200 kV gun CST microwave studio simulations
Shield modifications

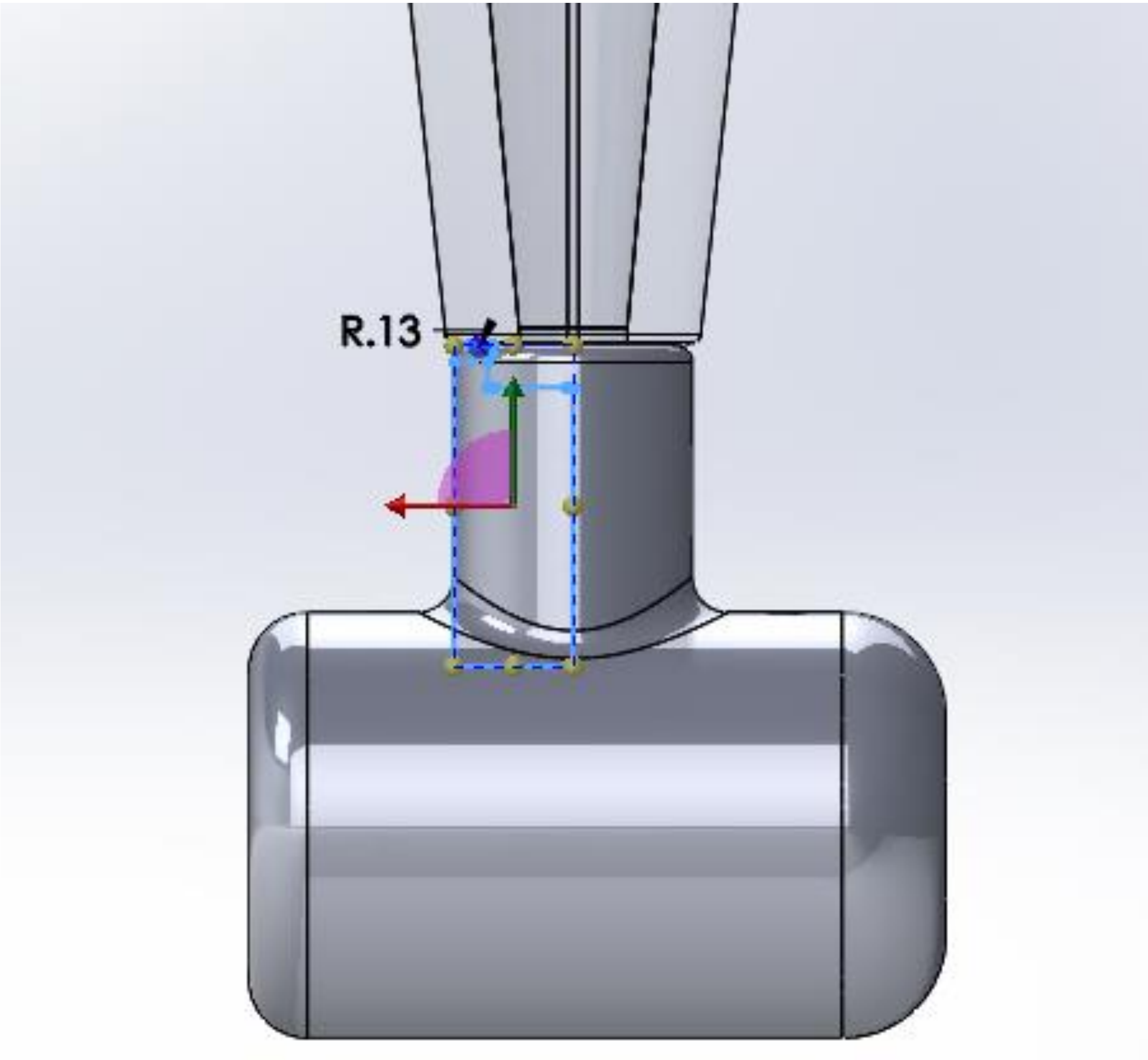
Gabriel Palacios

gabrielp@jlab.org
07/11/18

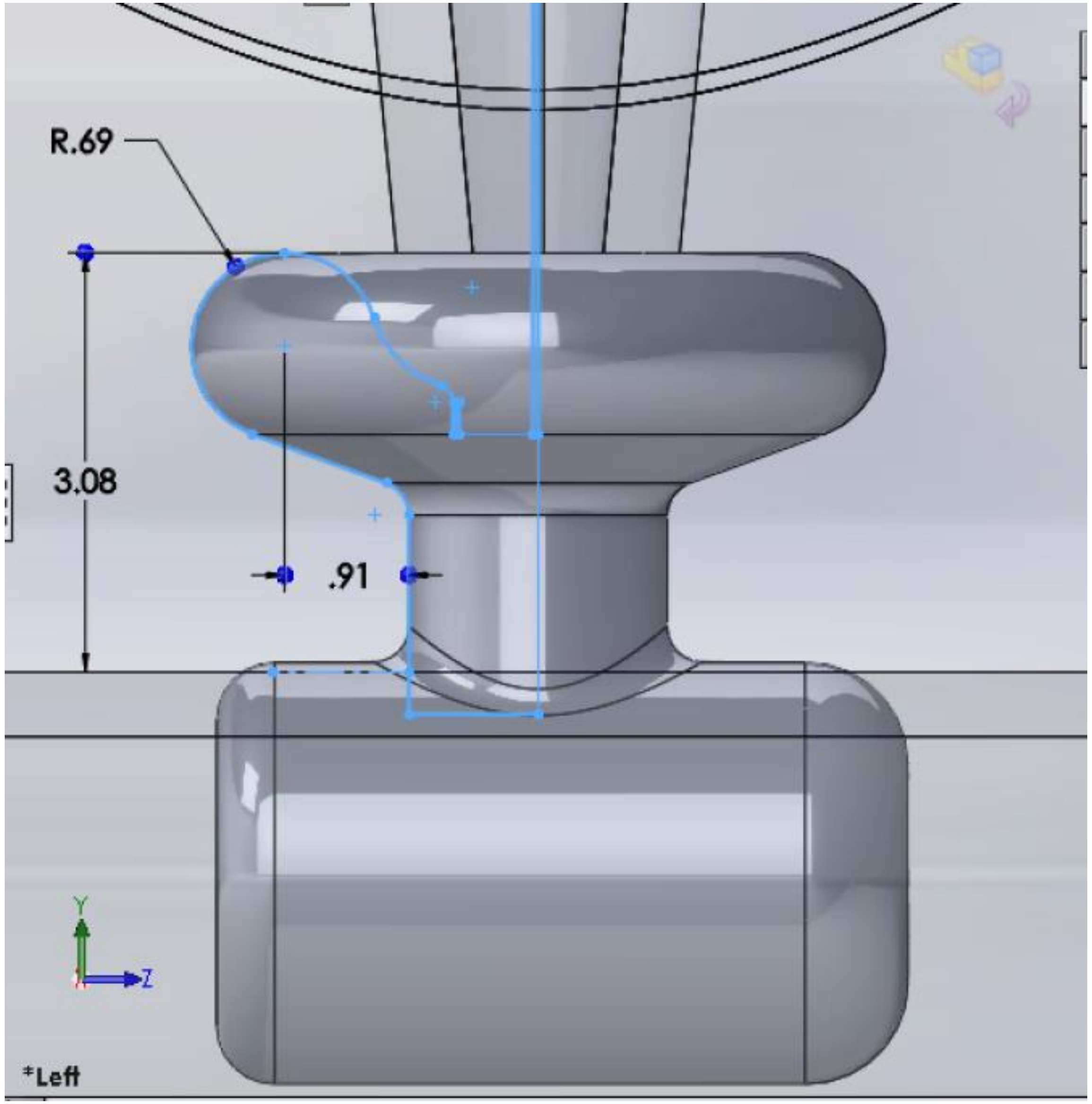
Summary

- Solidworks
  - Geometry modifications: 4 new shield proposals.
    - Shields 1 and 2 have decreasing height
    - Shields 3 and 4 have decreasing radius
- CST
  - Details of simulation
  - Electric field and potential plots and false color images
- Additional slides

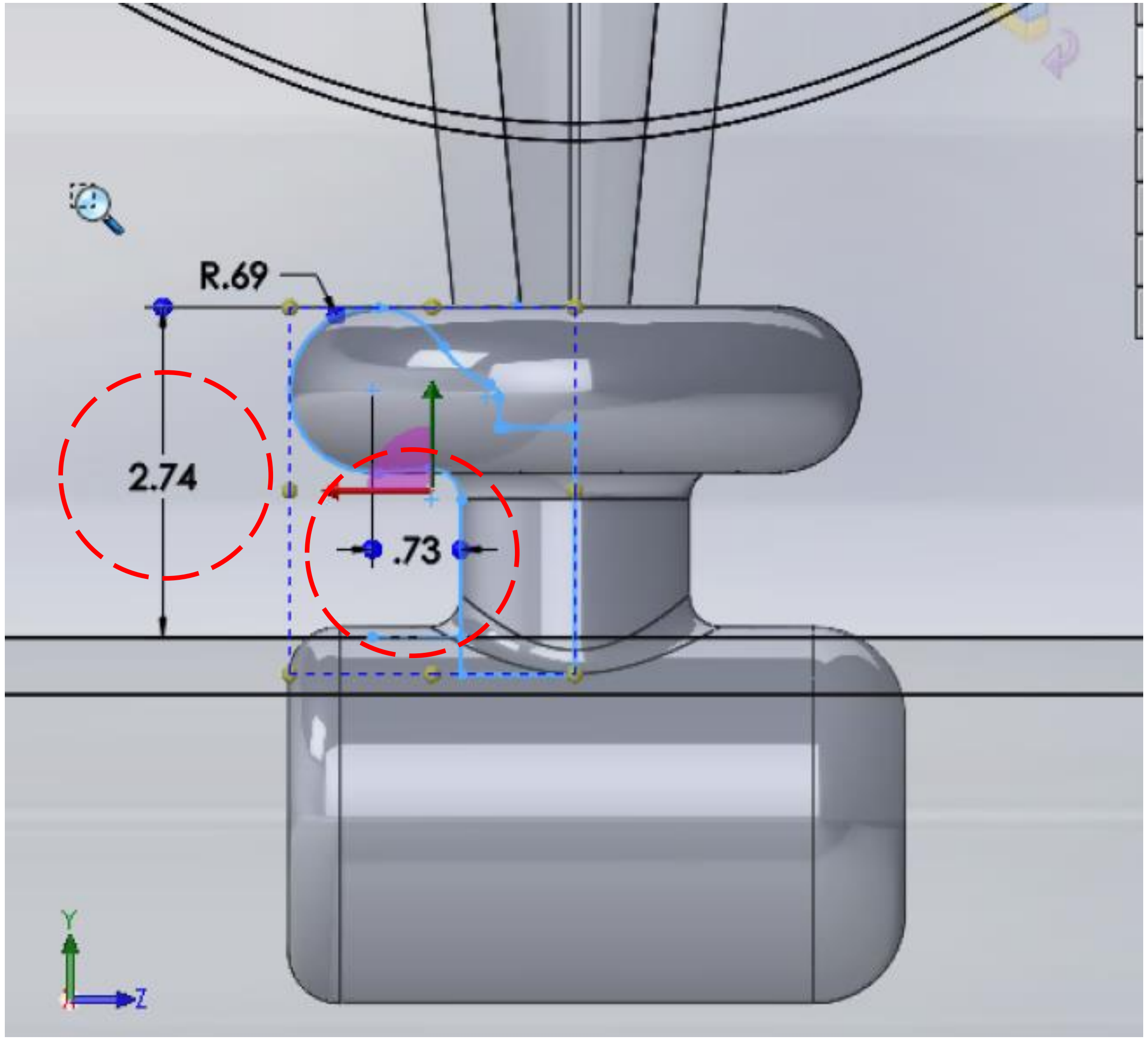
Solidworks geometry modifications: No shield



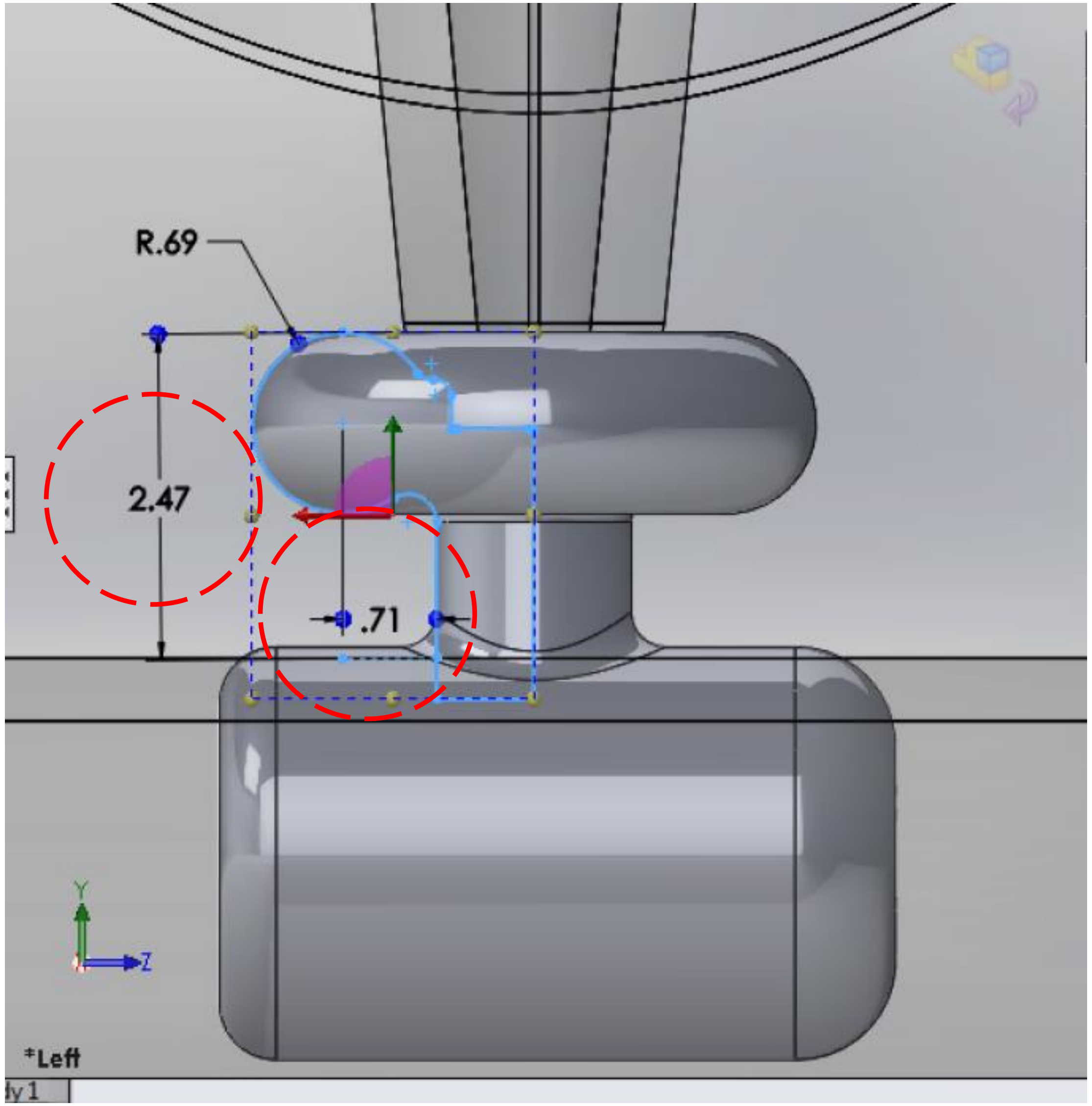
Solidworks geometry modifications: Original



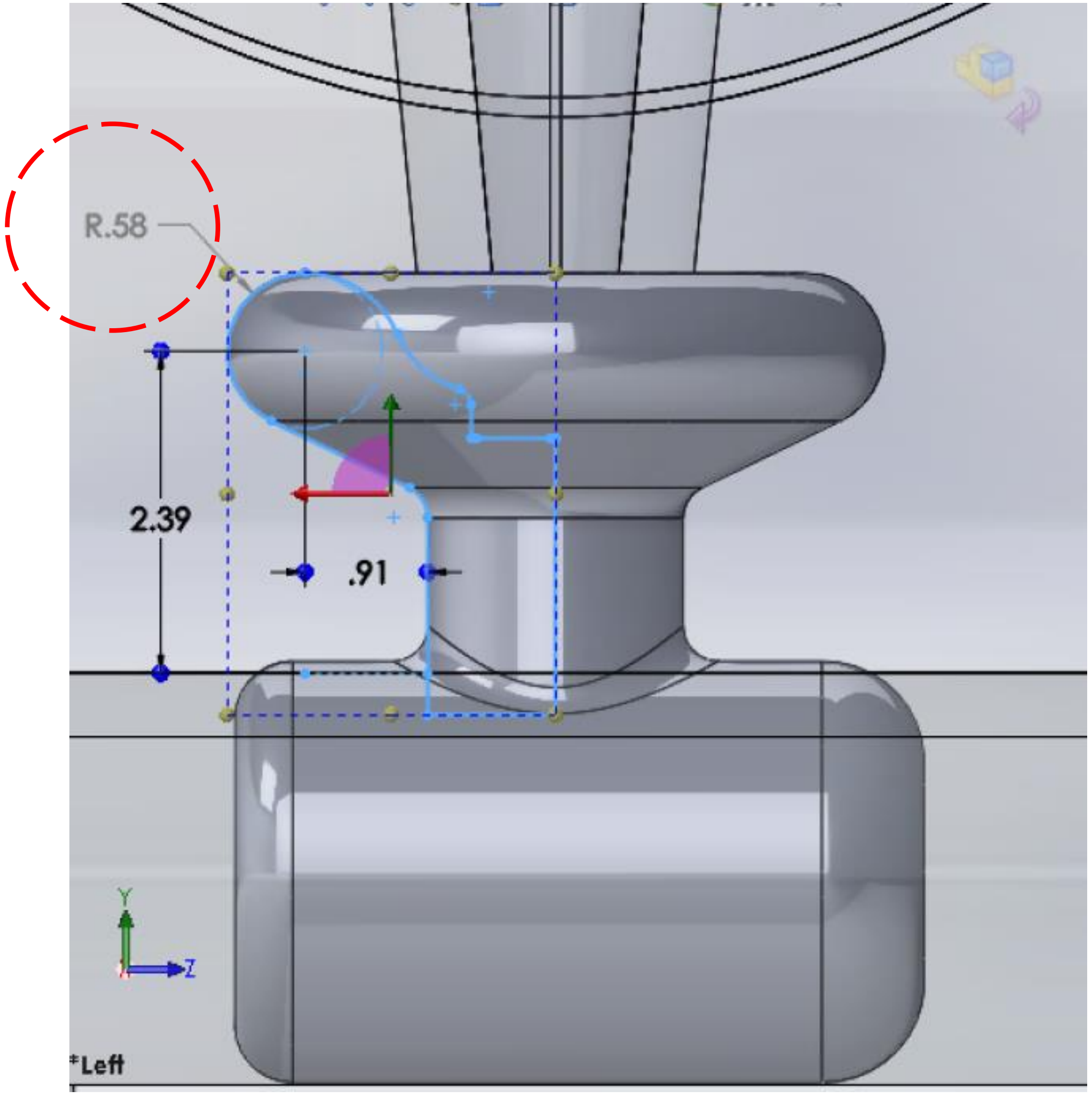
Solidworks geometry modifications: Shield 1



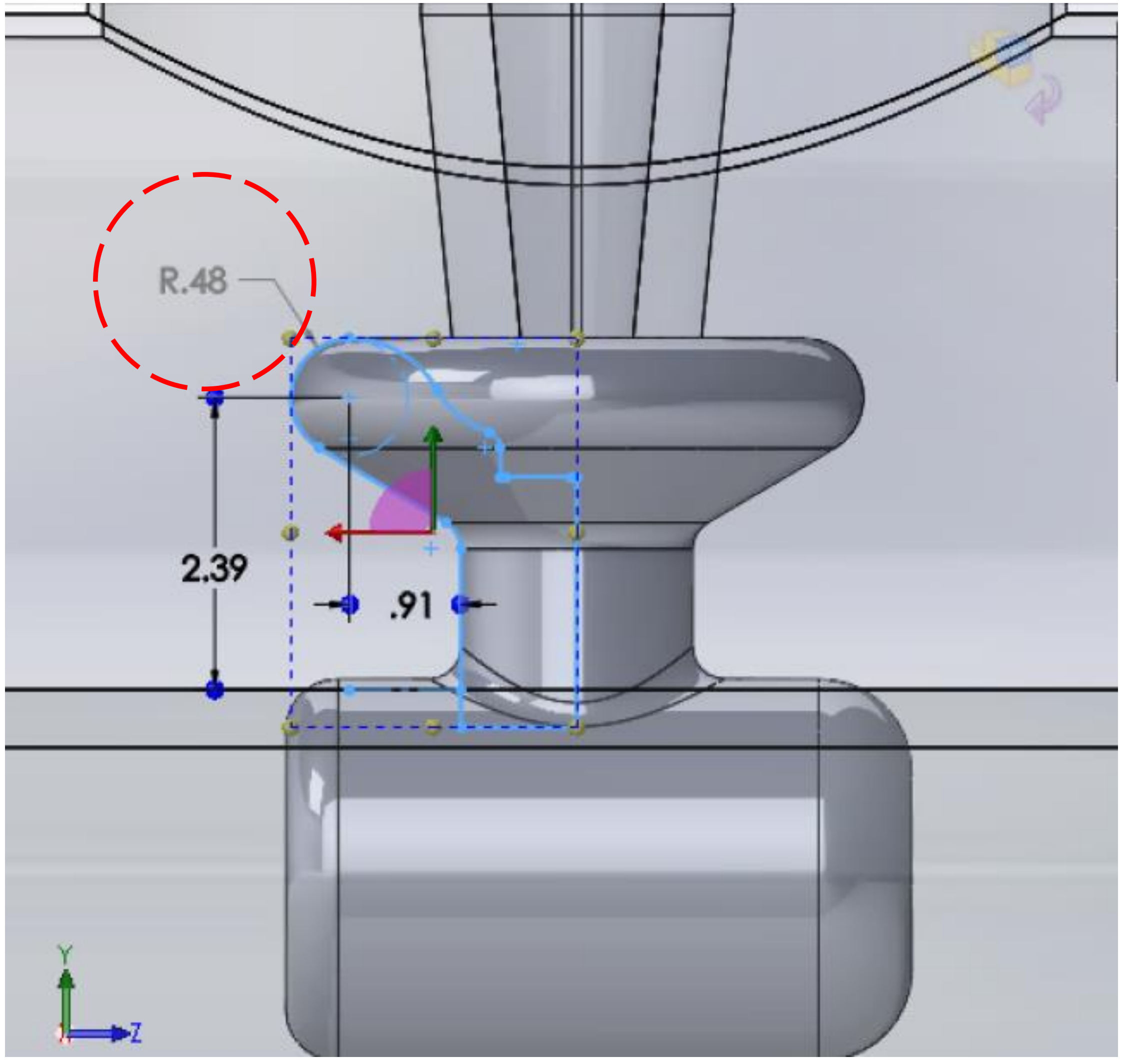
Solidworks geometry modifications: Shield 2



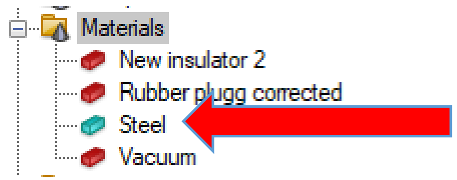
Solidworks geometry modifications: Shield 3



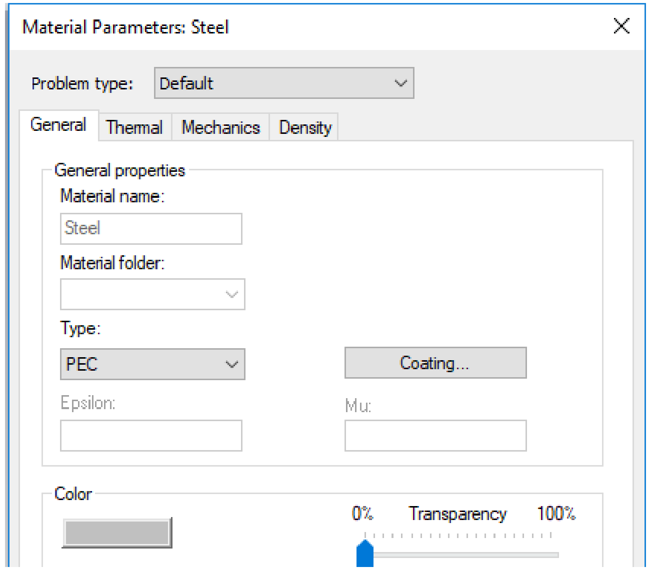
Solidworks geometry modifications: Shield 4

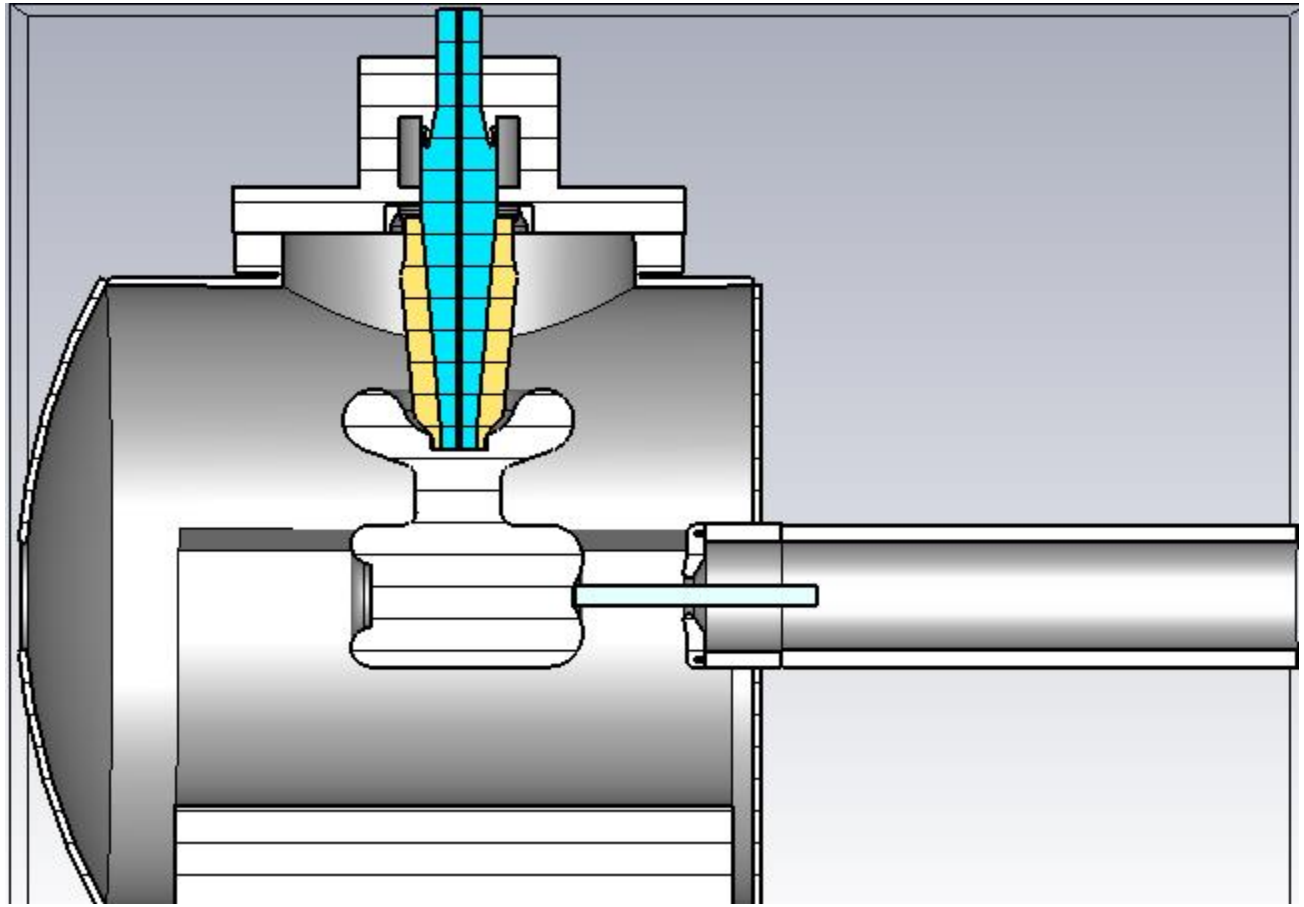


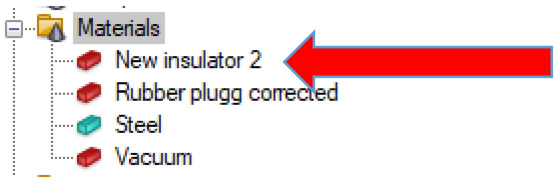
CST materials: PEC



- Steel for all metal components with Perfect electric conductor (PEC). Since this is a preset we don't need to define anything. Also, Thermal, Mechanical and Density properties are not included in the calculation.

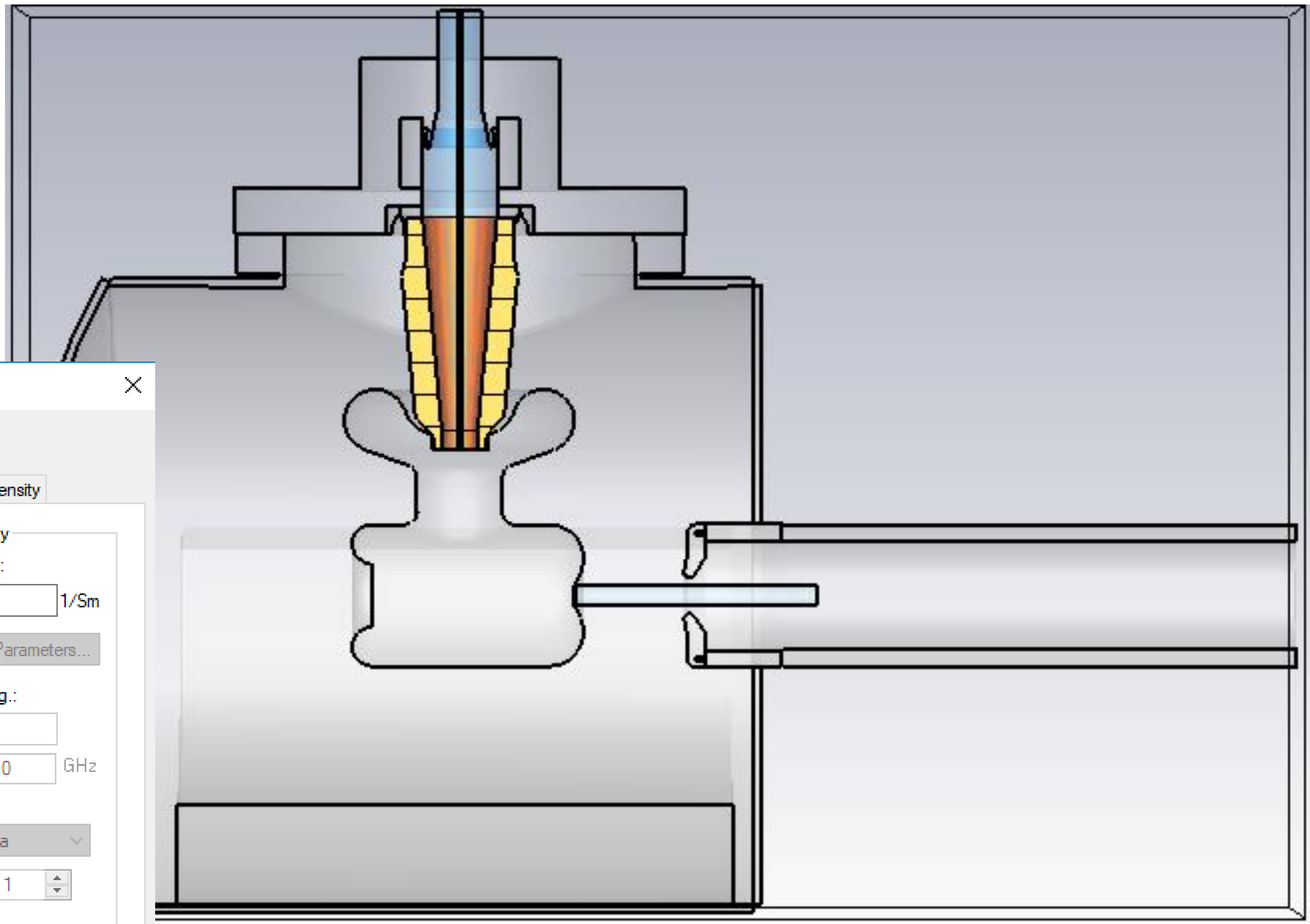


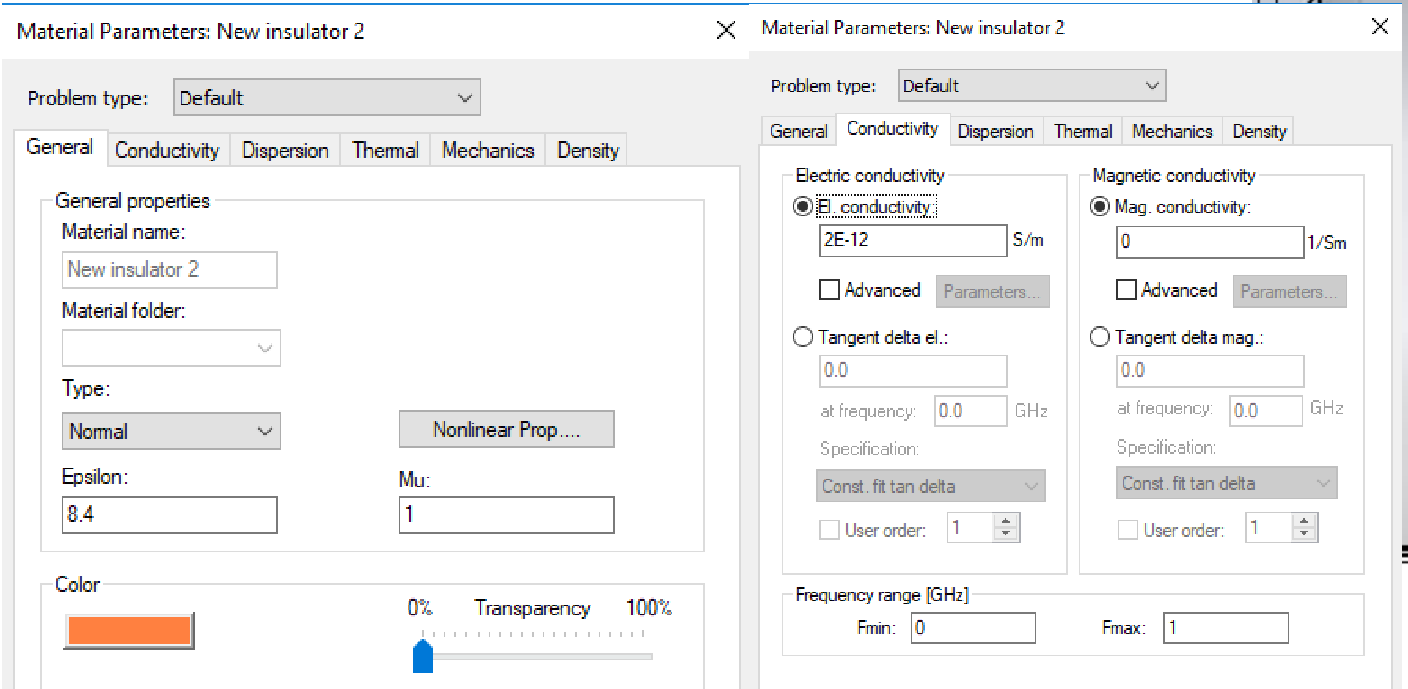


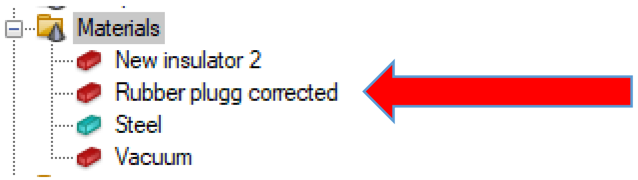


CST materials: Insulator

- For **black** alumina I used the same parameters as in COMSOL.
- ε=8.4
- σ=2E-12 [S/m]

