200kV gun COMSOL simulations Upper shield

Gabriel Palacios

gpala001@odu.edu
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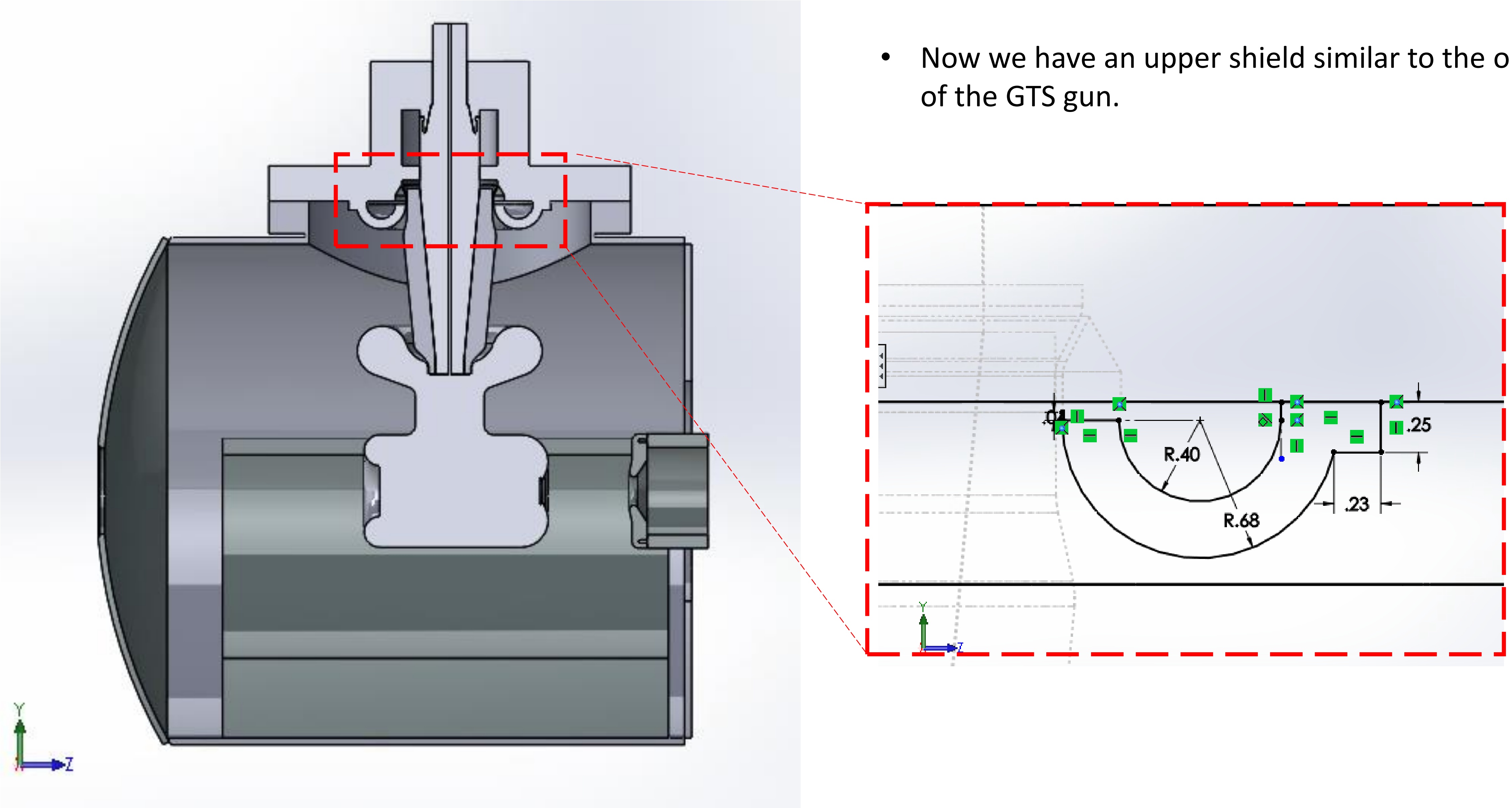
Summary

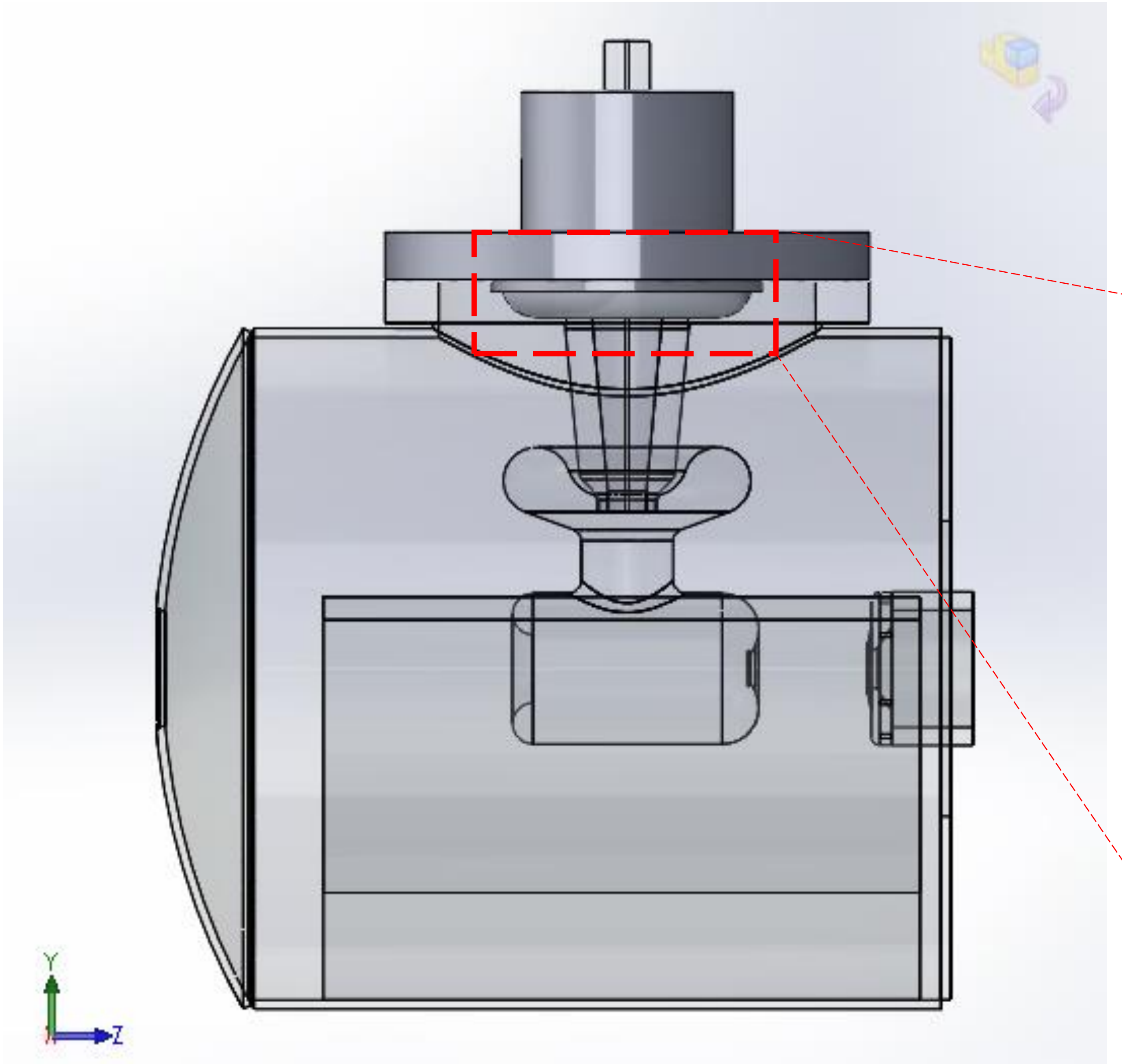
- Solidworks model
- COMSOL details on simulation
  - Materials
  - Electrostatics
  - Mesh
  - Study
  - Results
  - Plots
- Next steps
- Extra slide with coordinate system

Solidworks model:

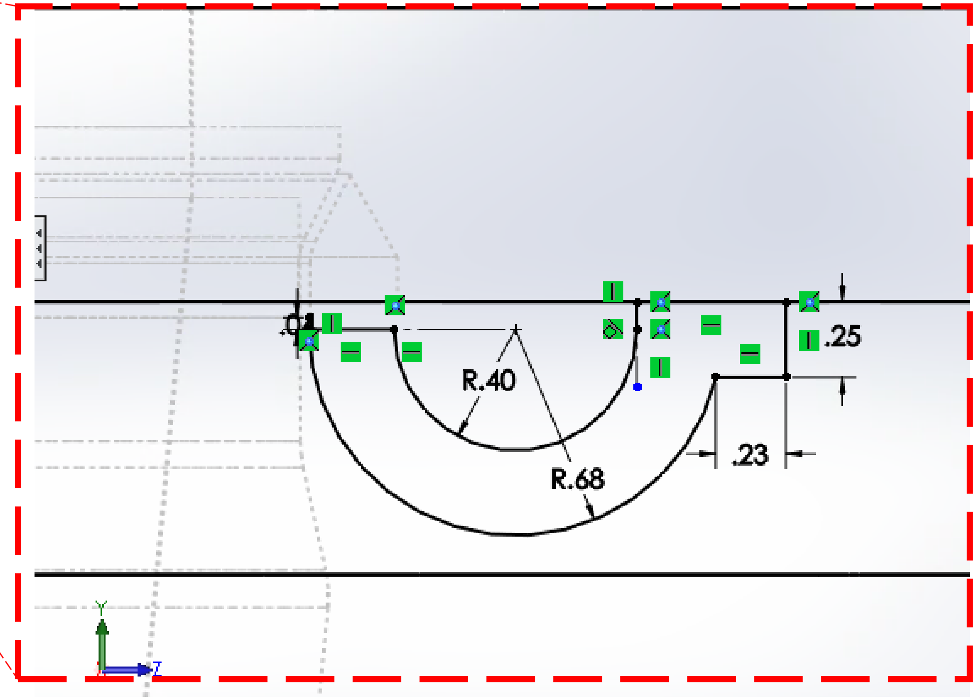


- Now we have an upper shield similar to the one of the GTS gun.

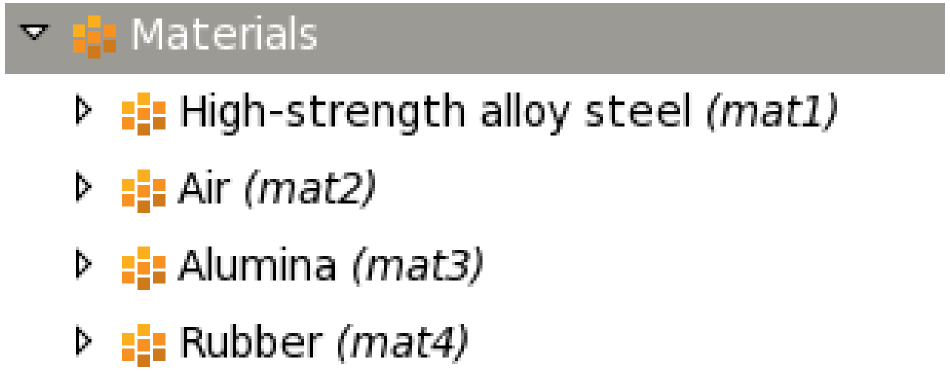
Solidworks model:



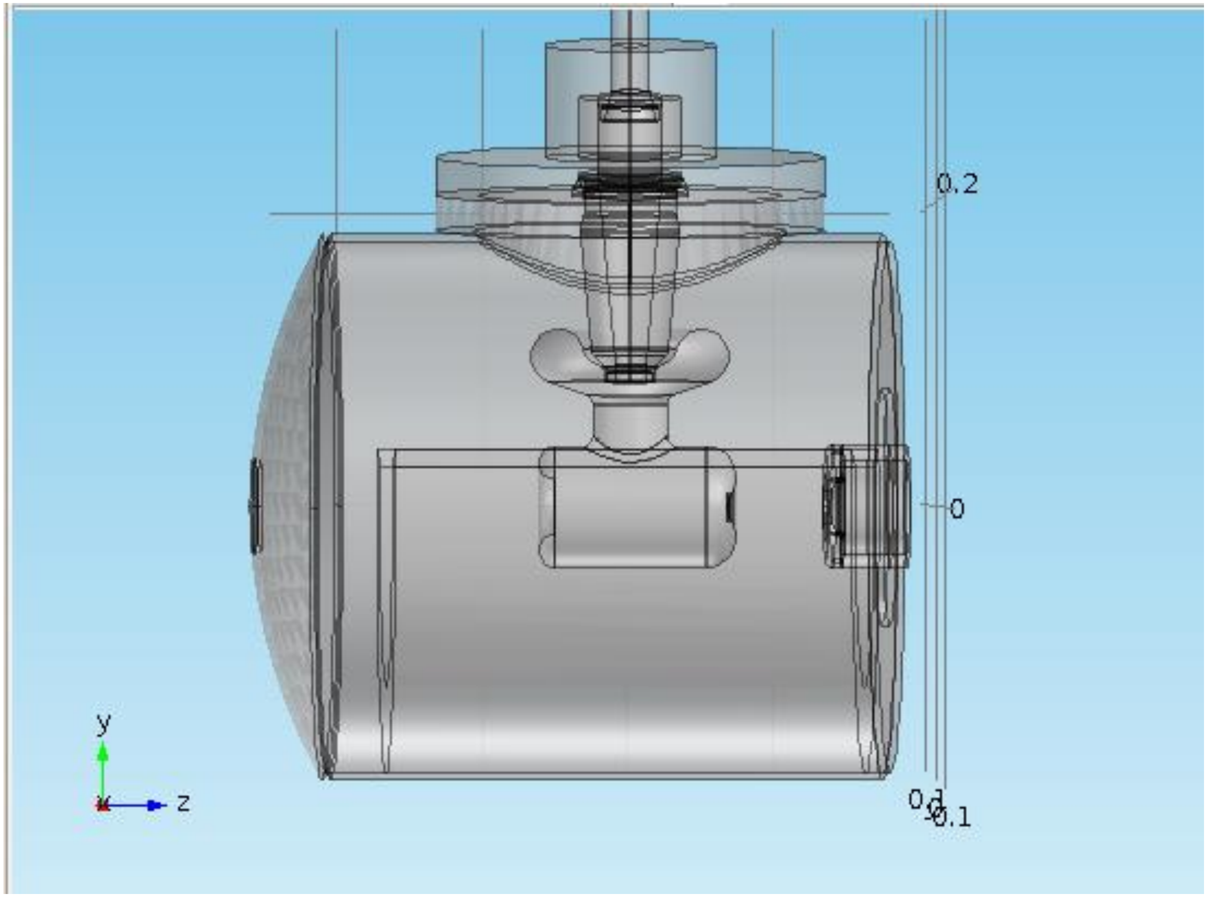
- It looks a little bit like this:



COMSOL materials:



- Stainless steel for all metal components (including upper shield)with Relative permittivity 1 and conductivity of 1.1E6 S/m
- Air for the vacuum surroundings.
  - NOTE: air conductivity was set to 1E-40 S/m.
- Alumina for the ceramic.
  - Relative permittivity 8.4 and conductivity of 2E-12 S/m for the black alumina.
- Rubber for the HV cable plug with Relative permittivity 2.37 and conductivity of 1E-14 S/m .



