

Correcting Undersampled Cardiac Sources in Equivalent Double Layer Forward Simulations

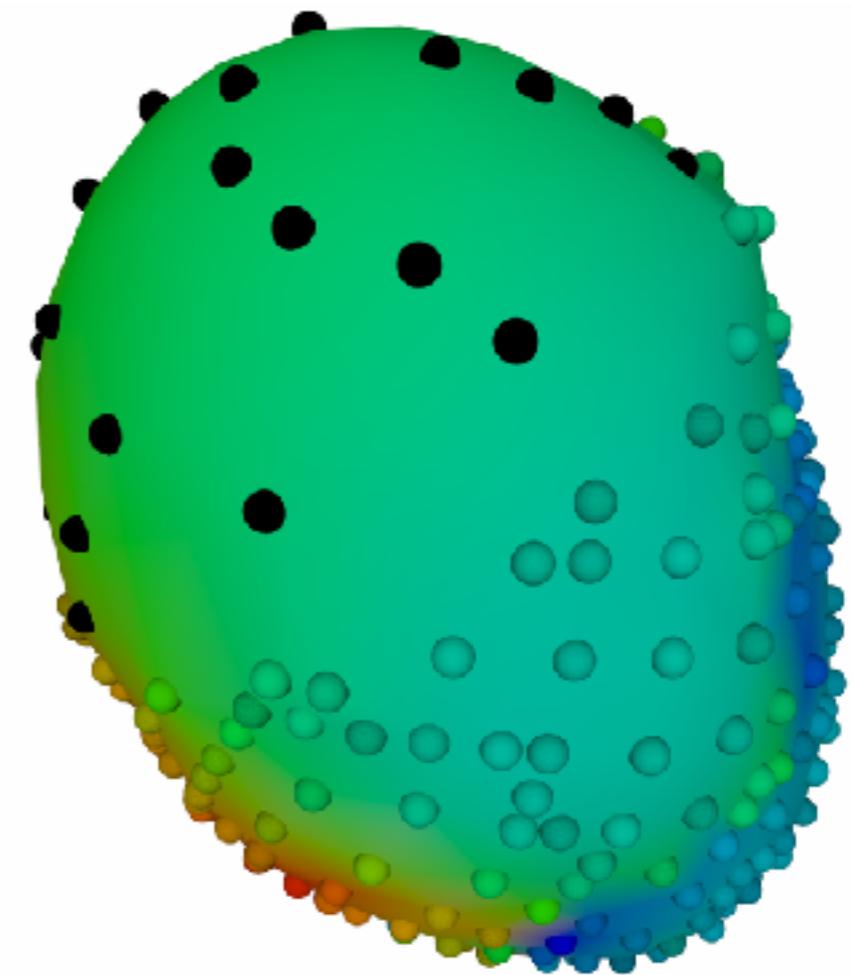
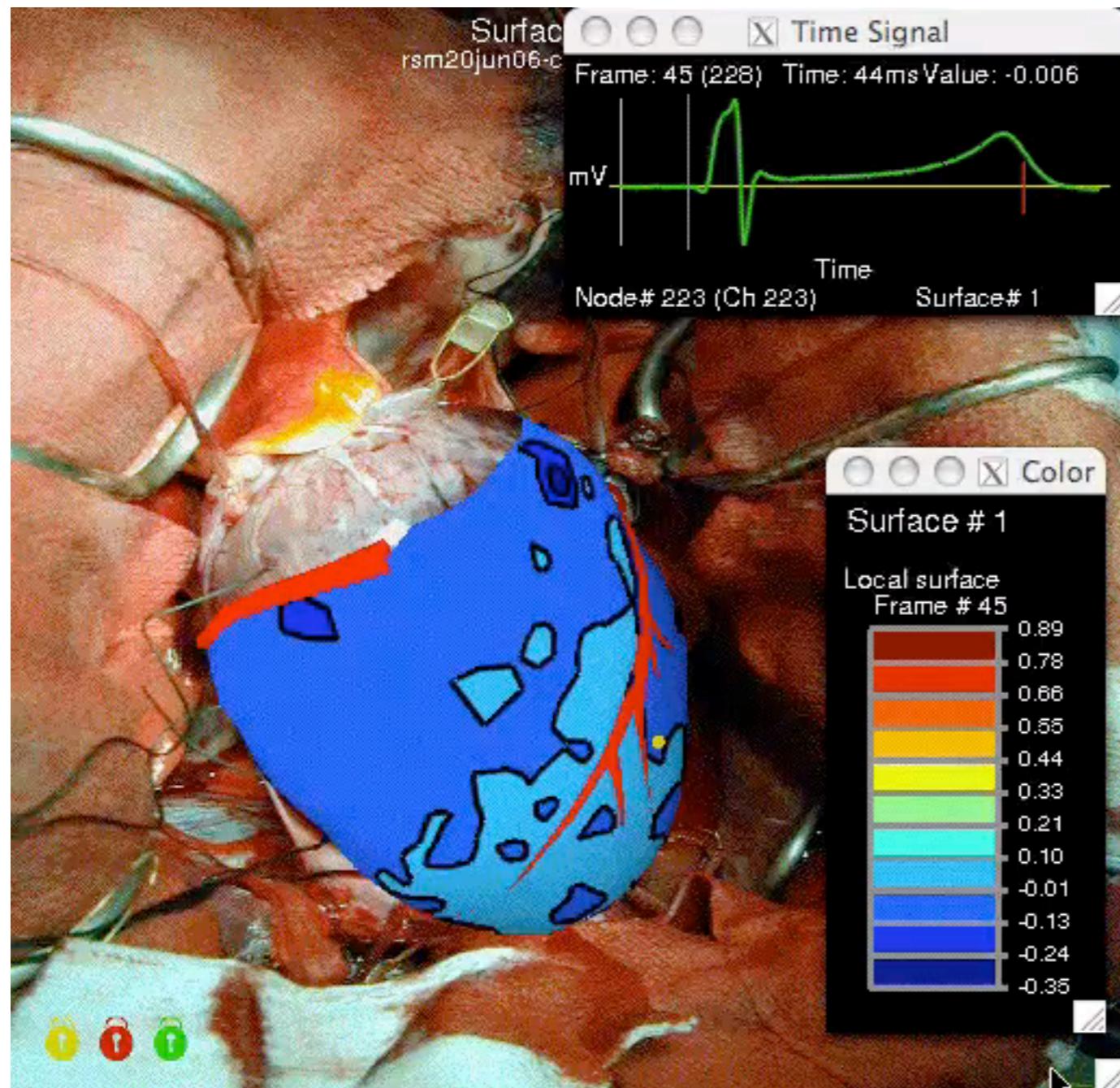
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Salt Lake City, USA

Institute of Biomed. Eng., KIT, Karlsruhe, Germany,
Donders Centre for Neuroscience, Radboud University,
Nijmegen, Netherlands

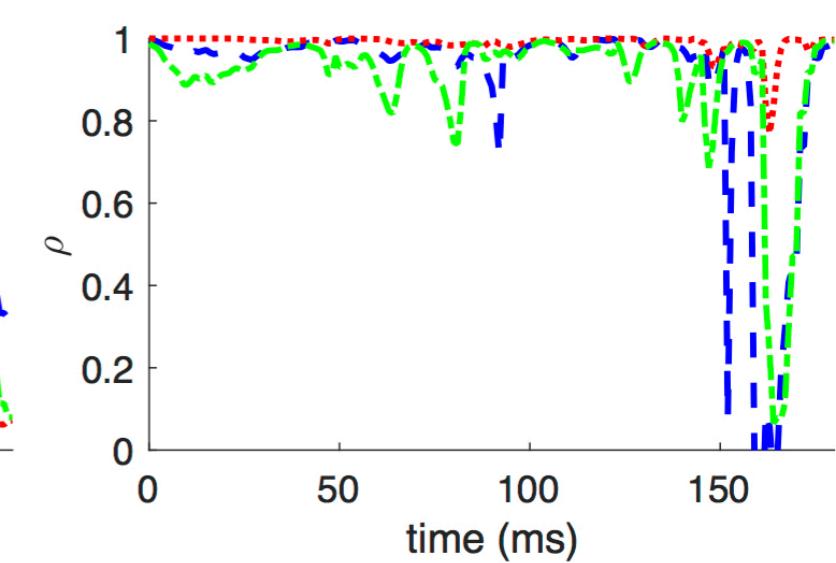
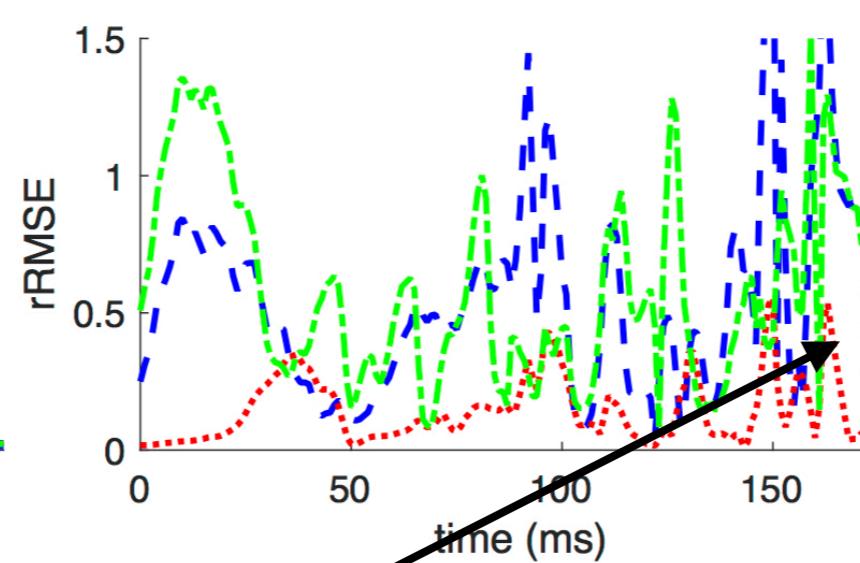
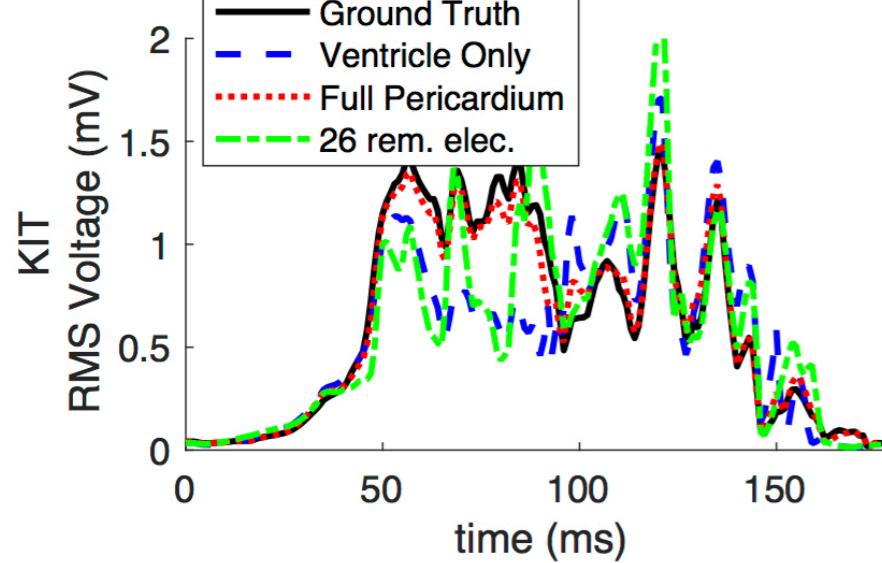
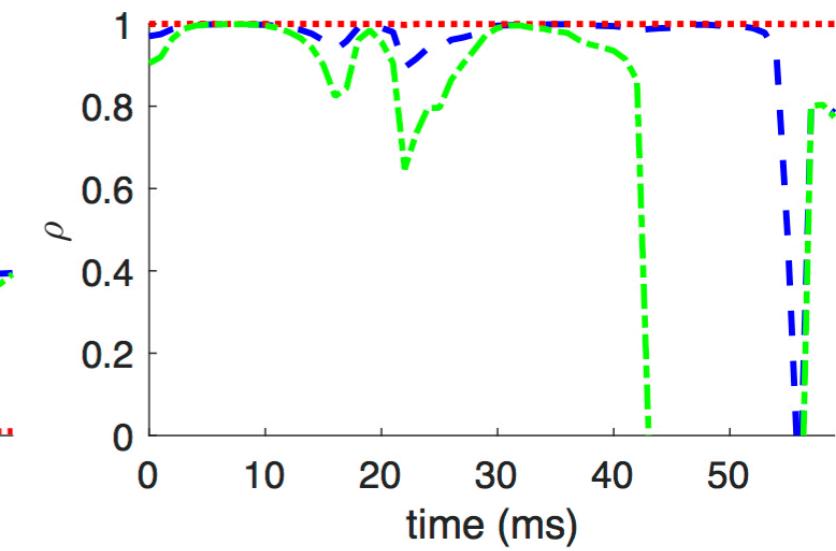
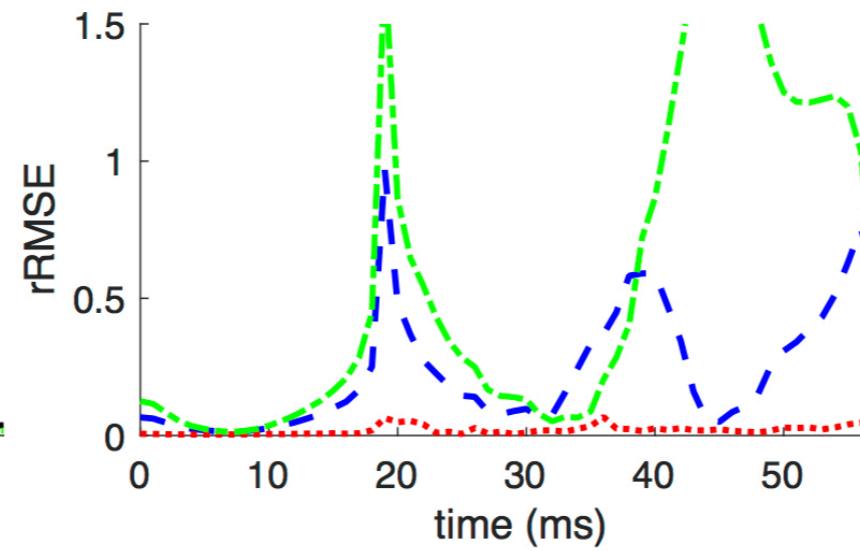
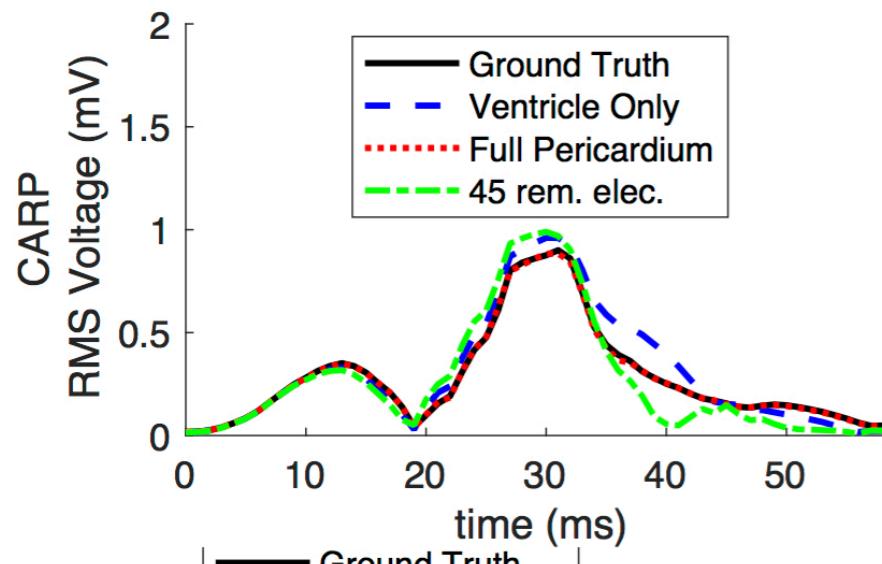


Atrial Sampling



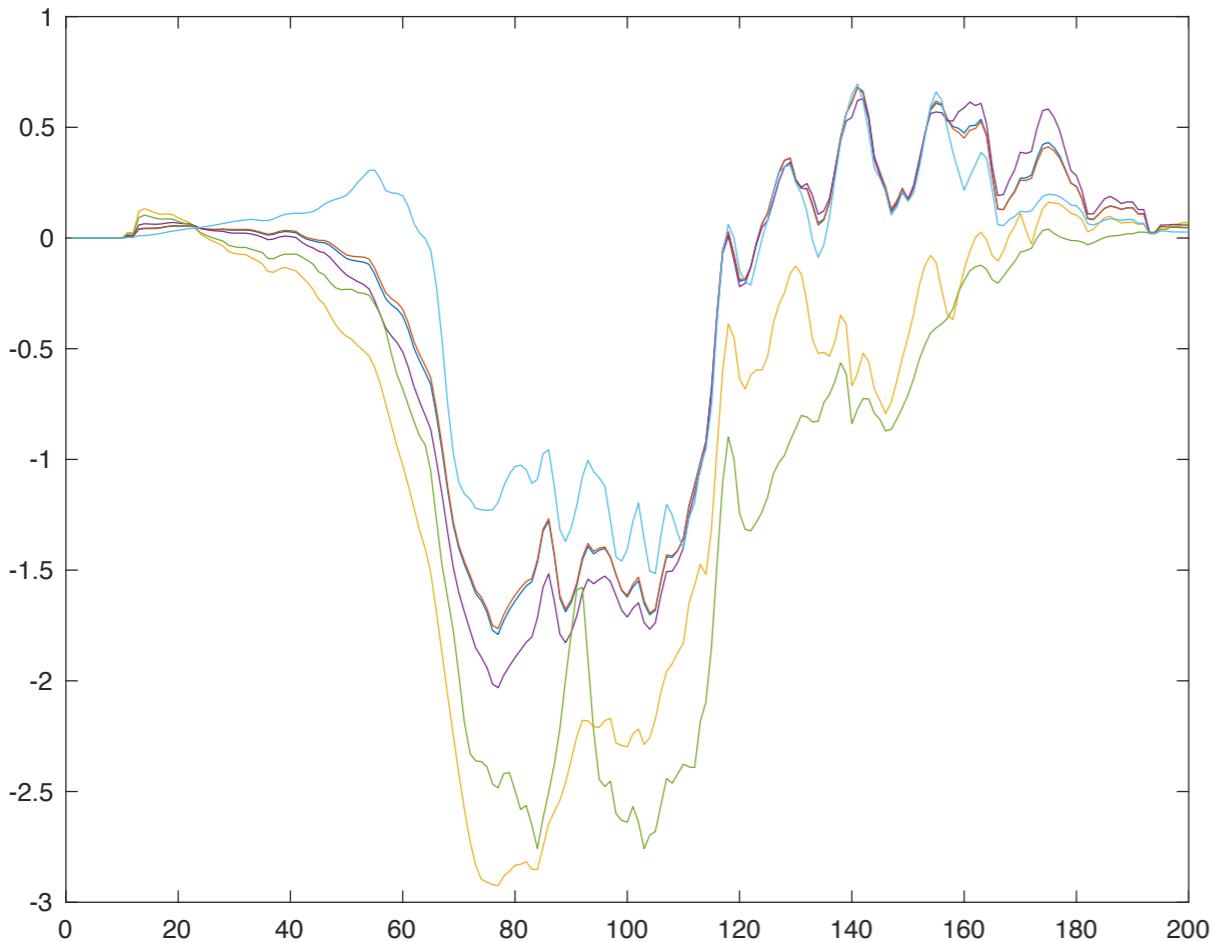
Tat, et al., Front. in Physiol, vol 9 p. 1304 , 2018

