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

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THE DJINN - ENODISE CONFERENCE

Aeroacoustic Installation Effects
In Conventional and New Propulsion Systems
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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)

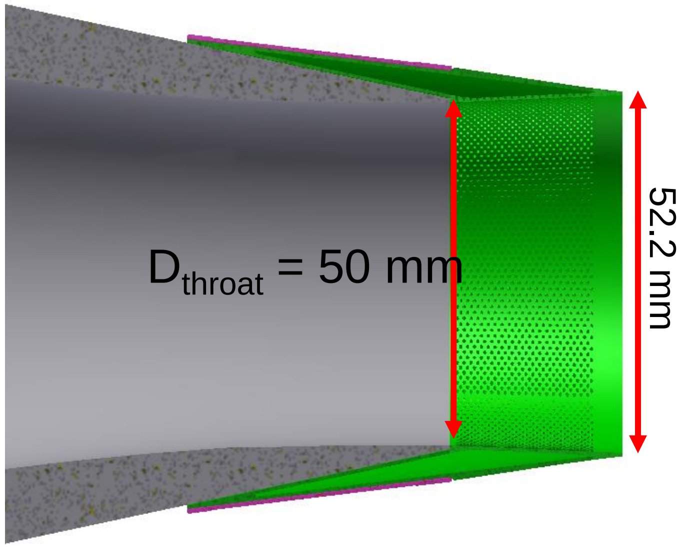
Nozzle prototypes

- 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

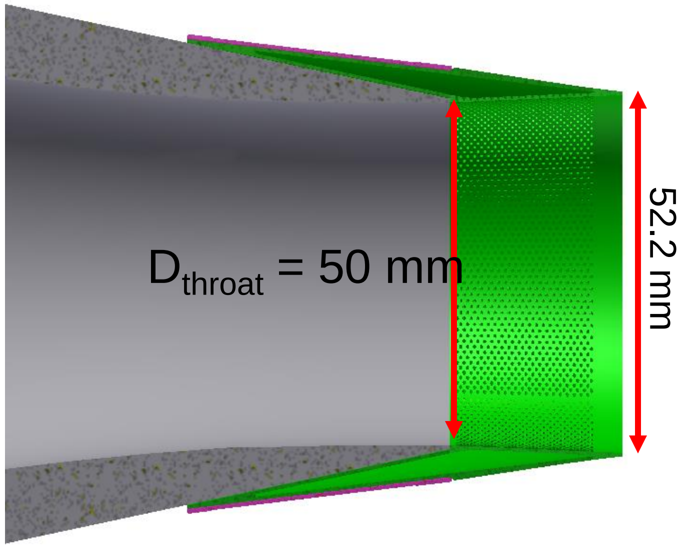


convergent-divergent inner contour

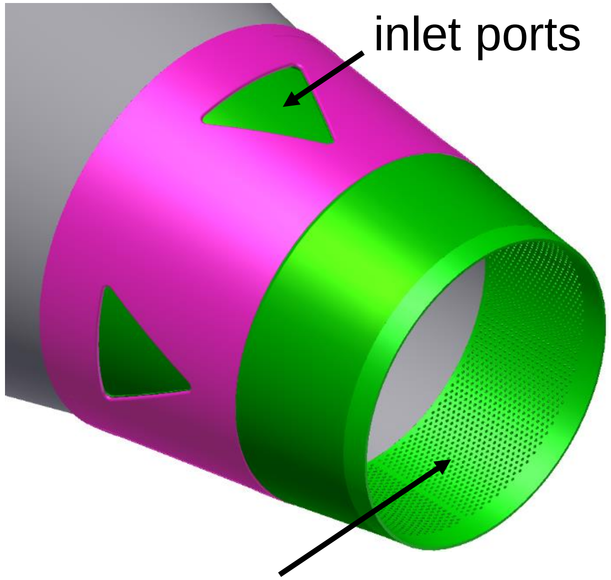
baseline convergent nozzle

Nozzle prototypes

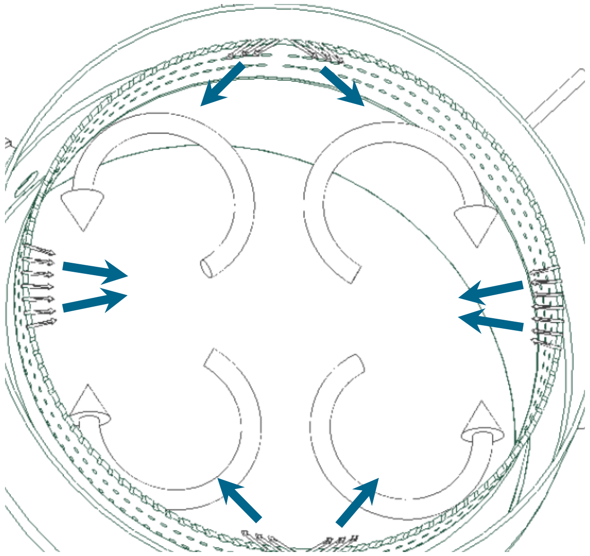
- Baseline convergent nozzle
- convergent-divergent nozzle – D increases by 4 %
- convergent-divergent nozzle with vortex generating liner (VoGeL / *NRTOpen)*
  - idea: generate streamwise vorticity in the jet, using a bias flow with variable angle to the wall normal



convergent-divergent inner contour



bias flow liner


bias flow pattern & vortical field sketch

Nozzle prototypes

- Baseline convergent nozzle
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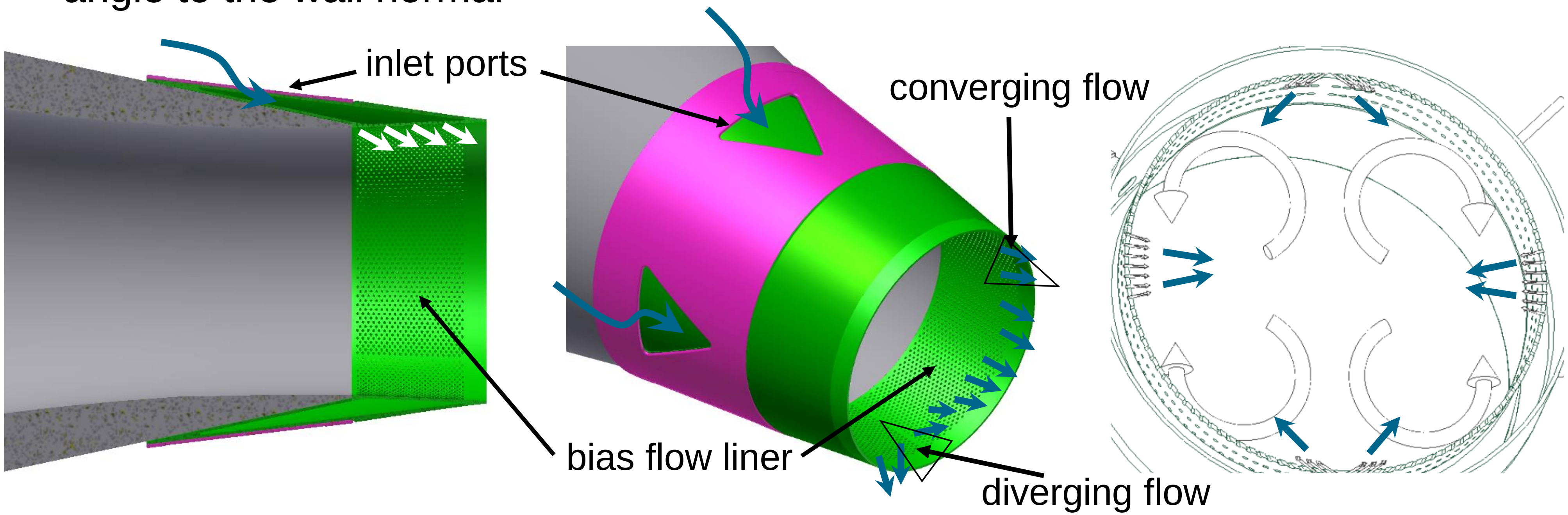


convergent-divergent inner contour

bias flow pattern & vortical field sketch

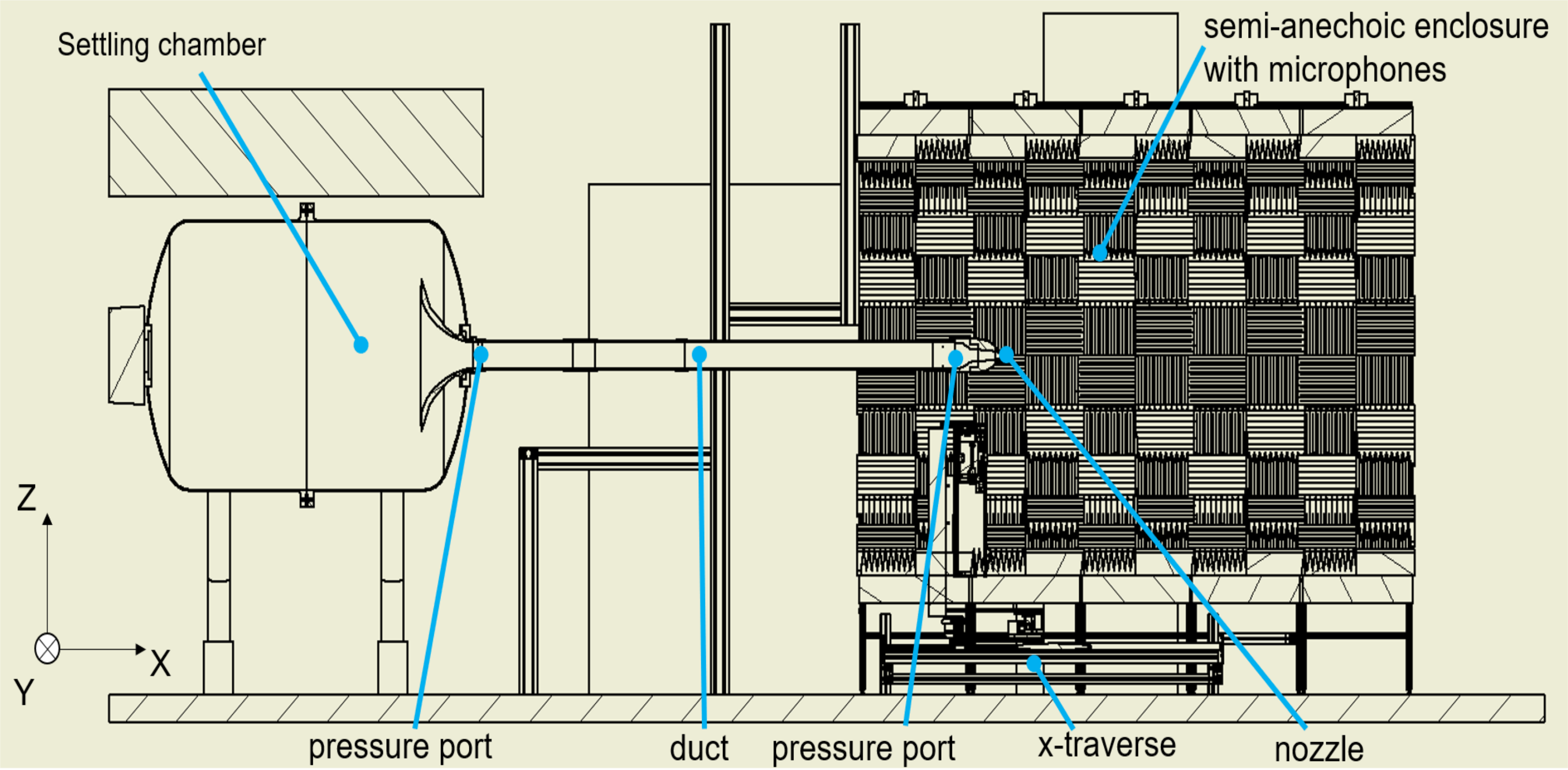
The JExTRA aeroacoustic facility for jet-noise investigations at small scale

