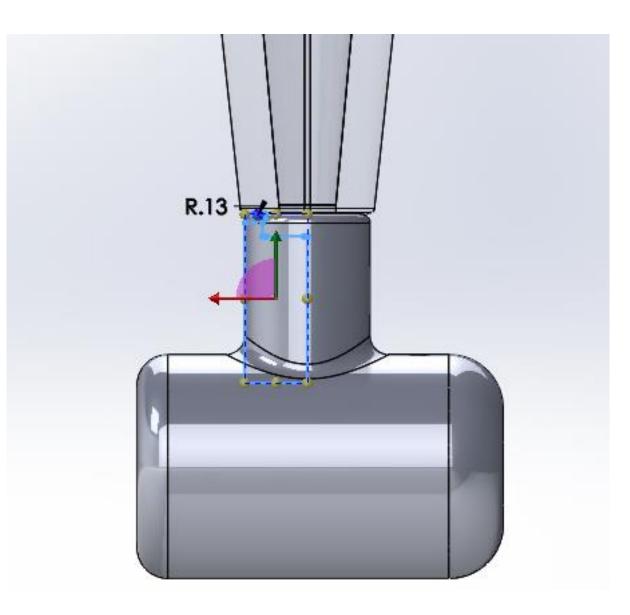
200 kV gun CST microwave studio simulations Shield modifications

Gabriel Palacios

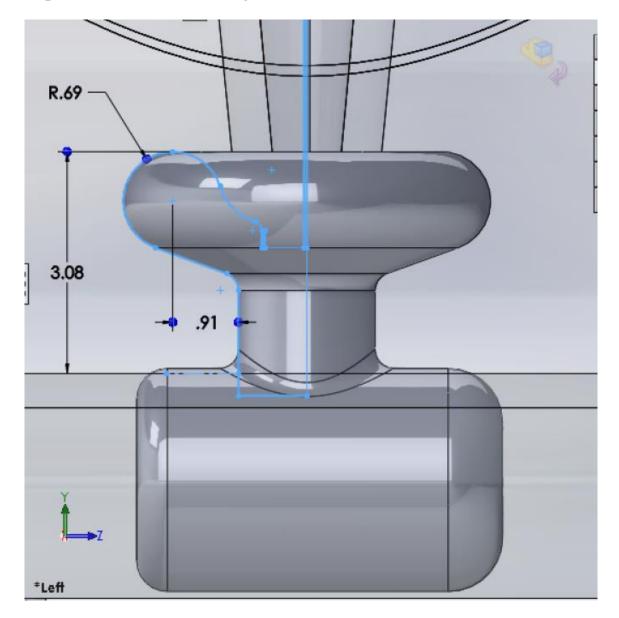
gabrielp@jlab.org 07/11/18

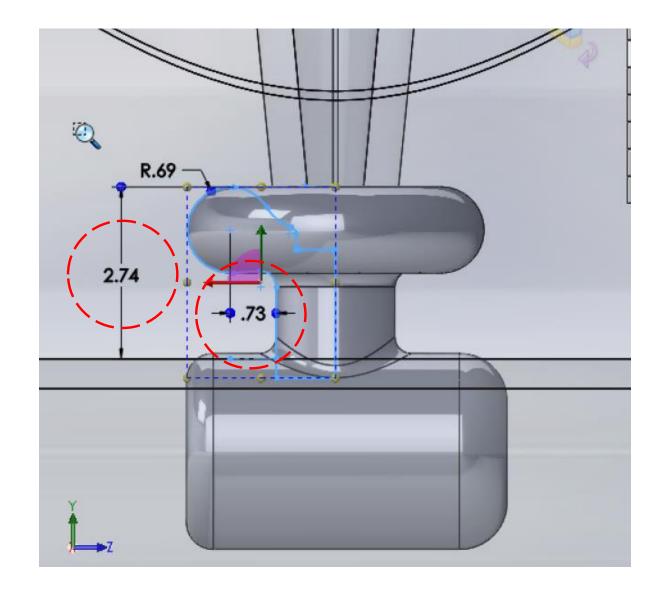
Summary

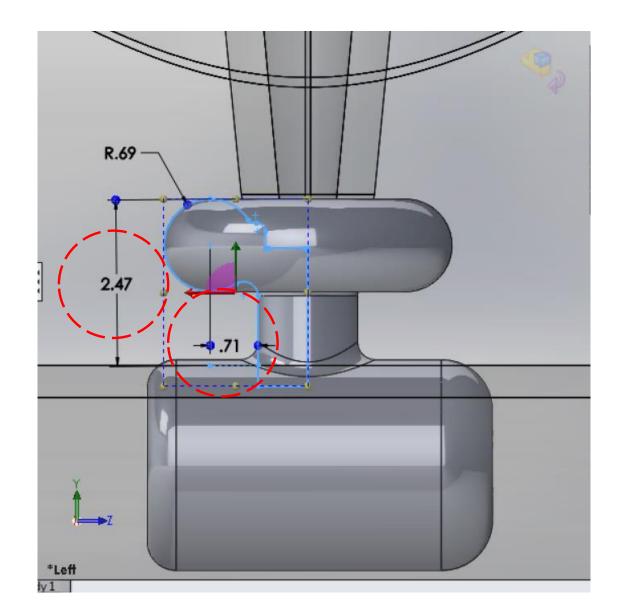
- Solidworks
 - Geometry modifications: 4 new shield proposals.
 - Shields 1 and 2 have decreasing height
 - Shields 3 and 4 have decreasing radius
- CST
 - Details of simulation
 - Electric field and potential plots and false color images
- Additional slides

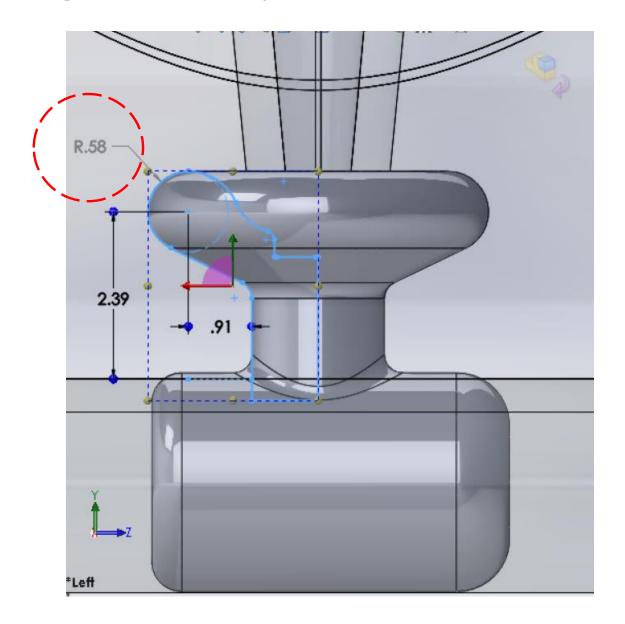


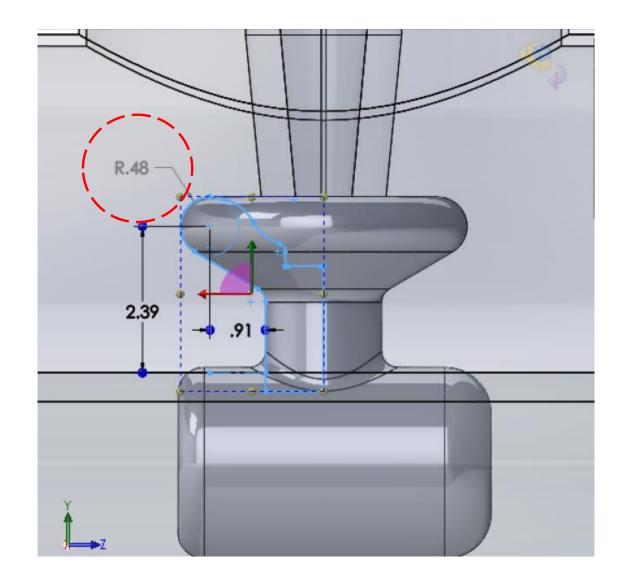
Solidworks geometry modifications: Original

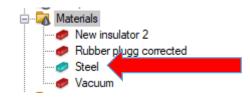








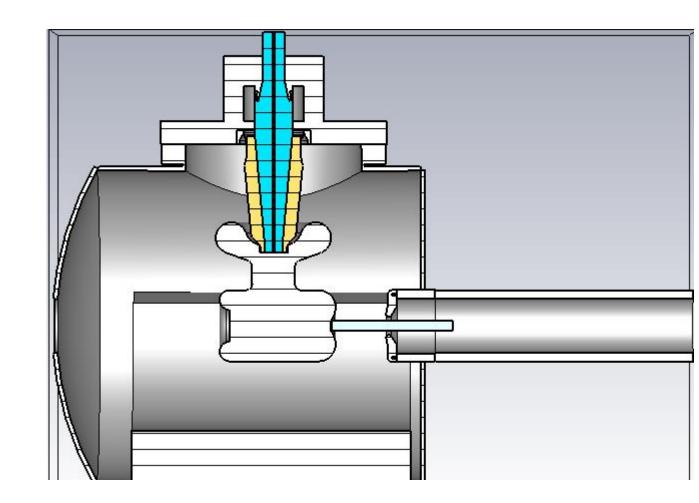


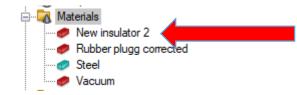


CST materials: PEC

 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 Material name: Steel	
Material folder:	
Туре:	
PEC 🗸	Coating
Epsilon:	Mu:
Color	0% Transparency 100%

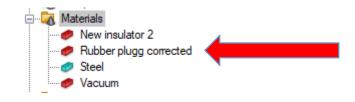




CST materials: Insulator

- 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 General Conductivity Dispersion Thermal Mechanics Density General properties 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] 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]

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

Materials New insulator 2 Rubber plugg corrected Steel Vacuum

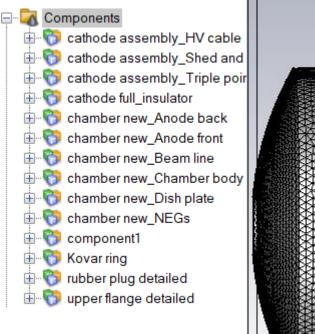
CST materials: vacuum

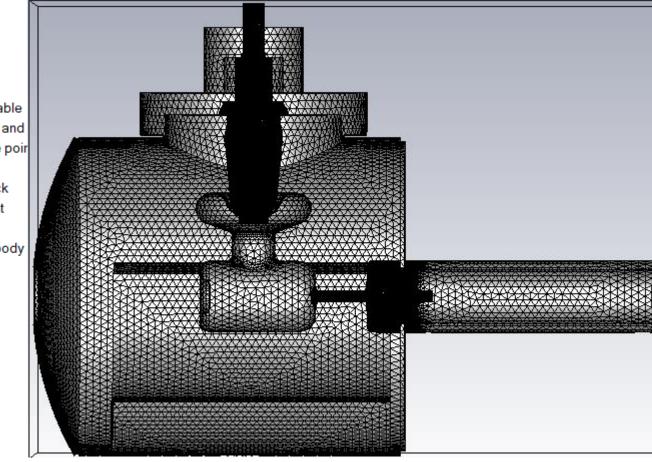
- For vacuum cylinder and surroundings.
- ε=1.0
- $\sigma = 0 [S/m]$

0-0[3/11]				
Material Parameters: Vacuum	X Material Parameters: Vacuum	×		
Problem type: Default ✓ General Conductivity Dispersion Thermal Mechanics Density	Problem type: Default General Conductivity Dispersion Thermal Mechanics Electric conductivity Magnetic condu		2	
General properties Material name: Vacuum Material folder:	El. conductivity: S/m	tivity: 1/Sm d Parameters		
Type: Nomal V Nonlinear Prop Epsilon: Mu: 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] Fmin: 0 Fmax: 1e+09			

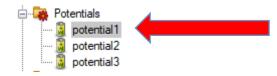
CST mesh:

- 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.



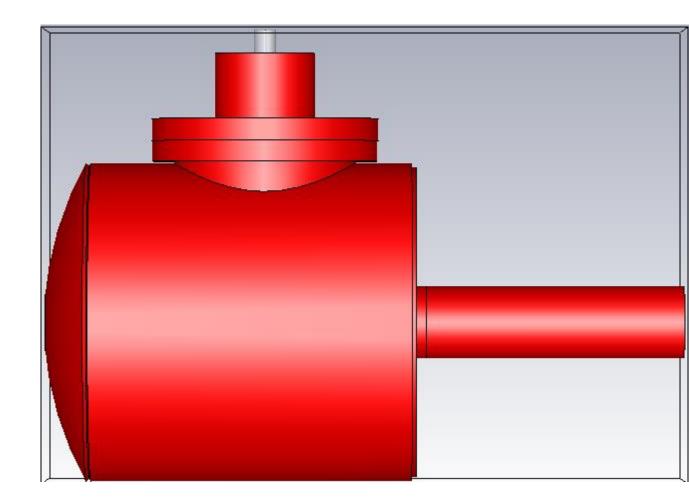


CST simulation: Potential



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

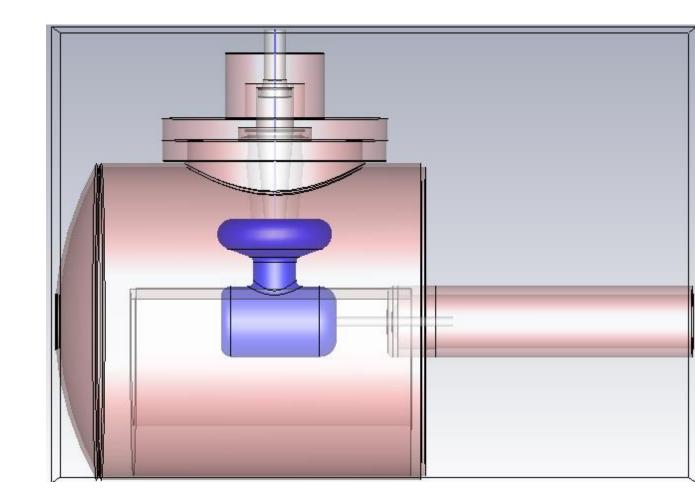
Edit Potential		×
Name: potential1		ОК
Potential value:		Cancel
0	v	Help
Phase:		
0	deg	
Type		



CST simulation: Potential

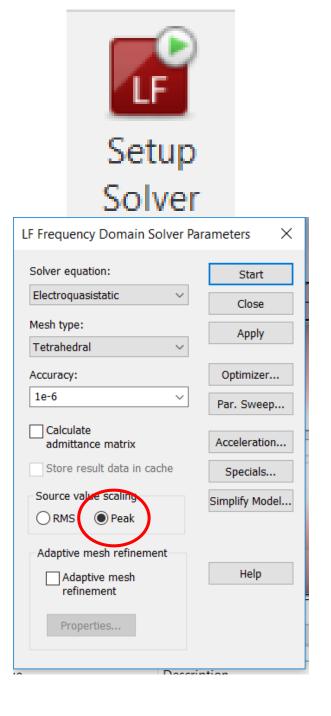


 Cathode electrode (including Pierce geometry), shield and high voltage cable at -200 kV.



