IEA Task 39 – Quiet Wind Turbines Status of the NACA63018 serration benchmark

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Outline

- Active Partners
- Objectives
- Wind tunnel models and serrations
- Facility overview
- Update low Reynolds number team
- Update high Reynolds number team
- Conclusions

Active Partners

DLR

DTU

VIRGINIA TECH

TU Delft Delft University of Technology

UNIVERSITY OF TWENTE.

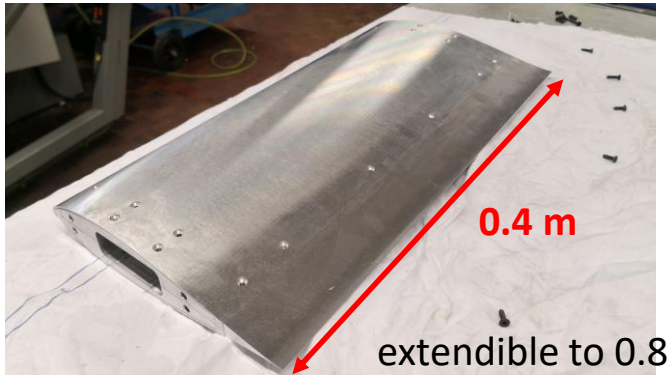
TECHNISCHE UNIVERSITÄT BERLIN

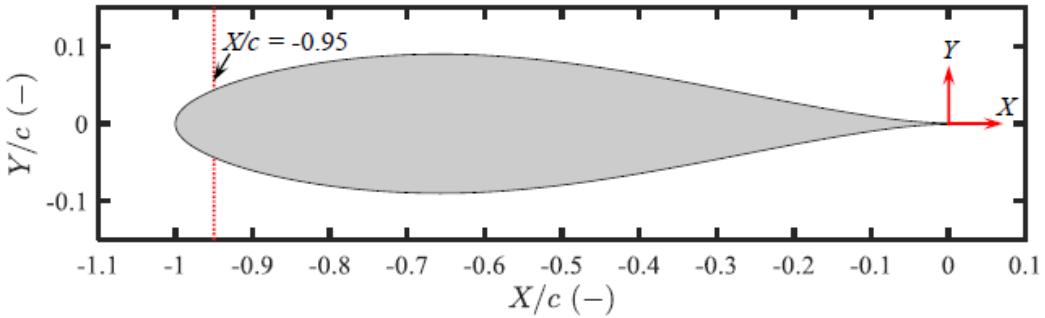
Objectives of the benchmark exercise

- Cross compare acoustic measurements in a wide range of aero-acoustic facilities for a low noise aerofoil configuration
- Align testing and post-processing methods
- Identify reason for the scatter of the data and try to reduce it
- Investigate the scalability of the results for small and large facilities
- Provide a data base for model validation
- Provide uncertainty estimates representative for aero-acoustic testing of low noise aerofoil configurations

