EU DJINN (Decrease Jet Installation Noise)
Horizon 2020
GA No 861438

DLR - JExTRA
Berlin, Germany

VKI - JAFAAR
Rhode-Saint-Genèse, Belgium

SOTON - Doak Lab
Southampton, UK

CNRS - Bruit et Vent
Poitiers, France

ISOLATED JET NOISE
CROSS-COMPARISON
IN VARIOUS EU TEST FACILITIES
GEOMETRIC FAR-FIELD DATA VS SMALL R/D_J TESTS

NASA Glenn - SHJAR
Cleveland, Ohio, USA

Jente, Christian, DLR Braunschweig, Germany
Henri Siller, DLR - JExTRA Berlin, Germany
Julien Christophe, VKI - JAFAAR, Rhode-Saint-Genèse, Belgium
Jack Lawrence, SOTON - Doak Lab, Southampton, UK
+ Igor Maia / Peter Jordan, CNRS – Bruit et Vent, Poitiers, France
+ Annabel Markesteijn / Sergey Karabasov, QMUL providing NASA SJET data w/permission

DLR

Test case

- Model:
  Single stream engine nozzle, round/circular exit Ø50mm
- Operations:
  $M_j = M_{ac} = 0.6$, $U_j = 204.2$ m/s
  ISA test conditions: $p_0 = 101325$ Pa, $T_0 = T_j = 288.15$K (15°C)
  NPR = 1.27550, $T_{t,j}/T_{t,0} = 1.072$, $T_j/T_0 = 1$

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NASA - SHJAR

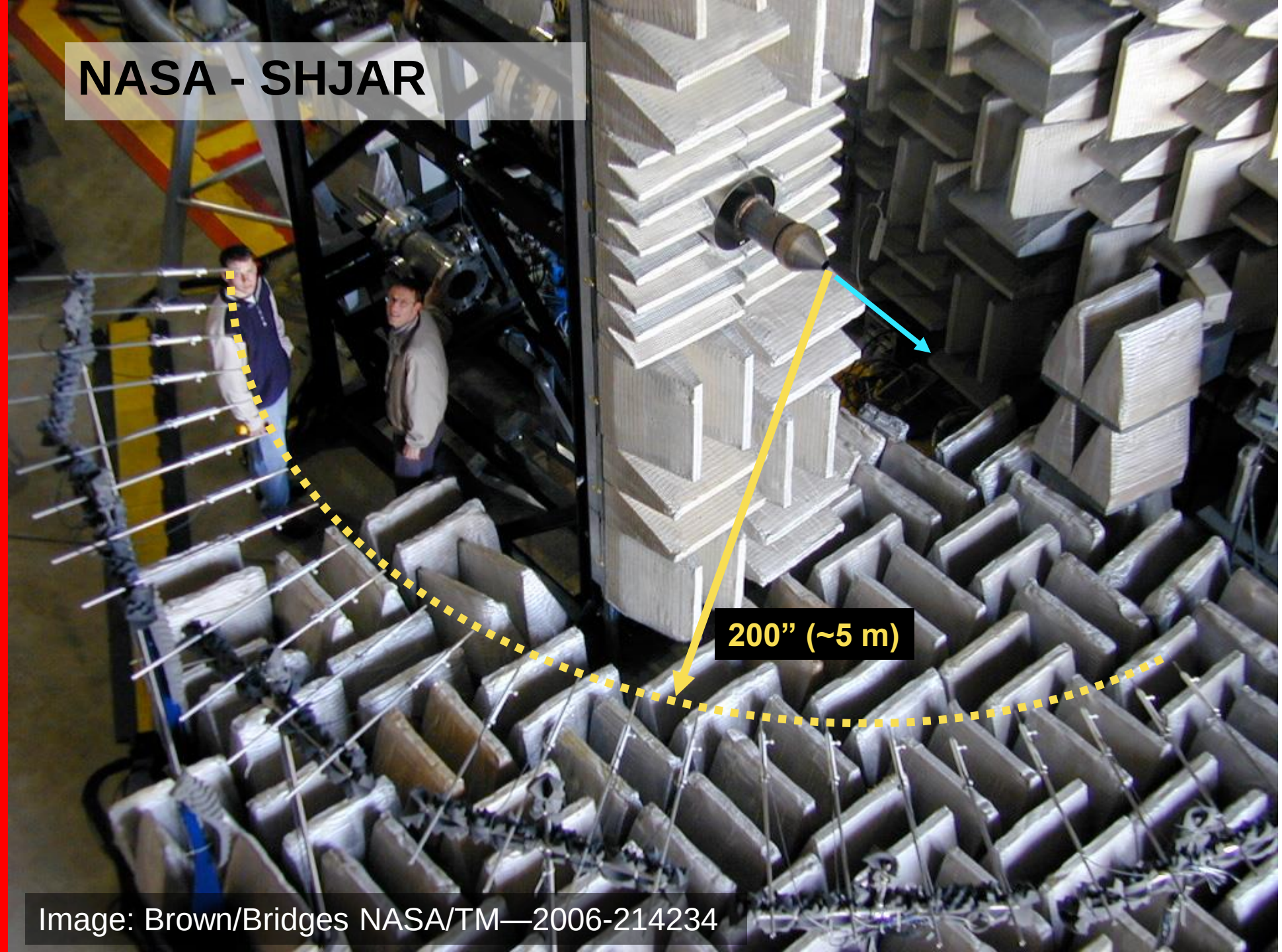

Image: Brown/Bridges NASA/TM—2006-214234

Reference data for geometric far field

Spherical array / arc
R/D_j=100* (large)
* assuming SMC000, 2” nozzle

Polar angle/resolution
24 Mics
$\Theta_{aft\text{-}front,eng.exit}$ [°] = 25…130
$\Delta\theta \sim 5°$

NASA - SHJAR

Image: Podboy NASA/GT2012-69801

Reference data for geometric far field

Spherical array / arc
R/D_j=100* (large)
* assuming SMC000, 2” nozzle

Polar angle/resolution
24 Mics
$\Theta_{aft\text{-}front,eng.exit}$ [°] = 25…130
$\Delta\theta$ [°] ~ 5

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Southampton ISVR - Doak Lab

Cylindrical array / line
$R_{cyl}/D_j=42$

12 Mics
$\theta_{aft\text{-}front,\ eng.exit}$ [°]
= 45 …140
$\Delta\theta$ [°] ~ 8

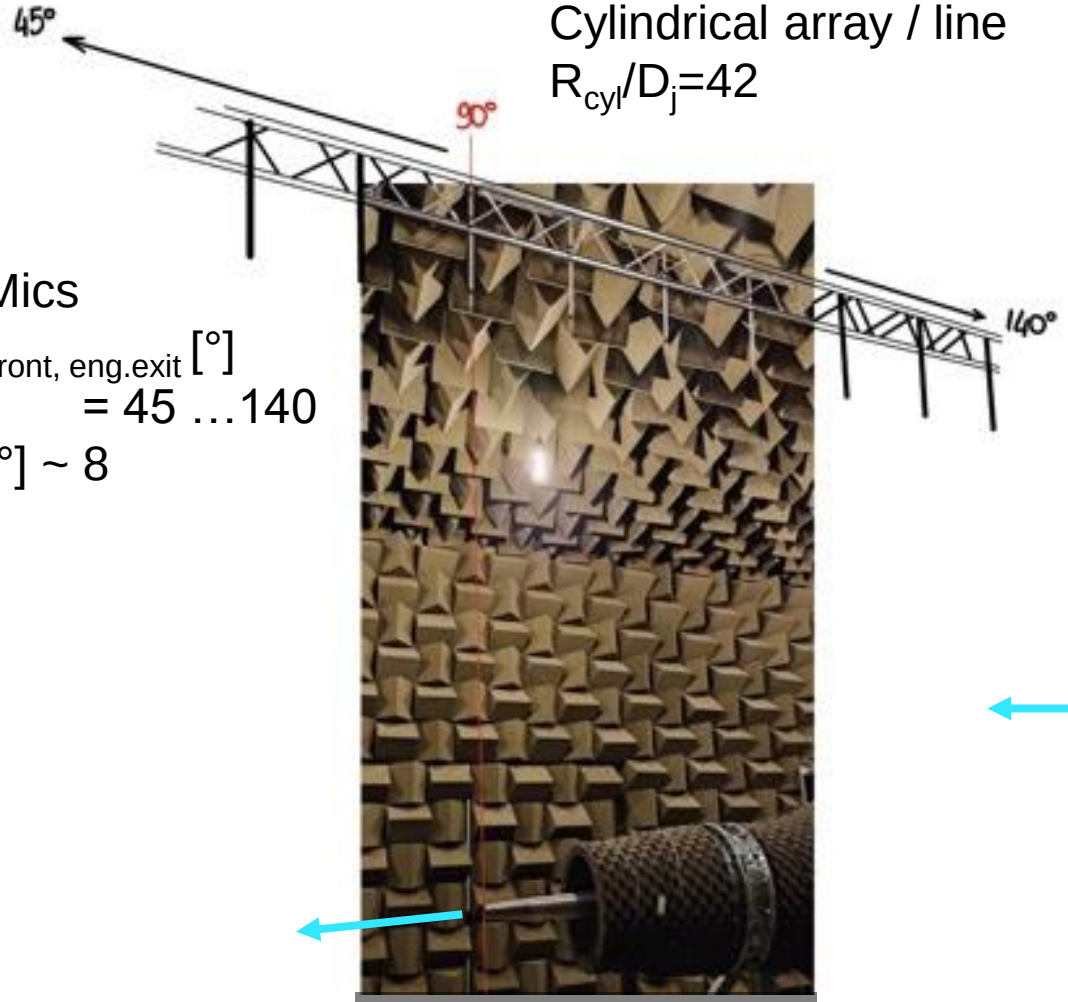


Image: J. Lawrence

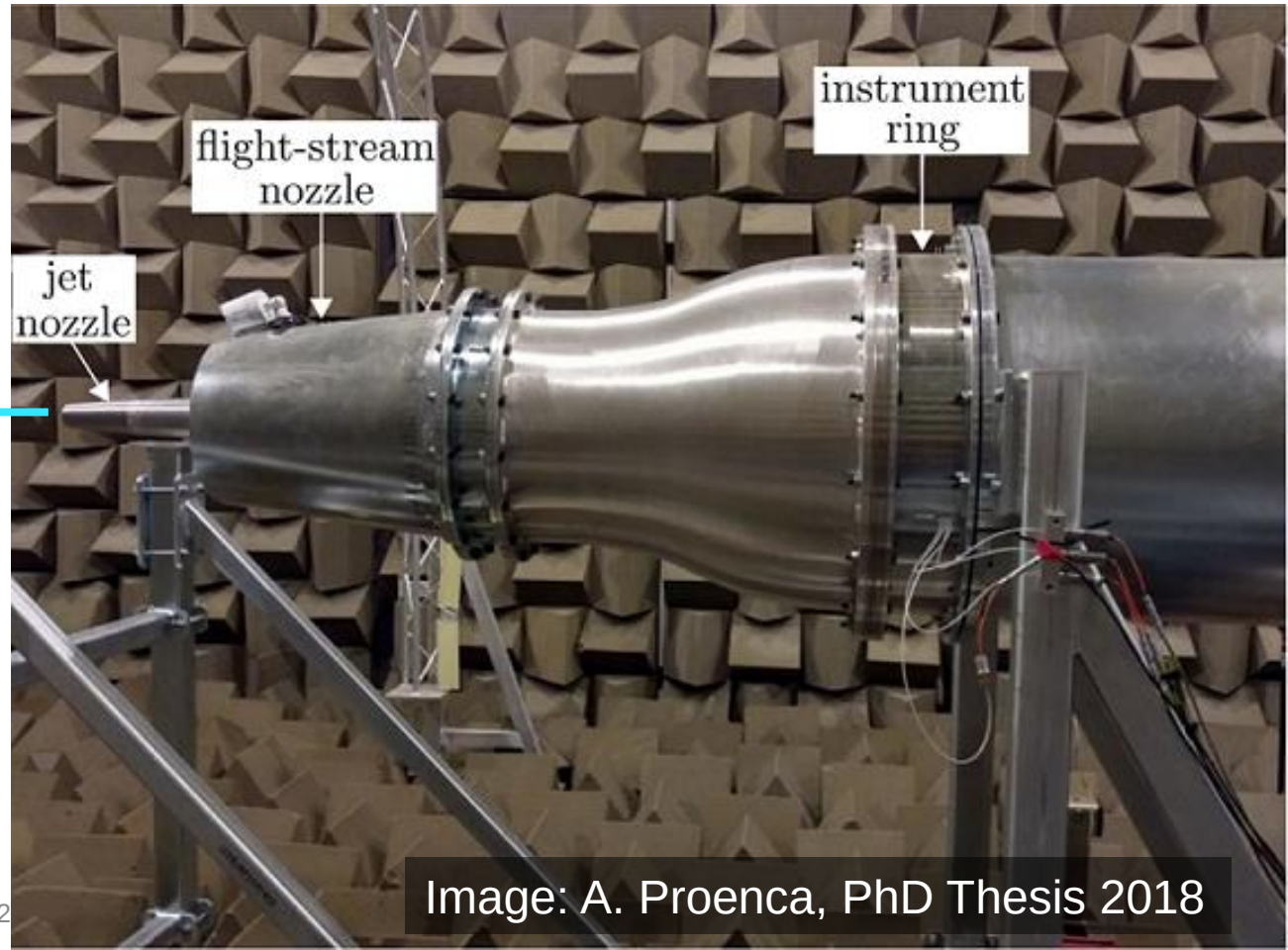
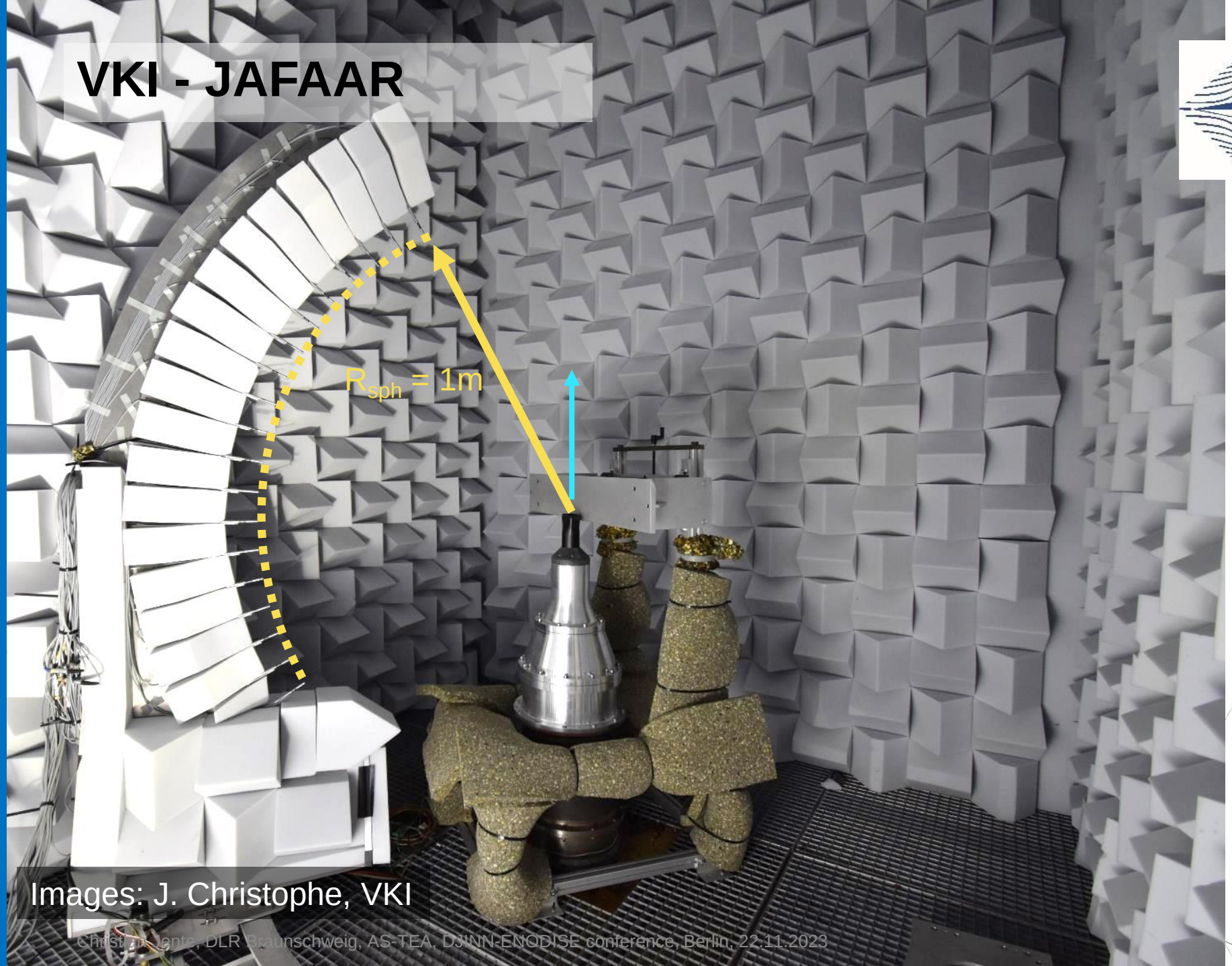