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:

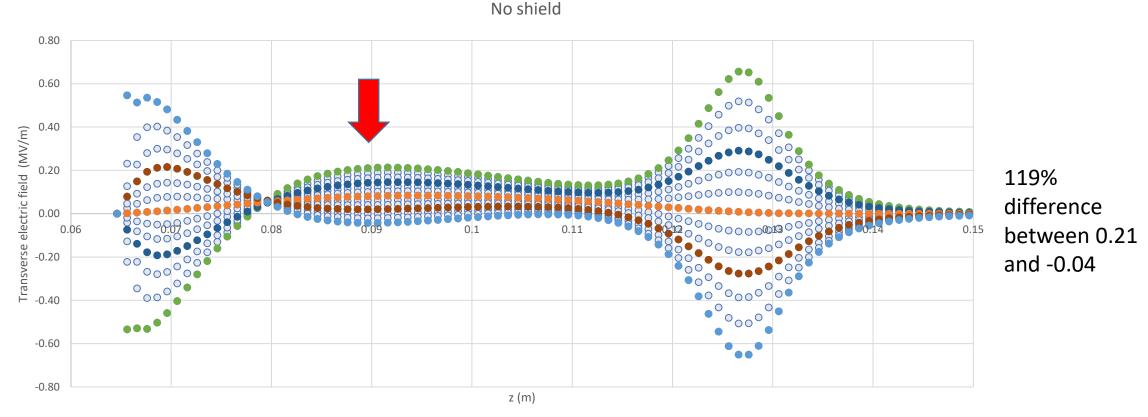
The data for the following plots was taken along the cathode anode gap as a function of the height (on the photocathode surface) varying from -6mm to 6mm.

on Plot		× × ×	
Label: Cut Line 2D 4	0.18		
▼ Data	0.14 -	HTT-	∽ , ∥ / -∥
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

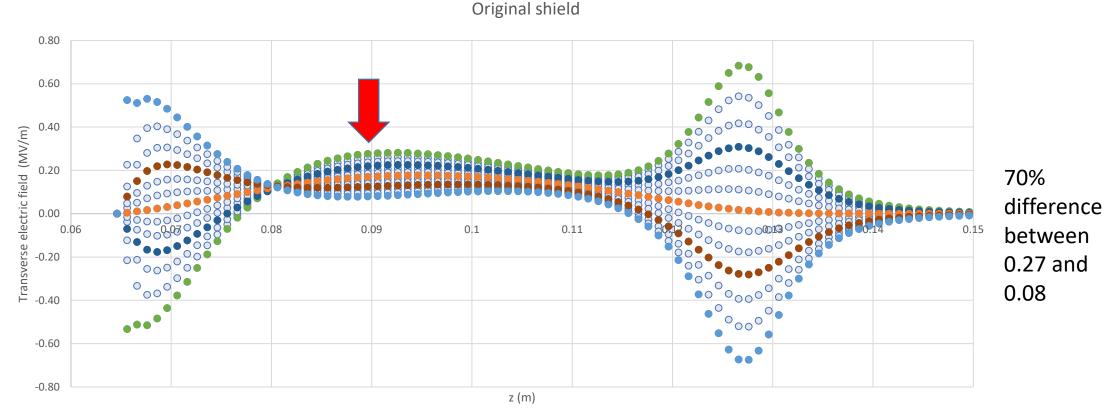
 As the Shield height is reduced, the max value in the middle region of the cathode-anode gap is reduced by 7% from 0.27 MV/m to 0.25 MV/m. The min value decreases in 50% from 0.08 MV/m to 0.04 MV/m. This min value is achieved by going upwards on the photocathode surface.

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

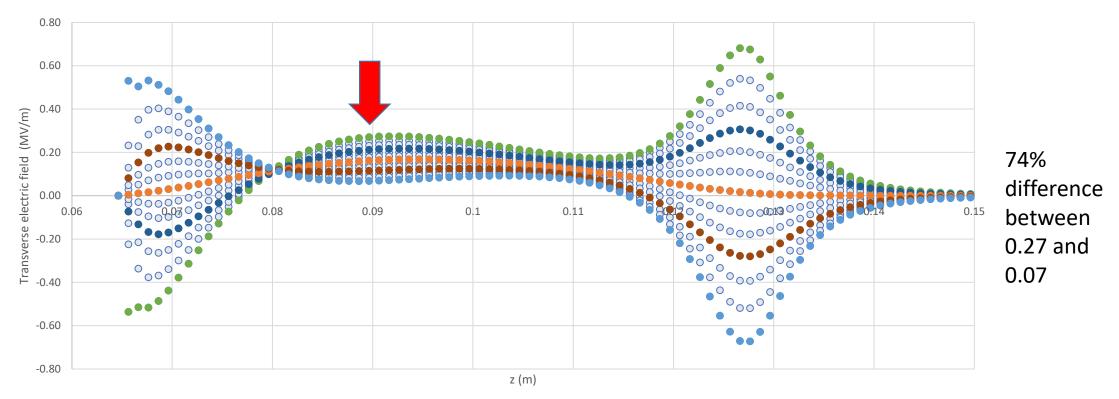


○ Field map ● y=-6mm ● y=-3mm ● y=0mm ● y=3mm ● y=6mm

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

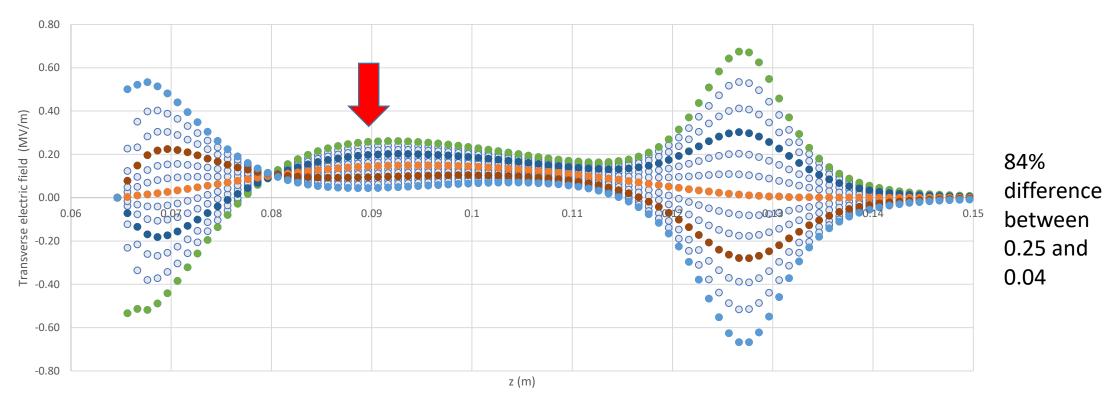


○ Field map • y=-6mm • y=-3mm • y=0mm • y=3mm • y=6mm

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

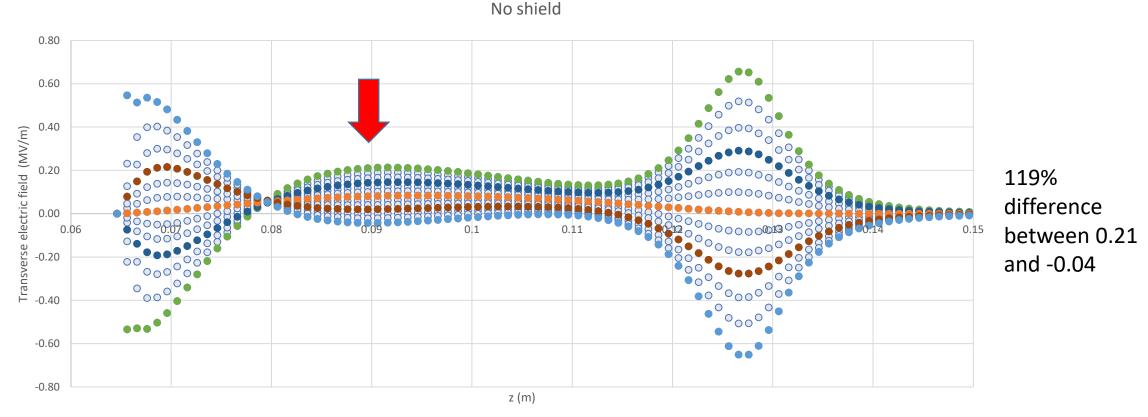


○ Field map • y=-6mm • y=-3mm • y=0mm • y=3mm • y=6mm

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

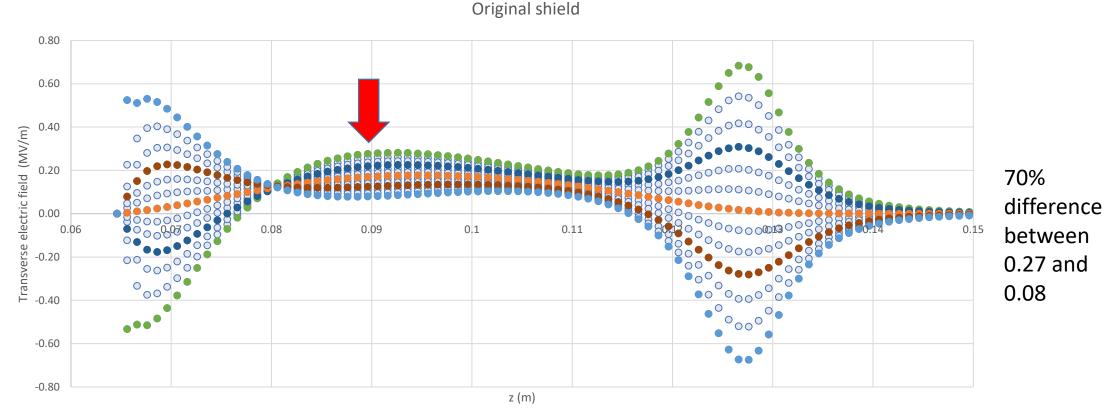
 As the Shield radius is reduced, the max value in the middle region of the cathode-anode gap is also reduced around 4% from 0.27 MV/m to 0.26 MV/m. The min value decreases in 37.5% from 0.08 MV/m to 0.05 MV/m. This min value is again achieved by going upwards on the photocathode surface.

CST results: Transverse electric field – No shield



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

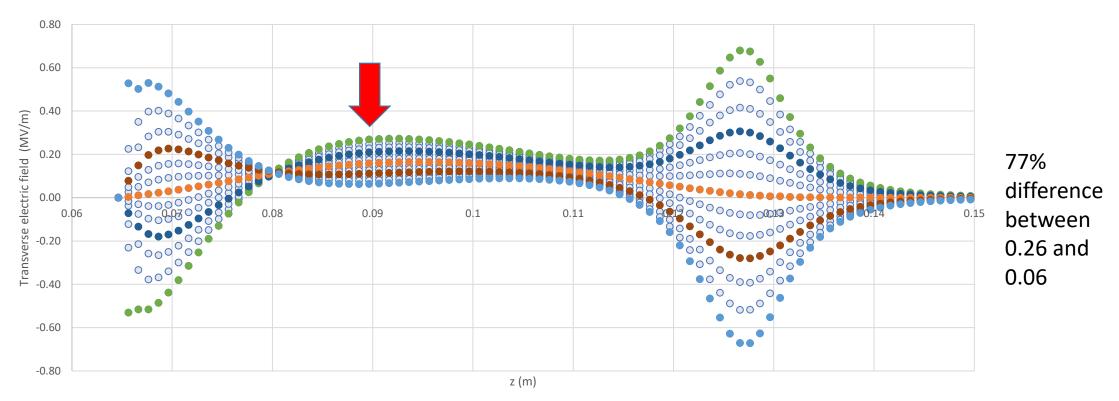
CST results: Transverse electric field – original shield