COMSOL electric currents:

- Electric Currents *(ec)*
  - Current Conservation 1
  - Electric Insulation 1
  - Initial Values 1
  - Ground 1
  - Electric Potential 1

Equation

Equation form:

Study controlled

Show equation assuming:

Study 1, Stationary

$$\nabla \cdot \mathbf{J} = Q_j$$

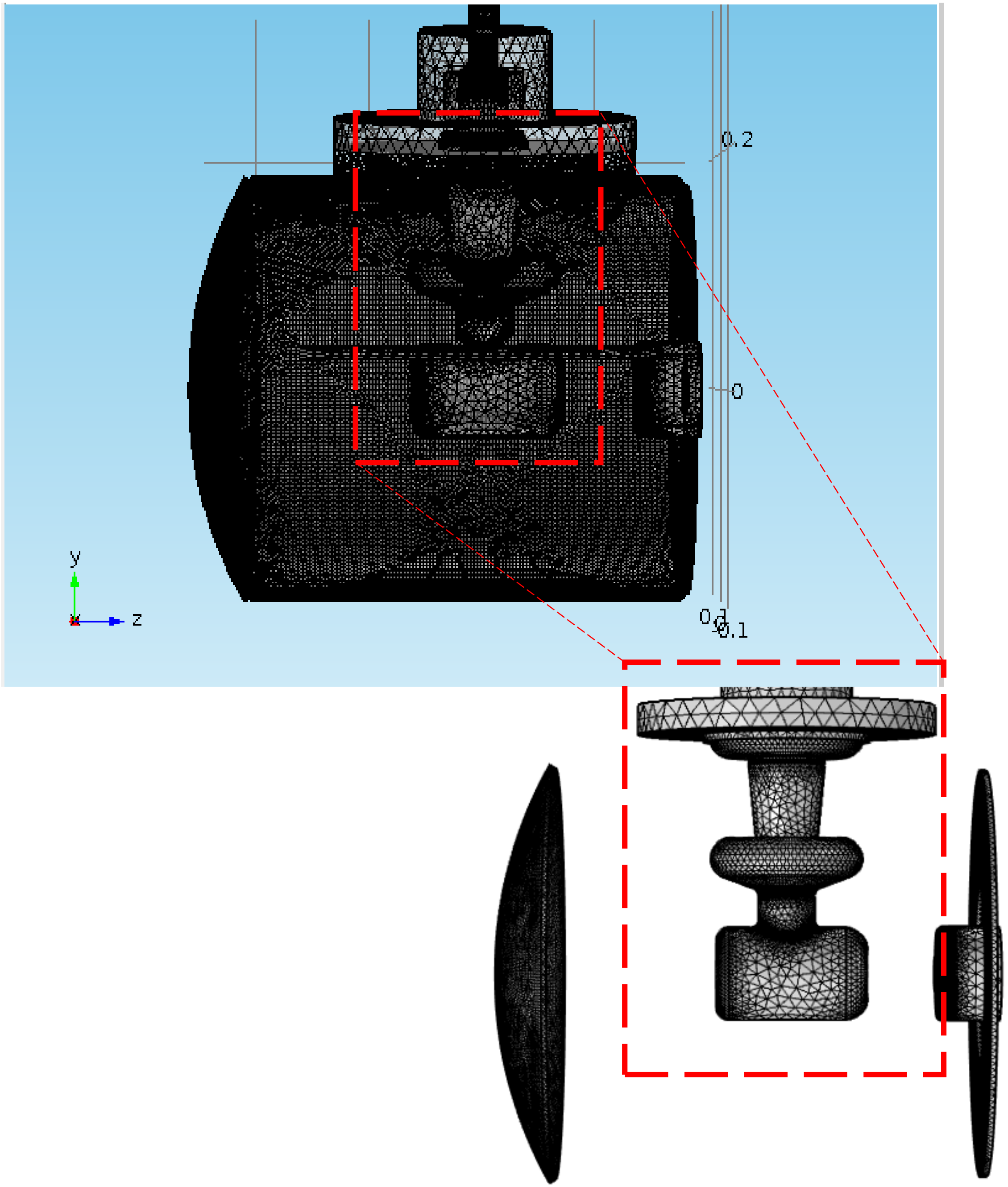
$$\mathbf{J} = \sigma \mathbf{E} + \mathbf{J}_e$$

$$\mathbf{E} = -\nabla V$$

- Current conservation in all domains.
- Electric insulation at the outer air boundary.
- Initial value (of potential) set to zero by default.
- Ground 1 at vacuum chamber, upper shield, NEGs, anode, flanges.
- Electric potential at -200kV at the cathode, cathode shield and HV cable.

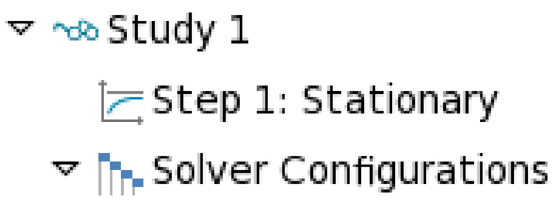
COMSOL mesh:

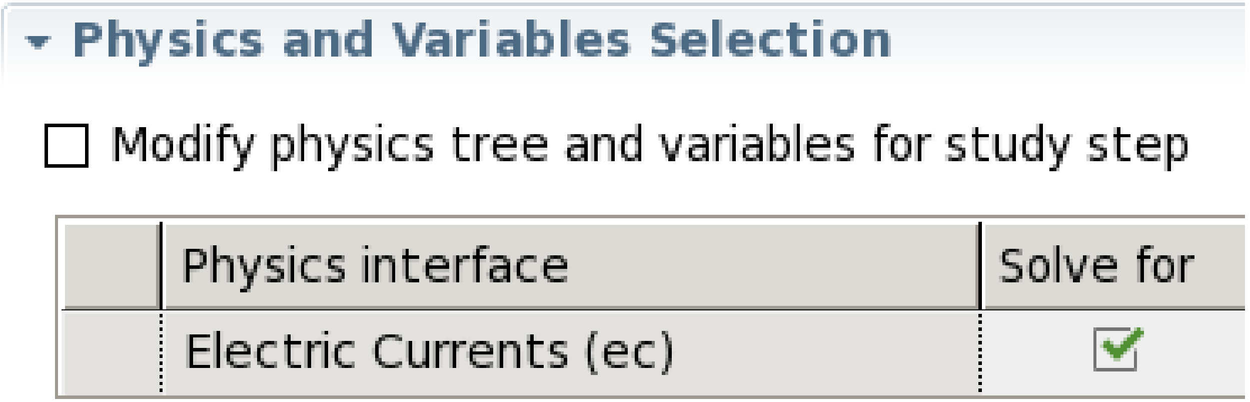
- Mesh 1
  - Size
  - Free Tetrahedral 1
  - Free Tetrahedral 2
  - Free Tetrahedral 3
  - Free Tetrahedral 4



- A general physics extra fine mesh was used to account for the smaller details.
- The mesh was separated into 4 pieces.

COMSOL study:

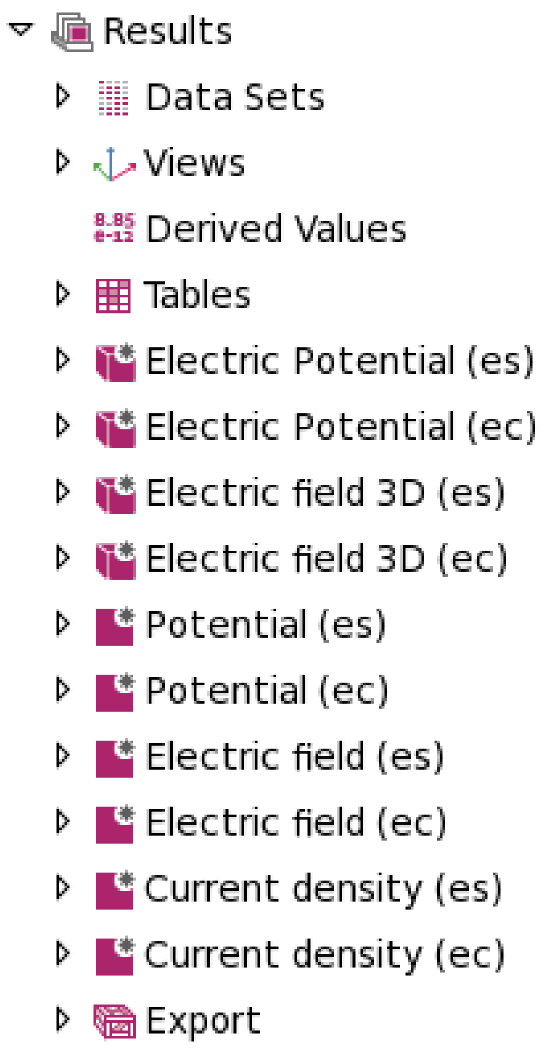




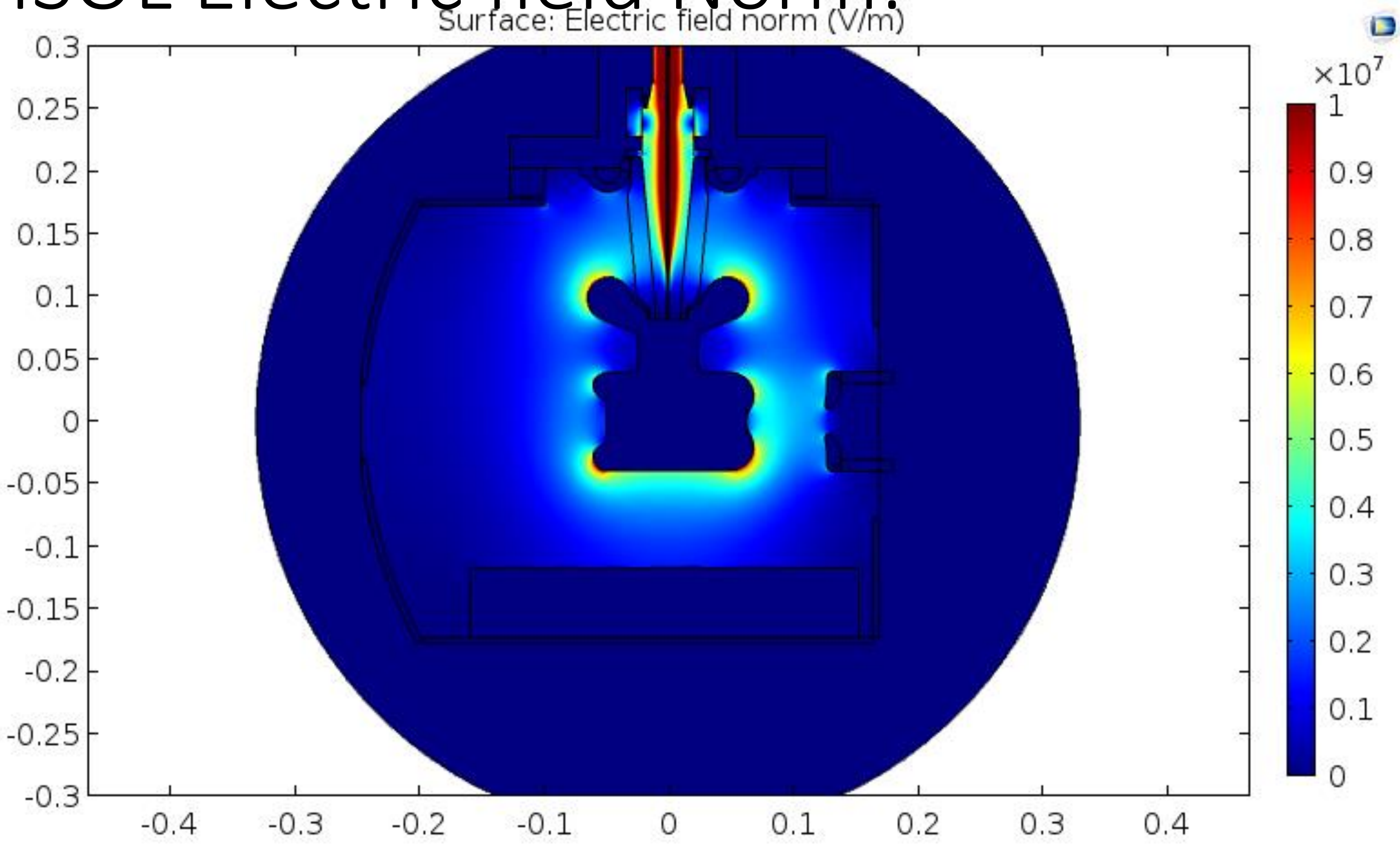
- The study solves for the electrostatics using the electric currents (to account for the conductivity of materials) and obtains a potential and electric fields.

