

# Verification of a Defibrillation Simulation Using Internal Electric Fields in a Human Shaped Phantom

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# Fibrillation

Normal Heart Beat

Fibrillation



Fibrillation

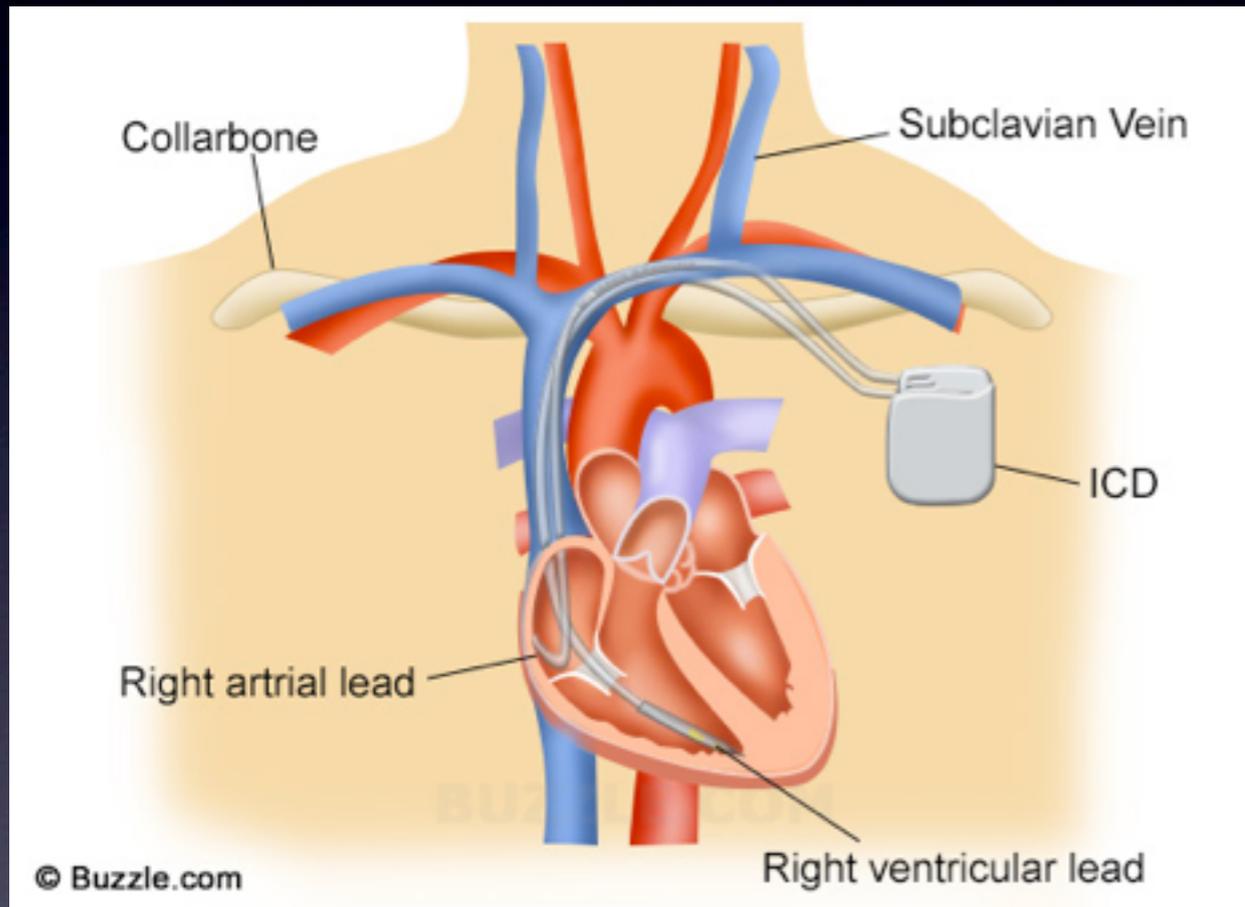
Electric Shock

Normal Heart Beat



# Defibrillation

## Implantable Cardioverter Defibrillator- ICD



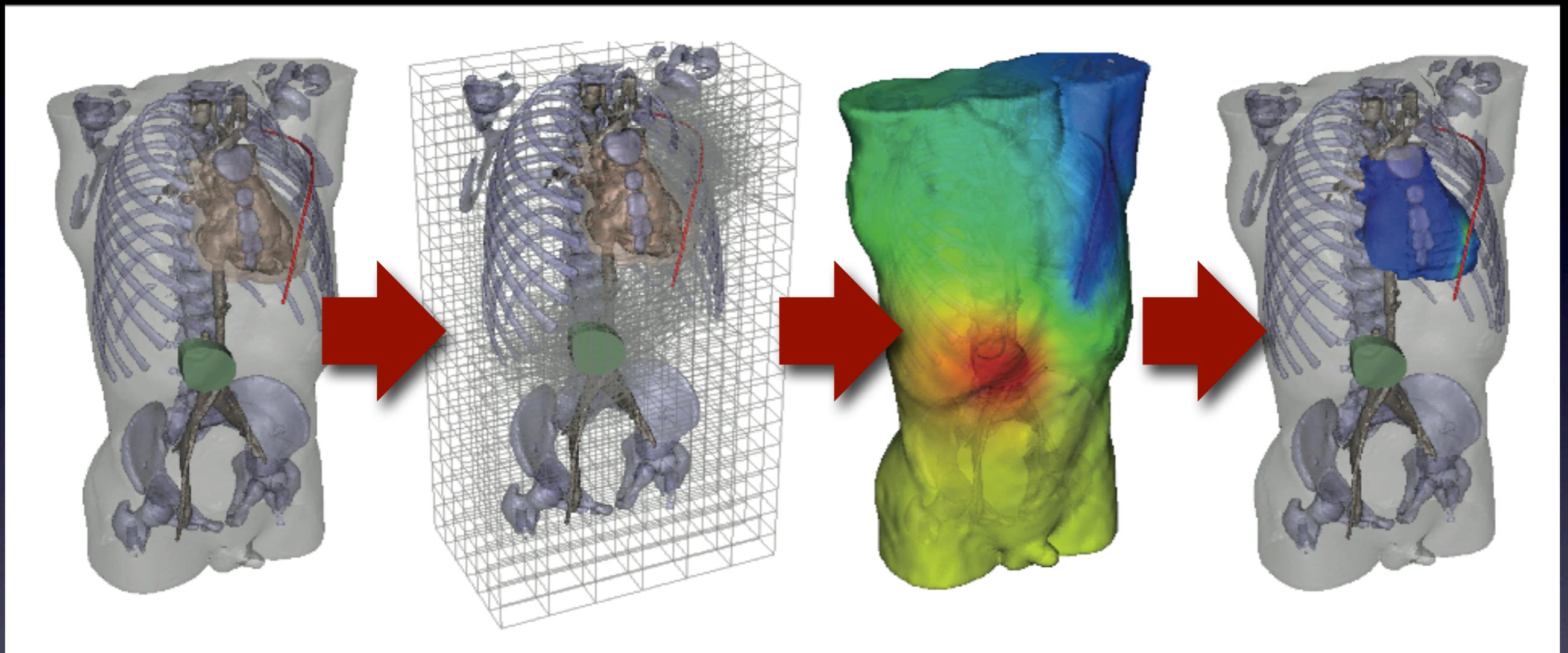
<http://www.buzzle.com/>

## Automatic External Defibrillator- AED



<http://www.wtamu.edu/>

# Our Pipeline: Model Generation



Place electrode leads

Build hex/tet mesh

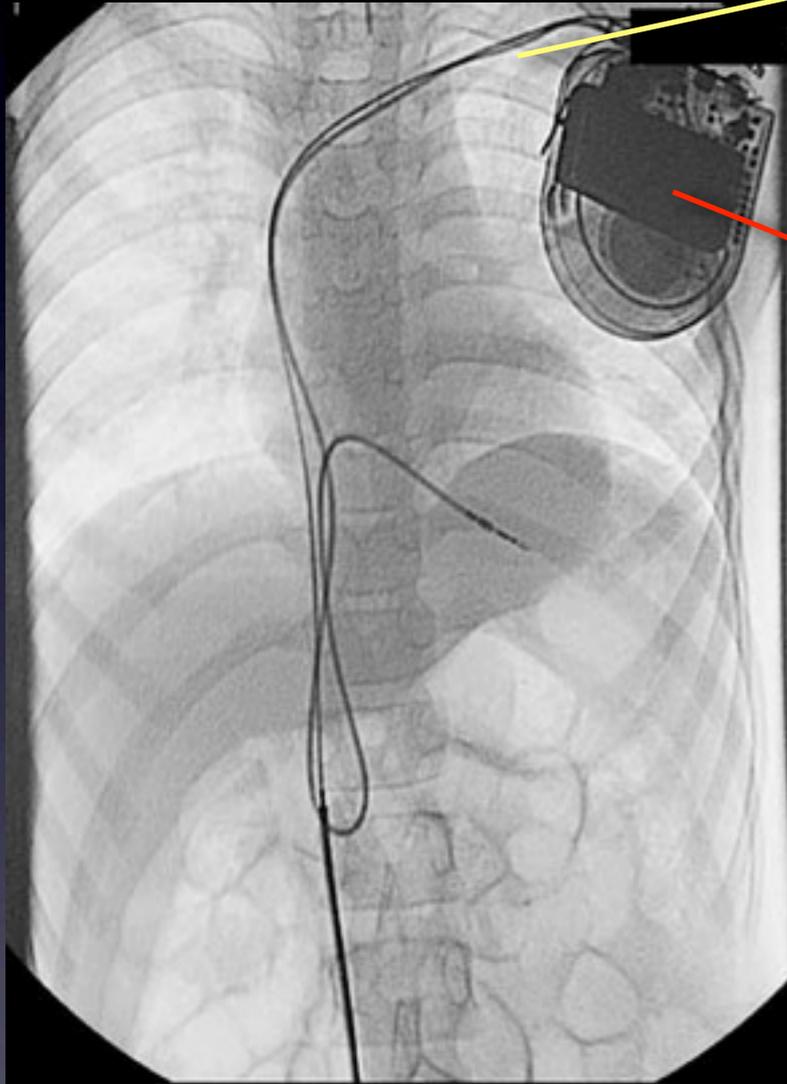
Solve potentials using FEM

Evaluate electric field strength