Image: A. Proenca, PhD Thesis 2018

VKI - JAFAAR



Images: J. Christophe, VKI

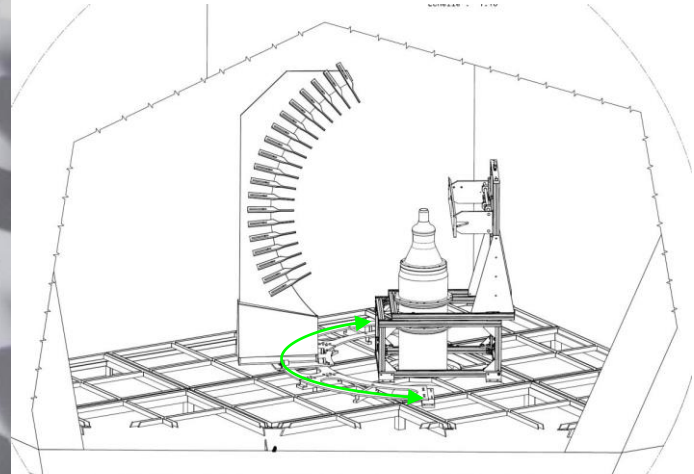
von KARMAN INSTITUTE FOR FLUID DYNAMICS

Spherical array / arc
R/D_j=20

Polar angle/resolution
18 Mics

$\Theta_{aft\text{-}front,eng.exit}$ [°] = 30…115
$\Delta\theta$ [°] = 5

Azimuthal resolution:



CNRS – Bruit et Vent

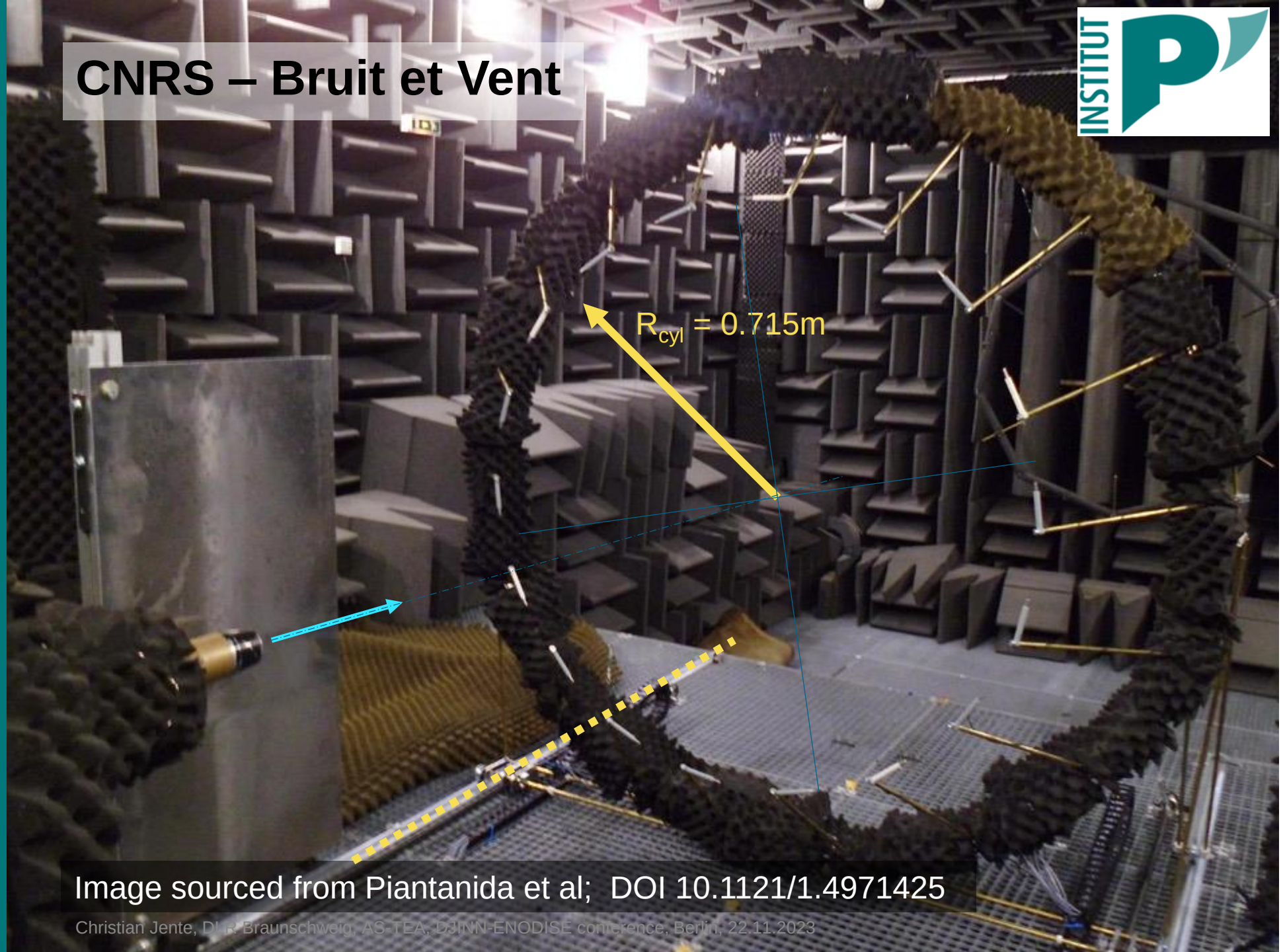


Image sourced from Piantanida et al; DOI 10.1121/1.4971425

Cylindrical array / line
R_{cyl}/D_j=14.3

Polar angle/resolution
by traversing in X
18 X-Positions

$\Theta_{aft\text{-}front,eng.exit}$ [°] = 20…95
$\Delta\theta$ [°] = 5

Azimuthal resolution:
18 Mics ($\Delta\psi$ = 20°)
grazing incidence

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DLR Berlin JExTRA

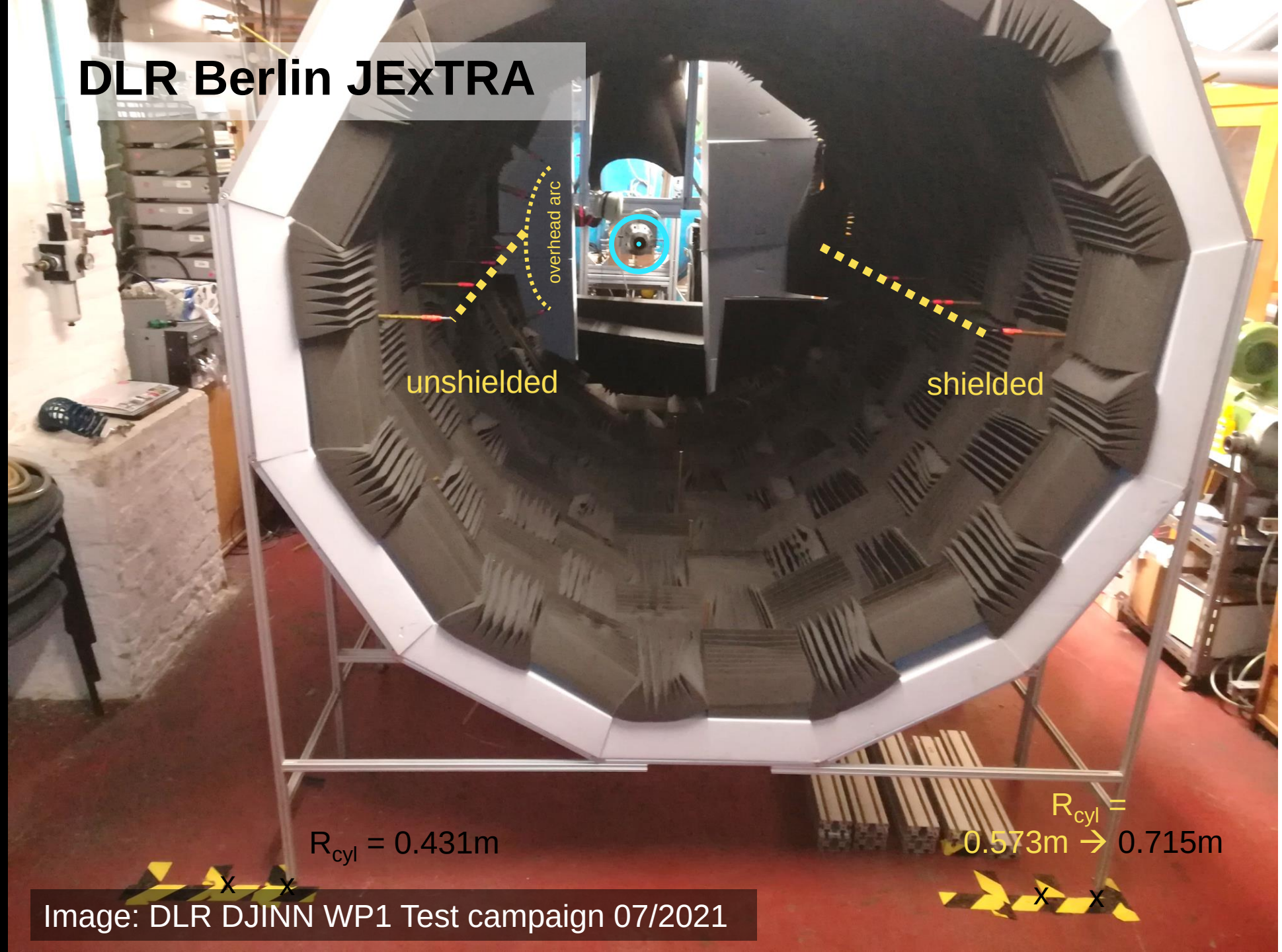

Image: DLR DJINN WP1 Test campaign 07/2021

Cylindrical array / Line
R_{cyl}/D_j=11.5 (default)

Polar angle/resolution
8 Mics (2022)

$\Theta_{aft\text{-}front,eng.exit}$ [°] = 16…110
$\Delta\theta$ [°] = 10…20

R_{cyl}/D_j=8.6
R_{cyl}/D_j=14.3 → for direct cross-comparison to CNRS

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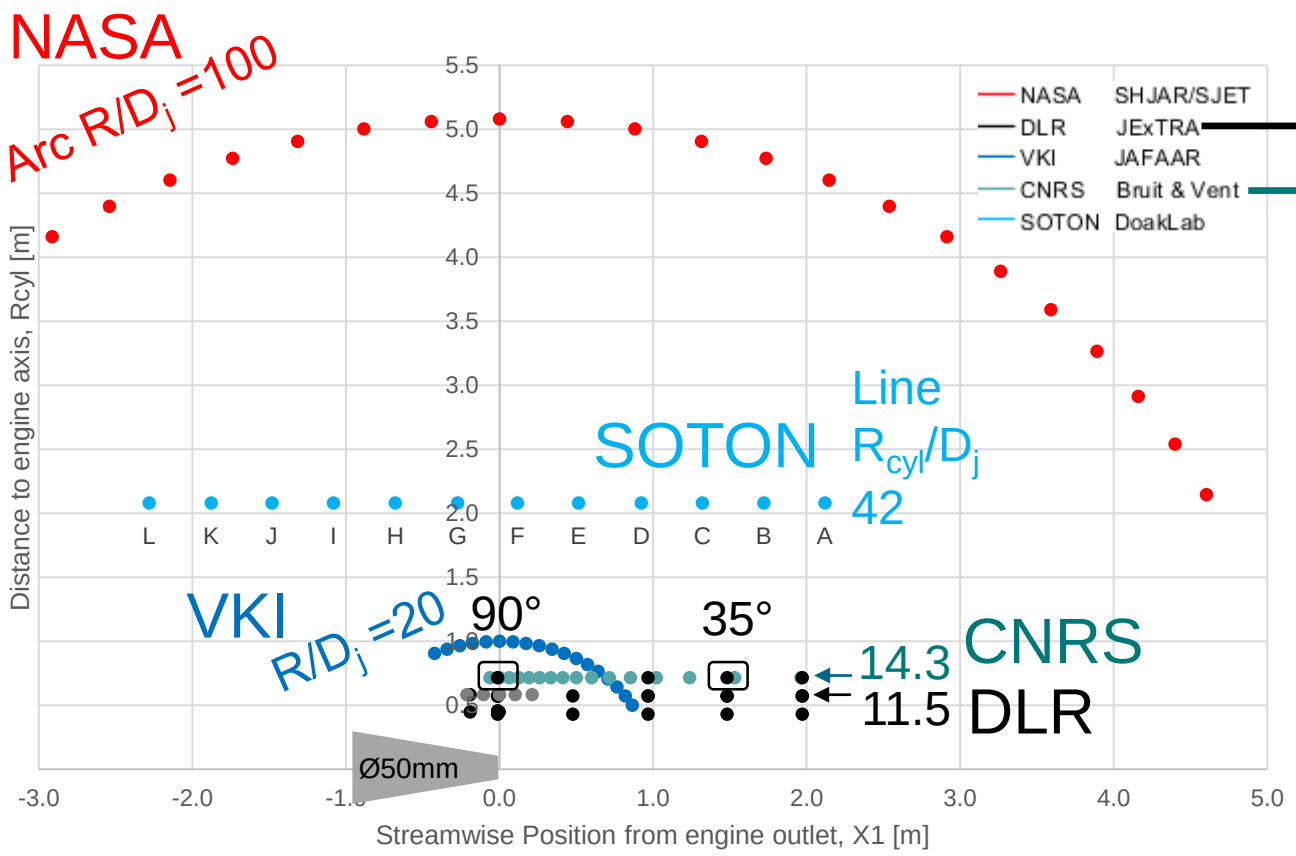
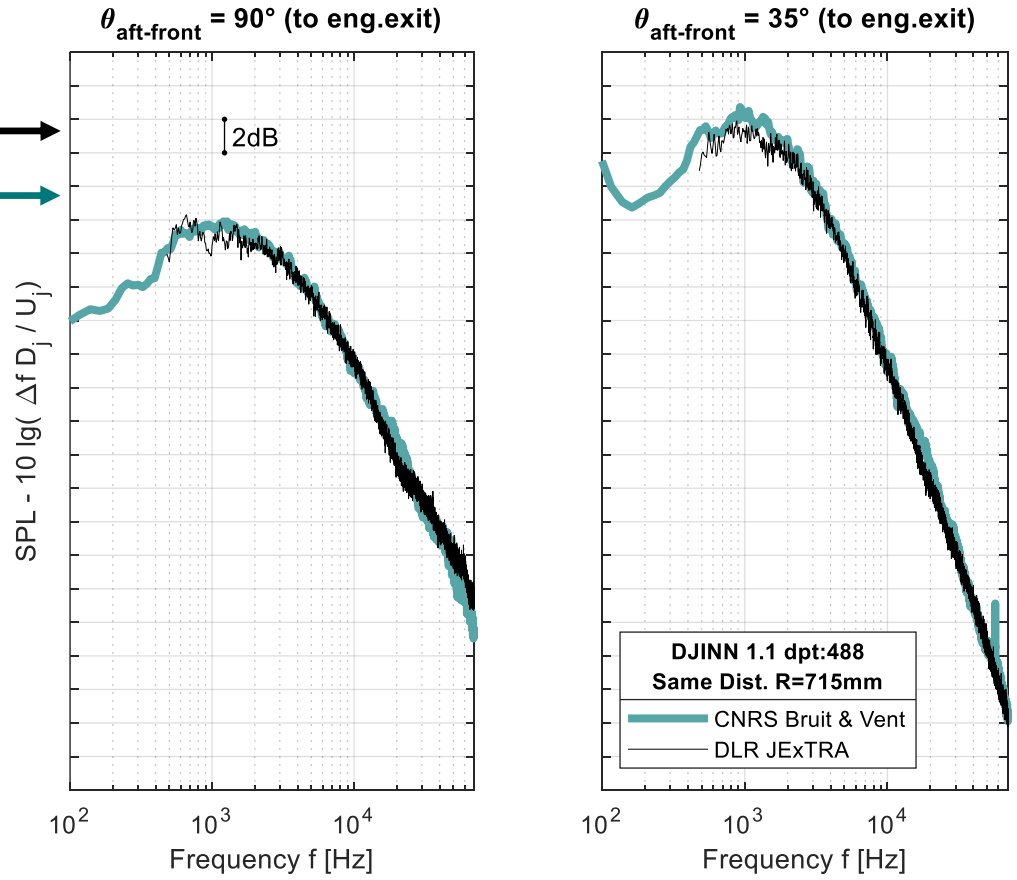
Comparison of Microphone Setup

Two small test facilities, same position: Does the data match?





