Middle-ear mechanics and sound localization in the lizard: a finite-element approach

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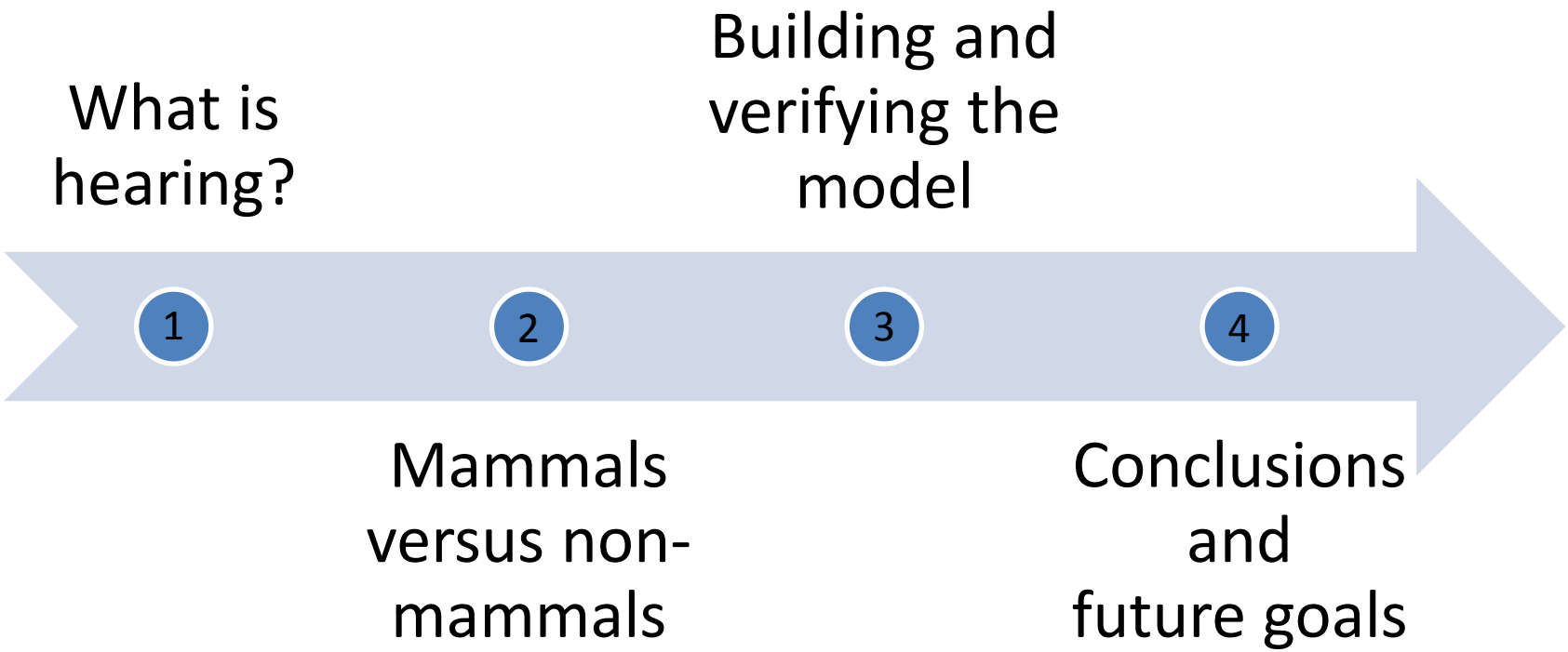
4th international workshop on
VALIDATION OF COMPUTATIONAL
MECHANICS MODELS

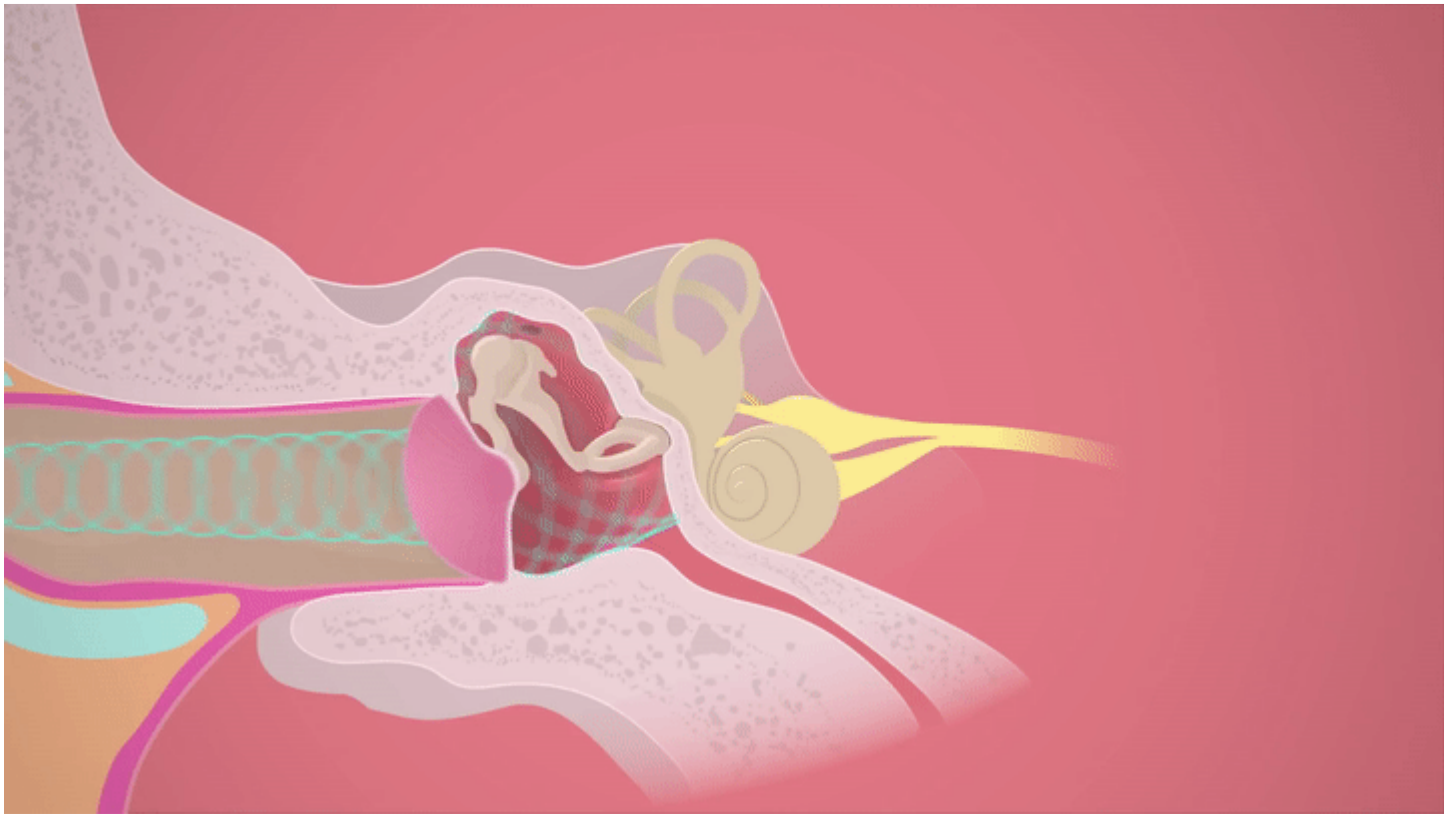
OUTLINE


What is hearing?
Building and verifying the model
1
2
3
4
Mammals versus non-mammals
Conclusions and future goals

WHAT IS HEARING?

- Sound detection

- Sound localization



Source: https://www.youtube.com/watch?v=Ie2j7GpC4JU

WHAT IS HEARING?

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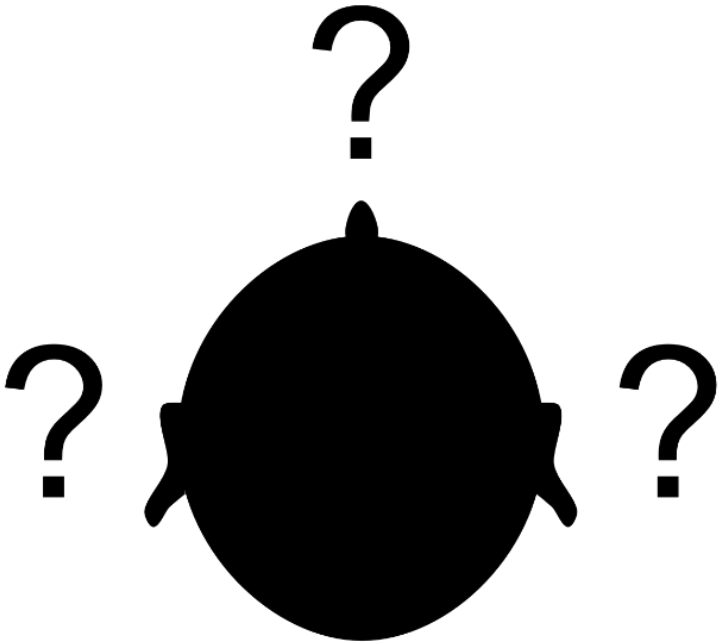

