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Fabric-Elasticity Relationships in Cortical Bone

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January, 2025

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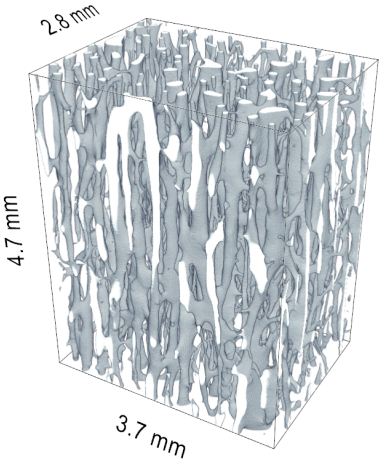
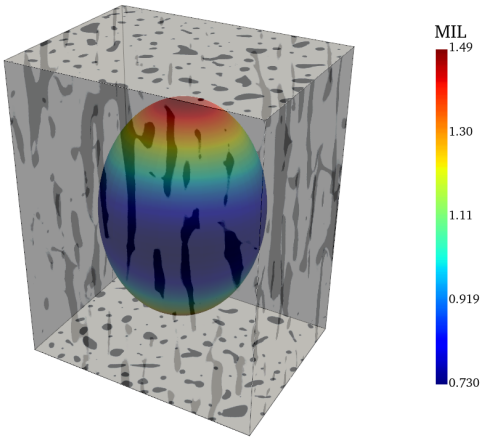
Material

Data

- 59 scans
- 6.5 µm voxel size
- RUS measurements
- CTAnalyser





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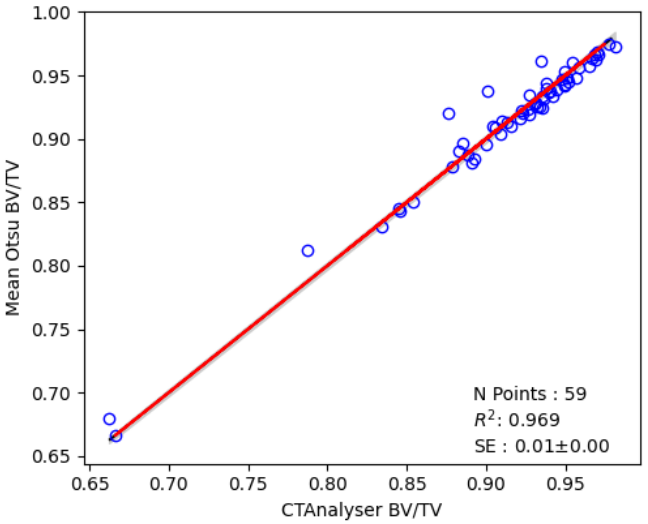
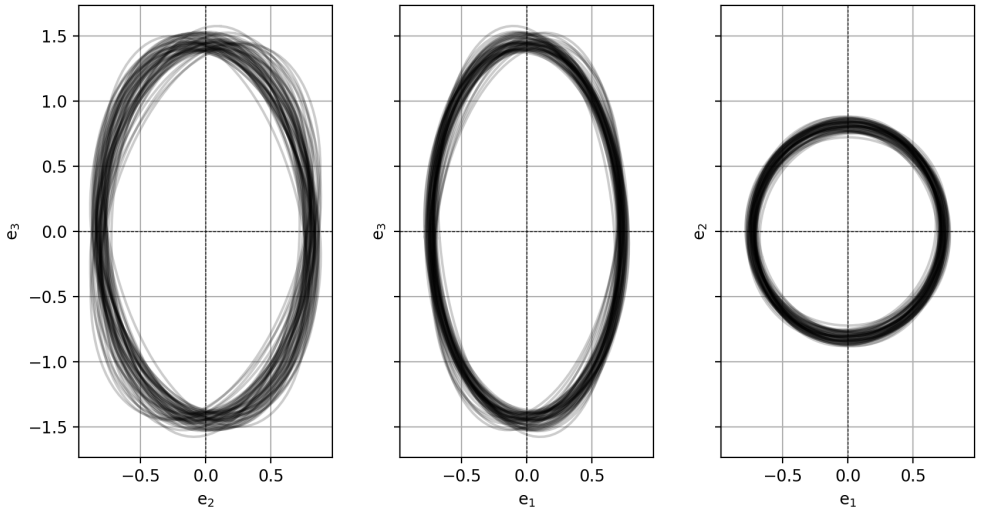
Segmentation

