

# A Sampling Strategy for Reducing Error in ECG Forward Simulation

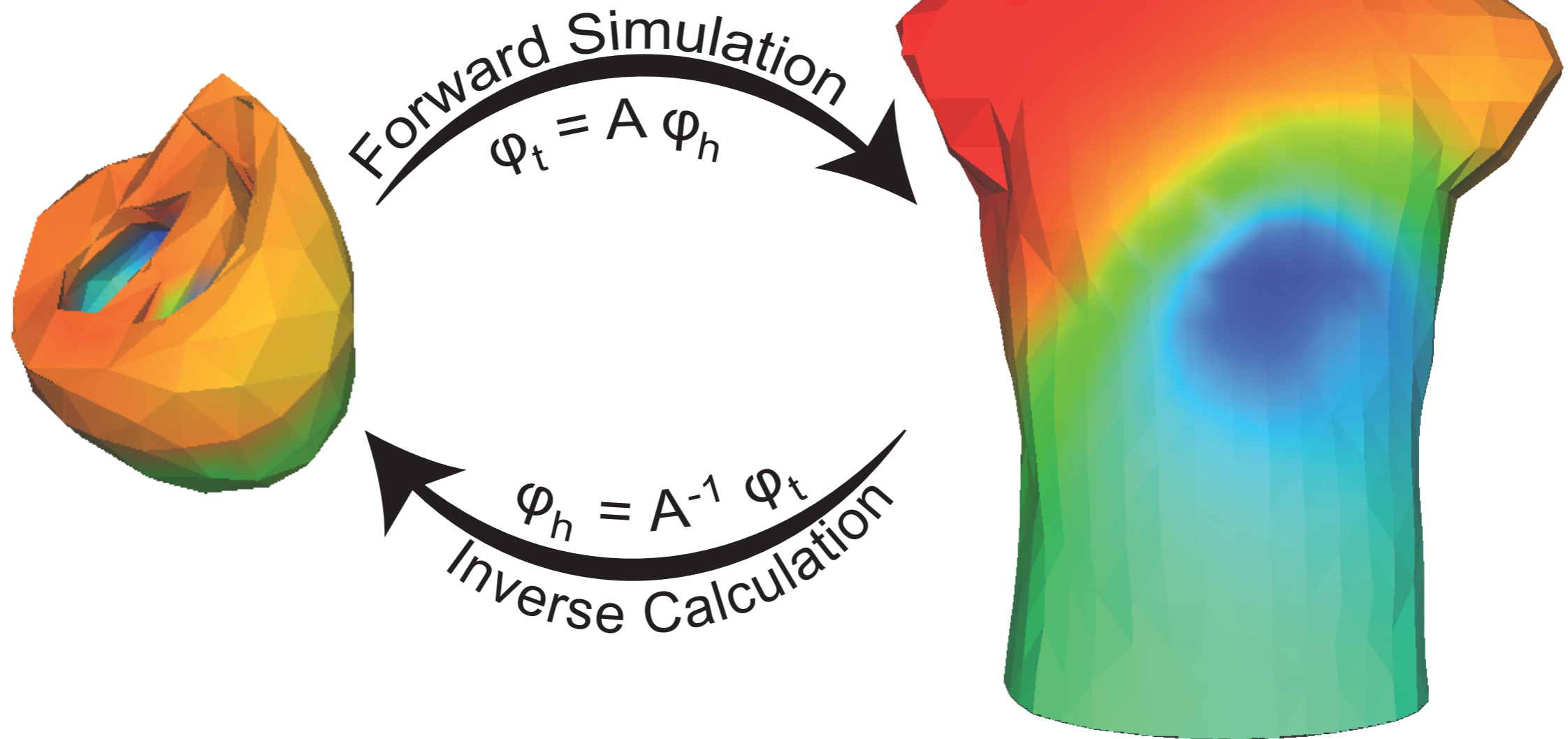
Jess Tate, Karli Gillette, Brett Burton, Wilson Good,  
Jaume Coll-Font, Dana Brooks, Rob MacLeod

University of Utah  
Northeastern University  
Graz University

# ECG Imaging

Heart Potentials ( $\varphi_h$ )

Torso Potentials ( $\varphi_t$ )

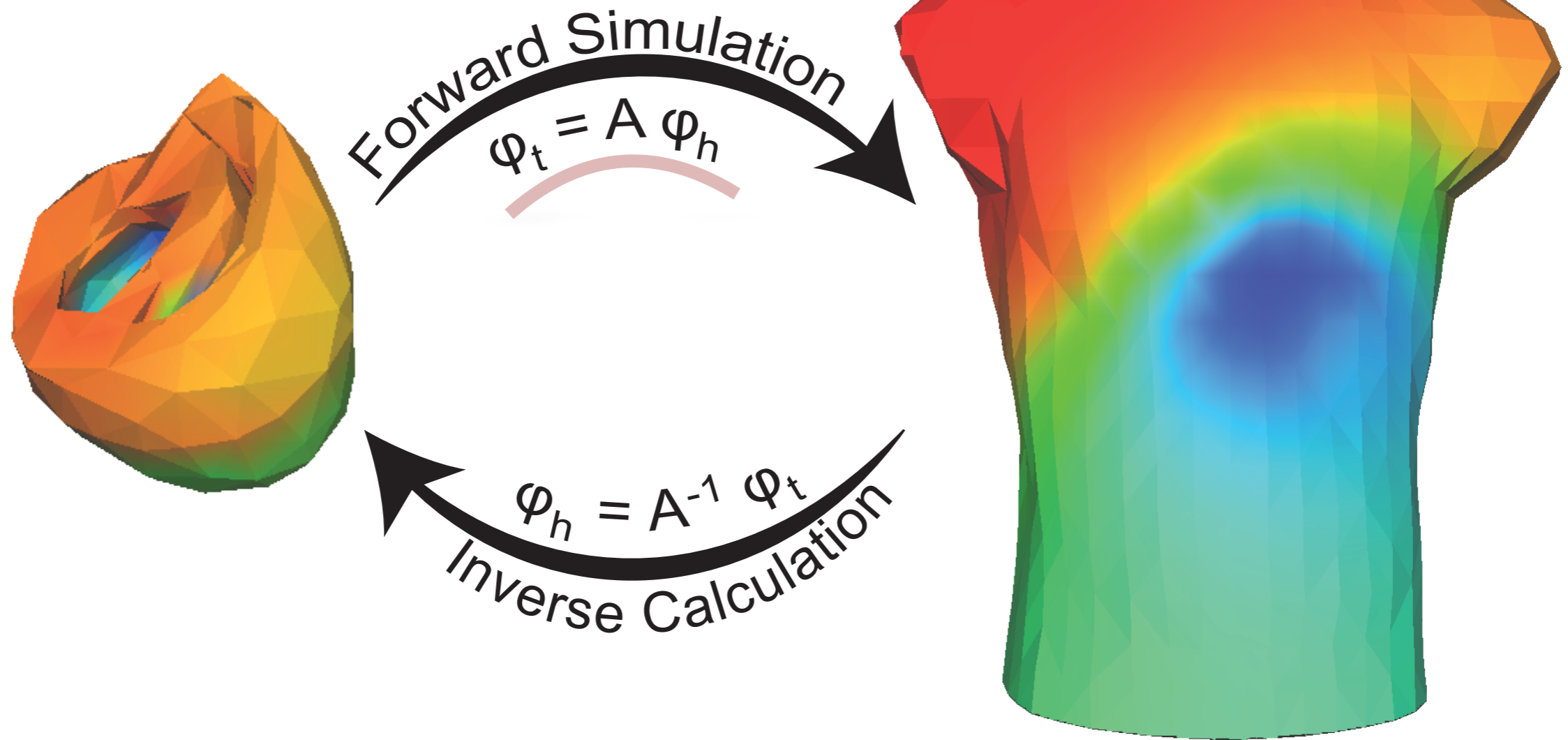


ECG Imaging Relies on Accurate Forward Models

# ECG Imaging

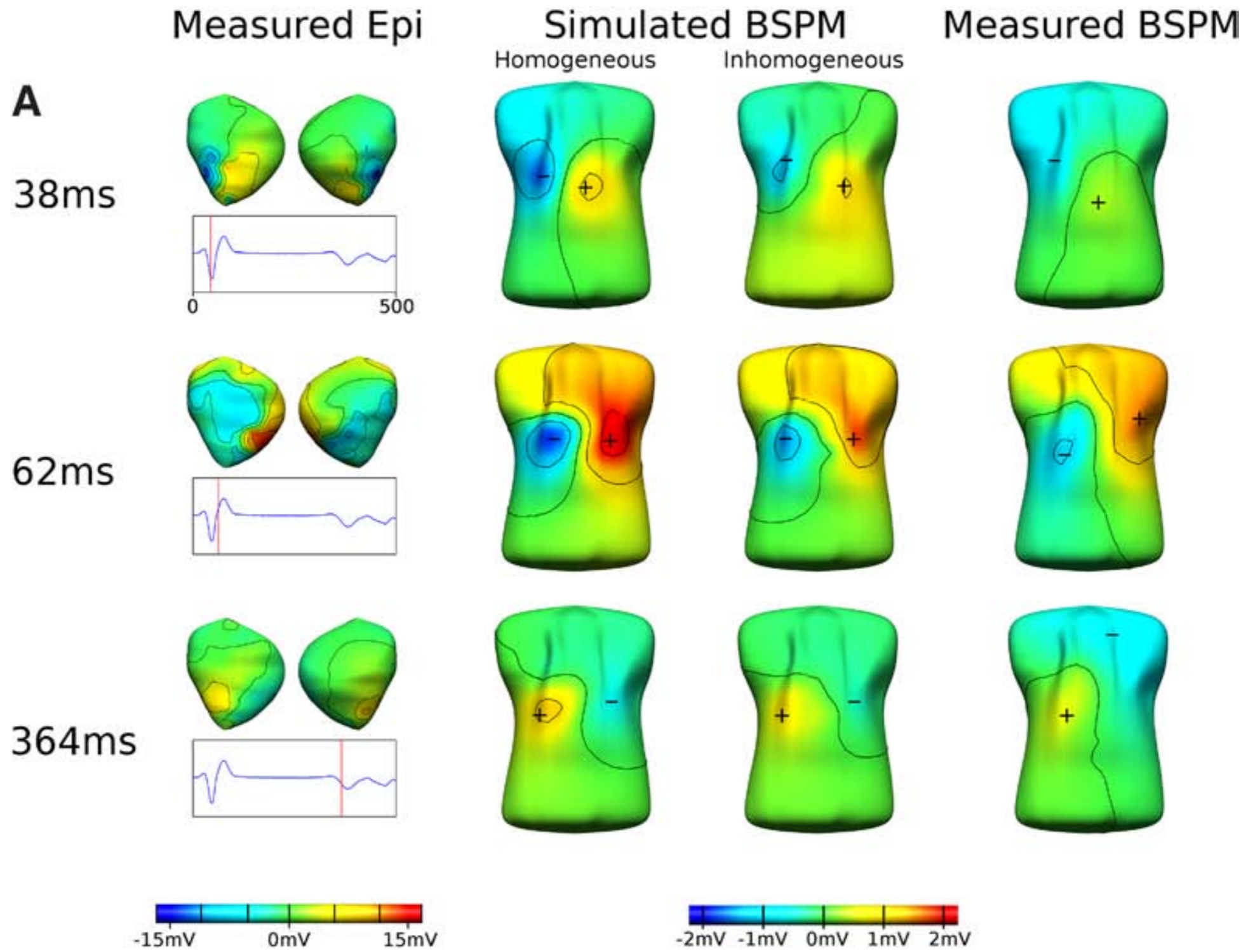
Heart Potentials ( $\varphi_h$ )

Torso Potentials ( $\varphi_t$ )



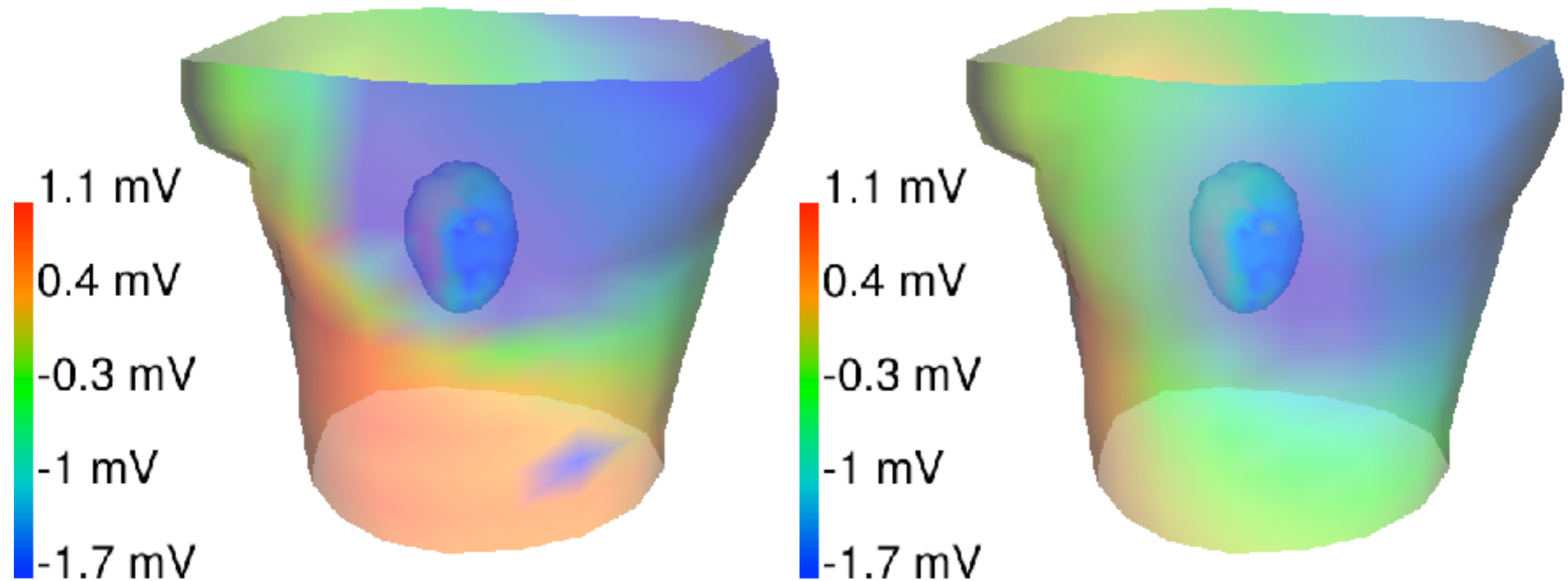
ECG Imaging Relies on Accurate Forward Models

# Error in Forward Simulation



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

# Error in Forward Simulation

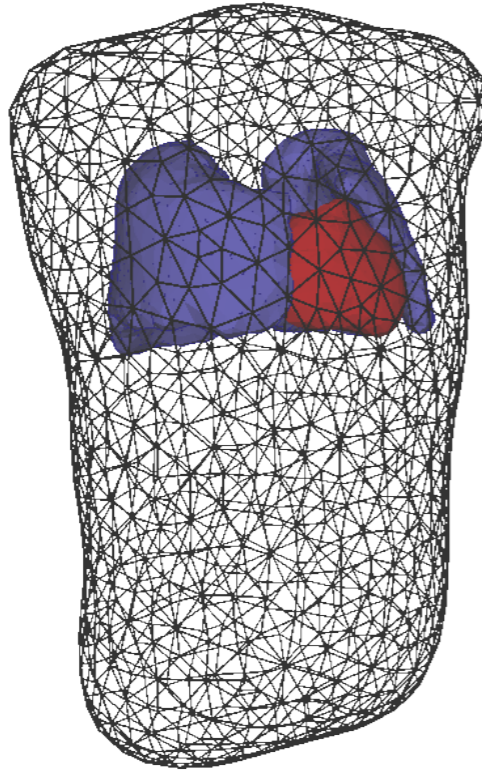


Recorded

Simulated

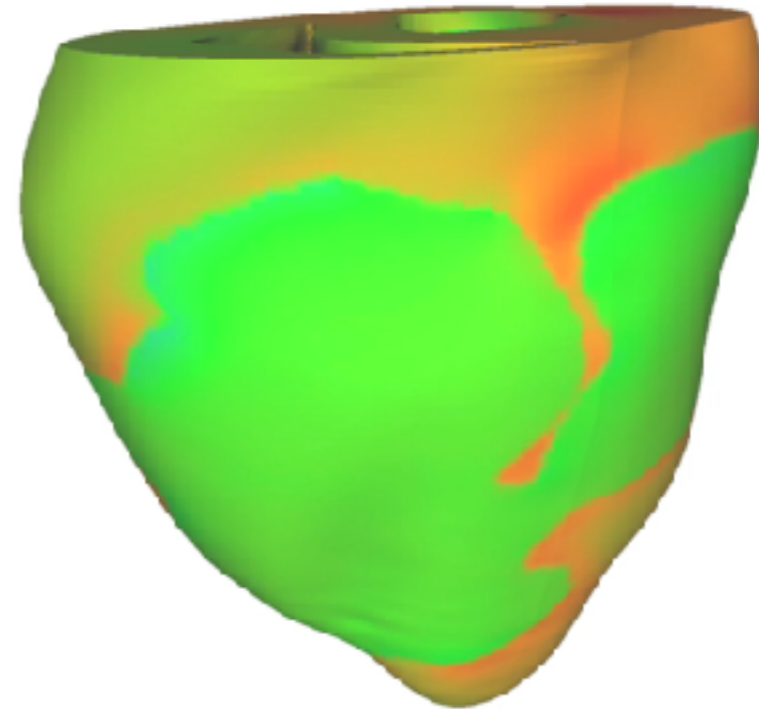
# Sources of Error

Geometry



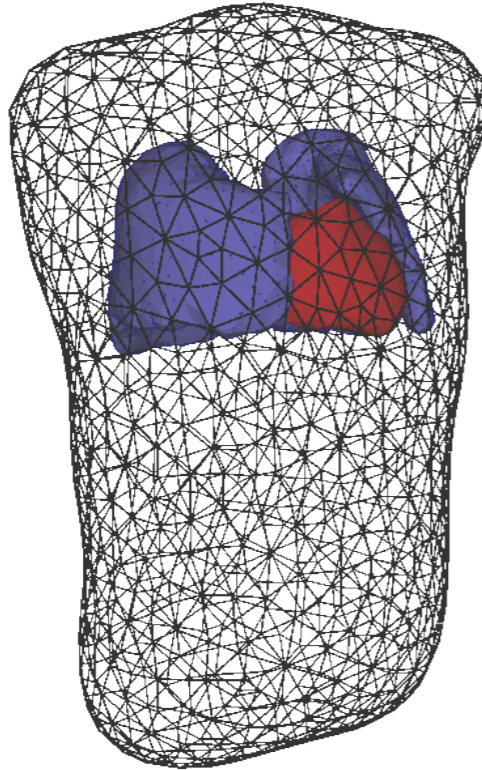
Sources

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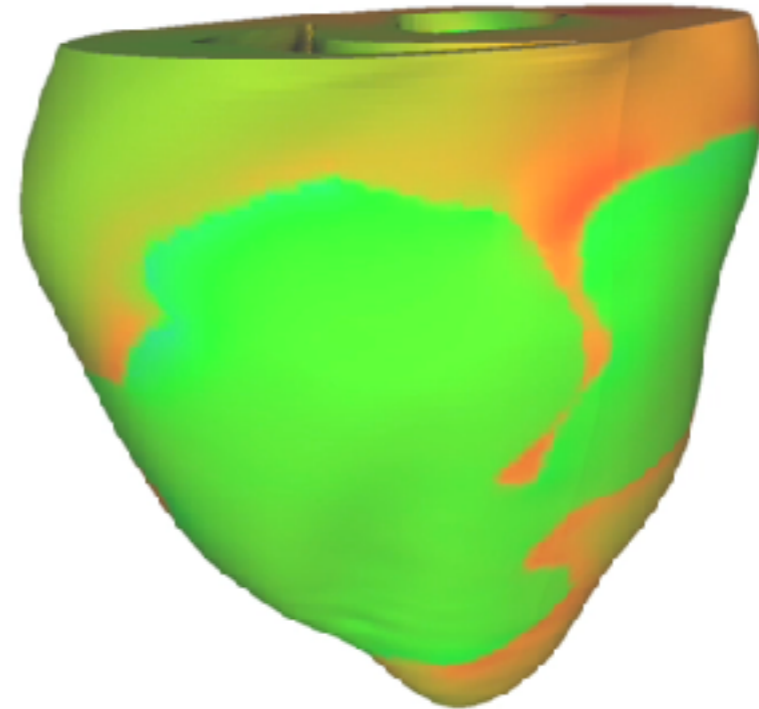
# Sources of Error

