Electrostatic simulations for protoDune-DP

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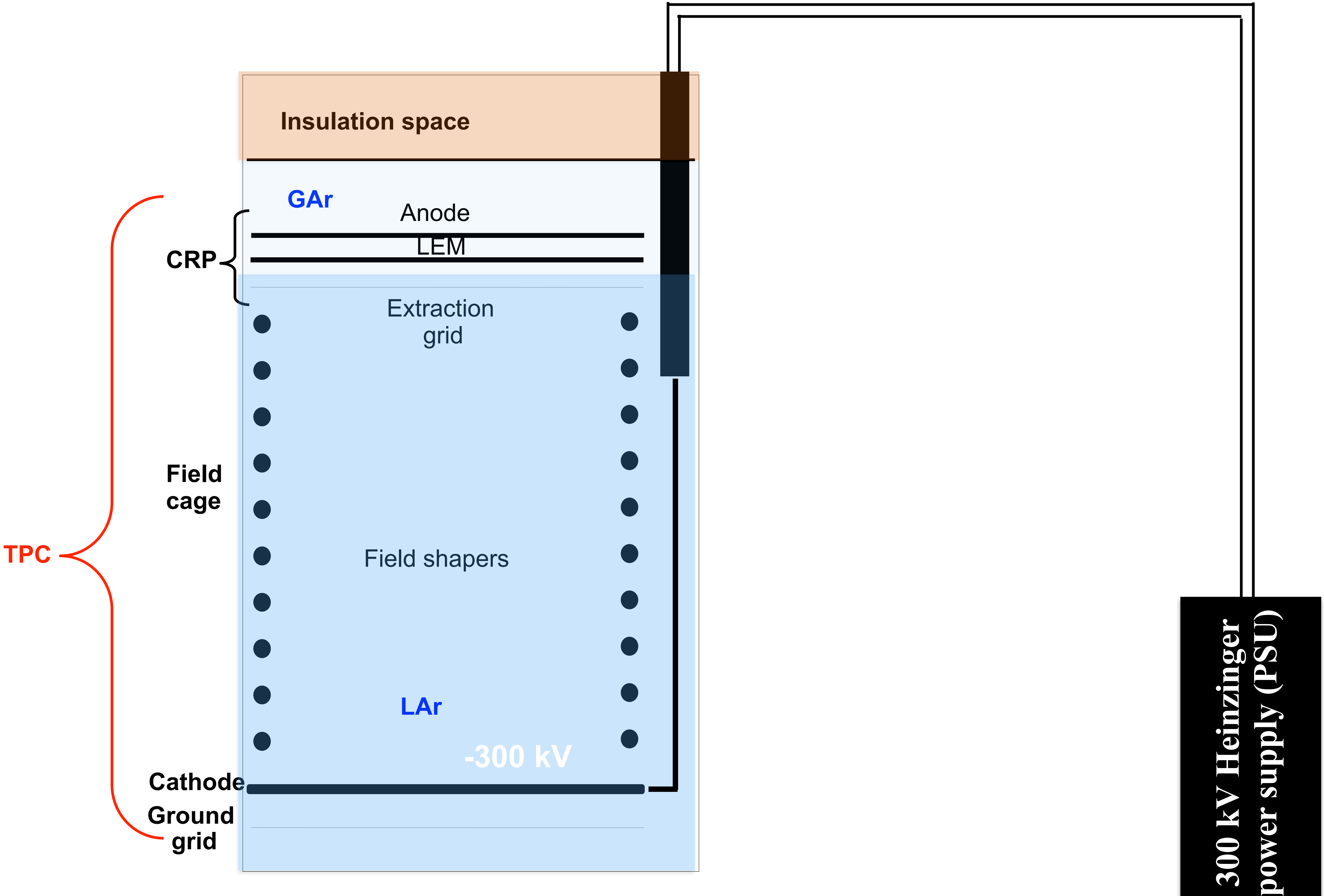
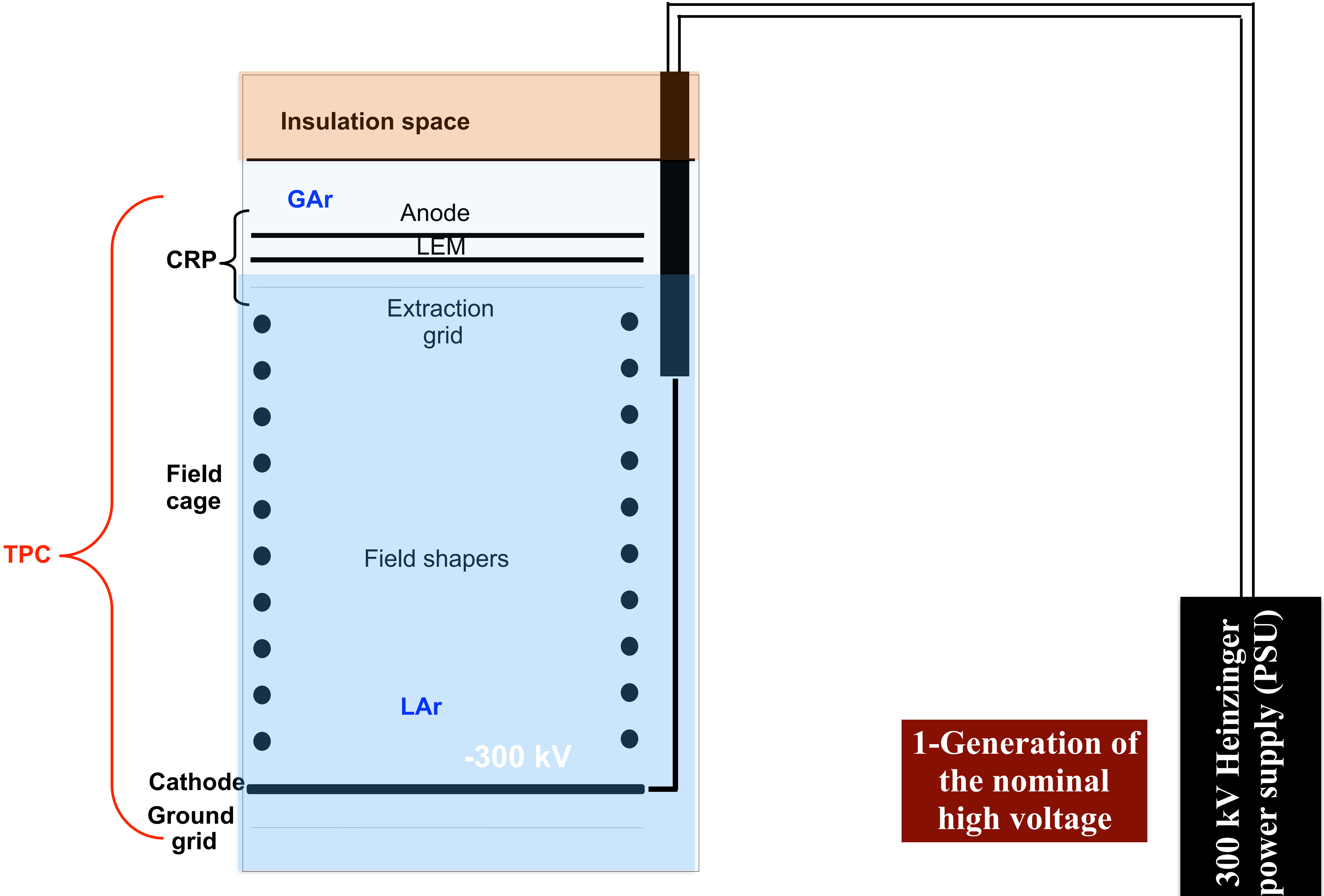
ProtoDUNE design review, 24th-25th April 2017

High voltage system in a nutshell

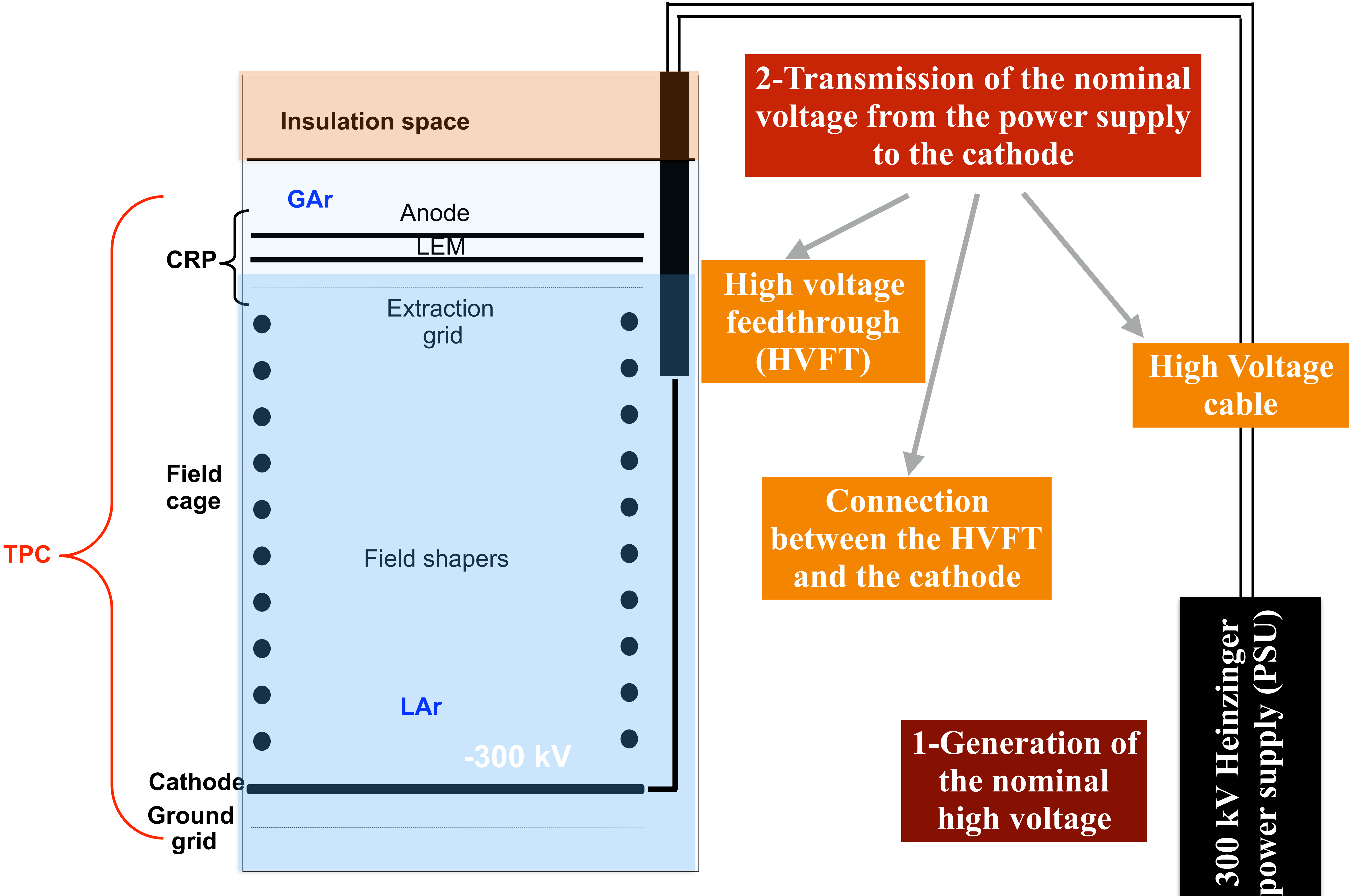


High voltage system in a nutshell

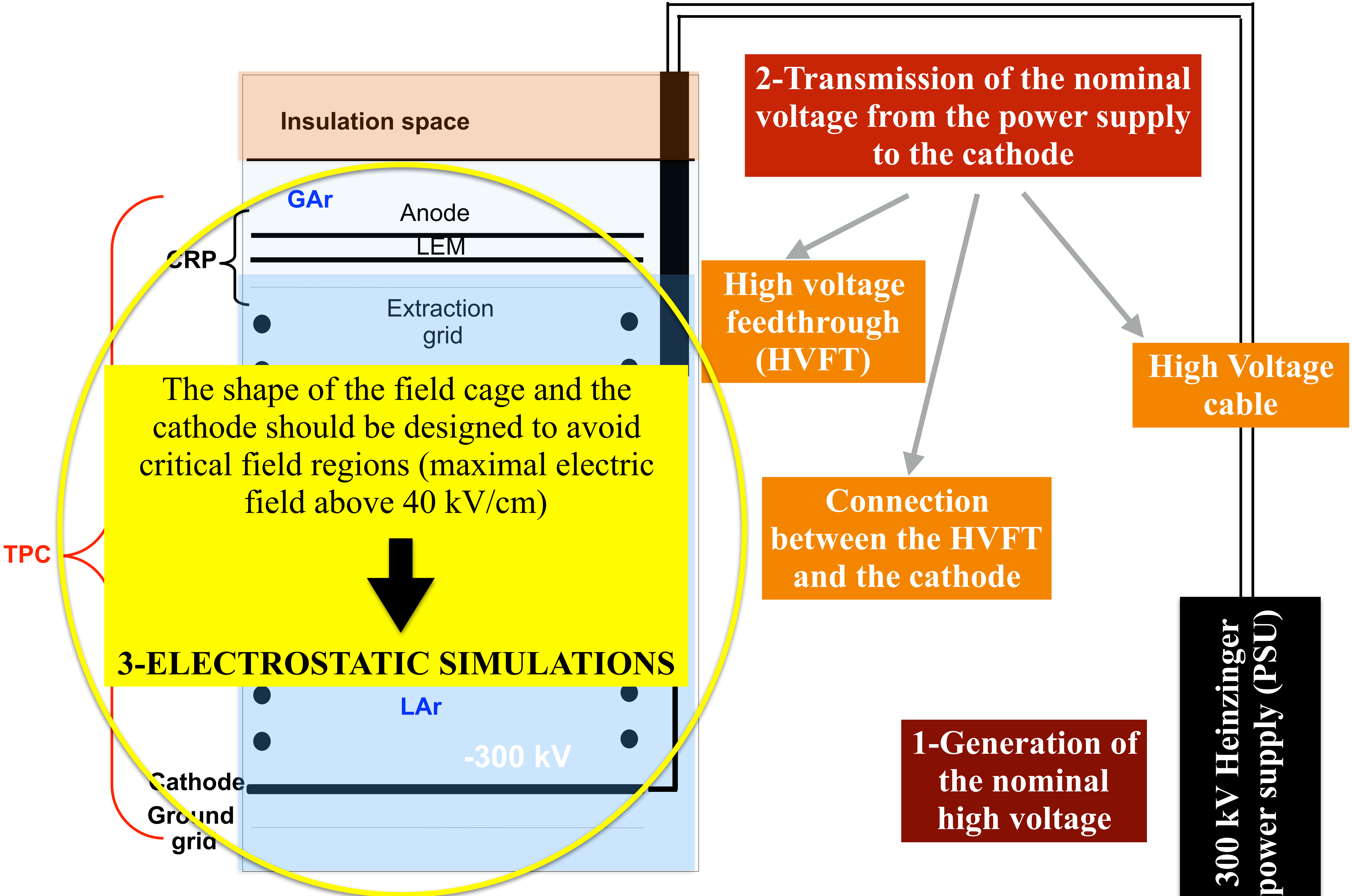


1-Generation of the nominal high voltage

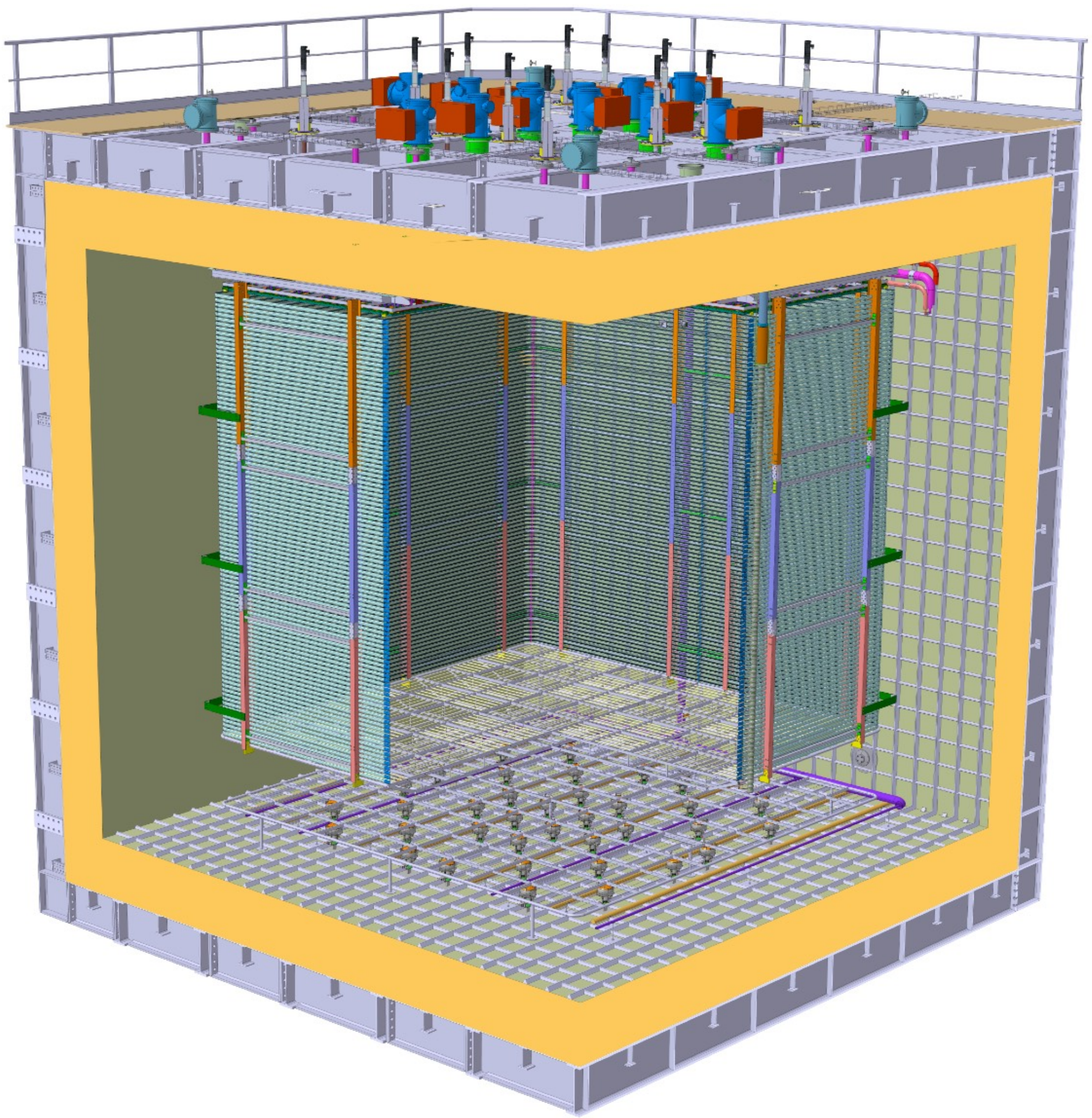
High voltage system in a nutshell



High voltage system in a nutshell



Simulations



Electrostatic simulations of the different parts of the detector performed with COMSOL multi physics:

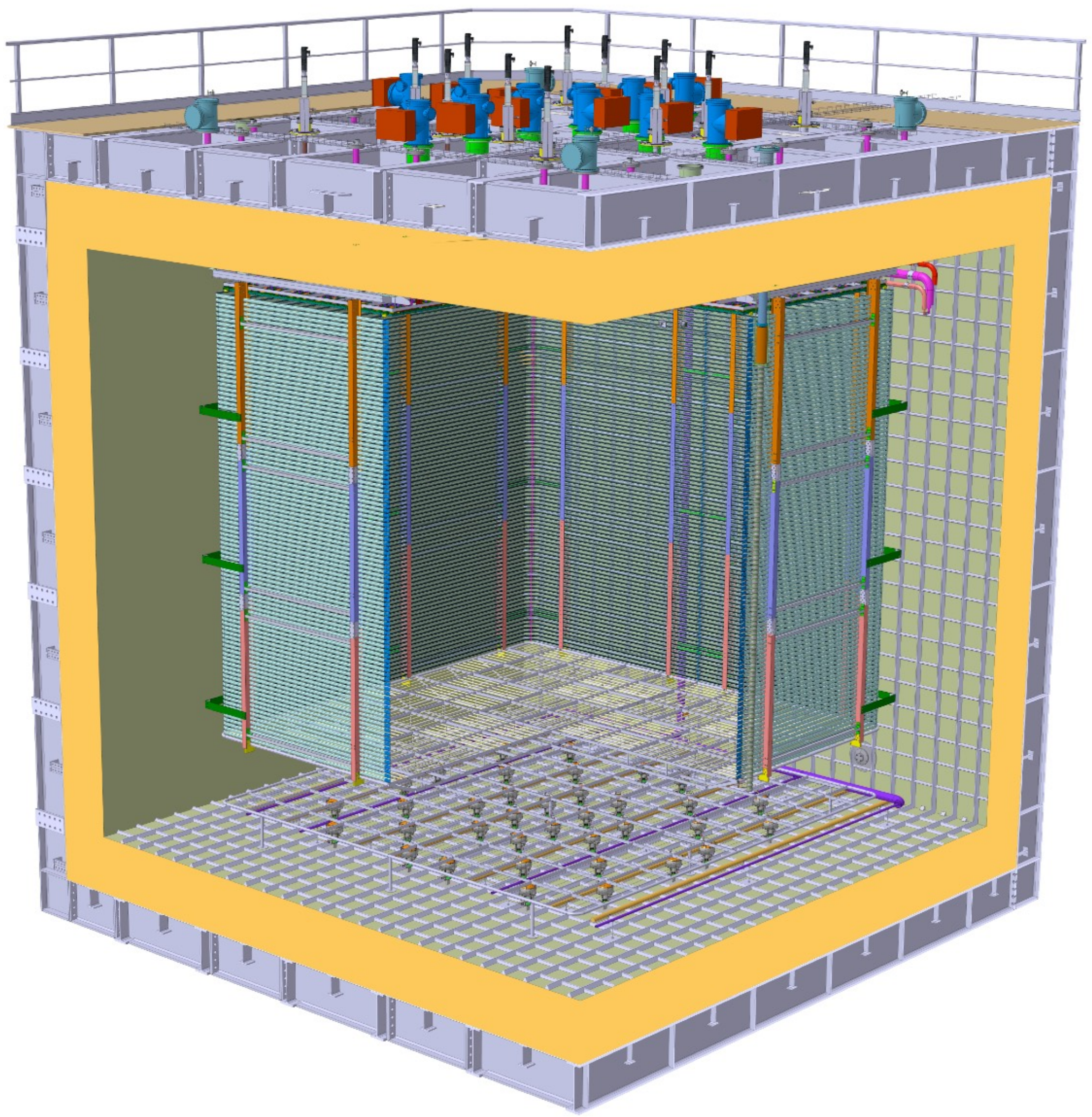
A. Field Cage

B. Cathode

C. Ground Grid

D. HVFT+connection to the cathode

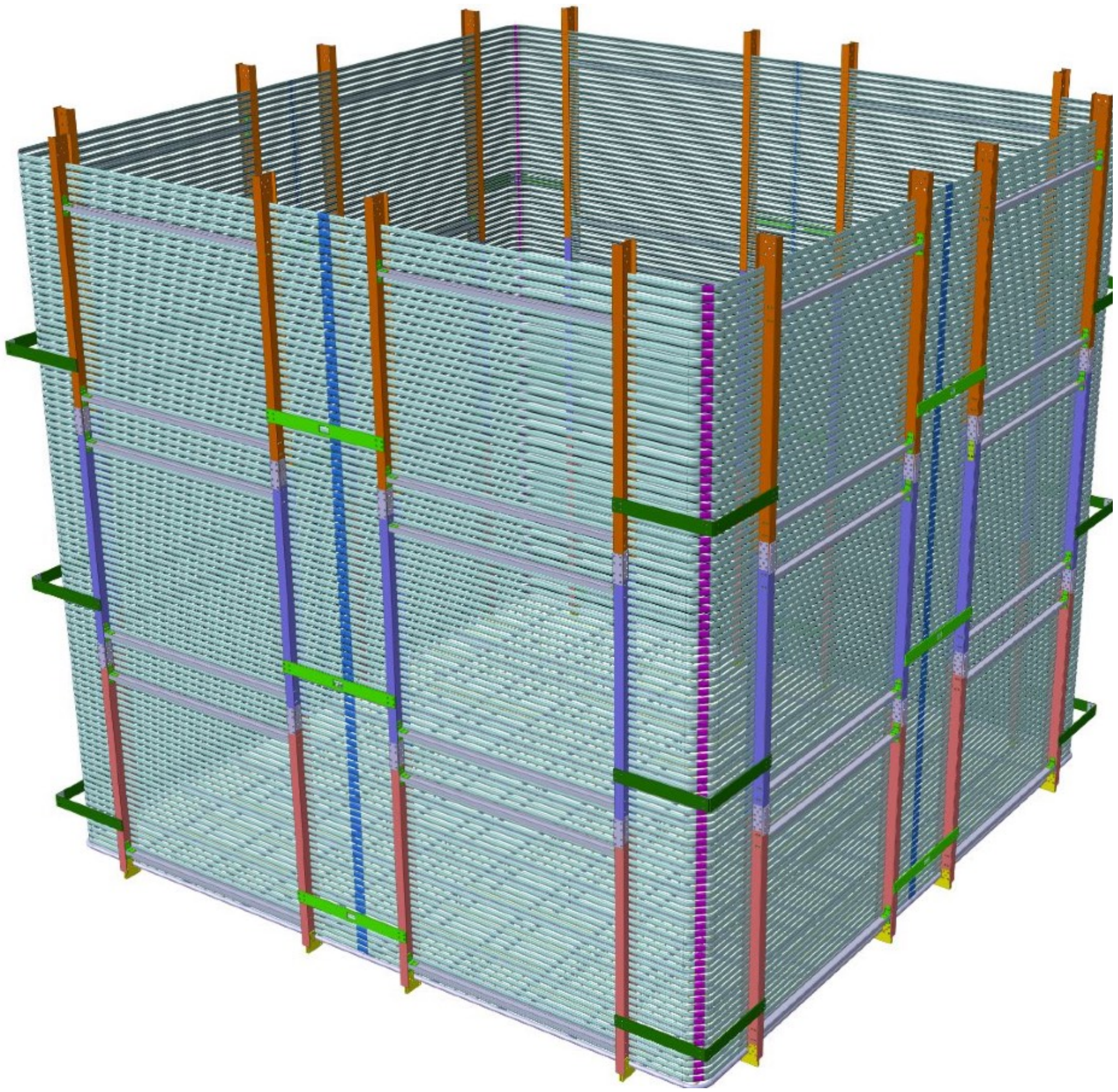
Simulations



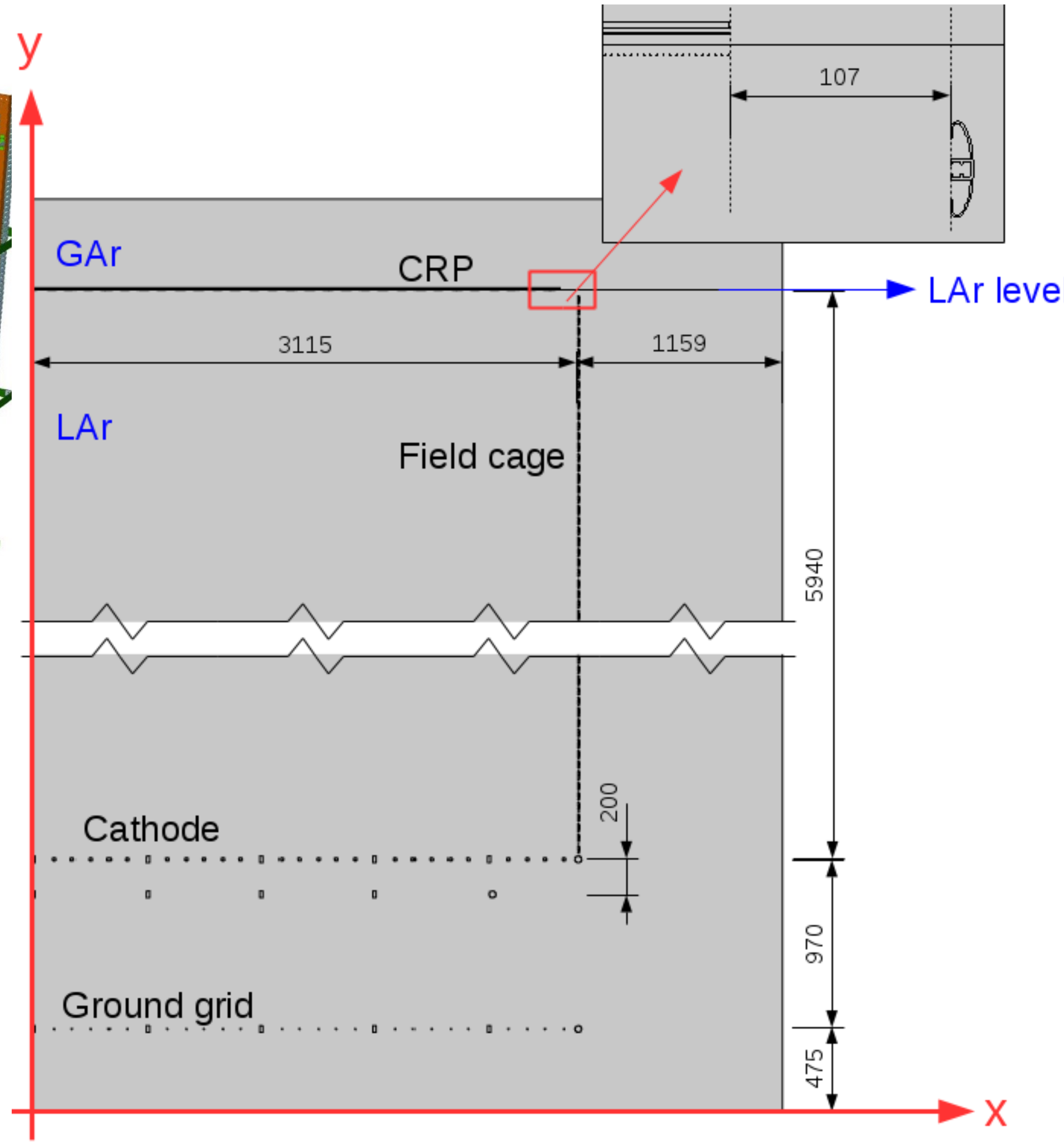
98 Field shapers separated 60 mm and with a potential difference between them of 3 kV.

	Distance to the stage above [mm]	Operating potential [kV]	Field to the stage above [kV/cm]
Anode	-	0	-
LEM(upper electrode)	2	-1	5
LEM(lower electrode)	1	-4	30
LAr level	5	-	-
Extraction grid	5	-6.5	2.5
First field shaper	60	-9.5	0.5
Last field shaper	60	-300.5	0.5
Cathode	60	-303.5	0.5

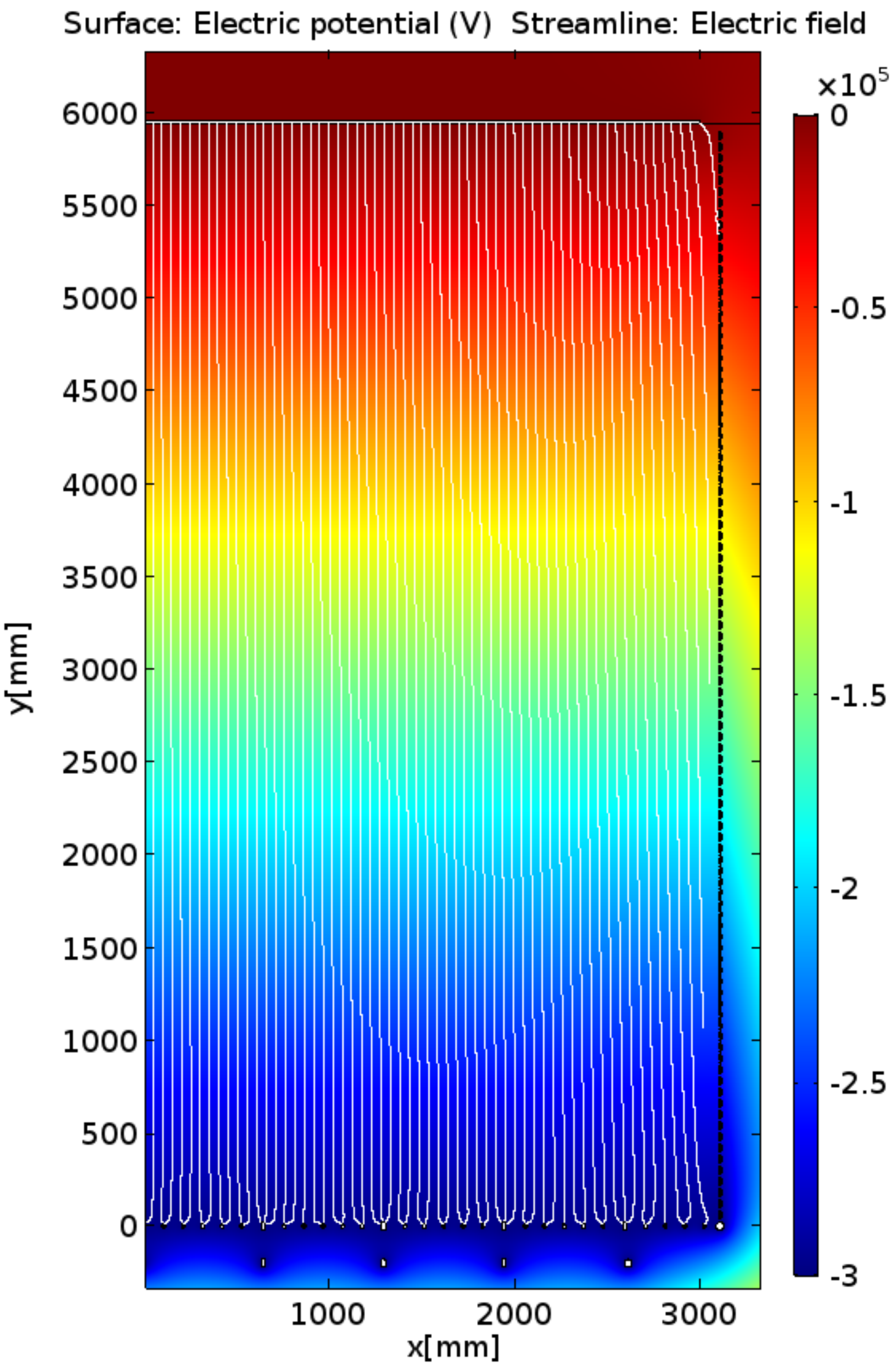
A)Field cage

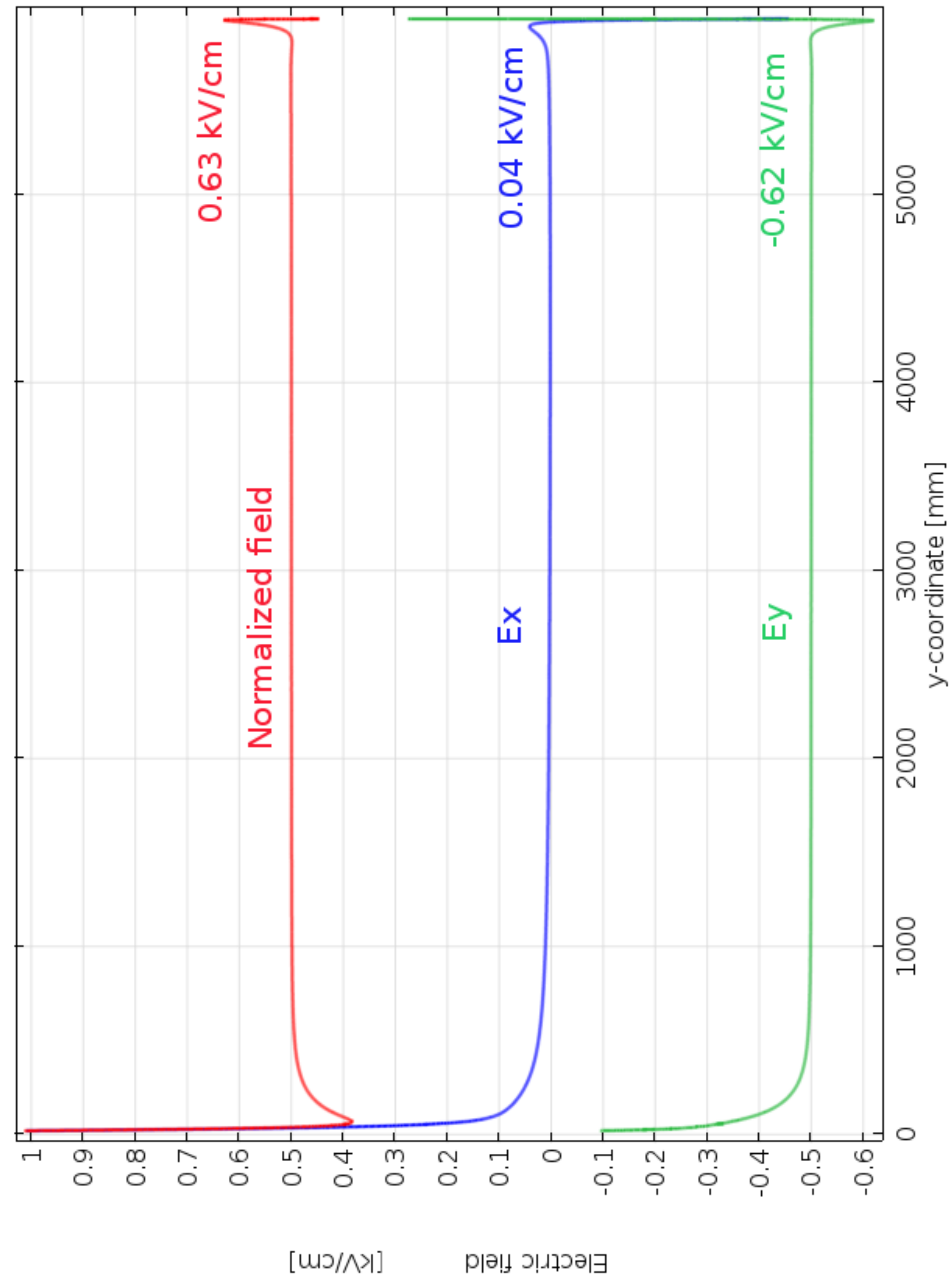


2D cross-section of a corner

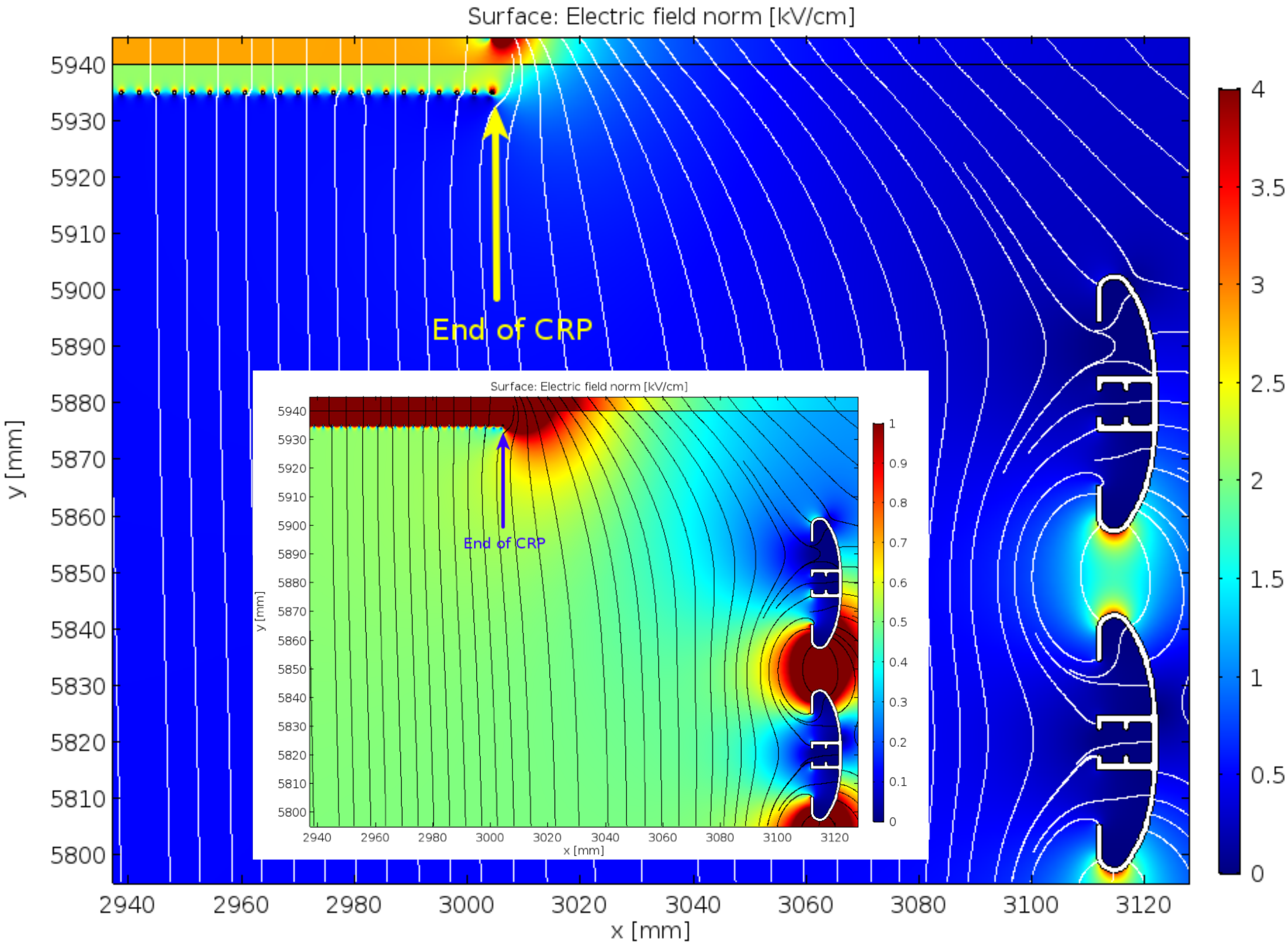


All dimensions given in mm


Surface: Electric potential (V) Streamline: Electric field
×10^5
0
-0.5
-1
-1.5
-2
-2.5
-3
y[mm]
x[mm]
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1000
2000
3000

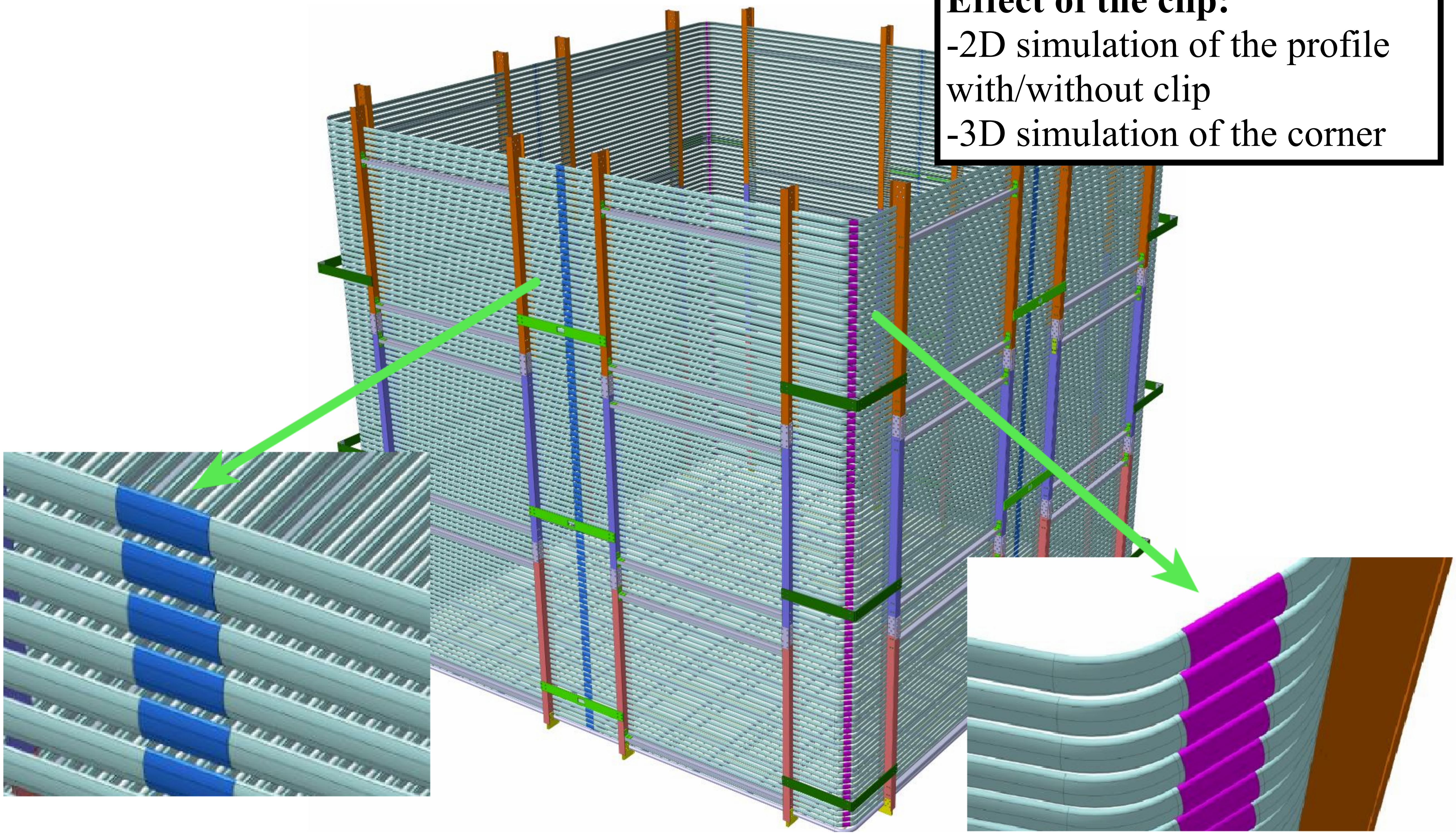

0.63 kV/cm
0.04 kV/cm
-0.62 kV/cm
Normalized field
Ex
Ey
y-coordinate [mm]
Electric field [kV/cm]

A)Field cage

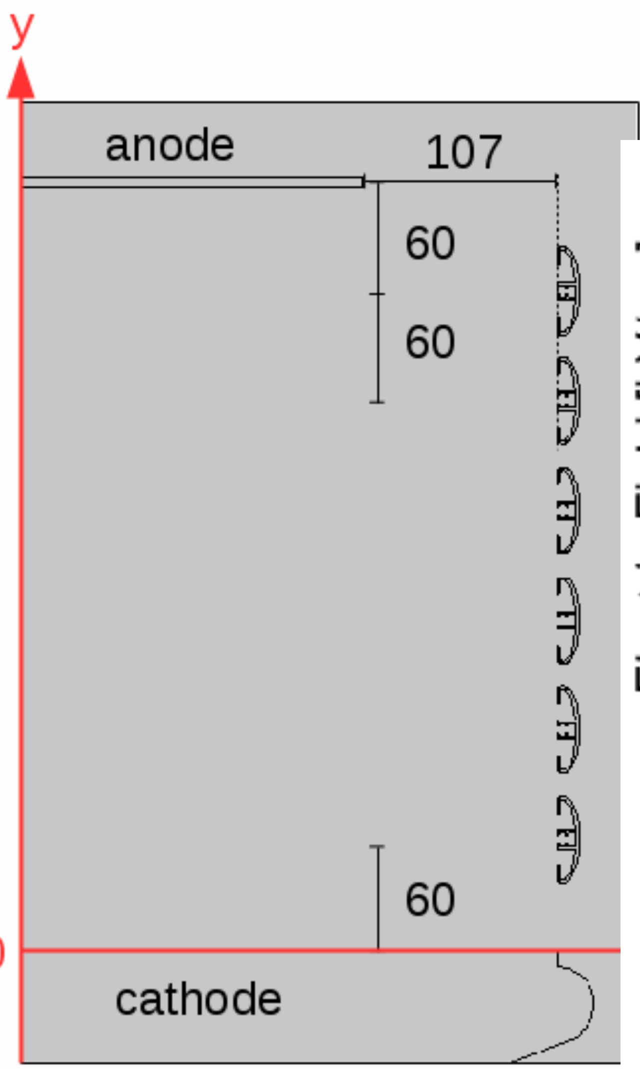

Surface: Electric field norm [kV/cm]
End of CRP
y [mm]
x [mm]
Surface: Electric field norm [kV/cm]
End of CRP
y [mm]
x [mm]

