Reduction of the geometrical complexity of Helmholtz resonators

P2 presentation Master thesis

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Note on the report

Mistake when handing in the report
Page 31 (39 in the pdf)
Forgot to explain the scoring system and add the sources for the table

1.4.3 Conclusion on the presented production techniques

This thesis aims to investigate the potential of cheaper techniques to increase the availability of resonant absorbing panels. Figure 34 is based upon findings from Groover (2010), Kals et al. (2007) and Kalpakjian and Schmid (2008). The scores are given in a way that more points means better score e.g. a cheap process will get more points than a expensive process. The author is aware that the sources used to make figure x are not very recent. It is assumed that the general proportions between the productions processes has remained the same.

As can be seen in figure 34 laser cutting scores high in all three categories. The main downside of laser cutting is the general inability to work on three dimensional objects. With the reduction of the geometrical complexity of the resonators this becomes less of an issue. Laser cutting will therefor be the starting point regarding production techniques within this Thesis.

From the additive manufacturing techniques fused filament printing has the lowest price. The precision of this technique is lower compared to the other techniques but the relative low price of the technique makes it interesting to investigate within the scope of this thesis. If the need for three dimensional geometry does arise, fused filament printing will be the selected production technique.

CNC milling is a third method with relative low costs. For machining flat sheets of material it is generally outperformed by laser cutting. But the ability to generate three dimensional geometry makes it an interesting production method. Although not the starting point regarding production techniques in both two and three dimensions, it will be considered as an option going forward.

	Price	Precision	Speed
CNC Milling	●●●●○	●●●○○	●●●○○
Laser cutting	●●●●●	●●●●●	●●●●○
Water Jet Cutting	●●○○○	●●●●○	●●●●●
Stereolithography	●○○○○	●●●●●	●○○○○
Selective laser sintering	●●●○○	●●●●●	●○○○○
Fused filament printing	●●●●○	●●○○○	●●●○○

Figure 34: Concluding table regarding production techniques

Table of contents

Problem statement

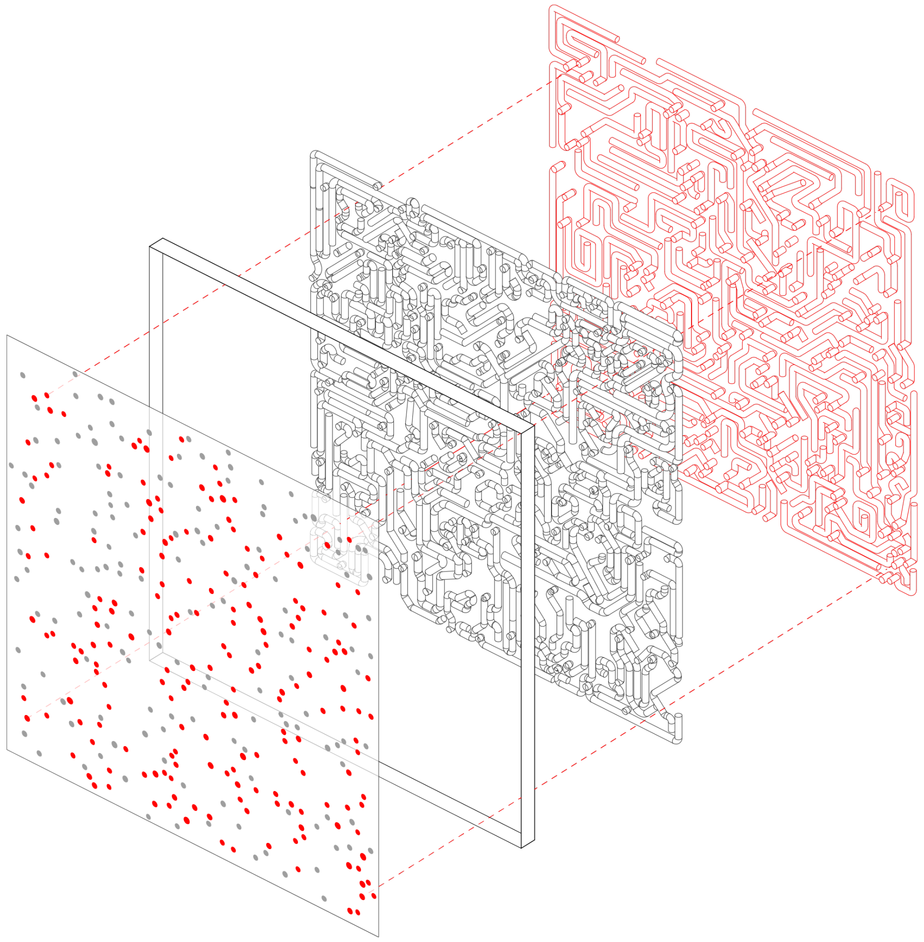


Figure 1: Costa (2016)

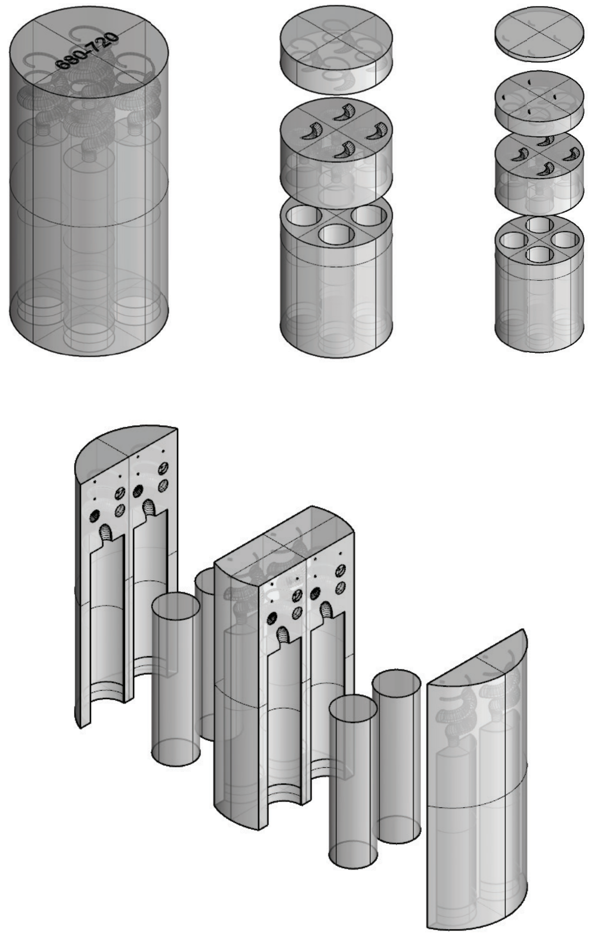


Figure 2: Scholten (2018)

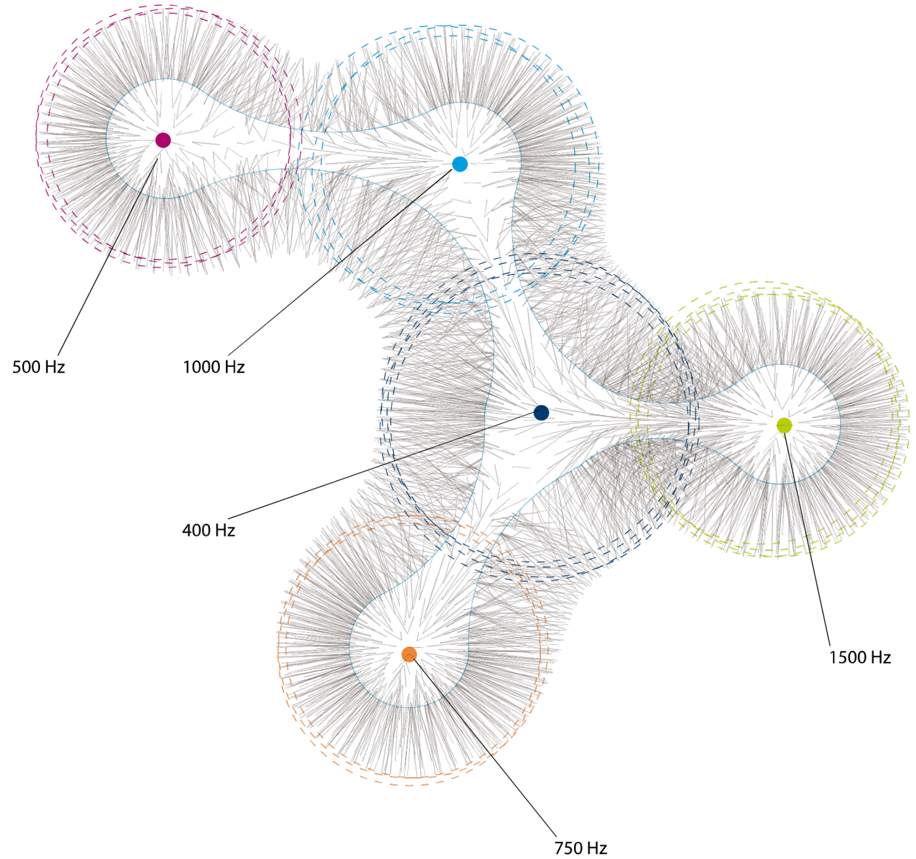


Figure 3: Setaki (2012)

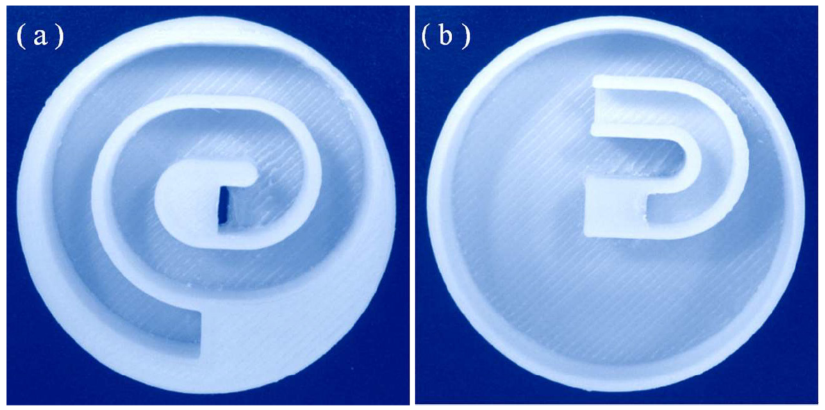


Figure 4: Cai et al. (2014)

Increase in geometric complexity for an increase in performance.
Decrease in ease of production, increase in price.

How can an acoustic panel based on cavity resonators be designed with reduced geometrical complexity while retaining a broadband high absorption coefficient for low frequencies?