Effect of No Atrial Sampling

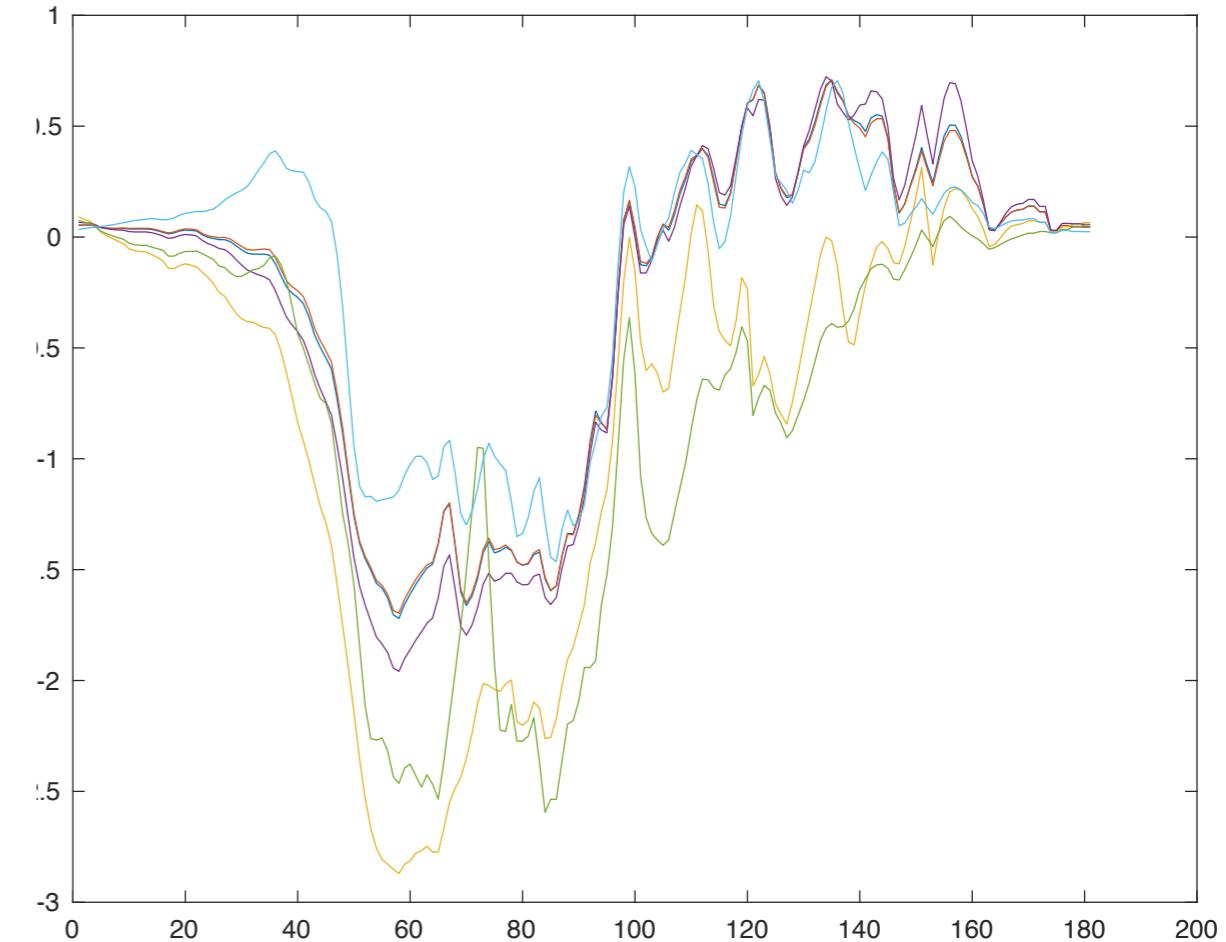


Higher Residual Error

Low Resolution Sources



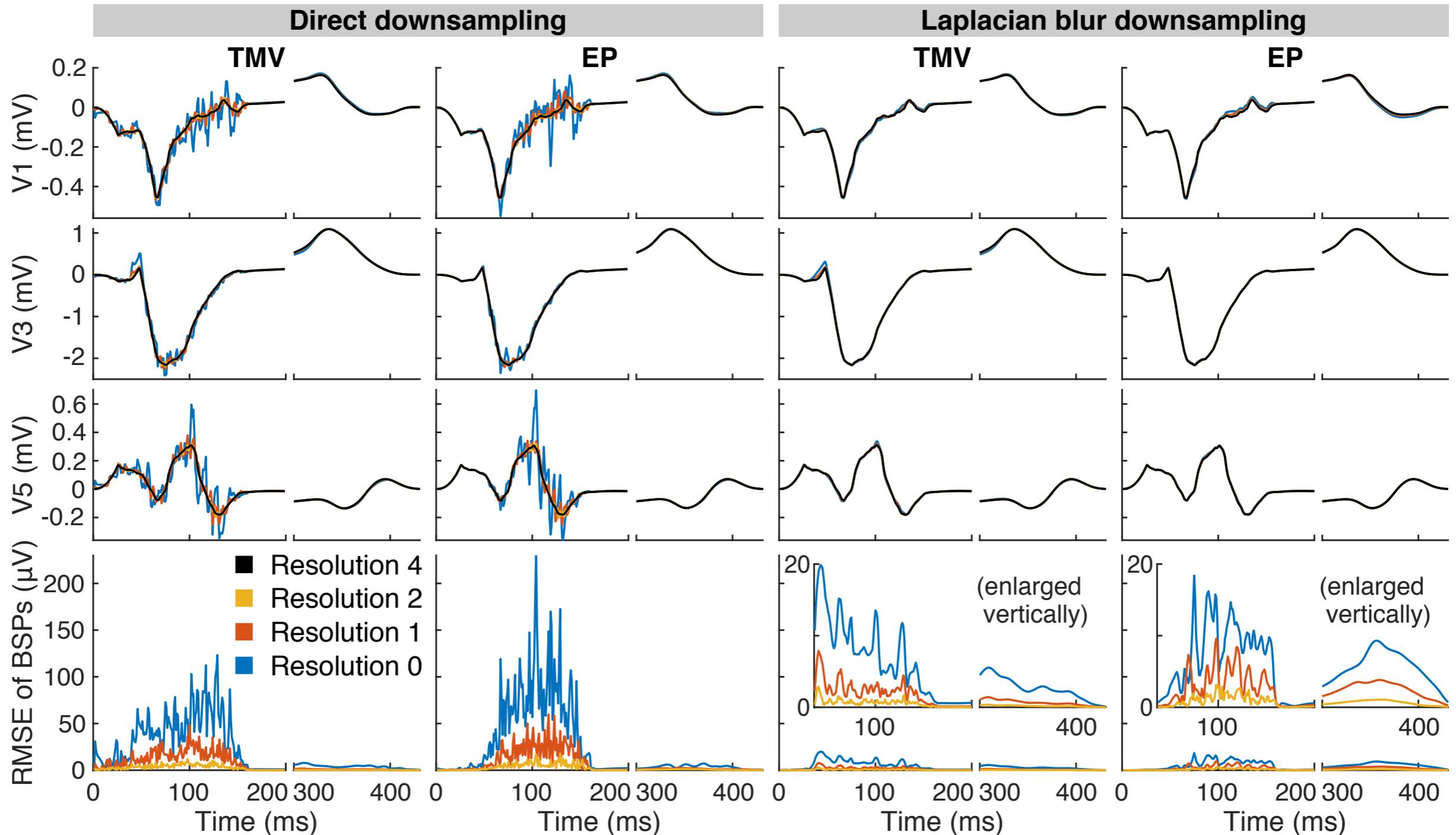
FEM



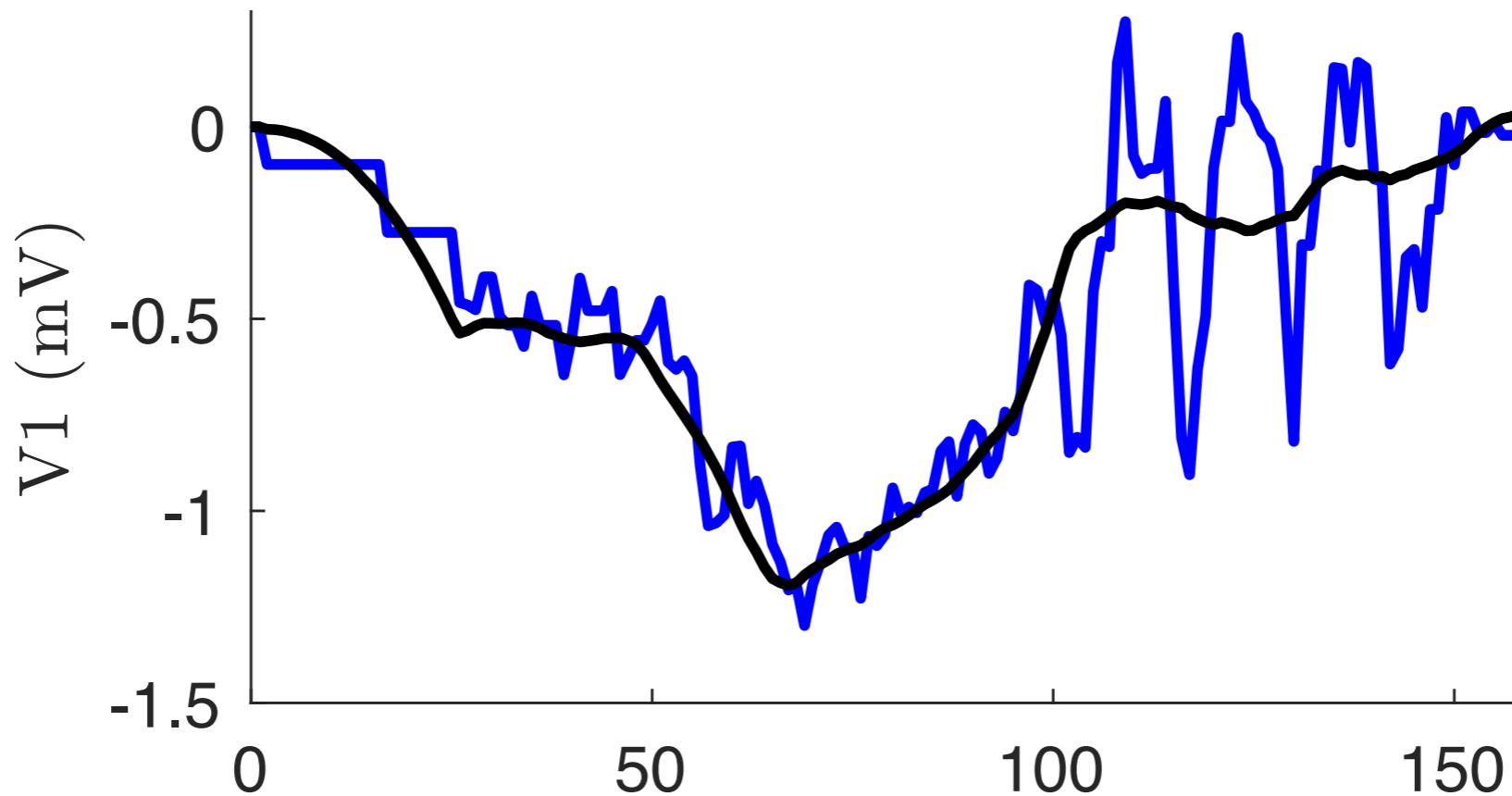
BEM

Reduced error with interpolation

Source Smoothing



Other Source Models?



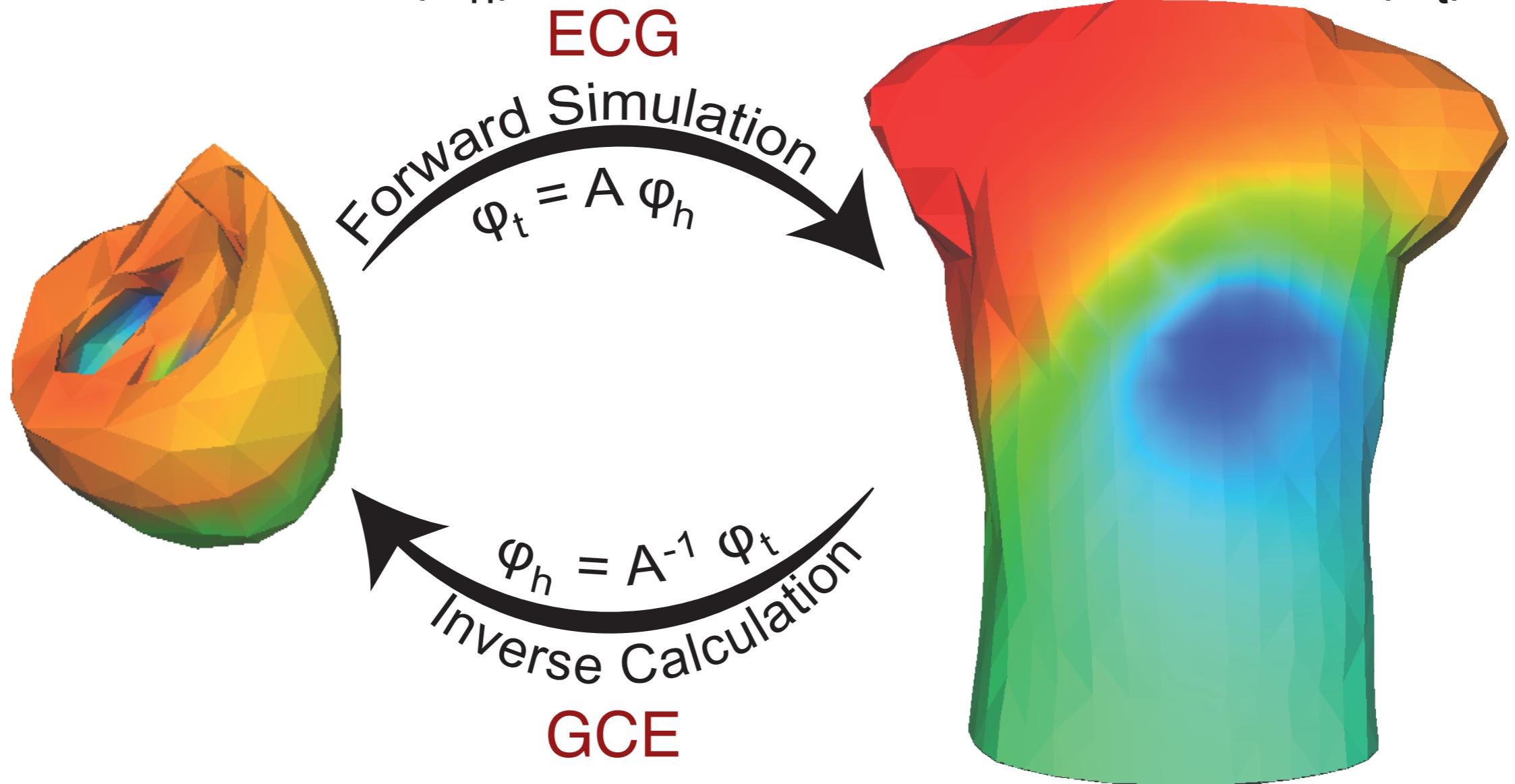
EDL

Can we reduce the error with interpolation?

ECG Imaging

Heart Potentials (ϕ_h)

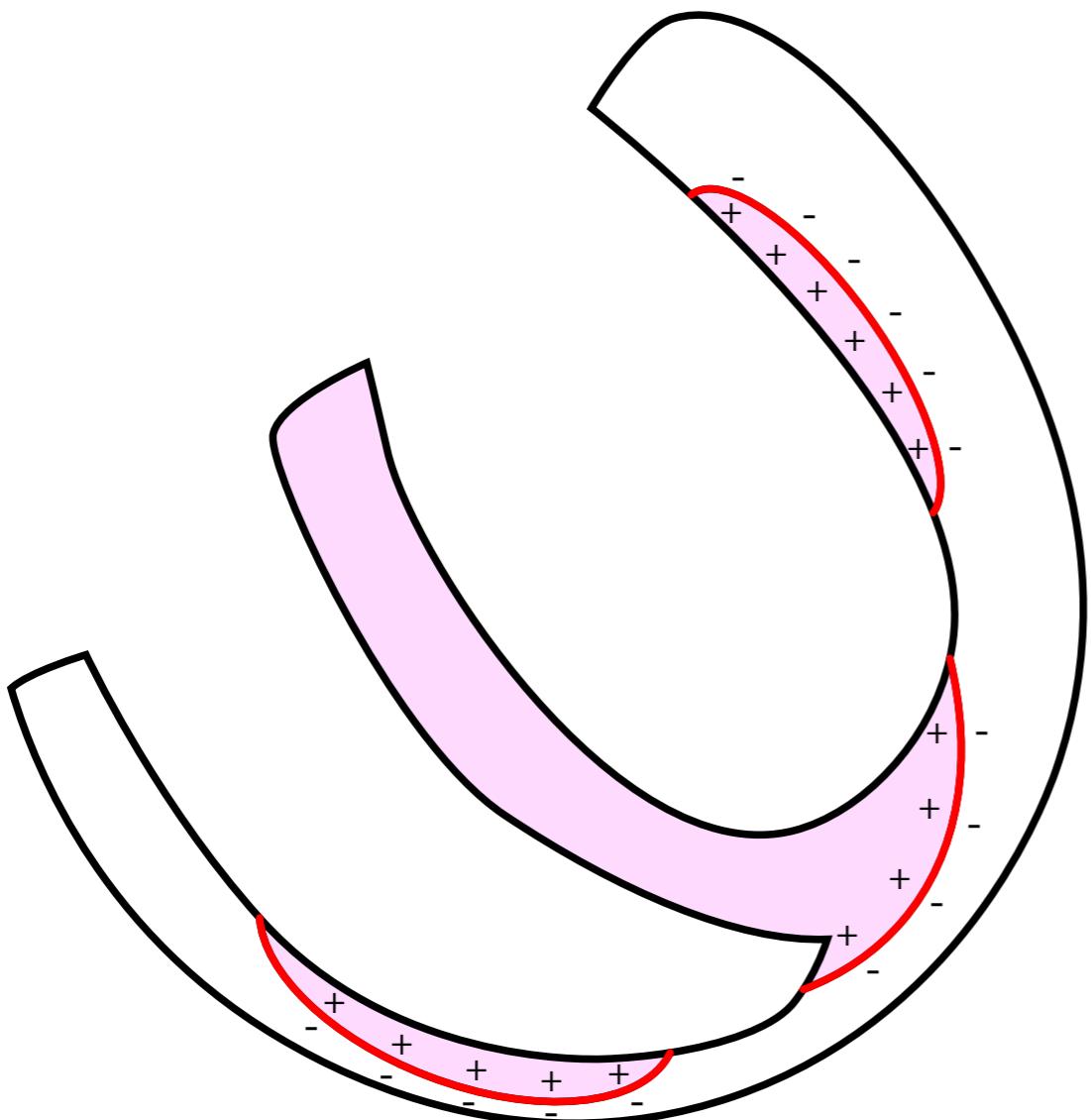
Torso Potentials (ϕ_t)



ECG Imaging Relies on Accurate Forward Models

Evaluate the effect of source sampling and interpolation strategies on EDL forward simulations

Uniform Dipole Layer



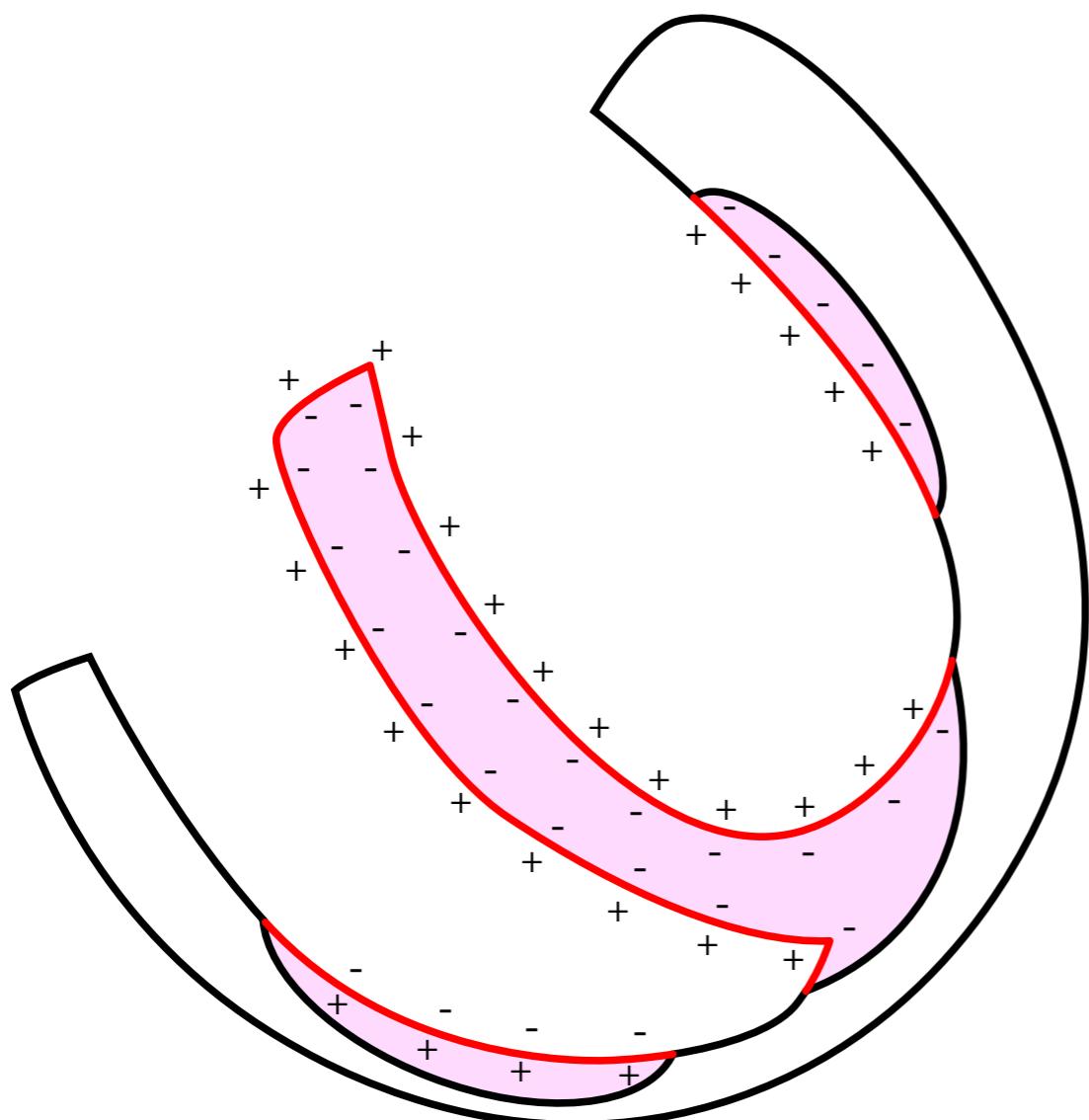
$$\varphi_{\infty}(\vec{r}') = \frac{1}{4\pi\sigma} \int_{S_d} \sigma_i \nabla \varphi_m(\vec{r}) d\omega.$$

Dipole
Layer
Strength

Solid Angle

van Oosterom, J. Electrocardiol., vol 35 suppl, pp 185-192, 2002

Equivalent Dipole Layer (EDL)



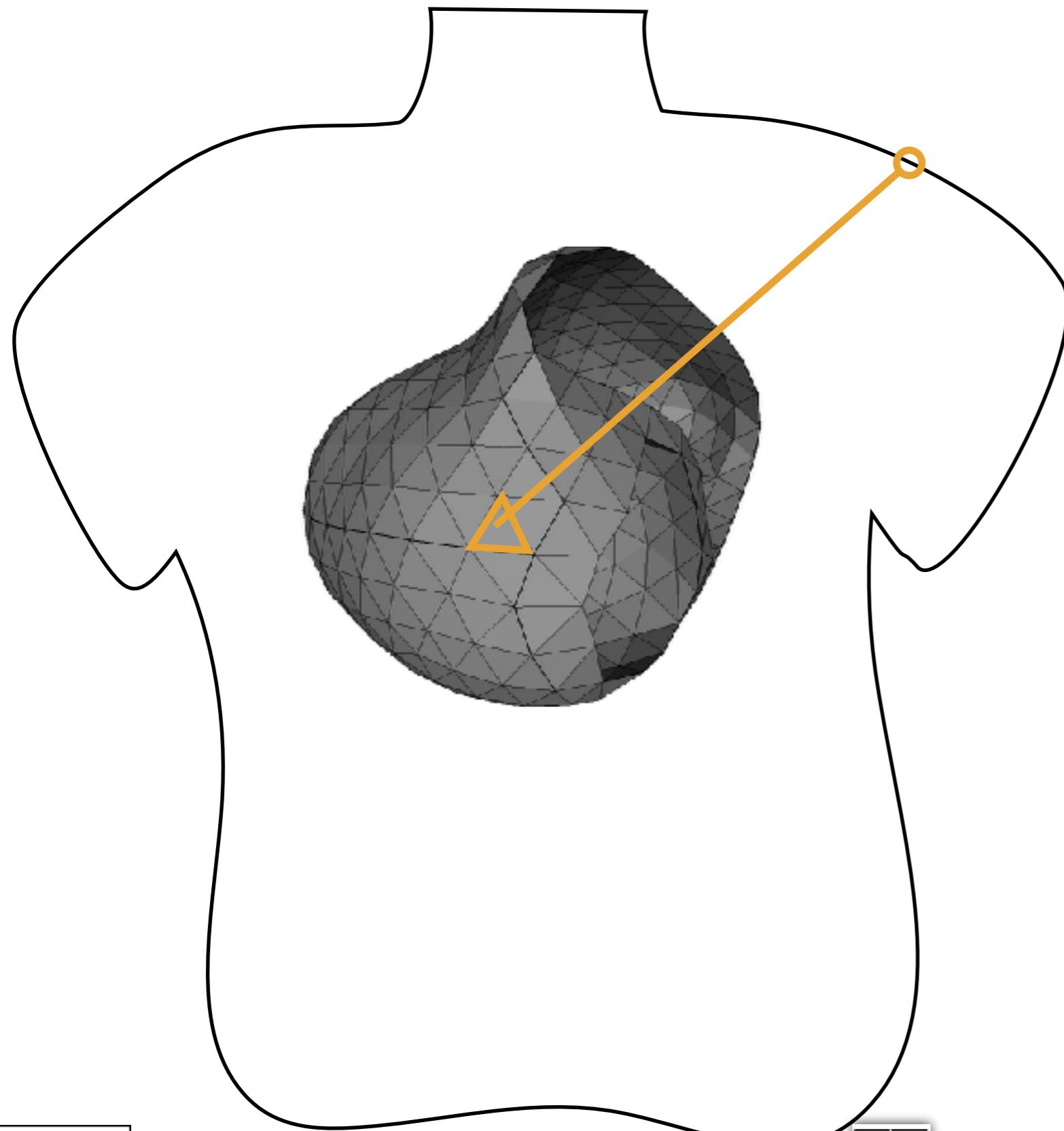
$$\varphi_{\infty}(\vec{r}') = \frac{1}{4\pi\sigma} \int_{S_d} \sigma_i \nabla \varphi_m(\vec{r}) d\omega.$$

Dipole Layer
Strength

Solid Angle

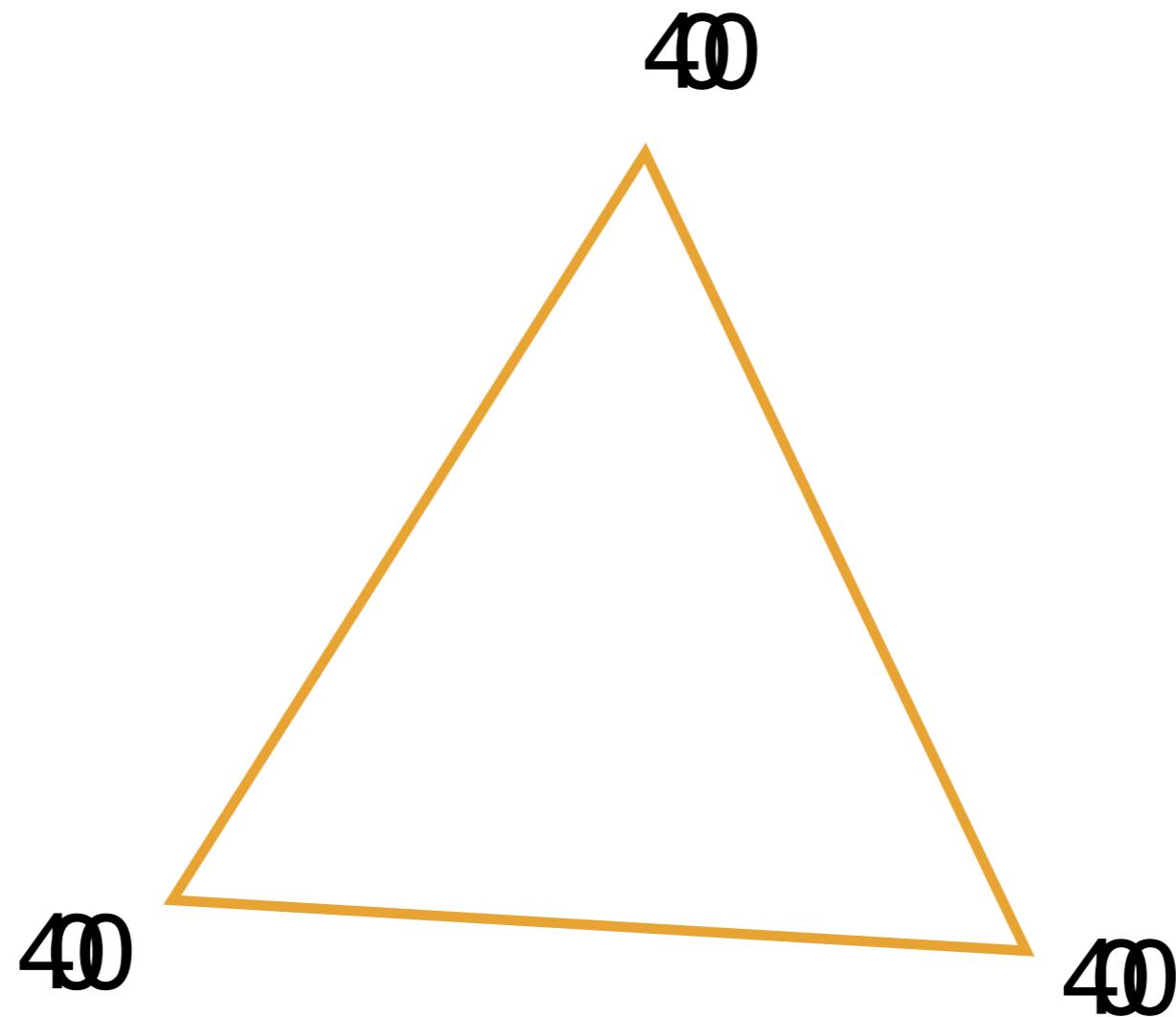
van Oosterom, J. Electrocardiol., vol 35 suppl, pp 185-192, 2002

