

200 kV gun CST microwave studio simulations

Shield modifications

Gabriel Palacios

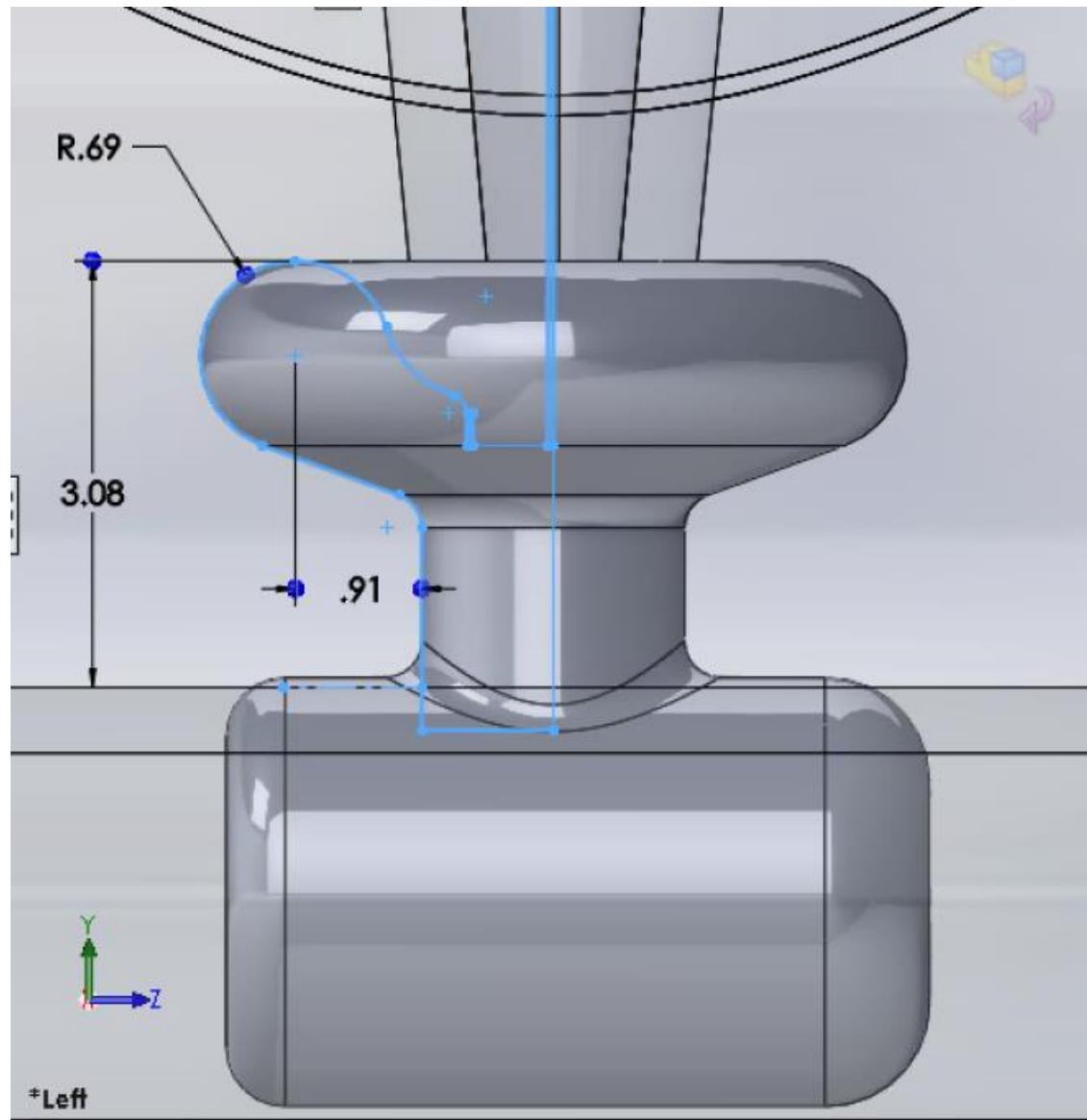
gabrielp@jlab.org

07/09/18

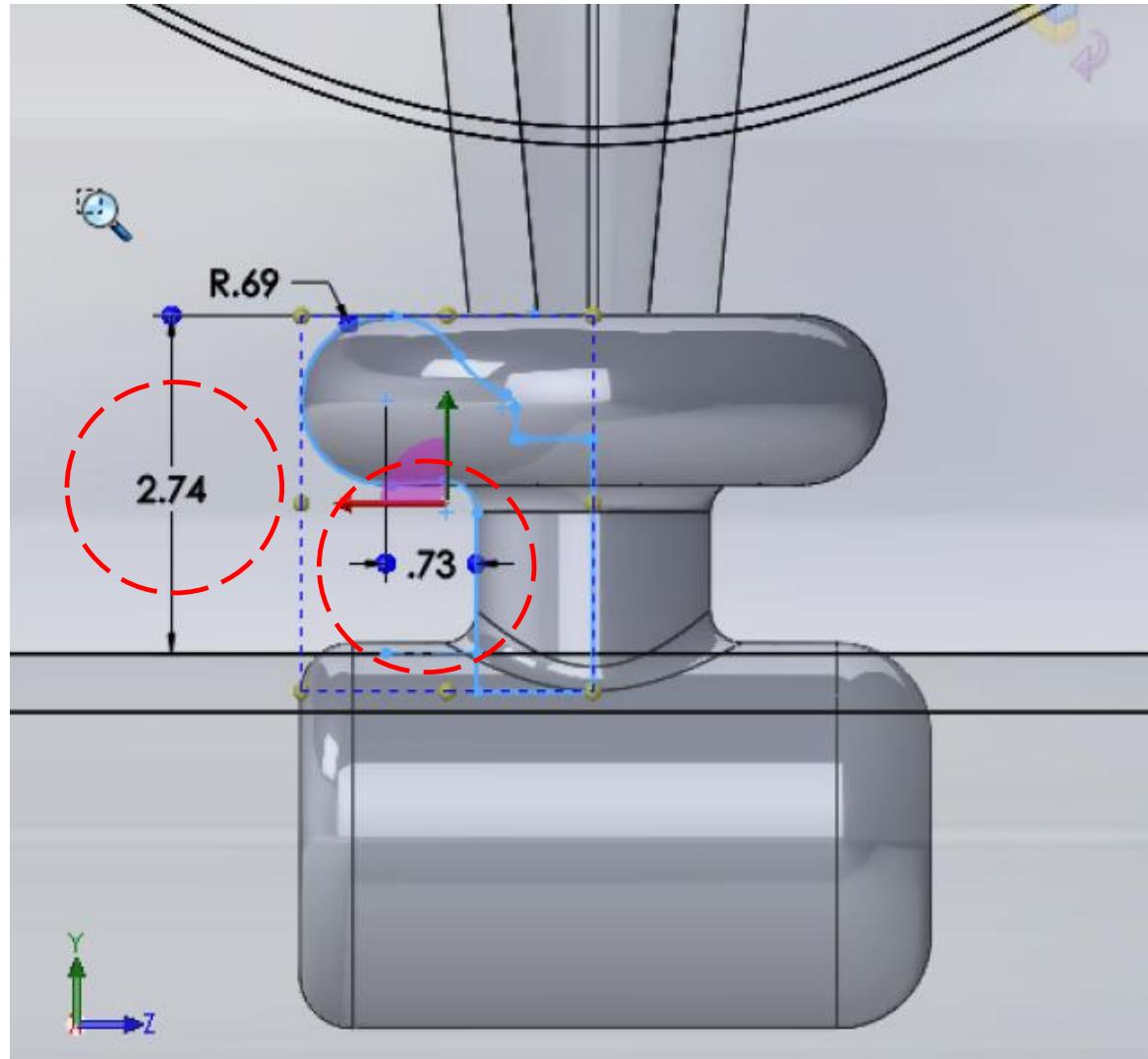
Summary

- 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

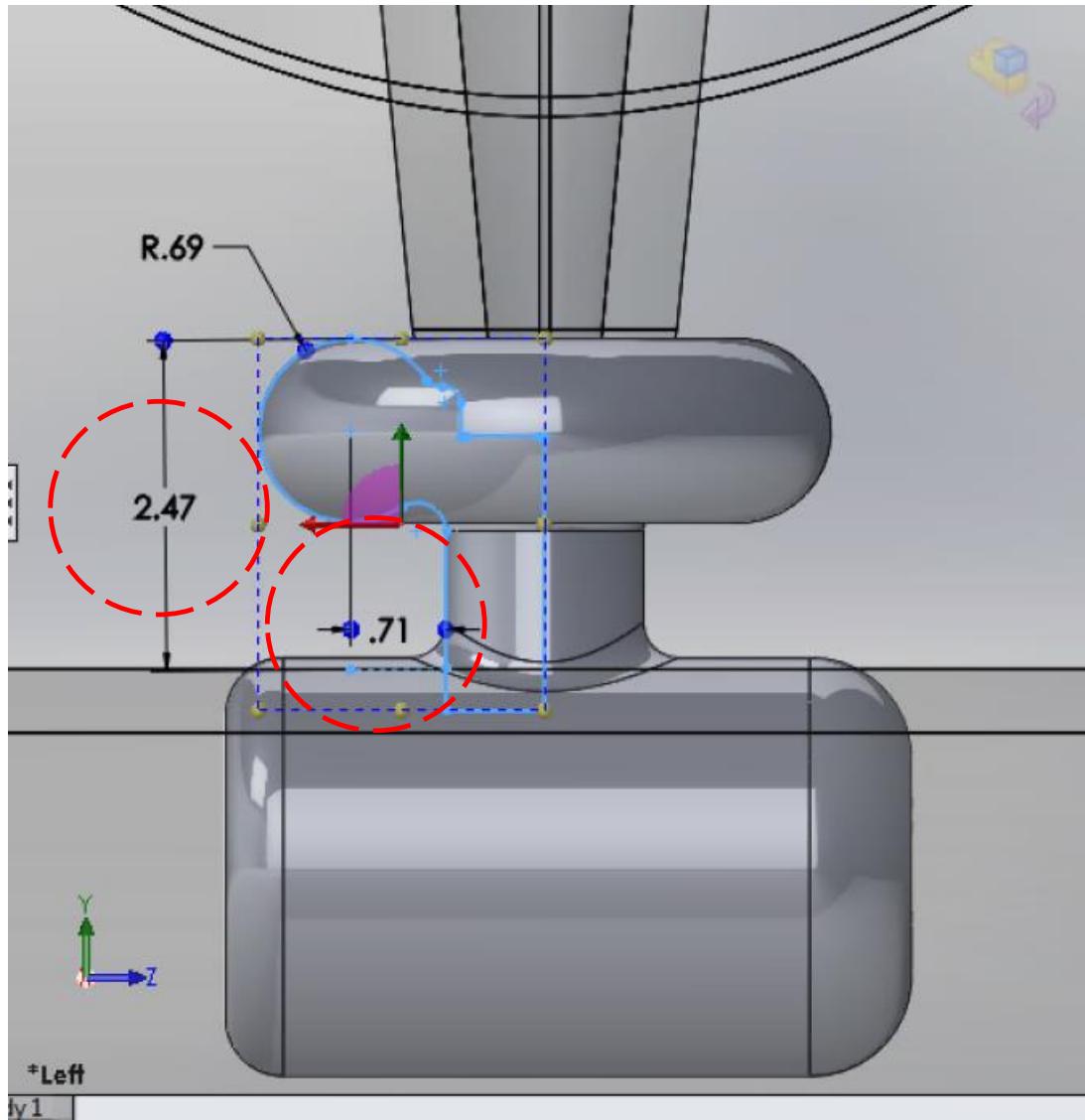
Solidworks geometry modifications: Original



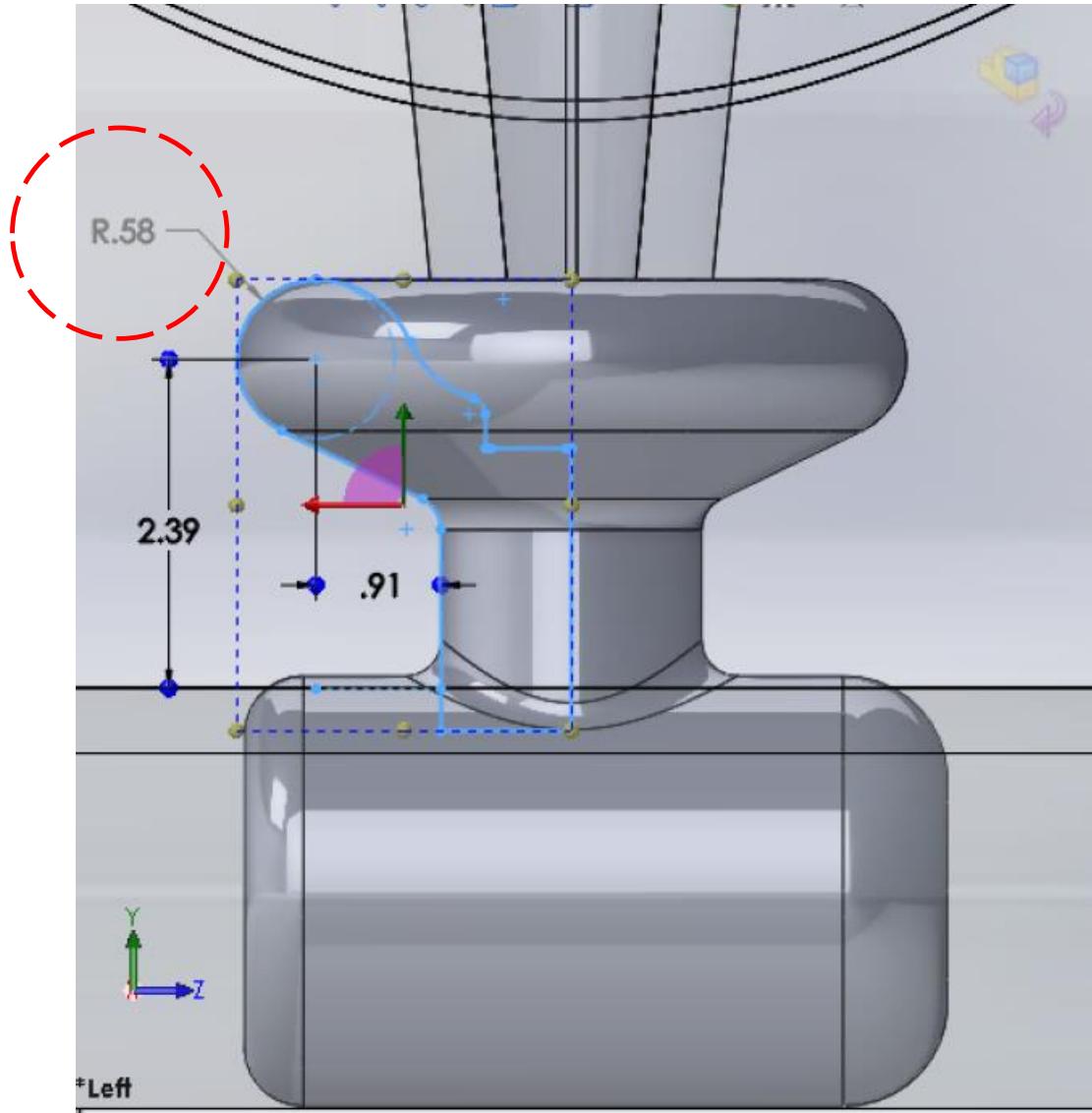
Solidworks geometry modifications: Shield 1



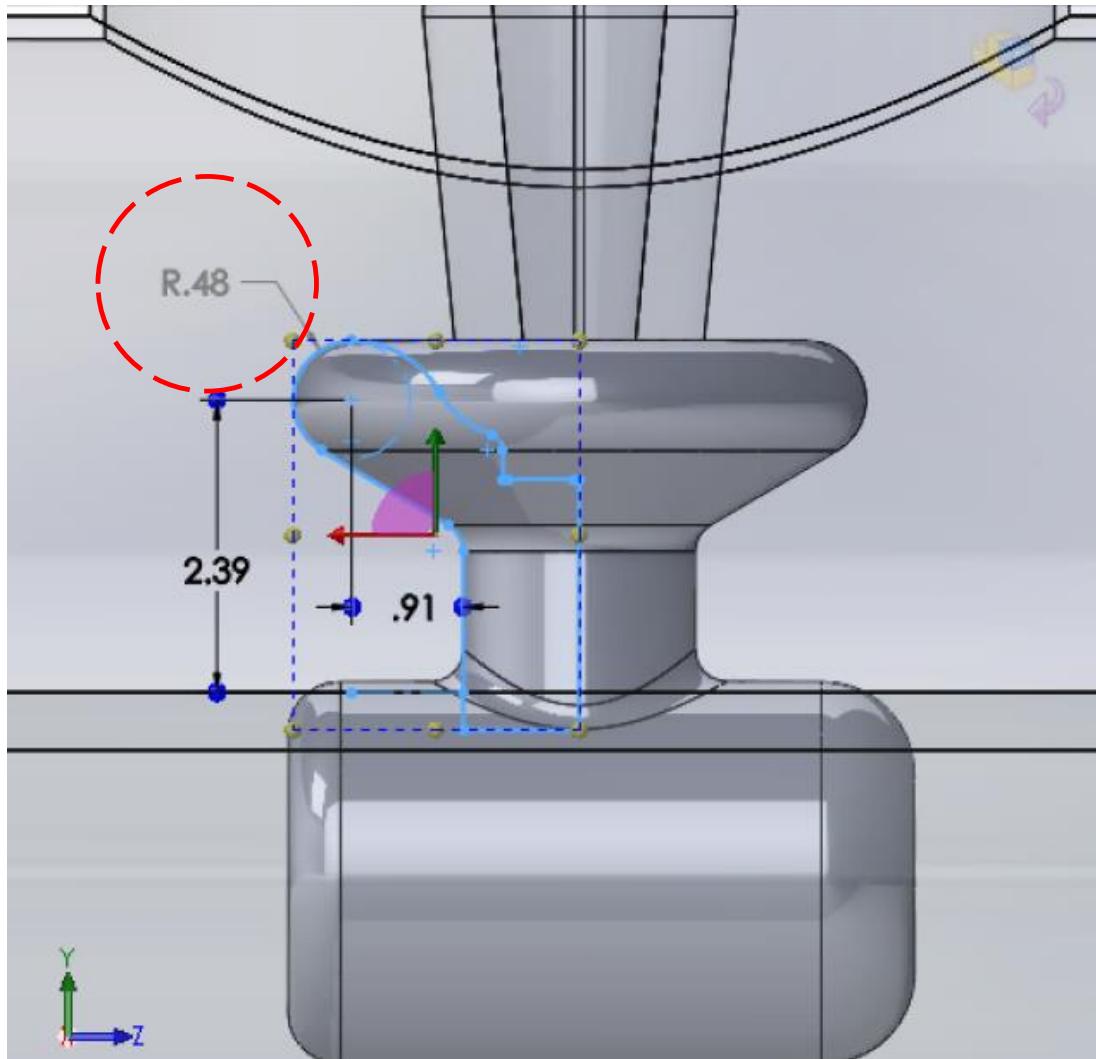
Solidworks geometry modifications: Shield 2



Solidworks geometry modifications: Shield 3

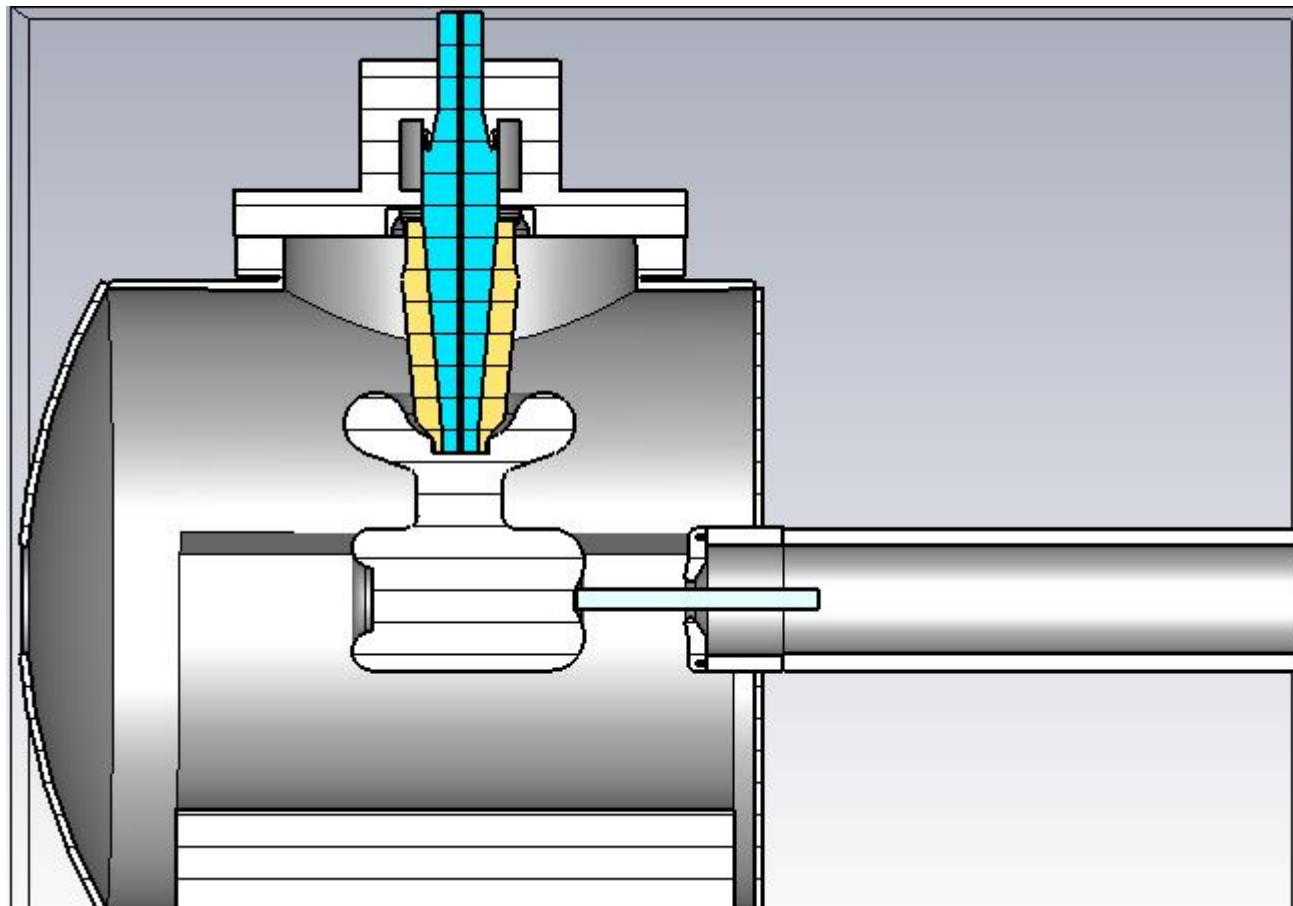
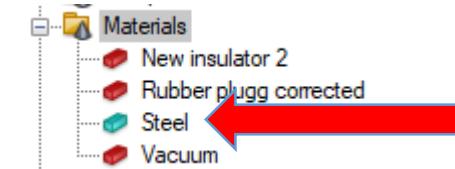
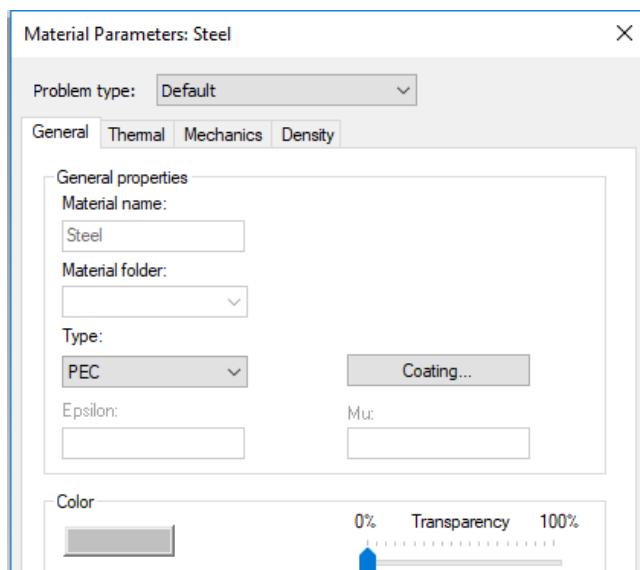


Solidworks geometry modifications: Shield 4



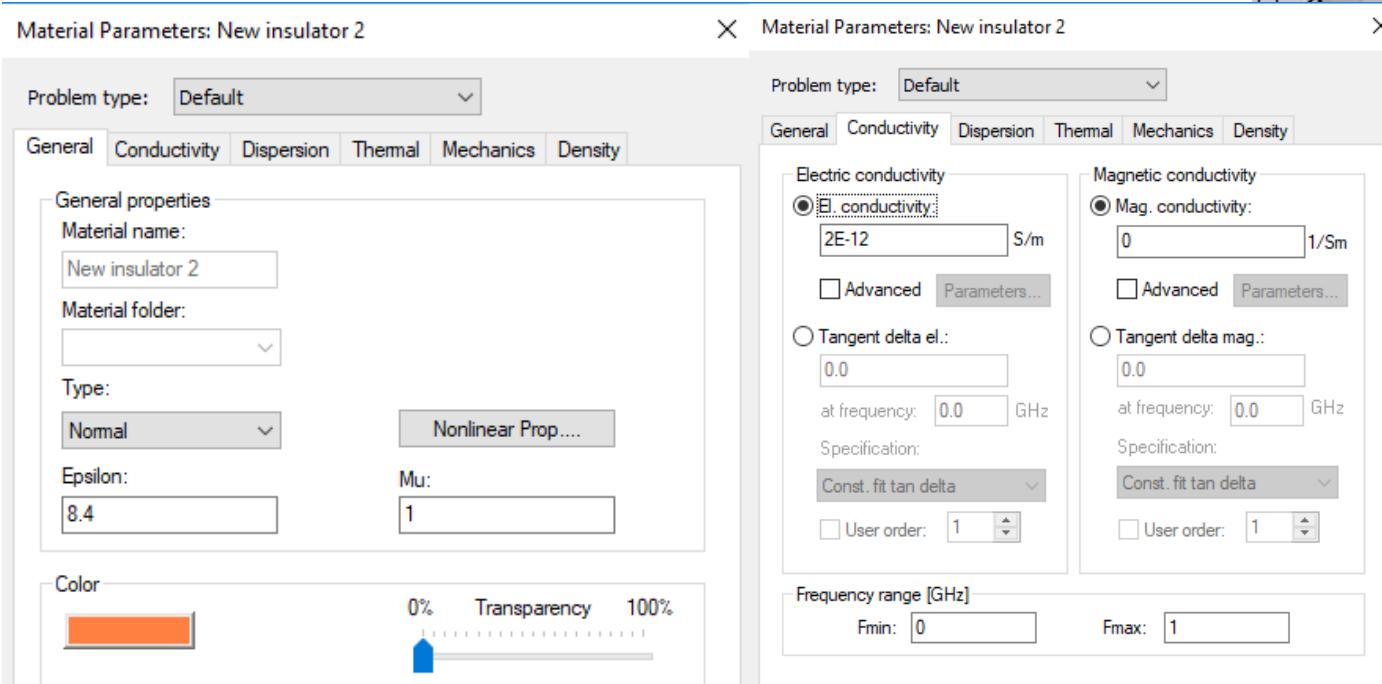
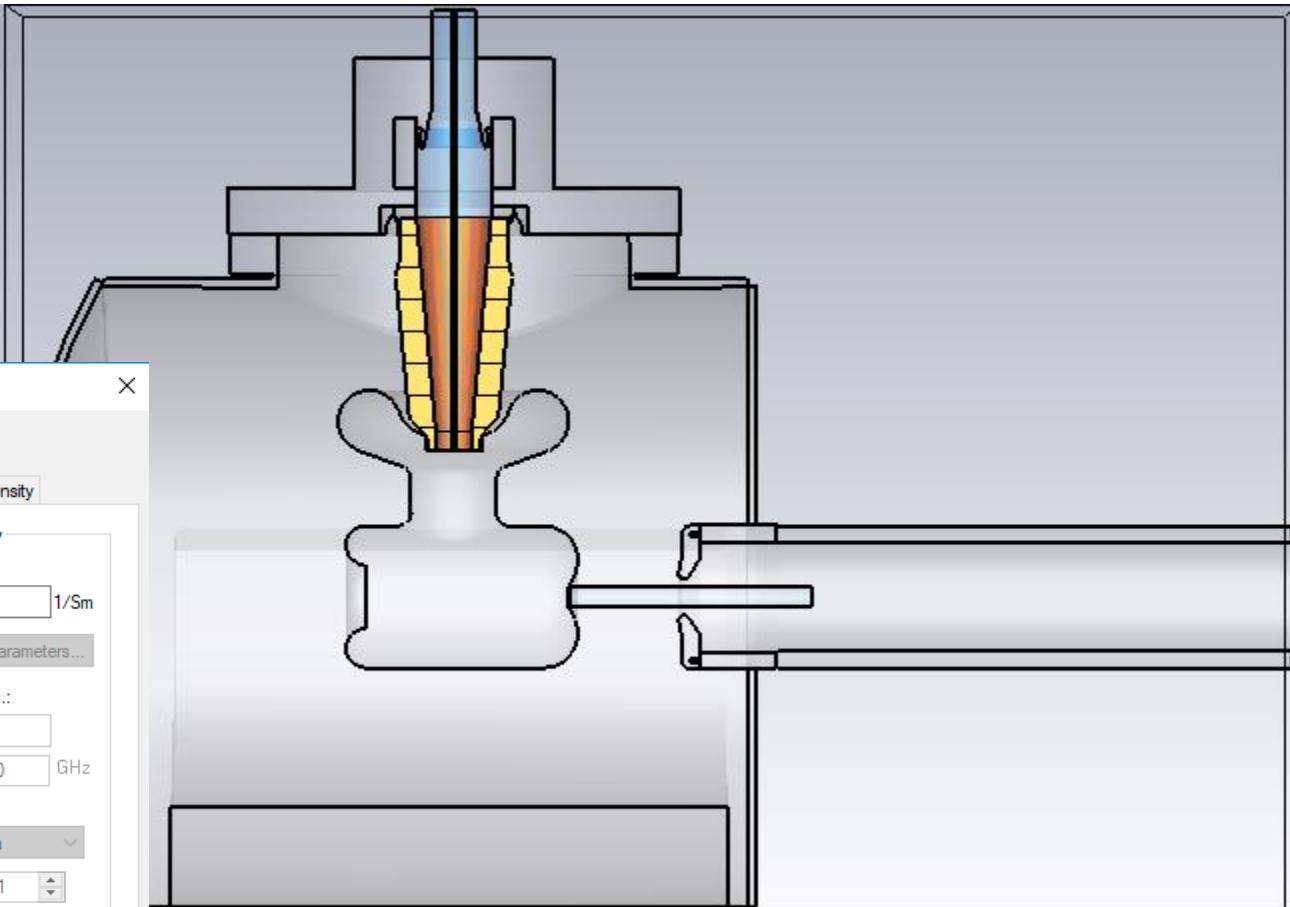
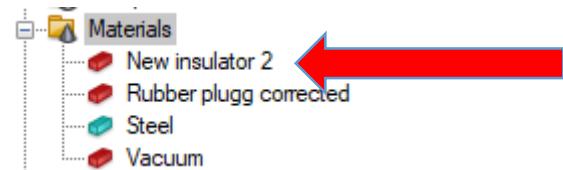
CST materials: PEC

- 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.