Motivation for JExTRA:

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

Features

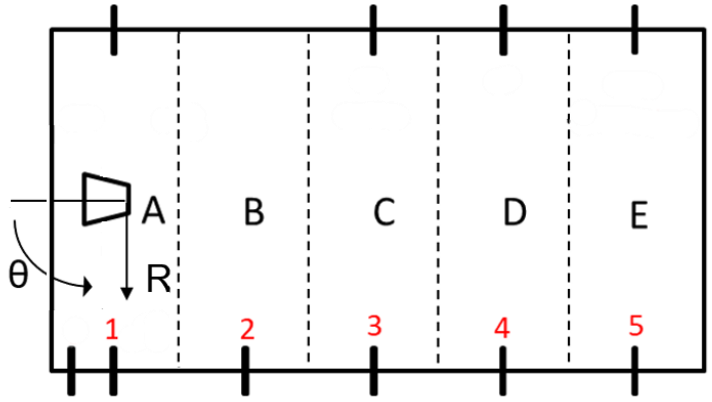
- pressure sensors
- temperature sensors
- motor speed control
- automatic monitoring of Mach number
- traversing system



Set-up for acoustic measurements in JExTRA

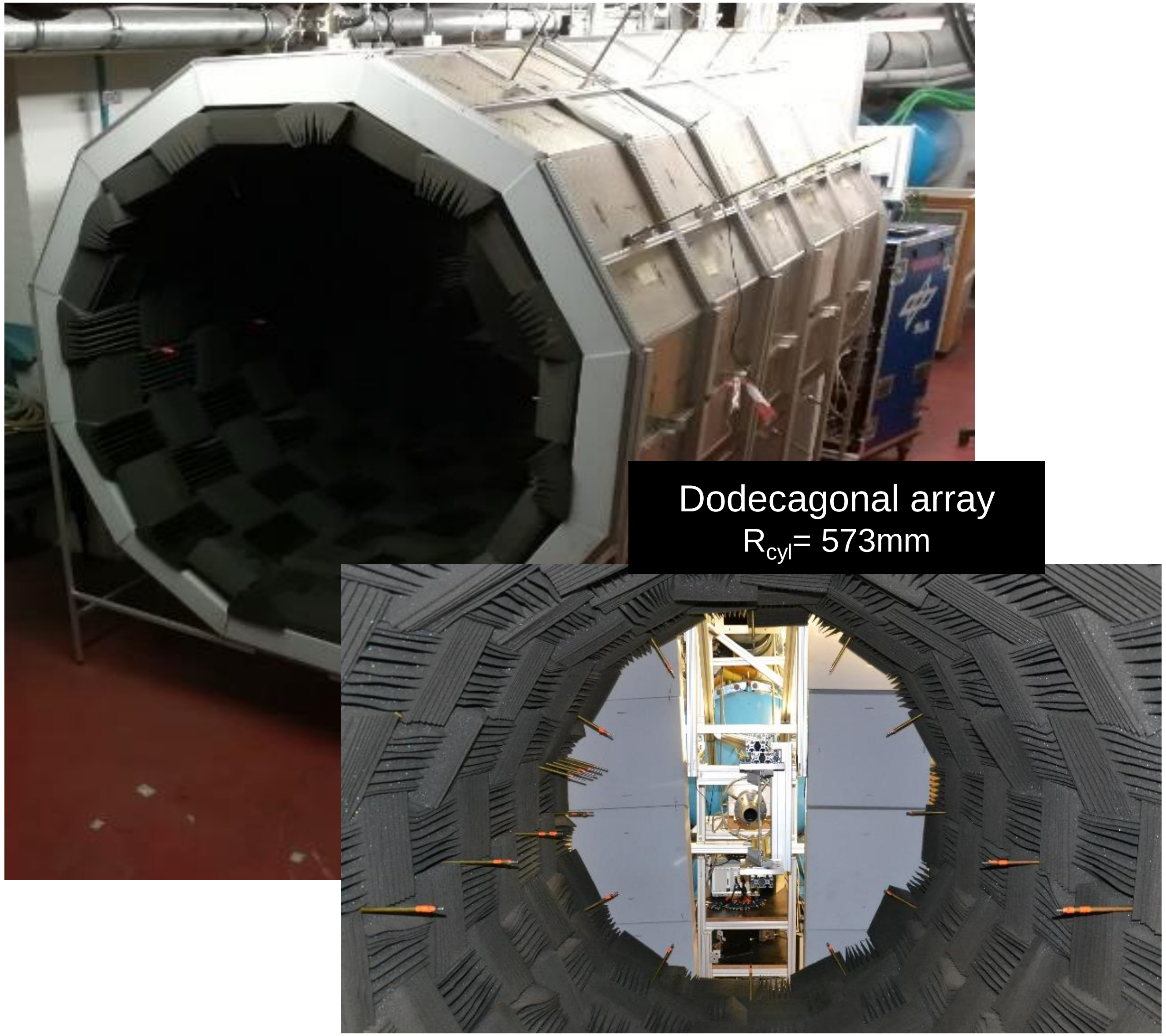
Low-reflection barrel

- 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



θ ≈ 89° 130° 149° 159° 164°

x/D = -0.3 9.5 19.3 29.6 39.4 (D=50 mm)

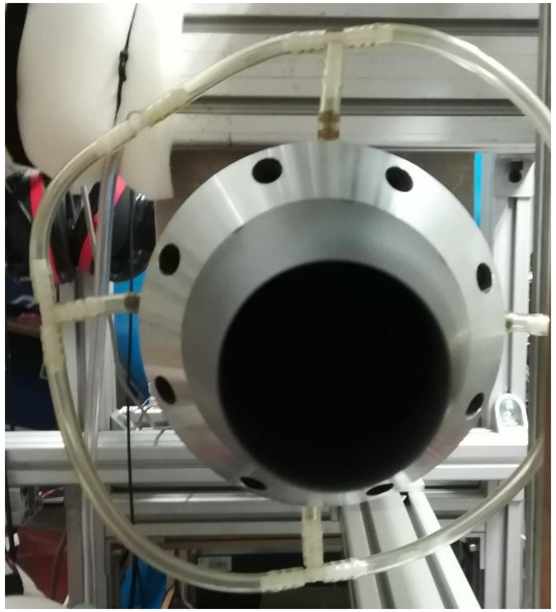


Dodecagonal array

R_{cyl}= 573mm

Aerodynamic measurements – isolated baseline nozzle

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

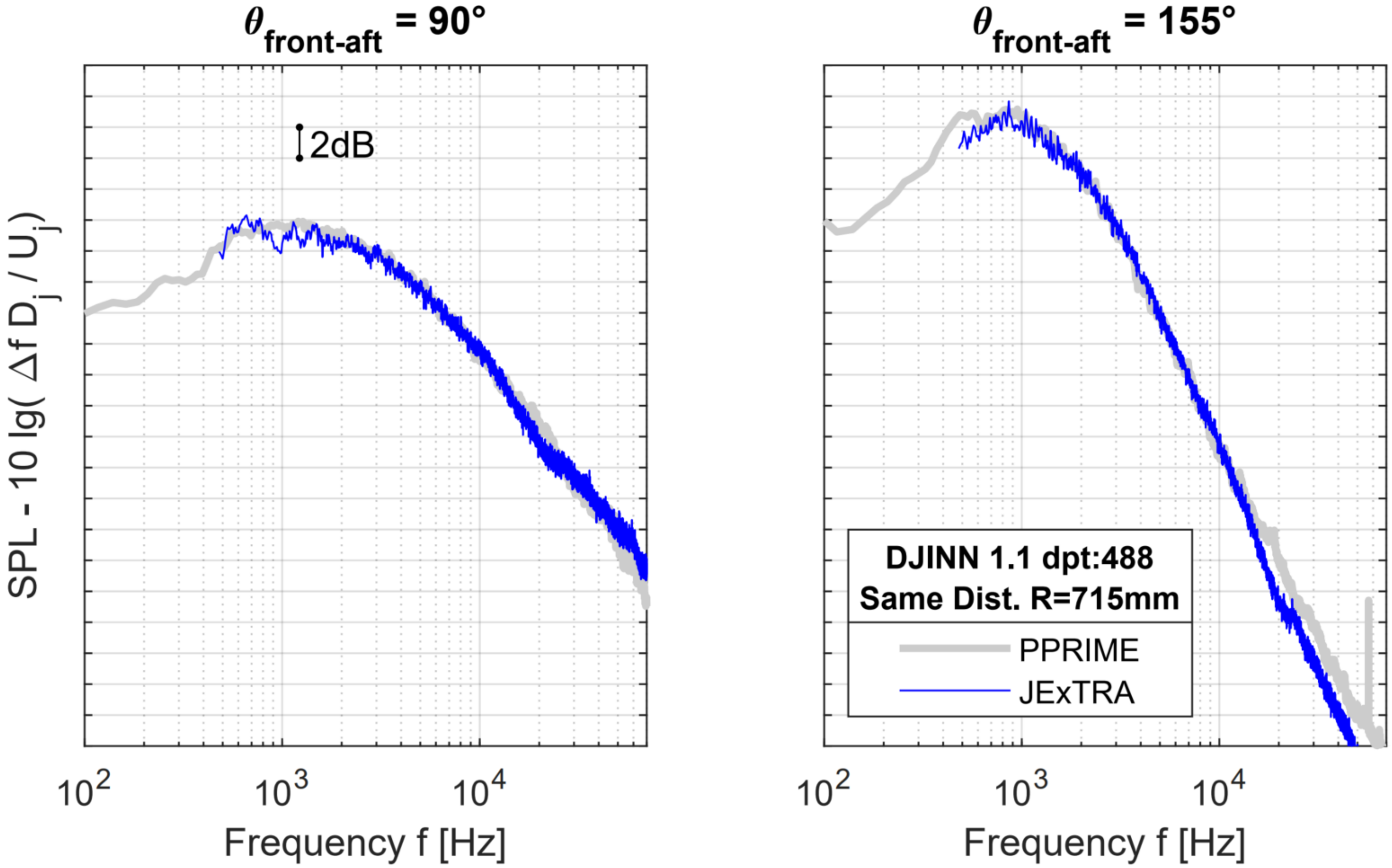


Cross-check of JExTRA with PPRIME acoustic results

Comparison of frequency spectra

with data from PPRIME (Poitiers)

