HARMONIC RESPONSE OF THE ORGAN OF CORTI : RESULTS FOR WAVE DISPERSION

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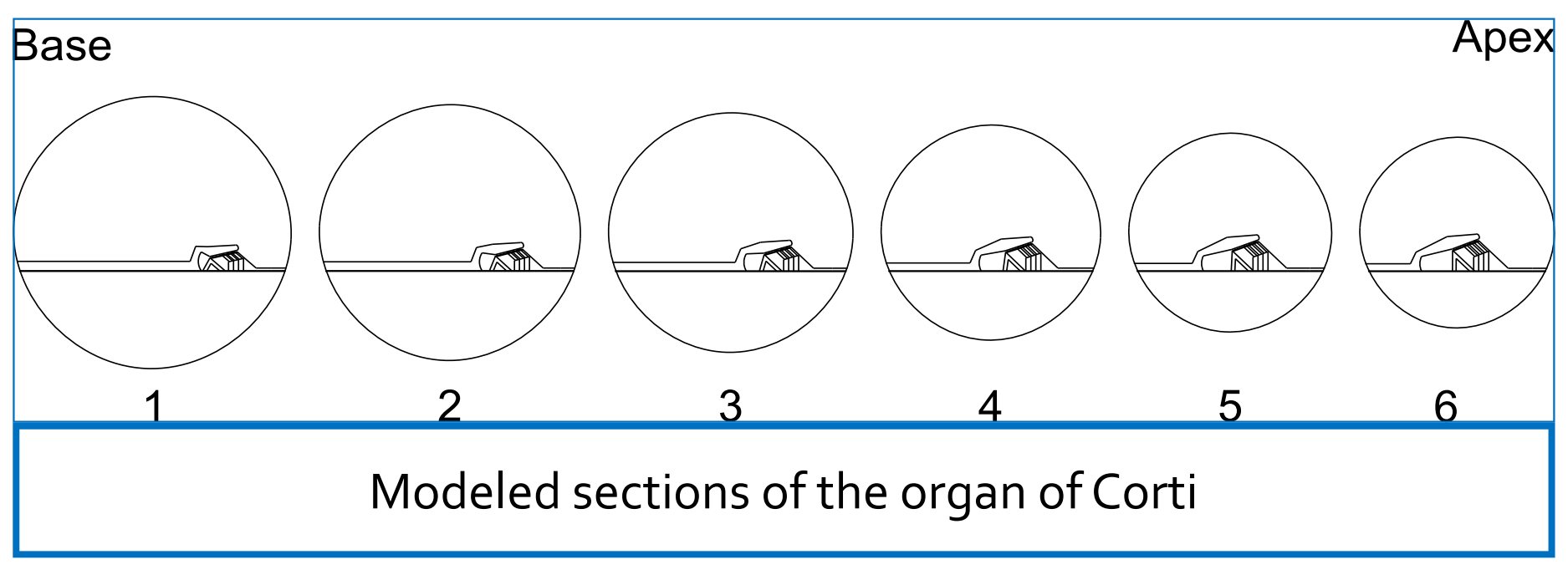
OBJECTIVES

- **Model the fine structure of the organ of Corti.**
- **Solving for the wavenumber and the propagative and evanescent corresponding modes.**
- **Studying different mechanical coupling for basilar membrane.**

