

A Sampling Strategy for Reducing Error in ECG Forward Simulation

Jess Tate, Karli Gillette, Brett Burton, Wilson Good,
Jaume Coll-Font, Dana Brooks, Rob MacLeod

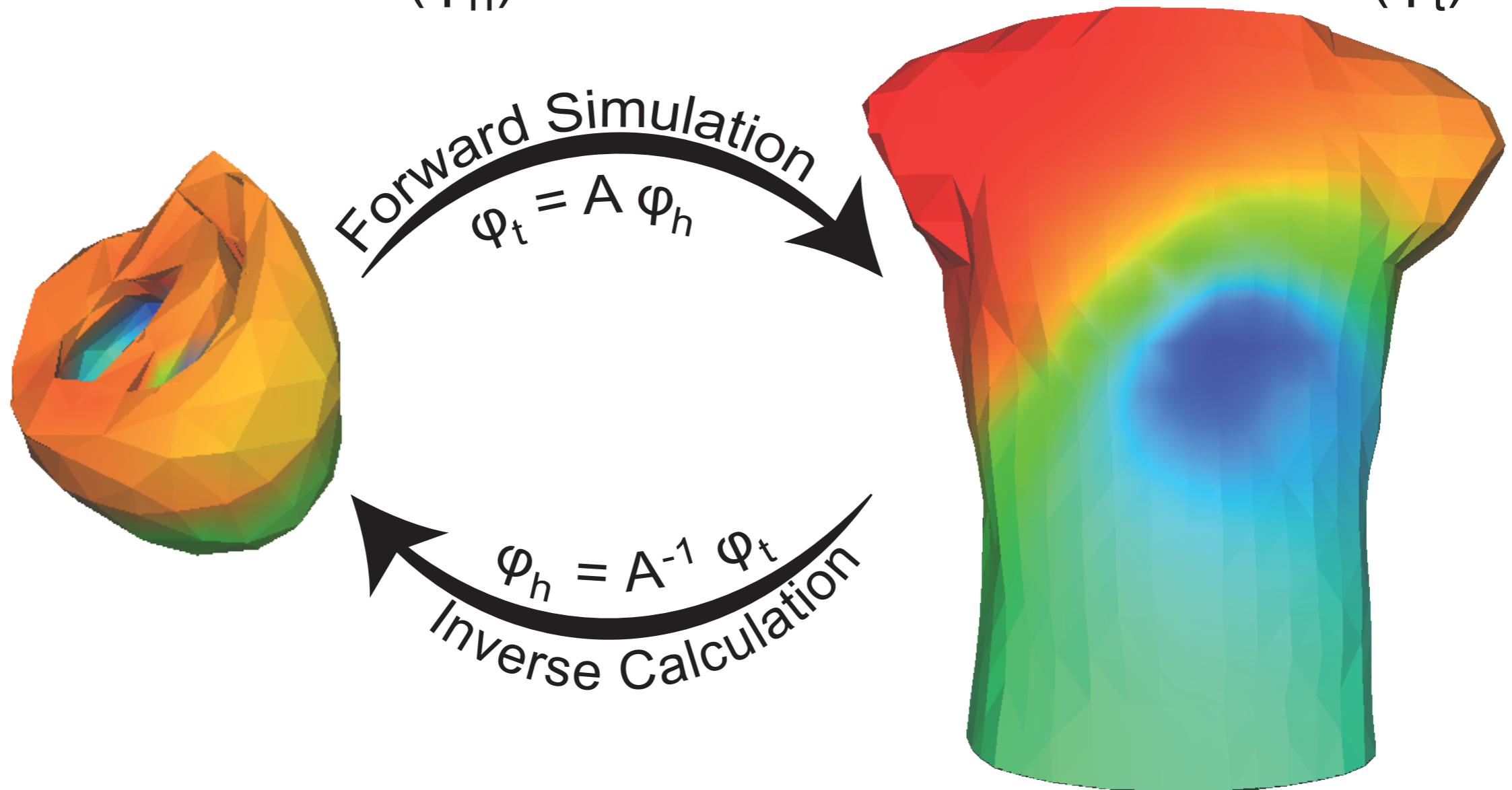
University of Utah
Northeastern University
Graz University



ECG Imaging

Heart Potentials (ϕ_h)

Torso Potentials (ϕ_t)

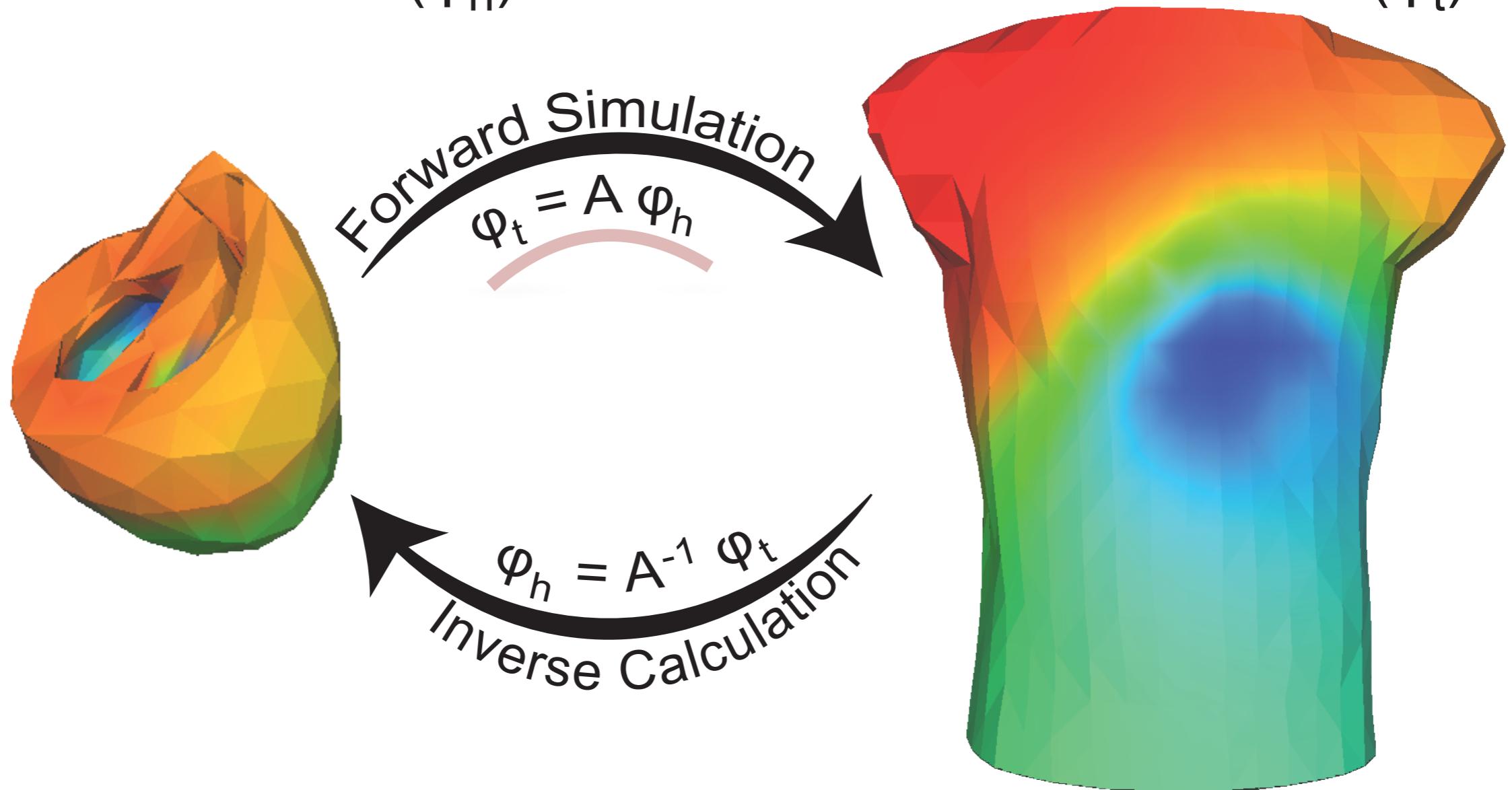


ECG Imaging Relies on Accurate Forward Models

ECG Imaging

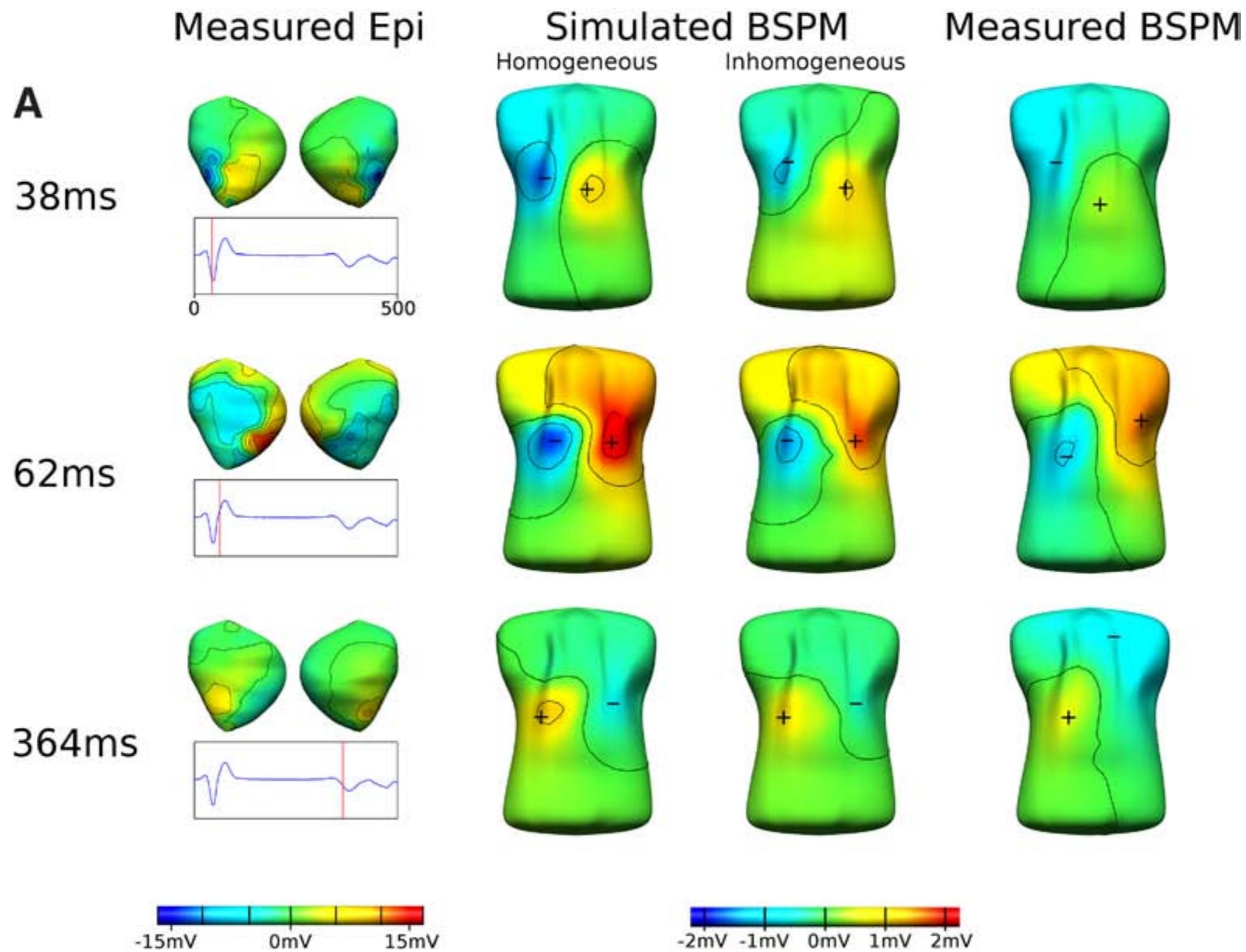
Heart Potentials (ϕ_h)

Torso Potentials (ϕ_t)



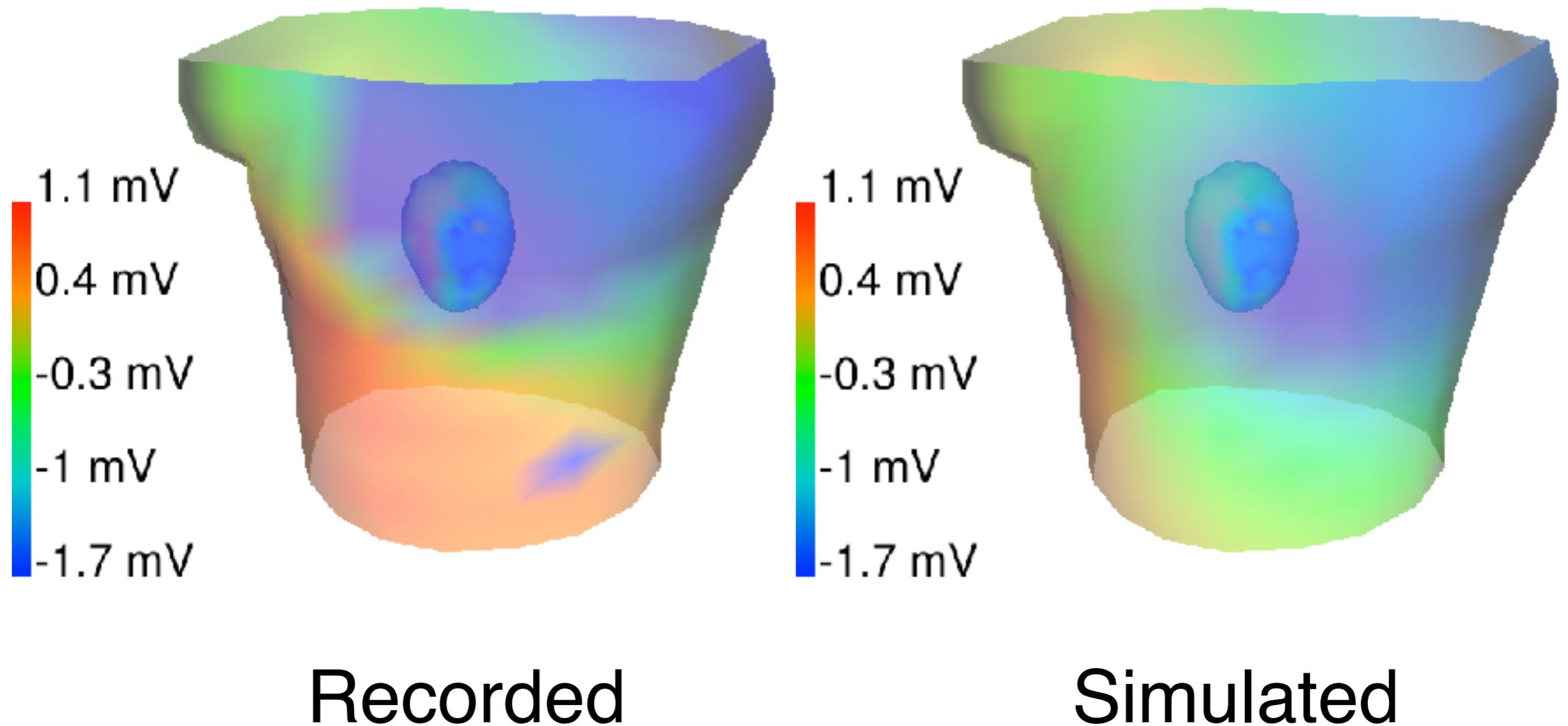
ECG Imaging Relies on Accurate Forward Models

Error in Forward Simulation



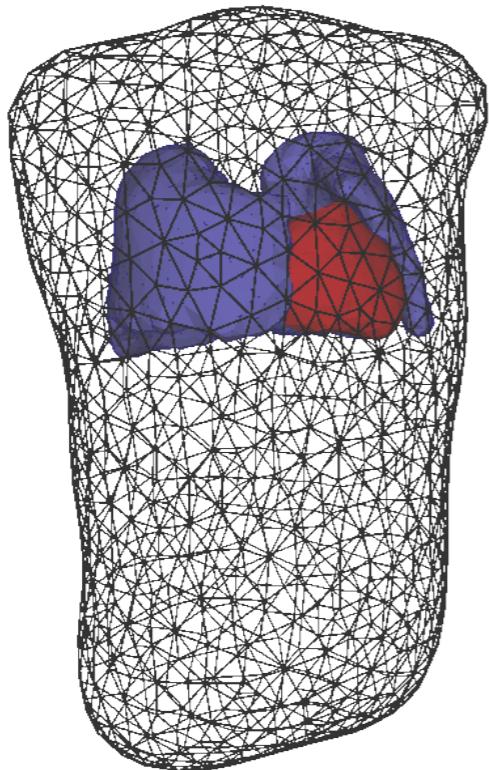
Bear, et al., CircArrhythmElectrophysiol.2015;8:677-684.