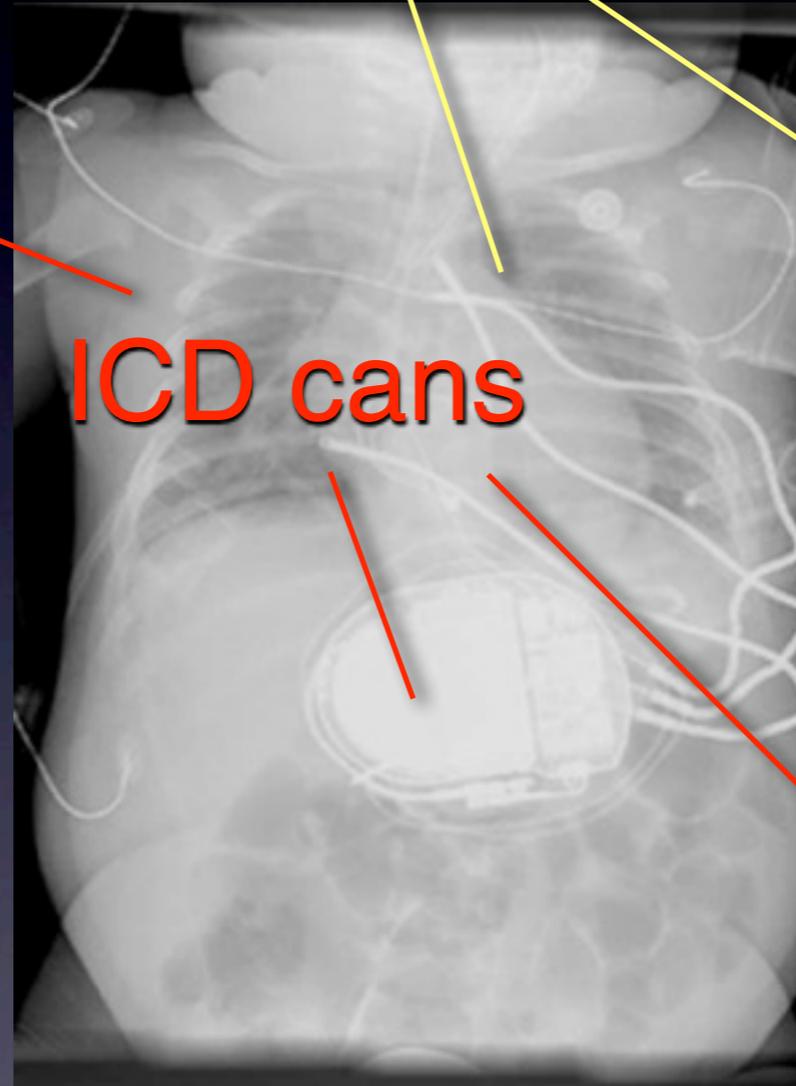
Performed with SCIRun

# Pediatric Defibrillation

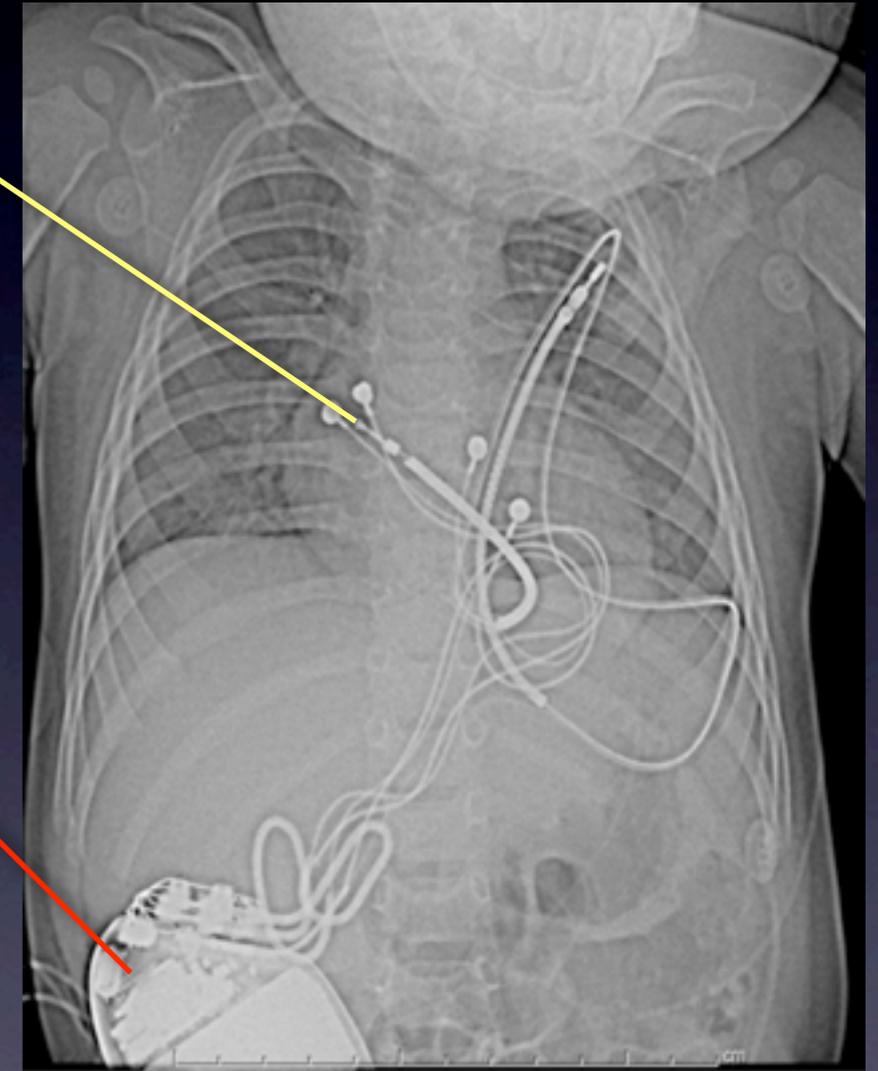
ICD leads



Gasparini, JCE, 2005



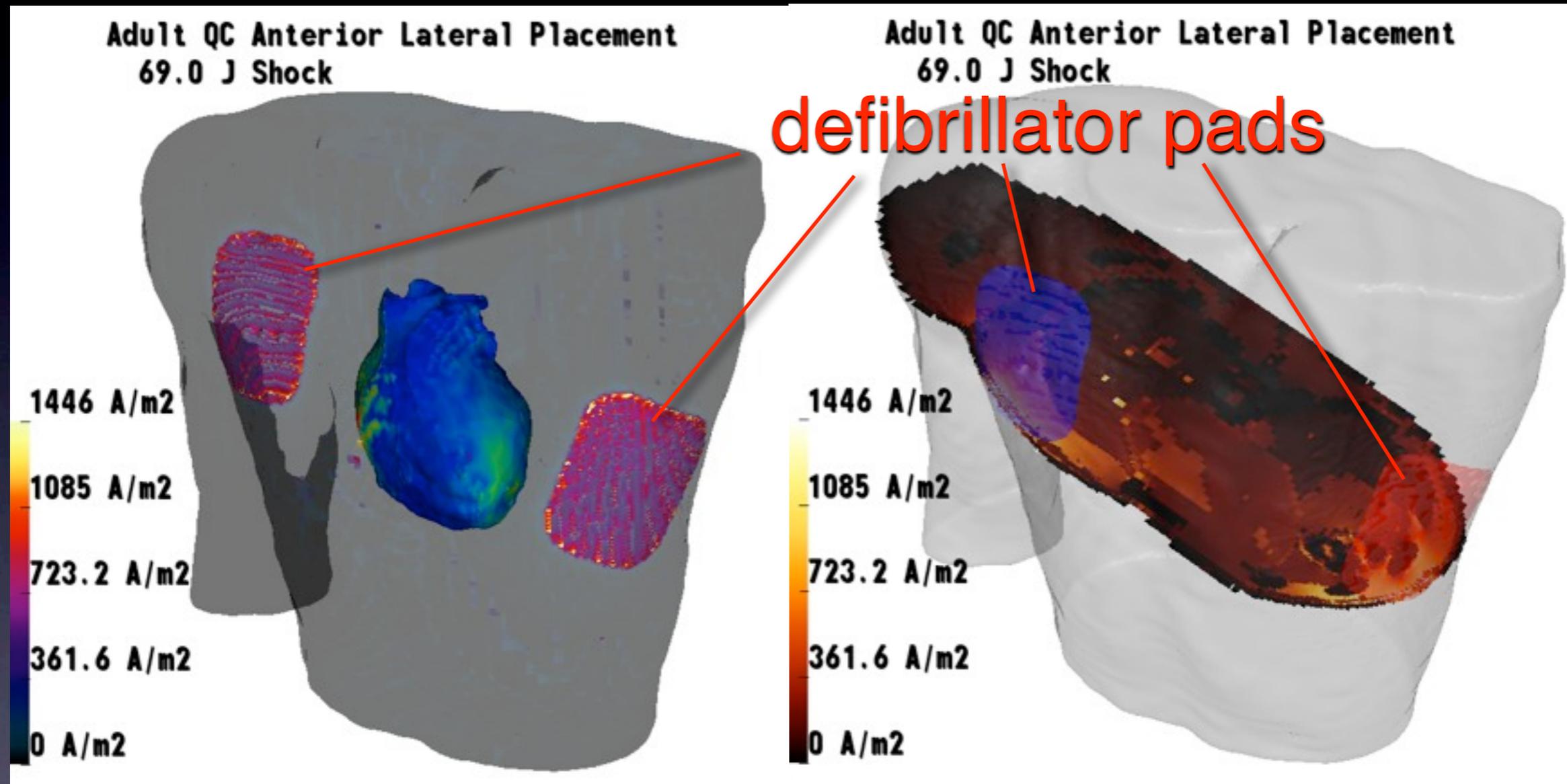
Stephenson, JCE, 2006



Children's Hospital Boston

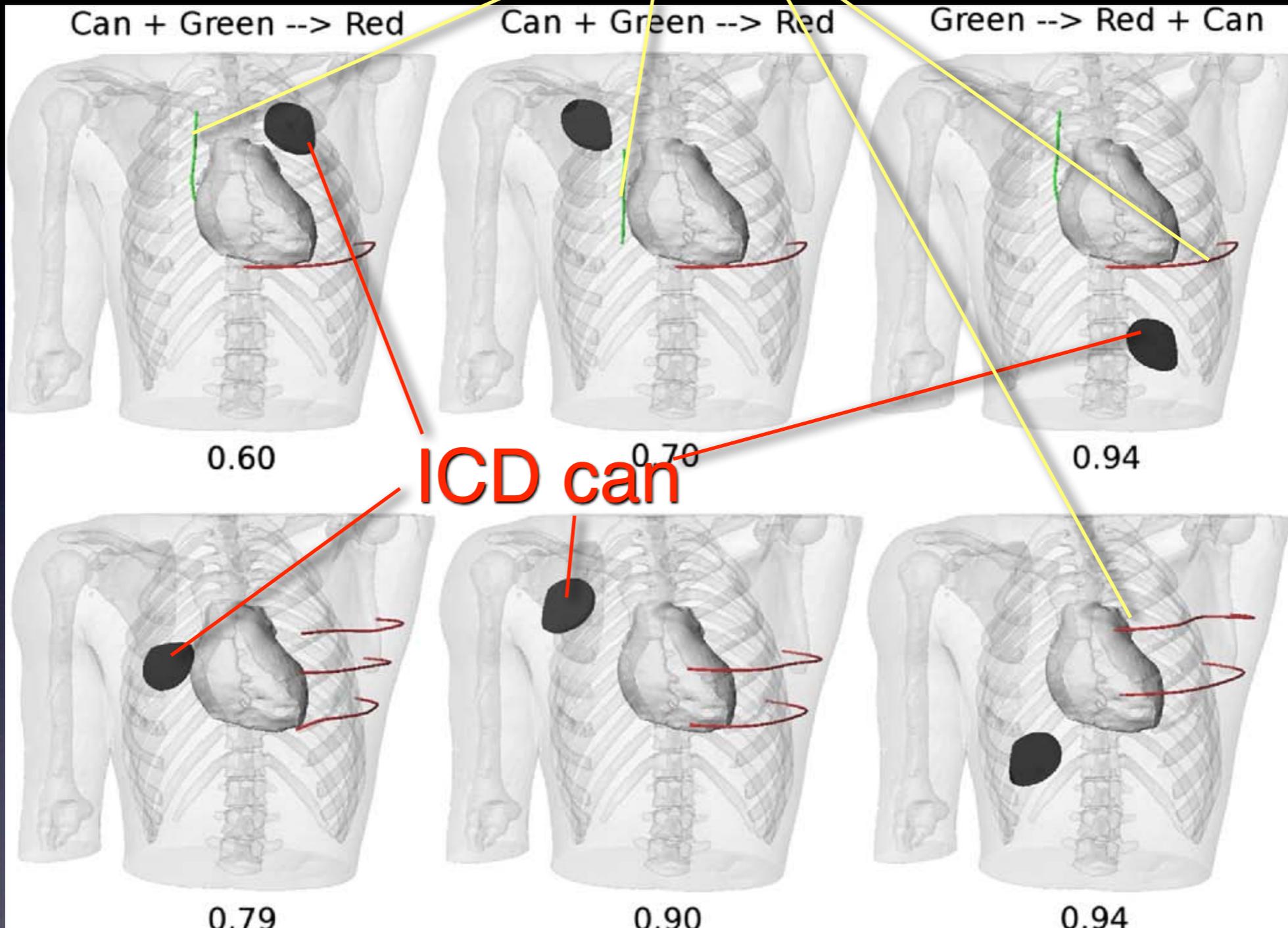
Jolley M, et al. Heart Rhythm J 2008;5(4):565--572

# External Defibrillation



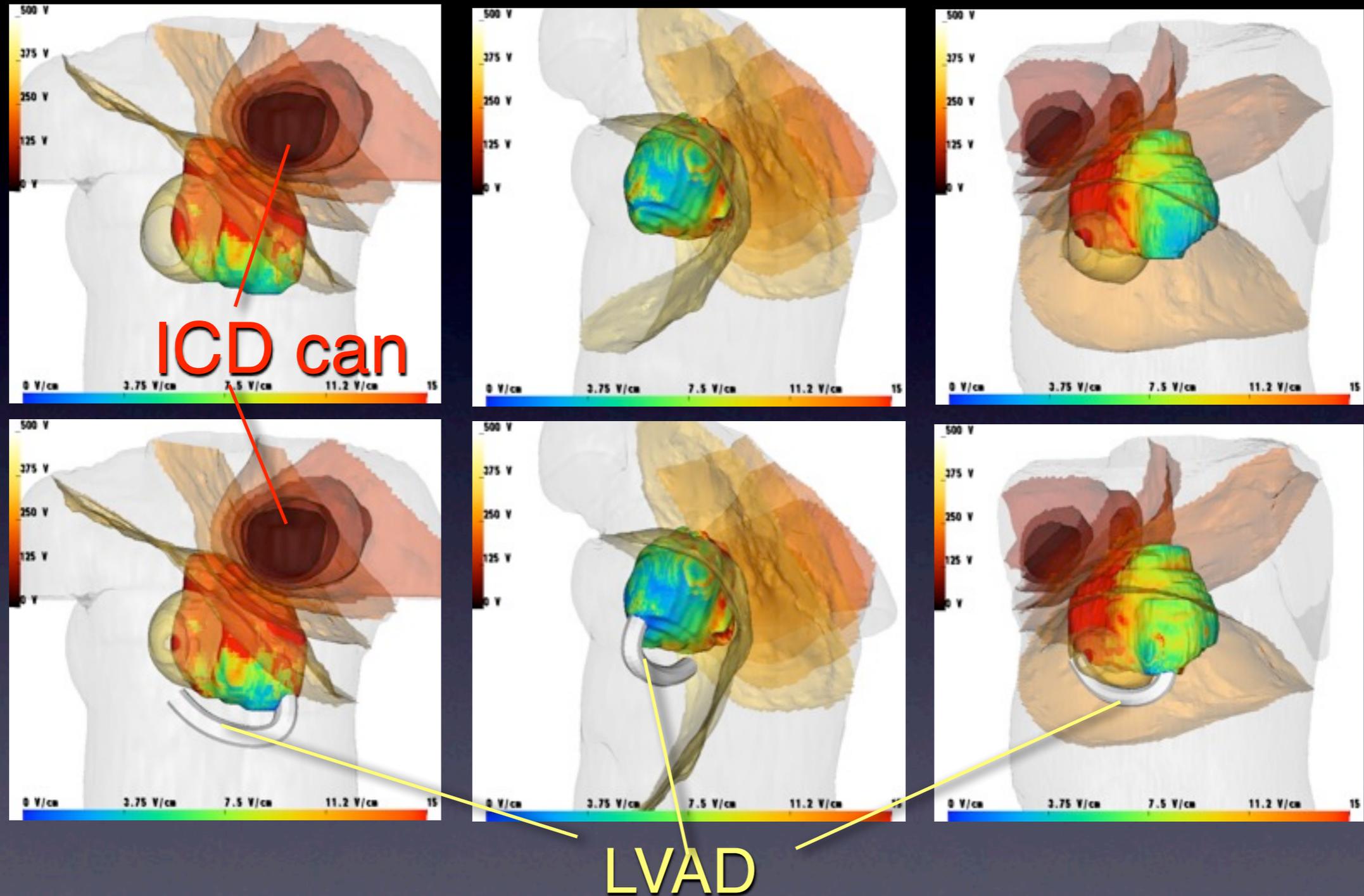
# New ICD Configurations

ICD leads



Jolley M, et al. Heart Rhythm J May 2010;7(5):692–698

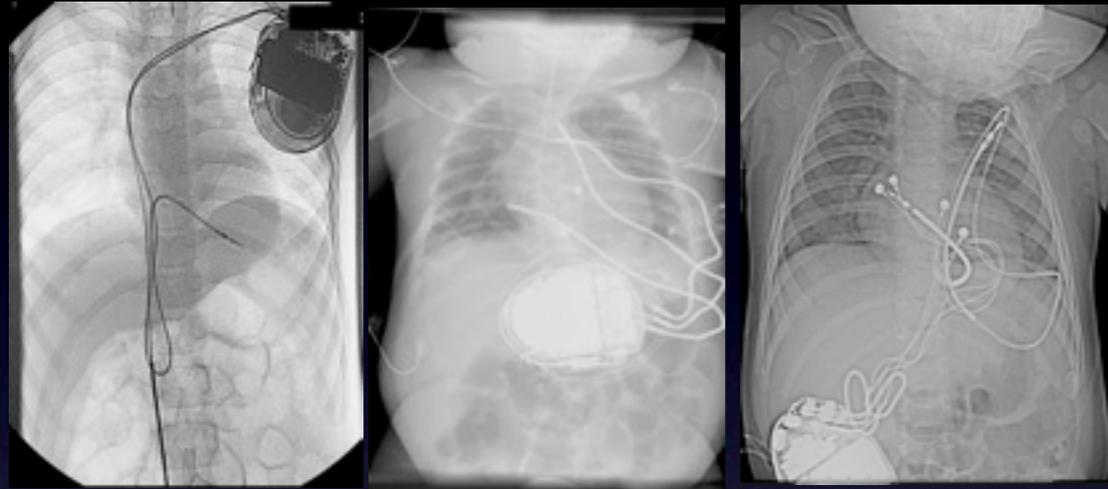
# Stray Metal in Torso



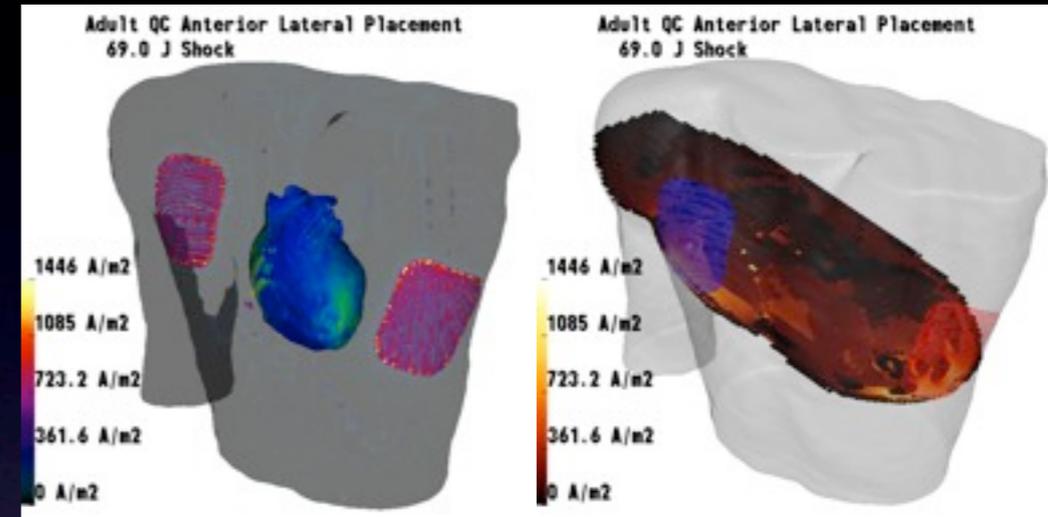
Pilcher T, et al. In American Heart Association, Scientific Sessions. November 2013

