Numerical Simulation of the Downstream Fan Noise
of a Coaxial Jet with a Shielding Surface

SEBU *project (*SE*mi-BU*ried engine), co-funded by* Airbus SAS *and* EREA

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and

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Air Systems Technology Department

Objective

Isolated nozzle

Shielded nozzle

Comparative study of both a classical and a modified co-axial engine, in order to evaluate both the :
- _installation shielding effect_ (secondary exhaust extension)
- highly inhomogeneous _mean flow effect_
on
the _downstream rear tone fan noise_

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General methodology

Preliminary RANS (3D/ 2D-axi) mean flow computation : CFD solver

Vo

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Vo

$\Rightarrow$

Near & mid-field propagation: n:
Euler's solver

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Preliminary RANS (3D/ 2D-axi) mean flow computation : CFD solver

Vo

$\Longrightarrow$

Kirchhoff frontier

Far field radiation : Kirchhoff's solver

Near & mid-field propagation: n: Euler's solver

Kirchhoff frontier

Outline

❑ **Preliminary tasks**

❑ **CAA Hybrid Methodology Tools**

❑ **2D study of the Shielding Effect in a Quiescent Medium**

❑ **2D study of the Shielding Effect in an Inhomogeneous Medium**

❑ **Conclusions of the 2D studies : Shielding and Mean Flow Effects**

❑ **Early 3D results : Isolated Nozzle in both a Quiescent and an Inhomogenous Medium**

❑ **Conclusions & Perspectives**

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# Preliminary tasks

Preliminary CFD (RANS) Computations (*QinetiQ*, *Fluent v.5*)
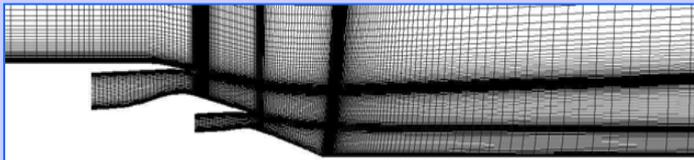
**Isolated axi-symmetric nozzle (2D mesh, partial view):
5 structured domains (94 805 elements)**
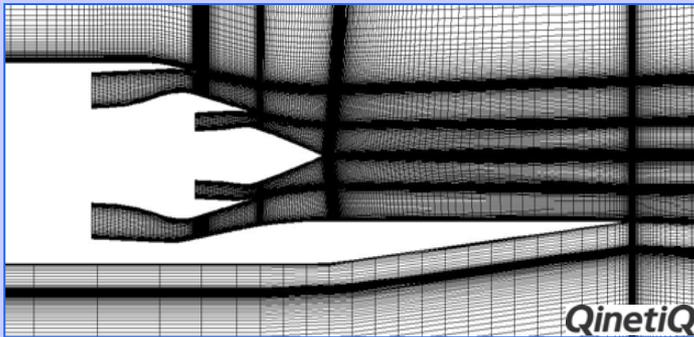
**Shielded nozzle (3D mesh, partial view):
10 structured domains (5 542 100 elements)**

High Subsonic Hot Jet, Take Off Conditions ($M^\infty = 0.25$ / $M^{max} \approx 0.9$) : Axial velocity results
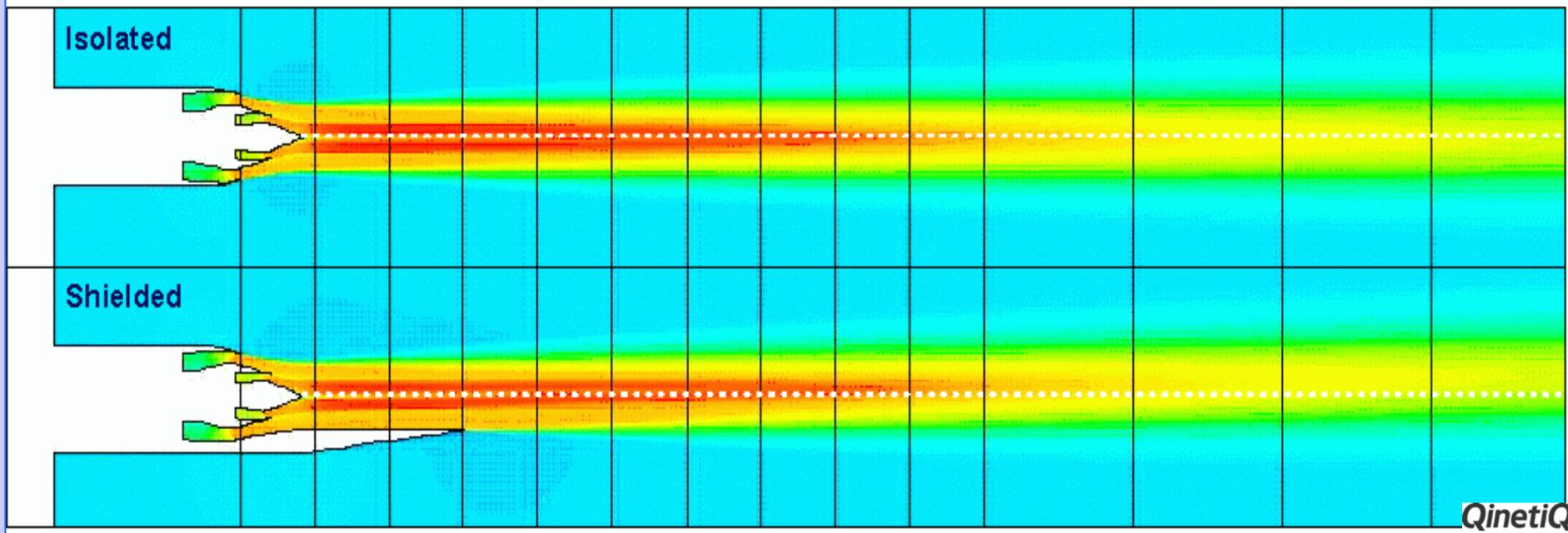
CAA Hybrid Methodology Tools

Near & Mid-Fields Propagation over Inhomogeneous Flows & Solid Bodies : *sAbrinA*
("Solver for Acoustic BRoadband Interaction with Aerodynamics")

* *Full Euler* or Navier-Stokes equations
* Complete (NLDE) or *Splitted variables* (hybrid CAA)
* *Finite Differences* or Volumes
* *High-order* (up to 6th order in space, up to 3rd order in time, up to 10th order for filters)

* *Multi-D*, *multi-domain*
* Specific boundary conditions (*rigid obstacle*, *symmetry plane*, *free-field*)

Far Field Radiation in Homogeneous Medium : *Kirch2D, Kirch3D*

* Frequential 2D or 3D codes (Kirchhoff integration)
* Frequency or *temporal*, *harmonic* or *broadband* signals
* Homogeneous medium (*at rest* or with *uniform flow*)

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2D Acoustic Grid Derivation

. Conservation of blocks number, frontiers and to
. Complete re-meshing of each block
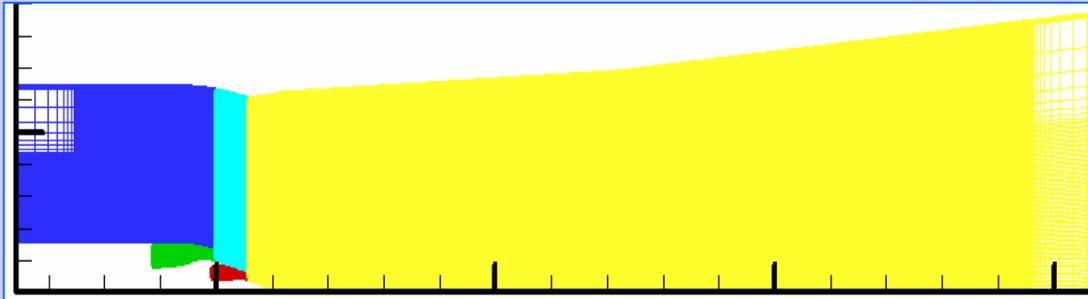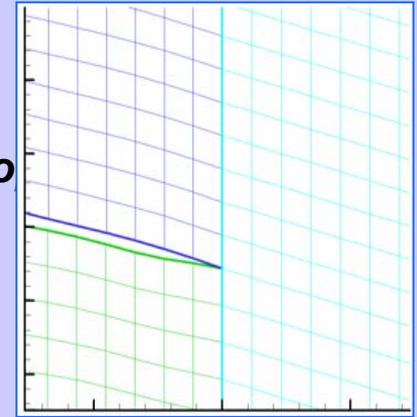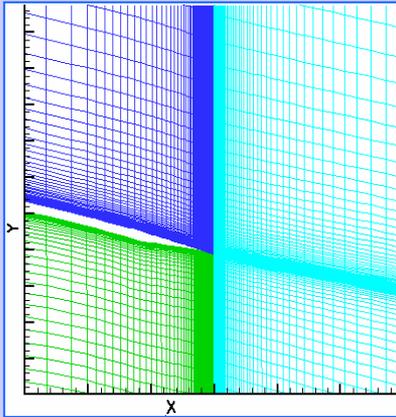
Isolated nozzle (2D mesh):
5 structured domains (64 408 element