Error in Forward Simulation

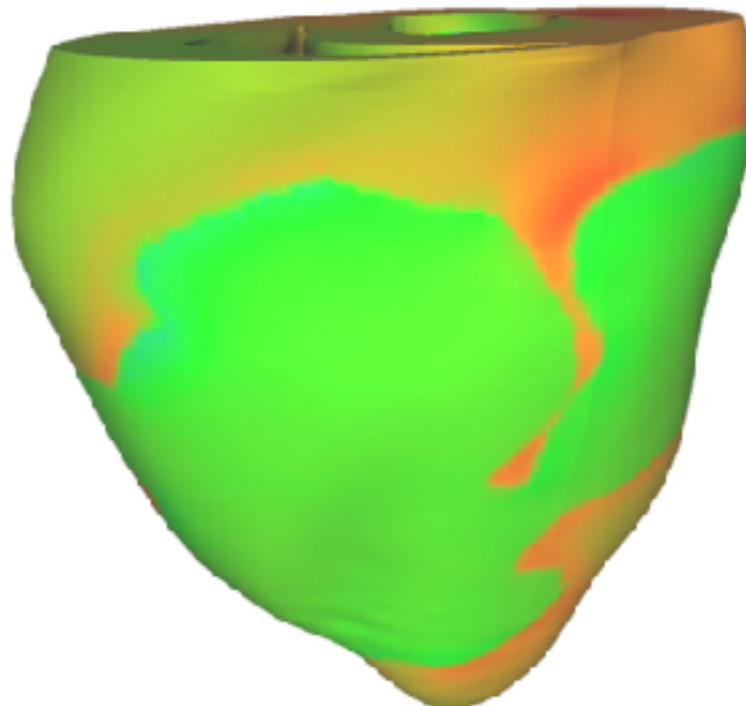


Sources of Error

Geometry

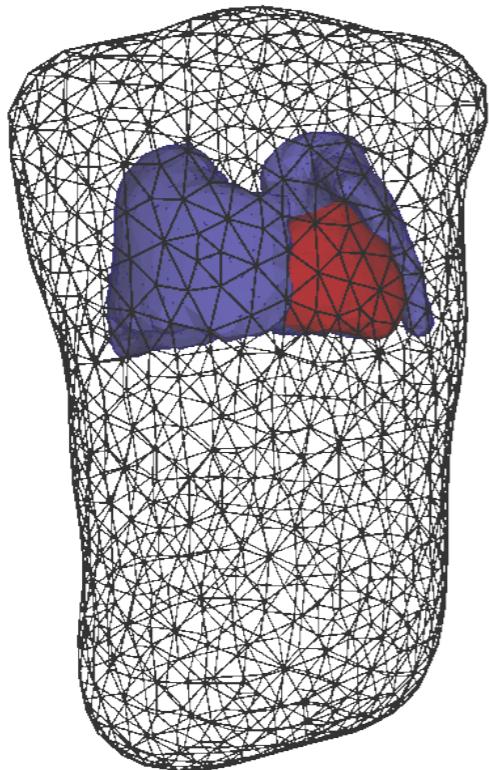


Sources

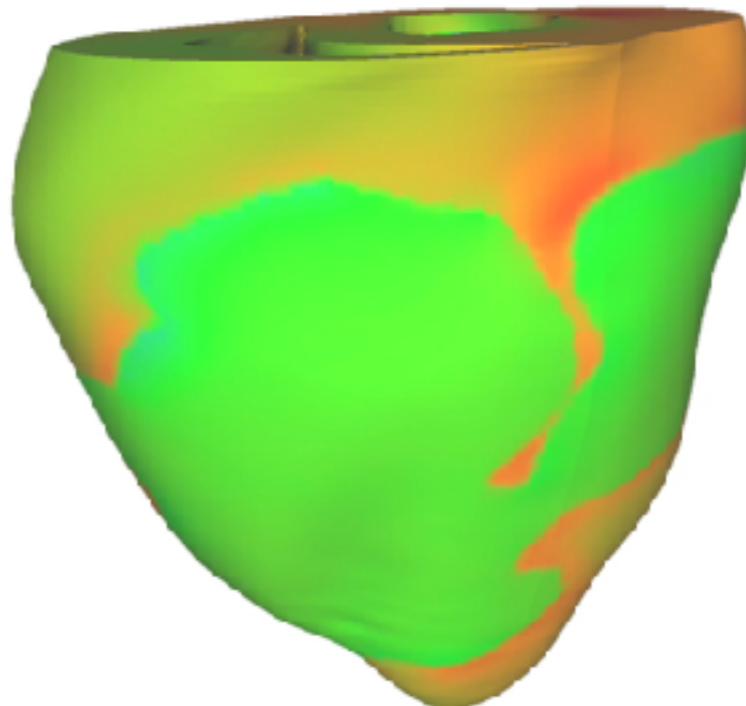


Sources of Error

Geometry



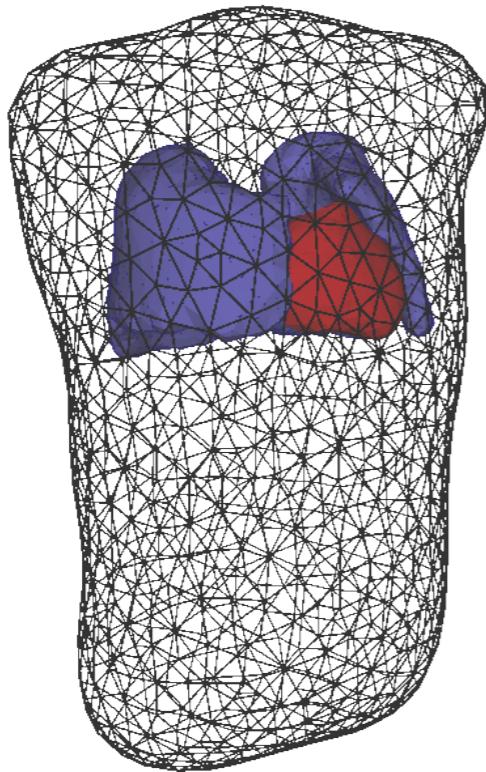
Sources



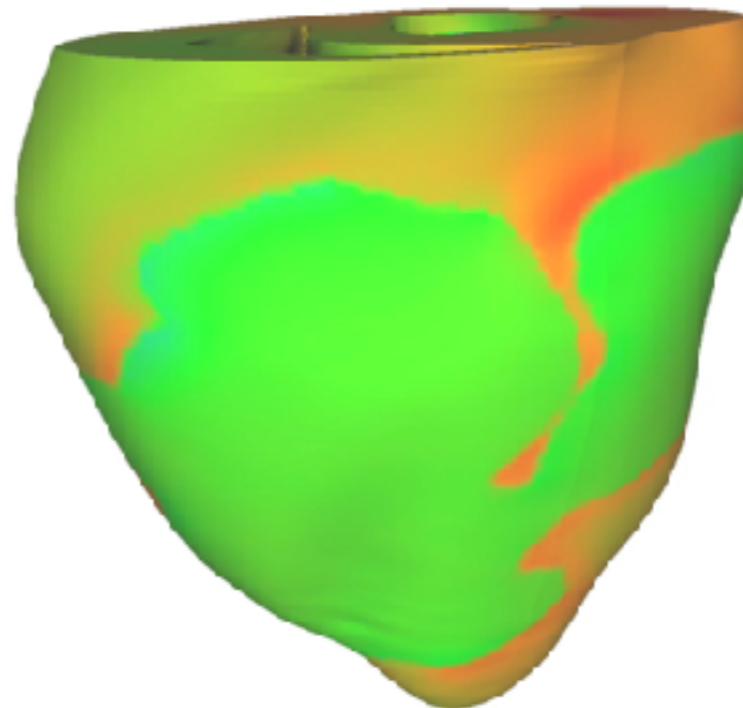
Sources of Error

Geometry

Matrix
A



Sources



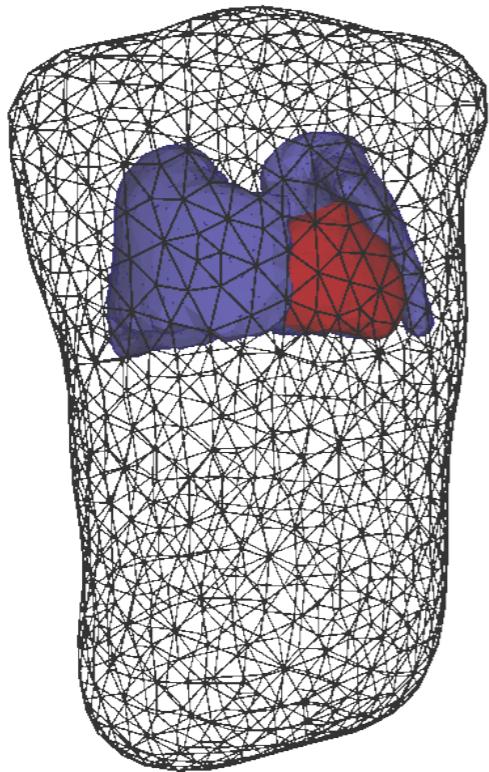
Vector
 Φ_h

Sources of Error

Geometry

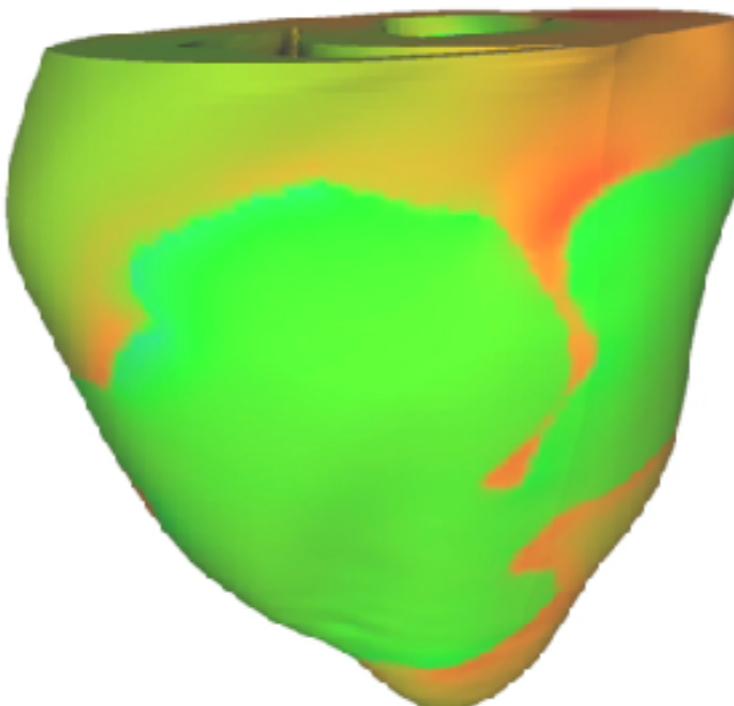
Matrix

A



Sources

Vector
 Φ_h



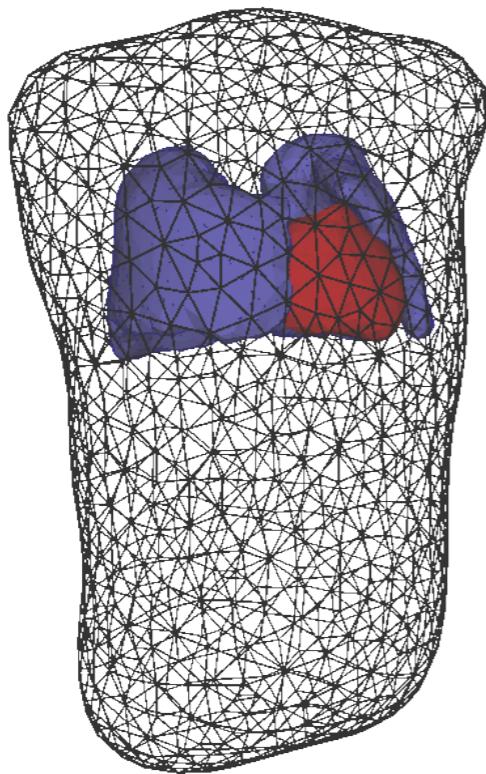
Registration
Segmentation
Conductivities
Meshing

