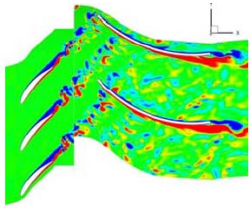


FLOCON

DLR

Adaptive and Passive Flow Control for Fan Broadband Noise Reduction

Selected final results

Lars Enghardt, DLR Berlin
FLOCON project coordinator

September 2008 – August 2012

2007 - 2013

Introduction

Motivation

- Air traffic is predicted to grow by 5% per year in the short and medium term.
- Technology advances are required to achieve his growth with acceptable levels of noise in particular at airport surroundings.
- ***Fan broadband noise*** is one of the most important aircraft noise sources at aircraft start and landing conditions.

Objectives

- Design noise reduction concepts and associated devices able ***to reduce fan broadband noise at source.***
- Assess the noise reduction concepts by conducting ***lab-scale experiments*** (to TRL 4).
- Complement the experiments by ***numerical simulations*** that are assessing the capability of currently available numerical tools to design low broadband noise treatments and configurations.
- ***Develop understanding*** of the mechanisms involved and extrapolate the results to the aero-engine environment using state-of-the-art numerical methods.
- Select the best concepts by ***balancing noise benefit and integration impact.***

FLOCON

EU FP7, 1st Call, Level 1 Project

Consortium

Research centers:

DLR - Deutsches Zentrum für Luft und Raumfahrt	(DE)
ONERA - Office National d'Études et Recherches Aérospatiales	(FR)
ISVR - Institute of Sound and Vibration Research	(UK)
NLR - Nationaal Lucht- en Ruimtevaart Laboratorium	(NL)

Industrial partners:

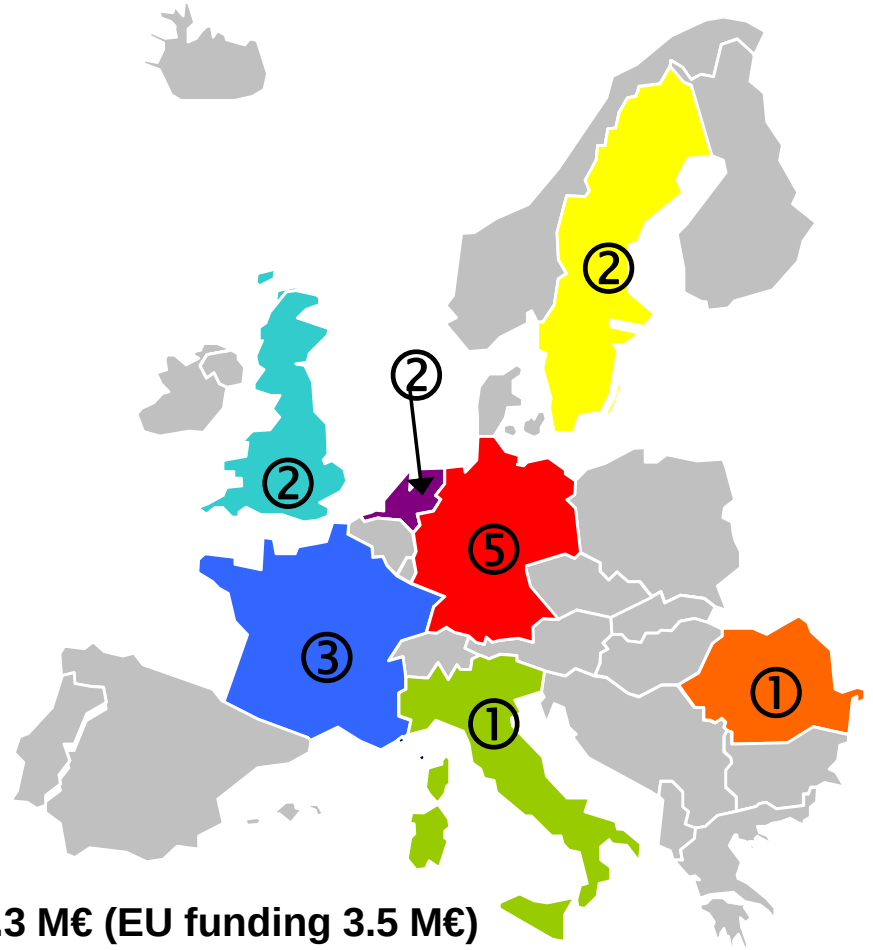
Snecma Moteurs	(FR)
Rolls-Royce plc	(UK)
EADS Innovation Works	(DE)
MTU Aero Engines	(DE)
VOLVO Aero Corporation	(SW)
AVIO SpA	(IT)

Universities:

Ecole Centrale de Lyon	(FR)
Universität Siegen	(DE)
Chalmers University of Technology	(SW)
Technische Universität Berlin	(DE)

SME:

Fluorem SAS	(FR)
Microflown Technologies BV	(NL)
Sandu M. Constantin PF	(RO)



- **Budget: 5.3 M€ (EU funding 3.5 M€)**
- **Project start: 1. September 2008**
- **Duration: 4 years (12 months extension at no costs)**
- **Coordination: DLR Berlin**

Work Package 2: Airfoil treatments for low-noise

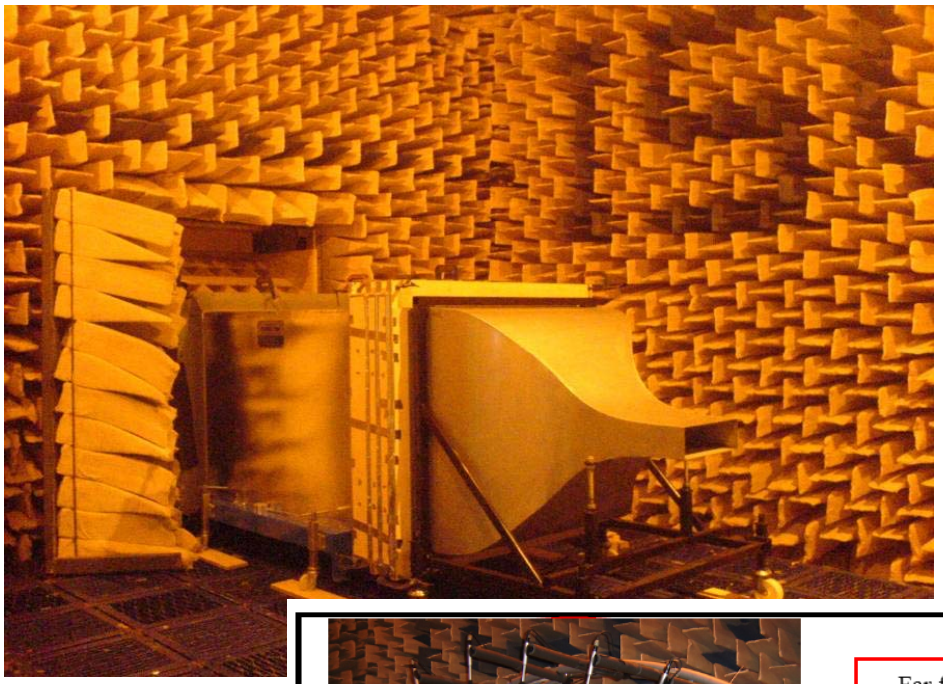
Objective

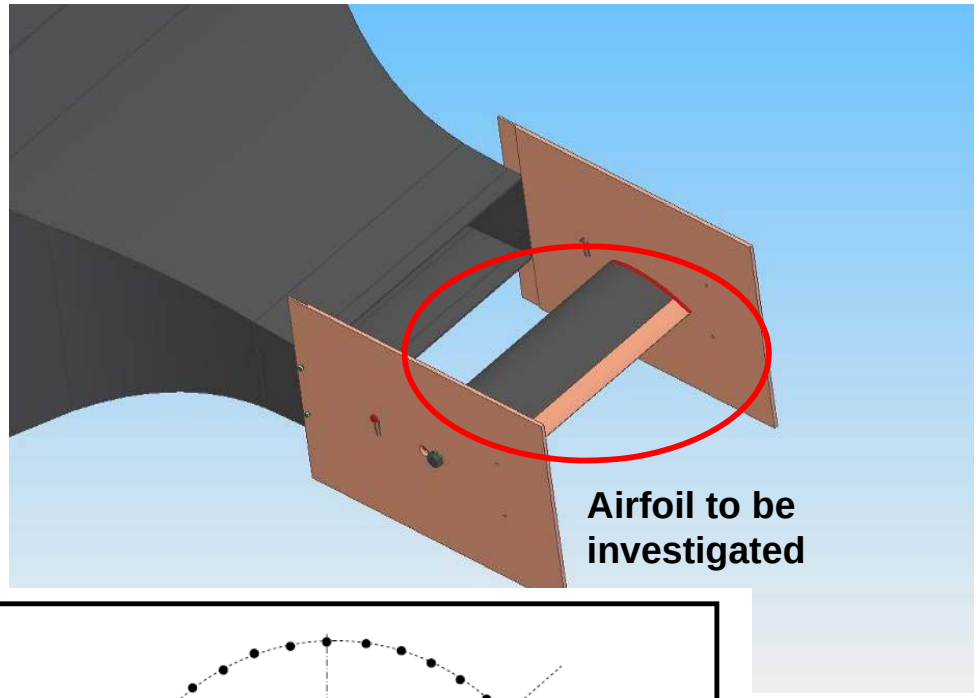
- Development of leading edge and trailing edge treatments for reducing airfoil self-noise and interaction noise and for reducing the turbulence in the wake.

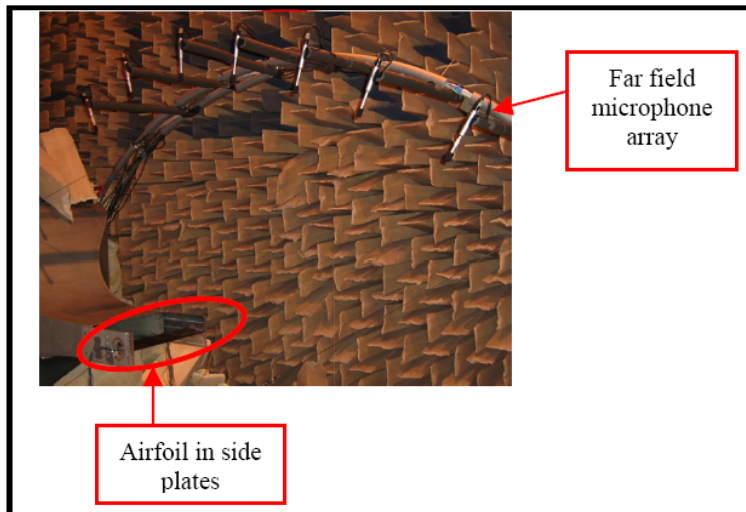
Workplan

- Demonstration and validation of these treatments in an open jet wind tunnel facility (TRL 2)
- Down-selection of the best trailing edge treatments for testing in a cascade rig (TRL 3) and of the best leading edge treatments for testing in a fan rig in WP3(TRL 4).
- Modelling of these treatments using RANS and LES CFD simulations.