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

CST results: Transverse electric field – Shield 3

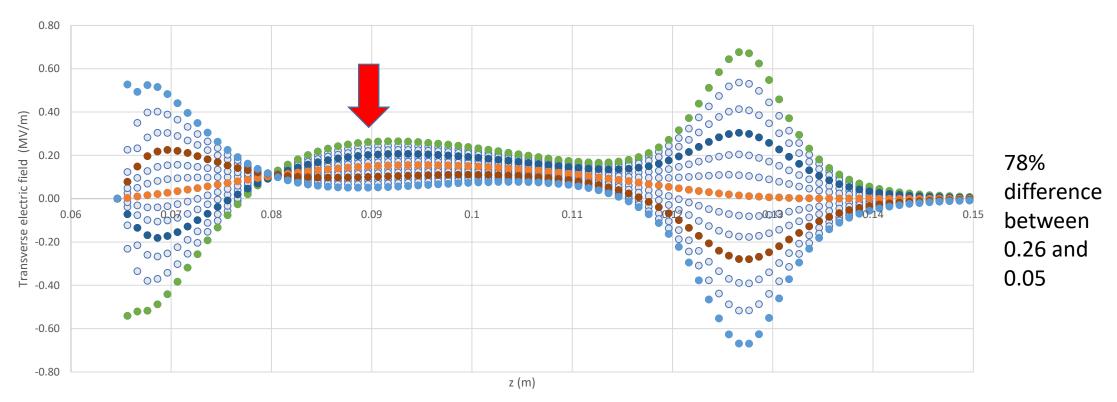
Shield 3



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

CST results: Transverse electric field – Shield 4

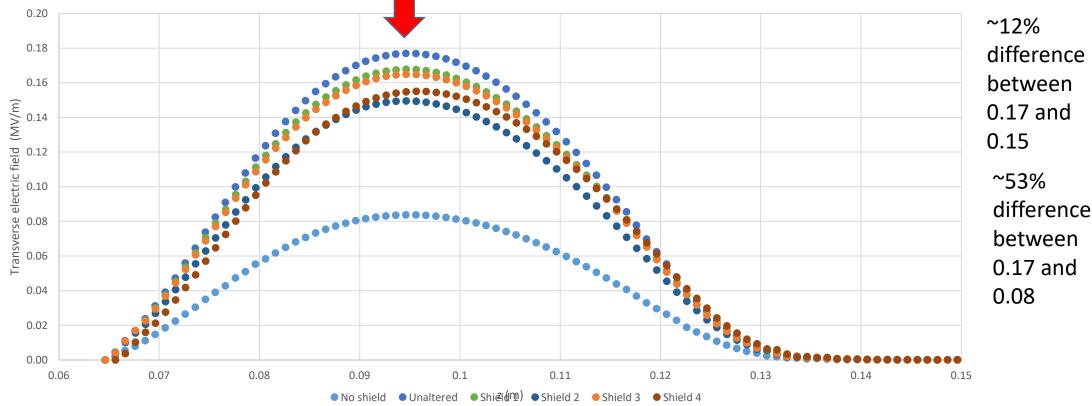
Shield 4



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

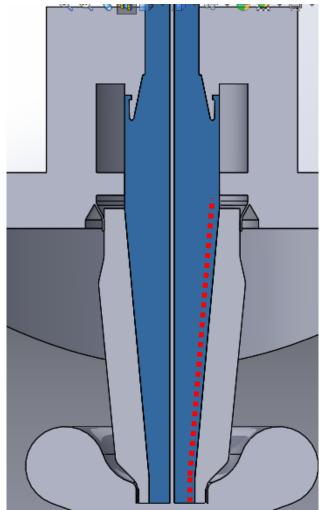
CST results: Transverse electric field – No shield vs Original vs all shields (1,2,3 & 4) at C-a gap center line

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



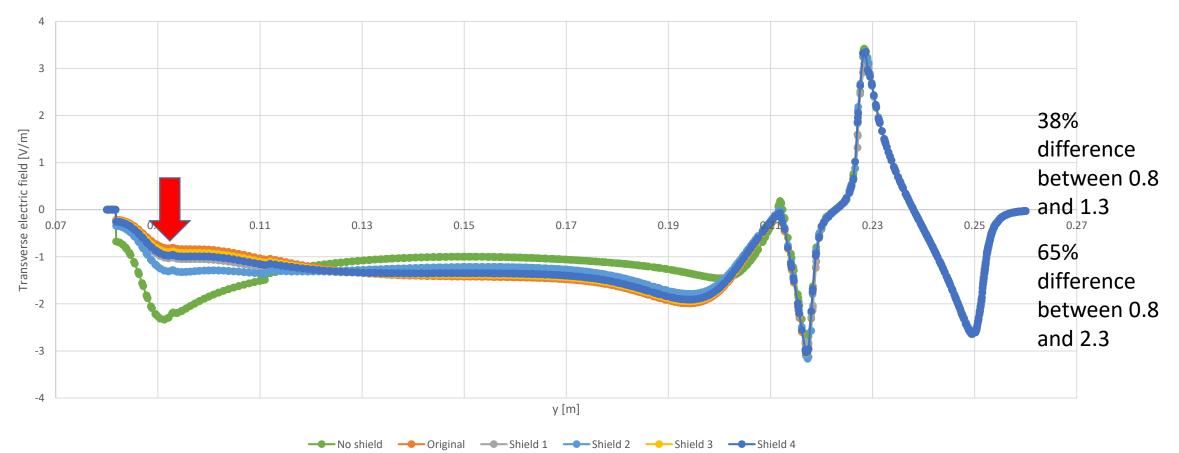
CST results: Transverse electric field – No shield vs Original vs all shields (1,2,3 & 4) at insulator interface

 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>



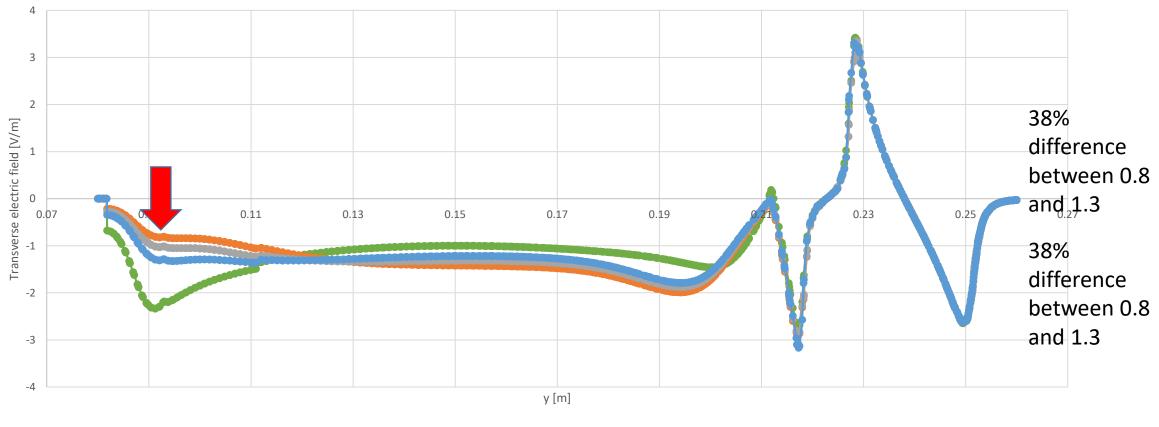
CST results: Transverse electric field – No shield vs Original vs all shields (1,2,3 & 4) at insulator interface

Different colors represent different shields.



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

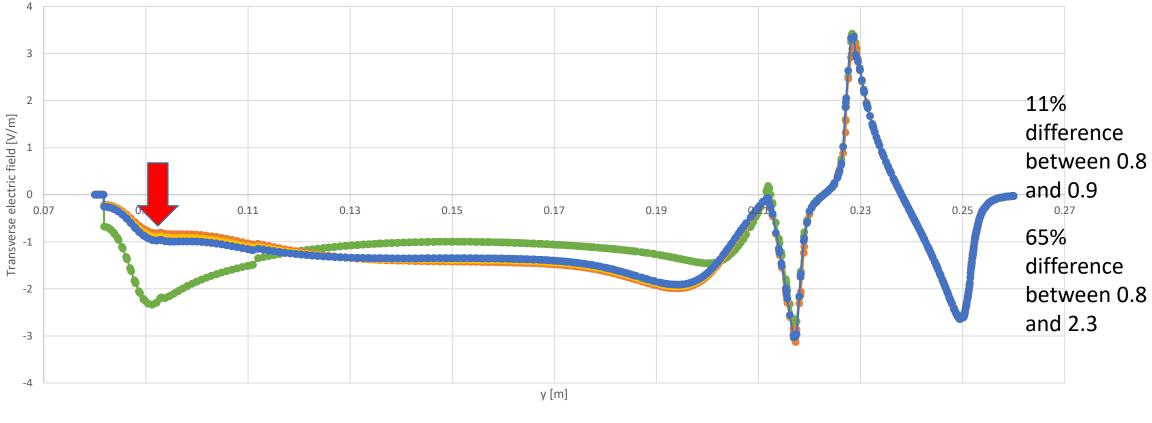
Different colors represent different shields.



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

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

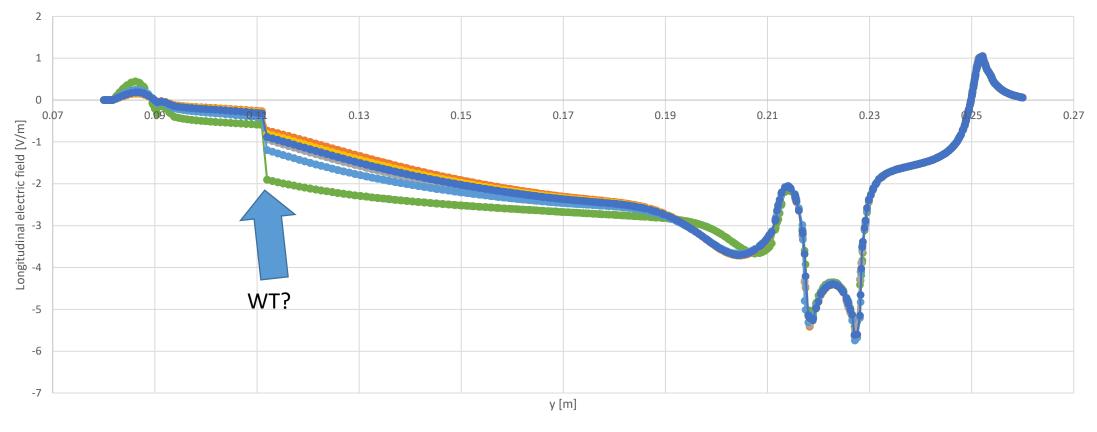
Different colors represent different shields.



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

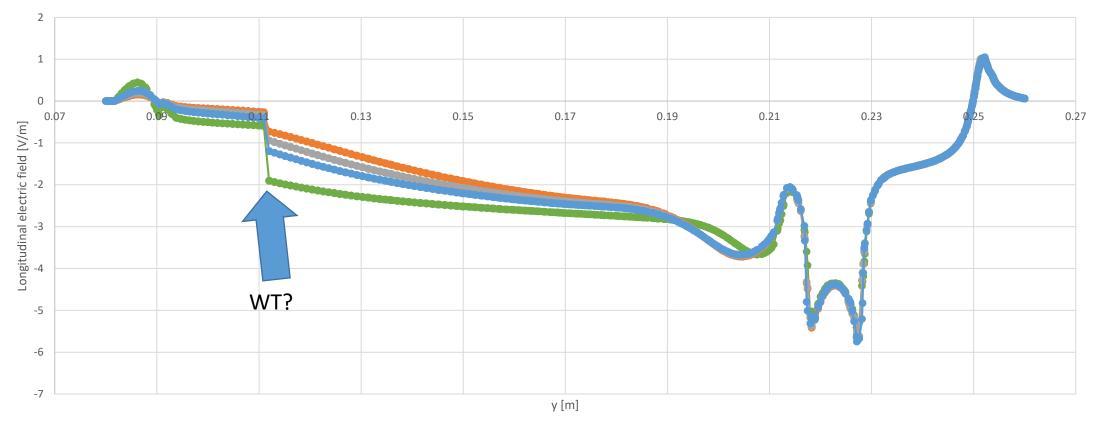
CST results: Longitudinal electric field – No shield vs Original vs all shields (1,2,3 & 4) at insulator interface

Different colors represent different shields.



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

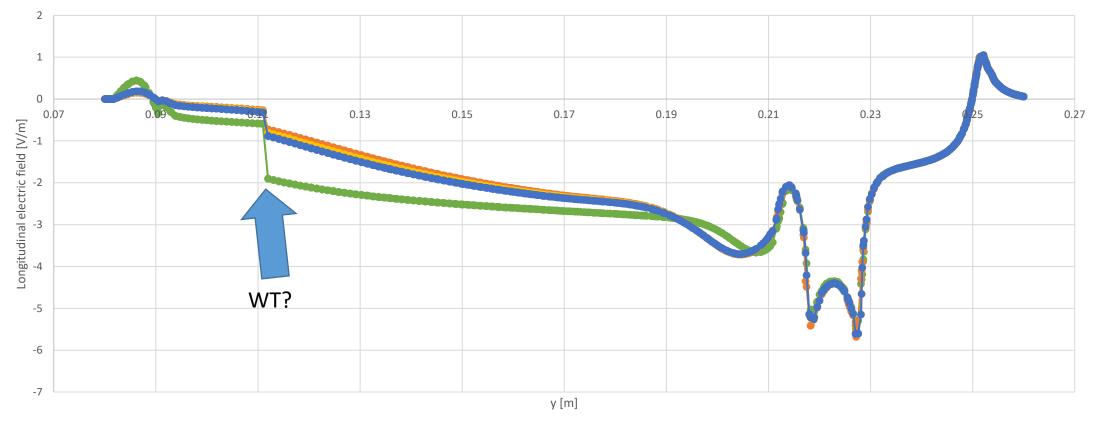
Different colors represent different shields.



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

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

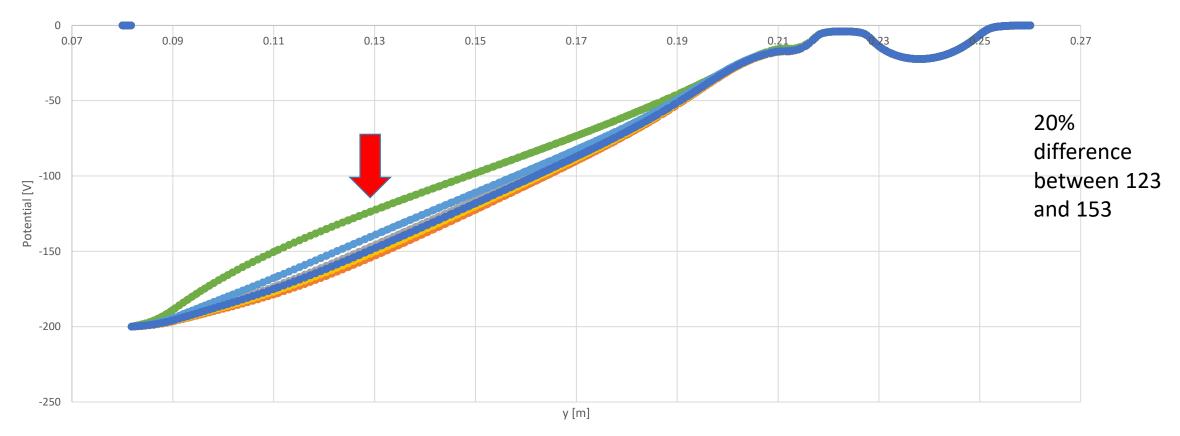
Different colors represent different shields.



