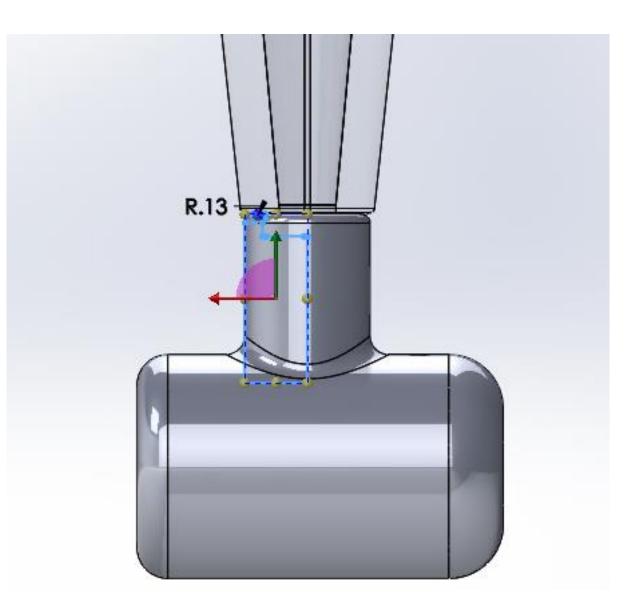
### 200 kV gun CST microwave studio simulations Shield modifications

**Gabriel Palacios** 

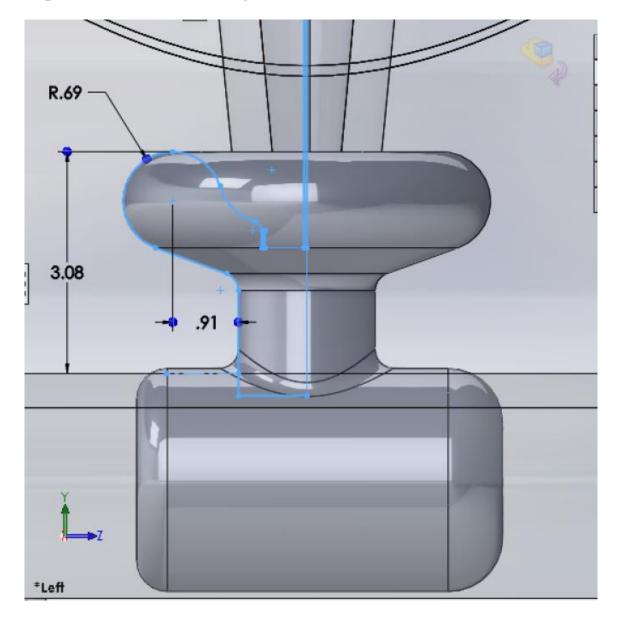
gabrielp@jlab.org 07/09/18

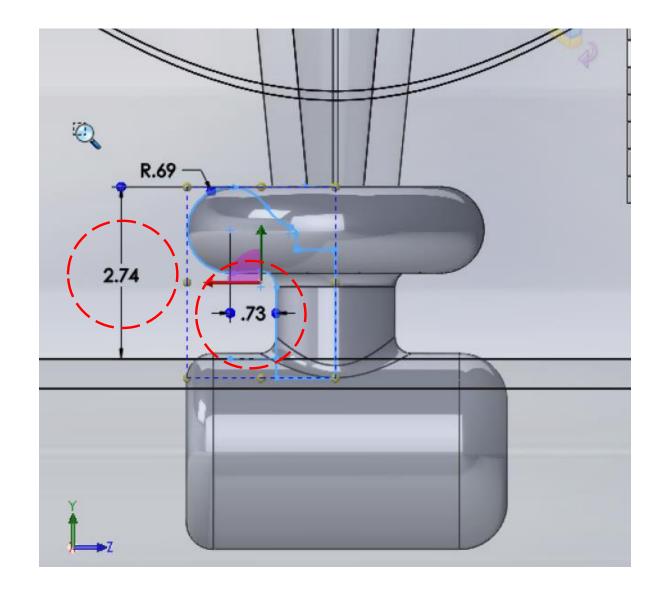
### Summary

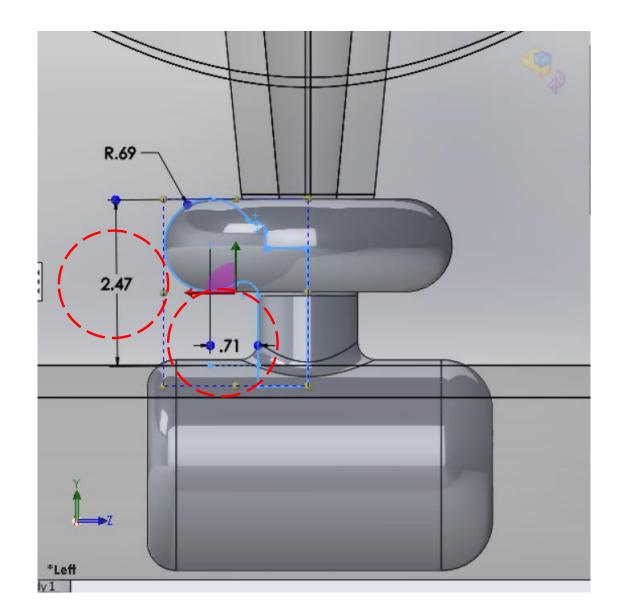
- Solidworks
  - Geometry modifications: 4 new shield proposals.
    - Shields 1 and 2 have decreasing height
    - Shields 3 and 4 have decreasing radius
- CST
  - Details of simulation
  - Electric field and potential plots and false color images
- Additional slides

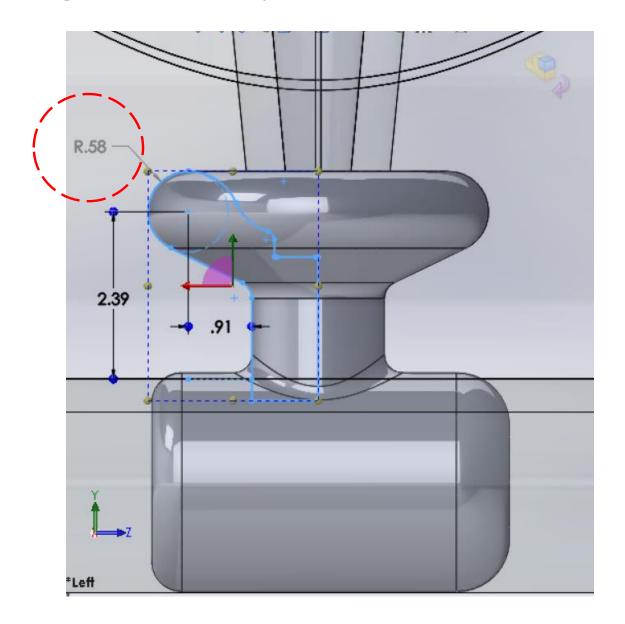


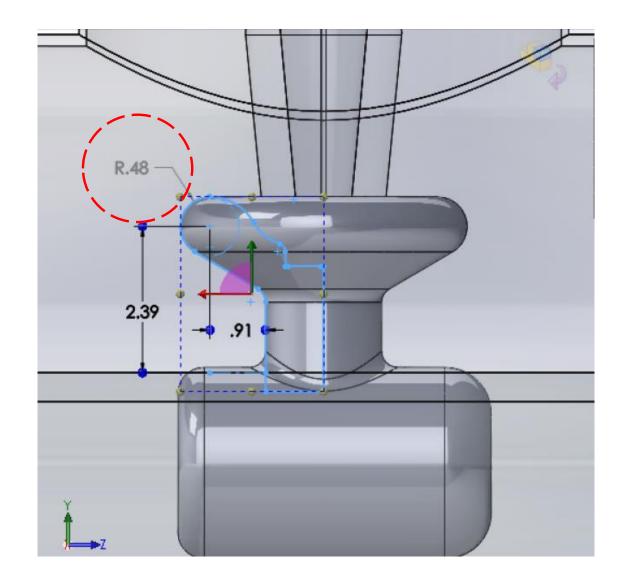
### Solidworks geometry modifications: Original

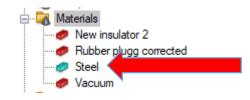








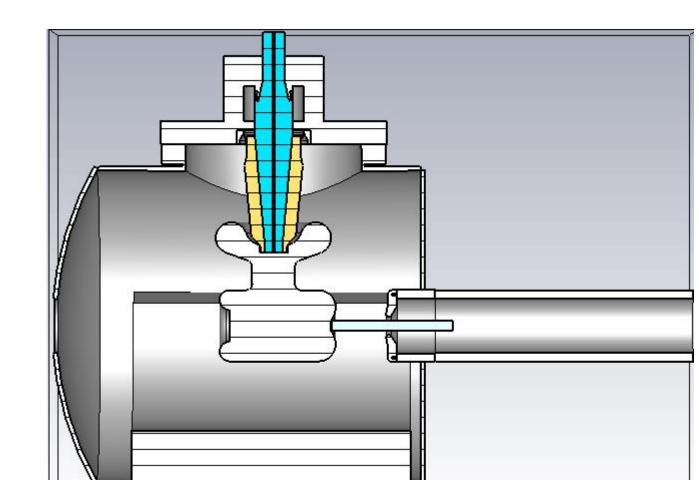


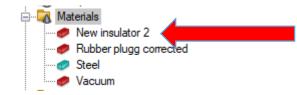


### CST materials: PEC

 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.

| Material Parameters: Steel                    | ×                    |
|---|----------------------|
| Problem type: Default                         | ~                    |
| General Thermal Mechanics Den                 | sity                 |
| General properties<br>Material name:<br>Steel |                      |
| Material folder:                              |                      |
| Туре:   |                      |
| PEC 🗸   | Coating              |
| Epsilon:                                      | Mu:                  |
| Color   | 0% Transparency 100% |

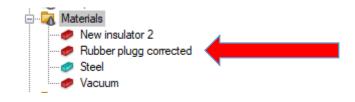




### CST materials: Insulator

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

| Material Parameters: New insulator 2   | K Material Parameters: New insulator 2 X  | OH HO |
|--|---|-------|
| Problem type: Default<br>General Conductivity Dispersion Thermal Mechanics Density<br>General properties<br>Material name: | Problem type:       Default         General       Conductivity       Dispersion       Thermal       Mechanics       Density         Bectric conductivity       Image: Conductivity       Image: Conductivity       Image: Conductivity       Image: Conductivity         Image: Conductivity       Image: Conductivity       Image: Conductivity       Image: Conductivity       Image: Conductivity         Image: Conductivity       Image: Conductivity       Image: Conductivity       Image: Conductivity       Image: Conductivity         Image: Conductivity       Image: Conductivity       Image: Conductivity       Image: Conductivity       Image: Conductivity       Image: Conductivity         Image: Conductivity< |       |
| New insulator 2       Material folder:       Type:       Normal       Epsilon:       Mu:       8.4                         | Advanced Parameters   Tangent delta el.: Tangent delta mag.:   0.0 0.0   at frequency: 0.0   GHz Specification:   Const. fit tan delta Const. fit tan delta   User order: 1   |       |
| Color 0% Transparency 100%   | Frequency range [GHz]<br>Fmin: 0 Fmax: 1  |       |



### CST materials: Insulator

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

|   | _  |  | ╛<br>╡ <mark>╎<mark>╎</mark><mark>╎</mark><br/>┨</mark> | 1 |
|---|--|--|---|---|
| Naterial Parameters: Rubber plugg corrected X   | Material Parameters: Rubber plugg corre                                | rected X   |   |   |
| Problem type: Default ~   | Problem type: Default<br>General Conductivity Dispersion Then          | mal Mechanics Density  |   |   |
| General Conductivity Dispersion Thermal Mechanics Density General properties Material name: | Electric conductivity  | Magnetic conductivity<br>Mag. conductivity:<br>0<br>1/Sm               |   |   |
| Rubber plugg corrected Material folder:   |  | Advanced Parameters  |   |   |
| Type:<br>Nomal V Nonlinear Prop<br>Epsilon: Mu:<br>2.37 1                                   | 0.0<br>at frequency: 0.0 GHz<br>Specification:<br>Const. fit tan delta | 0.0<br>at frequency: 0.0 GHz<br>Specification:<br>Const. fit tan delta |   |   |
| Color 0% Transparency 100%  | User order: 1 +<br>Frequency range [GHz]<br>Fmin: 0                    | User order: 1  |   |   |
|   | Fmin: 0  | Fmax: 1  |   |   |

Materials New insulator 2 Rubber plugg corrected Steel Vacuum

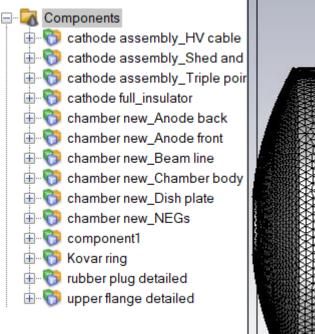
### CST materials: vacuum

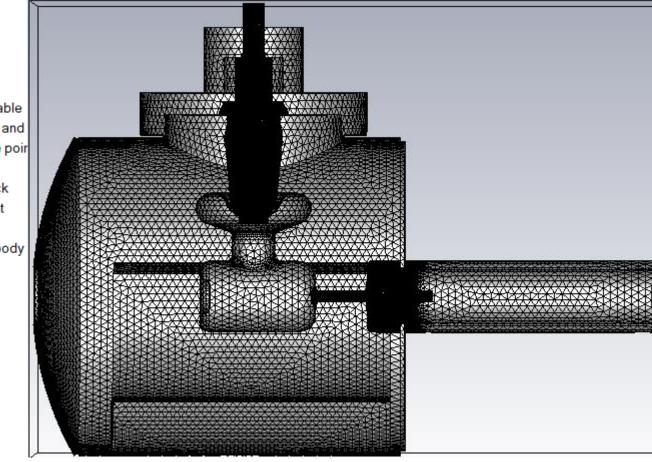
- For vacuum cylinder and surroundings.
- ε=1.0
- $\sigma = 0 [S/m]$

| 0-0[3/11]   |   |                                 |   |  |
|---|---|---------------------------------|---|--|
| Material Parameters: Vacuum   | X Material Parameters: Vacuum   | ×                               |   |  |
| Problem type:     Default     ✓       General     Conductivity     Dispersion     Thermal     Mechanics     Density | Problem type: Default<br>General Conductivity Dispersion Thermal Mechanics<br>Electric conductivity Magnetic condu              |                                 | 2 |  |
| General properties<br>Material name:<br>Vacuum<br>Material folder:  | El. conductivity:     S/m   | tivity:<br>1/Sm<br>d Parameters |   |  |
| Type:<br>Nomal V Nonlinear Prop<br>Epsilon: Mu:<br>1.0 1.0  | 0.0     0.0       at frequency:     0.0       By pecification:     Specification:       Const. fit tan delta     Const. fit tan | 0.0 Hz                          |   |  |
| Color 0% Transparency 100%  | Frequency range [Hz]<br>Fmin: 0 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.



