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A numerical investigation on the Discharges in Micromegas

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Motivation:

- The discharge phenomena in gaseous detectors is a complicated process.
- There are several factors responsible for it.

- The fine structures in MPGDs may give rise to localised high electric field.
- Such regions may influence the discharge in direct or indirect ways.

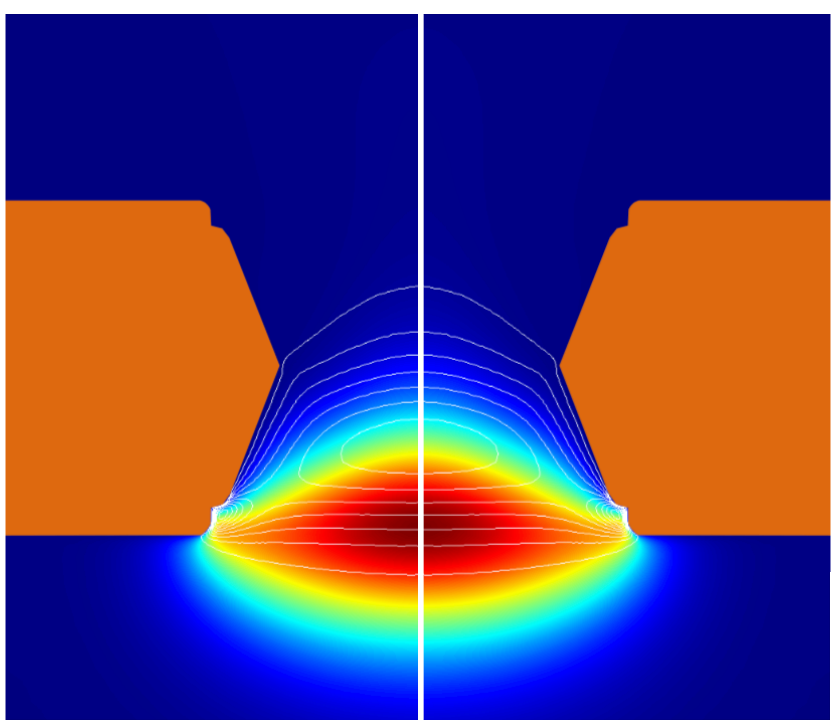
- This study aims to develop a numerical model for discharge
- To apply it for Micromegas geometry
- A systematic field study on different Micromegas geometry

Using COMSOL Multi-Physics for discharge modelling in full 3-D for Micromegas.

It worked quite good in 2D-axis symmetric geometry for GEM

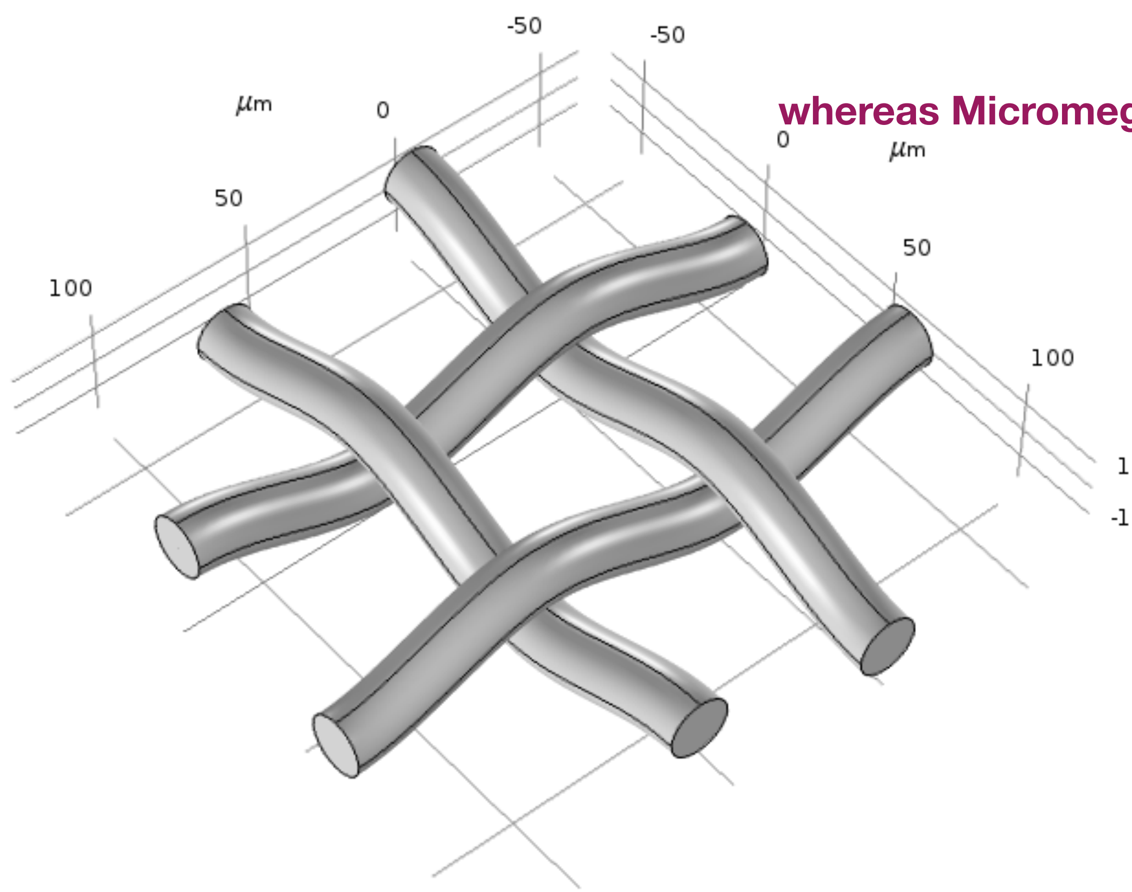
But, Micromegas is not 2D-axis symmetric...

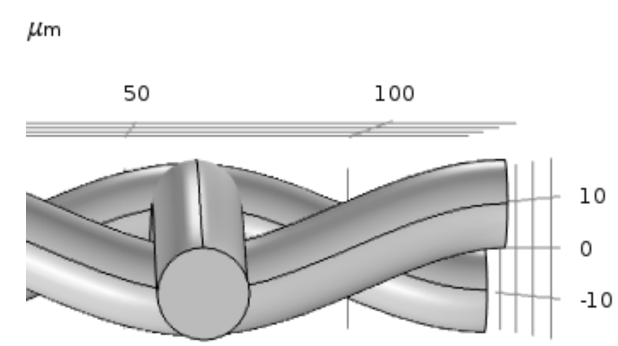
2D-axis symmetry is a good approximation for GEM



Filippo Resnati - RD-51 Open Lectures - 12/12/17 - CERN

whereas Micromegas is not rotational symmetric

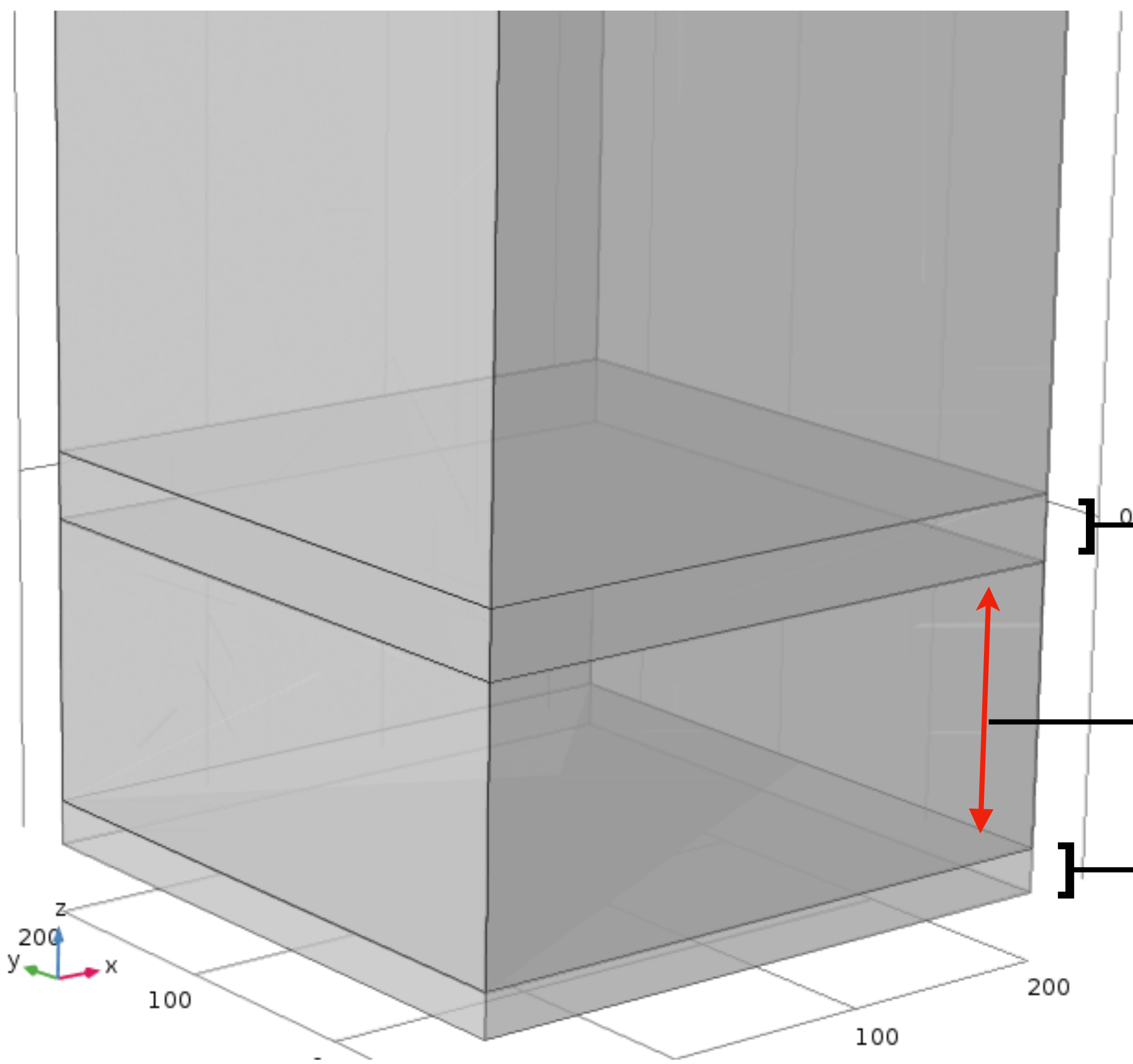




Let's start by solving the field in a parallel plate:

copper cathode at -600 V (not shown)

drift gap 1mm.



another electrode, 30 μm thick steel at -540 V.

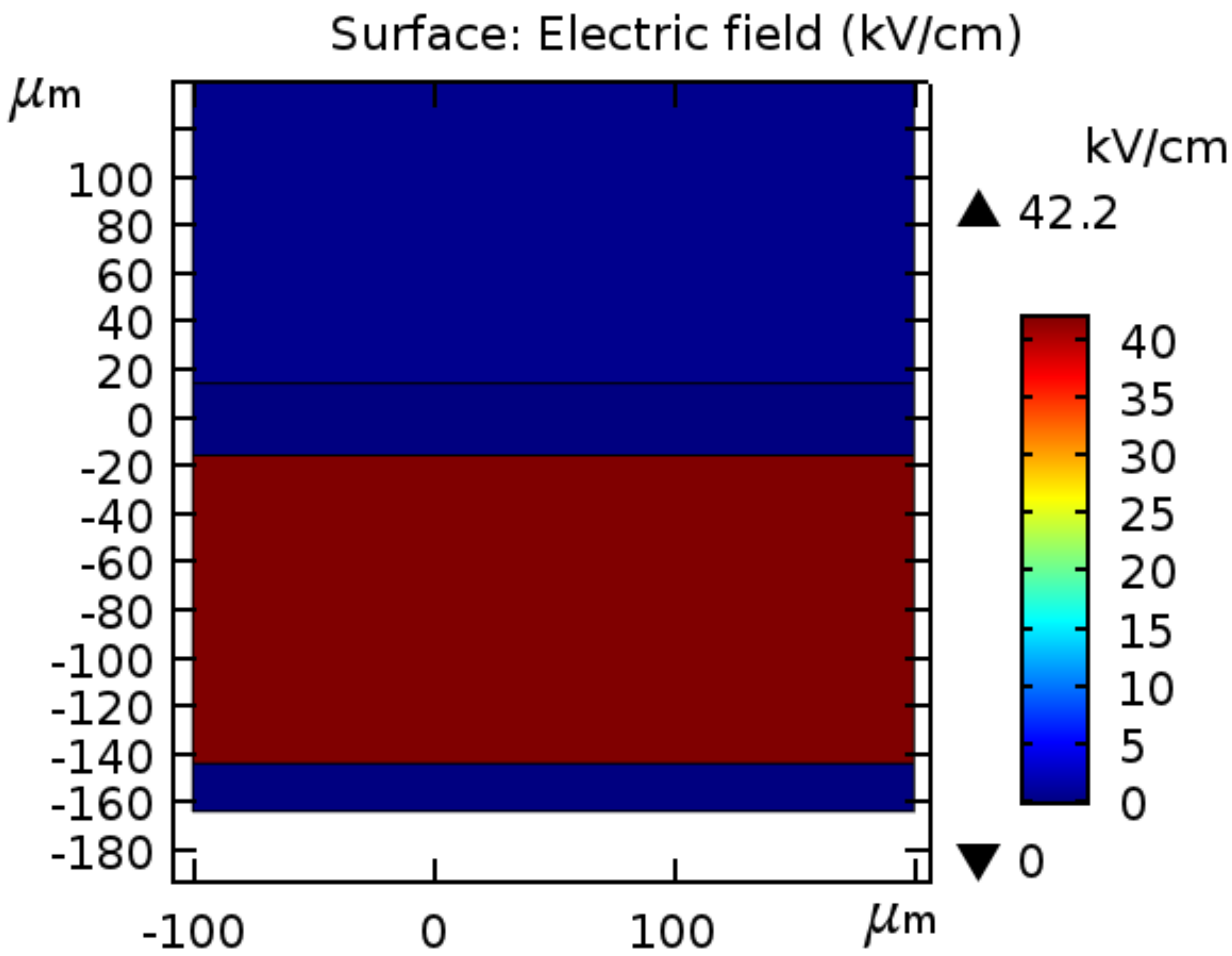
amplification gap 128 μm

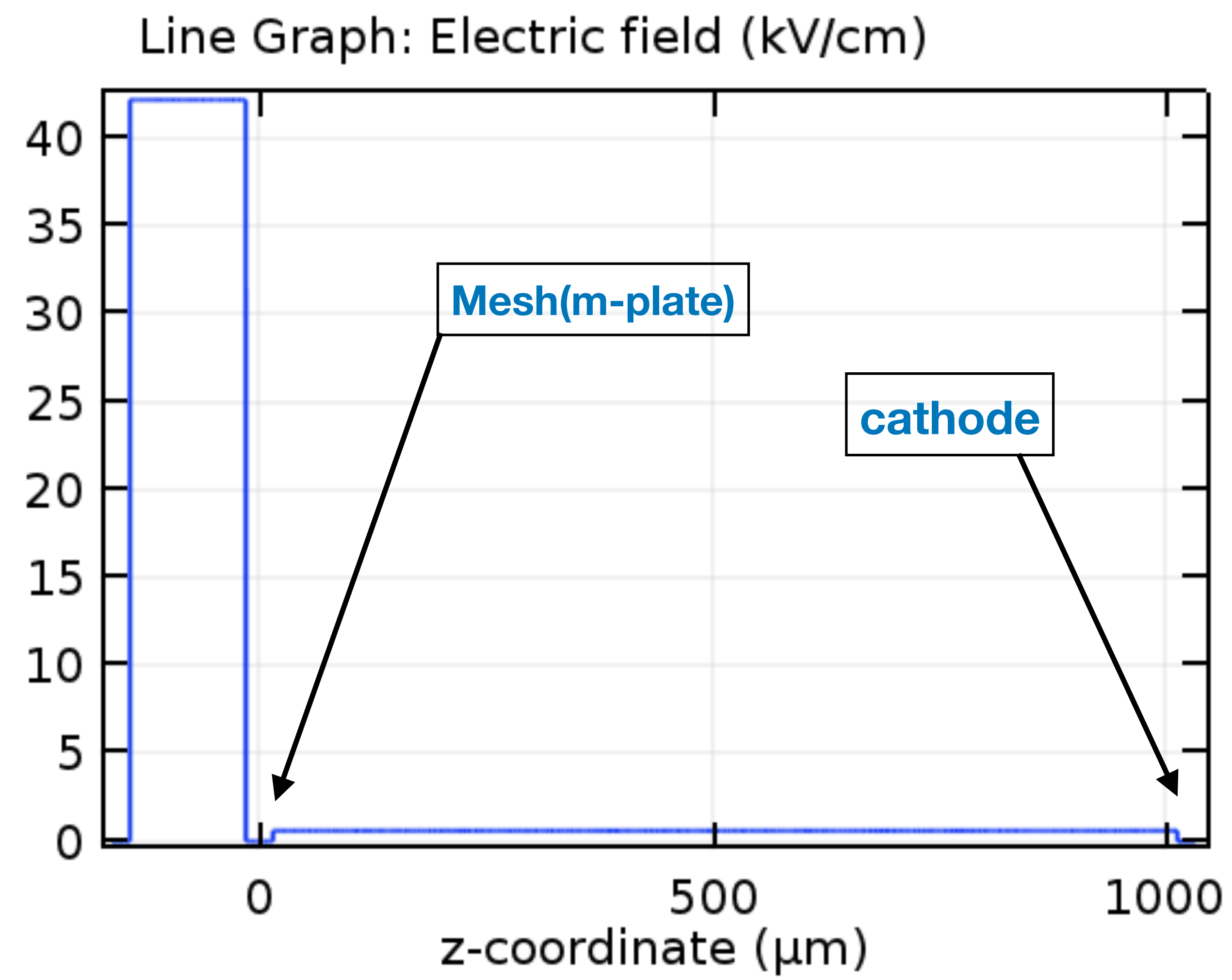
20 μm thick copper anode at Ground potential

parallel plates

Electric field (on the YZ plane)

Along a line on the YZ plane, at X=Y= half pitch





The electric field is uniform through out.

Building the discharge model

Building the physics model : (a simple approach)

Electrostatics (stationary solution)

$$E = -\nabla V$$

(electric field from given potential)

$$\nabla \cdot D = \rho_v$$

(for space charge)

[Electrostatics]

coupled

[Transport of Diluted species]

$$\frac{\partial C_i}{\partial t} + \nabla \cdot (-D_i \nabla C_i) + u \cdot \nabla C_i = R_i$$

$$R_i = n_e u(\alpha - AC - X)$$

charge transport and multiplication (time dependent solution)

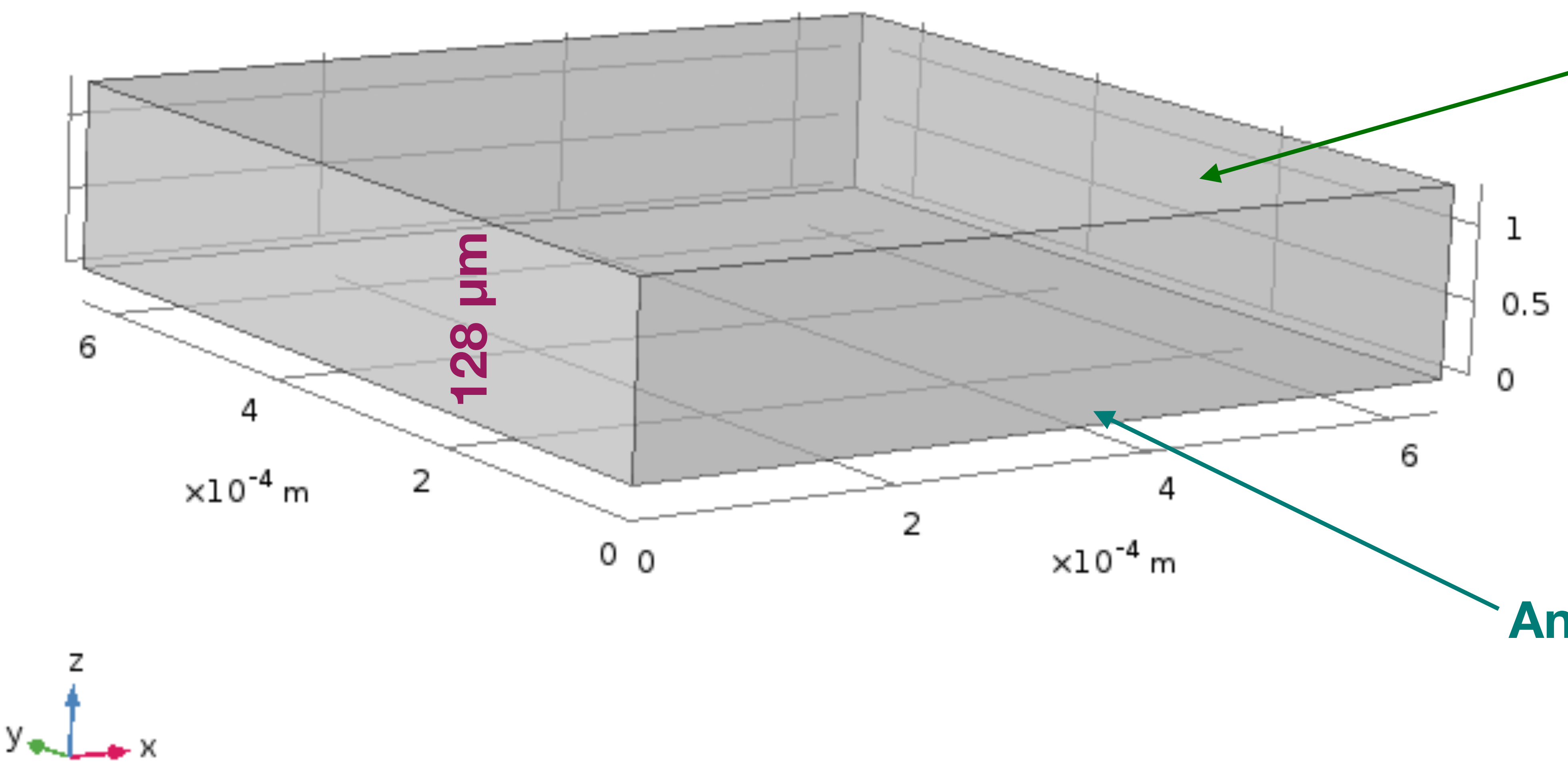
the transport parameters depend of the electric field. hence, to take into account the space charge effect, the coupling is important.

'i' is for electron and ion species
Di = diffusion tensor in
Ci = number density.
u = electron drift velocity
Ri = production rate.

α is Townsend coefficient
AC is attachment coefficient
X is for recombination

A full physical model can be found : RD51-Note-2011-005/14-03-2011, by P Fonte
However, the present model (diffusion assisted streamer) was well discussed in RD-51, Dec 2017

Solving it for parallel plates

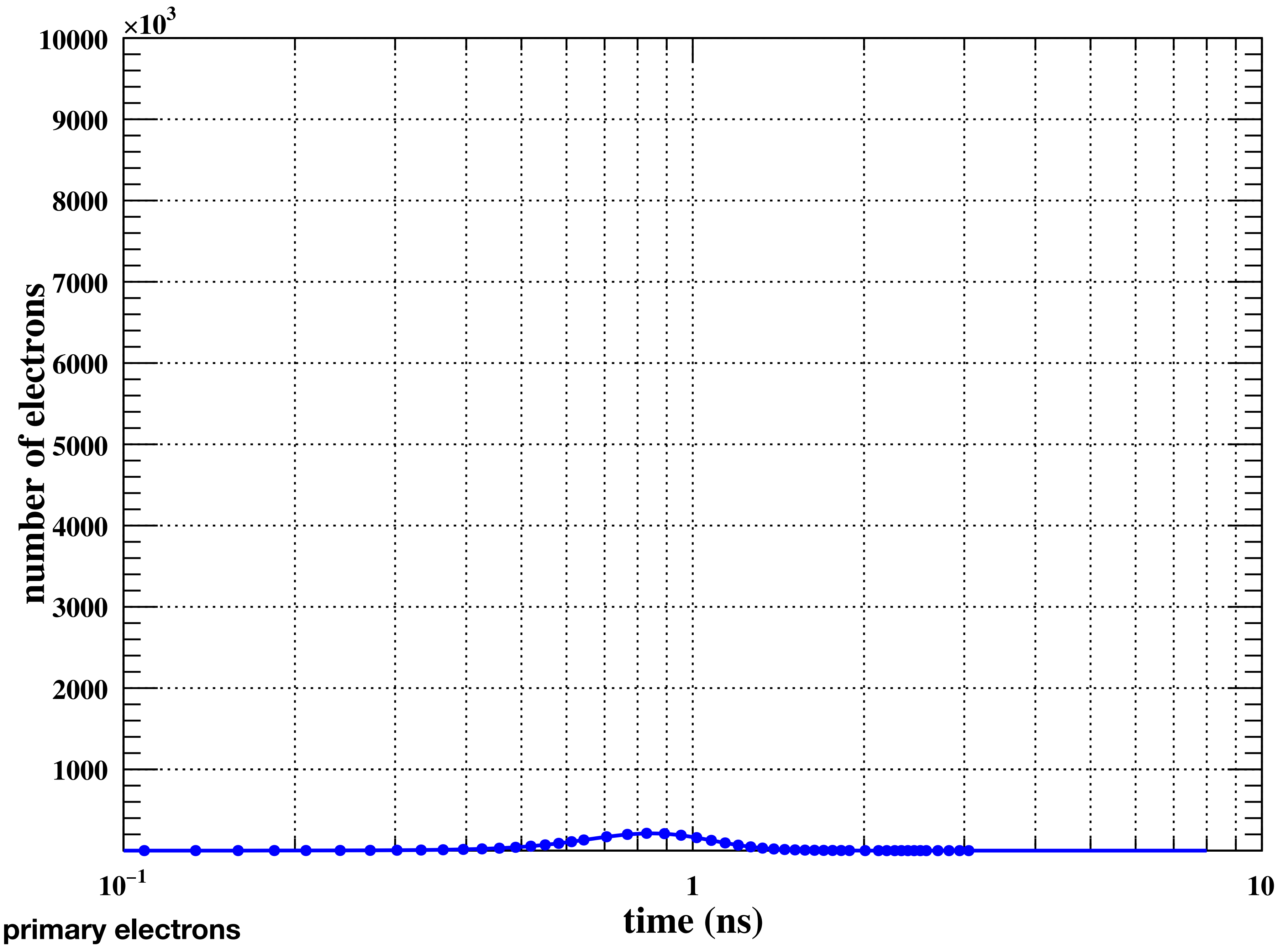


Cathode at '-V'

