PRELIMINARY INVESTIGATIONS OF JET INSTALLATION NOISE INFLUENCED BY A VORTEX GENERATING LINER AT THE NOZZLE INNER WALL

Henri Siller, Alessandro Bassetti and Wolfram Hage

Institute of Propulsion Technology – Engine Acoustics

THE DJINN - ENODISE CONFERENCE

Aeroacoustic Installation Effects
In Conventional and New Propulsion Systems
22-24 November 2023
Berlin Germany

DLR

Vortex generating liner in nozzle wall

DJINN WP1 context:

- design and test of novel noise reduction techniques for jet noise and jet installation noise
- idea: generate streamline oriented vorticity with a perforated liner
  - VoGeL concept by DLR

Experimental Plan:

- develop and test noise vortex generating liners for nozzles at small scale
- select most promising designs
- hope for selection for tests at increased scale models the AWB aeroacoustic wind tunnel at DLR Braunschweig (spoiler: these devices did not make it)

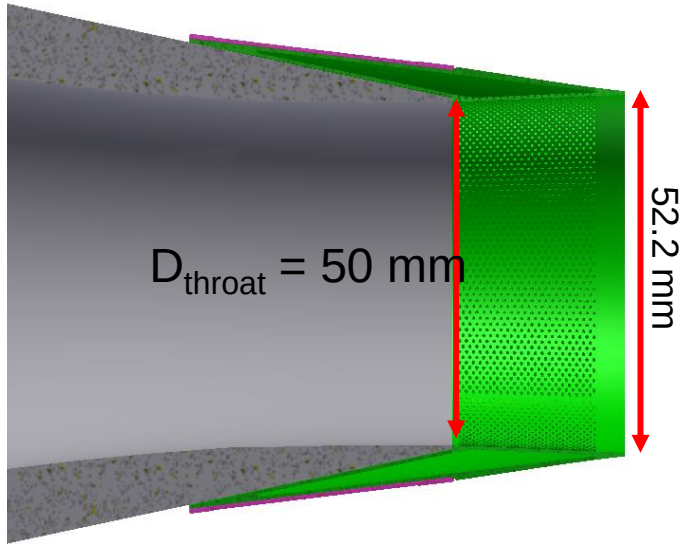
Nozzle prototypes

- Baseline convergent nozzle
  - diameter D = 50 mm
  - contoured inner wall and conical outer wall
  - manufactured by stereolithography

baseline convergent nozzle

Nozzle prototypes

- Baseline convergent nozzle
- convergent-divergent nozzle - D increases by 4 %
  NRTClean nozzle

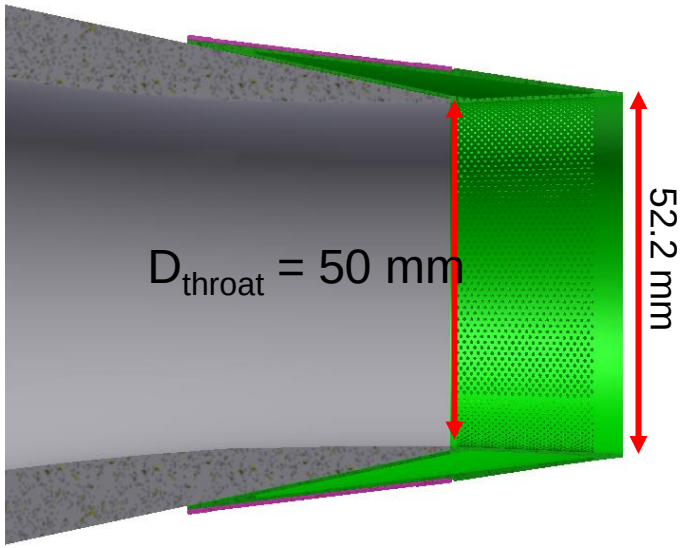


convergent-divergent inner contour

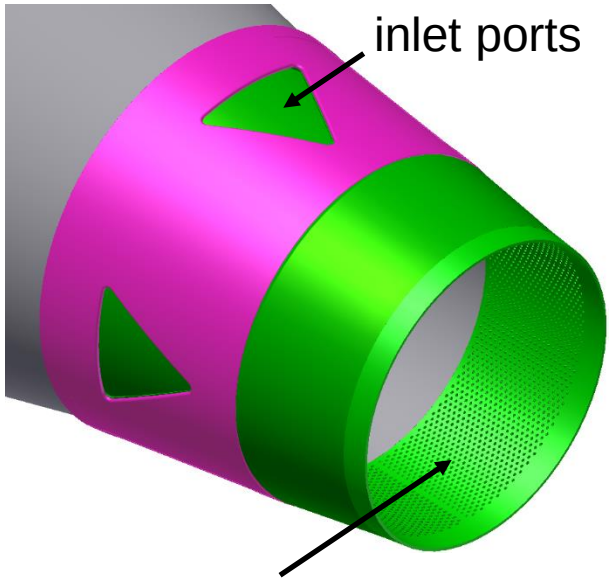
baseline convergent nozzle

Nozzle prototypes

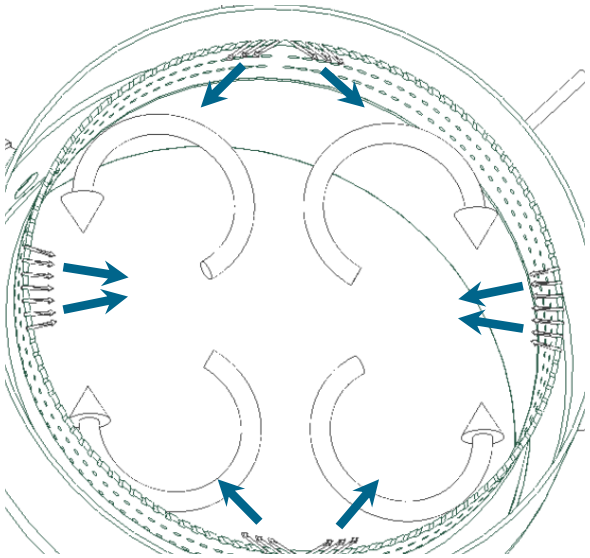
- Baseline convergent nozzle
- convergent-divergent nozzle – D increases by 4 %
- convergent-divergent nozzle with vortex generating liner (VoGeL / *NRTOpen)*
  - idea: generate streamwise vorticity in the jet, using a bias flow with variable angle to the wall normal



convergent-divergent inner contour



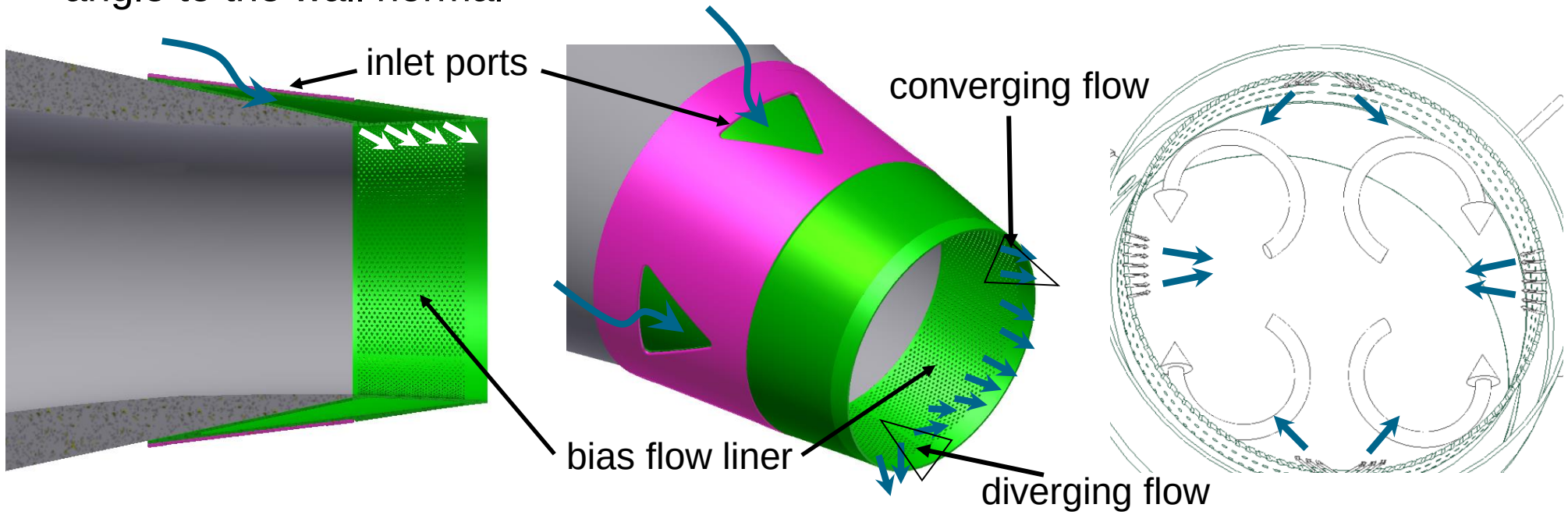
bias flow liner



bias flow pattern & vortical field sketch

Nozzle prototypes

- Baseline convergent nozzle
- convergent-divergent nozzle – D increases by 4 %
- convergent-divergent nozzle with vortex generating liner (VoGeL)
  - idea: generate streamwise vorticity in the jet, using a bias flow with variable angle to the wall normal



convergent-divergent inner contour

bias flow pattern & vortical field sketch

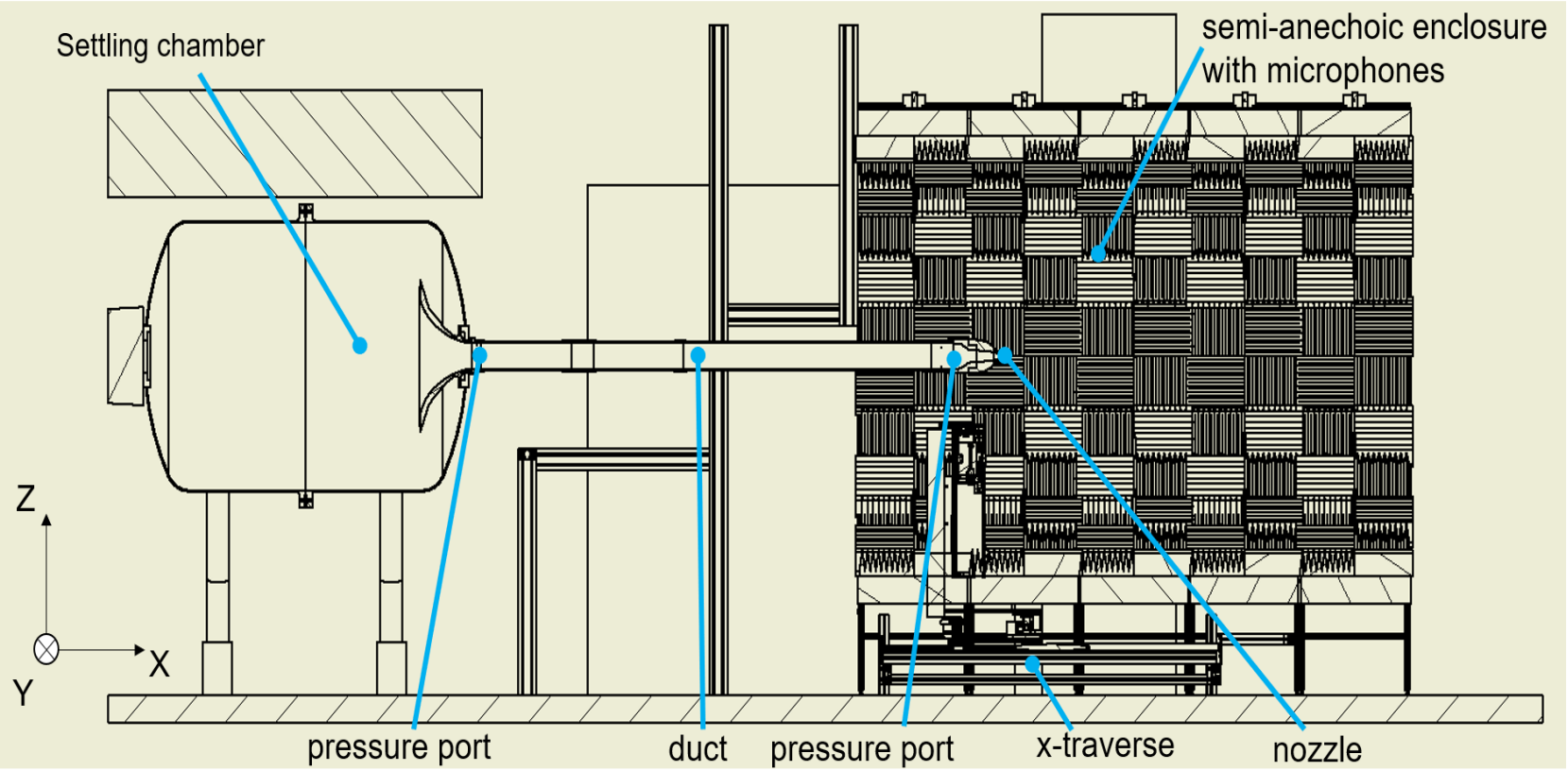
The JExTRA aeroacoustic facility for jet-noise investigations at small scale

