200kV gun COMSOL simulations
Ceramic insulator conductivity

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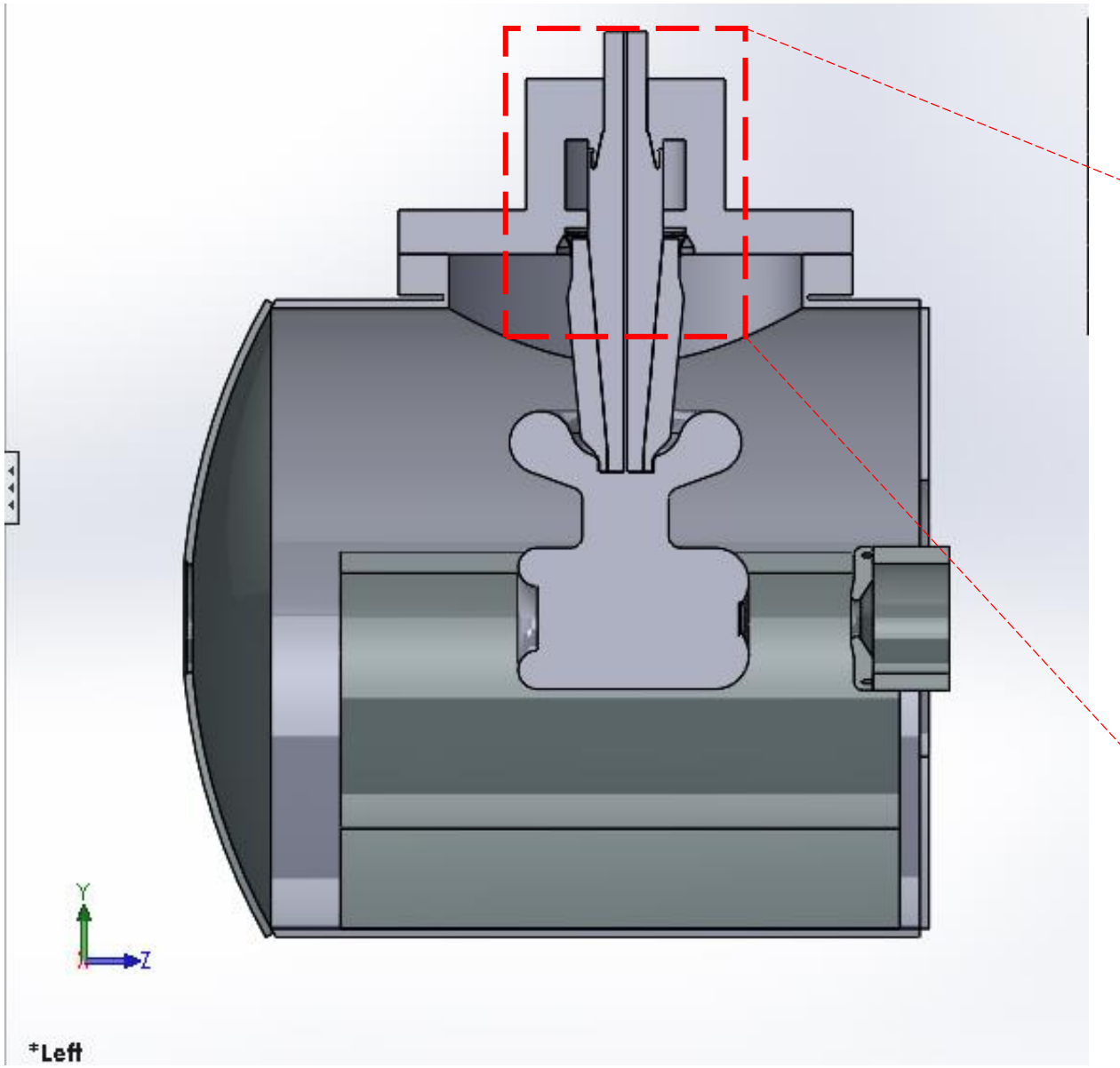
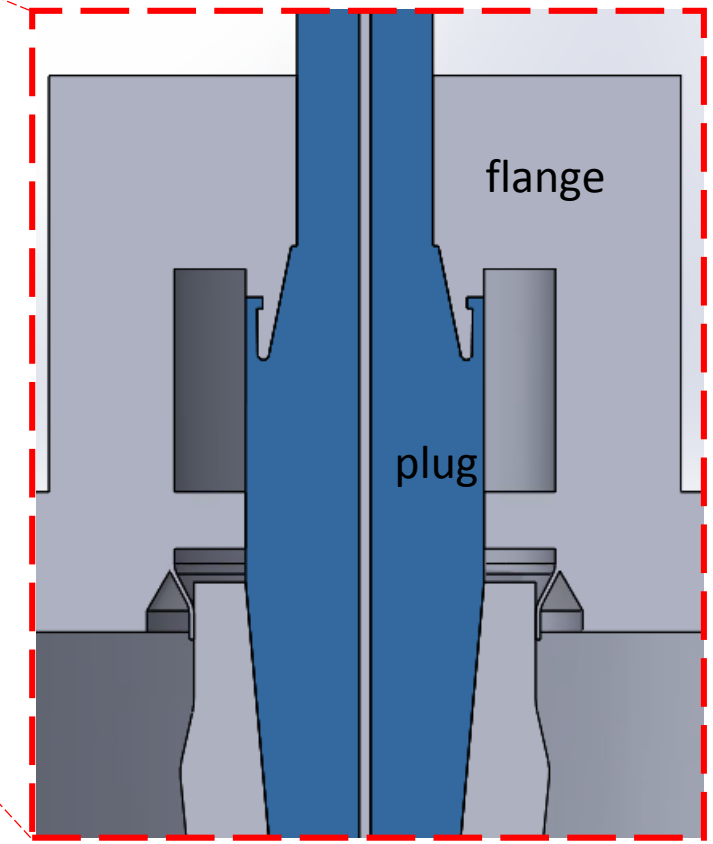
Summary

