Analyzing Source Sampling to Reduce Error in ECG Forward Simulations

Jess Tate, Karli Gillette, Brett Burton, Wilson Good, Jaume Coll-Font, Dana Brooks, Rob MacLeod
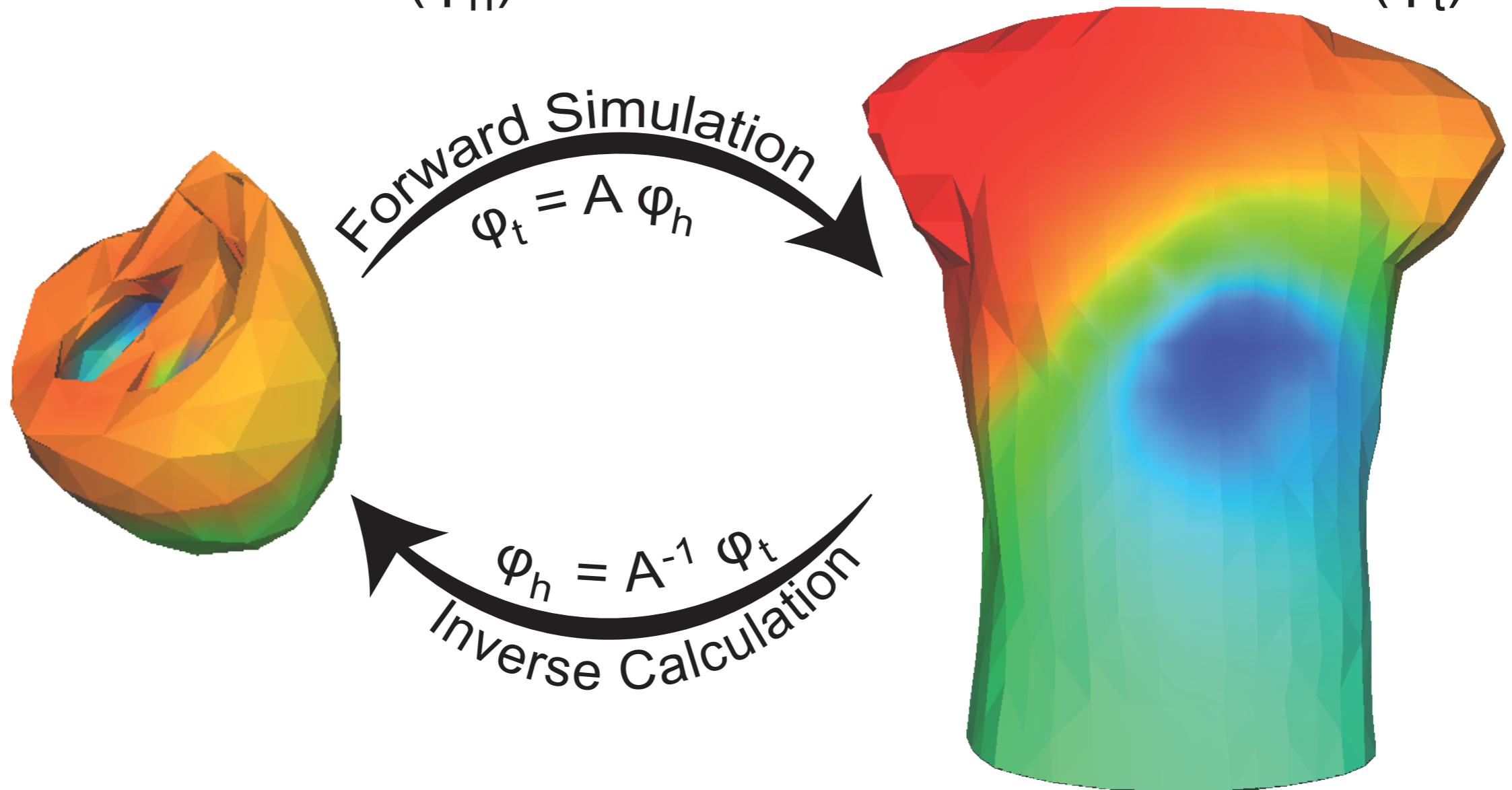
University of Utah
Northeastern University
Graz University

ECG Imaging

Heart Potentials (φ_h)

Torso Potentials (φ_t)

Forward Simulation
$\varphi_t = A\,\varphi_h$

$\varphi_h = A^{-1}\,\varphi_t$
Inverse Calculation
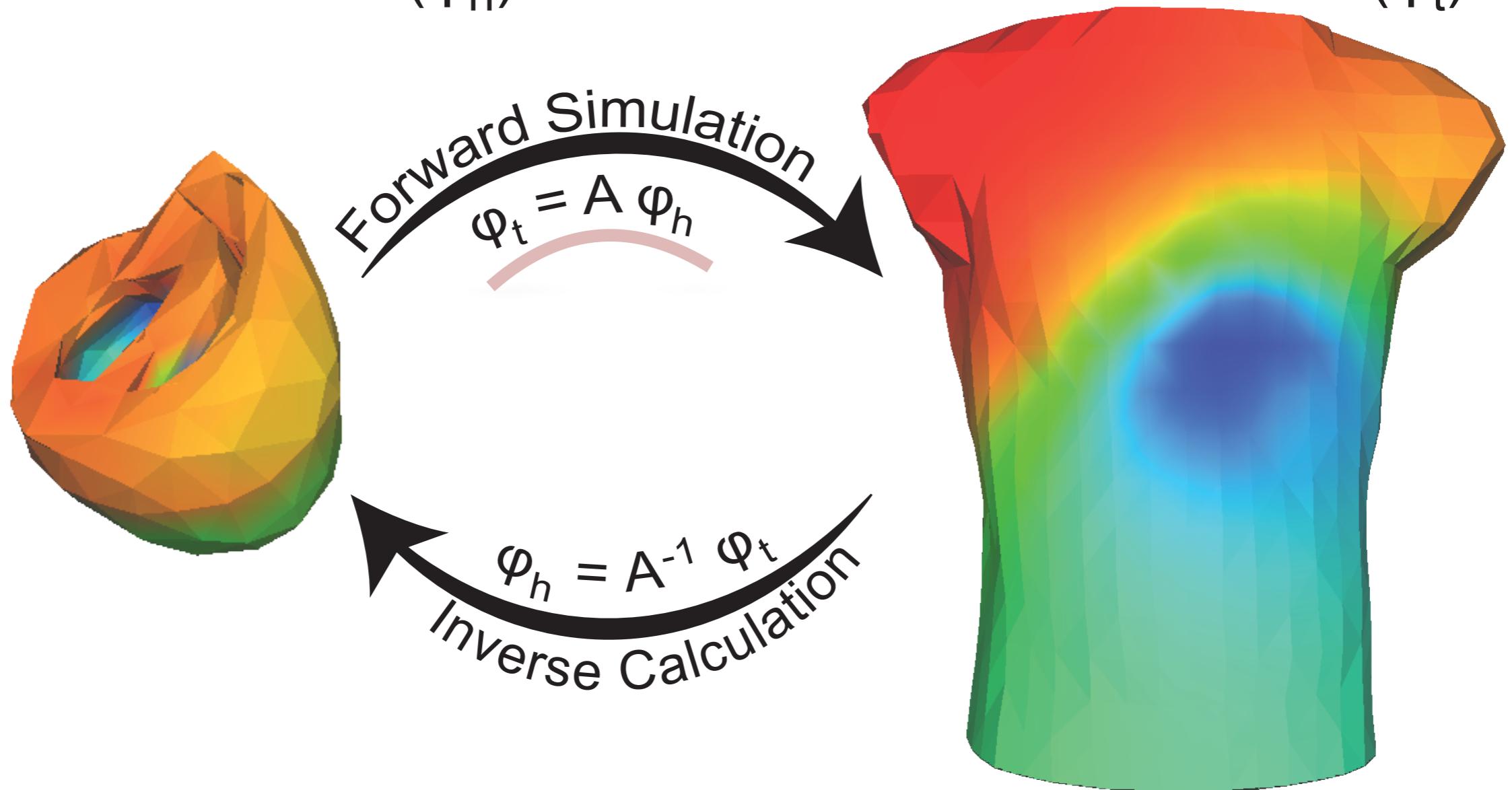
ECG Imaging Relies on Accurate Forward Models

ECG Imaging

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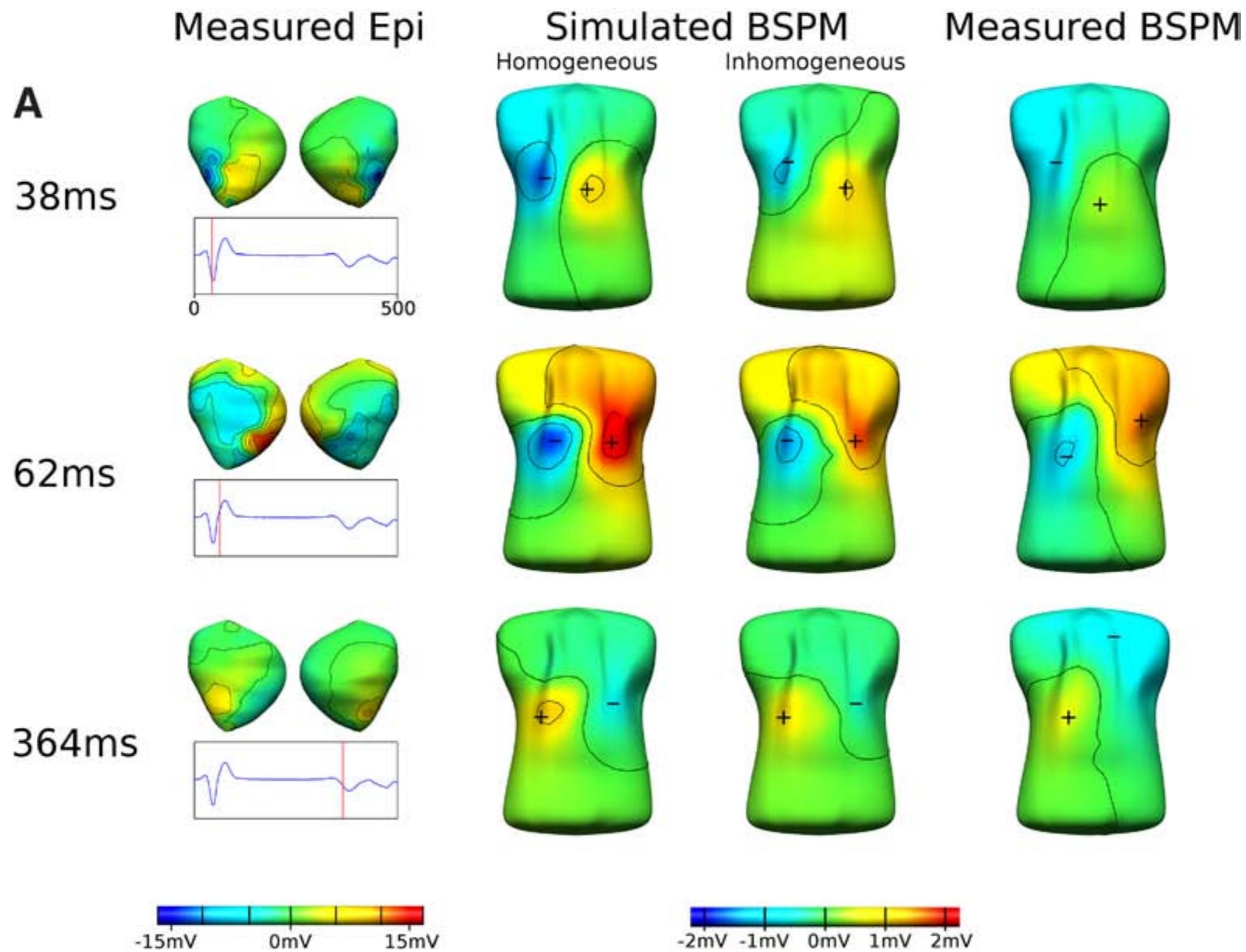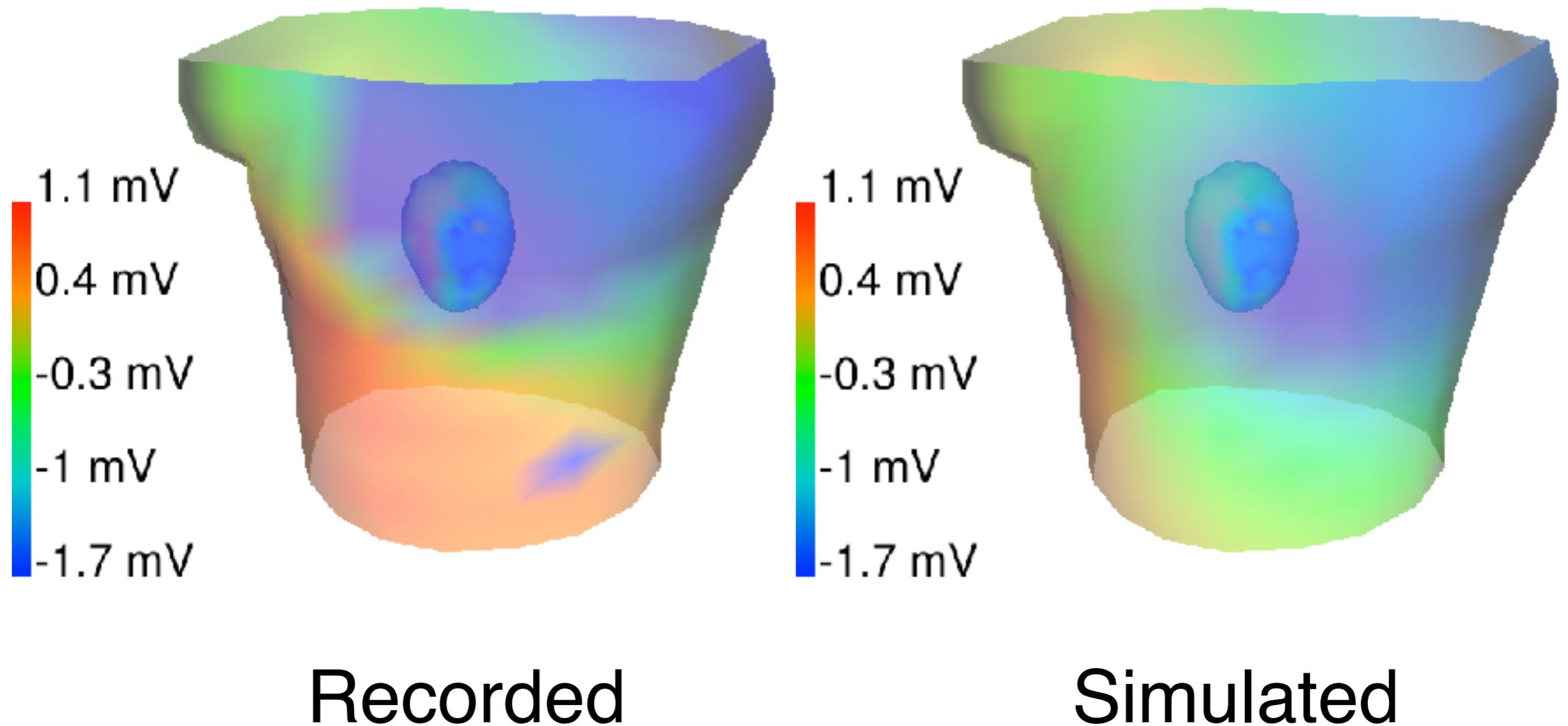
ECG Imaging Relies on Accurate Forward Models

Error in Forward Simulation
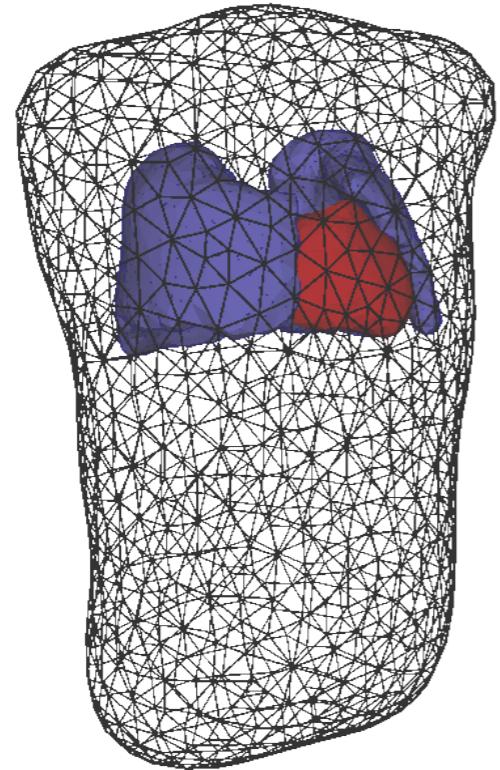
Bear, etal., CircArrhythmElectrophysiol.2015;8:677-684.

