



OST

Eastern Switzerland
University of Applied Sciences

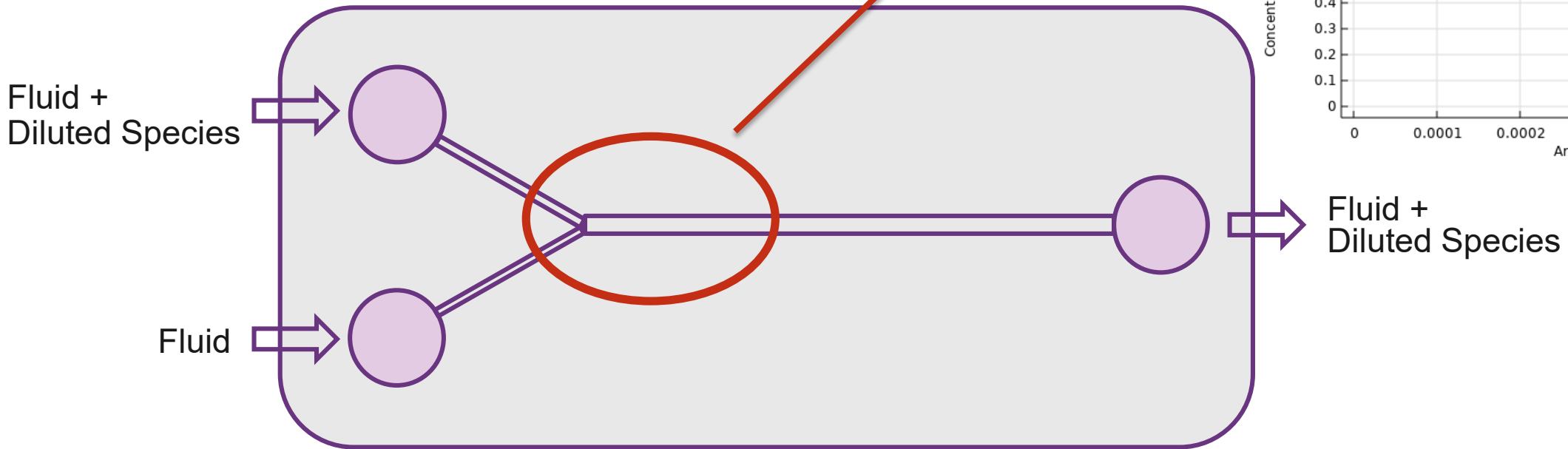
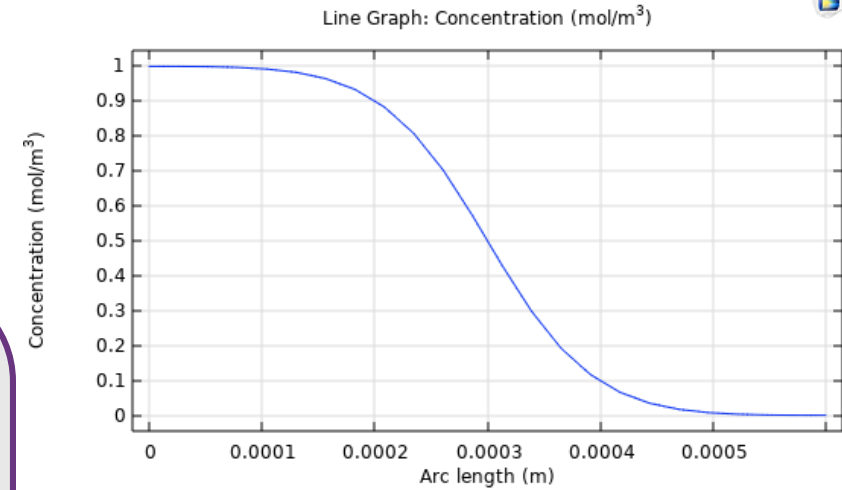
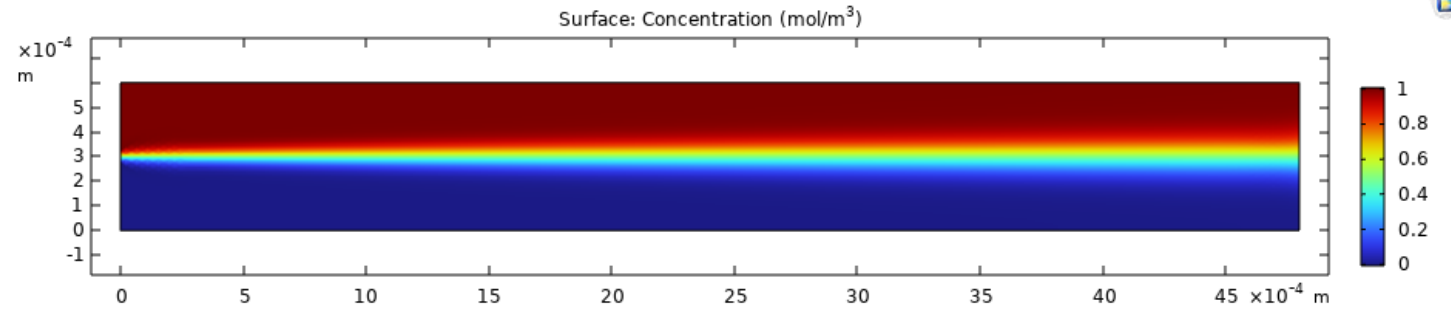
Acoustic Mixing

Modelling of Acoustically Induced Rapid Mixing Processes in Microchannels using Acoustic Streaming

Simon Wiesinger

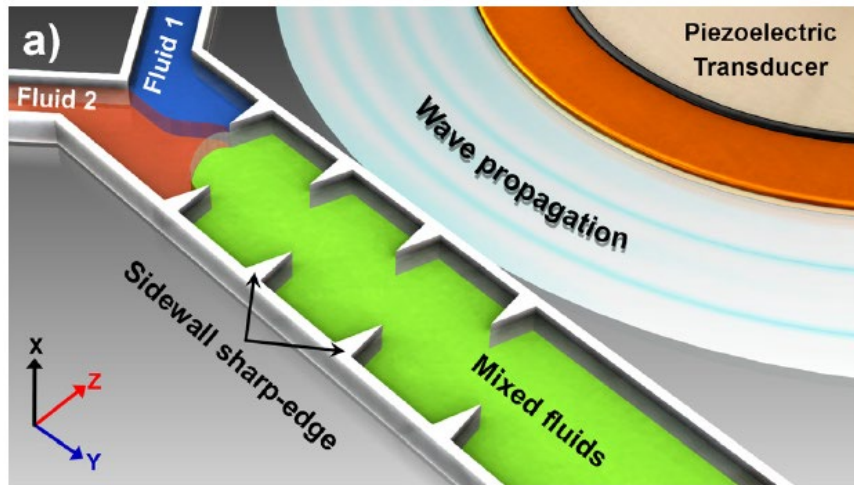
ICE – Institut for Computational Engineering

Introduction

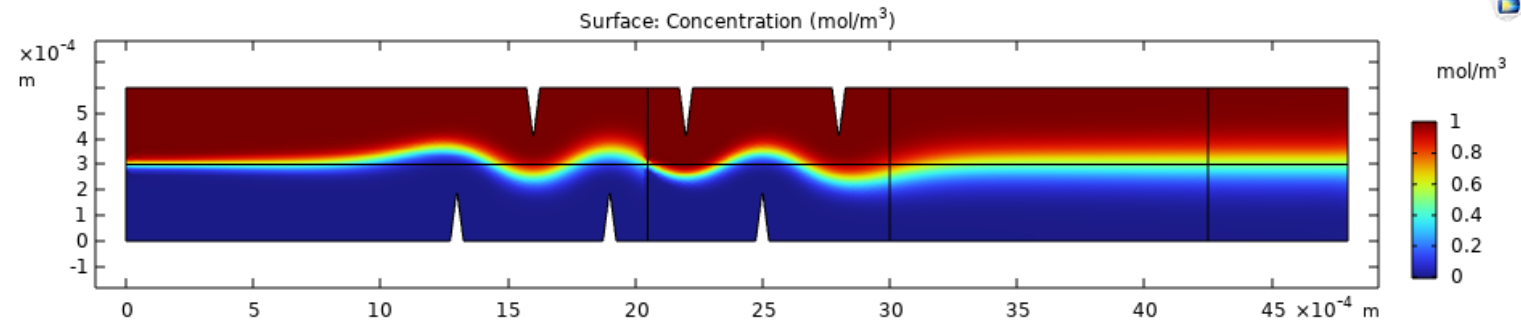


Lab-on-a-Chip System (schematics)