Motivation for JExTRA:

- need for a small facility
- easy access
- high availability
- great flexibility
- low cost
- equipment tests
- prototype tests

Features

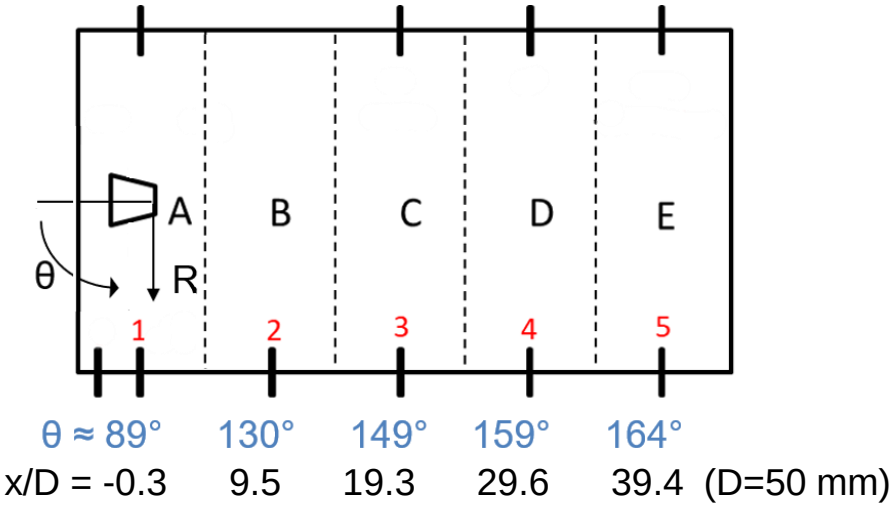
- pressure sensors
- temperature sensors
- motor speed control
- automatic monitoring of Mach number
- traversing system

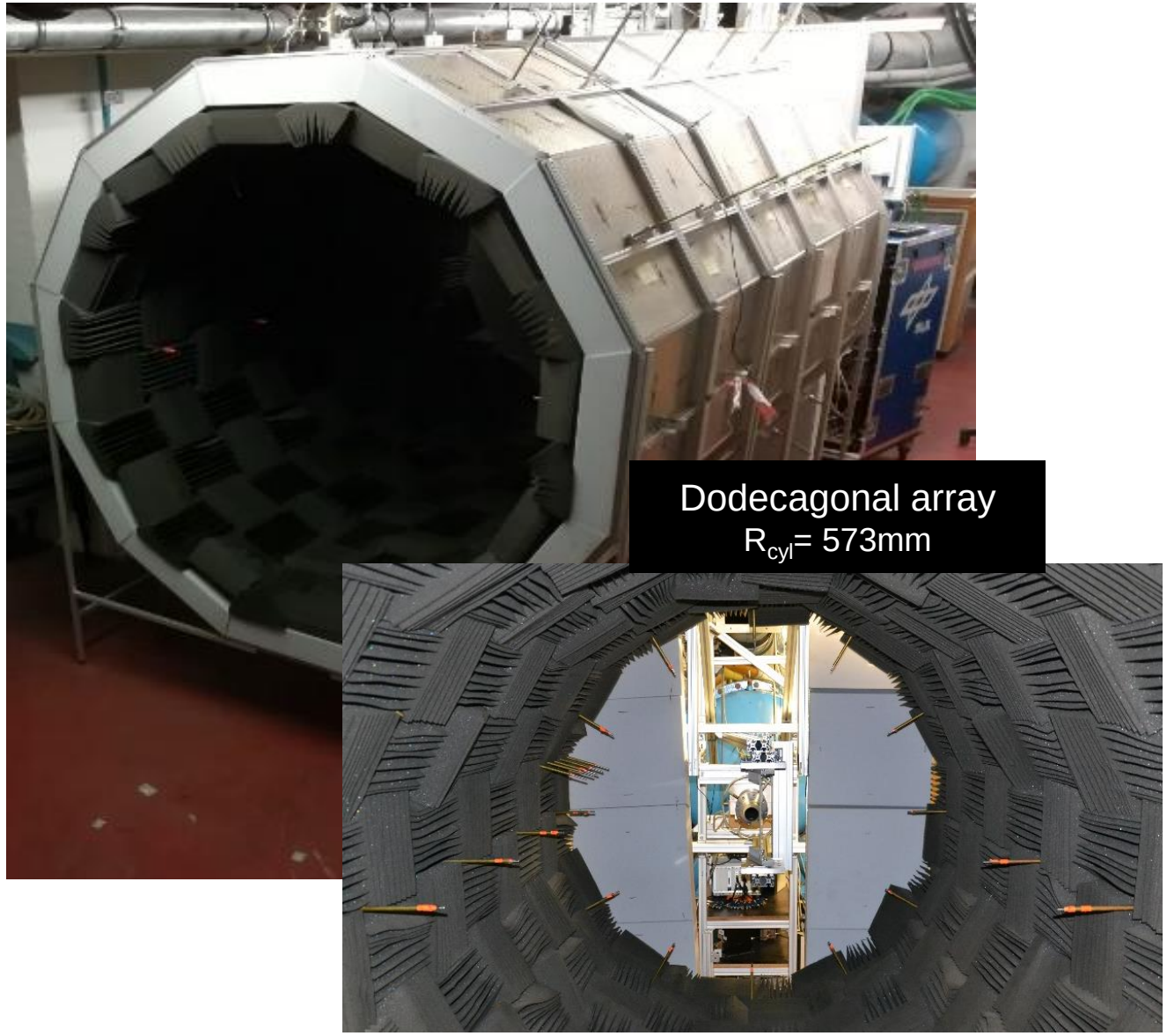


Set-up for acoustic measurements in JExTRA

Low-reflection barrel

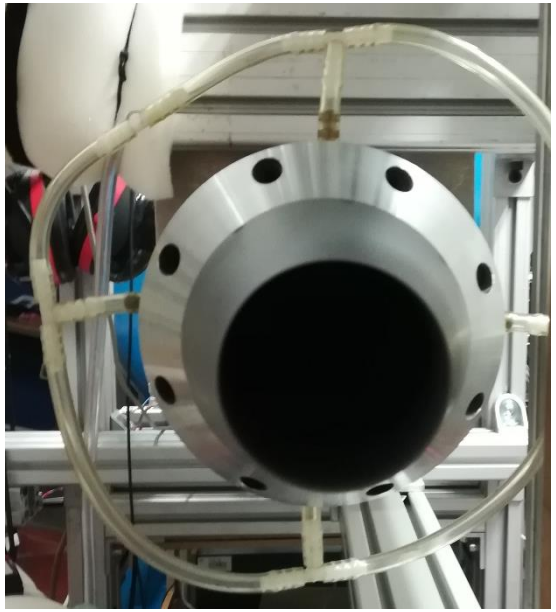
- foam lining on perforated aluminium plates
  - lower frequency limit ~ 500 Hz
- mounting points for microphone arrays
  - azimuthal (rings with12-microphones)
  - linear array in segments A and B