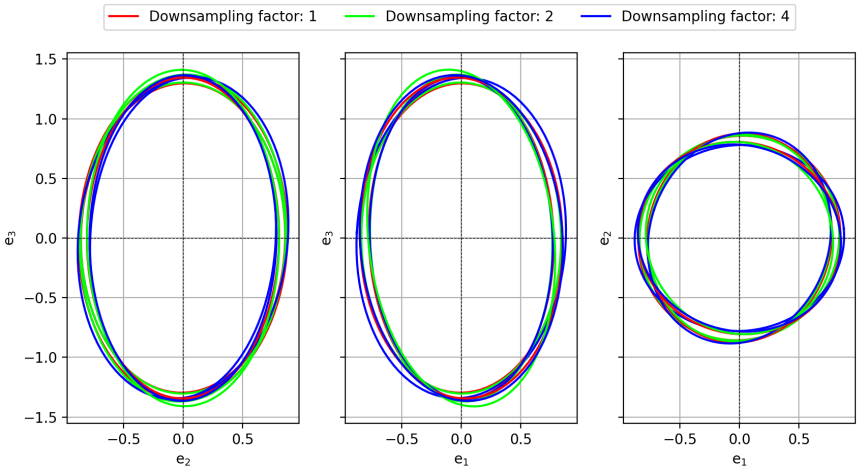
Mean Otsu threshold

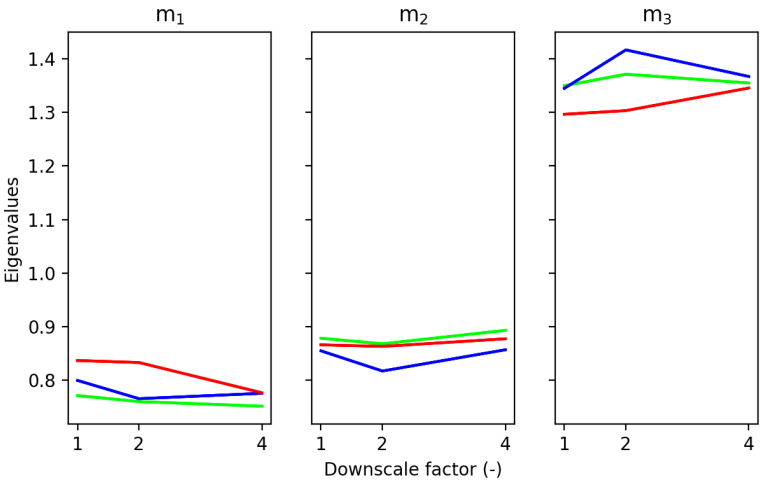


Fabric distribution



