Model-based effects screening of a violin including orthotropic material behaviors

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Presentation plan

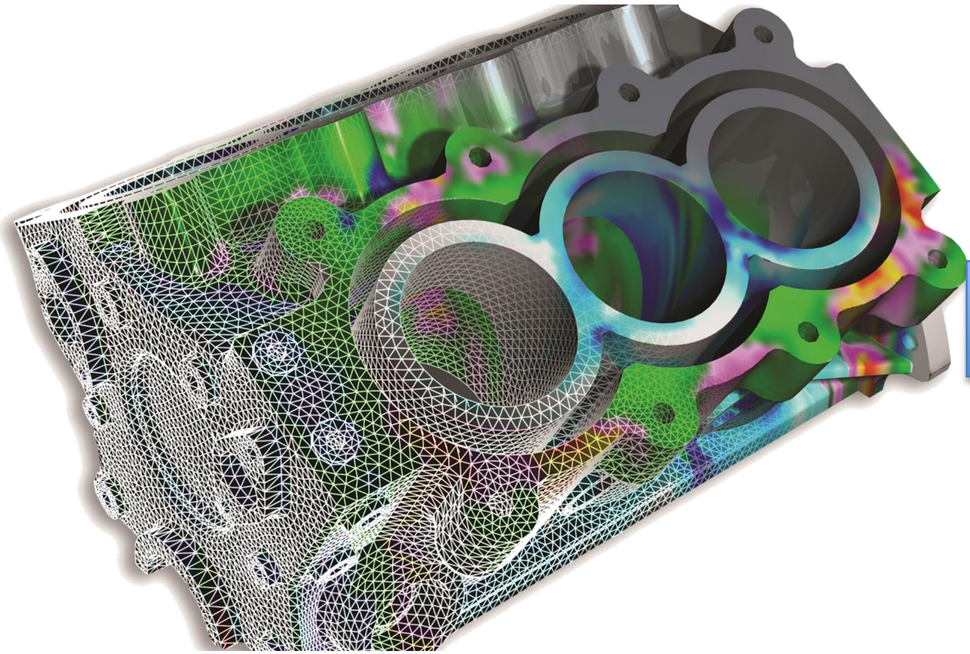
- Context and objectives
- Model-based effects screening
- Hypotheses and behavior law
- Violin modal behavior
- Results
- Discussion, perspectives and Q&A

Context

- Stringed instruments making requires selecting woods, traditional instruments shapes and craftmanship acquired throughout extensive practice
- Repairs and preset operations rather than building new instruments for the instrument makers
- Modeling approaches in transport, aerospatial, aeronautics, automobile, etc…
- Use computing power of personal computers to simulate the behavior of complex systems

Aim

- Transpose numerical methods from the industry to arts and craft domain
- Provide instrument makers decision support software to design and build stringed instruments.



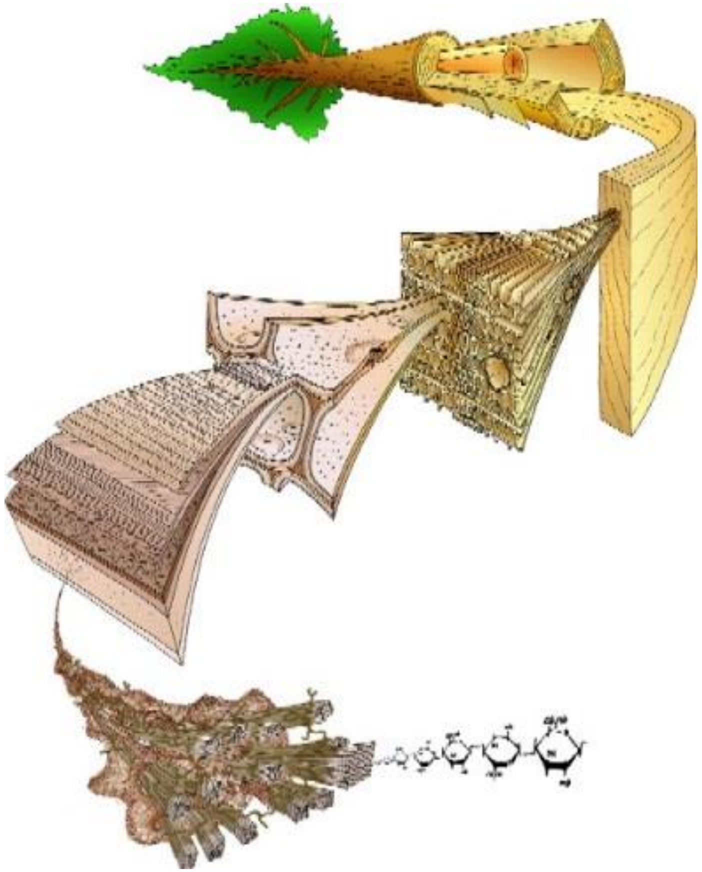
MSC Softwares

Objectives

- Use model-based effects screening to determine the elastic parameters which most influence the violin's dynamic
- Compare it to the traditionnal ways of selecting woods for luthiers

