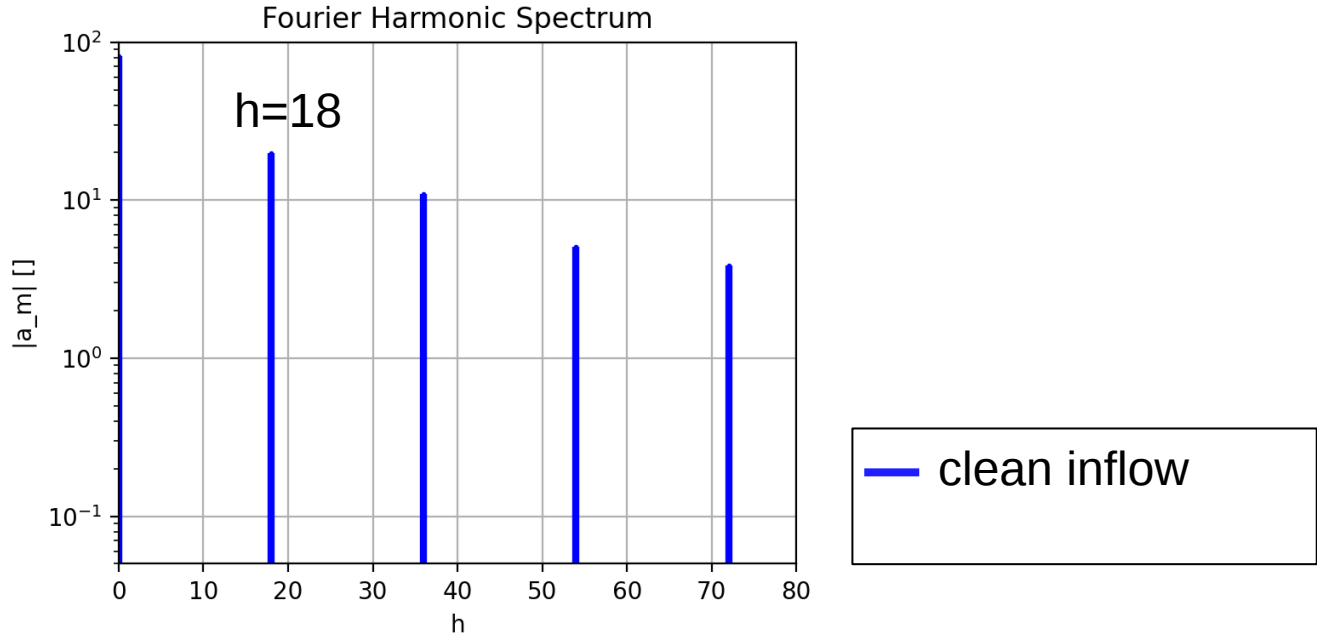
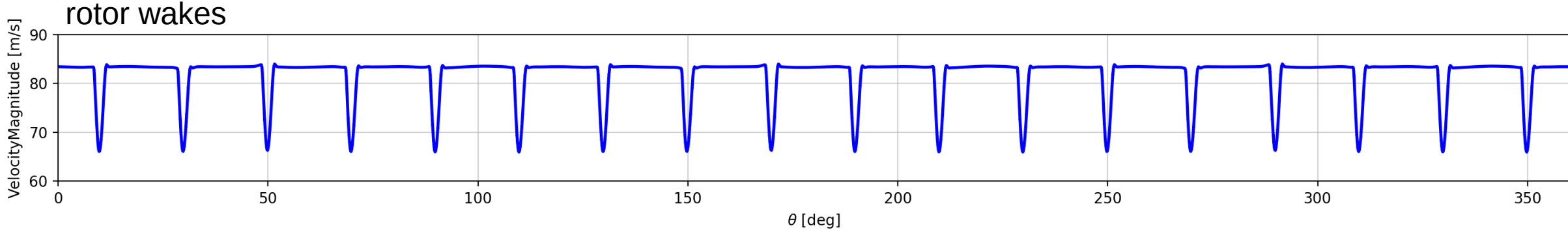
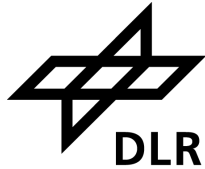
Quasi-3D simulation results

