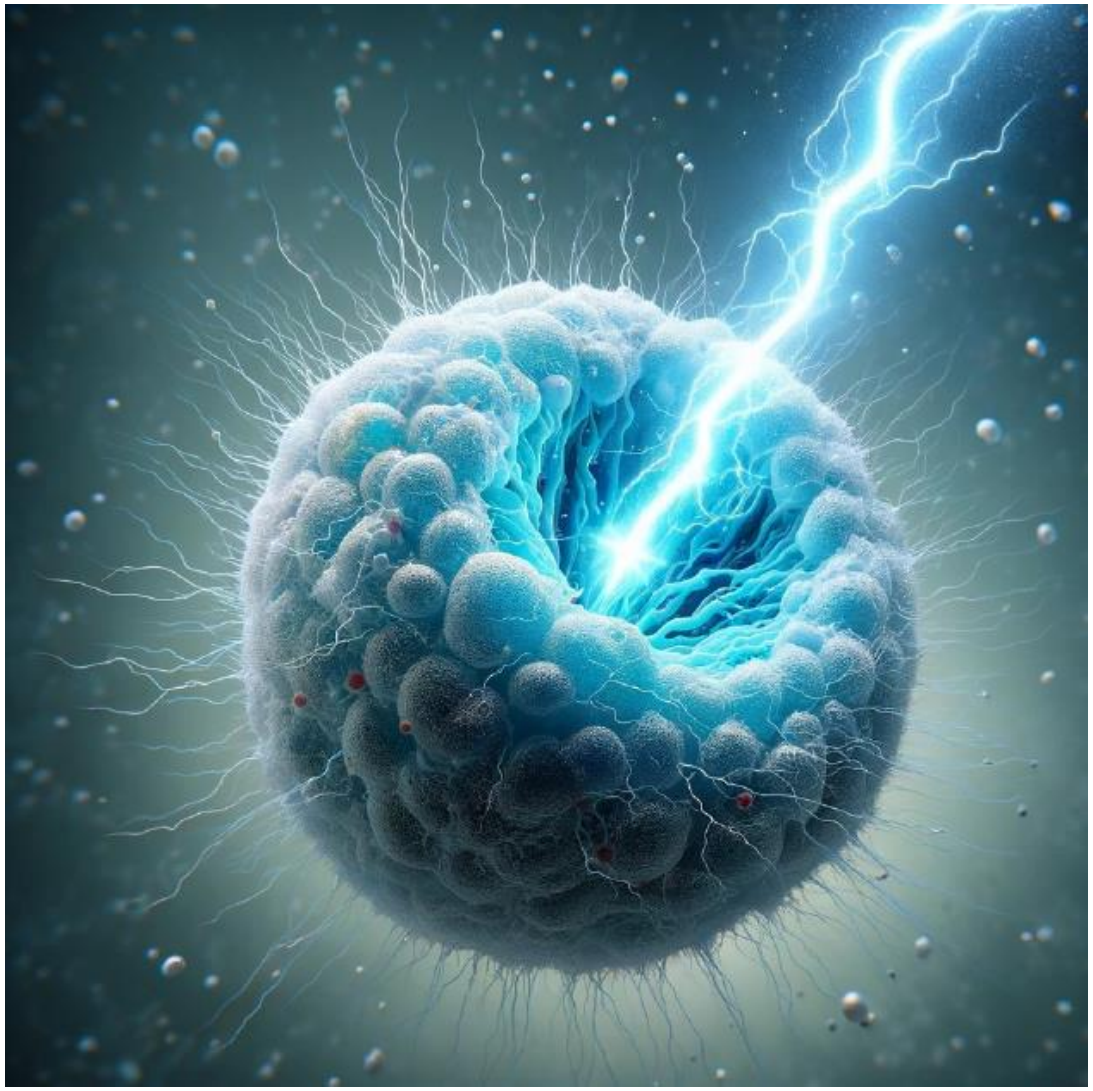

Numerical simulation of electroporation

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Electroporation

= formation of **pores** in the **cell membrane by short high-voltage pulses**

According to the electric field setting, length and number of pulses

Reversib

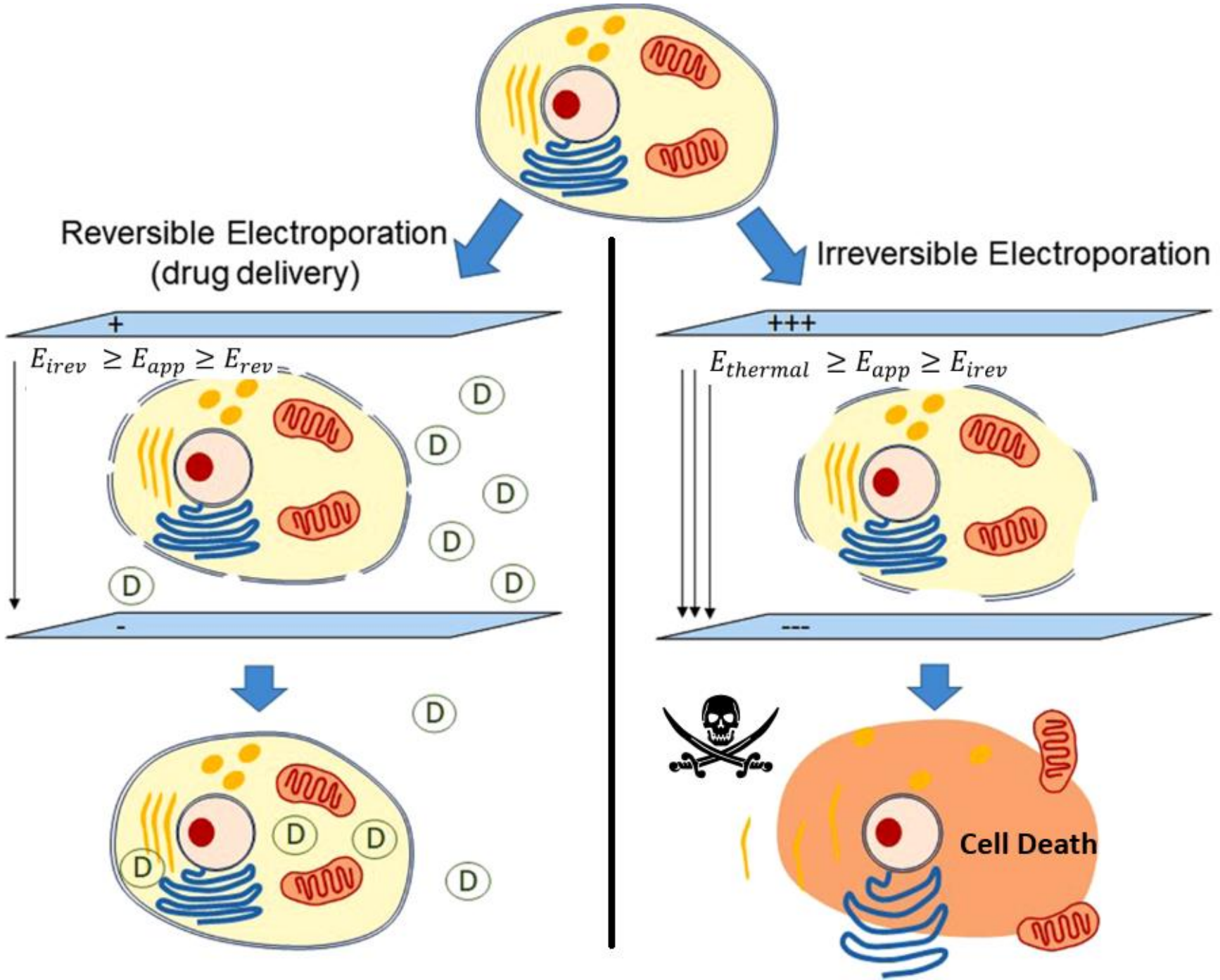
- **temporary** increase in cell membrane permeability through pores
- **transport of large molecules** (DNA, RNA, chemotherapeutics) → **gene transfection**

Irreversi

- **permanent** increase in cell membrane permeability
- induction of cell **death**

What happens

Threshold ***E~*** **(500-1000 V/cm)**



Irreversible electroporation in arythmology

=

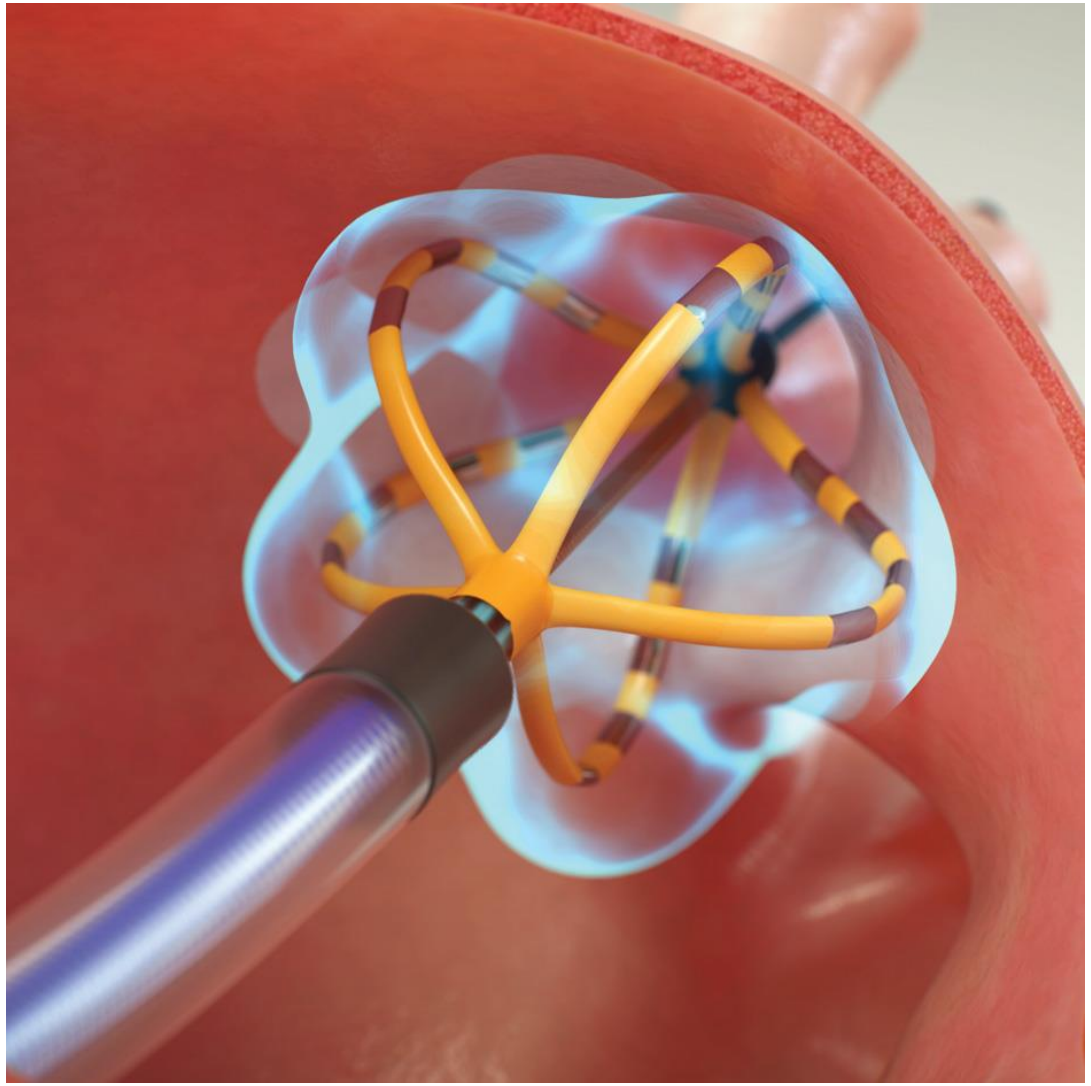
PULSED FIELD ABLATION

- **Cathetrisation therapy for atrial fibrillation**
- More **effective and faster** (compare to RF ablation)

Our scientific Questions???