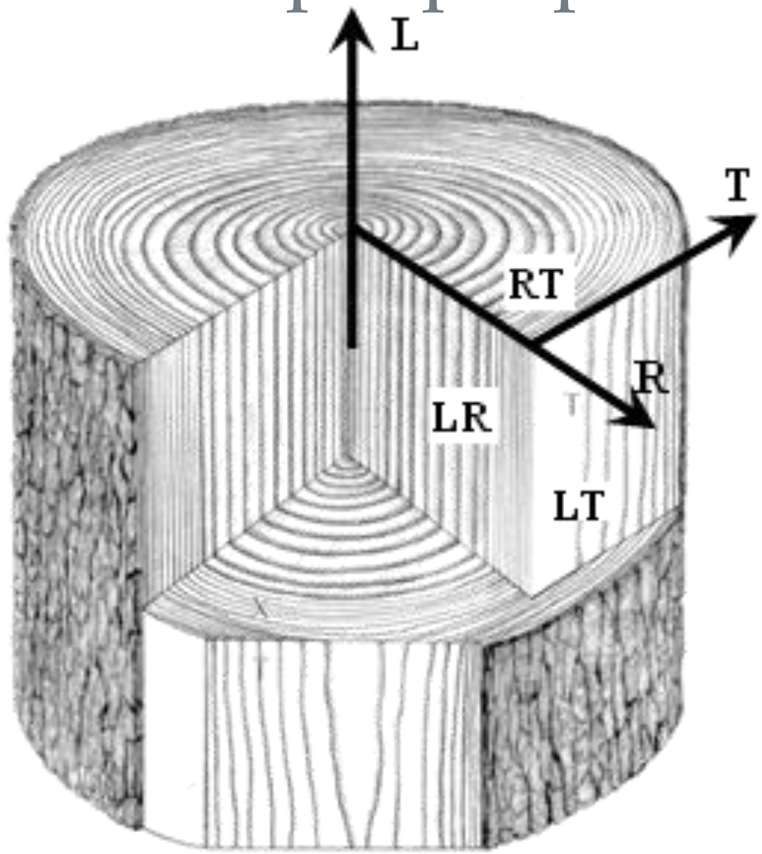
Material

- Multi-scale behavior



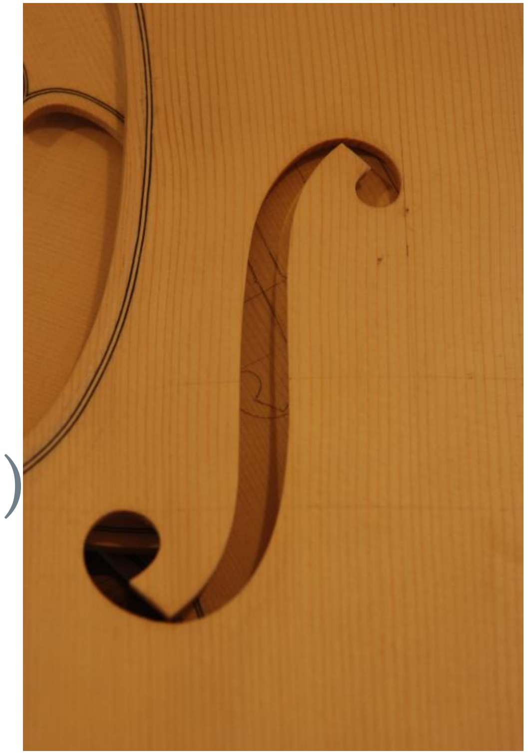
Harrington, 1998

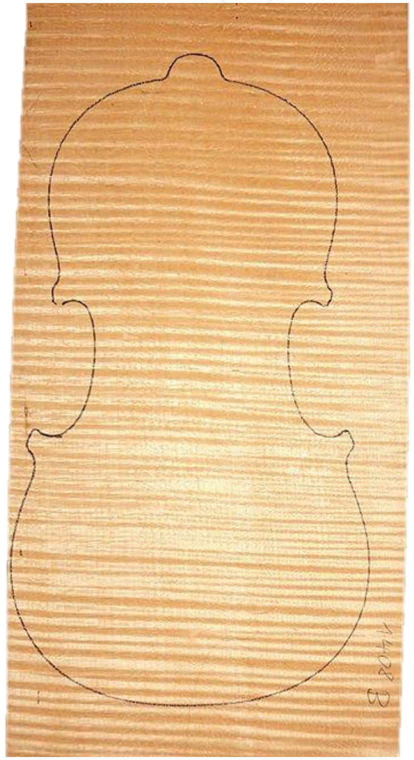
- Orthotropic properties



Hypotheses on for modeling wood

- Homogeneous
- Elastic linear behavior
- Three main directions LRT
- Constant density and stiffness of cellulose
- Finely selected wood (luthery wood)
- Straight fiber
- Low micro fibrils angle (5 to 10°)
- Dried wood



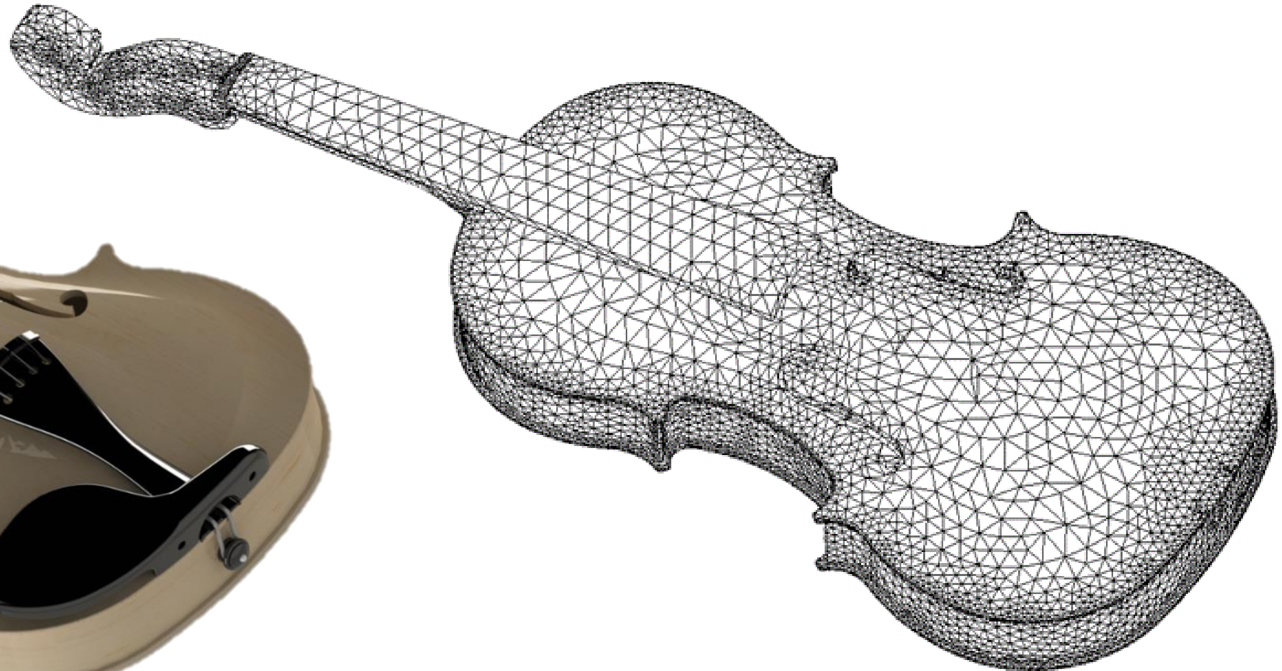


Behavior law

- D. GUITARD (1987) linear elastic laws
  - 3 Young's moduli through L, R, T
  - 3 Shear moduli and 3 poisson's ratios in LR, RT, TL planes
  - Isodensity/Moisture Content variability : ±10% (due to microfibrils angle, cellulose stiffness and density…)
  - Reference values modified by density
    - Higher proportion of tracheid (and so cell walls) - , for both soft woods and hardwoods.
    - Density varies from 0,8 to 1,1 around the reference value (0,45 _ 0,65)
  - Moisture Content then is applied from sorption isotherms curves (temperature and relative humidity corresponding to usual playing values of an instrument)
    - MC varies from 8% to 14%
    - + 1% MC means -3% on ER, ET, GLR, GRT, GTL and -1,5%EL

Finite element model of violin

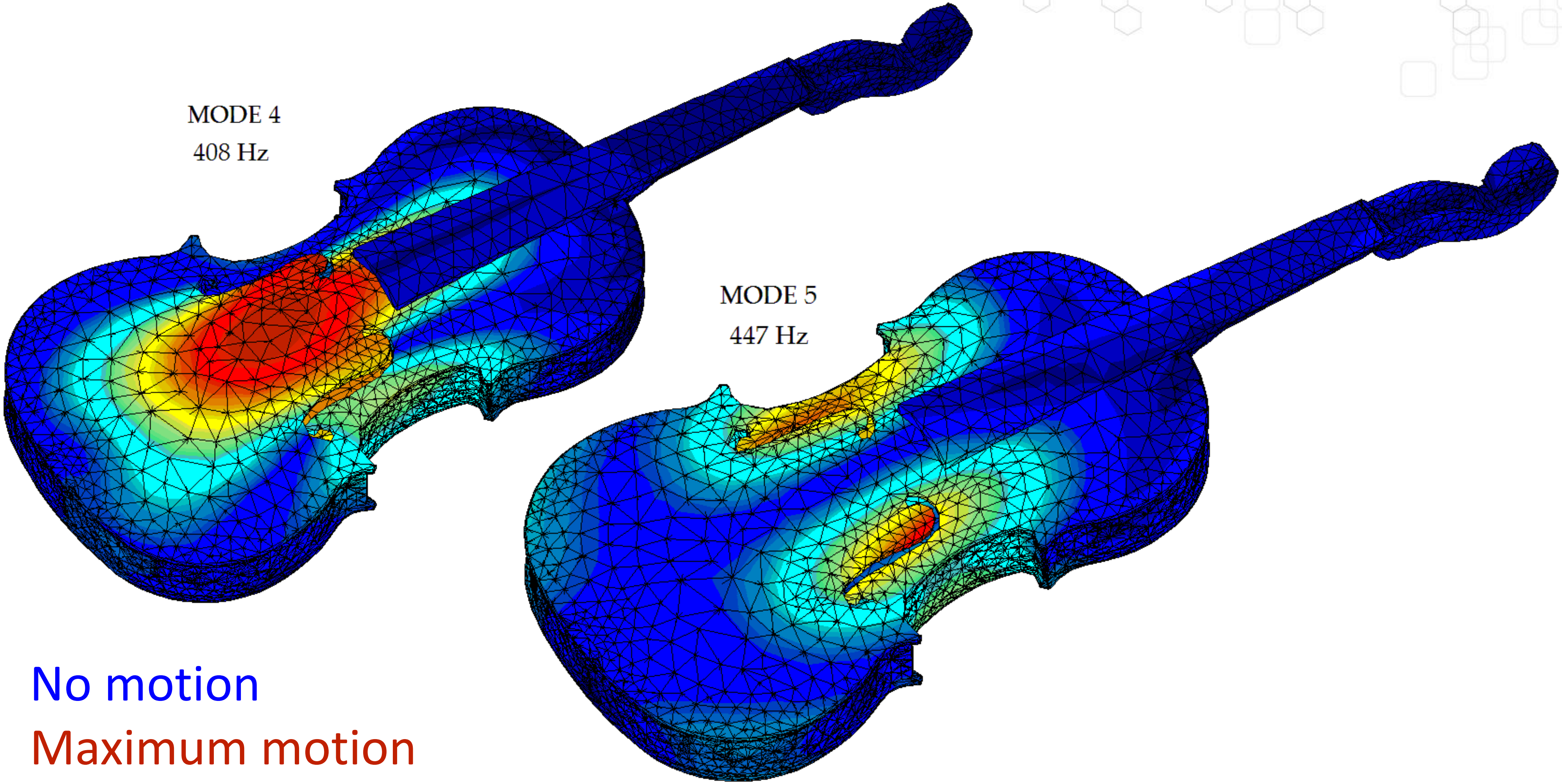
- SolidWorks, NASTRAN
- 25 solids, 9 materials
- TET10 mesh, 130000 Nodes, 75000 elements