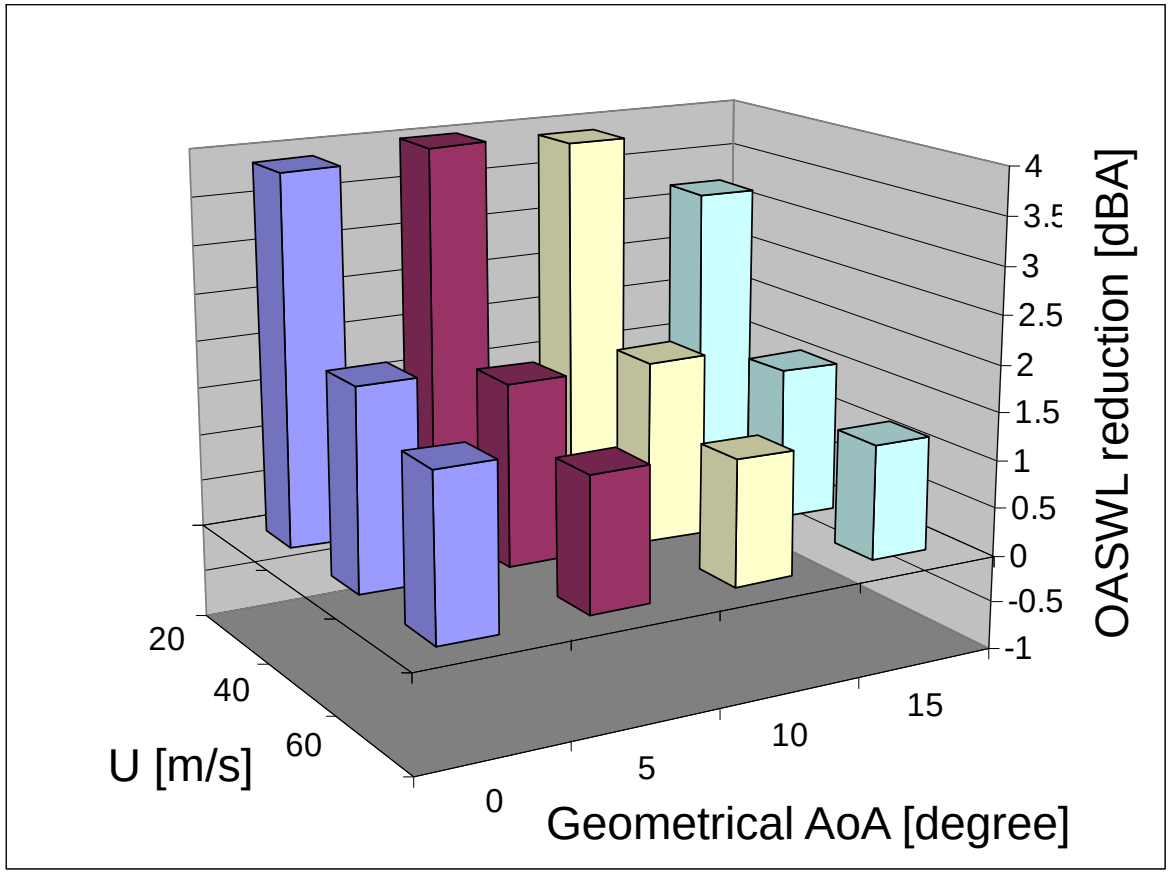
ISVR open jet wind tunnel

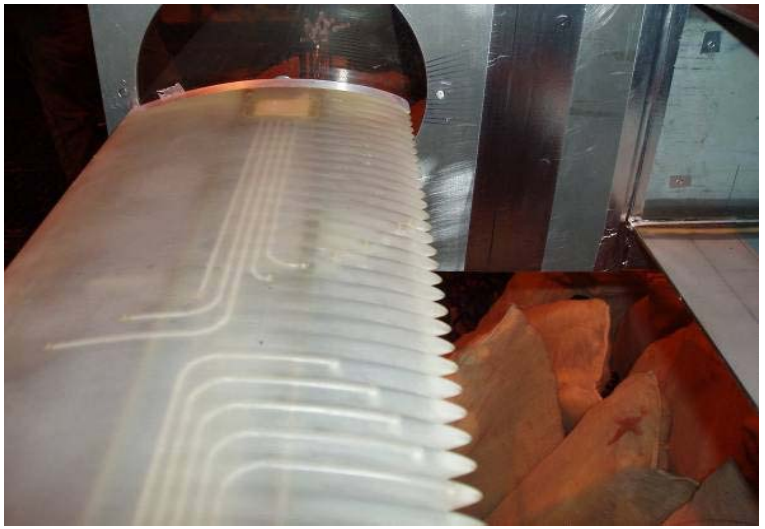


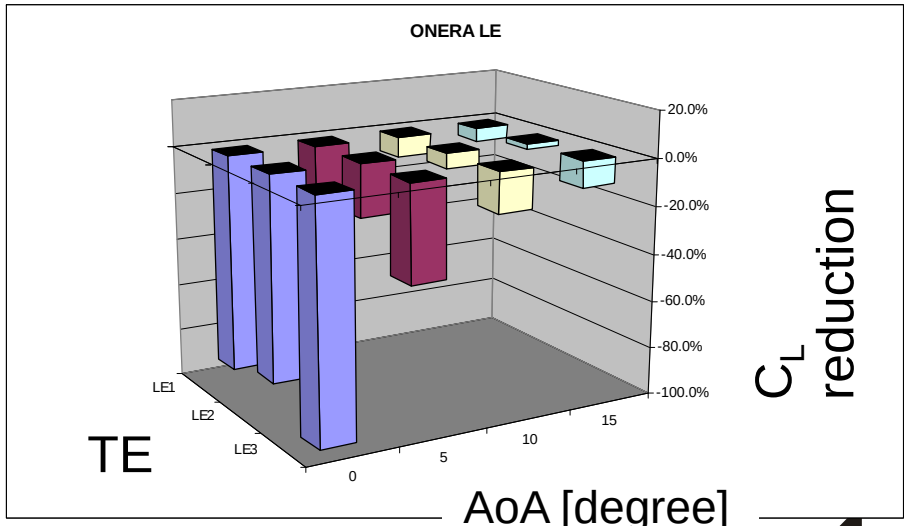




Leading edge treatment

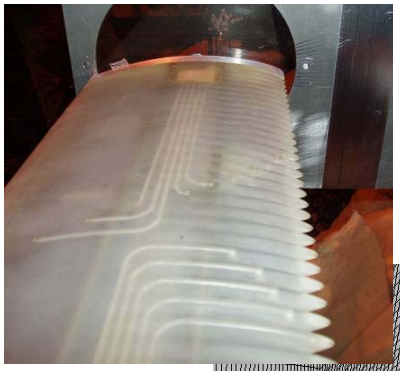


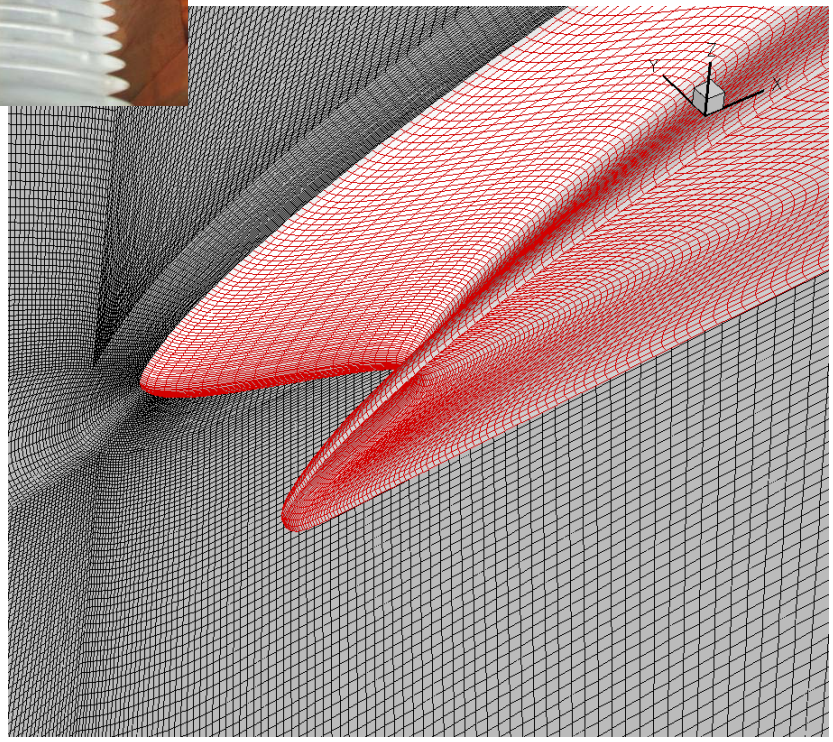




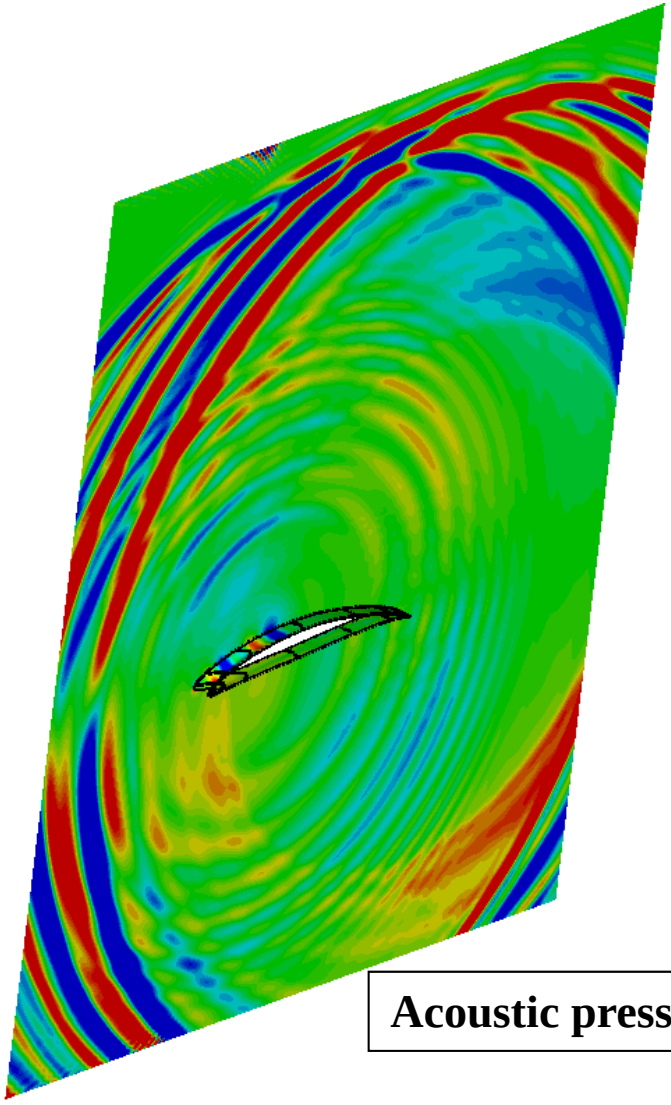
Down select of best LE treatment: ONERA wavy pattern

ONERA Euler computations on wavy-edge case



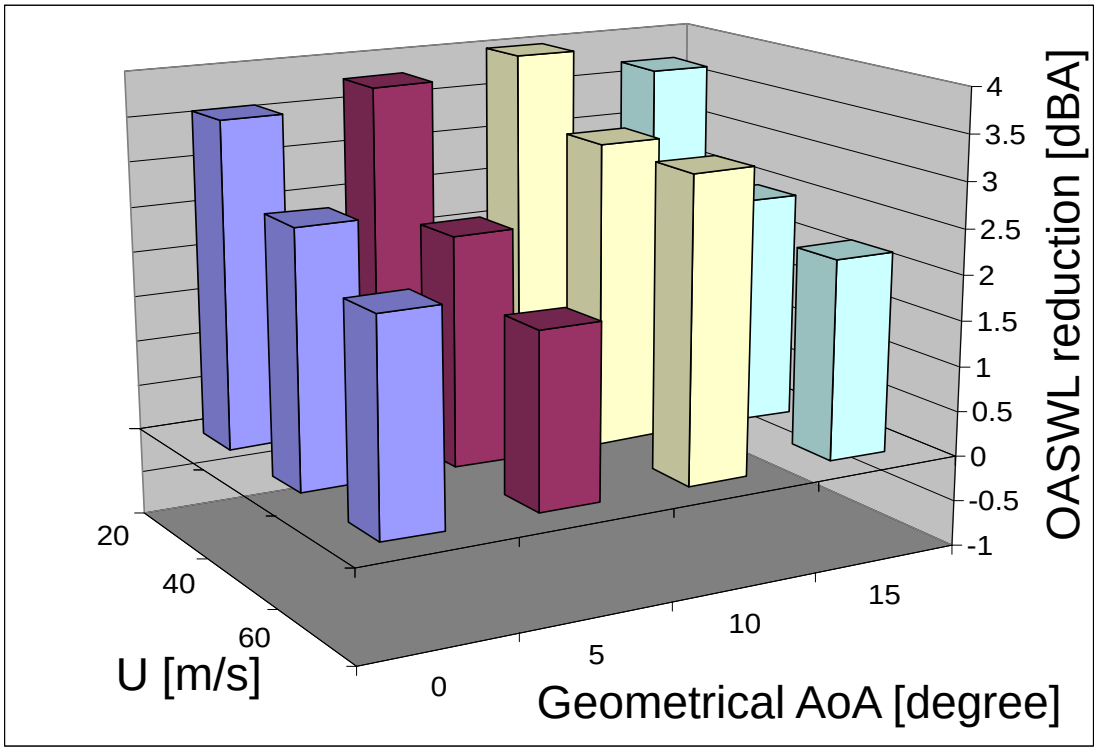


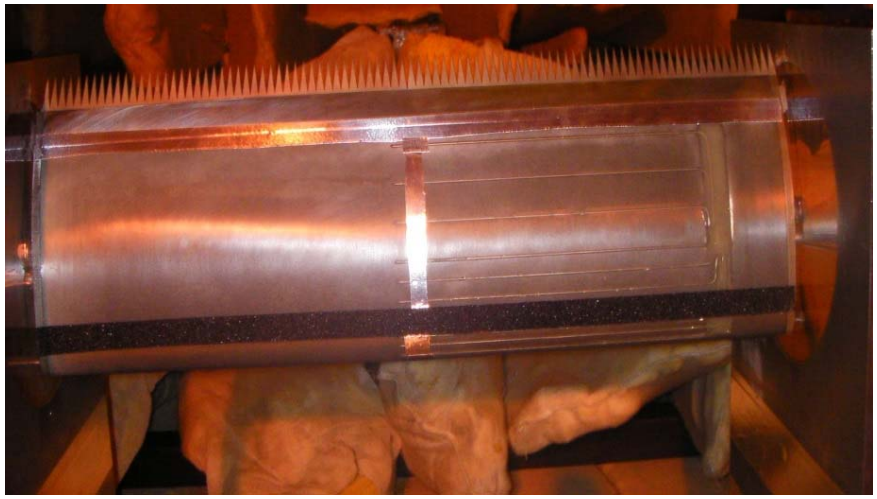
3D multi-bloc grid with 1 motif of 2S wing

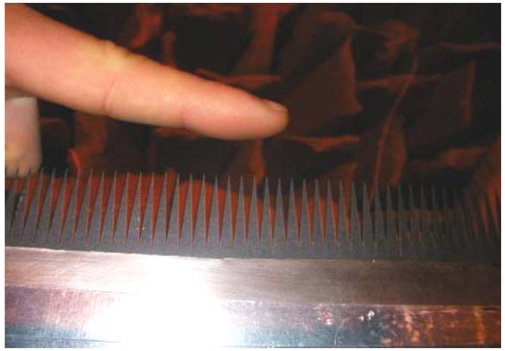


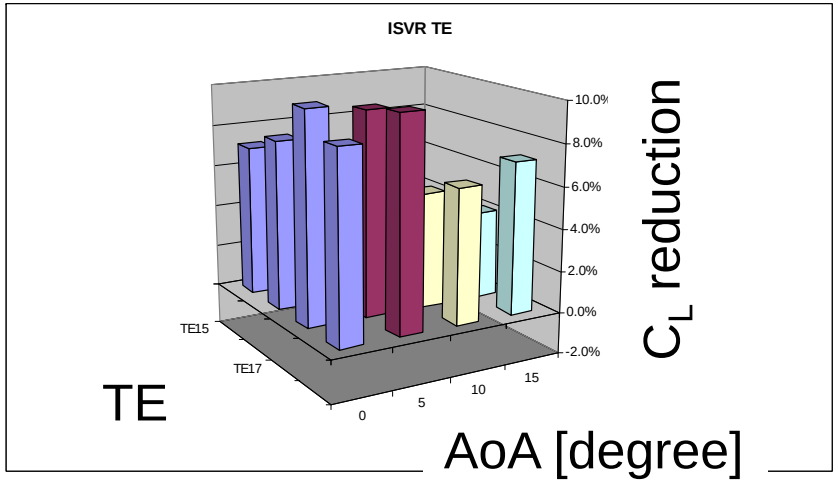
Acoustic pressure field (Pa)

