# Transmission loss of a muffler

Actran Student Edition Tutorial

# Workshop description

# Introduction

- This workshop demonstrates Actran capabilities to model an expansion chamber (simple muffler) and calculate its transmission loss

- The objectives of this workshop are the following:
  - Get introduced to muffler transmission loss
  - Use 2D geometry to model axi symmetric 3D problem
  - Distinguish plane wave duct propagation and non plane wave propagation

- Software version
  - Actran 2021.1 Student Edition



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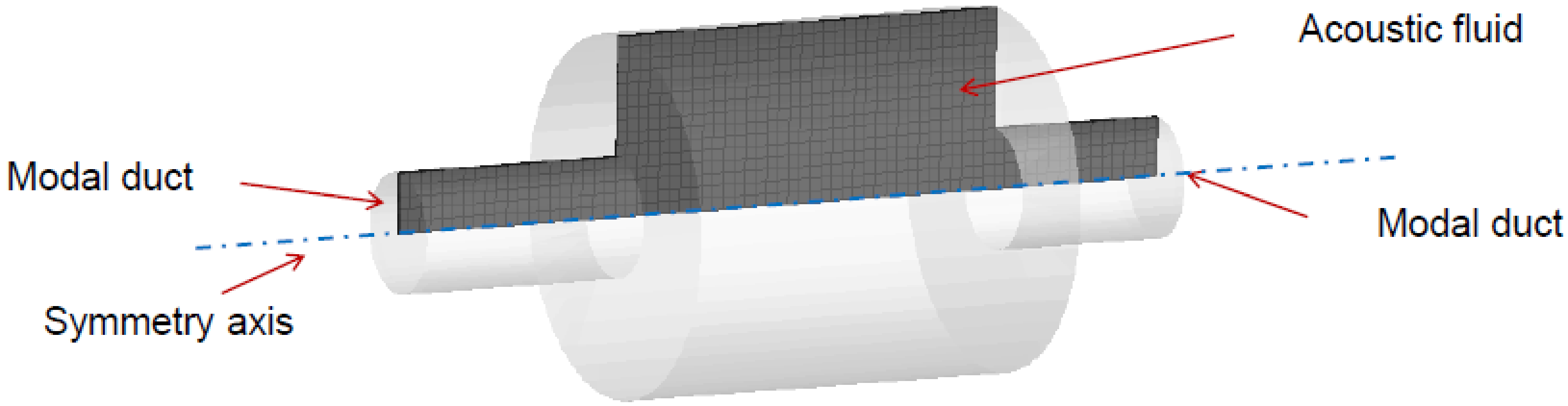
# Workshop description

- Through this workshop, we will model an expansion chamber using 2D axisymmetric modeling technique and calculate its transmission loss

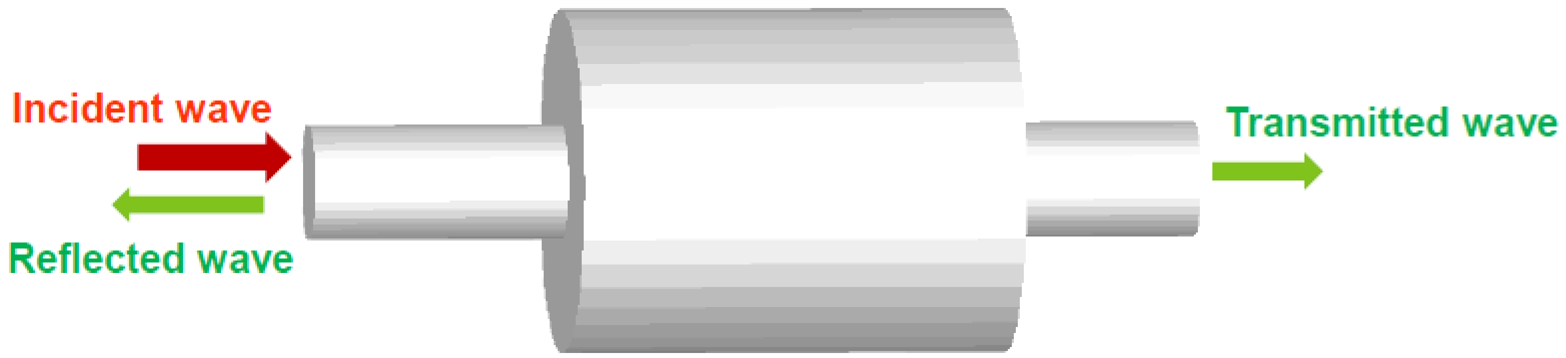
- The muffler is modeled in 2D
  - A finite fluid component is defined

- Muffler inlet and outlet are modeled by modal ducts
  - Modal basis components are defined



# Transmission loss of muffler

- Incident wave is partially transmitted and partially reflected by the muffler




- The Transmission Loss (TL) is the ratio between the incident power and transmitted power

$$TL = 10log_{10}\left(\frac{W_{incident}}{W_{transmitted}}\right)$$

- Acoustic anechoic condition is applied
  - at outlet for the transmitted wave
  - at inlet for the reflected wave



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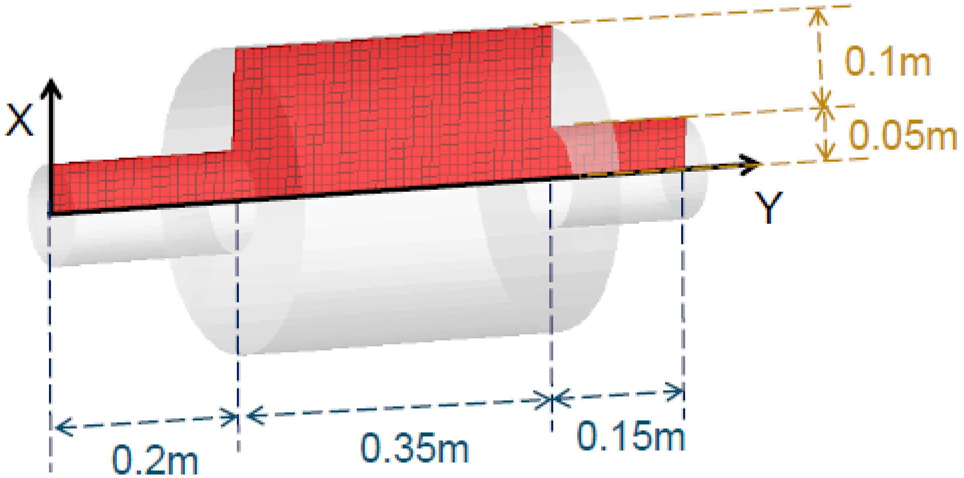
# Analytical solution

- For an expansion chamber, the analytical TL can be calculated using the equation

$$TL = 10\log\left[1 + \left(\frac{m^2 - 1}{2m}\sin kl\right)^2\right]$$

  - $m$: cross section area ratio between expansion chamber and inlet (outlet) tube (0.15 / 0.05)² = 9
  - $l$: length of expansion part of the chamber = 0.35 mm
  - $k$: wave number $= 2\pi f/c$

- This analytical solution is calculated with the assumption of plane wave propagation in the muffler



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# Workshop pre-processing

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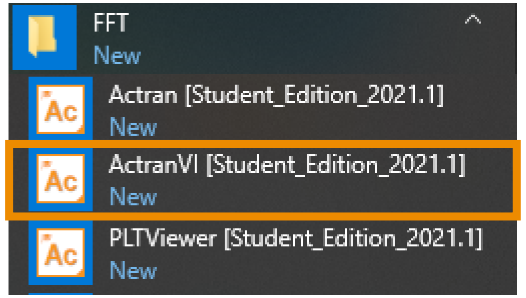
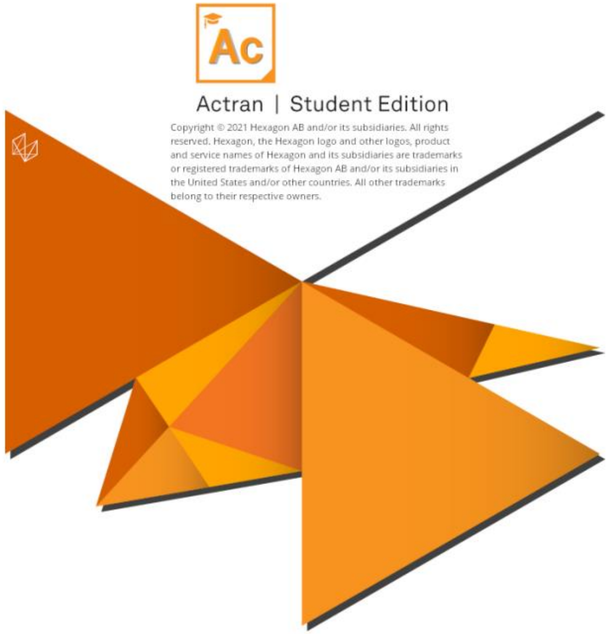
# Start ActranVI

- Start ActranVI:
  - Shortcut is available through the Windows Start Menu




*(Windows Start Menu)*



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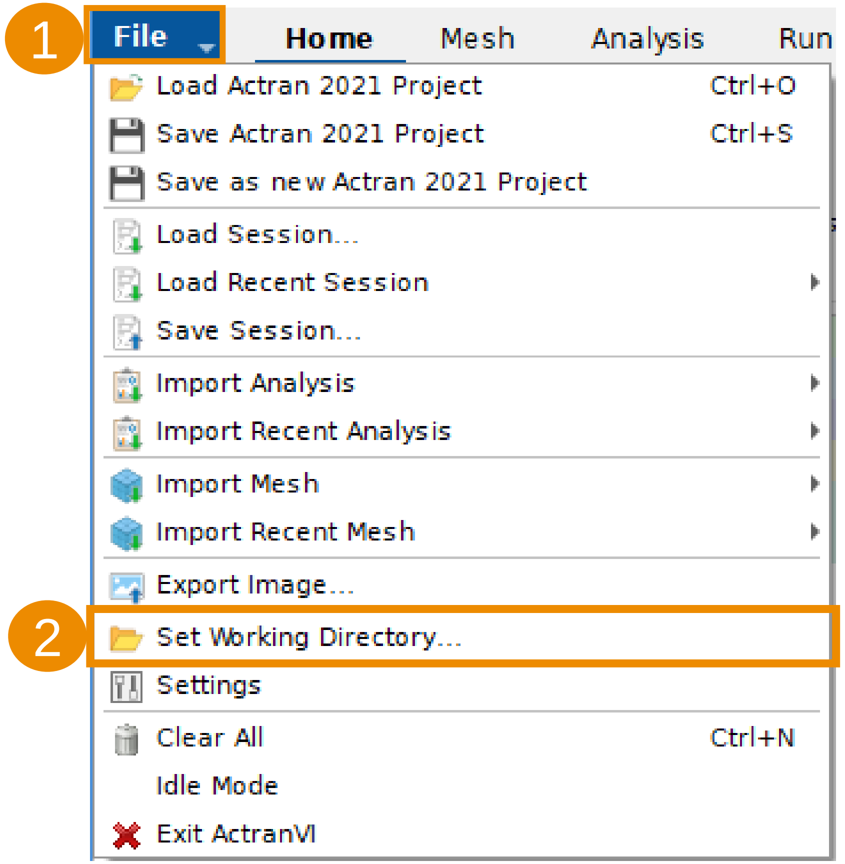
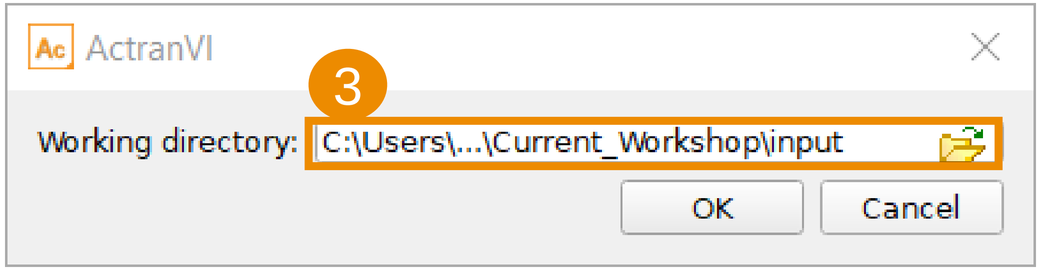
# Set the working directory

Select the workshop input directory as the working directory

- The working directory is the project directory where all ActranVI related files are output

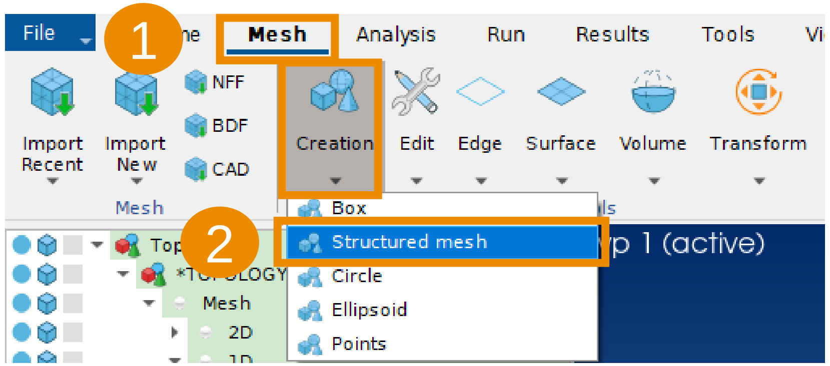
*The working directory path should not contain any space or special character*

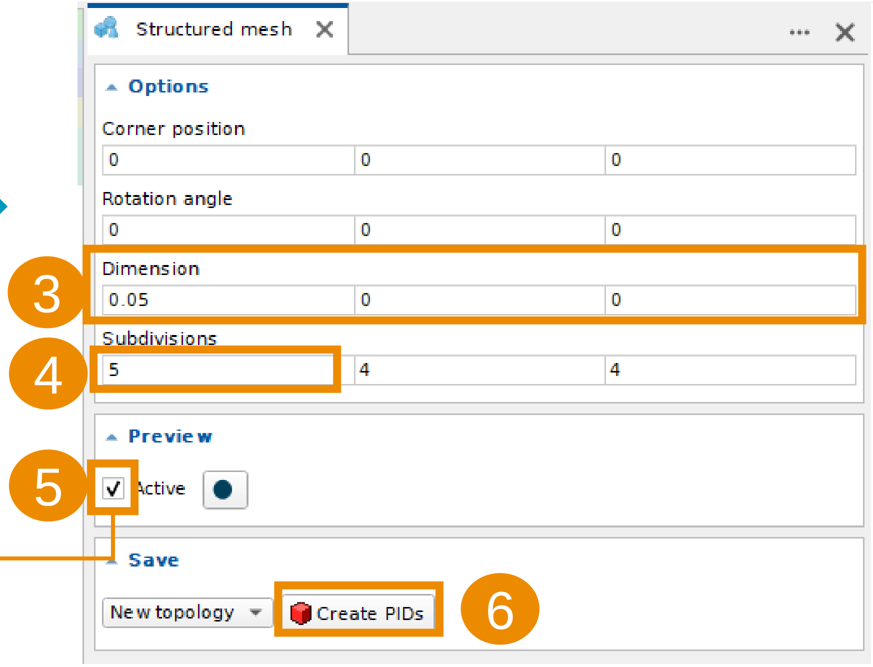


# Create the mesh

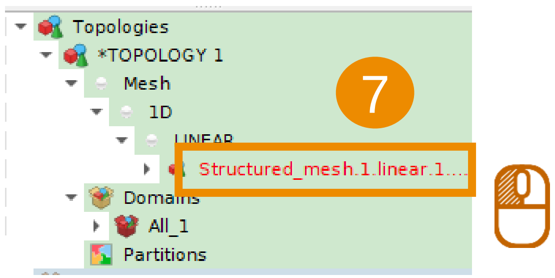
- Create an edge (1D structured mesh)