Effects screening methods

- Principles
  - Rank parameters (material, geometrical etc…) of a model by their effects on a defined output
    - Dynamical : eigenfrequencies, eigenvectors
    - Static : Deflection, deformation
- Morris method (applied statistics method)
  - One-At-a-Time method (OAT) (each run only one input parameter is given a new value)
  - Input parameter varies in an input space
  - Outputs are correlated with input variations
  - Allows to check the importance of a parameter, as well as coupling effects of parameters

Modal behavior of violin



No motion

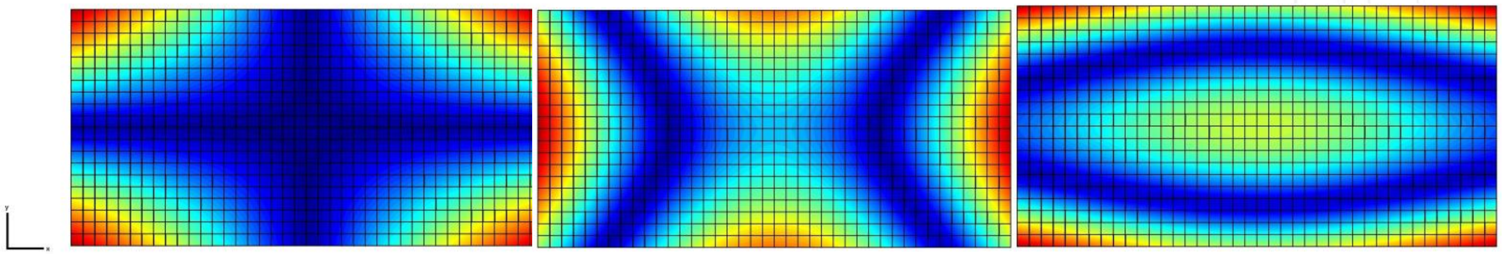
Maximum motion

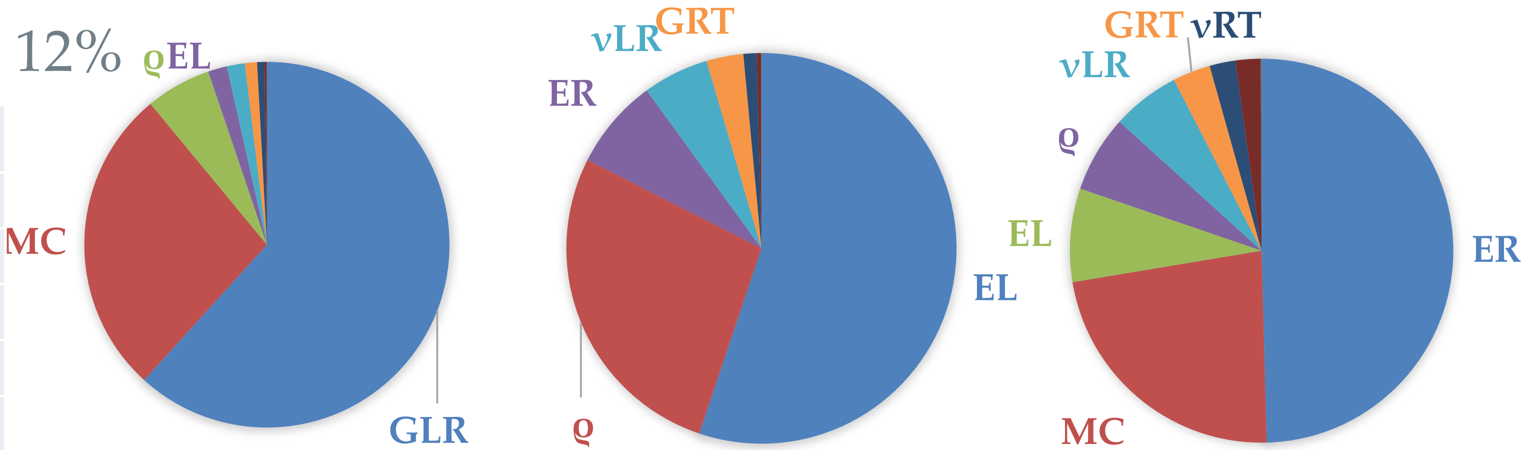
MISC. : Application on a plate

- LRT orientation
- Free-free conditions
- Spruce (softwood)
- 200x100x5 mm
- Density of 0,45 and MC 12%

Coefficients	Reference (Mpa)
ER	1000
ET	636
EL	13100
-1/SRT	2050.000
-1/STL	30800.000
-1/SLR	34200.000
GTL	745
GLR	861
GRT	83.6