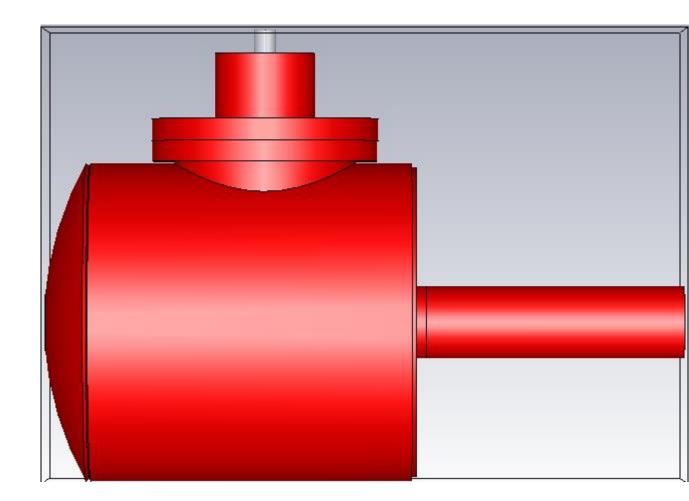


### CST simulation: Potential



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

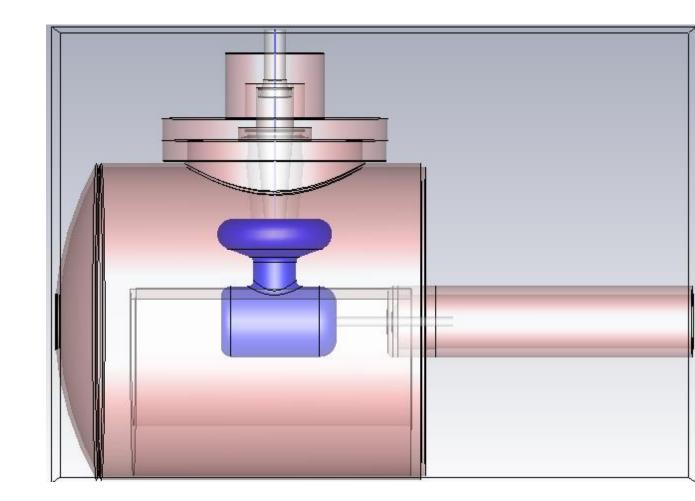
| Edit Potential      |     | ×      |
|---------------------|-----|--------|
| Name:<br>potential1 |     | ОК     |
| Potential value:    |     | Cancel |
| 0                   | v   | Help   |
| Phase:              |     |        |
| 0                   | deg |        |
| Type                |     |        |



### CST simulation: Potential

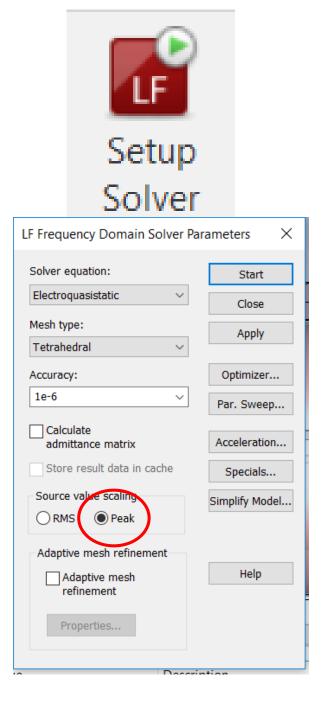


 Cathode electrode (including Pierce geometry), shield and high voltage cable at -200 kV.



### 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.

| ))E Export 3D Field Result     | ×                         |
|--------------------------------|---------------------------|
| Field Result                   |                           |
| E-Field [1]                    | Browse Results            |
|                                | Set Frq / Time Browse All |
|                                | frq = 0                   |
| Export Settings                |                           |
| ③ 3D Export in Volume          | 🗹 Use Subvolume           |
| ◯ 3D Export on Surfaces        | Xmin: Xmax:               |
| O Export Field on Pointlist    | Ymin: Ymax                |
| O Export Field on 2D Plane     | -0.006 0.006              |
| Normal: OX OY OZ               | Zmin: Zmax:               |
| Position: 0                    | 0.063 0.2                 |
| Stepsize: 0.001                |                           |
| File location of pointlist     |                           |
|                                |                           |
| relative to Master-Projectpath | BrowseFile                |
| File Options                   |                           |
| ASCII                          | Use Prefix                |
| O Binary (.bix)                | Use Postfix               |
| OK Cancel                      | Specials Help             |

### Cathode-anode gap:

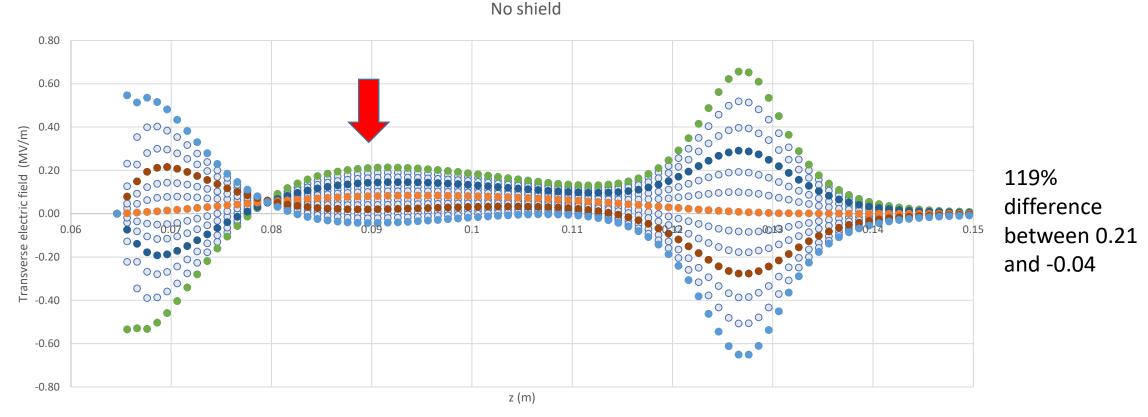
The data for the following plots was taken along the cathode anode gap as a function of the height (on the photocathode surface) varying from -6mm to 6mm.

| on Plot                       |            | × × ×                     |                   |
|-------------------------------|------------|---------------------------|-------------------|
| Label: Cut Line 2D 4          | 0.18       |                           |                   |
| ▼ Data                        | 0.14 -     | HTT-                      | <b>∽</b> , ∥ / -∥ |
| Data set: Cut Plane 1         | 0.12 -     |                           |                   |
| - Line Data                   | 0.1 //     |                           |                   |
| Line entry method: Two points | 0.06 - //  | i l                       |                   |
| x: y:                         | 0.04 -     |                           |                   |
| Point 1: 0.0642 0 m           | 0.02 -     |                           |                   |
| Point 2: 0.169 0 m            | -0.02 -    |                           |                   |
| ☑ Bounded by points           | -0.04 -    | $\langle $                |                   |
| Additional parallel lines     | -0.06 - \\ | N N                       | -                 |
| Distances: m 🔜                | -0.08-     |                           |                   |
|                               | -0.1-      |                           |                   |
| ► Advanced                    | -0.12 -    |                           |                   |
|                               | -0.16      |                           |                   |
|                               | -0.18      |                           | <u> </u>          |
|                               | -0.25 -0.2 | 2 -0.15 -0.1 -0.05 0 0.05 | 0.1 0.15 0.2 0.25 |

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

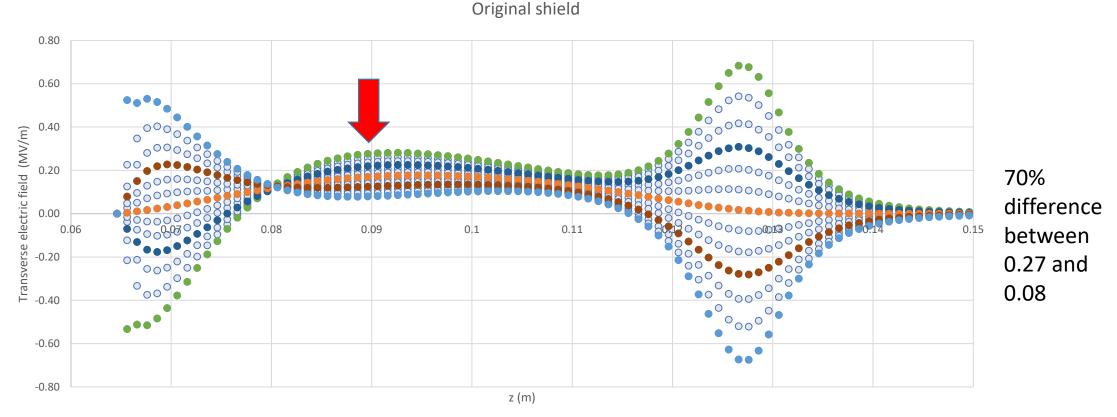
 As the Shield height is reduced, the max value in the middle region of the cathode-anode gap is reduced by 7% from 0.27 MV/m to 0.25 MV/m. The min value decreases in 50% from 0.08 MV/m to 0.04 MV/m. This min value is achieved by going upwards on the photocathode surface.

# CST results: Transverse electric field – No shield



○ Field map • y=-6mm • y=-3mm • y=0mm • y=3mm • y=6mm

# CST results: Transverse electric field – original shield

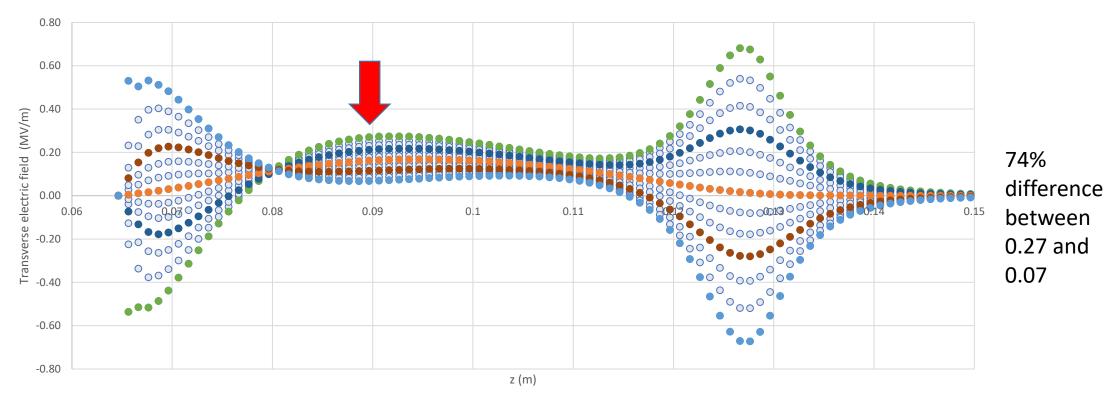


○ Field map ● y=-6mm ● y=-3mm ● y=0mm ● y=3mm ● y=6mm

### CST results: Transverse electric field – Shield 1

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

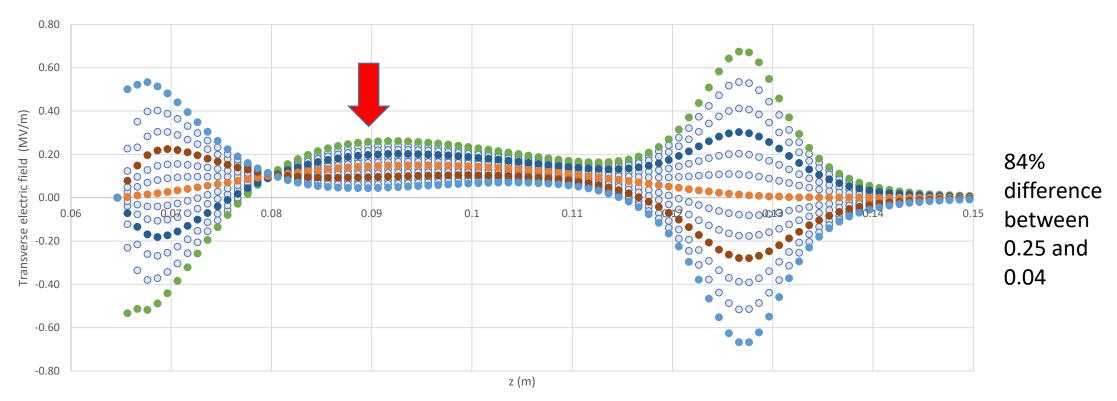


○ Field map • y=-6mm • y=-3mm • y=0mm • y=3mm • y=6mm

### CST results: Transverse electric field – Shield 2

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

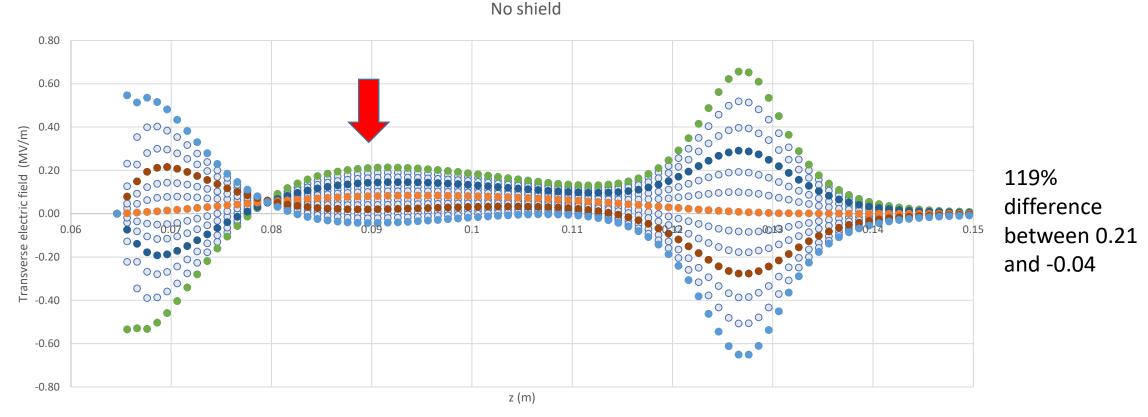


○ Field map • y=-6mm • y=-3mm • y=0mm • y=3mm • y=6mm

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

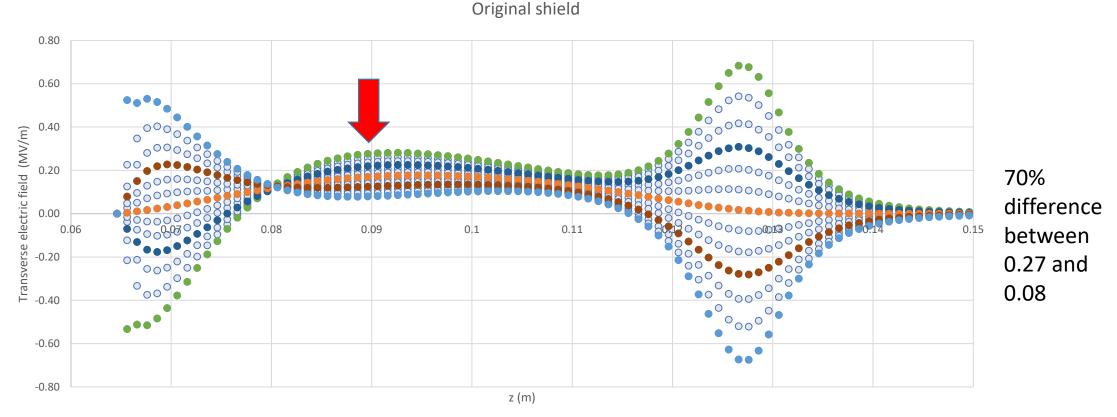
 As the Shield radius is reduced, the max value in the middle region of the cathode-anode gap is also reduced around 4% from 0.27 MV/m to 0.26 MV/m. The min value decreases in 37.5% from 0.08 MV/m to 0.05 MV/m. This min value is again achieved by going upwards on the photocathode surface.

