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Validation of measurement strategies and anisotropic models used in electrical reconstructions

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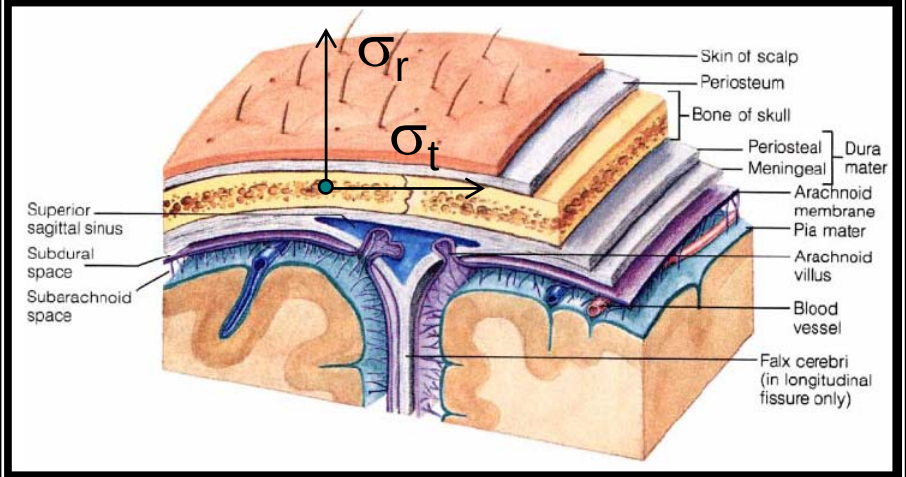
Comsol for low frequency EM problems

- Electro/Magneto statics in 2 and 3D

- Complex geometries and measurement configurations
  - Electrical Impedance Tomography
  - Magnetic Resonance EIT
  - Electrical Bidomains (Cardiac, Neural Tissues)
  - Transcranial Stimulation

Motivation - Skull structure

Adult Bone



Marieb E. N. “Human anatomy & physiology”

Fetal Bone

Frontal Bone

Human fetal skull, decalficied; H&E stain, 40x

Periosteum

Cancellous bone

© Neas and Shao

$\sigma_{Cancellous} \approx 10\sigma_{Compact}$

$t_{Cancellous} \approx t_{Compact}$

Intramembranous ossification

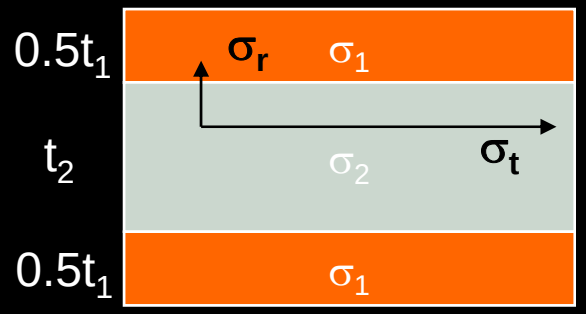
http://cwx.prenhall.com/bookbind/pubbooks/martini10/chapter5/medialib/membrano.html

http://education.vetmed.vt.edu/Curriculum/VM8054/Labs/Lab8/Examples/exmembos.htm

How complex should a layered model be
in order to show truly anisotropic behavior?