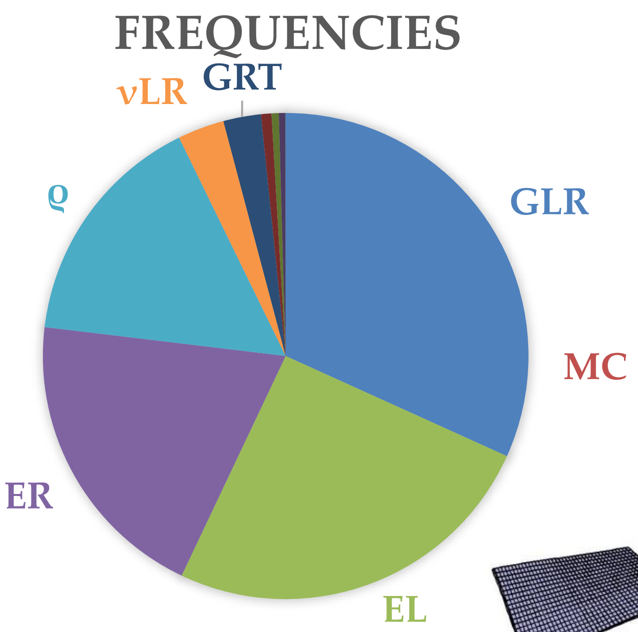
- First eigenmodes shapes

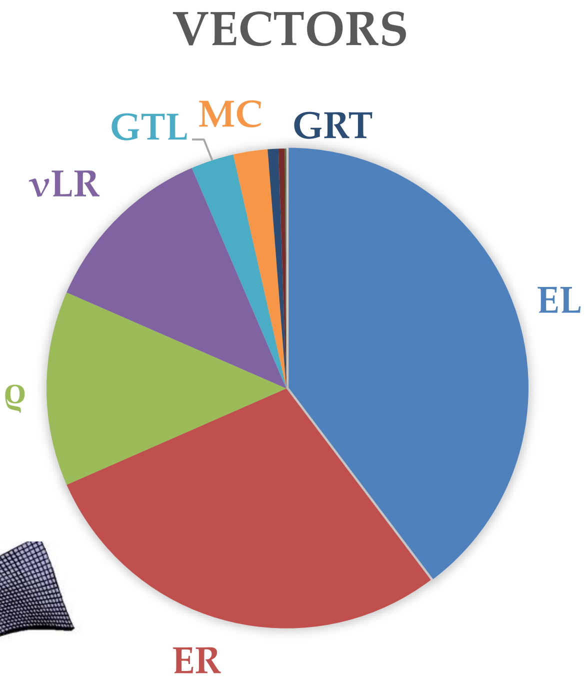




MISC. :Application on a plate

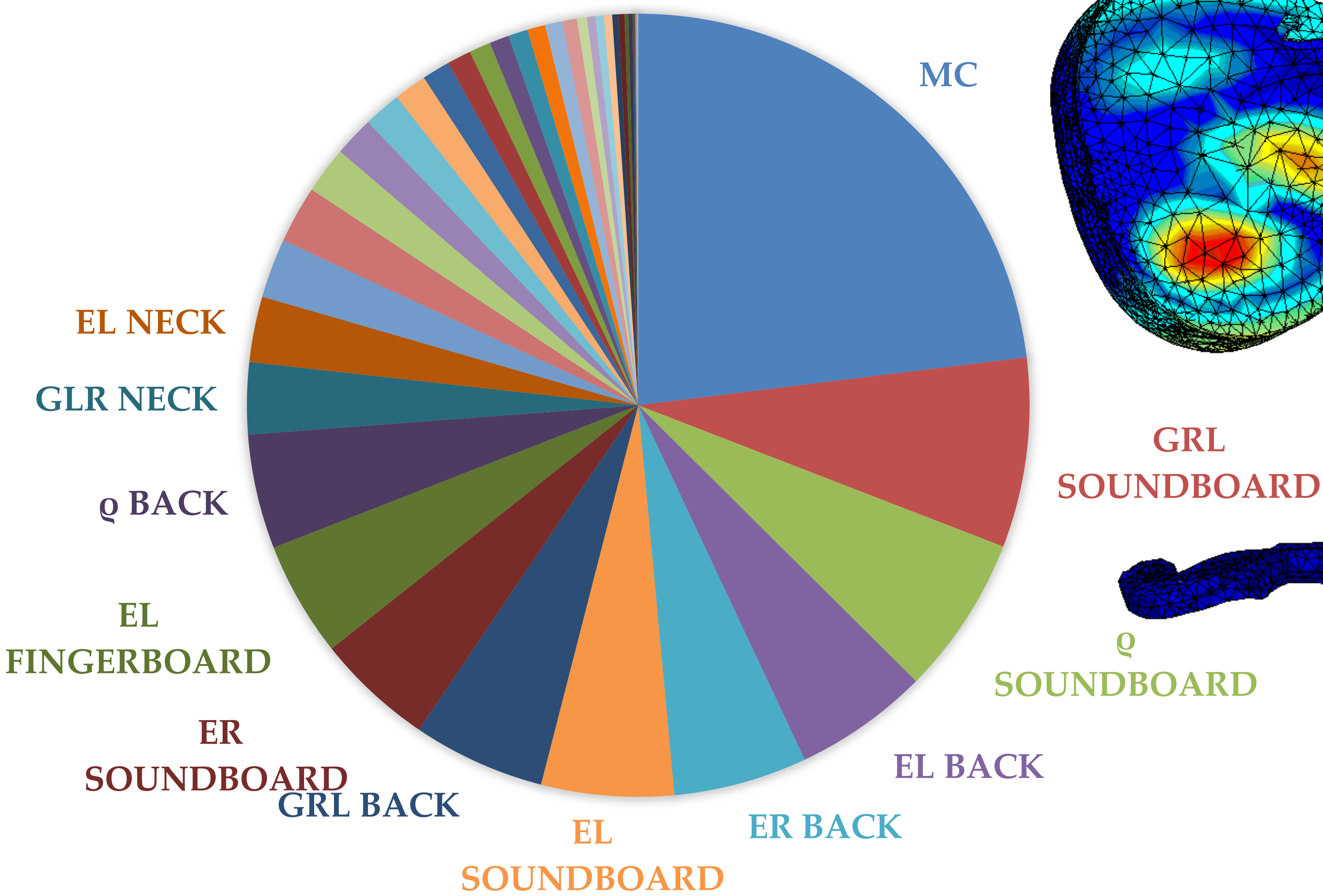
- Ranking on the 10 first modes

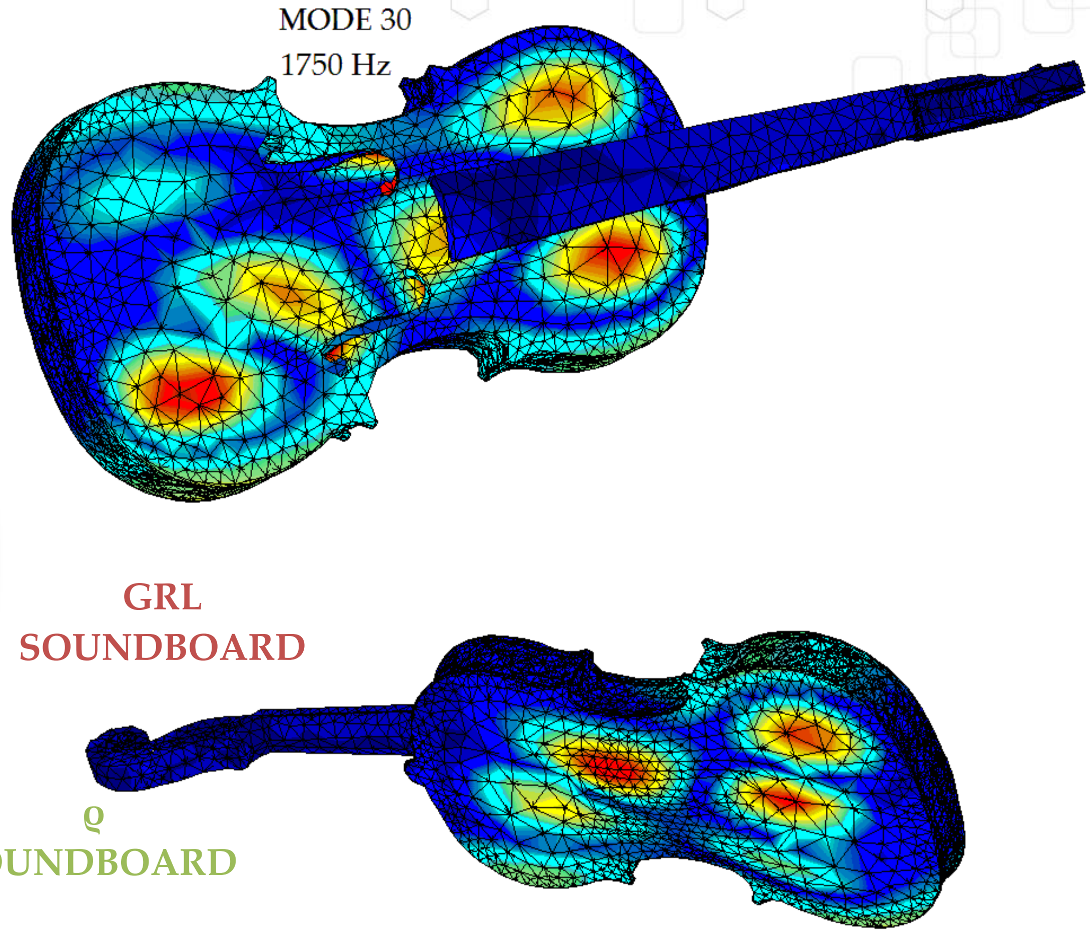




Results on high complexity modes

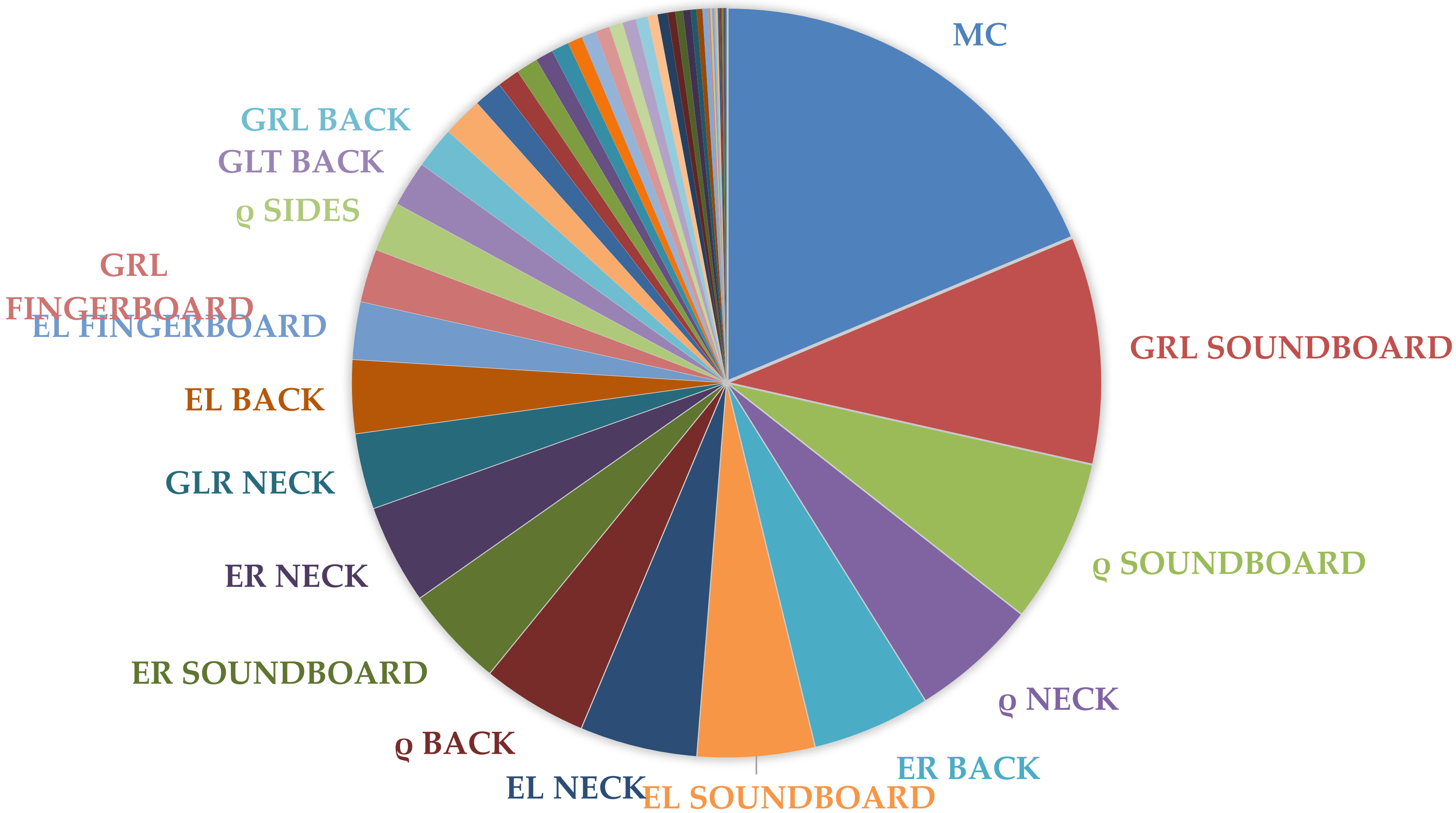
EIGENFREQUENCY





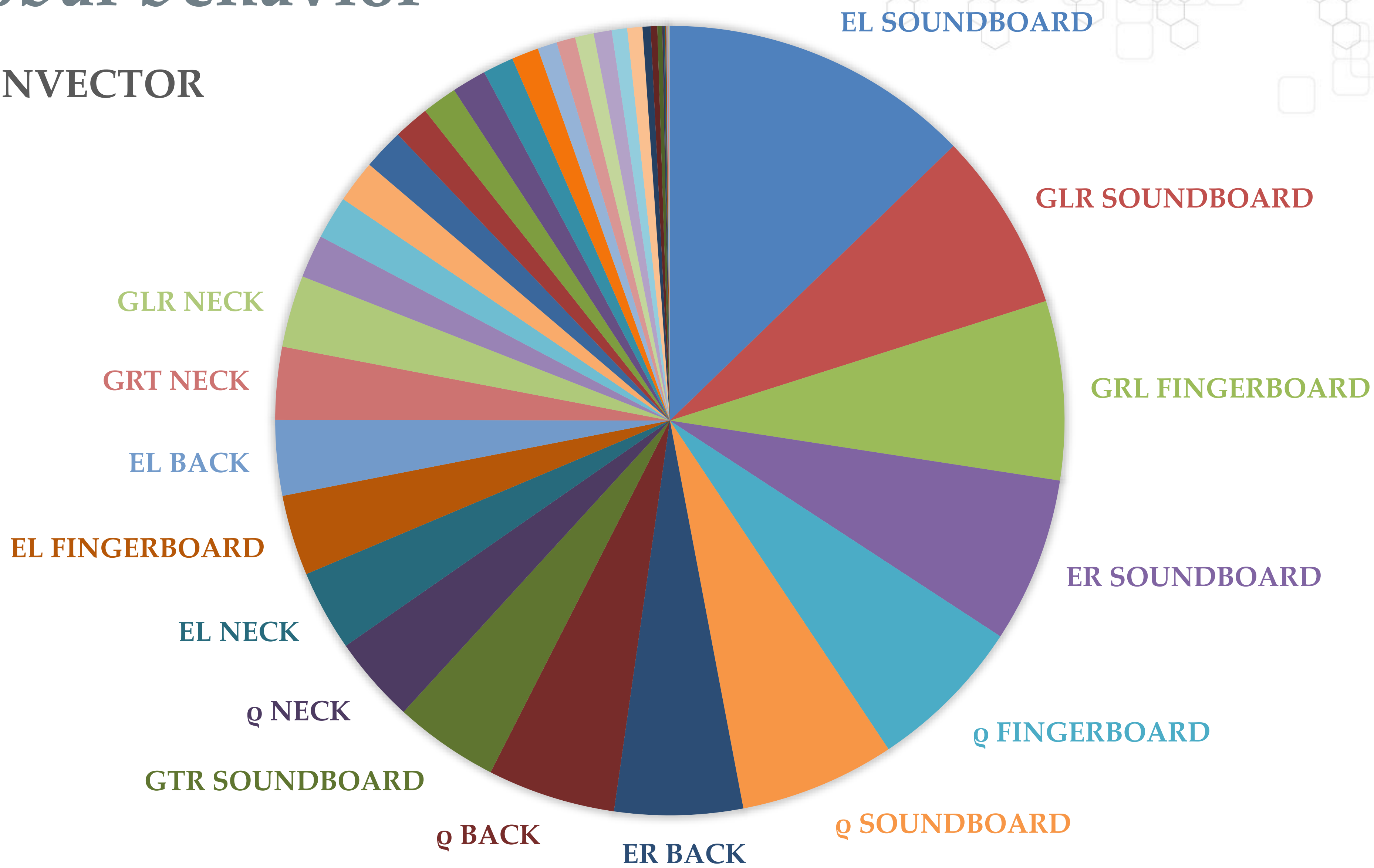