$$\Delta y_{min\ CAA} = 500\ \Delta y_{min\ CFD} = \lambda/10$$
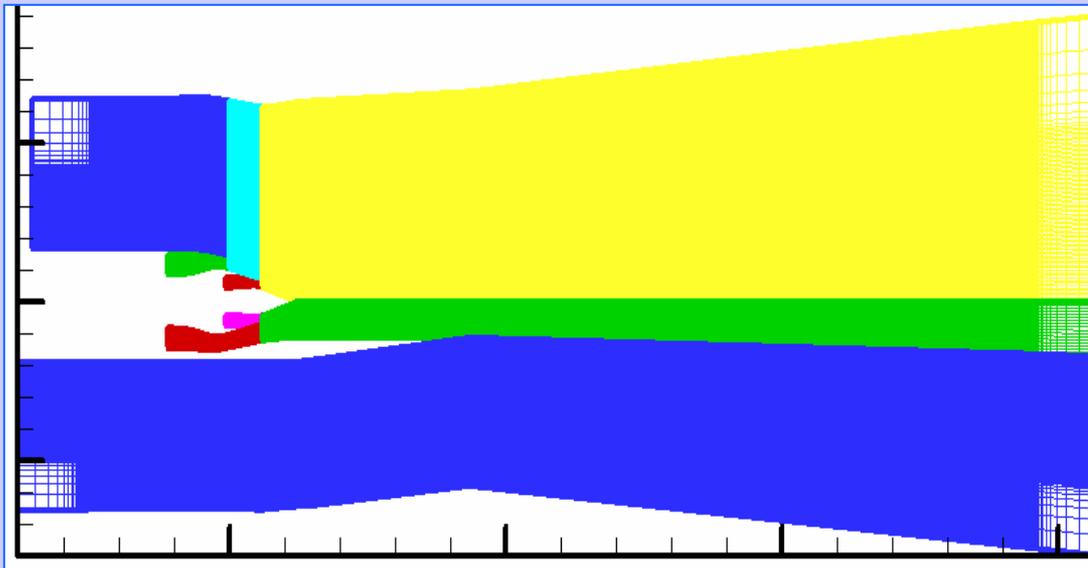
Shielded nozzle (2D mesh):
9 structured domains (154 442 eleme

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2D RANS Mean Flow Interpolation
(Barycentral bilinear technique)

**Density field on the CFD grid**

Density field on the CAA grid

Barycentral bilinear technique

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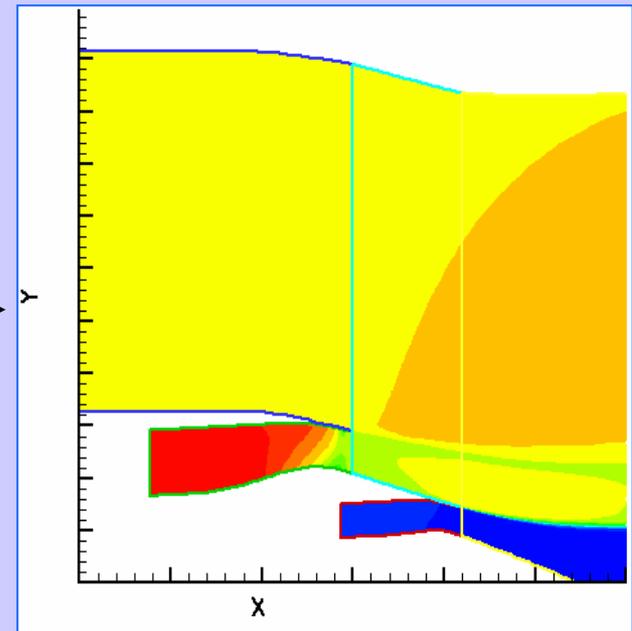
Shielding Effect on the Fan Noise 2D Propagation in a Quiescent Medium

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Fan Noise in a Quiescent Medium

(1/3) Near & Mid-Fields 2D Propagation (sAbrinA code)

Isolated nozzle : Instantaneous pressure field

*kR = 20*
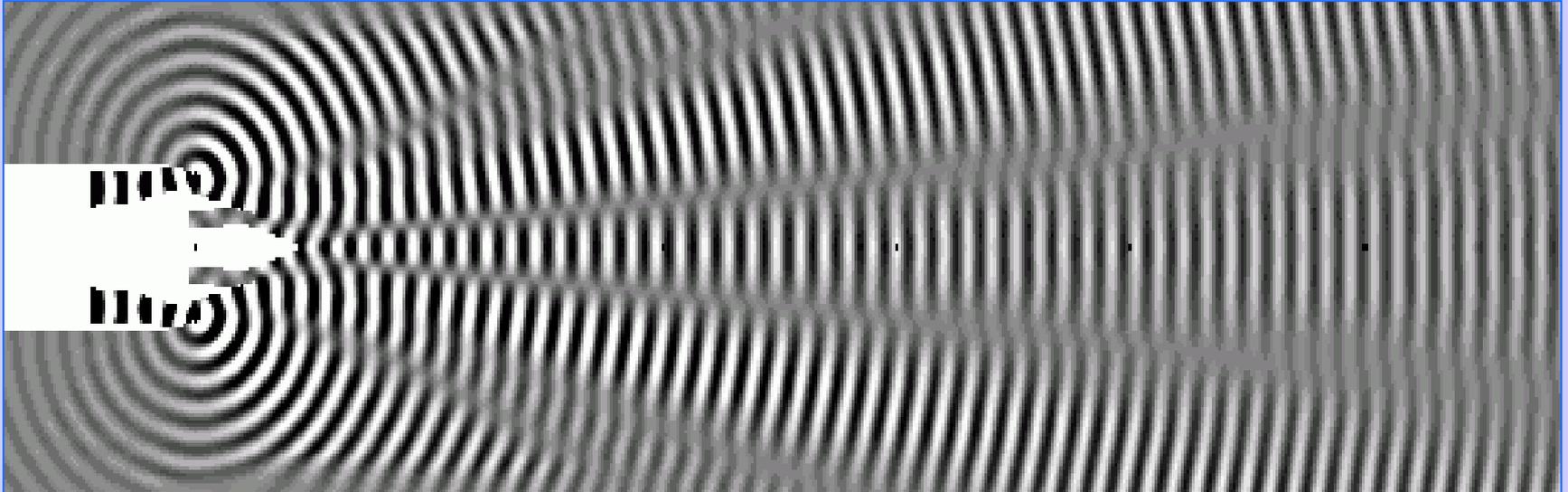
Shielded nozzle: Instantaneous pressure field
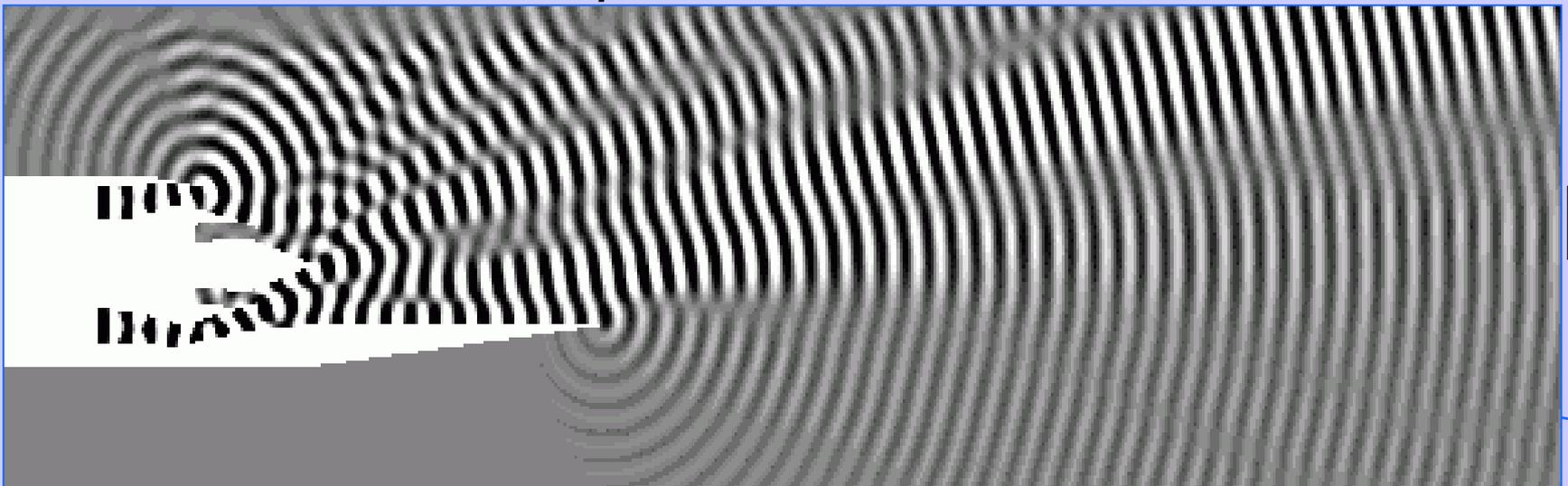
Fan Noise in a Quiescent Medium

(2/3) Far-Field 2D Radiation (Kirch2D code) and Validation (Sysnoise code)