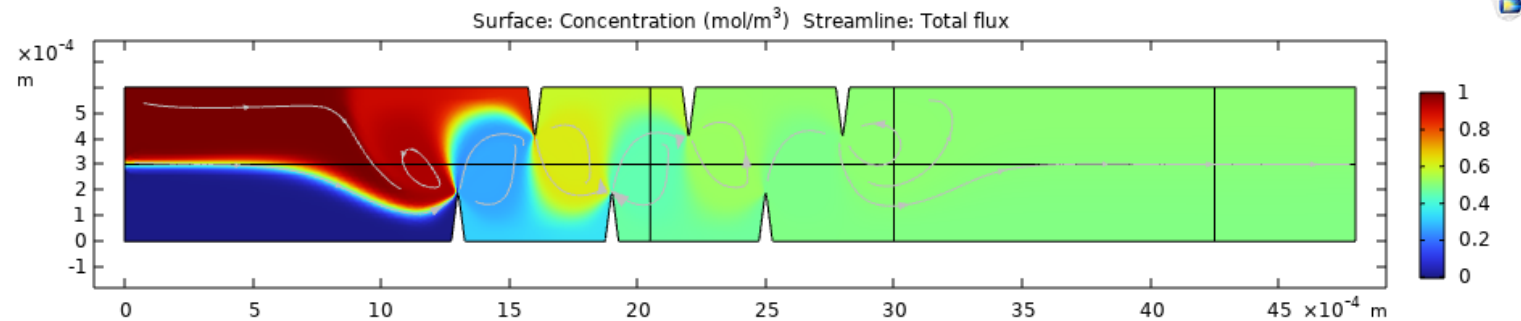
Introduction



Nama et. al. Investigation of Micromixing by acoustically oscillated sharp-edges



without Acoustic Actuation



with Acoustic Actuation

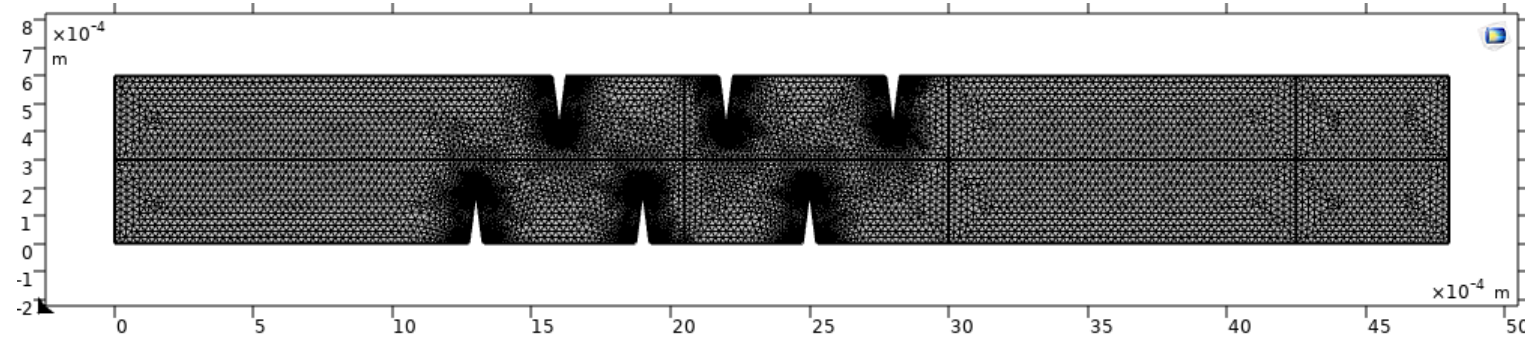
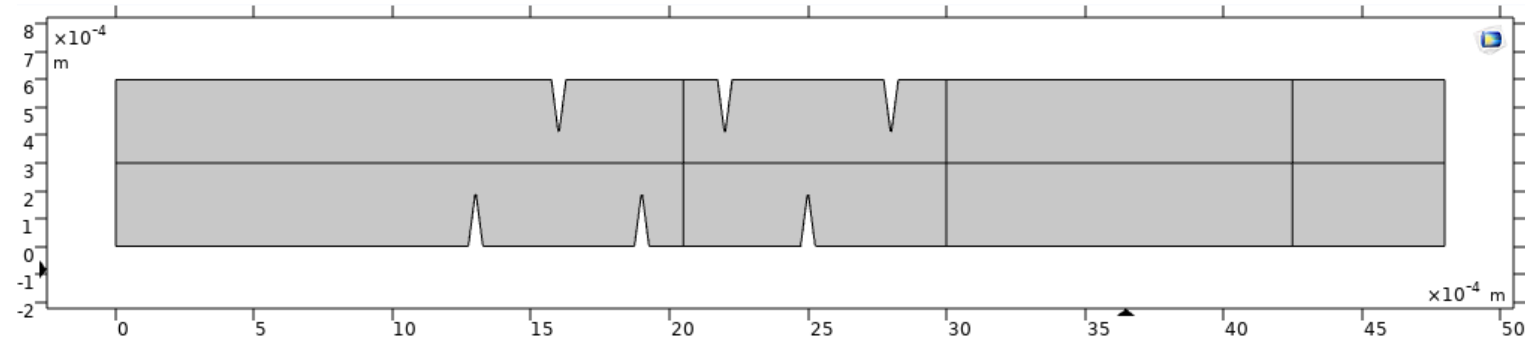
Project Scope

- Study the modelling of acoustic mixing
 - Implement acoustic mixing using the new acoustic streaming interface of Comsol Multiphysics
 - Use the implemented model to carry out a parameter study to
 1. study the influence of geometrical parameters on the mixing quality
 2. study the influence of process parameters on the mixing quality
- **Give recommendations for optimal microchannel setups**

Comsol Multiphysics Implementation

General Setup

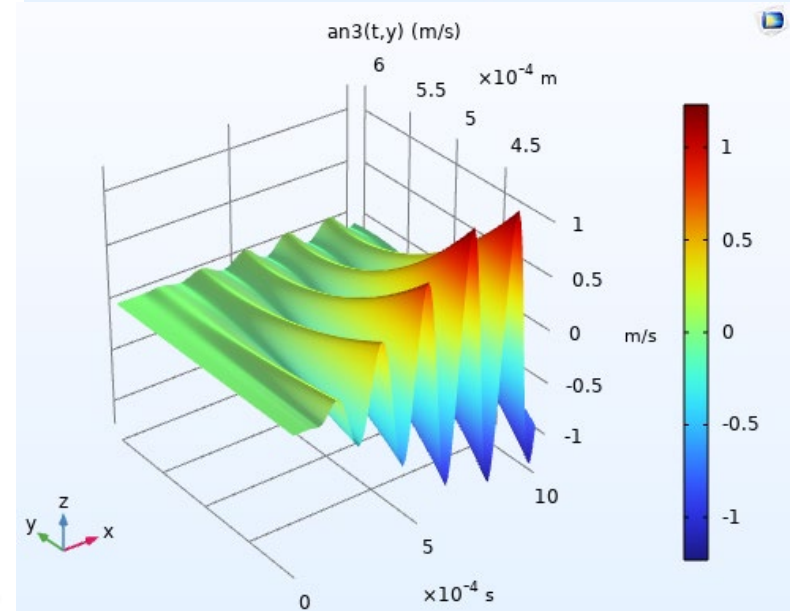
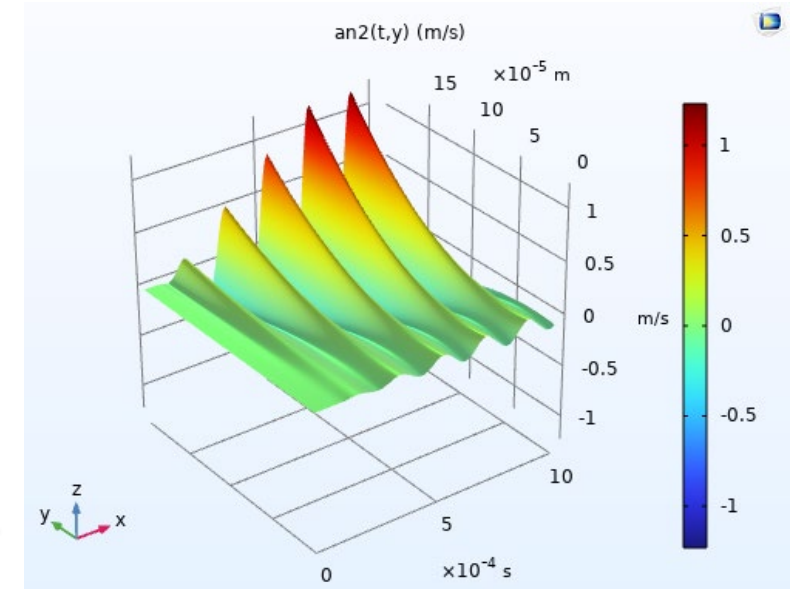
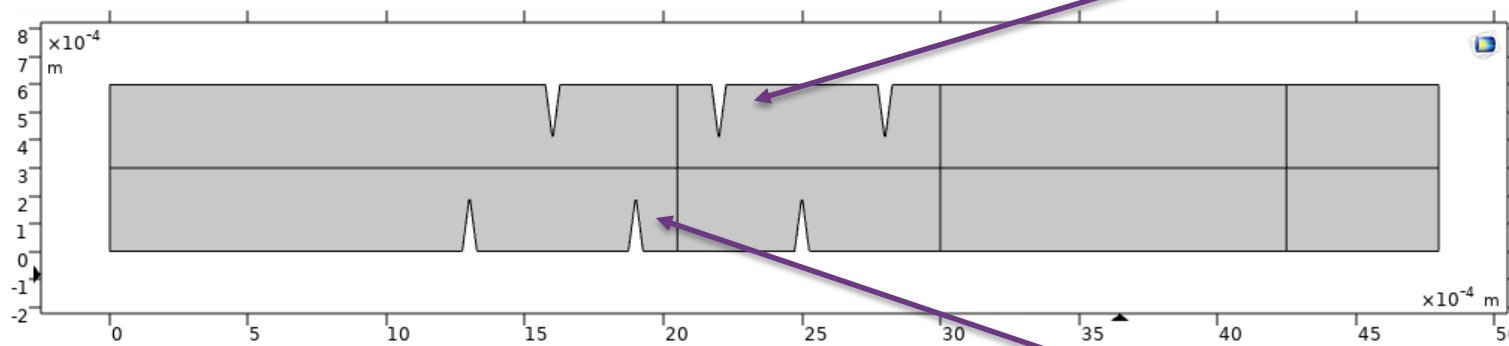
- Two inlets left side
- One outlet right side
- Three pairs of sharp edges
- Fine Mesh required
- About 24'000 elements



Actuation Signals


- Actuation is modelled according to *Nama. et. al.* where the actuation amplitude d_{exp} is a function of channel height z and tip height H

$$d_{exp}(z, H) = 25.3 \cdot d_0 \left[1.22 \left(\frac{z}{H} \right)^2 - 0.29 \left(\frac{z}{H} \right) \right]$$