Global behavior

EIGENFREQUENCIES



Global behavior

EIGENVECTOR

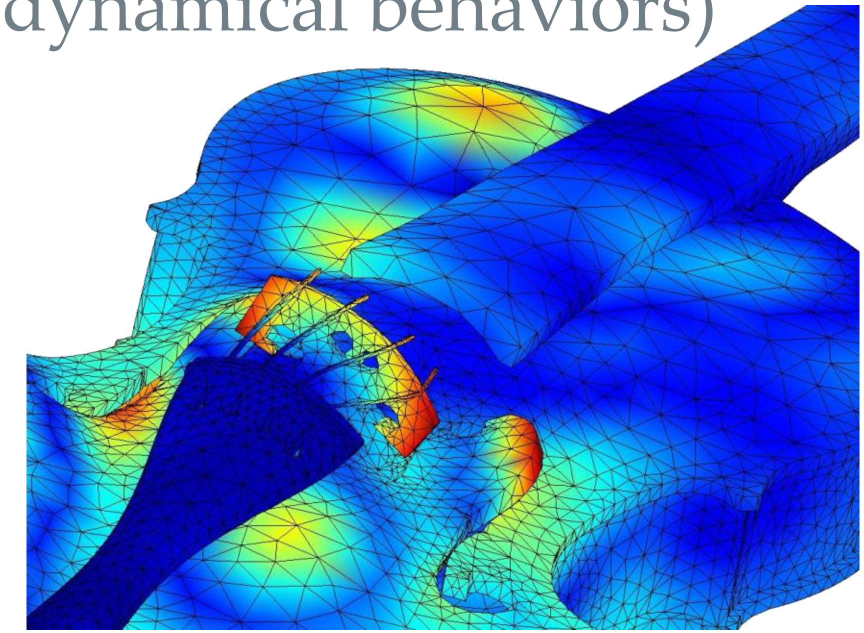


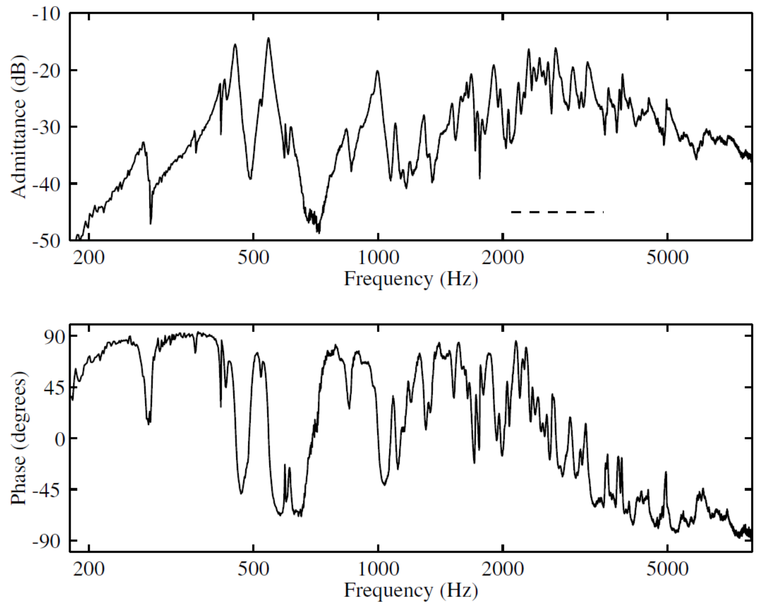
Discussion

- Is the variability of each parameter taken into account properly? (E.G. : MC)
- What is the reliability of the behavior's laws used?
- Are certain viscoelastic properties dominant?
- Is the unmounted behavior the same than the ready to use violin?