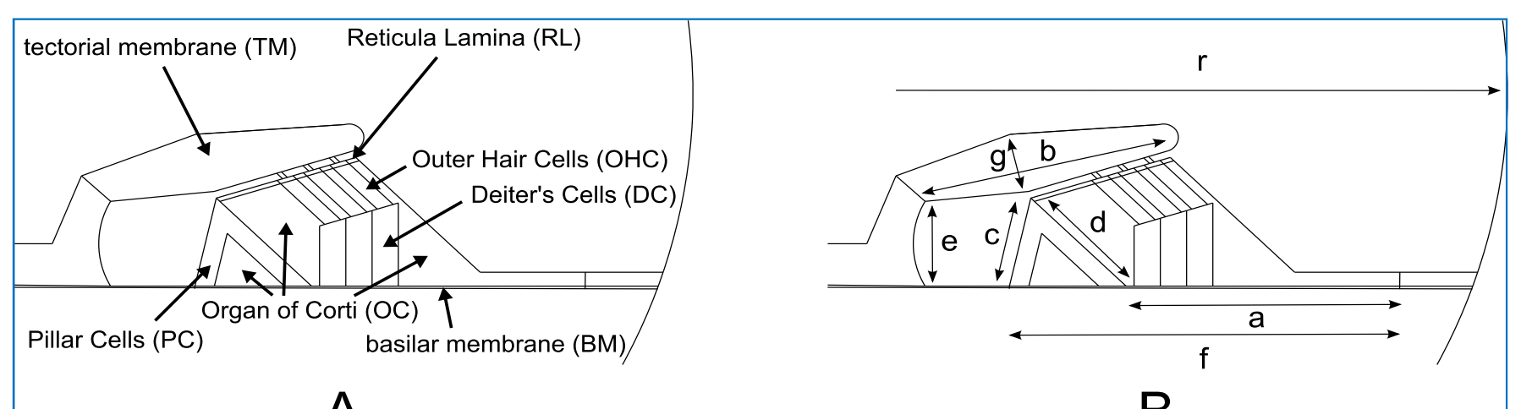
MODELING

Cochlea as an inhomogeneous waveguide



Modeled sections of the organ of Corti

- 6 cross sections of the organ of Corti modeled.
- Parametric shape from [Edge et al., 1998].
- Materials properties from [Cai & Chadwick, 2003].



Parameters (B) of the organ of Corti (A)

Finite elements analysis

- Two physics represented using COMSOL Multiphysics® : structural mechanics and acoustics.
- Domain conditions :

Fluid
$$\nabla\left(-\frac{1}{\rho_C}(\nabla p)\right)-\frac{k_{eq}^2}{\rho_C}p=0$$
$$k_{eq}{}^2=\left(\frac{\omega}{c_c}\right)^2-k_z{}^2$$

Interaction
$$-n.\left(\frac{1}{\rho_C}(\nabla.p)\right)=\ddot{u}_n$$

Solid
$$-\rho\omega^2u-\nabla.\sigma=0$$

- Boundary conditions :

-Hard walls on ducts boundaries.

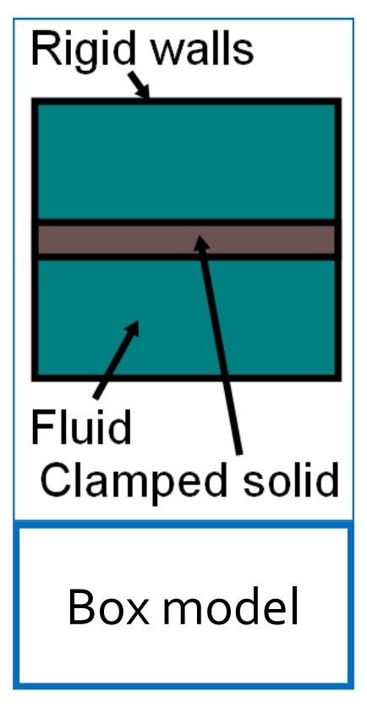
-Continuity of velocity on fluid/structure boundaries.

- Eigenvalue problem (kz) for imposed frequency ω.

