Comsol's New Thermoviscous Interface and Computationally Efficient Alternative Formulations for FEM

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Reden B.V.
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Reden

- **Reden: RE**search **DE**velopment **N**etherlands.
- Using simulations to aid our customers in development of their products and/or production processes.
- Most our simulations use FEM.

University of Twente

- PhD theses:
  - 1998 Beltman
  - 2000 Van der Eerden
  - 2001 Basten
  - 2007 Hannink
  - 2010 Kampinga
  - 2010 Nijhof
- Contact:
  - Ysbrand Wijnant (Y.H.Wijnant@utwente.nl)
- Project partner:

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- Introduction to viscothermal acoustics and models
- Model of a microphone
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Thermoacoustics interface: Applications

- Comsol included a thermoacoustics interface in its new acoustics module.
- This interface can be used to model acoustics including the dissipative effects of viscous friction and heat transfer.

Thermoacoustics interface: Applications

- Comsol included a thermoviscous interface in its new acoustics module.
- This interface can be used to model acoustics including the dissipative effects of viscous friction and heat transfer.
- Typical applications are small acoustic transducers.

Thermoacoustics interface: Physics

Viscothermal acoustics:

- Acoustics = momentum & compressibility
- Viscous friction
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Wave propagation

Diffusion

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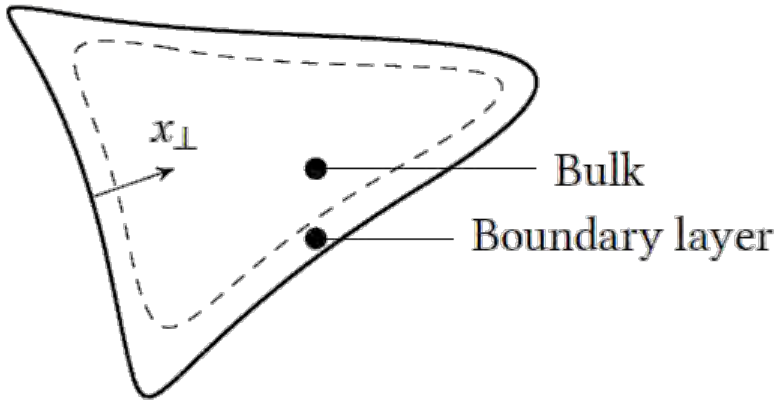