Objectives

-Workflow for the production of resonant panels
-Resonator design with reduced geometrical complexity

Overvieuw of the project

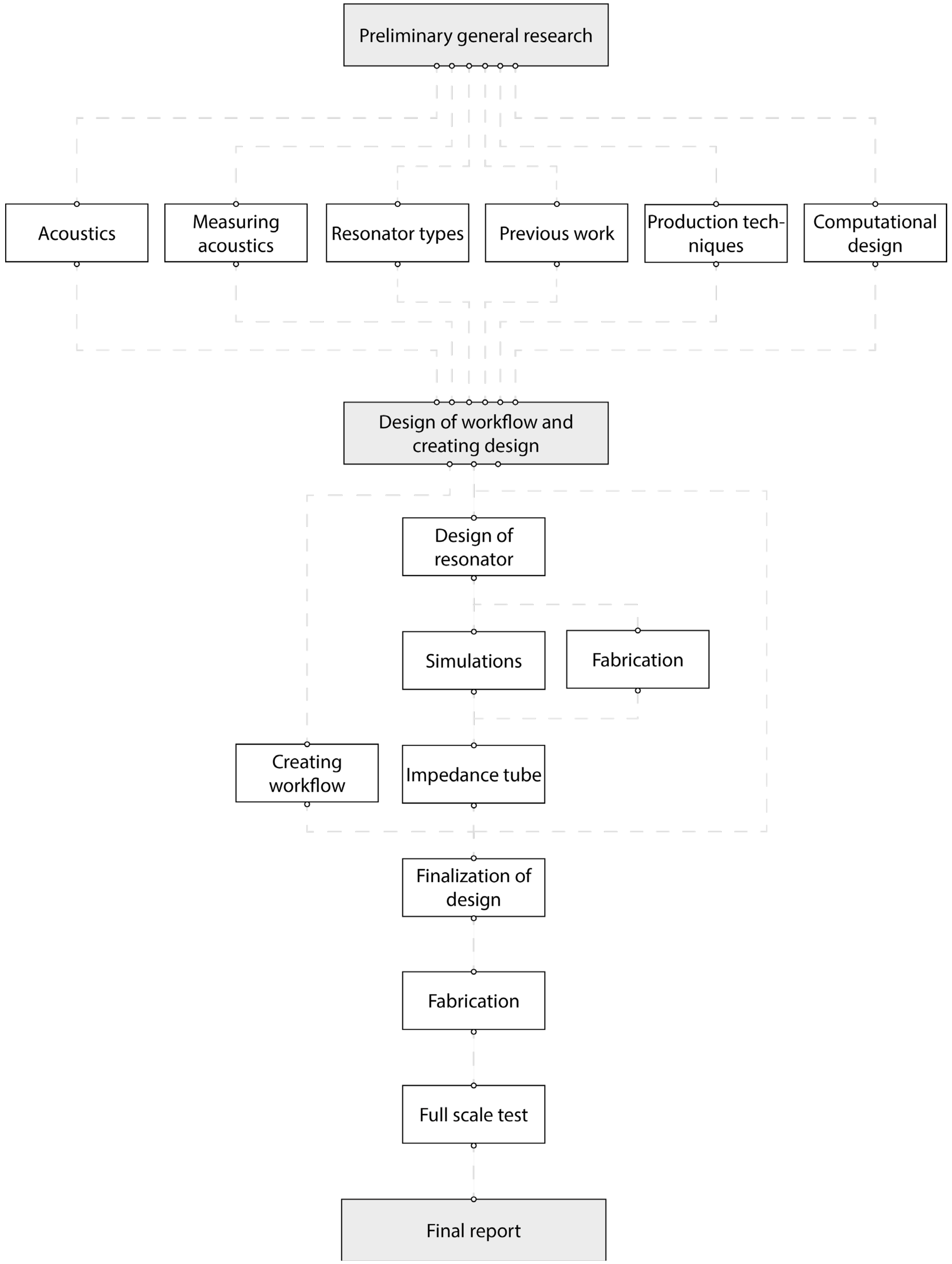


Figure 5: Process through the project, Own work

Result from the literature revieuw

Literature revieuw - resonators

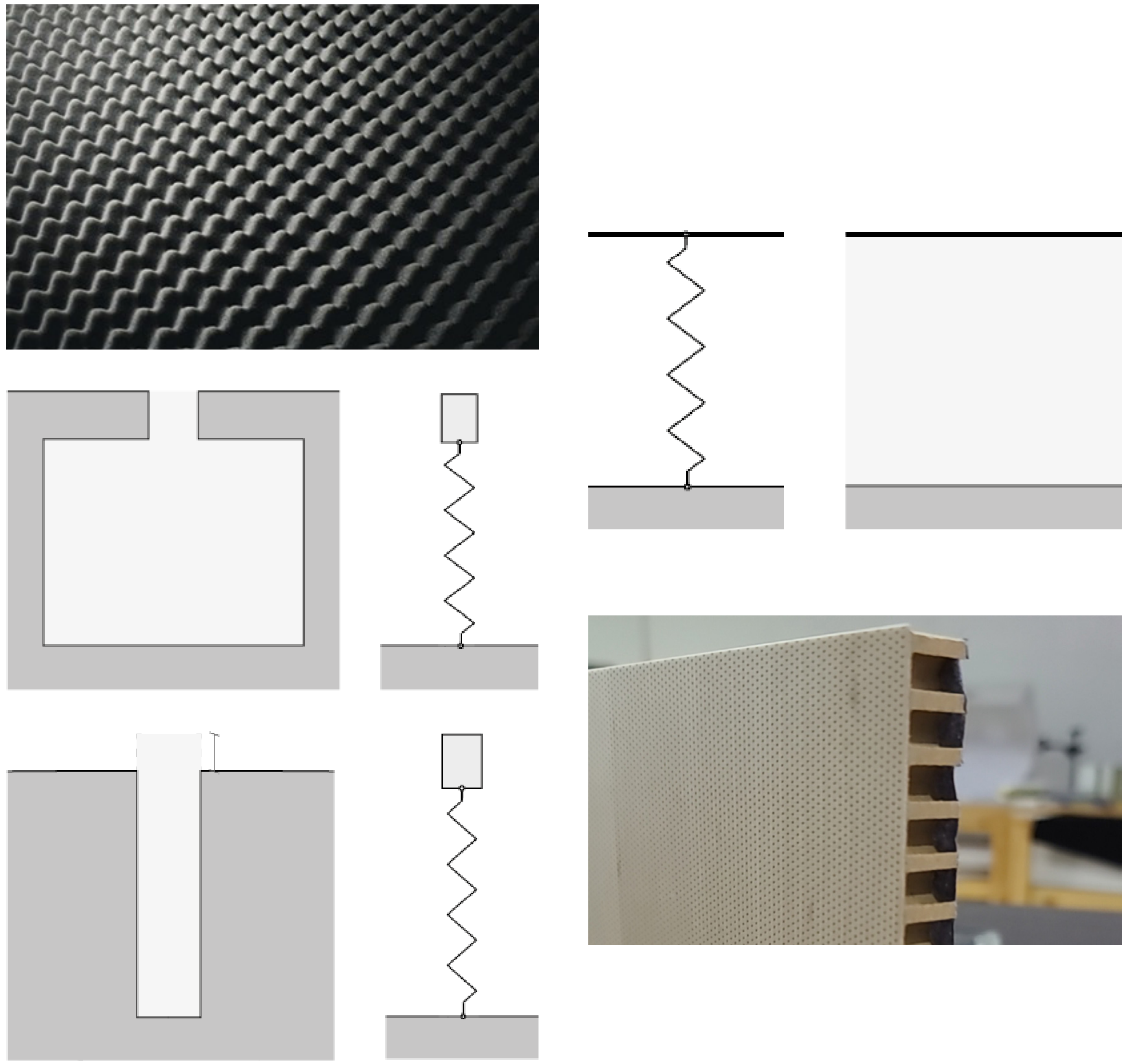


Figure 6: a. porous material , b. Helmholtz resonator, c. 1/4 wavelength tube, d. panel absorber, e. micro perforated panel

	Geometrical complexity, presison required	Predictabilty	Low frequency absorption	Broadband absorption
Porous absorber	●●●●○	●●○○○	●○○○○	●●●●●
Helmholtz resonator	●●●○○	●●●●●	●●●●●	●●○○○
1/4 wavelength tube	●●○○○	●●●●○	●●●●●	●○○○○
Panel absorber	●●●●○	●○○○○	●●●●○	●●○○○
Micro perforated panel	●○○○○	●●●○○	●●●●○	●●●●○

Figure 7: Concluding table on sound absorbers

Helmholtz resonator - large amount of information available, Formula’s available for good predictability (Godbold, 2008), Geometric freedom in Orifice, neck and cavity (kinsler et al. 2000). Opportunity to combine cavitys (Sacredote et al.1951).