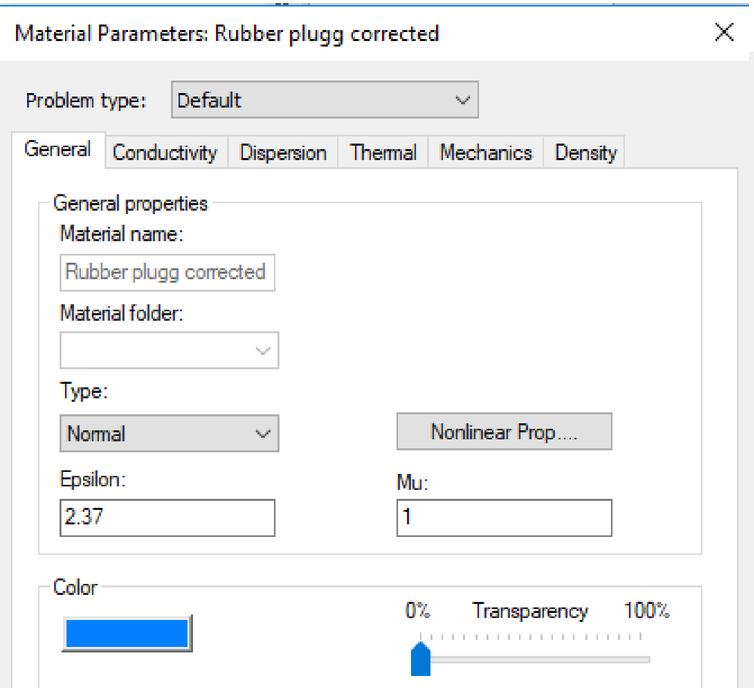


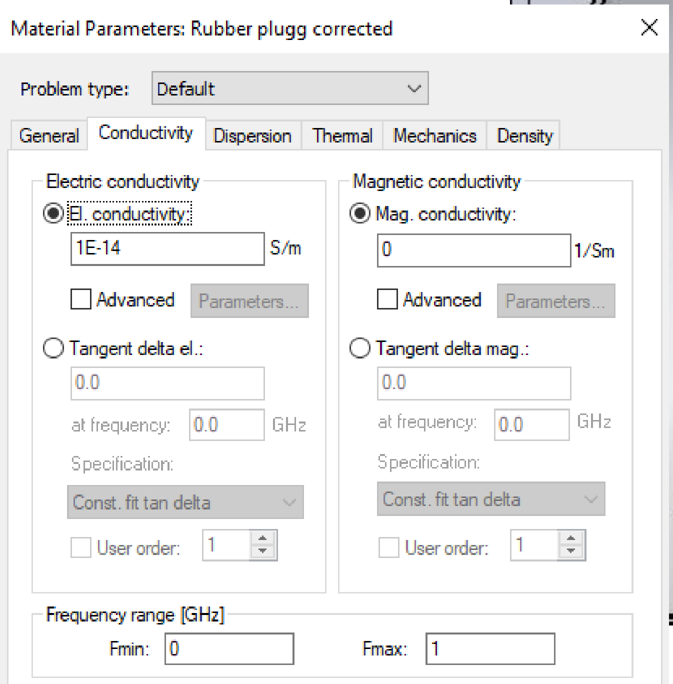


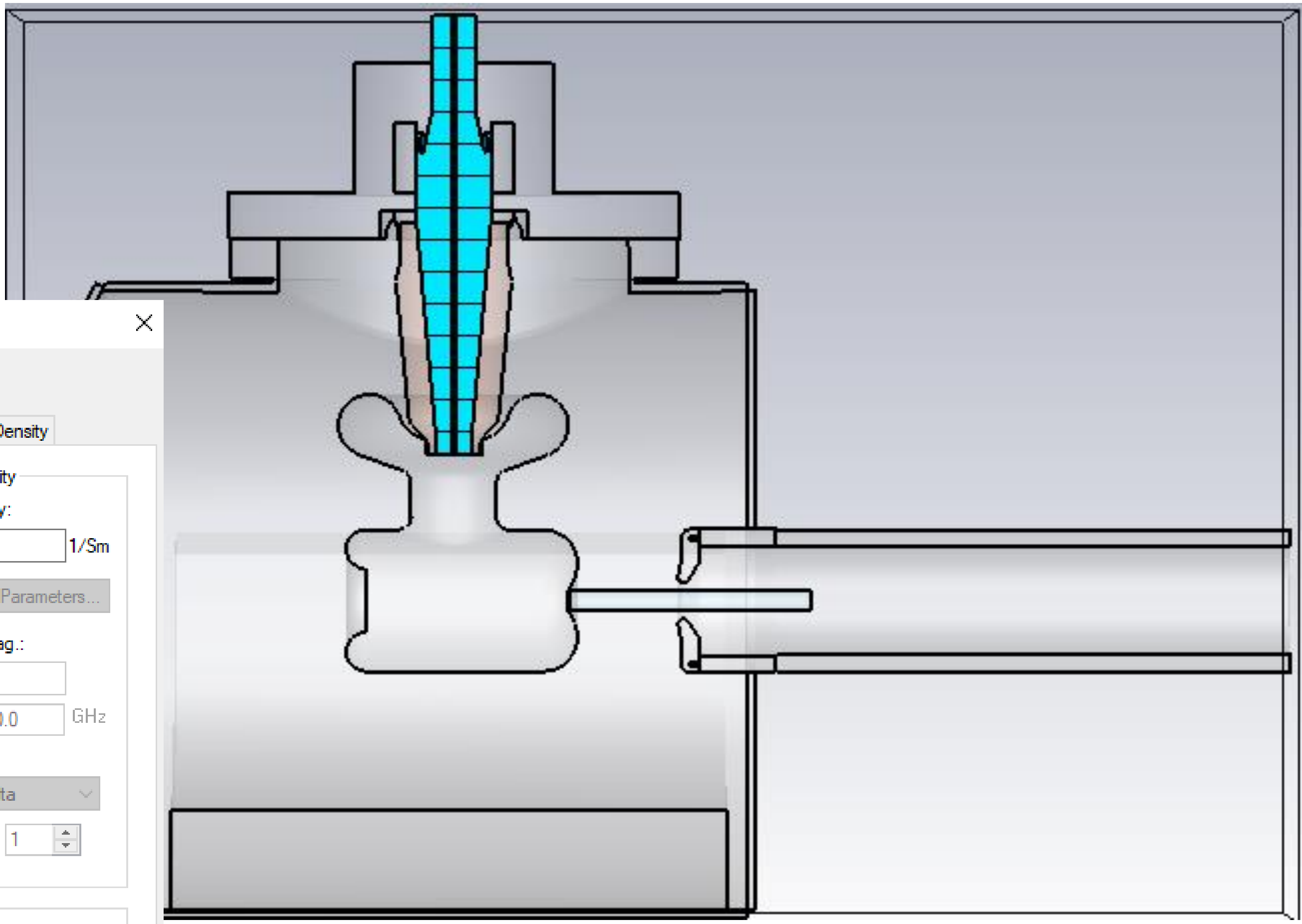


CST materials: Insulator

- For rubber I used the same parameters as in COMSOL.
- ε=2.37
- σ=1E-14 [S/m]

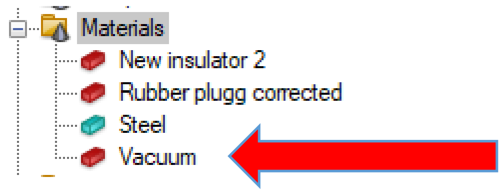


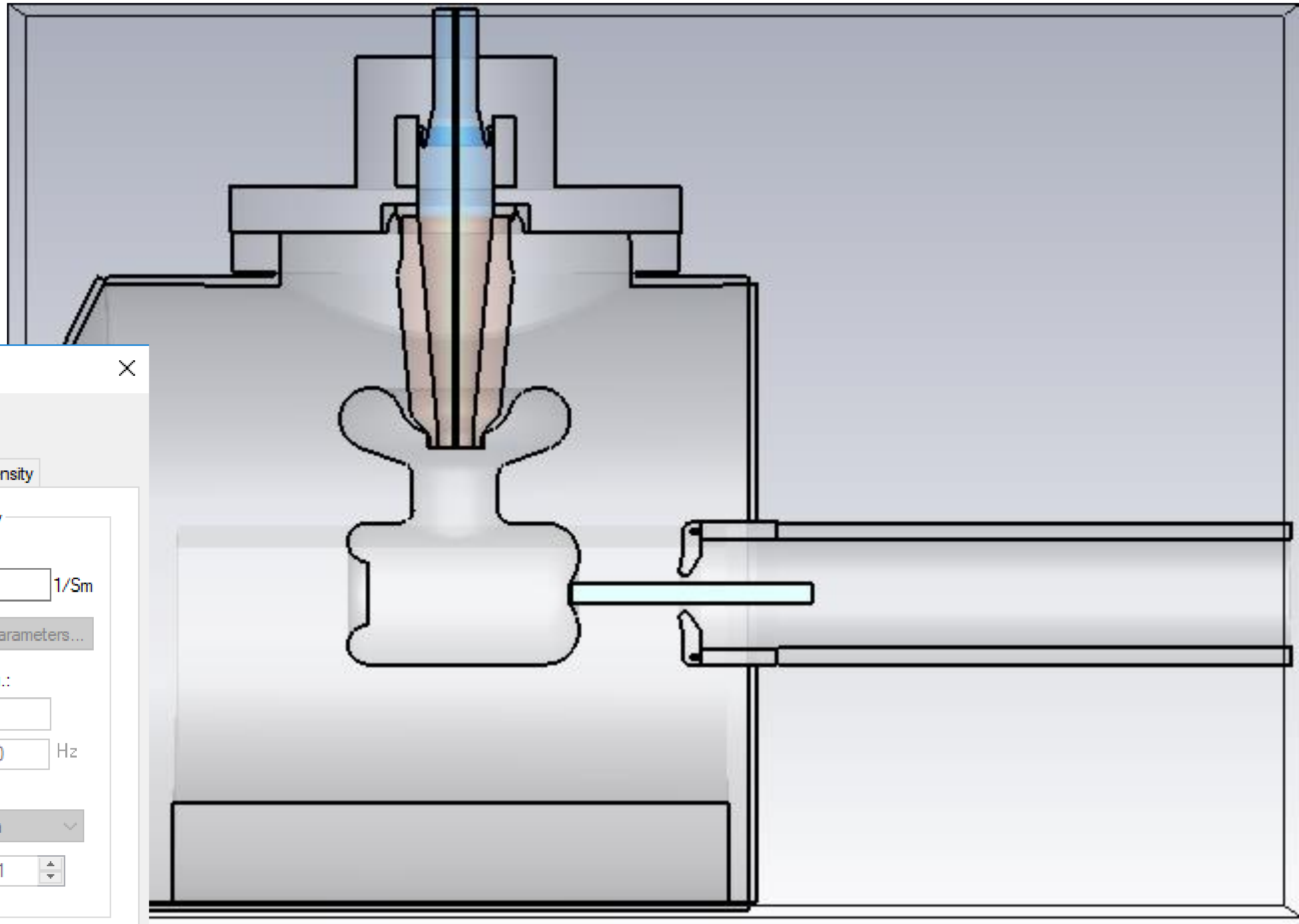


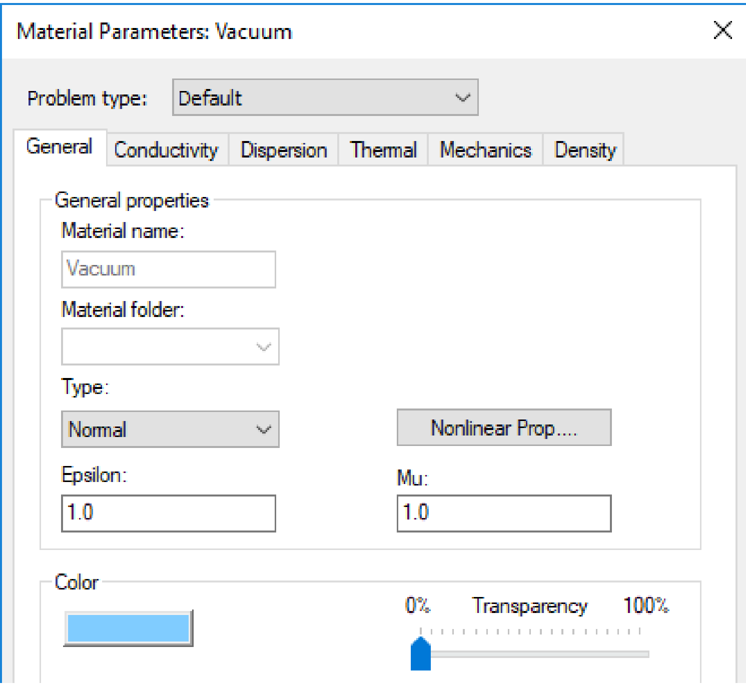


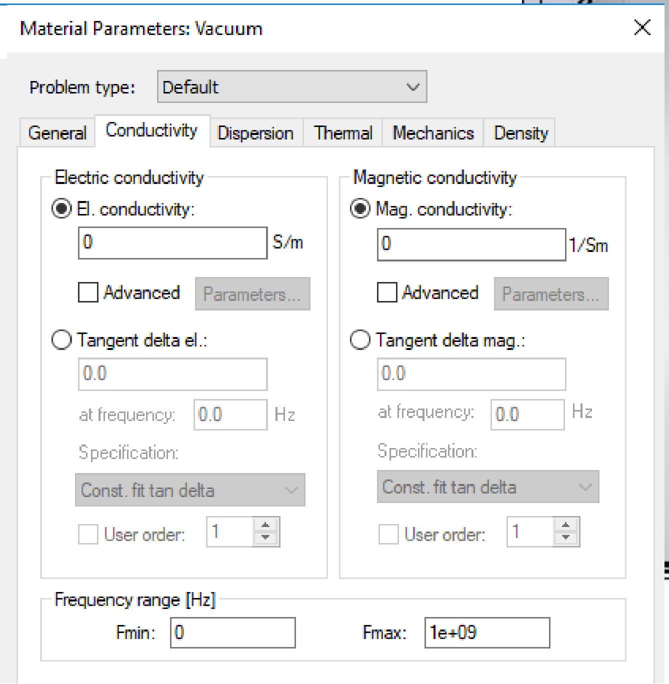
CST materials: vacuum

- For vacuum cylinder and surroundings.
- ε=1.0
- σ=0 [S/m]



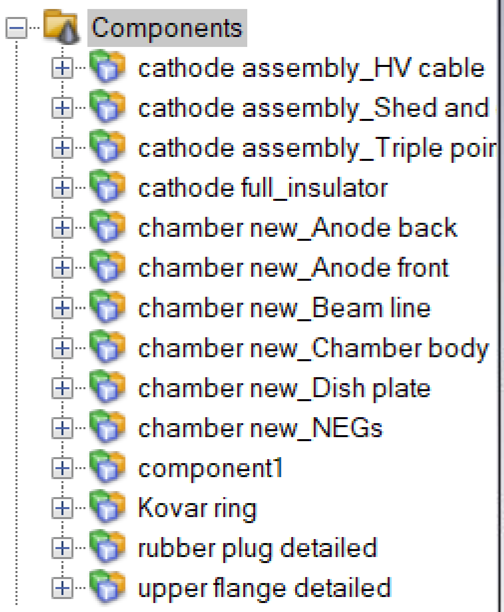


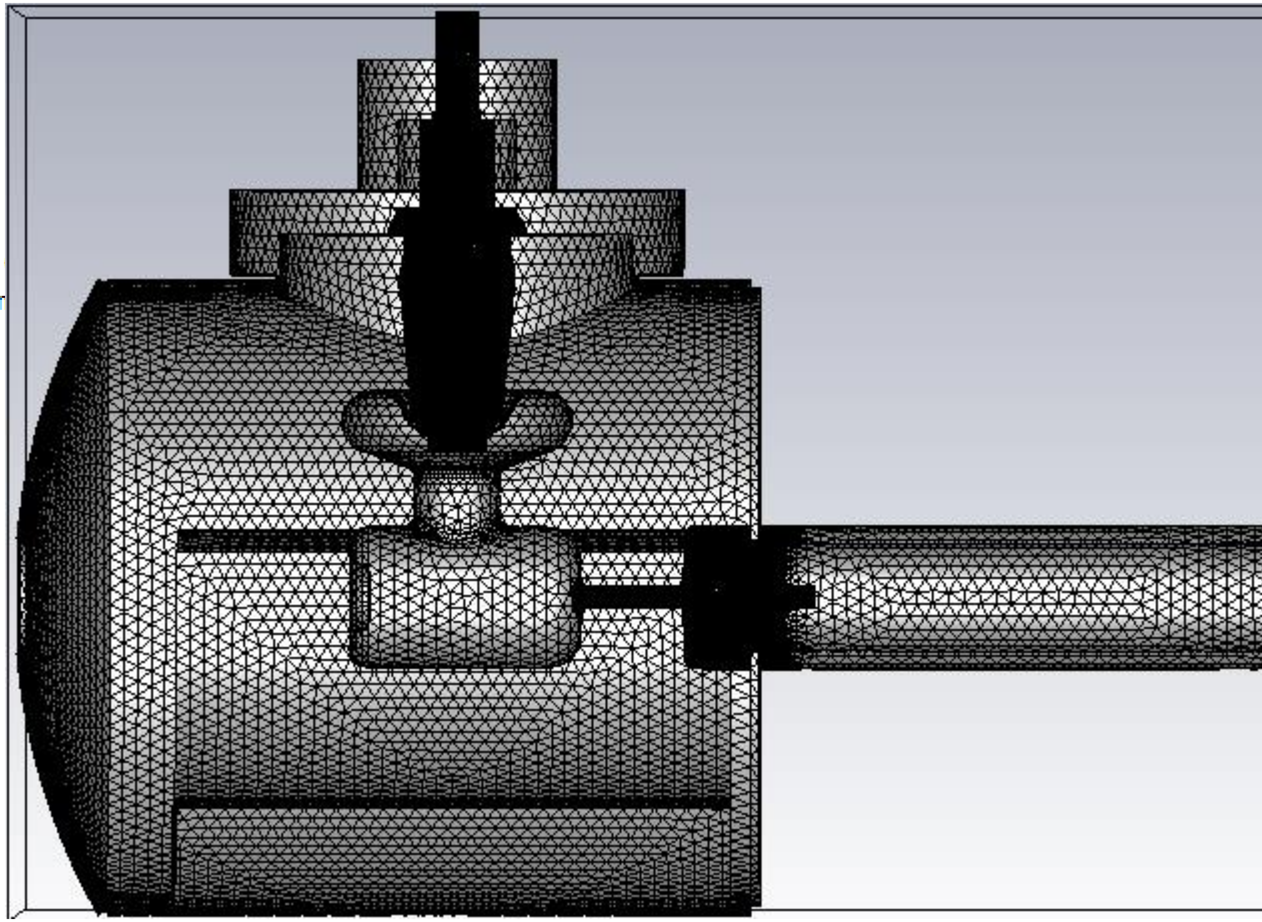




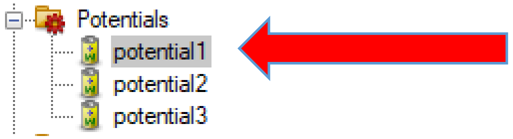
CST mesh:

- The mesh was separated into (maybe too many) pieces. :P
- The important part is, I only set some individual parts that require fine detail and left the rest to be auto-meshed.

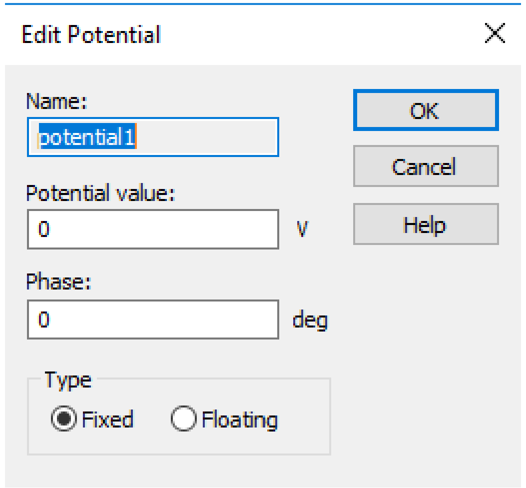


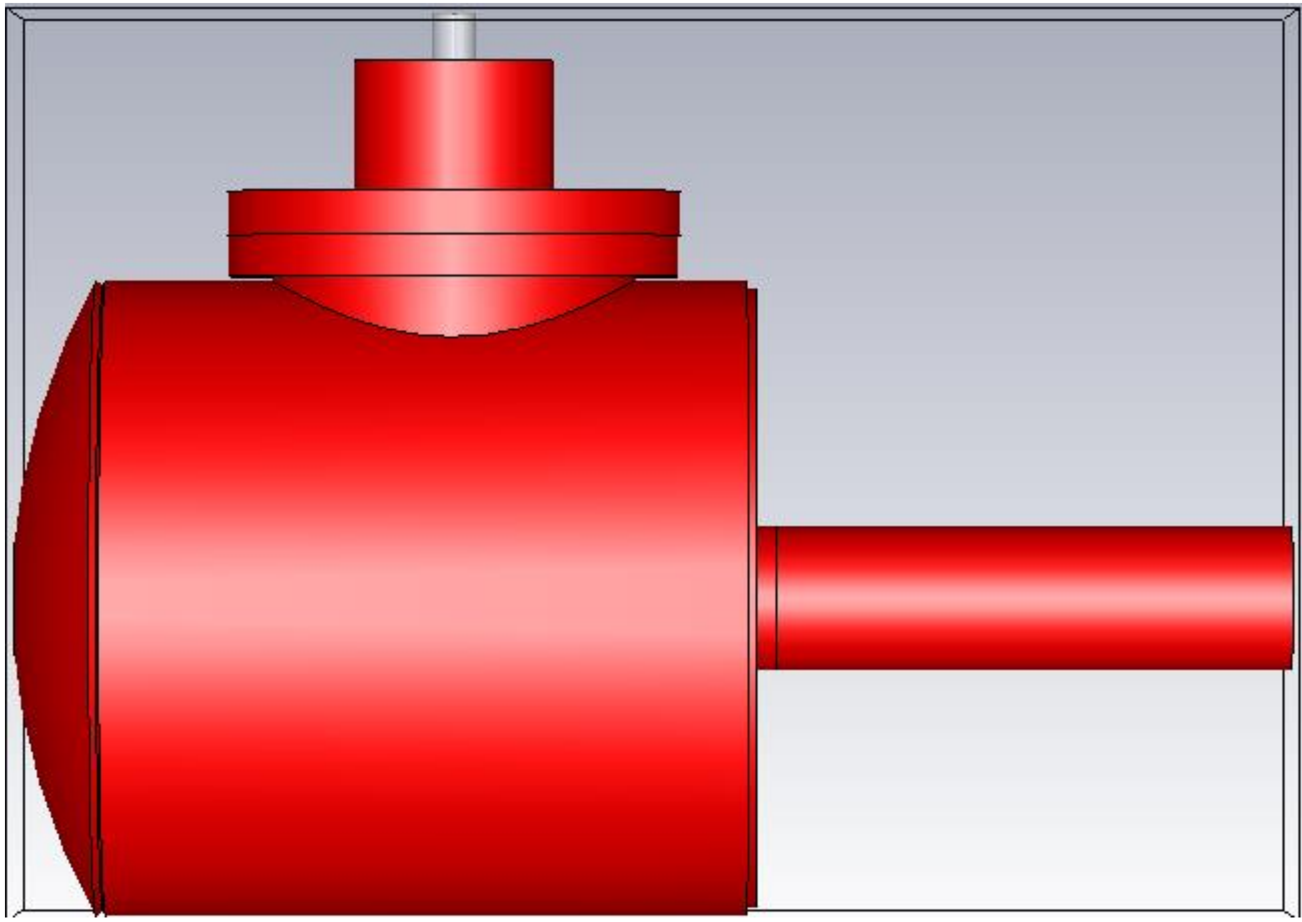


CST simulation: Potential

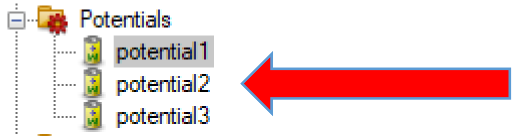


- Chamber, upper flange, Kovar ring, anode and beam-pipe at 0 V.

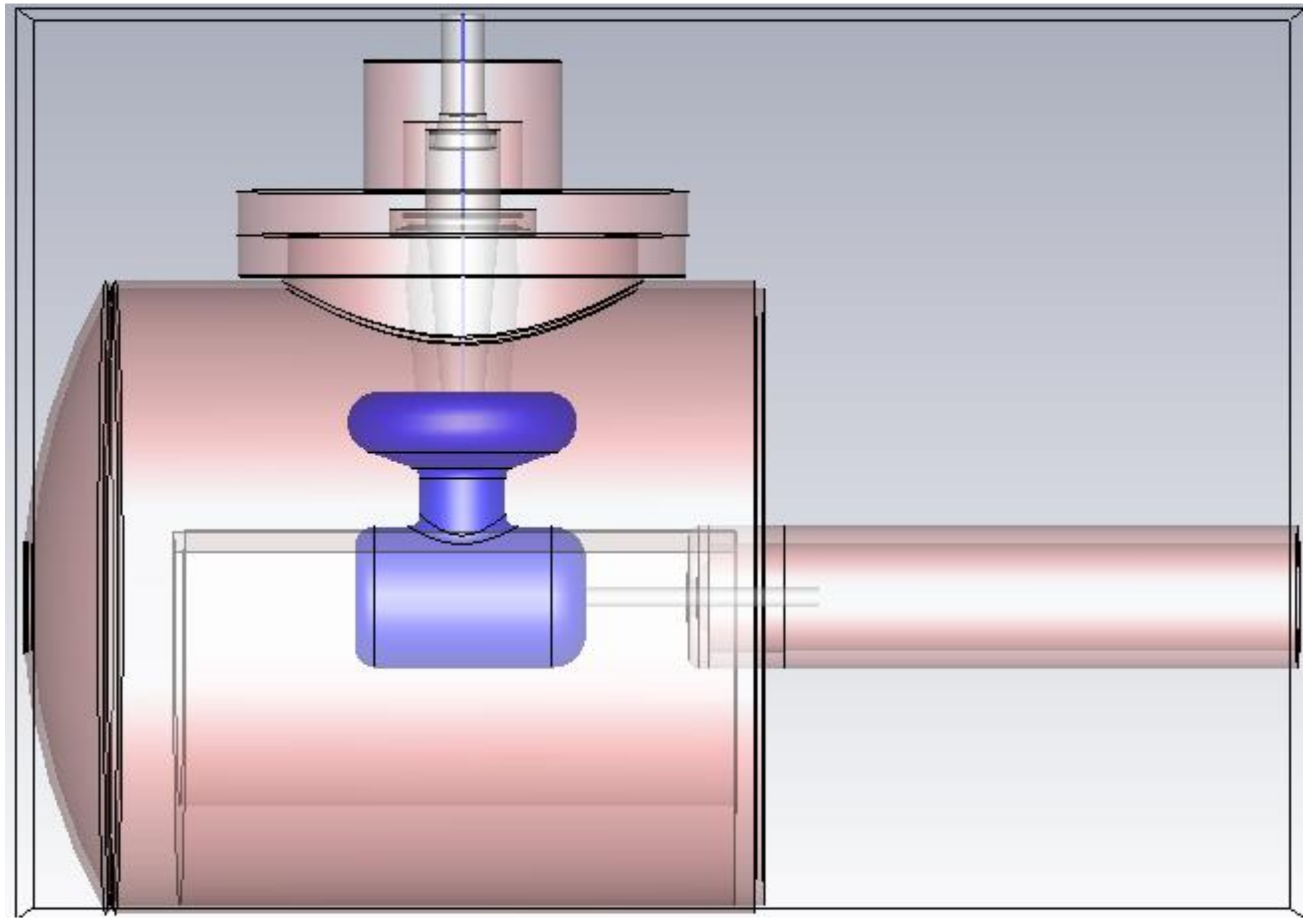




CST simulation: Potential

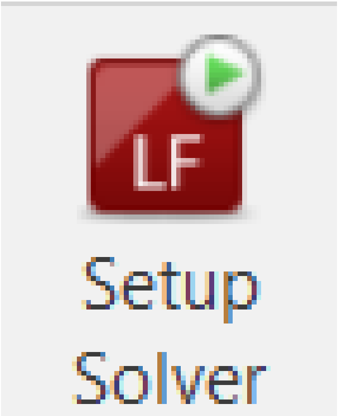


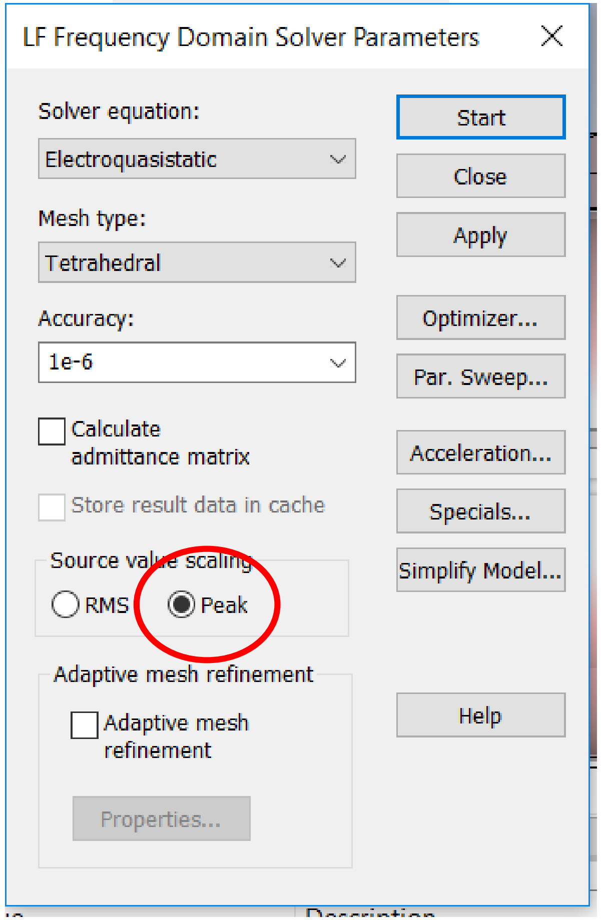
- Cathode electrode (including Pierce geometry), shield and high voltage cable at -200 kV.



CST simulation: Solver

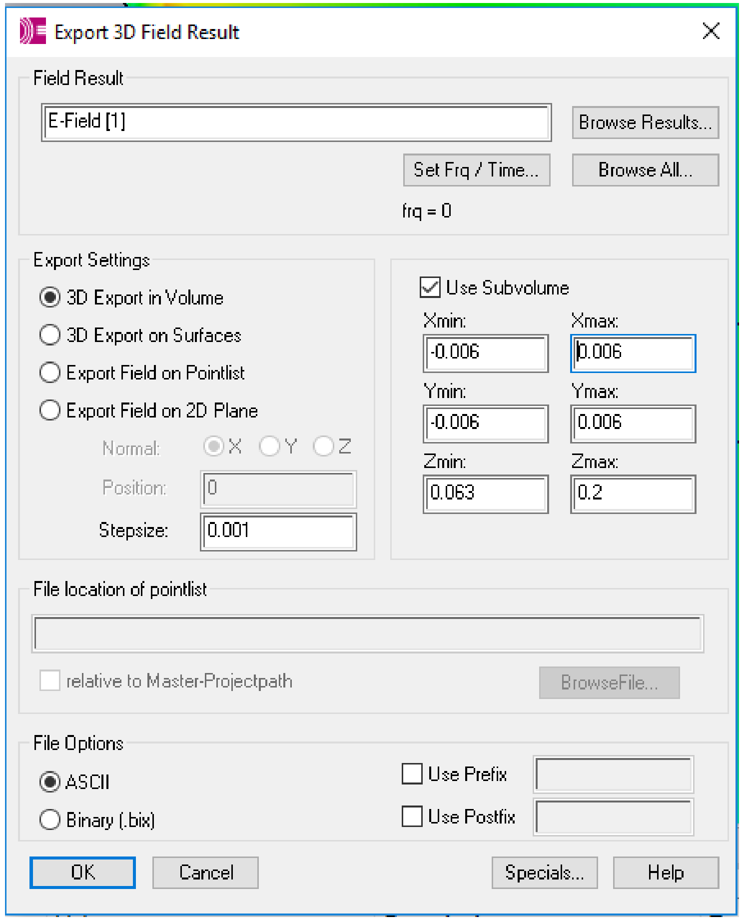
- Used the Low frequency as suggested by Fay.
- Did not use the adaptive mesh refinement this time.





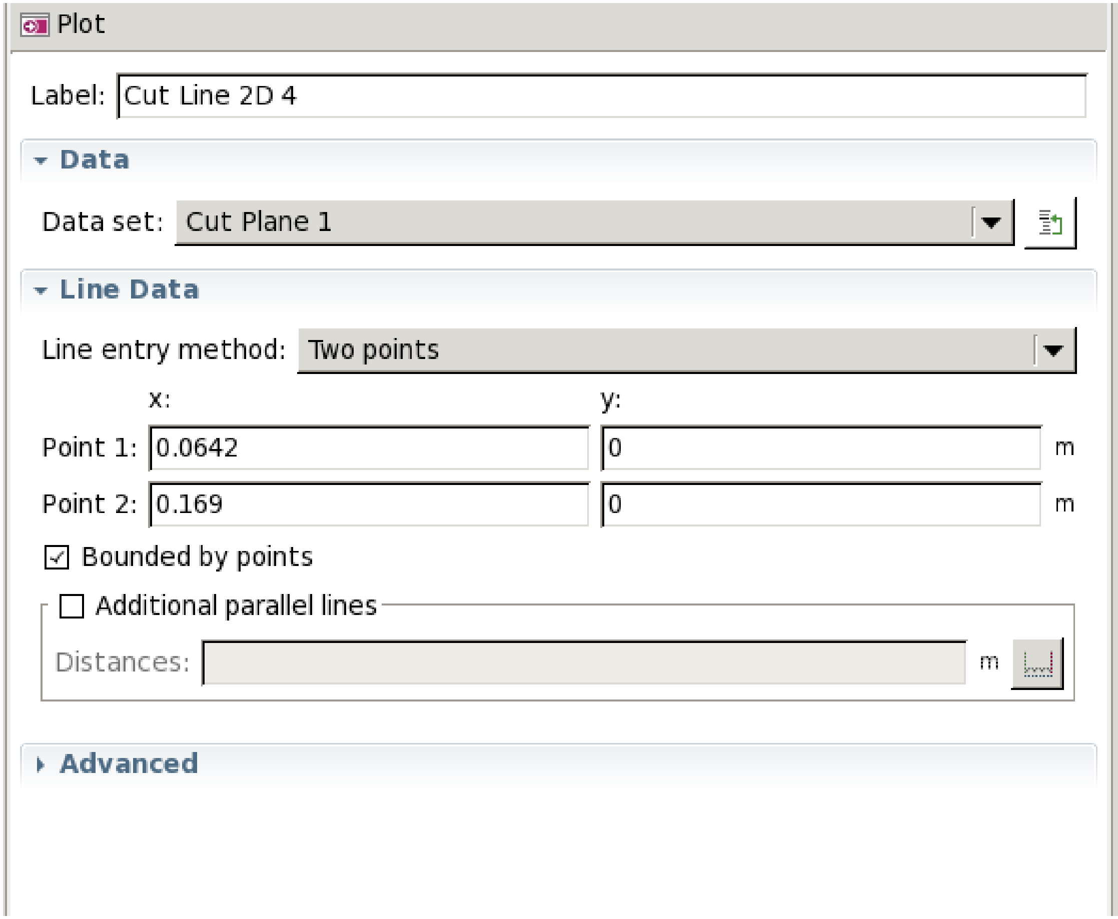
CST results:

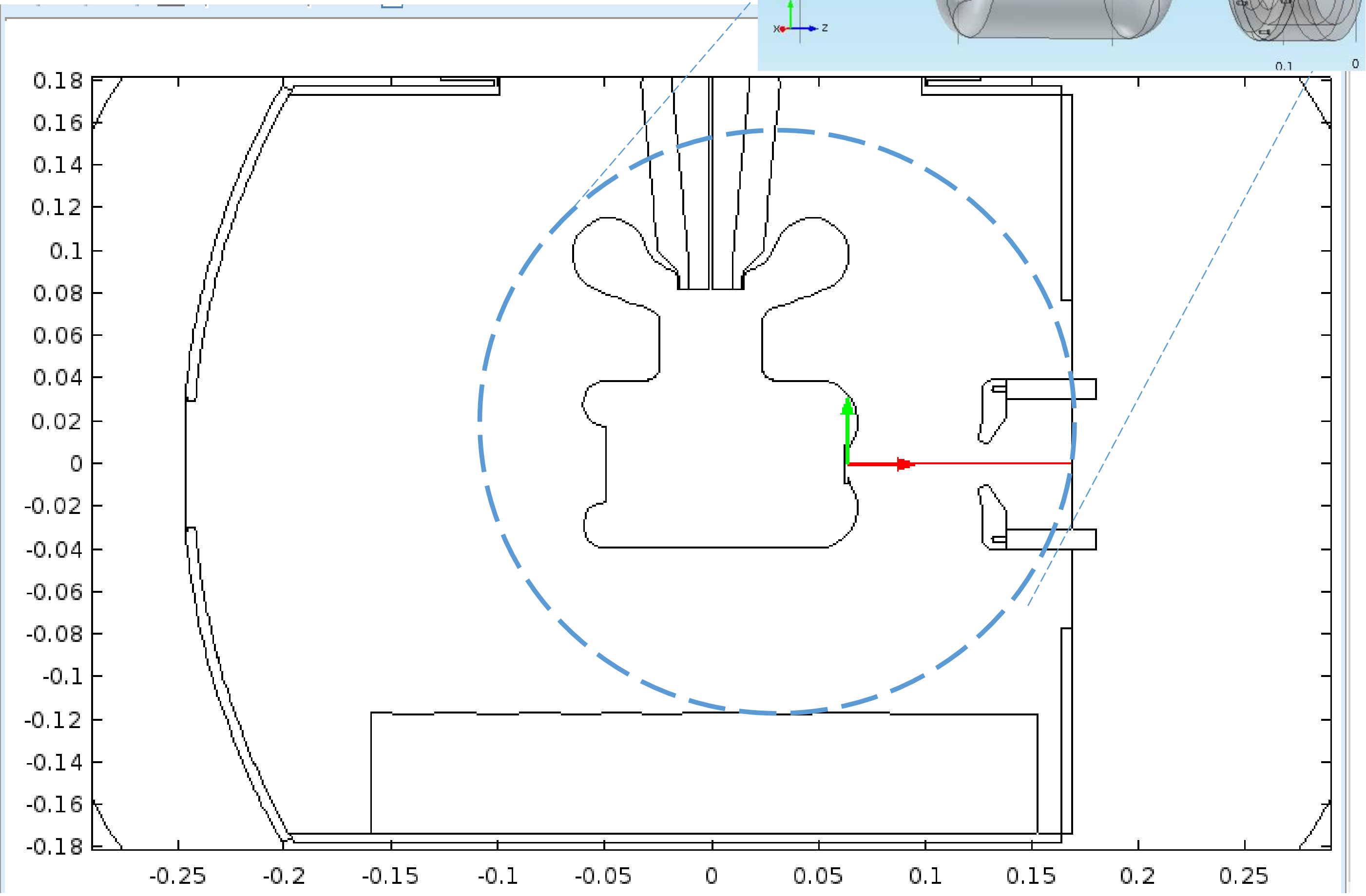
- The results for electric field magnitude and potential plotted and also presented as false color. Also produced 2D and 3D field maps for the cathode-anode gap.

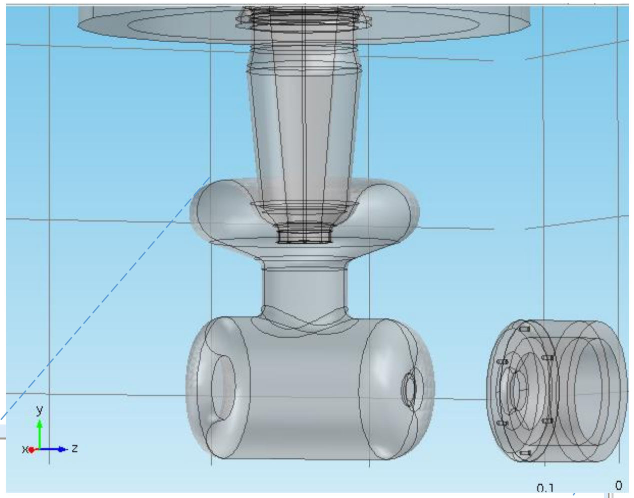


Cathode-anode gap:

The data for the following plots was taken along the cathode anode gap as a function of the height (on the photocathode surface) varying from -6mm to 6mm.





