COMSOL CONFERENCE 2018 LAUSANNE

B&C SPEAKERS

A simulation test bench for decay times in room acoustics

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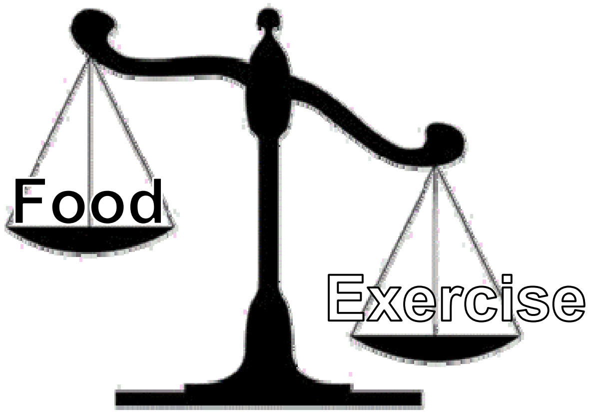
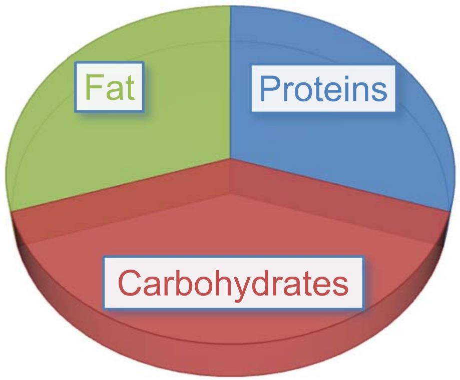
OLD