- Postprocessing:
Connect3D with XTPP*

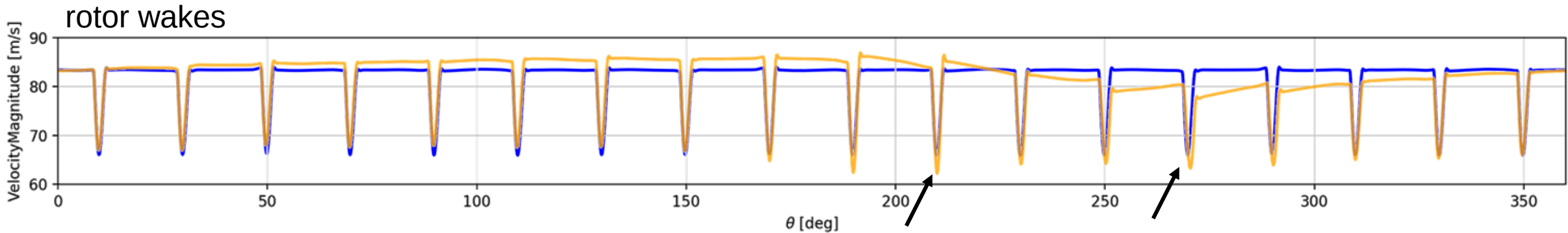
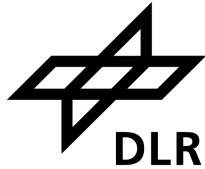