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

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

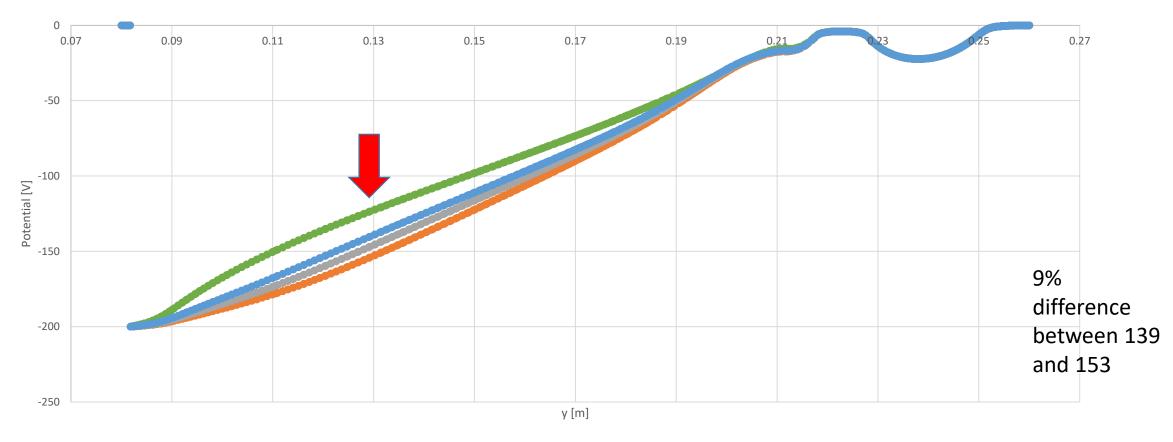
Different colors represent different shields.



● 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

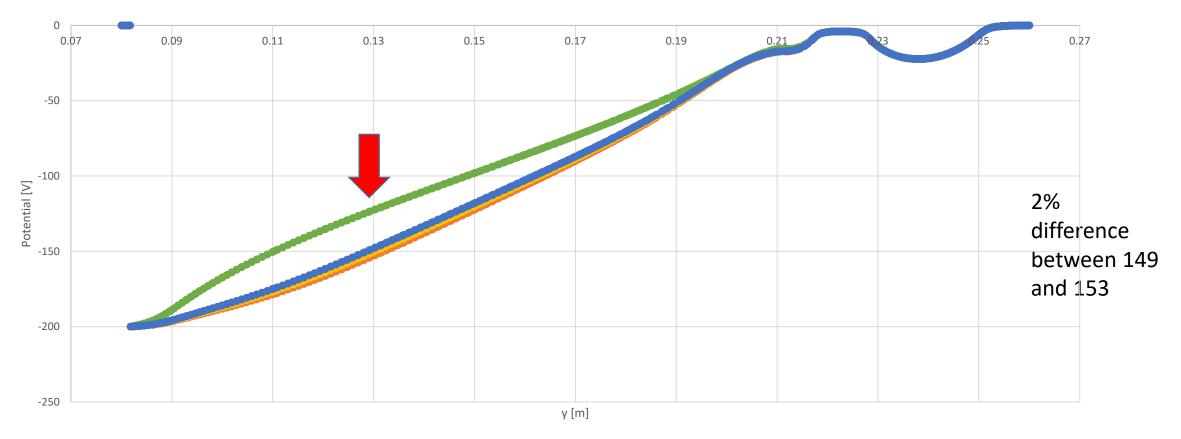
Different colors represent different shields.



● 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.

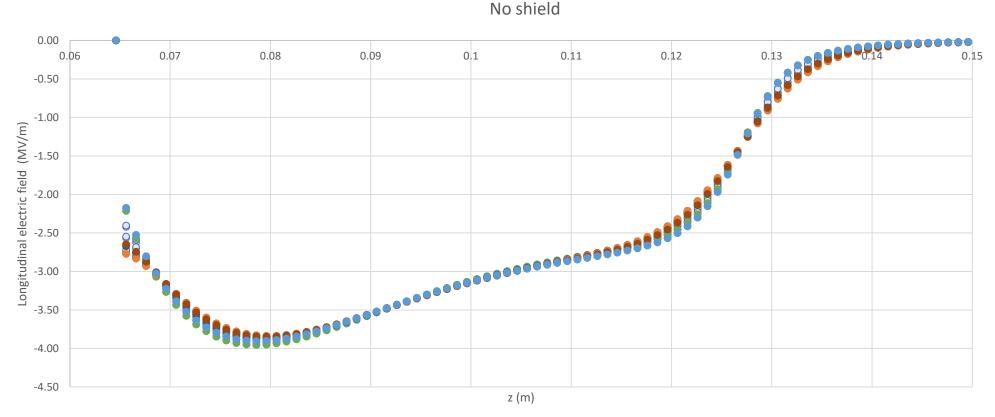


● No shield ● Original ● Shield 3 ● Shield 4

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.

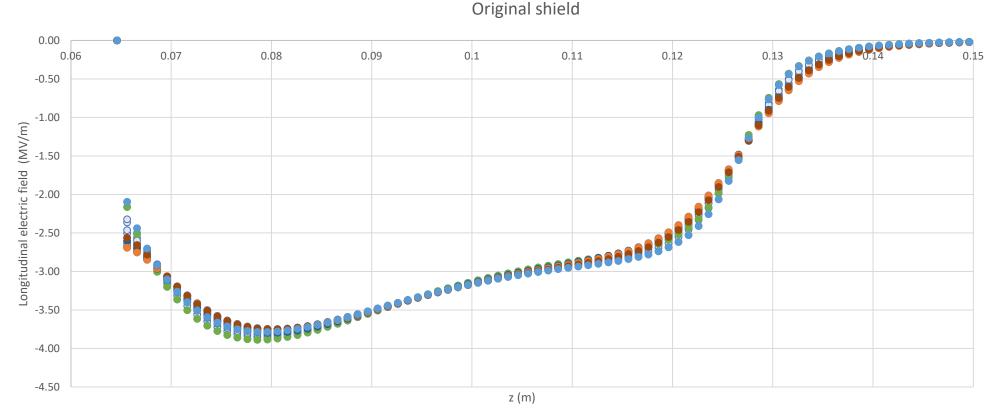
The gray data set is the whole field map. The different colors show how the longitudinal electric field changes as a function of height on the photocathode in the interval -6mm<y<6mm



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

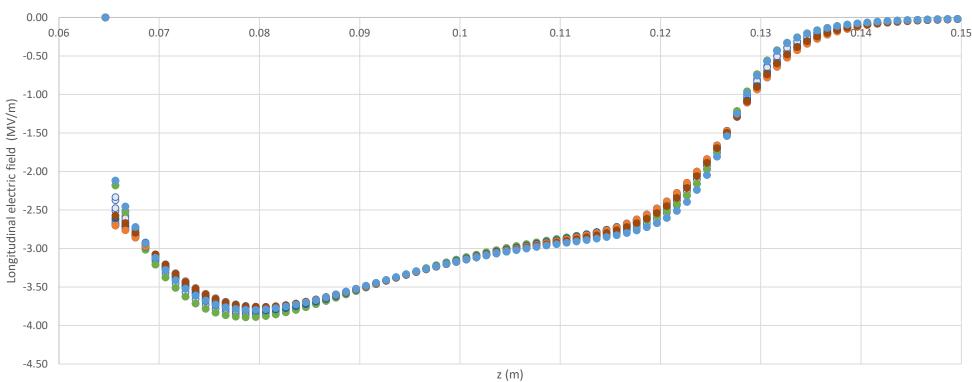
CST results: Longitudinal electric field – original shield

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

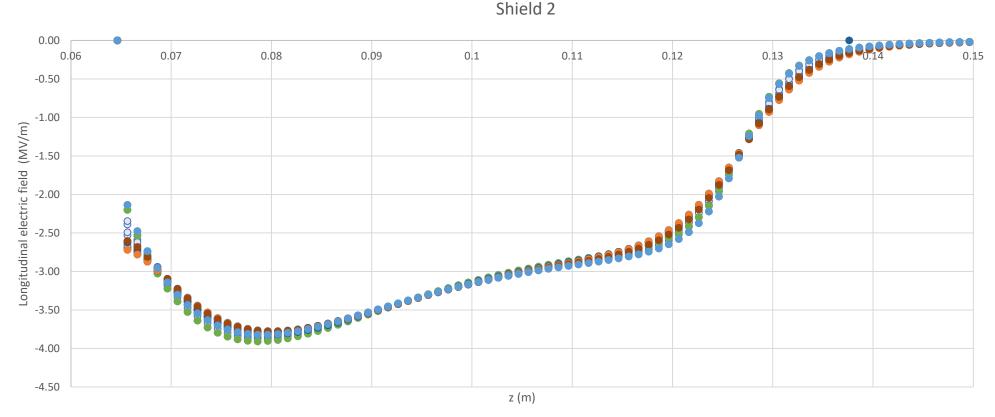
The gray data set is the whole field map. The different colors show how the longitudinal electric field changes as a function of height on the photocathode in the interval -6mm<y<6mm



Shield 1

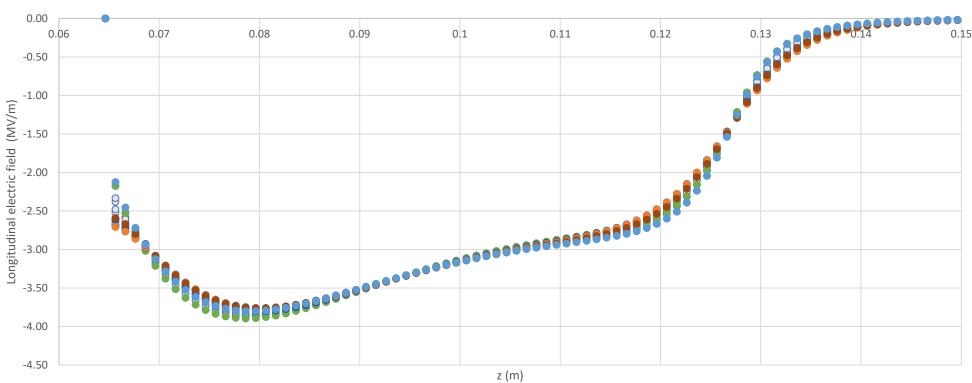
○ Field map ● y=-6mm ● y=-3mm ● y=0mm ● y=3mm ● y=6mm

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

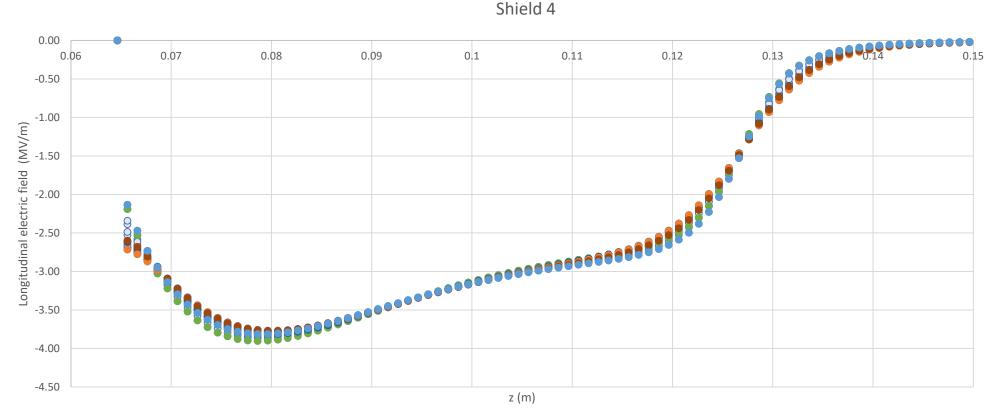
The gray data set is the whole field map. The different colors show how the longitudinal electric field changes as a function of height on the photocathode in the interval -6mm<y<6mm



