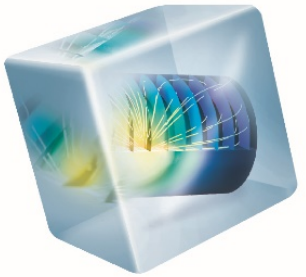
Stefano Bertoldo

PRELIMINARY COMPARISON OF SIMULATED AND MEASURED SIGNALS FROM SEGMENTED DETECTORS

GOALS

- Laser annealed junctions
- Segmentation of junctions with good passivation
- Accurate simulation of the detector behavior
- Simulated signals from segments

COMSOL MULTIPHYSICS®



DRIFT WITHOUT DIFFUSION

Approximations:
- Electric field not influenced by charges movement
- Point charge

$$\dot{\vec{x}}_e(t) = -\mu_e \vec{E}(\vec{x}_e(t))$$
$$\dot{\vec{x}}_h(t) = \mu_h \vec{E}(\vec{x}_h(t))$$

POISSON EQUATION

$$\nabla^2 V(\vec{x}) = N_b\left[1 - e^{-\frac{qV(\vec{x})}{k_B T}}\right]$$

$$i_n(t) = q[\mu_e \vec{E}(\vec{x}_e(t)) \cdot \overrightarrow{E_n}(\vec{x}_e(t)) + \mu_h \vec{E}(\vec{x}_h(t)) \cdot \overrightarrow{E_n}(\vec{x}_h(t))]$$
$$Q_n(t) = \int_0^t i_n(\tau) d\tau$$

DRIFT WITH DIFFUSION

Approximations:
- Einstein relation (diffusion proportional to mobility)
- Isotropic diffusion

$$\dot{c_e}(\vec{x}, t) - \nabla[D_e \nabla c_e(\vec{x}, t) - \mu_e c_e(\vec{x}, t) \nabla V(\vec{x})] = 0$$
$$\dot{c_h}(\vec{x}, t) - \nabla[D_h \nabla c_h(\vec{x}, t) + \mu_h c_h(\vec{x}, t) \nabla V(\vec{x})] = 0$$

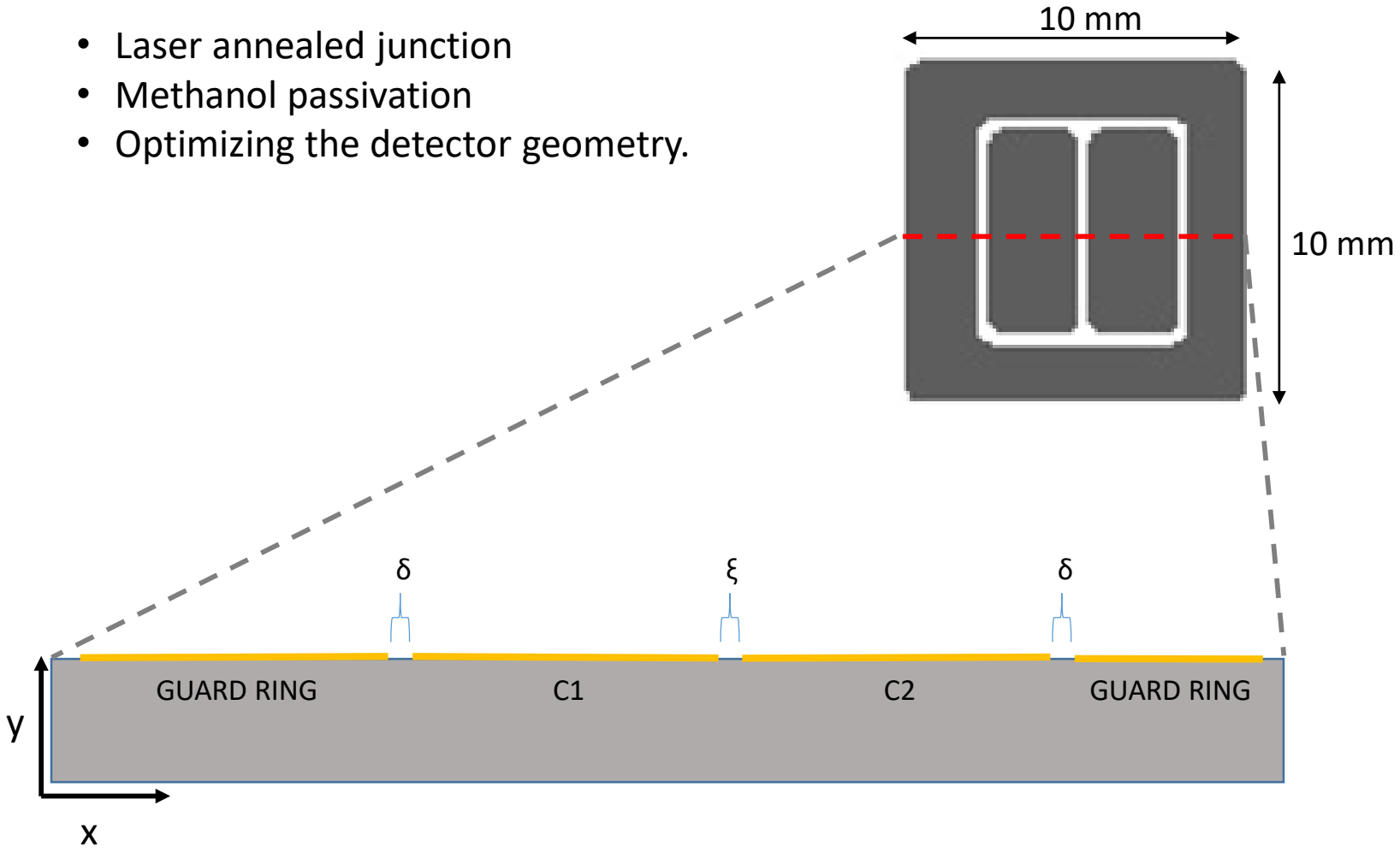
POISSON EQUATION

$$\nabla^2 V(\vec{x}) = N_b\left[1 - e^{-\frac{qV(\vec{x})}{k_B T}}\right]$$

$$i_n(t) = \int_\Omega [\mu_e c_e(\vec{x}, t) \vec{E}(\vec{x}) \cdot \overrightarrow{E_n}(\vec{x}) + \mu_h c_h(\vec{x}, t) \vec{E}(\vec{x}) \cdot \overrightarrow{E_n}(\vec{x})] \, d\vec{x}$$
$$Q_n(t) = \int_0^t i_n(\tau) d\tau$$

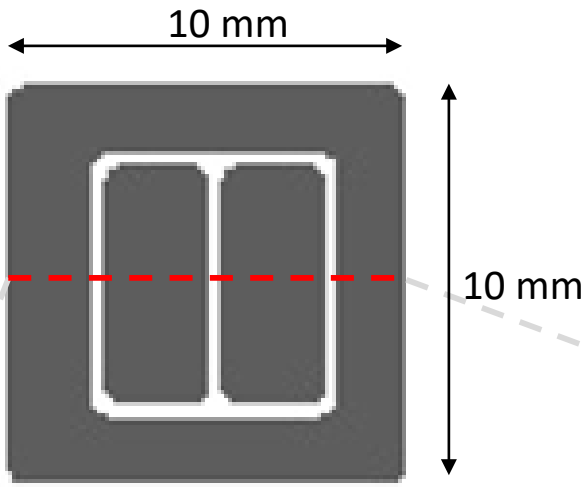
SEGMENTED p-TYPE DETECTOR

- Laser annealed junction
- Methanol passivation
- Optimizing the detector geometry.



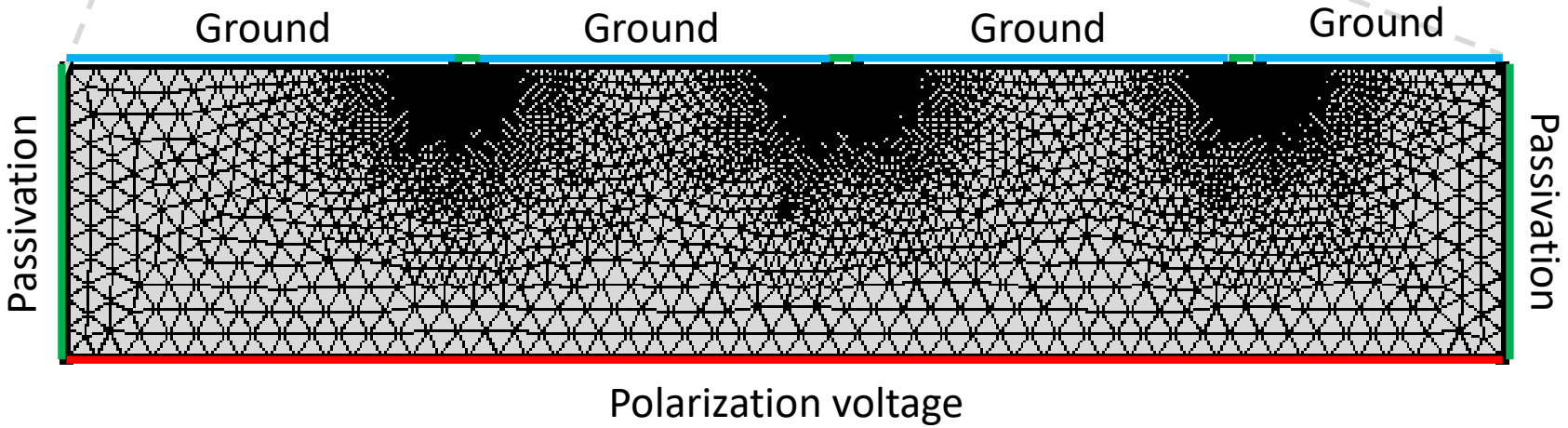
GEOMETRY AND MESH

2D simulation → central zone approximation

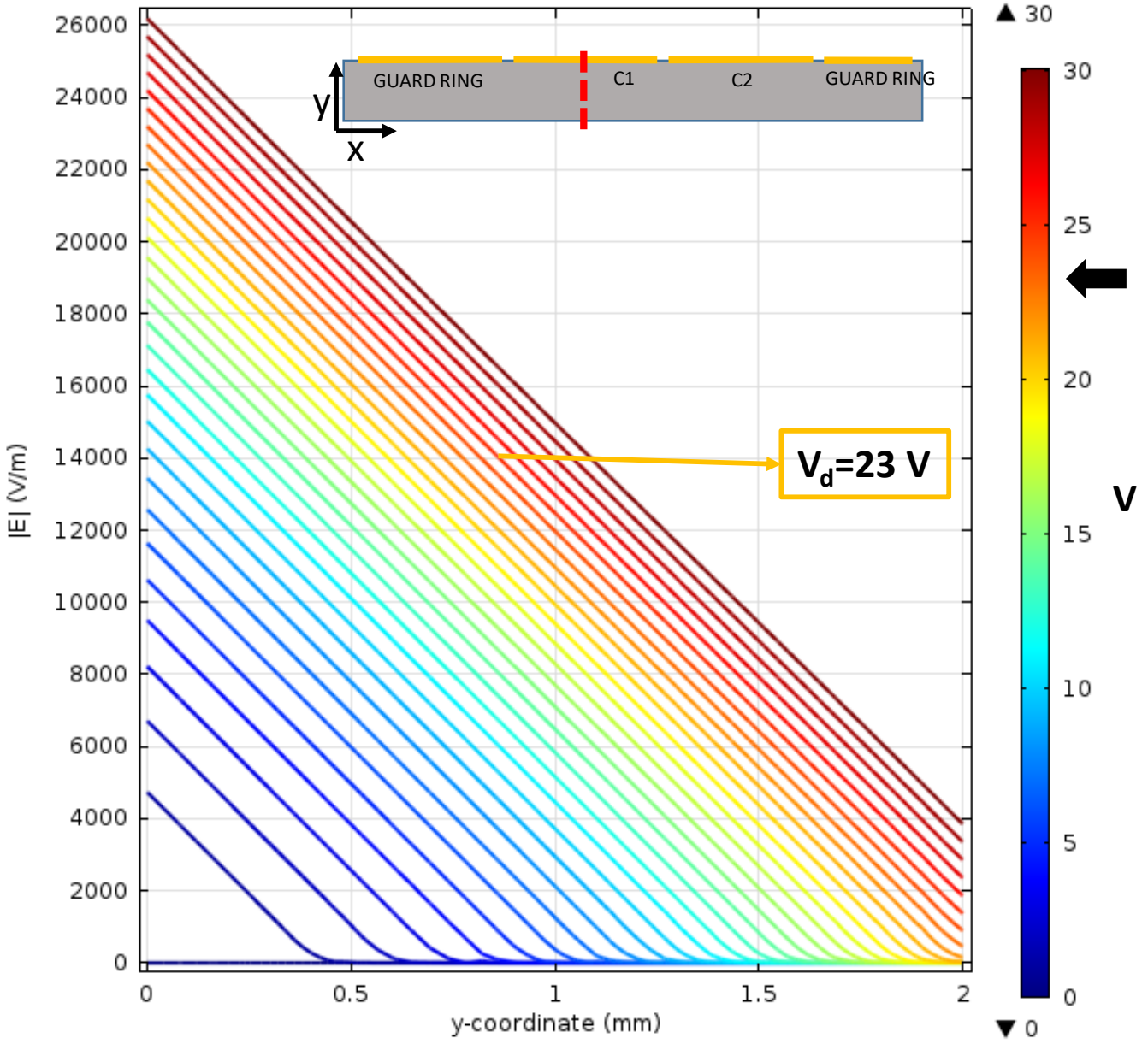


First model:
p+/p/n+ detector (2D)