Aerodynamic measurements – isolated baseline nozzle

- Nozzle model
  - diameter D = 50 mm
  - manufactured using stereolithography

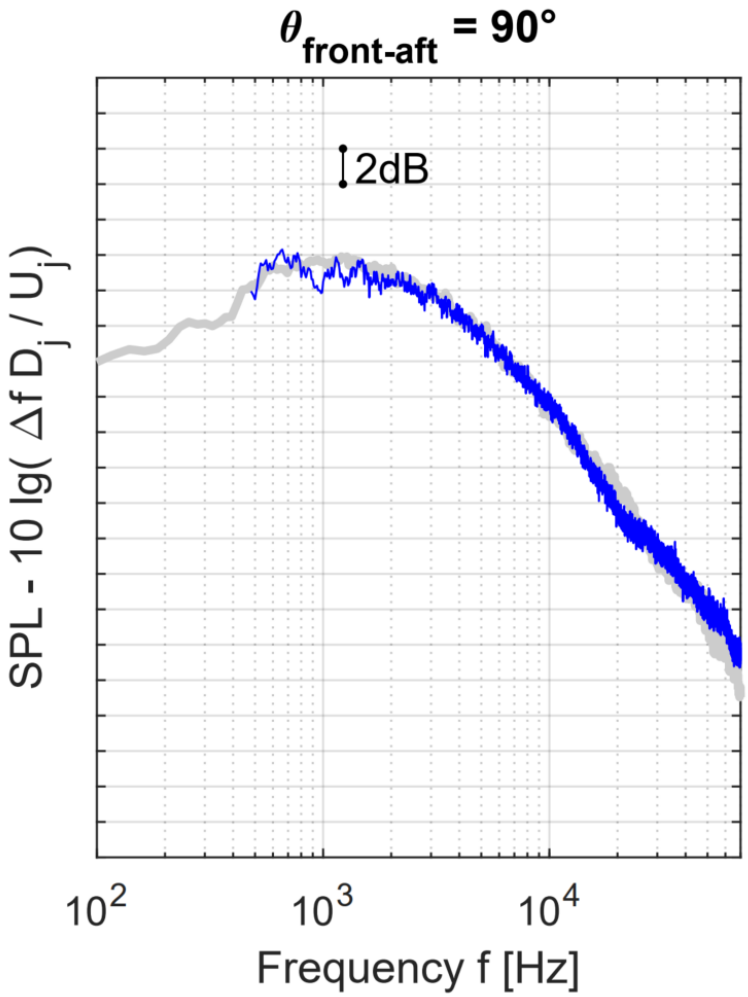


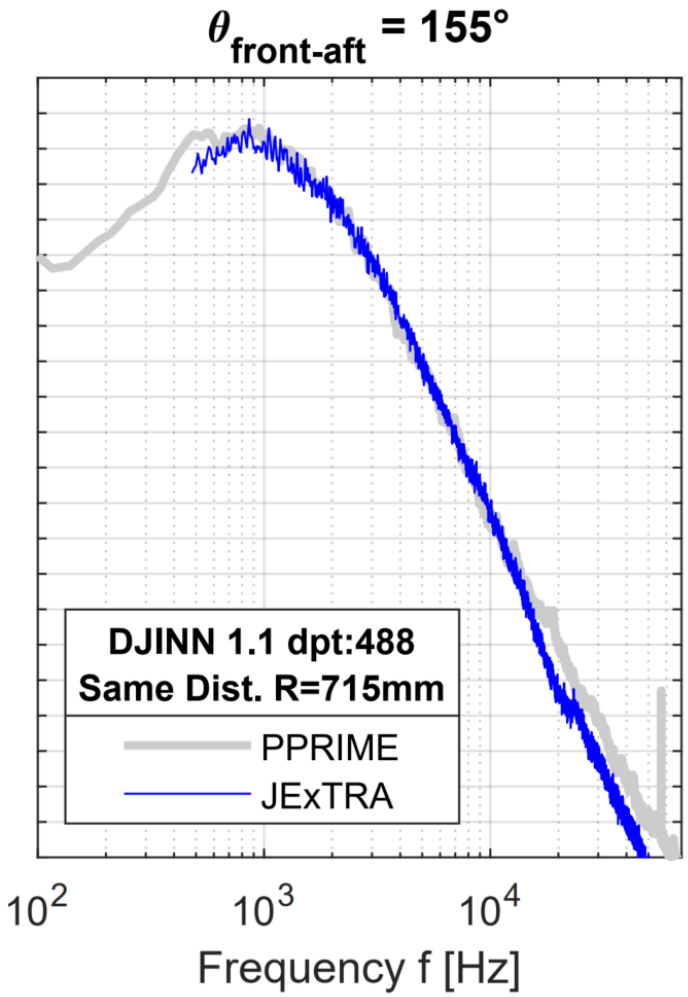
Cross-check of JExTRA with PPRIME acoustic results

Comparison of frequency spectra

with data from PPRIME (Poitiers)

- isolated nozzle,
  D= 50 mm, Ma = 0.6
- angular positions and distance to the jet matched
- close agreement
  500 Hz to 10 kHz
- below 500 Hz: room-acoustics
- good agreement within 2 dB in the relevant frequency range

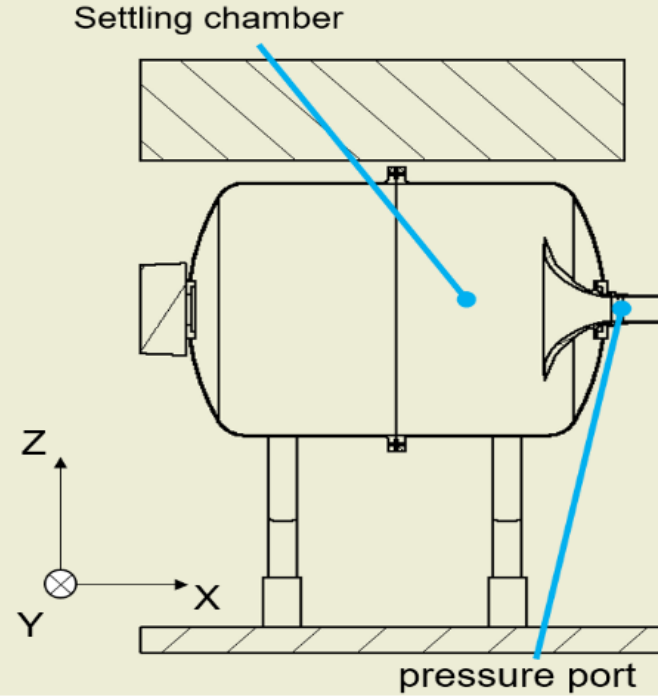


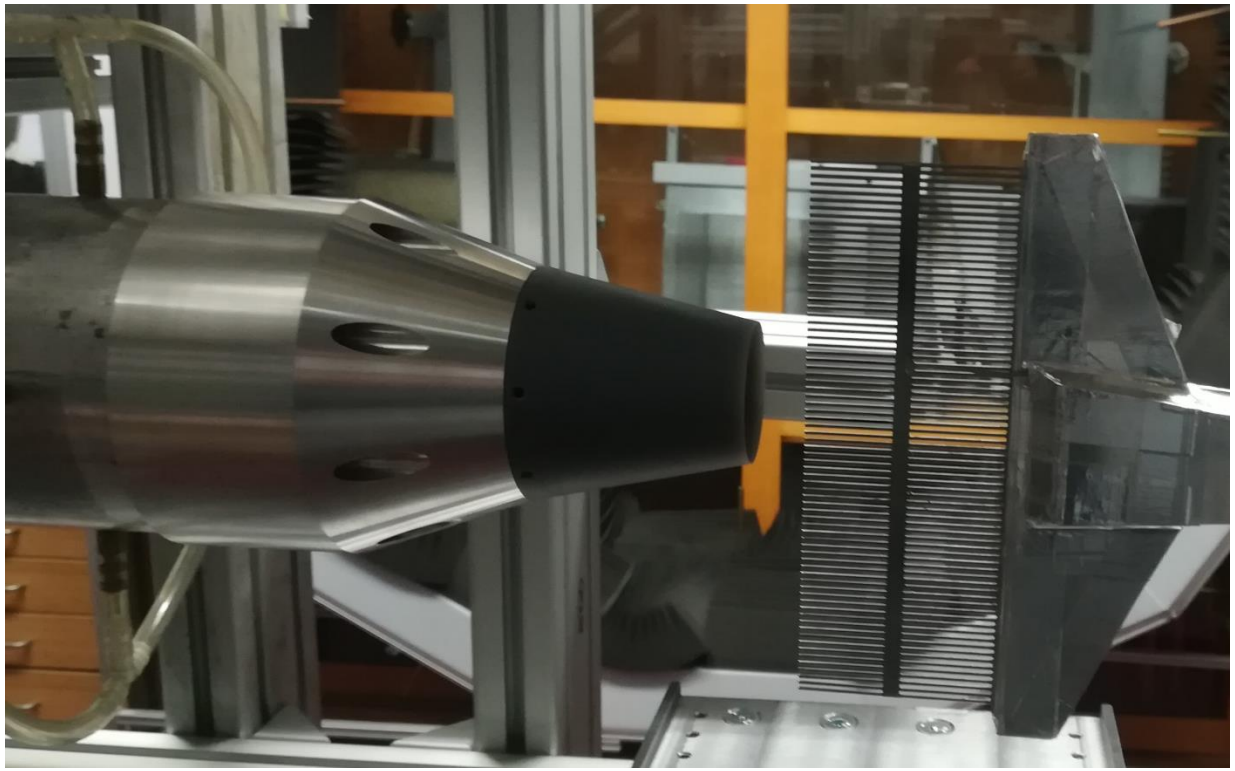


Aerodynamic measurements

Flow field downstream the nozzle scanned with a Pitot rake

- 48 tubes spaced by 3 mm ($\Delta z/D = 0.06$ for the D = 50 mm nozzle)

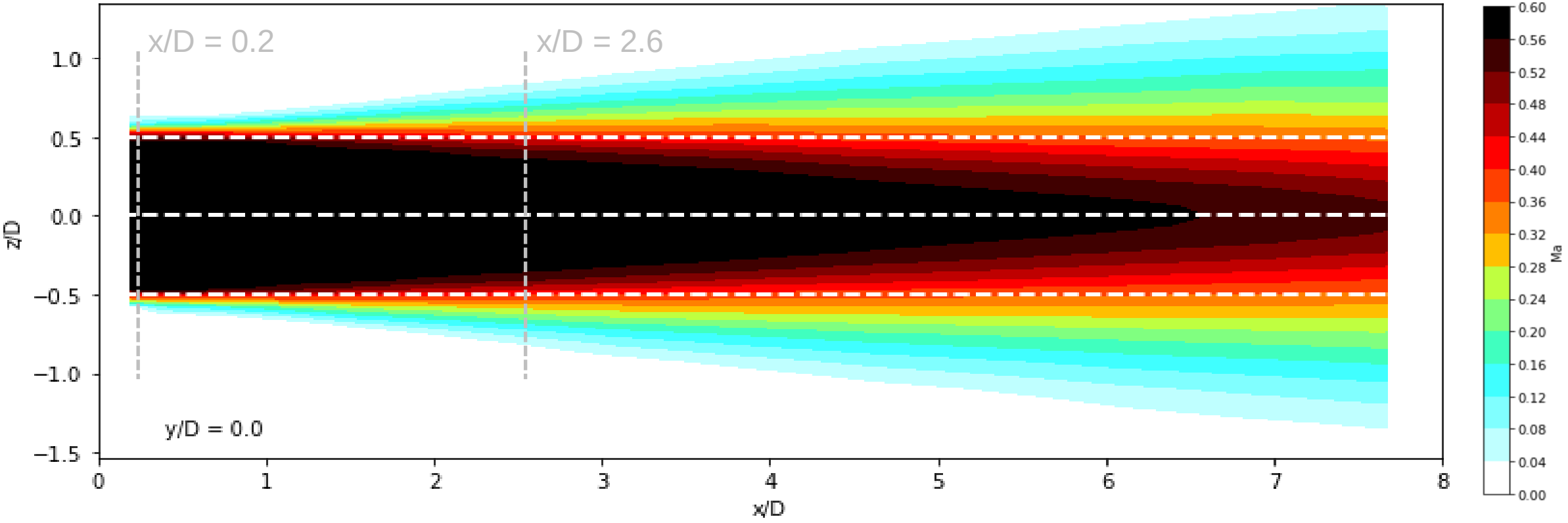




DJINN Measurements of the baseline configuration

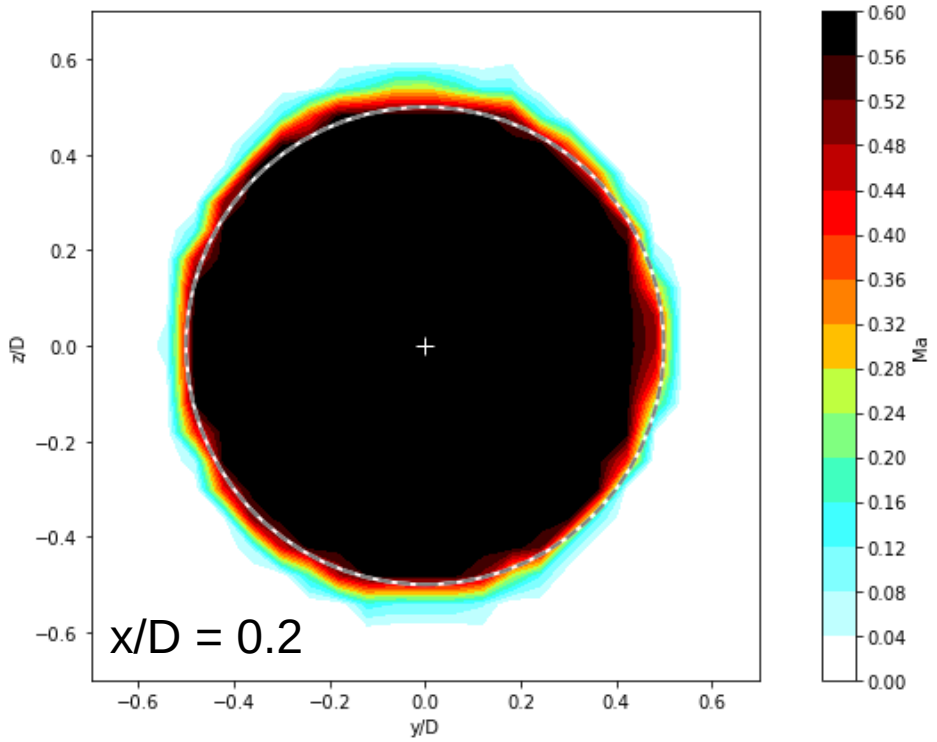
Aerodynamic measurements – isolated baseline nozzle