Geometry



Sources

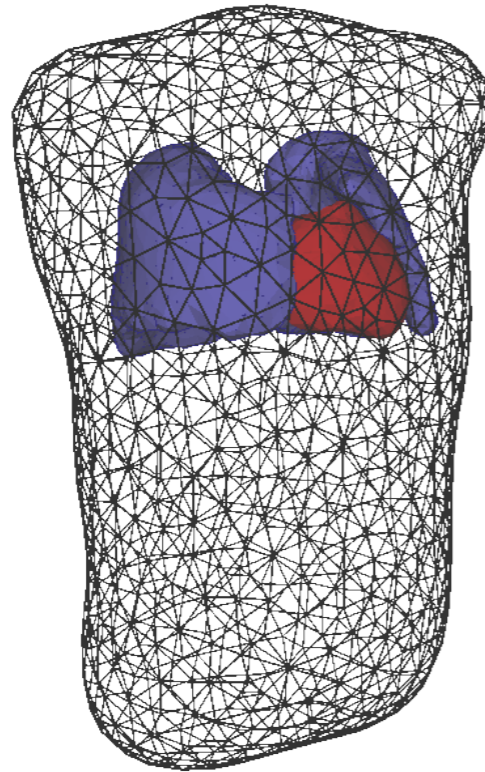
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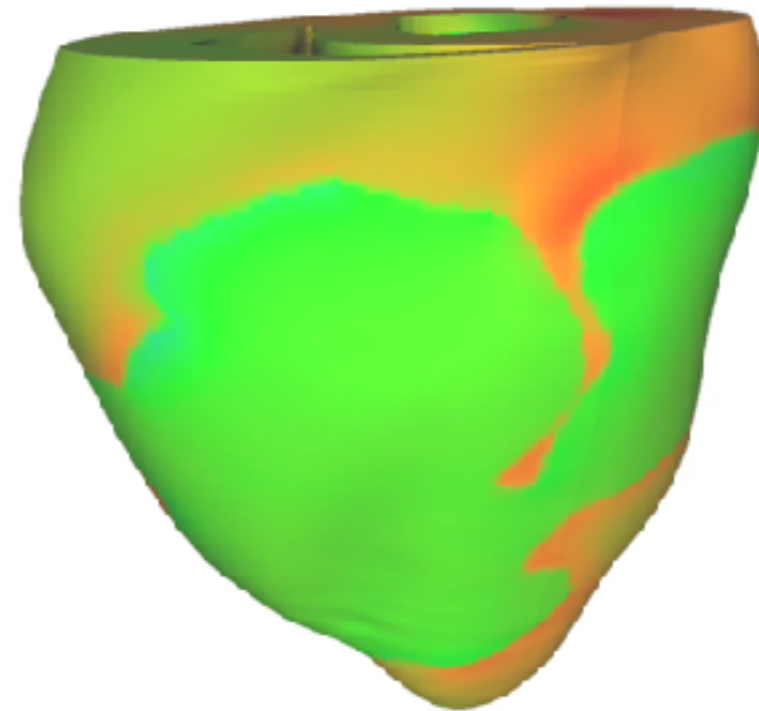
# Sources of Error