Comsol Multiphysics Implementation

Interfaces

 Pressure Acoustics, Frequency Domain (*acpr*)


Pressure Acoustics,
Frequency Domain

Acoustics

 Laminar Flow (*spf*)

Laminar Flow

Acoustic Streaming

 Thermoviscous Acoustics, Frequency Domain (*ta*)

Thermoviscous
Acoustics,
Frequency Domain

Acoustics, near wall

 Laminar Flow 2 (*spf2*)

Laminar Flow

Background Flow

Acoustic Mixing Model


 Transport of Diluted Species (*tds*)

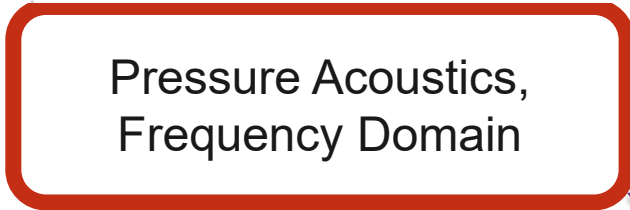
Transport of Diluted
Species

Concentration


Comsol Multiphysics Implementation

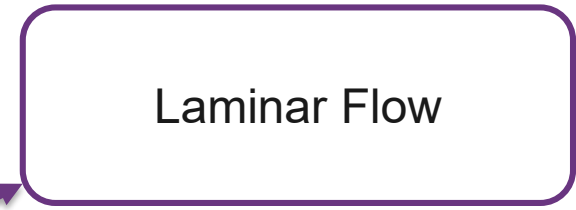
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Acoustics

 Laminar Flow (*spf*)



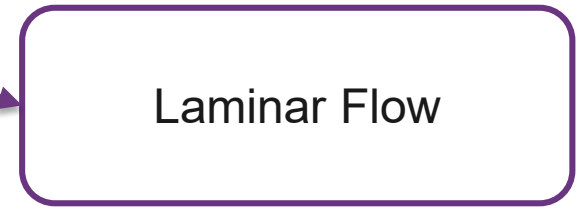
Acoustic Streaming

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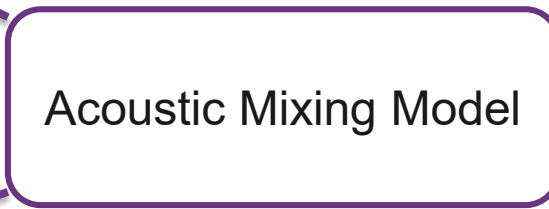


Acoustics, near wall

 Laminar Flow 2 (*spf2*)



Background Flow




 Transport of Diluted Species (*tds*)



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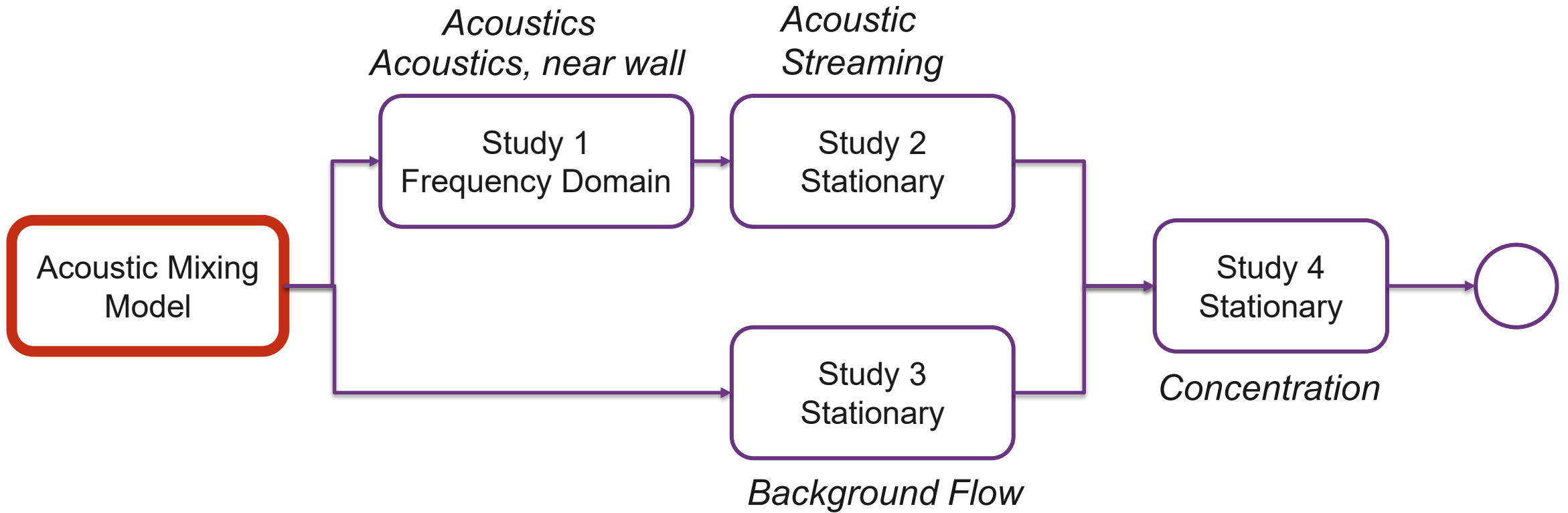
Background Flow

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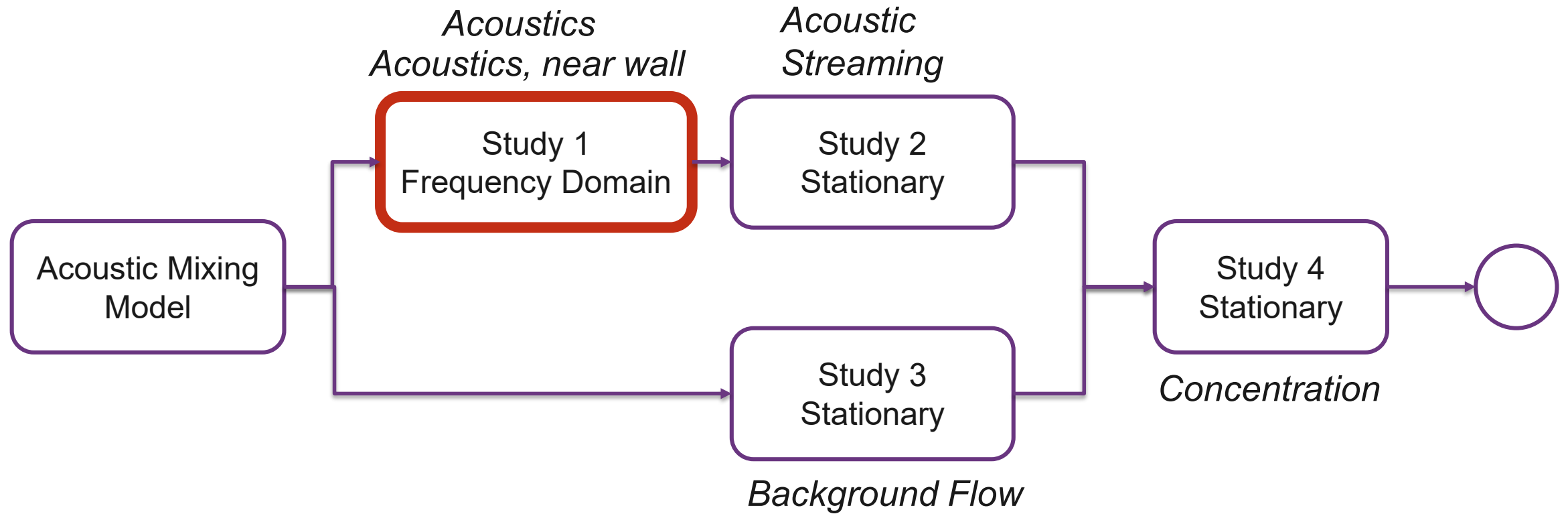
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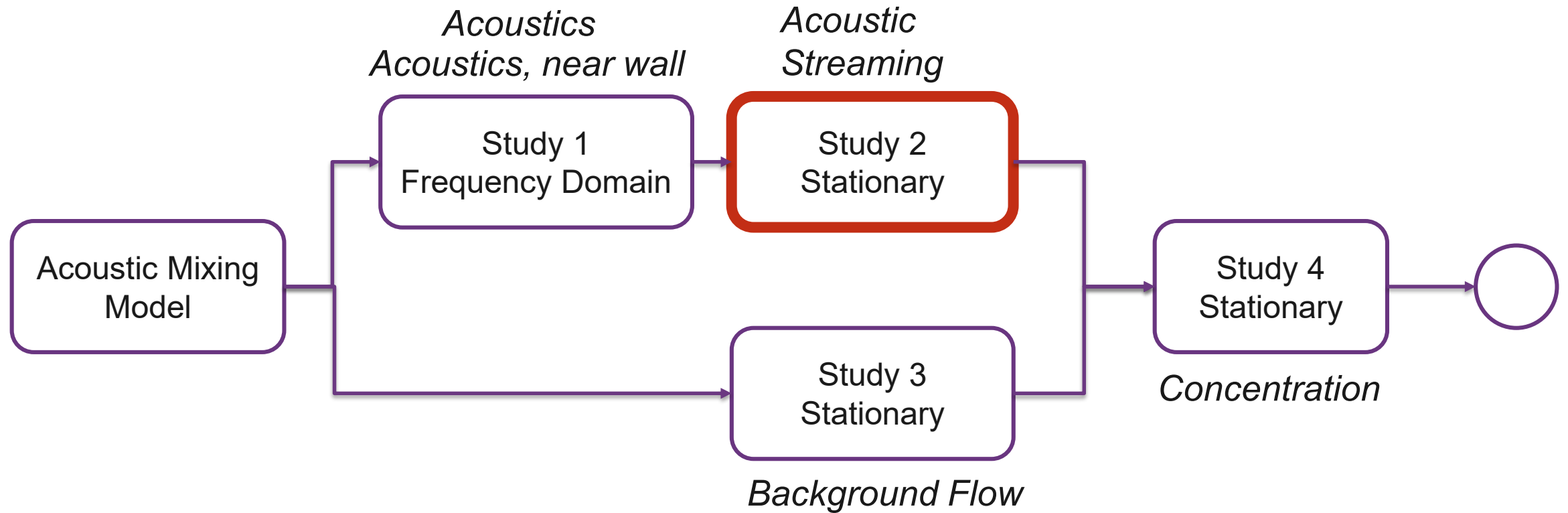
Interfaces