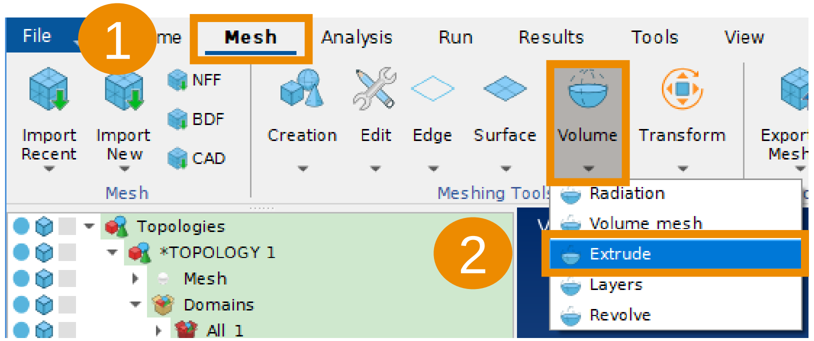

- Make sure it is selected

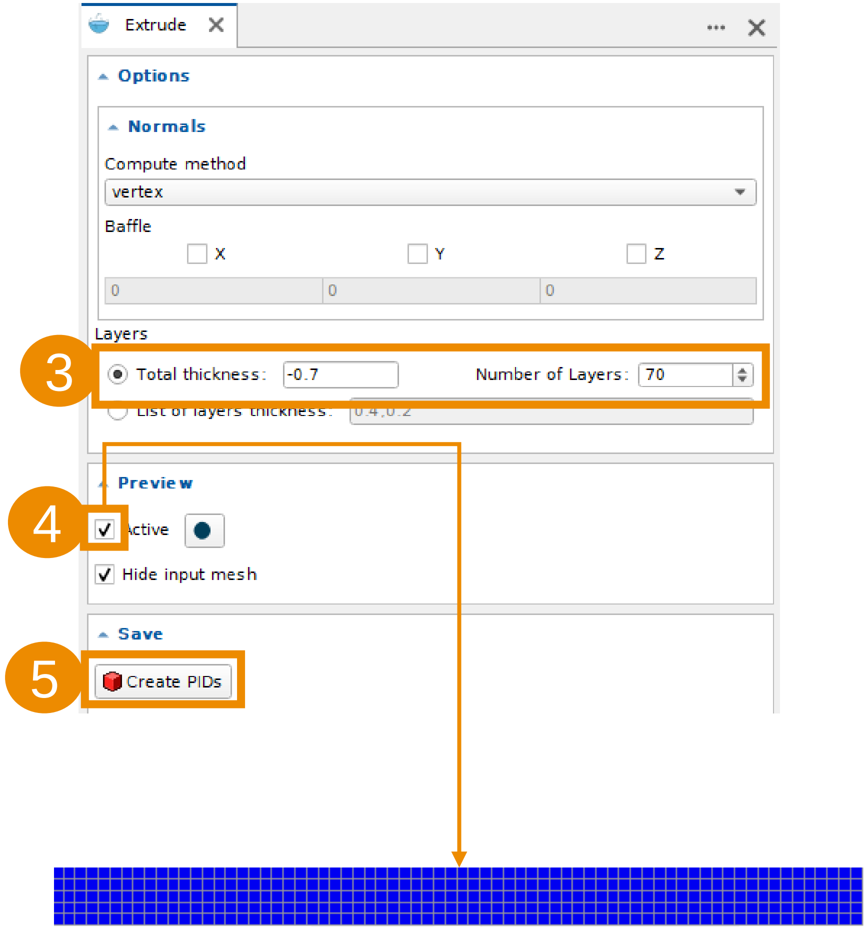




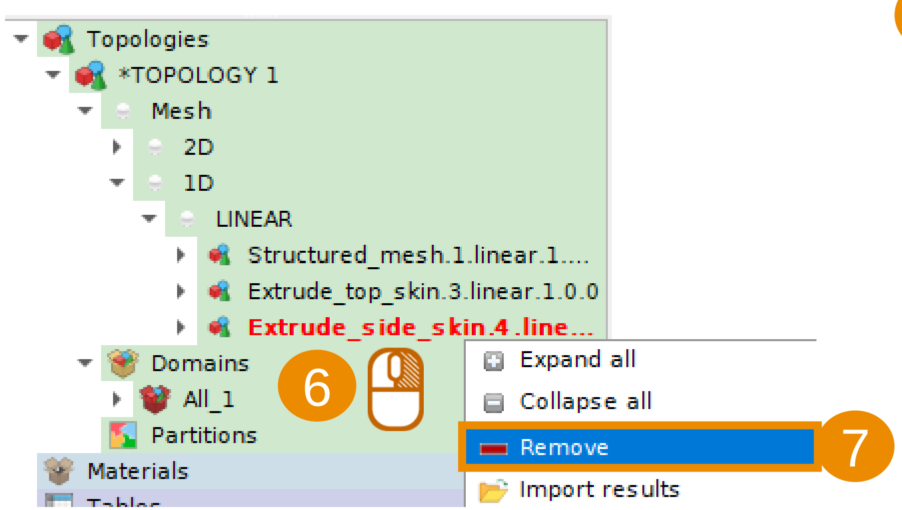
# Create the mesh

- Extrude it with a thickness **-0.7** (minus is for an extrusion in the right direction)




- Remove the PIDs Extrude_side_skin (1D)



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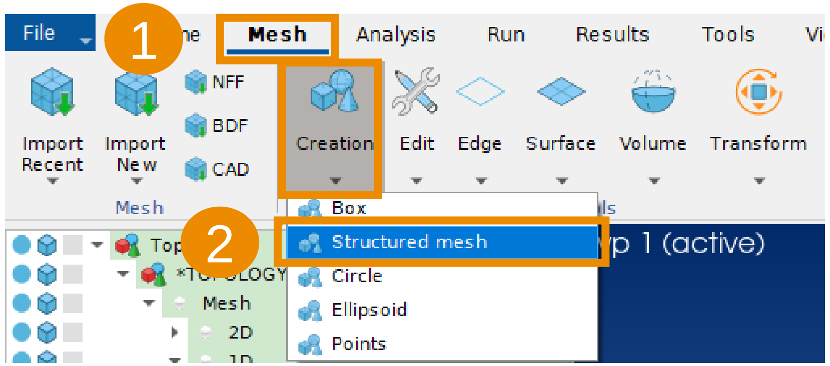
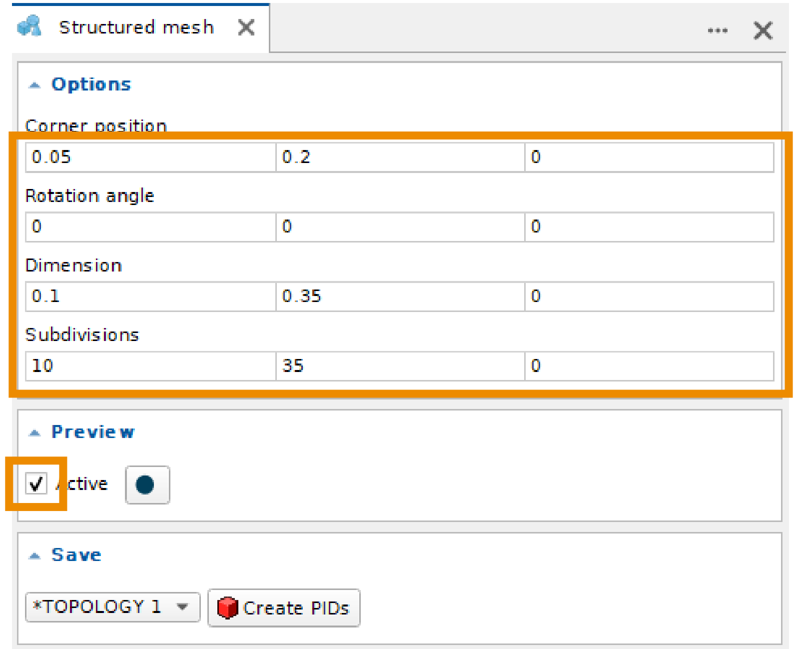
# Create the chamber cavity mesh

- Create a structured mesh

1

2



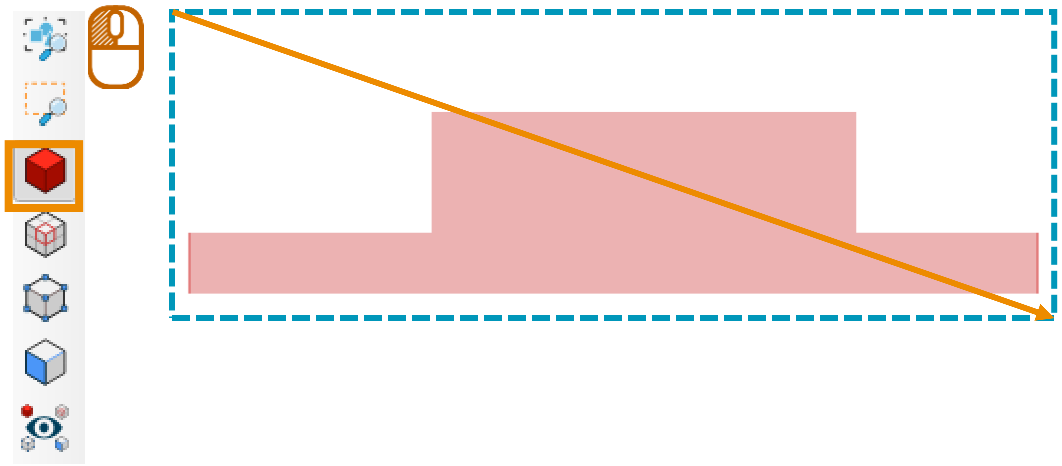




3

4

- Select all your PIDs

5 Ctrl +(hold)

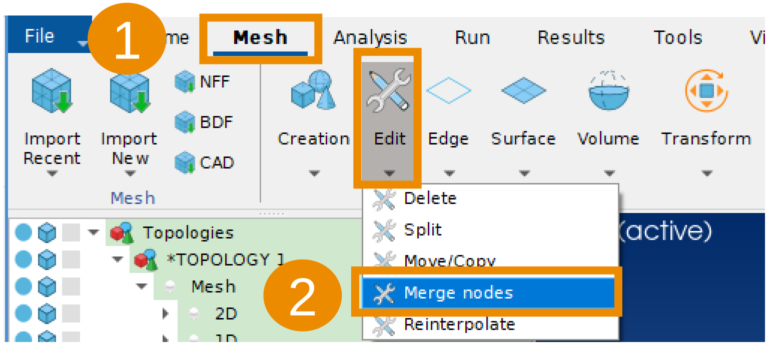


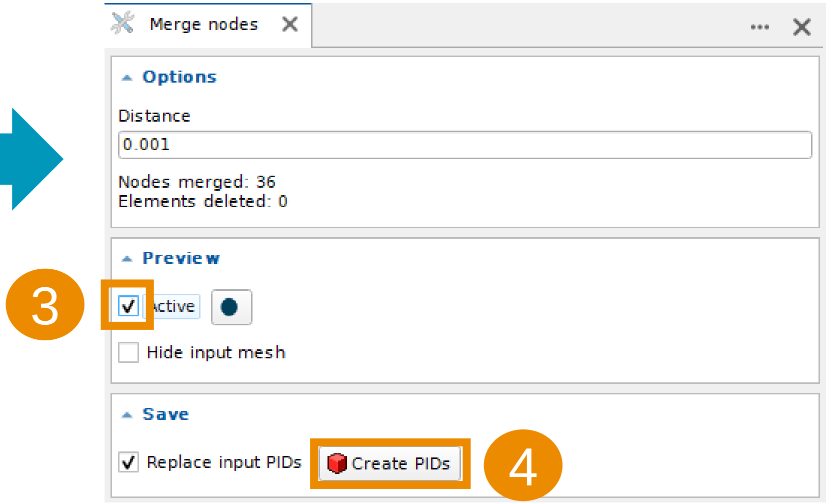
6

Drag & Release

# Create the mesh

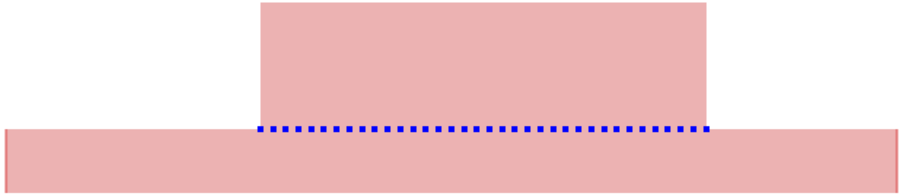
- Merge the adjacent nodes




NOTE

*Nodes at the interface of the extruded mesh and the structured mesh will be merged*