Geometry

Matrix  
A



Sources



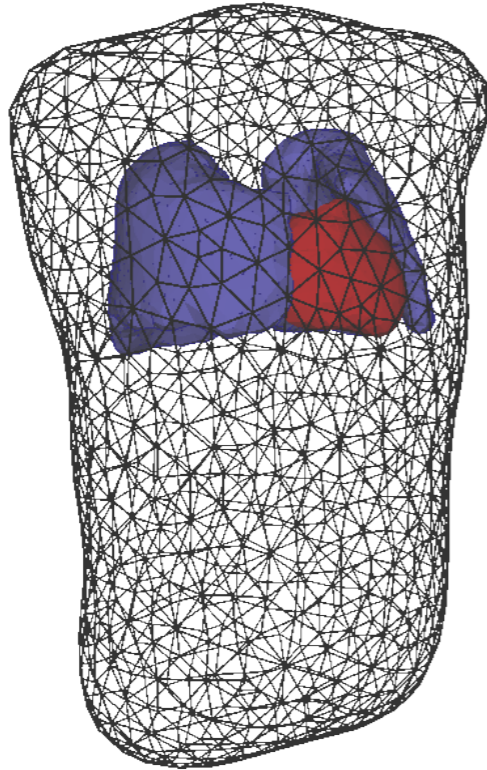
Vector  
 $\phi_h$



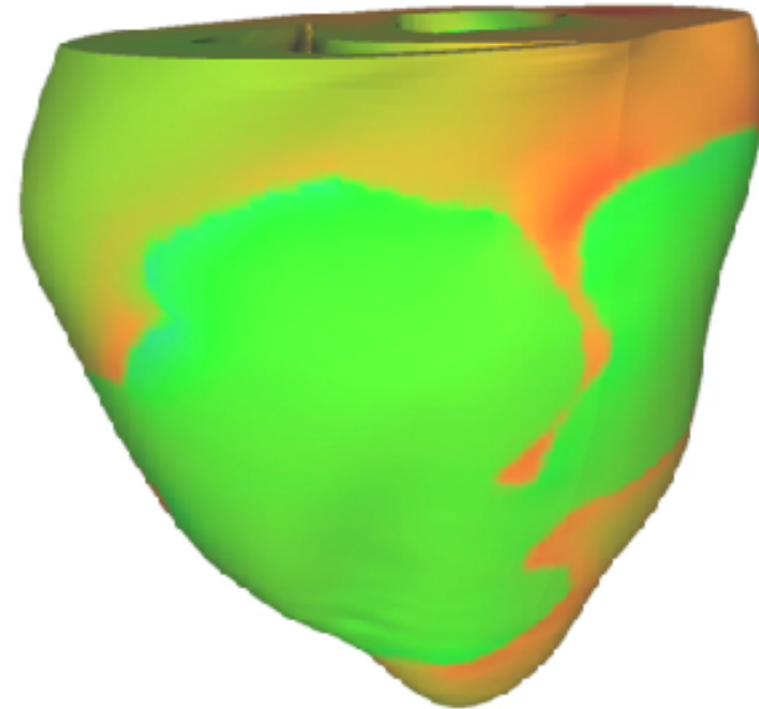
# Sources of Error

Geometry

Matrix  
A



Sources



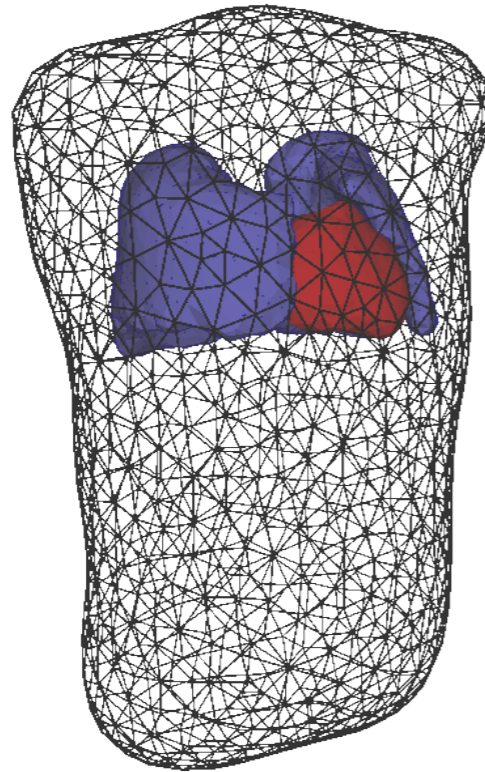
Vector  
 $\phi_h$

Registration  
Segmentation  
Conductivities  
Meshing

# Sources of Error

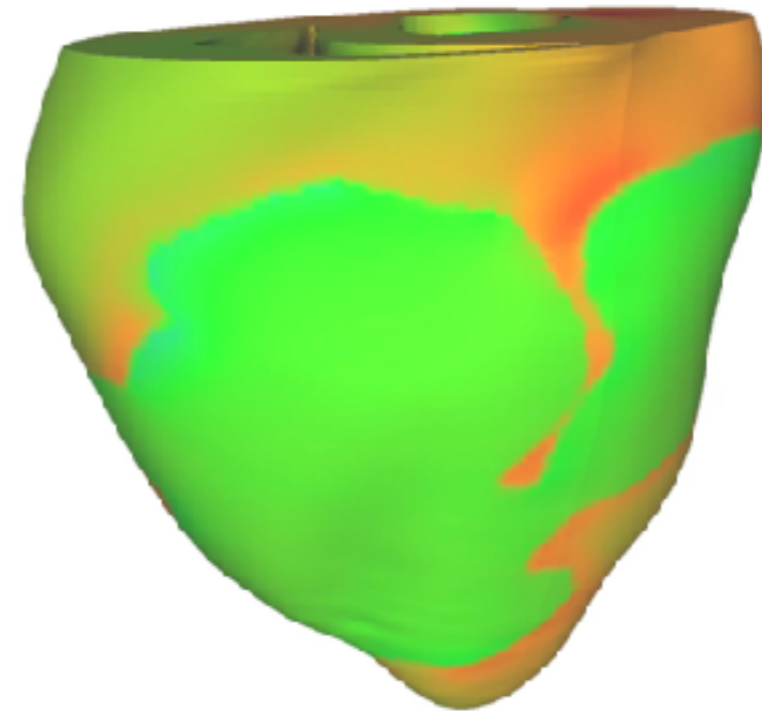
## Geometry

Matrix  
A



Registration  
Segmentation  
Conductivities  
Meshing

## Sources



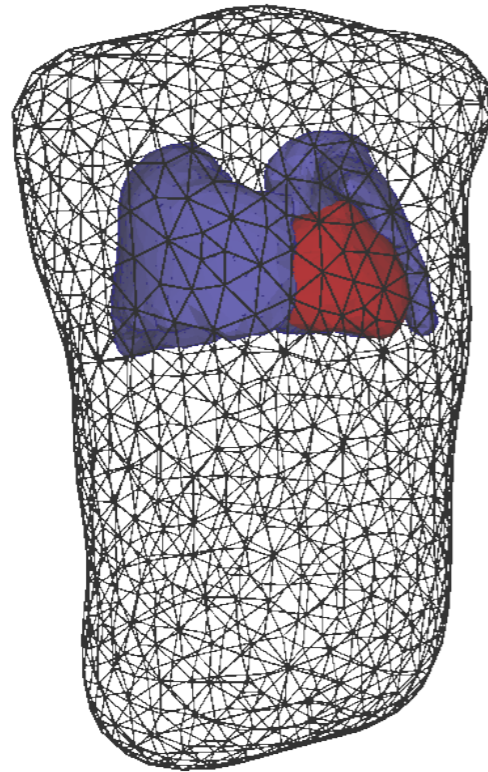
Vector  
 $\phi_h$

Geometry  
Source Model  
Noise  
Sampling

# Sources of Error

Geometry

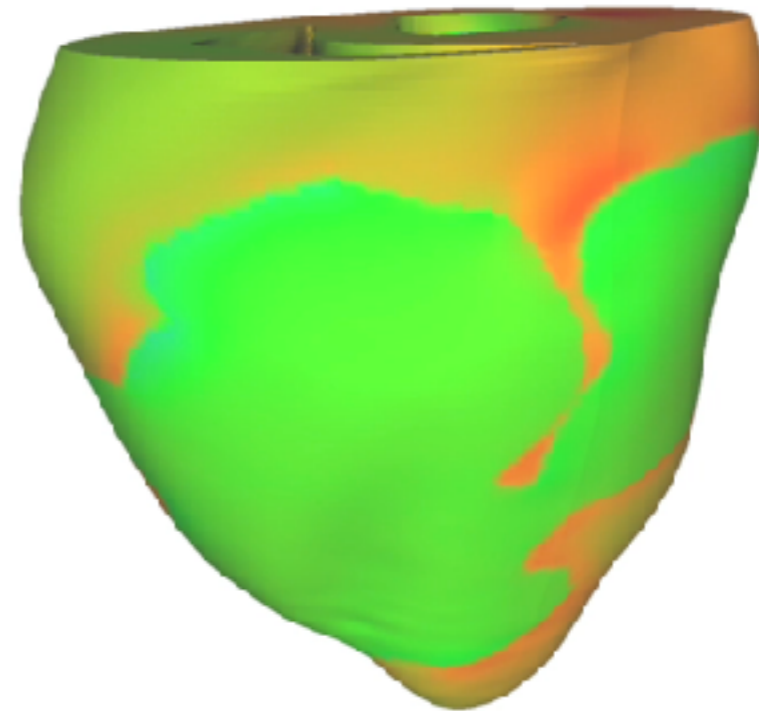
Matrix  
A



Registration  
Segmentation  
Conductivities  
Meshing

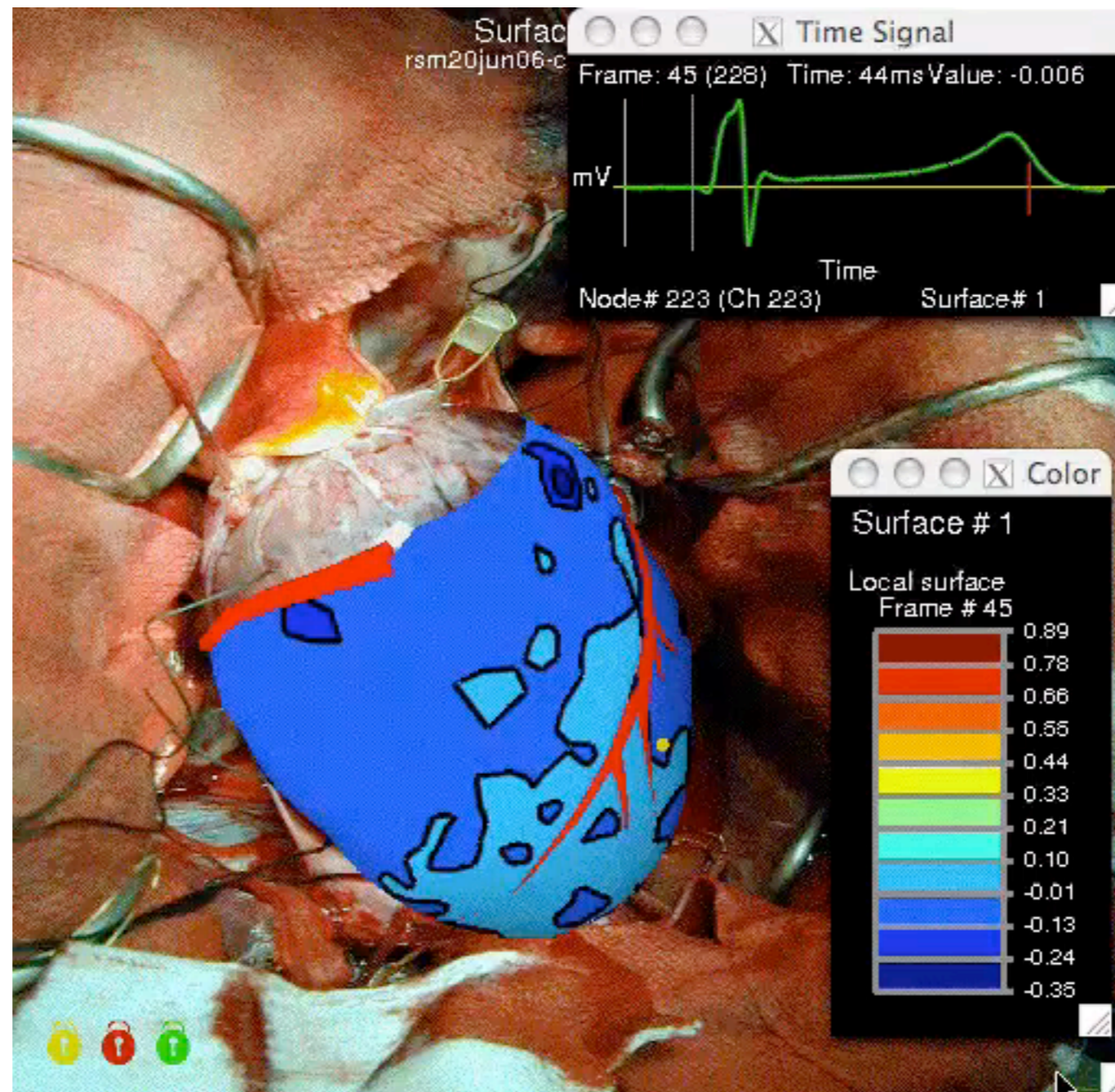
Sources

Vector  
 $\phi_h$



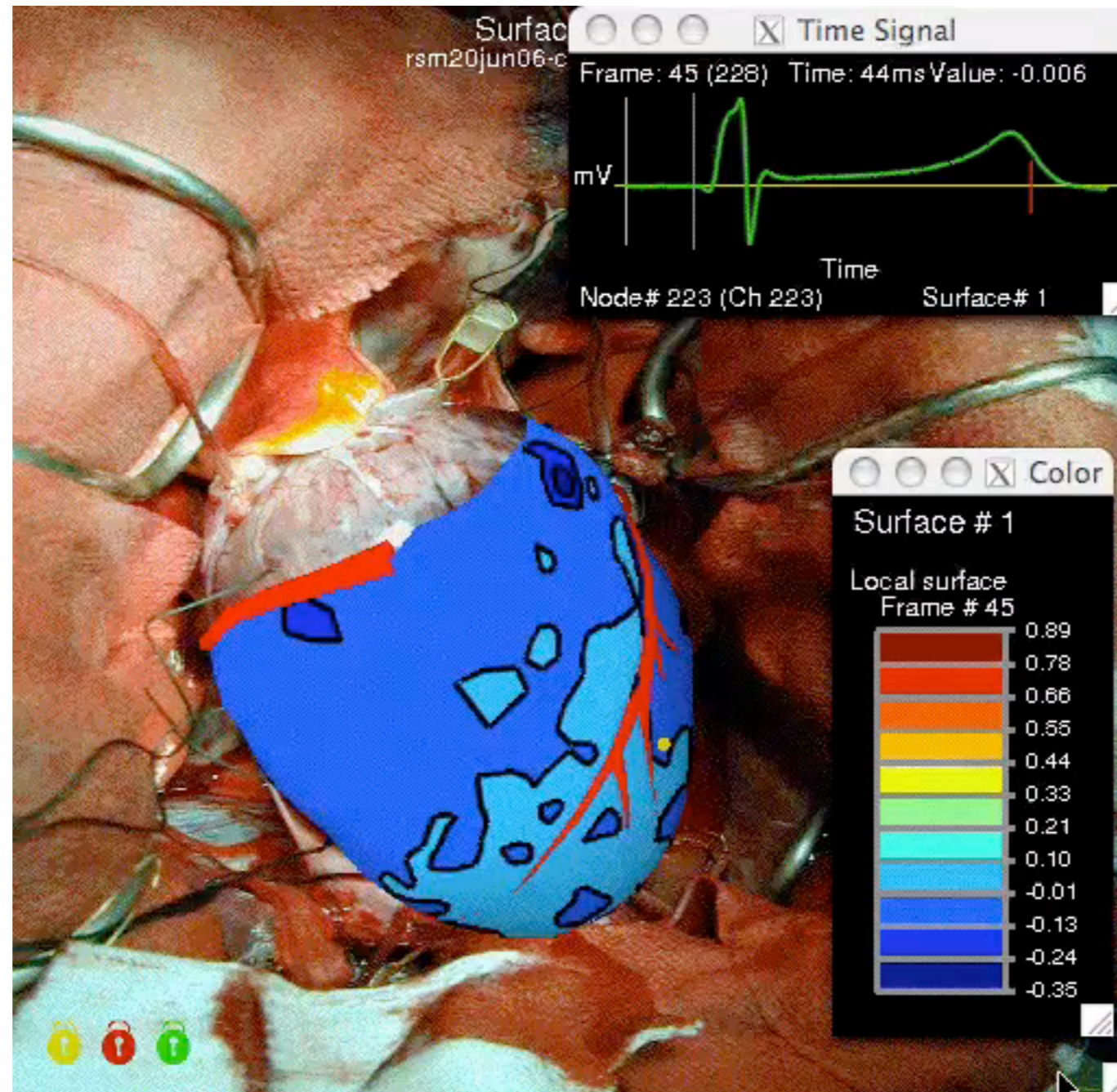
Geometry  
Source Model  
Noise  
**Sampling**

# Source Recording



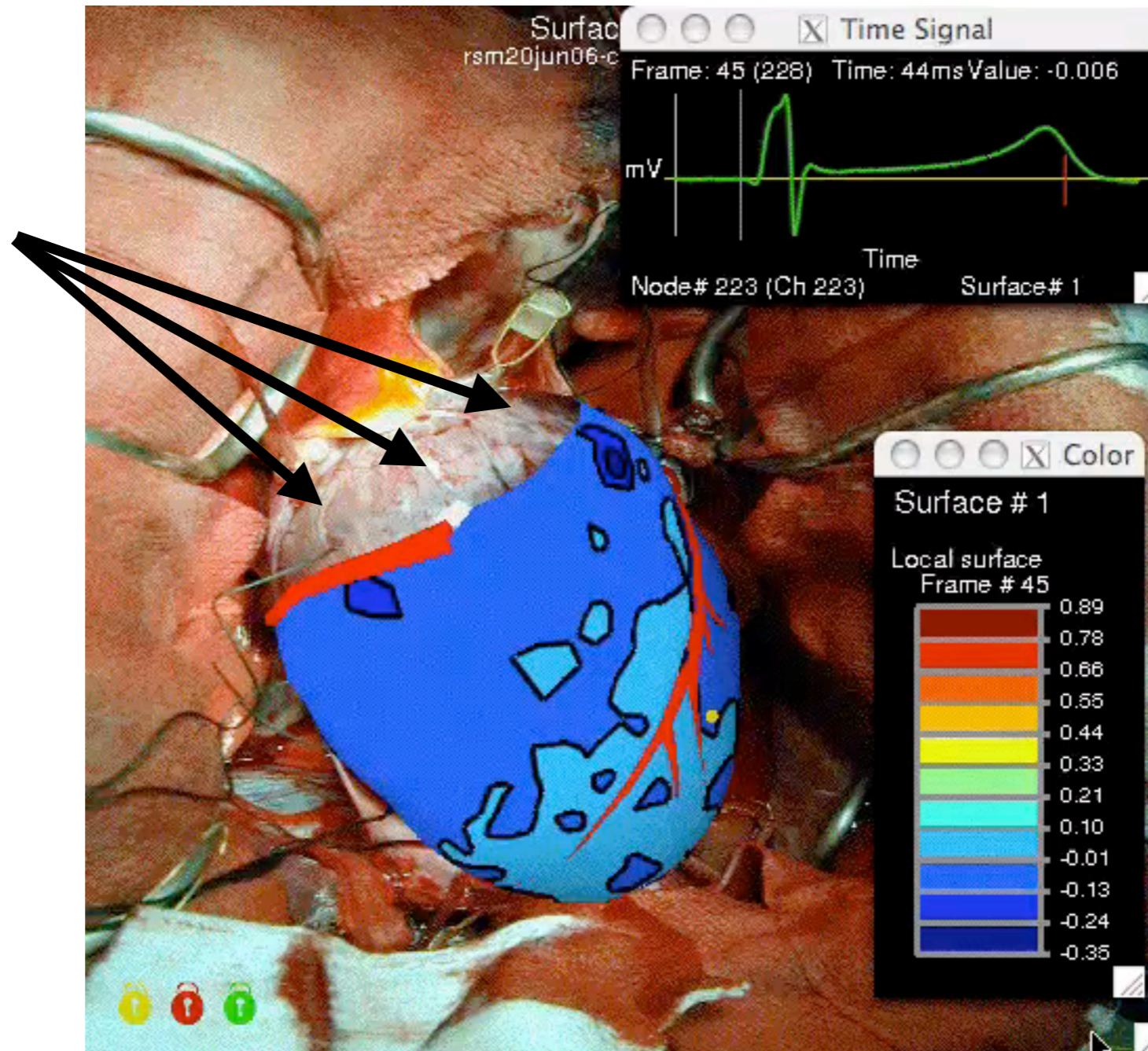
## Epicardial Sock

# Source Recording



## Epicardial Sock (Ventricle Only)

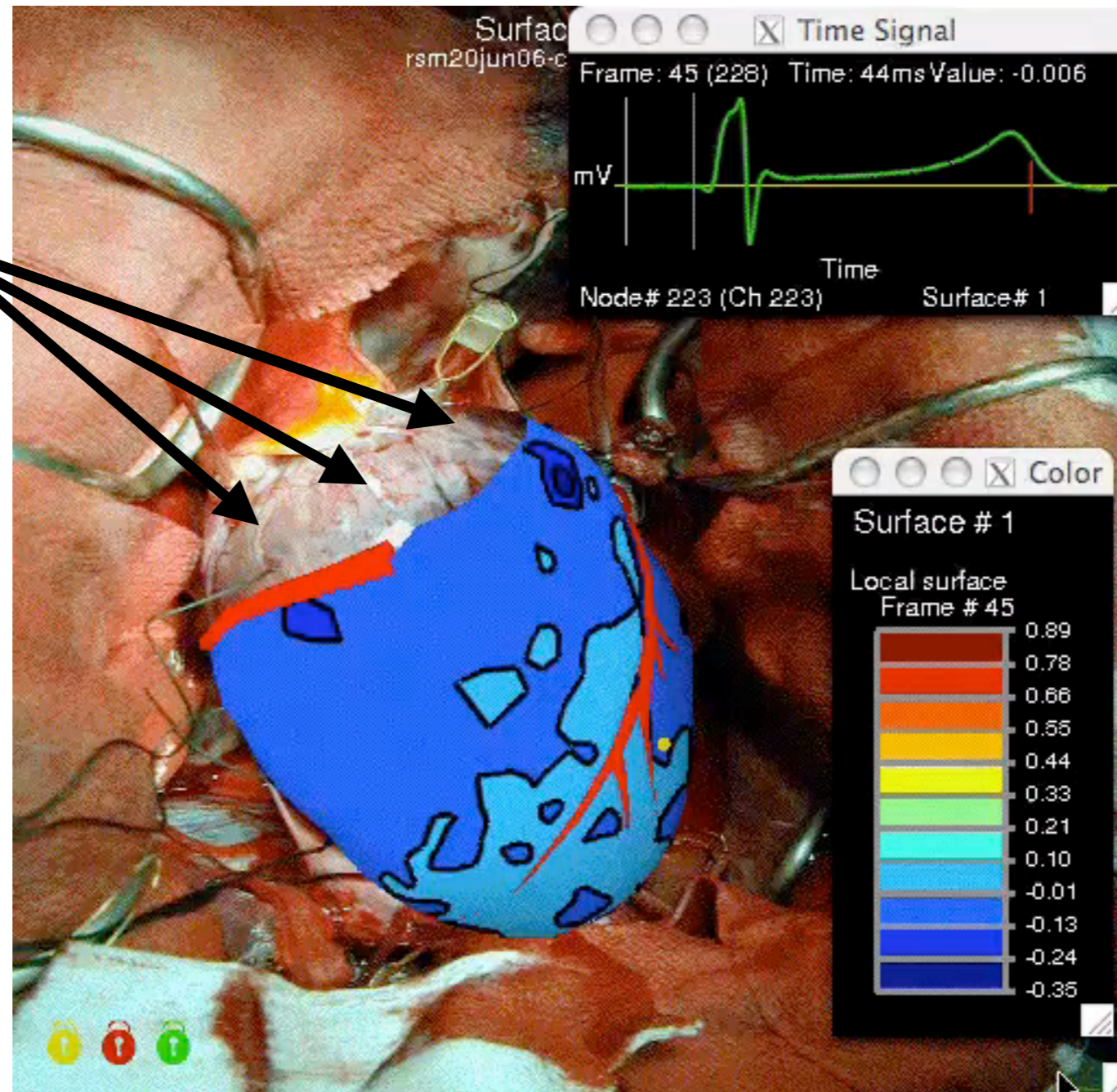
# Source Recording



Epicardial Sock  
(Ventricle Only)

# Source Recording

Missing Sources?

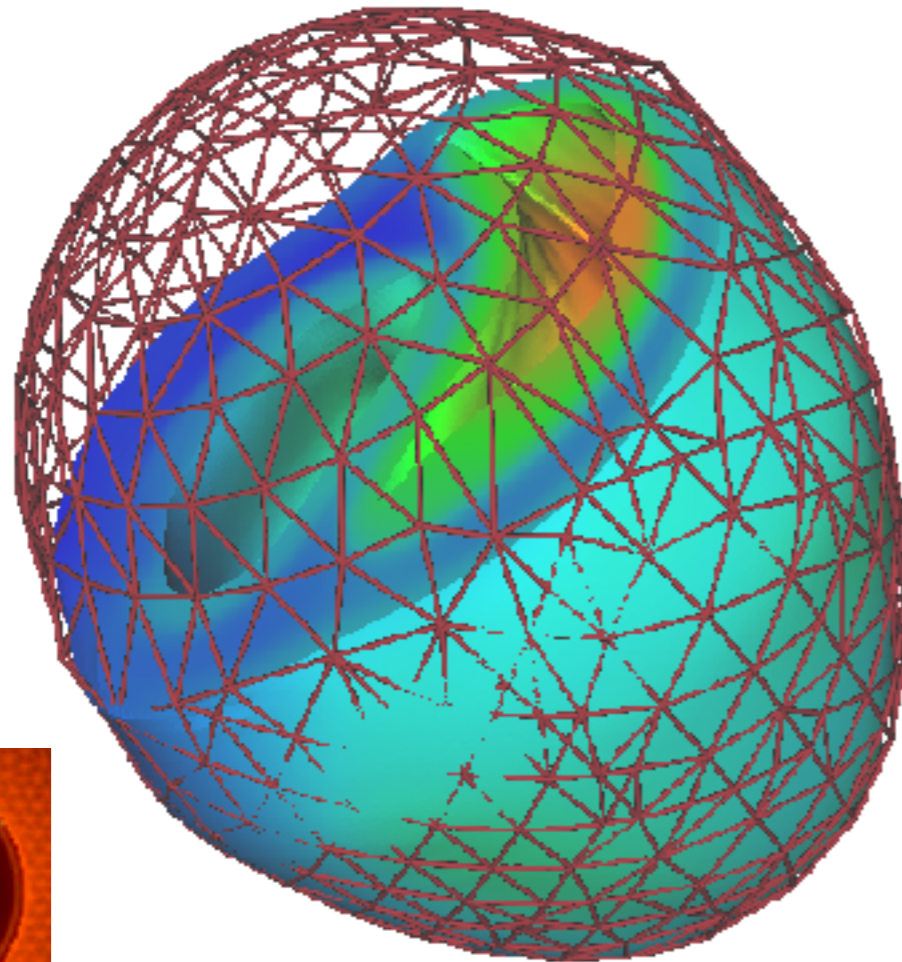


Epicardial Sock  
(Ventricle Only)

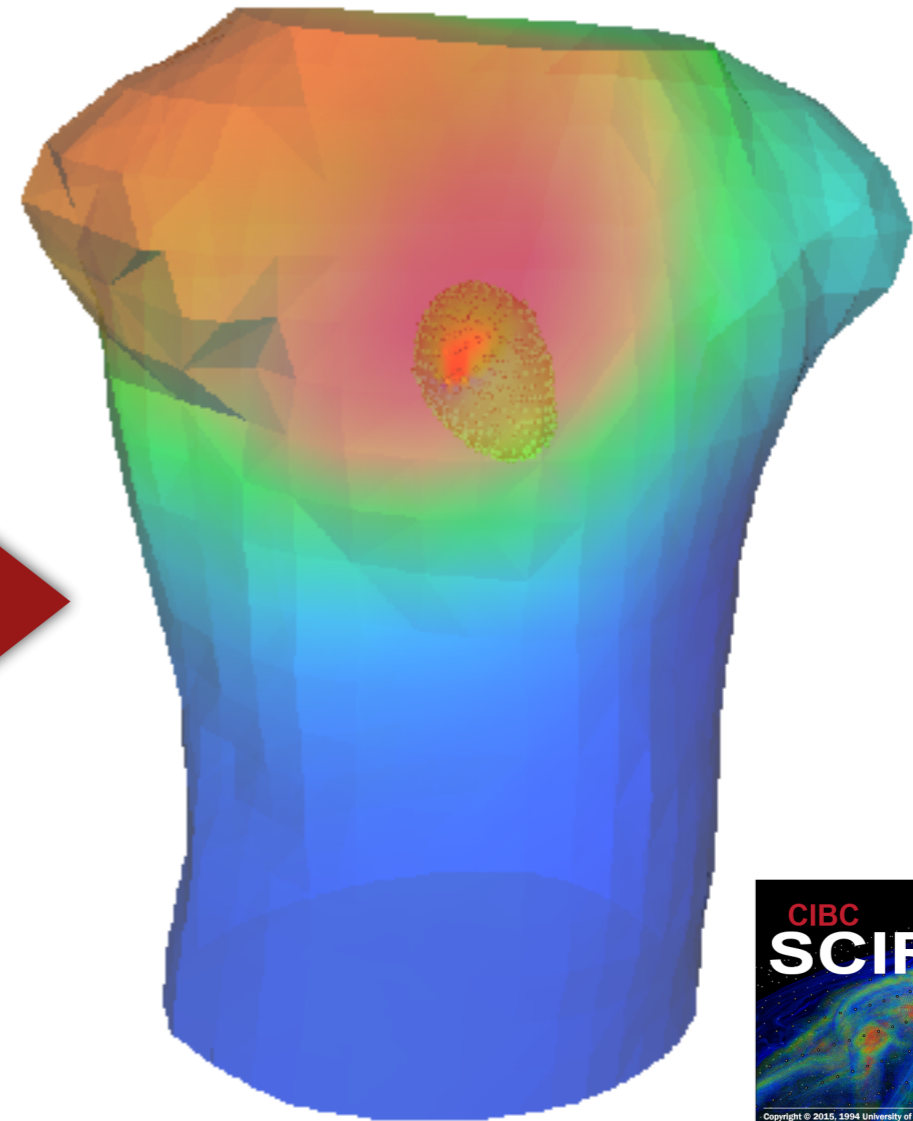
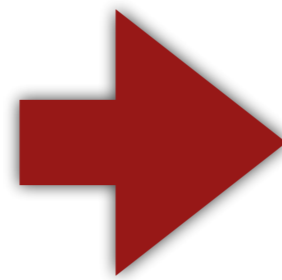
# Test sampling strategies of the atrial region to reduce error in forward simulation