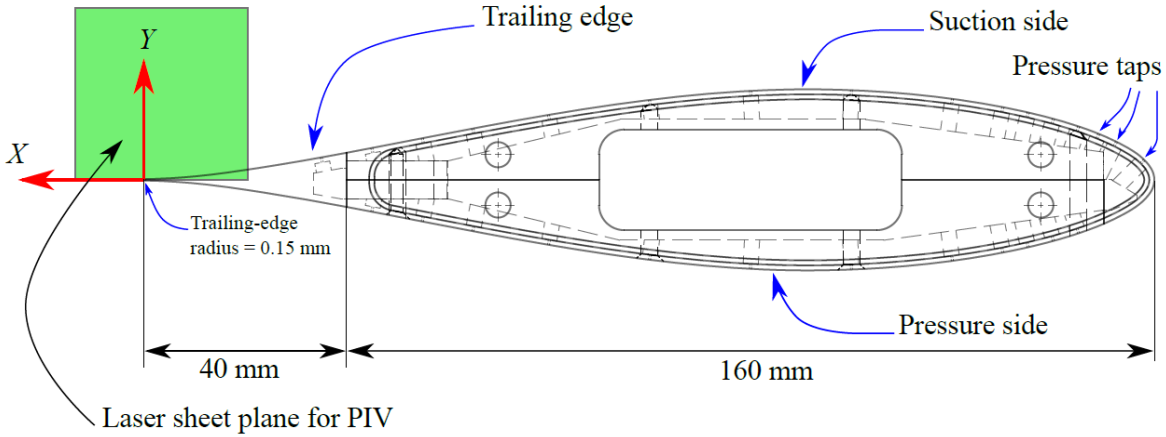
Two NACA 63_3-018 aerofoils

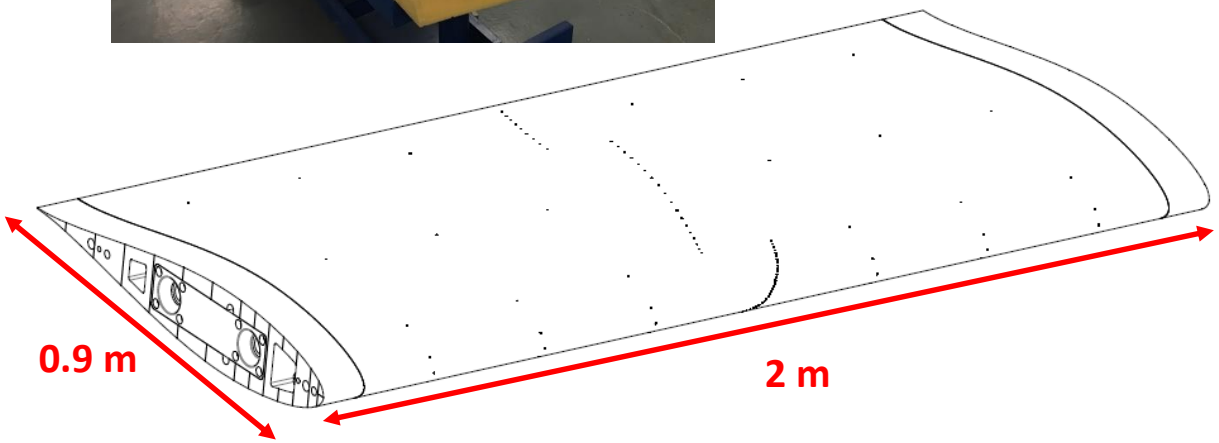
Low Reynolds number Model



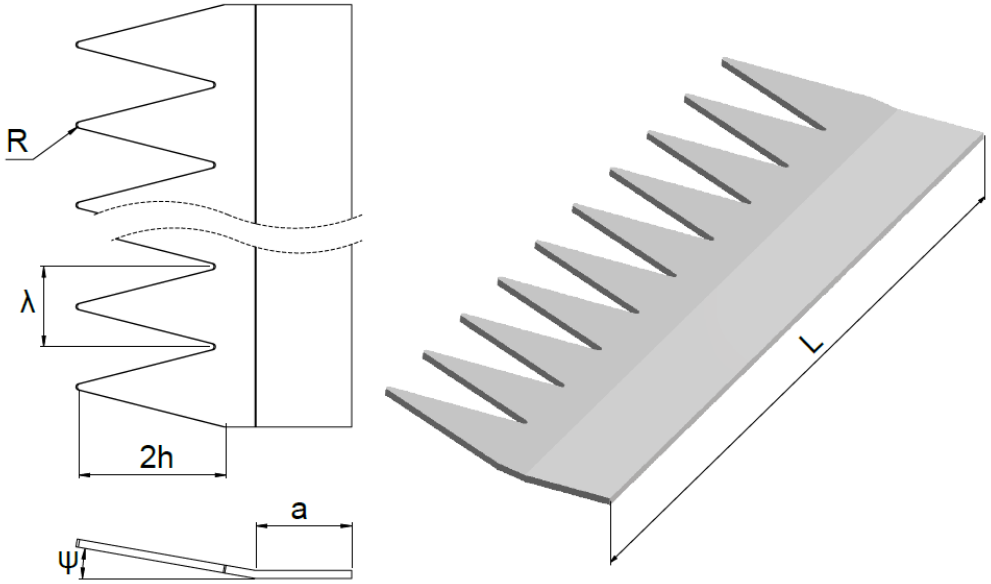


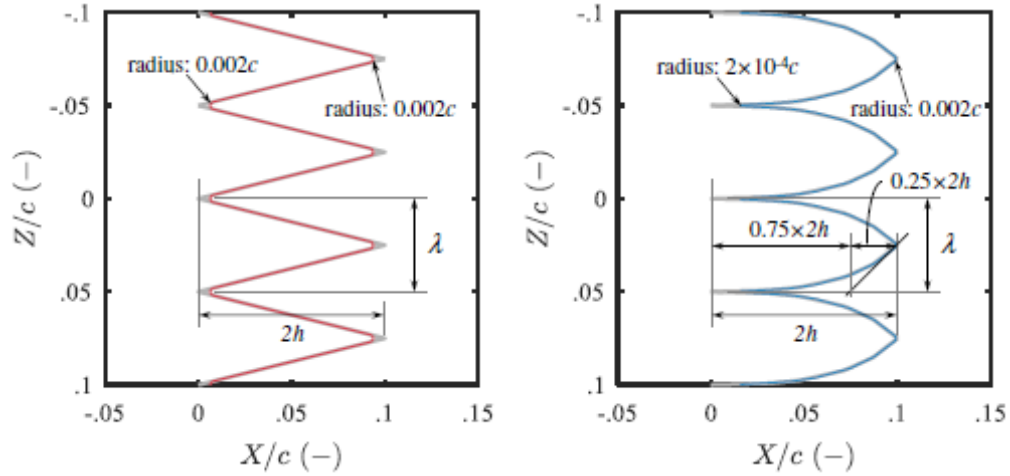
High Reynolds number Model



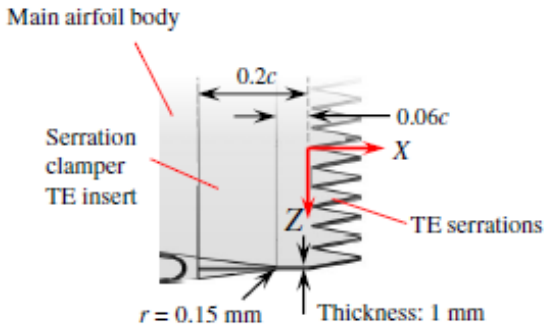


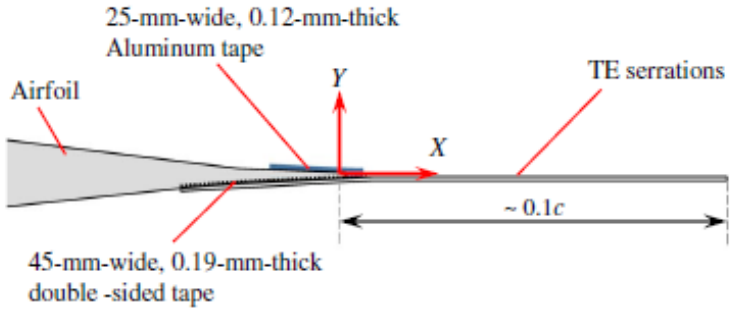
Serration geometries





Name	S0	S4	SI
type	Saw-tooth	Saw-tooth	Iron
Height (2h)	0.1 chord	0.1 chord	0.1 chord
Wavelength ()	h	h	h
Flap angle ()	0 deg	4/8 deg	0 deg





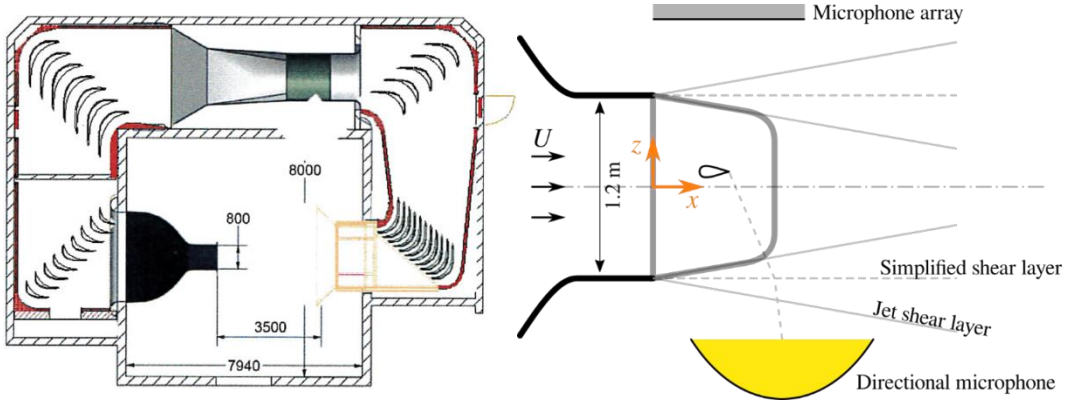
Facility and measurement overview (Update with TU Berlin)

Low Reynolds number Facilities																
Facility		Test section						Model			Measurements					
Name	Institution	Hard wall	Kevlar wall (anechoic)	Kevlar wall (integrated)	Open jet	Test section size [HxW] m	Max free stream velocity (m/s)	chord length [m]	span [m]	Serrations	aerofoil pressure ports	wake rake	Surface Microphones	Boundary layer (HW, PIV or BLPR)	Parabolic mirror (far field)	Microphone array (far field)
A-Tunnel (AT)	TUD				X	0.4 x 0.25/0.7	75/35	0.2	0.4	X	X	X		X		X
Aeroacoustic Wind Tunnel Braunschweig (AWB)	DLR				X	1.2 x 0.8	65	0.2		X	X				X	X
Aeroacoustic Wind Tunnel Facility (AF)	Utwente	X	X		X	0.7 x 0.9	60	0.2	0.7		X		X			X
Aeroacoustic Wind Tunnel Berlin	TUB				X	0.33 x 0.4	70	0.2	0.4	X	X					X

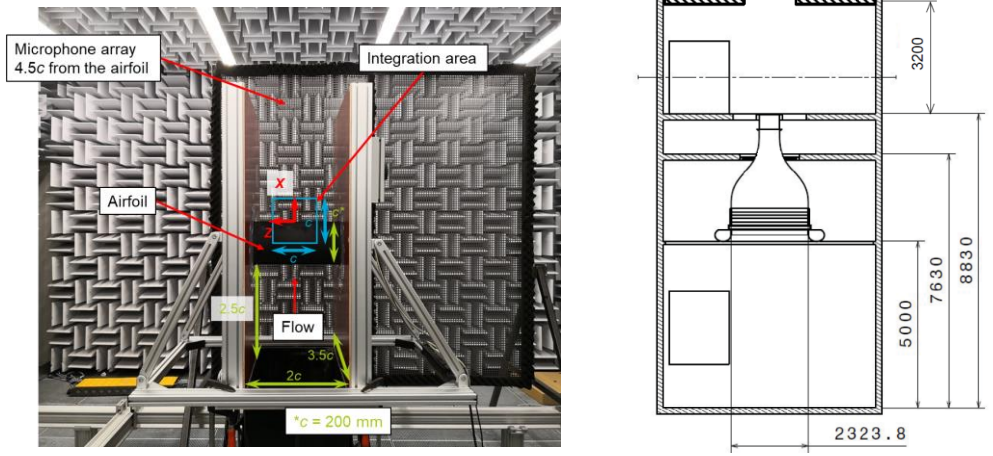
High Reynolds number Facilities																
Facility		Test section						Model			Measurements					
Name	Institution	Hard wall	Kevlar wall (anechoic)	Kevlar wall (integrated)	Open jet	Test section size [HxW] m	Max free stream velocity (m/s)	chord length [m]	span [m]	Serrations	aerofoil pressure ports	wake rake	Surface Microphones	Boundary layer (HW, PIV or BLPR)	Parabolic mirror (far field)	Microphone array (far field)
Low turbulence Tunnel (LTT)	TUD	X		X		1.25 x 1.8	120	0.9	1.25	X	X	X	X	X		X
Low Speed Wind Tunnel Braunschweig (NWB)	DLR	X			X	2.8 x 3.25	90	0.9	2.8	X	X	X			X	X
Poul la Cour Tunnel (PLCT)	DTU	X	X			2 x 3	110	0.9	2.0	X	X	X		X		X
Virginia Tech Stability Wind Tunnel (VTST)	VT	X	X			1.8 x 1.8	80	0.9	1.8		X					X