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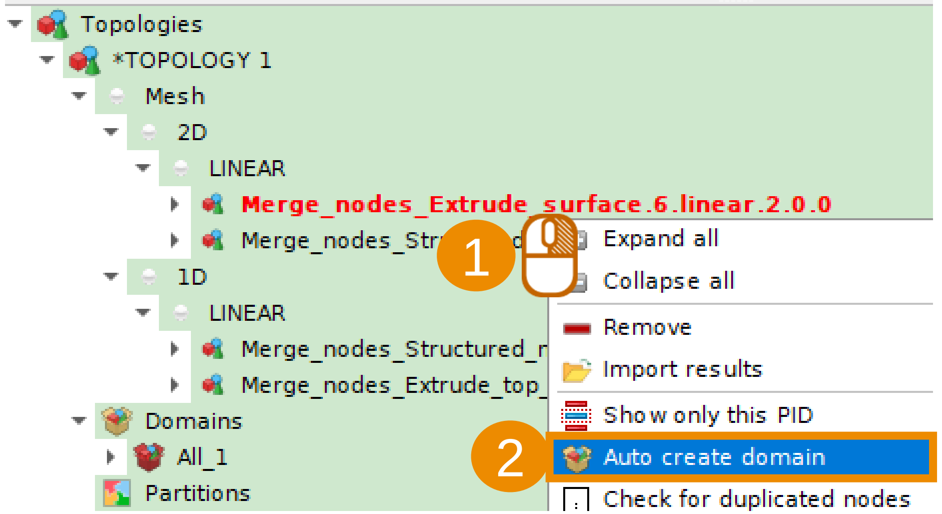
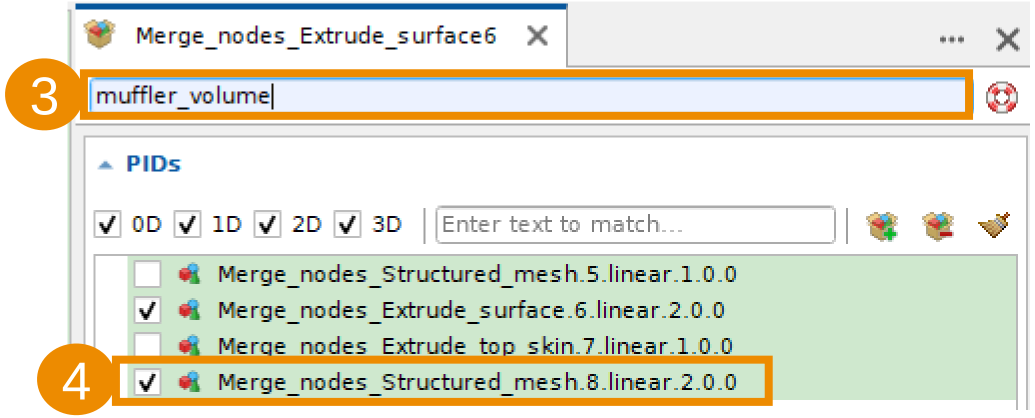
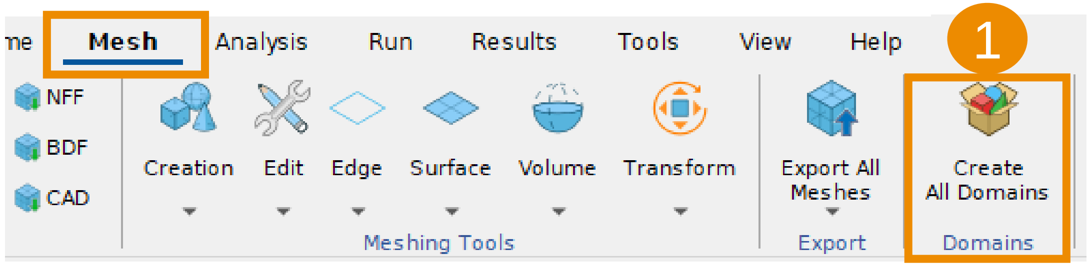
# Muffler volume domain definition

- Create a domain for the first 2D element set
- Rename it muffler_volume
- Add the second 2D element set to the muffler_volume domain

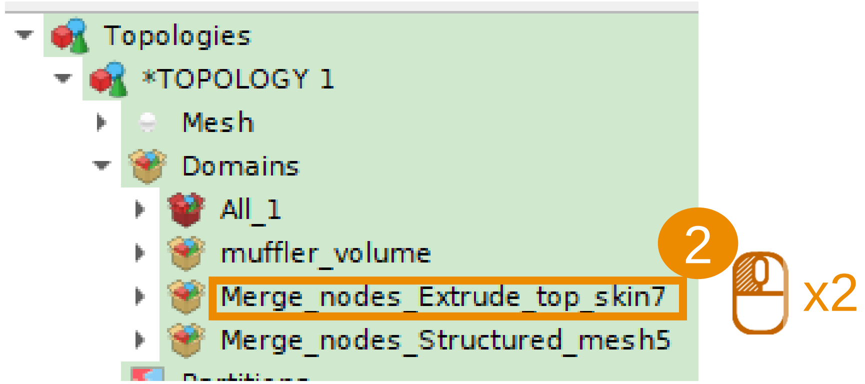


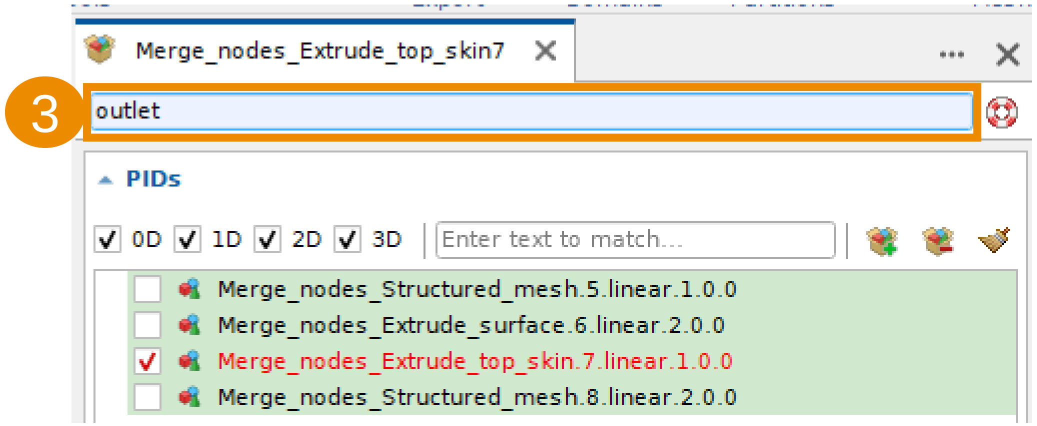



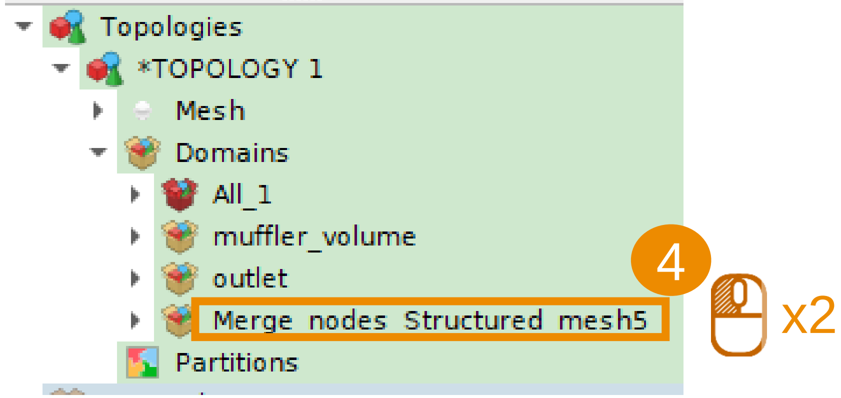
# Create the domains

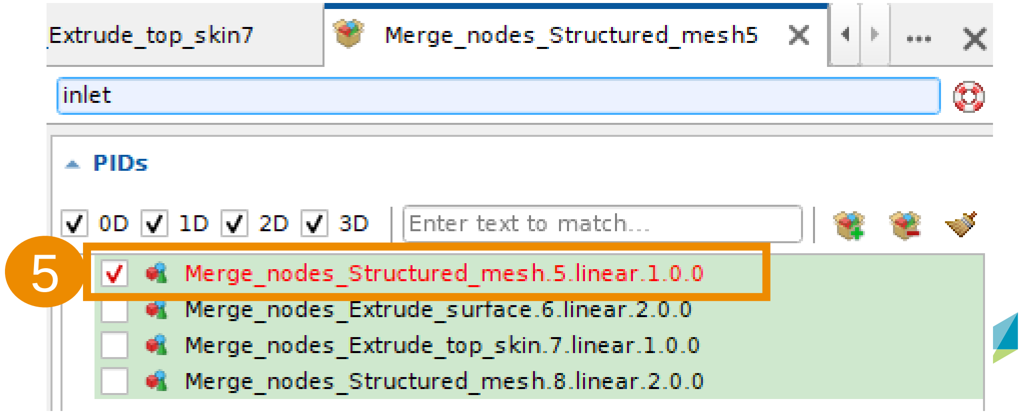



- Rename the domains like so:
  - Merge_nodes_Extrude_top_skin → outlet
  - Merge_nodes_Structured_mesh → inlet

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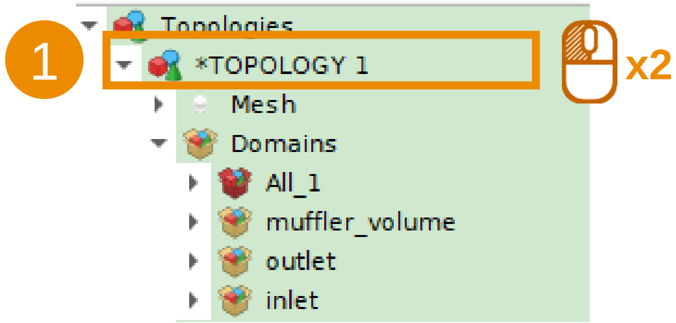
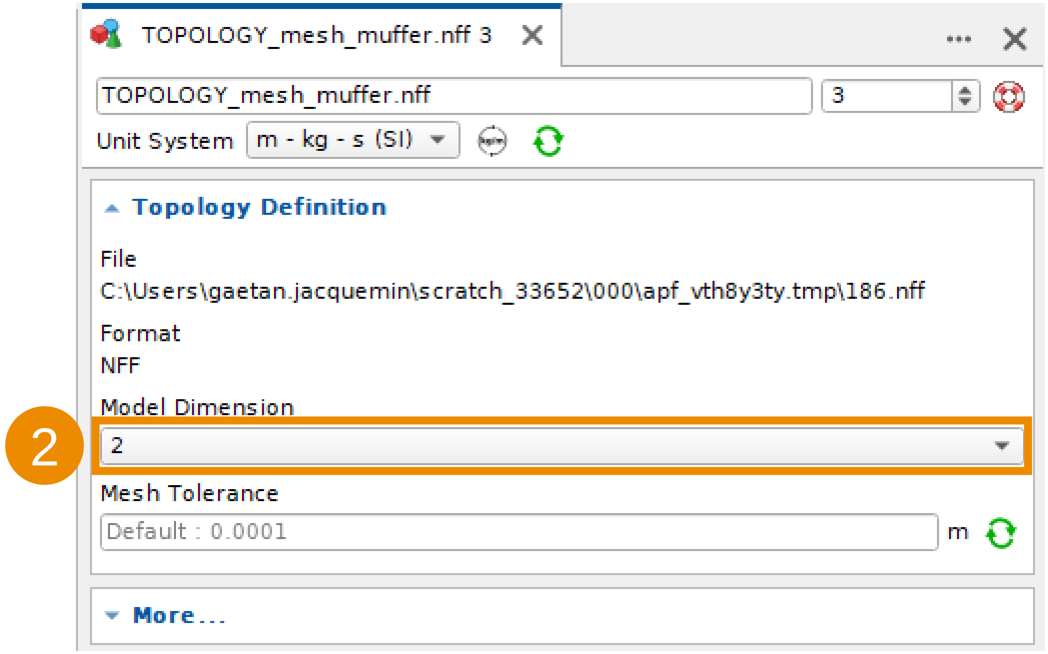
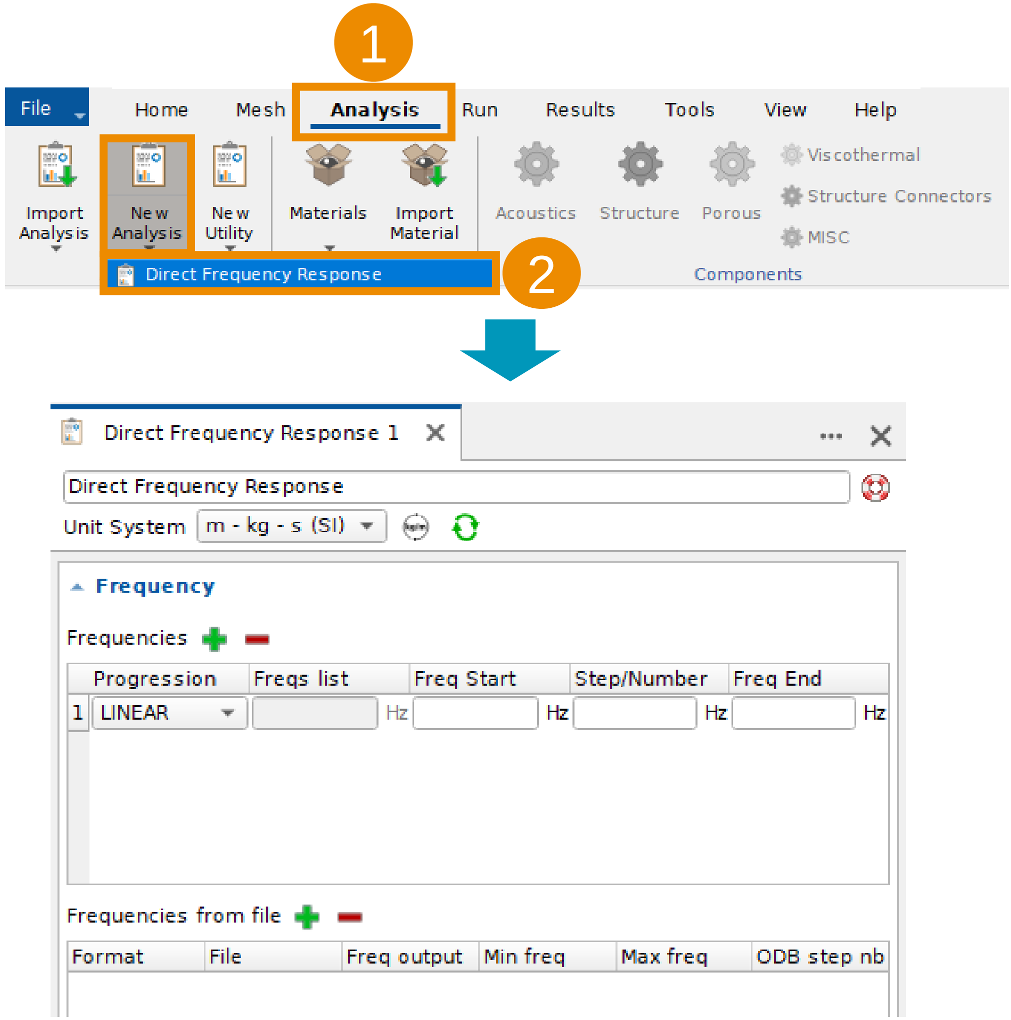
# Set the model dimension to 2D

- Set the dimension of the model to 2D (to apply later the axi-symmetry)



# Create the Actran analysis




Add a *Direct Frequency Response* analysis (DFR)

- A DFR is computation procedure which provides the response of an acoustic, vibro-acoustic or aero-acoustic system to a specific excitation in physical coordinates



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# Specify the frequency range of interest