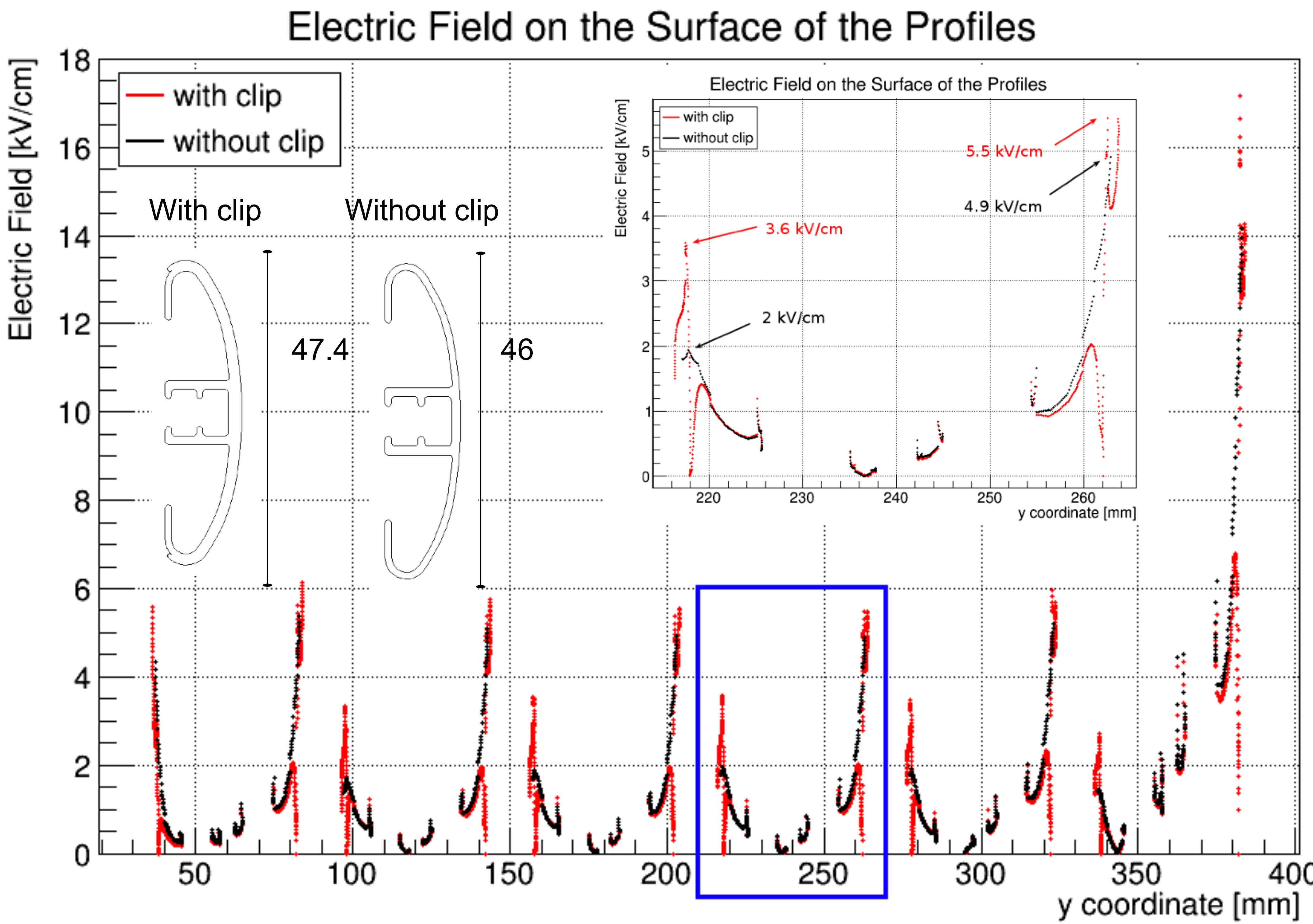
A)Field cage

Effect of the clip:
-2D simulation of the profile with/without clip
-3D simulation of the corner



A)Field cage





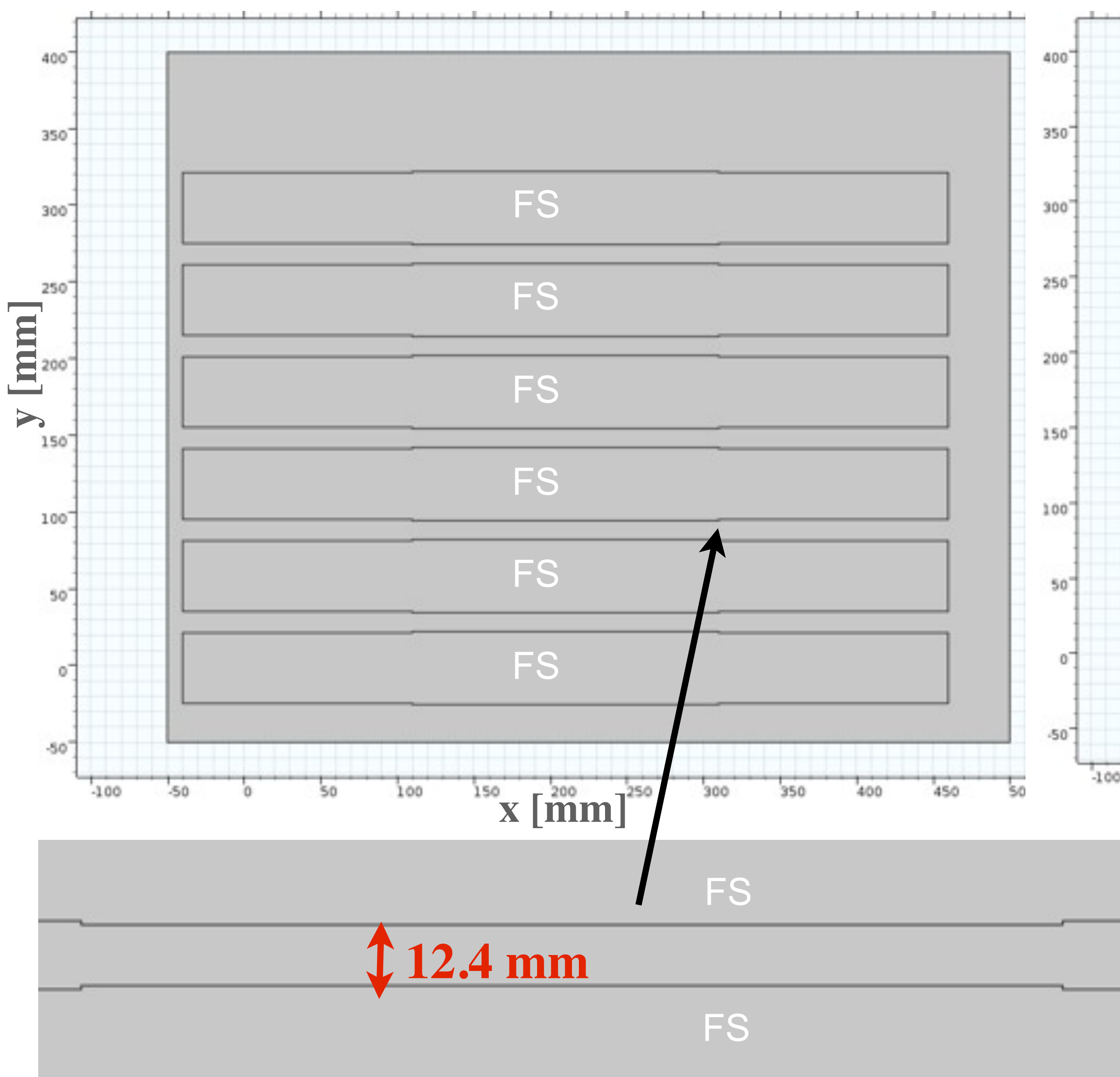
Simplified model considering 6 profiles with and without clip with a potential difference between them of -3kV

A)Field cage

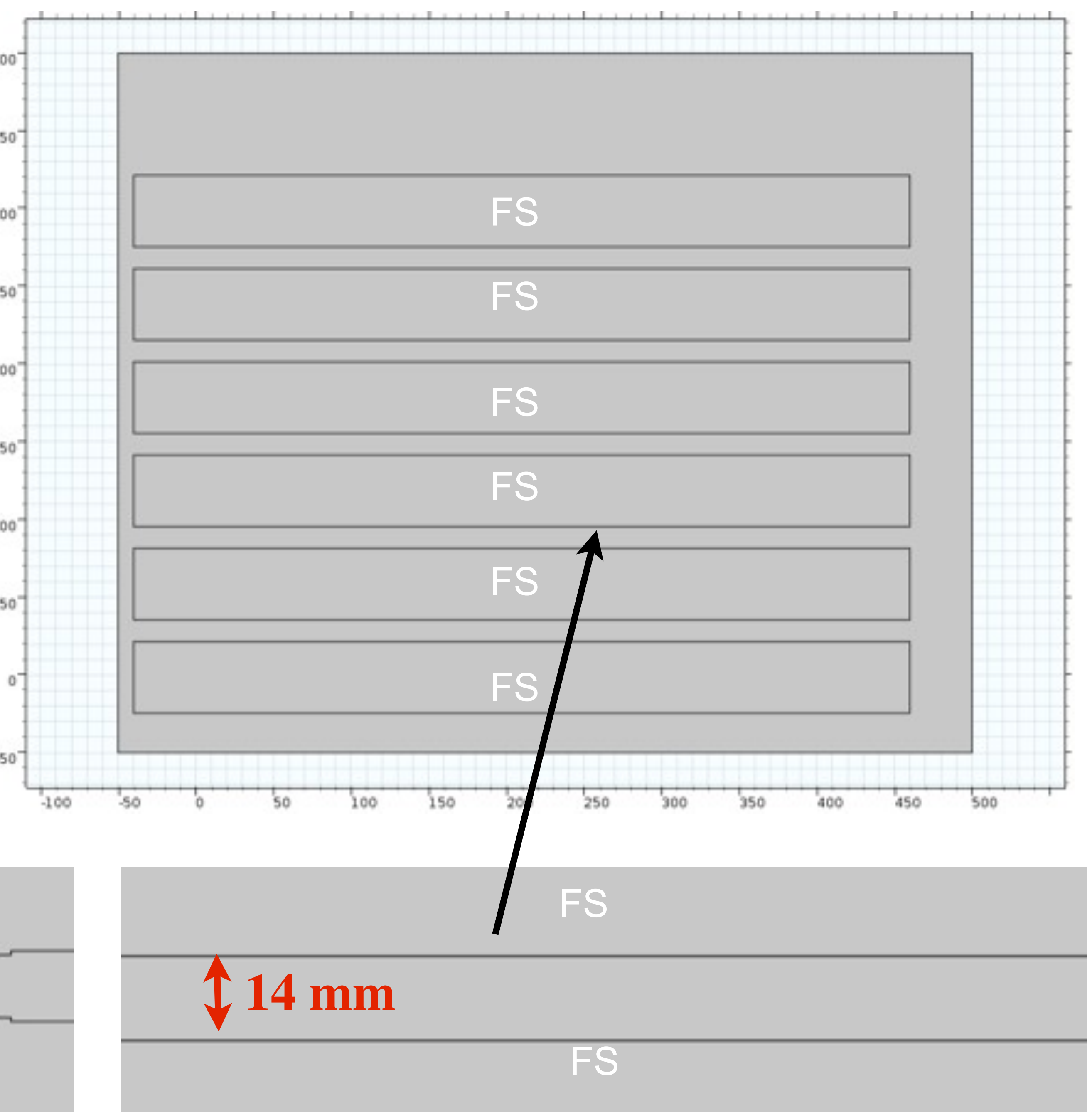
Front-view

Front-view of 6 profiles considering a potential difference between them of 3 kV, as in the 6x6x6 field cage

With clip

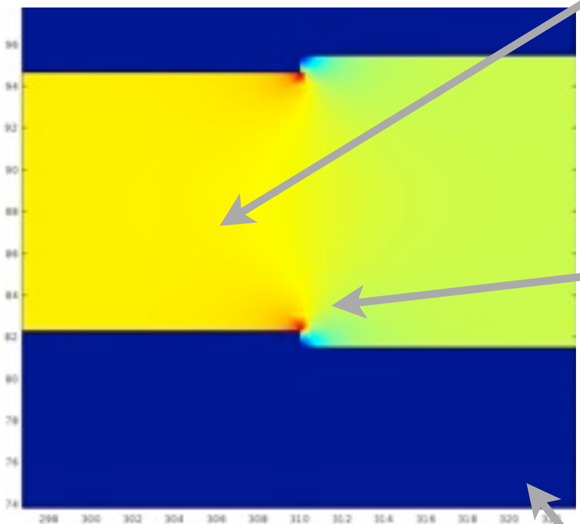


Without clip



Front-view

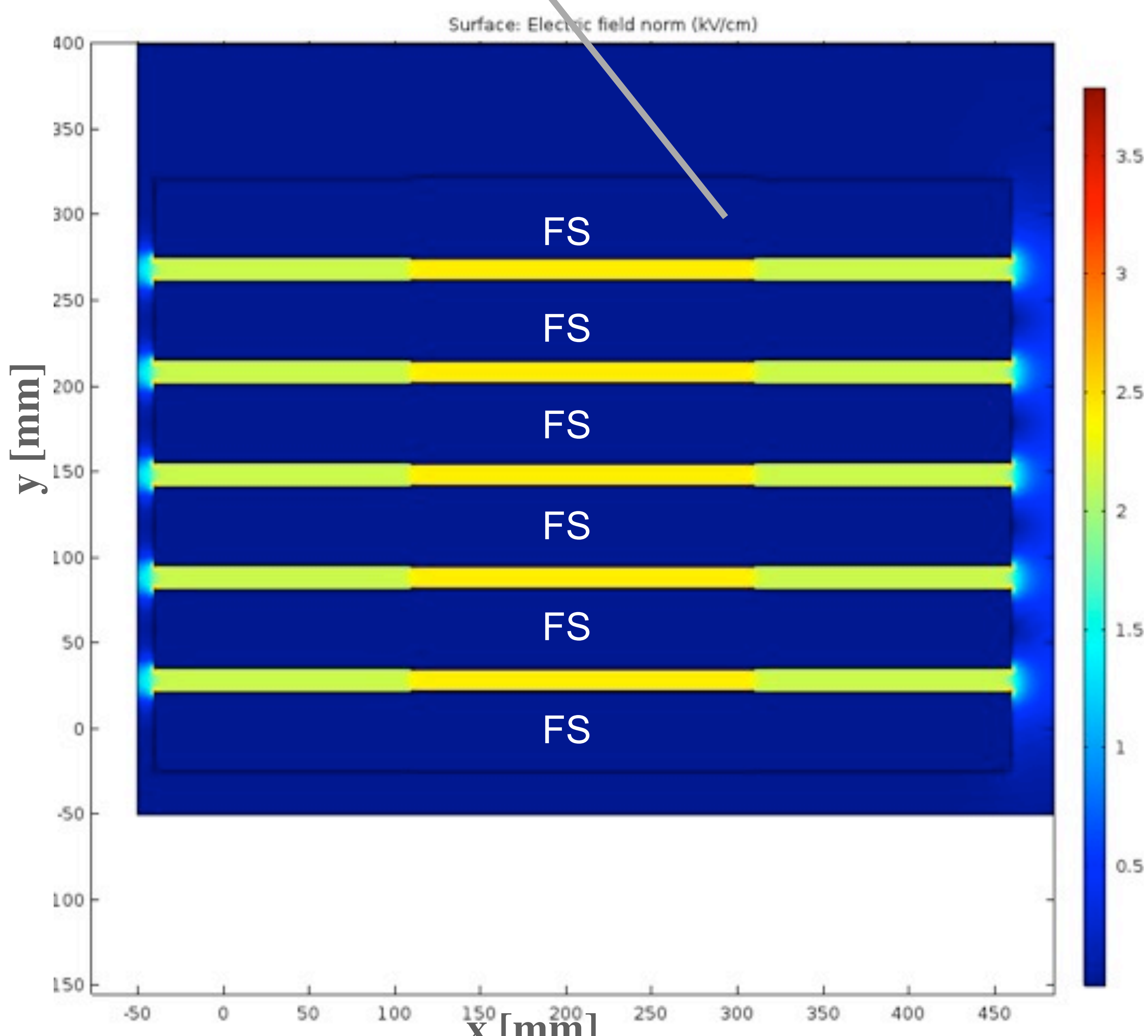
Surface: Electric Field [kV/cm]



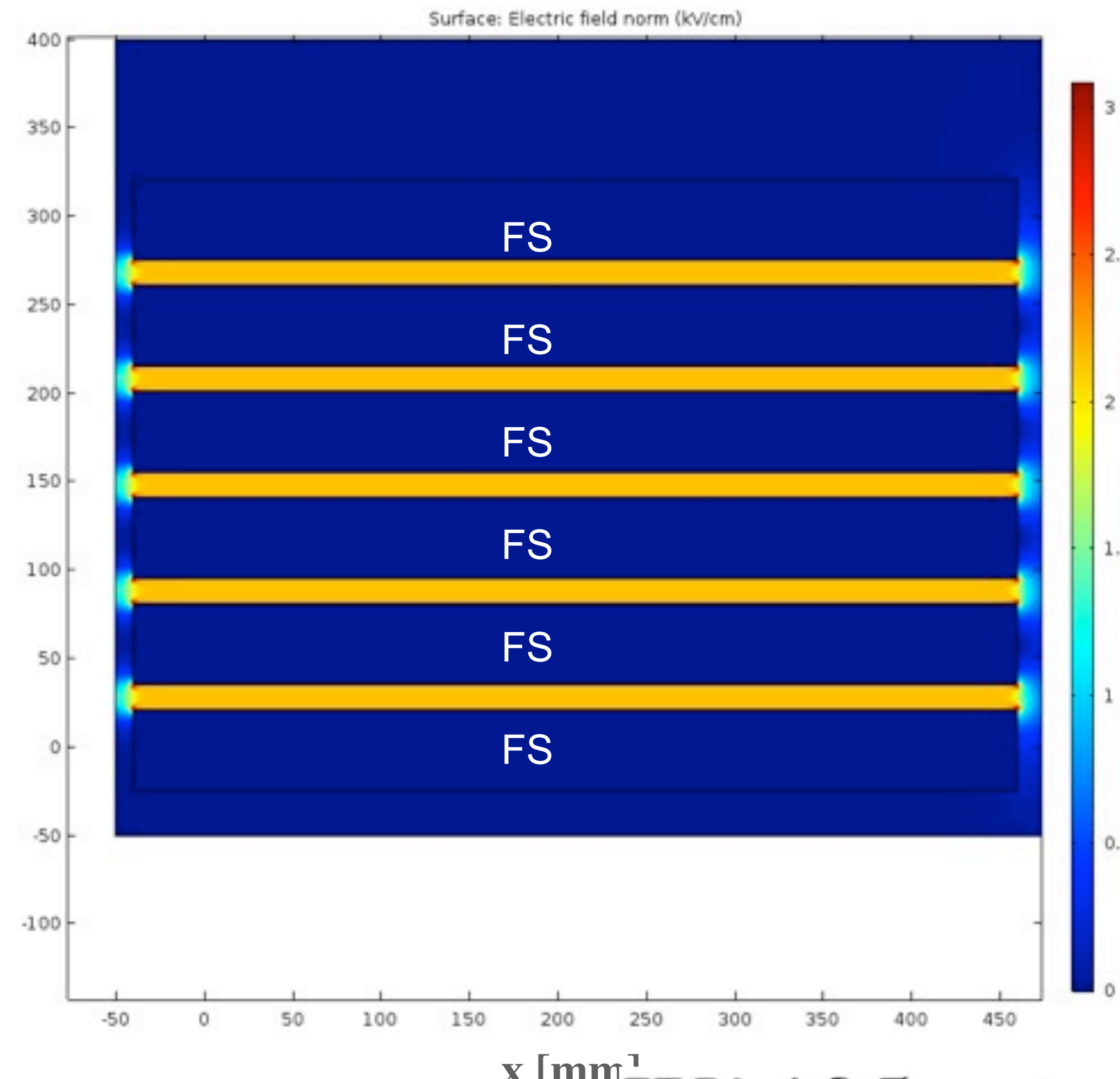
The fieldis larger in the region in between the clip, as the distance between the profiles is smaller

Edge effect in the end of the clip. Is it possible to round it?