Anode at ground potential

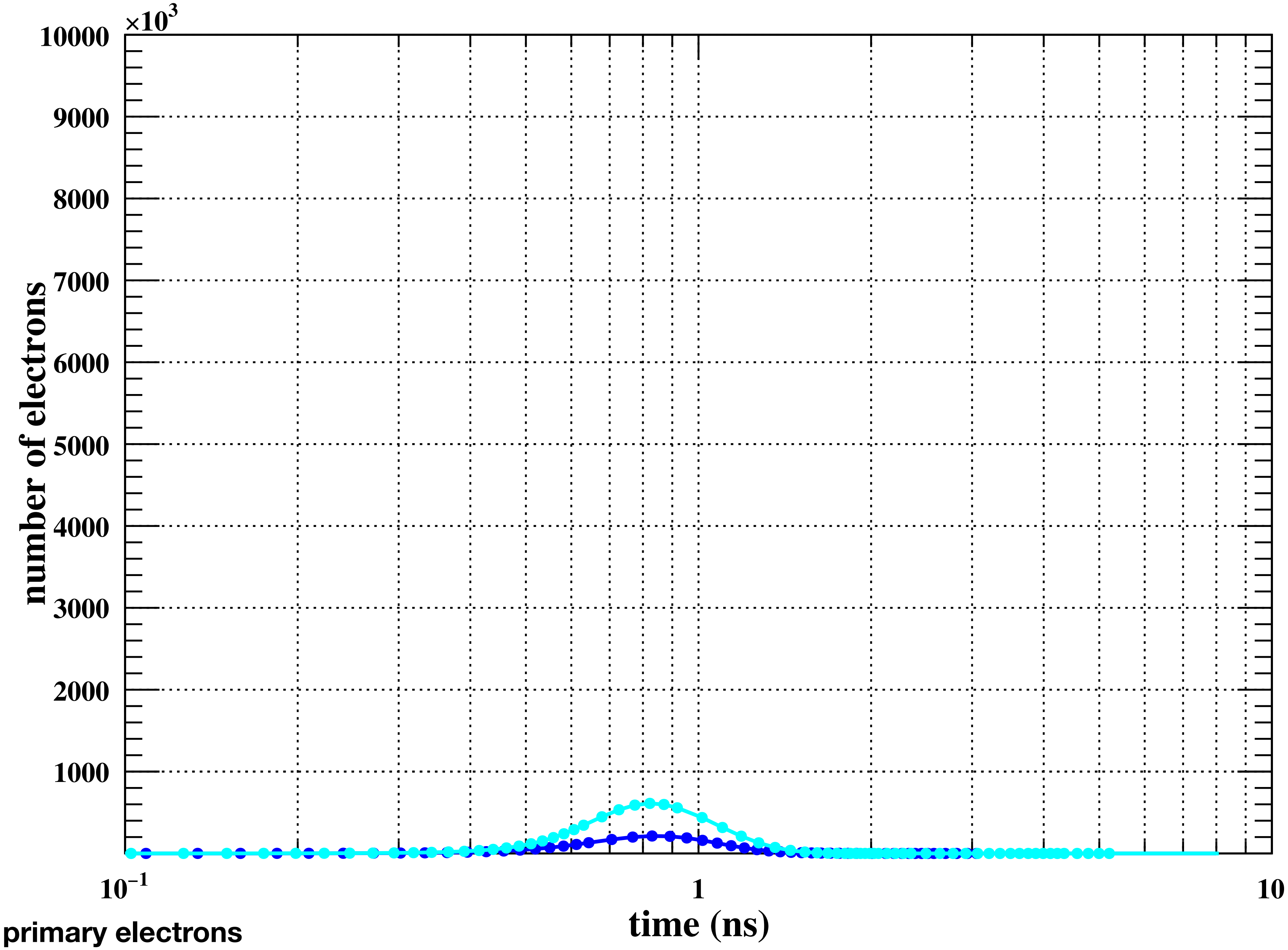
Gas Ar:CO2=70:30, penning 50

at -700 V



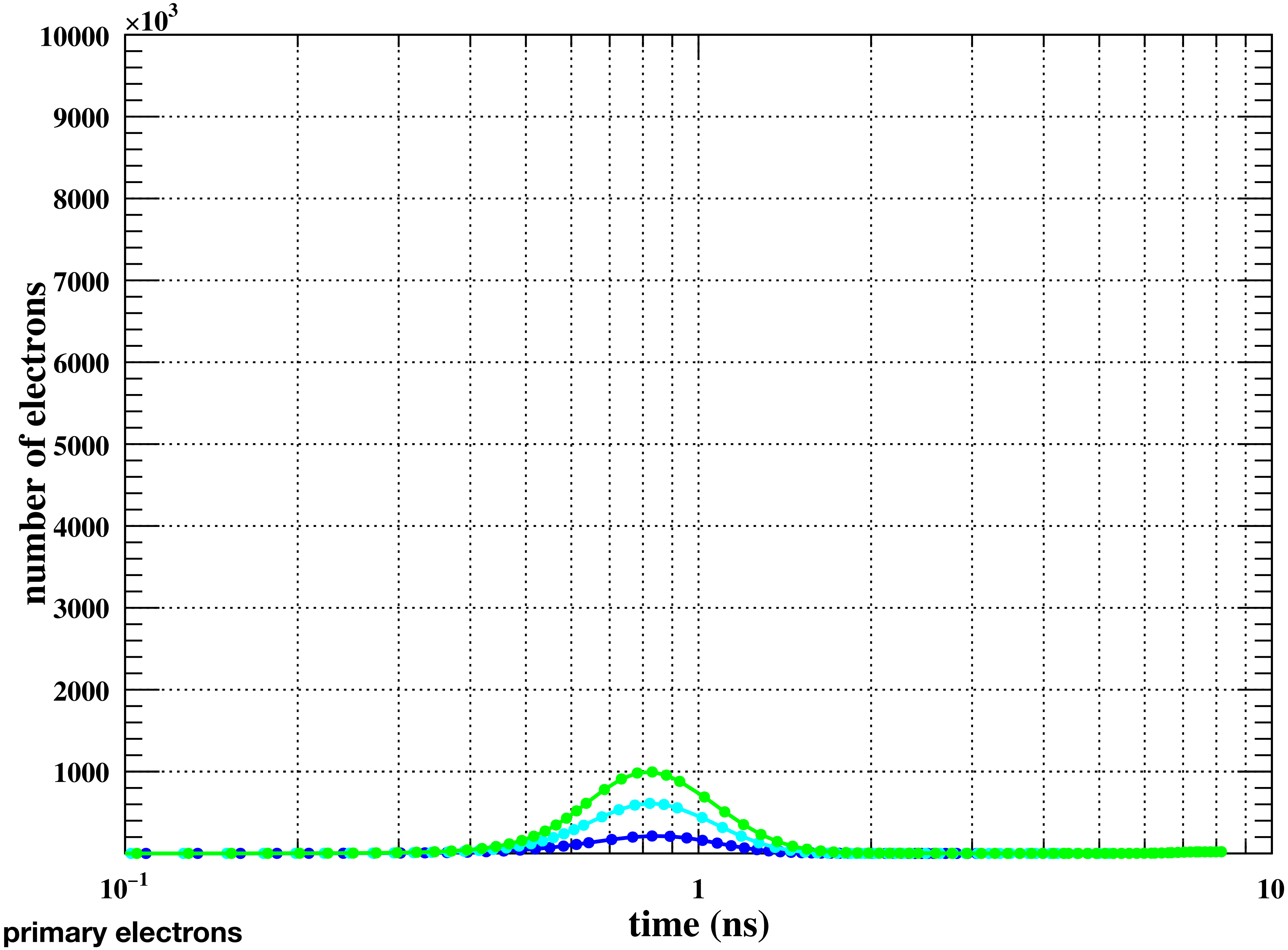
starts with 100 primary electrons

at -740 V



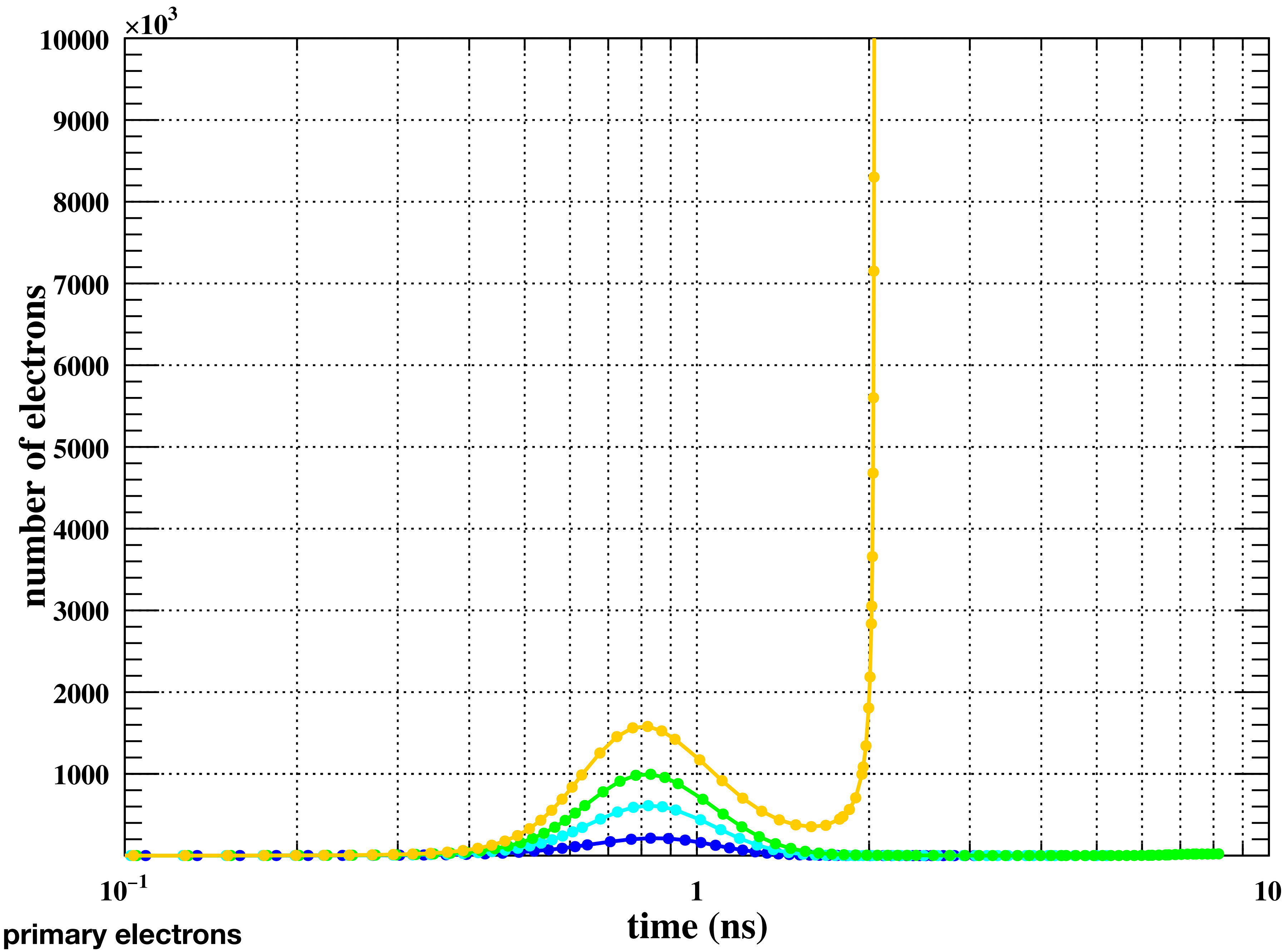
starts with 100 primary electrons

at -760 V



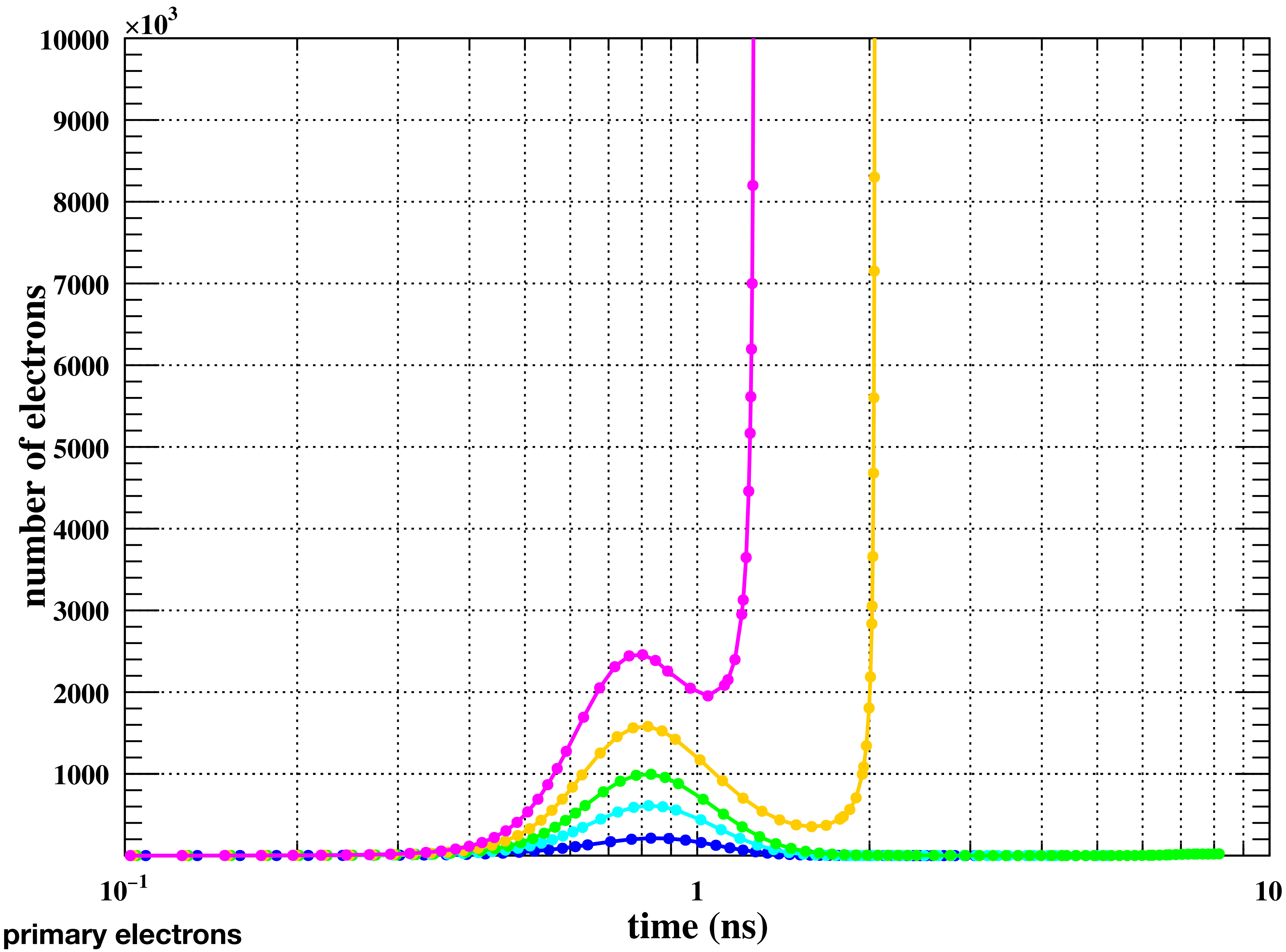
starts with 100 primary electrons

at -780 V



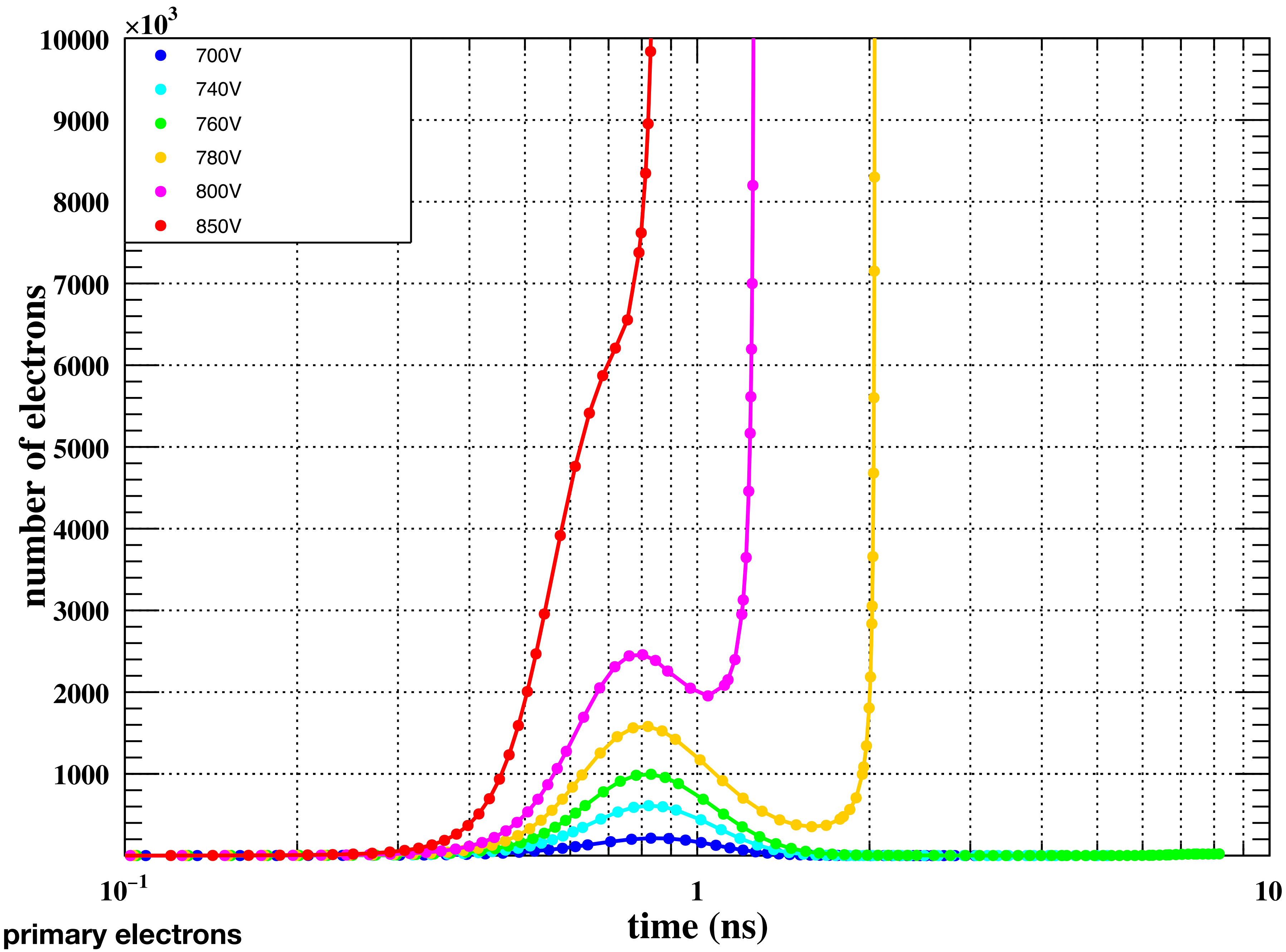
starts with 100 primary electrons

at -800 V



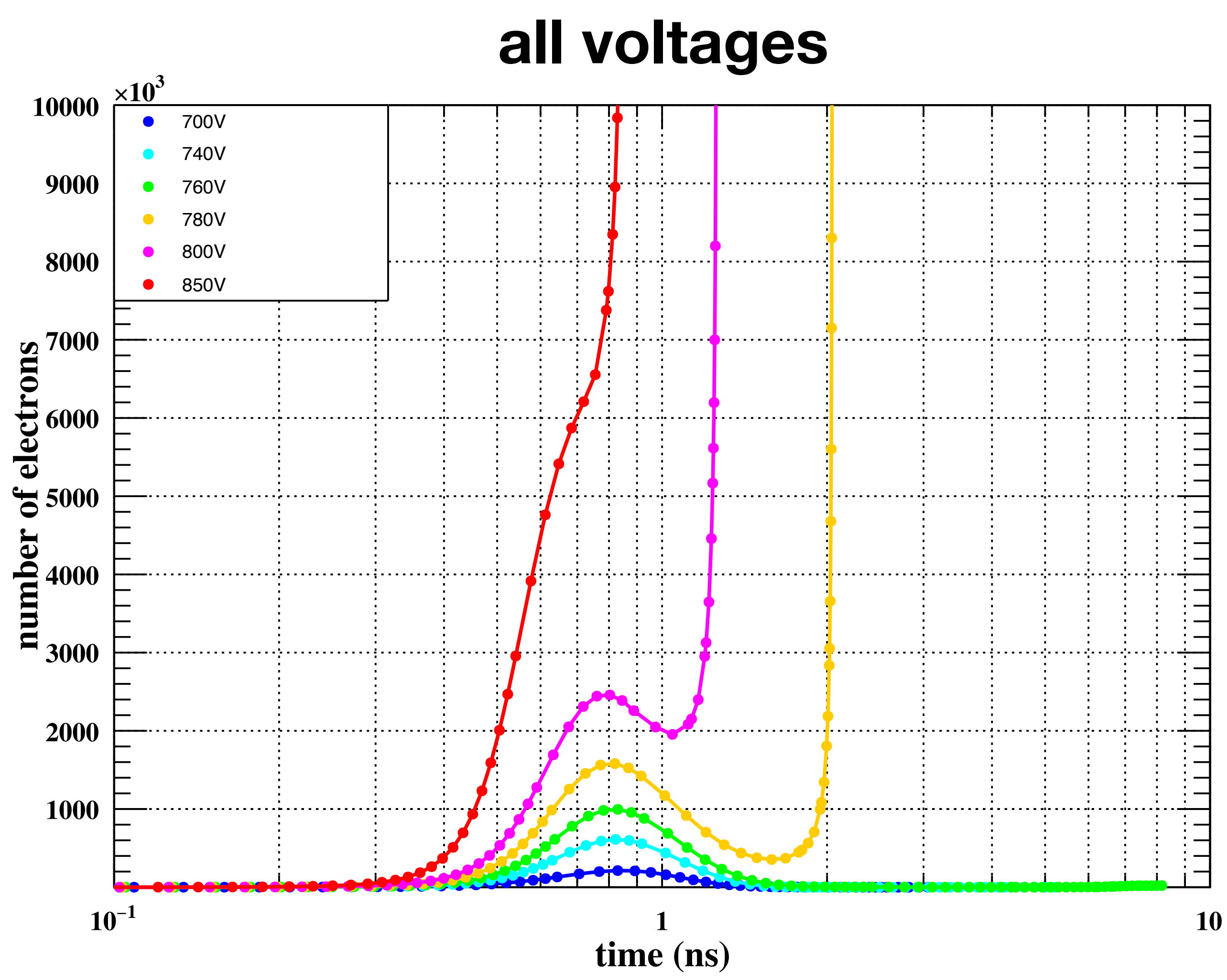
starts with 100 primary electrons

at -850 V



starts with 100 primary electrons

this we know



starts with 100 primary electrons

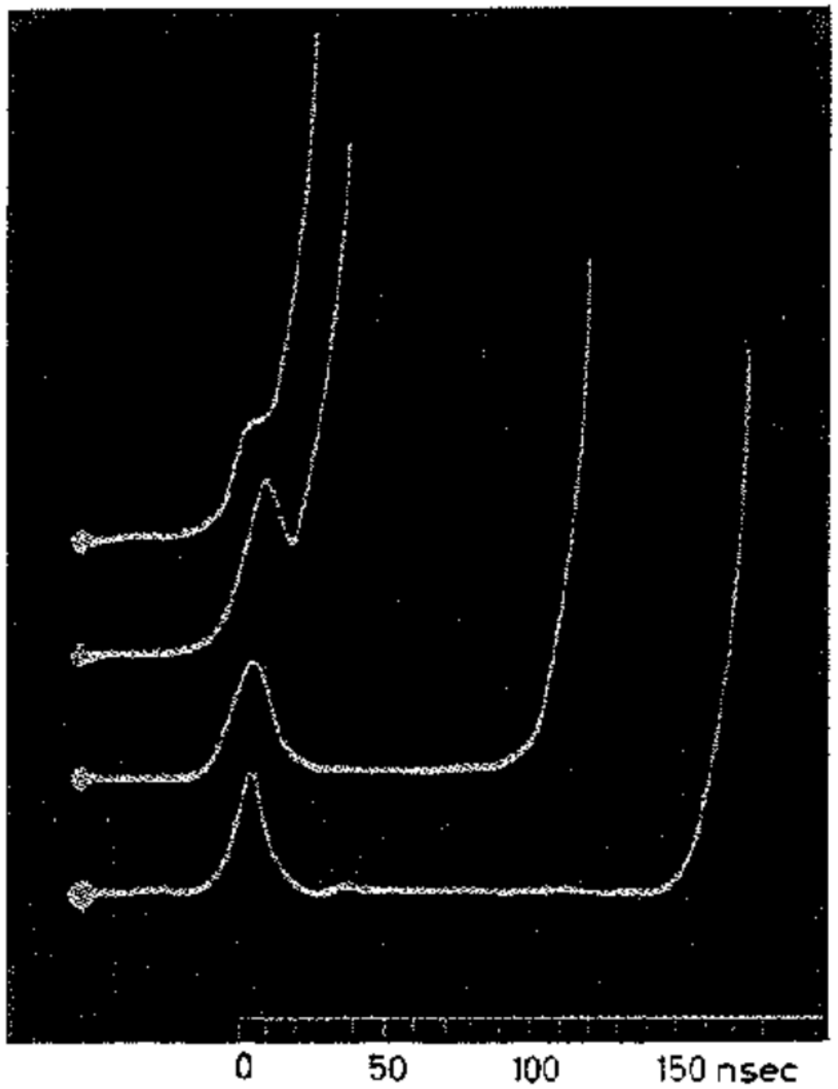
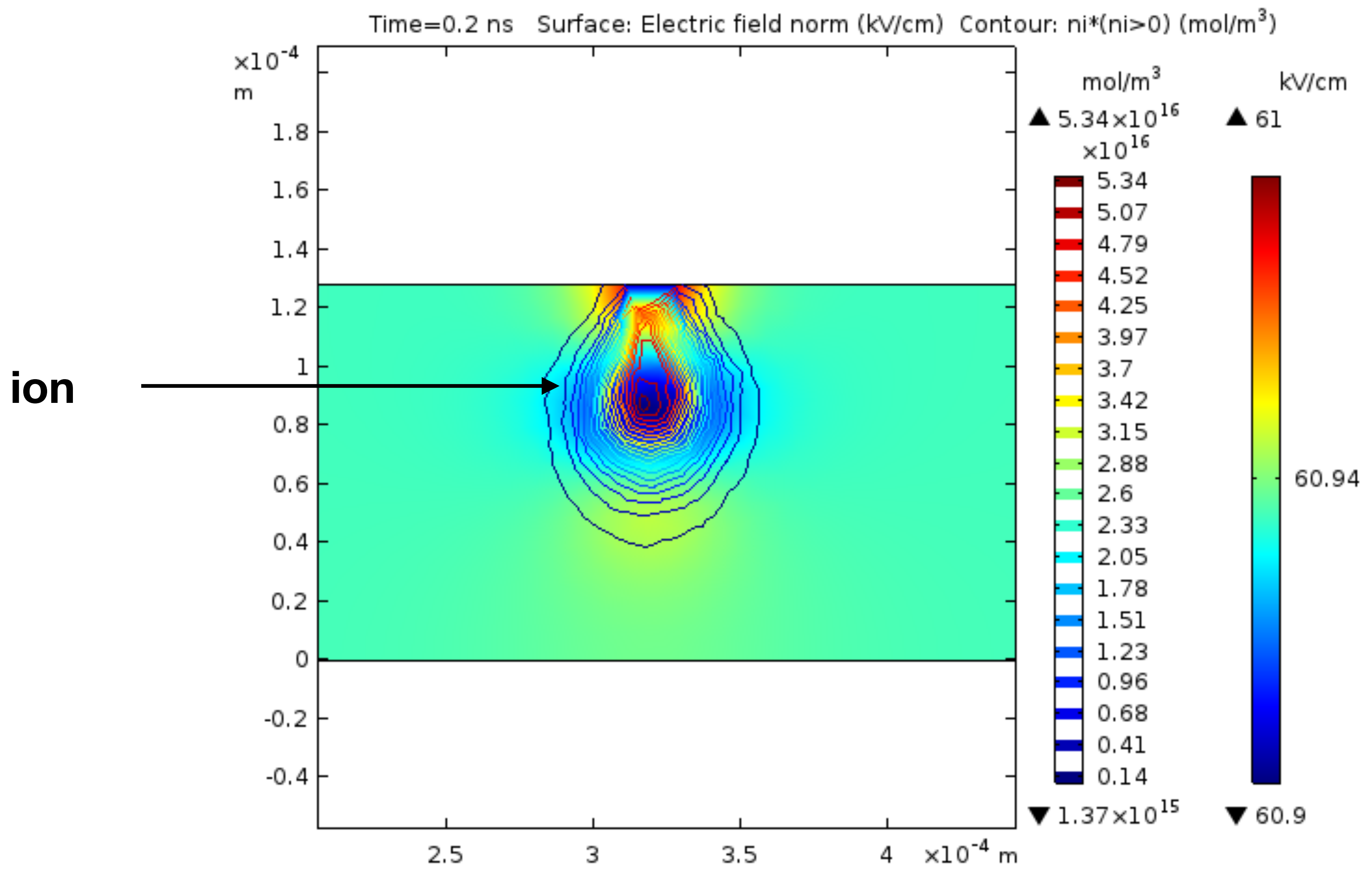
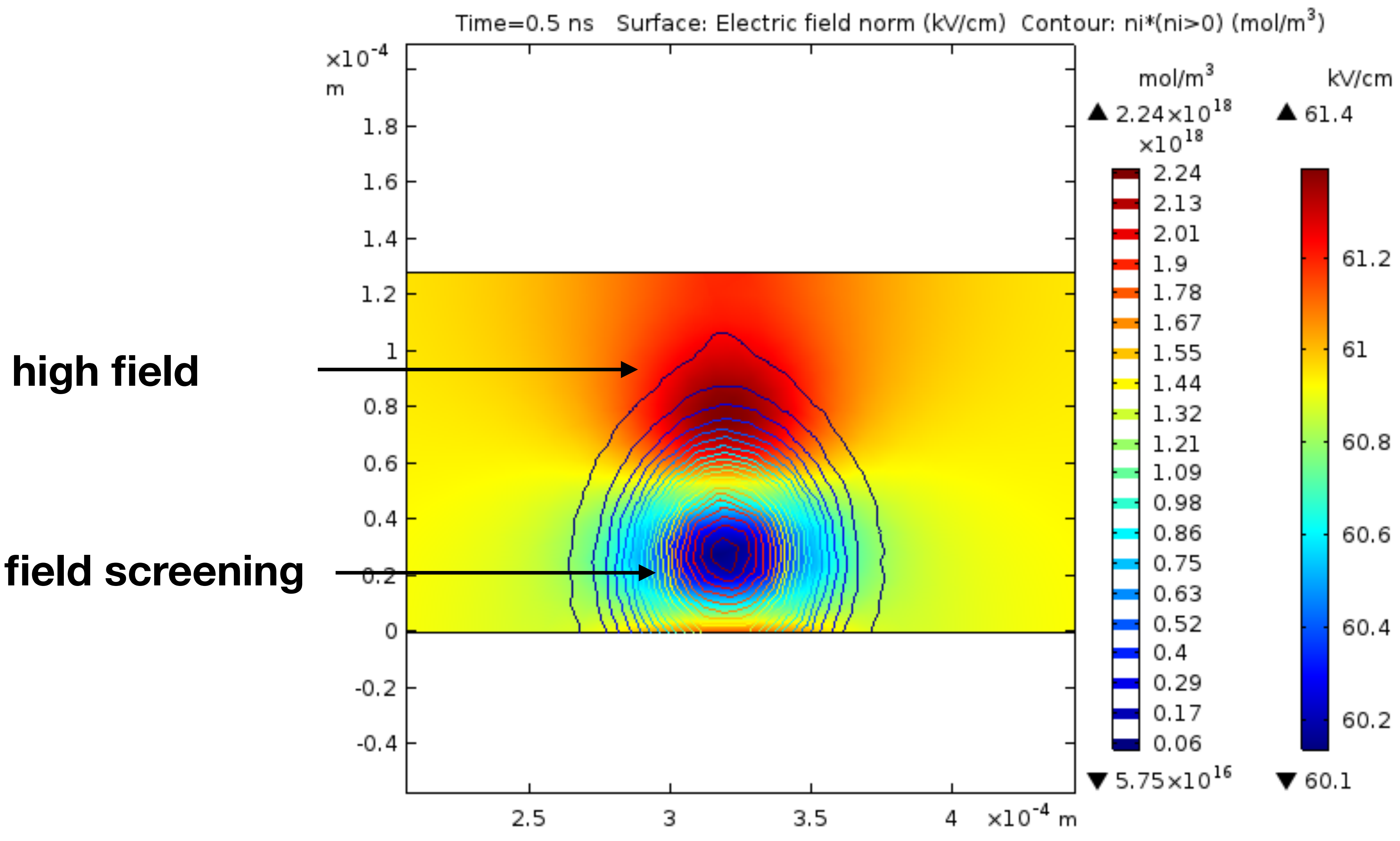