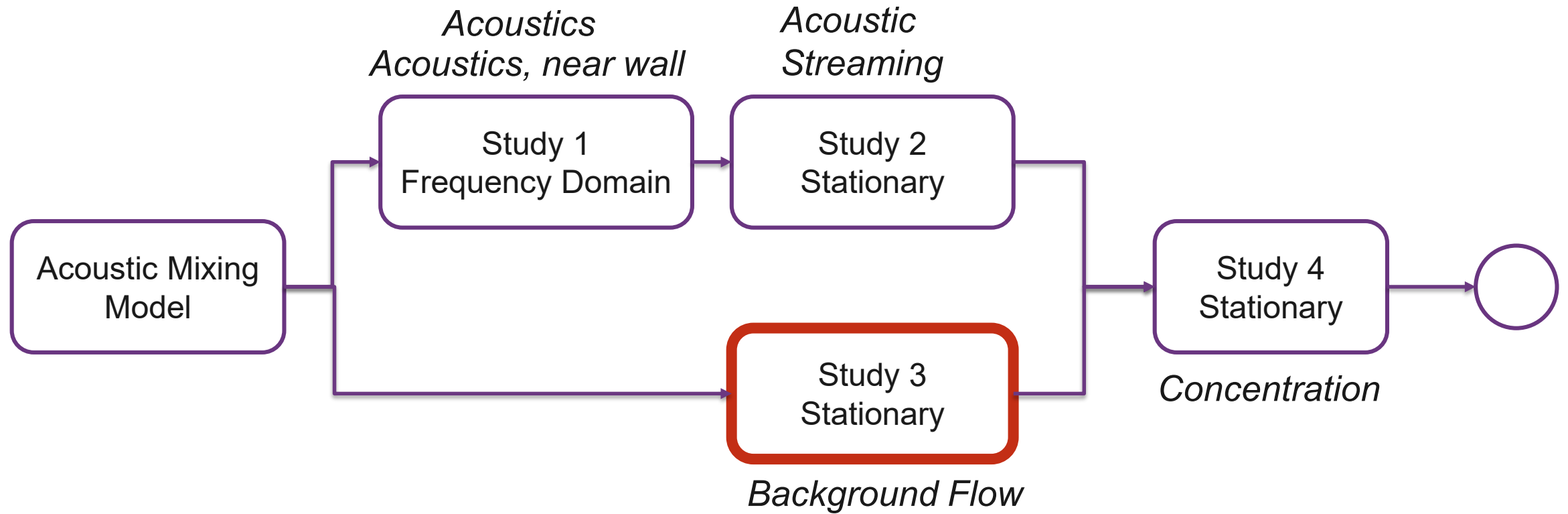
Interfaces



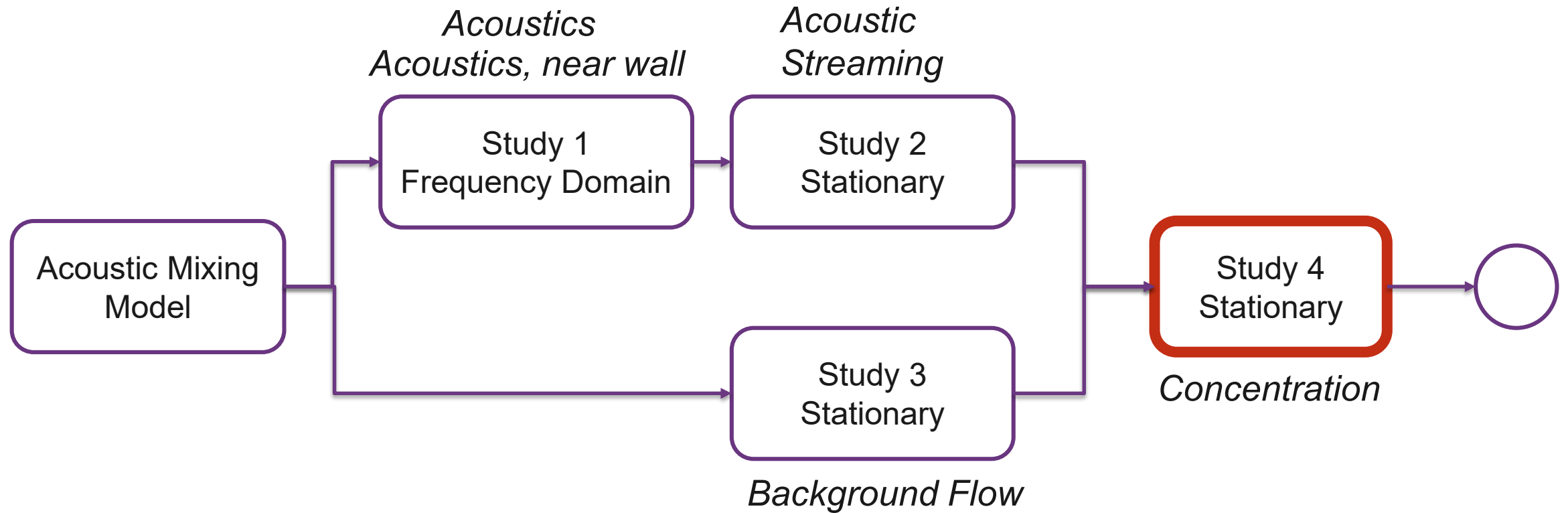
Interfaces



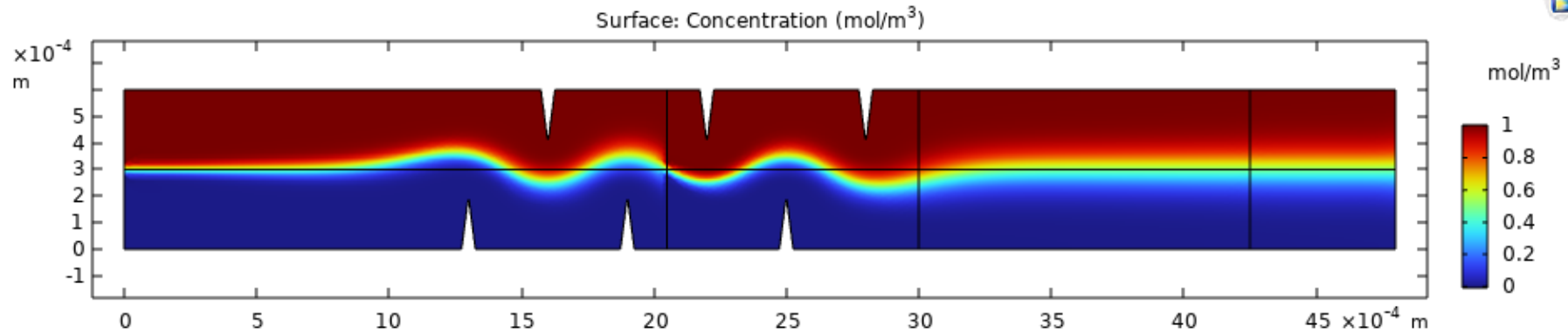
Interfaces



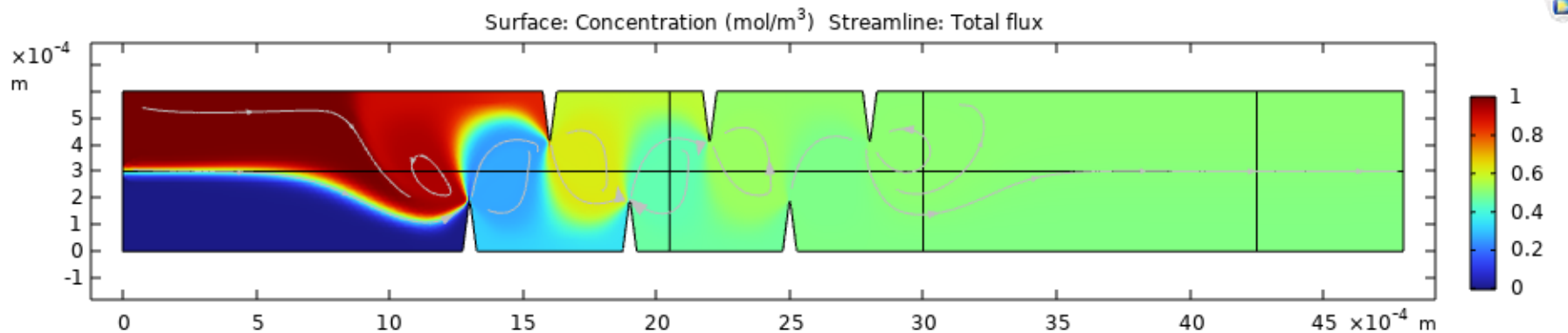
Interfaces



Test Simulation 2D



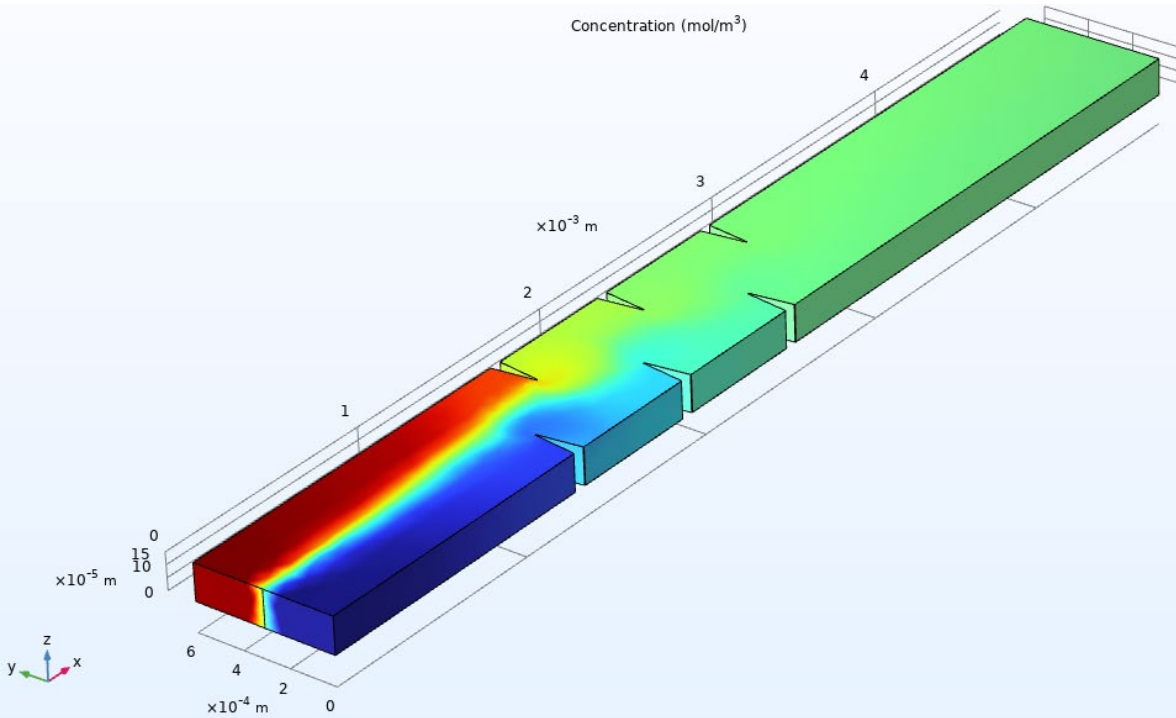
without Acoustic Actuation