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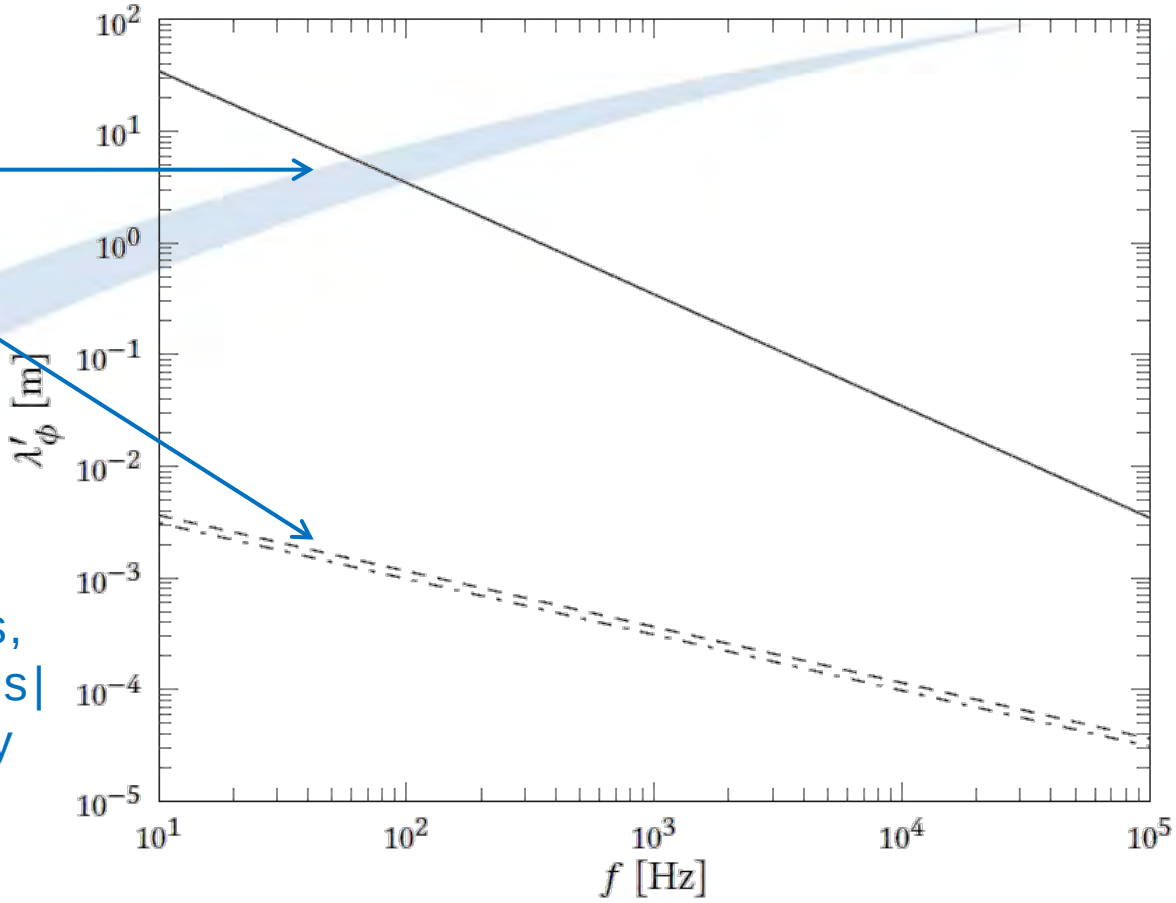

Length scales, |wave numbers| vs. frequency

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Linear time harmonic models:

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  - SLNS-model **> for any geometry, new**

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Reduced model have lower computational costs.

Use Of Comsol

- All models in this presentation and the accompanying paper are built in Comsol 3.5a using the PDE application mode.