Helmholtz resonator

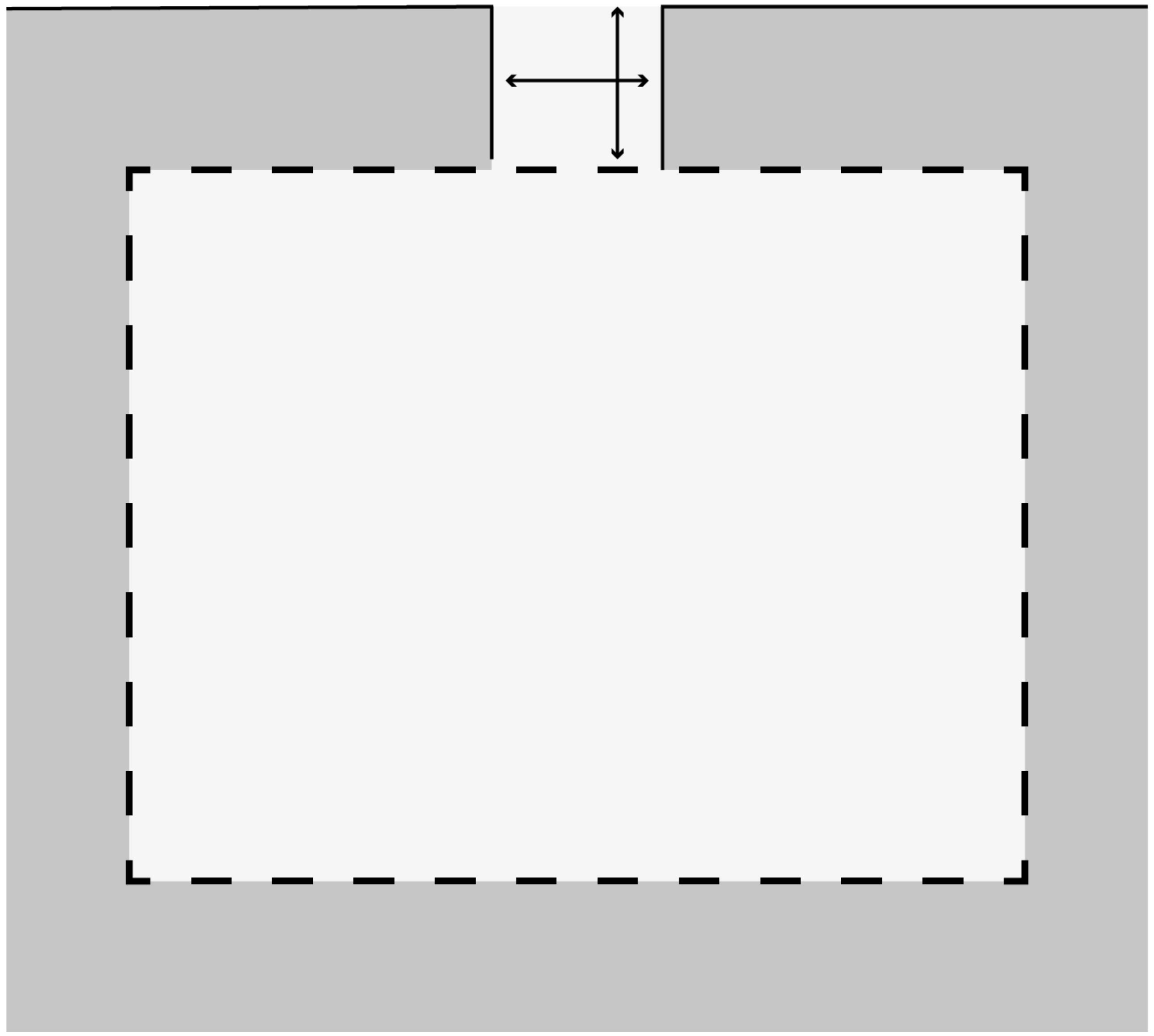
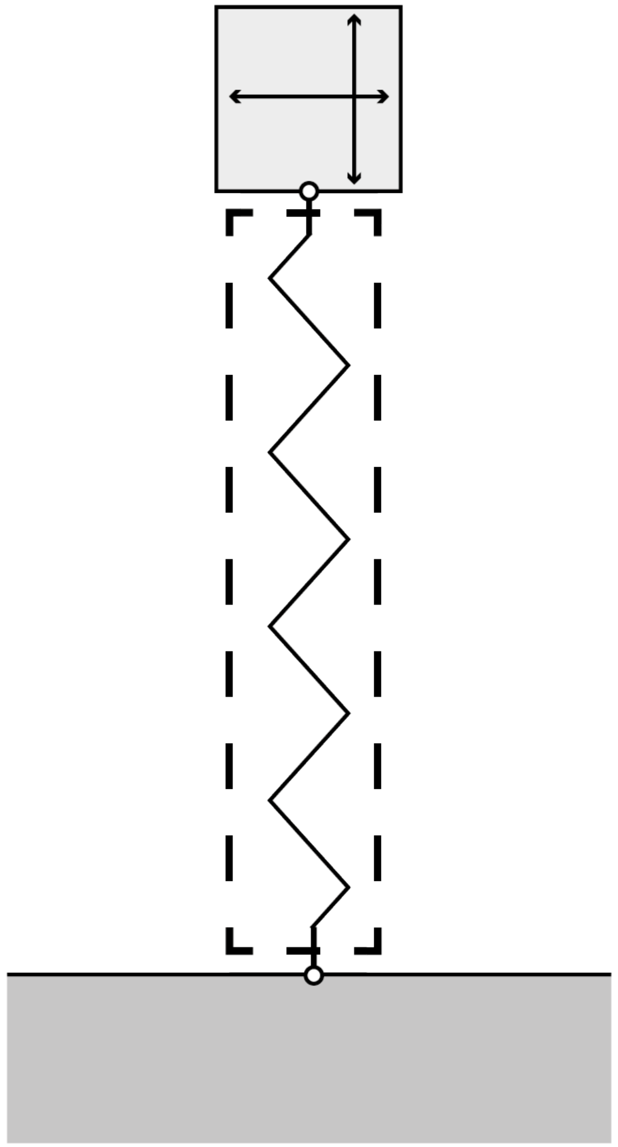


Figure 8: Helmholtz resonator 1, own work



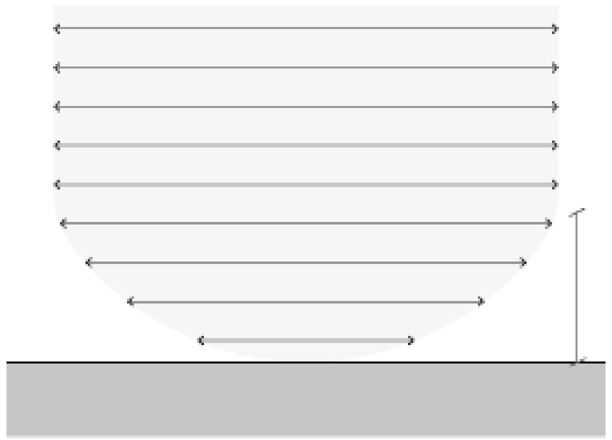


Figure 9: Visocus boundry layer, Own work

Experimentation

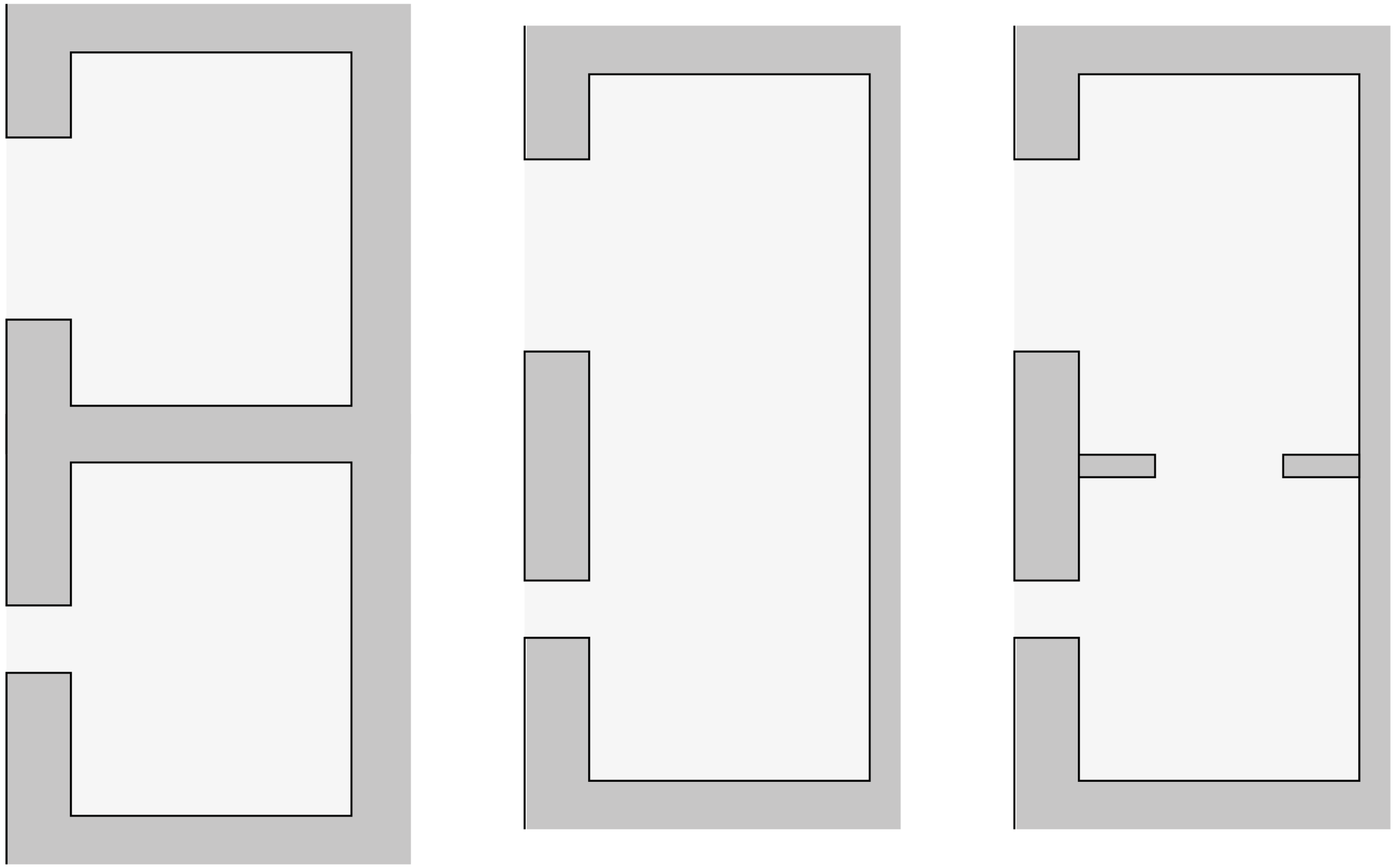


Figure 10: Full cavity seperation, no cavity seperation, partial cavity seperation

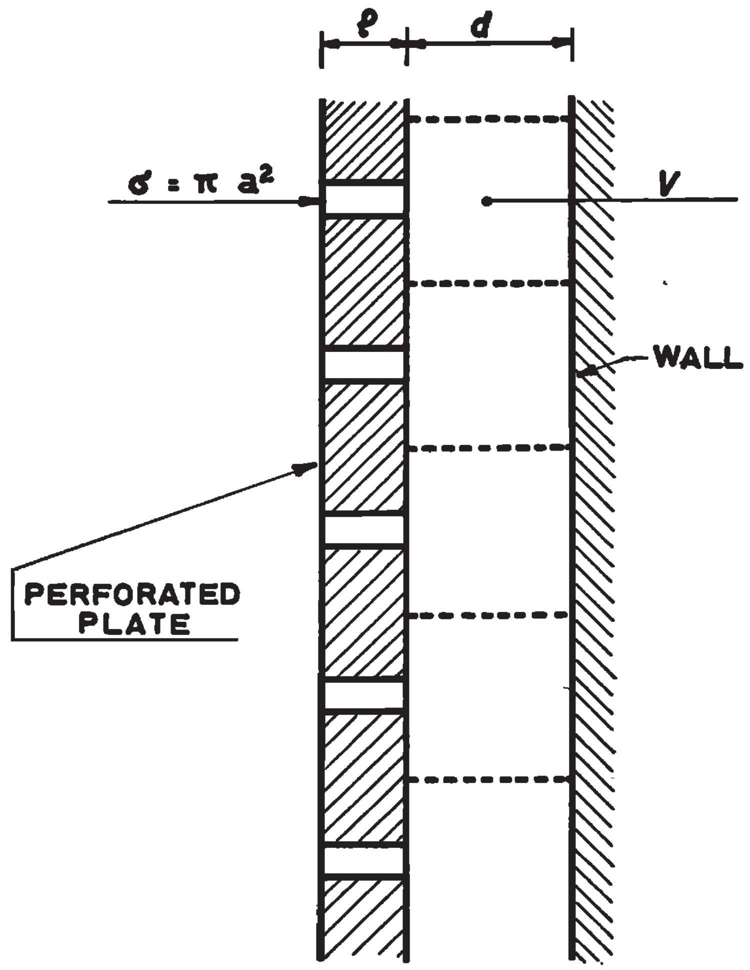


Figure 11: the practical device for the absorption of sound by resonance (Sacerdote, 1951)

Experiments to see the influence of the cavity seperation when looking at resonators with multiple orifice diameters.