# Simulation Applications

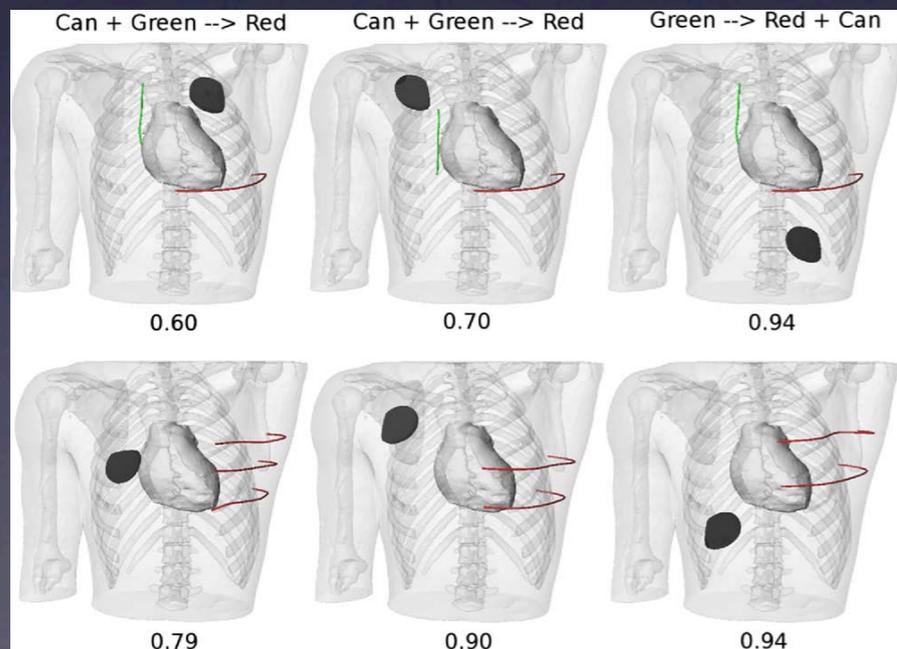
## Pediatric Defibrillation



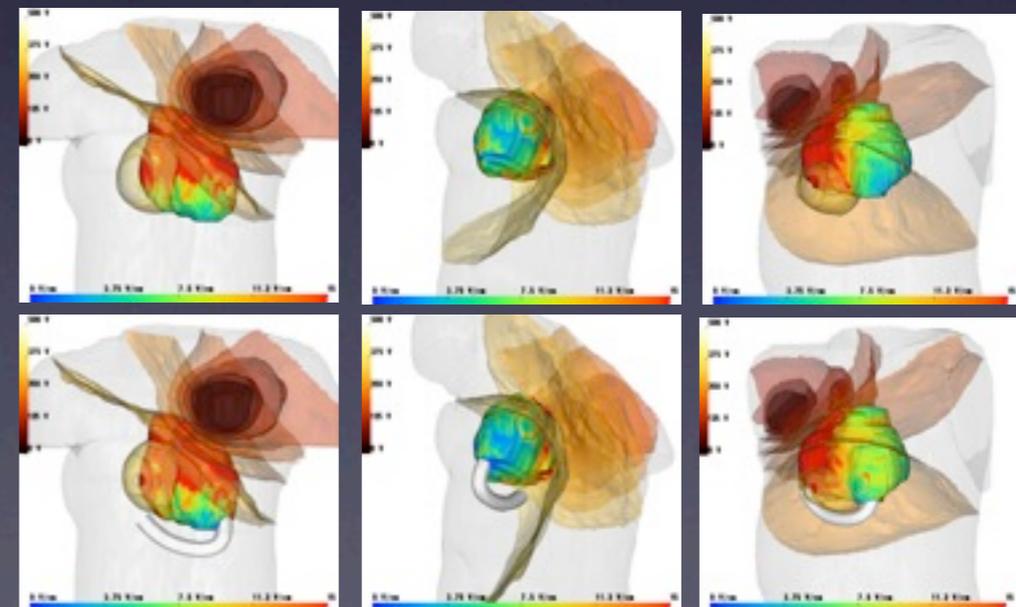
## External Defibrillation



## New Configurations



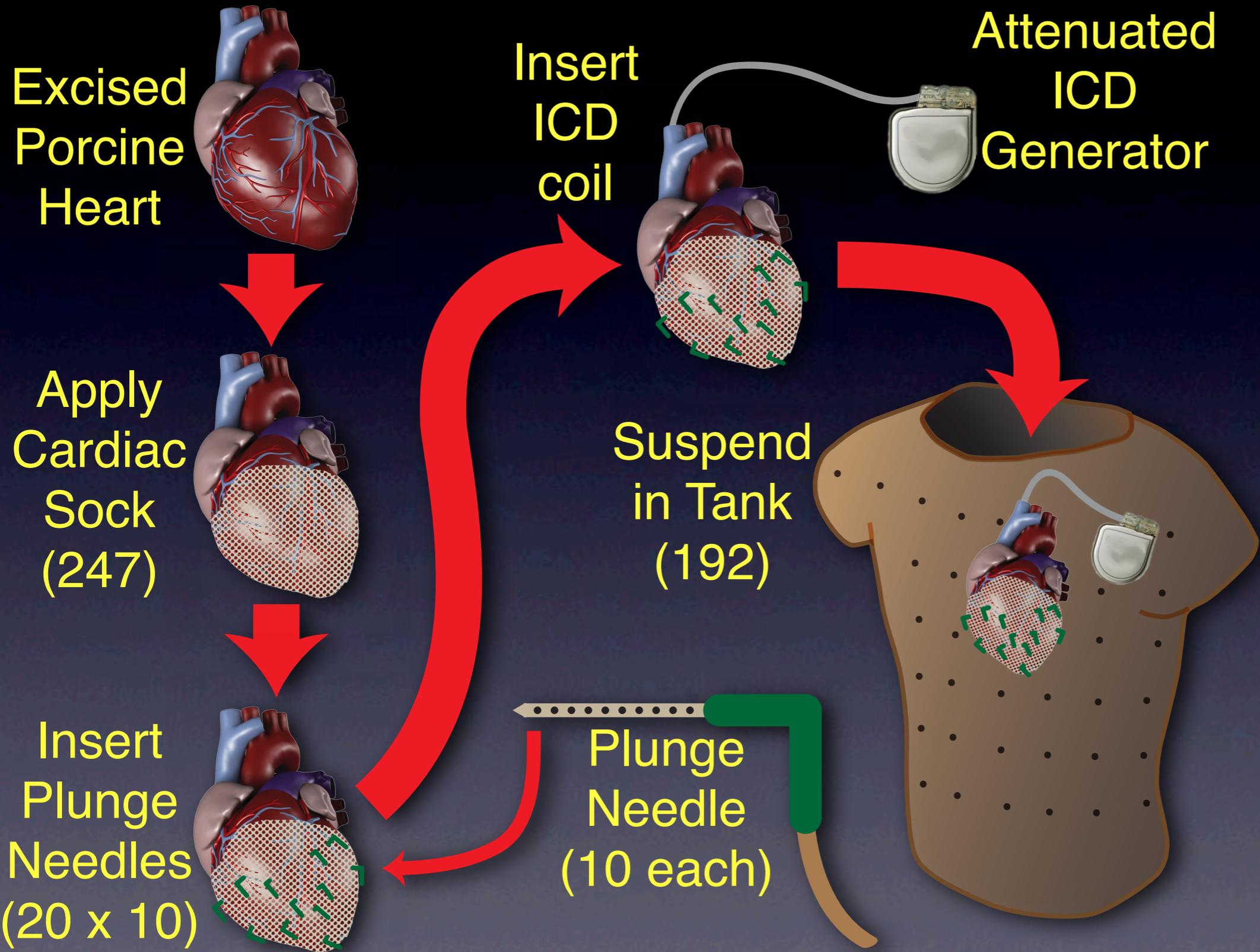
## Stray Metal



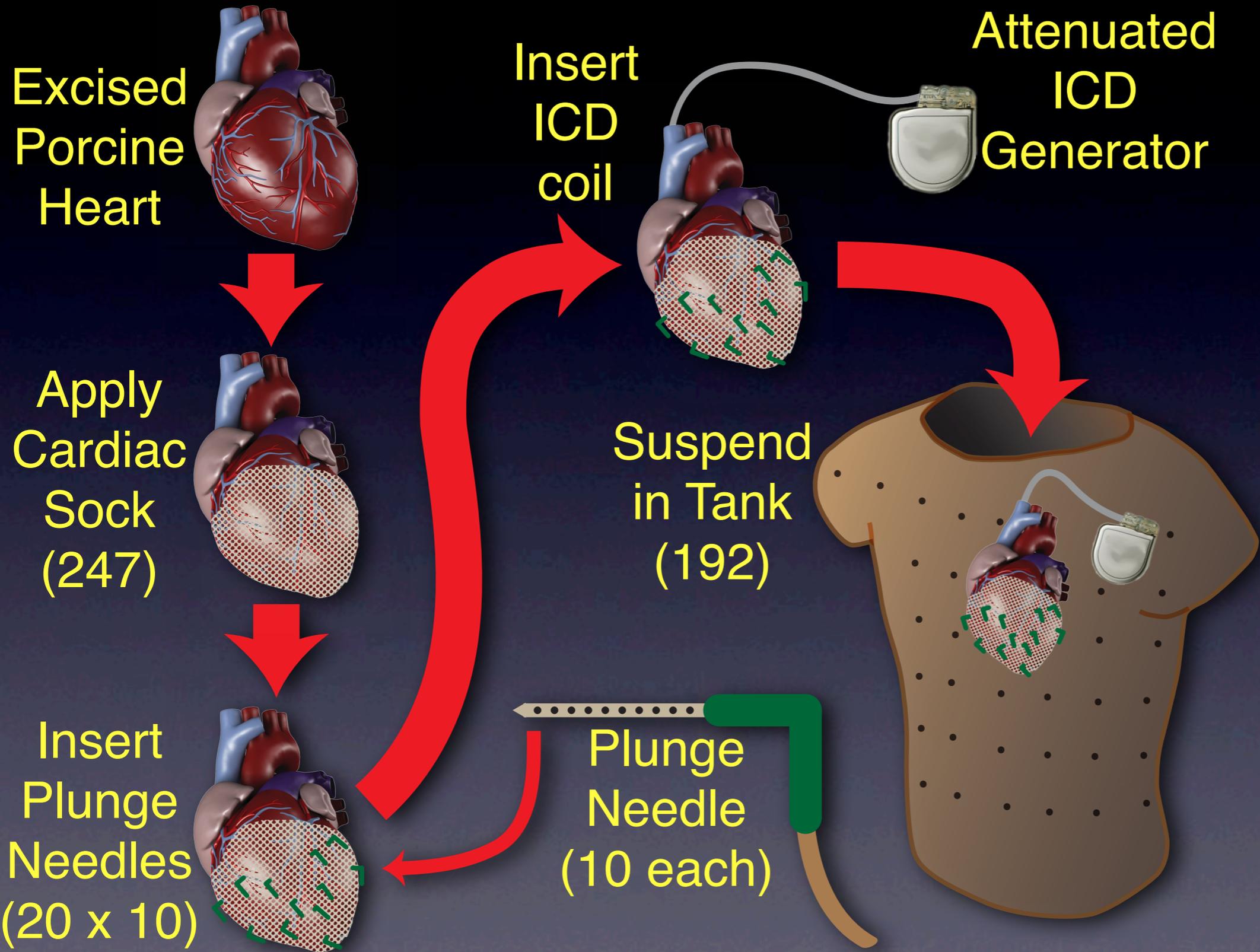
Goal:

Verification using a torso tank setup

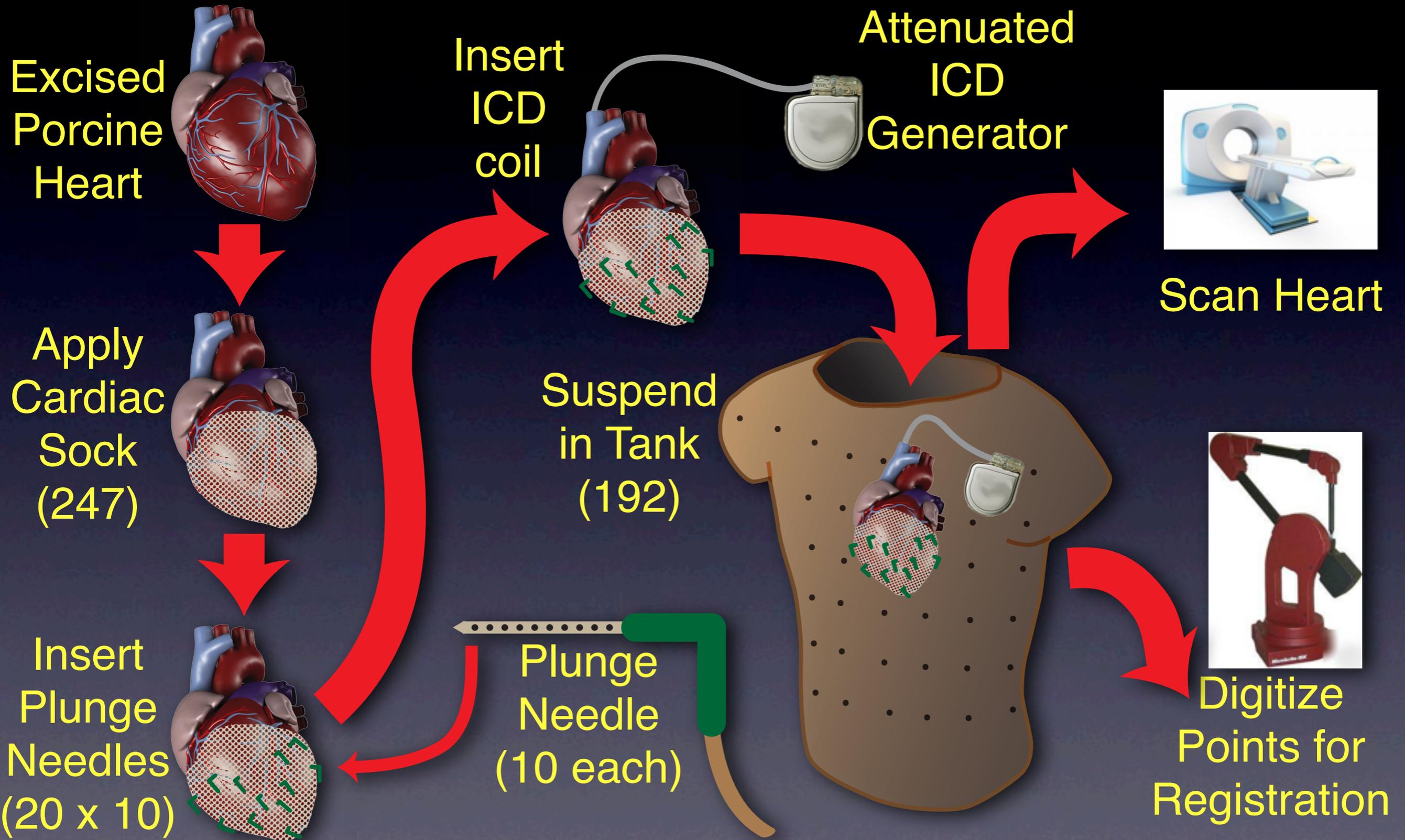
# Tank Experiments



# Tank Experiments



# Tank Experiments



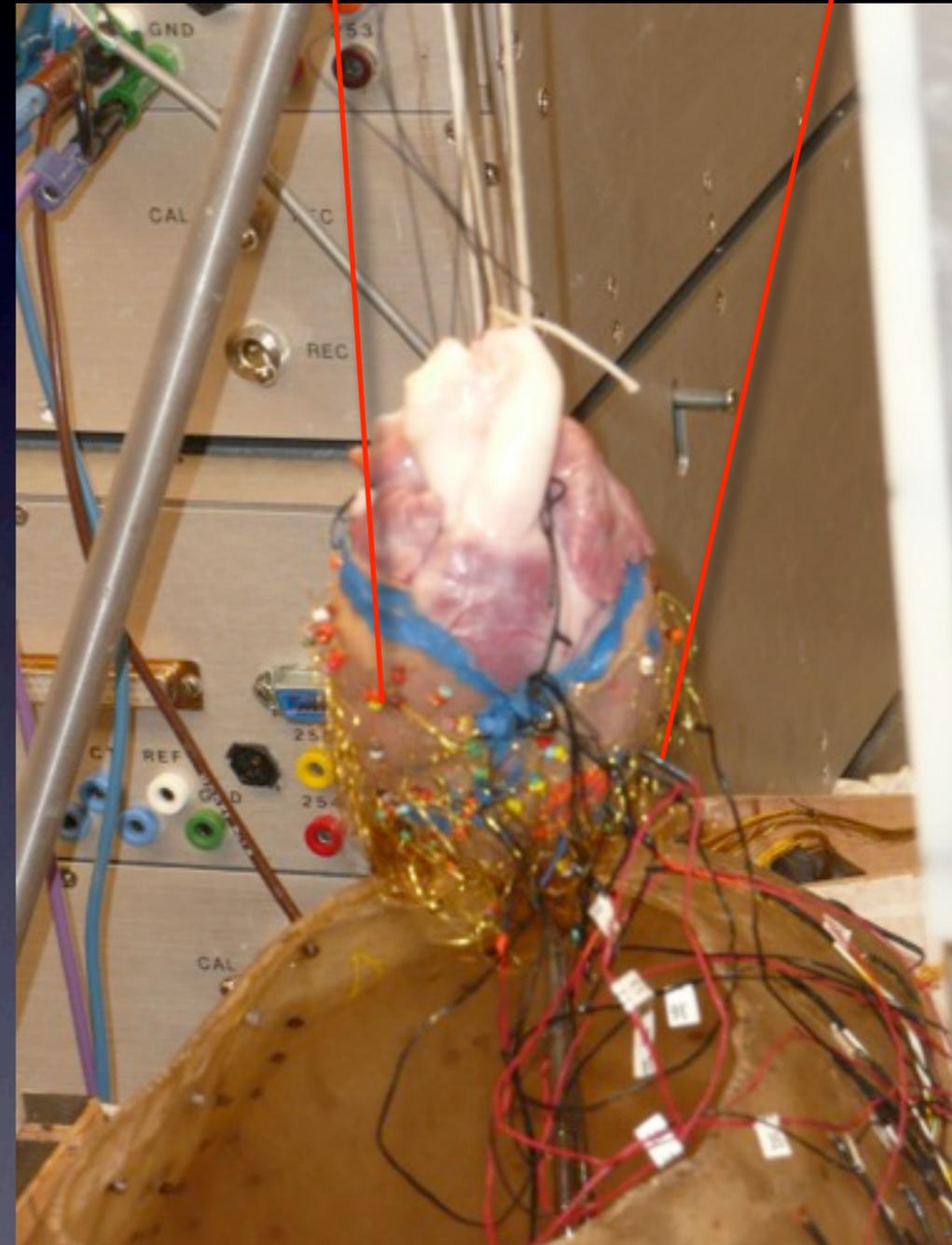
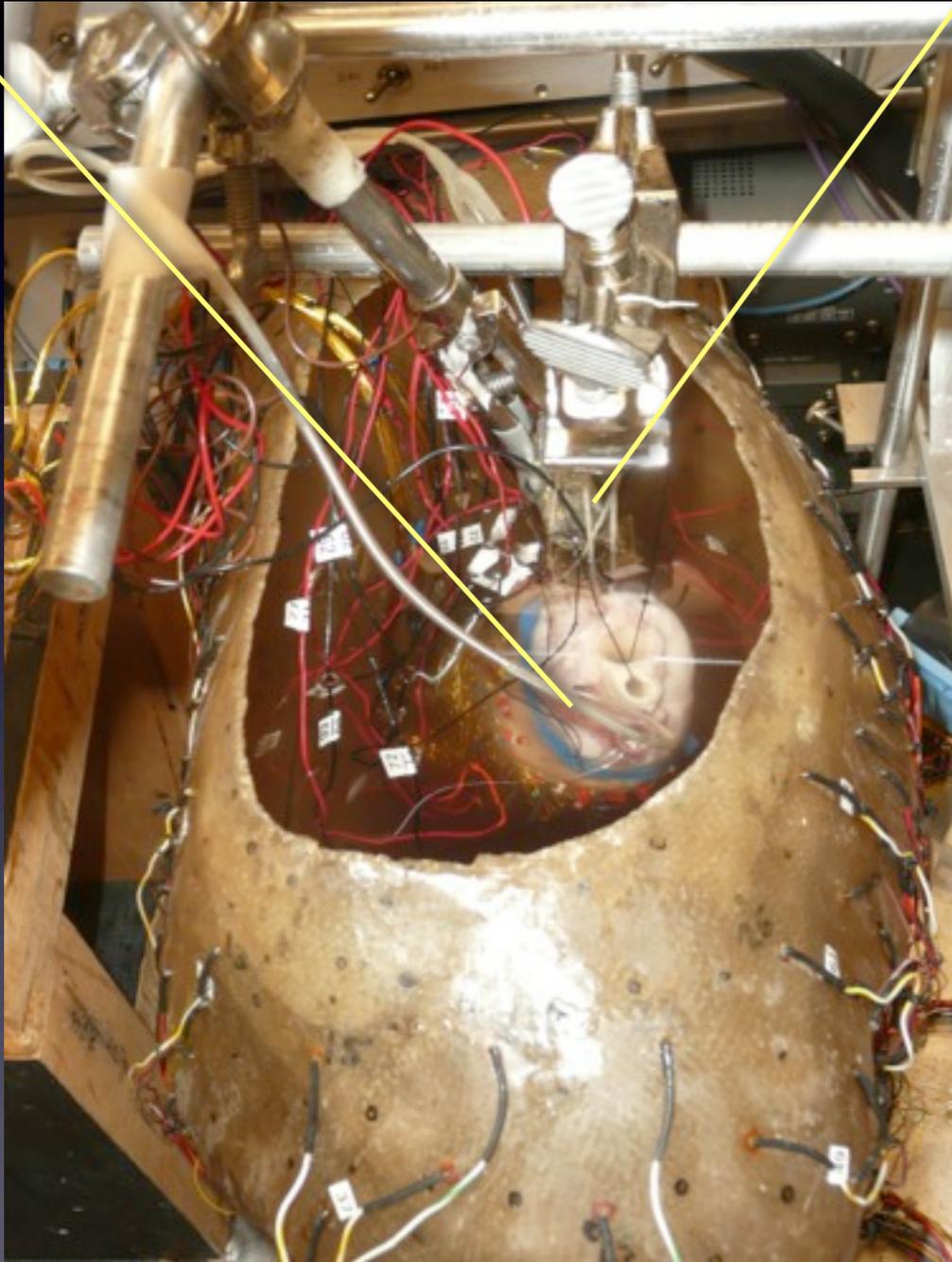
# Tank Experiments

ICD can

ICD can

sock

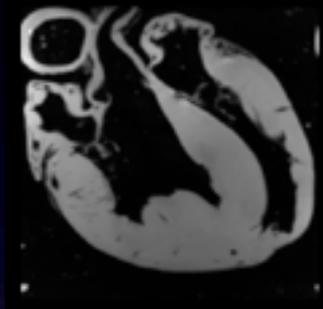
needles





# Simulation

MRI Scan



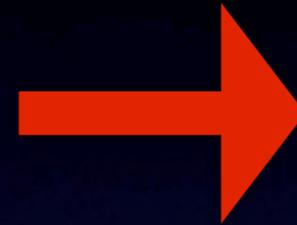
Seg3D



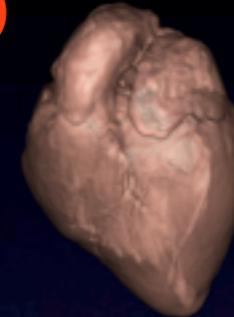
Segment



BioMesh3D



Make Heart Surface



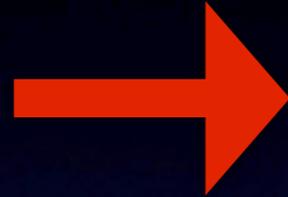
# Simulation

MRI Scan



Segment

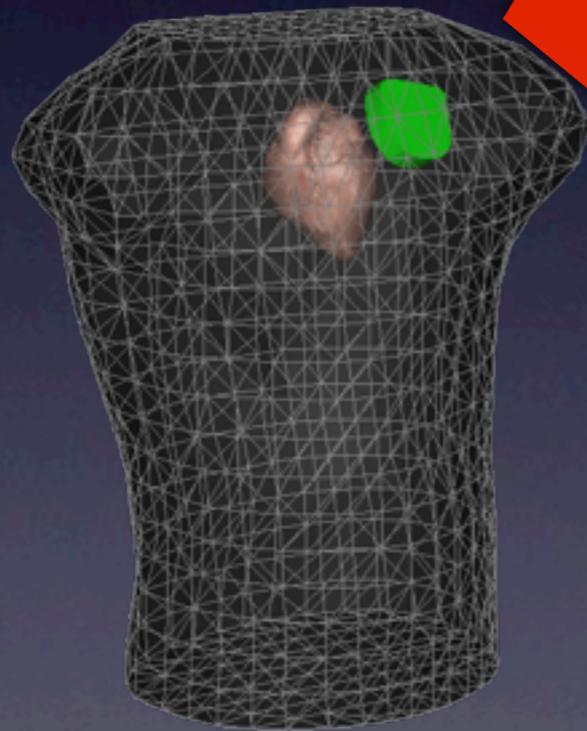
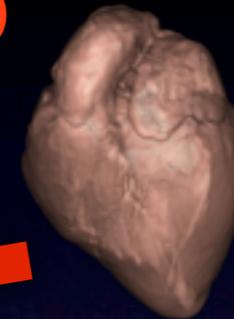
Seg3D