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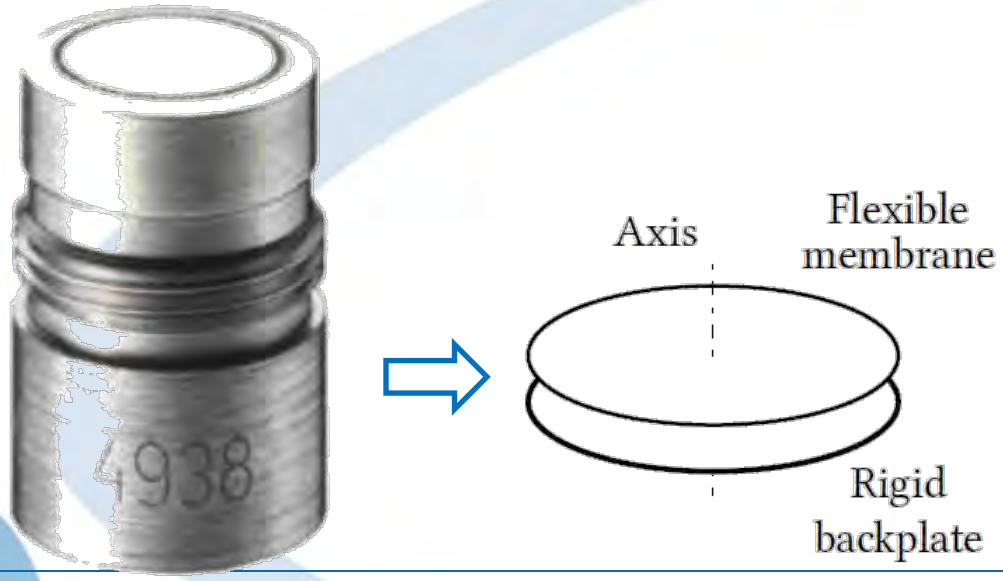
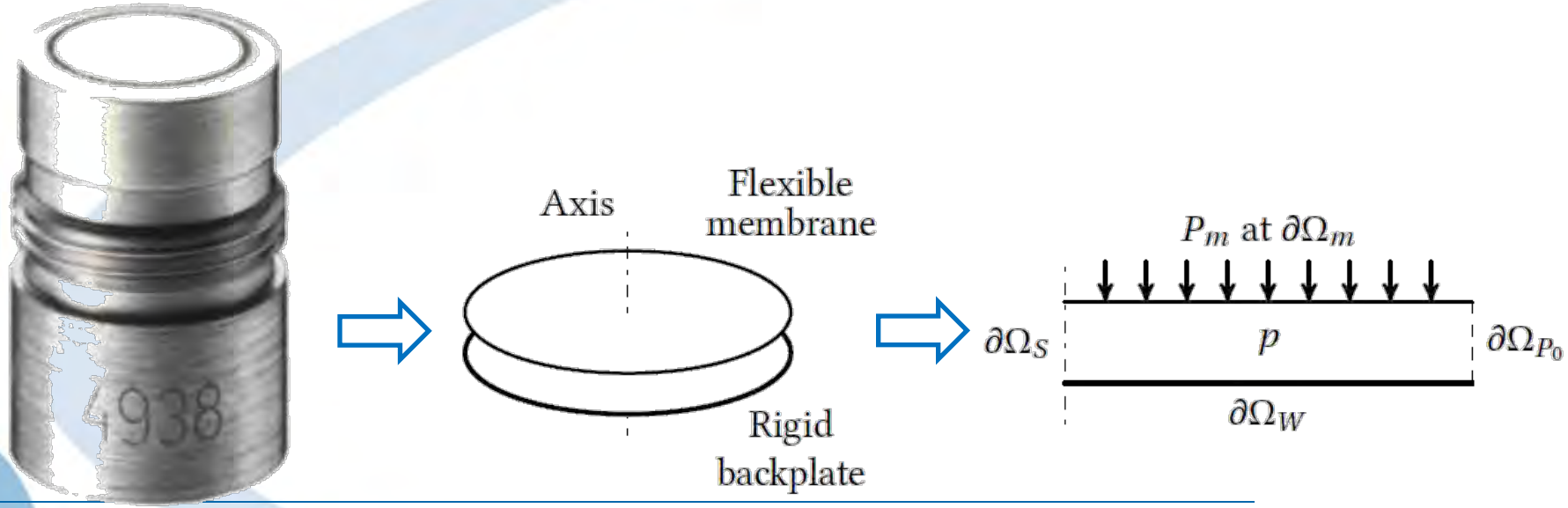