Sources of Error

Geometry

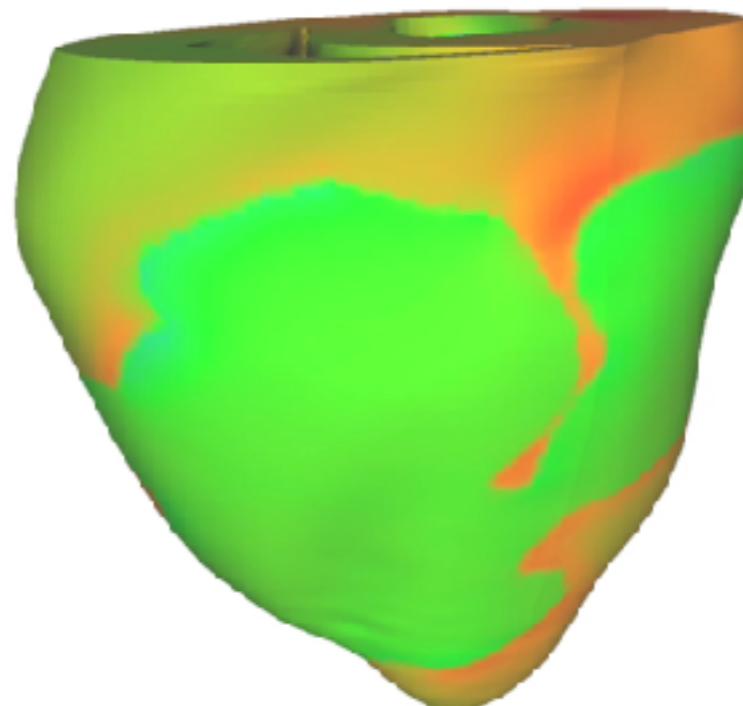
Matrix

A



Registration
Segmentation
Conductivities
Meshing

Sources



Vector
 Φ_h

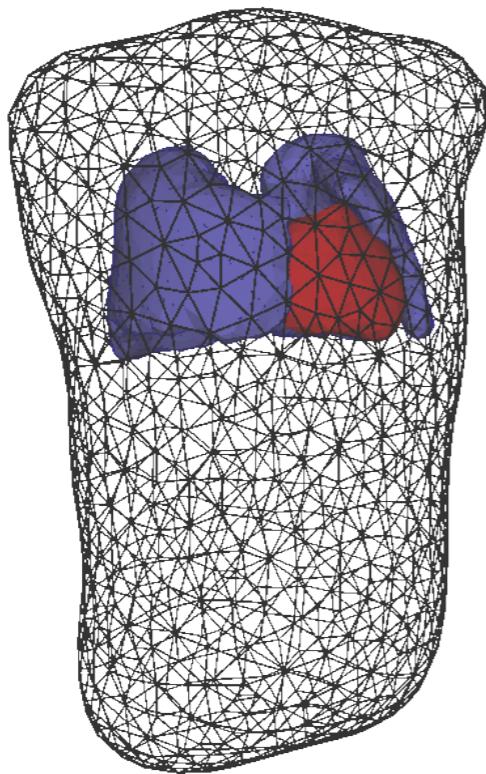
Geometry
Source Model
Noise
Sampling

Sources of Error

Geometry

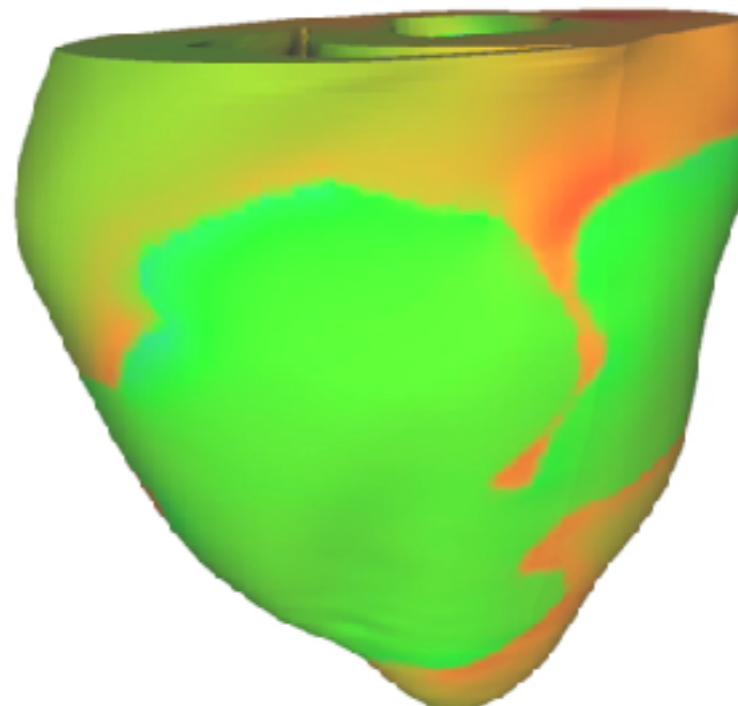
Matrix

A



Registration
Segmentation
Conductivities
Meshing

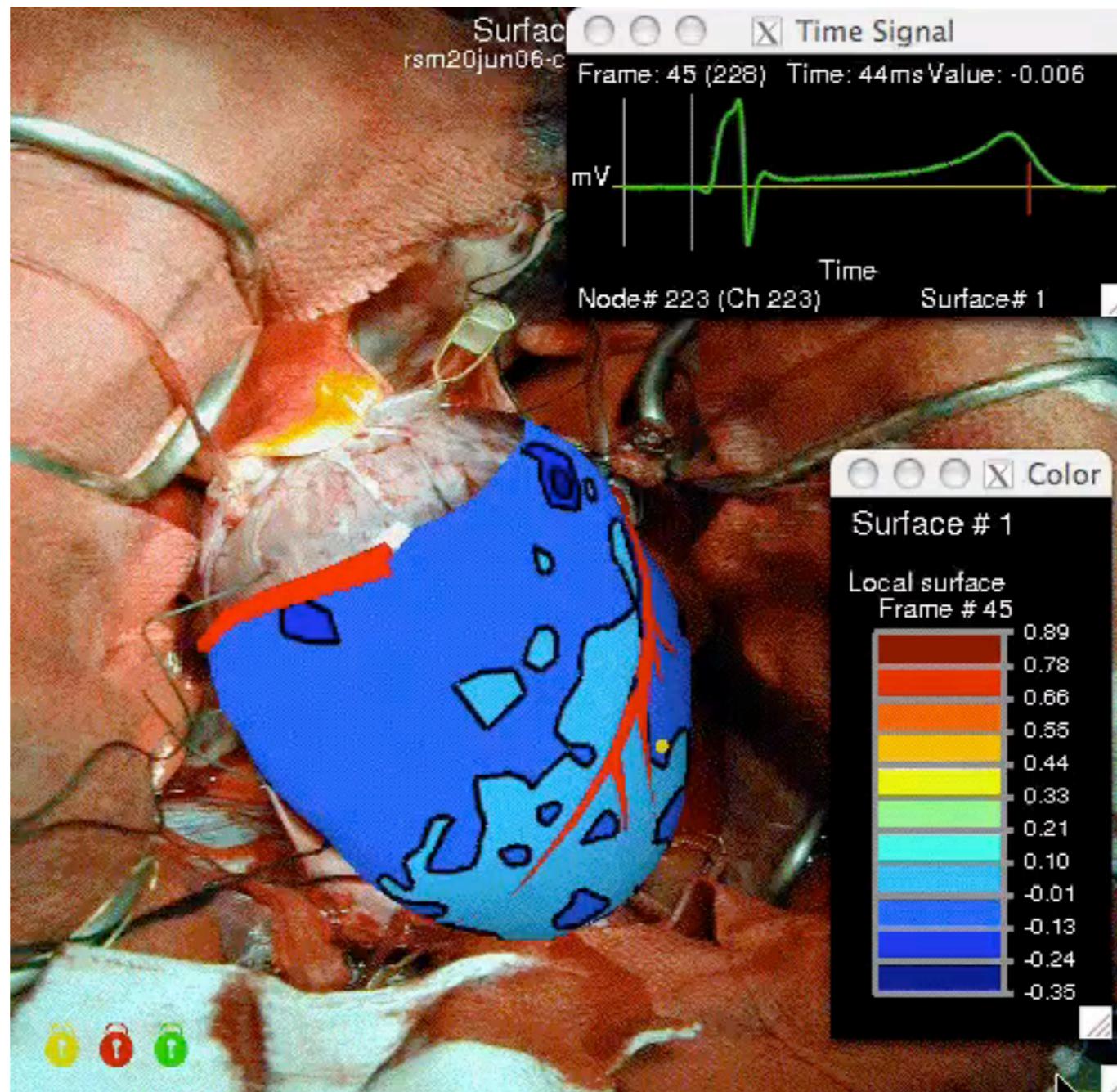
Sources



Vector
 Φ_h

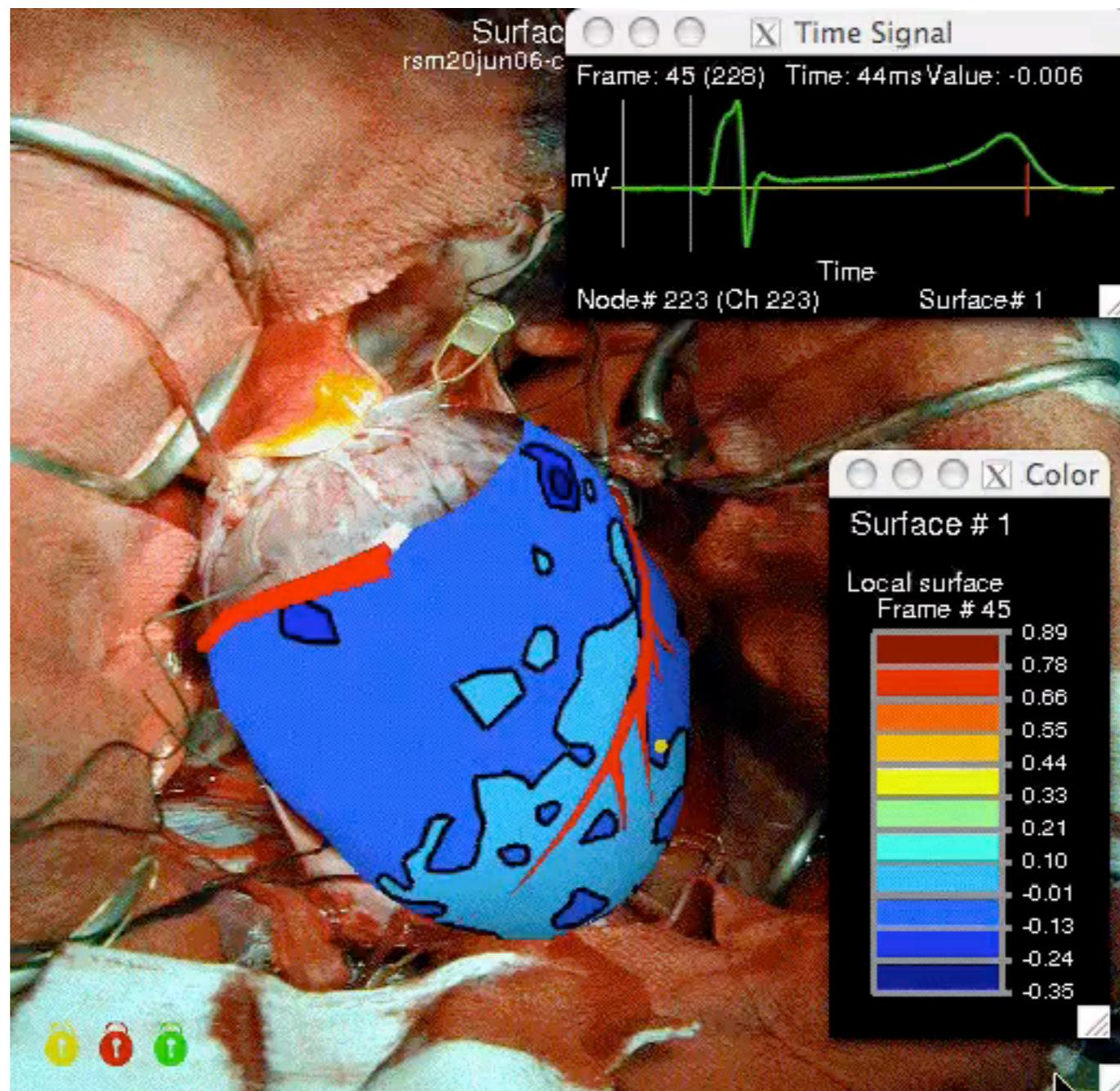
Geometry
Source Model
Noise
Sampling

Source Recording



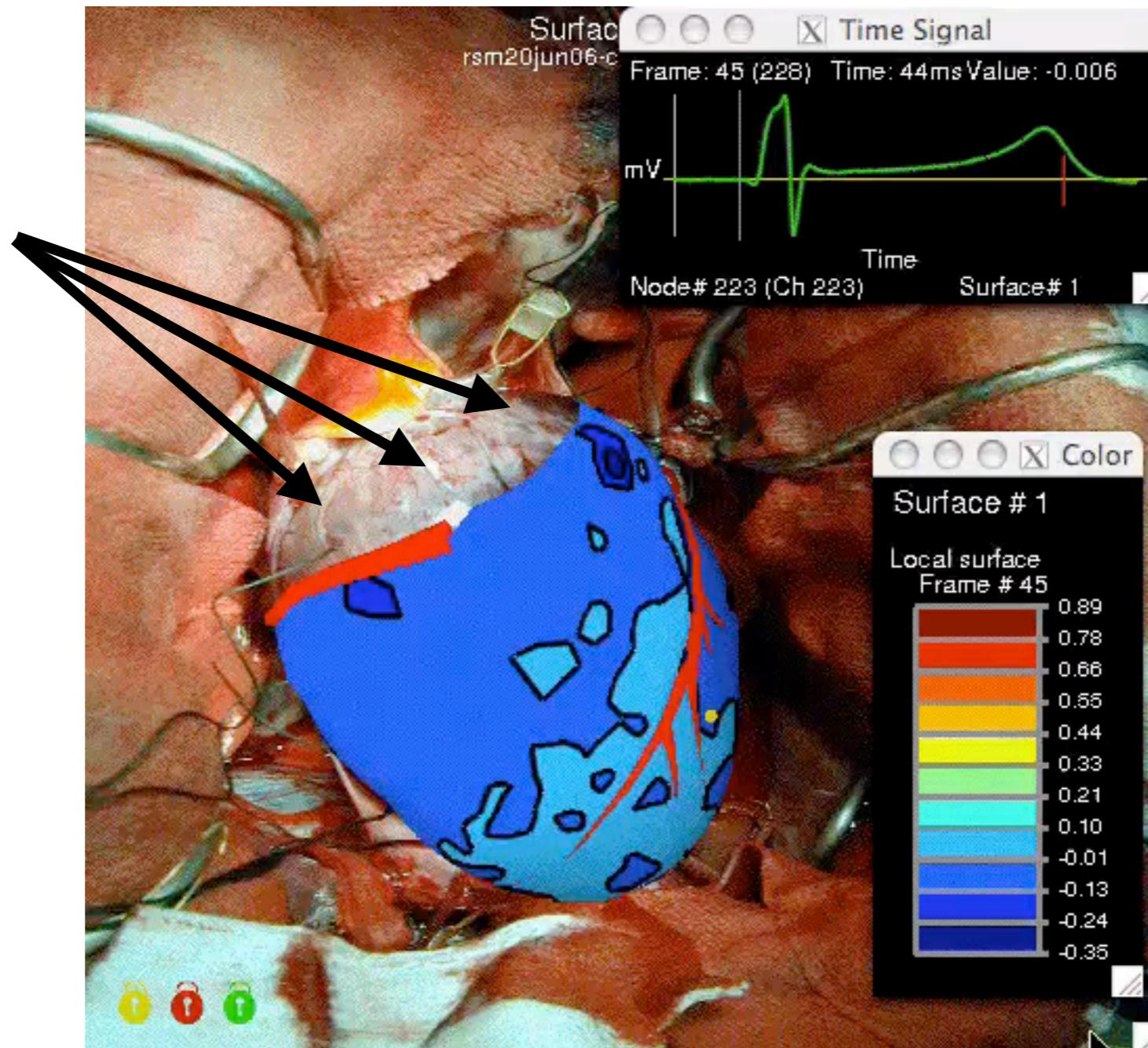
Epicardial Sock

Source Recording



Epicardial Sock
(Ventricle Only)

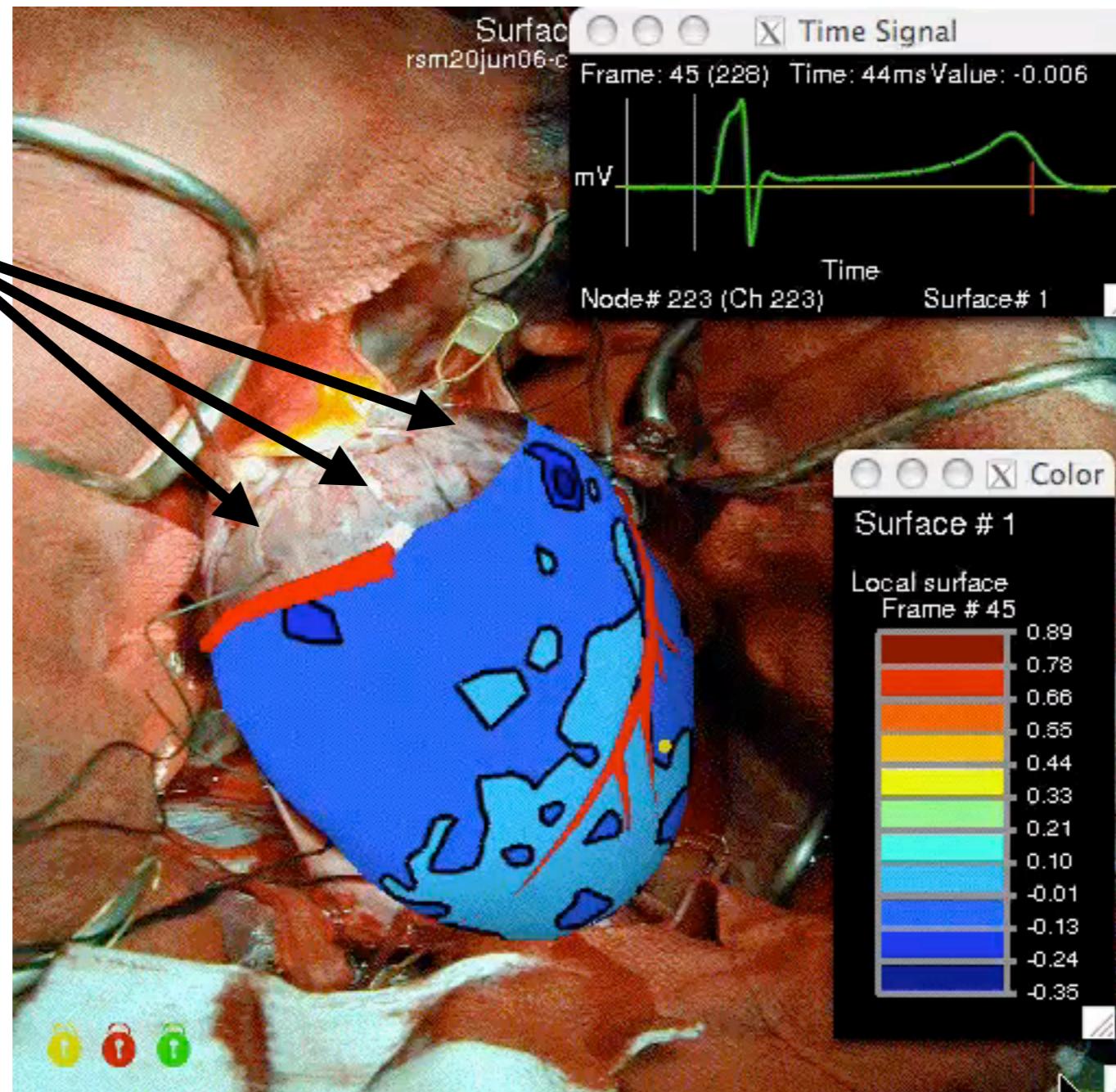
Source Recording



Epicardial Sock
(Ventricle Only)

Source Recording

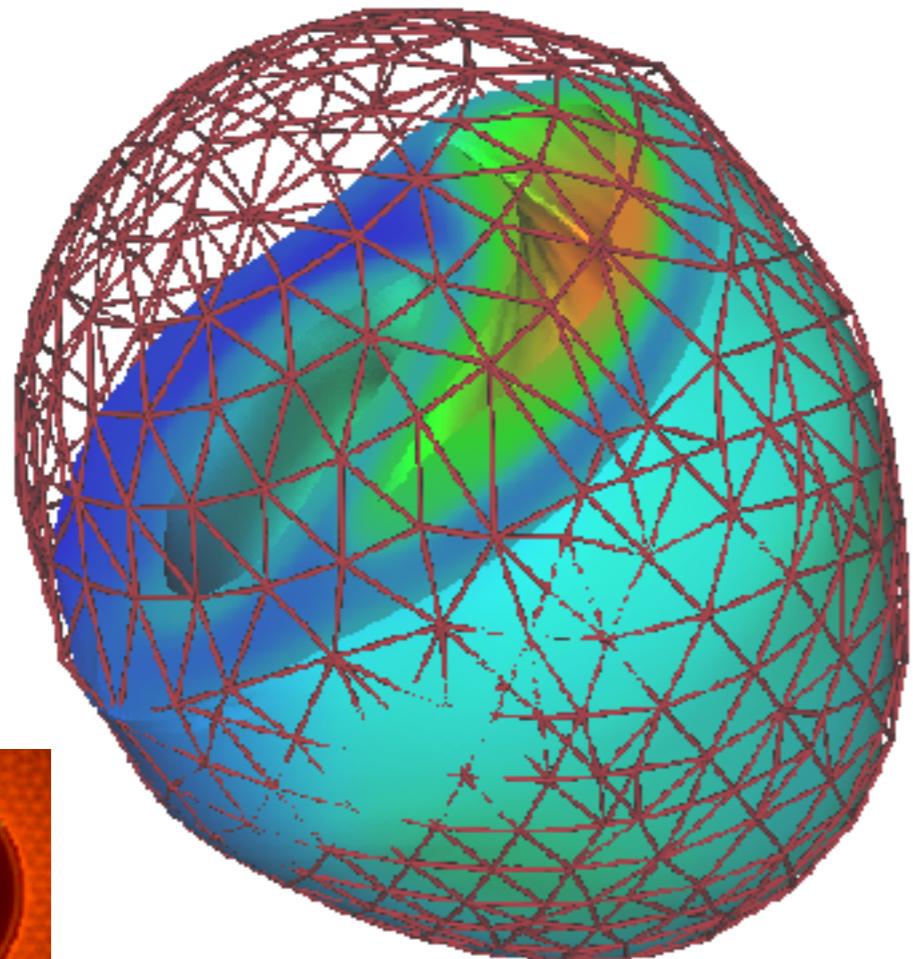
Missing
Sources?