Kirch2D validation

sAbrinA/Kirch2D validation

Euler/Kirchhoff

Euler

Exit boundary

Kirchhoff frontier

Exit boundary

Kirchhoff frontier

BEM

Euler/Kirchhoff

Isolated nozzle

Shielded nozzle

dB
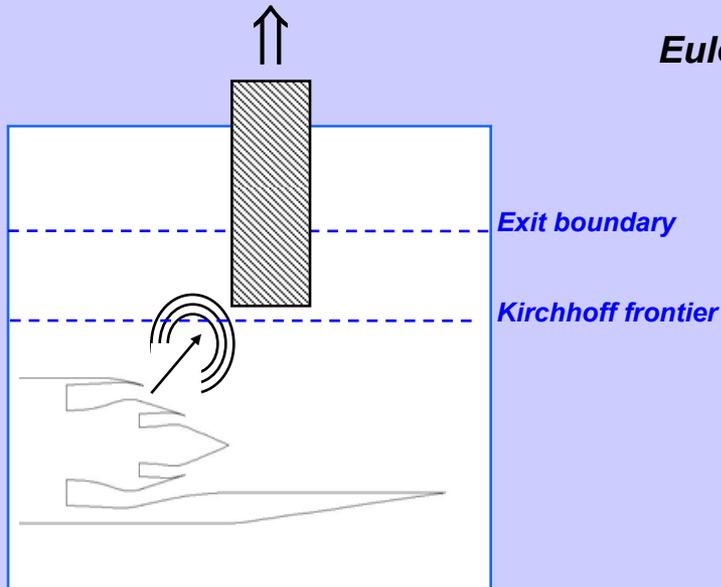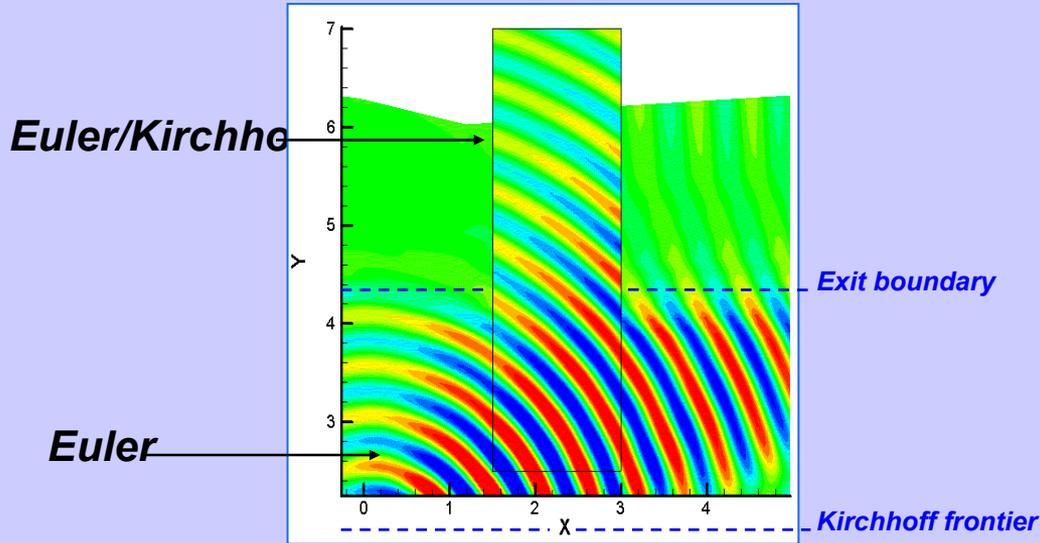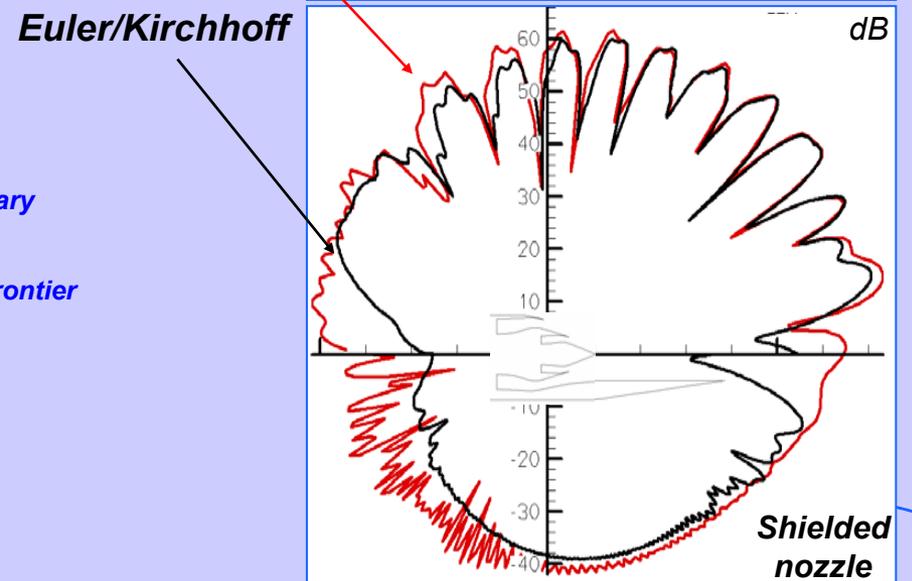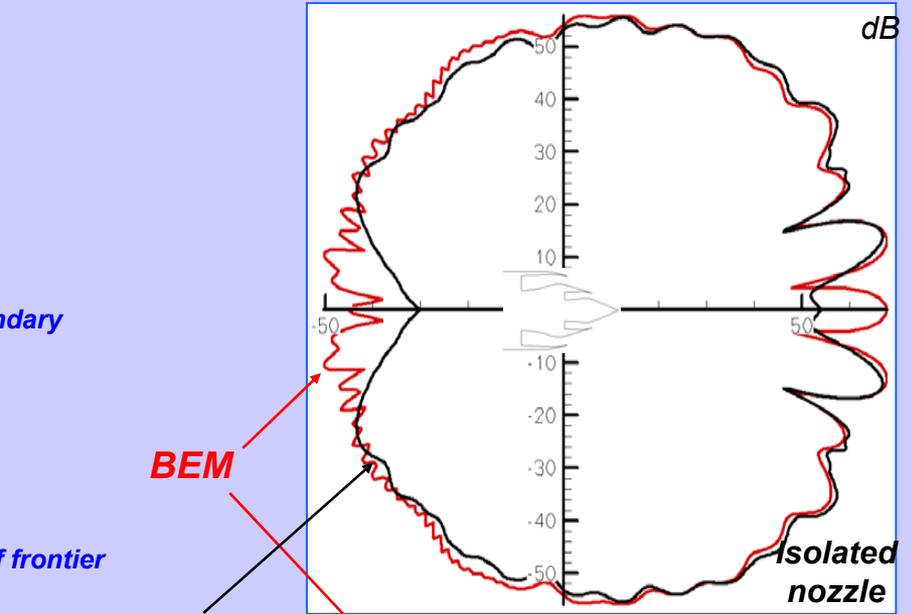
Fan Noise in a Quiescent Medium
(3/3) 2D Shielding Effect Analysis
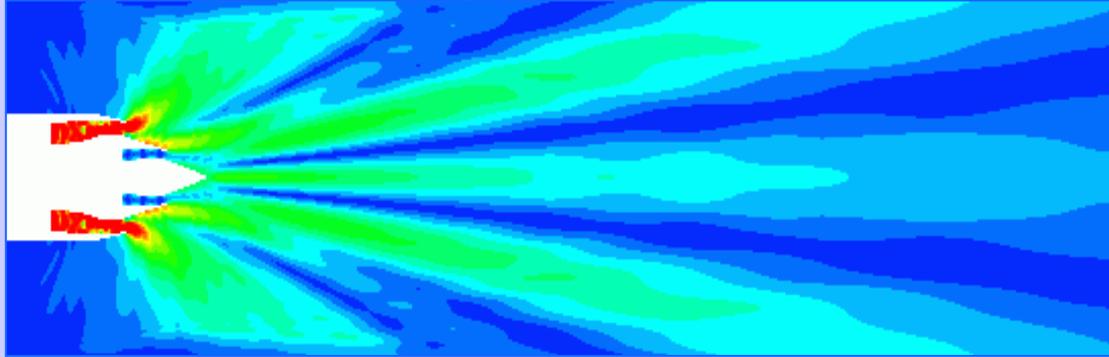
Far field directivity diagrams (dB)