Perspectives

- Checking the sensitivity of parameters to physical observations (e.g. bridge hill effect)
- Use results to help the model identification of parameters
- Using those method for other wooden structures (static or dynamical behaviors)

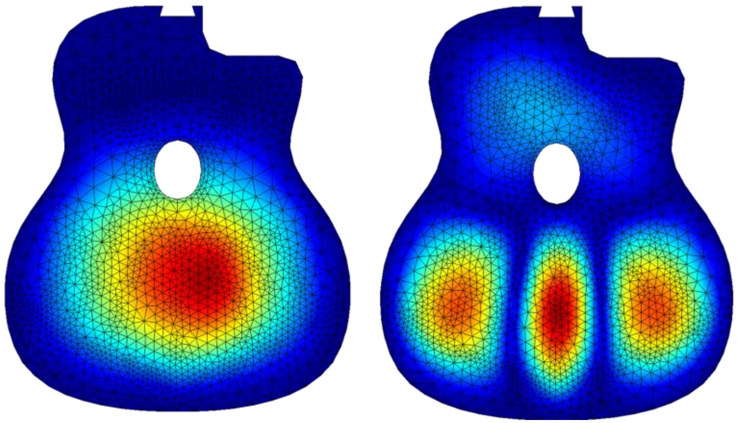




J. WOODHOUSE, 2005

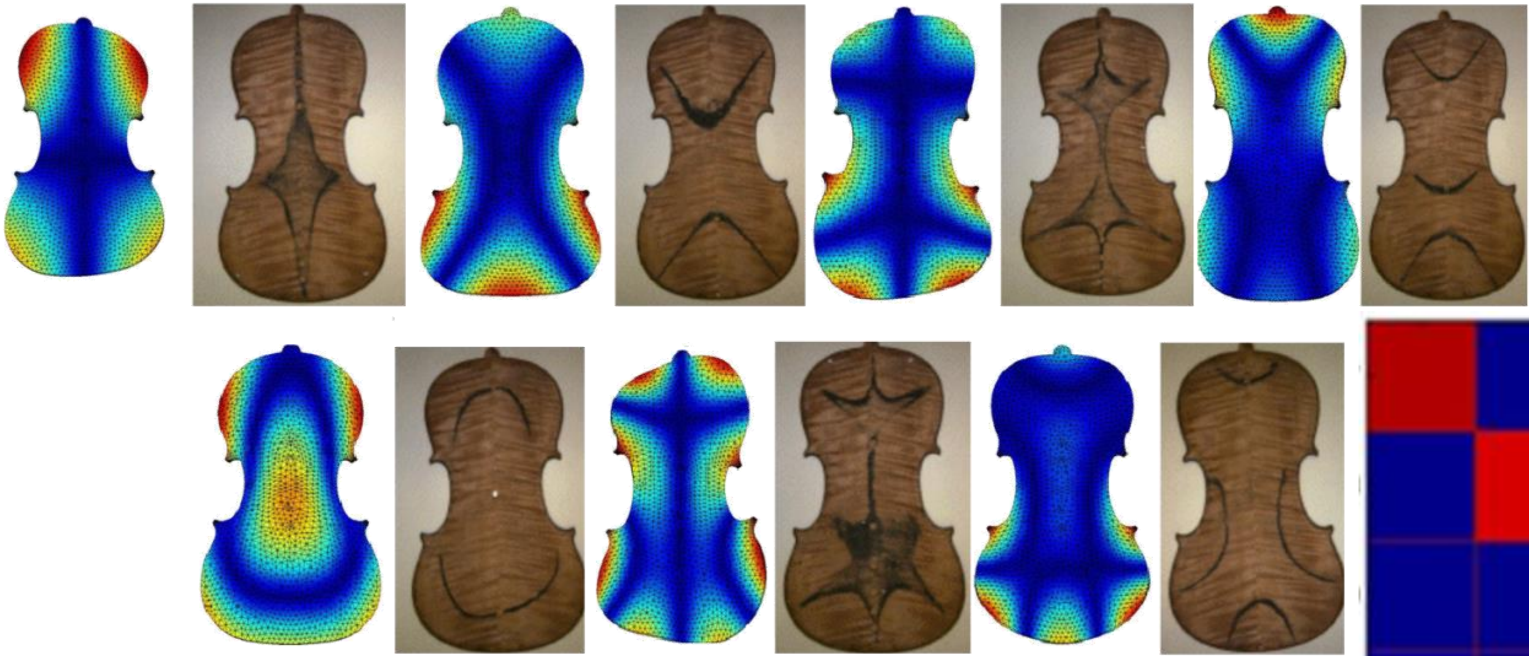
Future work

- Trying the method with different instruments
- Implement prestresses, viscoelastic behavior
- Introduce geometrical variabilities
- Finely check the effects of coupling between the parameters