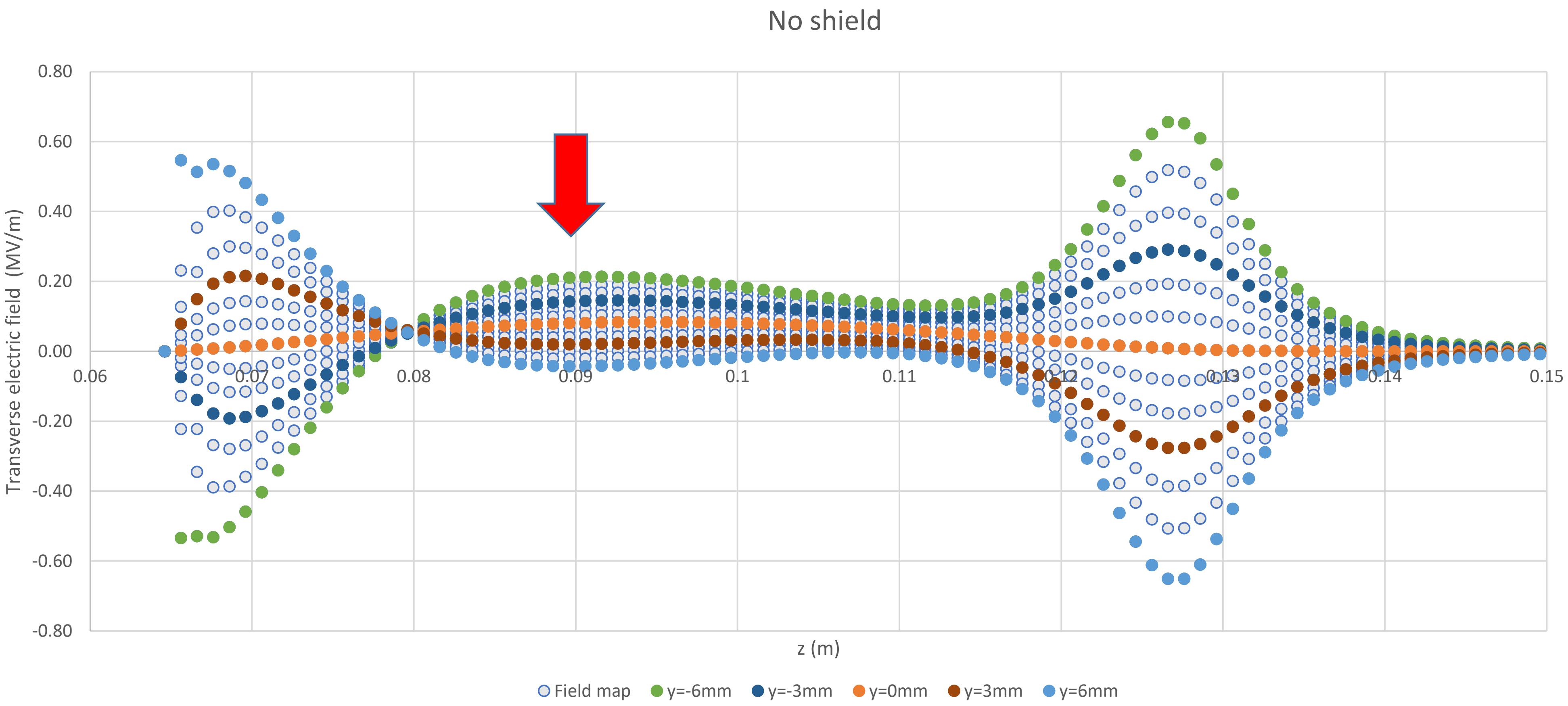


No shield vs Original vs Shield 1 vs Shield 2: Transversal electric field

- As the Shield height is reduced, the **max value** in the middle region of the cathode-anode gap is reduced by **7%** from **0.27 MV/m to 0.25 MV/m**. The **min value decreases in 50% from 0.08 MV/m to 0.04 MV/m.** This min value is achieved by going upwards on the photocathode surface.

CST results: Transverse electric field – No shield

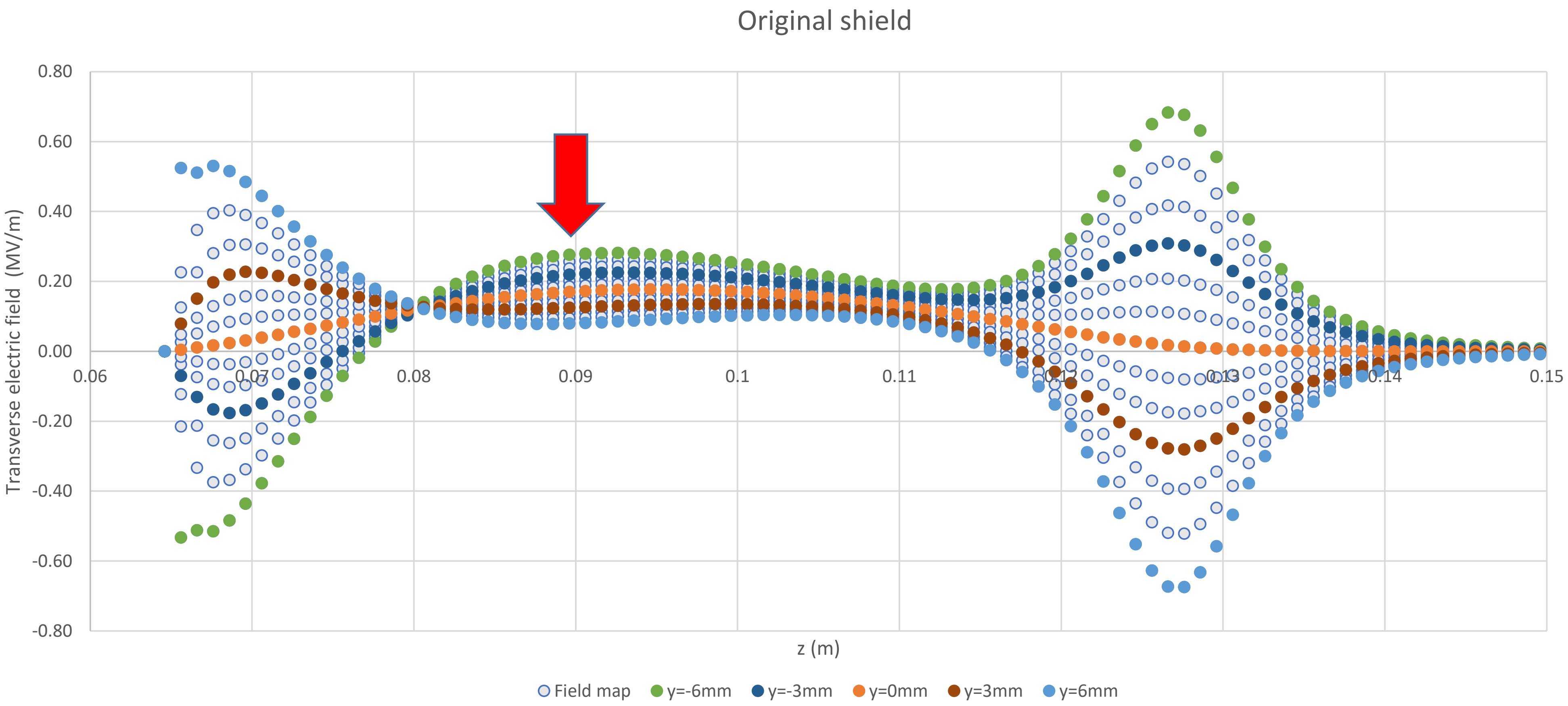
The gray data set is the whole field map. The different colors show how the transverse electric field changes as a function of height on the photocathode in the interval -6mm<y<6mm



119% difference between 0.21 and -0.04

CST results: Transverse electric field – original shield

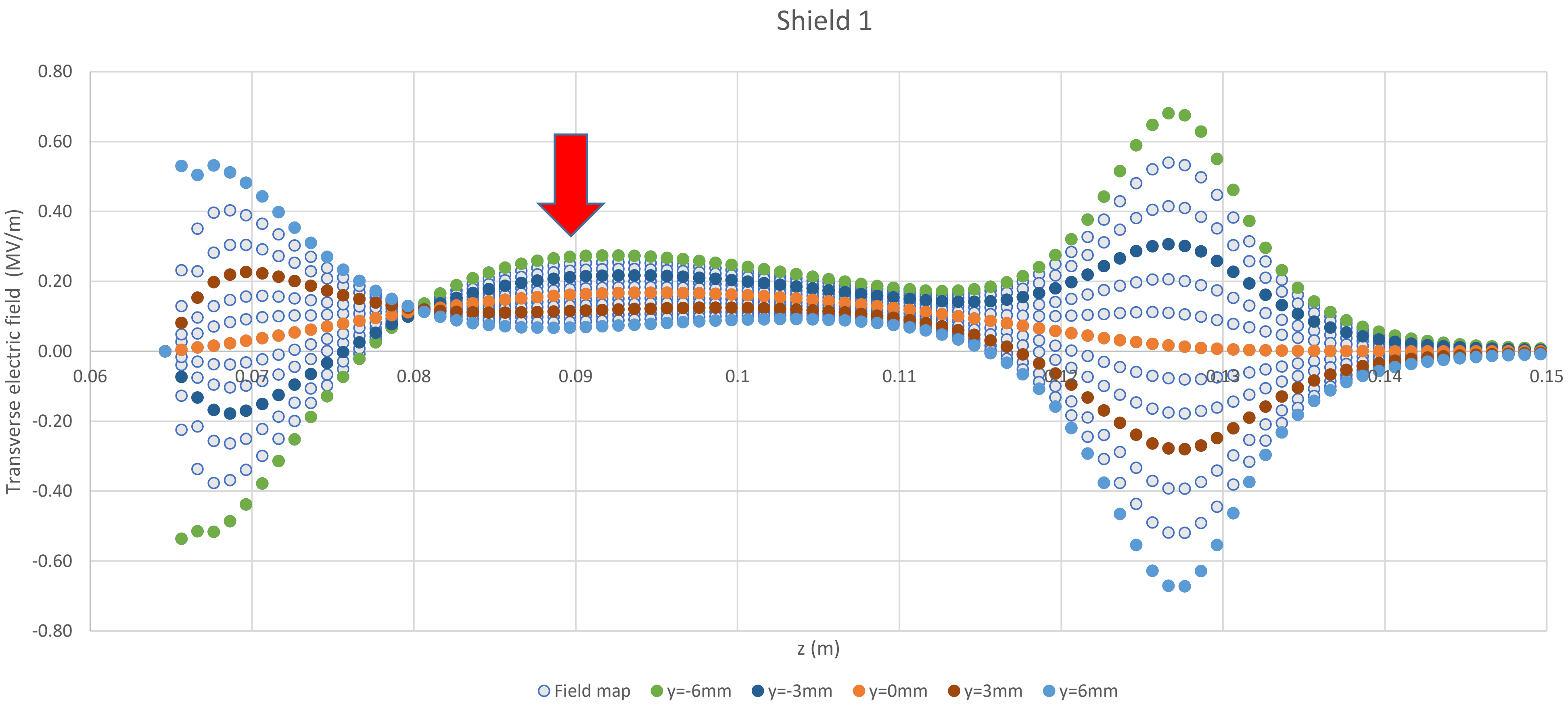
The gray data set is the whole field map. The different colors show how the transverse electric field changes as a function of height on the photocathode in the interval -6mm<y<6mm



70% difference between 0.27 and 0.08

CST results: Transverse electric field – Shield 1

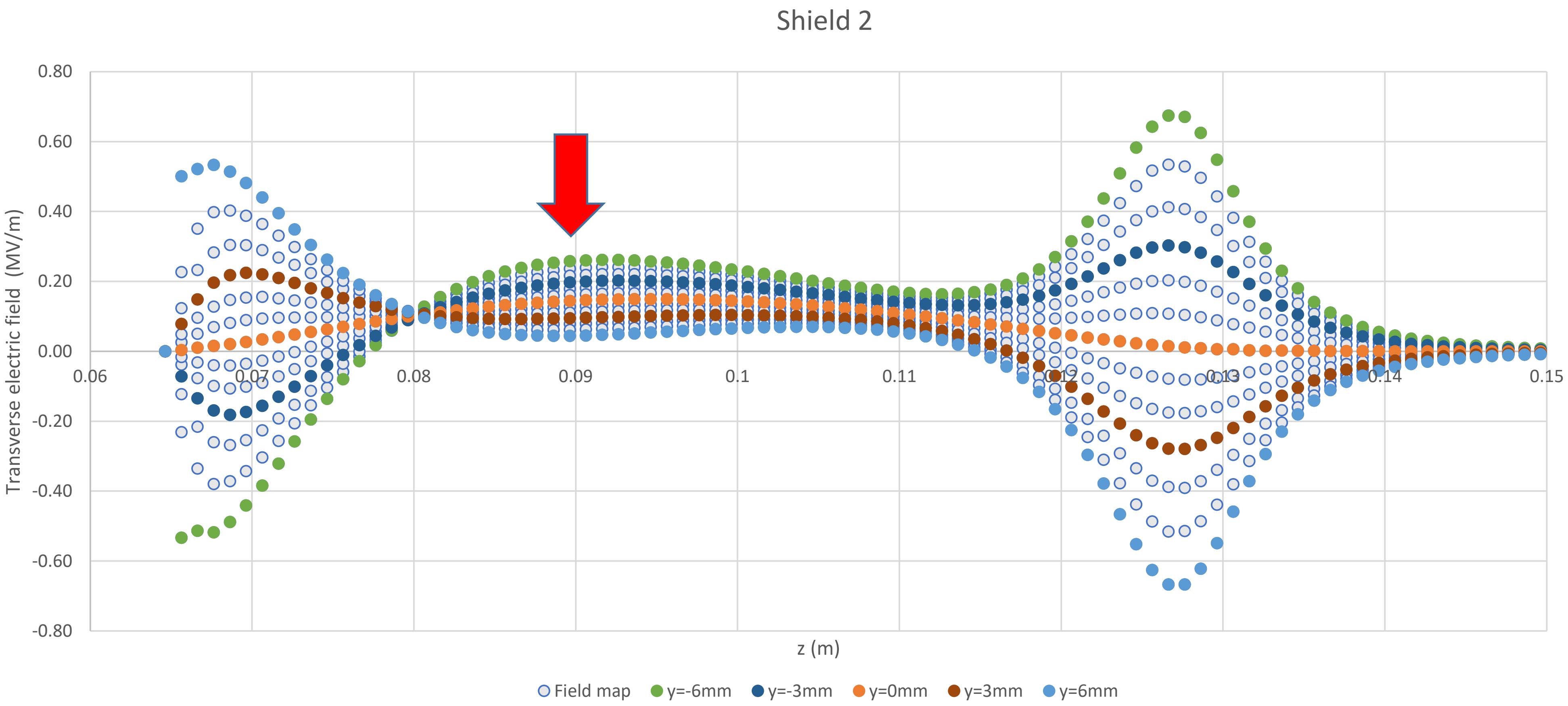
The gray data set is the whole field map. The different colors show how the transverse electric field changes as a function of height on the photocathode in the interval -6mm<y<6mm



74% difference between 0.27 and 0.07

CST results: Transverse electric field – Shield 2

The gray data set is the whole field map. The different colors show how the transverse electric field changes as a function of height on the photocathode in the interval -6mm<y<6mm



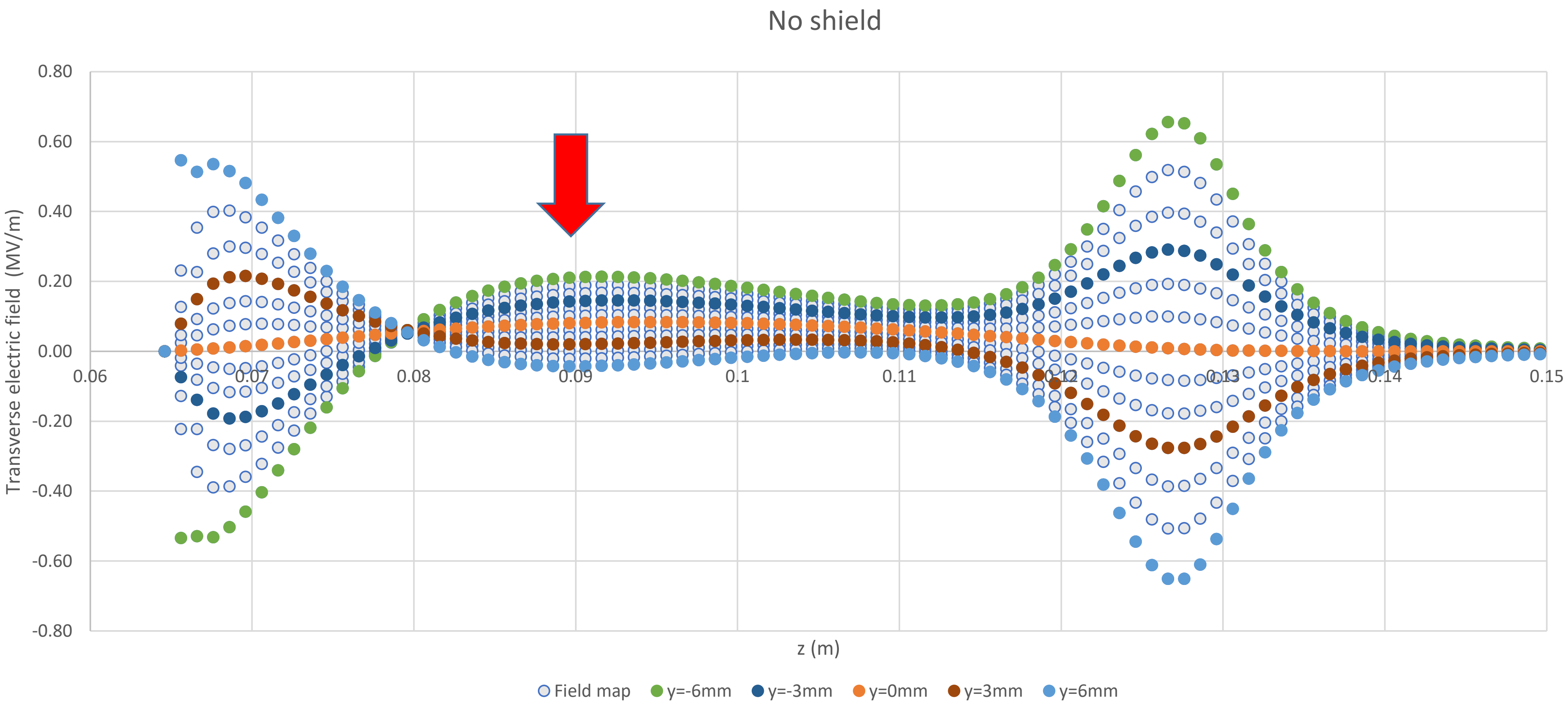
84% difference between 0.25 and 0.04

No shield vs Original vs Shield 3 vs Shield 4 : Transversal electric field

- As the Shield radius is reduced, the **max value** in the middle region of the cathode-anode gap is also reduced around 4% from **0.27 MV/m to 0.26 MV/m**. The **min value decreases in 37.5% from 0.08 MV/m to 0.05 MV/m.** This min value is again achieved by going upwards on the photocathode surface.

CST results: Transverse electric field – No shield

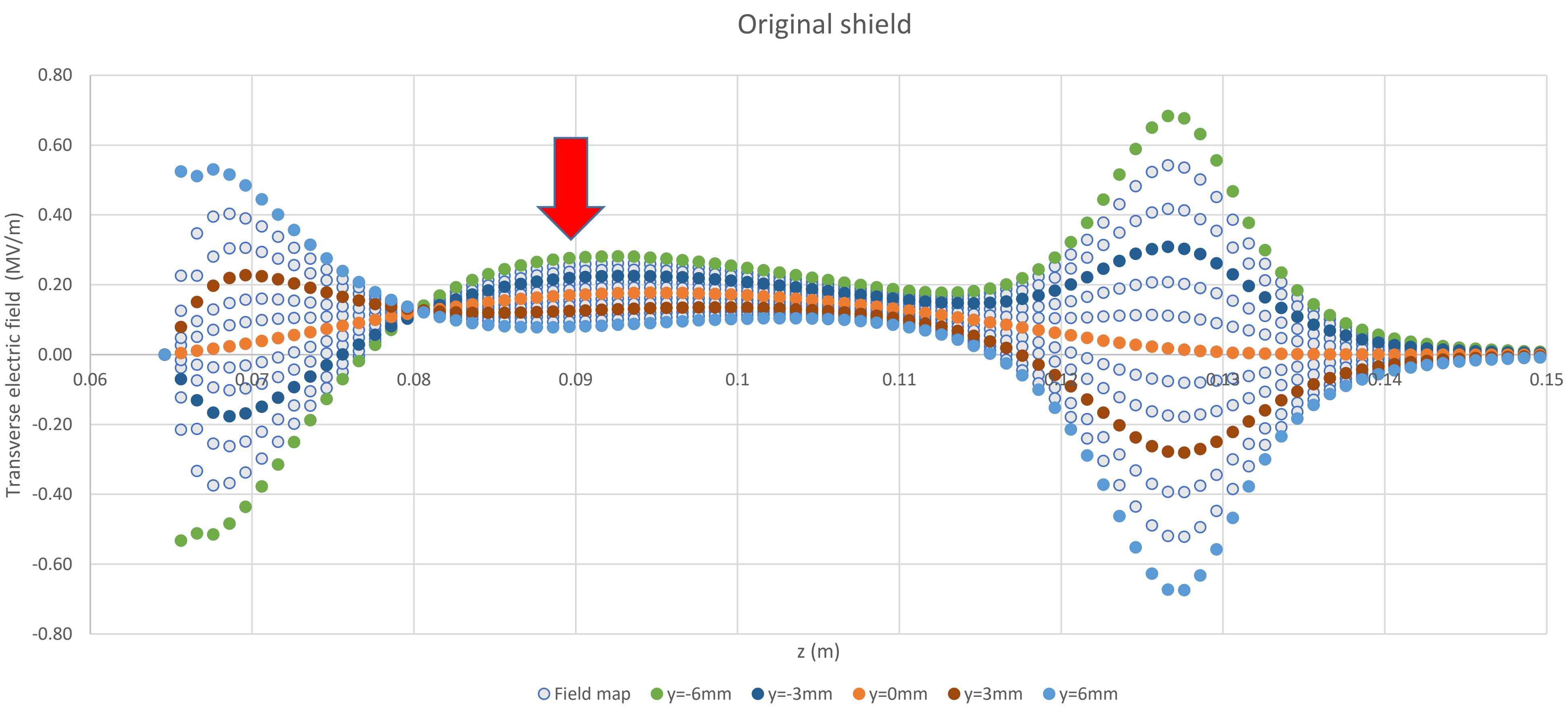
The gray data set is the whole field map. The different colors show how the transverse electric field changes as a function of height on the photocathode in the interval -6mm<y<6mm



119% difference between 0.21 and -0.04

CST results: Transverse electric field – original shield

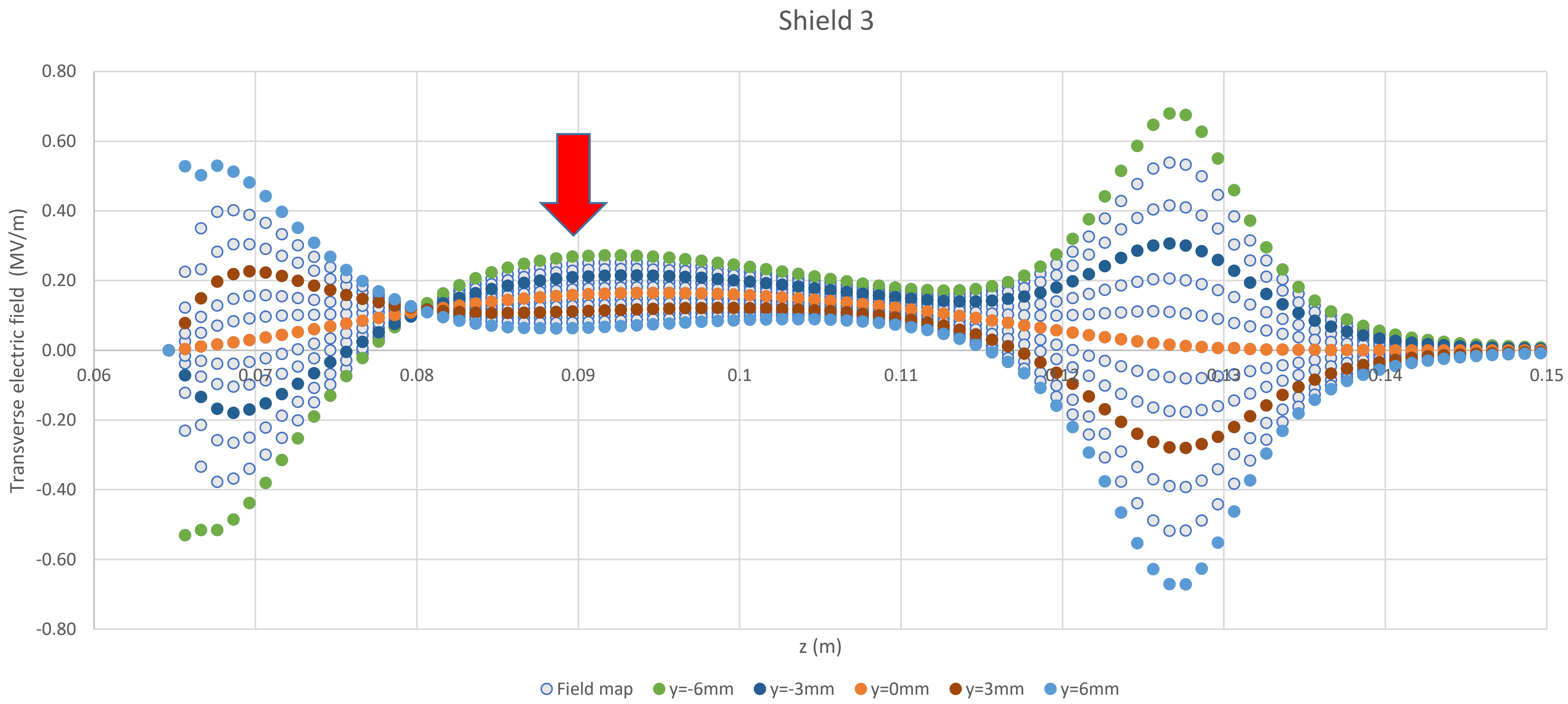
The gray data set is the whole field map. The different colors show how the transverse electric field changes as a function of height on the photocathode in the interval -6mm<y<6mm



70% difference between 0.27 and 0.08

CST results: Transverse electric field – Shield 3

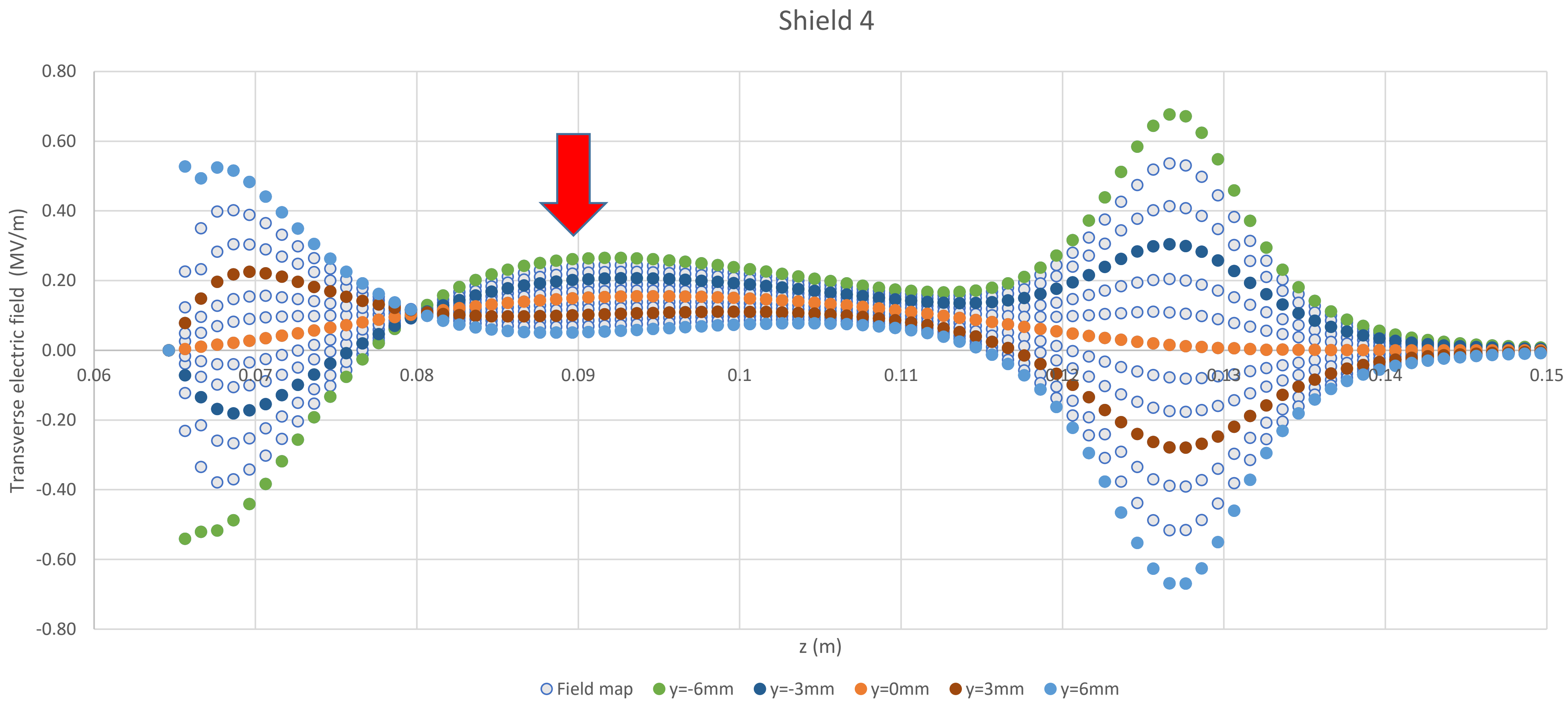
The gray data set is the whole field map. The different colors show how the transverse electric field changes as a function of height on the photocathode in the interval -6mm<y<6mm



77% difference between 0.26 and 0.06

CST results: Transverse electric field – Shield 4

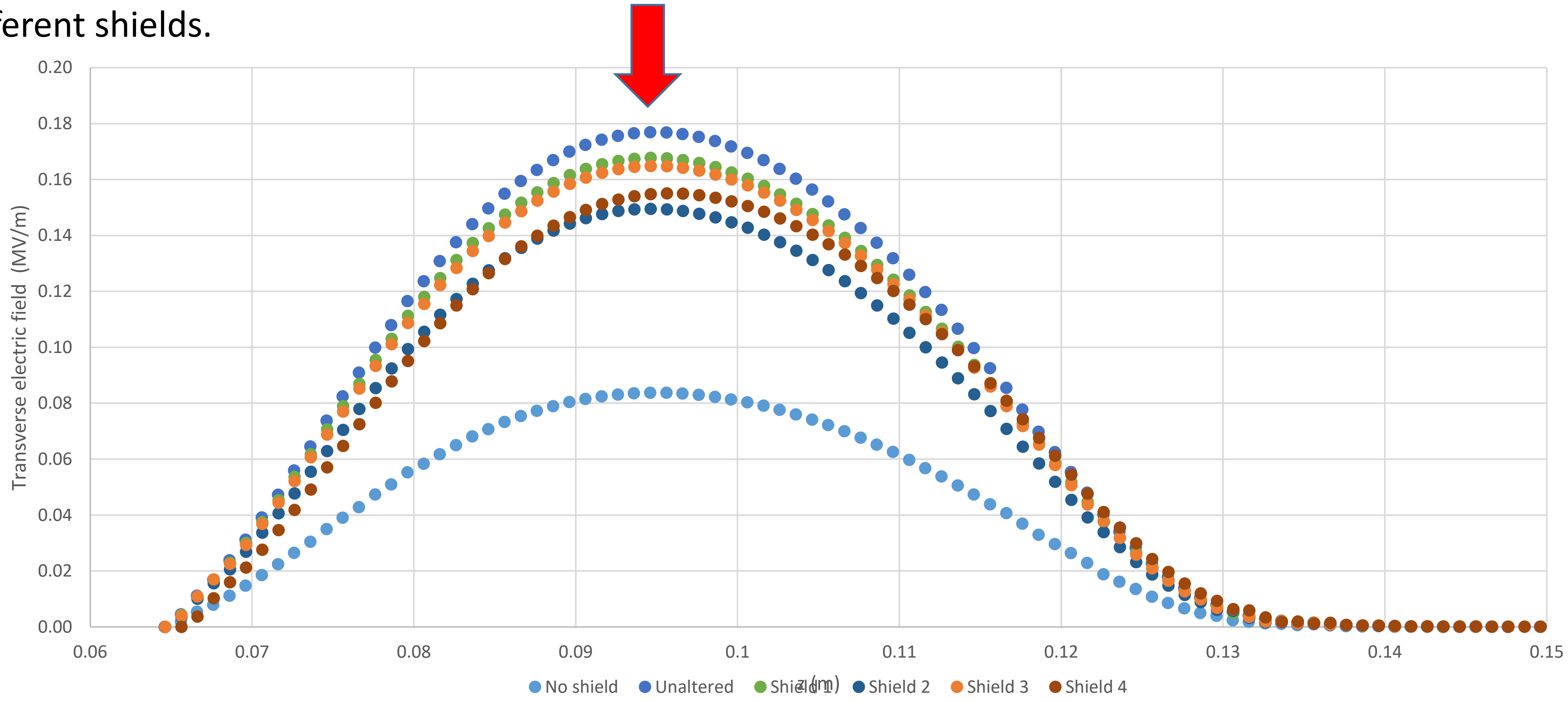
The gray data set is the whole field map. The different colors show how the transverse electric field changes as a function of height on the photocathode in the interval -6mm<y<6mm



78% difference between 0.26 and 0.05

CST results: Transverse electric field – No shield vs Original vs all shields (1,2,3 & 4) at C-a gap center line

All the data sets correspond to the center line in the cathode-anode gap. Different colors represent different shields.

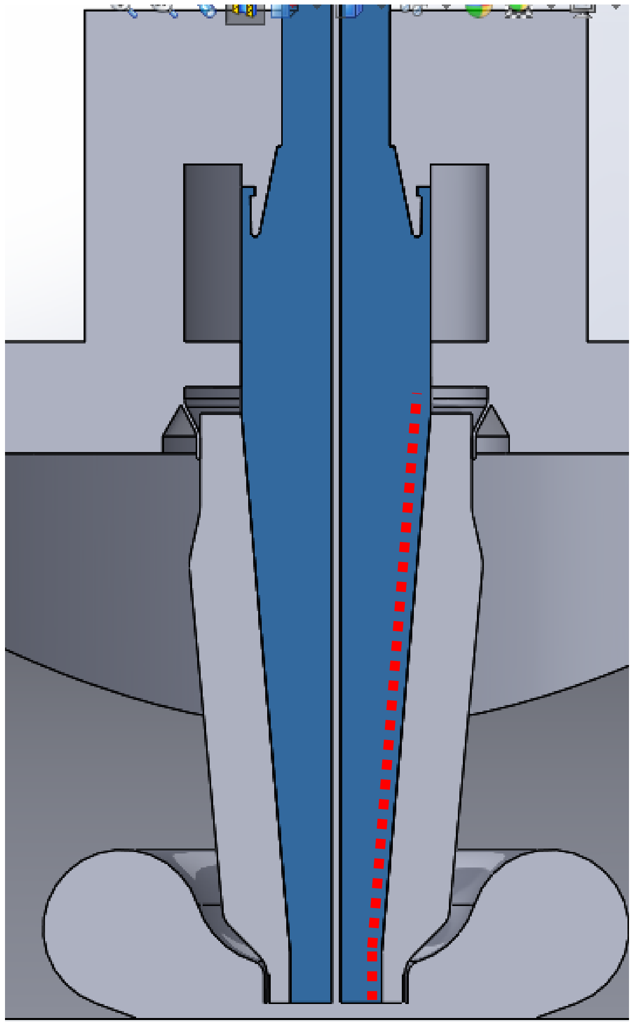


~12% difference between 0.17 and 0.15

~53% difference between 0.17 and 0.08

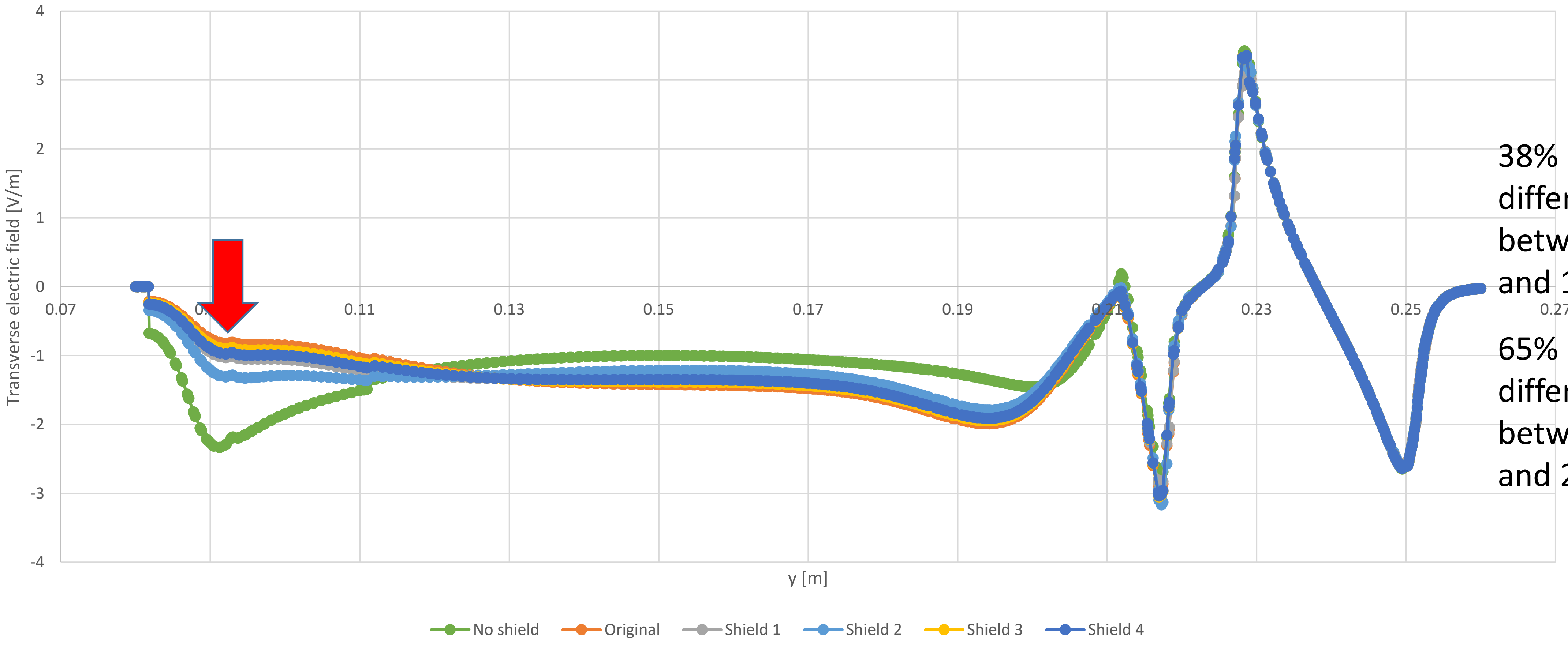
CST results: Transverse electric field – No shield vs Original vs all shields (1,2,3 & 4) at insulator interface

- The potential and electric fields along the rubber plug – ceramic insulator interface was obtained (as shown in the image as a red dotted line), plotted as a function of the height (y-coordinate).



CST results: Transverse electric field – No shield vs Original vs all shields (1,2,3 & 4) at insulator interface

Different colors represent different shields.