# CST results: Transverse electric field – No shield



○ Field map • y=-6mm • y=-3mm • y=0mm • y=3mm • y=6mm

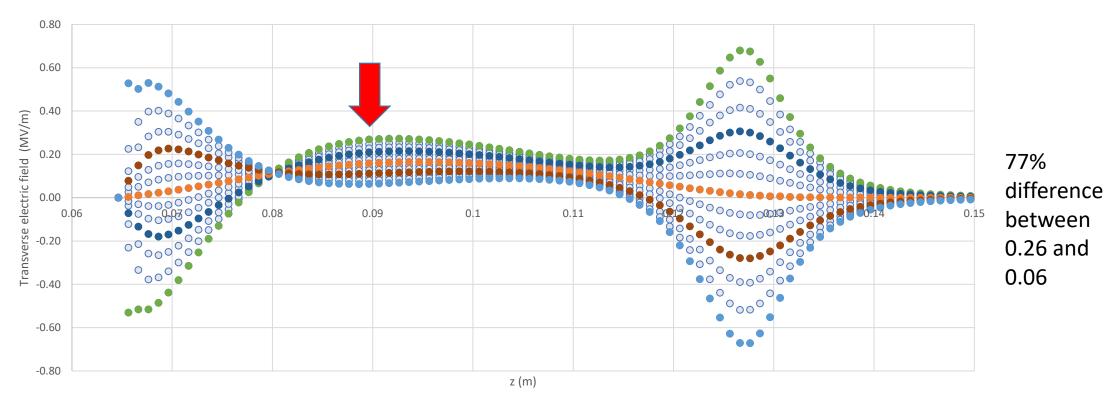
# CST results: Transverse electric field – original shield



○ Field map ● y=-6mm ● y=-3mm ● y=0mm ● y=3mm ● y=6mm

### CST results: Transverse electric field – Shield 3

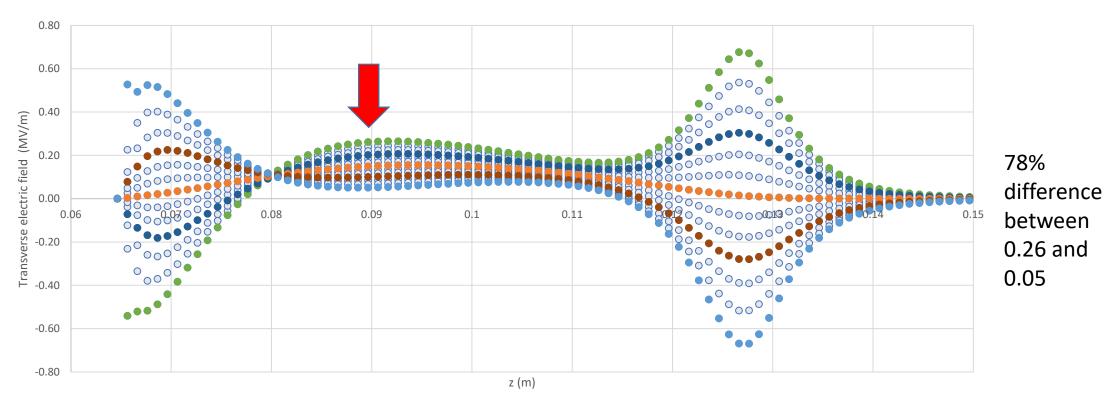
Shield 3



○ Field map • y=-6mm • y=-3mm • y=0mm • y=3mm • y=6mm

### CST results: Transverse electric field – Shield 4

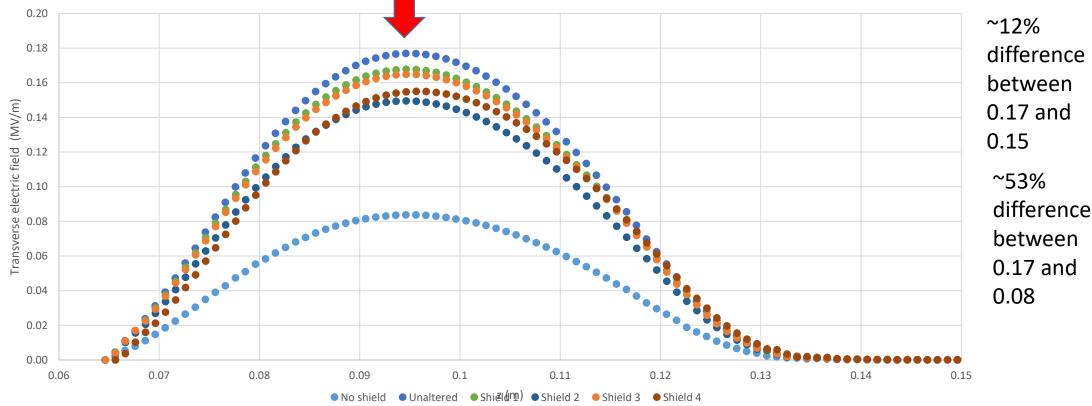
Shield 4



○ Field map • y=-6mm • y=-3mm • y=0mm • y=3mm • y=6mm

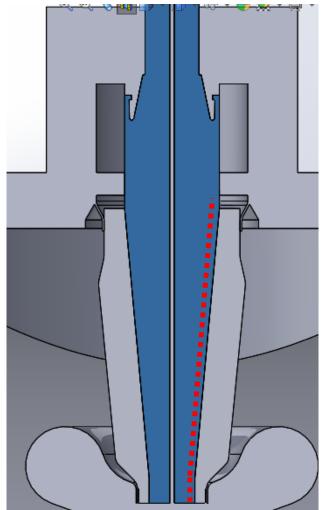
### CST results: Transverse electric field – No shield vs Original vs all shields (1,2,3 & 4) at C-a gap center line

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



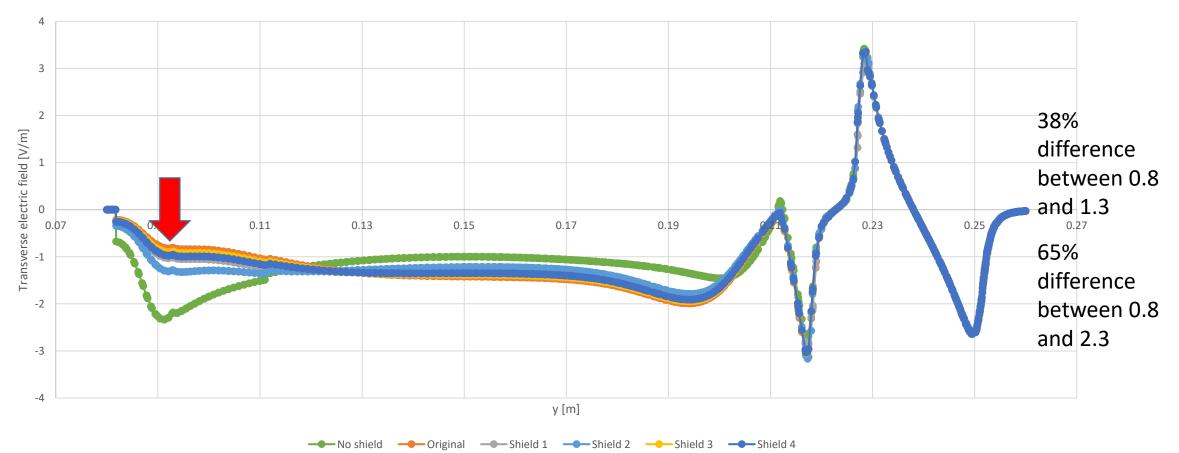
CST results: Transverse electric field – No shield vs Original vs all shields (1,2,3 & 4) at insulator interface

 The potential and electric fields along the rubber plug – ceramic insulator interface was obtained (as shown in the image as a red dotted line), <u>plotted</u> <u>as a function of the height (ycoordinate).</u>



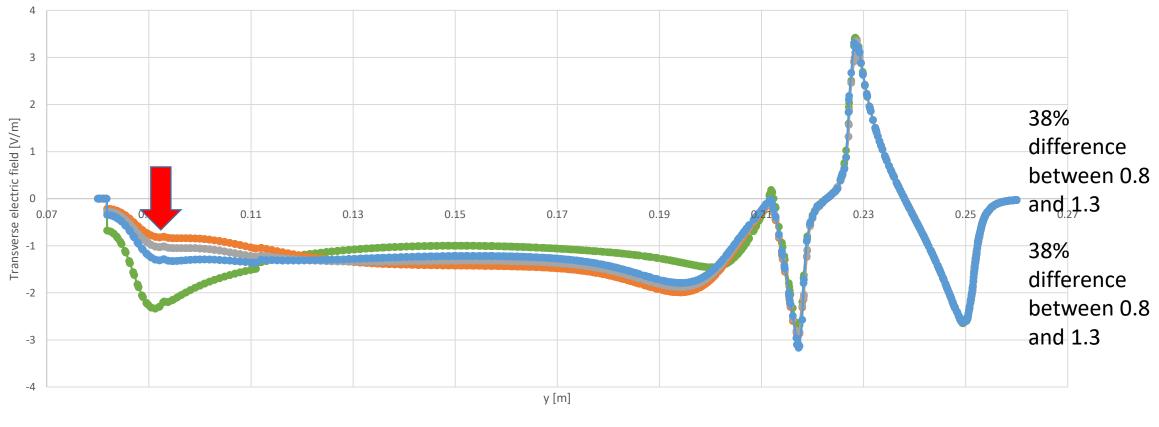
#### CST results: Transverse electric field – No shield vs Original vs all shields (1,2,3 & 4) at insulator interface

Different colors represent different shields.



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

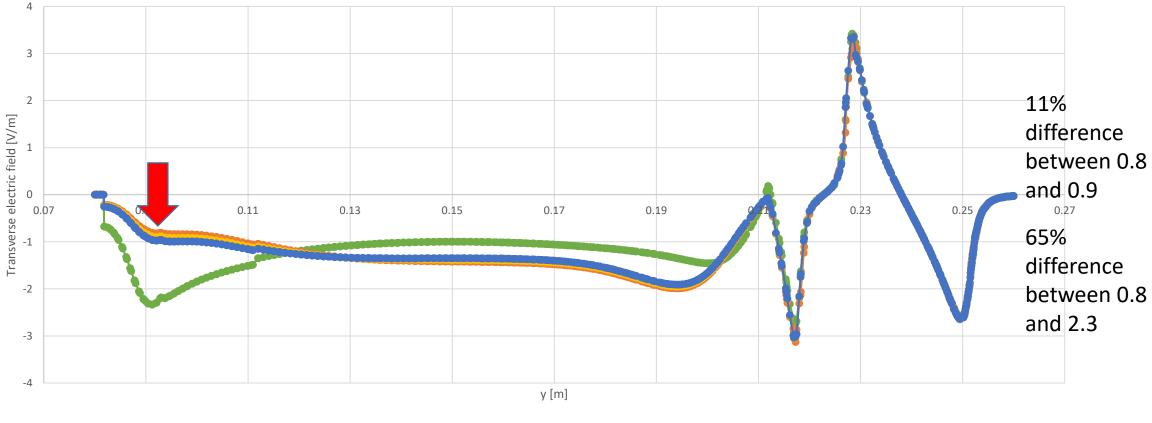
Different colors represent different shields.



---- No shield ---- Original ---- Shield 1 ---- Shield 2

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

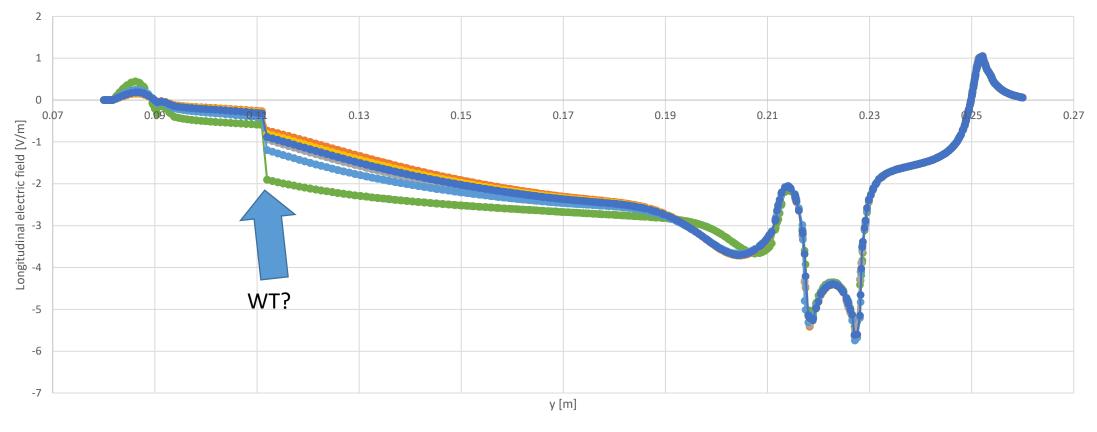
Different colors represent different shields.



---- No shield ---- Original ---- Shield 3 ---- Shield 4

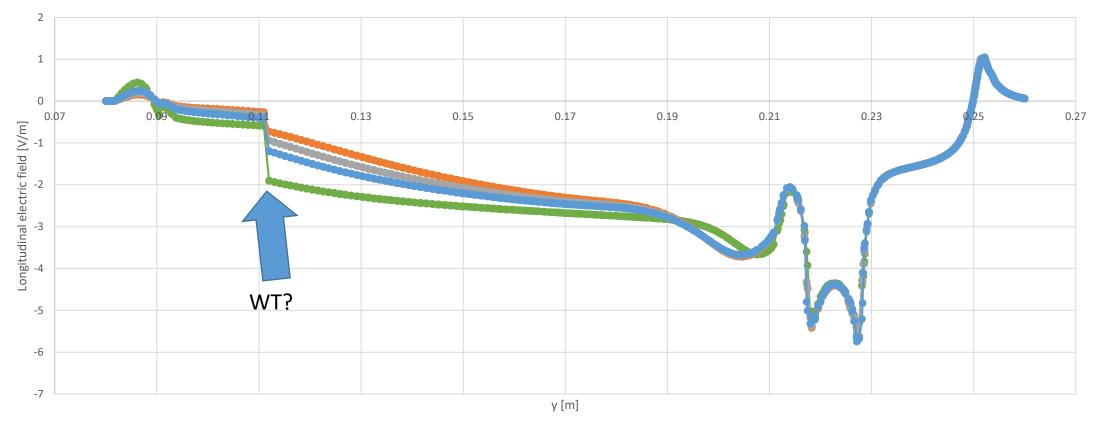
#### CST results: Longitudinal electric field – No shield vs Original vs all shields (1,2,3 & 4) at insulator interface

Different colors represent different shields.