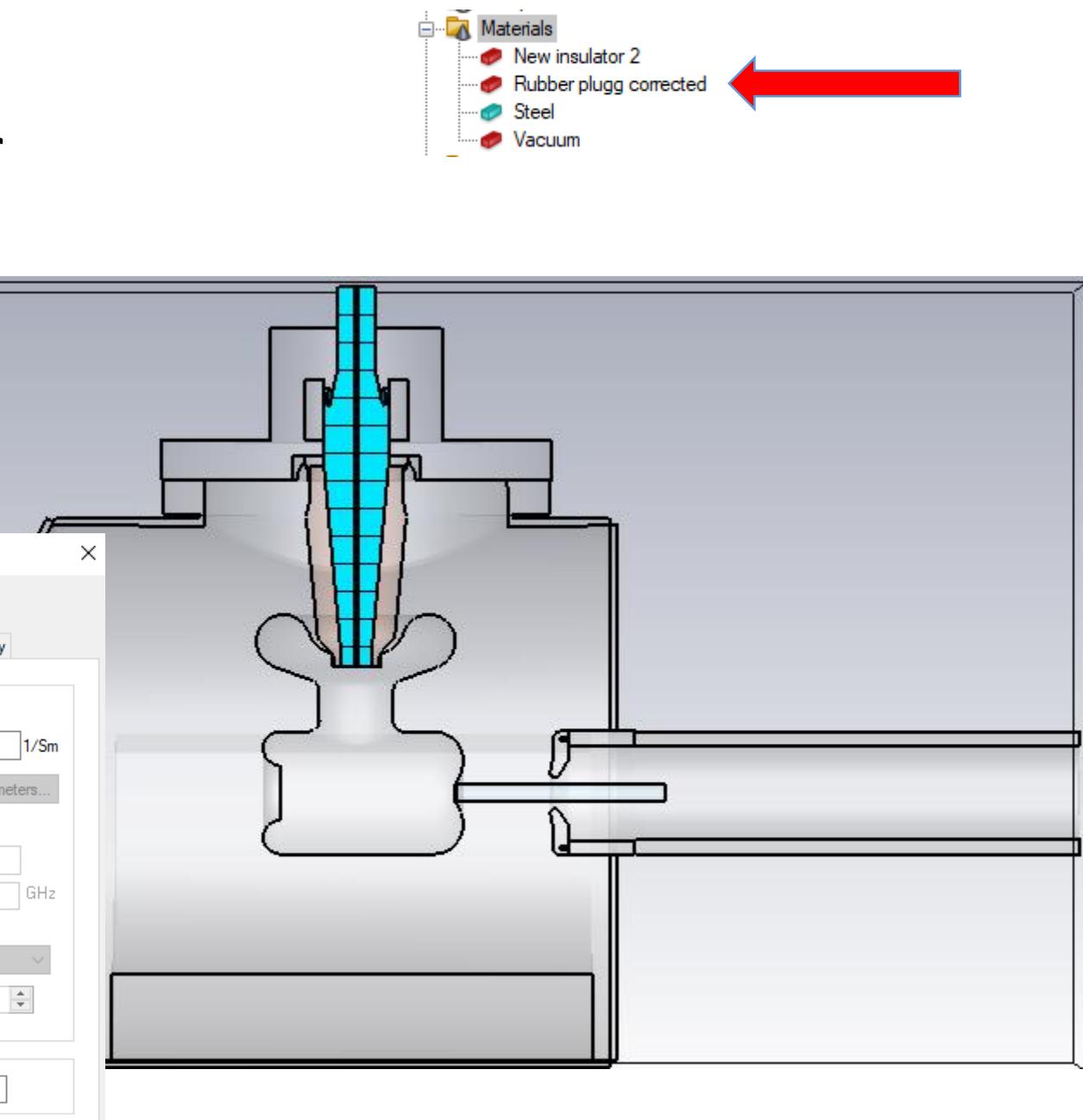
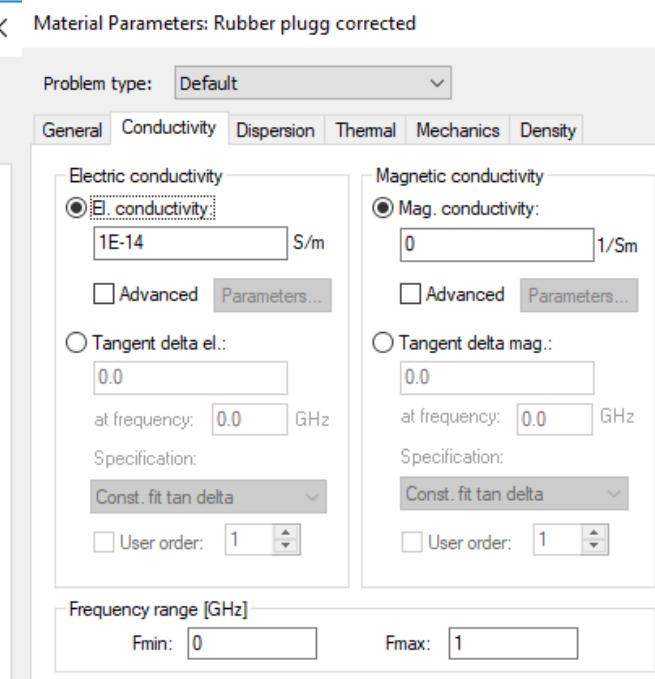
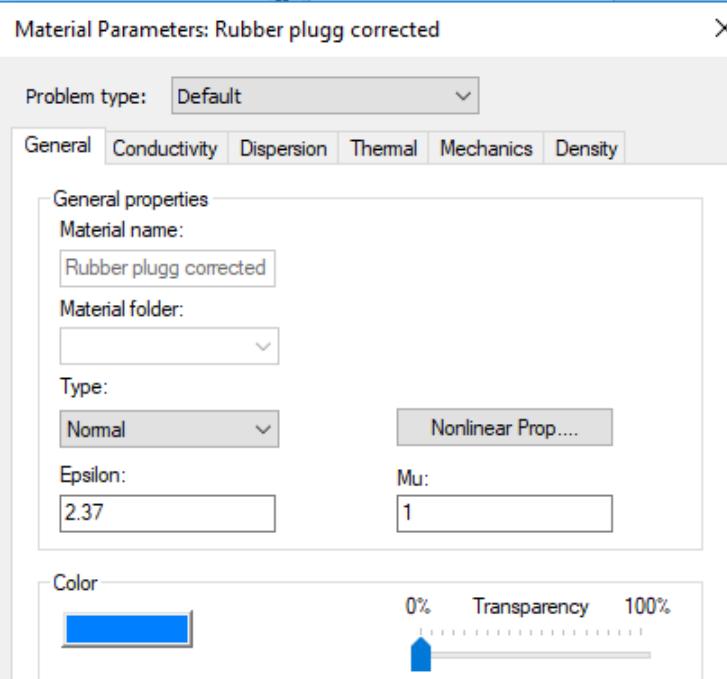
CST materials: Insulator

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



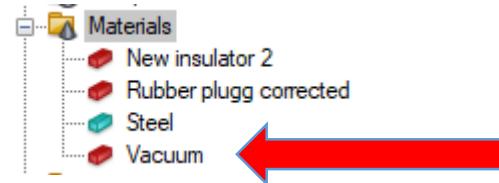
CST materials: Insulator

- For rubber I used the same parameters as in COMSOL.
- $\epsilon=2.37$
- $\sigma=1E-14$ [S/m]

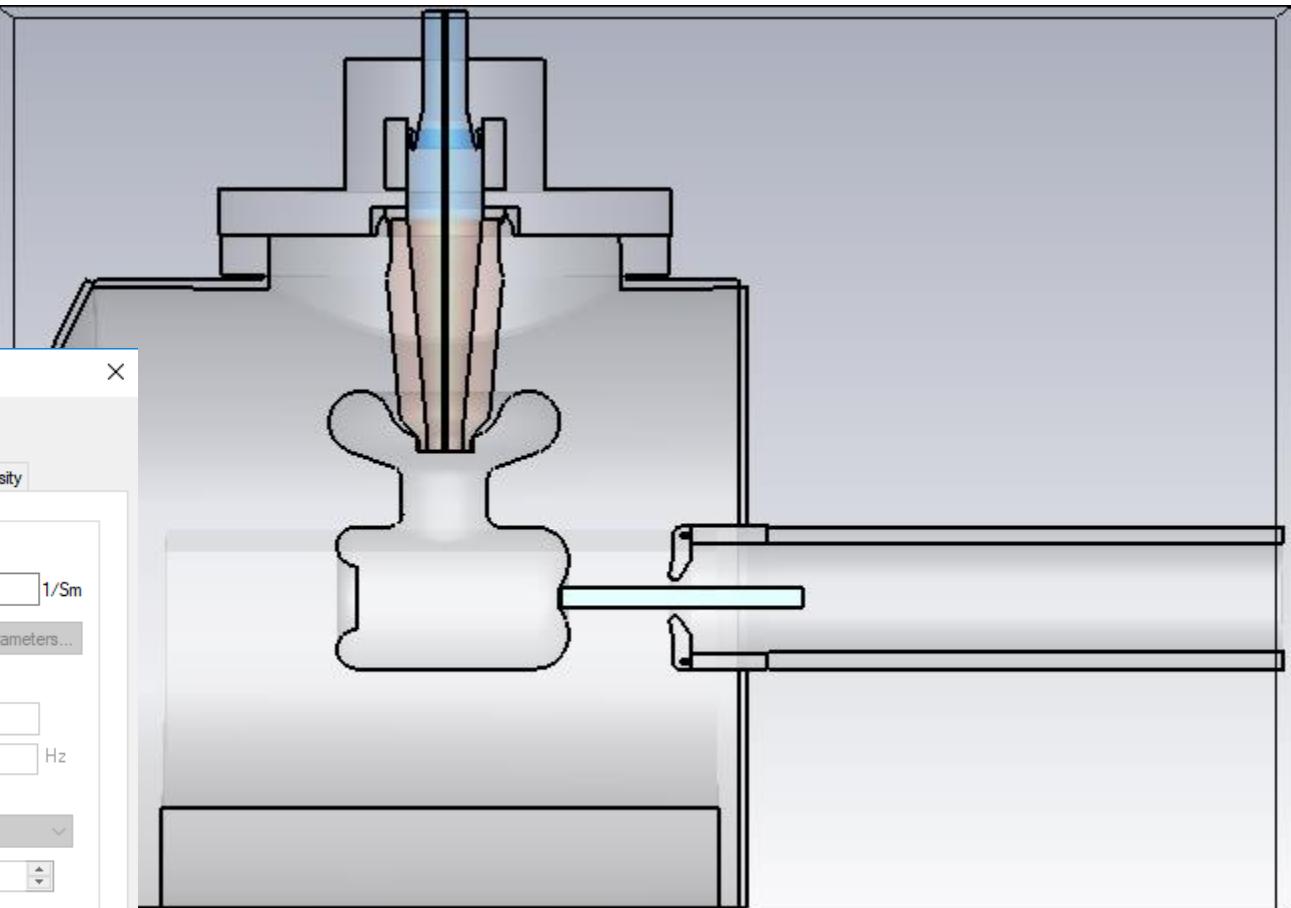


CST materials: vacuum

- For vacuum cylinder and surroundings.
- $\epsilon=1.0$
- $\sigma=0$ [S/m]

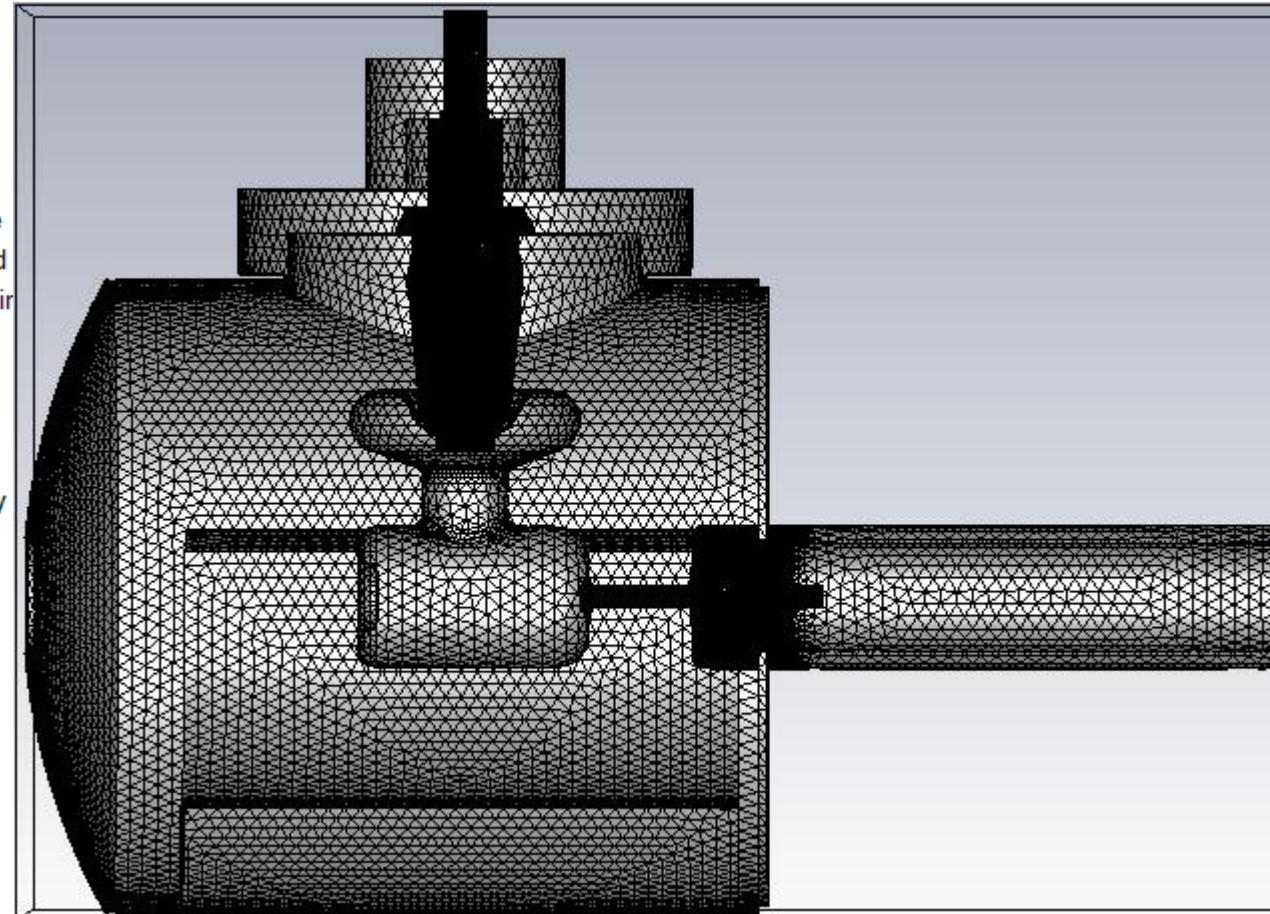
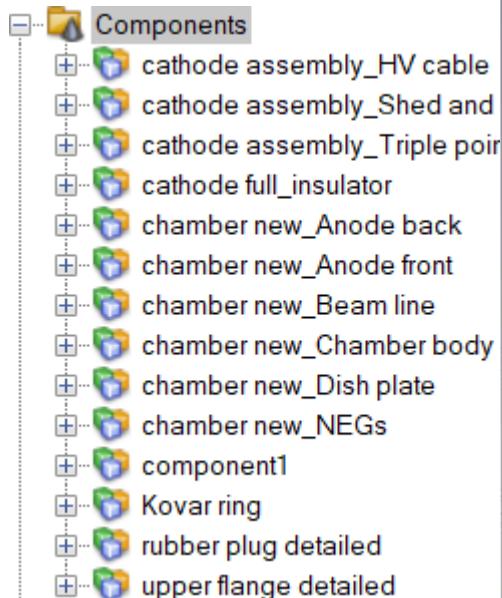


Two side-by-side 'Material Parameters: Vacuum' dialog boxes. Both show 'Problem type: Default'. The left dialog has tabs for General, Conductivity, Dispersion, Thermal, Mechanics, and Density. The right dialog has tabs for General, Conductivity, Dispersion, Thermal, Mechanics, and Density, with 'Conductivity' selected. Both dialogs show 'El. conductivity: 0 S/m' and 'Mag. conductivity: 0 1/Sm'. The right dialog also shows 'Tangent delta el.: 0.0 at frequency: 0.0 Hz' and 'Tangent delta mag.: 0.0 at frequency: 0.0 Hz'. Both dialogs have 'Frequency range [Hz]' fields with Fmin: 0 and Fmax: 1e+09.

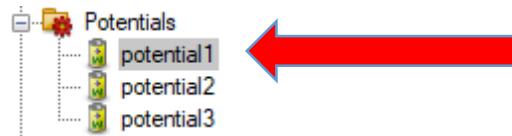


CST mesh:

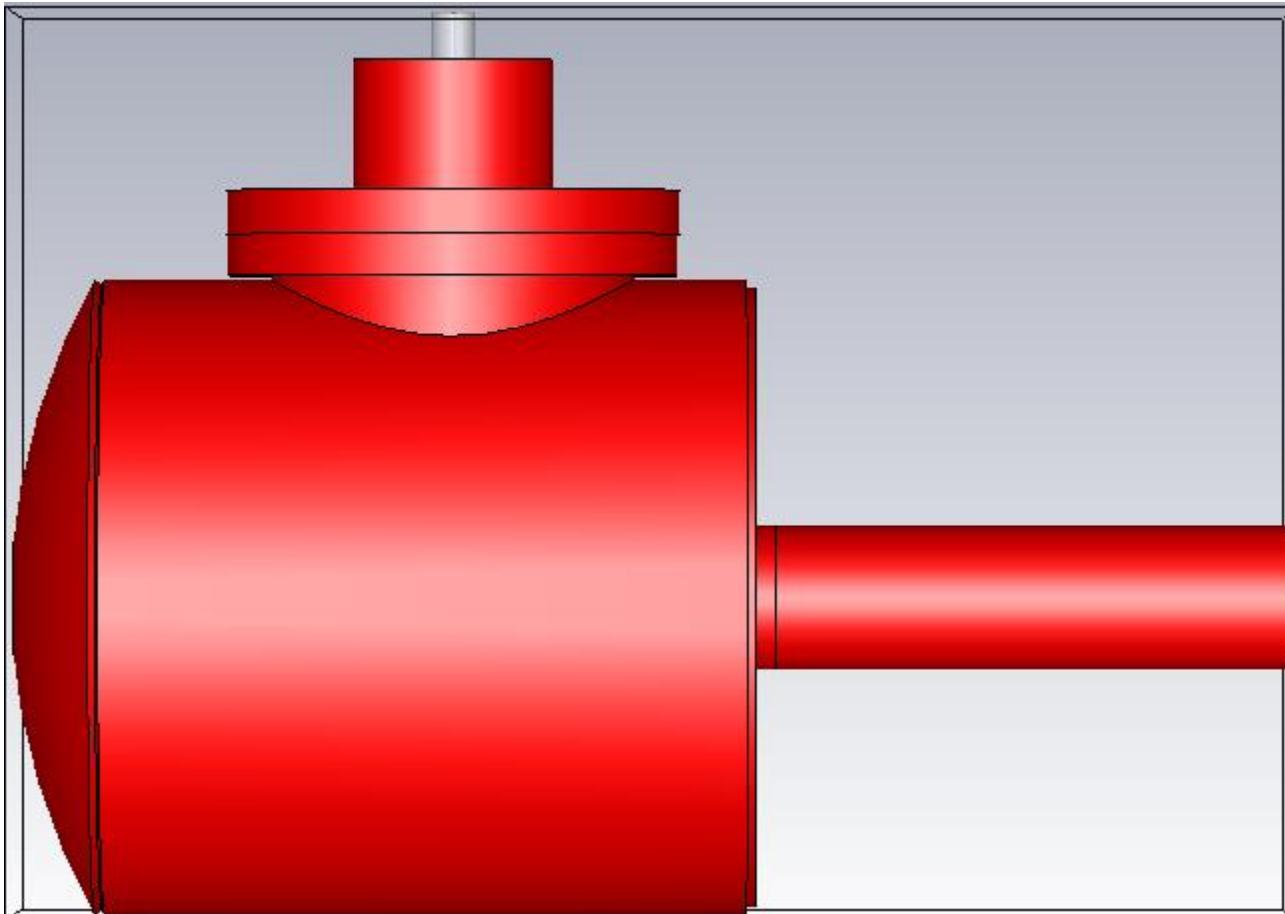
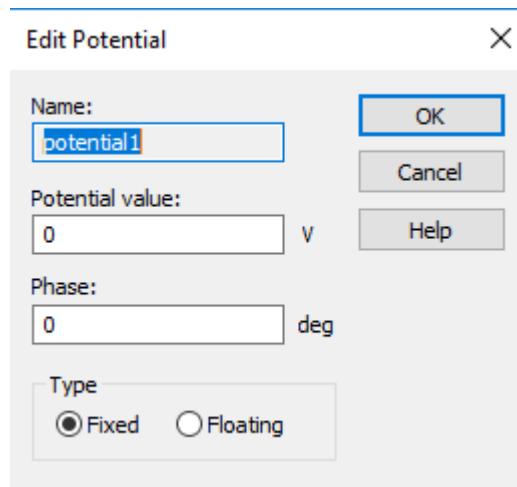
- The mesh was separated into (maybe too many) pieces. :P
- The important part is, I only set some individual parts that require fine detail and left the rest to be auto-meshed.



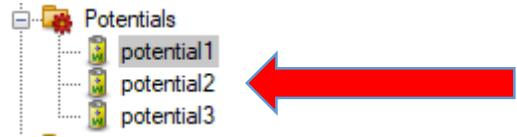
CST simulation: Potential



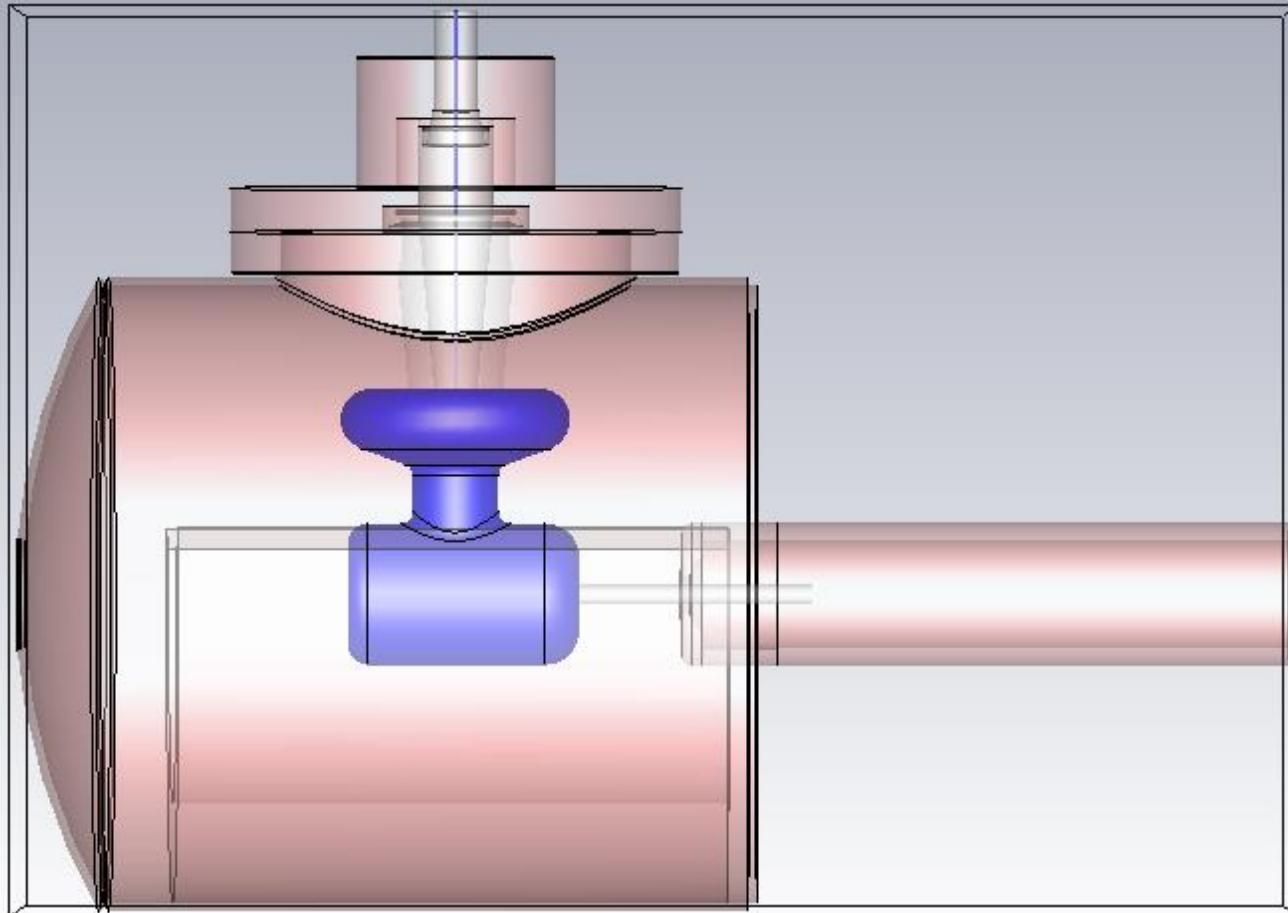
- Chamber, upper flange, Kovar ring, anode and beam-pipe at 0 V.



CST simulation: Potential

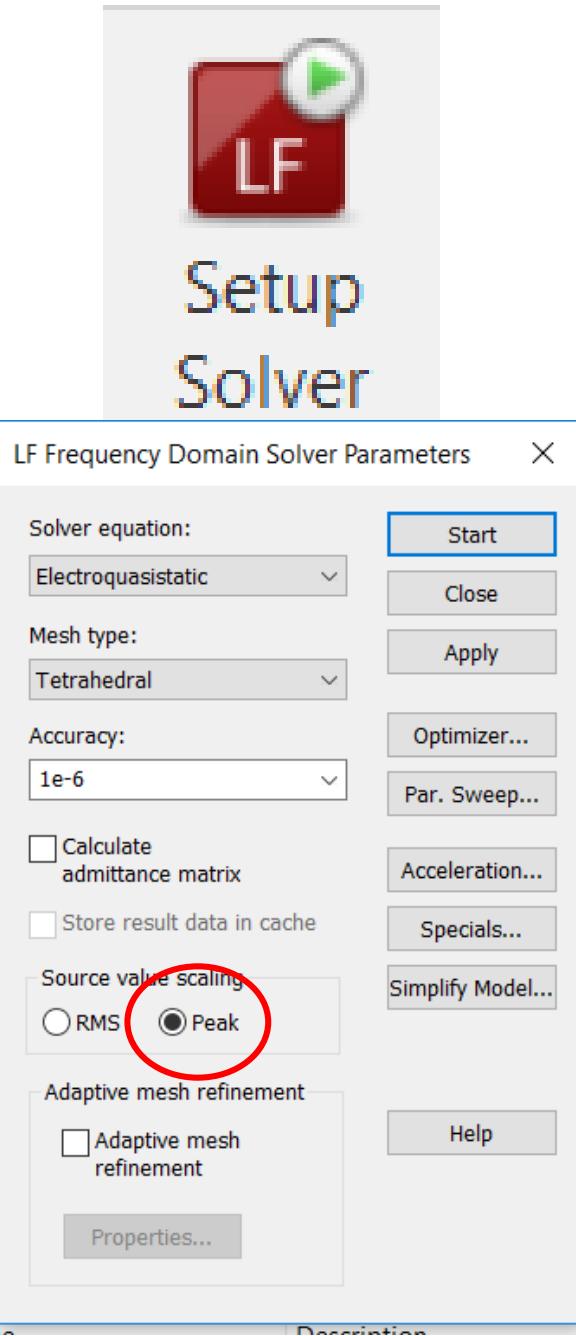


- Cathode electrode (including Pierce geometry), shield and high voltage cable at -200 kV.