Literature revieuw - production techniques

	Price	Precision	Speed
CNC Milling	●●●●○	●●●○○	●●●○○
Laser cutting	●●●●●	●●●●●	●●●●○
Water Jet Cutting	●●○○○	●●●●○	●●●●●
Stereolithography	●○○○○	●●●●●	●○○○○
Selective laser sin-tering	●●●○○	●●●●●	●○○○○
Fused filament printing	●●●●○	●●○○○	●●●○○

Figure 12: Concluding table regarding production techniques

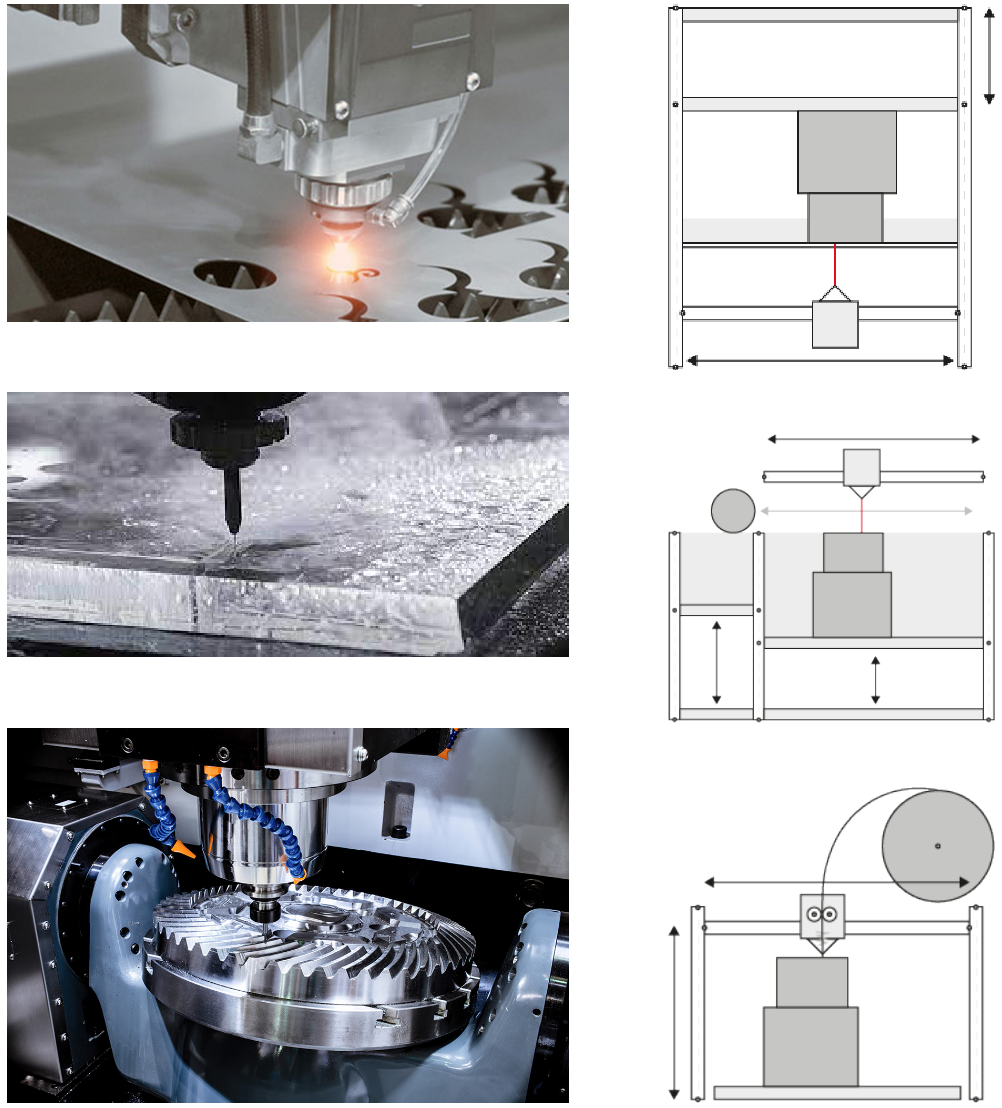


Figure 13: a. CNC milling, b. laser cutting, c. water jet cutting, d. stereolithography, e. Selective laser sintering, e. fused filament printing

Laser cutting for sheet material, Fused filament printing for more complex shapes
Based on: Groover (2010), Kals et al. (2007) and Kalpakjian and Schmid (2008)

Literature revieuw - optimization technique

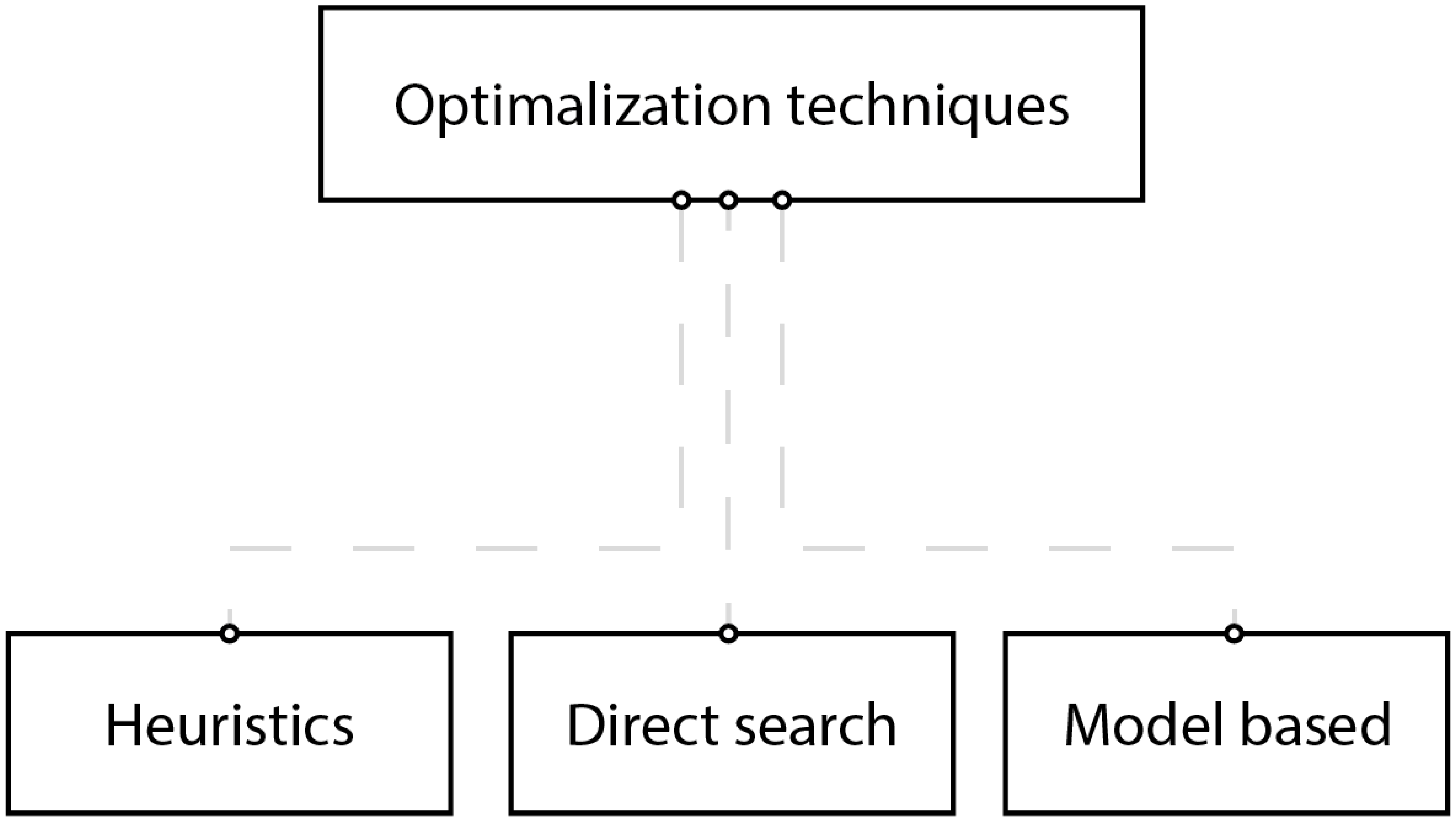


Figure 14: Optimization techniques, Own work

No final desision has been made, very dependent on the performance assesment and the way the optimization is defined.
Either weighted sum single objective or multi objective (wortmann, 2018)
Preliminary research result - Model based seems very appropriate (Yang et al, 2016)(Wortmann, 2018)(Ekici, 2019)