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

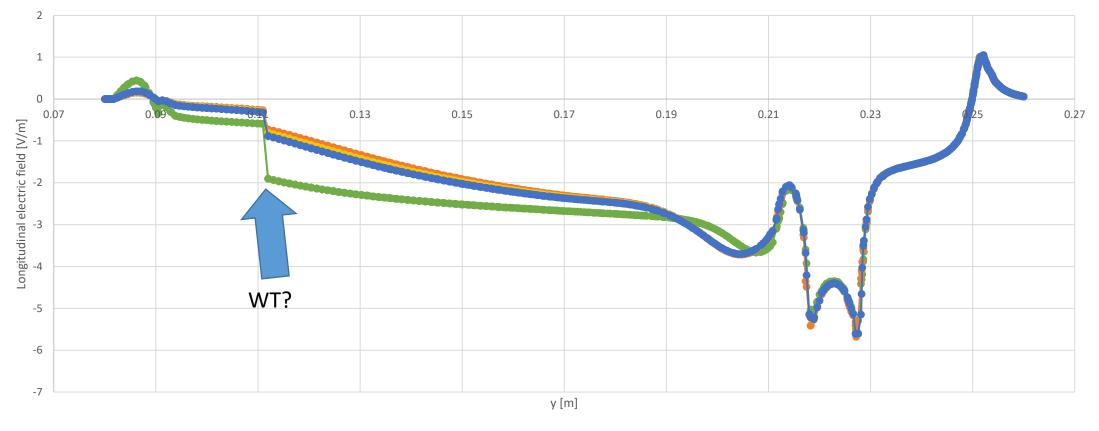
Different colors represent different shields.



----- No shield ----- Shield 1 ----- Shield 2

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

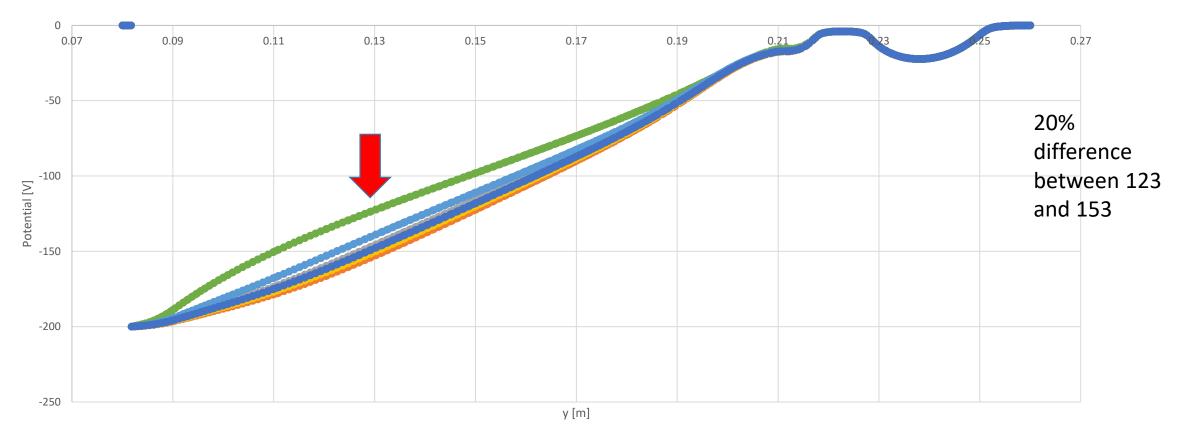
Different colors represent different shields.



---- No shield ---- Shield 3 ---- Shield 4

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

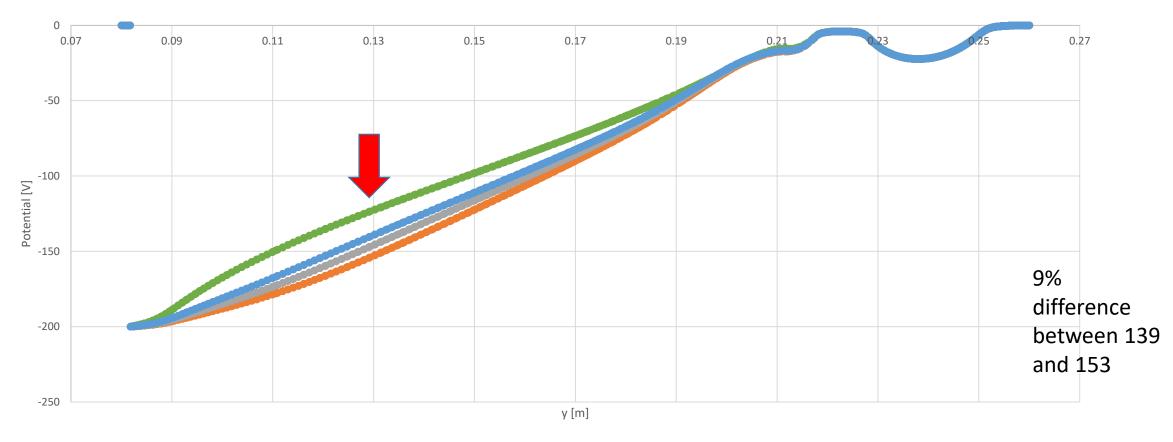
Different colors represent different shields.



● No shield ● Original ● Shield 1 ● Shield 2 ● Shield 3 ● Shield 4

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

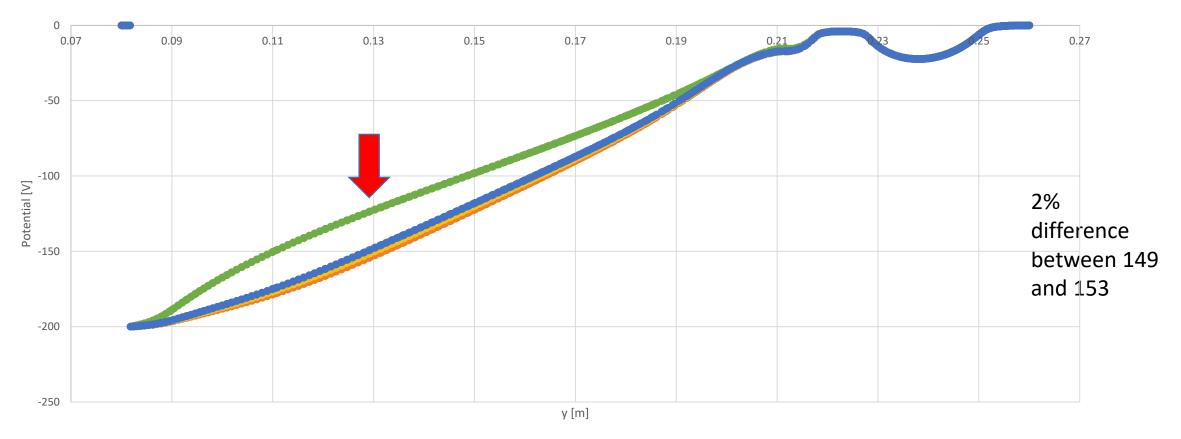
Different colors represent different shields.



● No shield ● Original ● Shield 1 ● Shield 2

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

Different colors represent different shields.

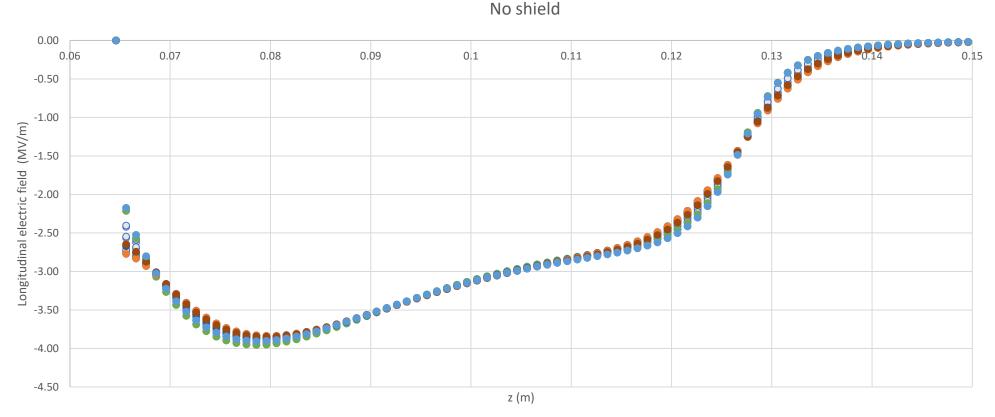


● No shield ● Original ● Shield 3 ● Shield 4

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.

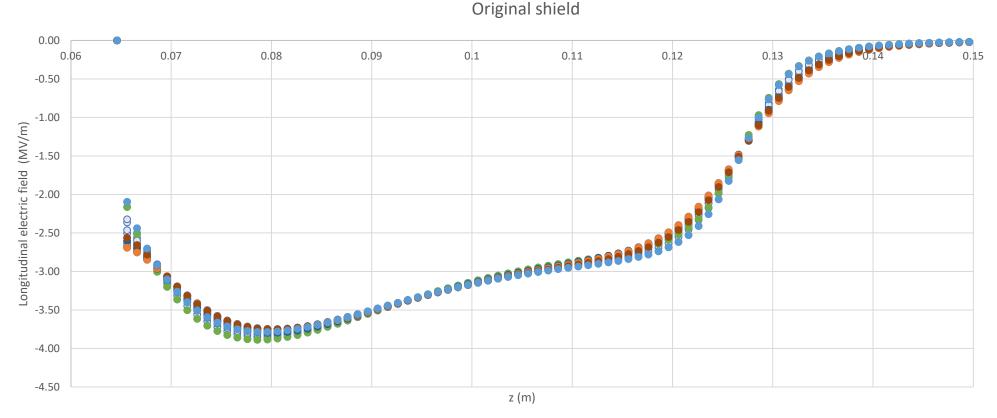
The gray data set is the whole field map. The different colors show how the longitudinal electric field changes as a function of height on the photocathode in the interval -6mm<y<6mm



○ Field map ● y=-6mm ● y=-3mm ● y=0mm ● y=3mm ● y=6mm

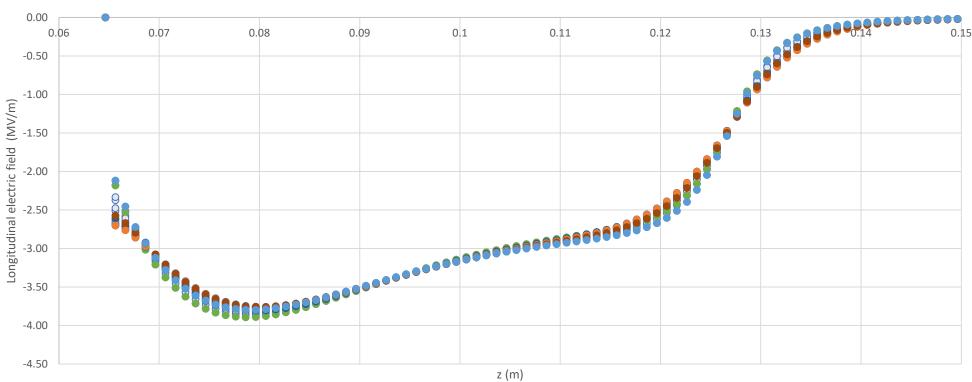
# CST results: Longitudinal electric field – original shield

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



○ Field map ● y=-6mm ● y=-3mm ● y=0mm ● y=3mm ● y=6mm

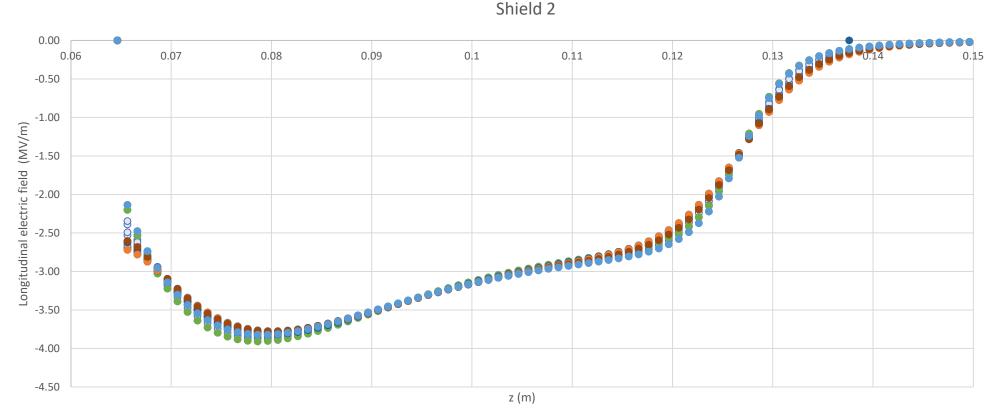
The gray data set is the whole field map. The different colors show how the longitudinal electric field changes as a function of height on the photocathode in the interval -6mm<y<6mm



Shield 1

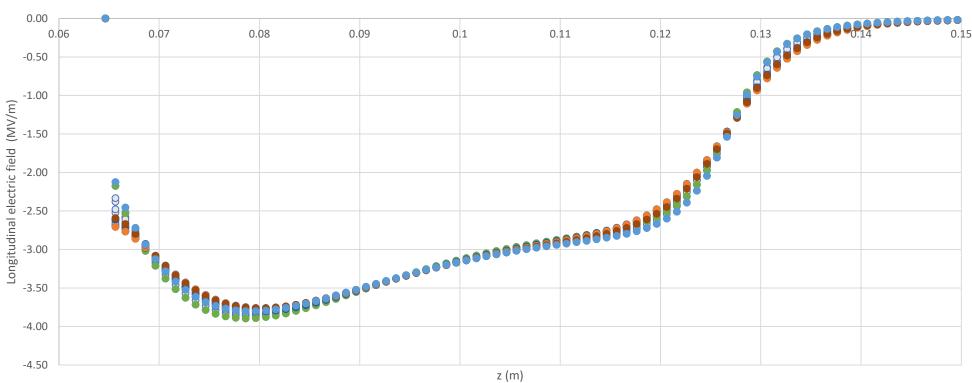
○ Field map ● y=-6mm ● y=-3mm ● y=0mm ● y=3mm ● y=6mm