Layered Structure

- Apparent anisotropy ratio

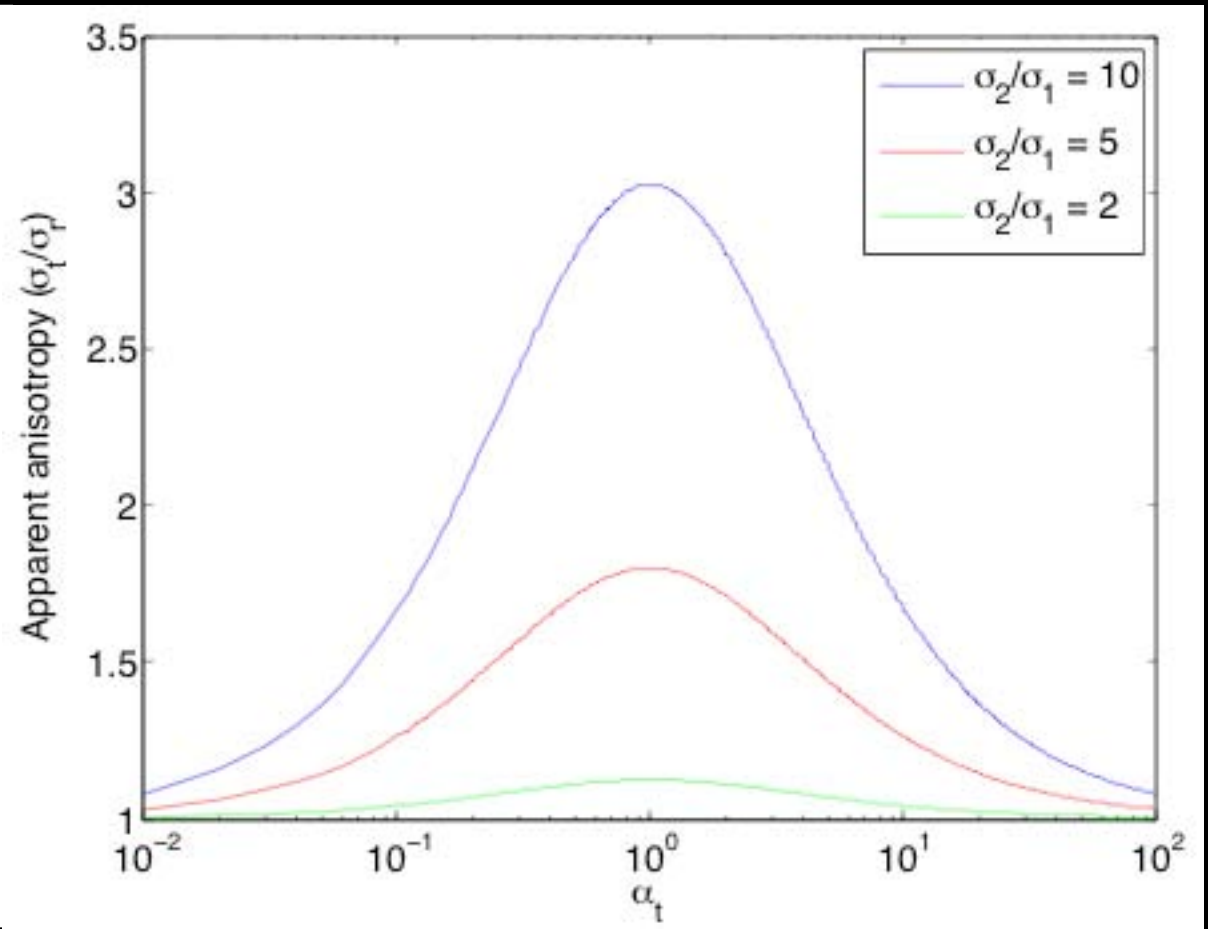


$$\sigma_t / \sigma_r$$

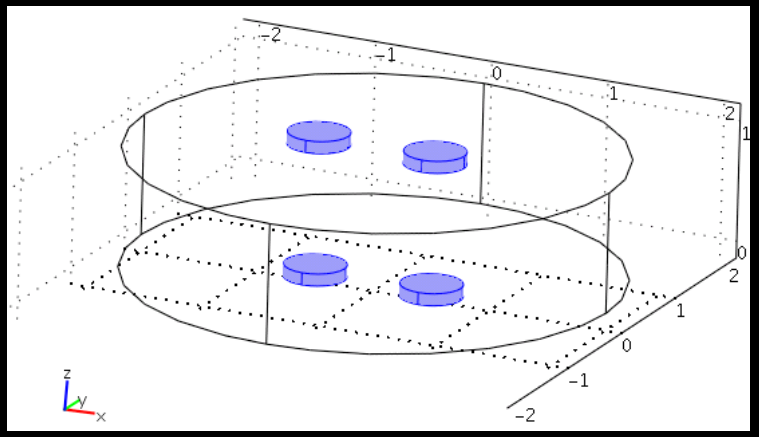
$$\left(\sigma_t / \sigma_r\right)_{\max} \approx \kappa$$