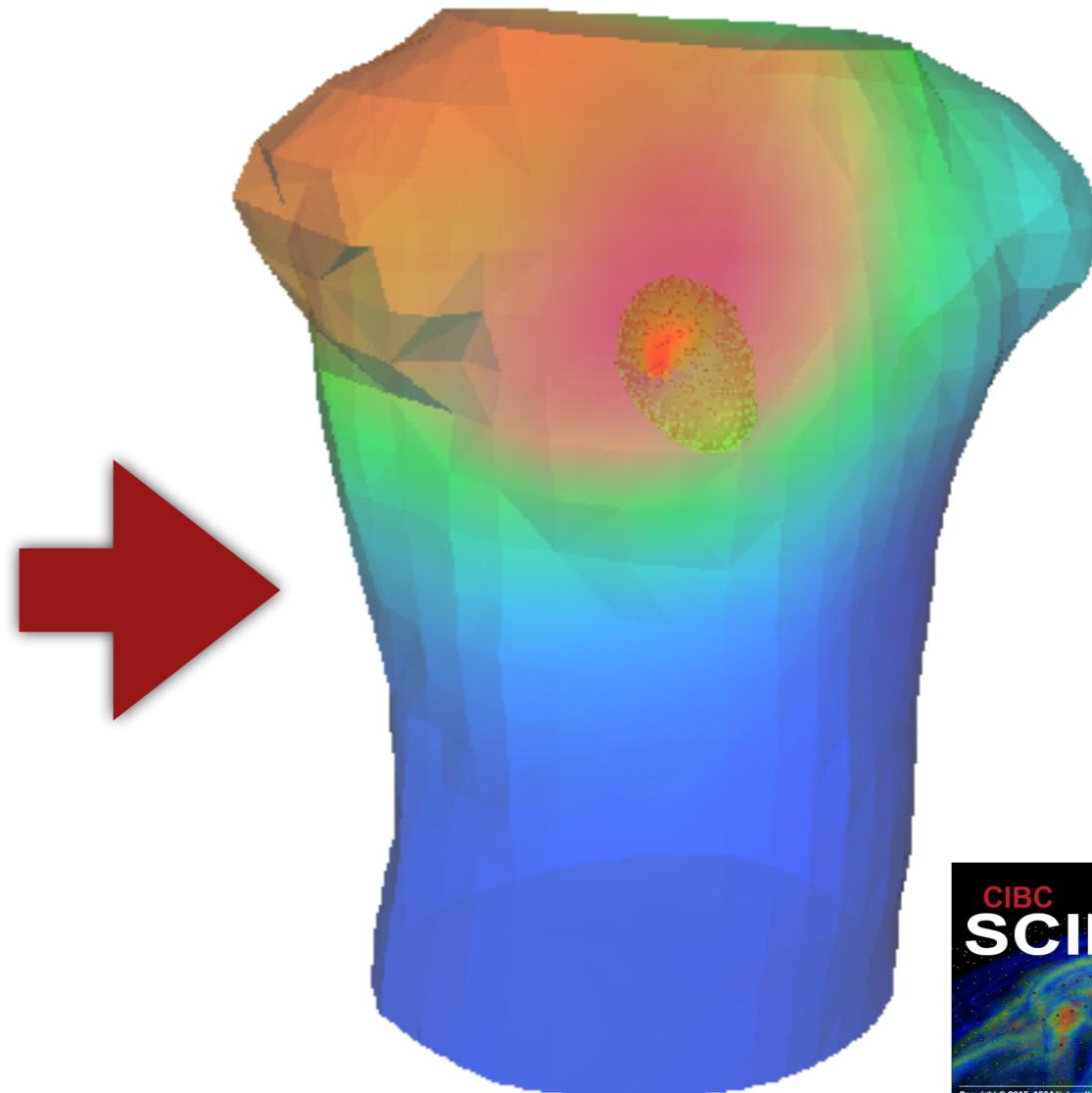
Epicardial Sock
(Ventricle Only)

Test sampling strategies of the atrial region to reduce error in forward simulation

Established Ground Truth



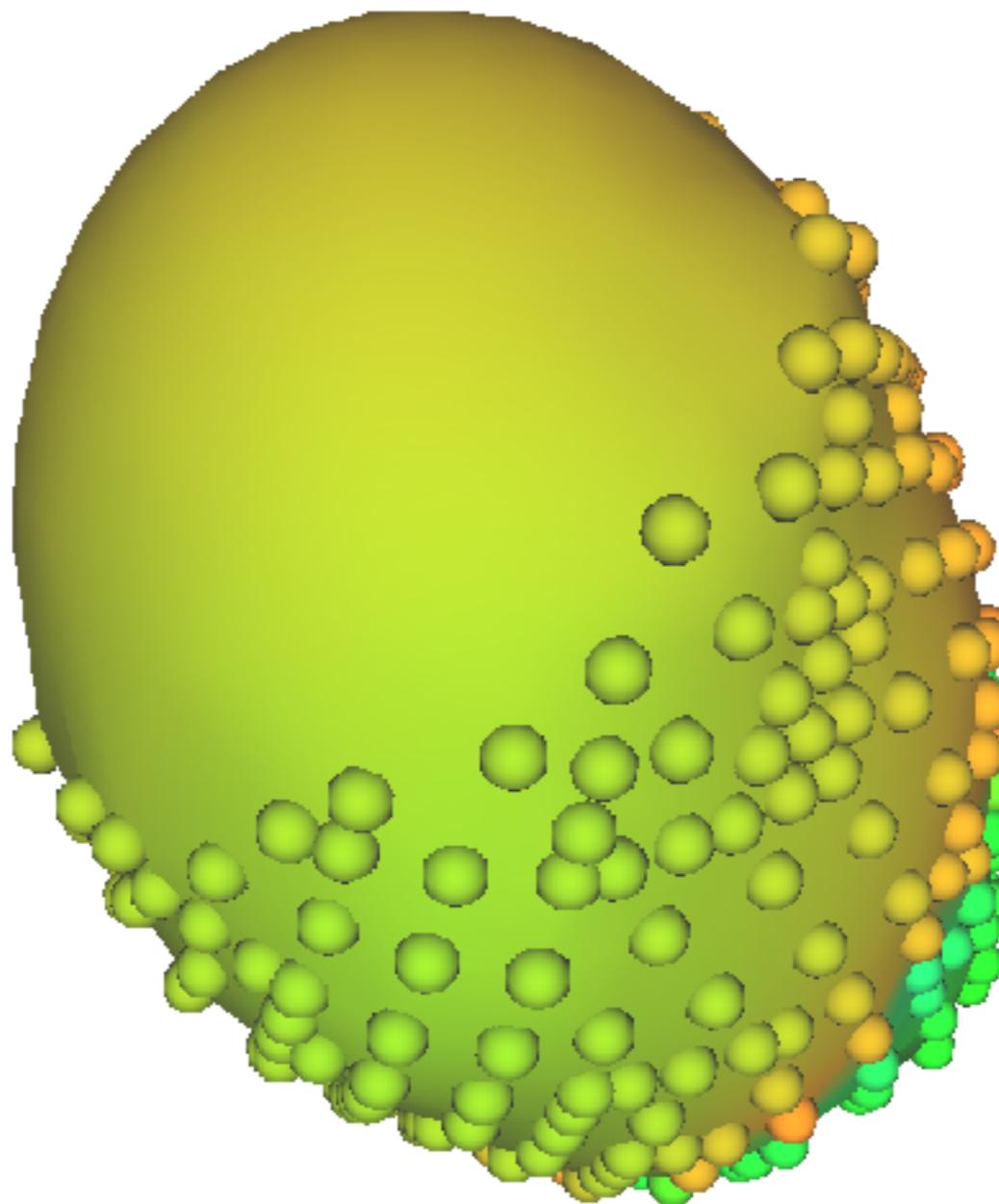
4 Simulated
Activation
Patterns



FEM Derived
Potentials

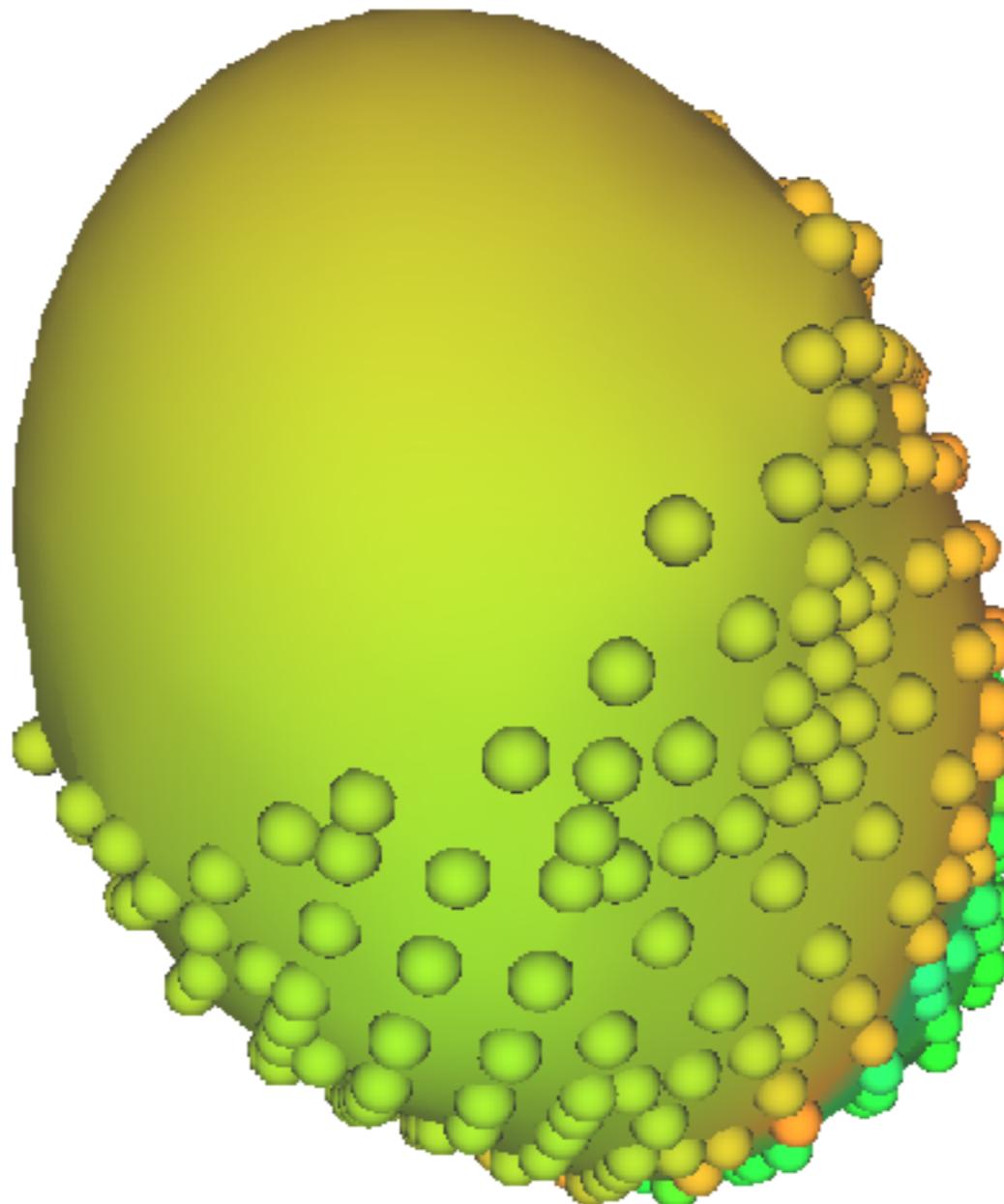


Varied Sampling



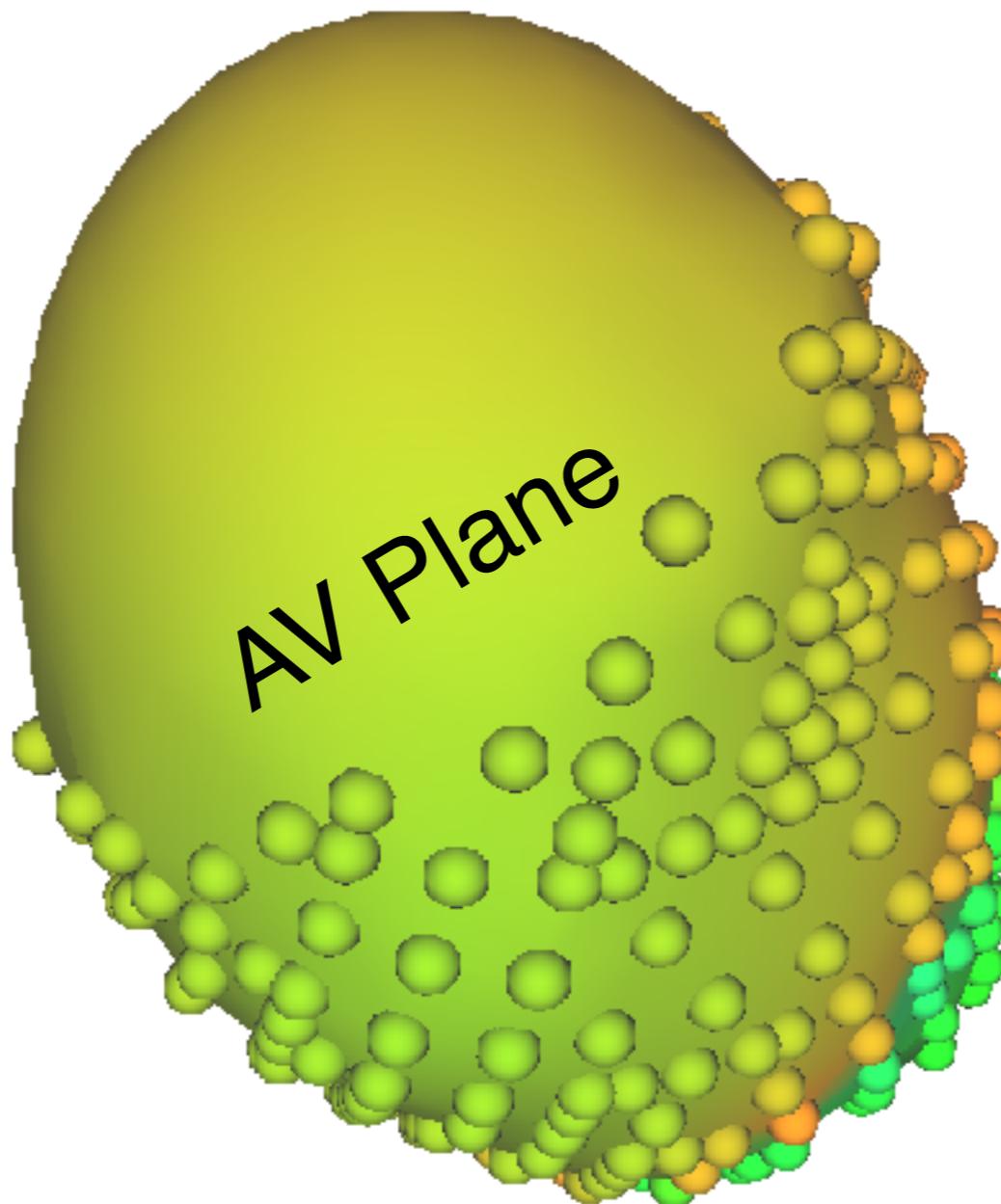
Varied Sampling

Atrial Roof

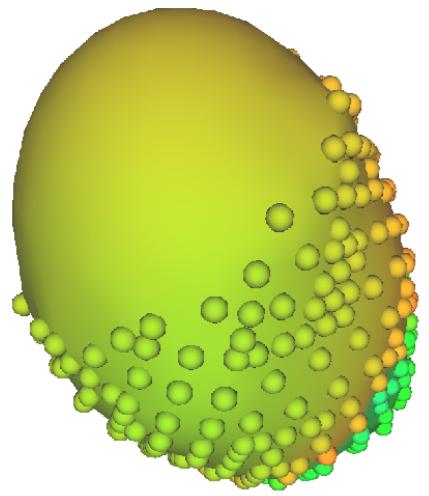


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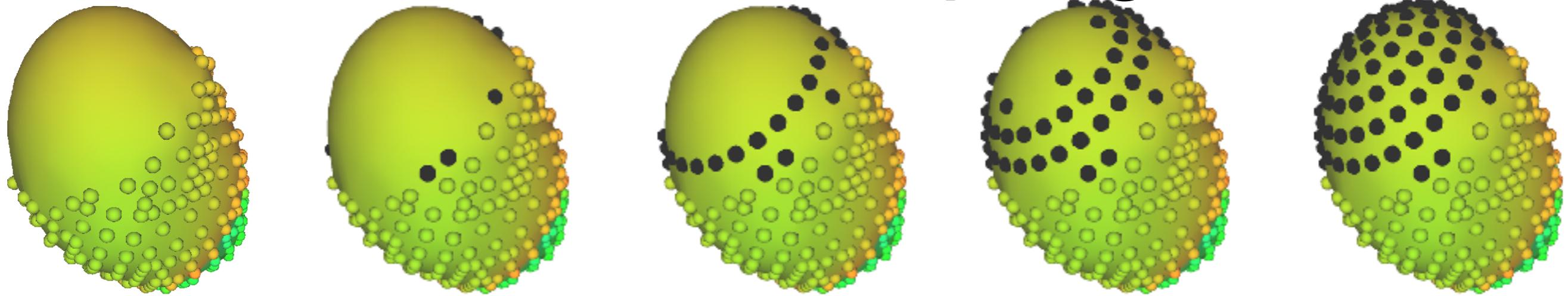
Atrial Roof