Isolated nozzle : RMS pressure near & mid-fields

Shielded nozzle : RMS pressure near & mid-fields

Isolated nozzle

Shielded nozzle

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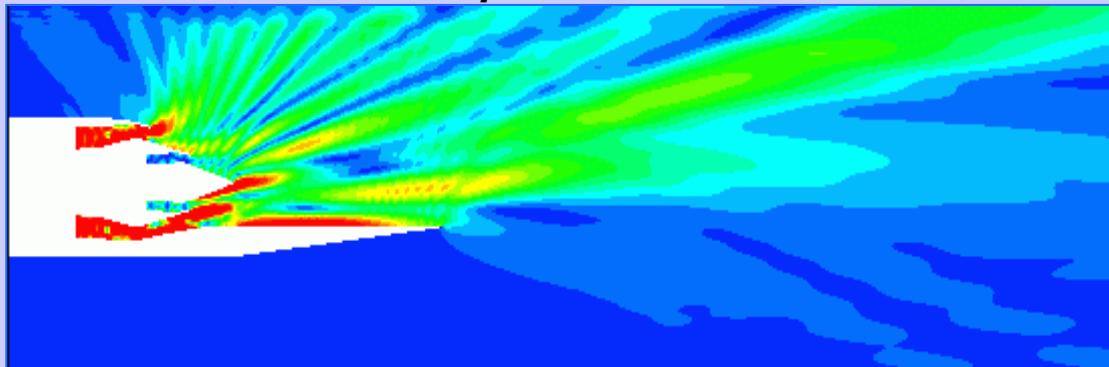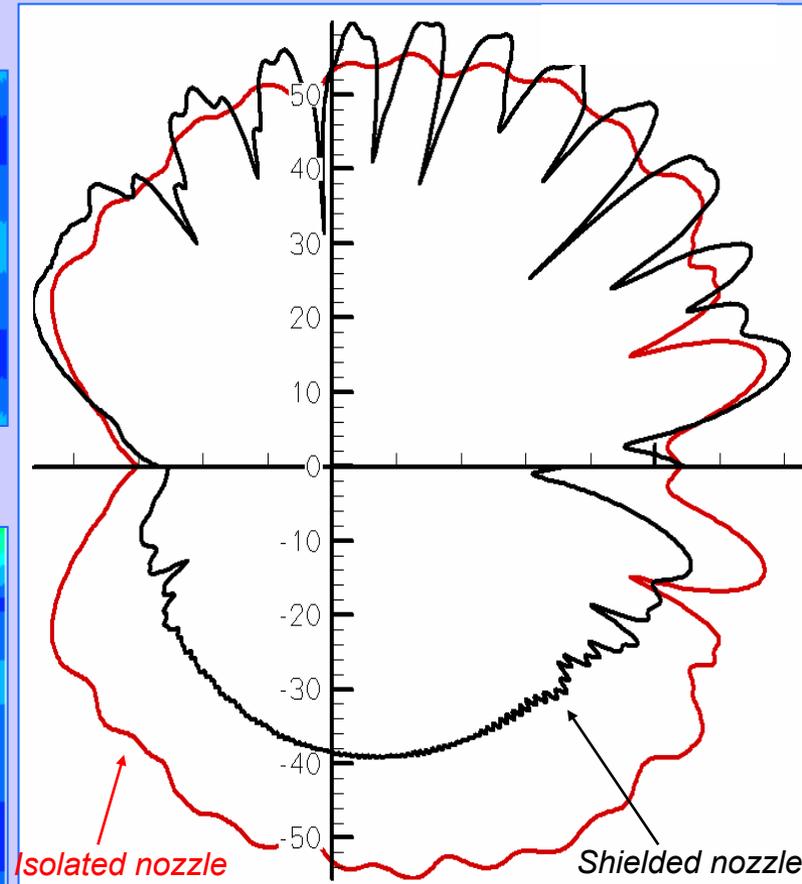
Shielding Effect on the Fan Noise 2D Propagation in an Inhomogeneous Medium

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Fan Noise in an Inhomogeneous Medium
(1/3) Near & Mid-Field 2D Propagation (sAbrinA code)

Isolated nozzle : Instantaneous pressure field   *kR = 20*
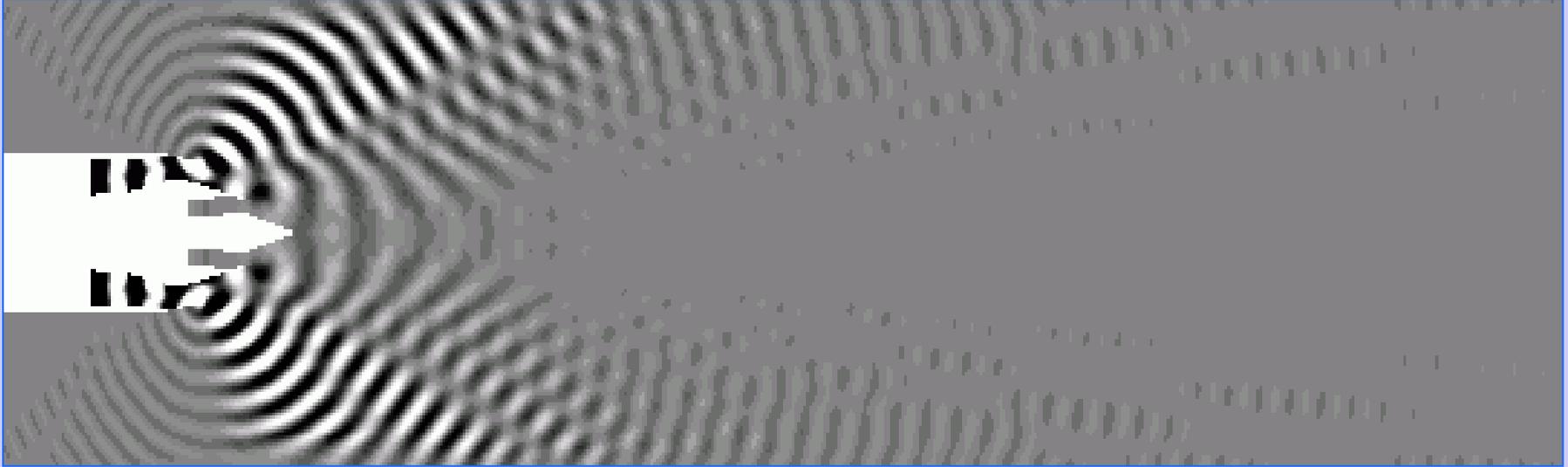
*Shielded nozzle: Instantaneous pressure field*
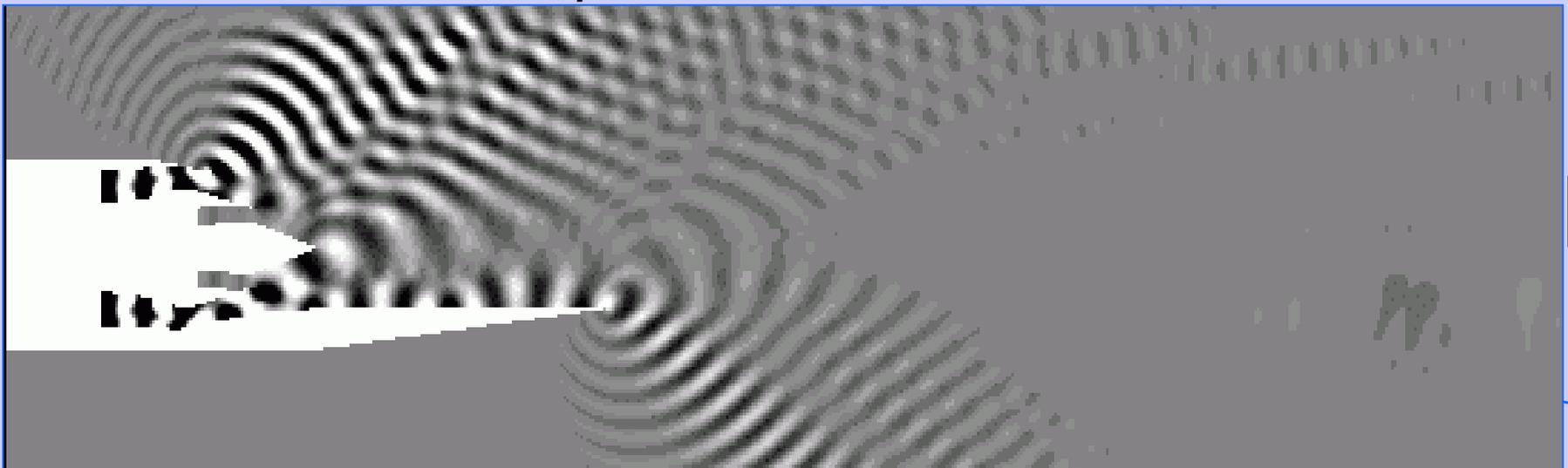
Fan Noise in an Inhomogeneous Medium
(2/3) Far-Field 2D Radiation (Kirch2D code)