*eXtended Triple Plane Pressure
mode matching technique

Quasi-3D simulation results

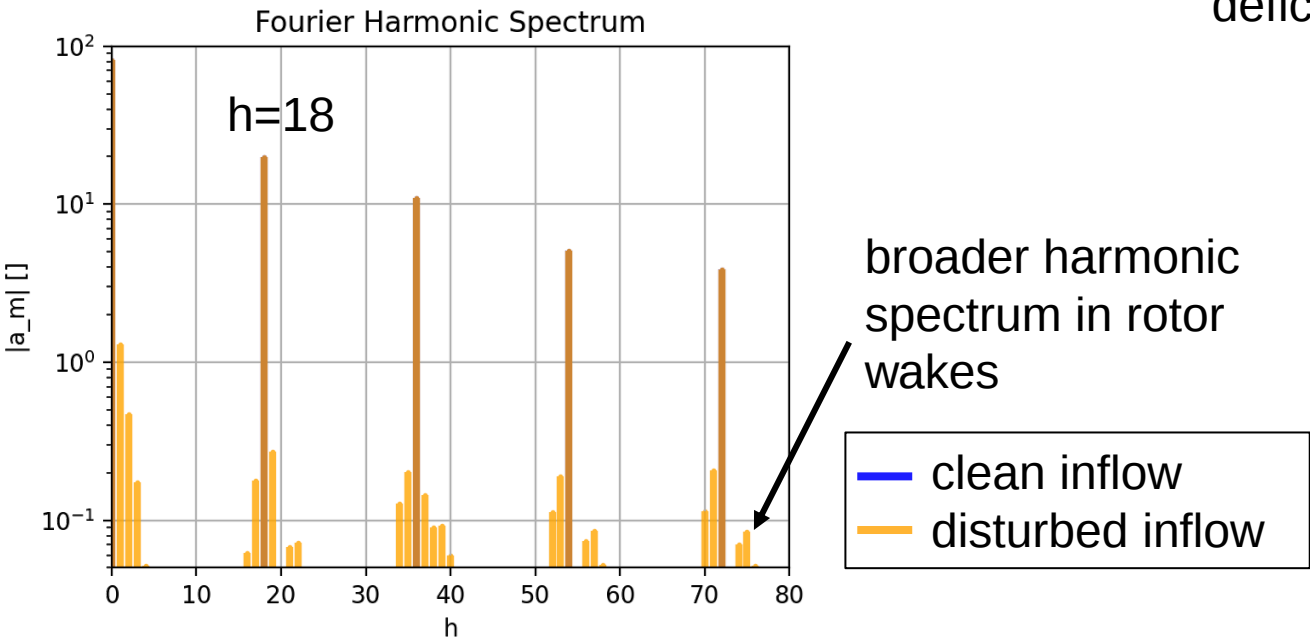