Low Reynolds number facilities

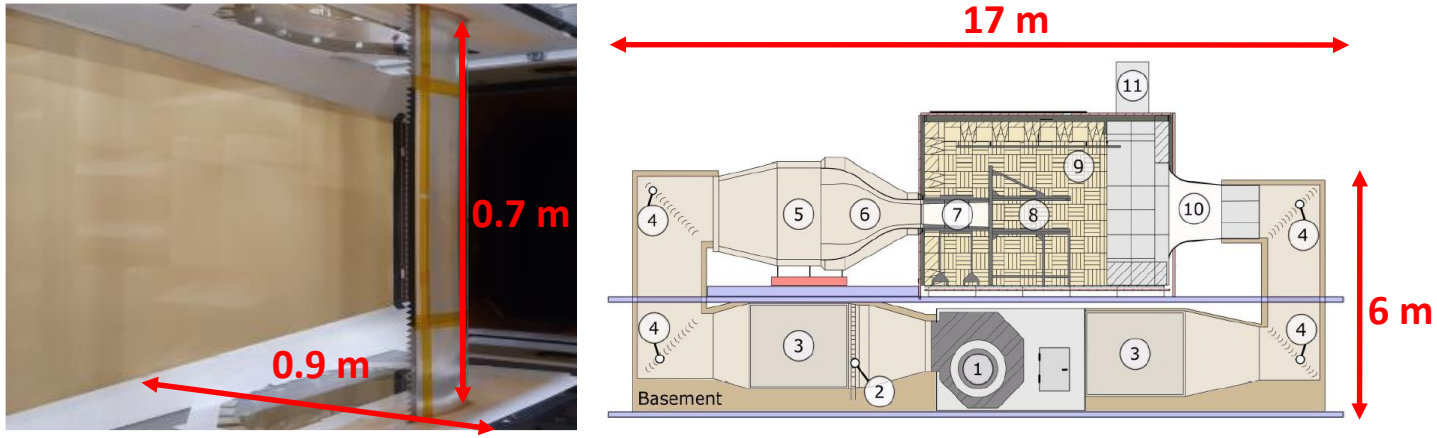
Aeroacoustic Wind Tunnel Braunschweig (AWB)



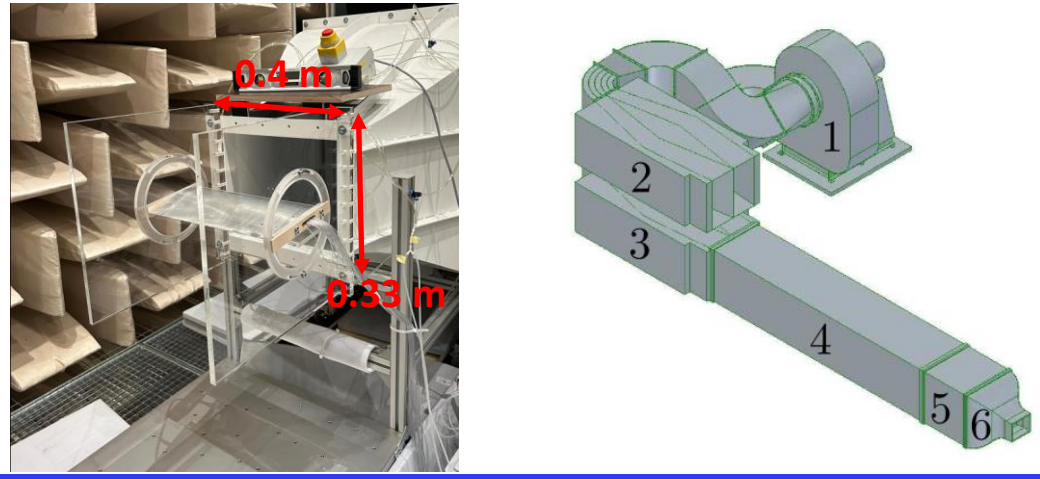
A-Tunnel (AT)



Acoustic Wind Tunnel Facility at Utwente (AF)



Aeroacoustic Wind Tunnel Berlin

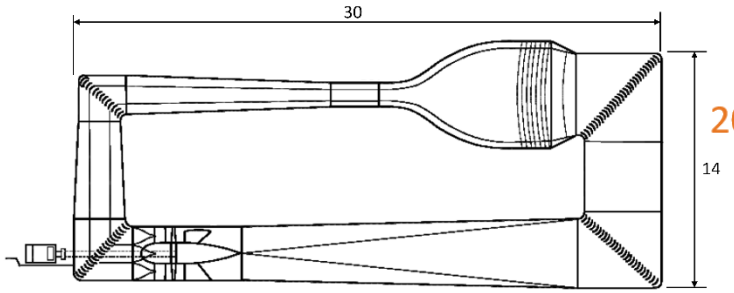


Low Reynolds number team update

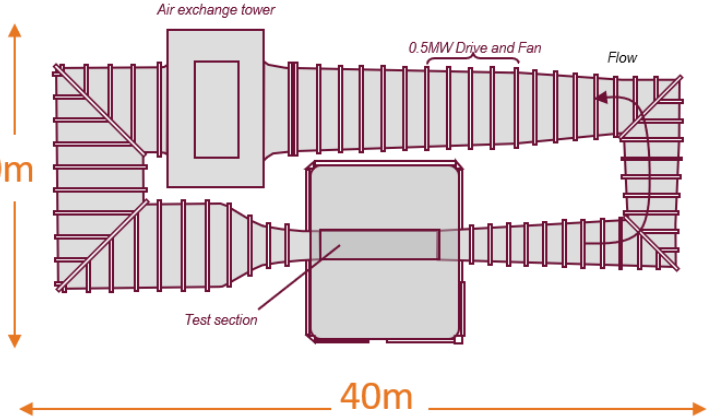
- TU Berlin has conducted measurements
- DLR has updated data
- Preliminary comparison is in progress

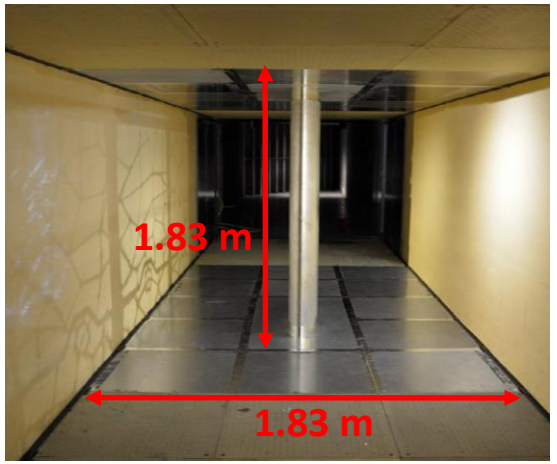
High Reynolds number facilities

Low Turbulence Tunnel (LTT)

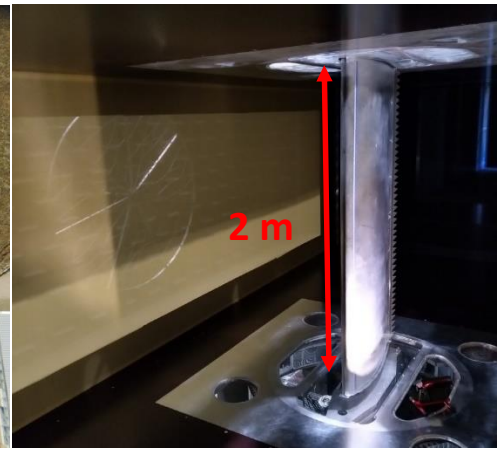


Stability Wind Tunnel (VTST)