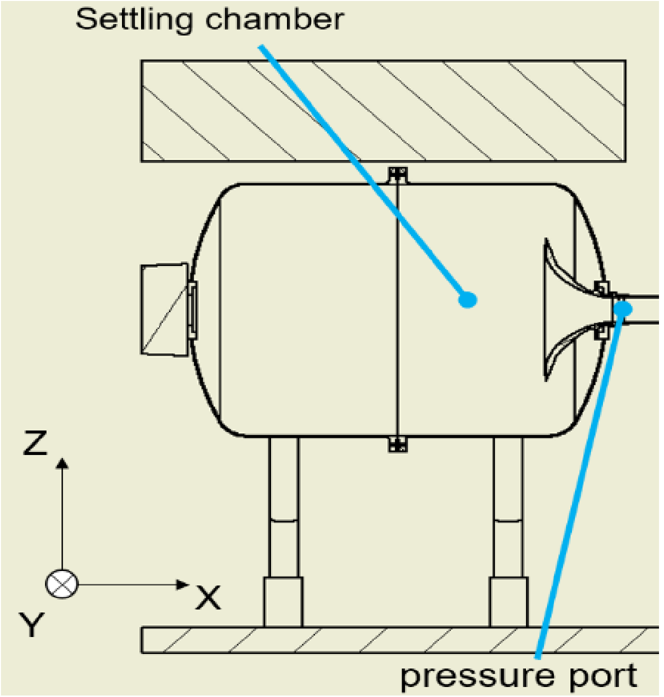
- isolated nozzle,
  D= 50 mm, Ma = 0.6
- angular positions and distance to the jet matched
- close agreement
  500 Hz to 10 kHz
- below 500 Hz: room-acoustics
- good agreement within 2 dB
  in the relevant frequency range

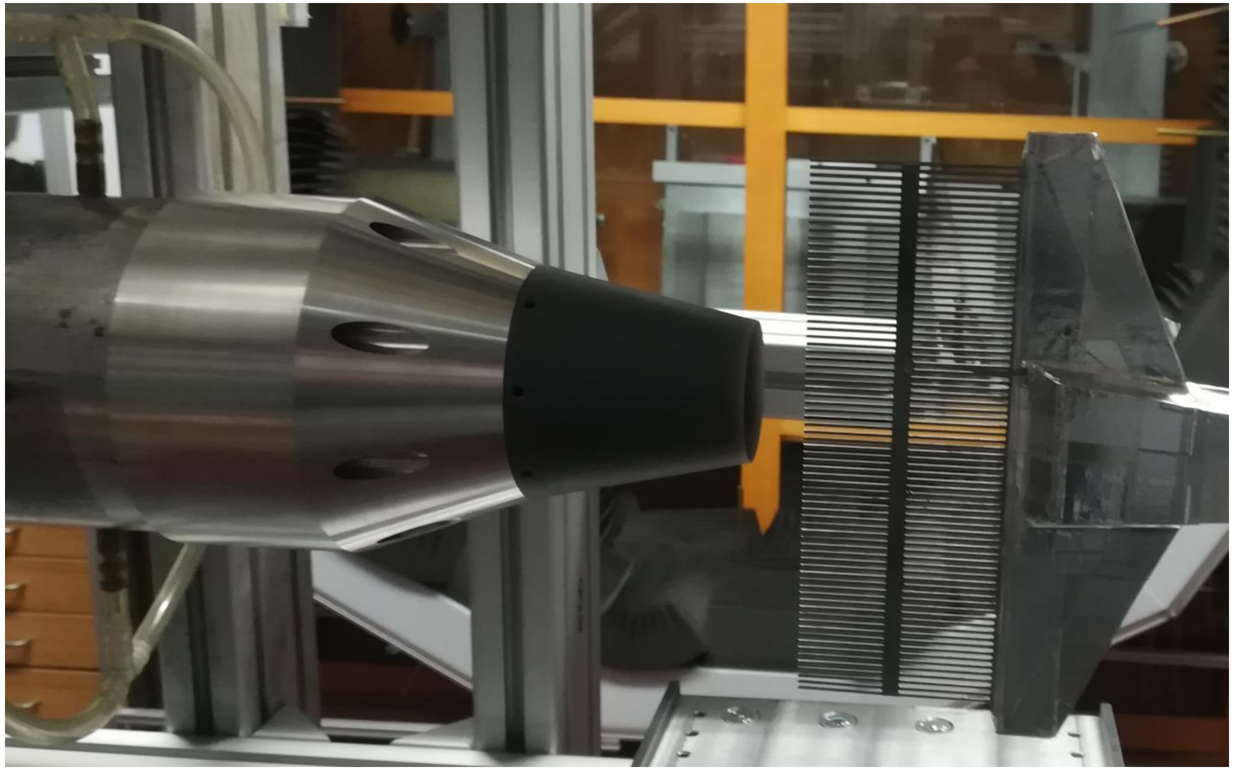


Aerodynamic measurements

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)

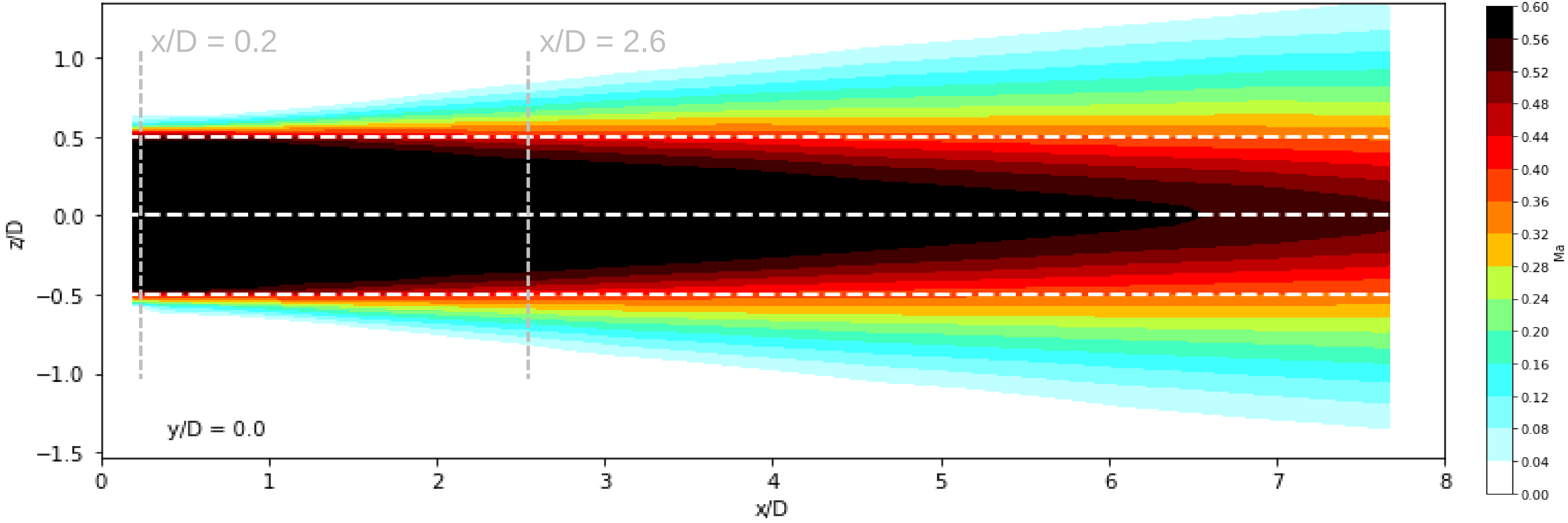




DJINN Measurements of the baseline configuration

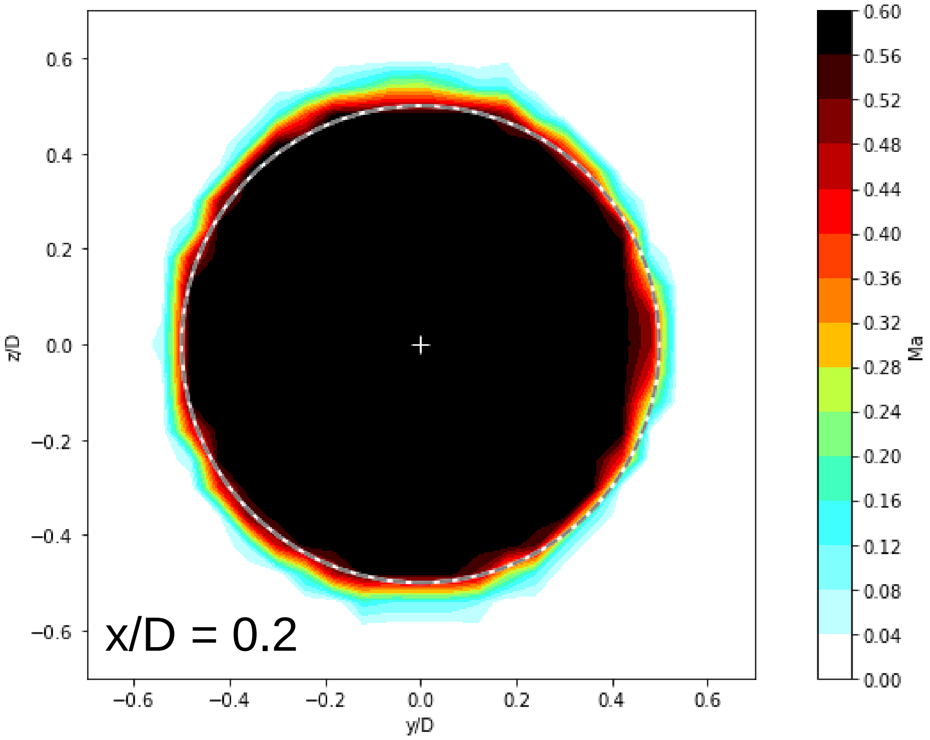
Aerodynamic measurements – isolated baseline nozzle

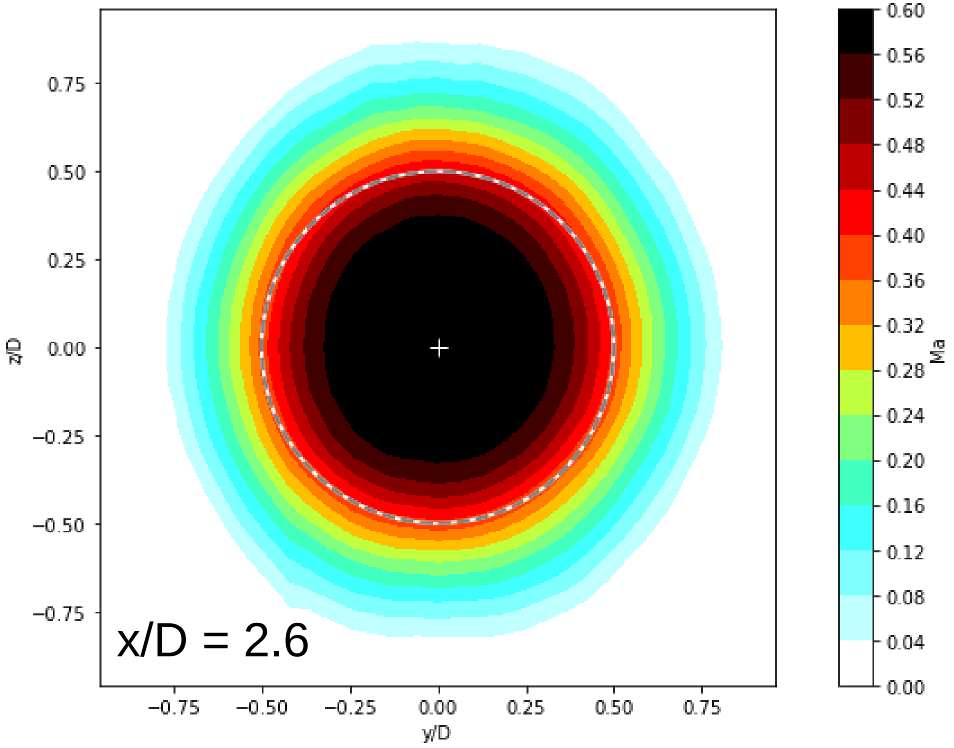
Streamwise Mach number from a longitudinal Pitot rake scan
Ma=0.6 at the nozzle exit.