Figure 5.14. Current oscillograms of static breakdown in methylal. Optical method. E/p = 64·4, pd = 230 Torr cm, d = 0·8 cm, T_{-} = 90 nsec RC = 5 nsec[36]



How the space charge is changing the field; applied voltage -780V (~61 kV/cm)



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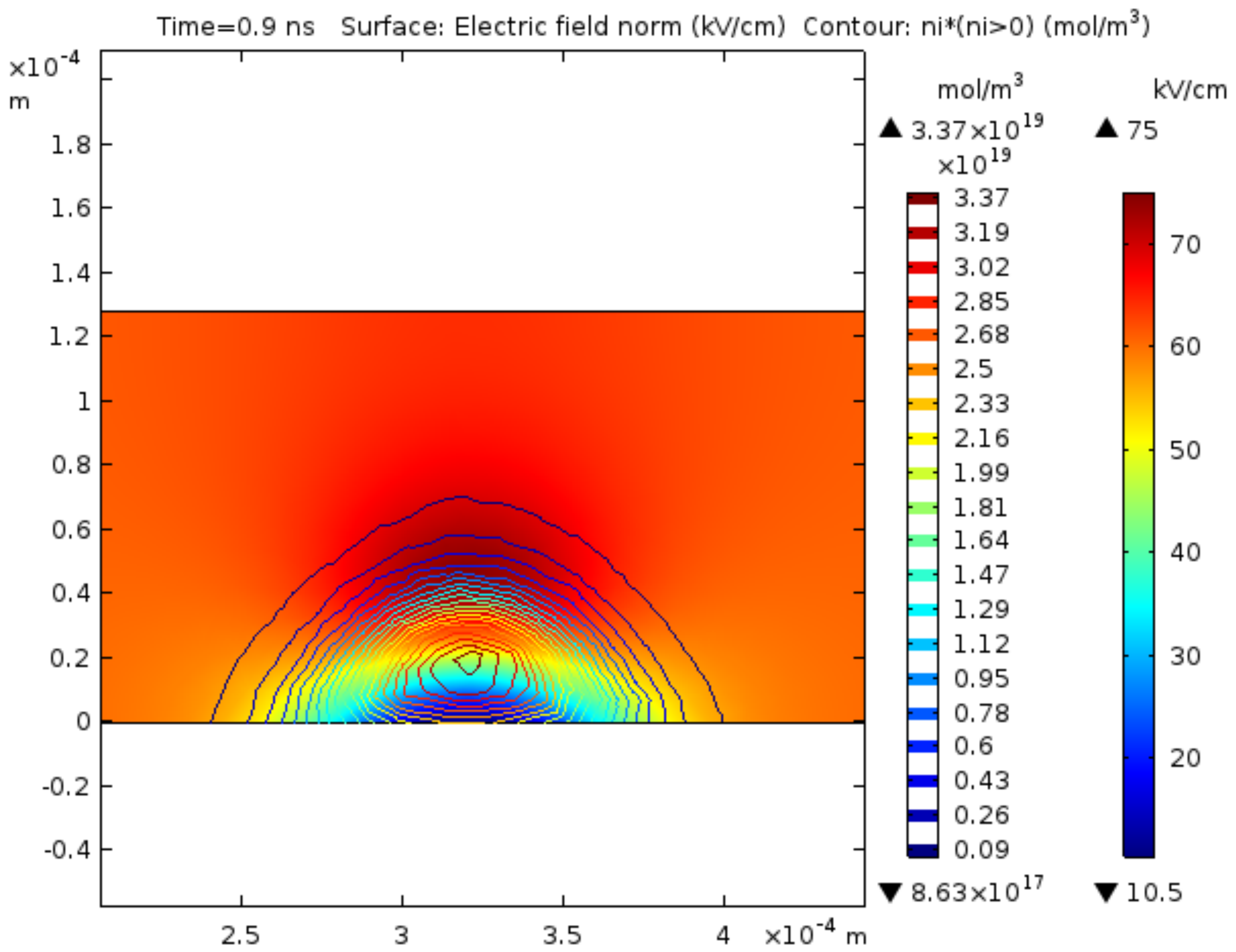

How the space charge is changing the field;
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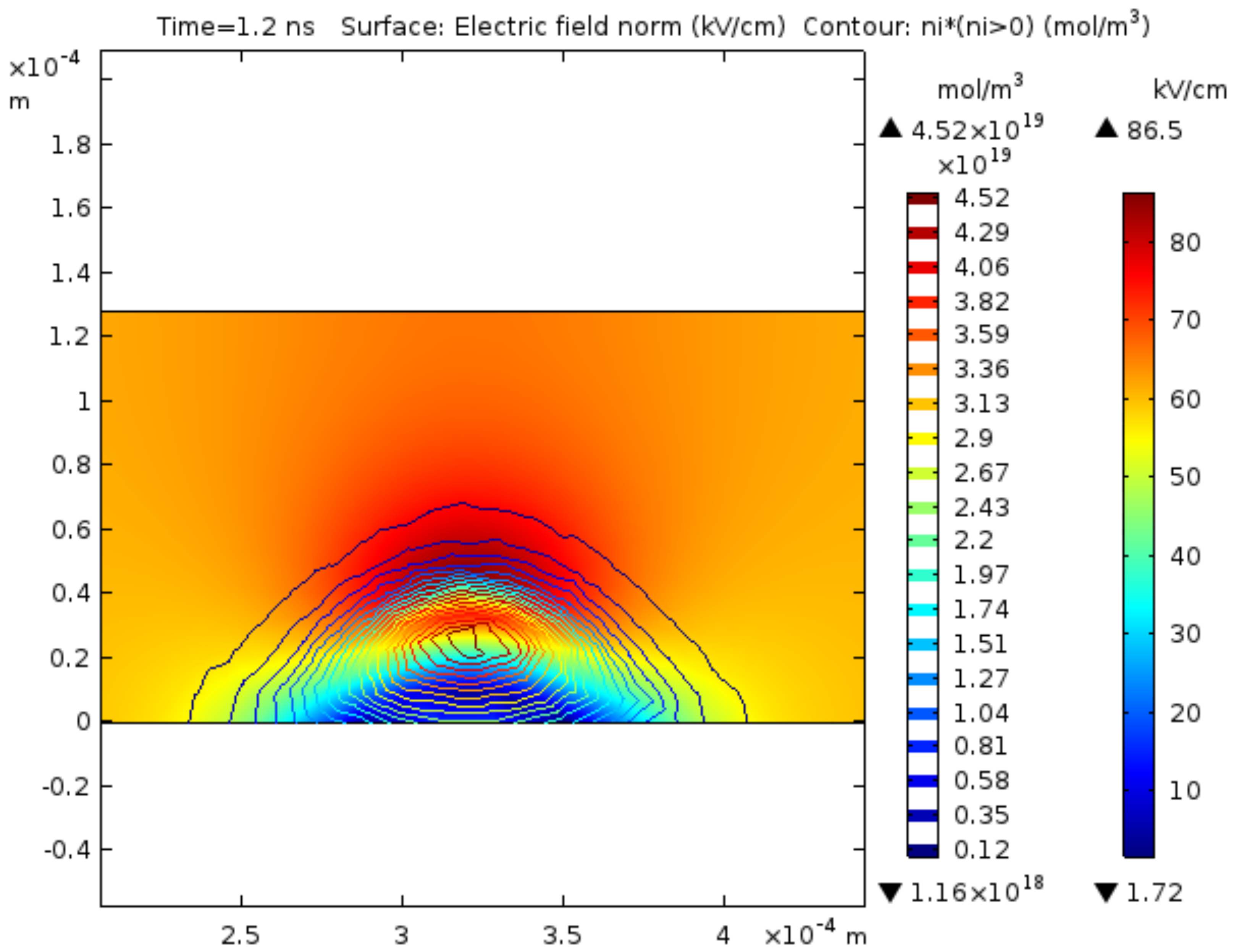

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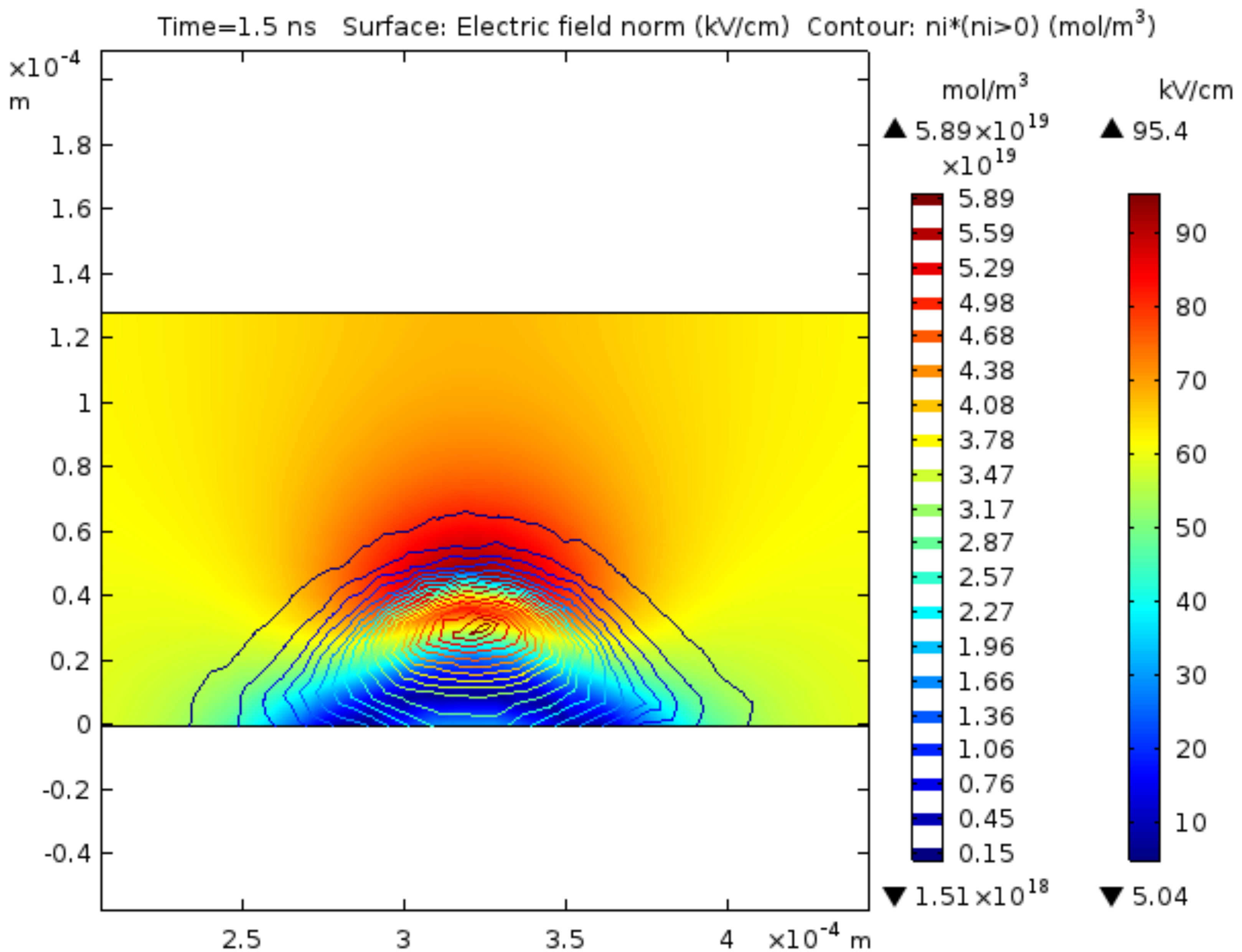
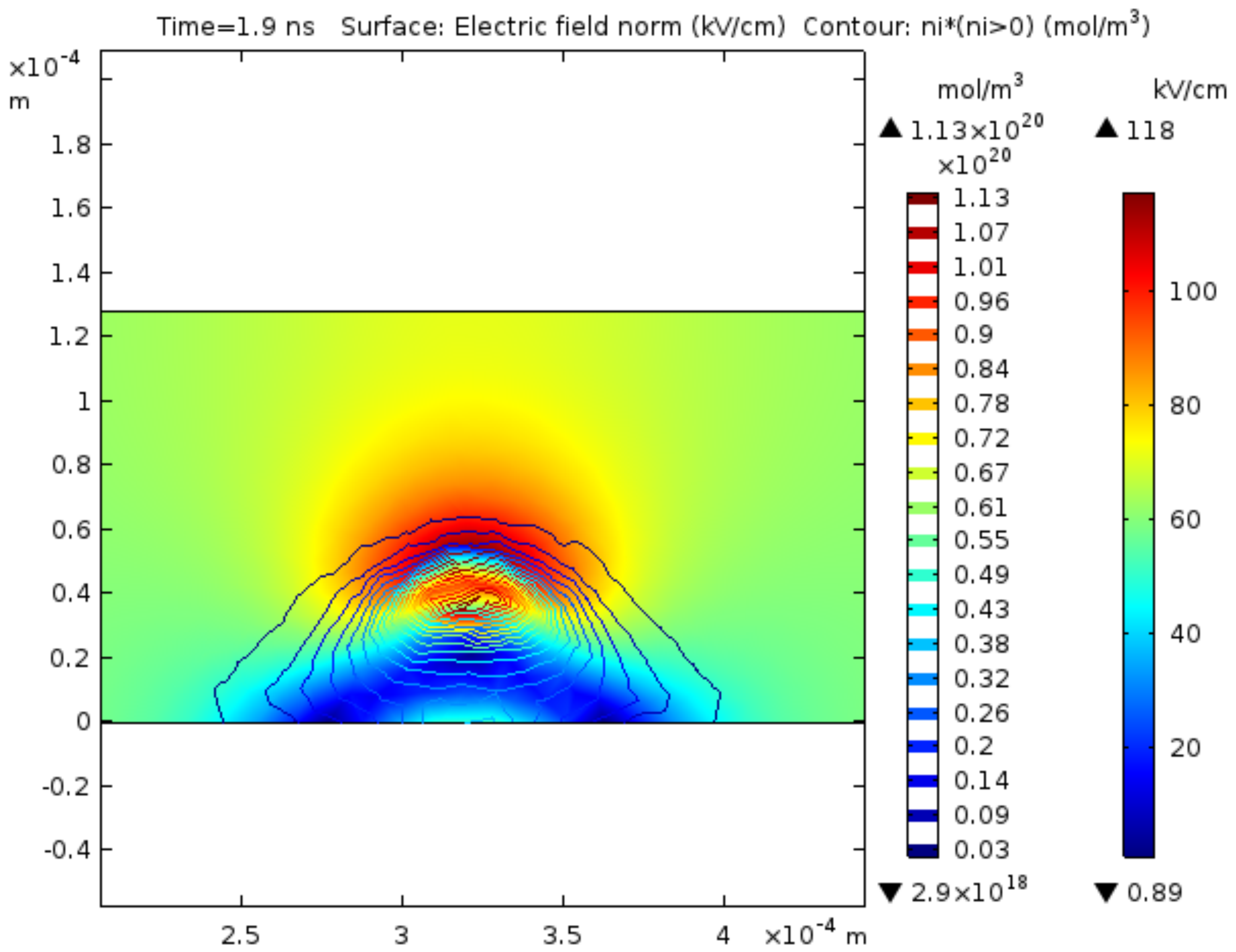
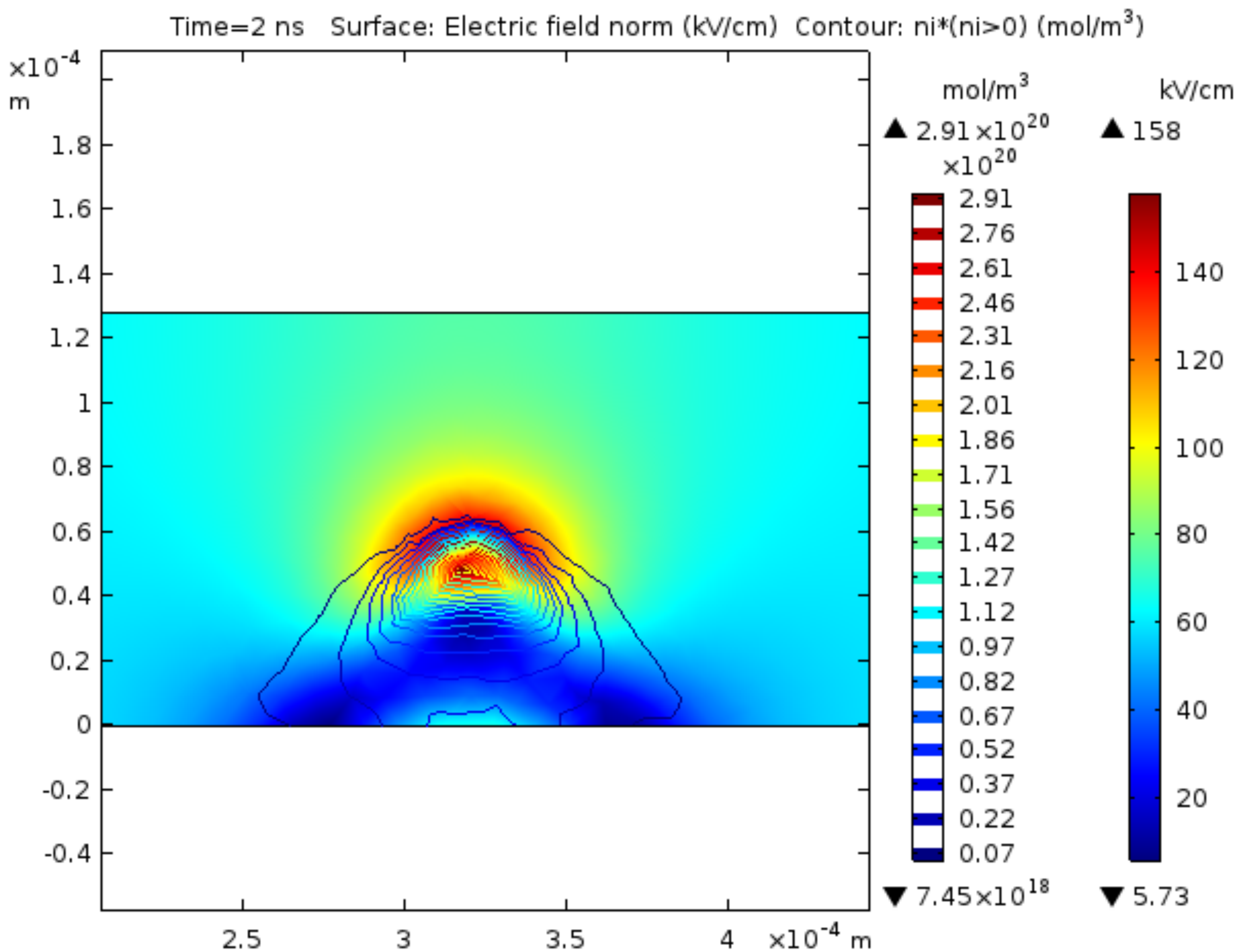


How the space charge is changing the field; applied voltage -780V (~61 kV/cm)

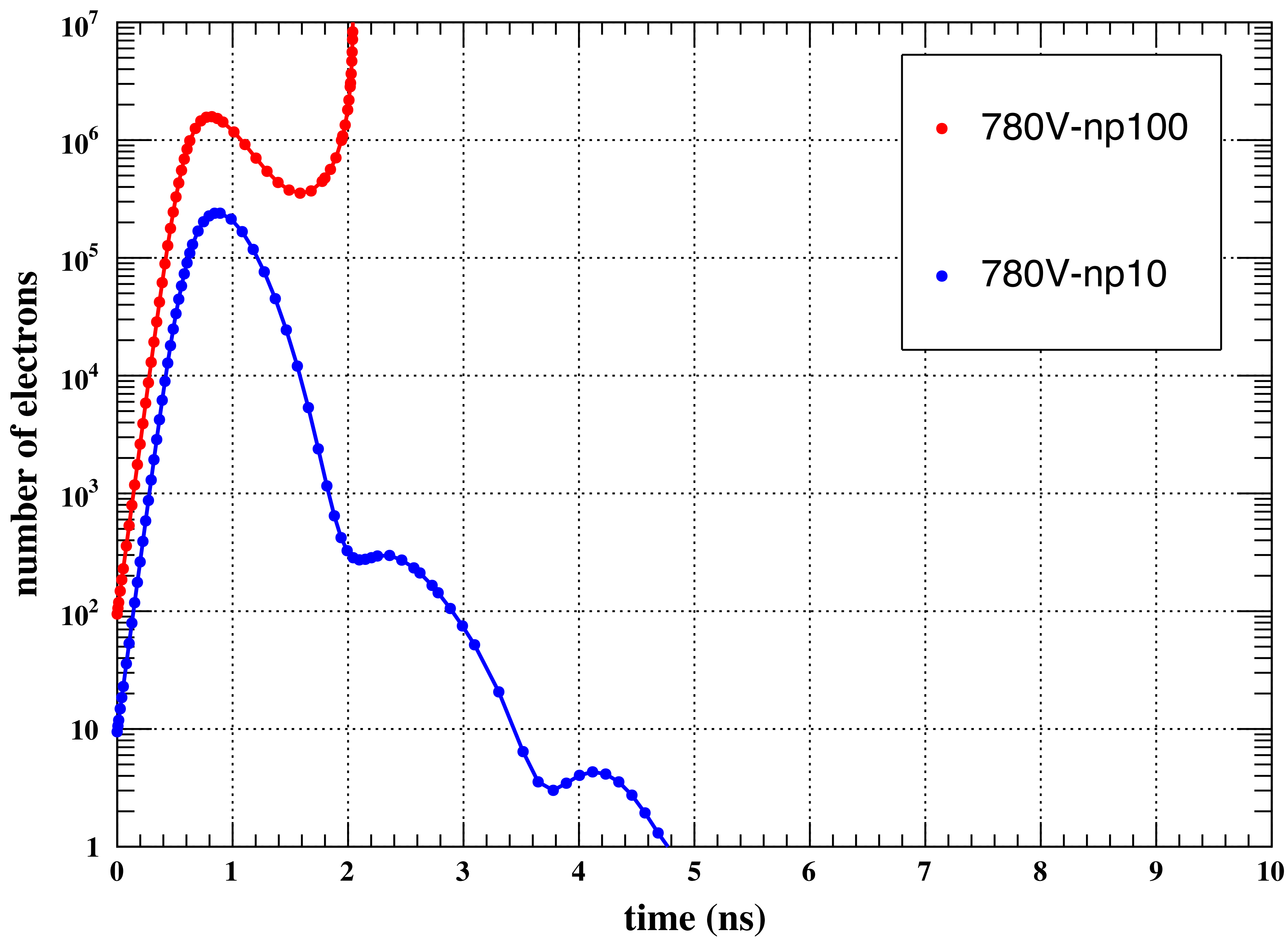


How the space charge is changing the field; applied voltage -780V (~61 kV/cm)



How the space charge is changing the field; applied voltage -780V (~61 kV/cm)