Kirch2D validation

sAbrinA/ Kirch2D validation

Euler/Kirchhoff

Euler

Exit boundary

Kirchhoff frontier

Exit boundary

Kirchhoff frontier

Vo

Isolated nozzle

dB

Without flow

With flow

Shielded nozzle

dB
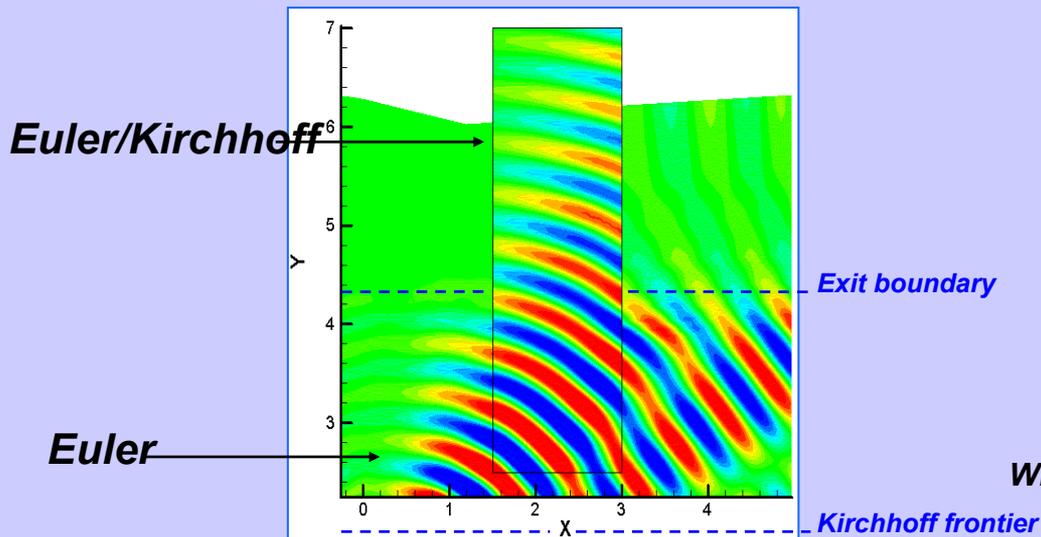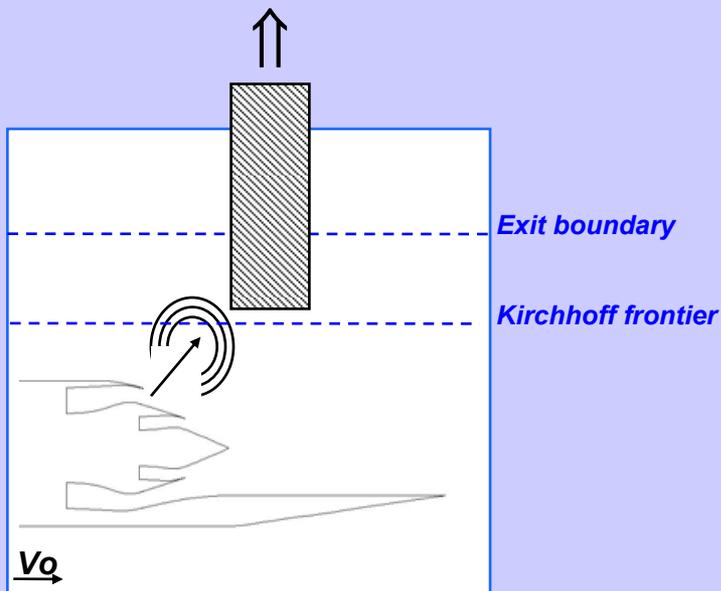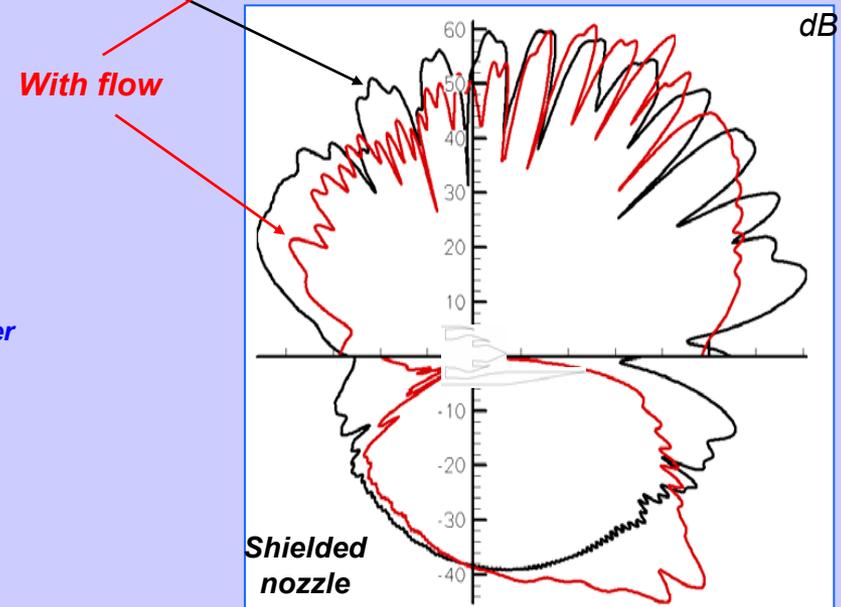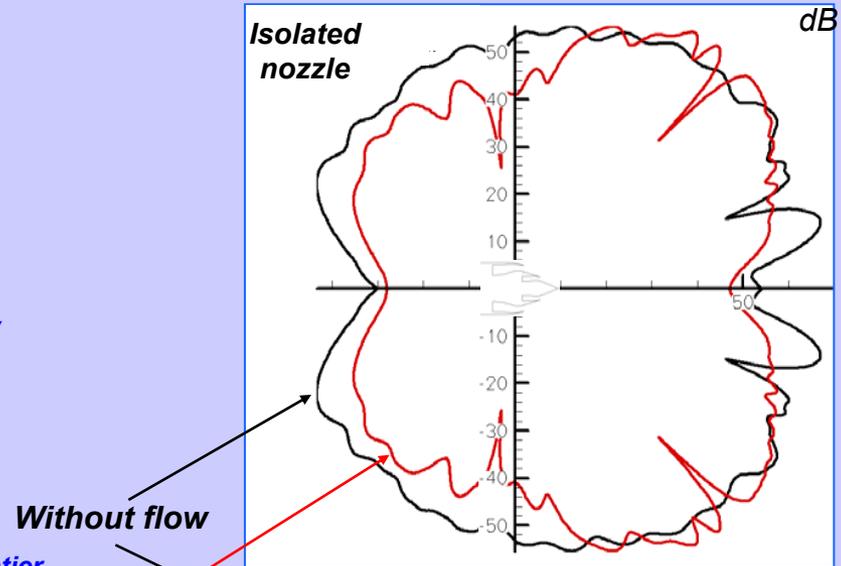
Fan Noise in an Inhomogeneous Medium
(3/3) 2D Shielding Effect Analysis

Far field directivity diagrams (dB)

Isolated nozzle : RMS pressure near & mid-fields

Shielded nozzle : RMS pressure near & mid-fields

Isolated nozzle

Shielded nozzle

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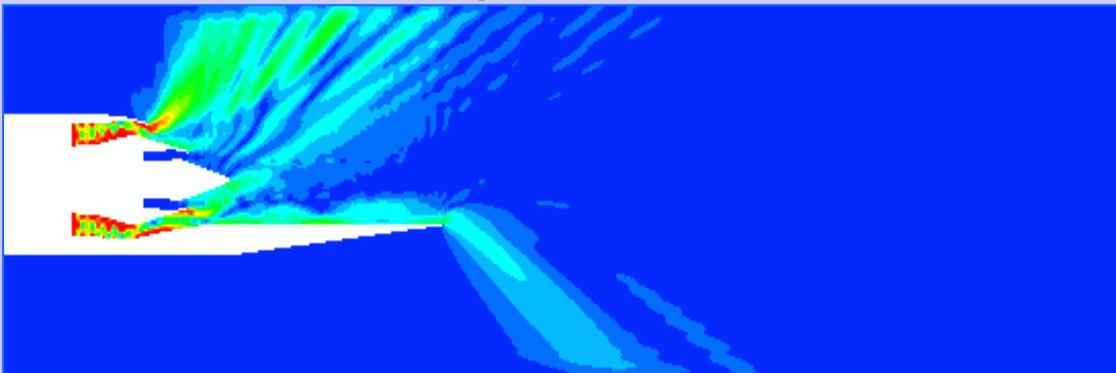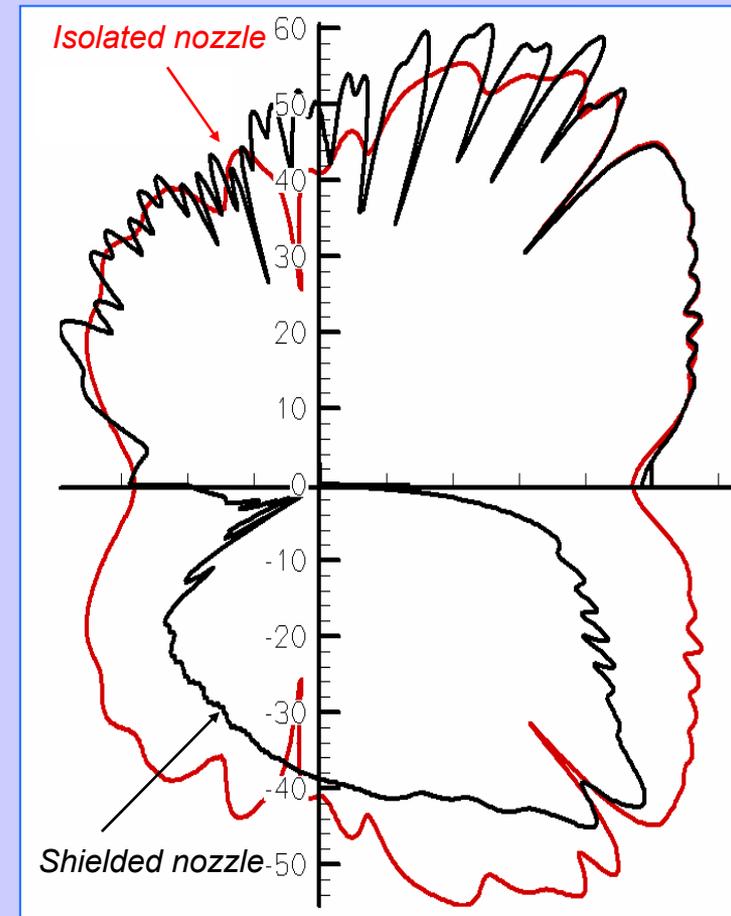
Fan Noise : Conclusions
Shielding & Highly Sheared Mean Flow 2D Effects Analysis