Resolution Effect - Fabric





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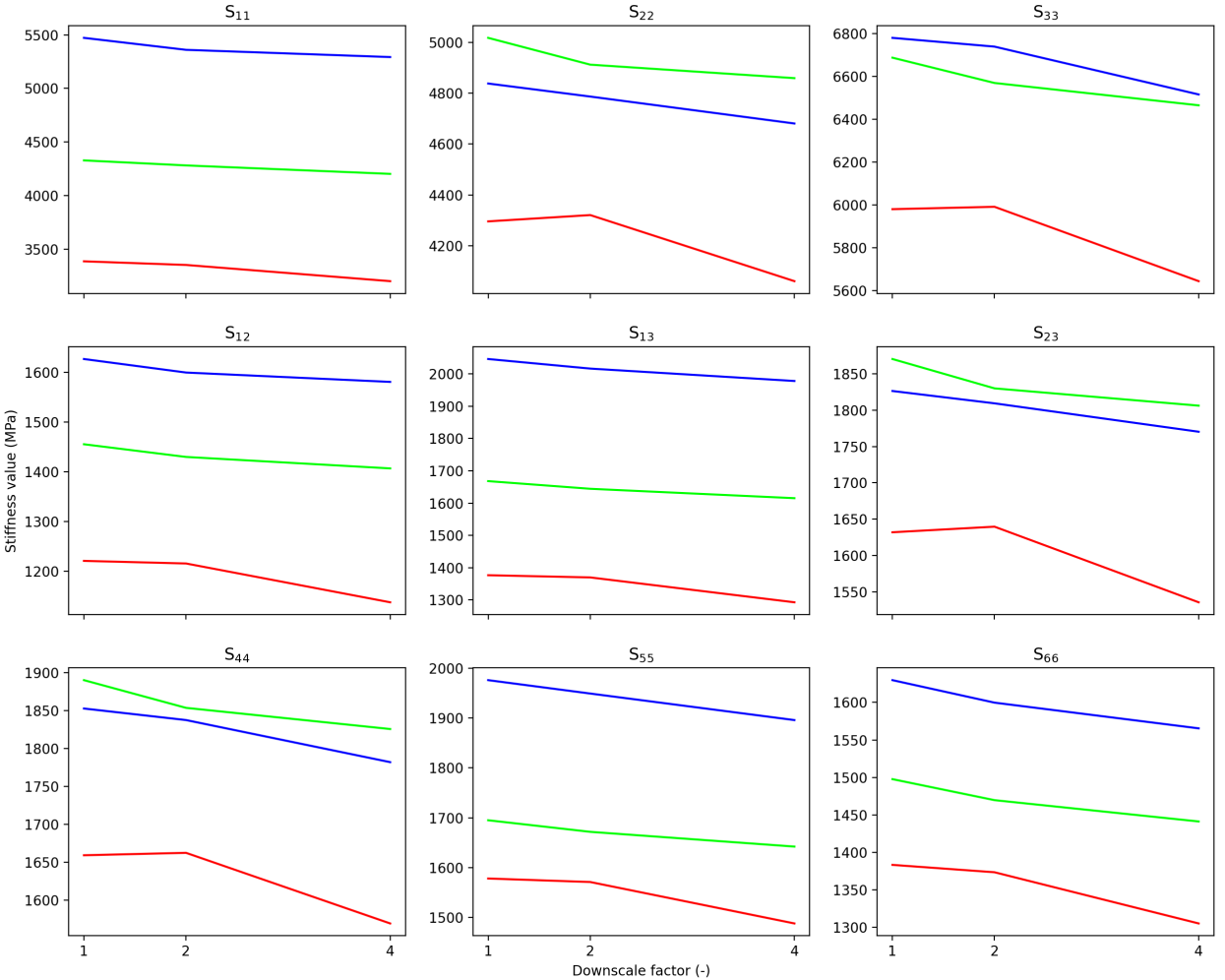