# Error in Forward Simulation
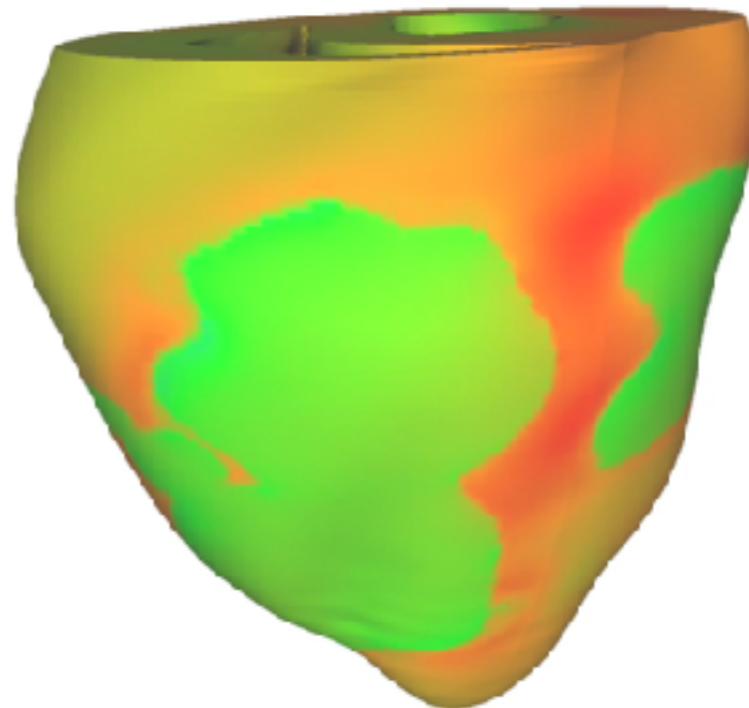
Recorded

Simulated

Origins of Error

Geometry

Sources

Origins of Error

Geometry

Sources

Origins of Error

Geometry

Sources

Matrix
A

Vector
ϕ_h

Origins of Error

Geometry

Sources

Matrix
A

Vector
ϕ_h

Registration
Segmentation
Conductivities
Meshing

Origins of Error

Geometry

Sources

Matrix
A

Vector
ϕ_h

Registration
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Meshing

Surface Accuracy
Eq. Source Model
Recording Noise
Source Sampling
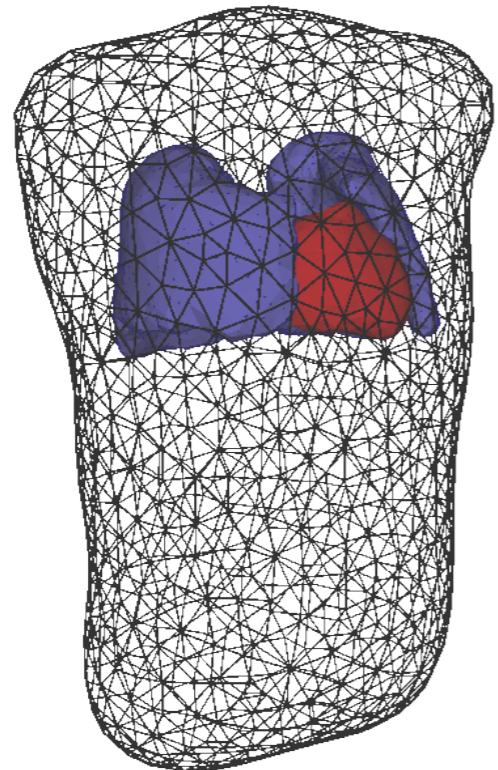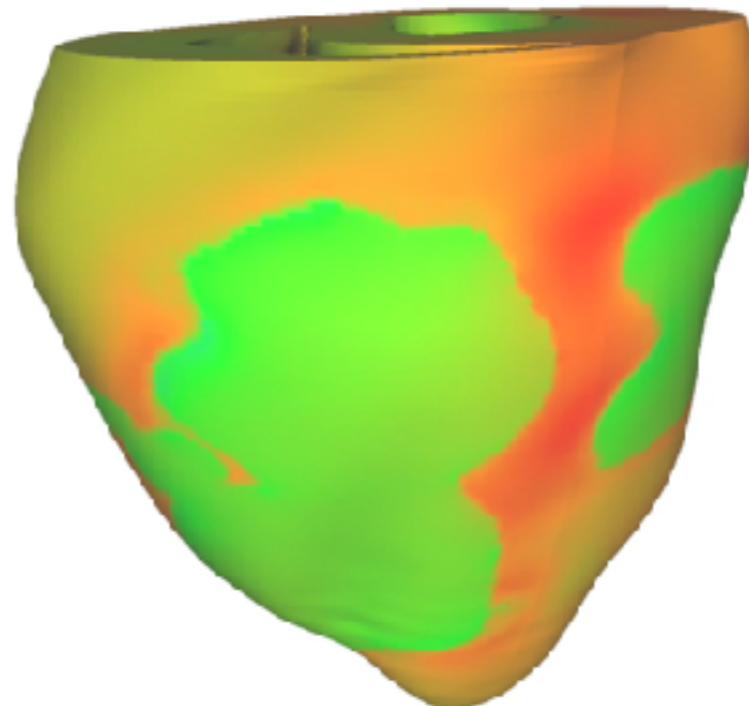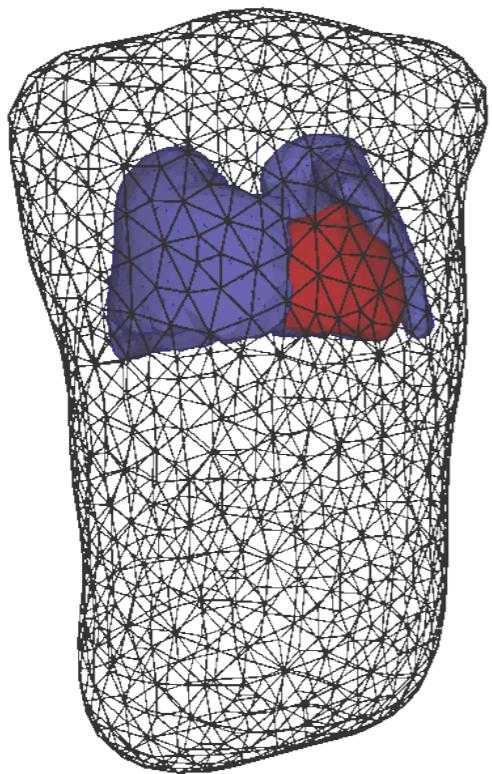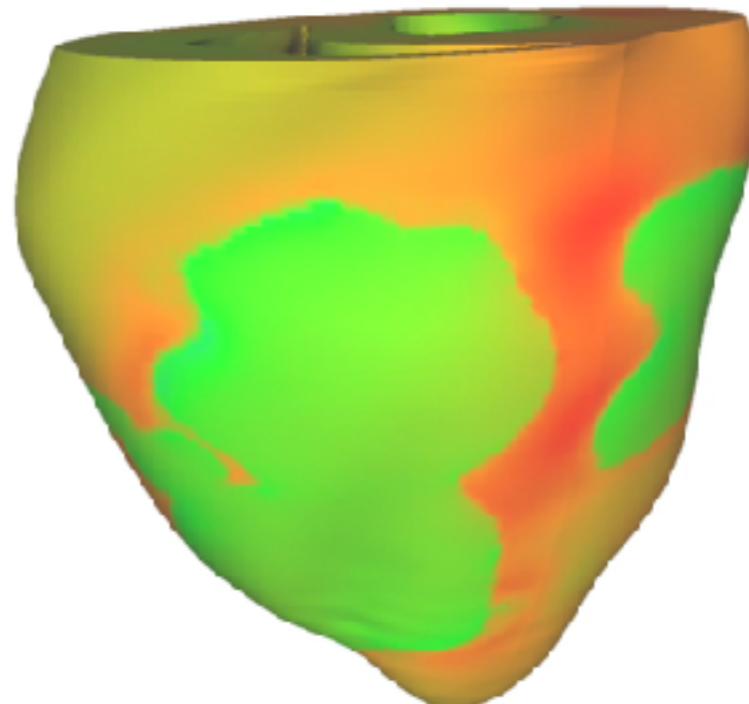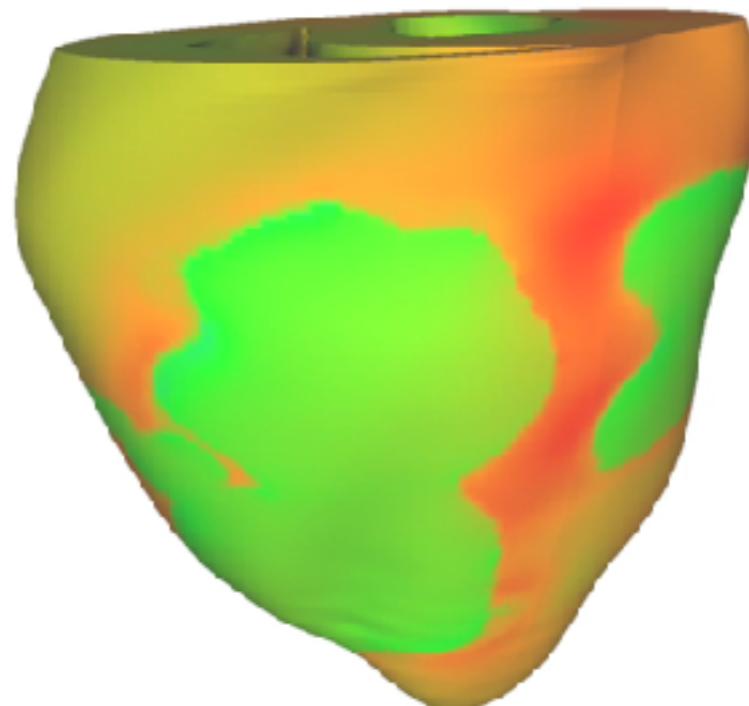
Origins of Error

Geometry

Matrix
A
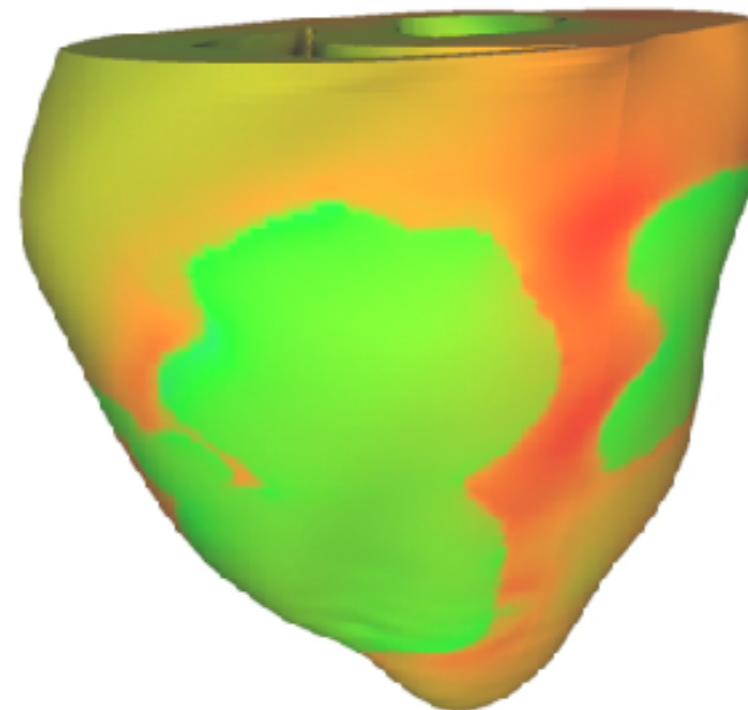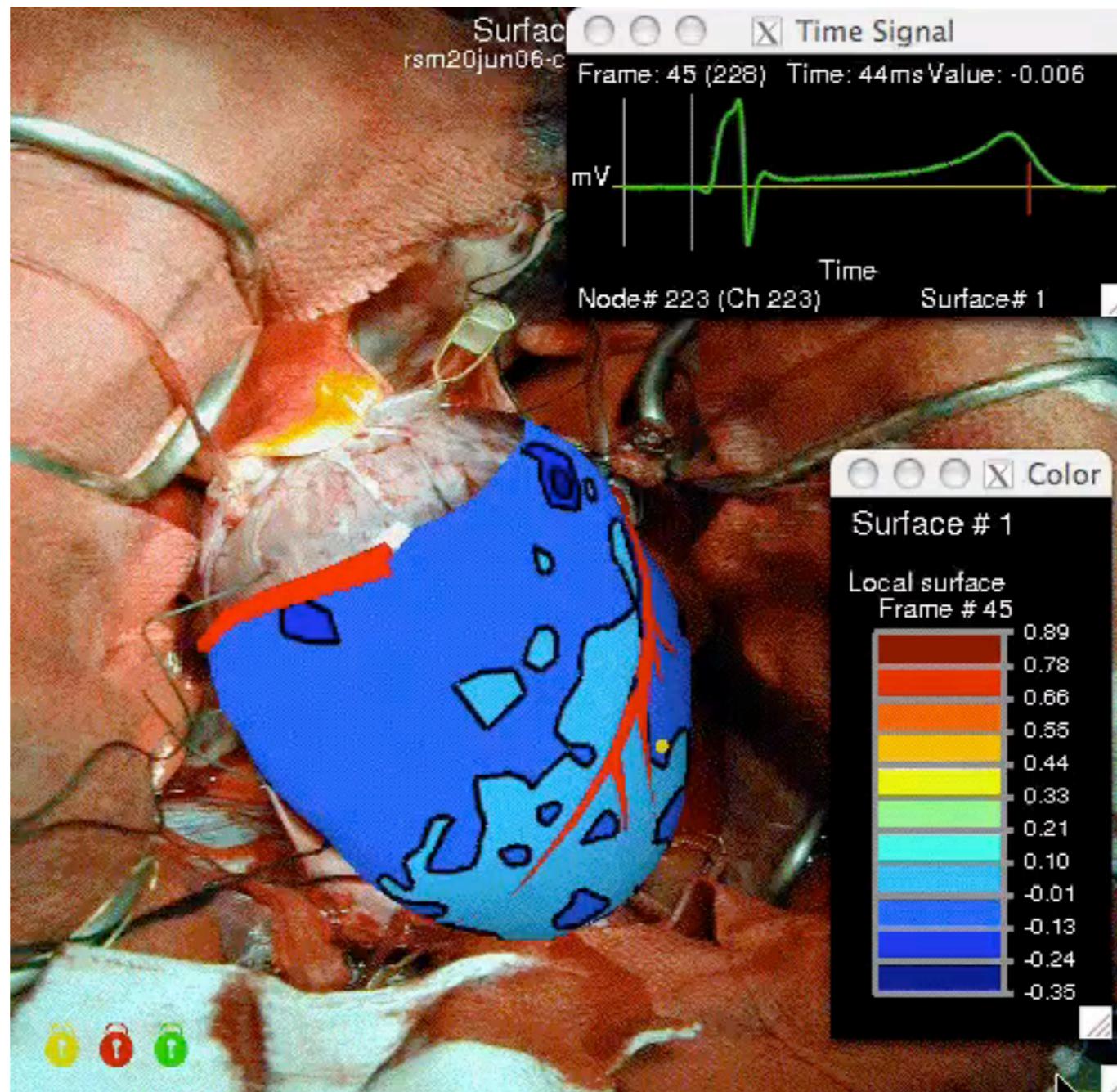
Sources

Vector
Φ_h

Registration
Segmentation
Conductivities
Meshing

Surface Accuracy
Eq. Source Model
Recording Noise

Source Sampling
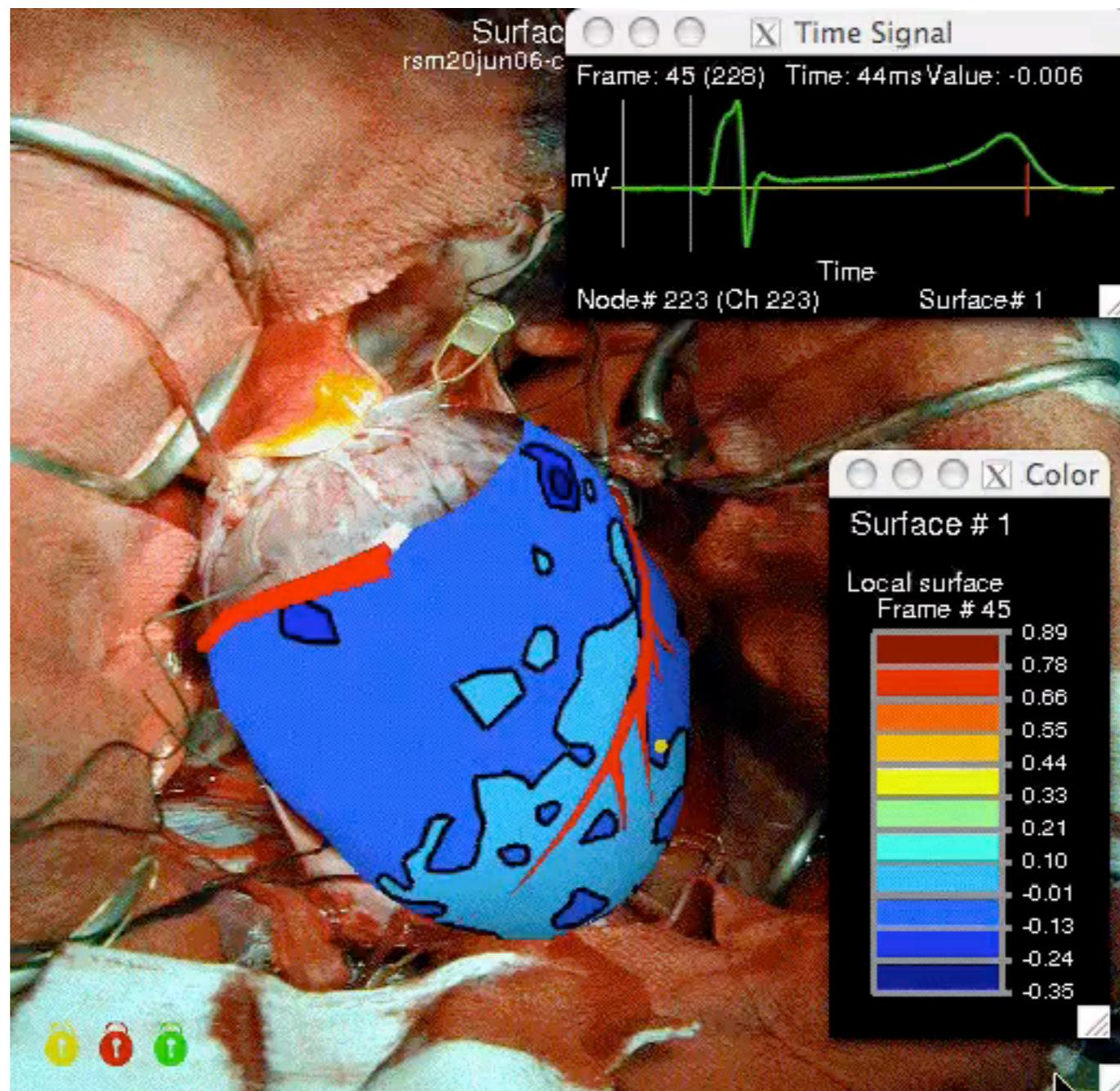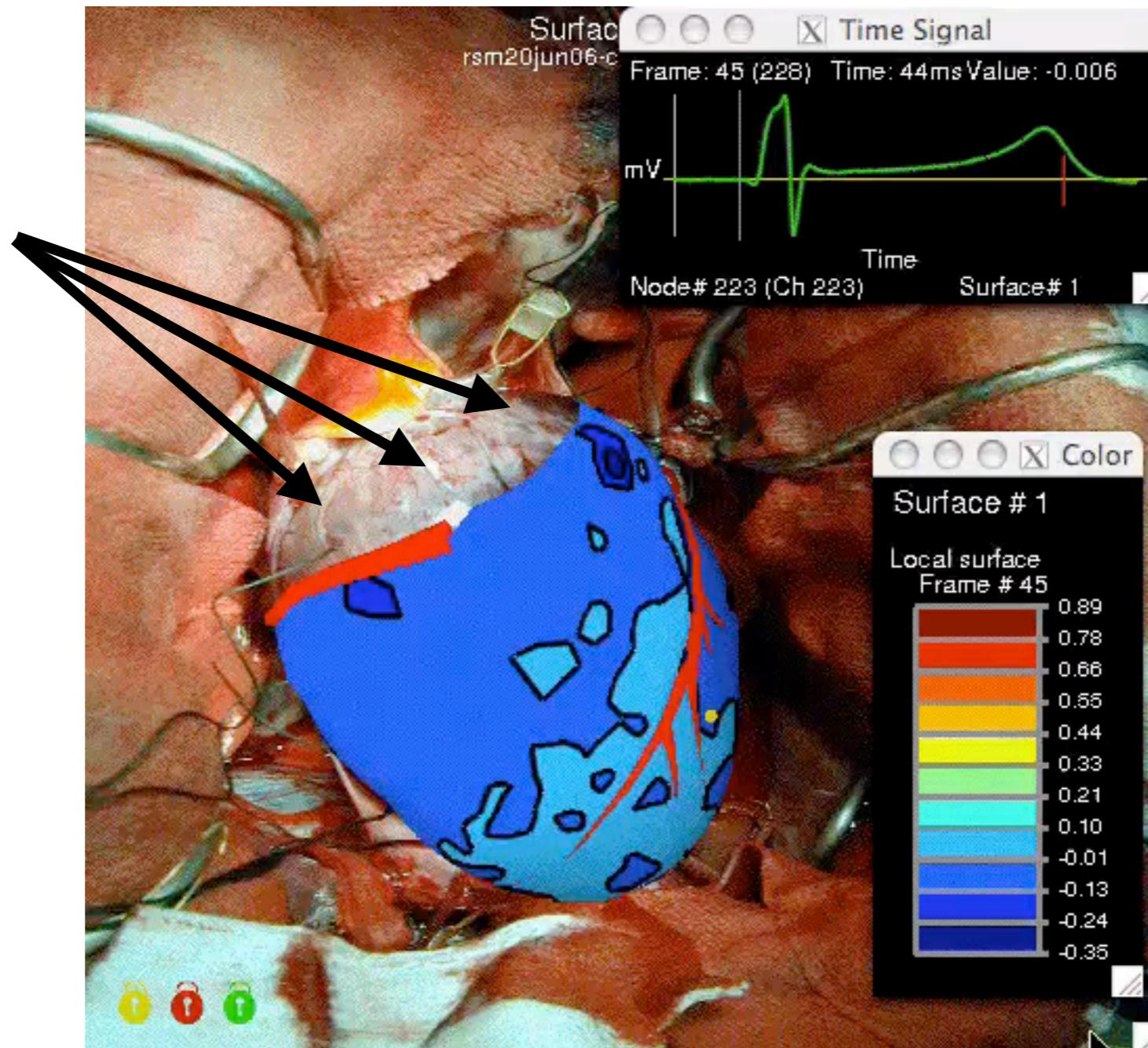
Source Recording