Trailing edge treatment



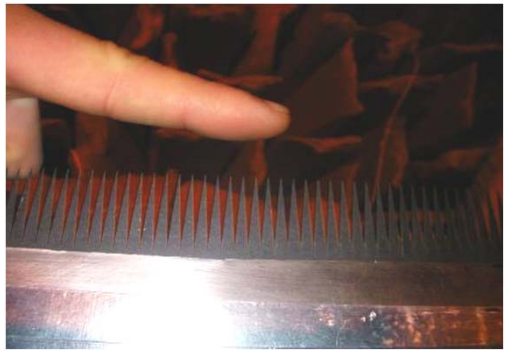


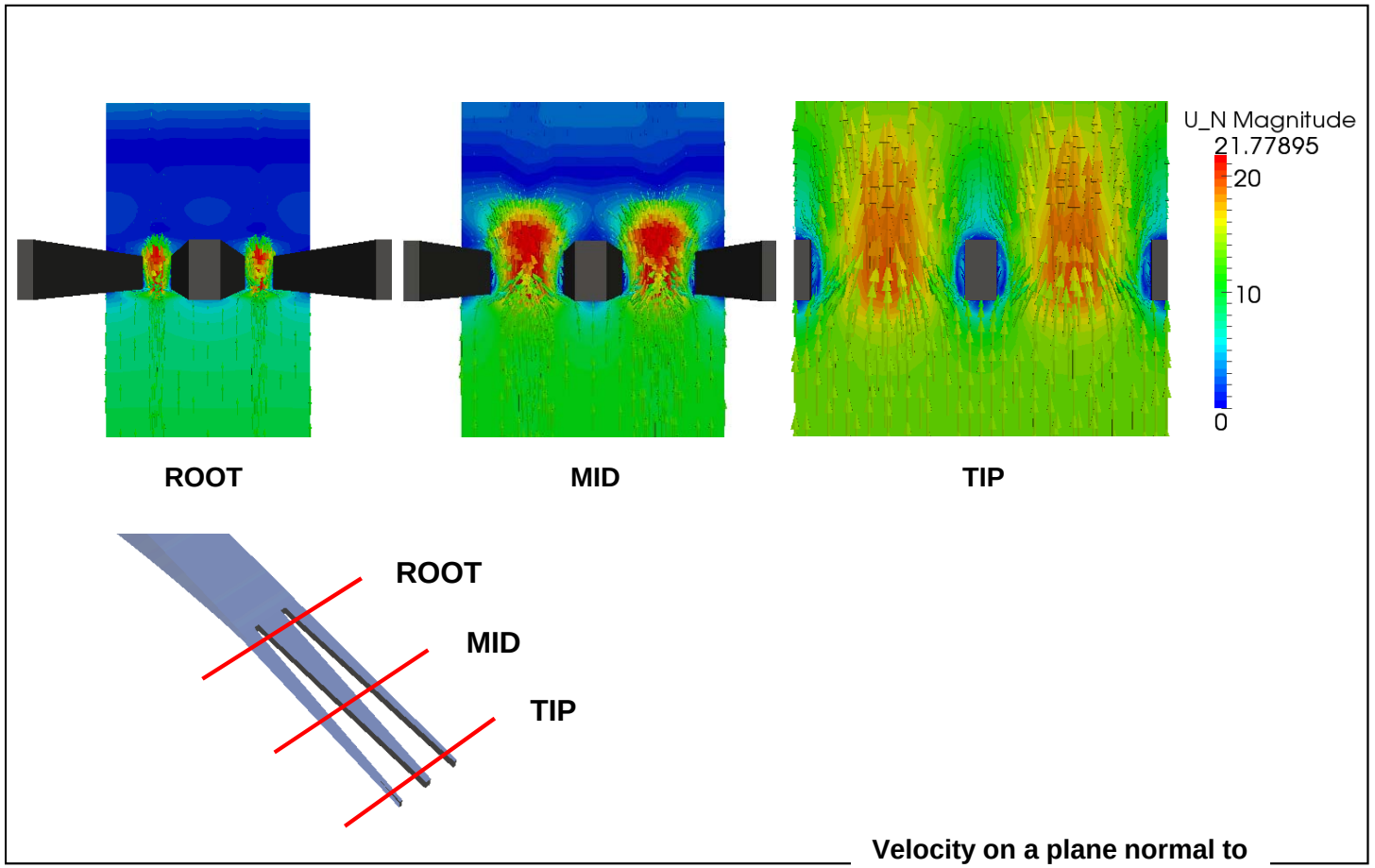




Down select of best TE treatment: ISVR serrated edge

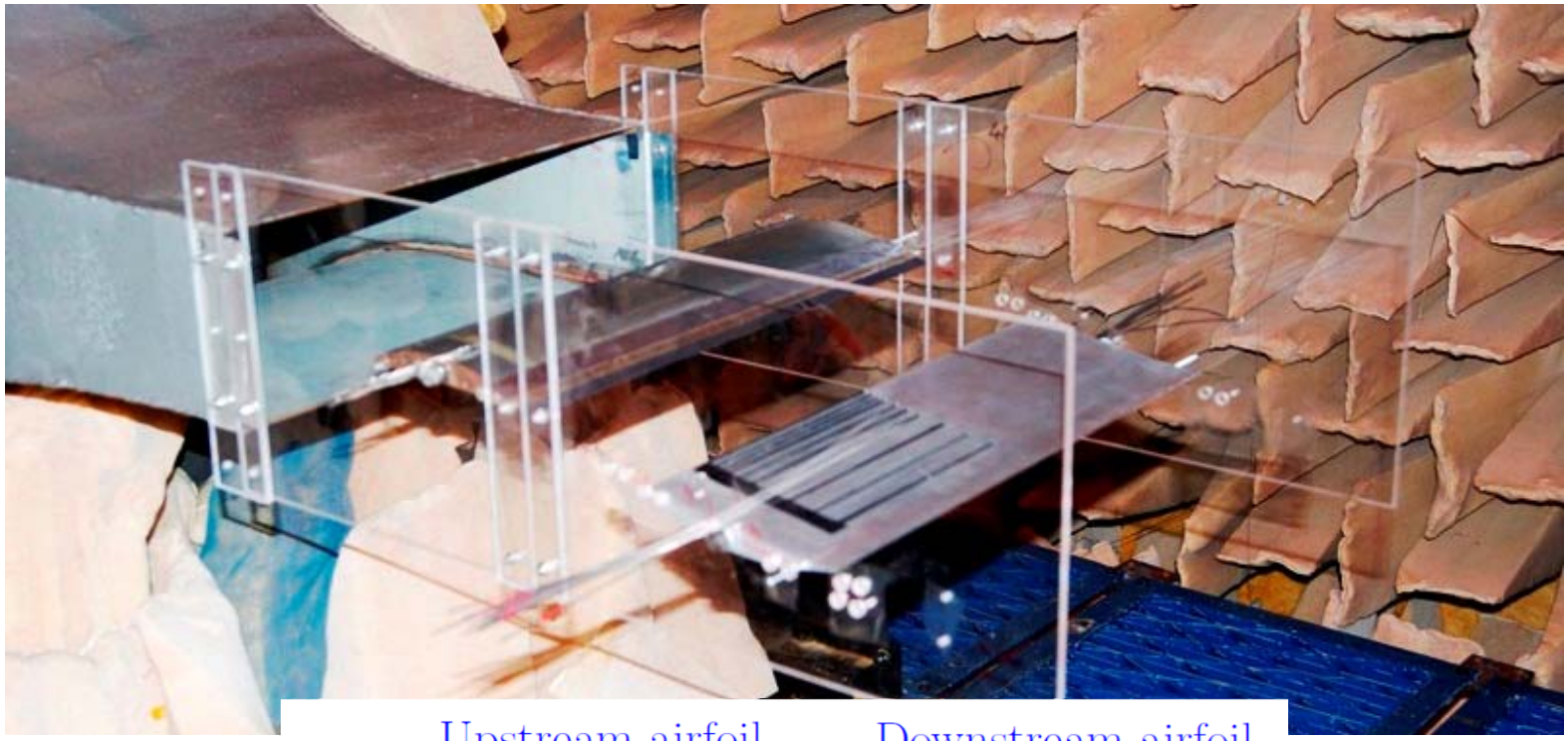
AVIO
3D LES on Treated airfoils

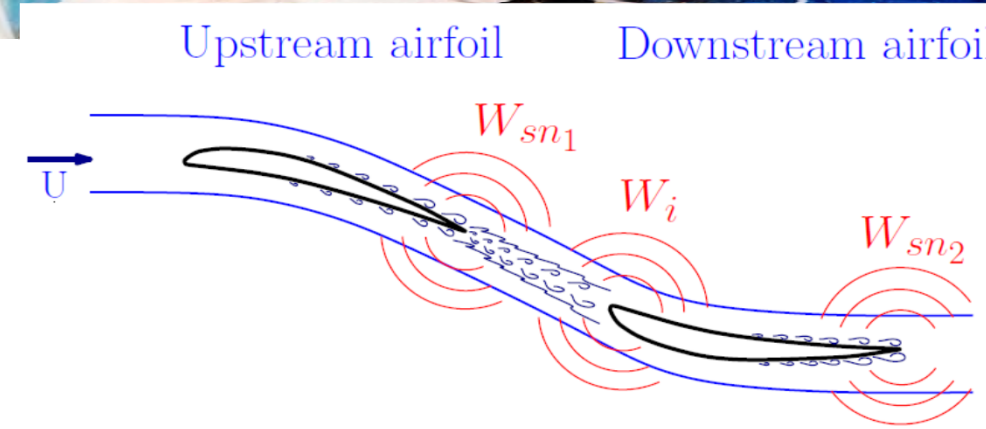




Velocity on a plane normal to the serration plate

ISVR tandem experiment





Work Package 3: Casing and airfoil treatments for low noise in a fan stage

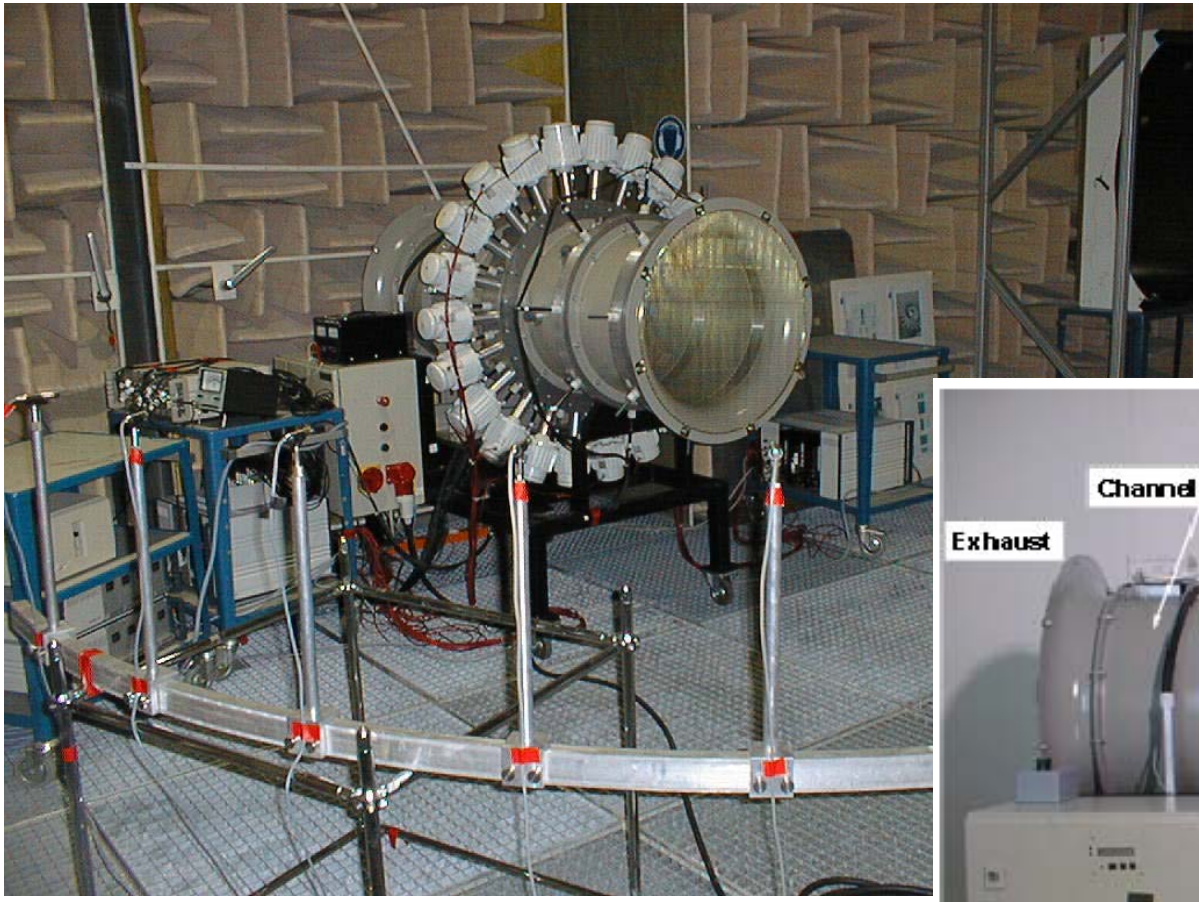
Objective

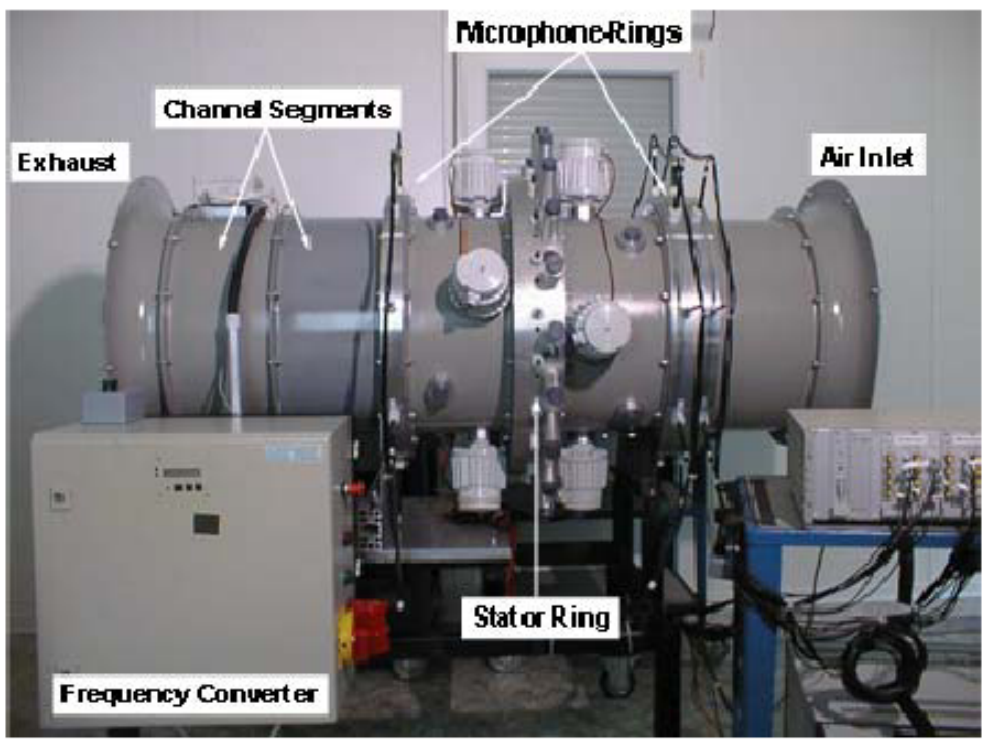
- Development of new and innovative technologies for fan broadband noise reduction focusing on airfoil treatments and the interaction between blade tip and fan casing.