BioMesh3D

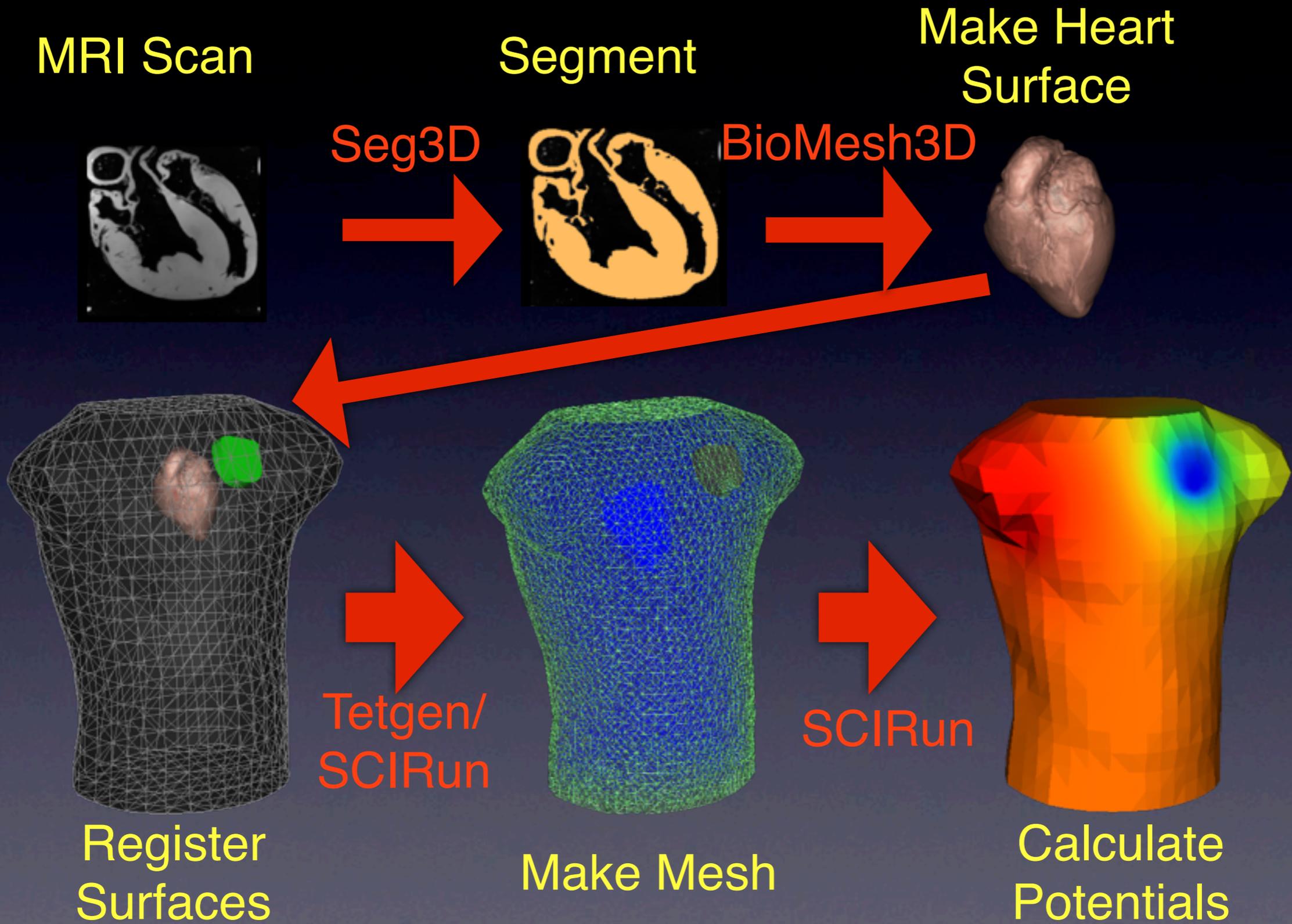


Make Heart Surface

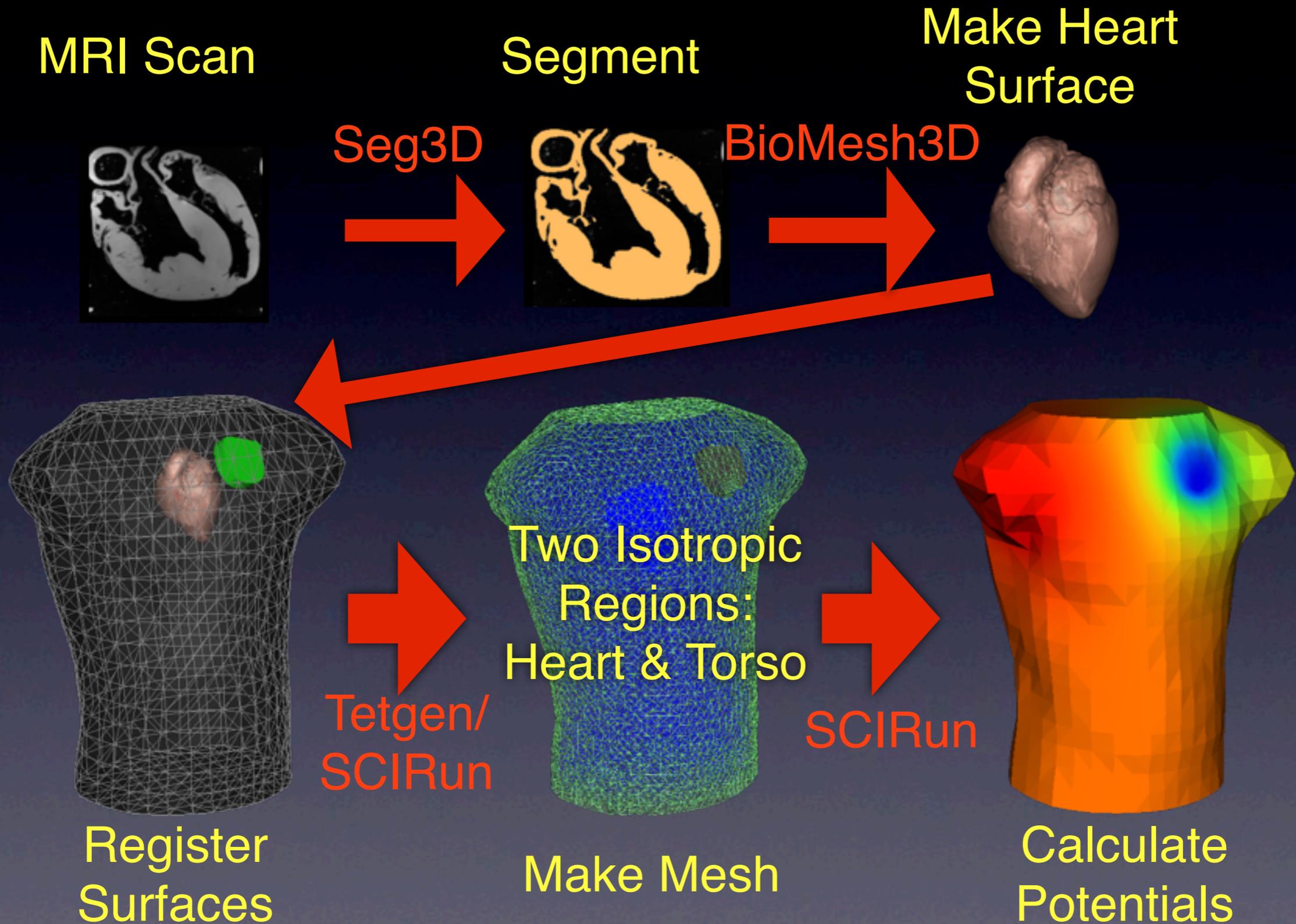


Register Surfaces

# Simulation



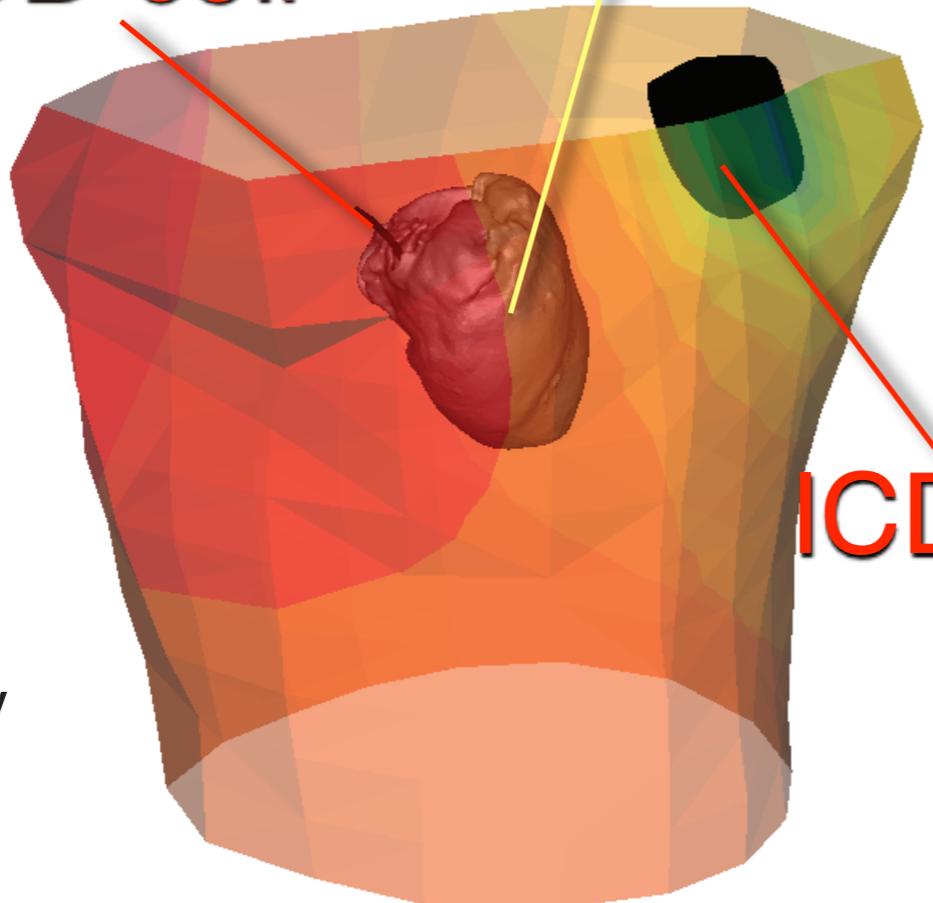
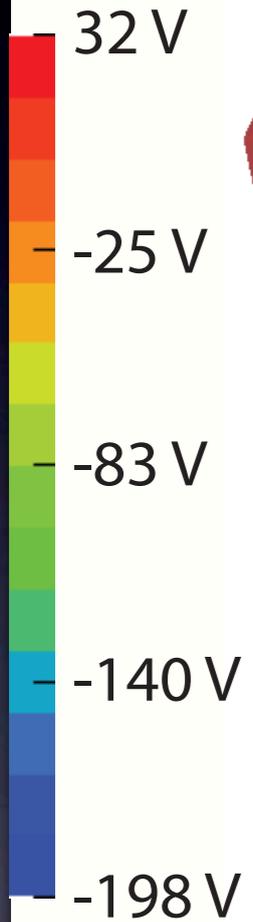
# Simulation



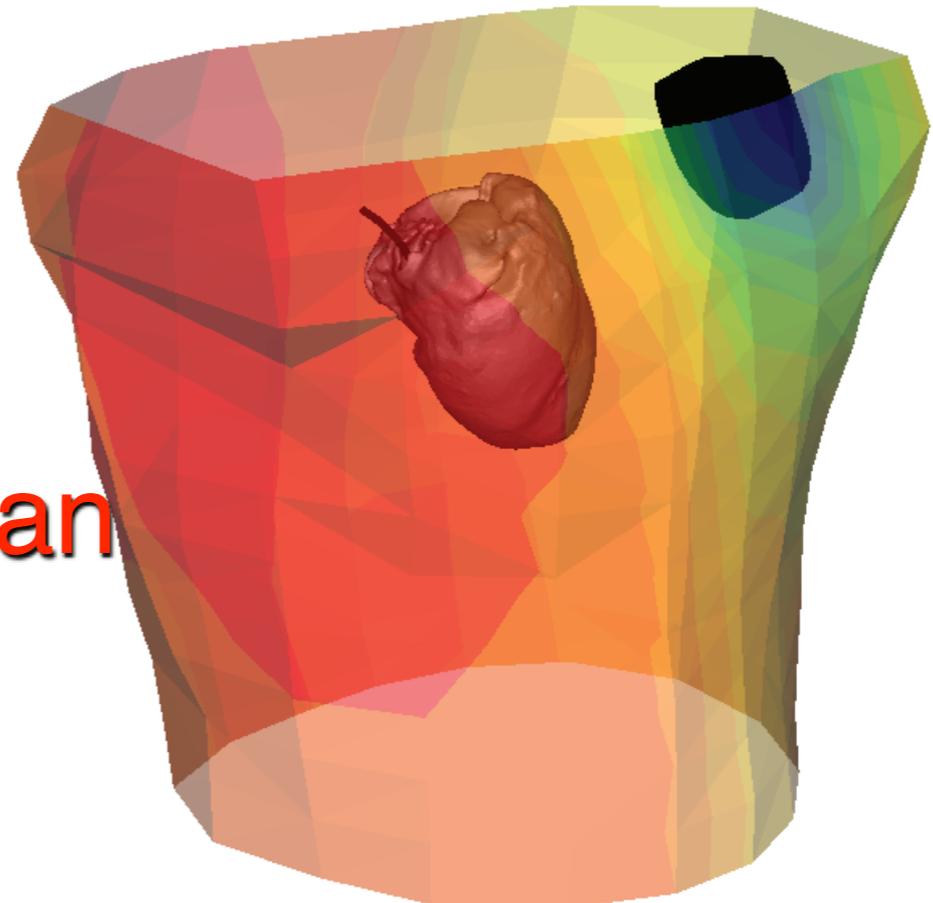
# Tank Surface

Heart

ICD coil

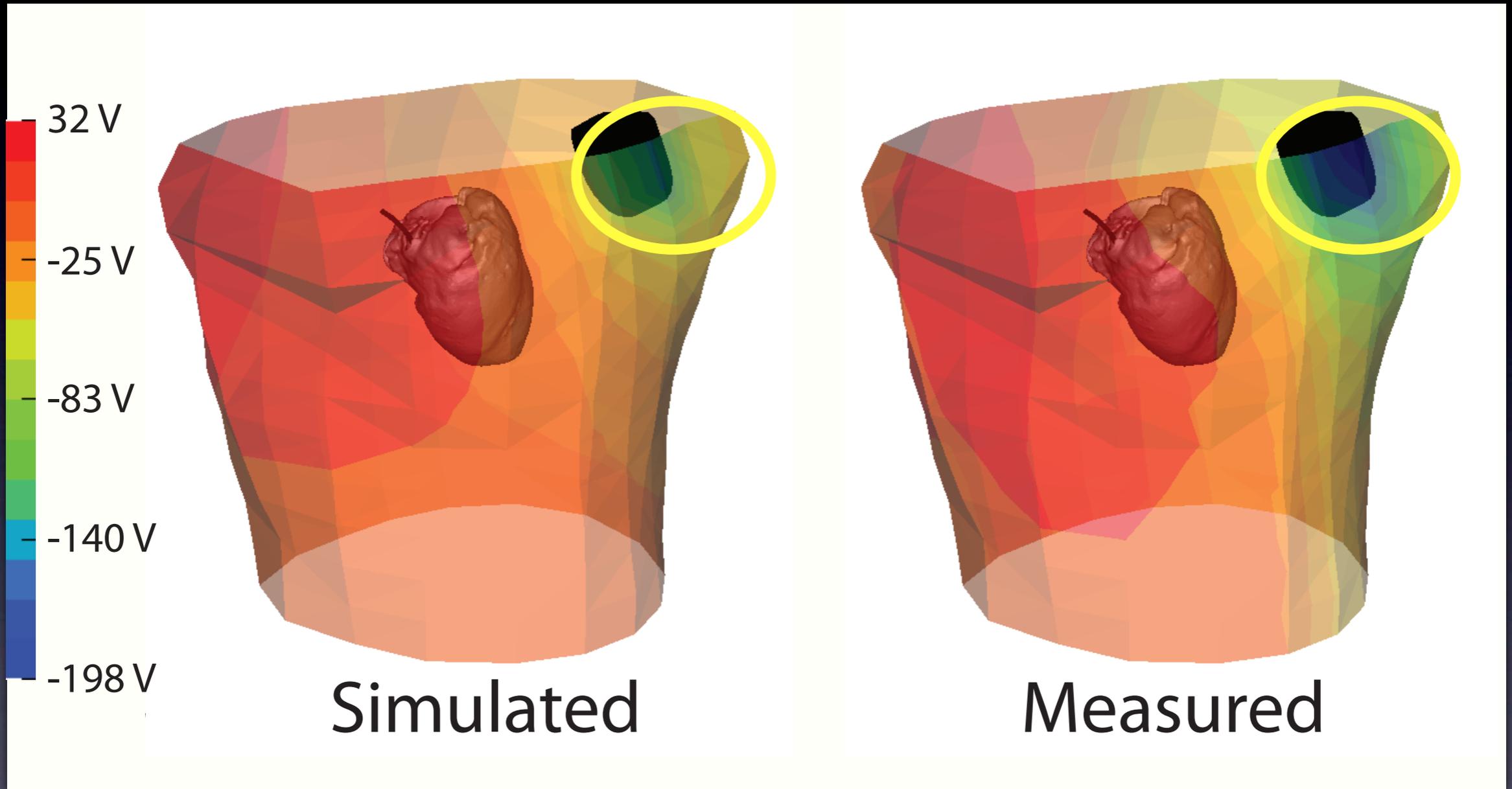


ICD can



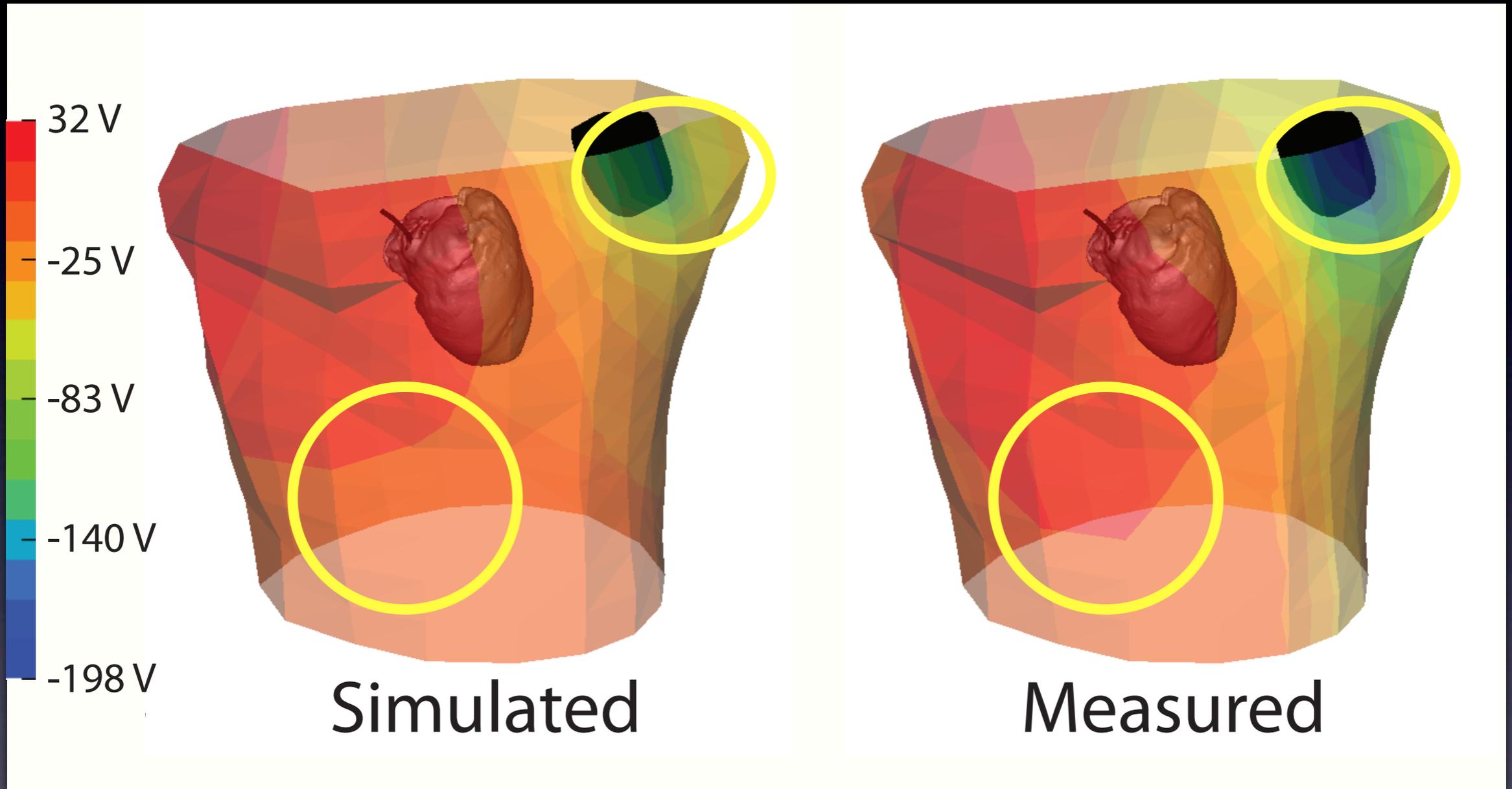
$$\rho=0.91, \bar{E}=23 \text{ V}, RE=28 \%$$