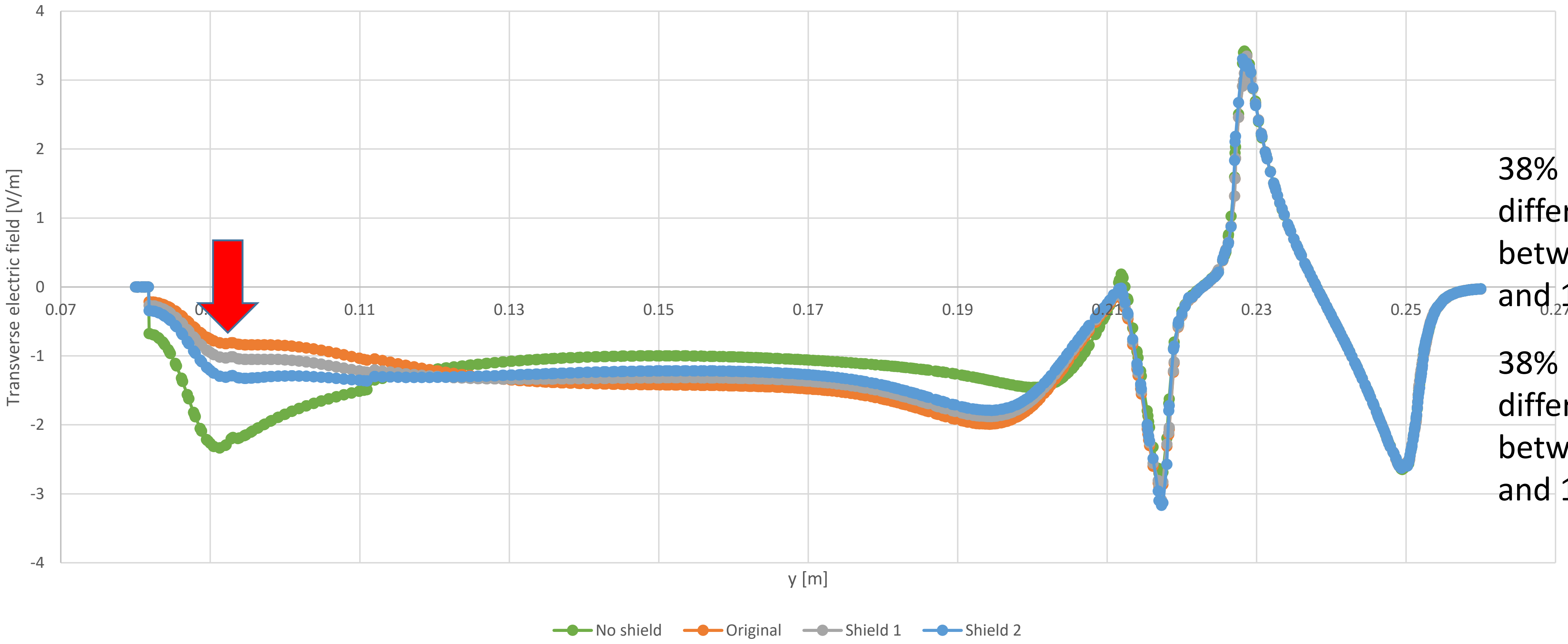


38% difference between 0.8 and 1.3

65% difference between 0.8 and 2.3

CST results: Transverse electric field – No shield vs Original vs shields 1&2 at insulator interface

Different colors represent different shields.

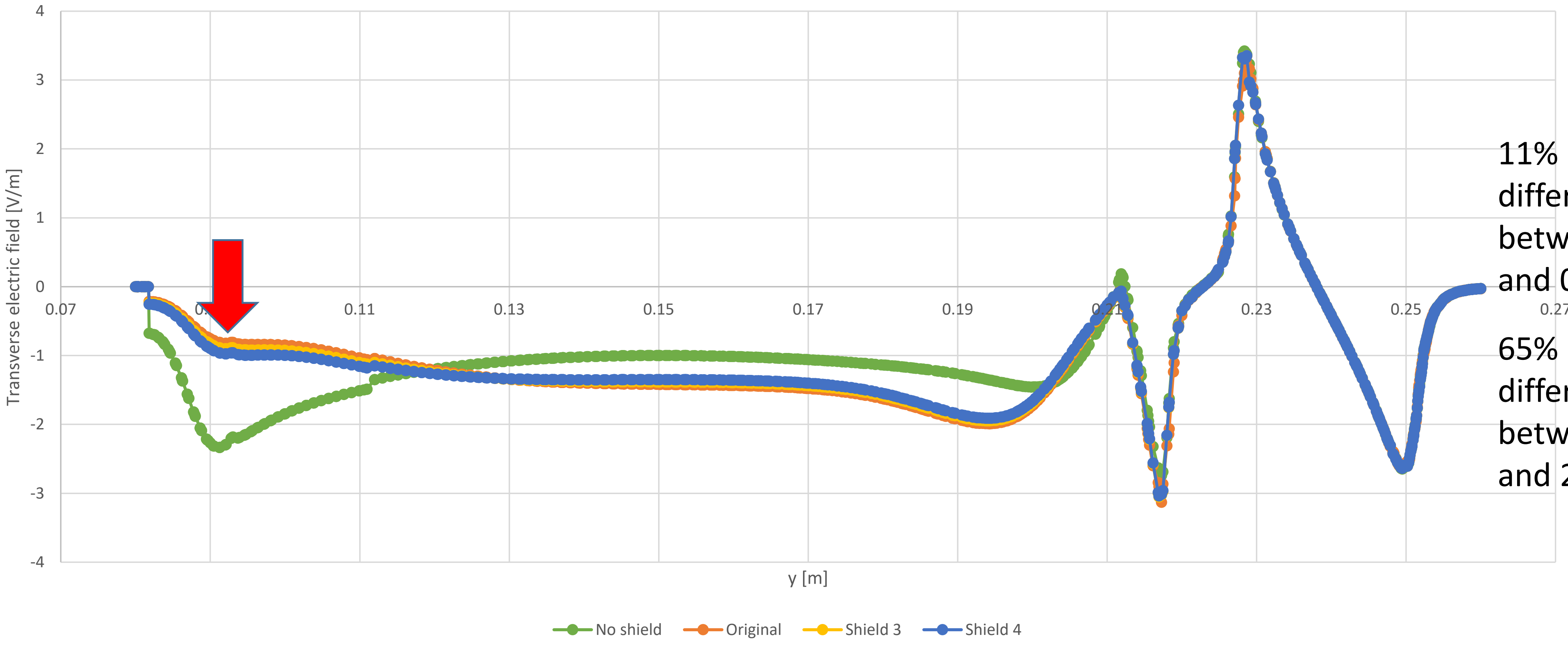


38% difference between 0.8 and 1.3

38% difference between 0.8 and 1.3

CST results: Transverse electric field – No shield vs Original vs shields 3&4 at insulator interface

Different colors represent different shields.

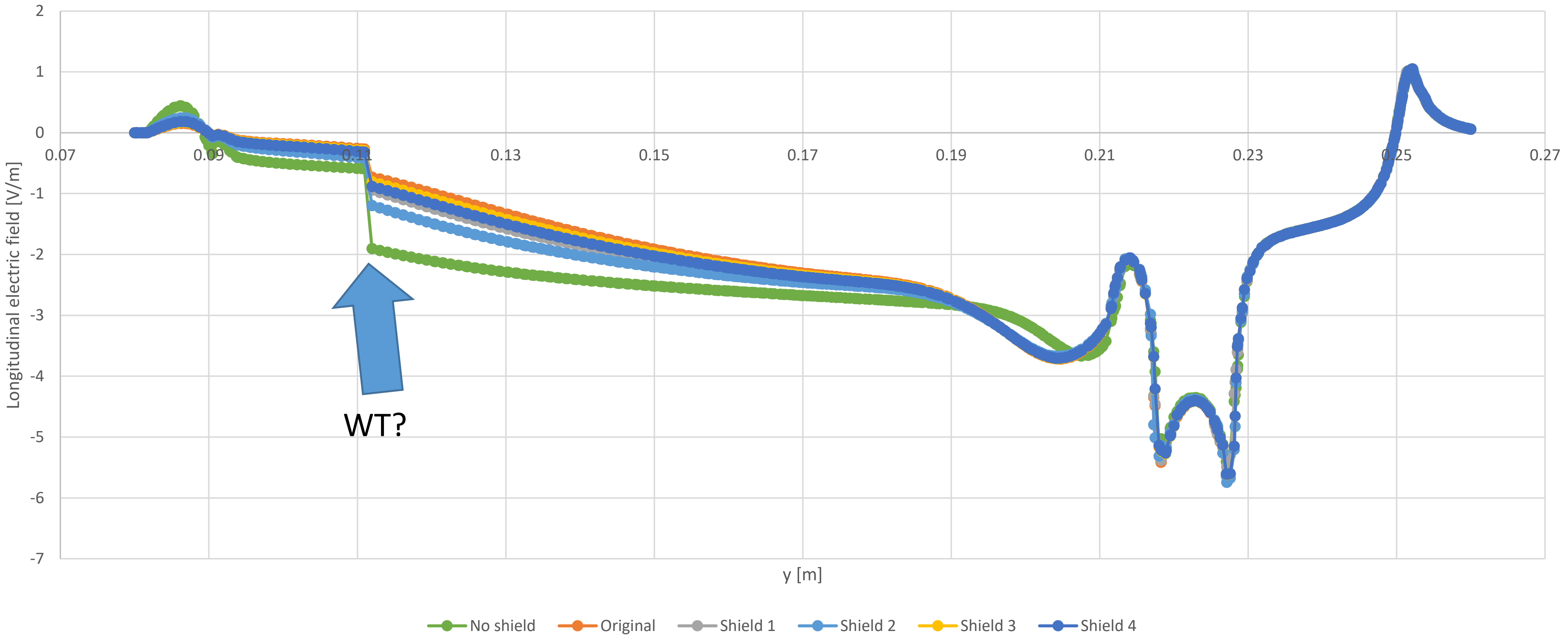


11% difference between 0.8 and 0.9

65% difference between 0.8 and 2.3

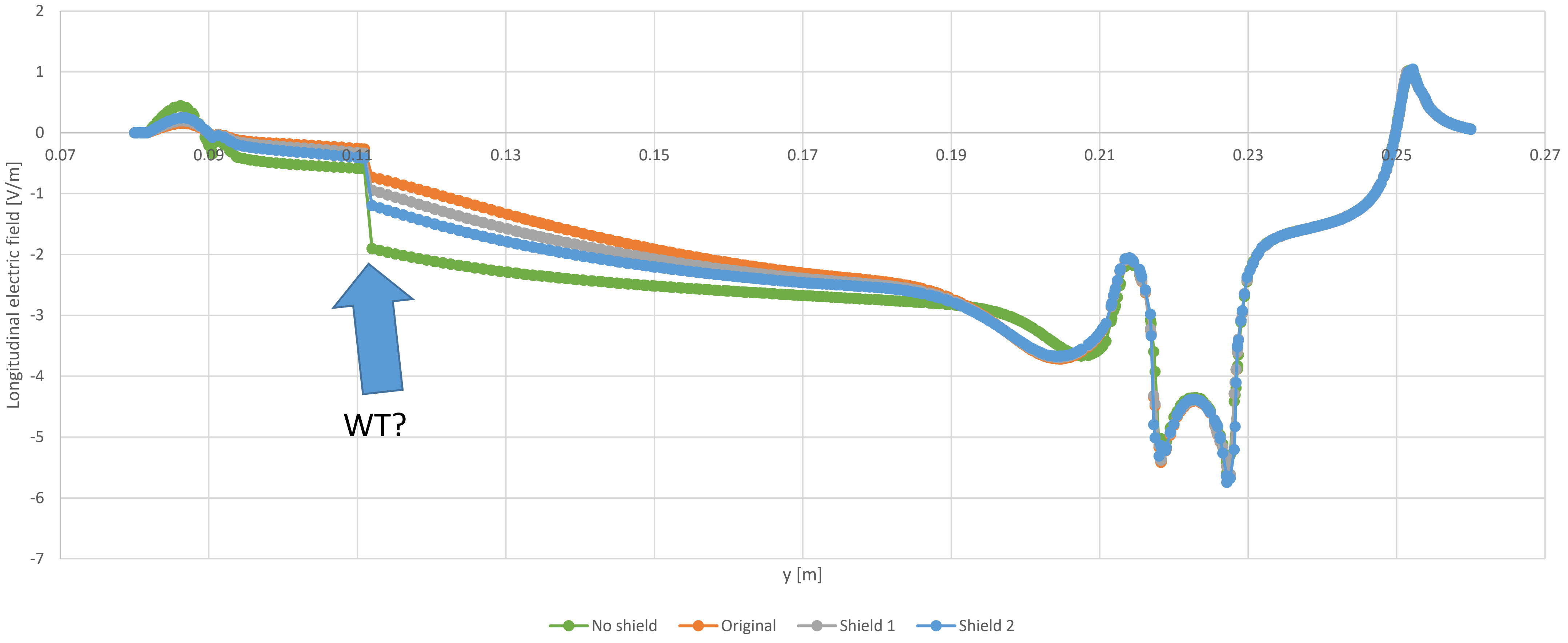
CST results: Longitudinal electric field – No shield vs Original vs all shields (1,2,3 & 4) at insulator interface

Different colors represent different shields.



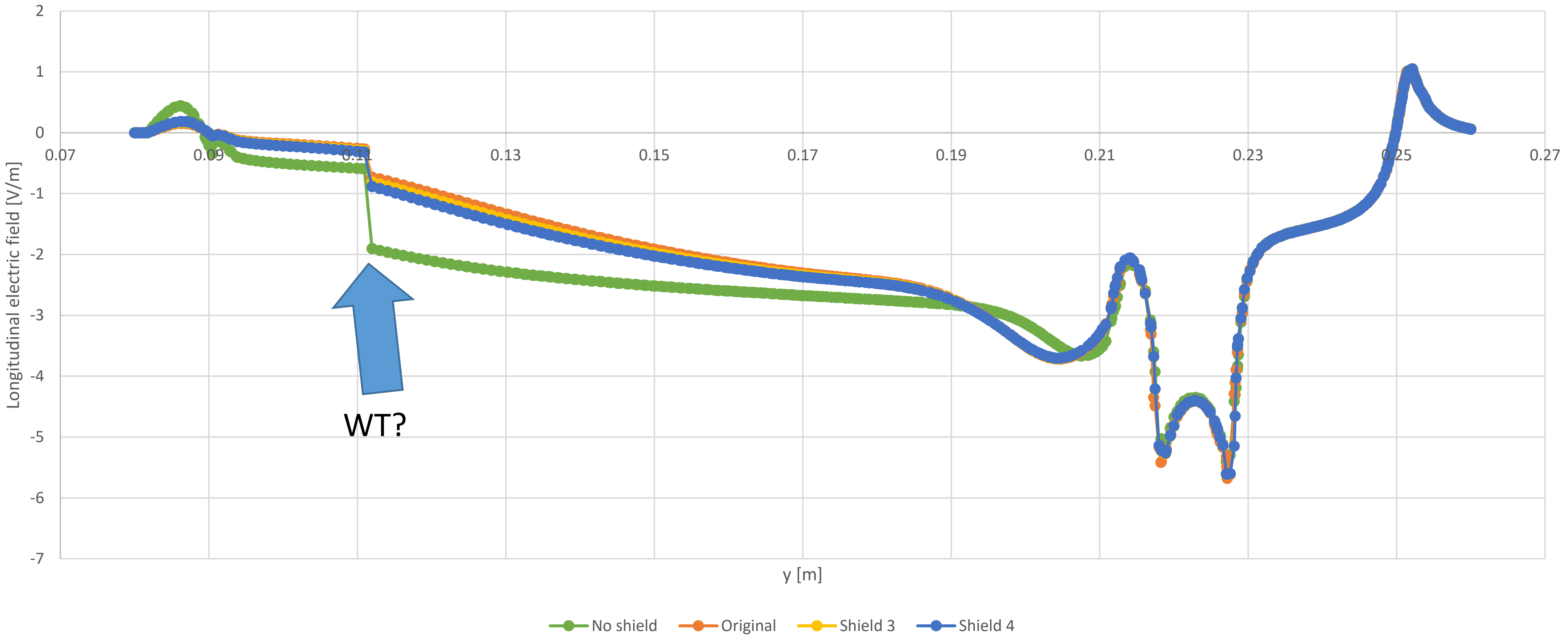
CST results: Longitudinal electric field – No shield vs Original vs shields 1&2 at insulator interface

Different colors represent different shields.



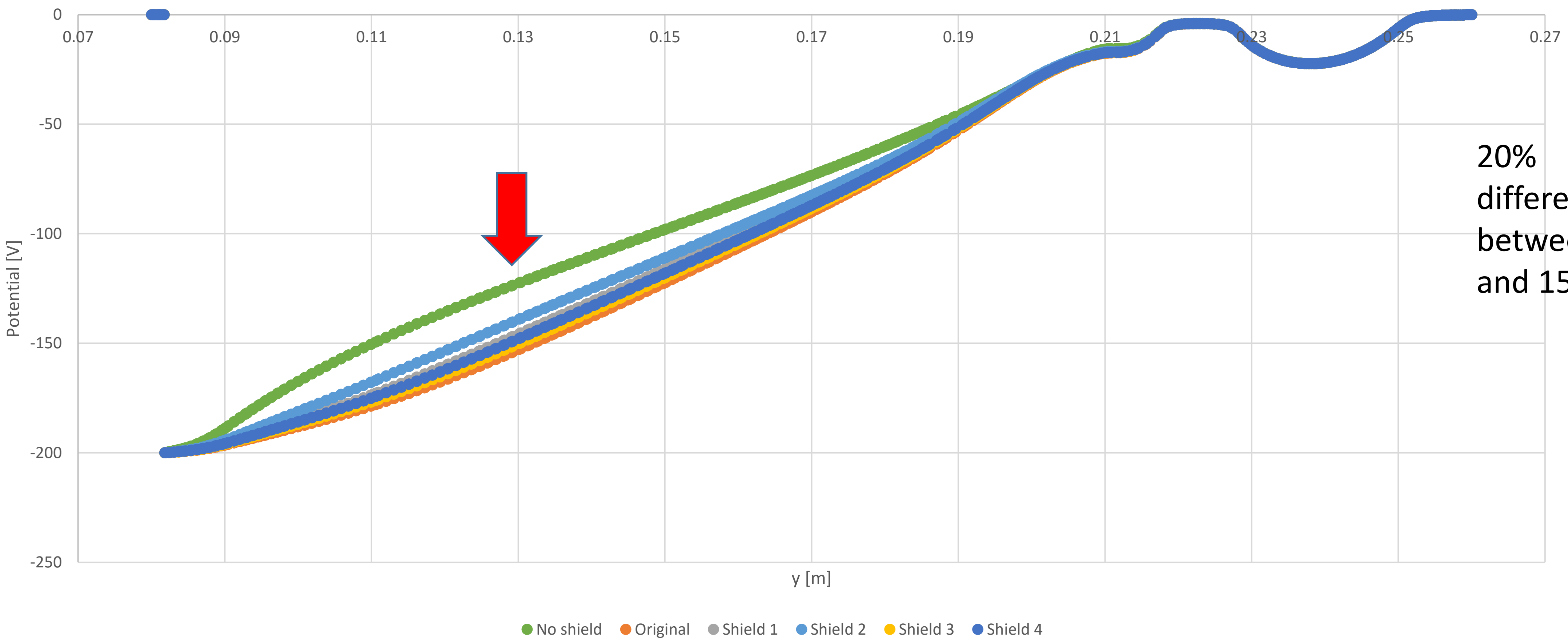
CST results: Longitudinal electric field – No shield vs Original vs shields 3&4 at insulator interface

Different colors represent different shields.



CST results: Potential – No shield vs Original vs all shields (1,2,3 & 4) at insulator interface

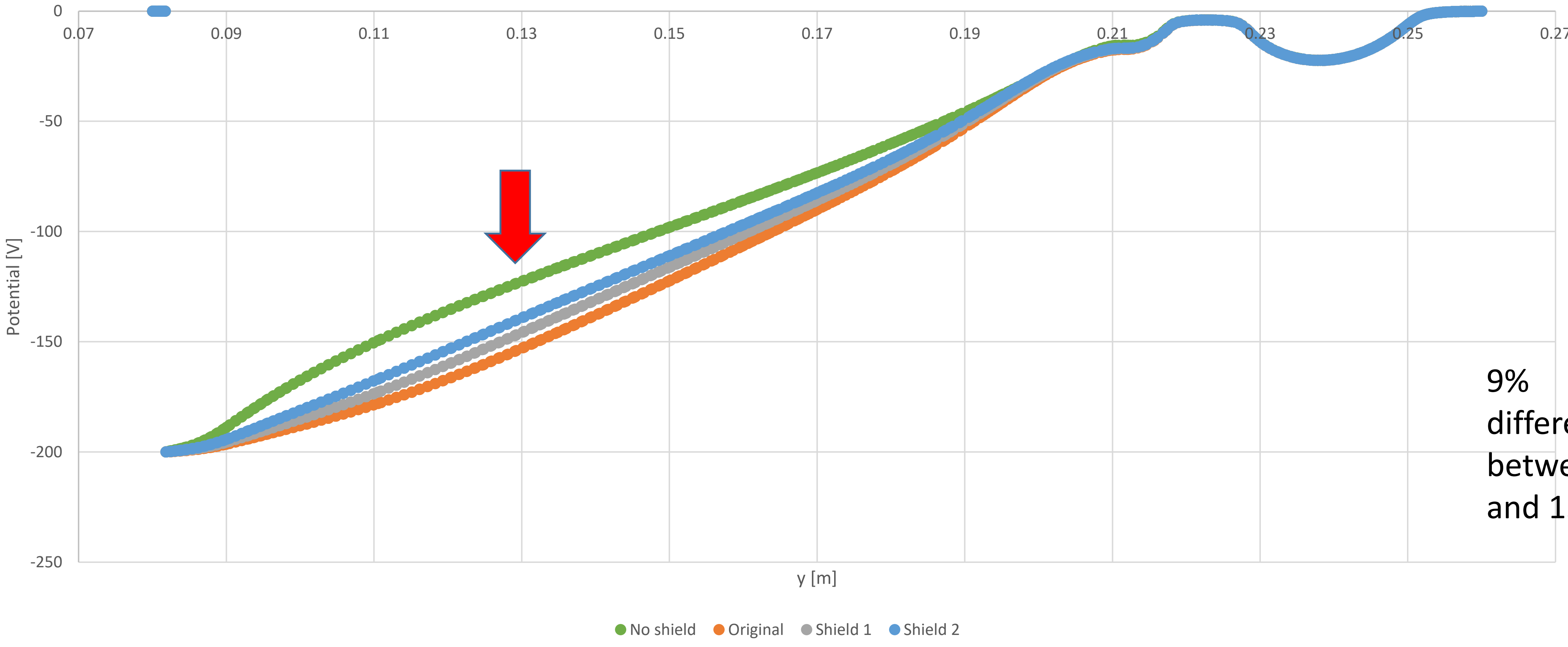
Different colors represent different shields.



20% difference between 123 and 153

CST results: Potential – No shield vs Original vs shields 1&2 at insulator interface

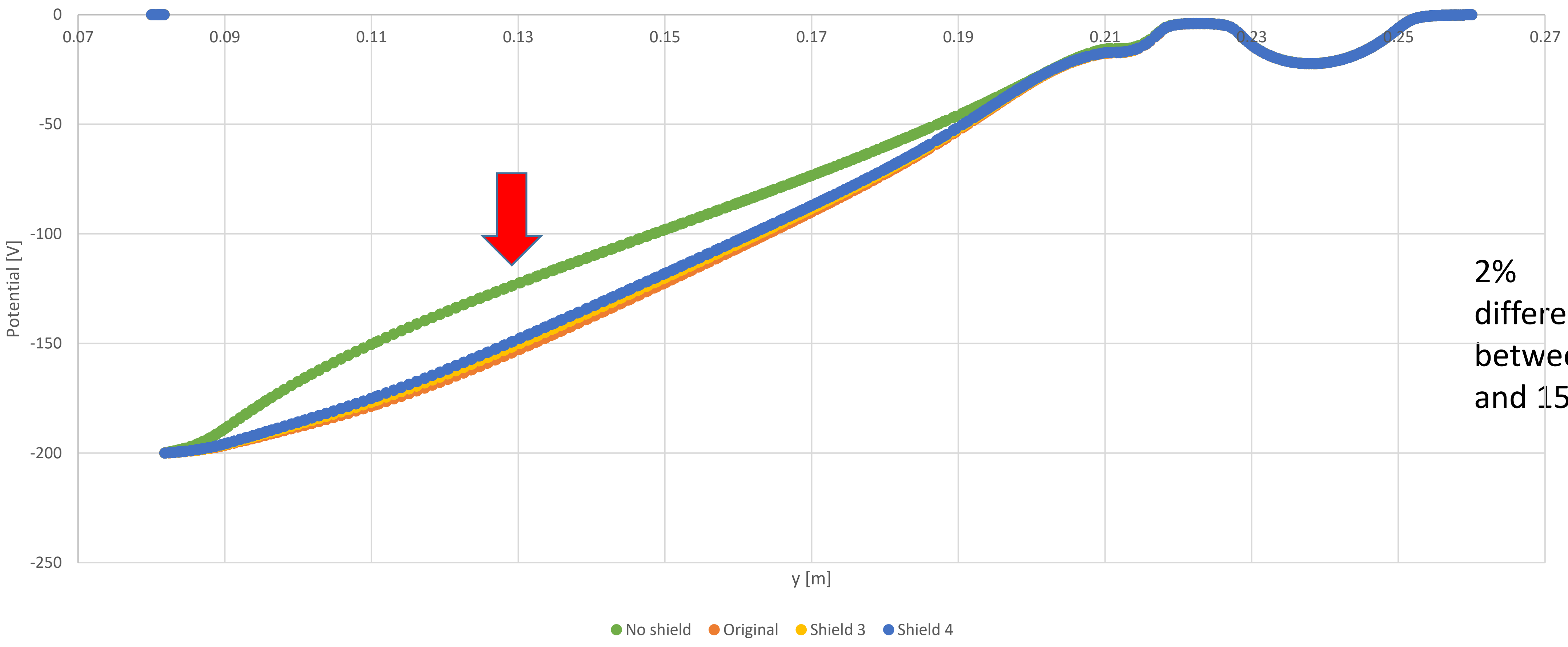
Different colors represent different shields.



9% difference between 139 and 153

CST results: Potential – No shield vs Original vs shields 3&4 at insulator interface

Different colors represent different shields.



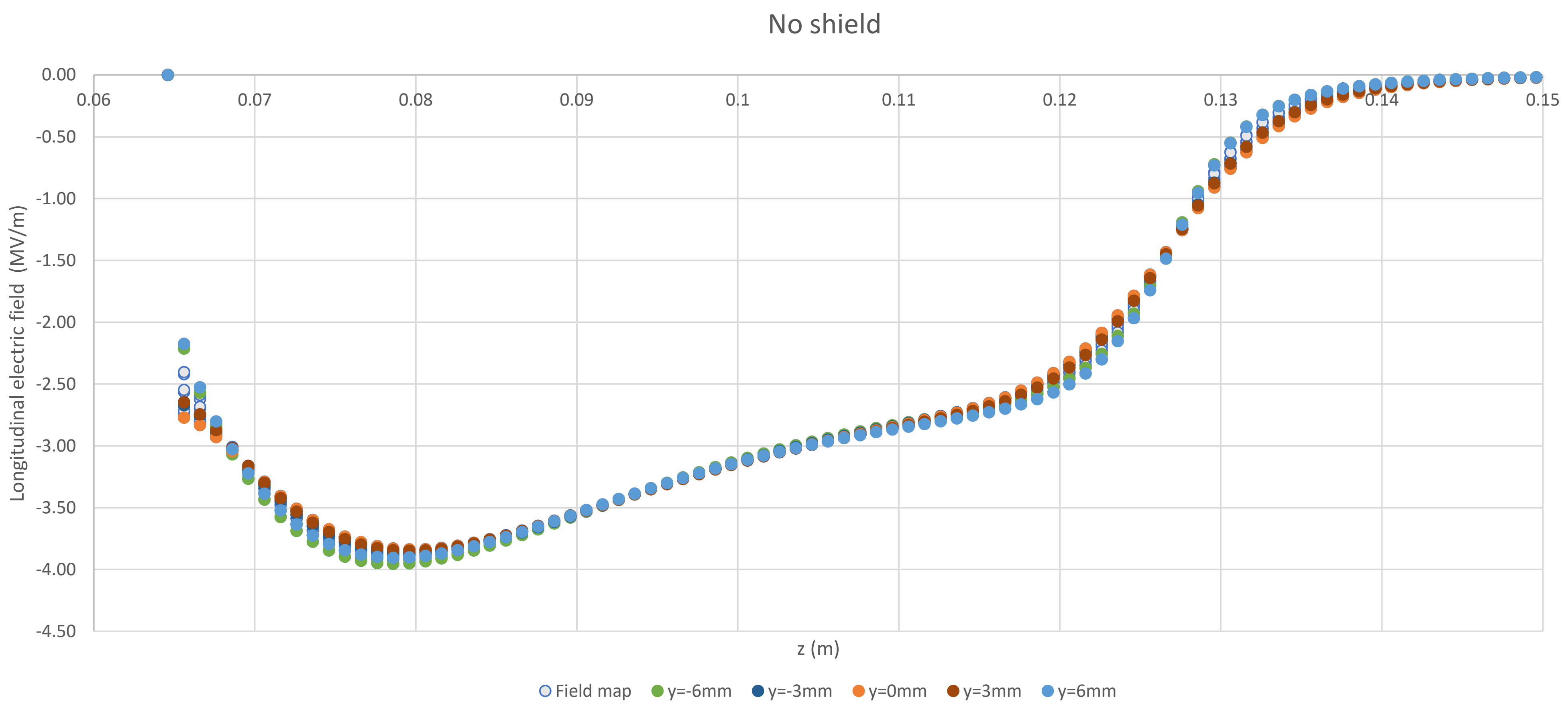
2% difference between 149 and 153

No shield vs Original vs all Shields (1,2,3 & 4): Longitudinal electric field at c-a gap

- You can notice the variation on the longitudinal electric field in the cathode-anode gap is minimal, due to a change of radius or a change in the shield height. The largest difference is around the z= 0.075 m, and its of ~3%. Similarly around z=0.12 m.

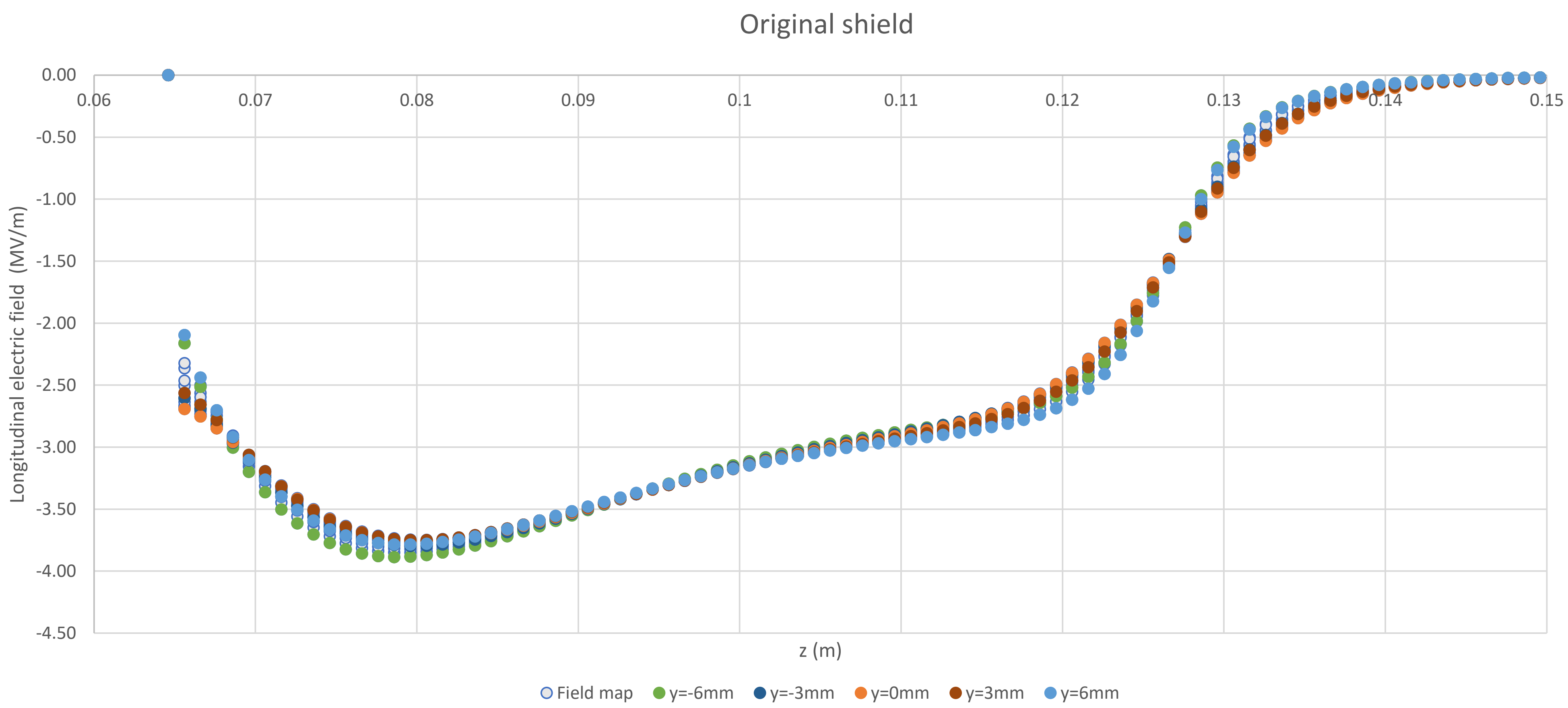
CST results: Longitudinal electric field – No shield

The gray data set is the whole field map. The different colors show how the longitudinal electric field changes as a function of height on the photocathode in the interval -6mm<y<6mm



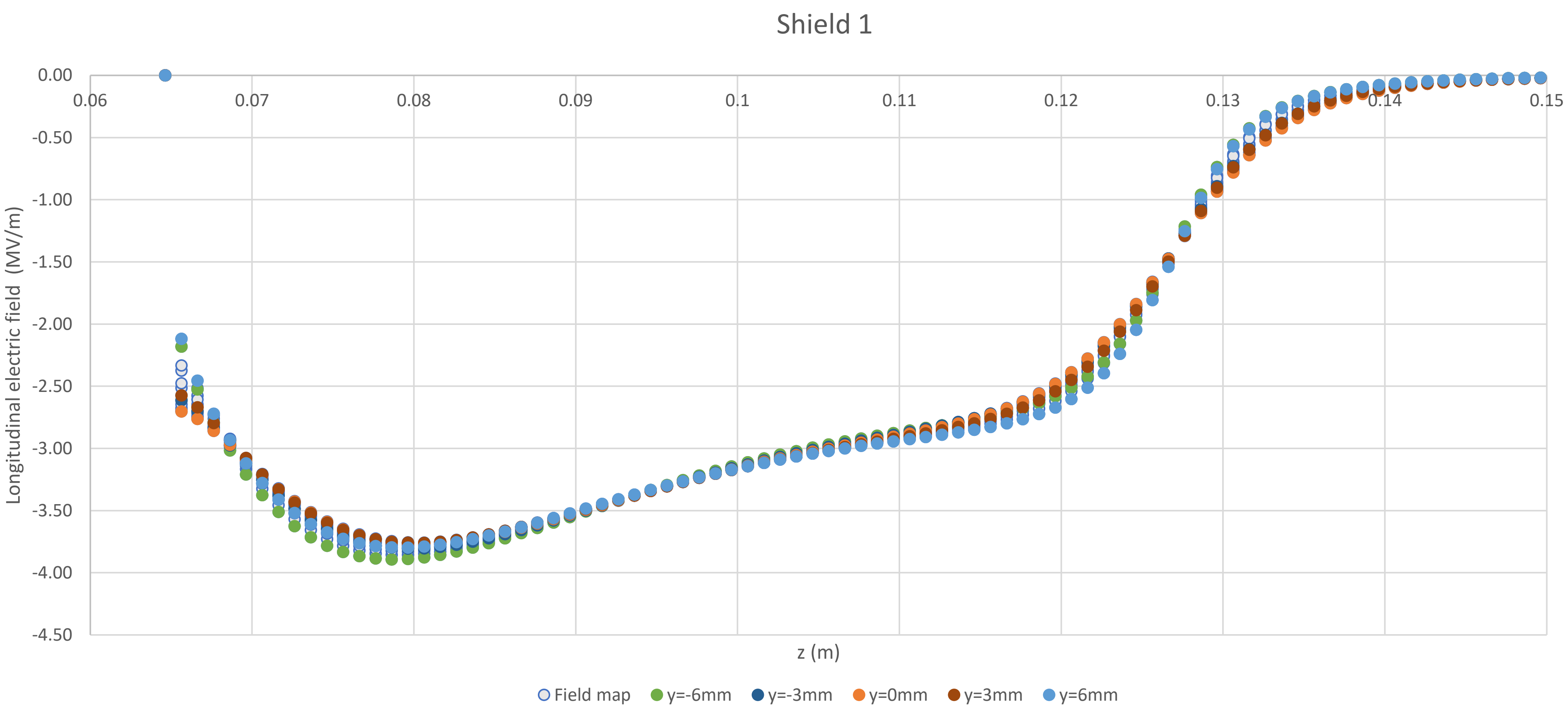
CST results: Longitudinal electric field – original shield

The gray data set is the whole field map. The different colors show how the longitudinal electric field changes as a function of height on the photocathode in the interval -6mm<y<6mm



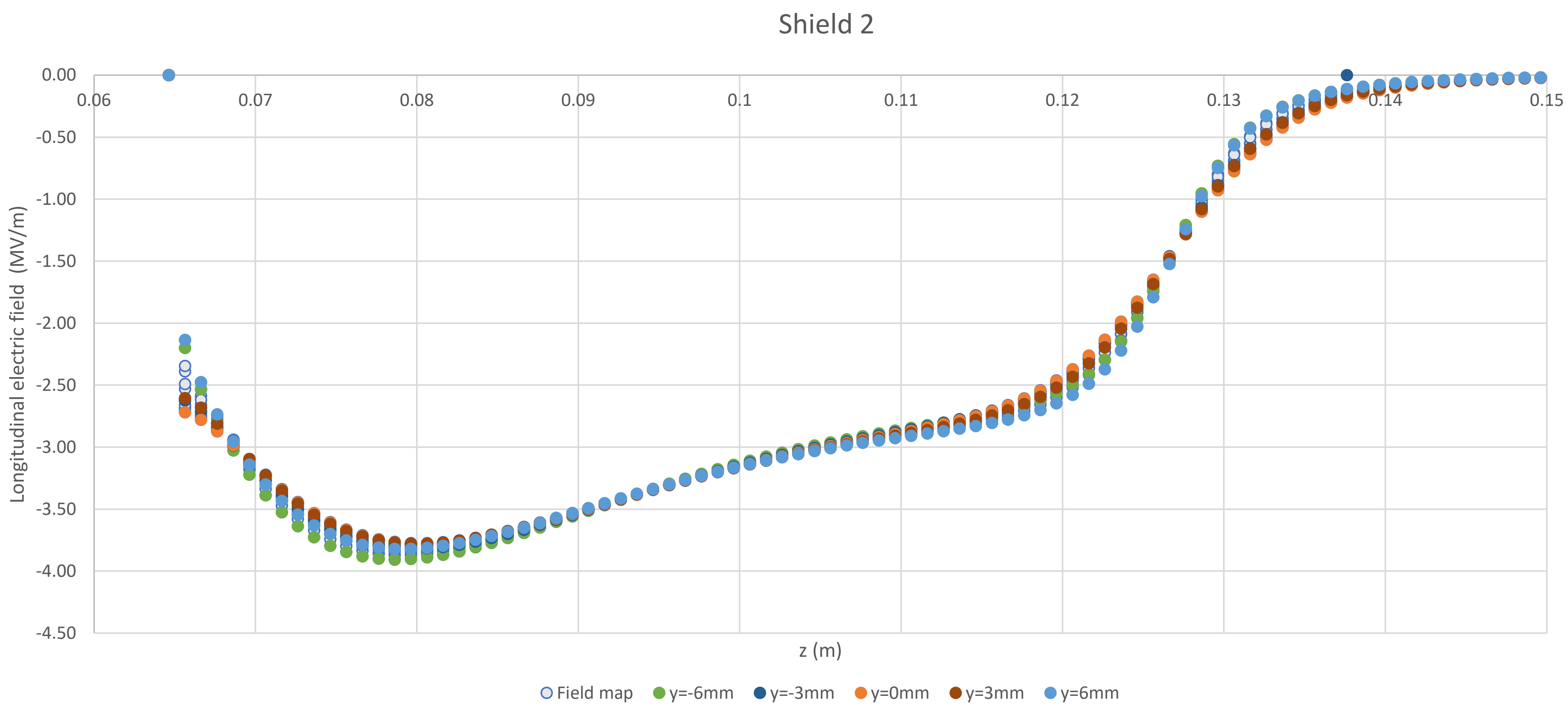
CST results: Longitudinal electric field – Shield 1