Aerodynamic measurements – isolated baseline nozzle

Mach number field at transverse sections
Ma = 0.6

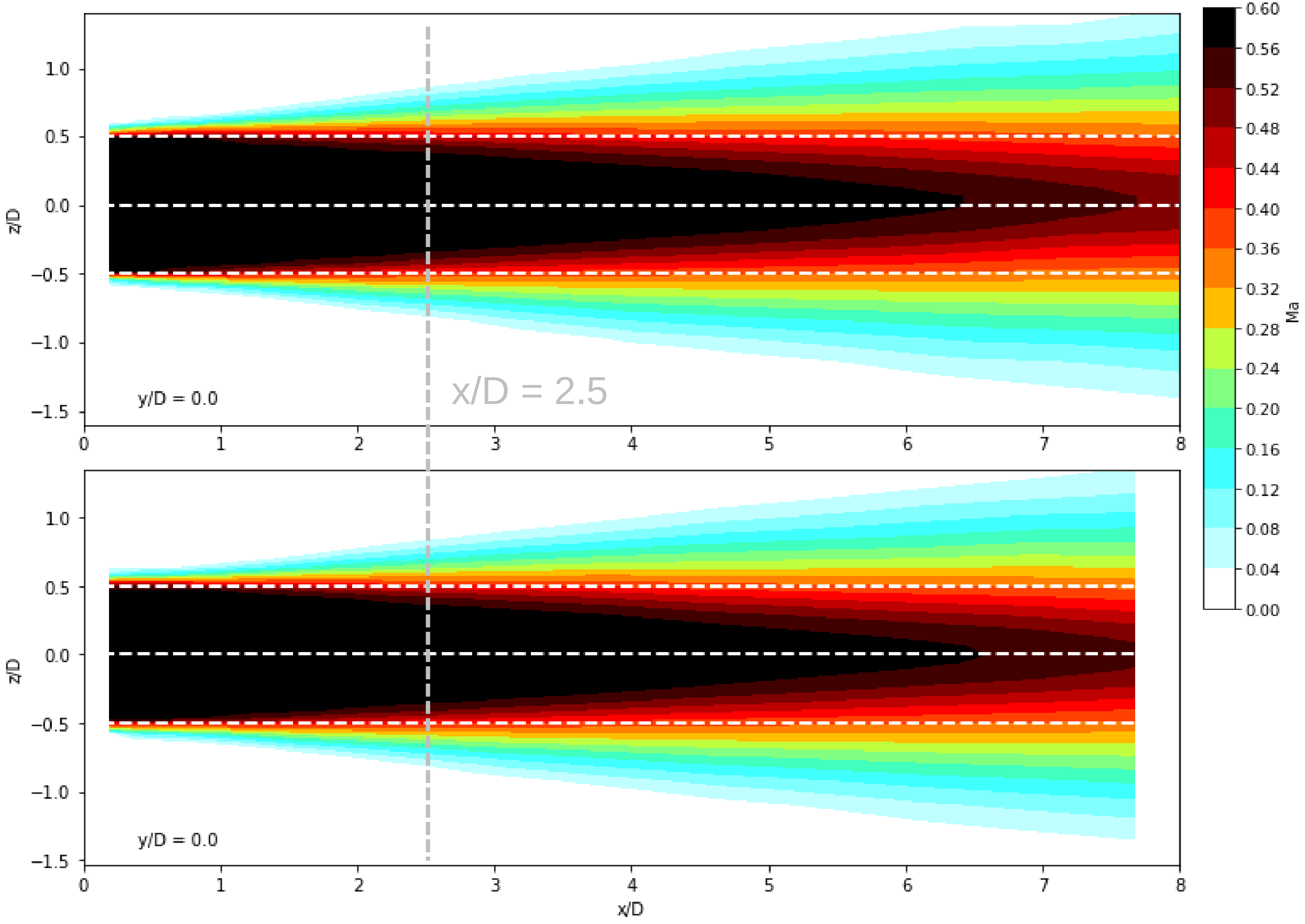




Streamwise Ma number profiles

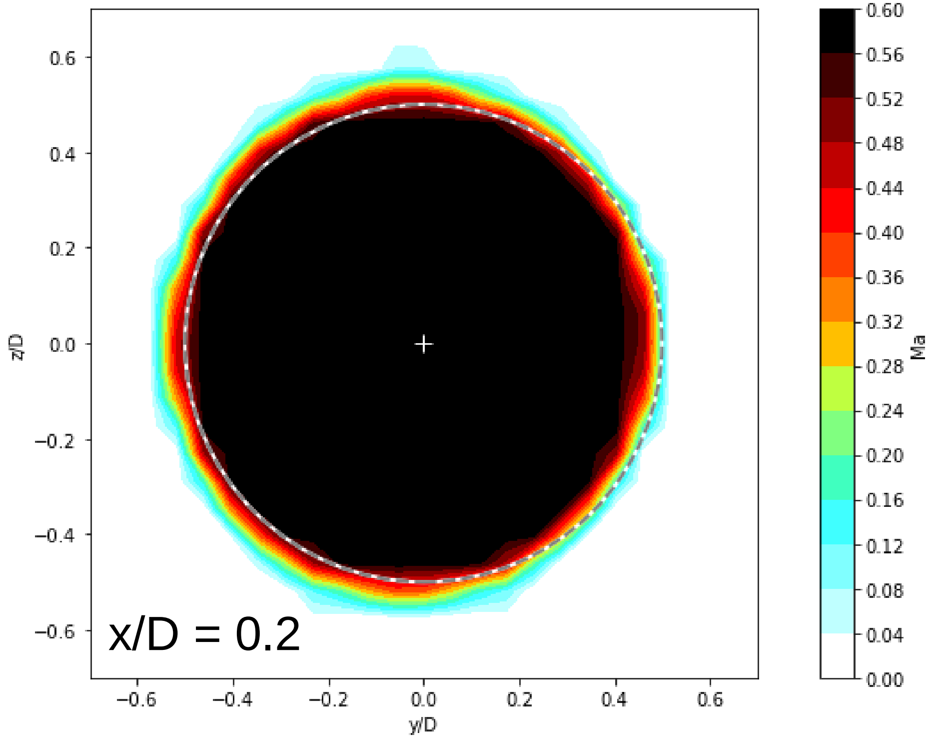
- convergent baseline nozzle
  D = 50 mm

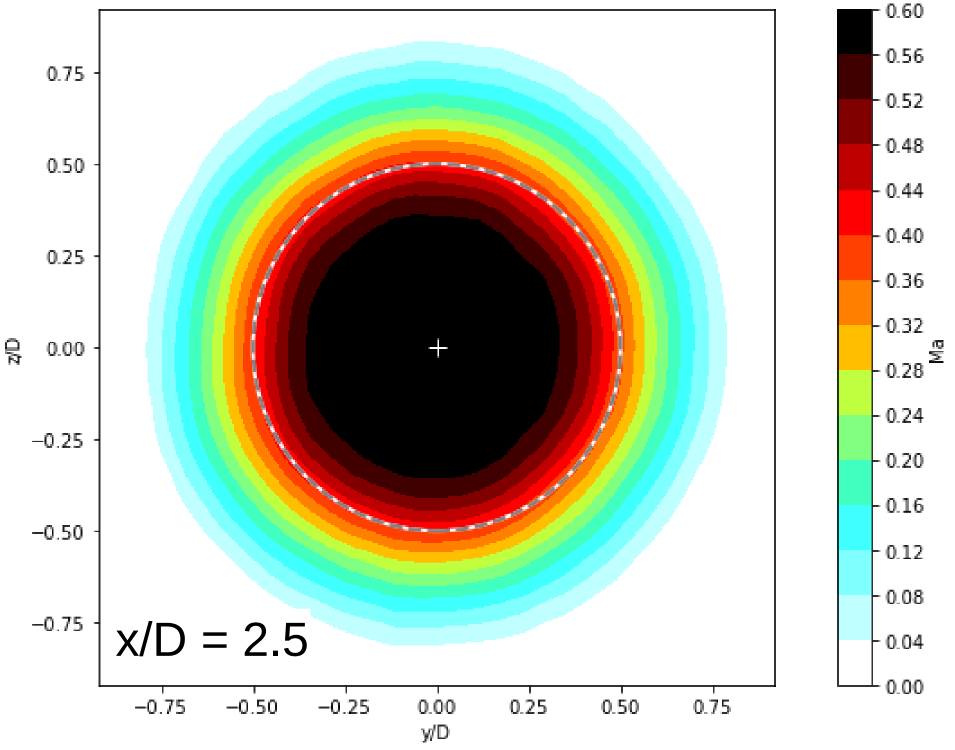
- convergent-divergent nozzle
  NRTClean
  throat diameter
  D_{th} = 50 mm
  end diameter
  D = 52.2 mm



Aerodynamic measurements – isolated convergent-divergent nozzle

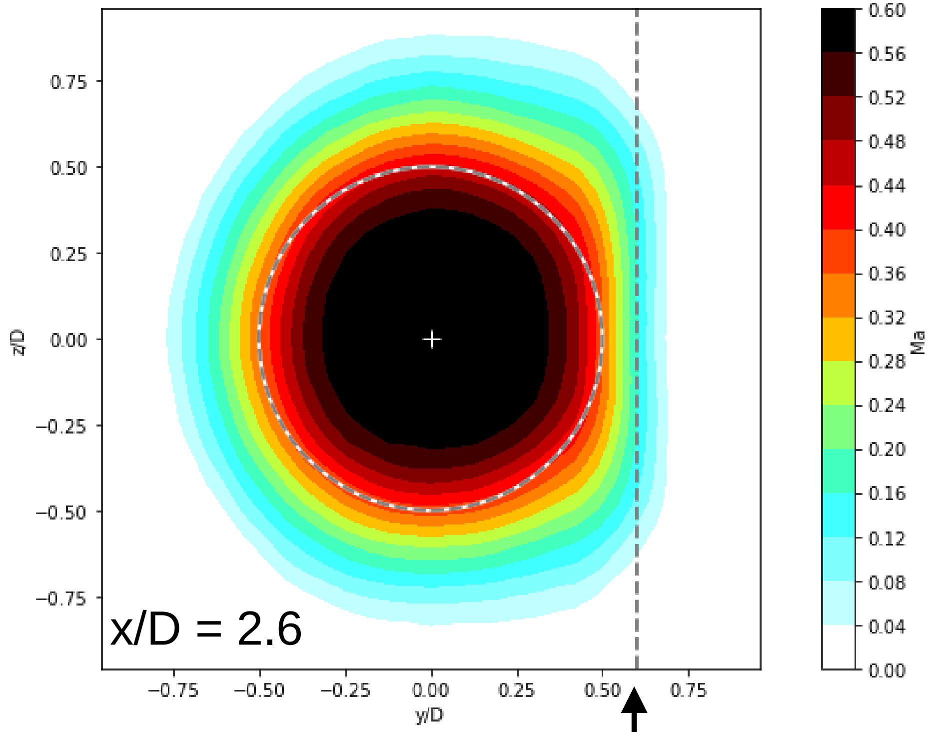
Mach number field at transverse sections of a Ma=0.6 jet
NRTClean