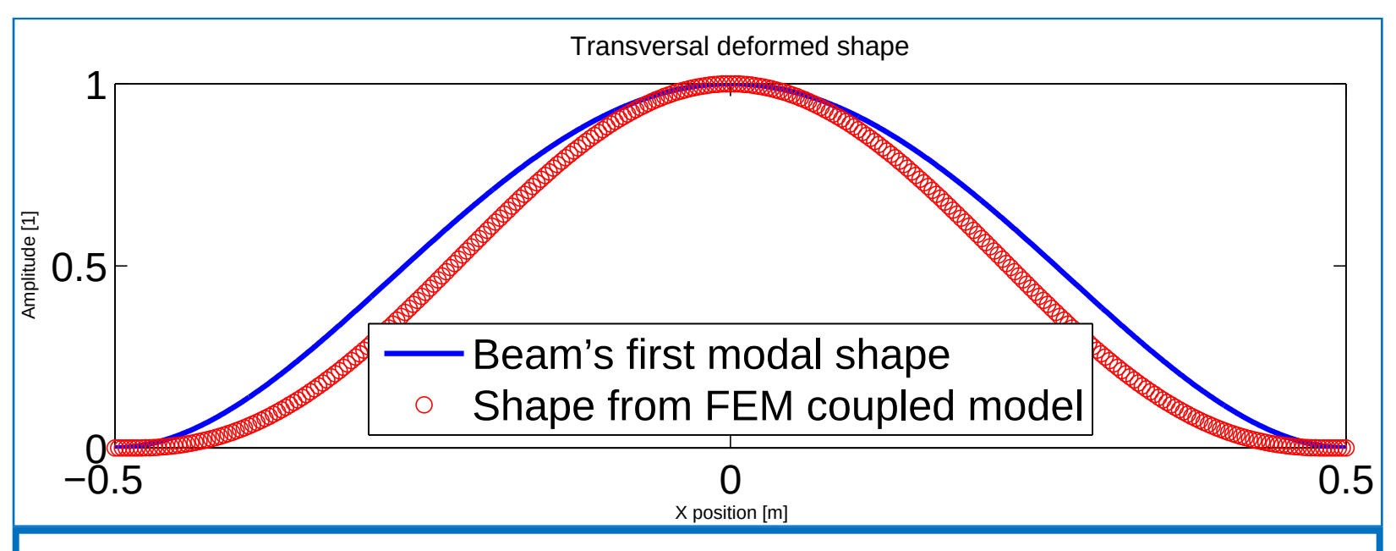
RESULTS

Comparison with WKB method

- Comparative model : box model, solid partition.
- Comparative results to WKB method for low frequencies (linear).
- Improvement with a strong coupling (no imposed mode shape) for high frequencies.