COMSOL results:

- After the solver finished obtaining the solutions, I produced a group of plots that show the potential and electric field in different cases as a visual aid. Then using the data sets, I extracted the information from a line parallel to the ceramic insulator-rubber plug boundary and plotted the potential and electric fields.



COMSOL Electric field Norm:

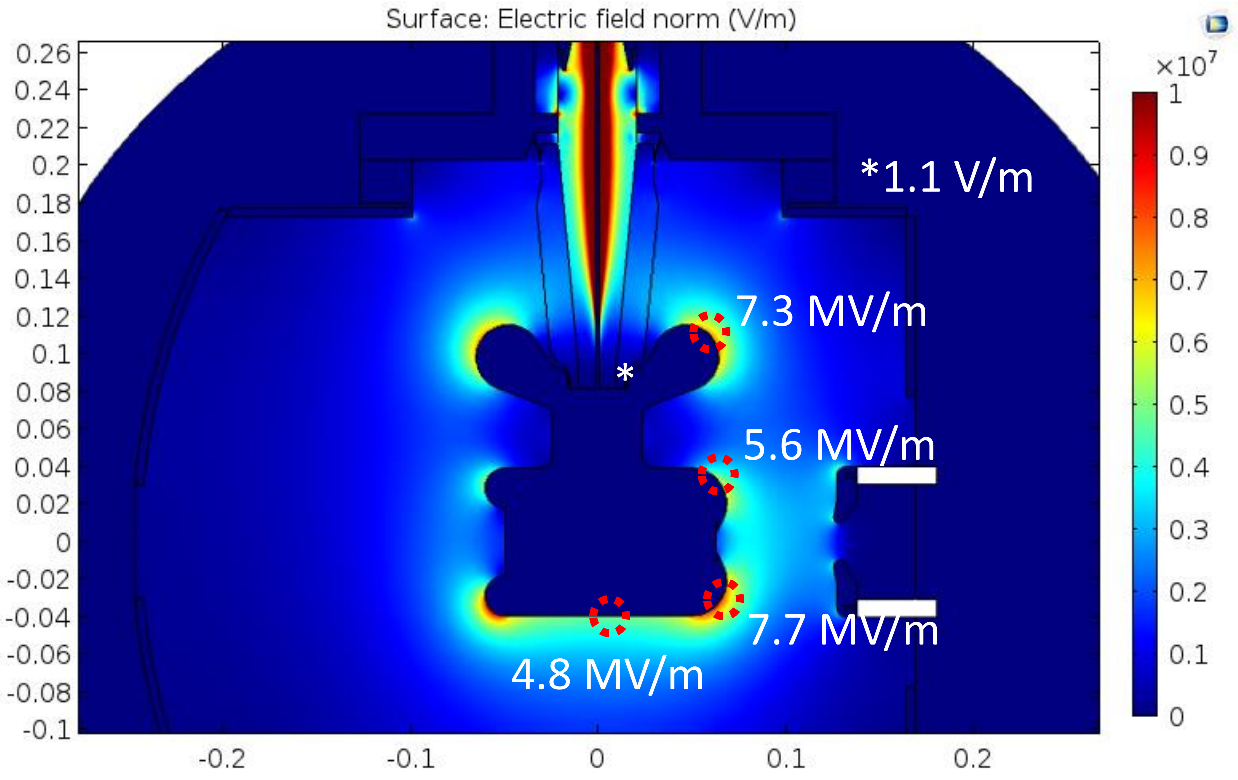


- This image shows the electric field norm |E| in MV/m as color intensity. The axis are coordinates in meters.

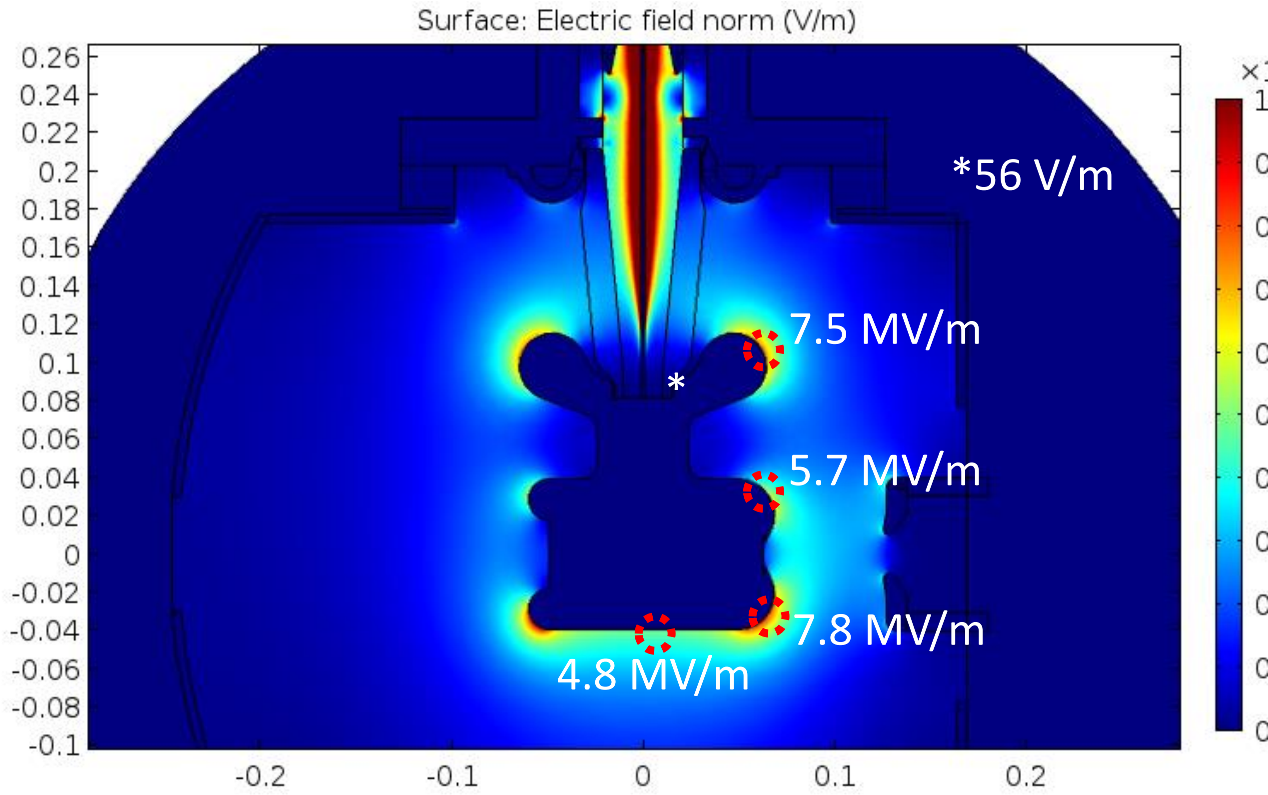
COMSOL Electric field Norm :

- This image shows the electric field norm |E| in MV/m as color intensity. The axis are coordinates in meters.

No upper shield



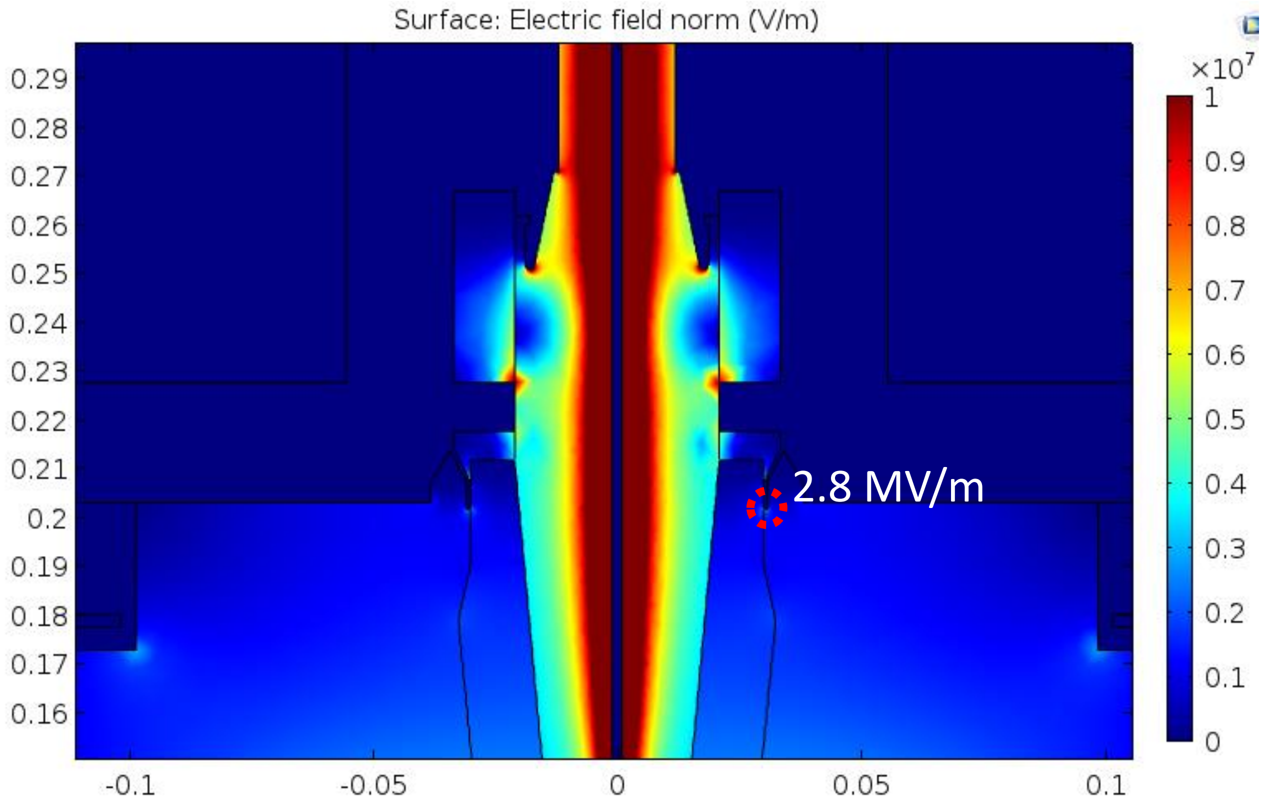
Upper shield



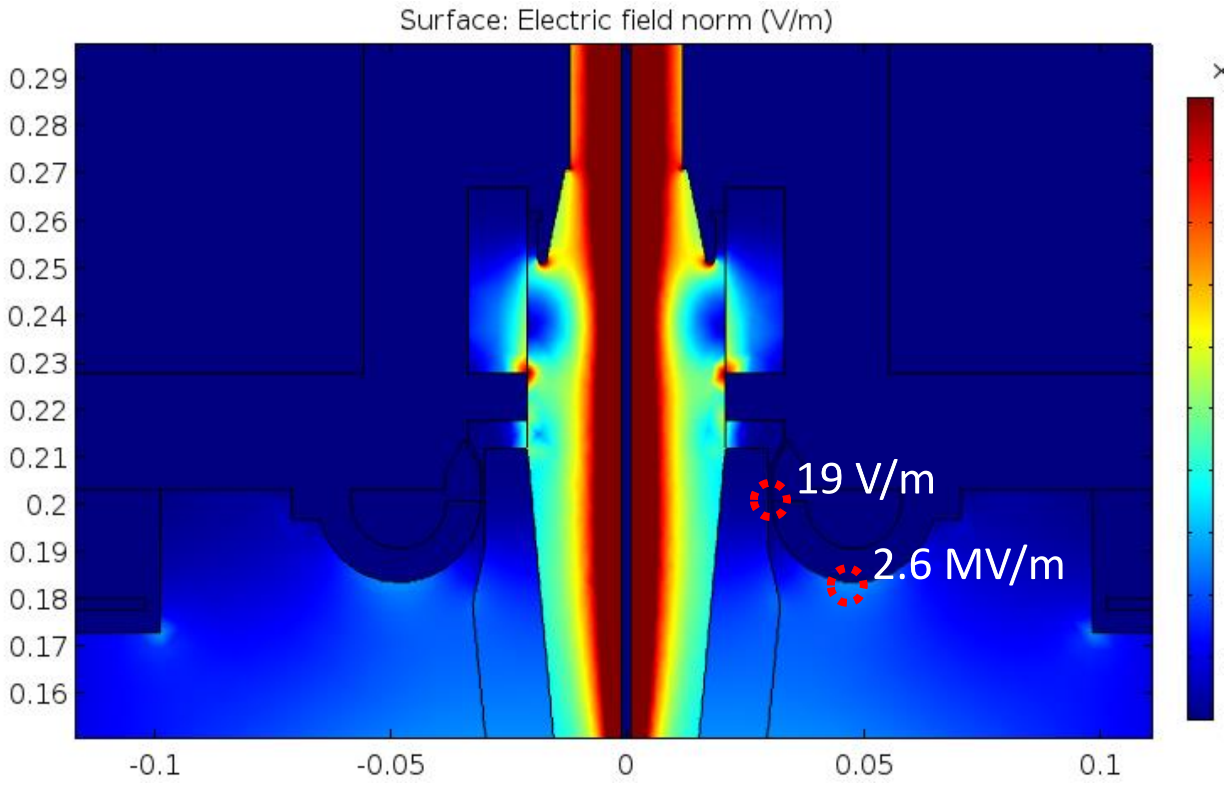
COMSOL Electric field Norm :

- This image shows the electric field norm |E| in MV/m as color intensity closer to the upper flange. The axis are coordinates in meters.