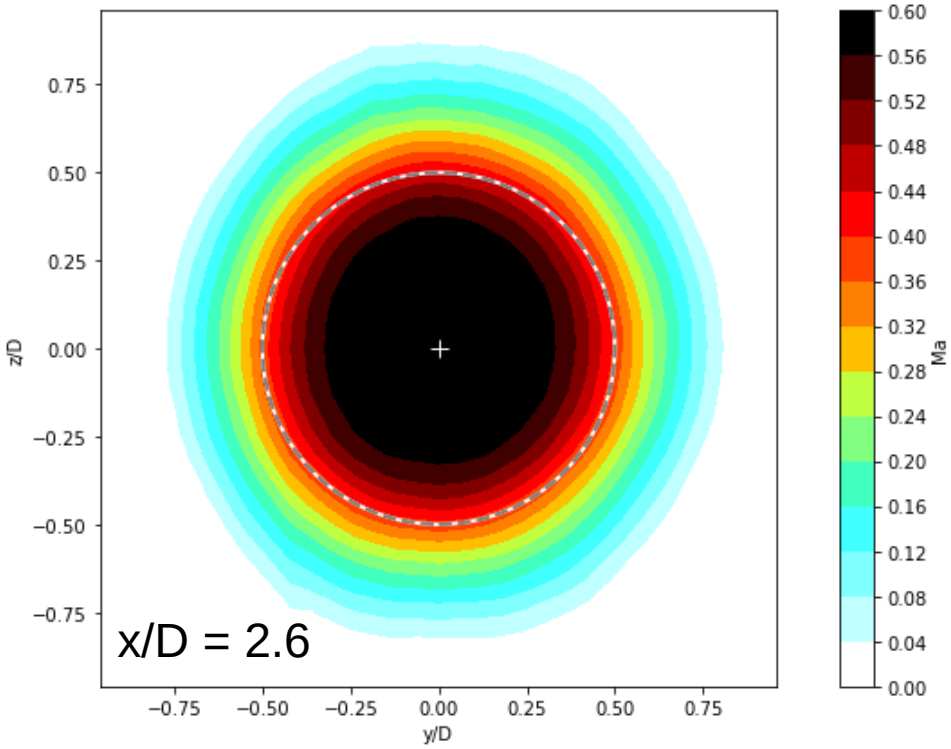
Streamwise Mach number from a longitudinal Pitot rake scan
Ma=0.6 at the nozzle exit.



Aerodynamic measurements – isolated baseline nozzle

Mach number field at transverse sections
Ma = 0.6

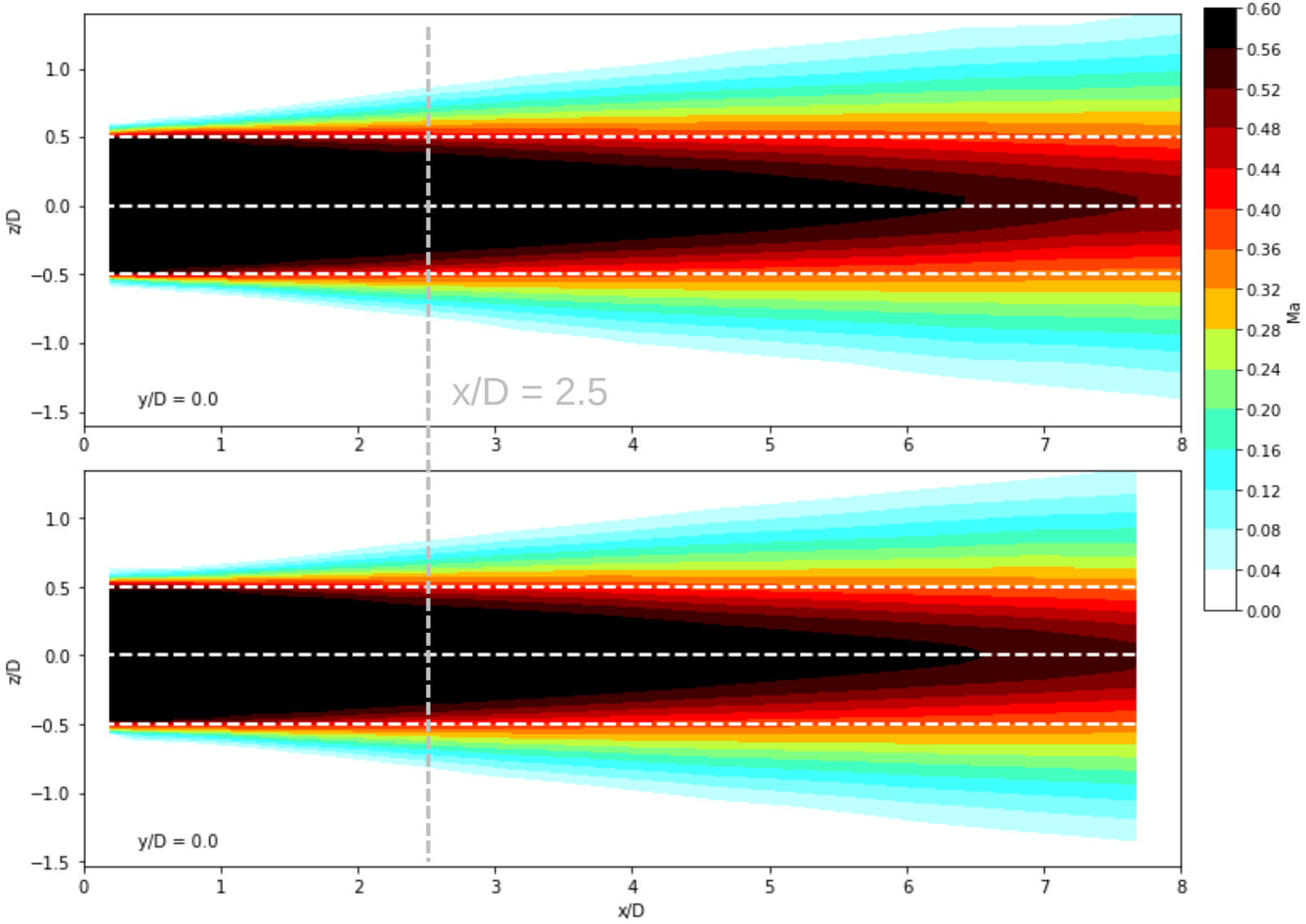




Streamwise Ma number profiles

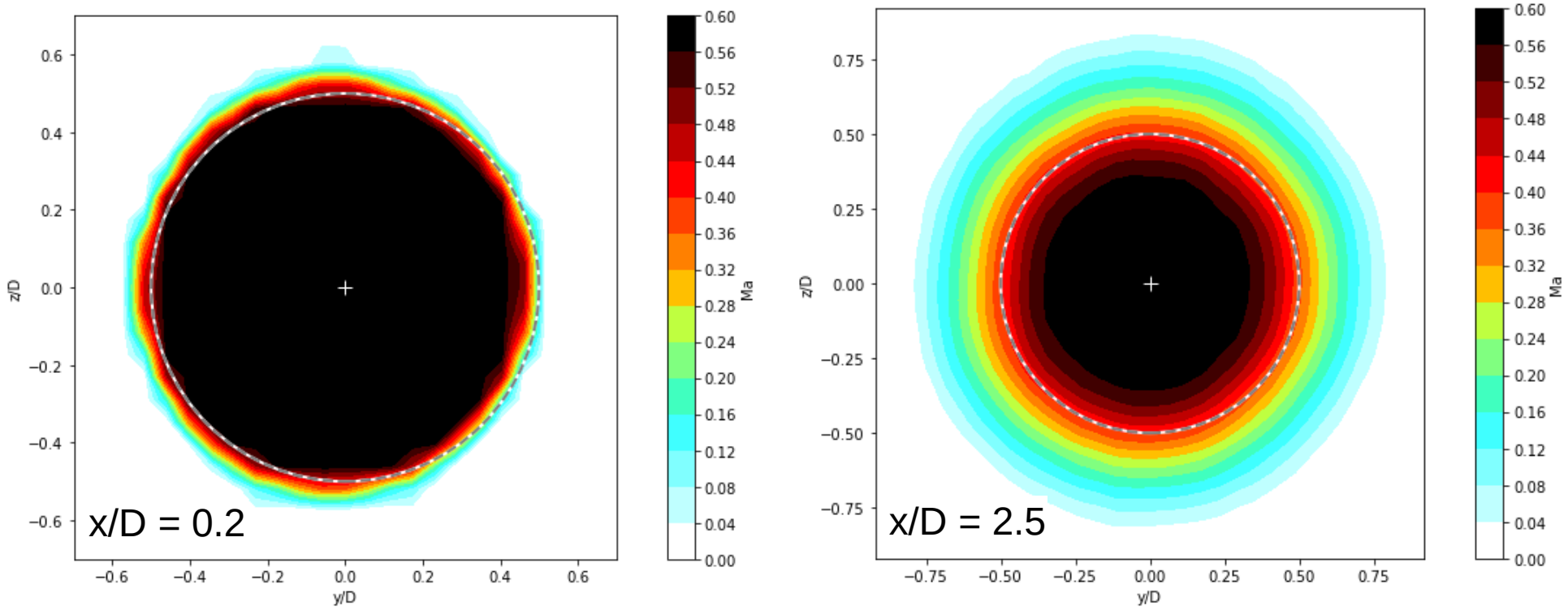
- convergent baseline nozzle
  D = 50 mm

- convergent-divergent nozzle
  NRTClean
  throat diameter
  D_{th} = 50 mm
  end diameter
  D = 52.2 mm