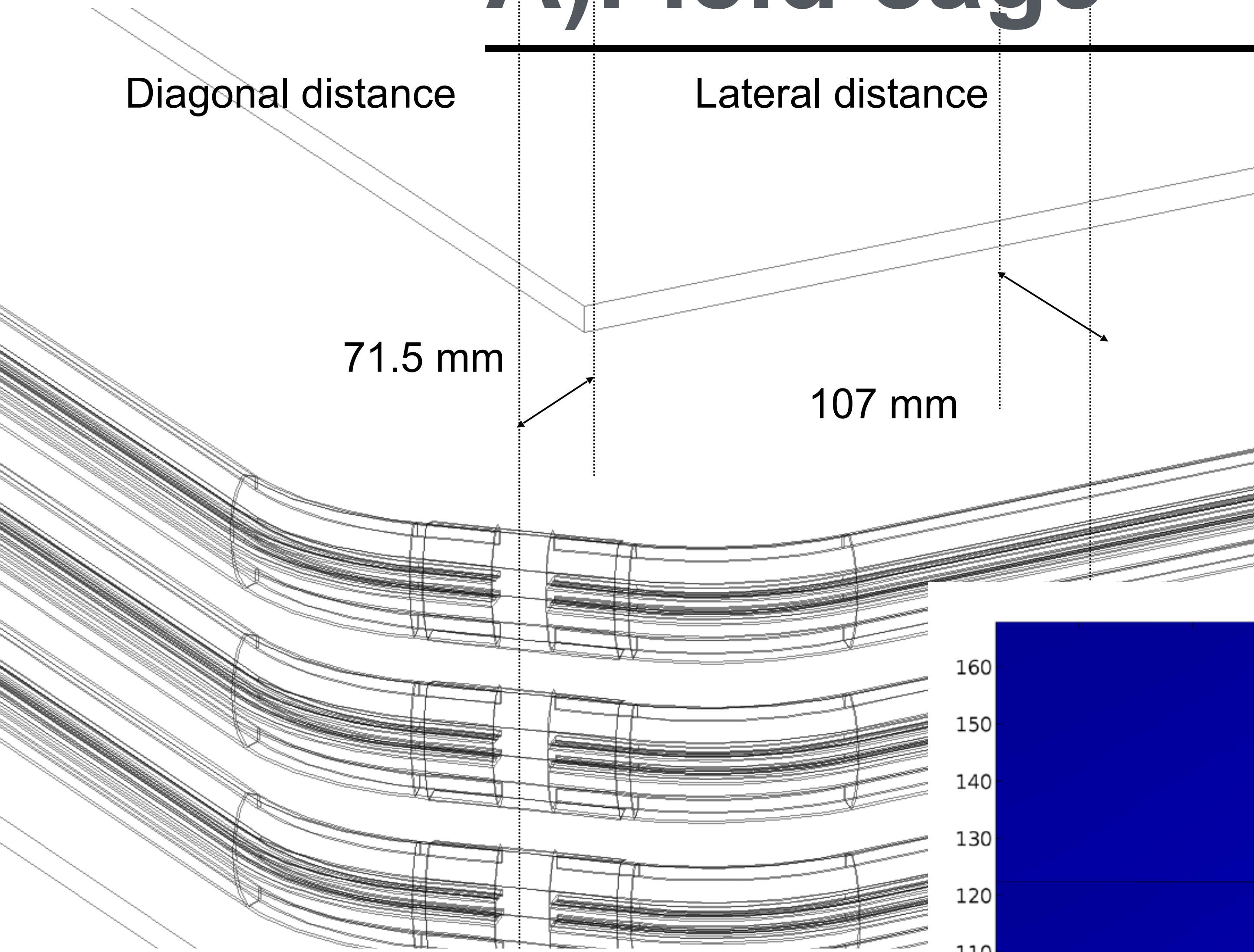
With clip



Without clip

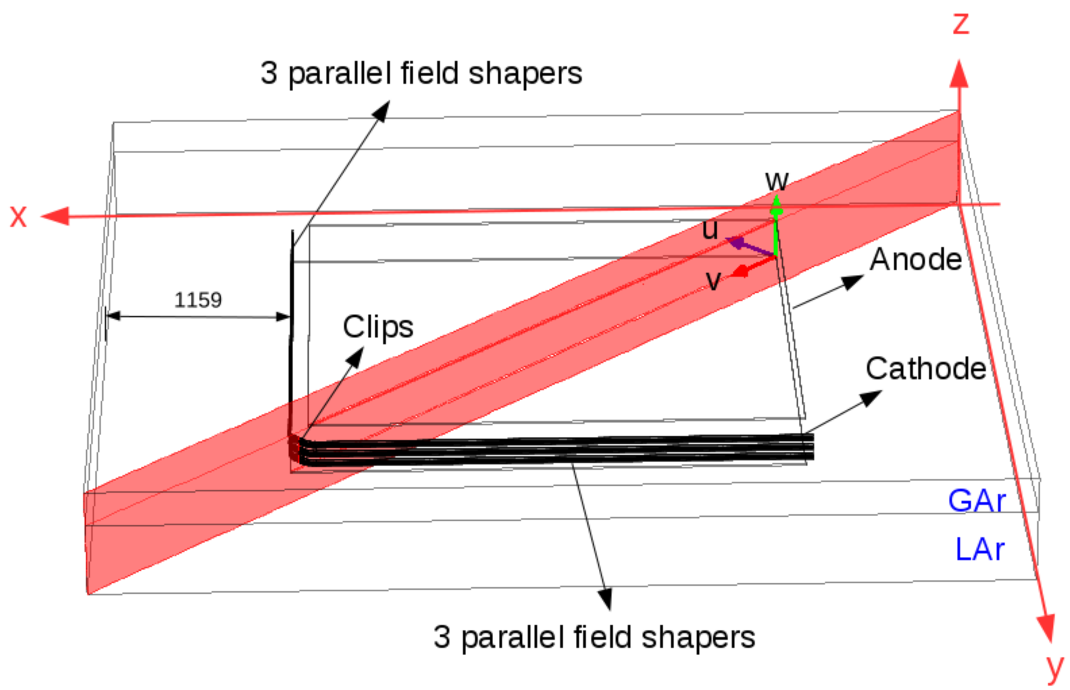


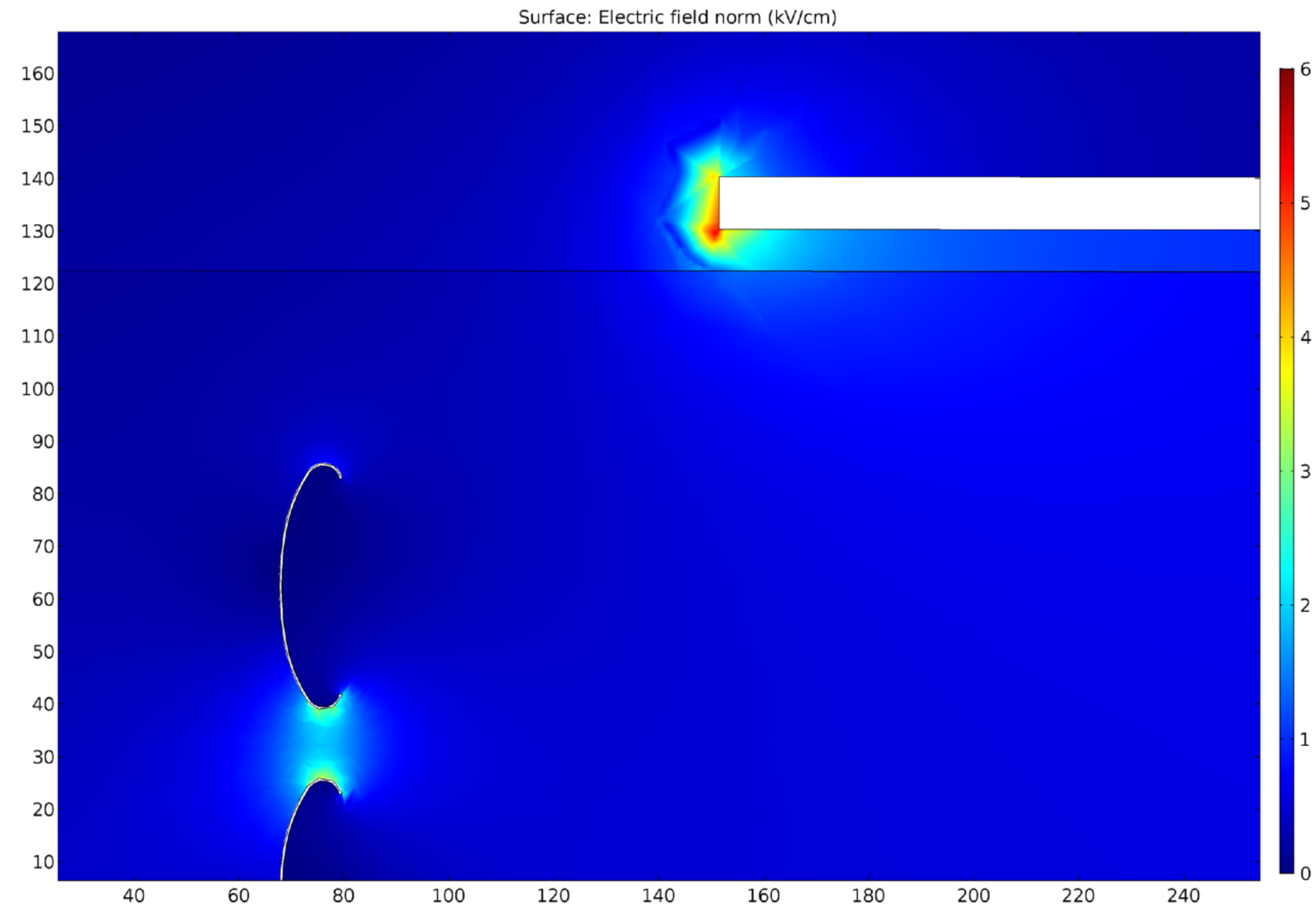
A)Field cage



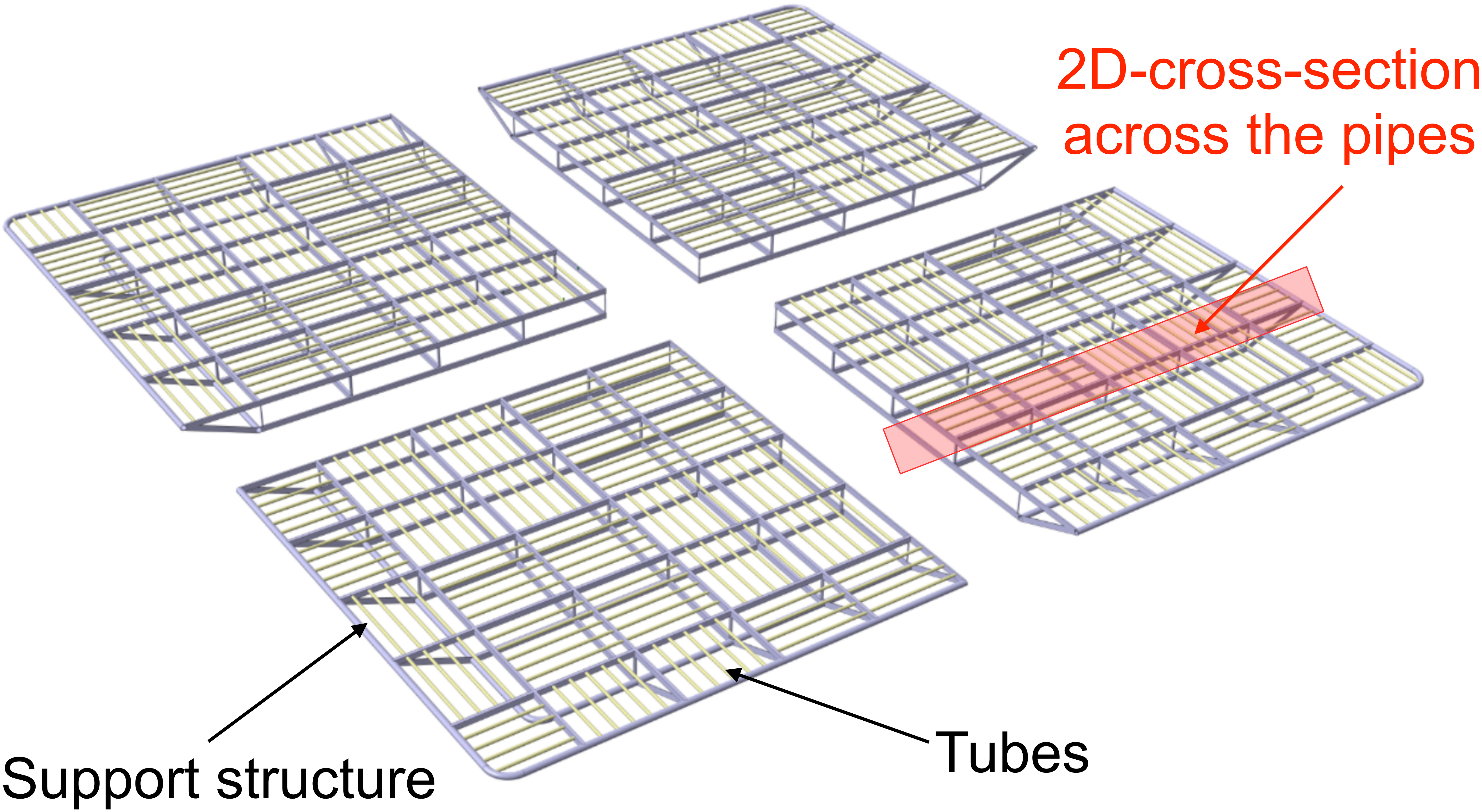
3D simulation of a corner

Surface: Electric field along the diagonal in kV/cm



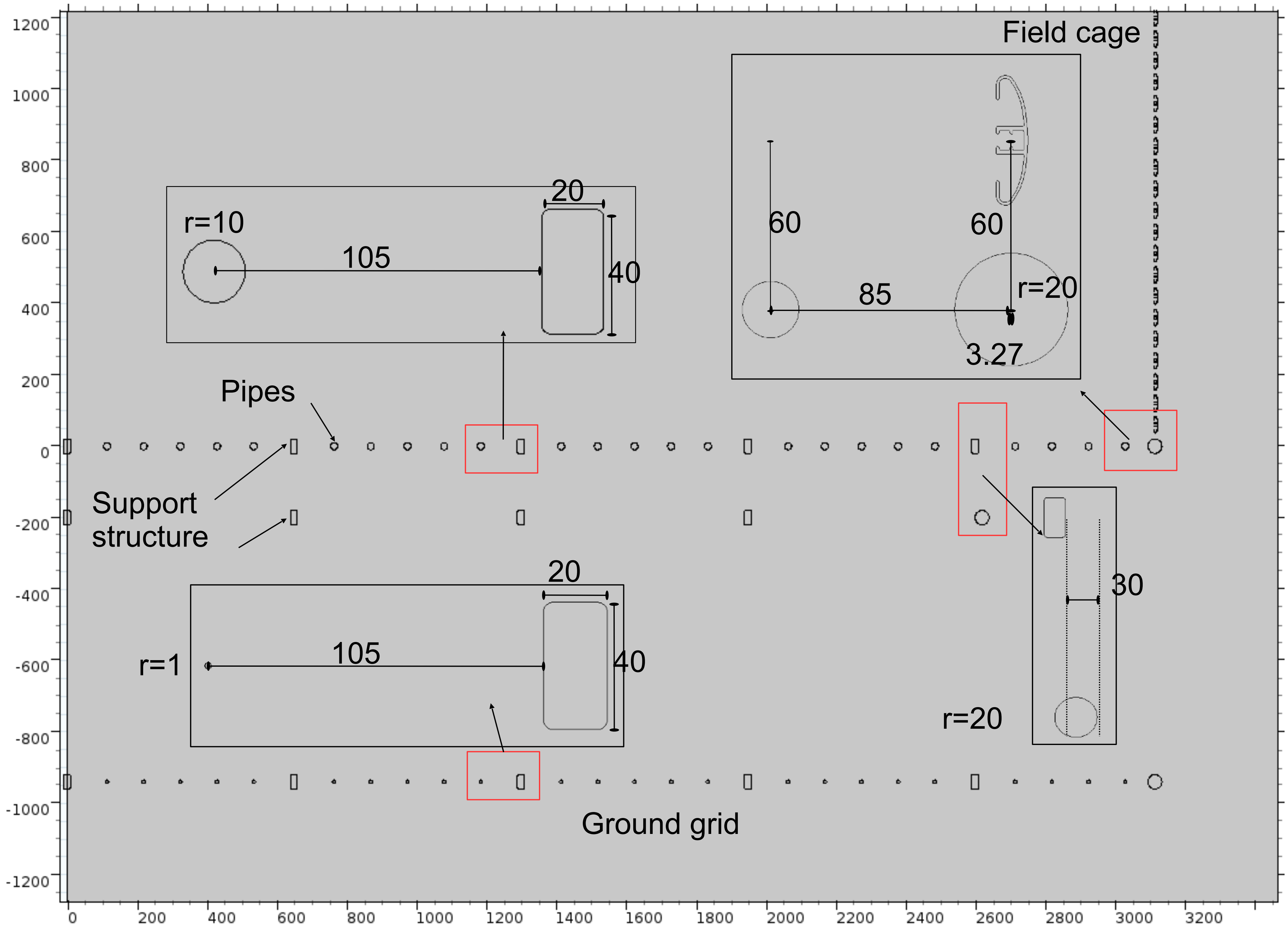


B)Cathode

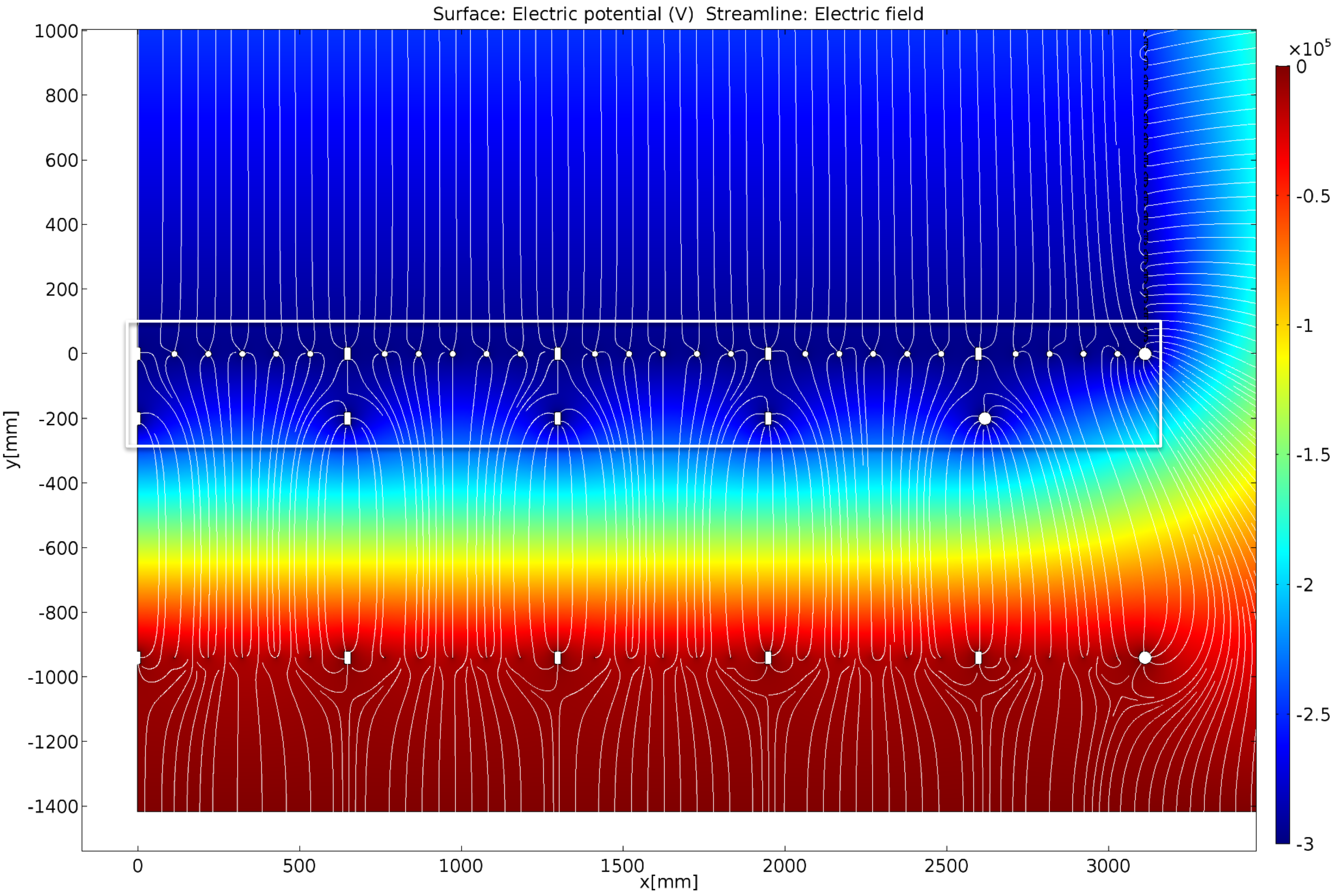


B)Cathode

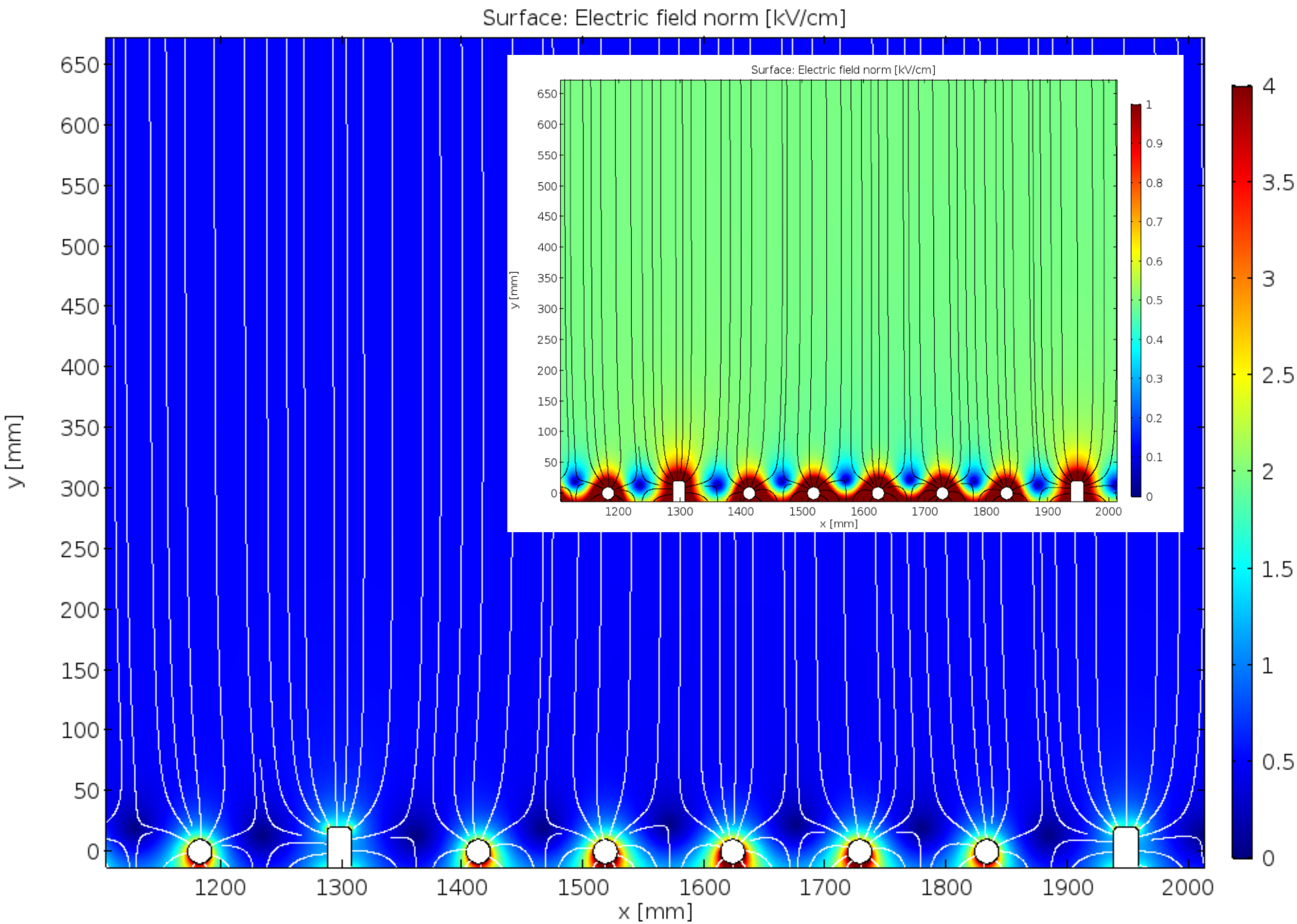
2D-cross-section across the tubes



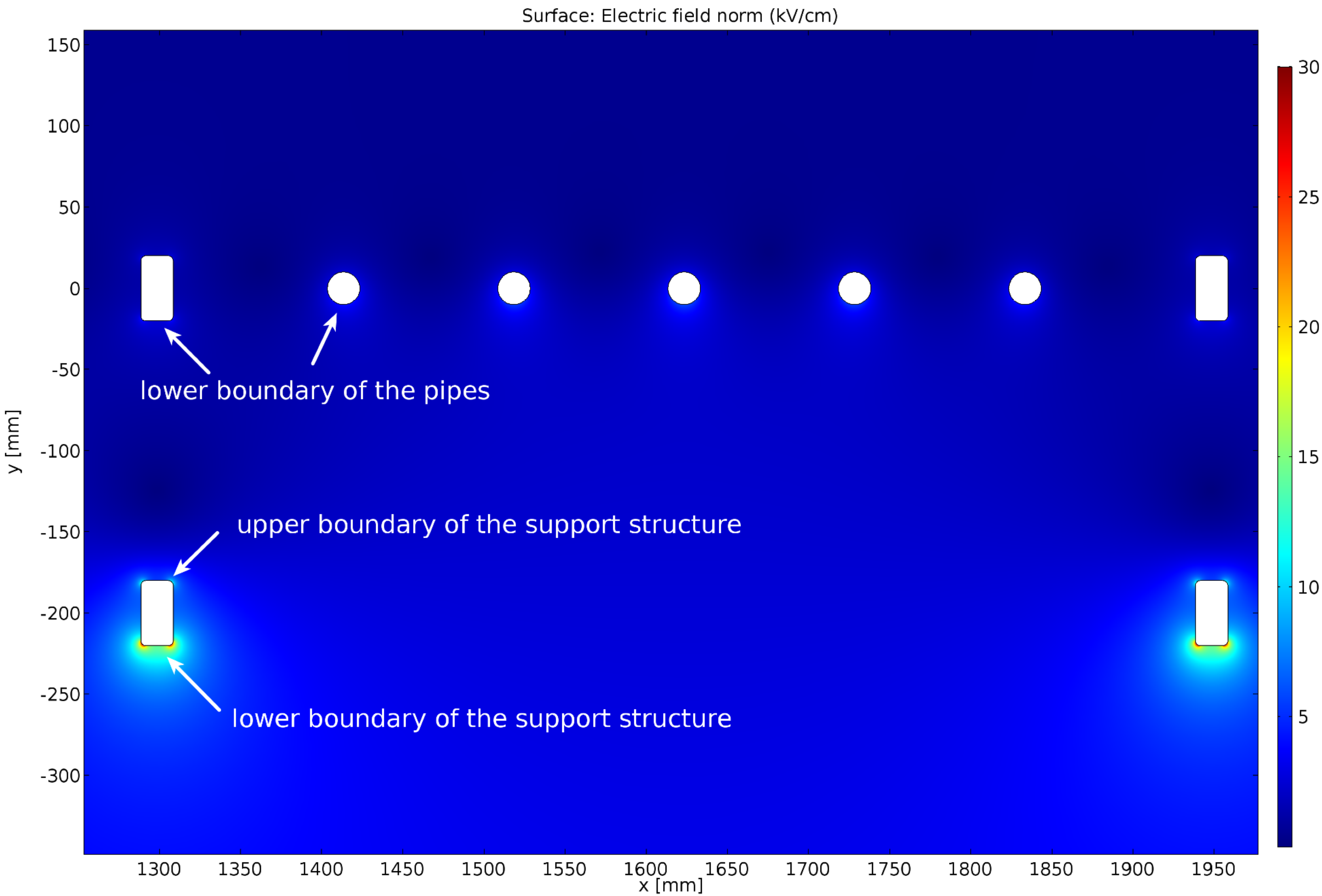
B)Cathode


Surface: Electric potential (V) Streamline: Electric field
y[mm]
x[mm]
×10^5
0
-0.5
-1
-1.5
-2
-2.5
-3
1000
800
600
400
200
0
-200
-400
-600
-800
-1000
-1200
-1400
0
500
1000
1500
2000
2500
3000