Published by H. Siller et al in: Jet-noise investigations in a small scale facility AIAA 2022-2865

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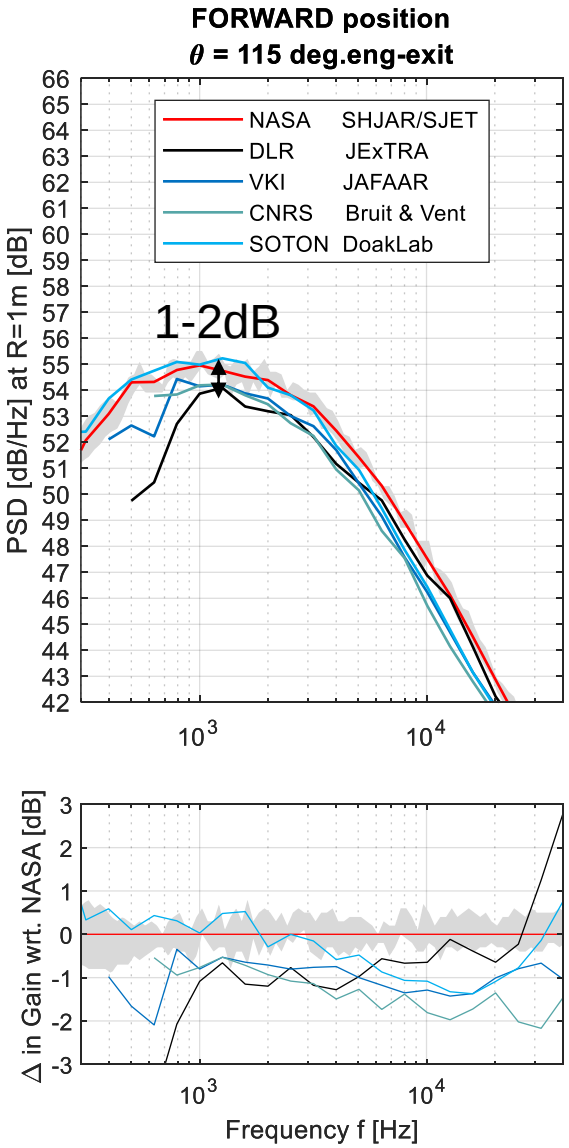
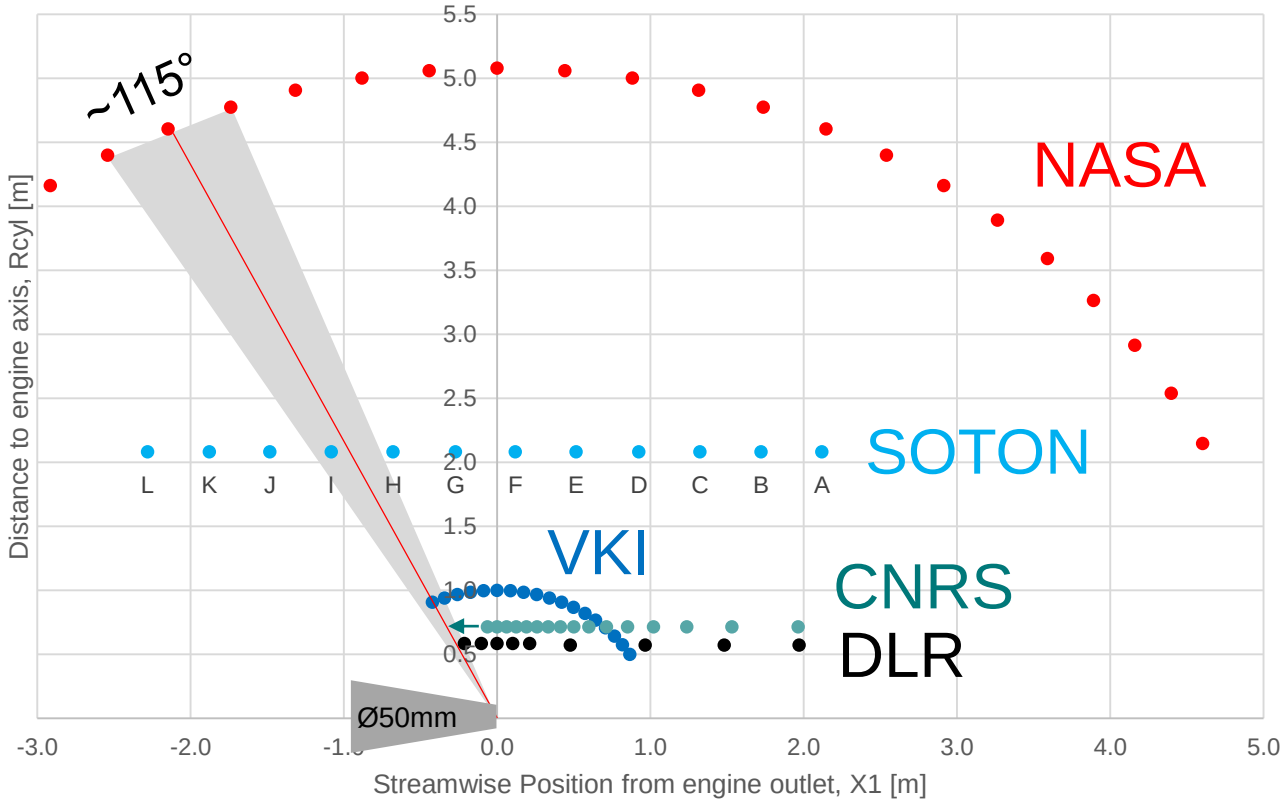
PSD / Narrowband spectrum w.r.t. engine exit (x=0)





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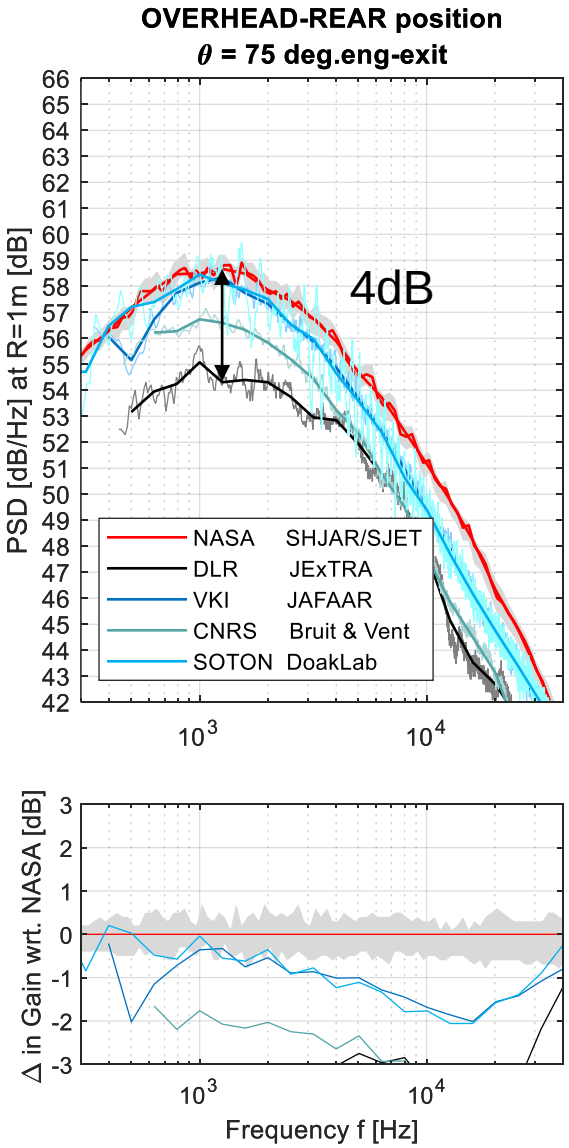
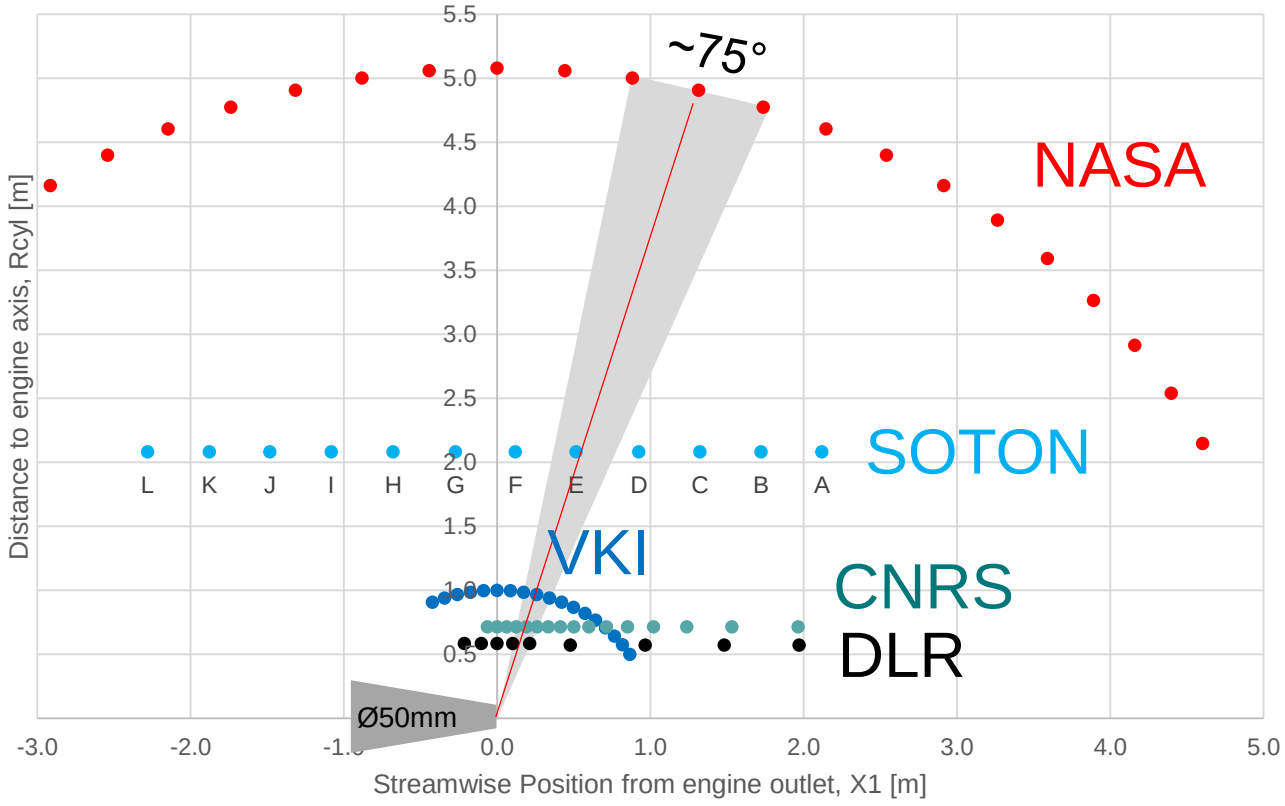
PSD / Narrowband spectrum w.r.t. engine exit (x=0)





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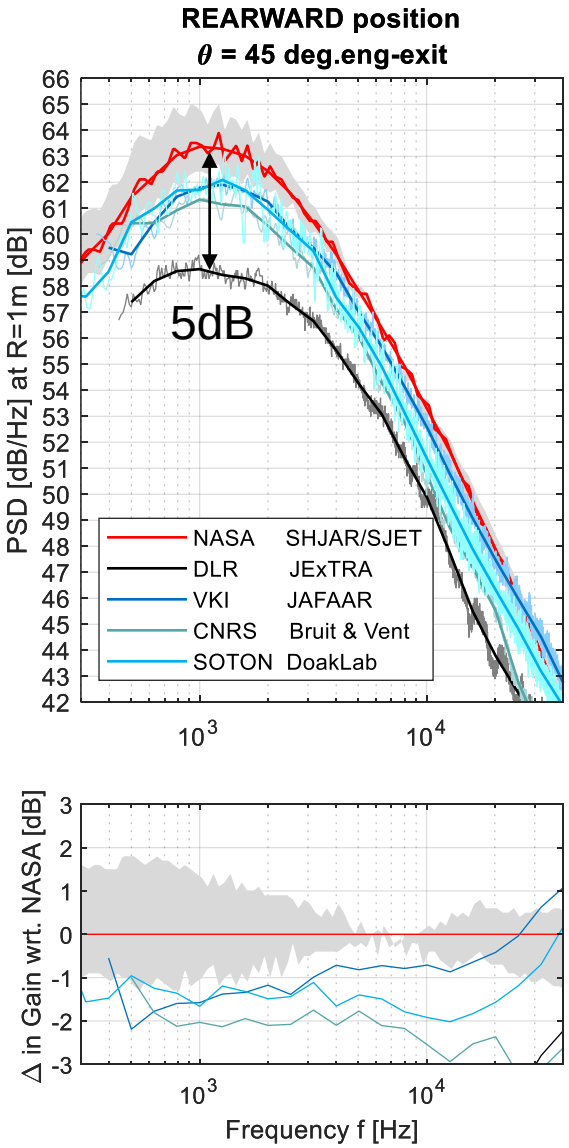
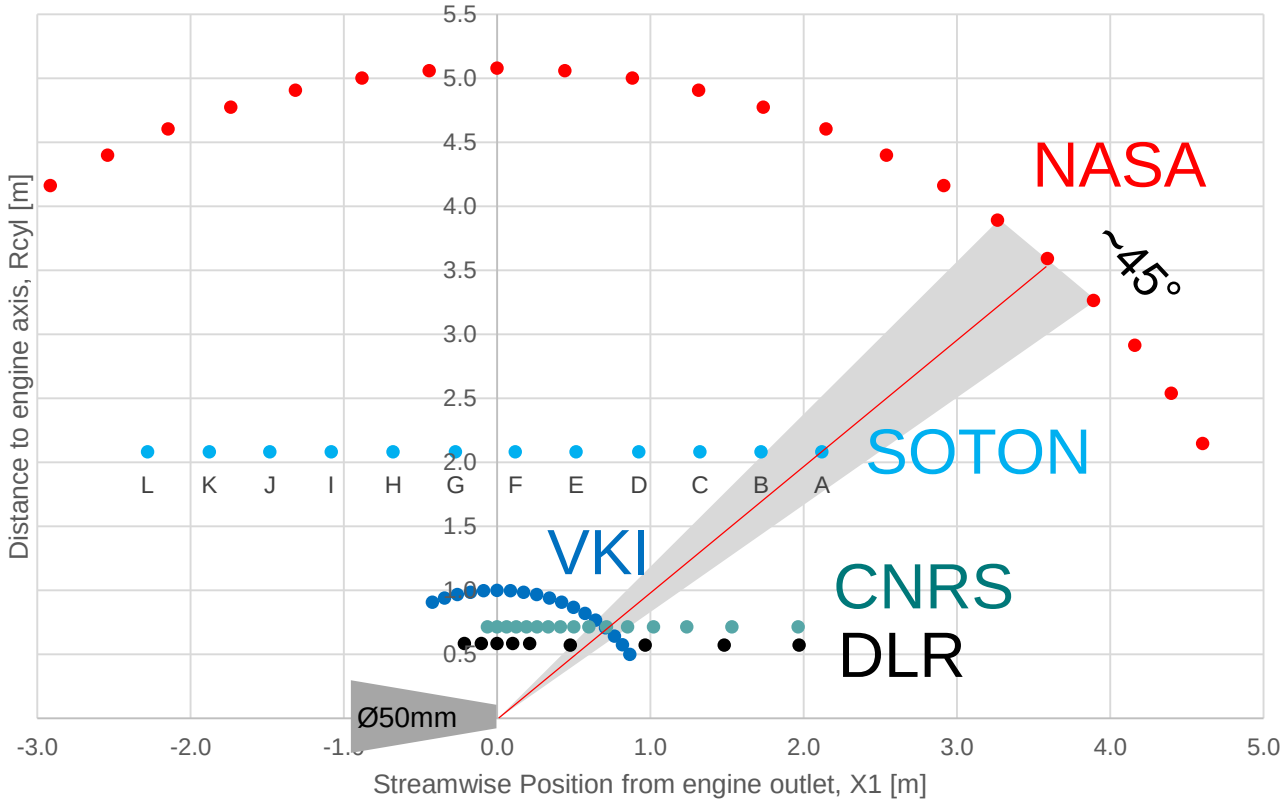
PSD / Narrowband spectrum w.r.t. engine exit (x=0)