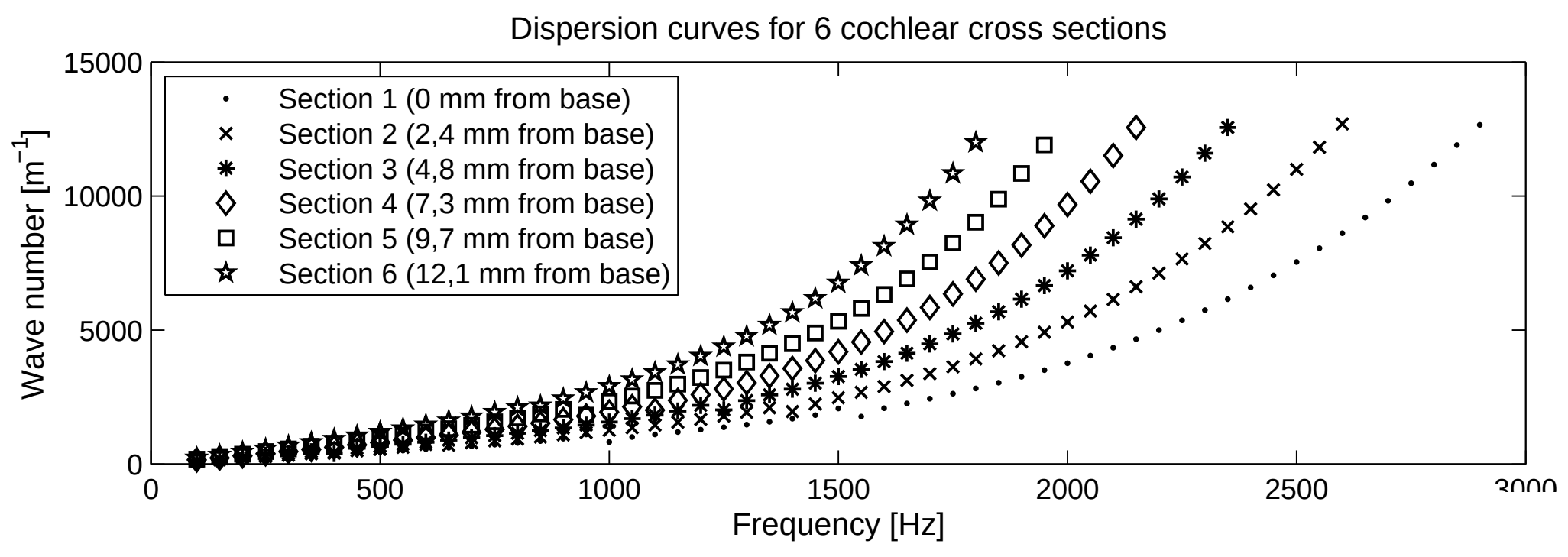


Box model



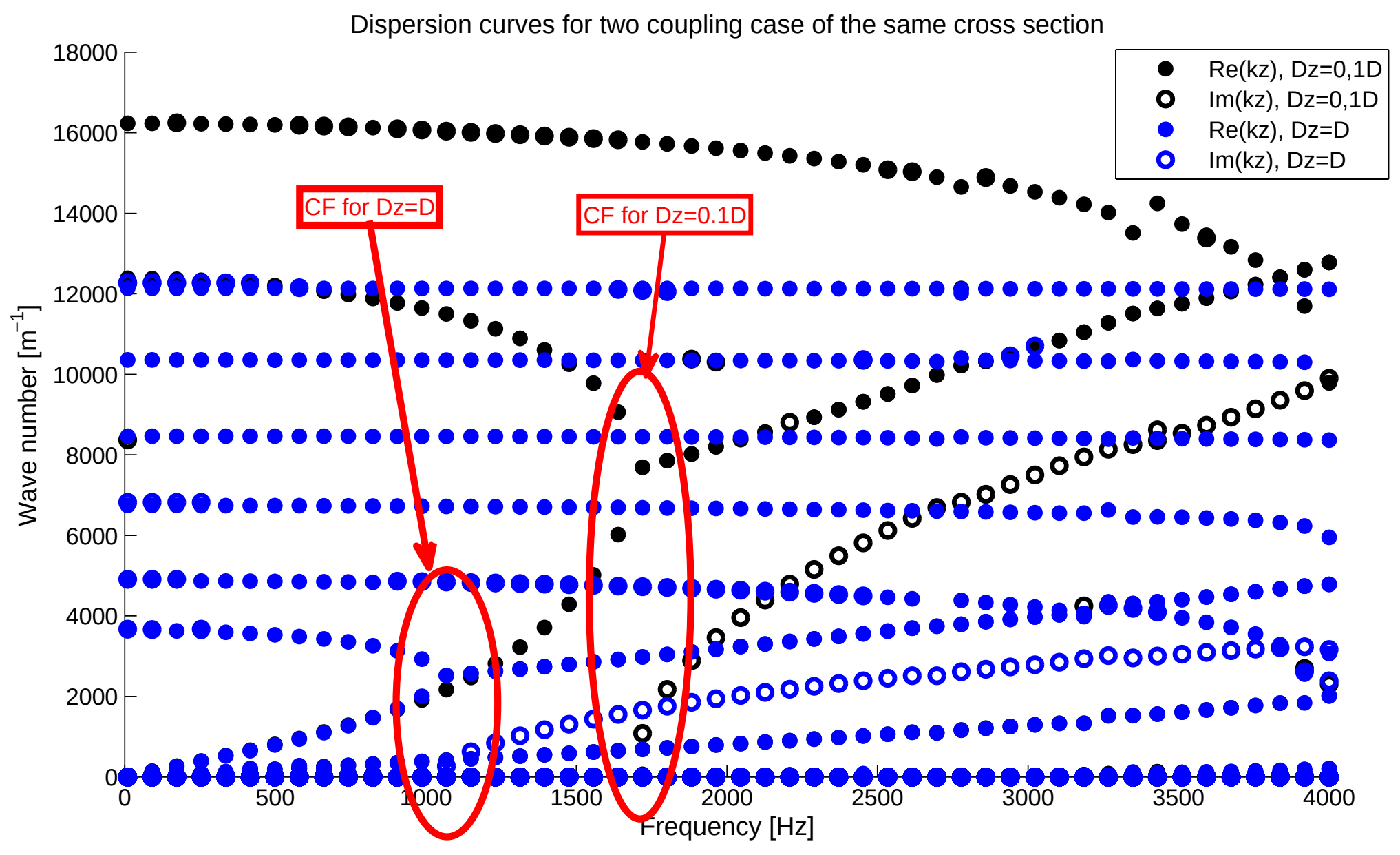
Comparison of deformed shapes assumed with WKB method and obtained by FEM coupled model