B)Cathode


Surface: Electric field norm [kV/cm]
y [mm]
x [mm]
650
600
550
500
450
400
350
300
250
200
150
100
50
0
1200
1300
1400
1500
1600
1700
1800
1900
2000
4
3.5
3
2.5
2
1.5
1
0.5
0
Surface: Electric field norm [kV/cm]
y [mm]
x [mm]
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

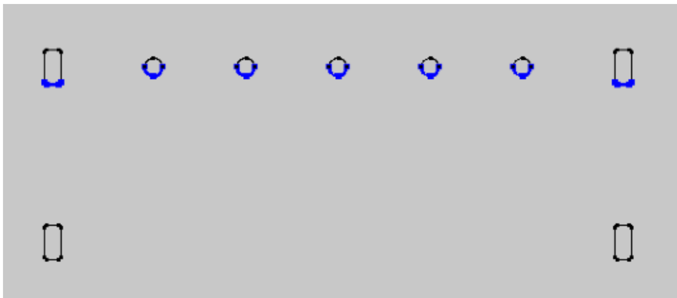
B)Cathode



Surface: Electric field norm (kV/cm)
150
100
50
0
-50
-100
-150
-200
-250
-300
y [mm]
1300
1350
1400
1450
1500
1550
1600
1650
1700
1750
1800
1850
1900
1950
x [mm]
30
25
20
15
10
5
lower boundary of the pipes
upper boundary of the support structure
lower boundary of the support structure

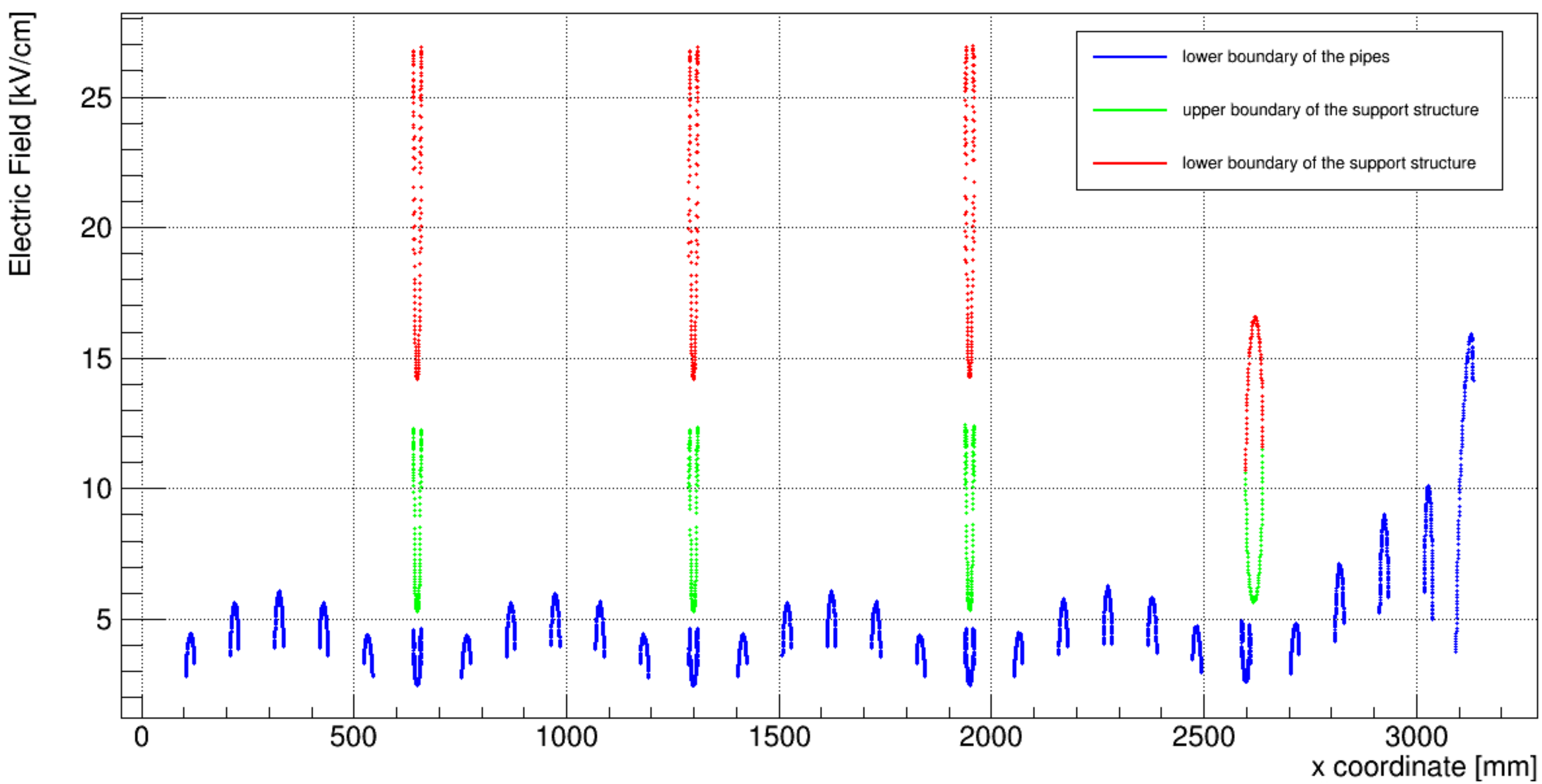
B)Cathode

lower boundary of the pipes

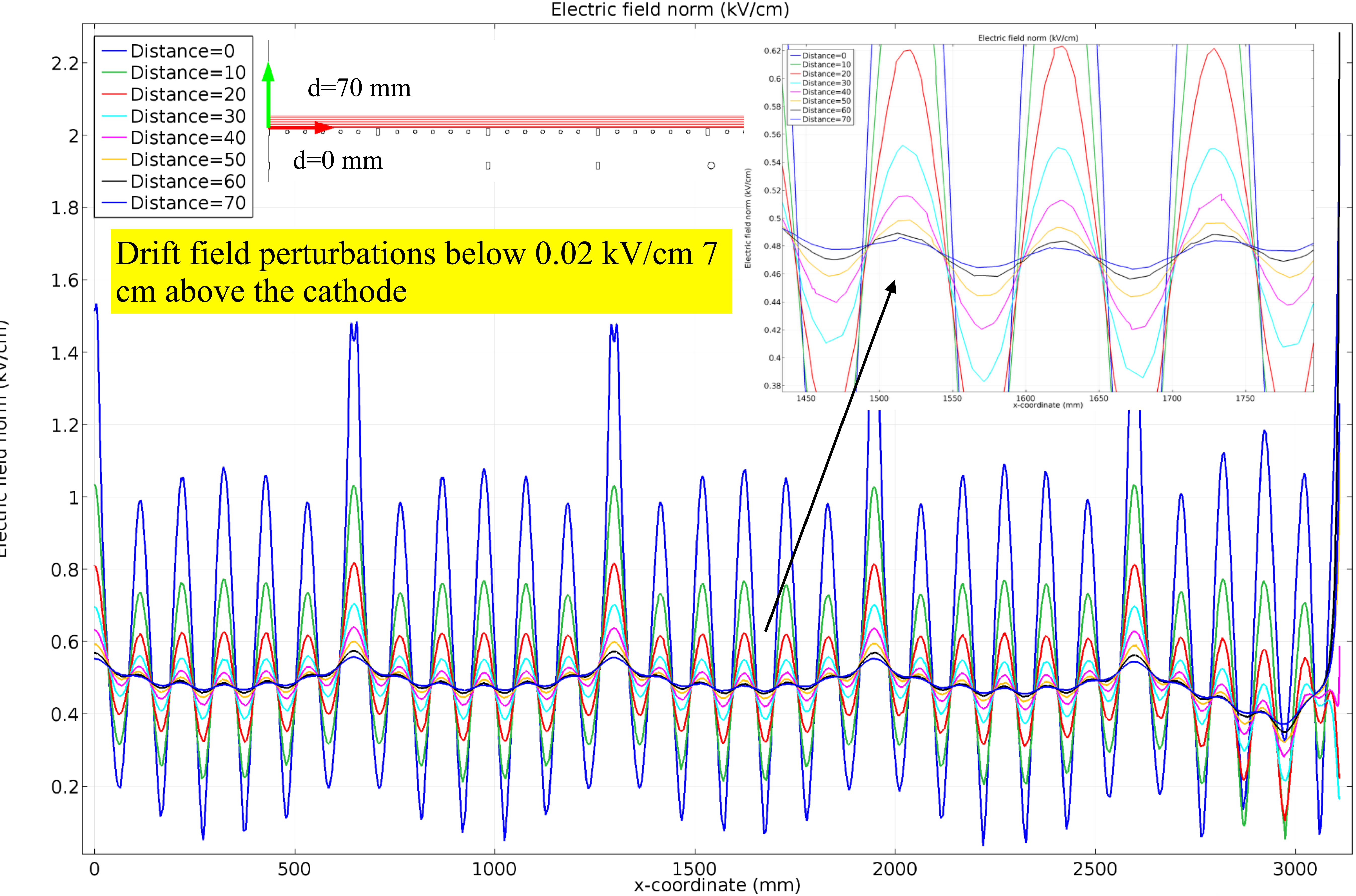


upper boundary of the support structure

lower boundary of the support structure

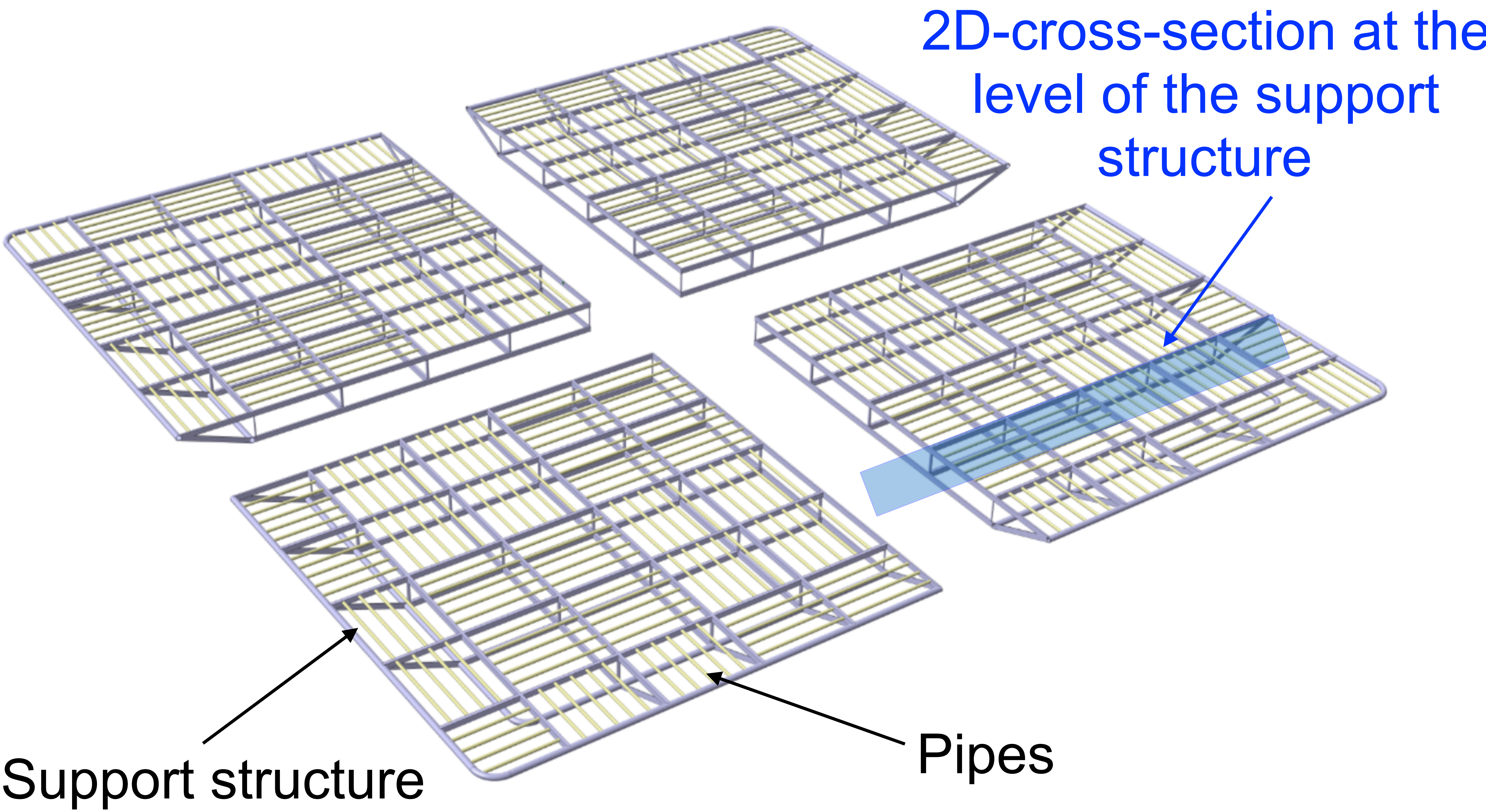


B)Cathode

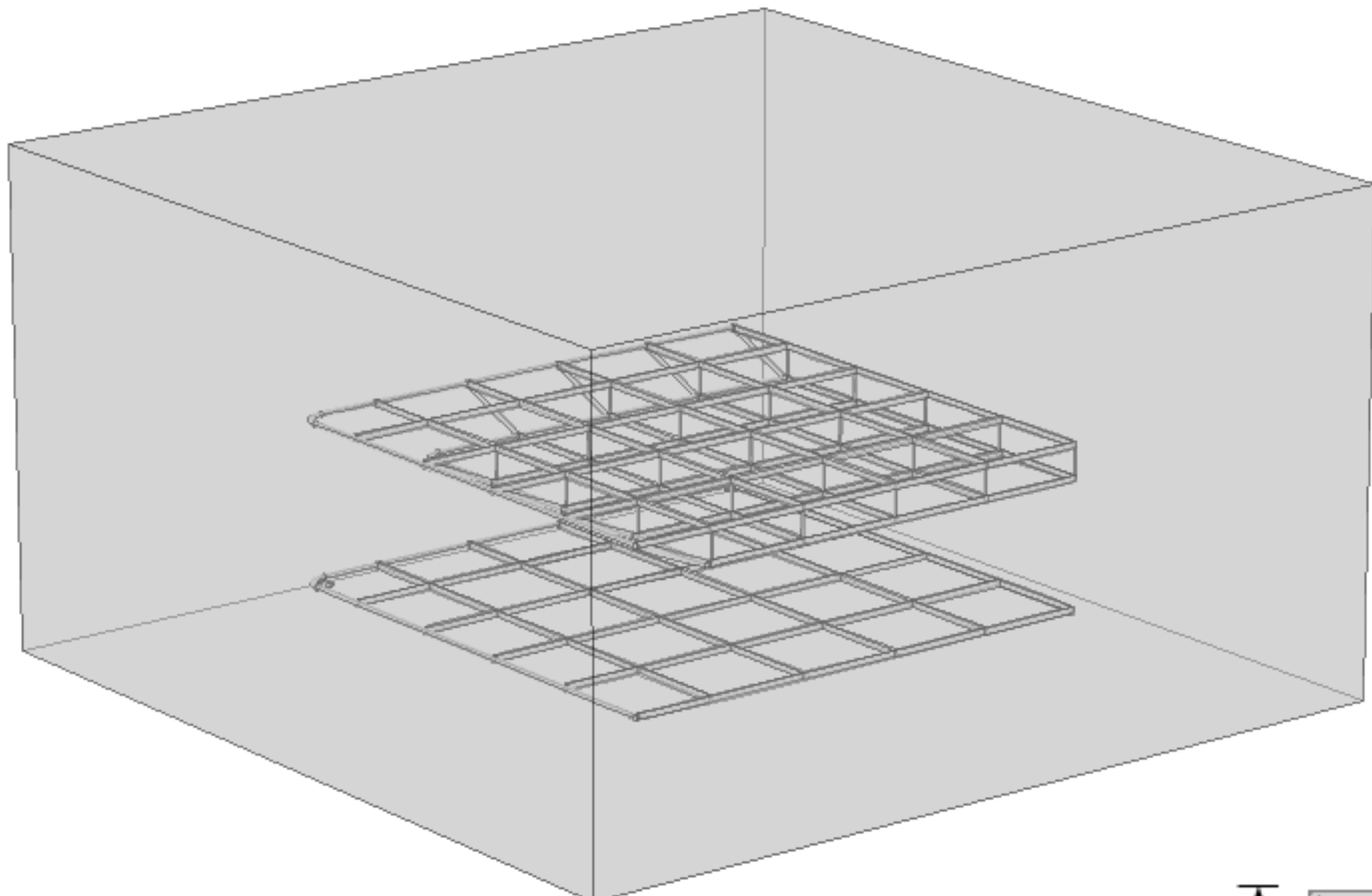


Electric field norm (kV/cm)
Distance=0
Distance=10
Distance=20
Distance=30
Distance=40
Distance=50
Distance=60
Distance=70
d=70 mm
d=0 mm
Drift field perturbations below 0.02 kV/cm 7 cm above the cathode
Electric field norm (kV/cm)
x-coordinate (mm)

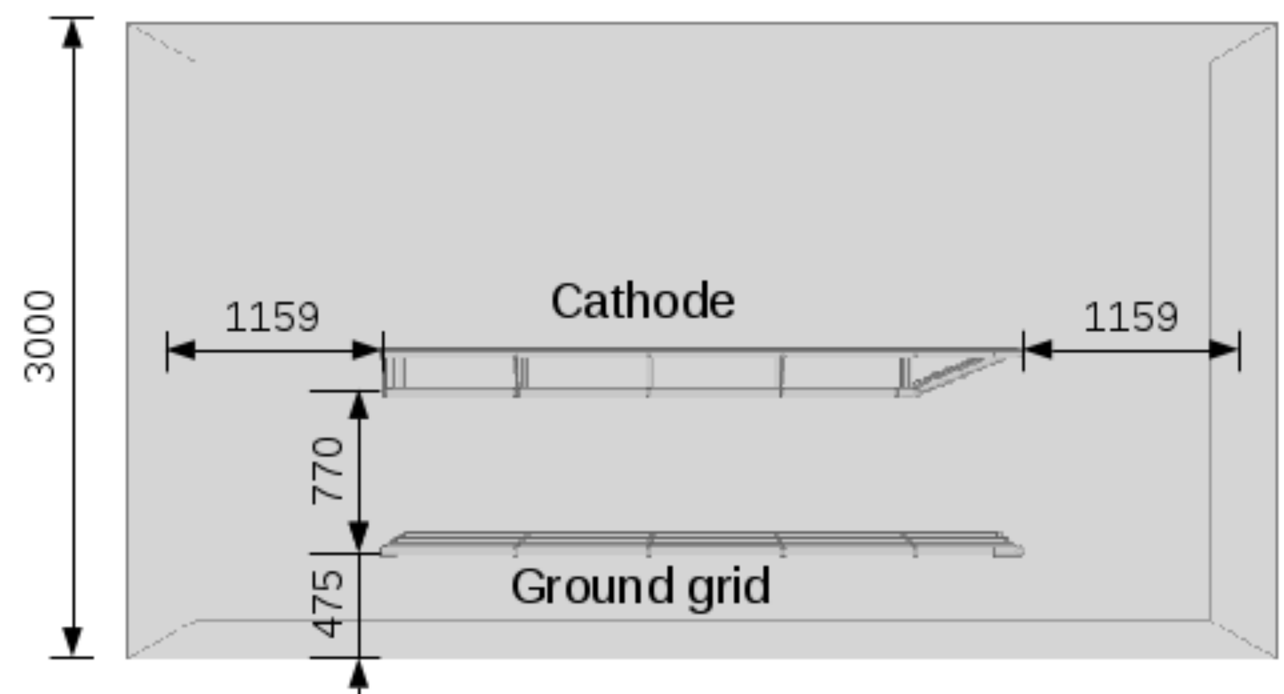
B)Cathode


2D-cross-section at the
level of the support
structure
Support structure
Pipes

B)Cathode



3D simulation of a corner of the cathode.
Small tubes not taken into account to simplify the simulation