The gray data set is the whole field map. The different colors show how the longitudinal electric field changes as a function of height on the photocathode in the interval -6mm<y<6mm



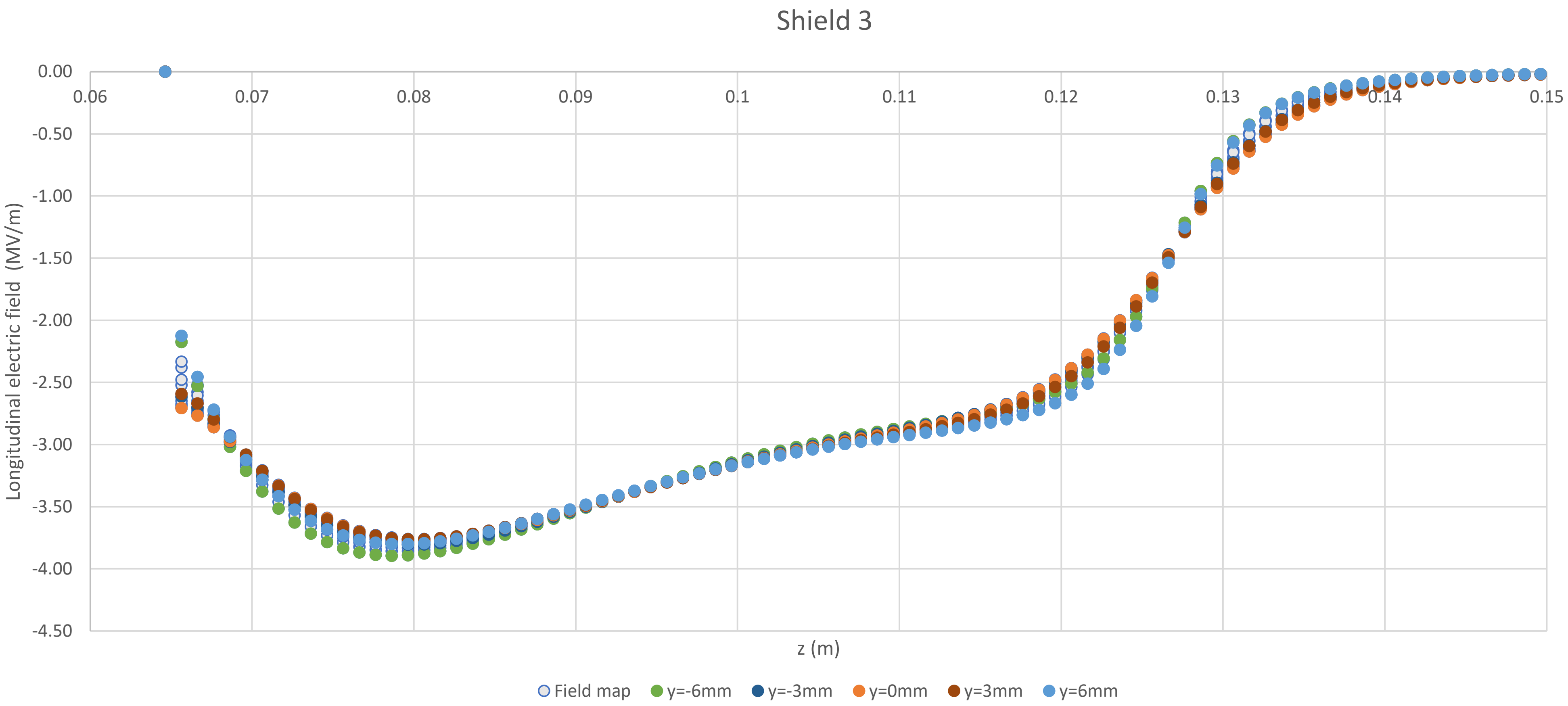
CST results: Longitudinal electric field – Shield 2

The gray data set is the whole field map. The different colors show how the longitudinal electric field changes as a function of height on the photocathode in the interval -6mm<y<6mm



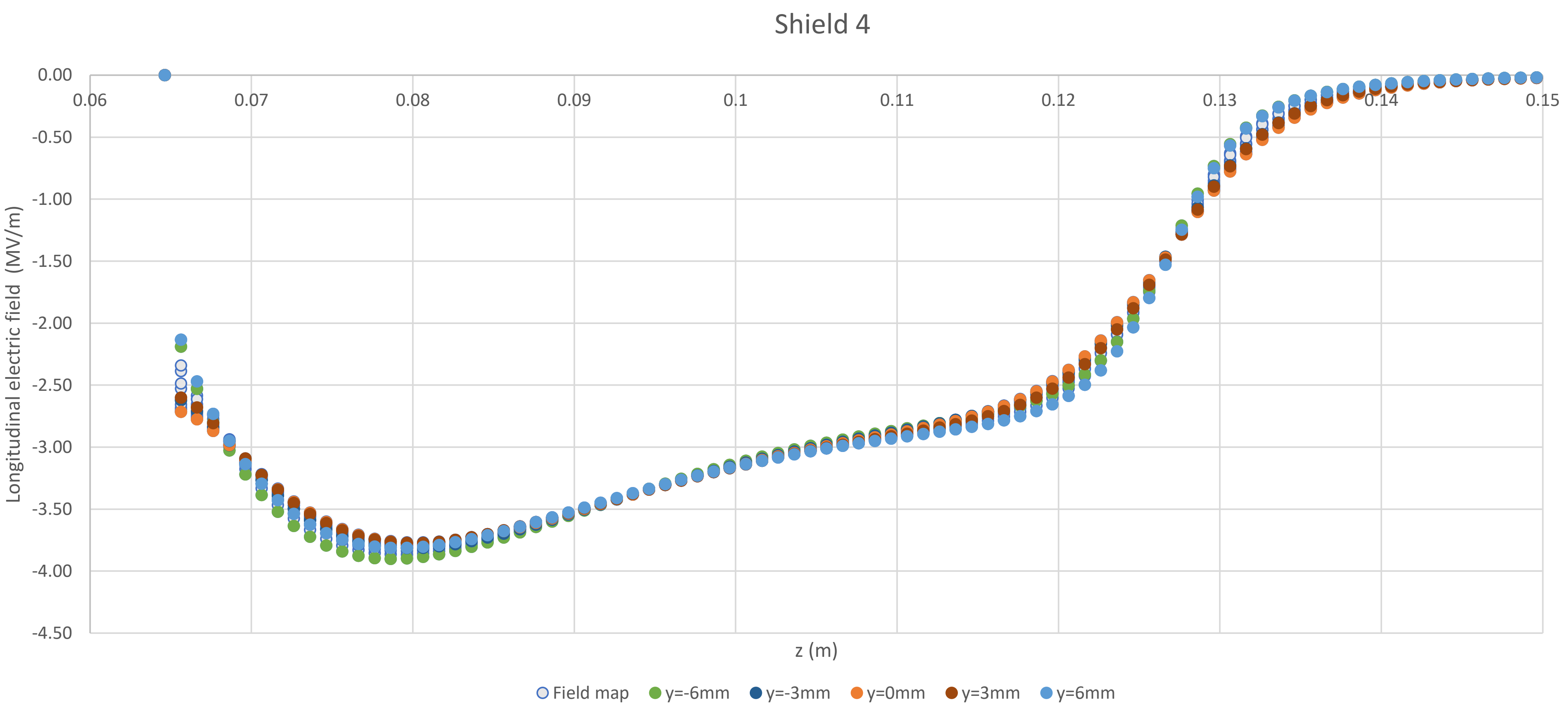
CST results: Longitudinal electric field – Shield 3

The gray data set is the whole field map. The different colors show how the longitudinal electric field changes as a function of height on the photocathode in the interval -6mm<y<6mm



CST results: Longitudinal electric field – Shield 4

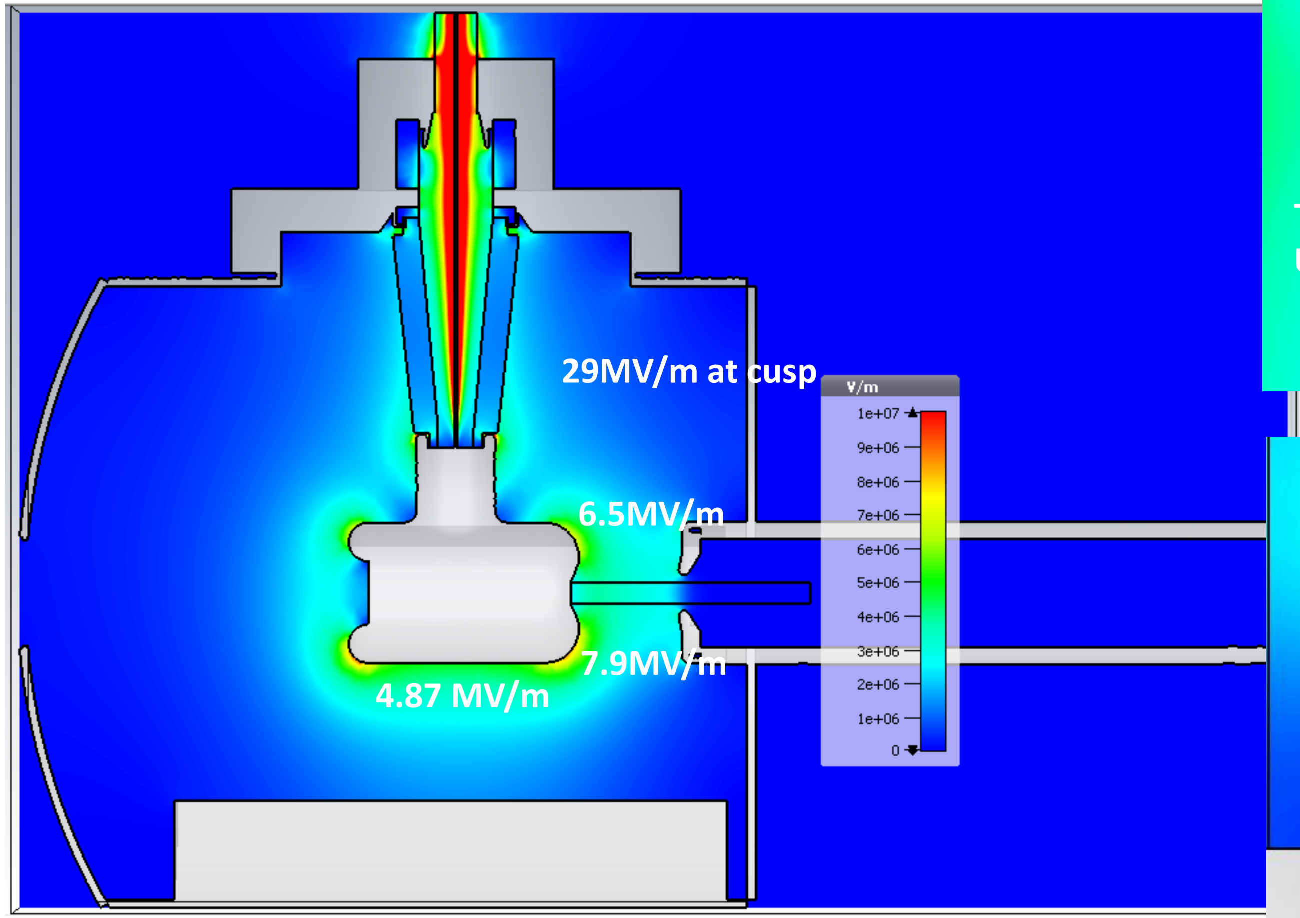
The gray data set is the whole field map. The different colors show how the longitudinal electric field changes as a function of height on the photocathode in the interval -6mm<y<6mm

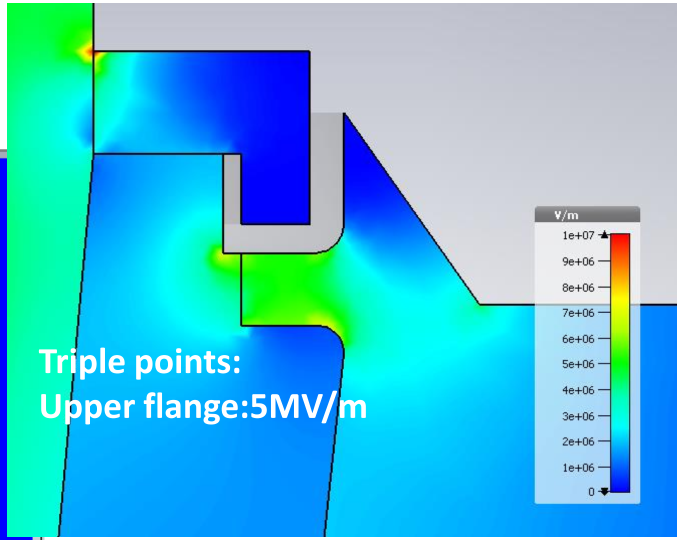


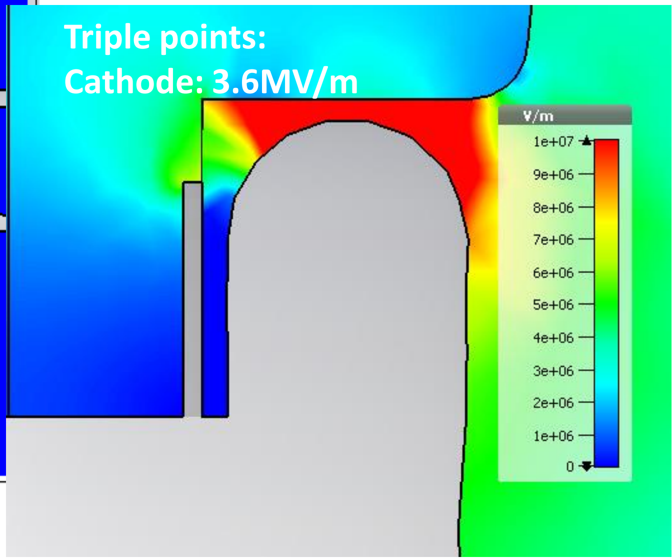
False color

Electric field norm: No shield vs Original vs shields 1&2

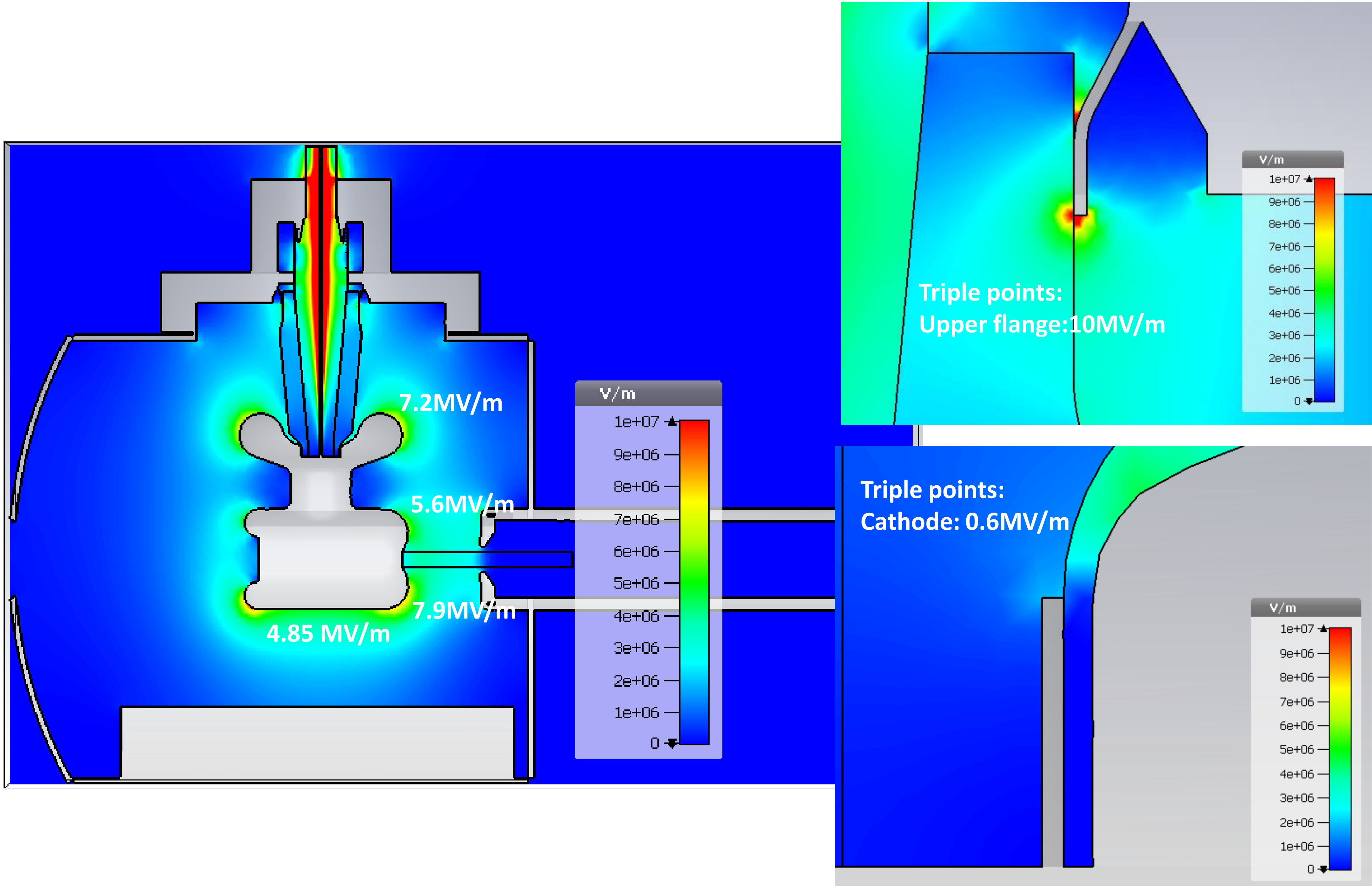
CST results: Electric field norm– No shield



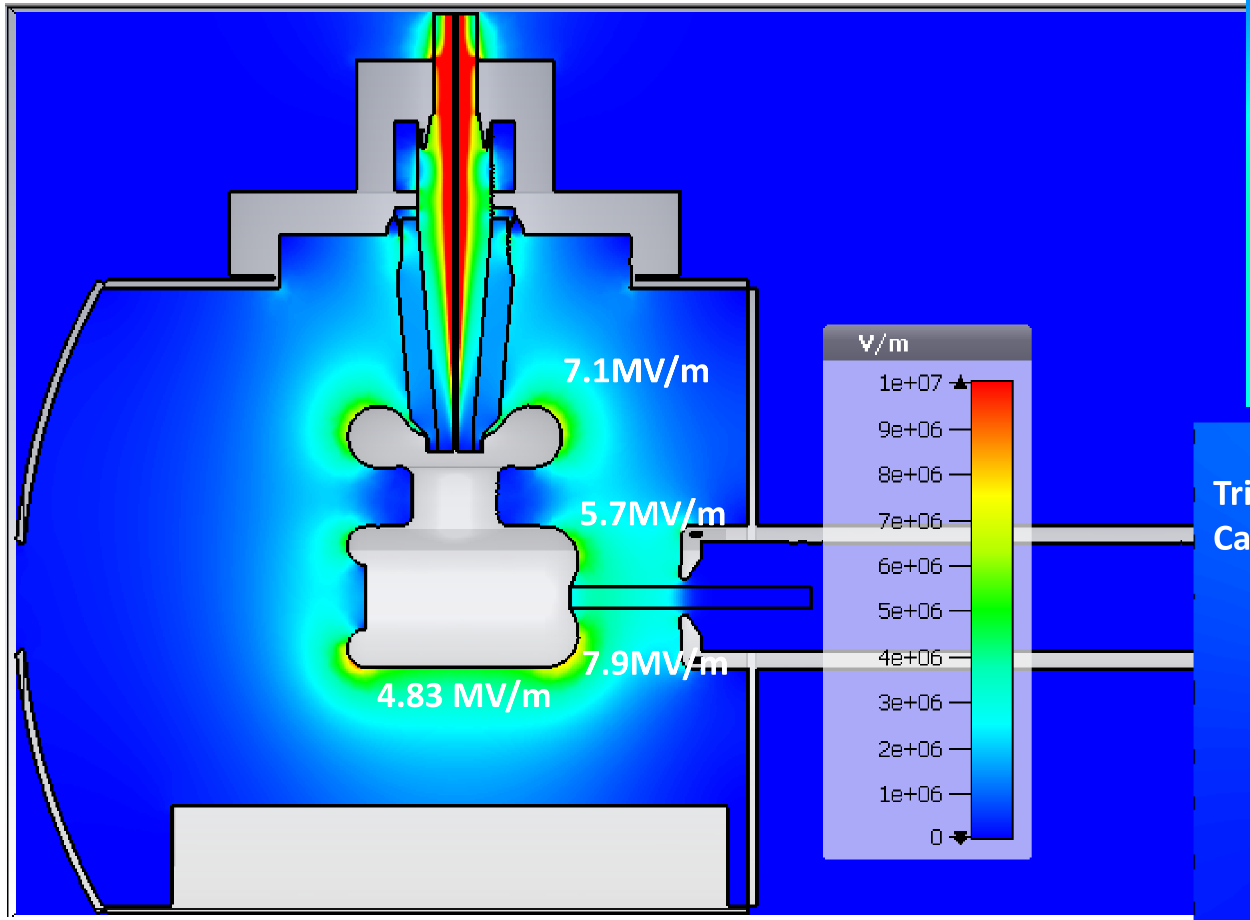


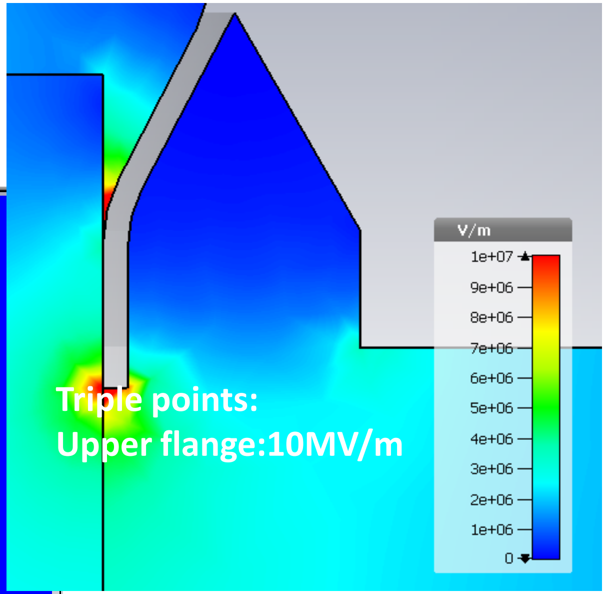


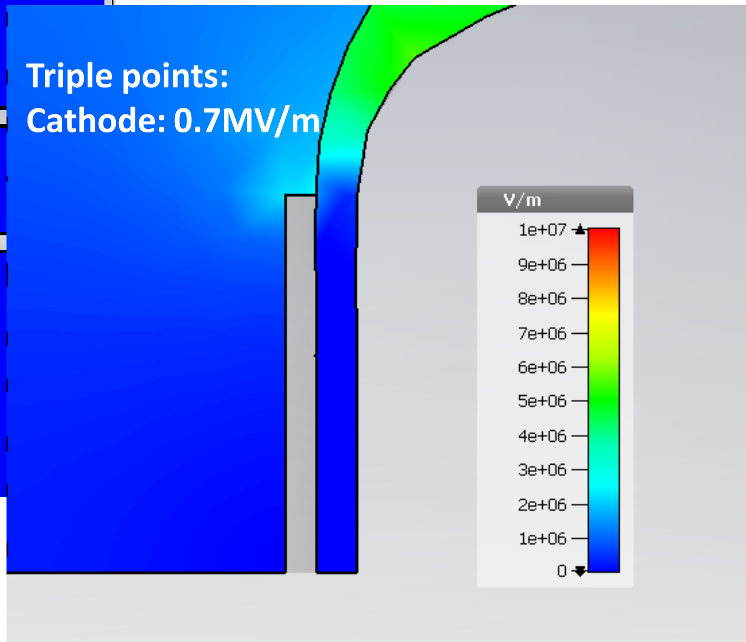
CST results: Electric field norm– original shield



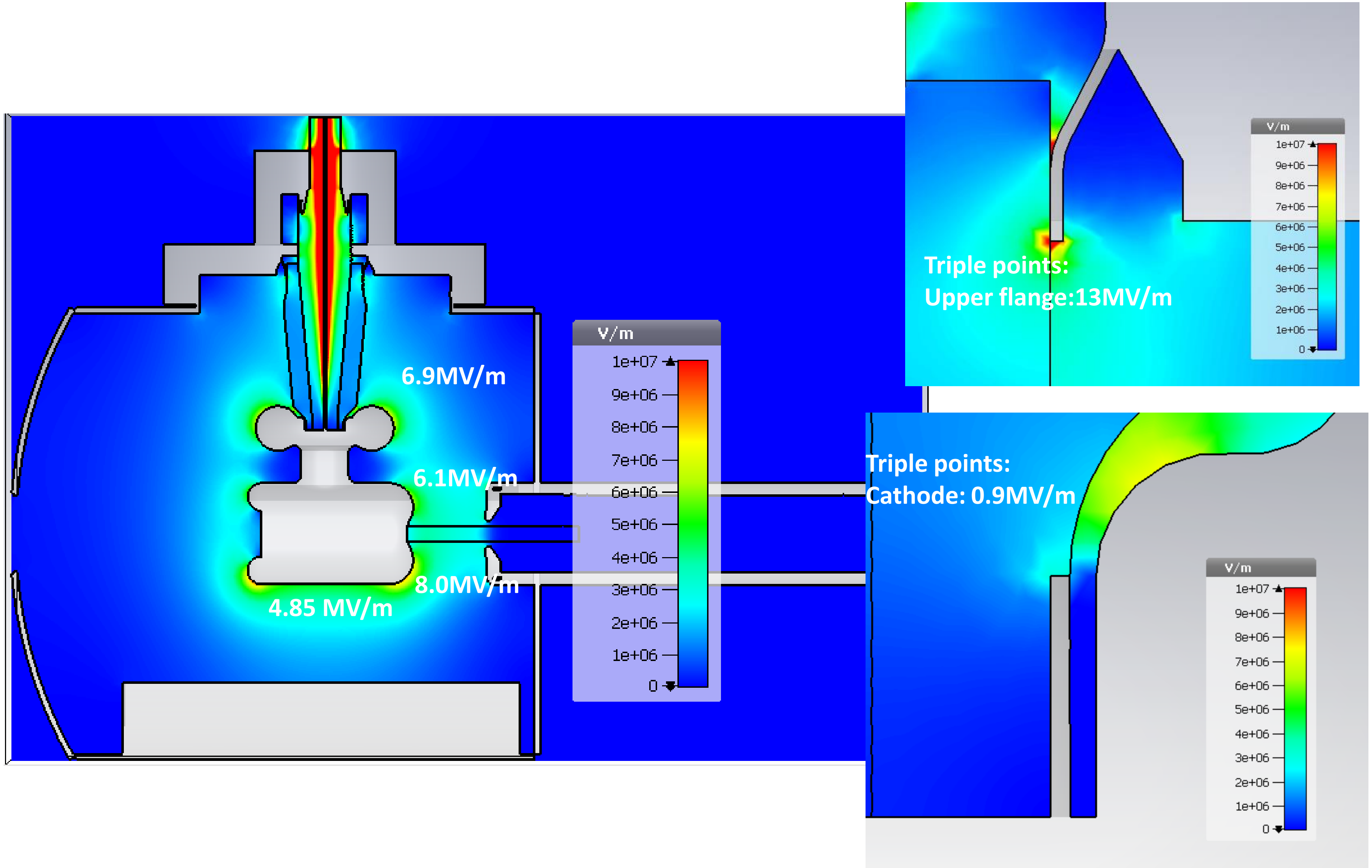
CST results: Electric field norm– Shield 1





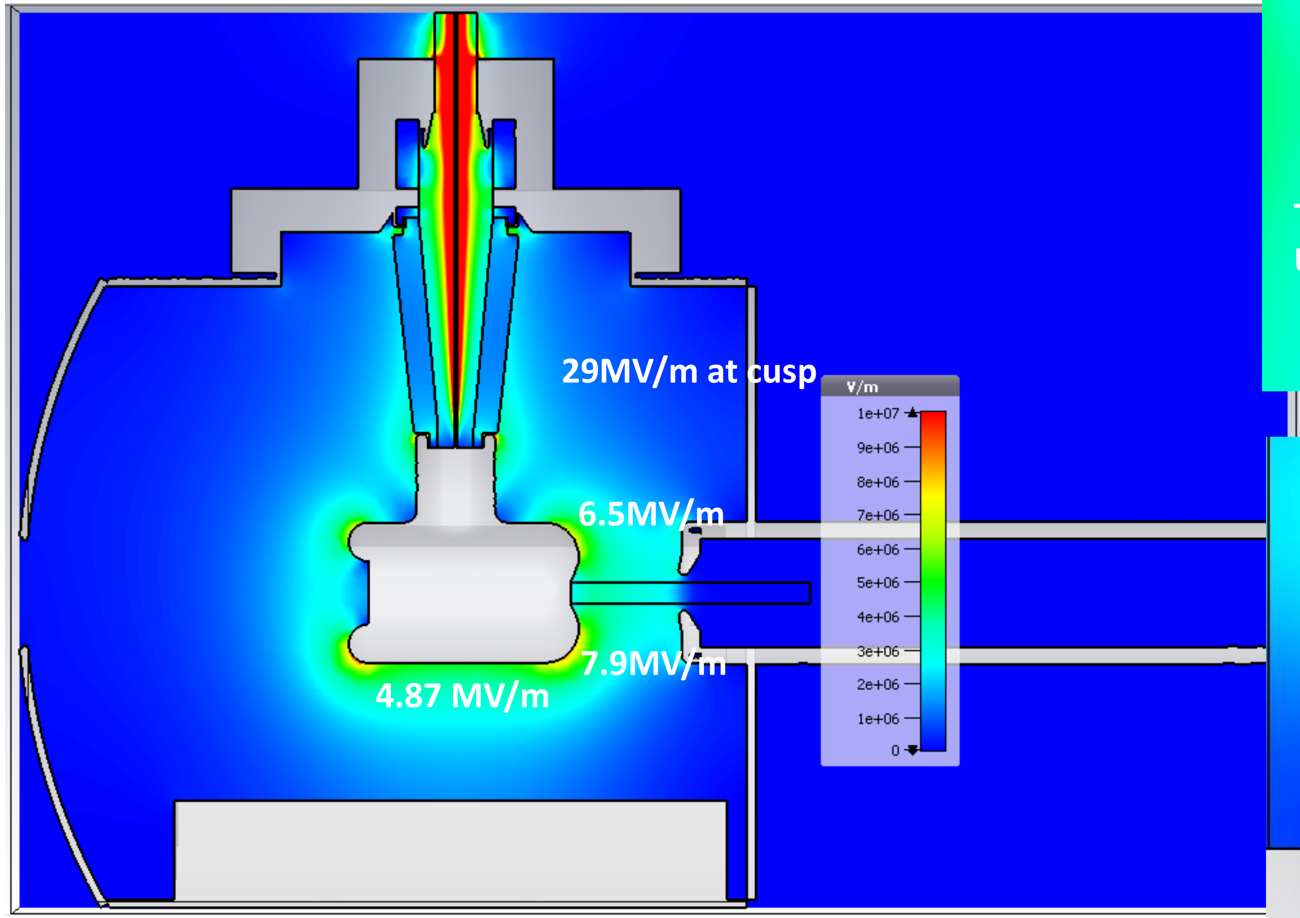


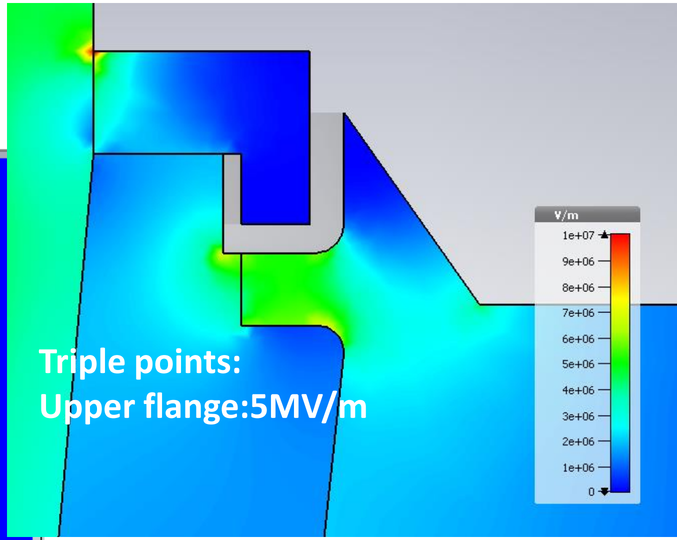
CST results: Electric field norm– Shield 2

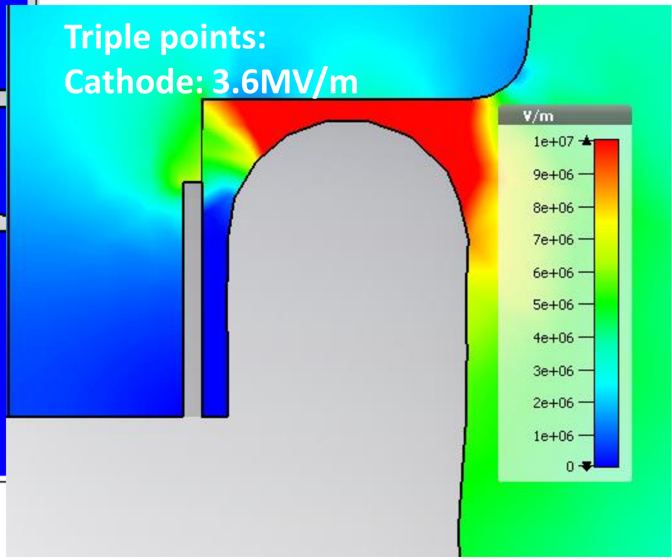


Electric field norm: No shield vs Original vs shields 3&4

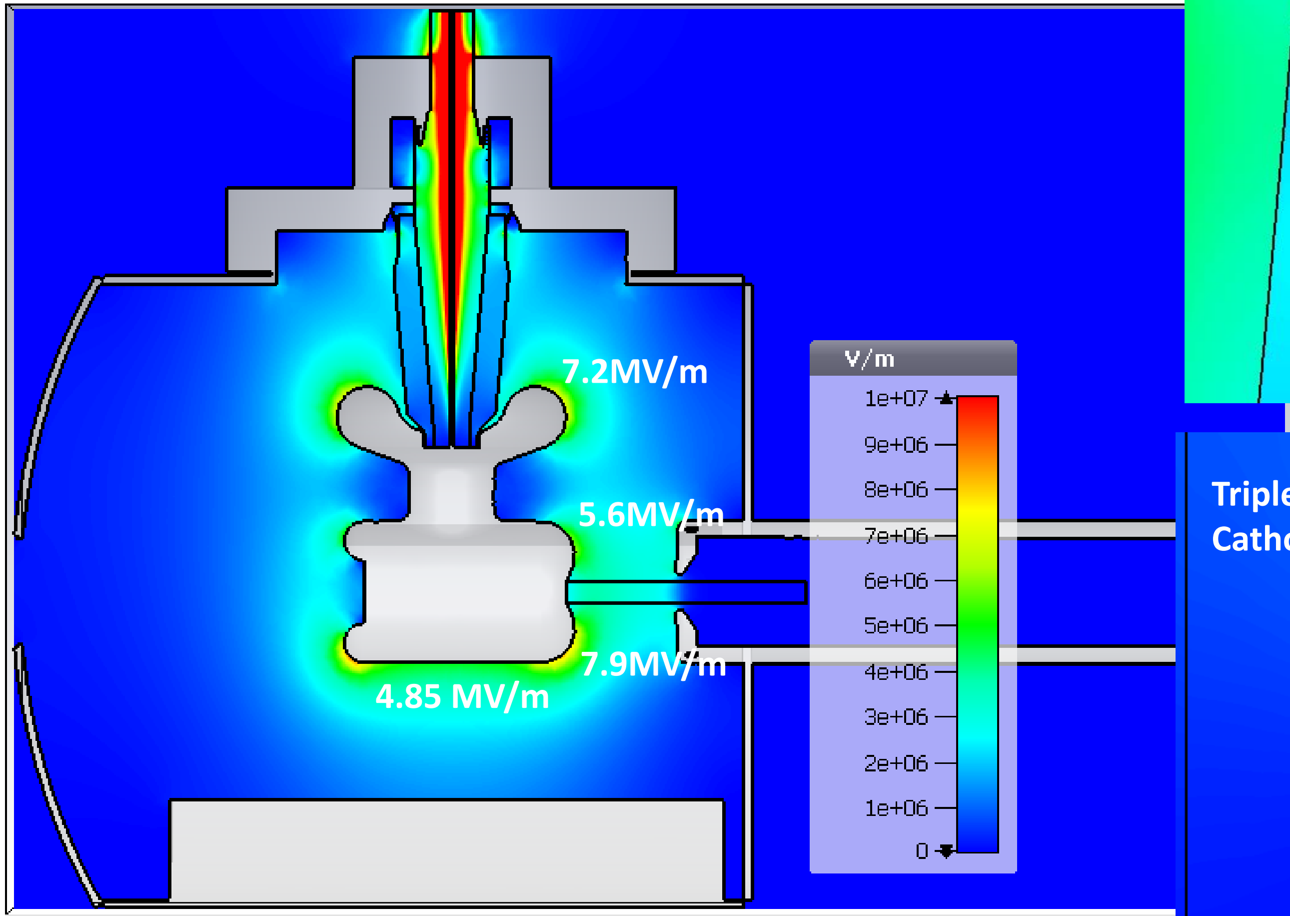
CST results: Electric field norm– No shield