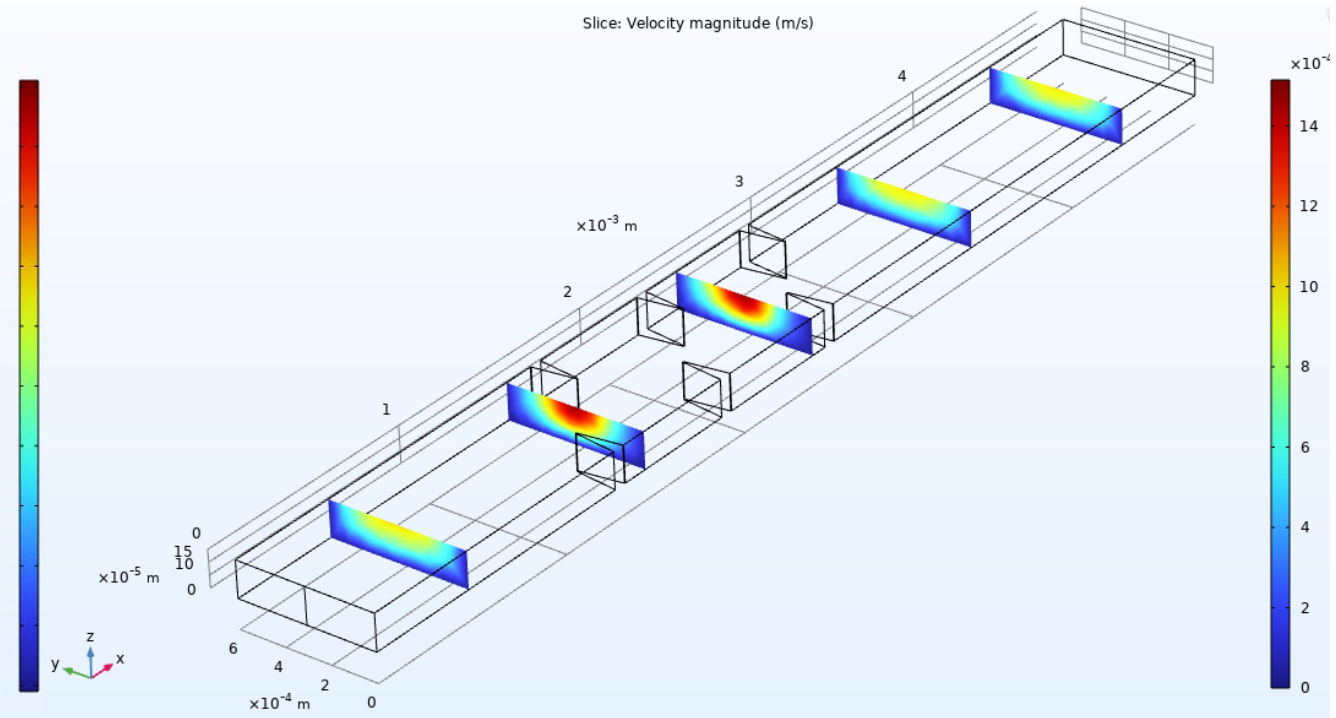
with Acoustic Actuation

Comsol Multiphysics Implementation

Test Simulation 3D



Concentration



Velocity Field (slices)

Parameter Study

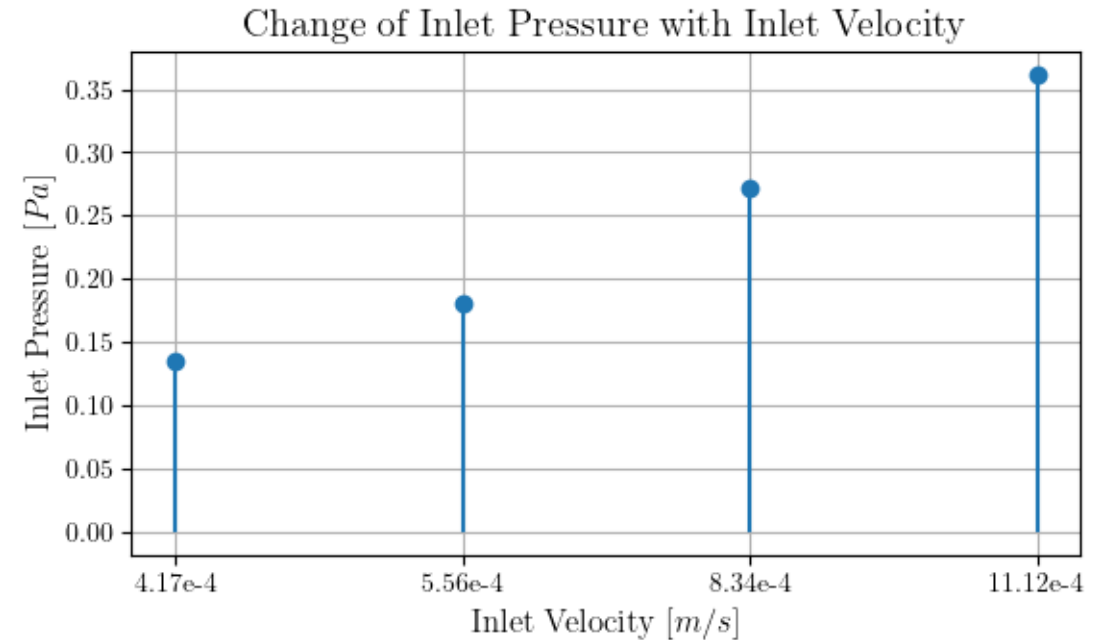
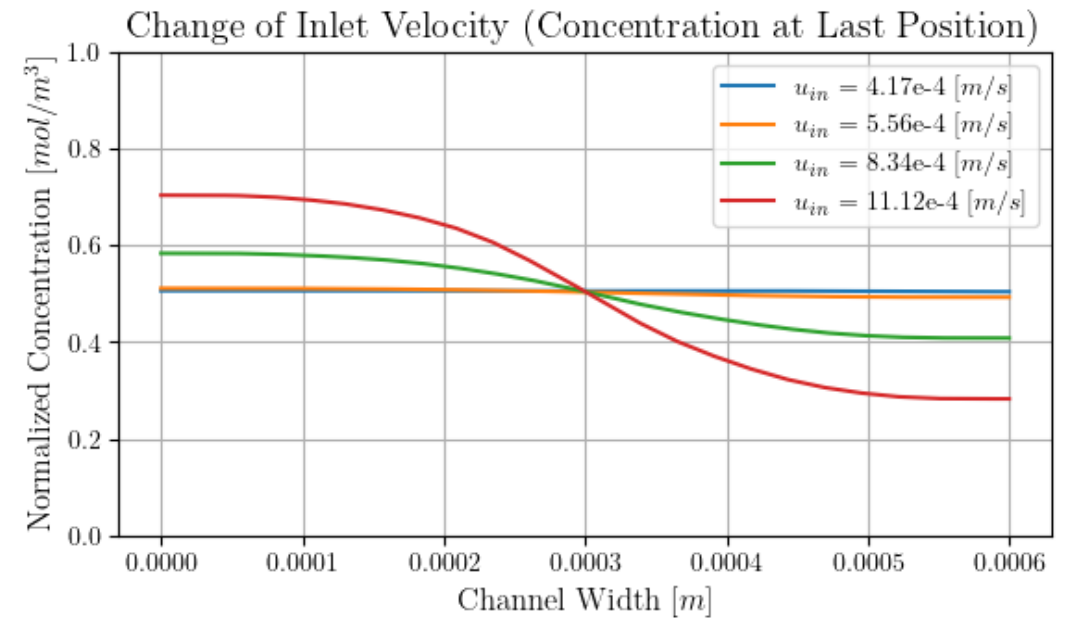
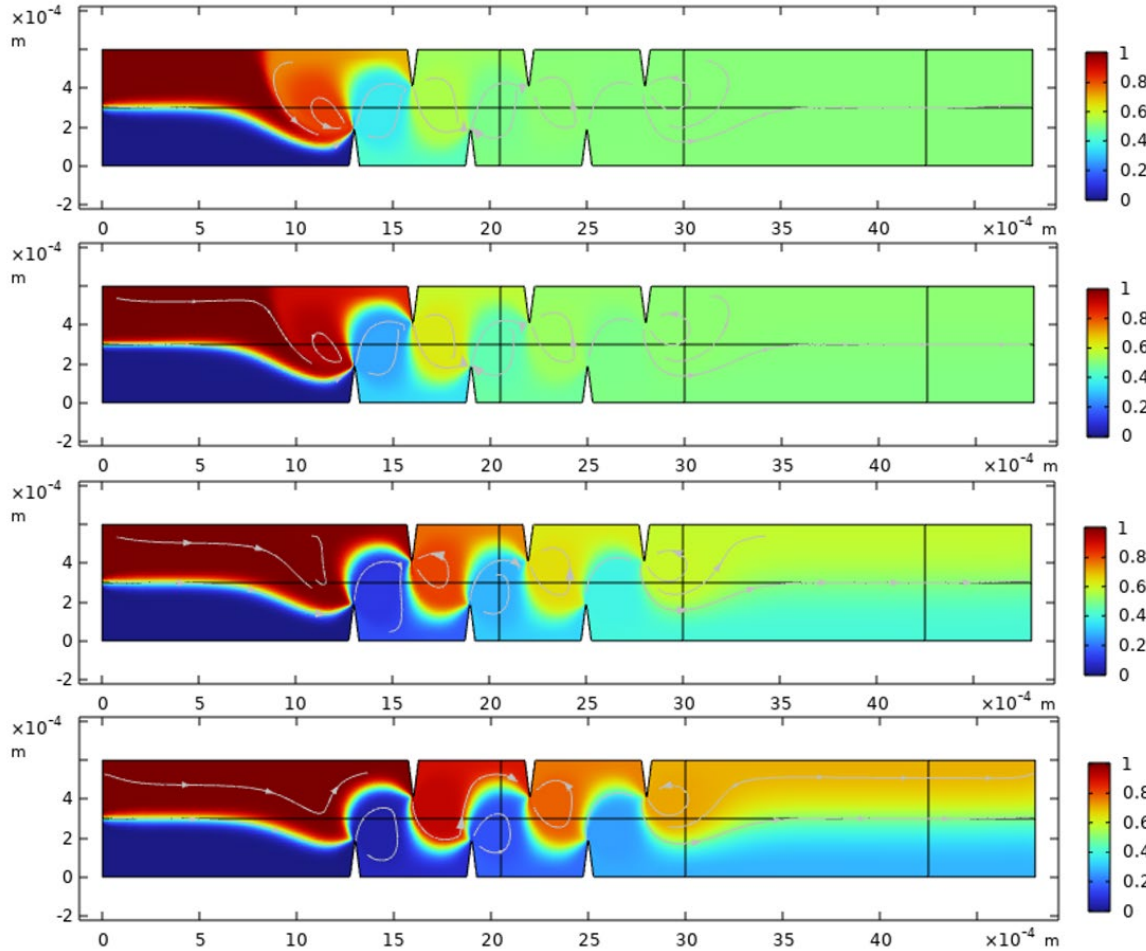
Setup