Epicardial Sock

Source Recording

Epicardial Sock
## (Ventricle Only)
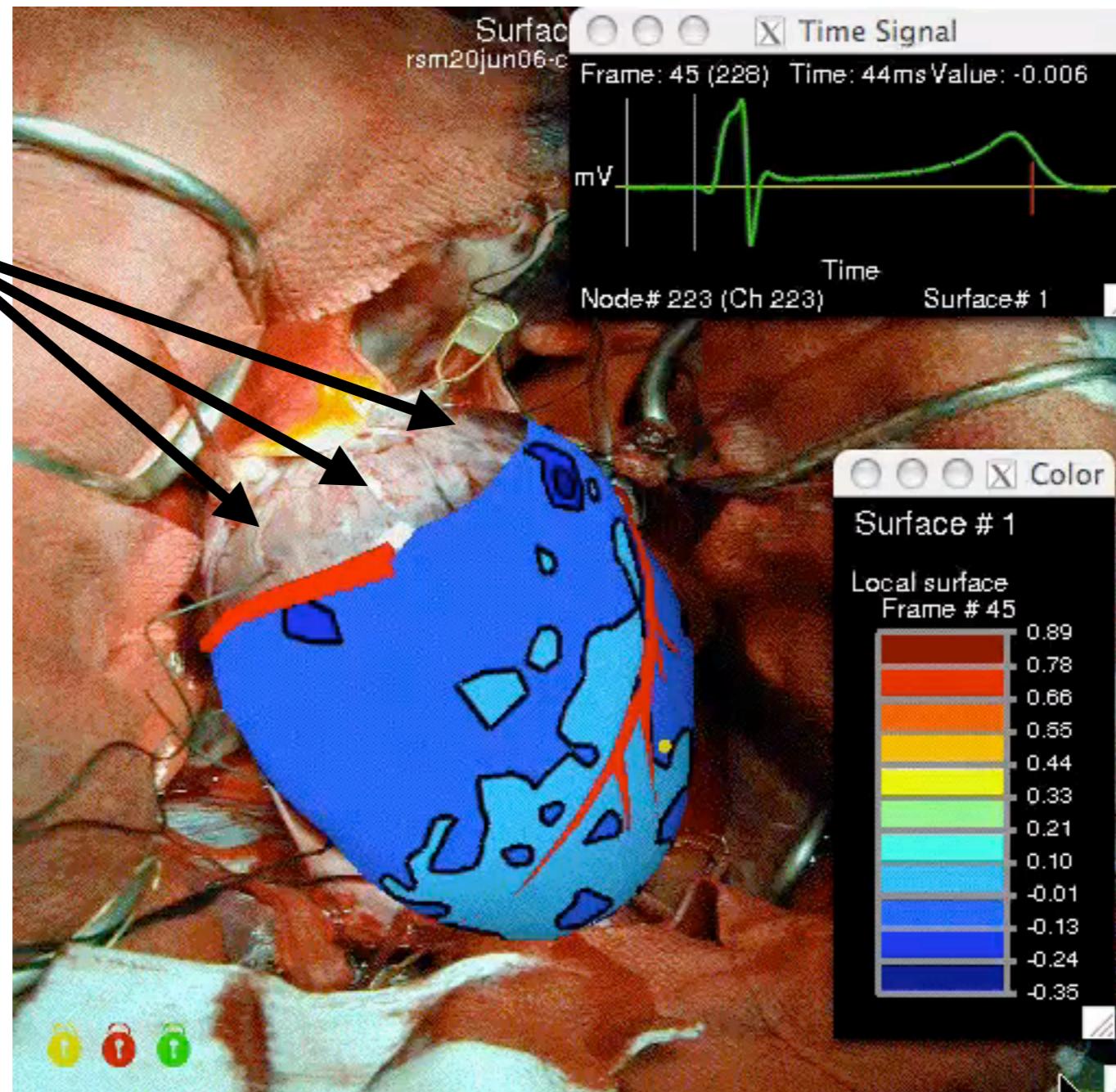
Source Recording

Epicardial Sock
## (Ventricle Only)

Source Recording

Missing Sources?
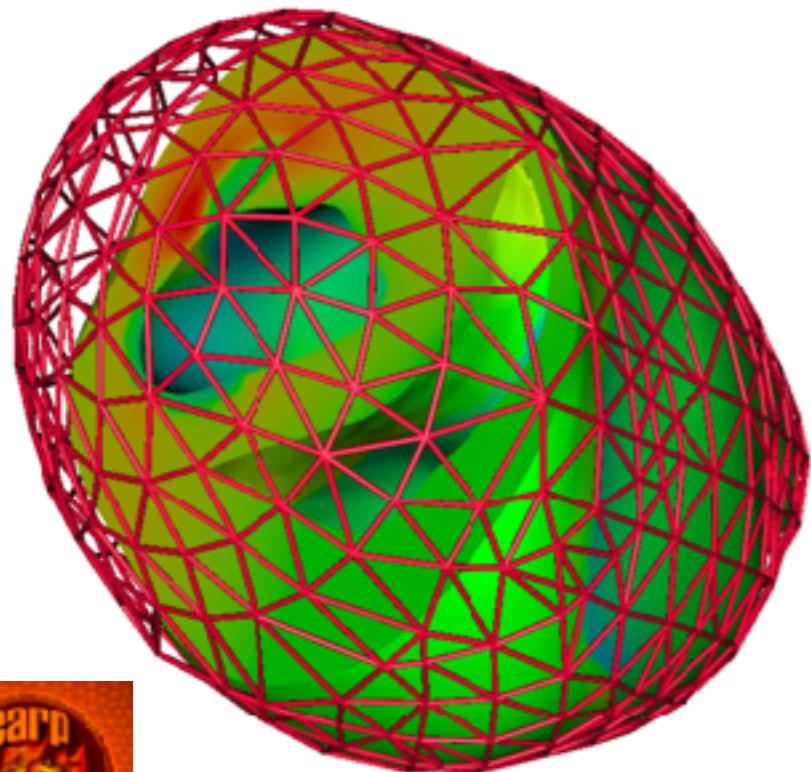
Epicardial Sock
(Ventricle Only)
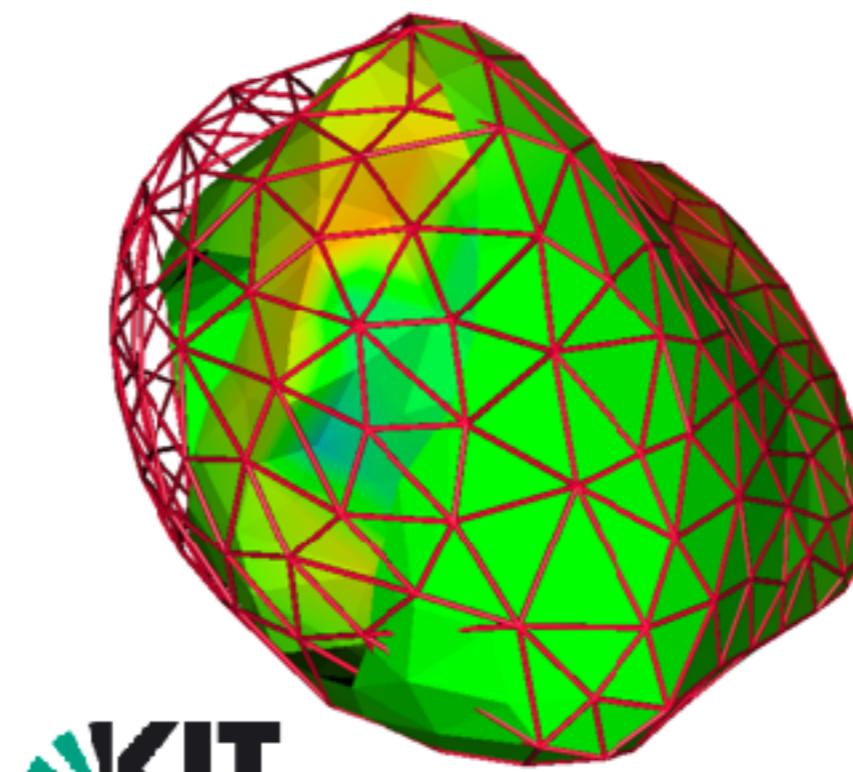
Test sampling strategies of the atrial region to reduce error in forward simulation
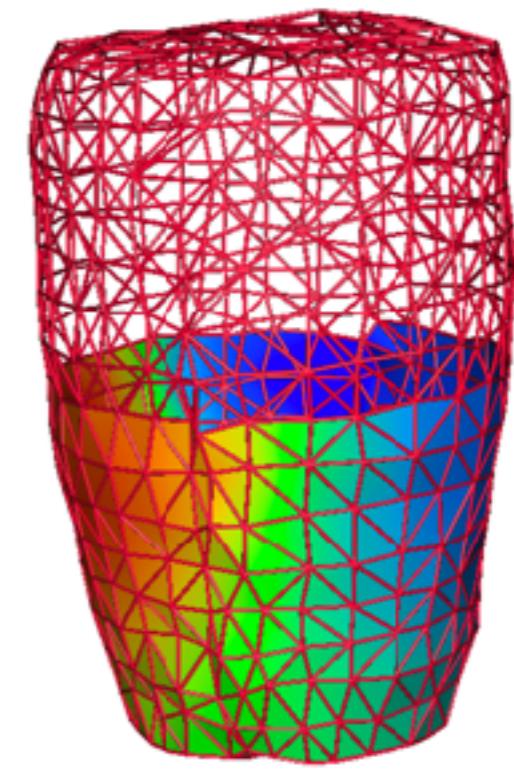
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Cardiac Sources
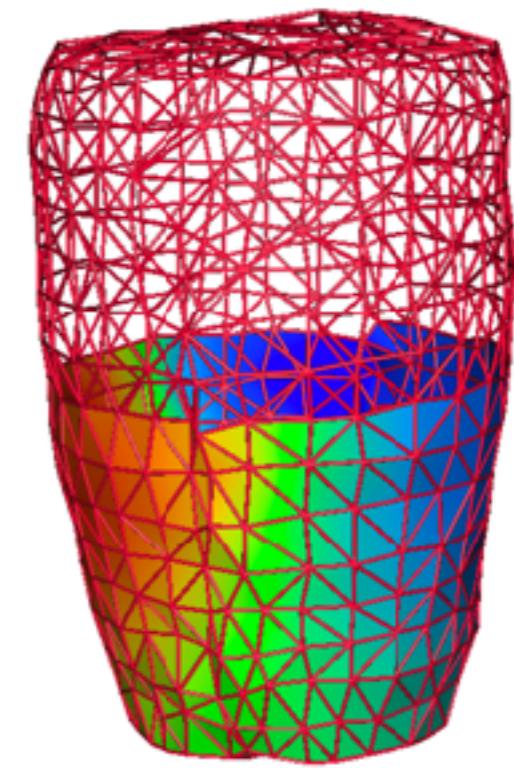
CARP
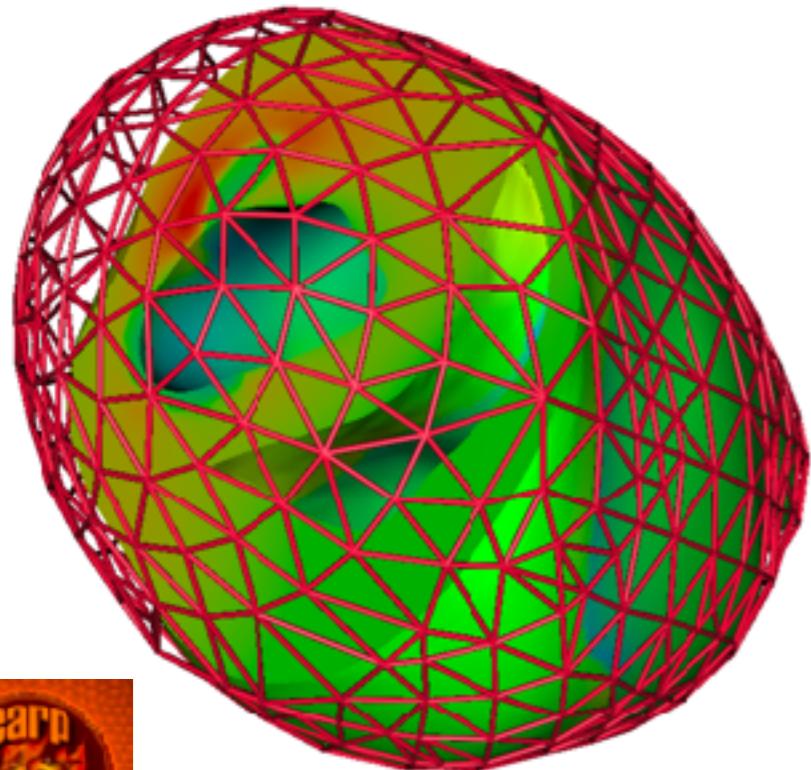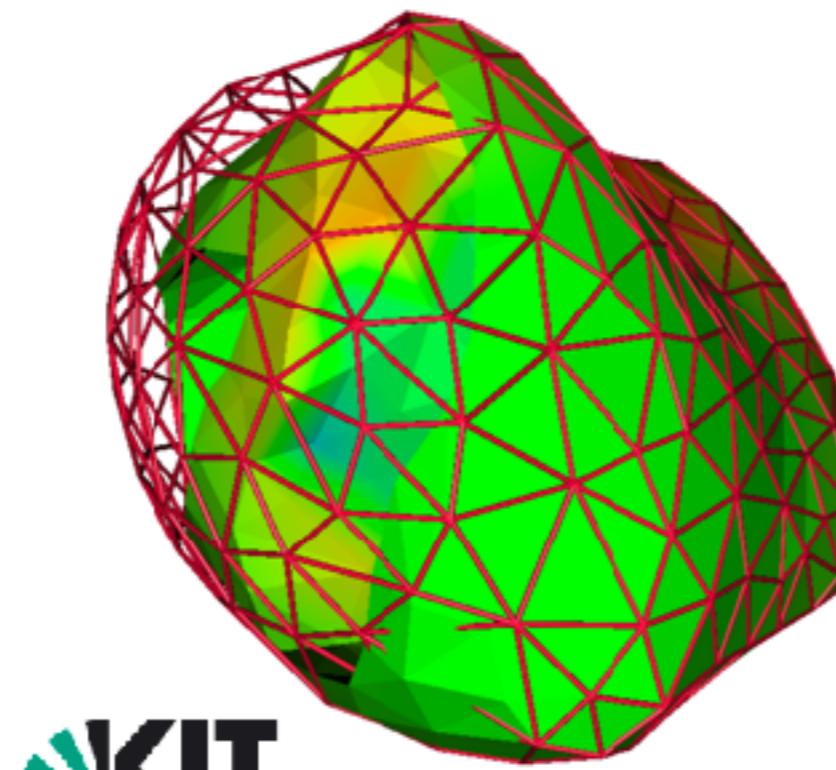
KIT

CAGE

Cardiac Sources

CARP

KIT

CAGE

4 Simulation Activation Patterns

sinus/septum stimulation
left ventricle stimulation
right ventricle stimulation
apex stimulation

Cardiac Sources
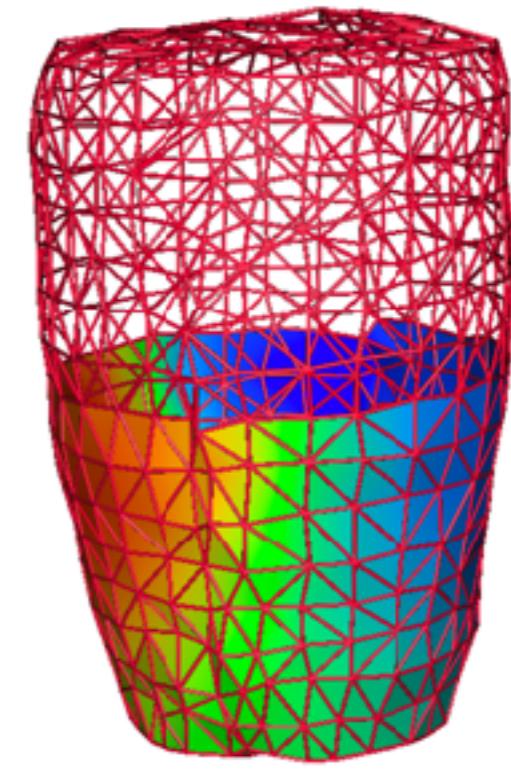
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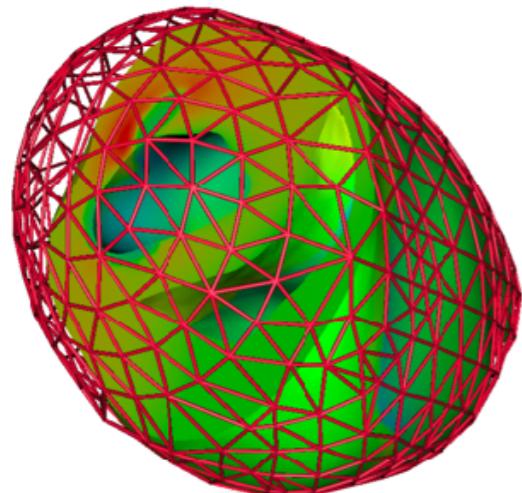
KIT

CAGE

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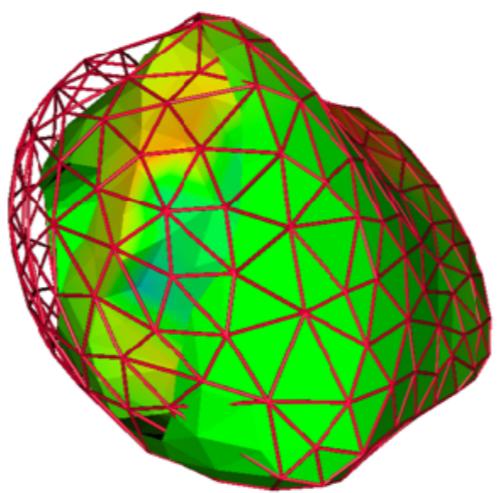
Recorded Potentials