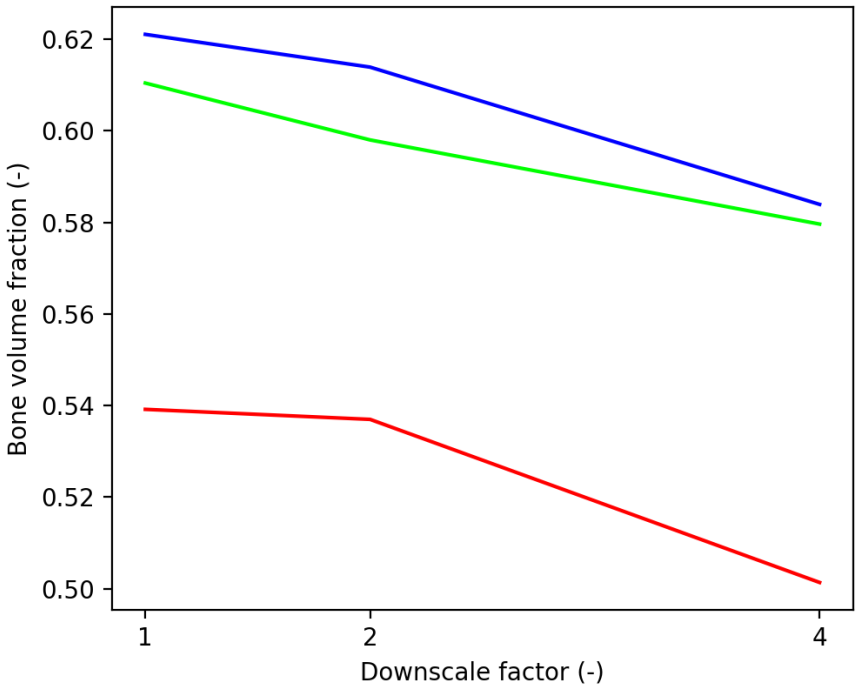
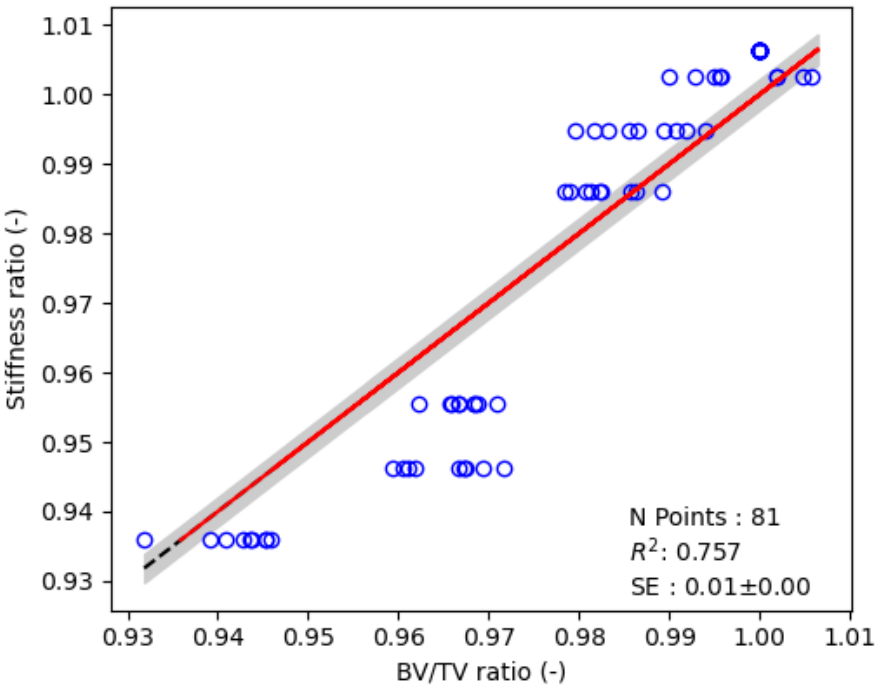
Resolution Effect - Elasticity