Quasi-3D simulation results



higher
velocity
deficit

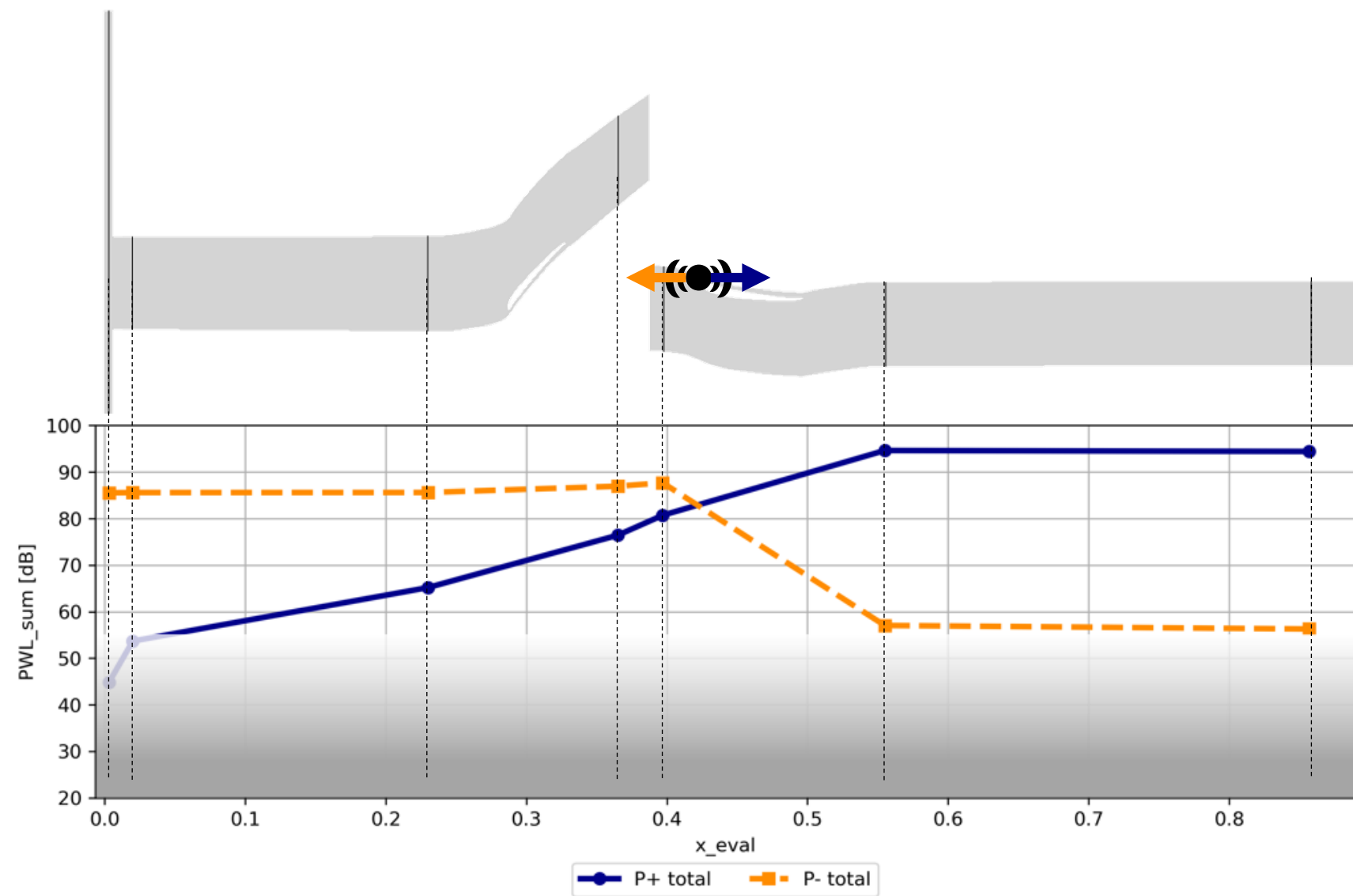
circumferential
shift



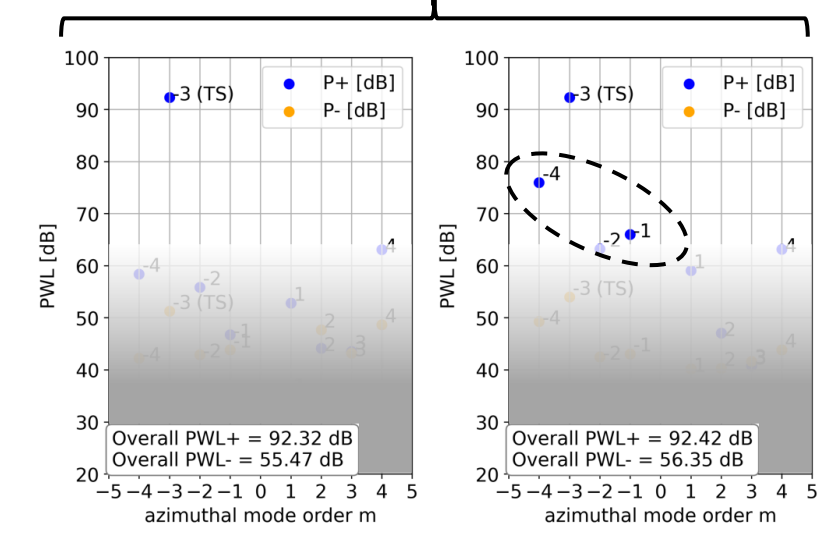