kR = 20

Isolated nozzle, without flow
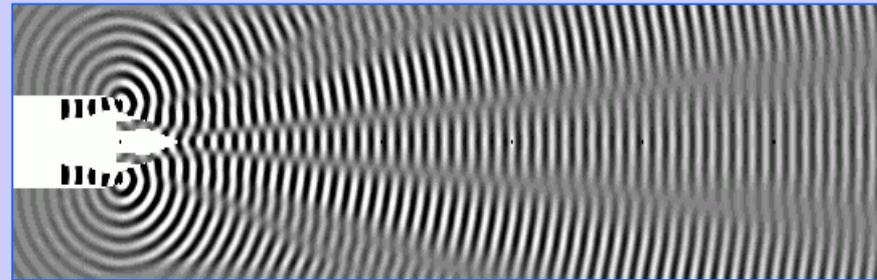
Isolated nozzle, with flow
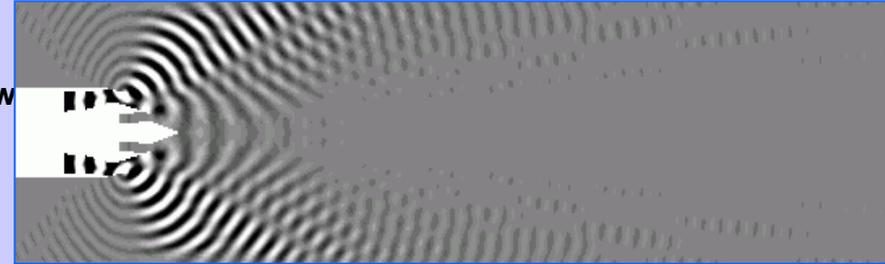
Mean flow

$\Longleftrightarrow$

effect

Shielding **effect**
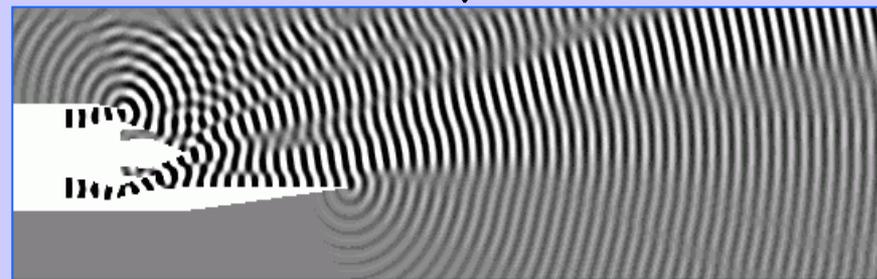
Shielding **effect**

Mean flow

$\Longleftrightarrow$

effect

Shielded nozzle, without flow
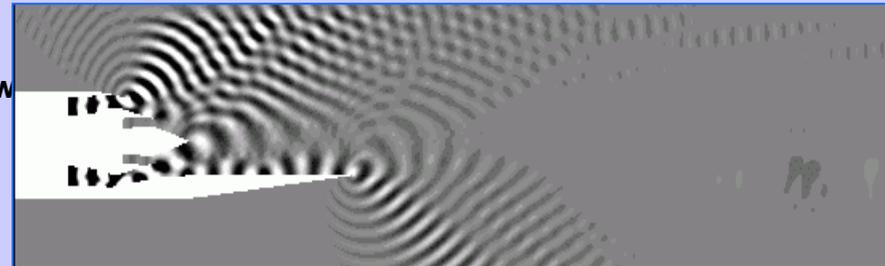
Shielded nozzle, with flow

- **Important shielding effect on the rear fan noise in a quiescent medium**

- **Important mean flow refraction effect on the rear fan noise**

- **Significant attenuation of the shielding effect by the mean flow**

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Fan Noise 3D Propagation in both a Quiescent and an Inhomogenous Medium, for the Isolated Nozzle

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Fan Noise for the Isolated Nozzle
Preliminary task : mesh and mean-flow 2D ⇒ 3D extension

**3D CAA mesh
(1,606,000 points / 25 angular planes)**
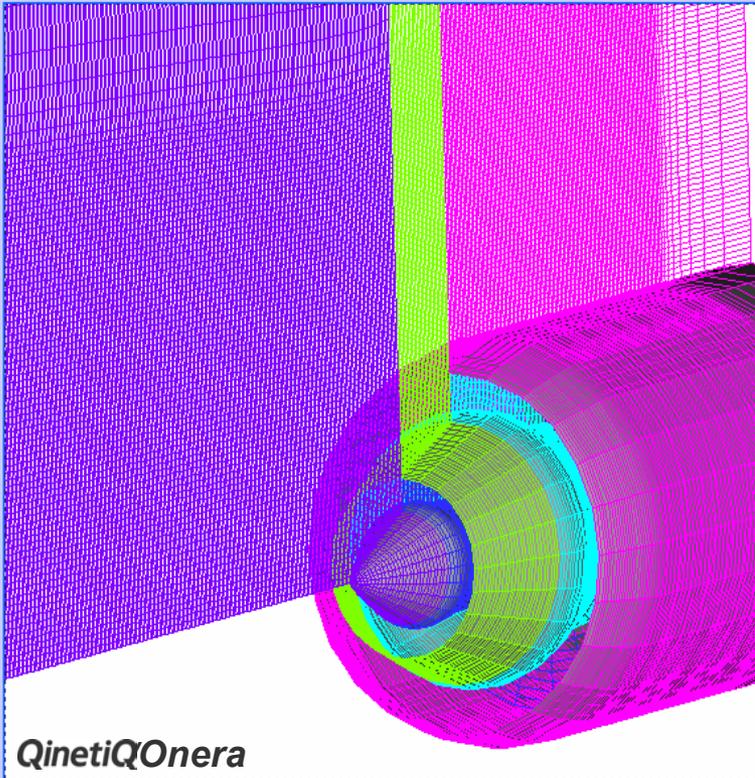
QinetiQ/Onera

**<u>Requirements</u> :
12 points per apparent angular wavelenght
⇓
spinning modes of order up to 2**

**3D axi-symetric mean flow (axial velocity)**

QinetiQ/Onera

333.7
312.8
292.0
271.1
250.2
229.4
208.5
187.7
166.8
146.0
125.1
104.2
83.4
62.5
41.7
20.8

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Spinning mode of order 0 (plane wave)

**Spinning mode of order 2**

Spinning mode of order 0 (plane wave)
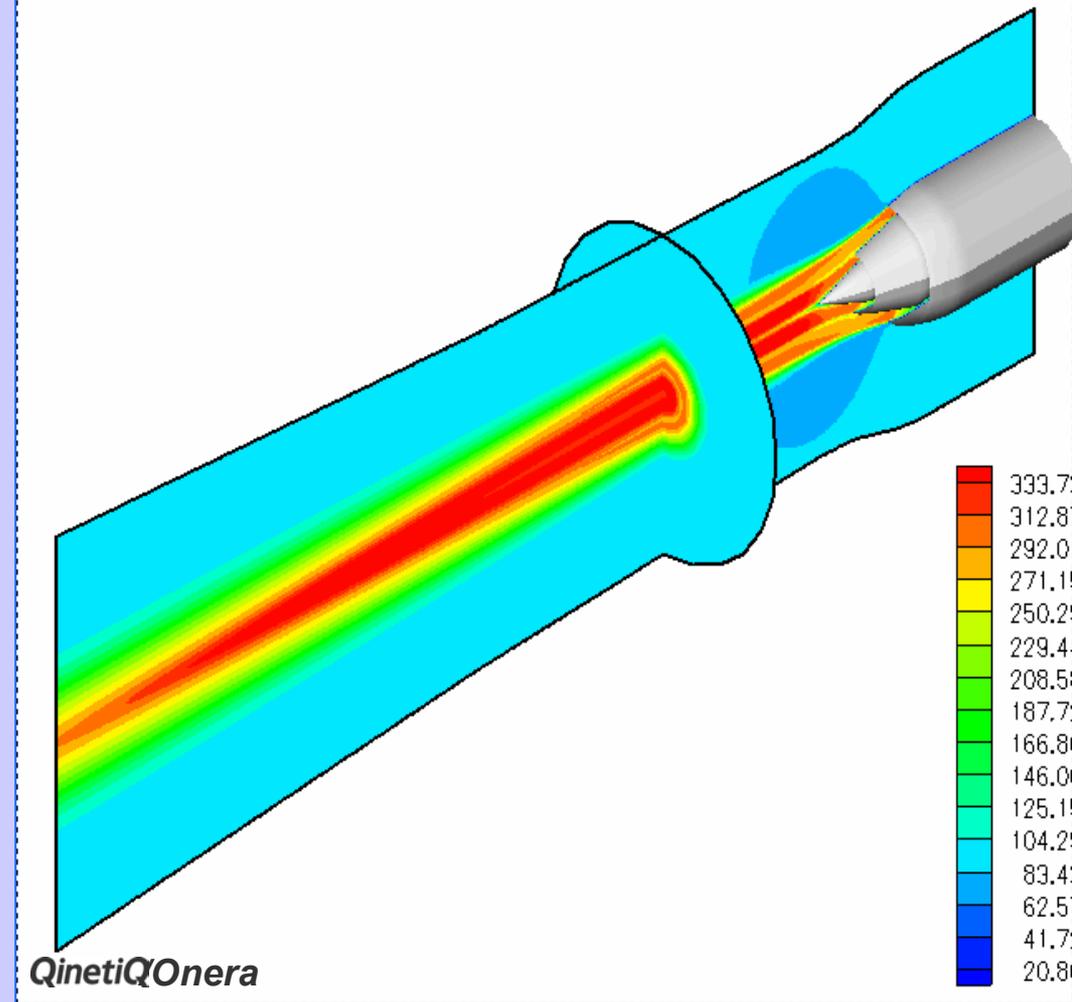
Spinning mode of order 2