$$\kappa = \frac{\left(\sigma_2 + \sigma_1\right)^2}{4\sigma_1\sigma_2}$$

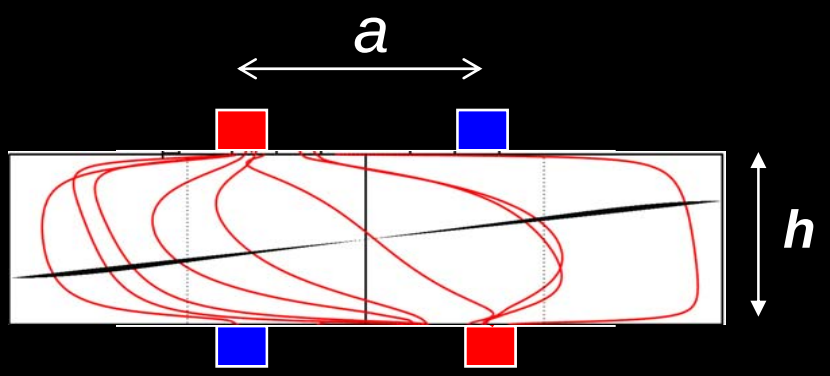
$$\alpha_t = \frac{t_2}{t_1}$$



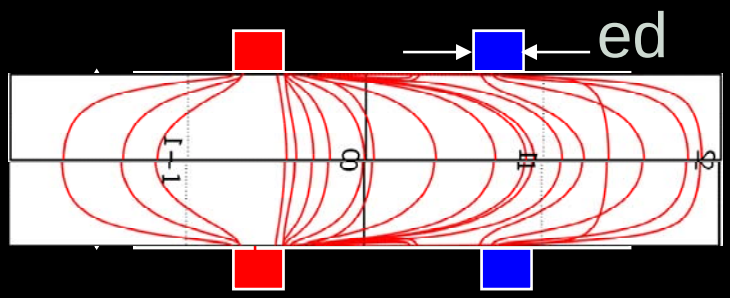