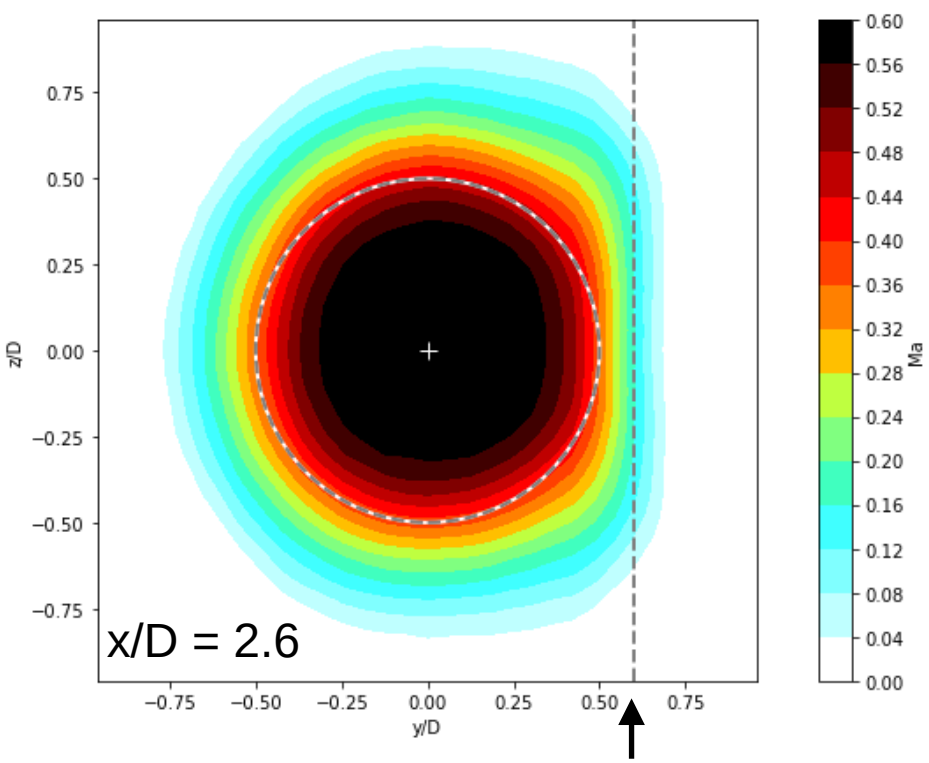
Aerodynamic measurements – isolated convergent-divergent nozzle

Mach number field at transverse sections of a Ma=0.6 jet
NRTClean

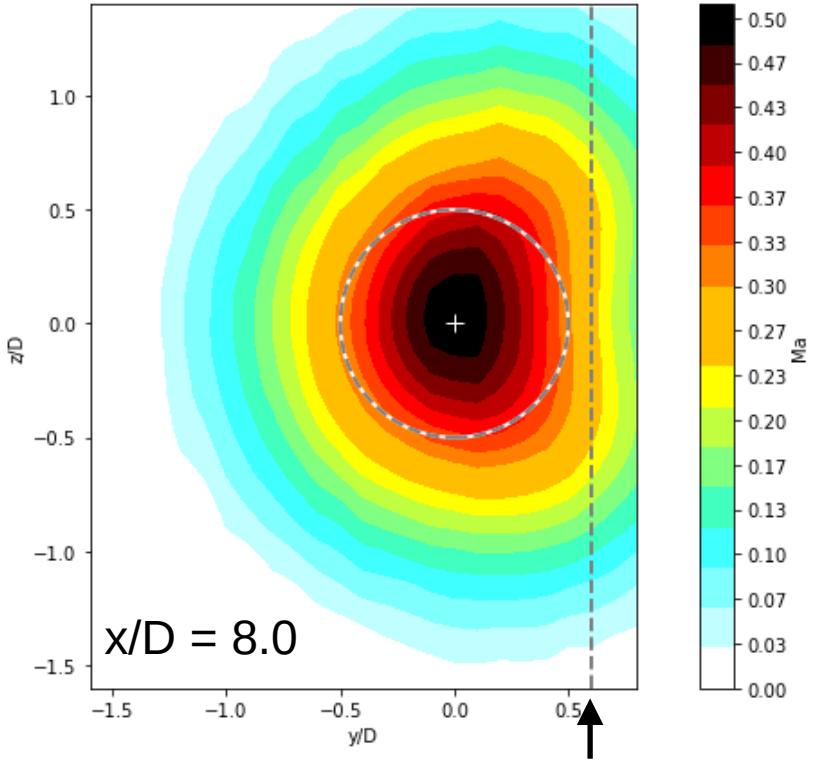


Aerodynamic measurements – baseline nozzle with plate installed

Mach number field at transverse sections
Ma = 0.6



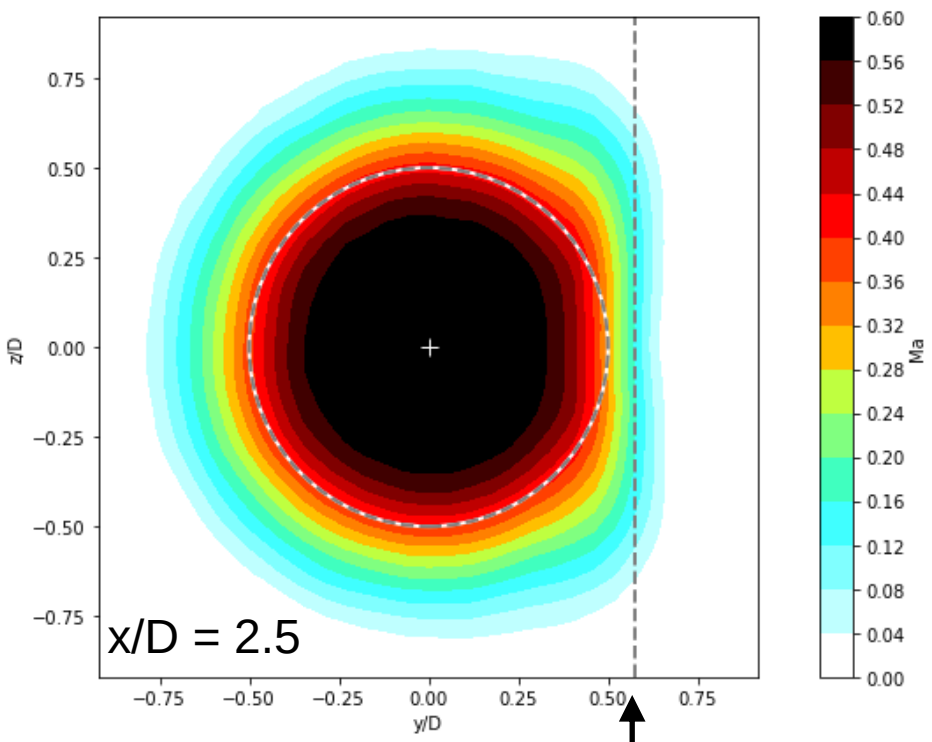
trailing edge of plate



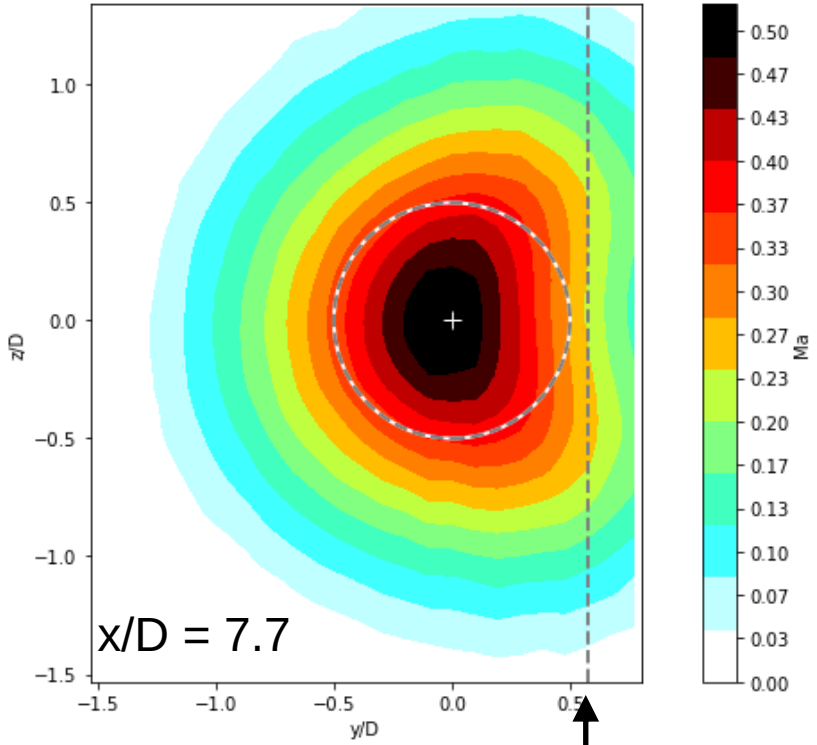
trailing edge of plate

Aerodynamic measurements – convergent-divergent nozzle with plate installed

Mach number field at transverse sections of a Ma=0.6 jet
NRTClean



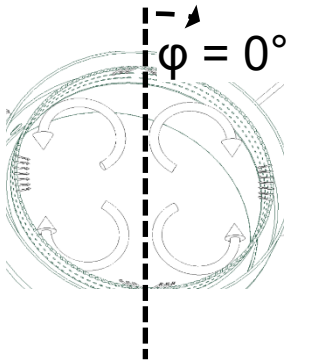
trailing edge of plate

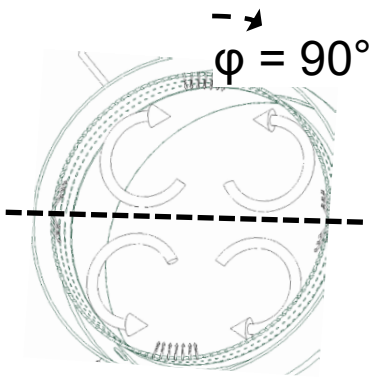


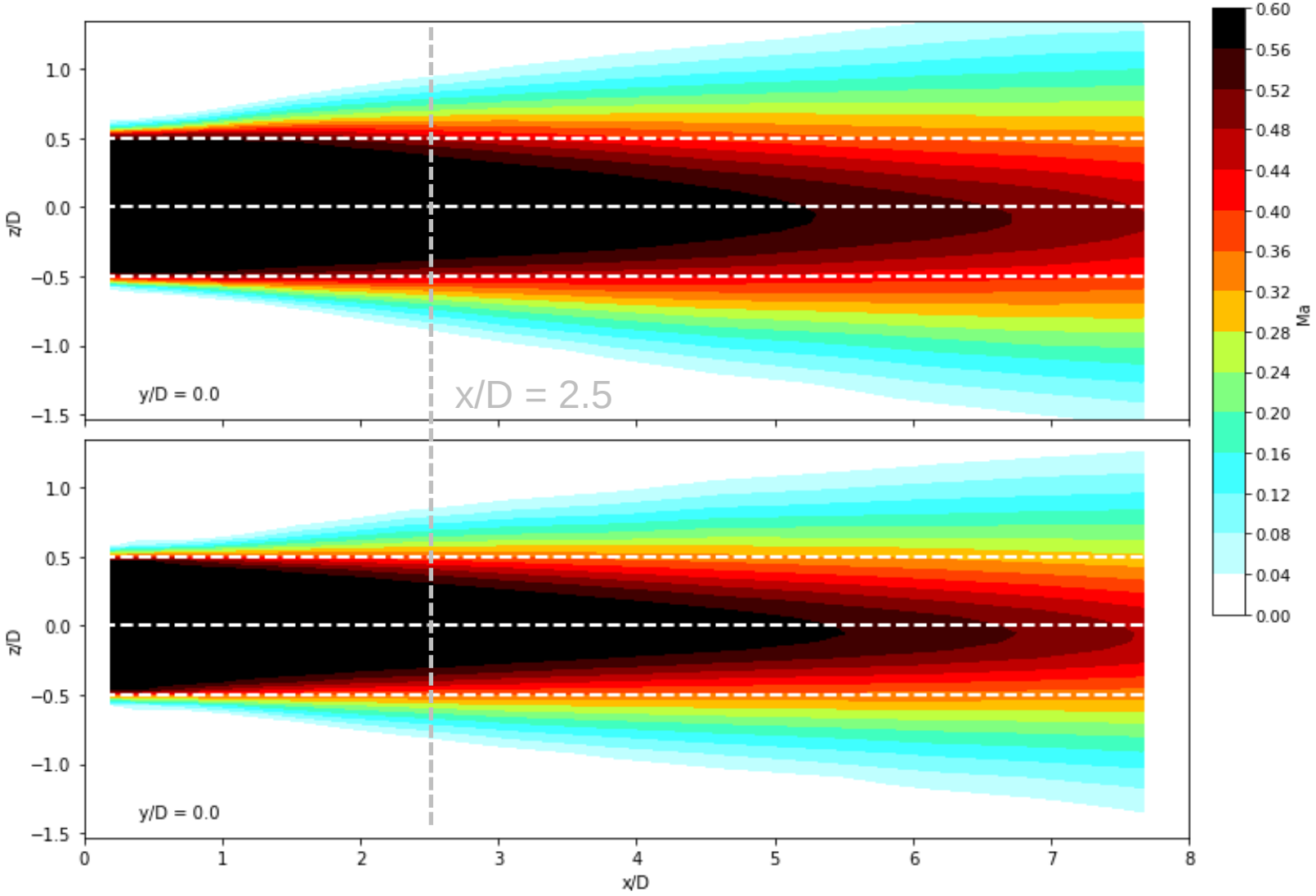
trailing edge of plate

Streamwise profiles – nozzle with vortex generating liner (VoGeL)