Ground Truth
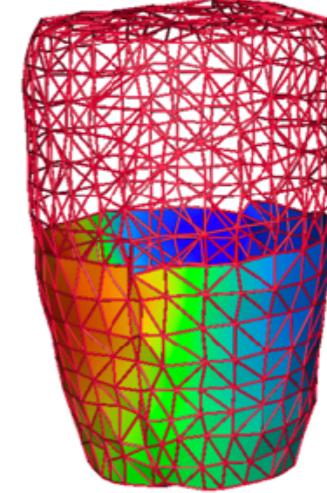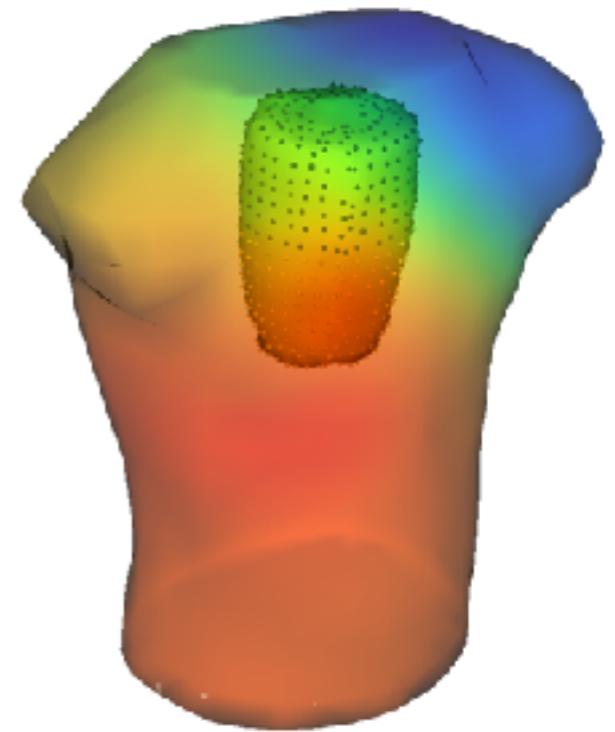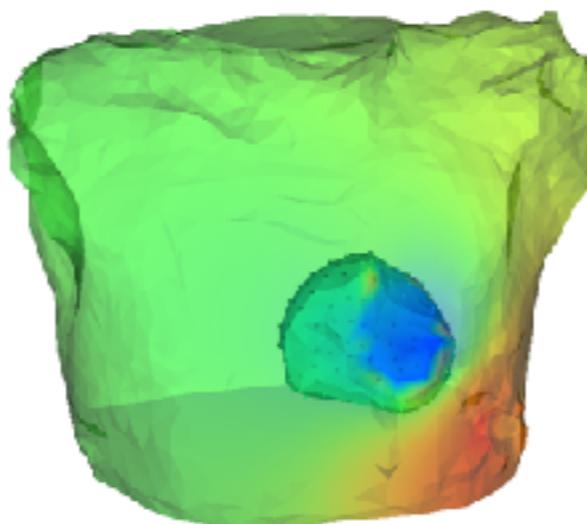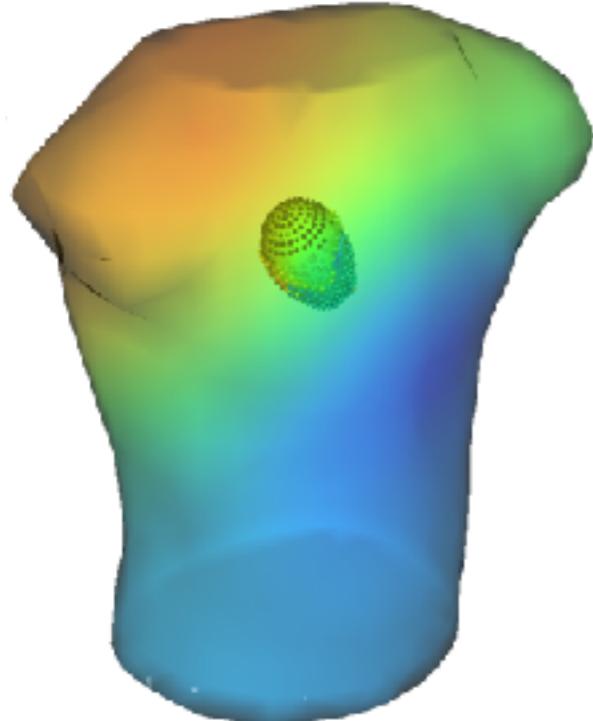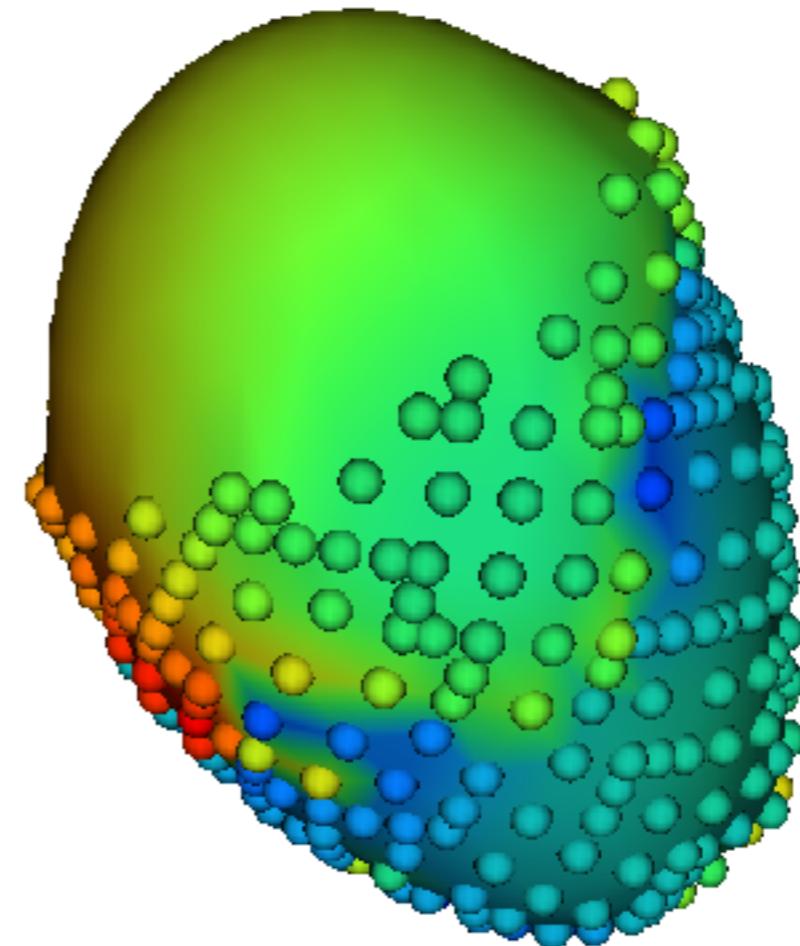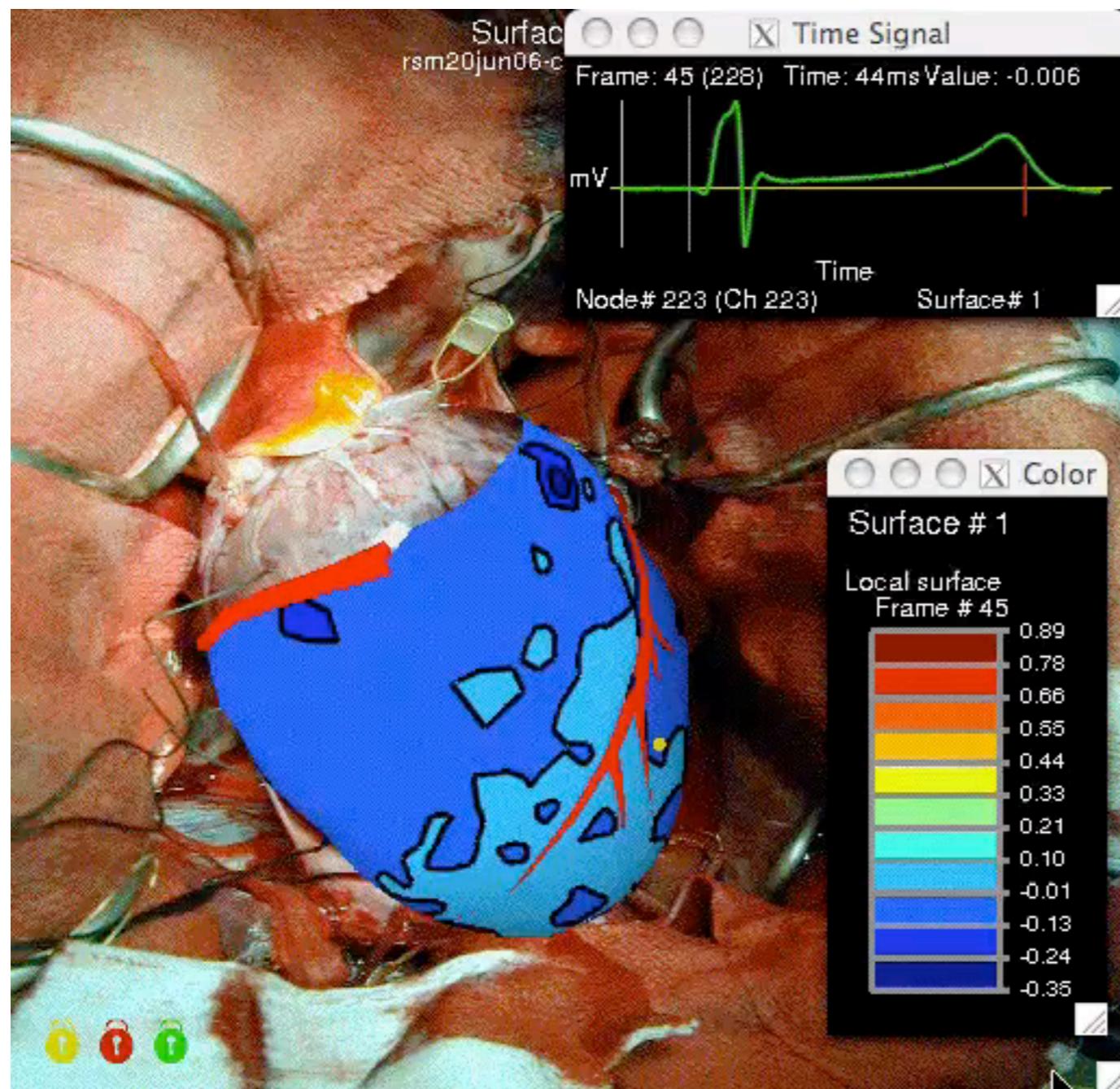
CARP KIT CAGE
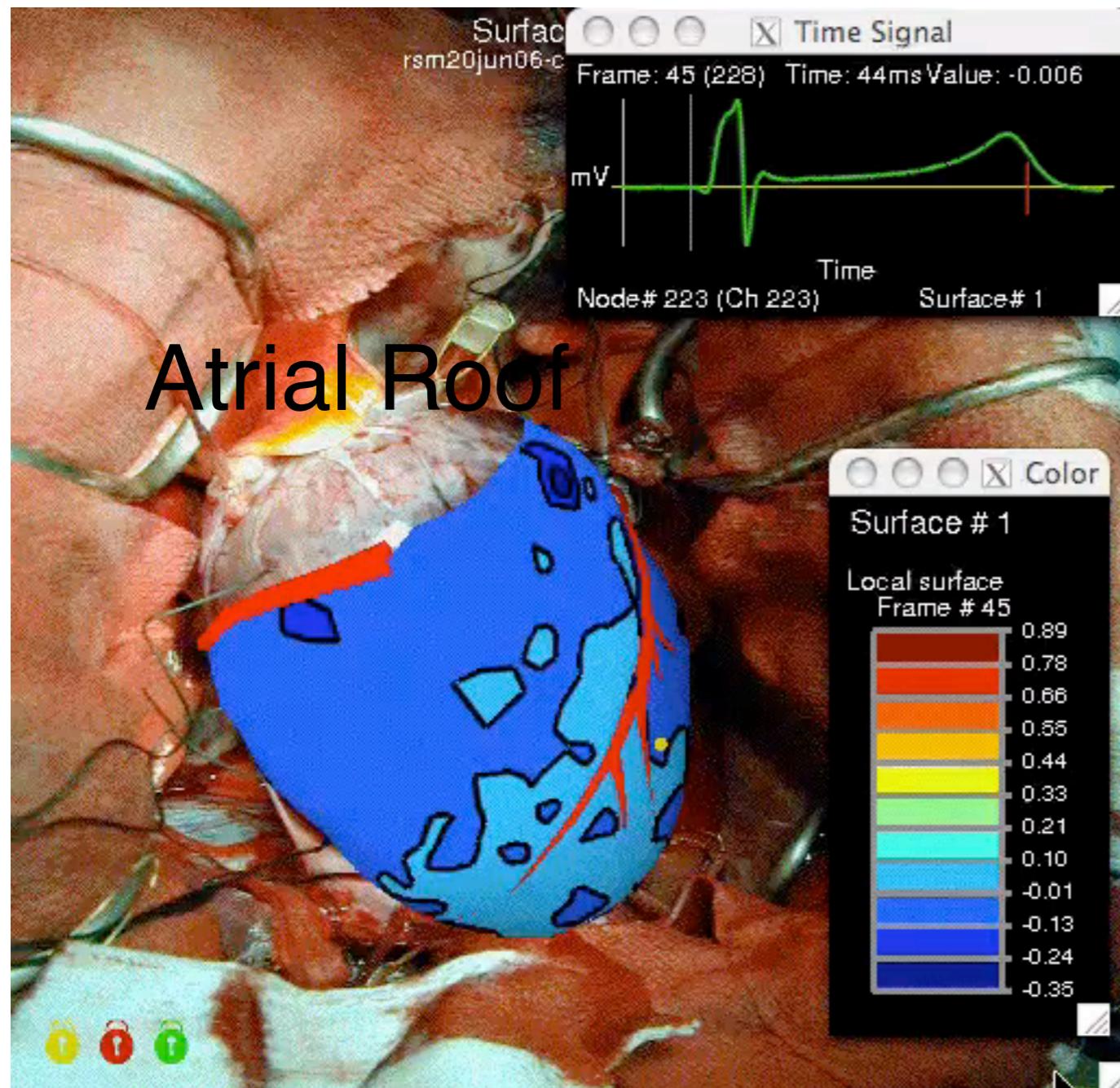
FEM
Simulation
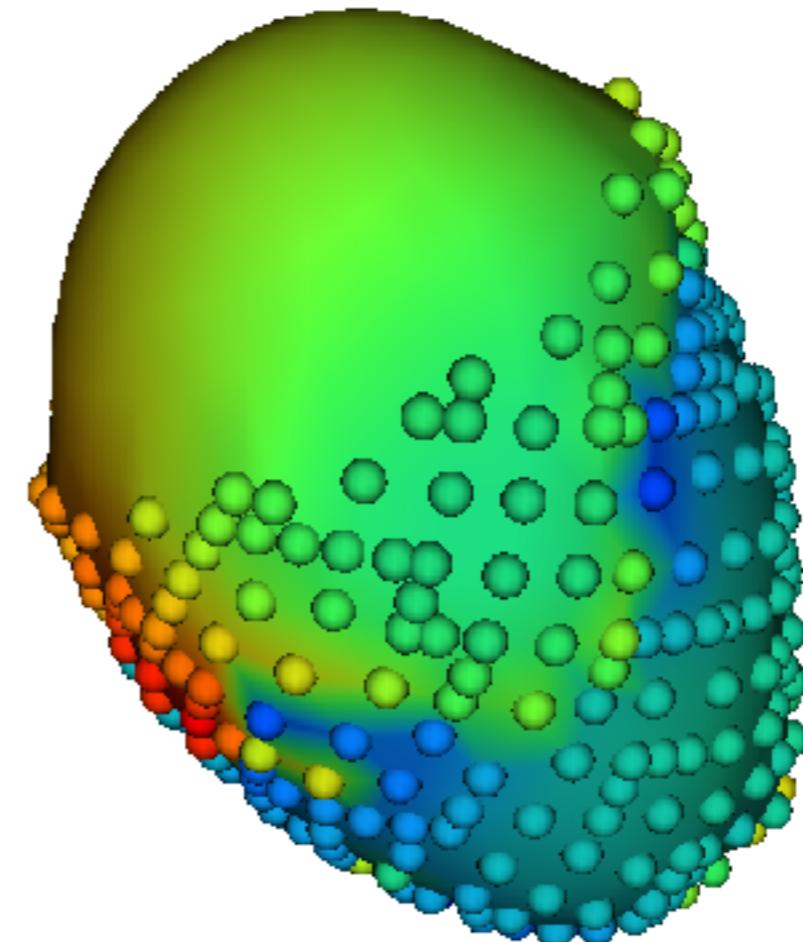
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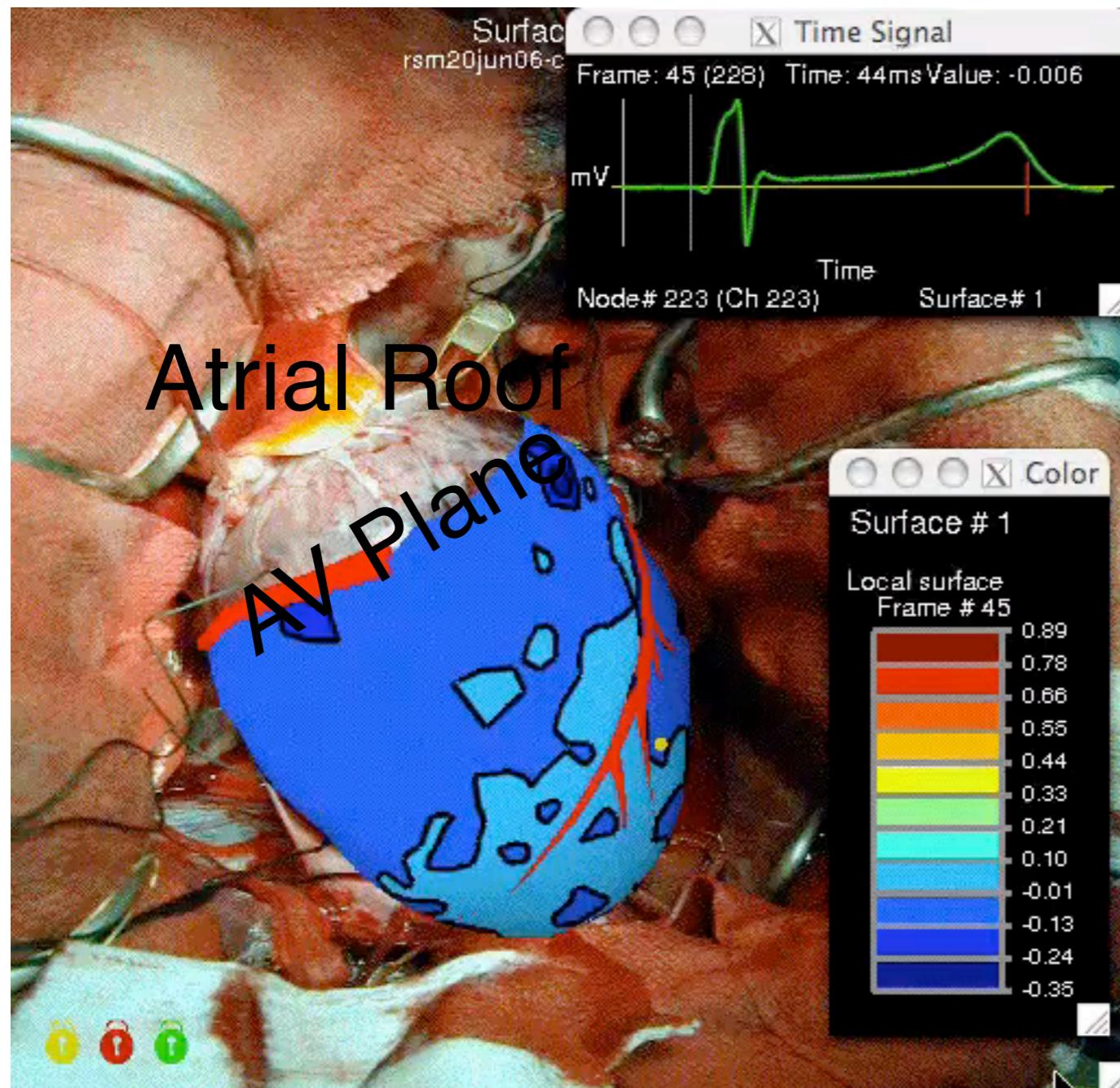
Atrial Sampling