No upper shield



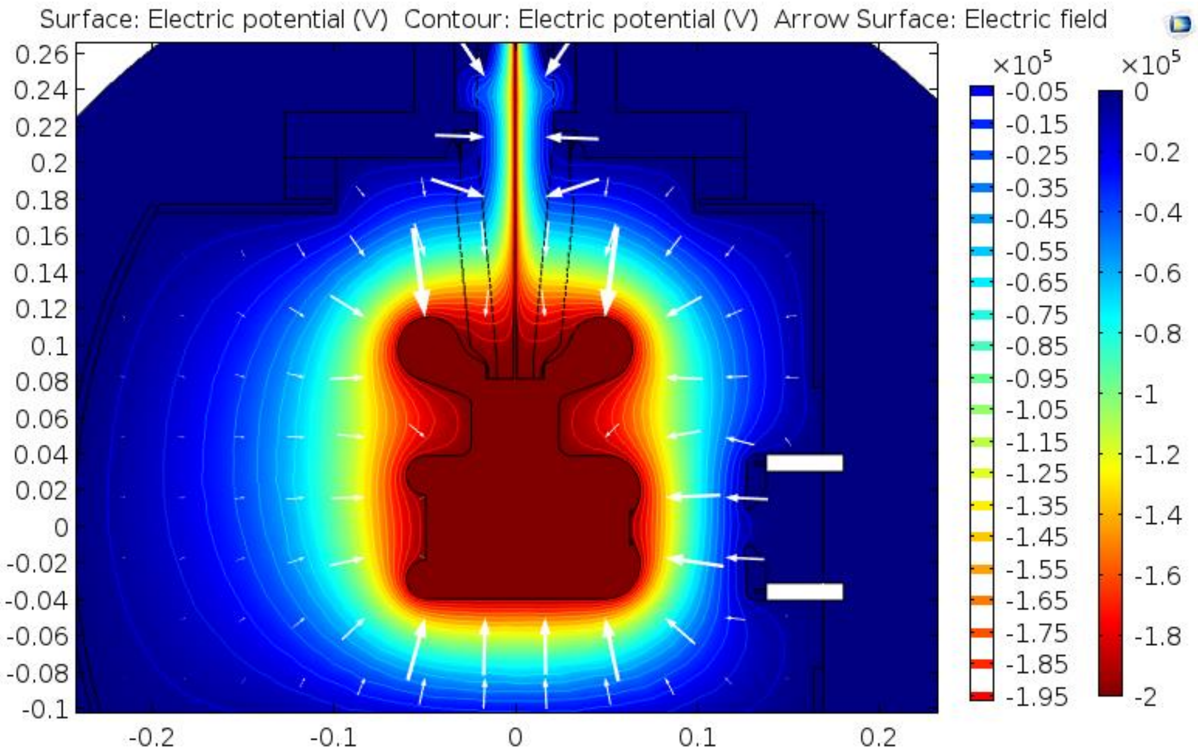
With upper shield



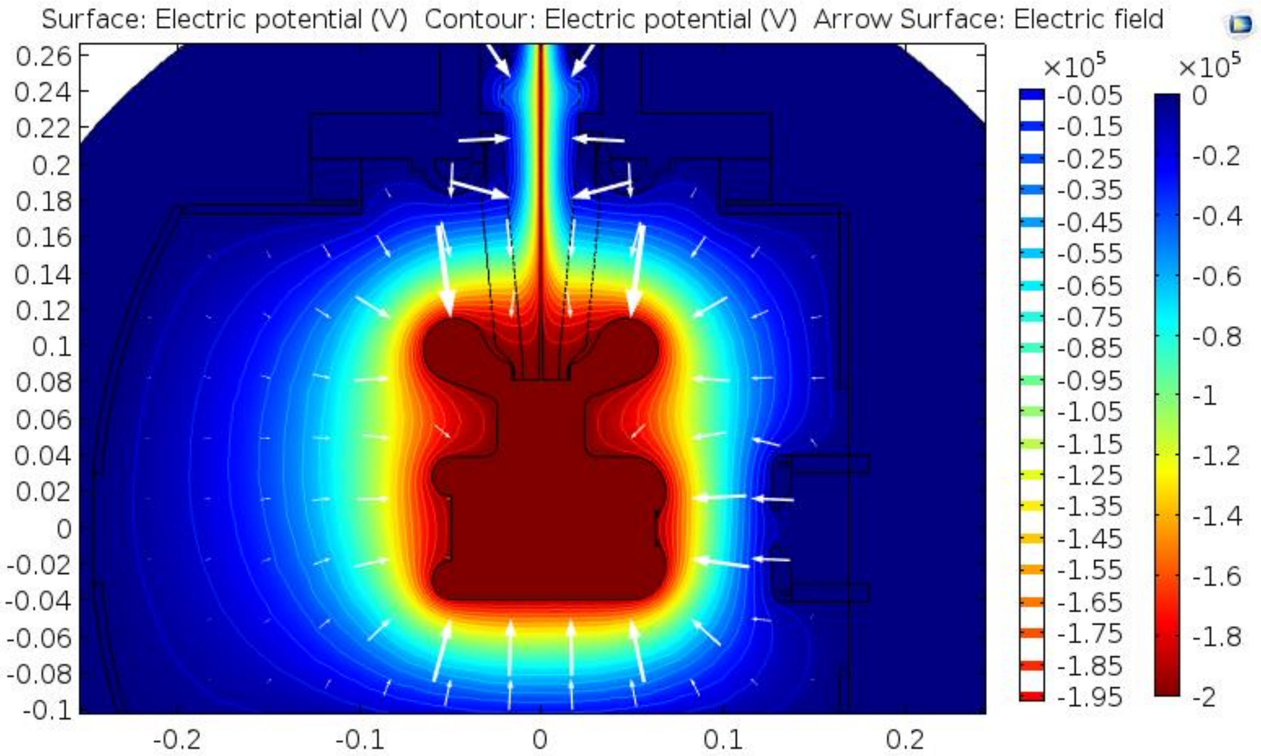
COMSOL Potential:

- This image shows the potential as color intensity (with equipotential lines). The white arrows size is proportional to the intensity of the electric field at the arrow tip. The axis are coordinates in meters.

No upper shield



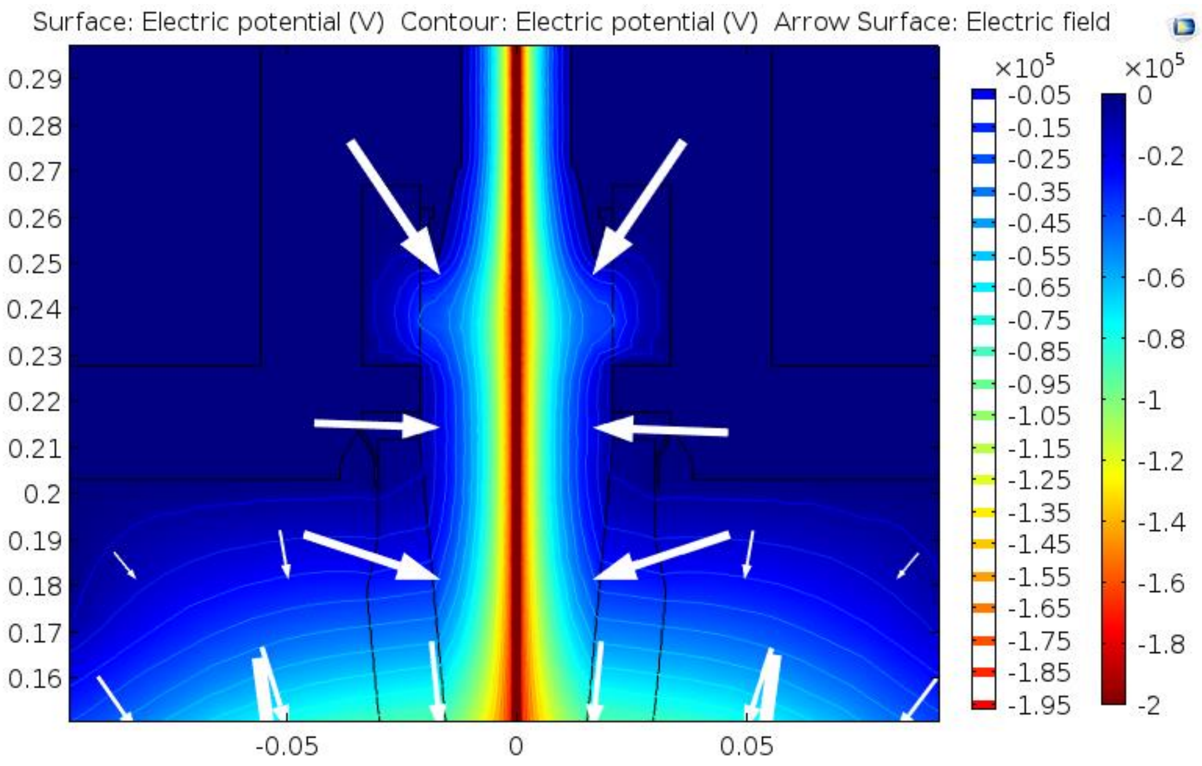
Upper shield



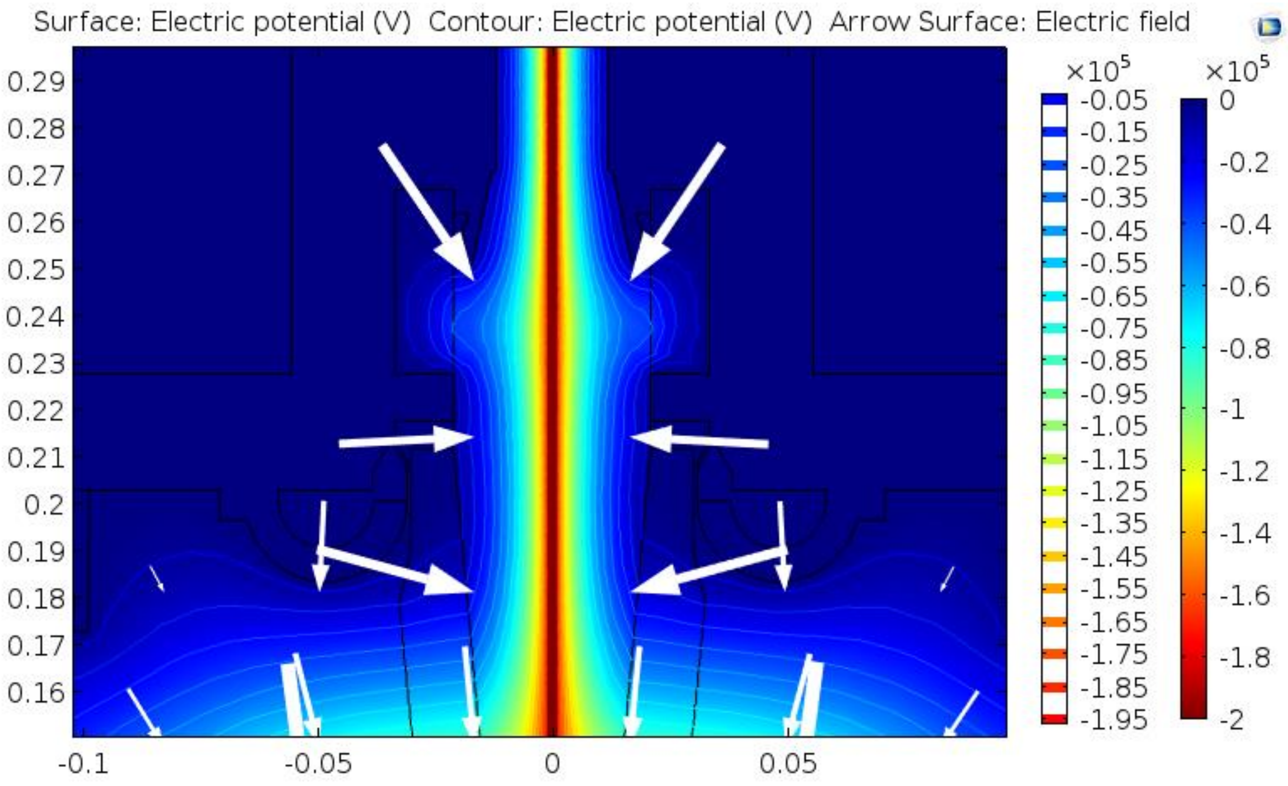
COMSOL Potential:

- This image shows the potential as color intensity (with equipotential lines) closer to the upper flange. The white arrows size is proportional to the intensity of the electric field at the arrow tip. The axis are coordinates in meters.