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



○ Field map ● y=-6mm ● y=-3mm ● y=0mm ● y=3mm ● y=6mm

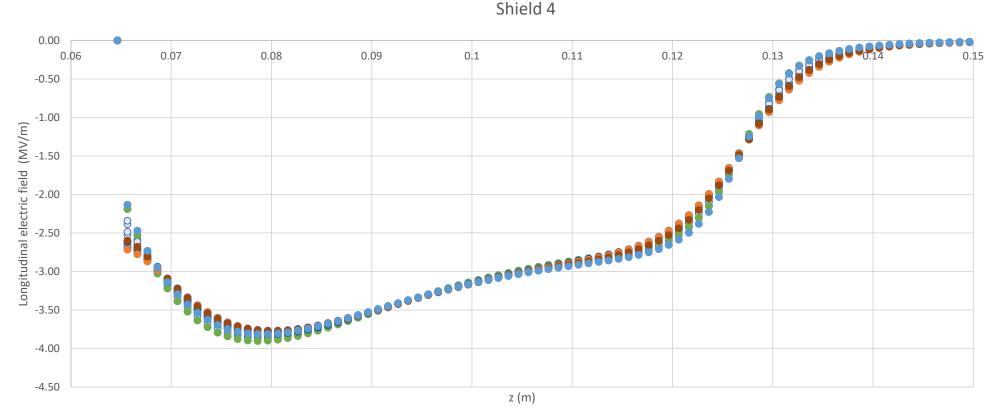
The gray data set is the whole field map. The different colors show how the longitudinal electric field changes as a function of height on the photocathode in the interval -6mm<y<6mm