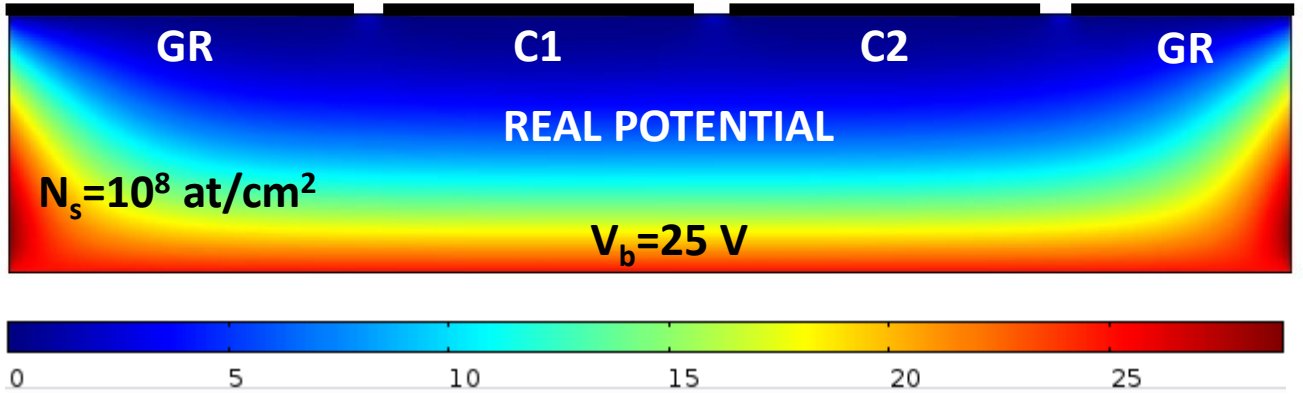
$N_s=10^8$ at/cm^2



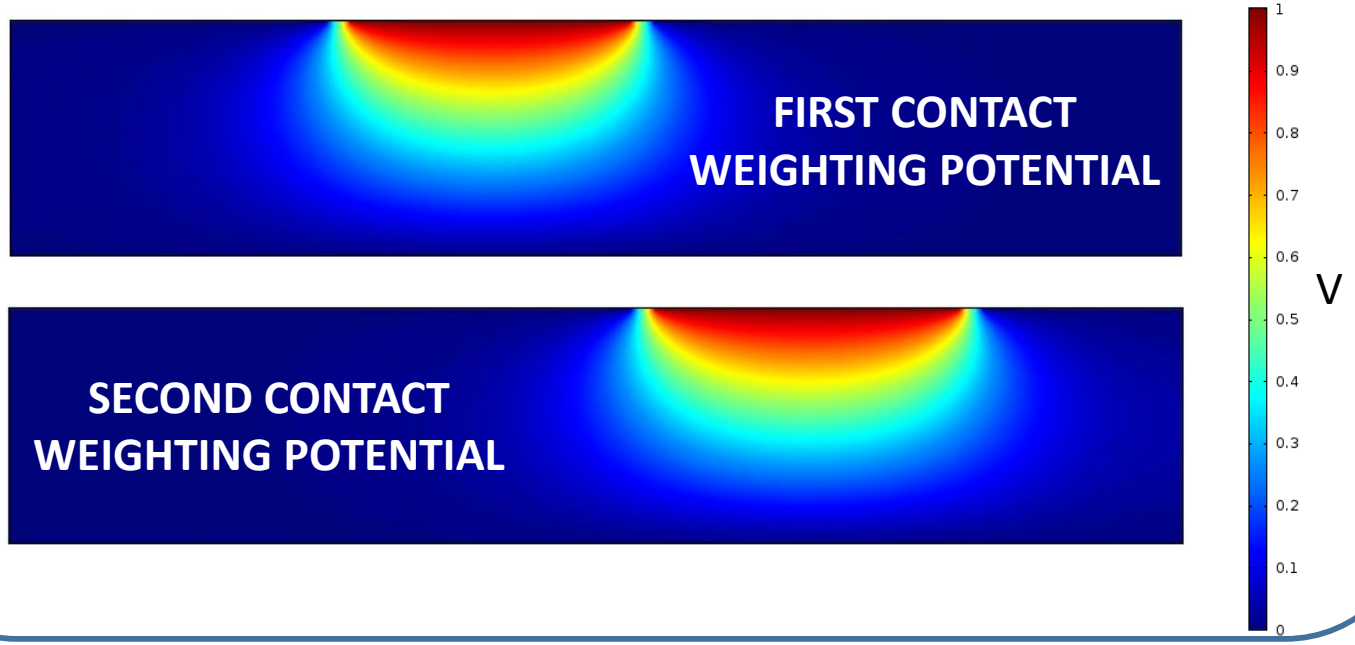
DEPLETION VOLTAGE



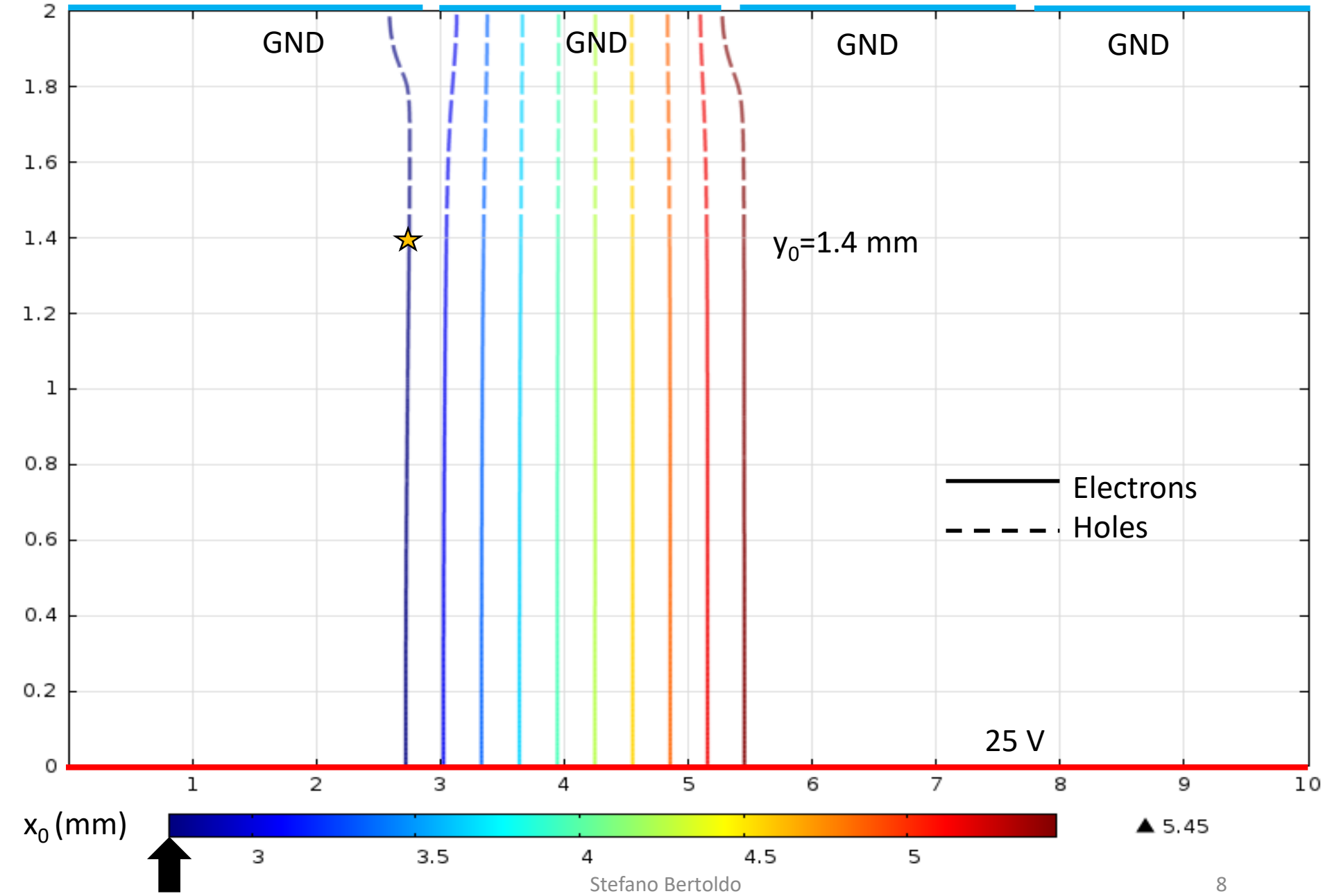
REAL AND WEIGHTING POTENTIALS



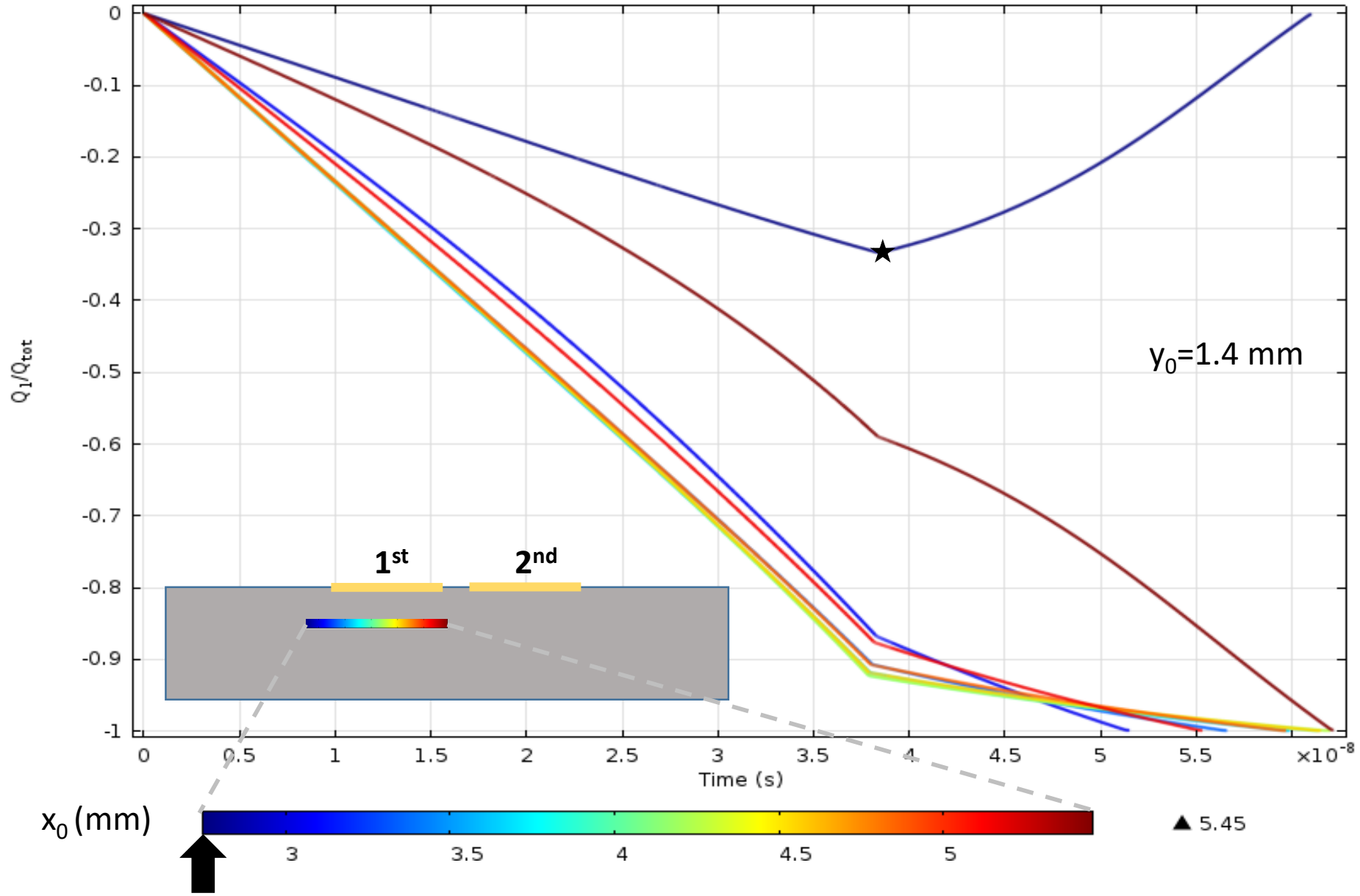
Shockley-Ramo Theorem → Weighting potentials



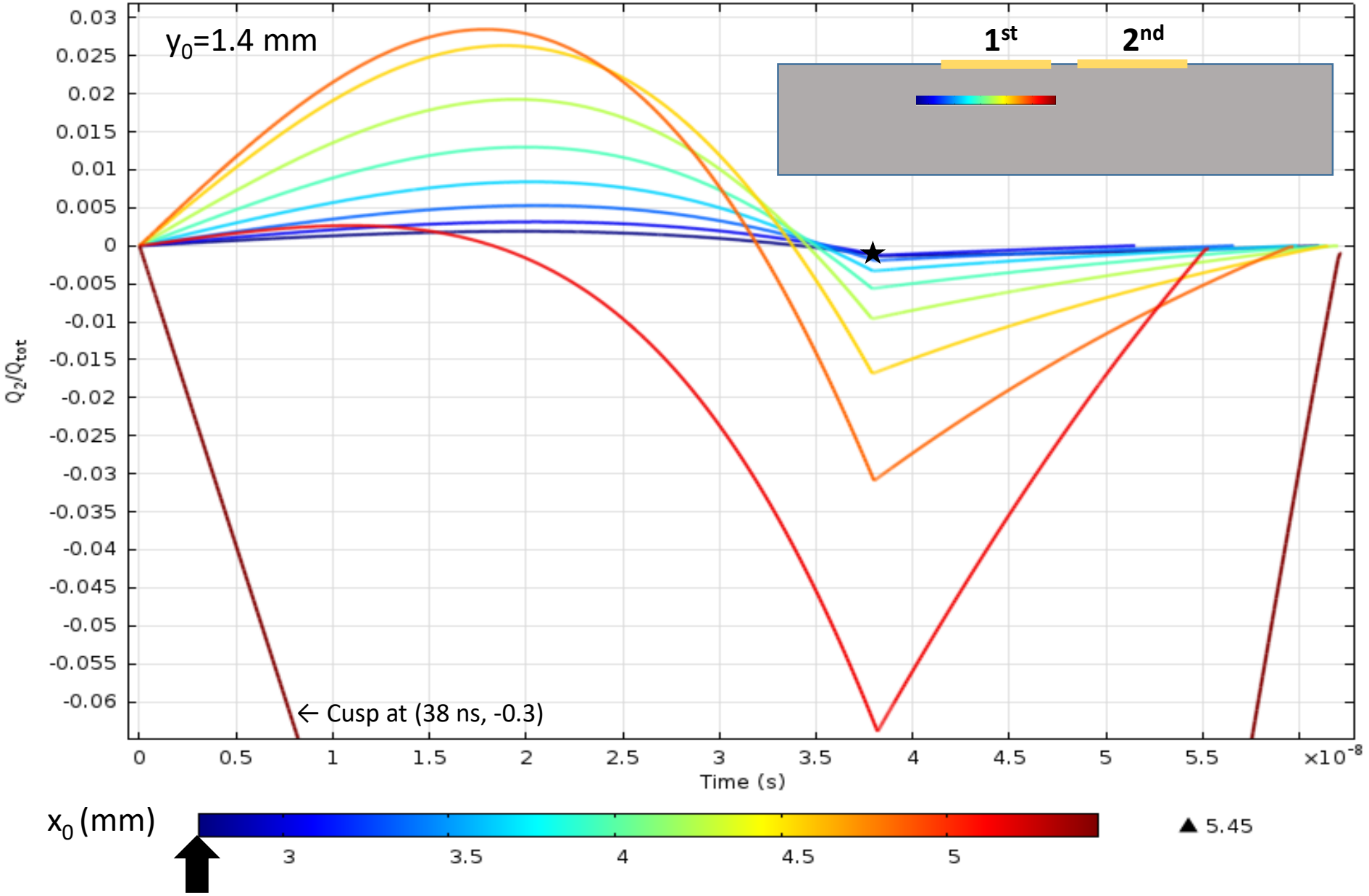
CHARGE TRAJECTORIES



1st CONTACT SIGNALS



2nd CONTACT SIGNALS



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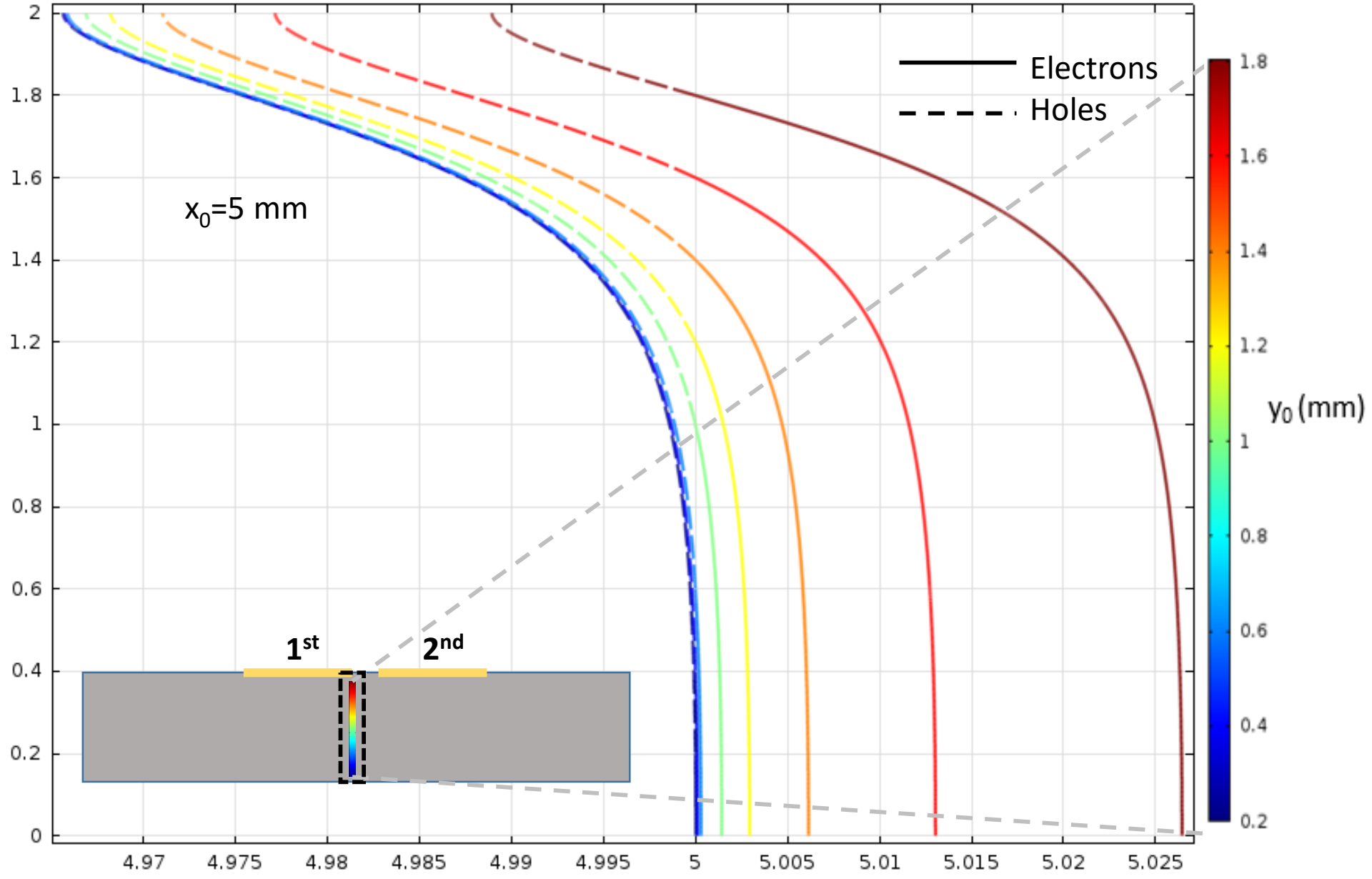