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

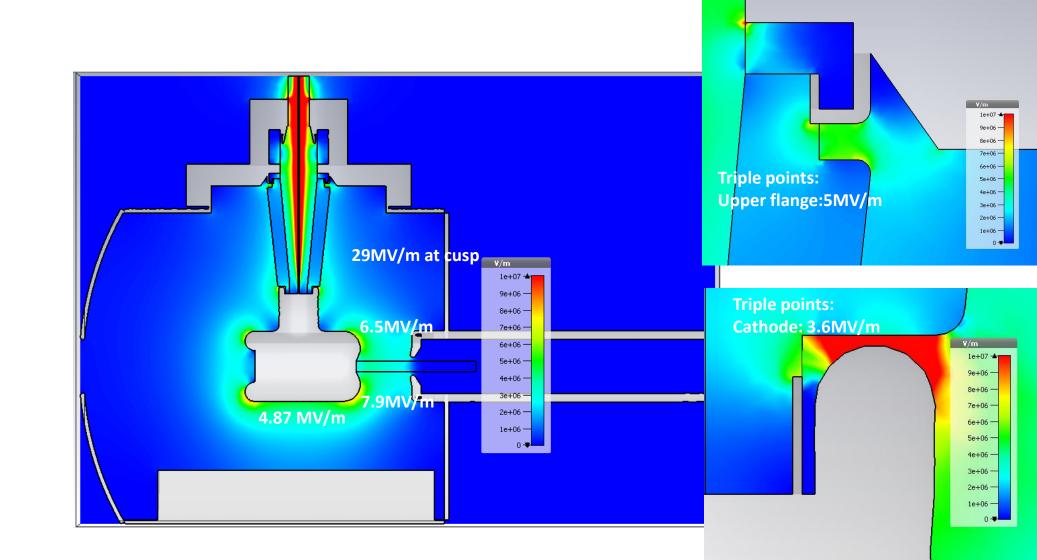


○ Field map • y=-6mm • y=-3mm • y=0mm • y=3mm • y=6mm

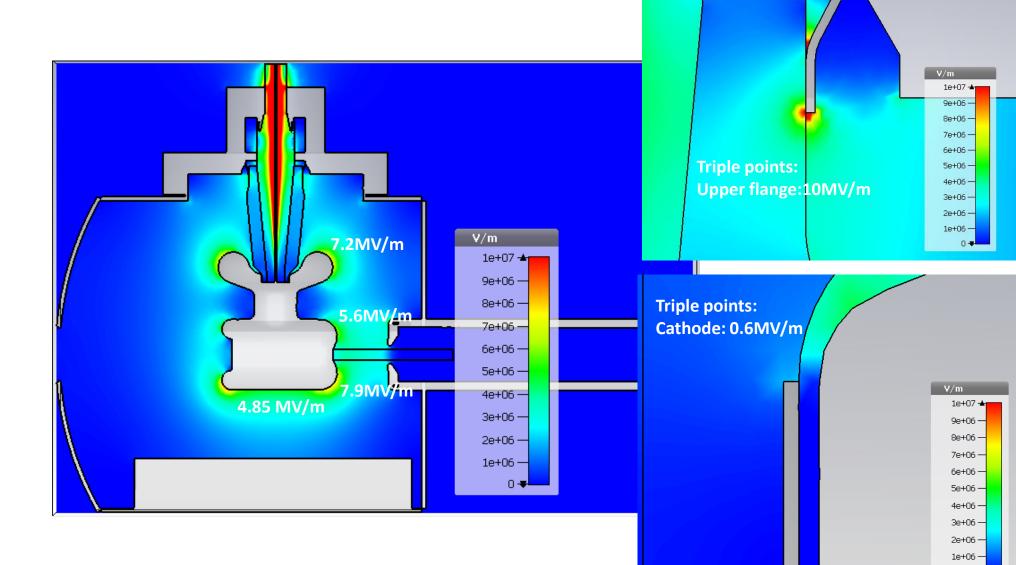
False color

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

CST results: Electric field norm- No shield

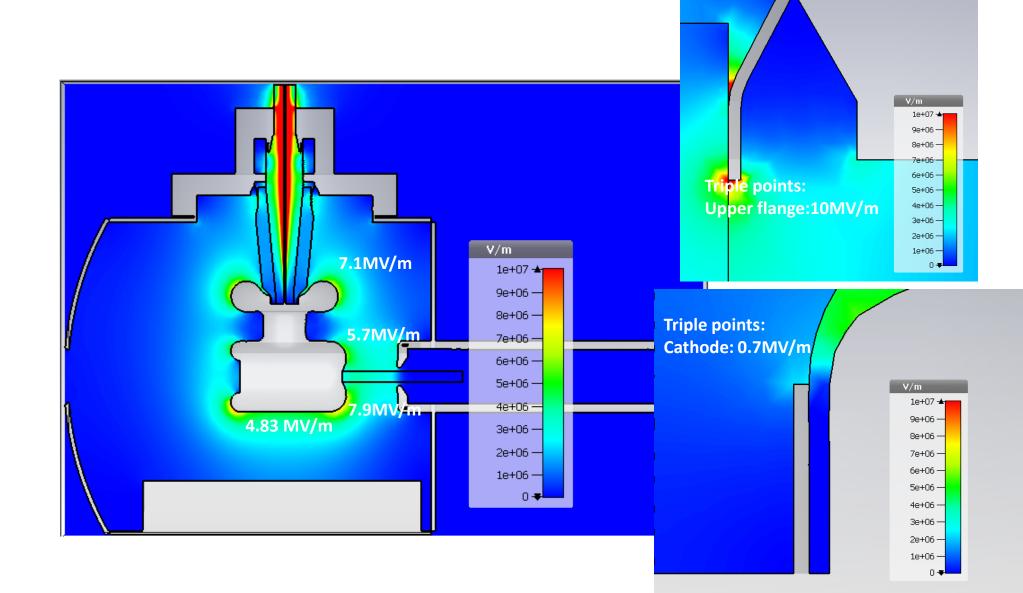


CST results: Electric field norm– original shield

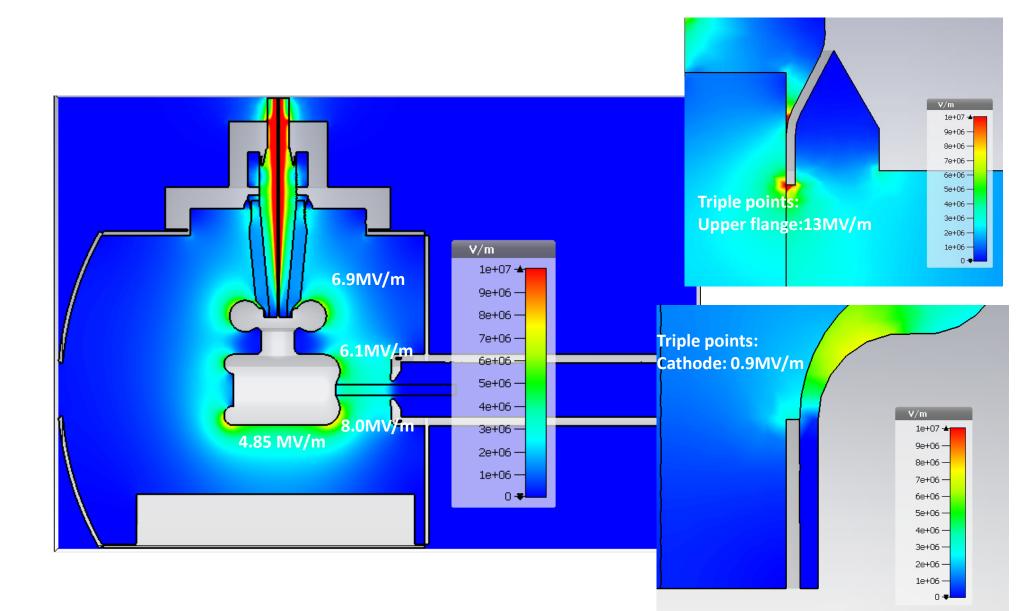


0.-

CST results: Electric field norm-Shield 1

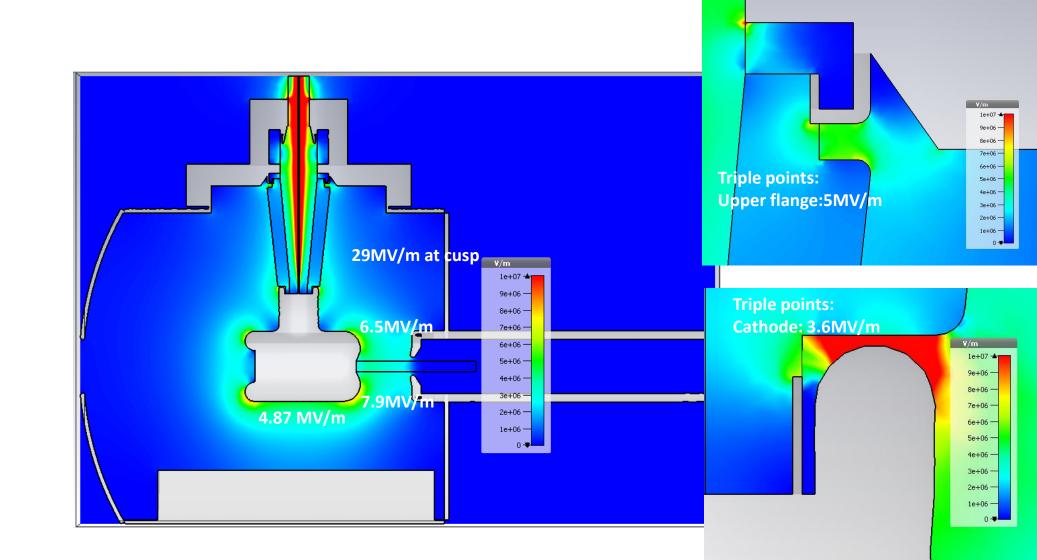


CST results: Electric field norm– Shield 2

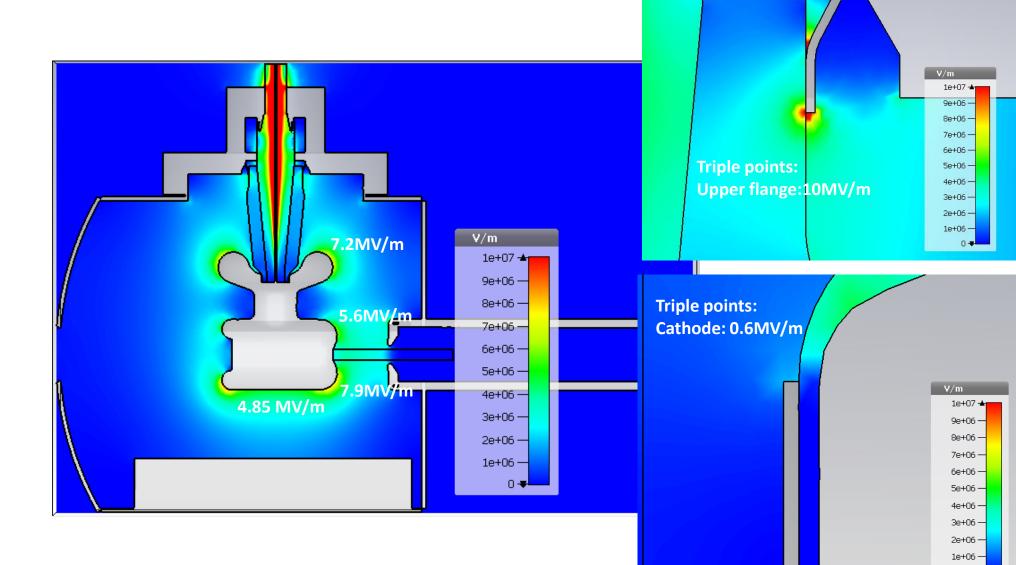


Electric field norm: No shield vs Original vs shields 3&4

CST results: Electric field norm- No shield

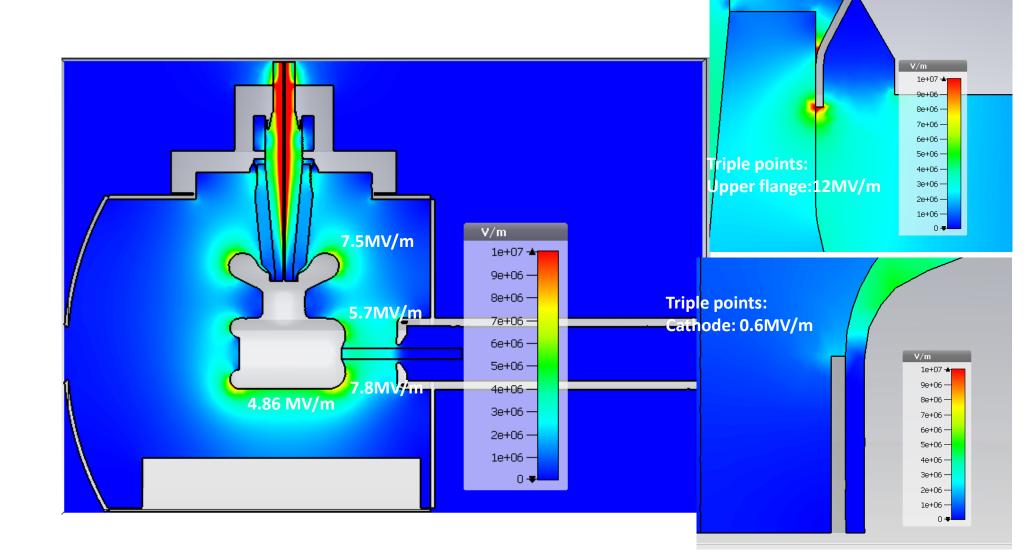


CST results: Electric field norm– original shield

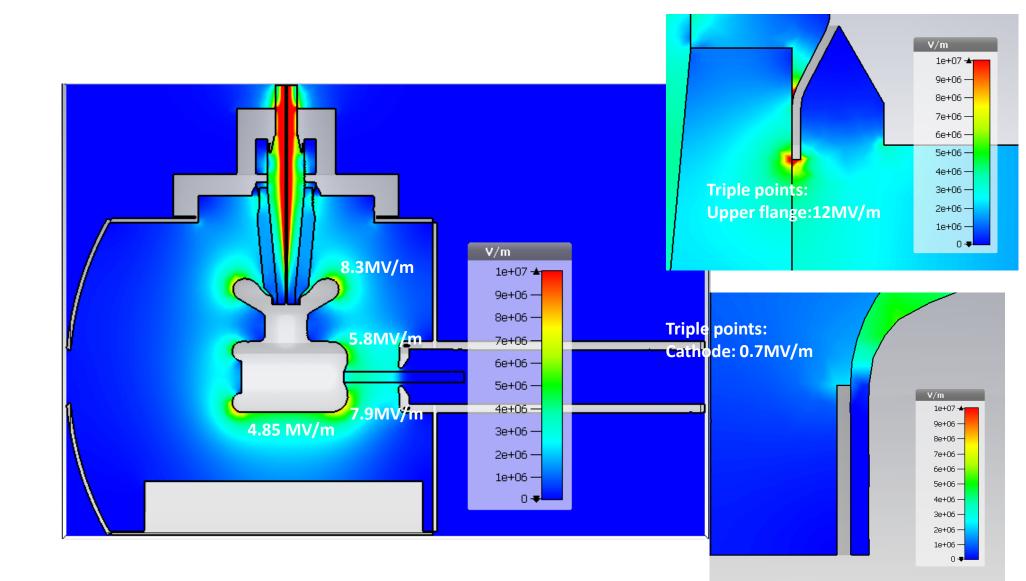


0.-

CST results: Electric field norm– Shield 3



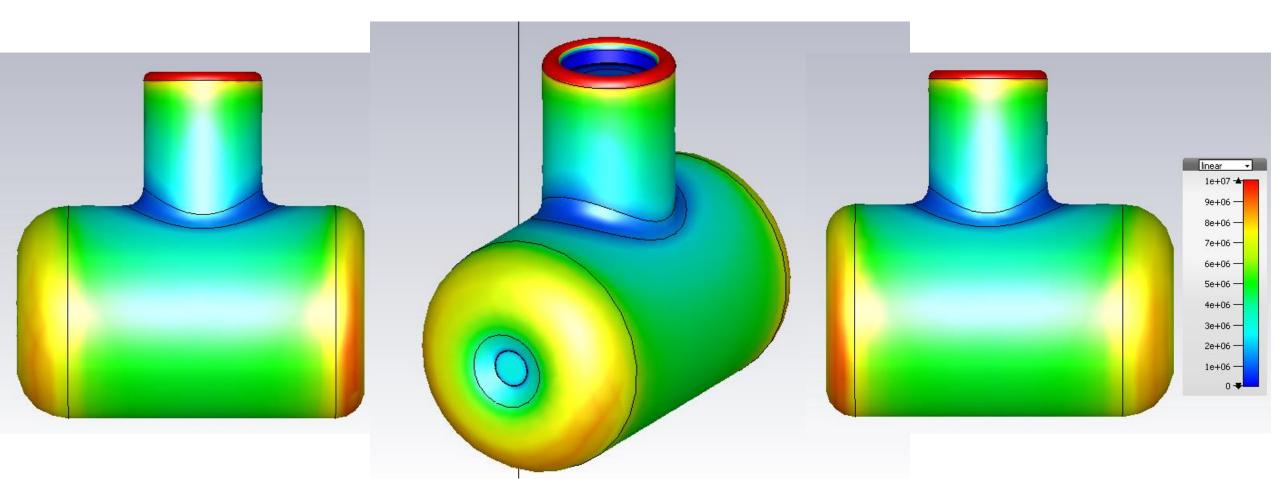
CST results: Electric field norm– Shield 4