Workplan

- Demonstration and validation of these technologies (selected best concept from WP2, special overtip treatment) on a low speed laboratory rotating rig
- Demonstration of vane trailing edge treatment technology for fan broadband noise reduction under rotating rig flow conditions

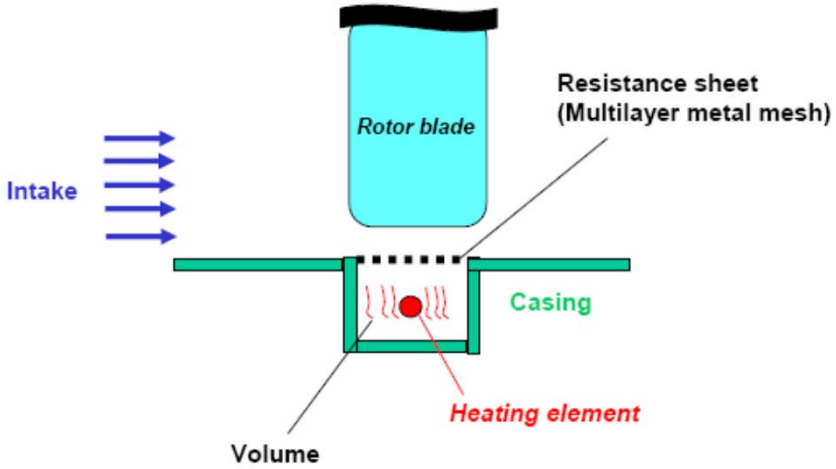
EADS low speed fan rig

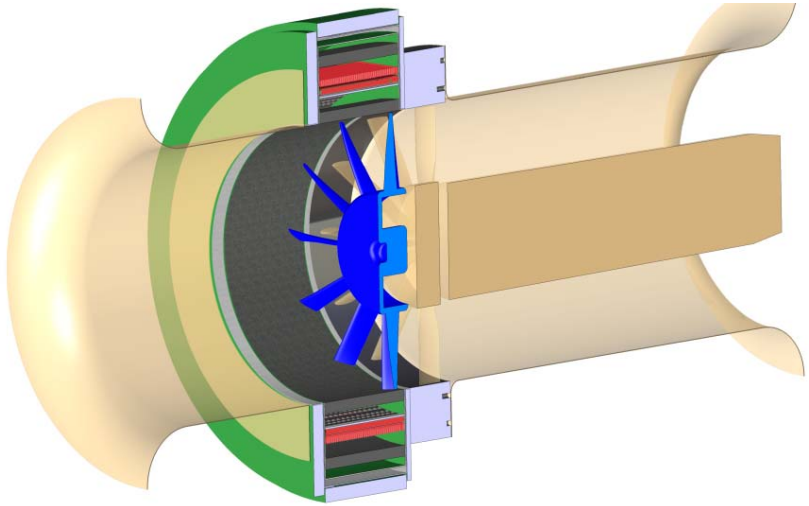


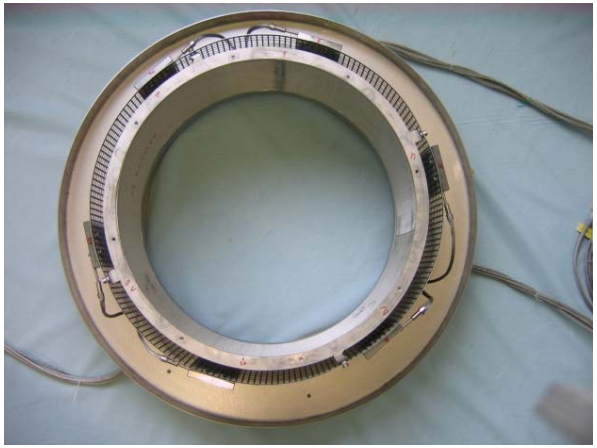


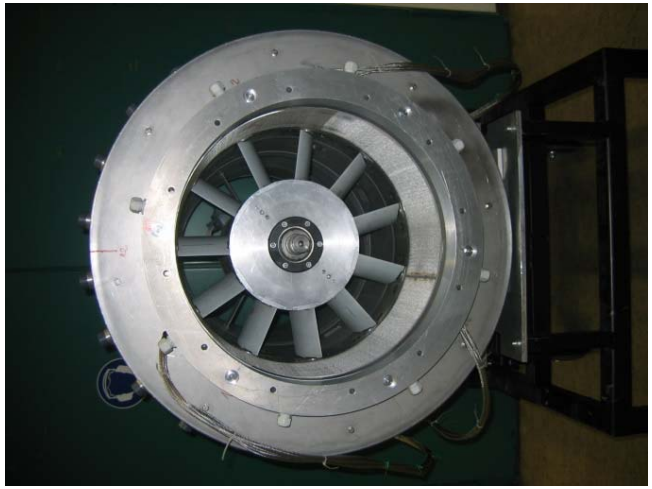
EADS - Overtip acoustic treatment

Tuneable Overtip Acoustic Treatment





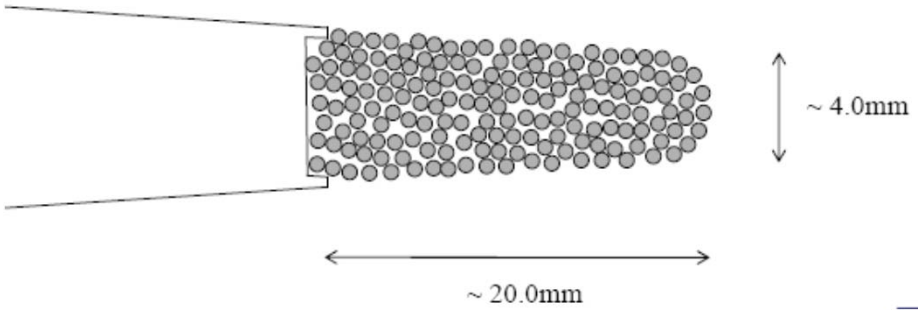




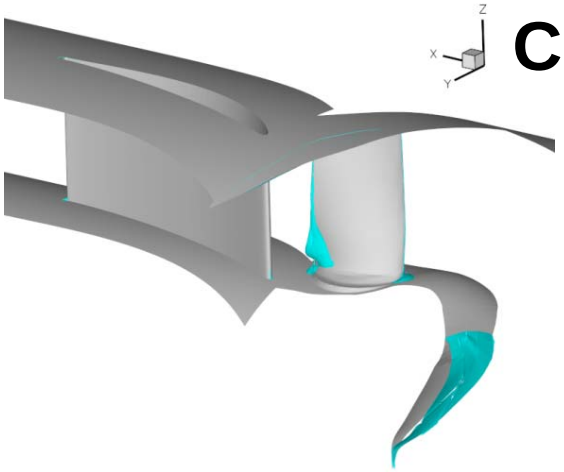
OGV treatments

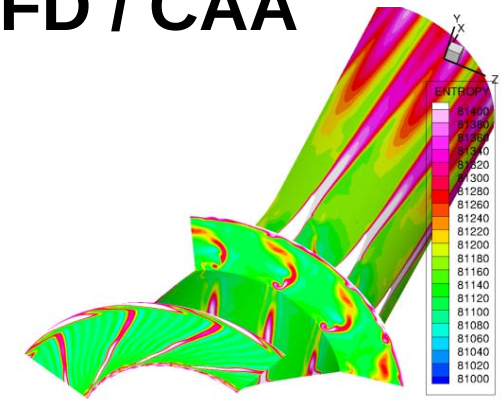
OGV Treatment

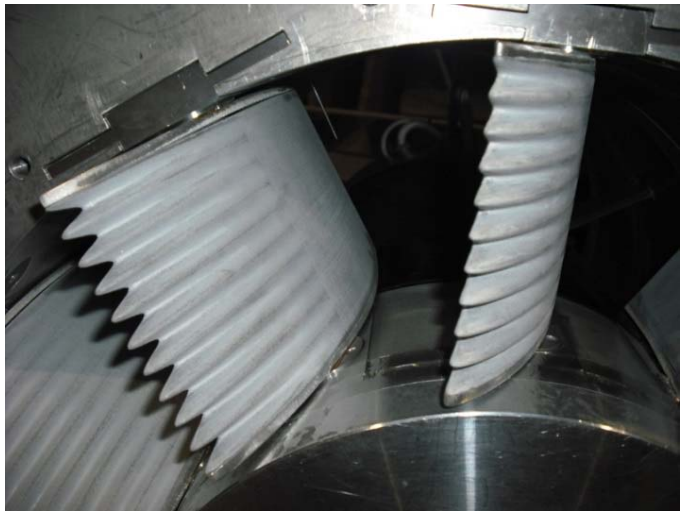
Porous Trailing Edge
Sinter metal spheres