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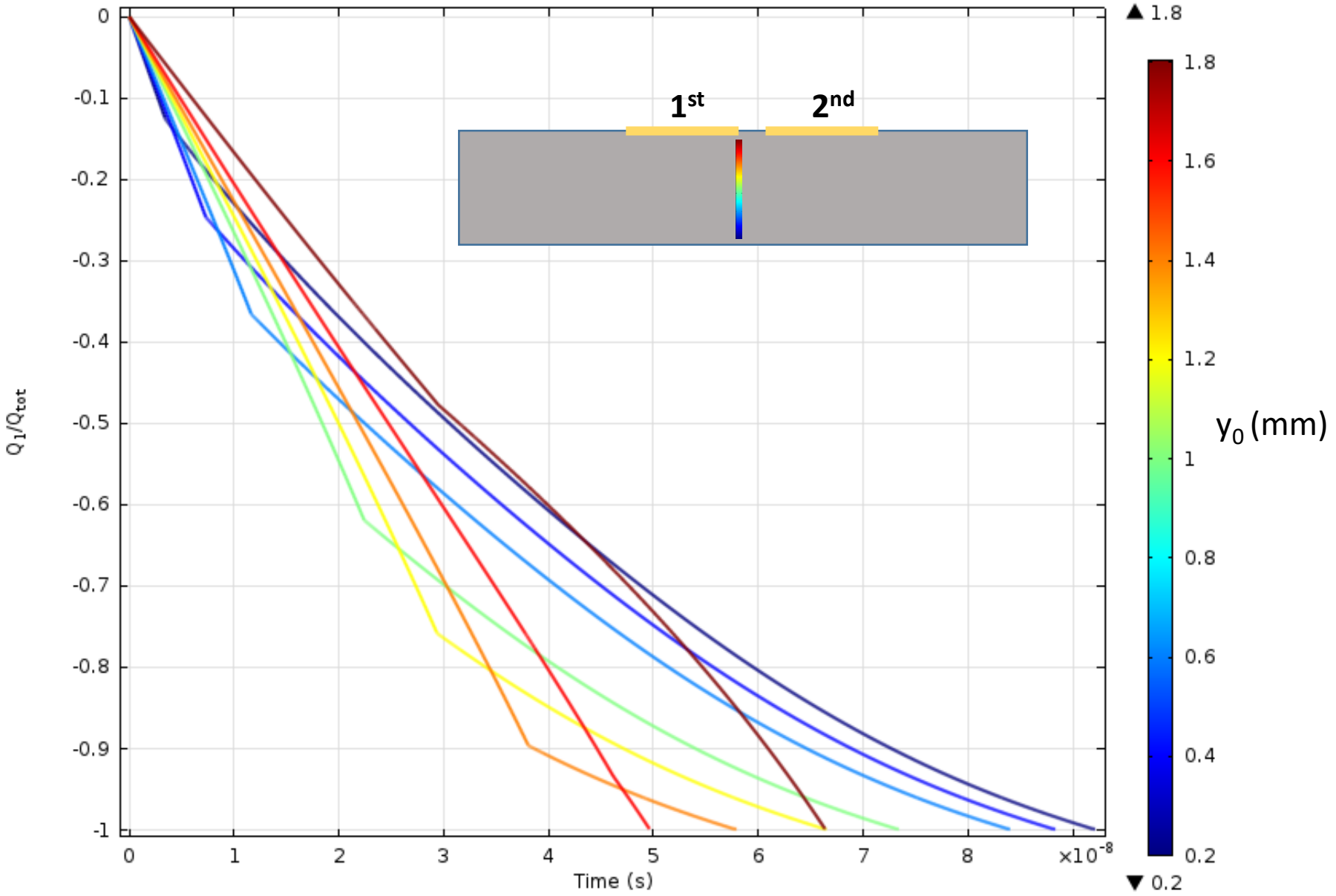
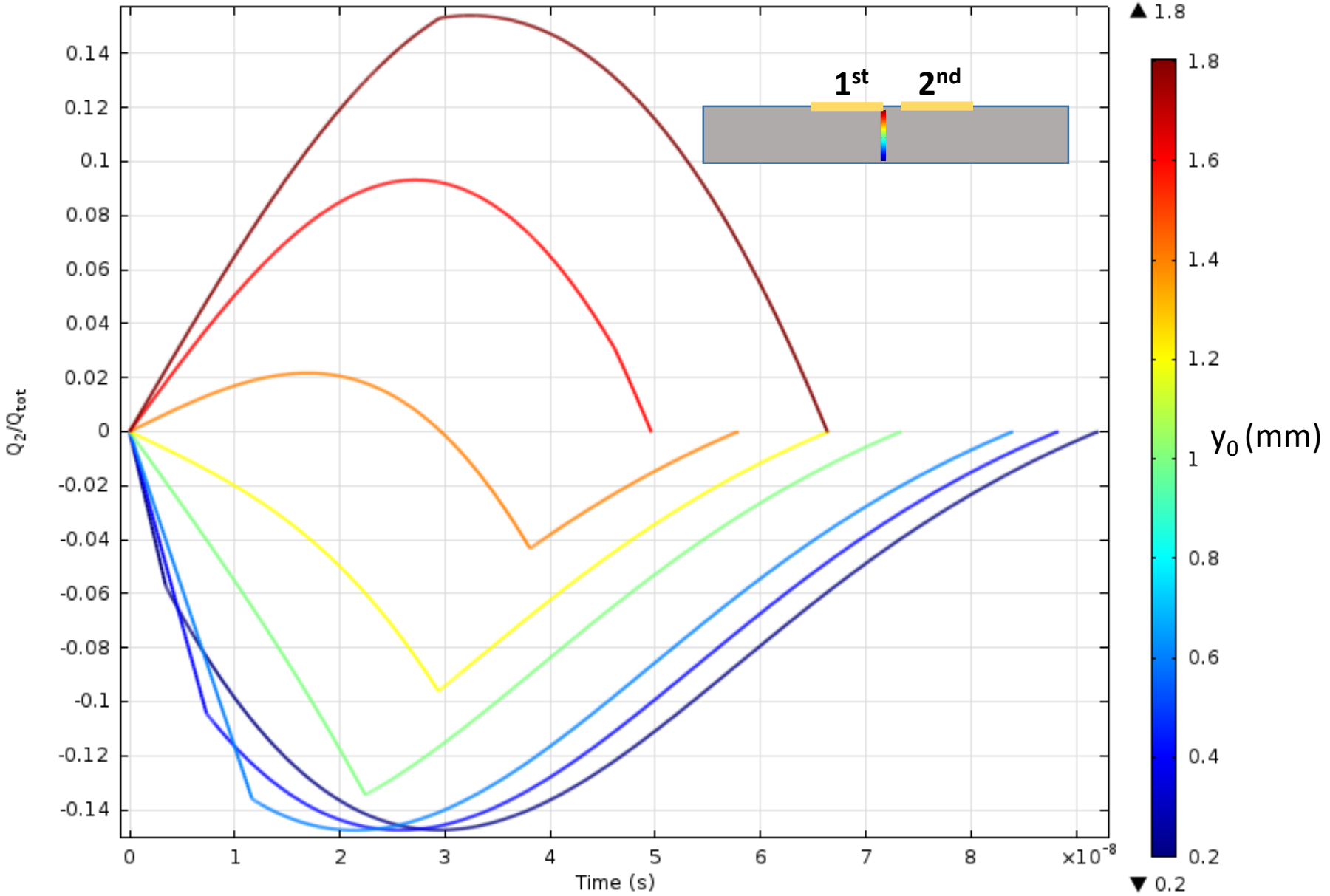
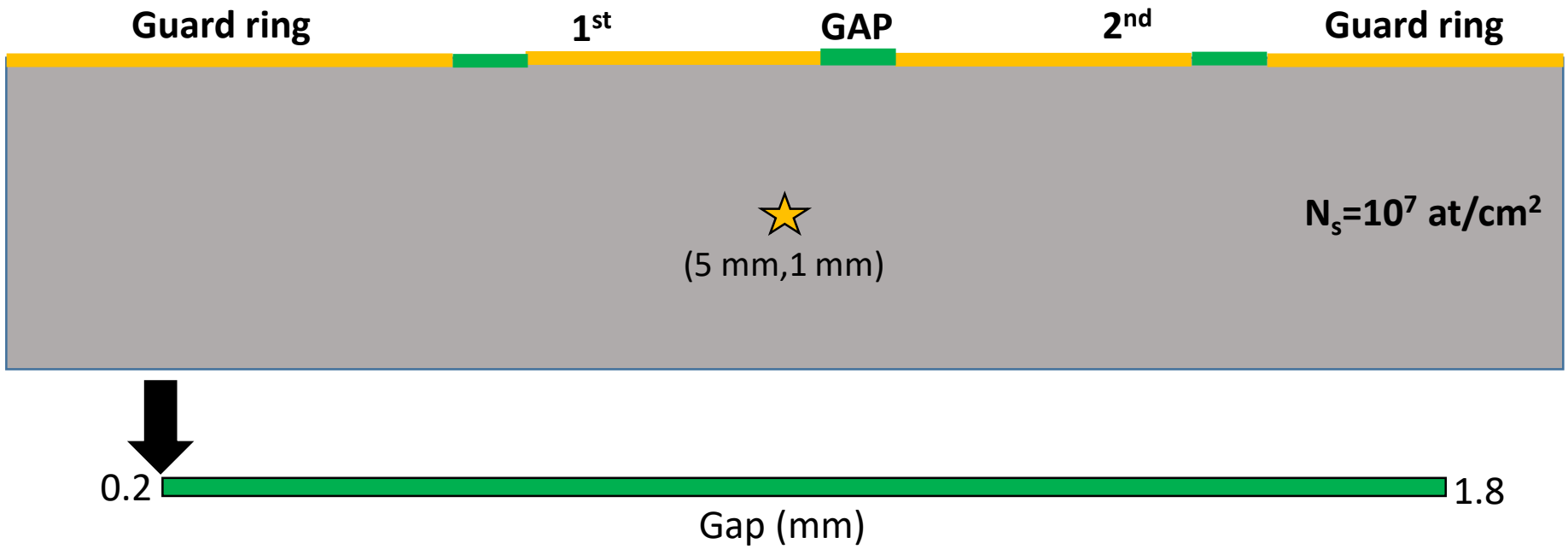
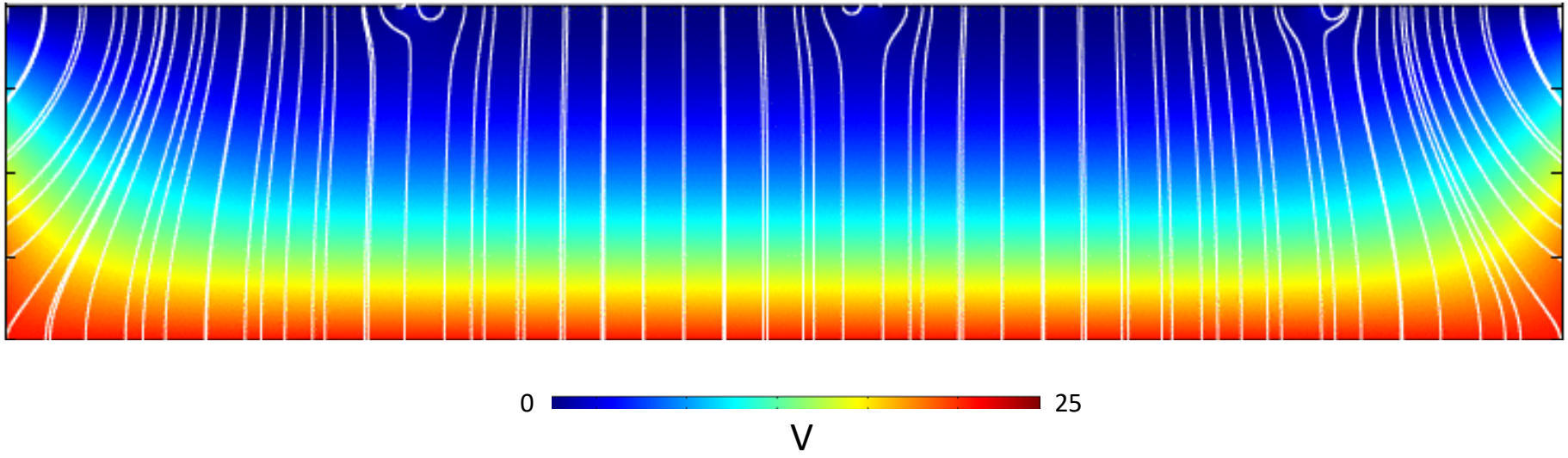