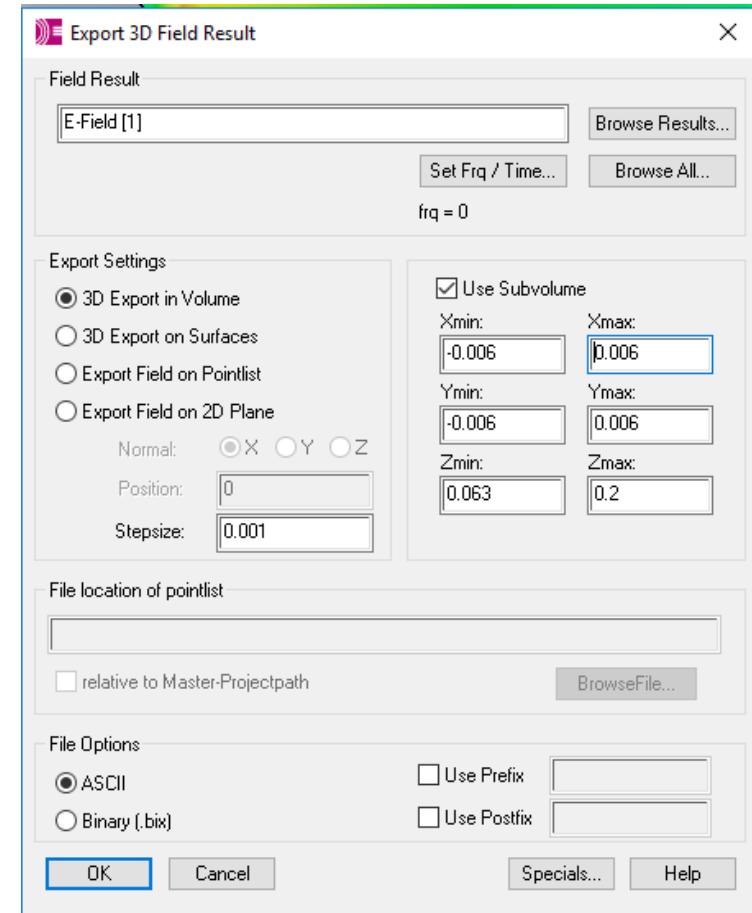
CST simulation: Solver

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



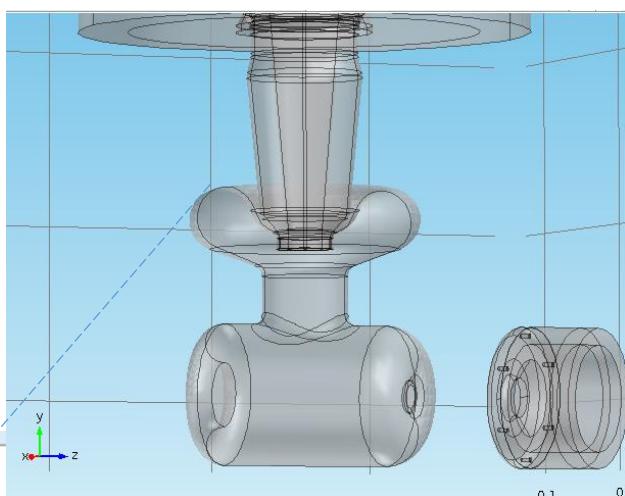
CST results:

- 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.



Plot

Label: Cut Line 2D 4

Data

Data set: Cut Plane 1

Line Data

Line entry method: Two points

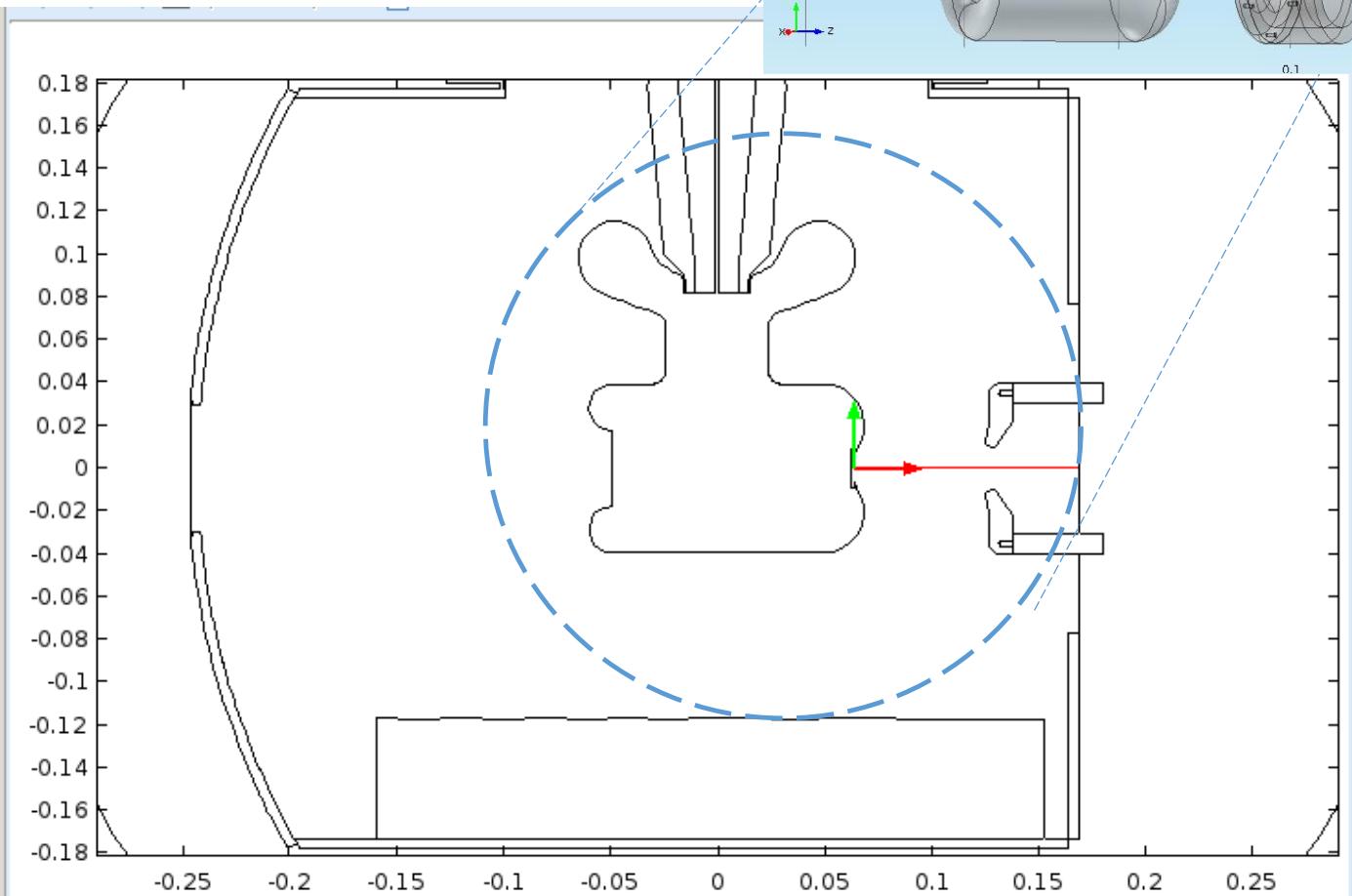
x: Point 1: 0.0642 m y: 0 m
Point 2: 0.169 m 0 m

Bounded by points

Additional parallel lines

Distances: [] m

Advanced

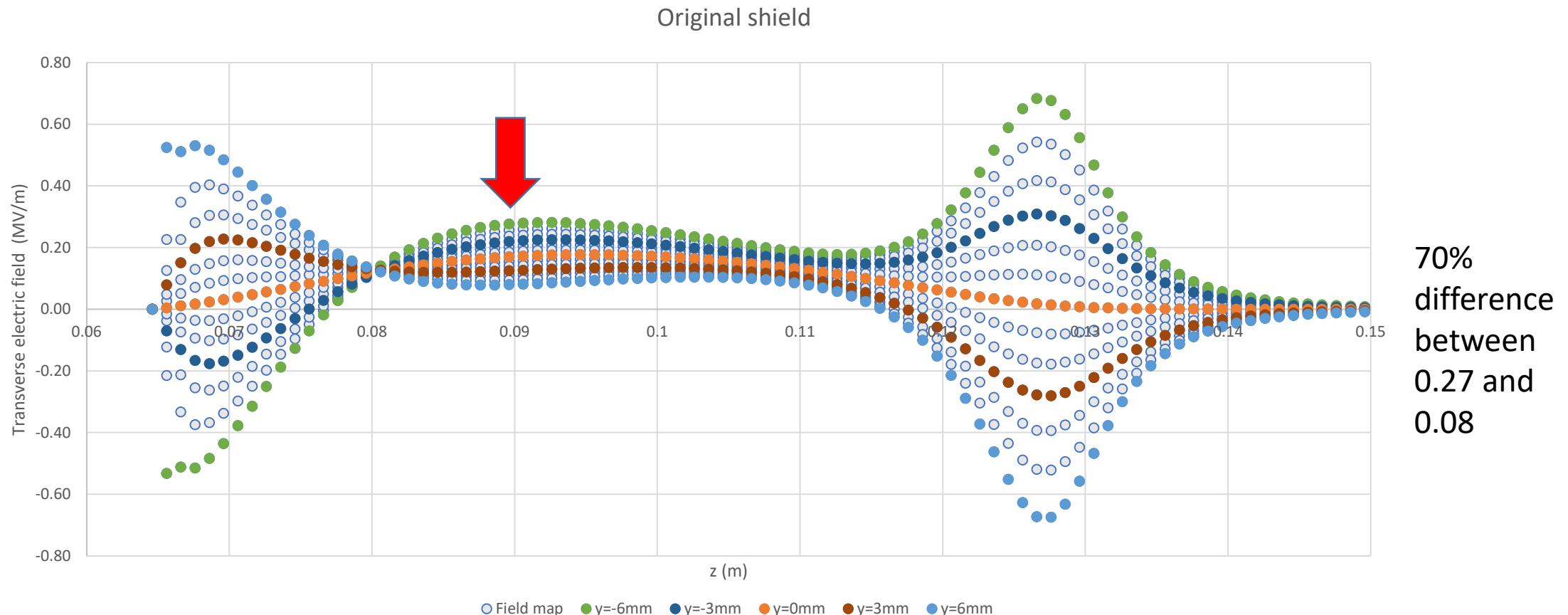


Original vs Shield 1 vs Shield 2: Transversal electric field

- 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.

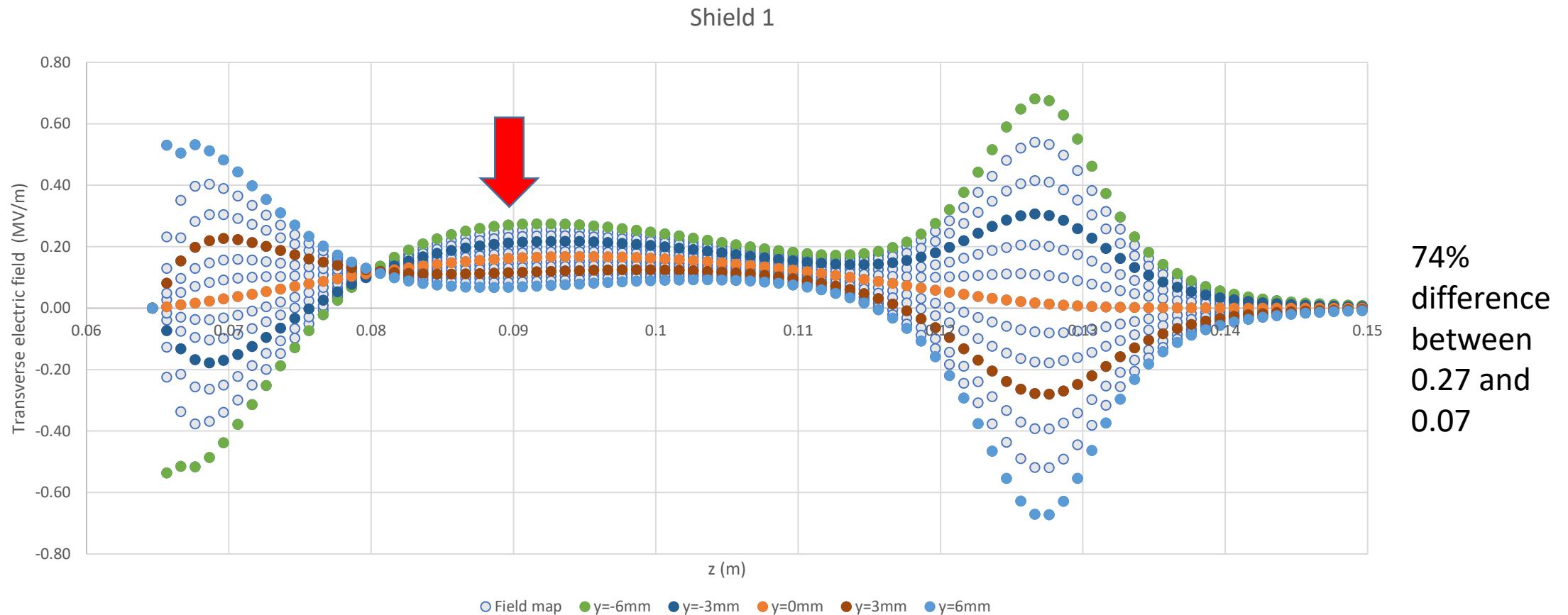
CST results: Transverse electric field – original shield

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 $-6\text{mm} < y < 6\text{mm}$



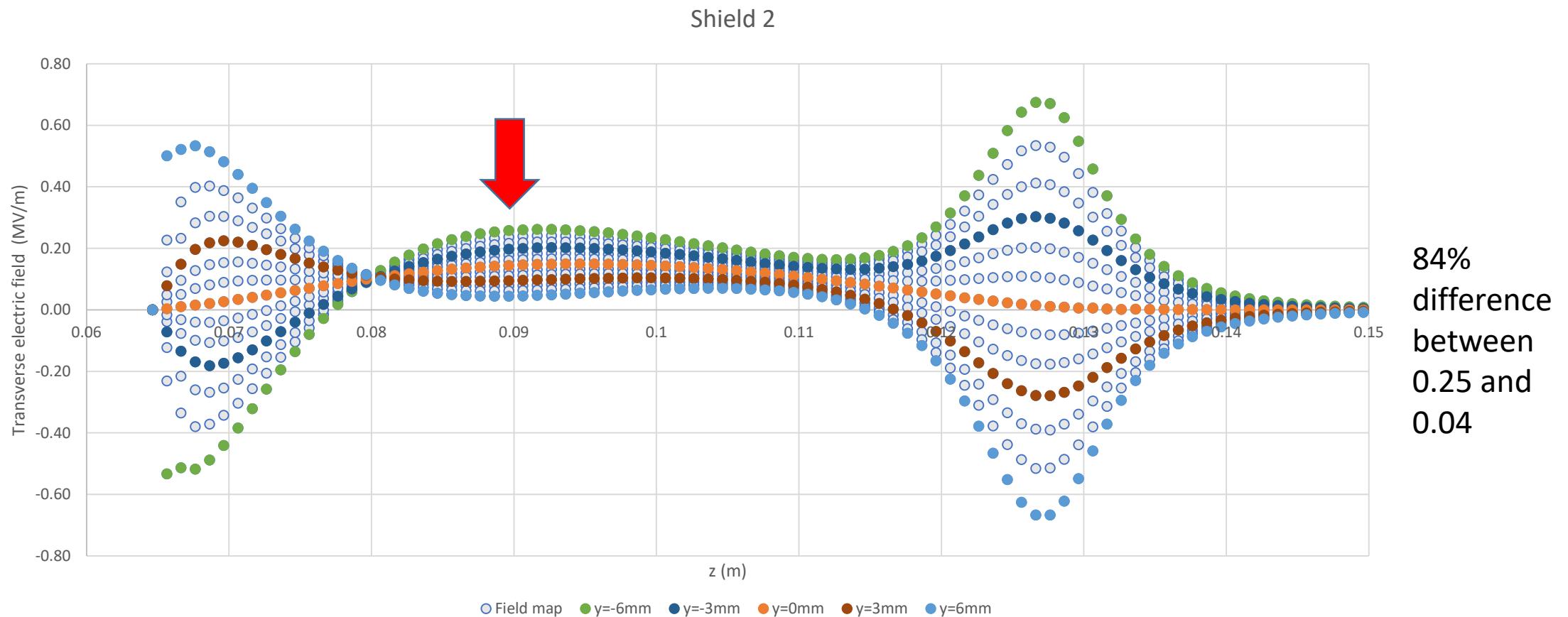
CST results: Transverse electric field – Shield 1

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 $-6\text{mm} < y < 6\text{mm}$



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 $-6\text{mm} < y < 6\text{mm}$

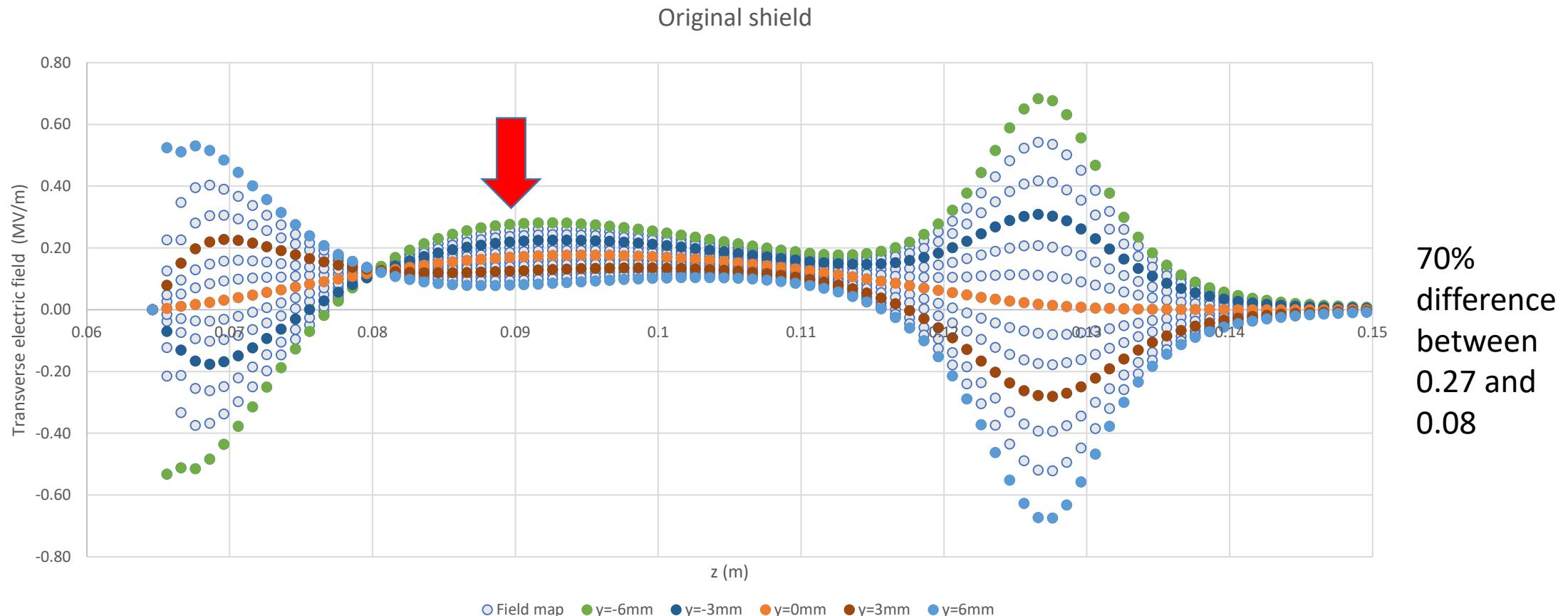


Original vs Shield 3 vs Shield 4 : Transversal electric field

- 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.

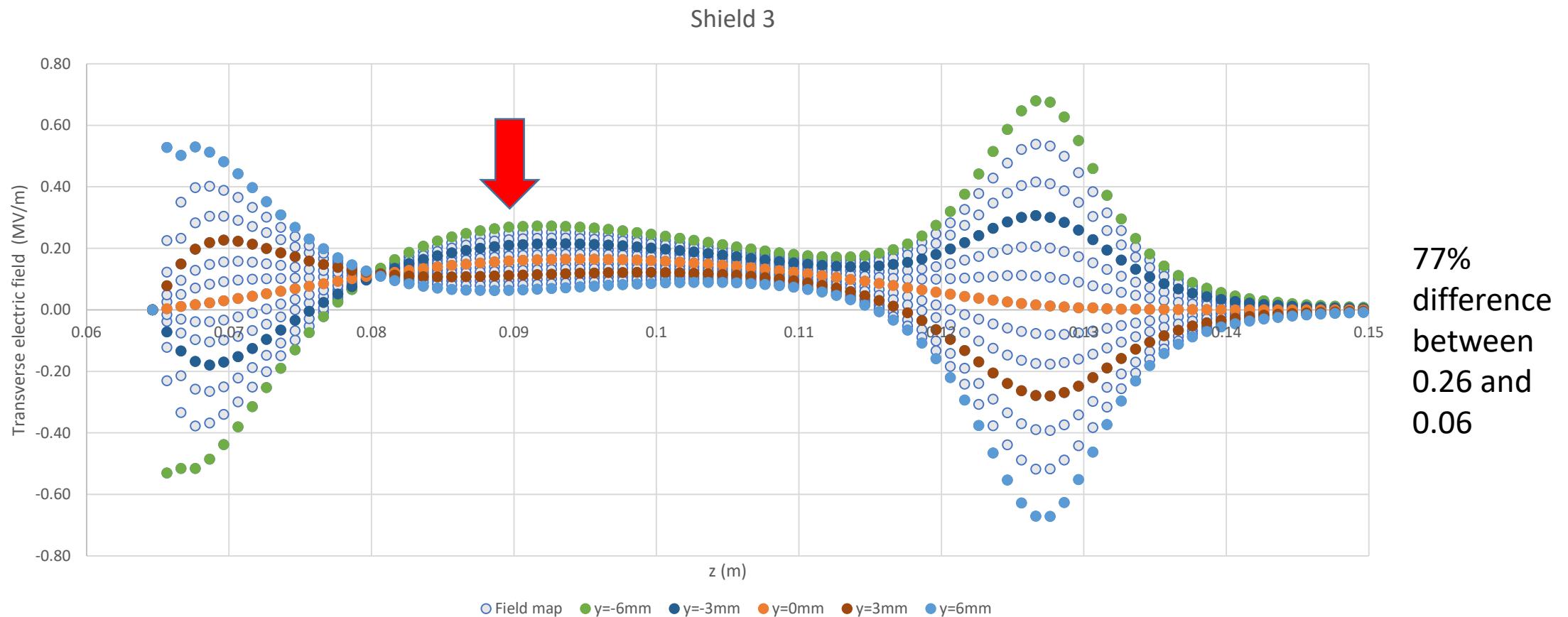
CST results: Transverse electric field – original shield

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 $-6\text{mm} < y < 6\text{mm}$



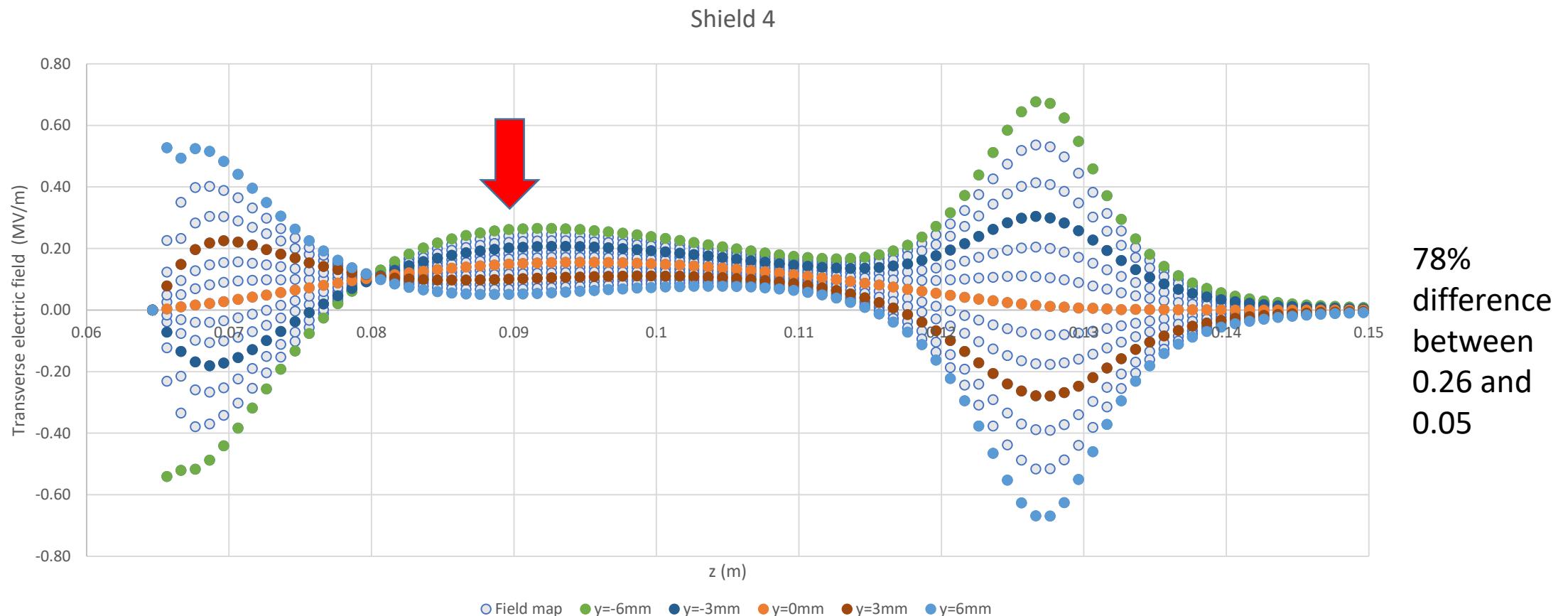
CST results: Transverse electric field – Shield 3

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 $-6\text{mm} < y < 6\text{mm}$



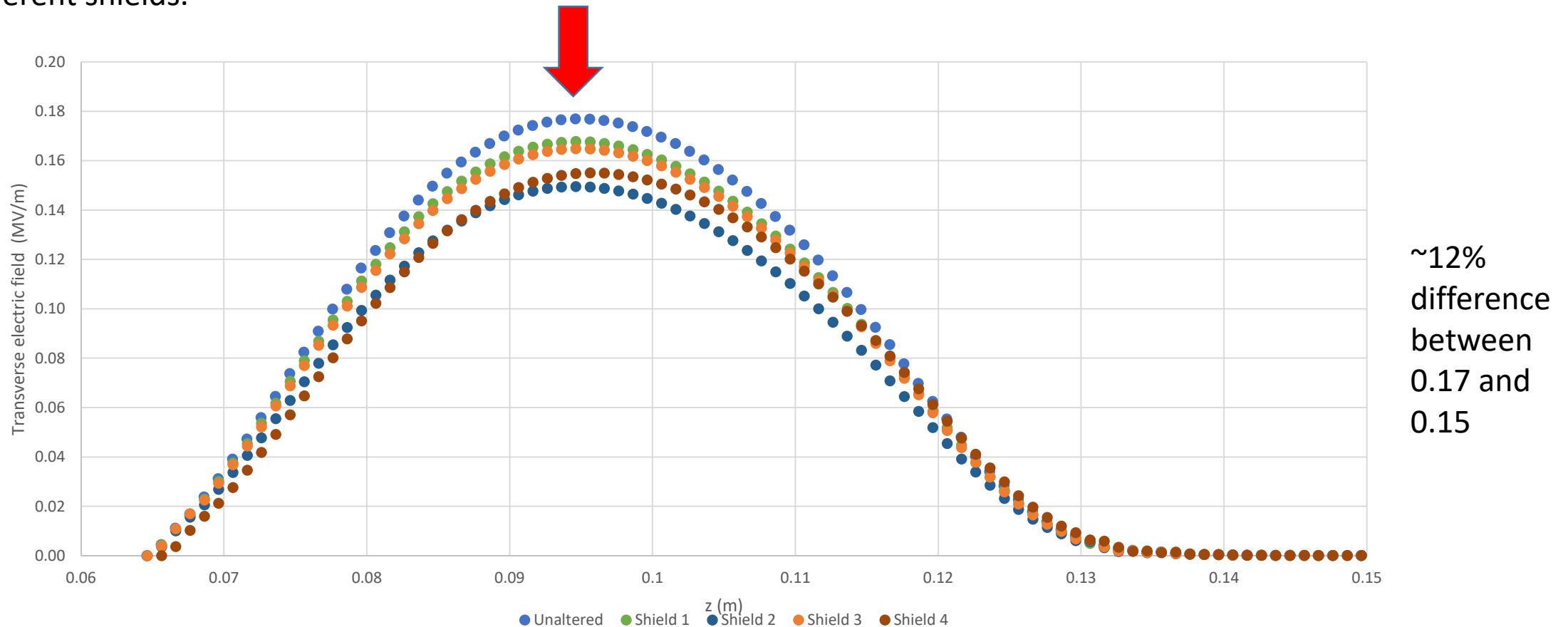
CST results: Transverse electric field – Shield 4

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 $-6\text{mm} < y < 6\text{mm}$