Threshold for irreversible electroporation of cardiomyocytes

Heamolysis induction



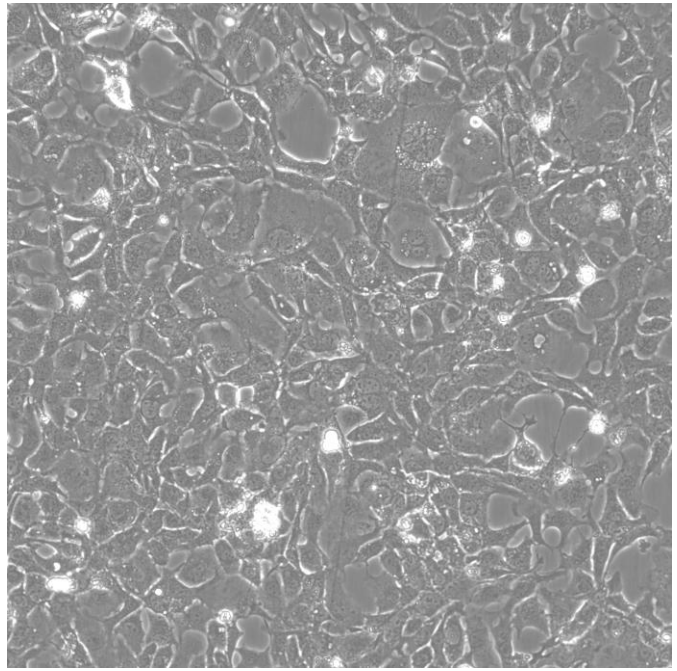
FARAPULSE - catheter for the treatment of atri

Methods

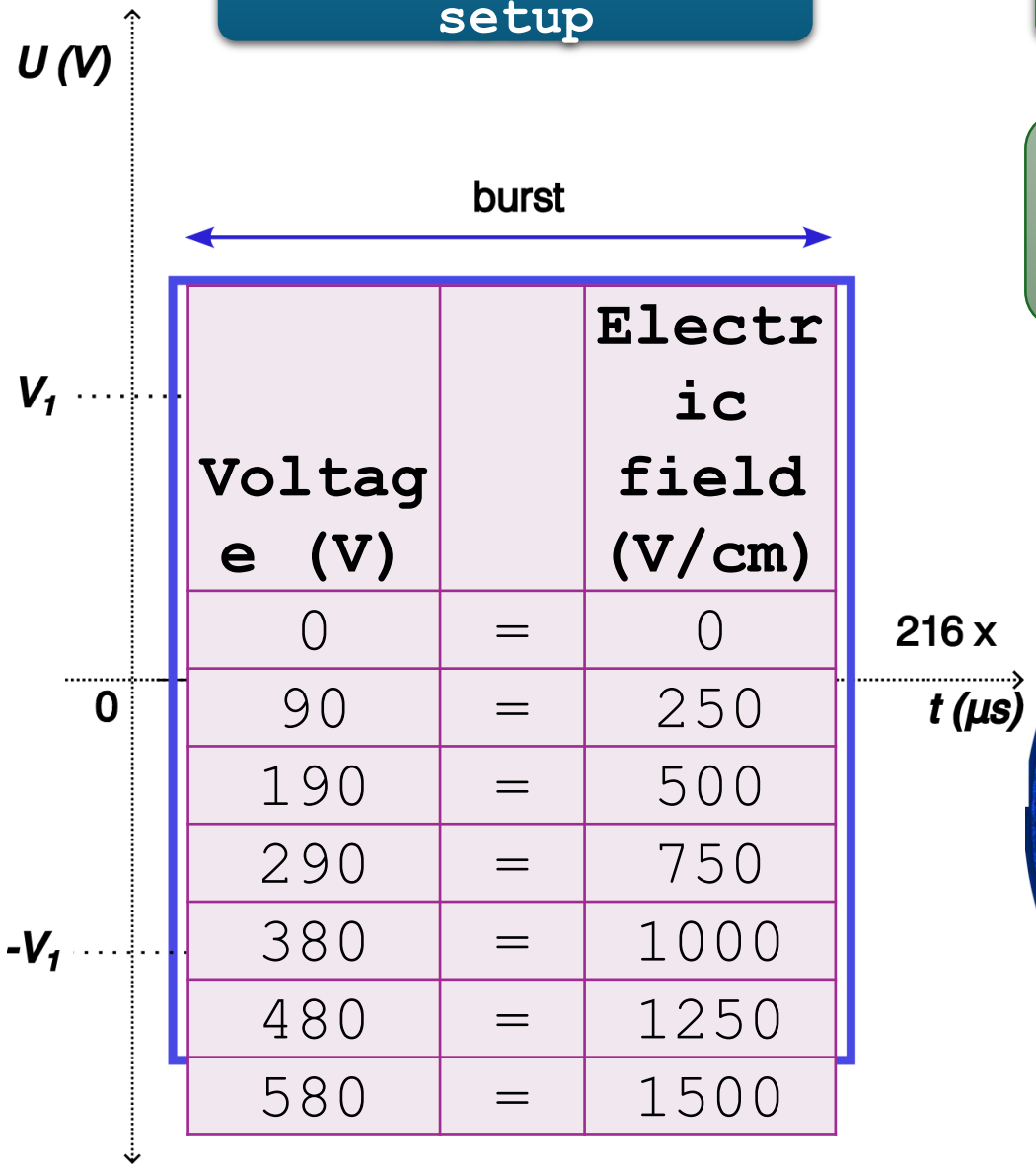
Threshold for irreversible electroporation of cardiomyocytes

Cell model

- immortalized **mouse atrial cardiomyocyte** tumor line (HL-1)



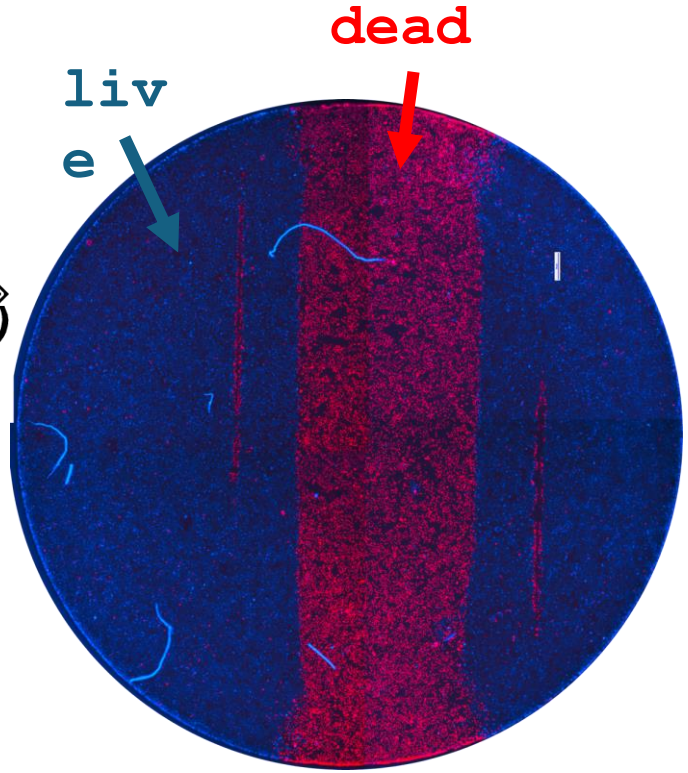
Electroporation setup



Voltage (V)		Electric field (V/cm)
0	=	0
90	=	250
190	=	500
290	=	750
380	=	1000
480	=	1250
580	=	1500

Detection of cell death

- Fluorescence microscopy
- 1 hour, 24 hours



Methods

Heamolysis induction

Blood samples

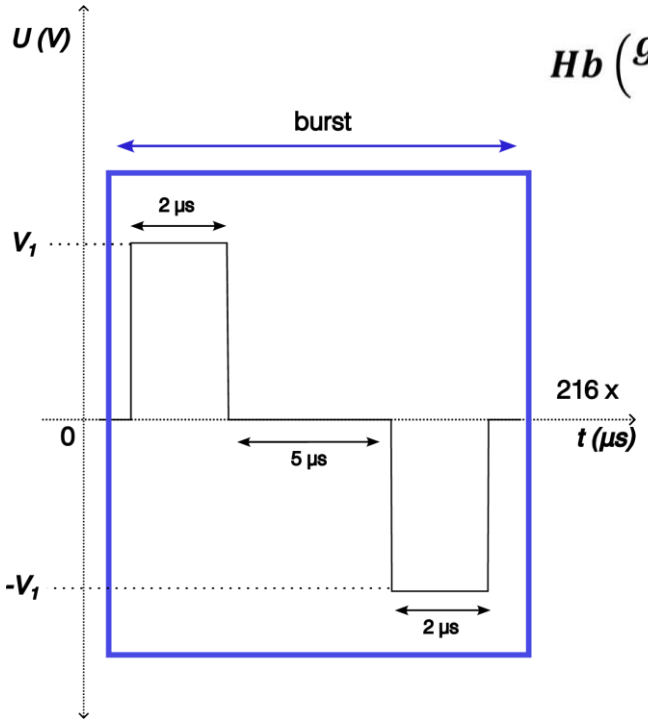
- Collection of blood from12 healthy volunteers