- Geometry used
- COMSOL details on simulation
  - Materials
  - Electrostatics
  - Electric currents
  - Mesh
  - Study
  - Results
  - Plots
- Future steps

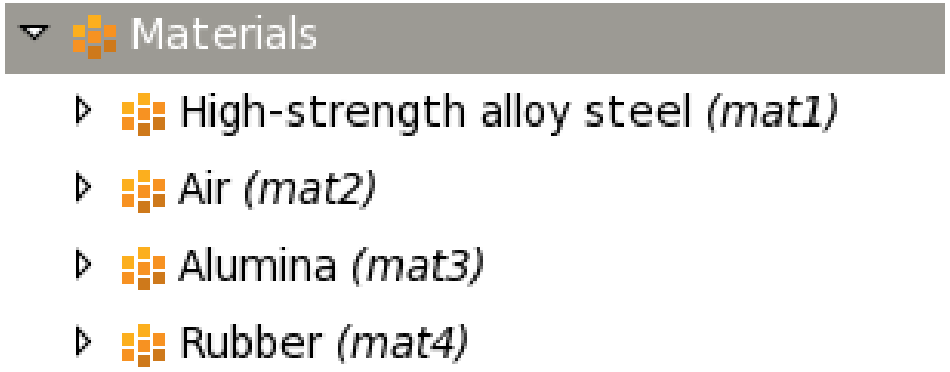
Solidworks model:



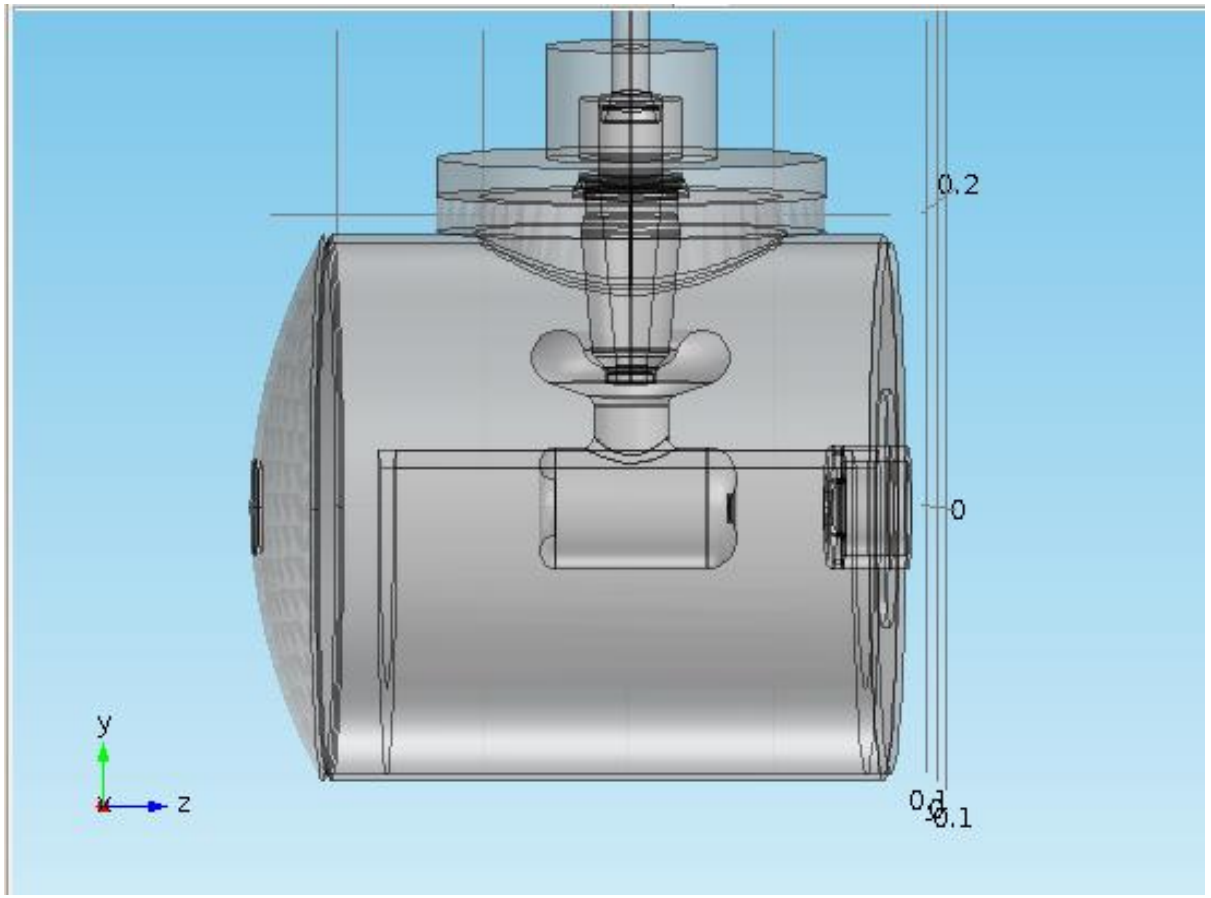
- In this simulation I used the latest model that includes the detail of the shed inside the rubber plug and the upper flange.



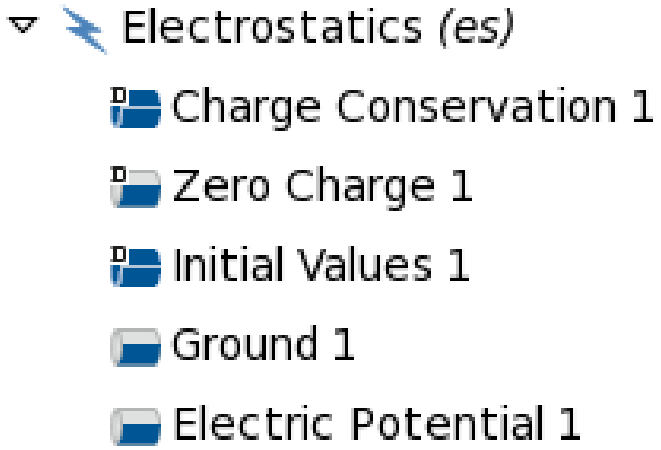
COMSOL materials:



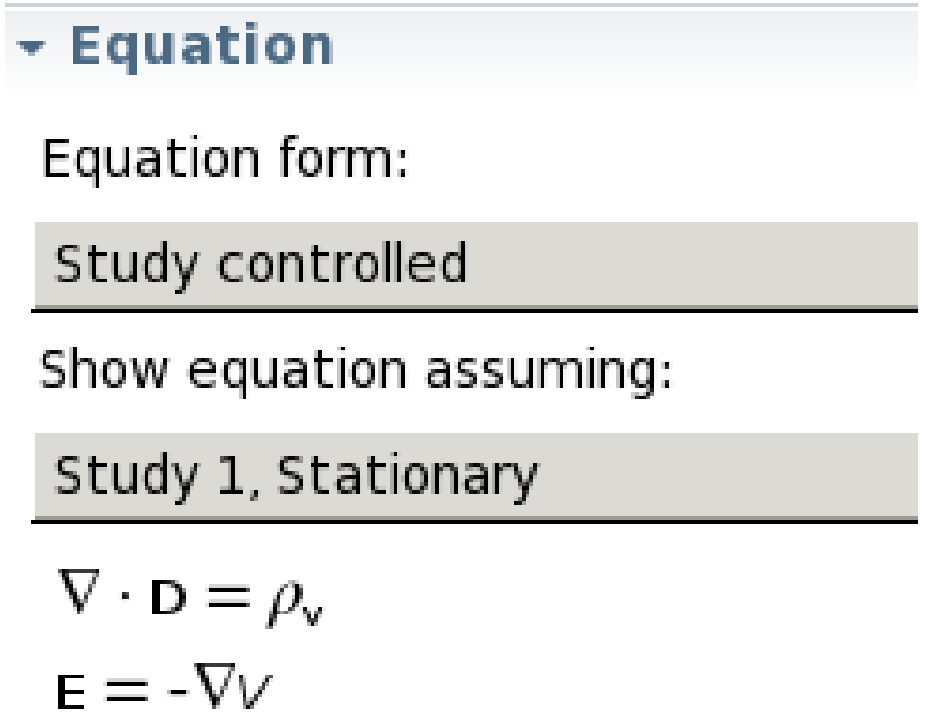
- Stainless teel for all metal components with Relative permittivity 1 and conductivity of 1.1E6 S/m
- Air for the vacuum surroundings.
  - NOTE: air conductivity was set to 1E-40 S/m.
- Alumina for the ceramic.
  - Relative permittivity 8.4 and conductivity of 2E-12 S/m for the black alumina.
  - Relative permittivity 9.1 and conductivity of 2E-14 S/m for the white alumina.
- Rubber for the HV cable plug with Relative permittivity 2.37 and conductivity of 1E-14 S/m .



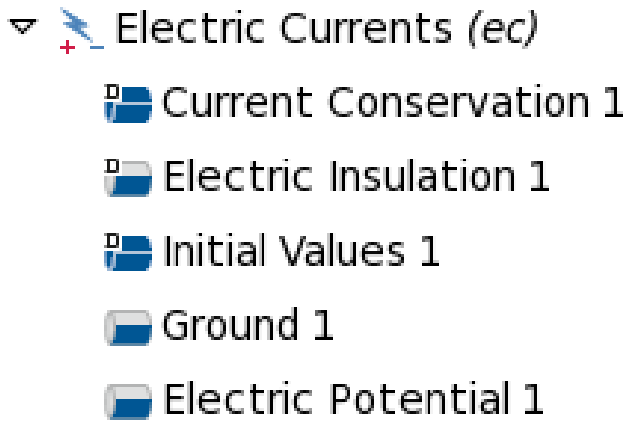
COMSOL electrostatics:



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



COMSOL electric currents:



- 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, NEGs, anode, flanges.
- Electric potential at -200kV at the cathode, shed and HV cable.