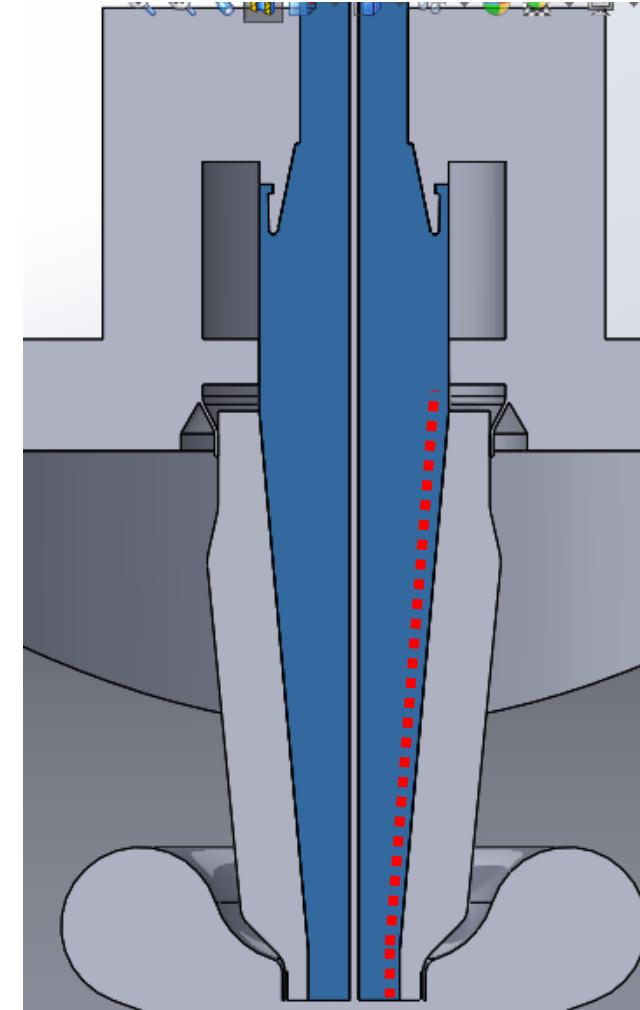
CST results: Transverse electric field – Original vs all shields (1,2,3 & 4) at C-a gap center line

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



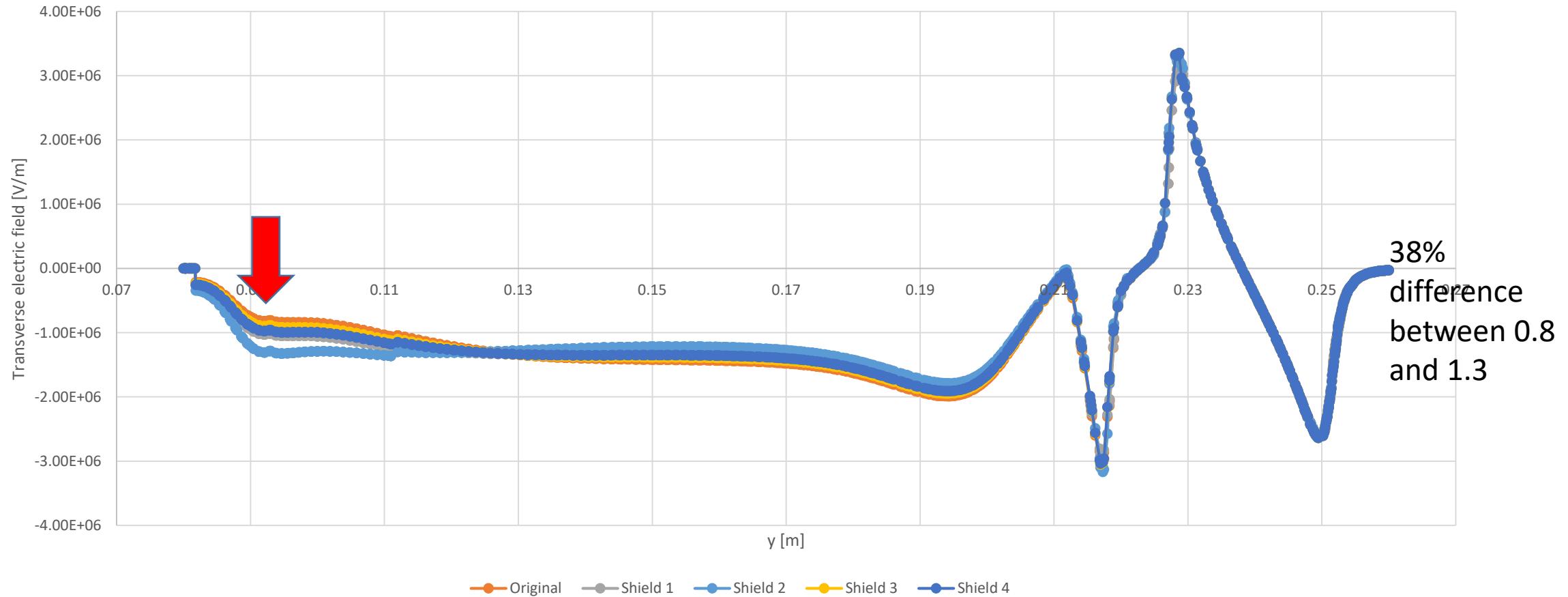
CST results: Transverse electric field – Original vs all shields (1,2,3 & 4) at insulator interface

- 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).



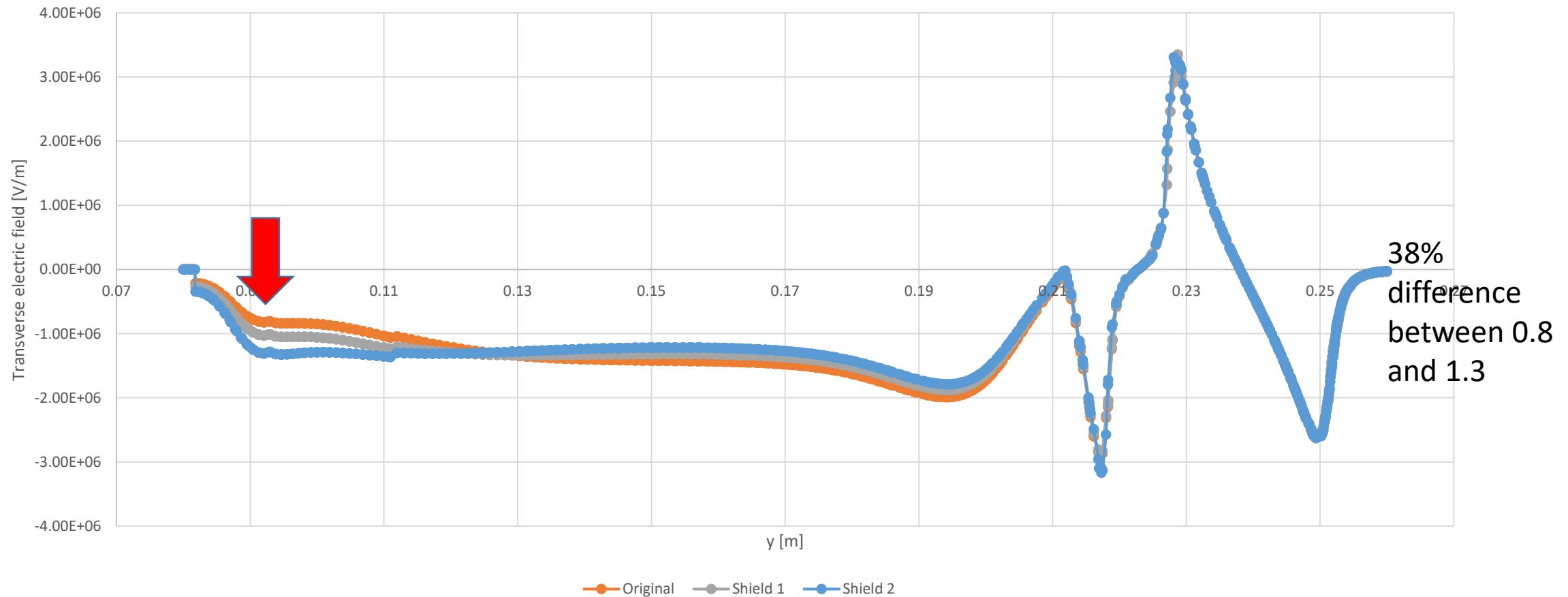
CST results: Transverse electric field – Original vs all shields (1,2,3 & 4) at insulator interface

Different colors represent different shields.



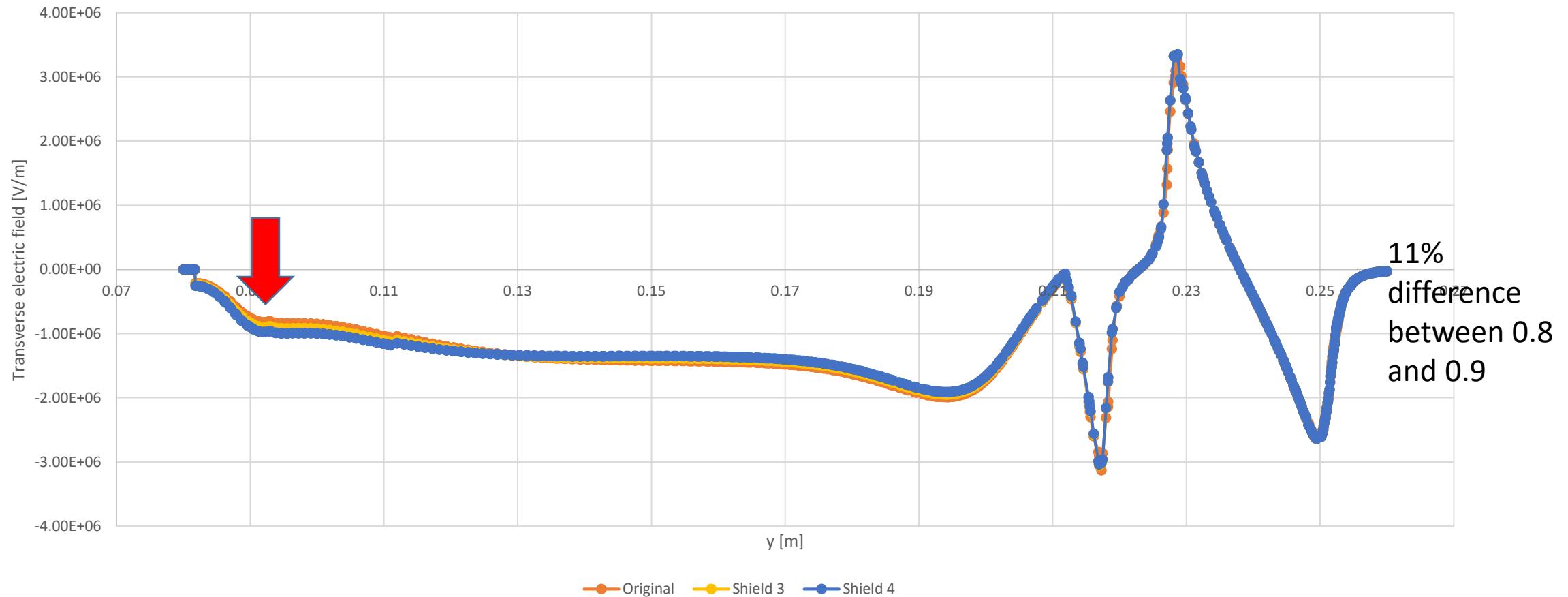
CST results: Transverse electric field – Original vs shields 1&2 at insulator interface

Different colors represent different shields.



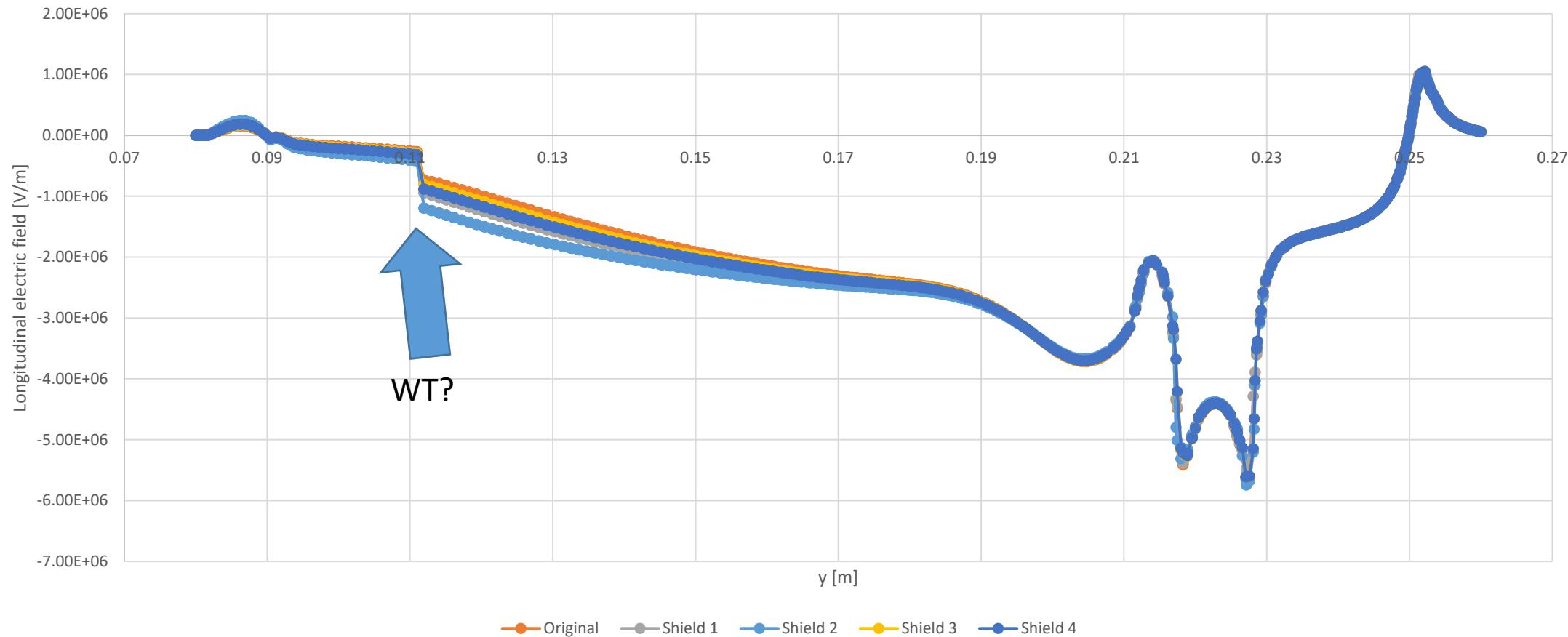
CST results: Transverse electric field – Original vs shields 3&4 at insulator interface

Different colors represent different shields.



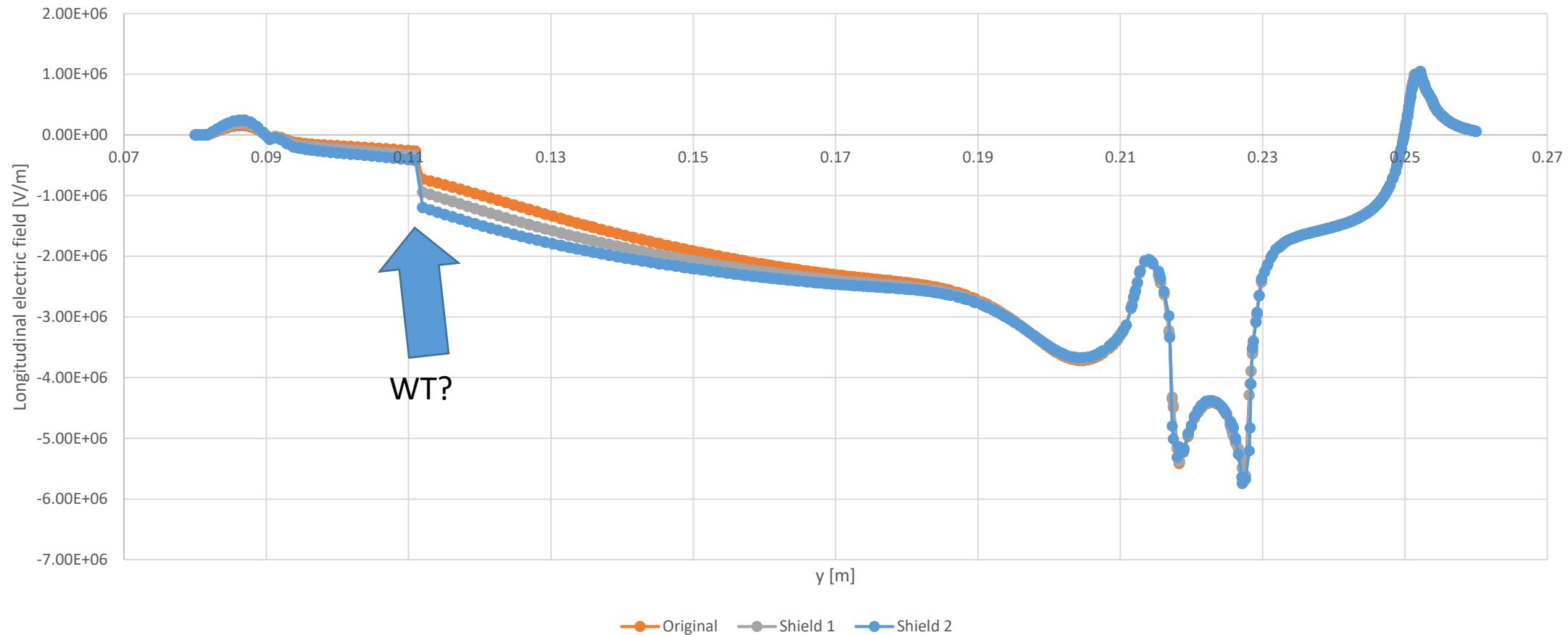
CST results: Longitudinal electric field – Original vs all shields (1,2,3 & 4) at insulator interface

Different colors represent different shields.



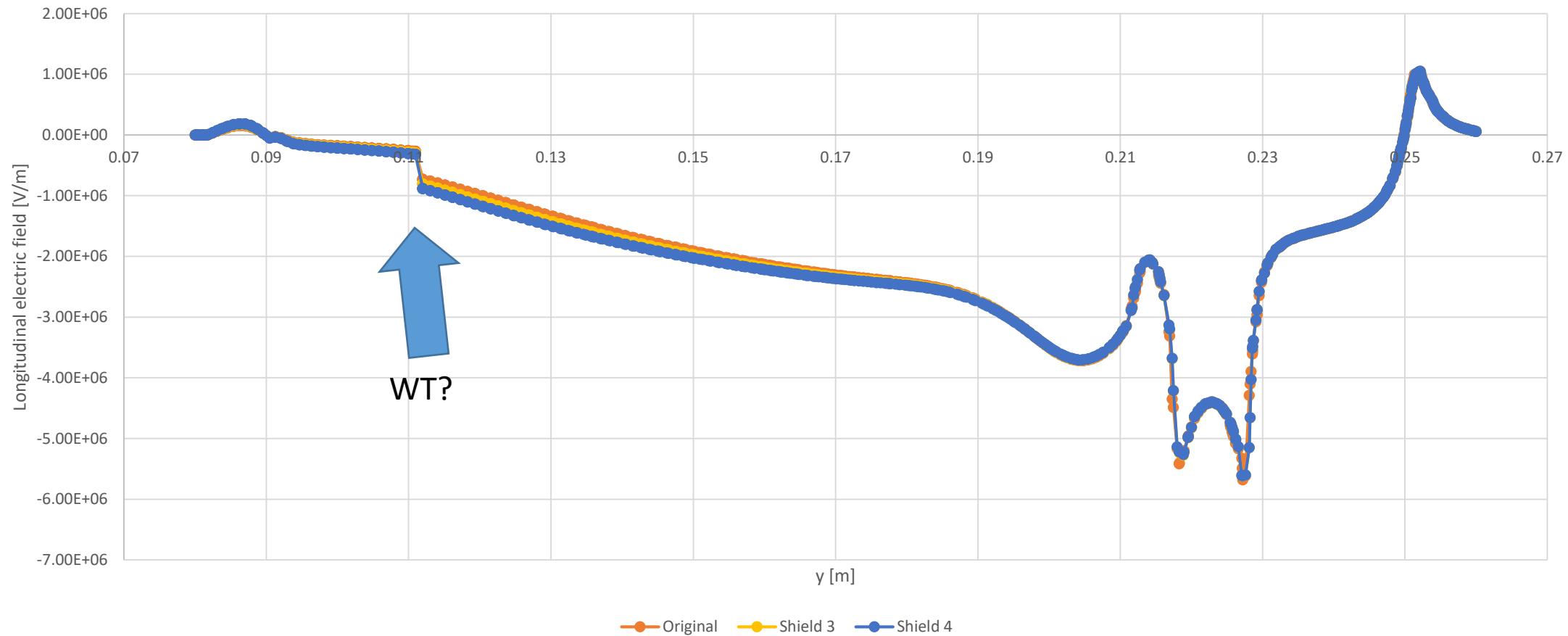
CST results: Longitudinal electric field – Original vs shields 1&2 at insulator interface

Different colors represent different shields.



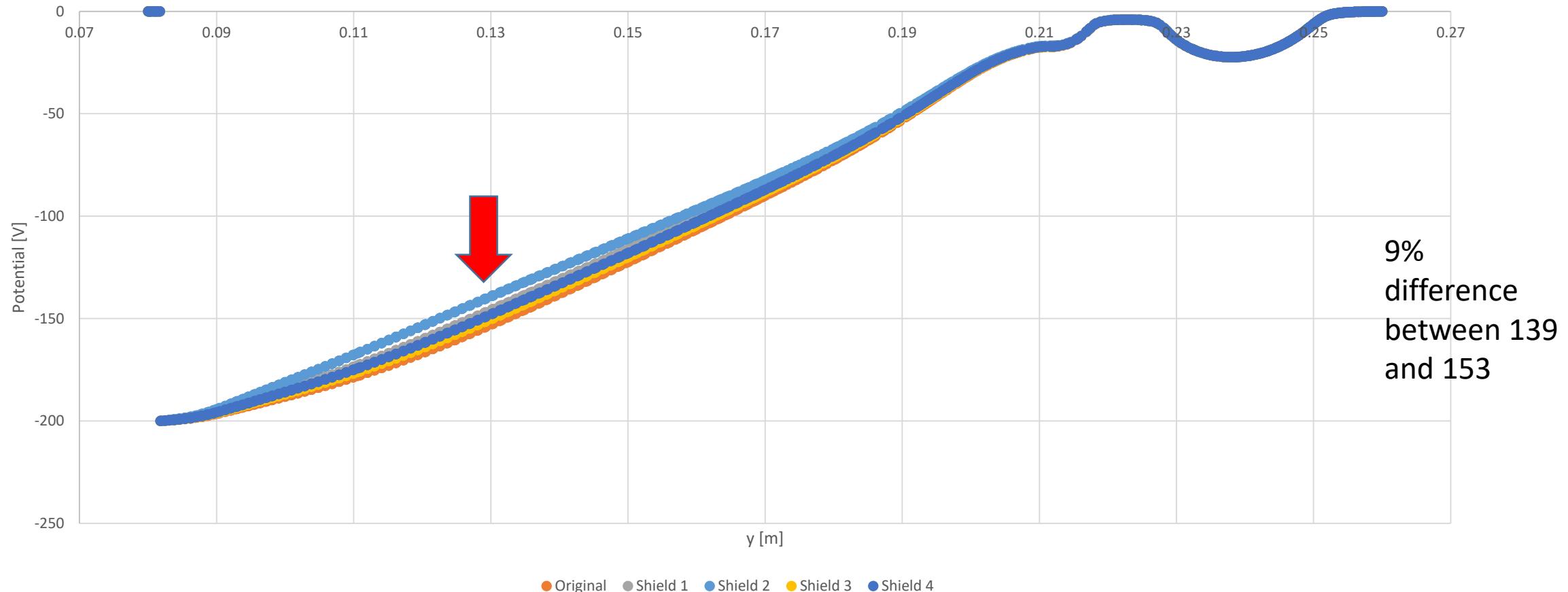
CST results: Longitudinal electric field – Original vs shields 3&4 at insulator interface

Different colors represent different shields.



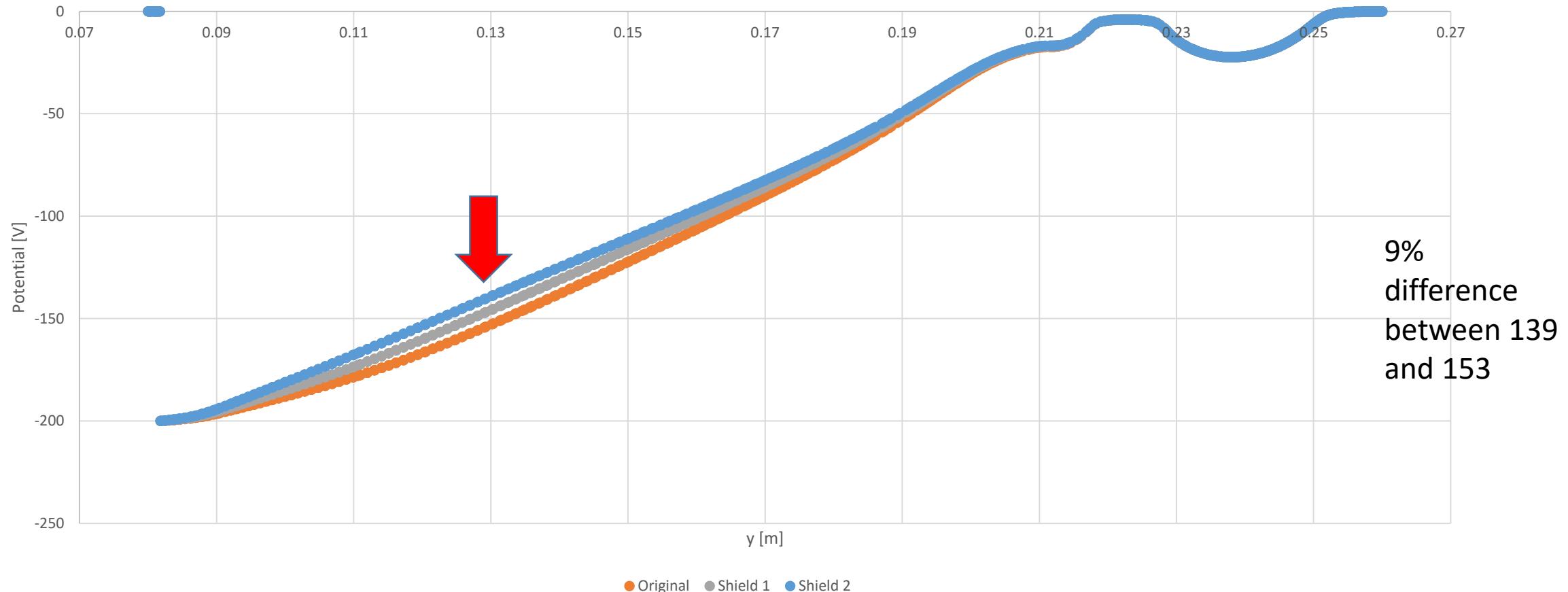
CST results: Potential – Original vs all shields (1,2,3 & 4) at insulator interface

Different colors represent different shields.



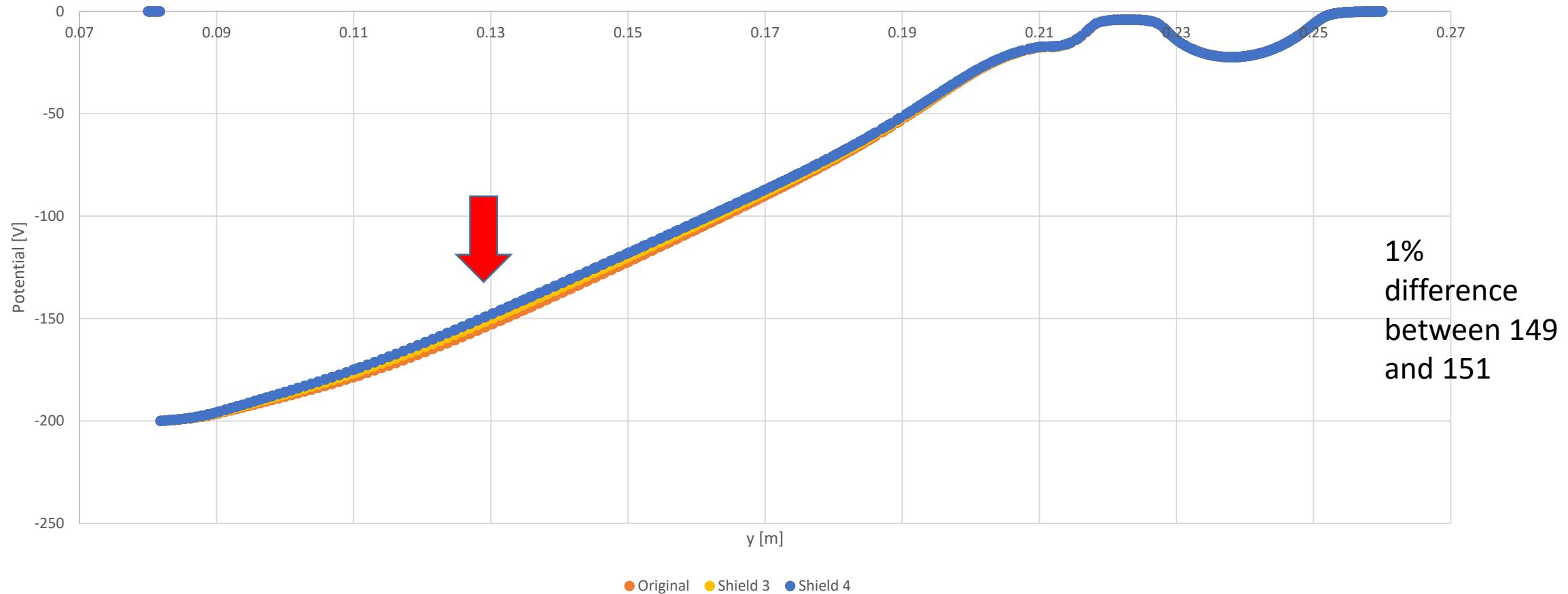
CST results: Potential – Original vs shields 1&2 at insulator interface

Different colors represent different shields.