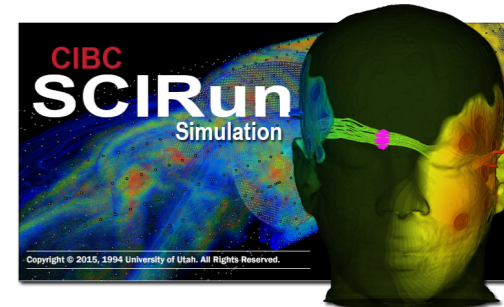
# Established Ground Truth



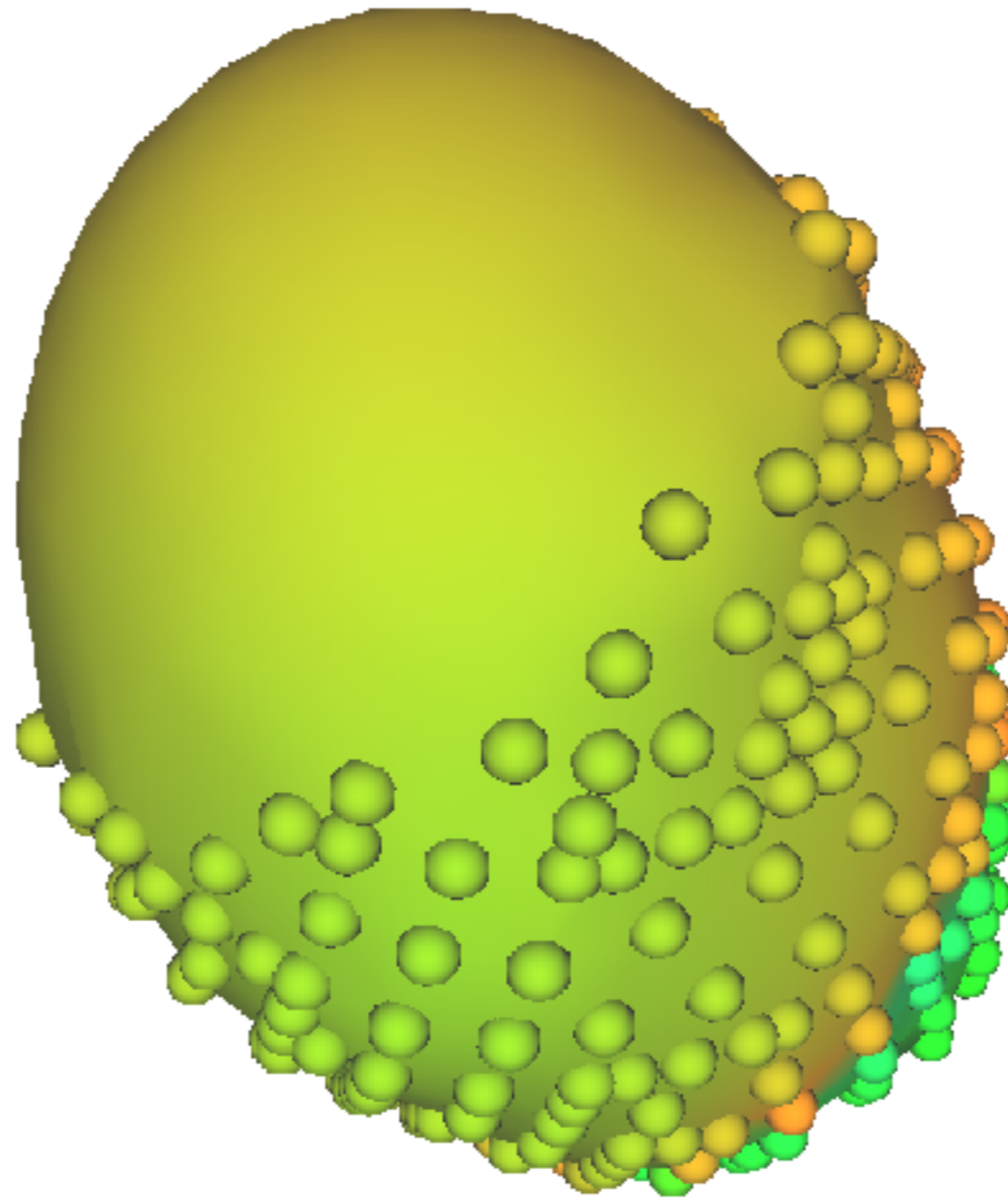
4 Simulated  
Activation  
Patterns



FEM Derived  
Potentials

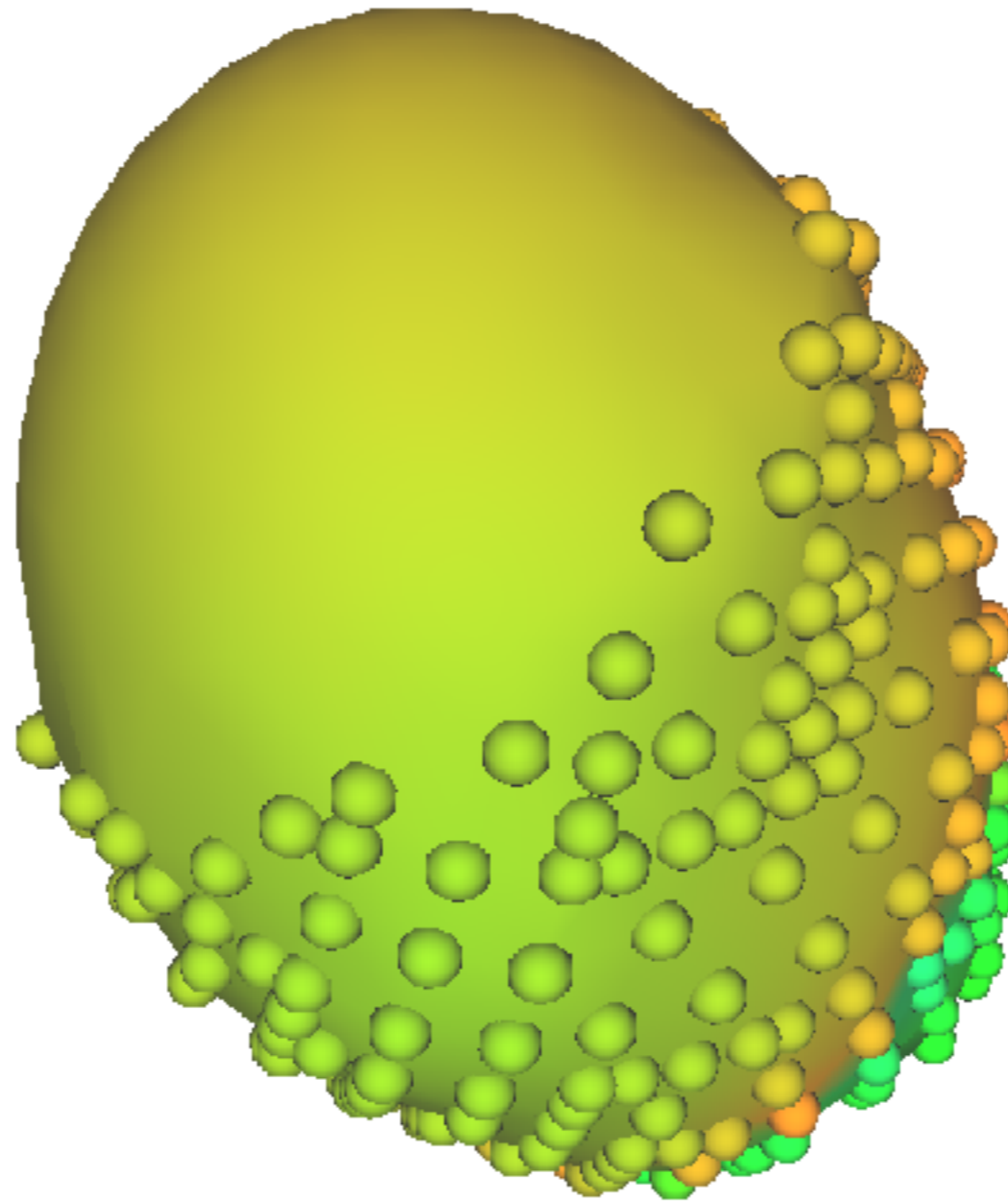


# Varied Sampling



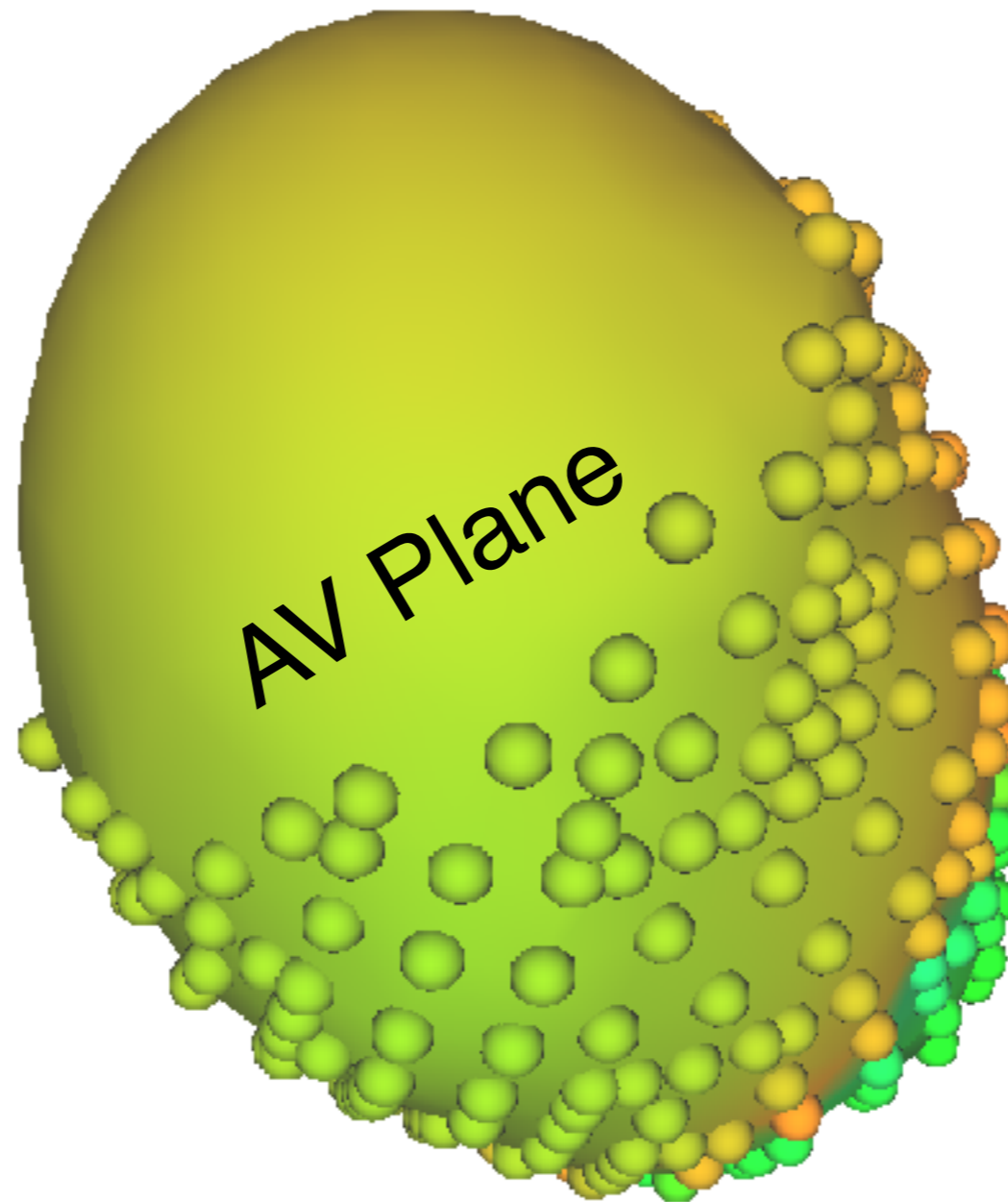
# Varied Sampling

## Atrial Roof

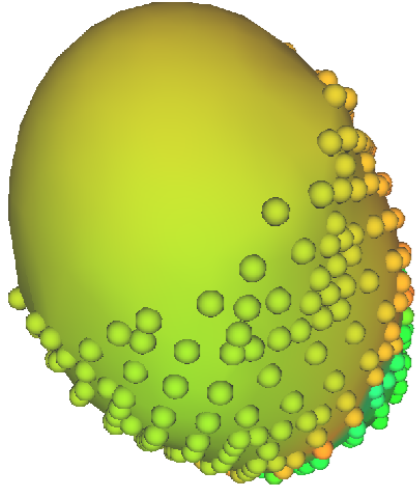


# Varied Sampling

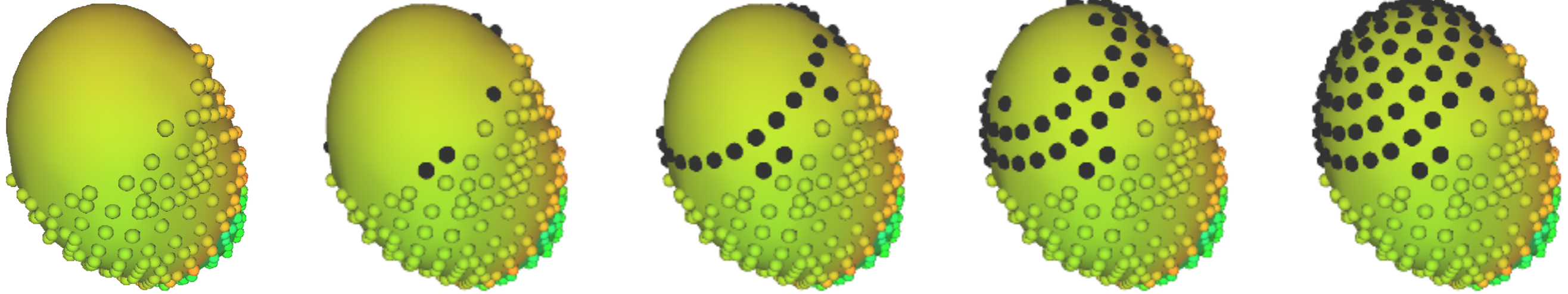
## Atrial Roof



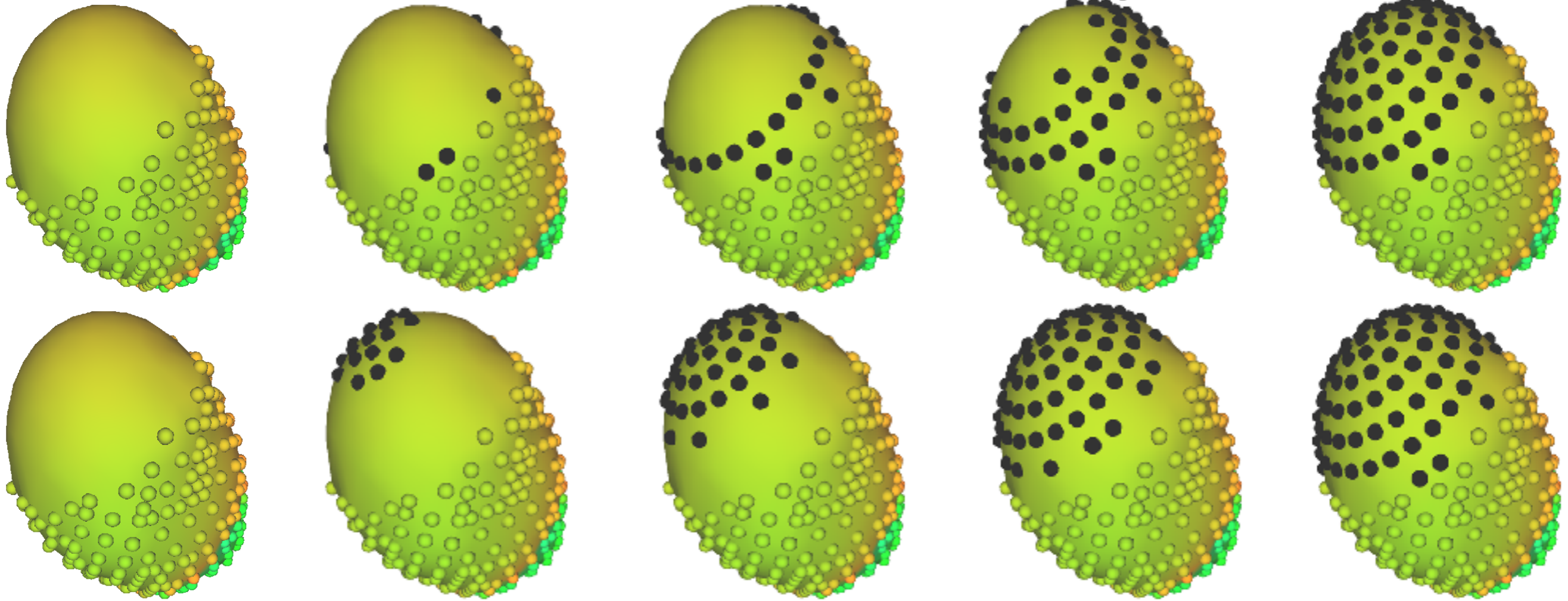
# Varied Sampling



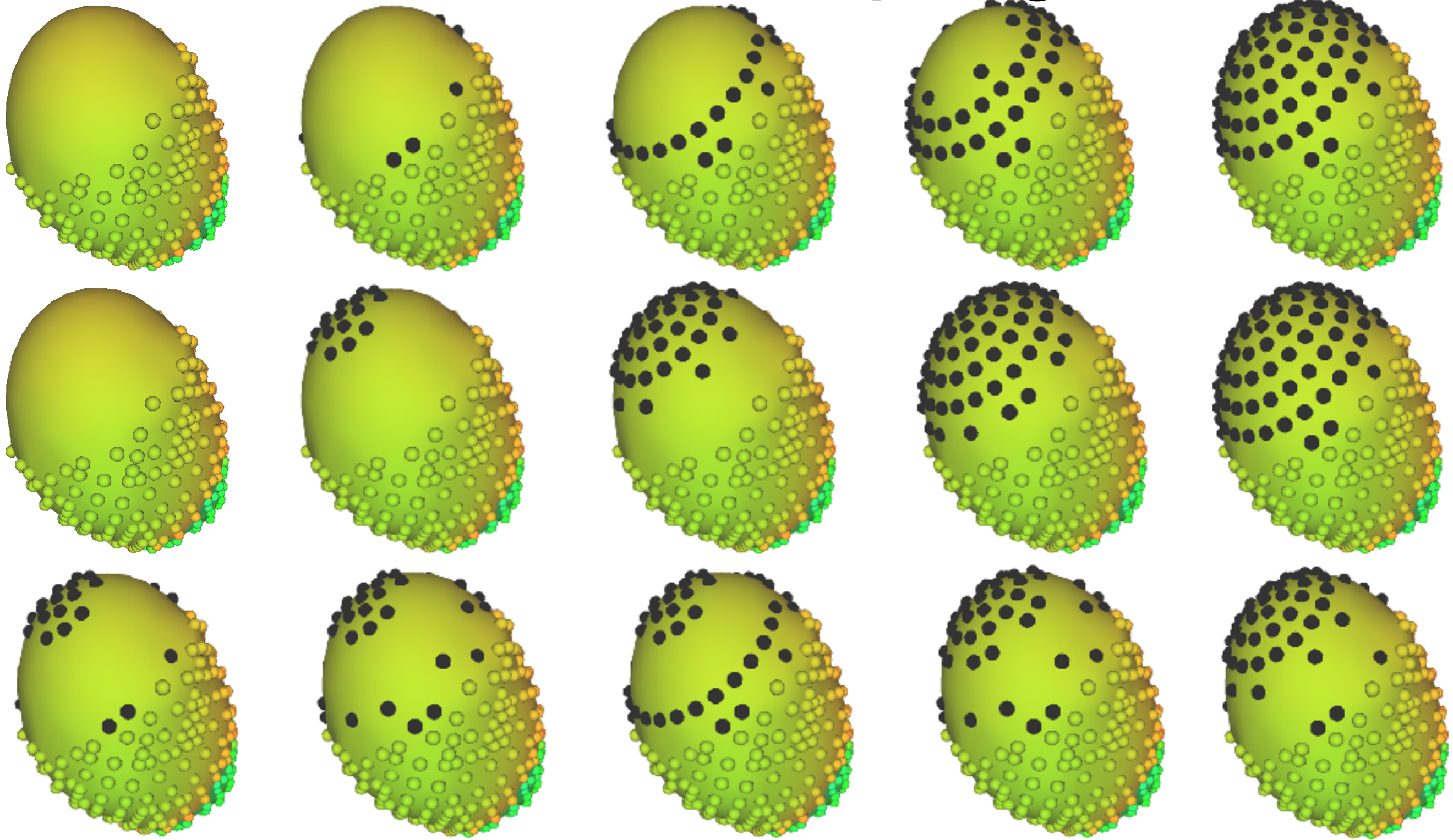
# Varied Sampling



# Varied Sampling

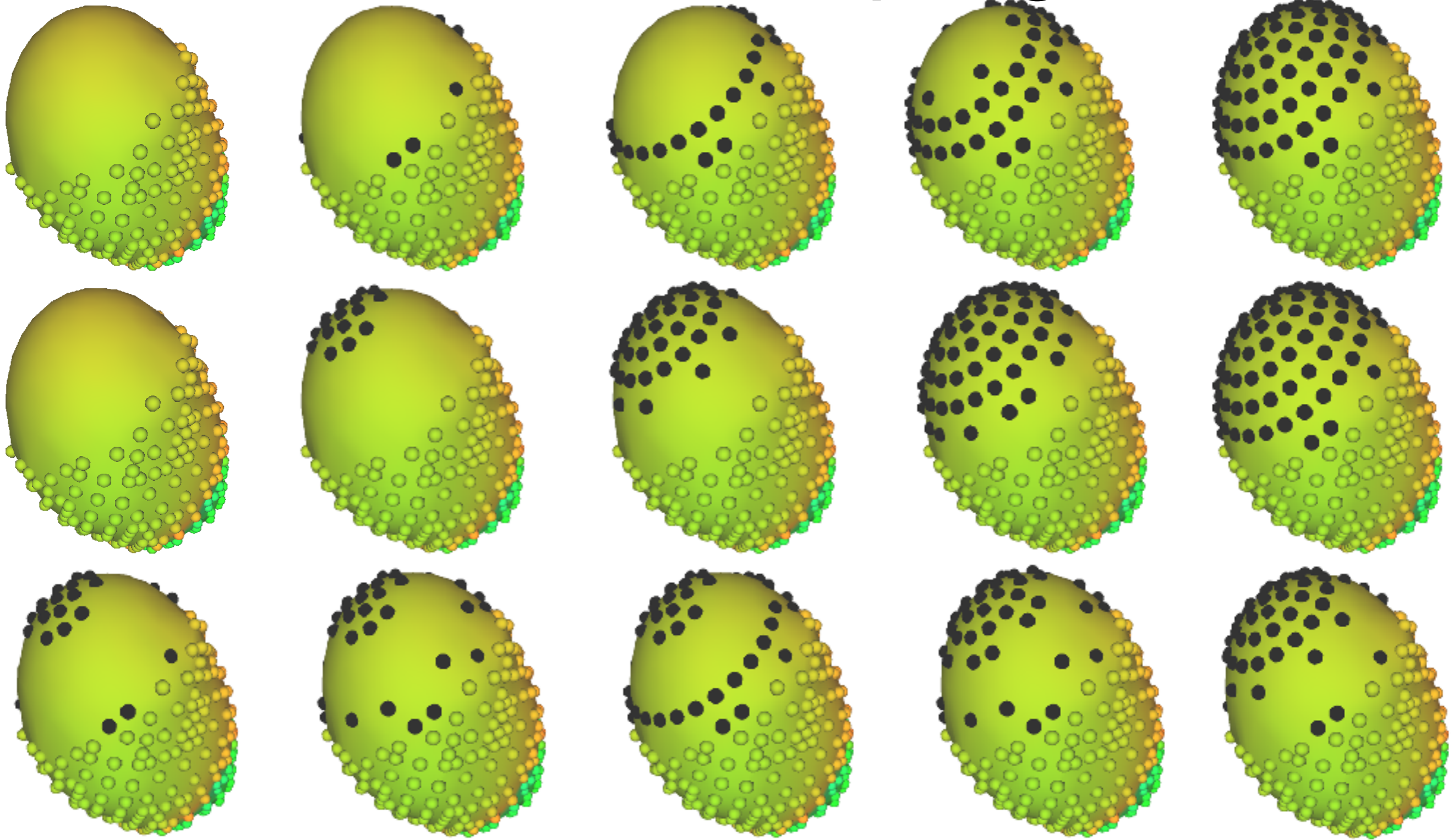


# Varied Sampling



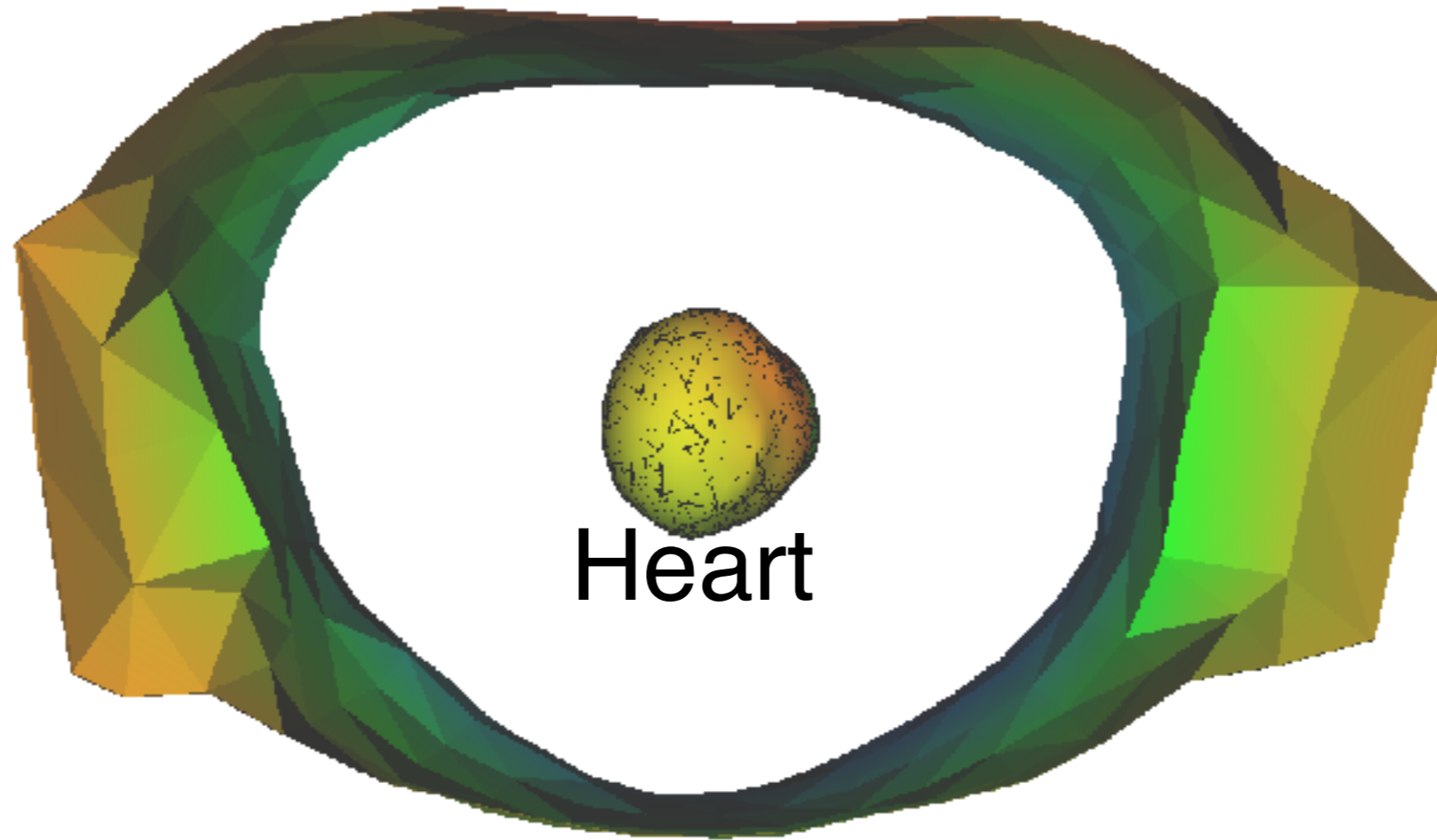


# Varied Sampling



## Laplacian Interpolation

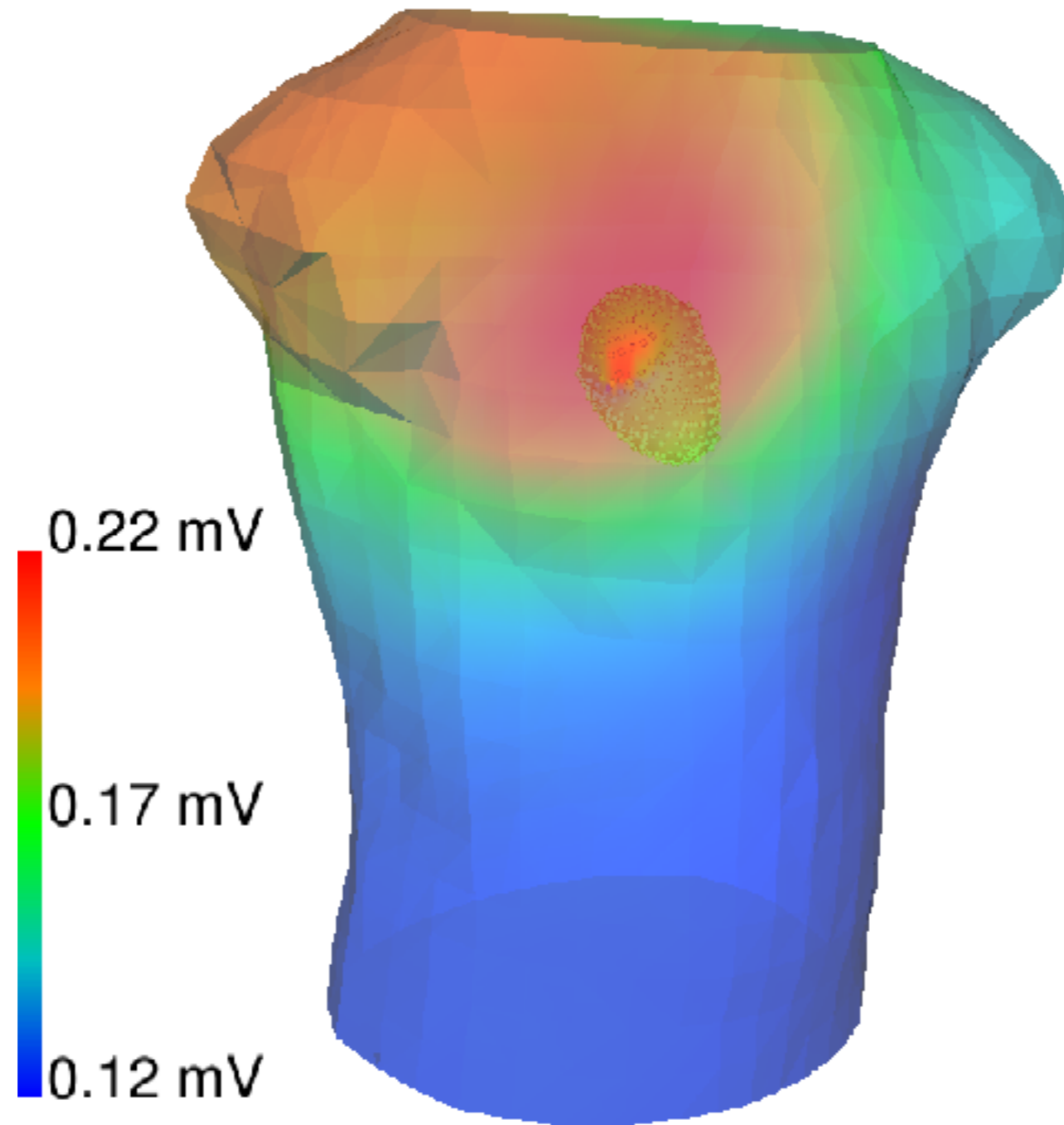
# Forward Simulation with BEM



Heart

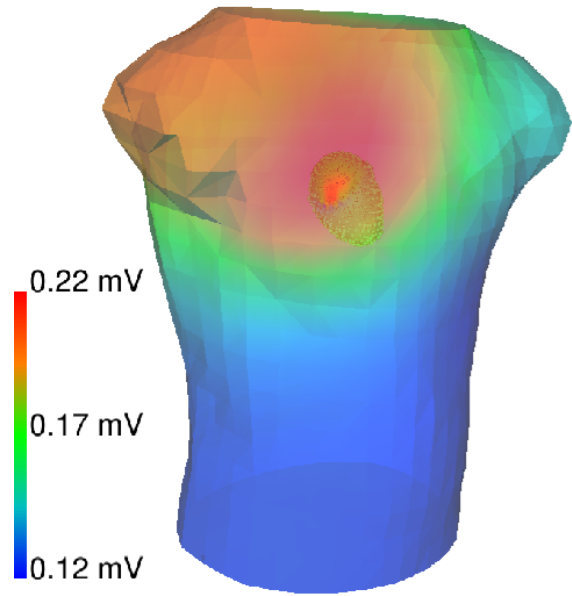
Torso