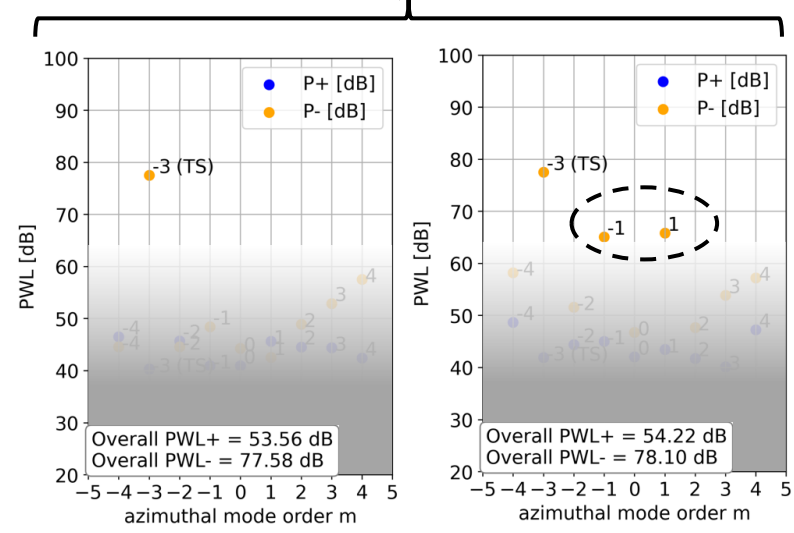
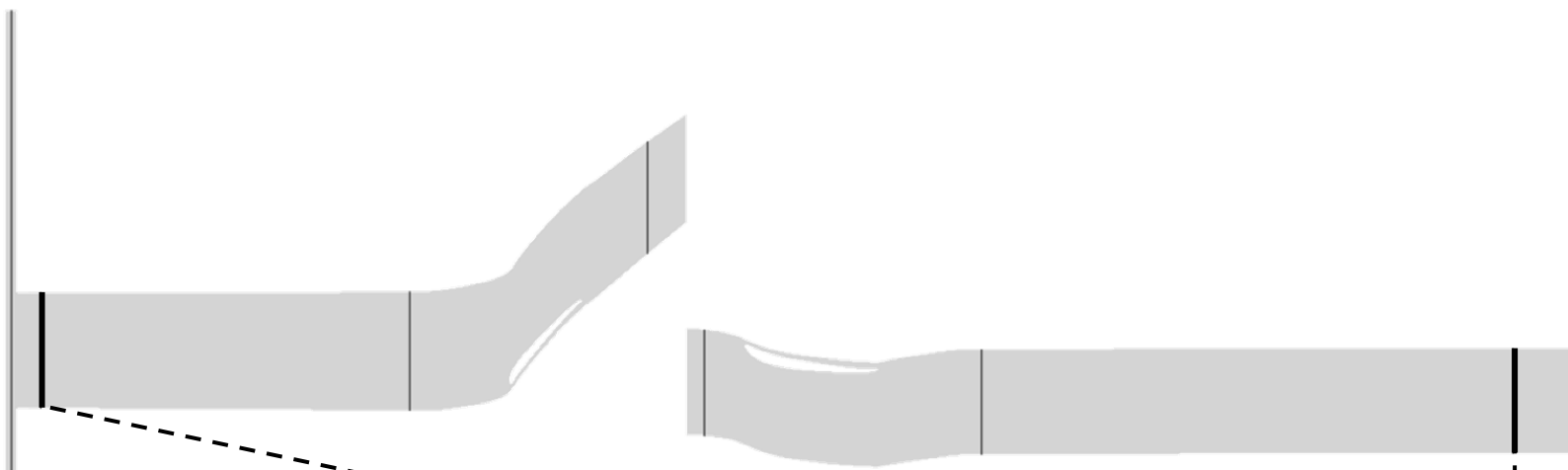
broader harmonic
spectrum in rotor
wakes