With different primaries



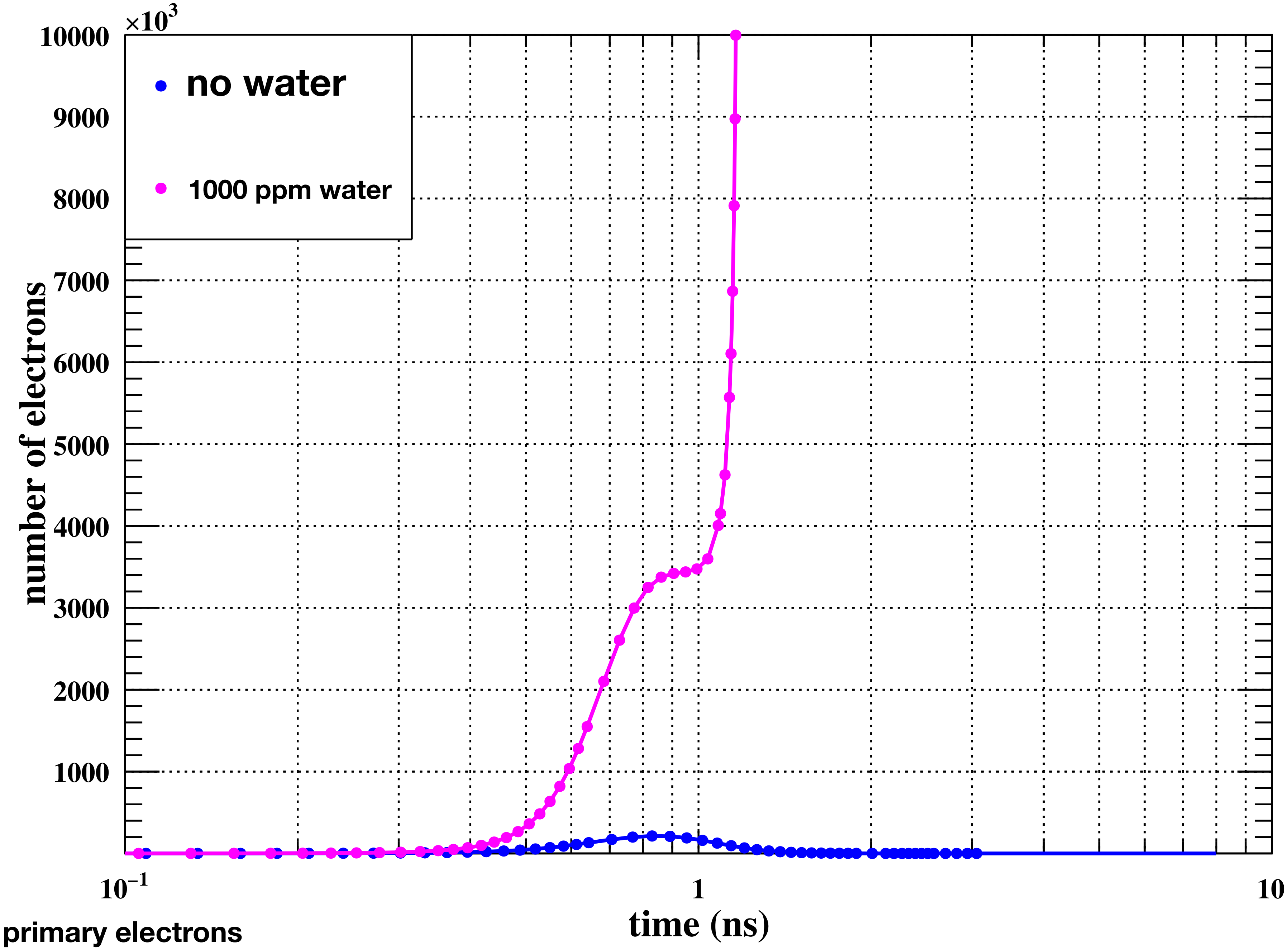
gain=16K

gain=25K

for field screening

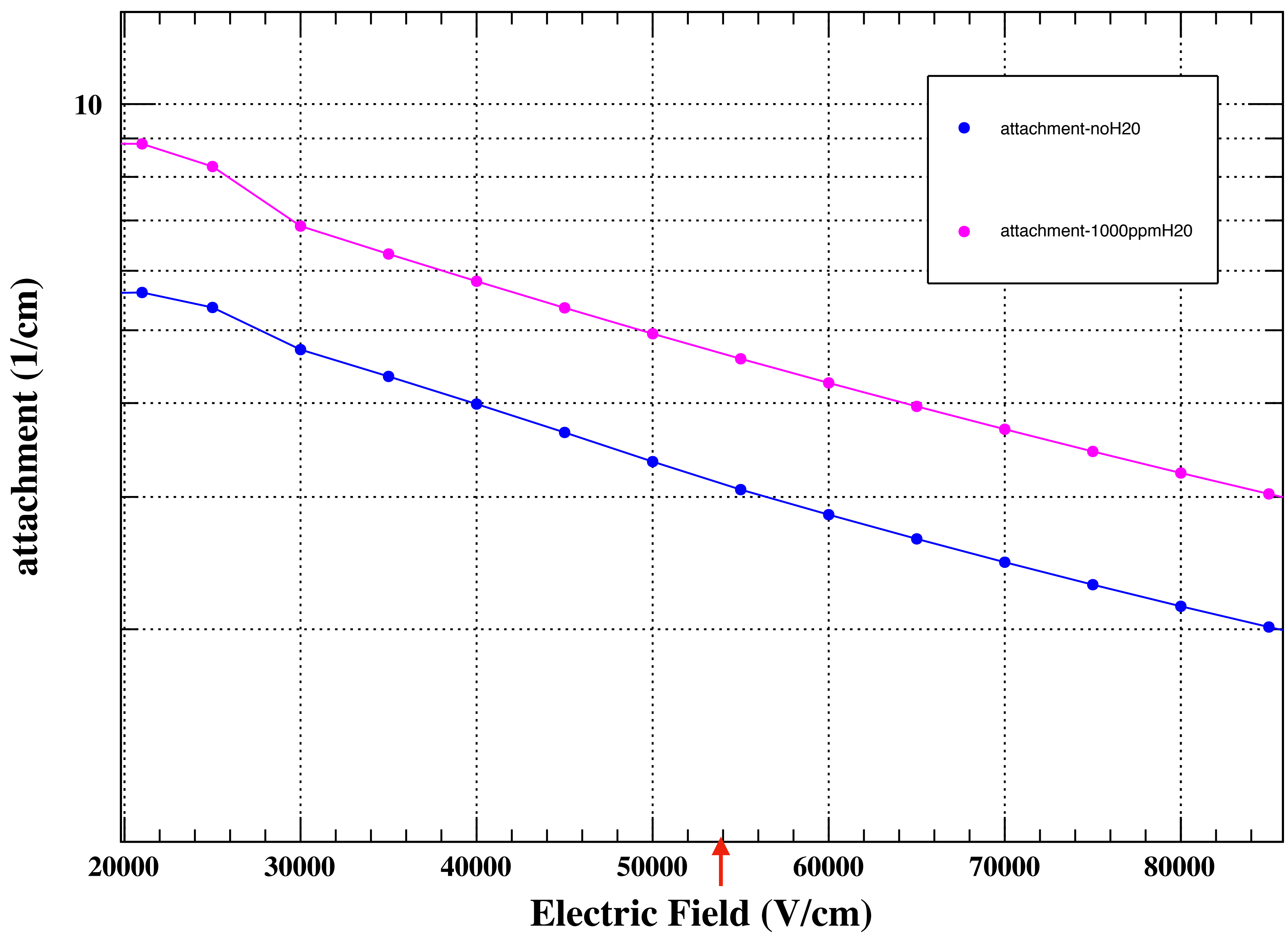
at 700 V

The effect of adding 1000 ppm of water (which is 4 % r.h.)

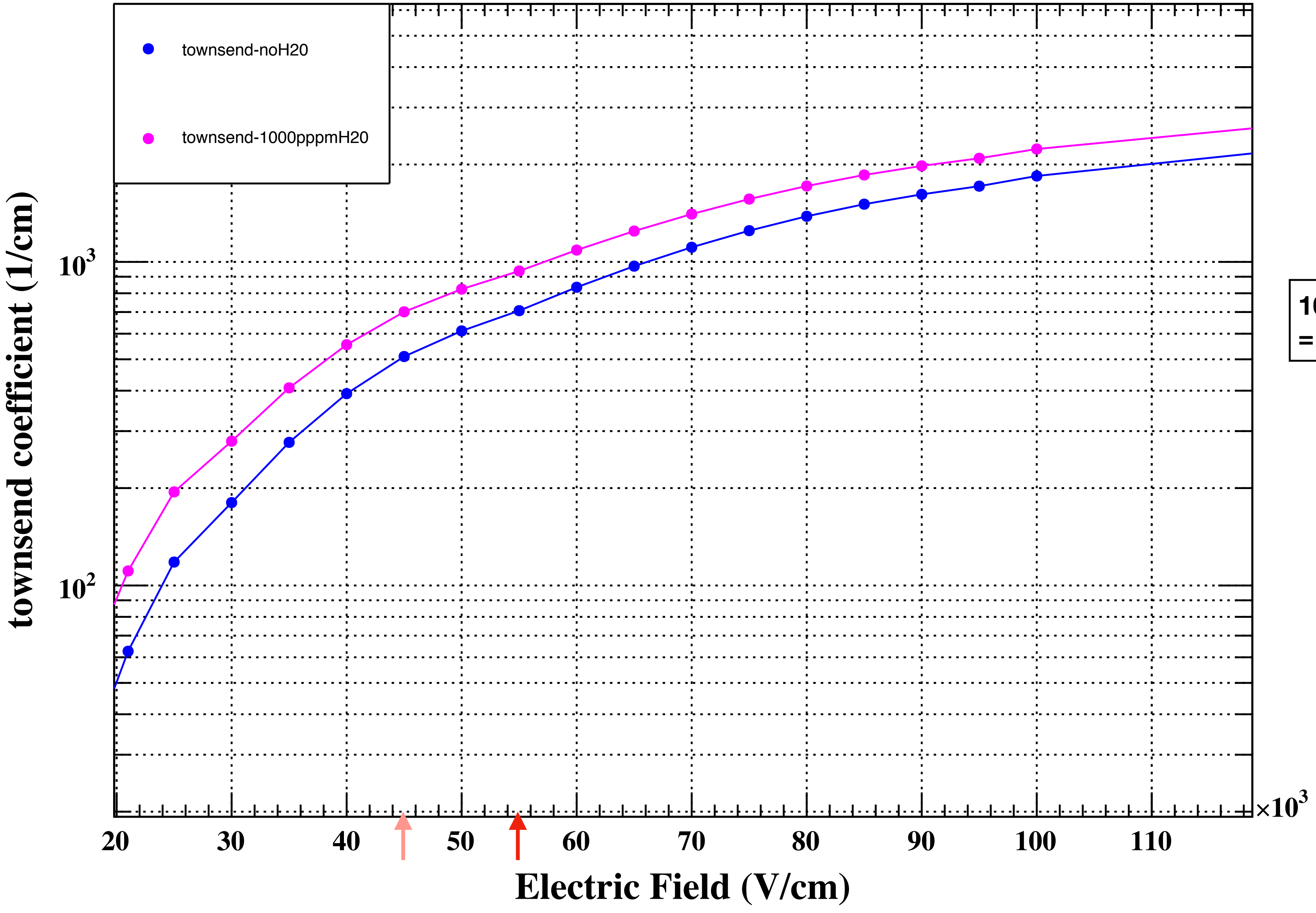


starts with 100 primary electrons

Ar:CO2=70:30


10
attachment (1/cm)
20000
30000
40000
50000
60000
70000
80000
Electric Field (V/cm)
attachment-noH20
attachment-1000ppmH20

Ar:CO2=70:30

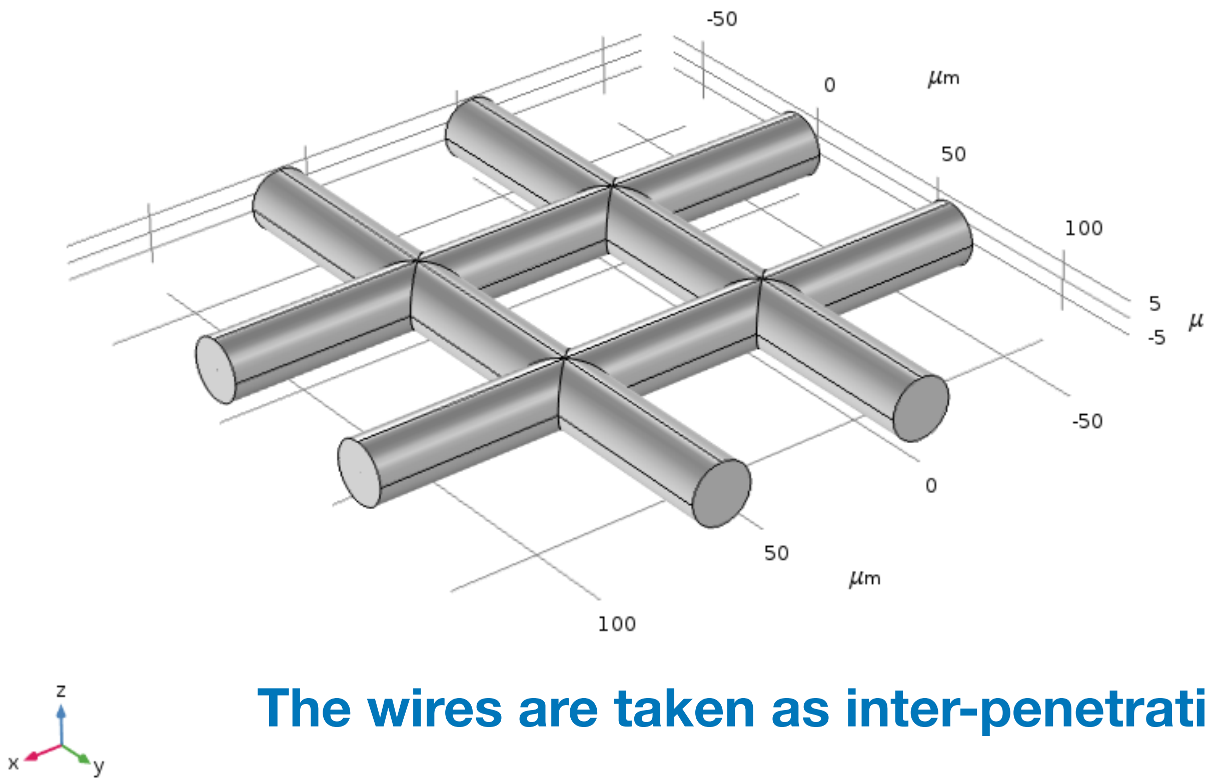


10000 V/cm * 128 μm
= 128 V

Solving this for Micromegas

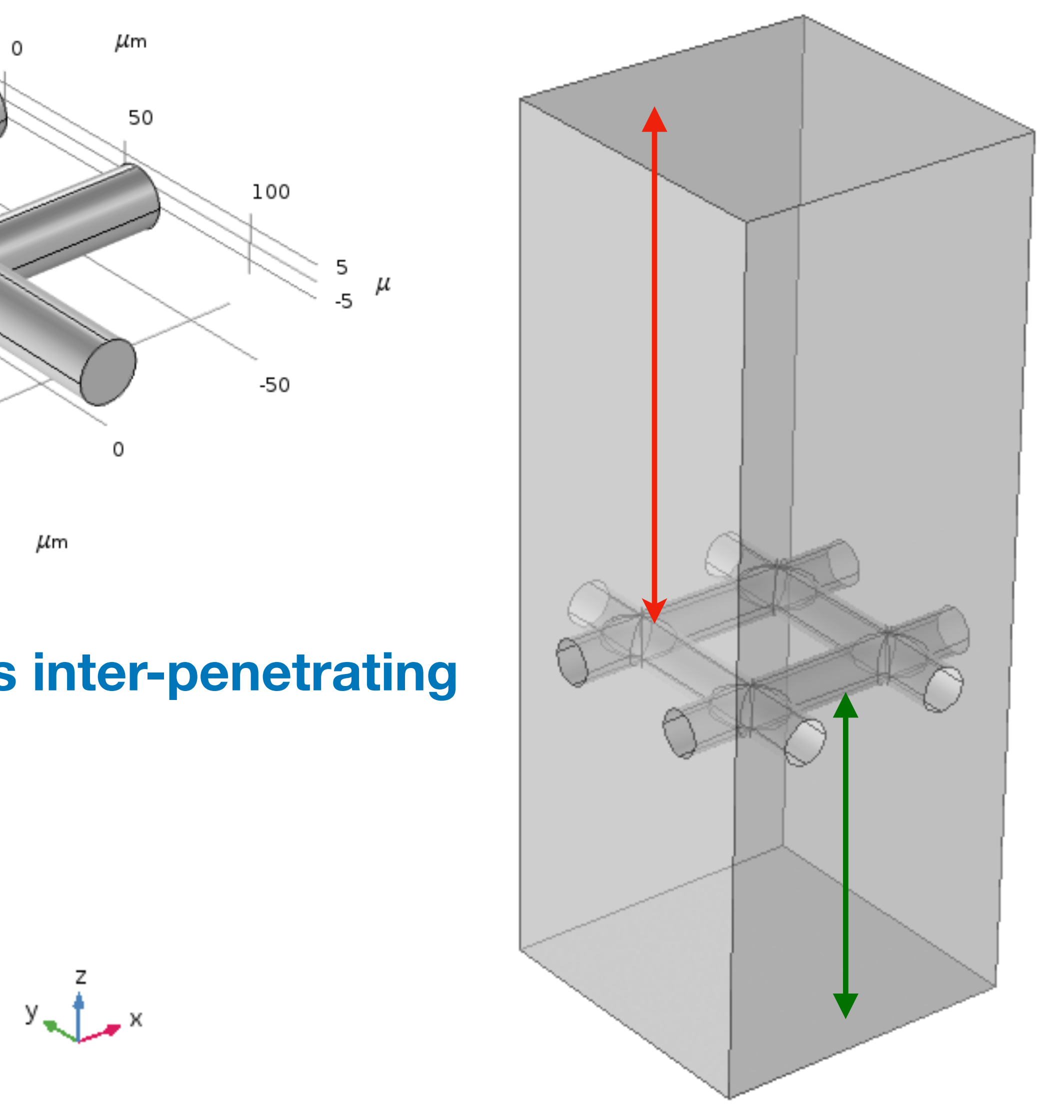
Building the geometry :

18/45 Calendared-like :



The wires are taken as inter-penetrating

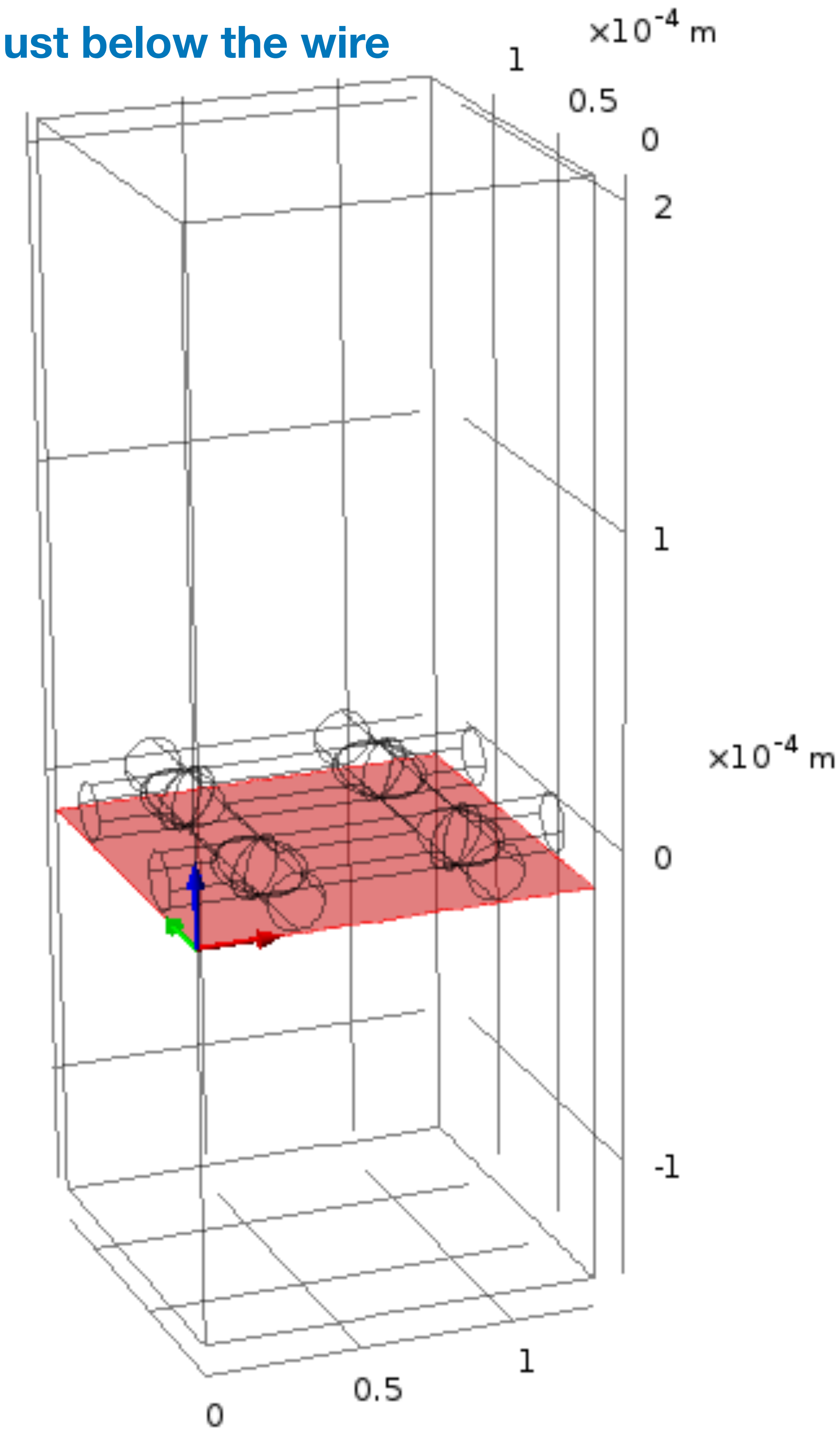
- Wire diameter 18 µm
- Edge to Edge 45 µm
- Axis to Axis 63 µm



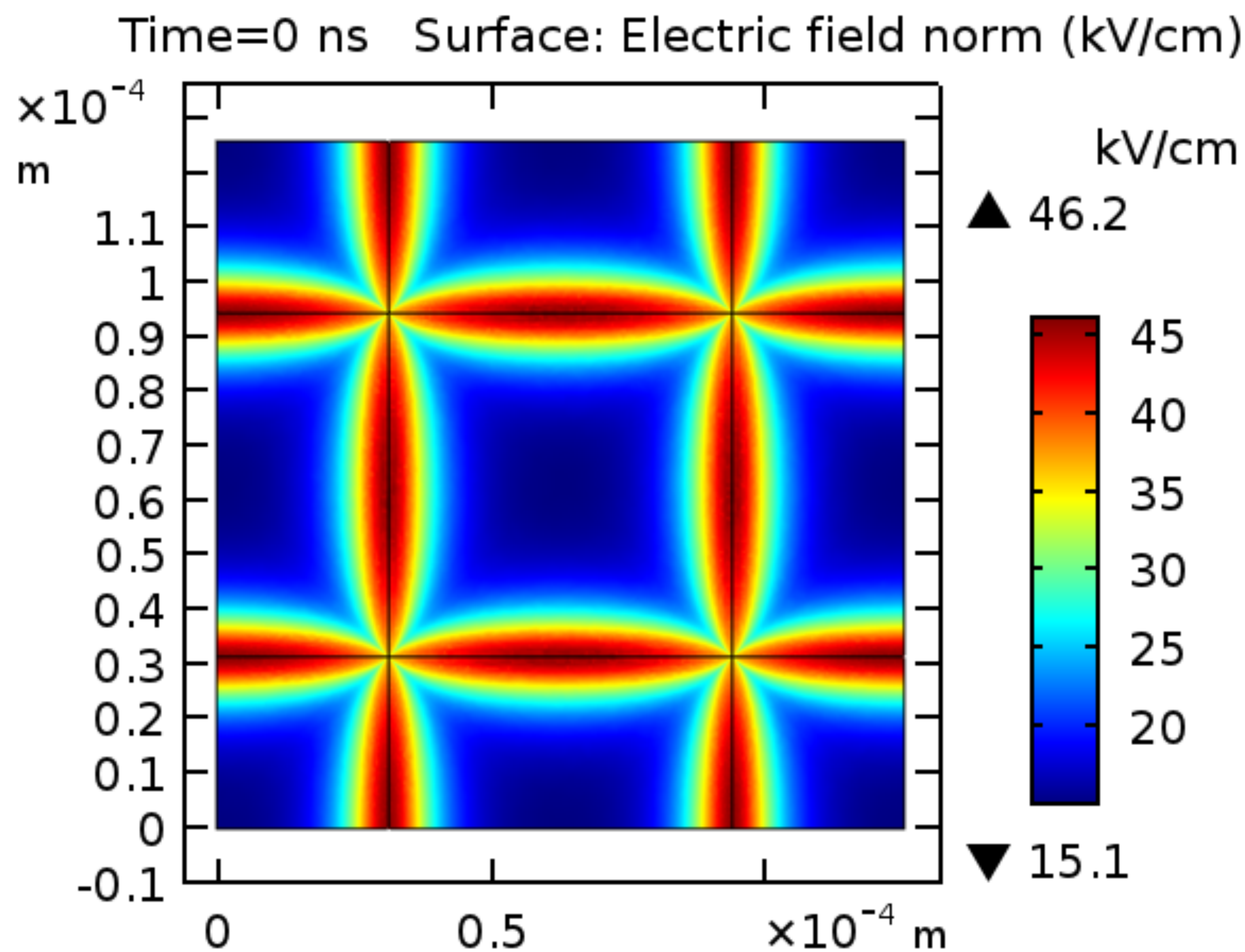
drift gap = 200 µm
amplification gap = 128 µm