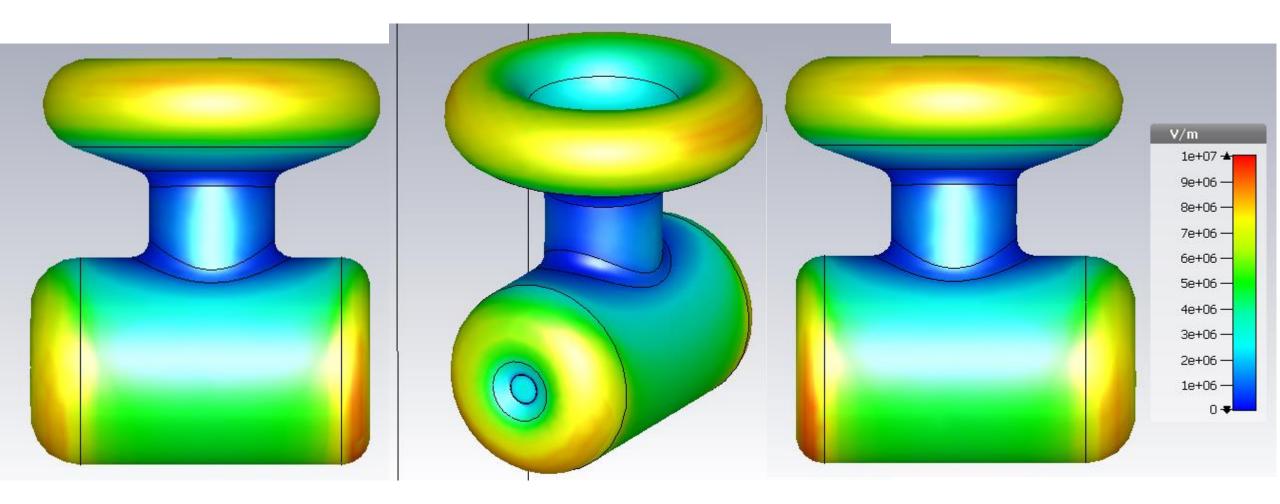
Electric field norm: No shield vs Original vs shields 1 vs shields 2

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

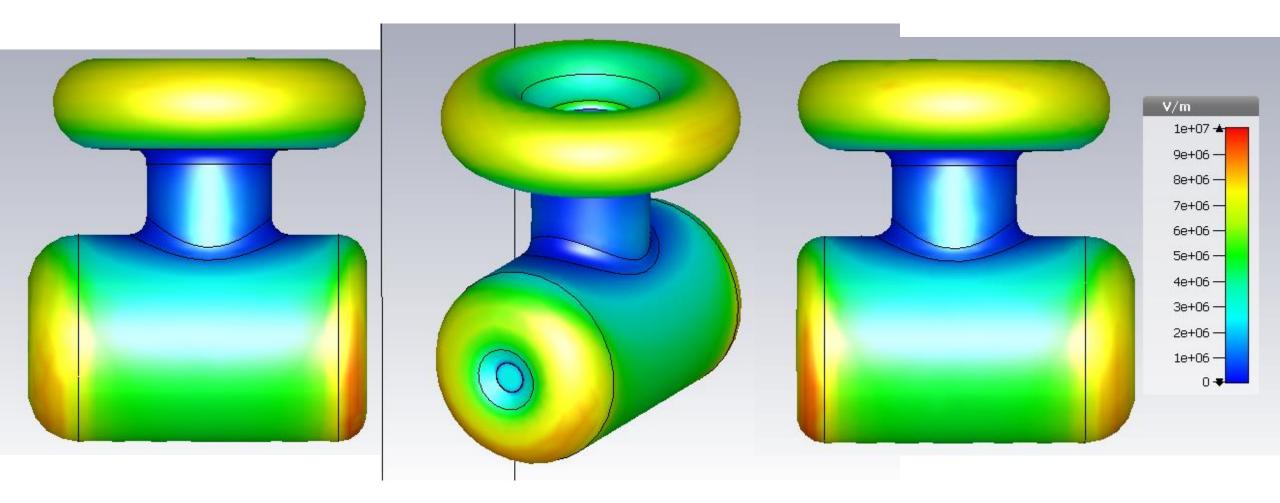
CST results: Electric field norm- No shield



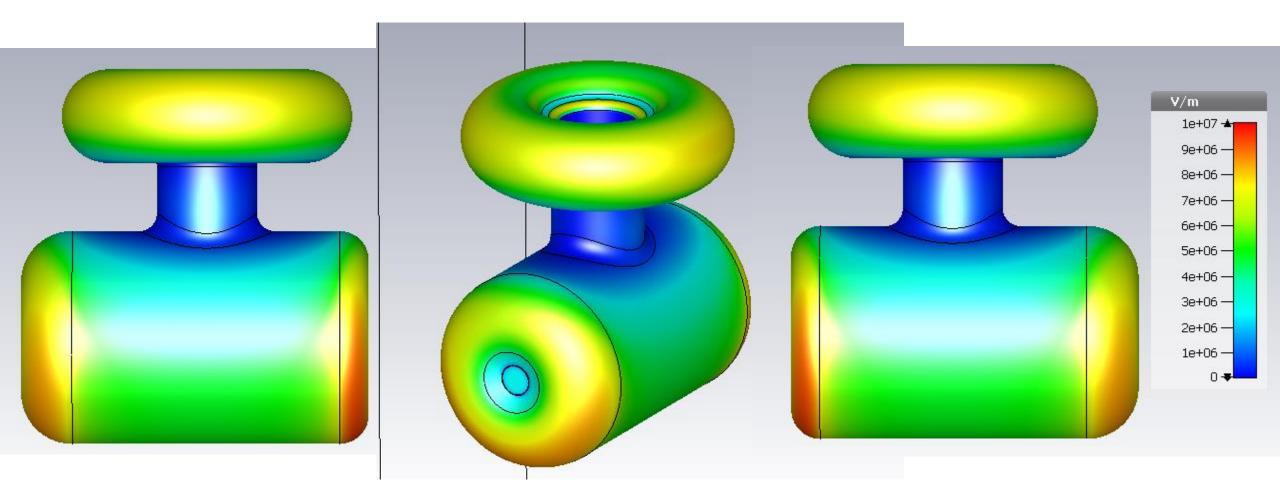
CST results: Electric field norm– Original



CST results: Electric field norm– Shield 1



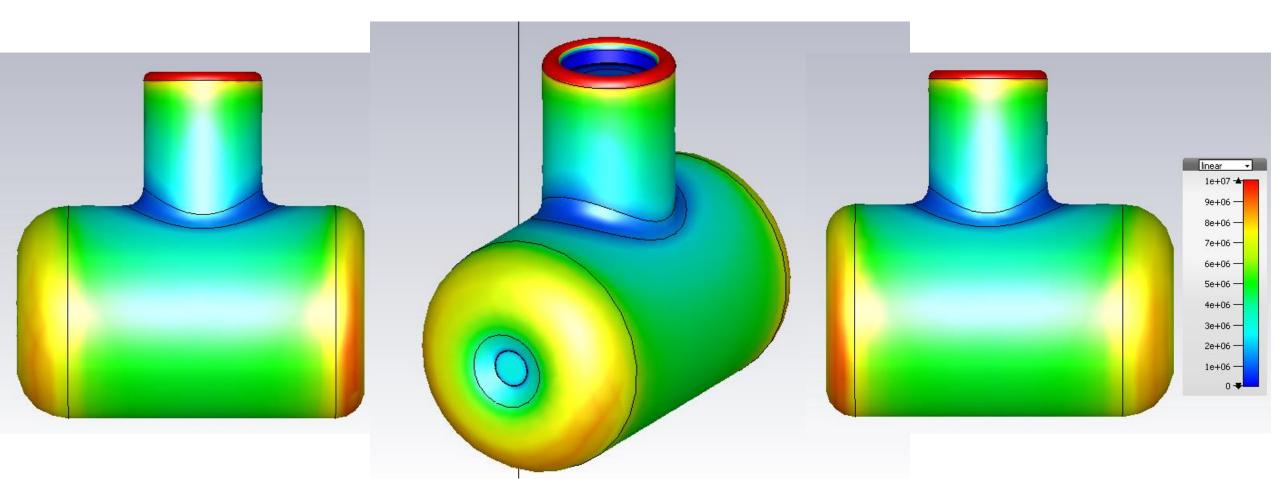
CST results: Electric field norm– Shield 2



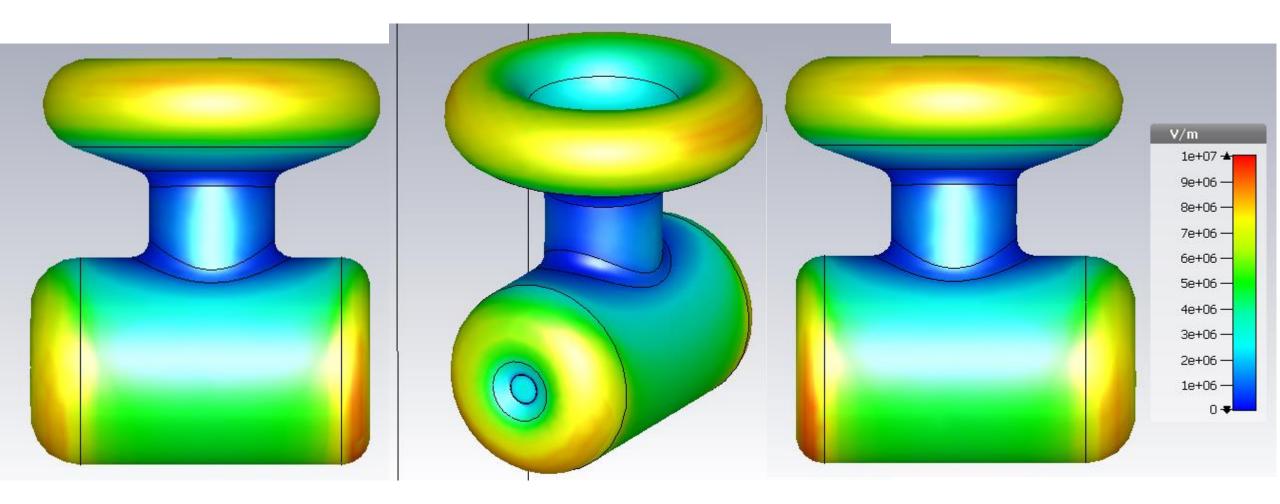
Electric field norm: No shield vs Original vs shields 1 vs shields 2

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

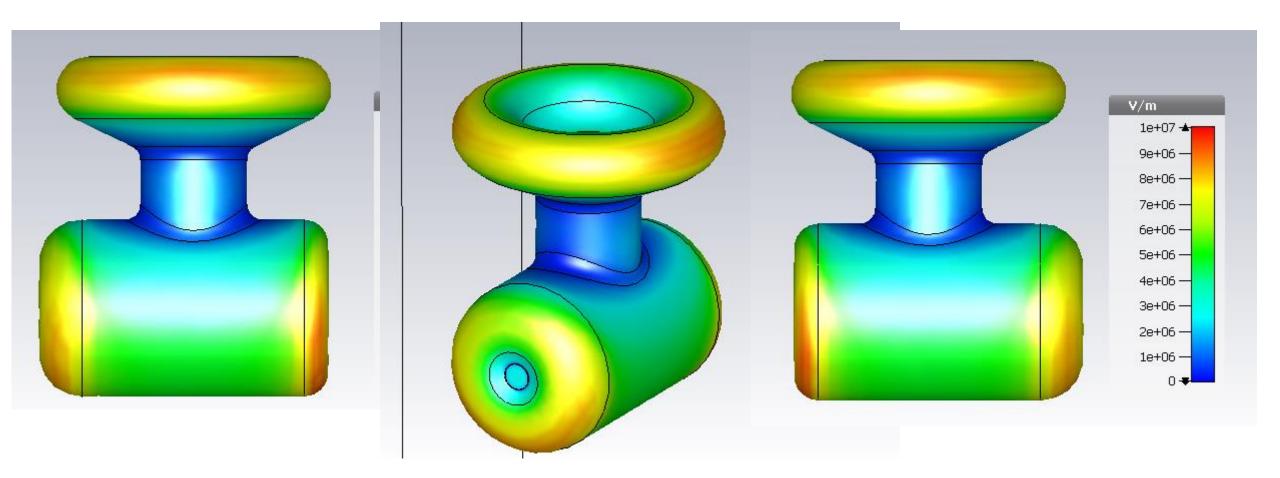
CST results: Electric field norm- No shield