Calculating EDL



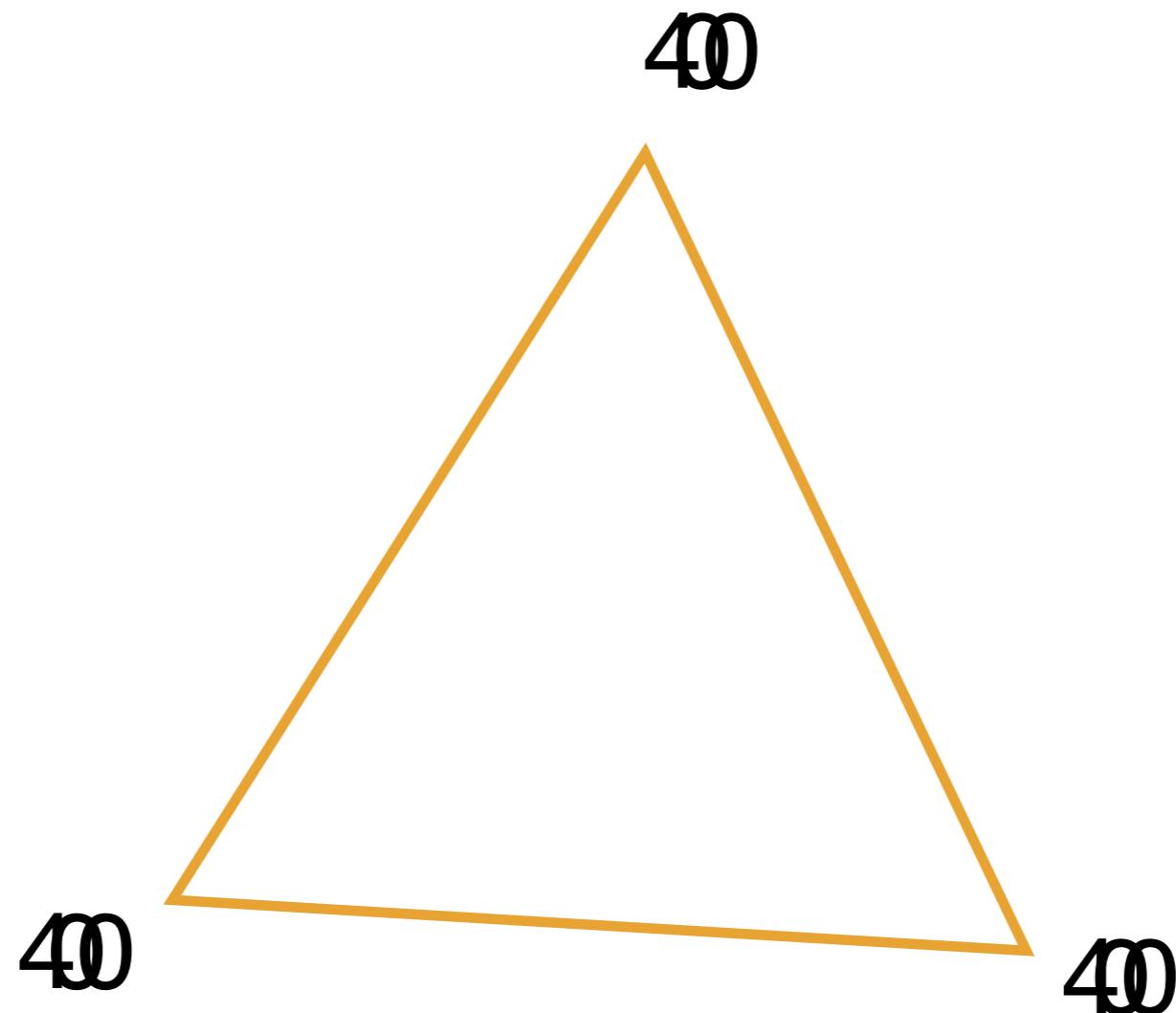
For each face:
Compute solid angle
Apply dipole strength

Interpolating EDL



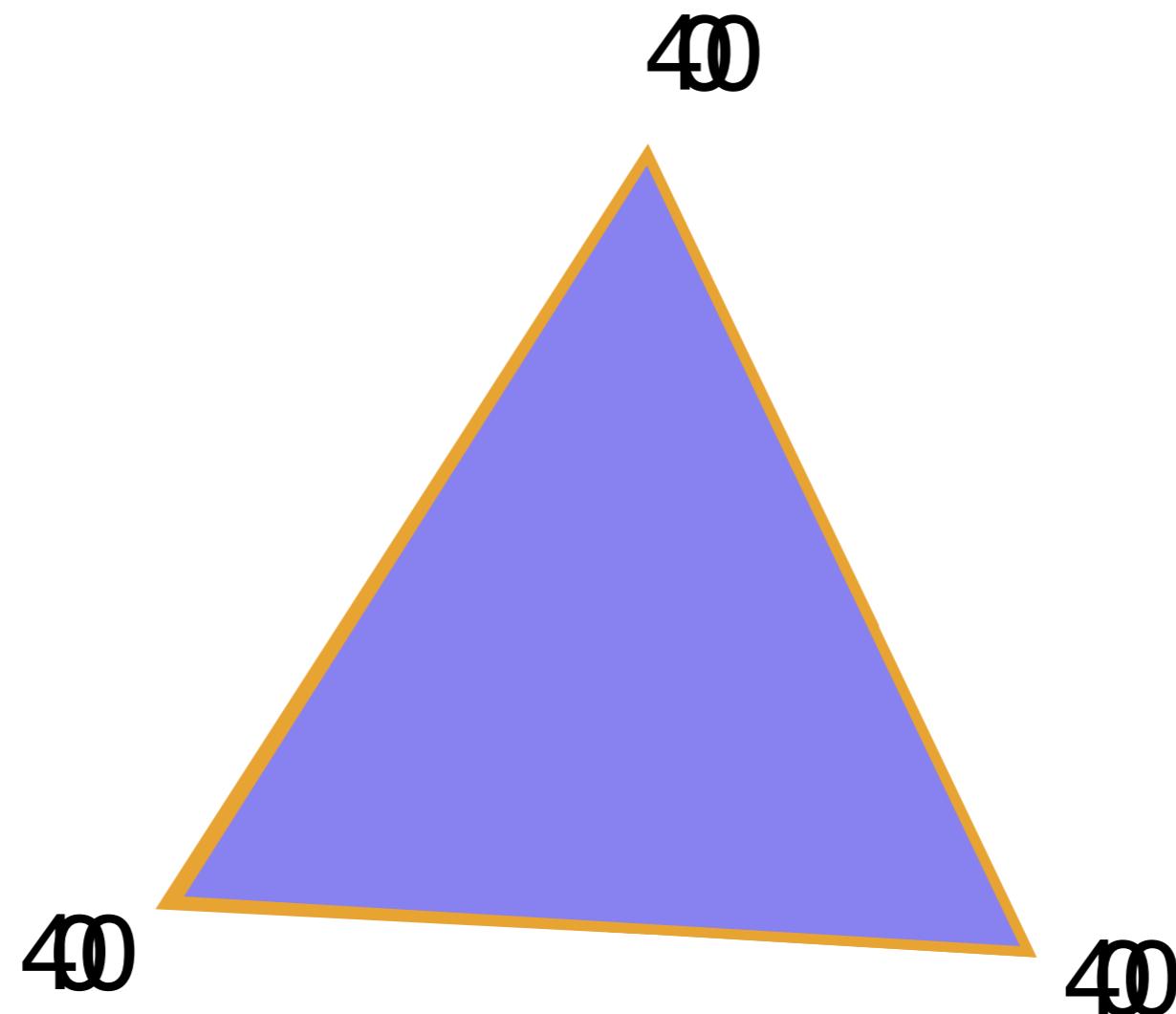
Constant (None)

Interpolating EDL



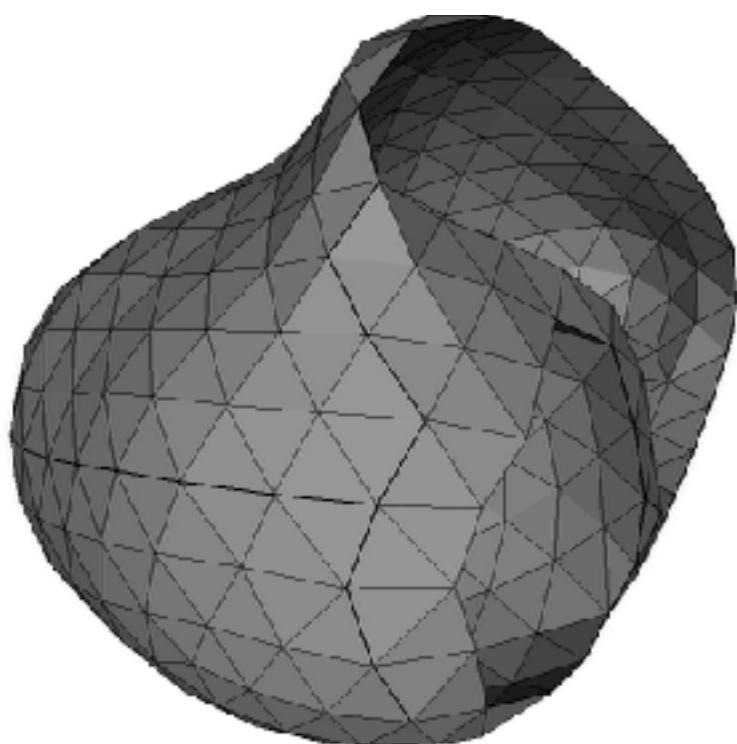
Triangle Weighting

Interpolating EDL

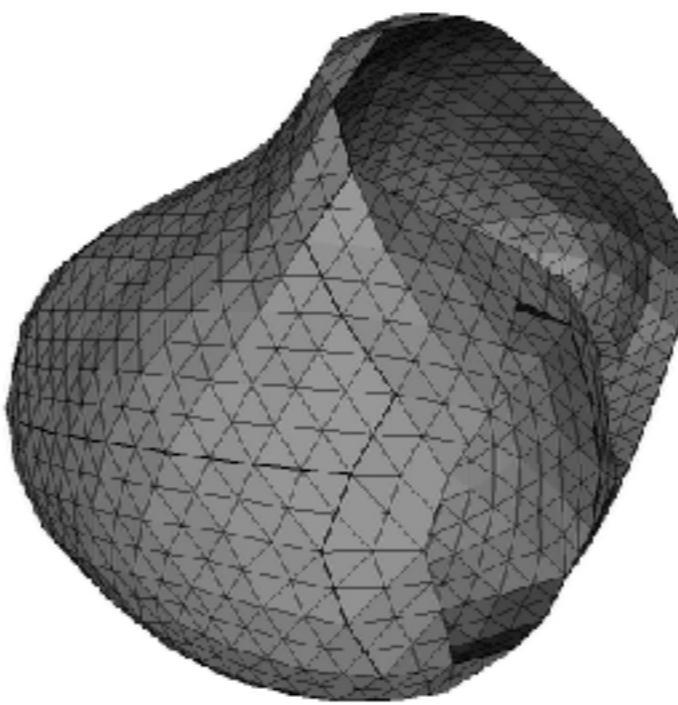


Triangle Splitting

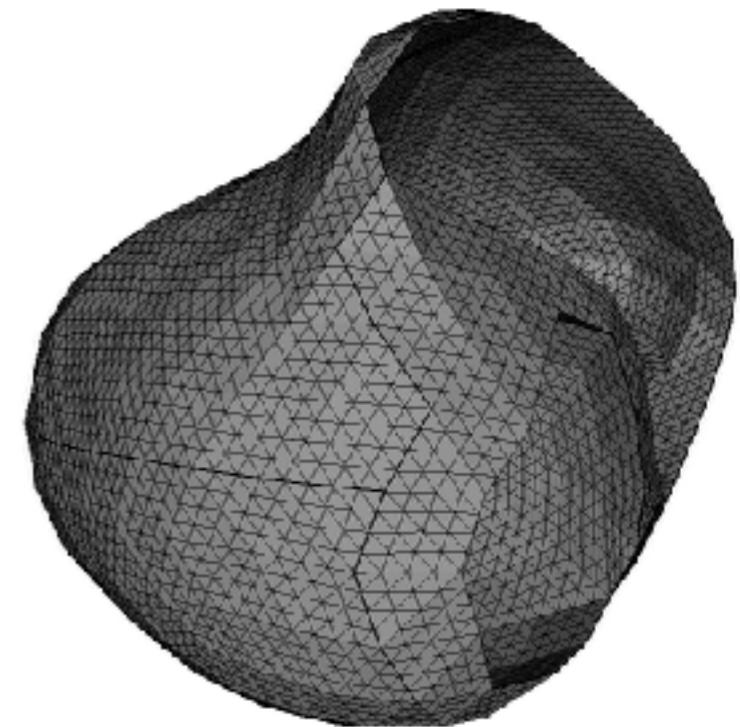
Sampling Resolutions



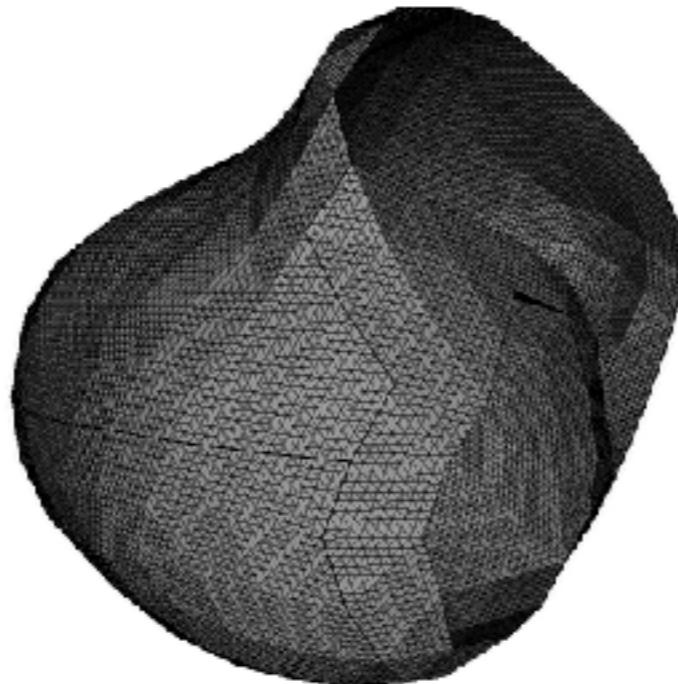
Res 0 (578 nodes)



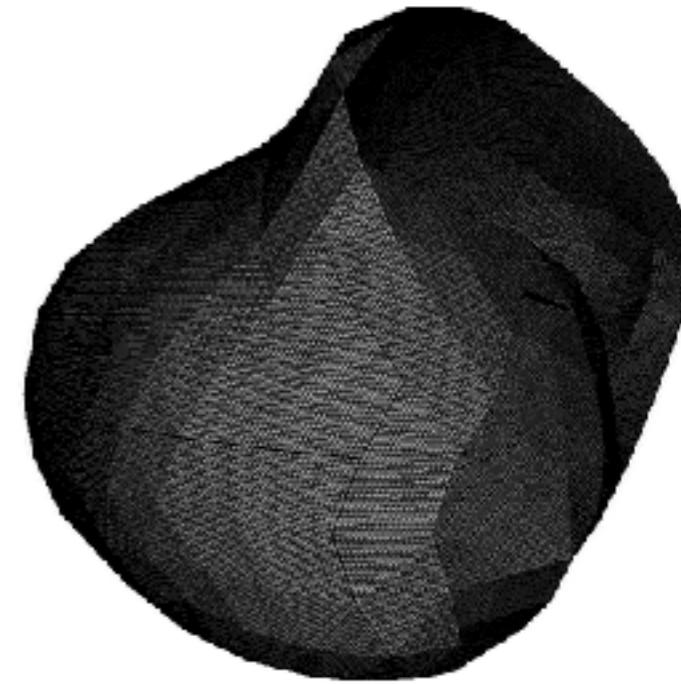
Res 1 (2,306)



Res 2 (9,218)



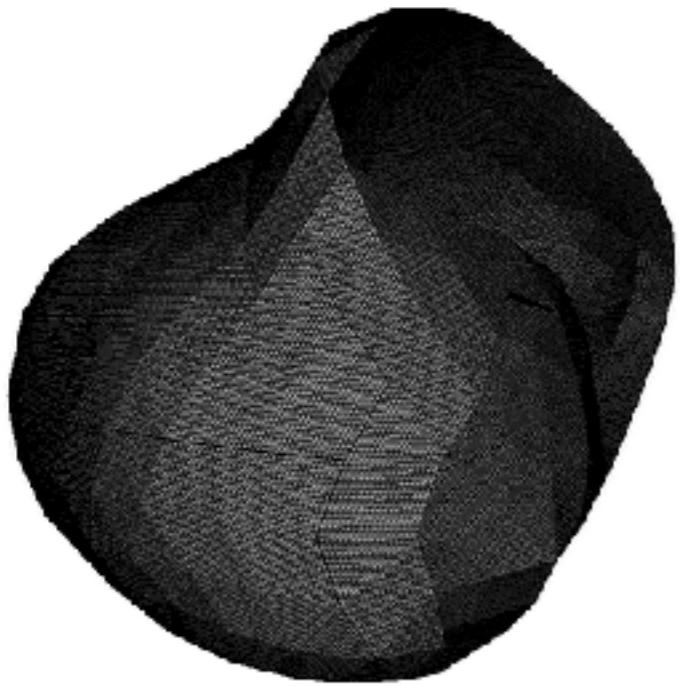
Res 3 (36,866)



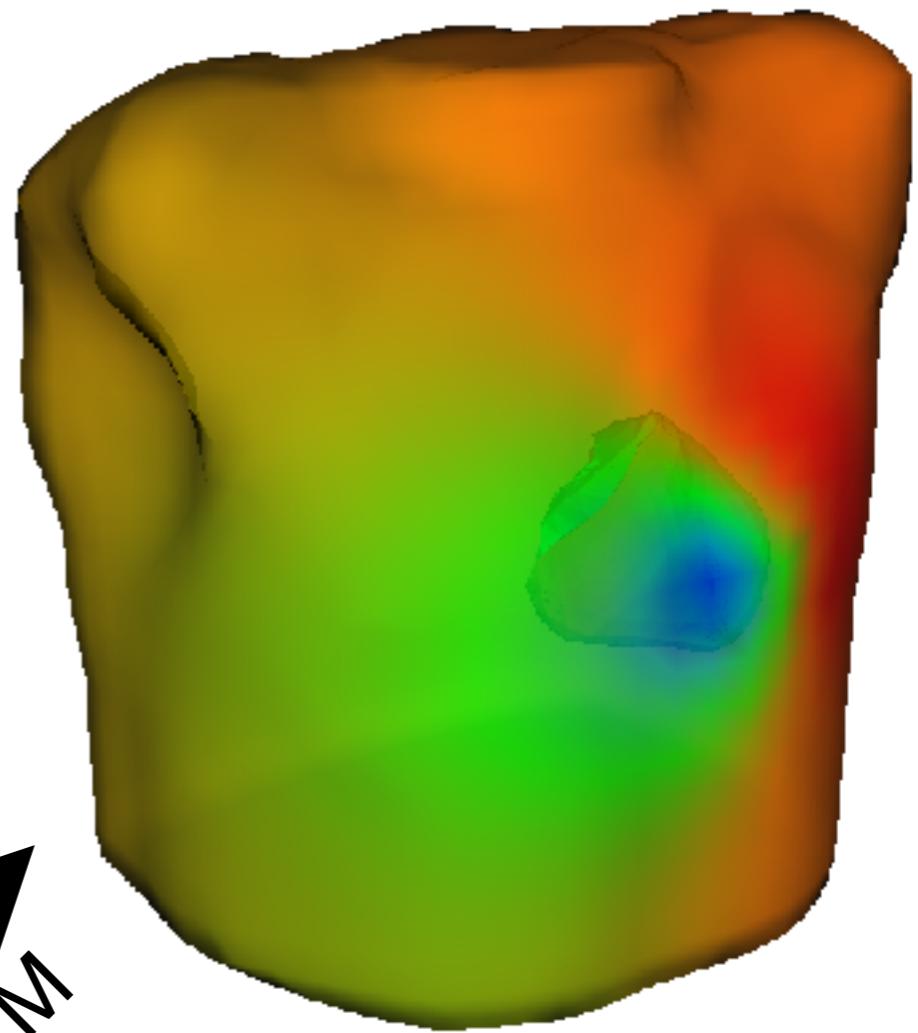
Res 4 (147,458)