Resolution Effect - Elasticity II





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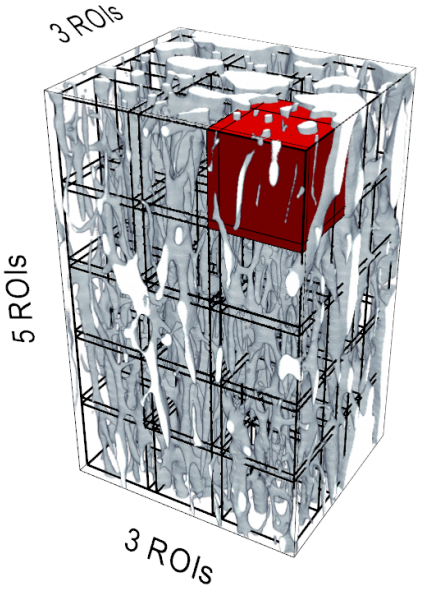
Convergence Study

Setup

- 1mm ROI side length
- 3x3x5 ROIs
- 65 µm margin
- Groups of 1, 2, ..., 45 ROIs

→ ~2^{45} possibilities



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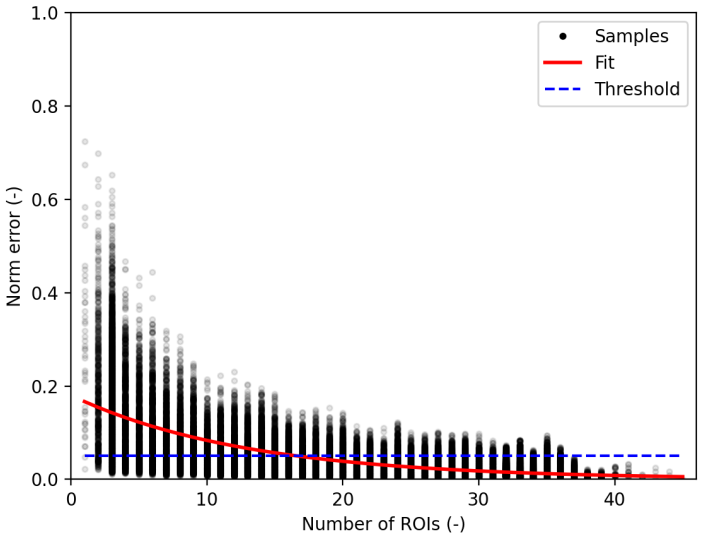
Convergence Study

Sampling

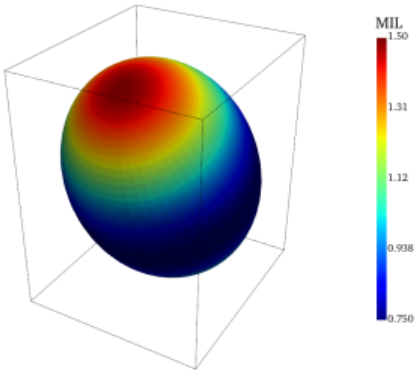
- Balanced clustering
  → Linear sum assignment
  → $216*10^6$ possibilities
- N samples = 1000
- Norm Error
- Threshold = 0.05