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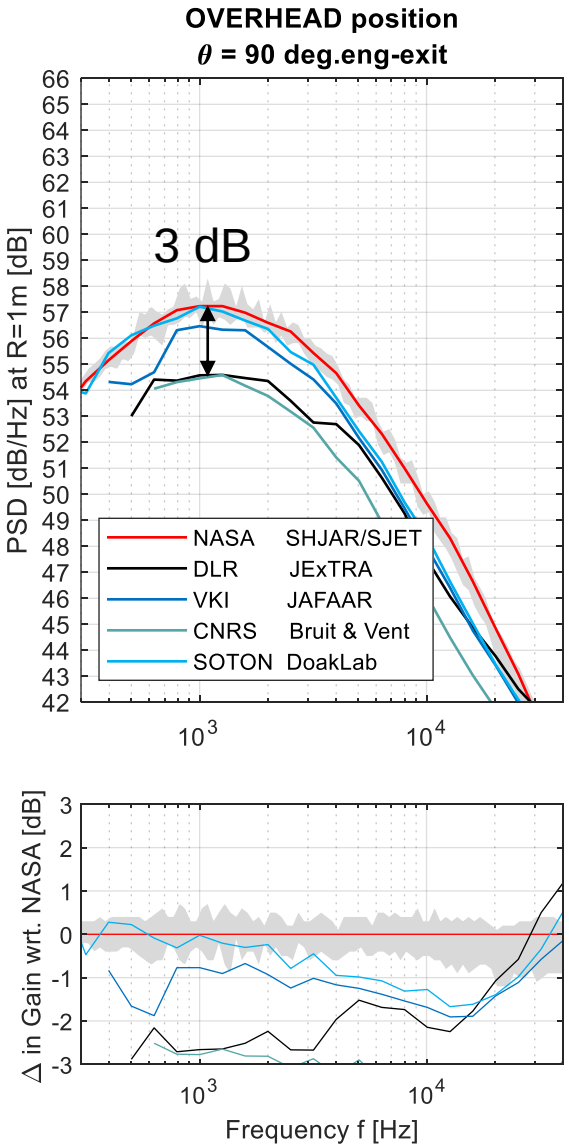
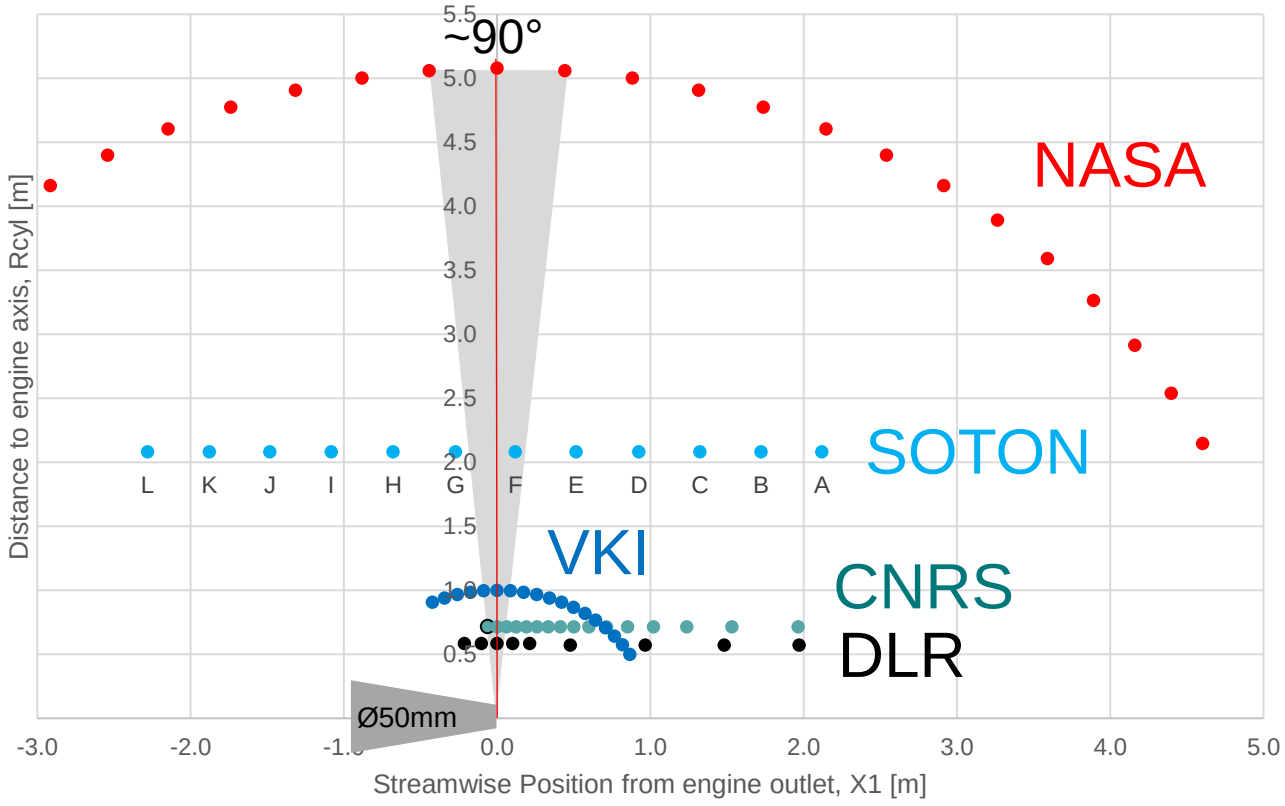
PSD / Narrowband spectrum w.r.t. engine exit (x=0)





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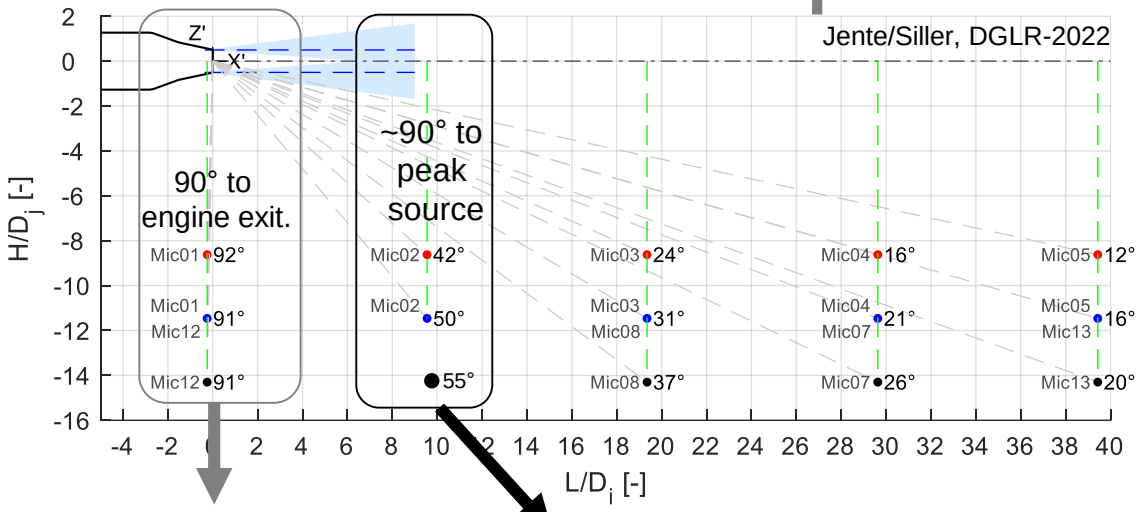
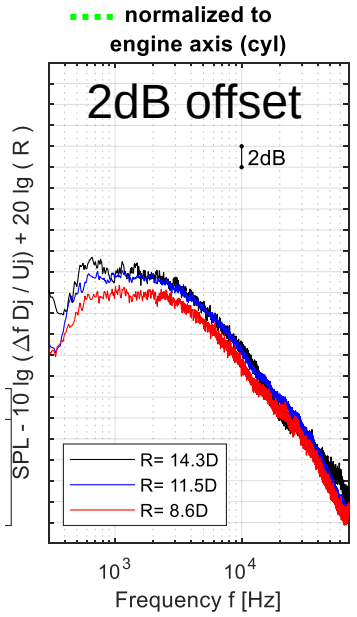
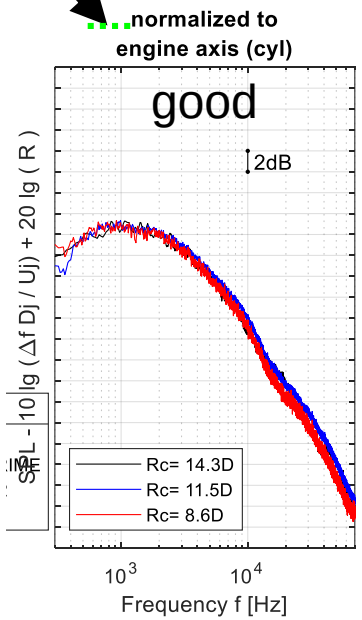
How to perform the geometric normalization?
MRP = Peak source position







Mechanisms of jet noise generation: classical theories and recent developments K. Viswanathan 2009

Elliptic mirror source localization

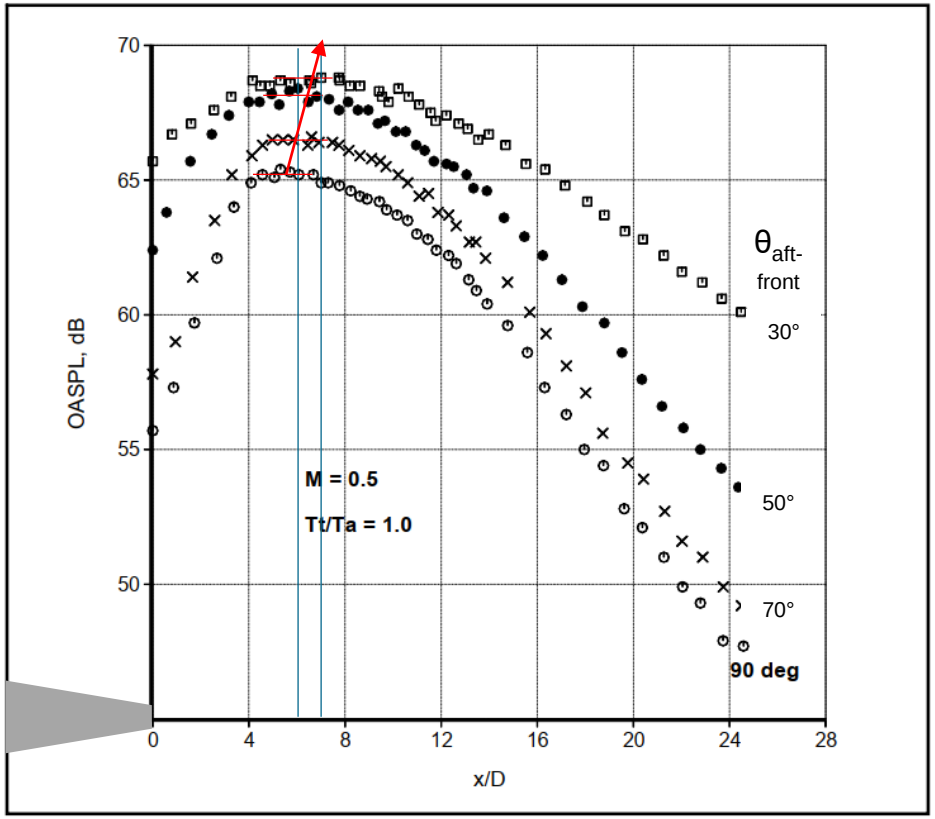


Figure 5. Axial distribution of overall source strengths. M=0.5, Tt/Ta=1.0.