Ground Truth

Res 4

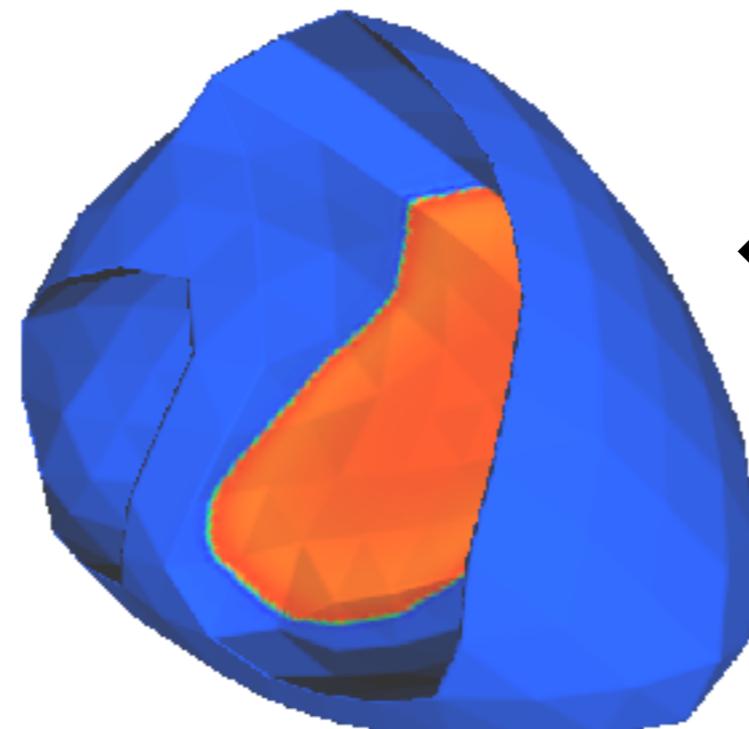


BSPM

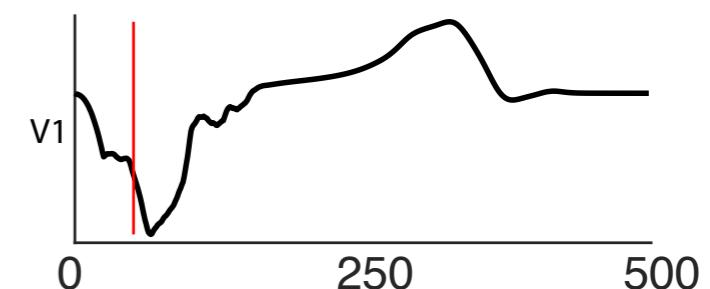


TMP

Bidomain
Simulation

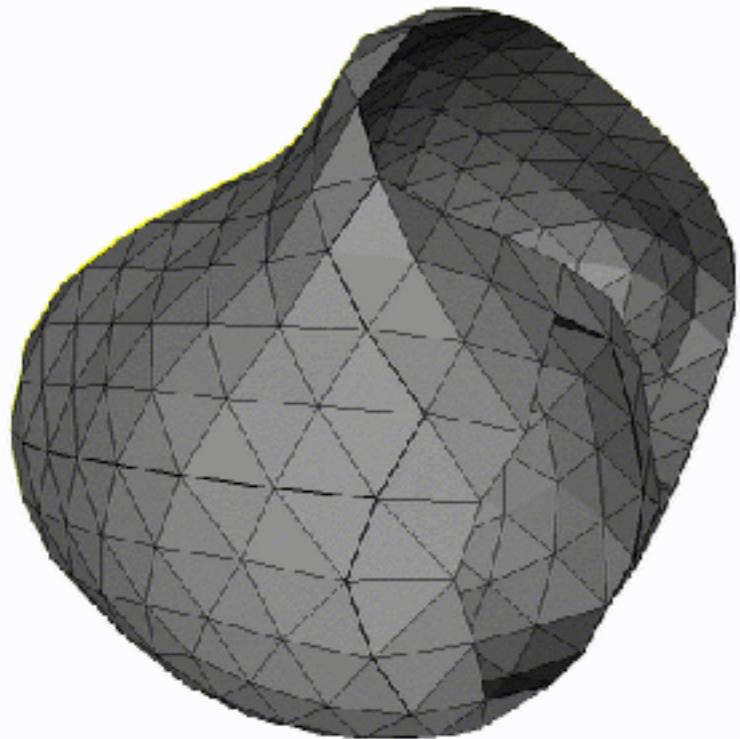


BEM

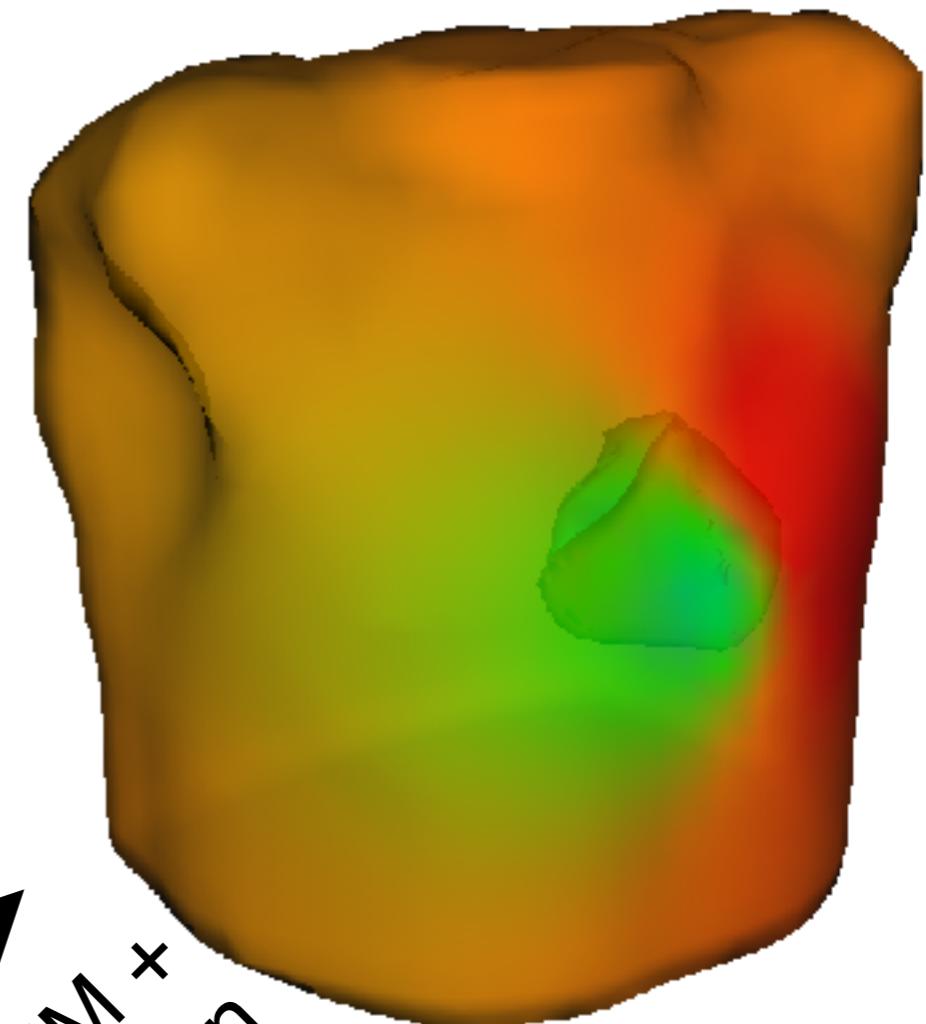


EDL Pipeline

Mesh

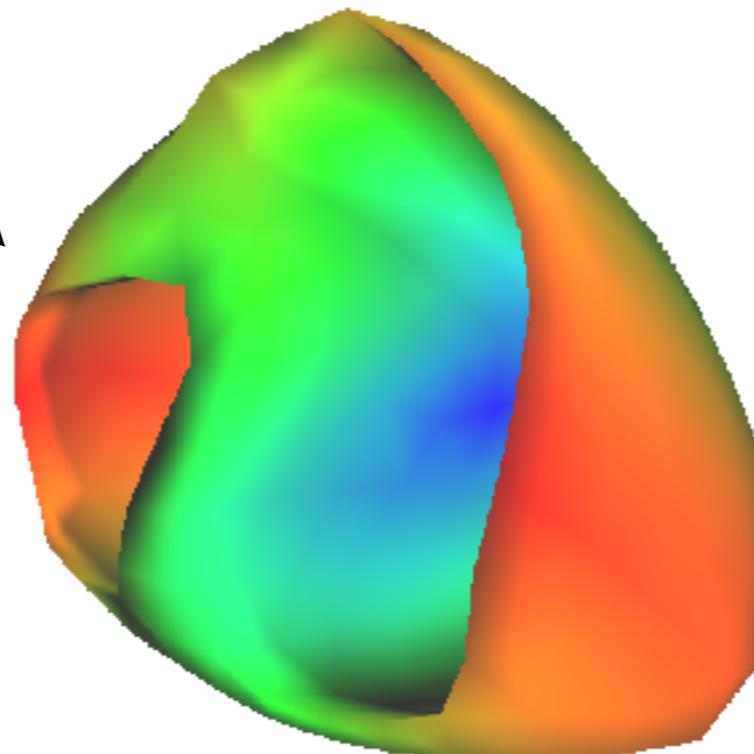


BSPM



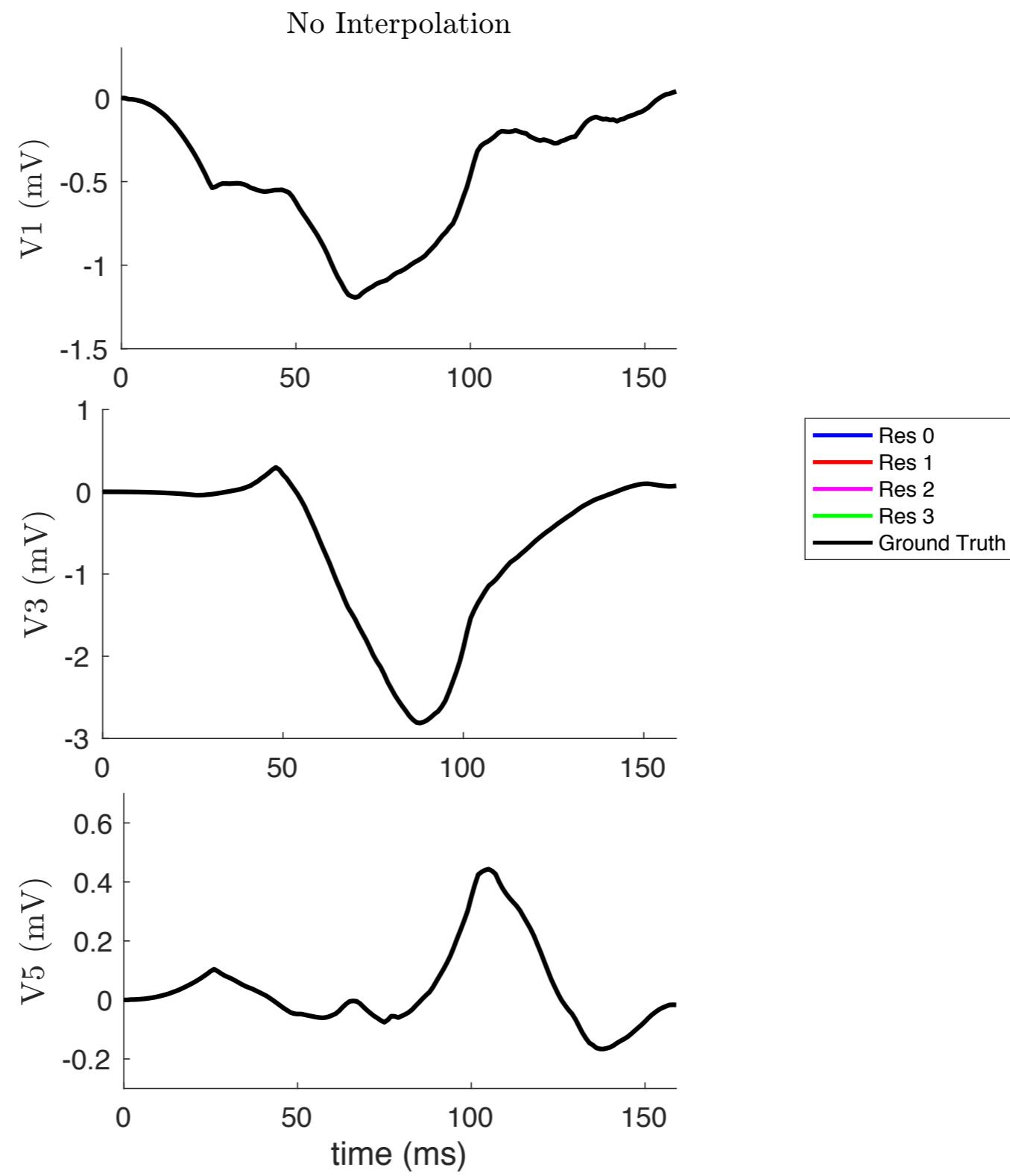
Activation Times

Mapping

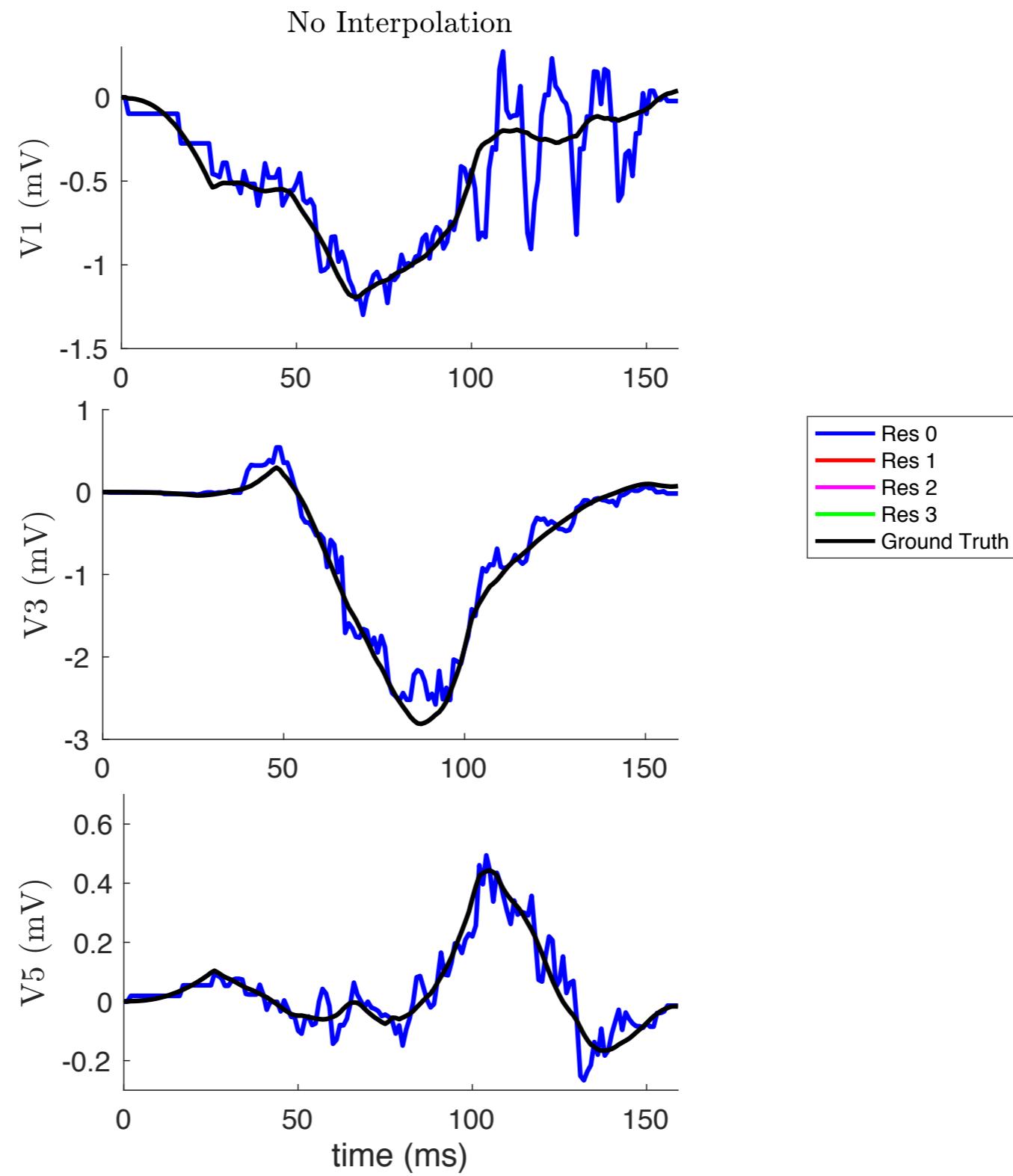


EDL BEM⁺
Interpolation

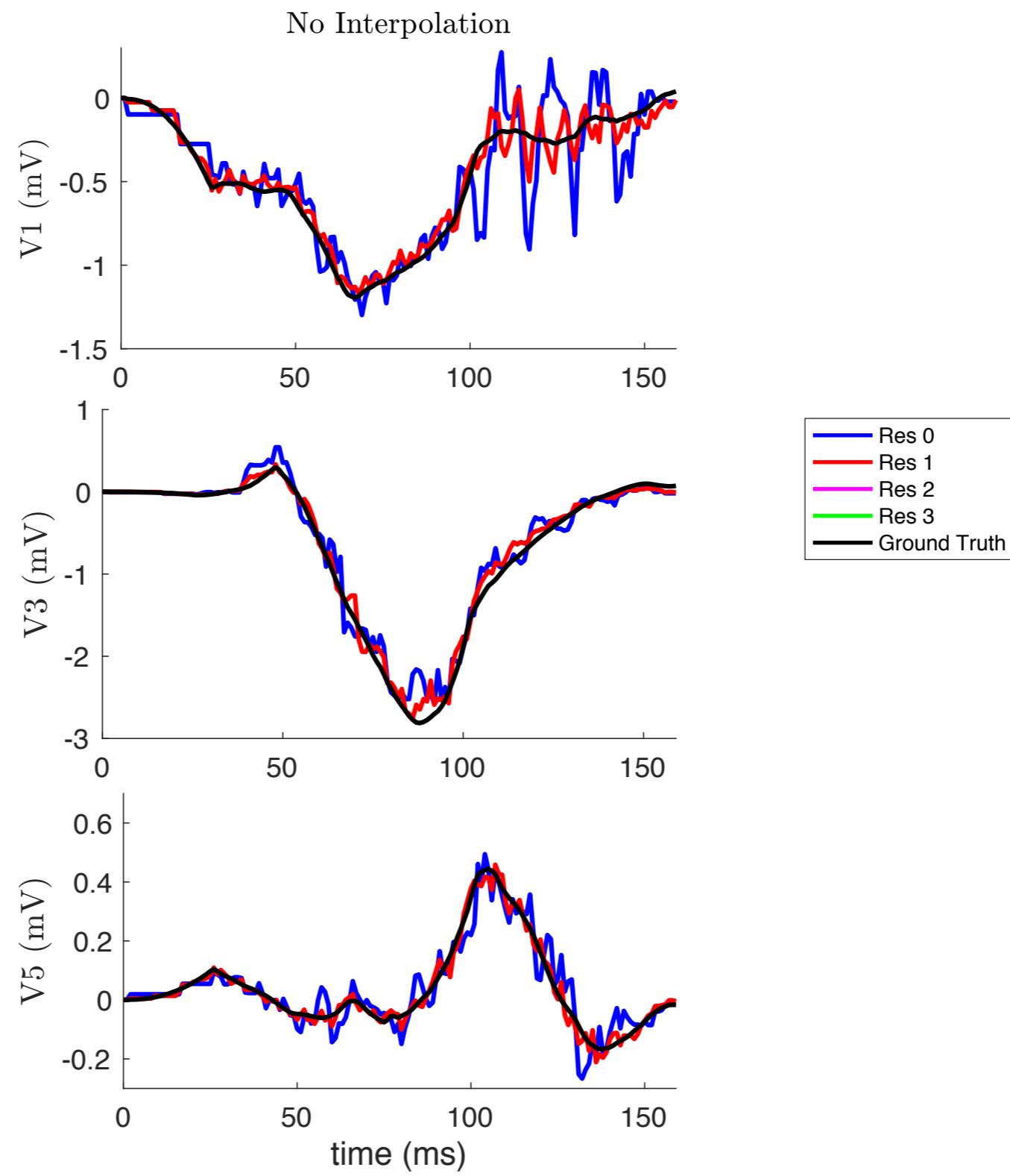
Effect of Undersampling



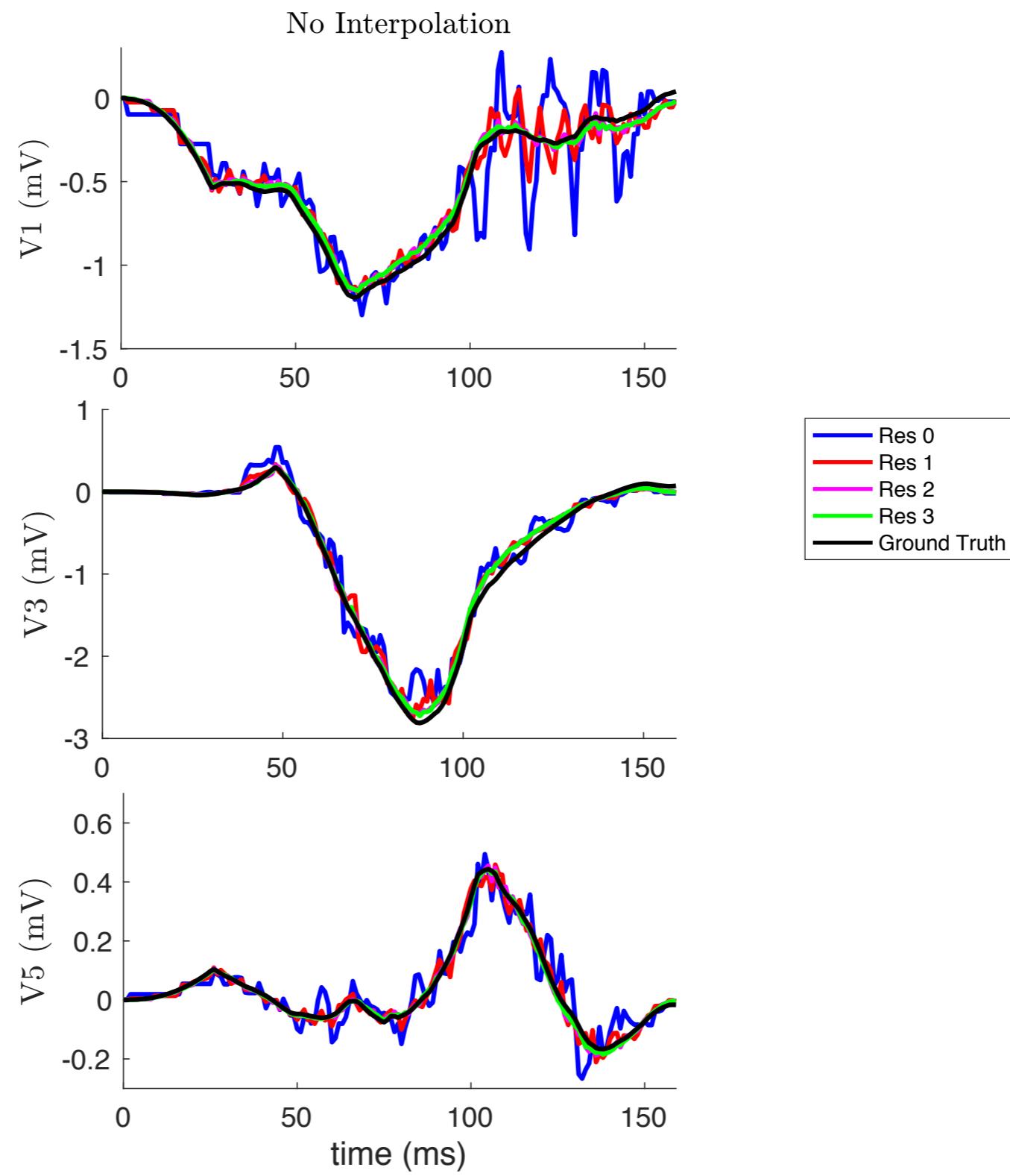
Effect of Undersampling



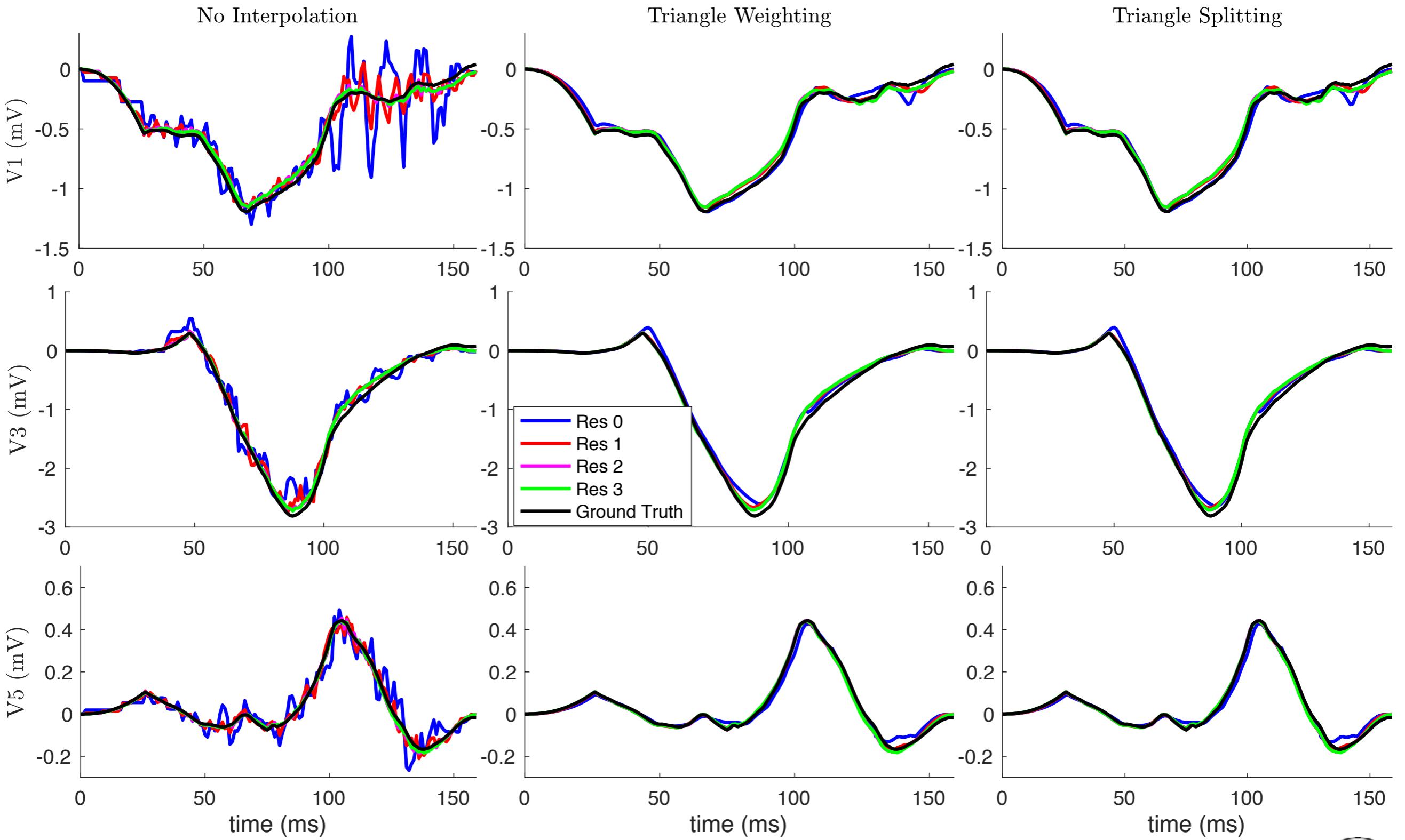
Effect of Undersampling



Effect of Undersampling

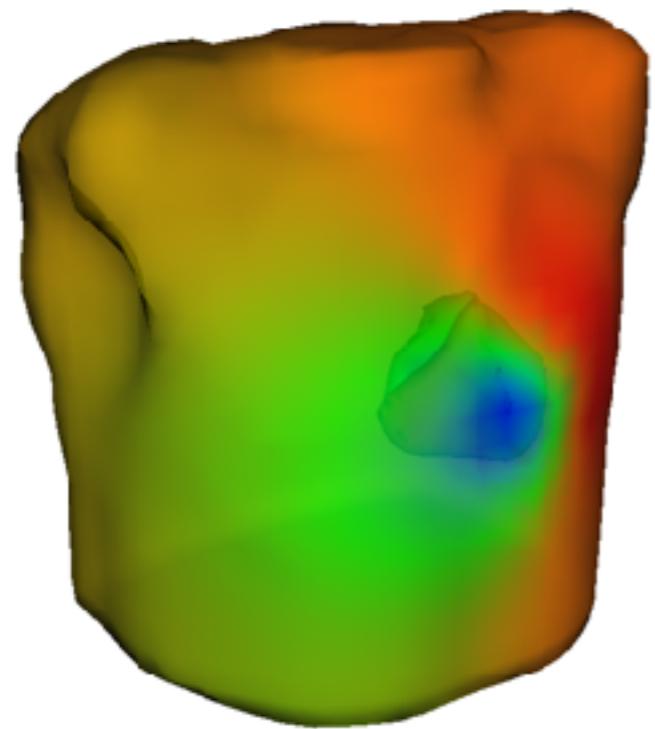


Effect of Interpolation

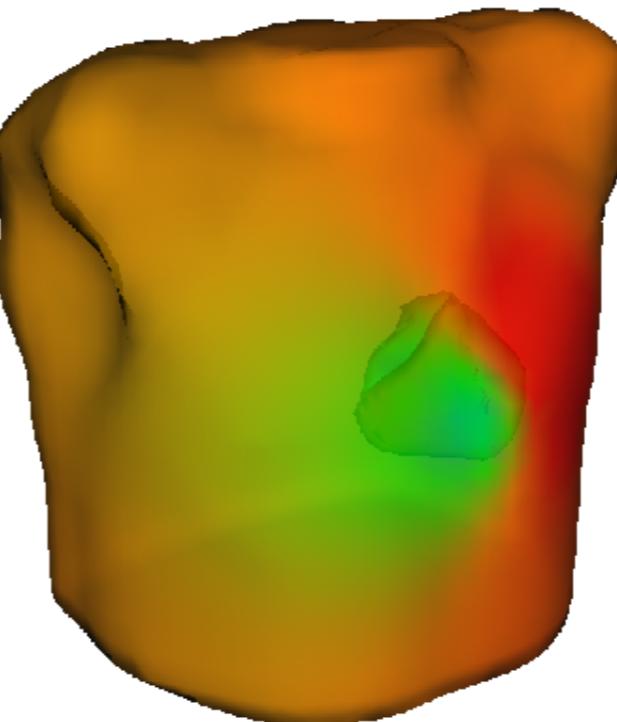
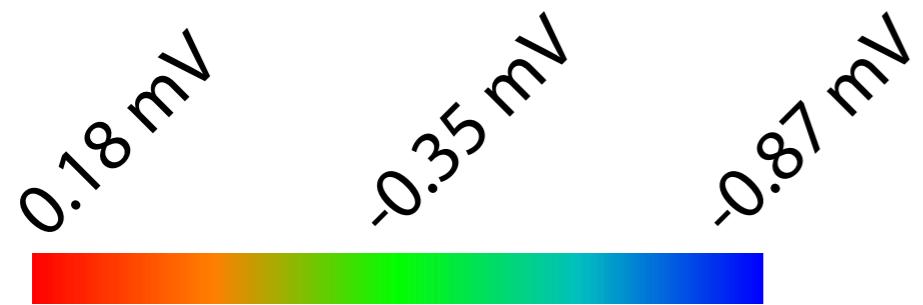