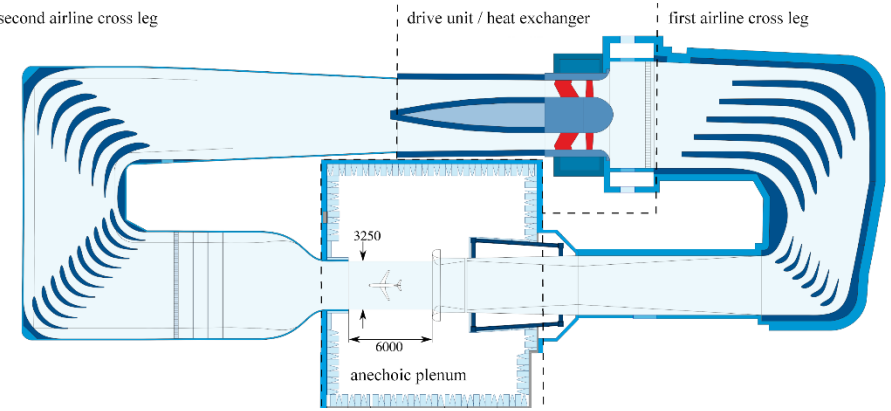


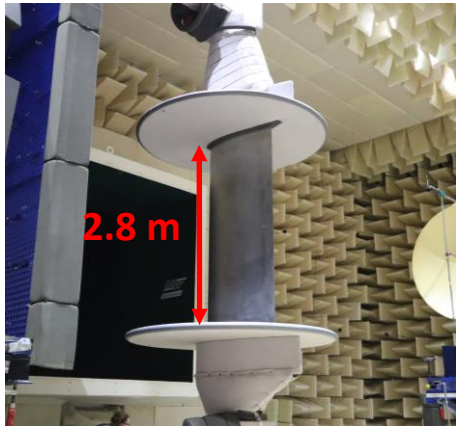


Poul La Cour Wind Tunnel (PLCT)



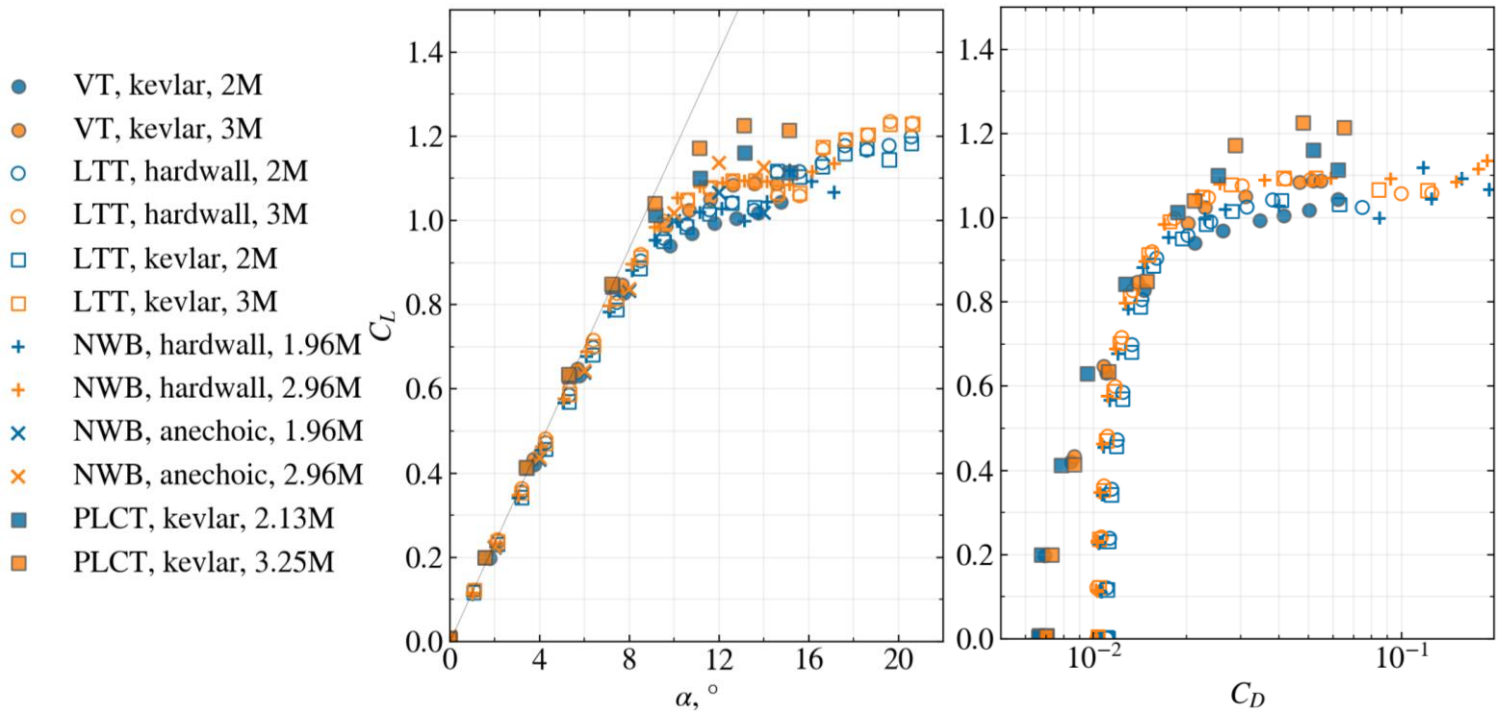
Low Speed Wind Tunnel Braunschweig (NWB)

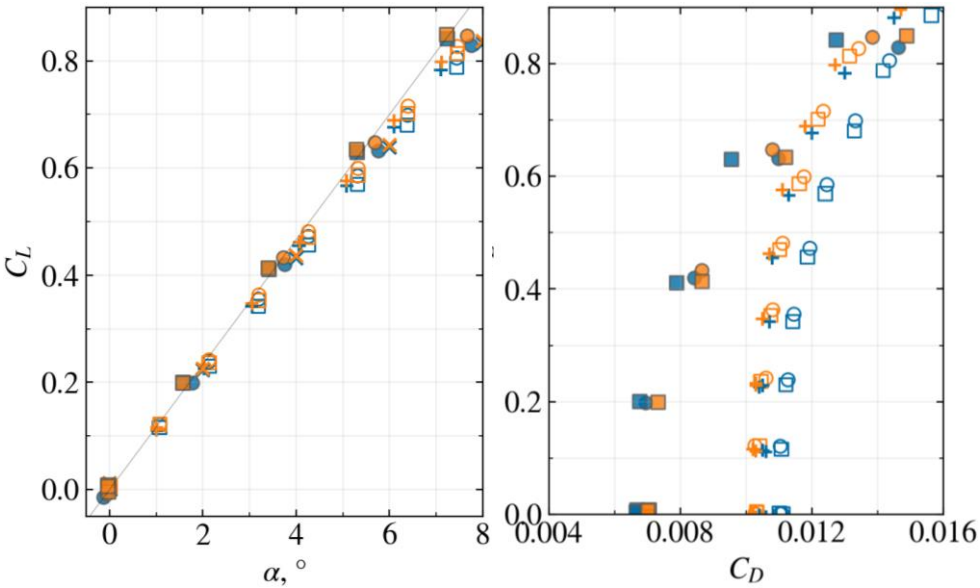




High Reynolds number Team Aerodynamics

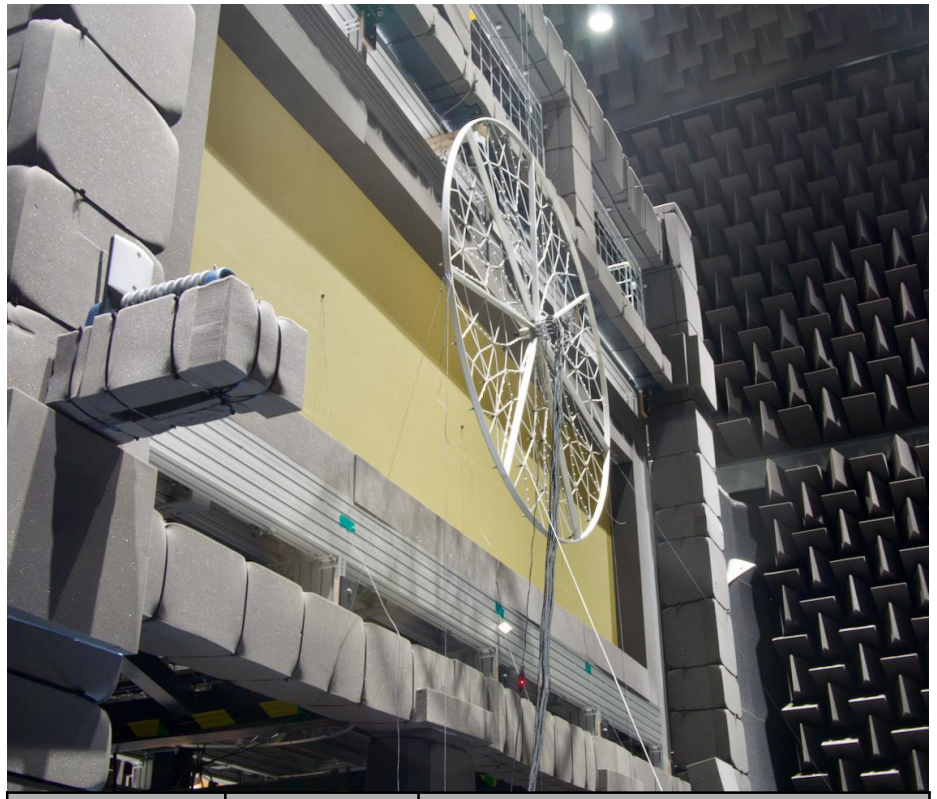
VT & PLCT : C_D pressure
LTT & NWB : C_D total