# Predicted solution

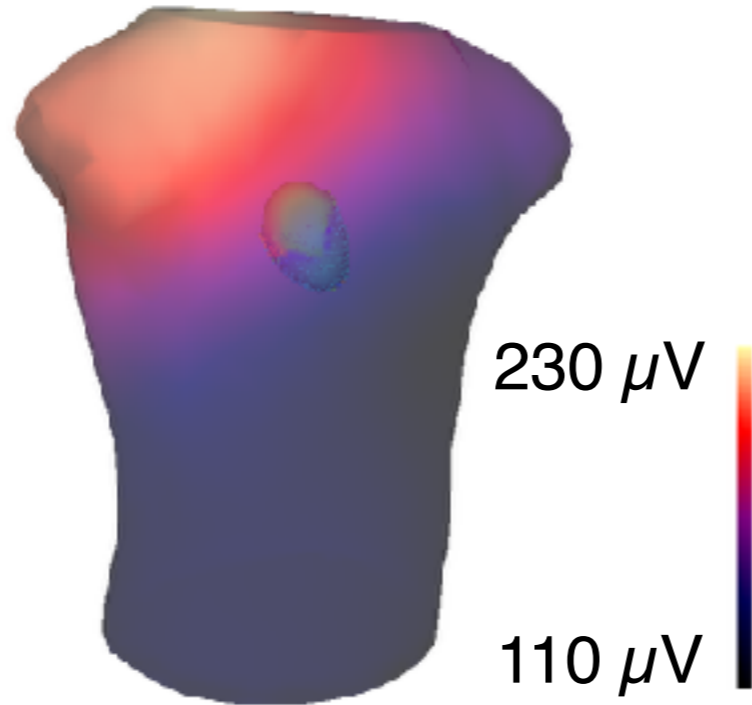


Ground Truth

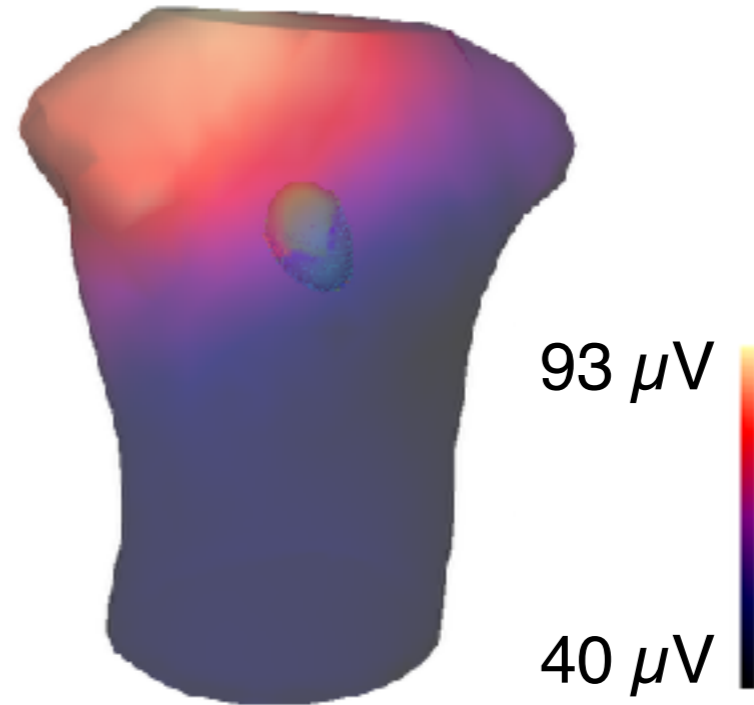
# Difference in Prediction



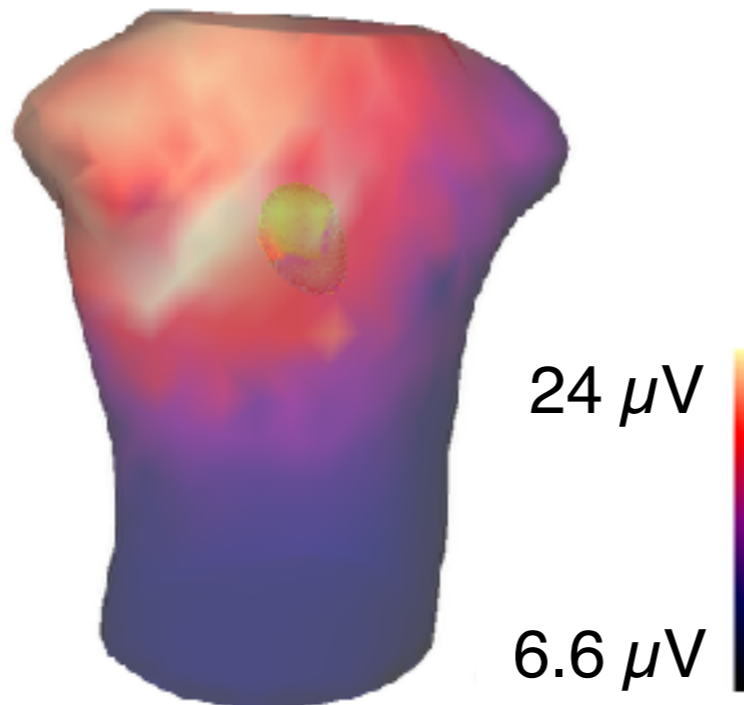
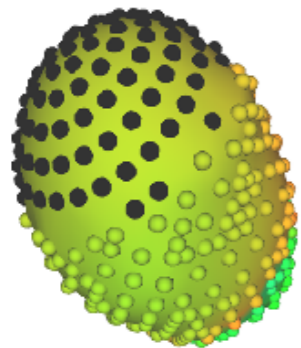
Ground Truth



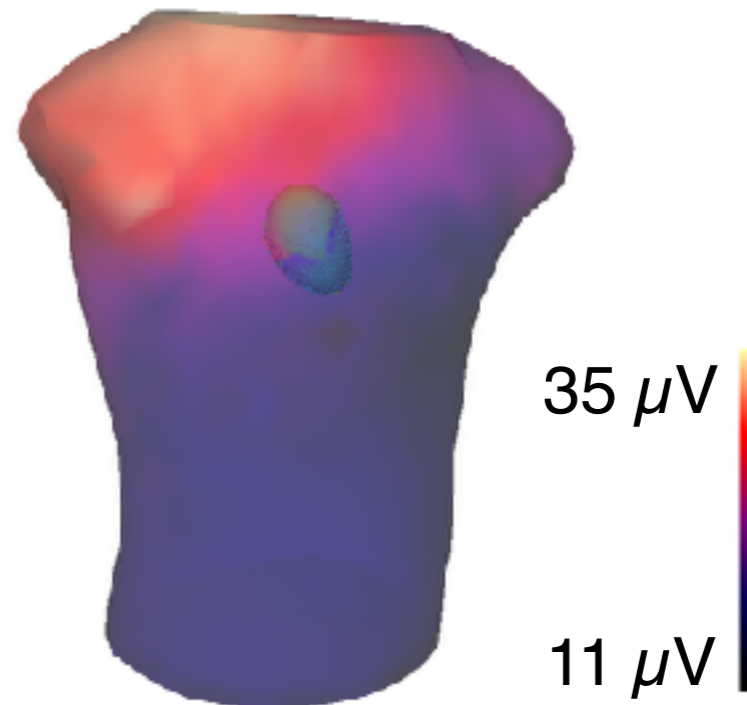
Ventricular Only



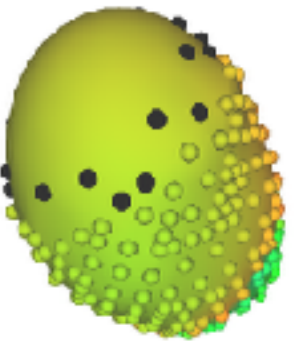
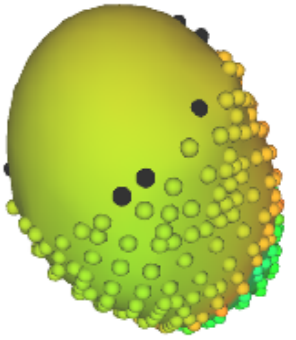
15 More Electrodes



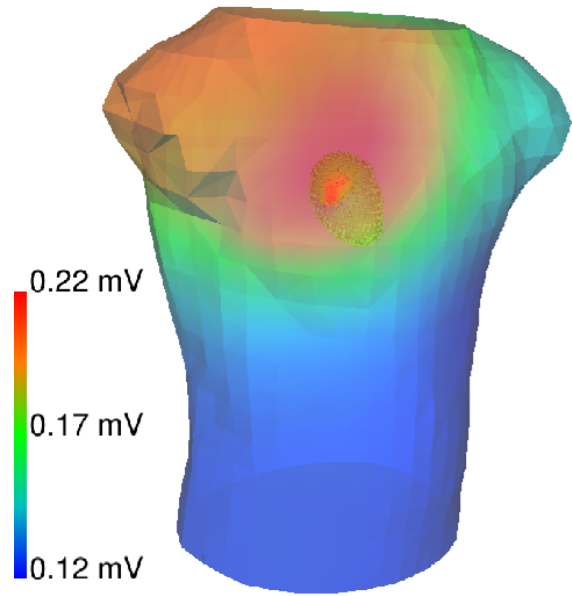
Full Sock



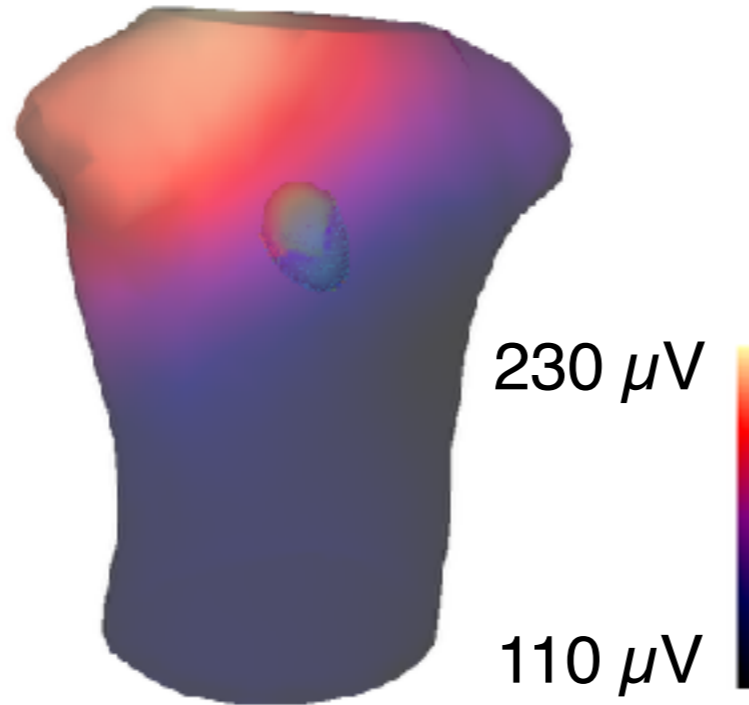
30 More Electrodes



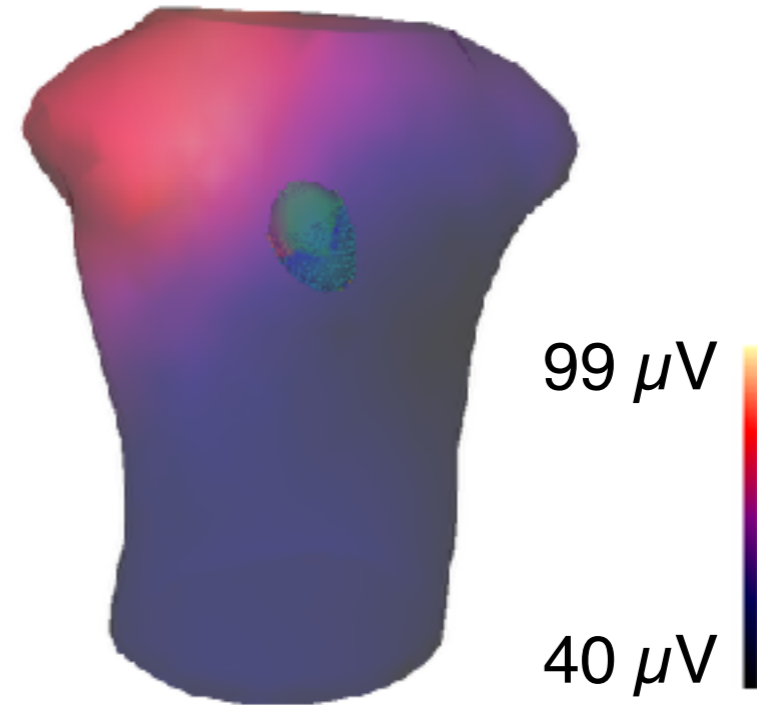
# Difference in Prediction



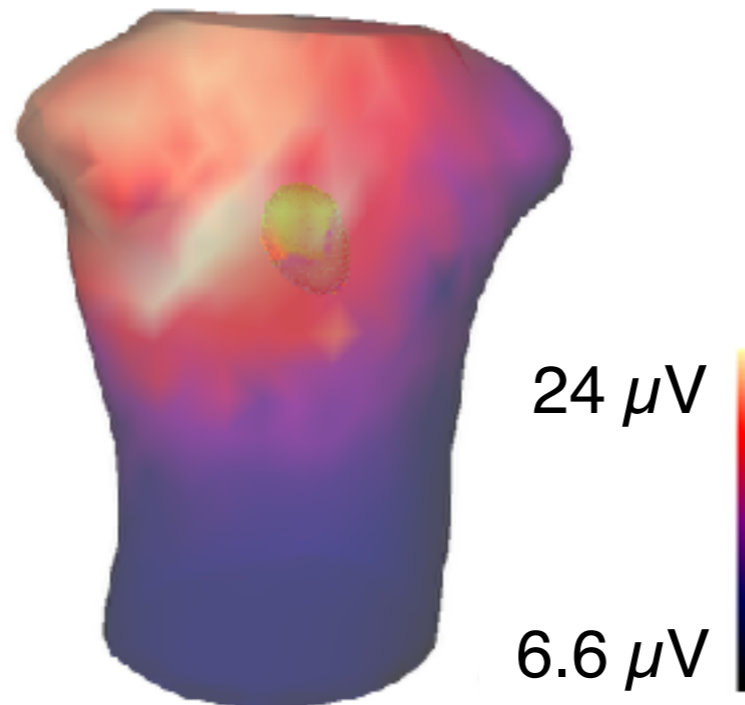
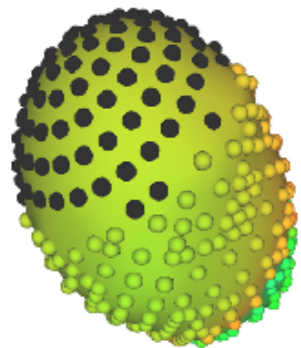
Ground Truth



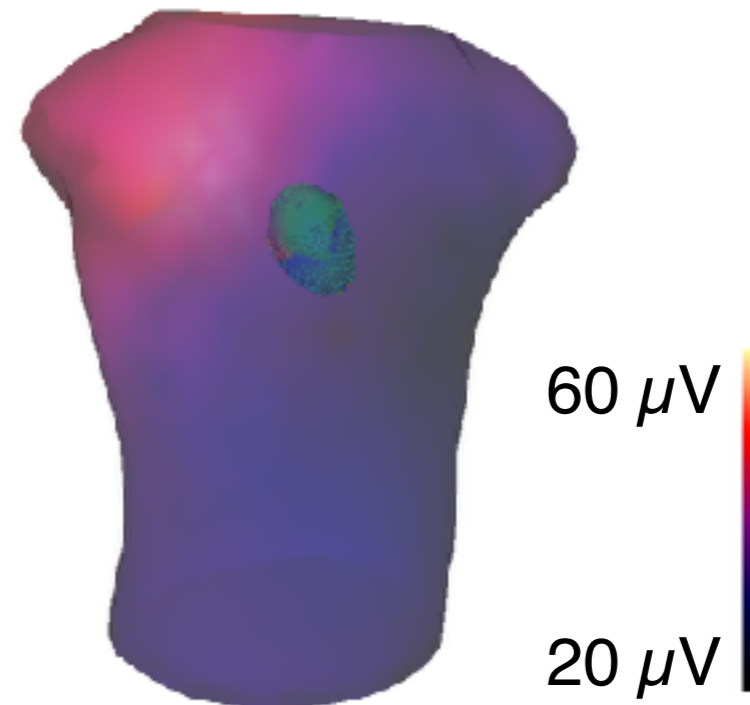
Ventricular Only



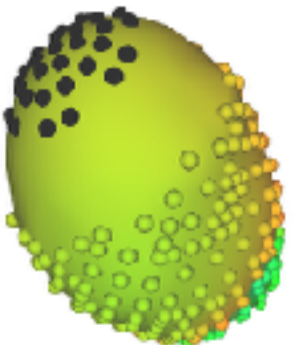
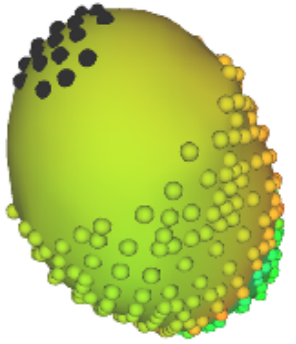
16 More Electrodes