The proposed workflow

Design of the computational workflow

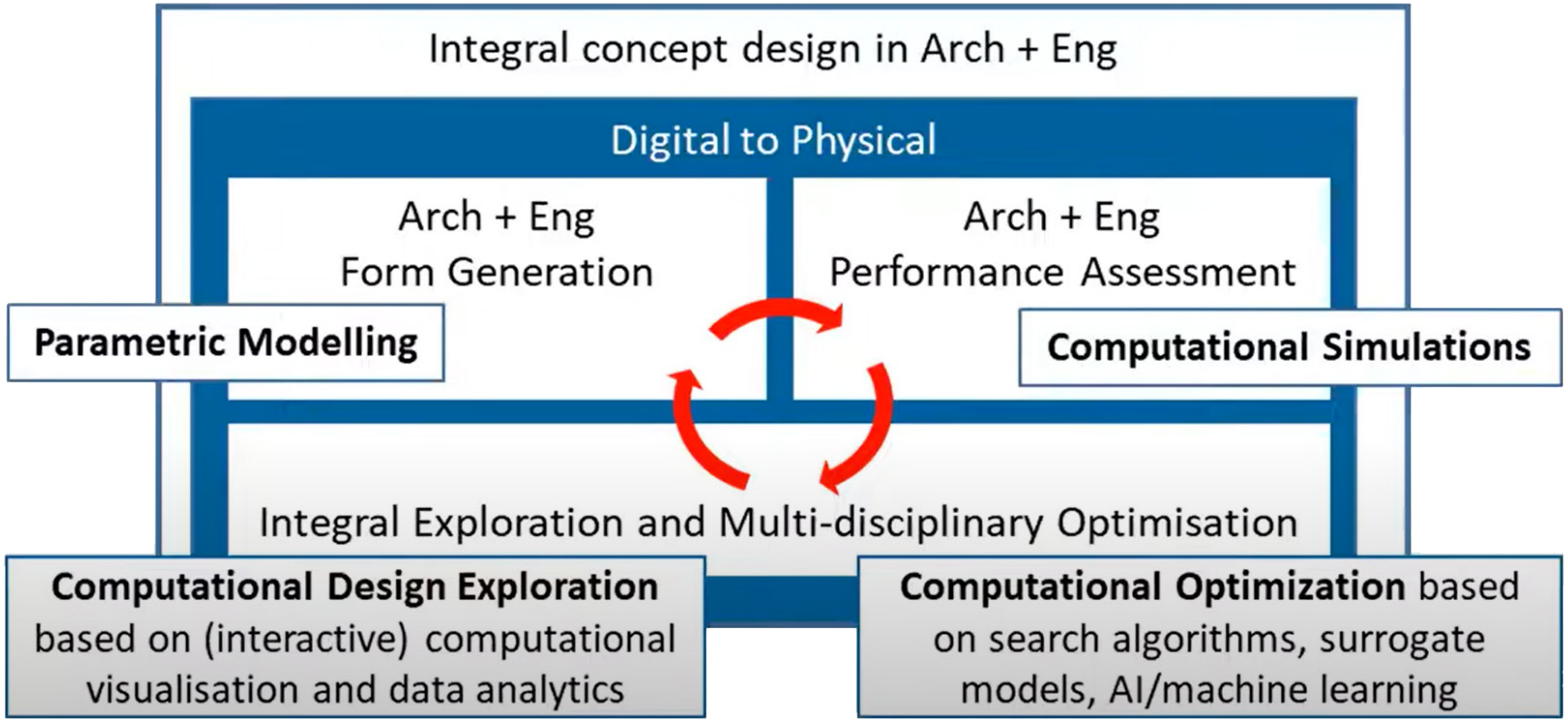


Figure 15: Integral concept design in Arch + Eng, From: https://m.youtube.com/watch?v=BNv4jYQiQiw&t=15s

Performative computational design. The design process followed within this thesis

Form generation

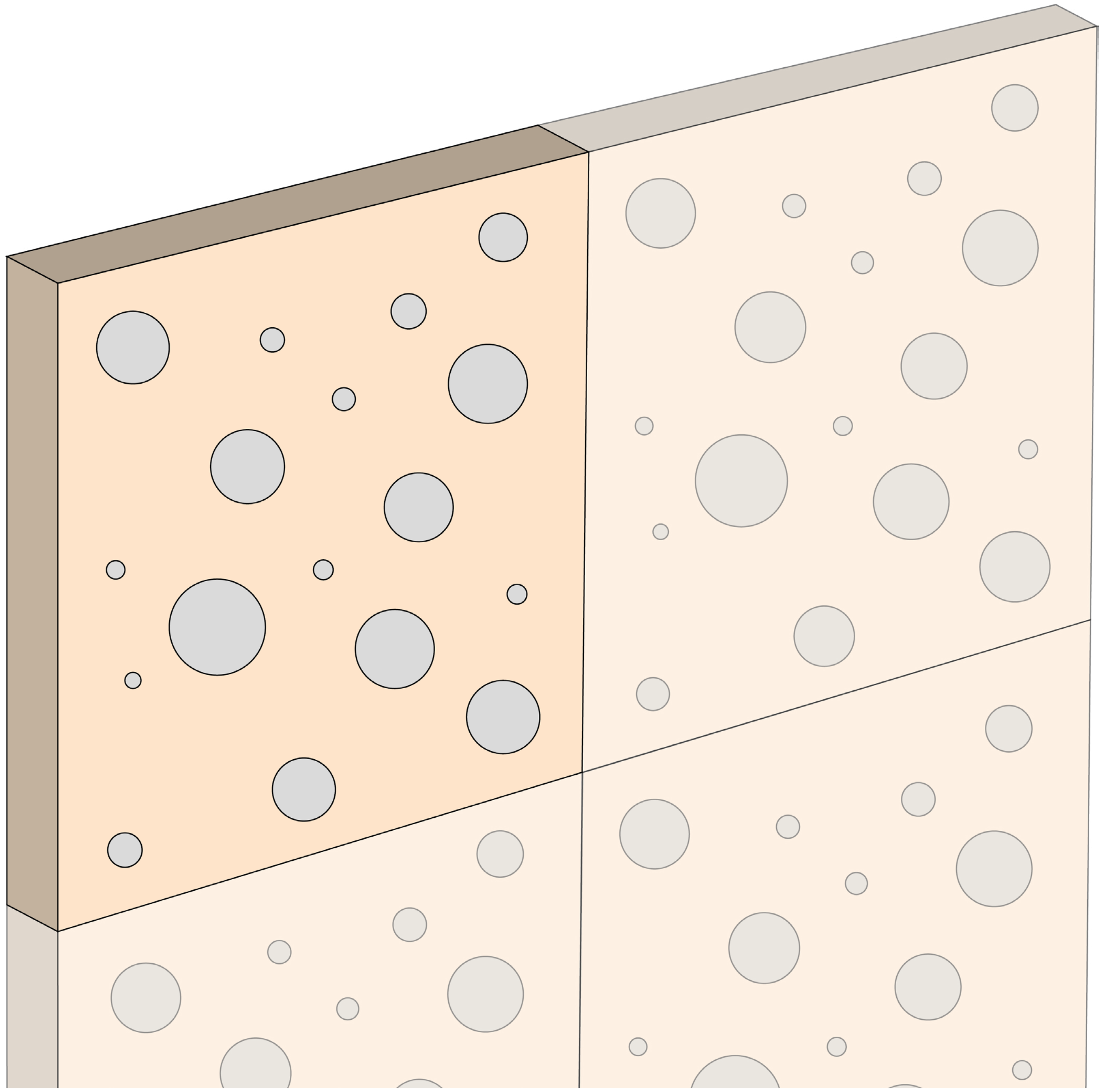


Figure 16: Resonant panel based on Helmholtz resonators, Own work

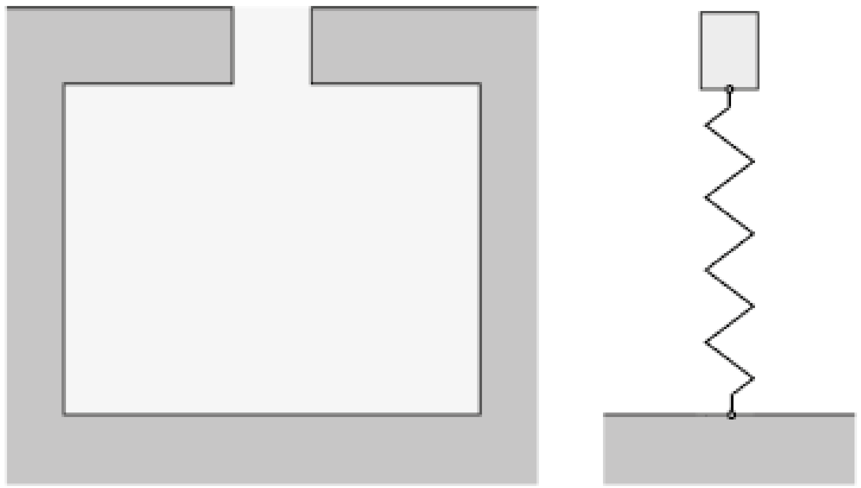


Figure 17: Helmholtz resonator, Own work

Panel based on Helmholtz resonators with different orifice diameters, Helmholtz resonatros with combined cavities. Form generation will be done within Rhino/ Grashopper

Performance assesment

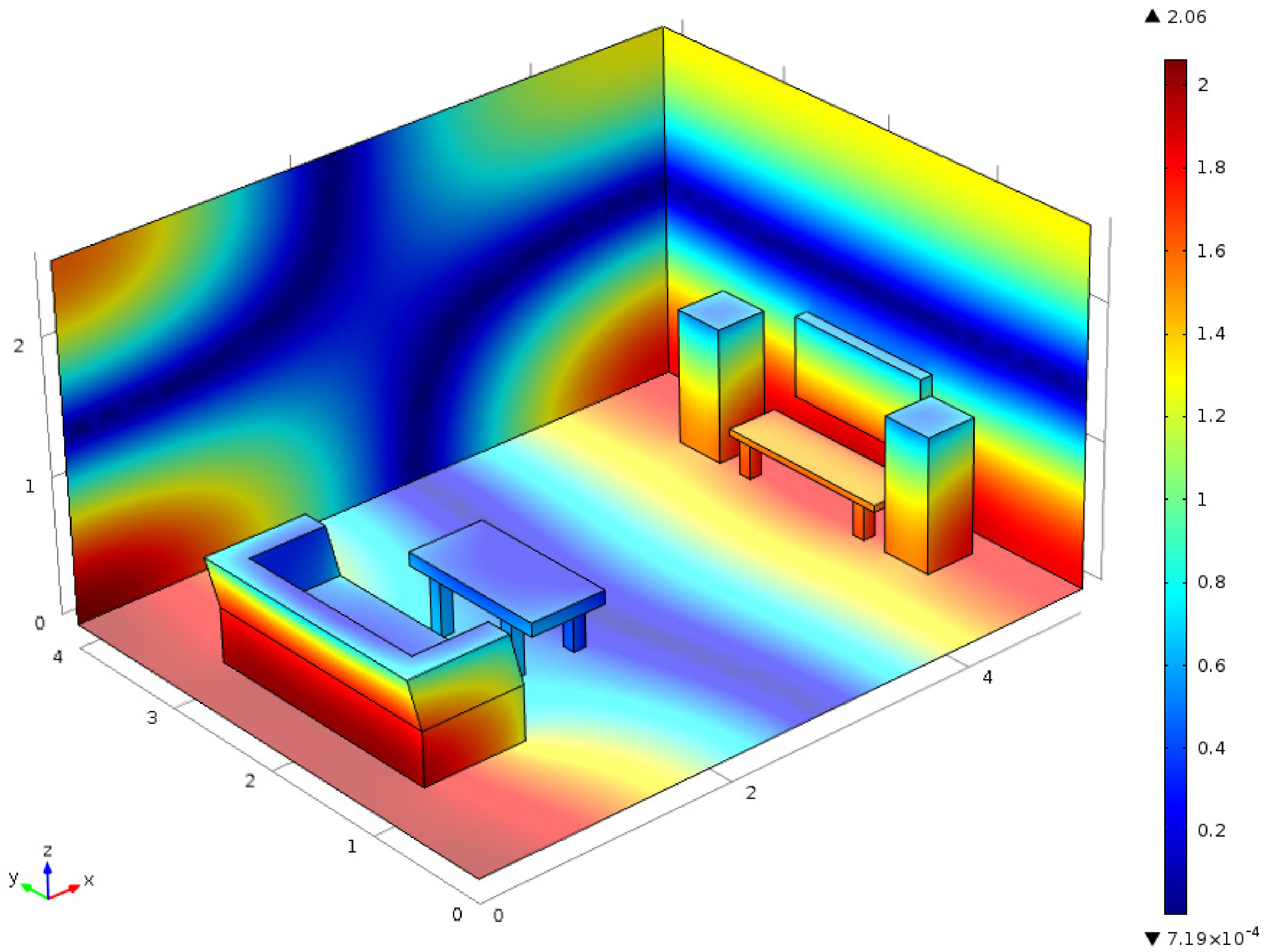


Figure 18: Pressure distribution for the first eigenmode inside a small room. From: https://www.comsol.com/blogs/modeling-room-acoustics-with-comsol-multiphysics/