→ 15-16 ROIs



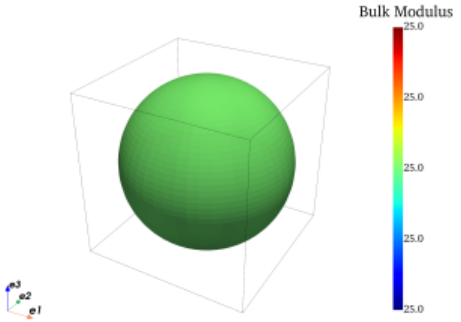
Material Effect

Structure

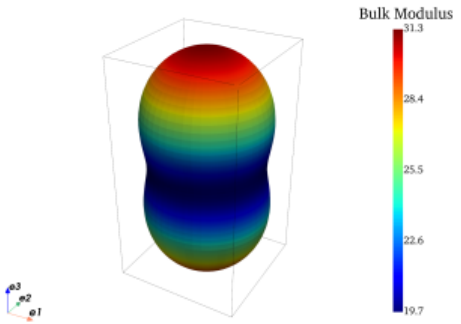


Fabric

Material

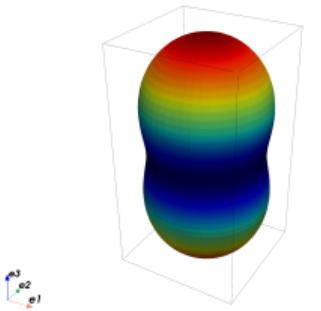


Isotropic



Transverse Isotropic

Mechanics



Transverse Isotropic

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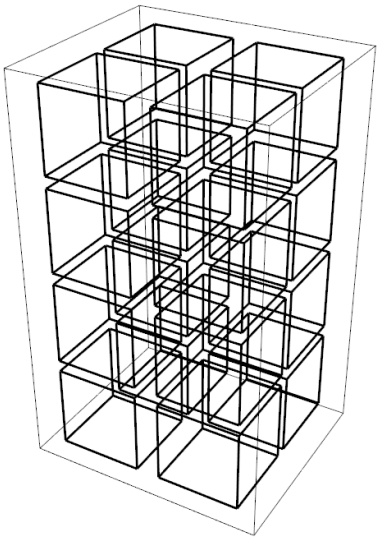
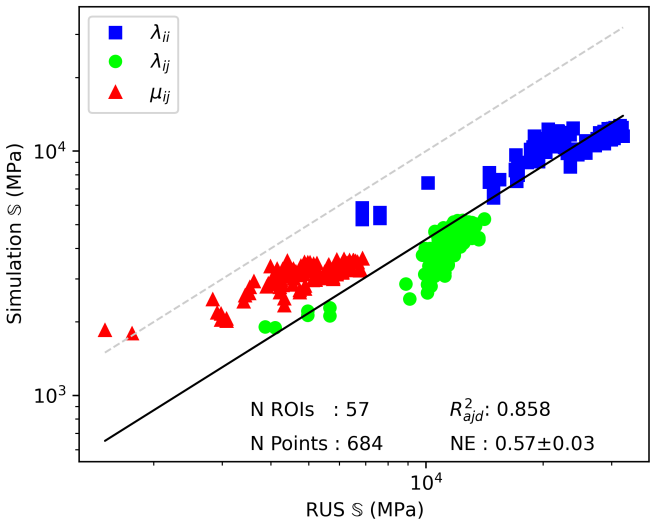
Homogenization

Setup

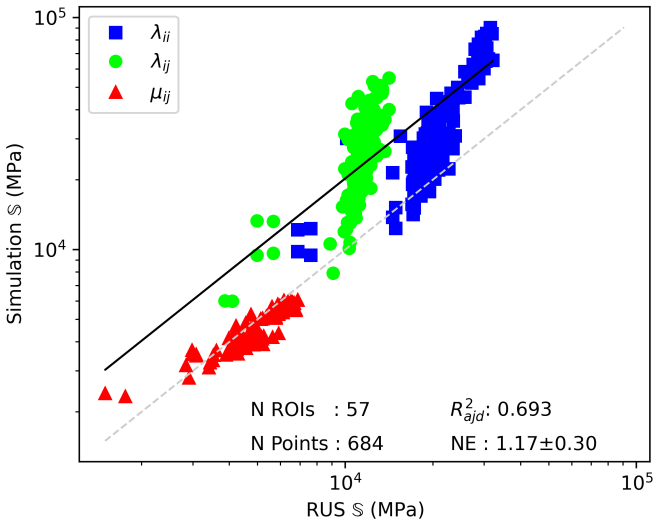
- Downsampling factor: 2
- 16x1mm^3 ROIs
- Isotropic vs transverse
- Mean $\mathbb{S}$ / Sample