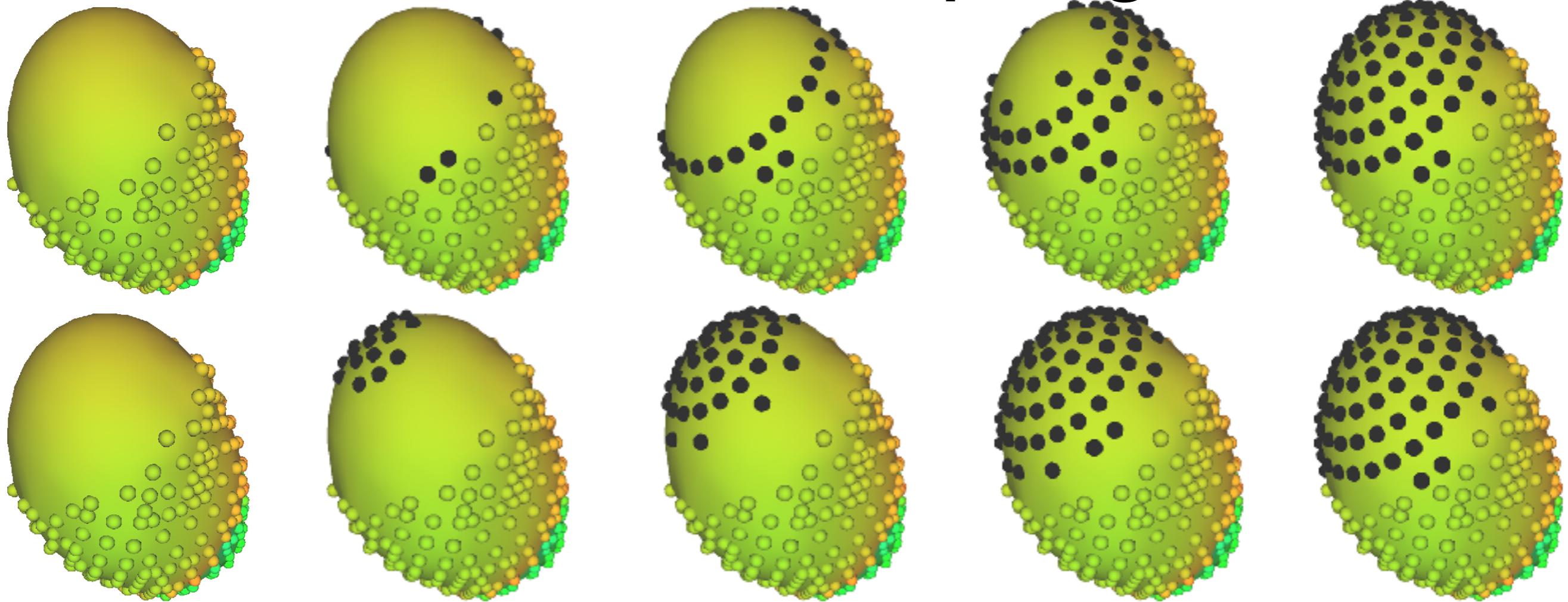
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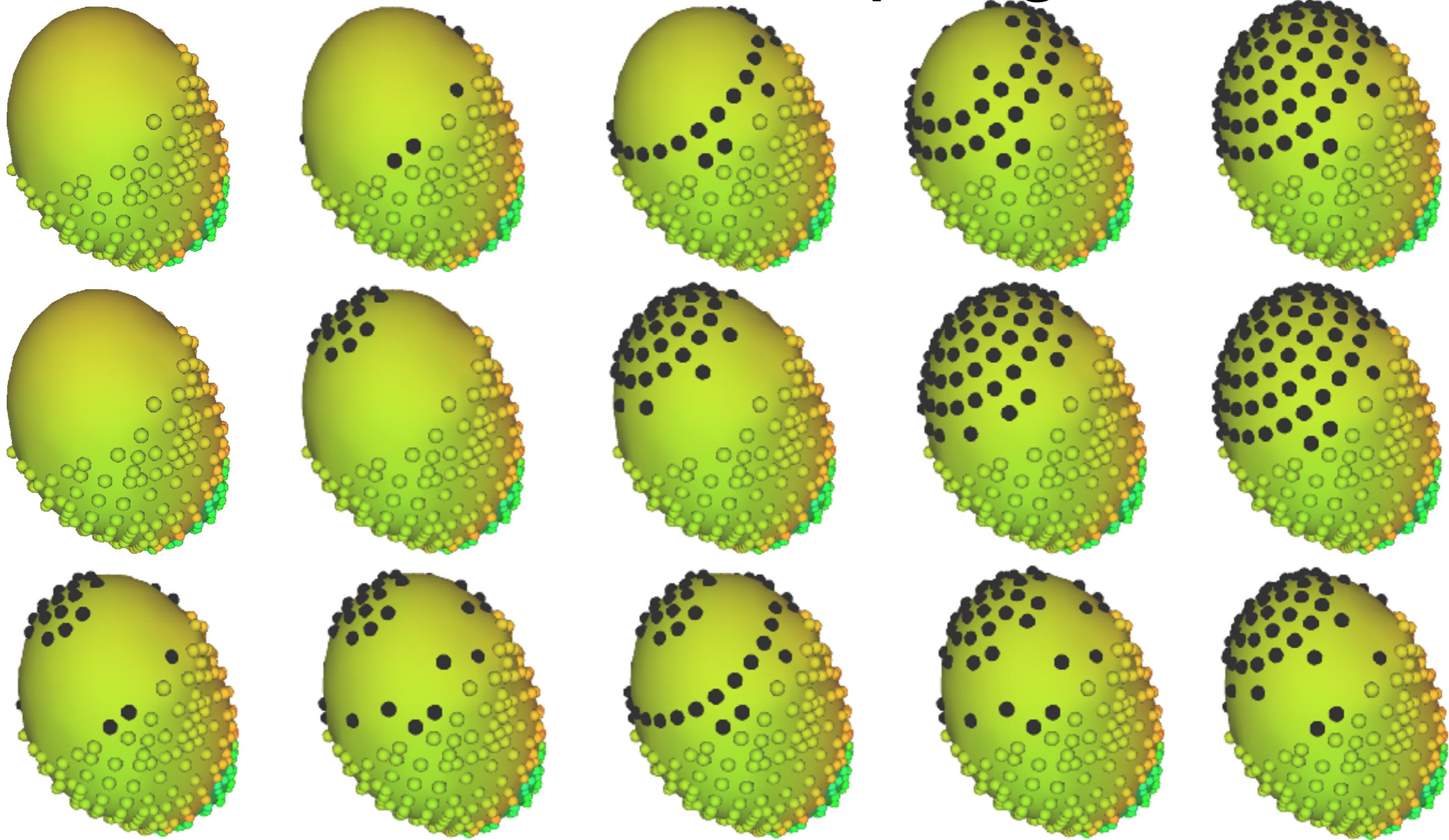
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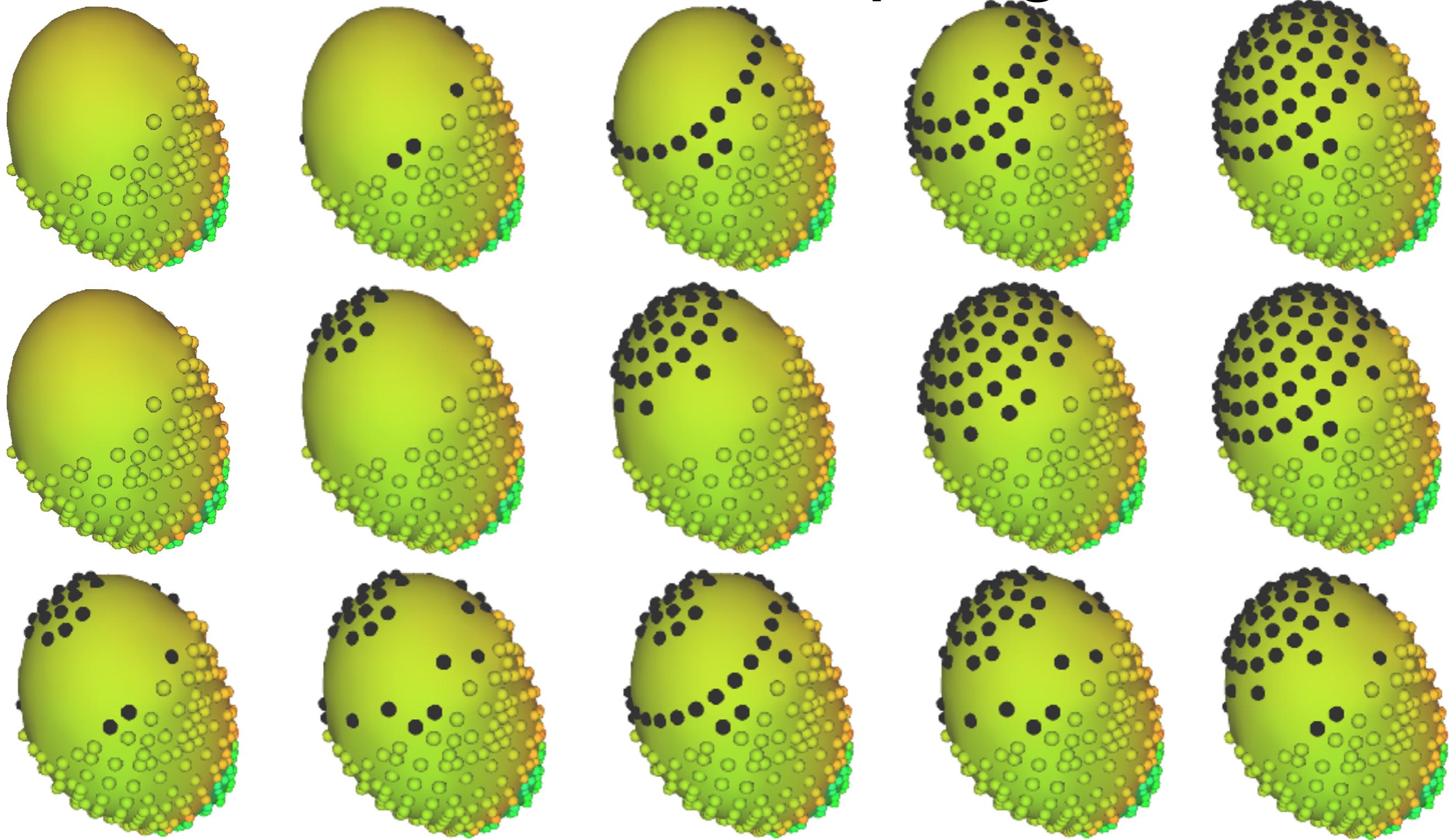
Varied Sampling



Varied Sampling

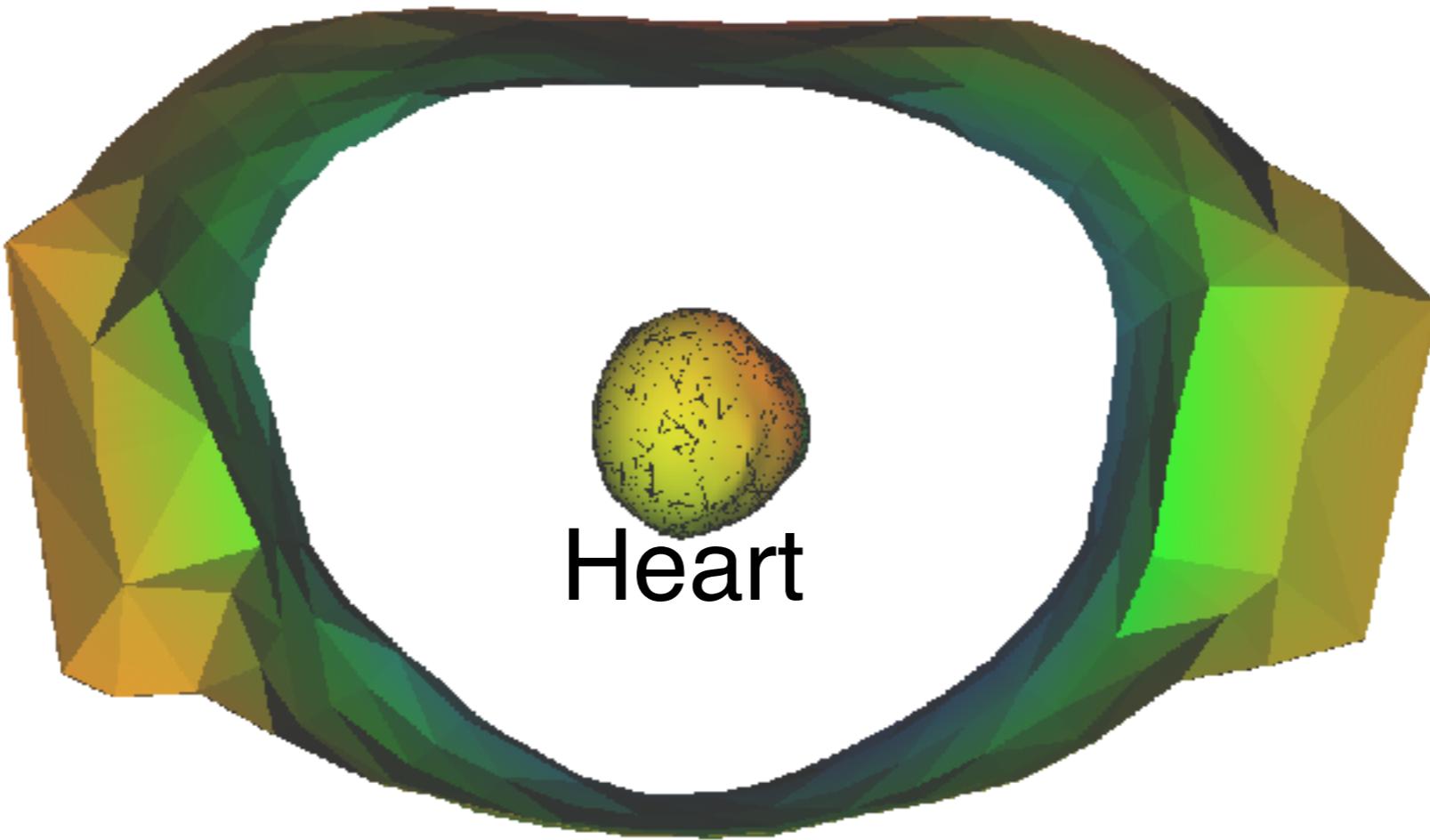


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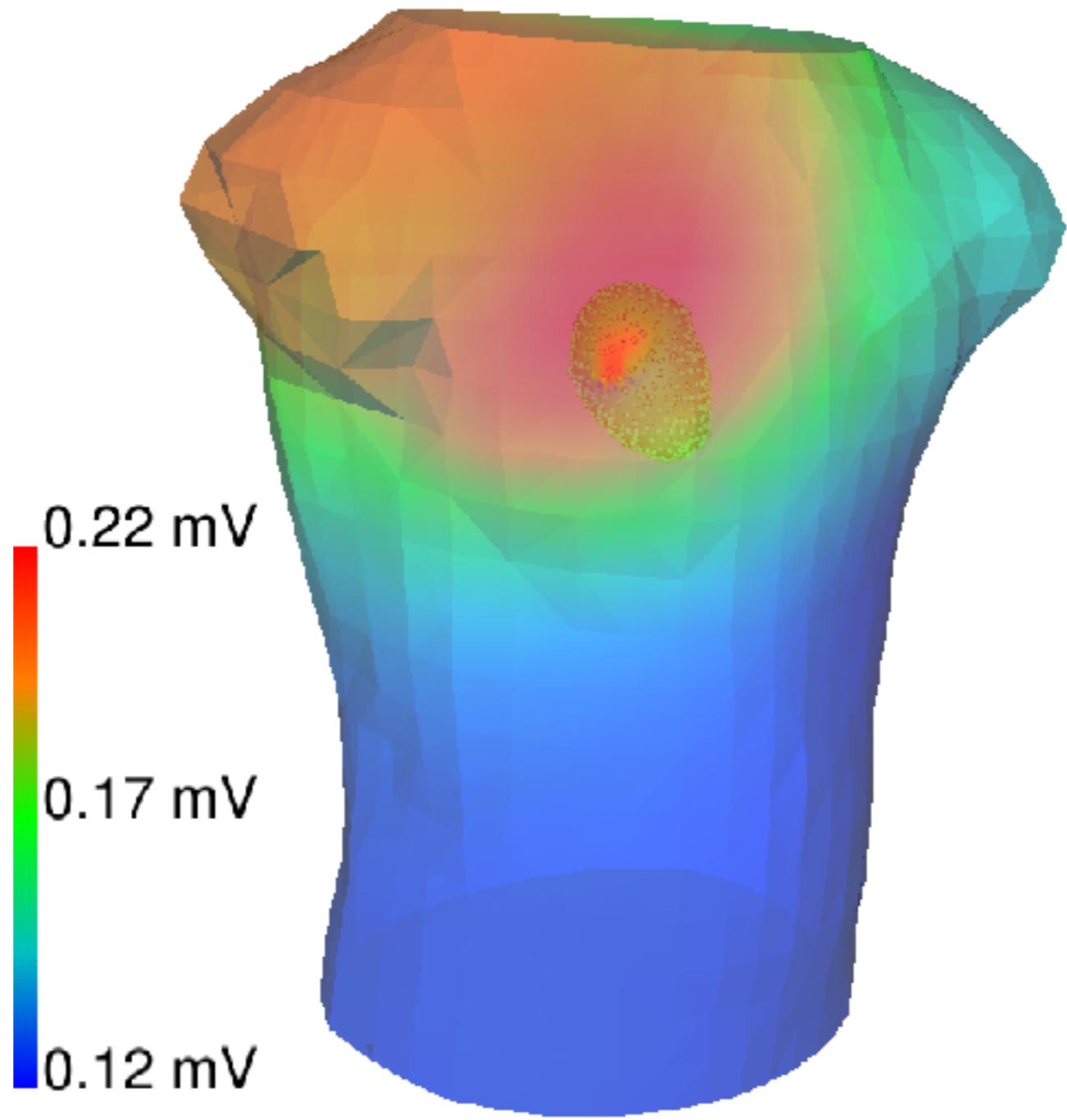
Laplacian Interpolation