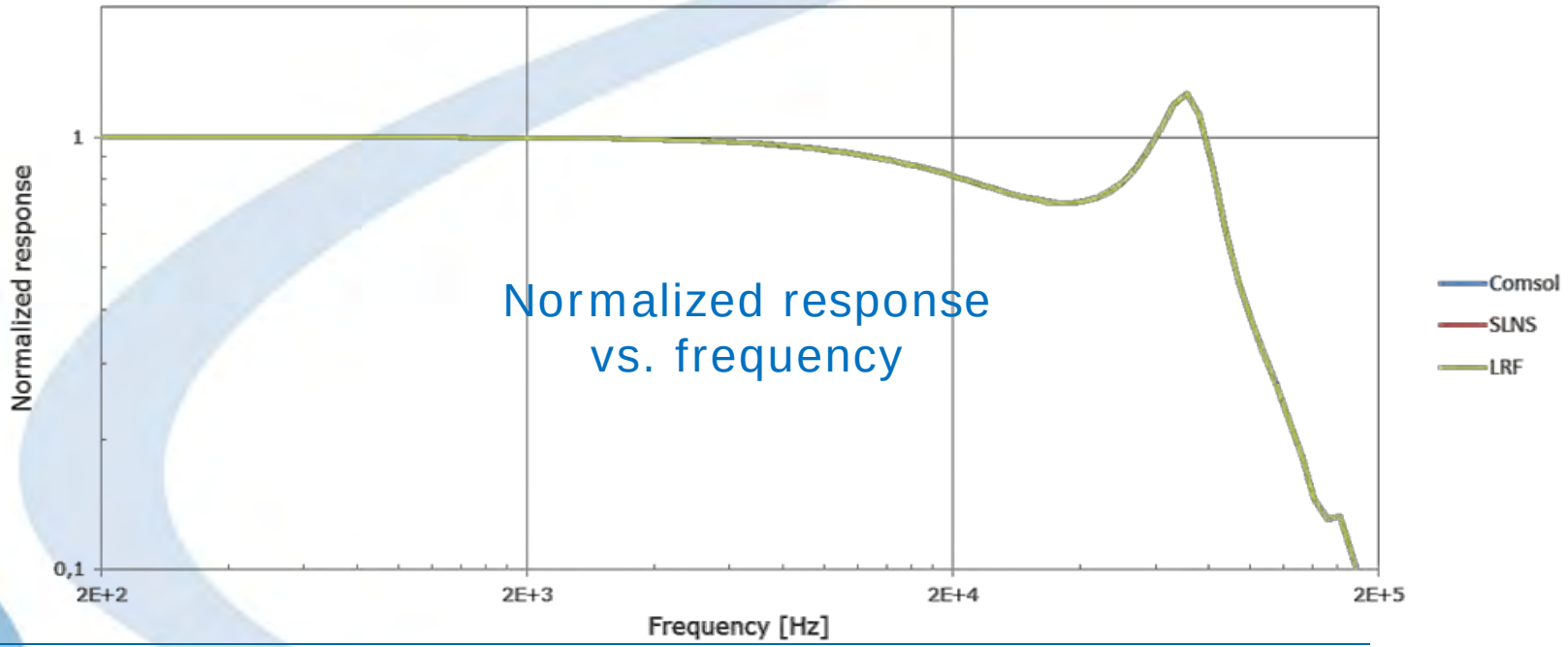
Application 1: Microphone

- A microphone contains fluid structure interaction.
  - The structure is a tensed membrane.
  - The fluid is the air layer below the membrane.
- The response is the mean membrane displacement caused by a uniform unit pressure.



Application 1: Microphone

- Comsol's model, the SLNS model and the LRF model predict the same response.
- The Bossart/Cremer model is inaccurate and not shown.