Shield 3

○ Field map • y=-6mm • y=-3mm • y=0mm • y=3mm • y=6mm

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

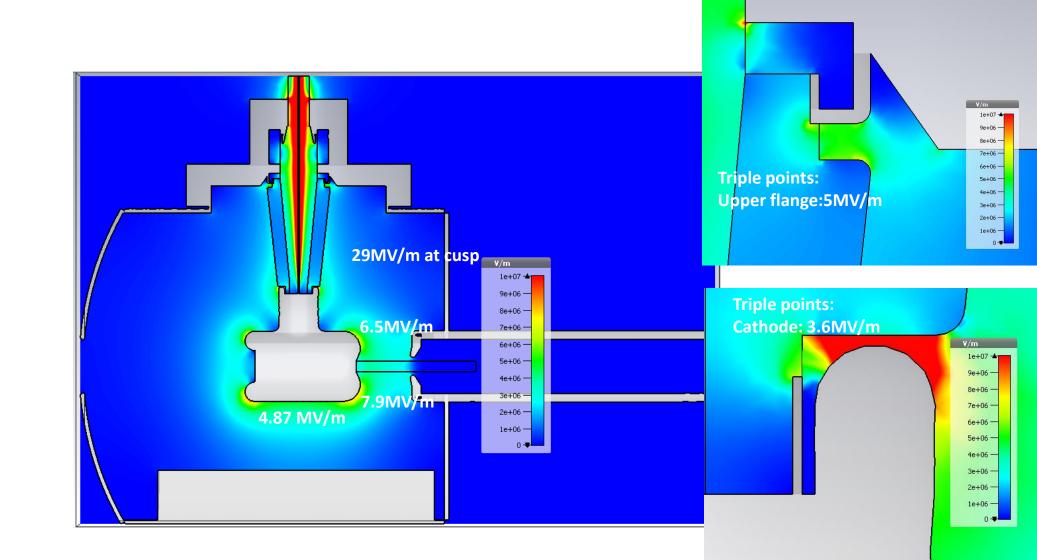


○ Field map • y=-6mm • y=-3mm • y=0mm • y=3mm • y=6mm

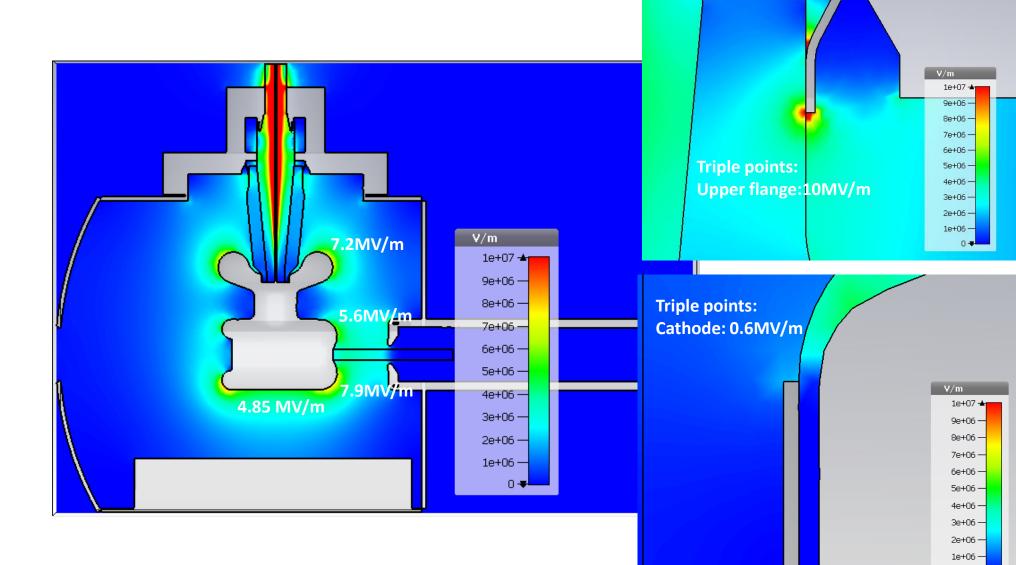
#### False color

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

### CST results: Electric field norm- No shield

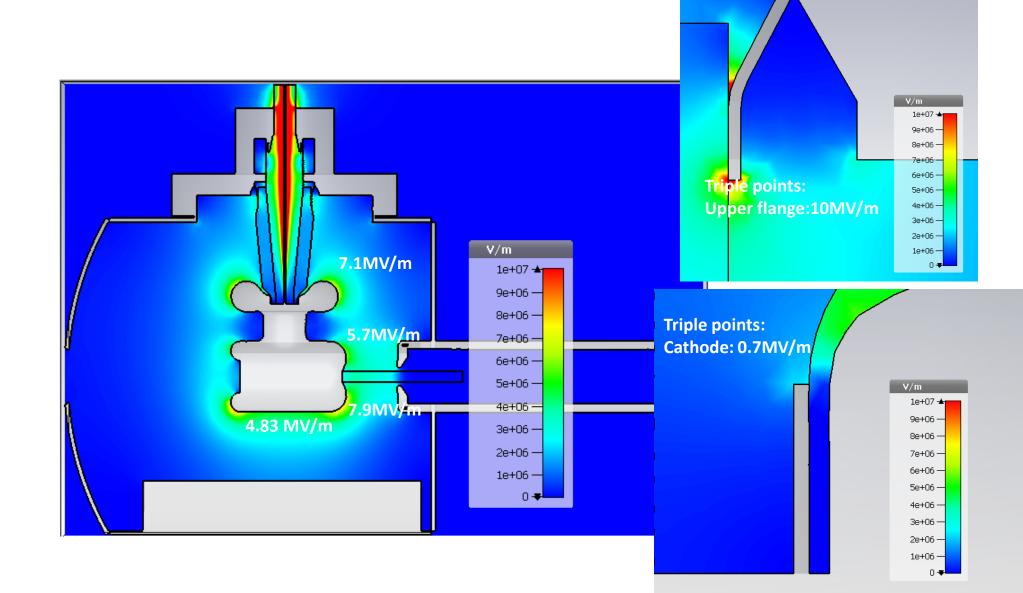


# CST results: Electric field norm– original shield

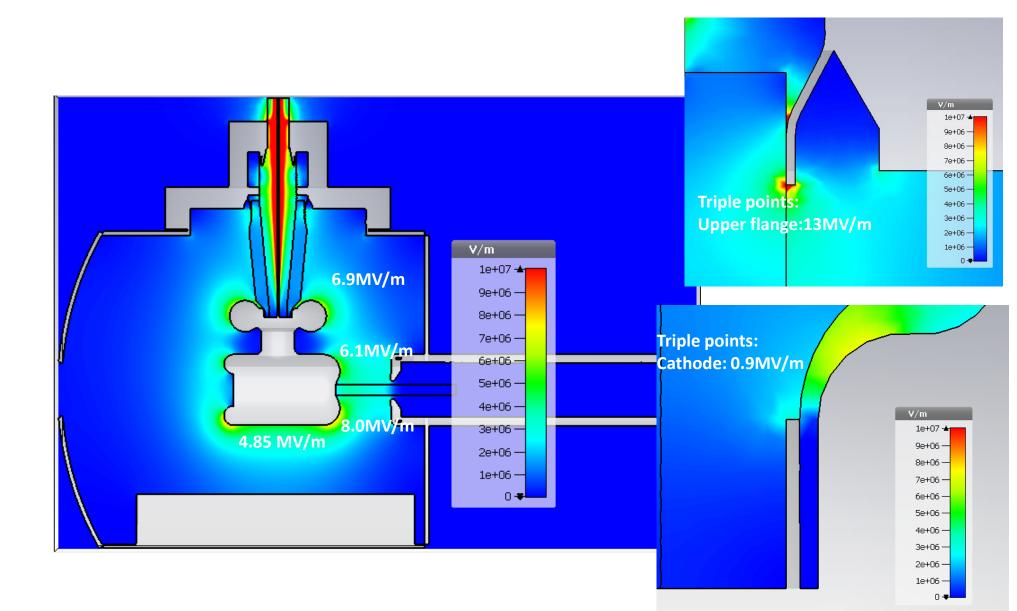


0.-

### CST results: Electric field norm-Shield 1

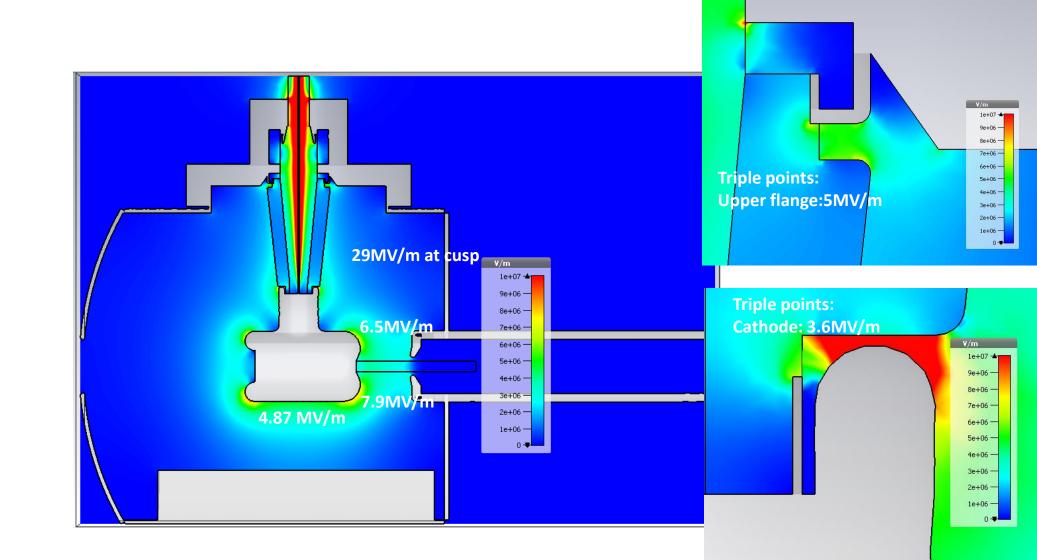


### CST results: Electric field norm– Shield 2

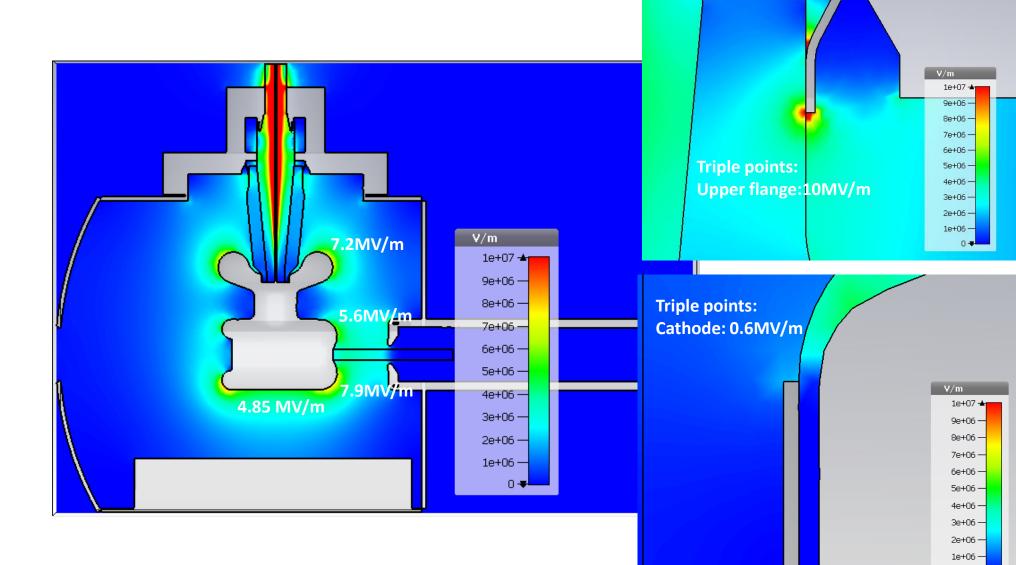


## Electric field norm: No shield vs Original vs shields 3&4

### CST results: Electric field norm- No shield

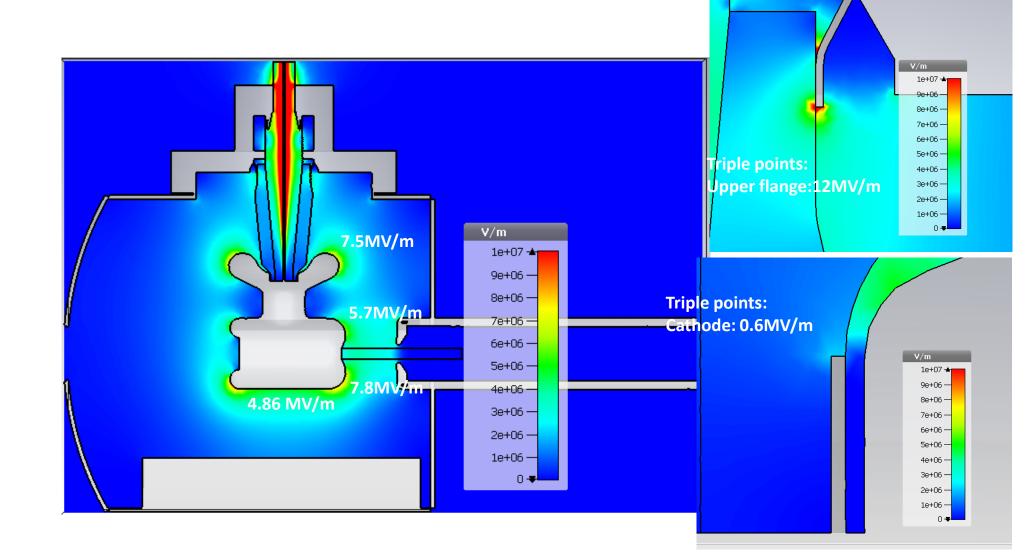


# CST results: Electric field norm– original shield

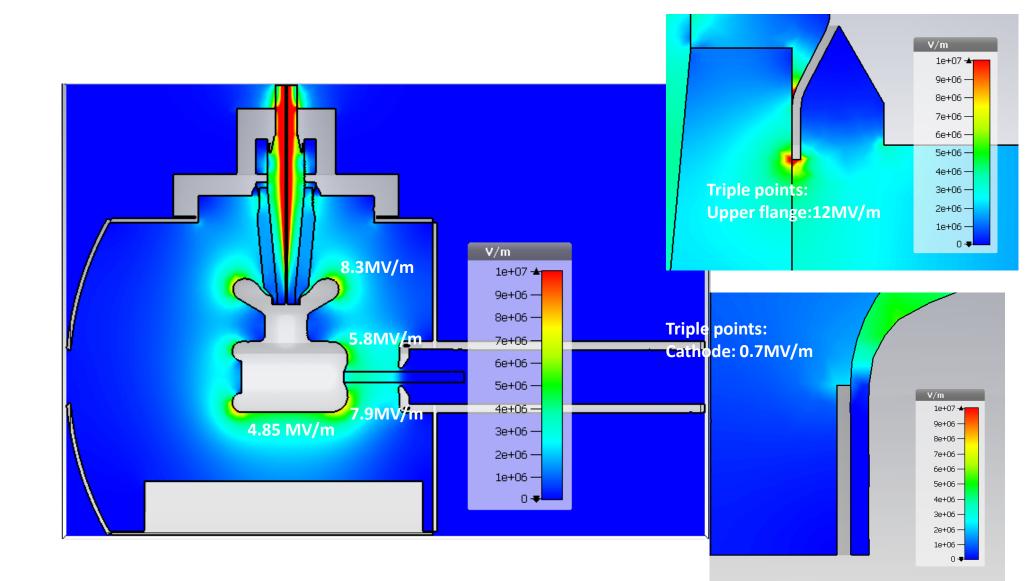


0.-

### CST results: Electric field norm– Shield 3



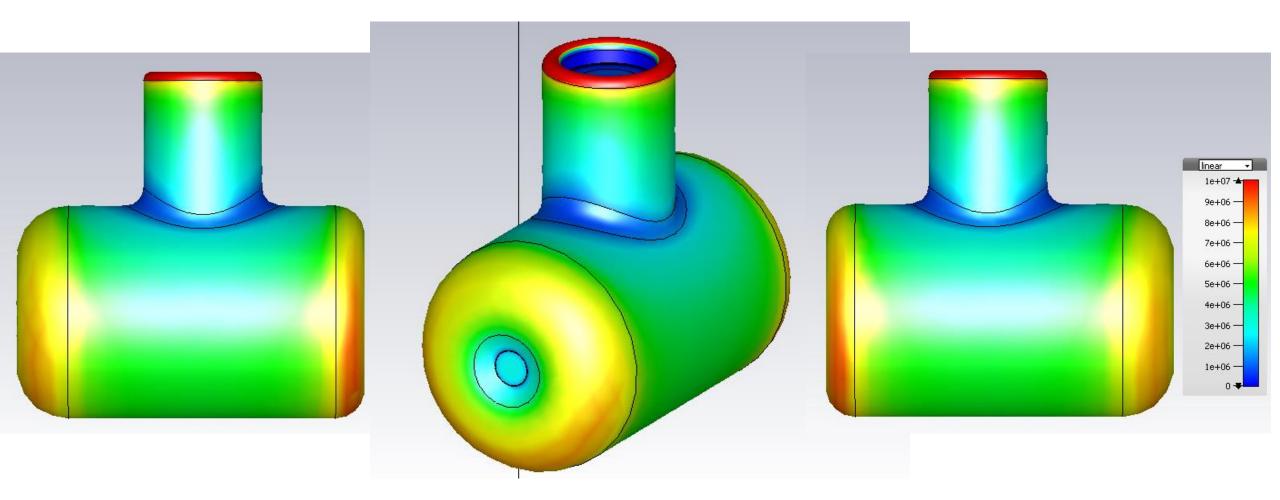
### CST results: Electric field norm– Shield 4



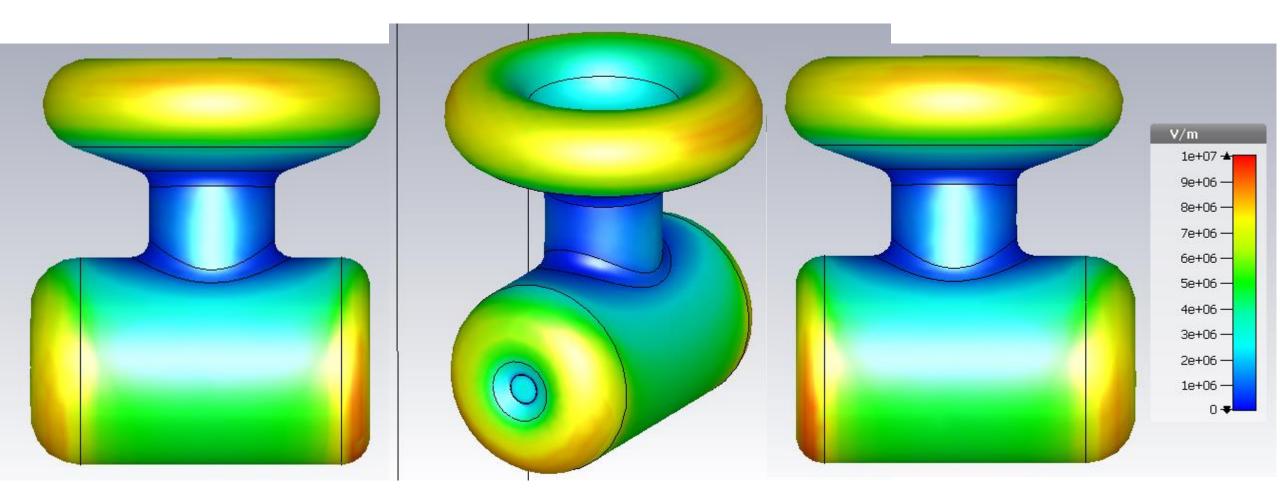
# Electric field norm: No shield vs Original vs shields 1 vs shields 2

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

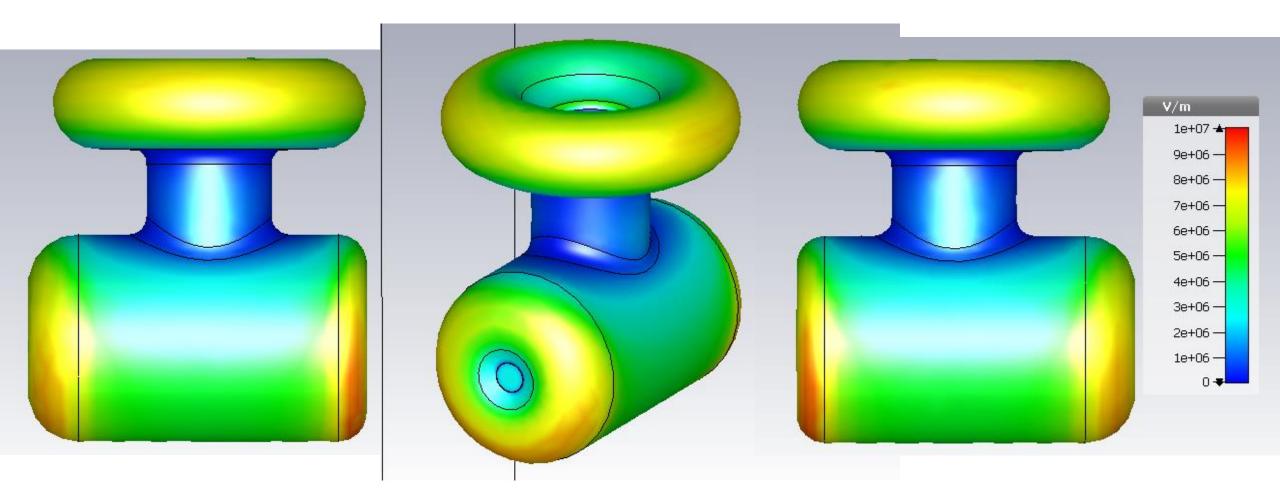
#### CST results: Electric field norm- No shield



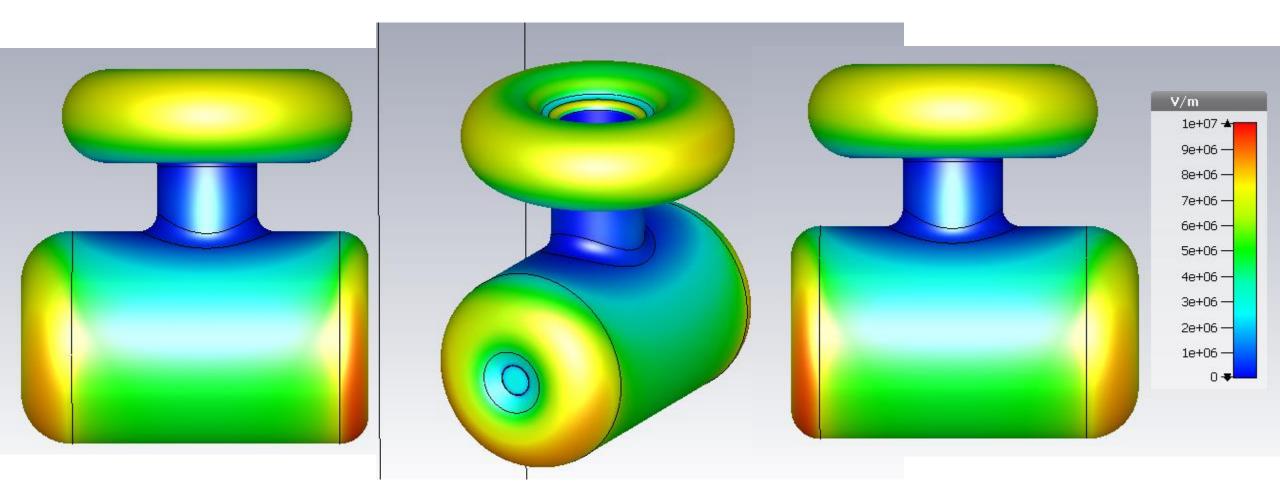
### CST results: Electric field norm– Original



#### CST results: Electric field norm– Shield 1



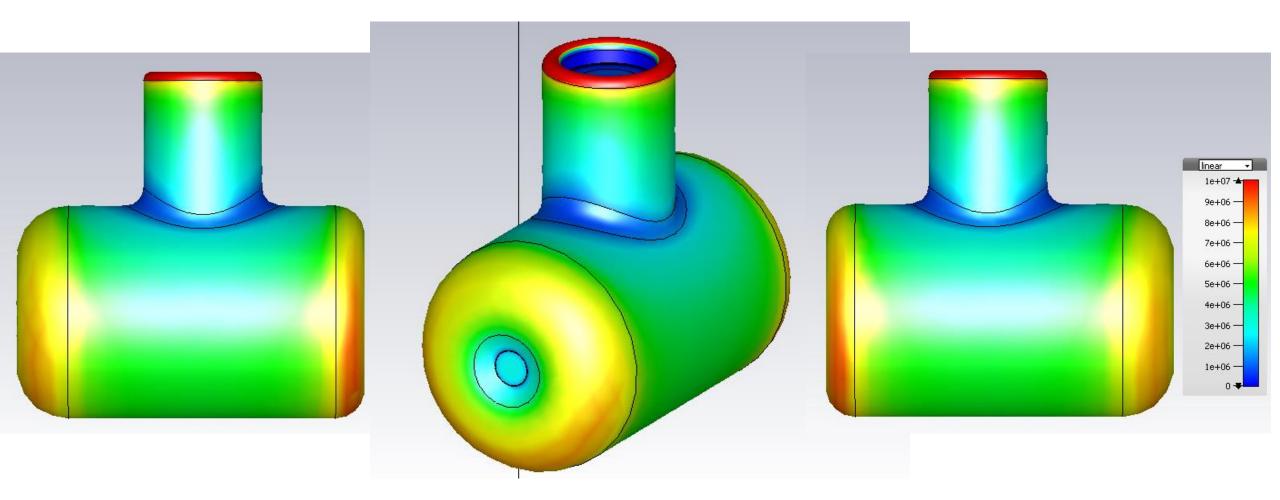
#### CST results: Electric field norm– Shield 2



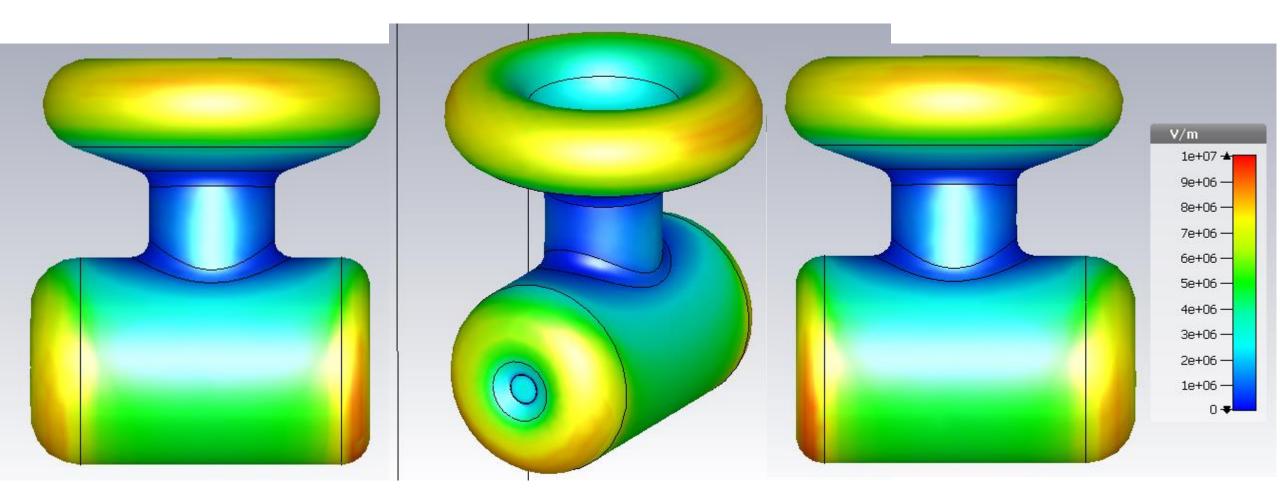
# Electric field norm: No shield vs Original vs shields 1 vs shields 2