NEW

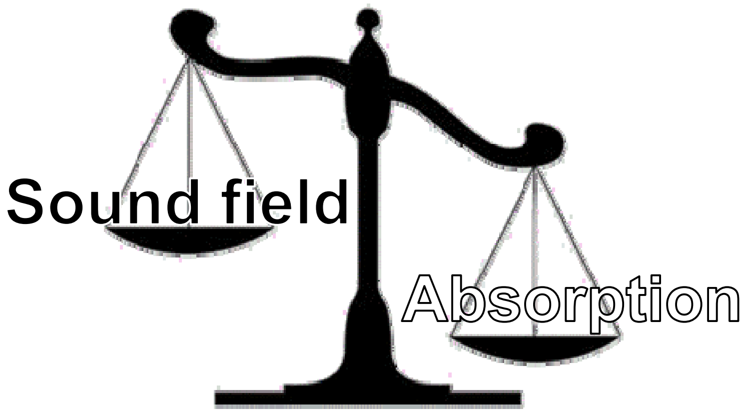
CALORIES



NUTRIENTS



REVERBERATION

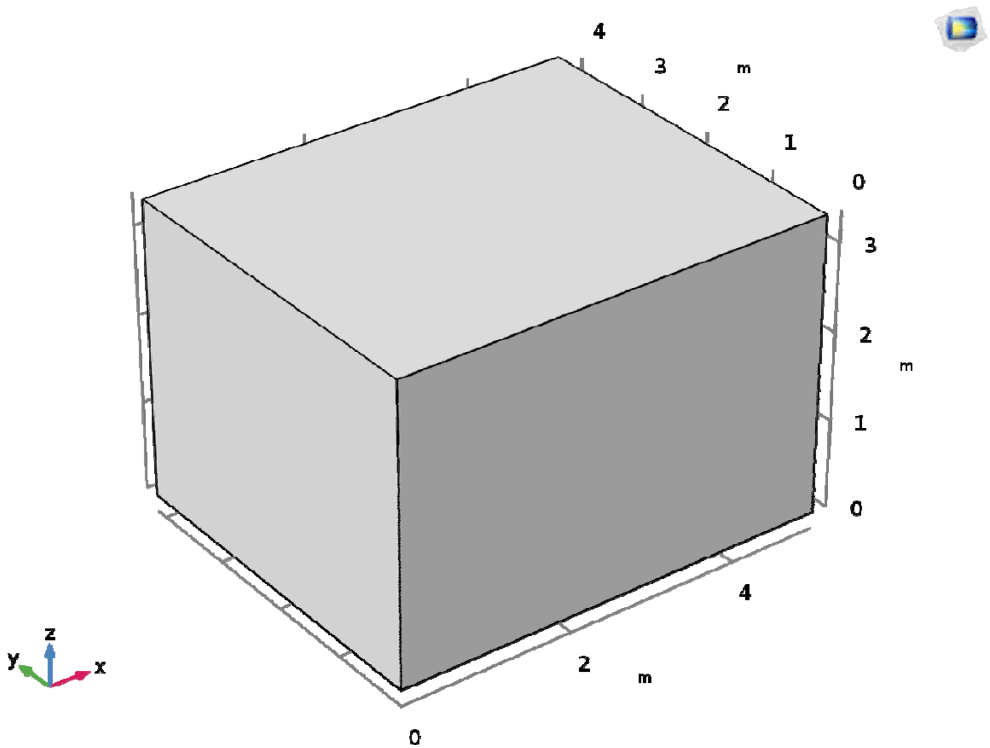


NORMAL MODES

- Shape
- Frequency
- Decay time

Rectangular room

- Size: 70 m^3
  5.02 × 4.15 × 3.36 m

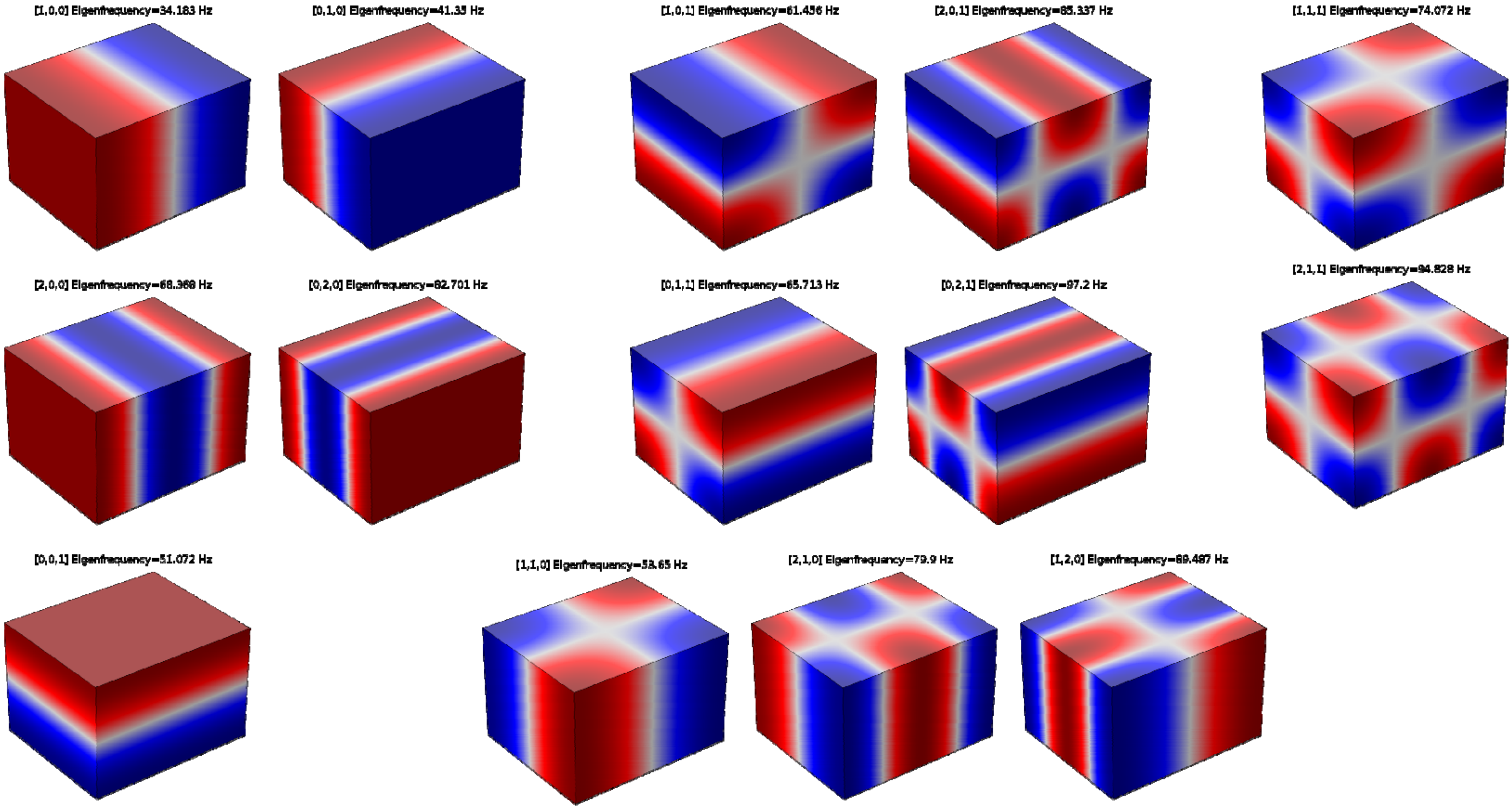


- Modes below 100 Hz:

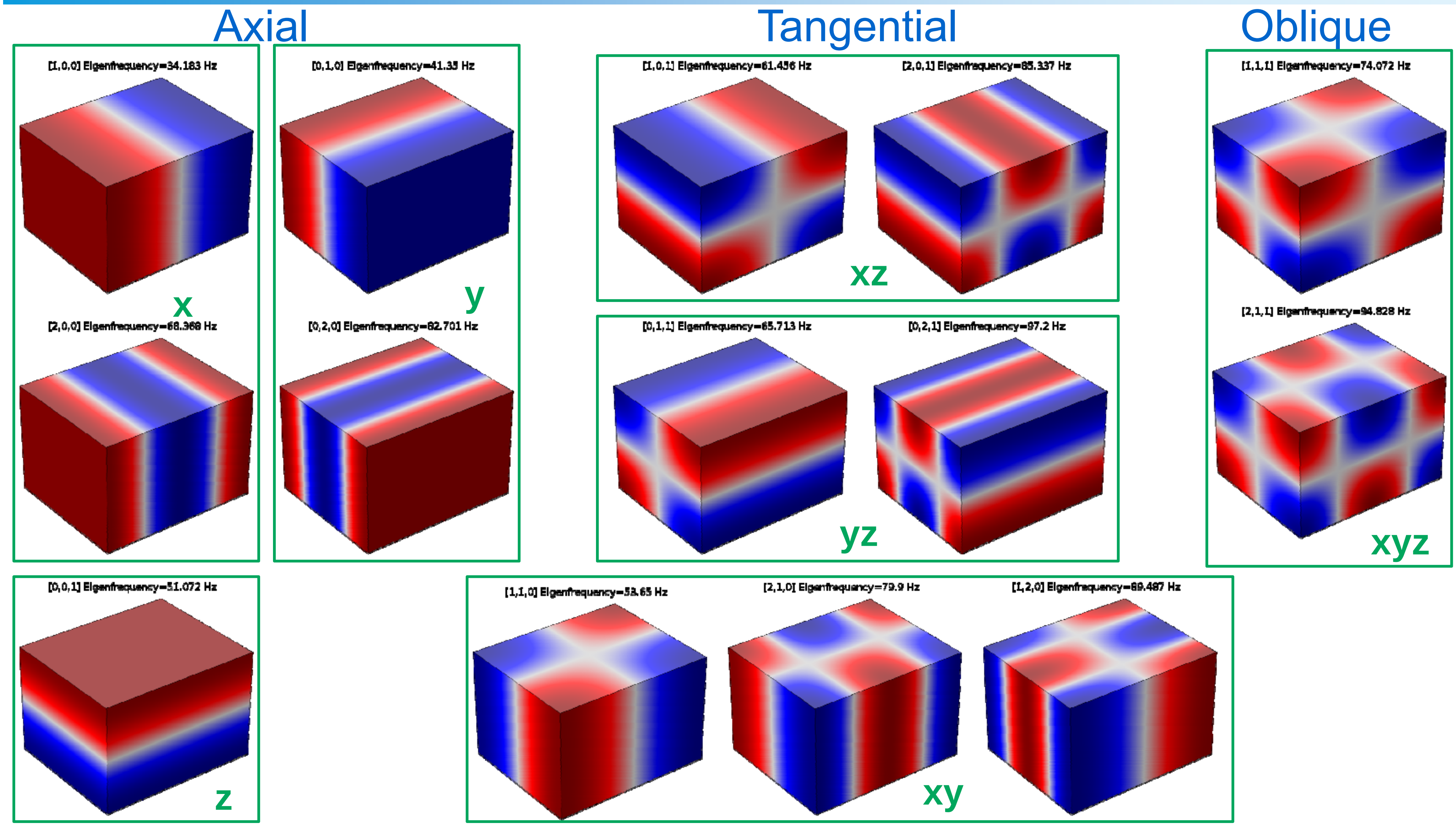
Mode	Frequency (Hz)
[1,0,0]	34.2
[0,1,0]	41.4
[0,0,1]	51.1
[1,1,0]	53.7
[1,0,1]	61.5
[0,1,1]	65.7
[2,0,0]	68.4
[1,1,1]	74.1
[2,1,0]	79.9
[0,2,0]	82.7
[2,0,1]	85.3
[1,2,0]	89.5
[2,1,1]	94.8
[0,2,1]	97.2