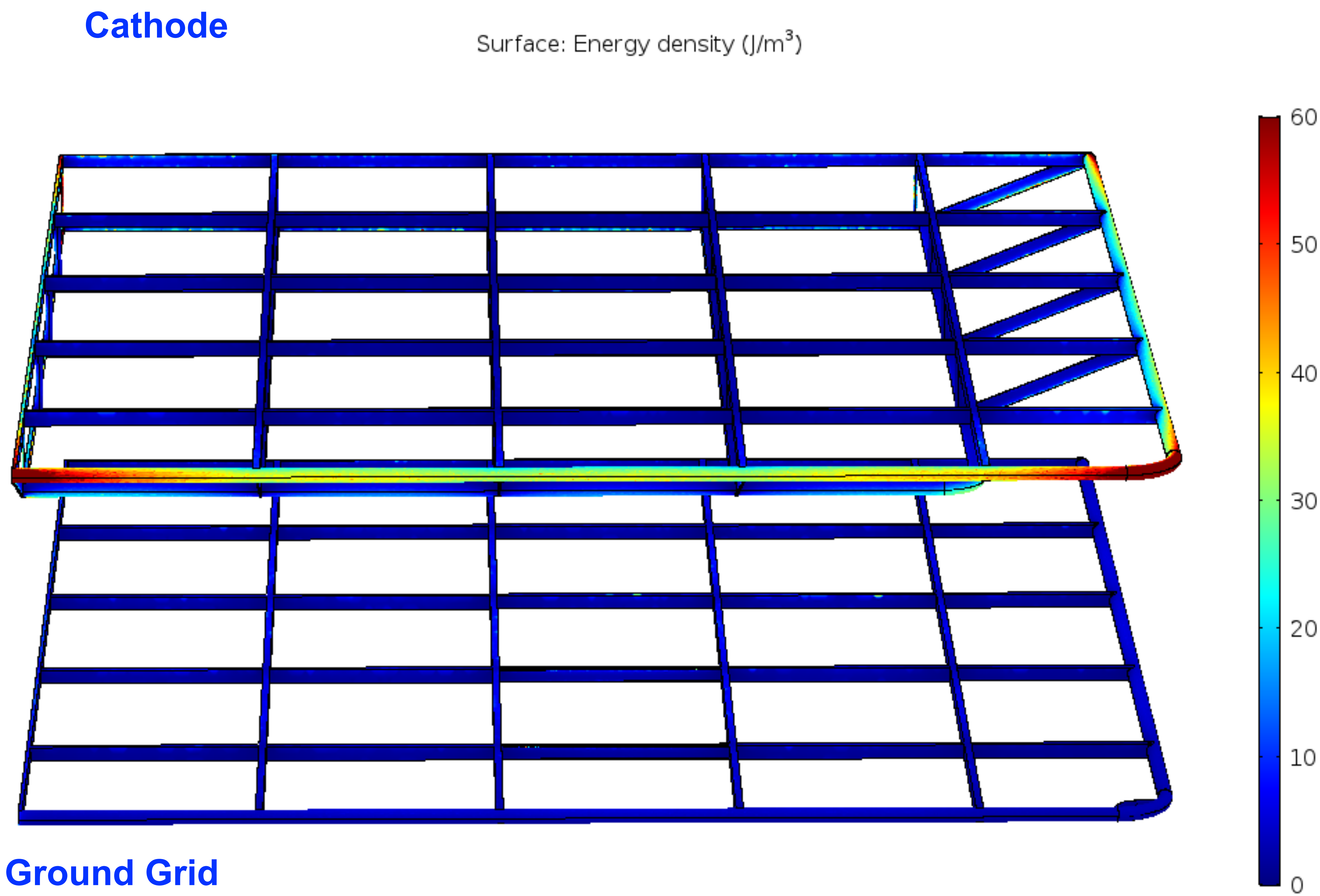


Capacitance obtained from simulations

$C_{1/4}$= 0.37 nF

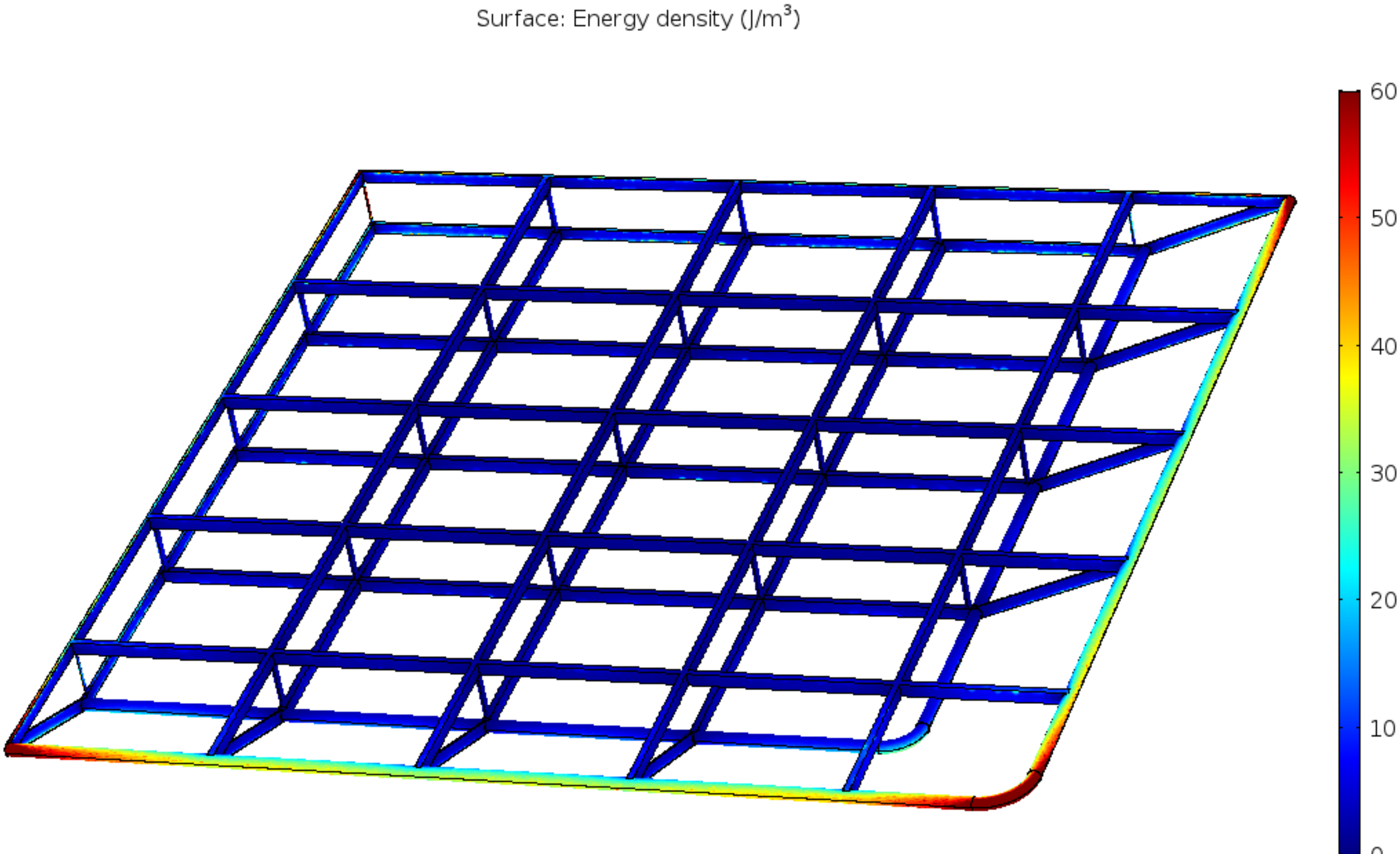
E = $1/2CV^2$=16.6 J

B)Cathode

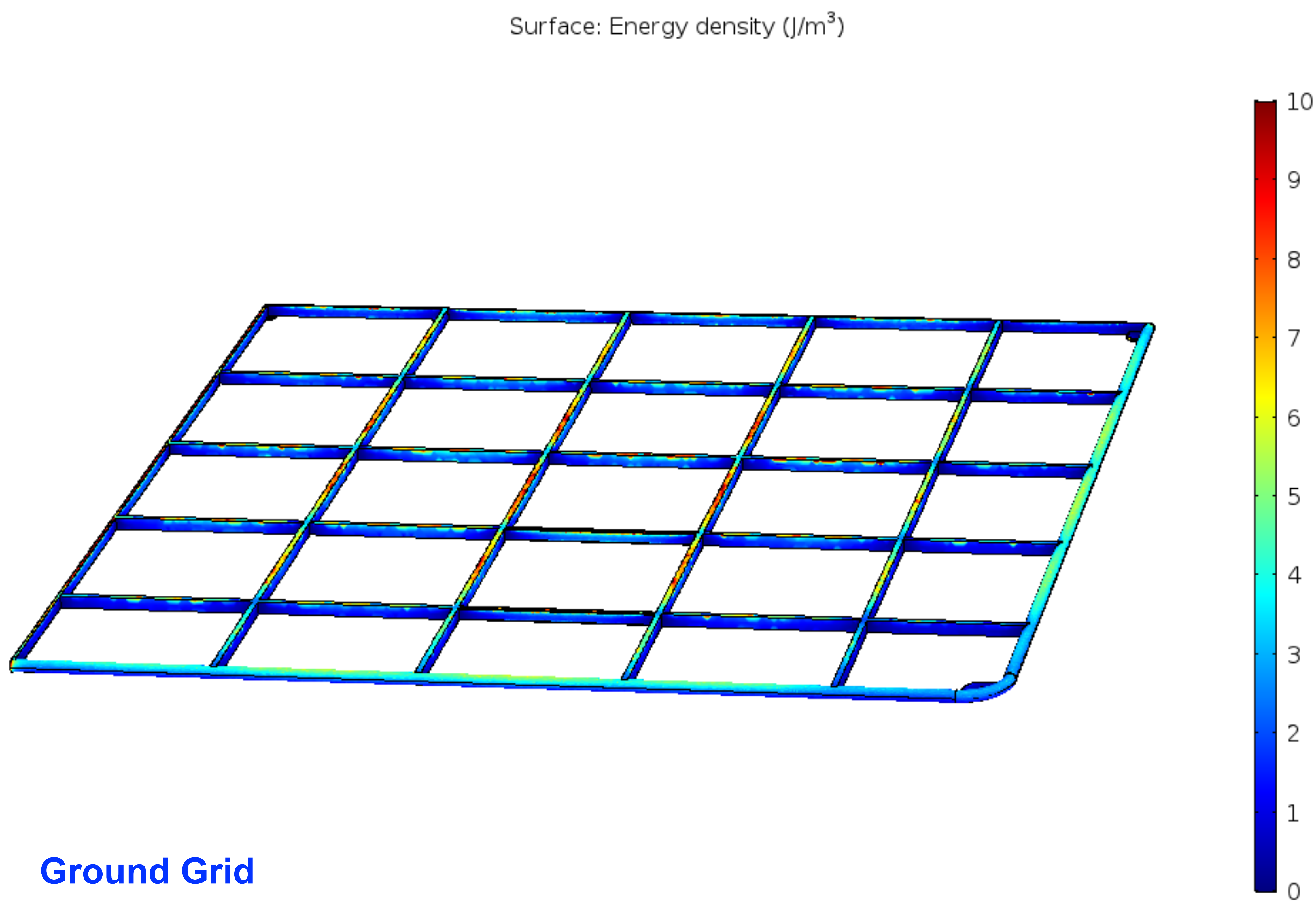

Cathode
Surface: Energy density (J/m³)
60
50
40
30
20
10
0
Ground Grid

B)Cathode

Cathode

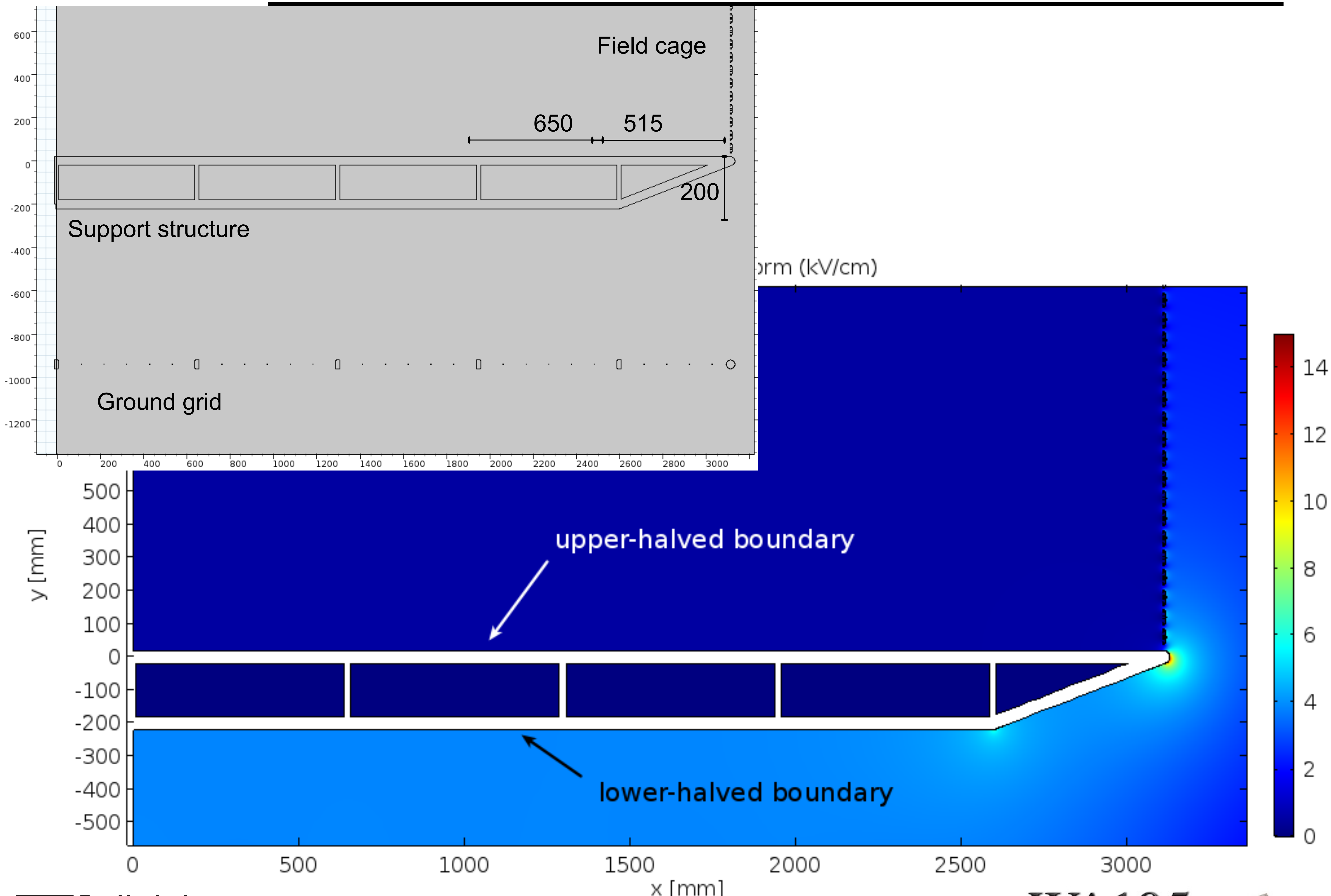


B)Cathode



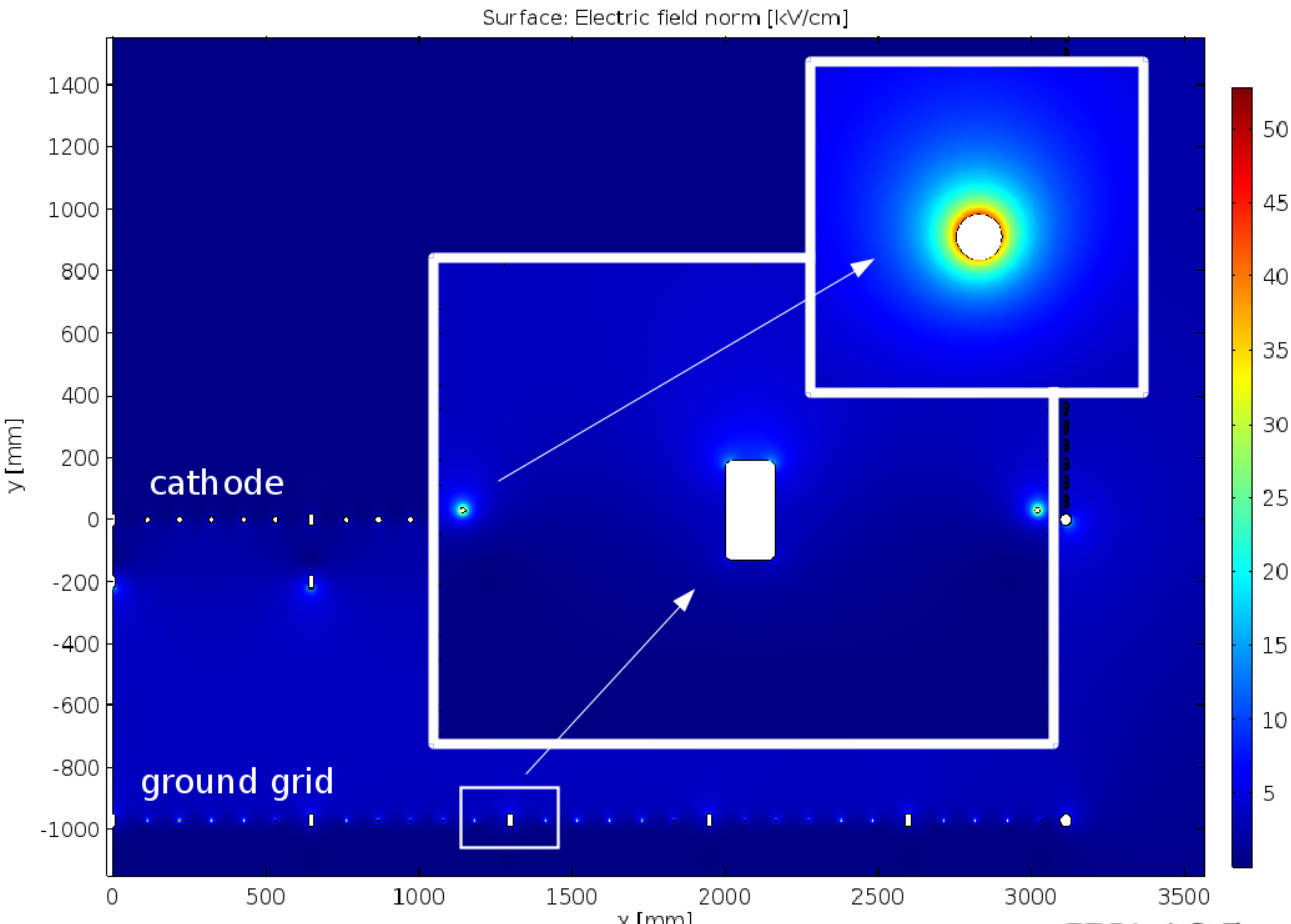
Ground Grid

B)Cathode

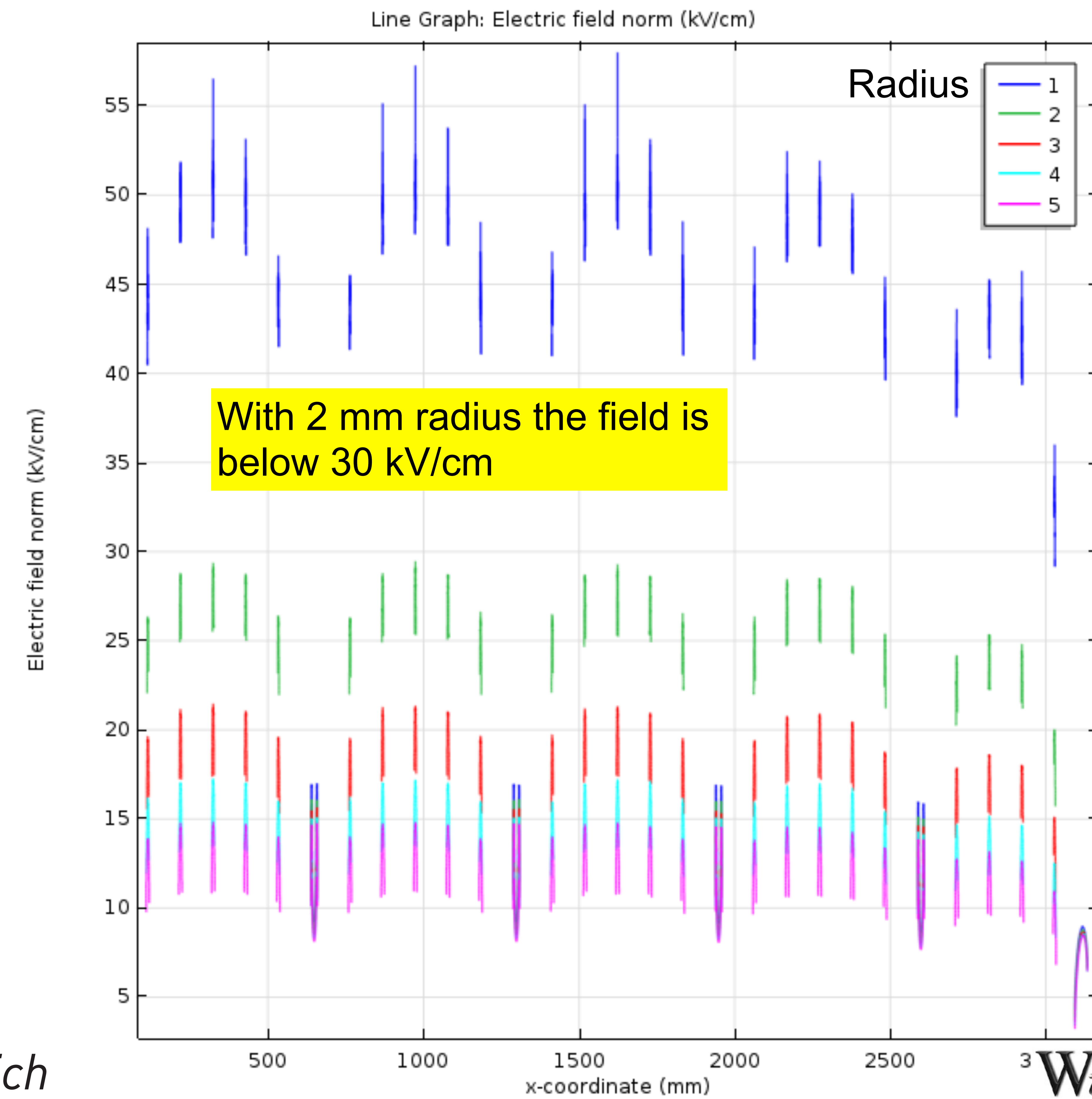


Field cage
650
515
200
Support structure
Ground grid
orm (kV/cm)
upper-halved boundary
lower-halved boundary
y [mm]
x [mm]