Let's use $X=7D_j$

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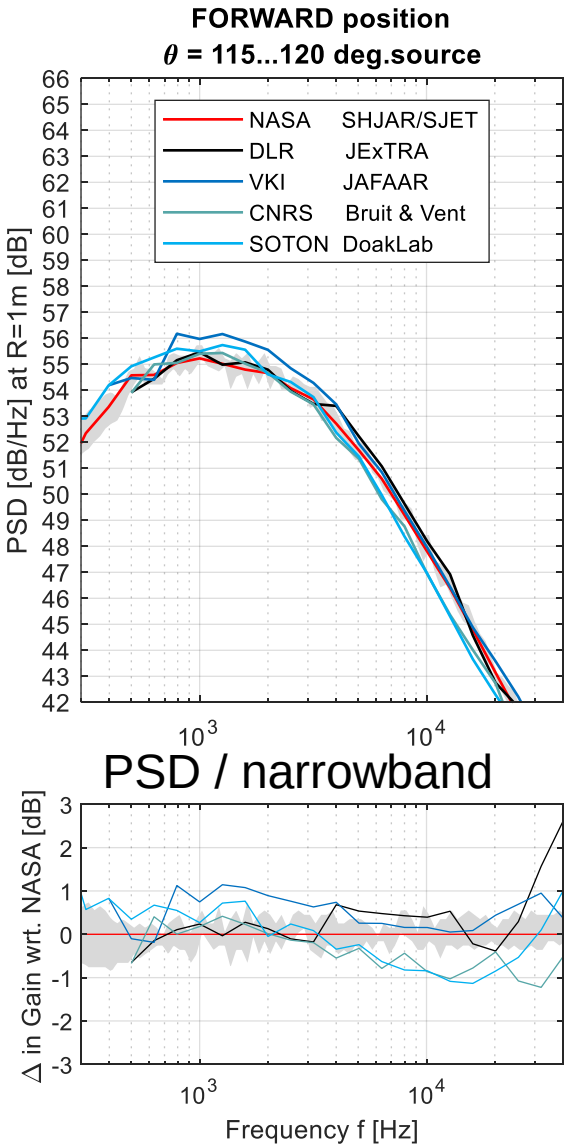
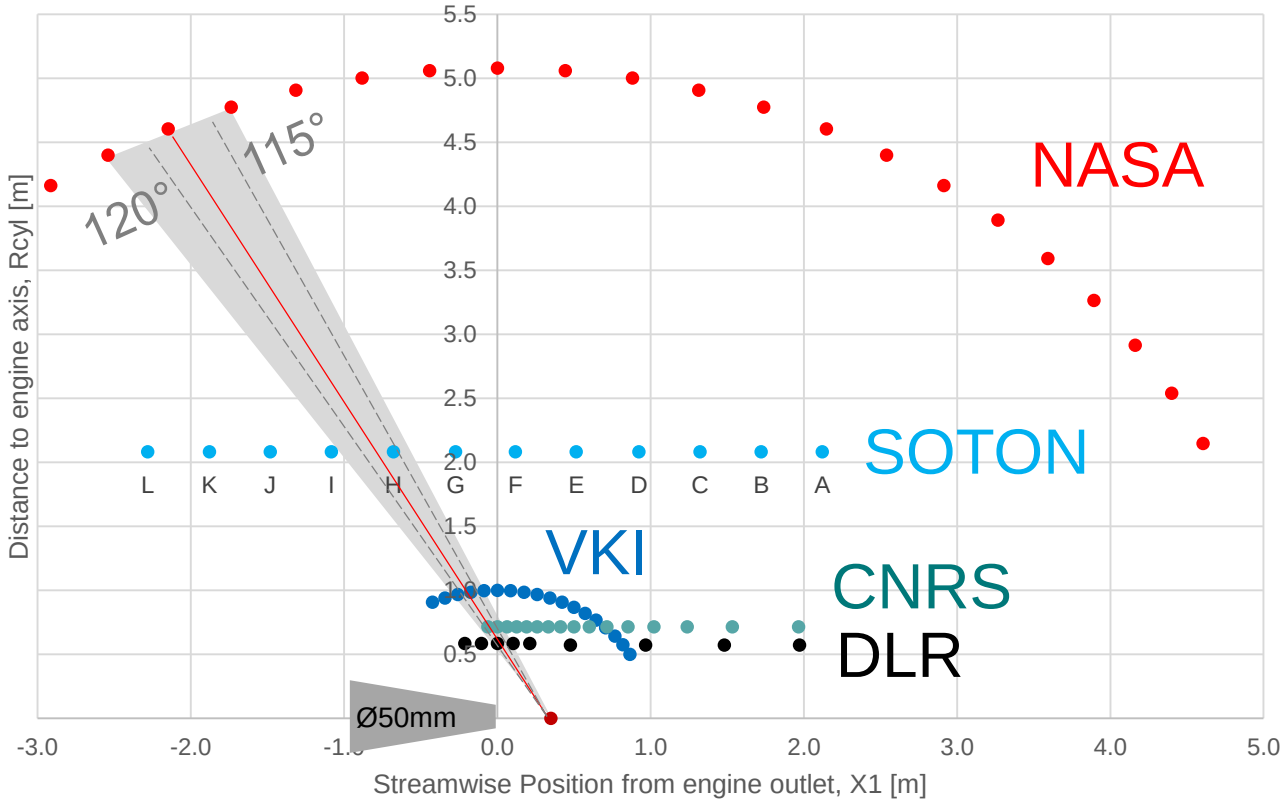
20 lg (R) normalization w.r.t. peak source (x≈7D$_j$)





	polar angle Θ	
	eng.exit	source
■	115	118,5
■	108	116,3
■	100	118,0
■	95	120,0
■	90	121,0

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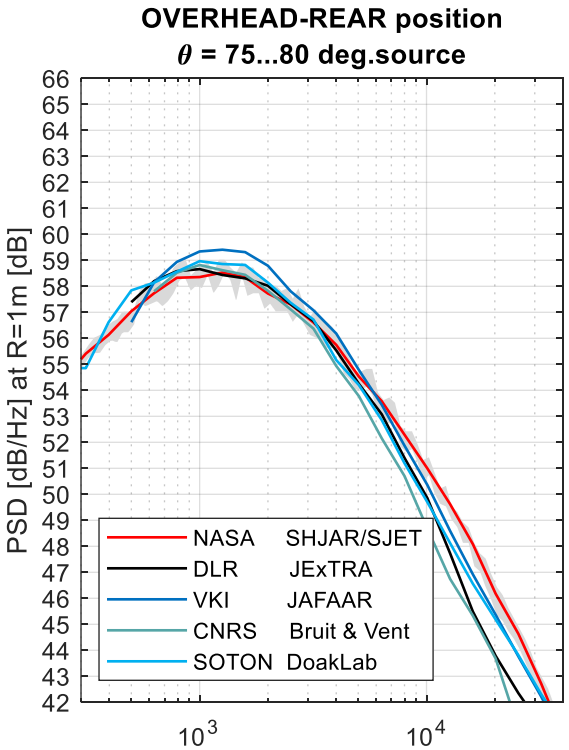
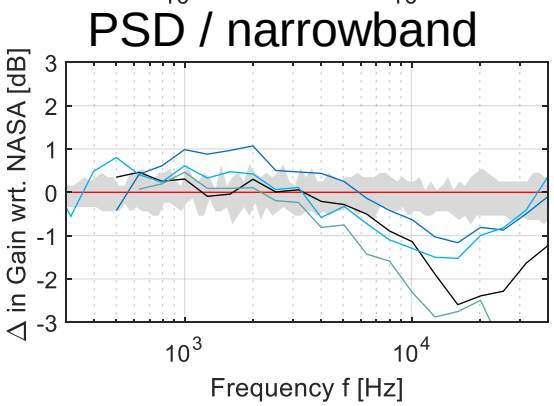
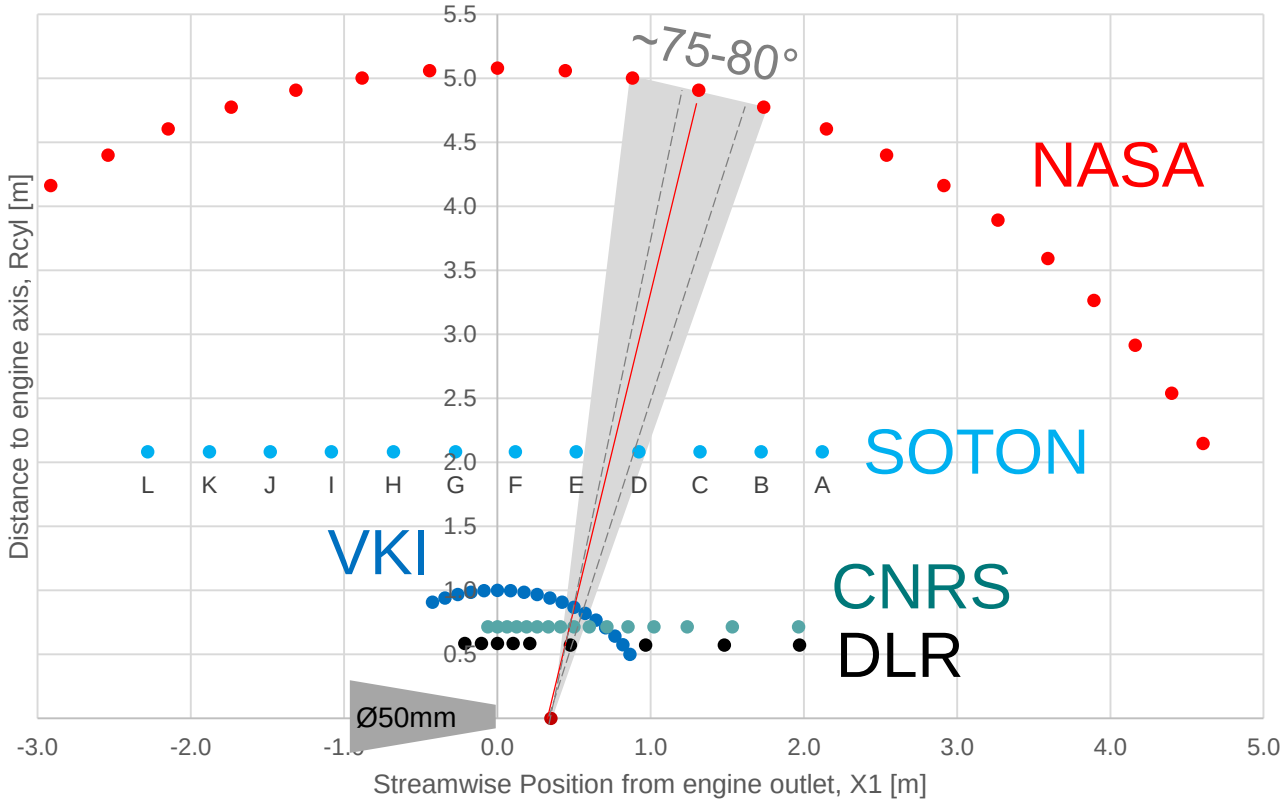
PSD / Narrowband spectrum w.r.t. peak source ($x \approx 7D_j$)







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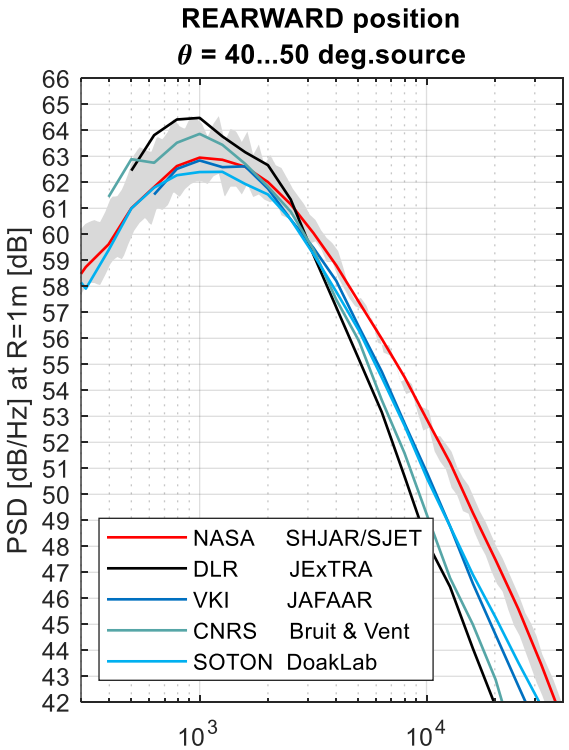
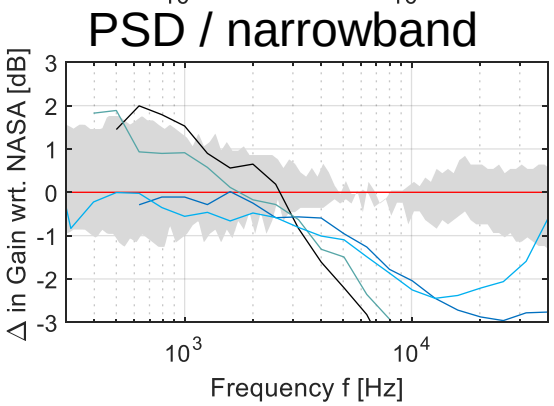
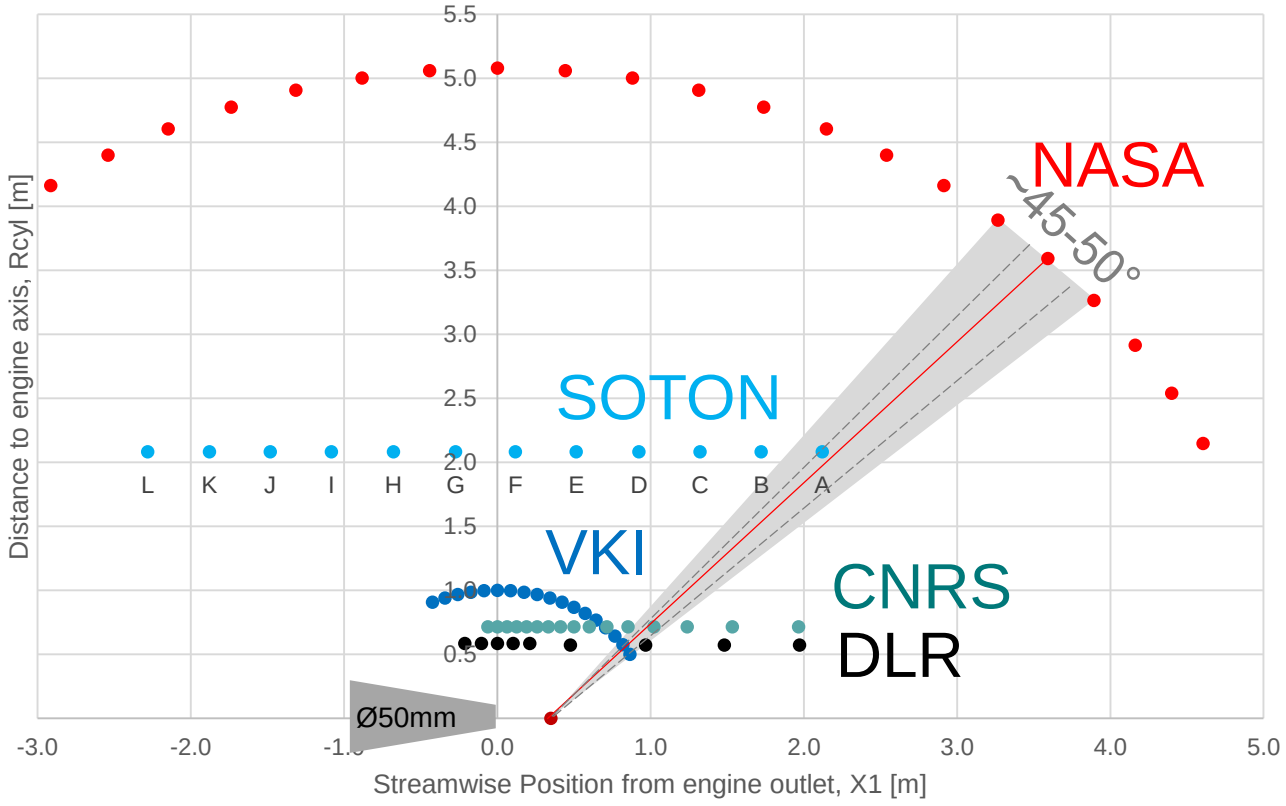
PSD / Narrowband spectrum w.r.t. peak source ($x \approx 7D_j$)







