

# THE EFFECT OF AXON SHAPE AND MYELINATION ON DIFFUSION SIGNALS IN A REALISTIC SIMULATION ENVIRONMENT



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## BACKGROUND

- The application of microstructure techniques in diffusion imaging (e.g. axon diameter<sup>1</sup> and membrane permeability estimation<sup>2</sup>) are often validated using Monte Carlo simulations.
- The geometric substrates are usually highly simplified cylindrical models that have a limited number of compartments.

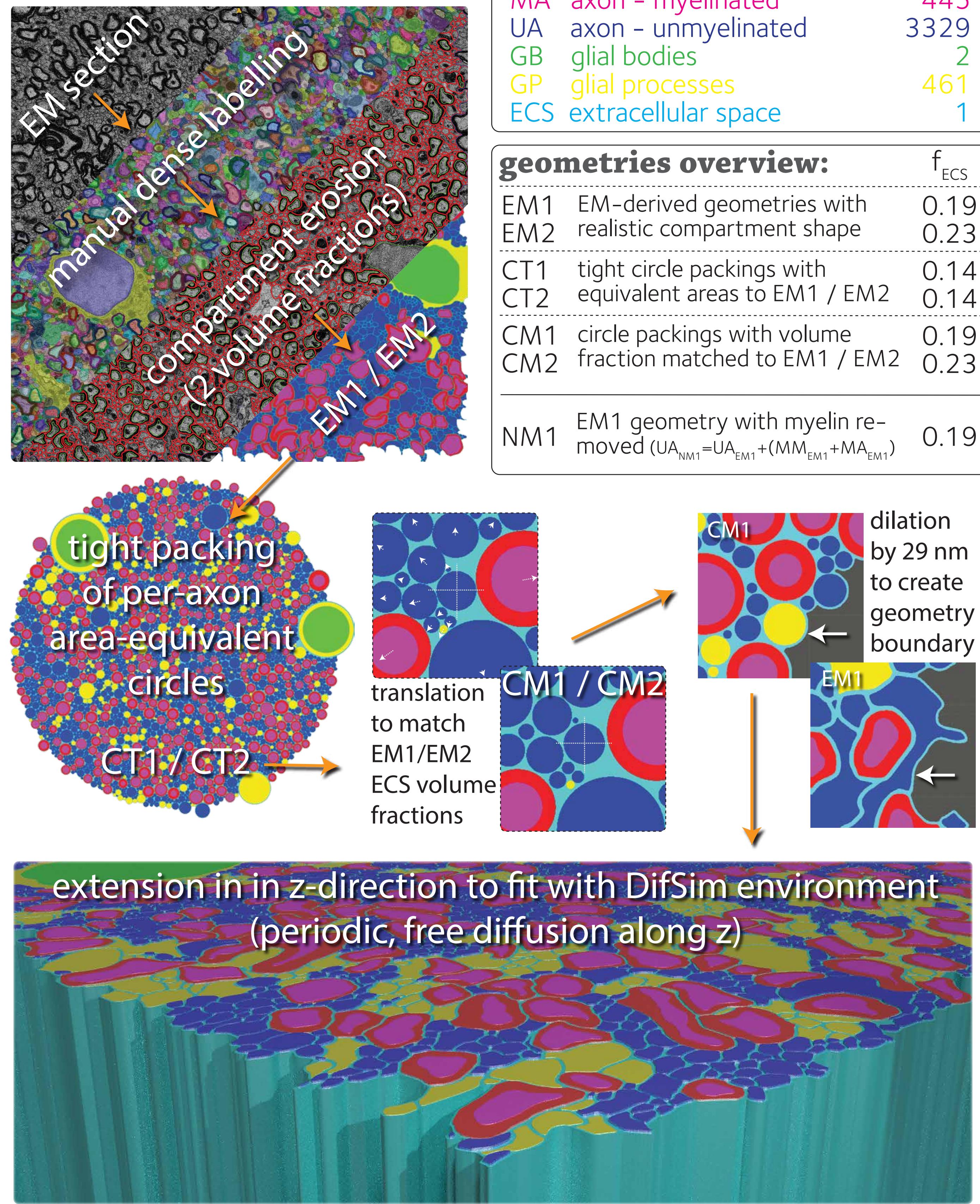
This work explores more realistic geometry derived from electron microscopy (EM) and aims to showcase how the influence of shape and compartments on the diffusion signal can be investigated.