Simulations vs RUS

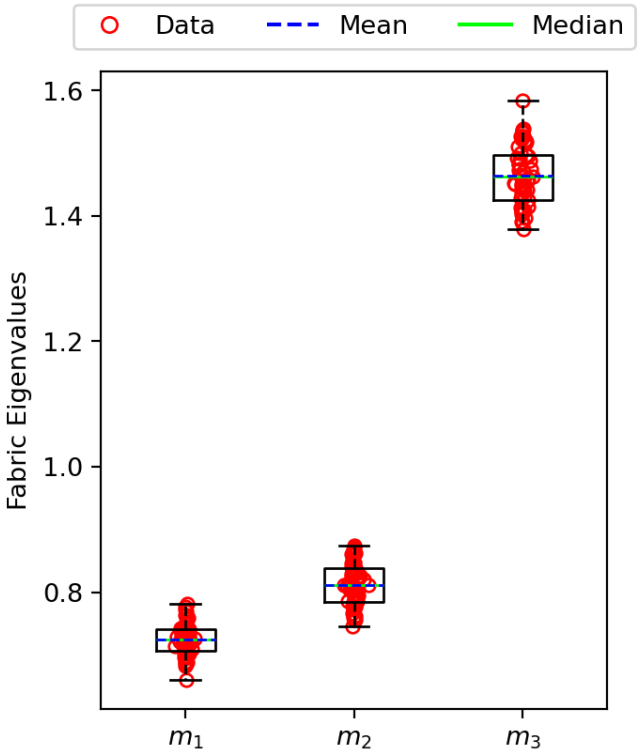


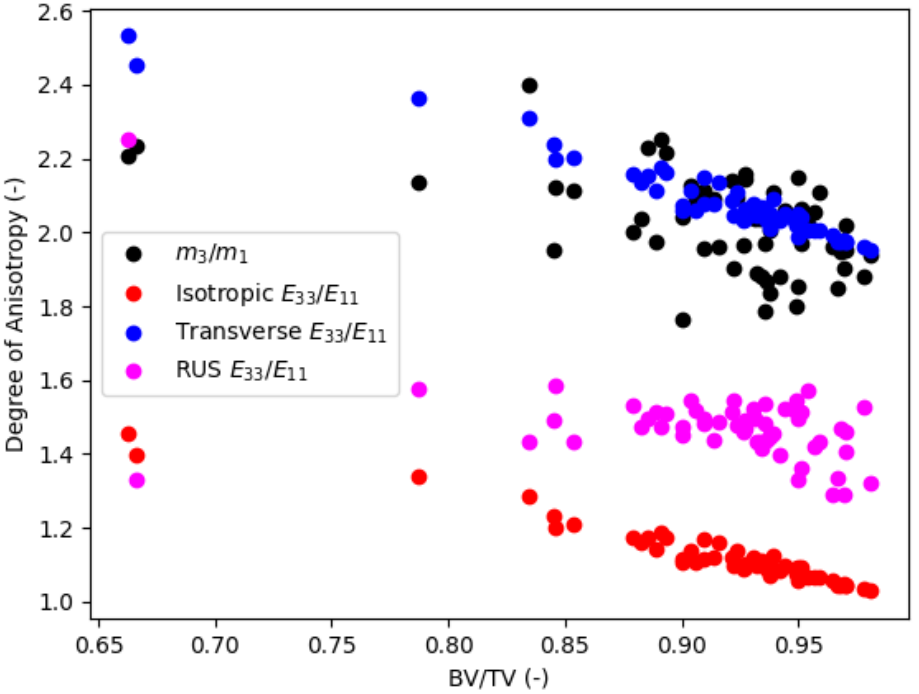
Isotropic Material



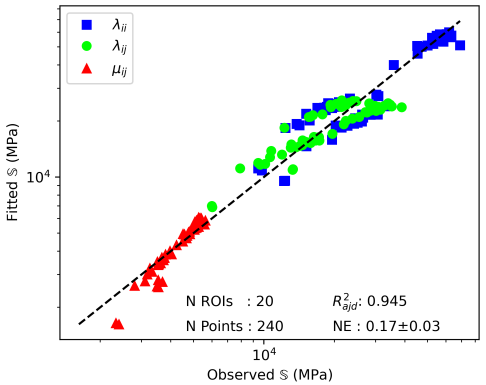
Transverse Isotropic Material

Anisotropy

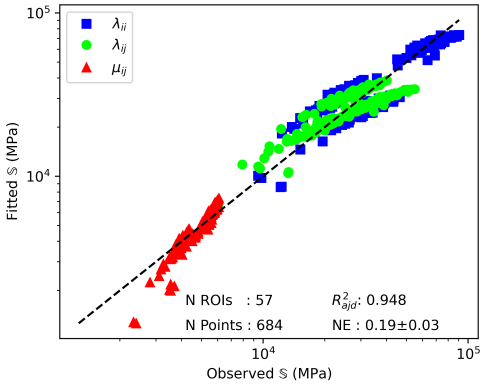

Data
Mean
Median
Fabric Eigenvalues
1.6
1.4
1.2
1.0
0.8
m_1
m_2
m_3


Degree of Anisotropy (-)
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
m_3/m_1
Isotropic E_{33}/E_{11}
Transverse E_{33}/E_{11}
RUS E_{33}/E_{11}
0.65
0.70
0.75
0.80
0.85
0.90
0.95
BV/TV (-)