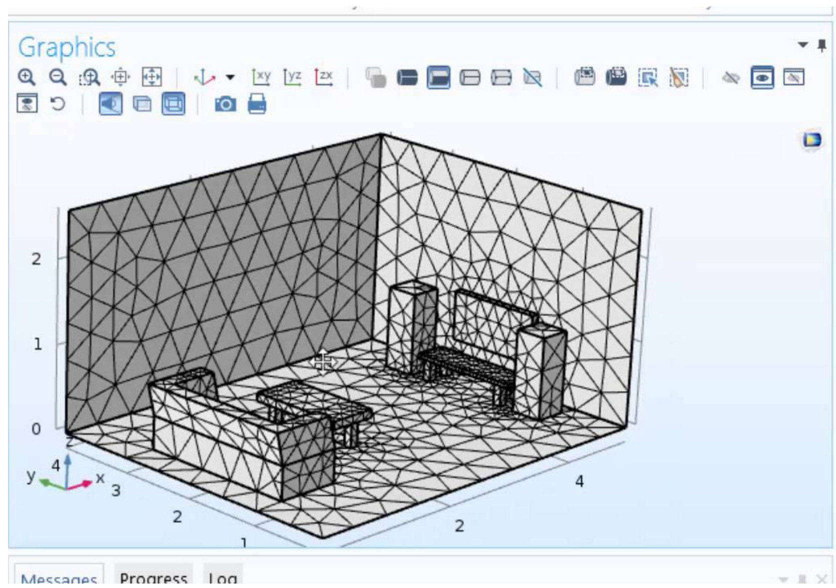


Figure 19: Introduction to COMSOL acoustics 1, From: https://www.youtube.com/watch?v=8V7t1PSIVfM

Simulations will be performed within Comsol. Python scripting for the implementations of the formula's within grashoppen

Optimalization and design exploration

Model based optimizations are especially effective when looking at daylighting or computational fluid dynamics (Wortmann, 2018).
Kriging and radial basis functions are particularly suitable for simulations-based problems from engeneering field and architectural design optimization.

As mentioned before the optimalization technique is not determined yet. When a multi objective optimization is required a model based approach will be atempted. In a single objective weighted sum the technique is to be determined.

The design exploration will focus on an evenly distributed absorption curve over the problem freqencys with as high as possible absorption coefficients. The workflow will show a couple of the best options for the user to choose from.

Materialization

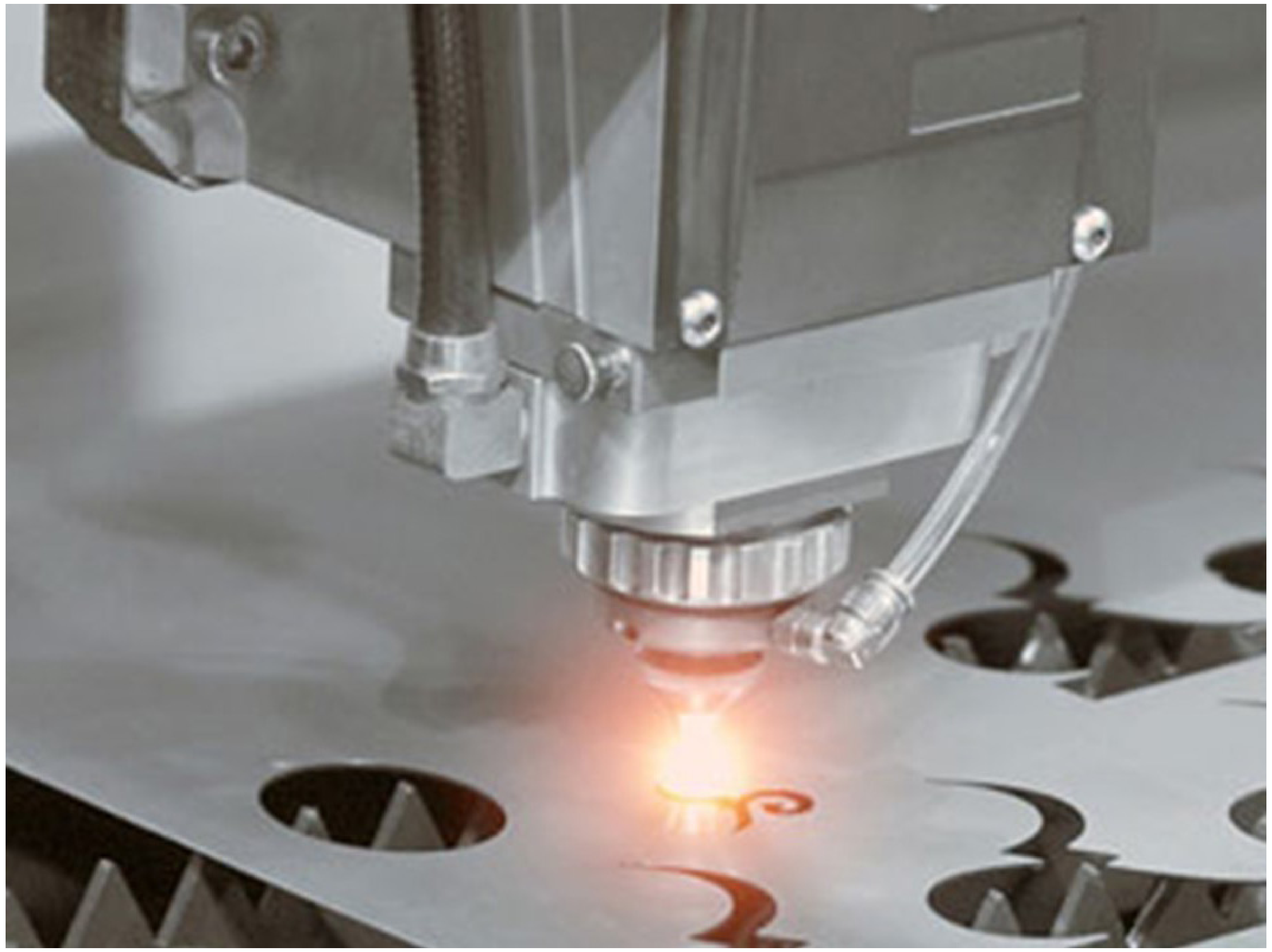


Figure 20: Laser cutting, From: https://www.paulmeijering.nl/en/customization/laser-cutting-of-sheets/

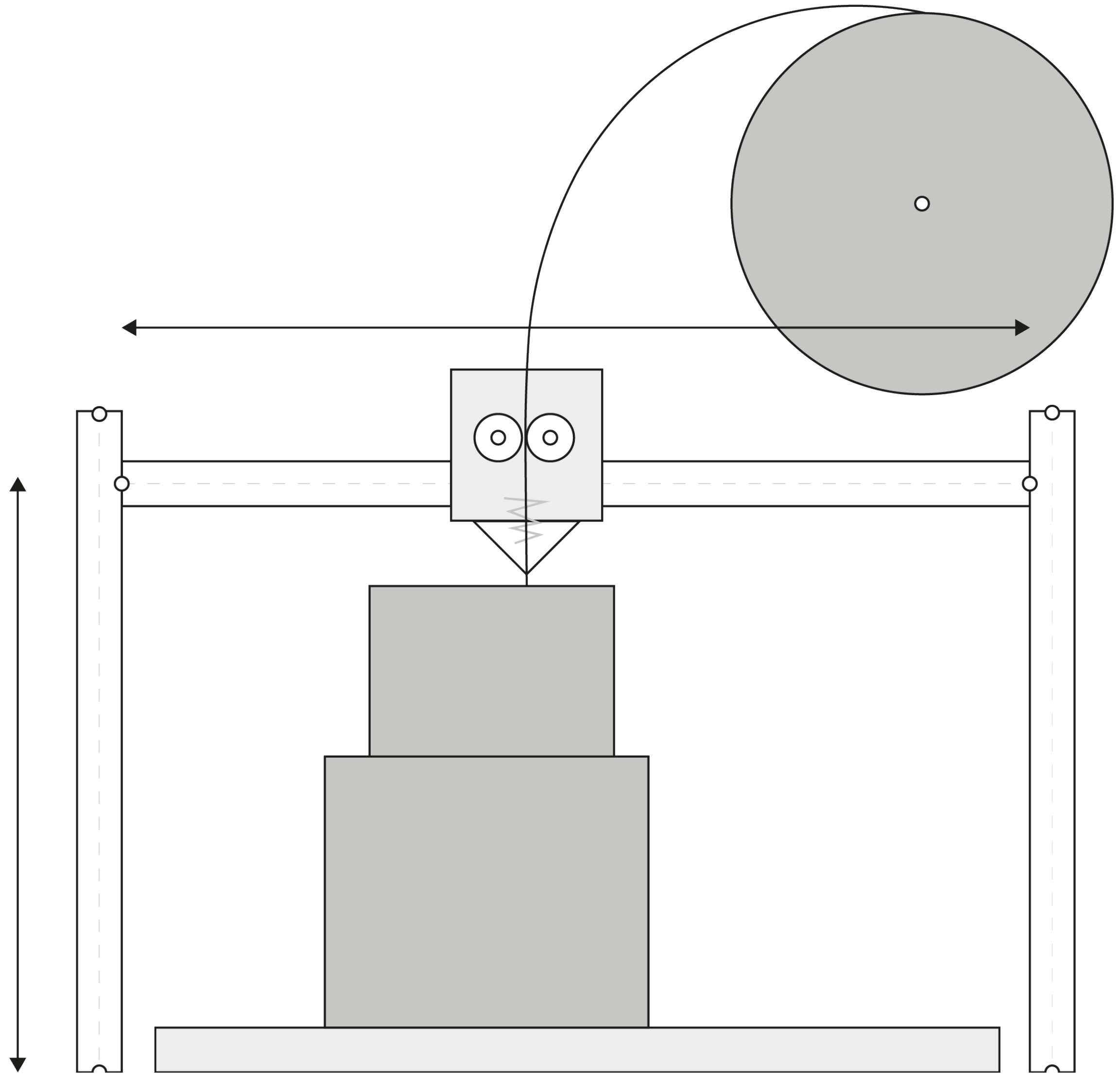


Figure 21: Fused filament printing, own work

Initial only laser cutting. Secondarily fused fillament printing as add ons to the panel (if nessesary)