# Tank Surface



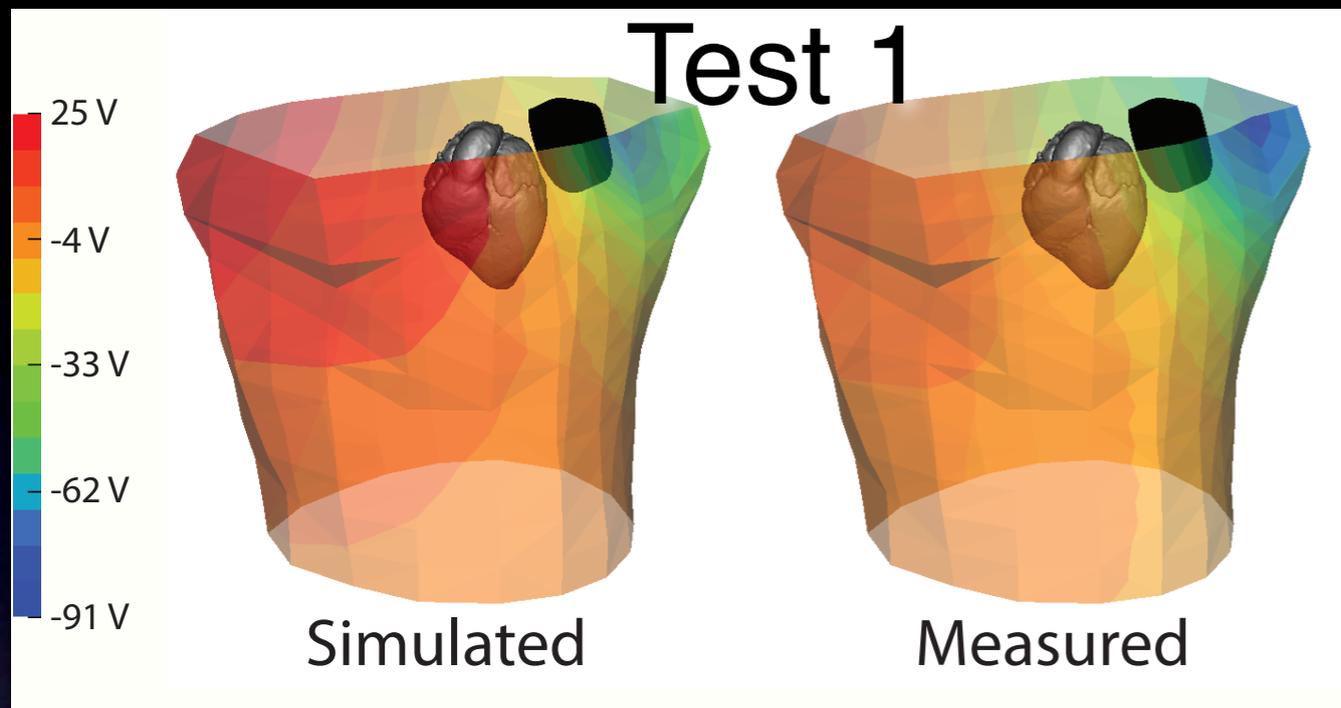
$\rho=0.91, \bar{E}=23 \text{ V}, RE=28 \%$

# Tank Surface

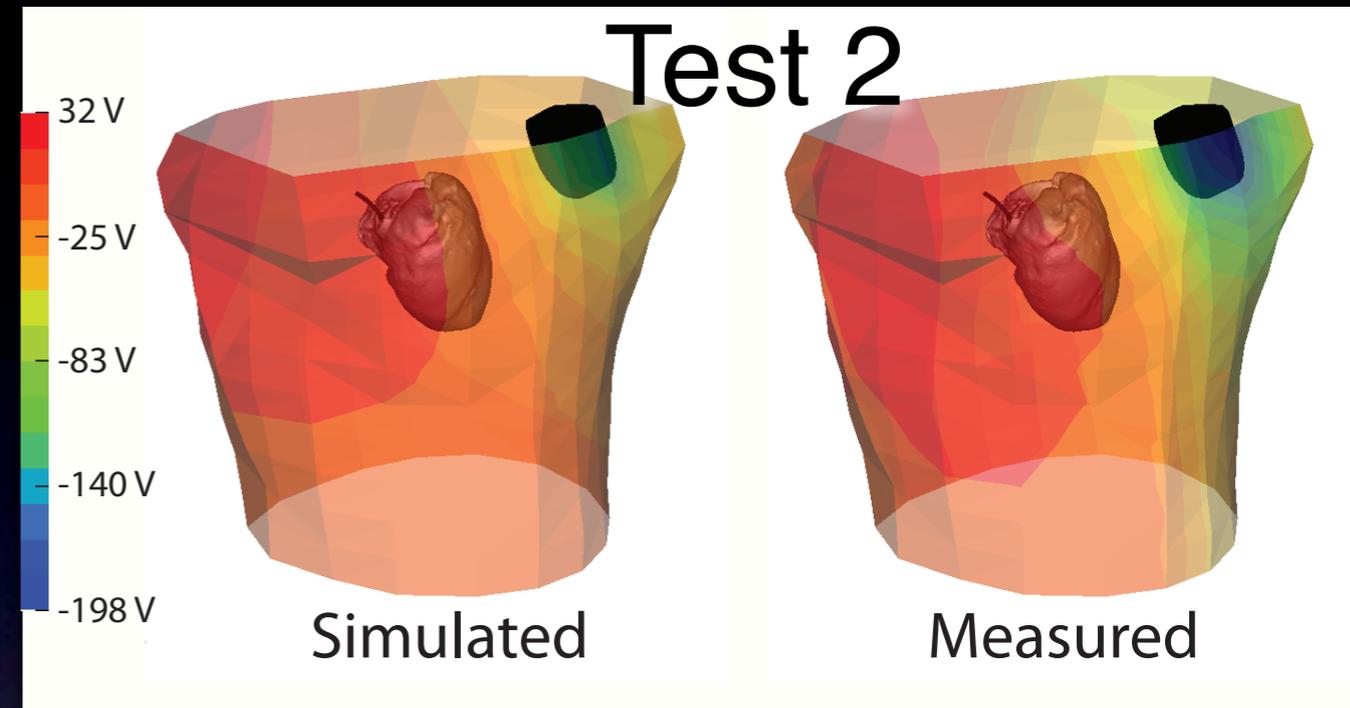


$\rho=0.91, \bar{E}=23 \text{ V}, RE=28 \%$

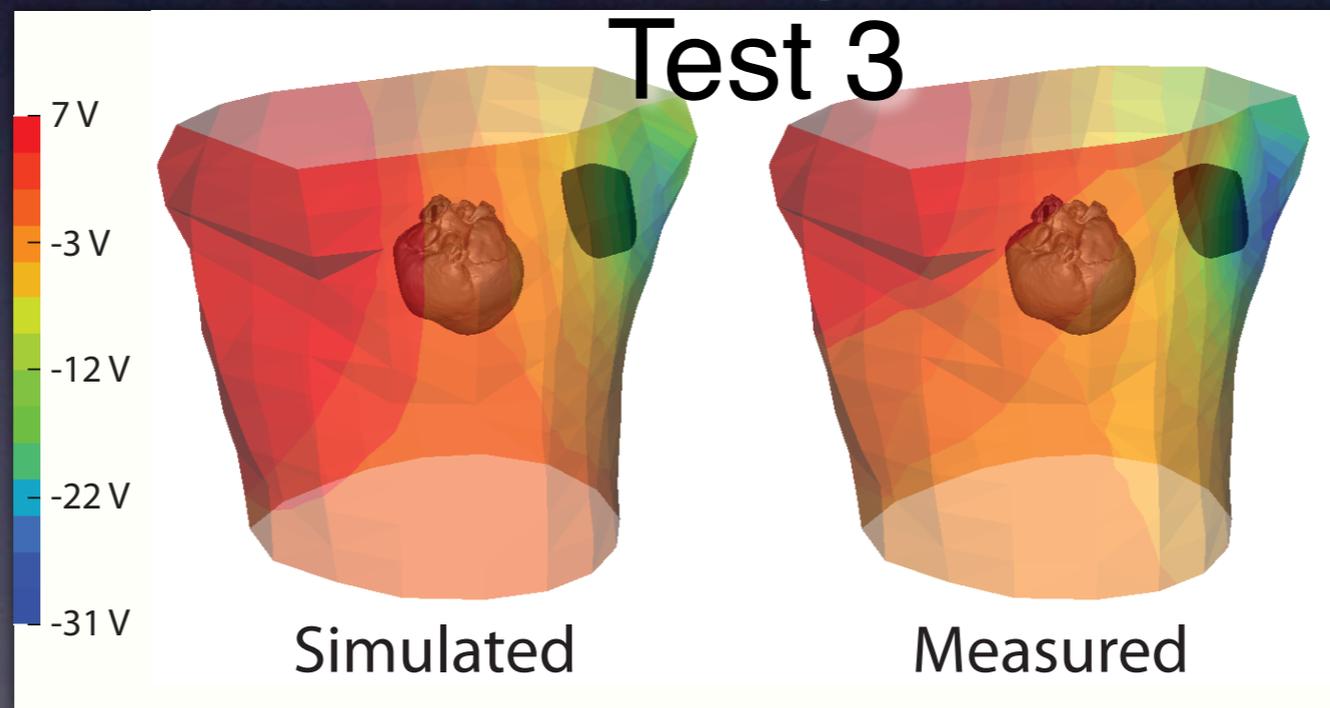
# Tank Surface



$\rho=0.83$ ,  $\bar{E}=12$  V, RE=31 %



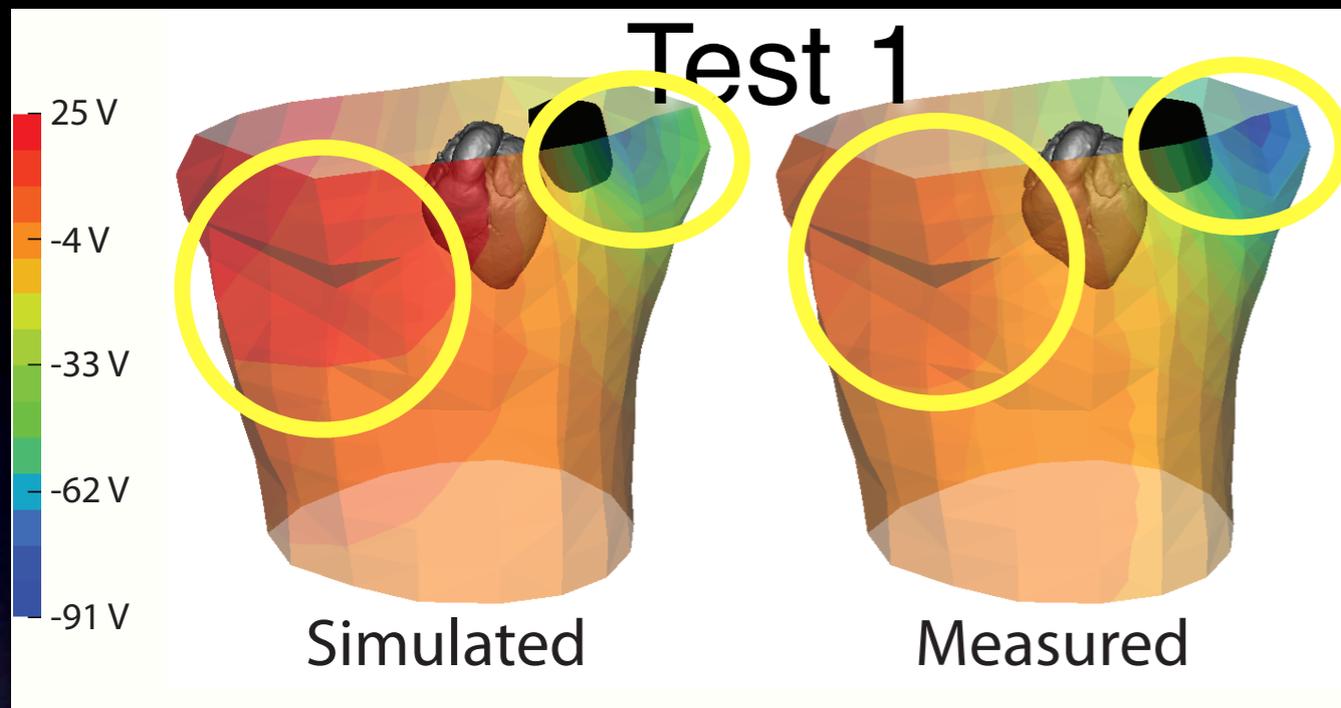
$\rho=0.91$ ,  $\bar{E}=23$  V, RE=28 %



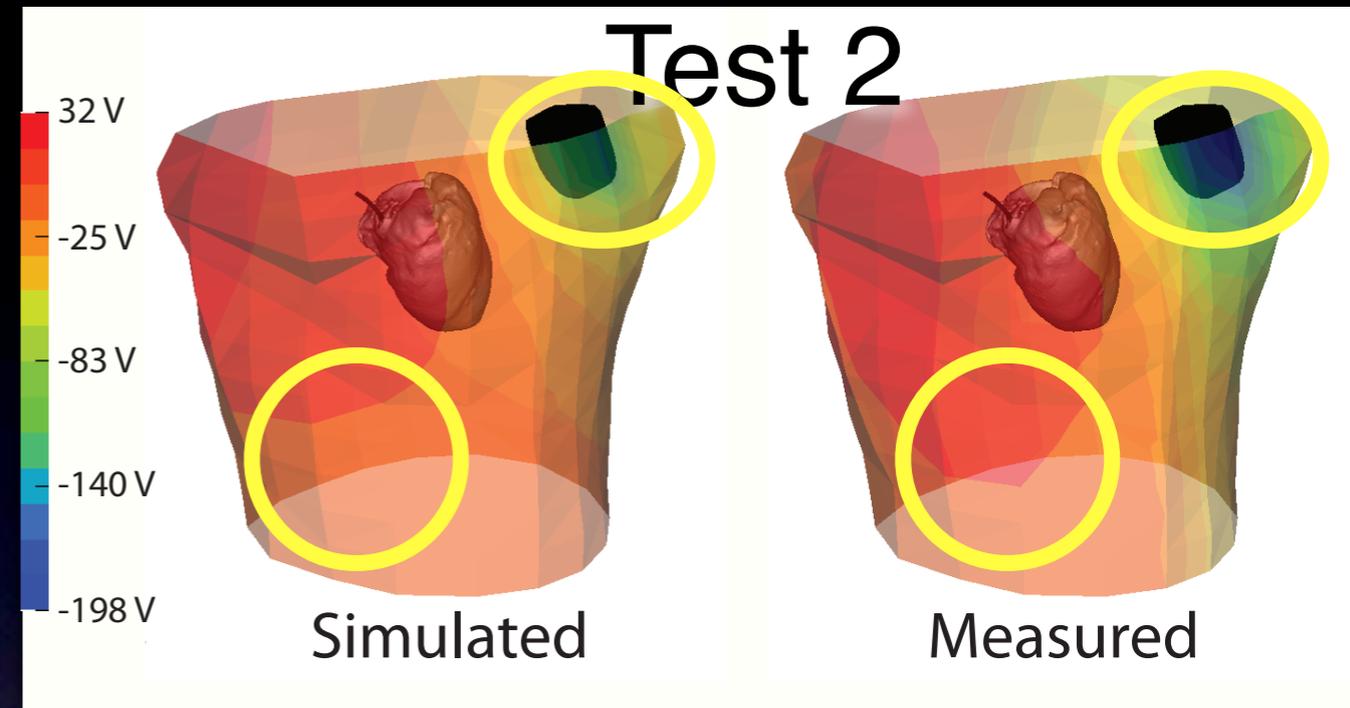
$\rho=0.88$ ,  $\bar{E}=3.9$  V, RE=23 %