Forward Simulation with BEM



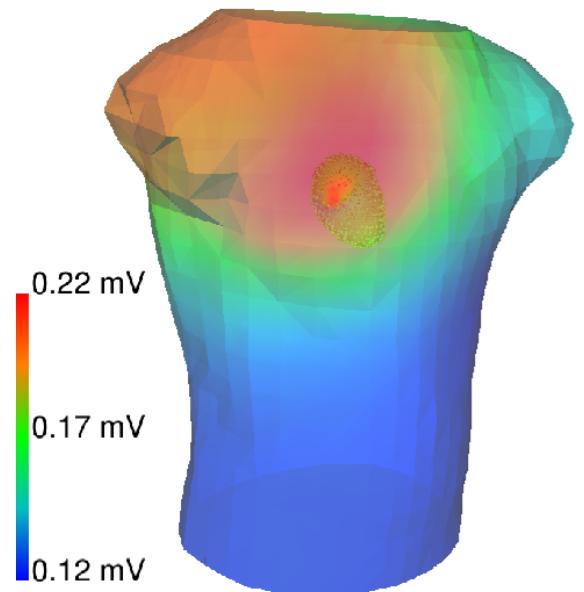
Torso

Predicted solution

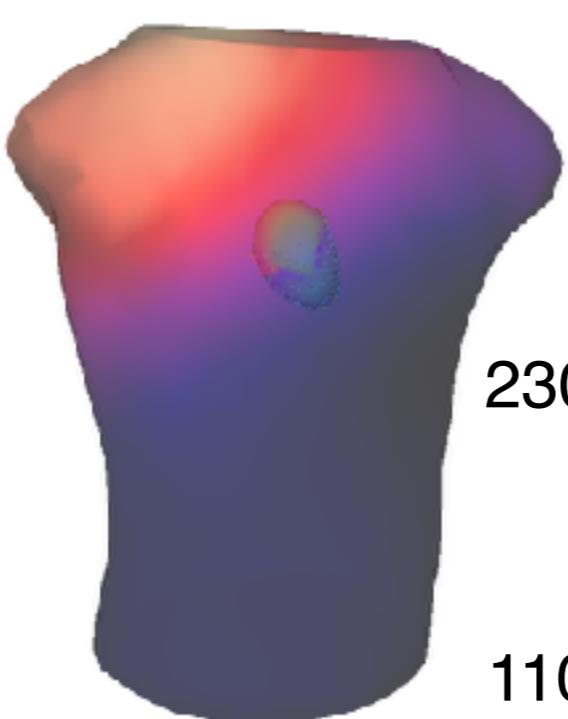


Ground Truth

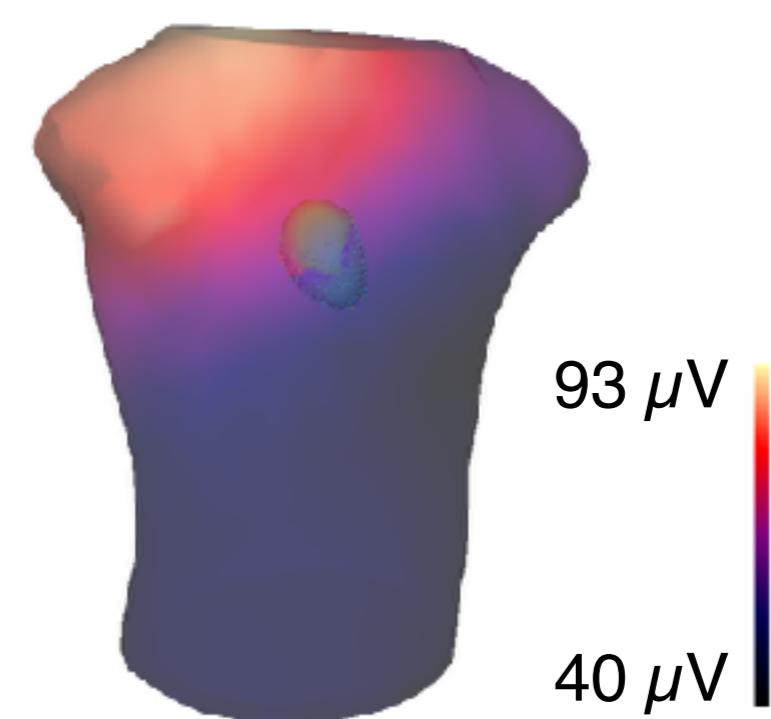
Difference in Prediction



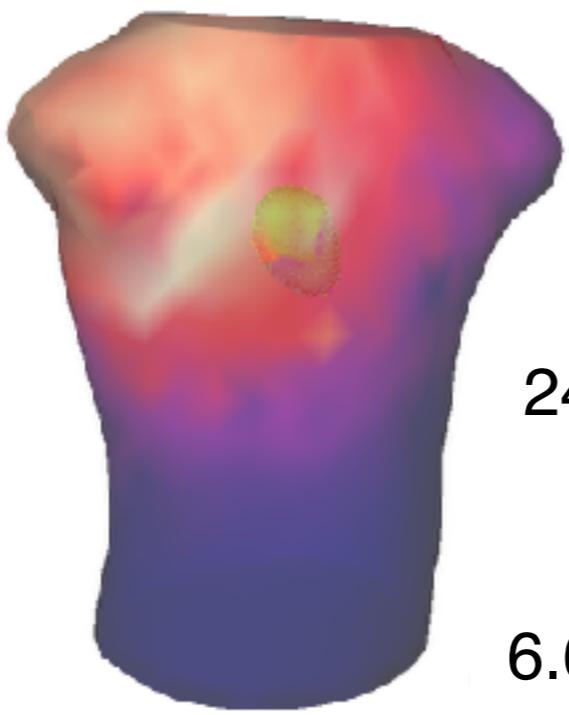
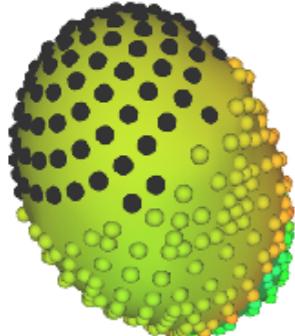
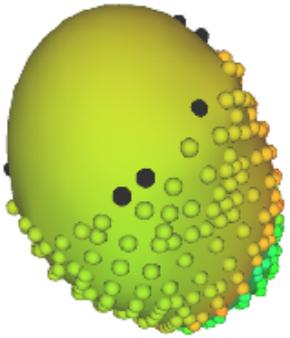
Ground
Truth



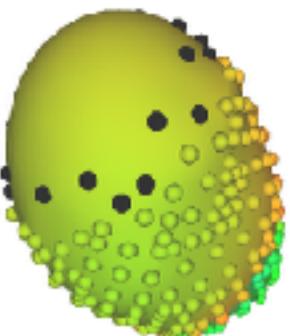
Ventricular Only



15 More Electrodes

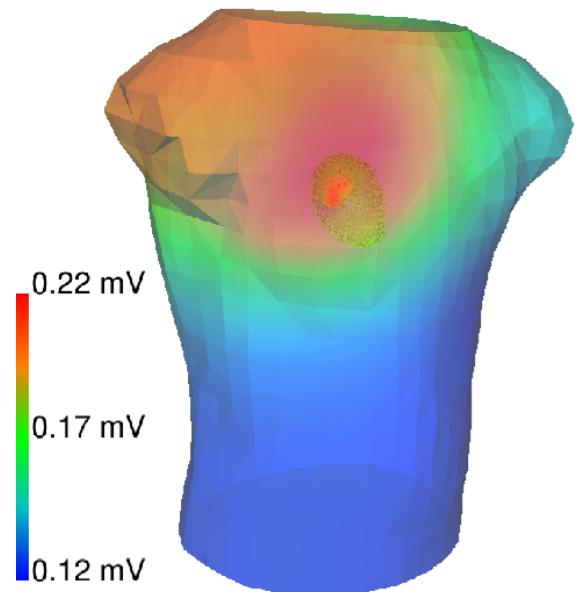


Full Sock

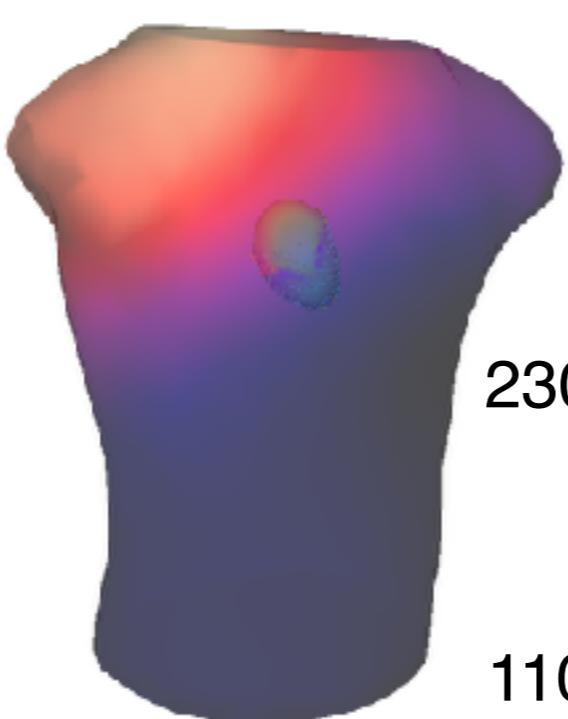


30 More Electrodes

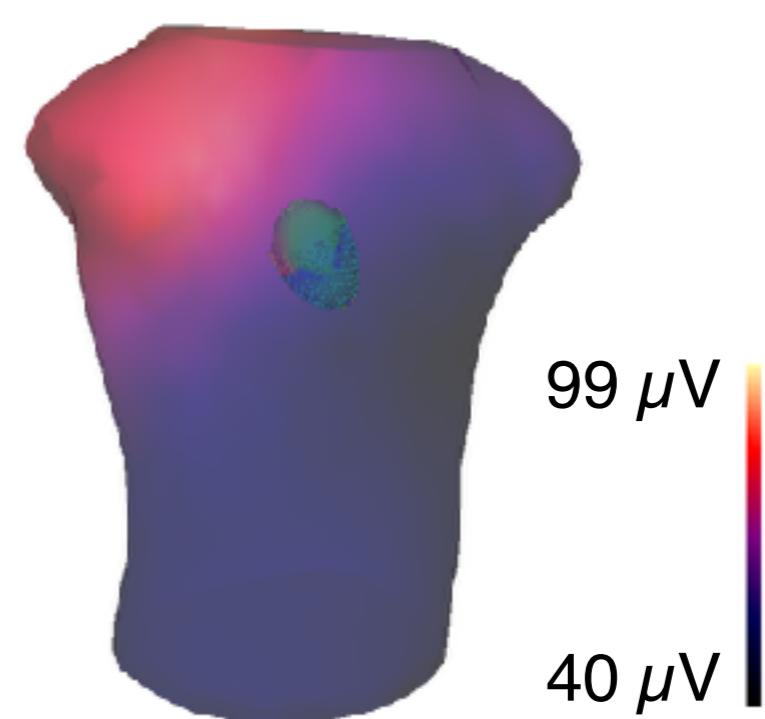
Difference in Prediction



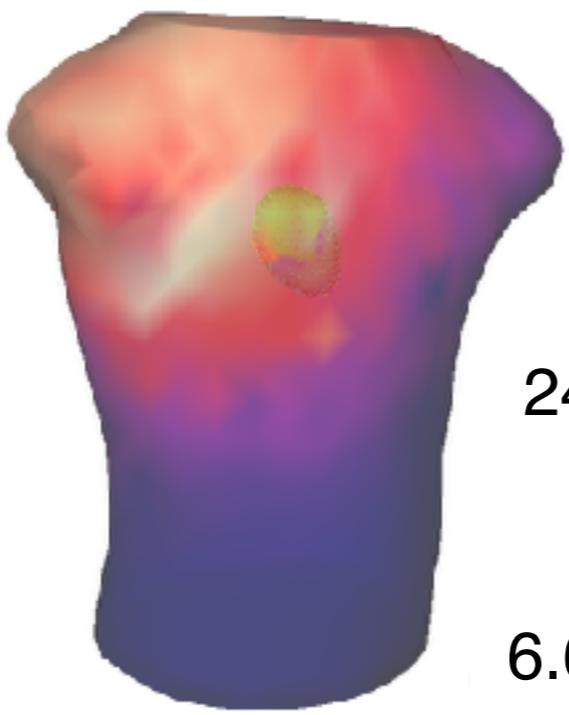
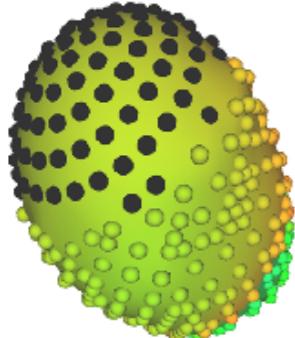
Ground
Truth



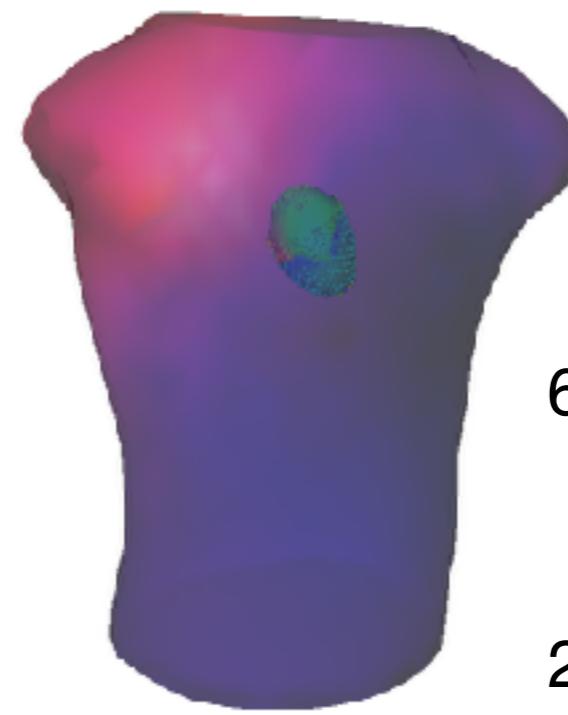
Ventricular Only



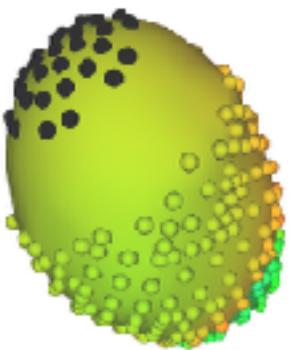
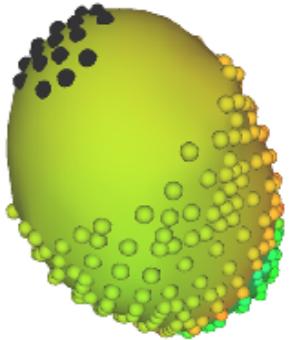
16 More Electrodes



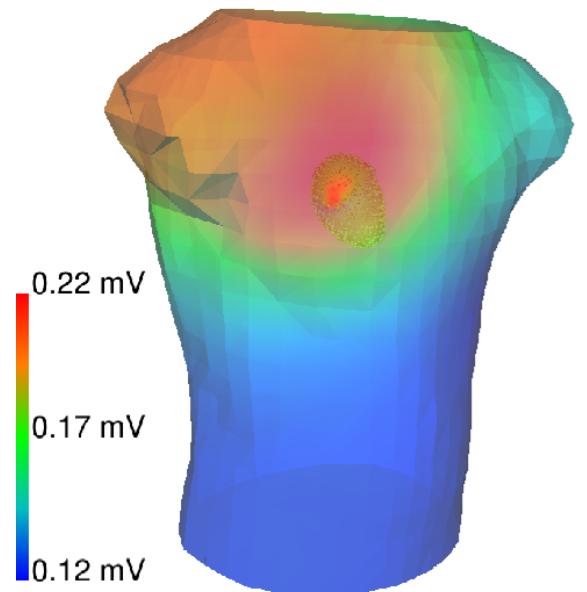
Full Sock



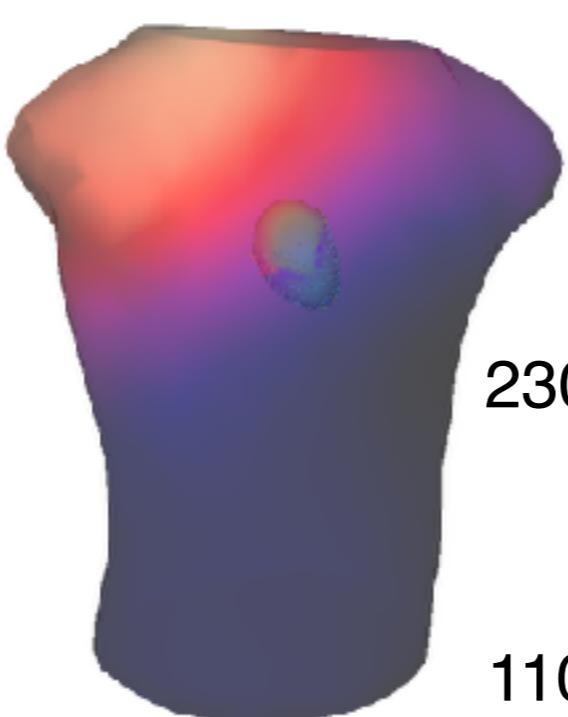
31 More Electrodes



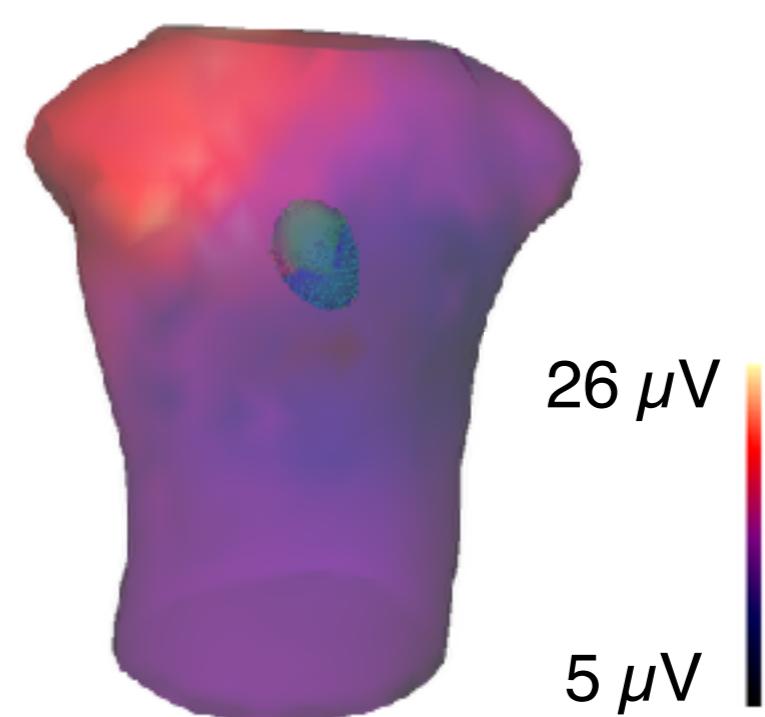
Difference in Prediction



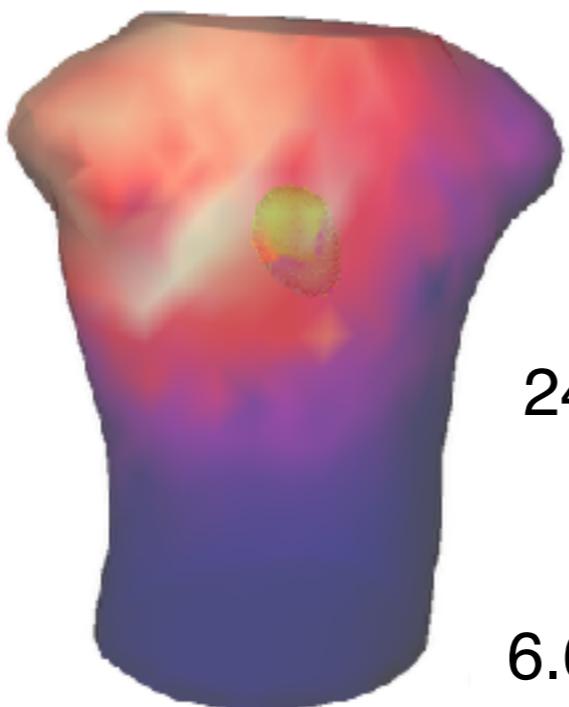
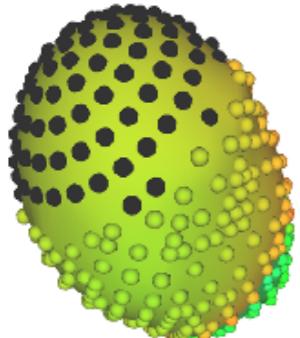
Ground
Truth



