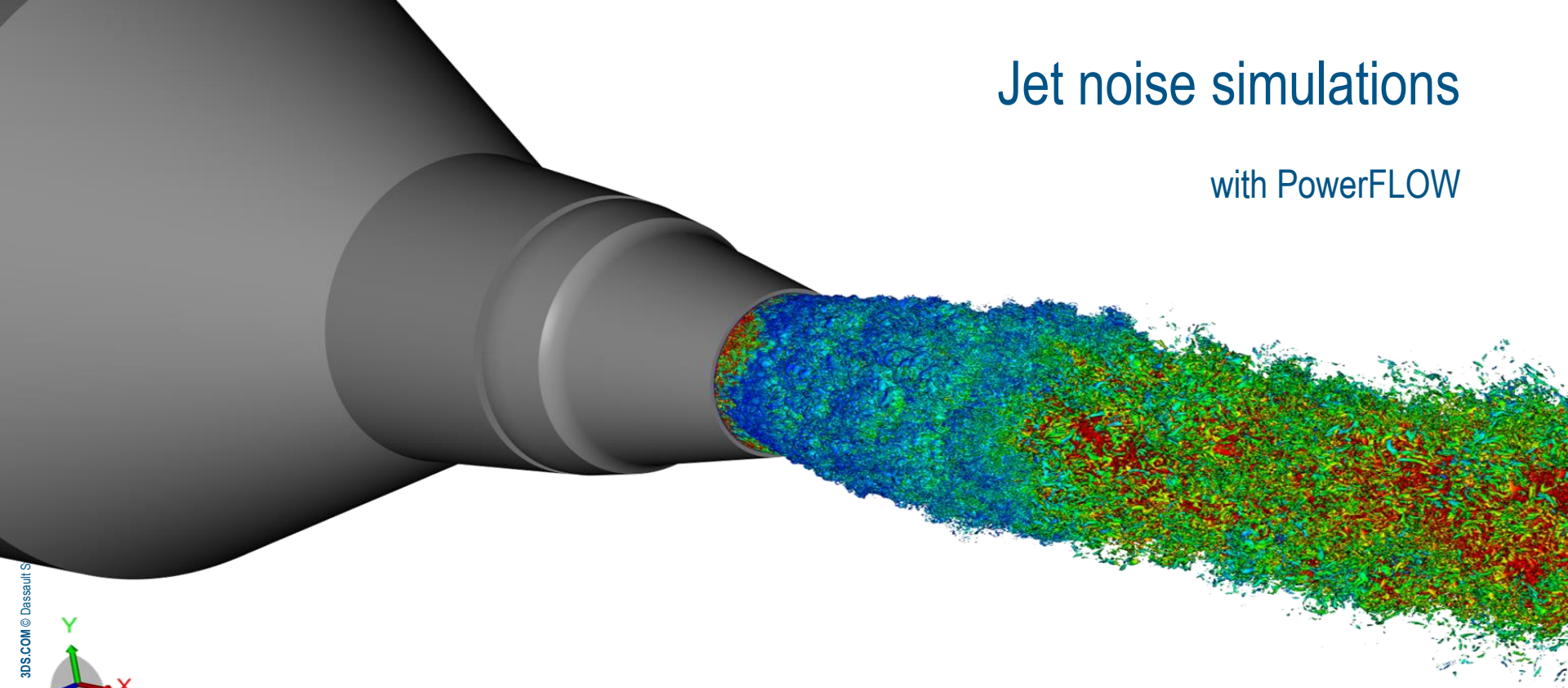
Jet noise simulations

with PowerFLOW



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Wouter van der Velden

TU Delft/3DS Workshop on PowerFLOW simulations of aircraft noise,
Delft, the Netherlands

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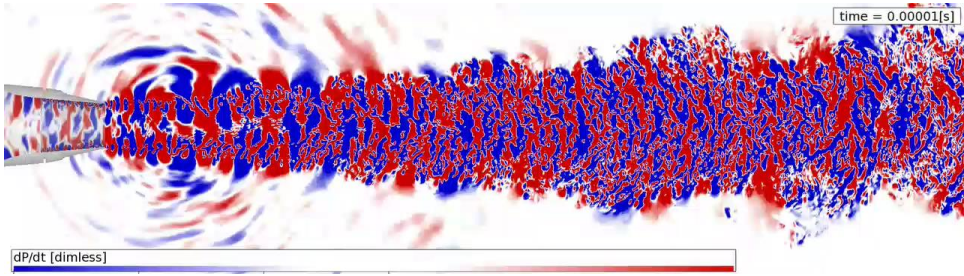
Background