Measurement Configurations



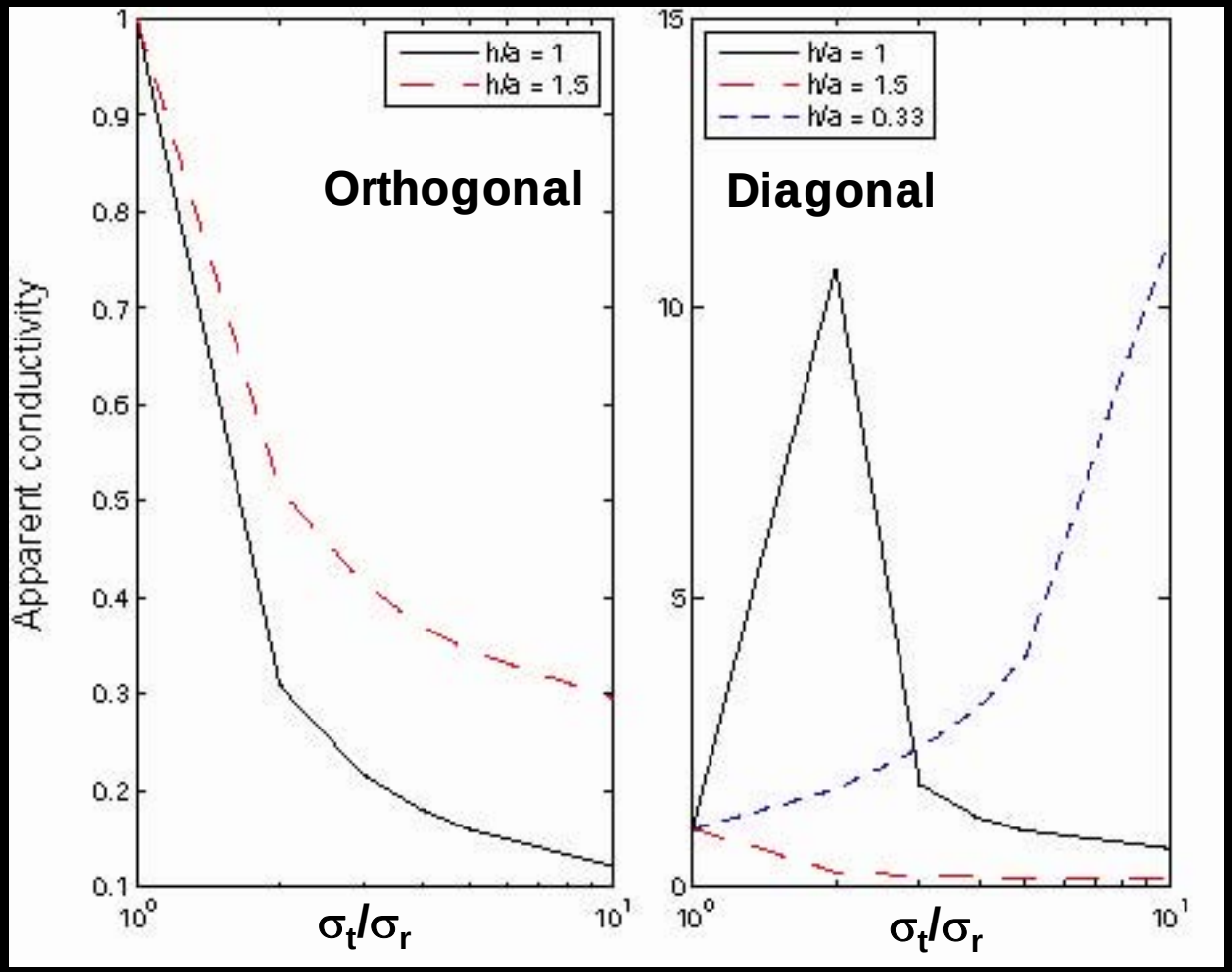
- Diagonal



- Orthogonal



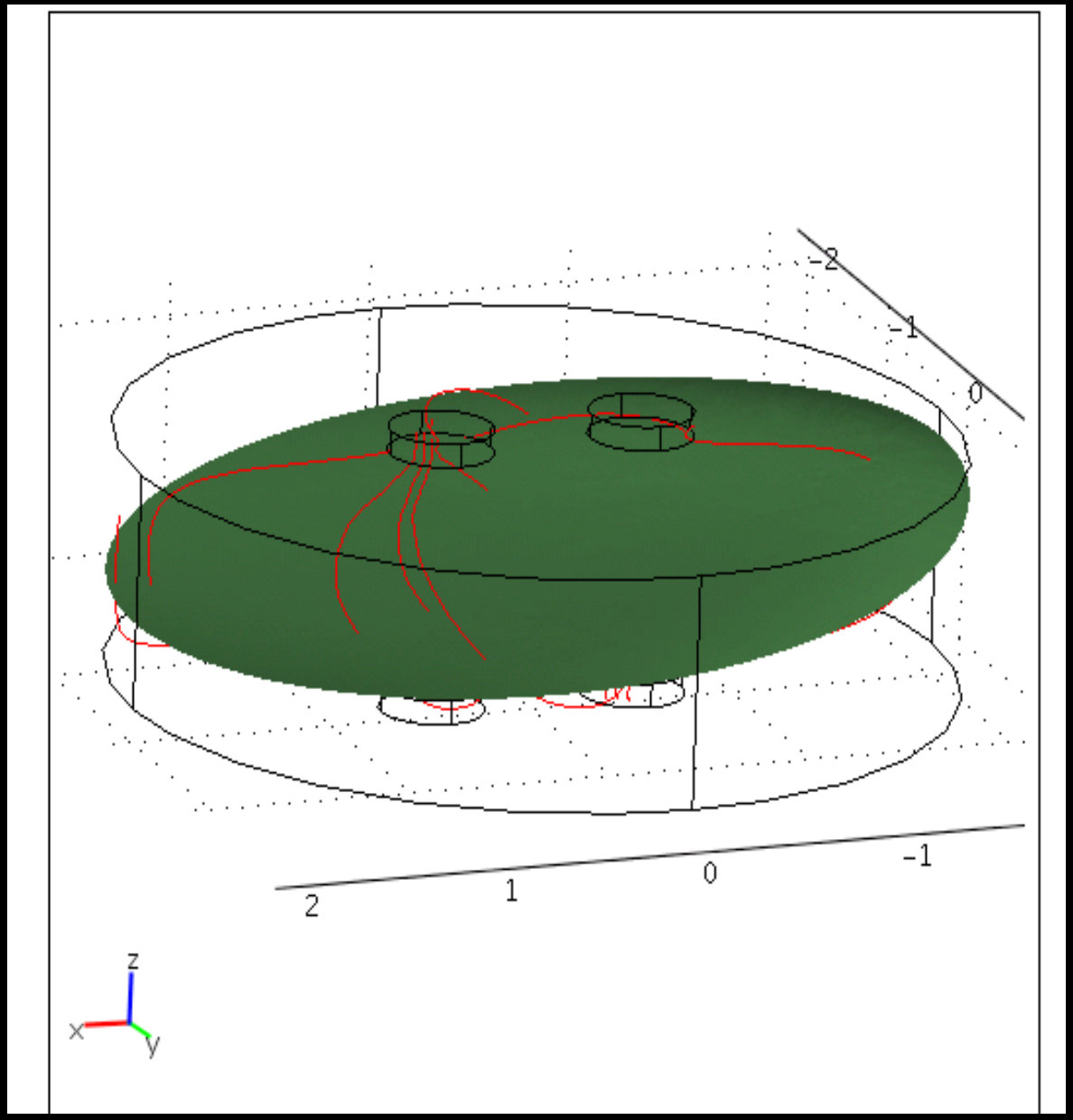
Conductivity dependence on anisotropy ratio