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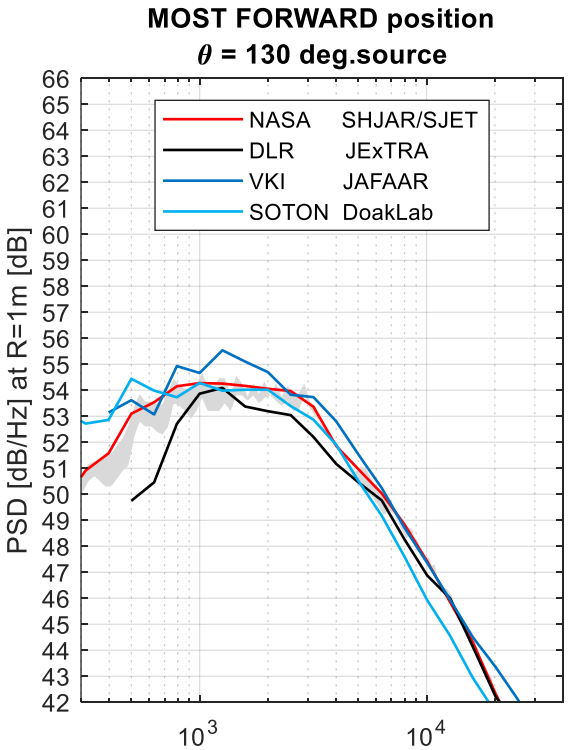
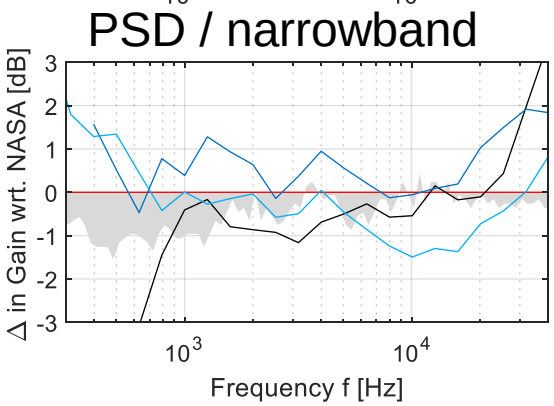
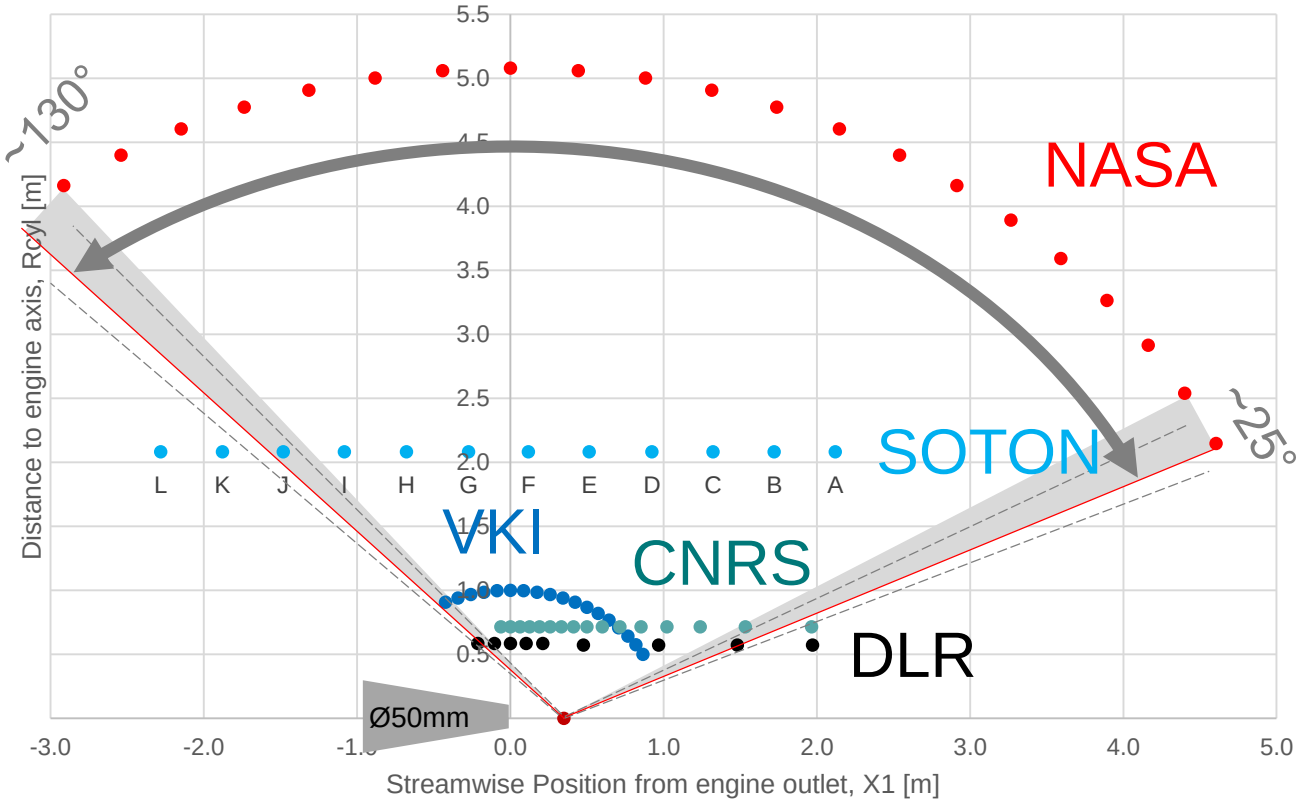
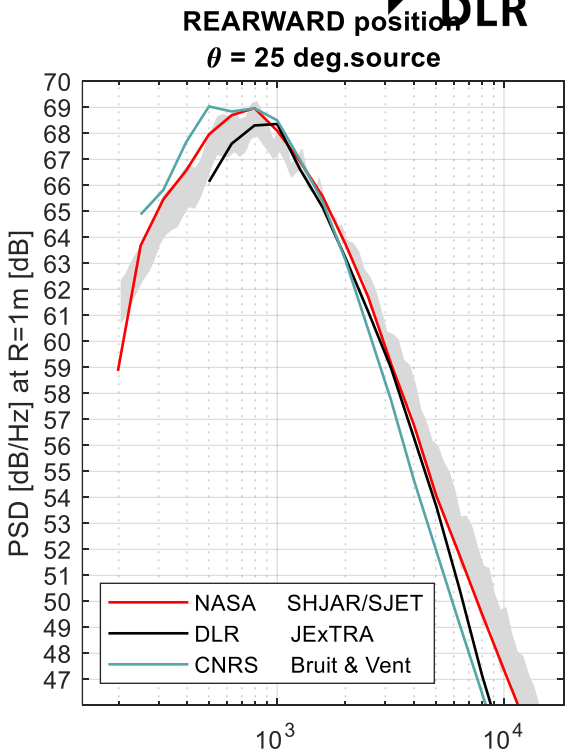
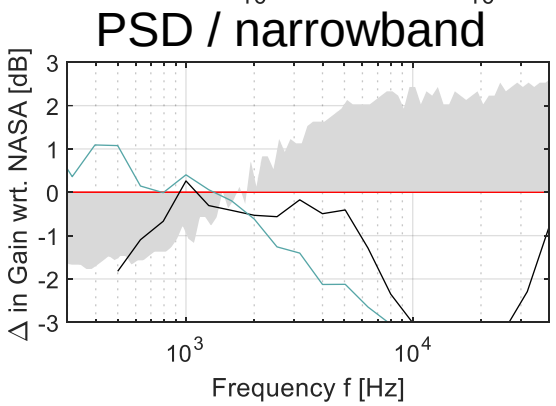
PSD / Narrowband spectrum w.r.t. peak source (x≈7D$_j$)











Normalization to 7D$_j$ fixed peak source achieves good low freq. comparability along Δθ = 105°.

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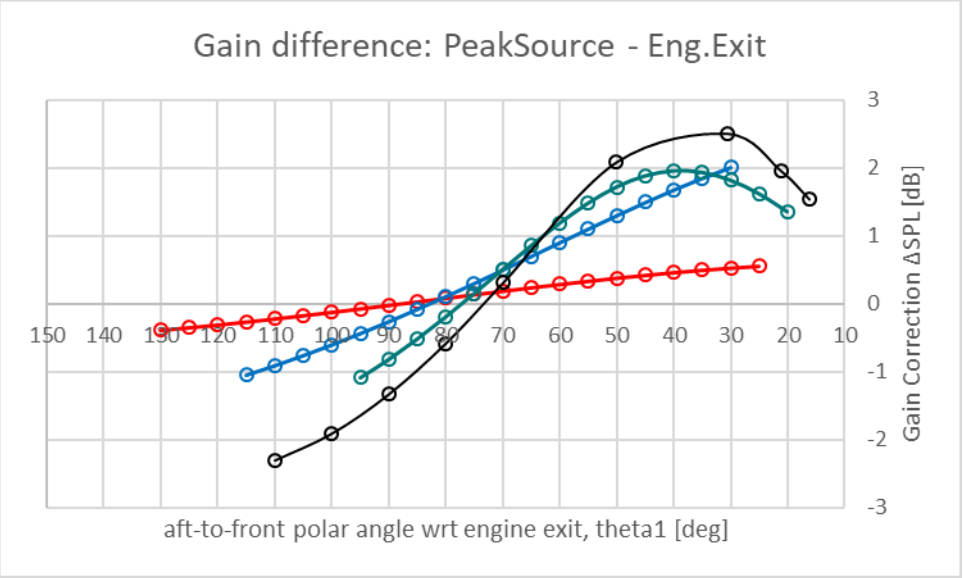
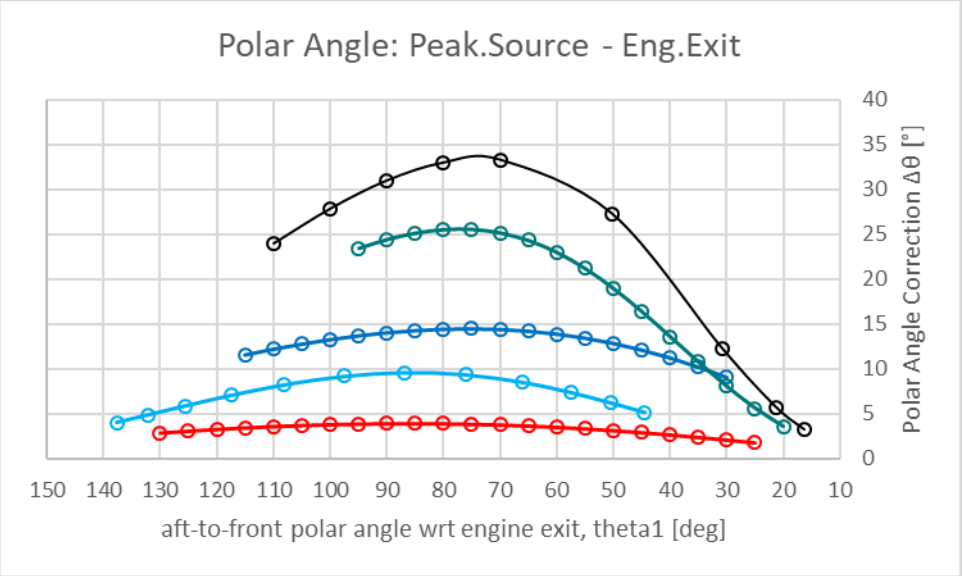
Correction 1: Getting the correct measurement reference point is the single most important correction

The geometric far field is often defined as the minimum distance required to treat the source as a point source.

R/D=100
for a distributed source (here x=0..7D along engine axis)

gain uncertainty: 0.5dB
Polar angle delta: max. 5° offset





Correction 2: small deviations in test rig operations

- $I \propto \frac{\rho_m^2}{\rho_0} \frac{1}{a_0} \cdot U_j^8 \cdot \left(\frac{D_j}{R_{mic}}\right)^2$
- $I \propto \frac{p}{RT_j} \frac{1}{(\gamma R T_0)^{\frac{5}{2}}} \cdot U_j^8 \cdot \left(\frac{D_j}{R_{mic}}\right)^2$ (AIAA 2022-2826)

Property		ISA-Norm	NASA Glenn	DLR	CNRS	SOTON	VKI
> Jet velocity -80 lg (U_j/204.2m/s)	[dB]	0	+0.12	-1.06	-0.88*	-0.26	+0.20
> Test room temperature +25 lg (T_0/288.15K)	[dB]	0	-0.07	+0.49	+0.55*	+0.17	0.00*
> Jet temp. +10 lg (T_j/288.15K)	[dB]	0	-0.03	+0.26	+0.22*	-0.28	-0.41
> pressure -10 lg (p_0/101325Pa)	[dB]	0	-0.00*	-0.02	0.00*	-0.05	+0.05
	[dB]	**0**	**+0.02**	**-0.33**	**-0.11±0.07***	**-0.41**	**-0.16±0.20***

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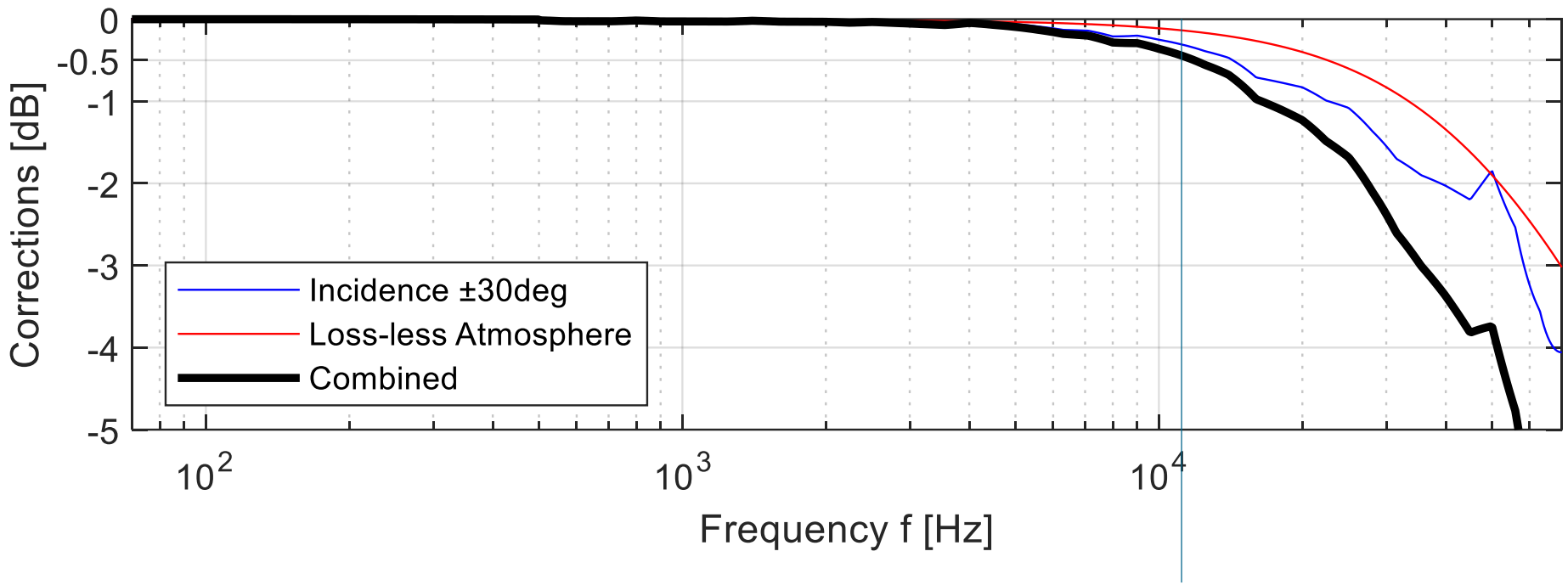
Correction 3: High-frequency range
loss less atmosphere | microphone incidence



Standard corrections for a ¼” free field response microphone (installed at R=1m) are negligible for f < 10 kHz