Atrial Roof
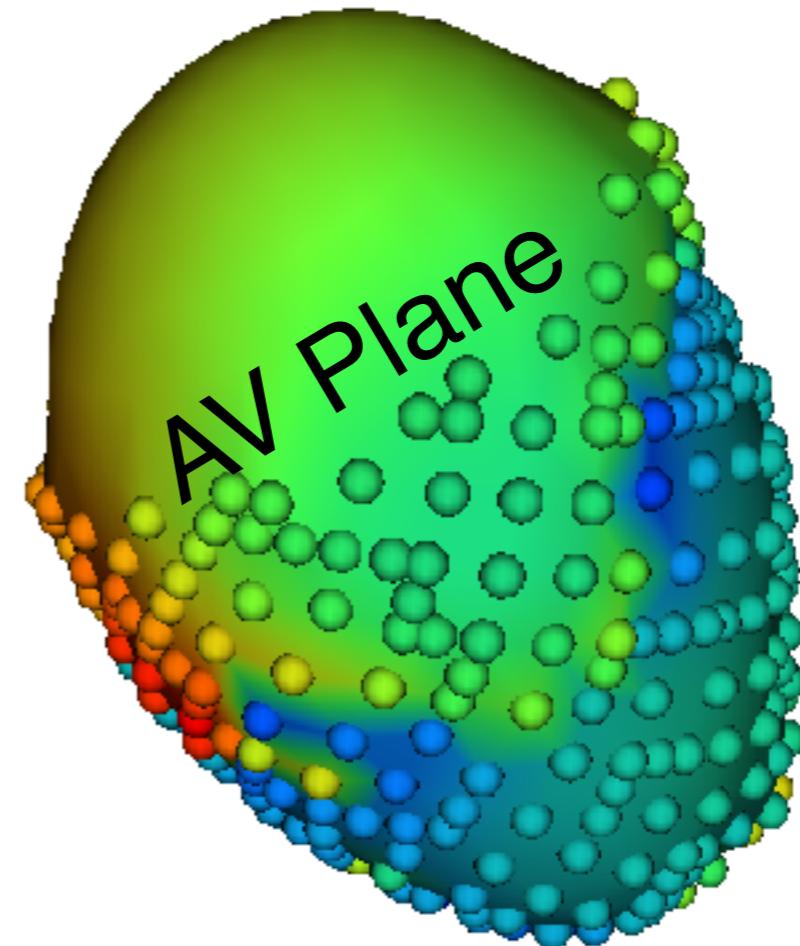
Atrial Roof
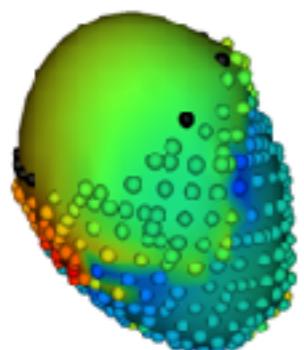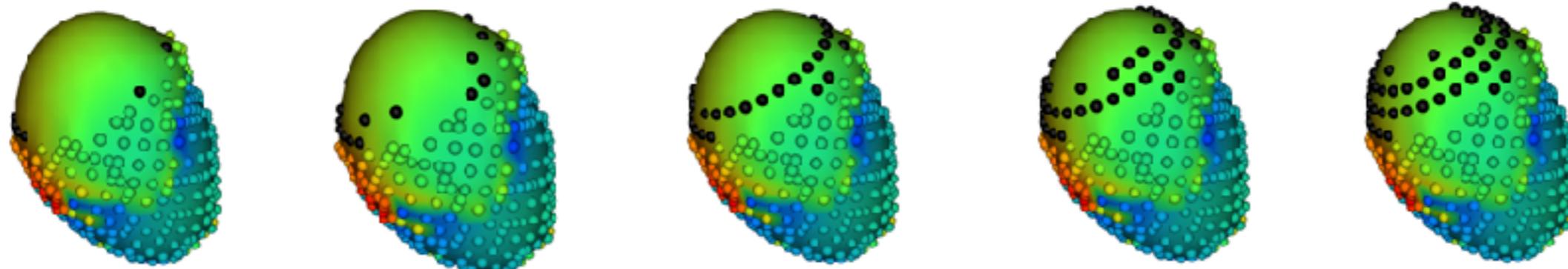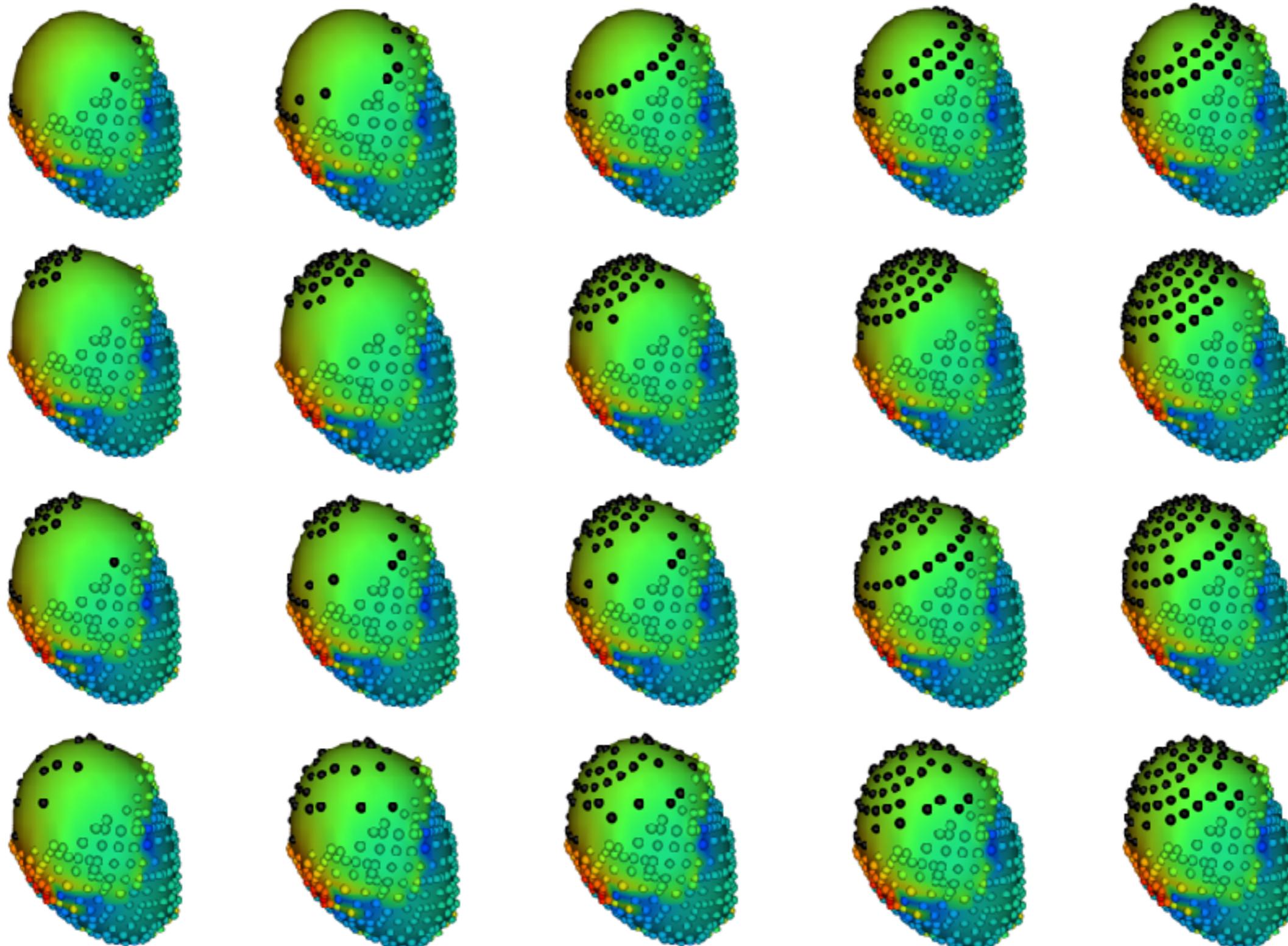
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Atrial Sampling

Varied Sampling

Varied Sampling

Varied Sampling

Varied Sampling

ECG Forward Simulation

Sampled
Sources

Interpolated
Sources

Torso

Heart

Laplacian
Interpolation

BEM
Simulation
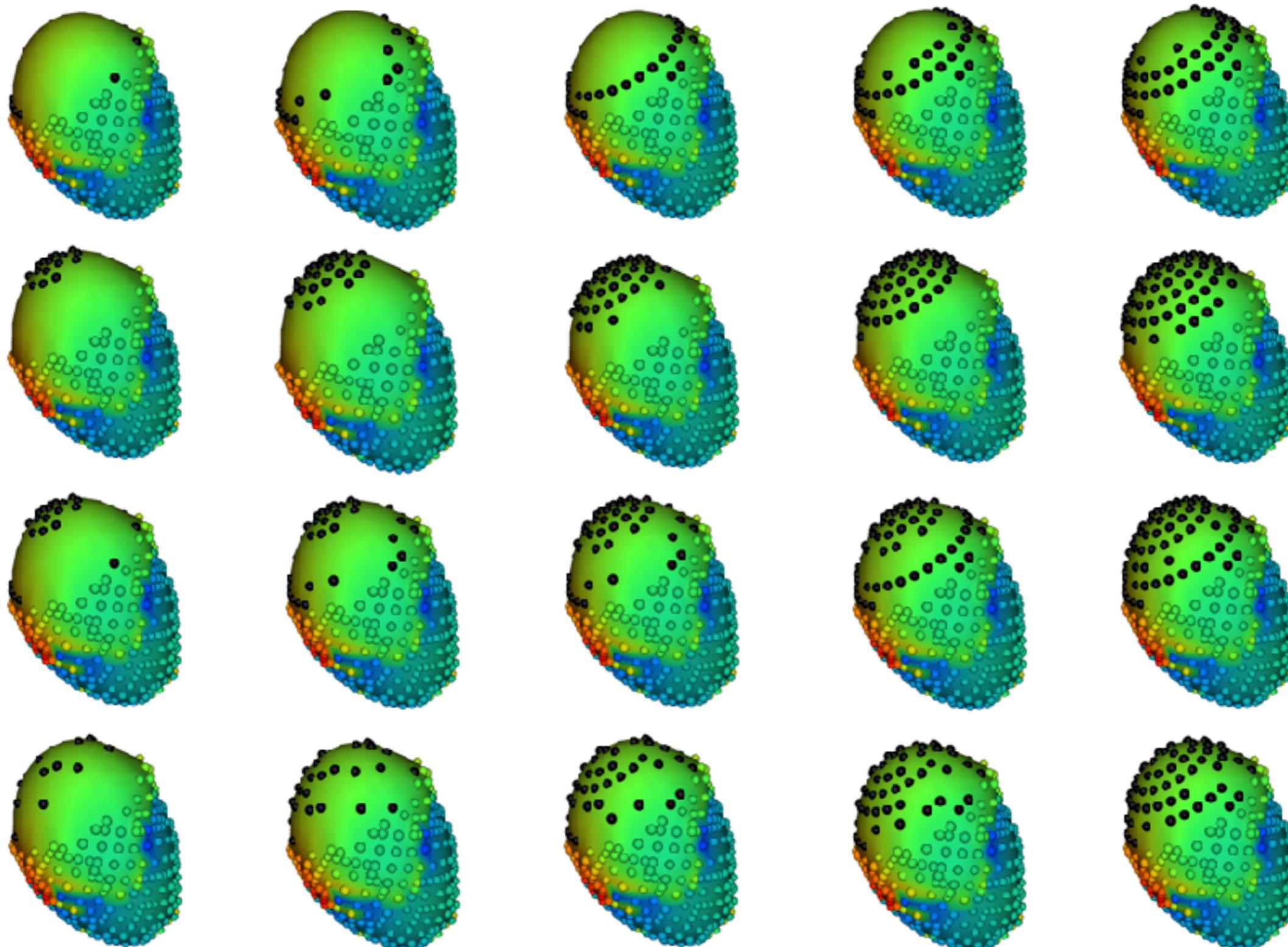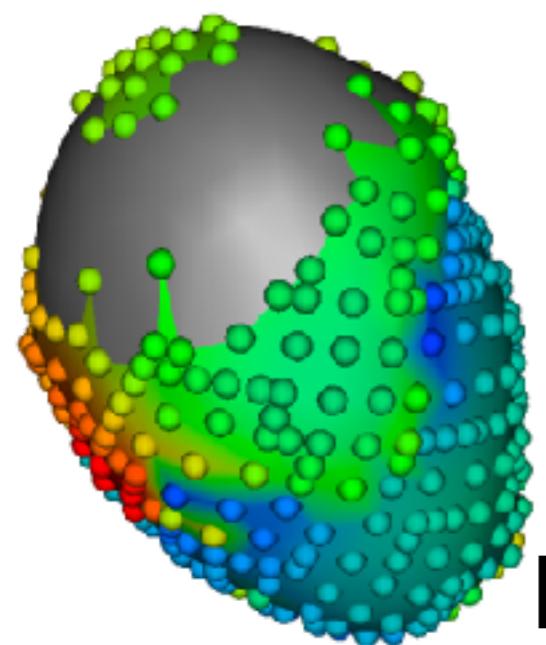
ECG Forward Simulation
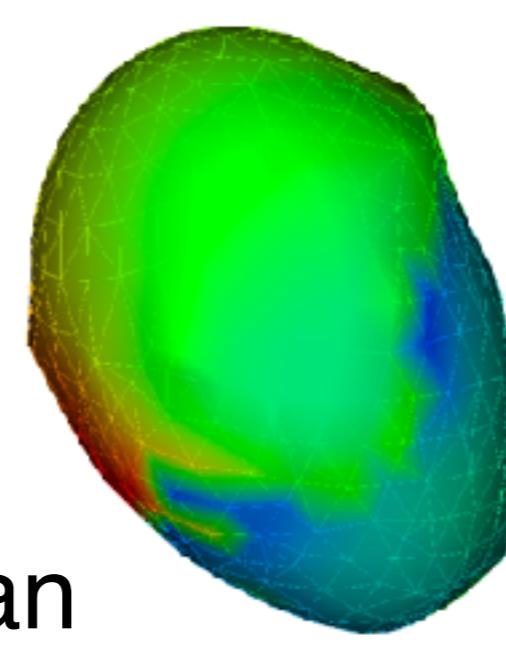
Sampled
Sources

Interpolated
Sources

Laplacian
Interpolation
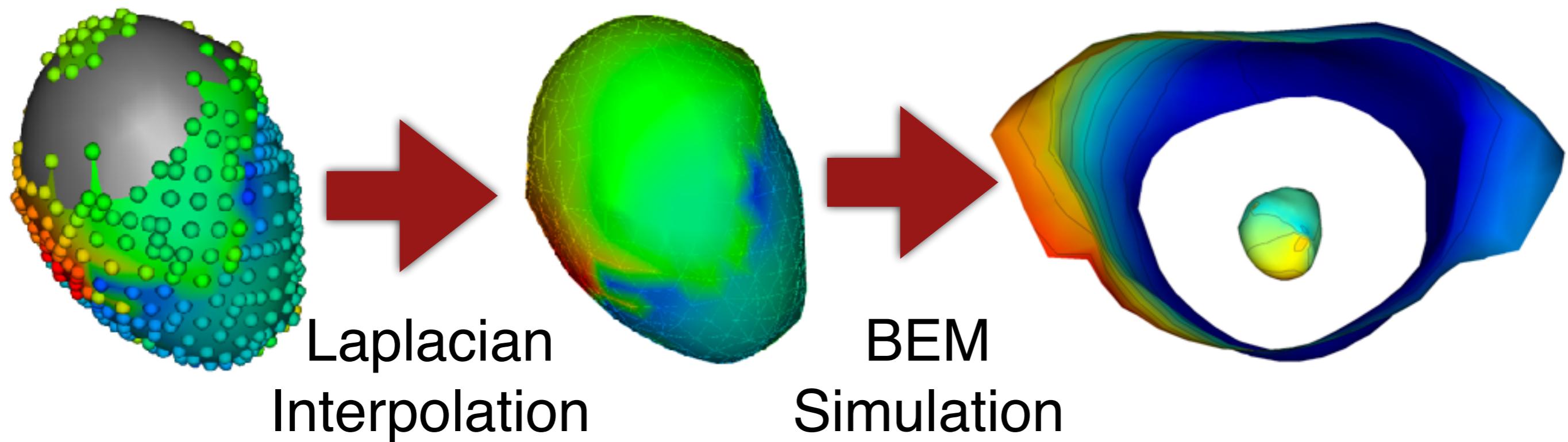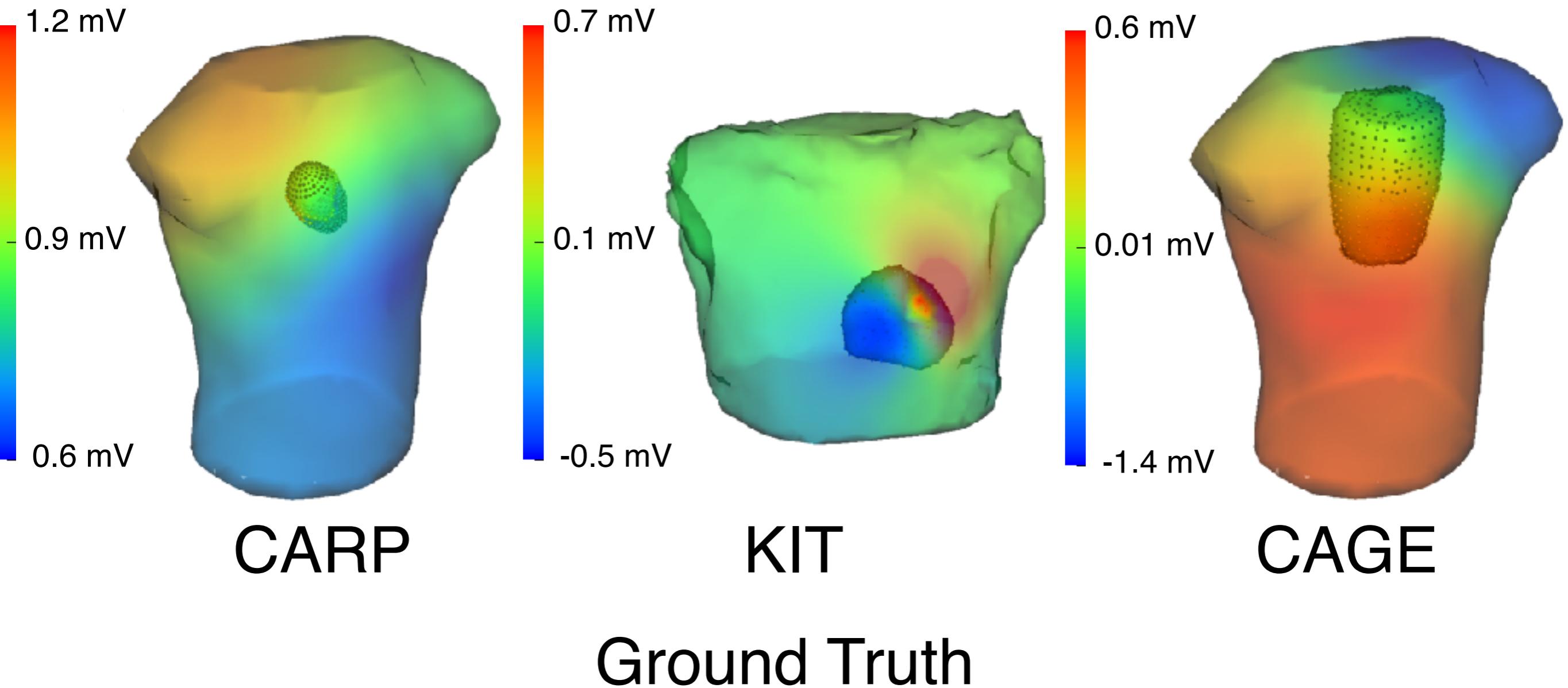
BEM
Simulation