Mode classification

Axial | Tangential | Oblique



Mode classification



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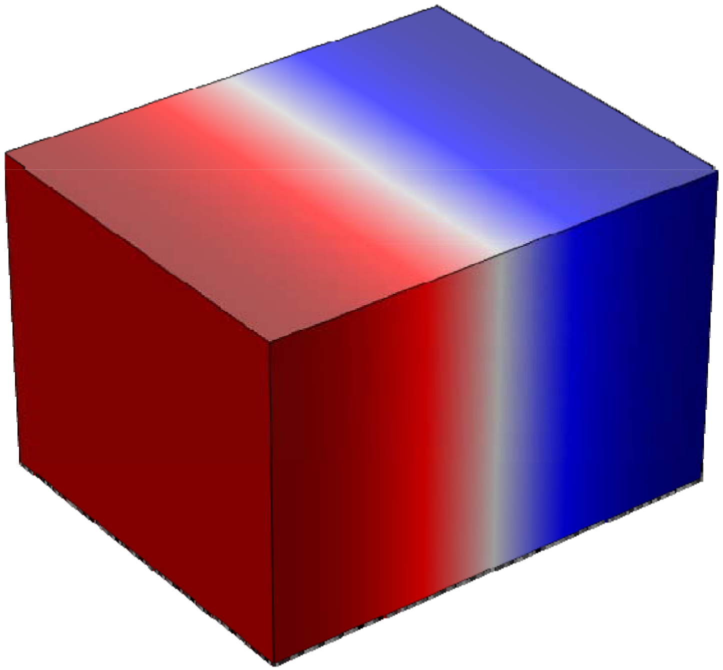
Modal decay times in COMSOL