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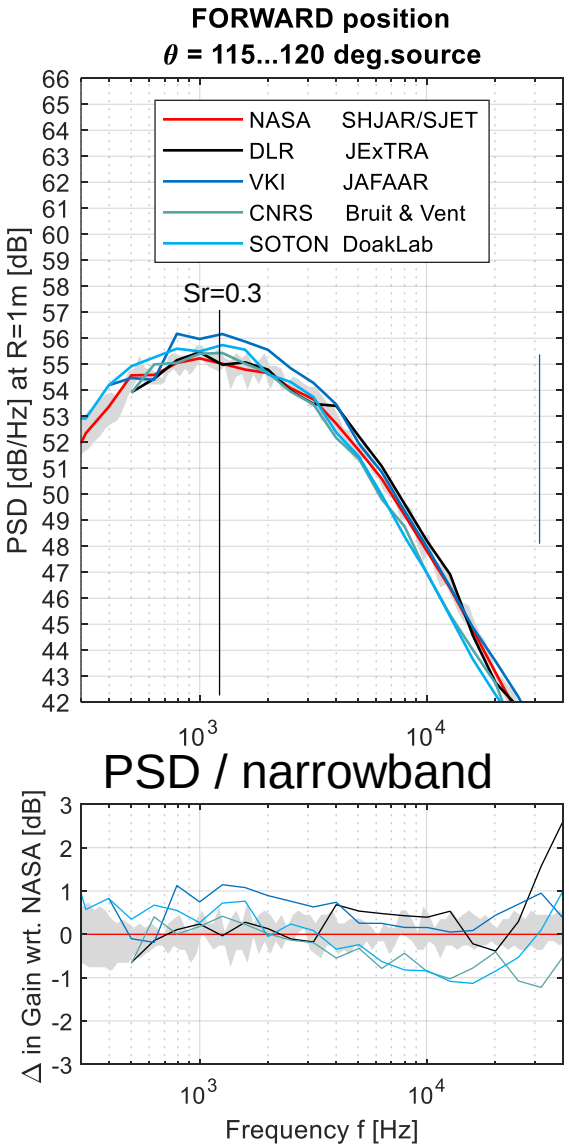
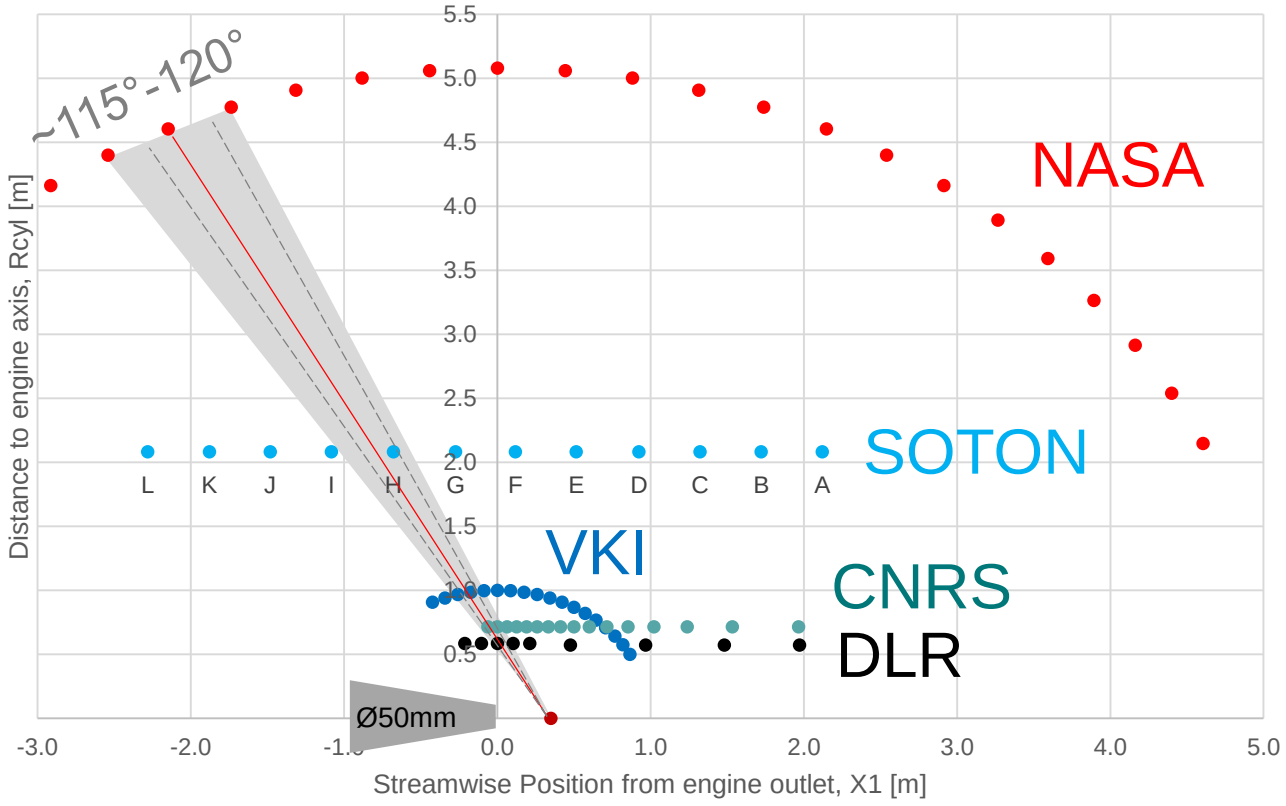
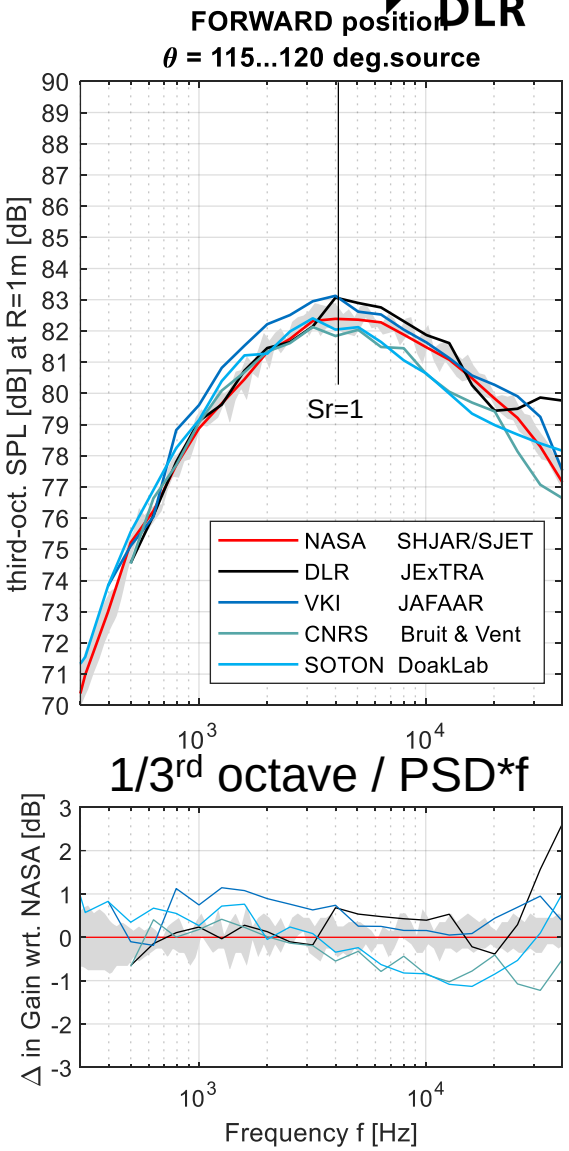
20 lg (R) normalization w.r.t. peak source (x≈7D$_j$)







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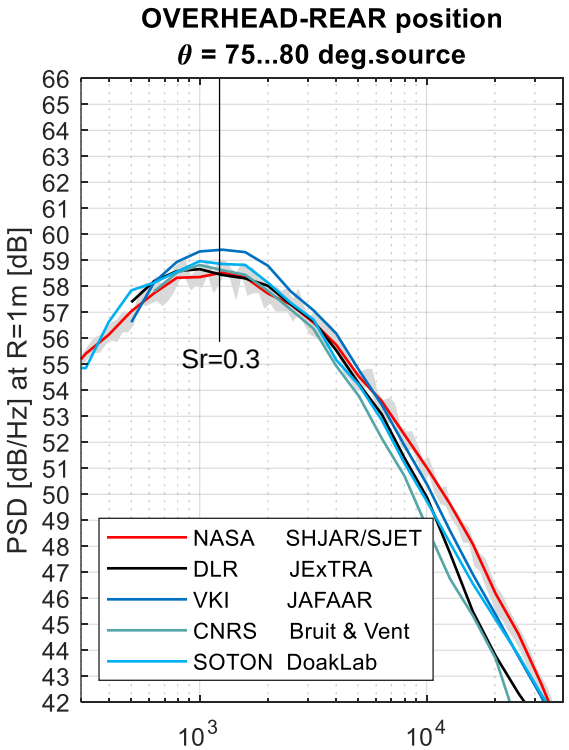
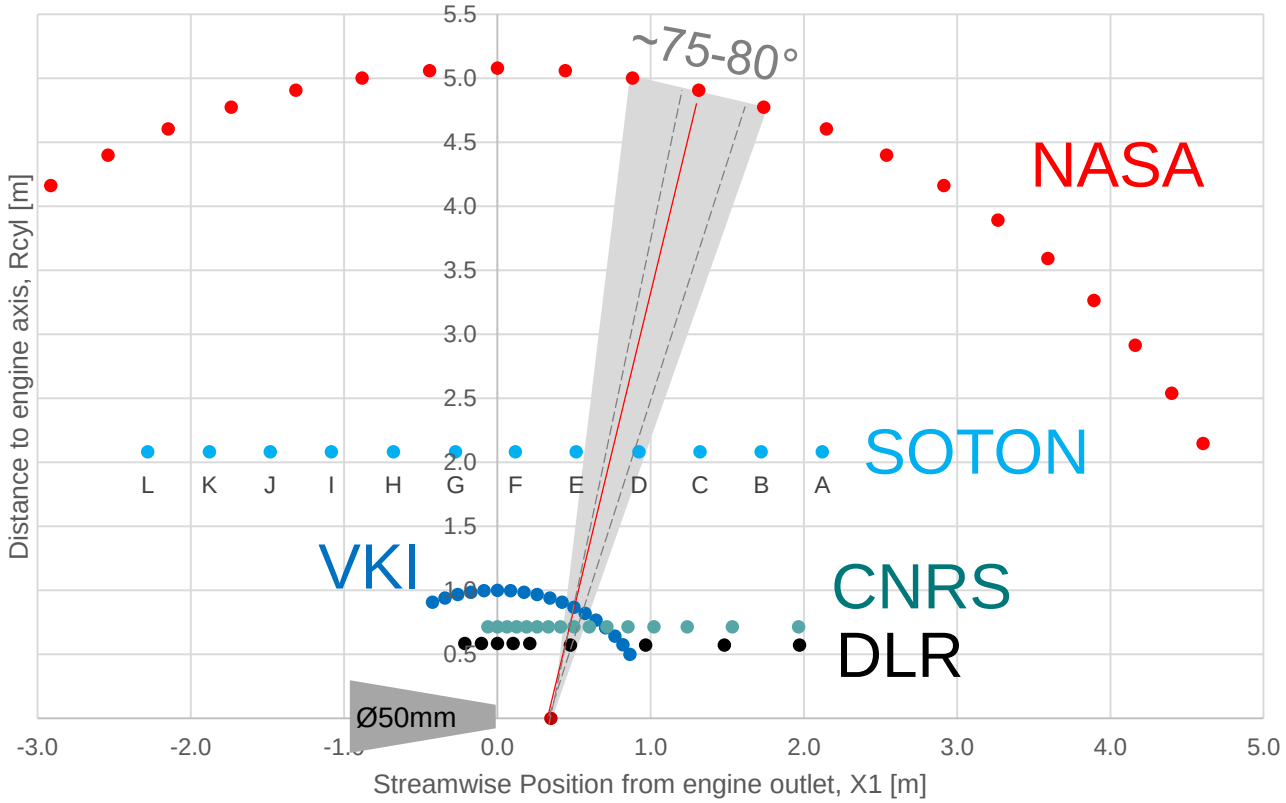
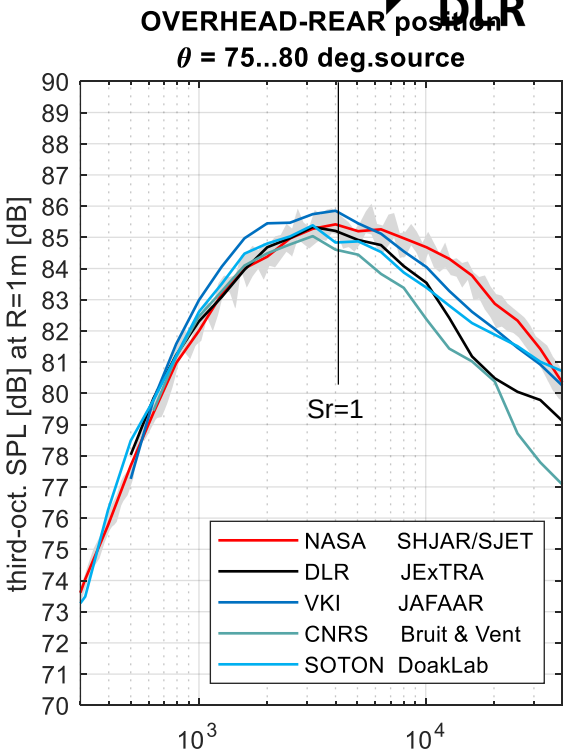
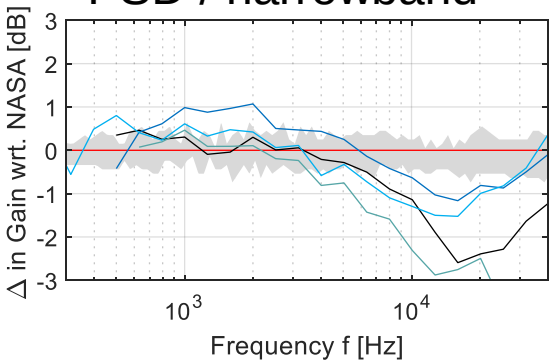
PSD / Narrowband spectrum w.r.t. peak source (x≈7D$_j$)