CST results: Potential – Original vs shields 3&4 at insulator interface

Different colors represent different shields.

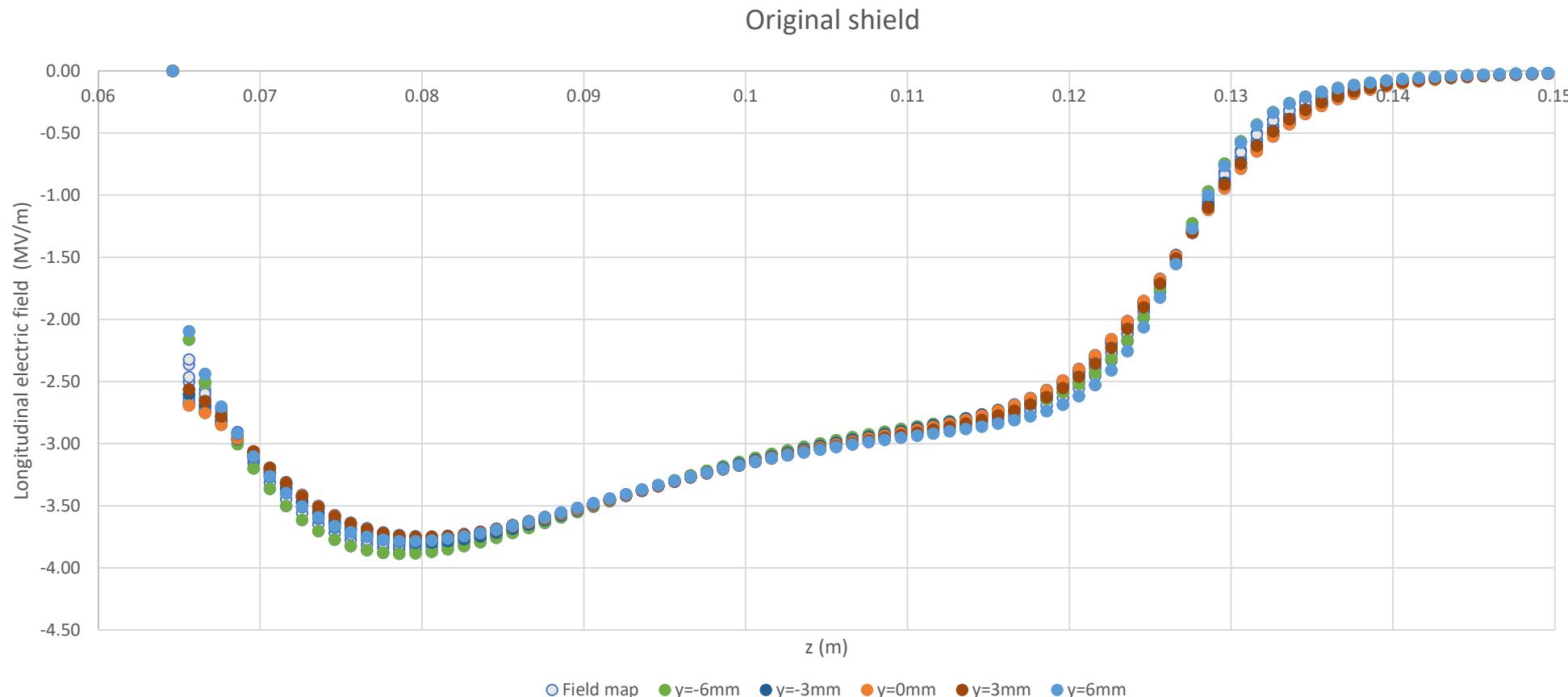


Original vs all Shields (1,2,3 & 4): Longitudinal electric field at c-a gap

- 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.

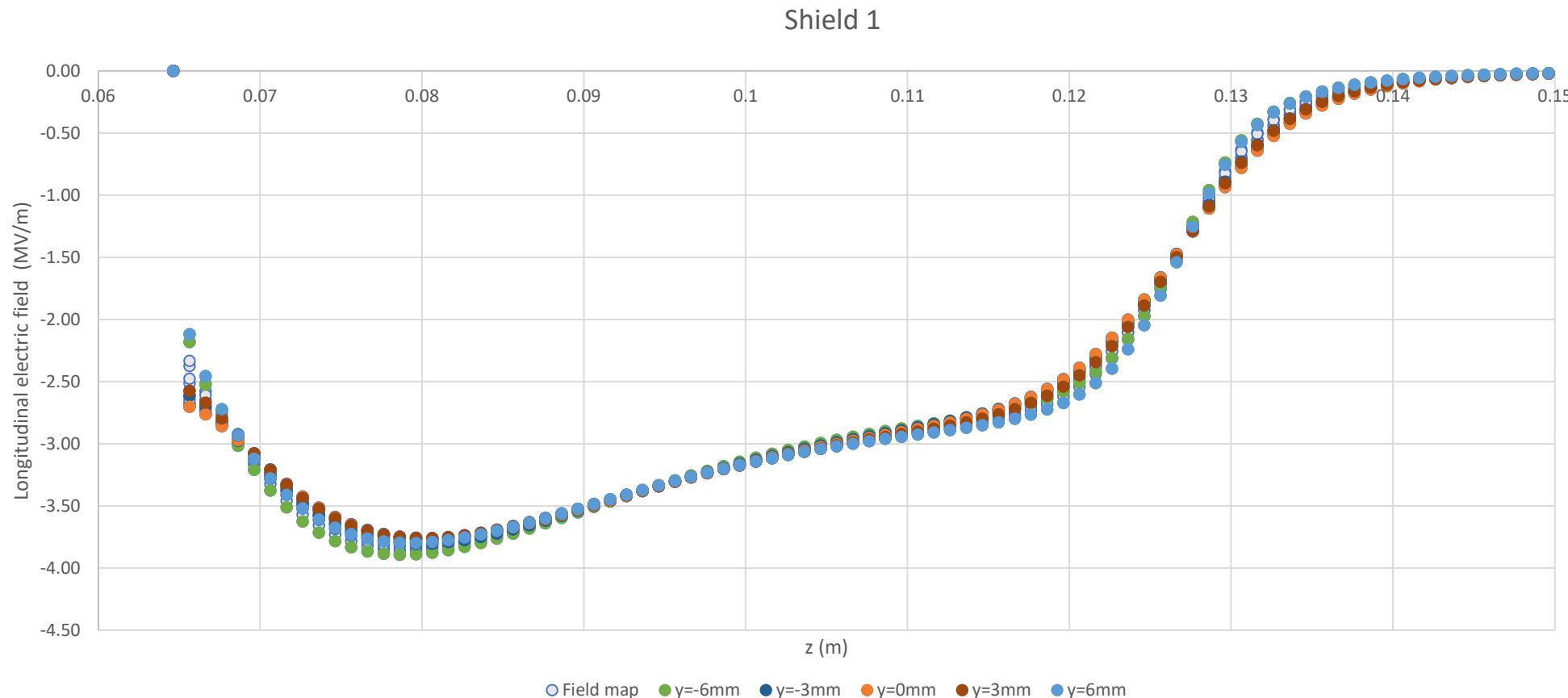
CST results: Longitudinal electric field – original shield

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 $-6\text{mm} < y < 6\text{mm}$



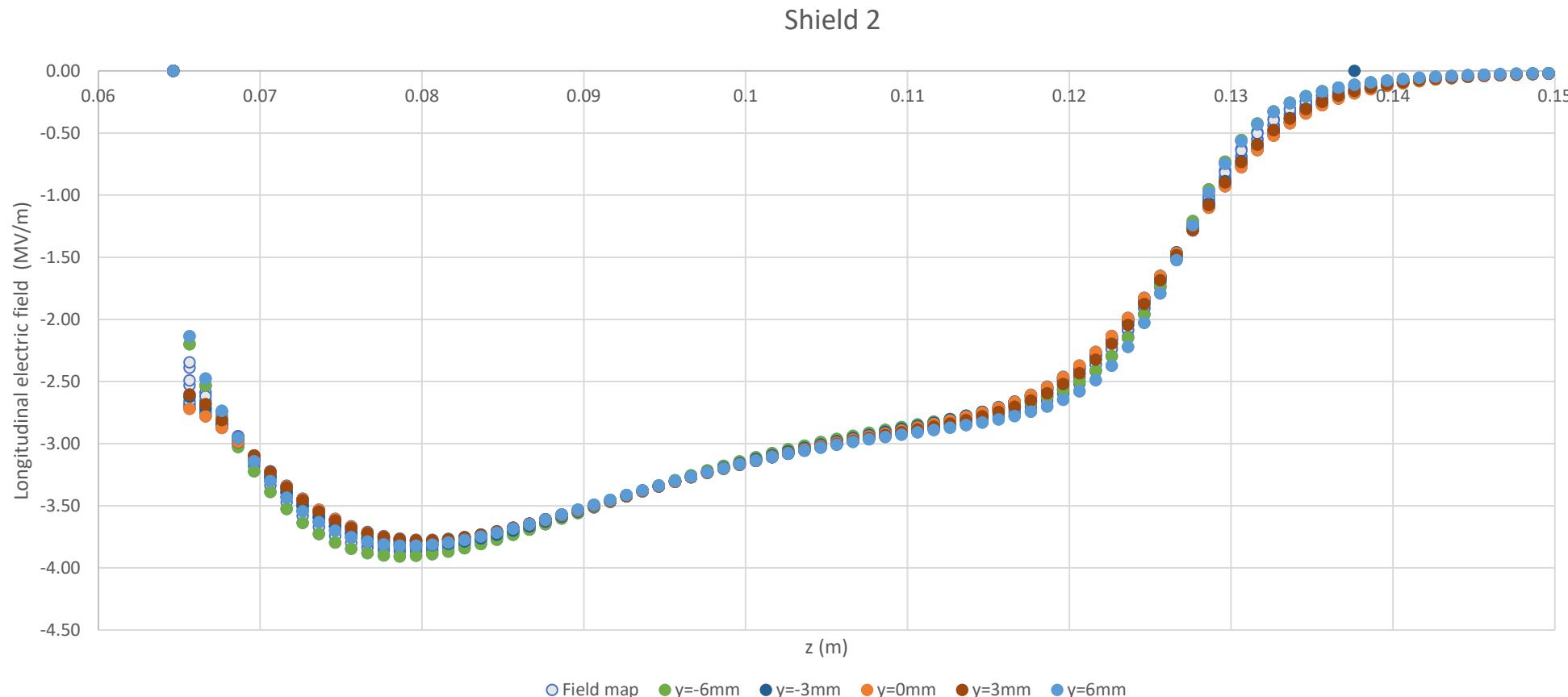
CST results: Longitudinal electric field – Shield 1

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 $-6\text{mm} < y < 6\text{mm}$



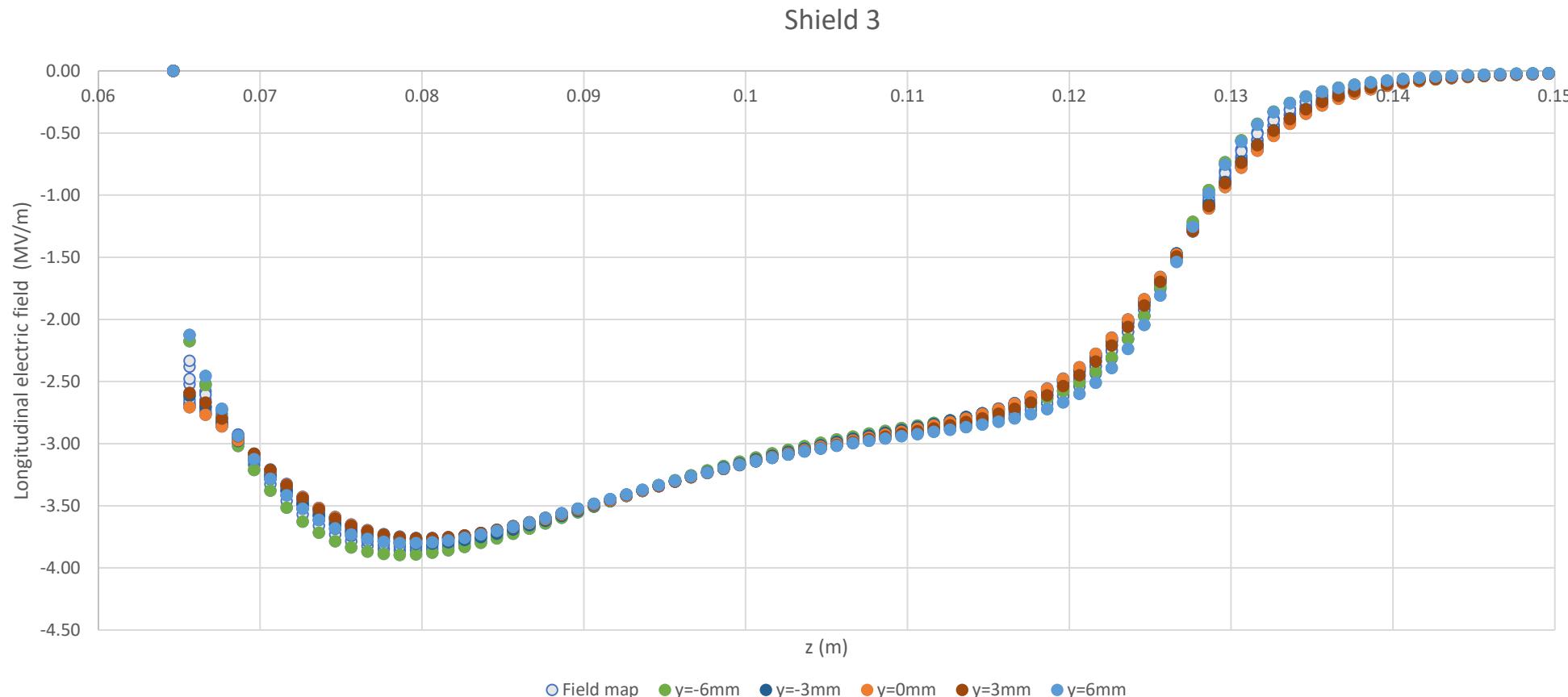
CST results: Longitudinal electric field – Shield 2

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 $-6\text{mm} < y < 6\text{mm}$



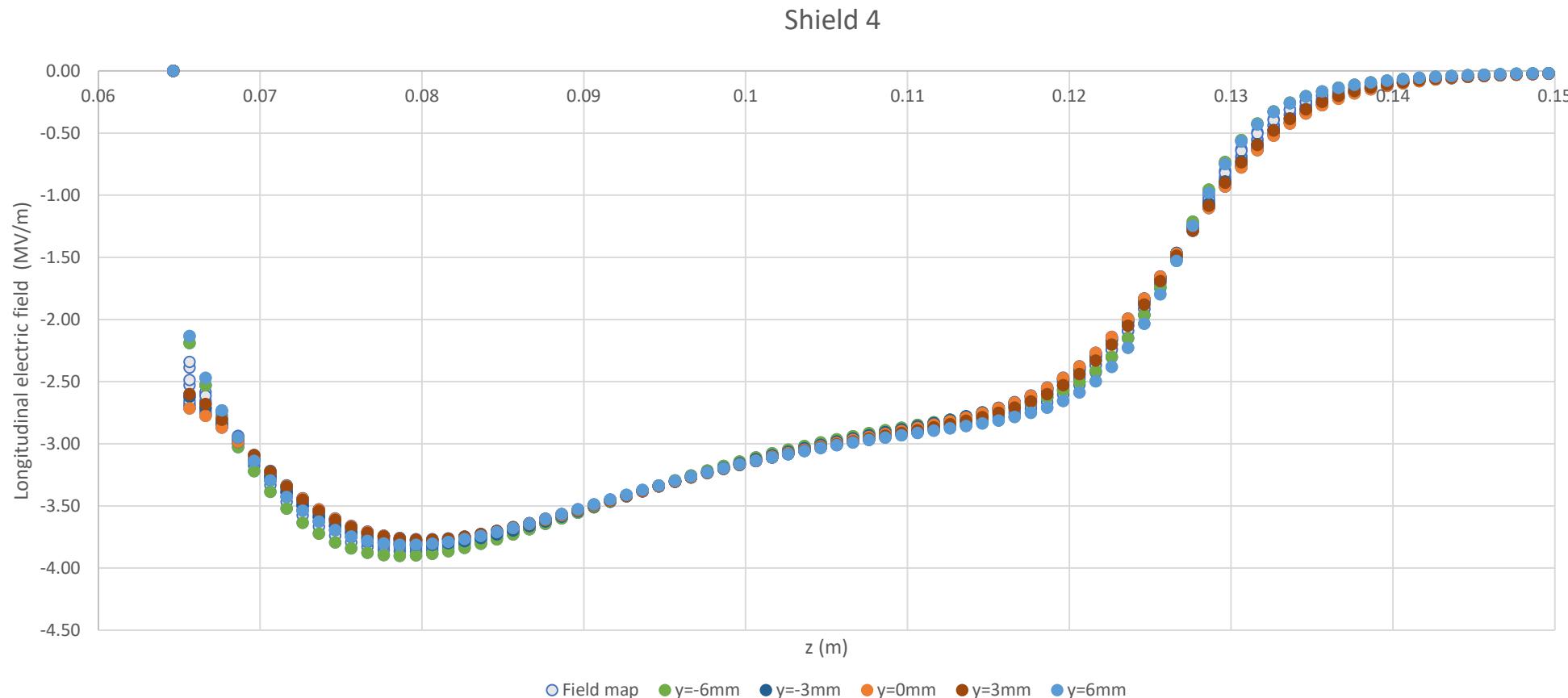
CST results: Longitudinal electric field – Shield 3

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 $-6\text{mm} < y < 6\text{mm}$



CST results: Longitudinal electric field – Shield 4

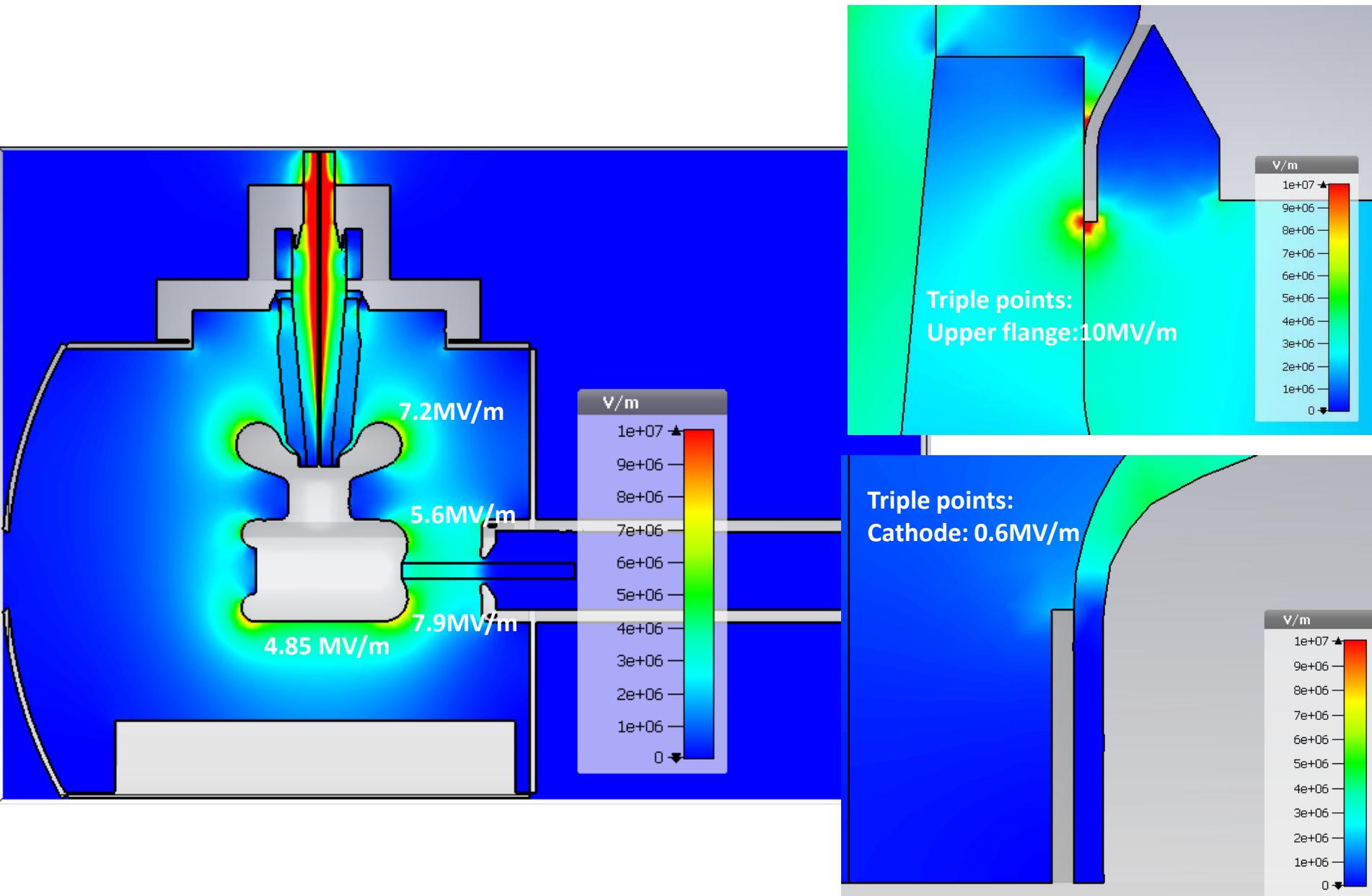
The gray data set is the whole field map. The different colors show how the longitudinal electric field changes as a function of height on the photocathode in the interval $-6\text{mm} < y < 6\text{mm}$



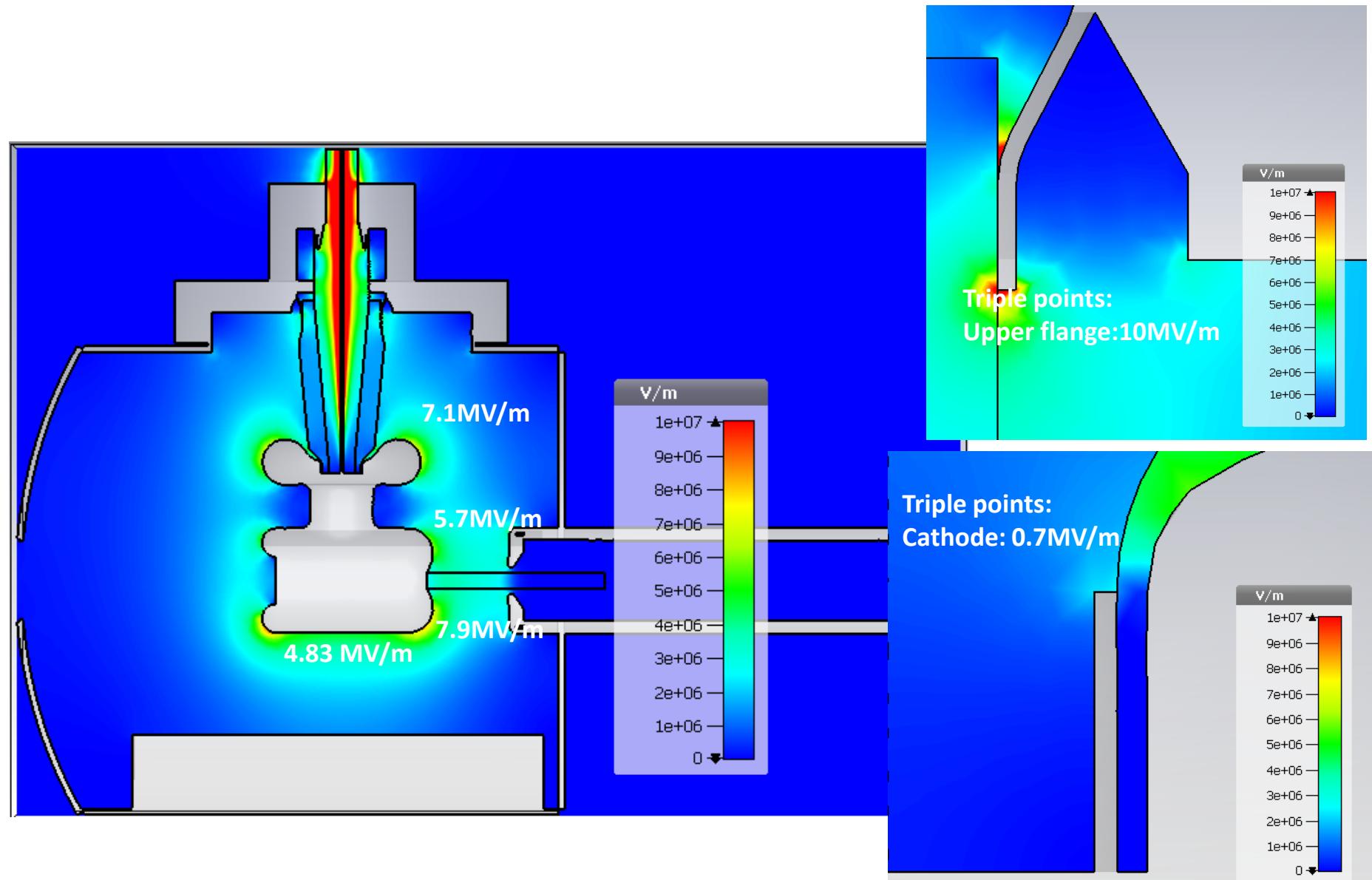
False color

Electric field norm: Original vs shields 1&2

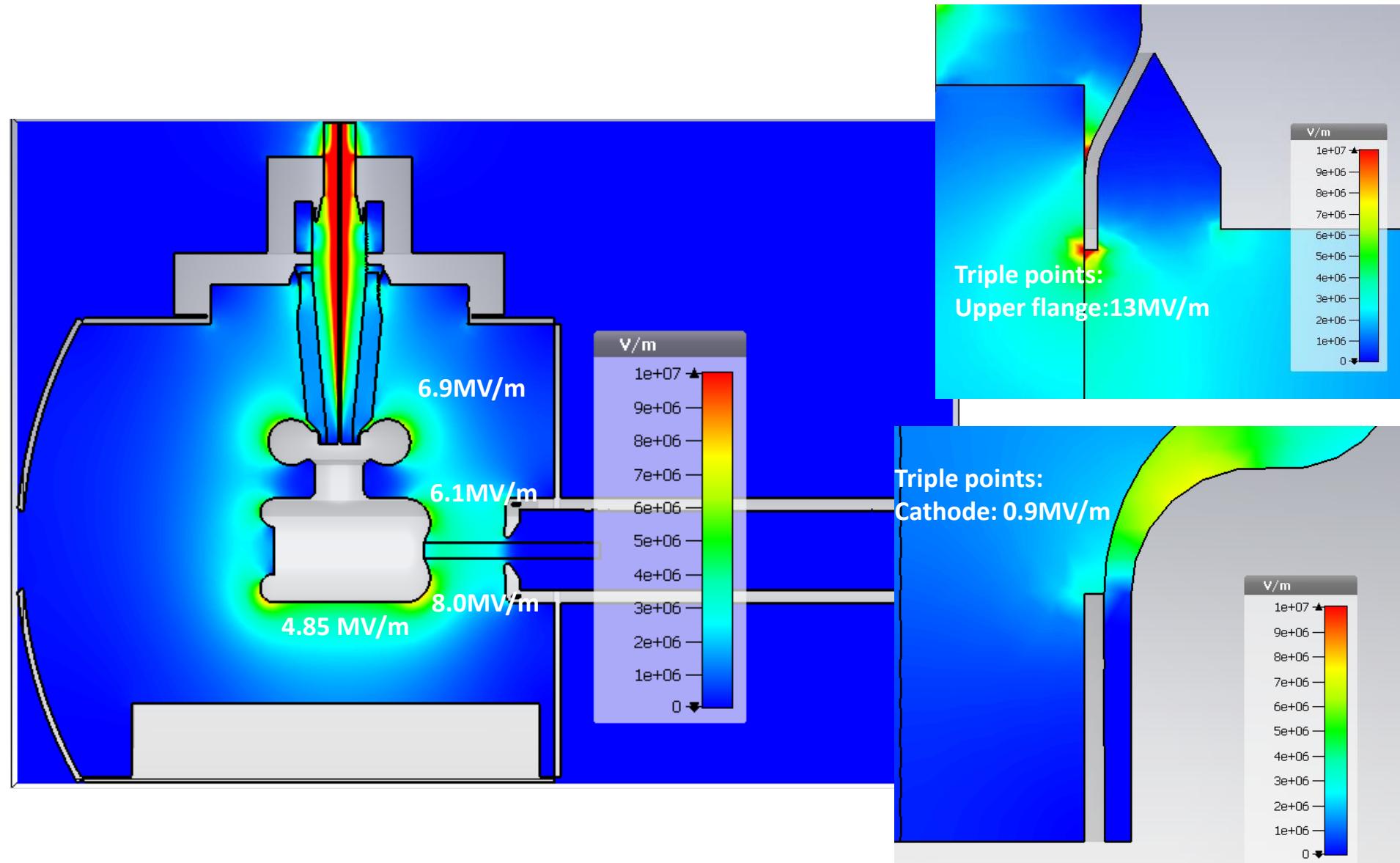
CST results: Electric field norm– original shield