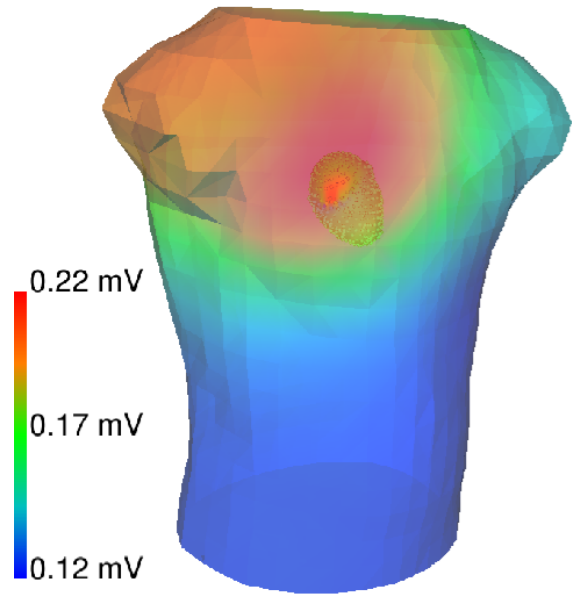
Full Sock



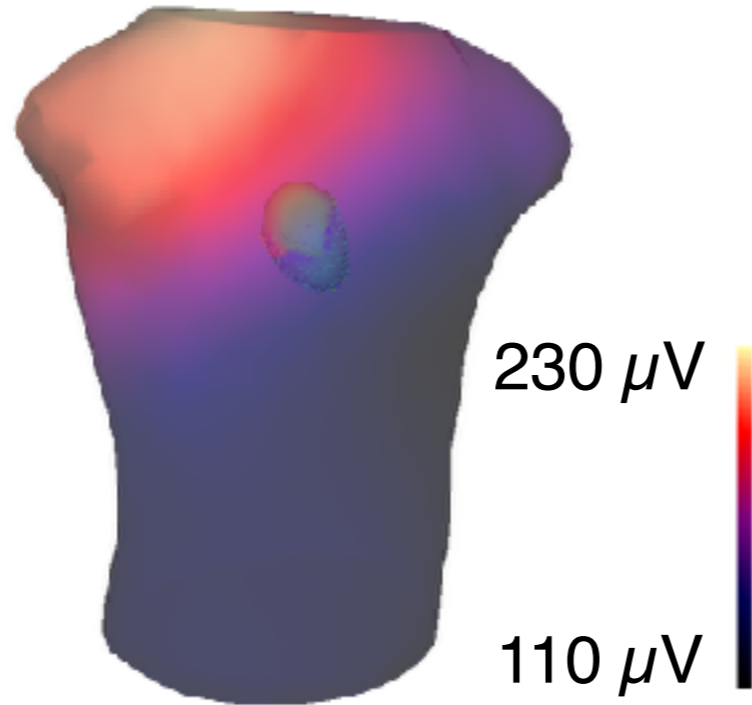
31 More Electrodes



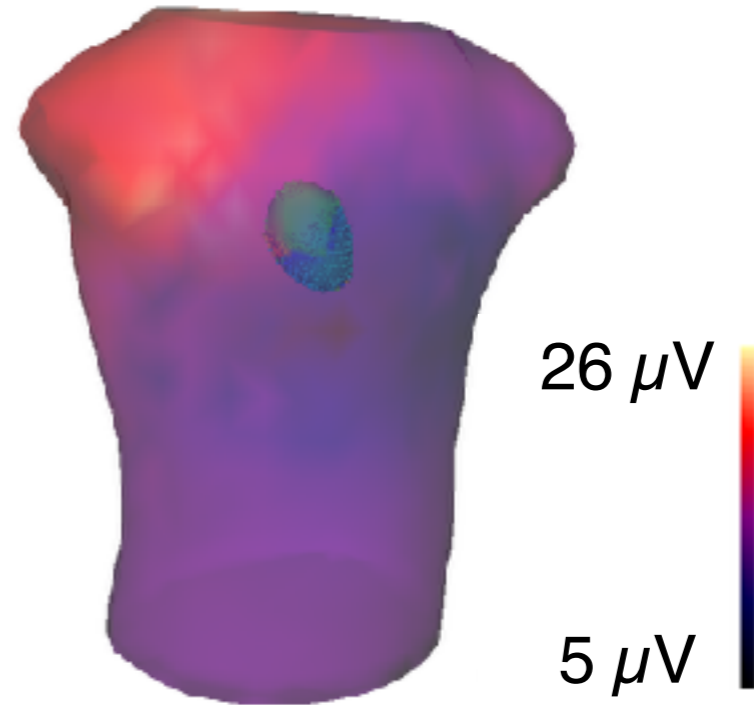
# Difference in Prediction



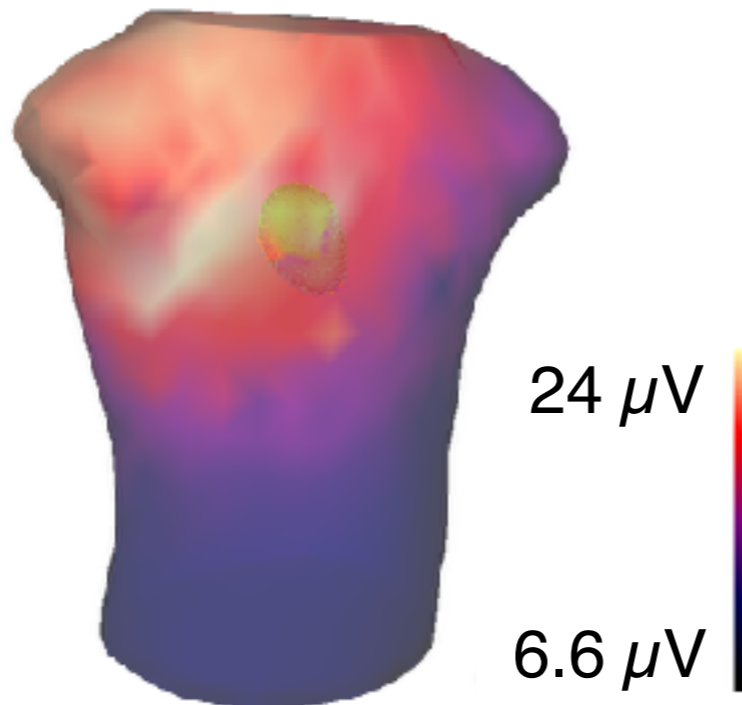
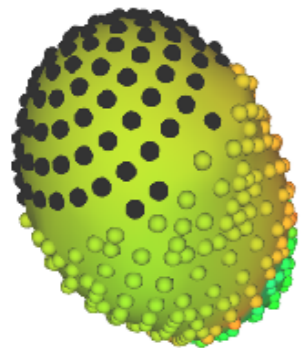
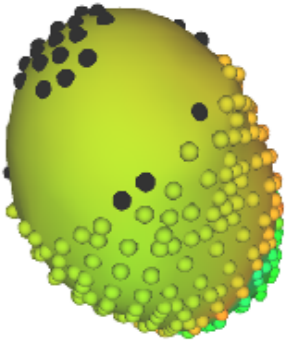
Ground Truth