## The acoustic fluctuations must be captured

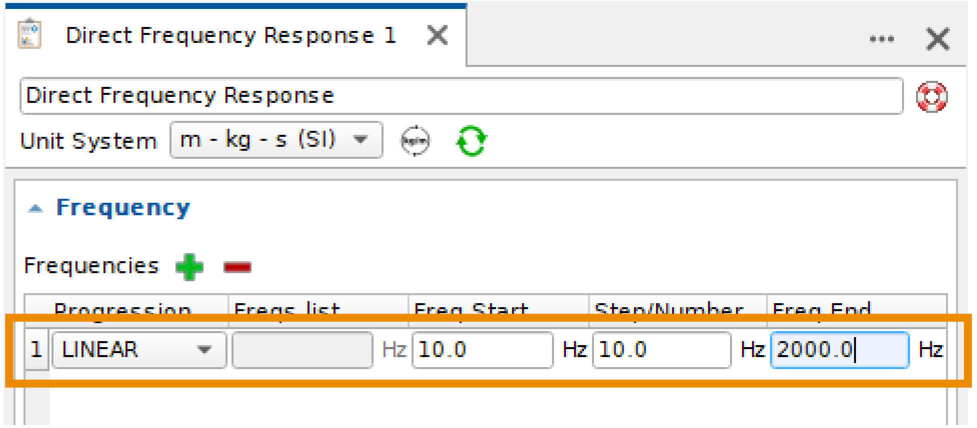
- Maximum frequency (smallest wavelength) is driven by the largest element length
- For linear elements, 8 elements per wavelength can be used (rule of thumb)
- Mesh largest element length is 10 mm
  → maximum frequency is 4250 Hz

$$\left.\begin{aligned} f_{max} &= \frac{c}{\lambda_{min}} \\ L_{max} &= \frac{\lambda_{min}}{8} = 0.01\ m \end{aligned}\right\} \quad f_{max} = \frac{340}{8 * 0.01} = 4250\ Hz$$

## Set the computed frequencies in the analysis properties

- This analysis is performed from 10 Hz to 2000 Hz, with a step of 10 Hz

1



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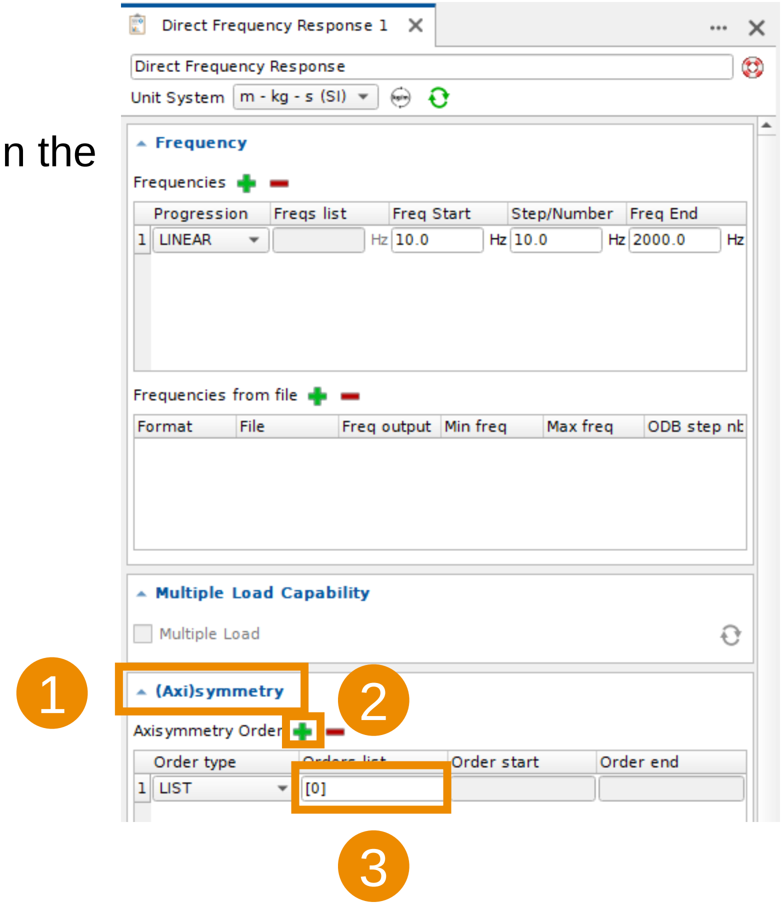
# Axi-symmetry definition

- The Actran model is a 2D axi symmetric model. This should be defined in the Direct Frequency Analysis properties
  - Set the Axisymmetry Order to 0. This specifies a constant solution with varied azimuthal angle in the duct cross section

- By default, the Y axis is always the axis of revolution, The mesh of axisymmetric problems must be located in the right half (X > 0) of the XY plane.



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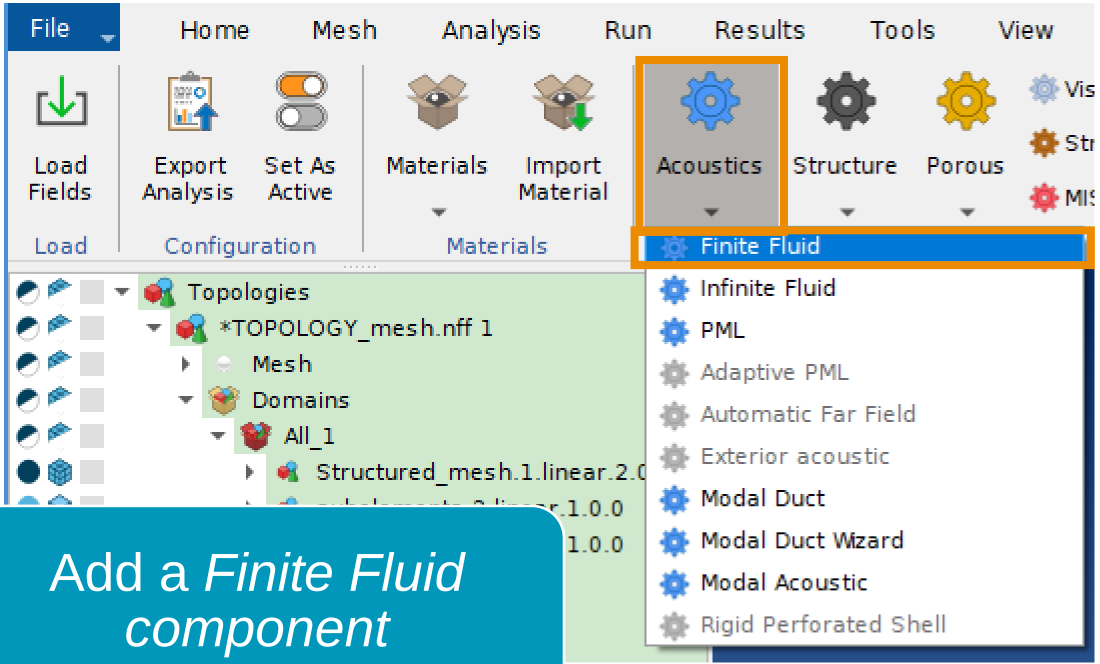
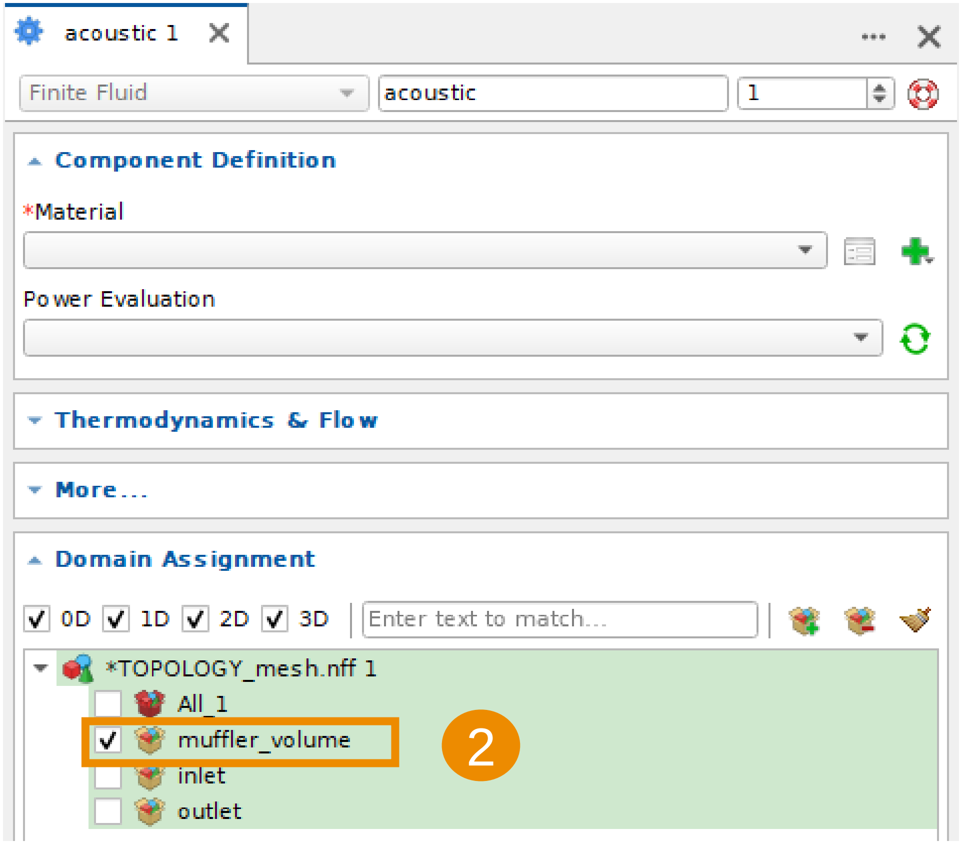
# Create a Finite Fluid component (1)




Add a *Finite Fluid component*

Set up the *Finite Fluid component* domain



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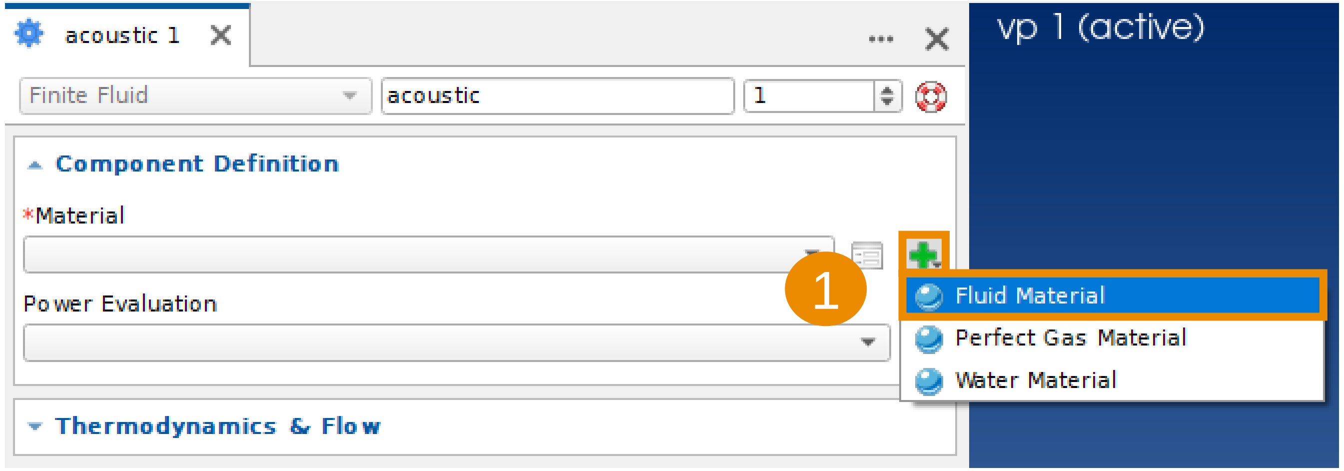
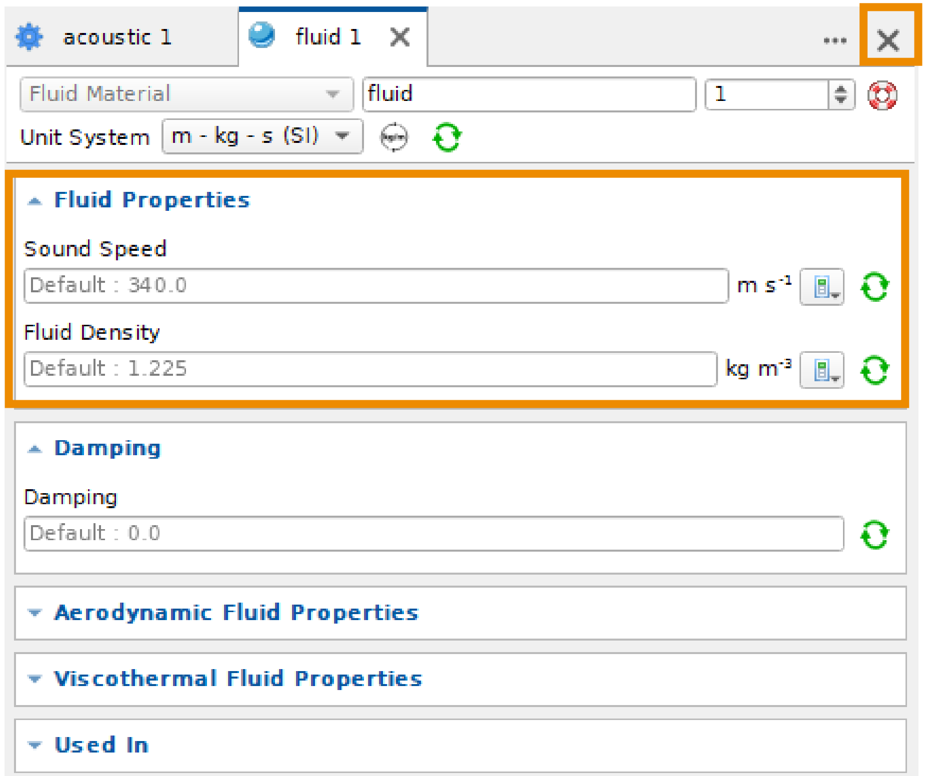
# Create a Finite Fluid component (2)

Define a material for air

- Add a Fluid Material
- Leave the values by default :
  - $c = 340\ m/s$
  - $\rho = 1.225\ kg/m^3$




Close both property windows (material & component)



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# Modal ducts components

- For in duct propagation problems, acoustic wave can be seen as a mathematical superposition of duct modes
- In Actran, such an analytical representation is used in order to specify non-reflecting BC as well as to inject energy through a given system assuming a connection to semi-infinite ducts
- Two types of modes can be defined:
  - Constrained: allows injecting energy in the system and must be defined in the +1 direction (see further slides) if the first axis points inside the system
  - Free : allows representing a non-reflecting BC and must be defined in the -1 direction (see further slides) if the first axis points inside the system (+1 otherwise)