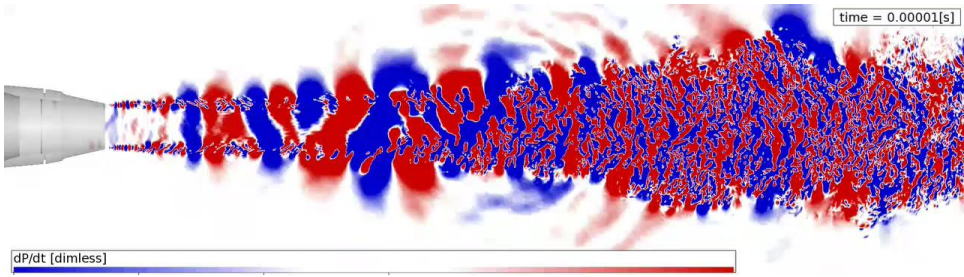
Jet-flap interaction noise is still producing a non-negligible contribution to the overall noise despite the recent improvement in turbofan designs

High-subsonic flow LBM solver improvements

- Earlier versions of PowerFLOW (5.x) solves the entropy solver using a FDM grid
  - Loss of symmetry in azimuthal direction of second order moments (standard deviation)
  - Pressure disturbance and conservation issues across interfaces between VR's



- Updated version of PowerFLOW (6.x) solves the total energy equation on the actual LBM grid



- Acknowledgements to Exa's physics team
  - P. Gopalakrishnan, A. Jammalamadaka, Y. Li, R. Zhang & H. Chen