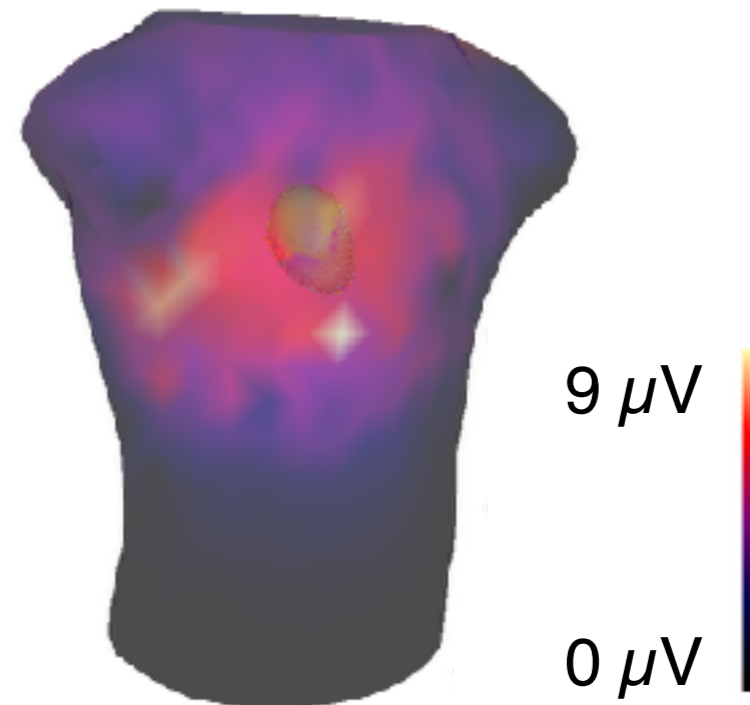
Ventricular Only



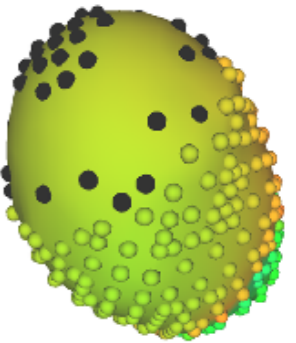
31 More Electrodes



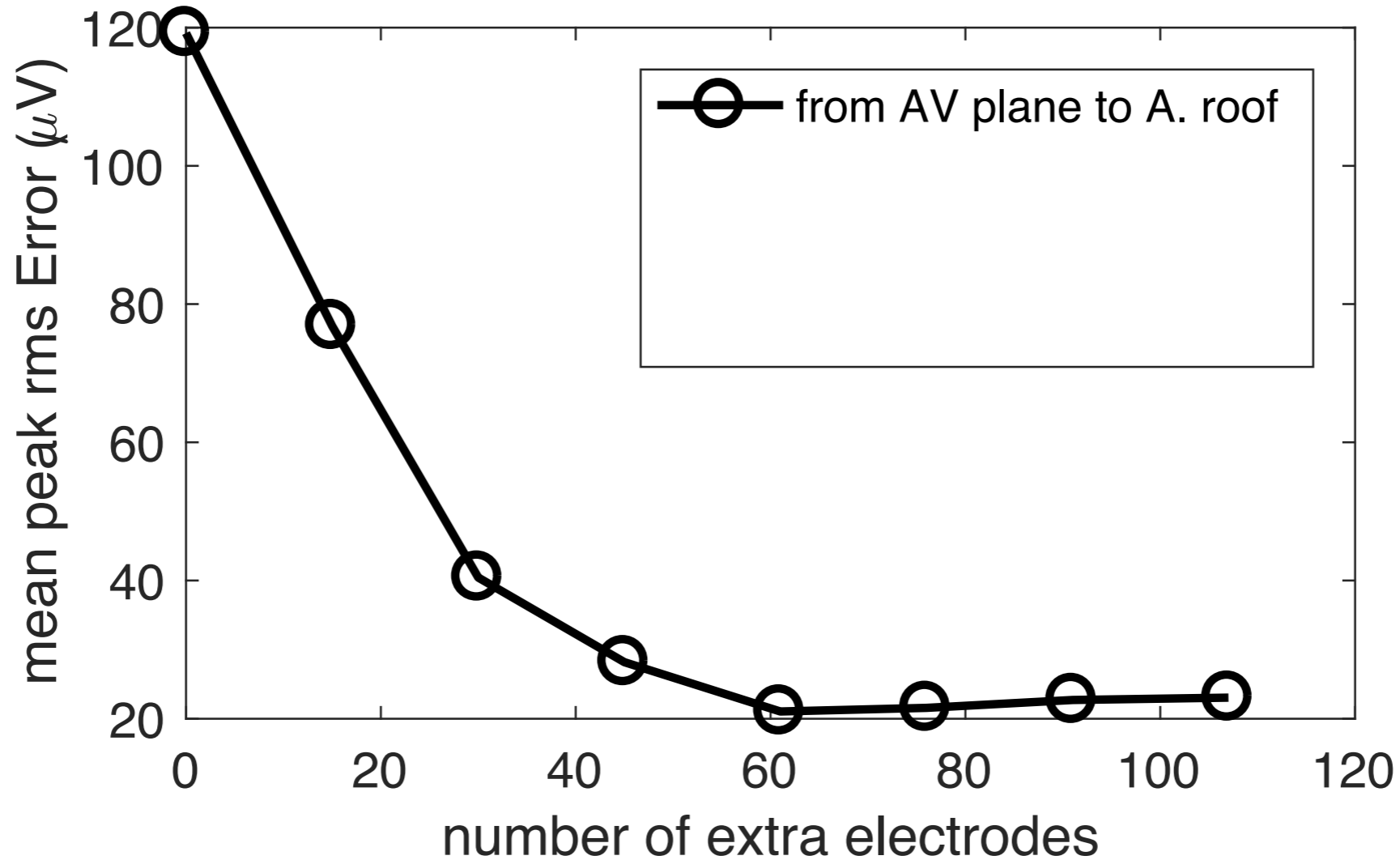
Full Sock



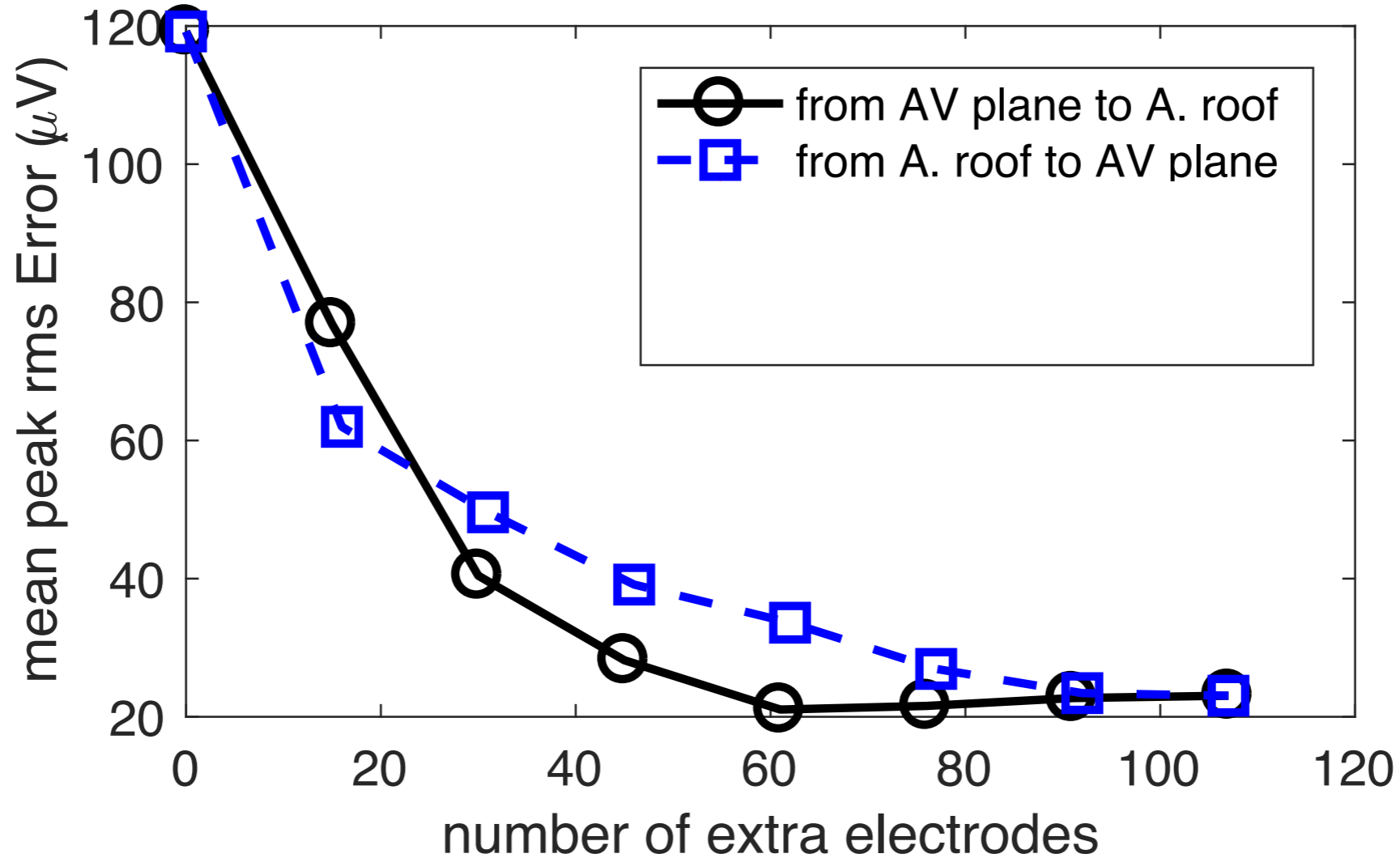
46 More Electrodes



# Comparing Sampling

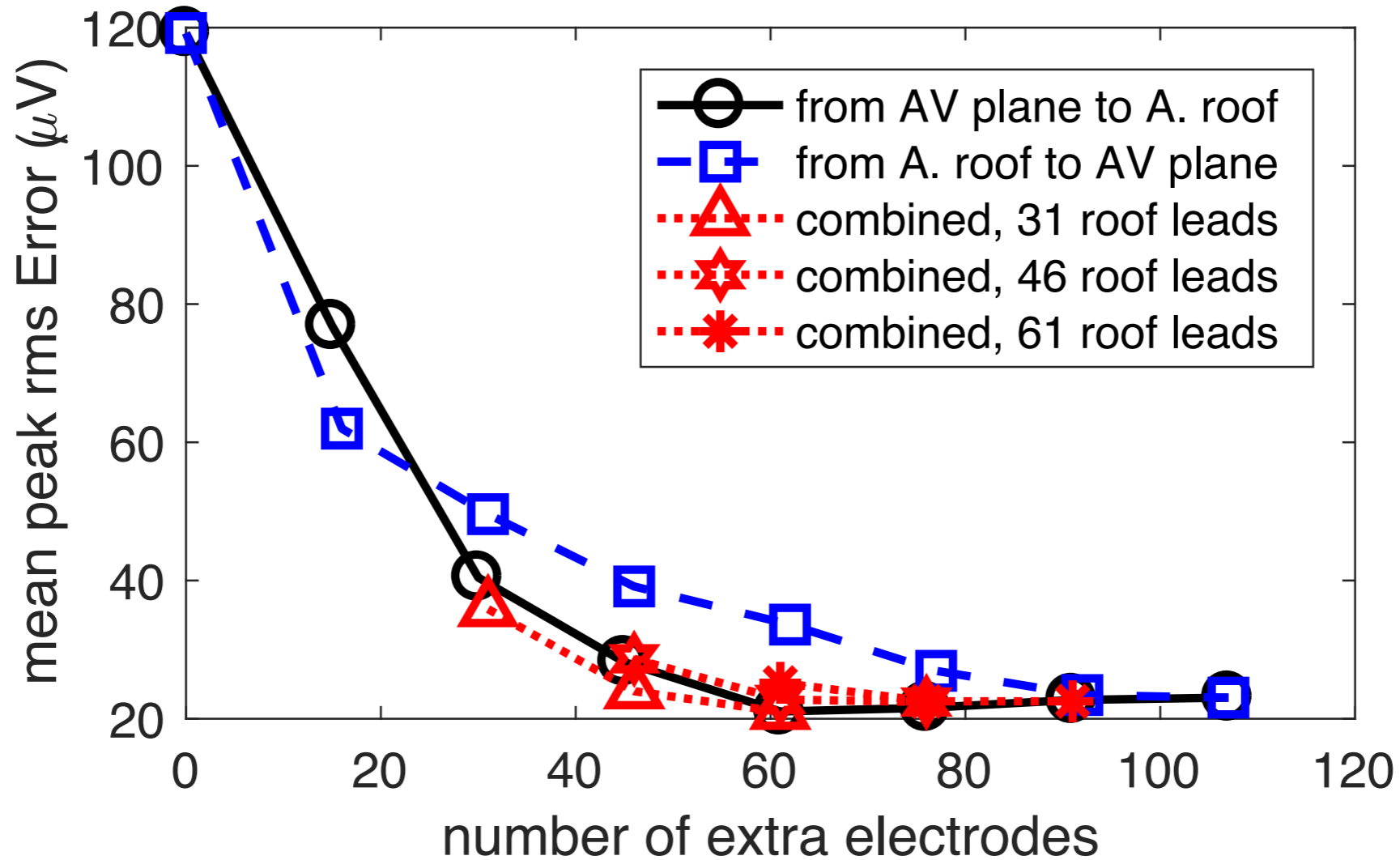


# Comparing Sampling

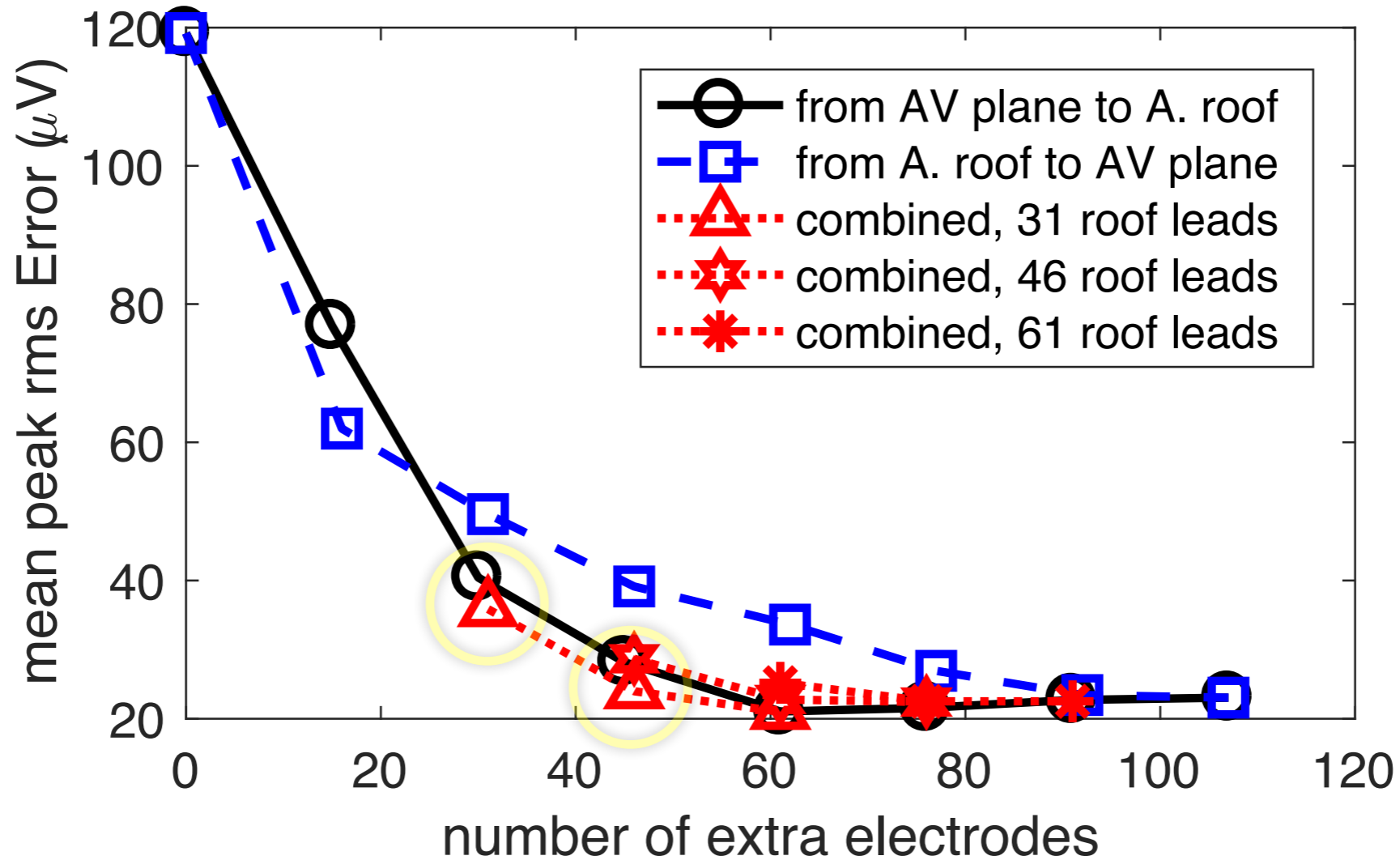




# Comparing Sampling



# Comparing Sampling



# Possible Sampling

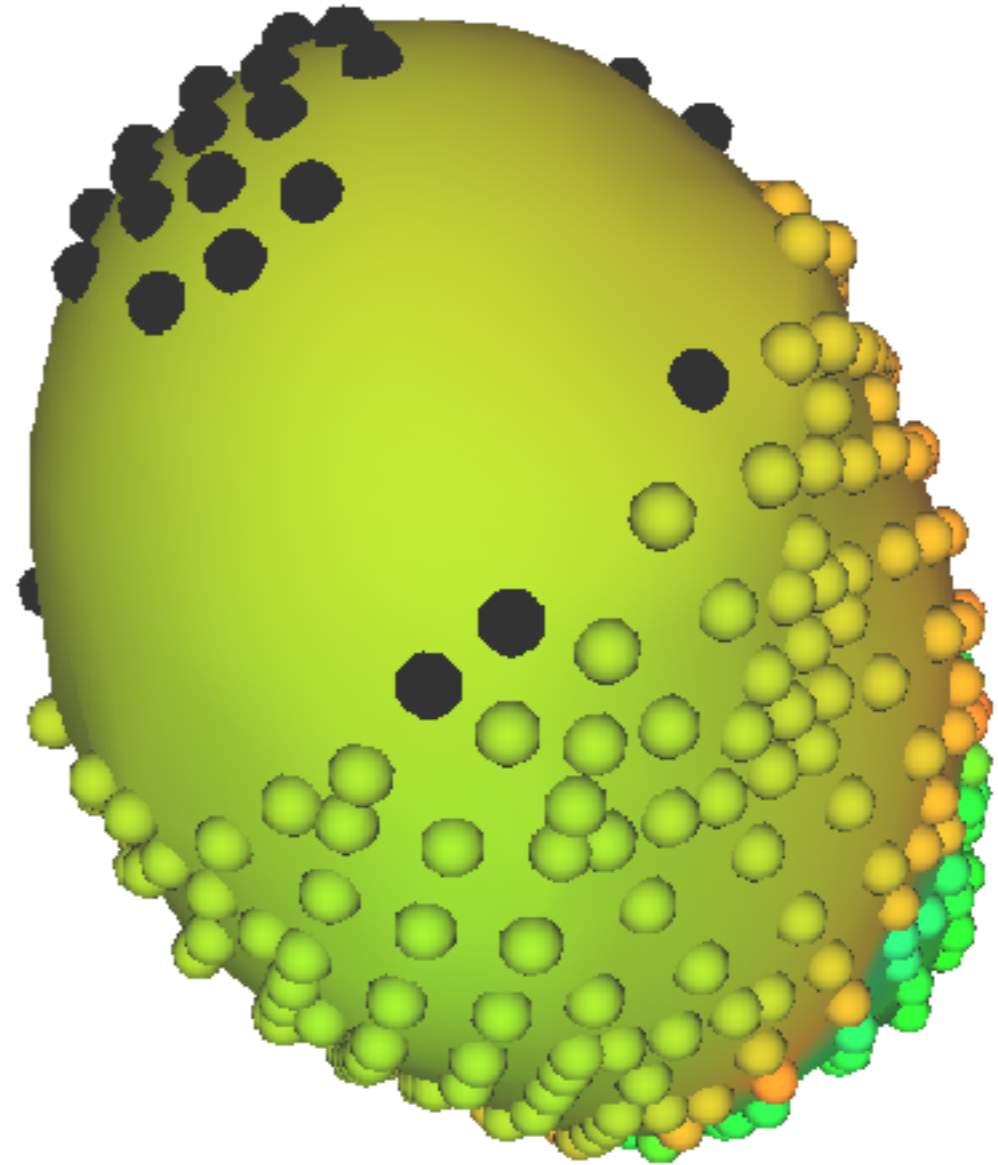