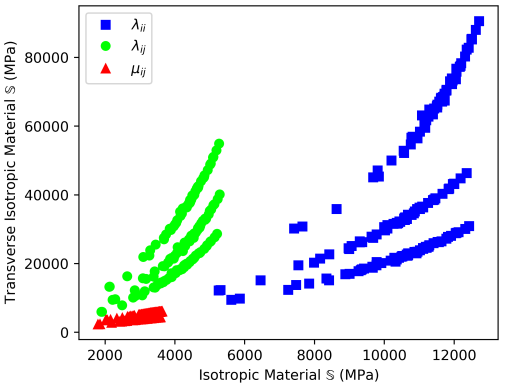
Homogenization



Isotropic



Transverse



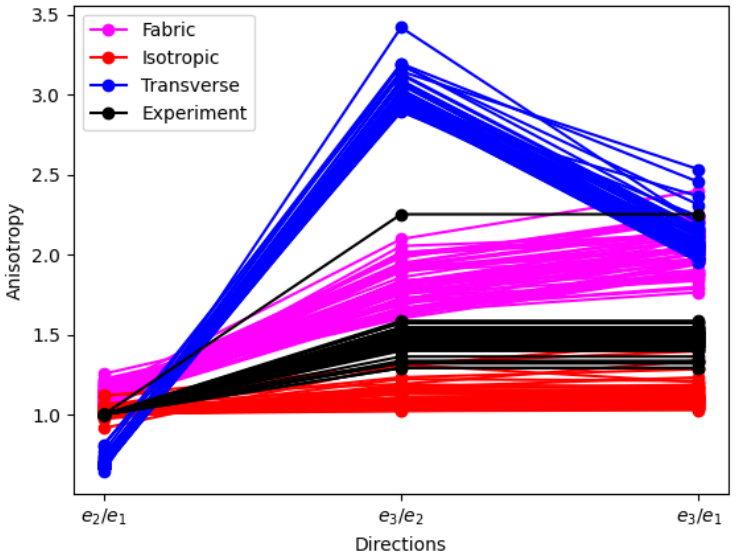
Comparison

Comparison with Trabecular Bone

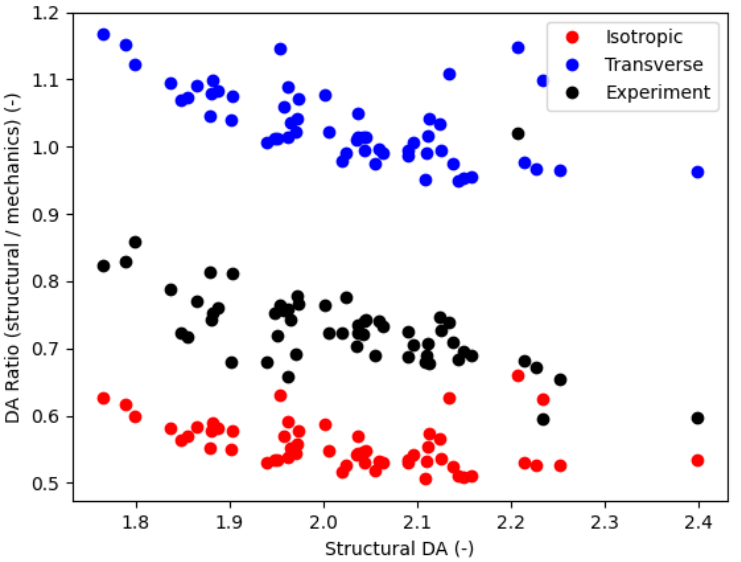
$$\mathbb{S}_{Ts} = \mathbb{S}_T / |\mathbb{S}_T| * |\mathbb{S}_I|$$

Study	Bone type	Resolution	λ_0	λ_0'	μ_0	k	l	DA
Gross et al.	Trab.	18	4609	3692	3738	1.60	0.99	1.67
Panyasantisuk et al.	Trab.	36	3841	3076	3115	1.60	0.99	1.54
Simon et al	Trab.	61	2738	1662	2187	1.60	0.99	1.99
Present study	Cort. ($\mathbb{S}_I$)	13	4882	4809	3645	1.60	0.99	2.02
Present study	Cort. ($\mathbb{S}_{Ts}$)	13	6309	6278	1194	1.60	0.99	2.02

Anisotropy



Main directions DA



DA ratios (e_3/e_1)

Comparison l Exponent

$$\mathbb{S}_{Is} = \mathbb{S}_I / |\mathbb{S}_I| * |\mathbb{S}_T|$$

Parameters	λ_0	λ_0'	μ_0	k	l
Isotropic	21480	21156	16035	1	0.075
Transverse	27757	26935	5070	1	0.66