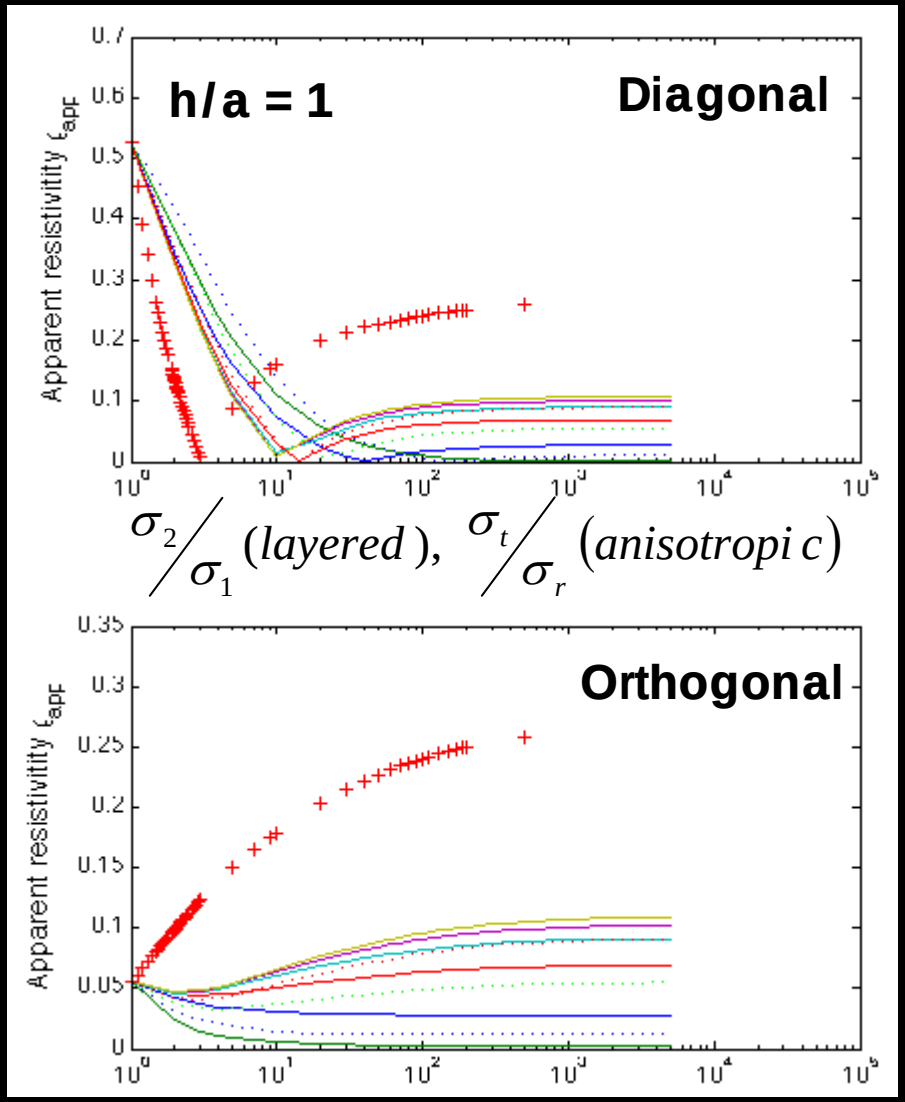
- Pure anisotropy
- Infinite finite thickness slab
- Analytic calculation

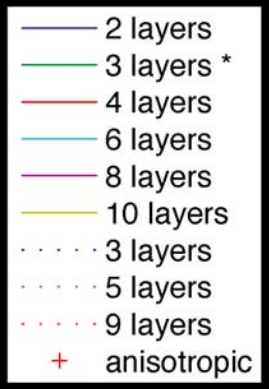
Diagonal Configuration

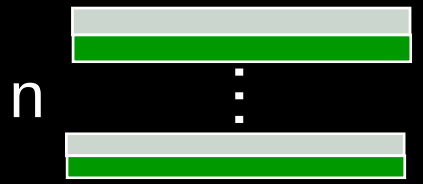
0V isosurfaces



Comparison of layered and anisotropic results (2d)