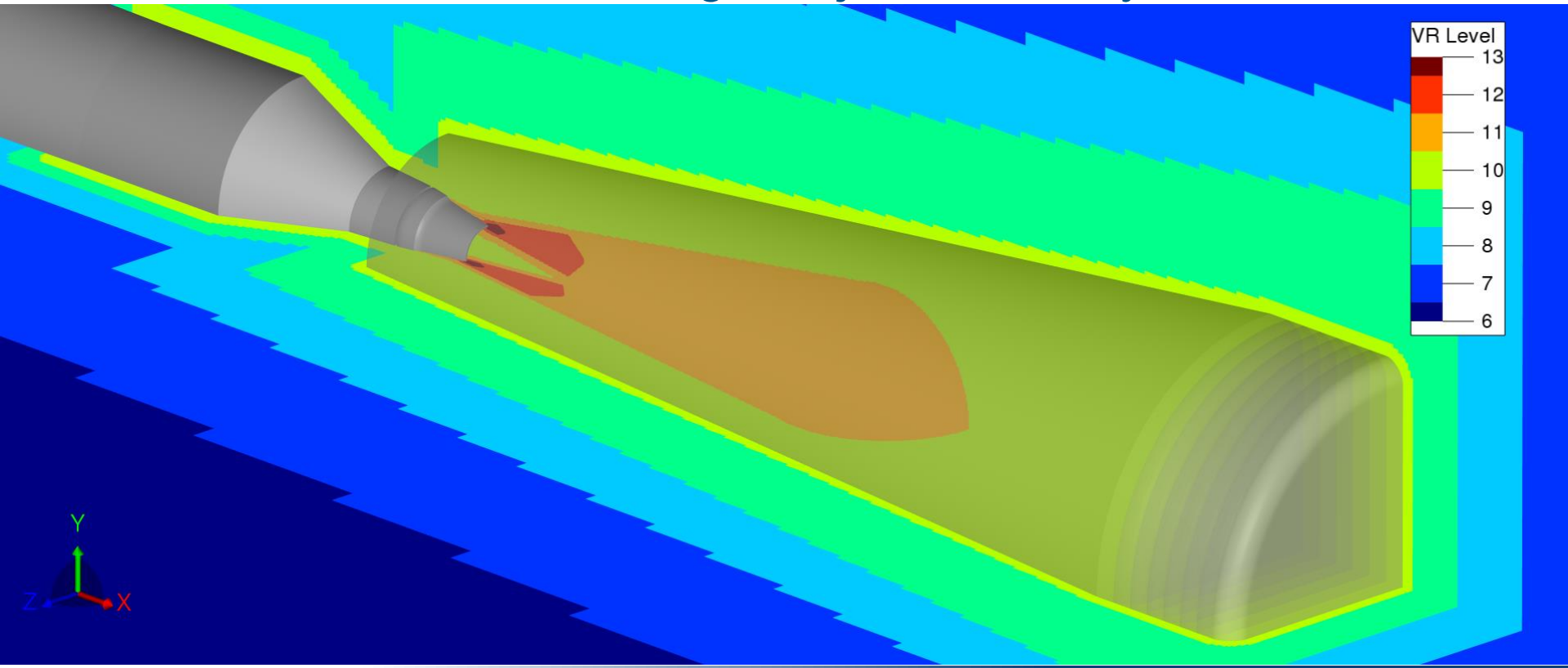
Test setup under consideration

	SP03	SP07	SP46
Ma	0.5	0.902	0.901
T/T_∞	0.955	0.842	2.702

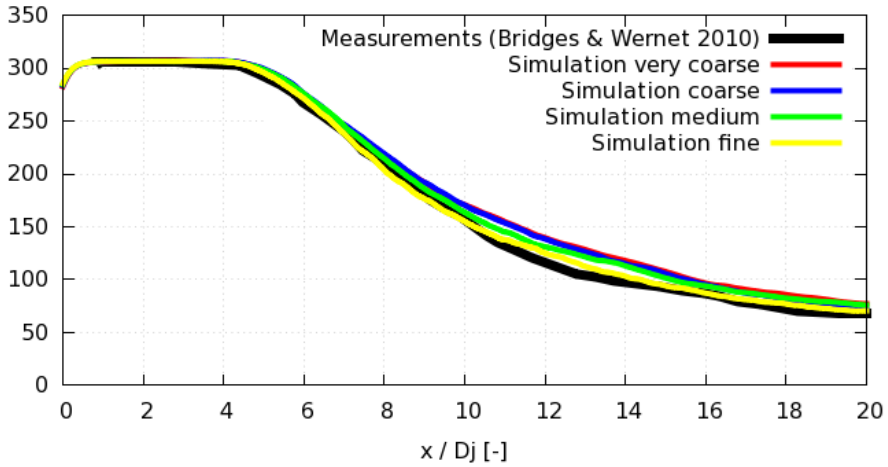
- 2 inch convergent SMC000 nozzle
  - Established benchmark case for jet flow and acoustics
  - Experiments from Small Hot Jet Acoustic Rig at NASA Glenn
- Computational setup
  - **Full nozzle modeled** to avoid time dependent boundary conditions
  - **Three setpoints** were investigated
  - Domain partitioned into **13 VR's**
  - Non-reflecting boundary conditions and sponge zones are used at outer domain, total temperature and pressure set at inlet
  - Medium resolution results in **y+=15** at nozzle exit
  - Far-field noise extracted from **permeable surface** (surrounding the plume using staggered cups downstream to filter the vortical perturbations)
  - Total simulation time ~0.1 physical seconds

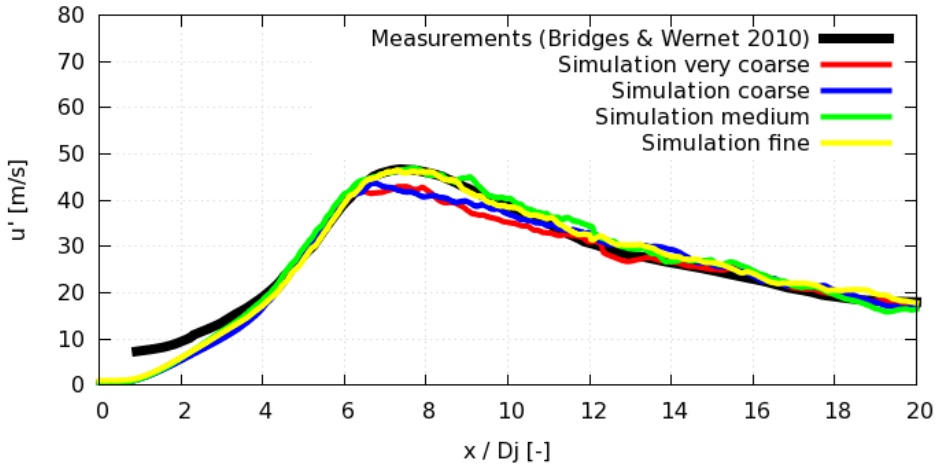
	Voxel size	Voxels	FEV	kCPUh
Very coarse	32	110	30	5
Coarse	45	250	65	15
Medium	64	625	160	45
Fine	90	1560	380	140