Electroporation setup

- Same as cardiomyocytes

Detection of heamolysis

- Colorimetric detection of free heamoglobin

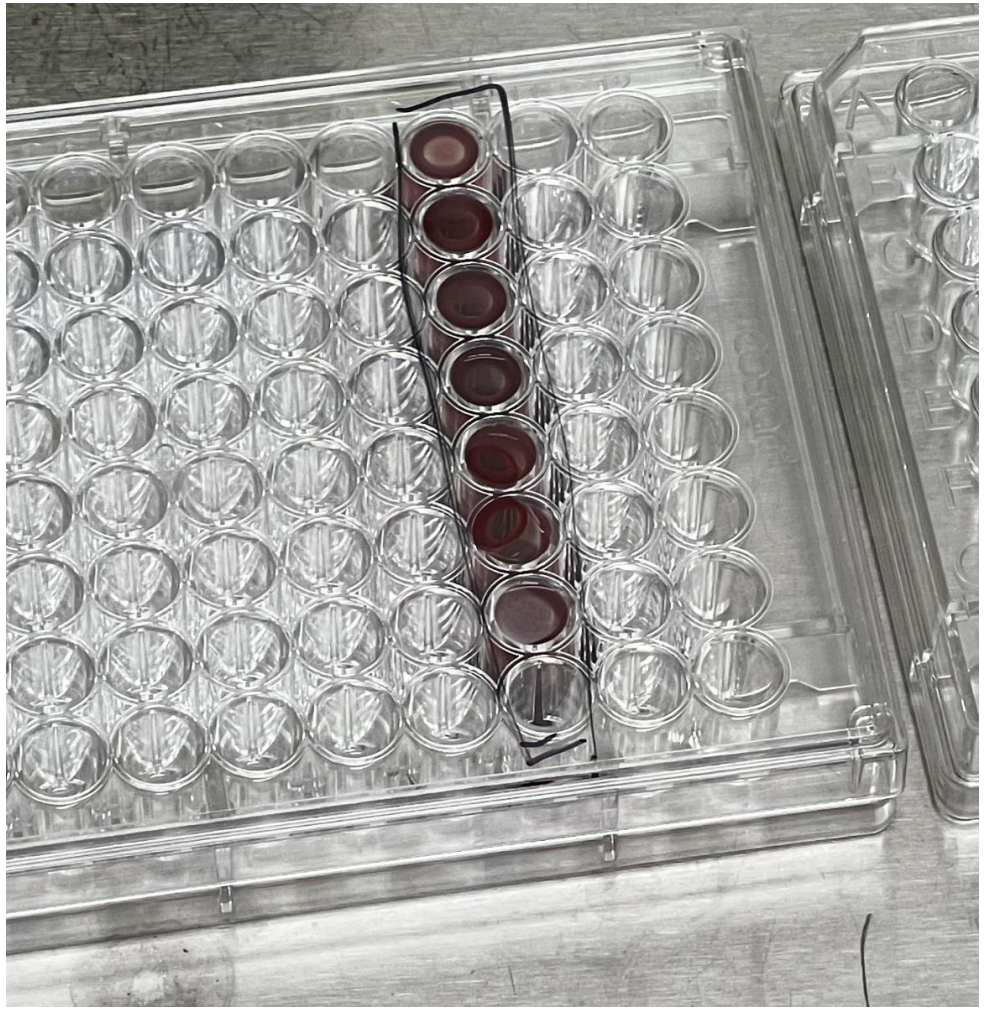


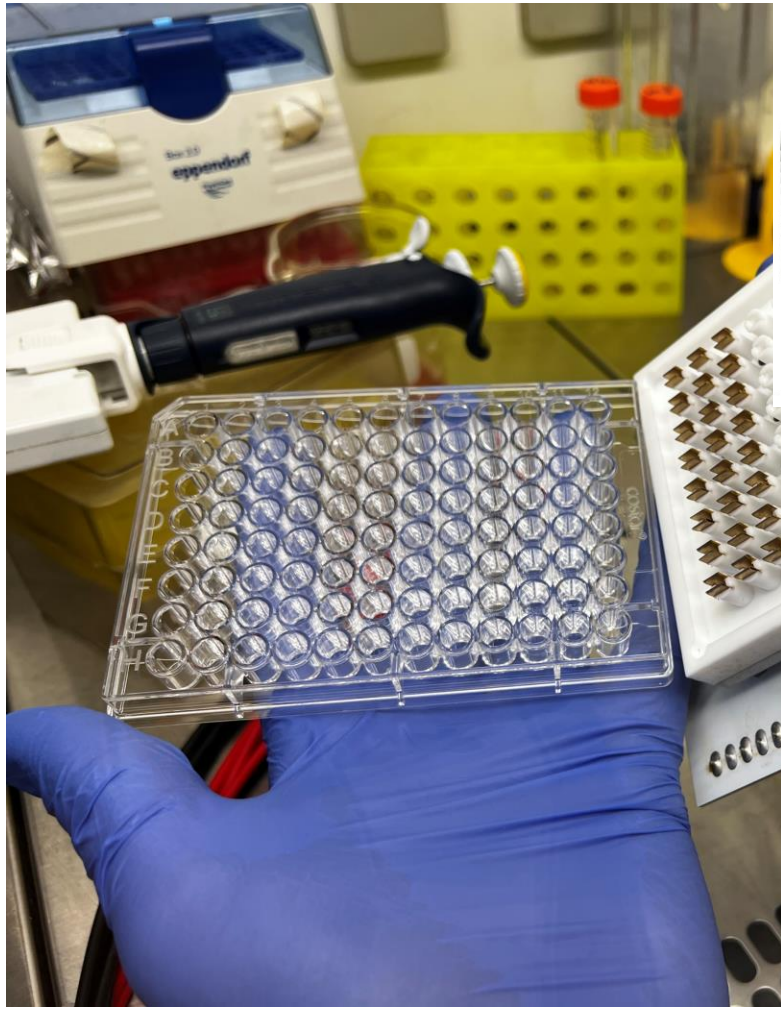
$$Hb\left(g/l\right) = \frac{k * (167.2 * A_{415} - 83.6 * A_{380} - 83.6 * A_{450})}{1000}$$