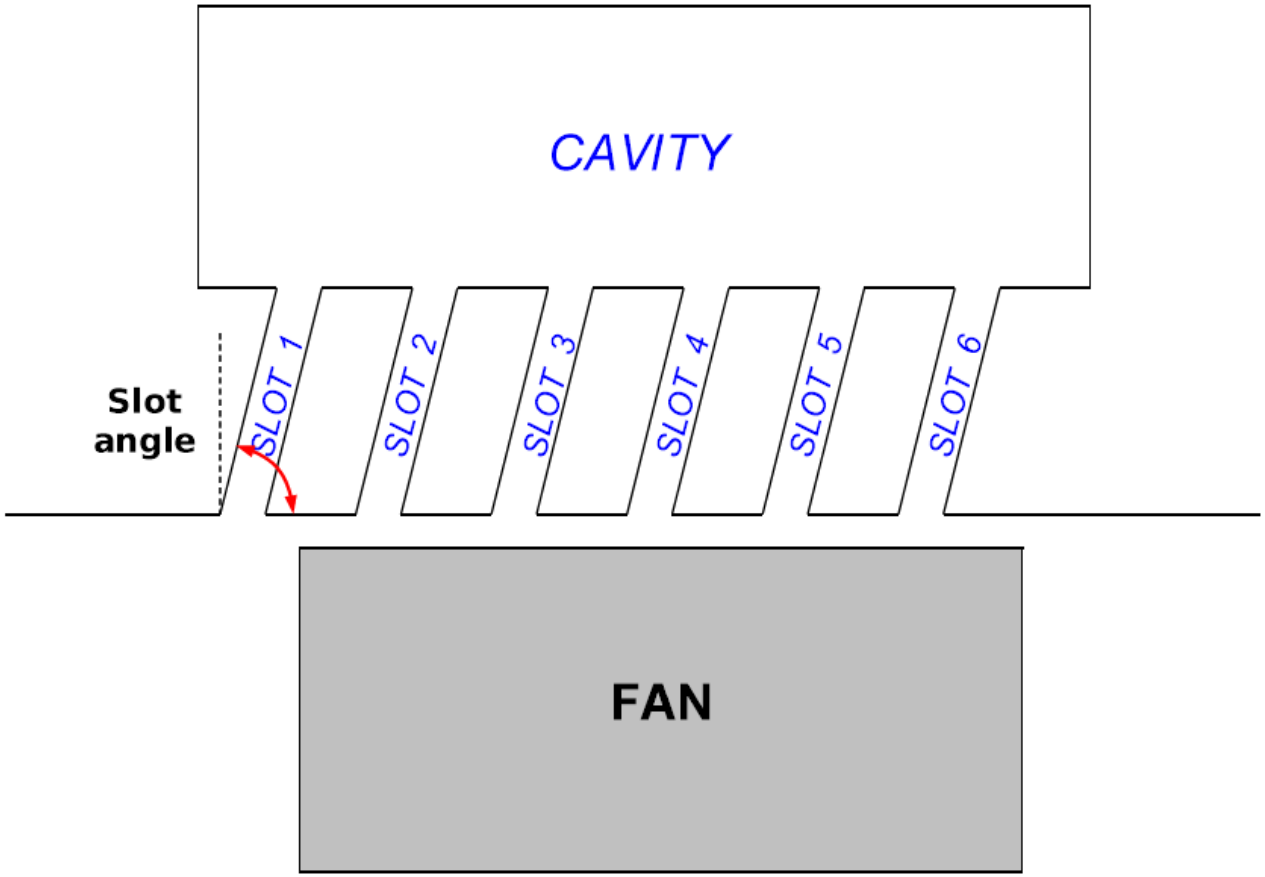
CFD / CAA







SN / FLU: Cavity Treatment



Work Package 4: Flow Control in a Fan Stage

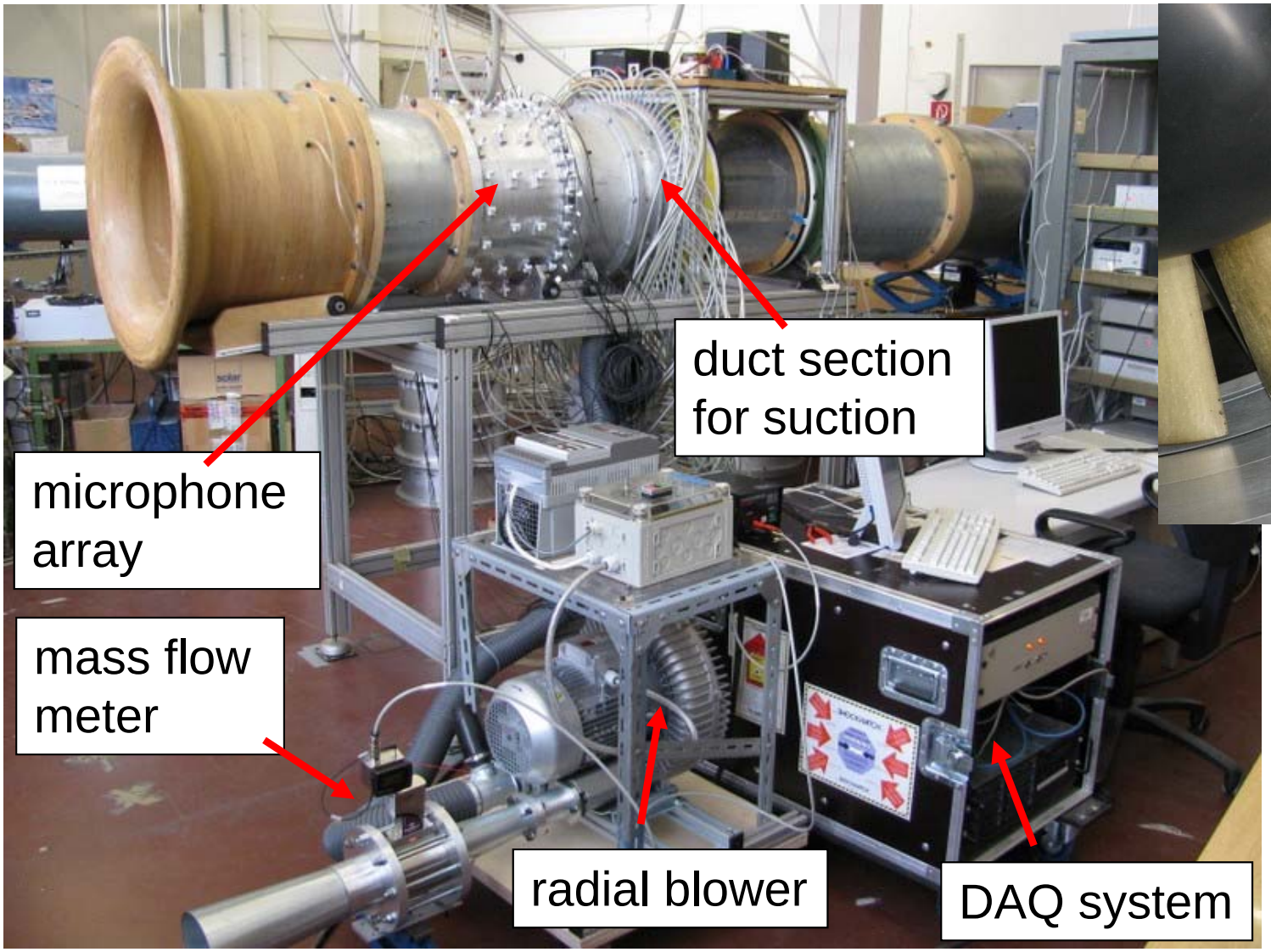
Objective

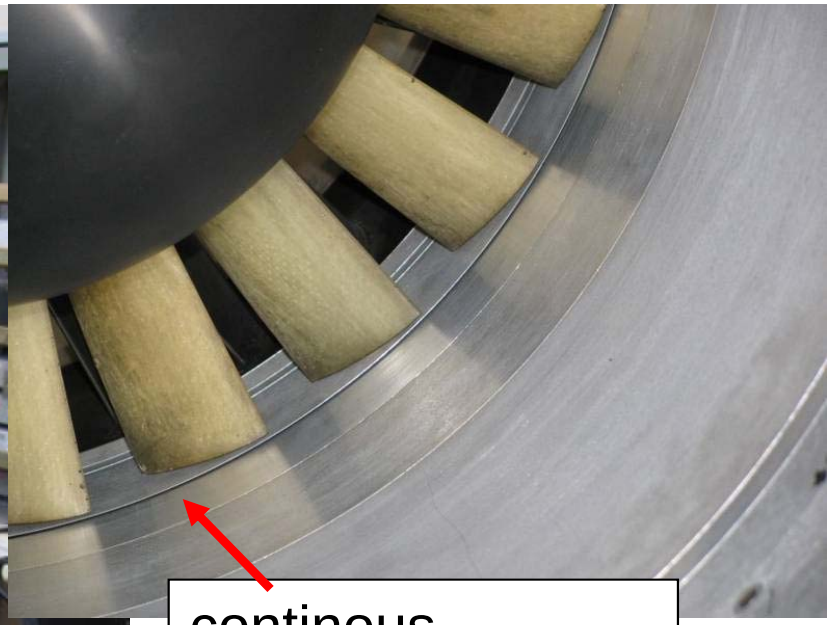
- To develop and assess several broadband noise reduction concepts by means of flow control in a fan-OGV stage.
- To understand the physical influence of the flow control concepts on broadband noise.

Workplan

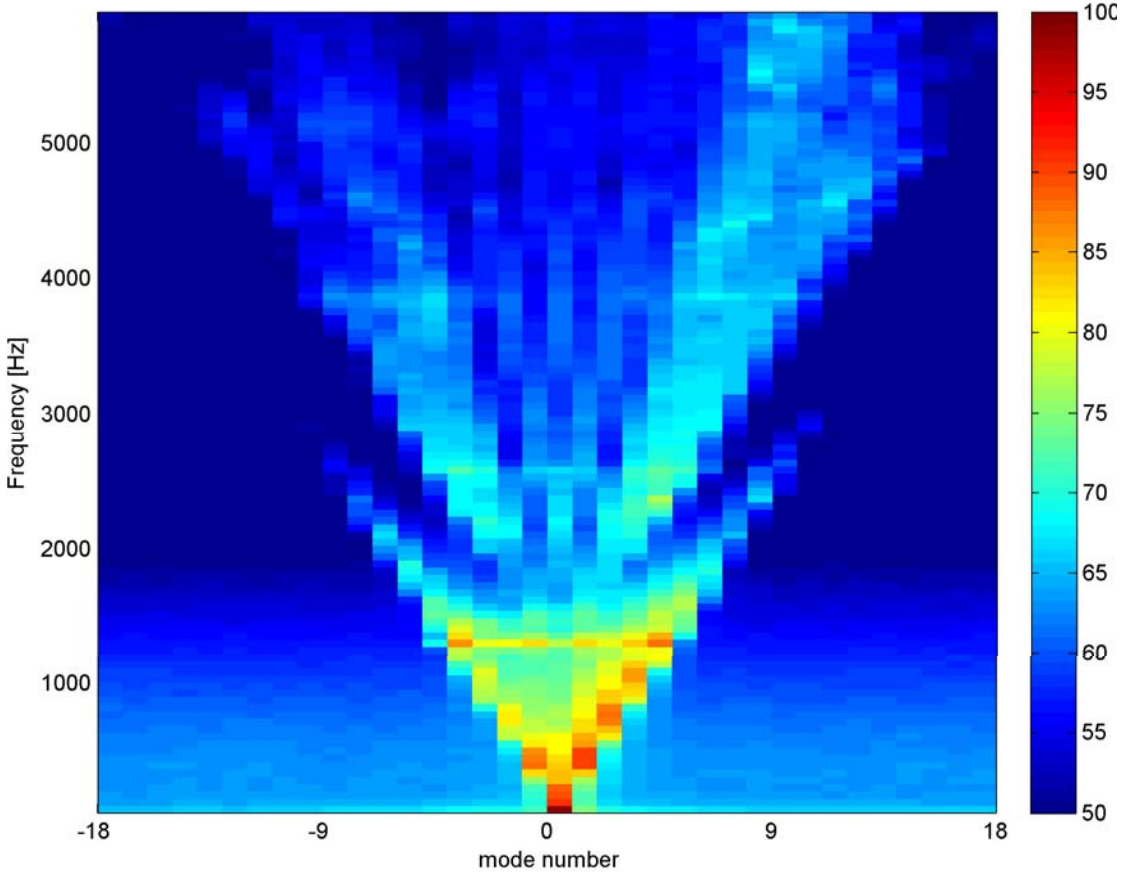
- Support the assessment of each concept with numerical and experimental investigations.
- Achieve broadband noise reductions in experiments performed under representative conditions of a fan-stage.