- *NRTOpen*
- orientation
  φ = 0°
  throat diameter
  D_{th} = 50 mm
  end diameter
  D = 52.2 mm
- rotated by
  φ = 90°

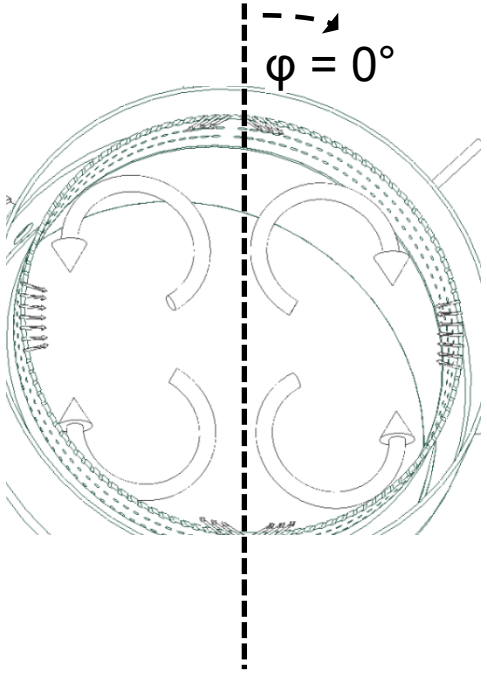


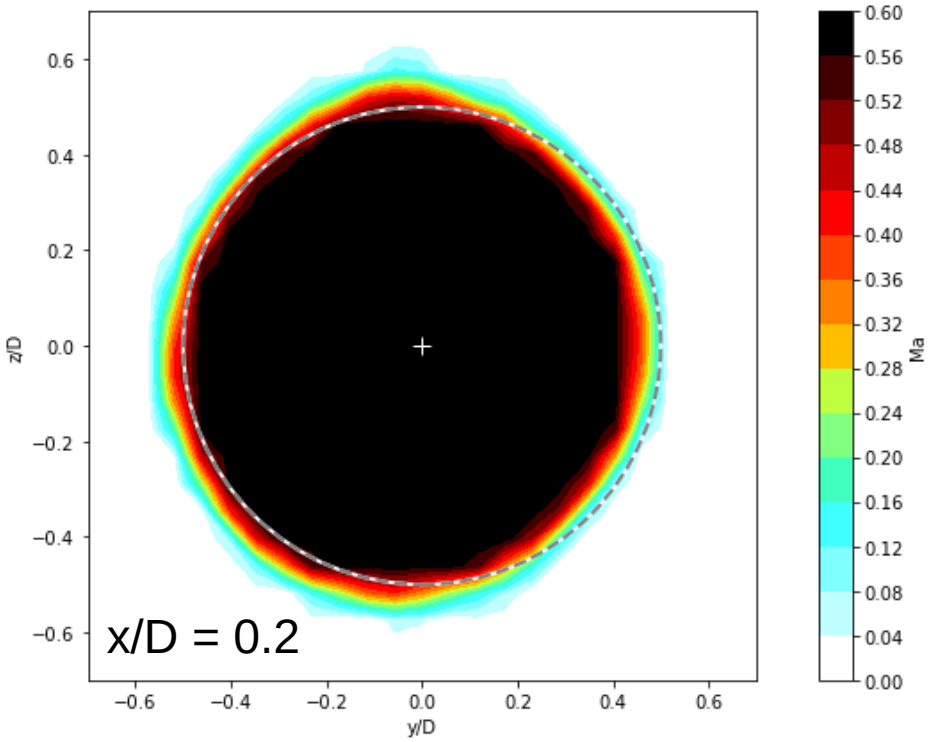


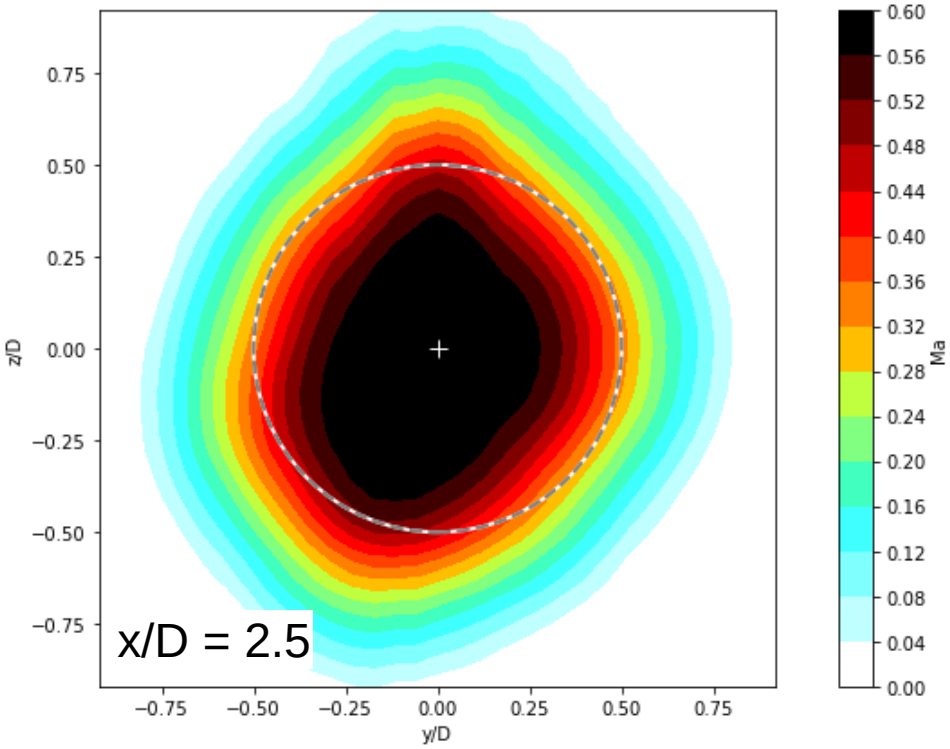


Aerodynamic measurements – isolated VoGeL nozzle

Mach number field at transverse sections of a Ma=0.6 jet
φ = 0° orientation: „squeeze“ towards the vertical axis
NRTOpen

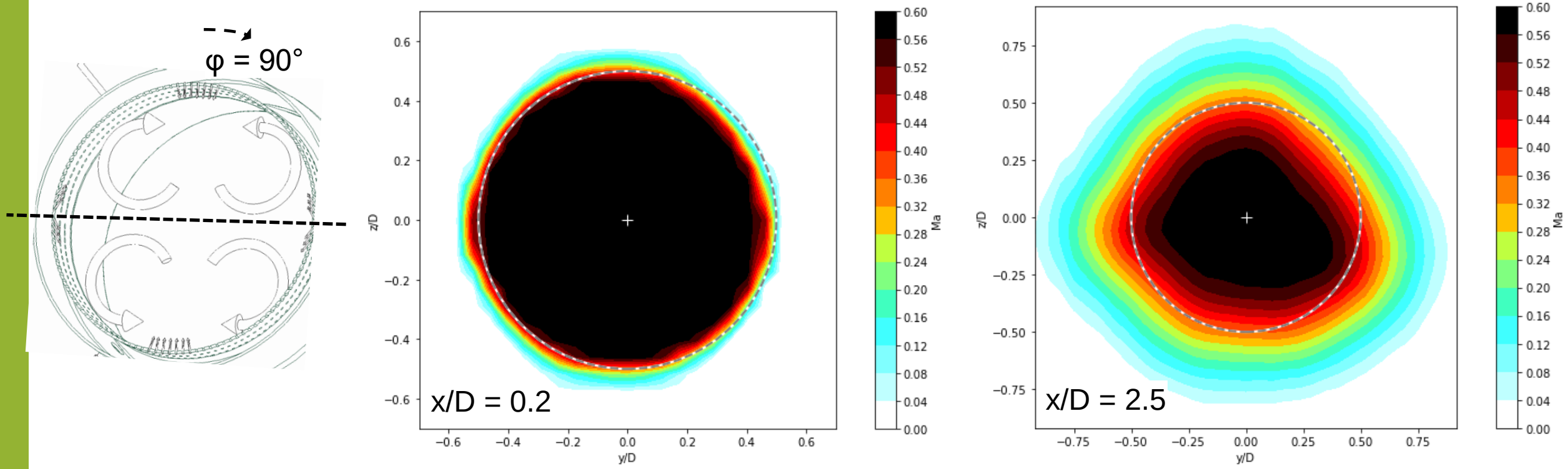






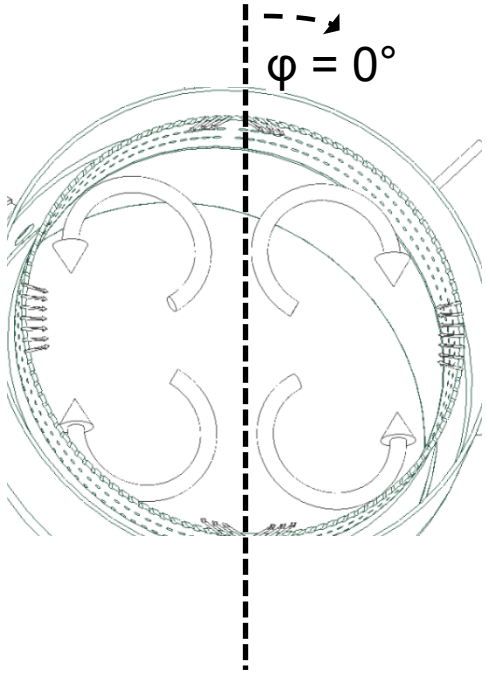
Aerodynamic measurements – isolated VoGeL nozzle