2nd CONTACT SIGNALS

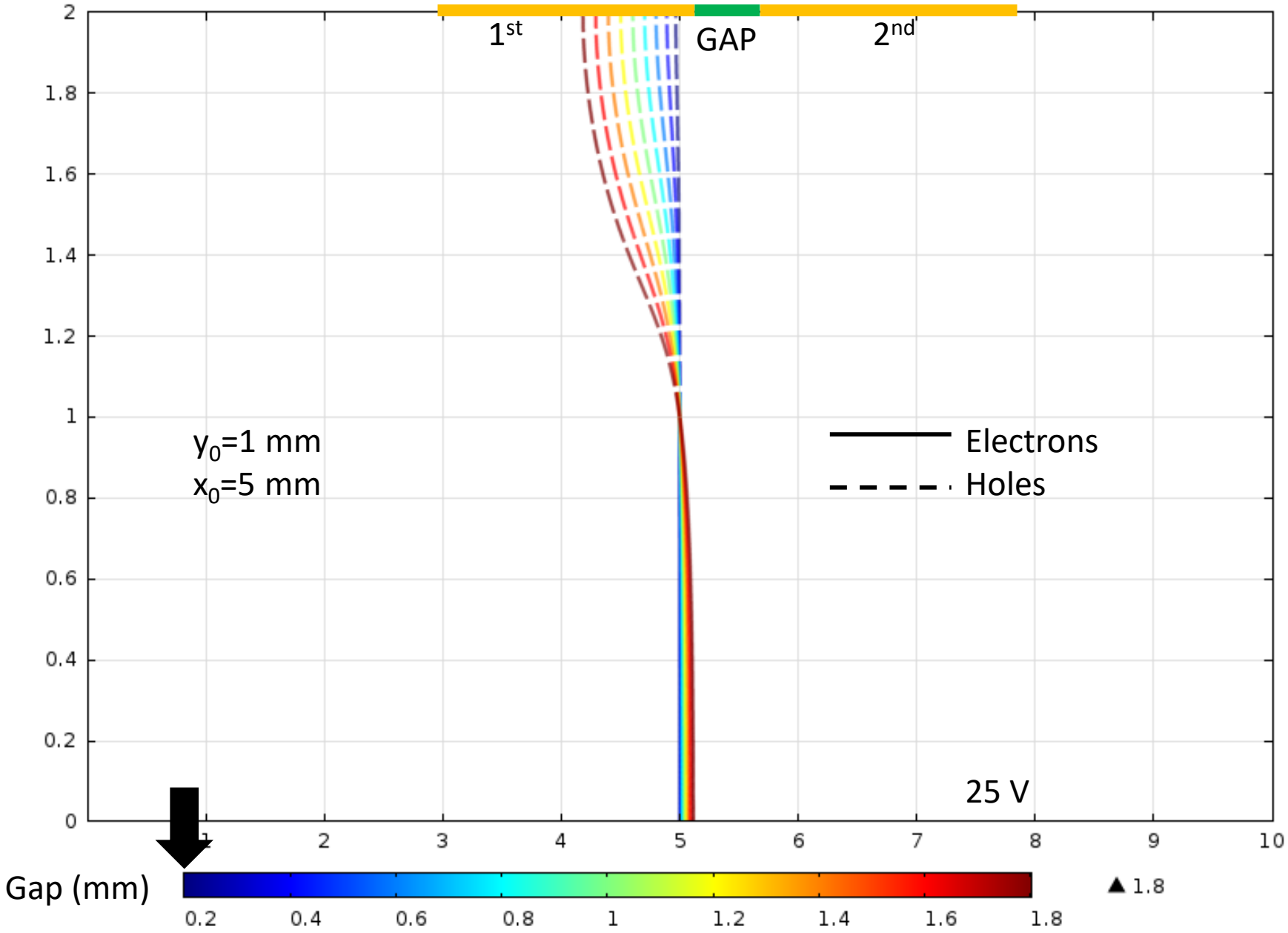


GAP DISTANCE SWEEP

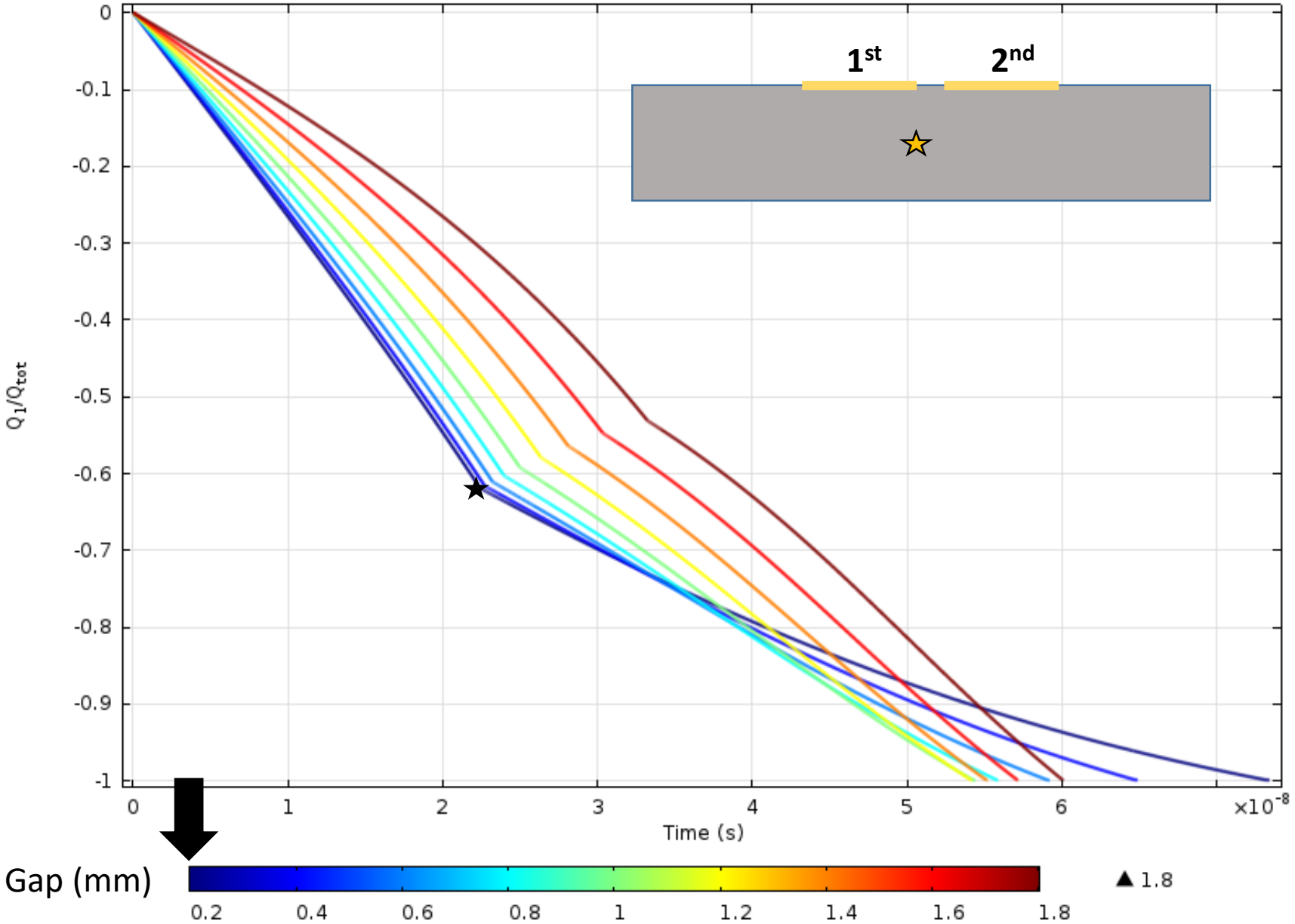




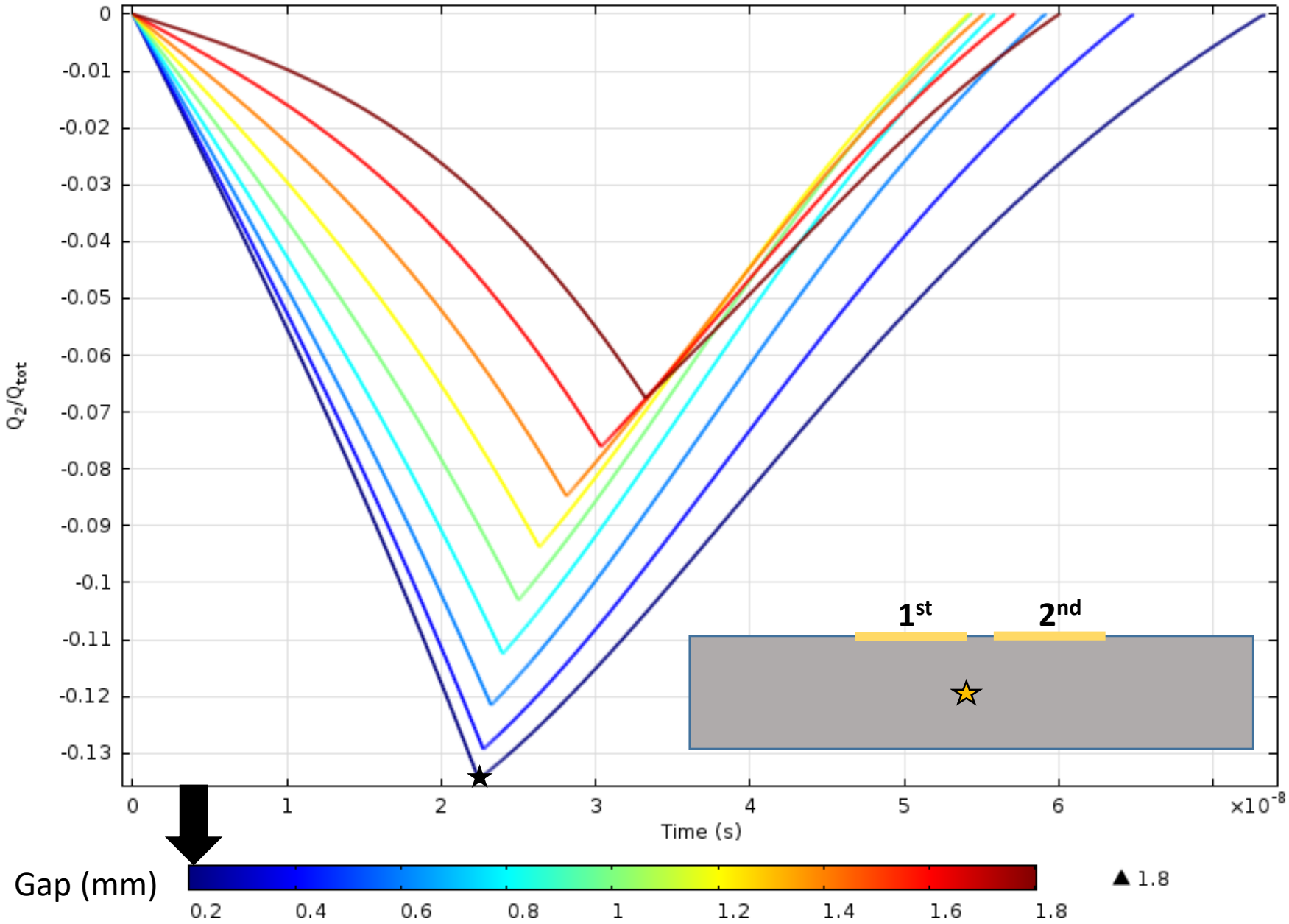
CHARGE TRAJECTORIES



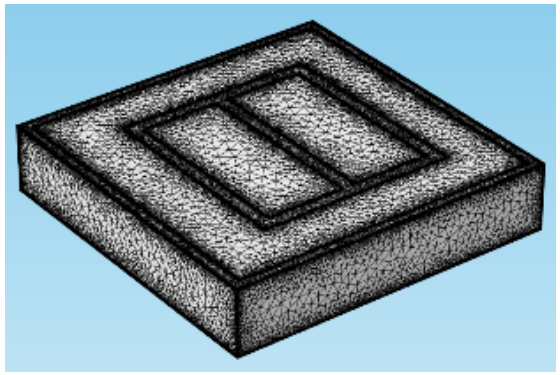
1st CONTACT SIGNALS

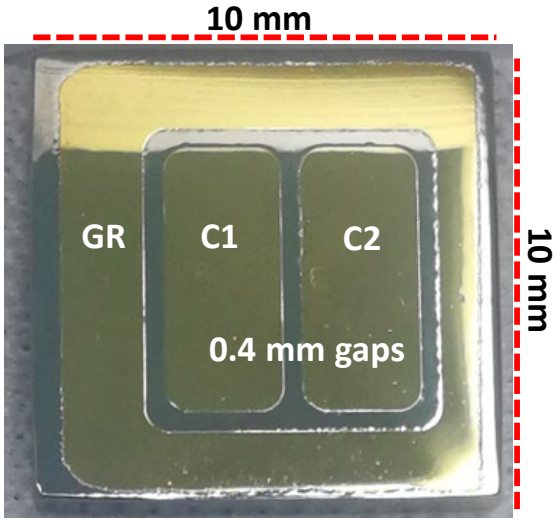


2nd CONTACT SIGNALS



3D MODEL STRUCTURE





Geometry & mesh:

Electrostatic system

Electrodynamic system

Electrostatic system: weighting fields

Ordinary differential equations

Depletion process

Surface charges effects

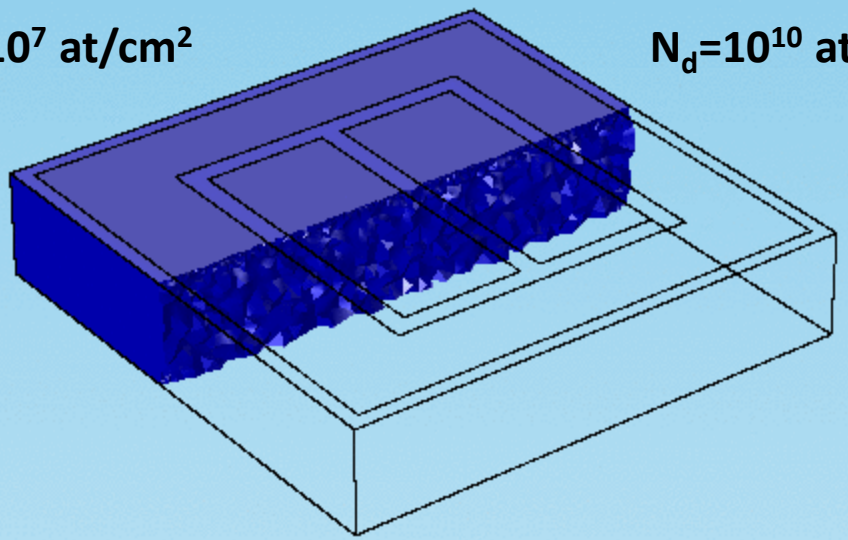
Capacitances

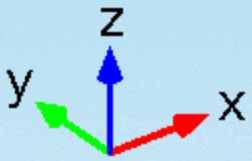
Leakage currents

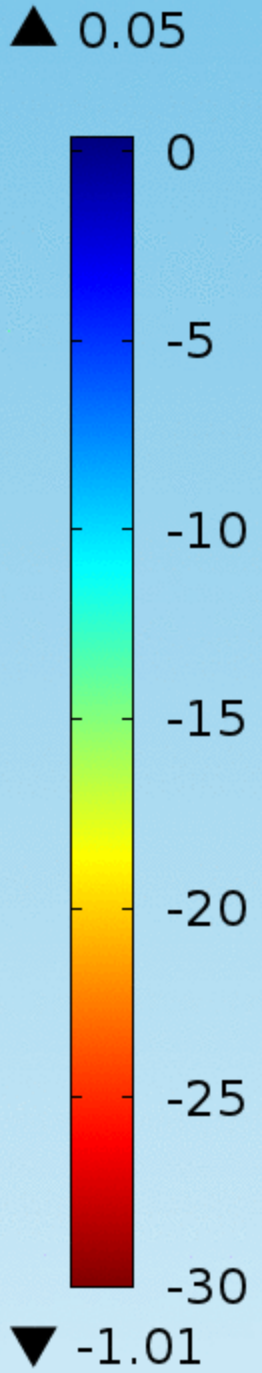
Signals simulation

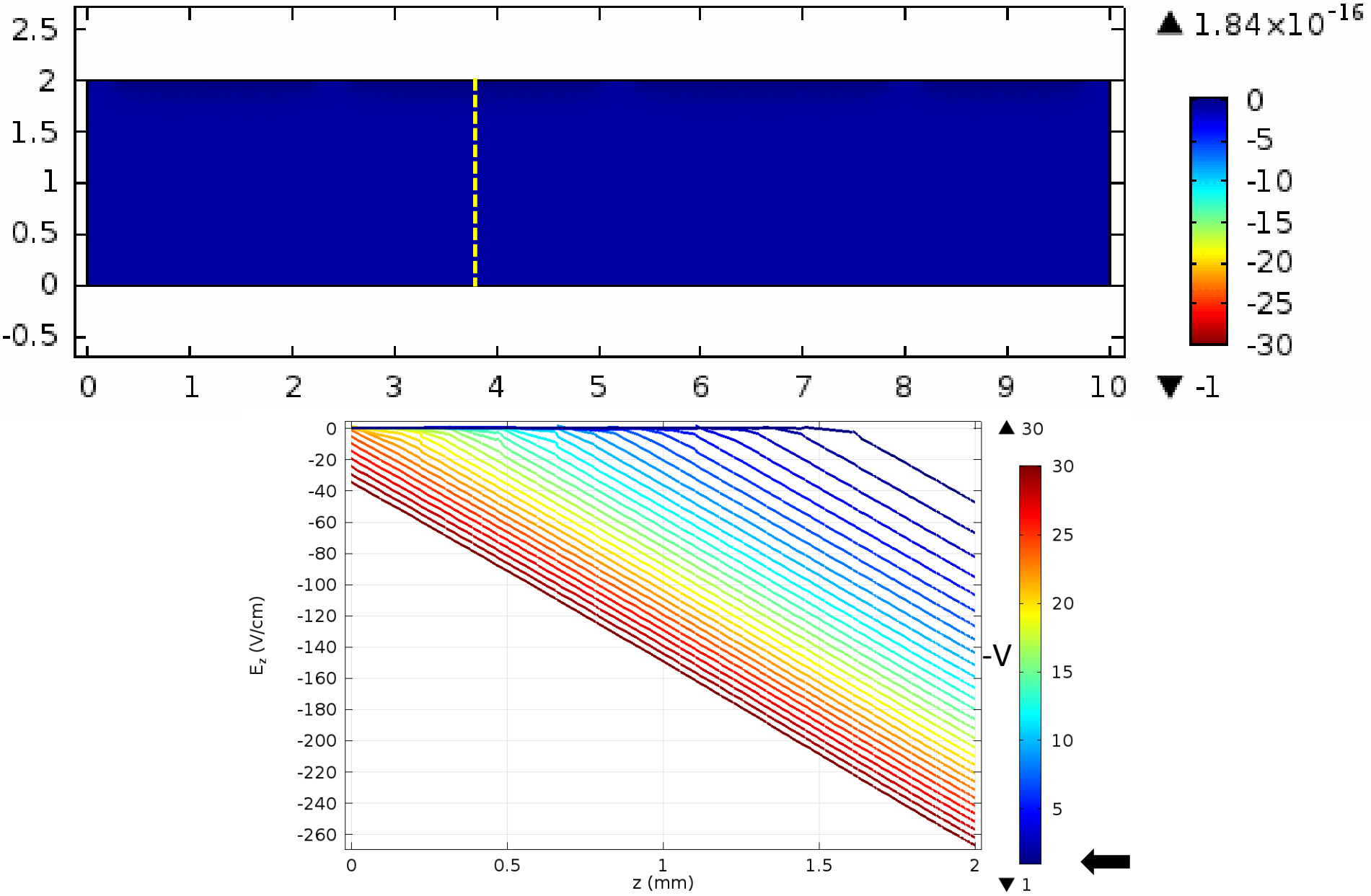
$N_s=10^7$ at/cm^2

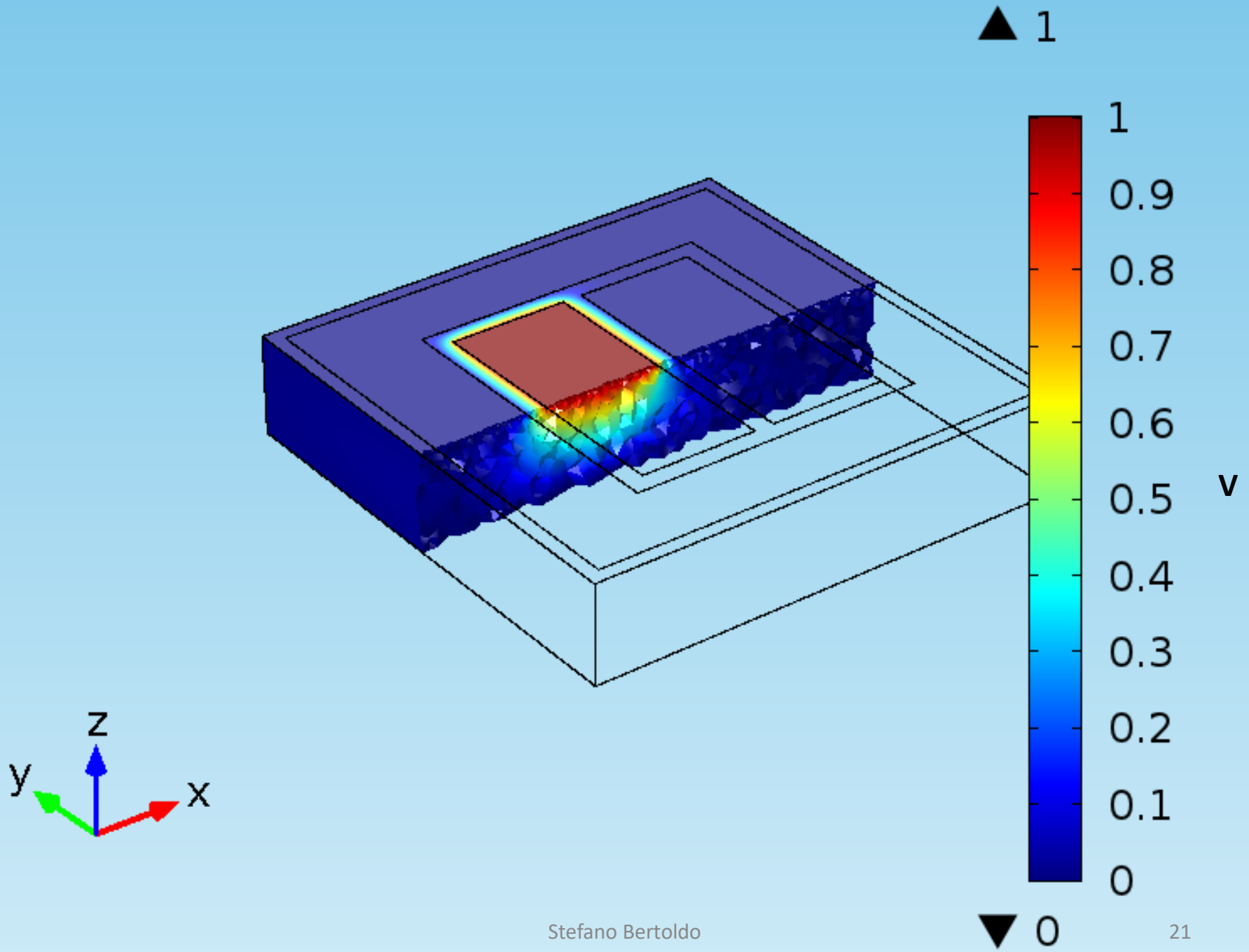
$N_d=10^{10}$ at/cm^3

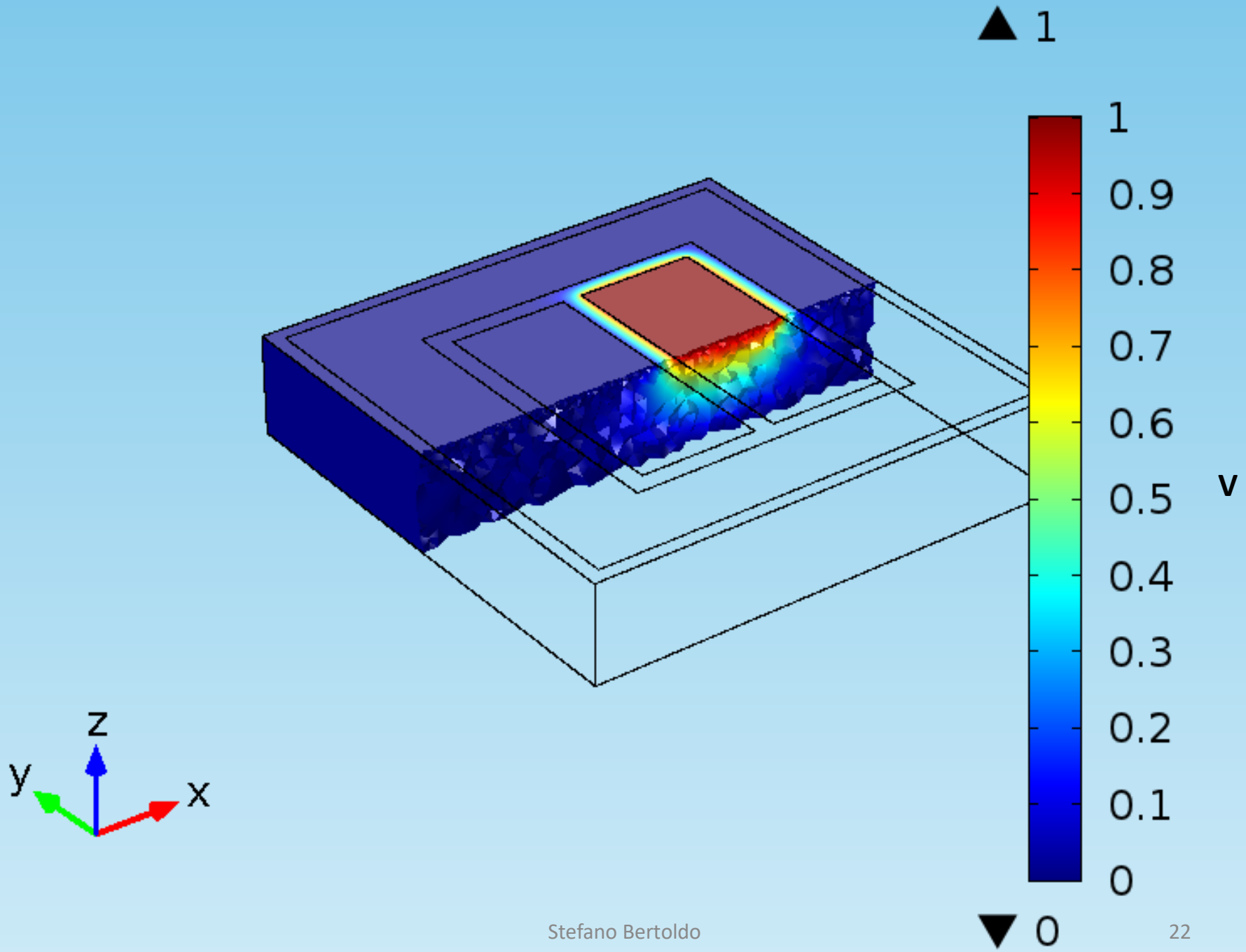




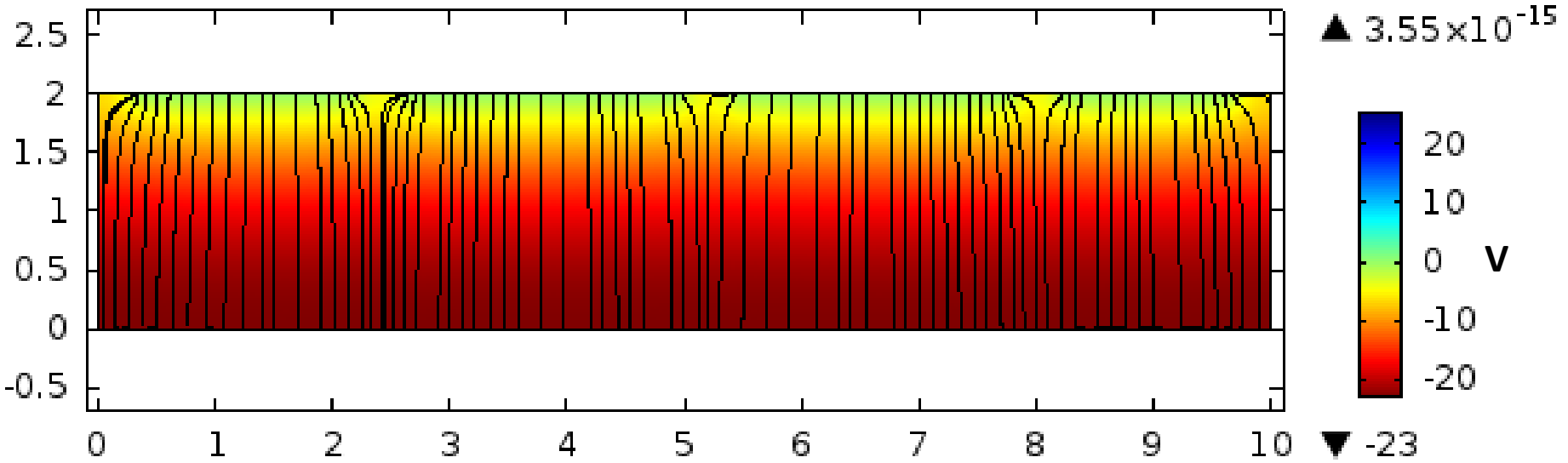



▲ 1.84×10^-16
0
-5
-10
-15
-20
-25
-30
▼ -1
2.5
2
1.5
1
0.5
0
-0.5
0 1 2 3 4 5 6 7 8 9 10
▲ 30
30
25
20
15
10
5
▼ 1
-V
E_z (V/cm)
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
-220
-240
-260
0 0.5 1 1.5 2
z (mm)