No upper shield

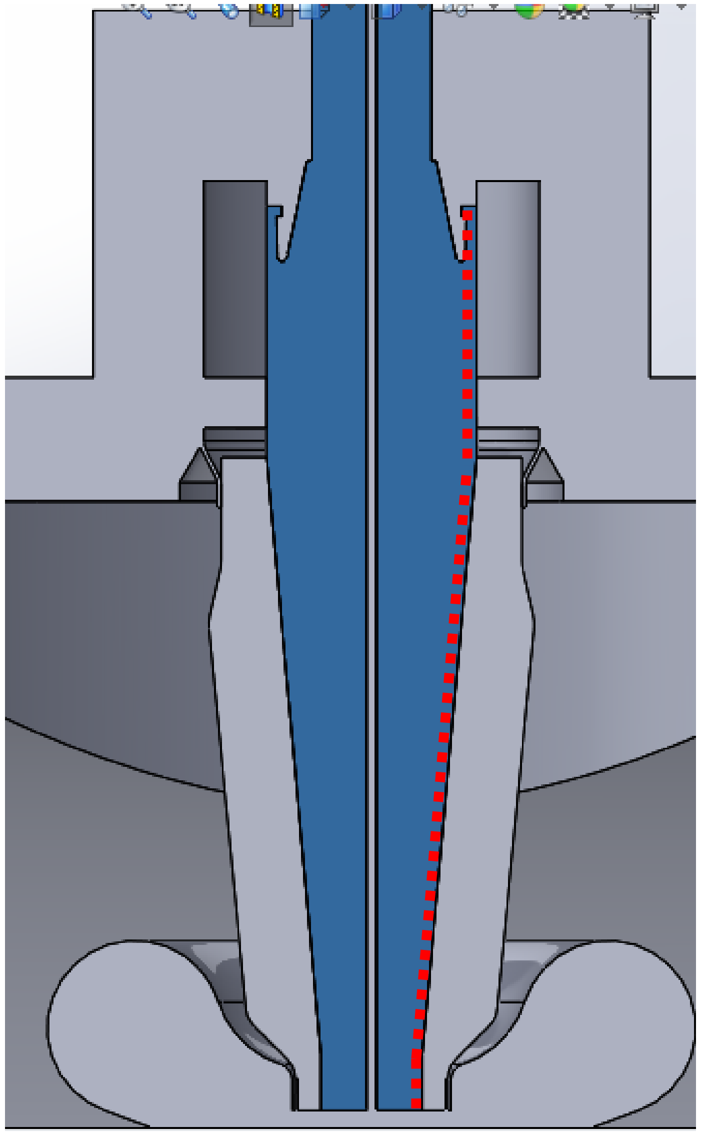


Upper shield

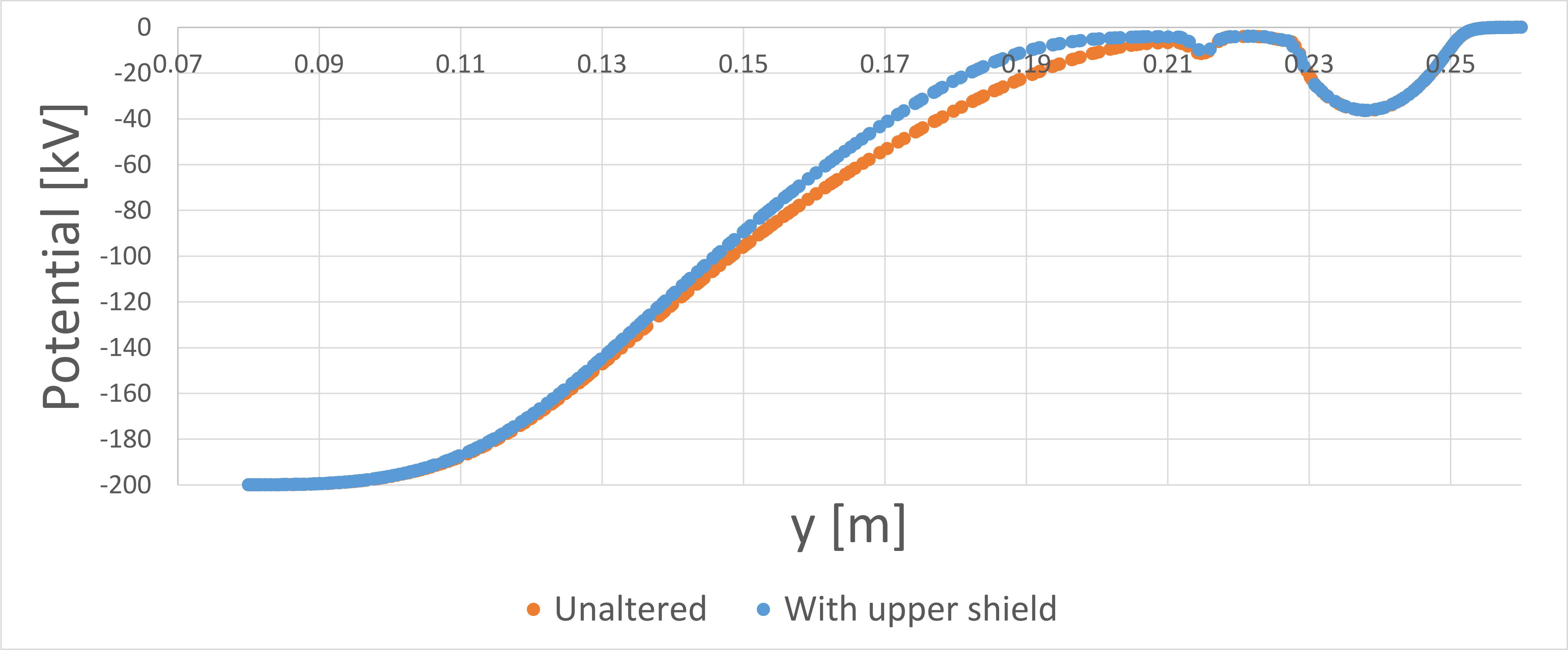


Plots of potential and electric field:

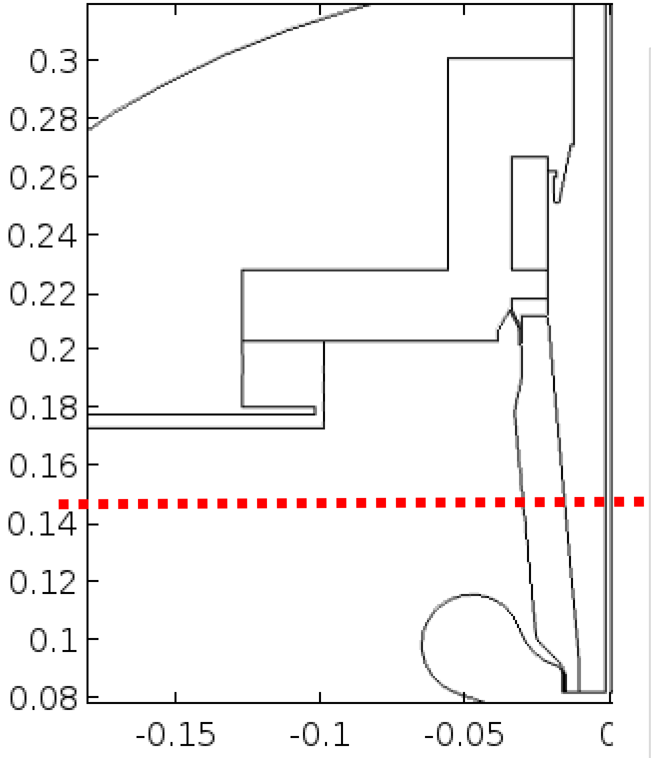
- The information about the potential and electric field along the rubber plug – ceramic insulator interface was obtained (as shown in the red dotted line), plotted as a function of the height (y-coordinate) and compared for two cases:
  - Gun **without** upper shield
  - Gun **with** upper shield



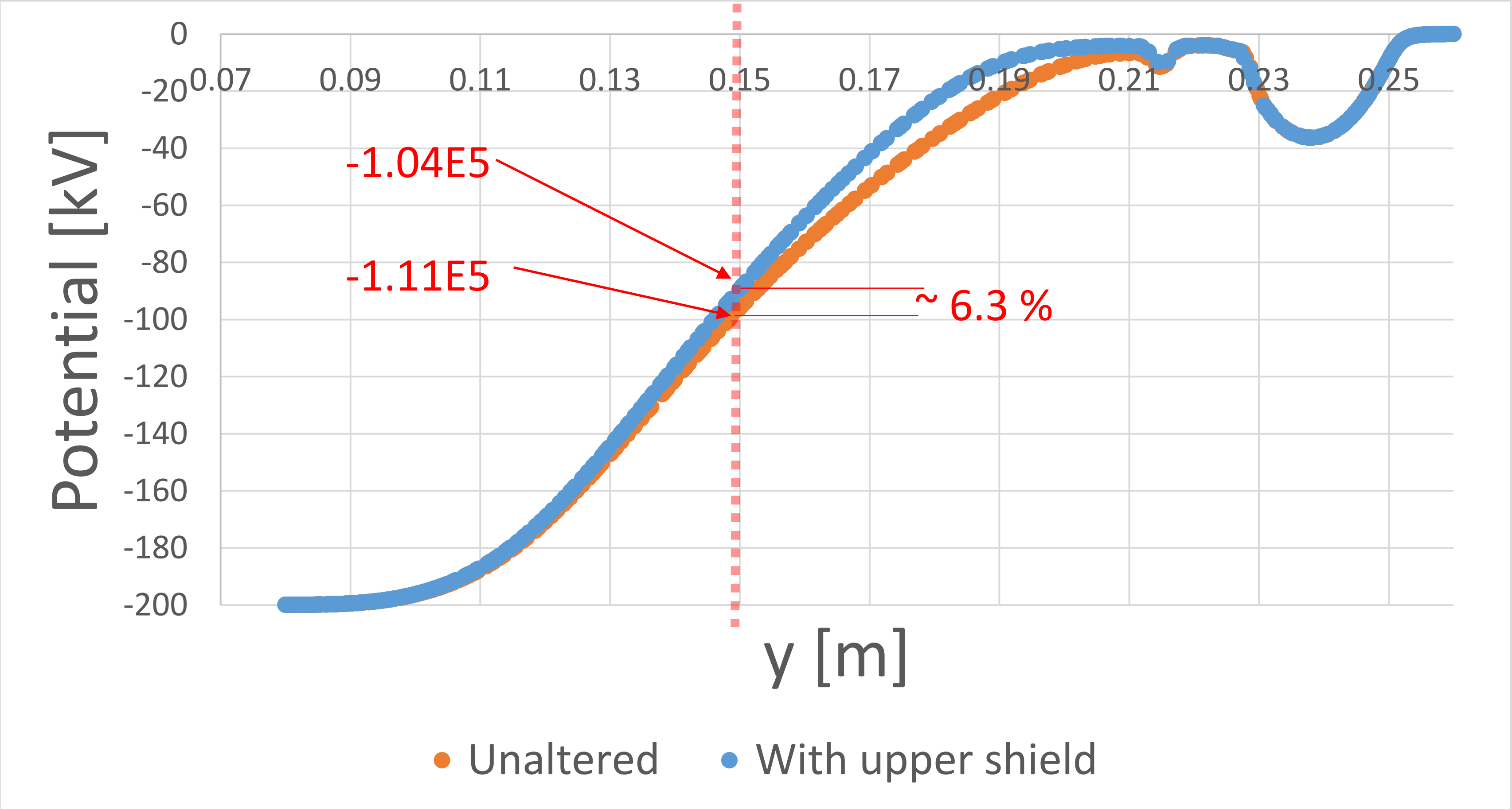
Potential along insulator :



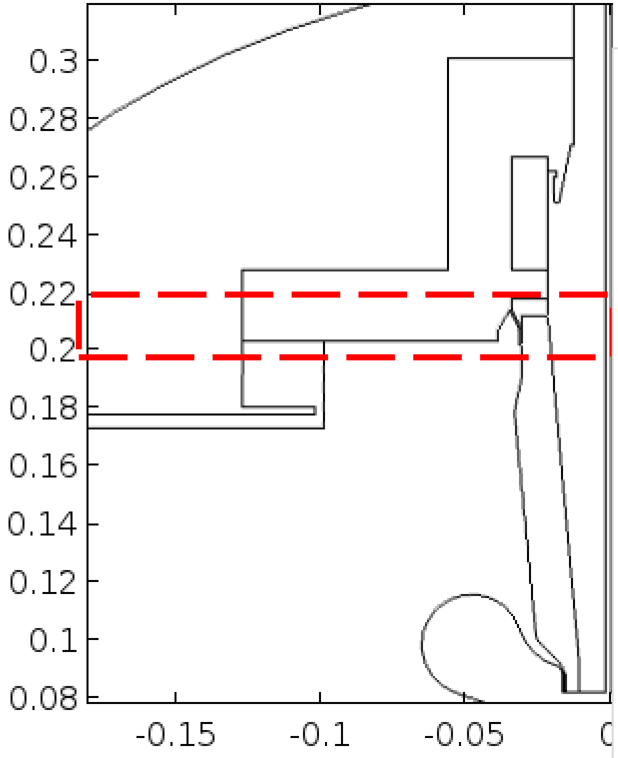
Potential along insulator, middle line:



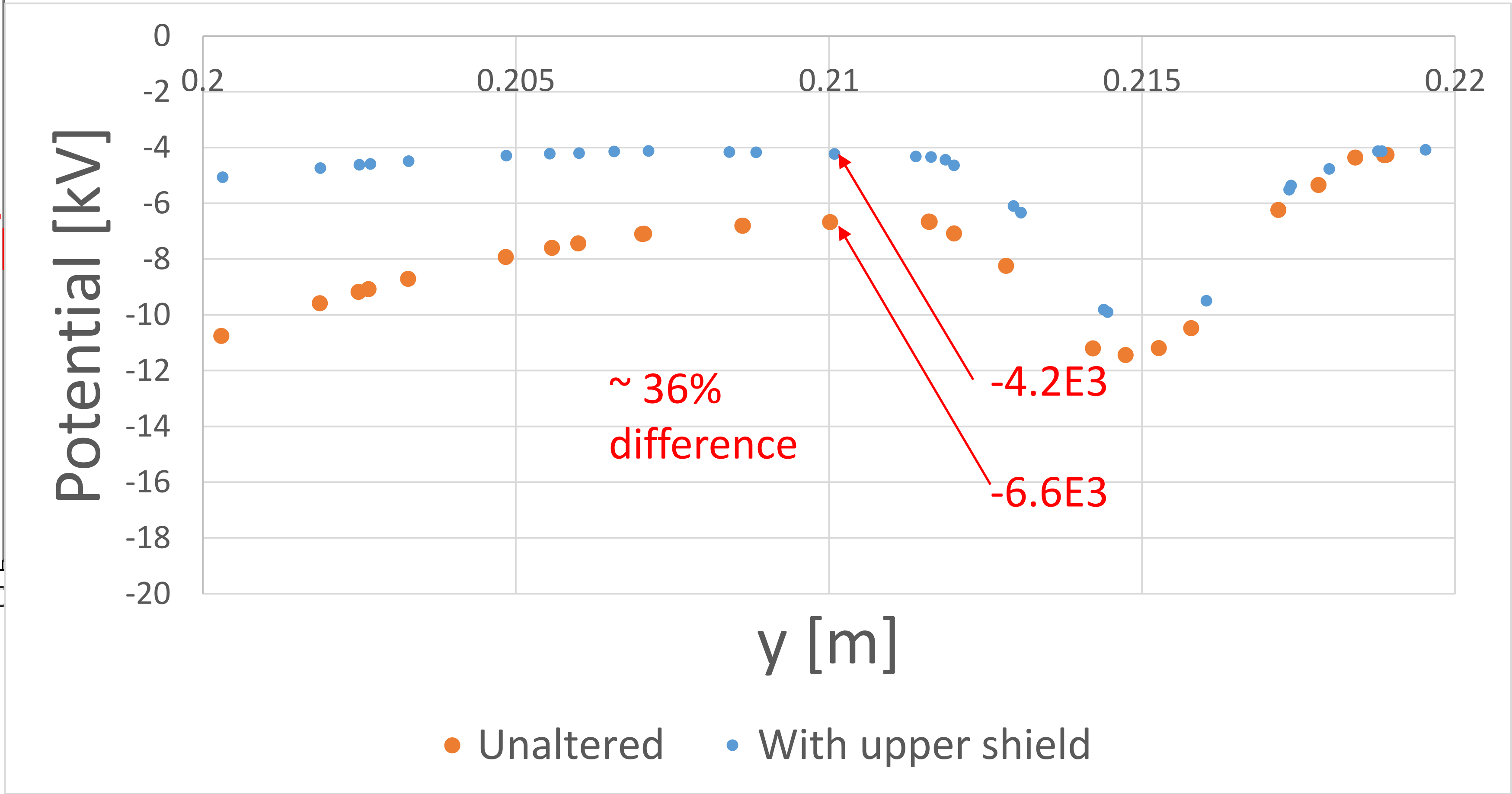
The height is ~0.14m



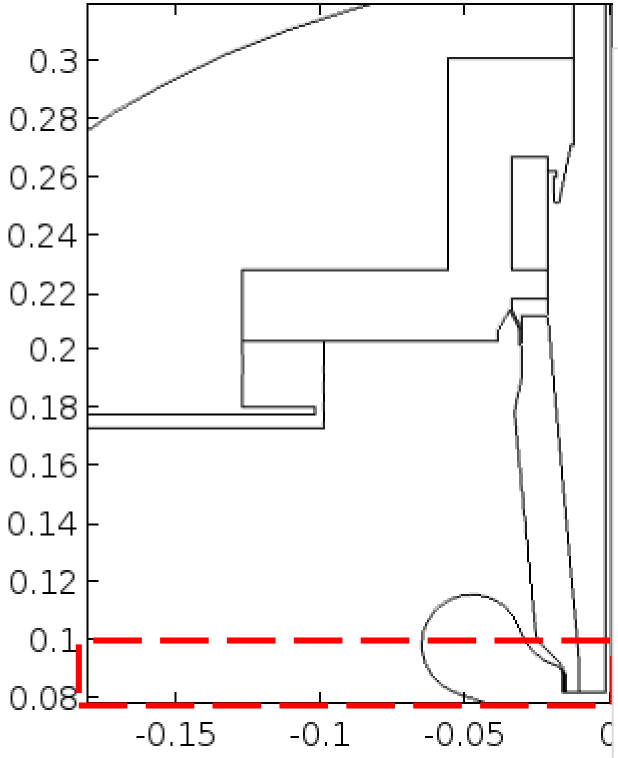
Potential near upper triple-point:



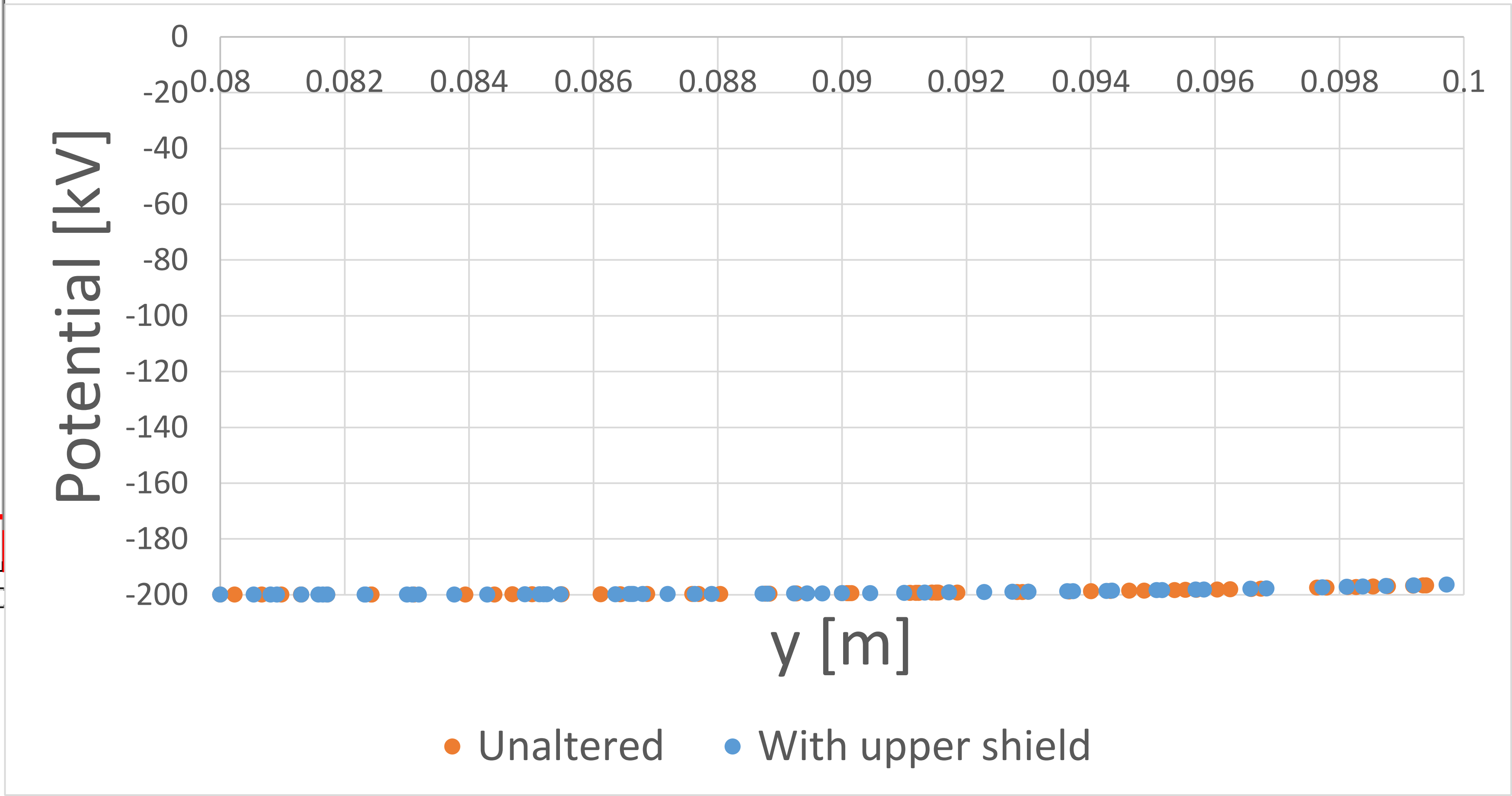
The height is ~0.14m



Potential near cathode triple point:

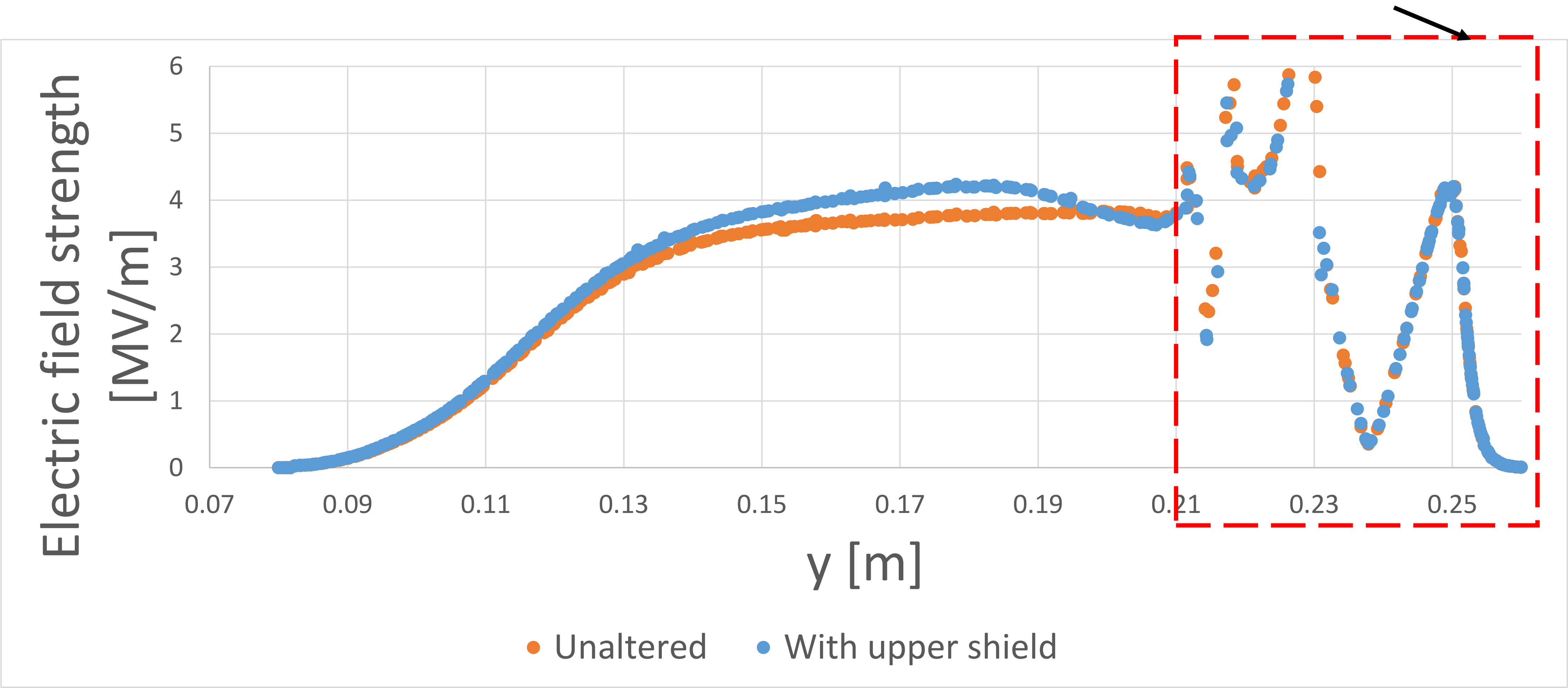


The height is ~0.14m



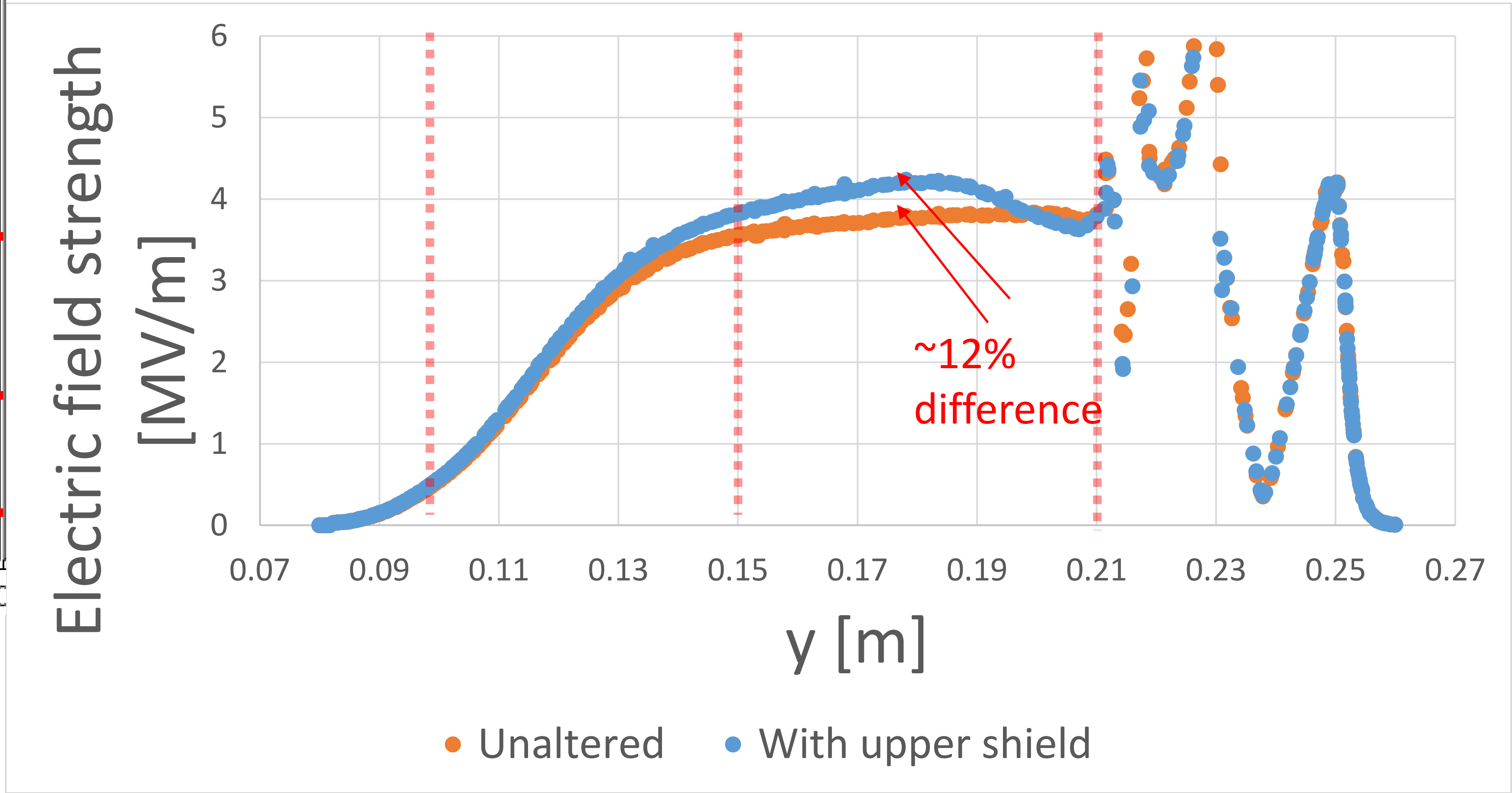
Electric field norm |E|:

This part might be simulation artifact near the rubber plug internal shield.