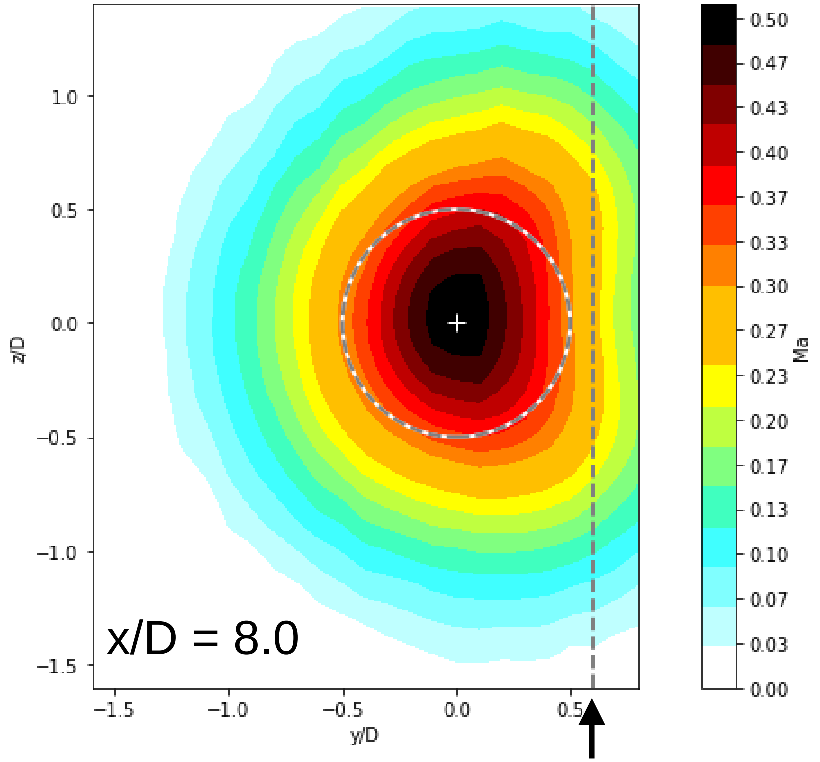


Aerodynamic measurements – baseline nozzle with plate installed

Mach number field at transverse sections
Ma = 0.6



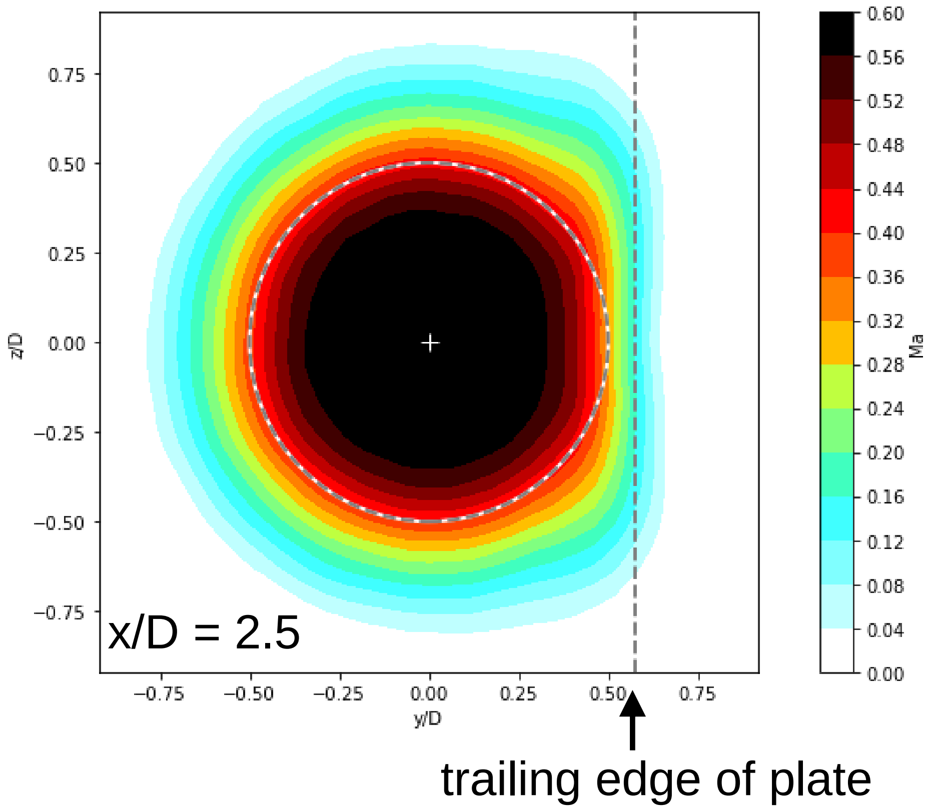
trailing edge of plate

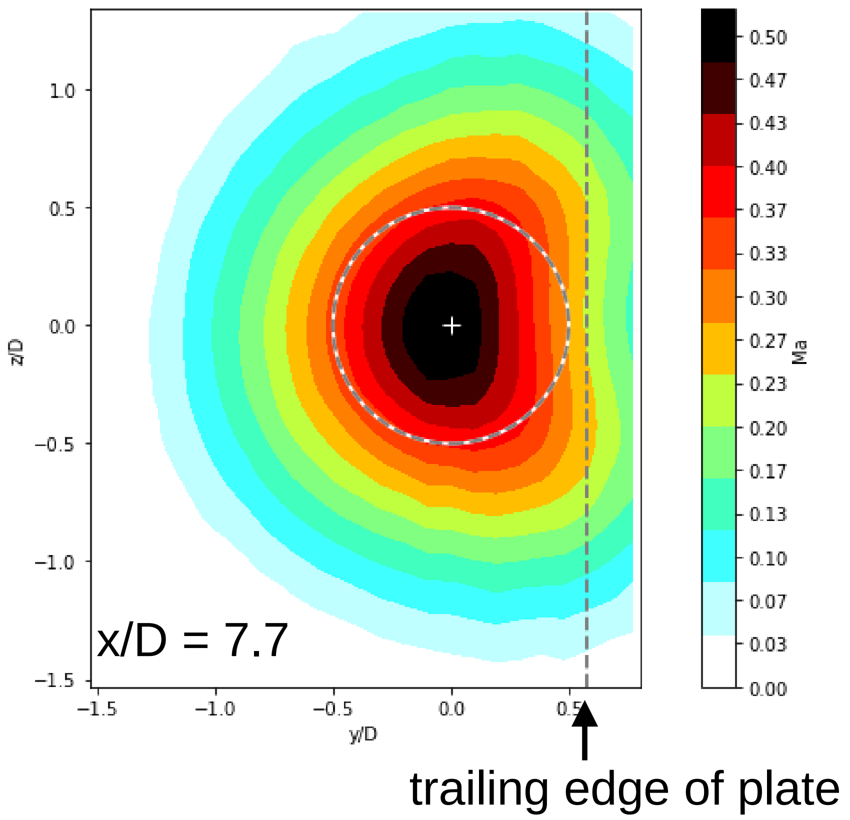


trailing edge of plate

Aerodynamic measurements – convergent-divergent nozzle with plate installed

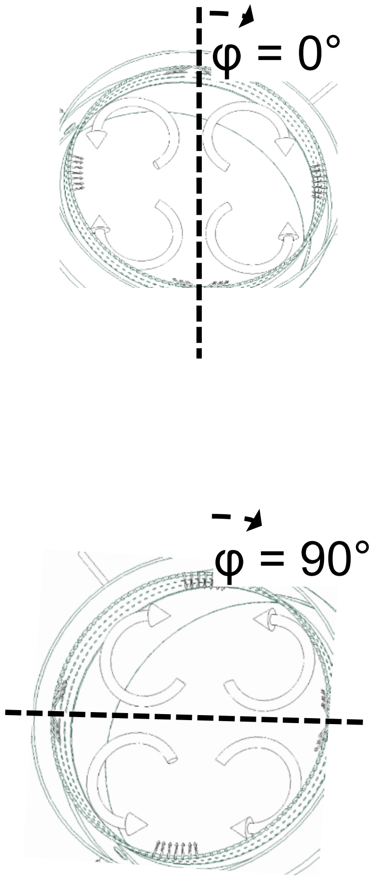
Mach number field at transverse sections of a Ma=0.6 jet
NRTClean

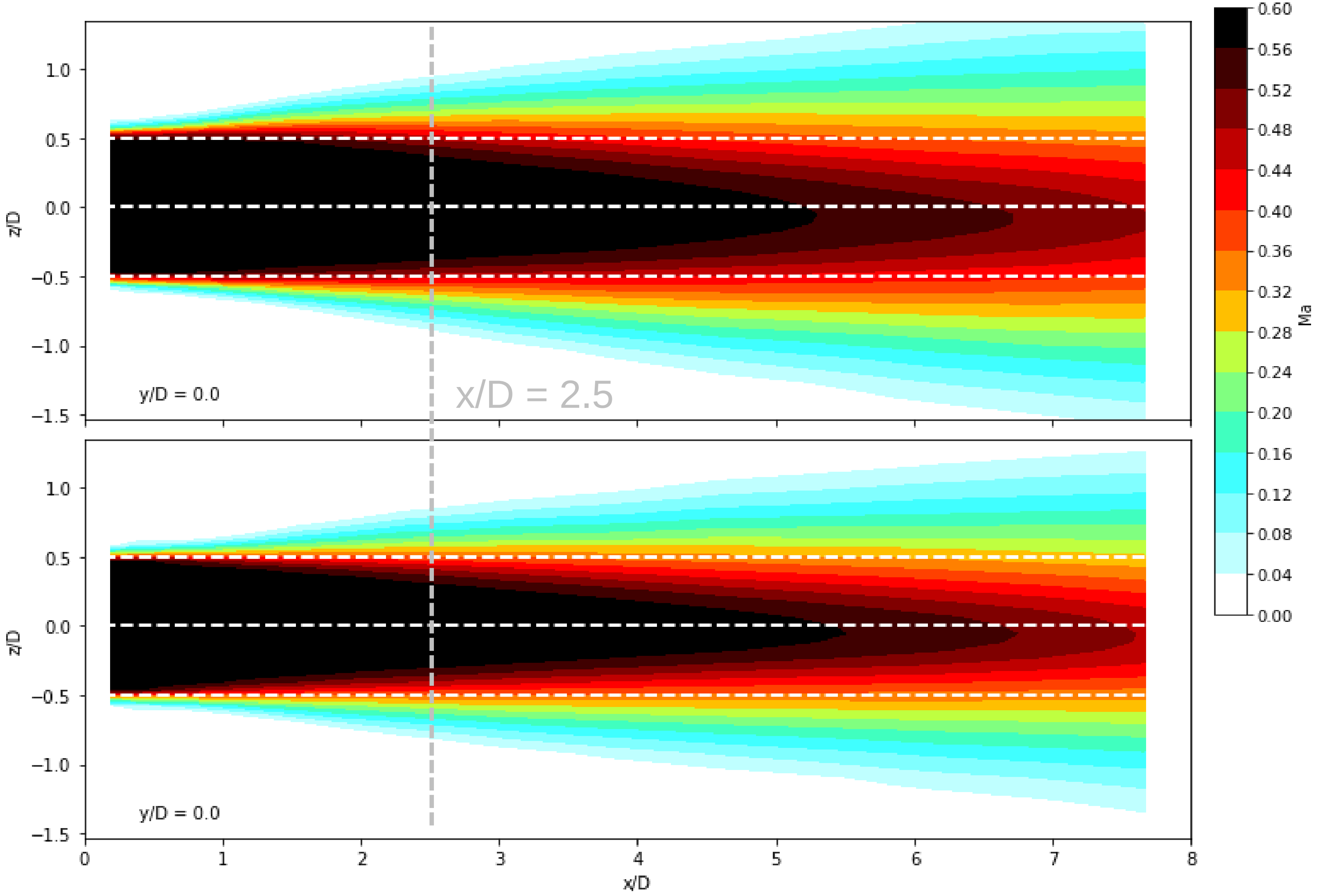




Streamwise profiles – nozzle with vortex generating liner (VoGeL)