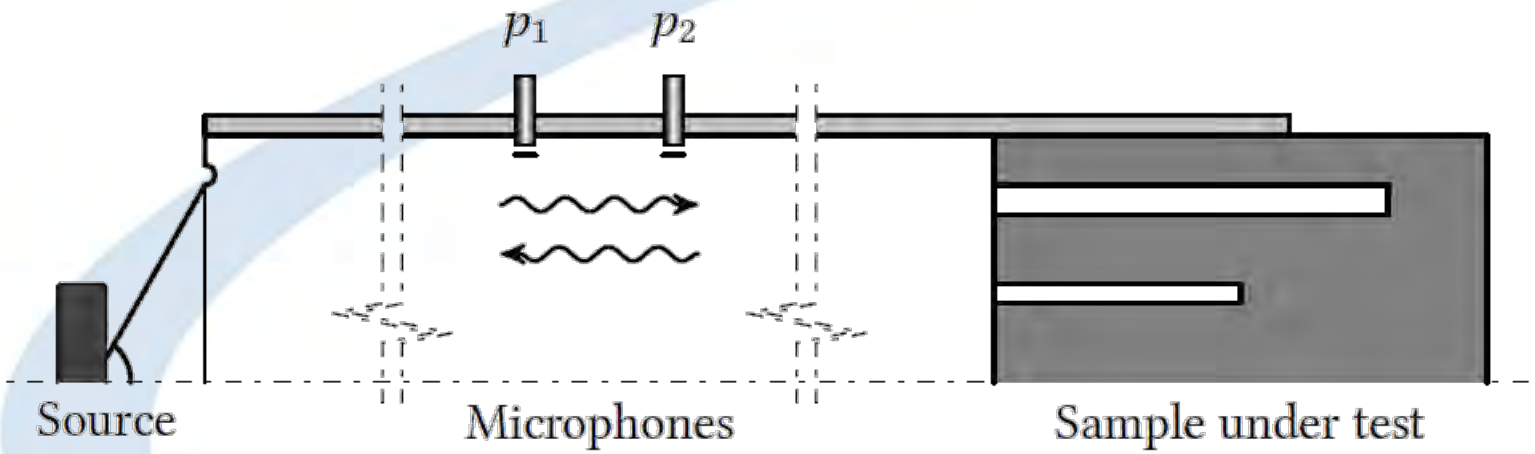
Application 1: Microphone

- The computational costs are given in the table, sorted from high to low.
- The SLNS model is more than a factor 2 faster than the full Comsol model.
- The LRF model is 60 times faster than the full Comsol model.

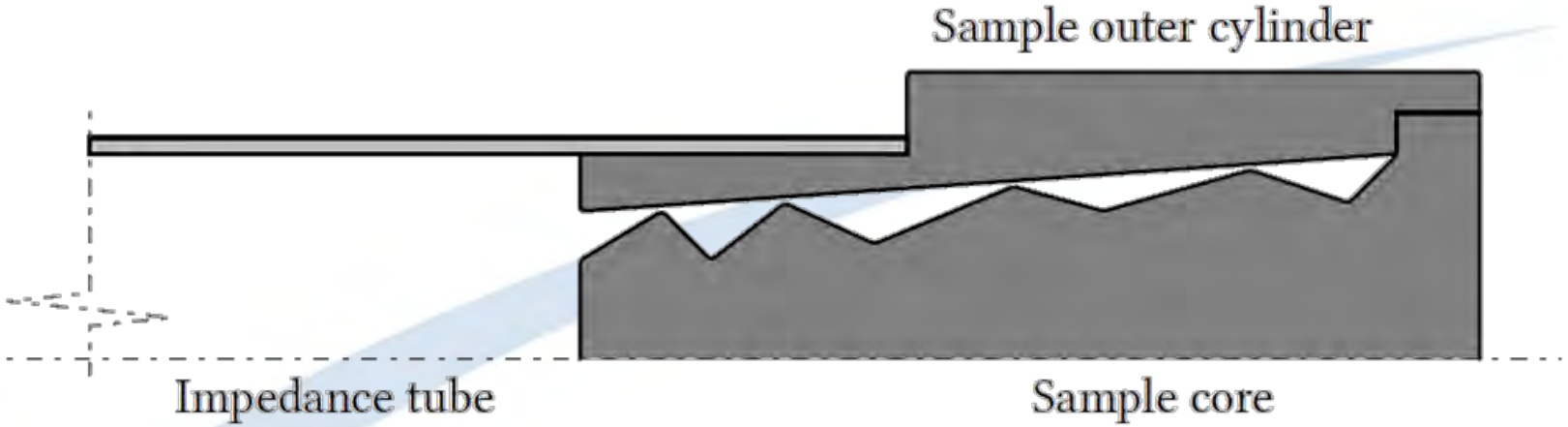
Model	time [s]	# of DOFs
Comsol	0.6	7440
SLNS	0.25	4422+2412
LRF	0.01	402

Application 2: Resonator

- Viscothermal effects can be used for sound absorbing resonators.
- Absorption can be measured with an impedance tube set-up.