## REALISTIC GEOMETRY FROM ELECTRON MICROSCOPY

- serial blockface scanning EM (Zeiss SEM+Gatan 3View)
- matrix: 4000x4000x469; FOV: 29.2x29.2x23.5  $\mu\text{m}$
- mouse corpus callosum (genu)



### Generating geometries for Monte Carlo simulation



## SIMULATION PARAMETERS

- Particle trajectories from MCCell<sup>3</sup>:
  - $dt = 1 \mu\text{s}$
  - for ECS, ICS, MM:  
 $D = [2.0; 0.75; 0.03] \mu\text{m}^2/\text{ms}$   
 $N = 35 * [0.95; 0.88; 0.50] \mu\text{m}^{-3}$
- dMRI signals from DifSim<sup>5</sup>:
  - PGSE parameter sweep
  - $\Delta = [2 - 160] \text{ ms}$
  - b-values: 100 - 32000  $\text{ms}/\mu\text{m}^2$
  - 30 diffusion gradient directions (perpendicular semicircle)

## INVESTIGATIONS

### AXON SHAPE:

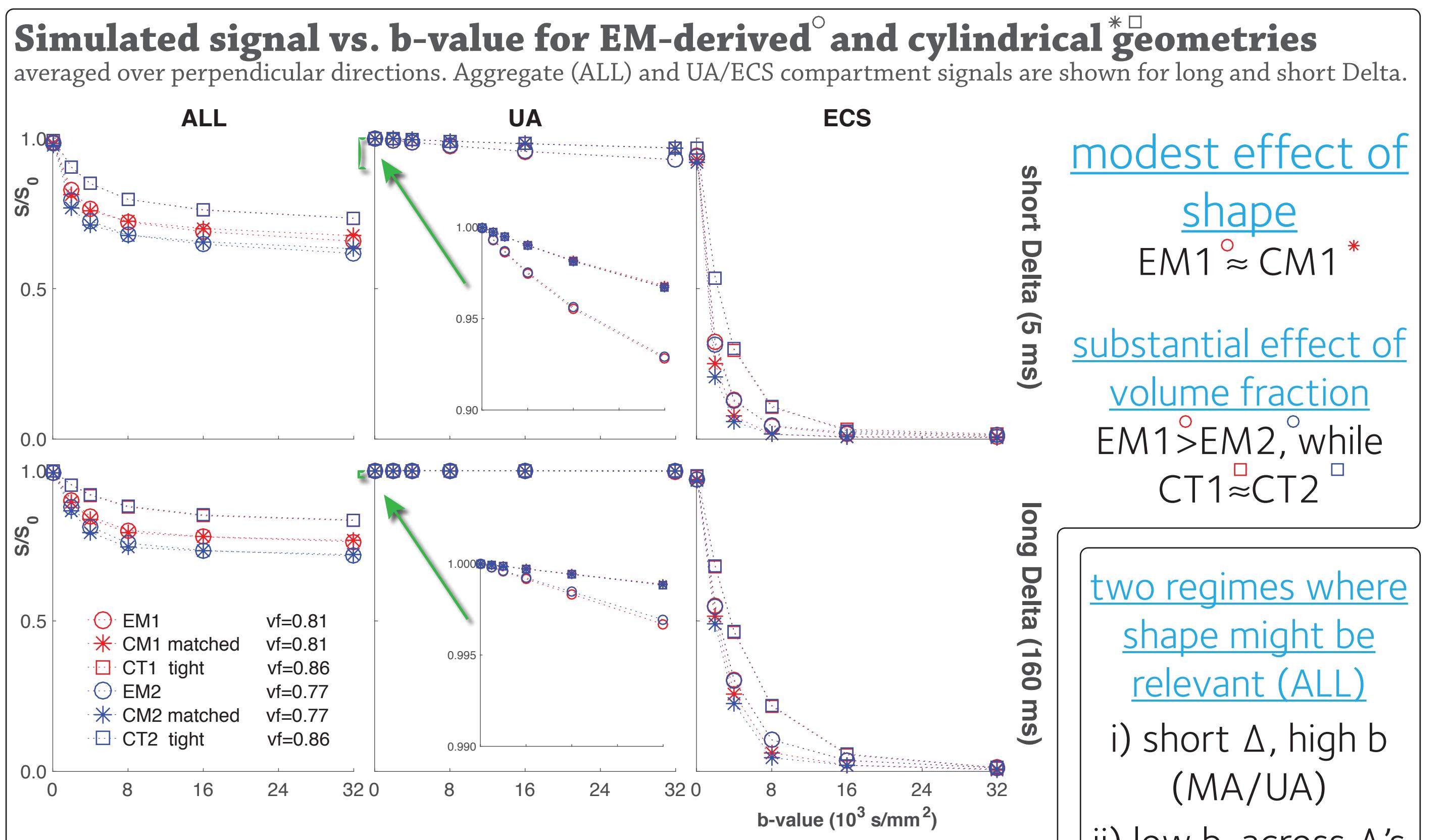
- EM1, EM2, CT1, CT2, CM1 and CM2
- impermeable membranes