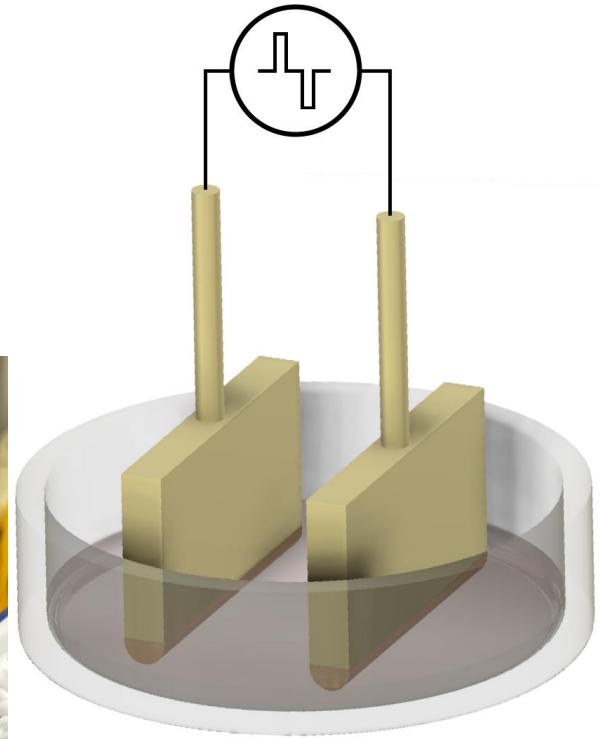
K = dillution

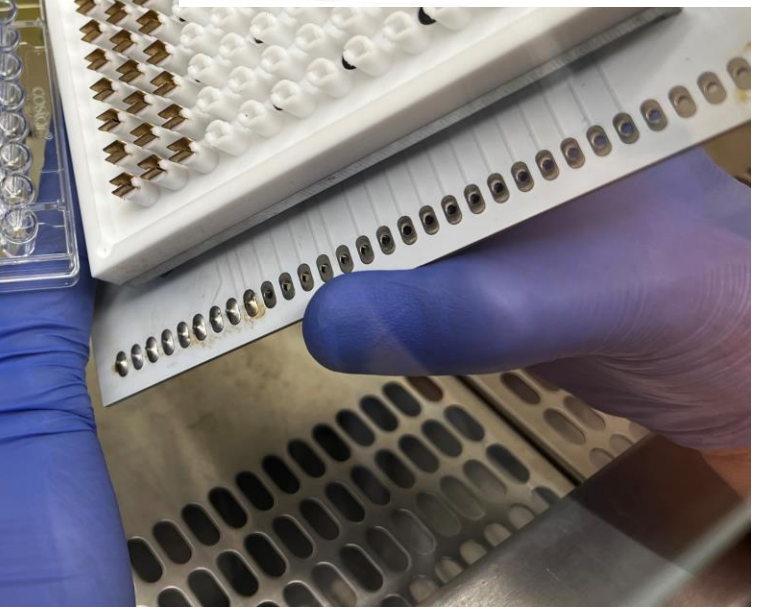
A = absorbance

Numerical model









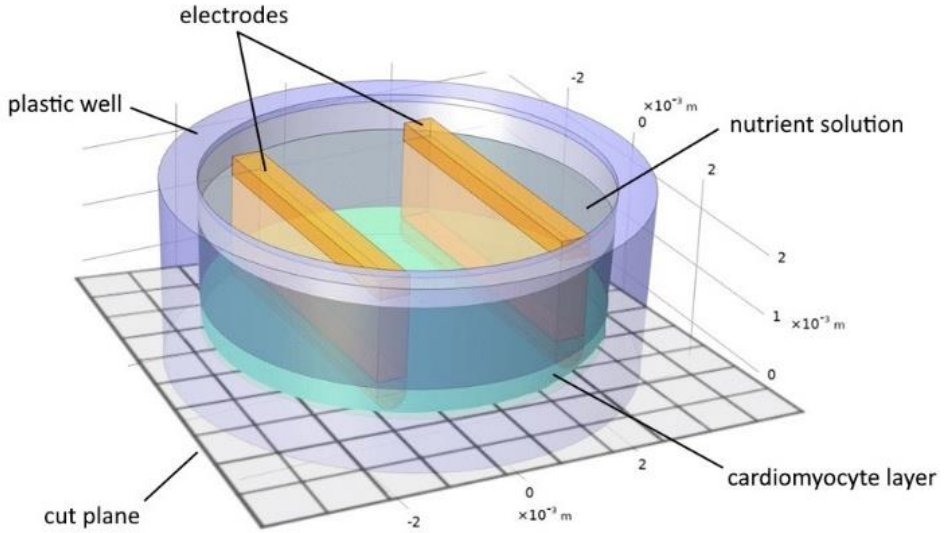
Numerical modelling

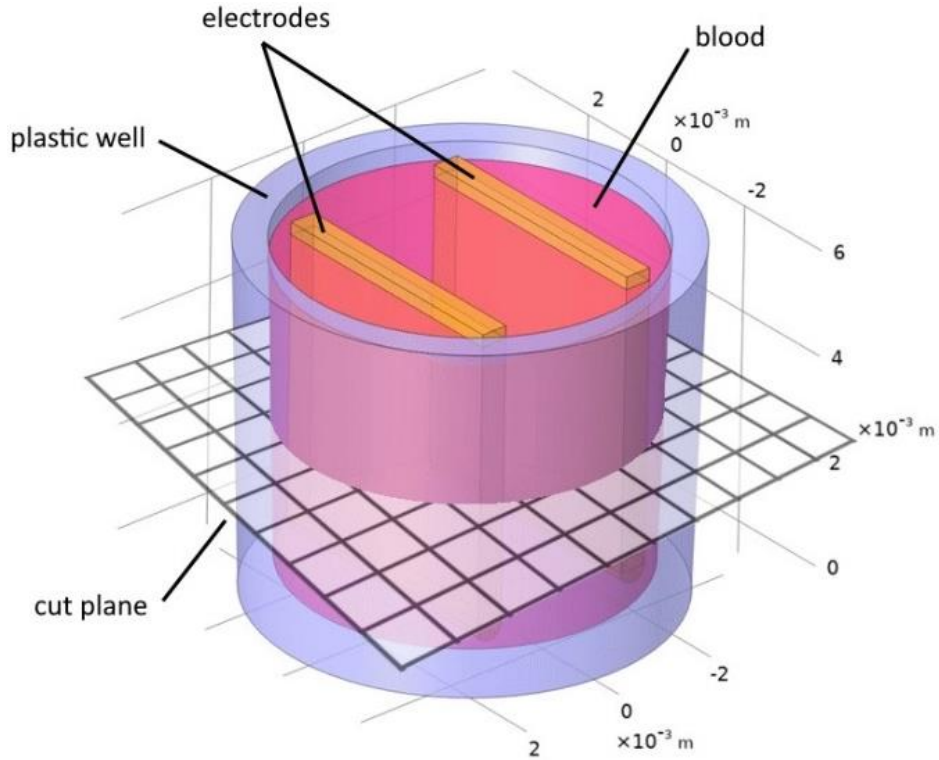
Electric fields

Electric currents

Temperature

Heat transfer in solids and fluids
Events
Laminar flow



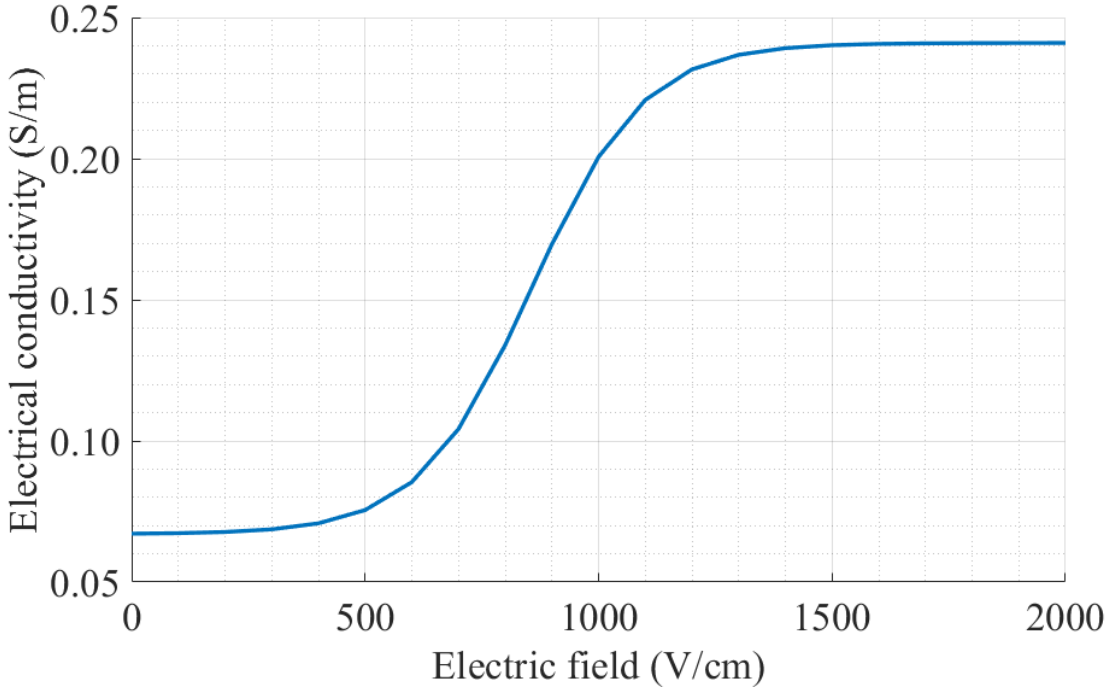


Electrical conductivity of tissue

- Dependent on frequency and applied electric field (permeabilization)

$$\sigma(E) = \frac{\sigma_0 + (\sigma_1 - \sigma_0)}{1 + 10 \cdot e^{\frac{E(i)\cdot 100 - A}{B}}}$$

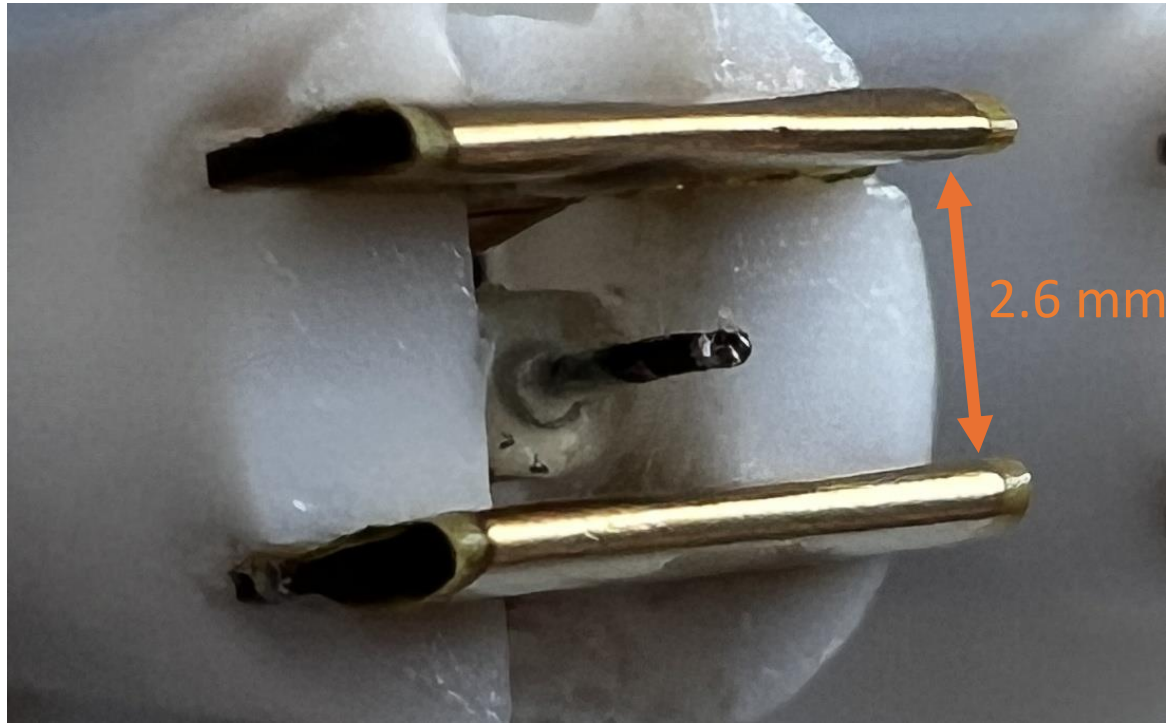
$$A = \frac{E_0 + E_1}{2} \qquad B = \frac{E_1 - E_0}{2}$$



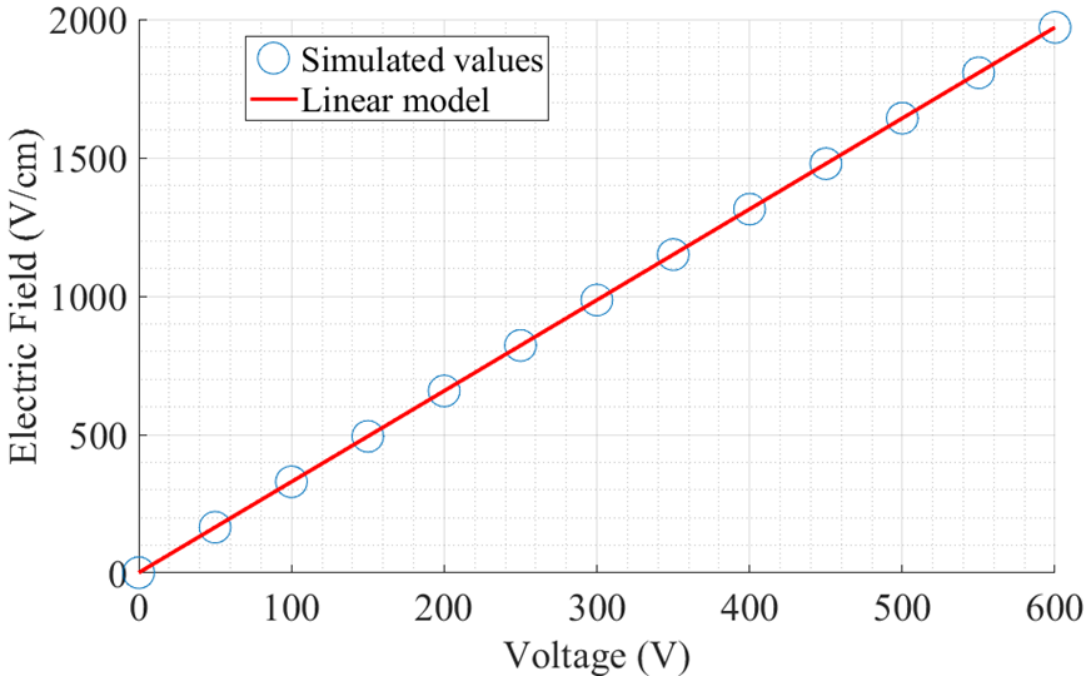
Parameter	Value
σ_0	0.067 (S/m)
σ_1	0.241 (S/m)

Temperature measurement

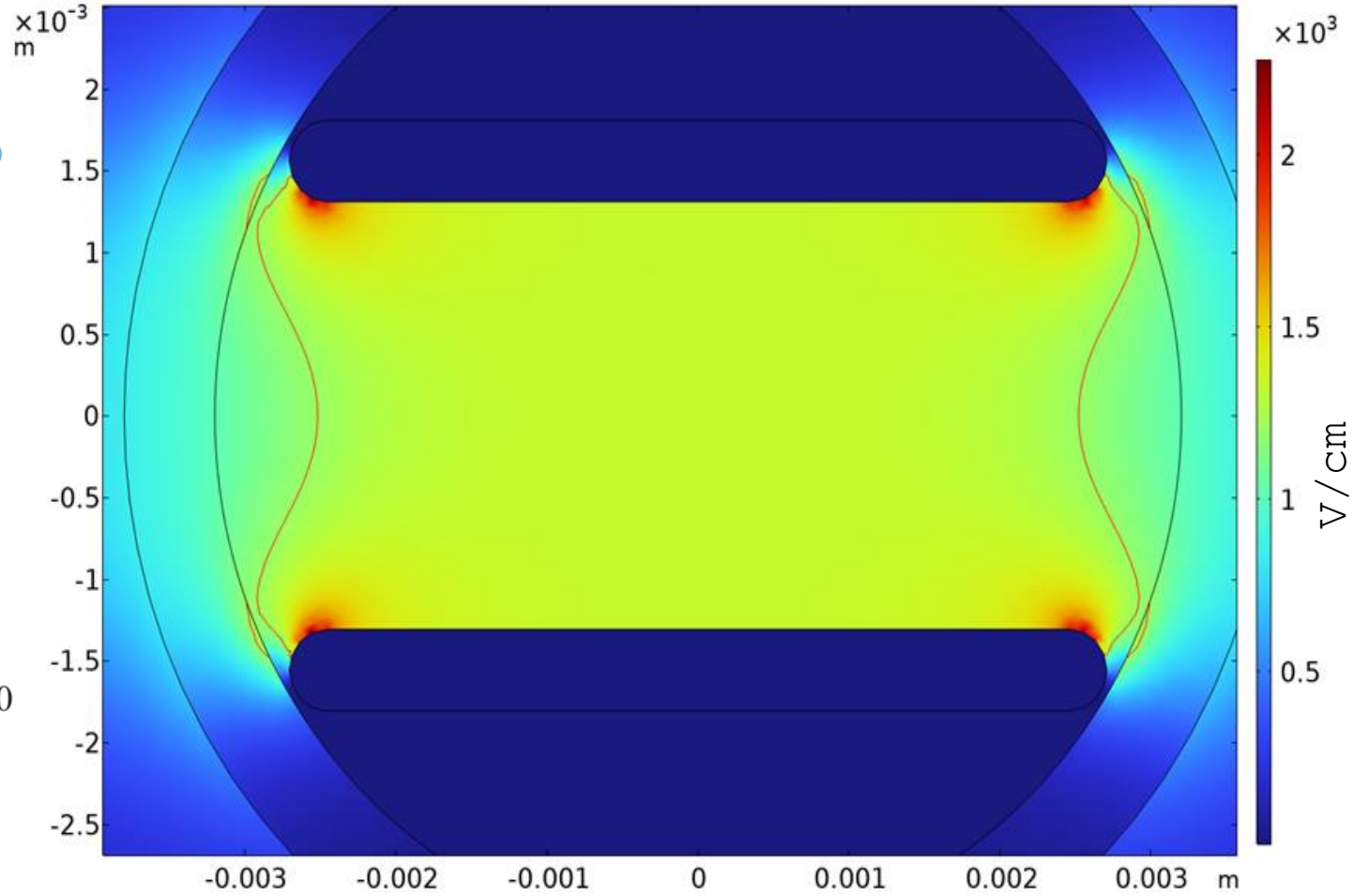
- Miniature negative temperature coefficient (NTC) temperature sensor
- Measurement frequency 100 Hz