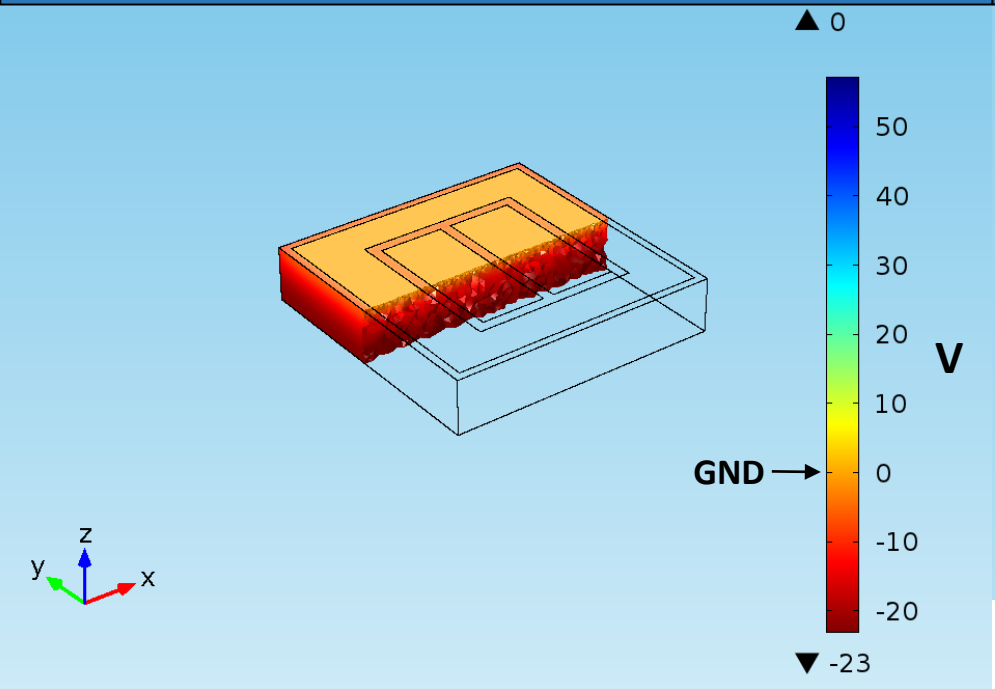

▲ 1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
▼ 0
V
z
y
x


▲ 1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
▼ 0
V
z
y
x

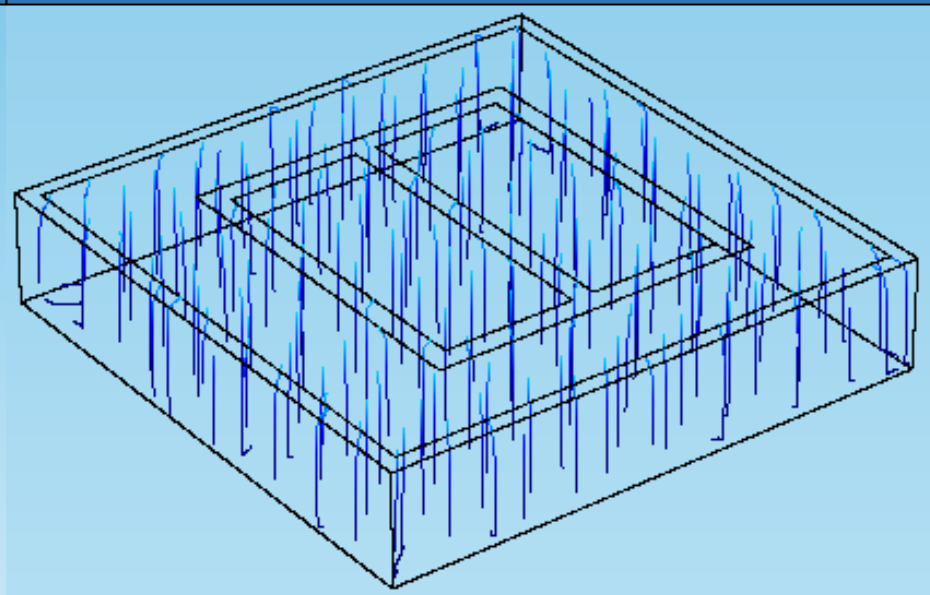
$N_s=1*10^4$ at/cm^2 T=110 K V_b=-23 V



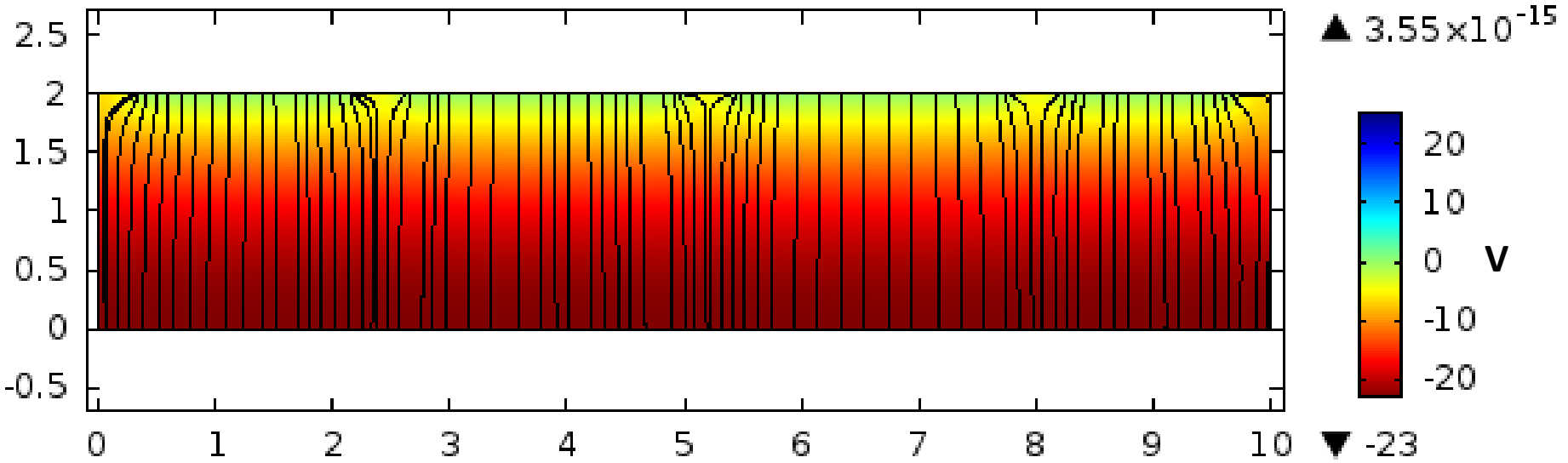
VOLTAGE DISTRIBUTION



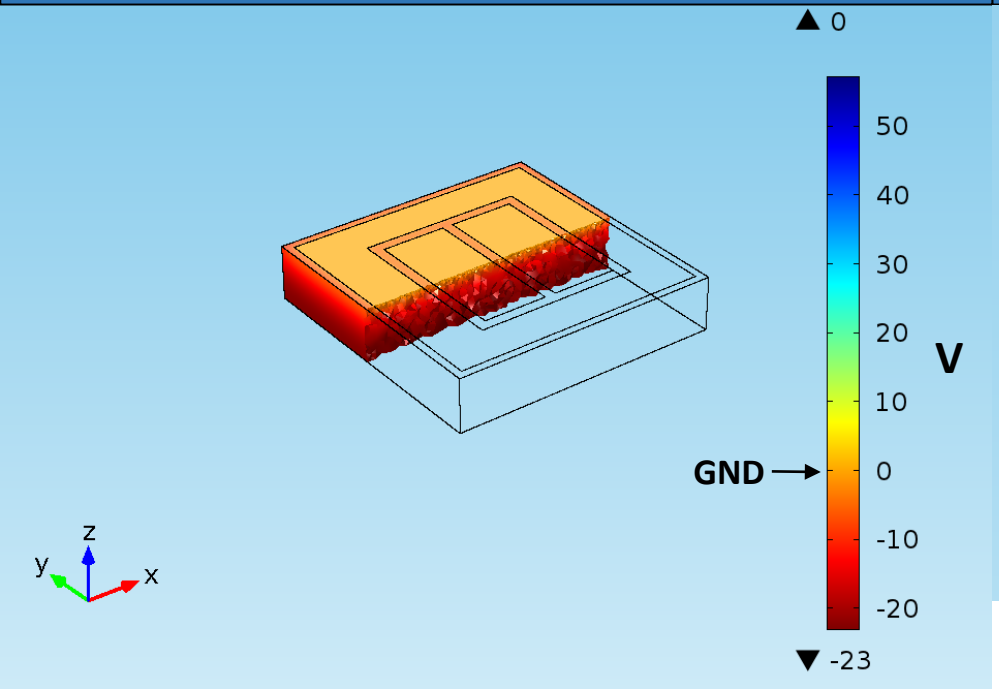
FIELDLINES



$N_s=1*10^7$ at/cm^2 T=110 K V_b=-23 V



VOLTAGE DISTRIBUTION



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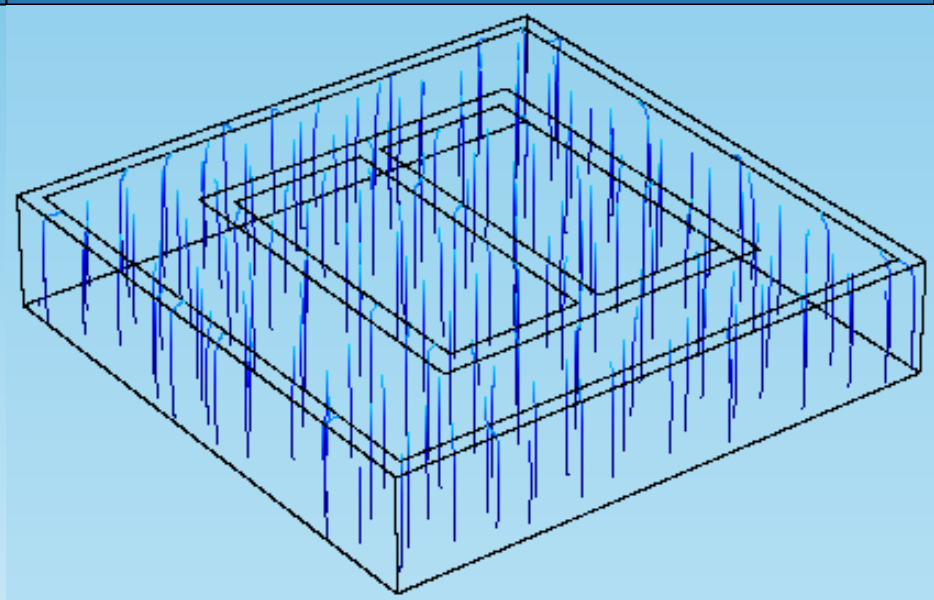
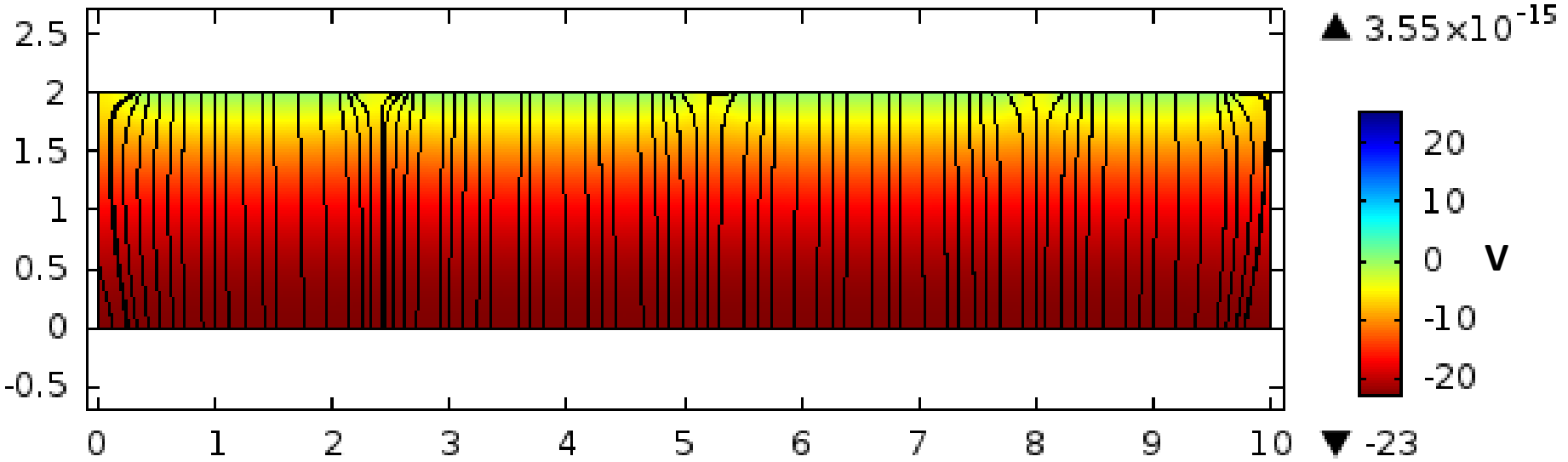
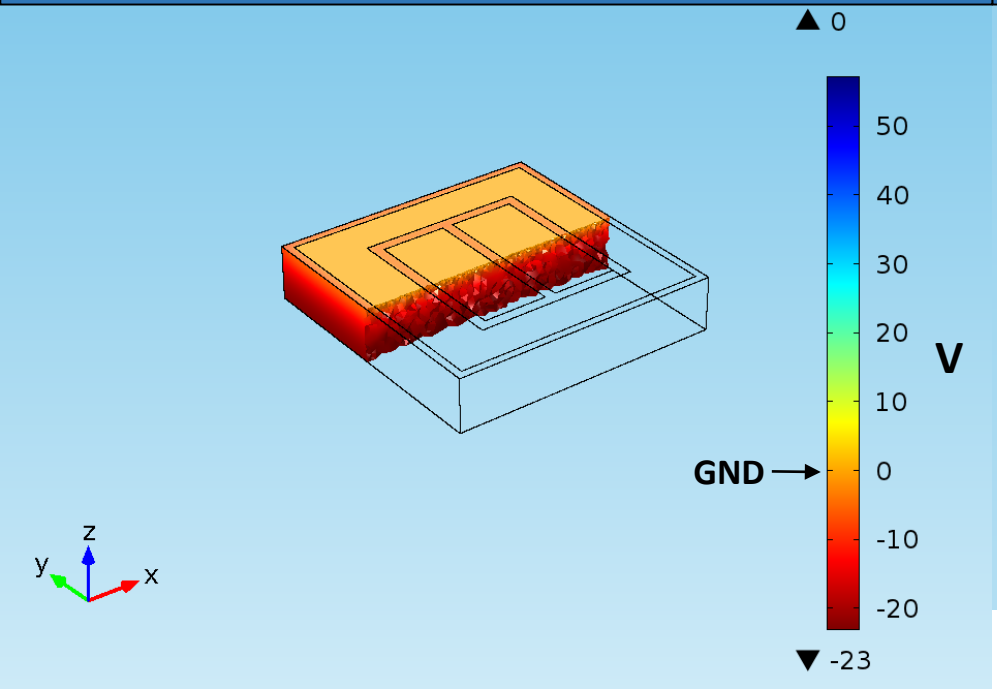


$N_s=1*10^8$ at/cm^2 T=110 K V_b=-23 V



VOLTAGE DISTRIBUTION



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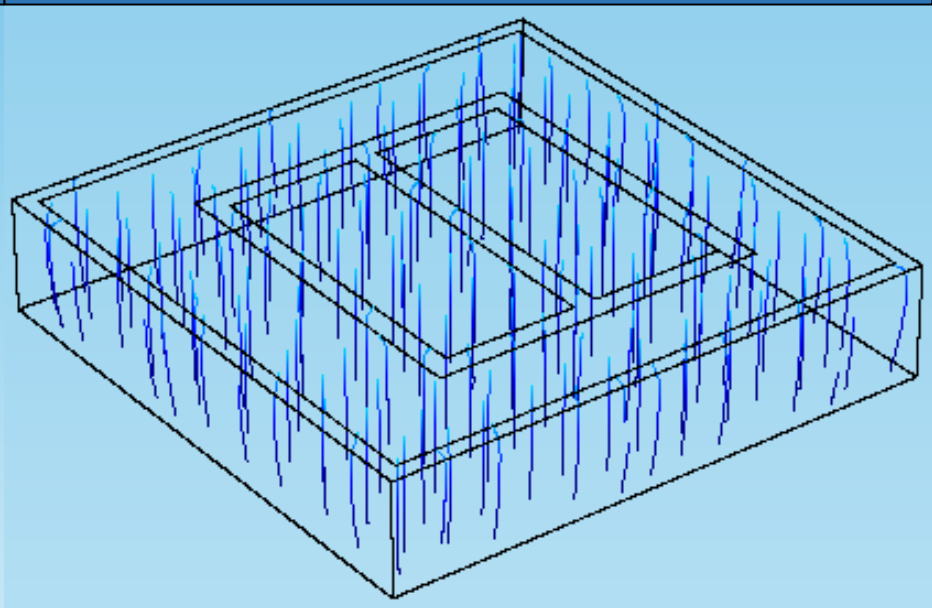
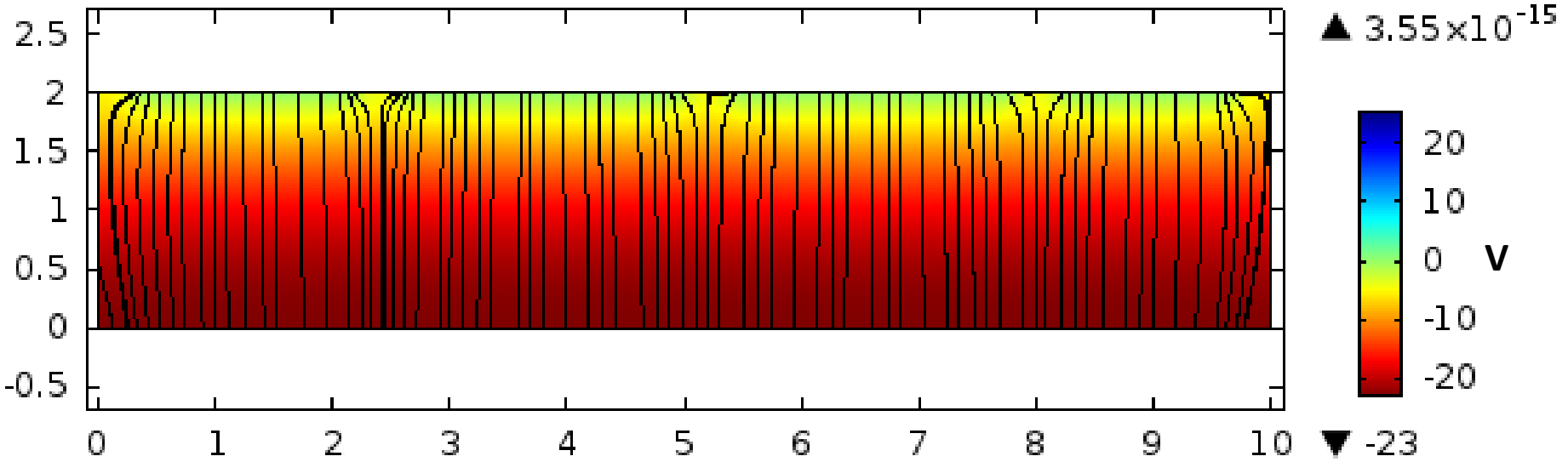
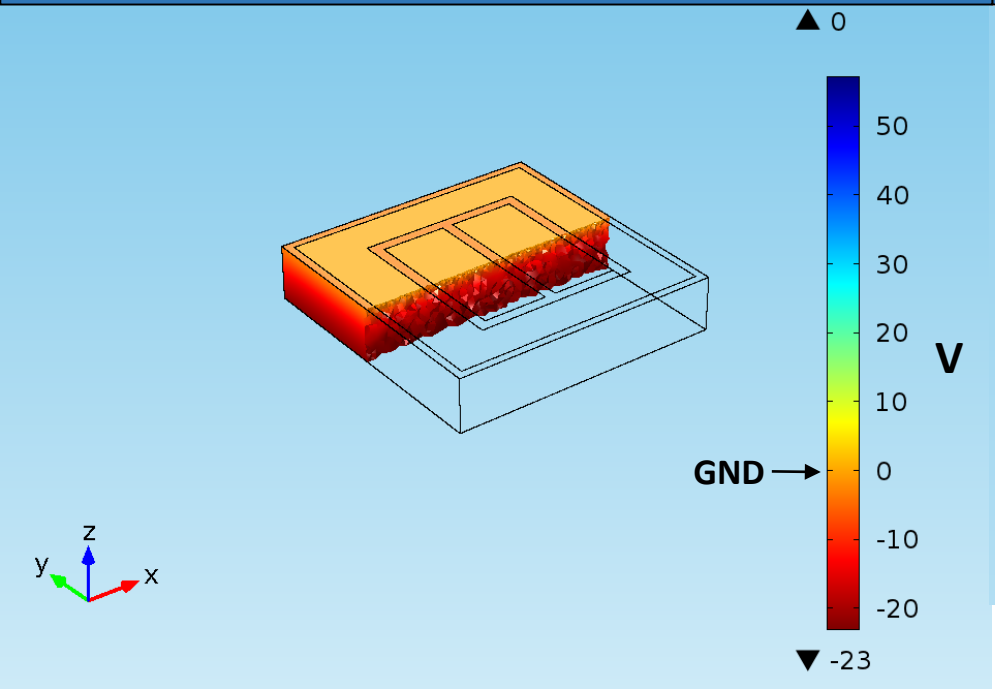