Variable resolution along the jet shear layer

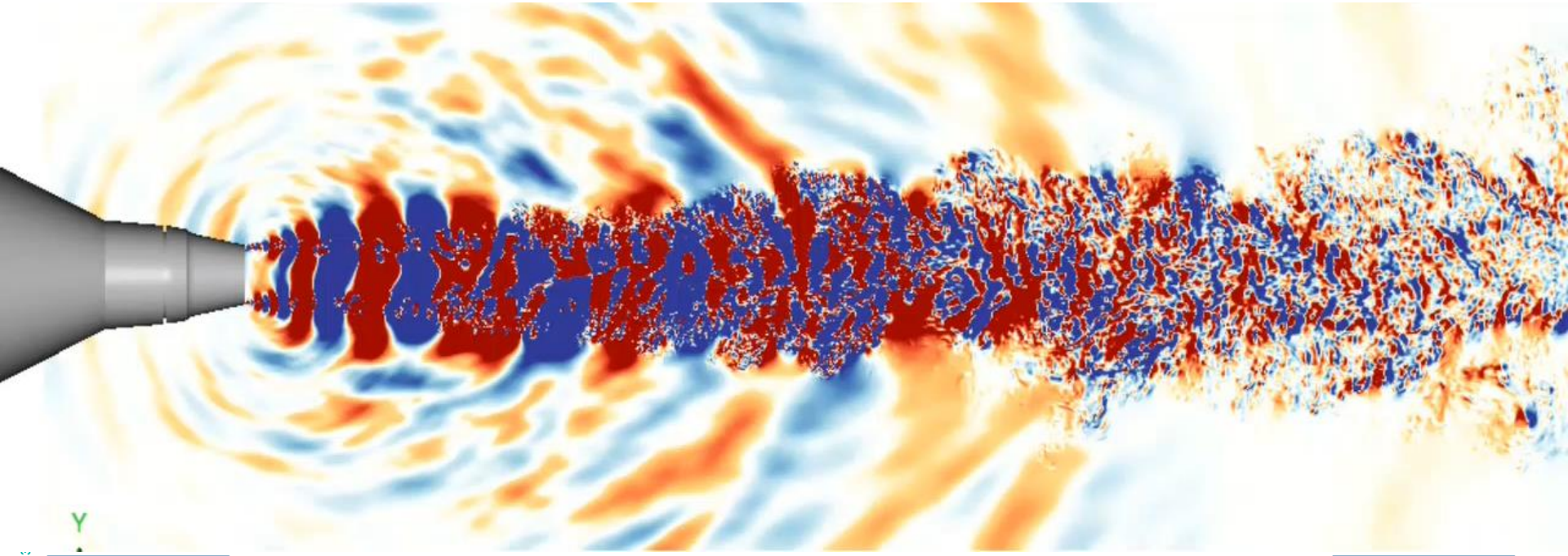


Flow field validation for setpoint 46





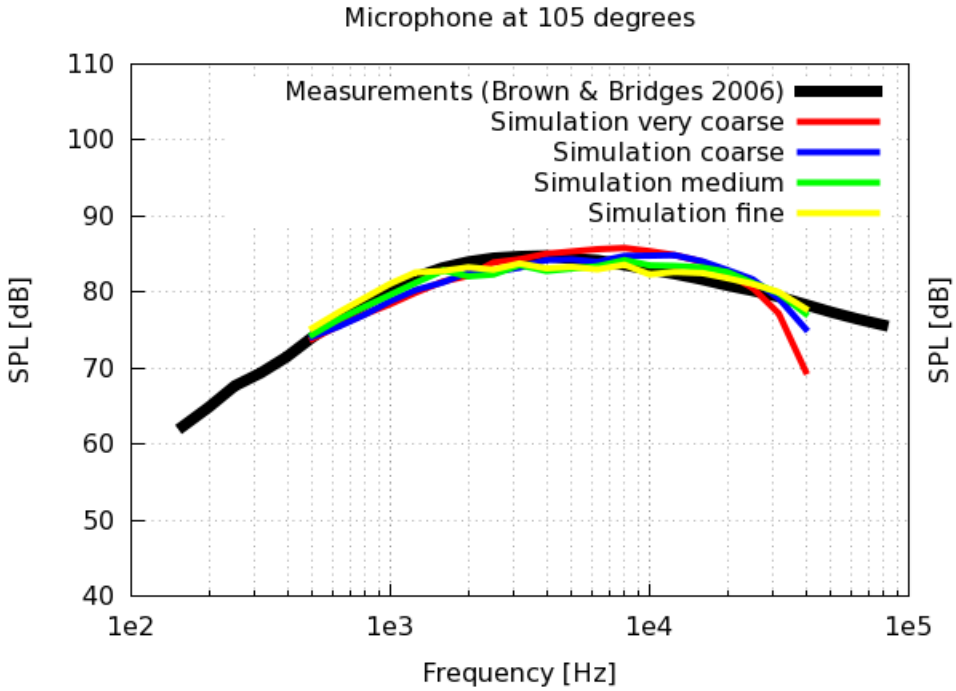
Acoustic validation for setpoint 46: overview