- Study of geometrical and process parameters
 - Inlet Velocity, Tip Angle, Tip Height, Tip Distance, Frequency
- Influence on mixing quality
- Original Configuration as basis (green)

Parameter	Value 1	Value 2	Value 3	Value 4	Value 5	Unit
Inlet Velocity	417	556	834	1112	-	$[\mu\text{m s}^{-1}]$
Tip Angle	12	-	15	-	18	$[\text{°}]$
Tip Height	160	-	200	-	240	$[\mu\text{m}]$
Tip Distance	0	-	200	-	300	$[\mu\text{m}]$
Frequency	4	4.5	5	5.5	6	$[\text{kHz}]$

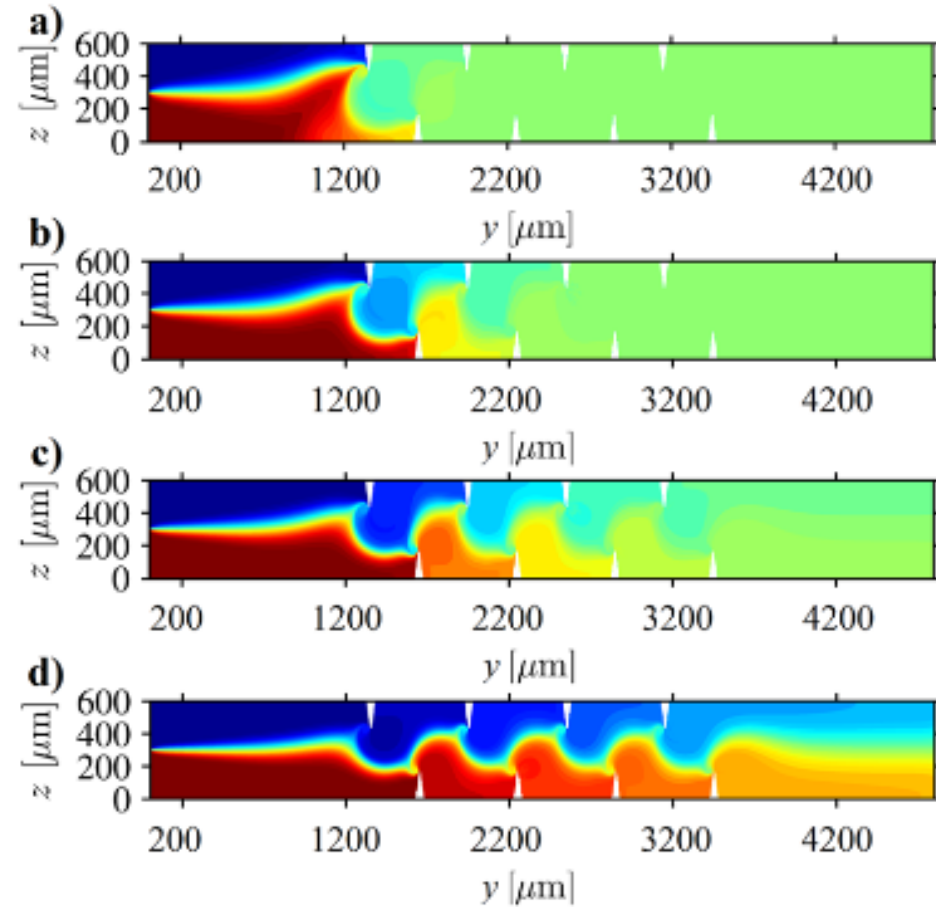
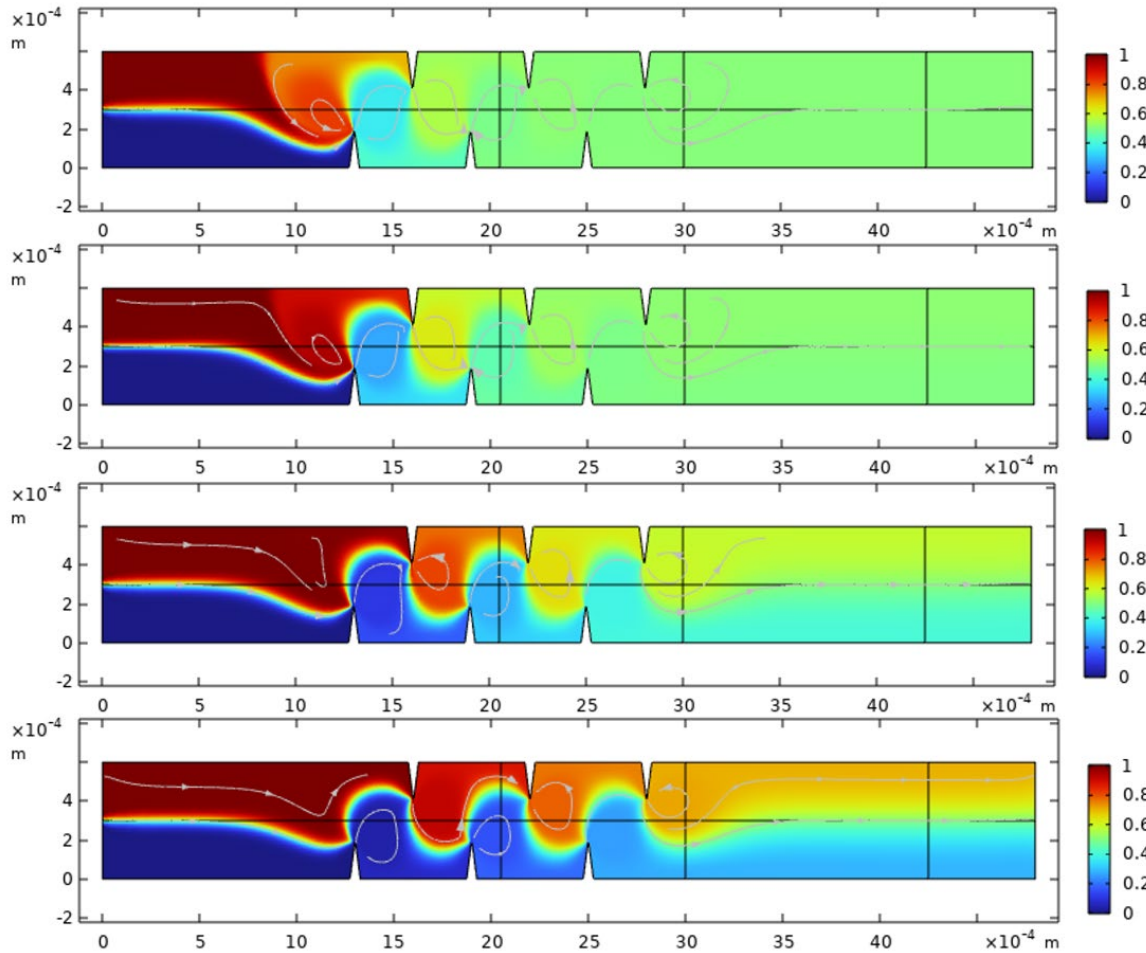
Parameter Study