More electrodes  
are better

Careful placement  
can reduce error

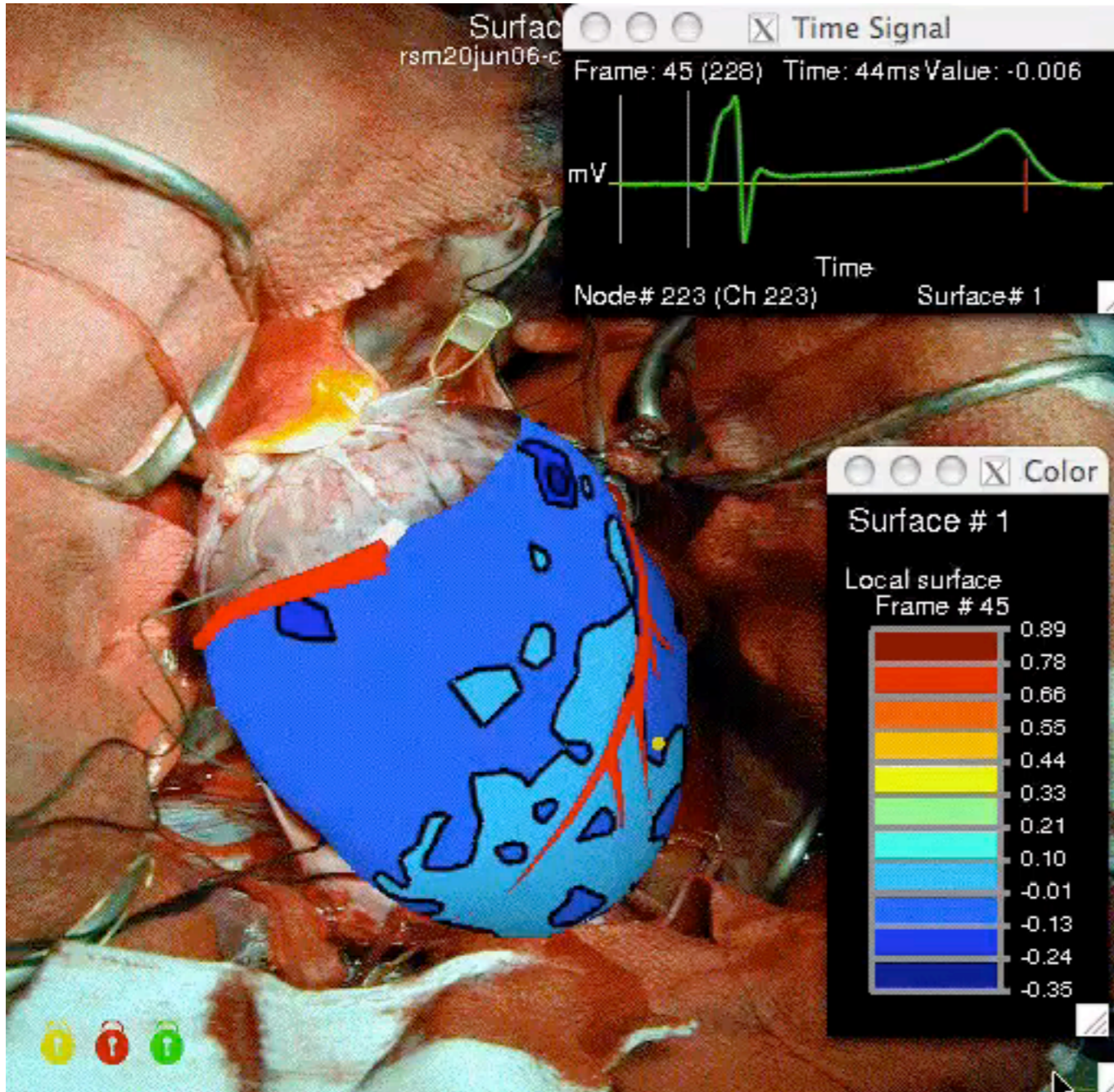
# Possible Sampling

More electrodes  
are better

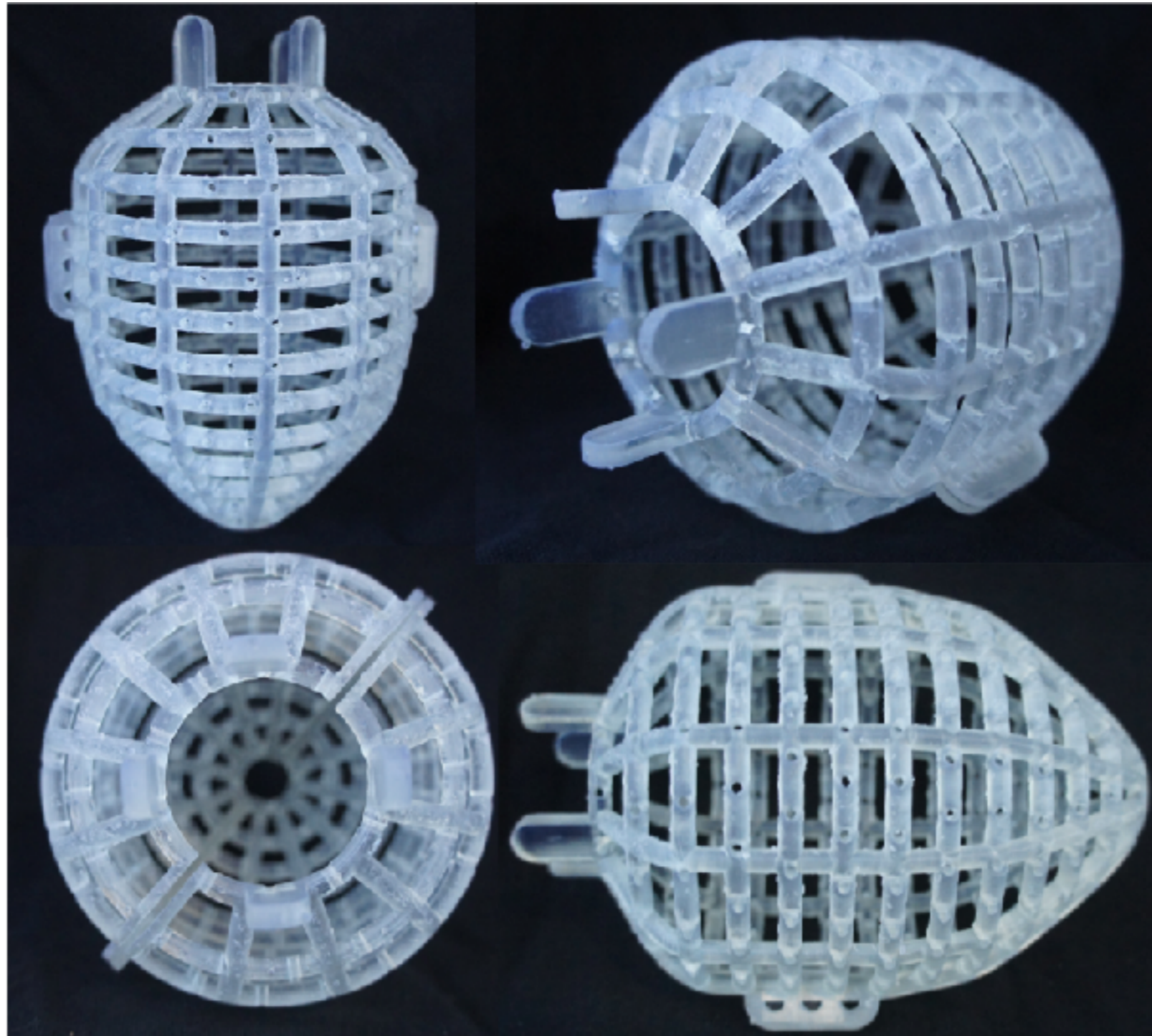
Careful placement  
can reduce error



# Experimental Strategy



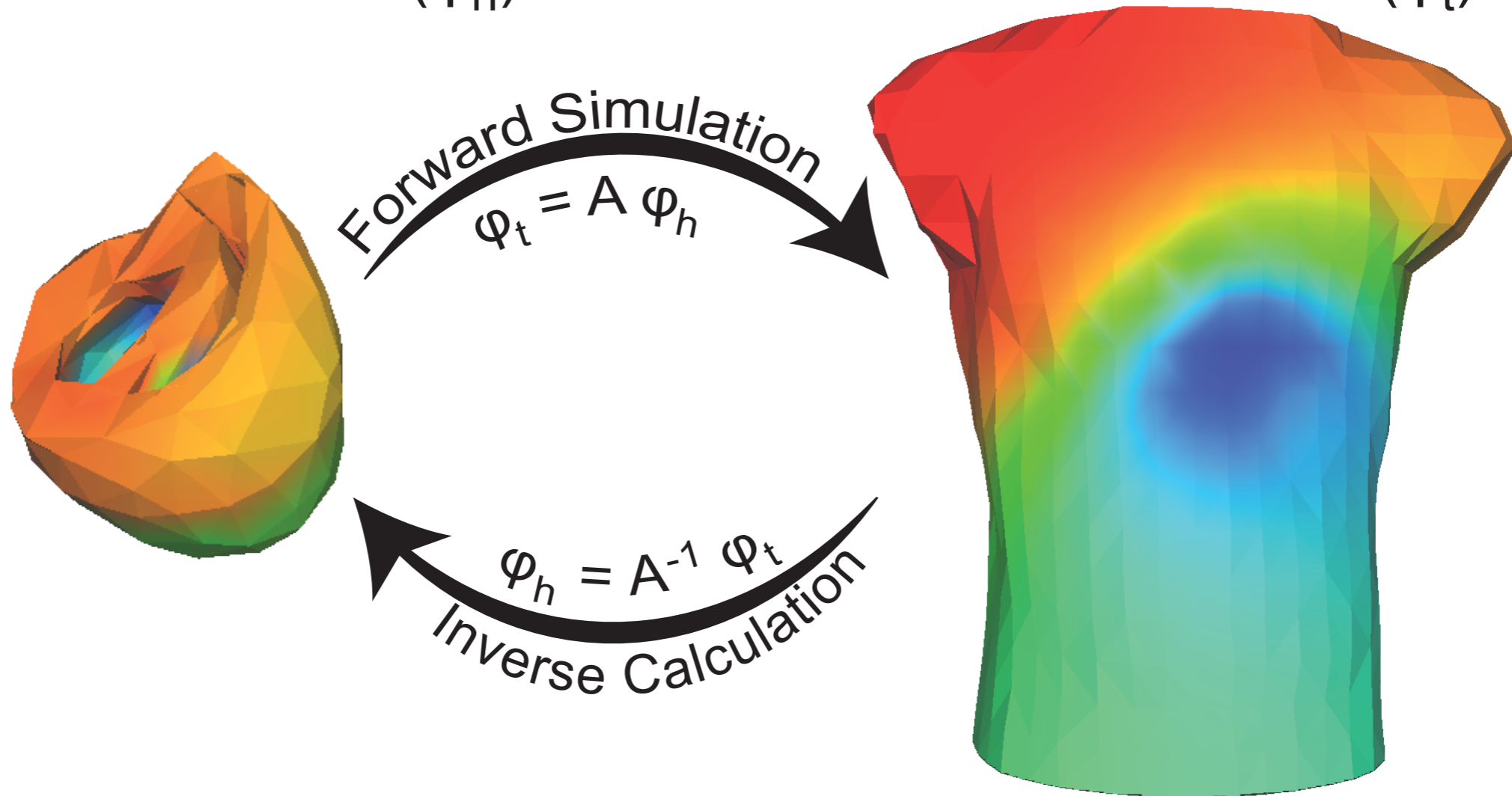
# Experimental Strategy



# Improve ECGI

Heart Potentials ( $\varphi_h$ )

Torso Potentials ( $\varphi_t$ )



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)