Fysical tests

Impedance tube test

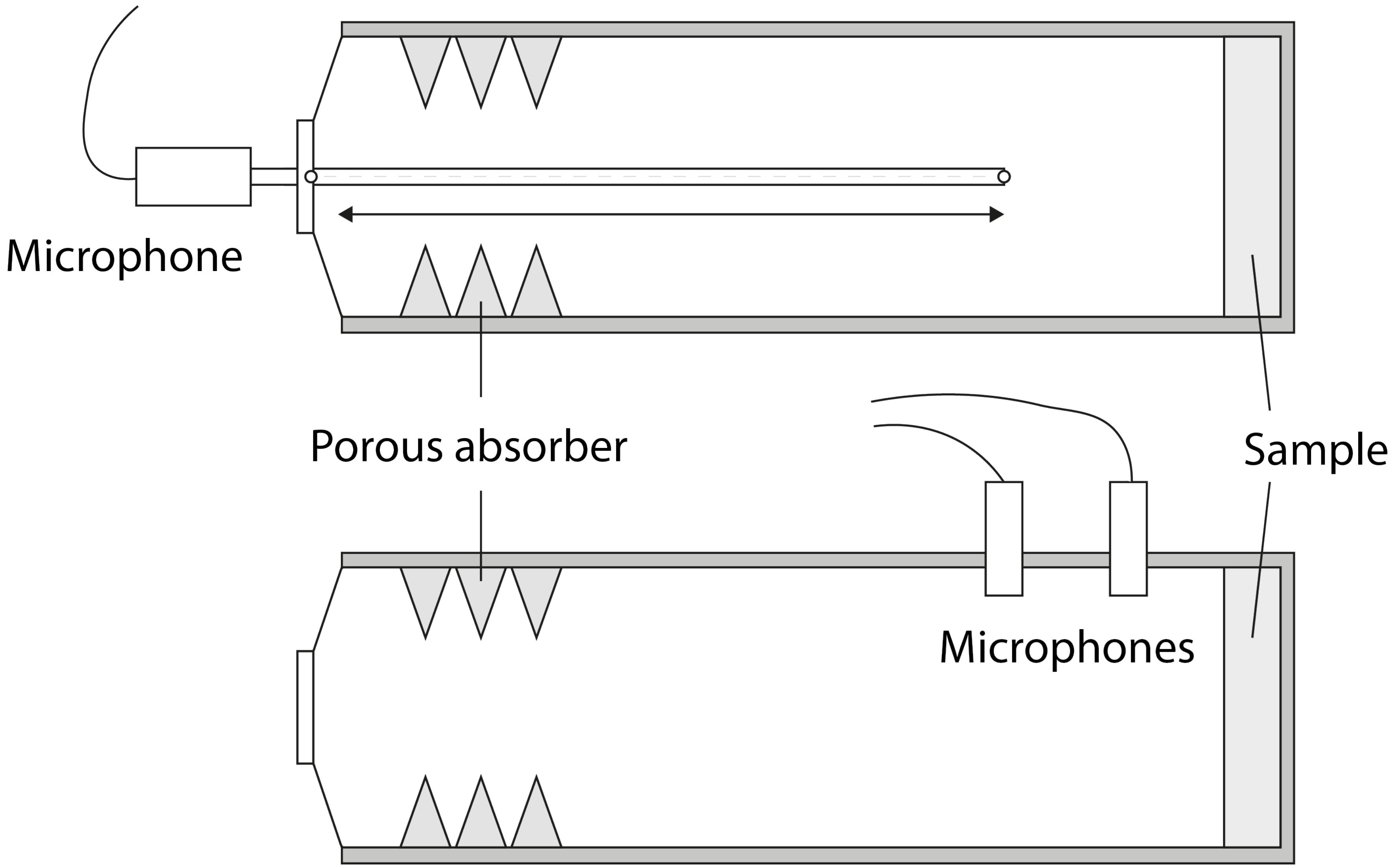


Figure 22: Impedance tubes, standing wave methode and transfer function methode

Figure 23: Impedance tube, https://innorenew.eu/equipment/impedance-tube/

Small scale physical test, mostly to see the effect of the cavity seperations.

Full scale test

Figure 24: Reverberation room, https://www.soundonsound.com/reviews/choosing-using-porous-absorbers

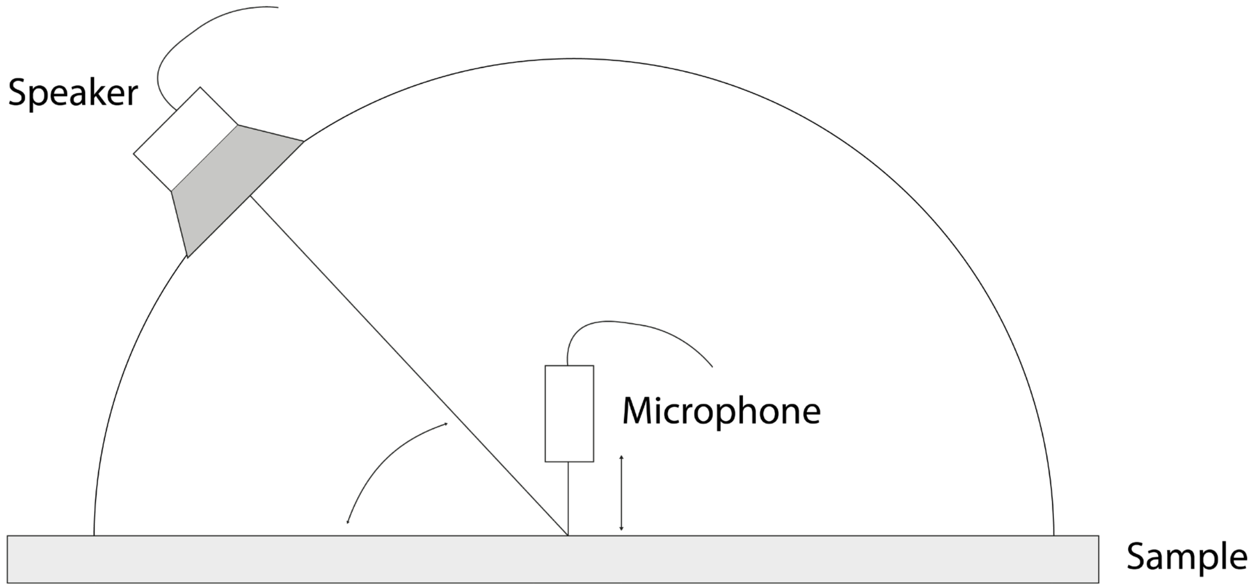
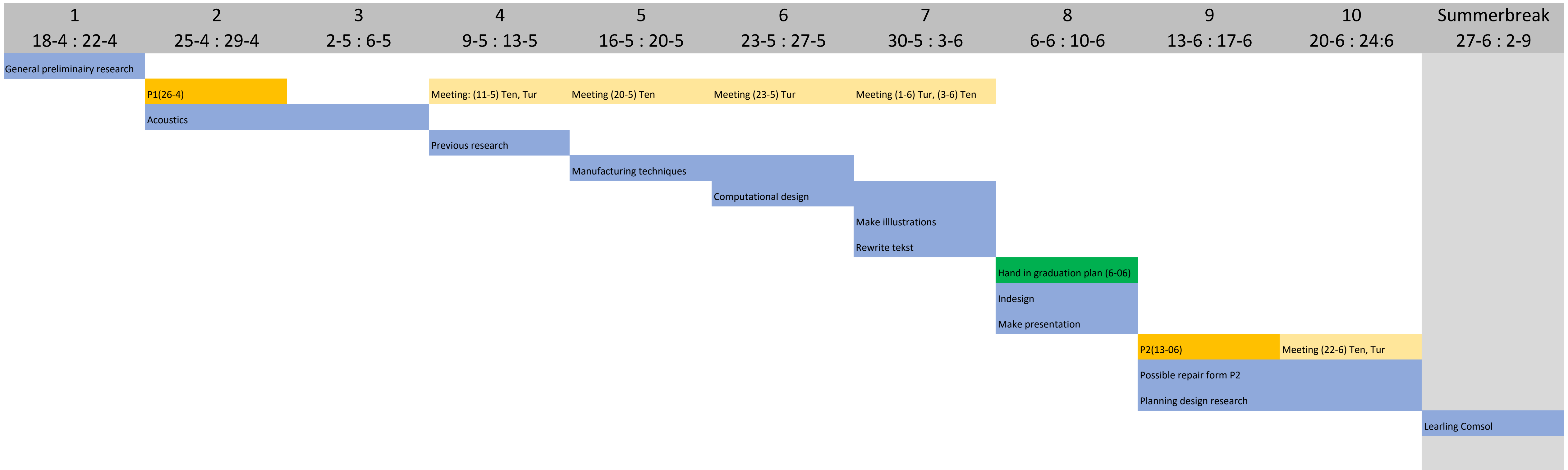


Figure 25: Two microphone free field methode, own work

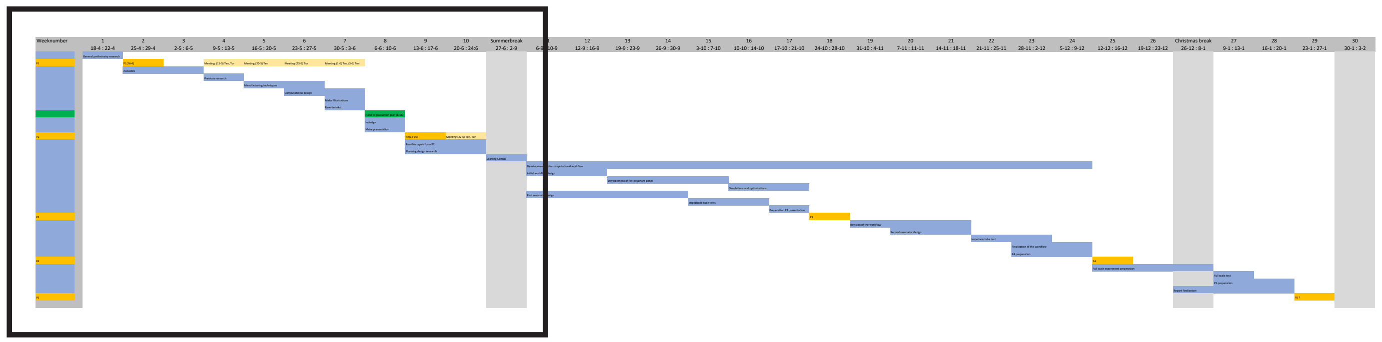
Only when there is time and results from the simulations and the impedance tube tests are promising.