High Reynolds number Team Acoustics

Hardware	Data acq.	Data processing
140 mic array ½” LinearX mics	t = 30 sec fs = 100 kHz Δf = 25Hz	• Conv. Beamforming + CleanSC • 50% overlap, Hanning window • 2d shear layer corr. • Diagonal removal
Elliptical acoustic mirror, ¼” B&Kmic		• Schlinker correction method (1977)



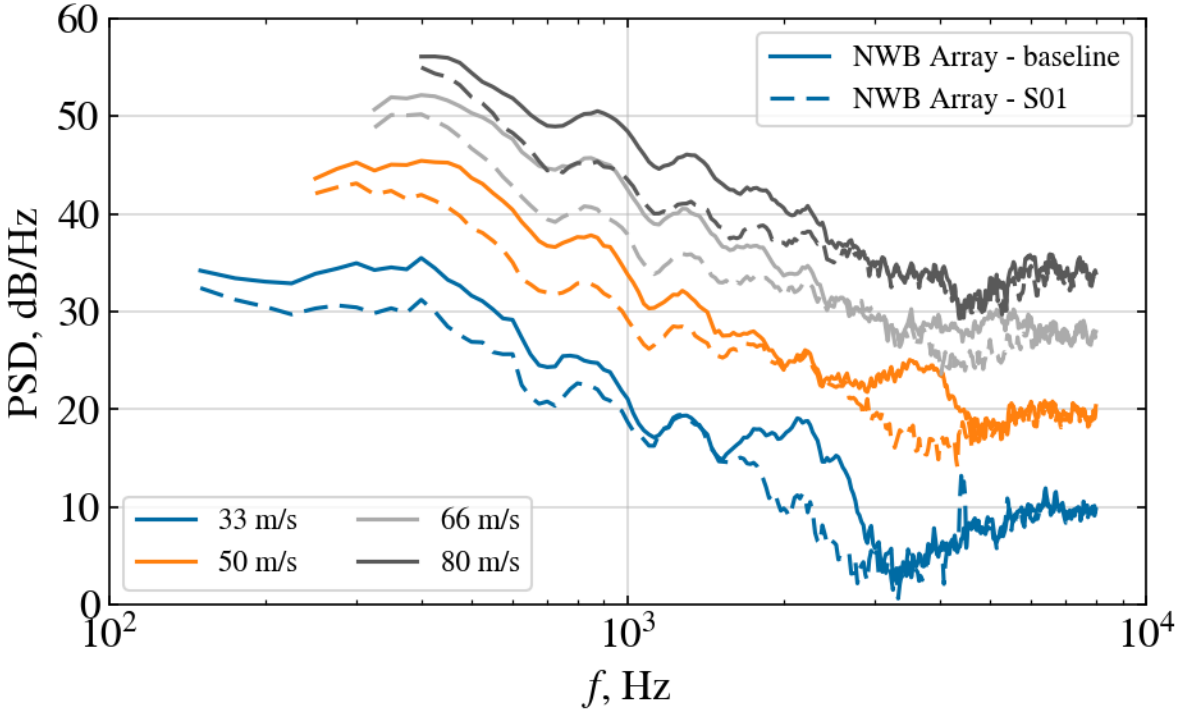
Hardware	Data acq.	Data processing
84 mic array ¼” B&K mics	t = 25 sec fs = 16 kHz Δf = 4Hz	• Conv. Beamforming • 50% overlap, Hanning window • 3d shear layer corr. • Diagonal removal

Hardware	Data acq.	Data processing
251 mic array ¼” GRAS mics	t = 32 sec fs = 51.2 kHz Δf = 6.25Hz	• 126 mics sub-array used • Conv. Beamforming +SiPP • 50% overlap, Hanning window • 3d shear layer corr. • Diagonal removal

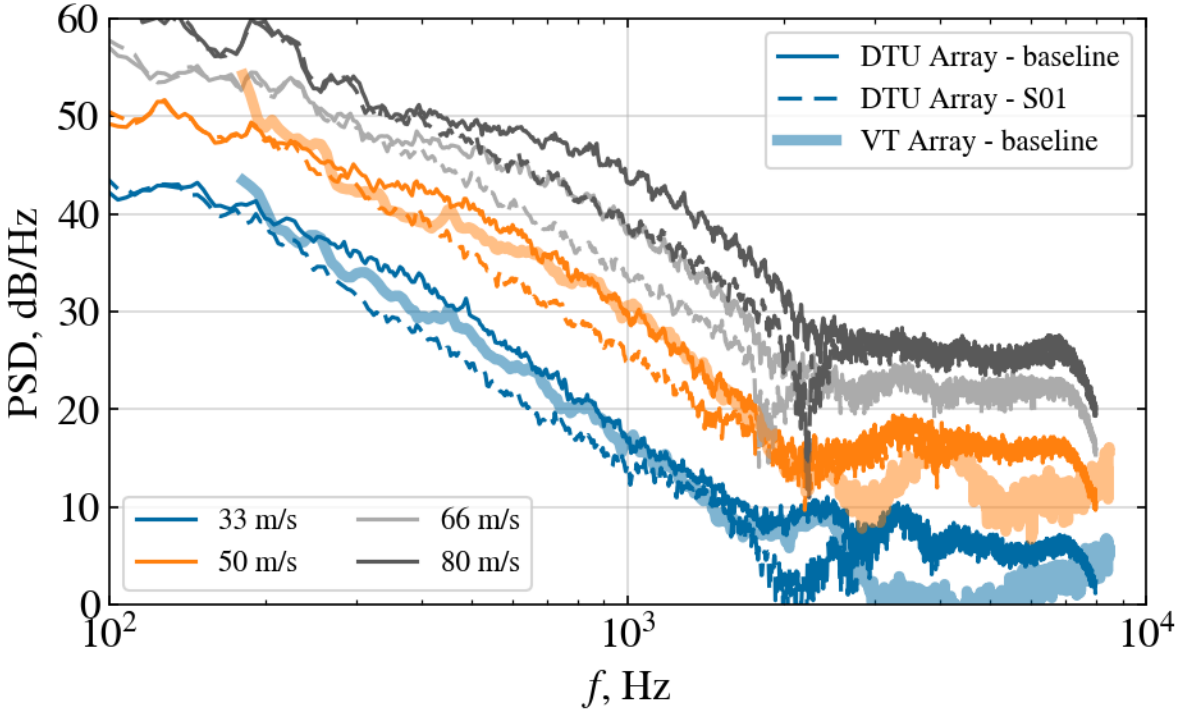
Baseline vs Serration, CL=0, Classical Beamforming