Fan Noise in a Quiescent Medium (Isolated Nozzle)
(3/3) Far-Field 3D Radiation & Validation (sAbrinA 3D / Kirch3D vs. Sysnoise)
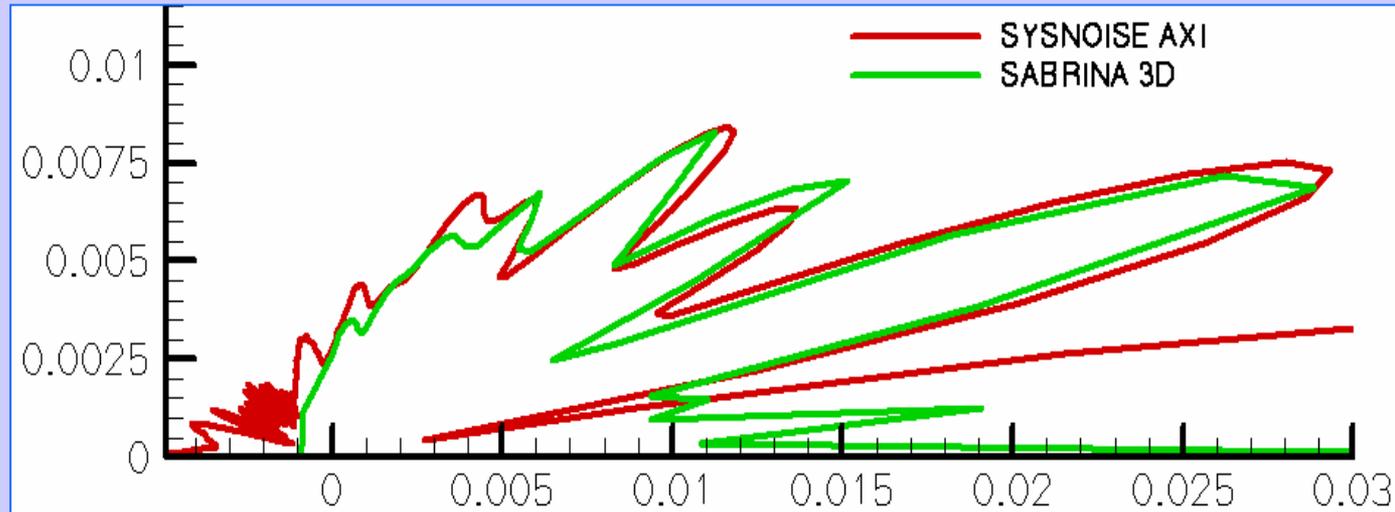
*Spinning mode of order 0 (plane wave)*

Spinning mode of order 2

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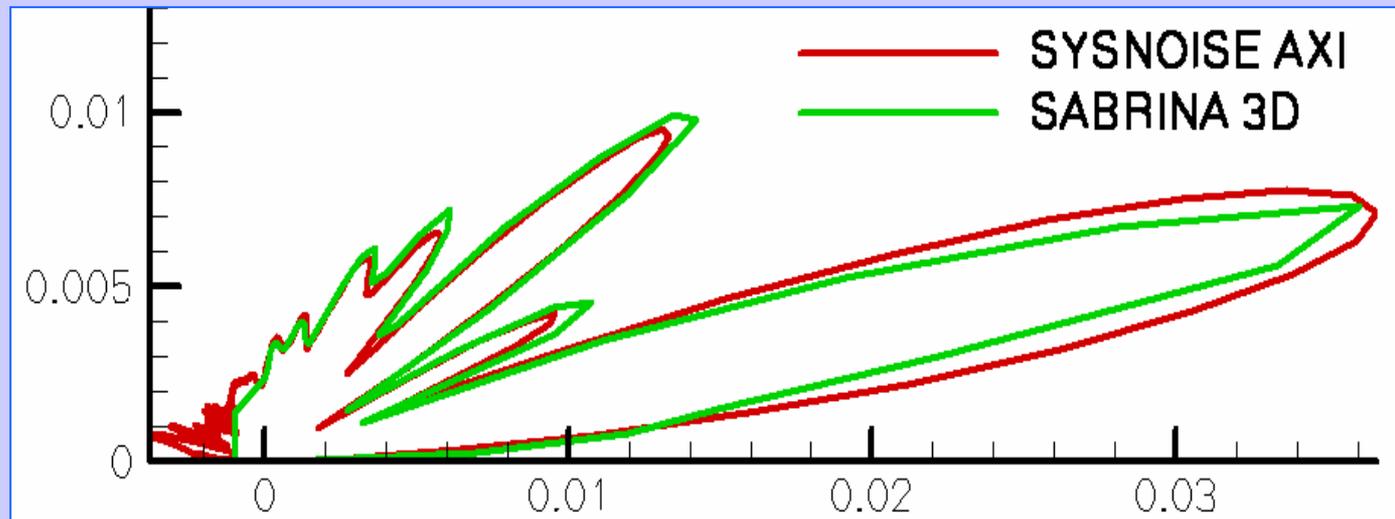
# Fan Noise in an Inhomogeneous Medium (Isolated Nozzle)
(1/2) Near & Mid-Field 3D Propagation (sAbrinA 3D)