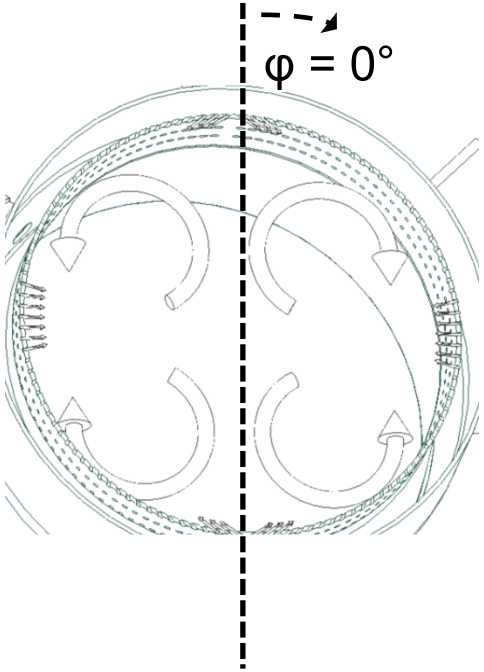
- *NRTOpen*
- orientation
  φ = 0°
  throat diameter
  $D_{th} = 50$ mm
  end diameter
  D = 52.2 mm
- rotated by
  φ = 90°

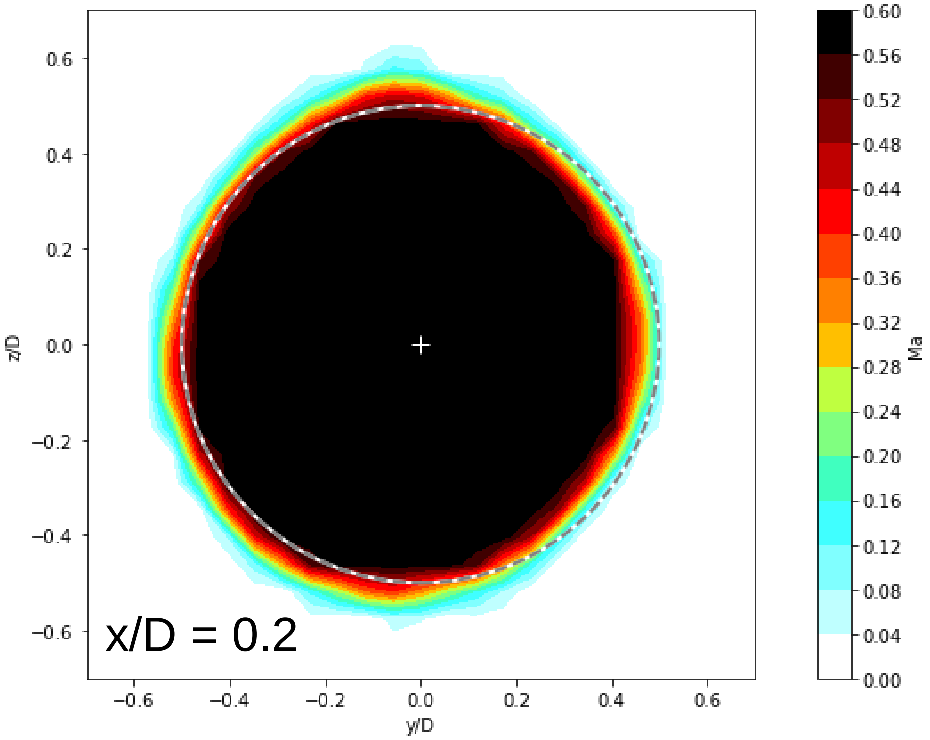


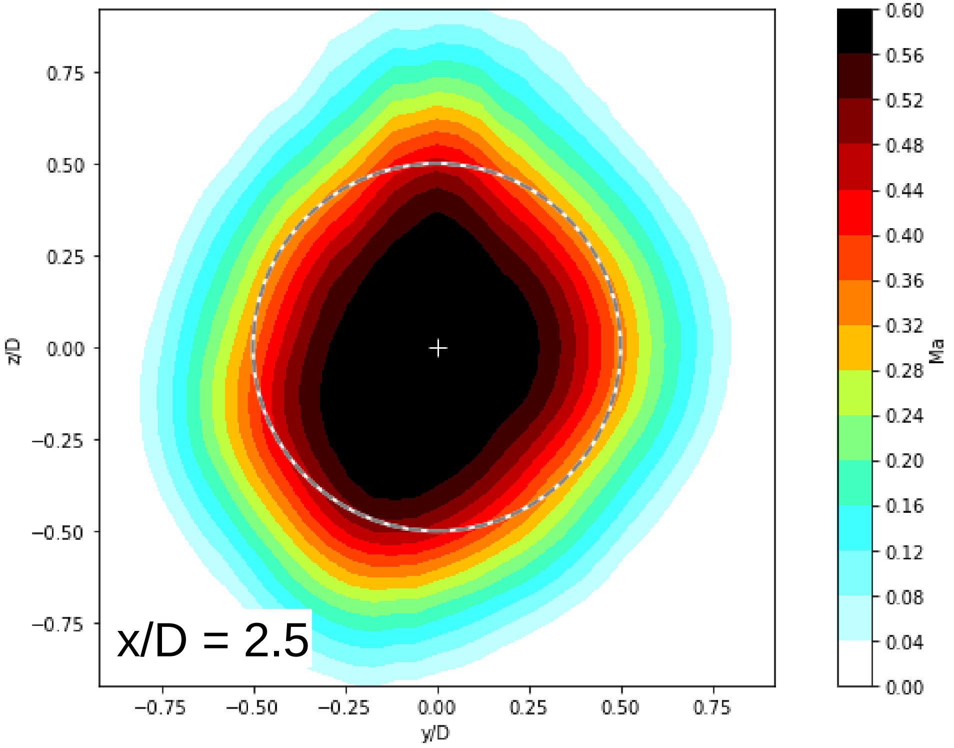


Aerodynamic measurements – isolated VoGeL nozzle

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

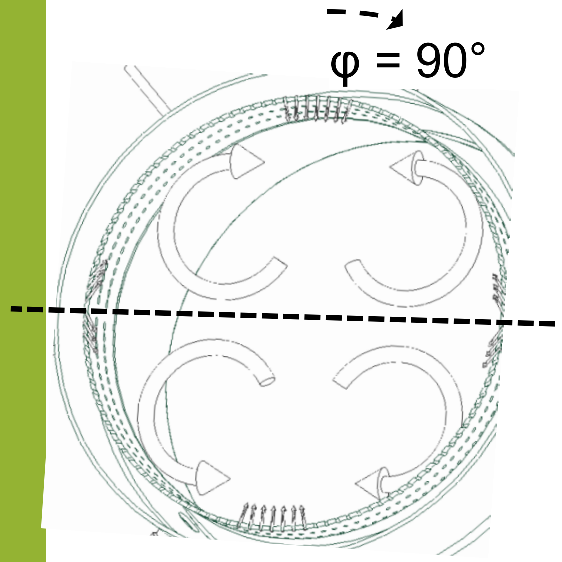