NWB / DTU / VT, Trip 5/5

NWB-Array



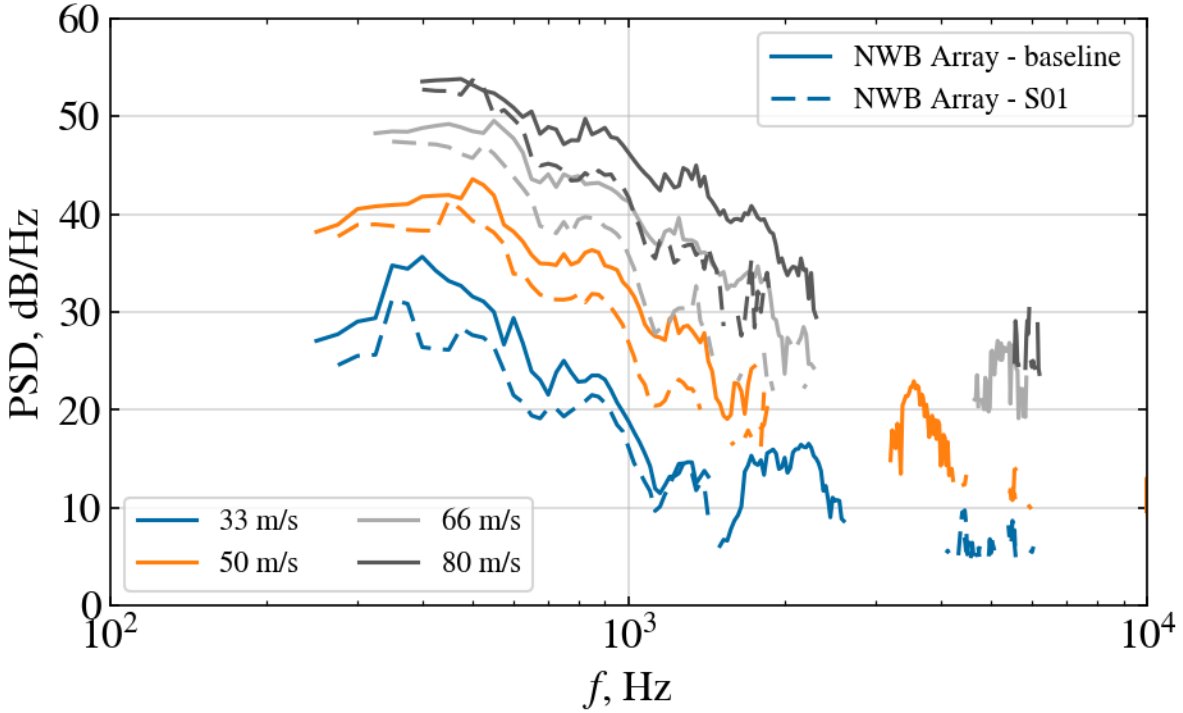
DTU-Array, VT-Array



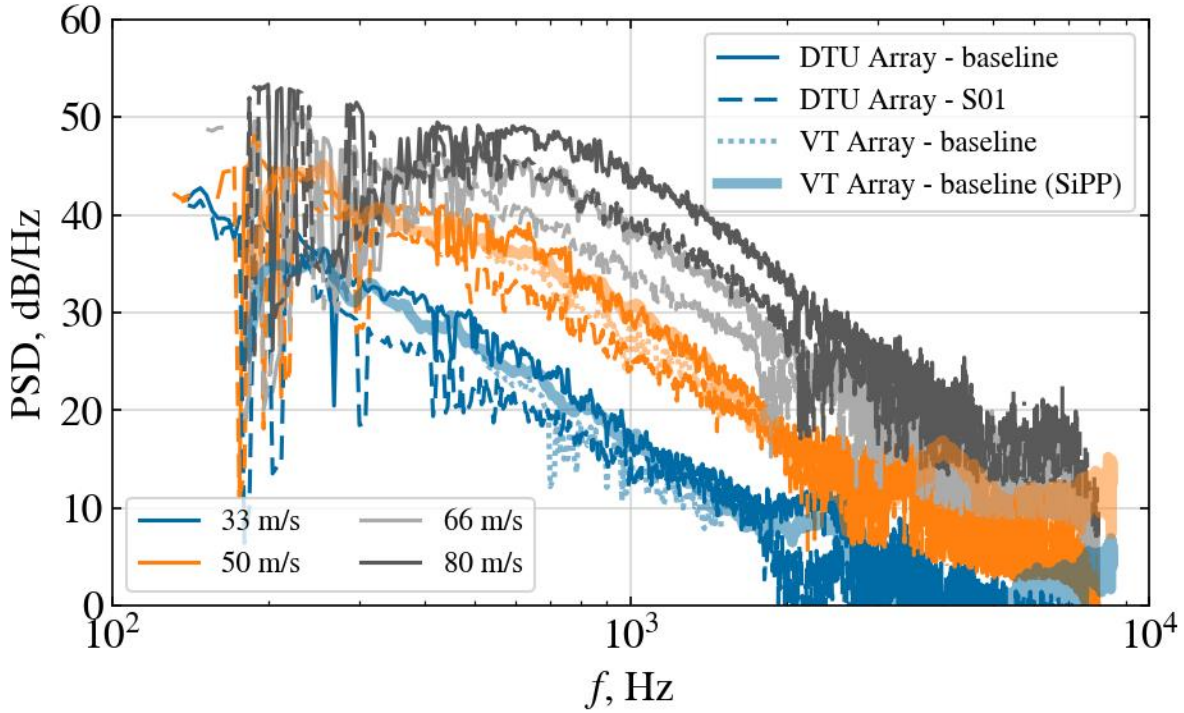
Baseline vs Serration, CL=0, CLEAN-SC

NWB / DTU / VT, Trip 5/5

NWB-Array



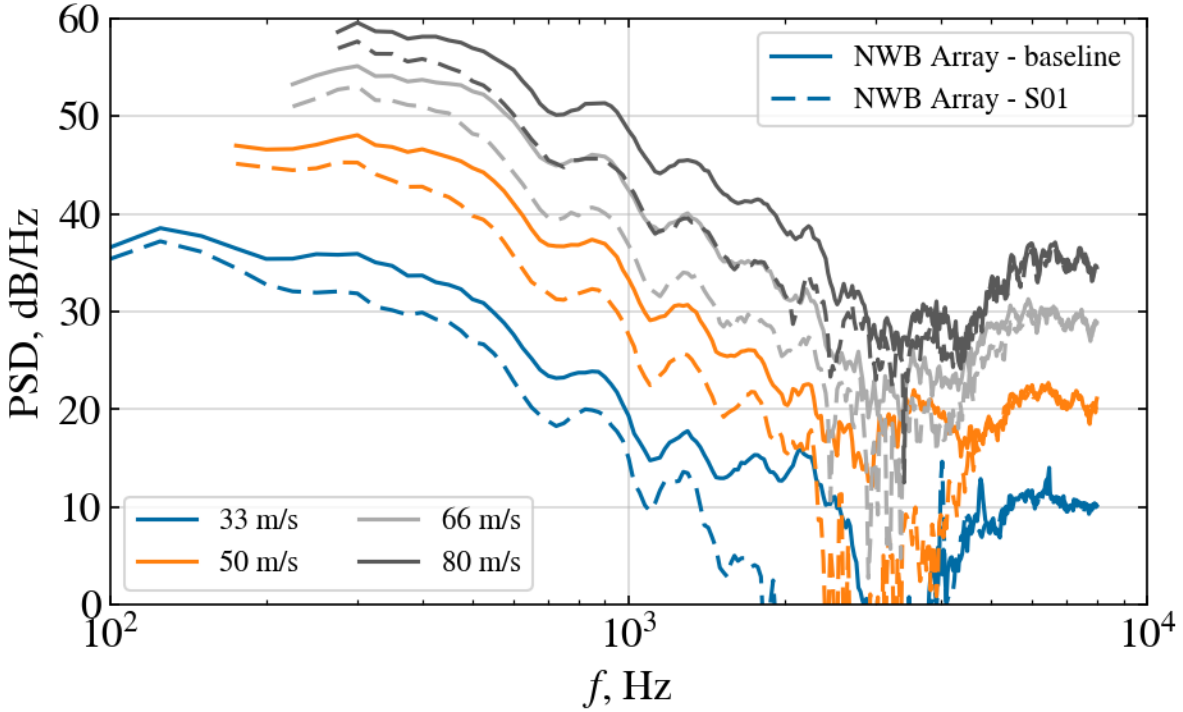
DTU-Array, VT-Array



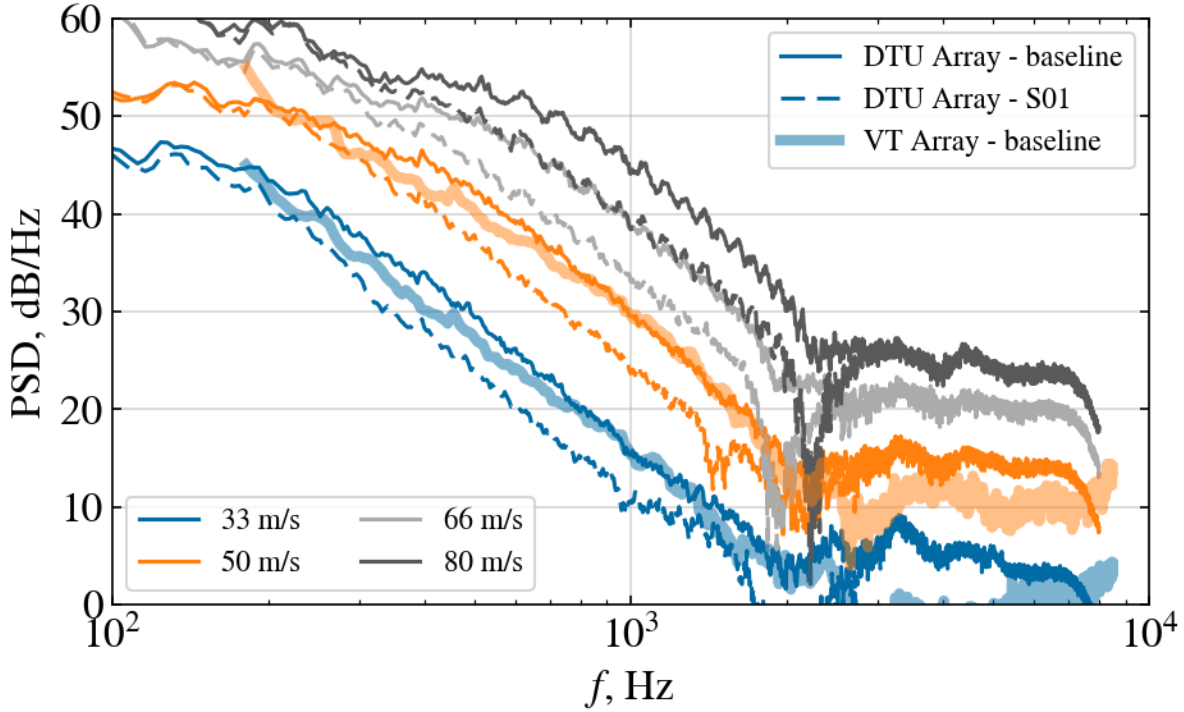
Baseline vs Serration, CL=0.5, Classical Beamforming