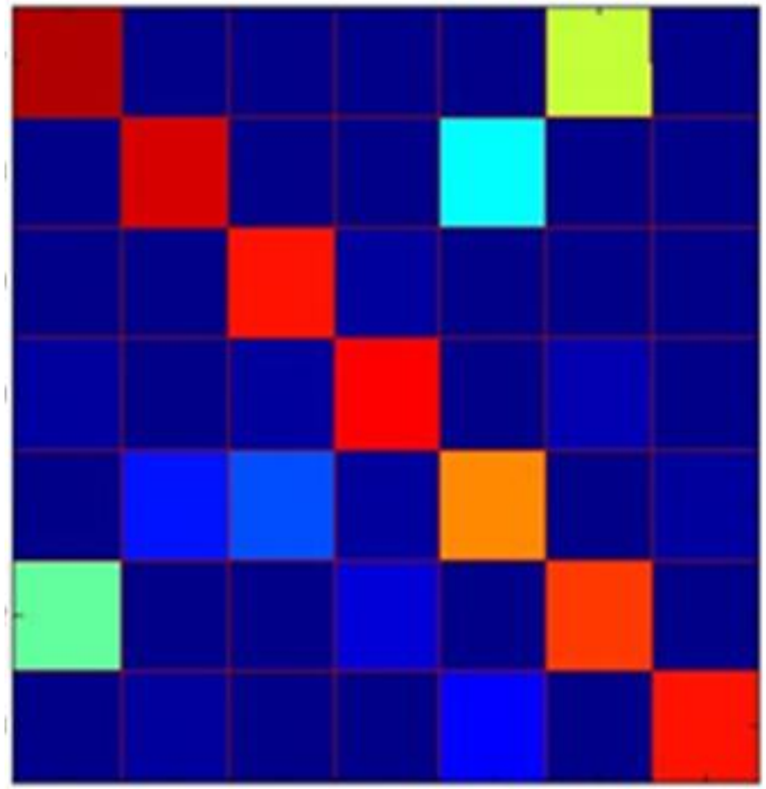


Thank you for your attention

MISCELLANEOUS



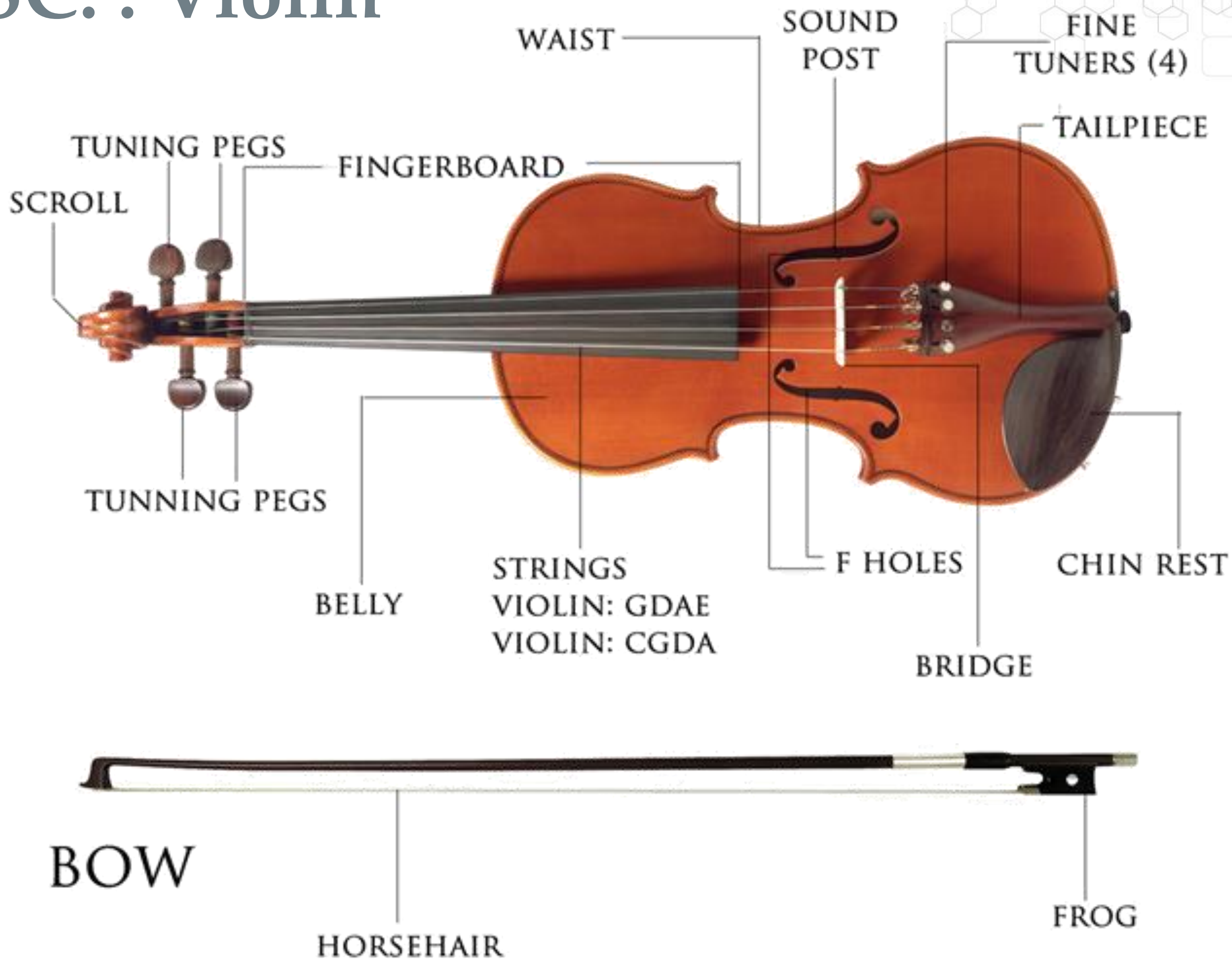
CHLADNI patterns courtesy of Joe WOLFFE



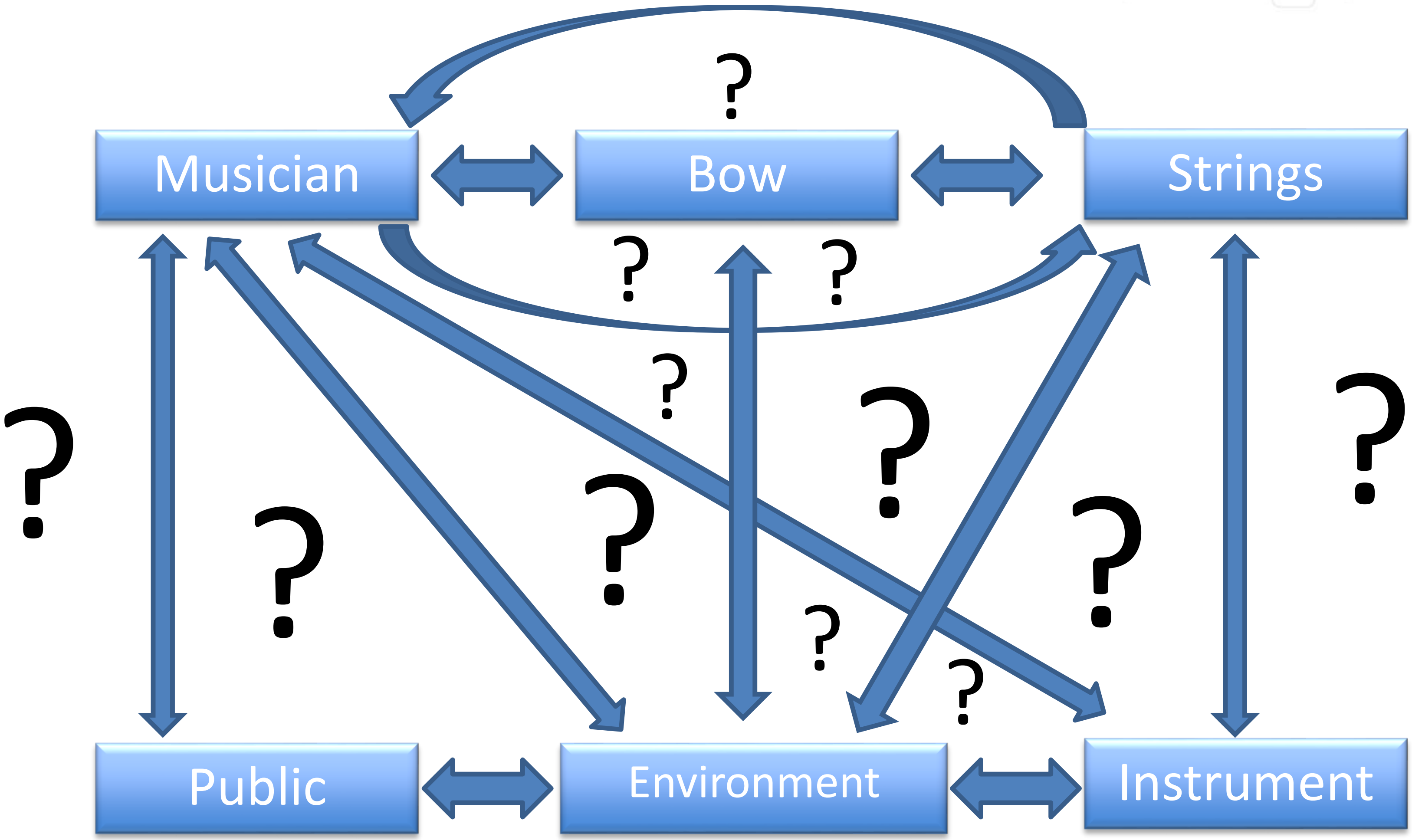
Violin

- Focusing on unmounted violin, all the fixed parts
- Avoiding most of the prestresses issues and presets variabilities