Results for the wavenumbers

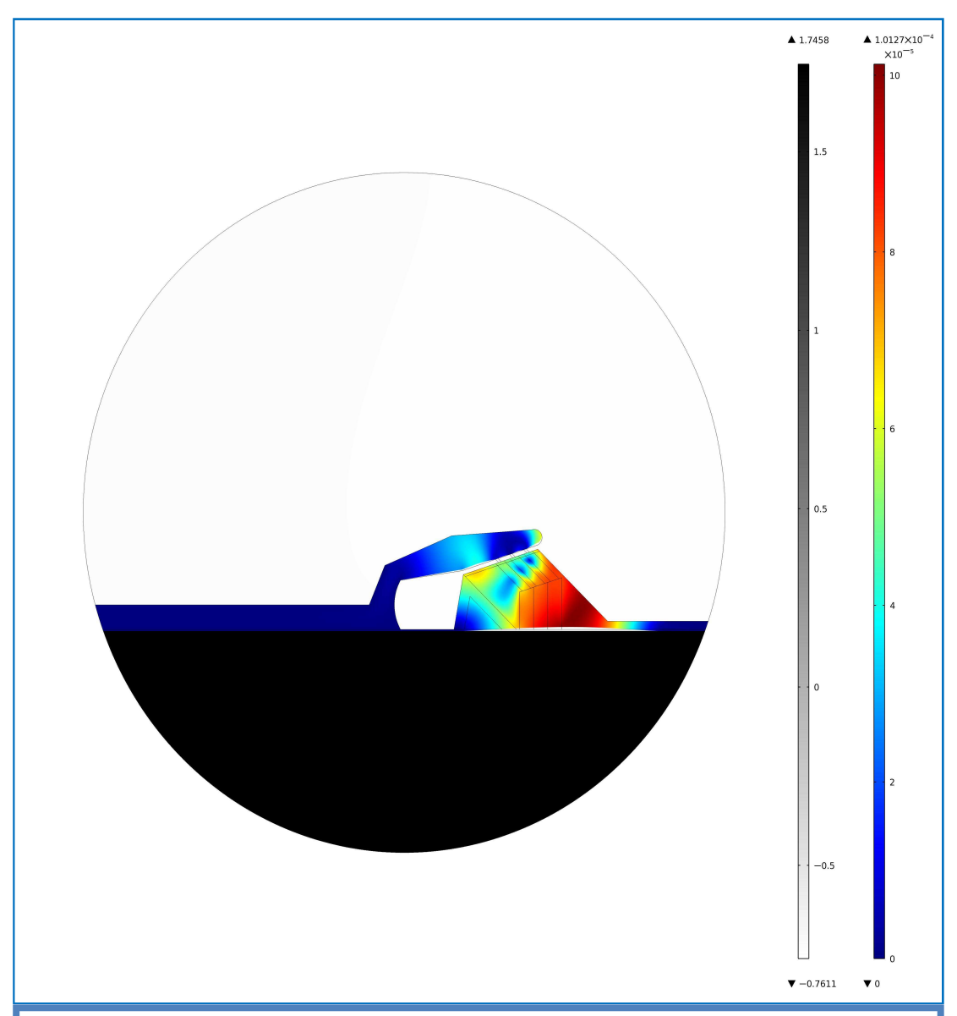


- Rapidly increasing wavenumbers after characteristic frequency (CF).
- Reduced repartition of CF's from base to apex (1,5-3 kHz).

- Increasing imaginary part of the wavenumber with longitudinal mechanical coupling.