mesh voltage = - 330 V
drift voltage = - 350 V

- **just below the wire**

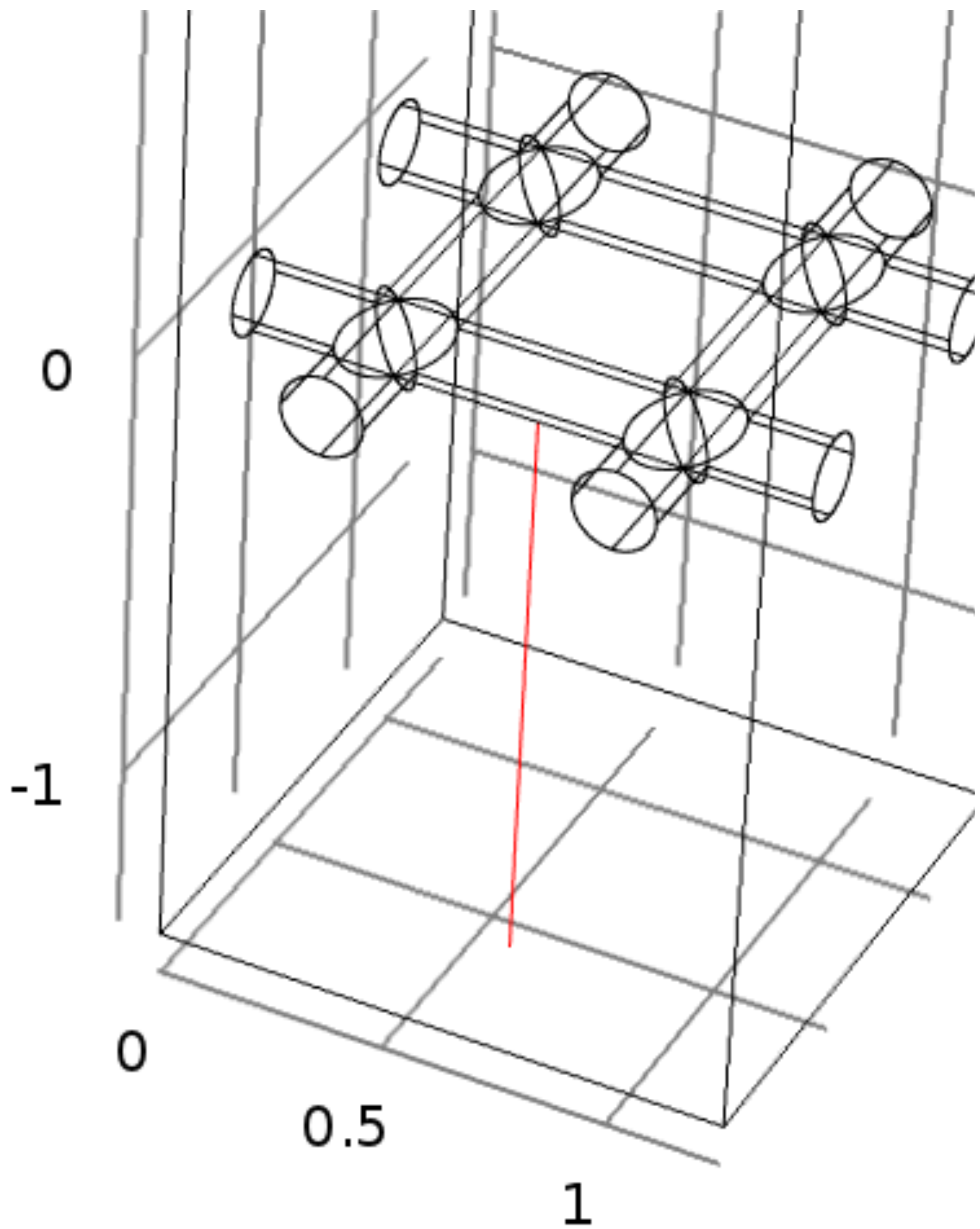


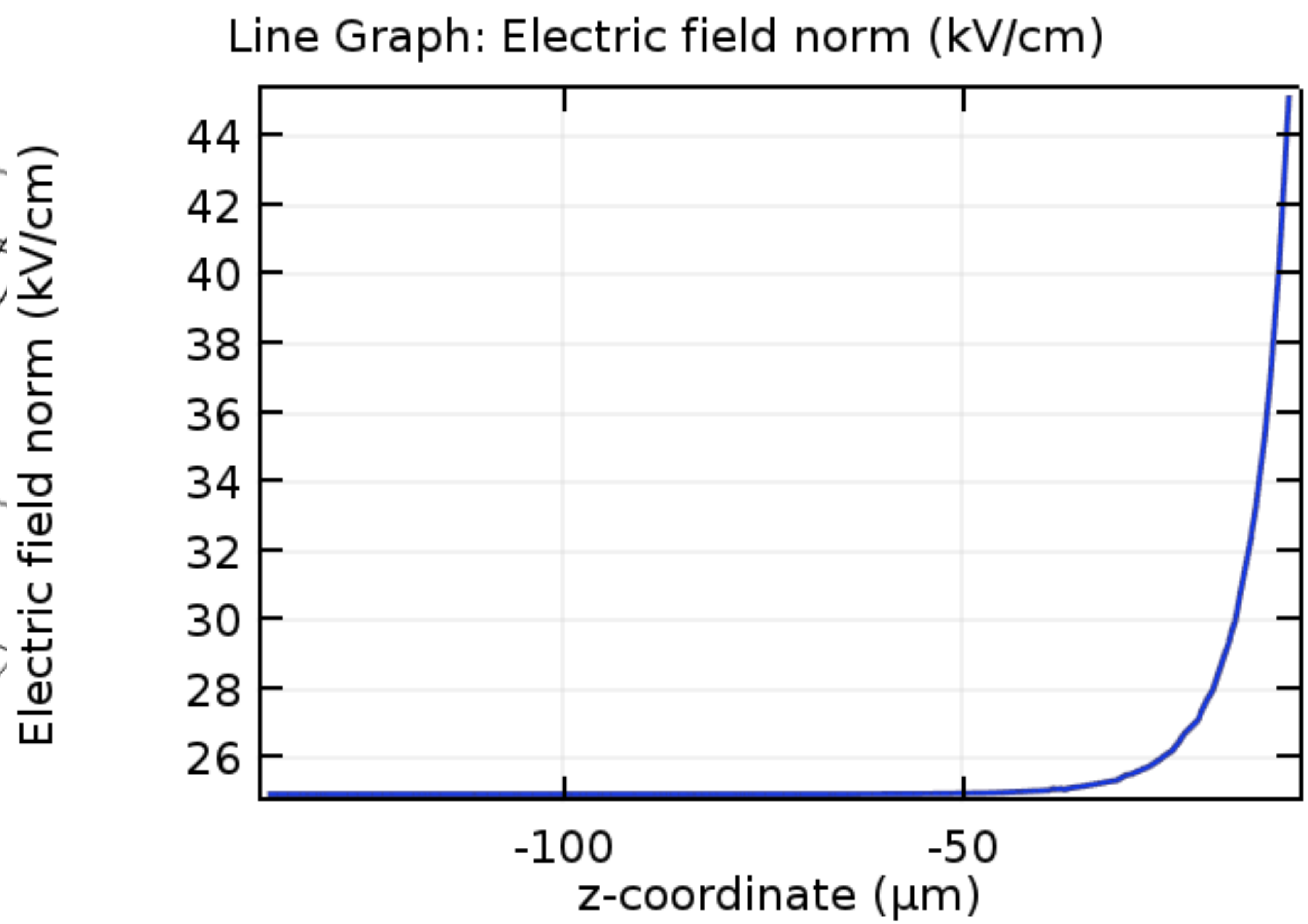
Result : Electric Field



Results: Electric Field

along a perpendicular line just below the wire (18-45)





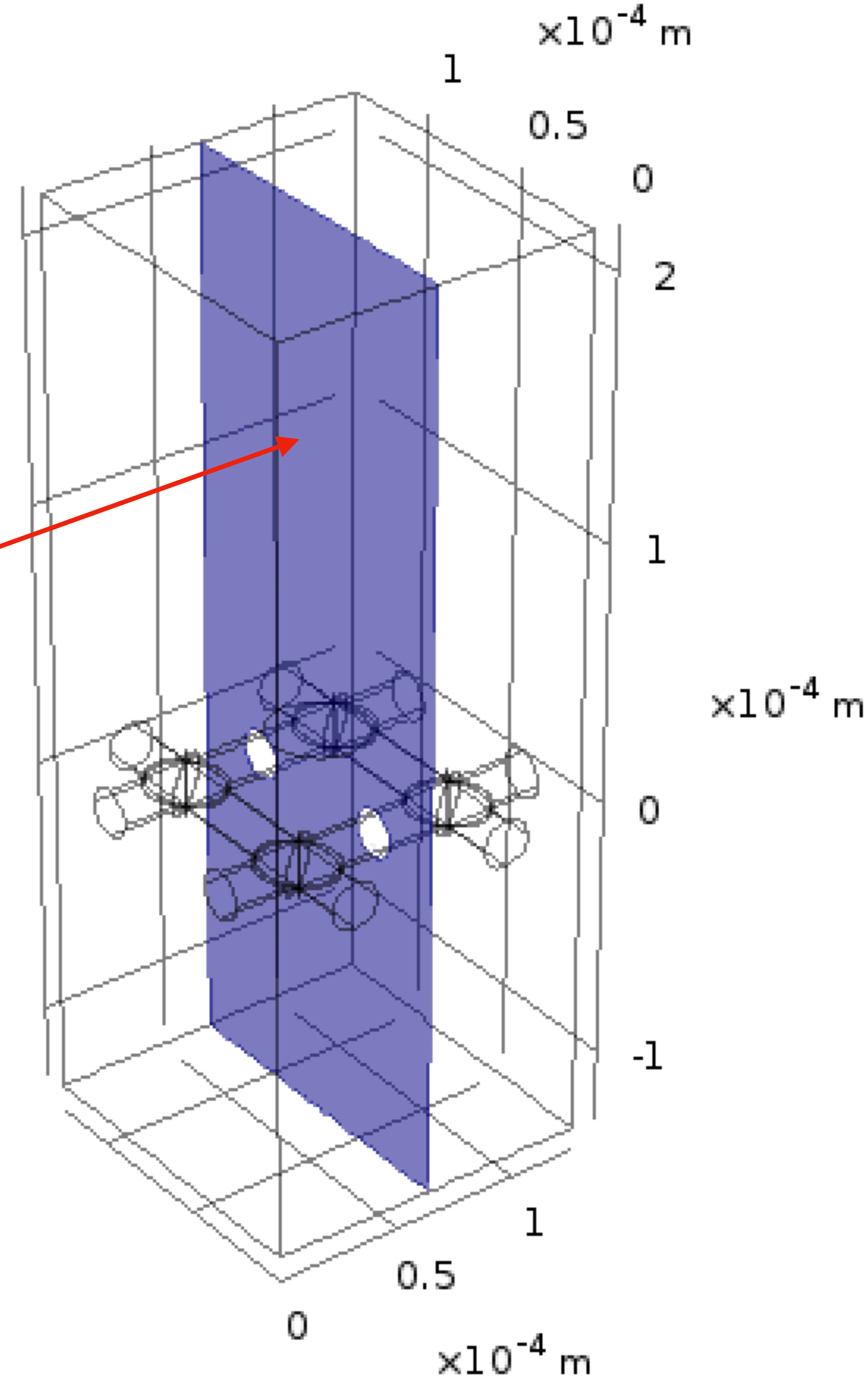
mesh voltage = —330 V

max field = 45.2 kV/cm ; average field = 24.9 kV/cm;

Results:

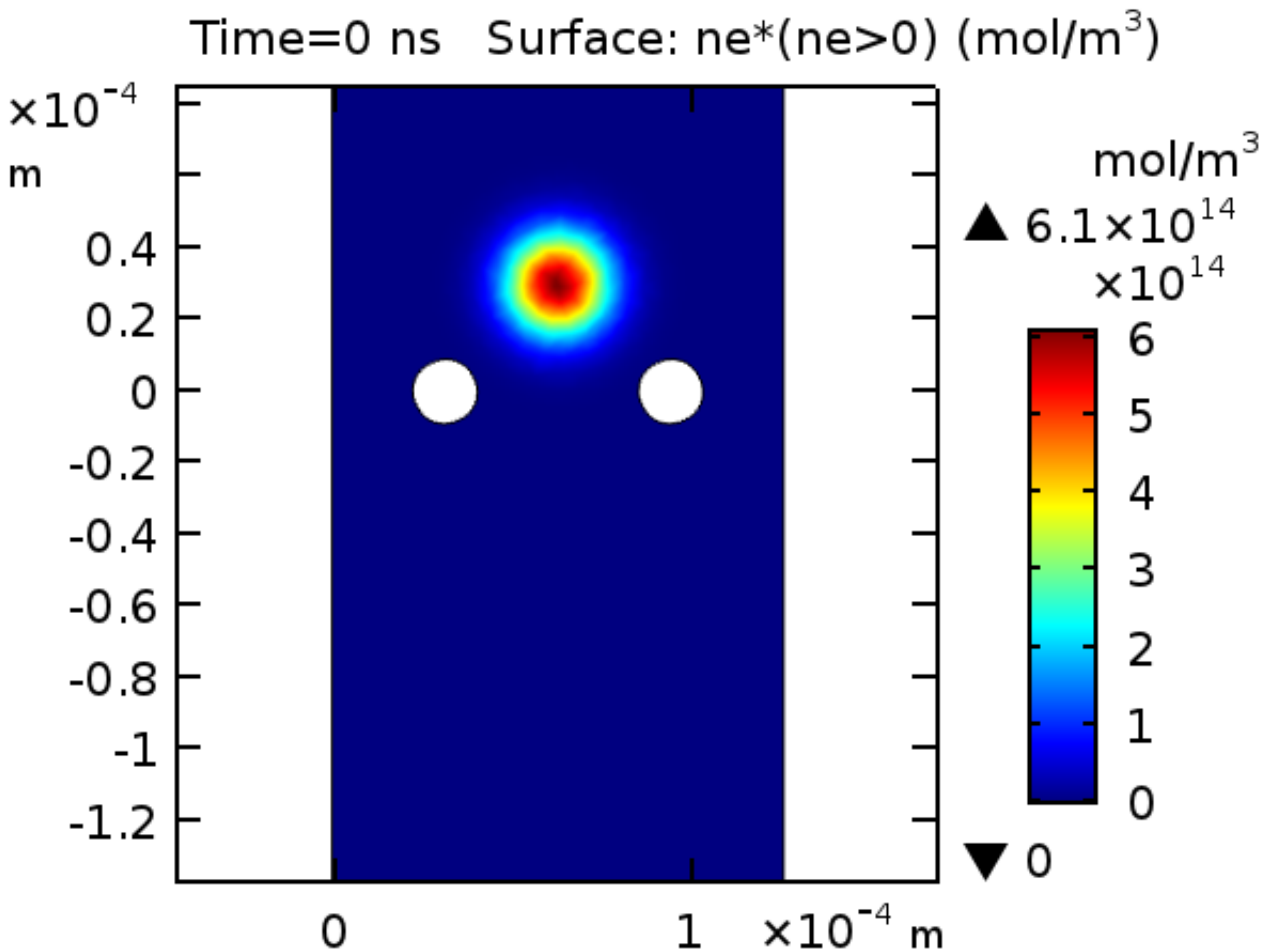
probing the charge transport on a plane

The probing plane



mesh voltage = - 330 V
drift voltage = - 350 V

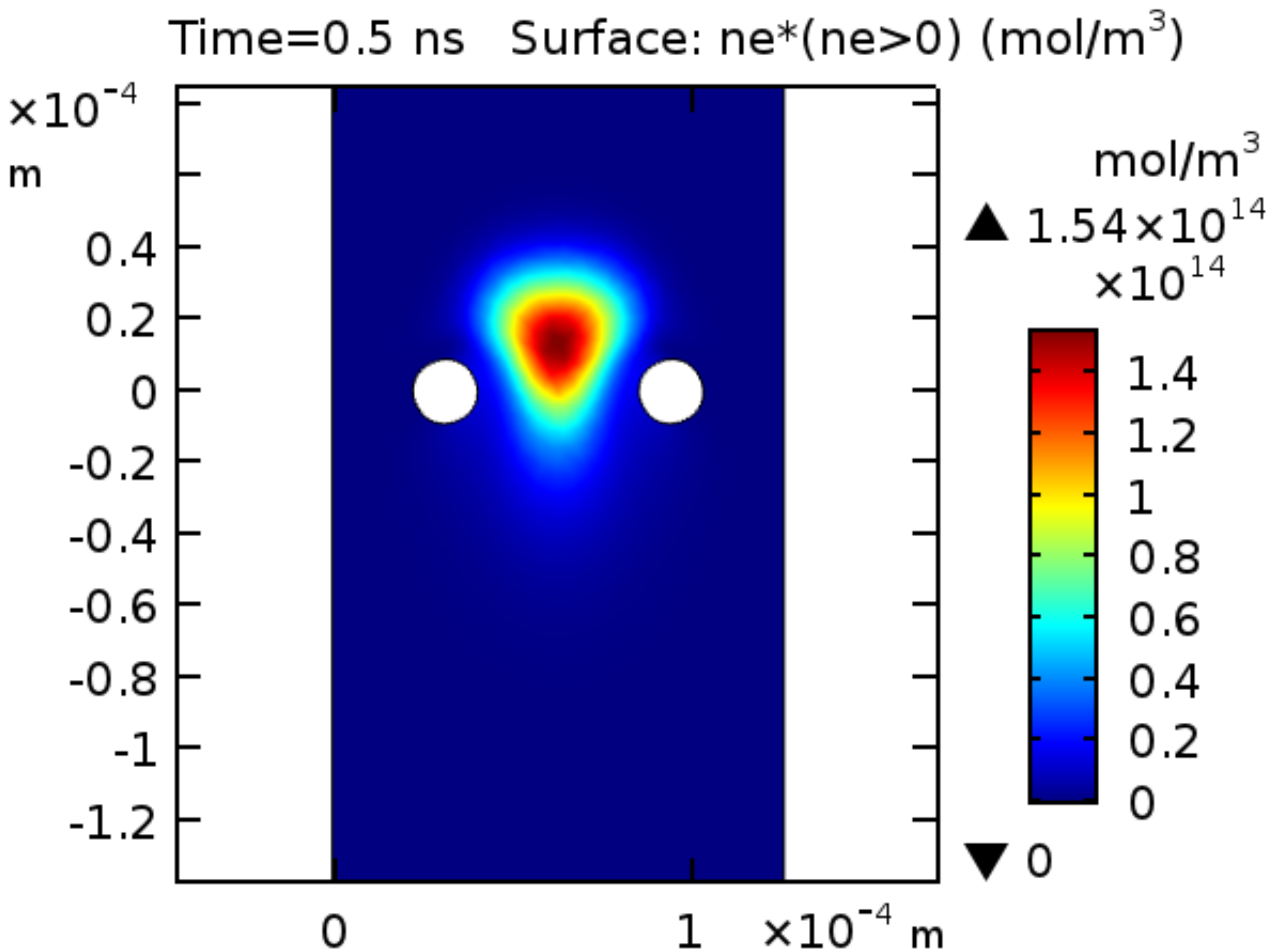
Results:



total electrons, n = 10

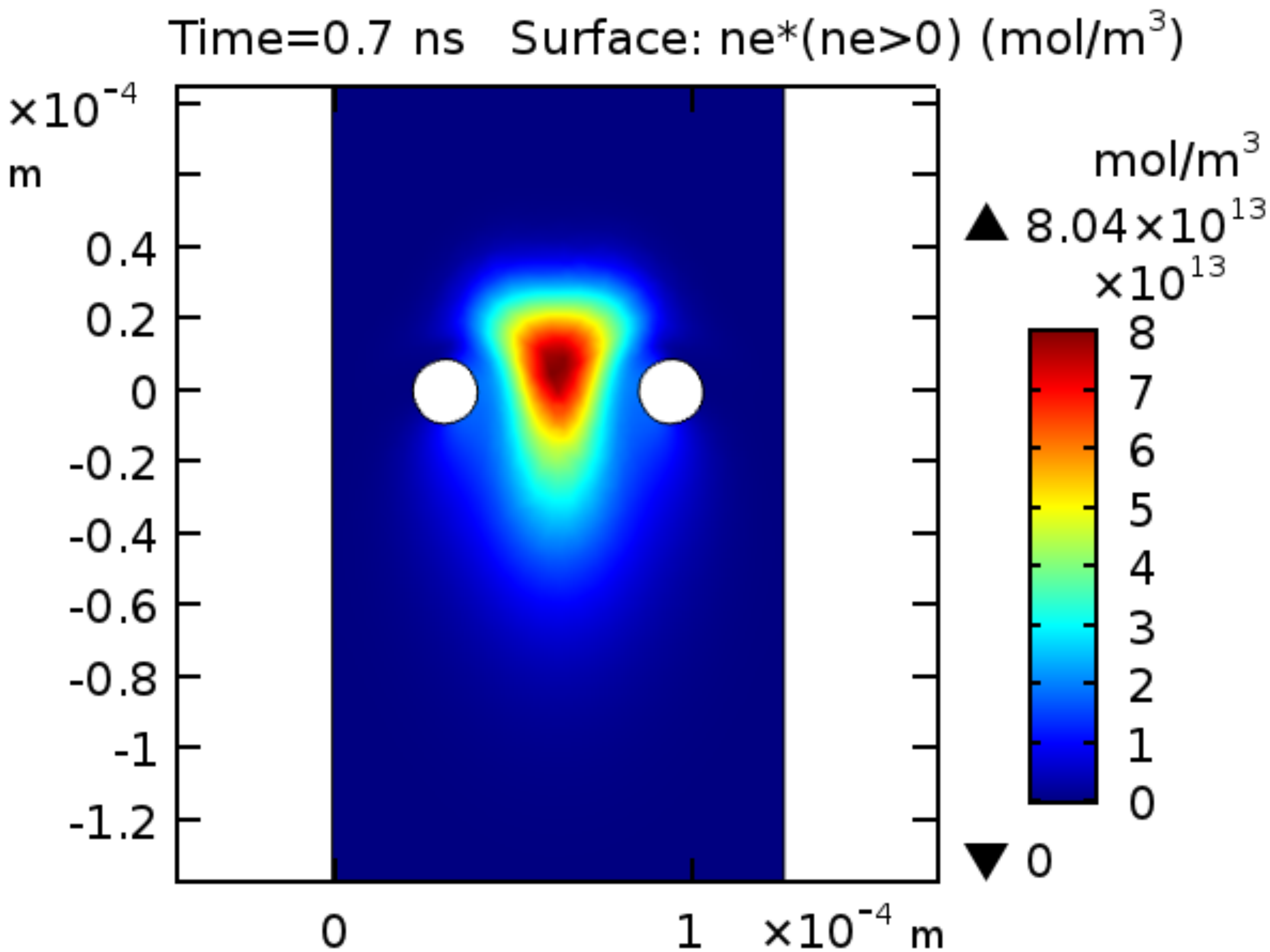
transport of the electrons and avalanche

Results:



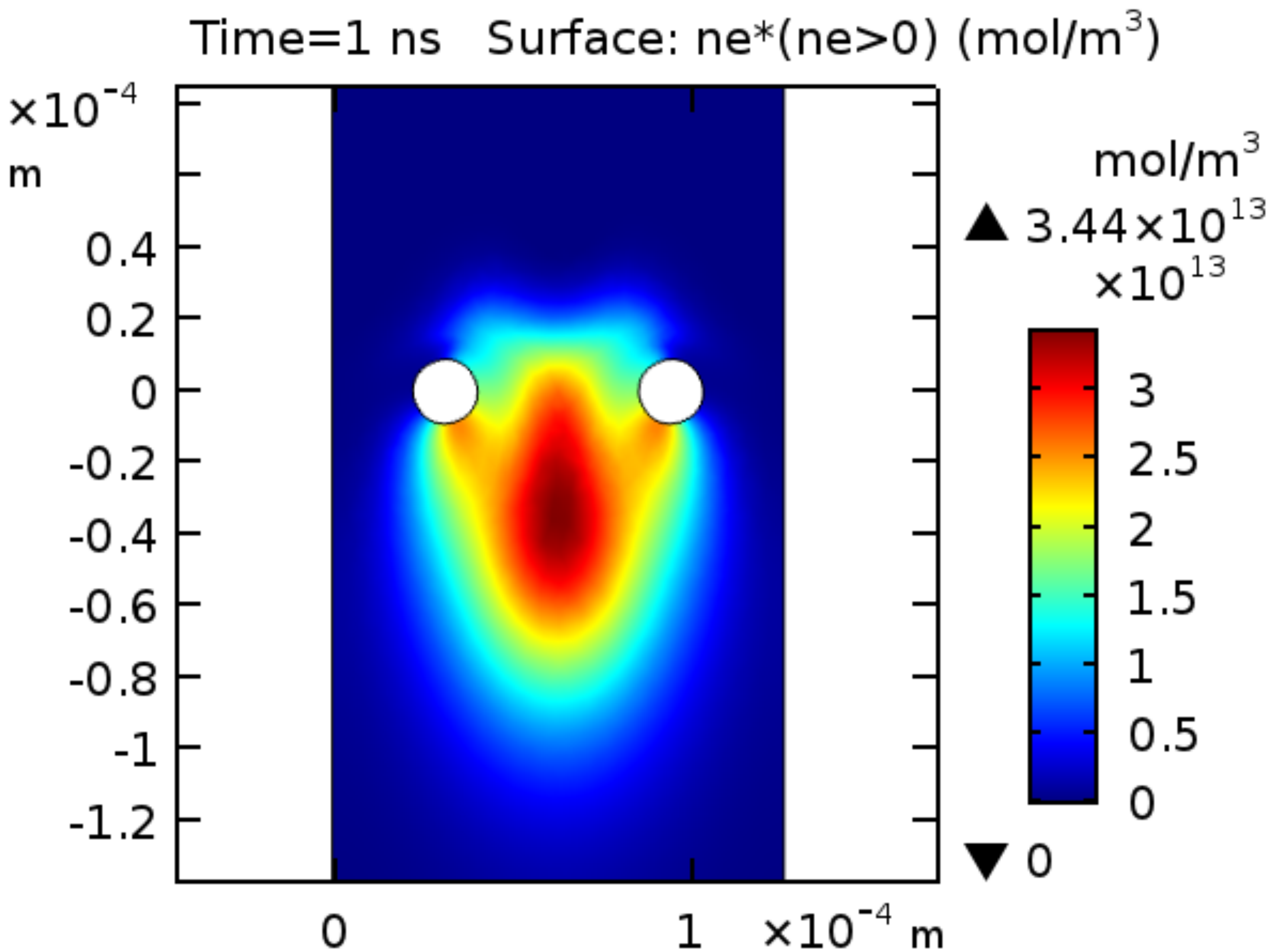
transport of the electrons and avalanche

Results:



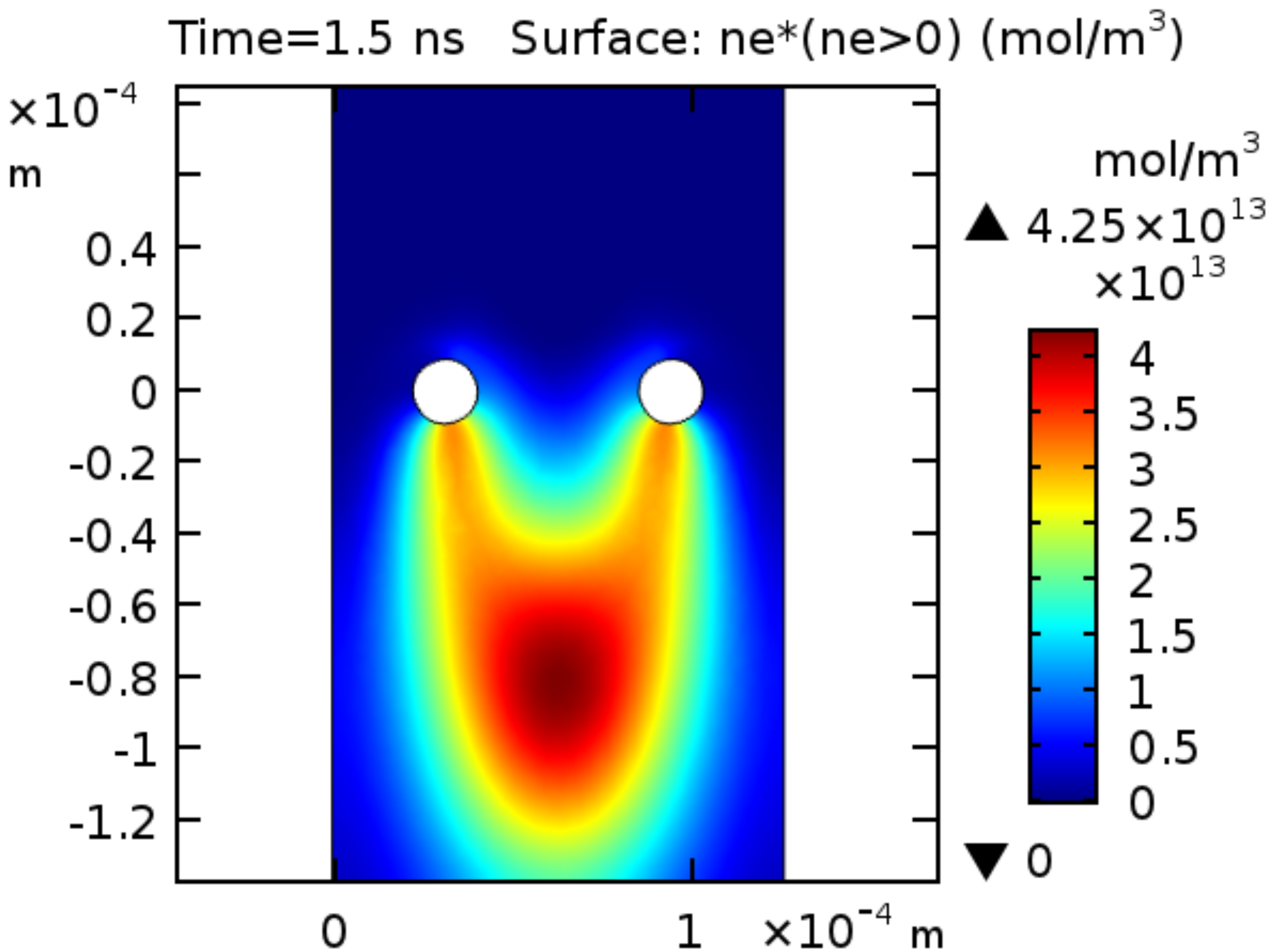
transport of the electrons and avalanche

Results:



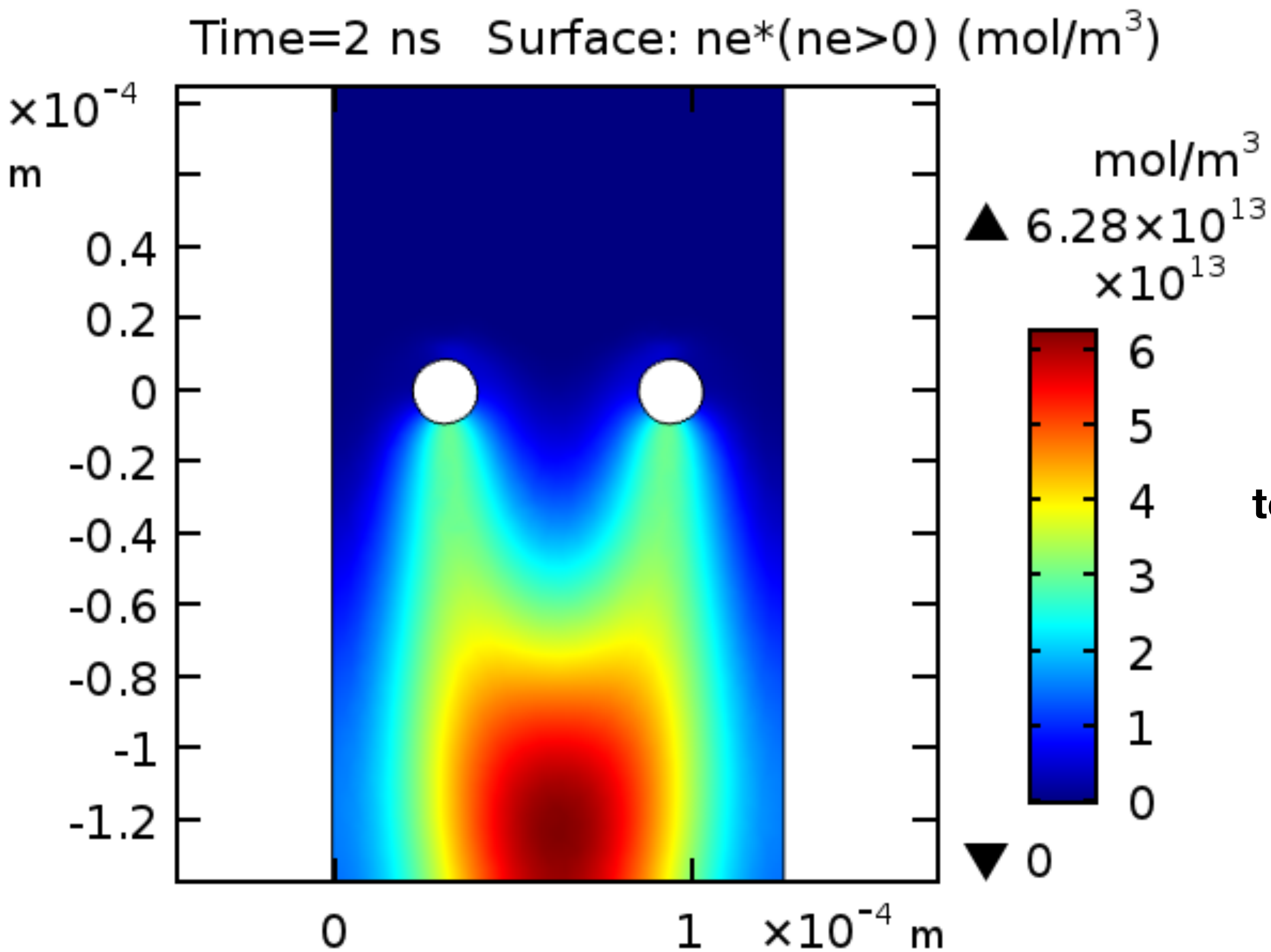
transport of the electrons and avalanche

Results:



transport of the electrons and avalanche

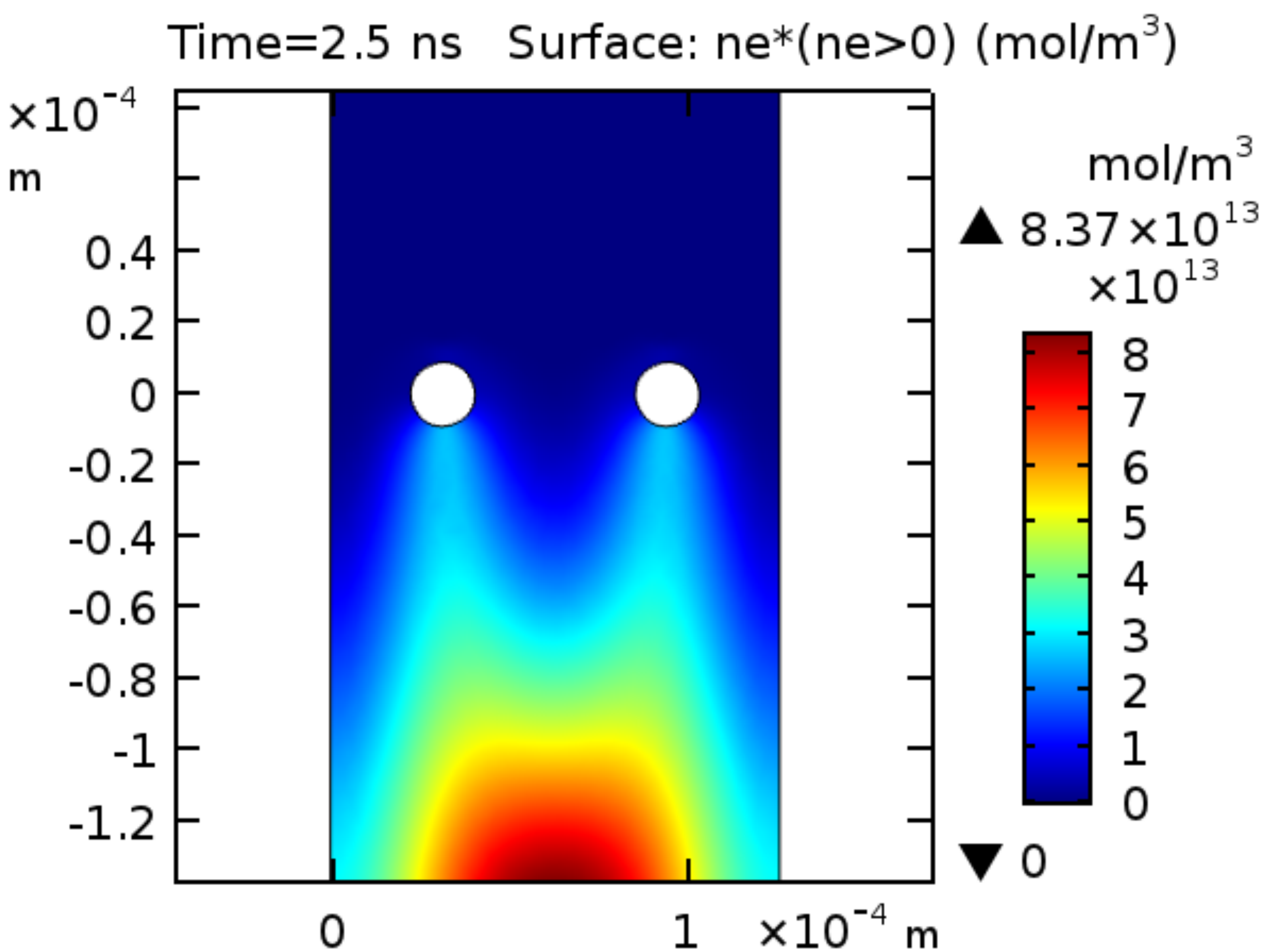
Results:



total electrons, n = ~54

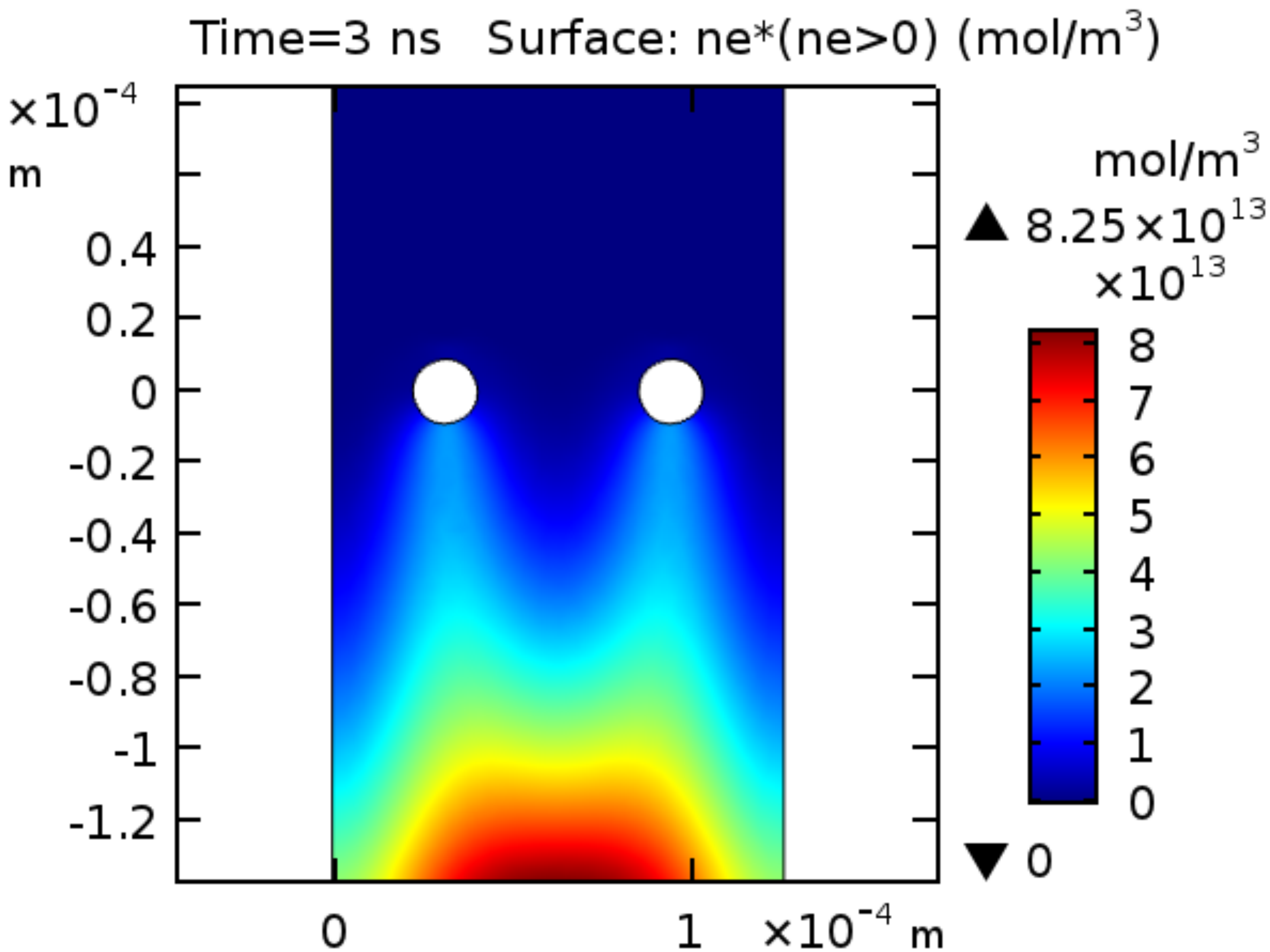
transport of the electrons and avalanche

Results:



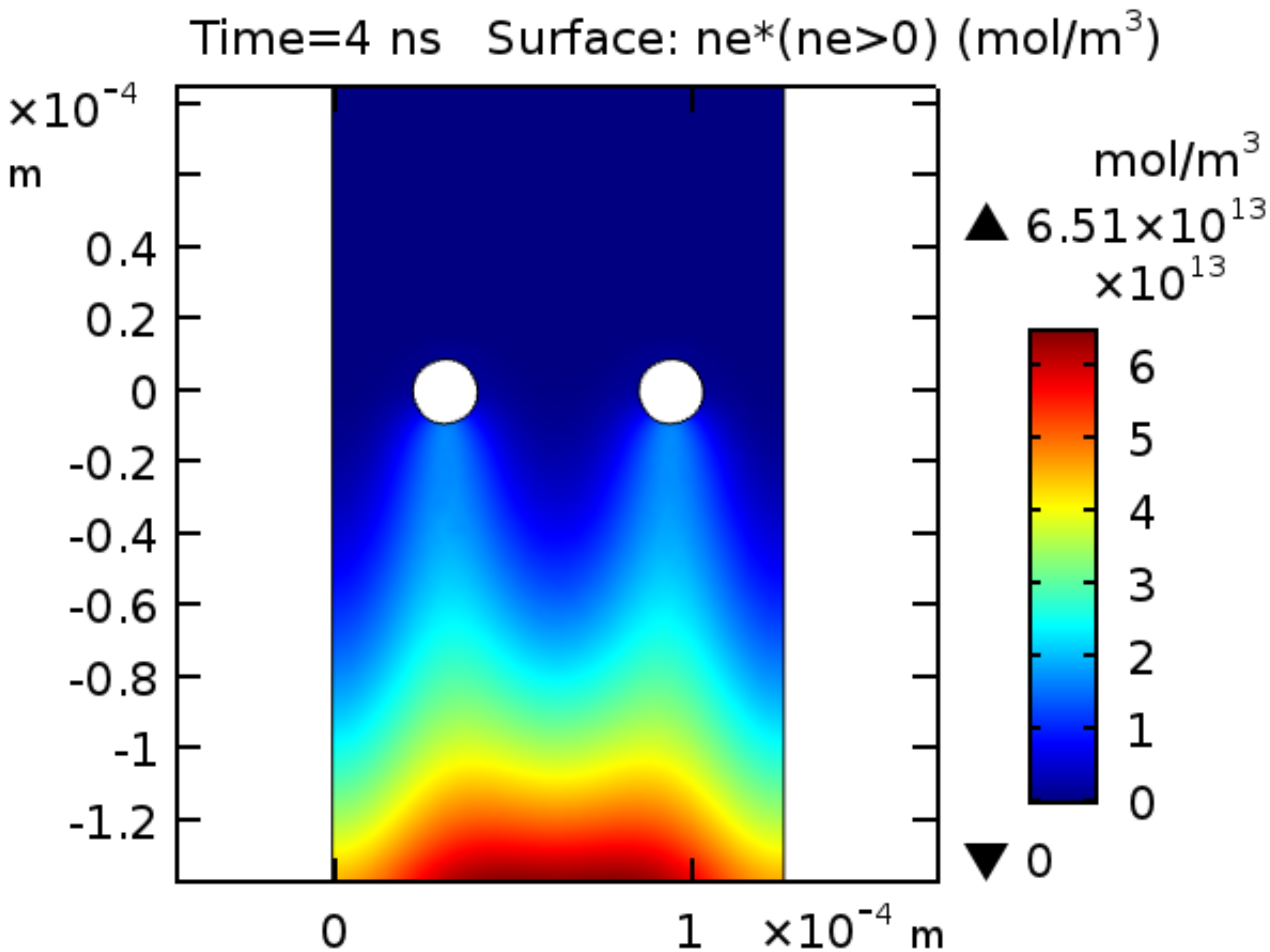
transport of the electrons and avalanche

Results:



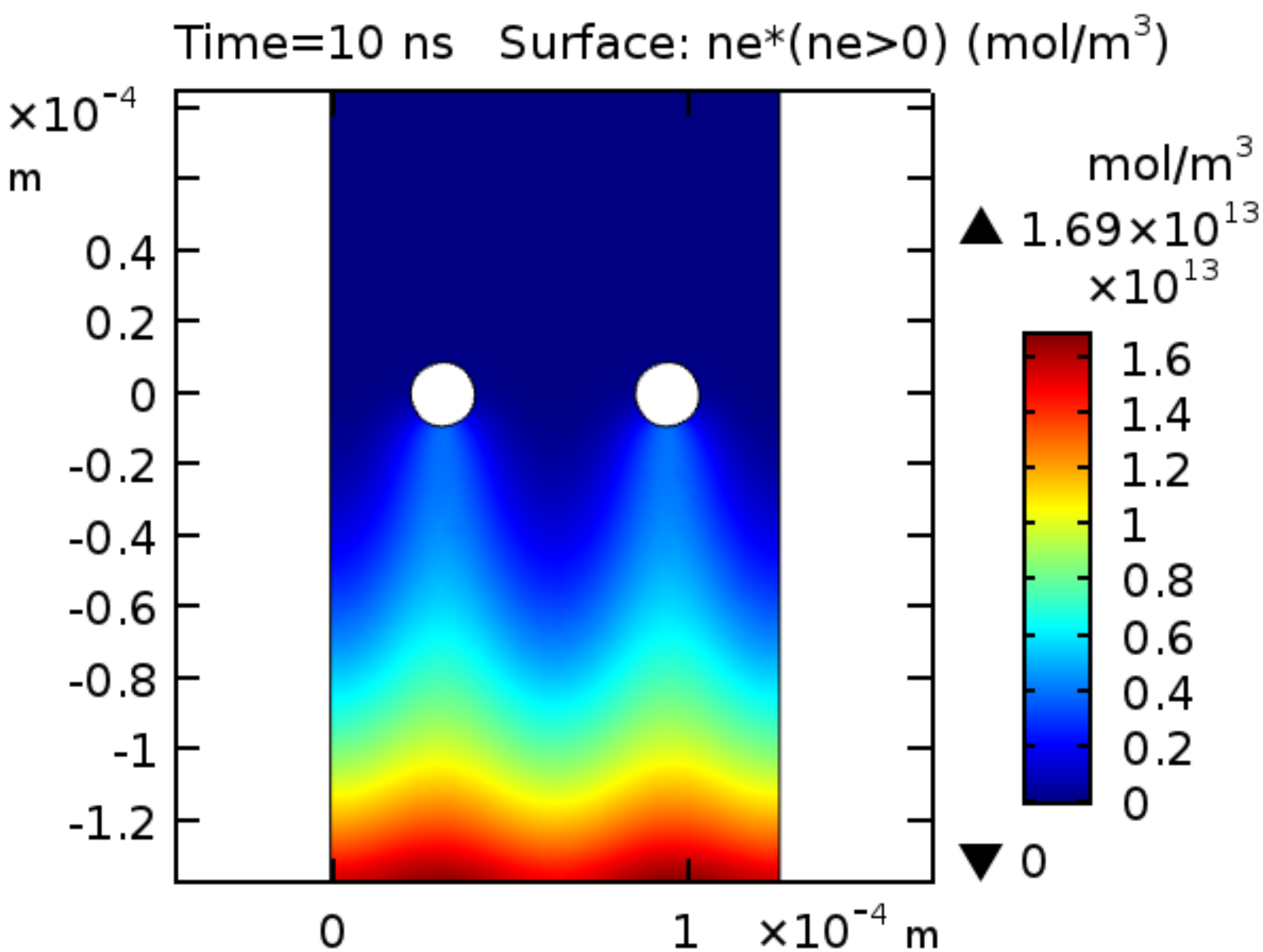
transport of
the electrons
and avalanche

Results:



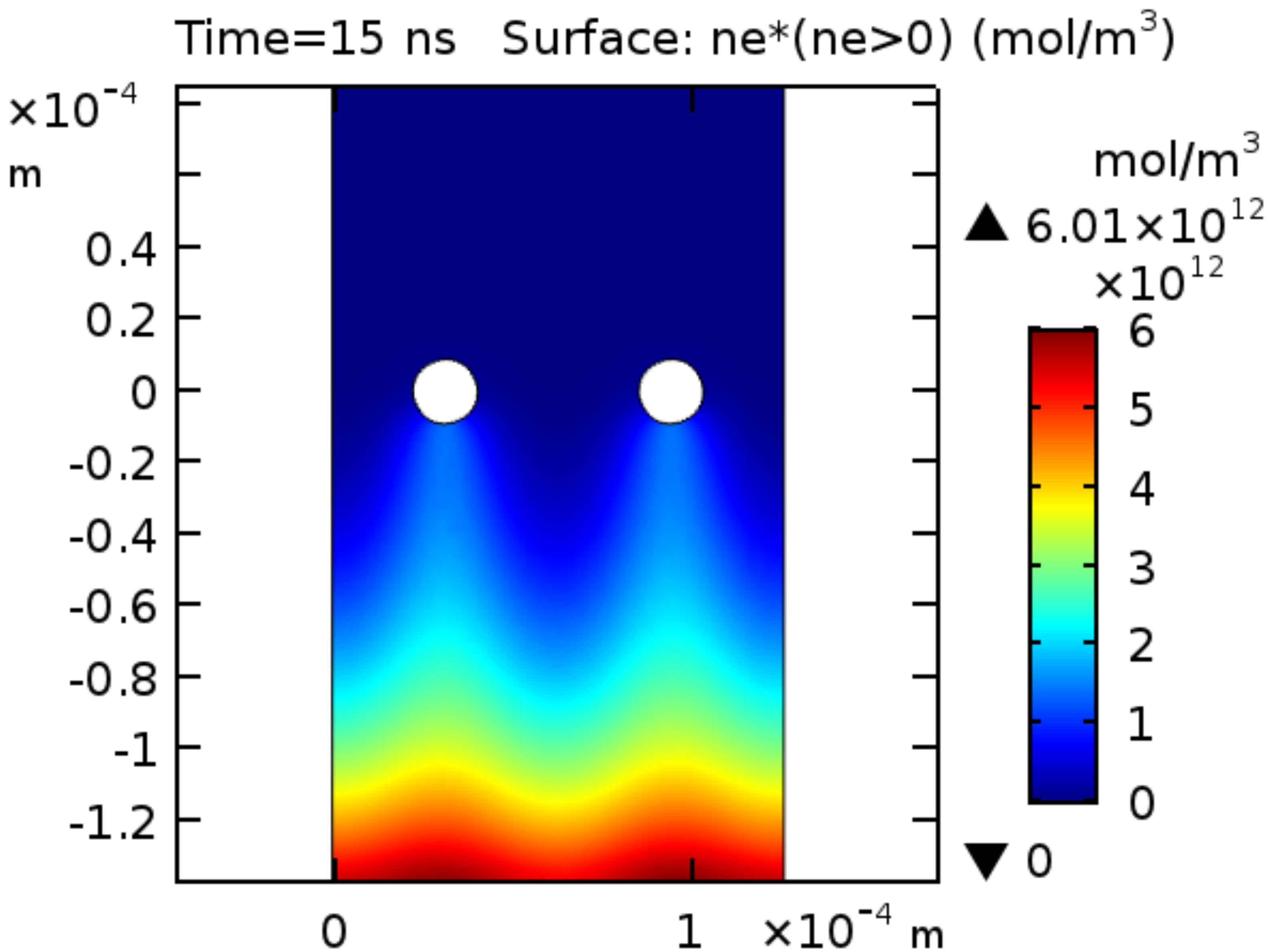
transport of the electrons and avalanche

Results:



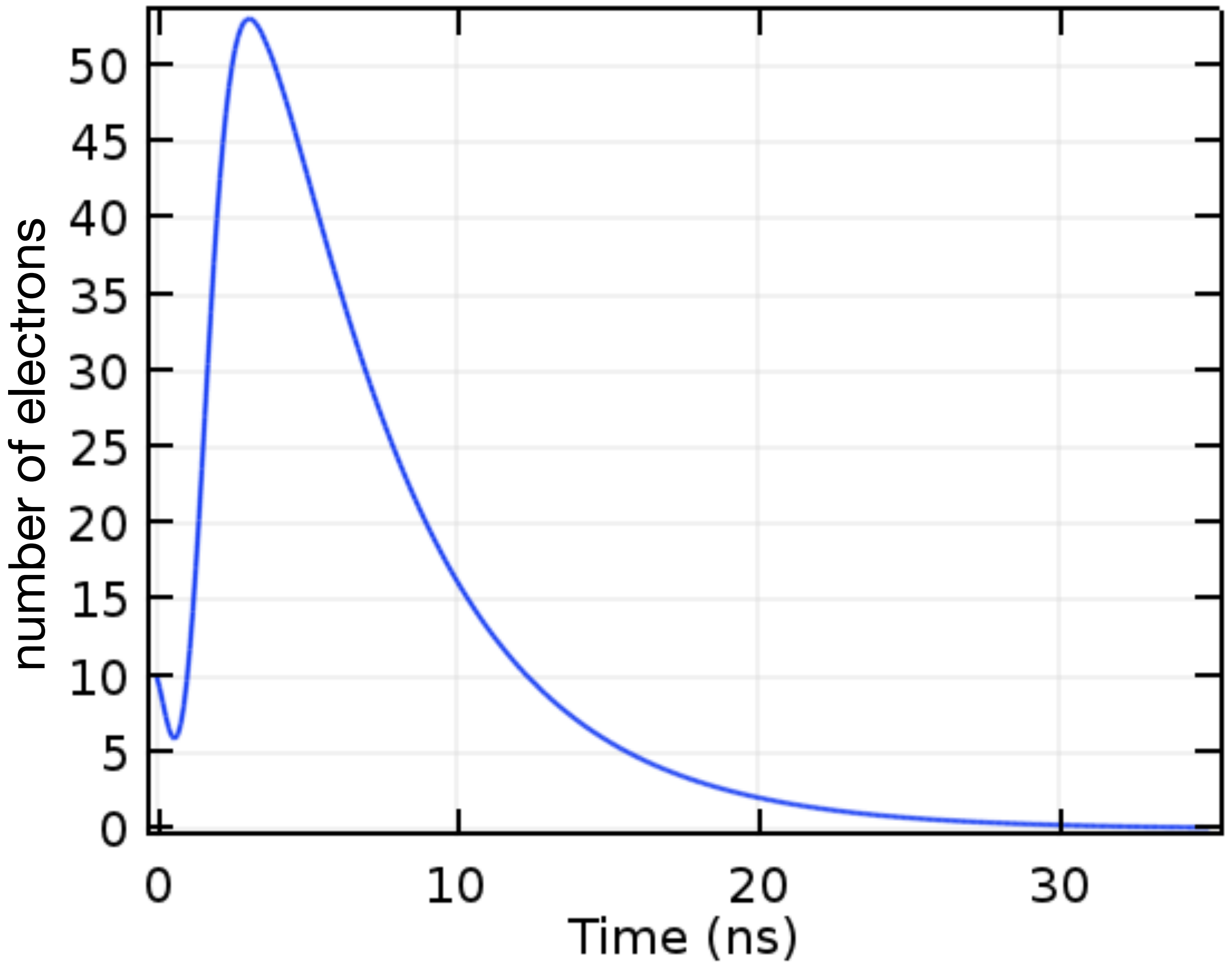
transport of the electrons and avalanche