Ventricular Only



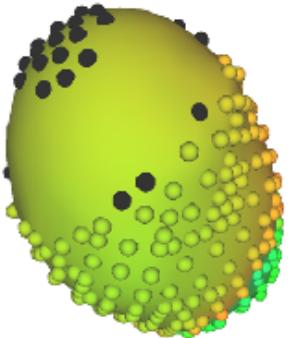
31 More Electrodes



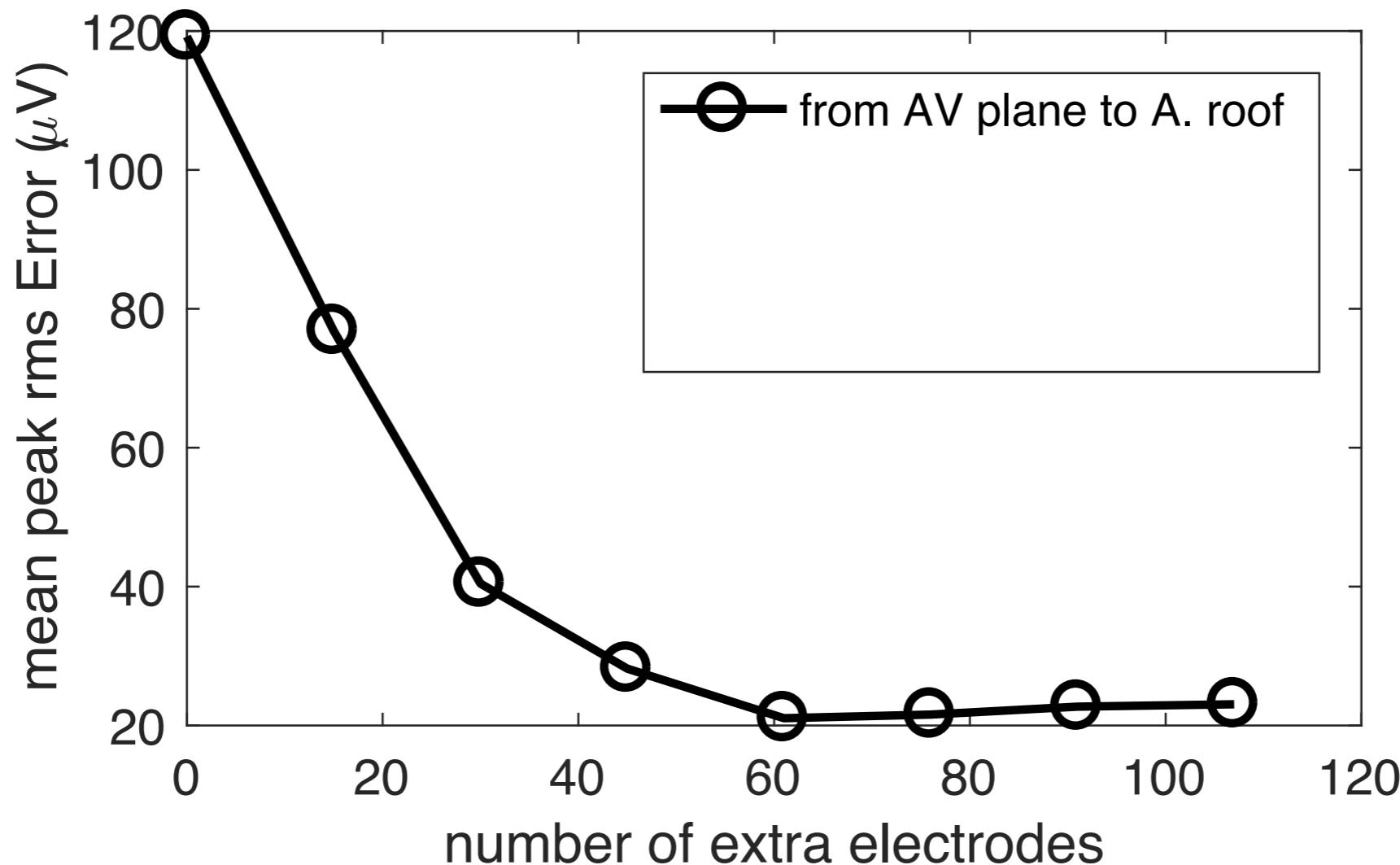
Full Sock



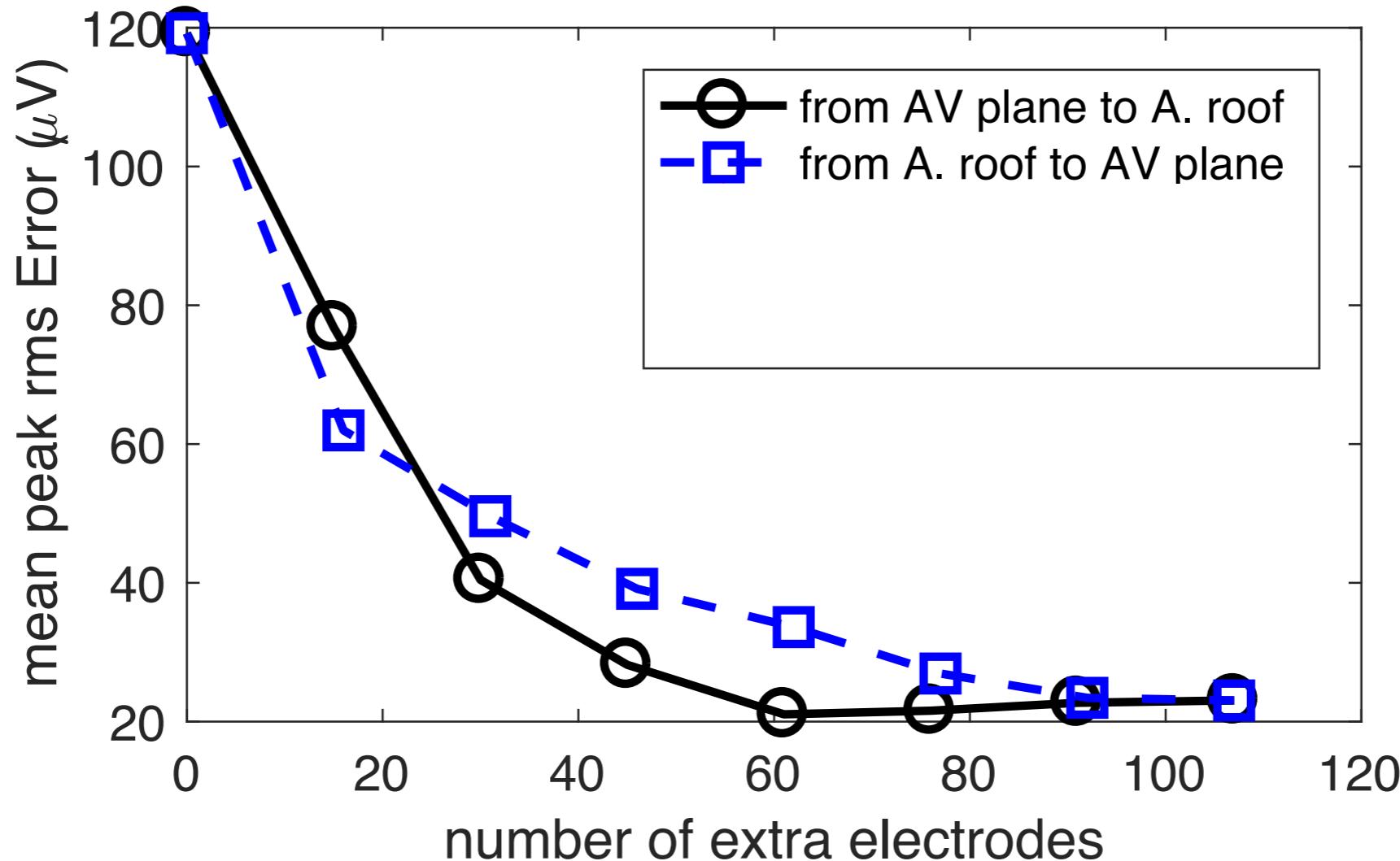
46 More Electrodes



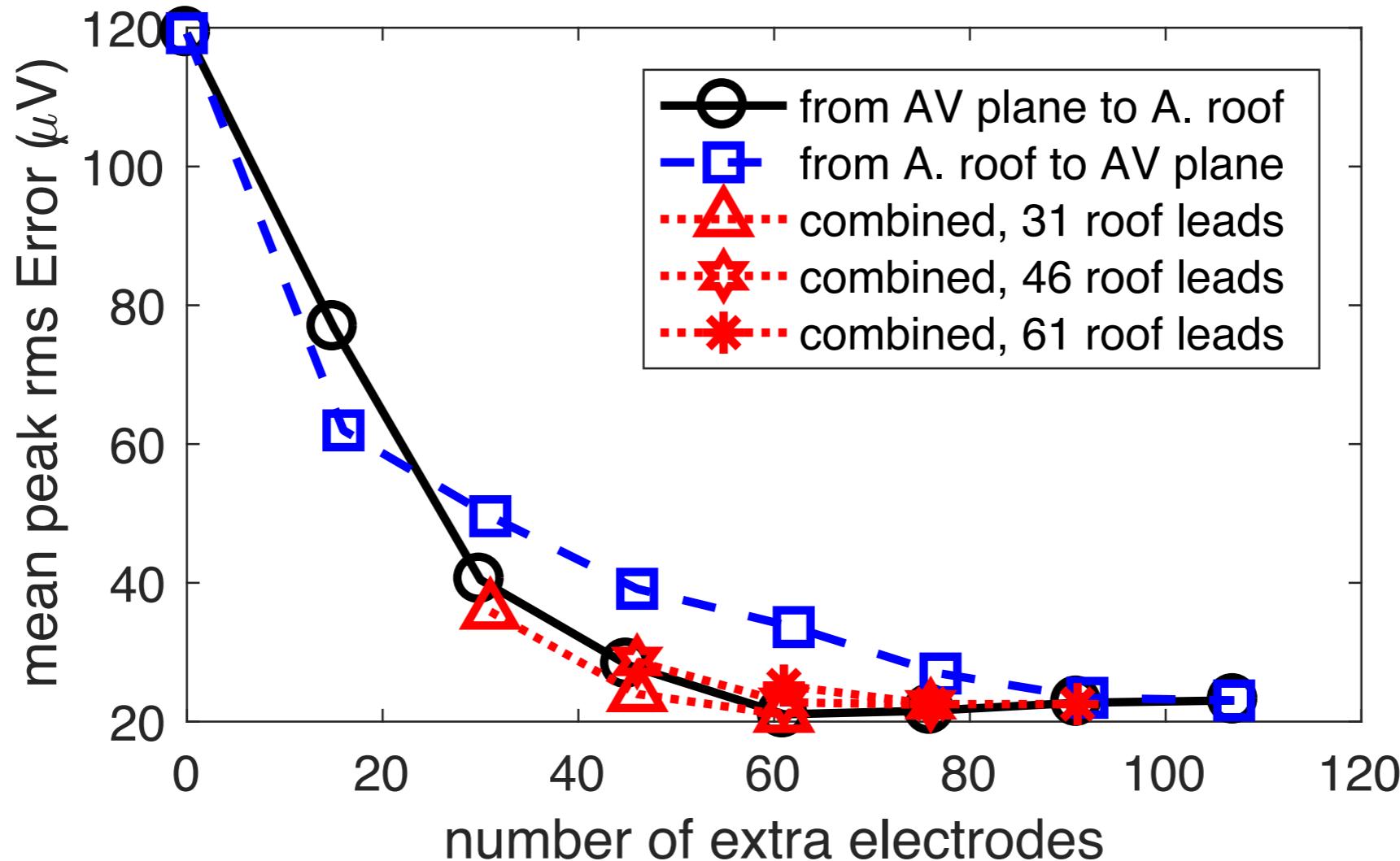
Comparing Sampling



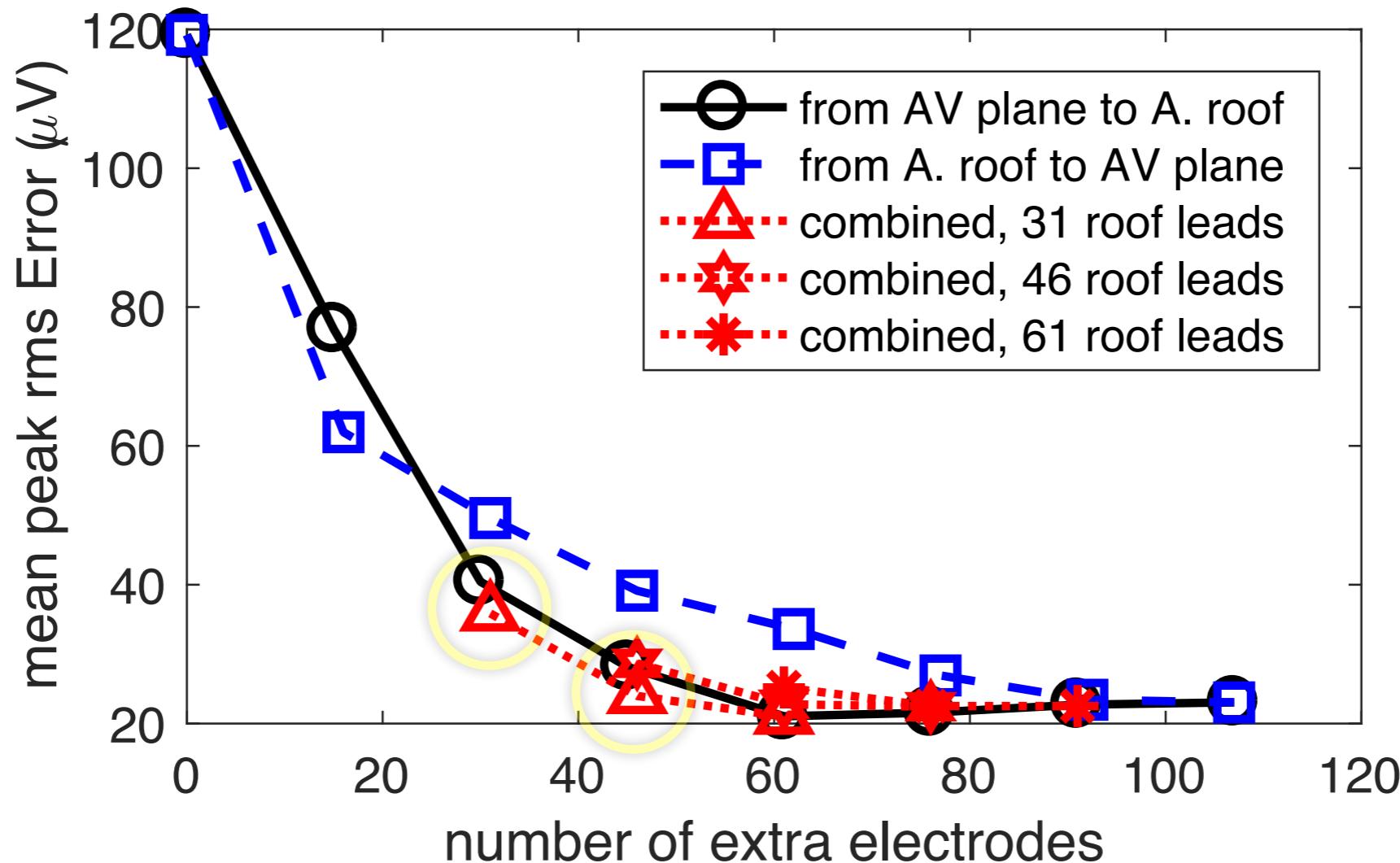
Comparing Sampling



Comparing Sampling



Comparing Sampling



Possible Sampling

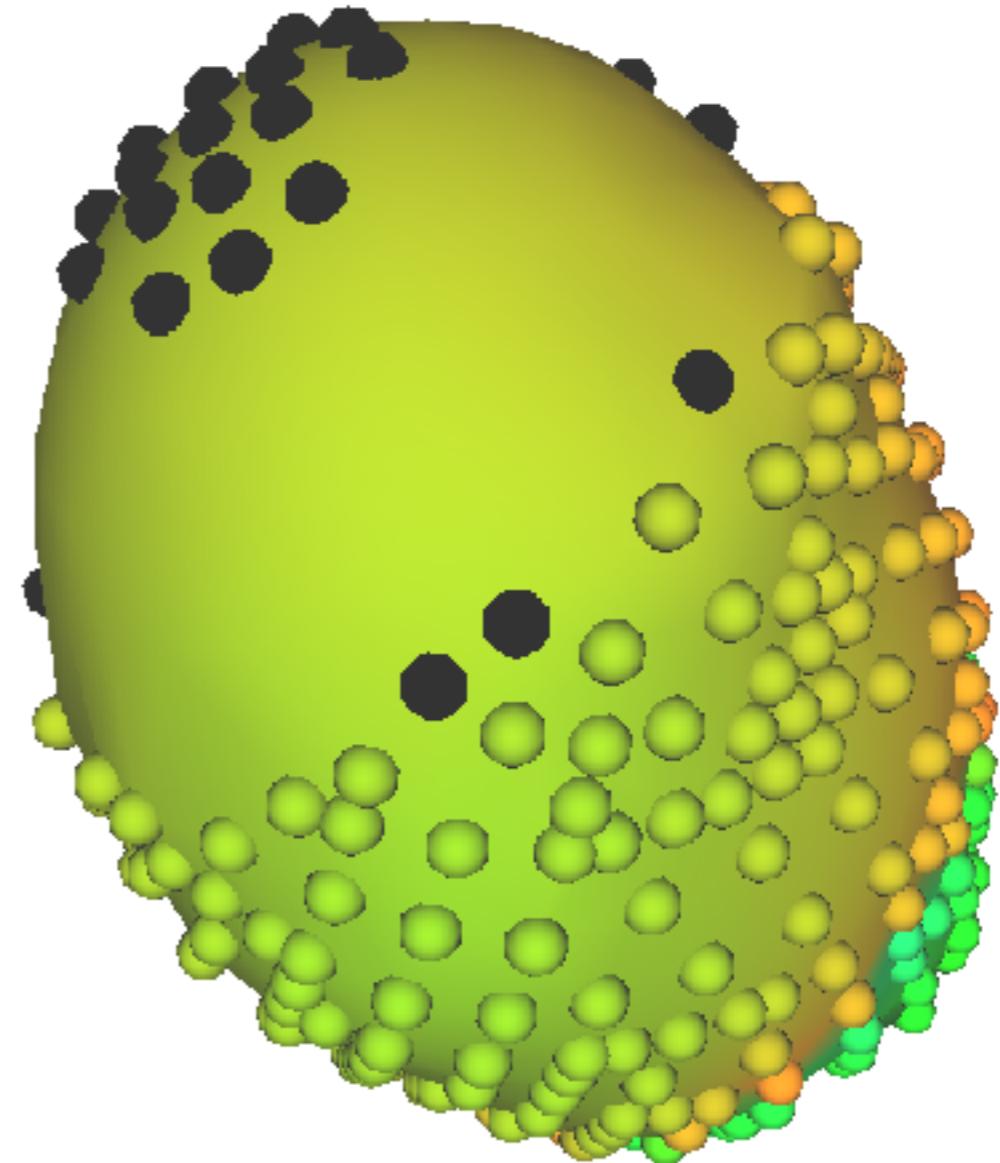
More electrodes
are better

Careful placement
can reduce error

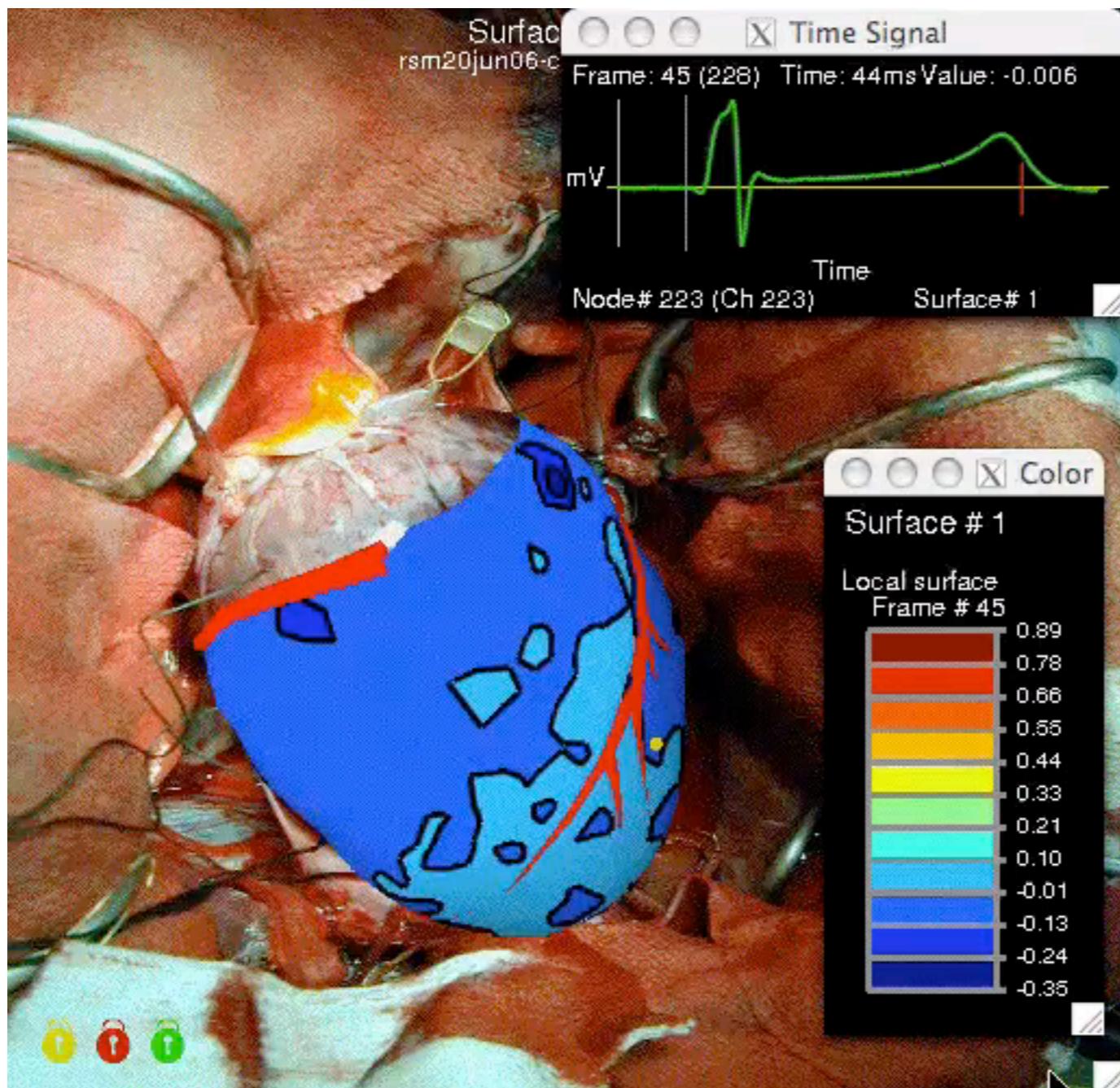