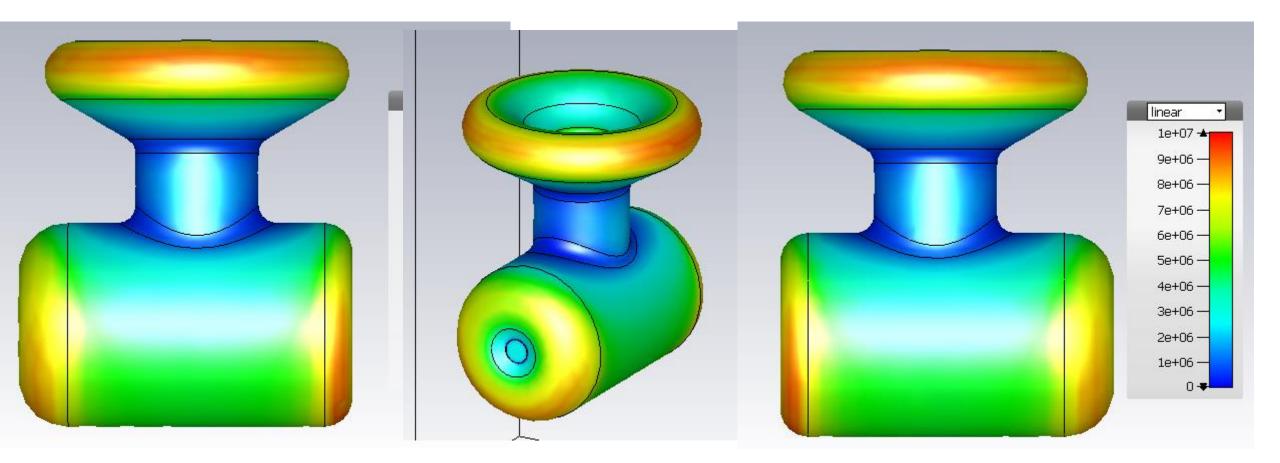
CST results: Electric field norm– Original



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.

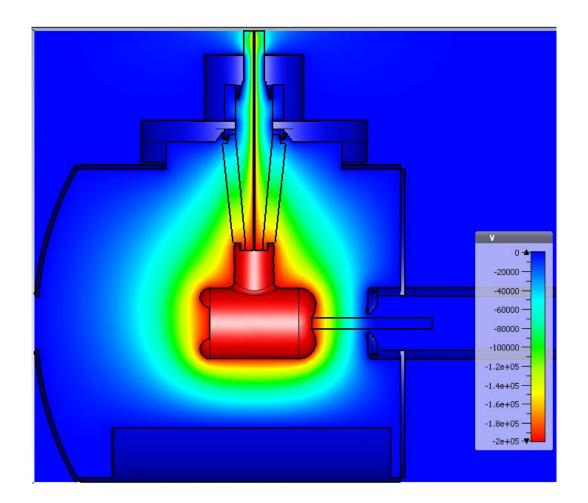
Fin.

Additional slides

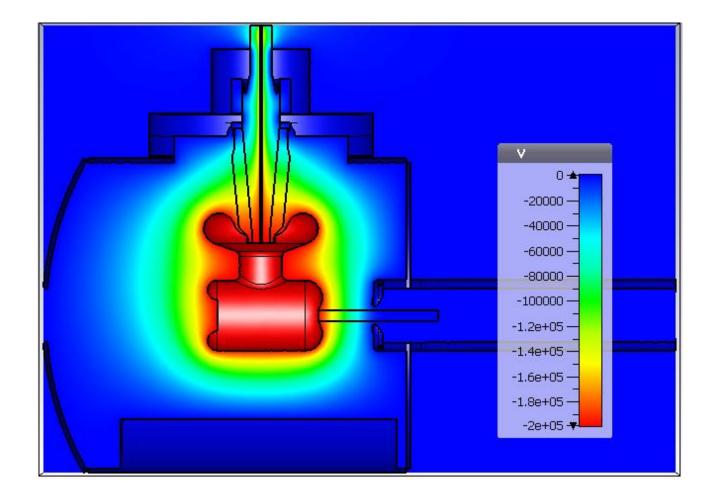
- Potentials false color
- Transverse field false color
- Longitudinal field false color

Potential: Original vs Shield 1 vs Shield 2

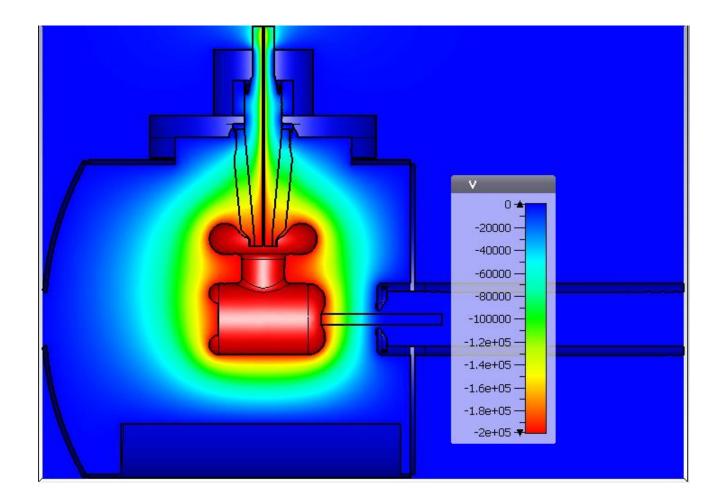
CST results: Potential – No shield



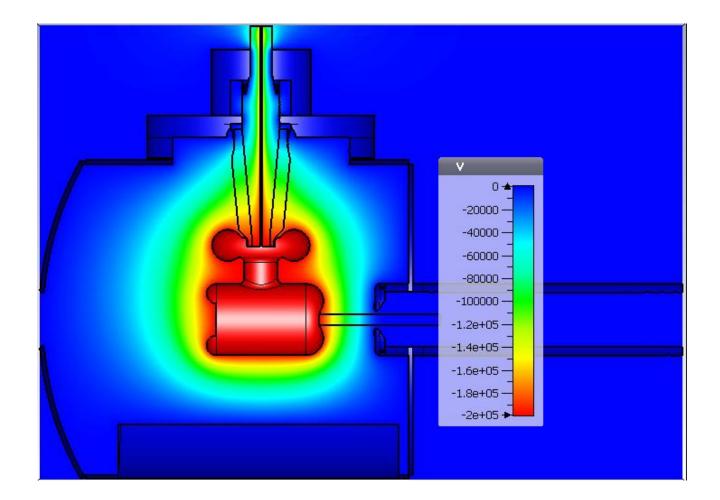
CST results: Potential – original shield



CST results: Potential – Shield 1

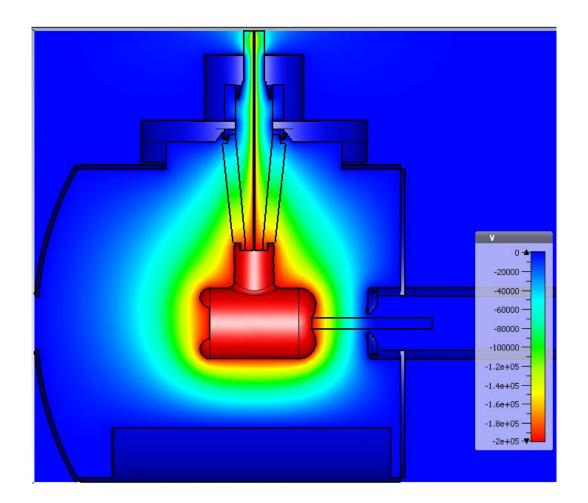


CST results: Potential – Shield 2

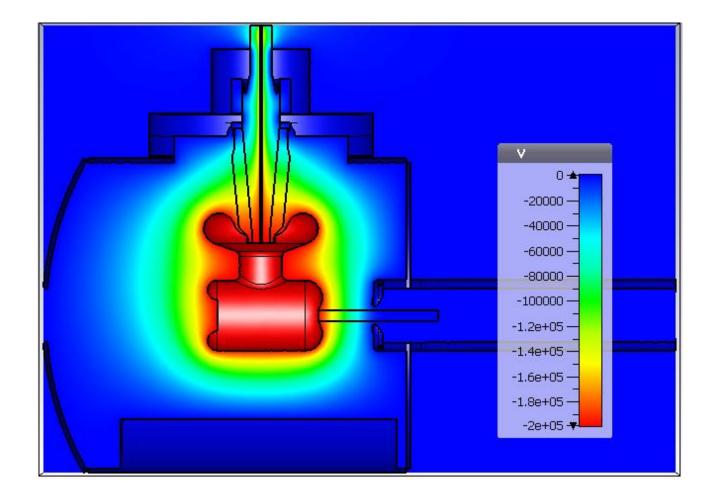


Potential: Original vs Shield 3 vs Shield 4

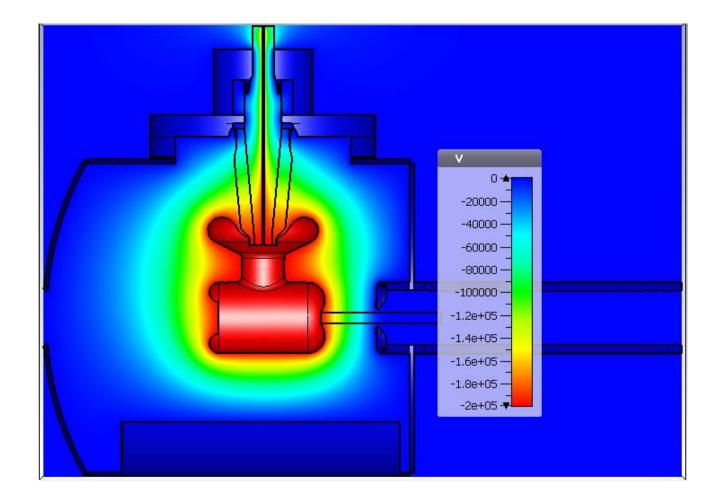
CST results: Potential – No shield



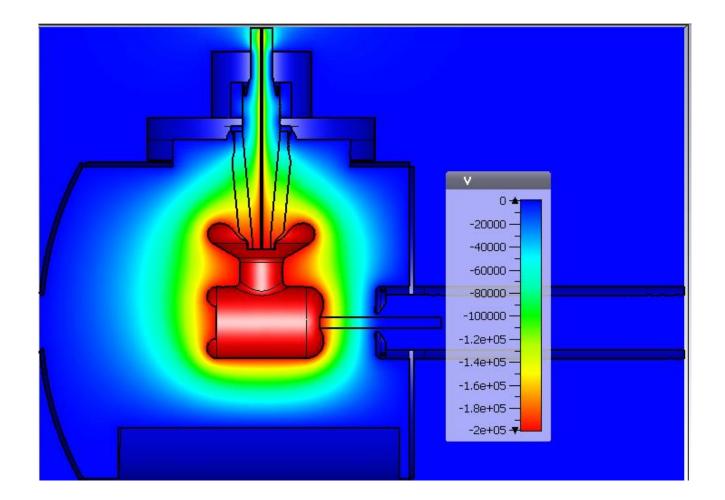
CST results: Potential – original shield



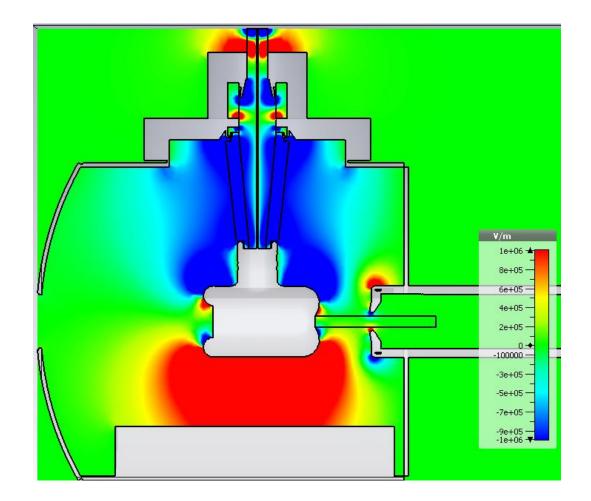
CST results: Potential – Shield 3



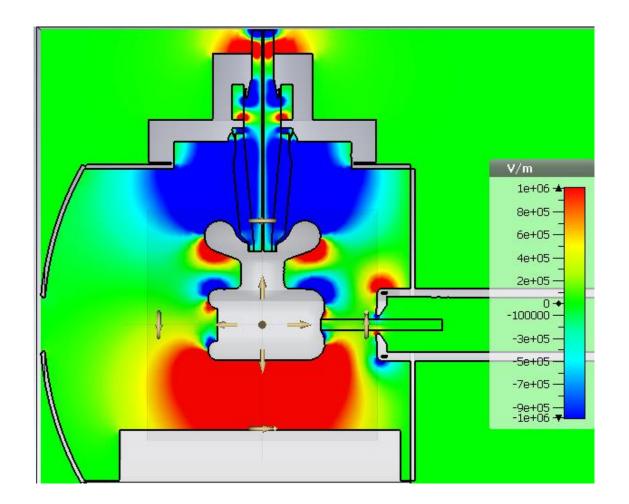
CST results: Potential – Shield 4



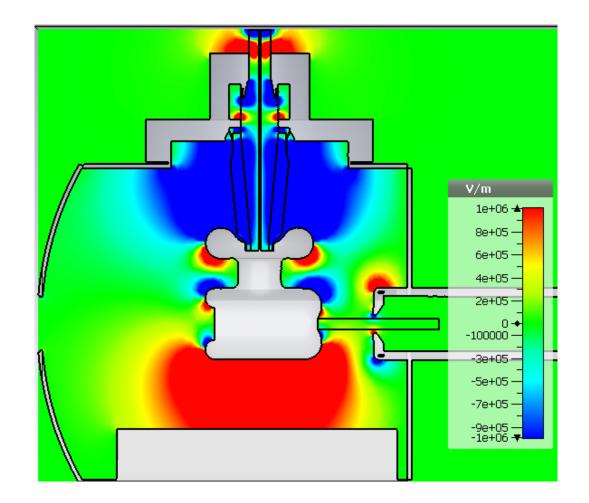
Transverse electric field: No shield



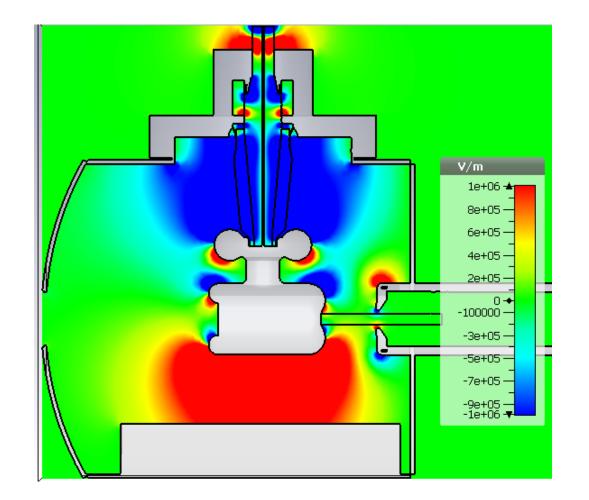
CST results: Transverse electric field – original shield