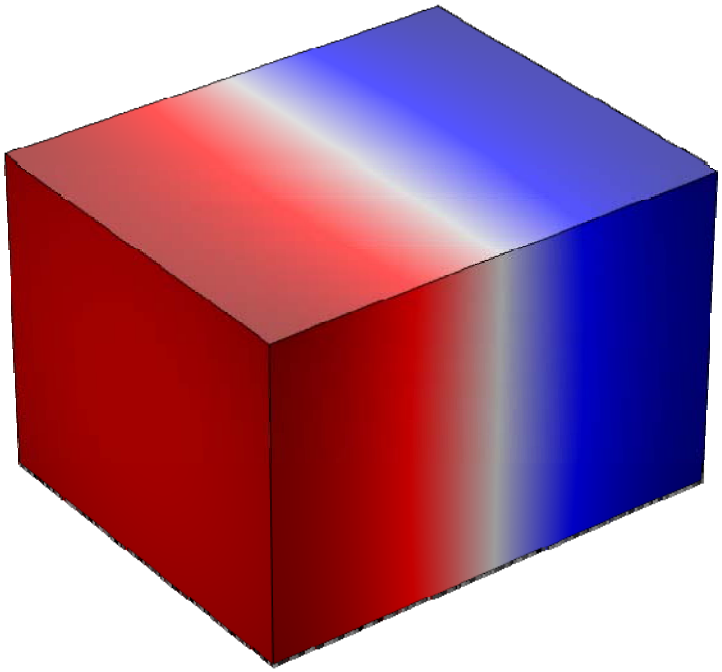
Sound Hard Walls

[1,0,0] Eigenfrequency=34.183 Hz



Finite Walls Impedance

[1,0,0] Eigenfrequency=34.182+0.36569i Hz

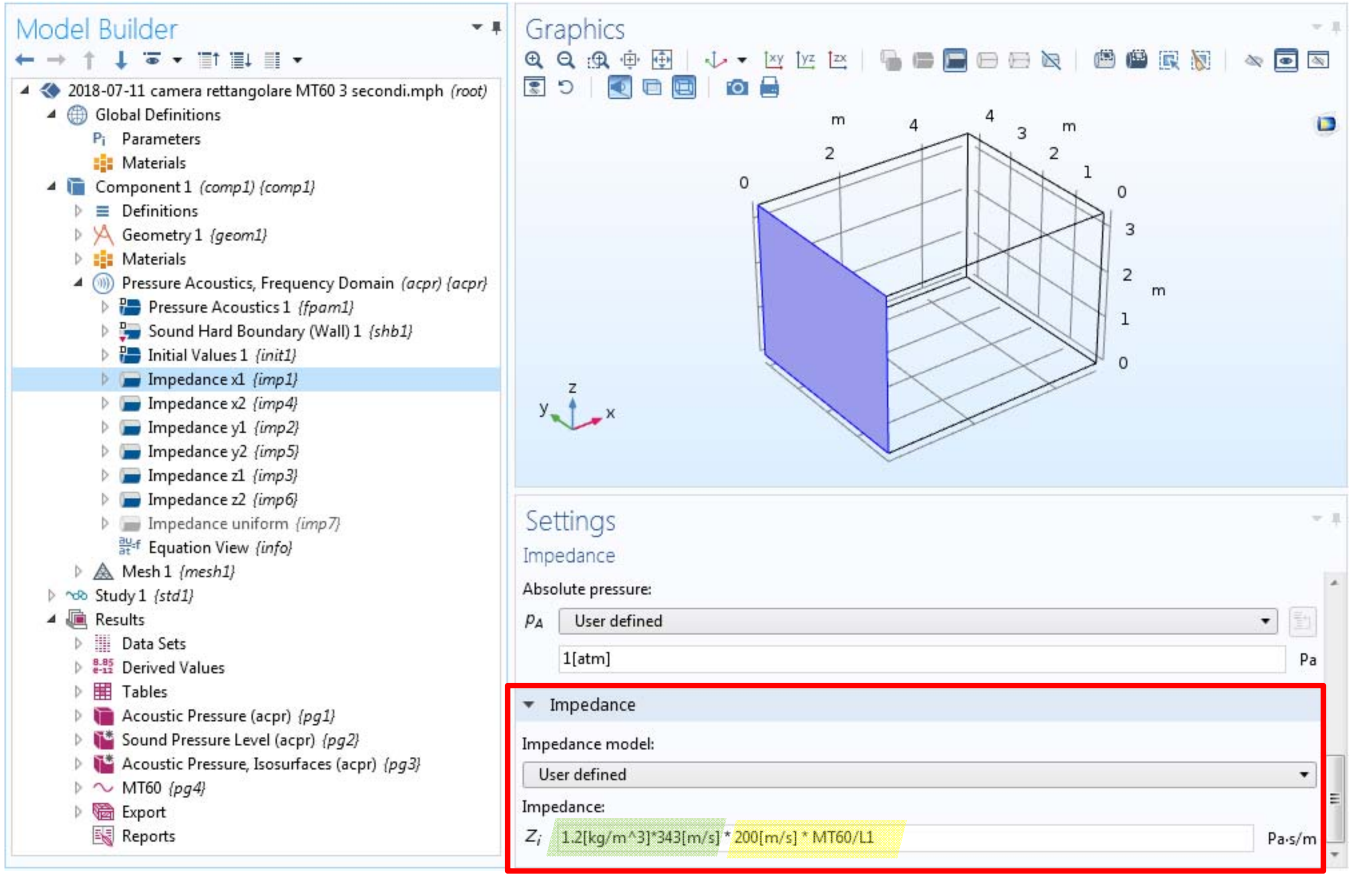


$$MT_{60} = \frac{1.1}{\text{imag}(freq)} \Rightarrow MT_{60} = \frac{1.1}{0.366[\text{Hz}]} = 3[\text{s}]$$