Possible Sampling

More electrodes
are better

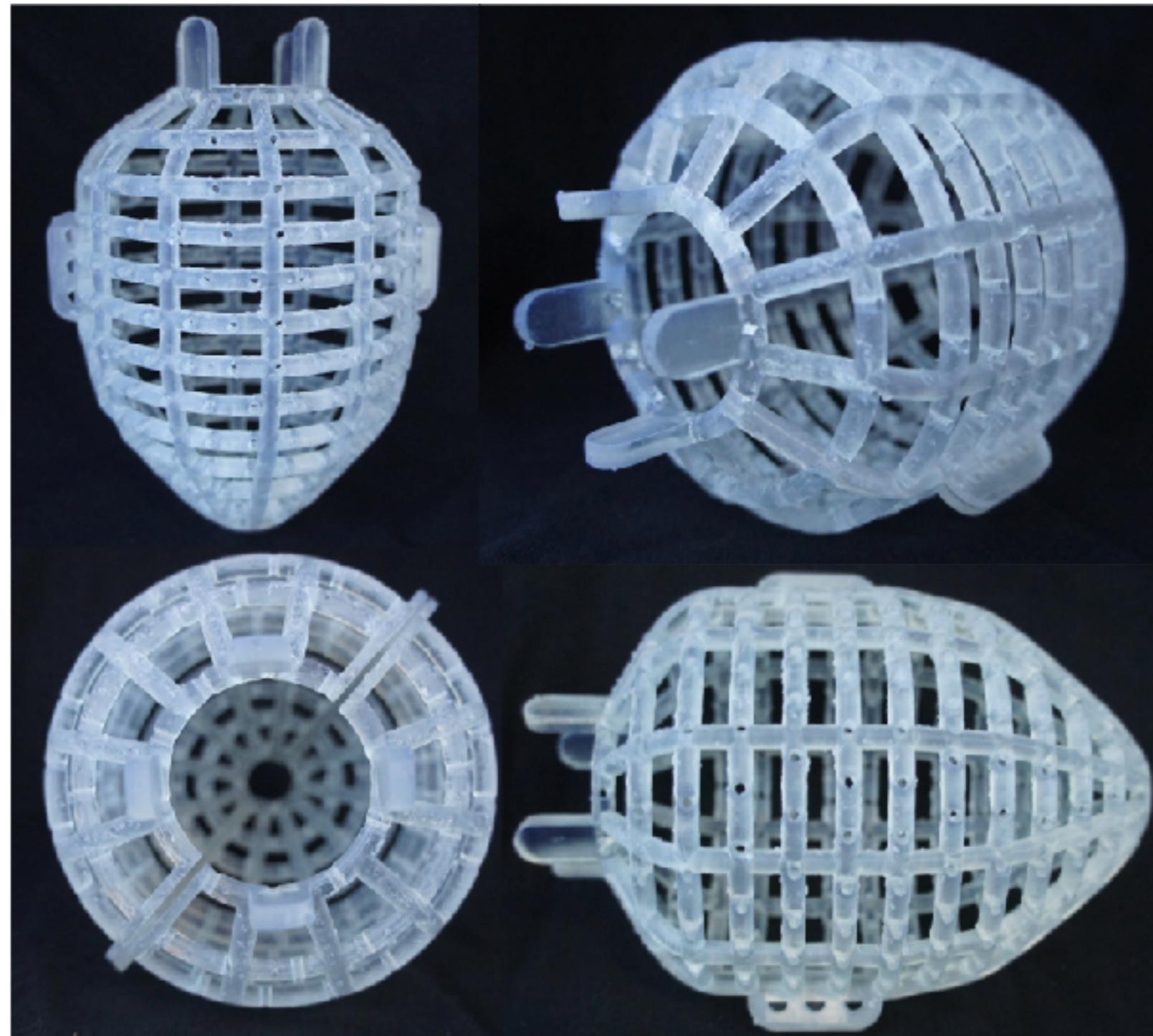
Careful placement
can reduce error



Experimental Strategy

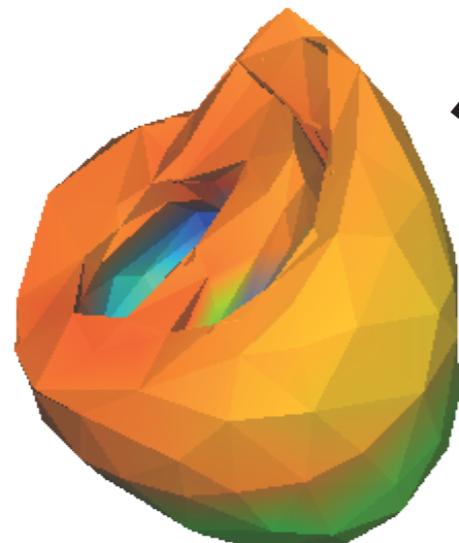


Experimental Strategy

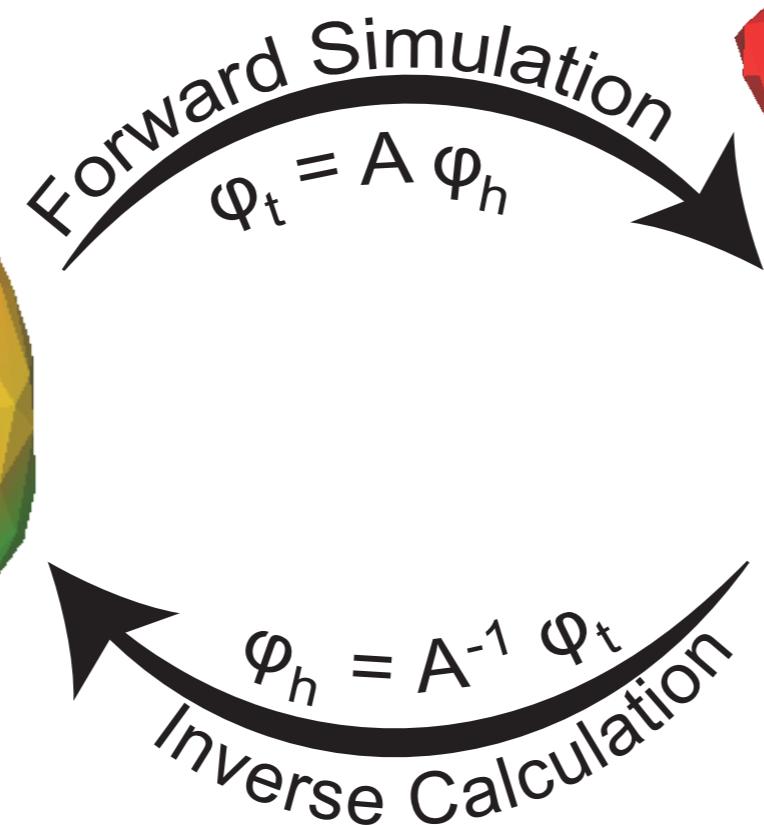
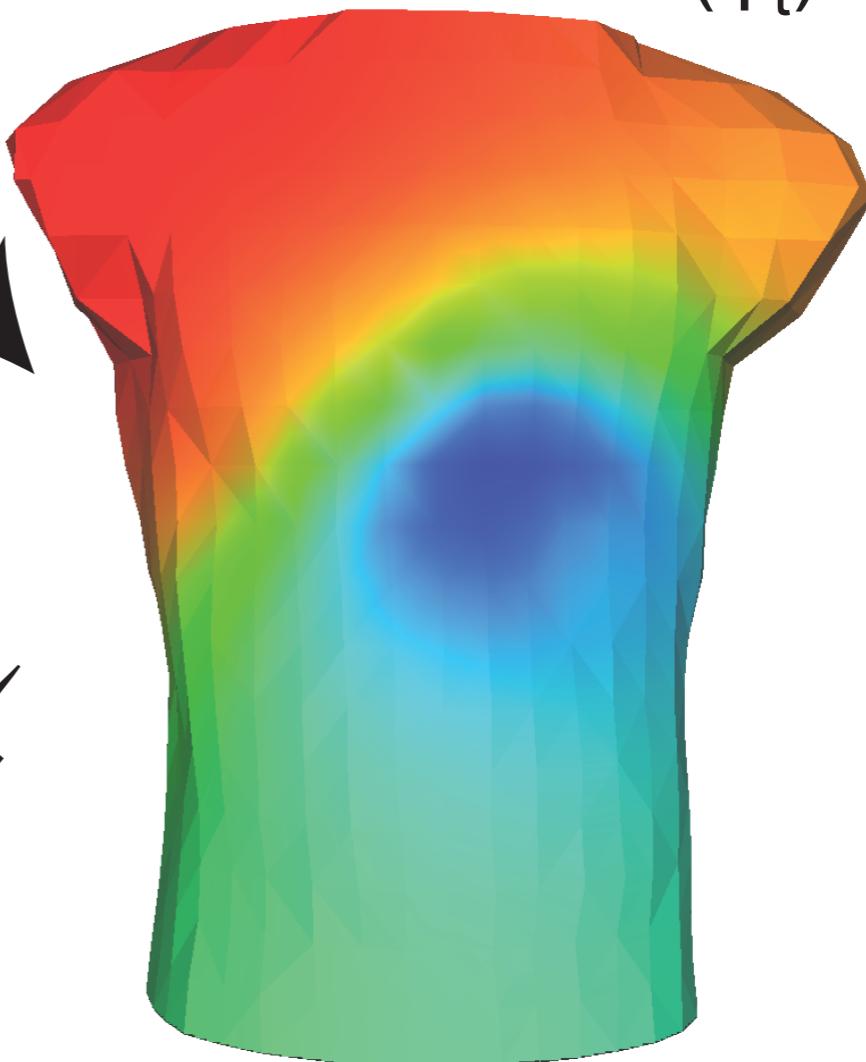


Improve ECGI

Heart Potentials (φ_h)



Torso Potentials (φ_t)



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

Center for Integrative Biomedical Computing

NIGMS NIH P41 GM103545-18

Cardiac Arrhythmia Research Package (CARP)