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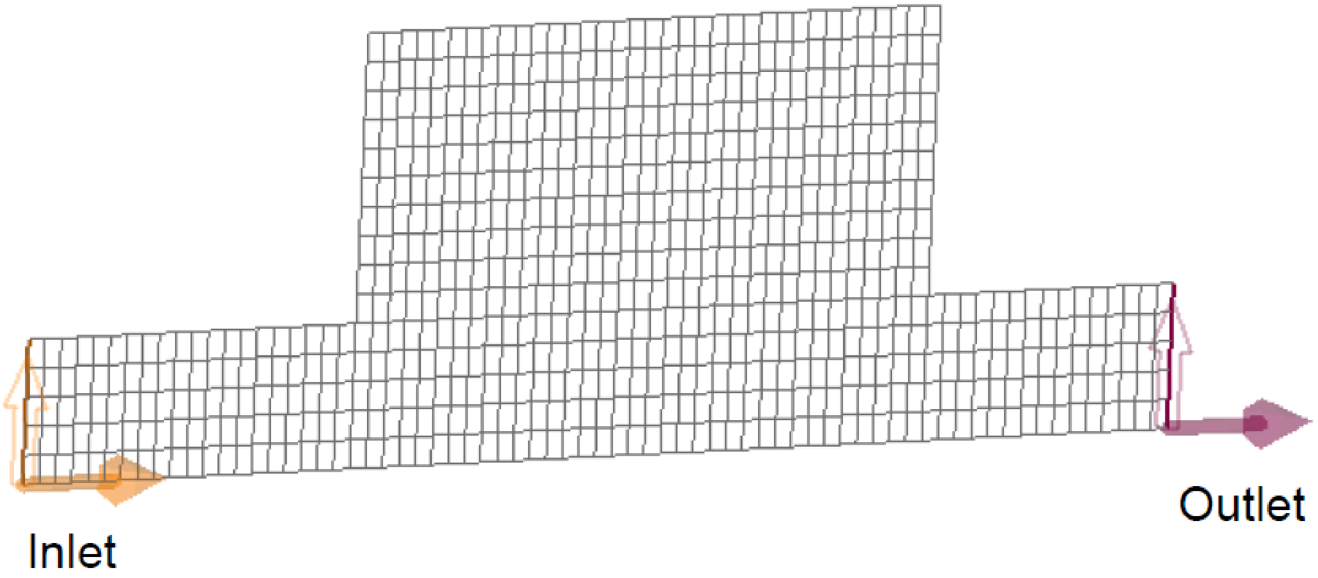
# Power quantities of duct modes

- In the PLT result, a duct modal basis contains two power quantities
  - Incident power: power along the positive direction (indicated by the thick arrow) of the duct mode
  - Reflected power: power opposite to the positive direction



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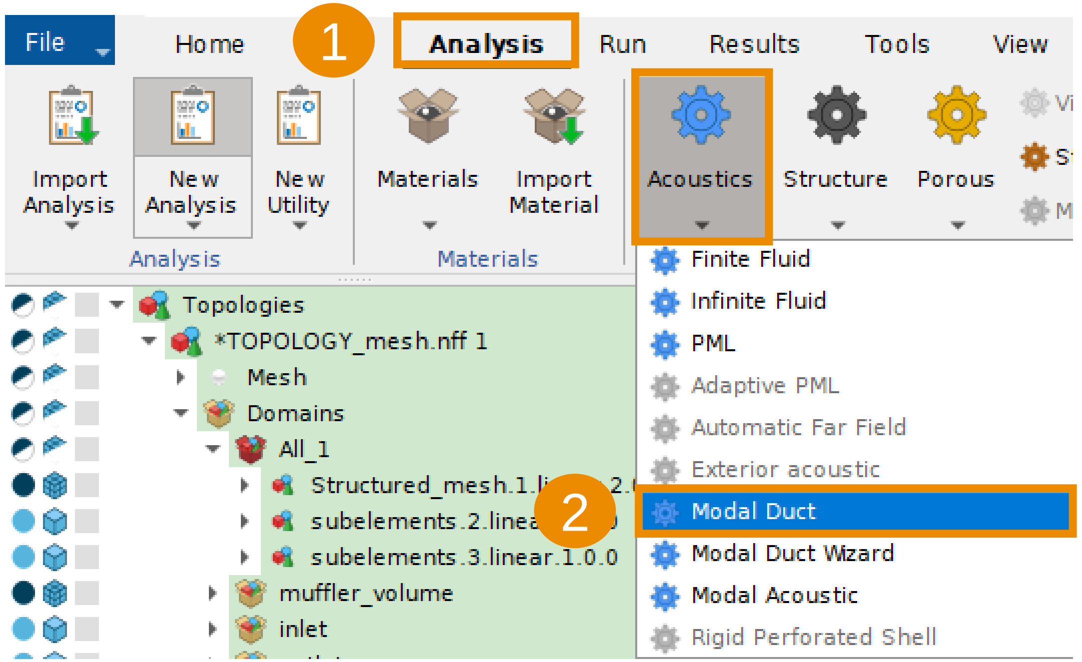
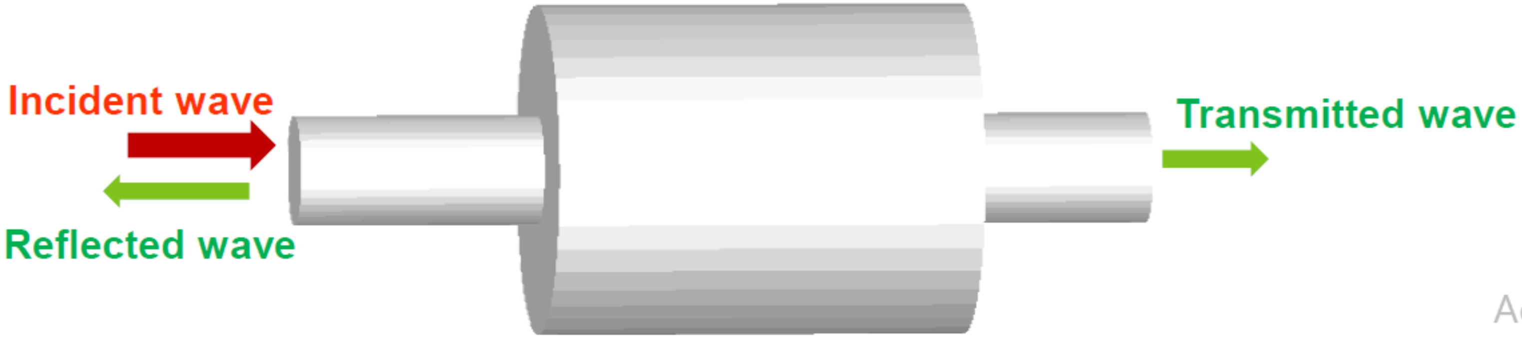
# Create a Modal Duct Component for the Inlet

- Add a modal duct component
- Incident wave is injected through this inlet modal duct component
- Reflected wave should be free to go through the inlet modal duct component

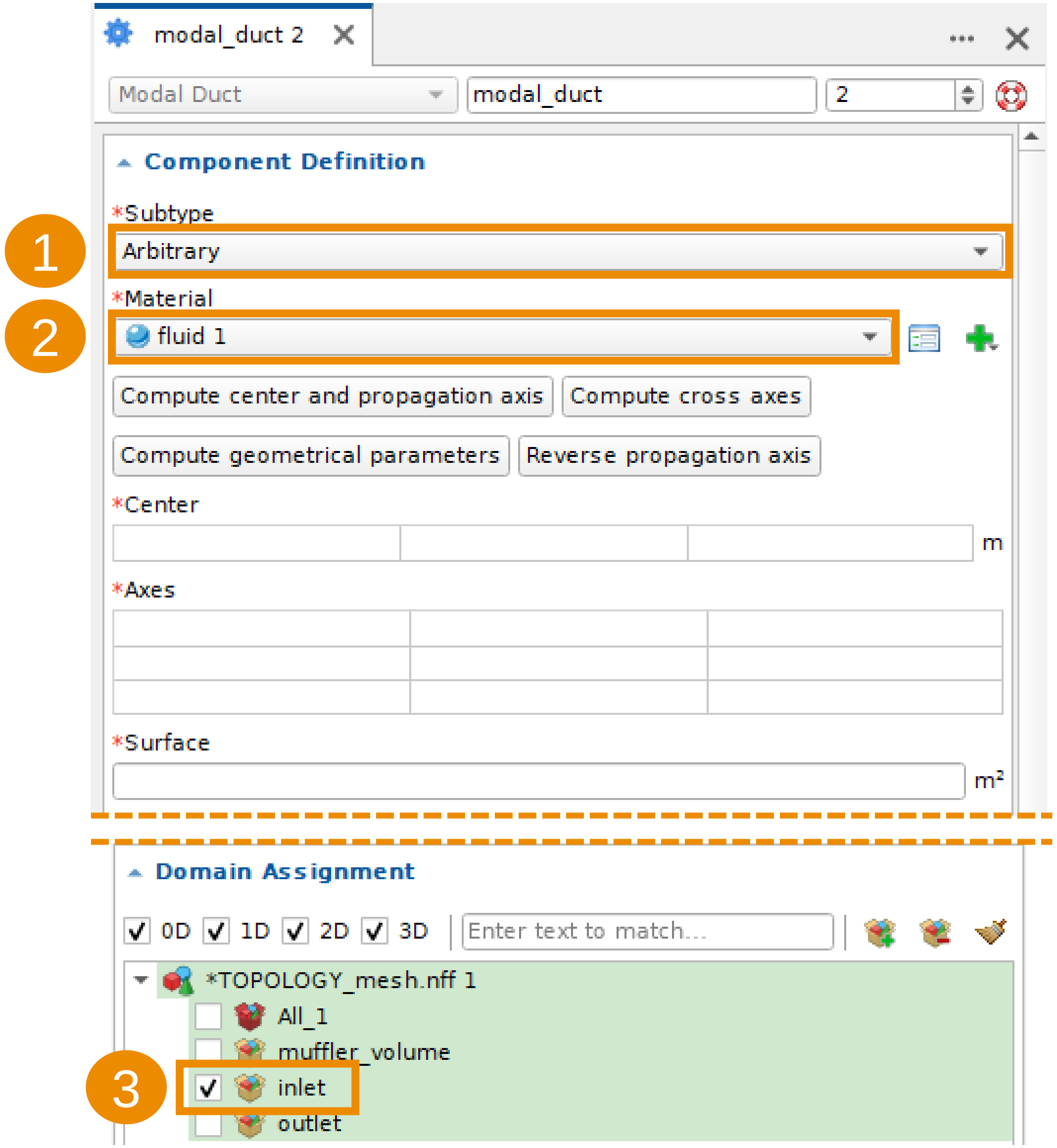


# Modal duct definition at the inlet (1)

Create a Modal Duct (arbitrary) component

Set the properties material and scope as indicated



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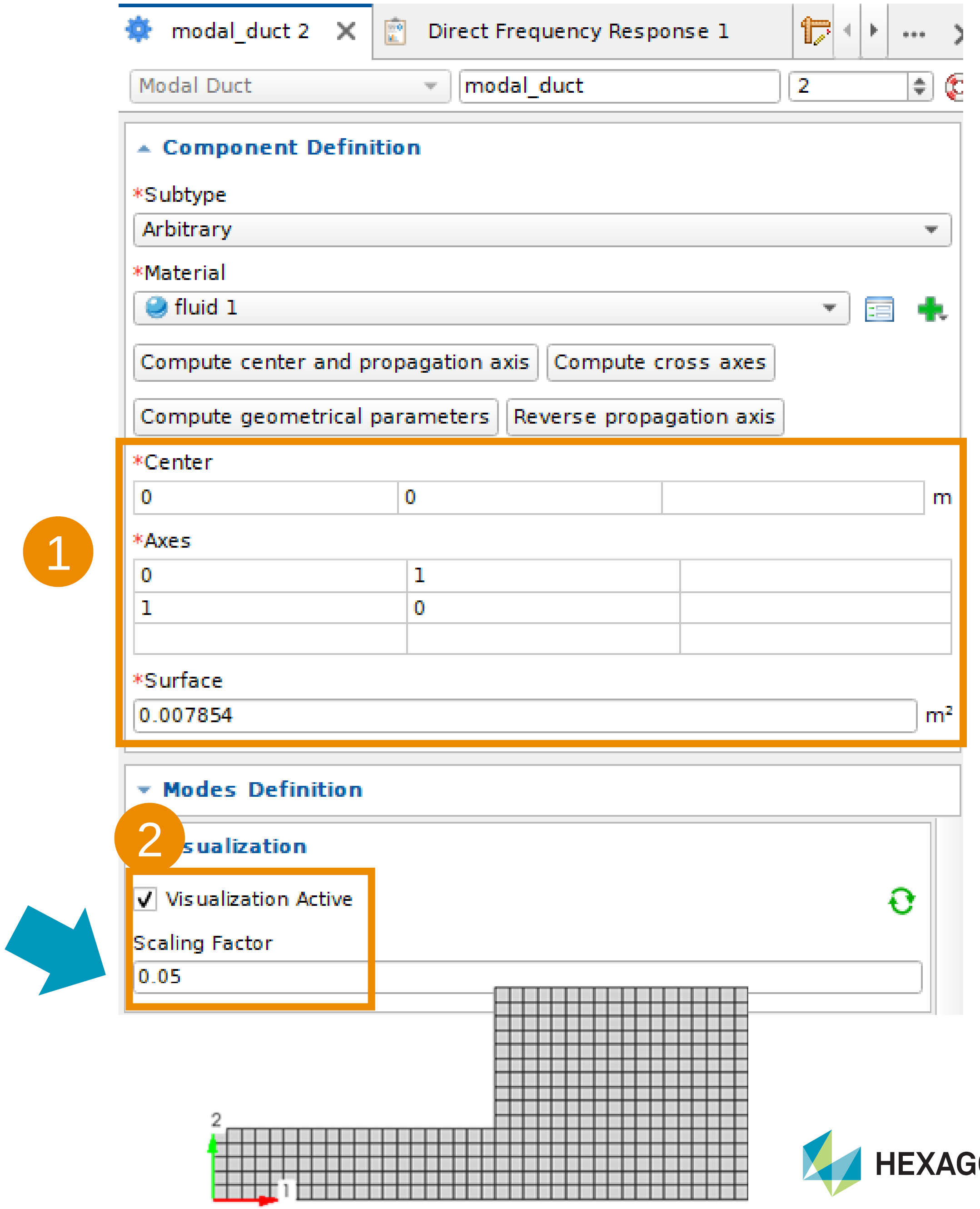
# Modal duct definition at the inlet (2)

Define the center, axes and surface of the modal duct component manually as shown