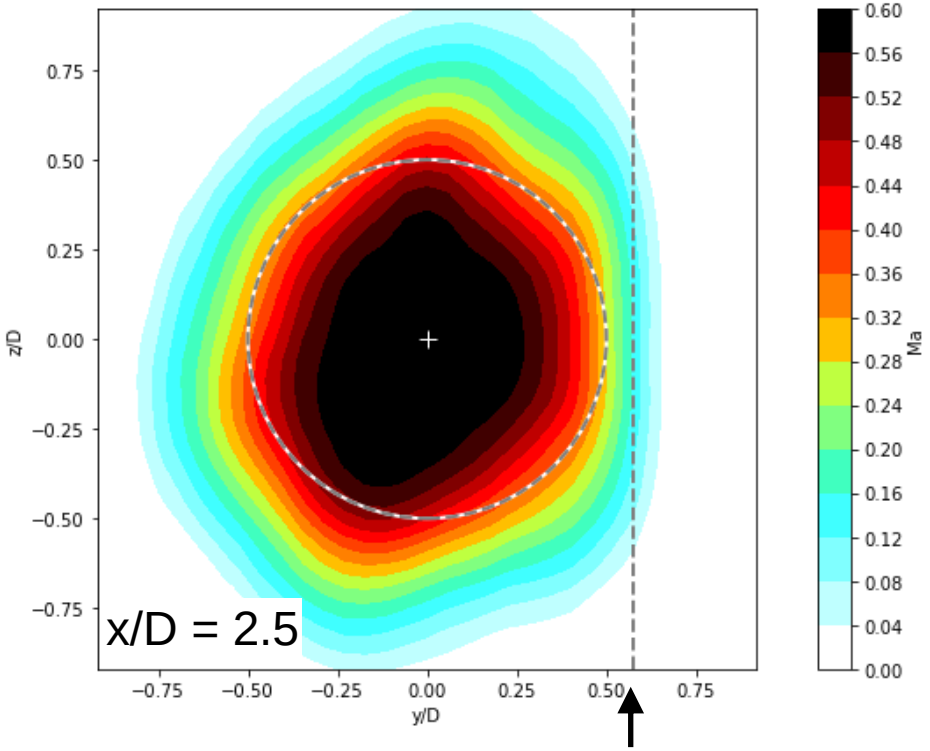
Mach number field at transverse sections of a Ma=0.6 jet
nozzle rotated by φ = 90°: „squeeze“ towards the horizontal axis (as expected)
NRTOpen

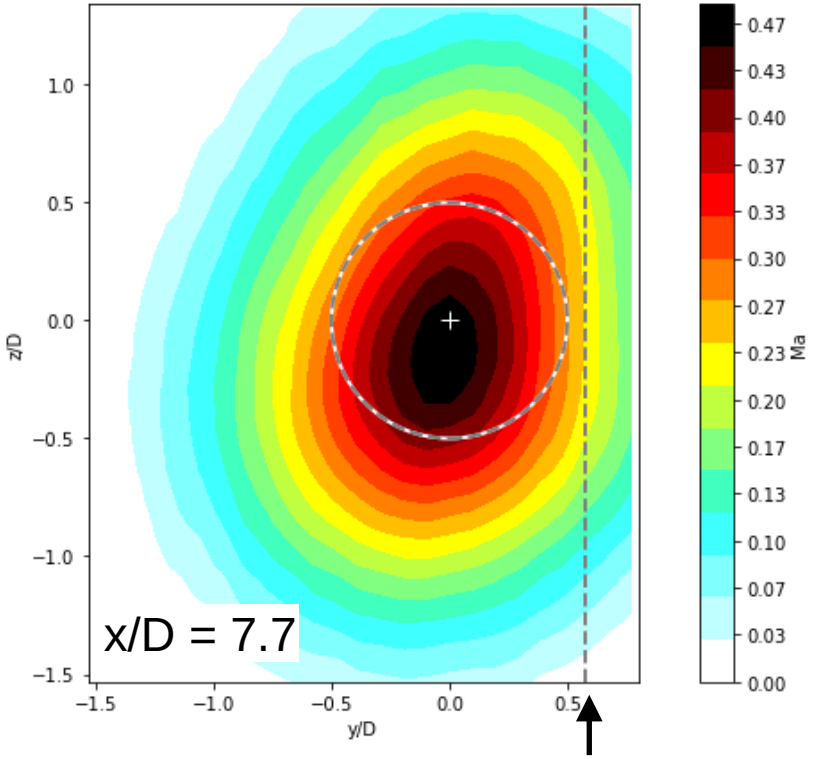


Aerodynamic measurements – VoGeL nozzle with plate installed

Mach number field at transverse sections of a Ma=0.6 jet
φ = 0° orientation: shearlayer to plate distance increases – reduced interaction
NRTOpen