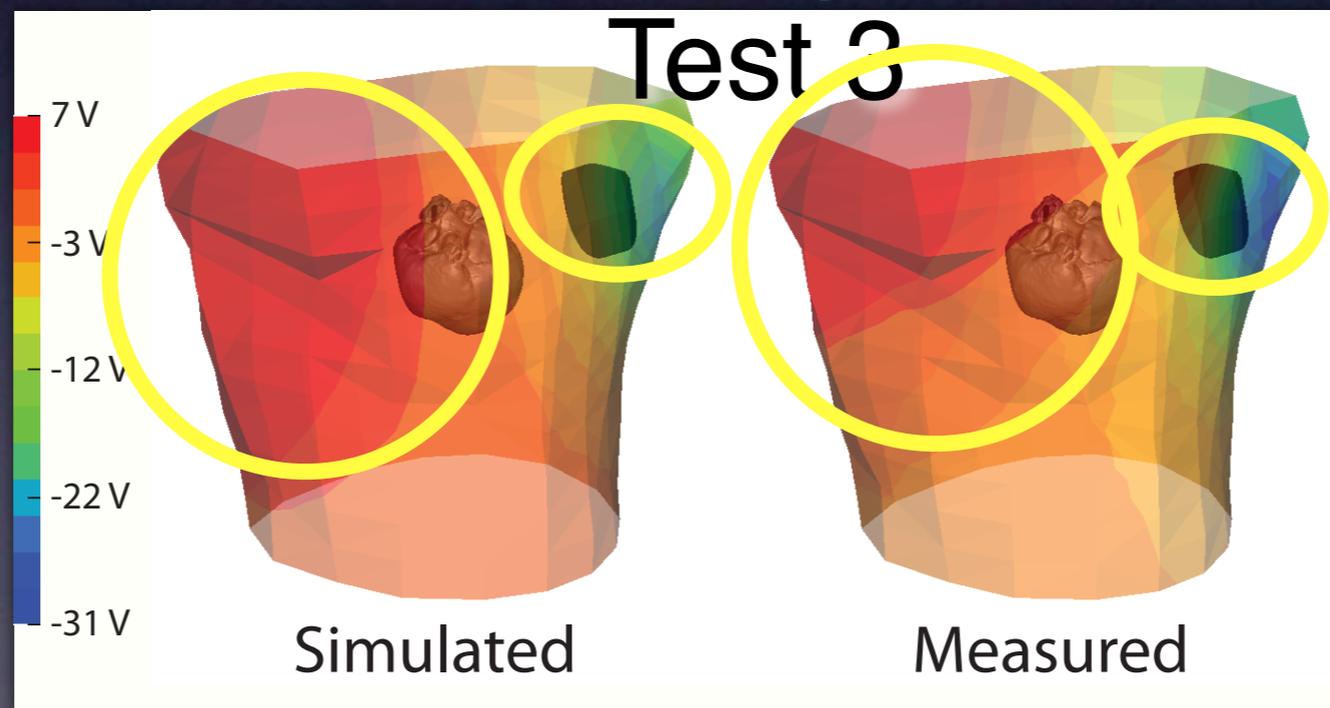
# Tank Surface



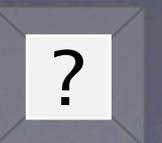
$\rho=0.83$ ,  $\bar{E}=12$  V, RE=31 %



$\rho=0.91$ ,  $\bar{E}=23$  V, RE=28 %

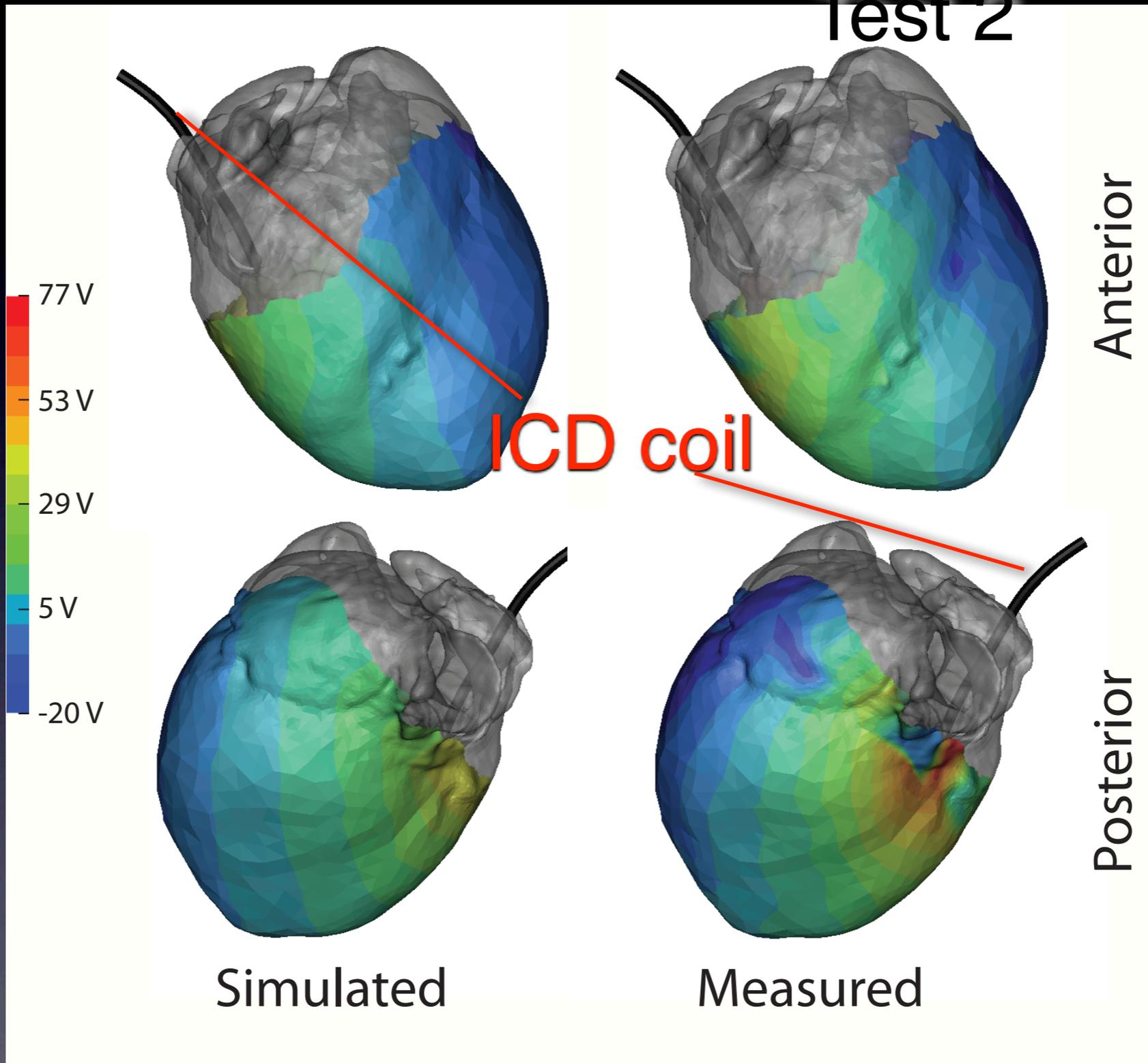


$\rho=0.88$ ,  $\bar{E}=3.9$  V, RE=23 %



# Cardiac Surface

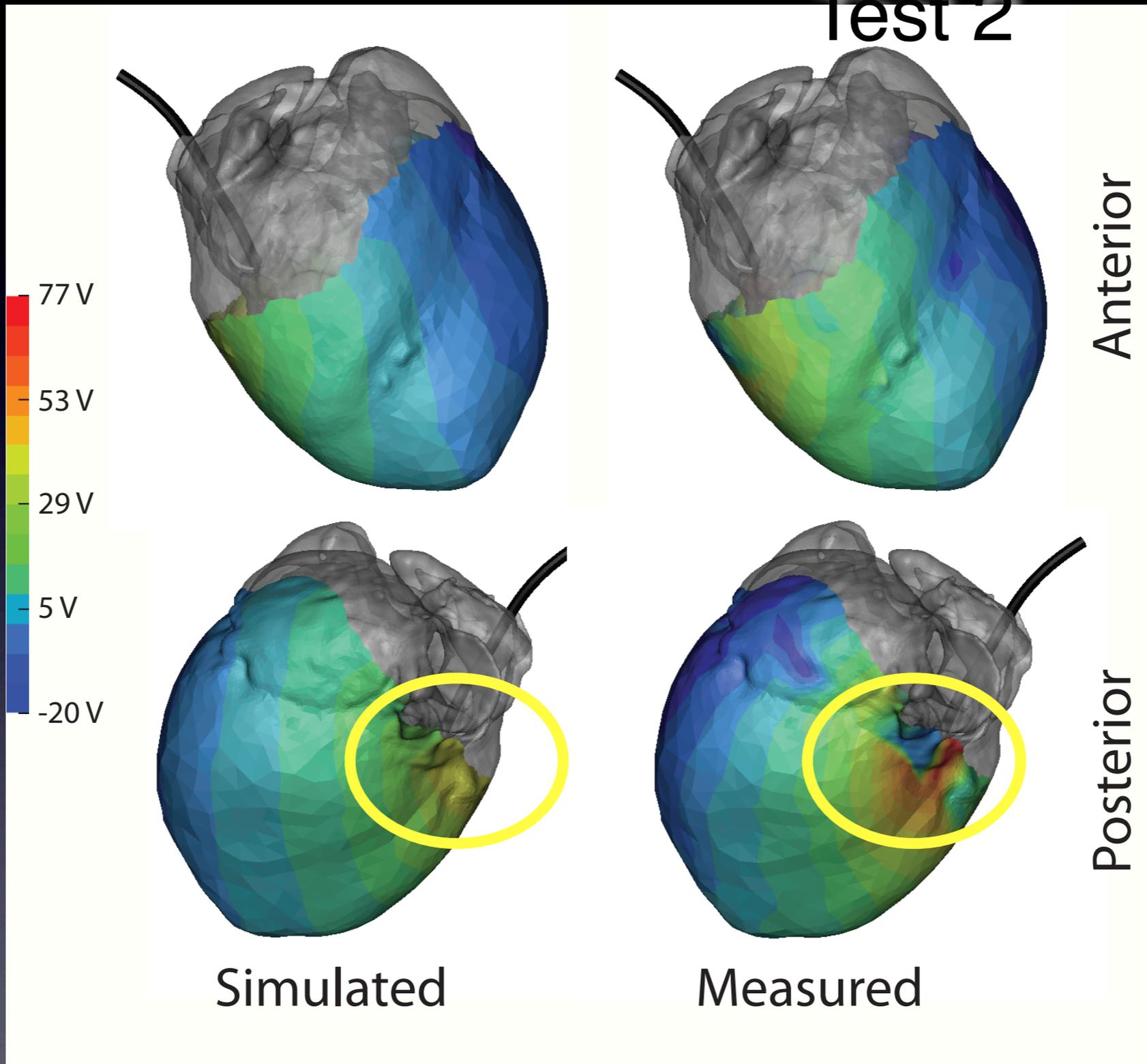
Test 2



$$\rho=0.85, \bar{E}=10 \text{ V}, RE=30\%$$

# Cardiac Surface

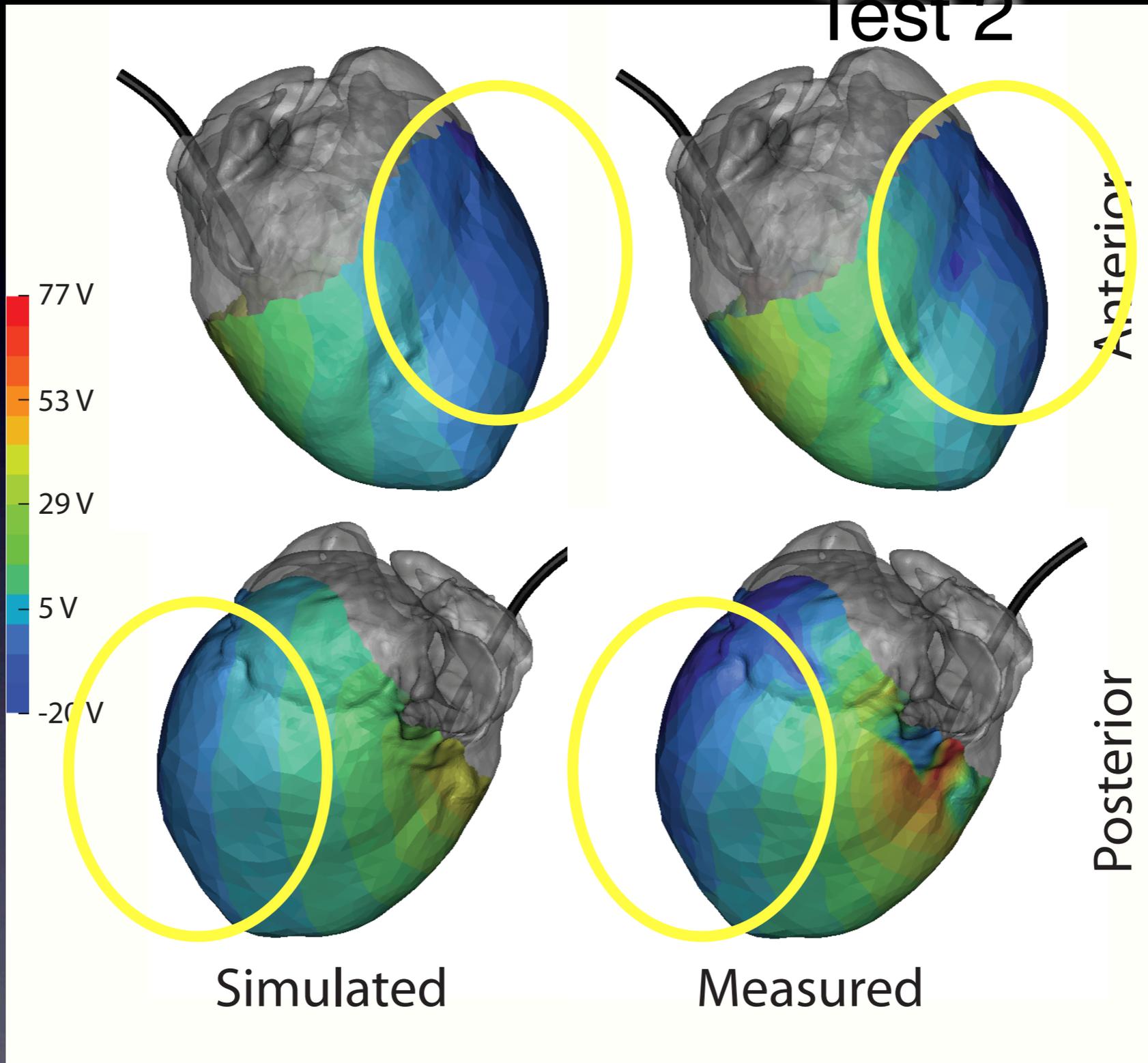
Test 2



$\rho=0.85$ ,  $\bar{E}=10$  V, RE=30%

# Cardiac Surface

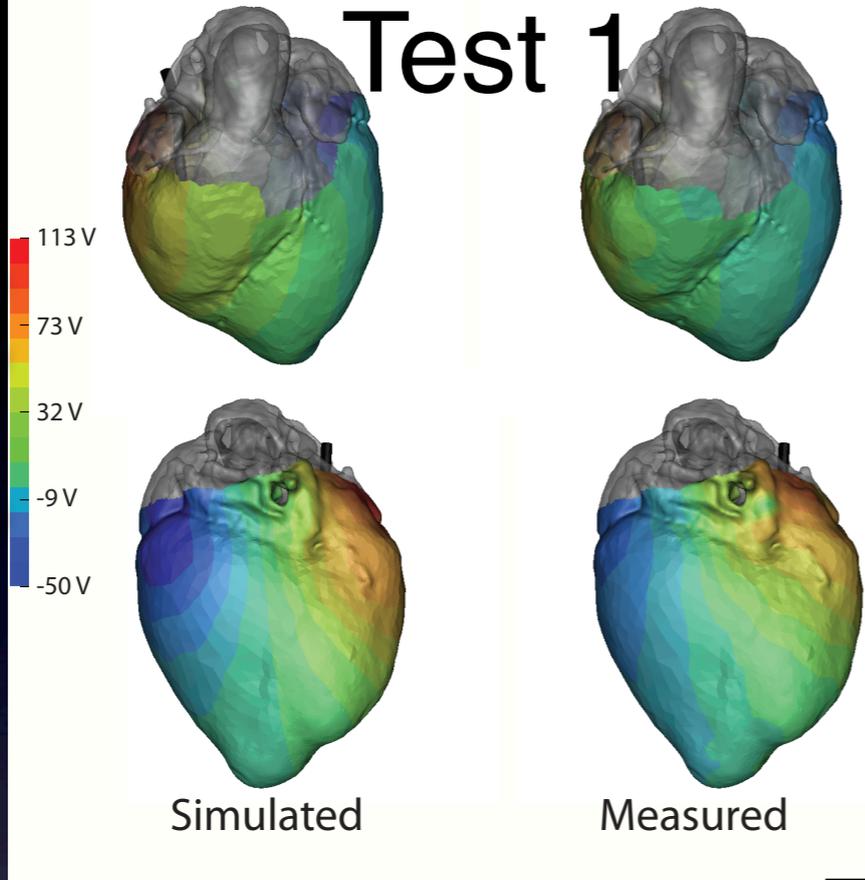
Test 2



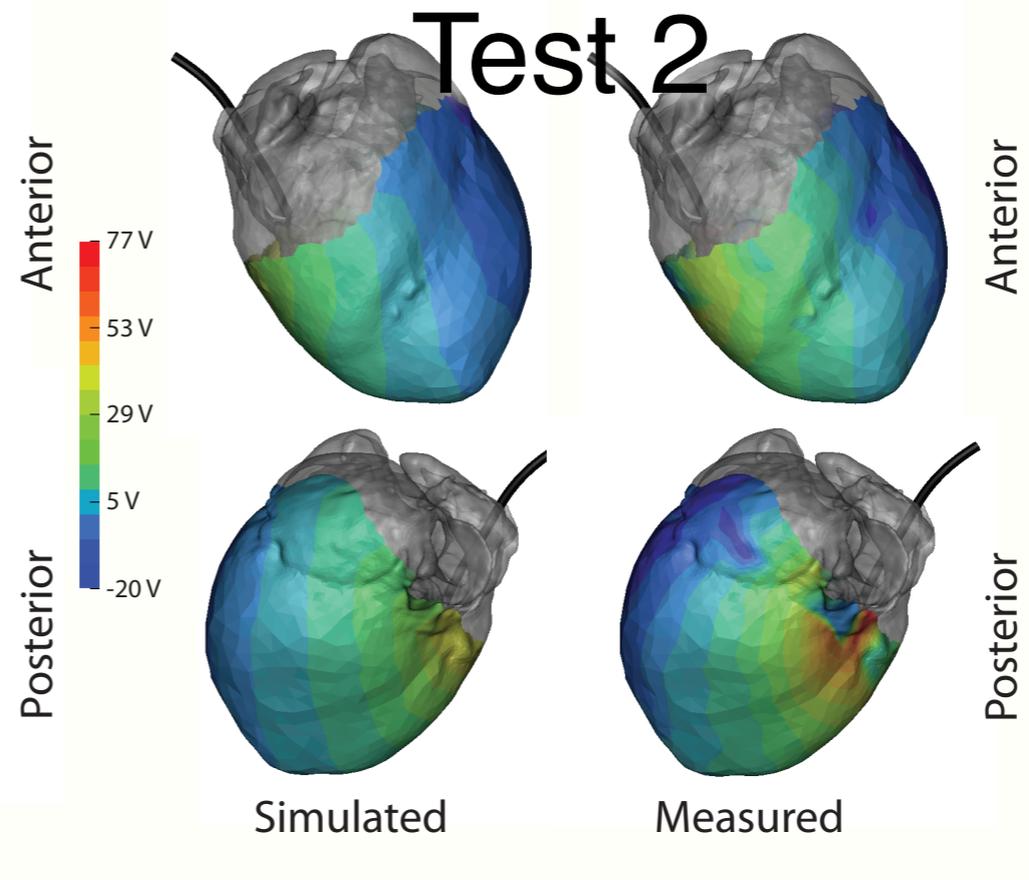
$\rho=0.85$ ,  $\bar{E}=10$  V, RE=30%

# Cardiac Surface

## Test 1



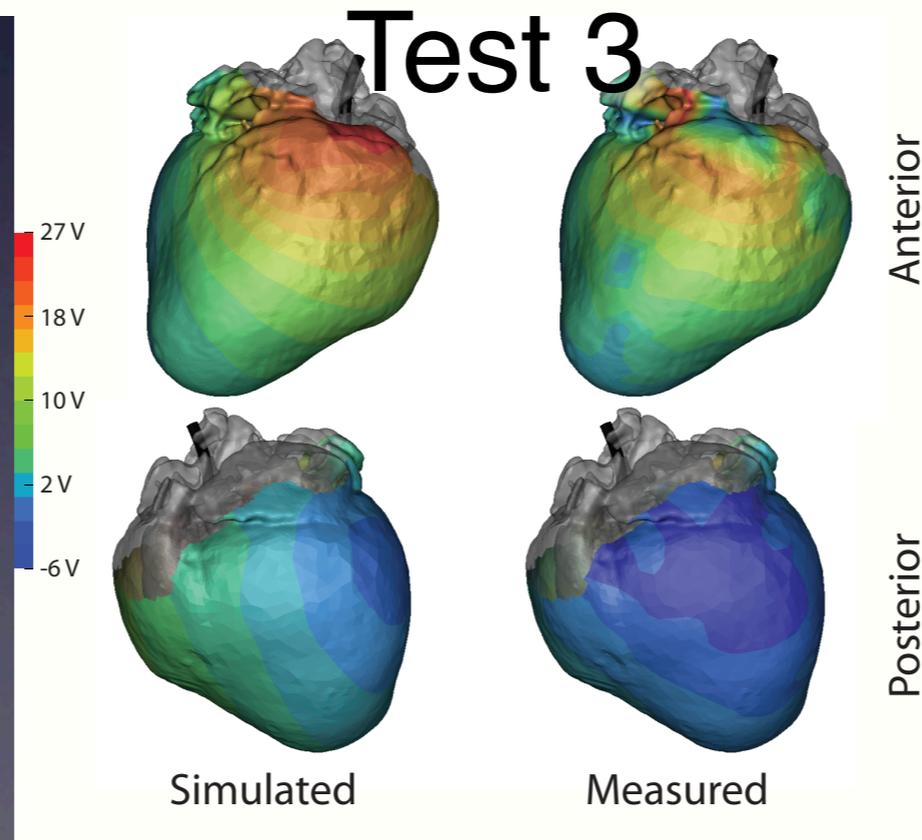