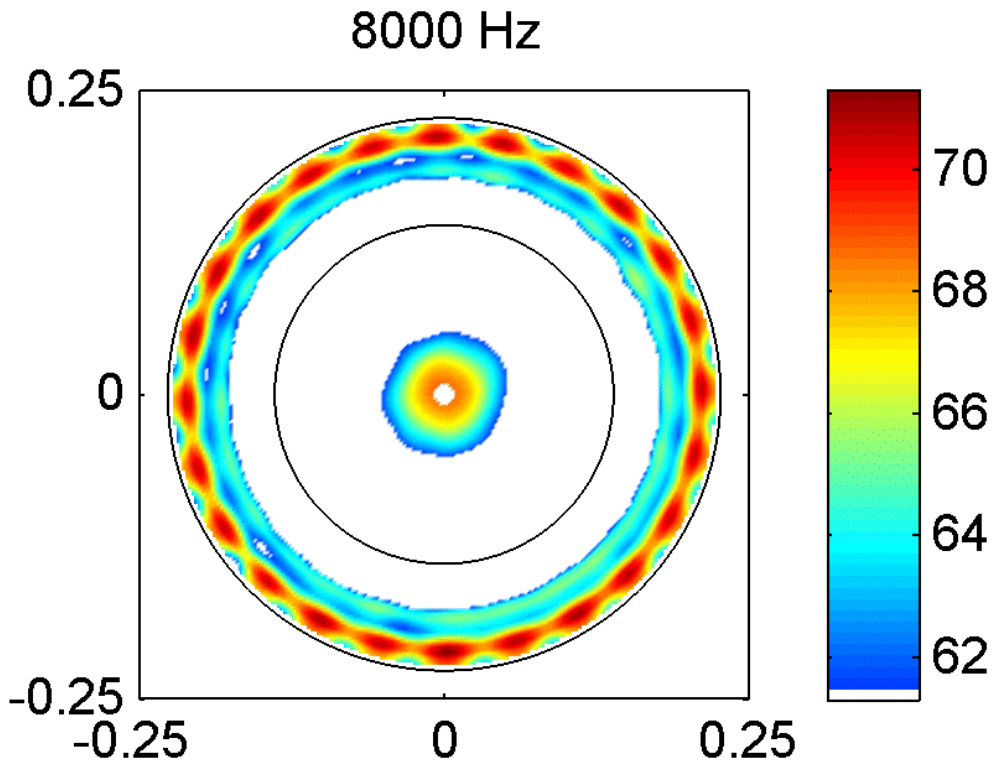
DLR laboratory scale fan rig



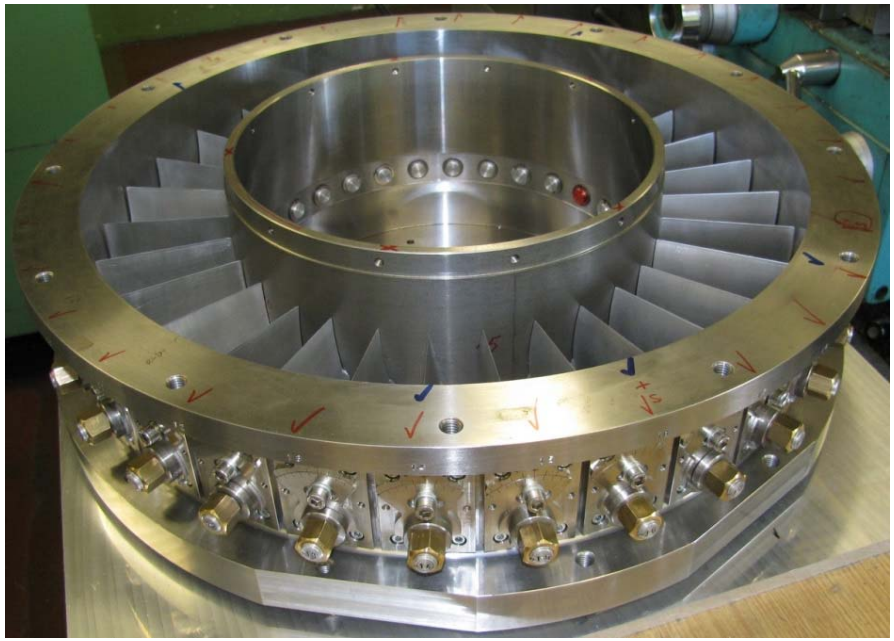


NLR: Source localization and azimuthal mode decomposition

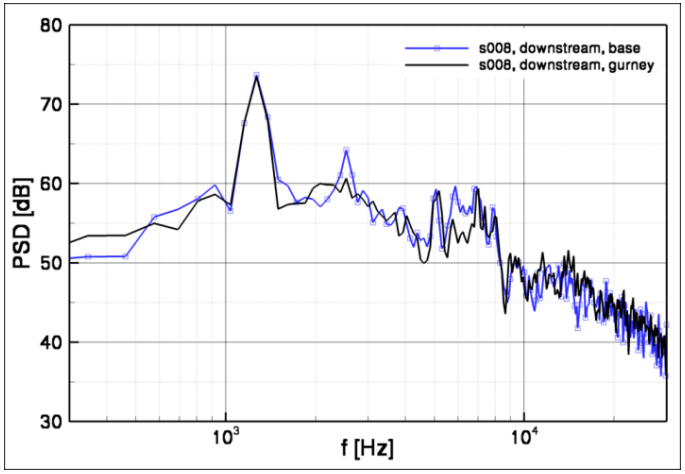




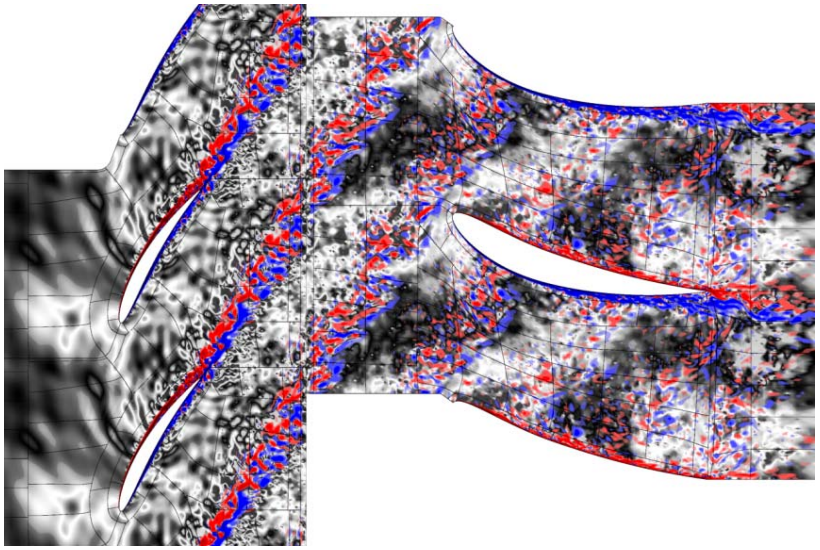
Adaptation of stator vane loading



DLR: Stator with variable vane stagger angle

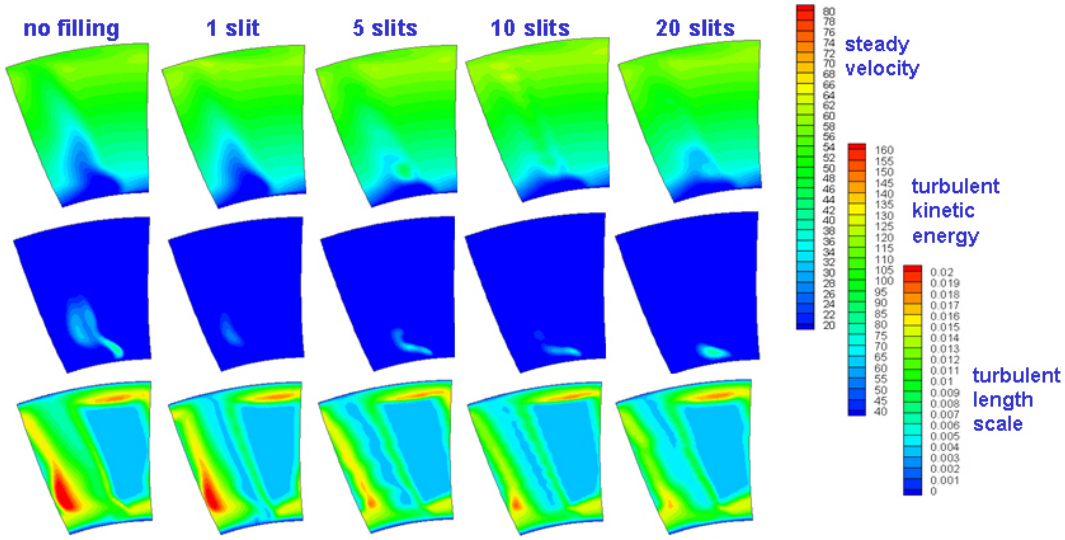


TUB: Noise impact of Gurney flaps

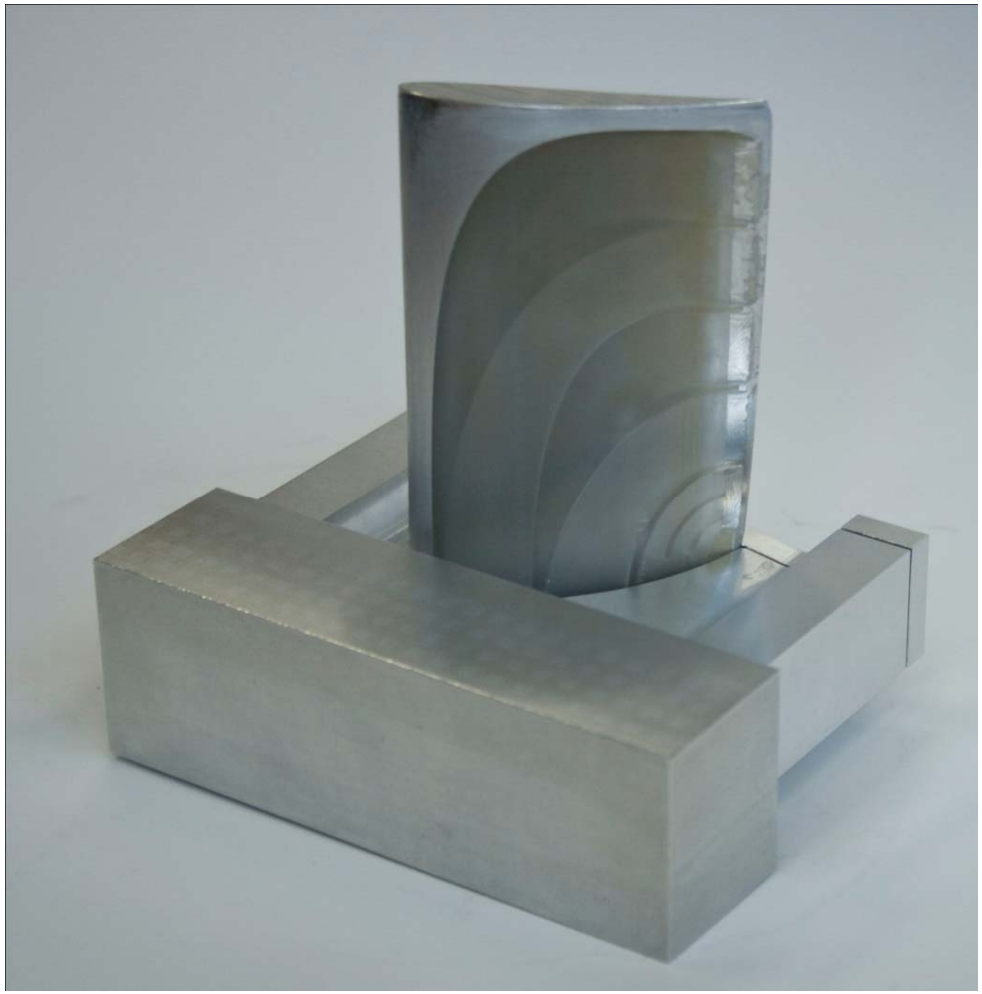


TUB: Instantaneous spanwise vorticity and pressure time derivative

Trailing edge blowing



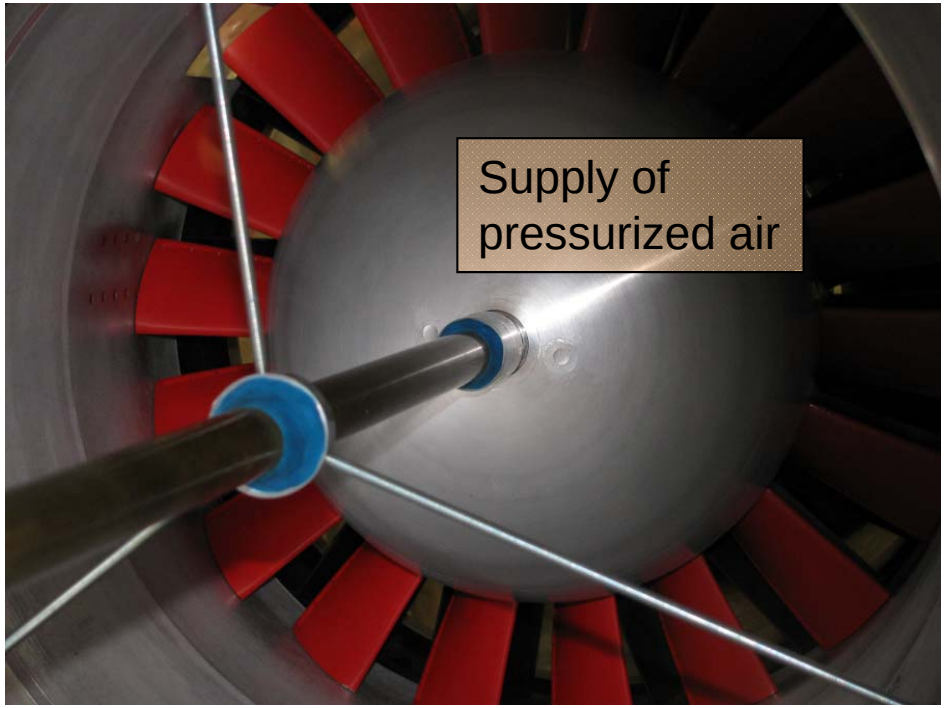
MTU: Simulation of wake filling (different slit counts)

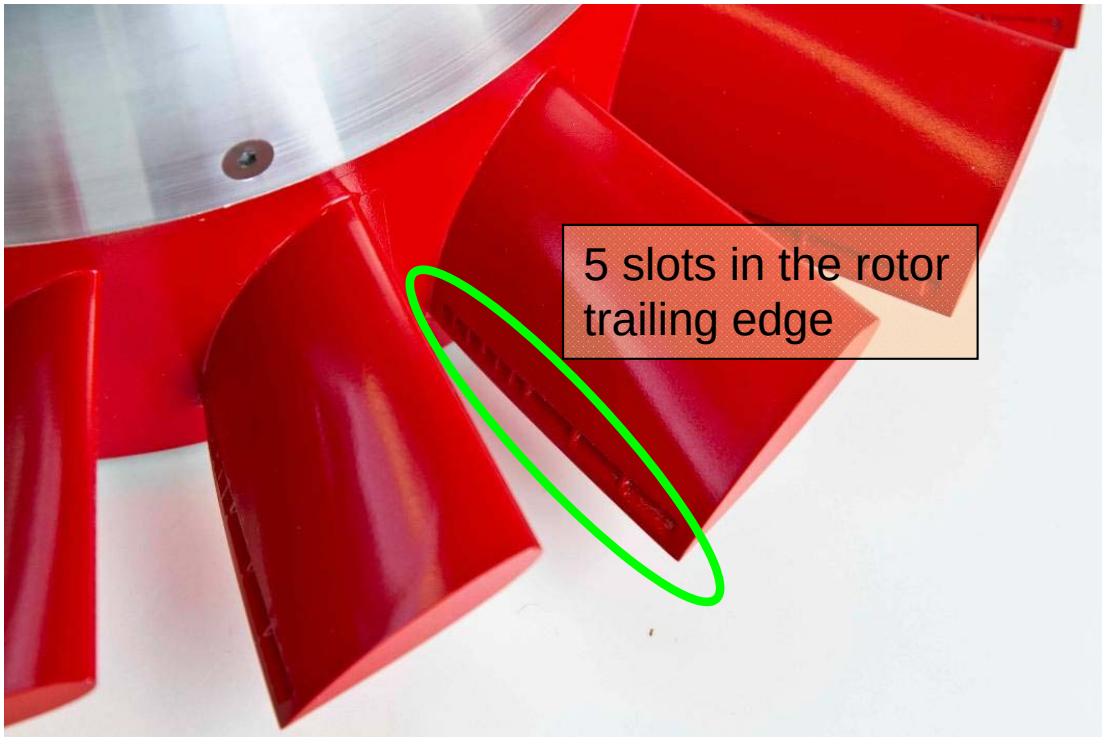


USI: Rotor blade with internal channels

Wake filling

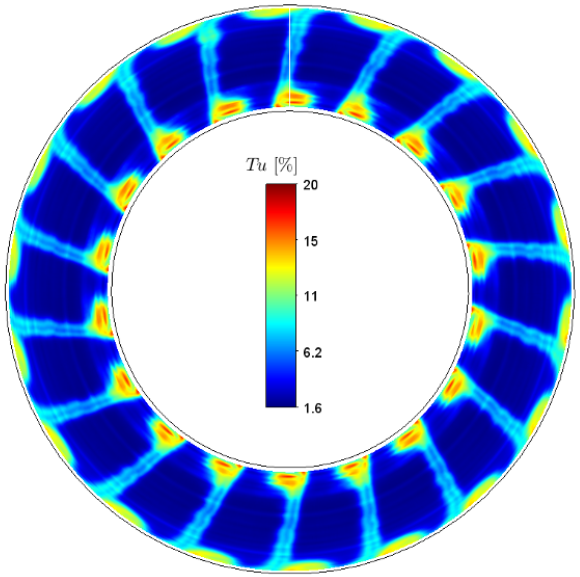
Experimental assessment of the wake filling

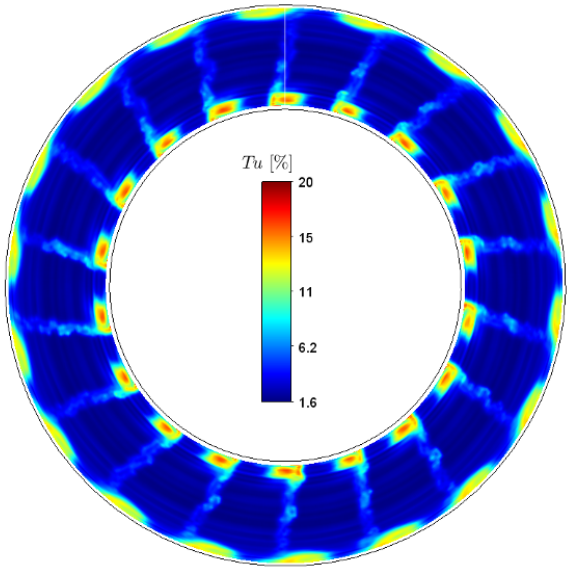




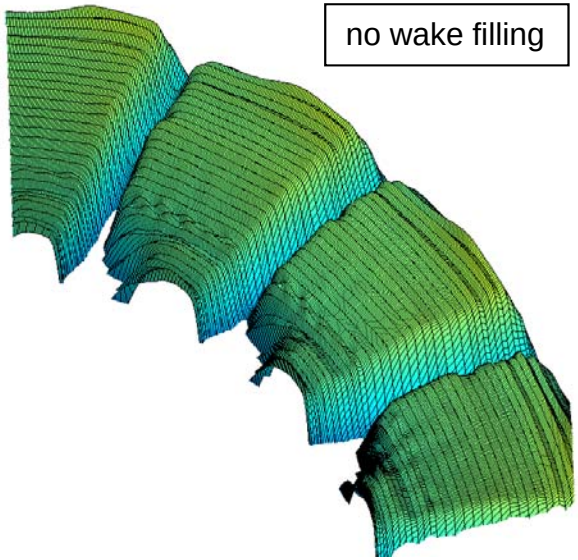
Wake filling

Turbulence intensity:

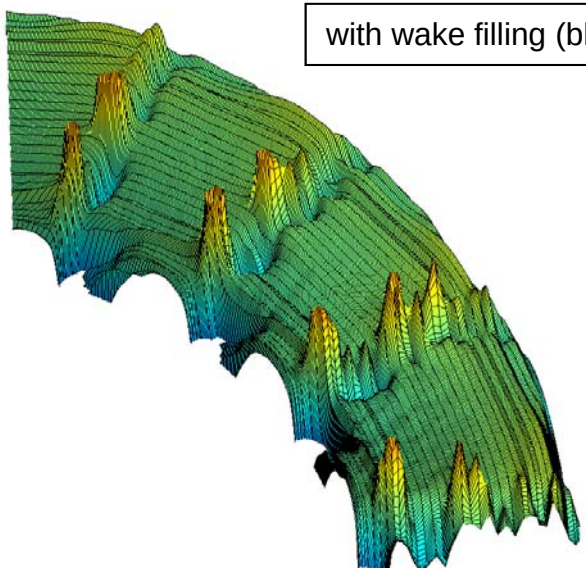




Axial Velocity:



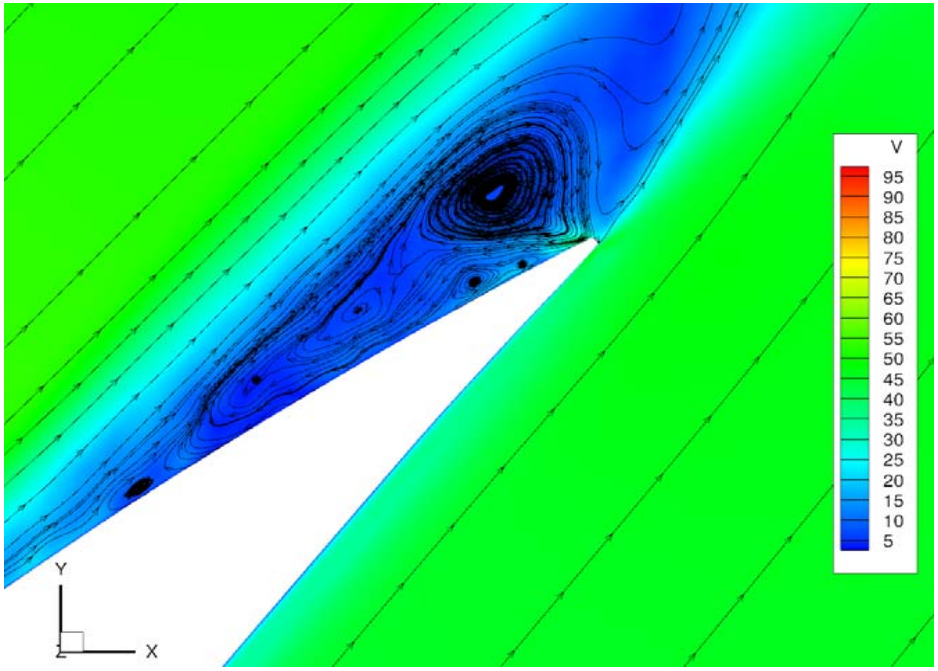
no wake filling

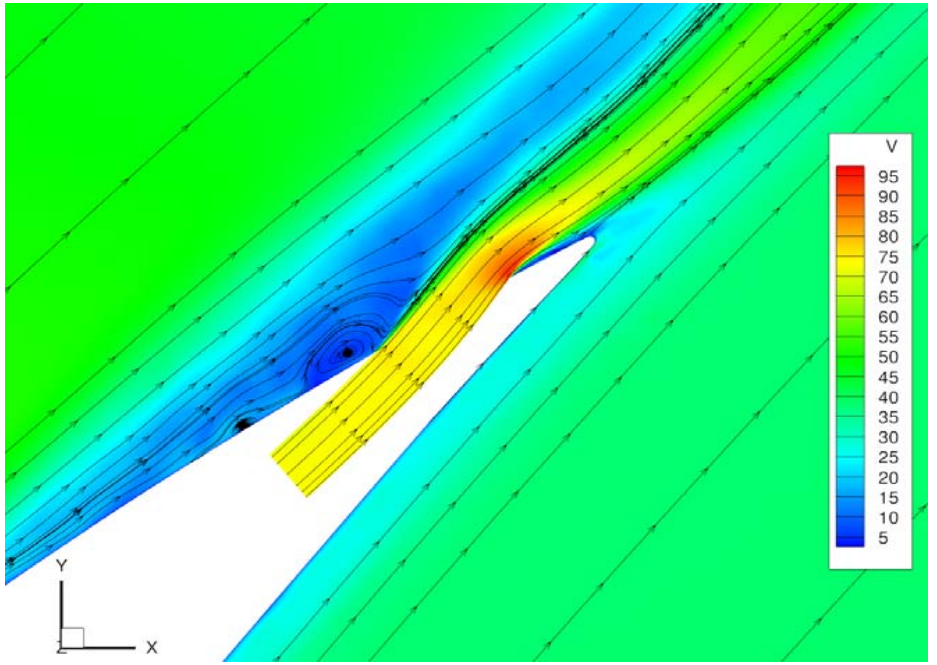


with wake filling (blowing 142 g/s)

ONERA: LES computation results

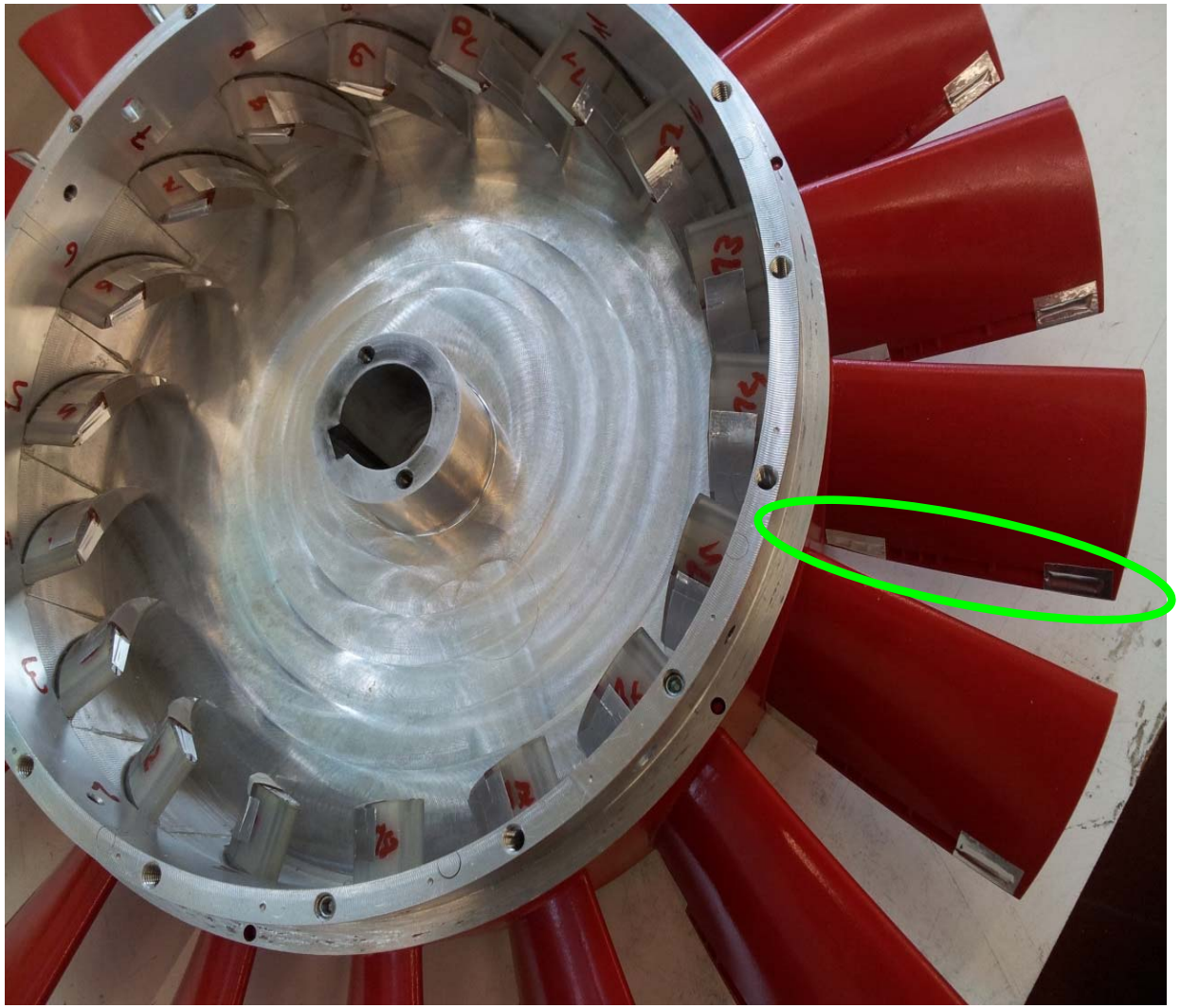
comparison of baseline and blowing case



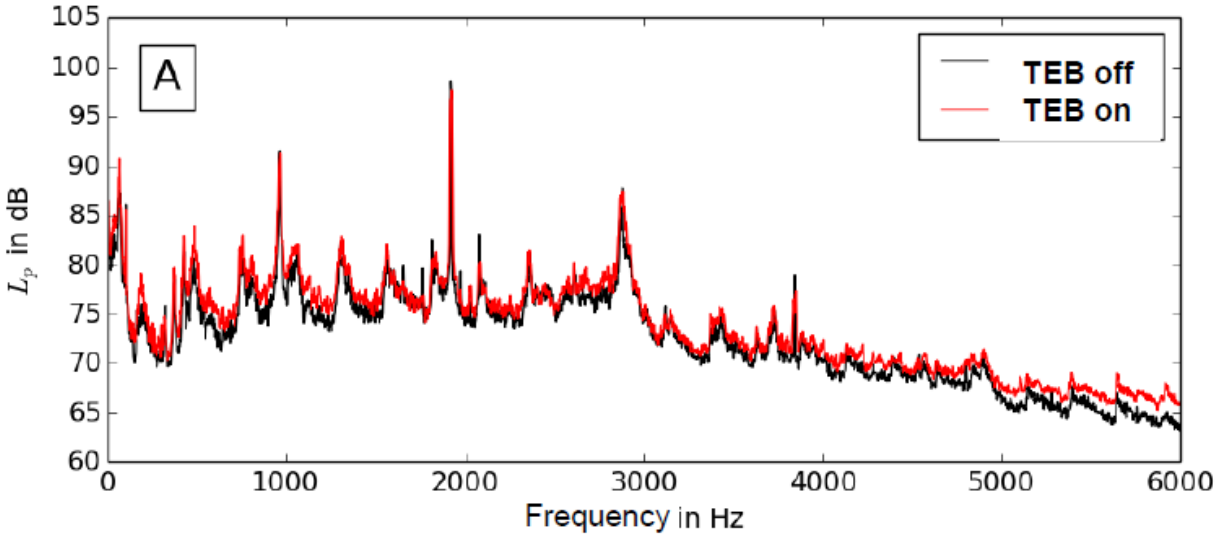


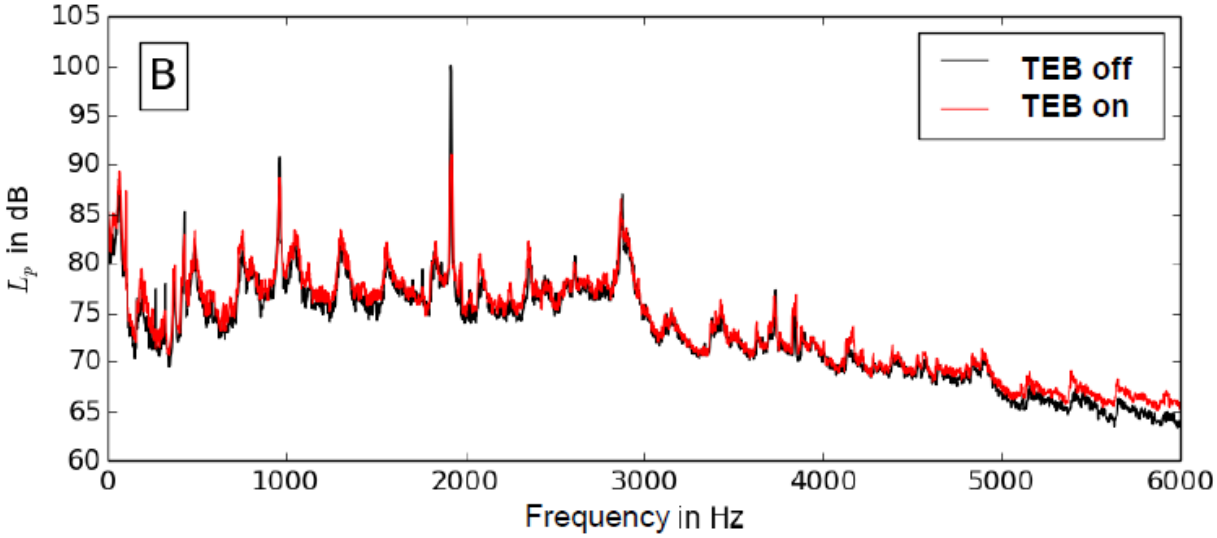
Average relative velocity amplitude and streamlines near the trailing edge of the rotor