CST results: Electric field norm– Shield 1

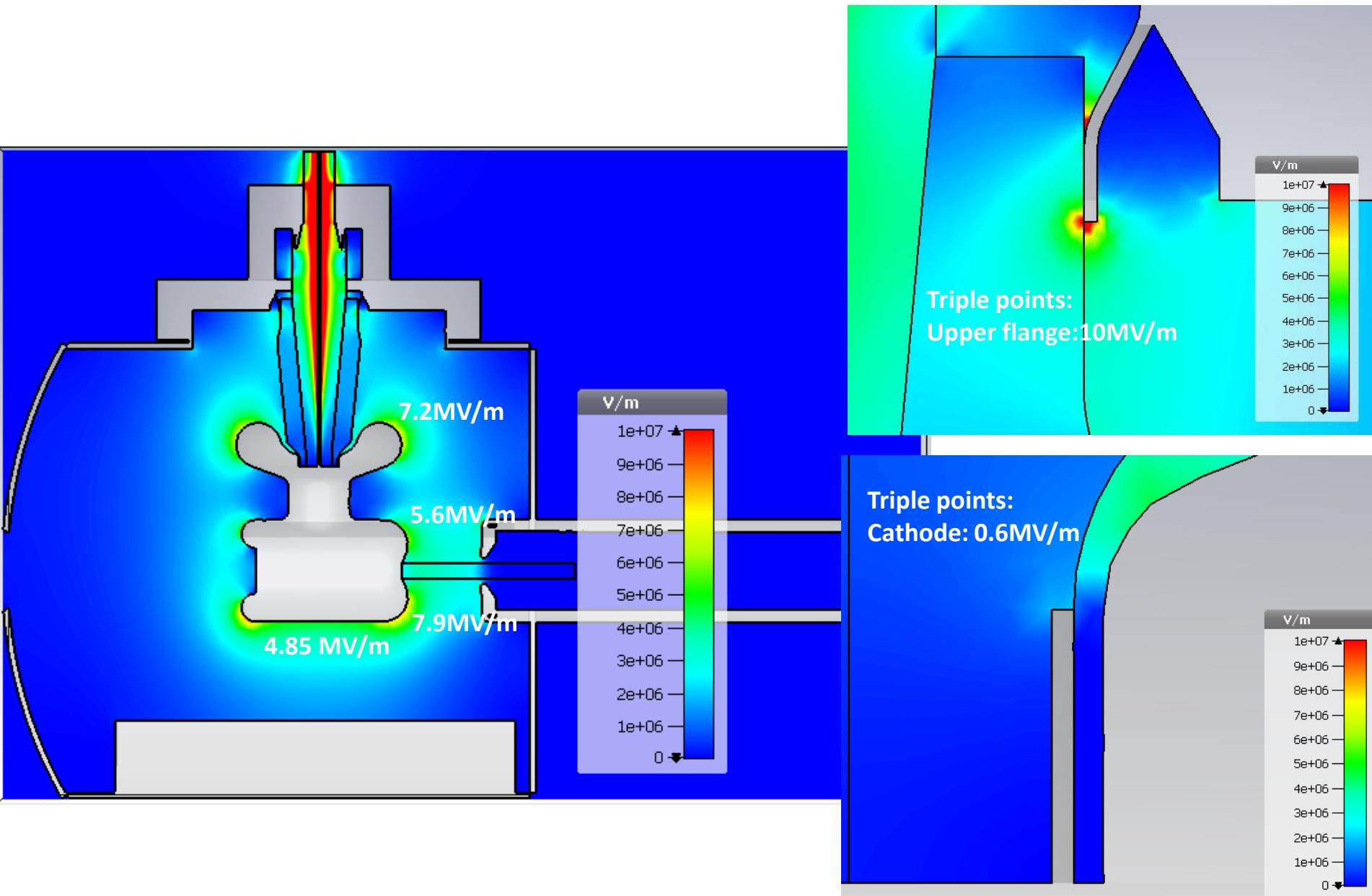


CST results: Electric field norm– Shield 2

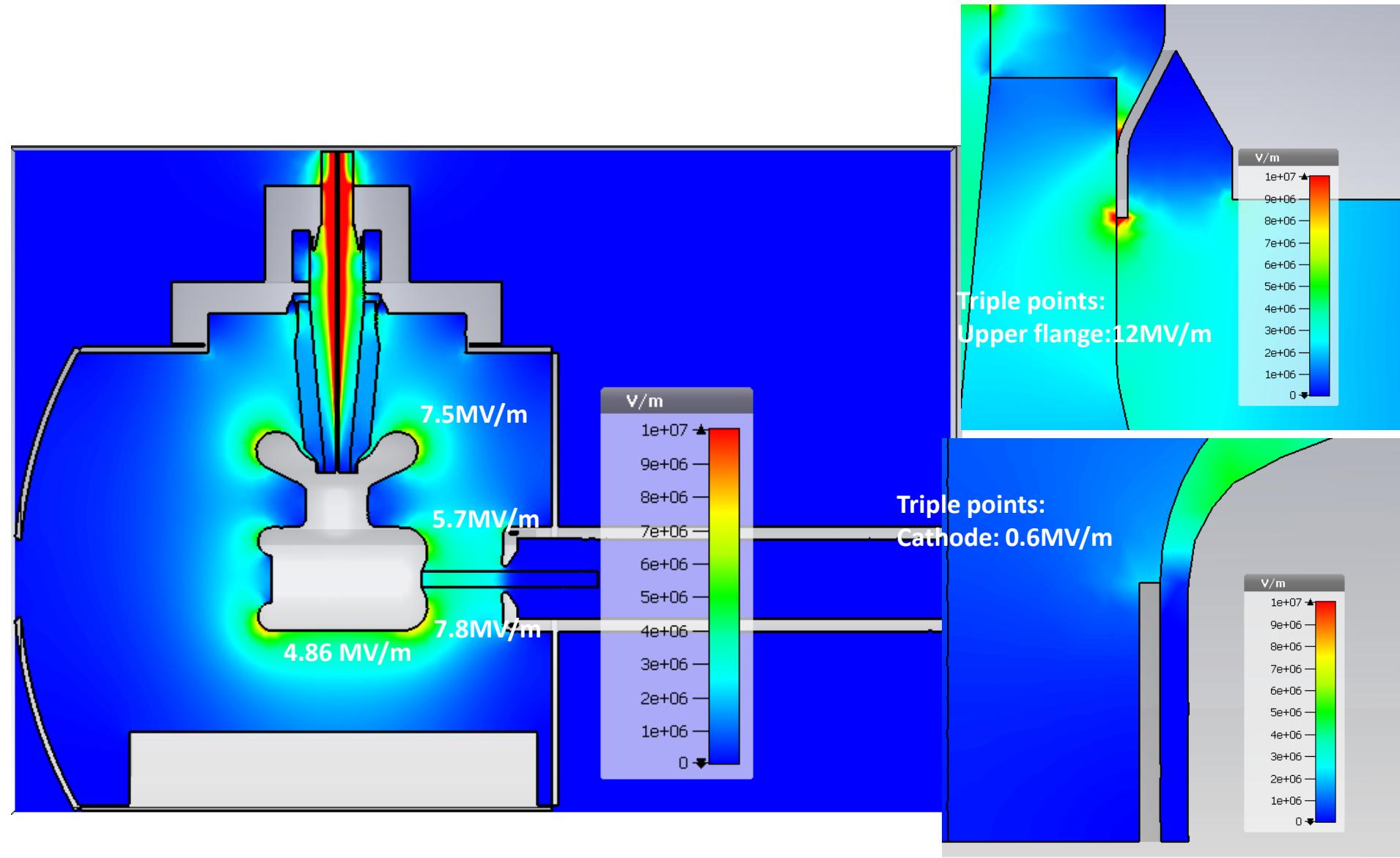


Electric field norm: Original vs shields 3&4

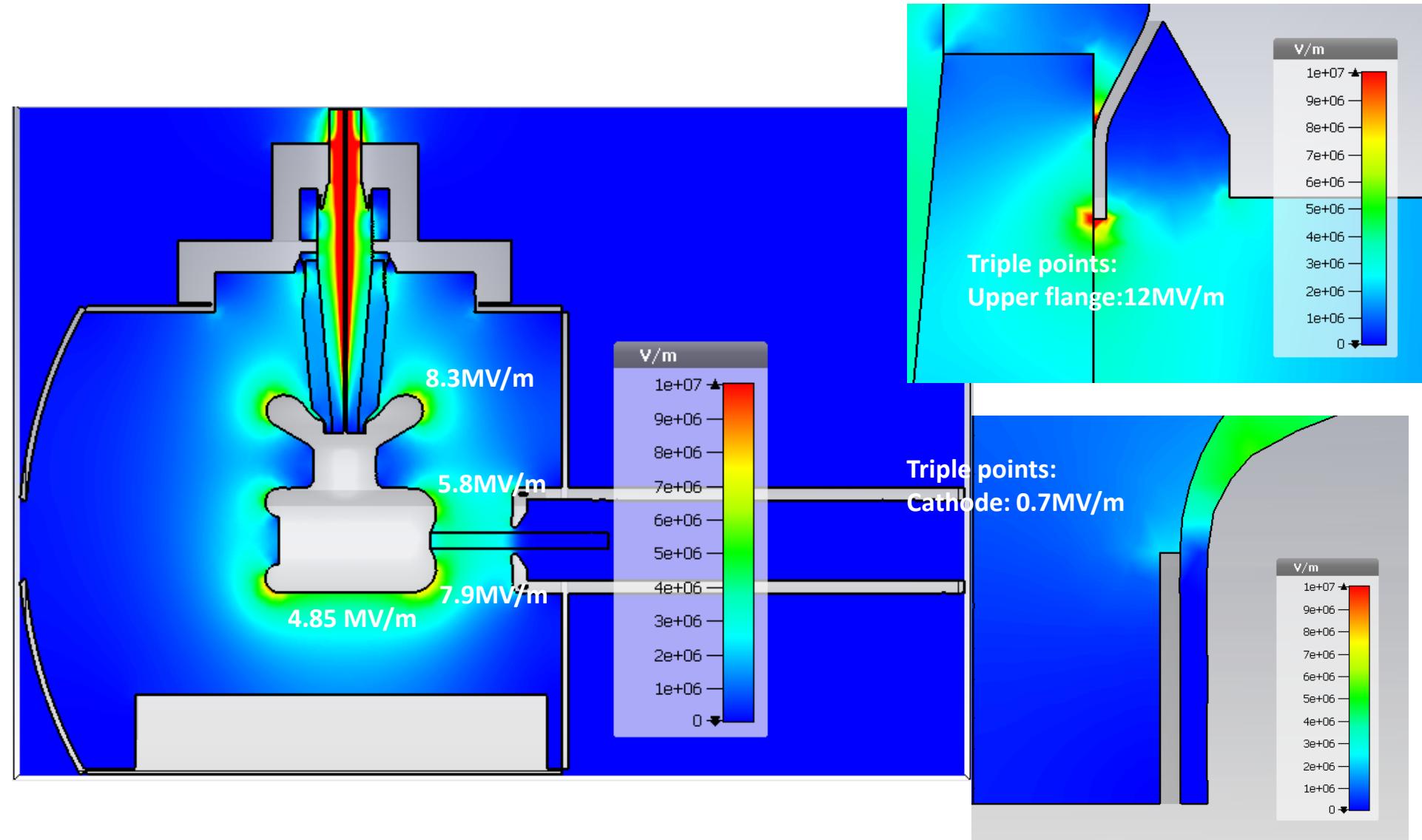
CST results: Electric field norm– original shield



CST results: Electric field norm– Shield 3



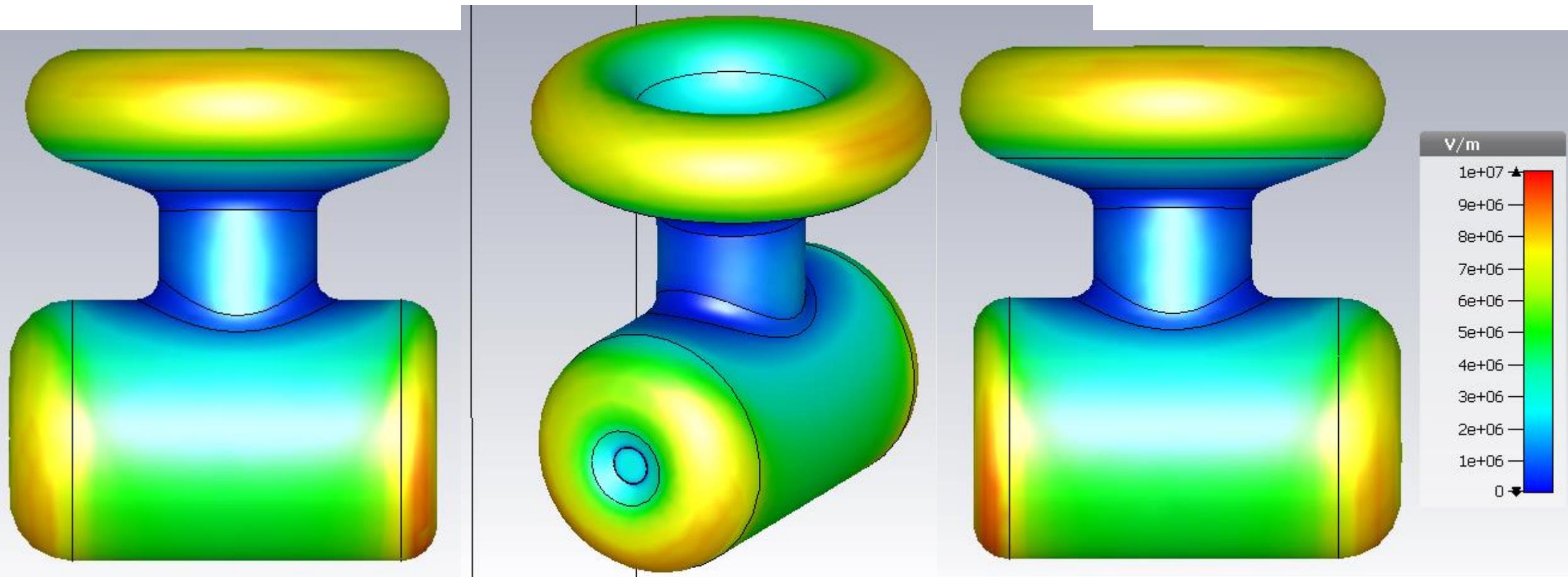
CST results: Electric field norm– Shield 4



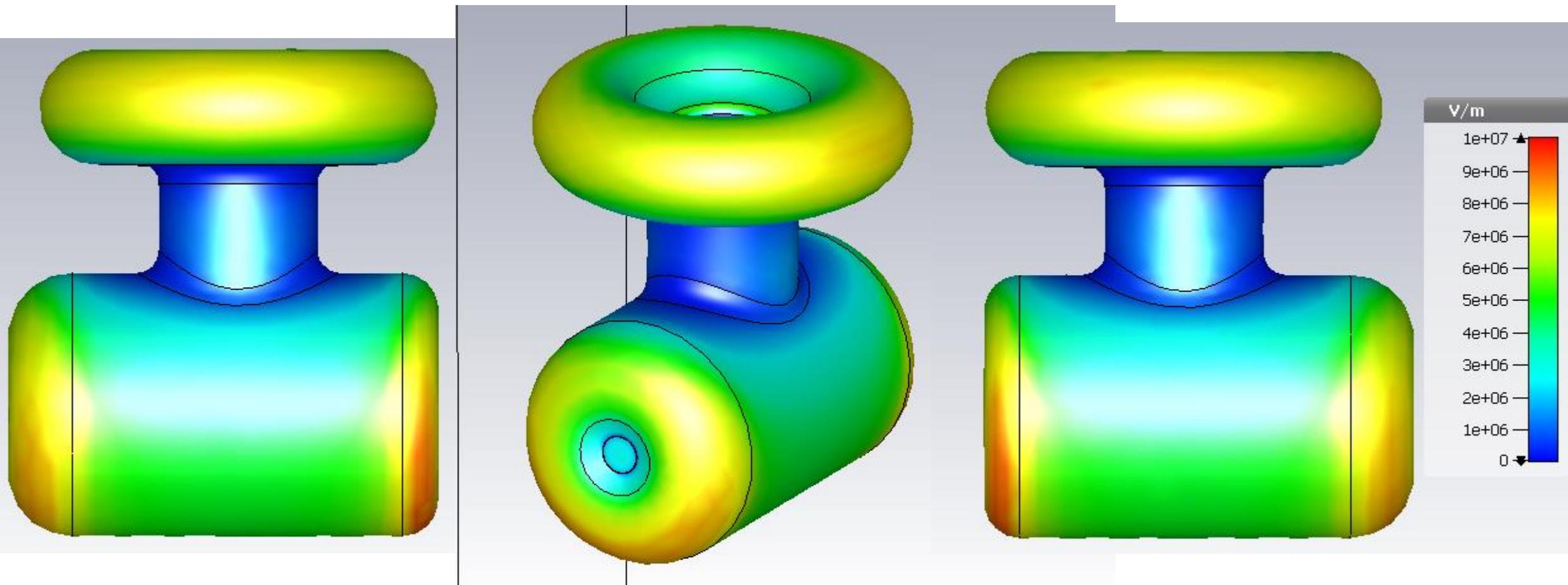
Electric field norm: Original vs shields 1 vs shields 2

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

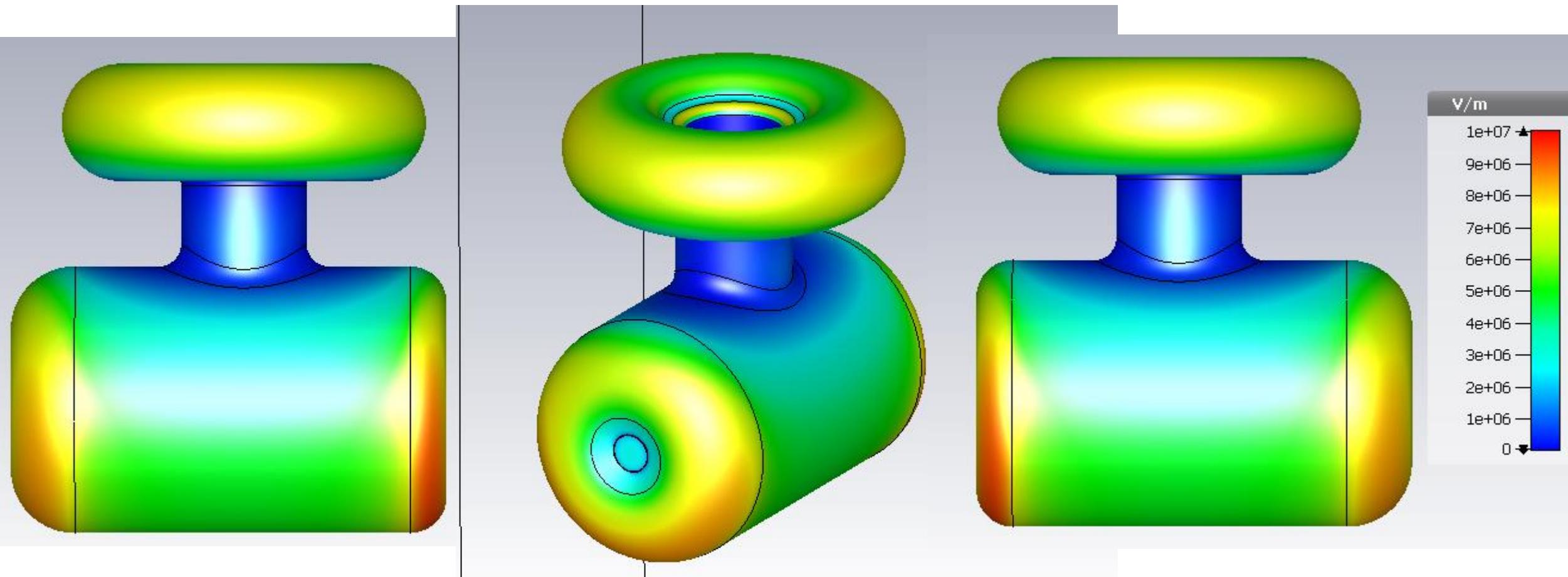
CST results: Electric field norm– Original



CST results: Electric field norm– Shield 1



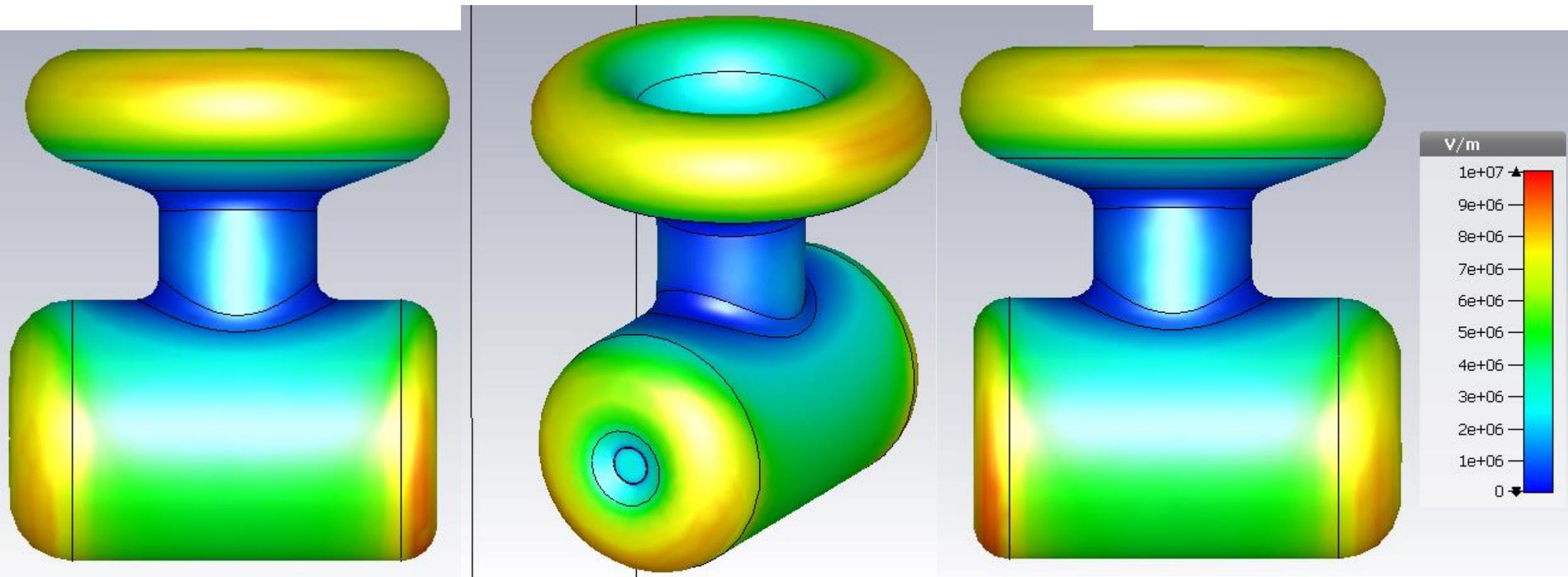
CST results: Electric field norm– Shield 2



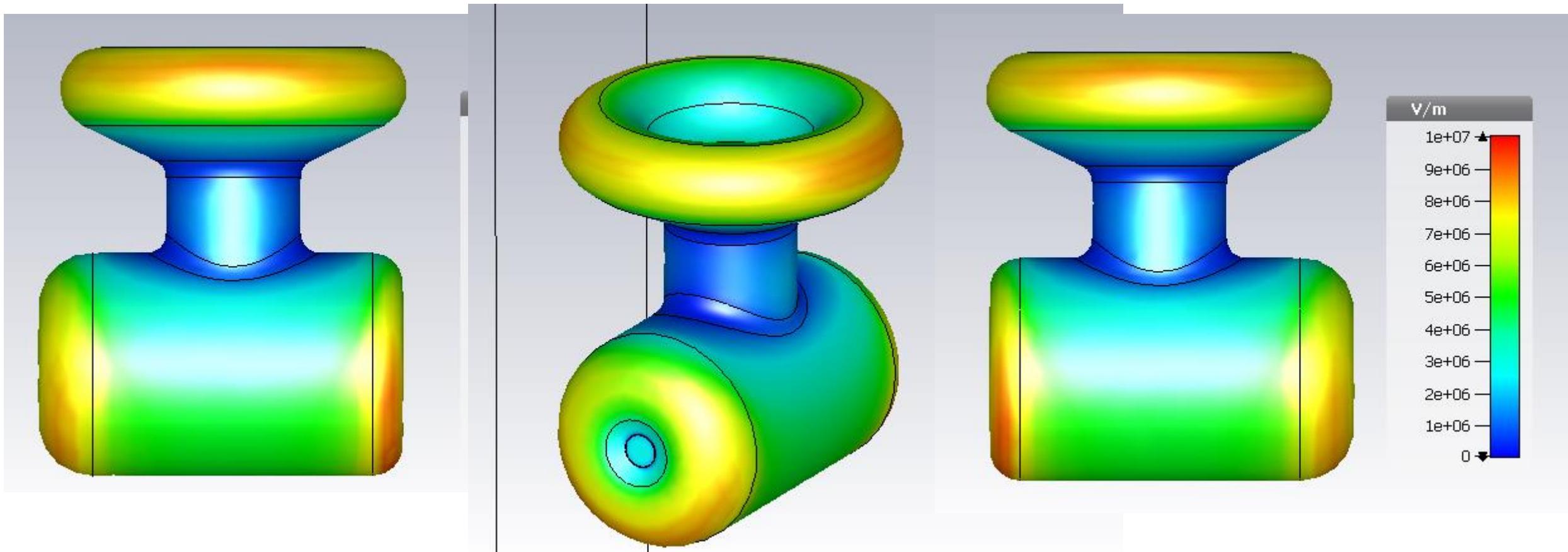
Electric field norm: Original vs shields 1 vs shields 2

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

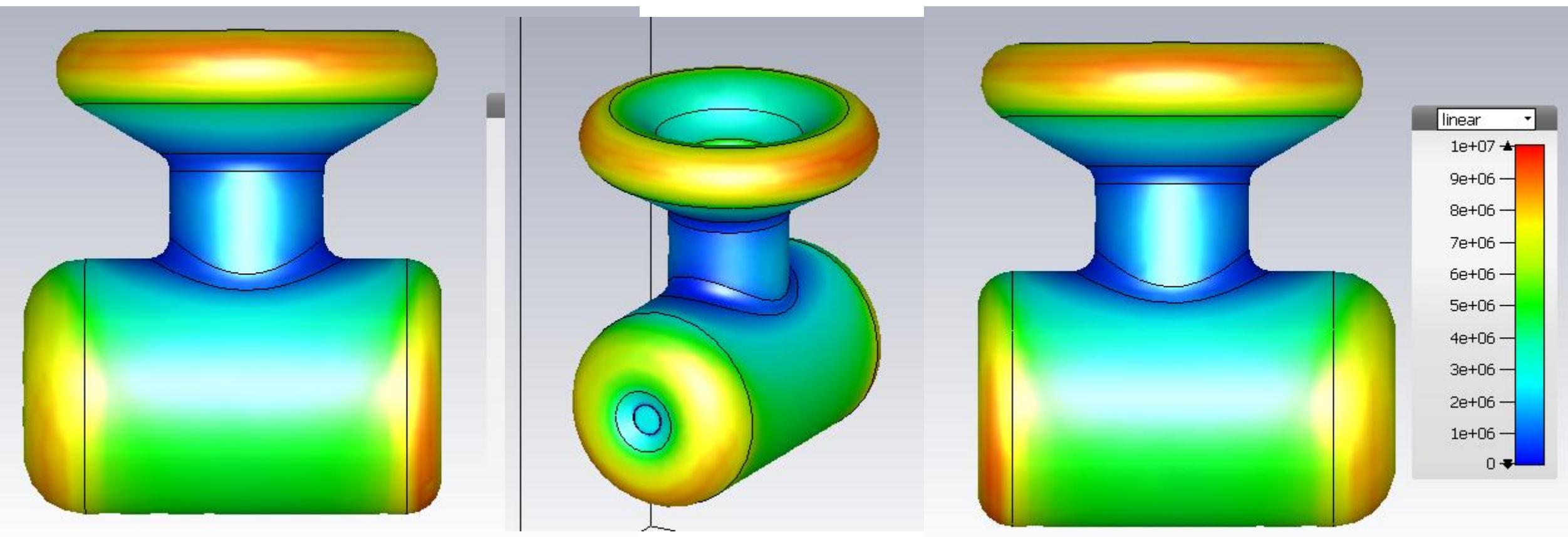
CST results: Electric field norm– Original



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 $\sim 1\text{MV/m}$.
 - Original vs shield 3 & 4
 - The radius change increases the field at its cusp to $\sim 8 \text{ MV/m}$ with some impact on the Pierce geometry.
 - All
 - Upper flange triple point appears and remains at $\sim 12 \text{ MV/m}$

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.