### MYELINATION:

- EM1 vs. NM1 (with / without myelin)
- three permeabilities: low-mod-high
  - transition probabilities  $[10^{-3}; 10^{-4}; 10^{-5}]$  for UA to ECS, others adapted accordingly
  - exchange into myelin sheath MM two orders of magnitude lower than into ICS

## RESULTS

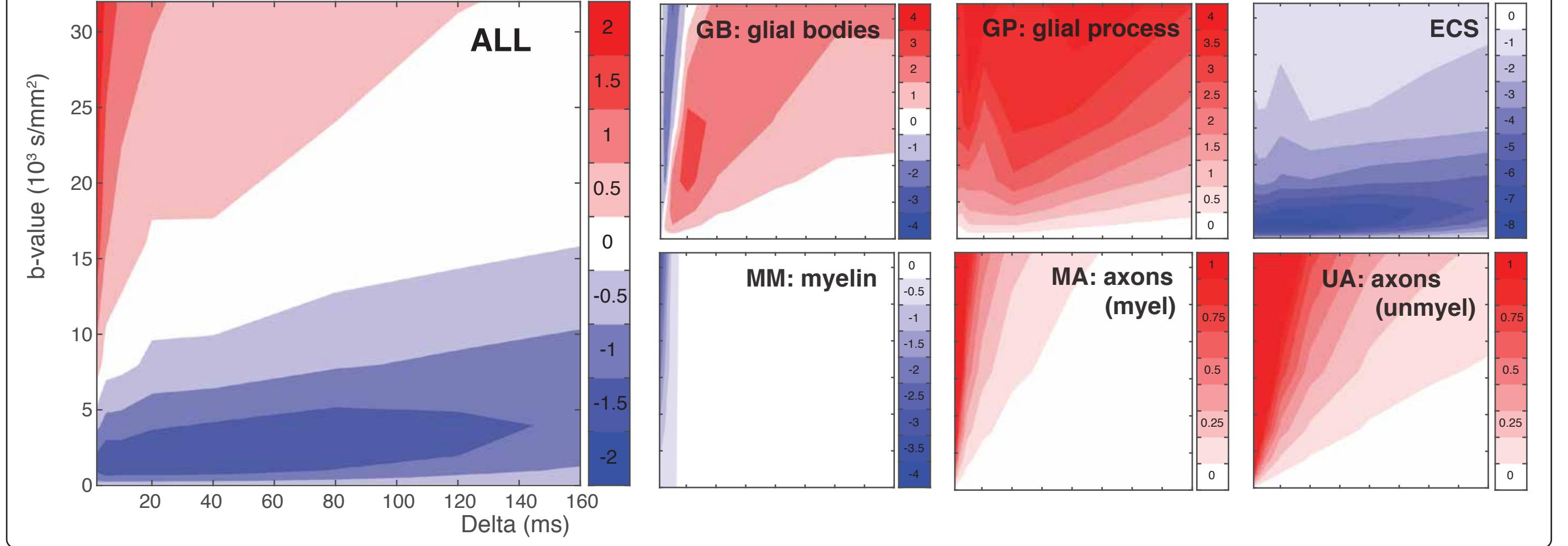
### AXON SHAPE:



### Percent difference between EM/matched cylinder models

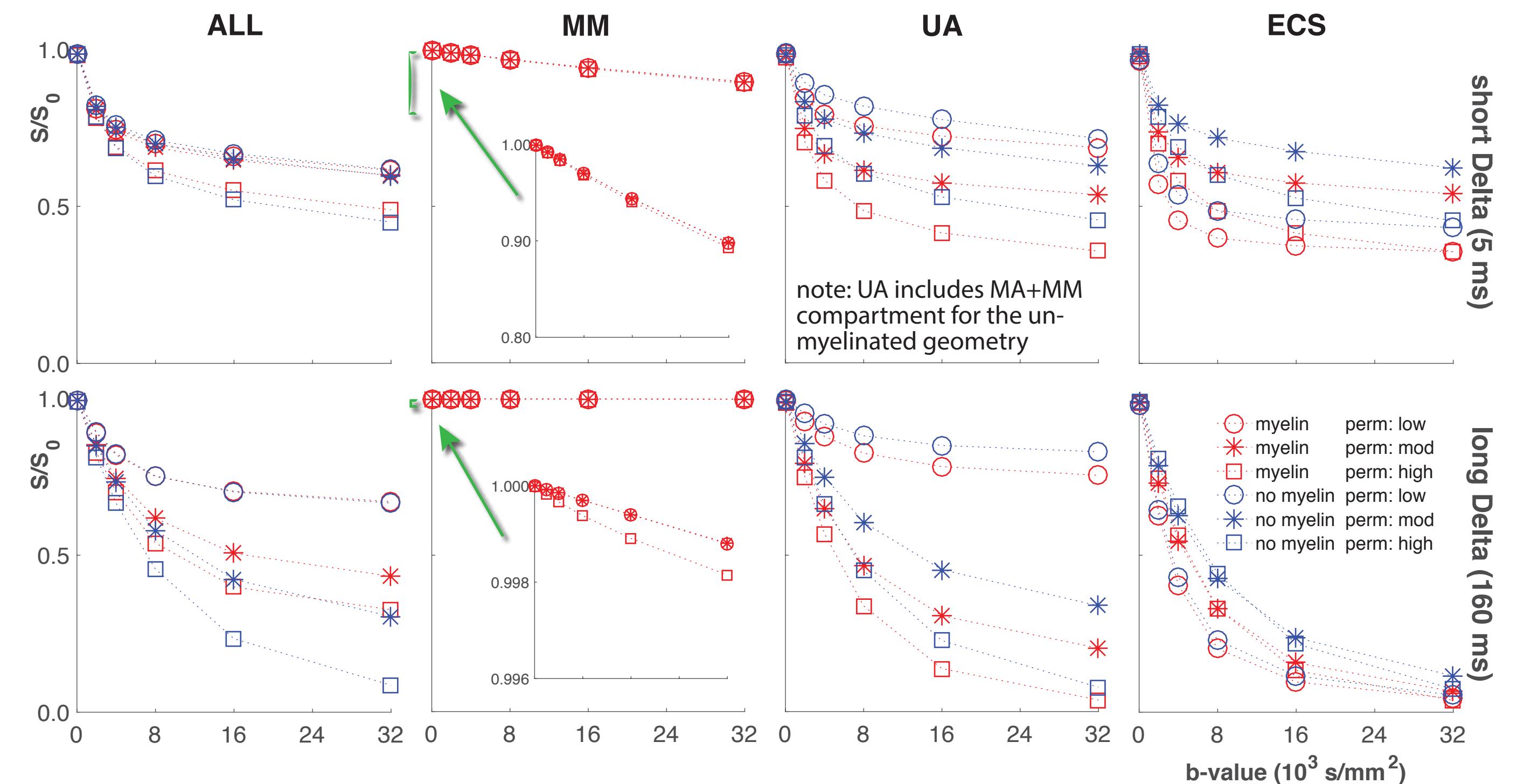
for the (direction-averaged) aggregate signal and the signal from the six compartments.