CST results: Transverse electric field – Shield 1

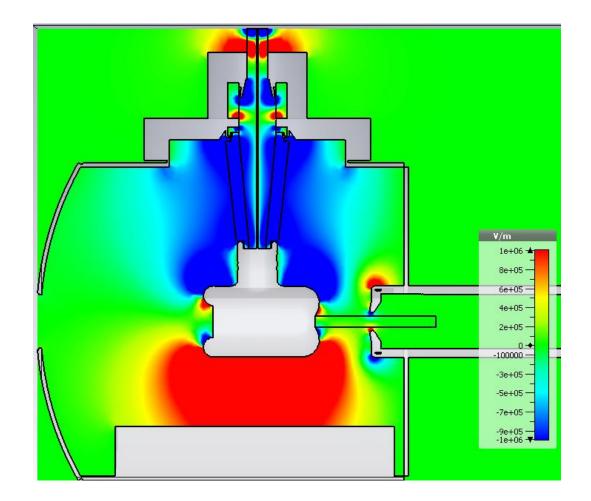


CST results: Transverse electric field – Shield 2

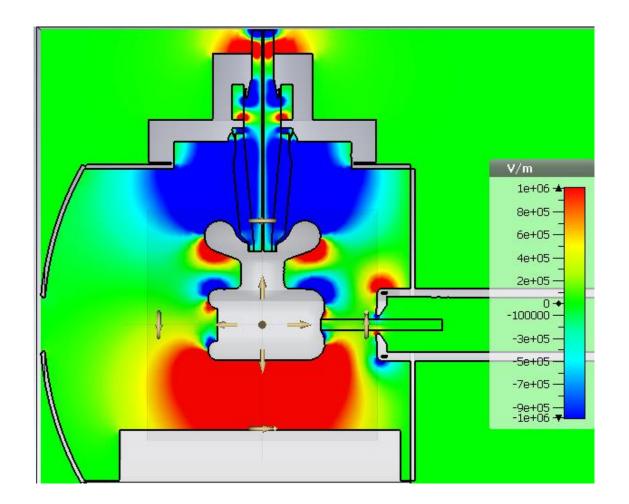


Transverse electric field: Original vs Shield 3 vs Shield 4

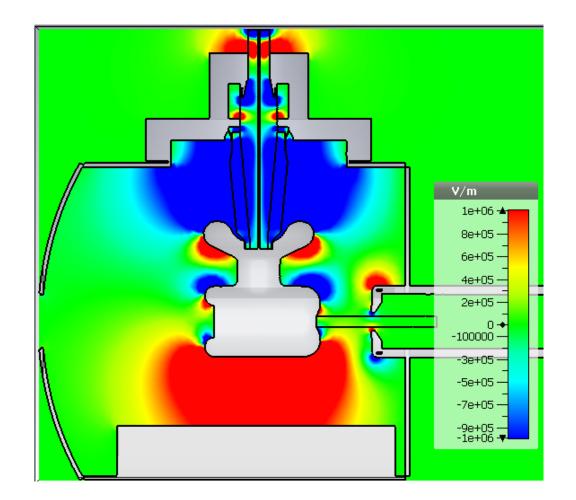
Transverse electric field: No shield



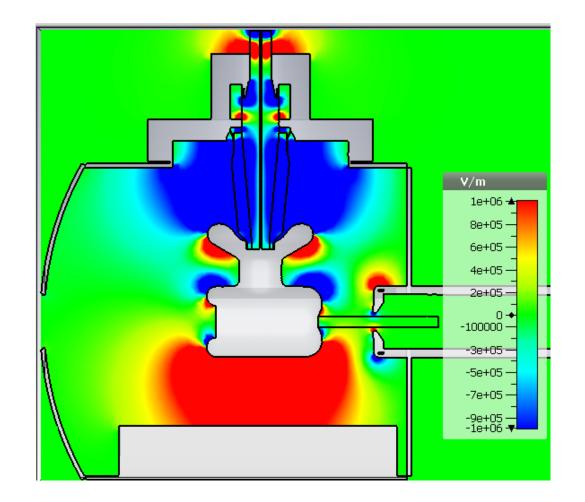
CST results: Transverse electric field – original shield



CST results: Transverse electric field – Shield 3

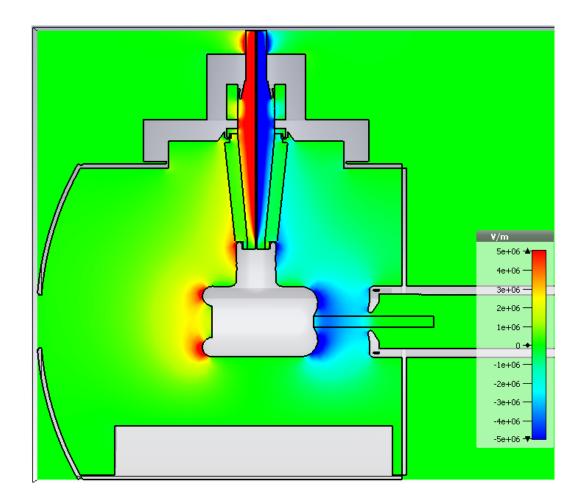


CST results: Transverse electric field – Shield 4

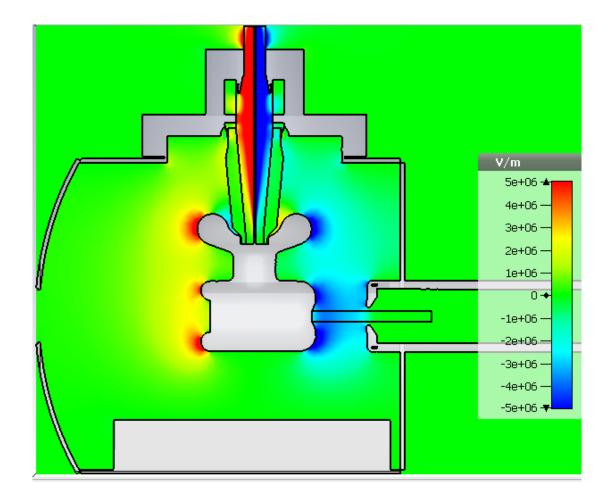


Longitudinal electric field: Original vs Shield 1 vs Shield 2

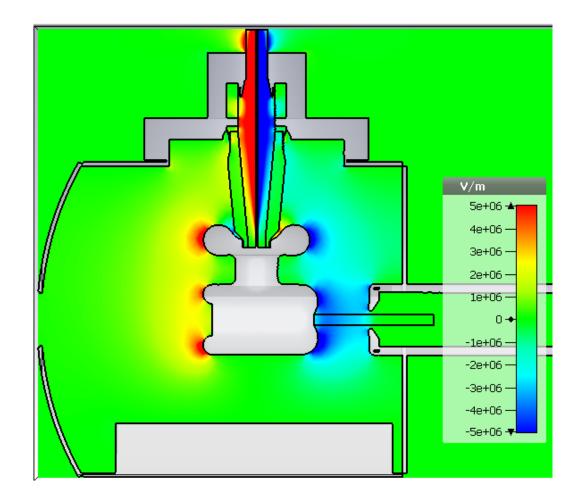
CST results: Longitudinal electric field – No shield



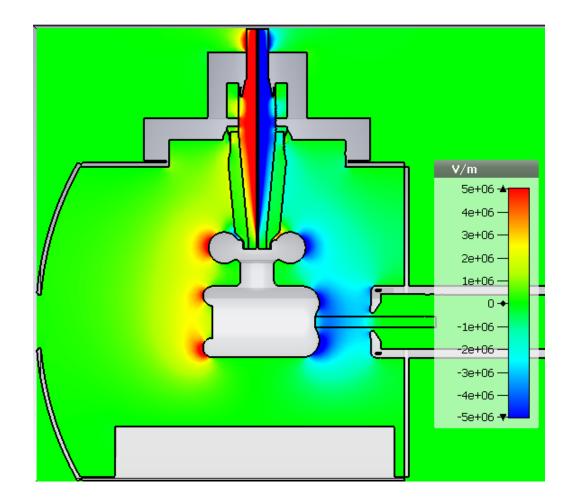
CST results: Longitudinal electric field – original shield



CST results: Longitudinal electric field – Shield 1

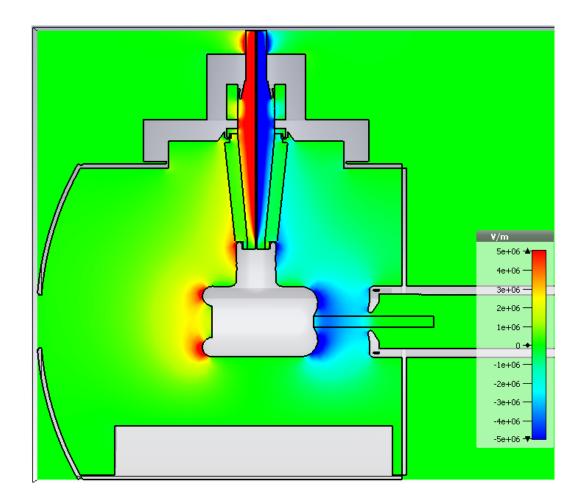


CST results: Longitudinal electric field – Shield 2

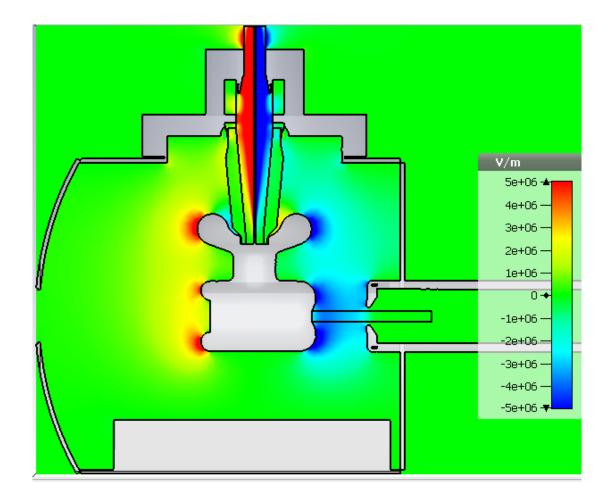


Longitudinal electric field: Original vs Shield 3 vs Shield 4

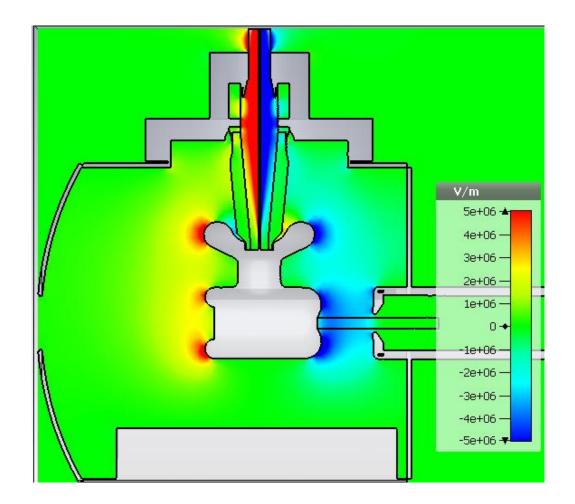
CST results: Longitudinal electric field – No shield



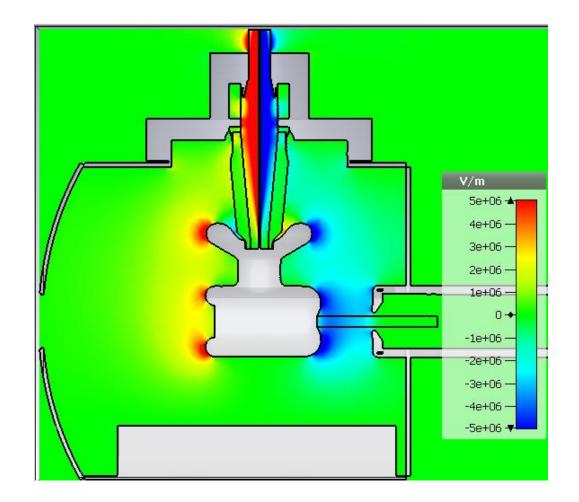
CST results: Longitudinal electric field – original shield



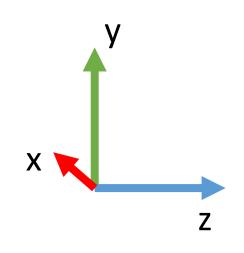
CST results: Longitudinal electric field – Shield 3



CST results: Longitudinal electric field – Shield 4



CST frame of reference:



X goes into the page.