Spatial interpolation can eliminate temporal oscillations, even with low source resolution

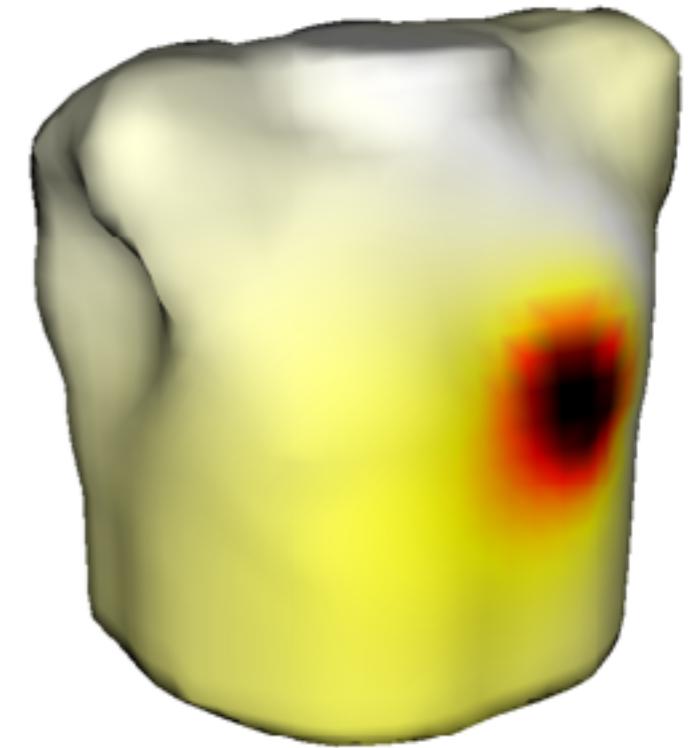
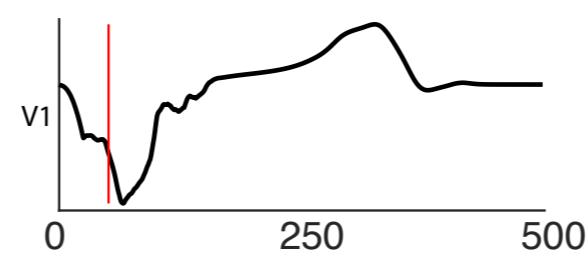
Effect of Undersampling



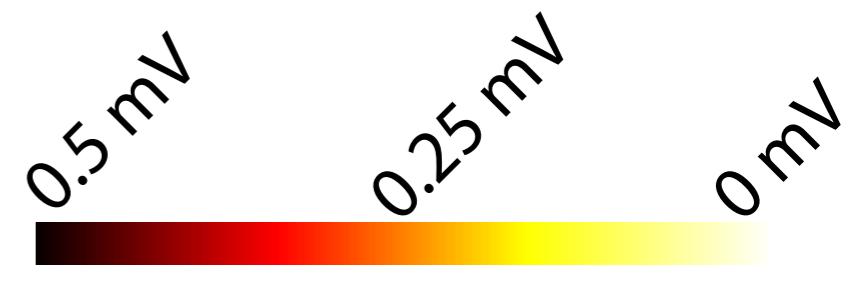
Ground Truth



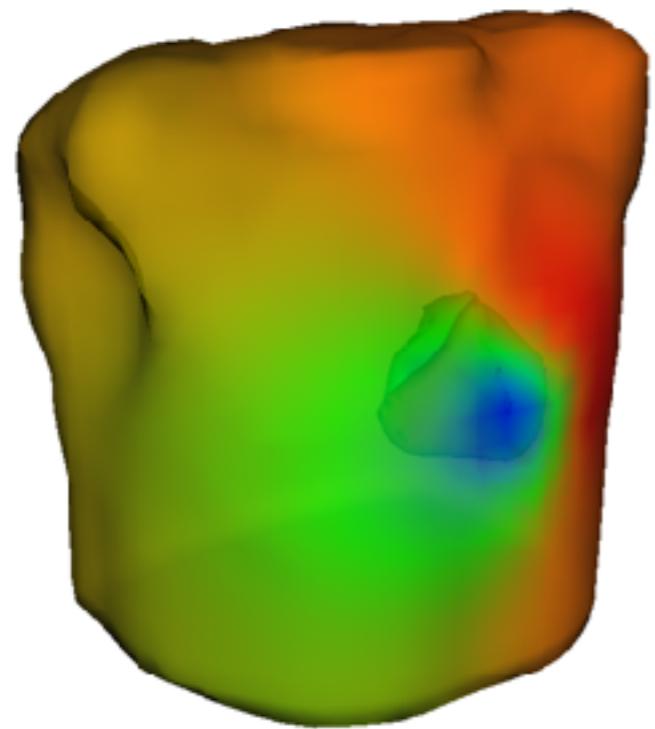
Res 0



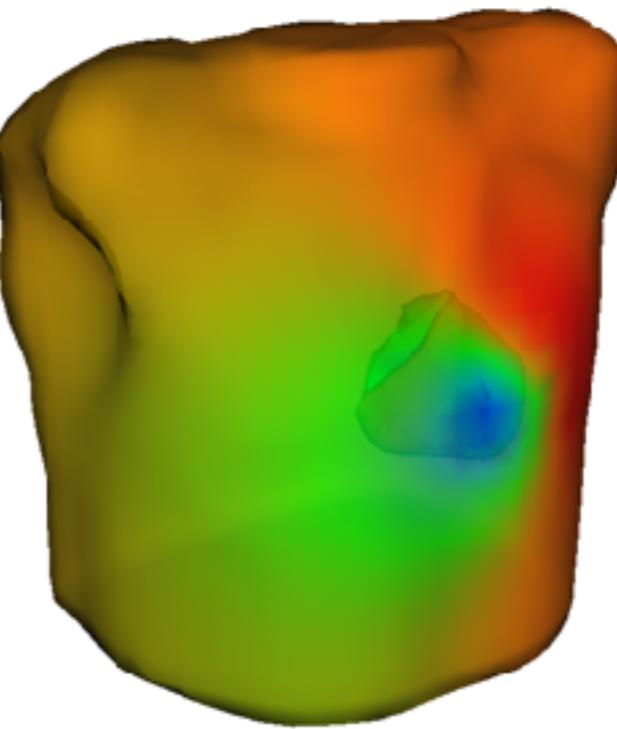
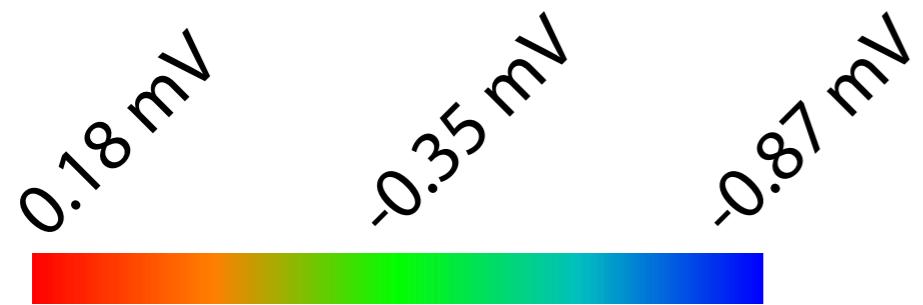
Difference



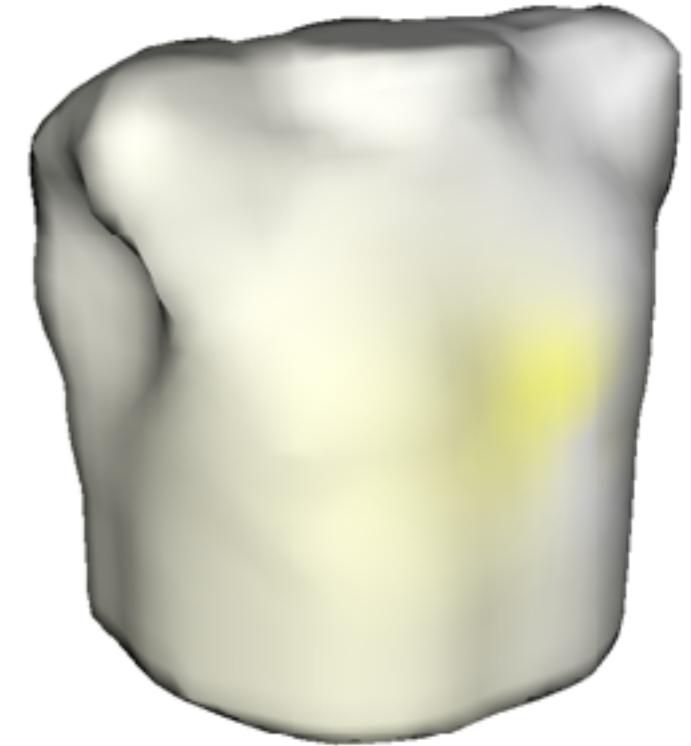
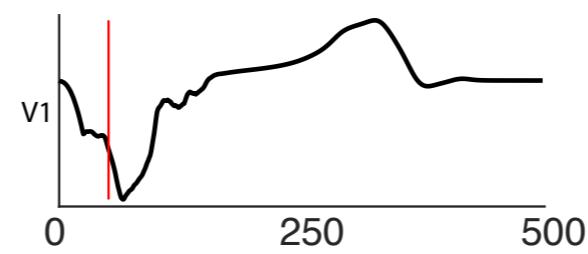
Effect of Undersampling



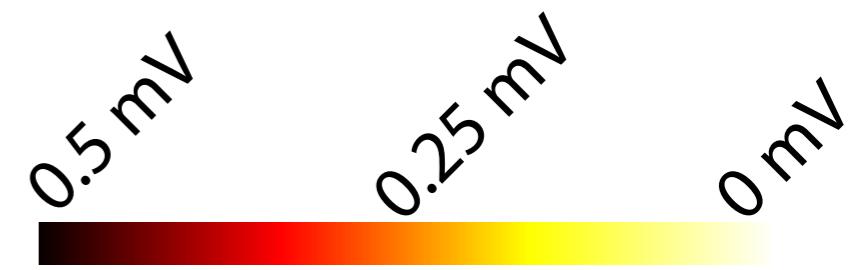
Ground Truth



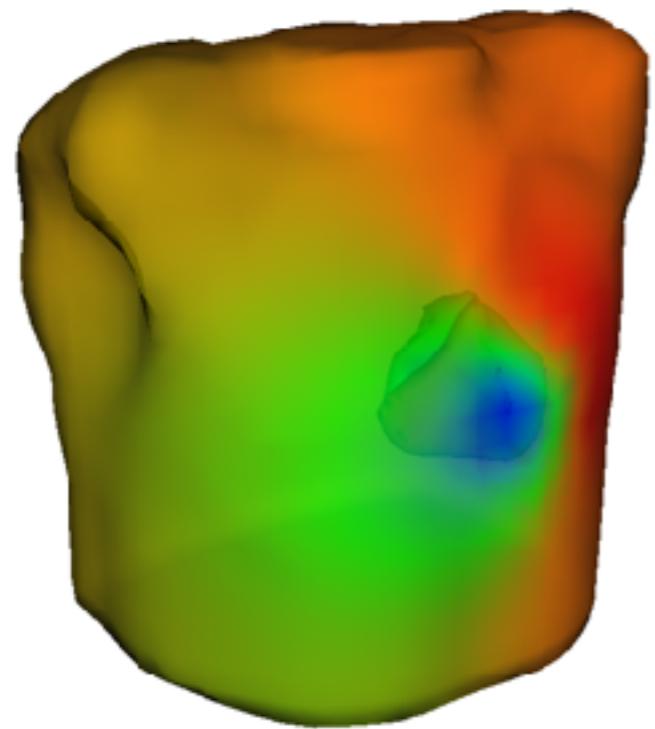
Res 1



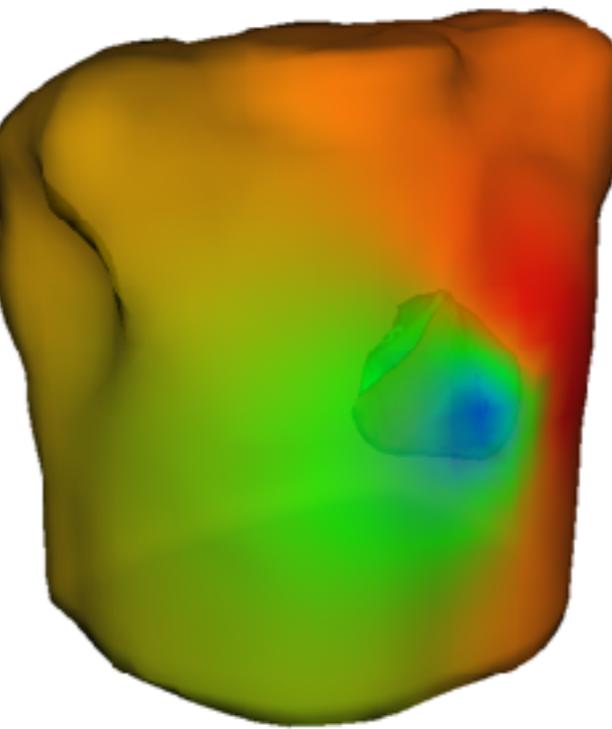
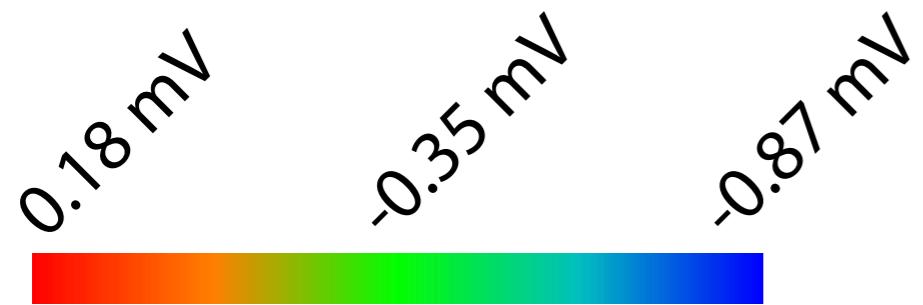
Difference



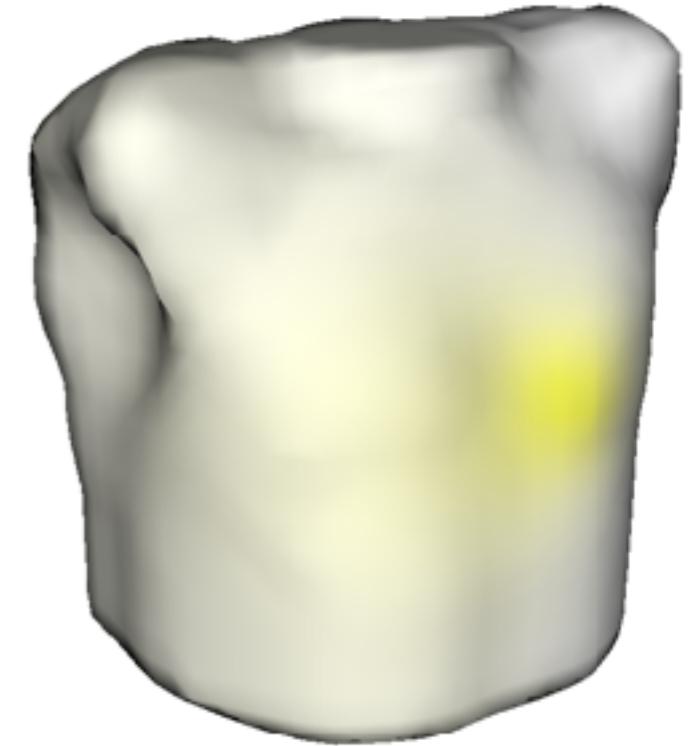
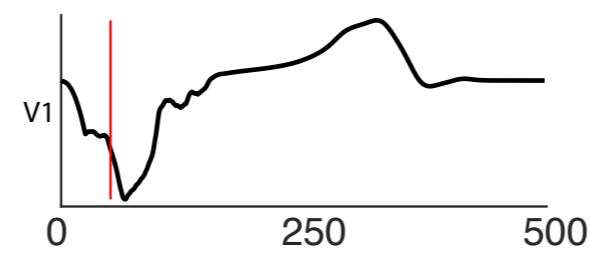
Effect of Undersampling



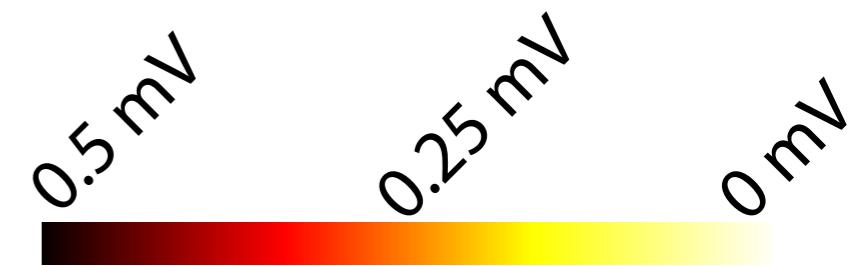
Ground Truth



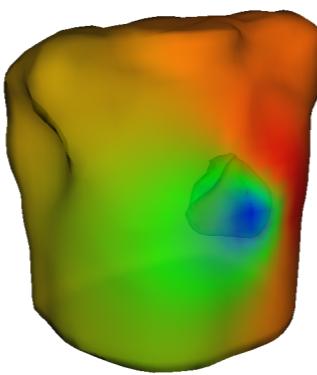
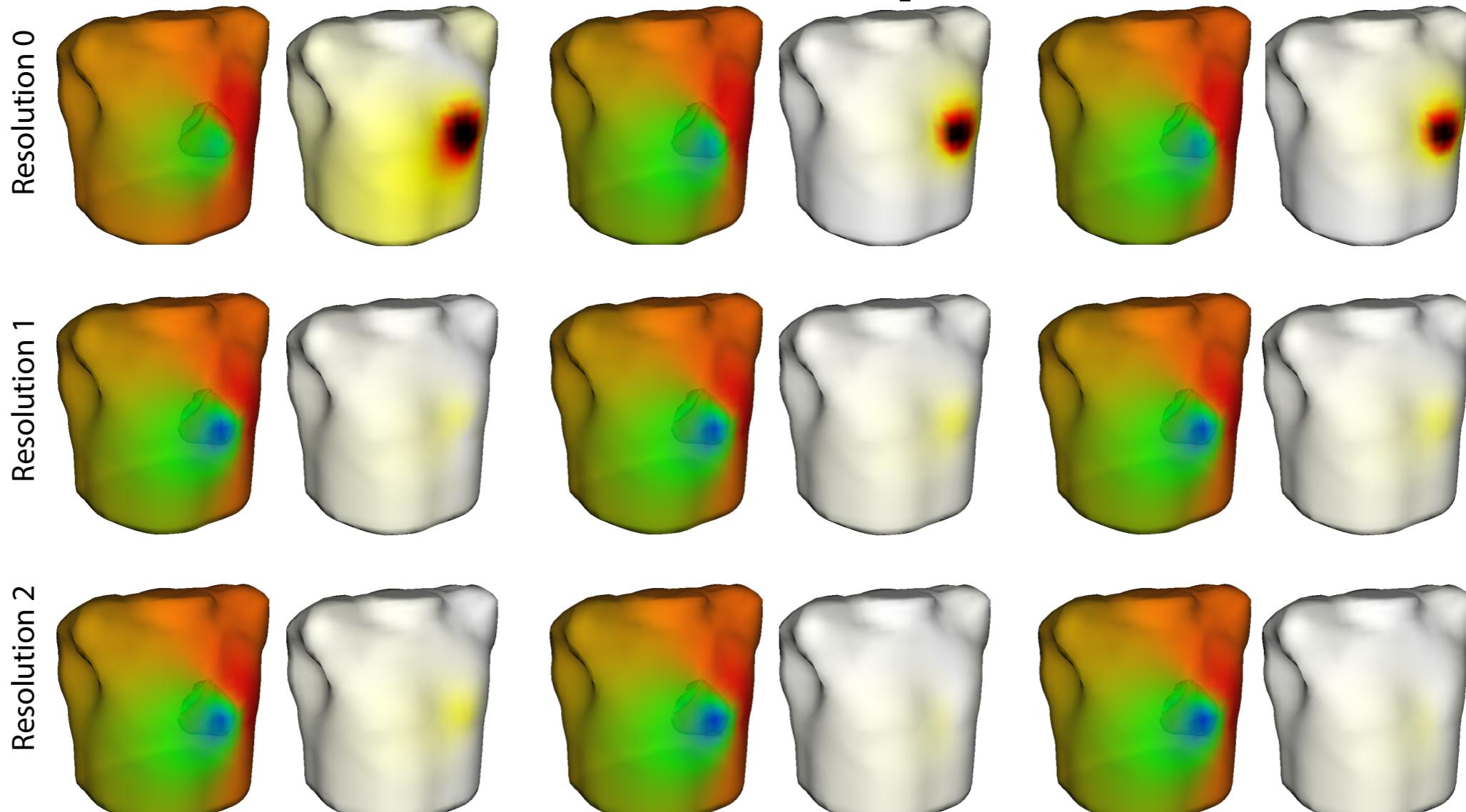
Res 2