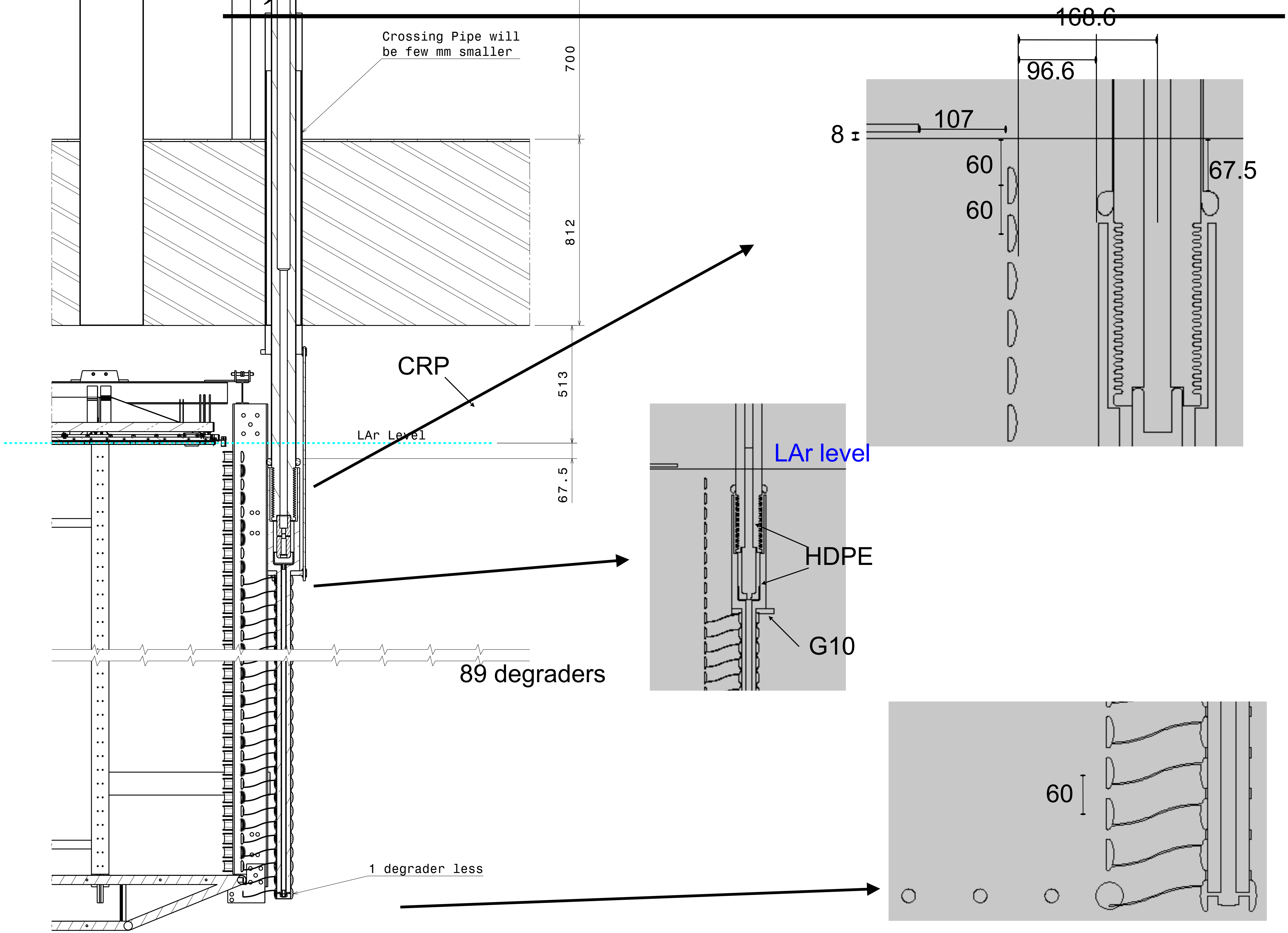
C)Ground grid



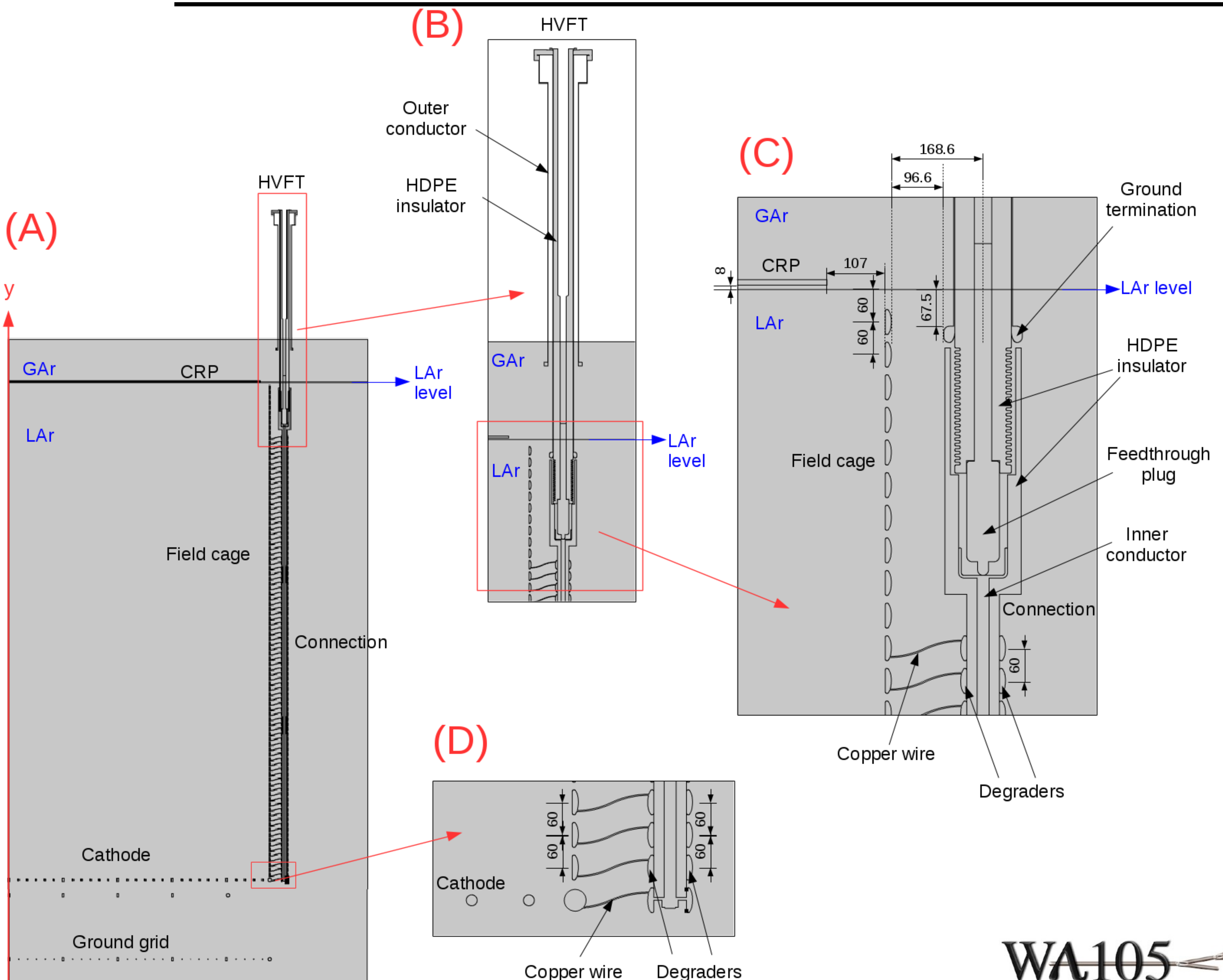
C)Ground grid



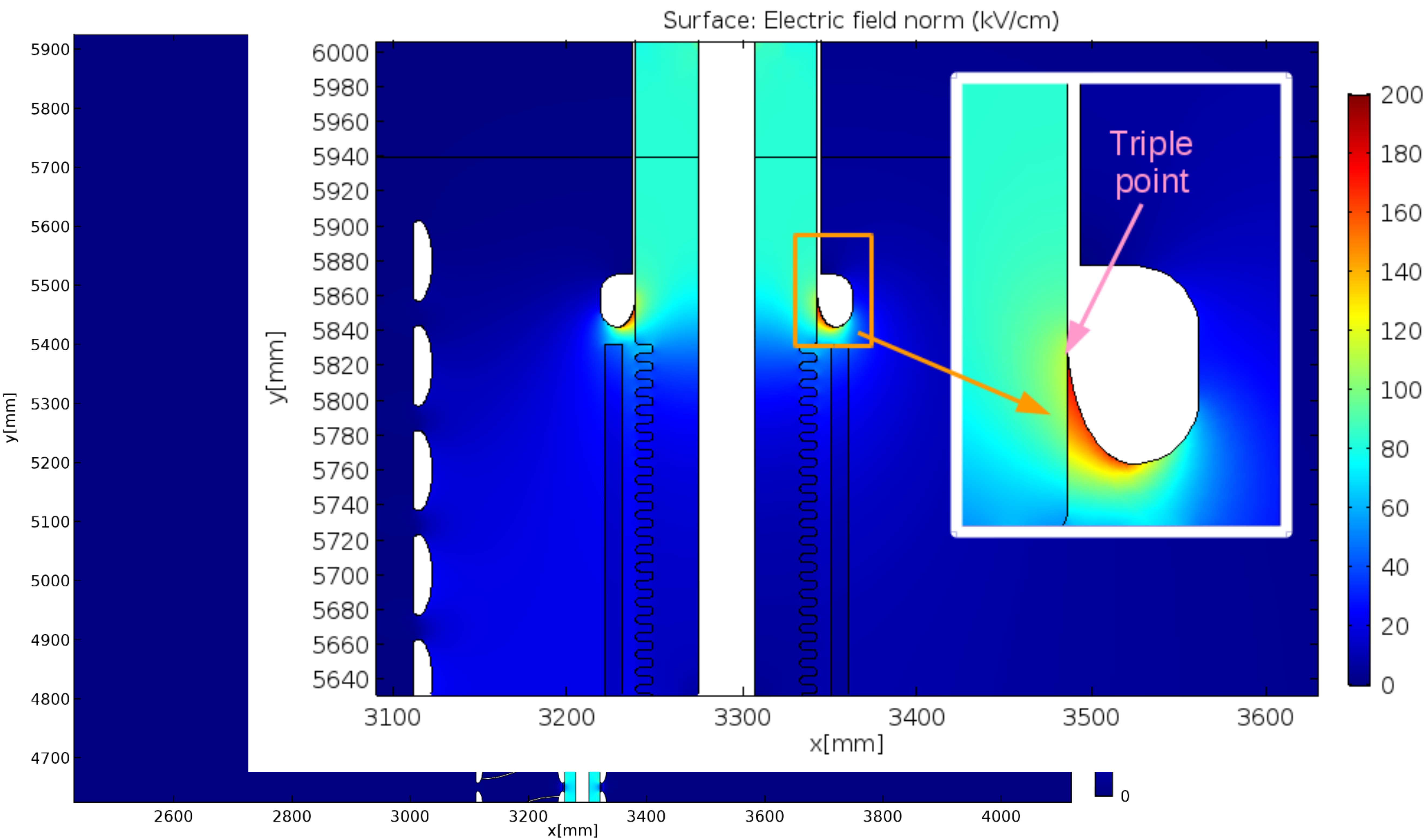
D)HVFT + connection to the cathode



D)HVFT + connection to the cathode

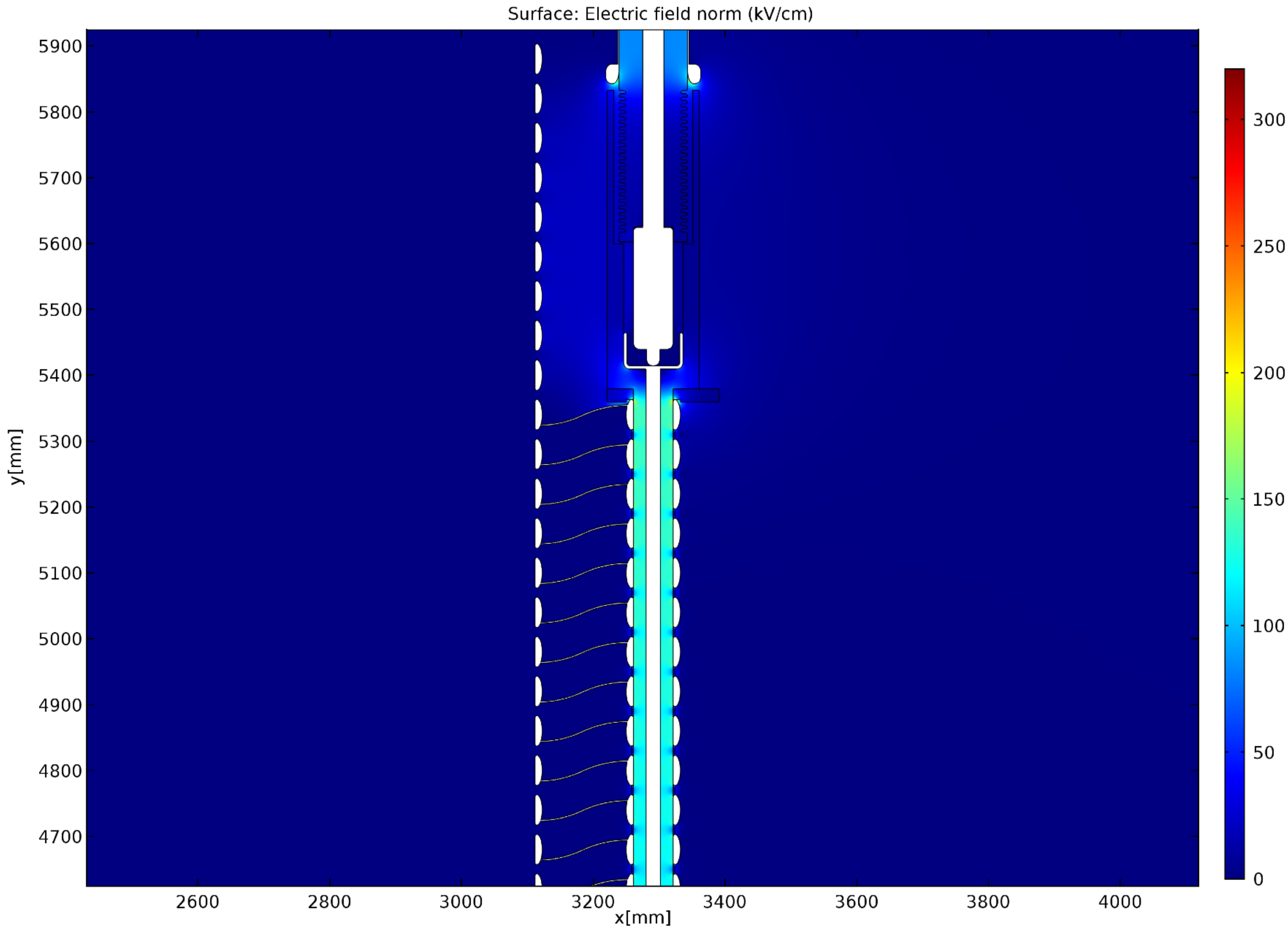


D)HVFT + connection to the cathode

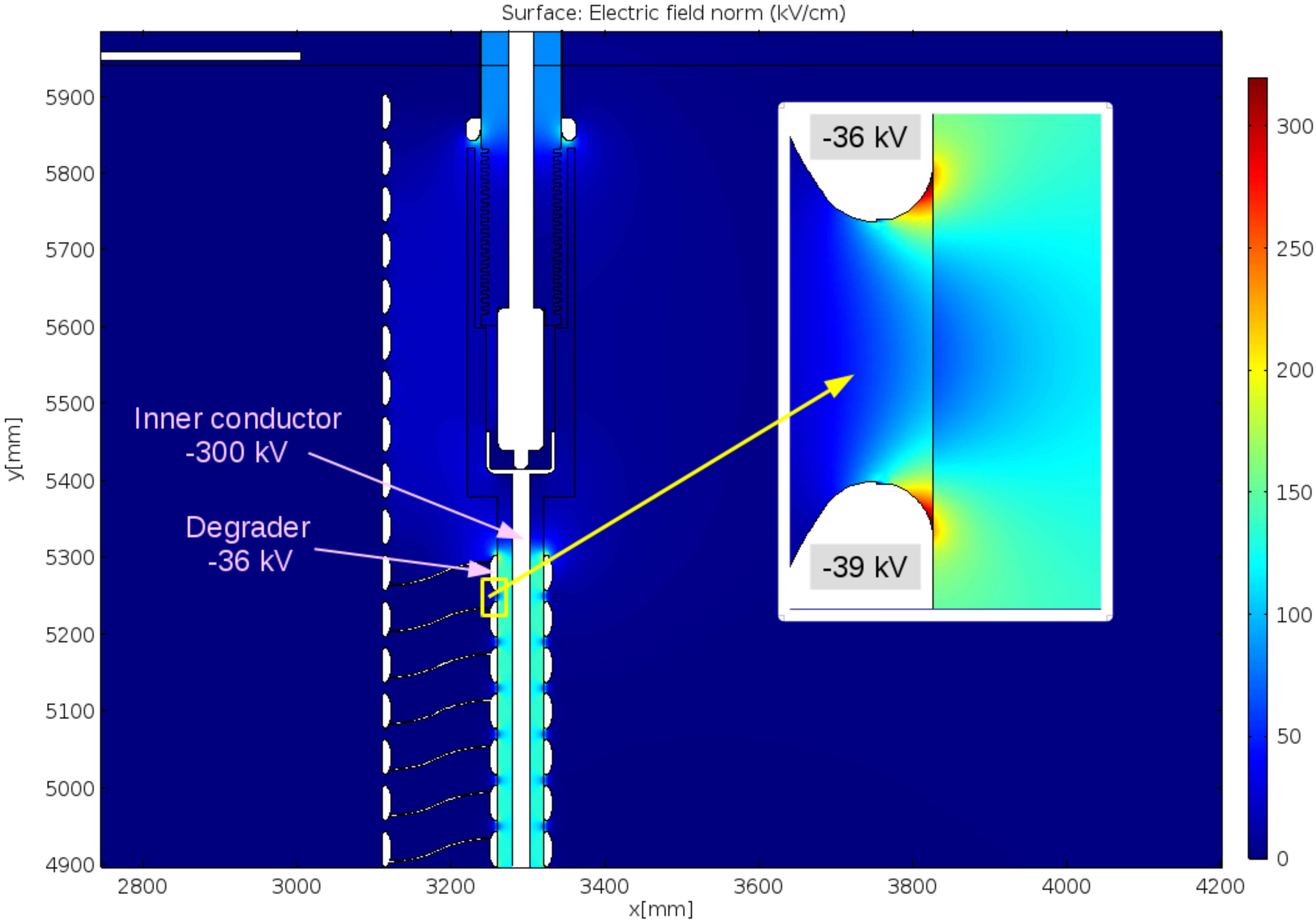


Electric field locally higher than our guideline, electric field in LAr below 40 kV/cm