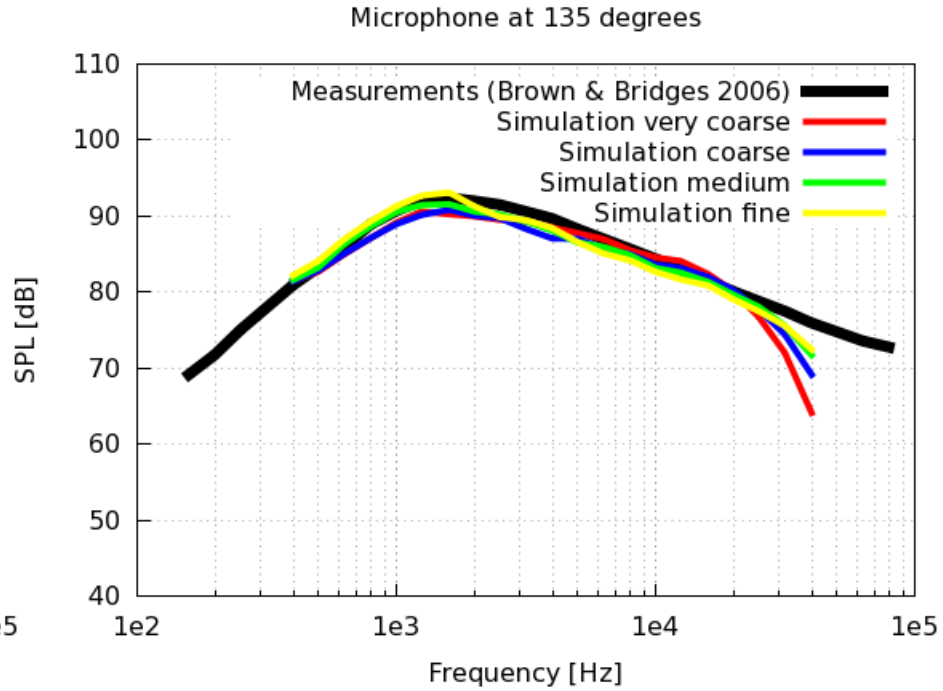


Sharp angles <90 degrees

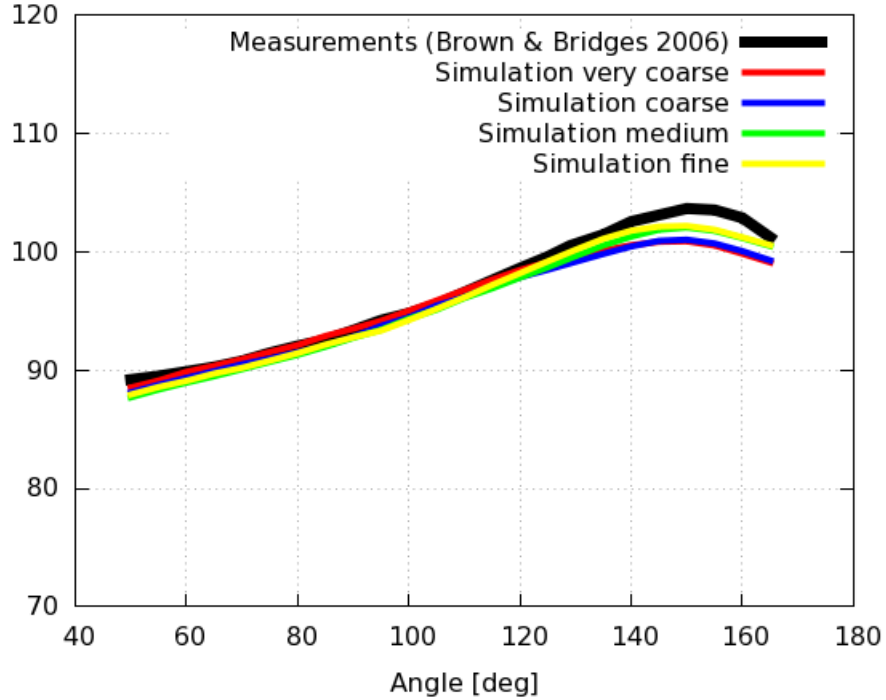
Shallow angles <90 degrees