NWB / DTU / VT, Trip 5/5

NWB-Array



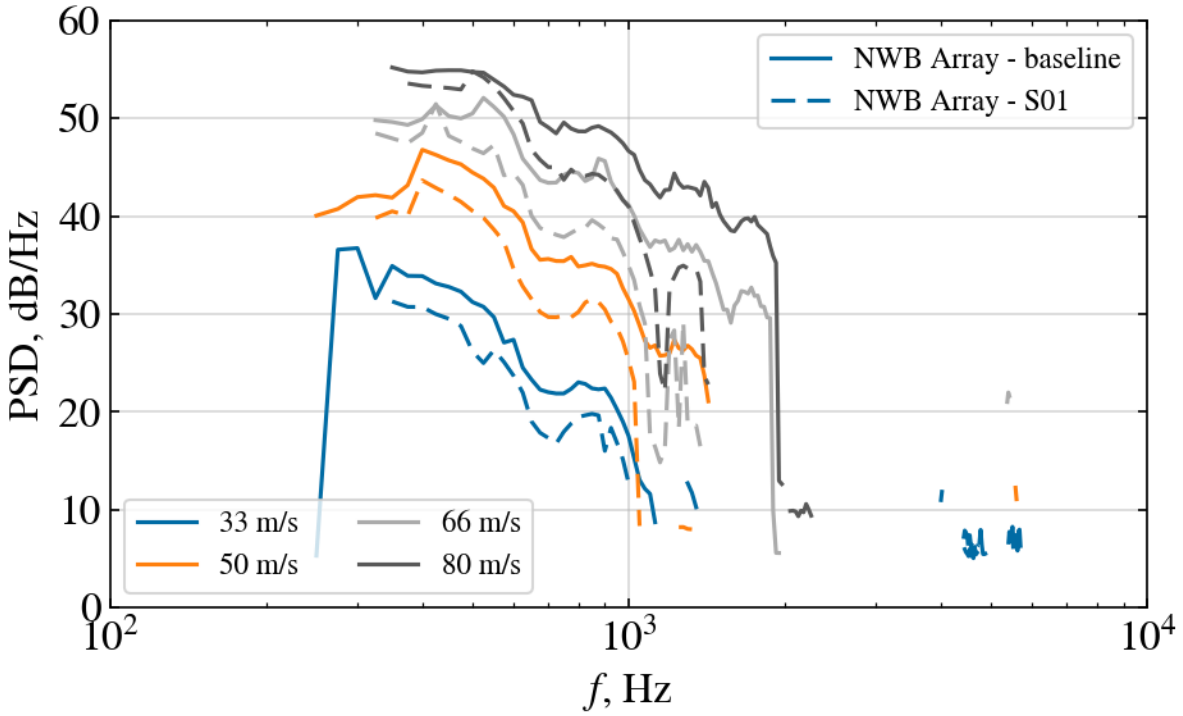
DTU-Array, VT-Array



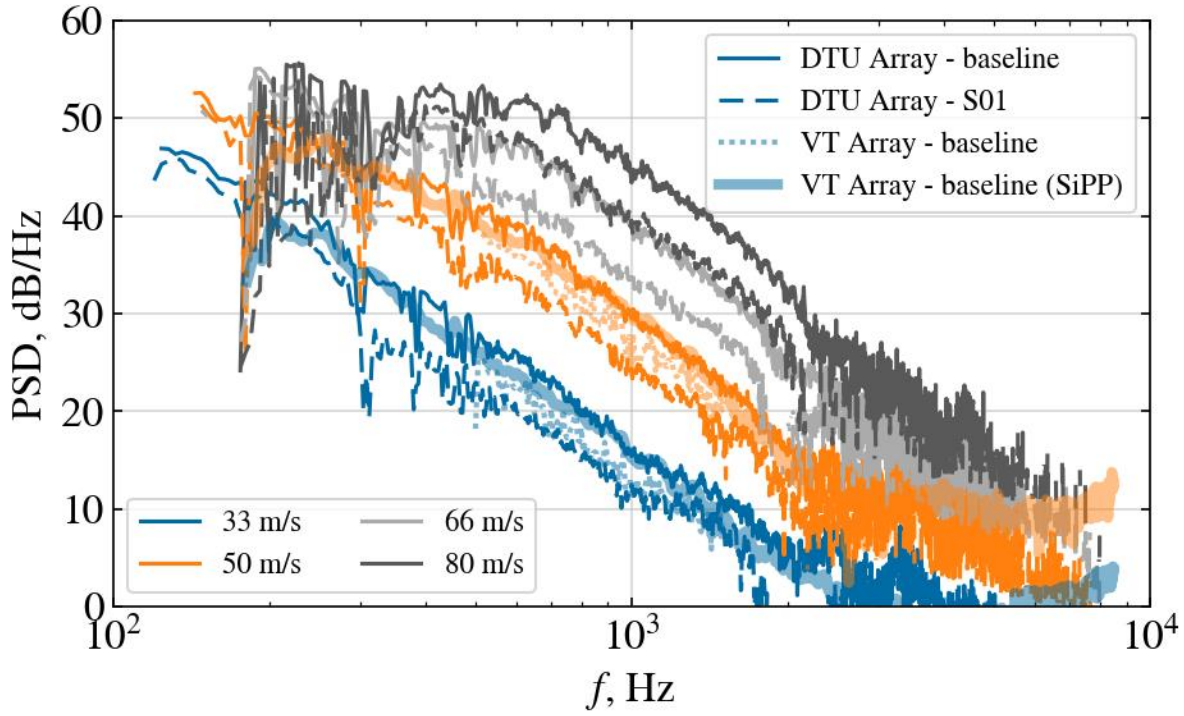
Baseline vs Serration, CL=0.5, CLEAN-SC

NWB / DTU / VT, Trip 5/5

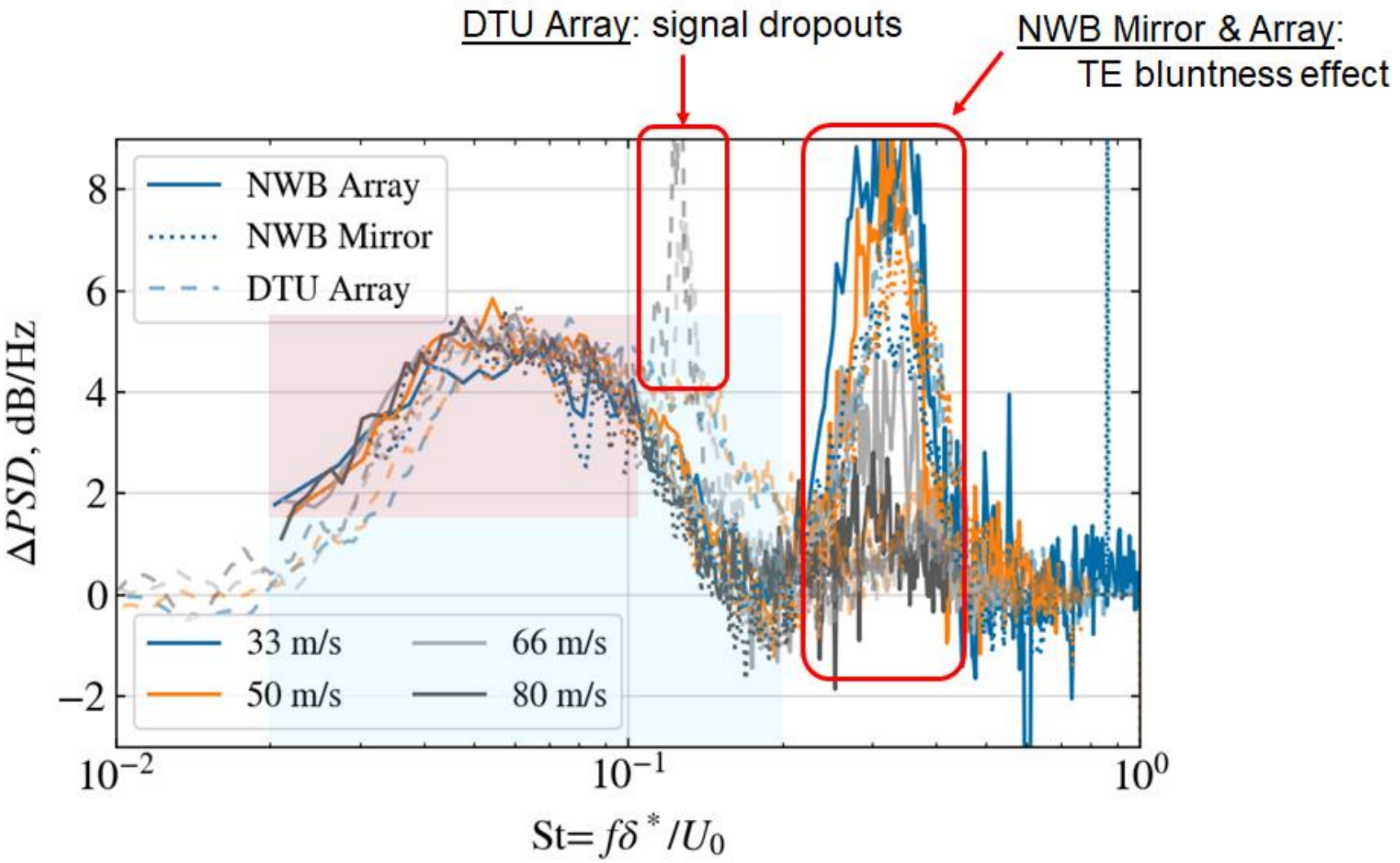
NWB-Array



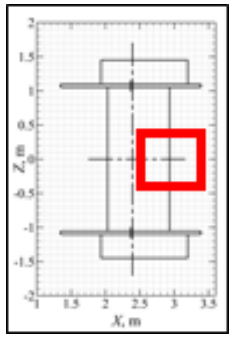
DTU-Array, VT-Array



Noise Reduction, CL=0



Source power integration area:

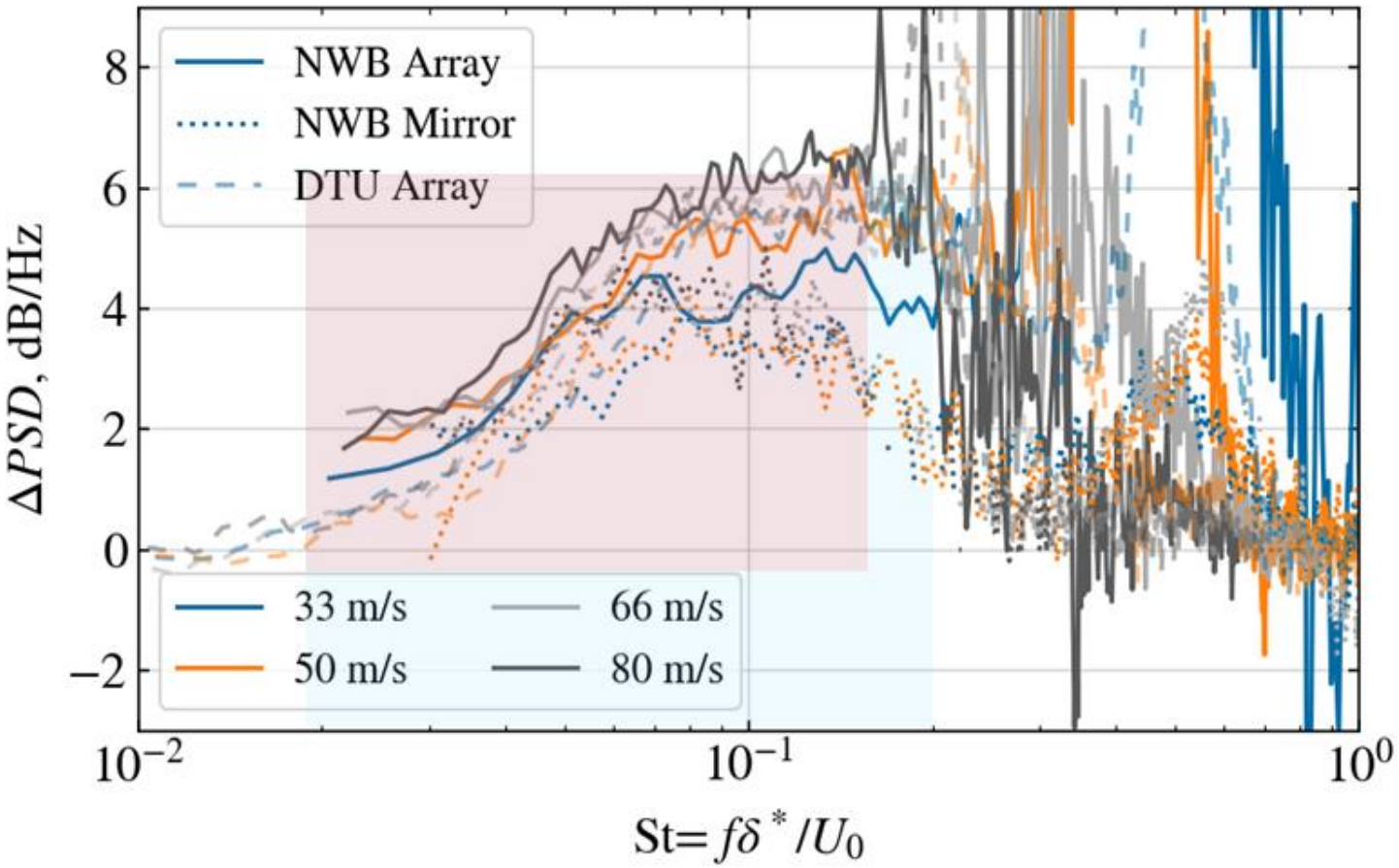


δ*: suction side displacement thickness (XFOIL)

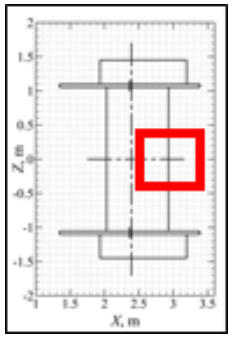
NWB: Classical beamforming after BGN removal

DTU: Classical beamforming

Noise Reduction, CL=0.5



Source power integration area:



δ*: suction side displacement thickness (XFOIL)

NWB: Classical beamforming after BGN removal

DTU: Classical beamforming

Conclusions

- New high quality validation data for Reynolds numbers up 6 million and Cl = 0.5
- Maximum deviation of the SPL below 3 dB using delay and sum beamforming, but better in a large frequency range
- Clean-SC further decreases deviations
- Scalability of the noise reduction through serrations
- TU Berlin joined the benchmark team (now 6 institutions)
- New participants are welcome
- The teams is working towards a (or several) publications

Funding sources

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