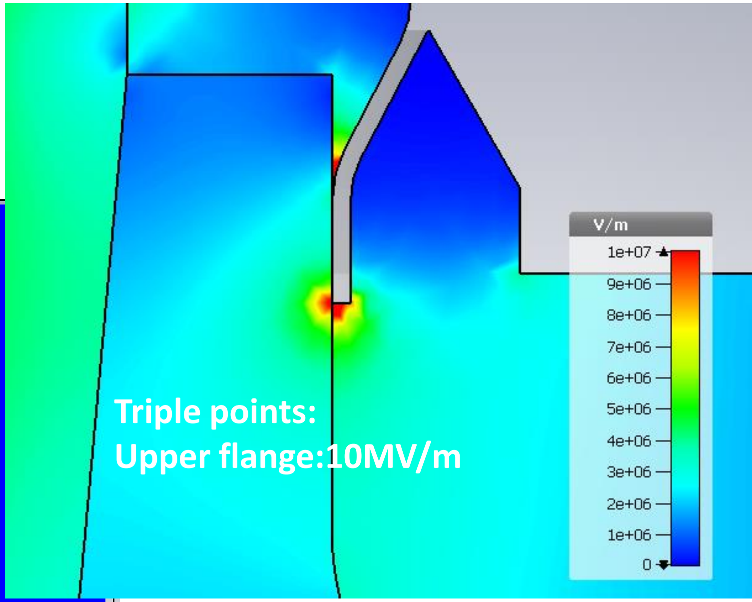


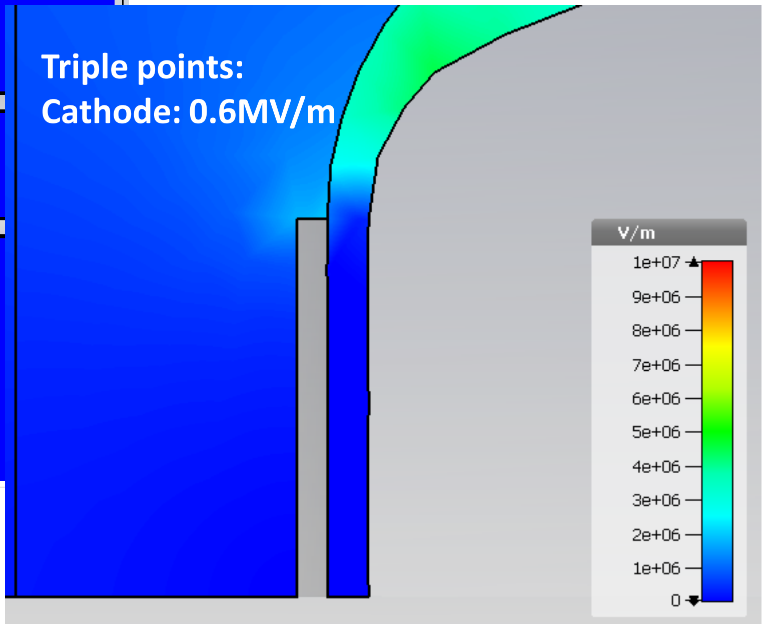




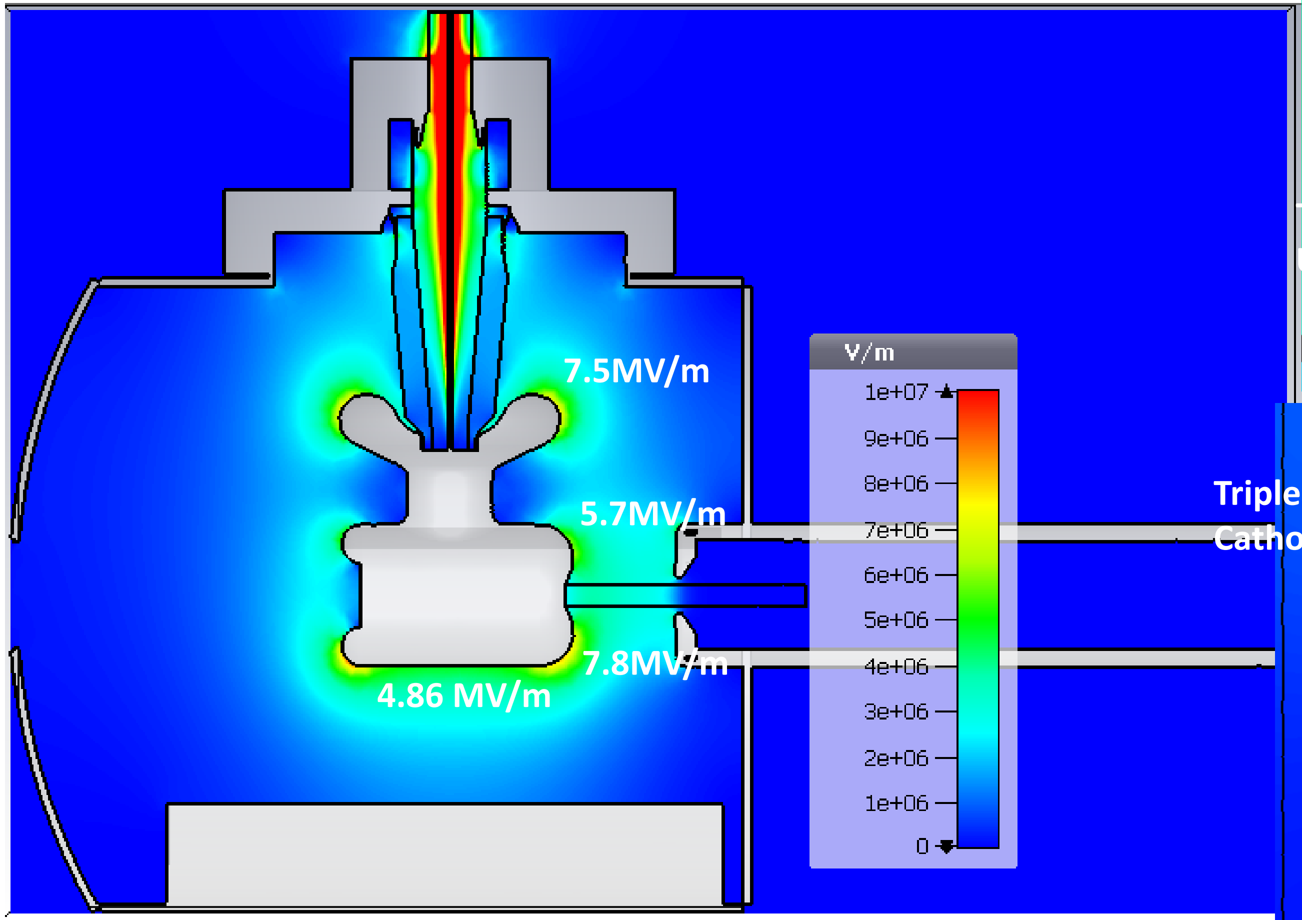
CST results: Electric field norm– original shield

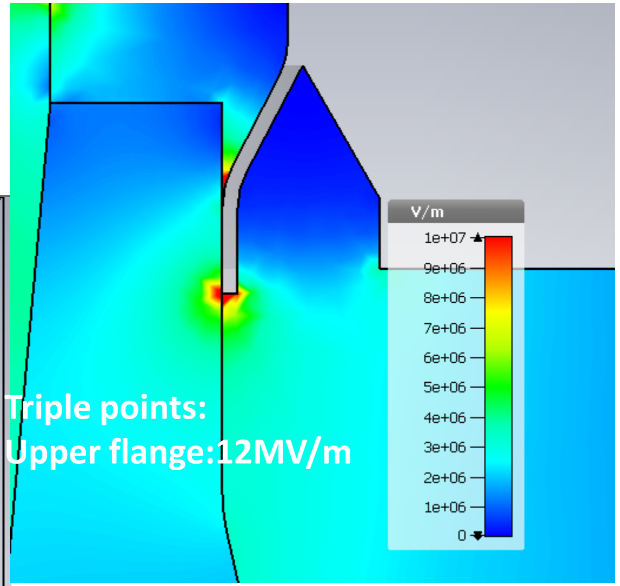


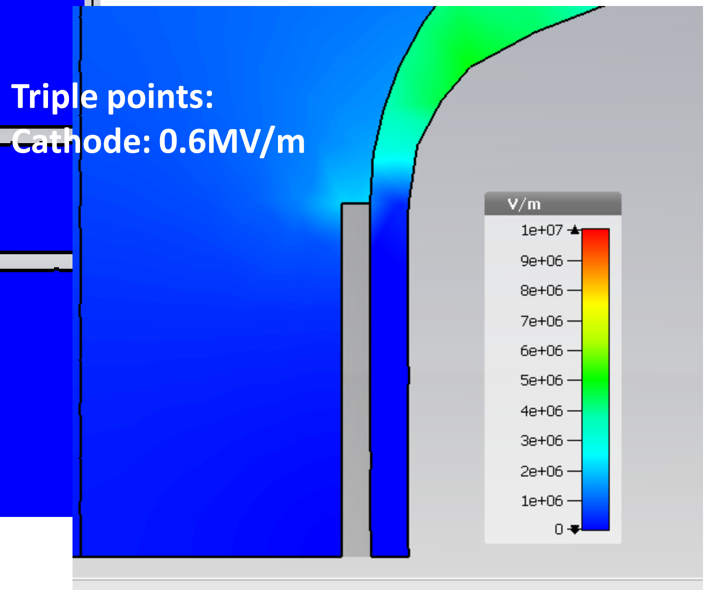




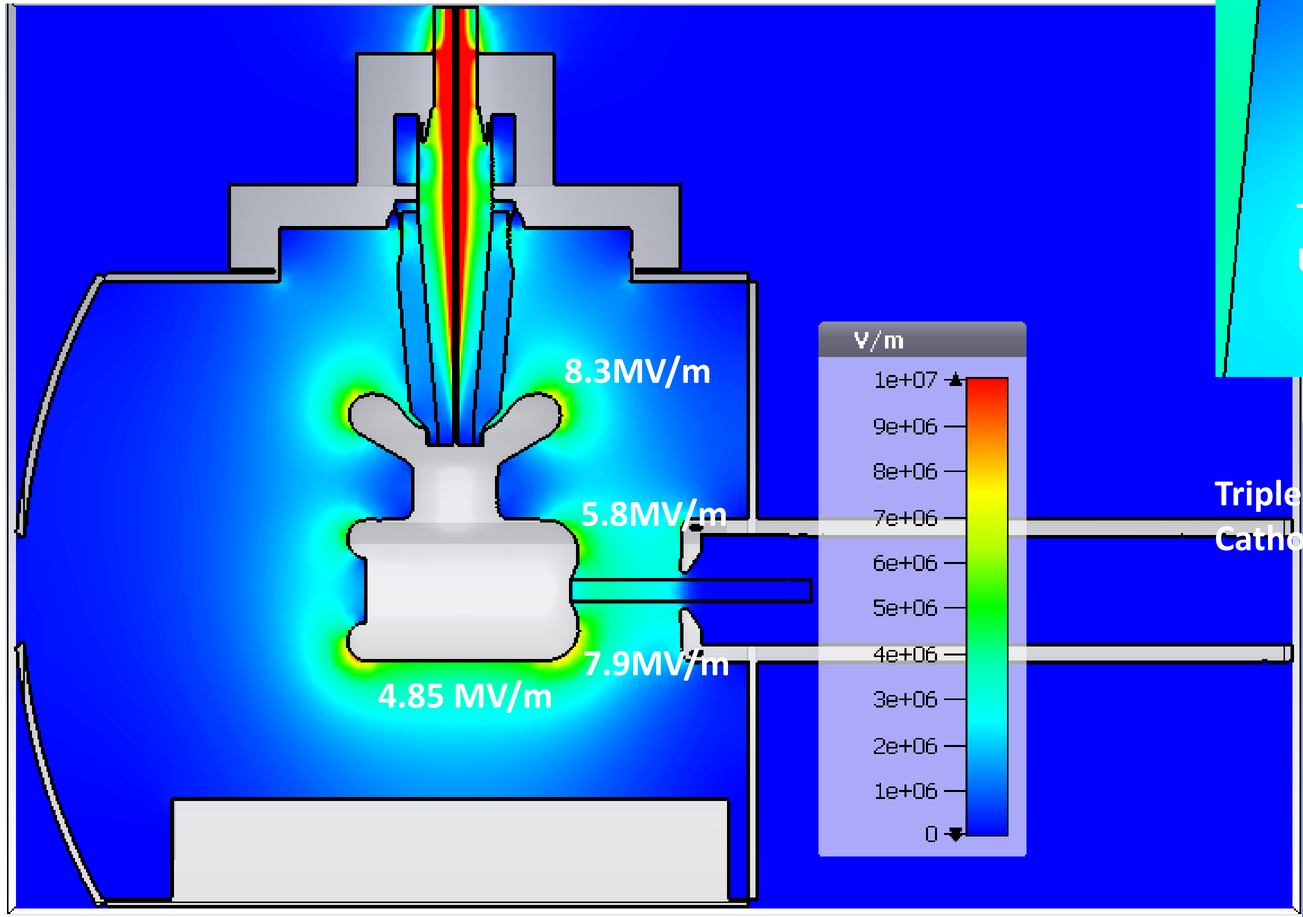
CST results: Electric field norm– Shield 3

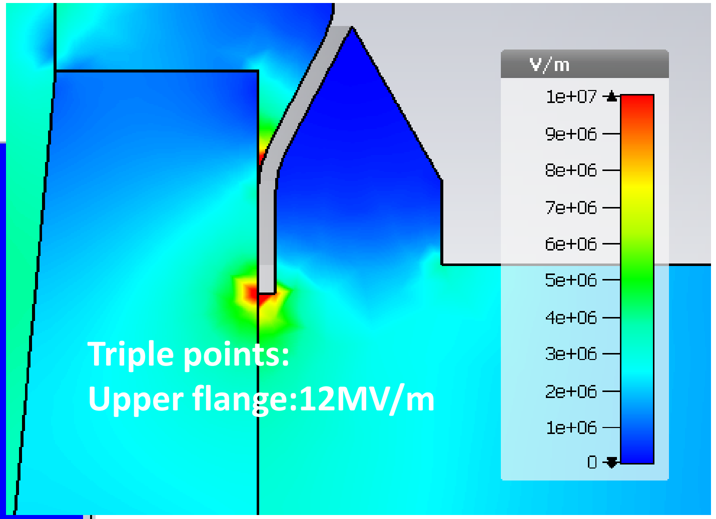


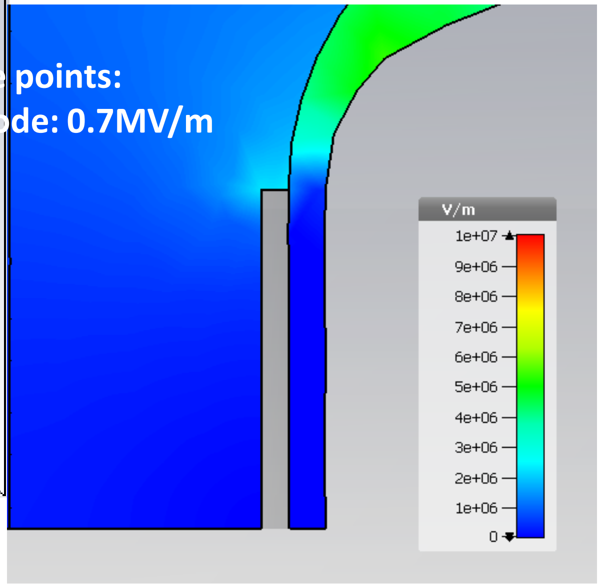




CST results: Electric field norm– Shield 4



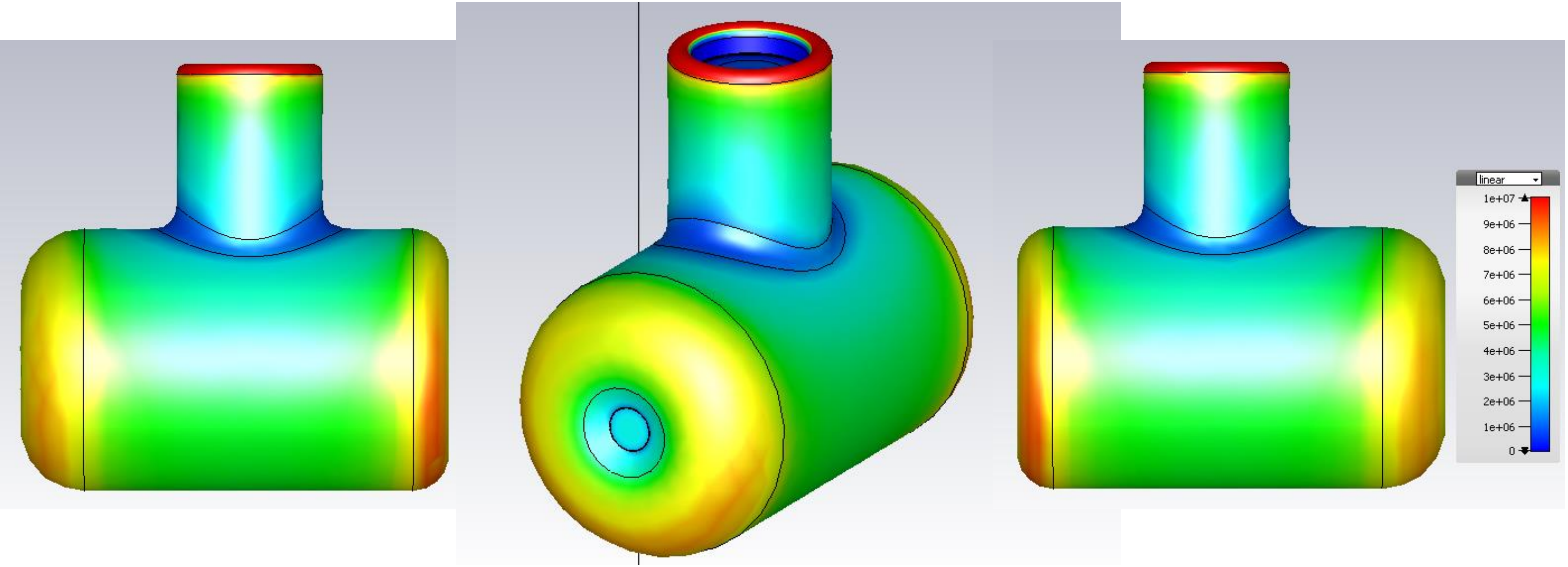




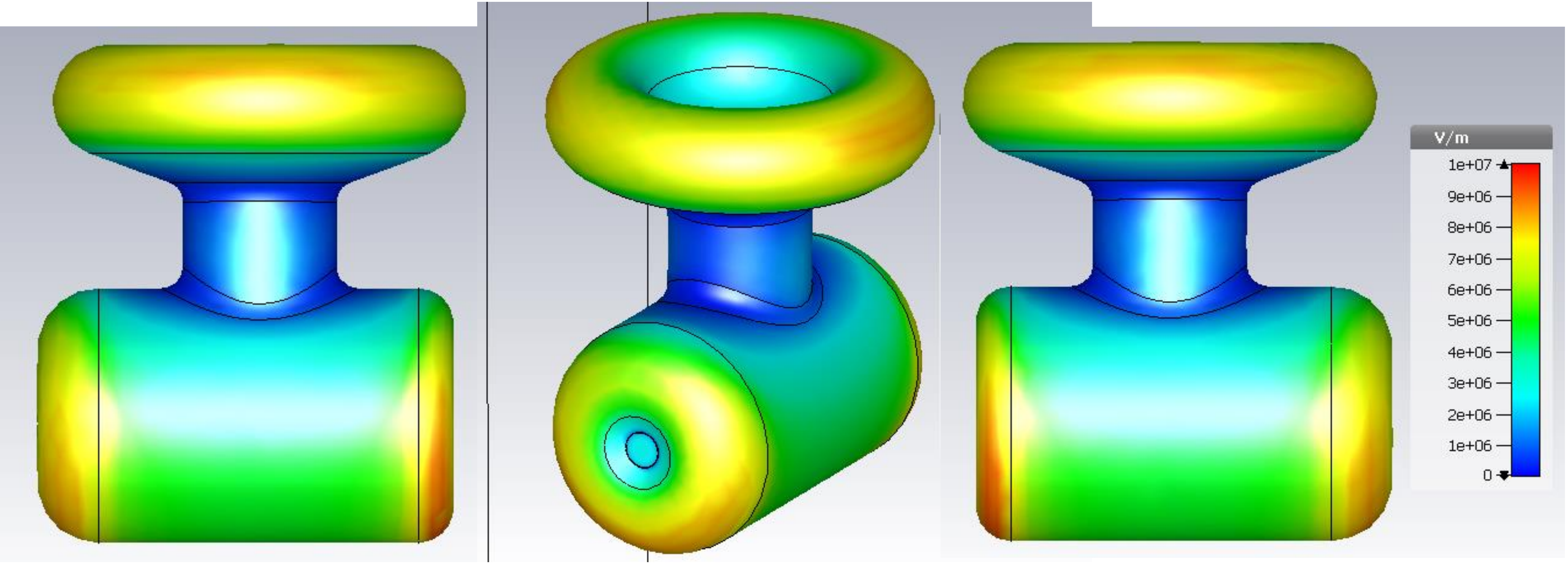
Electric field norm: No shield vs Original vs shields 1 vs shields 2

- On the metallic surface
- Pics are sadly not to scale, in all of them the cathode size is the same.

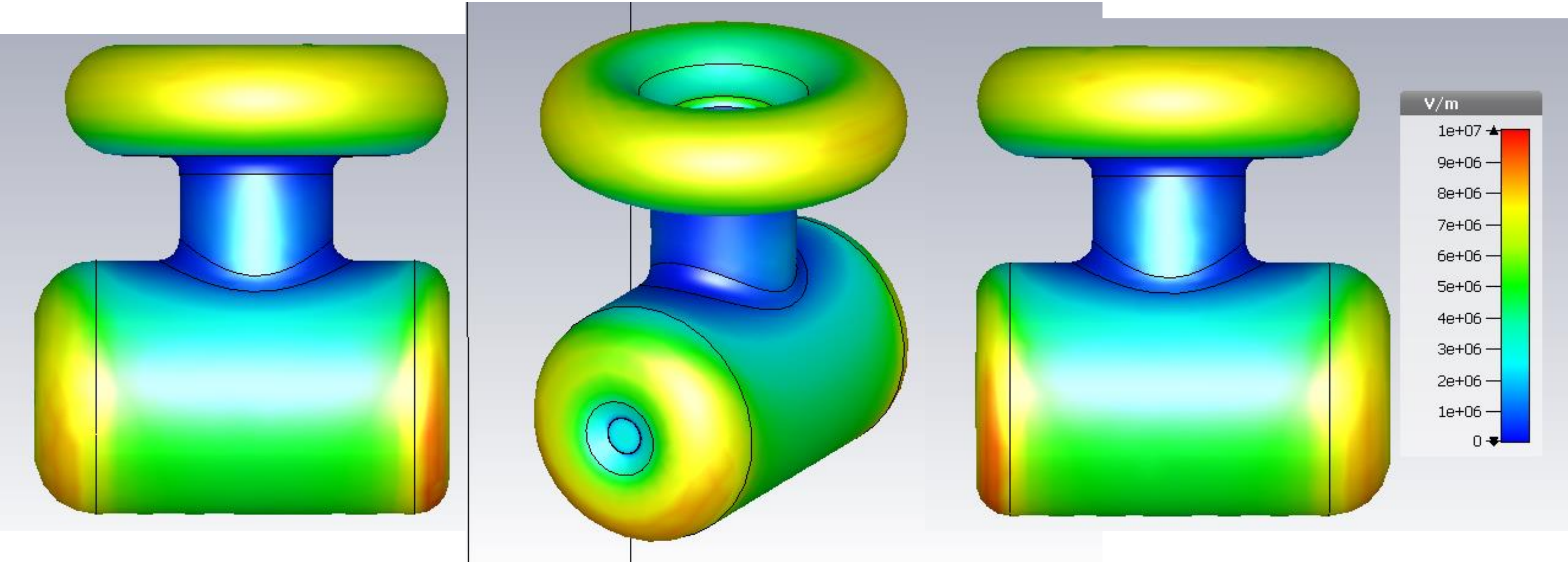
CST results: Electric field norm– No shield



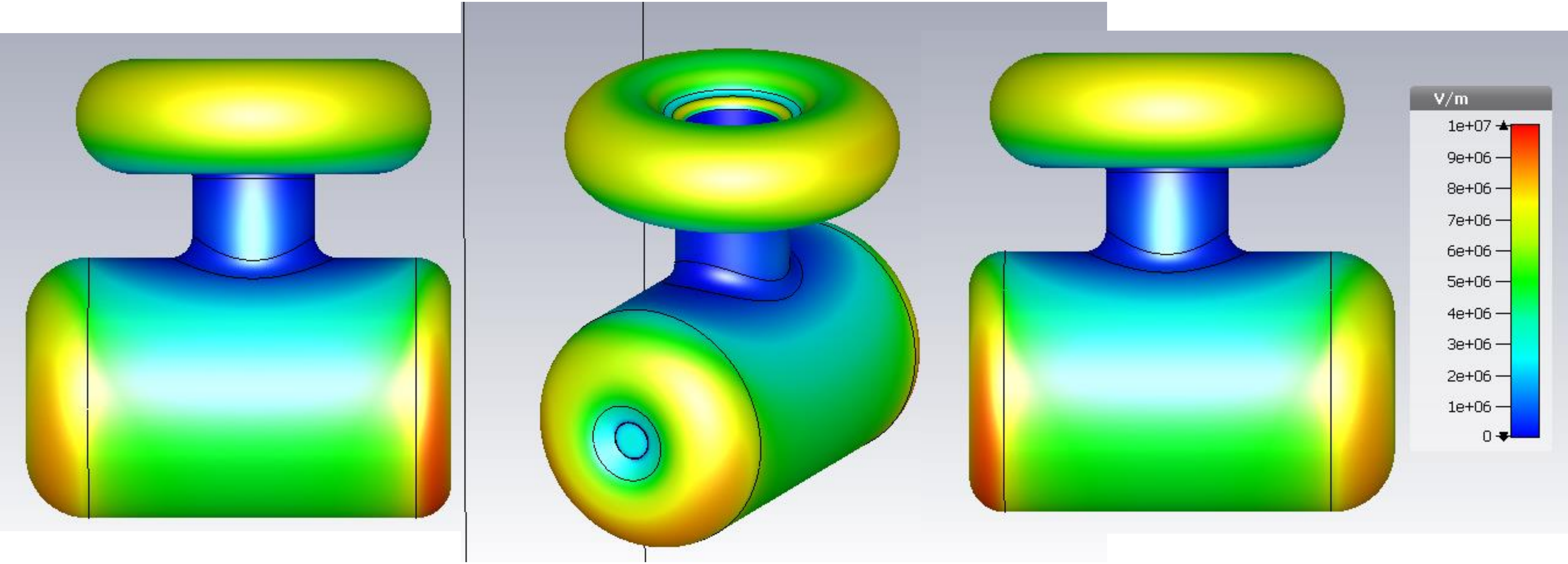
CST results: Electric field norm– Original



CST results: Electric field norm– Shield 1



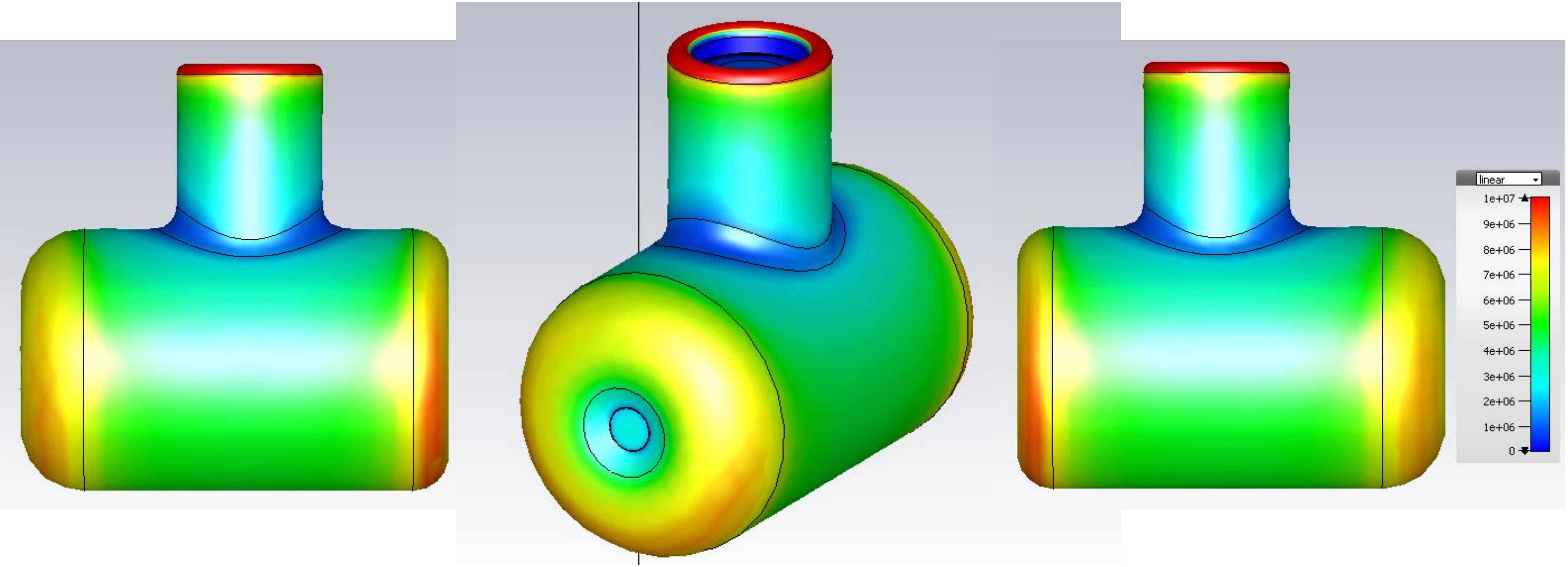
CST results: Electric field norm– Shield 2



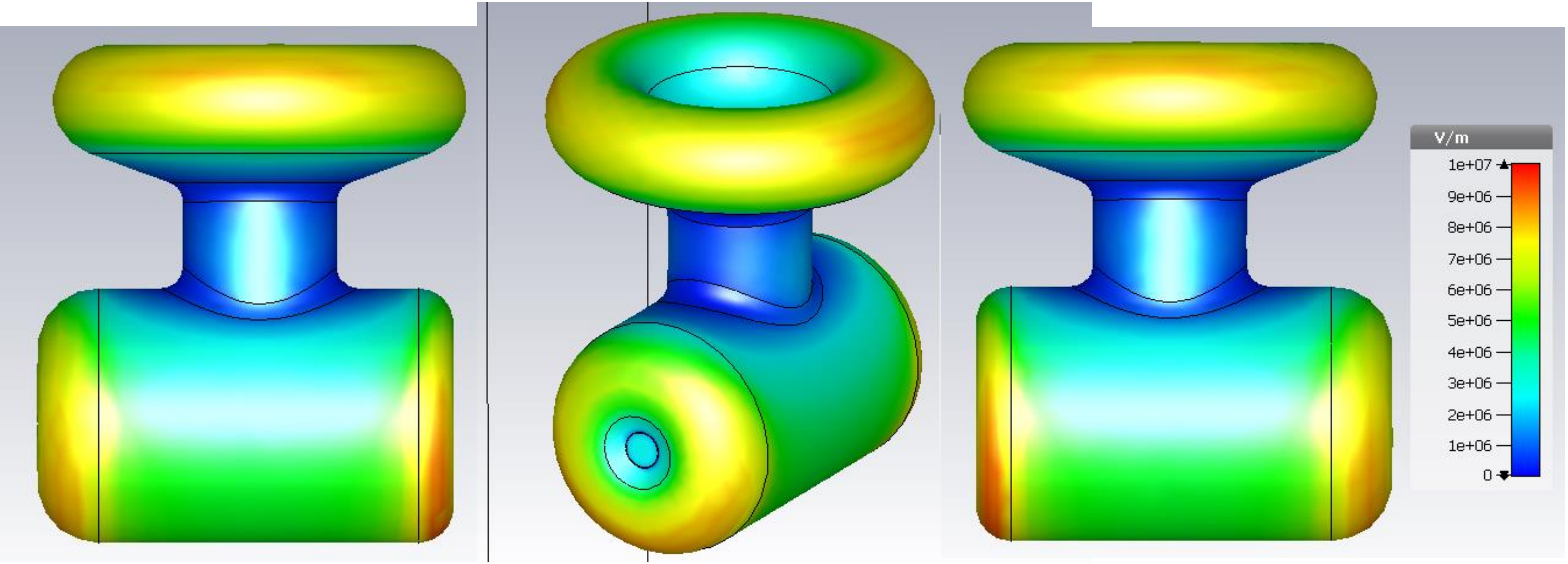
Electric field norm: No shield vs Original vs shields 1 vs shields 2

- On the metallic surface
- Pics are sadly not to scale, in all of them the cathode size is the same.

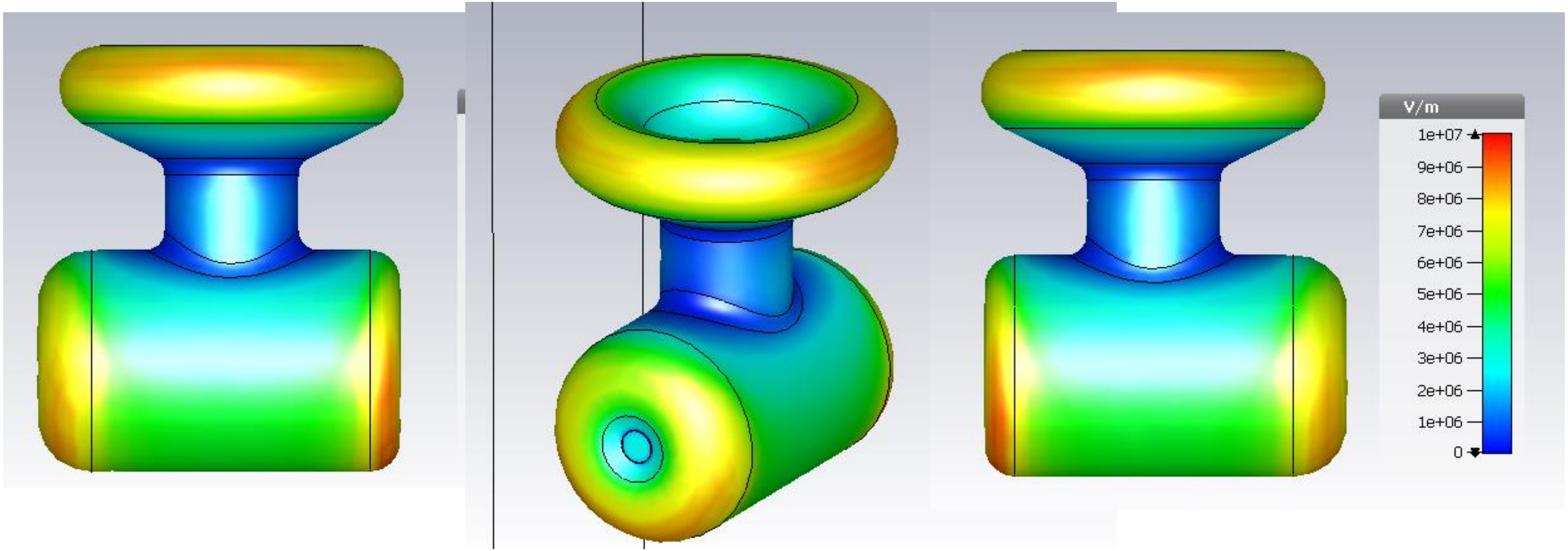
CST results: Electric field norm– No shield



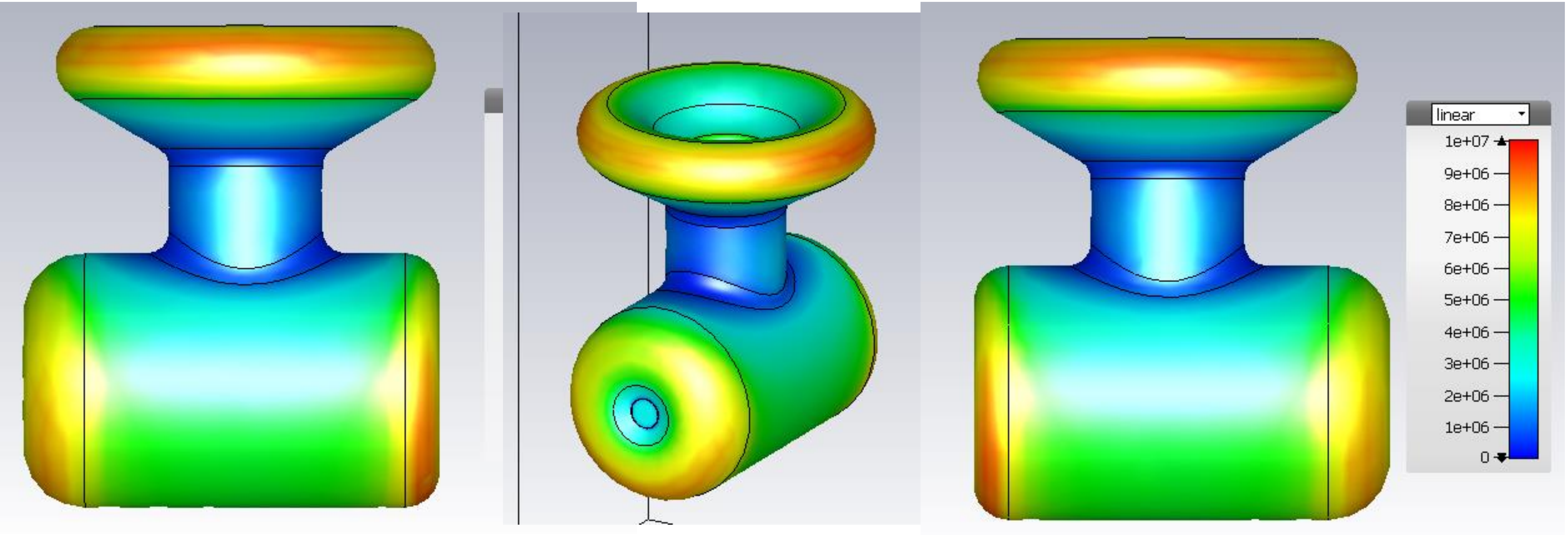
CST results: Electric field norm– Original



CST results: Electric field norm– Shield 3



CST results: Electric field norm– Shield 4



Preliminary conclusions

- Cathode anode gap
  - Transverse electric field
    - Original vs shield 1 & 2
      - Benefit if height is reduced **and** we produce beam from the top of the photocathode.
    - Original vs shield 3 & 4
      - Benefit if radius is reduced **and** we produce beam from the top of the photocathode.
    - Original vs shield 1,2, 3 & 4
      - If beam is produced at the center of the photocathode, I would pick Shields 2 or 4.
  - Longitudinal electric field
    - The changing of the shields has a small impact only.
- Insulator-rubber plug interface
    - The transverse electric field gets worst for shield 2. The rest remain close.
    - Longitudinal electric field has a discontinuity that must be revised.

Preliminary conclusions

- Cathode contour
  - Electric field norm
    - Original vs shield 1 & 2
      - The cusp field reduces, at cost of the fields on the Pierce geometry contour and the triple point which reaches ~ 1MV/m .
    - Original vs shield 3 & 4
      - The radius change increases the field at its cusp to ~8 MV/m with some impact on the Pierce geometry.
    - All
      - Upper flange triple point appears and remains at ~12 MV/m

Preliminary conclusions

- In short:
  - Height reduction =
    - Smaller vertical “kick” at cathode-anode gap
    - Worst transversal field at the insulator-rubber plug interface
    - Smaller field at the cusp
    - Worst field at triple point
  - Cusp radius reduction =
    - Smaller vertical “kick” at cathode-anode gap
    - Slightly worst transversal field at the insulator-rubber plug interface
    - Worst field at the cusp
    - Slightly Worst field at triple point

Future steps

- Mix between smaller radius and smaller height prototype.
- Maybe correct Shield 2 since it’s a bit slimmer.