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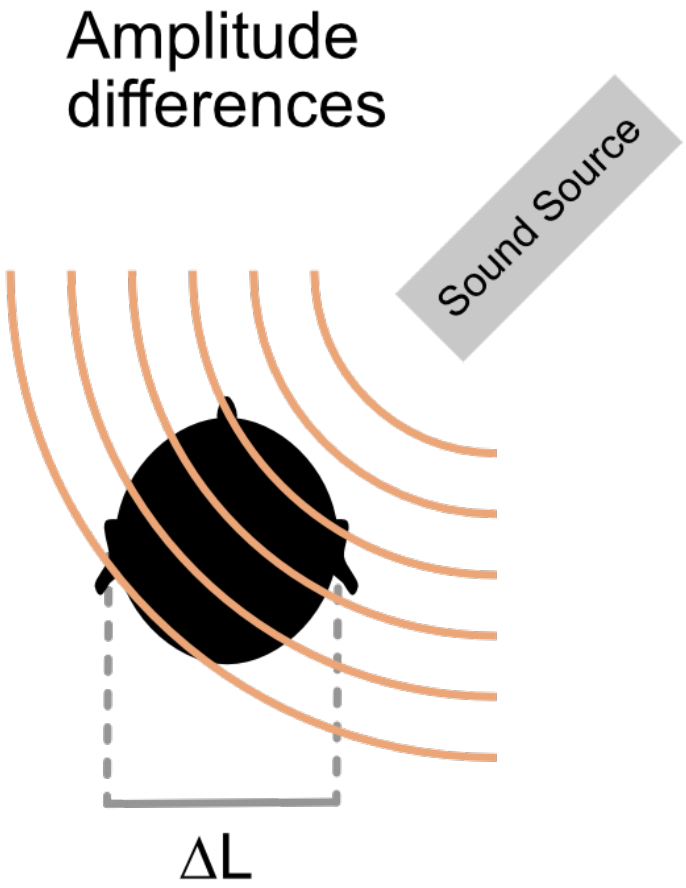
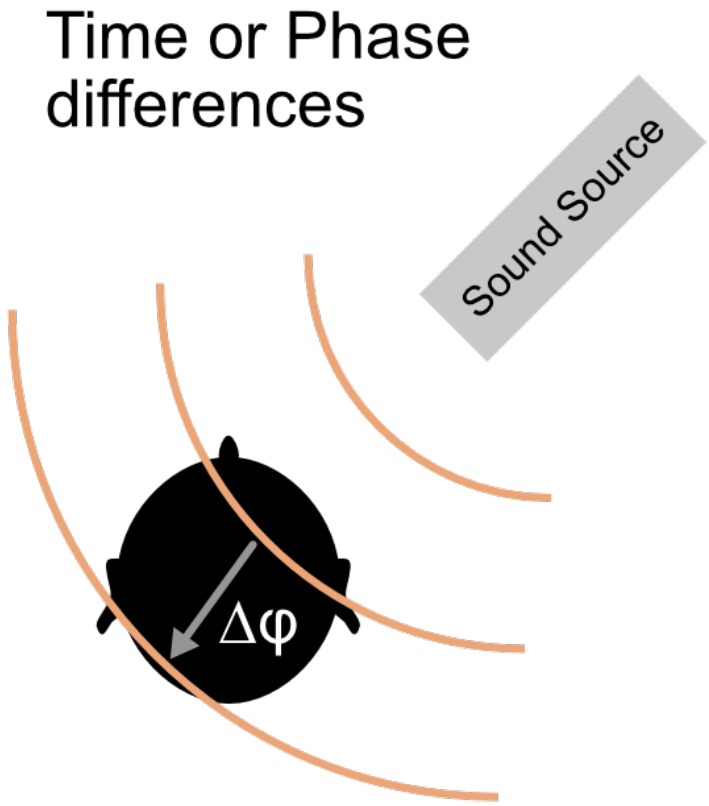




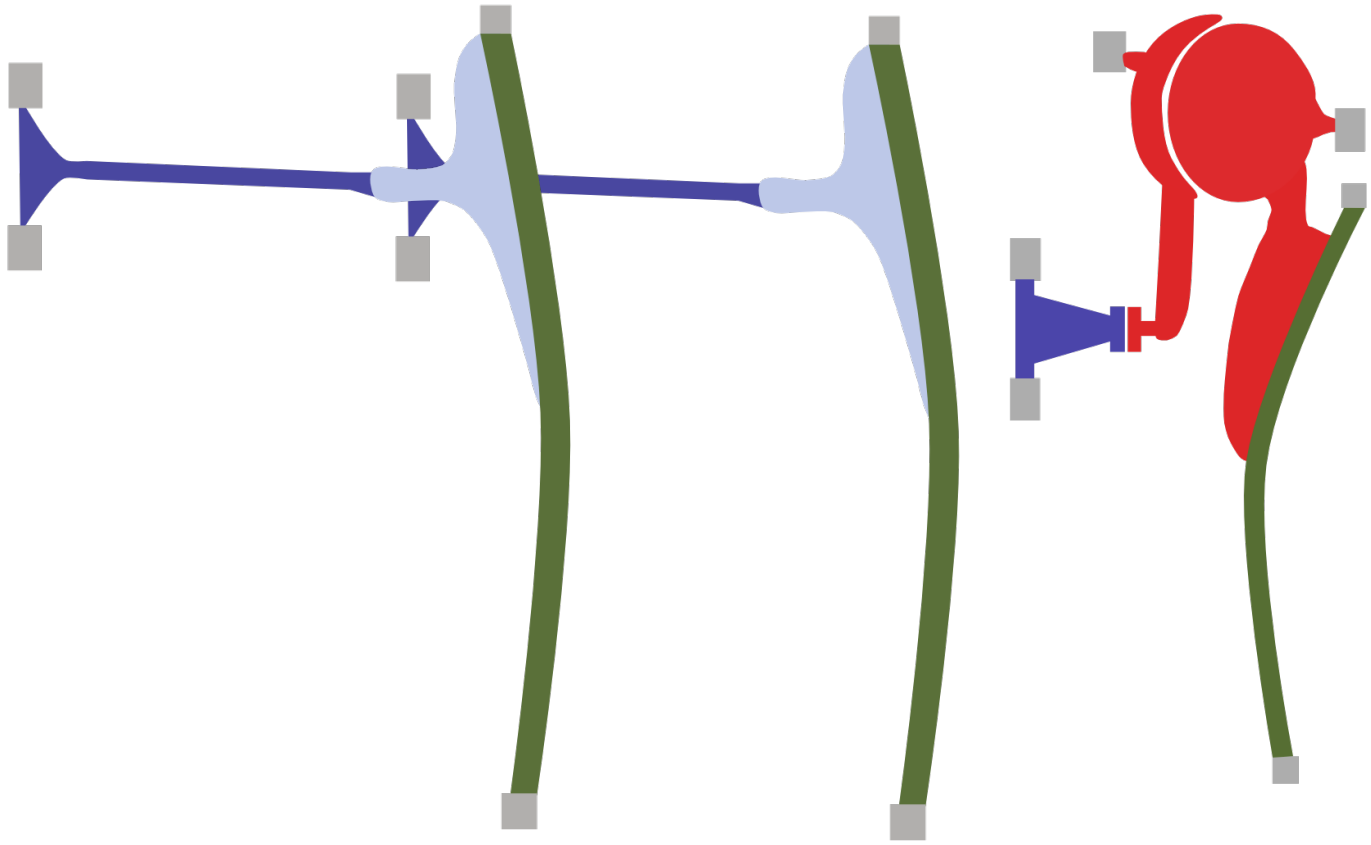
MAMMALS VS. NON-MAMMALS

- Does the previous explanation hold when investigating non-mammals?

- NO: Different anatomy, different approaches to hearing

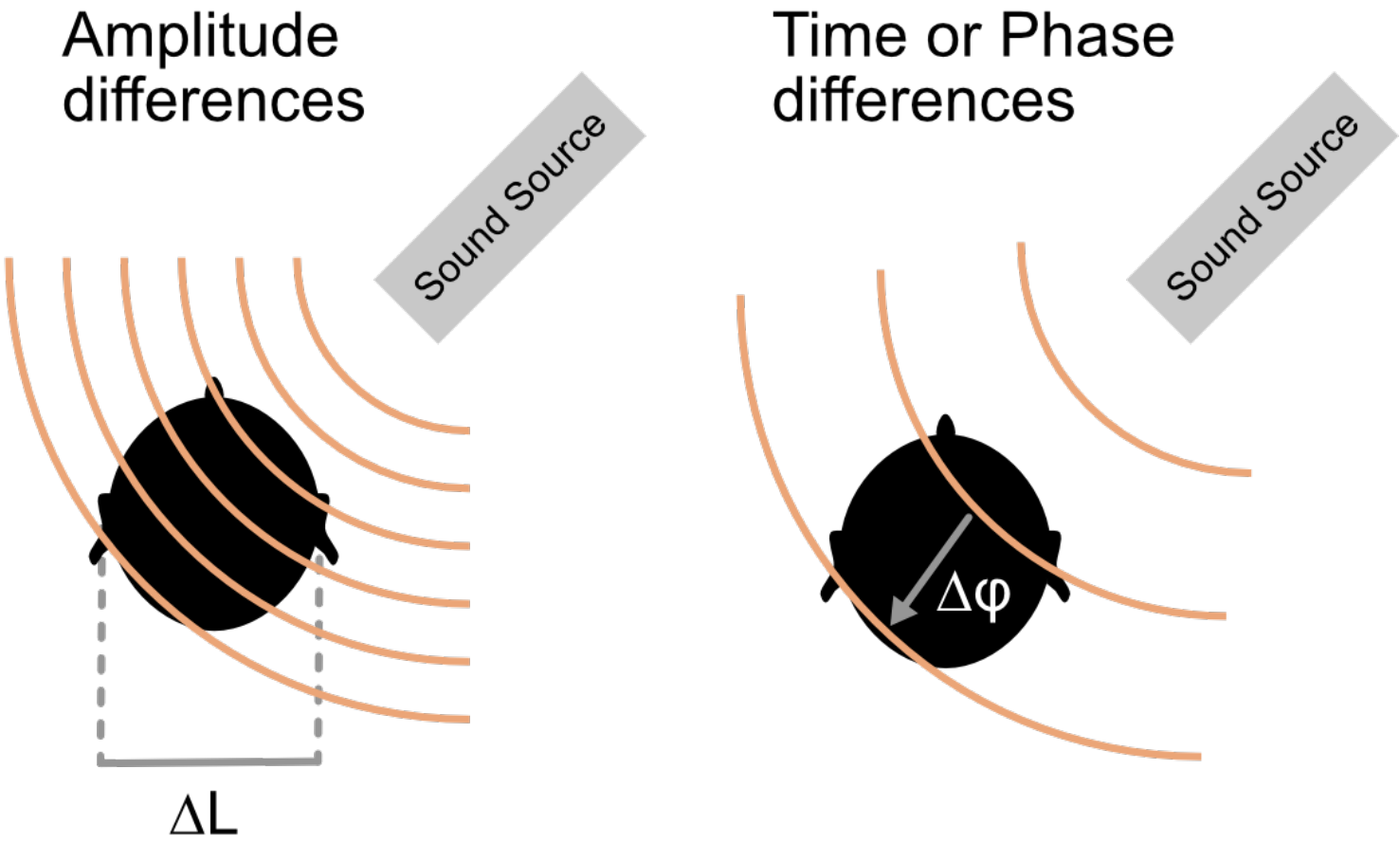
MAMMALS VS. NON-MAMMALS

- NO: Different anatomy, different approaches to hearing
- Higher flexibility means lower audible frequencies of sound