Predicted solution

CARP 1.2 mV / 0.9 mV / 0.6 mV

KIT 0.7 mV / 0.1 mV / -0.5 mV

CAGE 0.6 mV / 0.01 mV / -1.4 mV

Ground Truth

Predicted solution

CARP

KIT
Sock Only

CAGE

Relative Difference

CARP   KIT   CAGE

Sock Only

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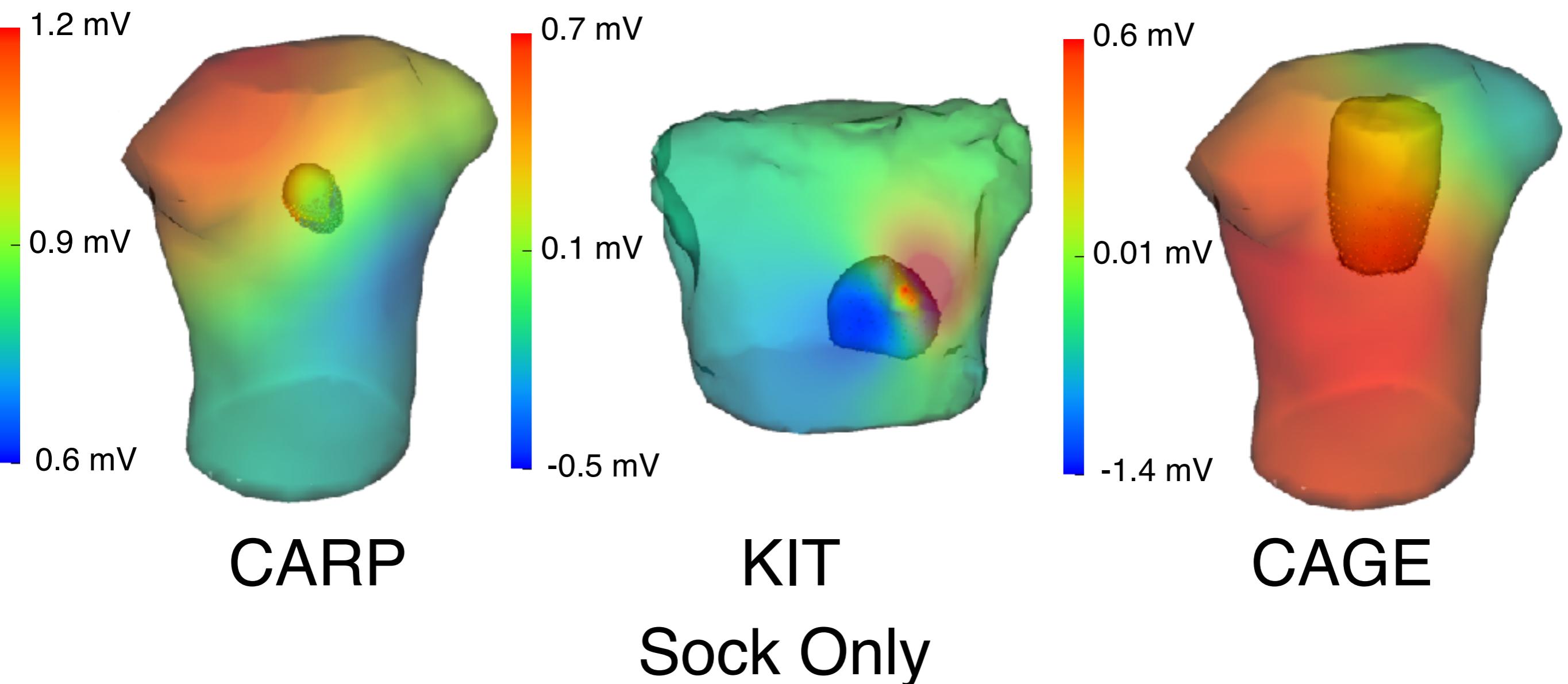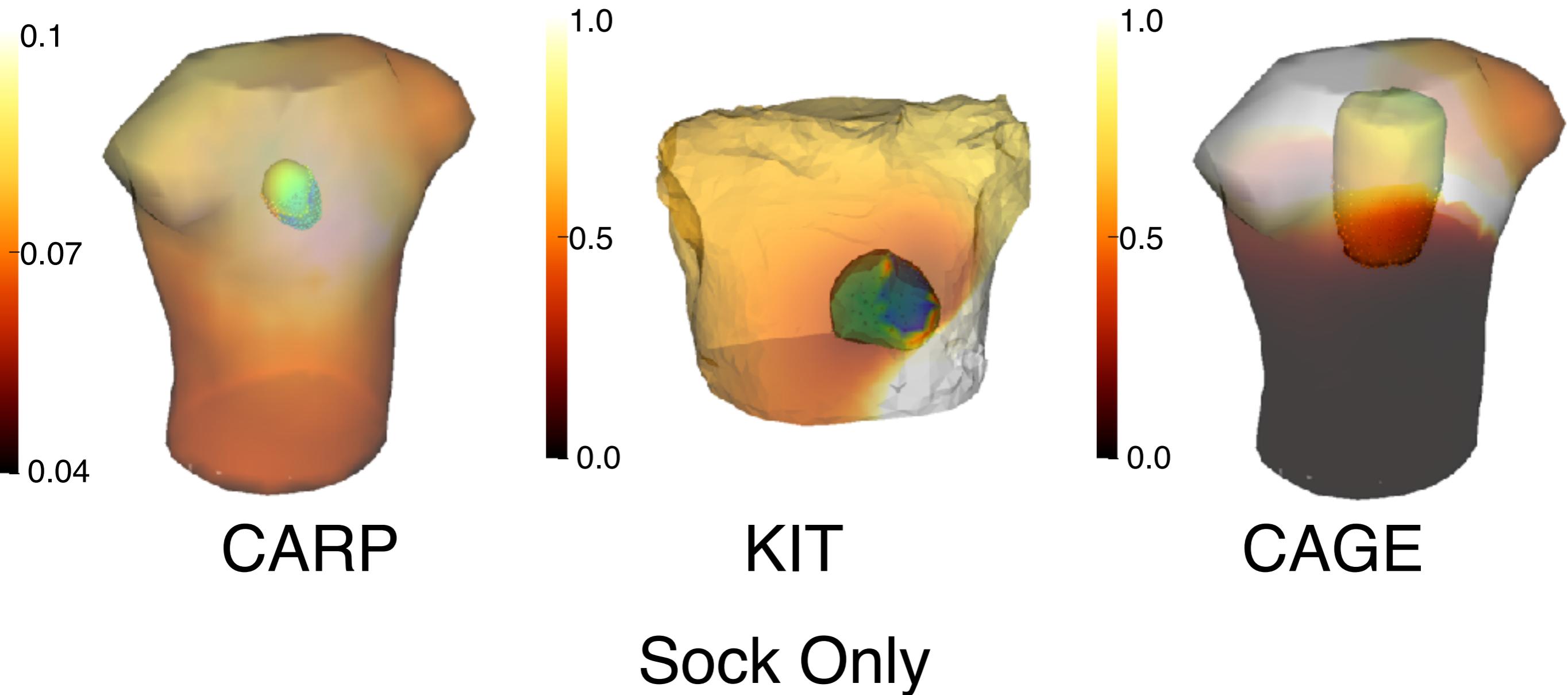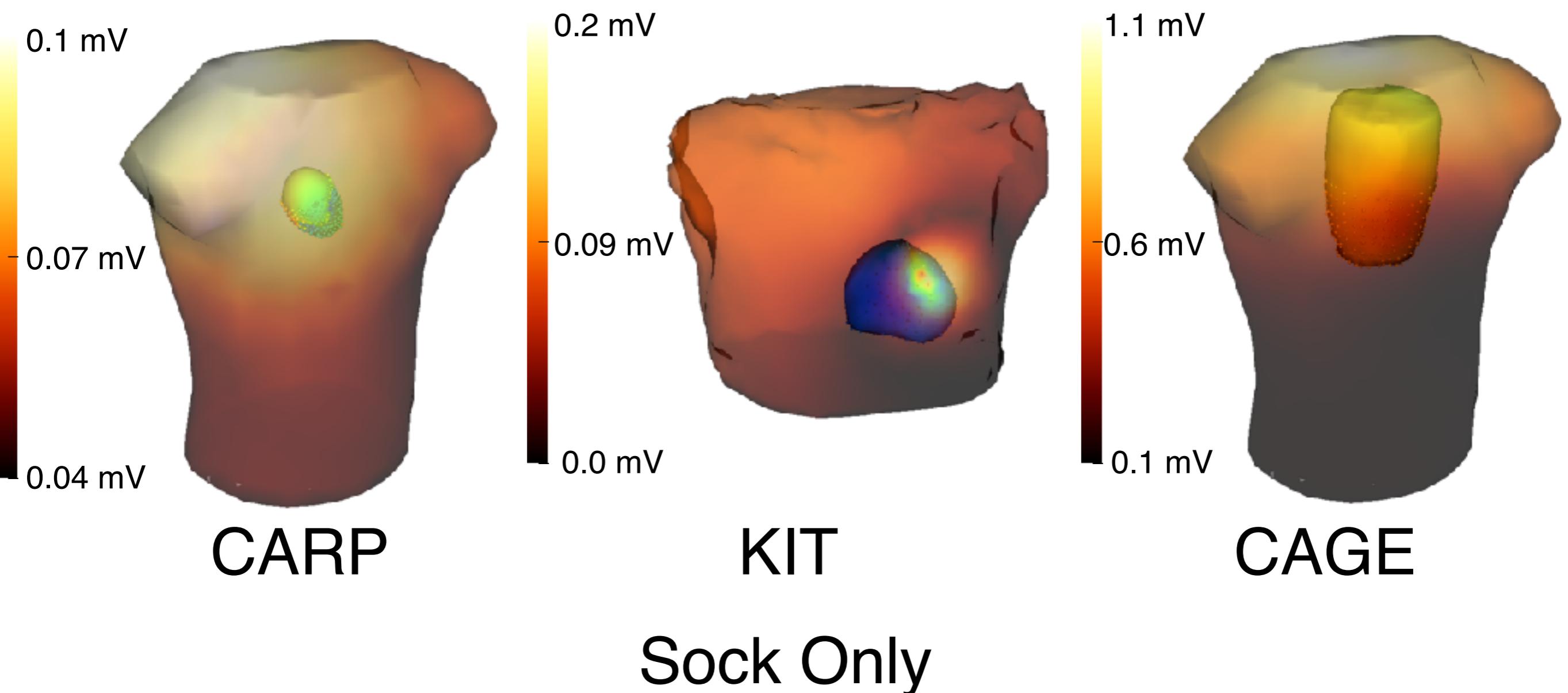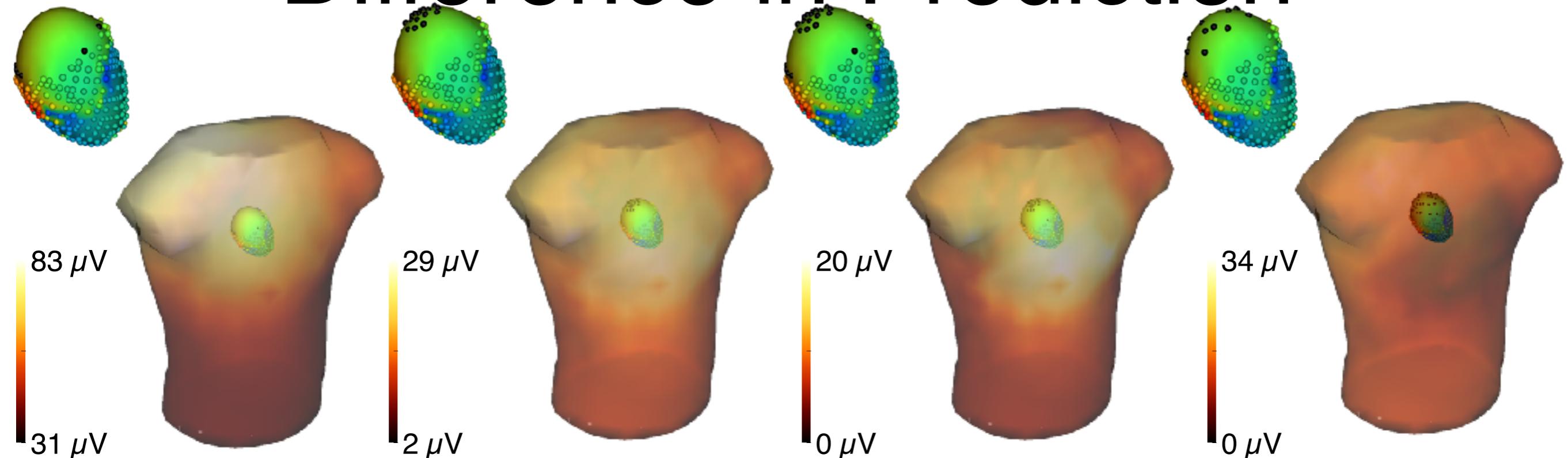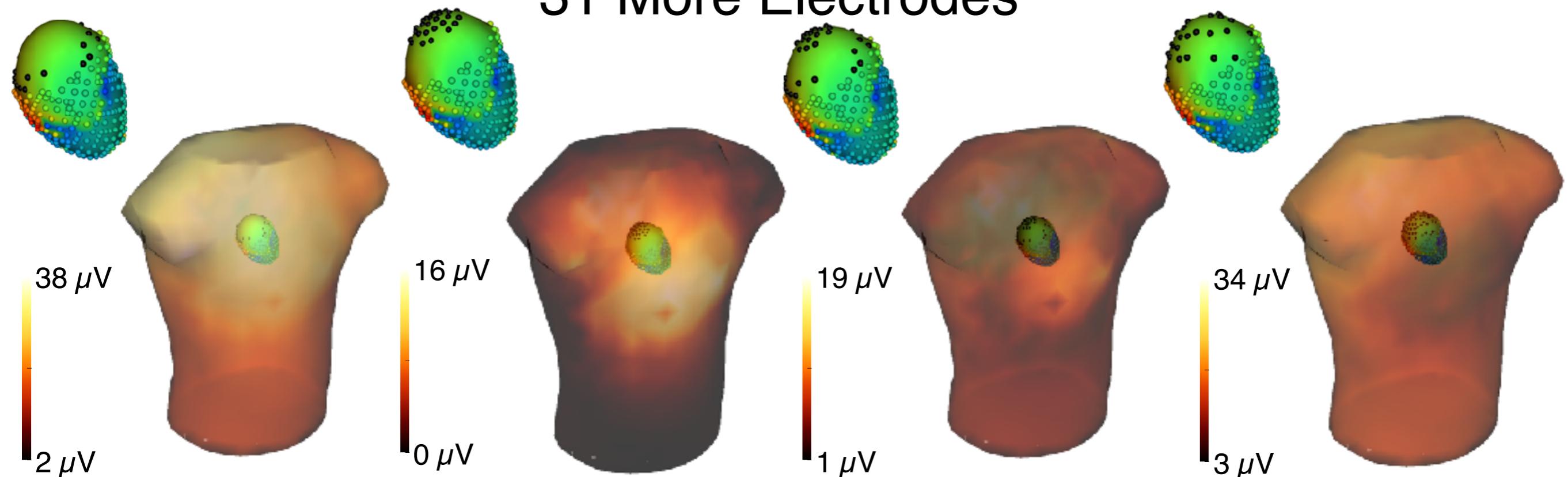
Absolute Difference