Results

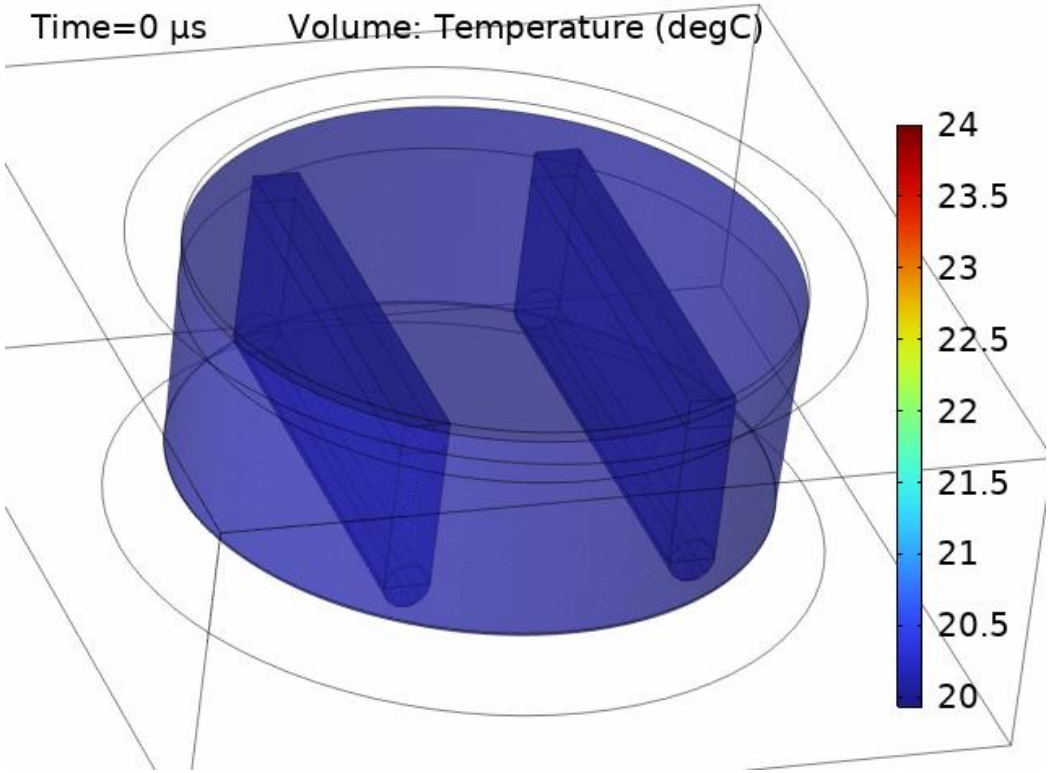


400 V
Isocontour 1200 V/cm

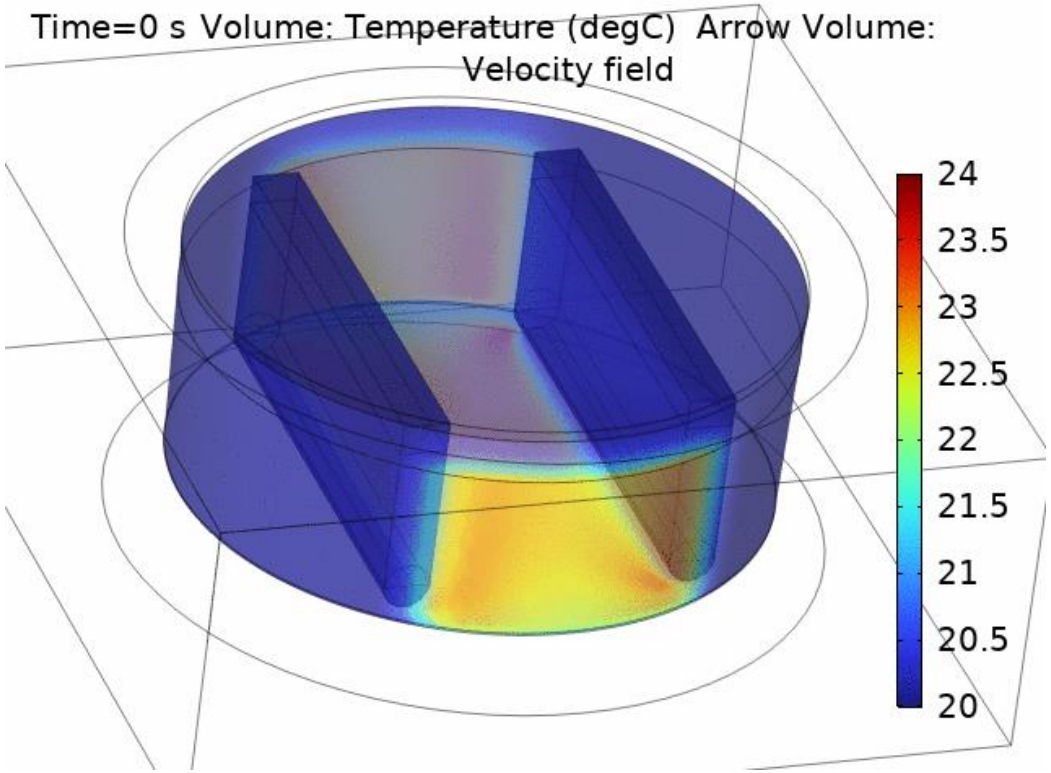


Results

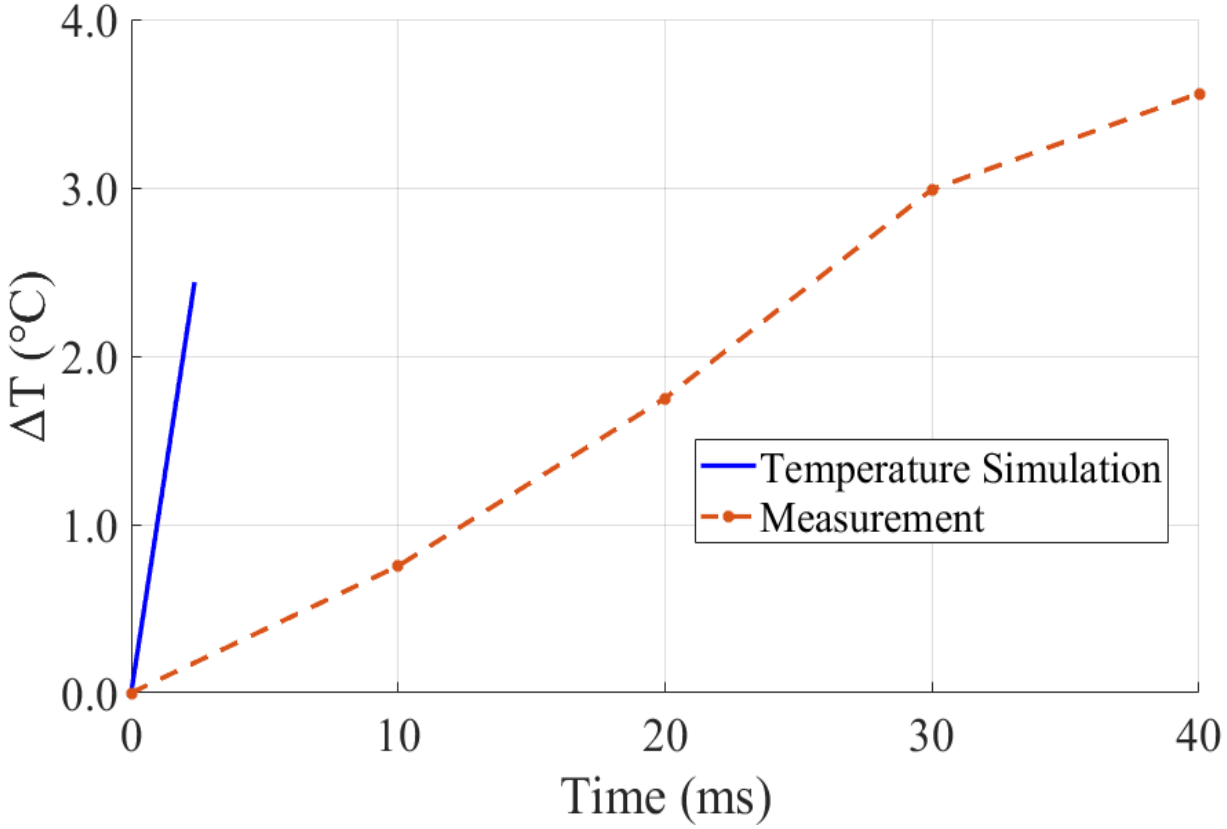
- Application of pulses

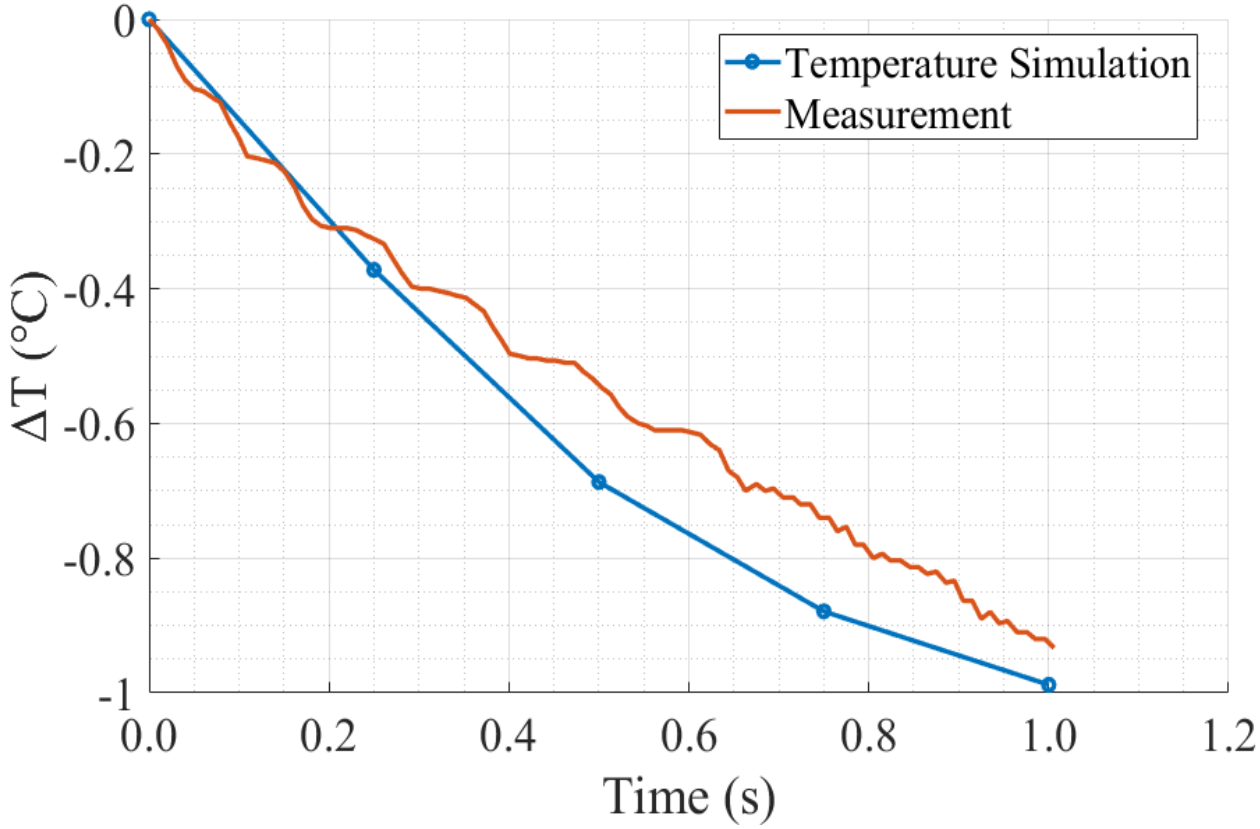


- Cooling

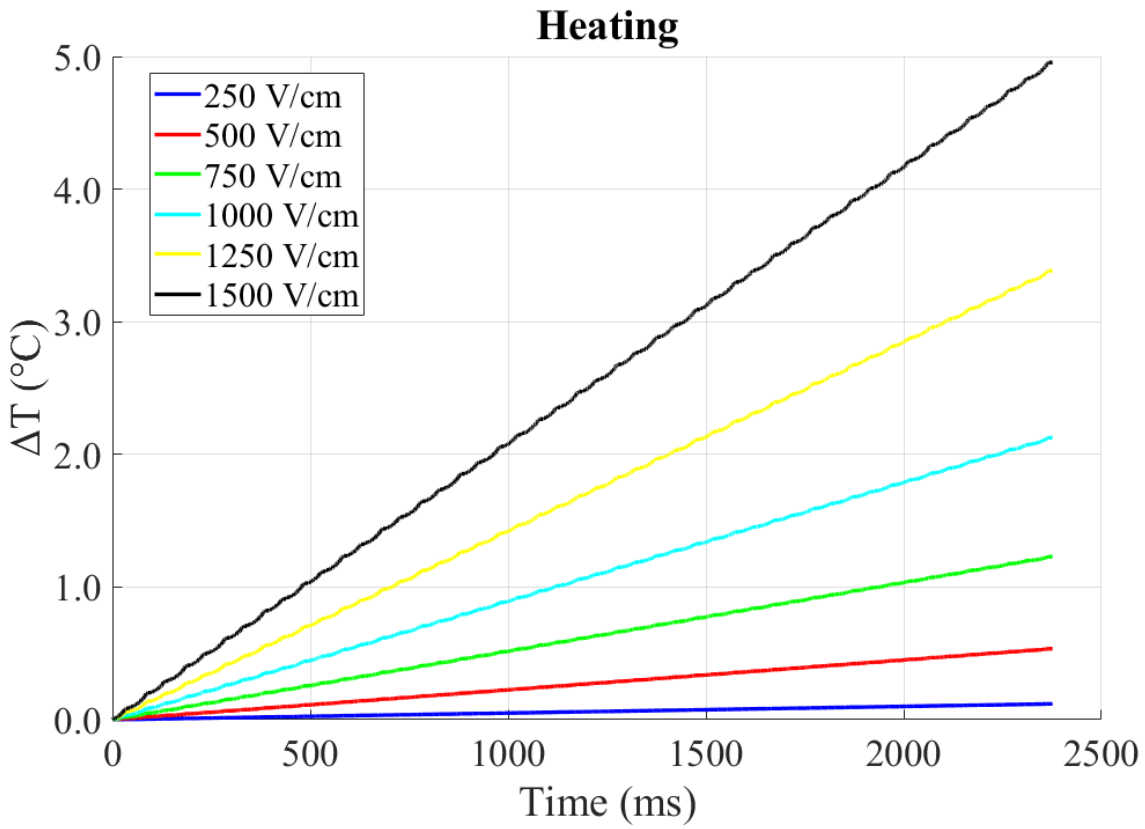


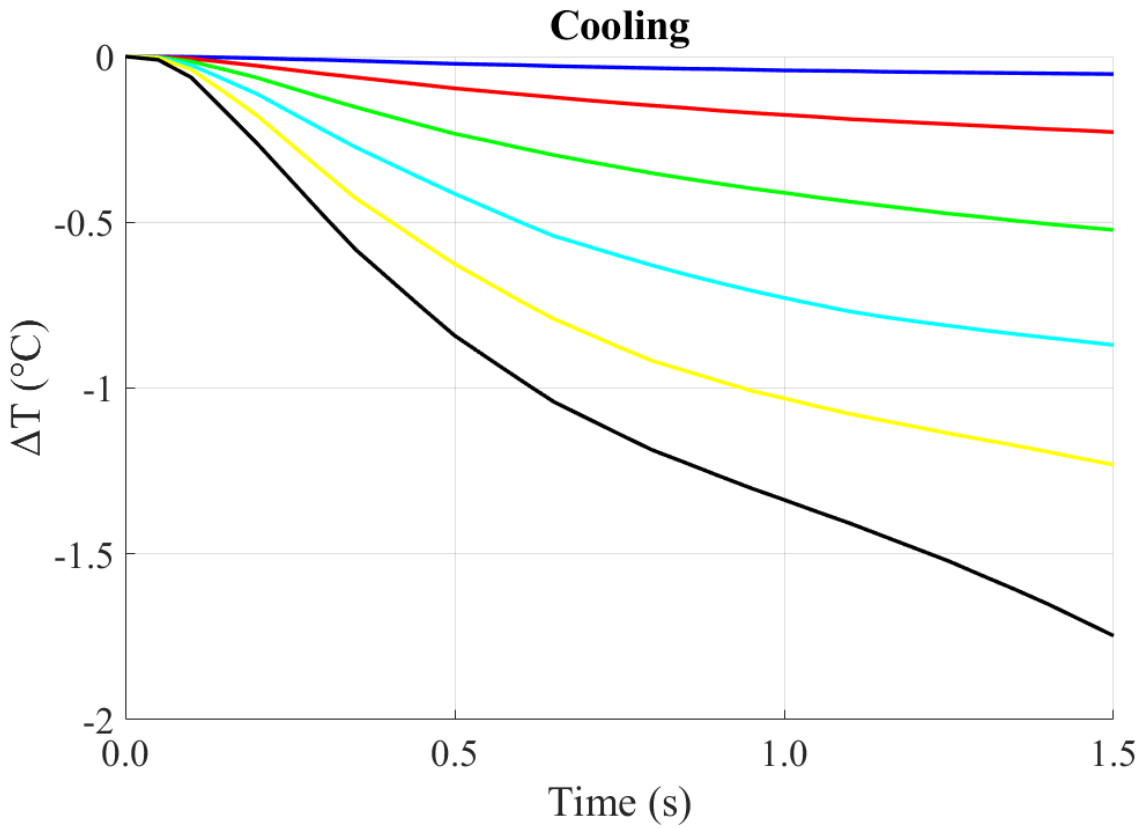
Temperature simulation - verification