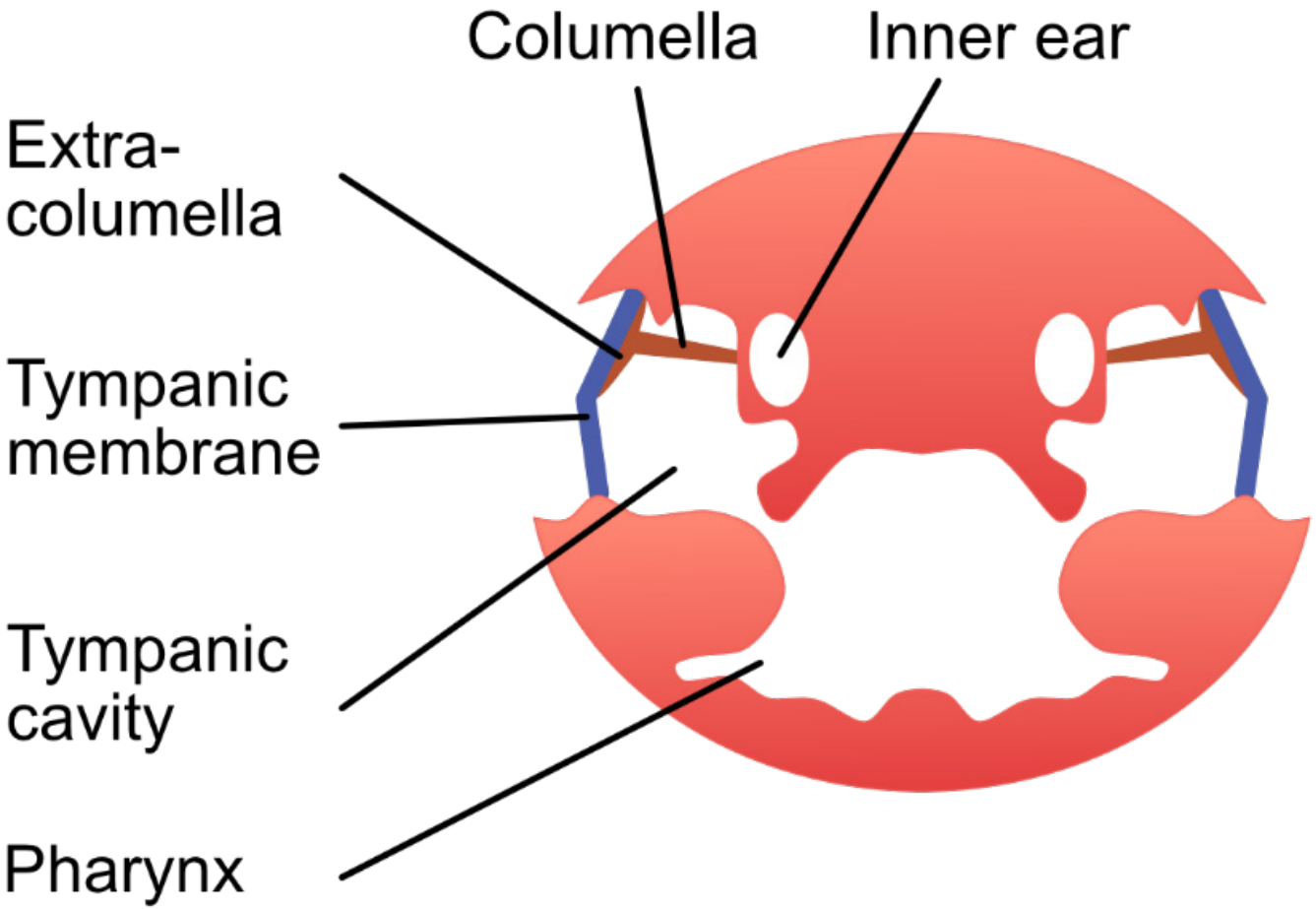
MAMMALS VS. NON-MAMMALS

- Higher flexibility means lower audible frequencies of sound
- No external localization cues are possible



MAMMALS VS. NON-MAMMALS

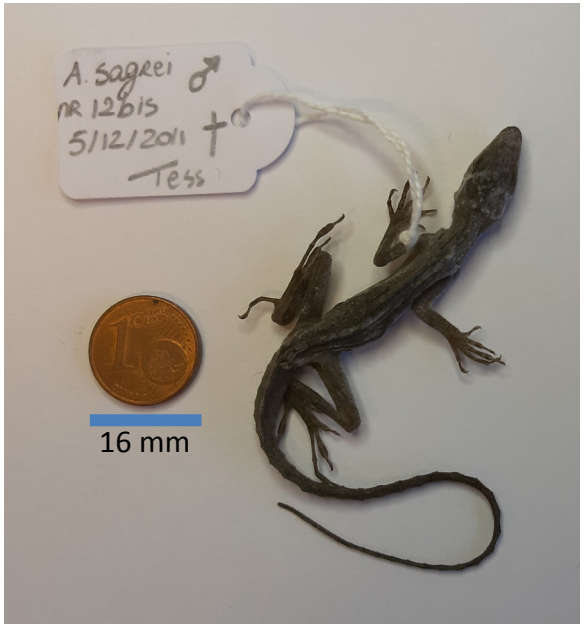
- Lizards use internally generated amplitude and timing differences

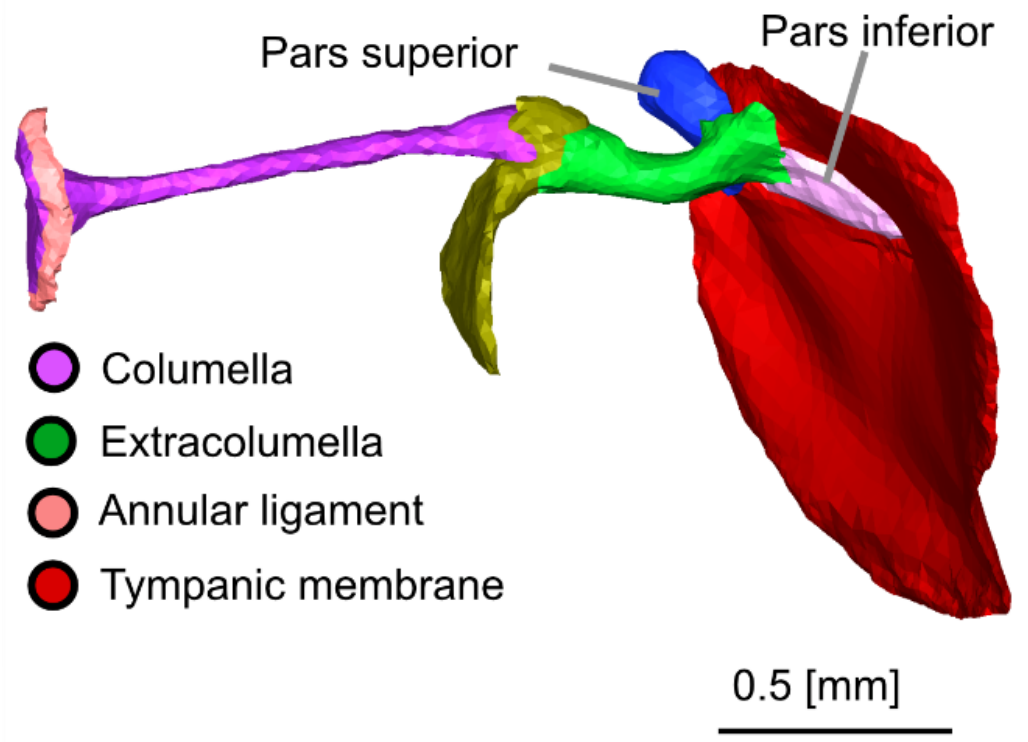


BUILDING THE MODEL

- The Brown anole (*Anolis sagrei*) is small lizard

- µCT scanning and subsequent image segmentation allows the creation of an accurate mesh for finite-element modelling