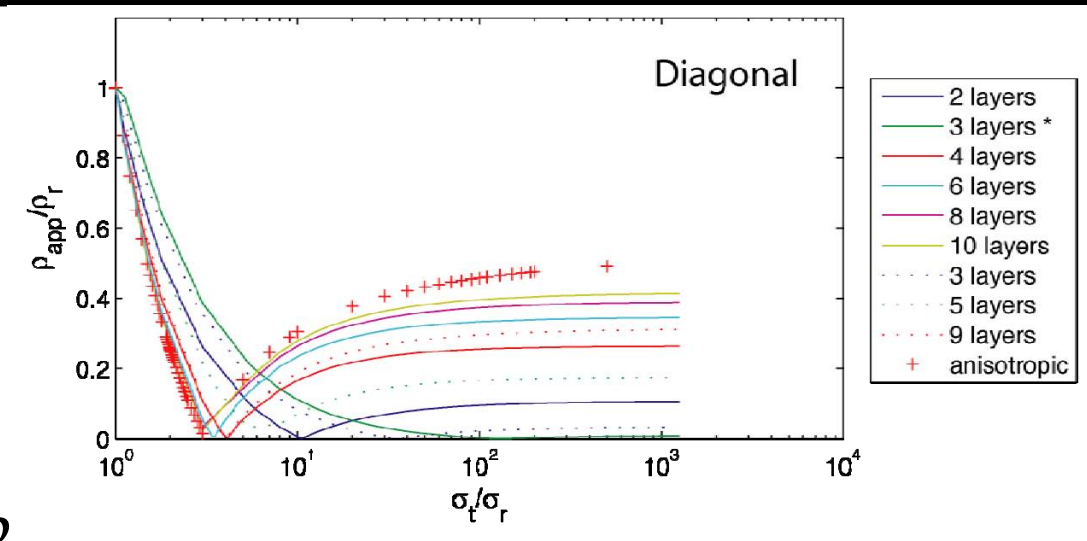


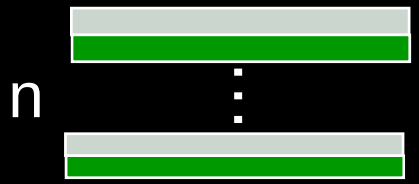




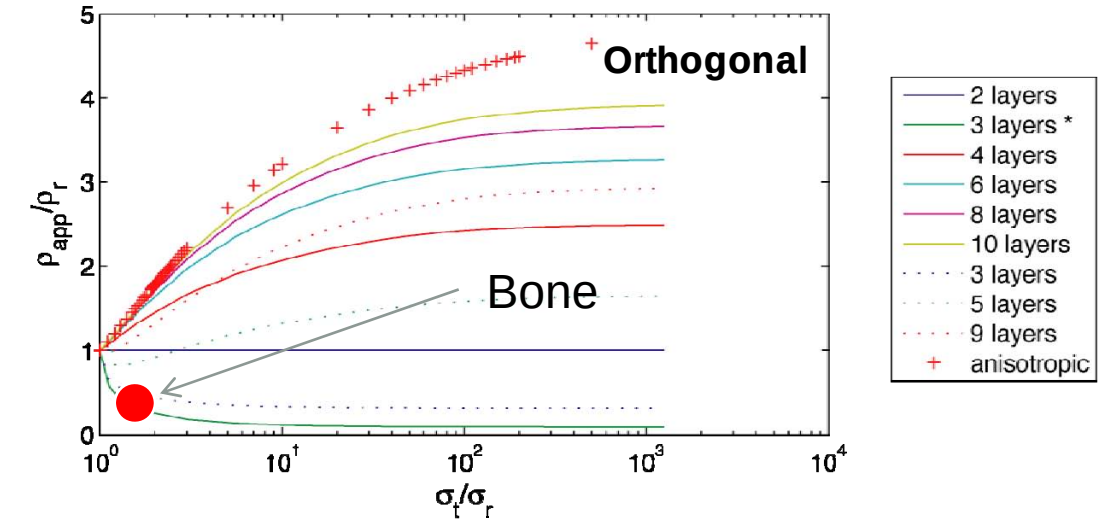
Sadleir and Argibay *Ann. Biomed. Eng.* (2007)