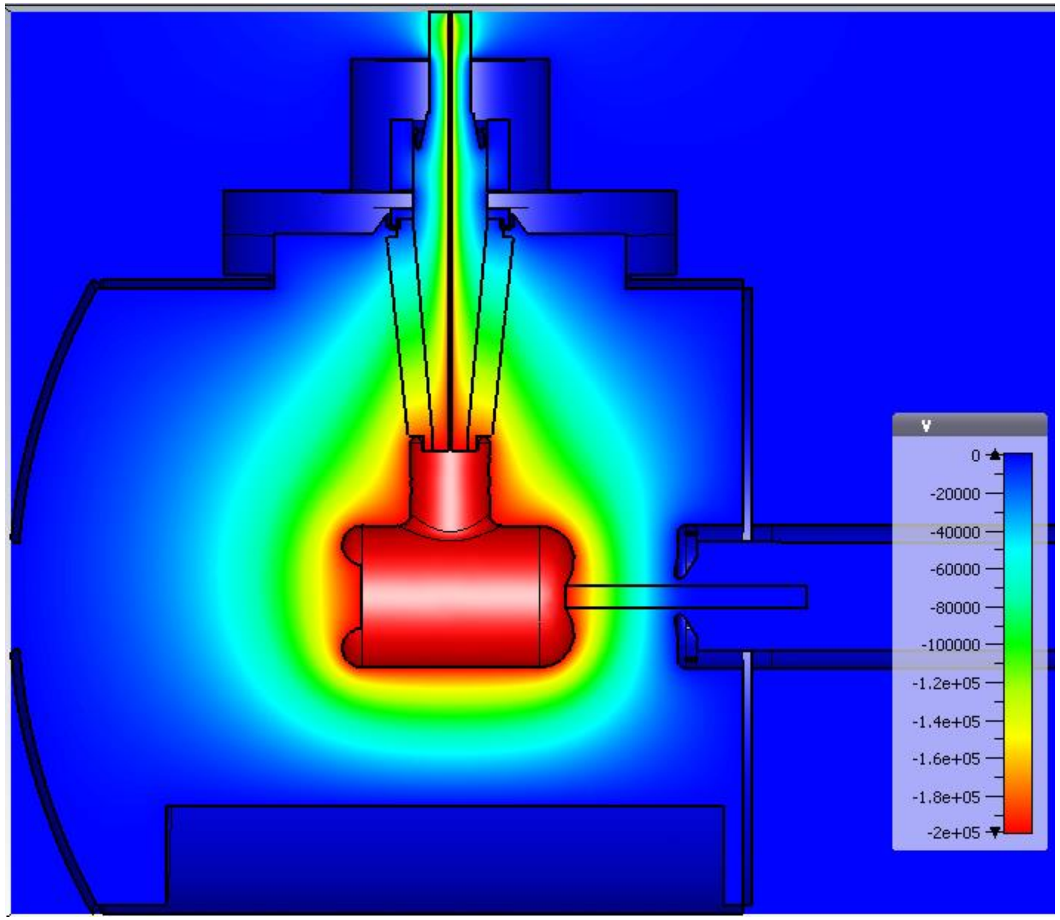
Fin.

Additional slides

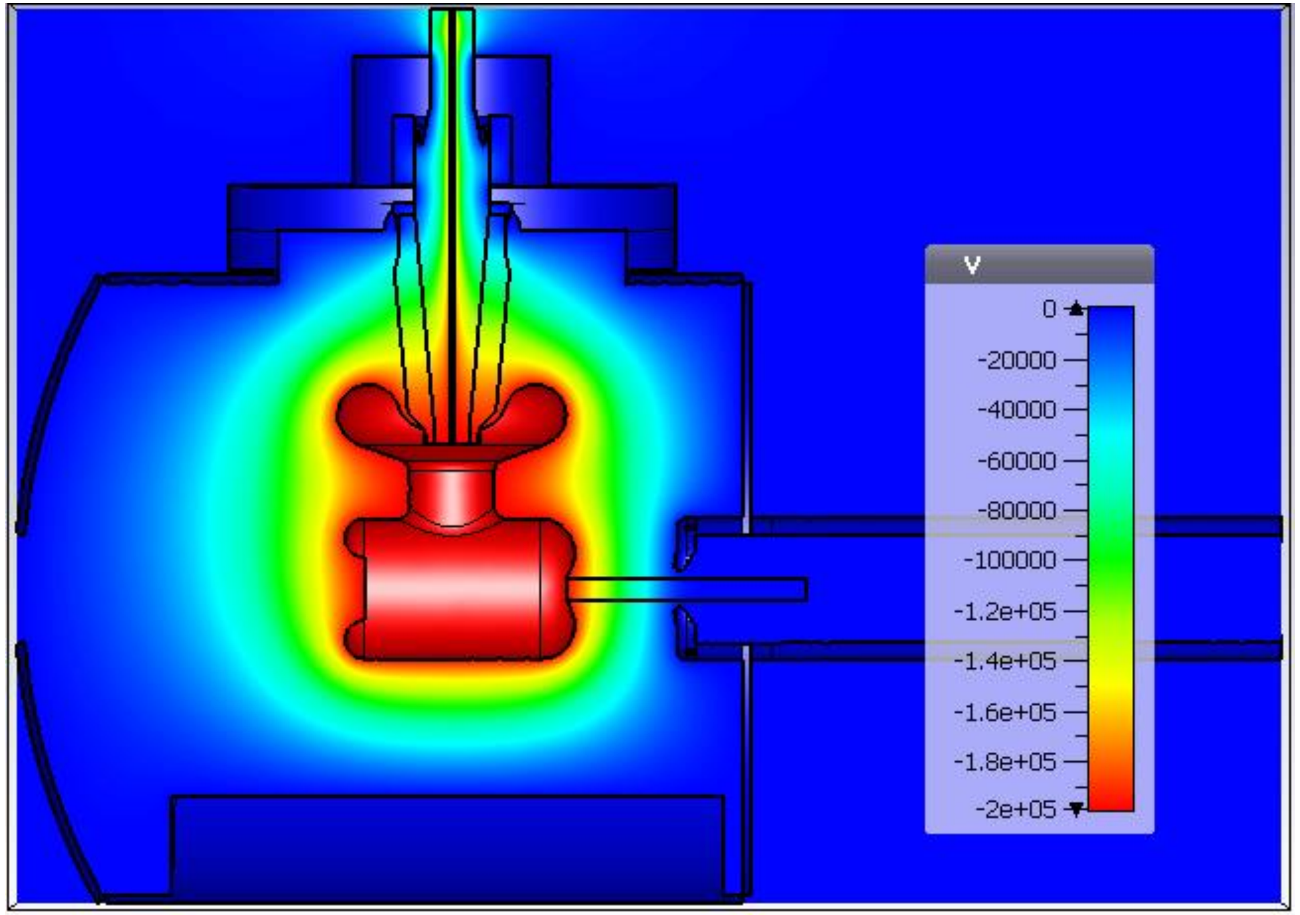
- Potentials false color
- Transverse field false color
- Longitudinal field false color

Potential: Original vs Shield 1 vs Shield 2

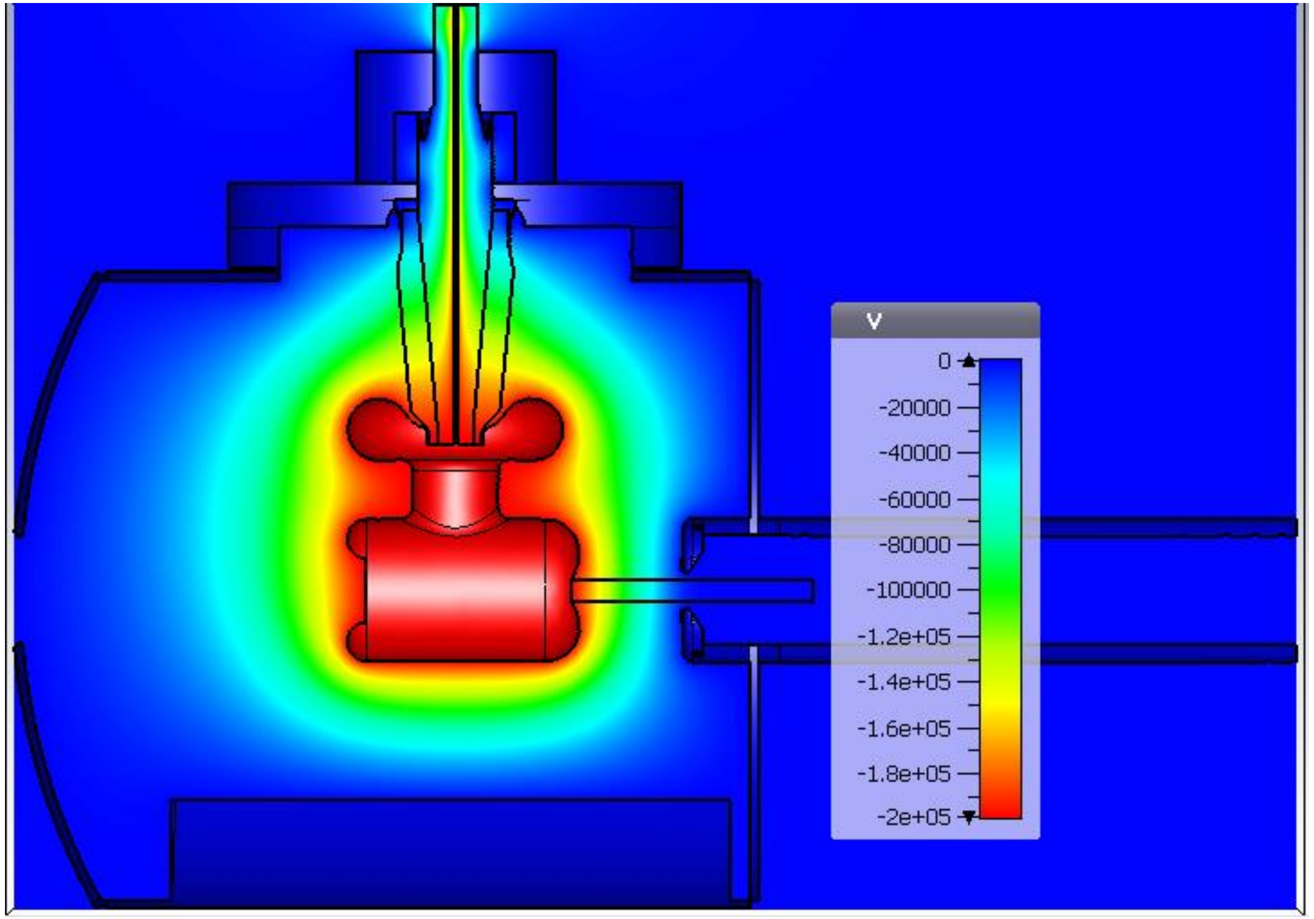
CST results: Potential – No shield



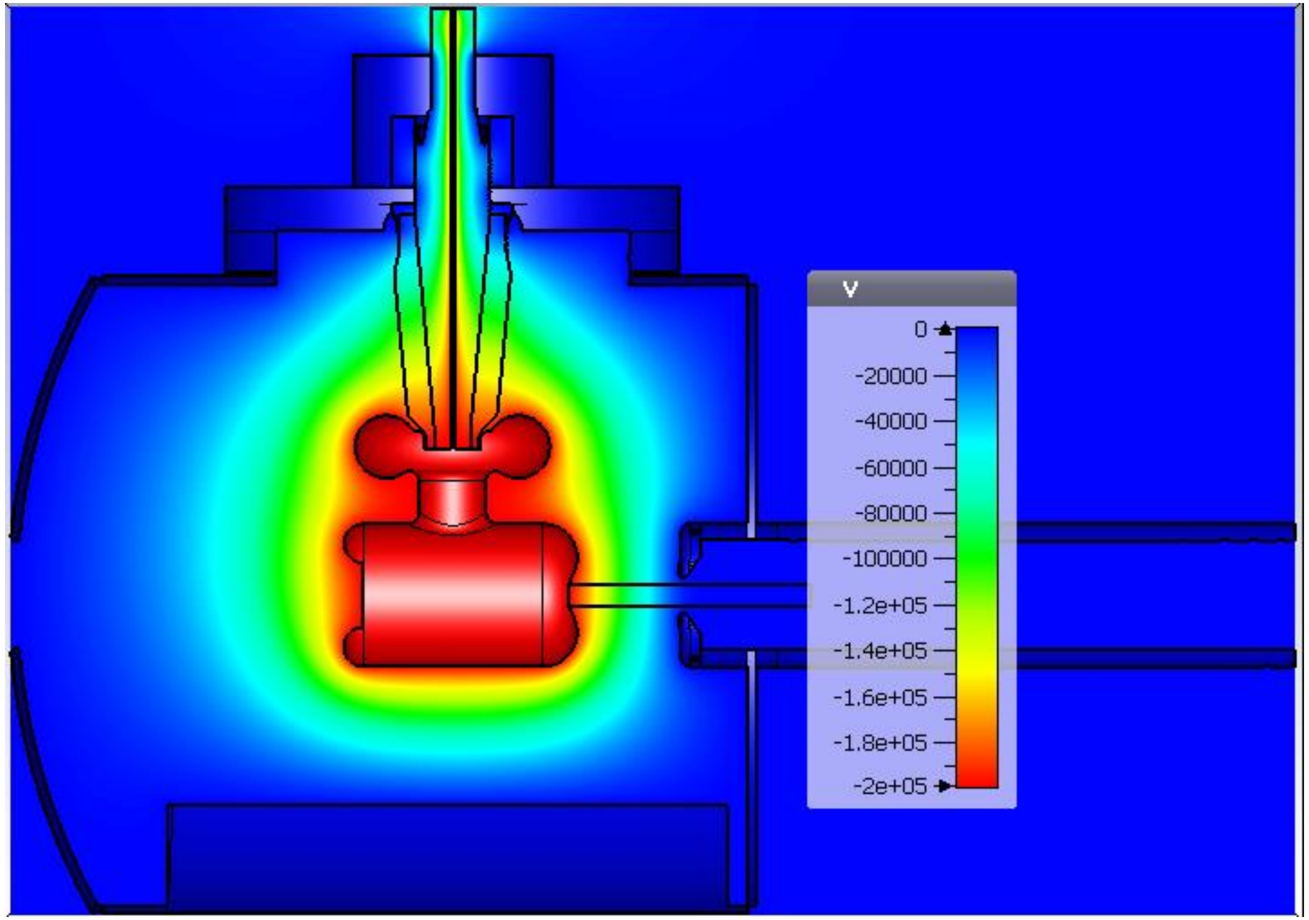
CST results: Potential – original shield



CST results: Potential – Shield 1

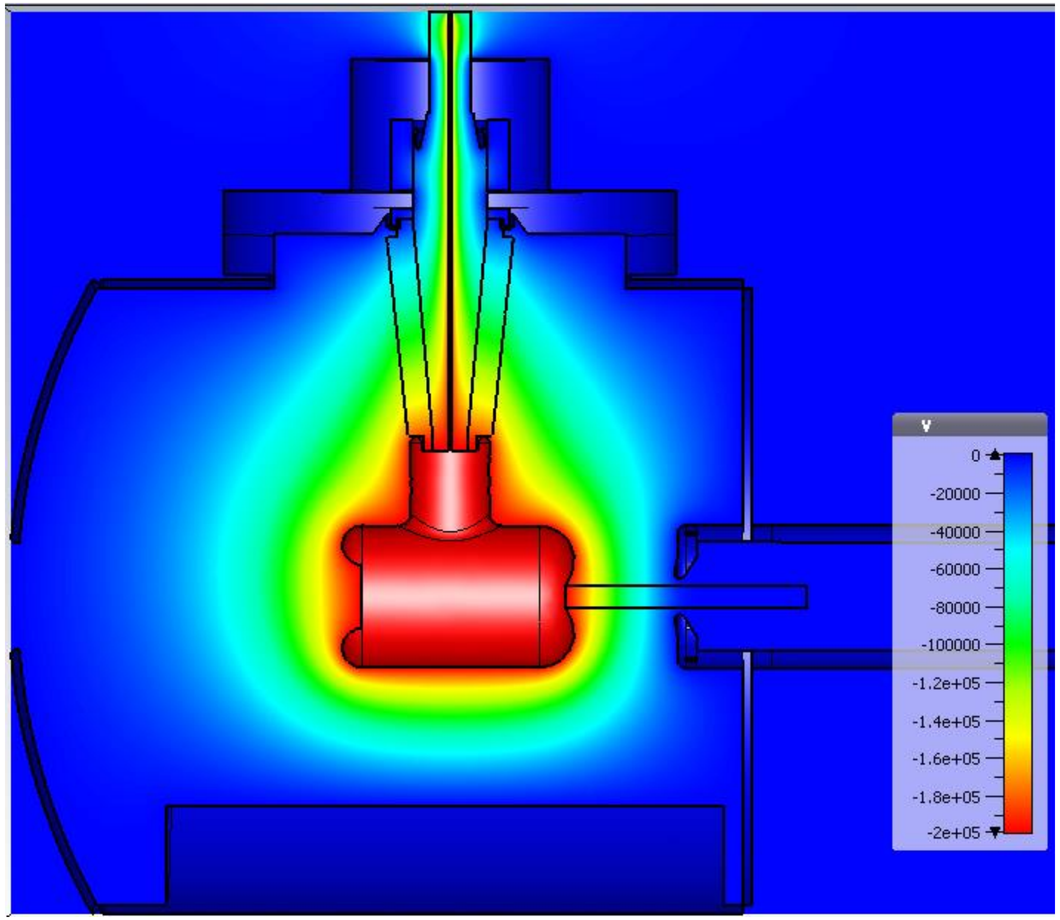


CST results: Potential – Shield 2

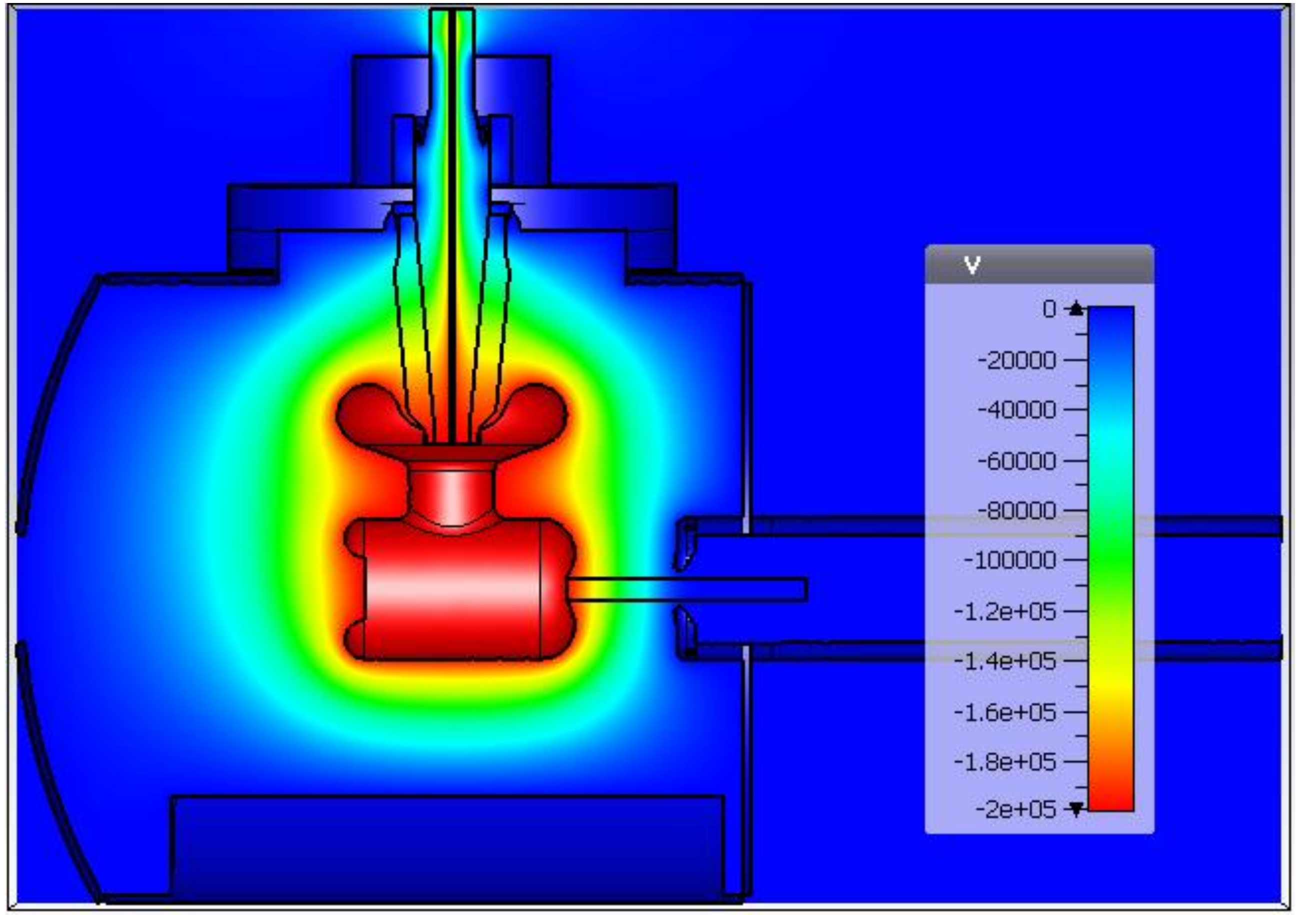


Potential: Original vs Shield 3 vs Shield 4

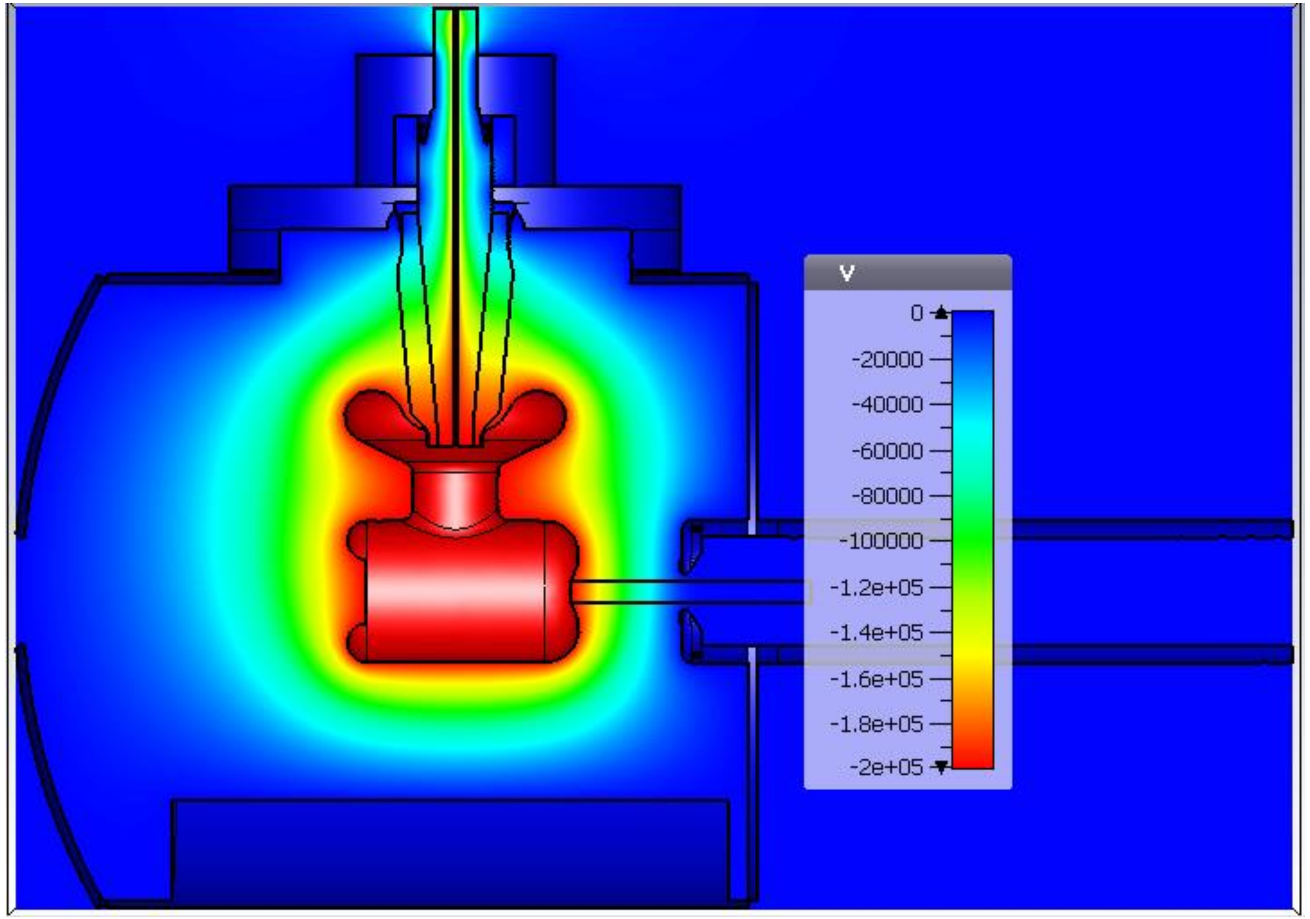
CST results: Potential – No shield



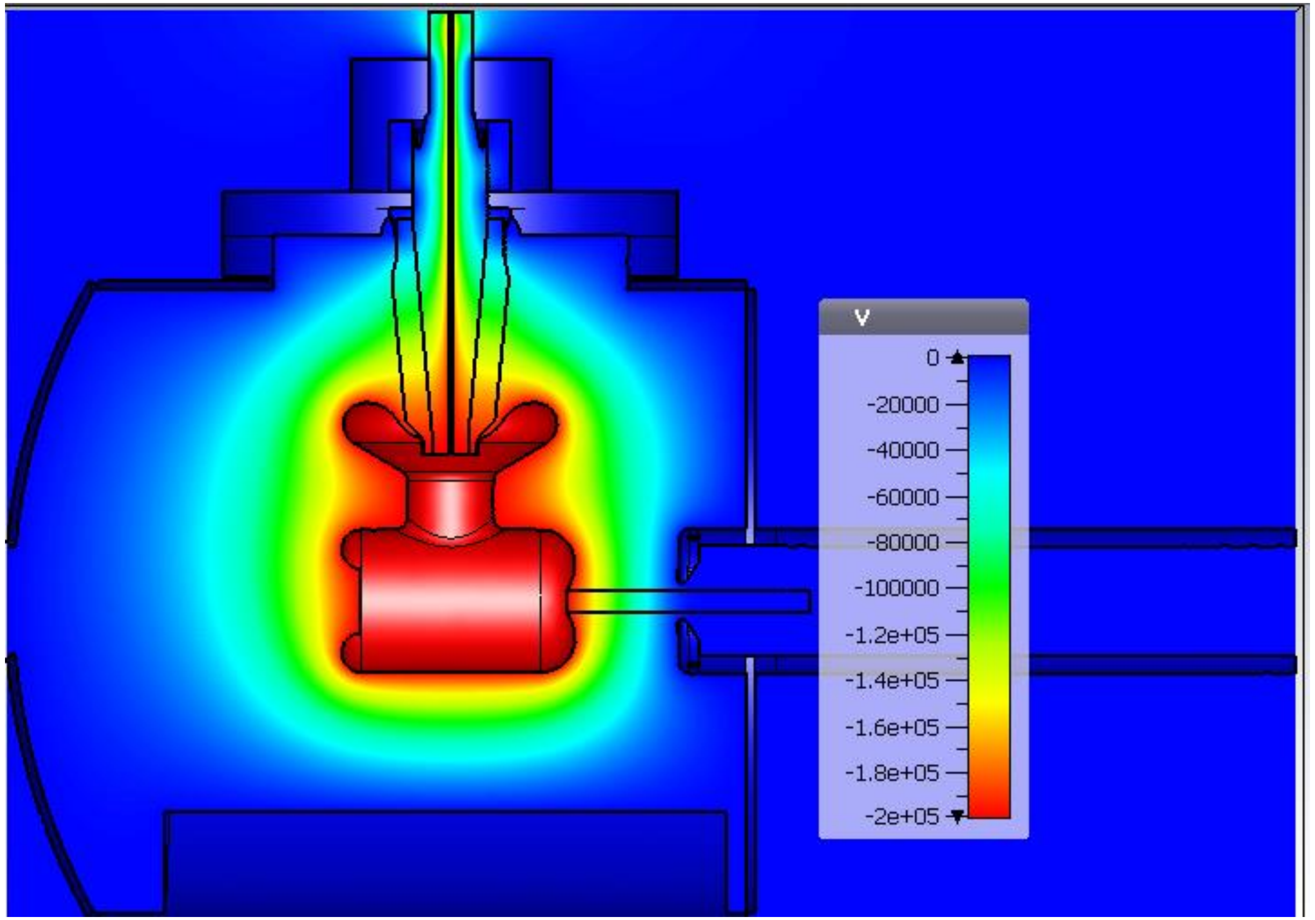
CST results: Potential – original shield



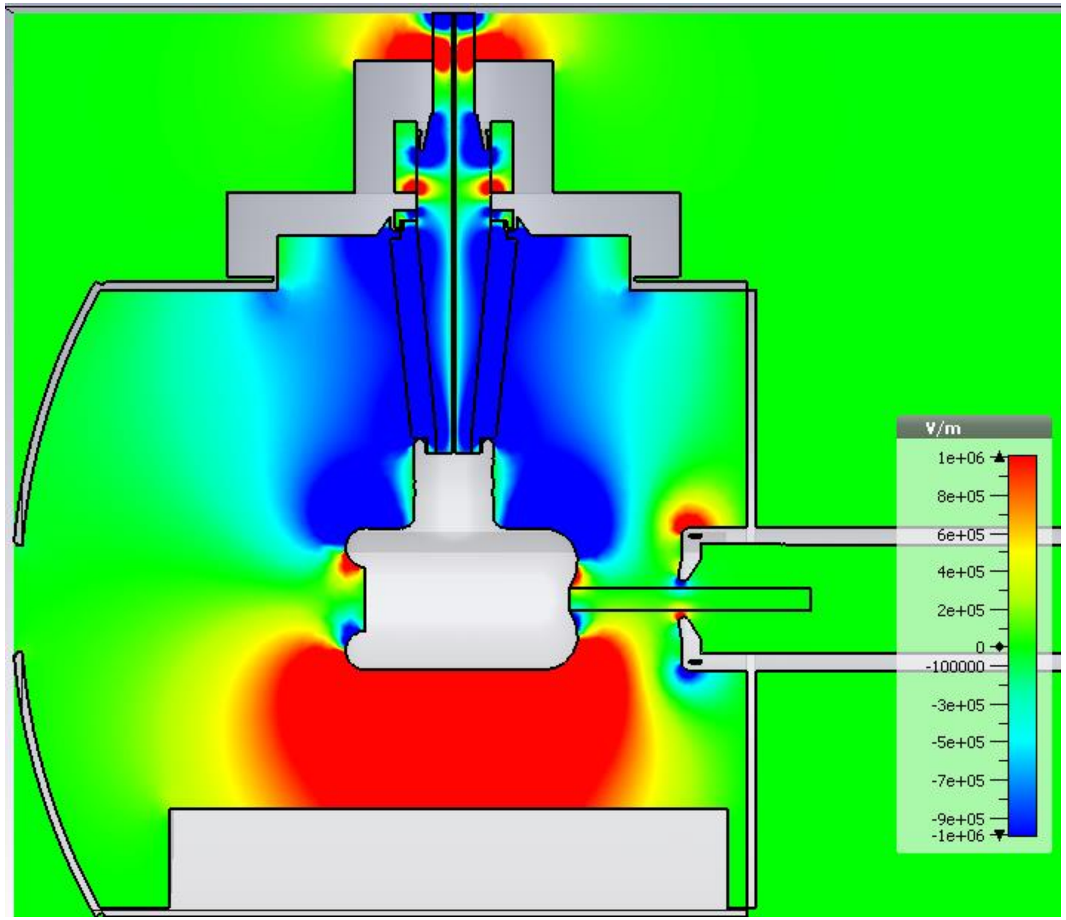
CST results: Potential – Shield 3



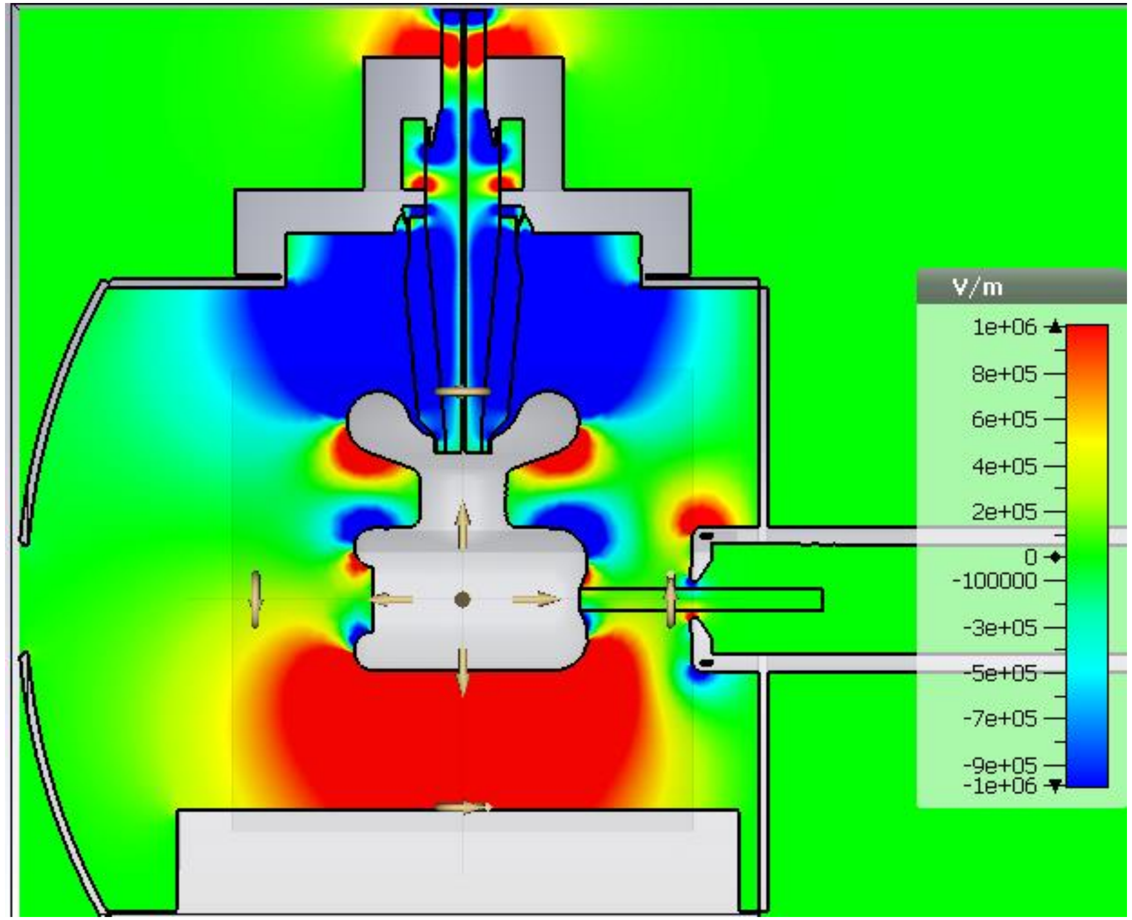
CST results: Potential – Shield 4



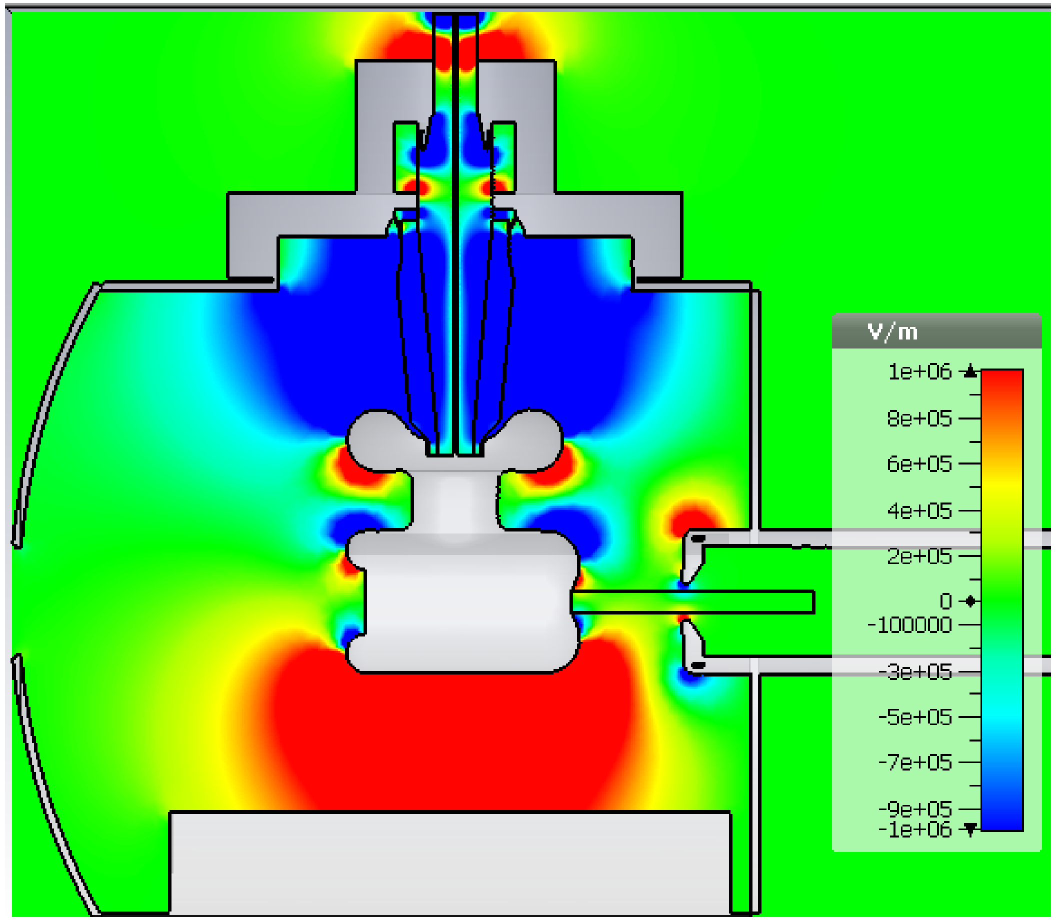
Transverse electric field: No shield



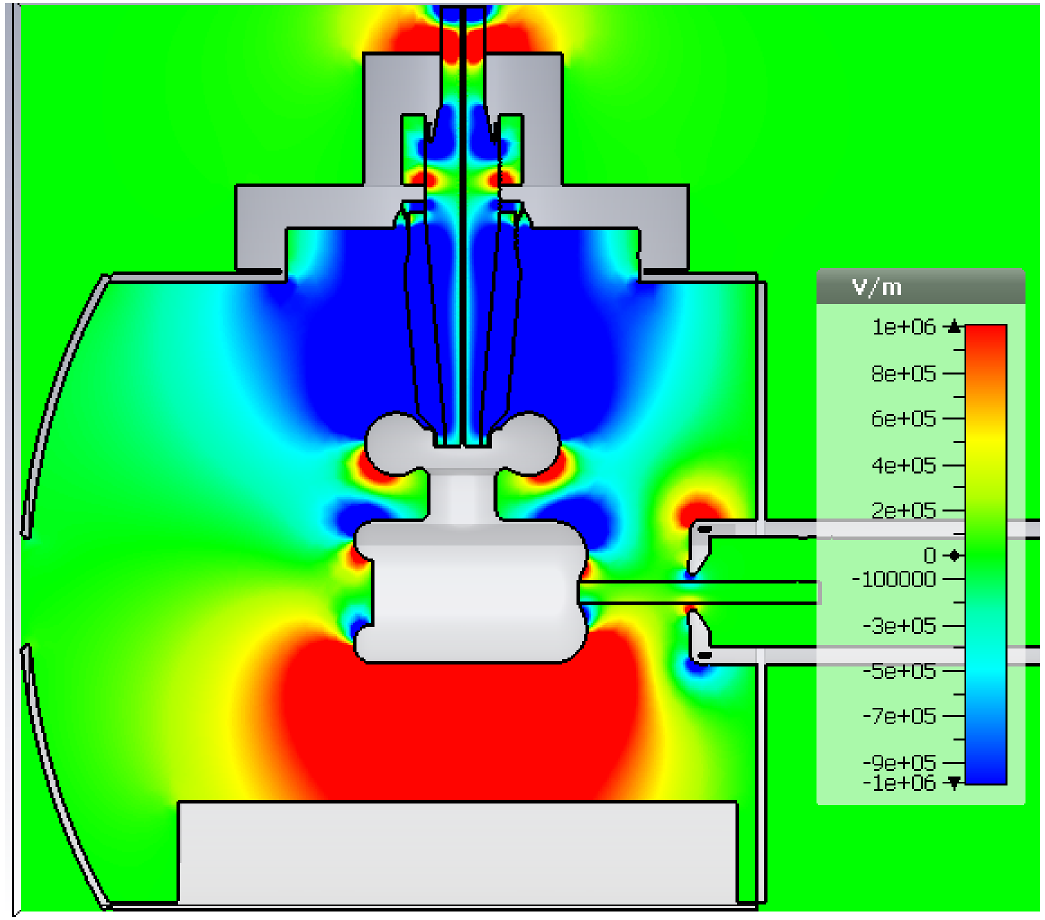
CST results: Transverse electric field – original shield