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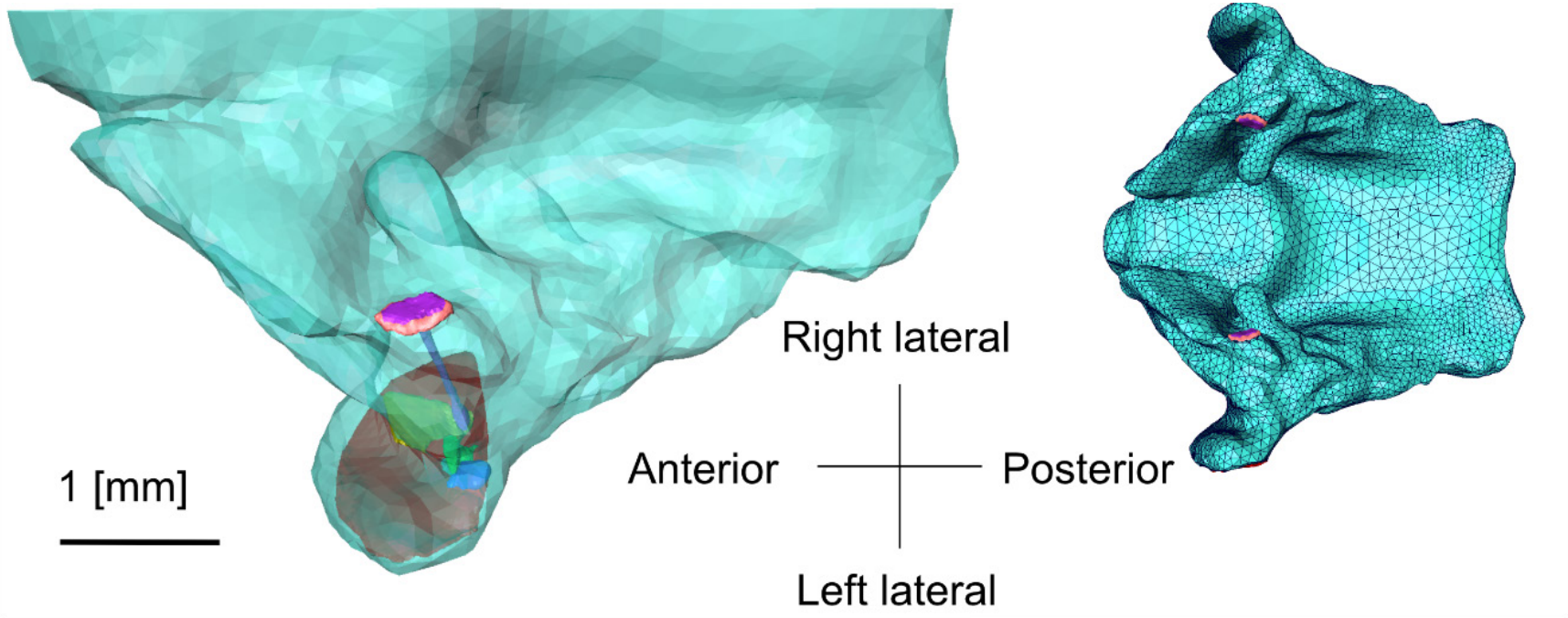
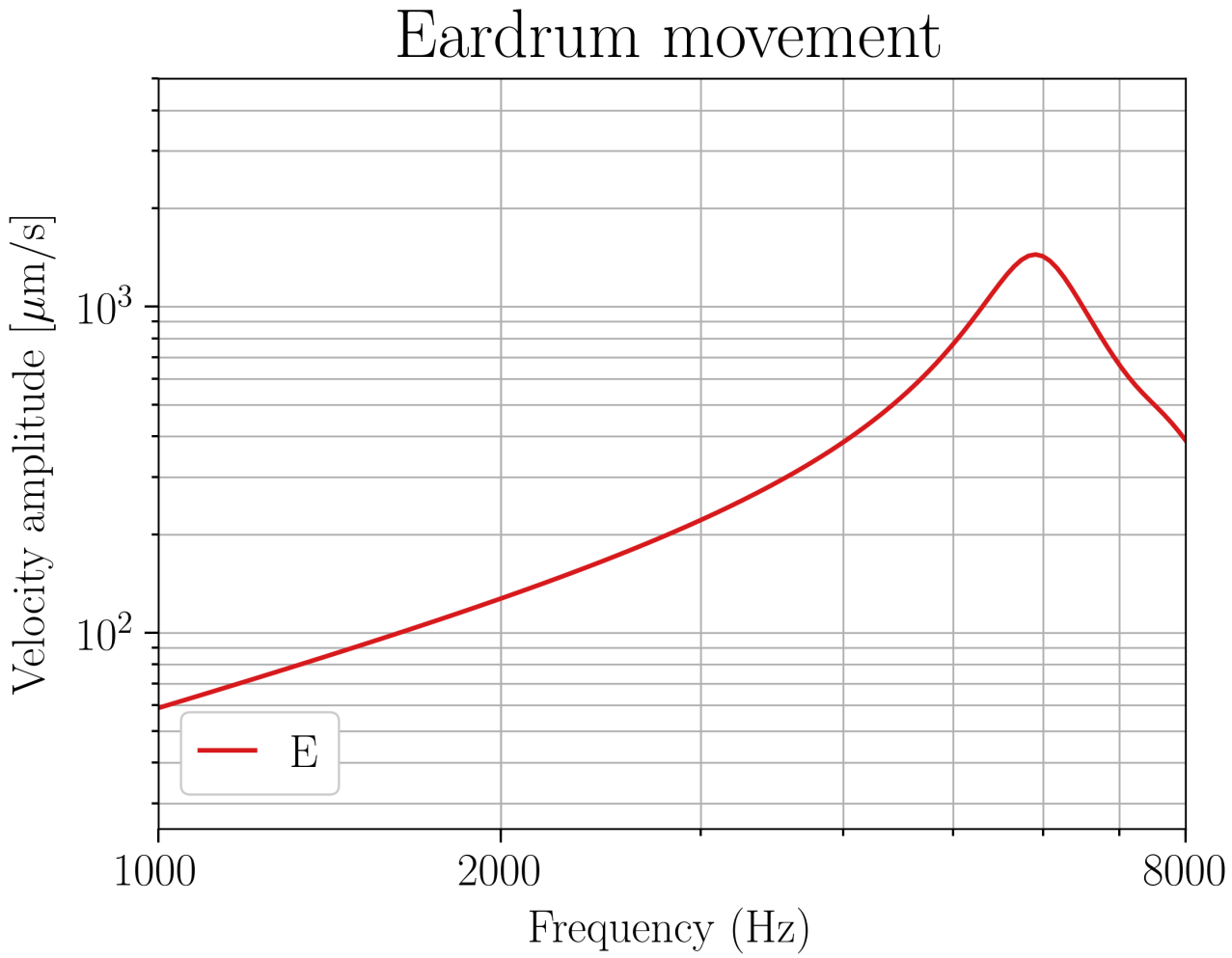


- A larger amount of flexibility should be observed when compared to mammals
- The eardrums should have a high amount of internal coupling

FLEXIBILITY OF THE LIZARD MIDDLE EAR

- The estimated resonance frequency from literature[2] is 3.7 kHz



2) Christensen-Dalsgaard, J., Manley, G.A., 2008. Acoustical Coupling of Lizard Eardrums. JARO 9, 407–416

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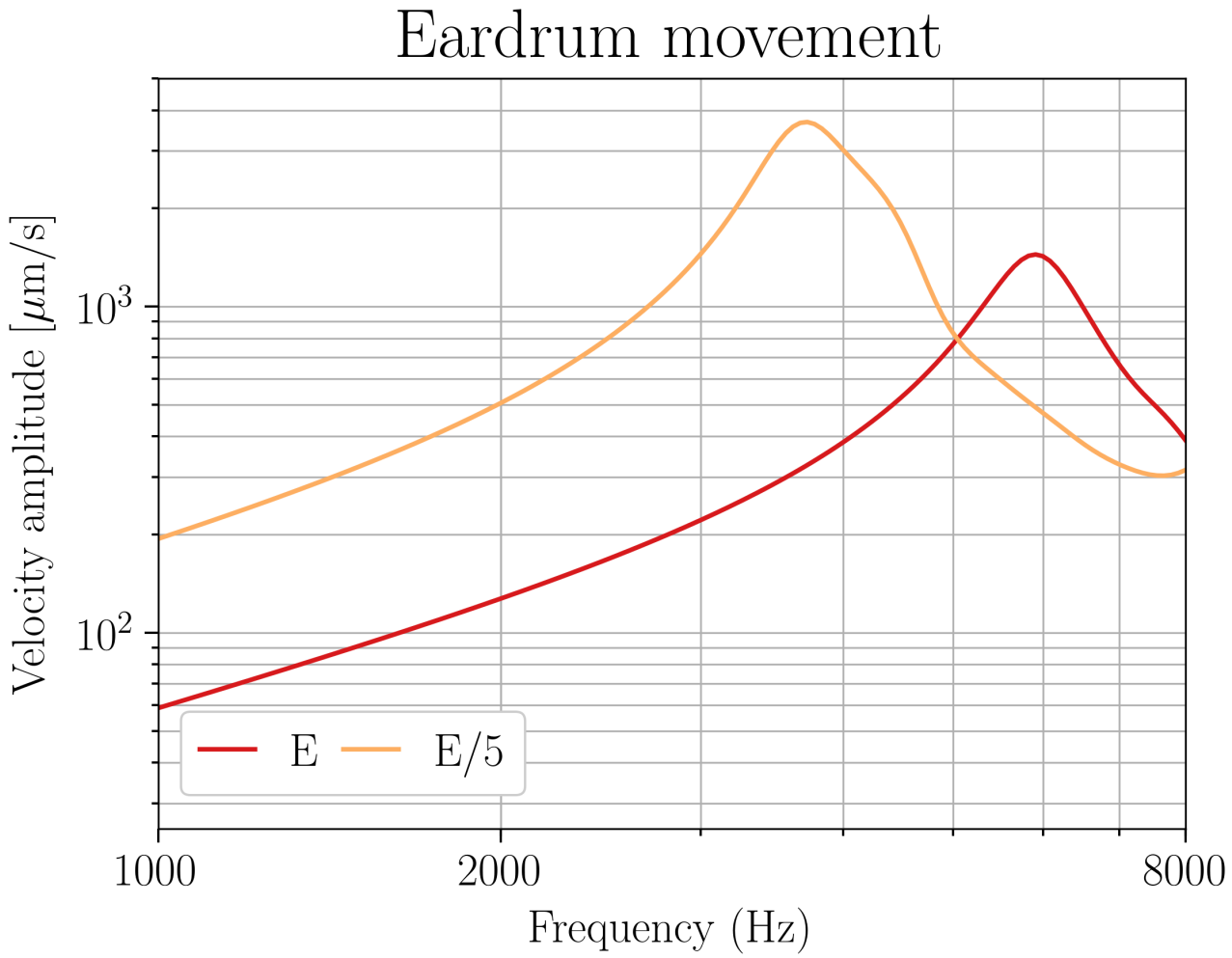