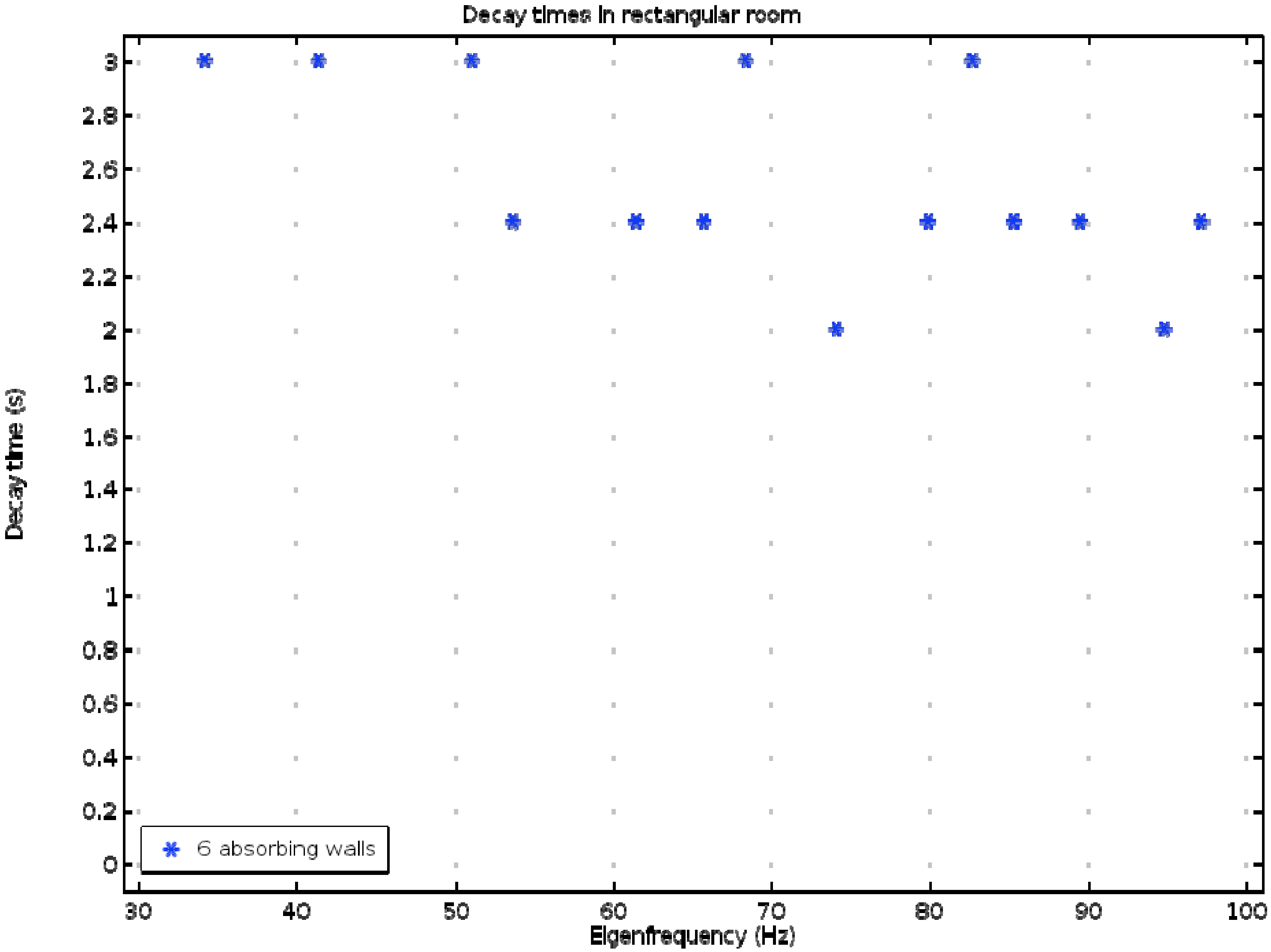
Wall impedance ↔ MT_{60}

Formula to get the same MT_{60} in all **axial** modes:

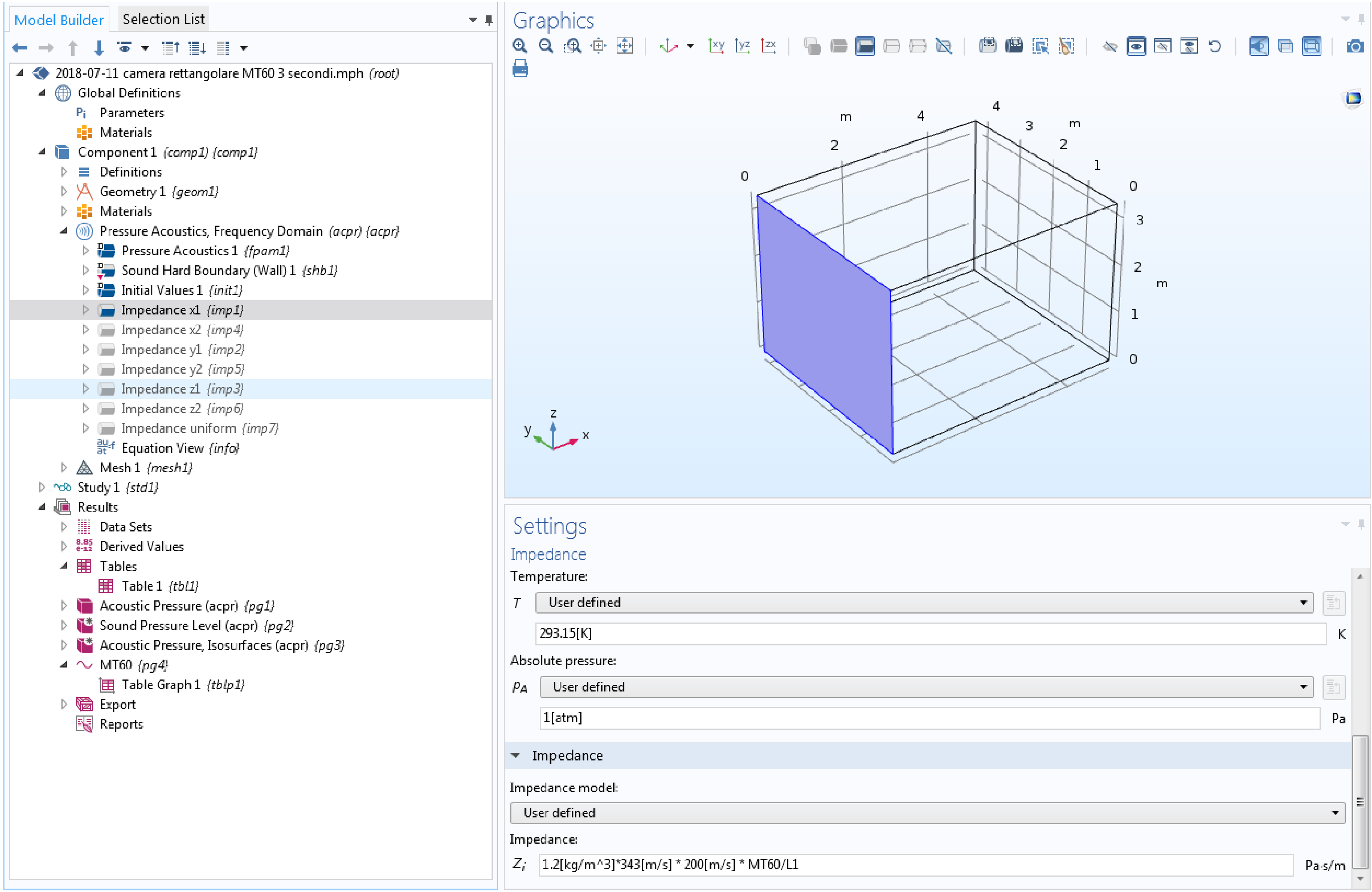
$$\zeta_i = \frac{Z_i}{\rho c} \approx 200\frac{MT_{60}}{l_i}$$