Application 2: Resonator



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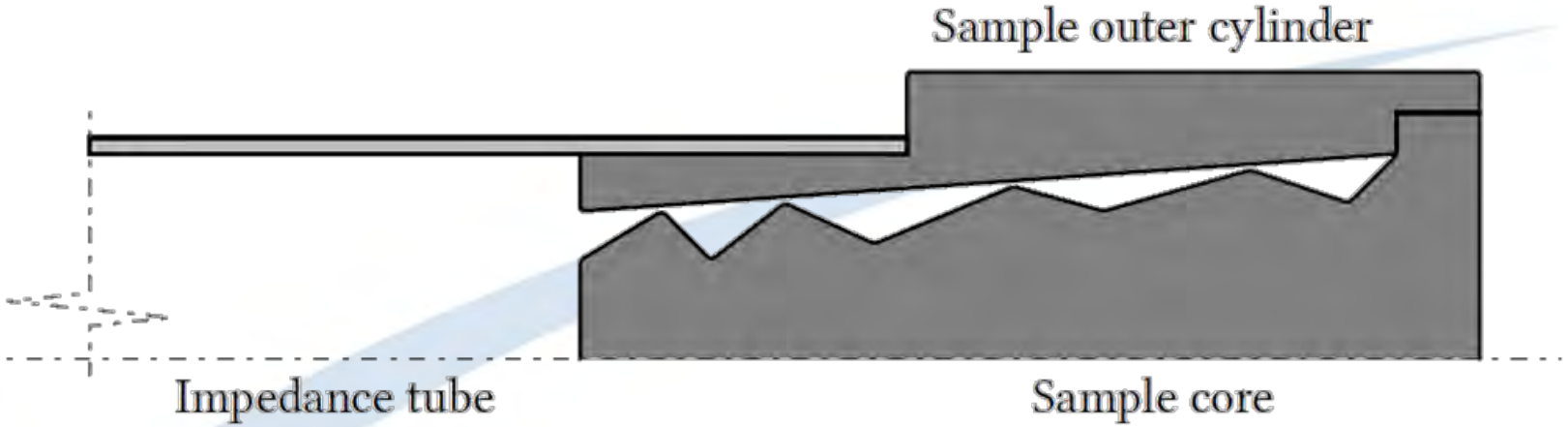