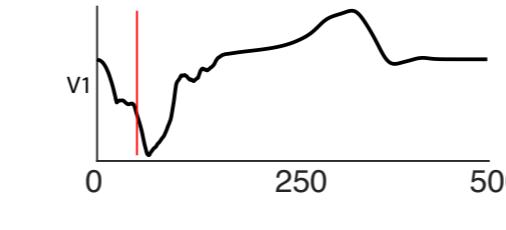
Difference



Effect of Interpolation

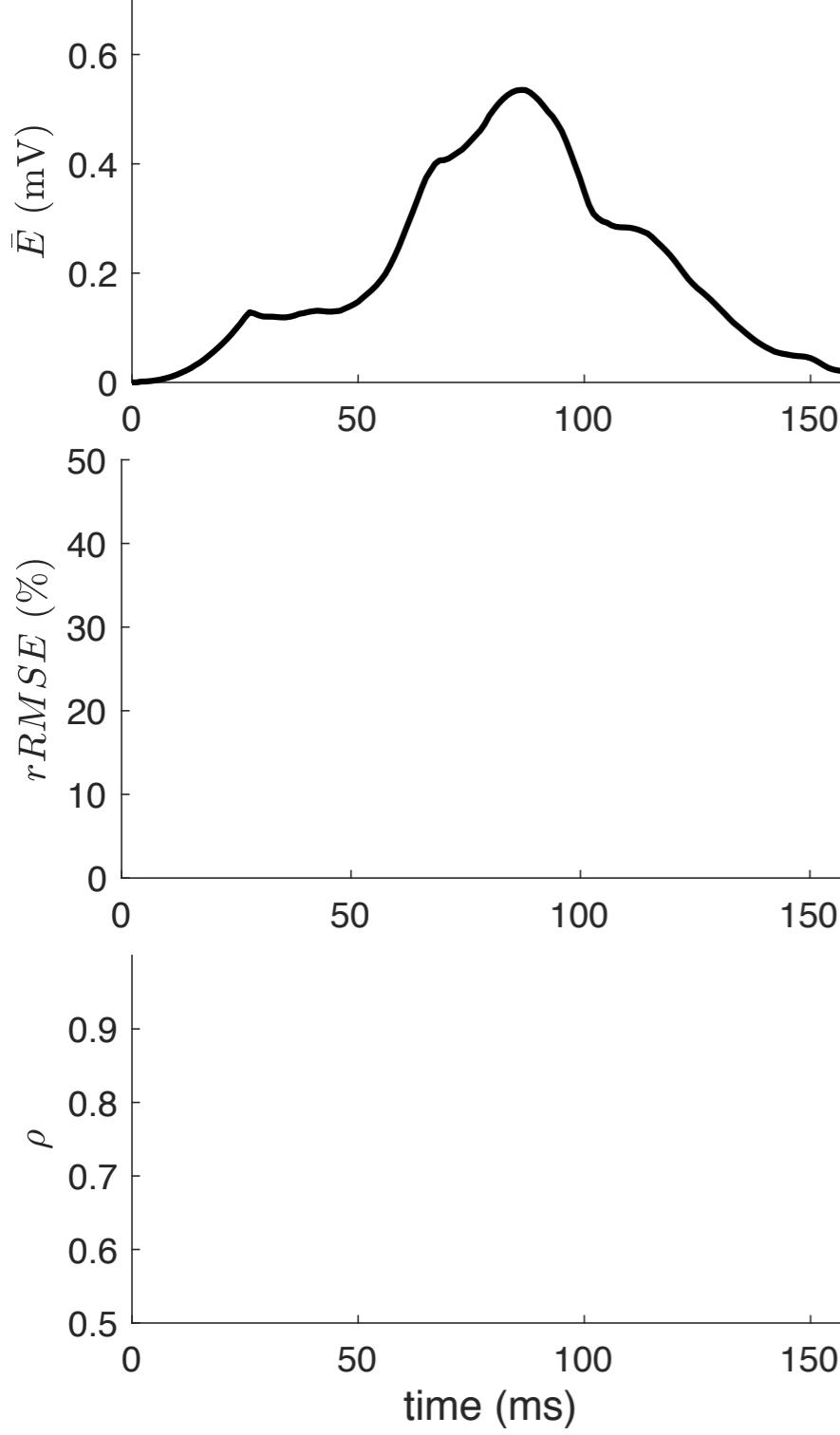


Ground Truth

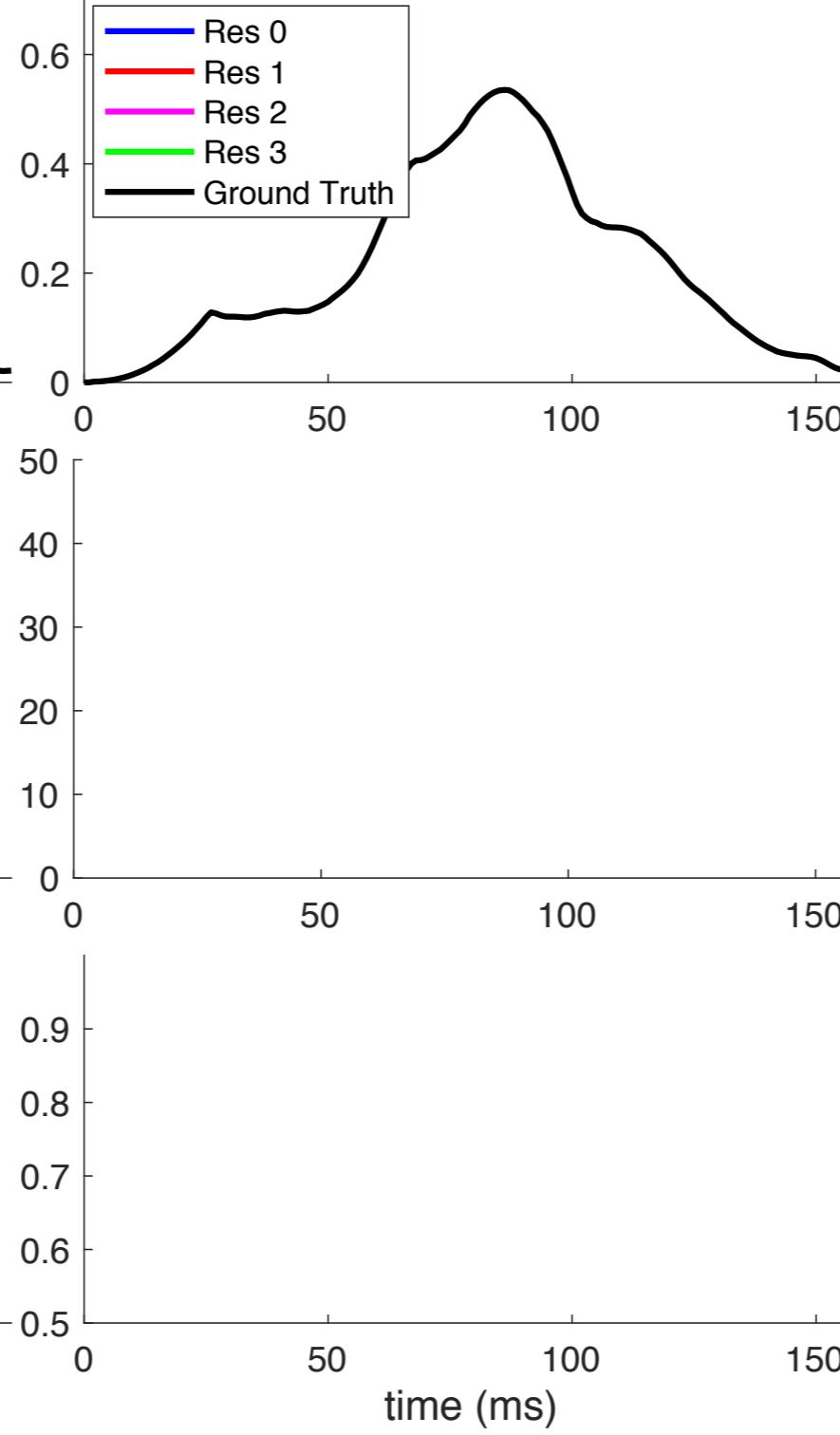


Metrics

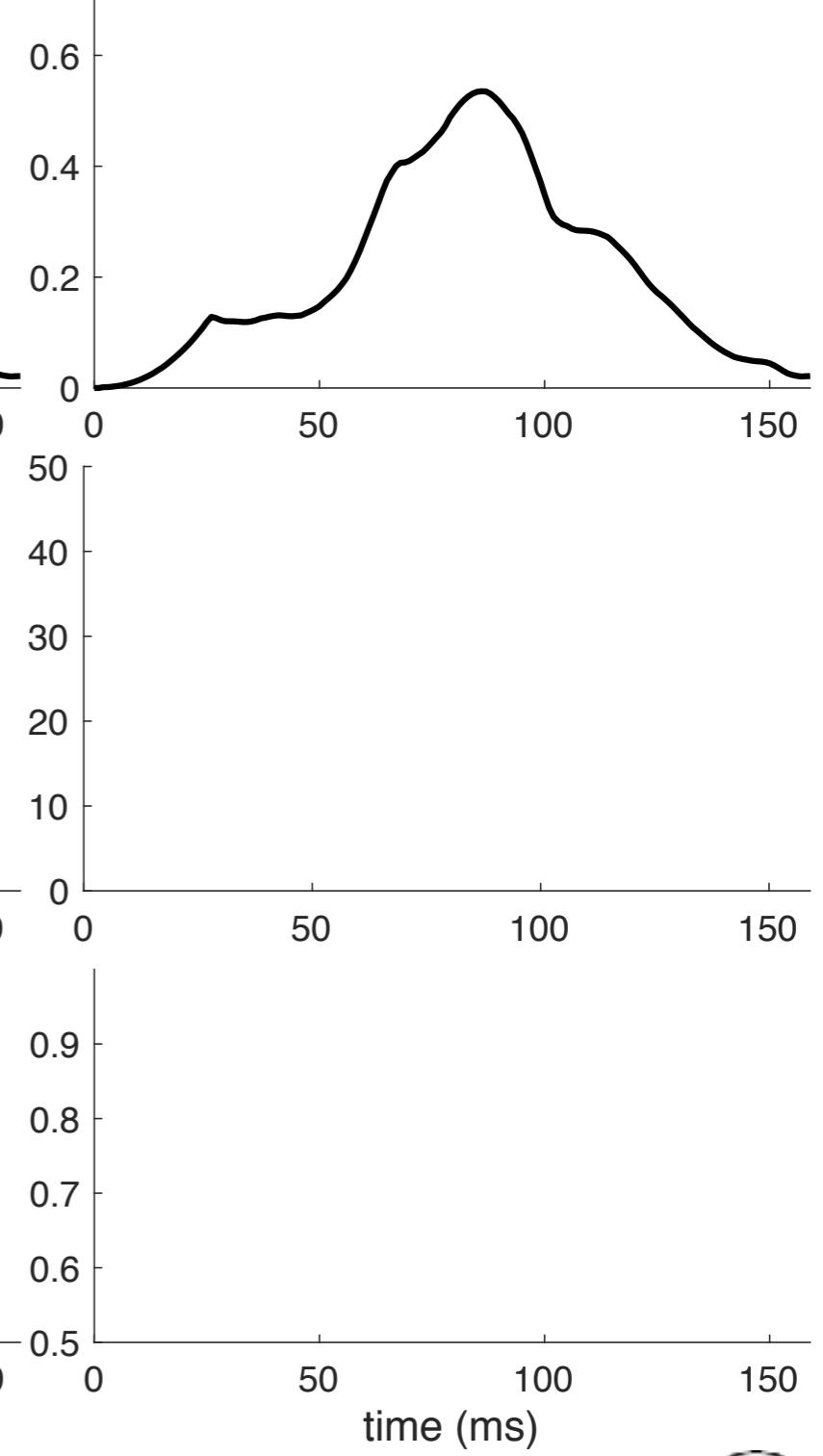
No Interpolation



Tringle Weighting

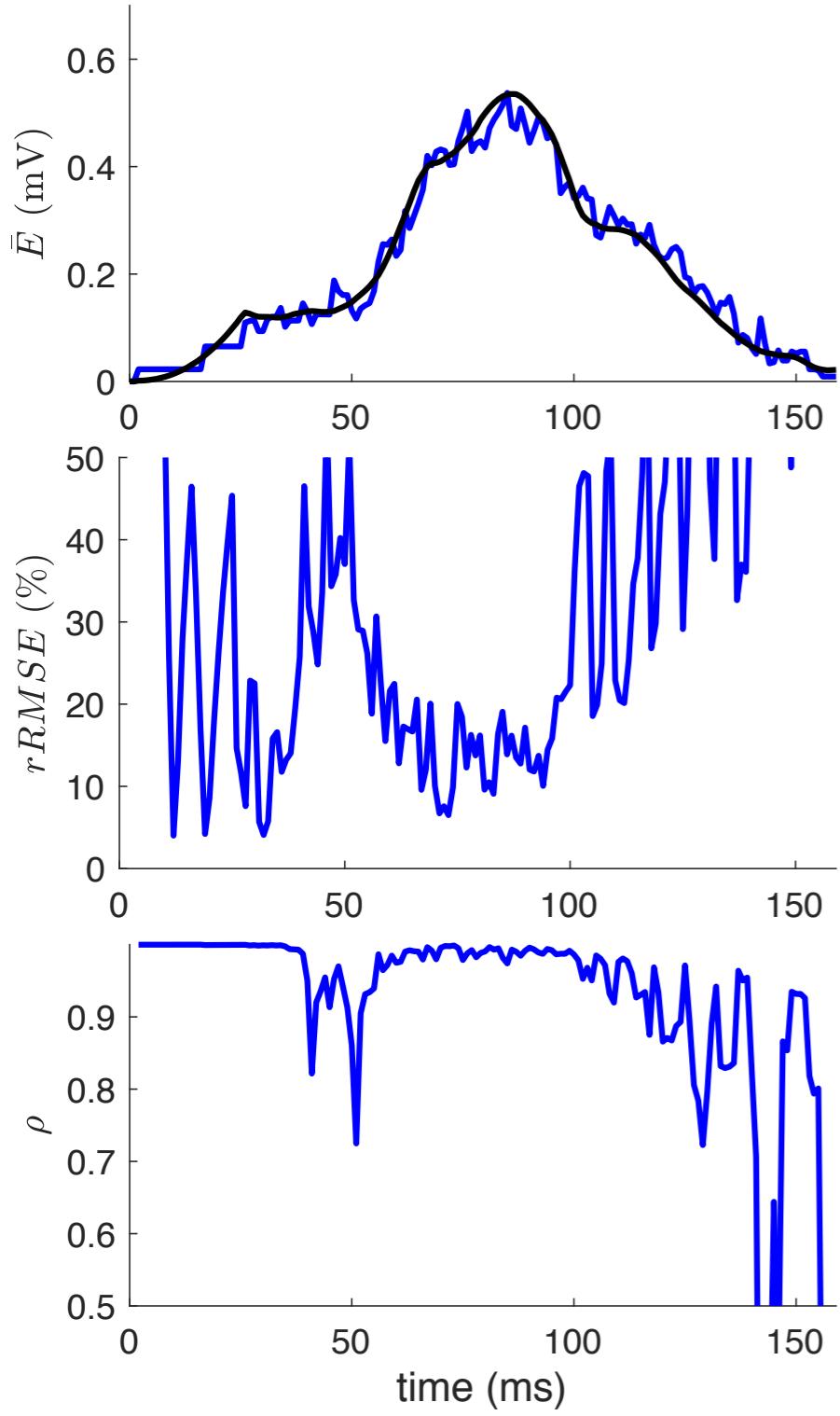


Tringle Splitting

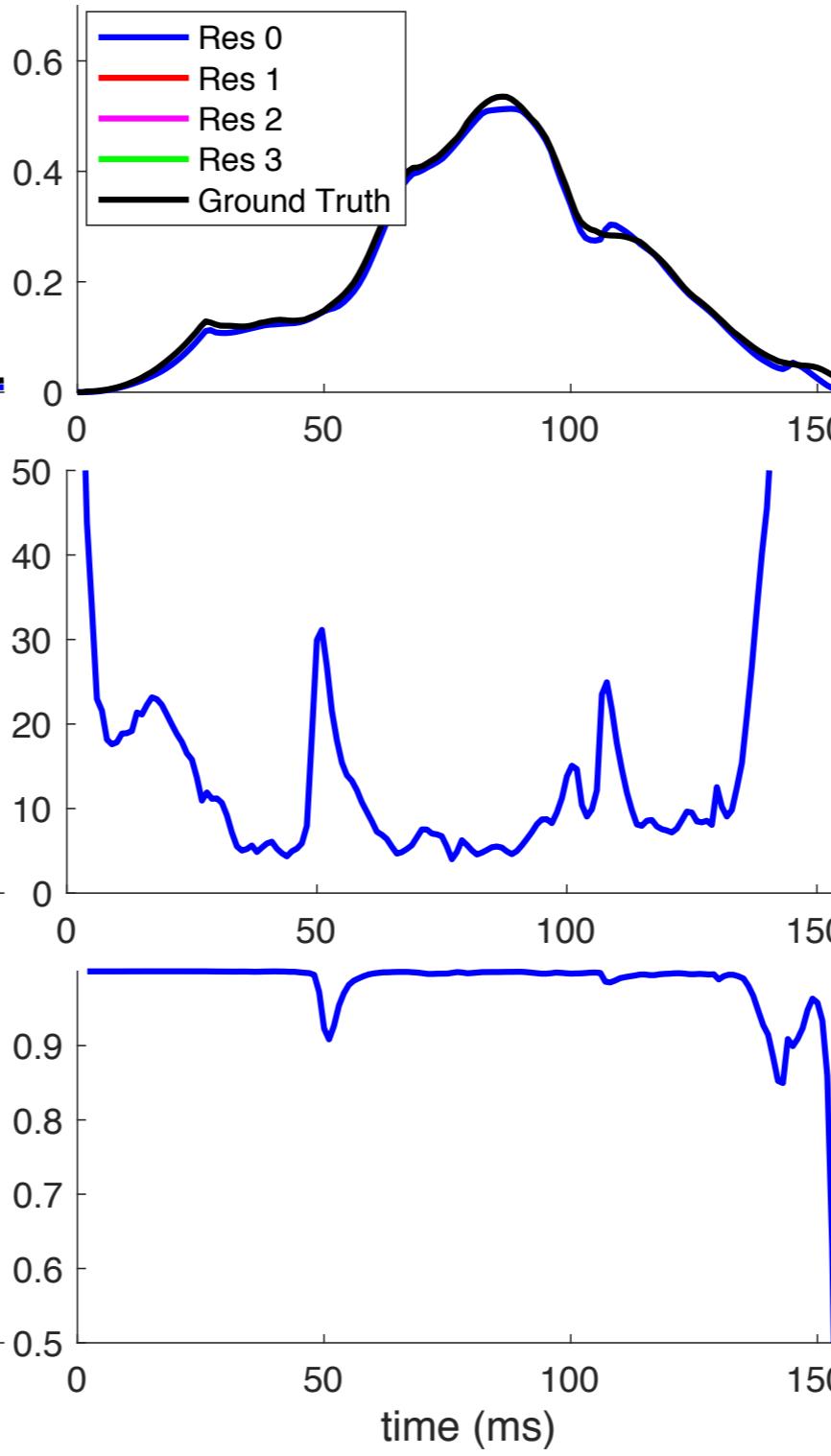


Metrics

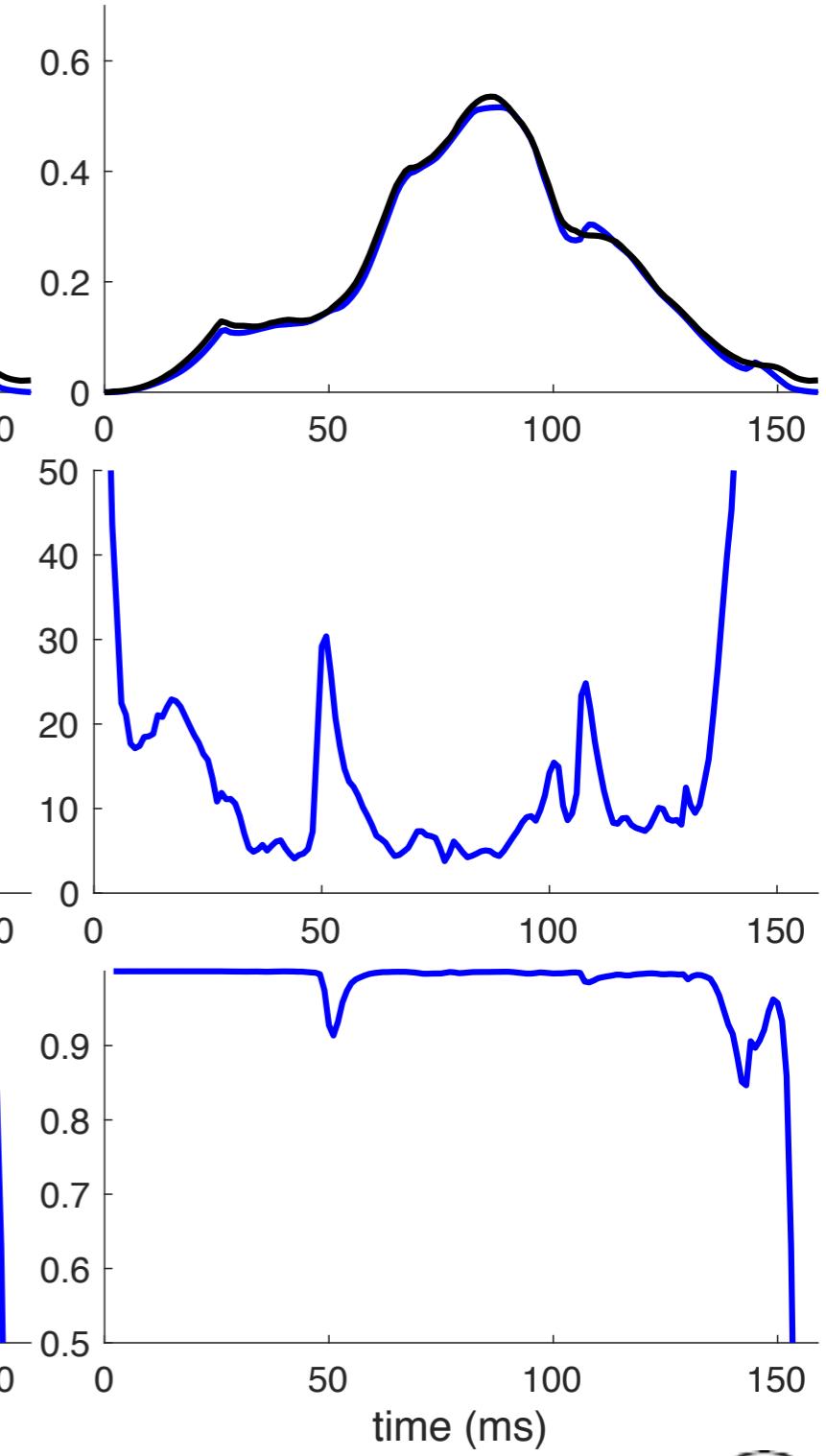
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Tringle Weighting

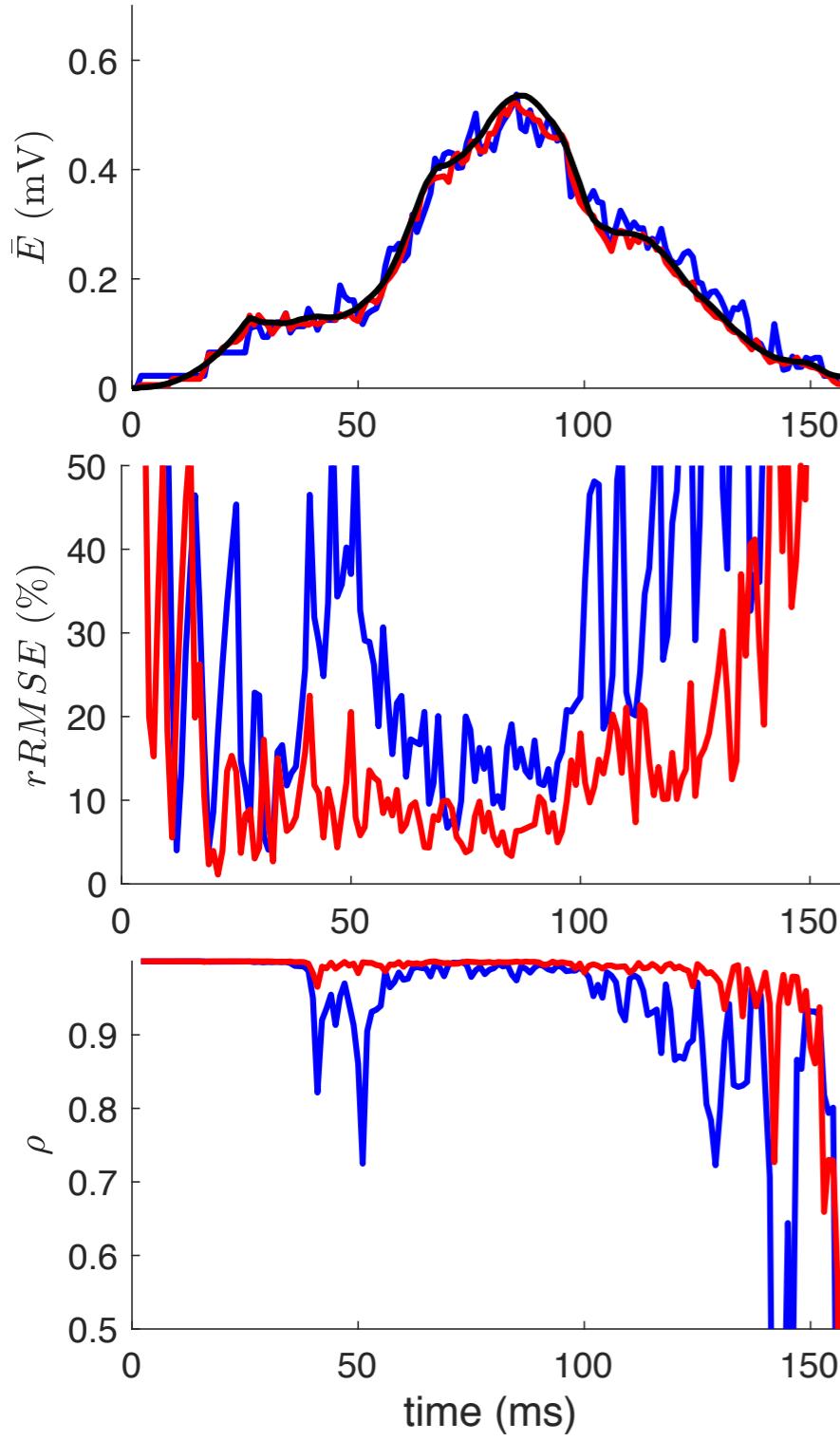


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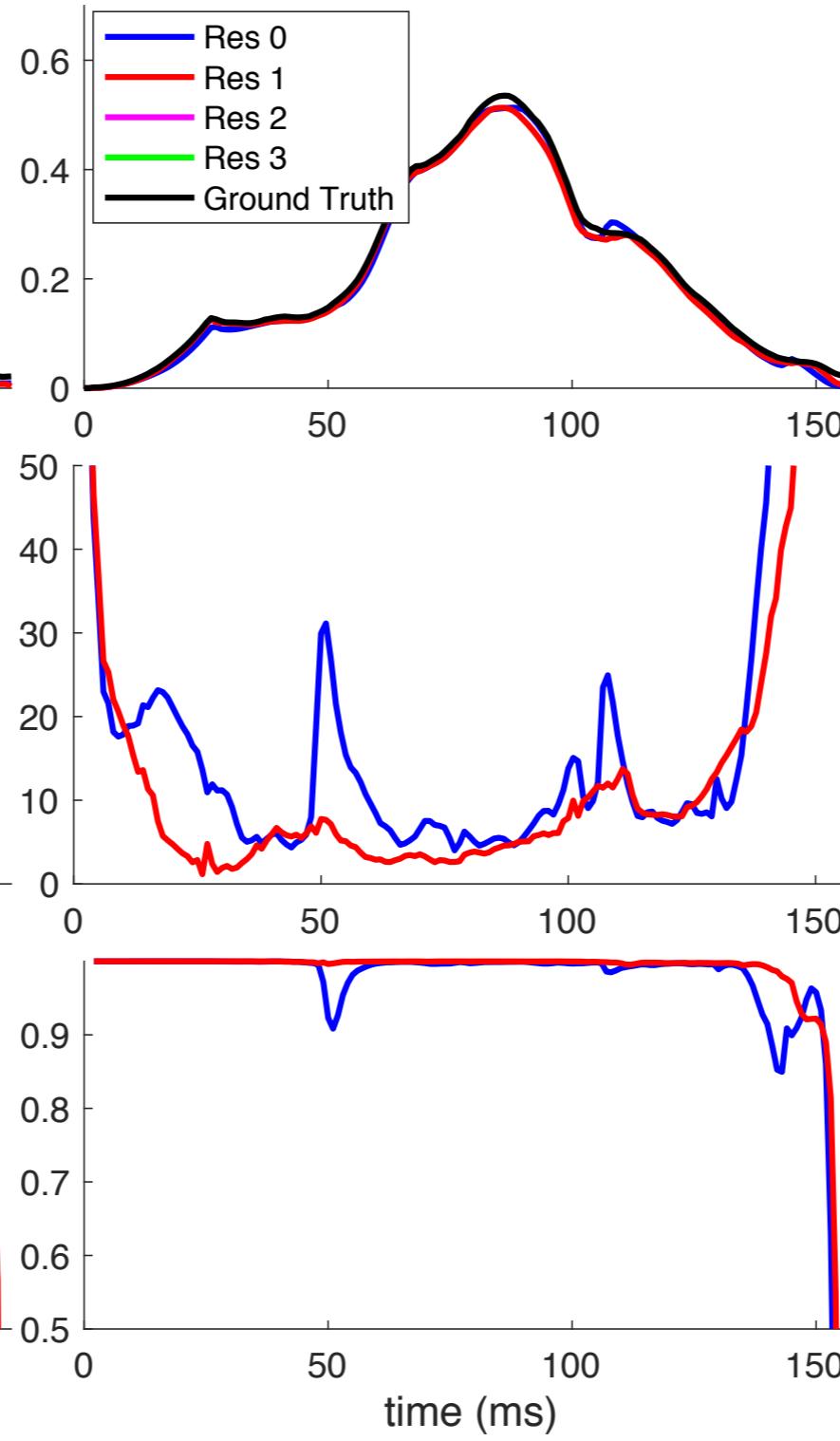