Effects of Inlet Velocity



Parameter Study

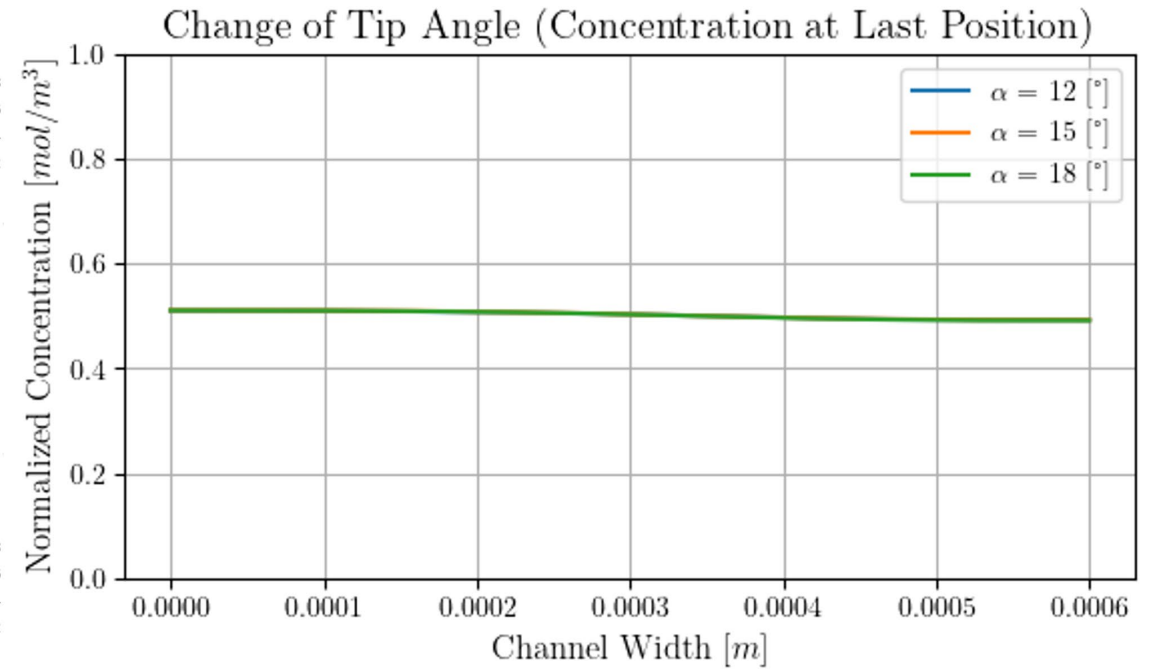
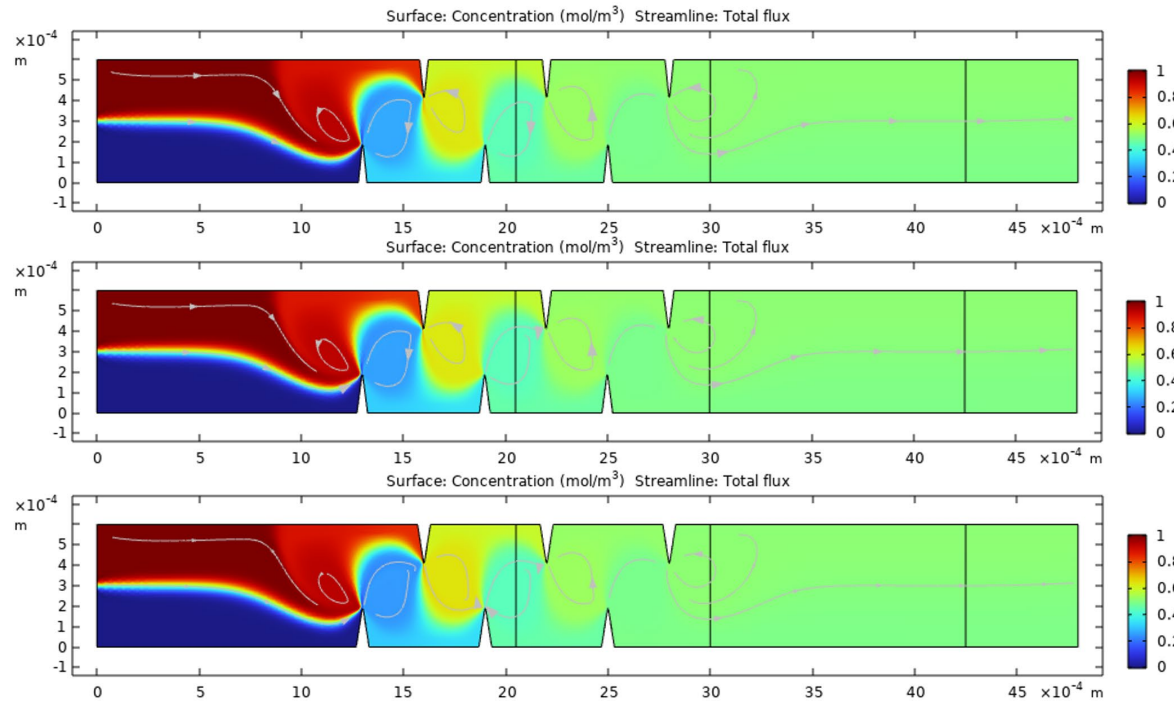
Effects of Inlet Velocity



Nama et. al. Investigation of Micromixing by acoustically oscillated sharp-edges

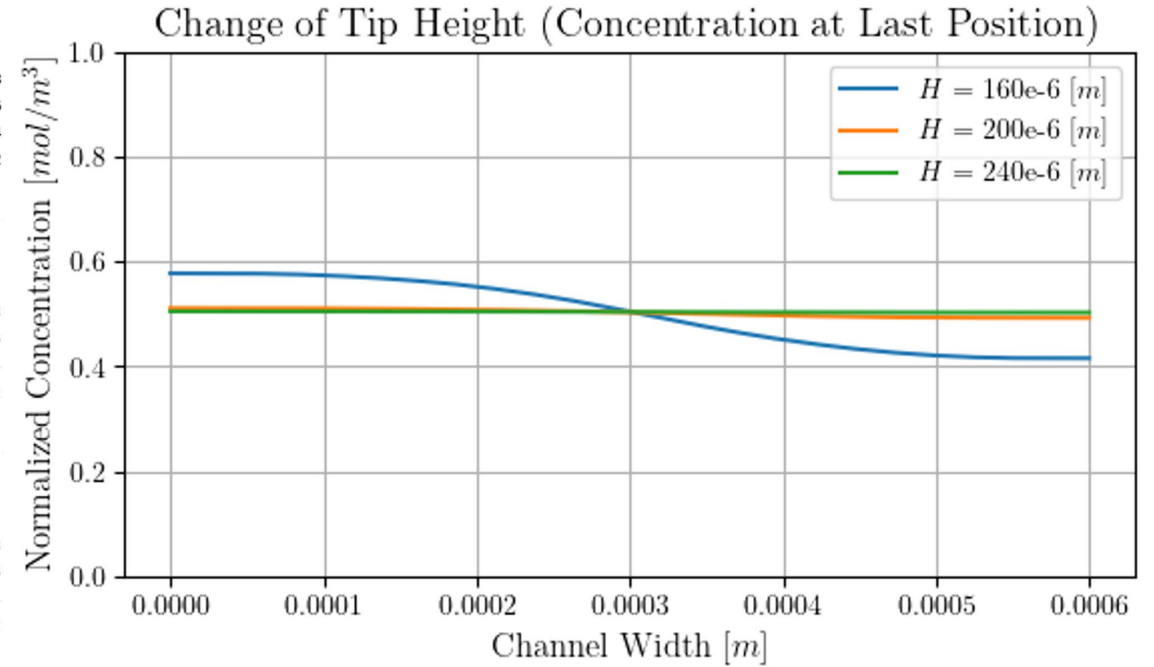
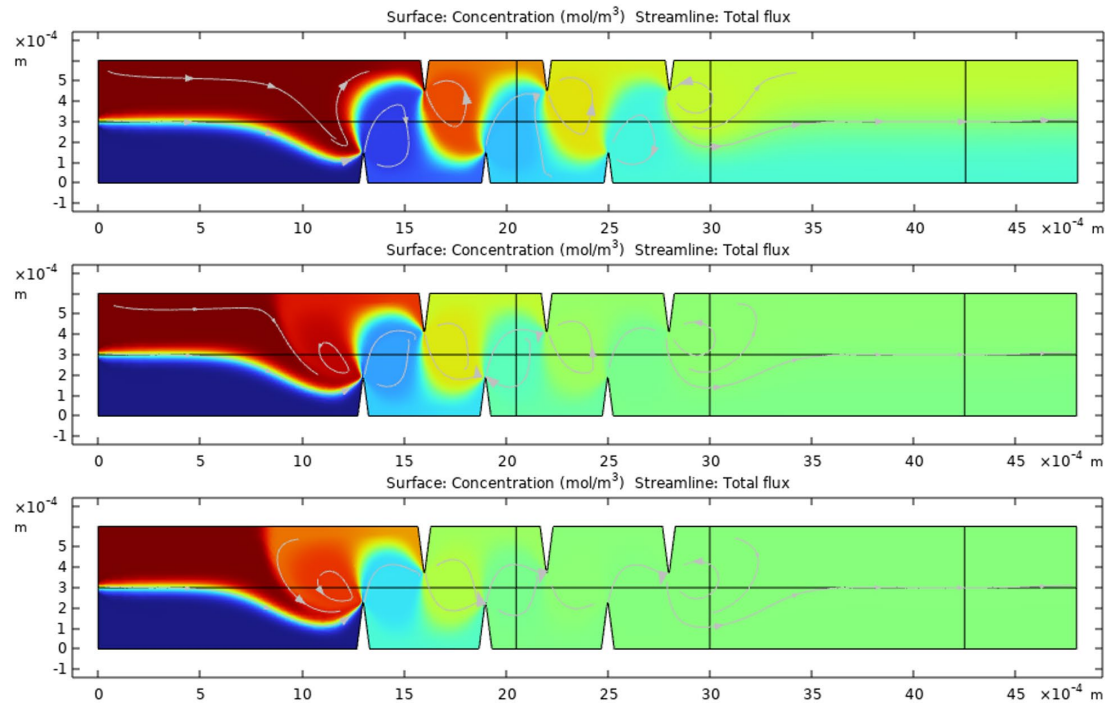
Parameter Study