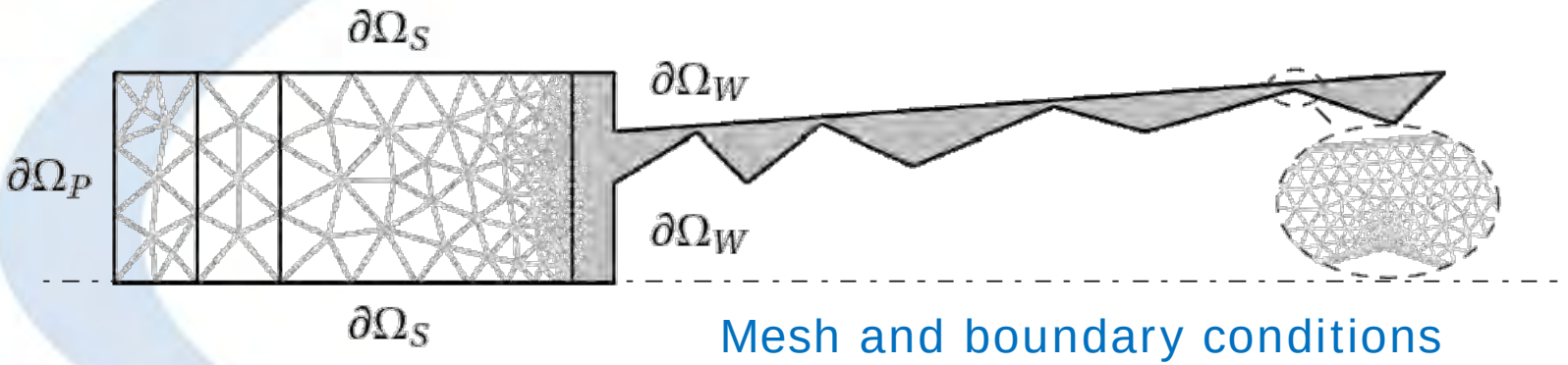
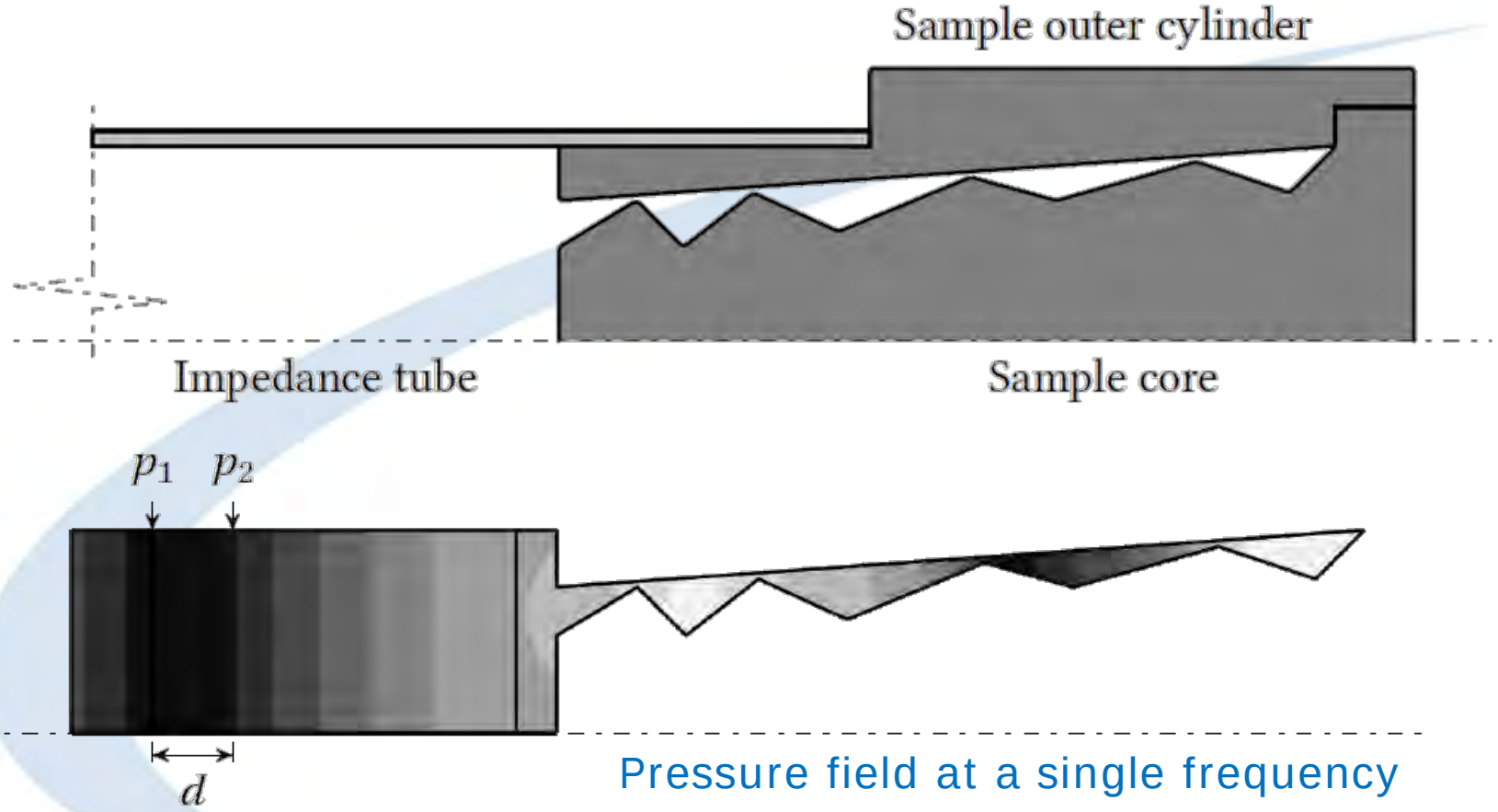