CST results: Transverse electric field – Shield 1

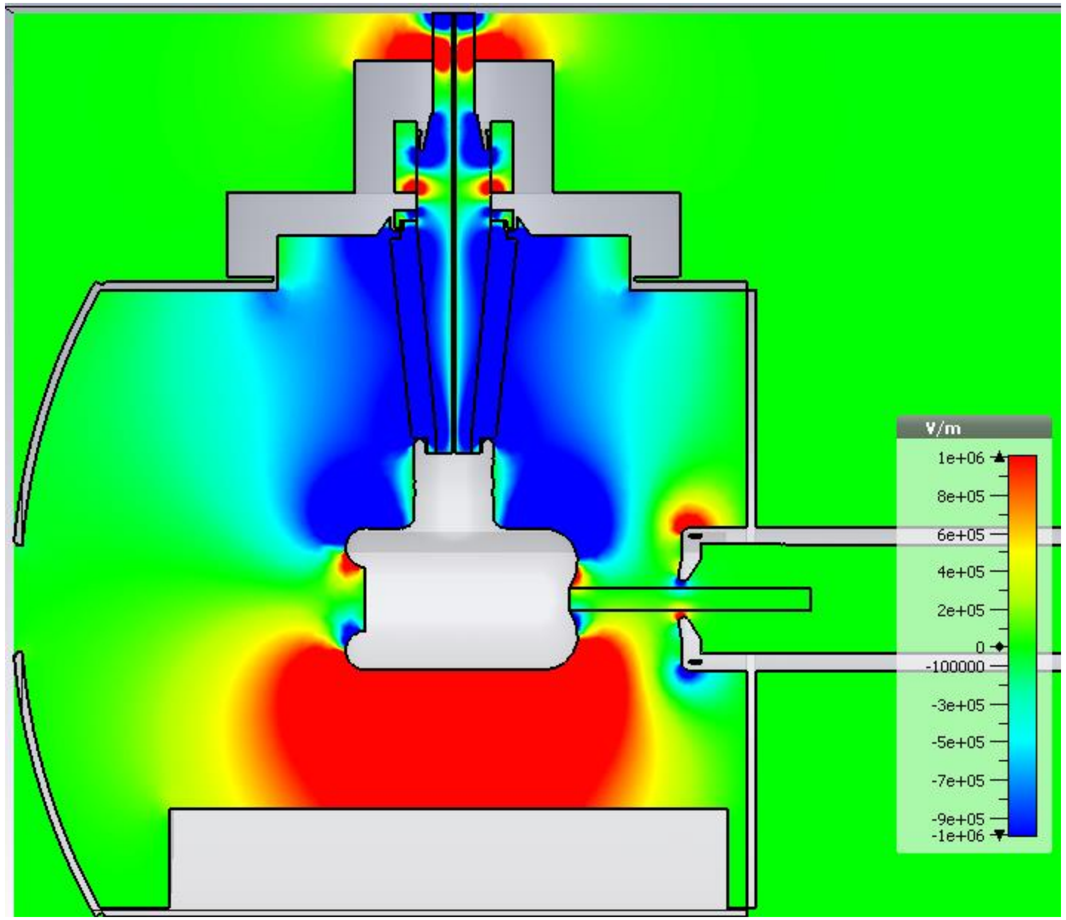


CST results: Transverse electric field – Shield 2

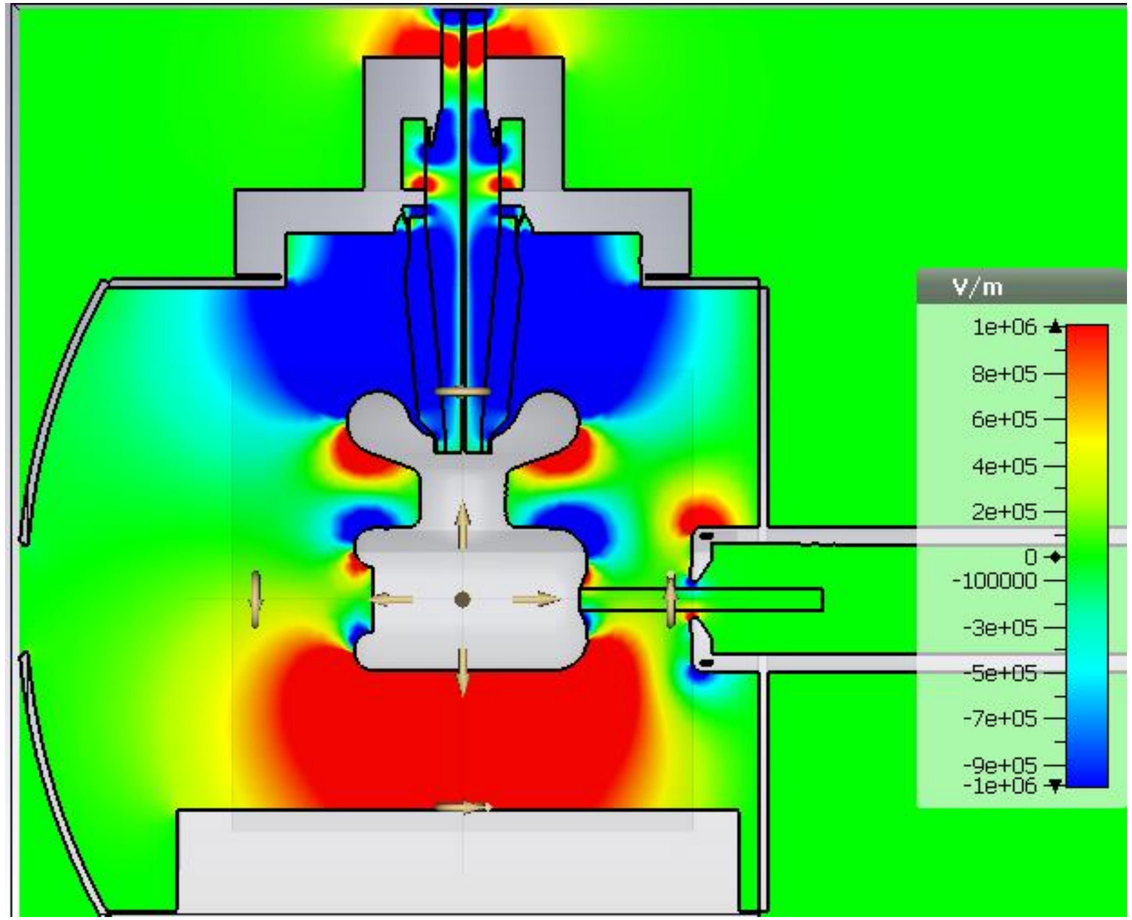


Transverse electric field: Original vs Shield 3 vs Shield 4

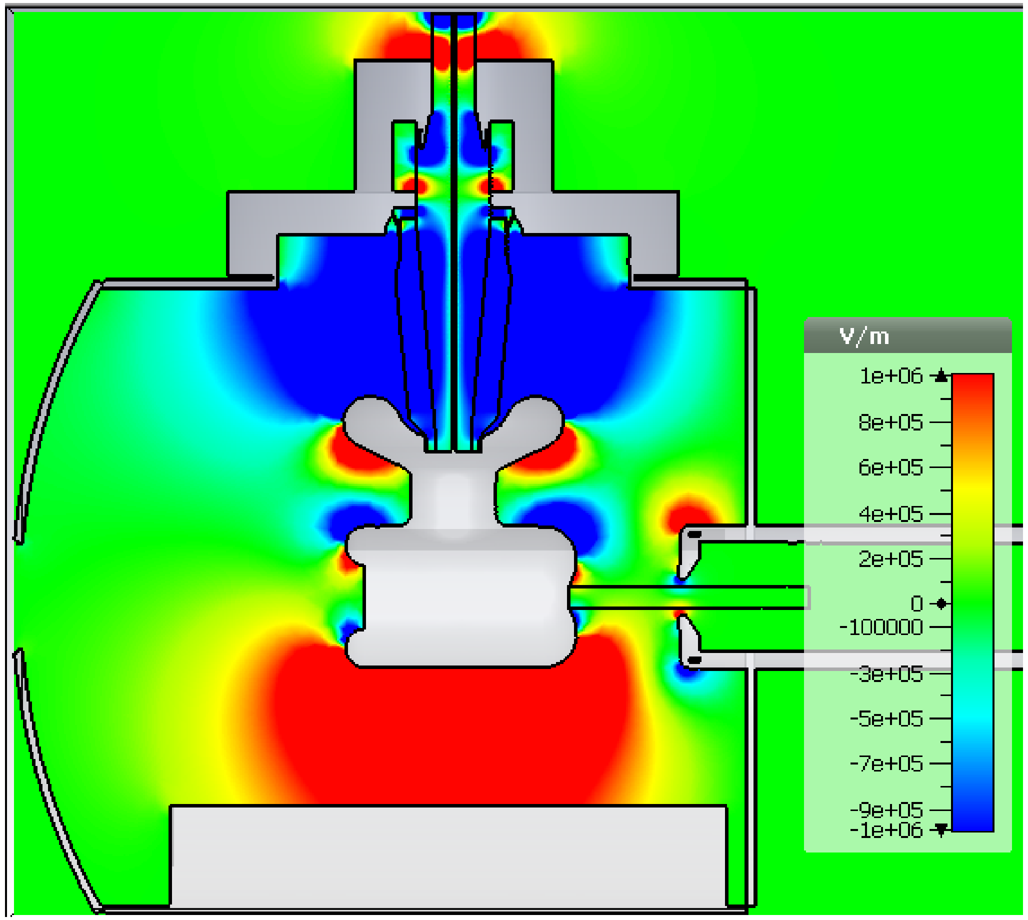
Transverse electric field: No shield



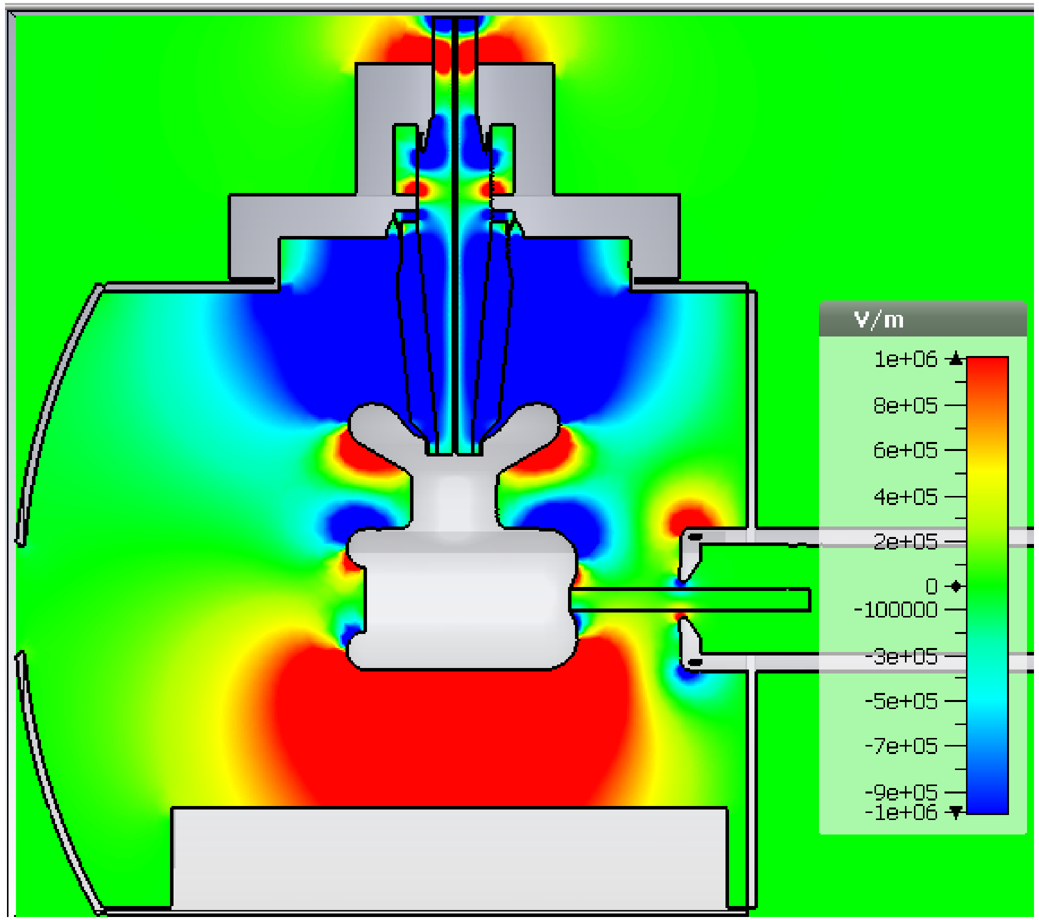
CST results: Transverse electric field – original shield



CST results: Transverse electric field – Shield 3

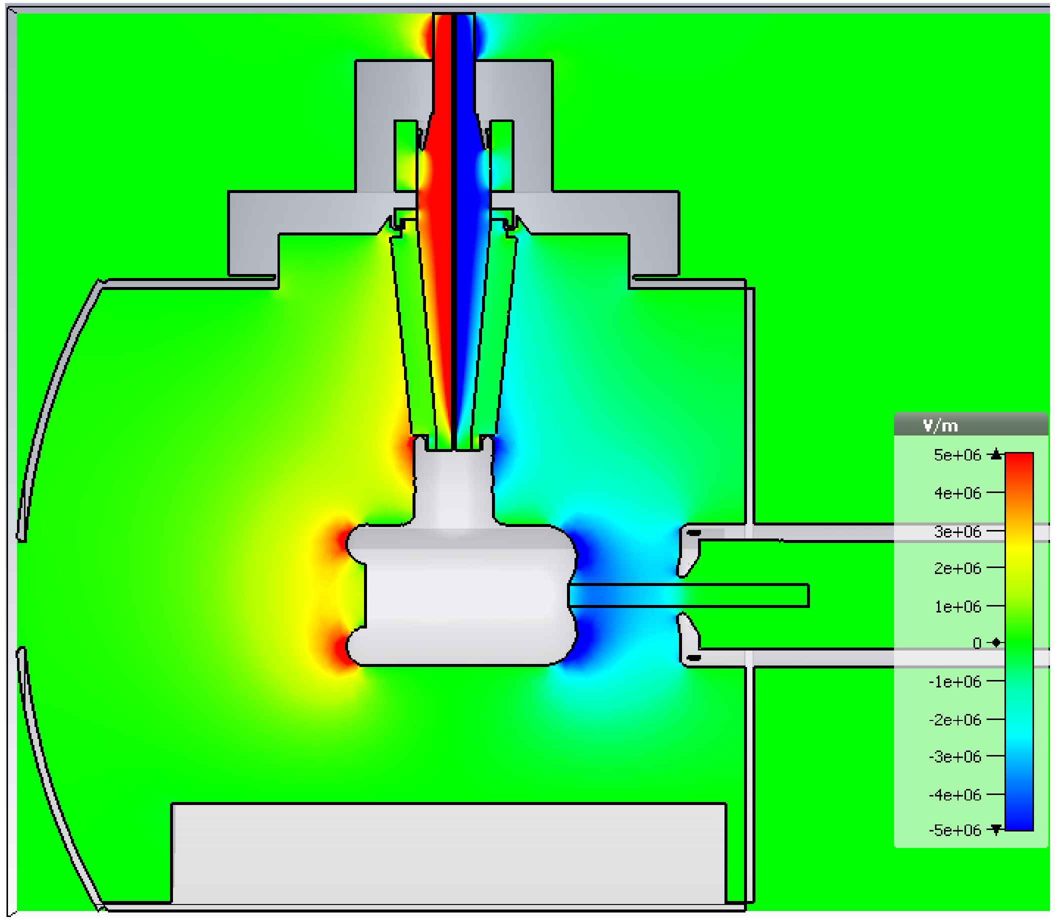


CST results: Transverse electric field – Shield 4

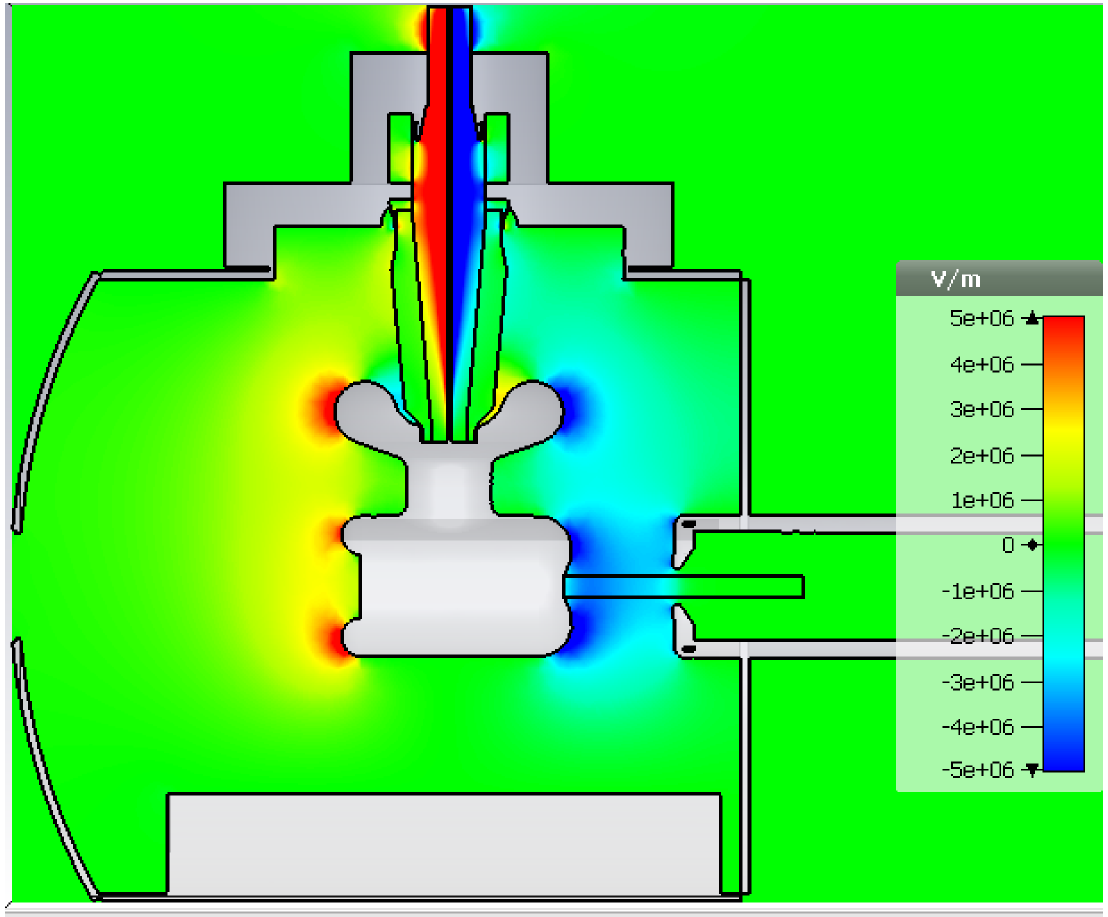


Longitudinal electric field: Original vs Shield 1 vs Shield 2

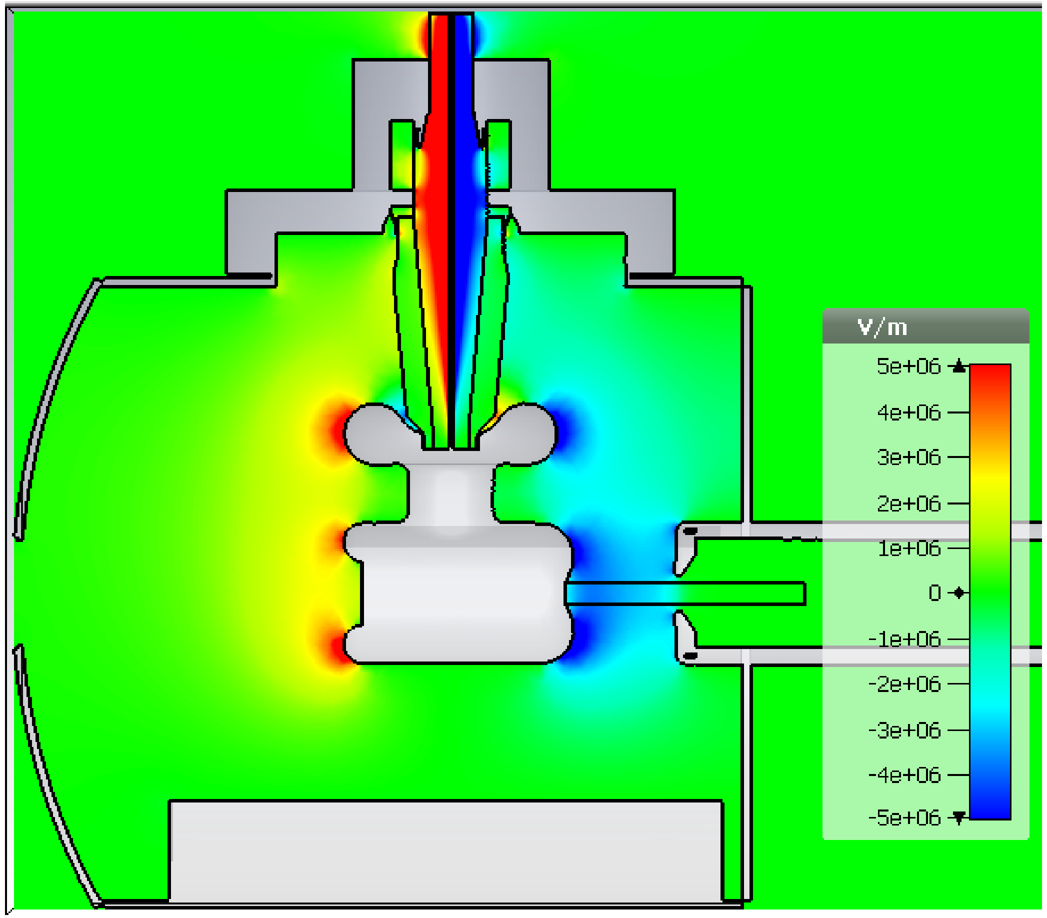
CST results: Longitudinal electric field – No shield



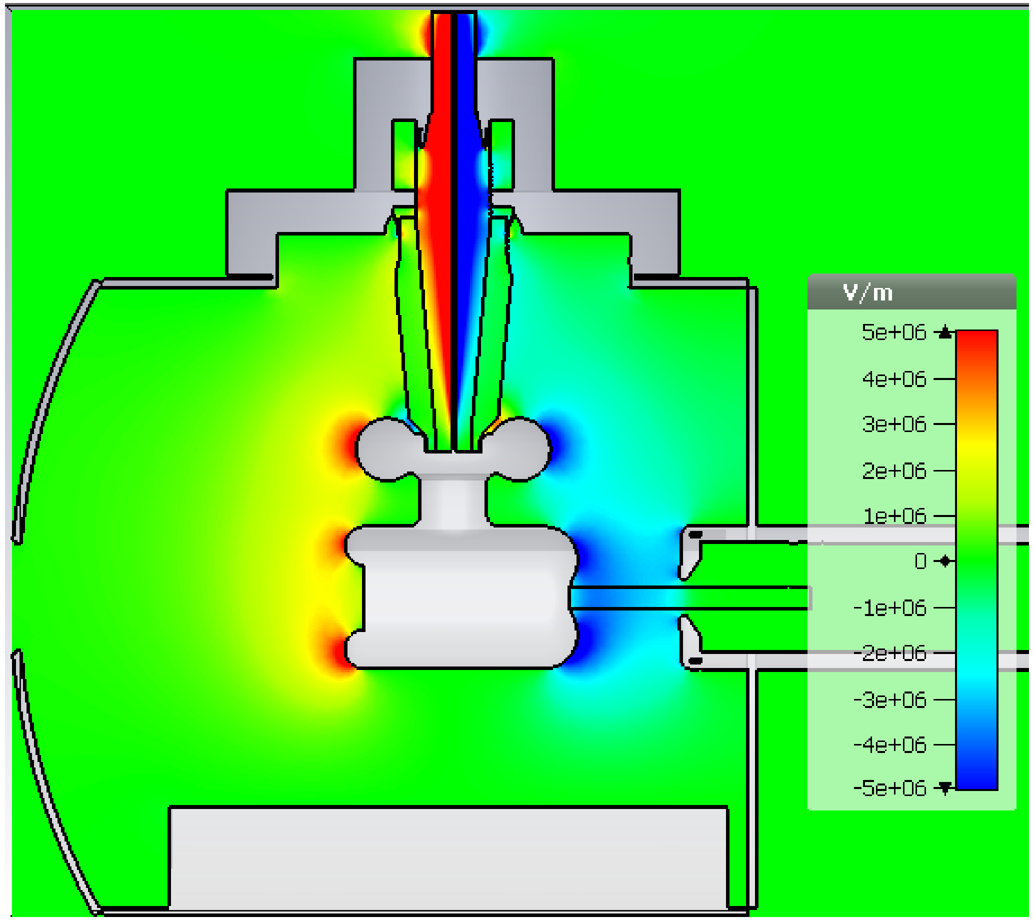
CST results: Longitudinal electric field – original shield



CST results: Longitudinal electric field – Shield 1

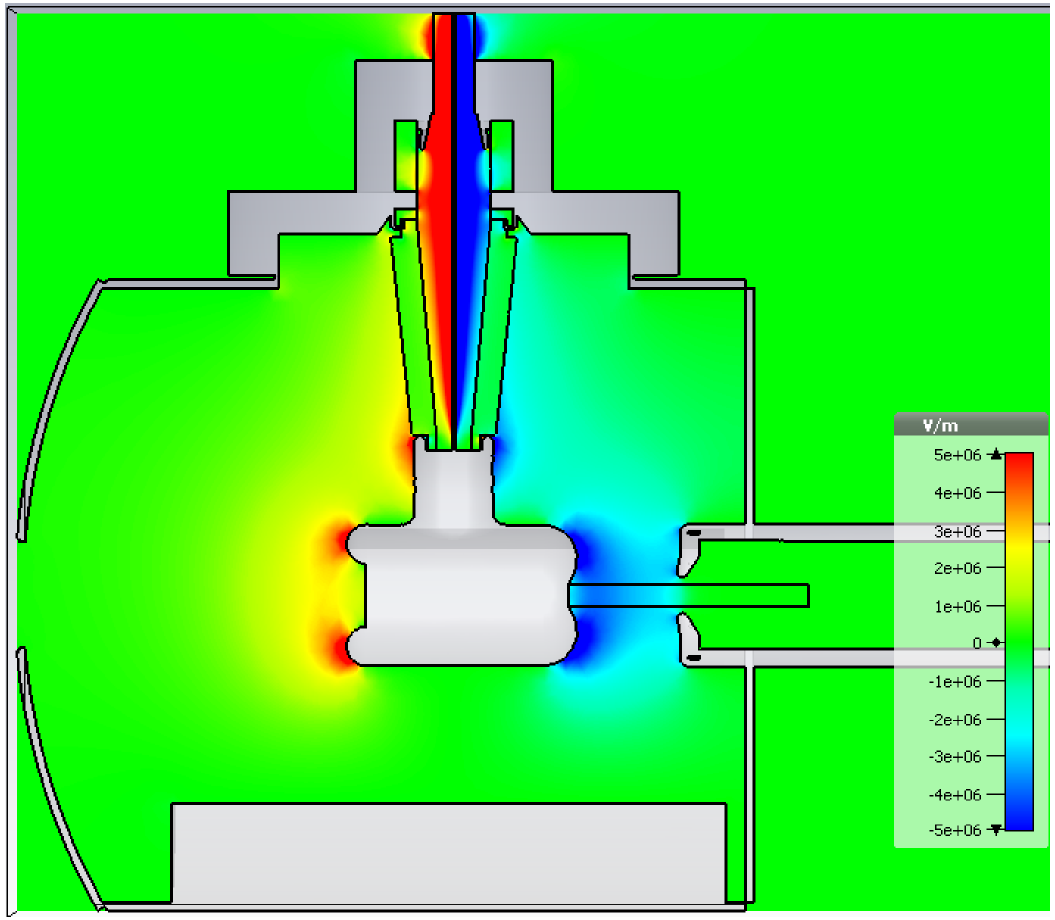


CST results: Longitudinal electric field – Shield 2

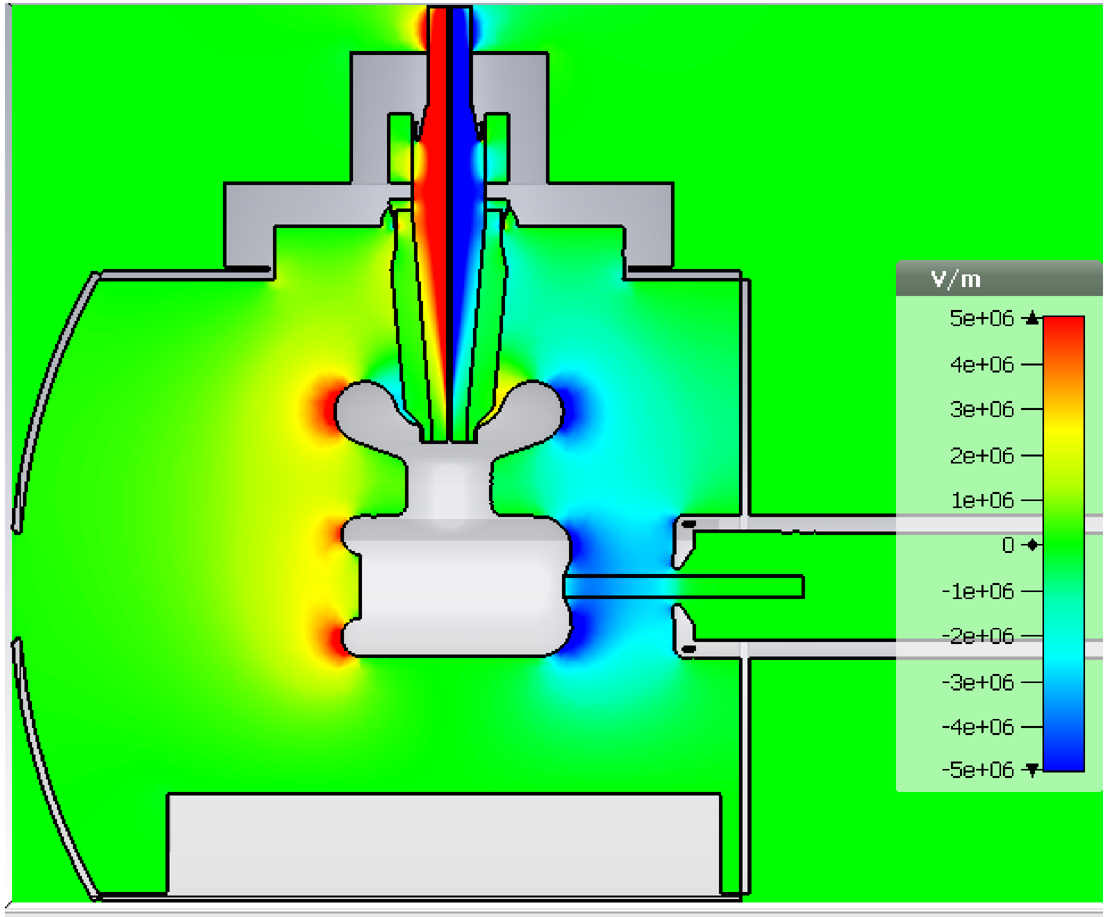


Longitudinal electric field: Original vs Shield 3 vs Shield 4

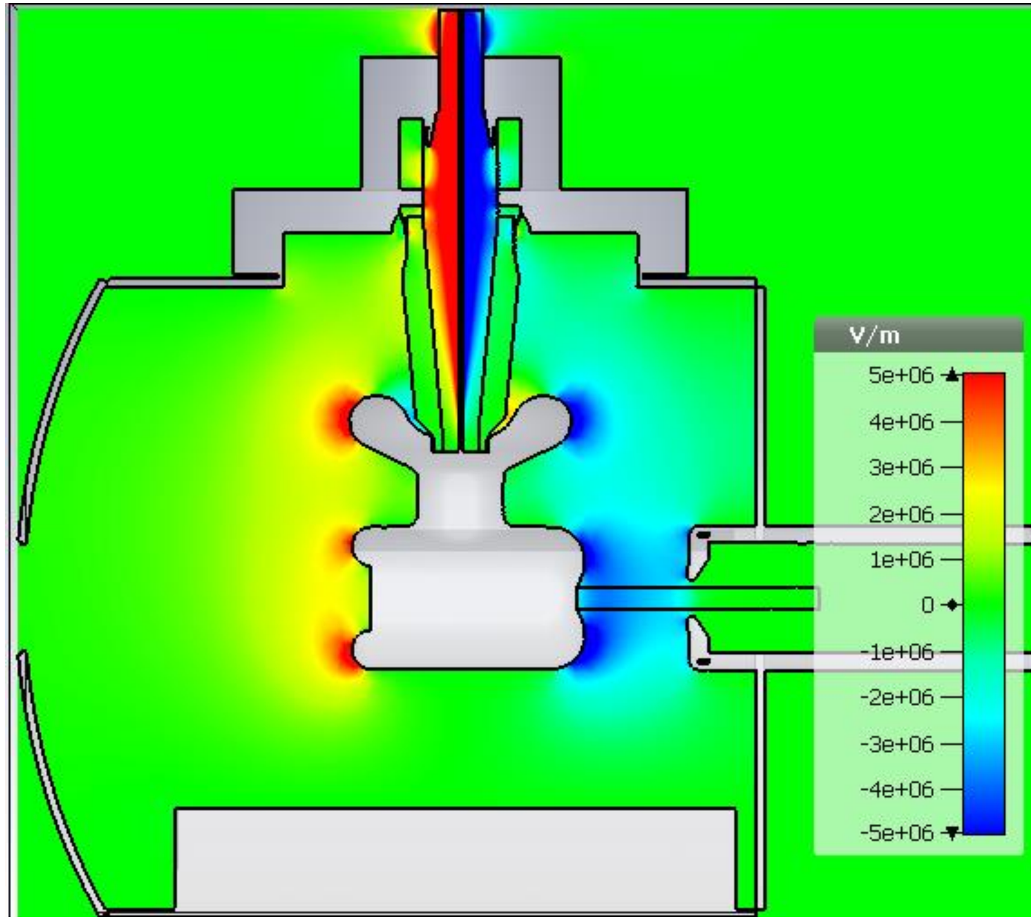
CST results: Longitudinal electric field – No shield



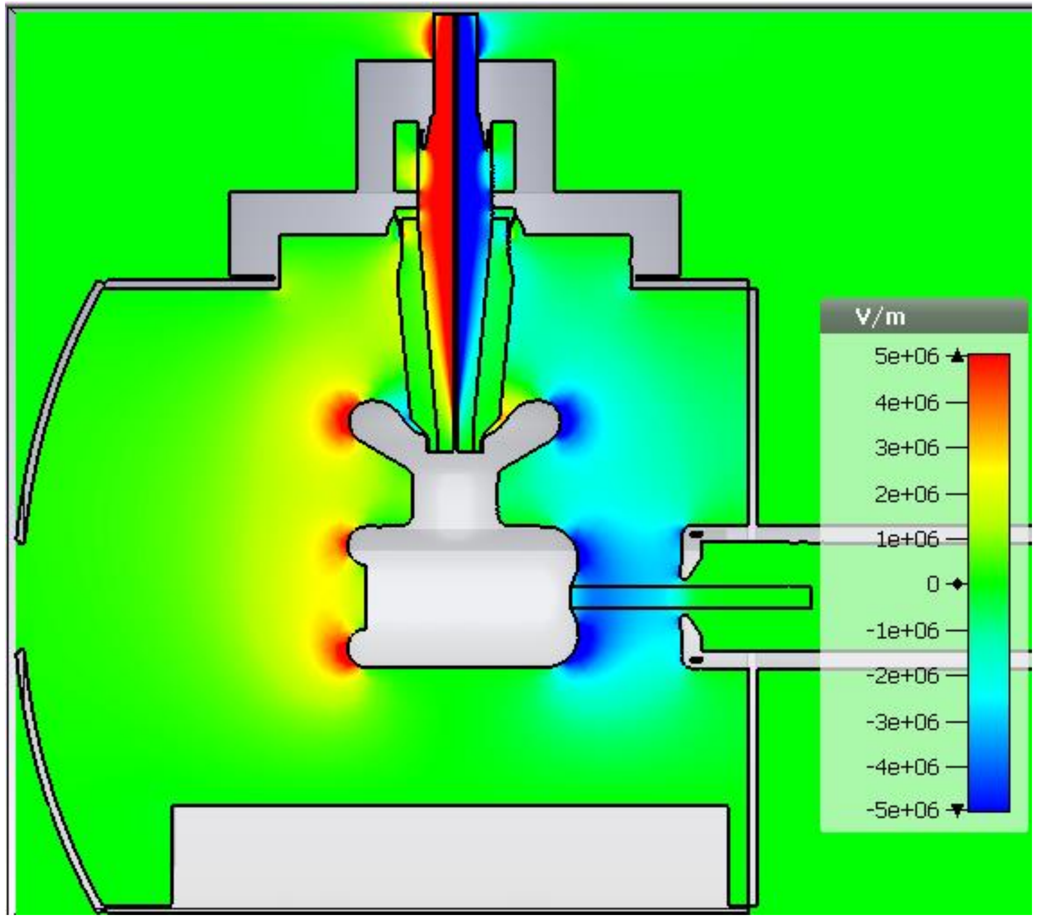
CST results: Longitudinal electric field – original shield



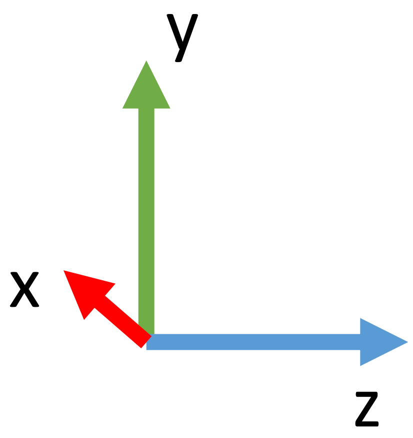
CST results: Longitudinal electric field – Shield 3



CST results: Longitudinal electric field – Shield 4



CST frame of reference:



X goes into the page.