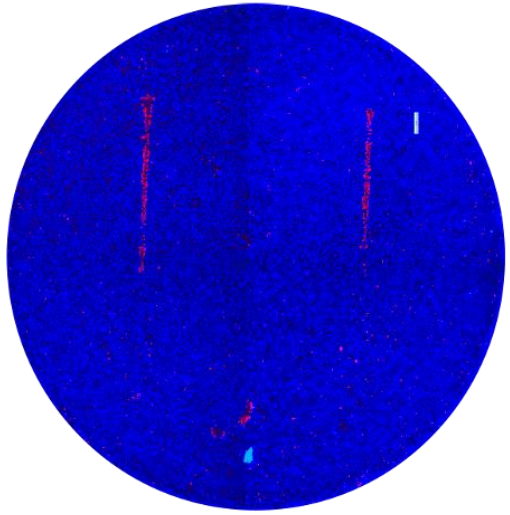
Temperature simulation





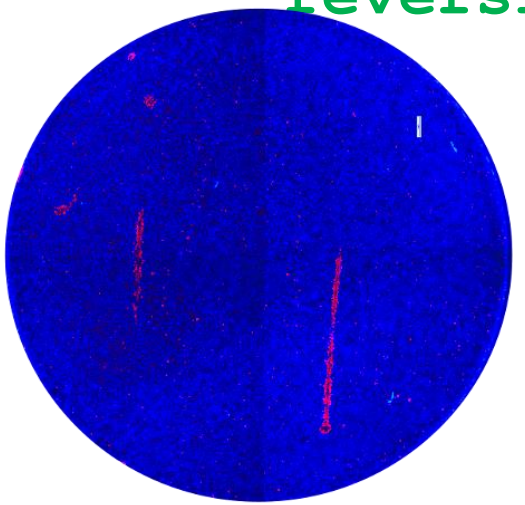
Results

control

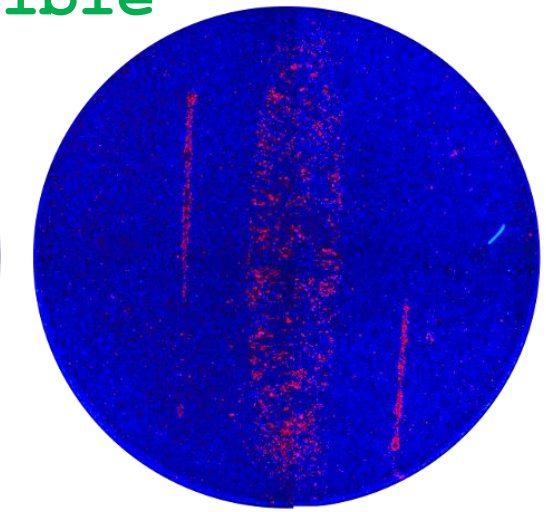


0 V/cm

Potencial reversible

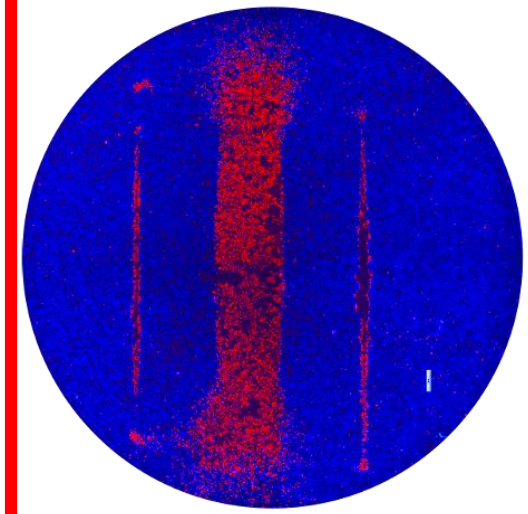


250 V/cm

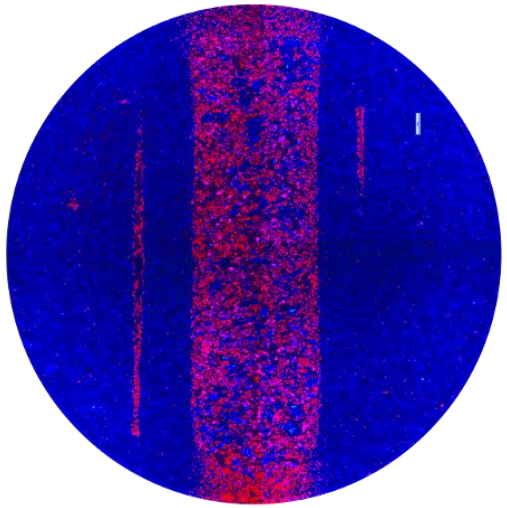


500 V/cm

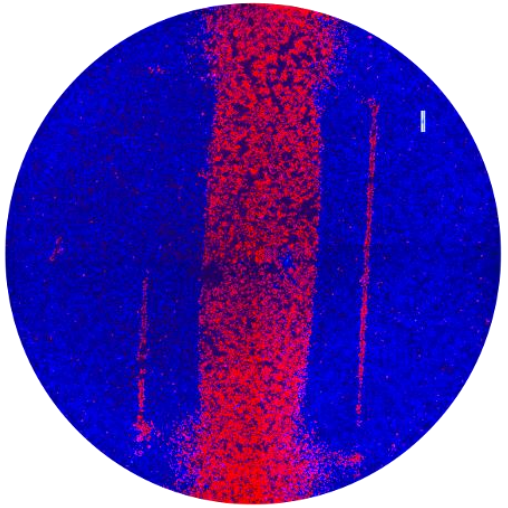