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

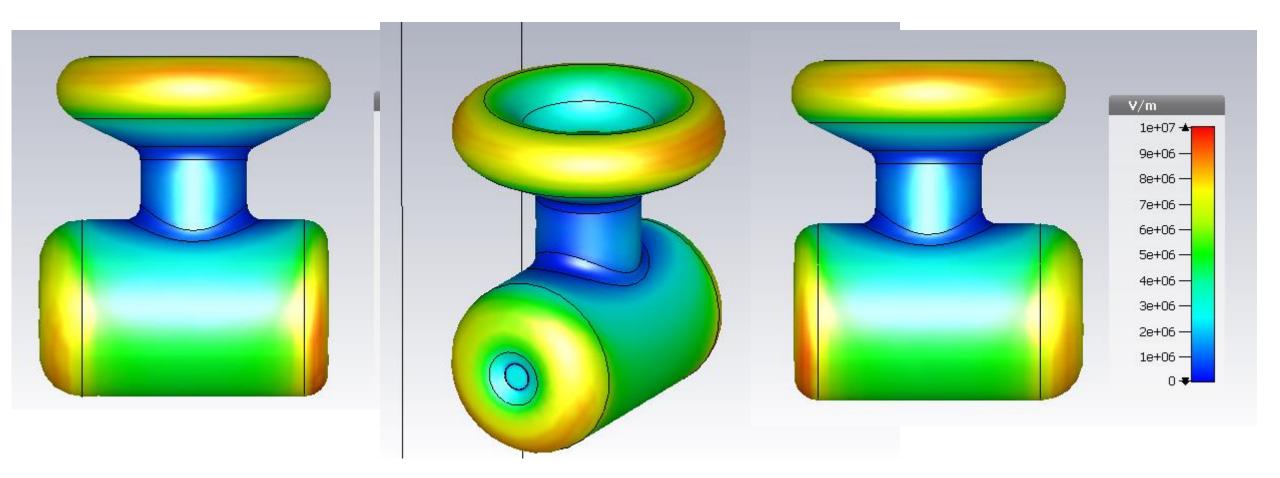
#### CST results: Electric field norm- No shield



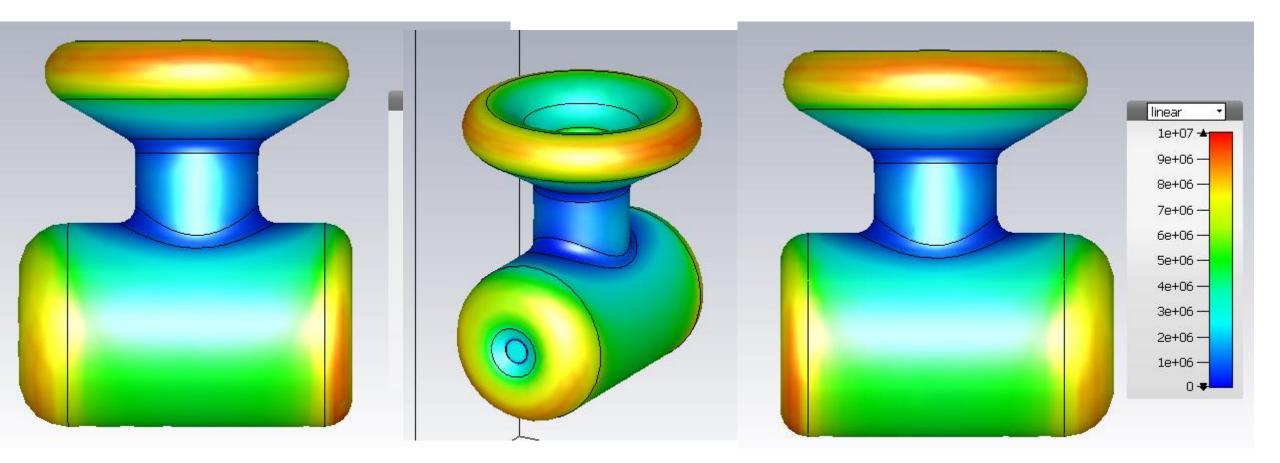
### CST results: Electric field norm– Original



#### 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.

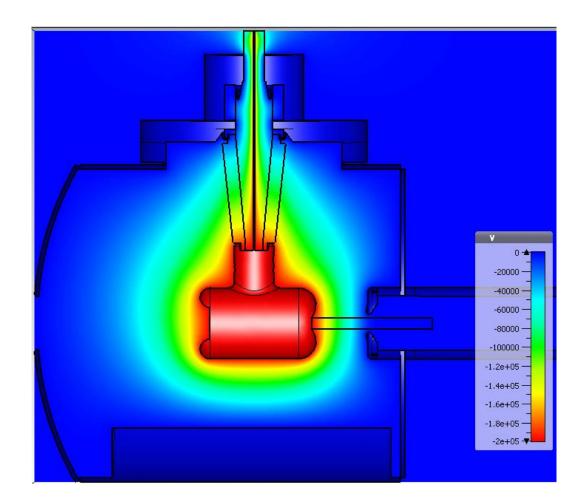
Fin.

## Additional slides

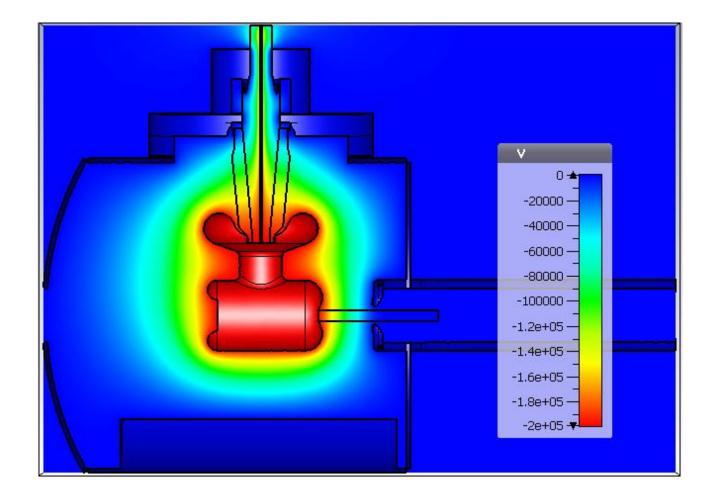
- Potentials false color
- Transverse field false color
- Longitudinal field false color

### Potential: Original vs Shield 1 vs Shield 2

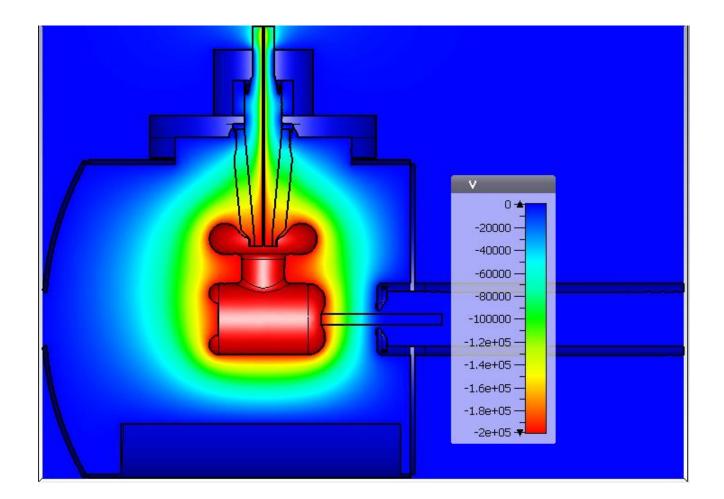
### CST results: Potential – No shield



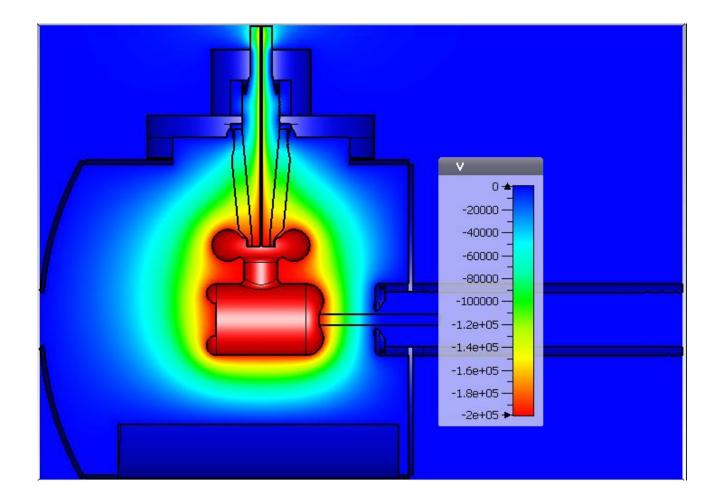
#### CST results: Potential – original shield



#### CST results: Potential – Shield 1

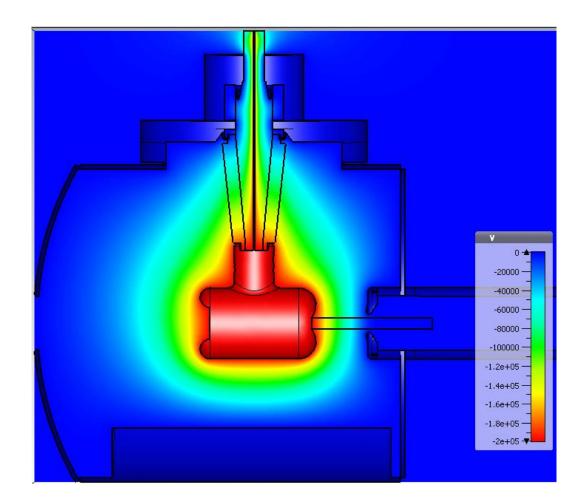


#### CST results: Potential – Shield 2

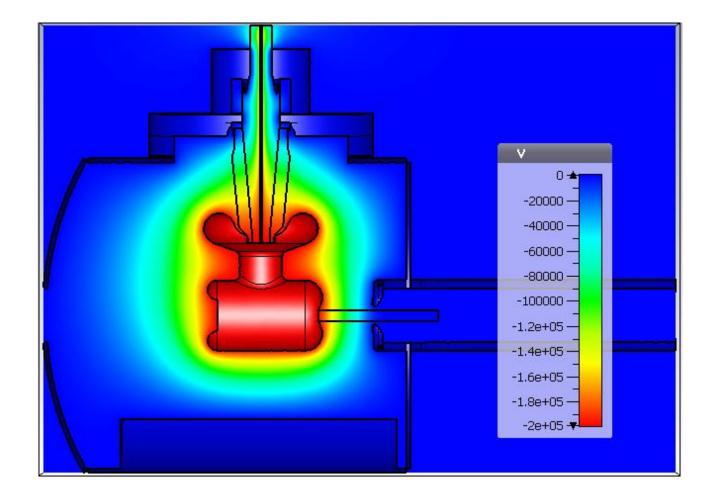


### Potential: Original vs Shield 3 vs Shield 4

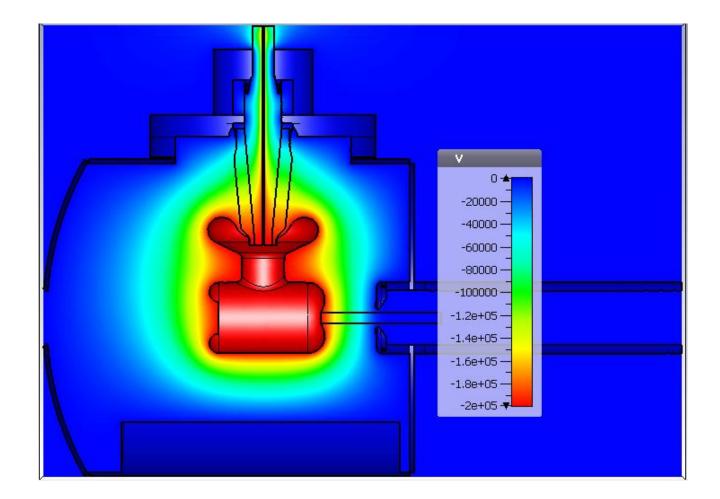
### CST results: Potential – No shield



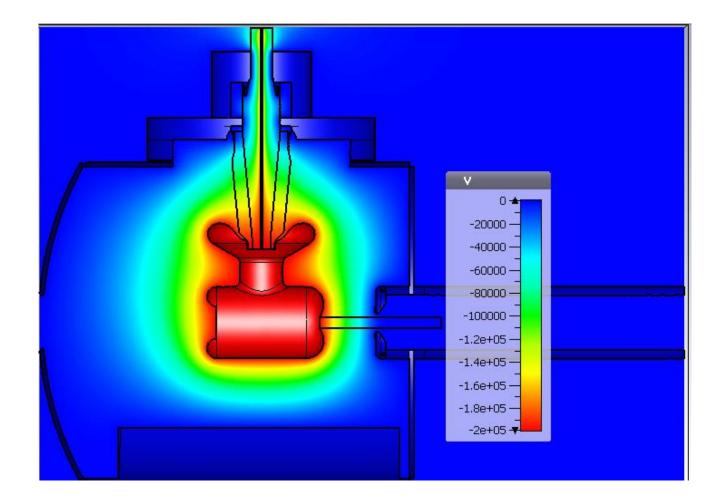
#### CST results: Potential – original shield



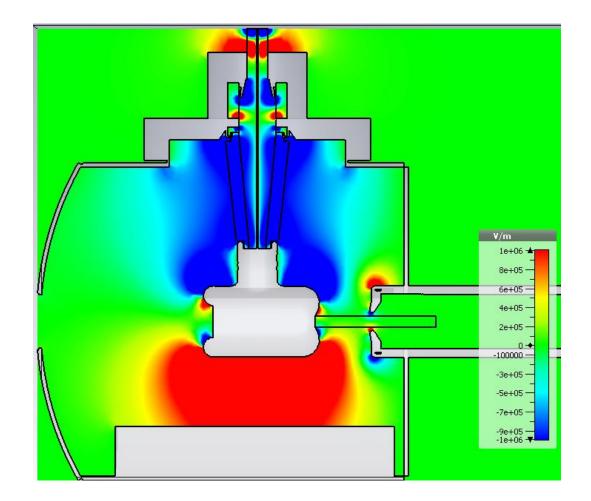
#### CST results: Potential – Shield 3



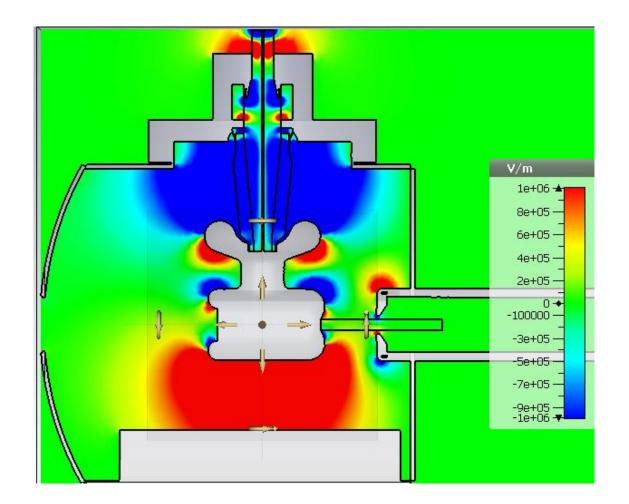
#### CST results: Potential – Shield 4



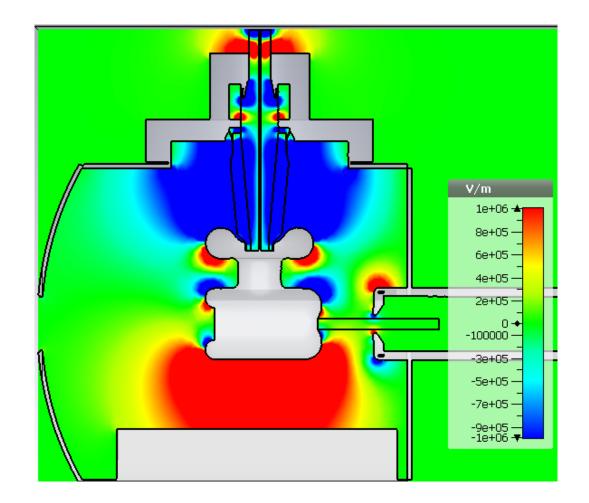
### Transverse electric field: No shield