Modeling comparison: (in 2d) - rescaled





ρ_{app} / ρ_r



h/a = 1

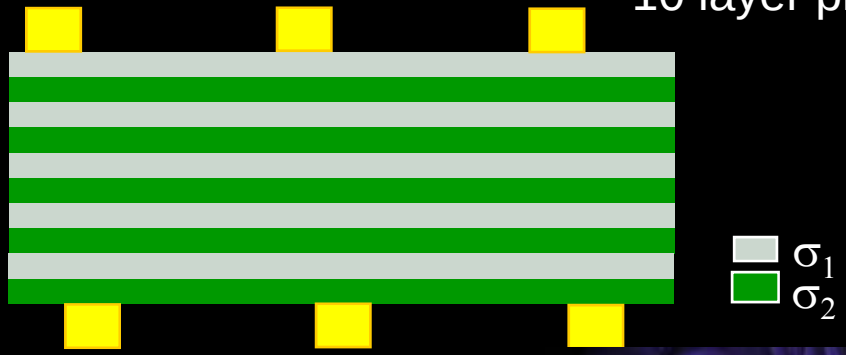
Anisotropic Phantoms

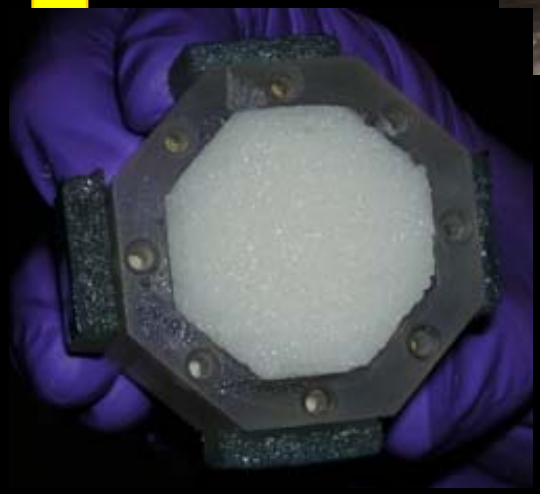
- Anisotropic conductivity reconstruction algorithms are emerging
  - DTI
  - MREIT
  - EIT
- These algorithms must be tested in controlled conditions
  - Predictable and well-characterized
  - Easily controlled anisotropy ratio
  - *Anisotropic*
  - Effect of using isotropic reconstruction method with anisotropic data