Mesh and boundary conditions

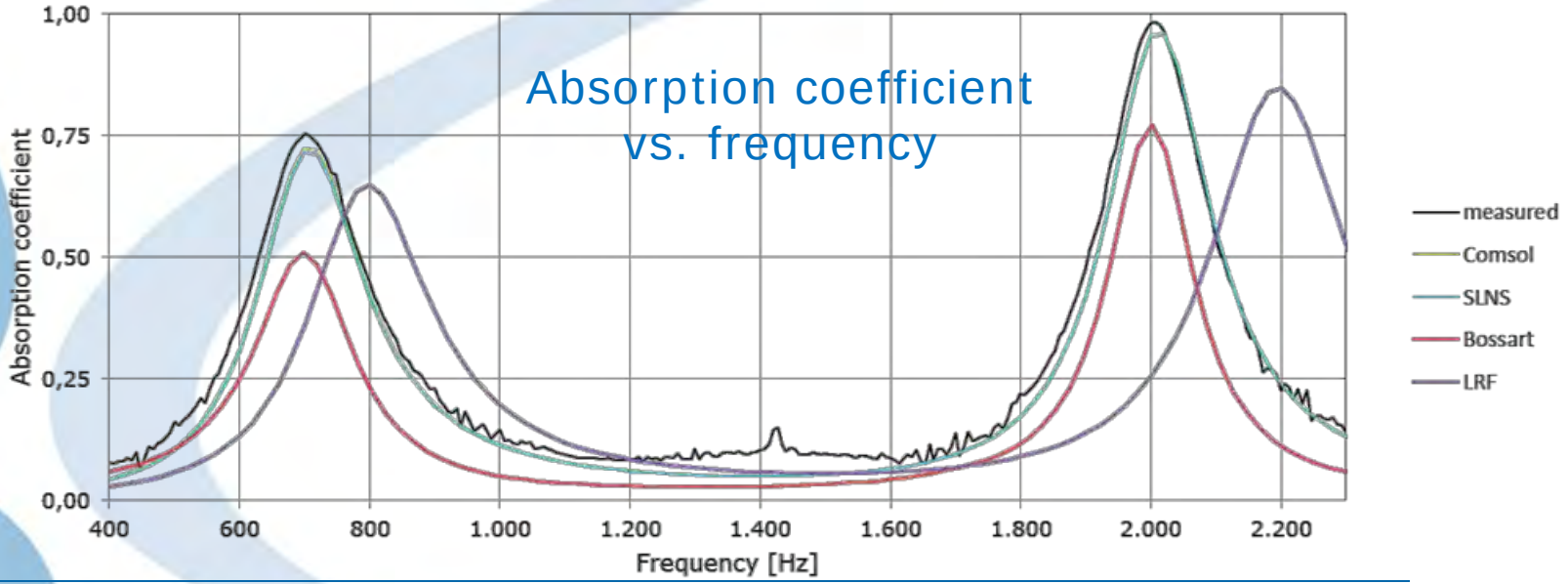
Application 2: Resonator



Pressure field at a single frequency

Application 2: Resonator

- Both Comsol's full model and the reduced SLNS model are accurate.
- Bossart/Cremer model does not predict enough damping.
- LRF model does not accurately predict the resonance frequencies.



Application 2: Resonator

- The computational costs are given in the table, sorted from high to low.
- The SLNS model is more than a factor 6 faster than the full Comsol model.

Model	time [s]	# of DOFs
Comsol	44	$584 \cdot 10^3$
SLNS	6.8	$(110+55) \cdot 10^3$
Bossart	0.7	$2x11 \cdot 10^3$
LRF	0.2	254

Remarks and Conclusions

- The new SLNS model is accurate and faster than the full model used in Comsol.
- Larger differences in computational costs are observed in 3D models and the SLNS model can still be made faster.
- The LRF model and the Bossart/Cremer are even faster than the SLNS model and are still applicable to many problems.
- The three reduced models resemble normal acoustics, while the full model resembles the Navier Stokes equations.
- COMSOL has made viscothermal acoustic modeling user friendly by providing the thermoacoustics interface.
  Hopefully, COMSOL will further pursue this course and consider the inclusion of more efficient models in future releases of the thermoacoustics interface.

Questions?