CARP   KIT   CAGE

Sock Only

Difference in Prediction

83 μV

31 μV

29 μV

2 μV

20 μV

0 μV

34 μV

0 μV
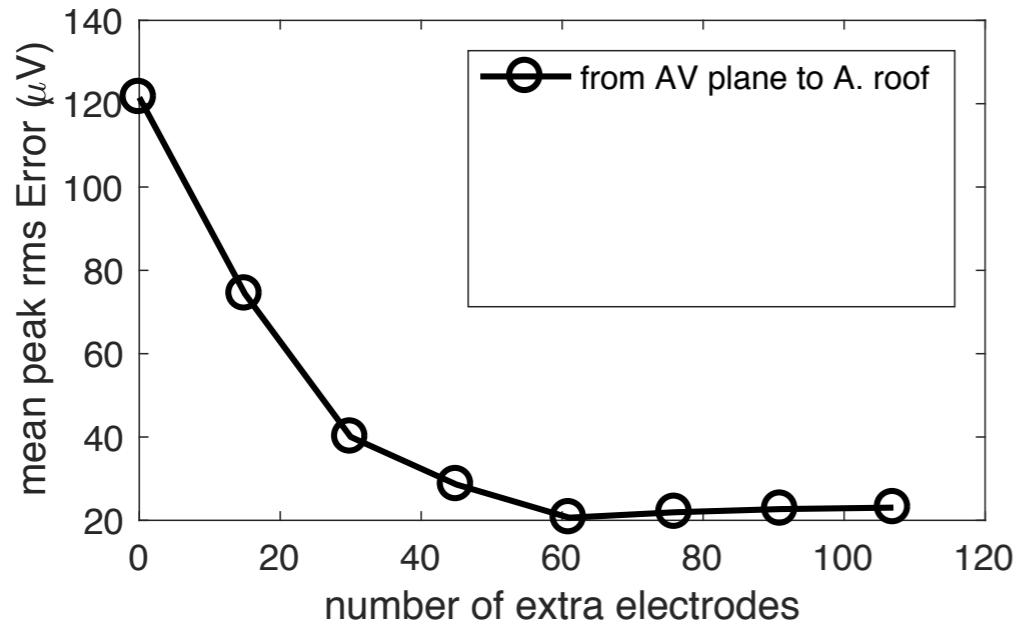
31 More Electrodes

38 μV

2 μV

16 μV

0 μV

19 μV

1 μV

34 μV

3 μV
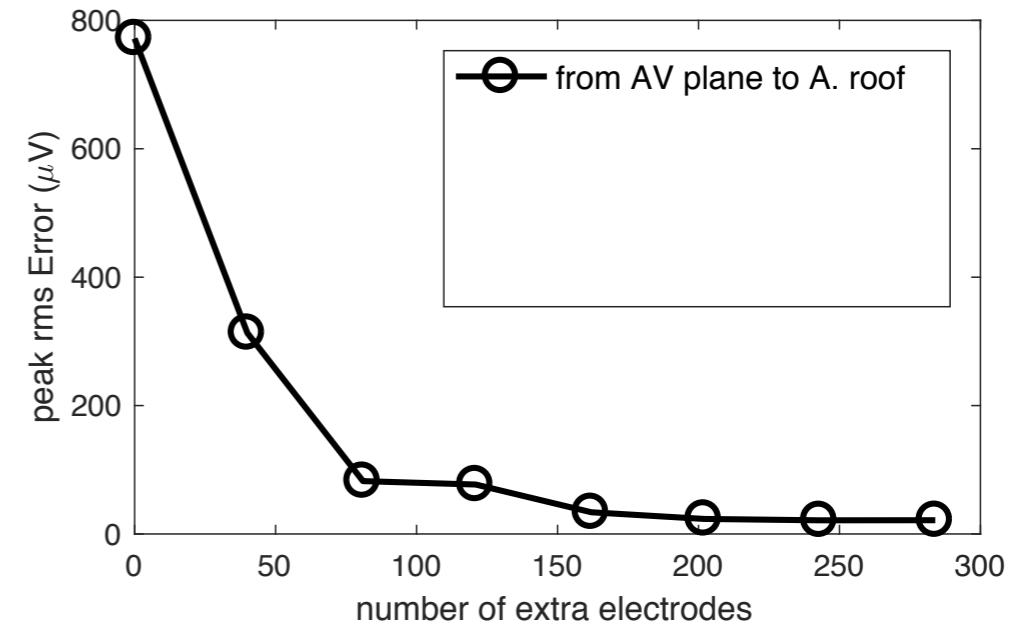
46 More Electrodes

Comparing Sampling
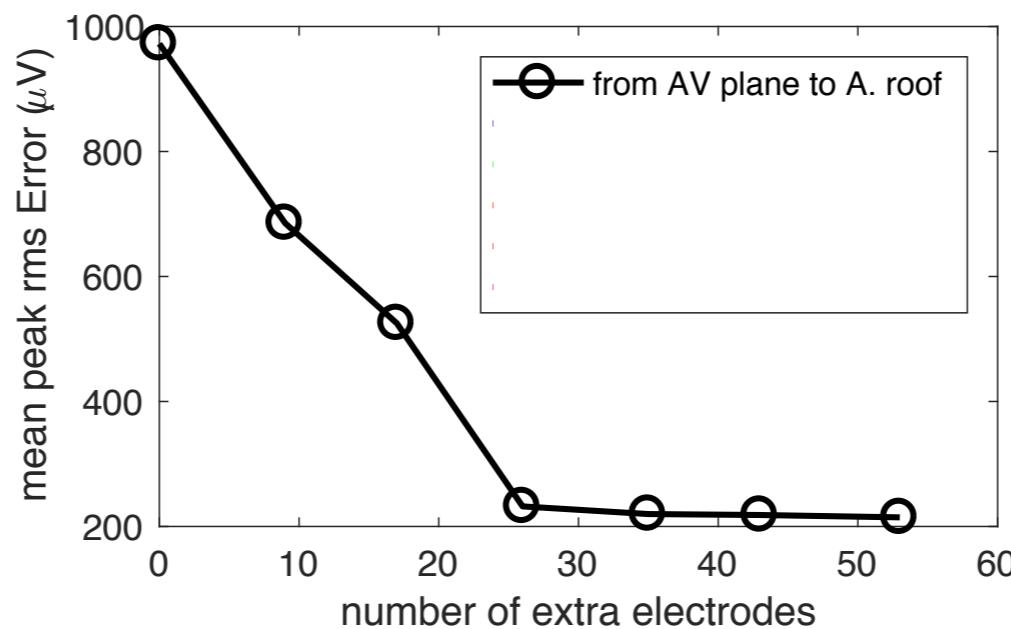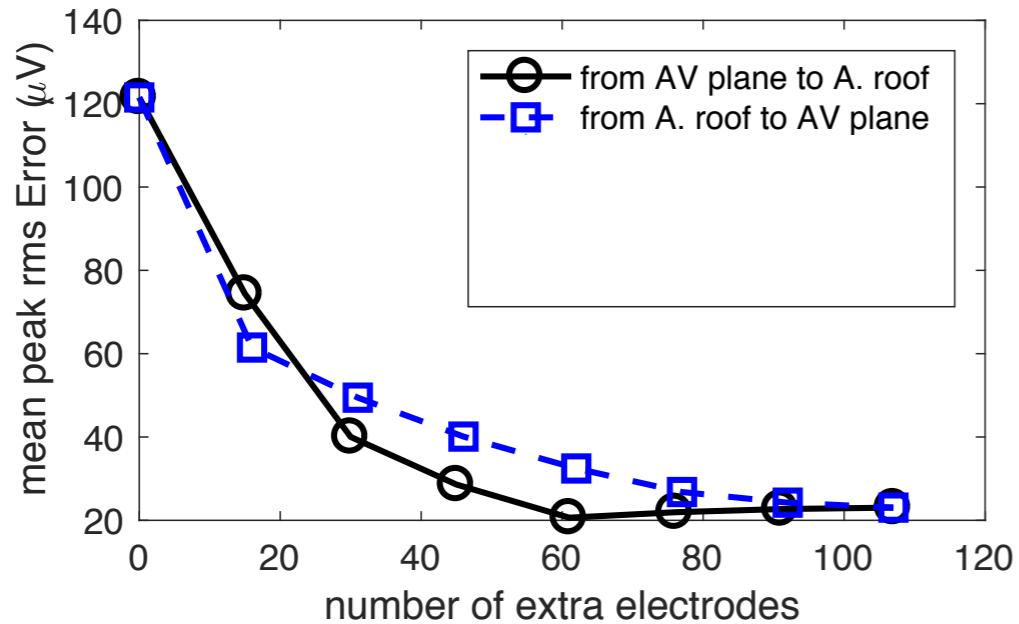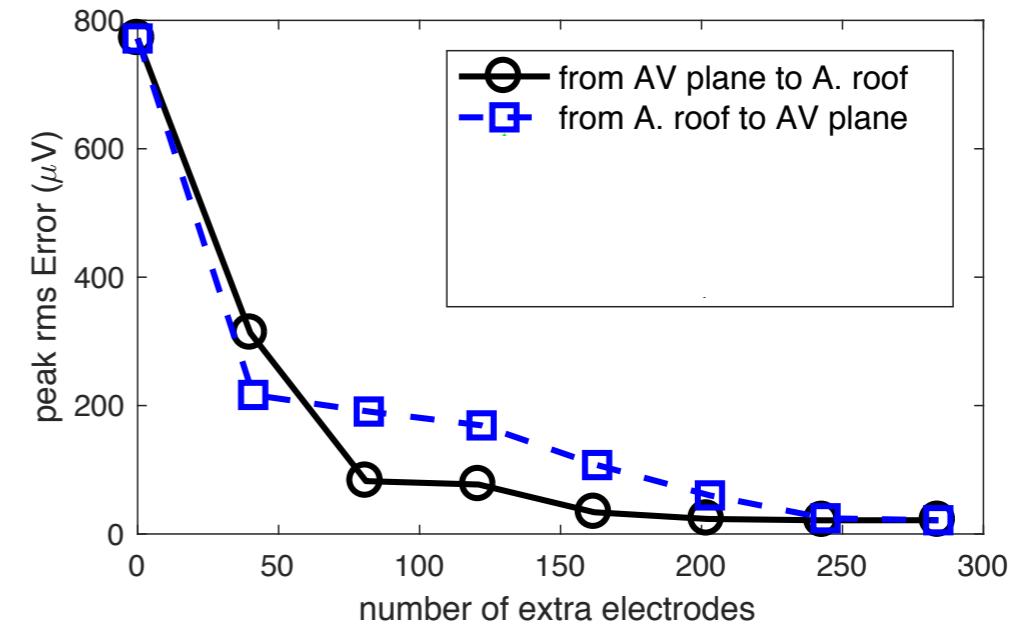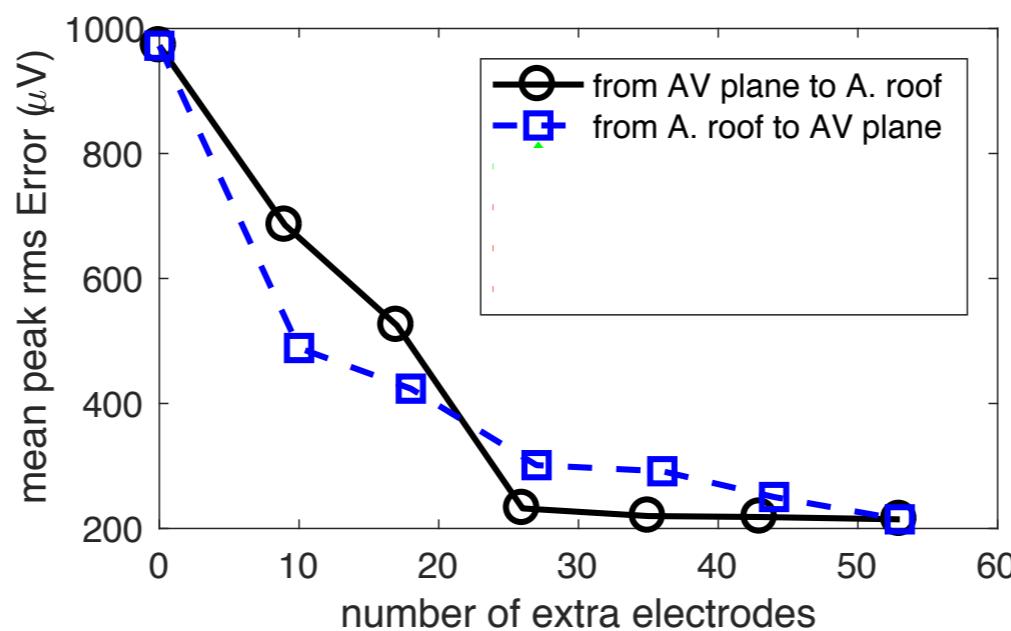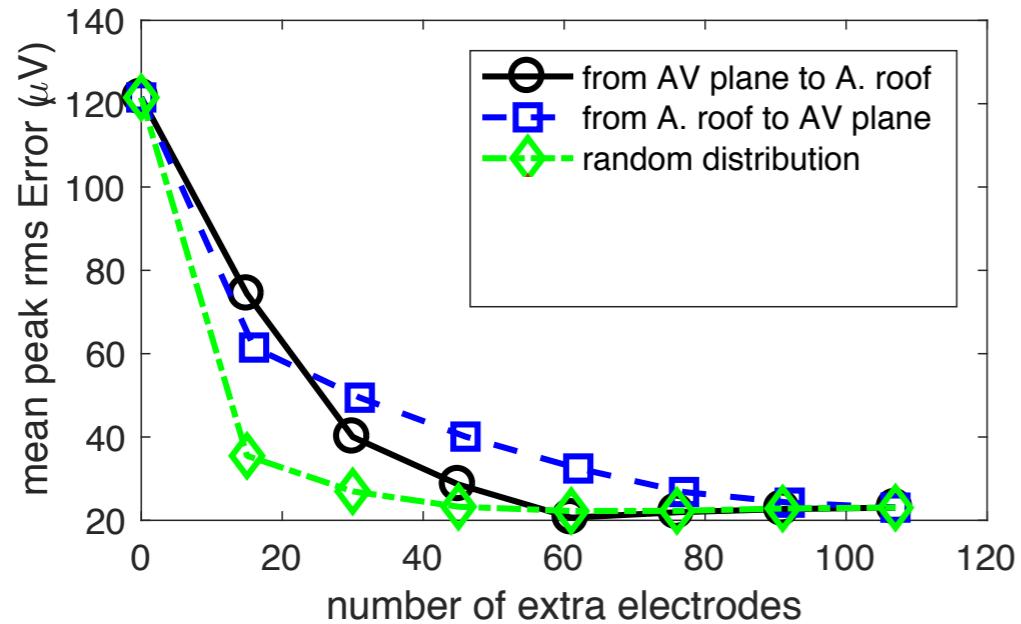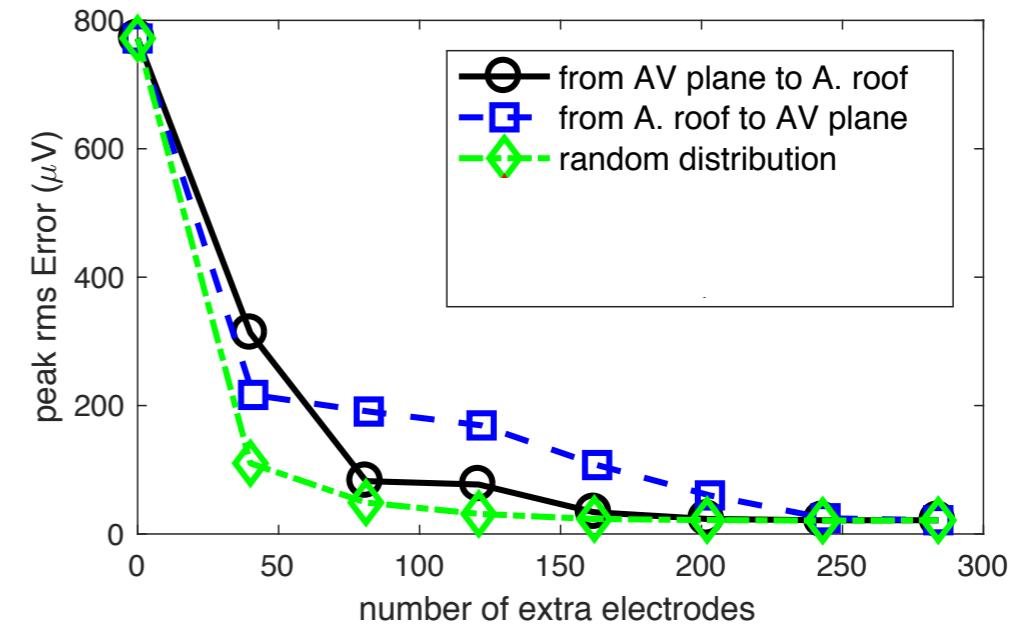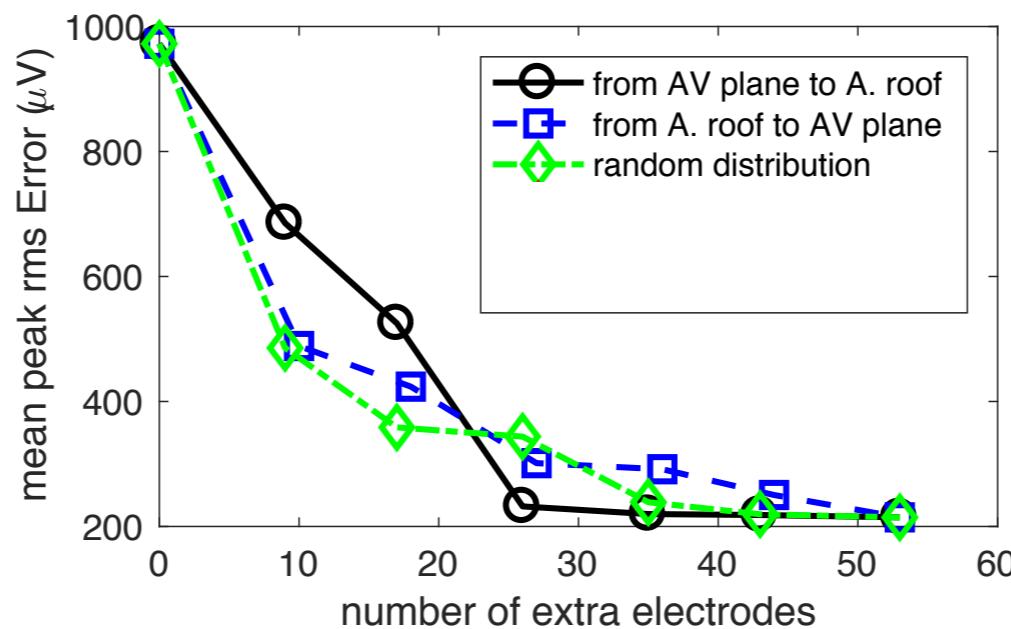
# Comparing Sampling
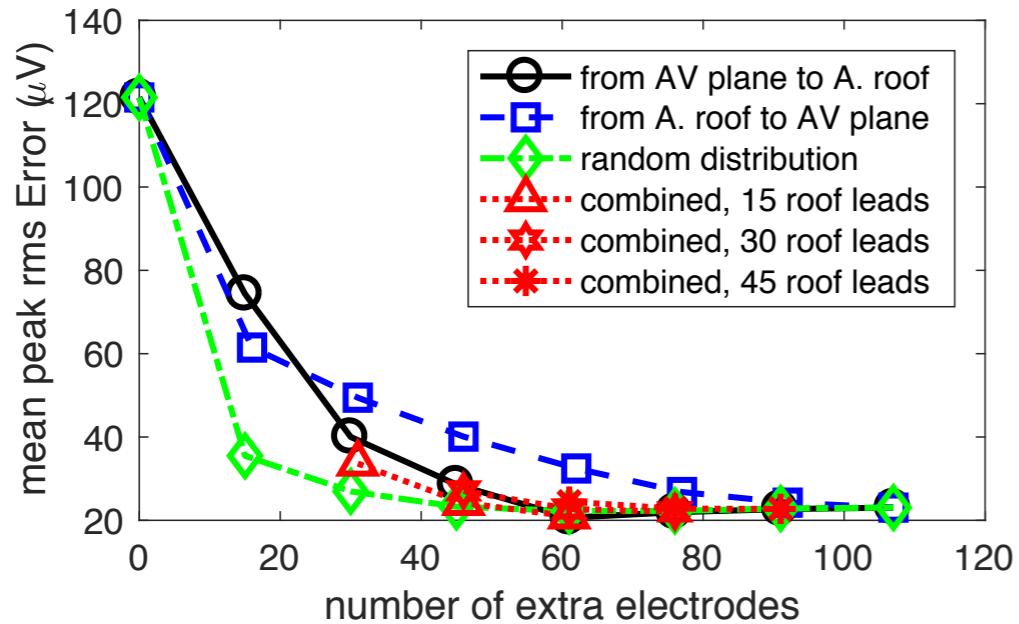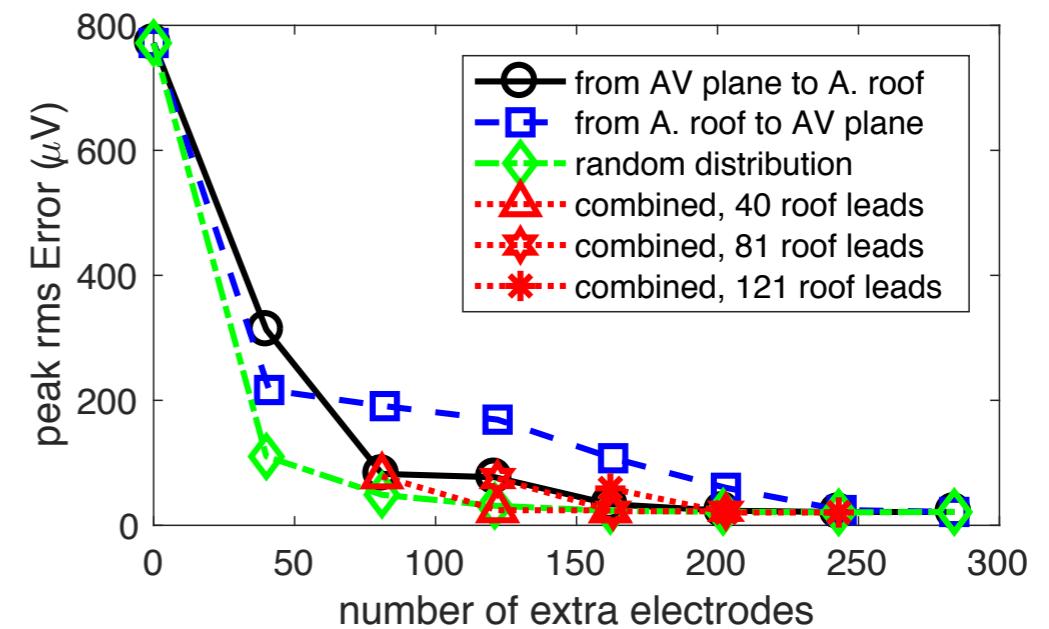
Comparing Sampling