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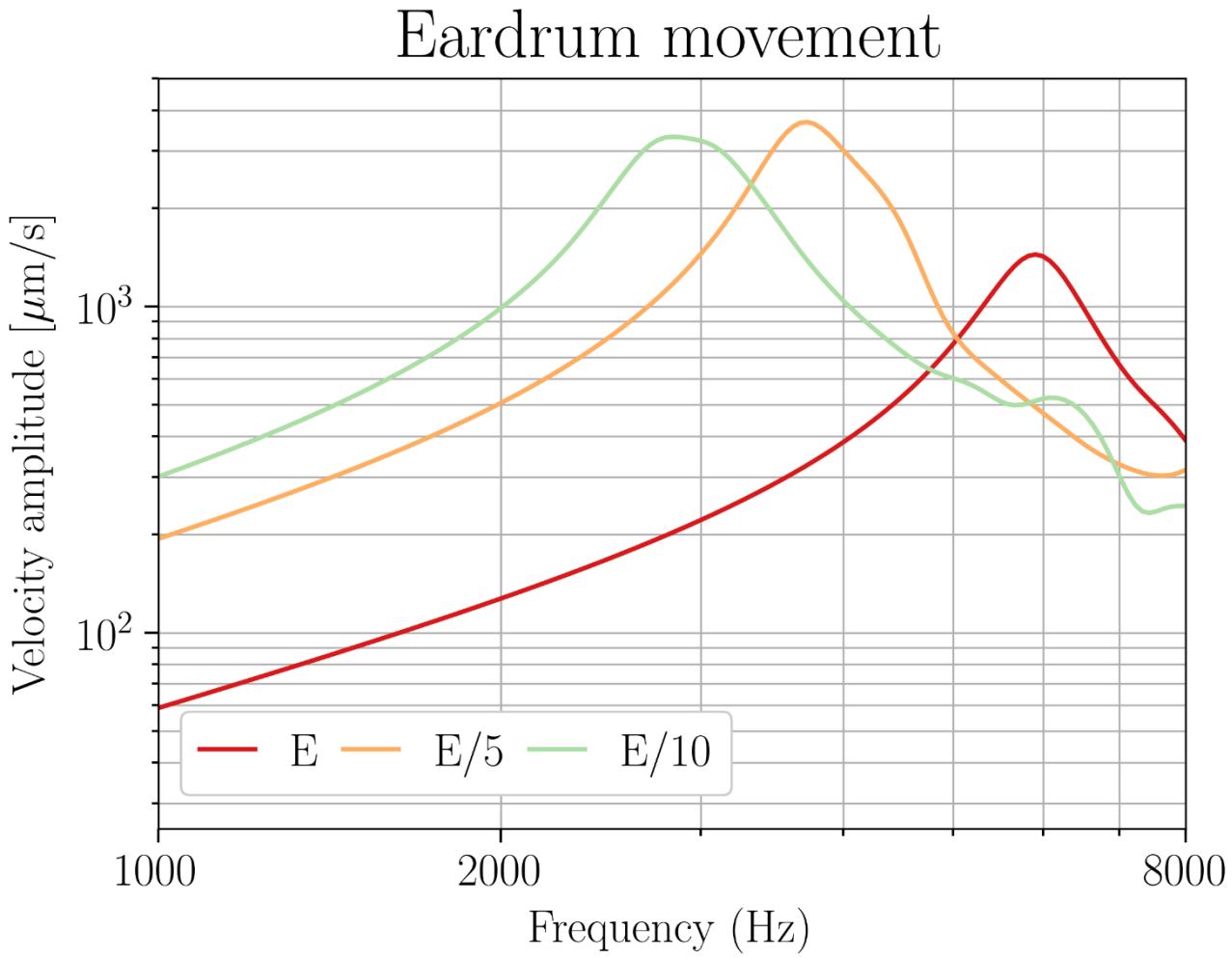

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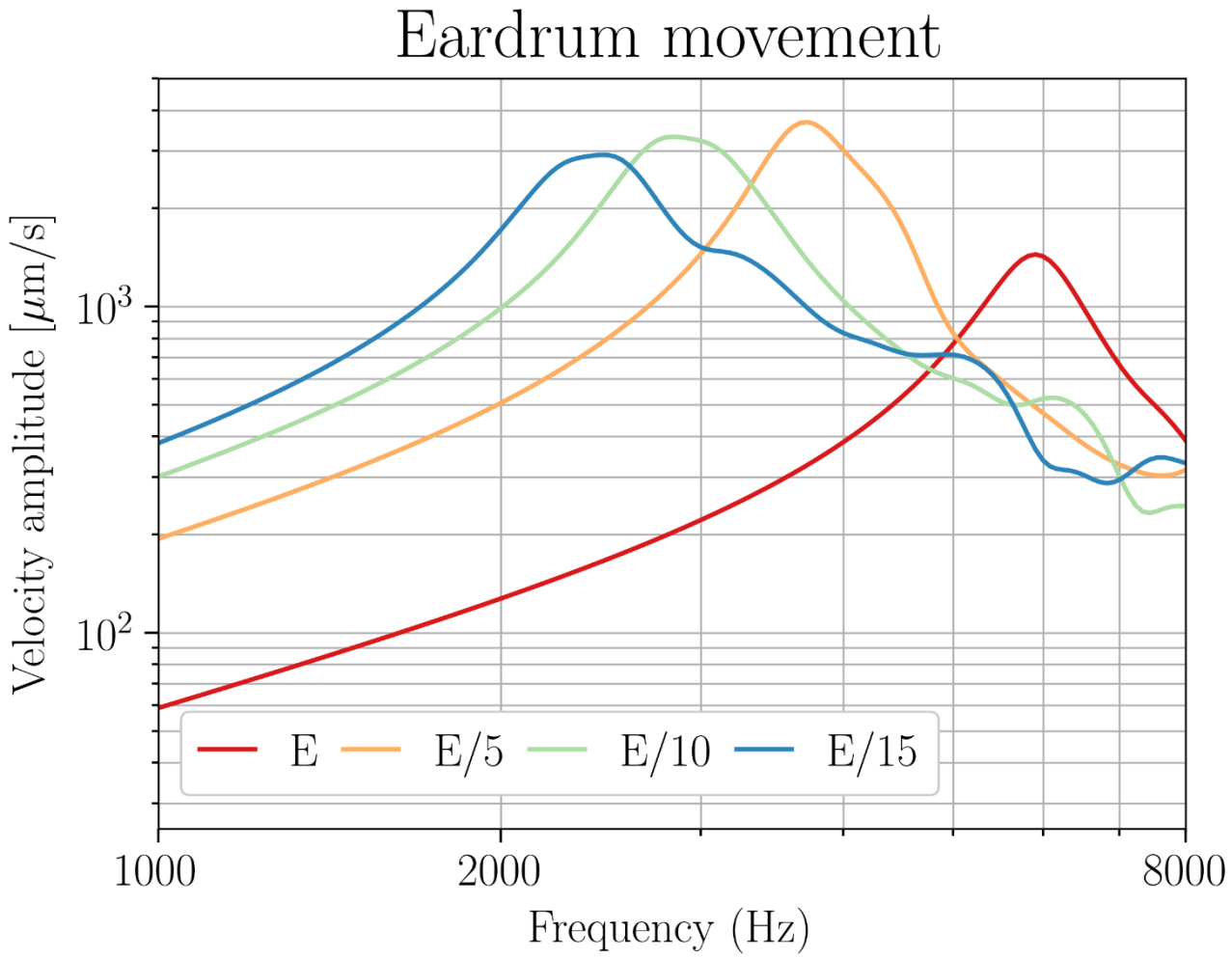

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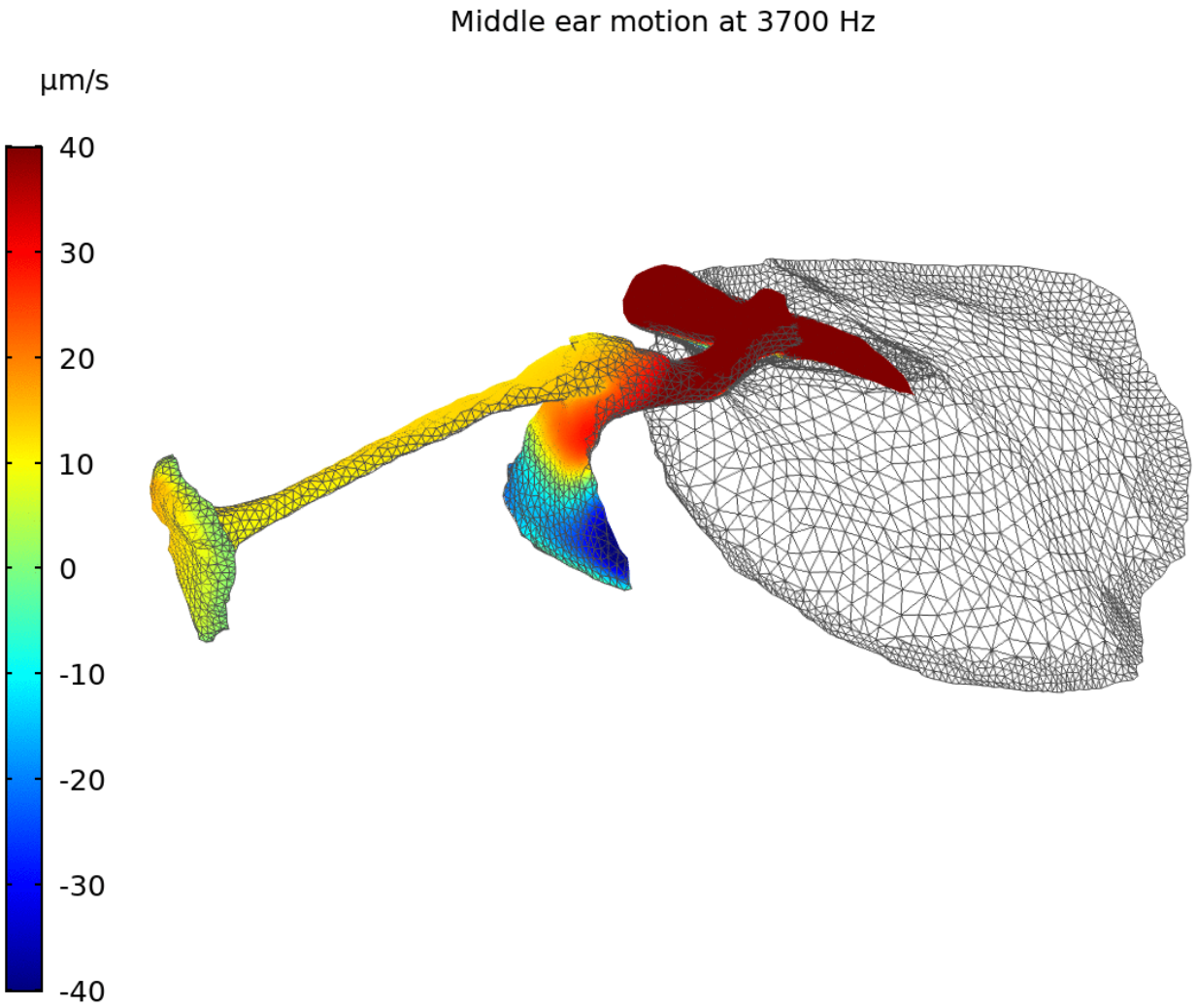
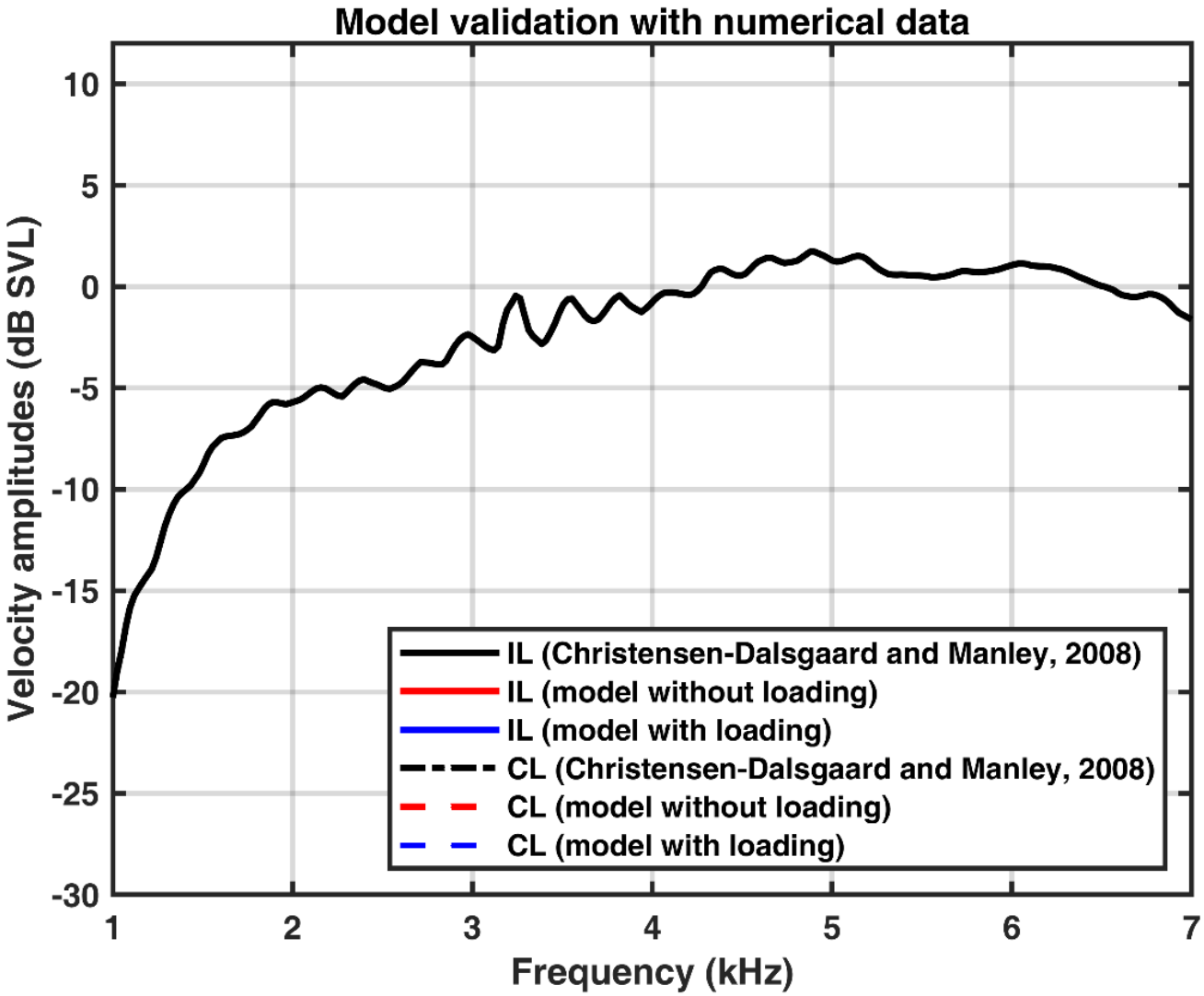
3D MOTION OF THE MIDDLE EAR