Irreversible



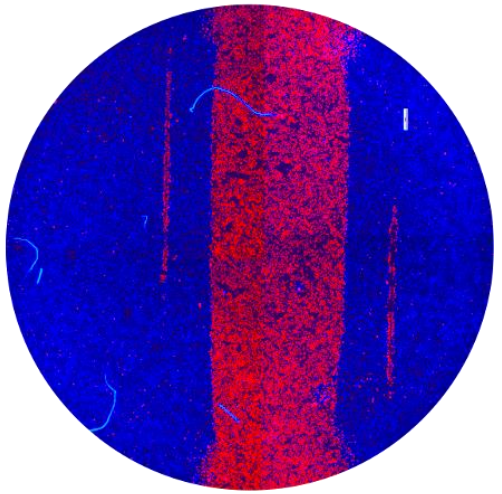
750 V/cm



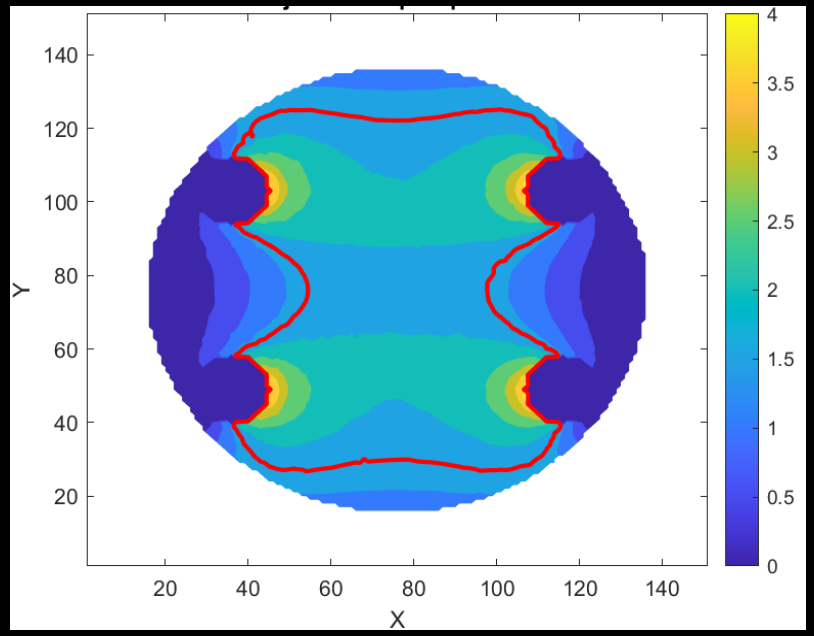
1000 V/cm

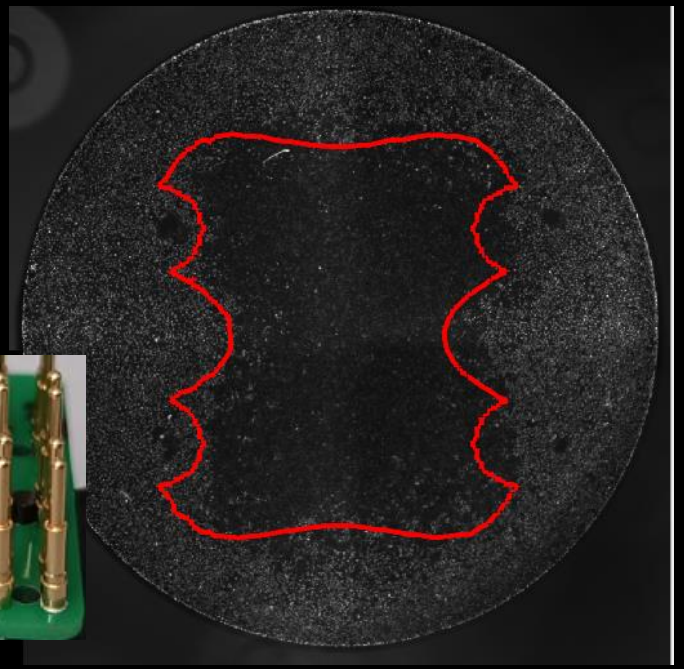


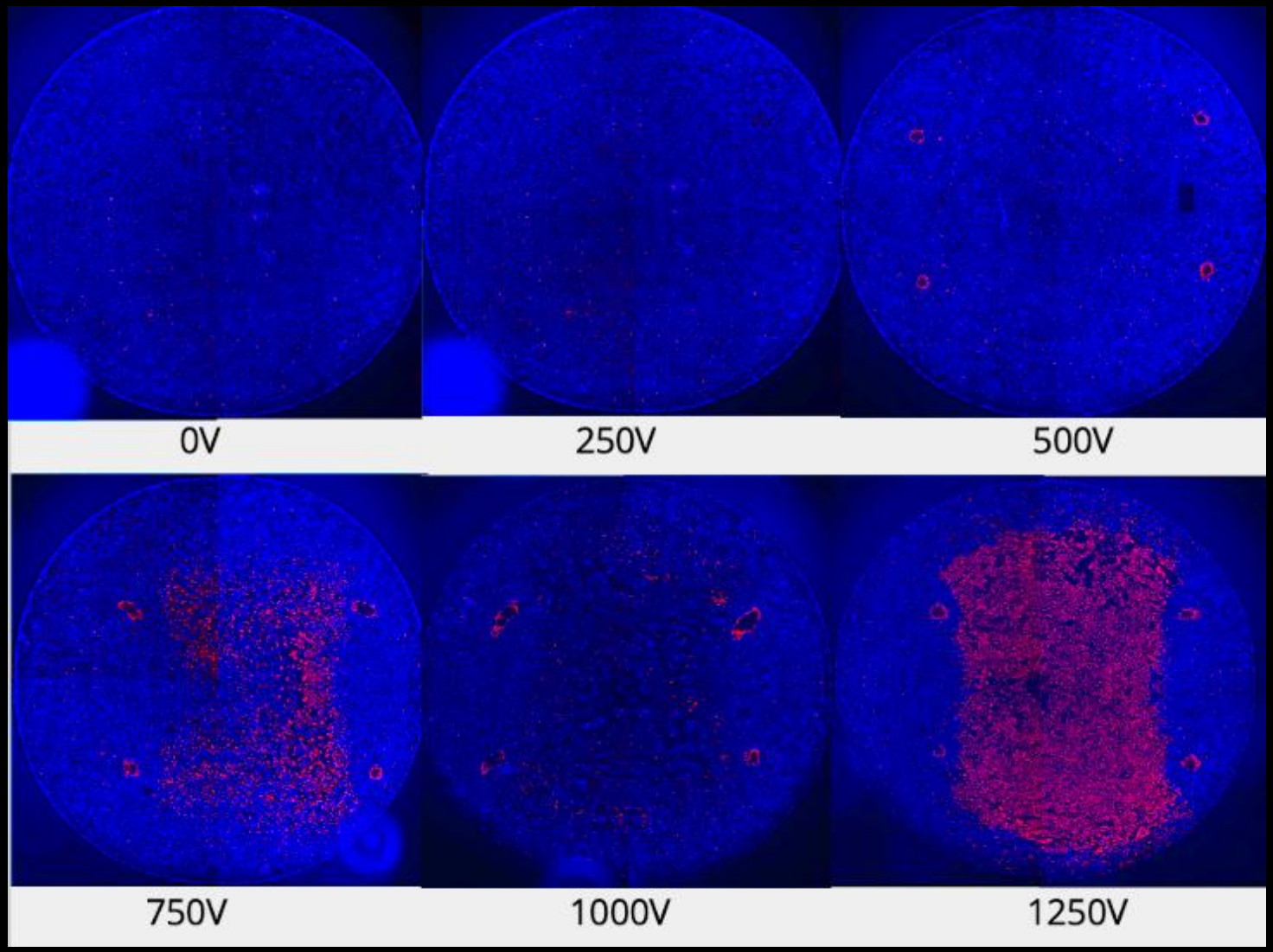
1250 V/cm

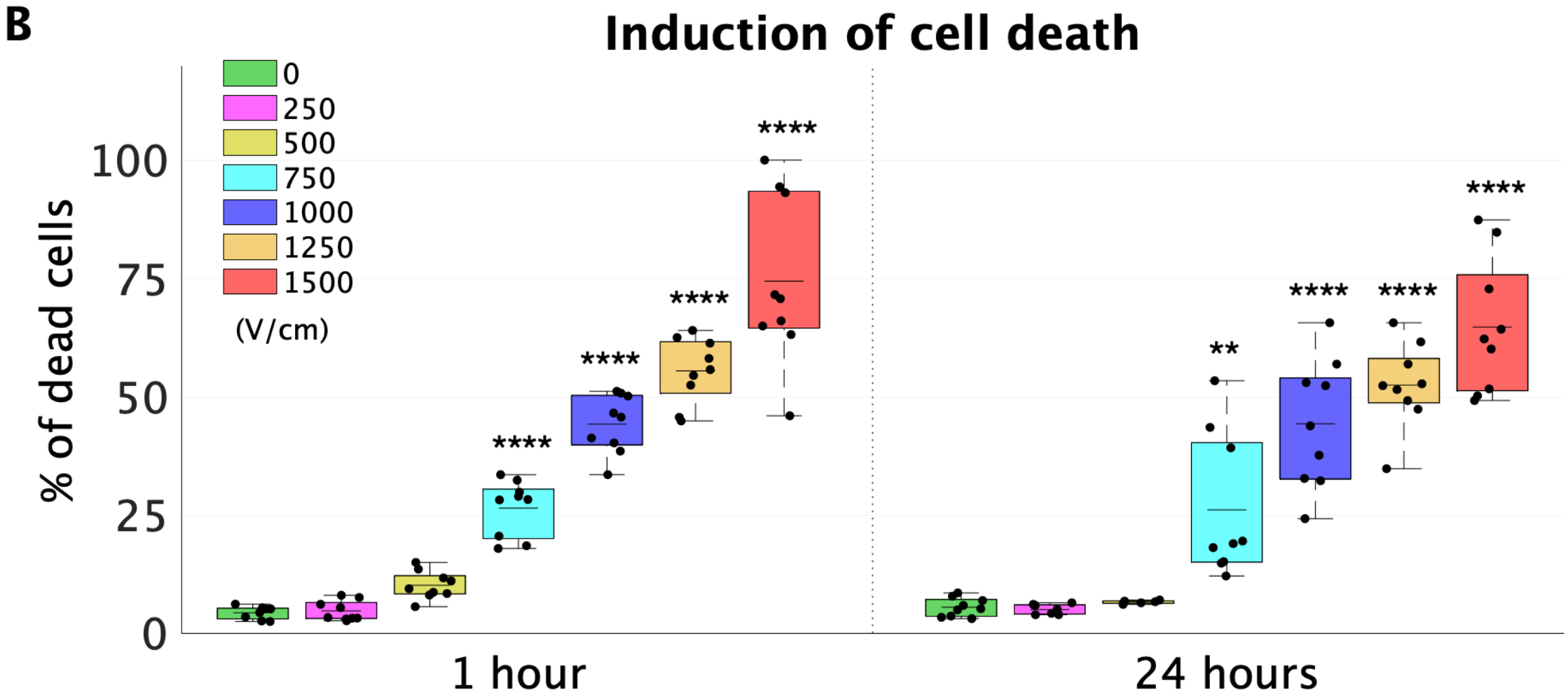


1500 V/cm

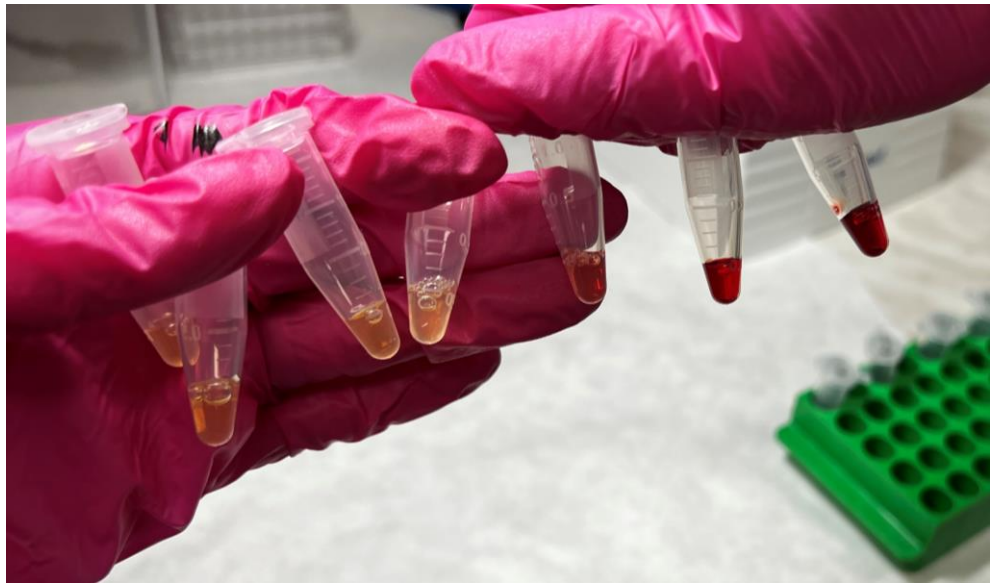

140
120
100
80
60
40
20
Y
20
40
60
80
100
120