- Influence of the orthotropic ratio.
- Sharper behavior with low orthotropic ratios.

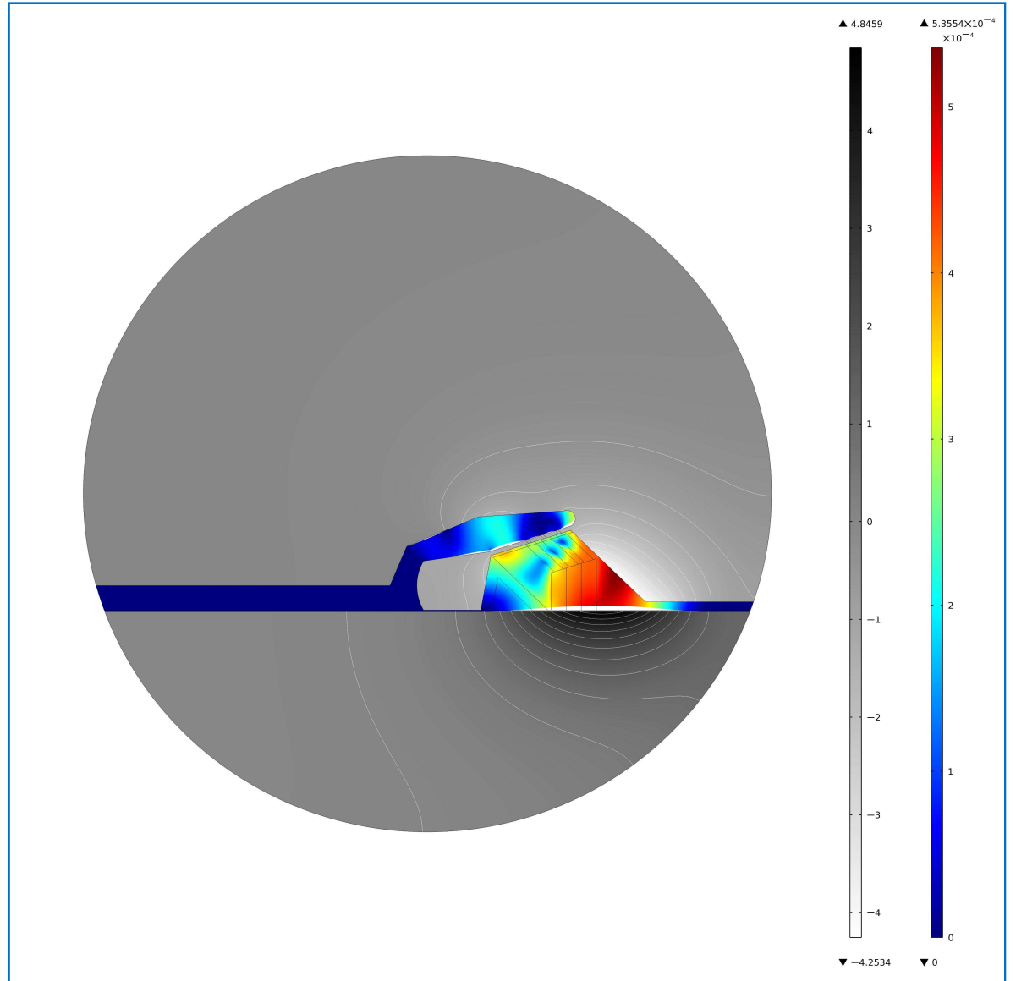


Corresponding mode shapes



Mode shape at 100 Hz. Pressure field (gray scale) and displacement field (color scale).