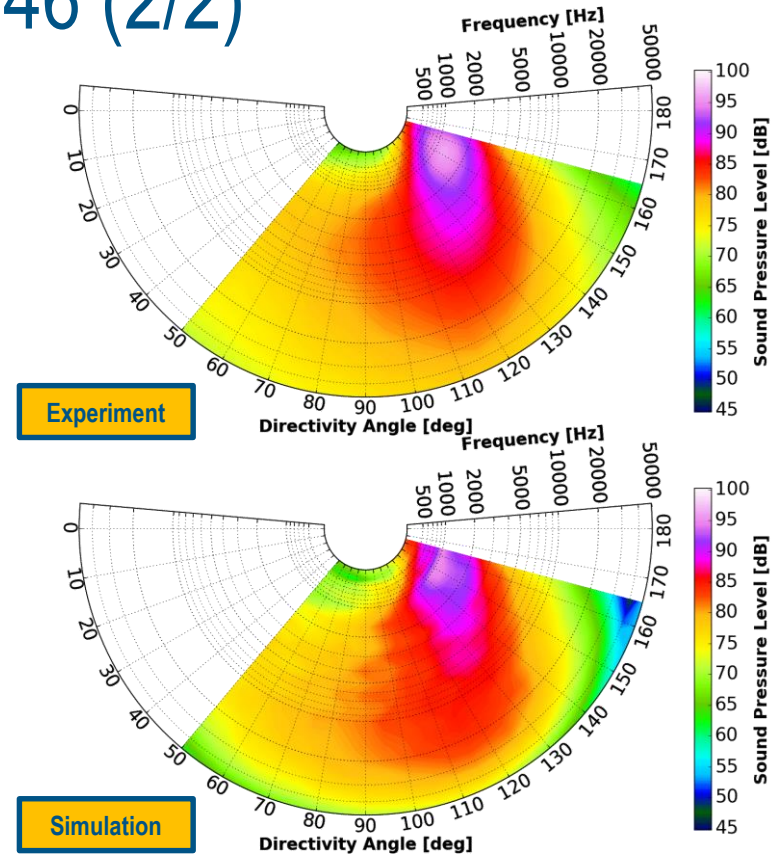
Acoustic validation for setpoint 46 (1/2)





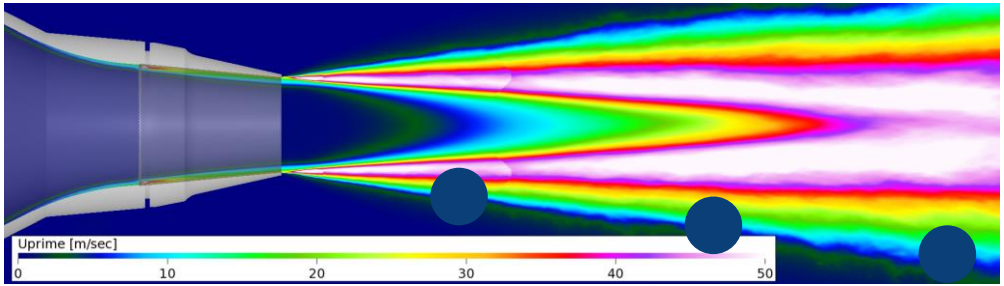
Acoustic validation for setpoint 46 (2/2)