VALIDATION WITH EXPERIMENTAL DATA



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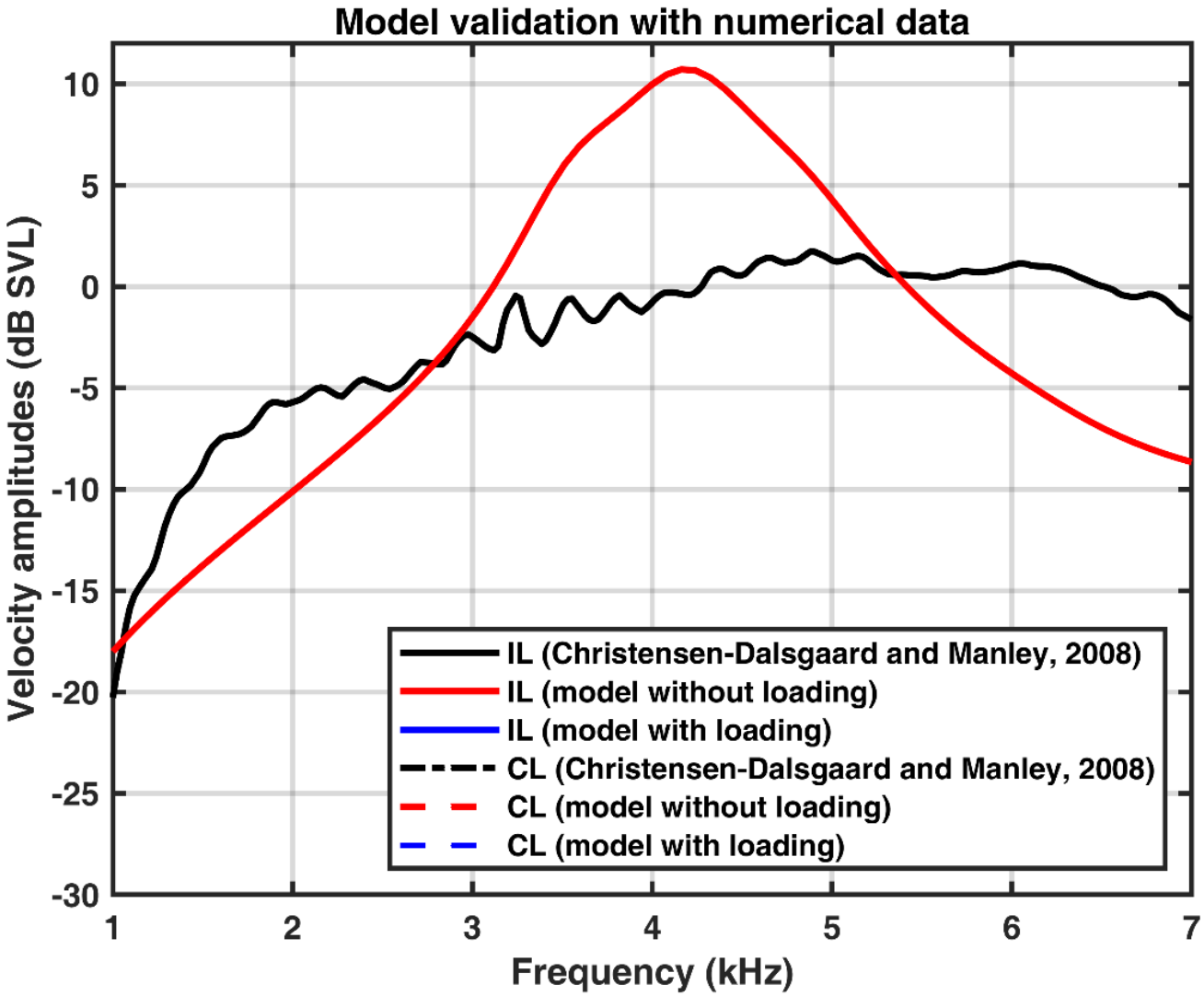

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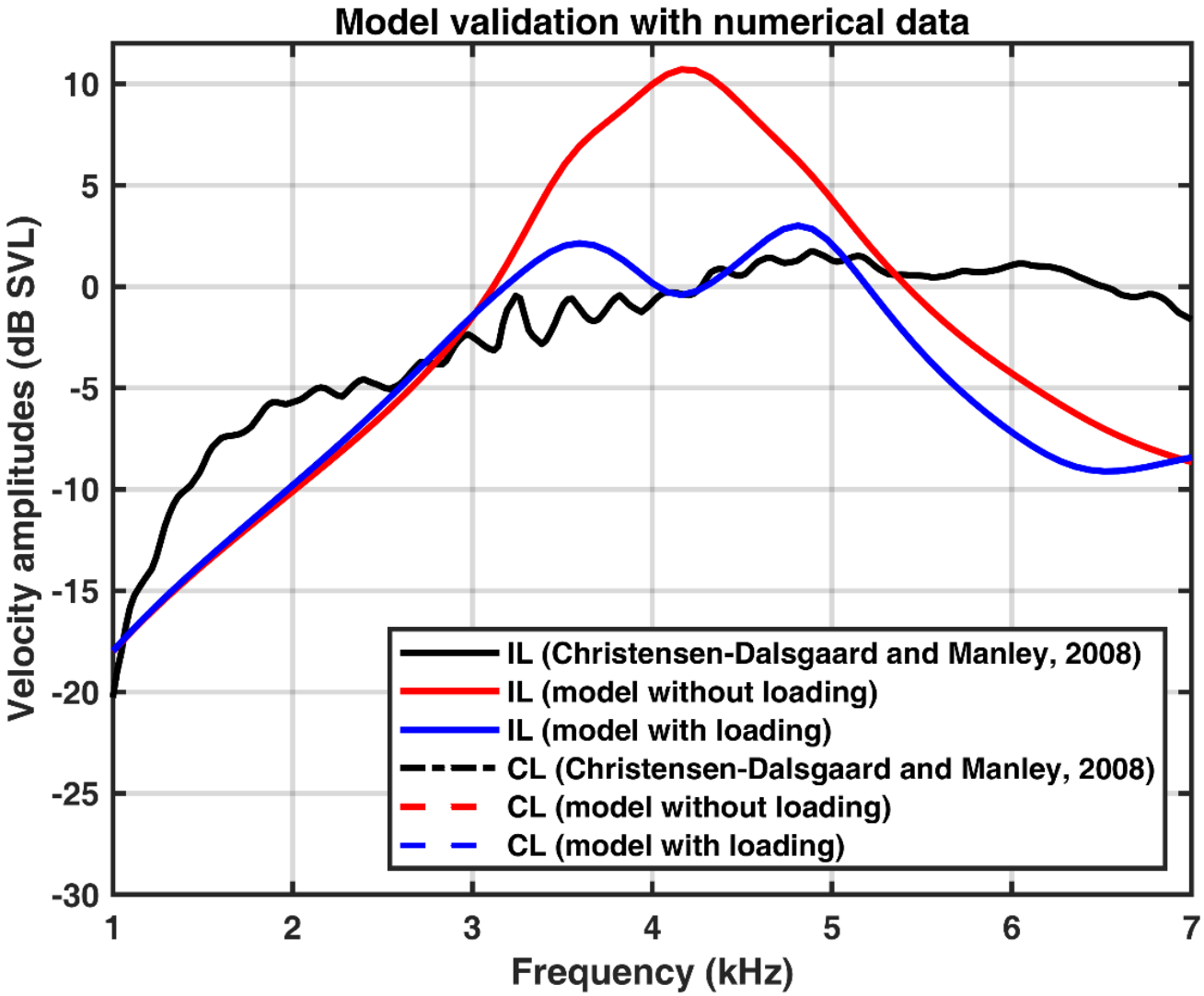