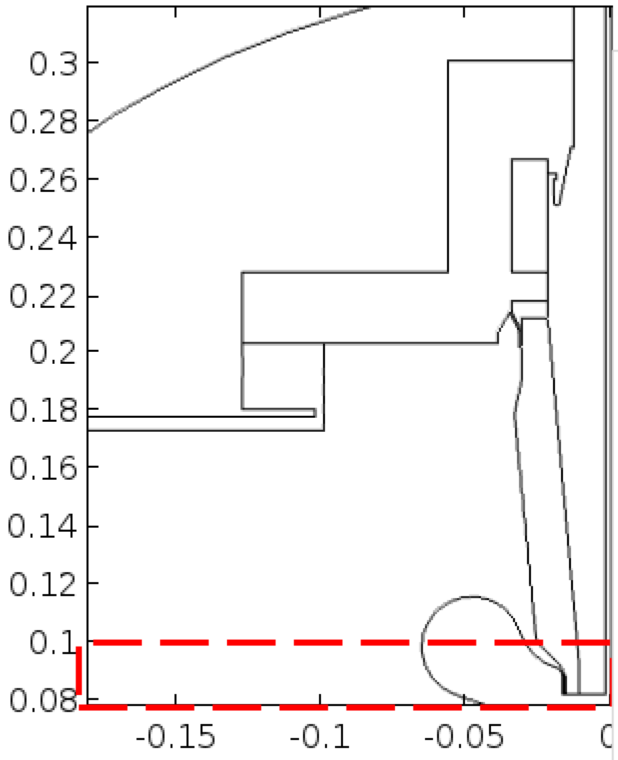


|E| field along insulator:

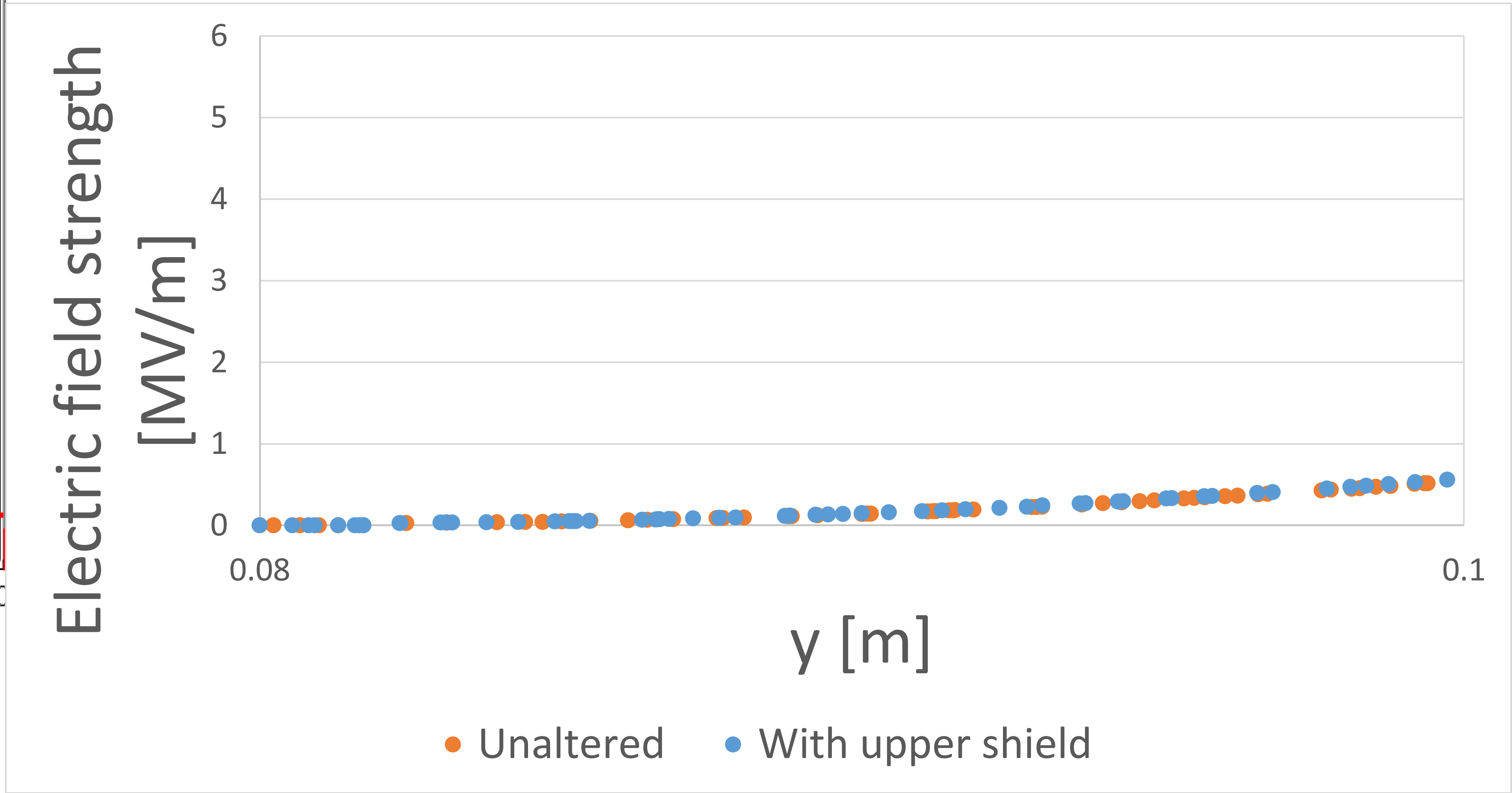
The height is ~0.14m



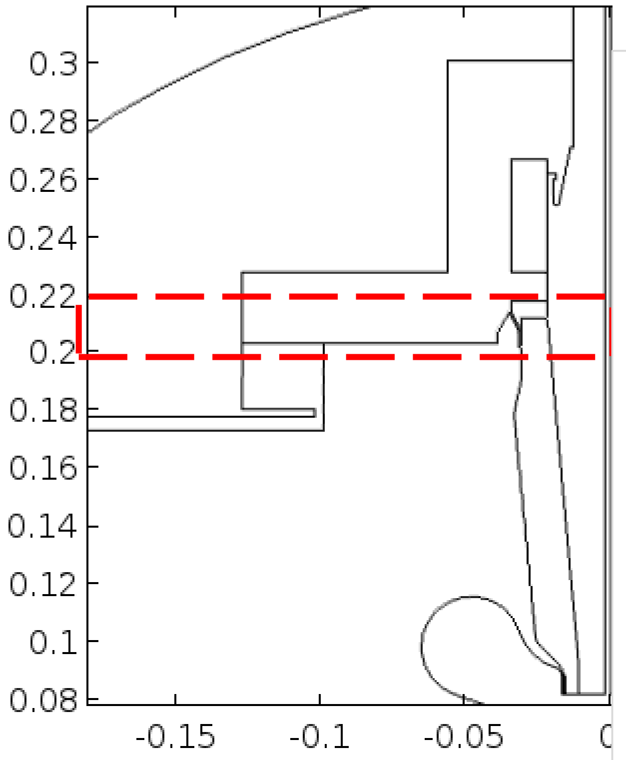
|E| near cathode triple point:



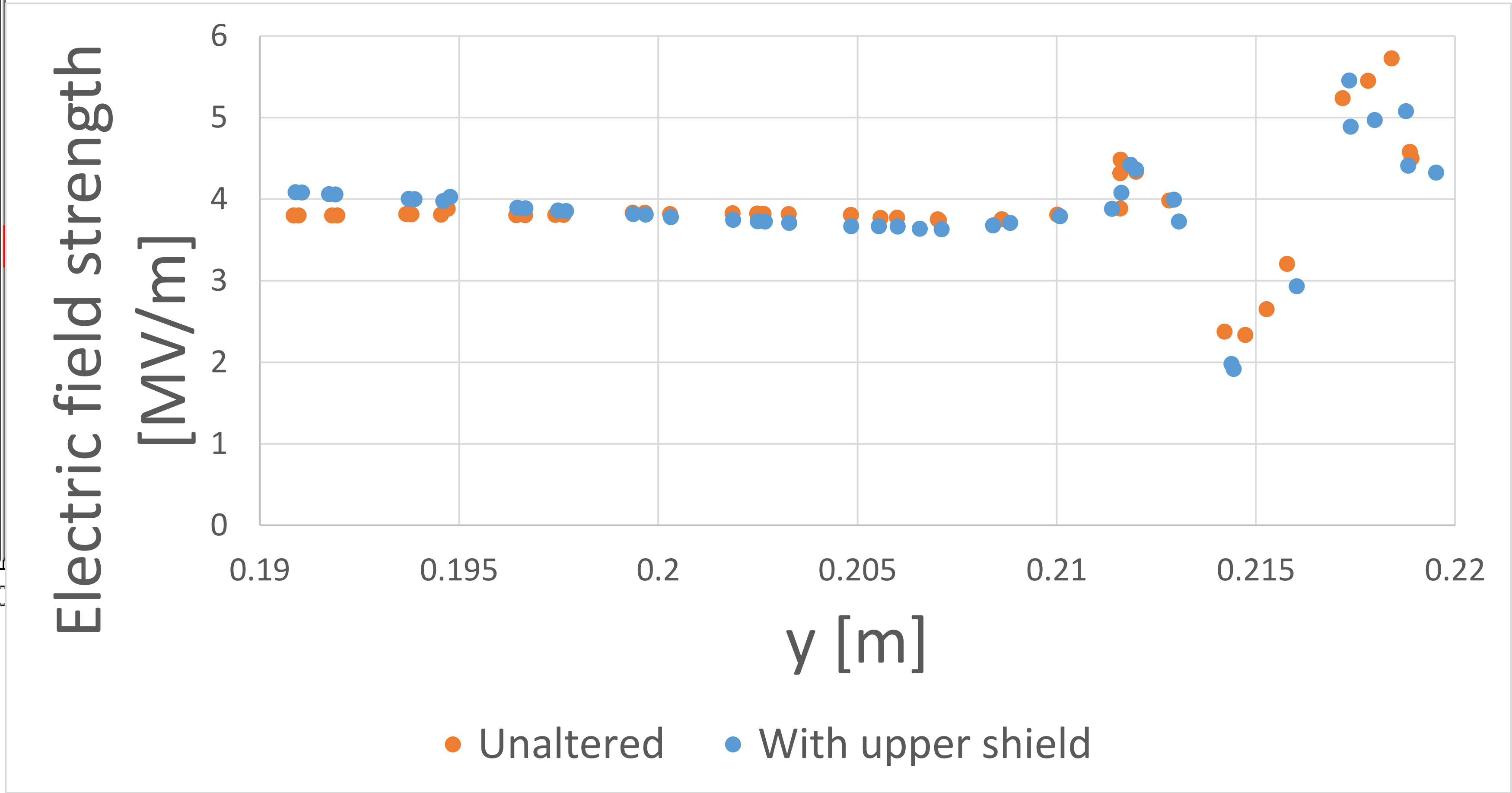
The height is ~0.14m



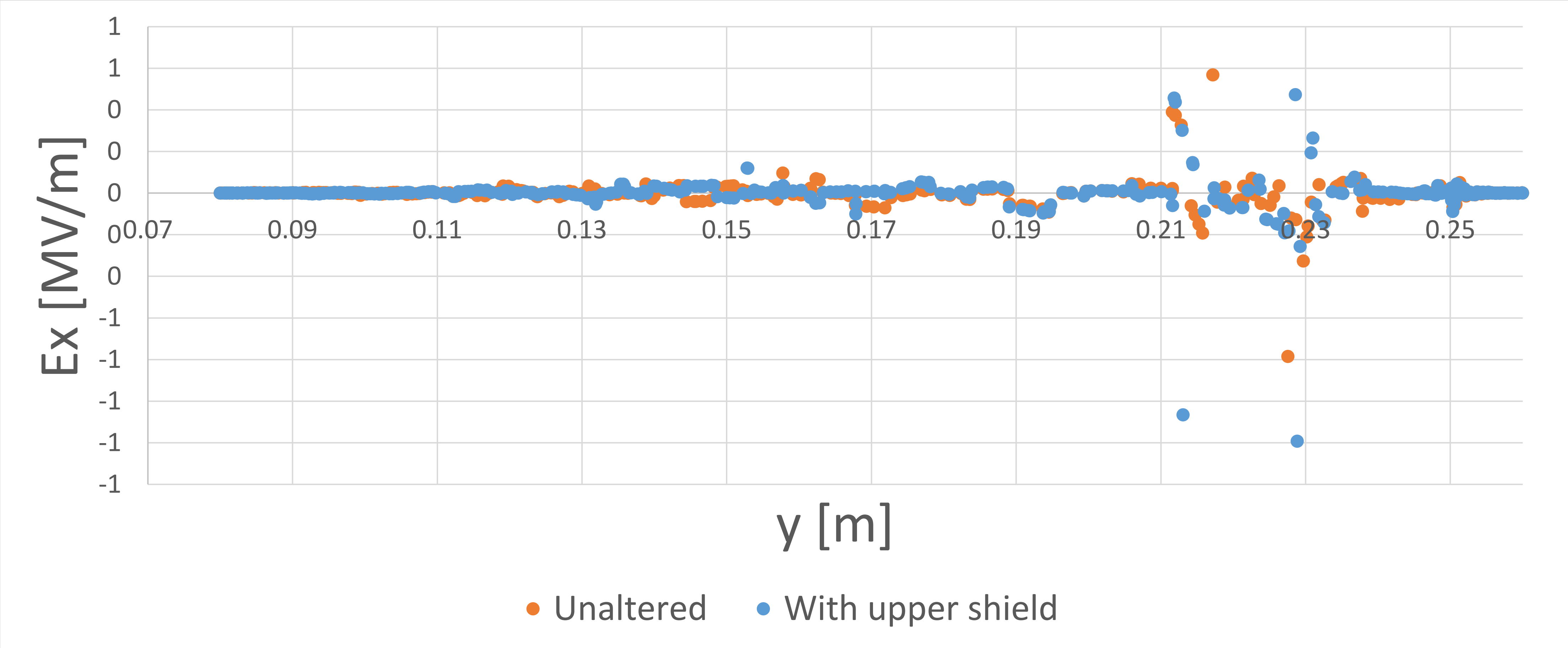
|E| near upper triple-point:



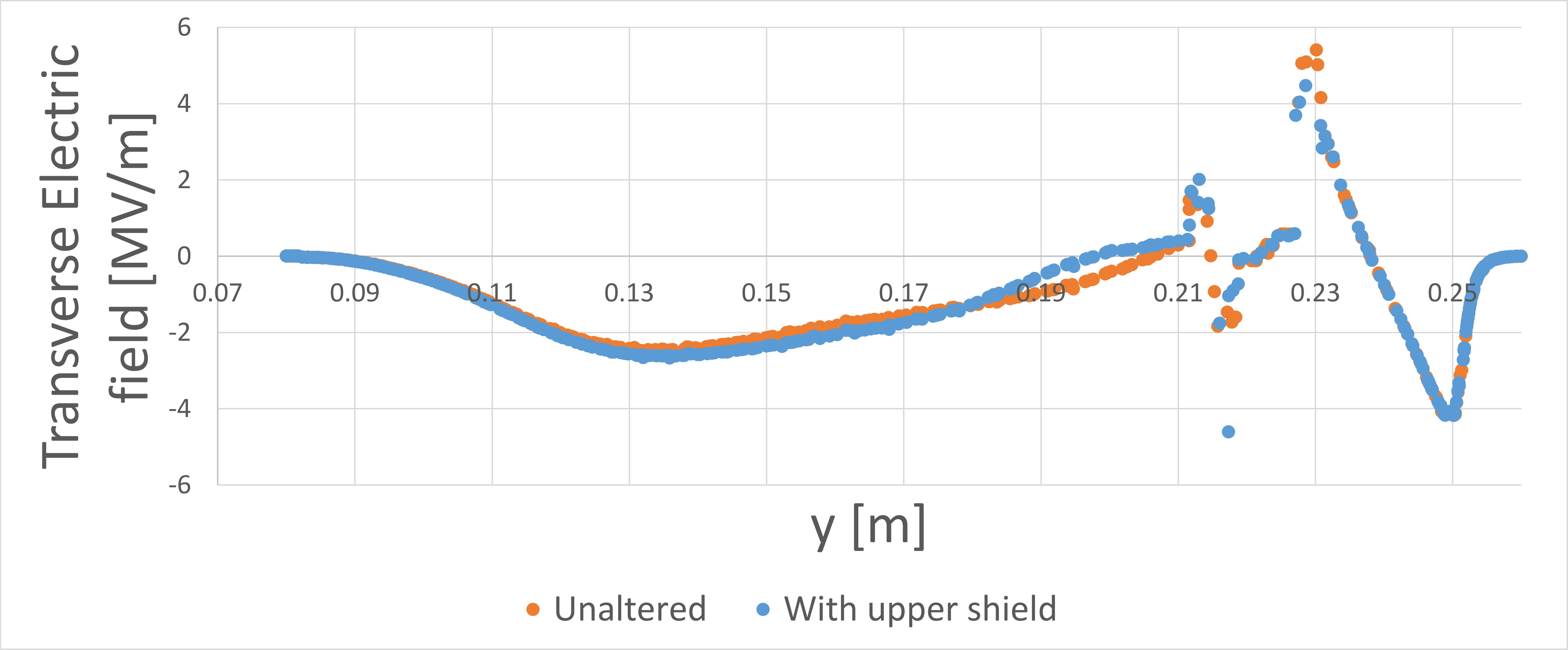
The height is ~0.14m



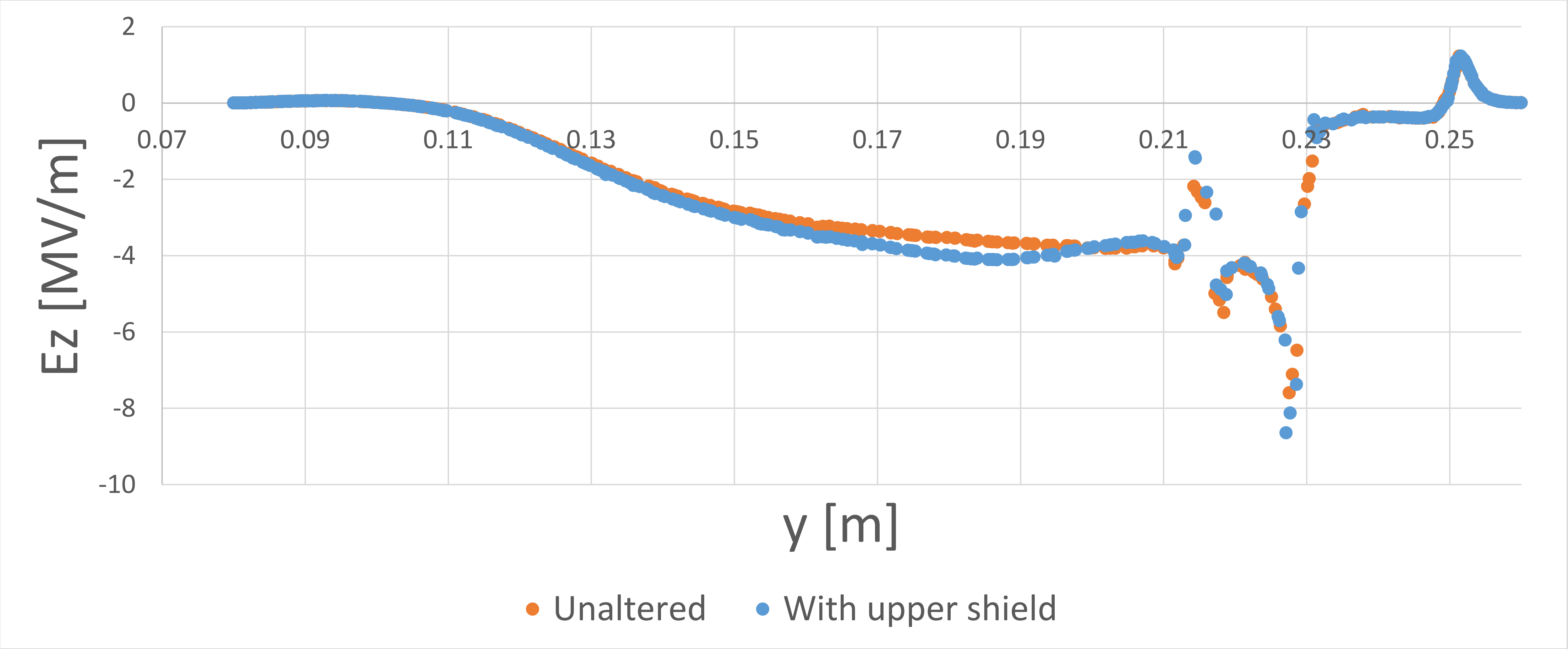
Electric field in the x-direction along insulator:



Electric field in the y-direction along insulator:



Electric field in the z-direction along insulator:



Preliminary conclusions

- The result is very similar to the GTS 300kV upper shield tests, namely:

From the point of view of electrostatics, the presence of a small hollow shield at the upper triple-point **reduces** the linearity of the potential, and thus to **increases** the electric field at that region.

- Although it might be a benefit related to the shielding of accelerated particles that would otherwise impact the region near the Kovar ring.
- Why is the plot of|E| not changing much near the upper triple point if there is a 36% difference in the potential in that region?

$$\boldsymbol{E} = -\Delta V = -(\partial_x, \partial_y, \partial_z)V$$

But: $|\boldsymbol{E}| = \sqrt{}(\boldsymbol{E_x^2} + \boldsymbol{E_y^2} + \boldsymbol{E_z^2})$

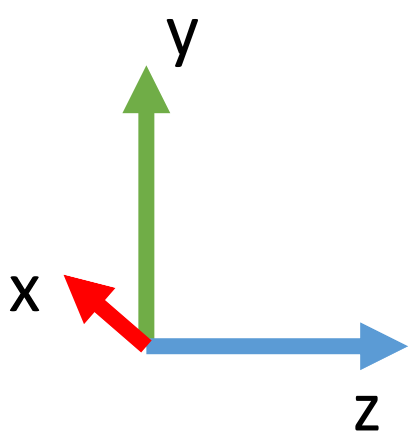
So we can see the individual gradients in the plots Ex, Ey, Ez.

Next steps.

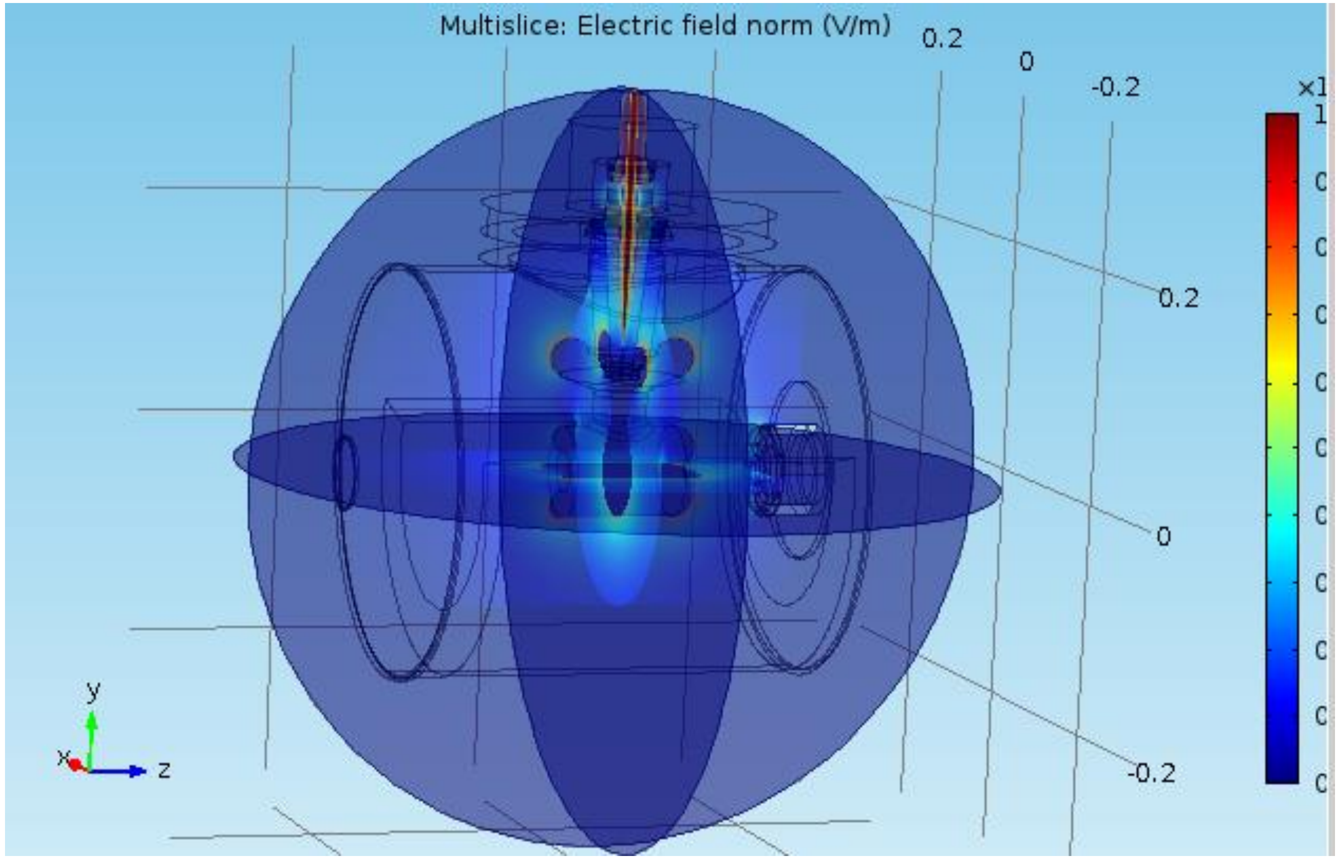
- Add plots for the cathode-anode gap
- ~~Add values of field at points on the periphery of the cathode and upper shield.~~

Fin.

COMSOL frame of reference:



X goes into the page.



- This image shows the electric field norm |E| in MV/m as color intensity. The coordinate system is as shown for all plots and images the origin is at the center of the cathode electrode. (The anode is at the right)