N_s=3.2*10^8 at/cm^2 T=110 K V_b=-23 V



VOLTAGE DISTRIBUTION



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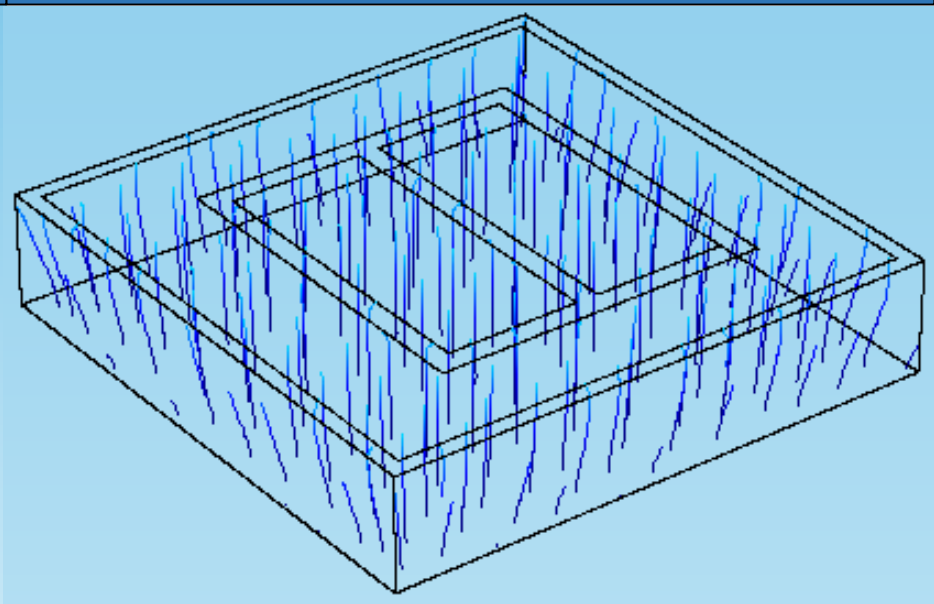
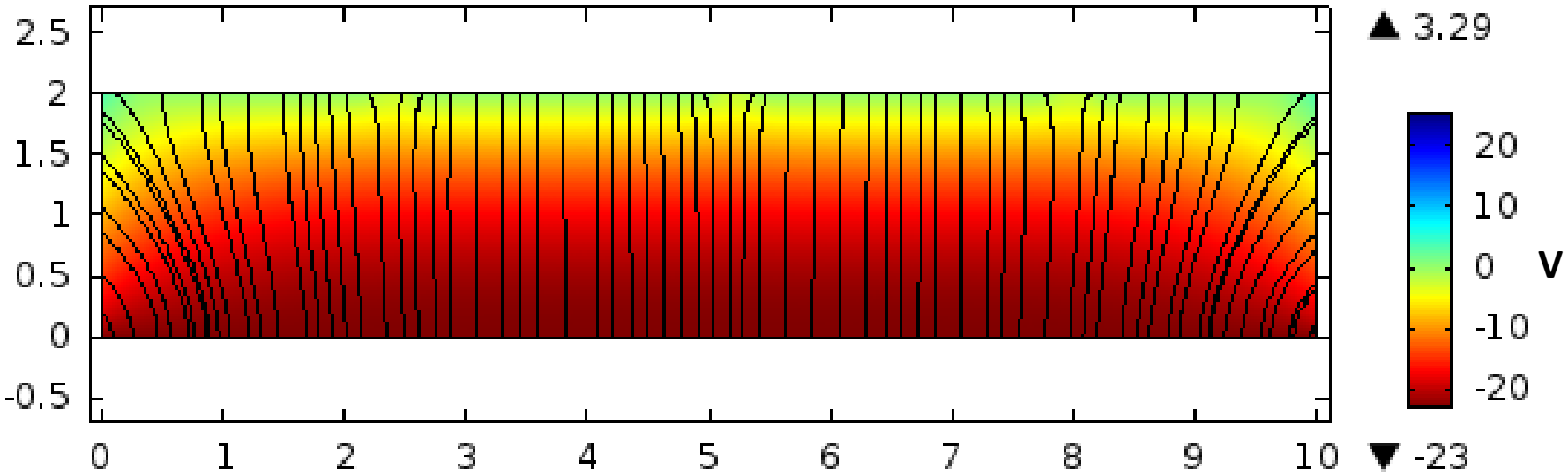
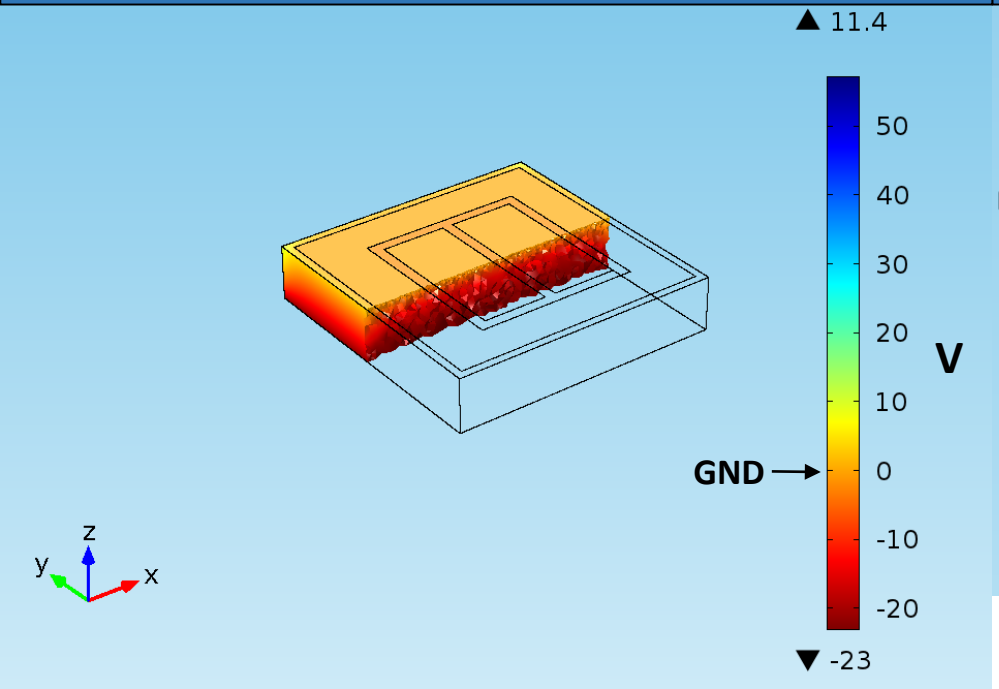


N_s=1*10^9 at/cm^2 T=110 K V_b=-23 V



VOLTAGE DISTRIBUTION



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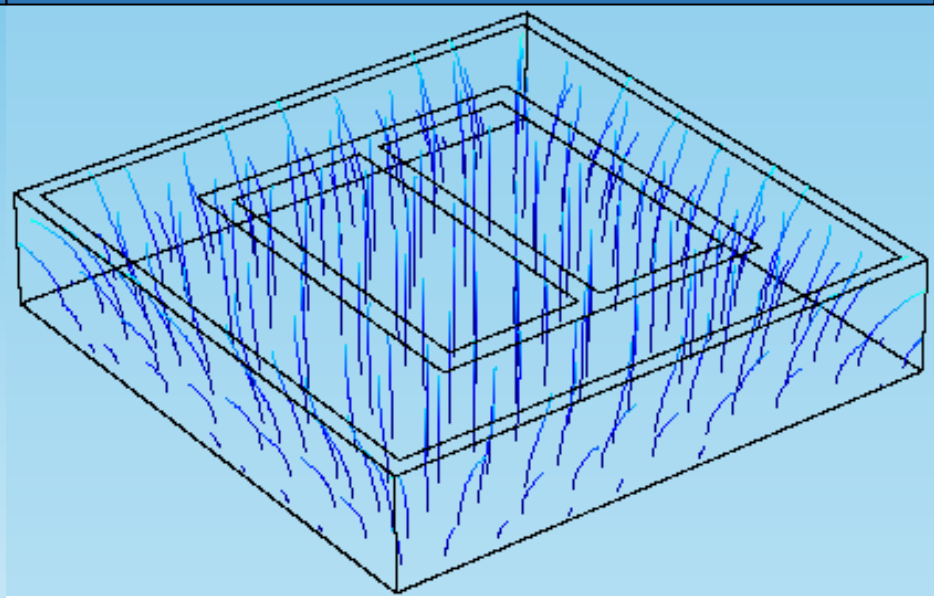
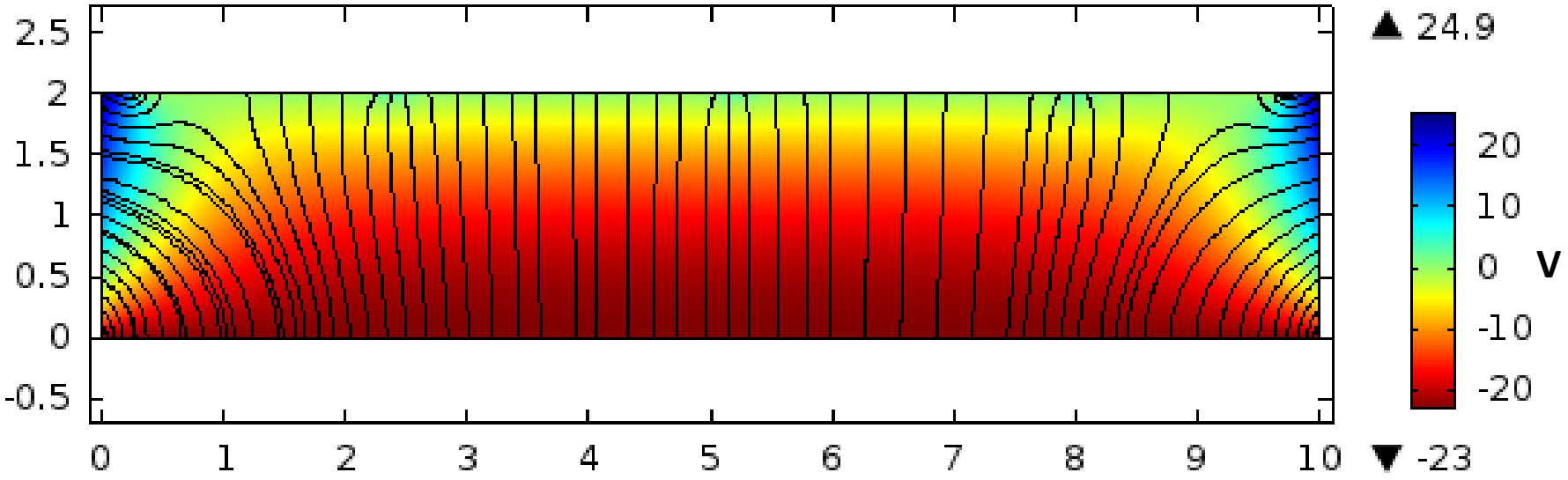
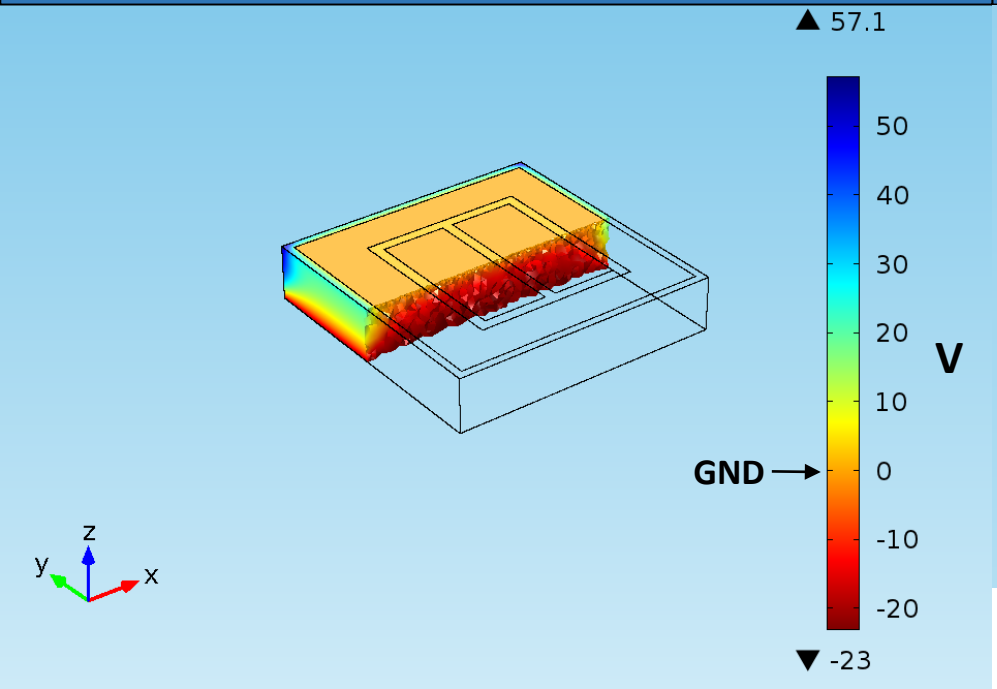