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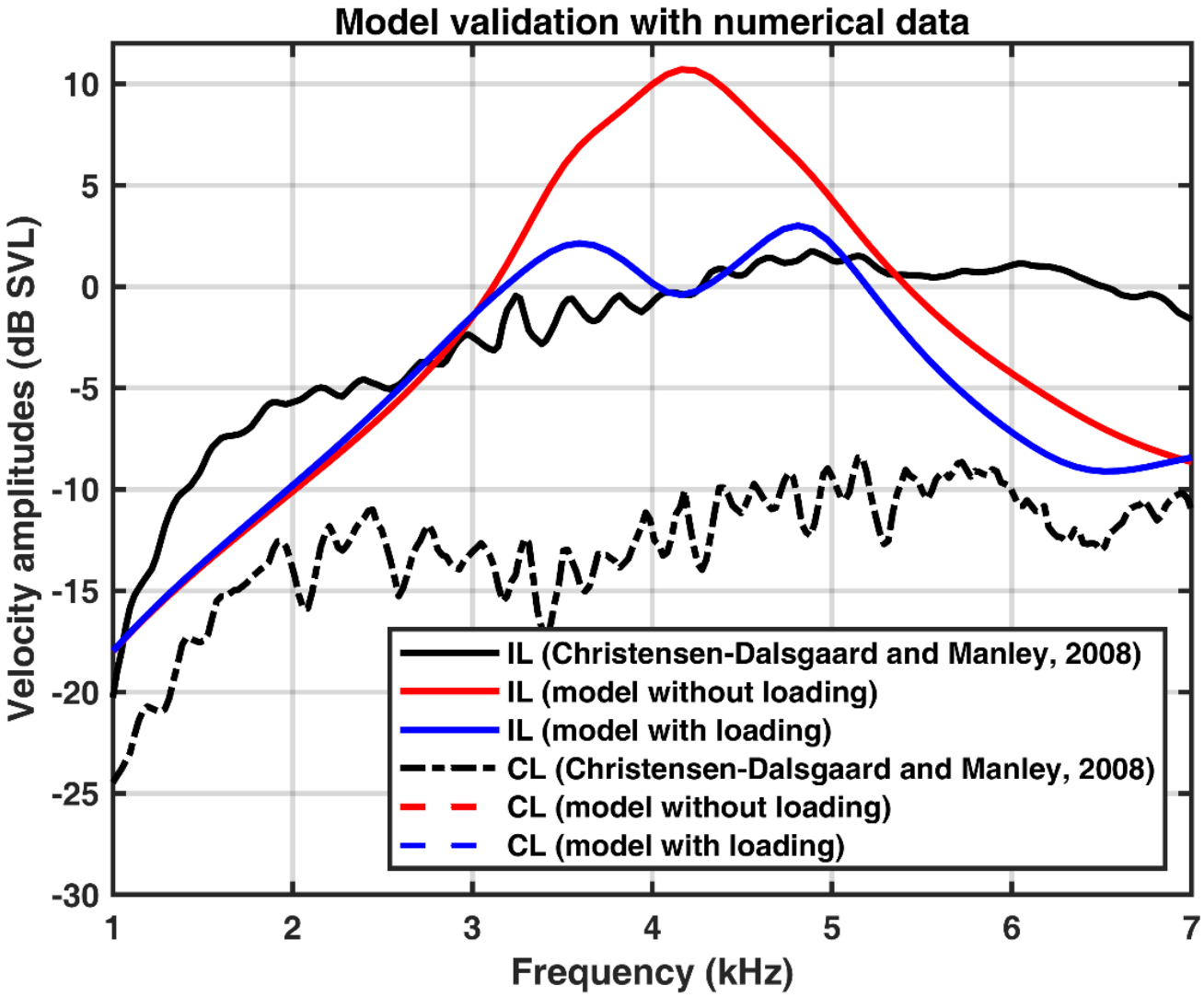

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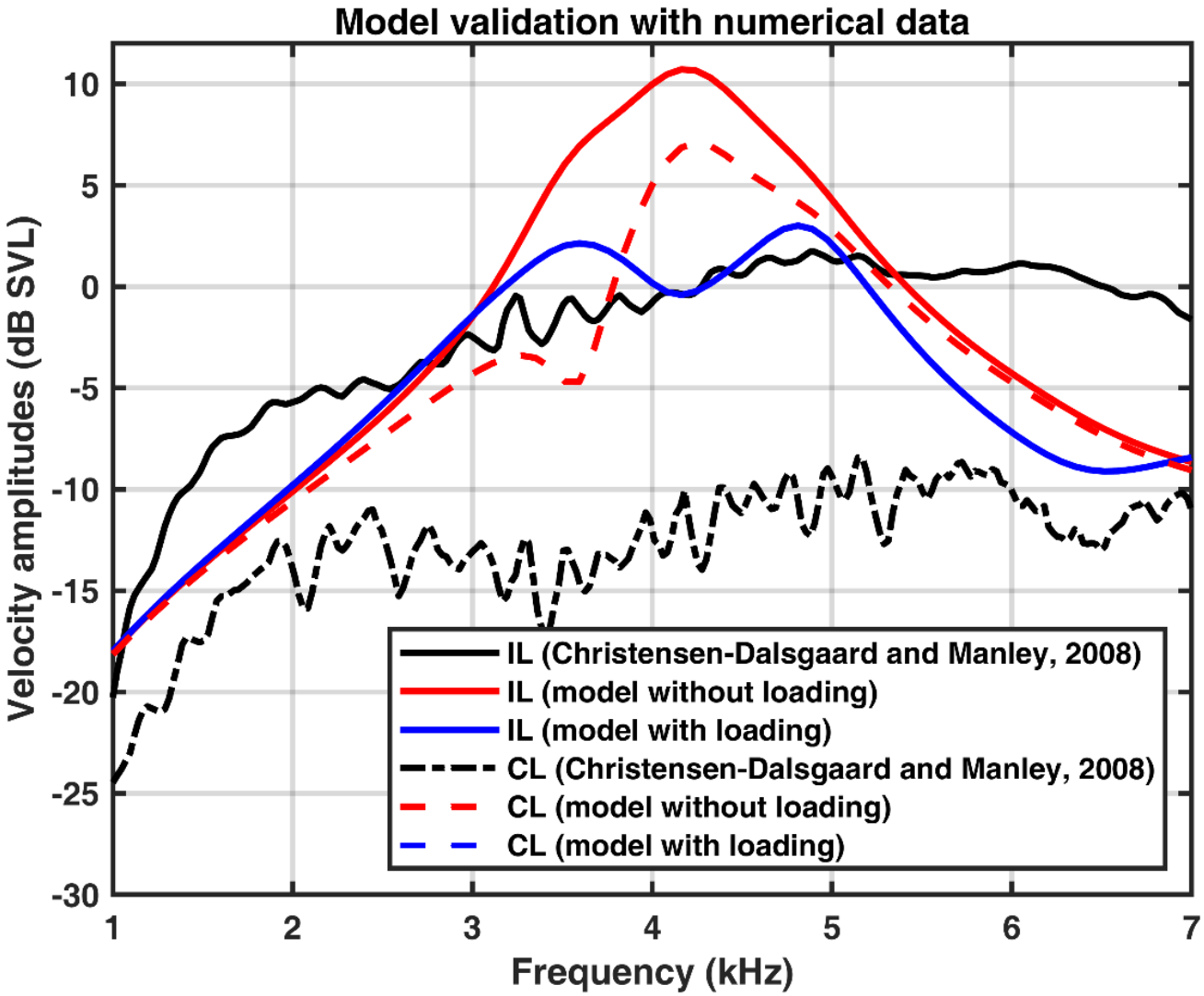

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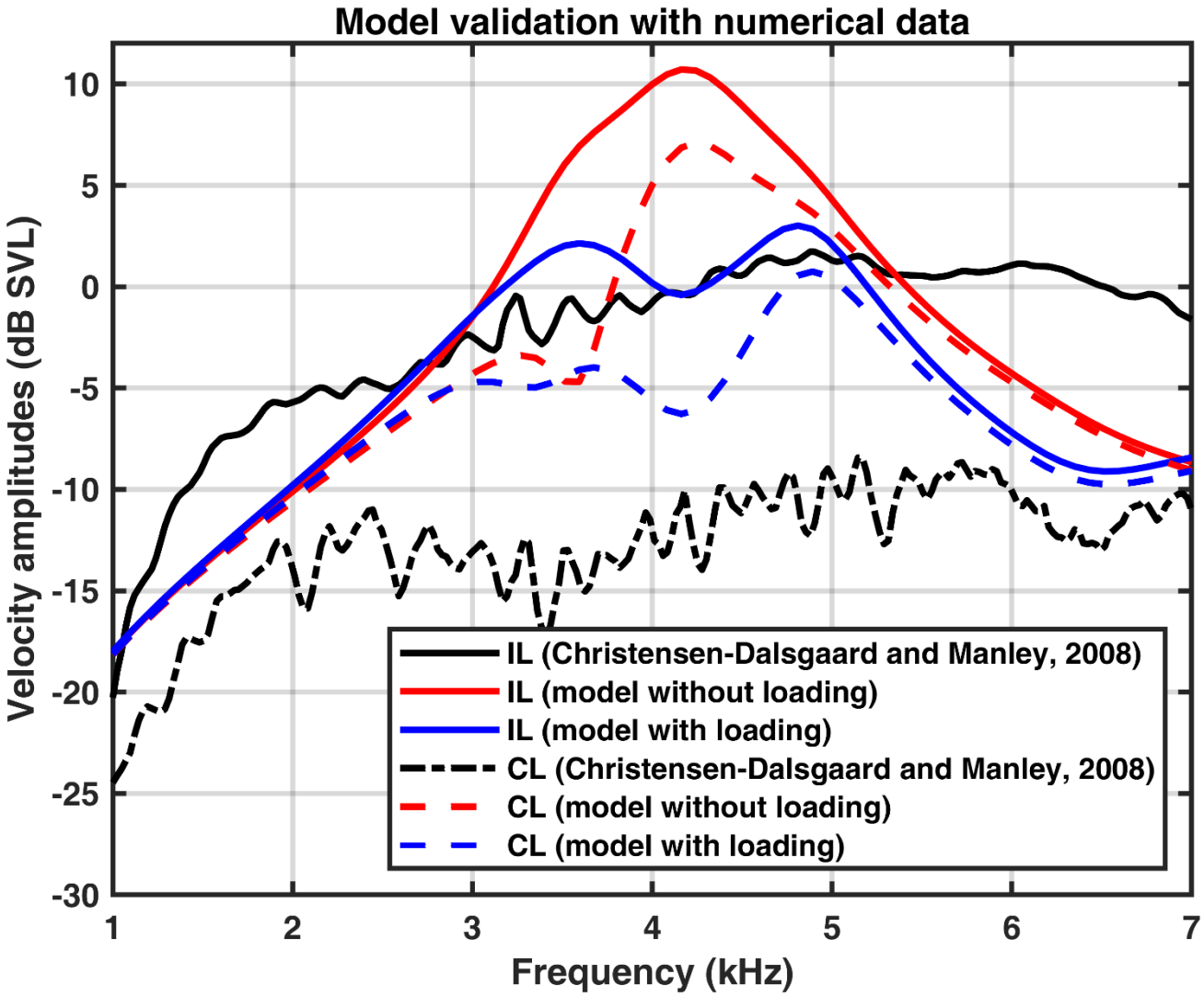