## Test 2



$\rho=0.94$   
 $\bar{E}=14 \text{ V}$   
 $RE=25\%$

$\rho=0.85$   
 $\bar{E}=10 \text{ V}$   
 $RE=30\%$

## Test 3



$\rho=0.88$   
 $\bar{E}=3.9 \text{ V}$   
 $RE=33\%$

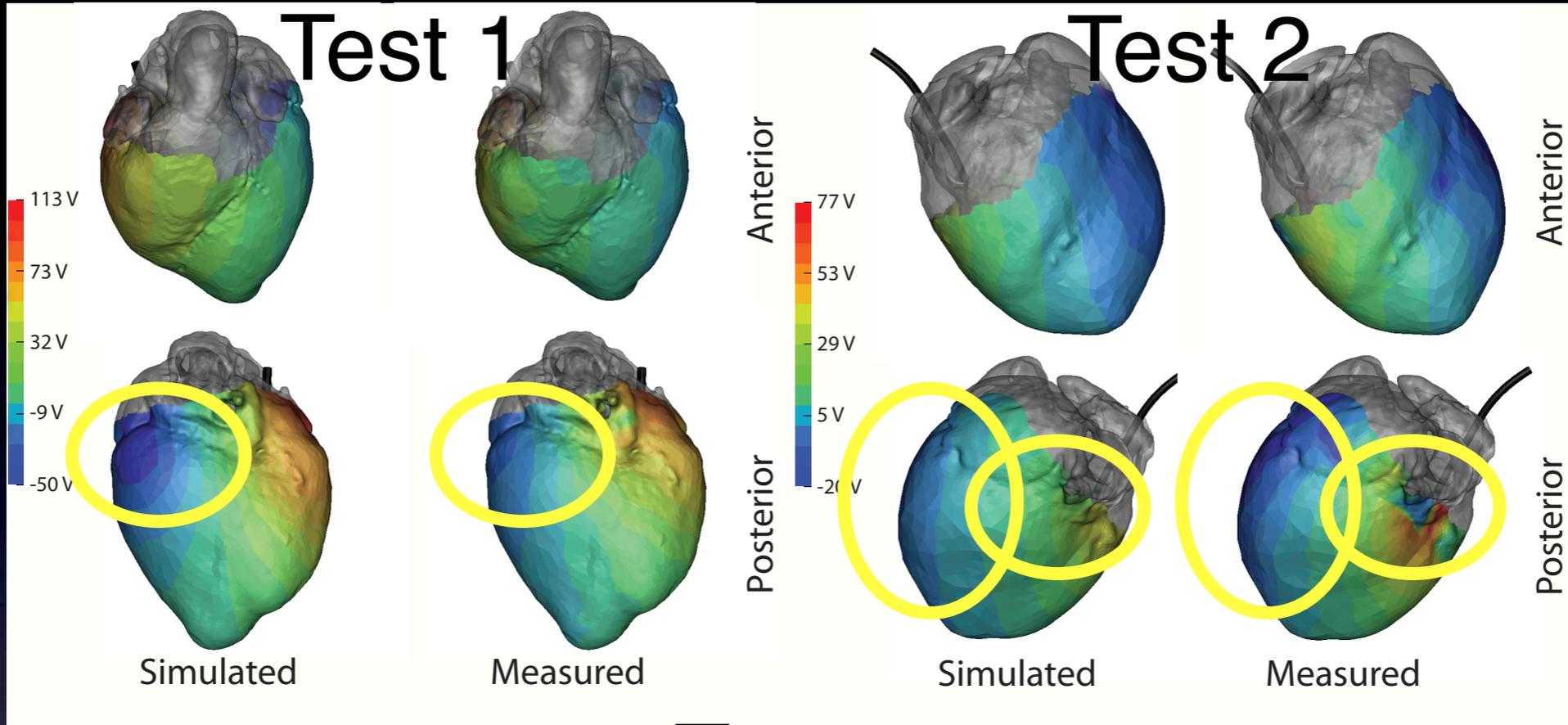
?

:

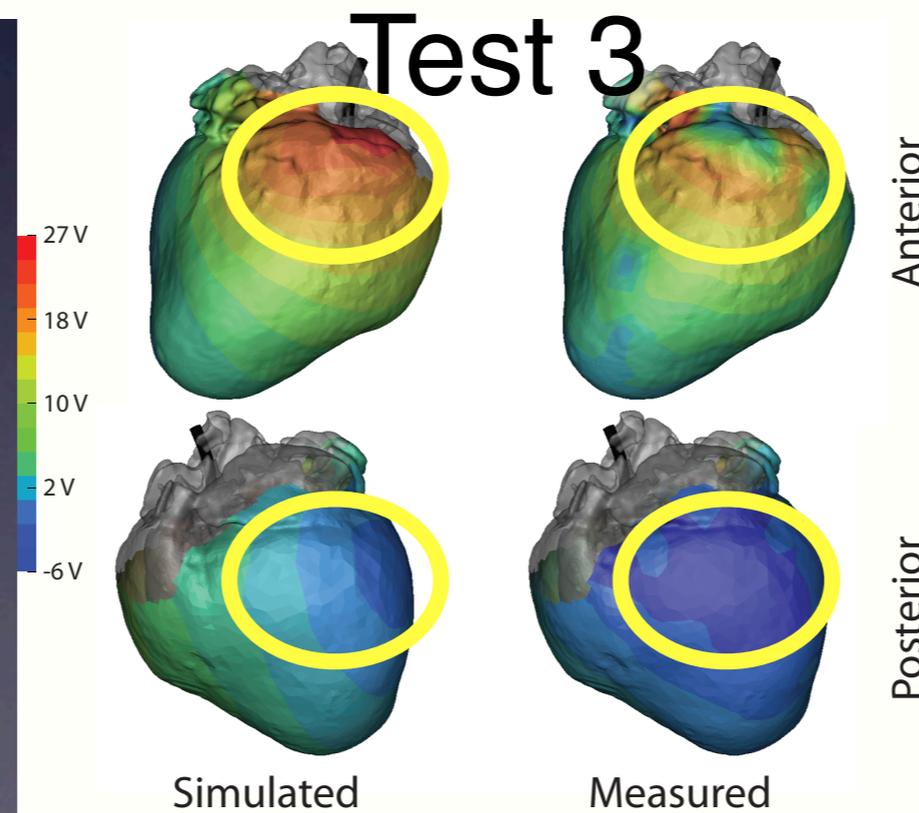
?

# Cardiac Surface

$\rho=0.94$   
 $\bar{E}=14 \text{ V}$   
 $RE=25\%$



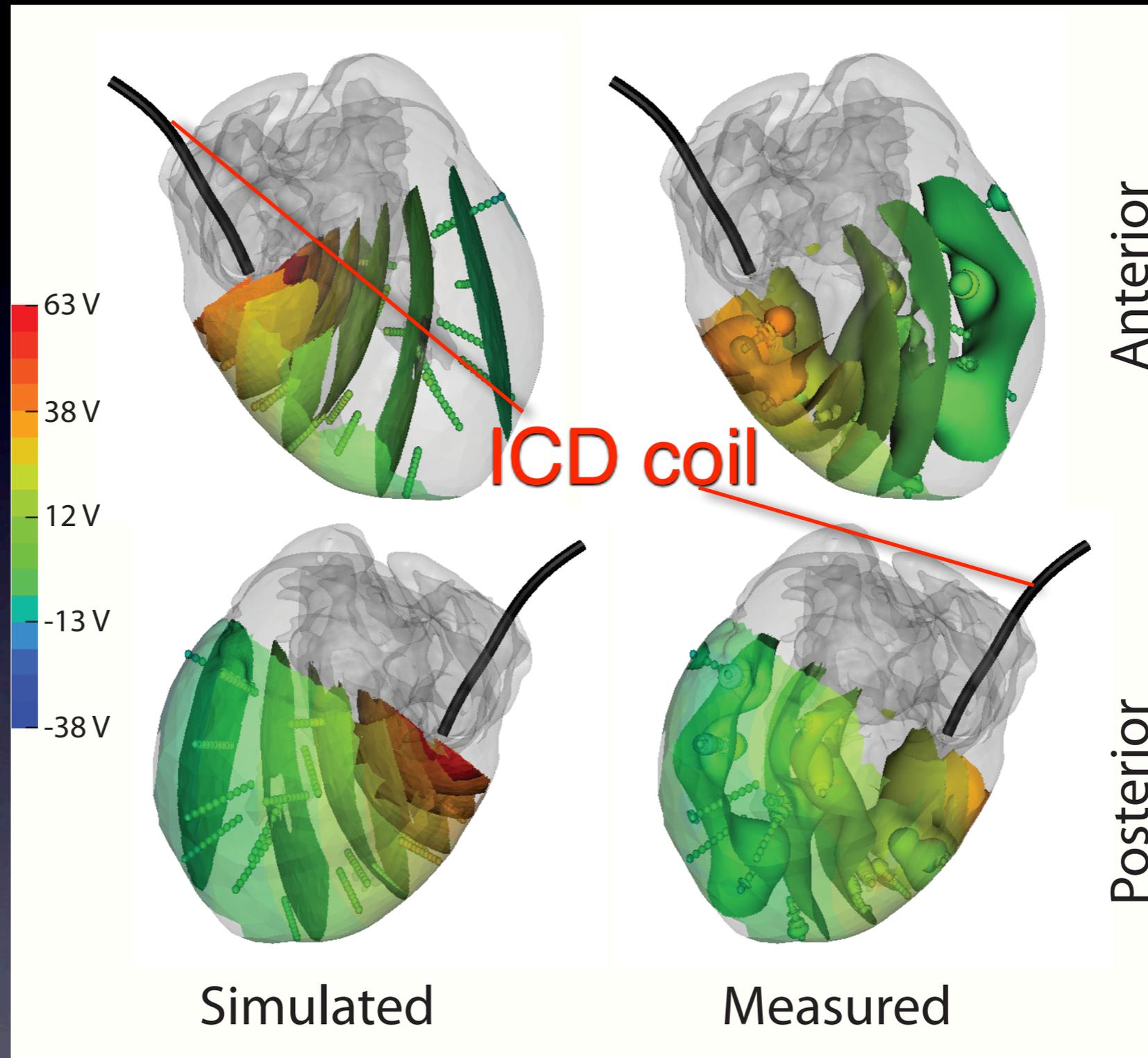
$\rho=0.85$   
 $\bar{E}=10 \text{ V}$   
 $RE=30\%$



$\rho=0.88$   
 $\bar{E}=3.9 \text{ V}$   
 $RE=33\%$

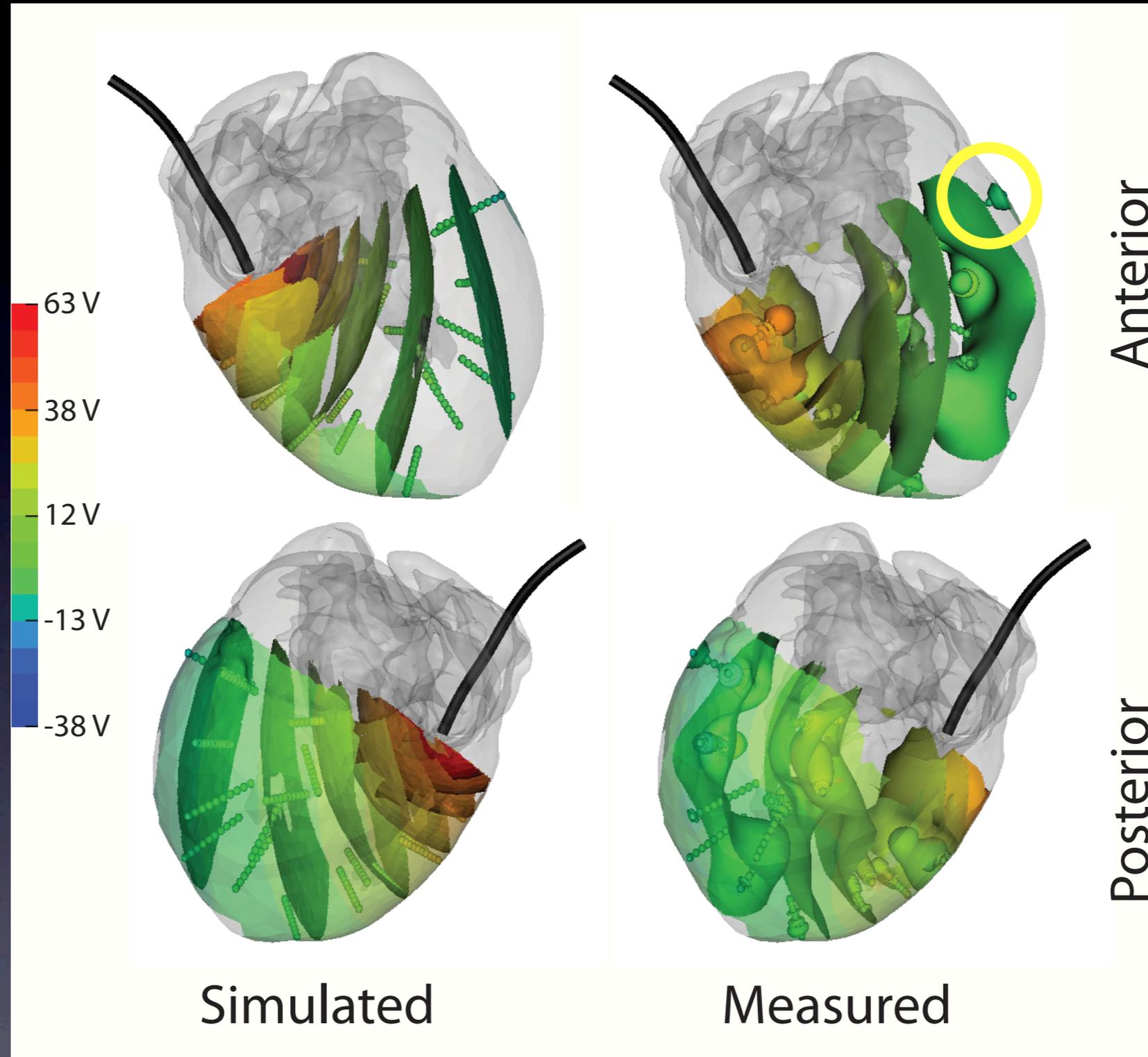


# Cardiac Volume



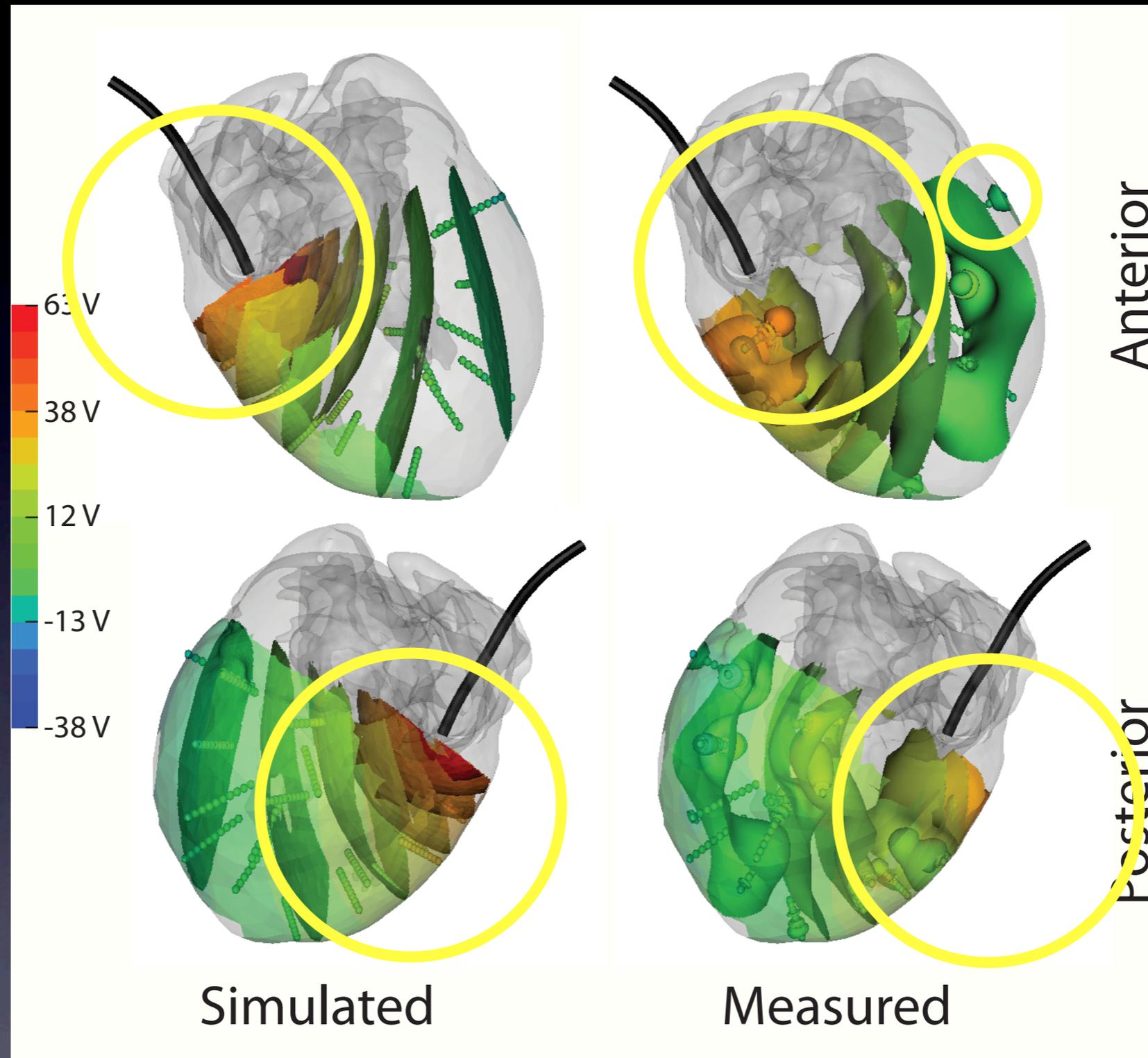
$$\rho=0.87, \bar{E}=12 \text{ V}, RE=26\%$$