N_s=3.2*10^9 at/cm^2 T=110 K V_b=-23 V



VOLTAGE DISTRIBUTION



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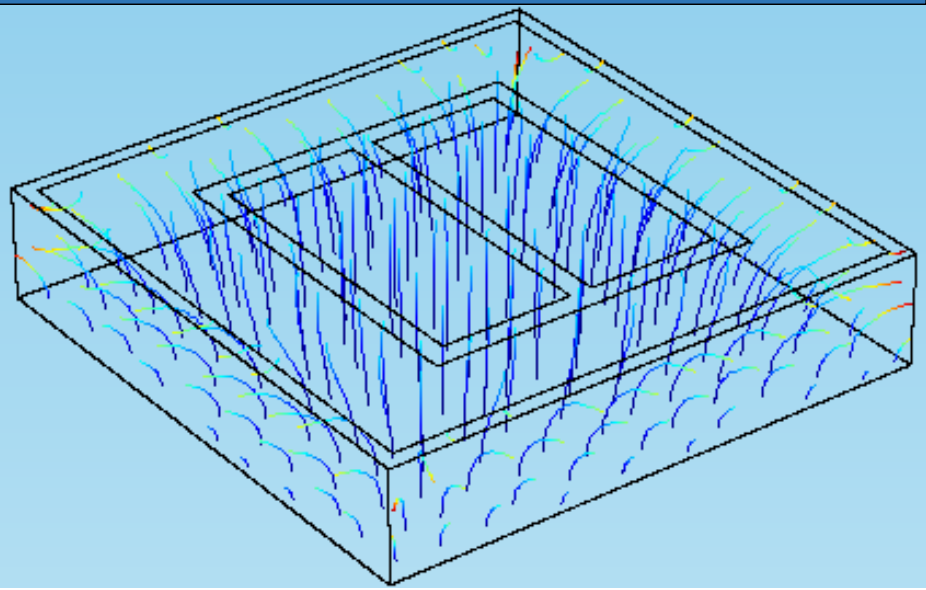
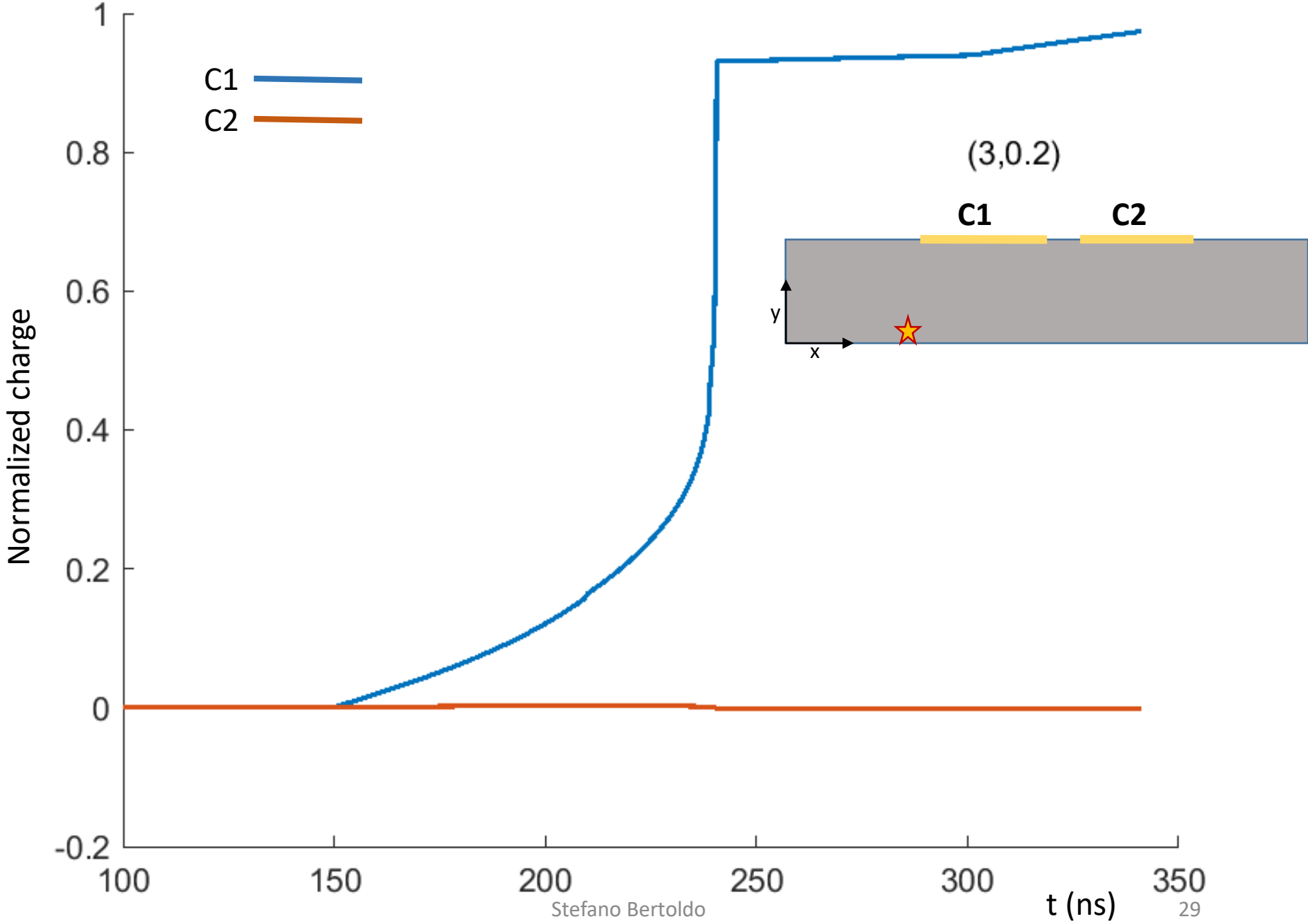
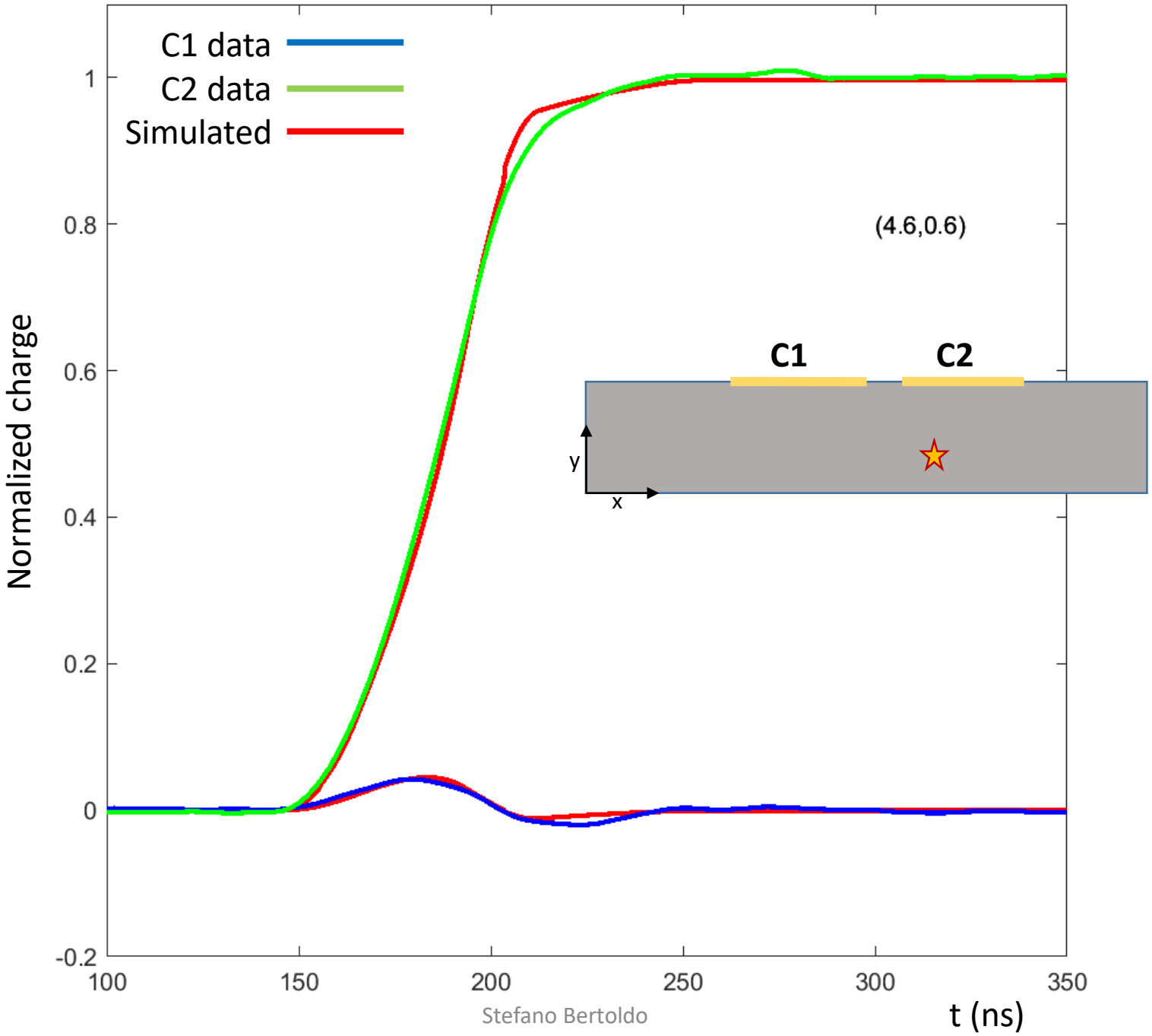
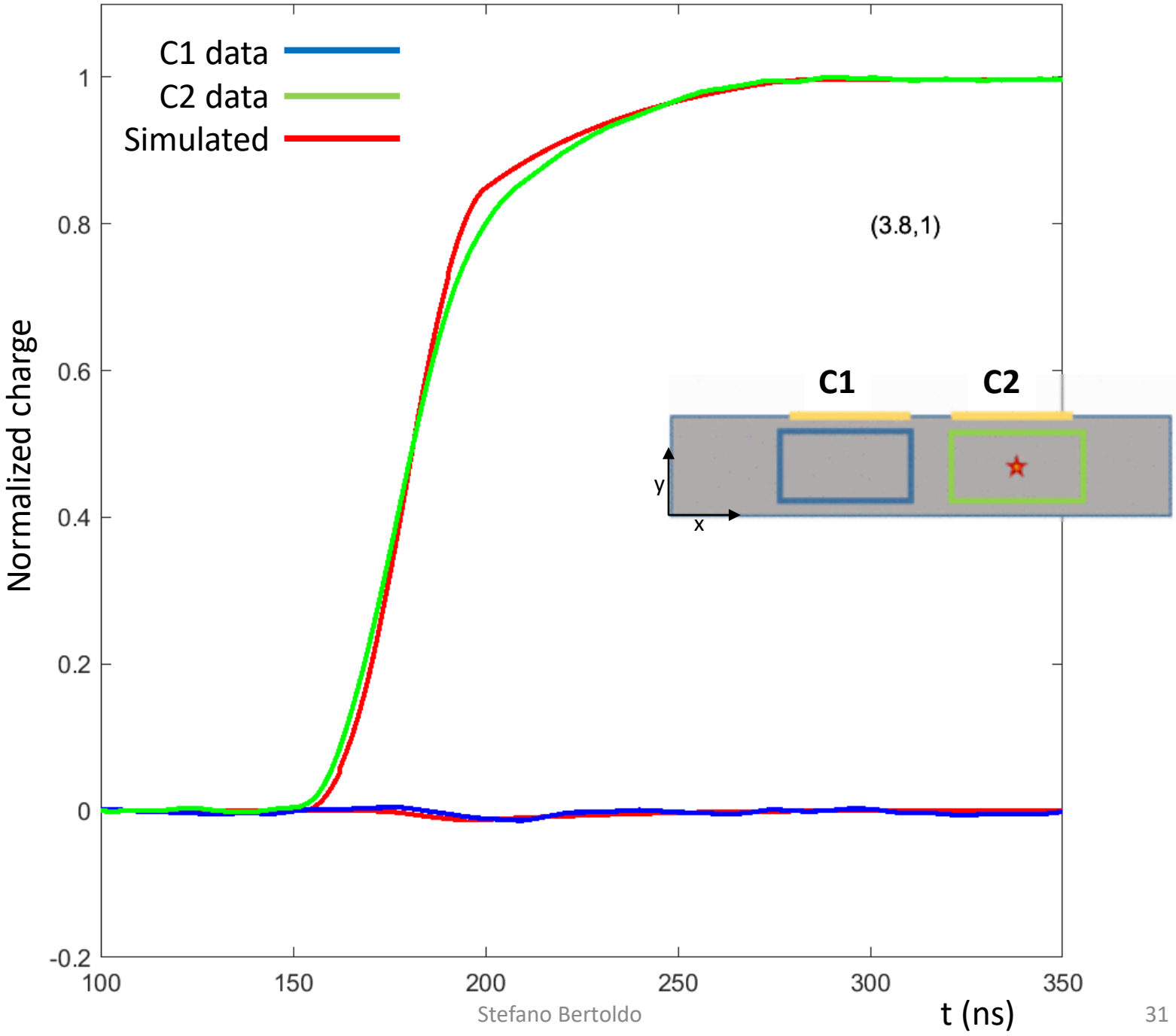



C1
C2
Normalized charge
t (ns)
(3,0.2)
C1
C2
y
x
1
0.8
0.6
0.4
0.2
0
-0.2
100
150
200
250
300
350


C1 data
C2 data
Simulated
(4.6,0.6)
C1
C2
y
x
Normalized charge
t (ns)
1
0.8
0.6
0.4
0.2
0
-0.2
100
150
200
250
300
350

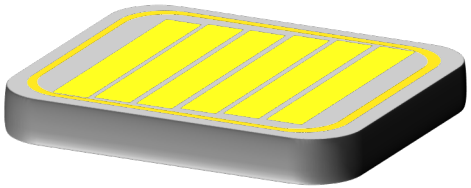

C1 data
C2 data
Simulated
(3.8,1)
C1
C2
y
x
Normalized charge
t (ns)
1
0.8
0.6
0.4
0.2
0
-0.2
100
150
200
250
300
350

FUTURE IMPROVEMENTS

- **Interpolating algorithm**
- **Electronic filtering**

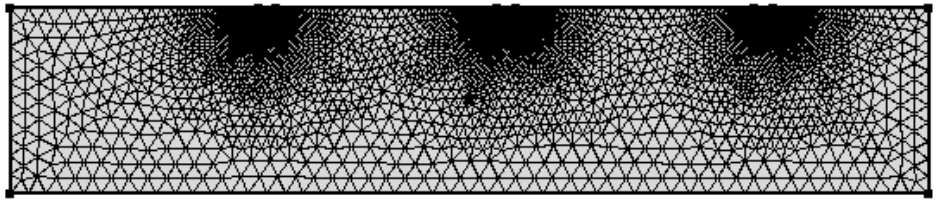
- Model refinement: recombination and generation processes
- C-V,I-V characteristics simulation and surface states dependency
- Leakage current model simulation
- New segmentation geometries

Rescaling (strip number, sizes) for the design of better detectors.

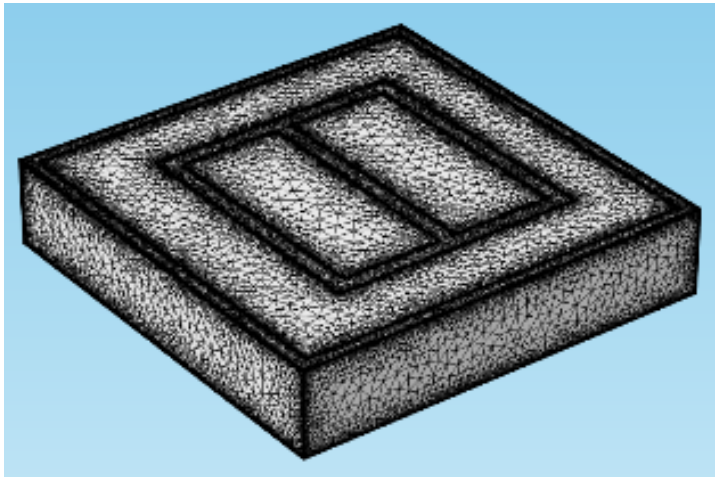


SUMMARY

- Goals of this simulation tool
- Models used
- 2D simulation of a fictional detector
  - Depletion process
  - Weighting potentials
  - Simulated trajectories
  - Simulated signals
  - Gap study



- 3D simulation of a real detector
  - Model outline
  - Depletion process
  - Weighting potentials
  - Passivation study
  - Simulated signals
  - Comparison with experimental signals

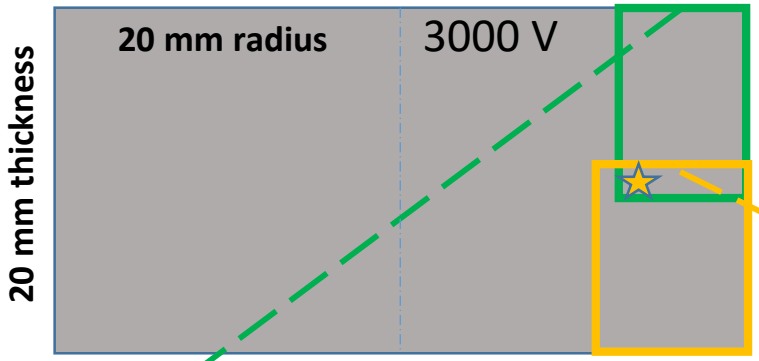


Thank you for the attention!

Stefano Bertoldo

PRELIMINARY COMPARISON OF SIMULATED AND MEASURED SIGNALS FROM SEGMENTED DETECTORS

DRIFT WITH DIFFUSION MODEL



P-type planar detector