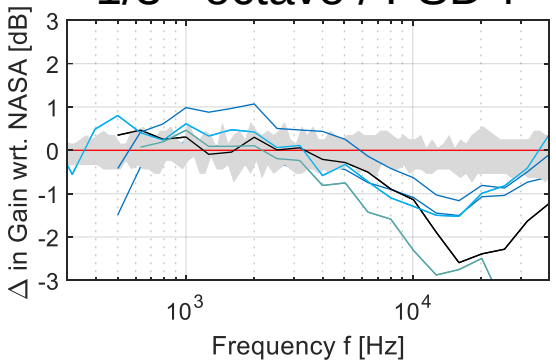




PSD / narrowband



1/3rd octave / PSD*f



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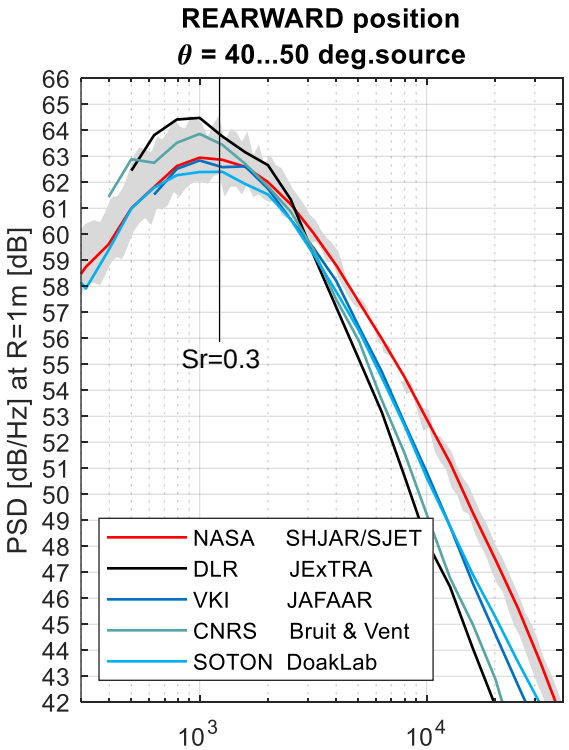
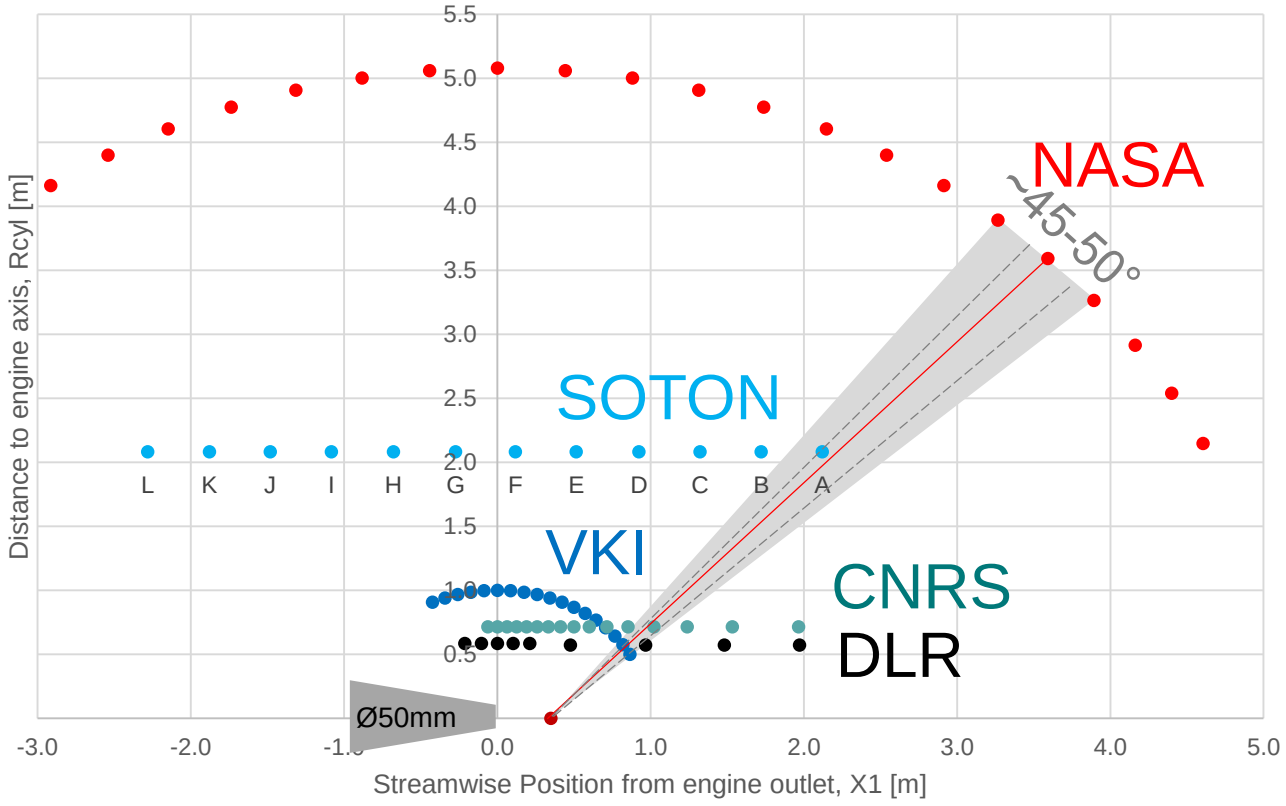
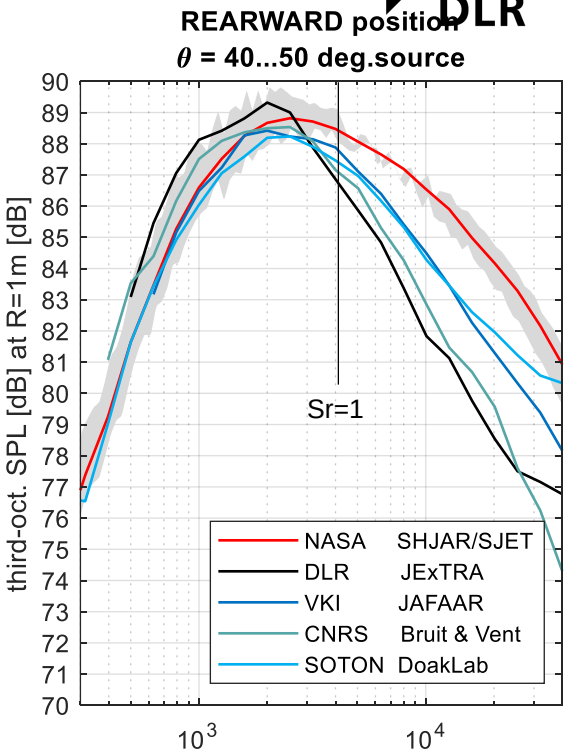
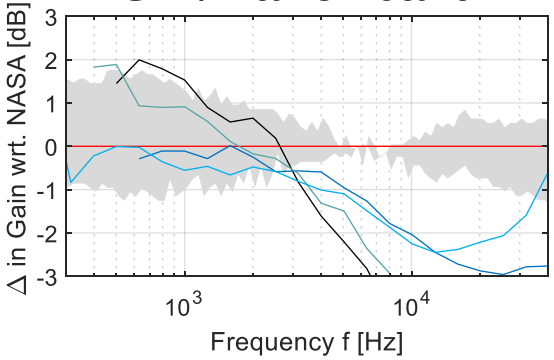
PSD / Narrowband spectrum w.r.t. peak source ($x \approx 7D_j$)



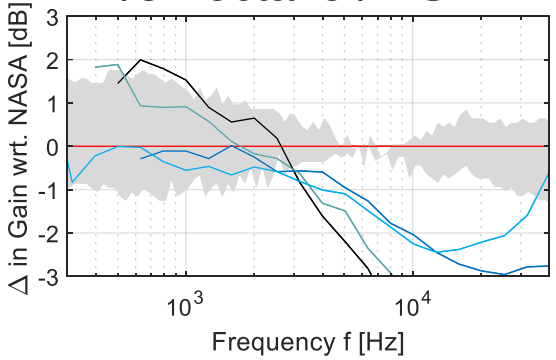




PSD / narrowband



1/3rd octave / PSD*f



High-frequency range Sr>1 is crucial for OASPL.
Rear-arc

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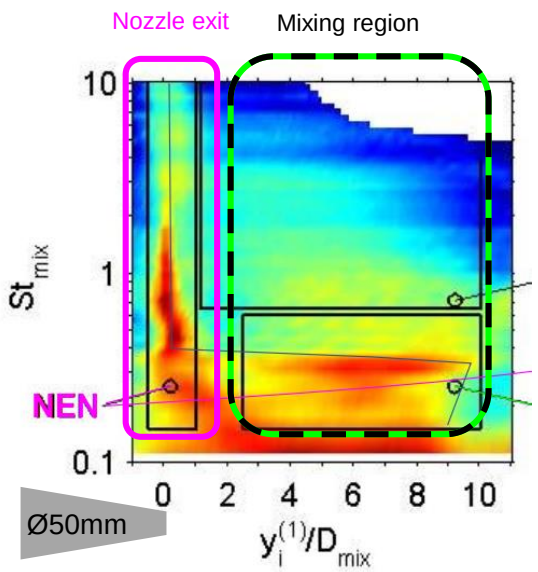
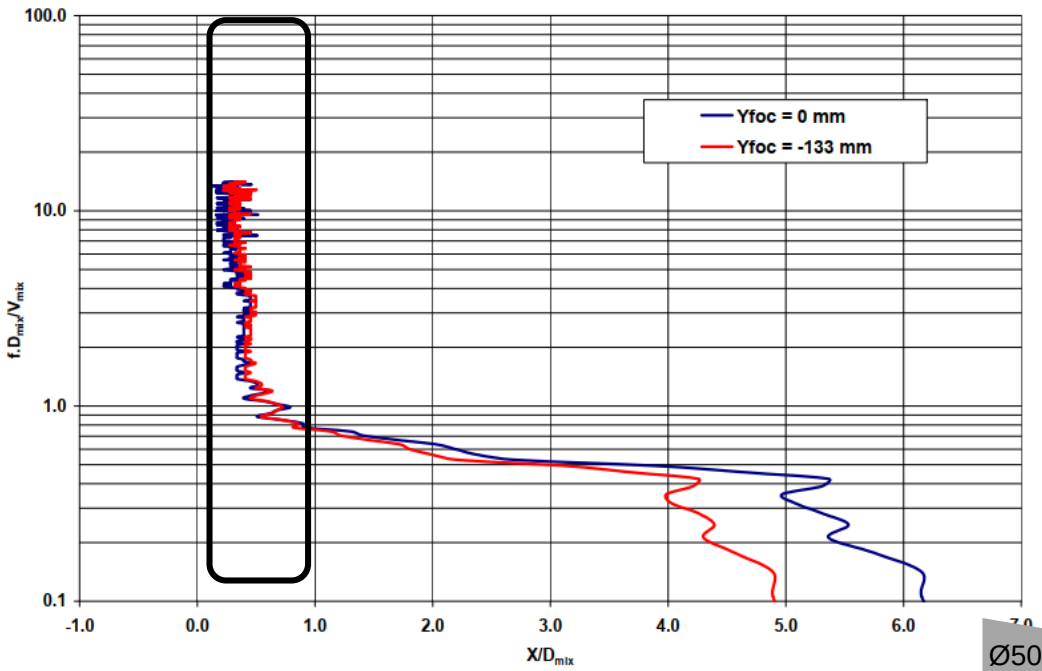
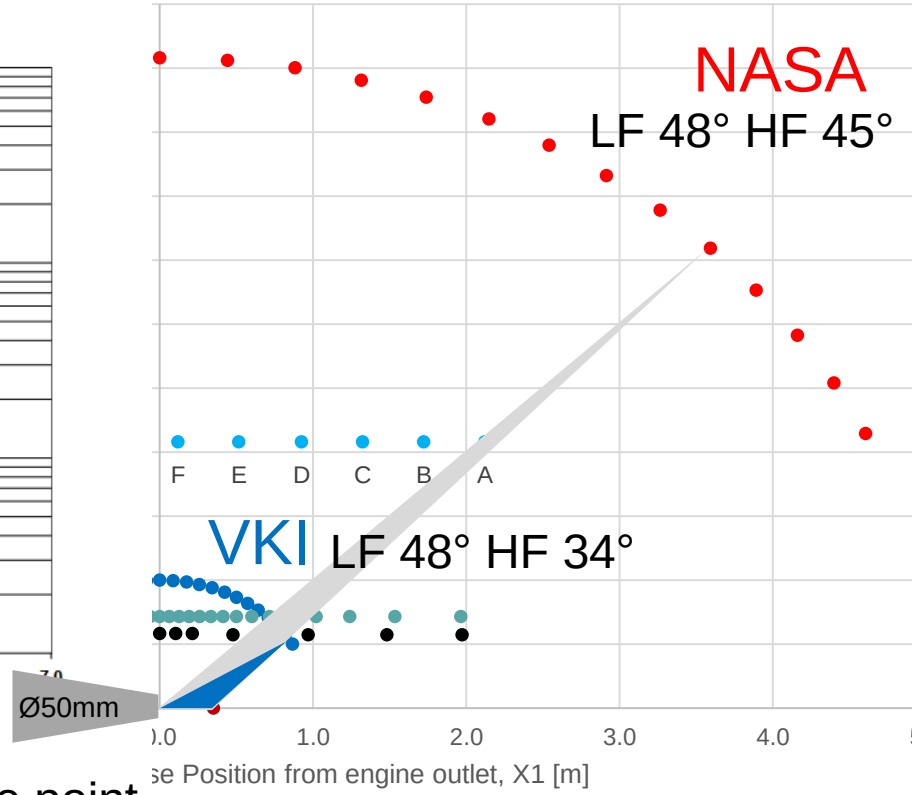
High frequency noise hypothesis 1: all HF noise located at engine exit



Vincent Fleury and Renaud Davy. Large-scale jet noise testing, reduction and methods validation „EXEJET": 5. analysis of jet-airfoil interaction noise by microphone array techniques. In 20th AIAA/CEAS Aeroacoustics Conference, AIAA AVIATION Forum. American Institute of Aeronautics and Astronautics, 2014.





Frequency resolved measurement reference point
Example: Huber et al AIAA2009-3371

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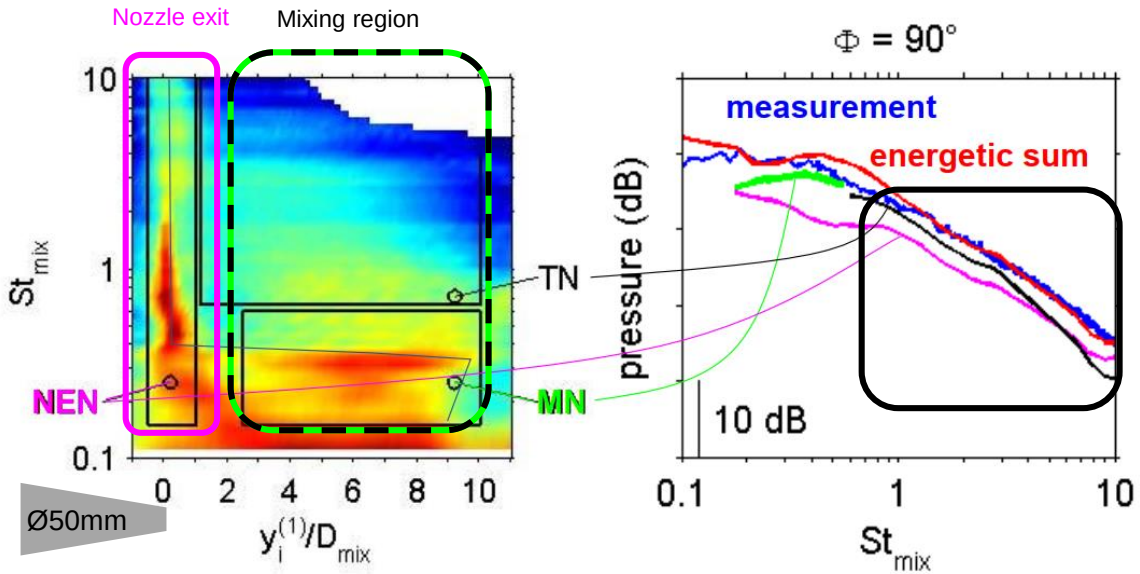
High frequency noise hypothesis 2: all HF noise distributed between x=0…7D_j



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Conclusions – for simple analysis

- Selecting the peak source location as measurement reference point is the single most important correction

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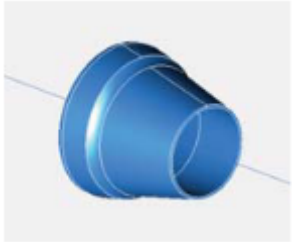
Viswanathan/Clark 2004: Effect of nozzle internal contour on jet aeroacoustics
Zaman AIAA 2011-2704

Initial state properties cross-comparison

NASA

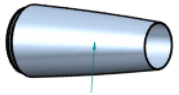
Round nozzle, 5° contraction

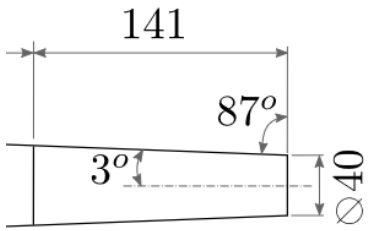
SMC000



Bridges/Wernet
AIAA 2015-0228

SOTON

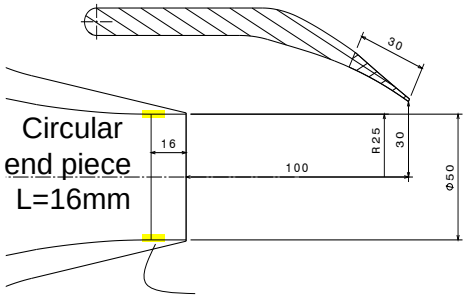




Proenca 2018
PhD Thesis

DLR

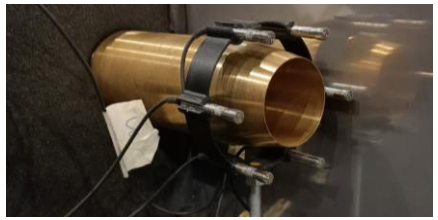
Jente AIAA2022-3040

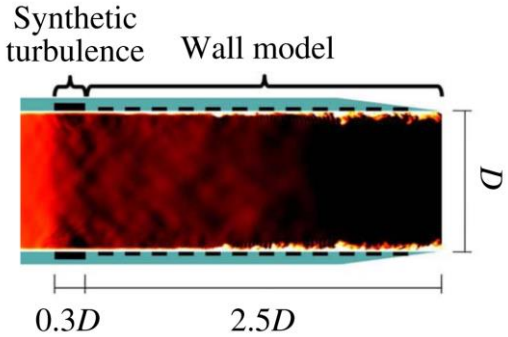


Virtual origin of
jet near field
shear layer at X [mm]=-10…-18
depending on operation

CNRS

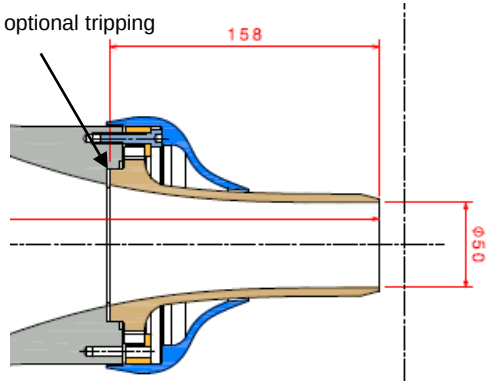
Mancinelli/Jordan DJINN 2023





carborundum strip Bres JFM2018

VKI



Christophe 2023 DJINN

	NASA	SOTON	DLR	CNRS	VKI
Straight duct			max 0.4 D	up to 2.5 D	~1.5 D fairly straight 3.2 D to tripping pos.
determined Peak Source Loc.			7.0±0.5 D	6.5±0.5 D	5±0.5 D

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