# Cardiac Volume



$$\rho=0.87, \bar{E}=12 \text{ V}, RE=26\%$$

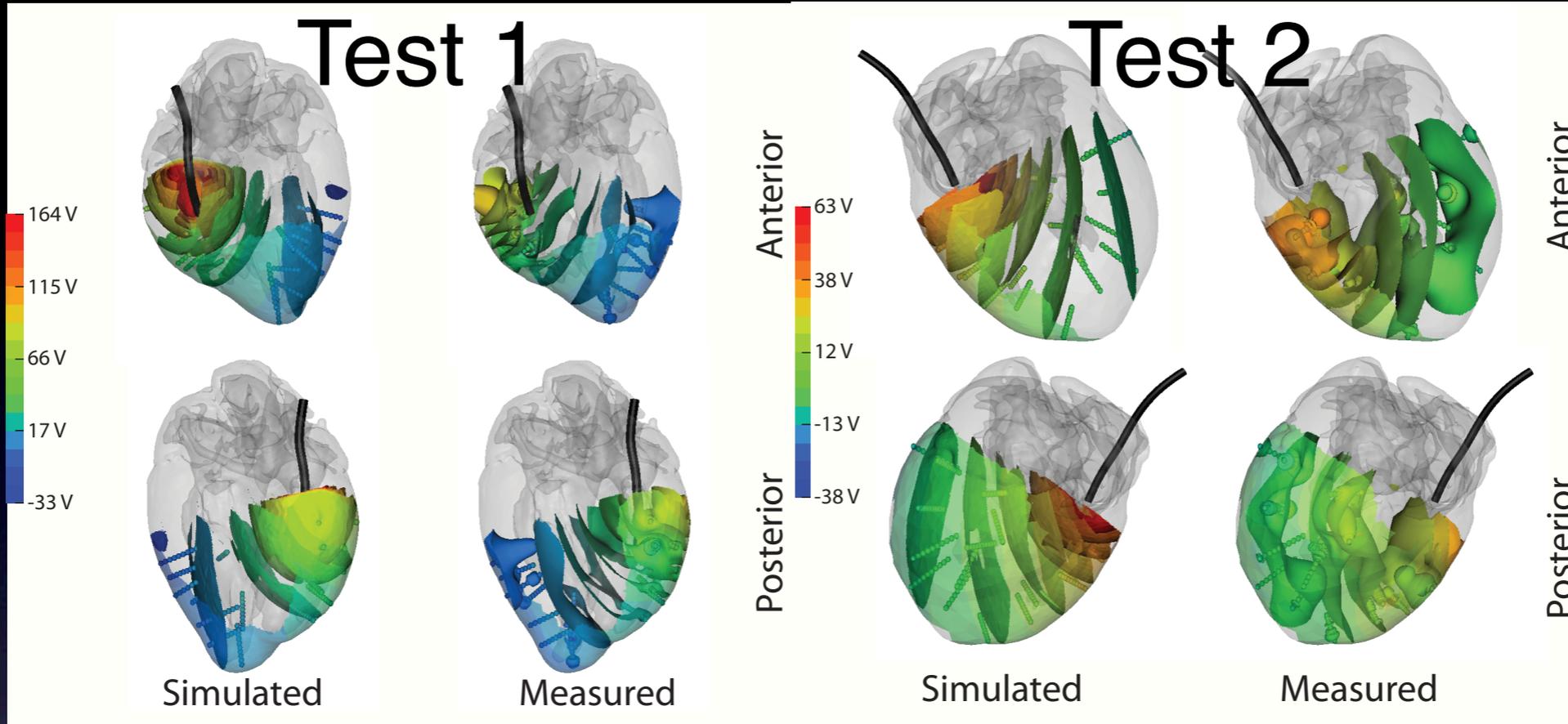
# Cardiac Volume



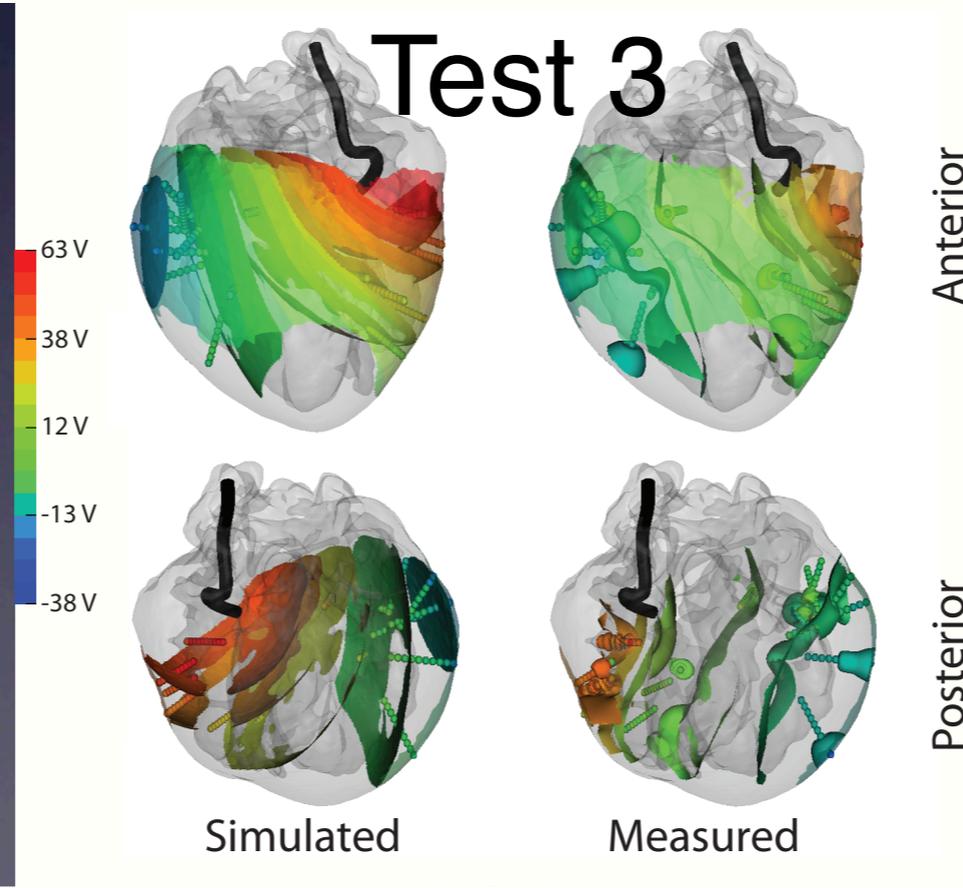
$$\rho=0.87, \bar{E}=12 \text{ V}, RE=26\%$$

# Cardiac Volume

$\rho=0.91$   
 $\bar{E}=14 \text{ V}$   
 $RE=28\%$



$\rho=0.87$   
 $\bar{E}=12 \text{ V}$   
 $RE=26\%$

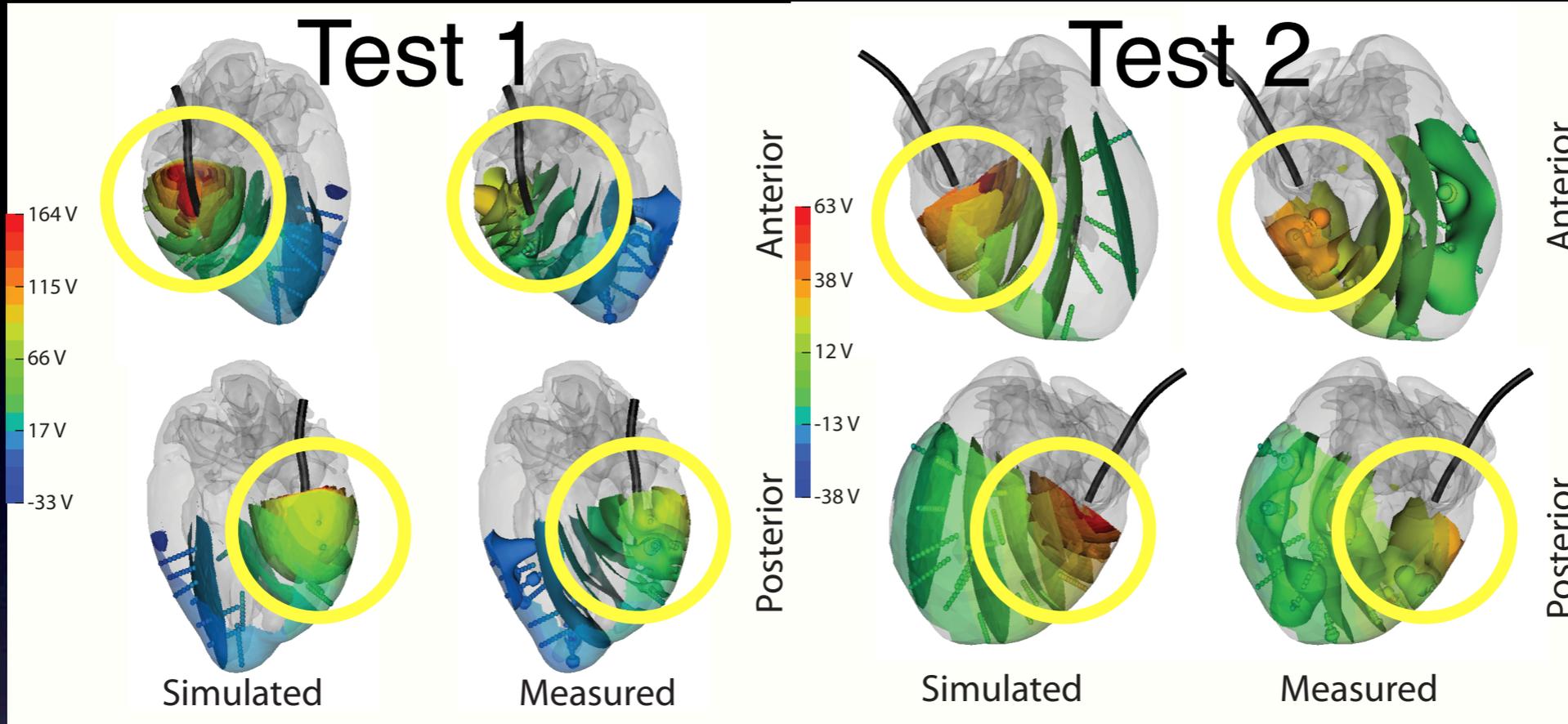


$\rho=0.96$   
 $\bar{E}=2.8 \text{ V}$   
 $RE=8.2\%$

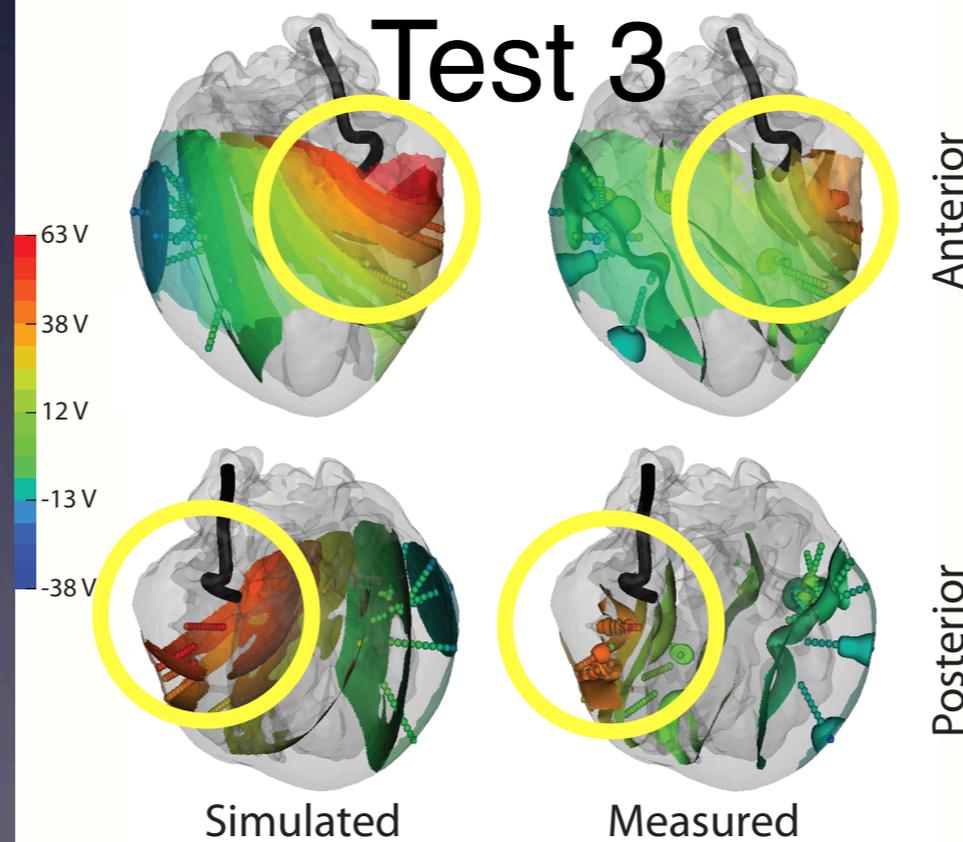


# Cardiac Volume

$\rho=0.91$   
 $\bar{E}=14 \text{ V}$   
 $RE=28\%$



$\rho=0.87$   
 $\bar{E}=12 \text{ V}$   
 $RE=26\%$



$\rho=0.96$   
 $\bar{E}=2.8 \text{ V}$   
 $RE=8.2\%$

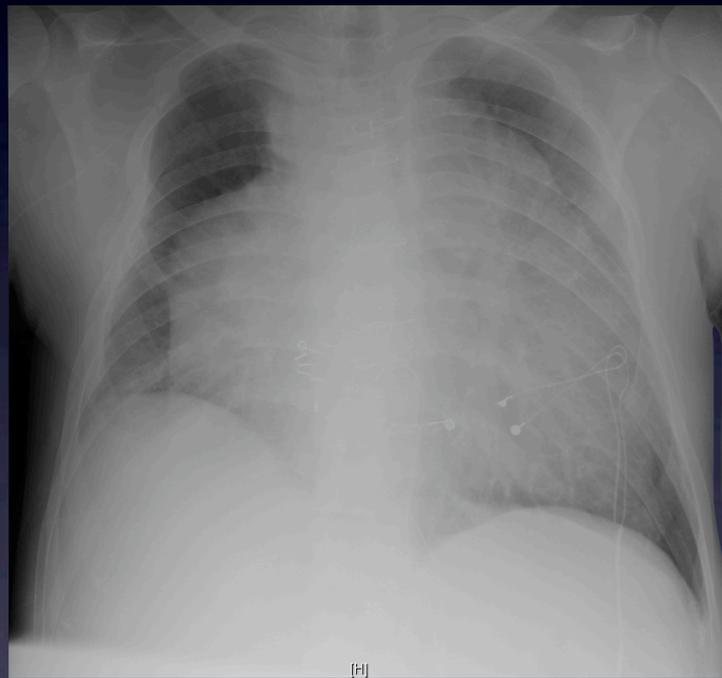


# Conclusions

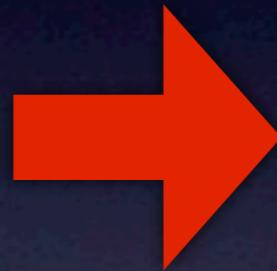
Experiments Verify our Simulation

Likely Errors: Conductivity & Registration

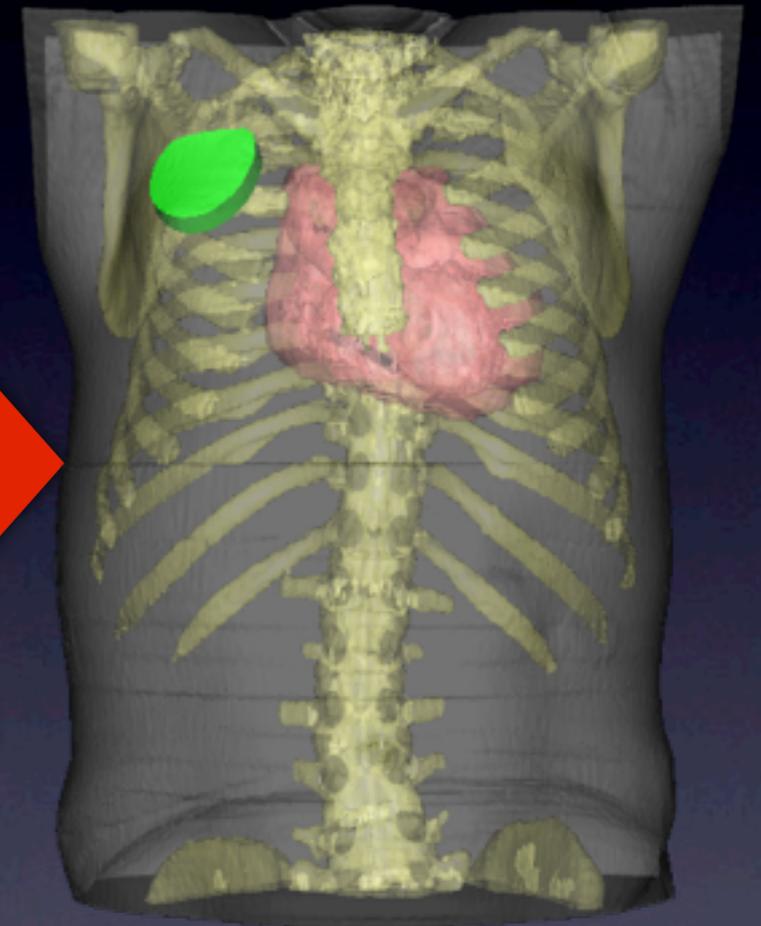
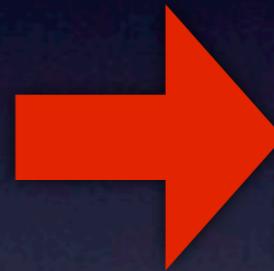
# Patient Specific ICD Treatment



Scan of Patient



Simulation  
Pipeline



Placement with  
Minimal DFT

# Acknowledgements

## Advisor

Rob MacLeod

## Lab Members

Kedar Aras

Brett Burton

Josh Blauer

Liz Jarrus

## Clinical Collaborators

Thomas Pilcher

Elizabeth Saarel

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Alicia Blooth

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