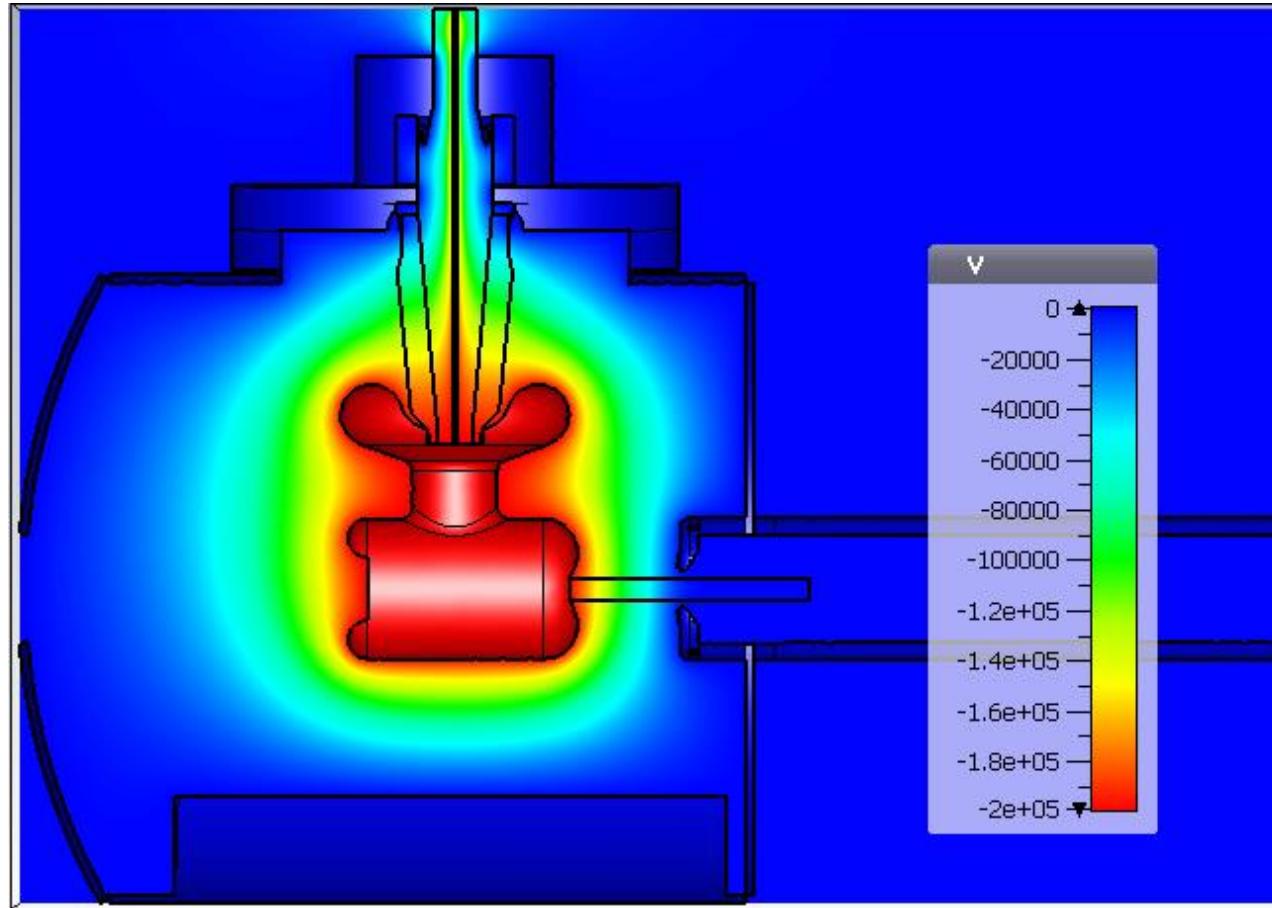
Fin.

Additional slides

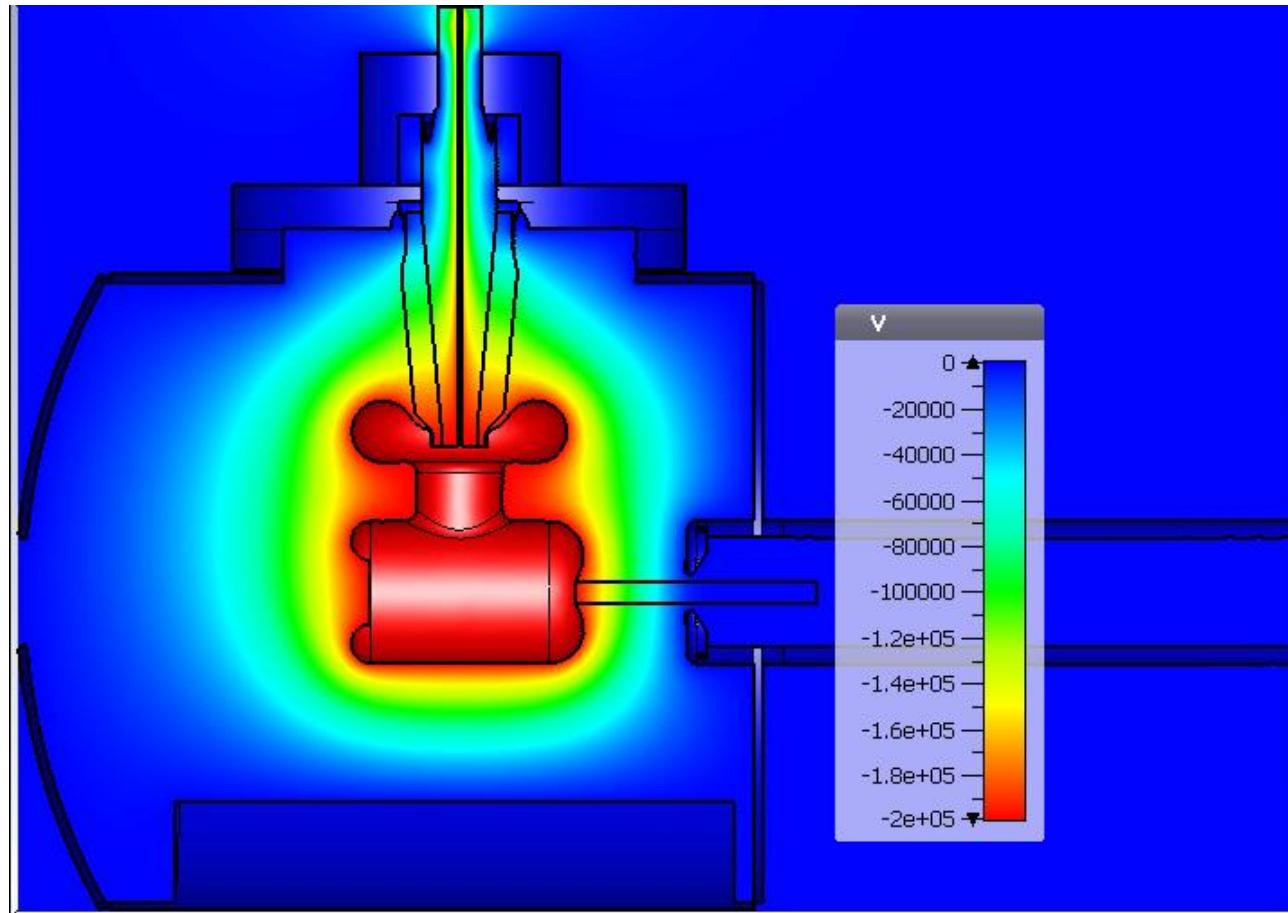
- Potentials false color
- Transverse field false color
- Longitudinal field false color

Potential: Original vs Shield 1 vs Shield 2

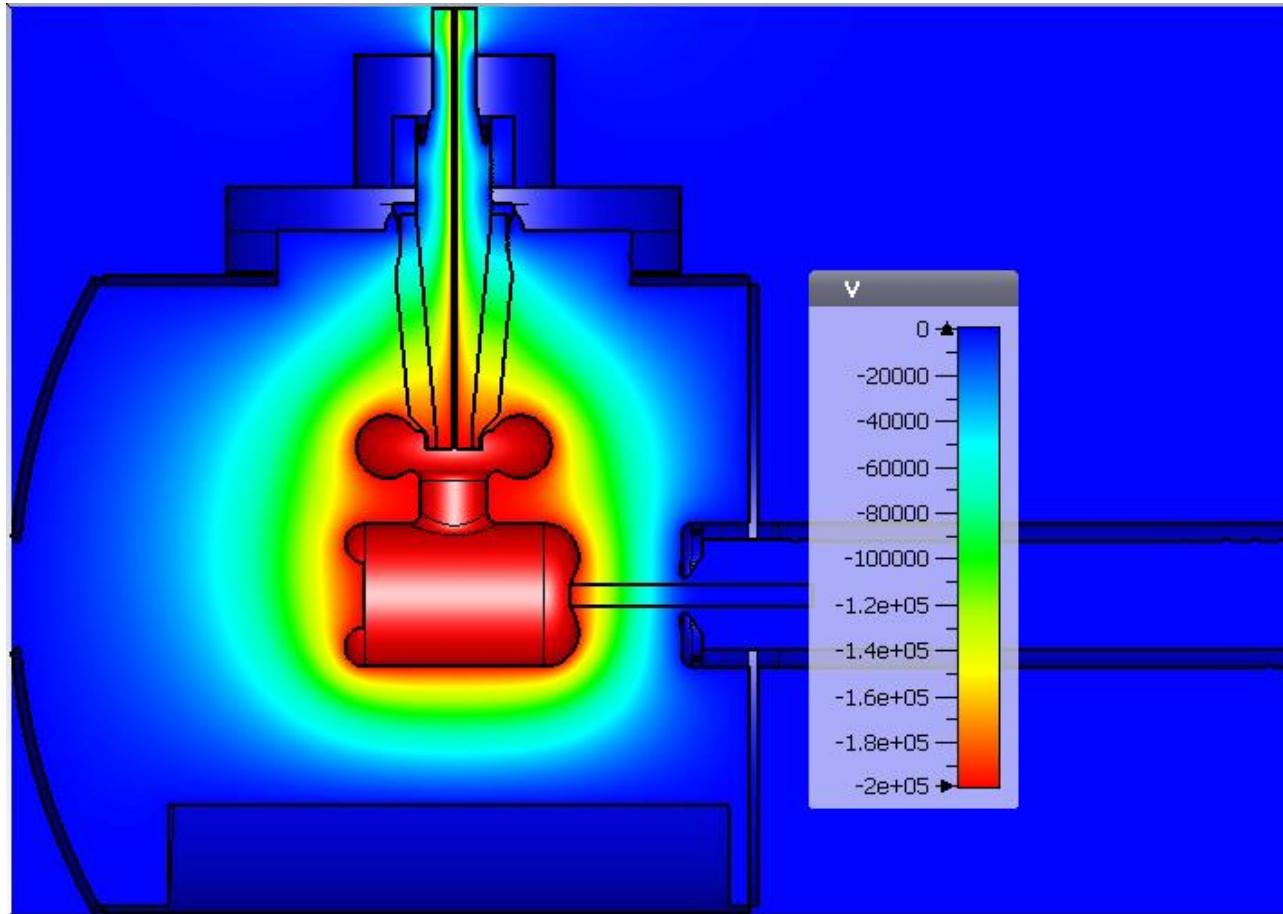
CST results: Potential – original shield



CST results: Potential – Shield 1

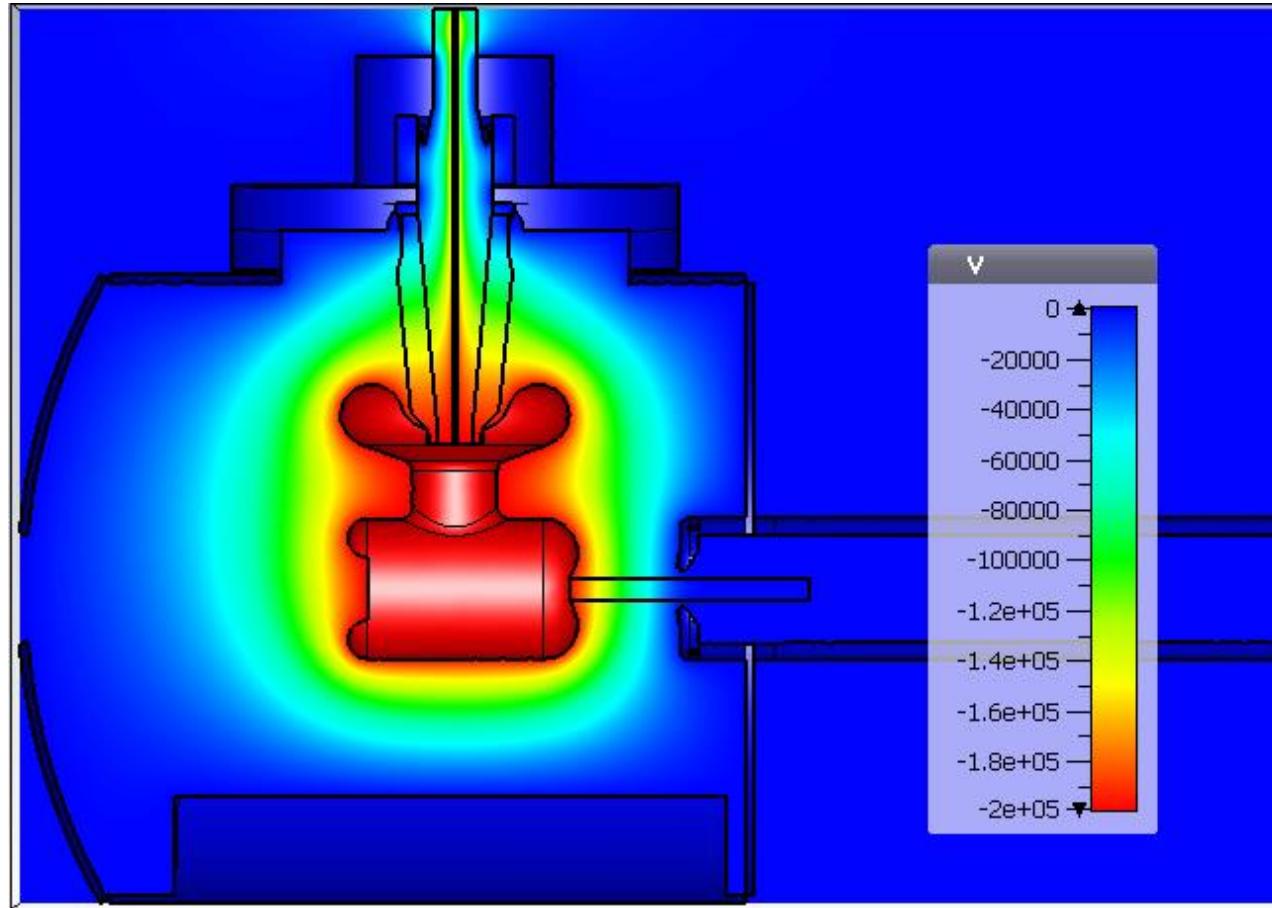


CST results: Potential – Shield 2

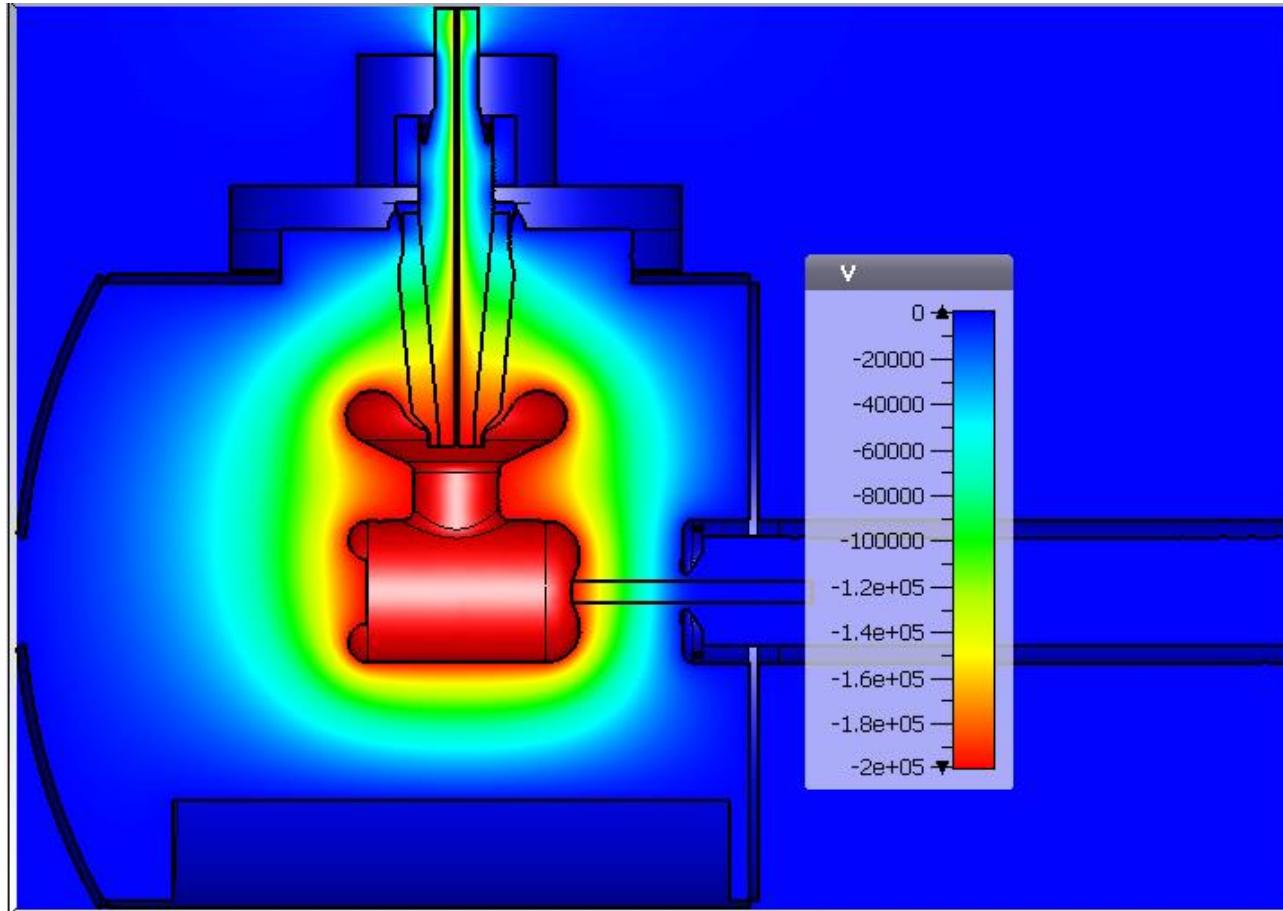


Potential: Original vs Shield 3 vs Shield 4

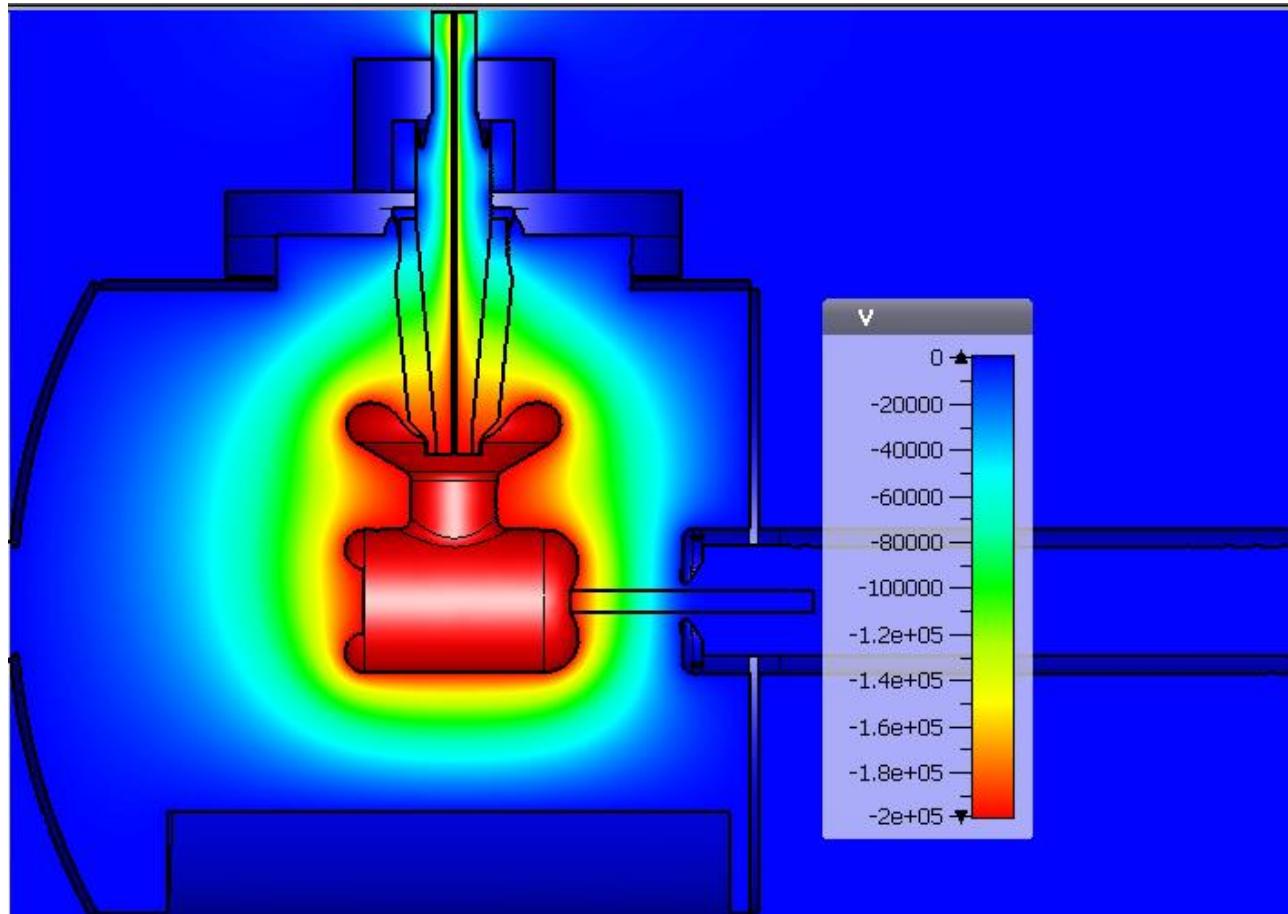
CST results: Potential – original shield



CST results: Potential – Shield 3

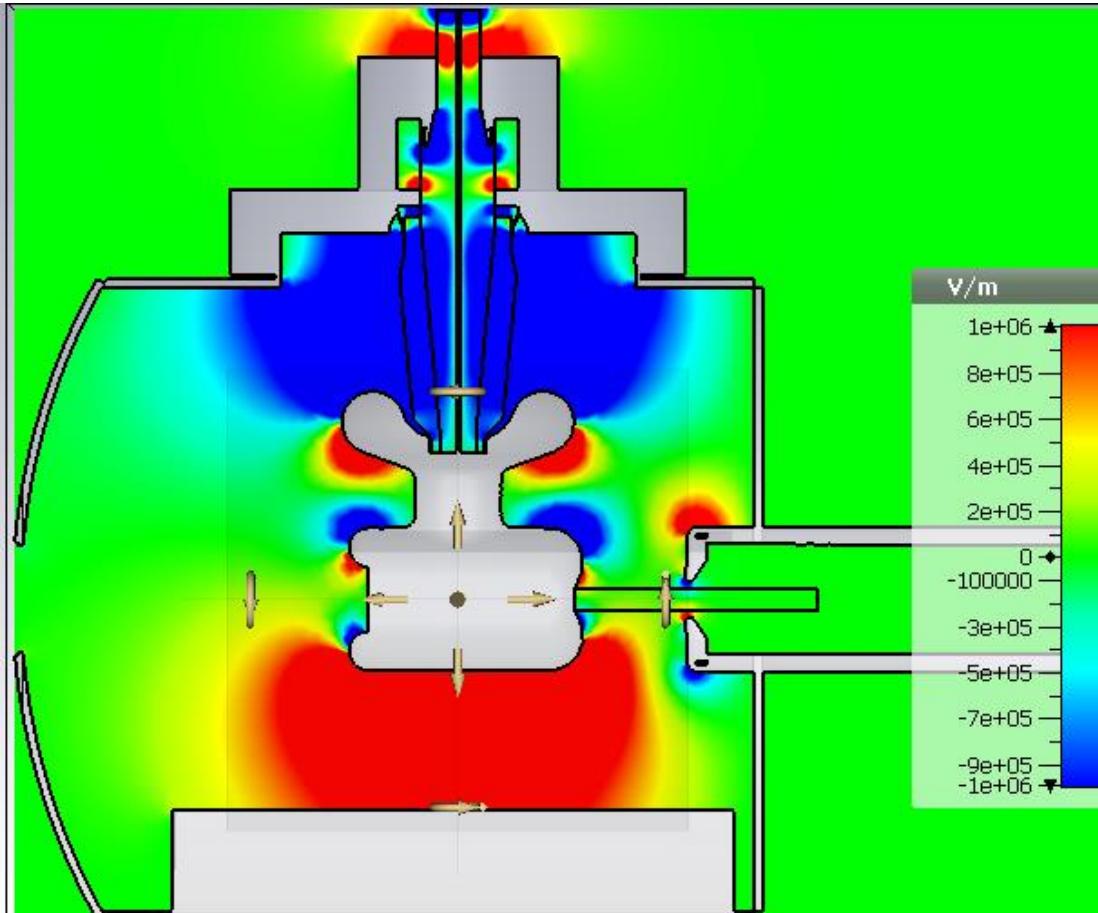


CST results: Potential – Shield 4

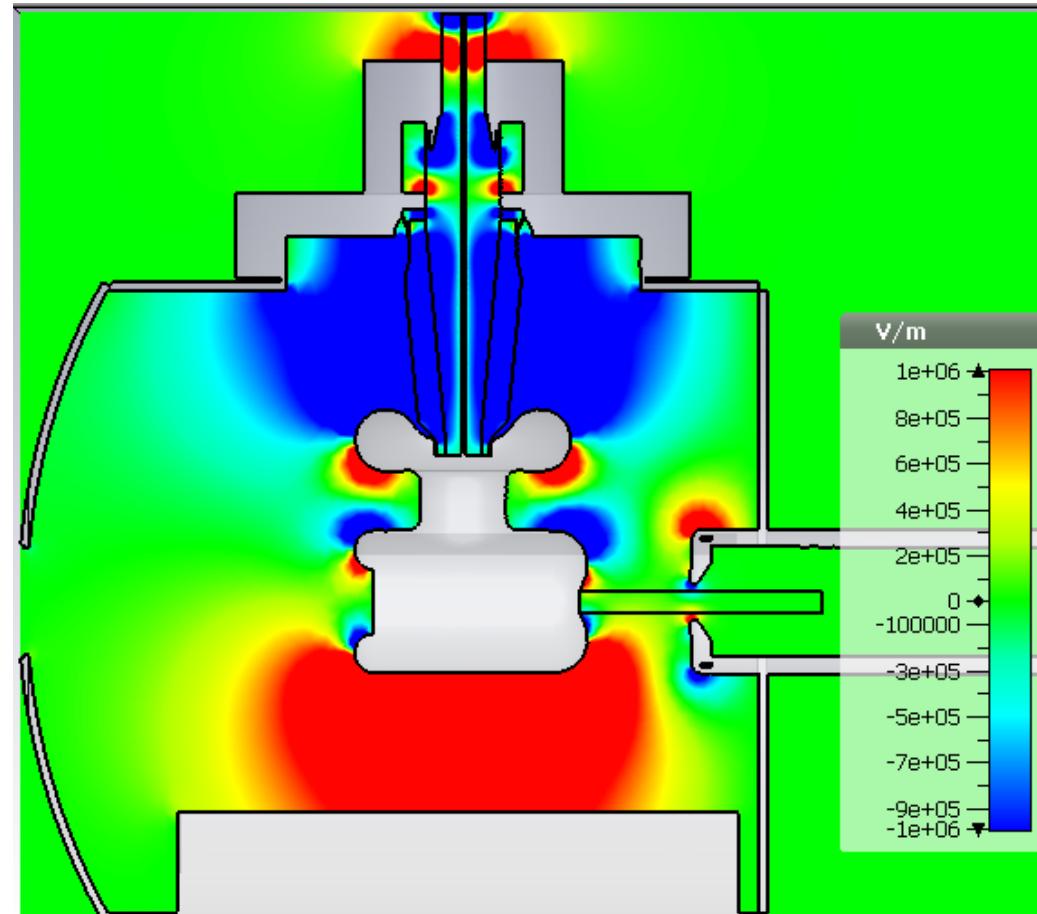


Transverse electric field: Original vs Shield 1
vs Shield 2

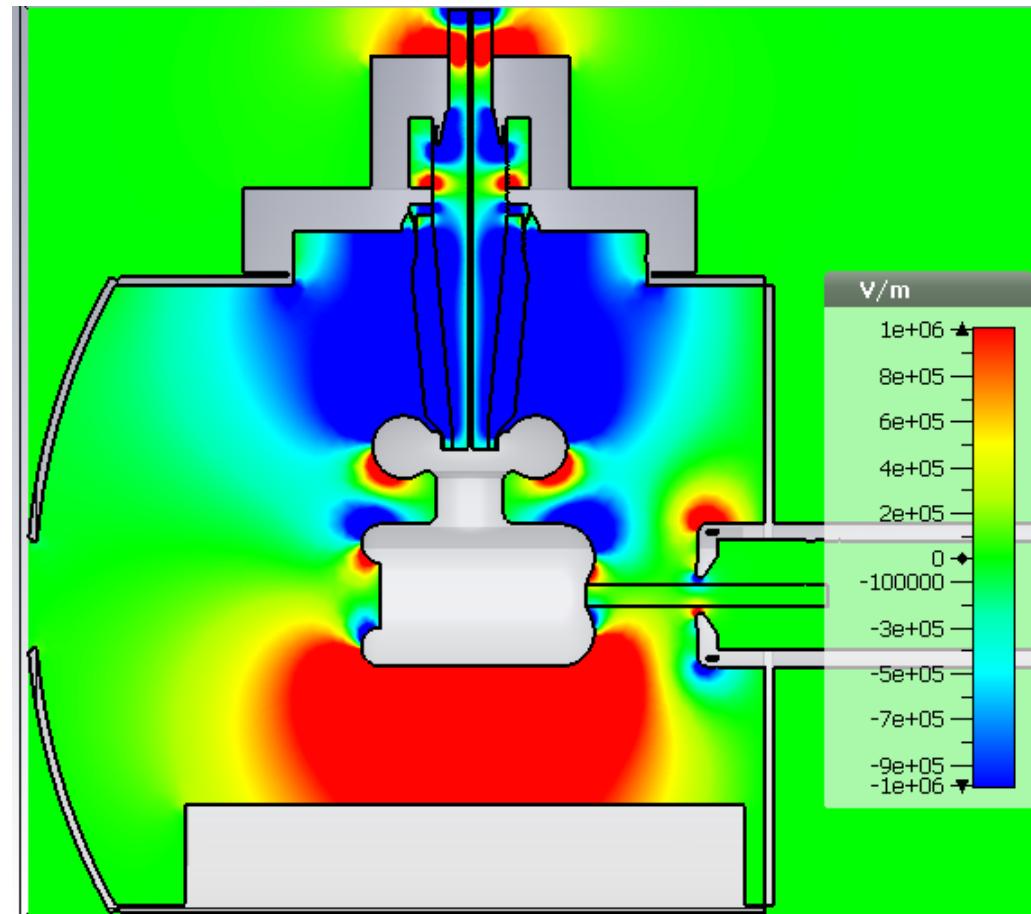
CST results: Transverse electric field – original shield