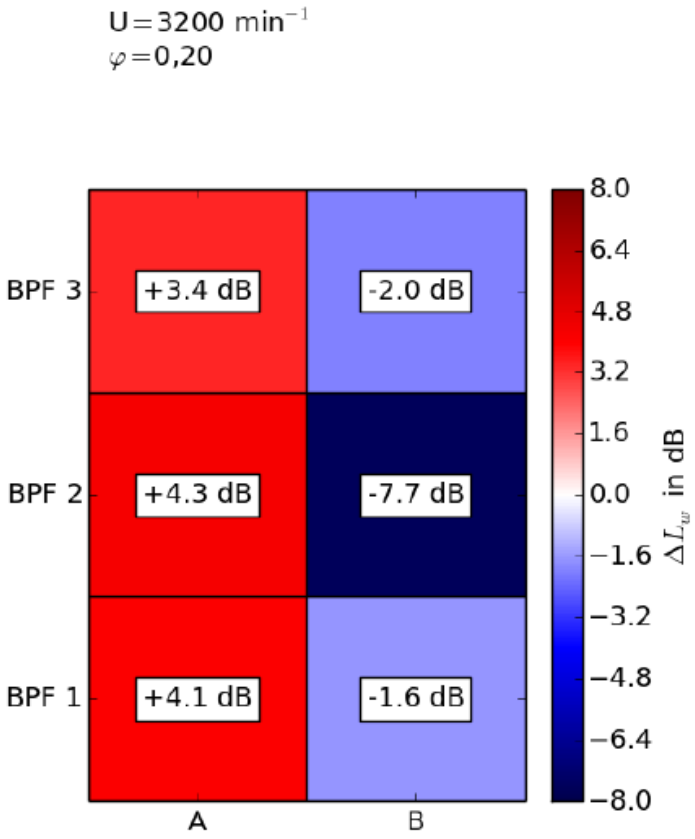
Wake filling (post FLOCON)



Wake filling (post FLOCON)







Technology Evaluation

- Virtual platforms used for the in-flight noise transposition:

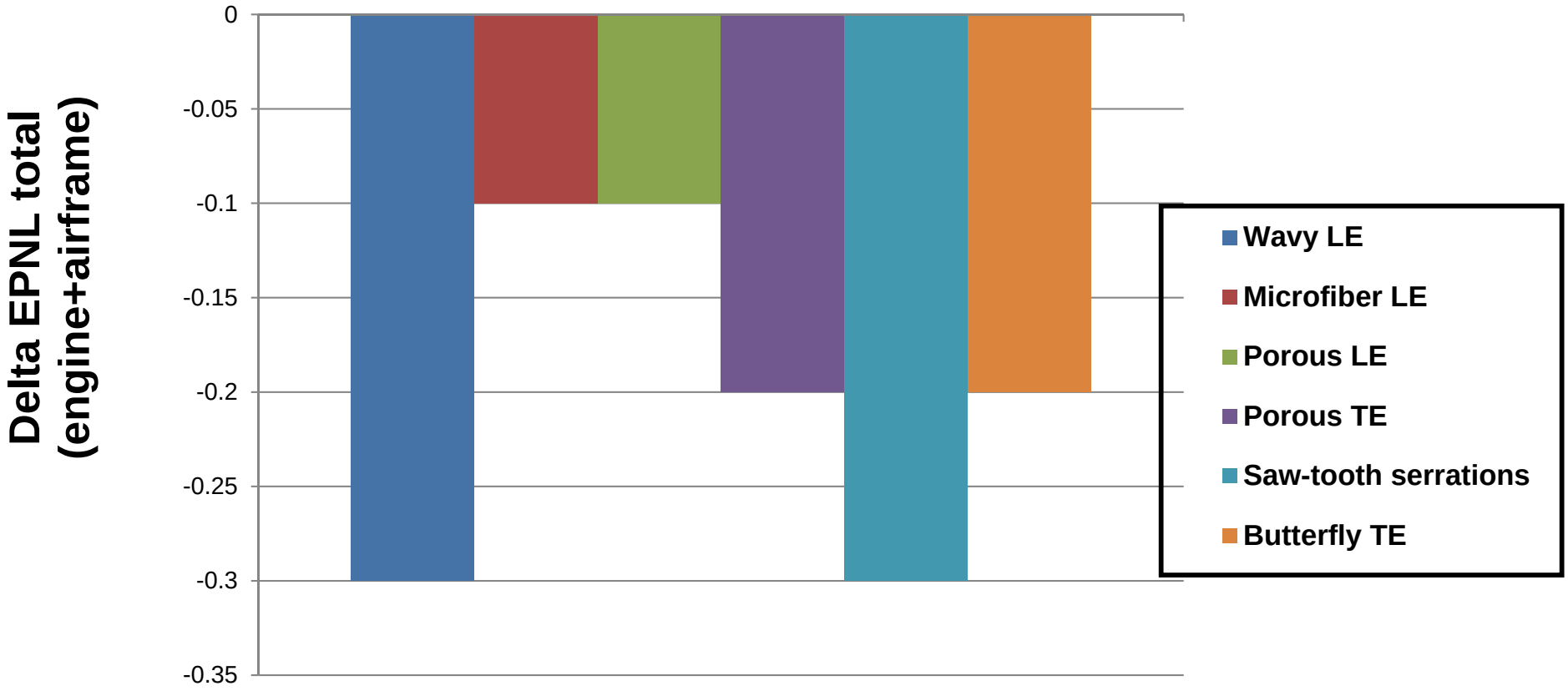
  - The FLOCON technology is assessed on the Short-Medium Range (SMR) and Long-Range (LR) OPENAIR virtual aircraft platforms

  - The SMR engine platform AP2-EP1b
    - is a turbofan BPR 9 engine
    - engine modelling provided by SN
    - The technology level of this engine is coherent with an initial EIS date in year 2012

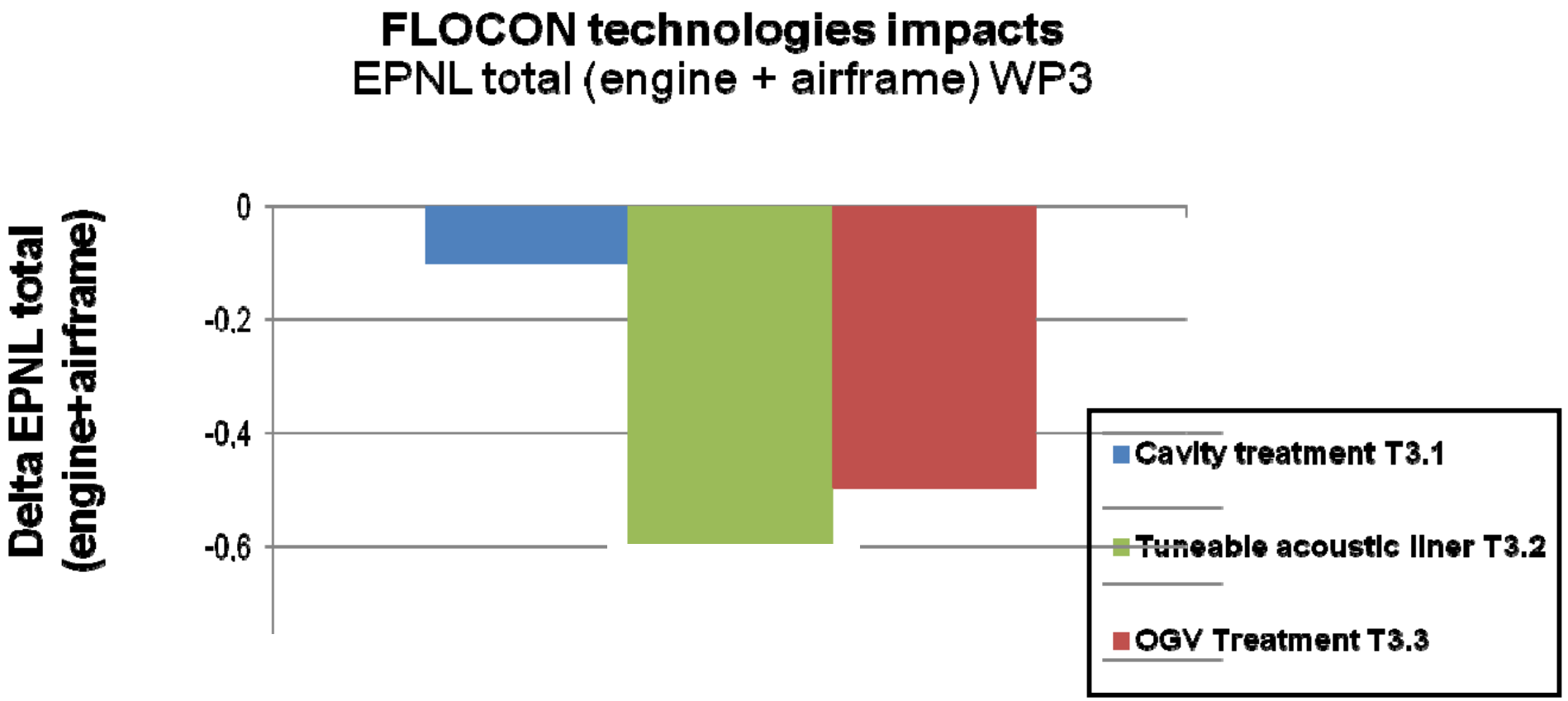
Technology Evaluation

FLOCON technologies impacts

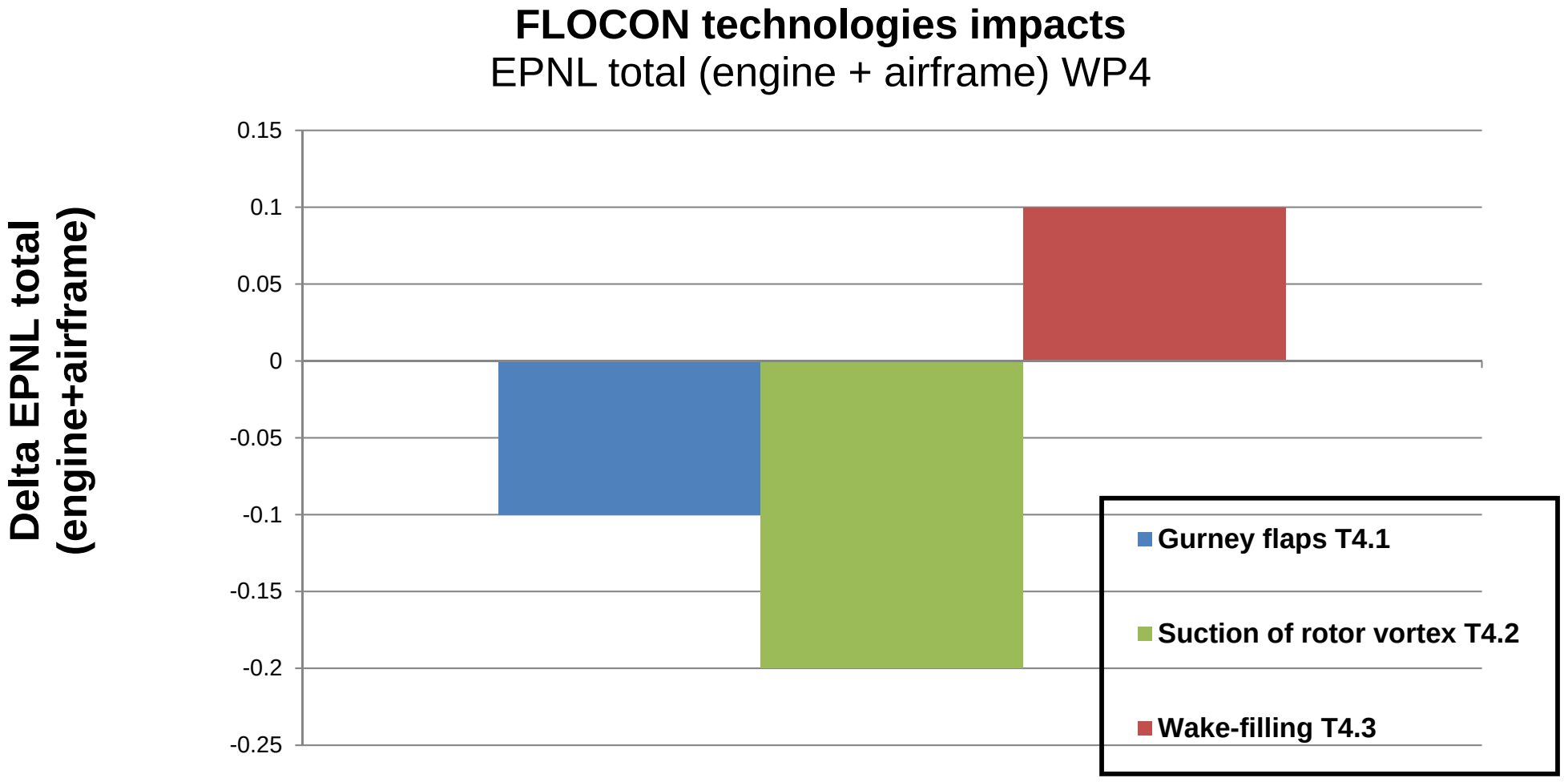
EPNL total (engine + airframe) WP2

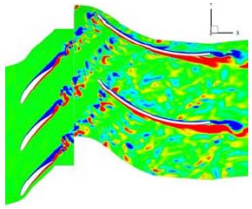


Technology Evaluation



Technology Evaluation





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Summary: Final results

- A wide range of concepts was considered and developed to Technology Readiness Level 4 (laboratory scale validation):
  - Rotor trailing edge blowing
  - Rotor tip vortex suction
  - Rotor overtip treatments
  - Rotor and Stator leading and trailing edge treatments
  - Partly lined stator vanes
- Experiments were performed on 4 rigs: two rotating rigs, supported by more detailed measurements on a single airfoil and on a cascade.
- Numerical methods were used to optimize the concepts for experimental validation and to extrapolate the results from laboratory scale to real engine application.
- The potential benefit of each concept was assessed, including any associated penalties (weight, complexity, aerodynamic performance).
- Recommendations were made as to which concepts could be integrated into new engine designs or will require further validation at industrial rig or full engine-scale.