MISC. : Violin

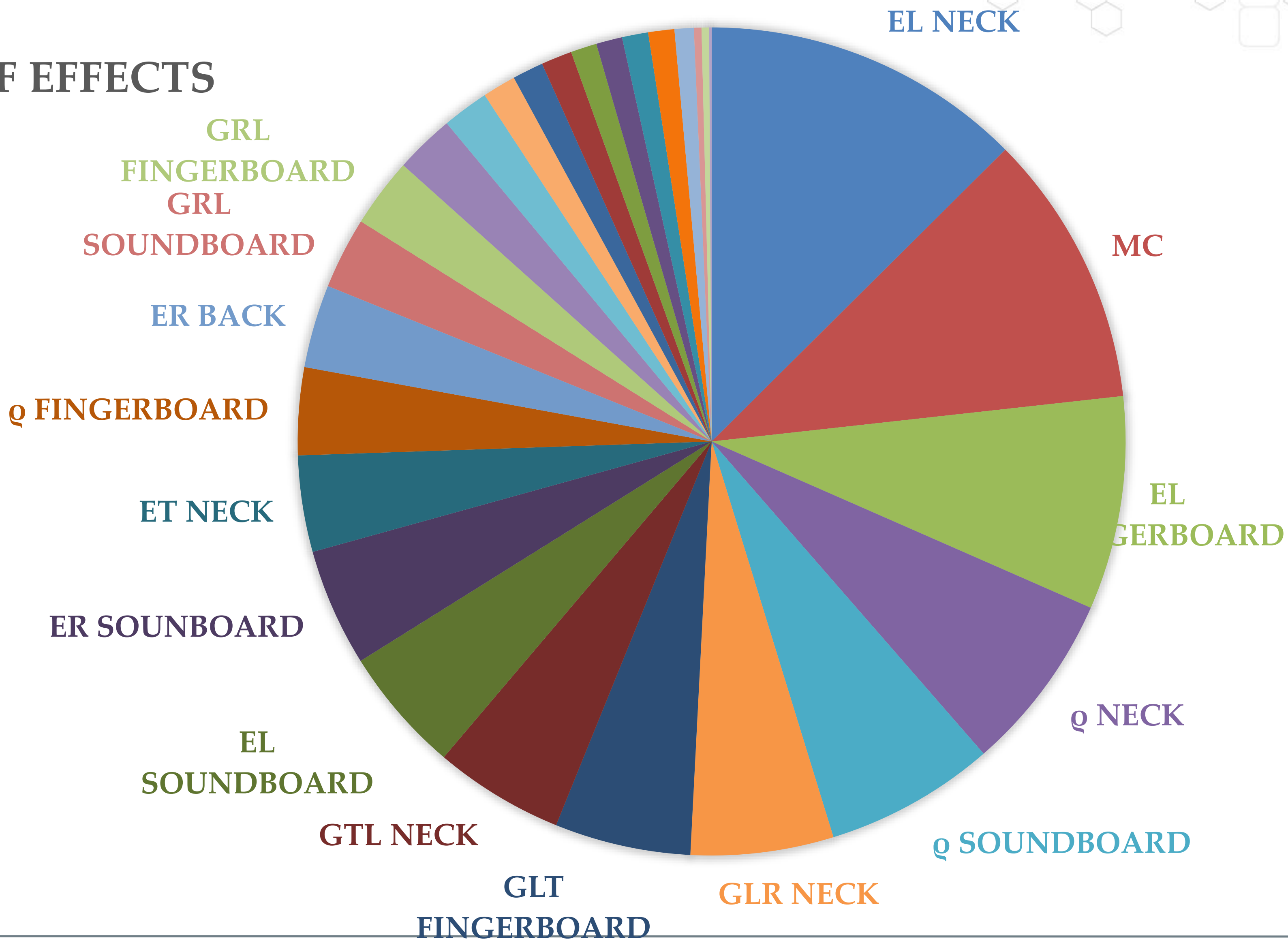

WAIST
SOUND POST
FINE TUNERS (4)
TAILPIECE
TUNING PEGS
FINGERBOARD
SCROLL
TUNNING PEGS
BELLY
STRINGS
VIOLIN: GDAE
VIOLIN: CGDA
F HOLES
CHIN REST
BRIDGE
BOW
FROG
HORSEHAIR

MISC. : Multiphysics

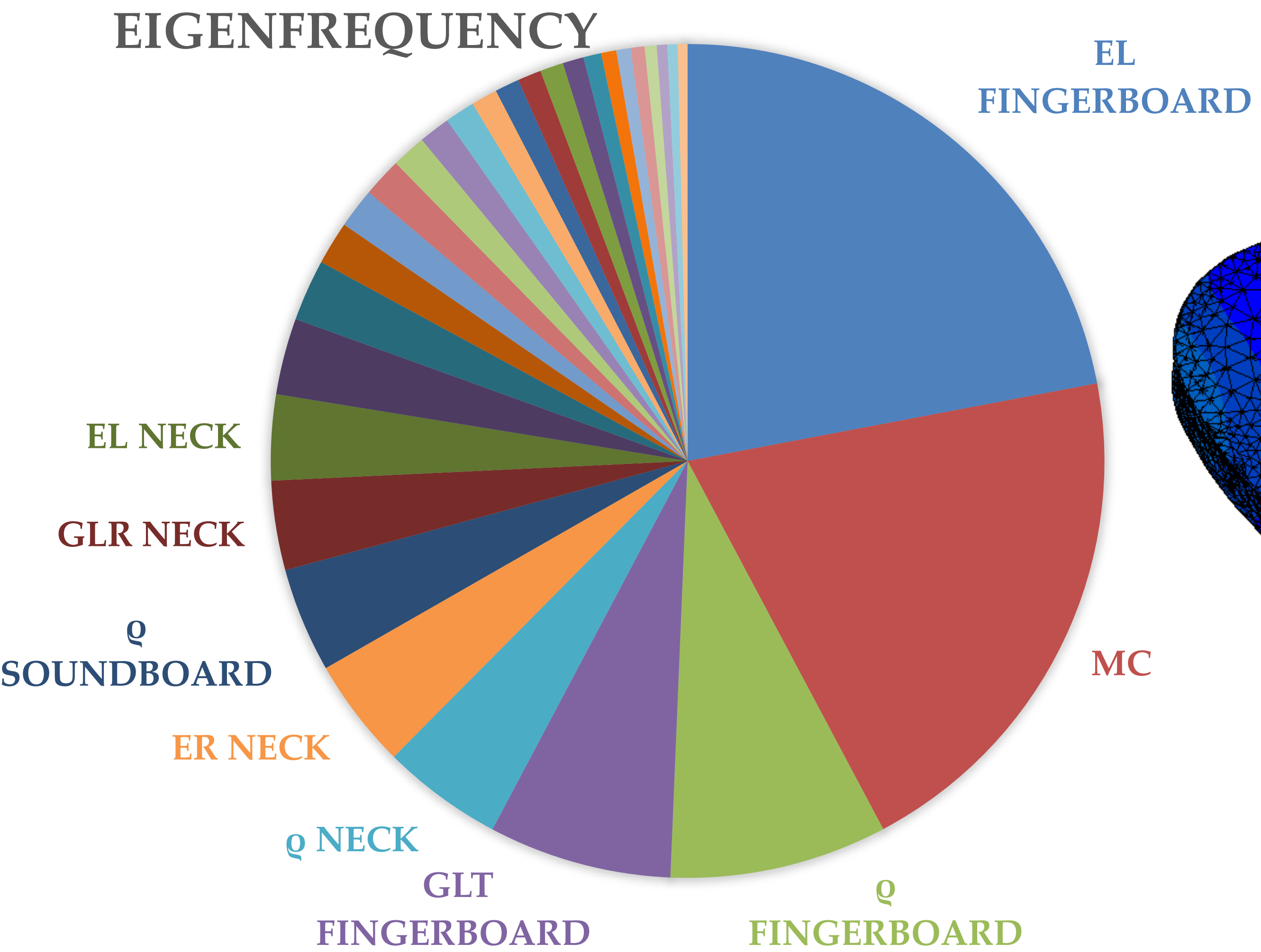


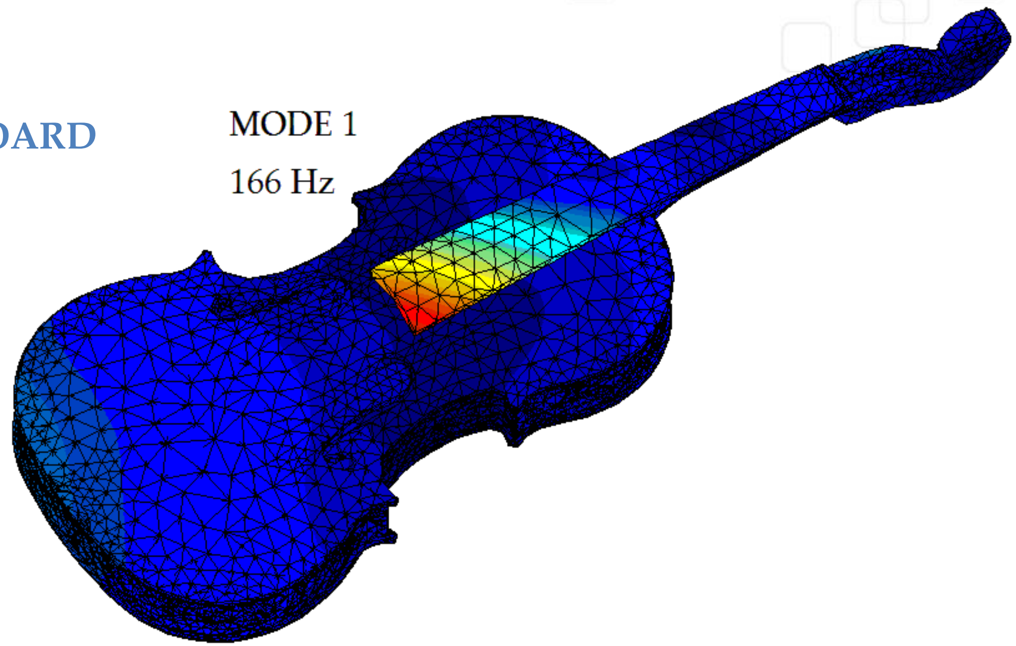
Global behavior

MOF EFFECTS



Results on one local mode





Results on more global modes