140
X
4
3.5
3
2.5
2
1.5
1
0.5
0

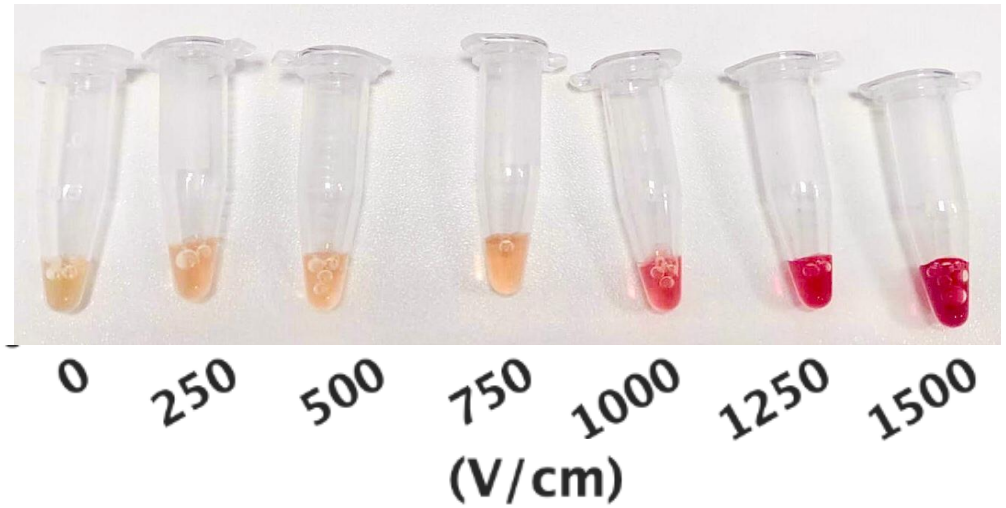


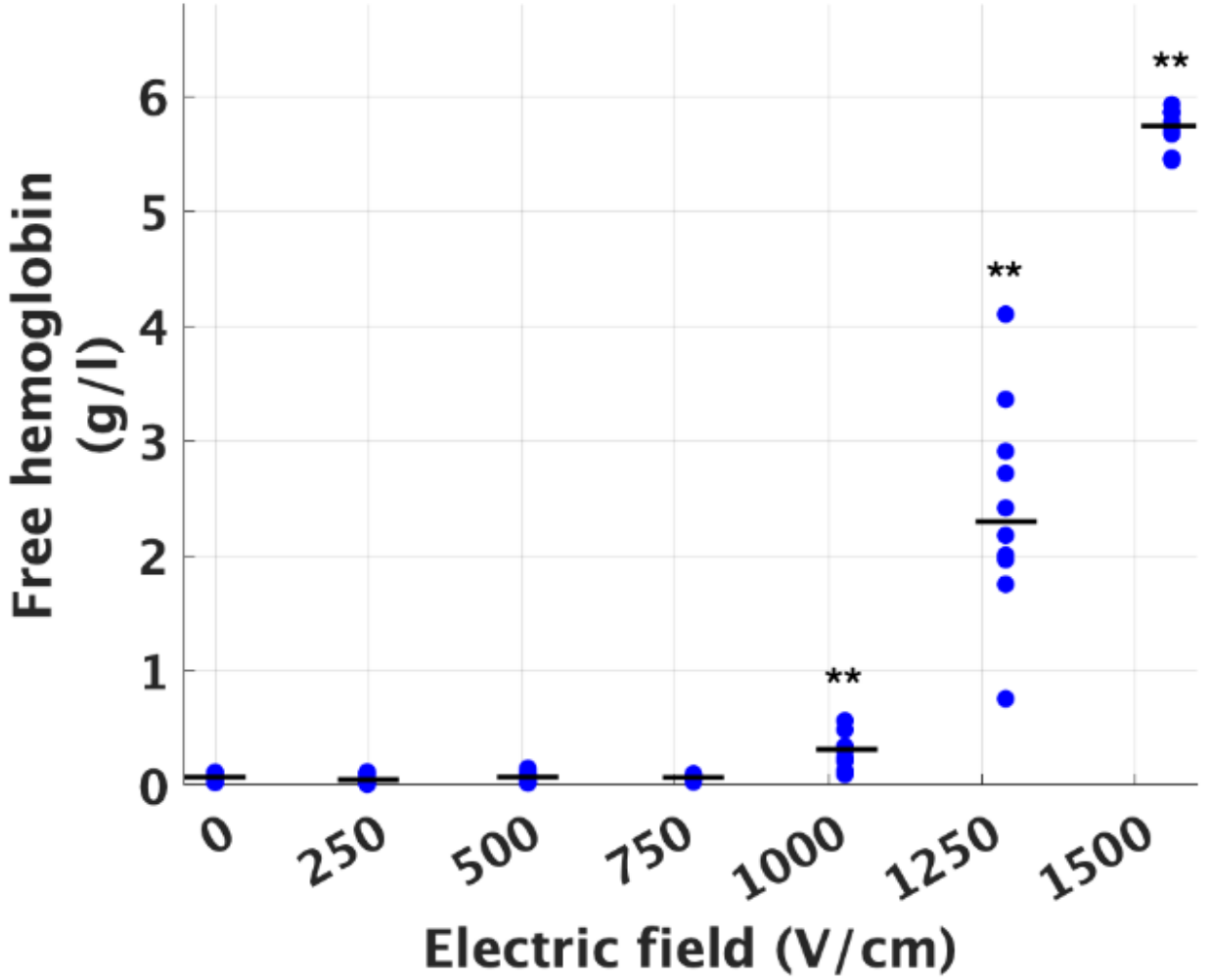

0V
250V
500V
750V
1000V
1250V


B
Induction of cell death
0
250
500
750
1000
1250
1500
(V/cm)
% of dead cells
100
75
50
25
0
****
****
****
****
**
****
****
****
1 hour
24 hours

Blood Experiment – Heamolysis







Thank you for your attention