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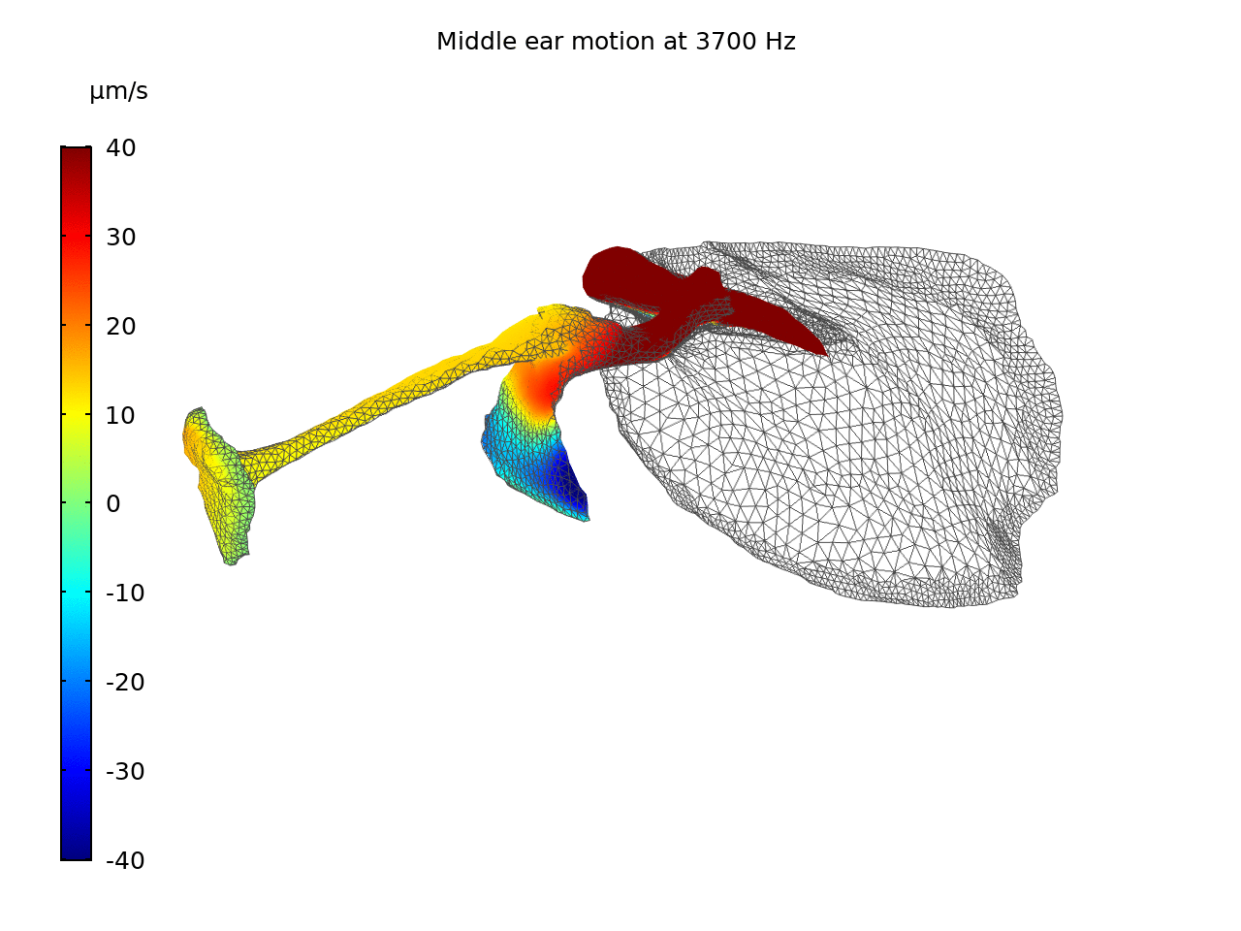
CONCLUSIONS

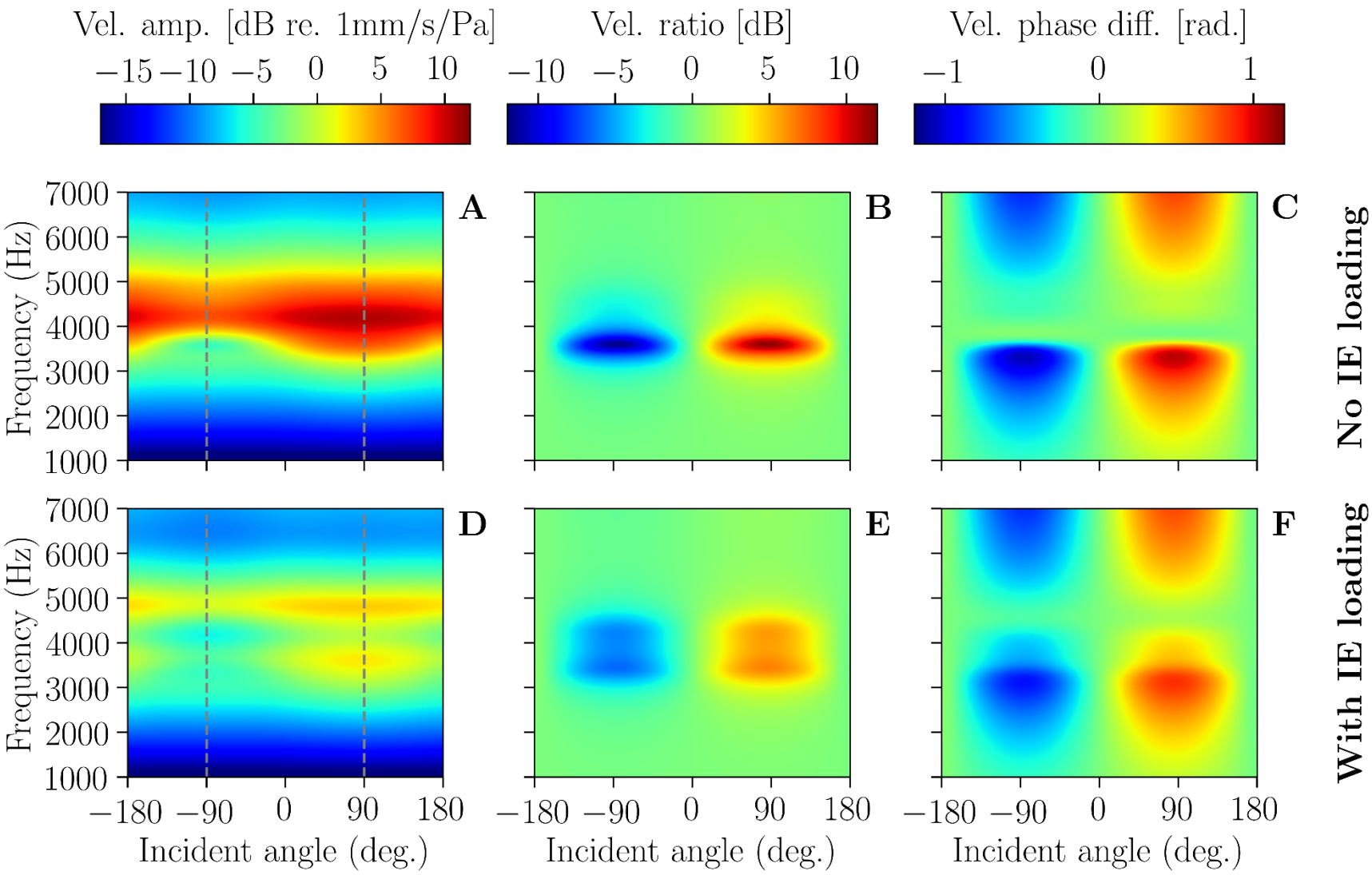
- During the model construction, complexity is sequentially added
  - Effect of different parameters are better observed
  - Model changes have to express the added physics
  - What physics to include remains up to the user
- Model results were mainly validated compared to the experimental data
  - Experimental data is scarce
  - Material properties are not well known
- More experimental data is being gathered to improve future models

Questions?



Livens, P., Muyshondt, P.G.G., Dirckx, J.J.J., 2019.
Sound localization in the lizard using internally coupled ears: A finite-element approach.
Hearing Research.

SUPPLEMENTARY SLIDE(S)



SUPPLEMENTARY SLIDE(S)

- The IE is a fluid filled structure and adds significant resistance (impedance) to the middle ear

- The inner ear was modeled with a three parameter model for the impedance Z_{IE}

$$Z_{IE} = R + i\left(M \cdot \omega - \frac{K}{\omega}\right)$$

- Values of *M*, *K* and *R* were calculated based on measurements on the Ostrich (e.g., m$\sim x^3$ and $M = m/A^2$ so $M \sim 1/x$)

- The pressure on the footplate is then found as

$$P = Z_{IE} \cdot U_{FP}$$