Rectangular room decay times



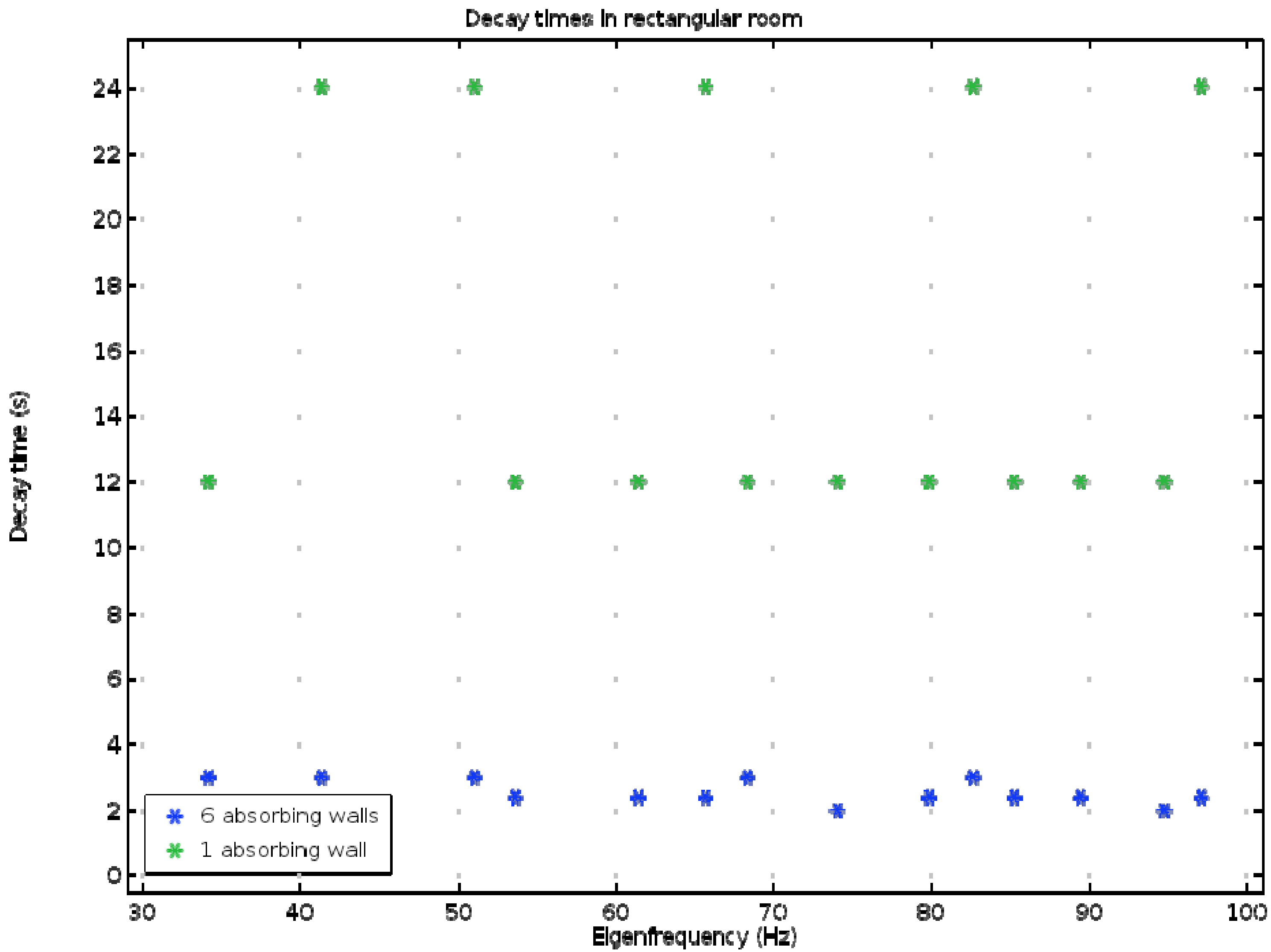
Single absorbing wall



Single absorbing wall

- Expectations
  - Decay time of axial modes in *x* will double
  - Decay time of all other modes will be even higher, because of reduced absorption from the *x* wall

Single absorbing wall: decay times



Single absorbing wall

- Expectations
  - Decay time of axial modes in *x* will double
  - Decay time of all other modes will be even higher, because of reduced absorption on the *x* wall
- Results
  - Decay time of axial modes in *x* is **4×**
  - Many modes have the same decay time as the axial modes in *x*
  - Only the modes with [0,*n*,*m*] mode index have a higher decay time

Conclusions

- Simple relationships between modal decay times and wall impedances can be found and tested
- Therefore, the acoustic impedance of real walls can be computed from measurements of modal decay times
- In the case shown, lateral walls account for **half** the absorption of axial modes
- FEM simulations are very helpful in investigating models of low frequency room acoustics

THIS IS JUST THE BEGINNING

Thank you!

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Theoretical Acoustics, pag. 572

$$q_{x0} \simeq \frac{1}{\pi i}\sqrt{ikl_x(\beta_{x0}+\beta_{x1})} \qquad q_{xn} \simeq n - i\frac{kl_x}{\pi^2 n}(\beta_{x0}+\beta_{x1})$$

$$K_n{}^2 \simeq \left(\frac{\pi q_{xn_x}}{l_x}\right)^2 + \left(\frac{\pi q_{yn_y}}{l_y}\right)^2 + \left(\frac{\pi q_{zn_z}}{l_z}\right)^2$$

$$K_n \simeq \eta_n - \frac{ik}{2\eta_n}\left(\epsilon_{n_x}\frac{\beta_{x0}+\beta_{x1}}{l_x} + \epsilon_{n_y}\frac{\beta_{y0}+\beta_{y1}}{l_y} + \epsilon_{n_z}\frac{\beta_{z0}+\beta_{z1}}{l_z}\right) \qquad (9.4.31)$$

$$\Psi_n \simeq \cos\left(q_{xn_x}\frac{\pi x}{l_x} + i\beta_{x0}\frac{kl_x}{\pi q_{xn_x}}\right) \times \cos\left(q_{yn_y}\frac{\pi y}{l_y} + i\beta_{y0}\frac{kl_y}{\pi q_{yn_y}}\right)\cos\left(q_{zn_z}\frac{\pi z}{l_z} + i\beta_{z0}\frac{kl_z}{\pi q_{zn_z}}\right)$$