Phantom Construction

- Number of layers required depends on sample size and interelectrode spacing

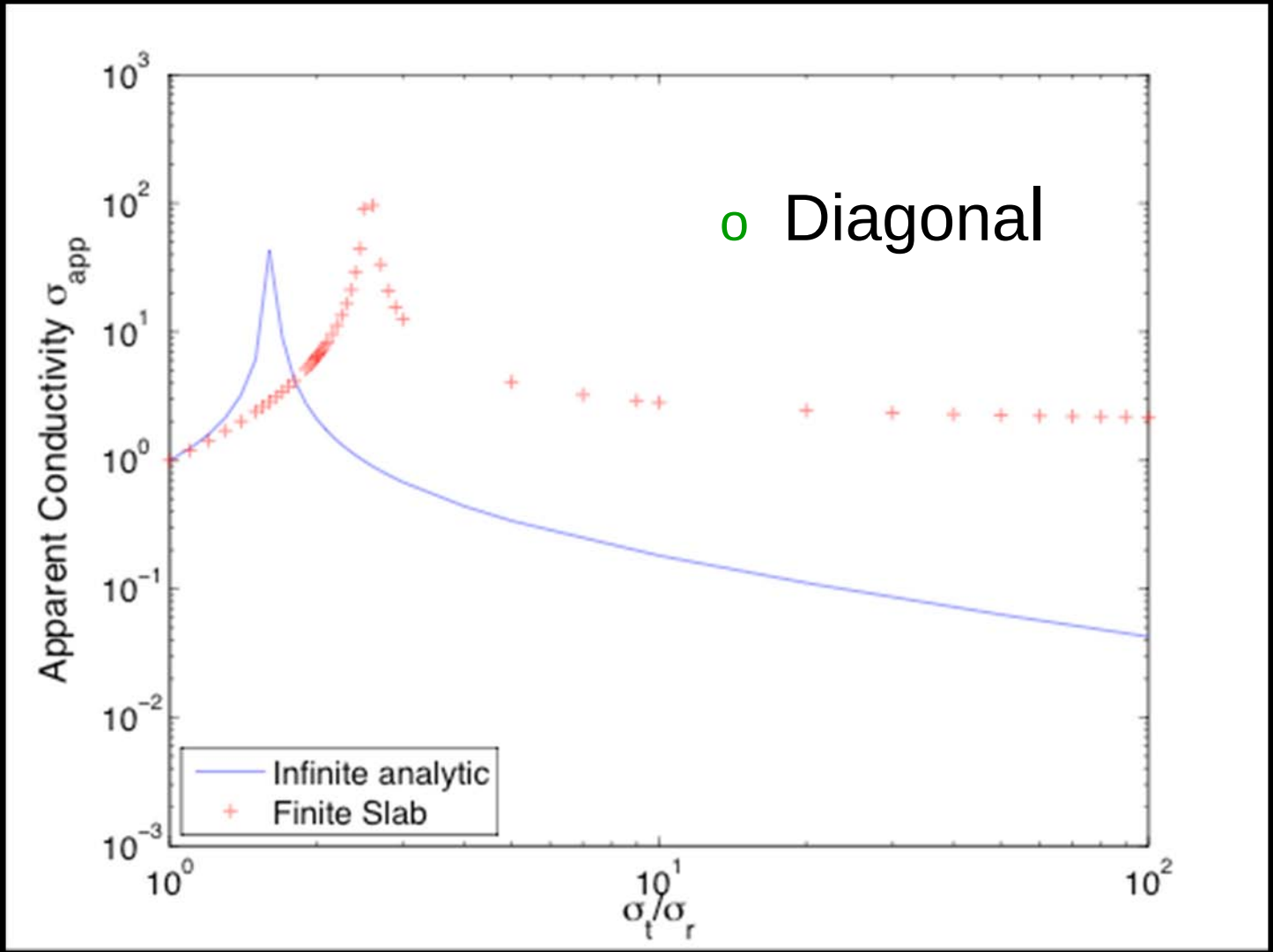
10 layer phantom





- TX-151 anomalies
  - Cut and paste
  - Alternate pouring

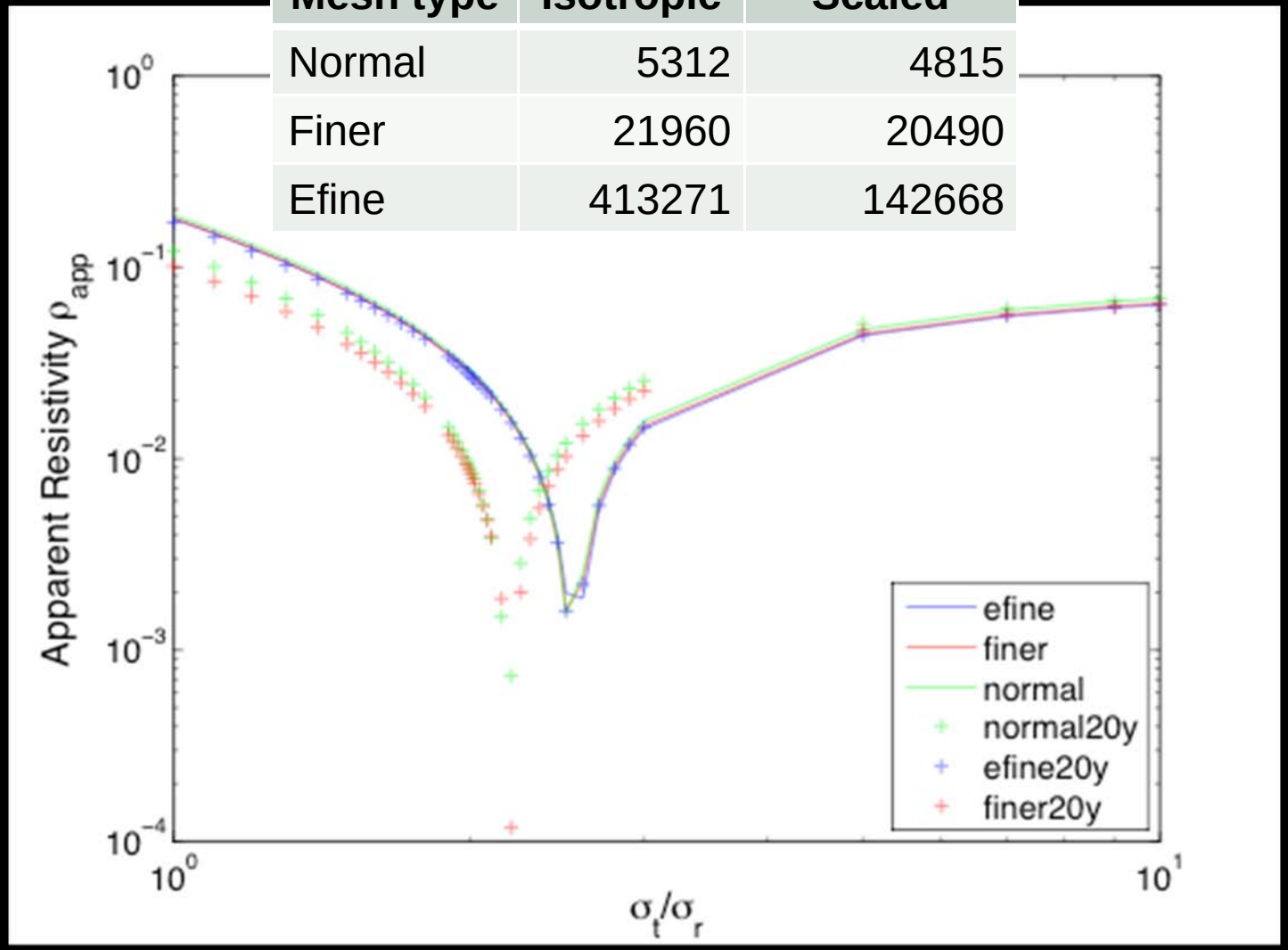
Anisotropic Solution



- Diagonal

Effect of scaled meshing

Mesh type	Isotropic	Scaled
Normal	5312	4815
Finer	21960	20490
Efine	413271	142668



Conclusions

- A satisfactorily anisotropic material can be constructed using alternating layers of contrasting conductivity materials
  - In 2d, a useful ratio is 10 layers/smallest electrode spacing
  - The amount of anisotropy can be controlled by varying the contrast, $\kappa < \sigma_2/\sigma_1 \quad (\sigma_2 > \sigma_1)$
- Solution accuracy can be tested by varying mesh scaling/anisotropy
- Bone does not behave as a homogeneous anisotropic structure