Activate the visualization to check the resulting modal duct definition



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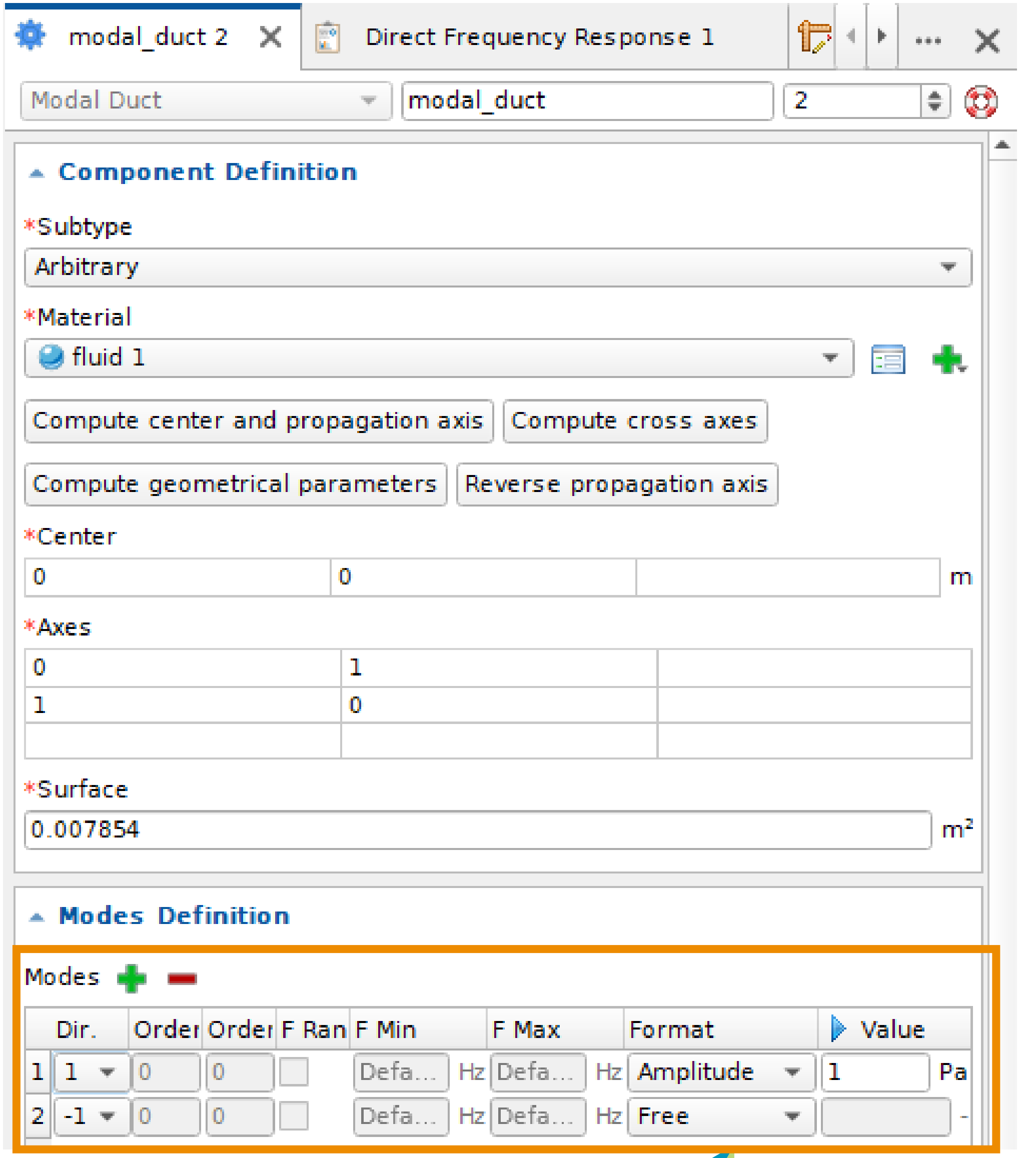
# Modal duct definition at the inlet (3)

**Create incident plane mode**

- Propagating towards the inside of the muffler
  → direction = 1

**Create anechoic condition for reflected wave**

- Waves propagating towards the outside of the model
  → direction = -1



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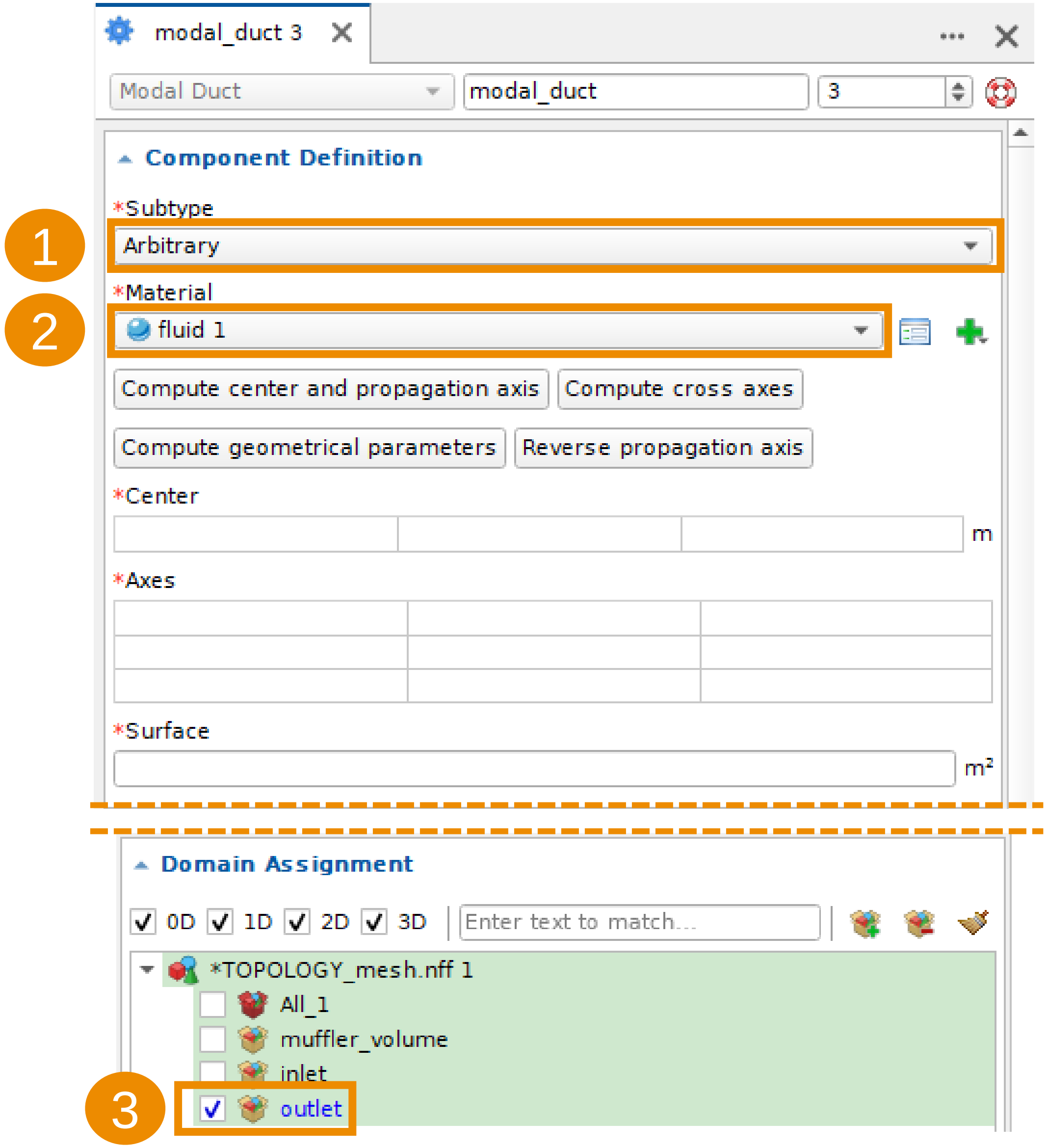
# Modal duct definition at the outlet (1)

Create a Modal Duct (arbitrary) component

Set the properties material and scope as indicated



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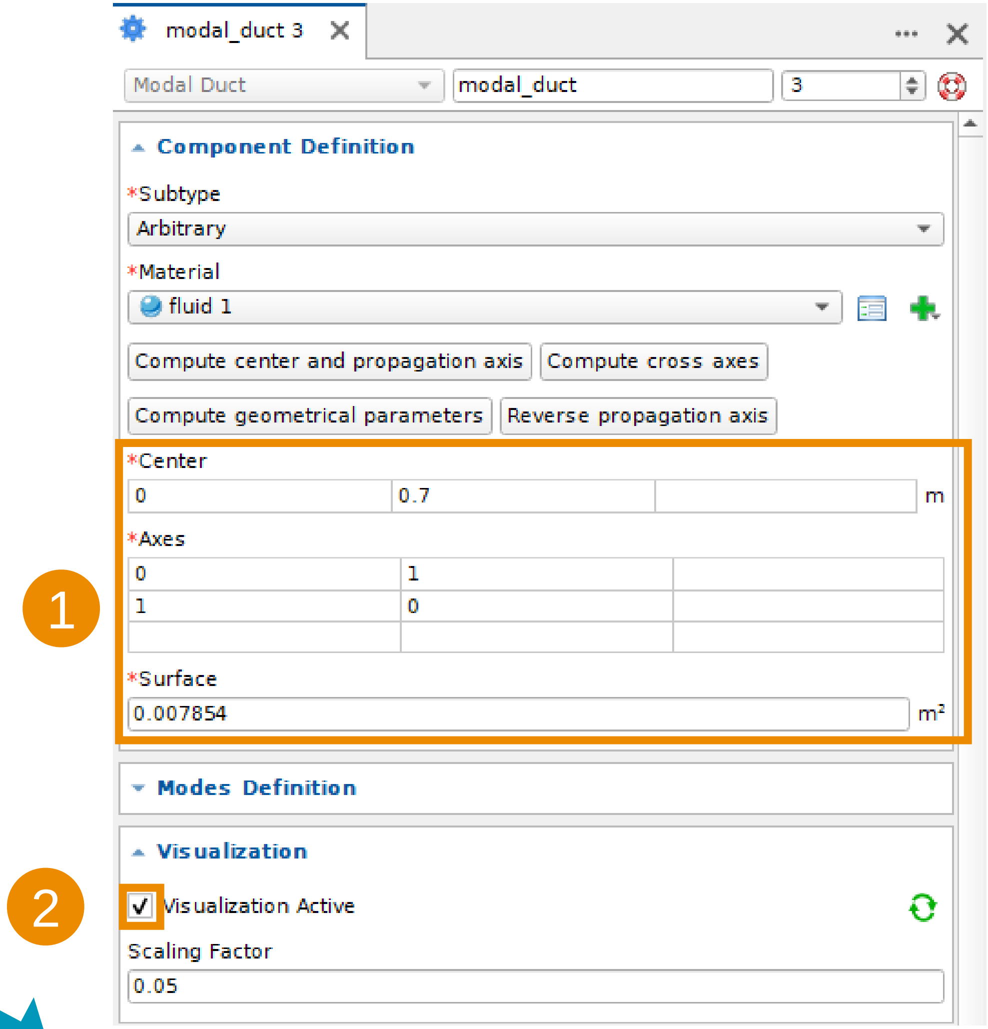
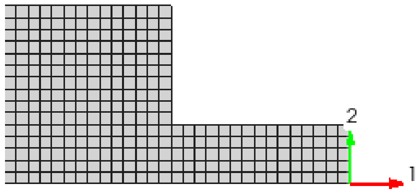
# Modal duct definition at the outlet (2)

Define the center, axes and surface of the modal duct component manually as shown

Activate the visualization to check the resulting modal duct definition



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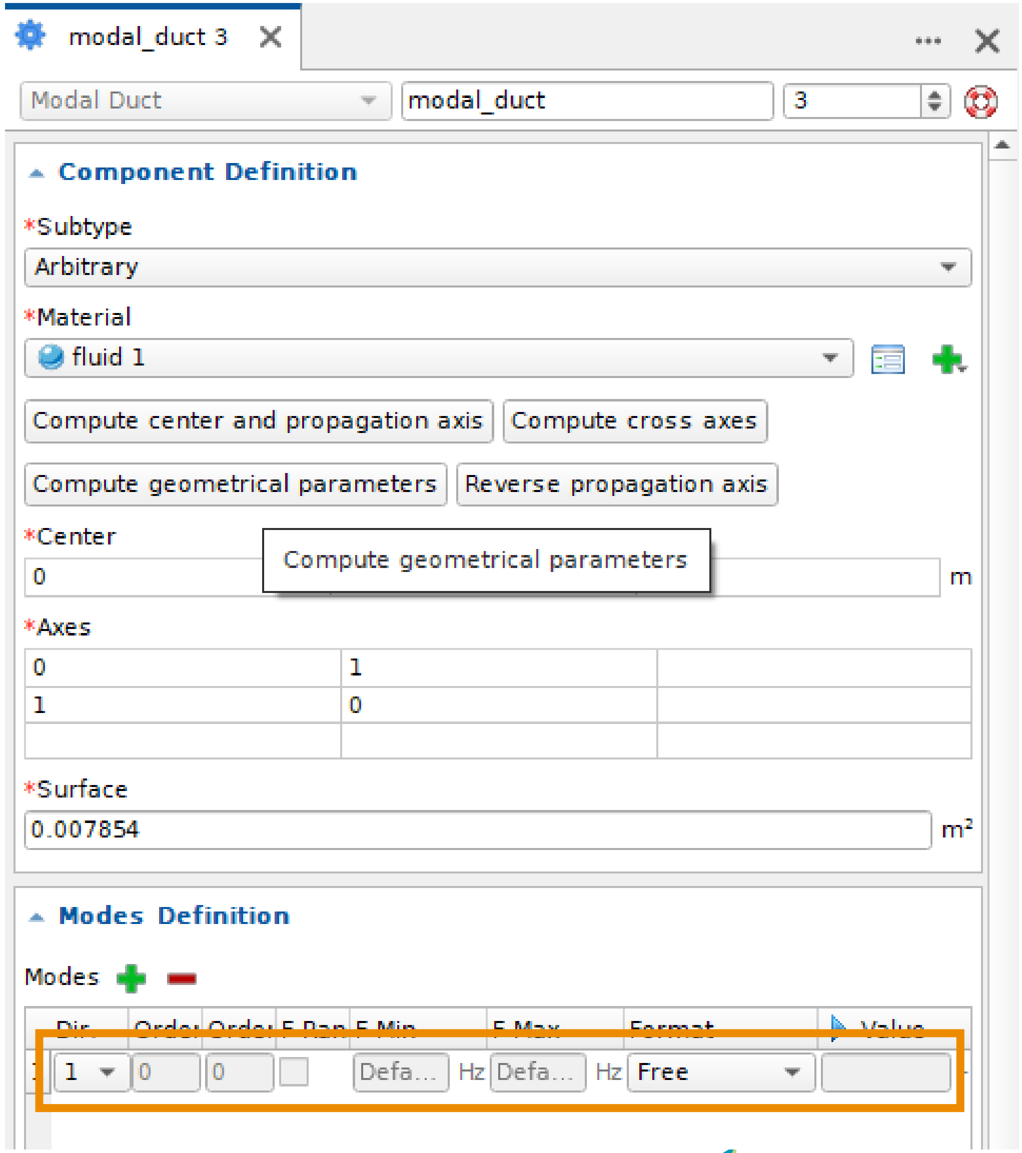
# Modal duct definition at the outlet (3)