*Spinning mode of order 0 (plane wave)*
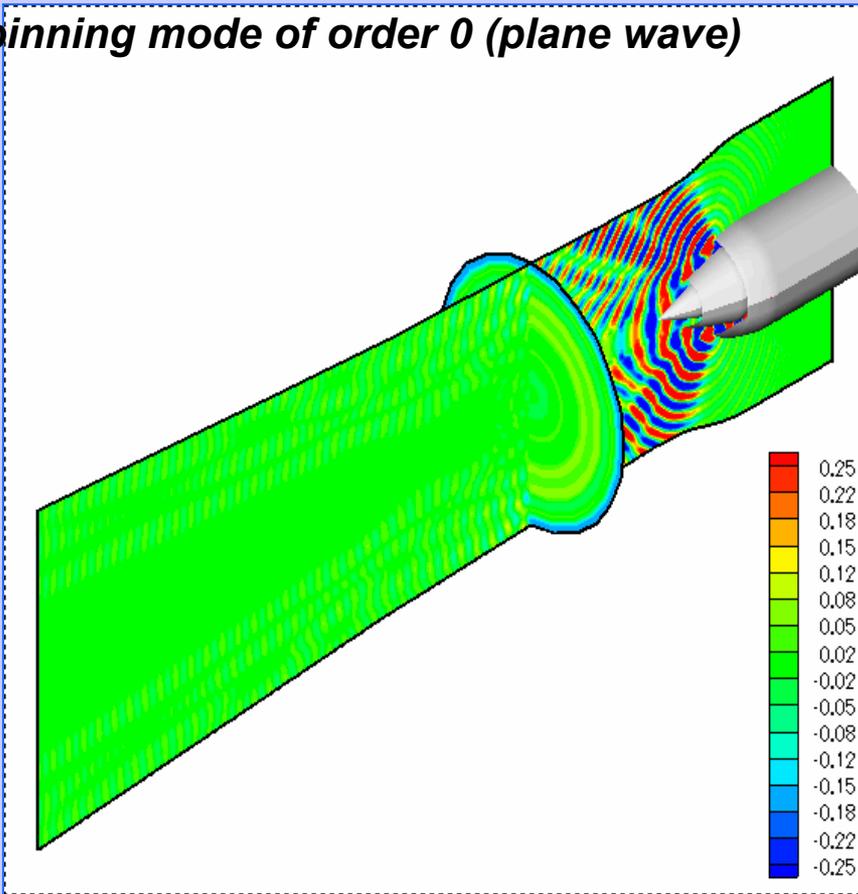
*Spinning mode of order 2*
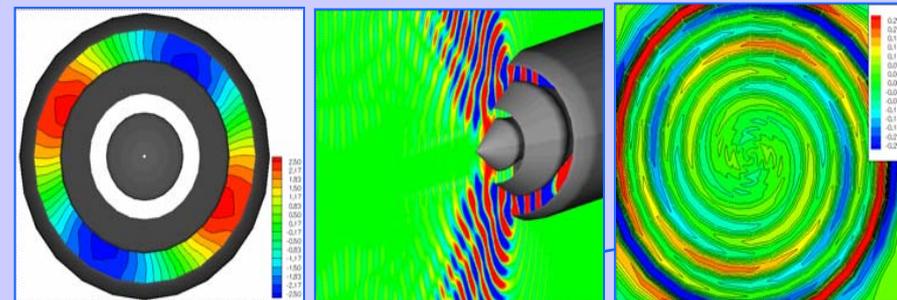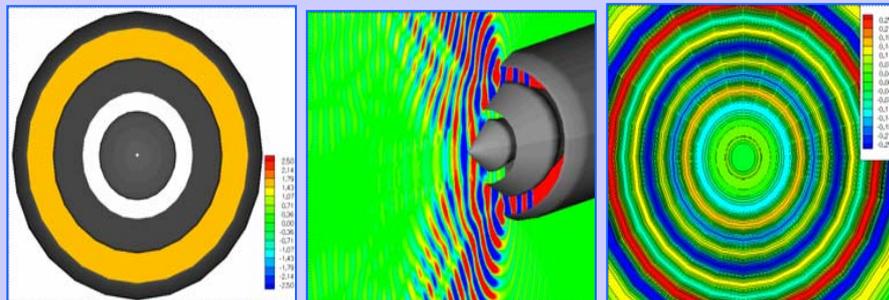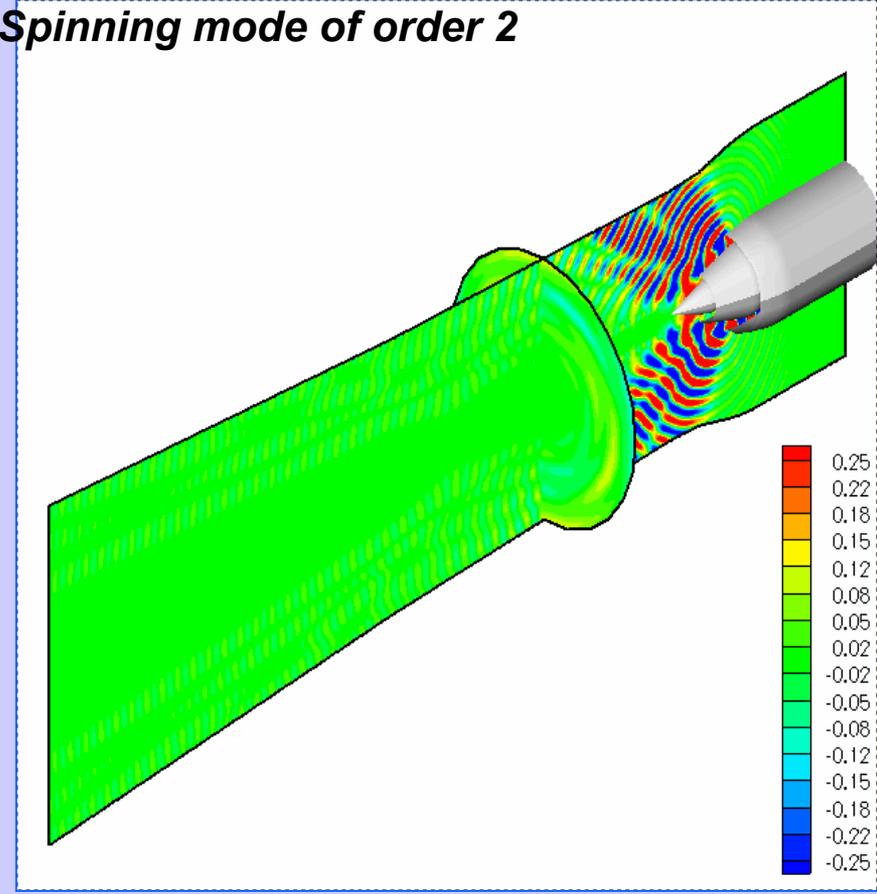
Fan Noise in an Inhomogeneous Medium (Isolated Nozzle)
Far-Field 3D Radiation (sAbrinA 3D/ Kirch3D), and Mean Flow Effects Analysis

Spinning mode of order 2

Spinning mode of order 0 (plane wave)

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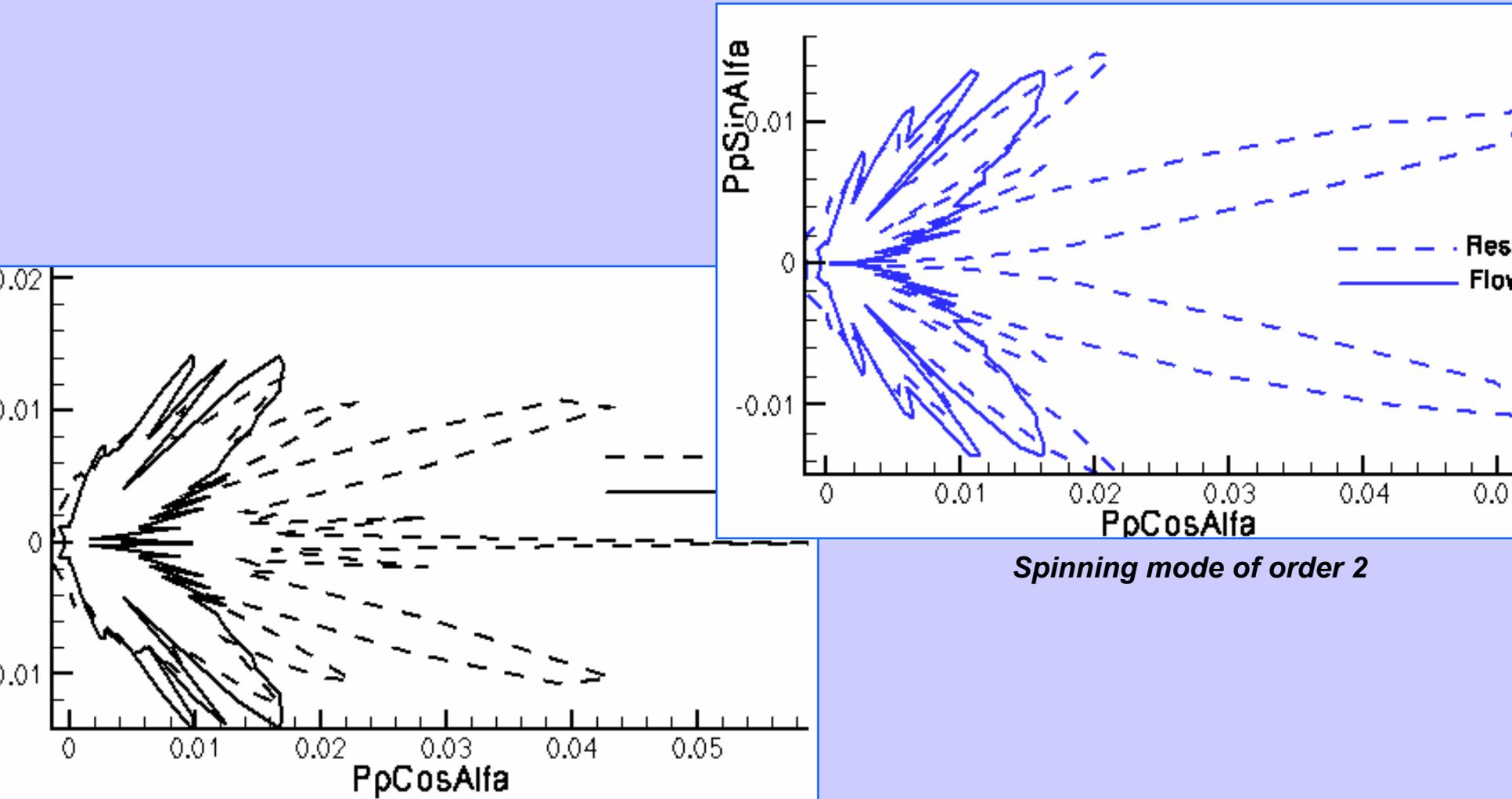
Conclusions

❑ **Validation** of the **hybrid methodology & tools** used for this kind of **engine applications**

❑ **Important shielding effect** on the **2D propagation** in a **medium at rest**

❑ **Important** (highly sheared) **mean flow refraction effect** on the **2D propagation**

❑ **Significant attenuation** of the **2D shielding effect** by the **(inhomogeneous) mean flow**

❑ **Extension** of the **isolated nozzle** study to **3D :** still **important mean flow refraction effects**

Perspectives

❑ **3D computations** over the **shielded nozzle (complex** 3D **geometry)**

❑ **Generation** of **exact fan noise modes**, in order to perform a **more realistic calculation (European Project "*NACRE*")**

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