- Propagative modes
- Uniform pressure field for low frequencies.
- Gradient pressure localized around BM for high frequencies.



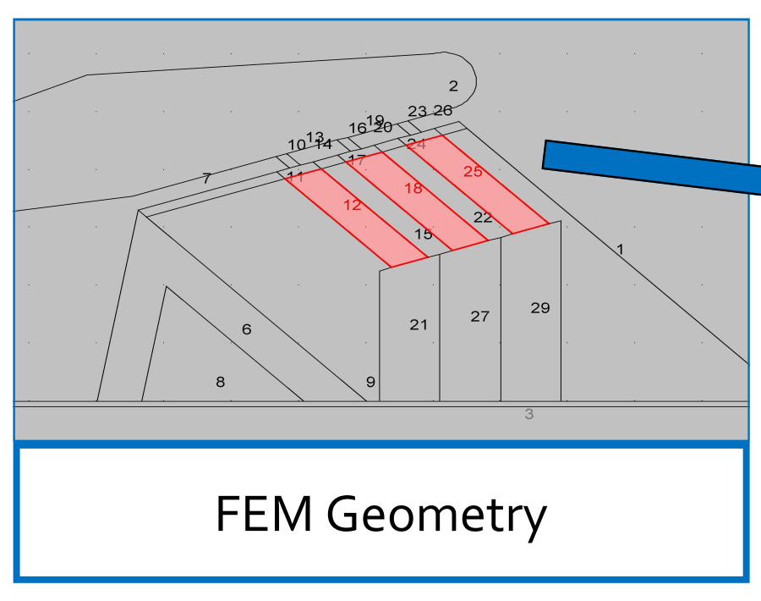
Mode shape at 2500 Hz. Pressure field (gray scale) and displacement field (color scale).

CONCLUSION

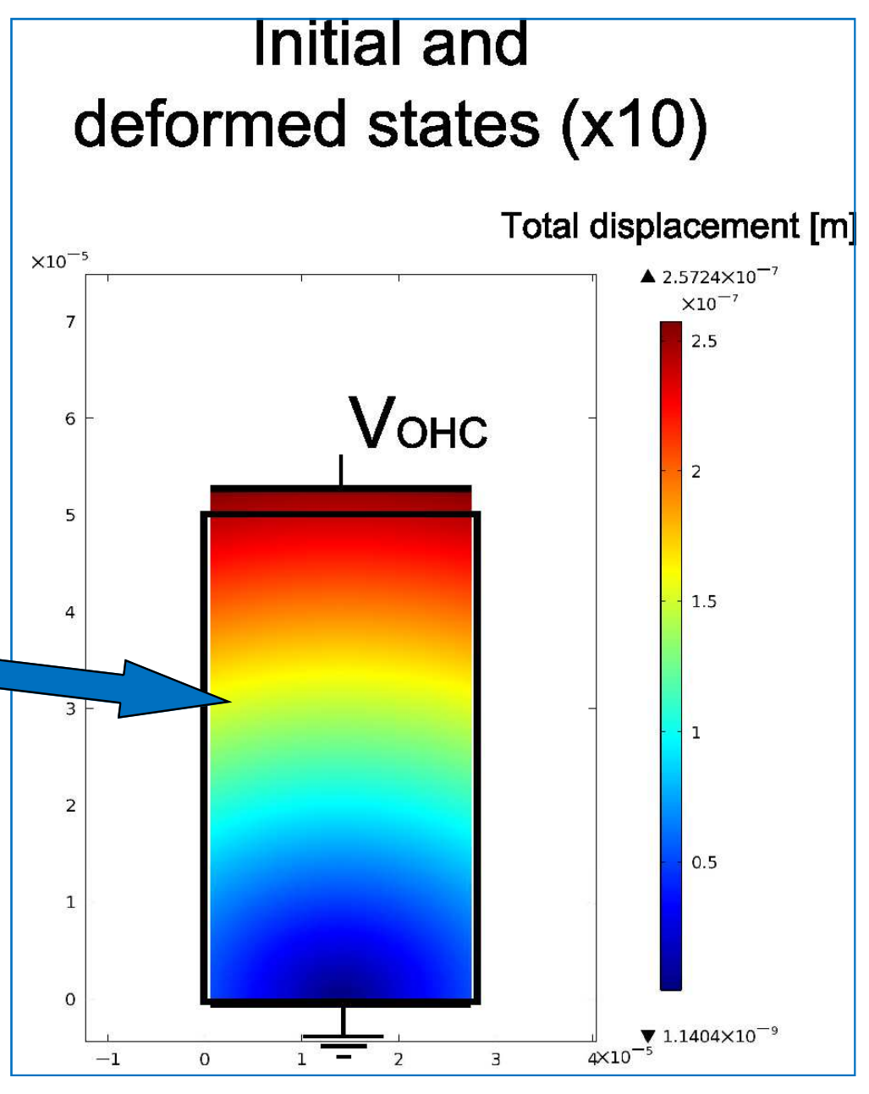
- **Qualitative results show good features.**
- **Quantitative results are good albeit shifted.**
- **Low computational costs.**
- **Efficient method and promising model.**