**Create anechoic condition for transmitted wave**

- Waves propagating towards the outside of the model → direction = +1



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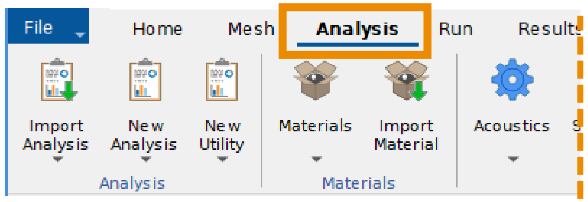
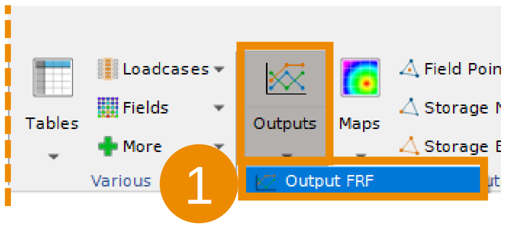
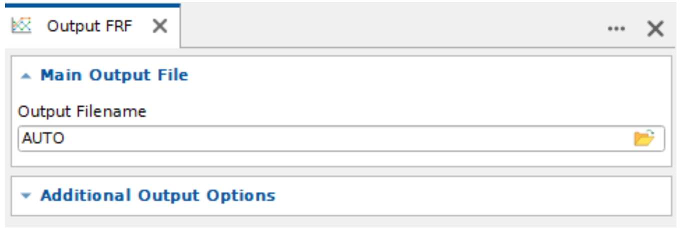
# Post-processing parameters

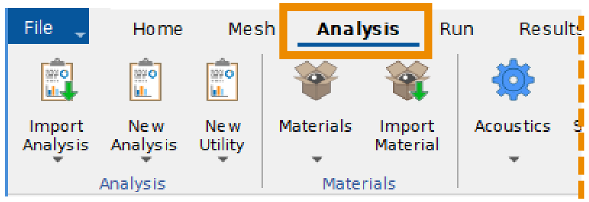
Create an output FRF

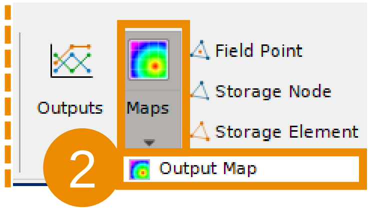


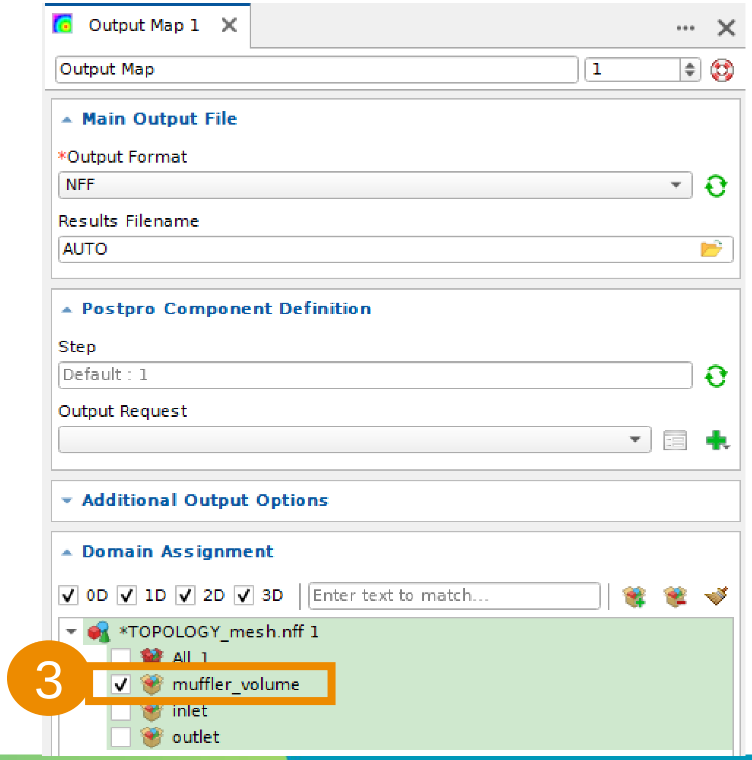




Create an output map



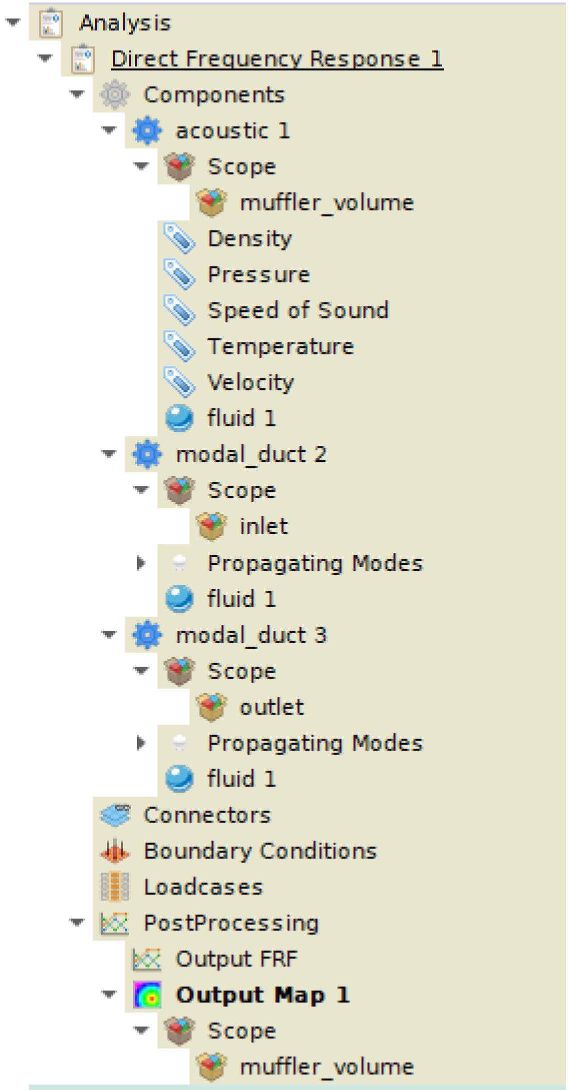



# Check the analysis

The *Analysis* setup is now complete

All the parts of the *Analysis* are available and editable on the data tree panel

Check if the data tree is identical to the one shown



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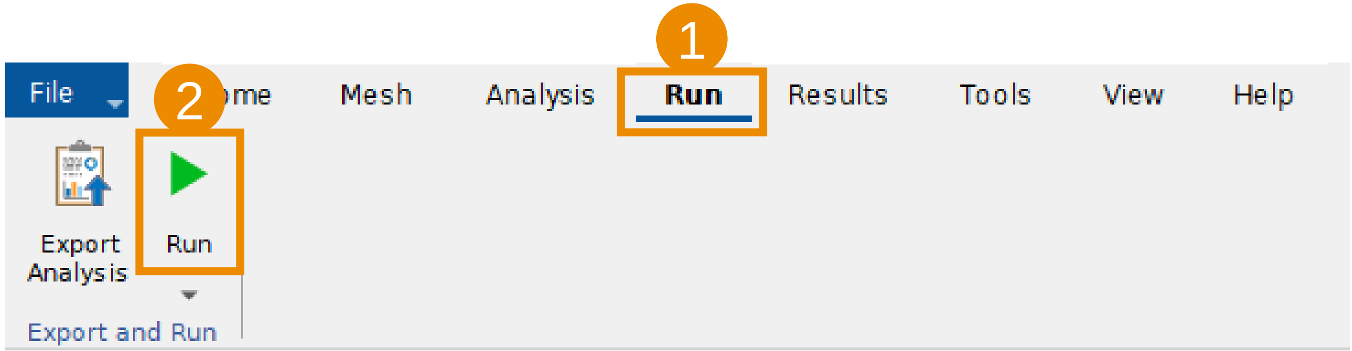
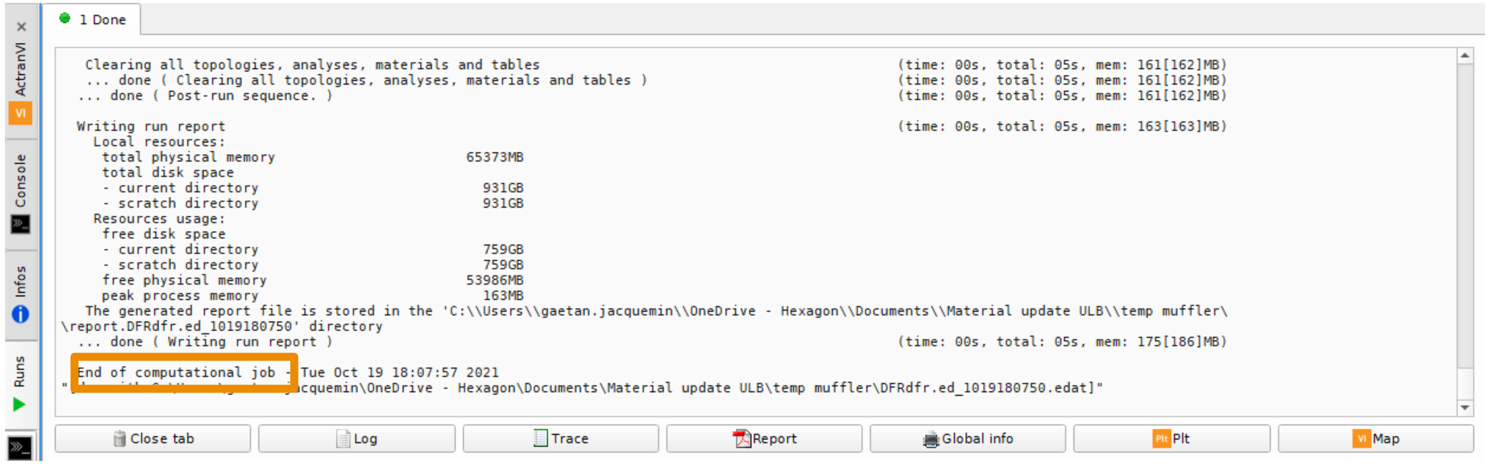
# Launch the Actran analysis in ActranVI

Launch the computation

Check the log showing the computation progress



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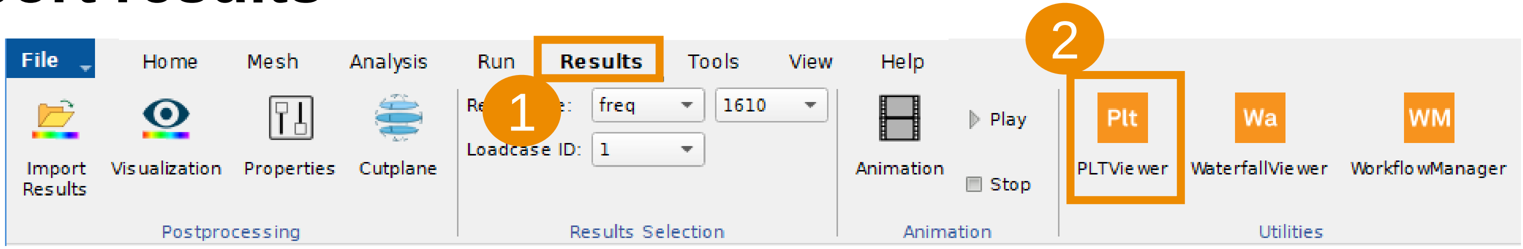
# Post-processing in the PLTViewer

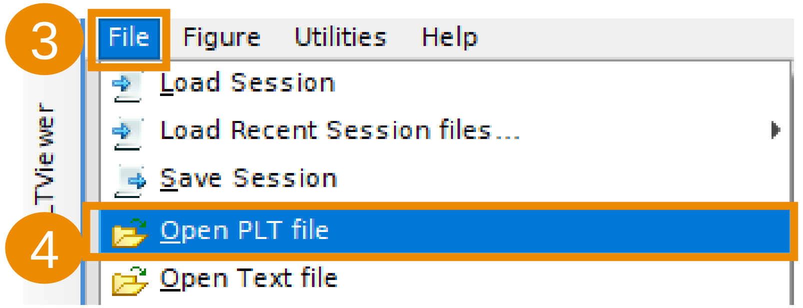
# Open PLTViewer and import results

Open PLTViewer

Import the *.plt computation result file

The different outputs are displayed



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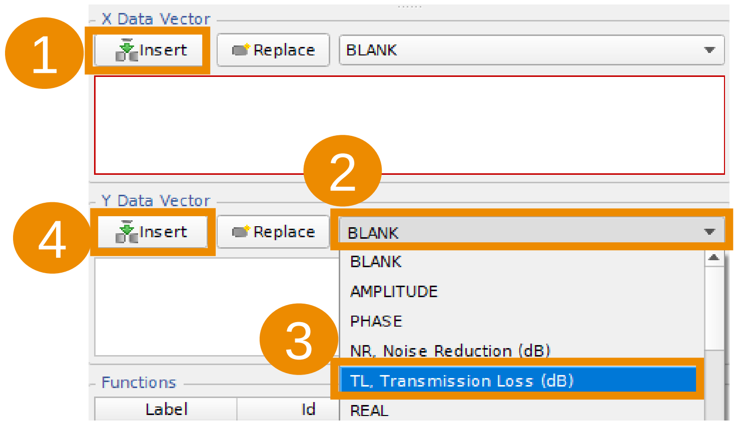
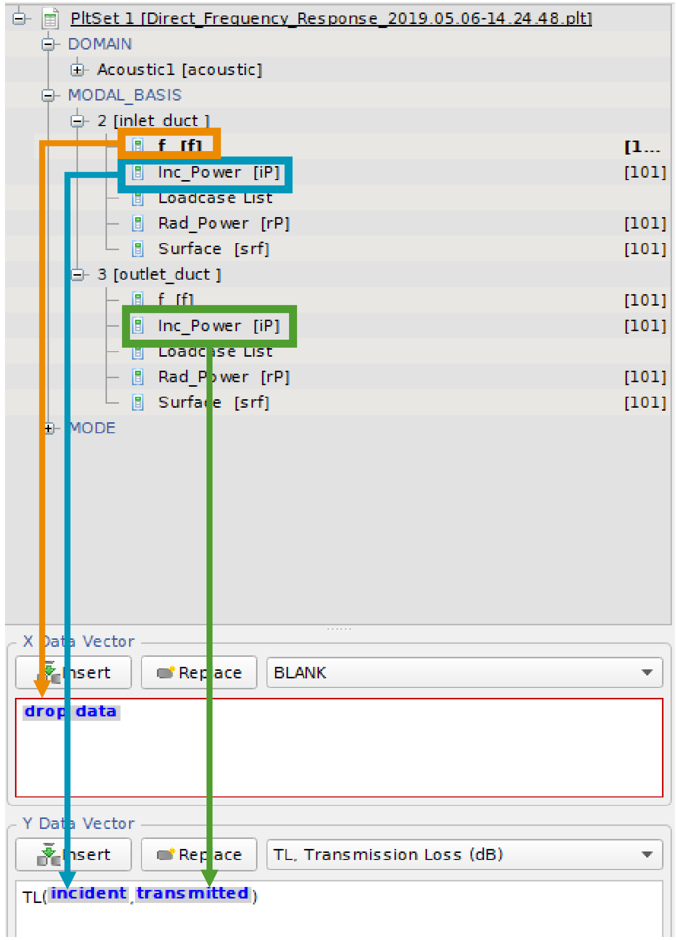
# Plot the Transmission Loss (TL)