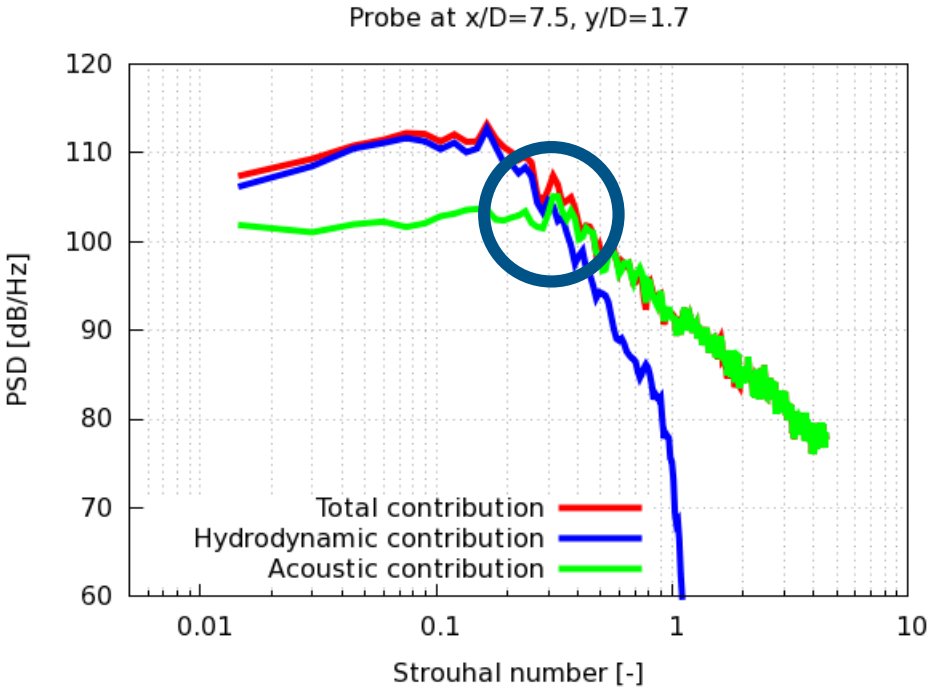


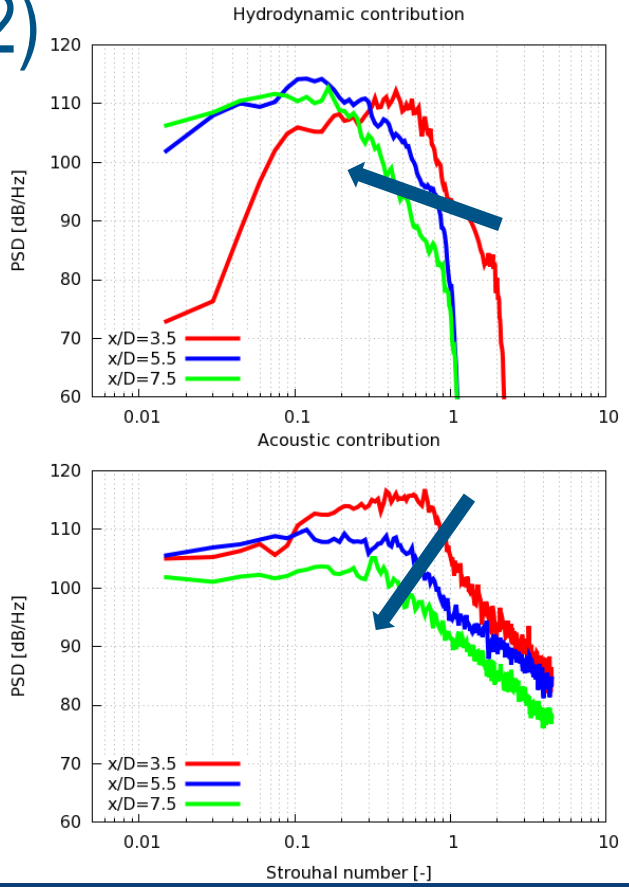
Wavelet decomposition

- Wavelet decomposition technique by *Mancinelli et al.* (2017)
  - Recursive de-noising procedure (WT3)
  - Separating the coherent (~hydrodynamic) and chaotic (~acoustic) flow motion
  - Characterized by the presence of structures with a supersonic phase velocity, thus radiating Mach waves
- Near-field
  - dB maps of near-field
  - Points close to the shear-layer boundary



Near-field wavelet decomposition (1/2)





Near-field wavelet decomposition (2/2)

Coherent

Chaotic