- clean inflow
- disturbed inflow

Quasi-3D simulation results



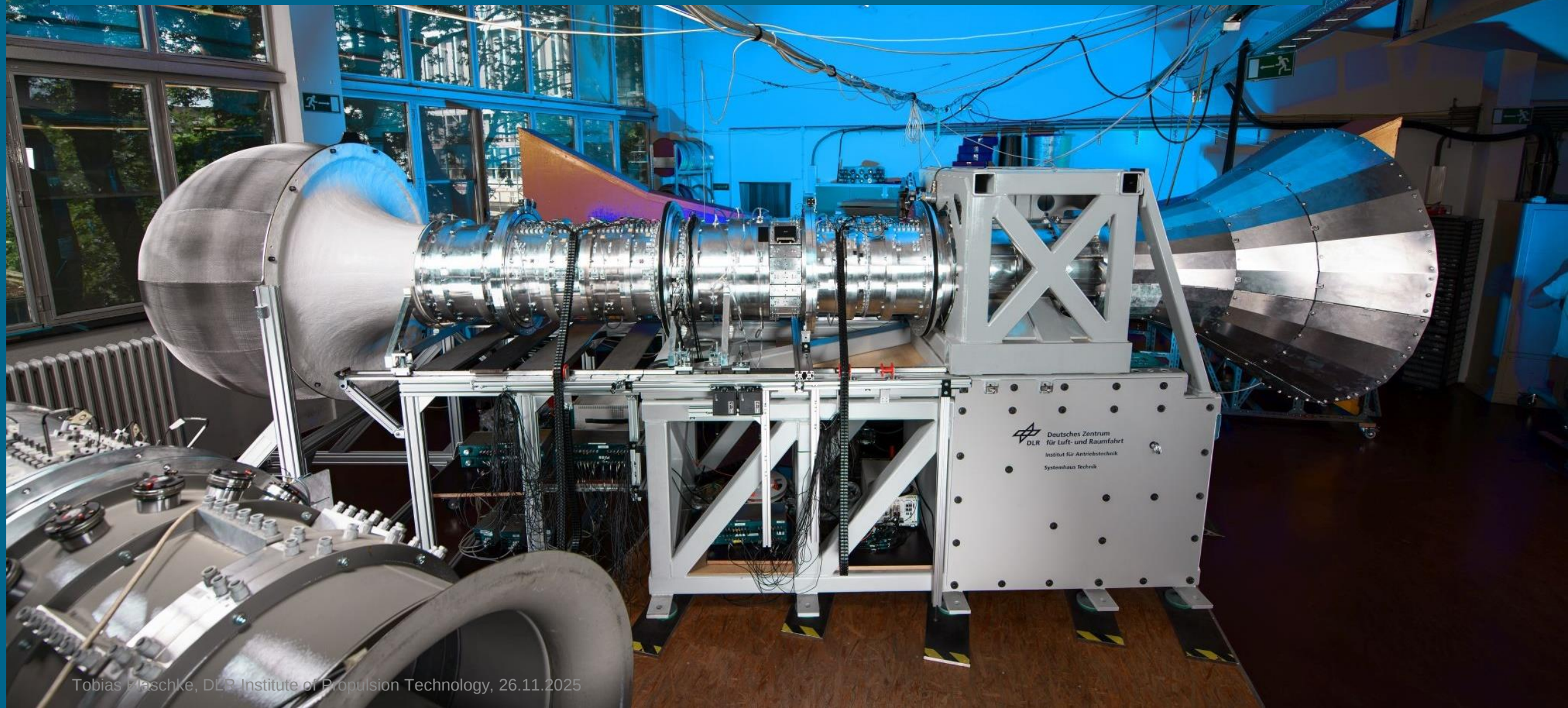
Quasi-3D simulation results



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- diverse use of TRACE in DLR **Engine Acoustics** Department, e.g.:
TRACE-HB to simulate tonal fan noise with inflow distortions
- together with experimental data: general understanding of **flow physics**
- separation of different noise excitation mechanisms

THANK YOU FOR YOUR ATTENTION



Topic: **Simulation of tonal noise of a fan stage for UAM applications with inflow distortions using TRACE-HB**

Date: 2025-11-26

Author: Tobias Blaschke, Sébastien Guerin, Antoine Moreau, Robert Jaron

Institute: Propulsion Technology

Image sources: All images “DLR (CC BY-NC-ND 3.0)” unless otherwise stated

- [1]** Klähn, Lukas; Caldas, Luciano; Meyer, Robert; Moreau, Antoine; Tapken, Ulf (2023): Experimental Investigation of Inflow-Distortion-Induced Tonal Noise in a Sub-Sonic Fan Test Rig, 2023. 29th International Congress on Sound and Vibration, ICSV 2023.
- [2]** Tapken, Ulf; Schade, Stephen; Klähn, Lukas; Rudolphi, Angelo; Behn, Maximilian; Meyer, Robert (2023): CRAFT test rig for assessing the aeroacoustic impact of fans of electrically powered urban/regional aircraft. CEAS-ASC Workshop 12.-13.10.2023, Budapest “Aeroacoustics of Electrically Driven Air Vehicles: Towards a Green and Quiet Aviation”.
- [3]** Tapken, U., Caldas, L., Meyer, R., Behn, M., Klähn, L., Jaron, R., Moreau, A., Enghardt, L. (2021): New test facility to investigate the noise generated by shrouded fans for small aircraft applications. DICUAM 2021 - Delft International Conference on Urban Air-Mobility, 15.-17. March 2021, Delft, Netherlands.