Insert the PLTViewer **TL** function

Drag & drop the output quantities

- **X data**: Frequency range *f*
- **Incident power**: Inlet *Inc_Power*
- **Transmitted power**: Outlet *Inc_Power*



# Comparison with analytical solution

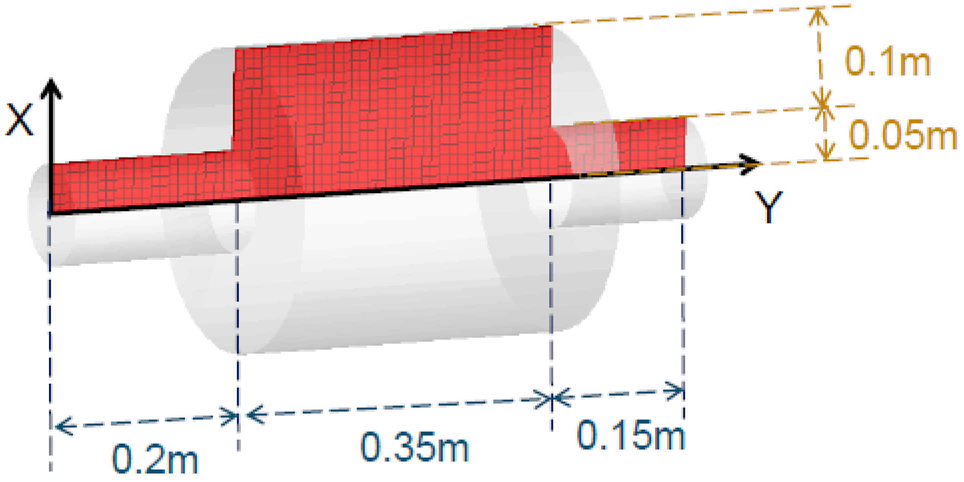
- For an expansion chamber, the analytical TL can be calculated using the equation

$$TL = 10 \log \left[ 1 + \left( \frac{m^2 - 1}{2m} \sin kl \right)^2 \right]$$

  - $m$: cross section area ratio between expansion chamber and inlet (outlet) tube (0.15 / 0.05)$^2$ = 9
  - $l$: length of expansion part of the chamber = 0.35 mm
  - $k$: wave number $= 2\pi f / c$

- This analytical solution is calculated with the assumption of plane wave propagation in the muffler

- The analytical solution has been calculated and is available in the file TL_analytical.txt



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# Comparison with analytical solution

- Plot the analytical solution
  - Open the results file: File menu → Open text file → chose file “TL_analytical.txt”
  - Add a new Function: Function 2
  - In Function 2, choose “BLANK” for Y Data vector
  - Click “Replace” under Y Data vector
  - Drag and drop the “col002” vector for the Y Data vector
  - Plot the analytical curve

- Adjust the curves parameters to plot the analytical solution with a dashed red line


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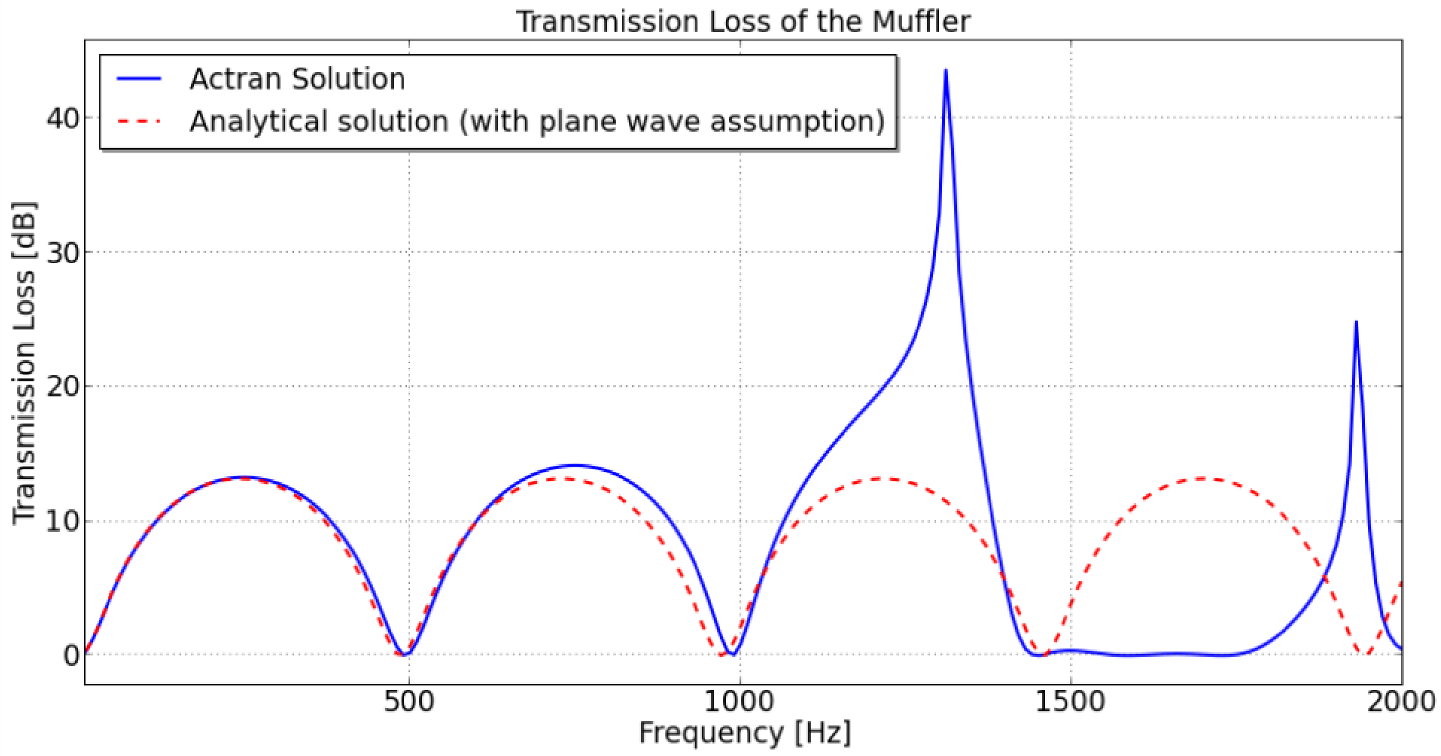
# Comparison with analytical solution

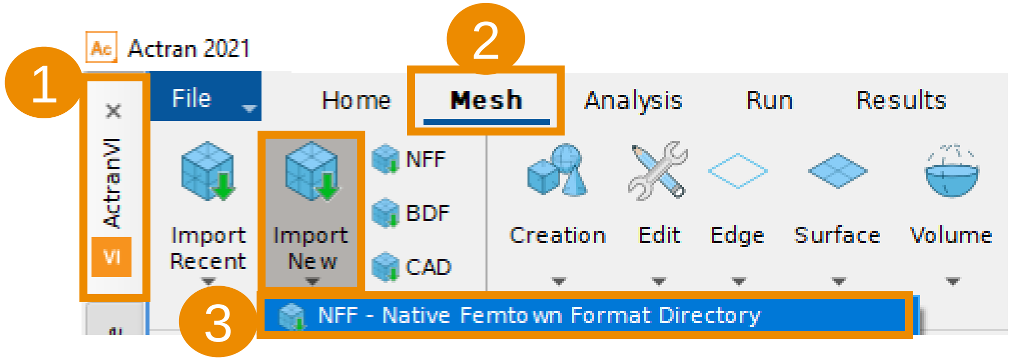
- Comparing Actran result with analytical solution:
  - Below about 1200Hz, there is a good correlation
  - Above this frequency, non plane wave starts to appear (see color maps on next page), and the analytical solution assuming plane wave is not suitable anymore



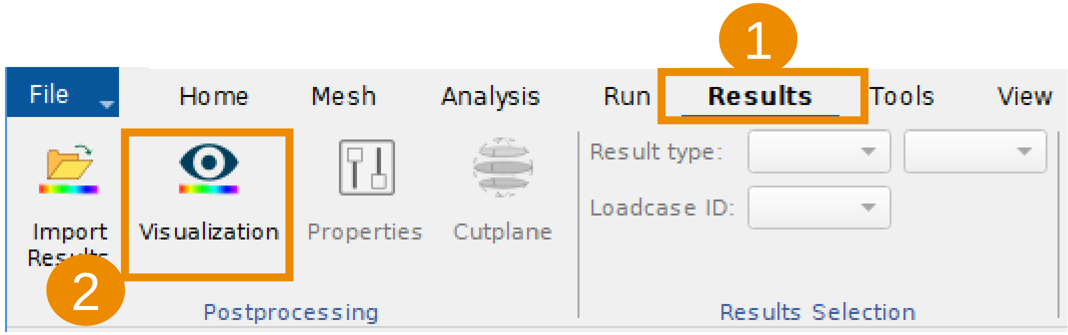
# Import the pressure results mesh

Go back to ActranVI

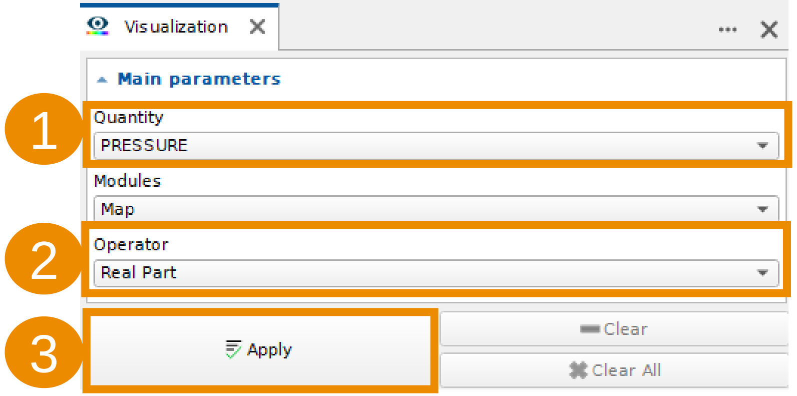
Load the output *.nff file containing the maps



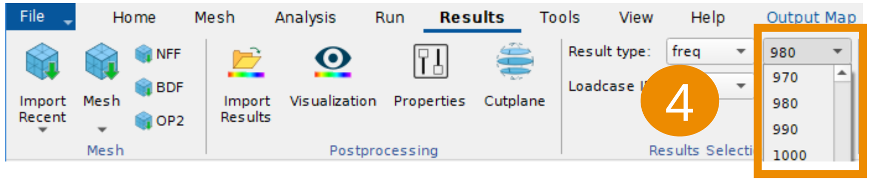
# Display pressure results

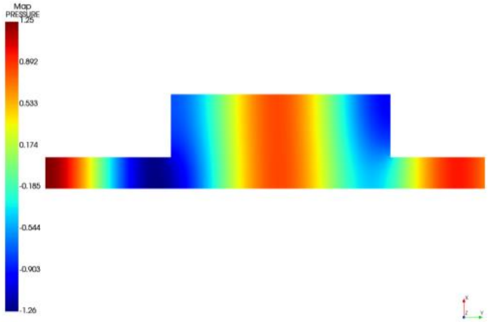



Display the Real Part of the pressure




Select the 980 Hz frequency





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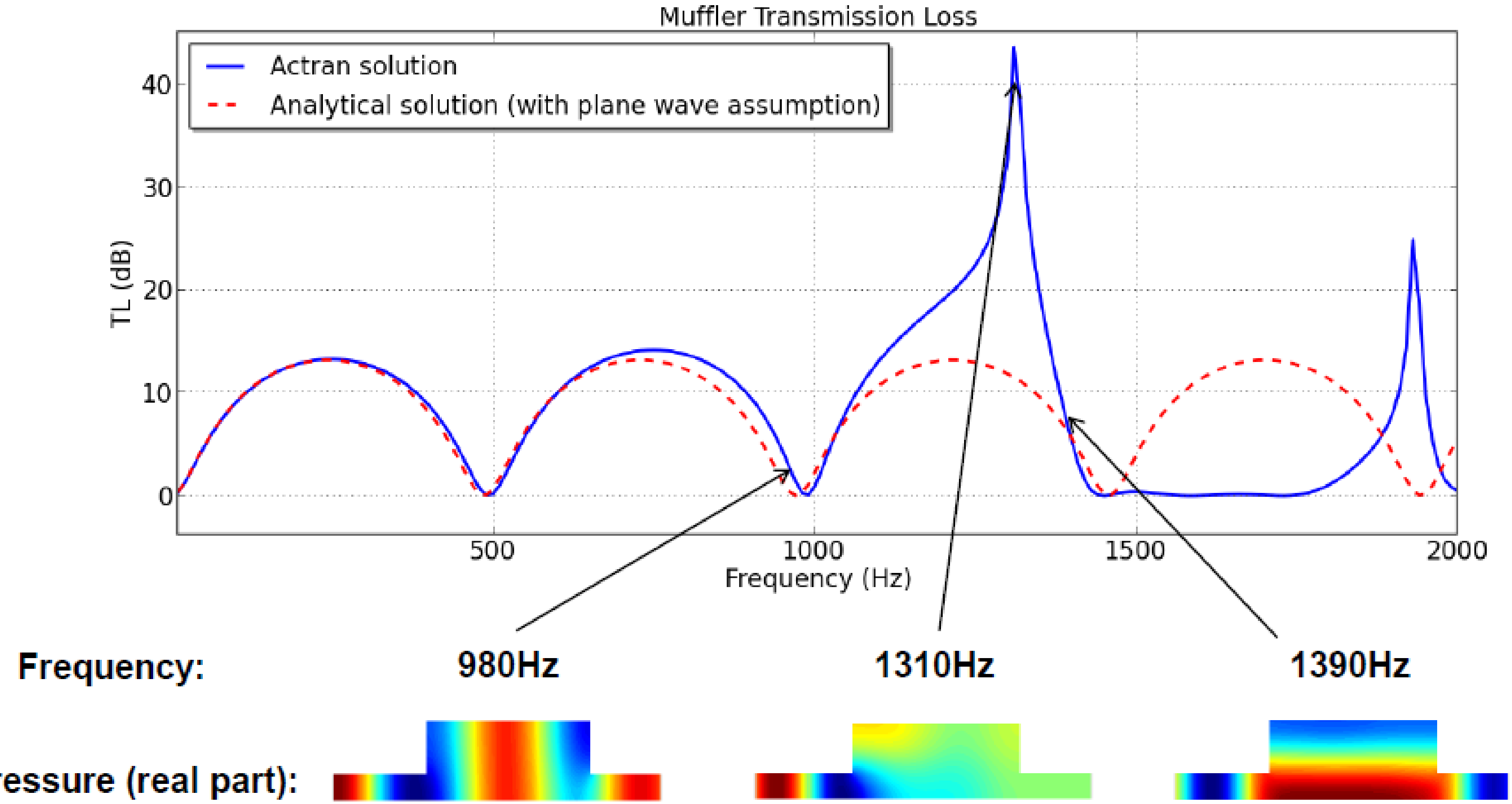
# Display pressure results

- From the Display Results tab, visualize the real part of the pressure at different frequencies



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