Effects of Tip Angle



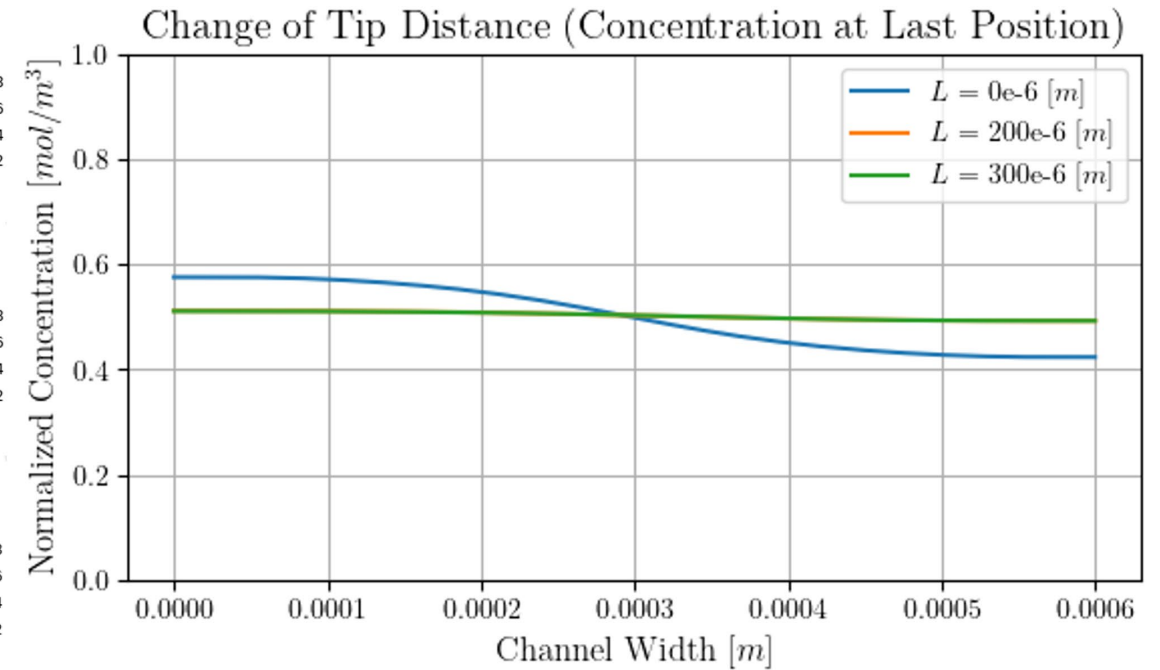
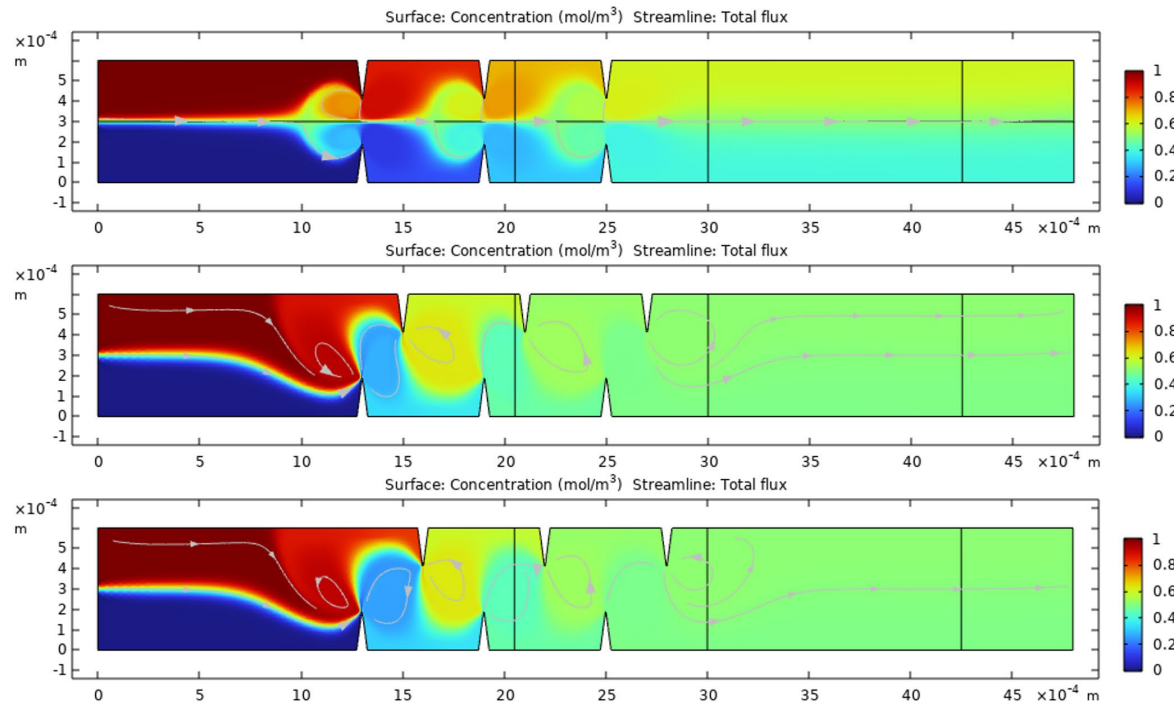
Parameter Study

Effects of Tip Height

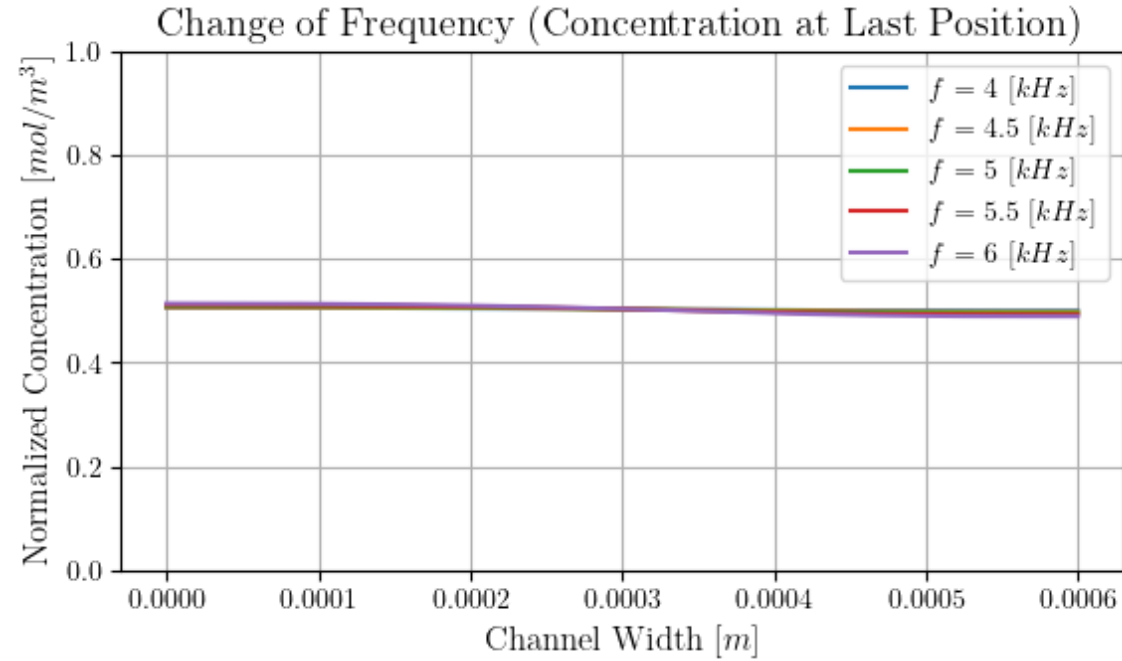


Parameter Study

Effects of Tip Distance



Effects of Actuation Frequency



Optimal Microchannel Setups

- Strong influence on mixing quality
 - Inlet Velocity (higher pressure, larger throughput)
 - Tip Height (higher pressure)
- Medium Influence
 - Tip Distance
- No Influence
 - Tip Angle
 - Actuation Frequency

- High throughput with medium mixing quality

- Medium to high inlet velocity and medium to low tip height

- Perfect and fast mixing with medium throughput

- Low inlet velocity and medium to high sharp edges

Conclusion

- Overall modelling acoustic mixing worked very well when using the acoustic streaming interface
 - Easy usage, fast simulations
 - Perfect for parameter studies
- Parameter study showed inlet velocity and tip height as crucial
 - Larger parameter space would improve results
- All in all, acoustic mixing was shown to be a very effective method