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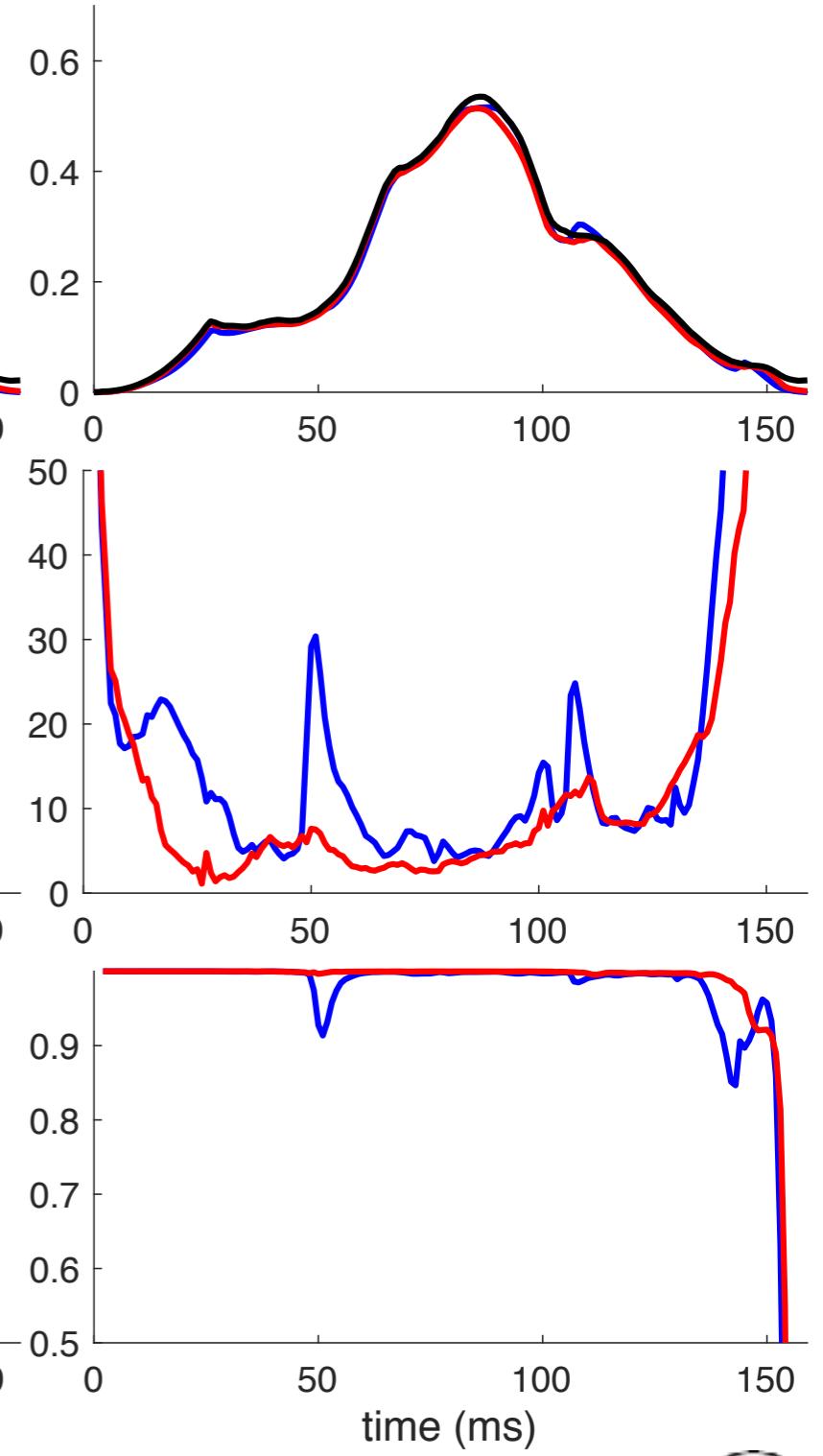
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Tringle Weighting

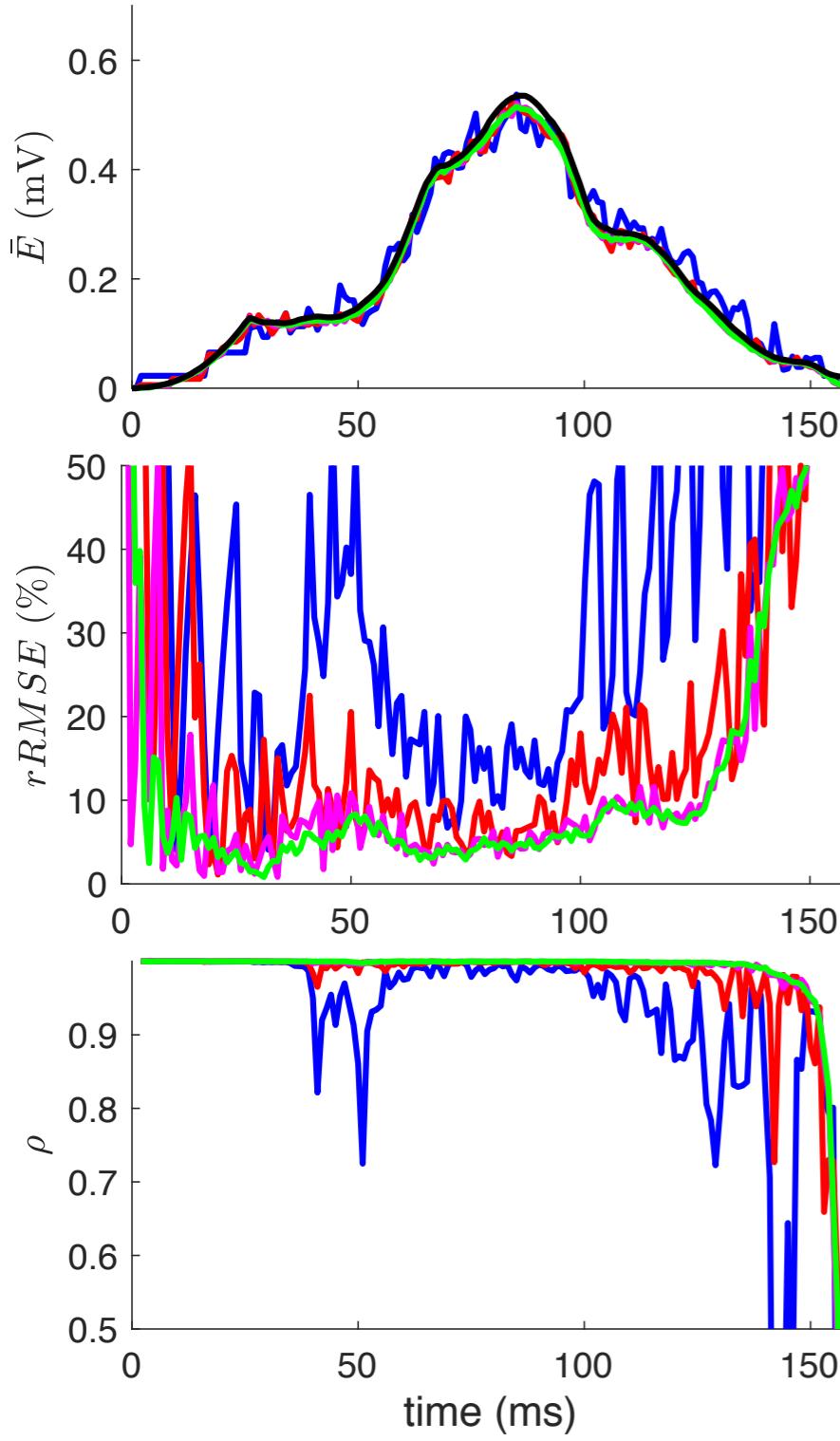


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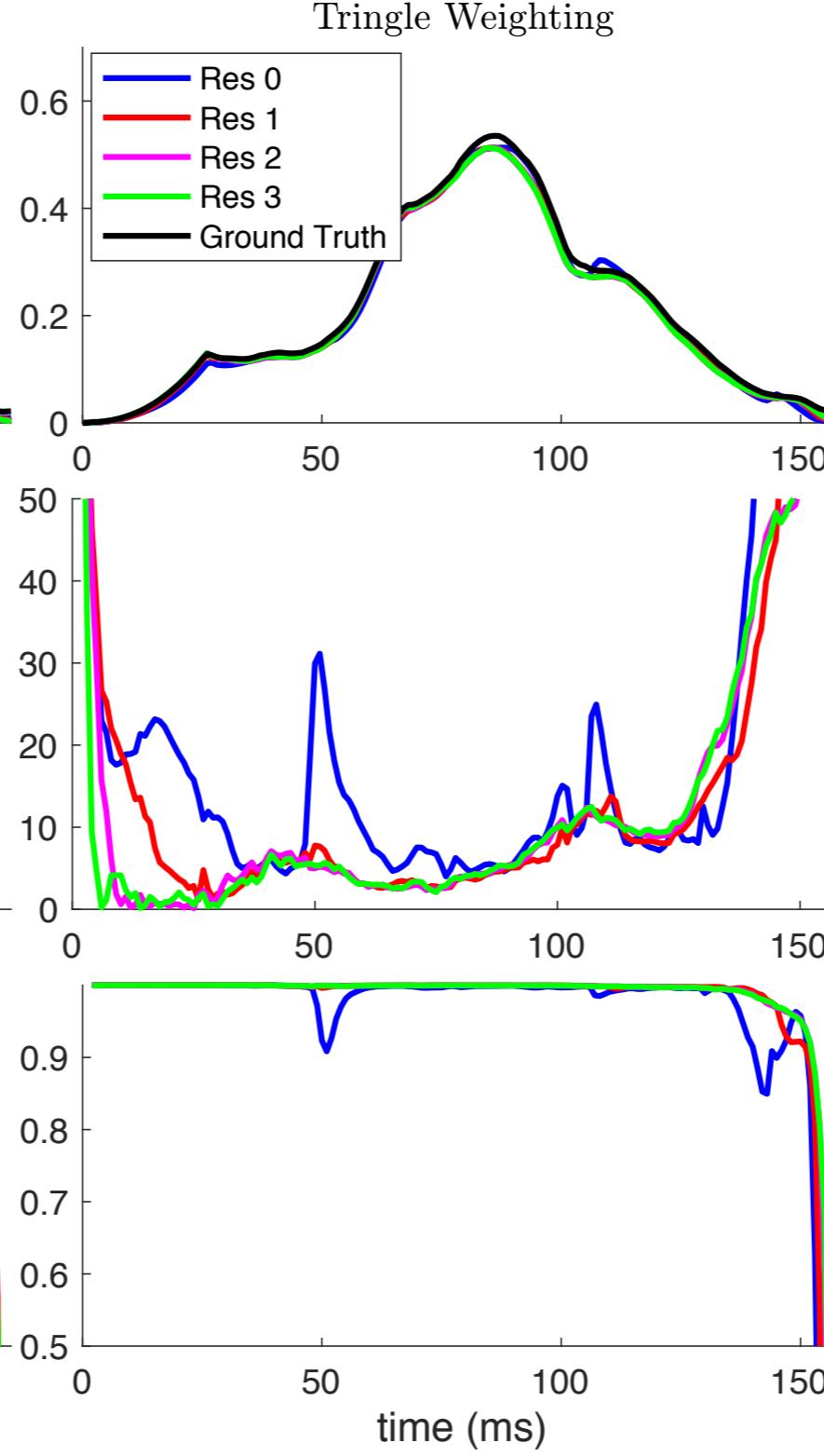


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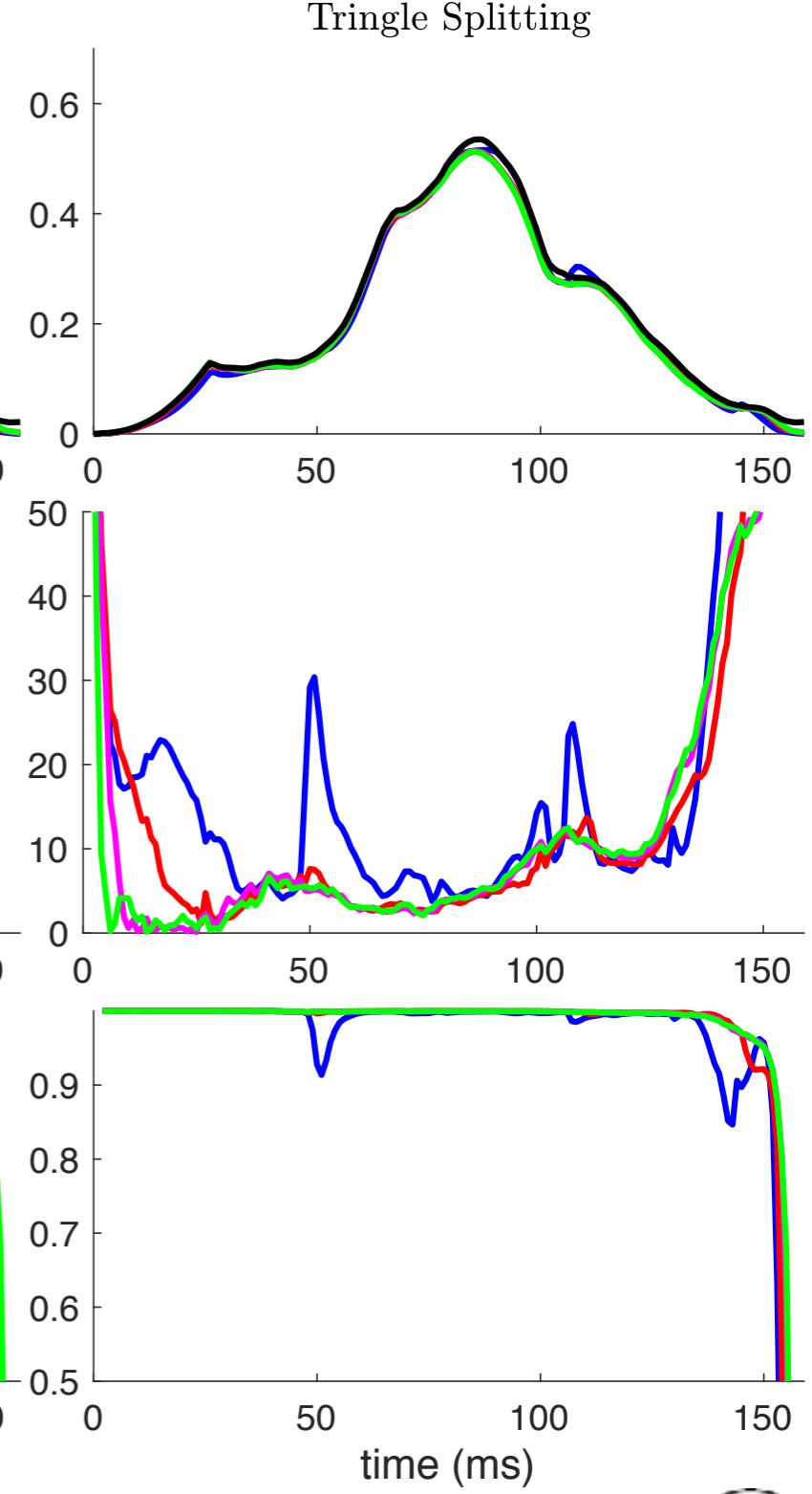
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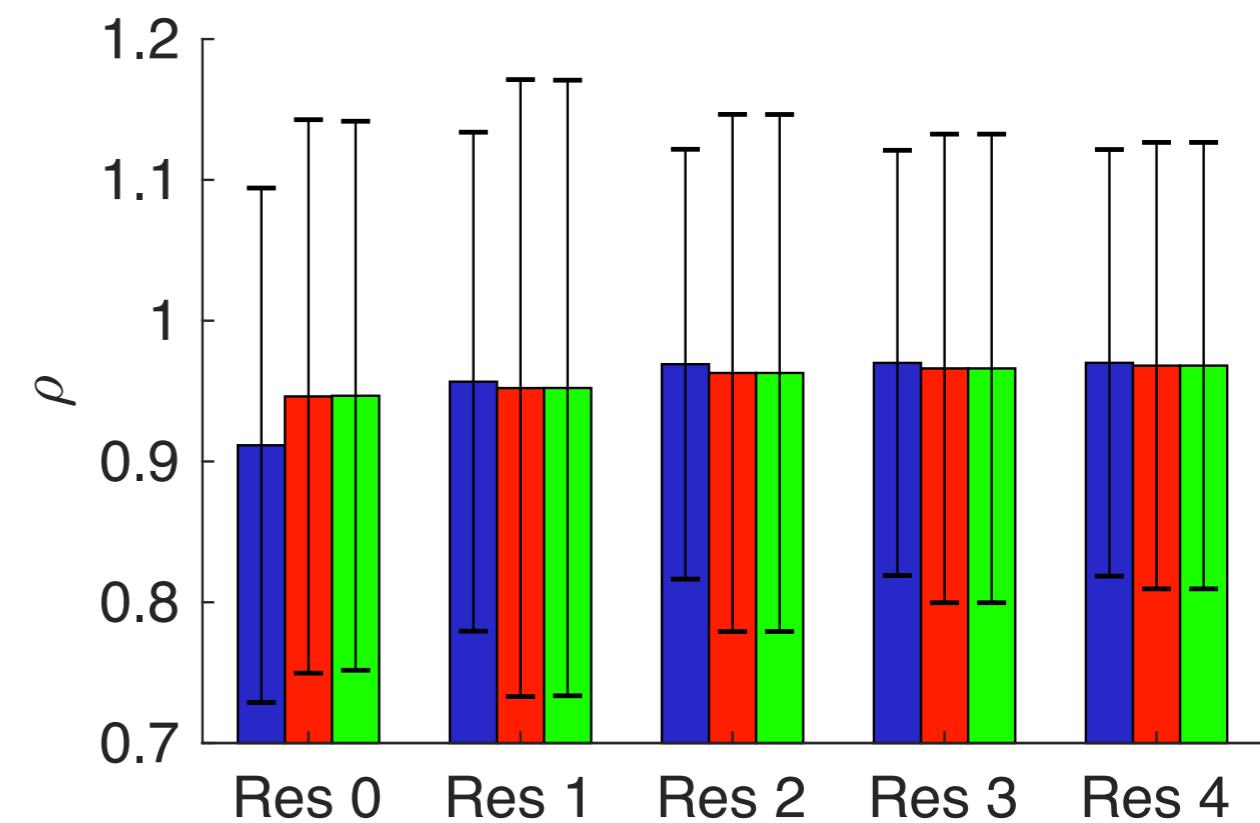
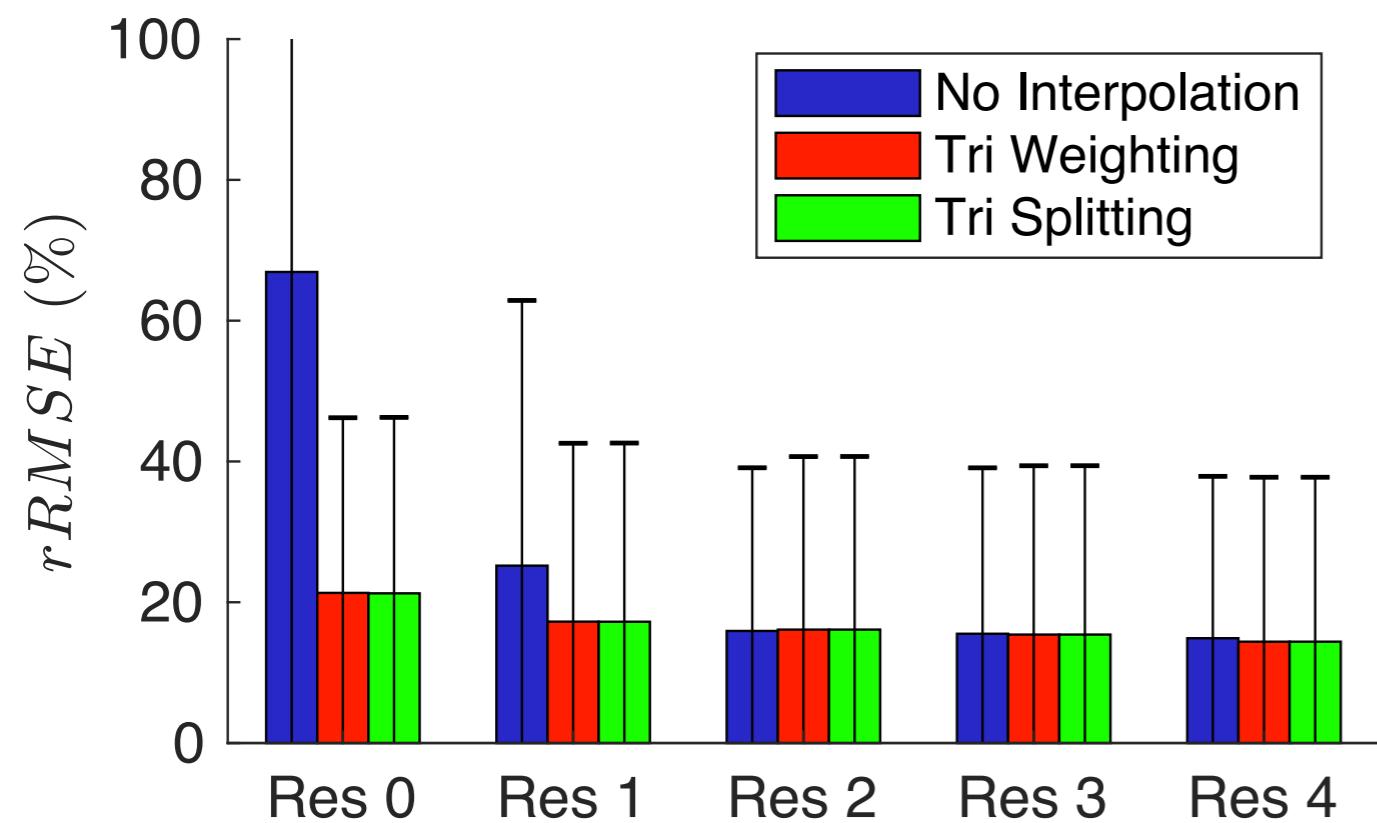
Tringle Weighting