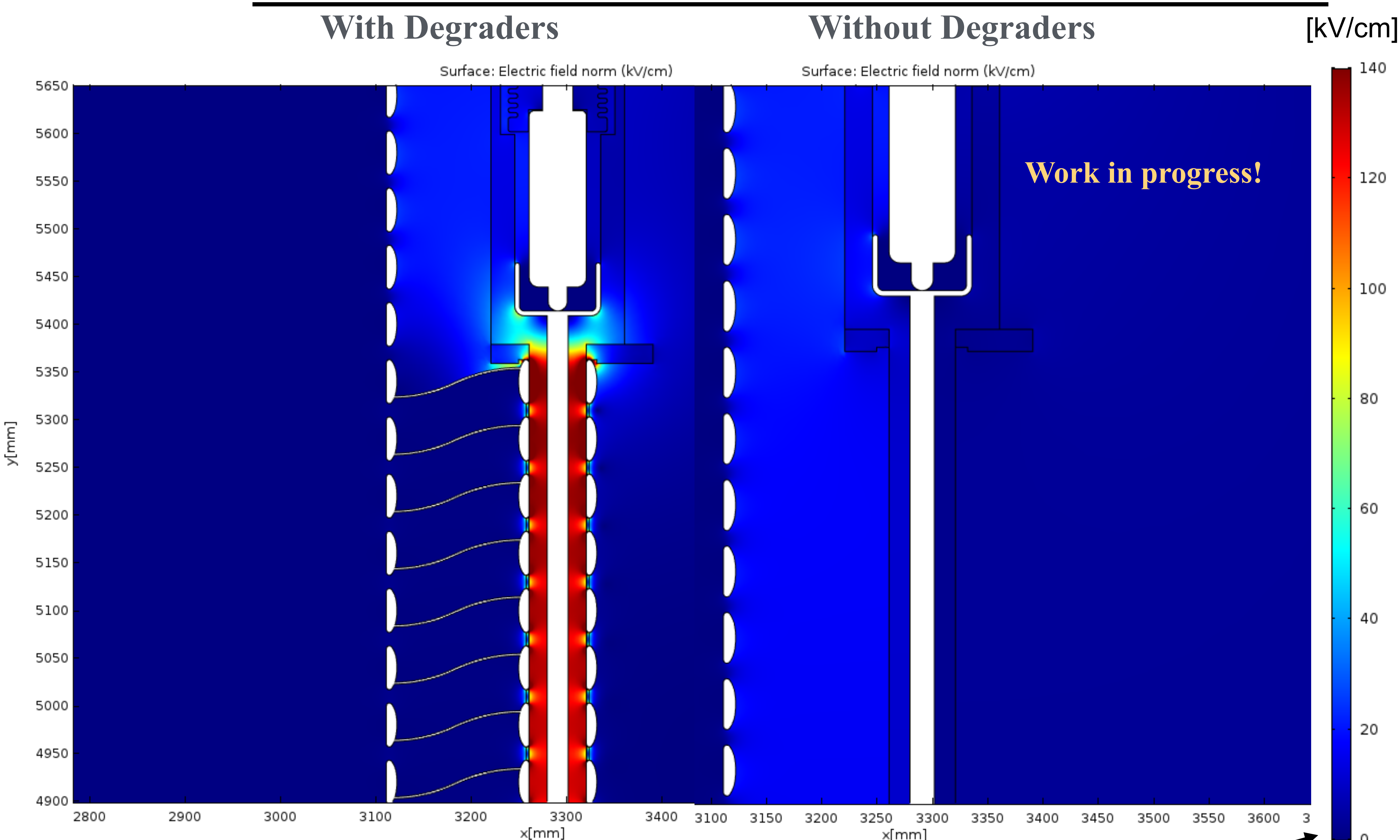
D)HVFT + connection to the cathode



D)HVFT + connection to the cathode

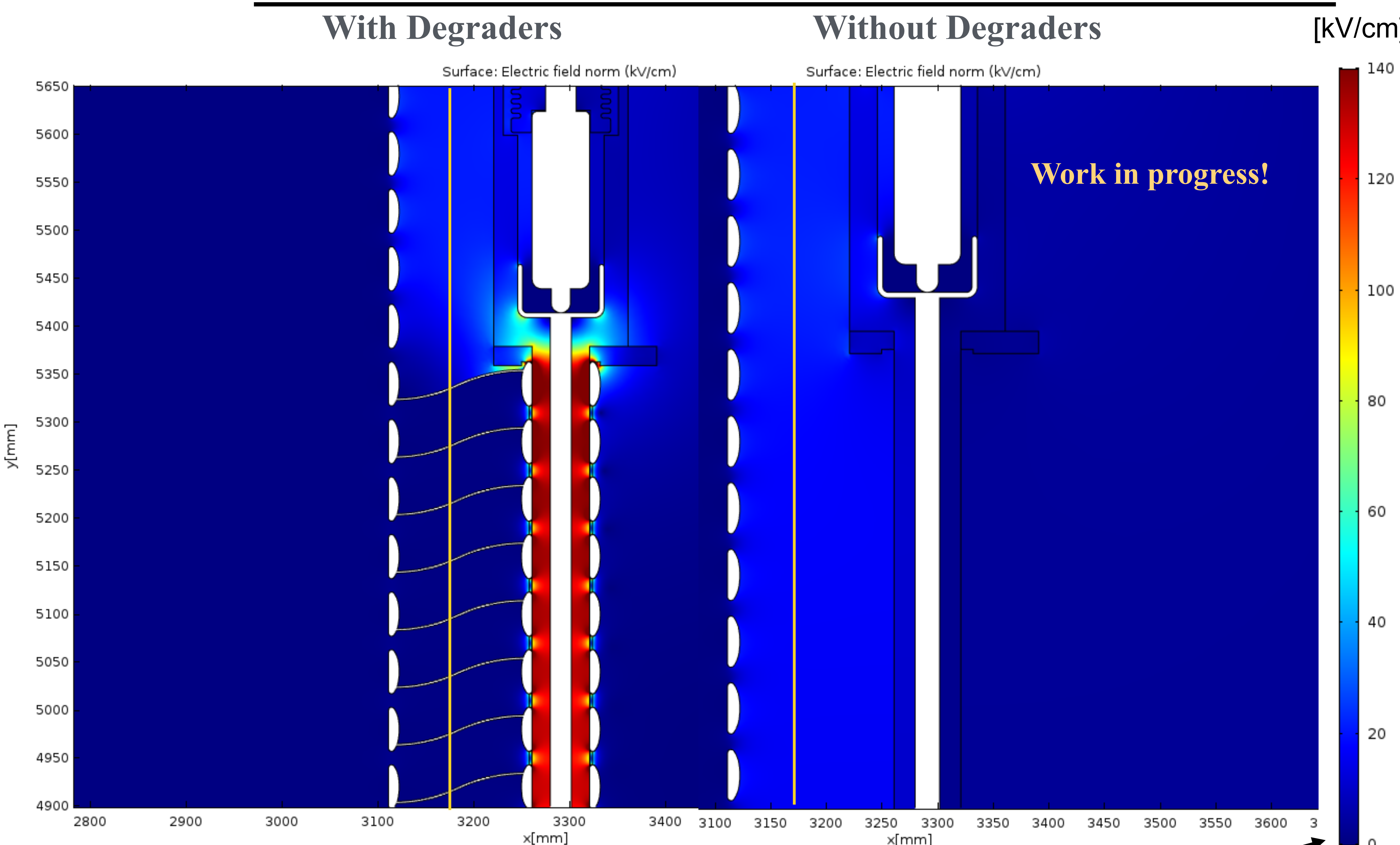


D)HVFT + connection to the cathode



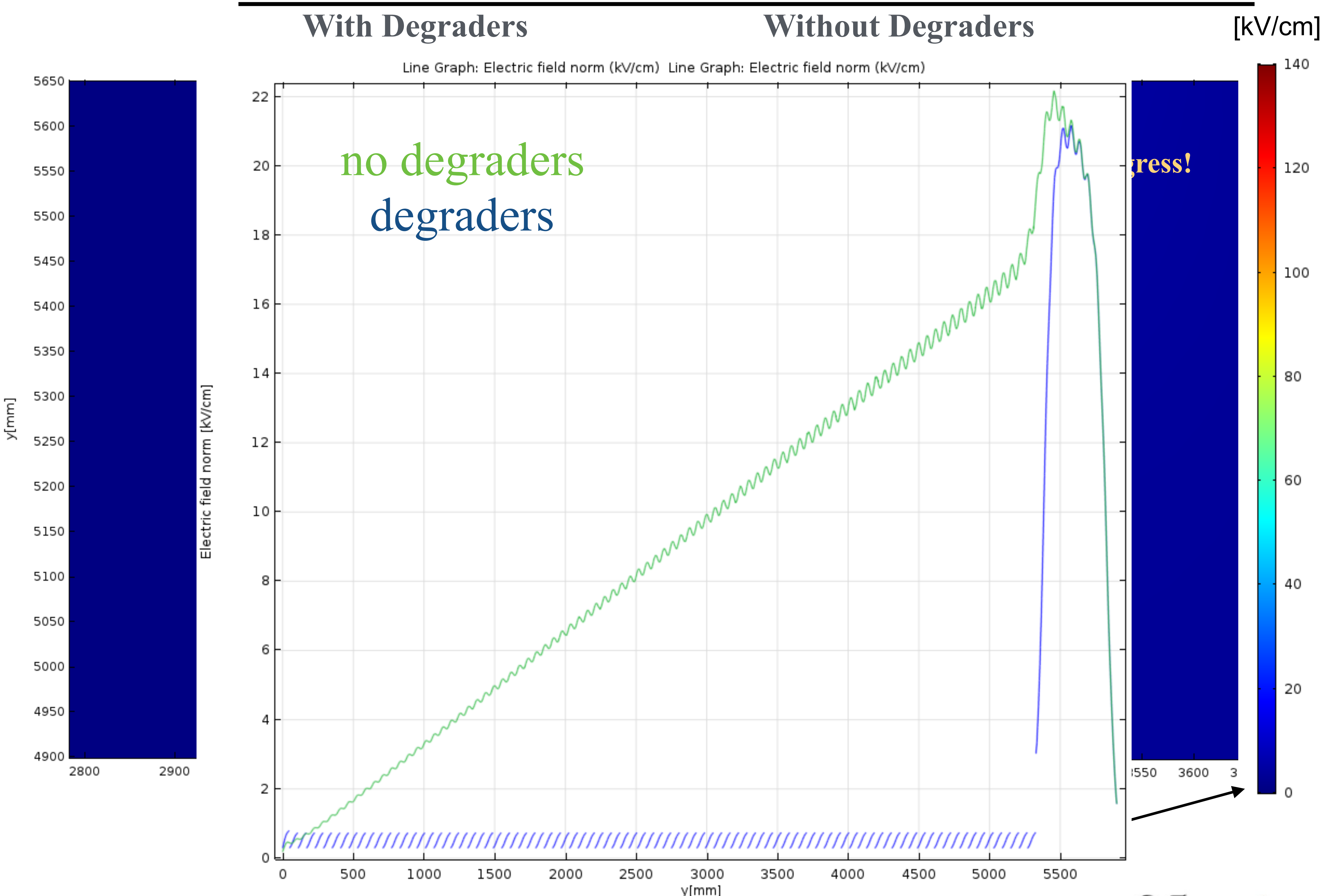
*scale adjusted to be able to compare both cases

D)HVFT + connection to the cathode



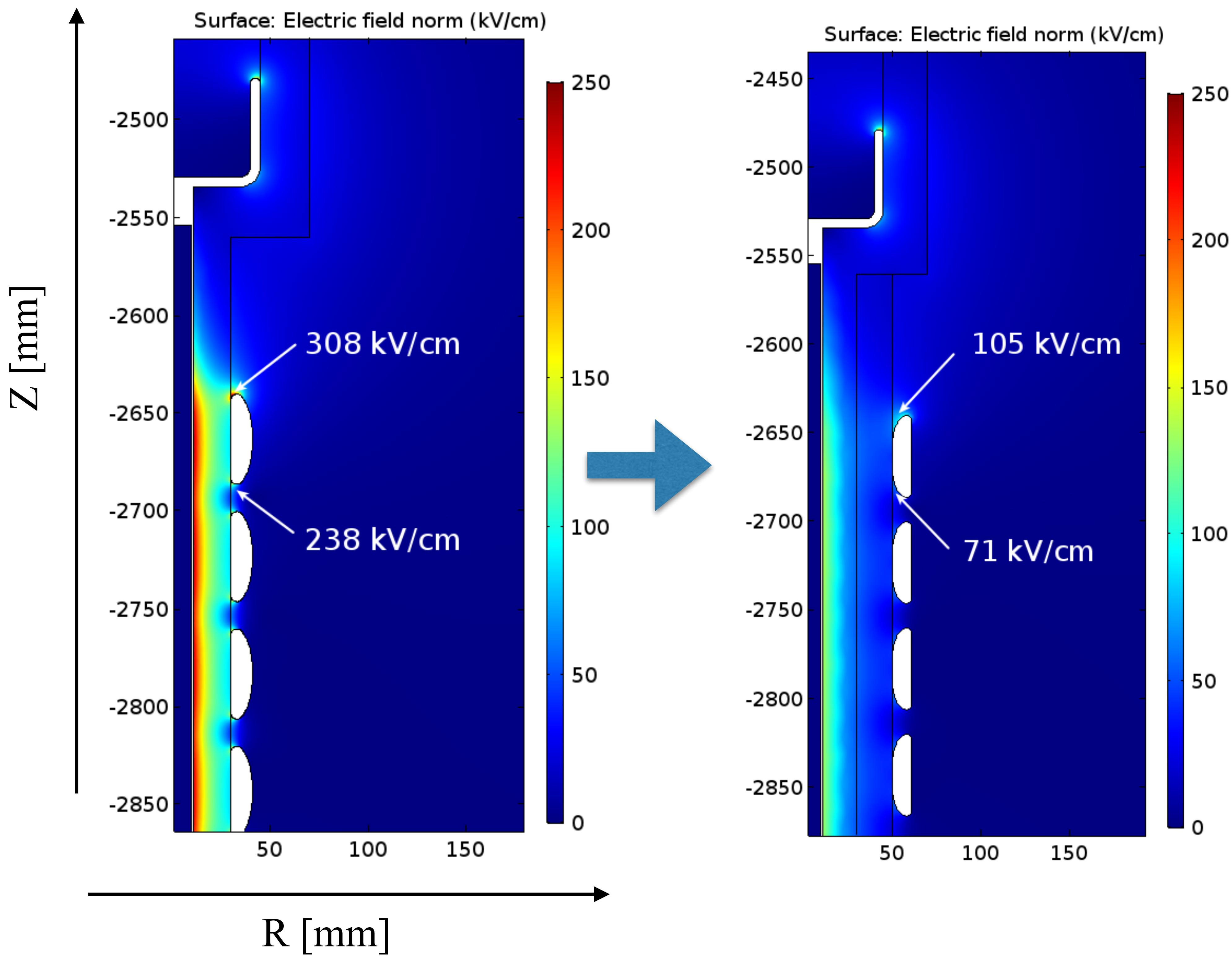
*scale adjusted to be able to compare both cases

D)HVFT + connection to the cathode



D)HVFT + connection to the cathode

- Improved design done by **Franco to minimise the high electric field locally**.

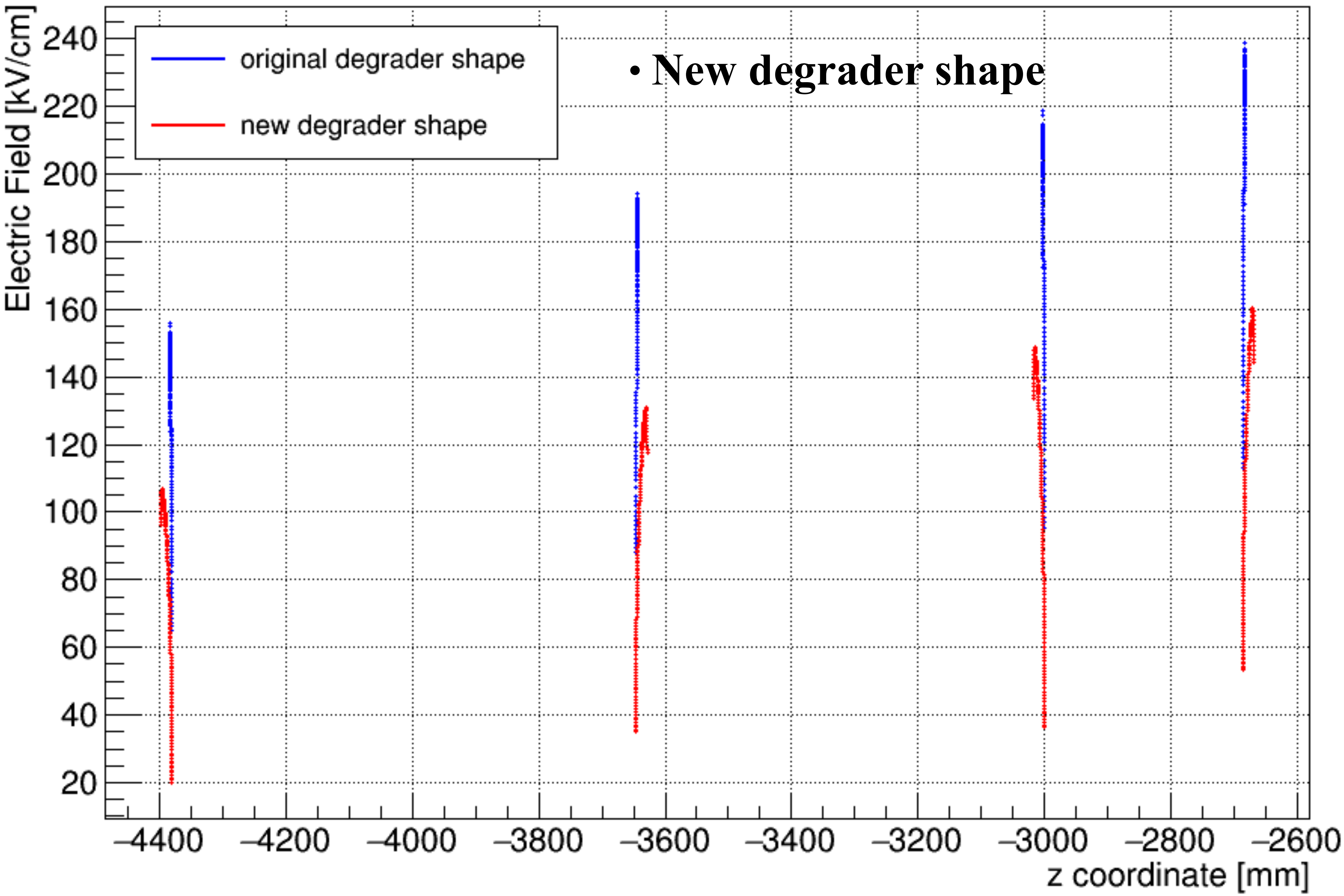


Main changes:

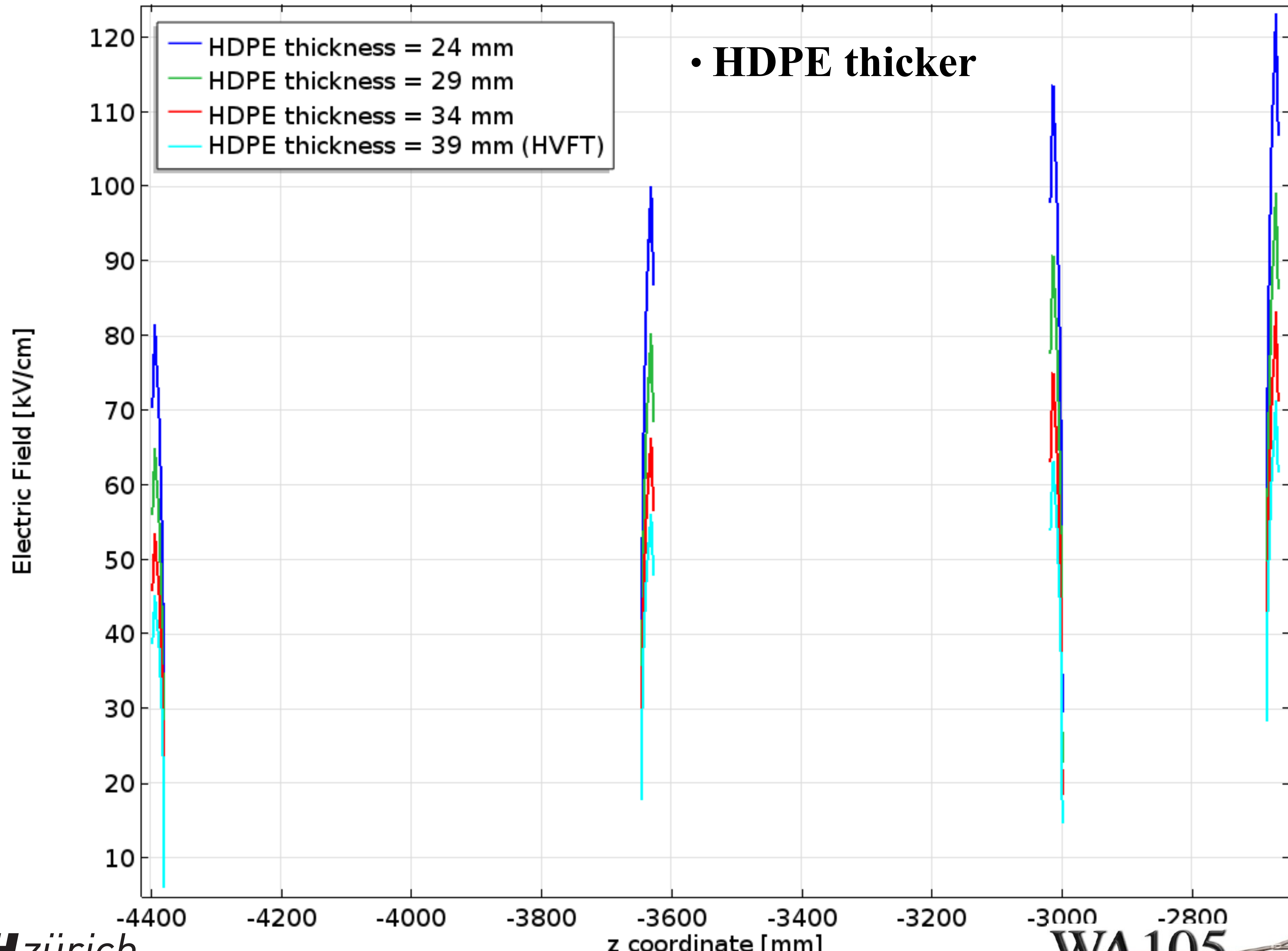
- **HDPE thicker**
- **New degrader shape**
- **No G10 spacers**

We need to verify mechanically the design

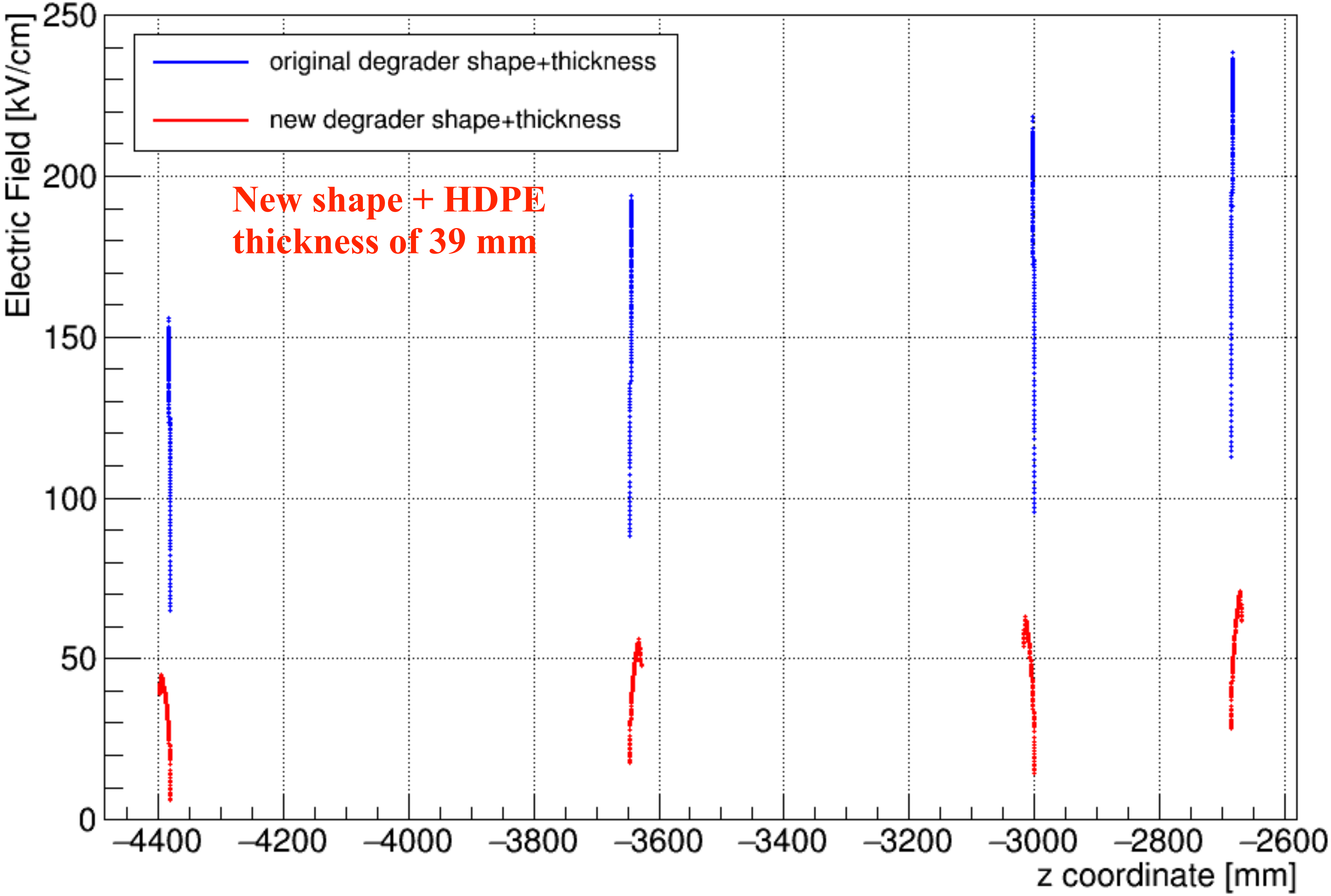
D)HVFT + connection to the cathode

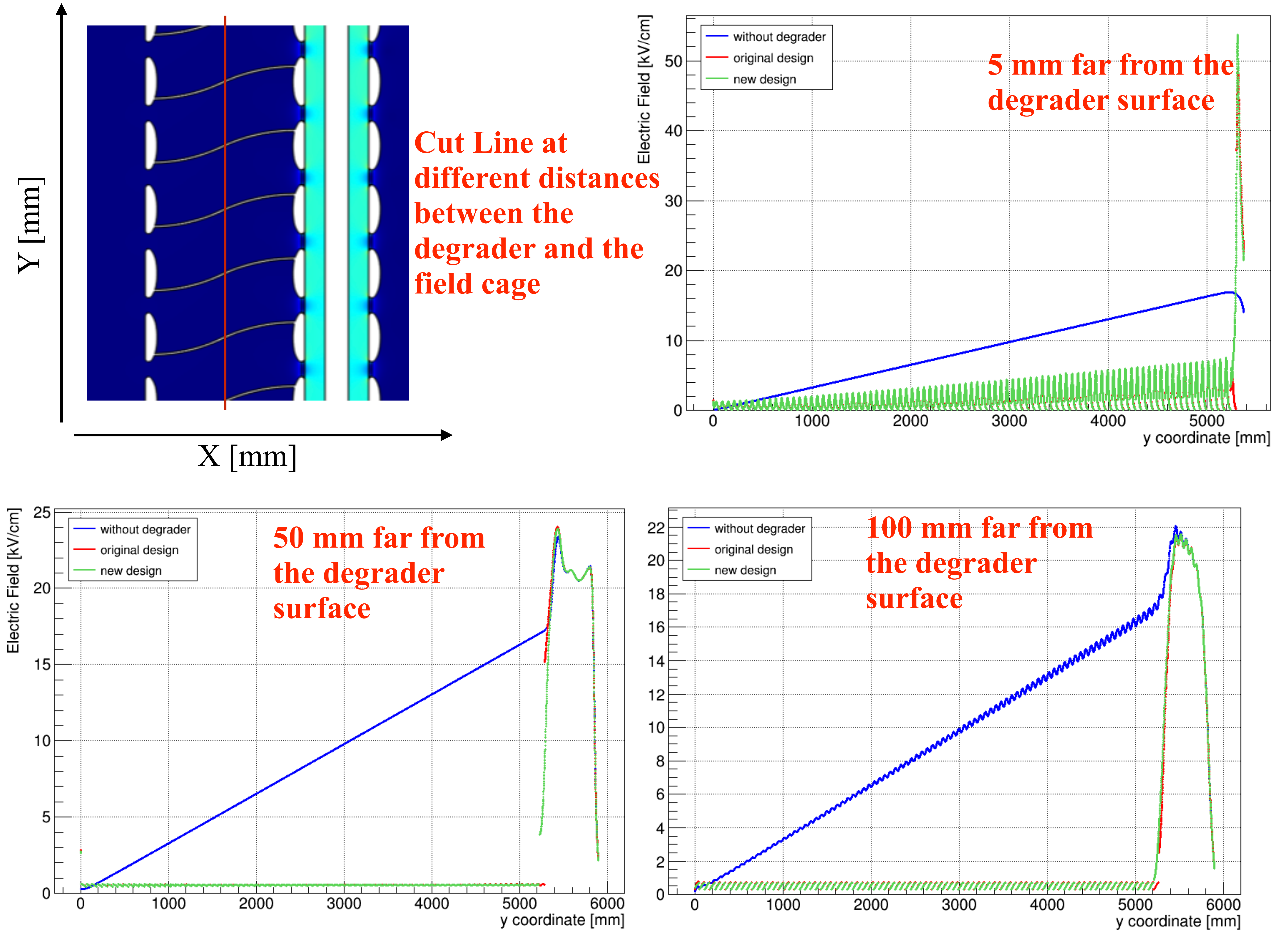


D)HVFT + connection to the cathode



D)HVFT + connection to the cathode




Y [mm]
X [mm]
Cut Line at different distances between the degrader and the field cage
Electric Field [kV/cm]
without degrader
original design
new design
5 mm far from the degrader surface
y coordinate [mm]
Electric Field [kV/cm]
without degrader
original design
new design
50 mm far from the degrader surface
y coordinate [mm]
without degrader
original design
new design
100 mm far from the degrader surface
y coordinate [mm]

Conclusions:

Simulations: electrostatic simulation of the whole field cage design

A. **Field cage:** final design 2D simulation performed:
   - **Clip:** based on simulations, the proposed design does not represent any problem.

B. **Cathode:**
   - Along all the structure the field is below 30 kV/cm.
   - Drift field uniformity acceptable above 7 cm from the cathode.
   - 3D simplified simulations performed .to estimate the capacitance.

C. **Ground grid:**
   - 2 mm radius wires to have a field below 30 kV/cm.

D. **High voltage feedthrough:**
   - Simulation of the field along the HVFT calculated and the highest field is reached at the end of the outer conductor.
   - Simulation and design of the connection between the HVFT and the cathode are work in progress.