CST results: Transverse electric field – Shield 1

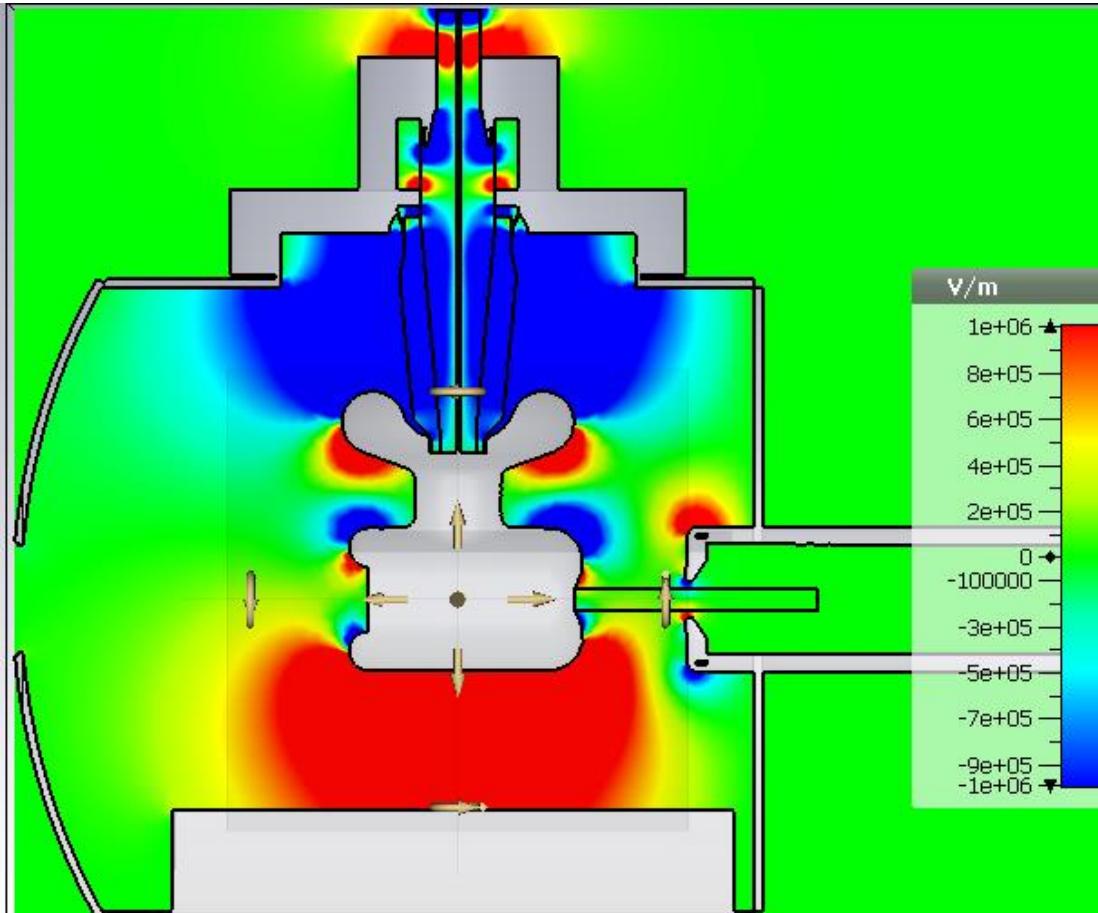


CST results: Transverse electric field – Shield 2

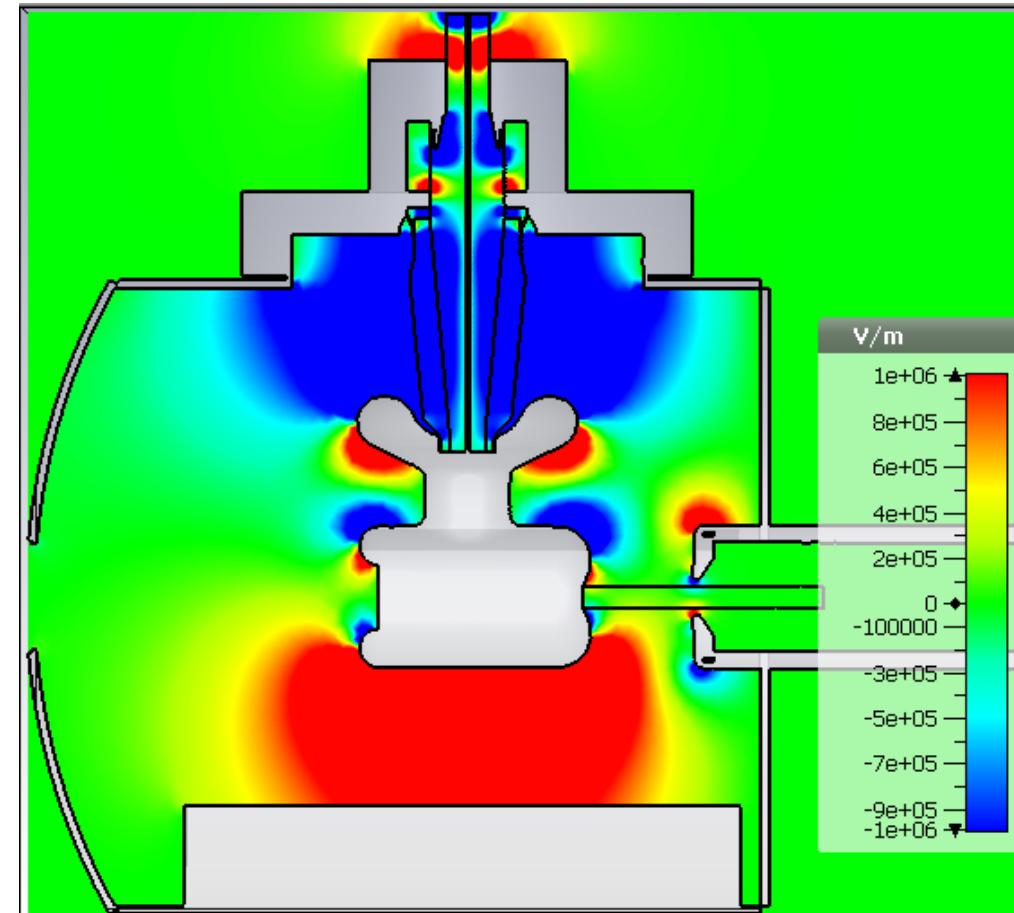


Transverse electric field: Original vs Shield 3
vs Shield 4

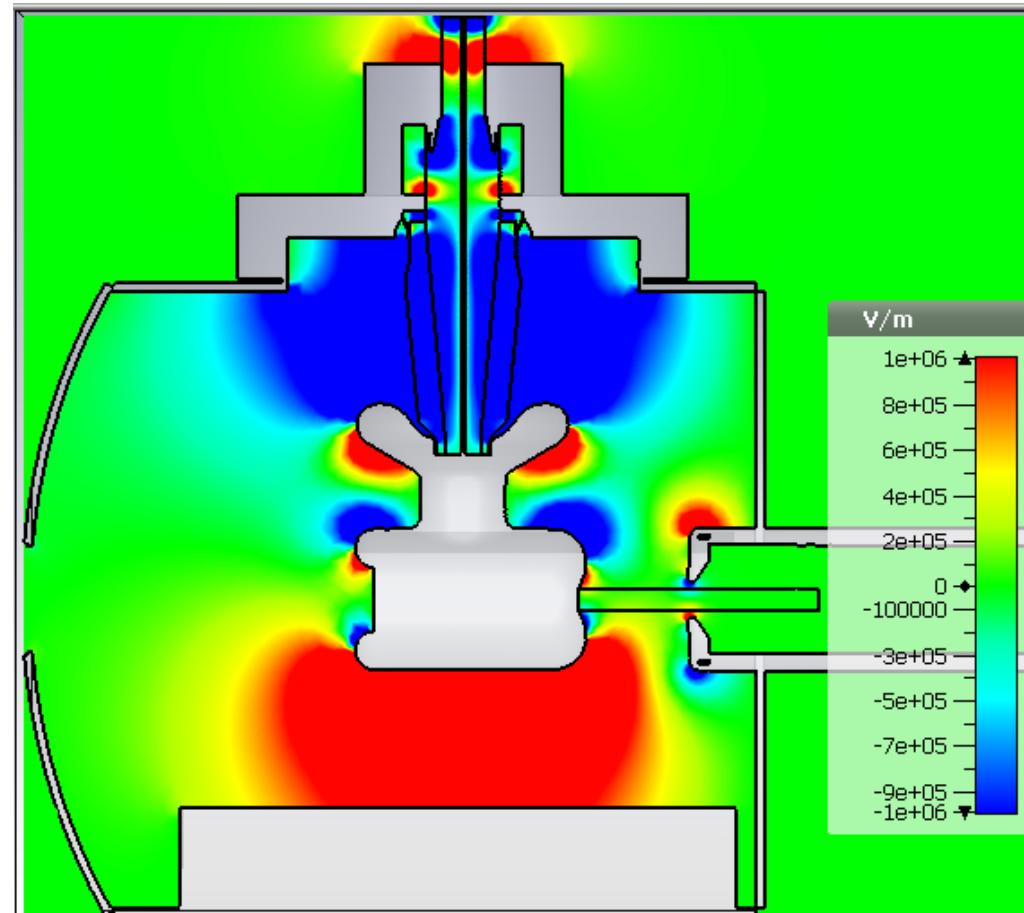
CST results: Transverse electric field – original shield



CST results: Transverse electric field – Shield 3

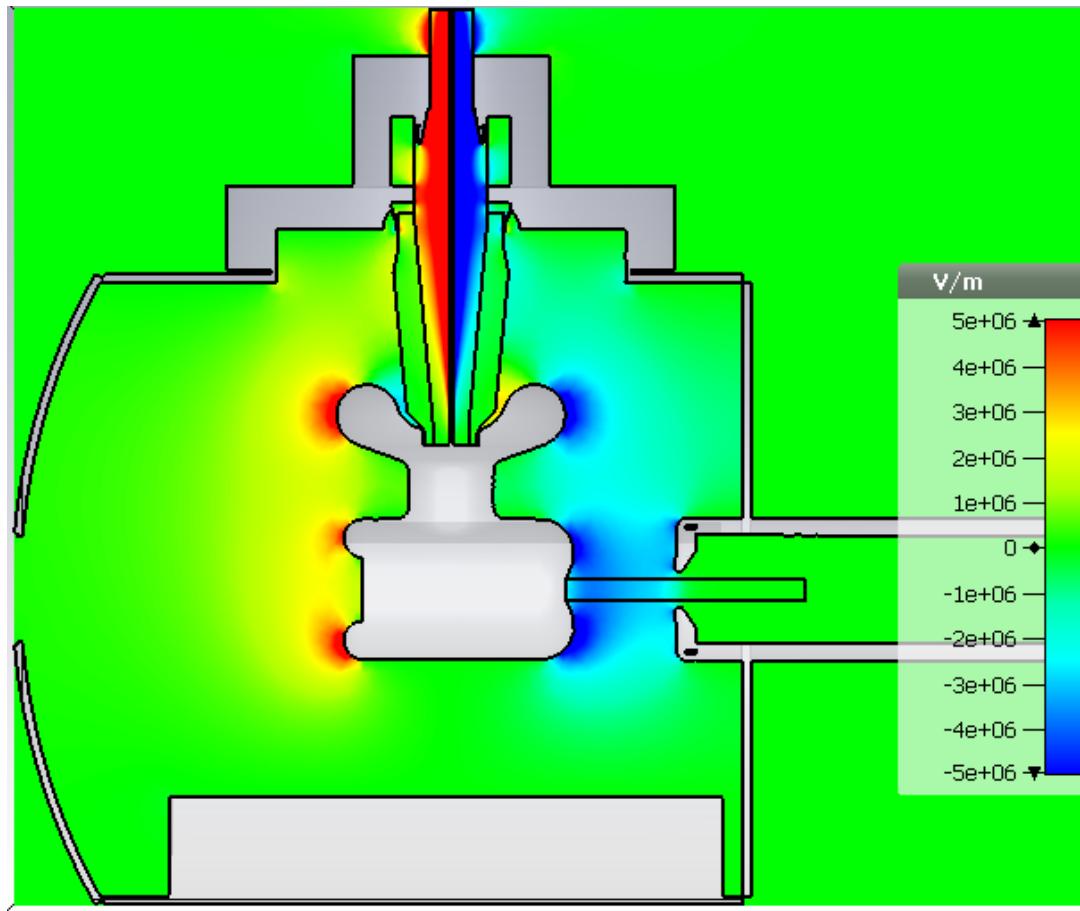


CST results: Transverse electric field – Shield 4

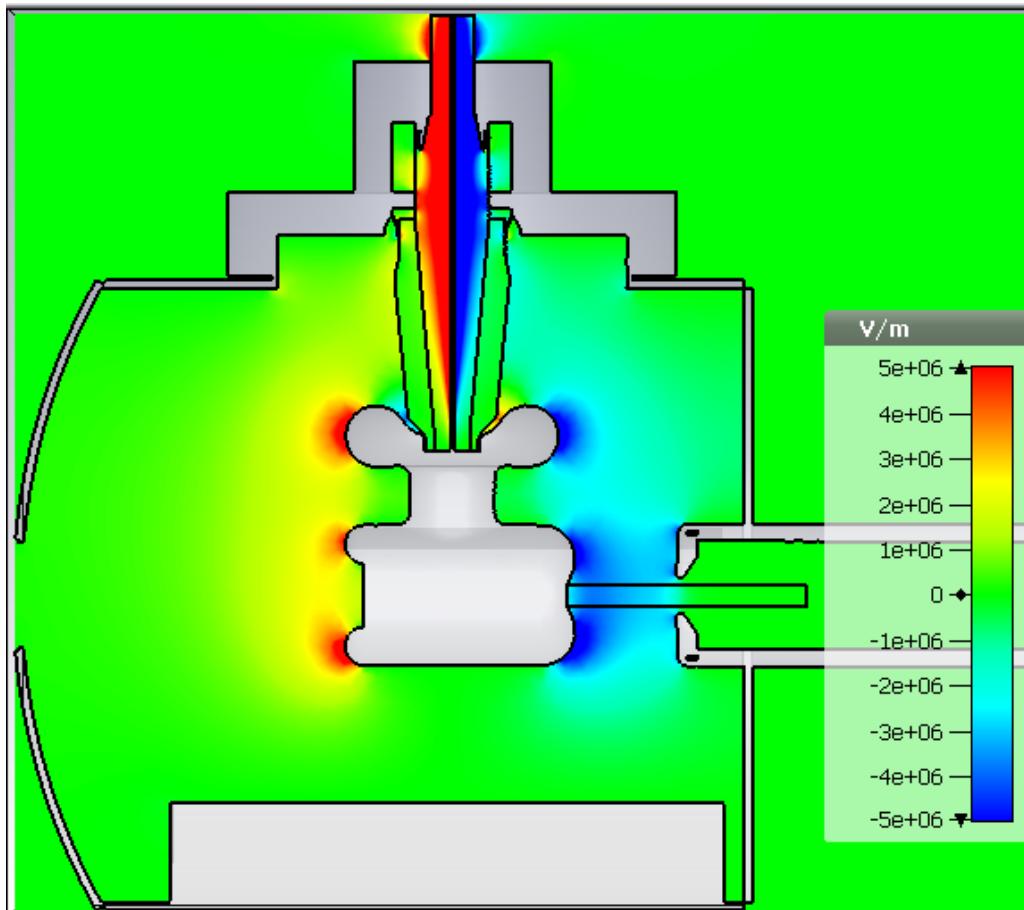


Longitudinal electric field: Original vs Shield 1
vs Shield 2

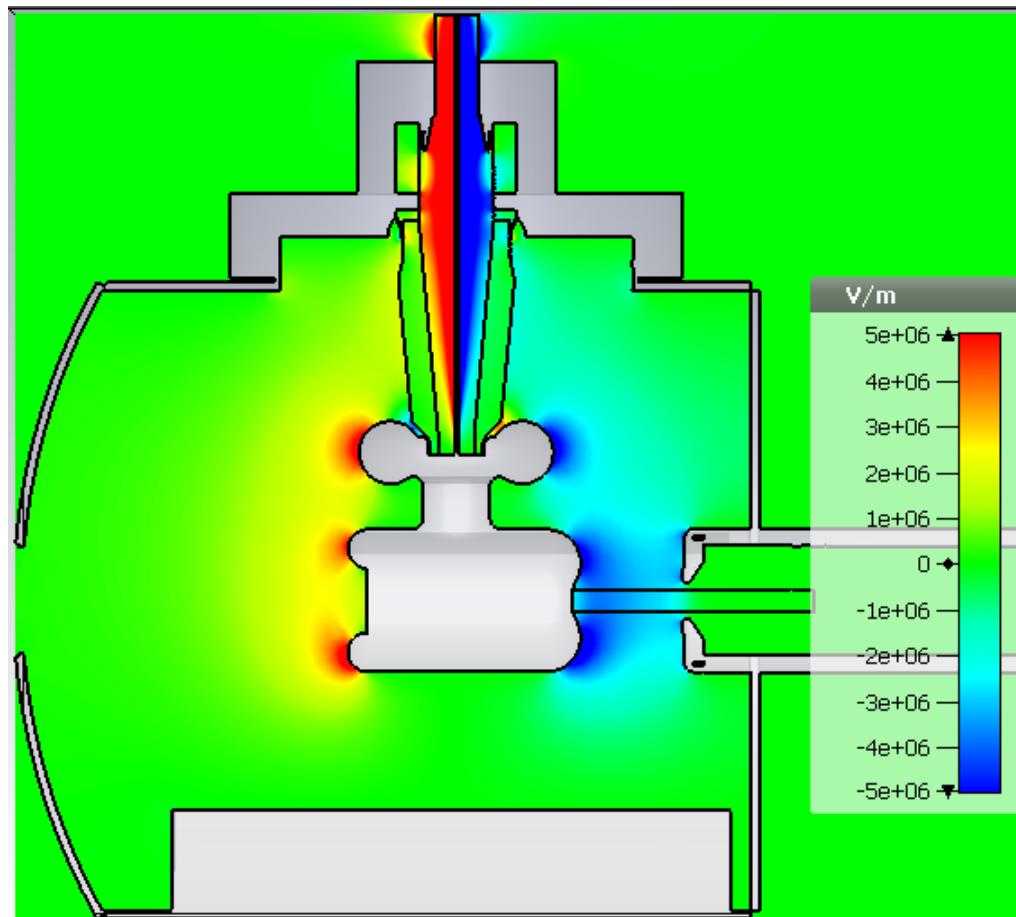
CST results: Longitudinal electric field – original shield



CST results: Longitudinal electric field – Shield 1

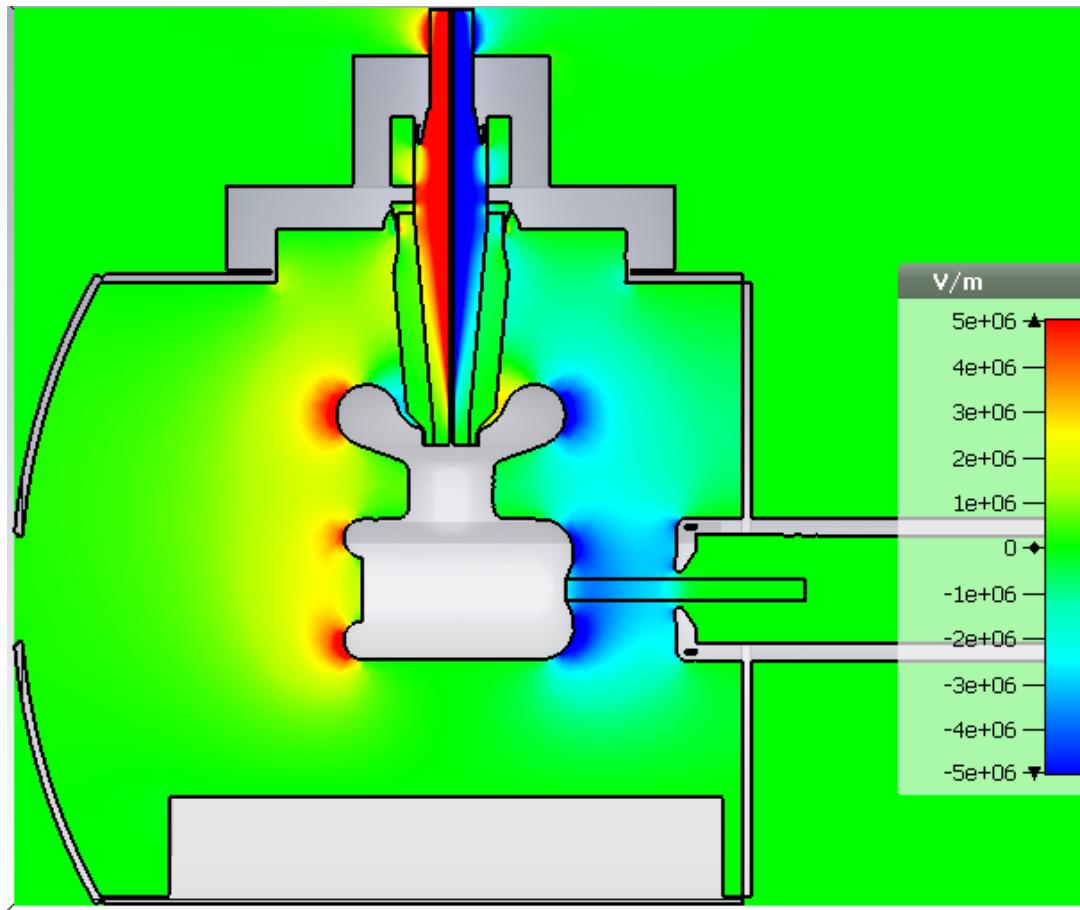


CST results: Longitudinal electric field – Shield 2

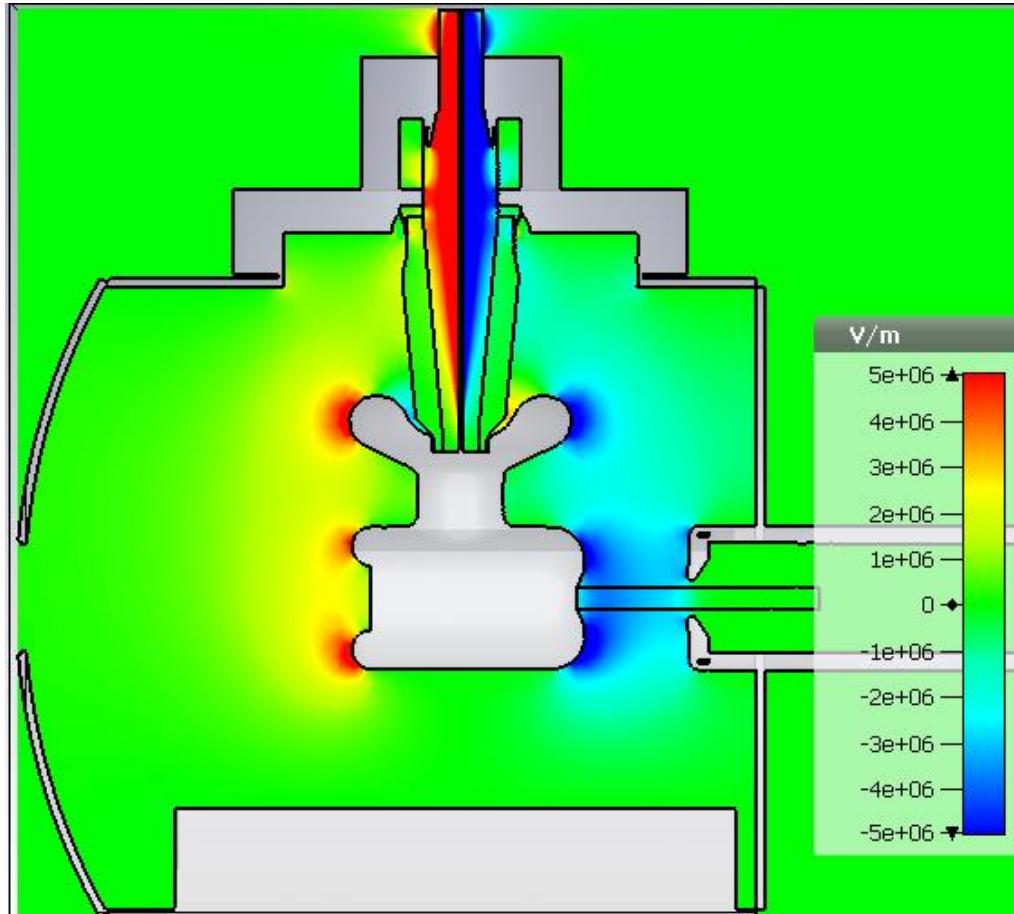


Longitudinal electric field: Original vs Shield 3
vs Shield 4

CST results: Longitudinal electric field – original shield

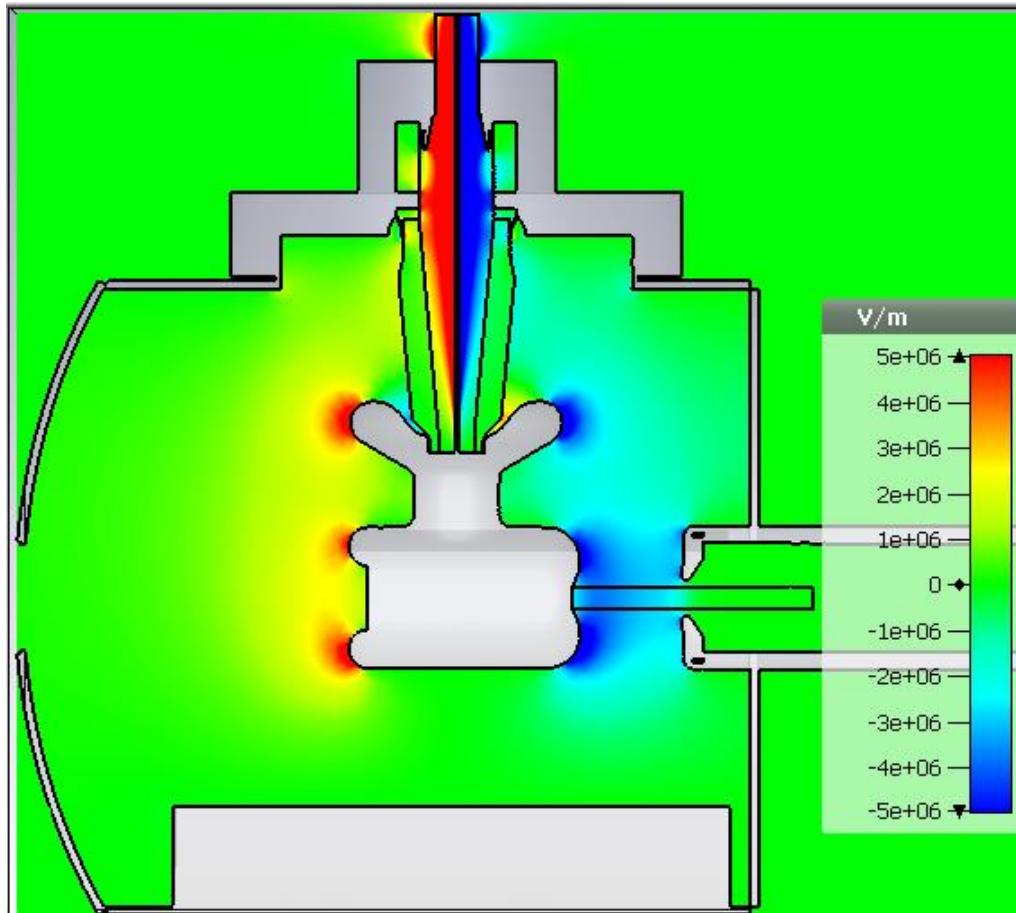


CST results: Longitudinal electric field – Shield 3

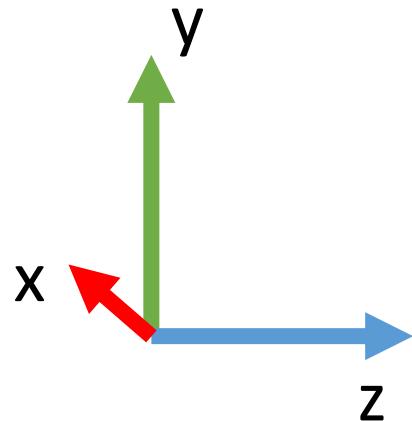


CST results: Longitudinal electric field – Shield

4



CST frame of reference:



X goes into the page.