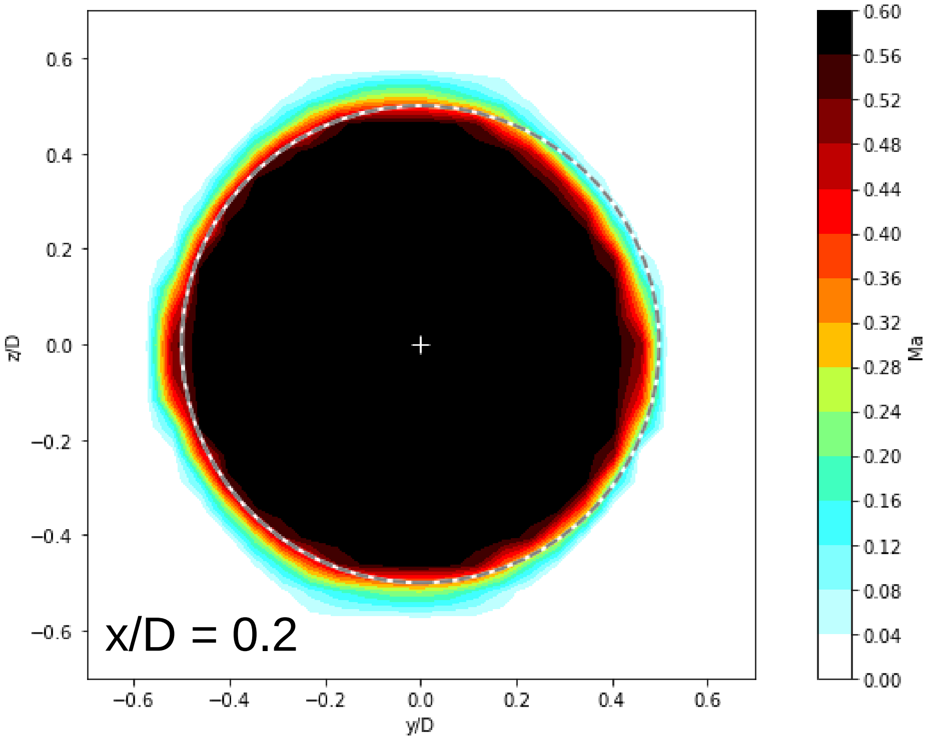


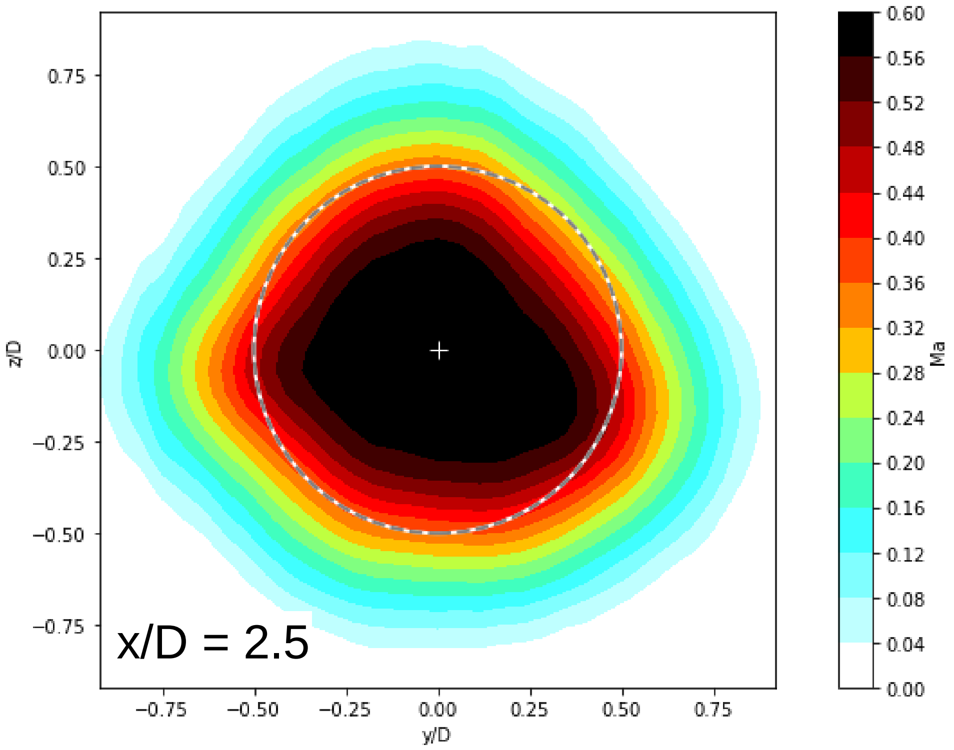


Aerodynamic measurements – isolated VoGeL nozzle

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

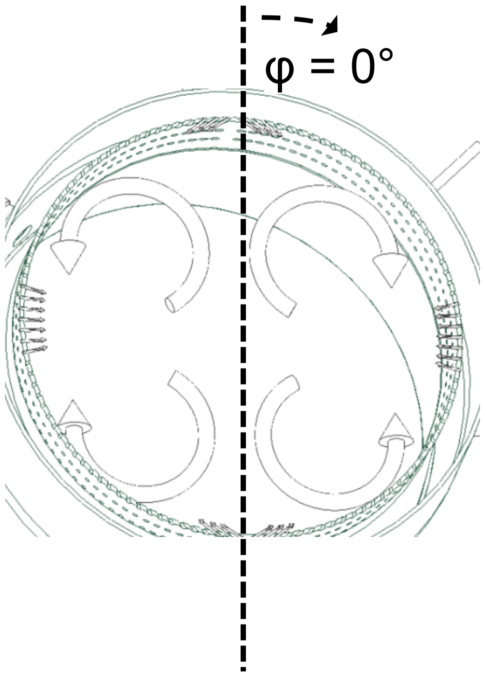


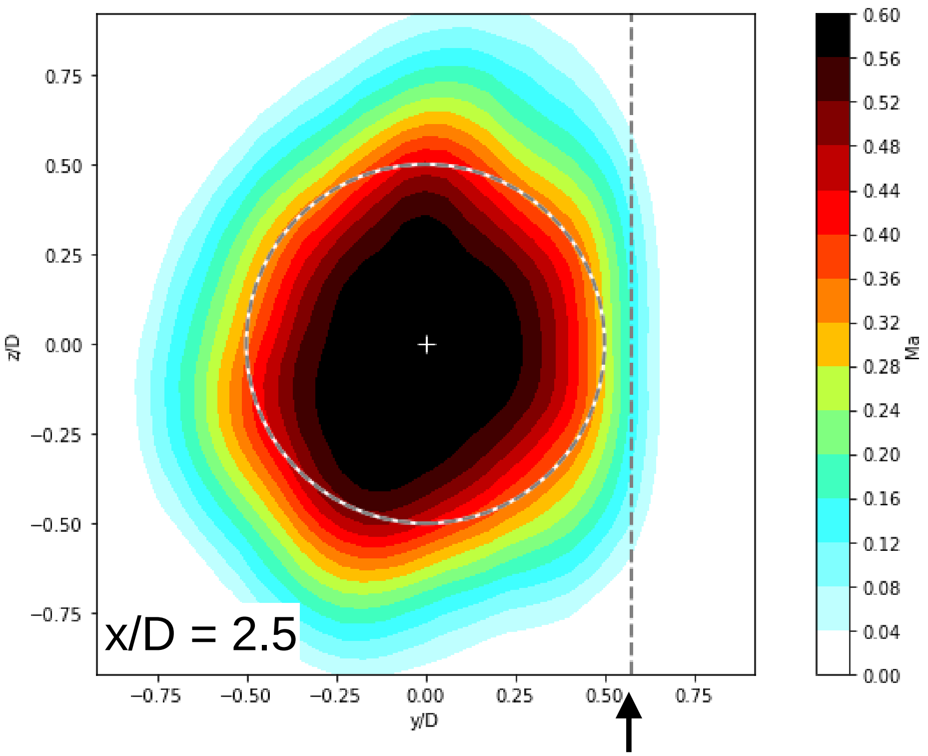




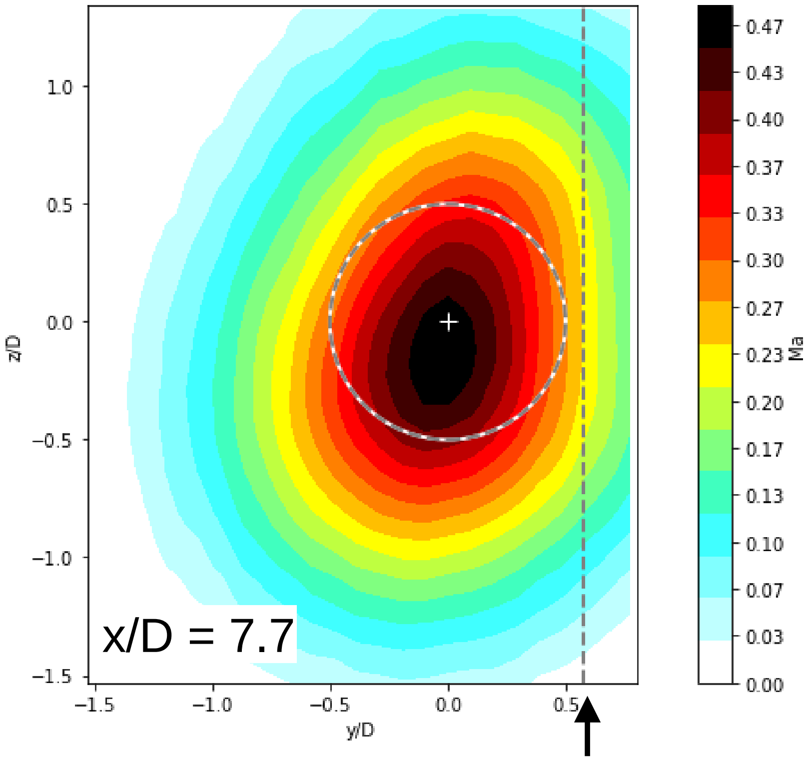
Aerodynamic measurements – VoGeL nozzle with plate installed