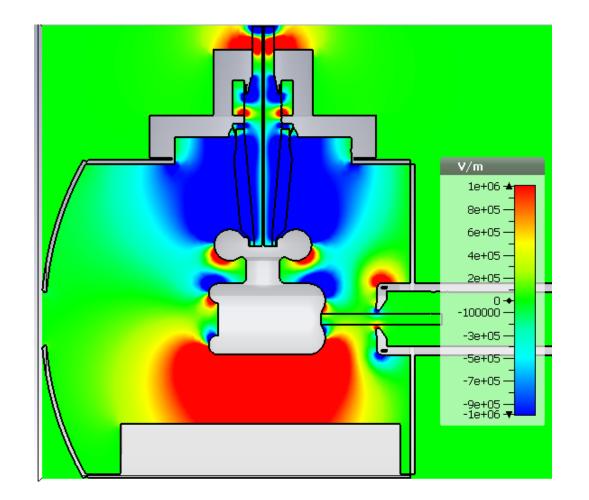
# CST results: Transverse electric field – original shield



### CST results: Transverse electric field – Shield 1

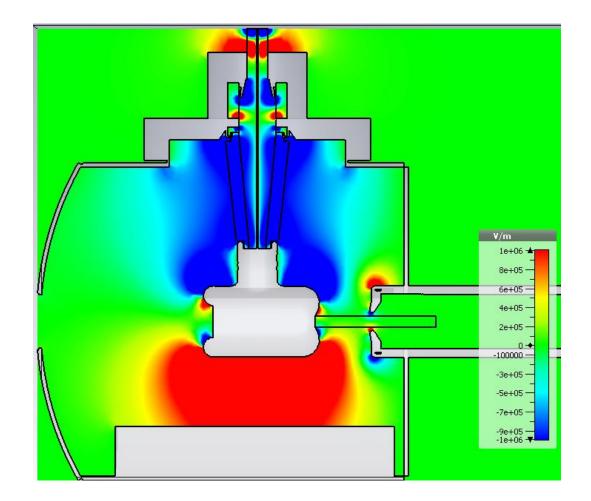


### CST results: Transverse electric field – Shield 2

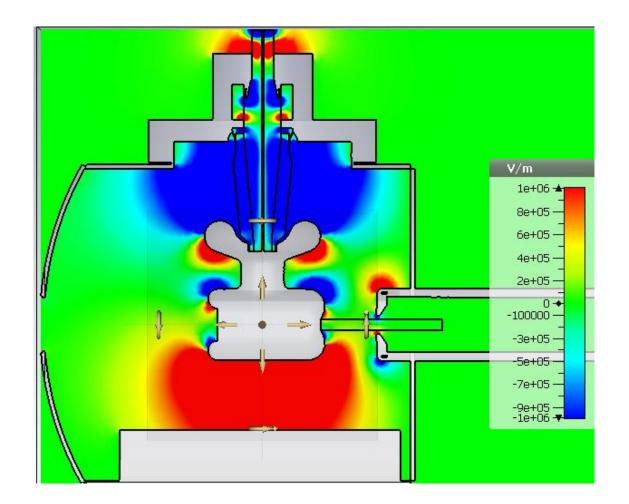


# Transverse electric field: Original vs Shield 3 vs Shield 4

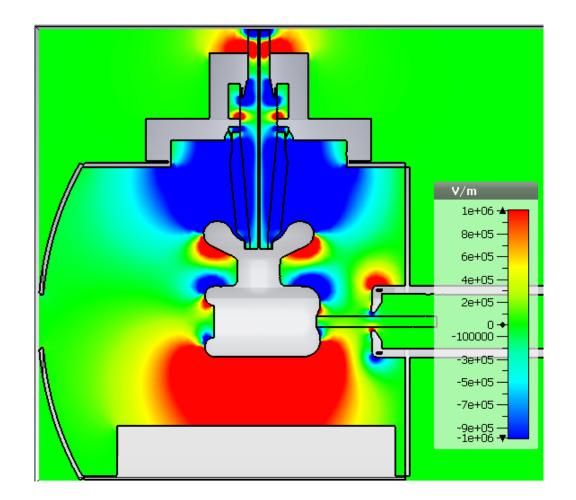
### Transverse electric field: No shield



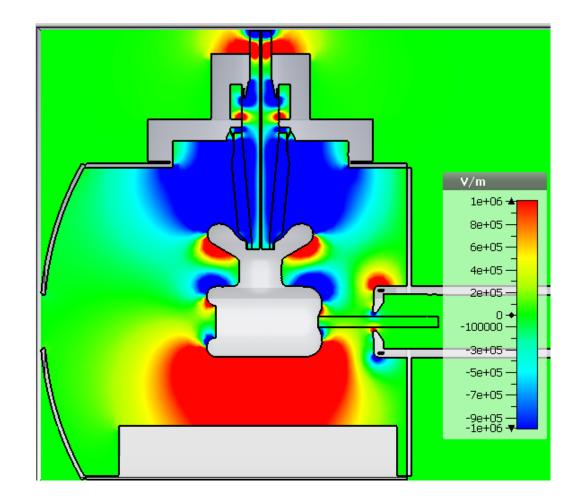
# CST results: Transverse electric field – original shield



### CST results: Transverse electric field – Shield 3

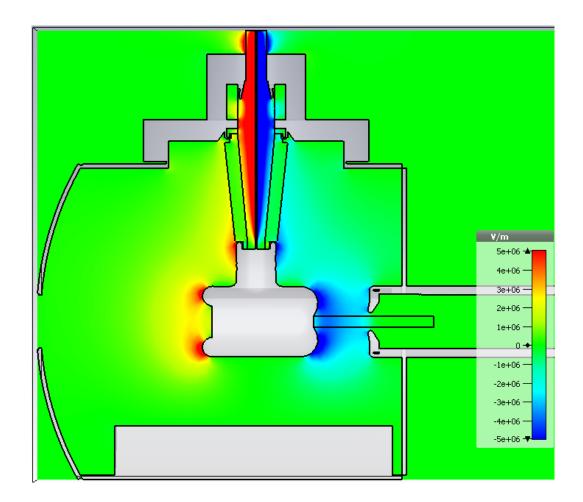


### CST results: Transverse electric field – Shield 4

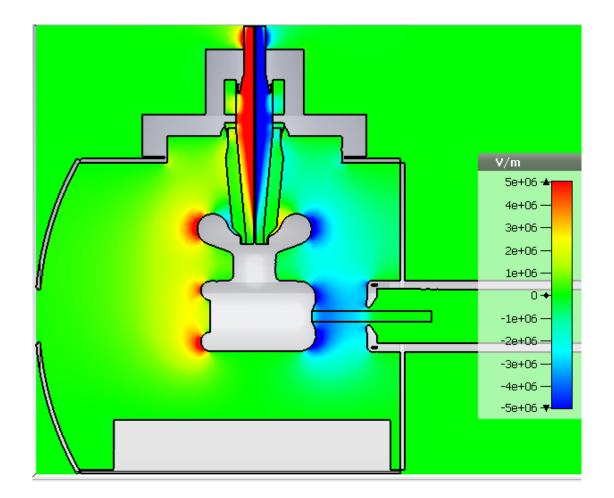


## Longitudinal electric field: Original vs Shield 1 vs Shield 2

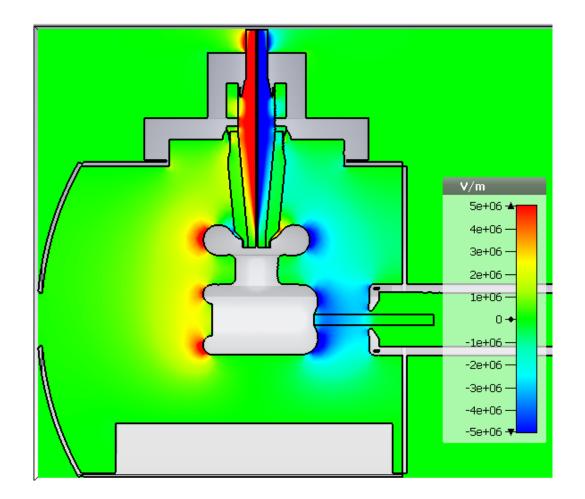
# CST results: Longitudinal electric field – No shield



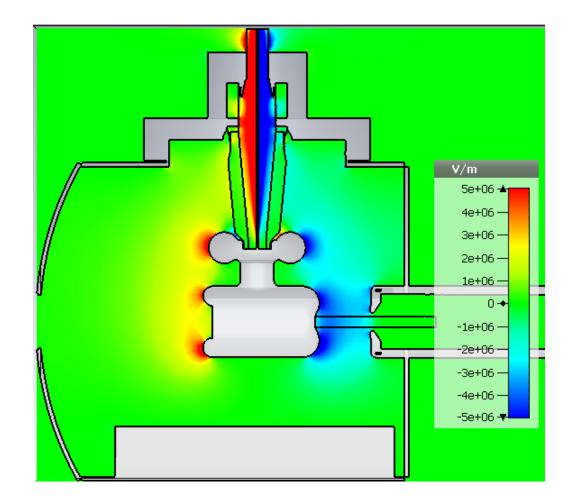
# CST results: Longitudinal electric field – original shield



## CST results: Longitudinal electric field – Shield 1

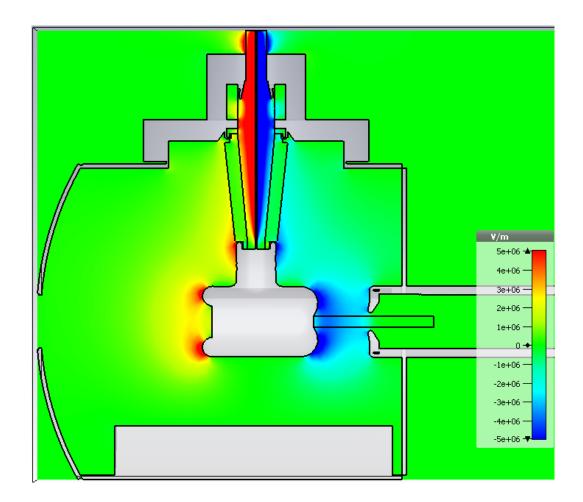


## CST results: Longitudinal electric field – Shield 2

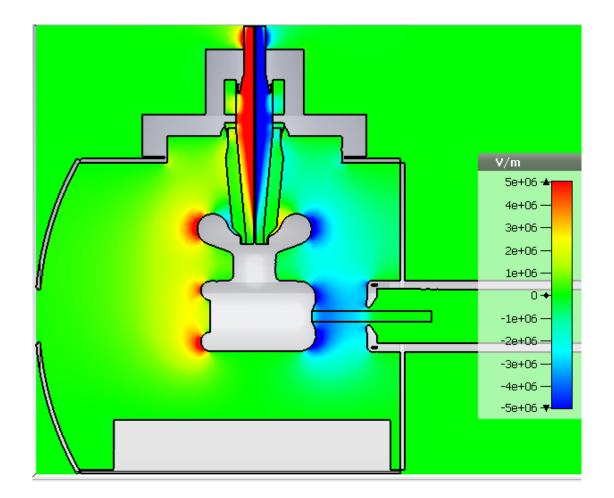


# Longitudinal electric field: Original vs Shield 3 vs Shield 4

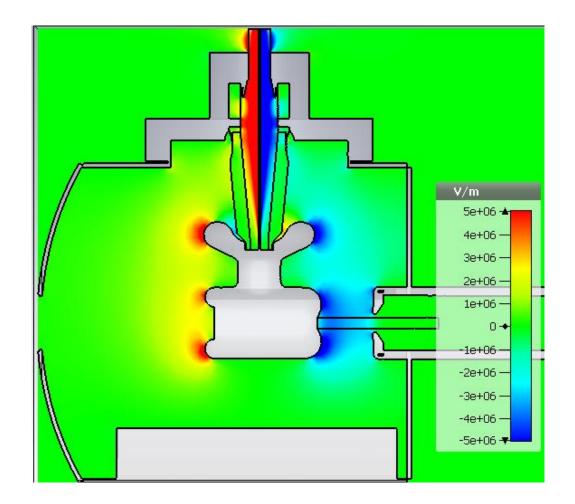
# CST results: Longitudinal electric field – No shield



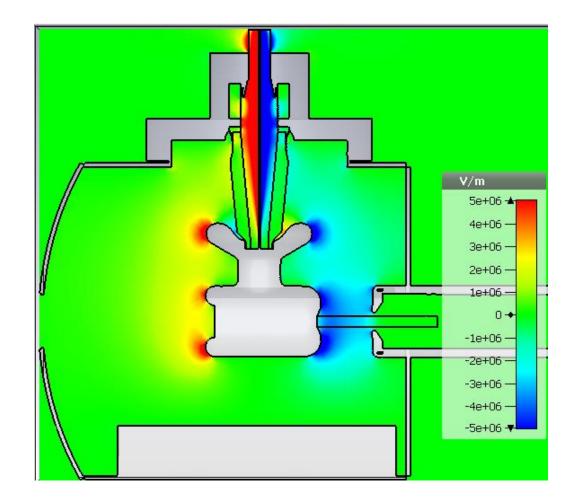
# CST results: Longitudinal electric field – original shield



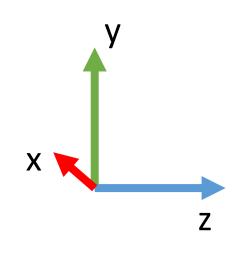
## CST results: Longitudinal electric field – Shield 3



## CST results: Longitudinal electric field – Shield 4



## CST frame of reference:



X goes into the page.