Planning

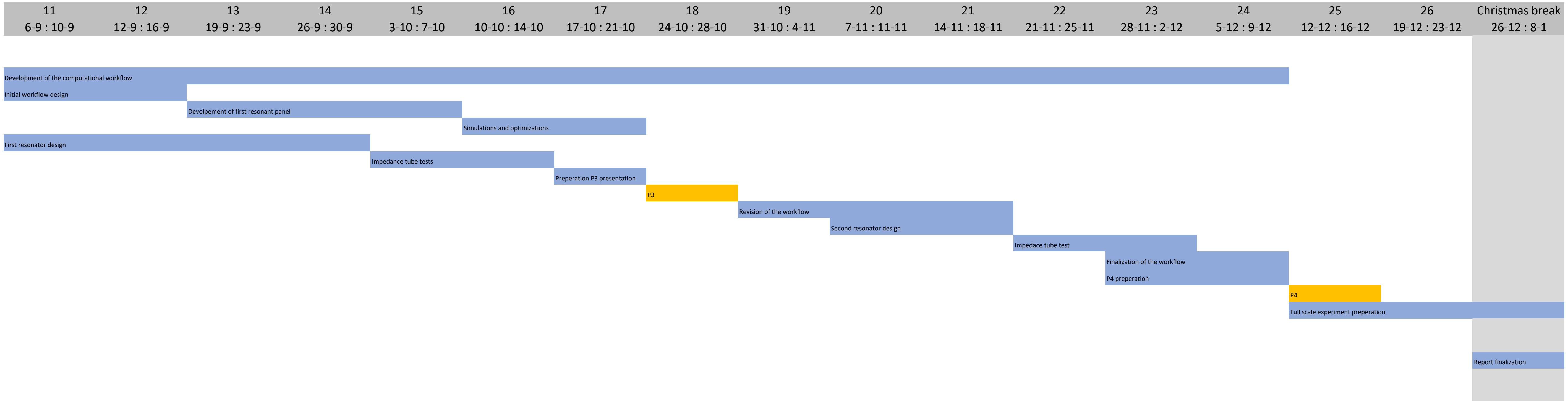
Timeline



1
18-4 : 22-4
2
25-4 : 29-4
3
2-5 : 6-5
4
9-5 : 13-5
5
16-5 : 20-5
6
23-5 : 27-5
7
30-5 : 3-6
8
6-6 : 10-6
9
13-6 : 17-6
10
20-6 : 24:6
Summerbreak
27-6 : 2-9
General preliminairy research
P1(26-4)
Meeting: (11-5) Ten, Tur
Meeting (20-5) Ten
Meeting (23-5) Tur
Meeting (1-6) Tur, (3-6) Ten
Acoustics
Previous research
Manufacturing techniques
Computational design
Make illustrations
Rewrite tekst
Hand in graduation plan (6-06)
Indesign
Make presentation
P2(13-06)
Meeting (22-6) Ten, Tur
Possible repair form P2
Planning design research
Learling Comsol



Timeline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12-9 : 16-9
13
19-9 : 23-9
14
26-9 : 30-9
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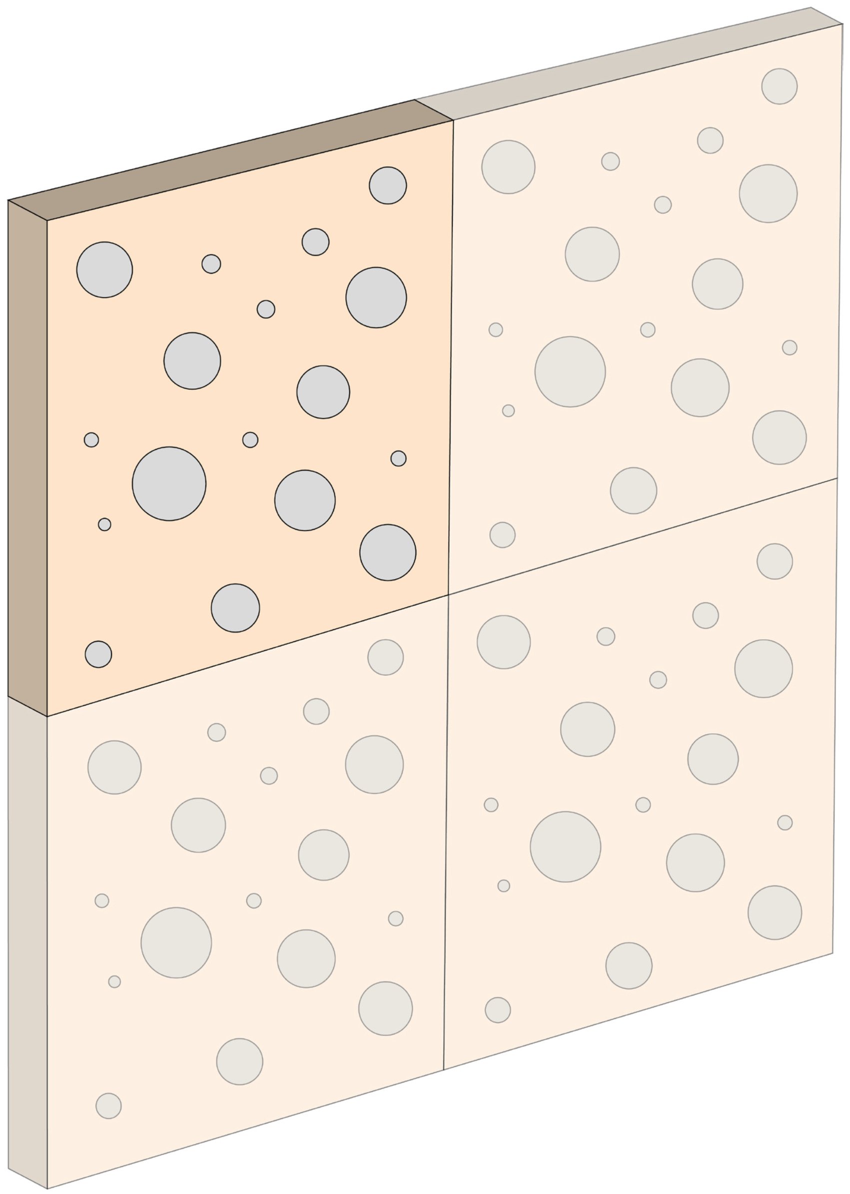
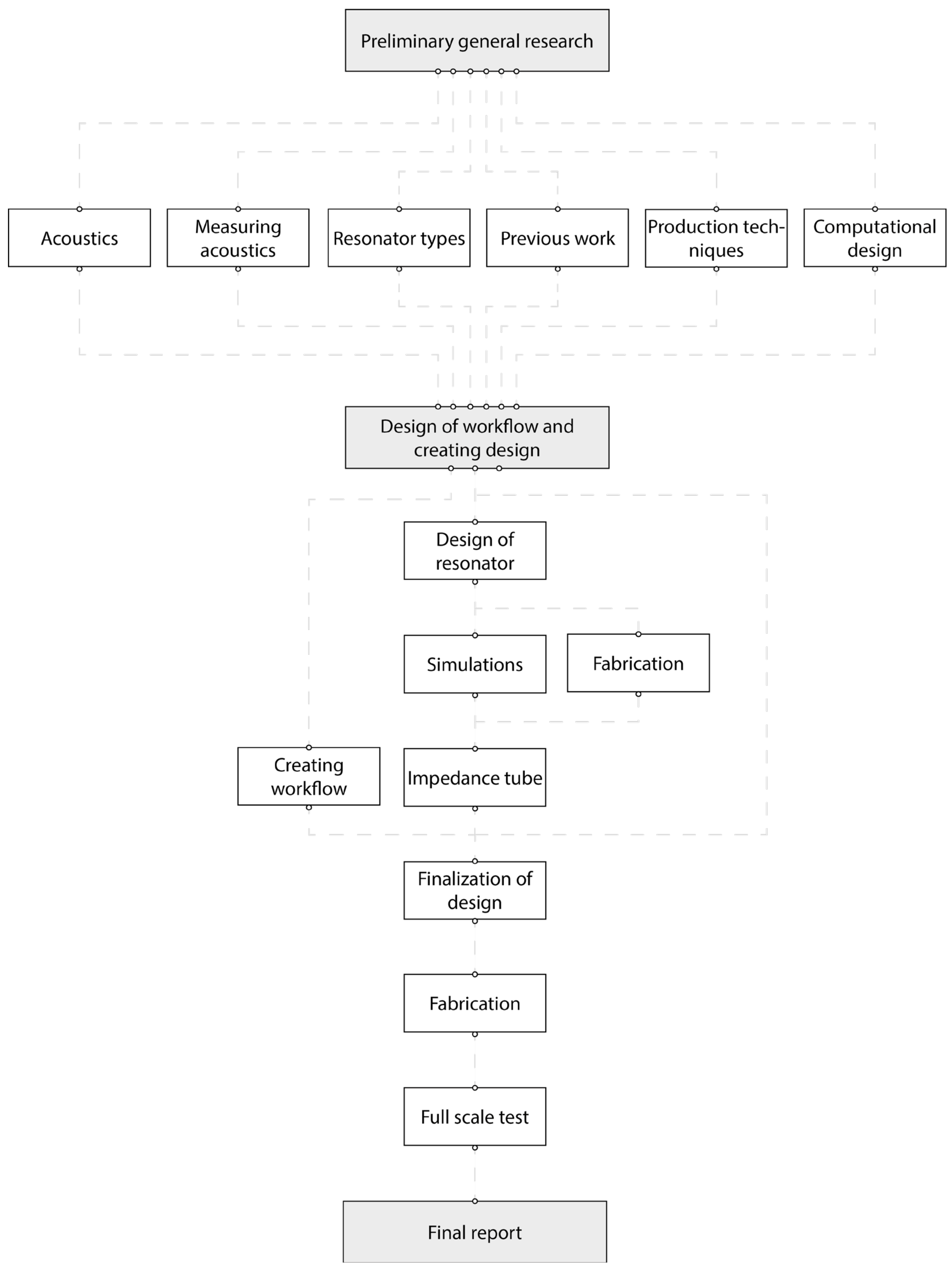
10-10 : 14-10
17
17-10 : 21-10
18
24-10 : 28-10
19
31-10 : 4-11
20
7-11 : 11-11
21
14-11 : 18-11
22
21-11 : 25-11
23
28-11 : 2-12
24
5-12 : 9-12
25
12-12 : 16-12
26
19-12 : 23-12
Christmas break
26-12 : 8-1
Development of the computational workflow
Initial workflow design
Devolpement of first resonant panel
Simulations and optimizations
First resonator design
Impedance tube tests
Preperation P3 presentation
P3
Revision of the workflow
Second resonator design
Impedace tube test
Finalization of the workflow
P4 preperation
P4
Full scale experiment preperation
Report finalization




Preliminary general research
Acoustics
Measuring acoustics
Resonator types
Previous work
Production tech-niques
Computational design
Design of workflow and creating design
Design of resonator
Simulations
Fabrication
Creating workflow
Impedance tube
Finalization of design
Fabrication
Full scale test
Final report