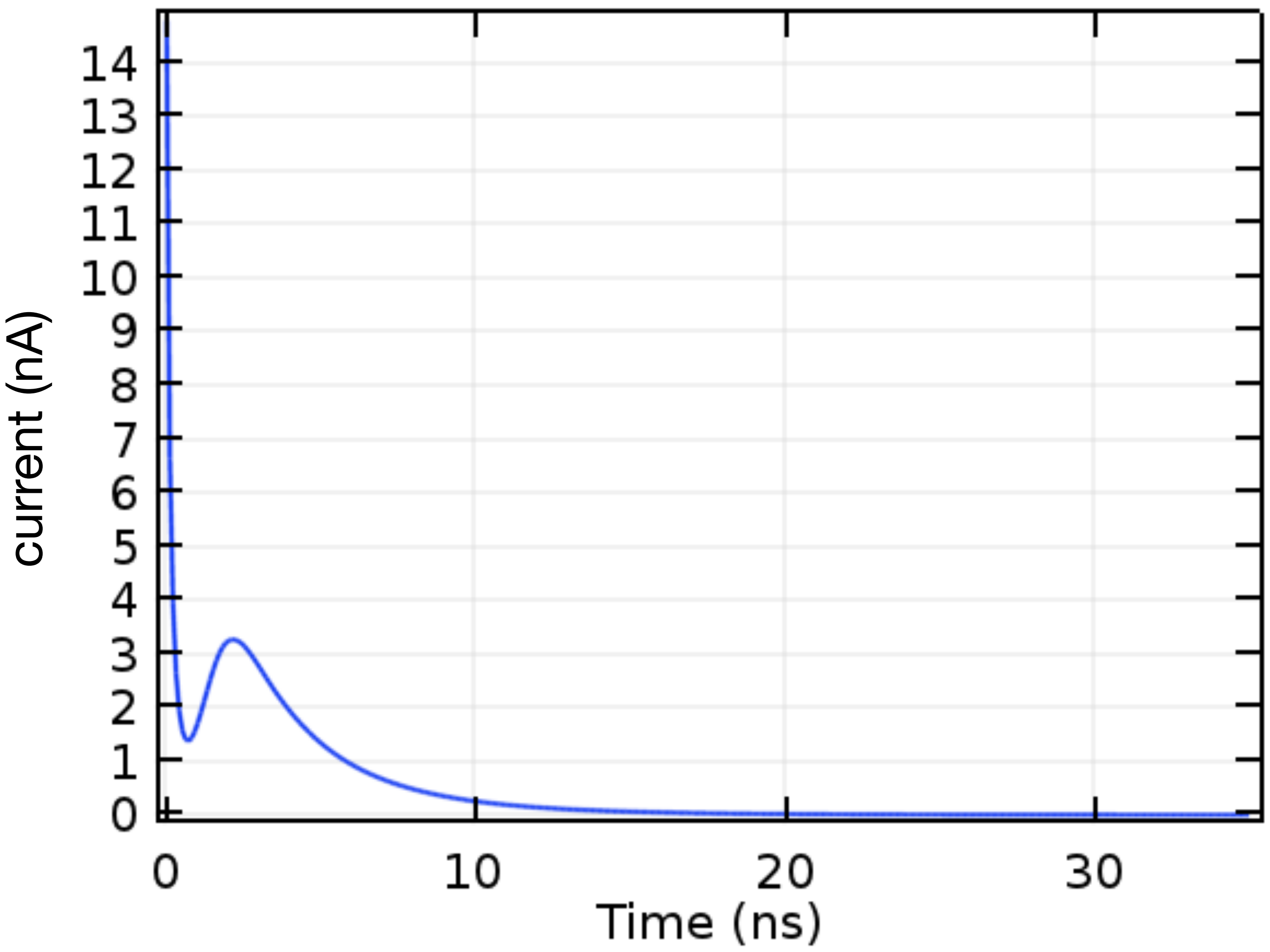
Results:



transport of the electrons and avalanche

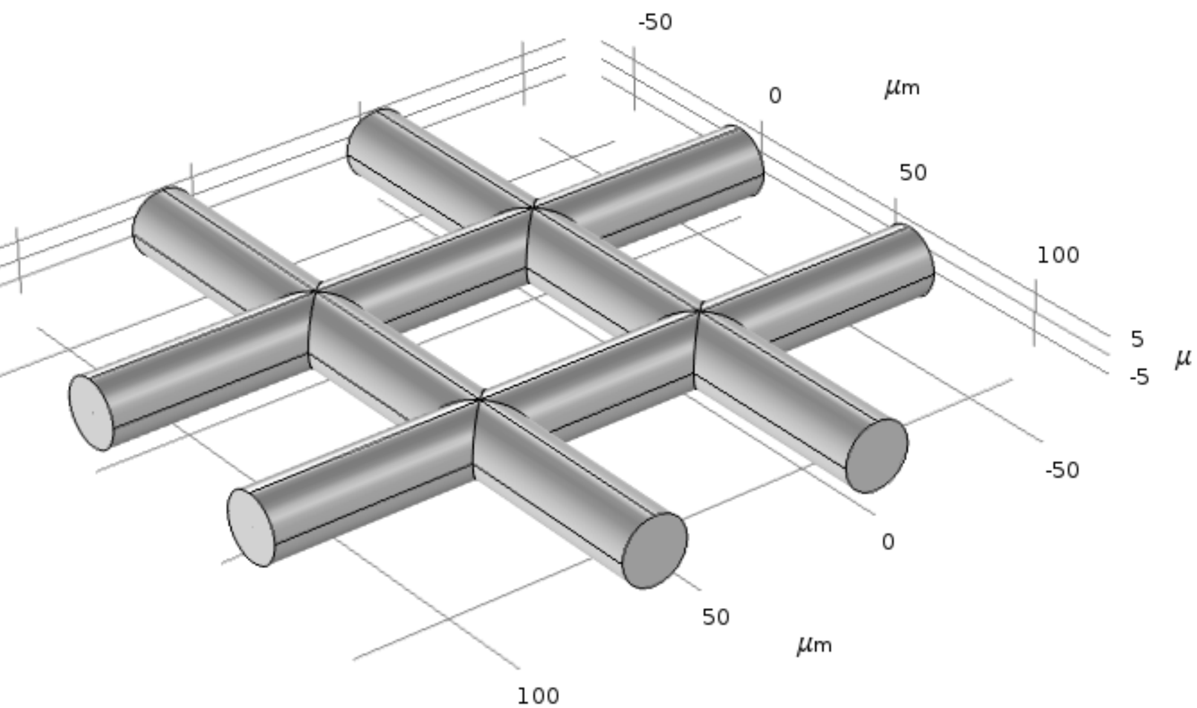
Results: total electron production over time (mesh = -330 V)

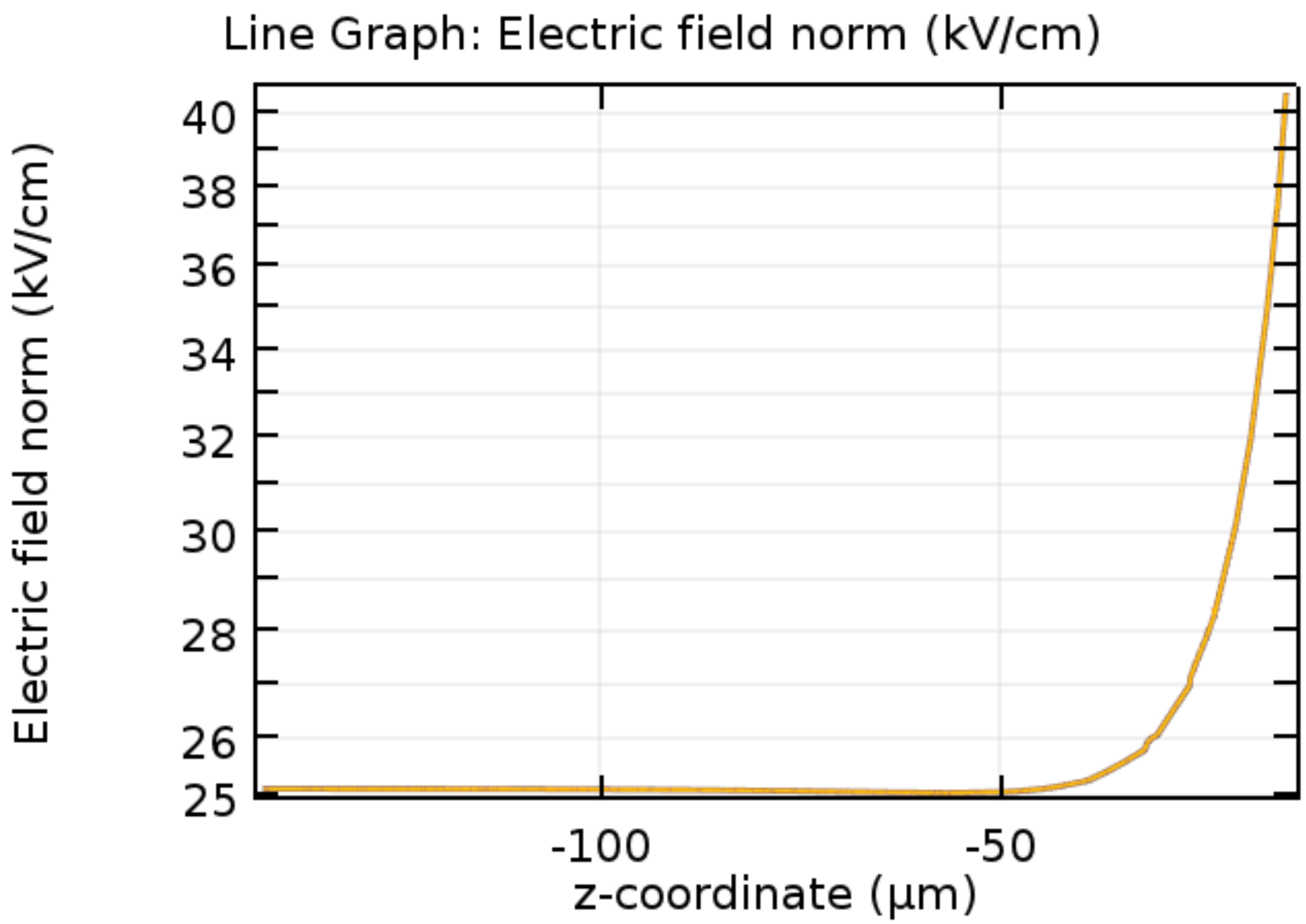




(current or production rate)

28/50 - Calendared-like :



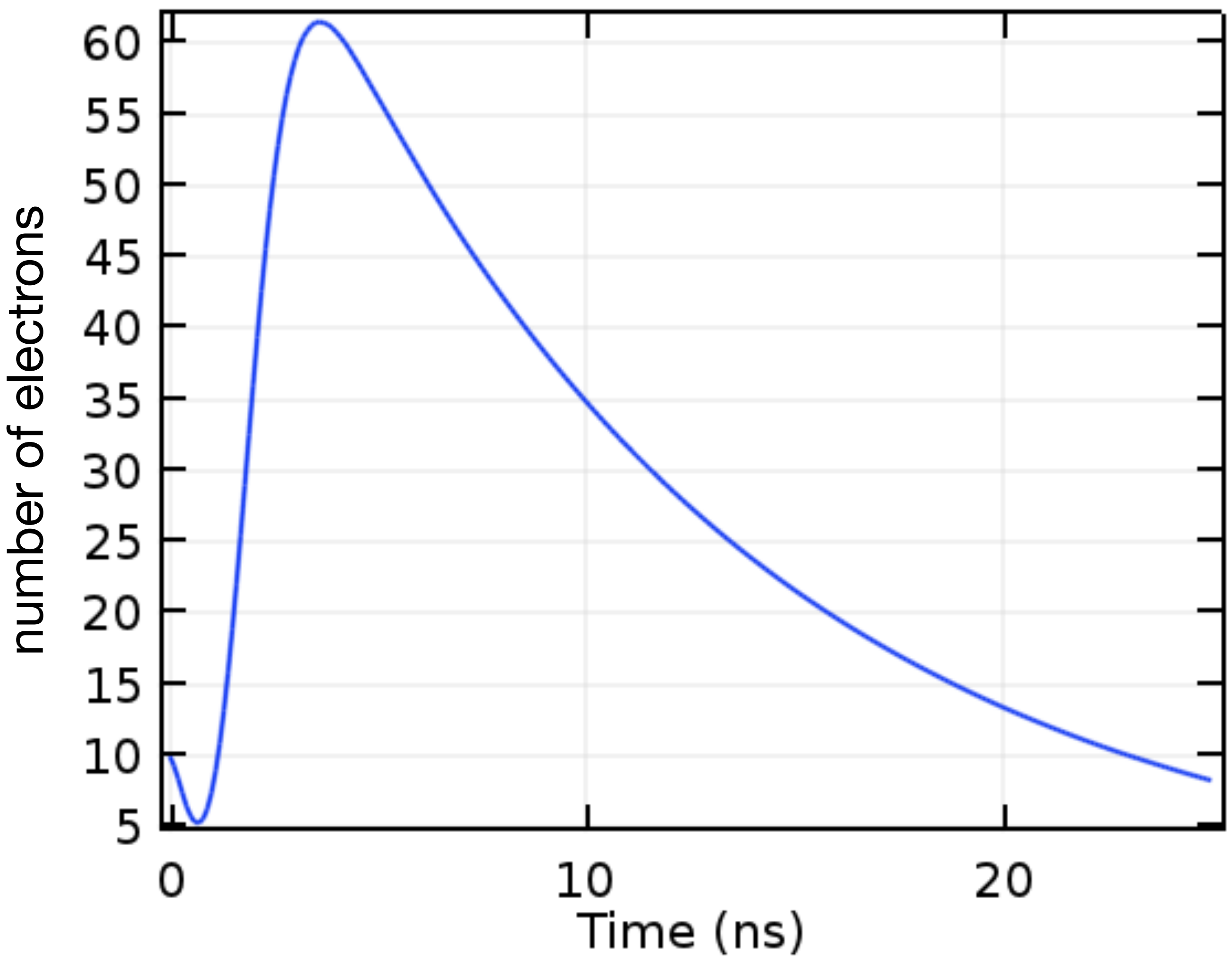


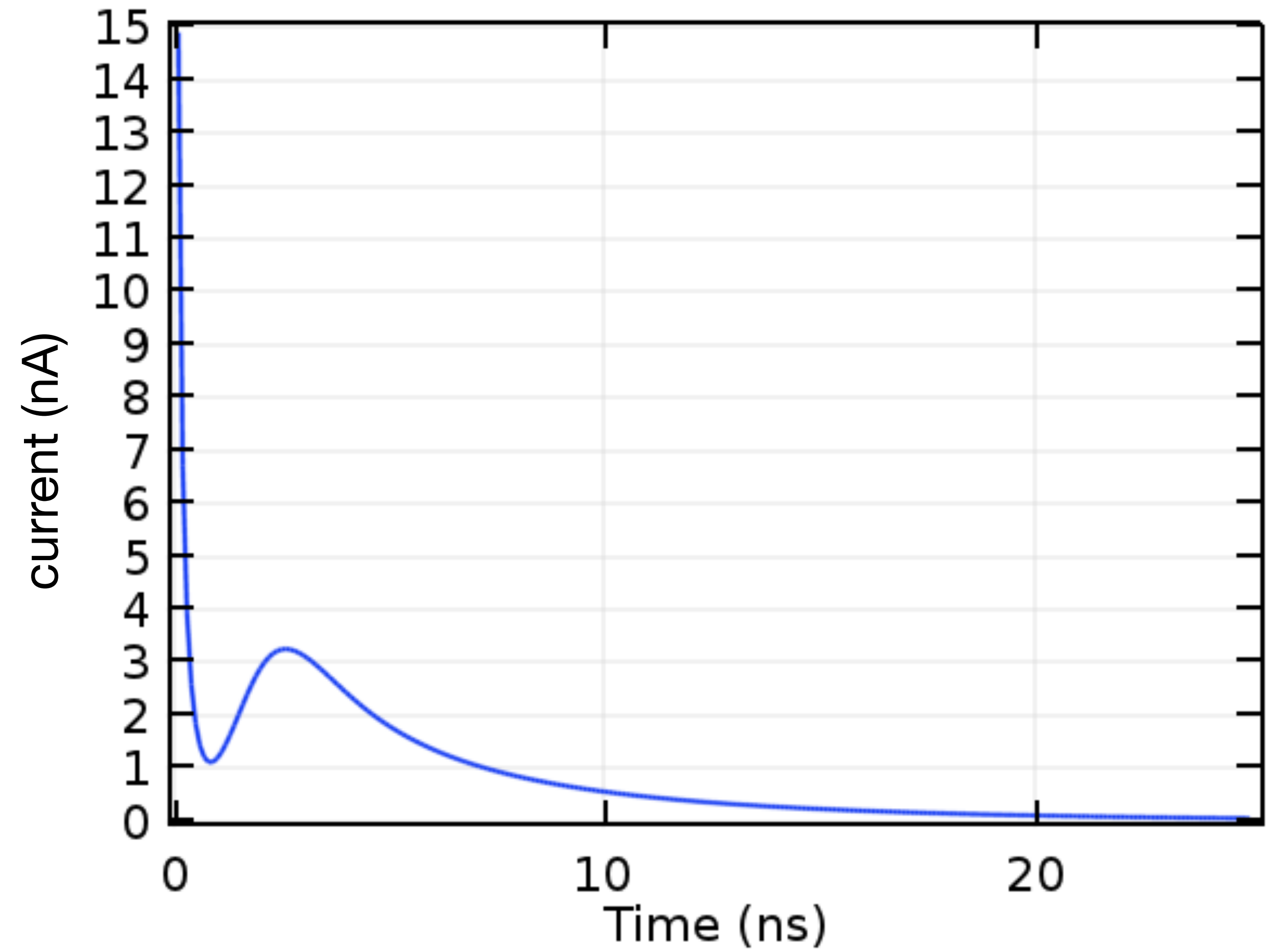
mesh voltage = —330 V

max field = 40.6 kV/cm ; average field = 25.1 kV/cm;

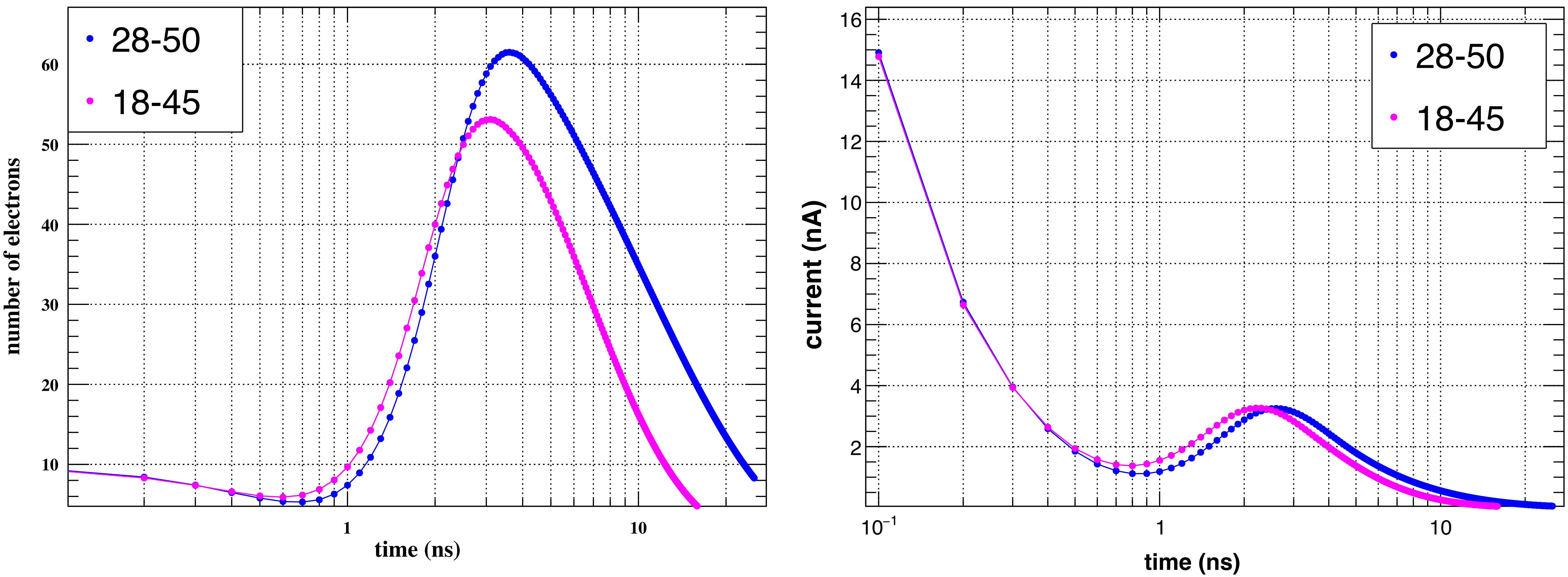
Results: total electron production over time

28-50 calendared, mesh voltage - 330 V

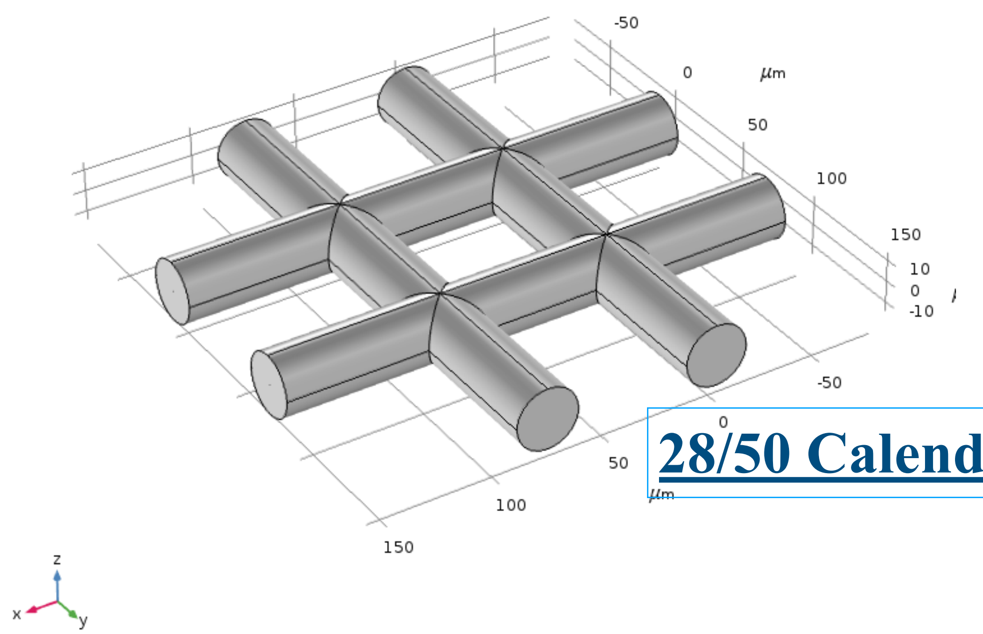




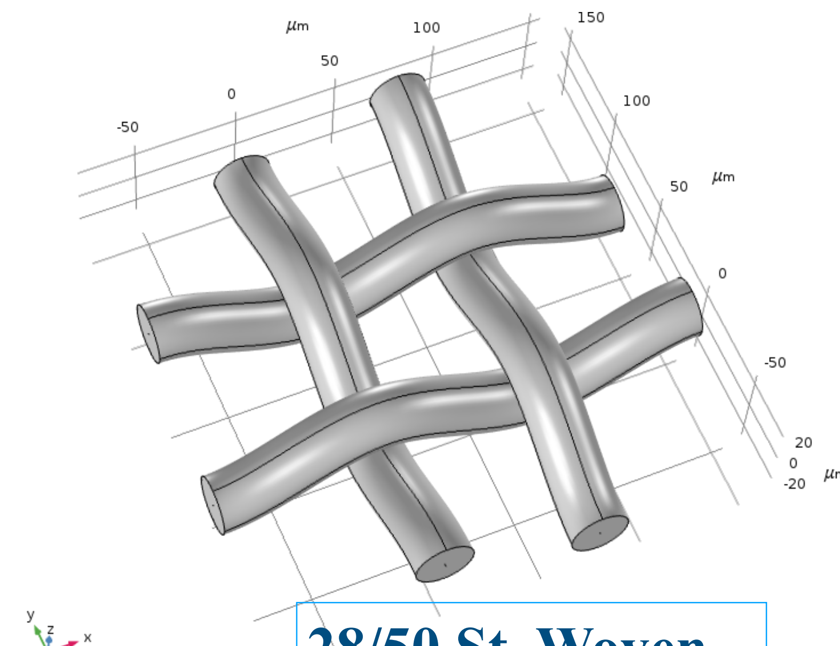
Results: compare 18-45 VS 28-50



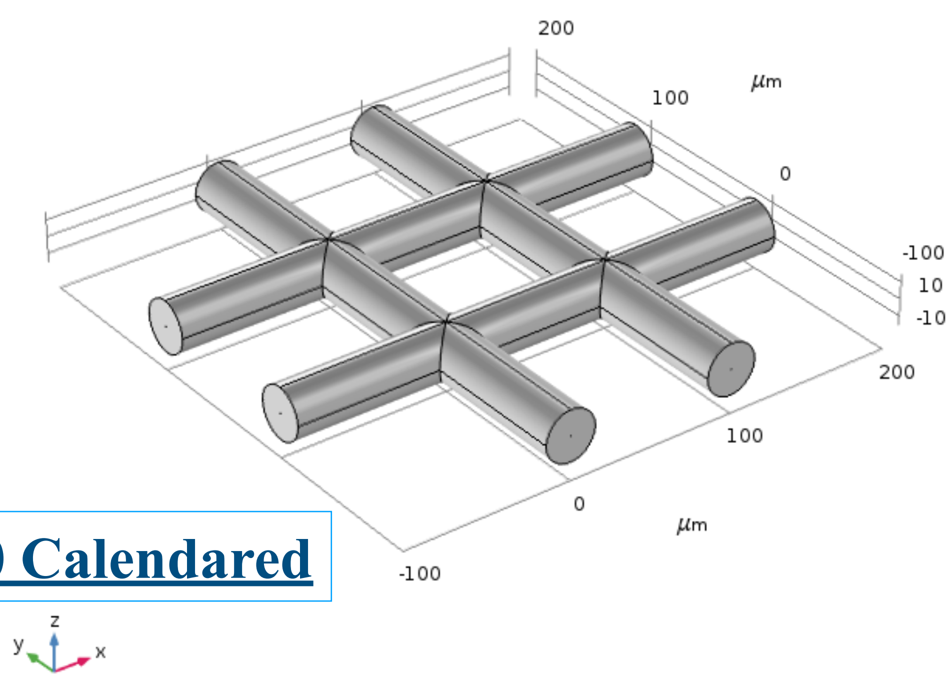
Field in some other Micromegas (around 30 μm wire diameter) is also studied



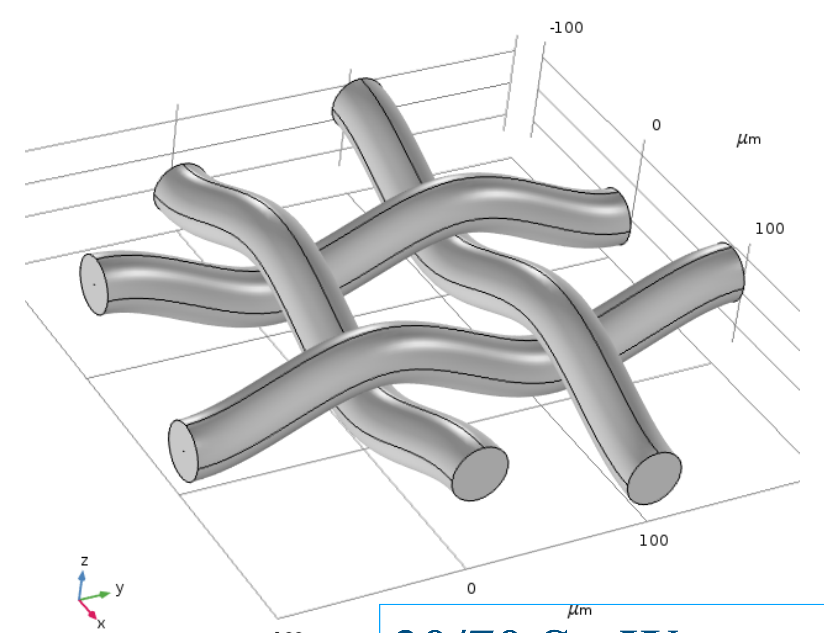
28/50 Calendared



28/50 St. Woven



30/70 Calendared



30/70 St. Woven

to order to generalise, all meshes are set to -540 V for this field study
Amplification gap 128 μm

Calendared

geometry (μm)	Maximum (kV/cm)	Average (kV/cm)	ε = (max/ave)
18/45	89.2	~40.5	2.2
22/56	88.3	~40	2.2
25/67	88.5	40	2.2
28/50	79.9	~40	1.9
30/70	84.2	~40	2.1
30/85	88.0	39.5	2.2

symmetric Woven

geometry (μm)	Maximum (kV/cm)	Average (kV/cm)	ε = (max/ave)
18/45	112.0	~38.7	2.9
22/56	110.0	~38.0	2.9
25/67	109.0	~37.5	2.9
28/50	104.0	38.2	2.7
30/70	104.0	~37.2	2.8
30/85	106.0	~36.5	2.9

Calendared would be a better choice over woven for HV stability

Conclusion:

- the occurrence and development of spark in 128 µm gap parallel plate is modelled
- dependence of humidity is shown in it
- regions with high electric field in different Micromeas geometry are identified
- a narrow voltage scan is performed to observe spark in 18-45 and 28-50
- influence of geometry is observed primarily; 28-50 and 18-45 show similar behaviour