$CM1 > EM1$ ;  $EM1 > CM1$



### MYELINATION:

### Signal behaviour with myelin and without myelin for three permeabilities<sup>o</sup>



## CONCLUSIONS

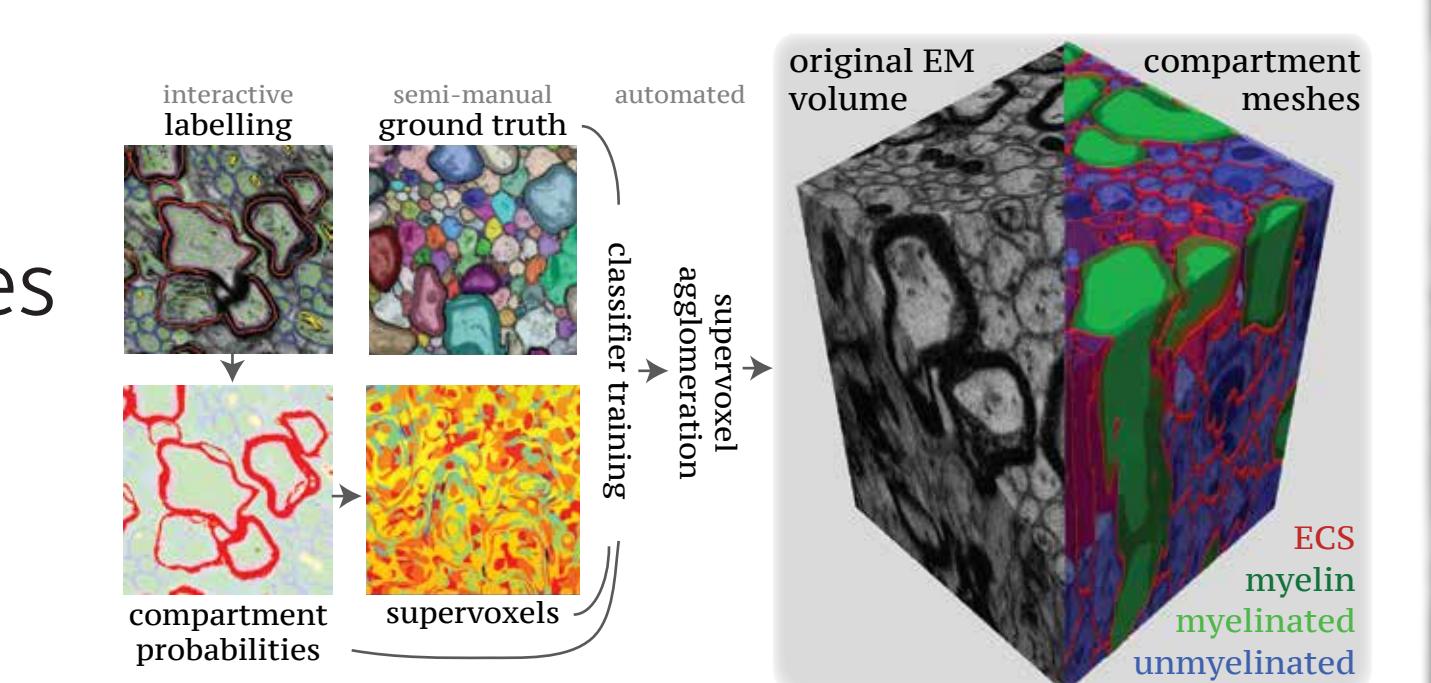
The EM-based geometry and simulation environment was developed as a flexible tool for investigating tissue features. Our two examples:

**AXON SHAPE:** The circular model seems a fair approximation for bundled axons in cross-section.

**MYELINATION:** At low permeability, myelin accounts for little variation.

## OUTLOOK

- microstructure parameter estimates
- further compartmentalisation
- using EM data in full 3D



## METHODS

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## CONCLUSION