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





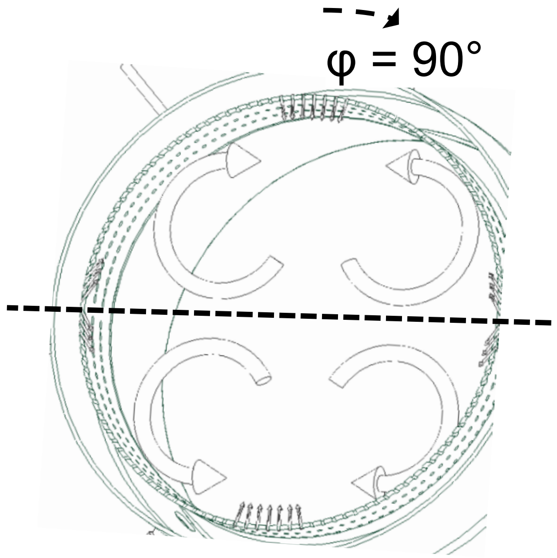
trailing edge of plate

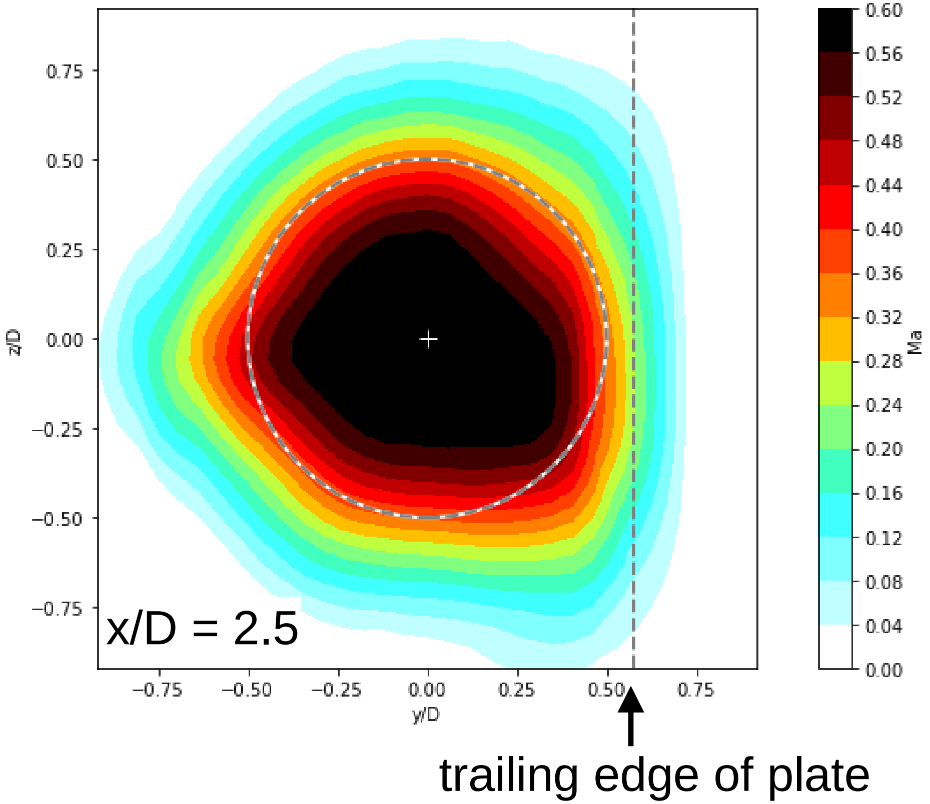


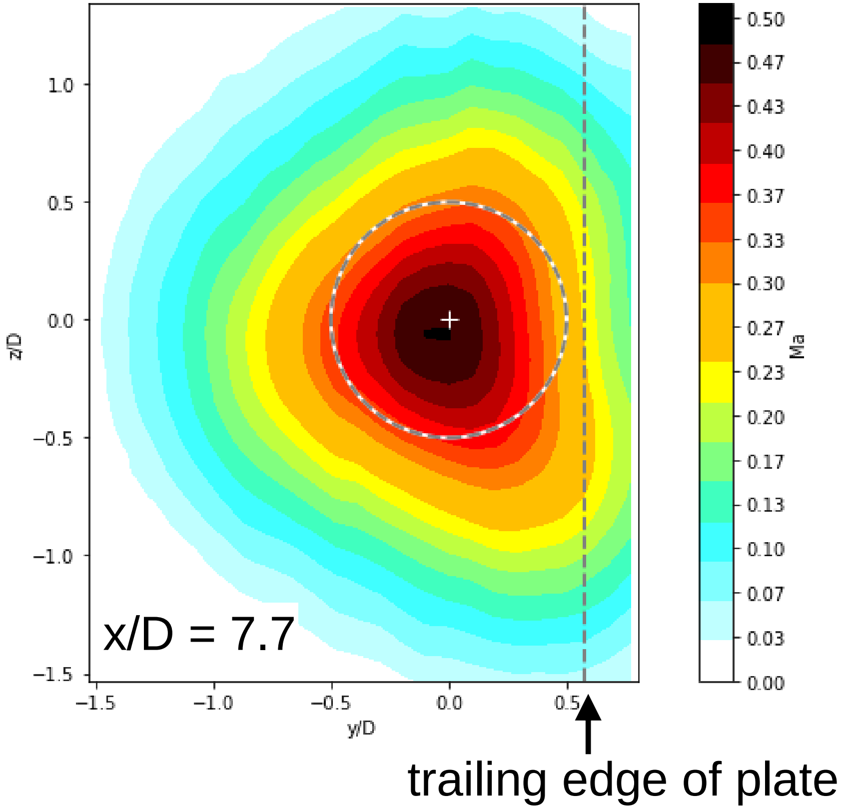
trailing edge of plate

Aerodynamic measurements – VoGeL nozzle with plate installed

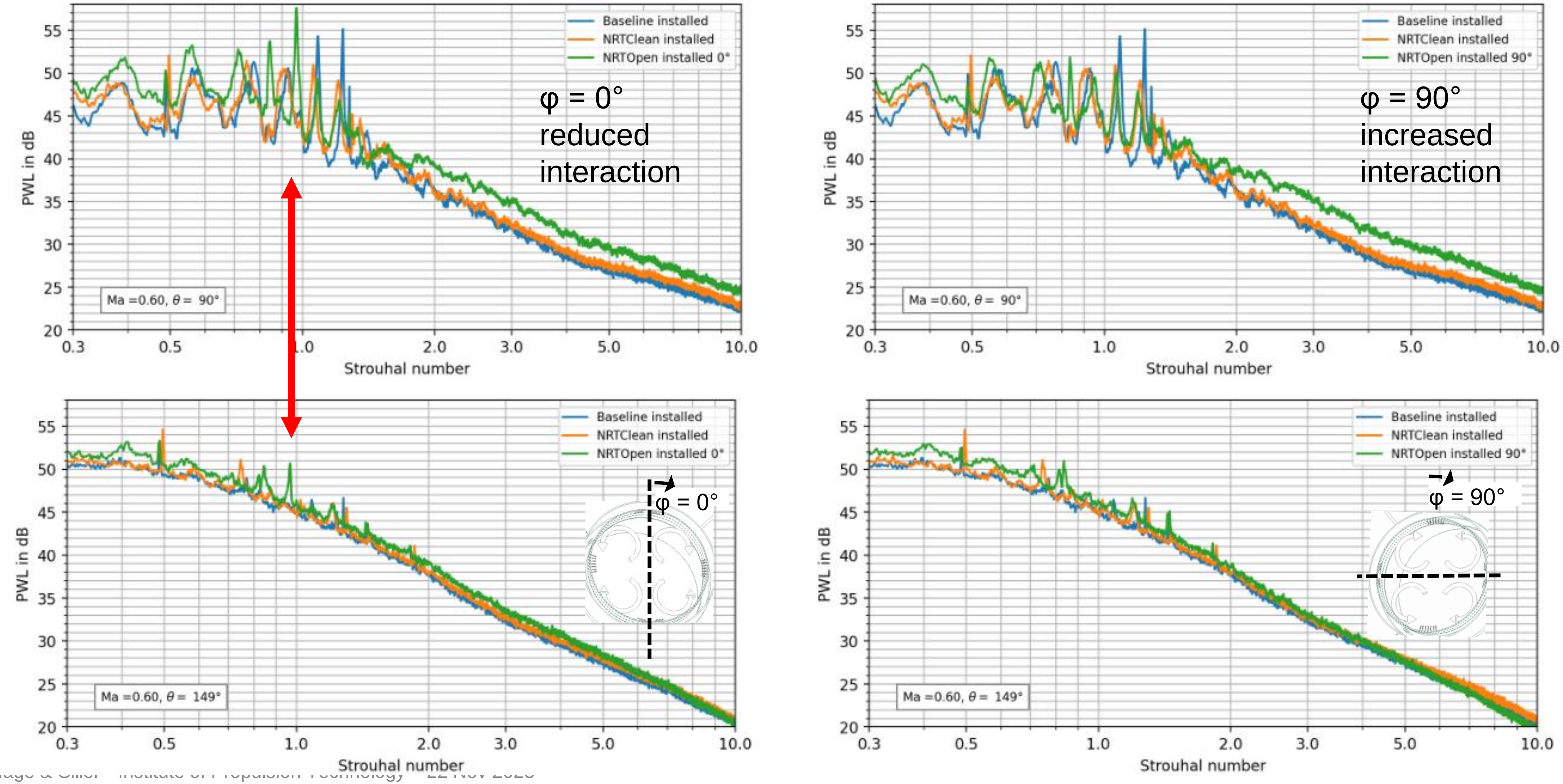
Mach number field at transverse sections of a Ma=0.6 jet
φ = 90° orientation: shearlayer to plate distance decreased – more interaction
NRTOpen



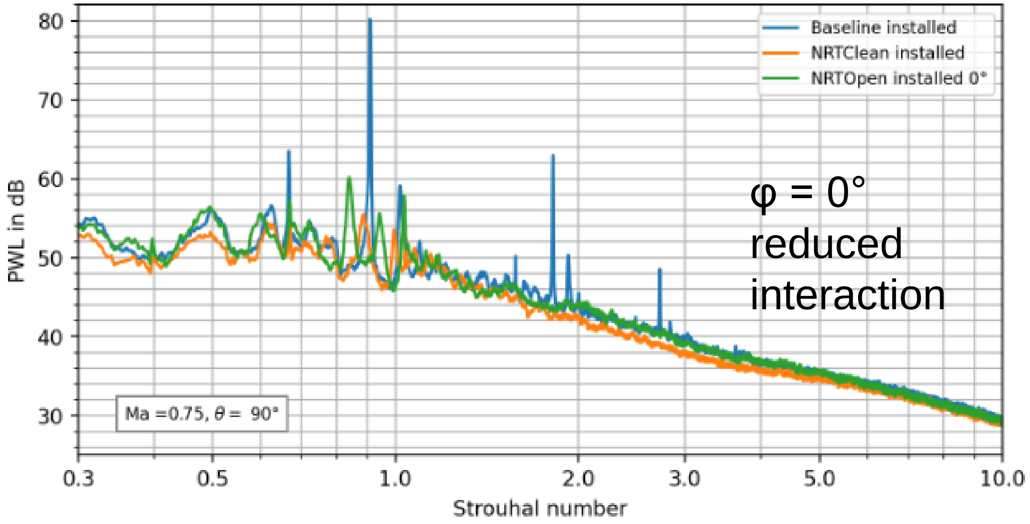


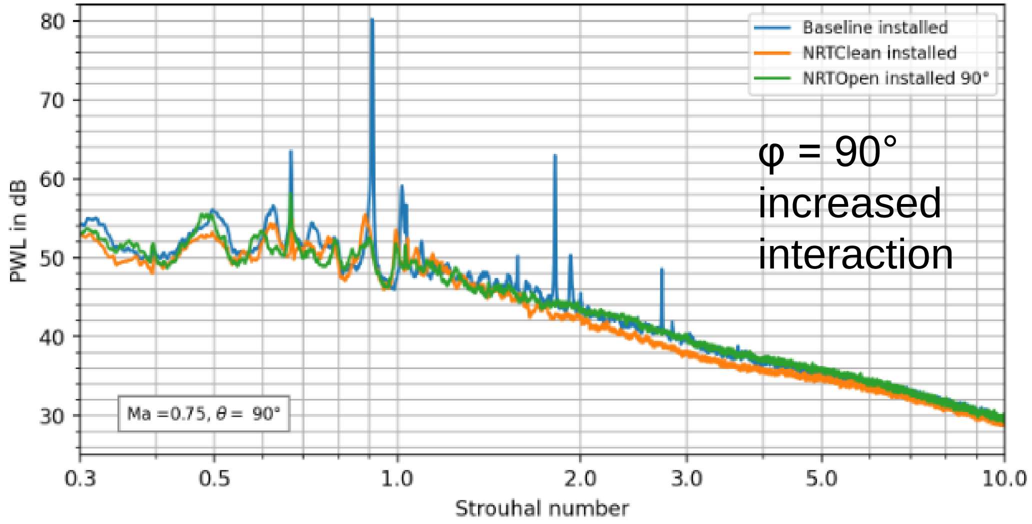


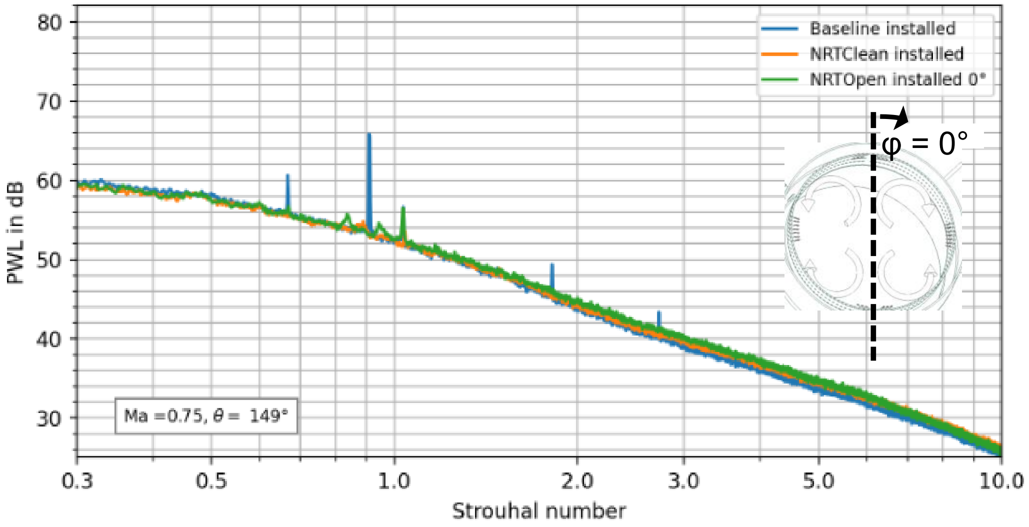
Acoustic measurements – baseline, CD and VoGeL nozzles at Ma=0.6

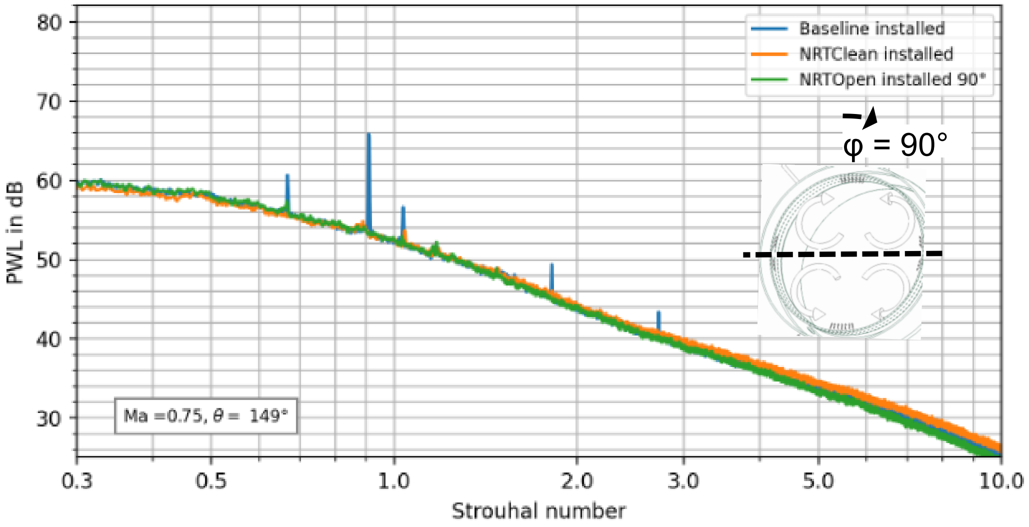


Acoustic measurements – baseline, CD and VoGeL nozzles at Ma=0.75









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??? ☺

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