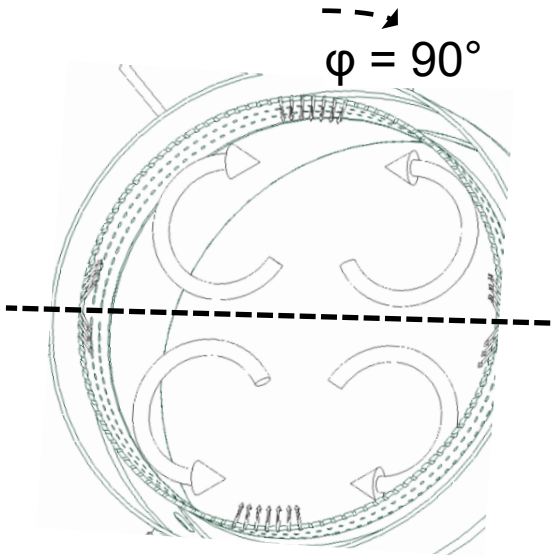


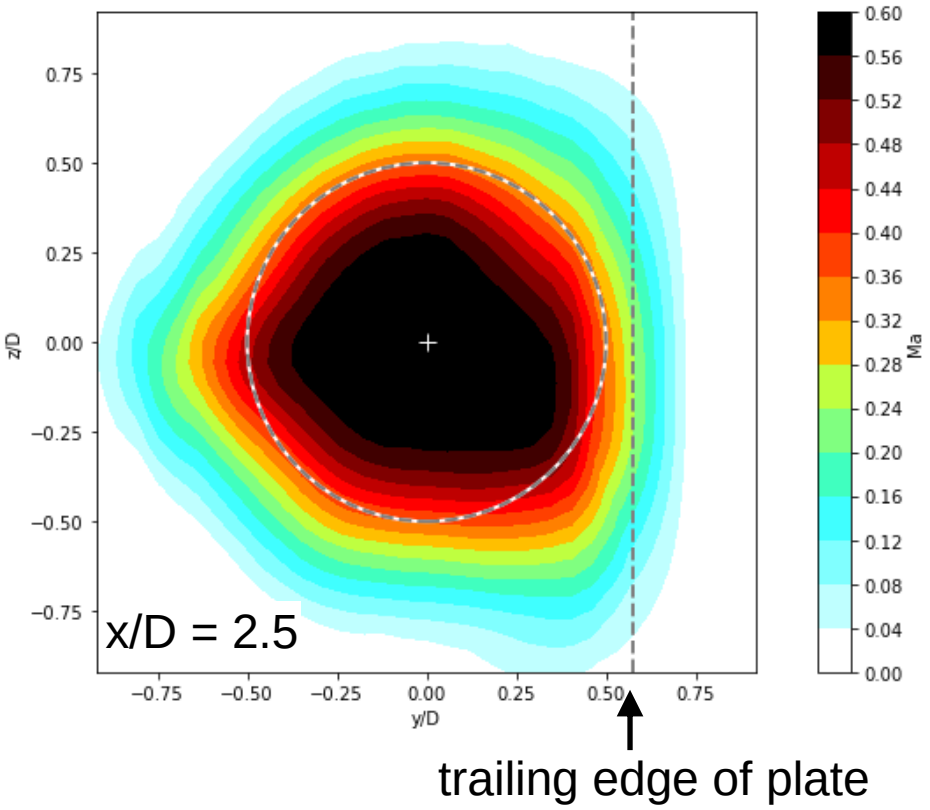


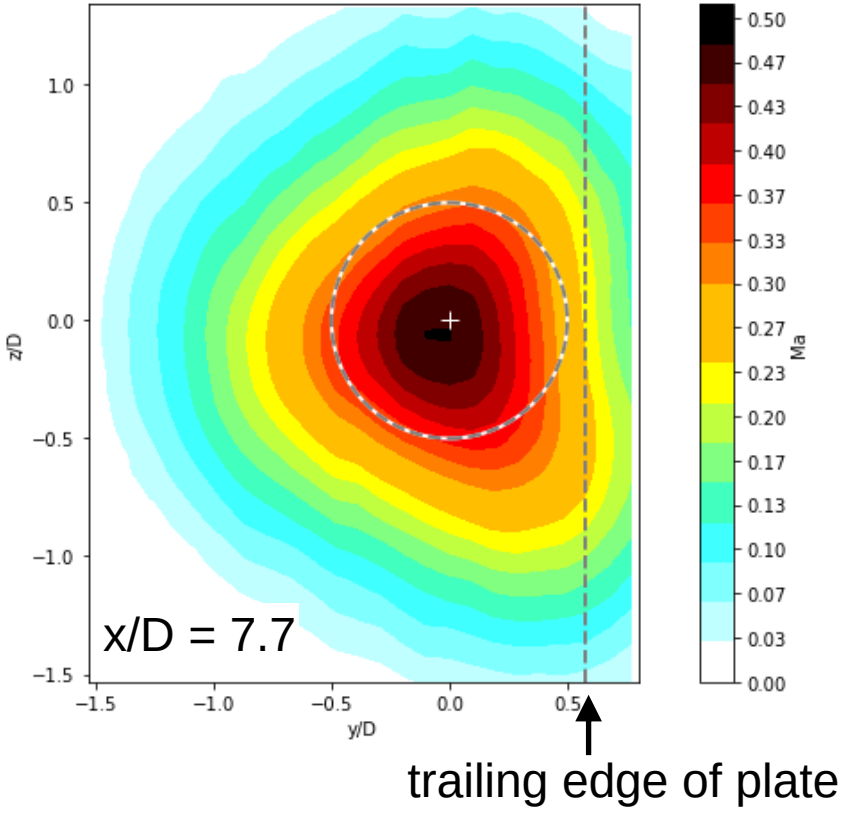


Aerodynamic measurements – VoGeL nozzle with plate installed

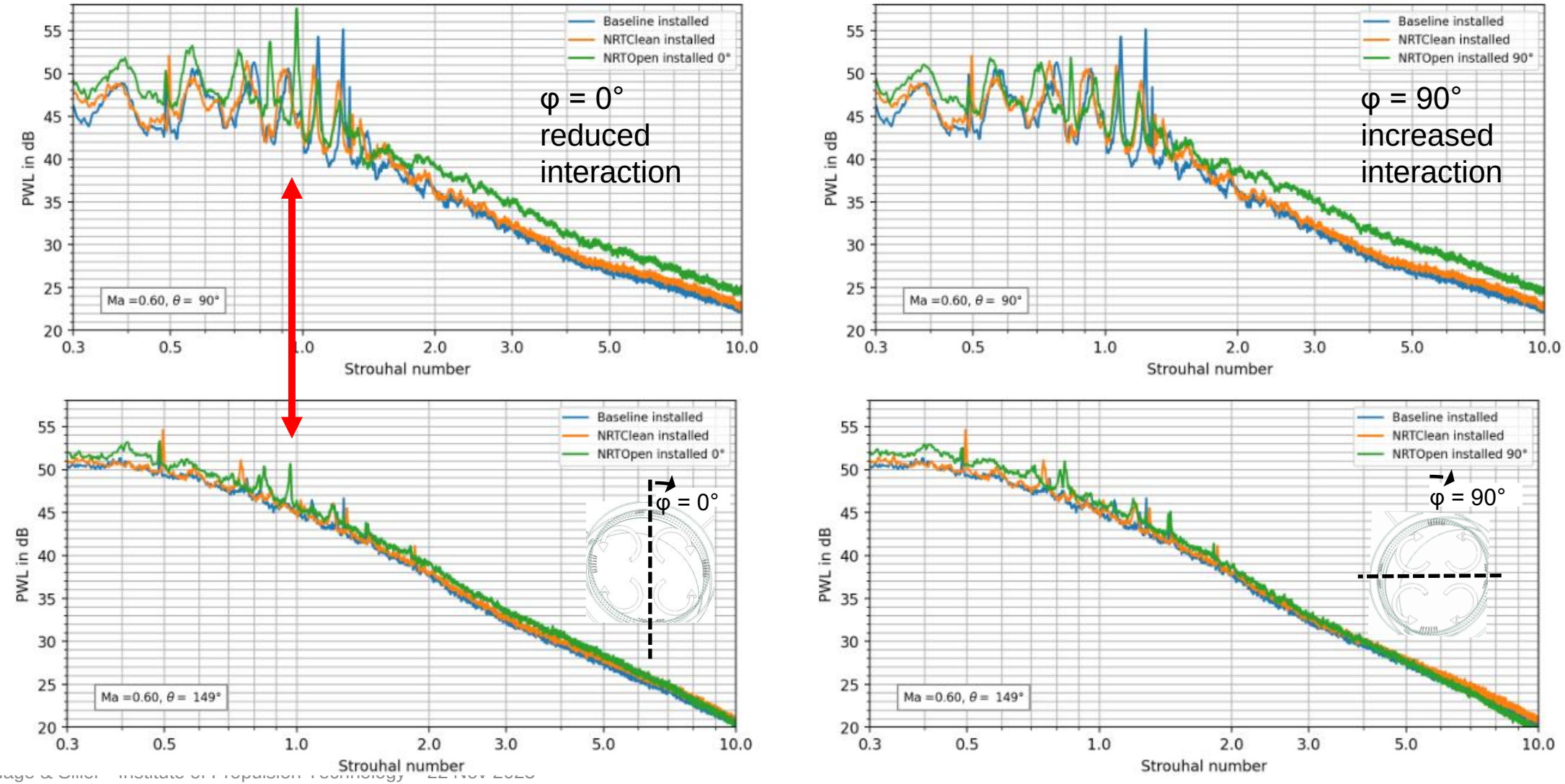
Mach number field at transverse sections of a Ma=0.6 jet
φ = 90° orientation: shearlayer to plate distance decreased – more interaction
NRTOpen



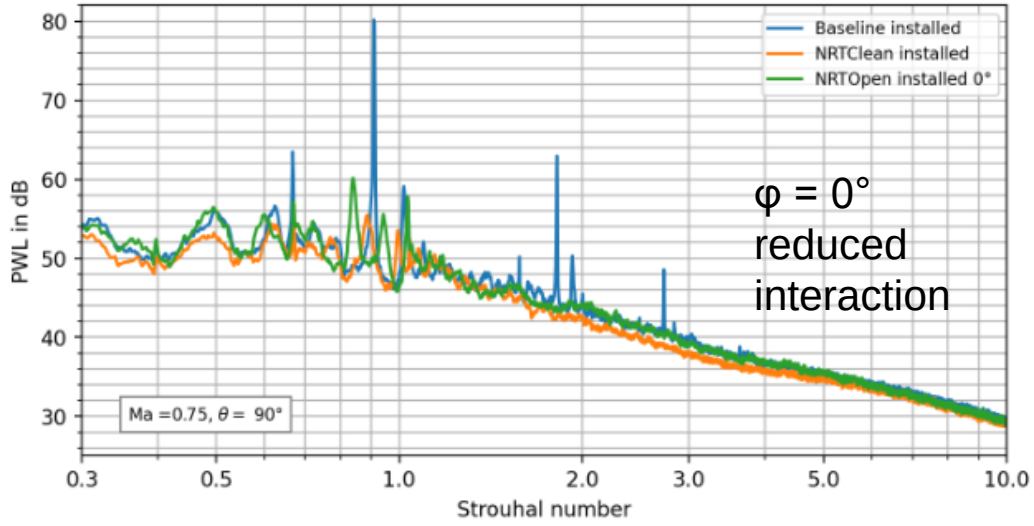


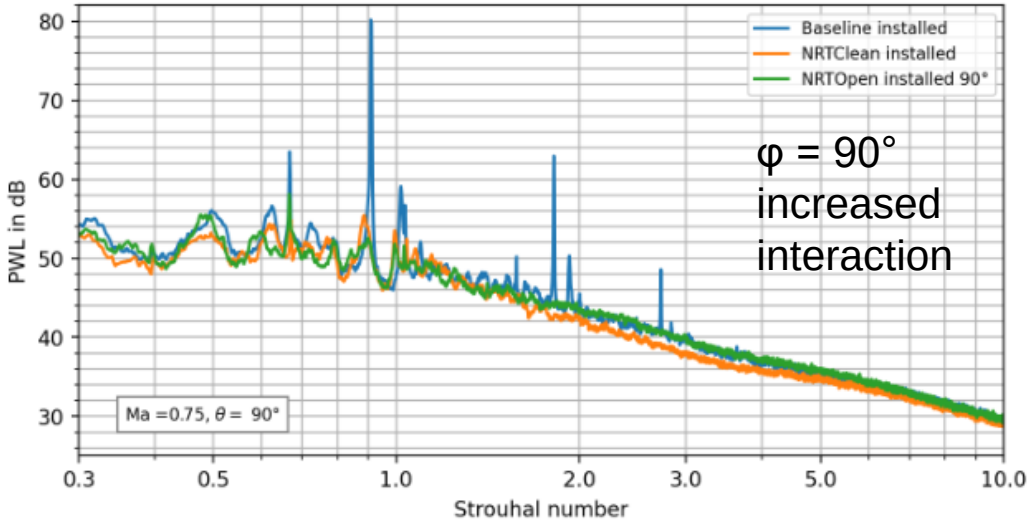


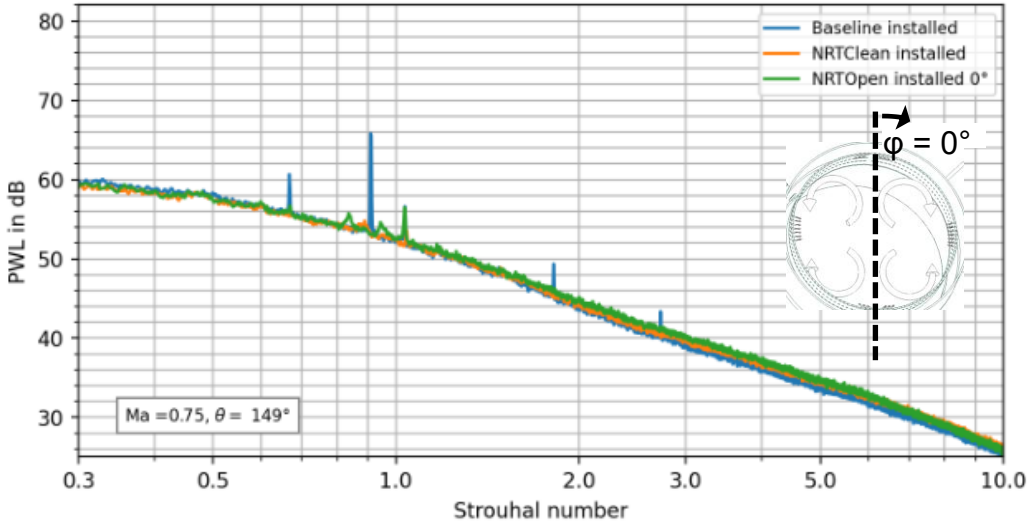
Acoustic measurements – baseline, CD and VoGeL nozzles at Ma=0.6

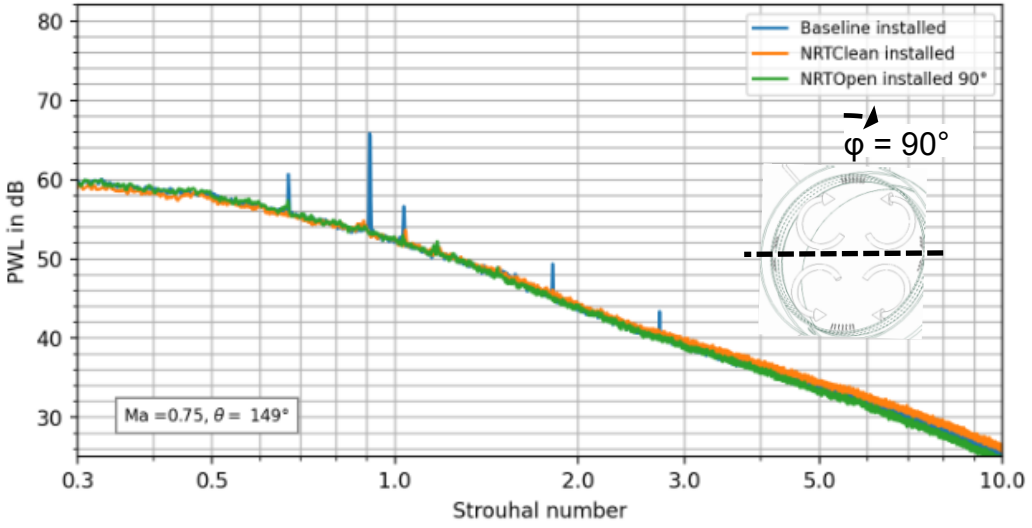


Acoustic measurements – baseline, CD and VoGeL nozzles at Ma=0.75









Conclusions

- Experiments in the DLR small the free-jet facility JExTRA for single-stream jets
  - acoustic results for an isolated jet are within 2 dB to data from PPRIME
- Experiments to reduce noise jet-wing interaction noise
  - isolated and nozzle-wing configurations
  - maximum nozzle-exit Mach number Ma=0.6 and 0.75
  - aerodynamic and acoustic measurements with different nozzle configurations
- A short diverging section applied to the baseline nozzle reduces jet-wing interaction tones
  - tonal components from nozzle - wing interaction are sensitive to increased nozzle-exit turbulence
- Test of the vortex generating liner (VoGeL) concept
  - basic idea: generate streamwise vorticity in the jet shear layer – similar to chevrons
  - bias flow through a perforated liner driven by the pressure gradient in the nozzle
  - vectored liner orifices generate streamwise vorticity
  - streamwise vorticity deforms the jet cross-section
  - the effect improves with increasing jet Mach number
  - potential noise reduction at high subsonic or supersonic jet velocities

Thanks for your attention

Any Questions??? ☺

Acknowledgements
Christian Jente from DLR Braunschweig
for his support, the discussions and the communication, especially in verifying the JExTRA acoustic data
and
Jean Baptiste Mansoux from ISAE SUPAERO Graduate School of Engineering, Toulouse, France,
supported the test and the initial data appraisal.

All images and diagrams are the property of DLR

The DJINN (Decrease Jet Installation Noise) project receives funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 861438.
The DJINN project is a collaboration between CFDB (Coordinator), AIRBUS, DASSAULT, SAFRAN, RRD, ONERA, DLR, SOTON, CERFACS, ICL, VKI, CNRS, and QMUL