Many many thanks to

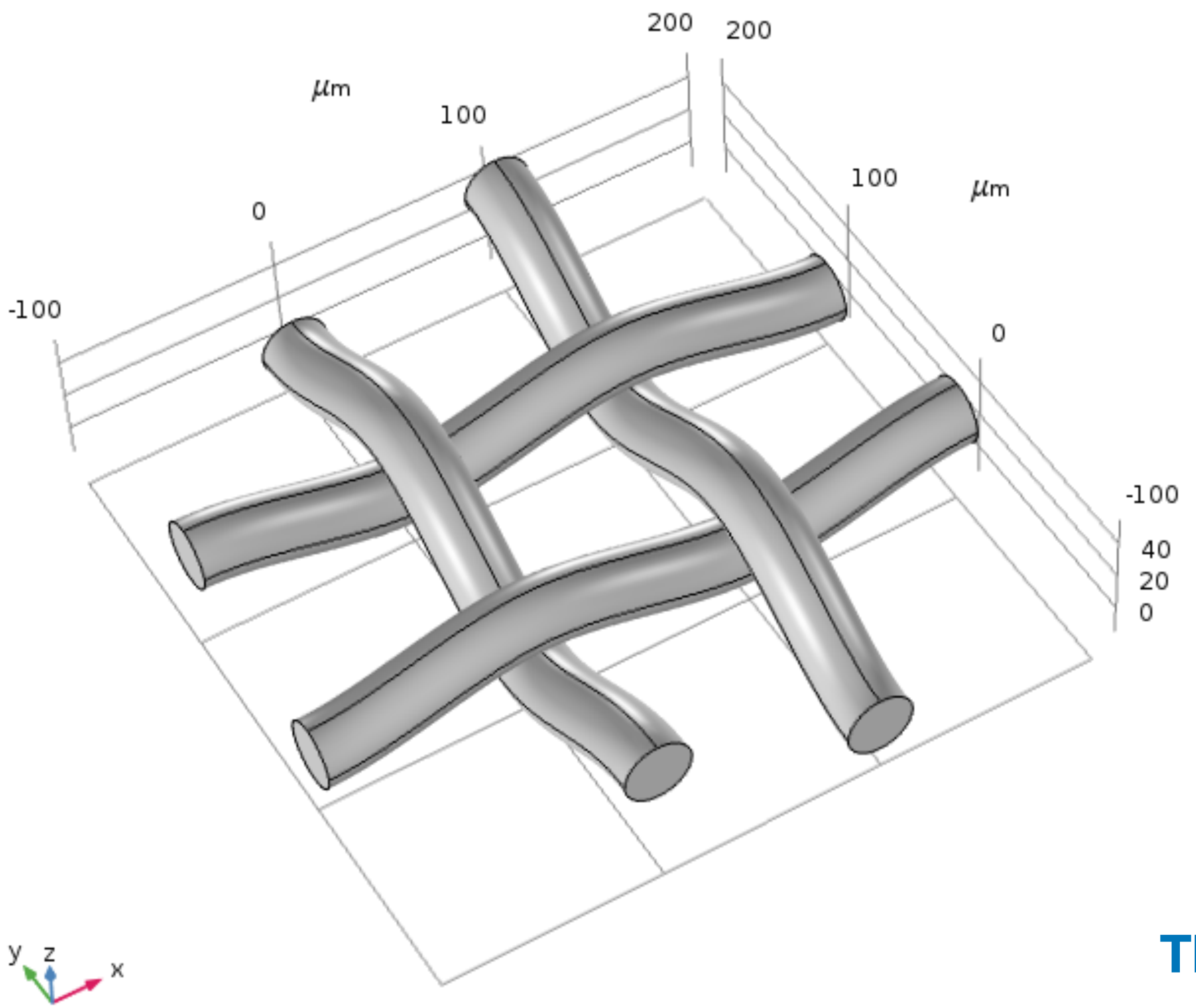
Filippo Resnati

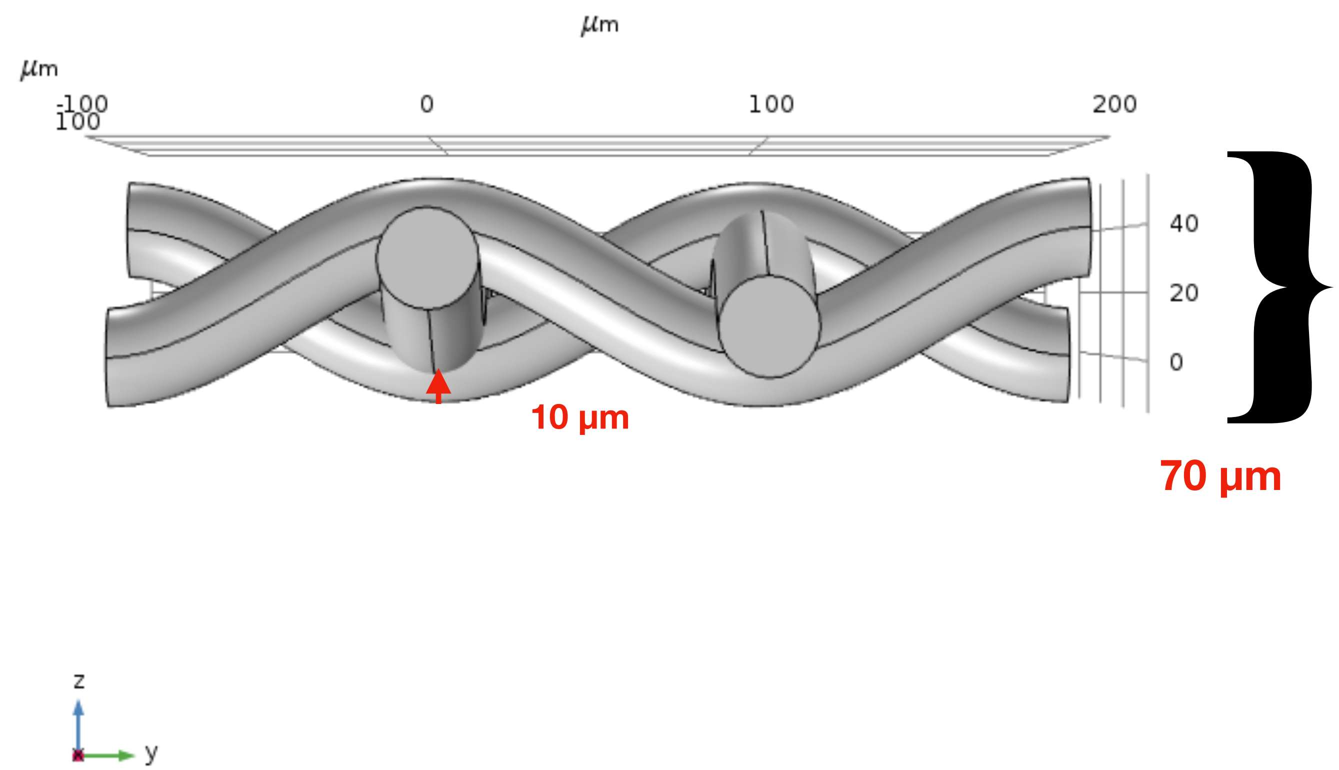
and the RD51 colleagues (specially Leszek, Fabio, Paul, Supratik)

for discussions and encouragement

Backup slides

The weaving is some times not symmetric (mesh thickness)



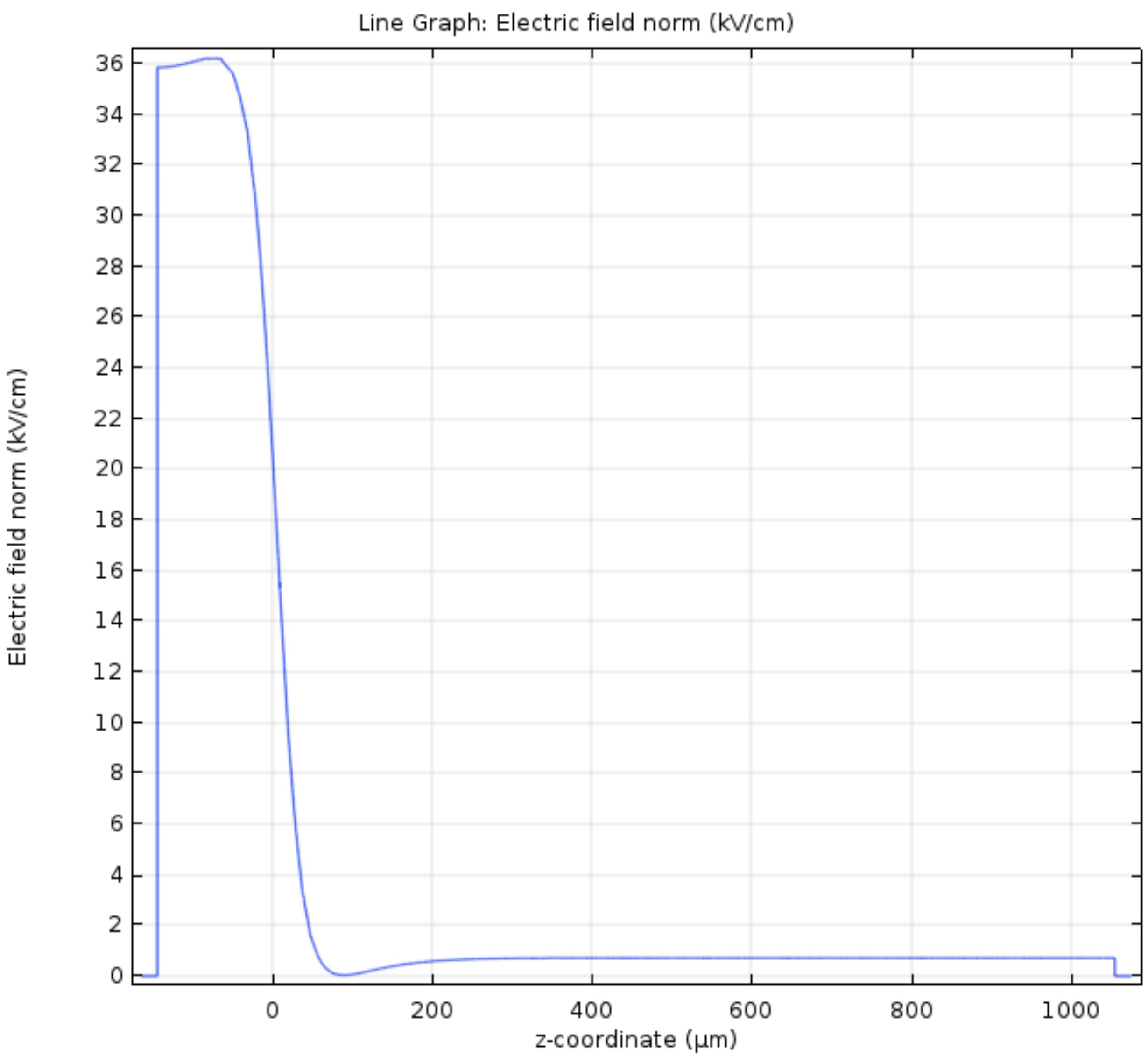


- **Wire diameter 30 µm**
- **Edge to Edge 70 µm**
- **Axis to Axis 100 µm**

The weaving amplitudes are different by 10 µm

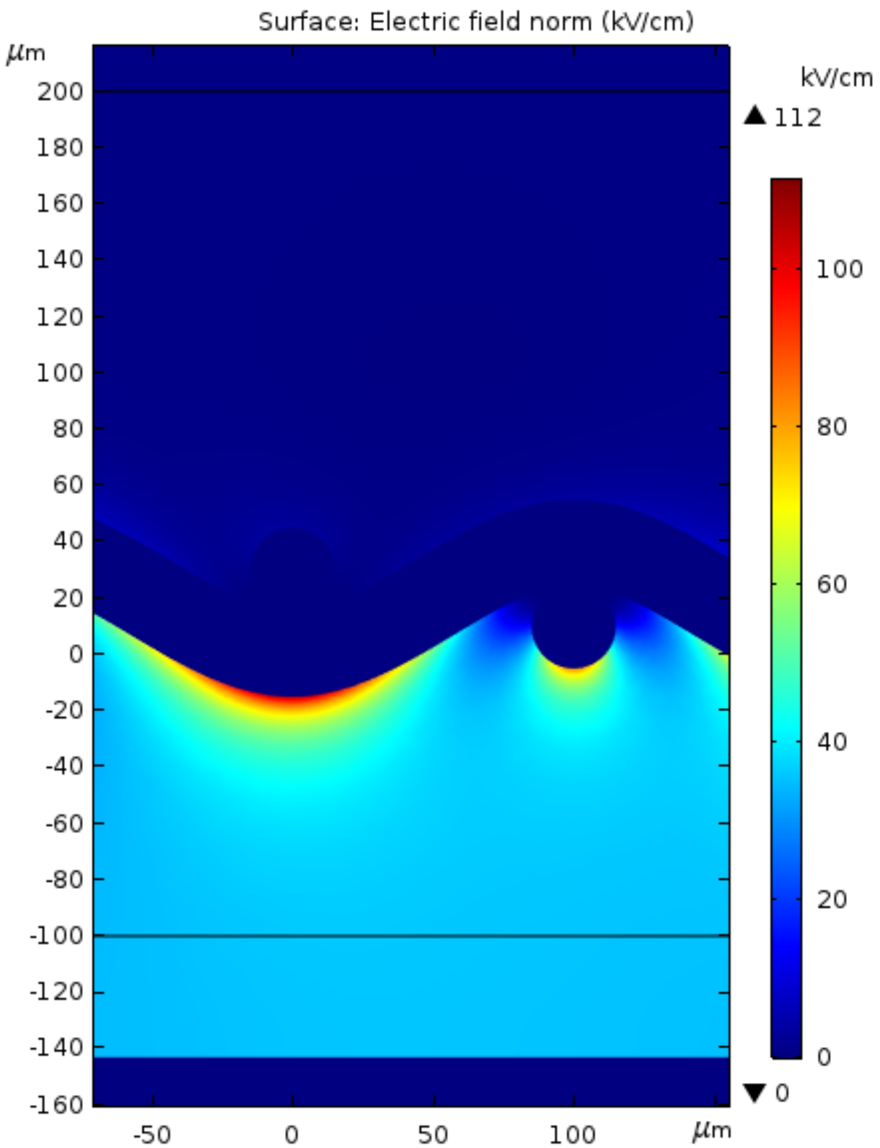
rest of the geometry is same as the last one

The field through the centre of the hole



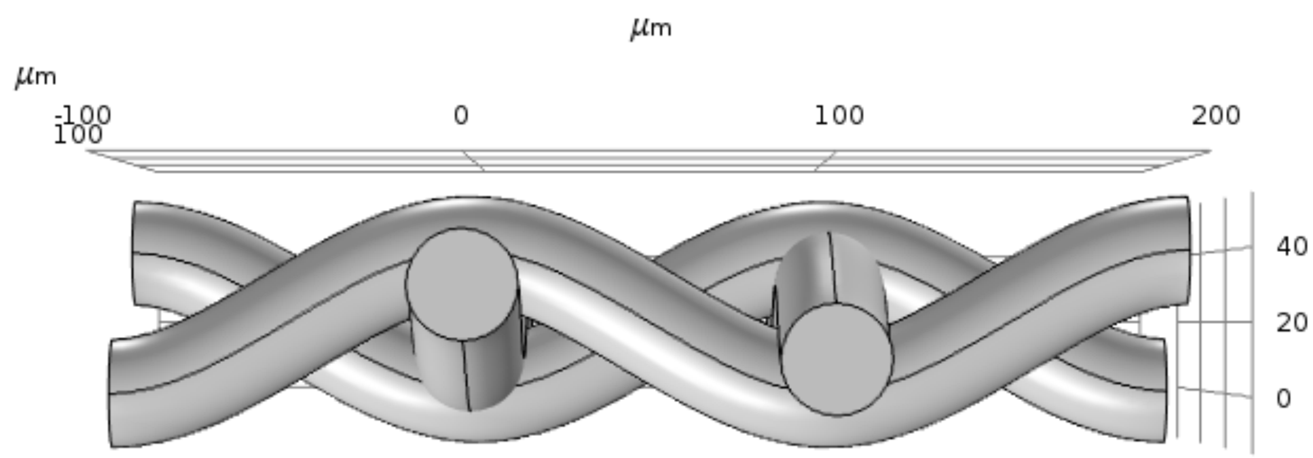
The average field is as expected

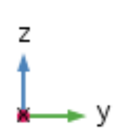
The field contour (on the YZ plane, at X=0)



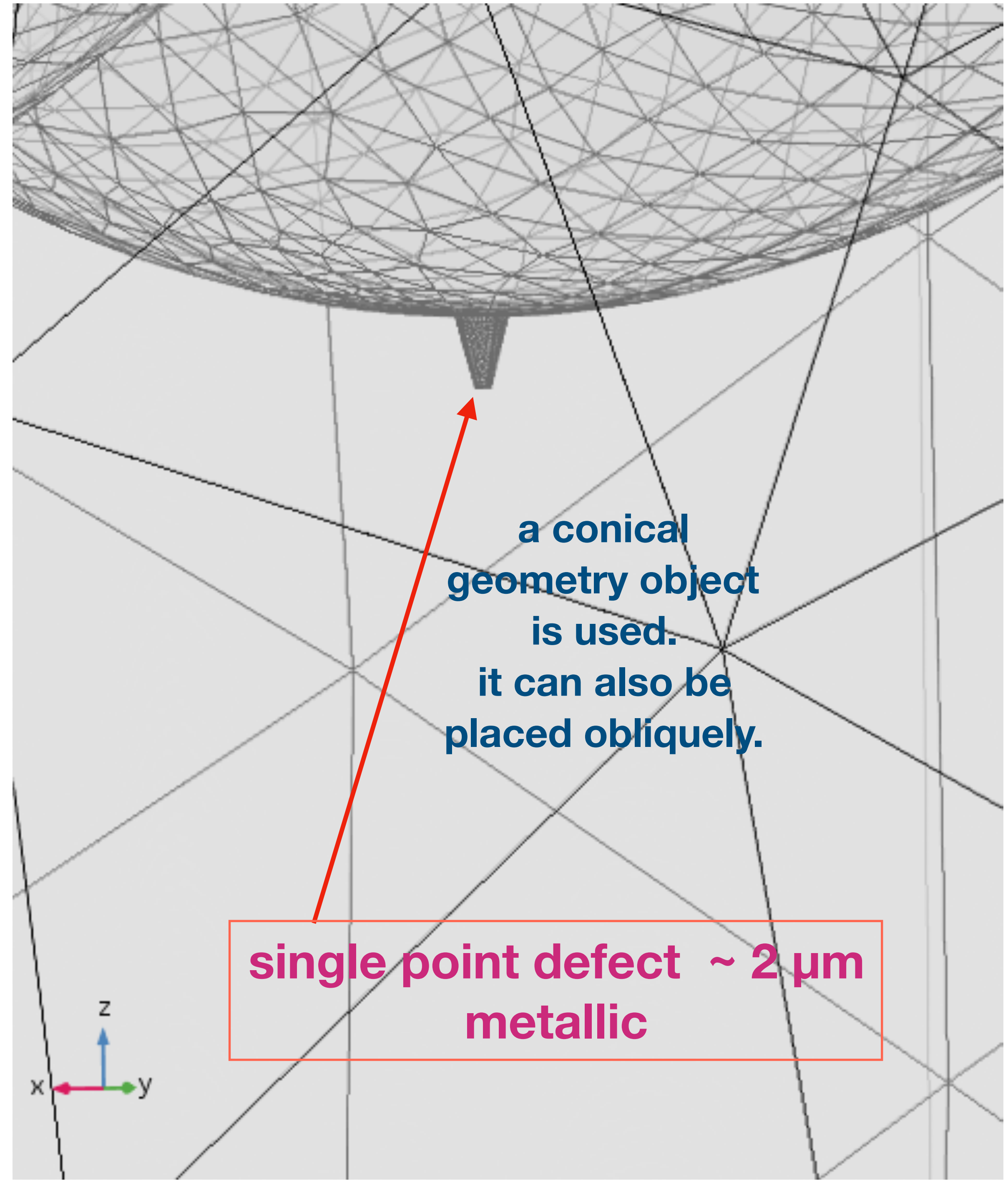
The maximum field is ~ 7% higher than standard woven

if there is any defect on the mesh surface

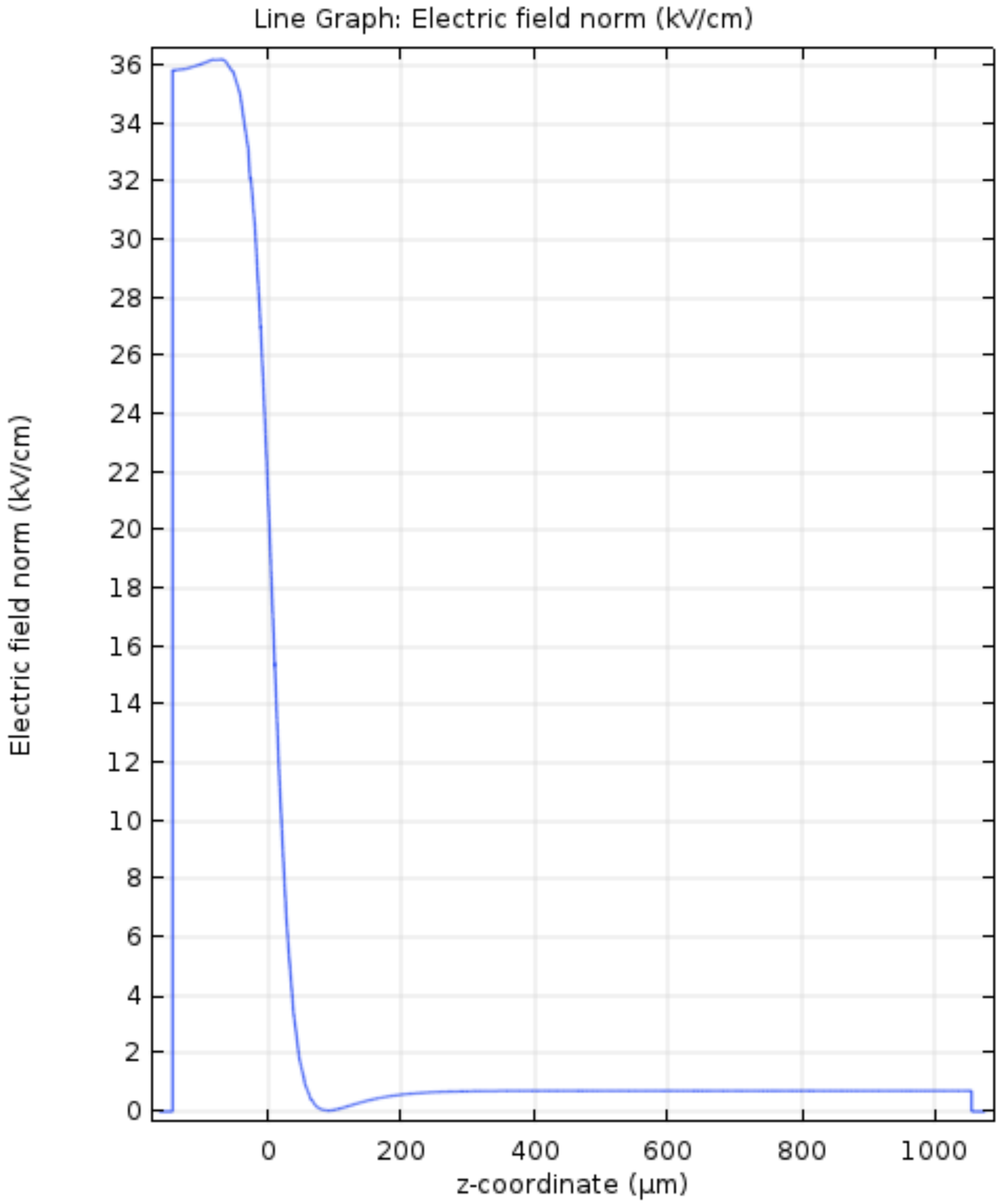




- Wire diameter 30 µm
- Edge to Edge 70 µm
- Axis to Axis 100 µm

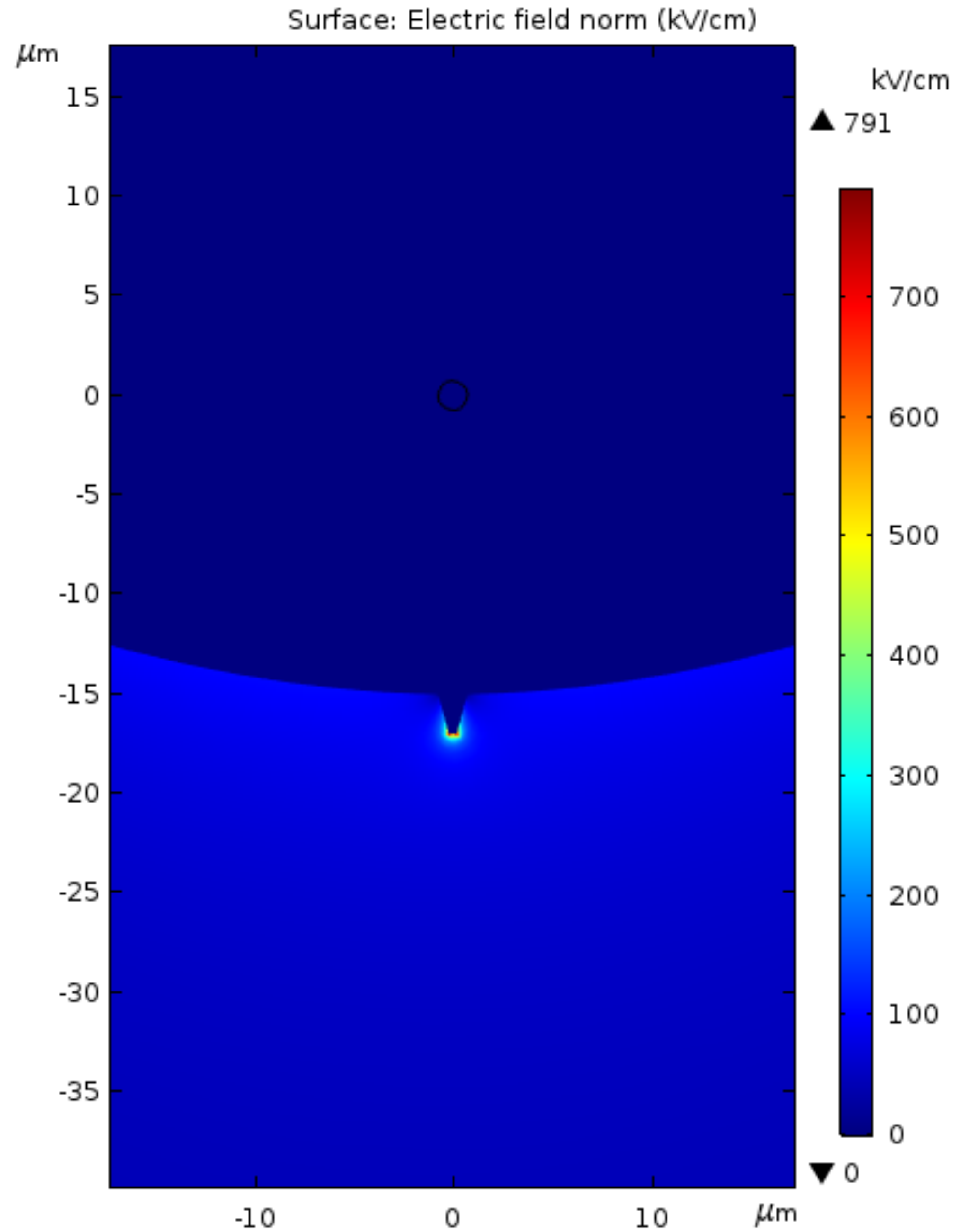


The field through the centre of the hole



this remains as before

The field contour (on the YZ plane, at X=0)



A very high field is localised around the defect

18-45
mesh= -350 V