Tringle Splitting

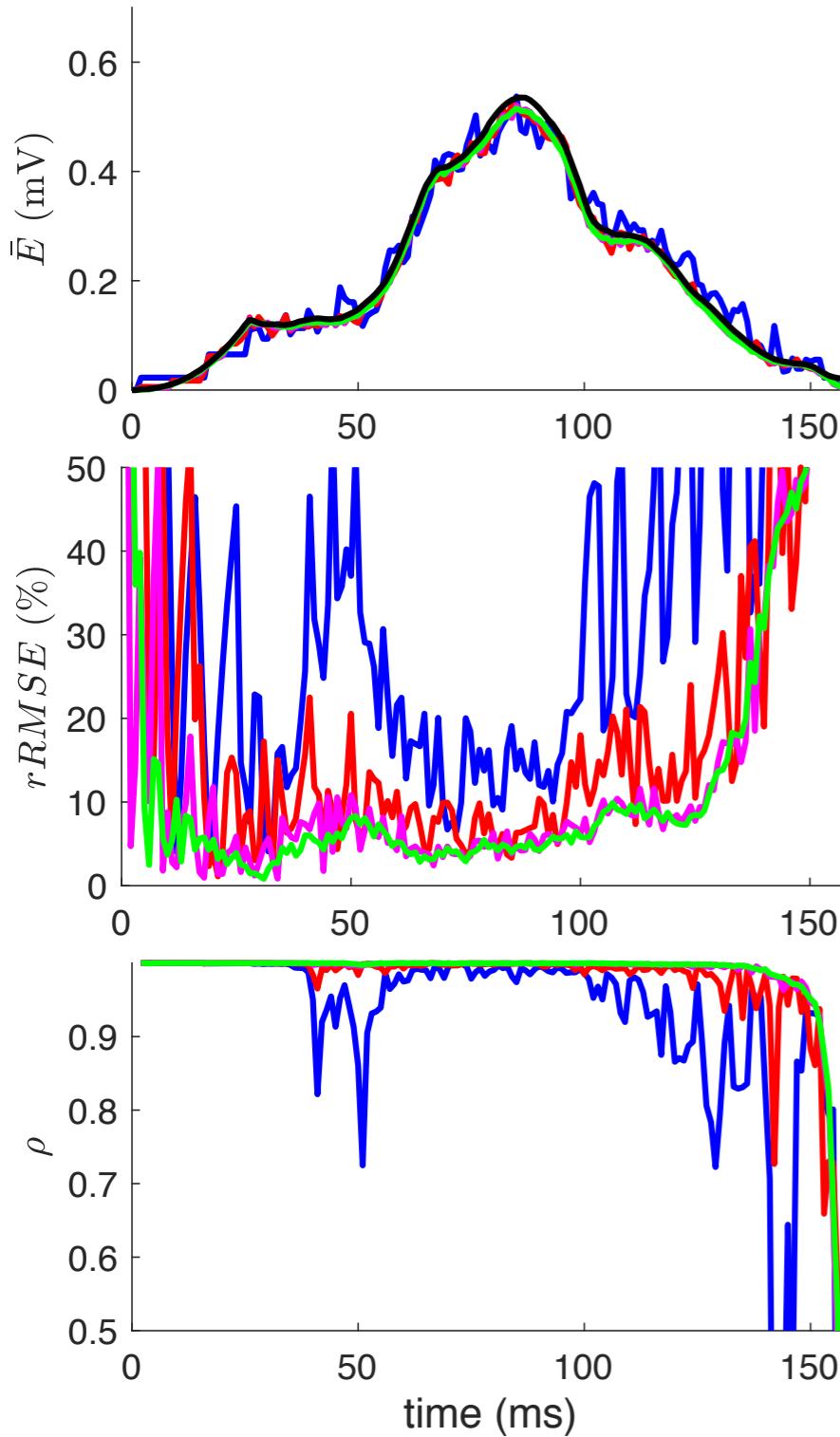


Mean +/- Std Dev of Metrics

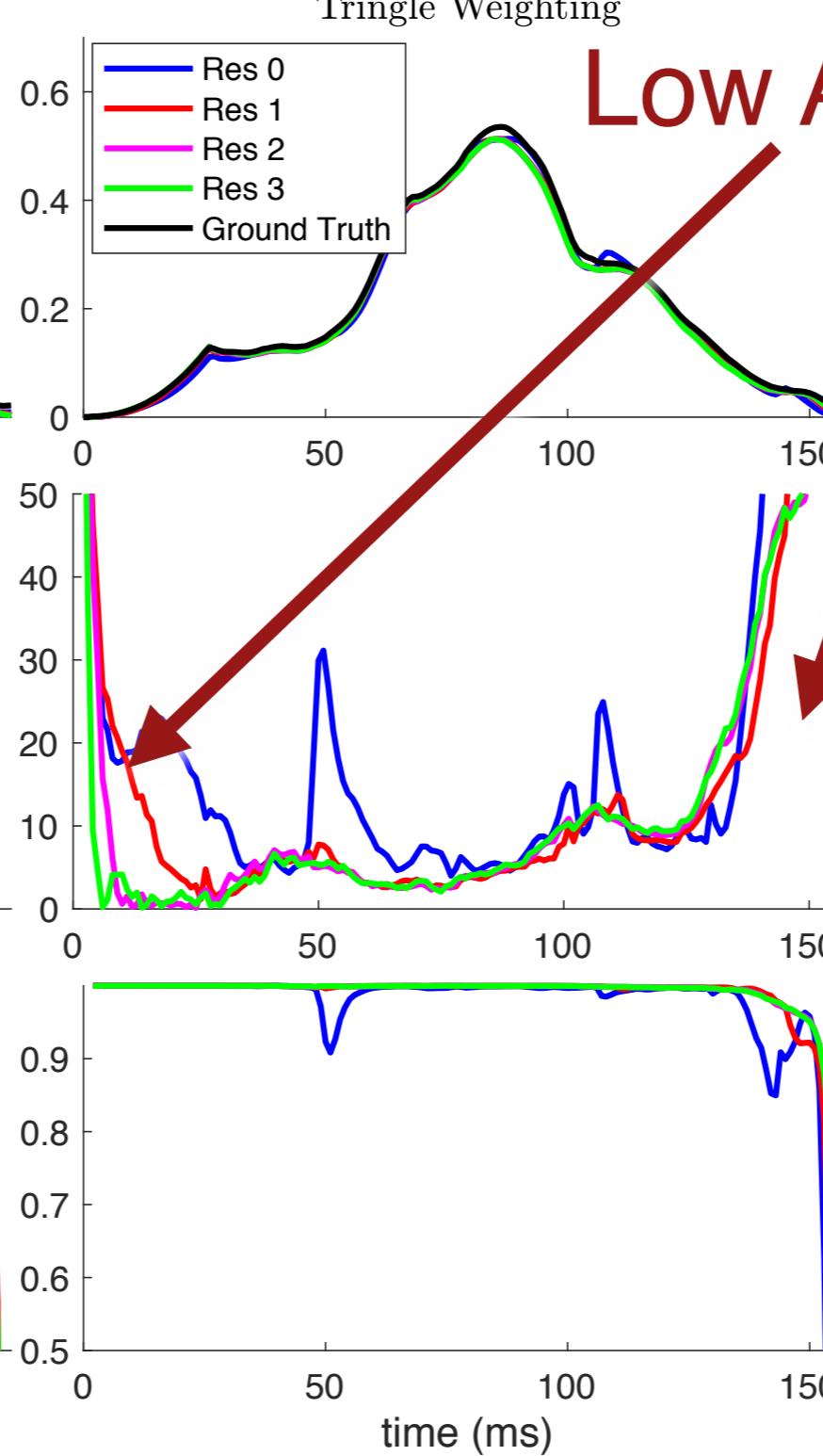


Metrics

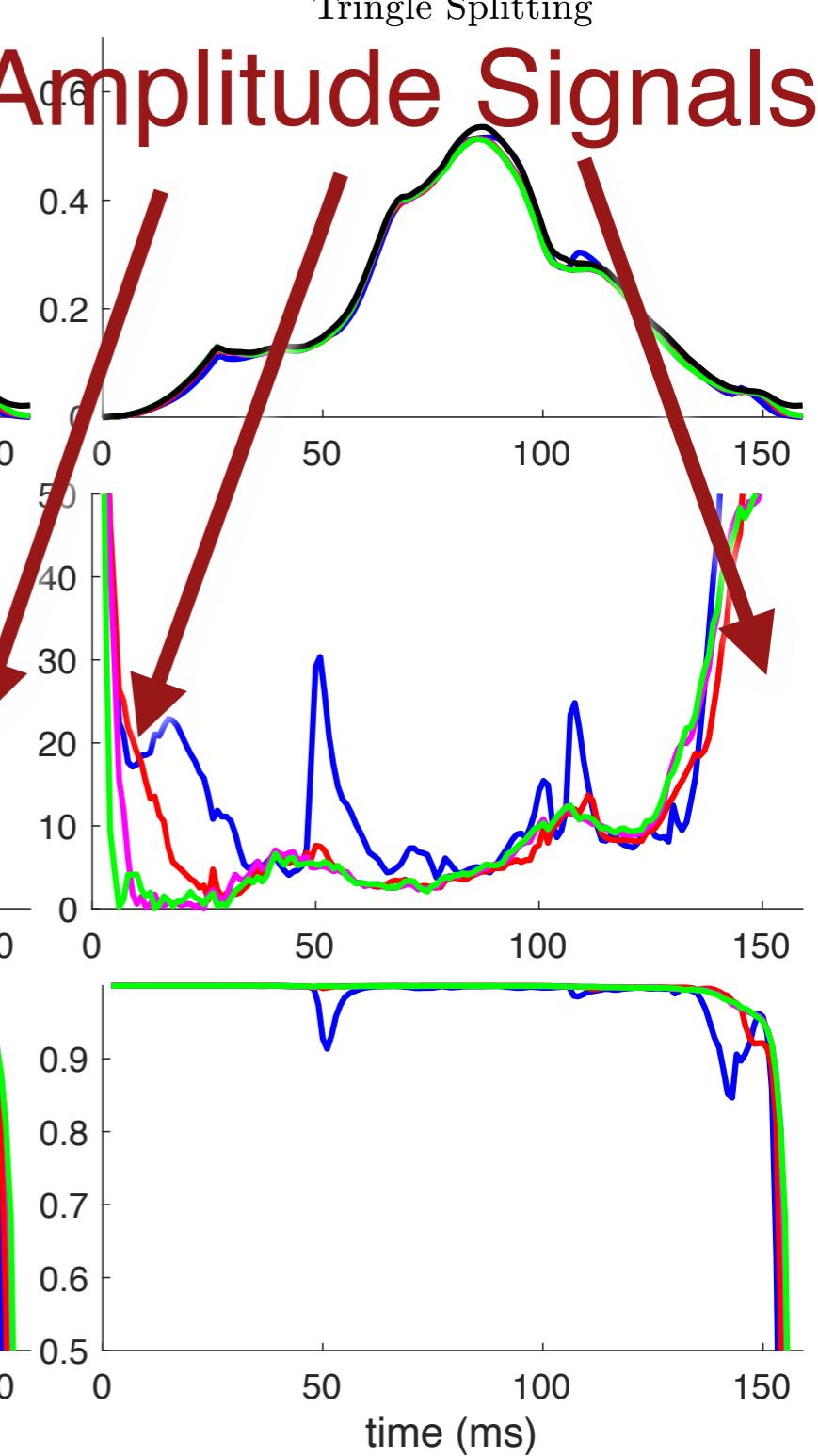
No Interpolation



Tringle Weighting



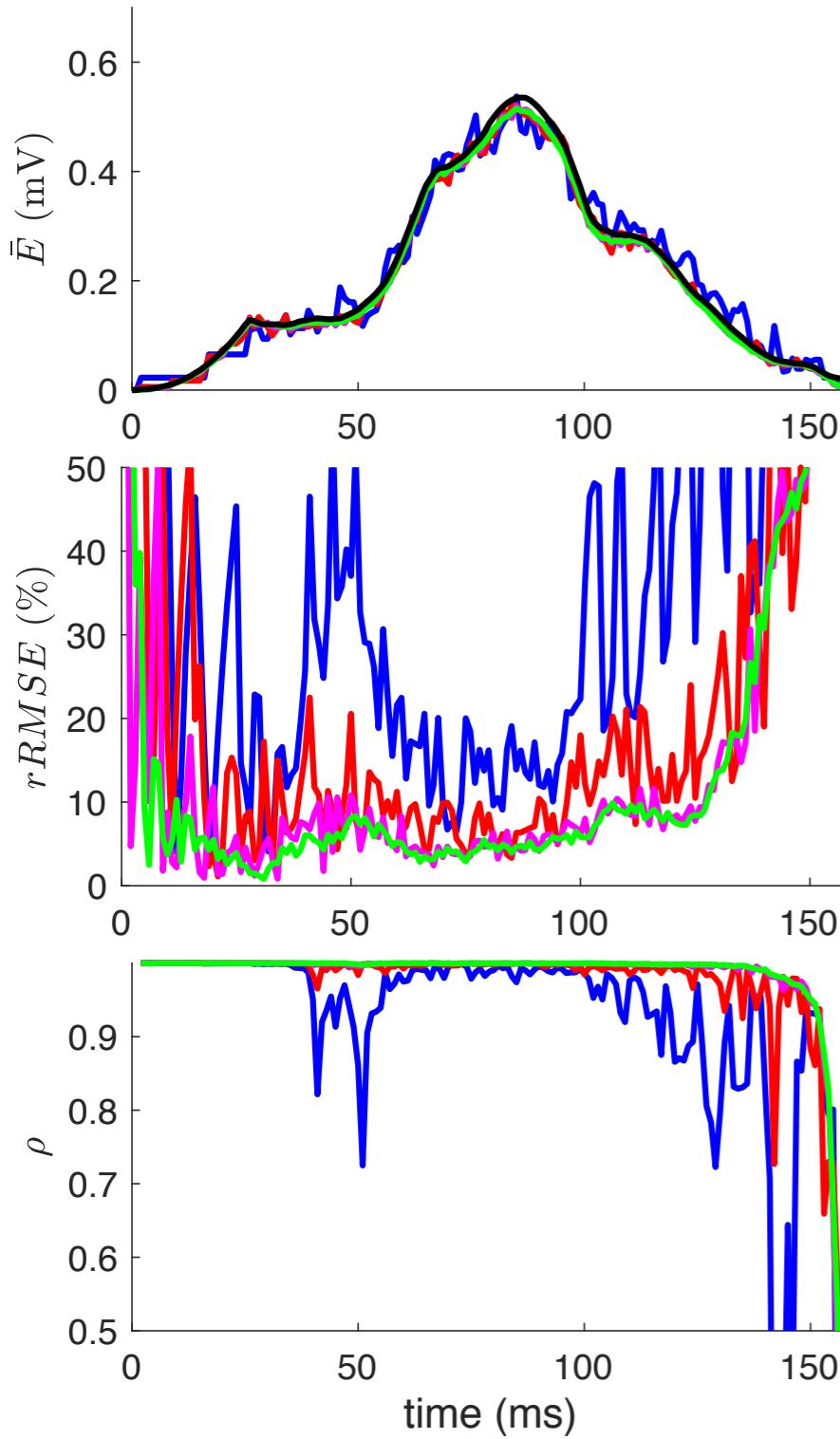
Tringle Splitting



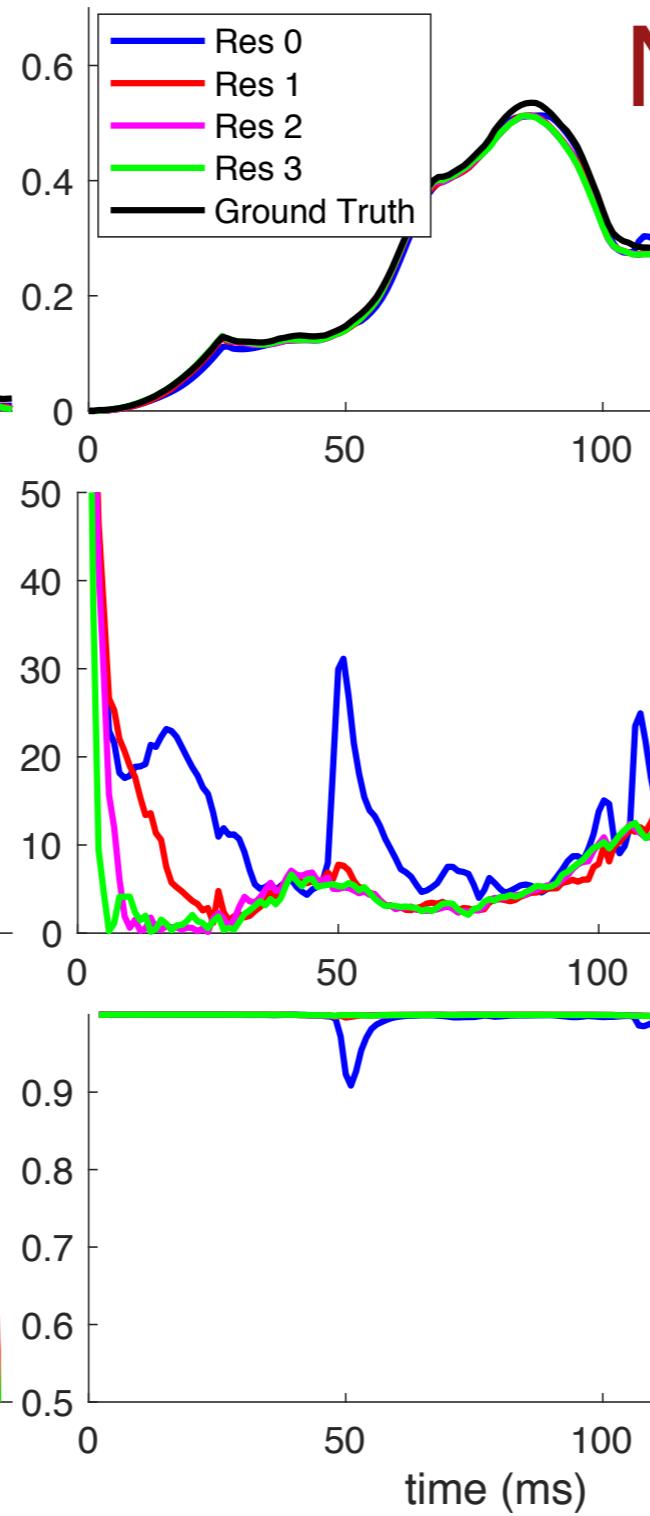
Low Amplitude Signals

Metrics

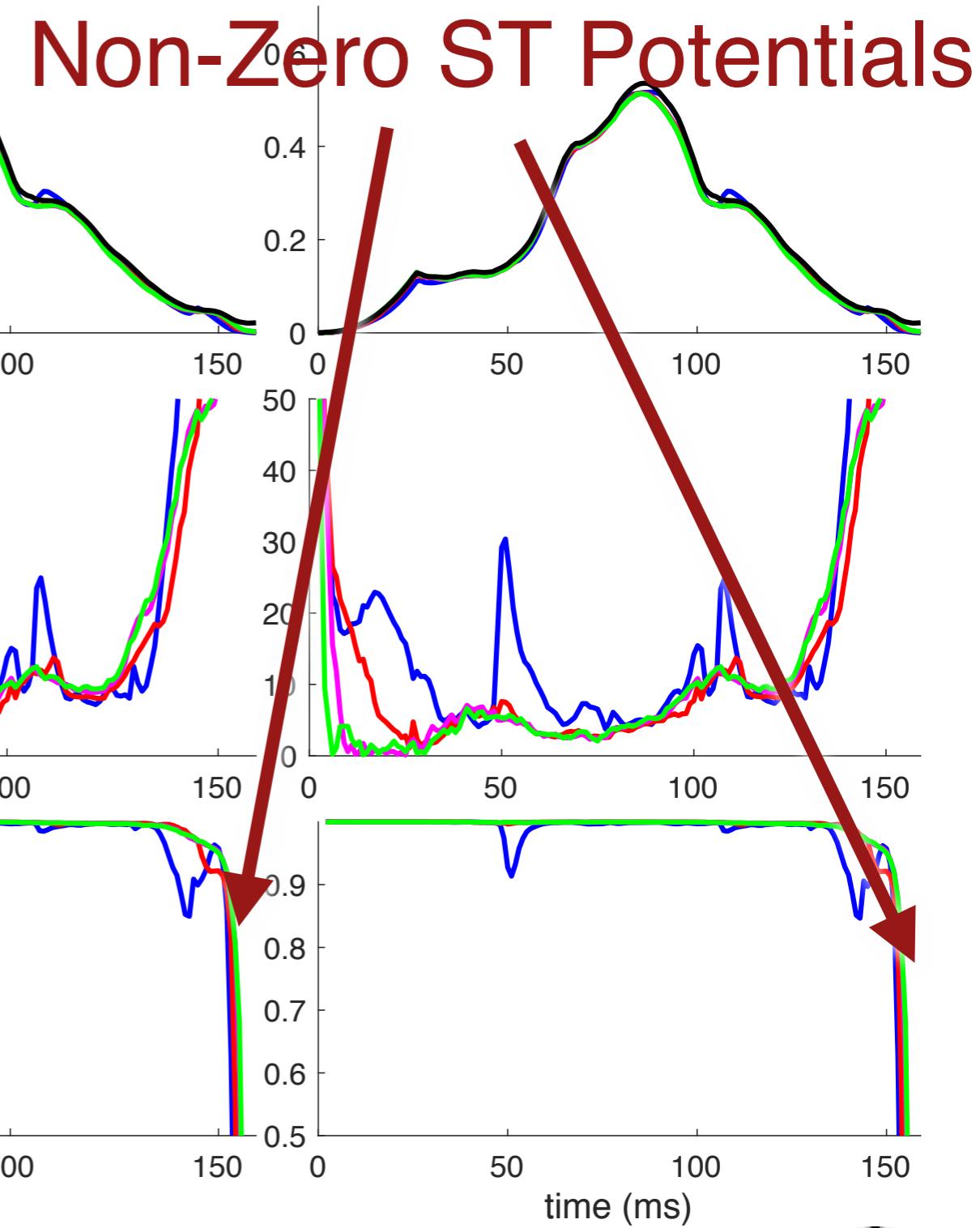
No Interpolation



Tringle Weighting



Tringle Splitting



Non-Zero ST Potentials

Spatial interpolation can reduce temporal
and spatial error

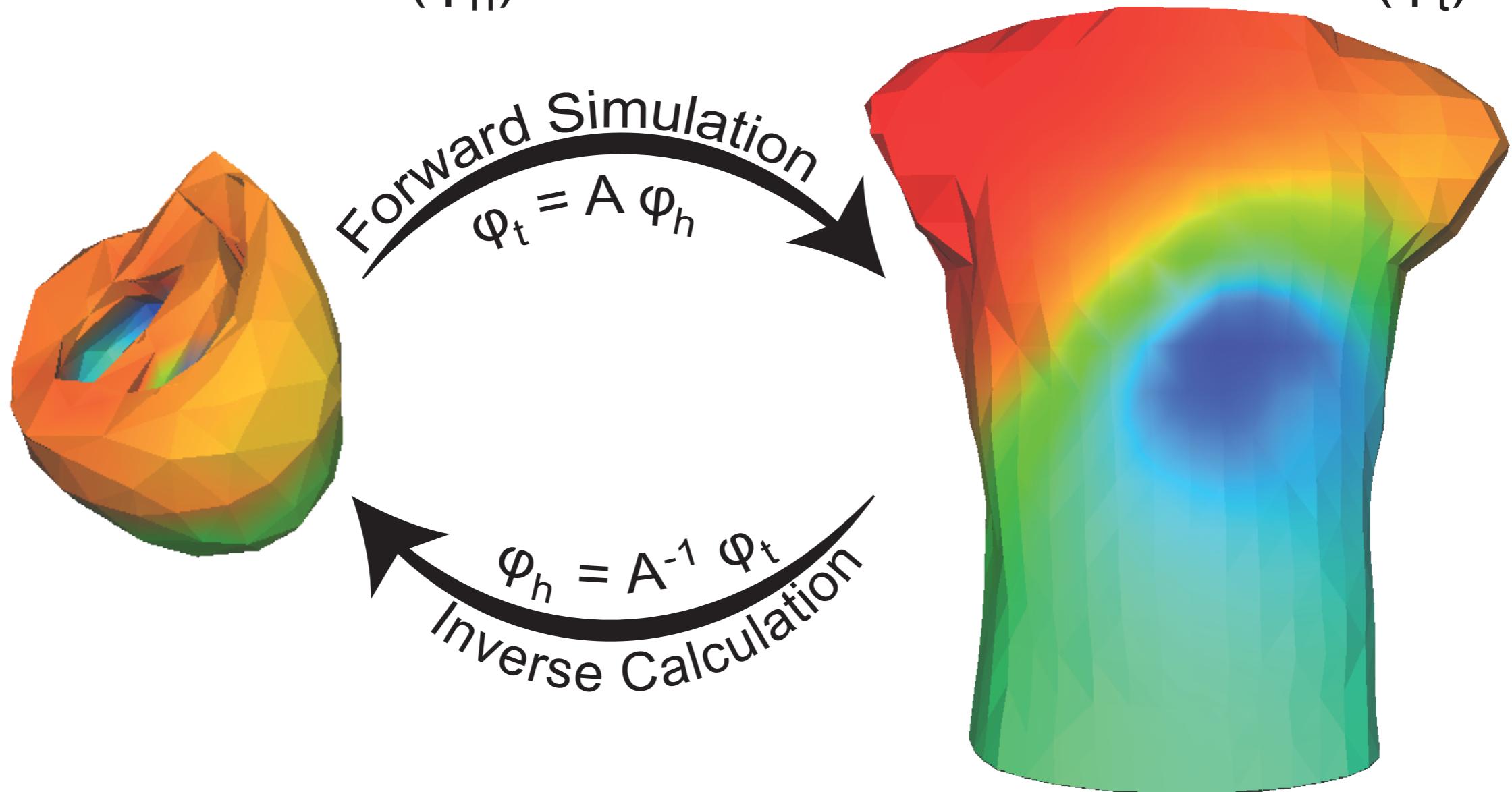
Triangle weighting and triangle splitting
performed similarly

EDL inverse is based on optimization
of the parameters

Improve ECGI (GCE)

Heart Potentials (ϕ_h)

Torso Potentials (ϕ_t)



With better source representation

Acknowledgements

People

Rob MacLeod

Thom Oostendorp

Steffen Schuler

Olaf Dössel

Dana Brooks

Support

Center for Integrative Biomedical Computing

NIGMS NIH P41 GM103545-18

University Medical Centre Mannheim and the
Karlsruhe Institute of Technology (KIT)