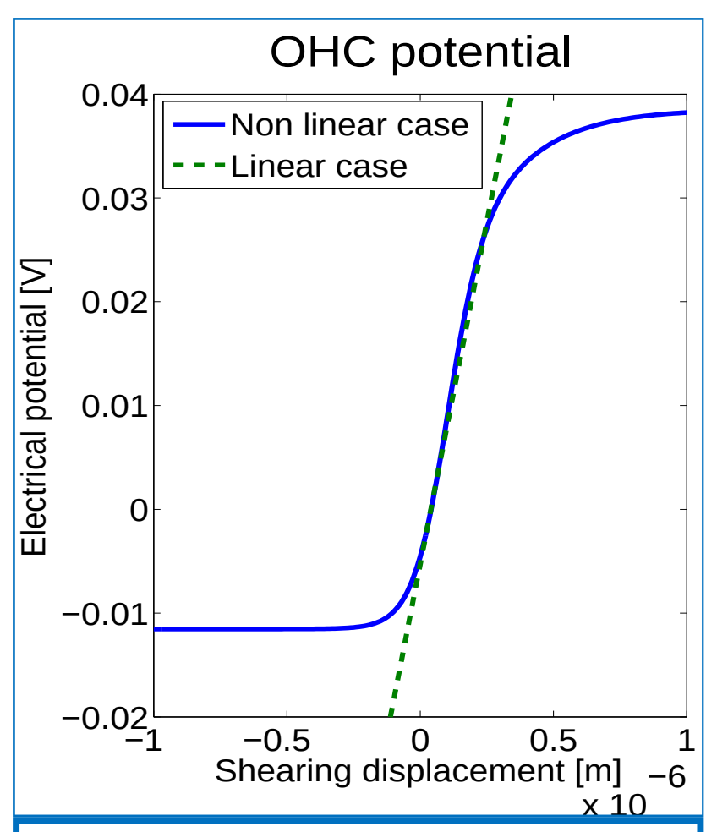
PERSPECTIVES

- Complex solutions including viscous damping
- Detailed sub-tectorial space : including IHC and OHC responses.
- Envelope function with help of WKB method.
- Outer Hair Cells and Hair Bundles electrical modeling.
- Mechanical longitudinal coupling for the entire solid domain.



FEM Geometry





Displacement potential laws