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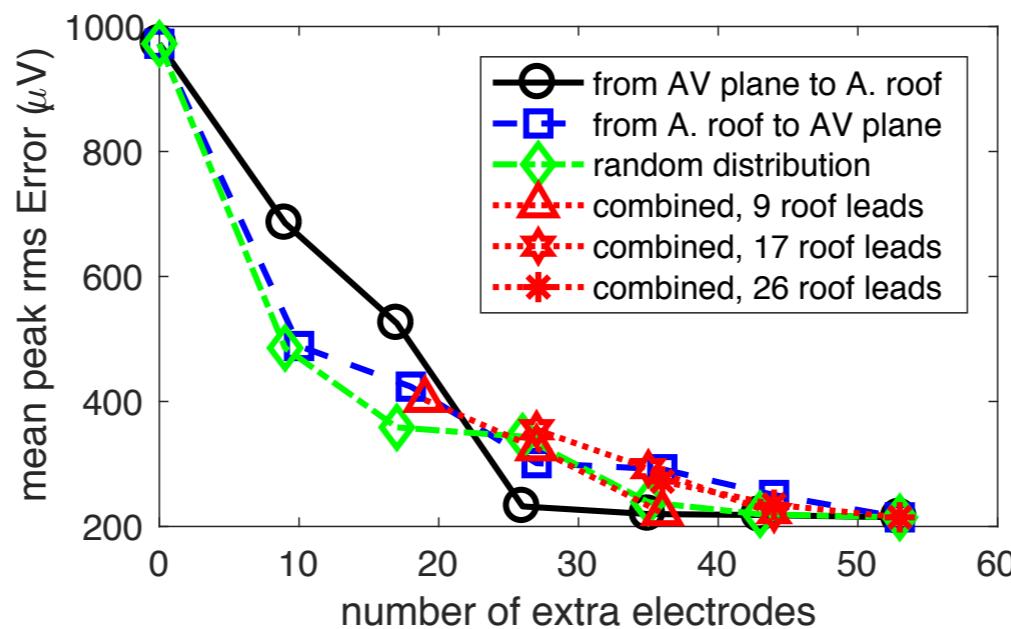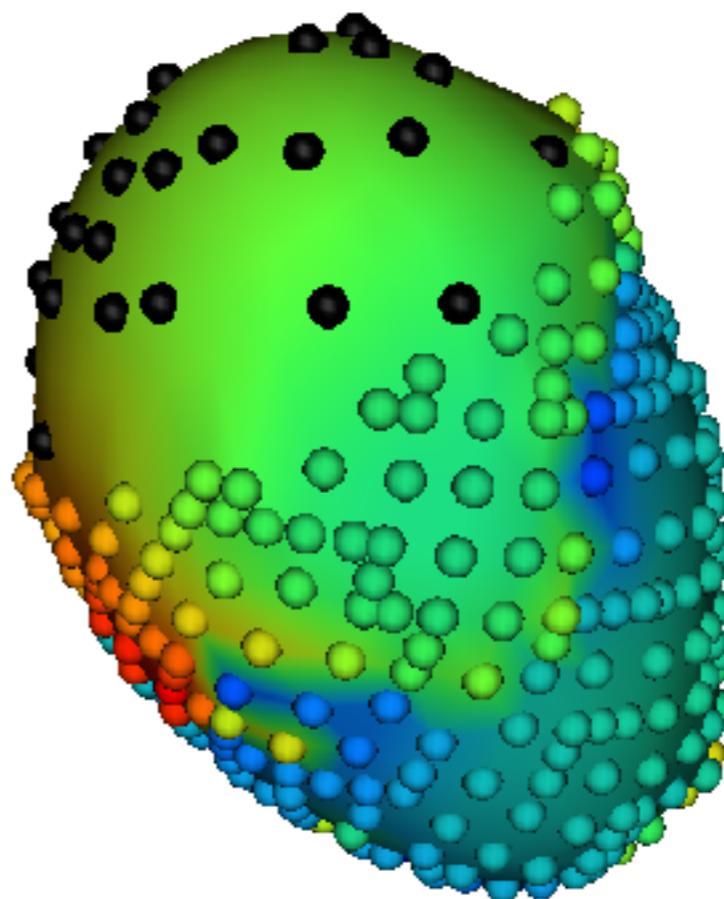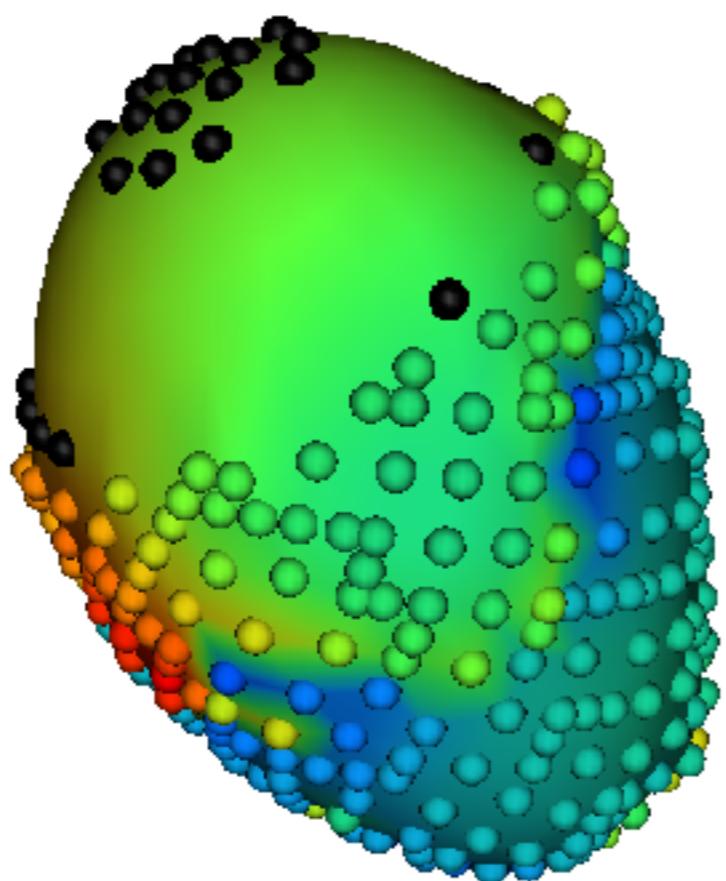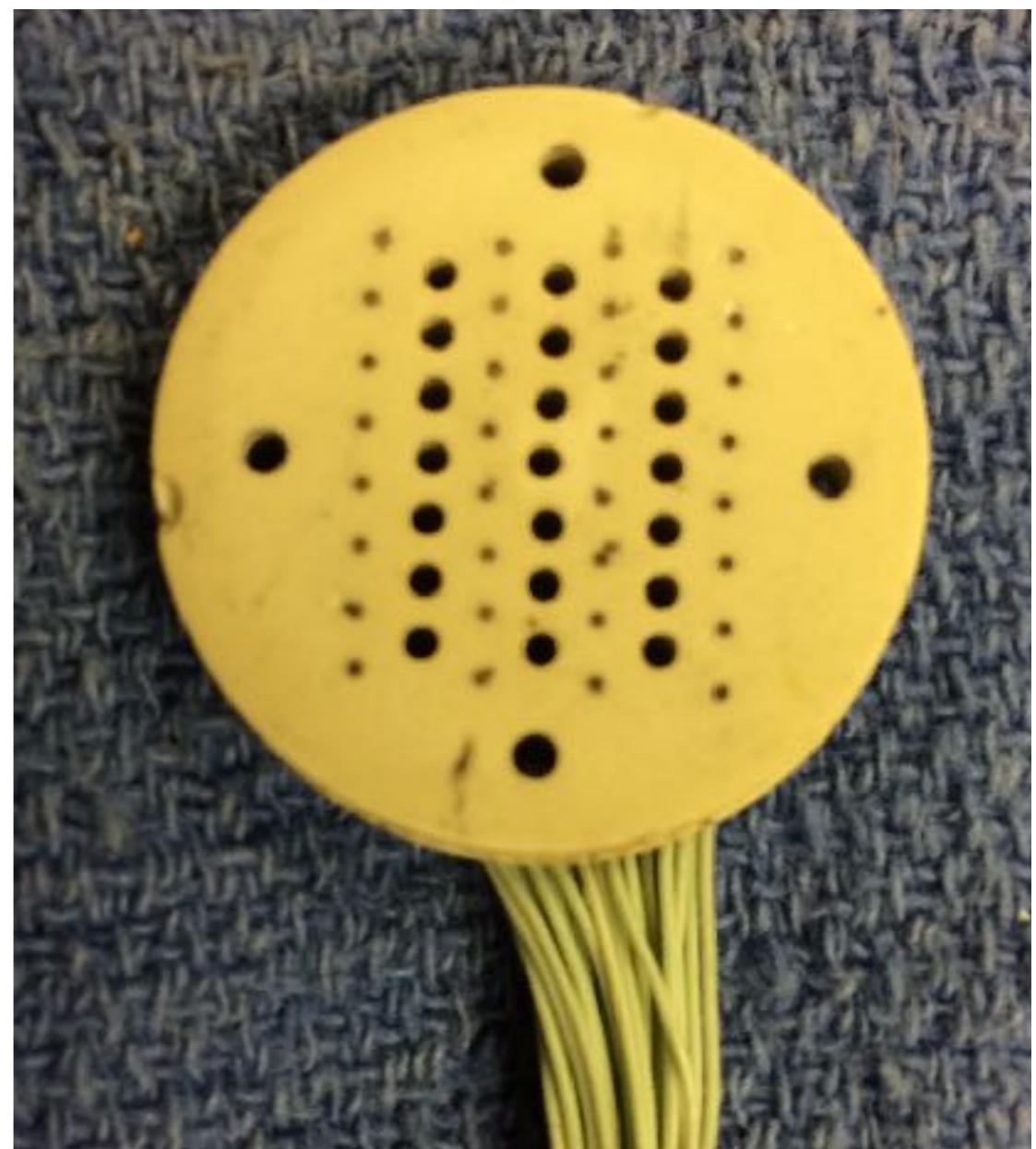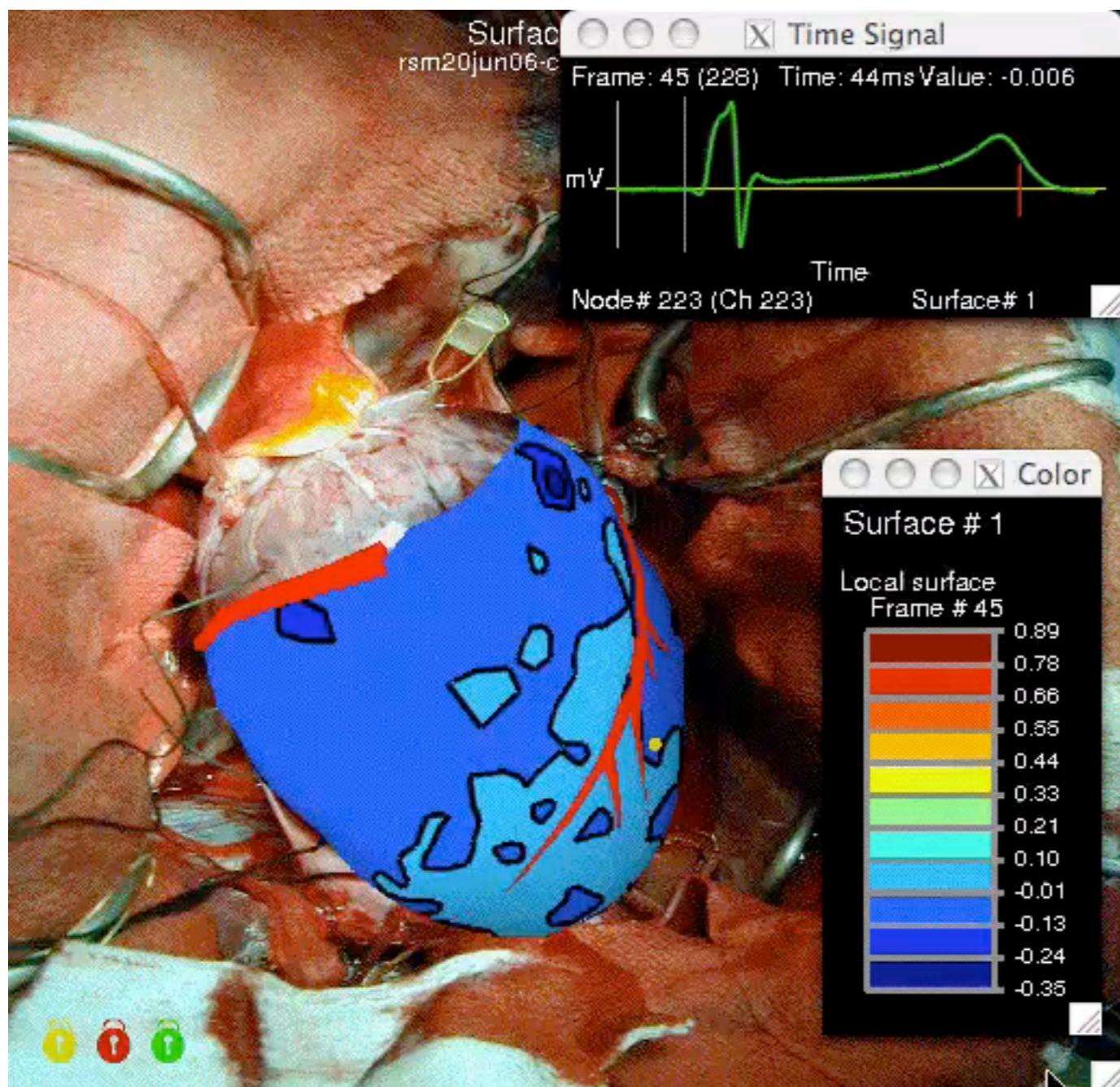
Possible Sampling

More electrodes are better
Sparse placement can reduce error

Possible Sampling
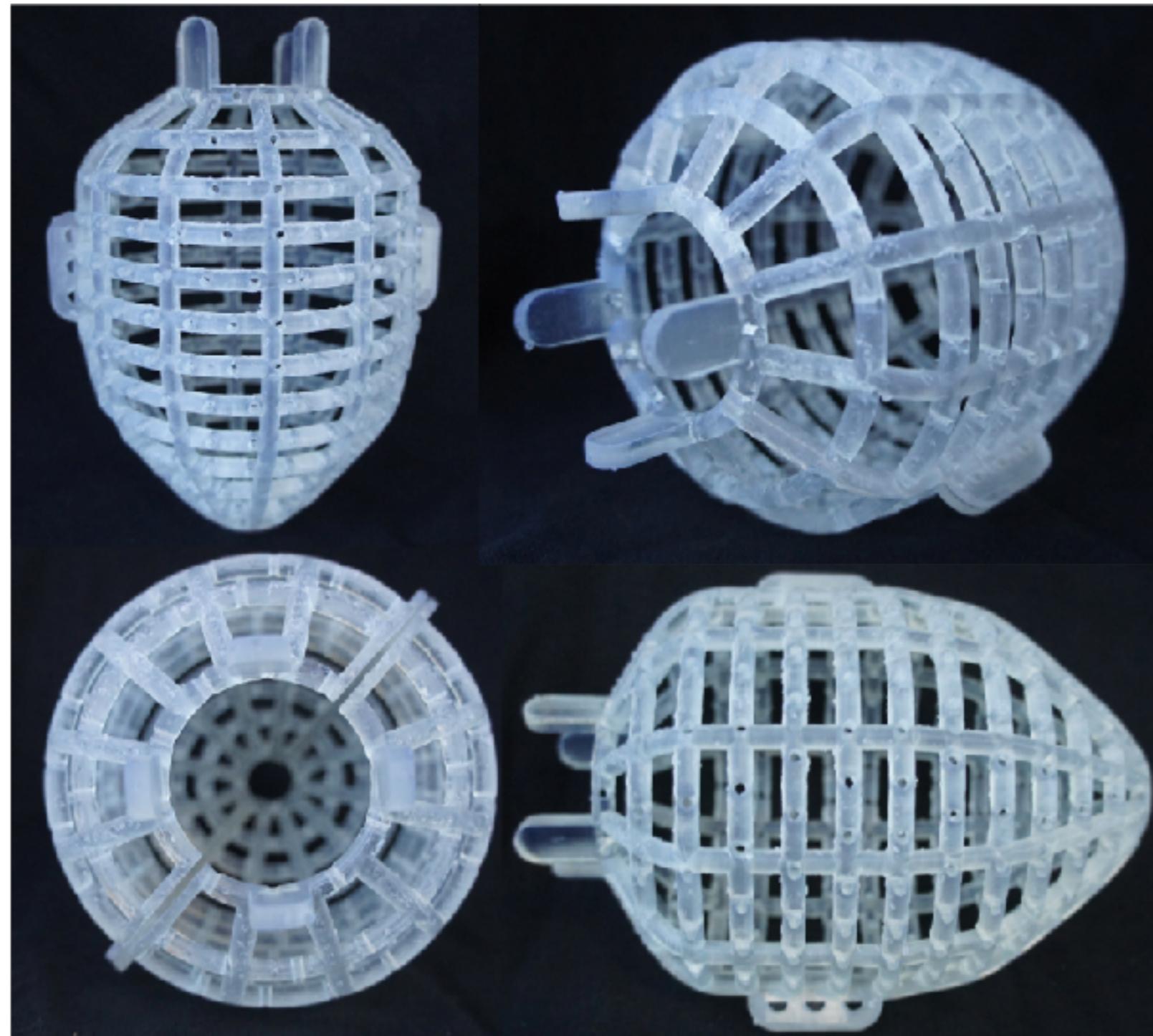
More electrodes are better
Sparse placement can reduce error

Experimental Strategy
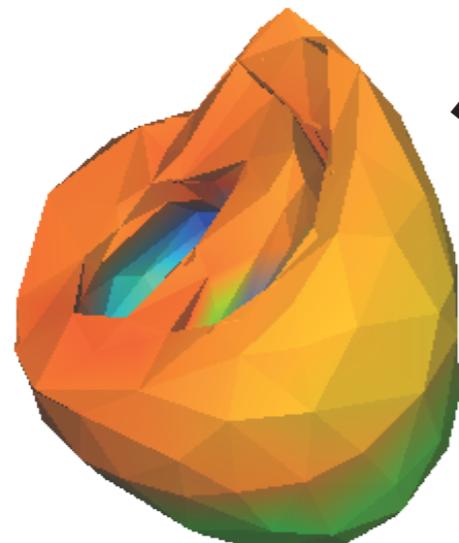
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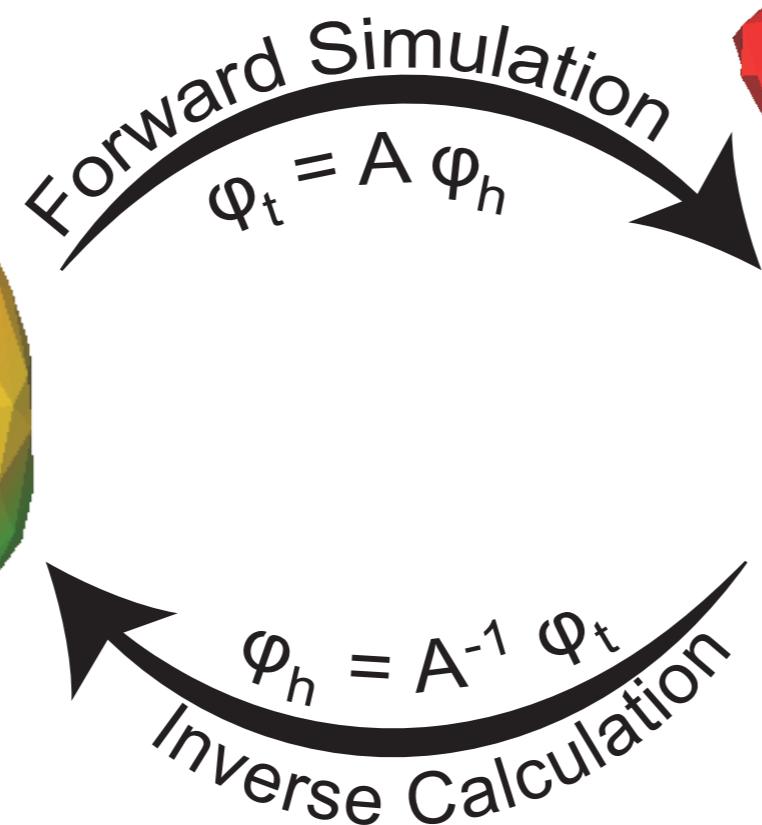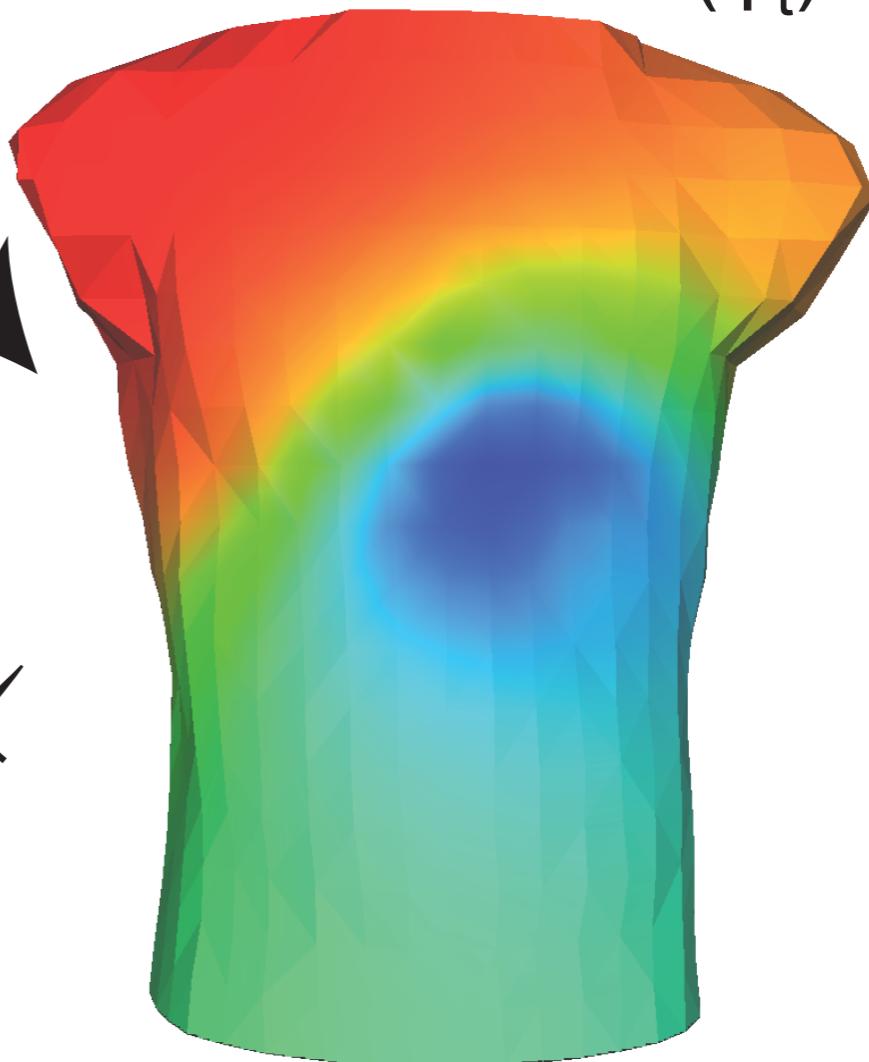
Improve ECGI

Heart Potentials (φ_h)

Torso Potentials (φ_t)

Forward Simulation
$$\varphi_t = A \, \varphi_h$$

$$\varphi_h = A^{-1} \, \varphi_t$$
Inverse Calculation

With better source representation

Acknowledgements

People

Rob MacLeod

Karli Gillette

Brett Burton

Wilson Good

Dana Brooks

Jaume Coll-Font

Dan White

Ayla Khan

Chris Bright

Brian Zenger

Jeroen Stinstra

Support

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CIBC