Equation

Equation form:

Study controlled

Show equation assuming:

Study 1, Stationary

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

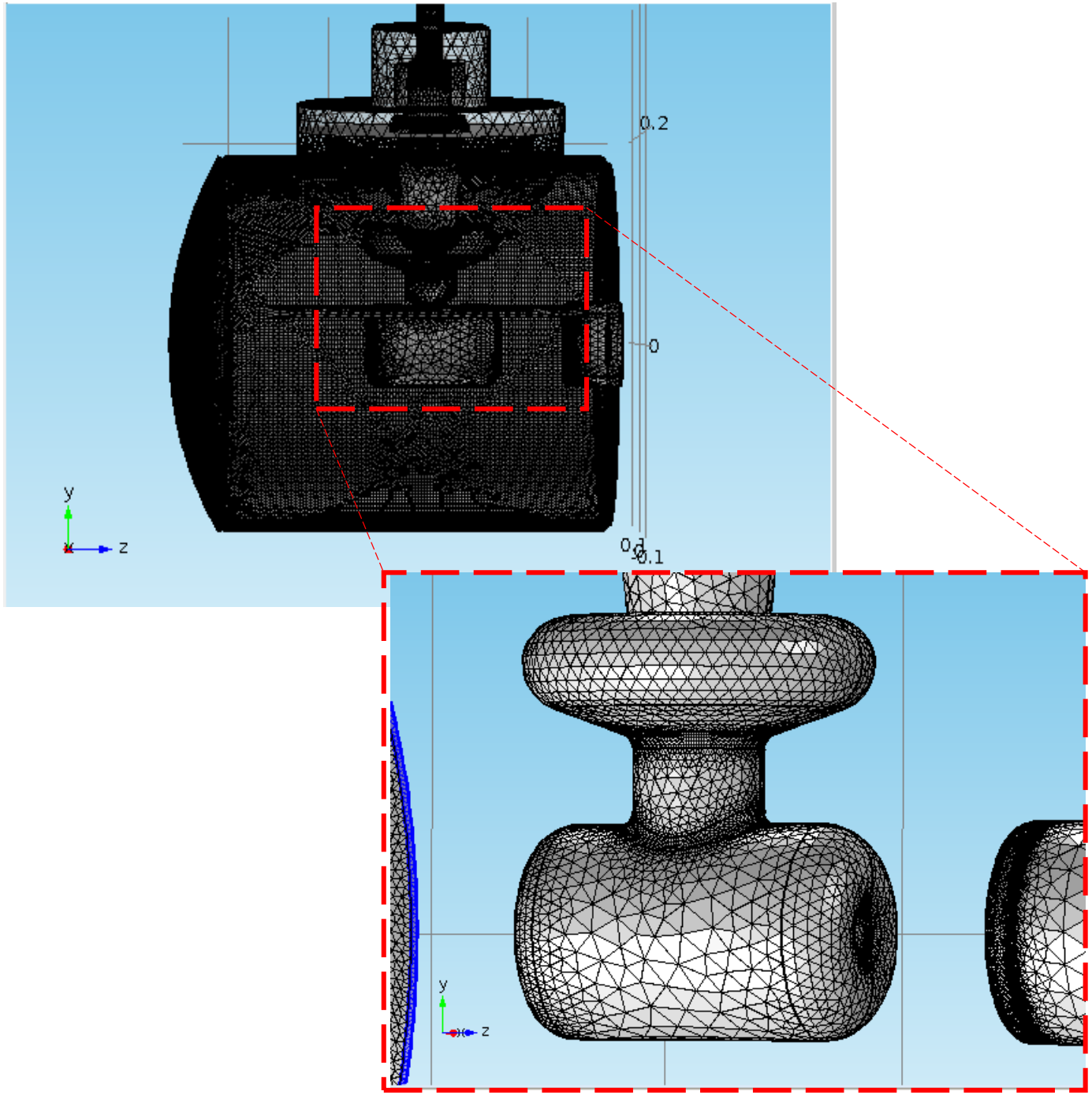
$$\mathbf{J} = \sigma \mathbf{E} + \mathbf{J}_e$$

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

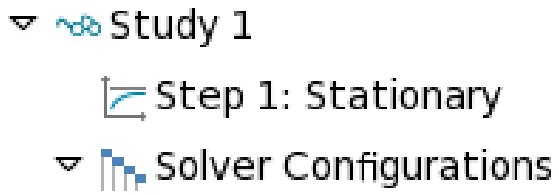
COMSOL mesh:

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

- An 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 and the electric currents separately and obtains a potential and electric fields for each solution.

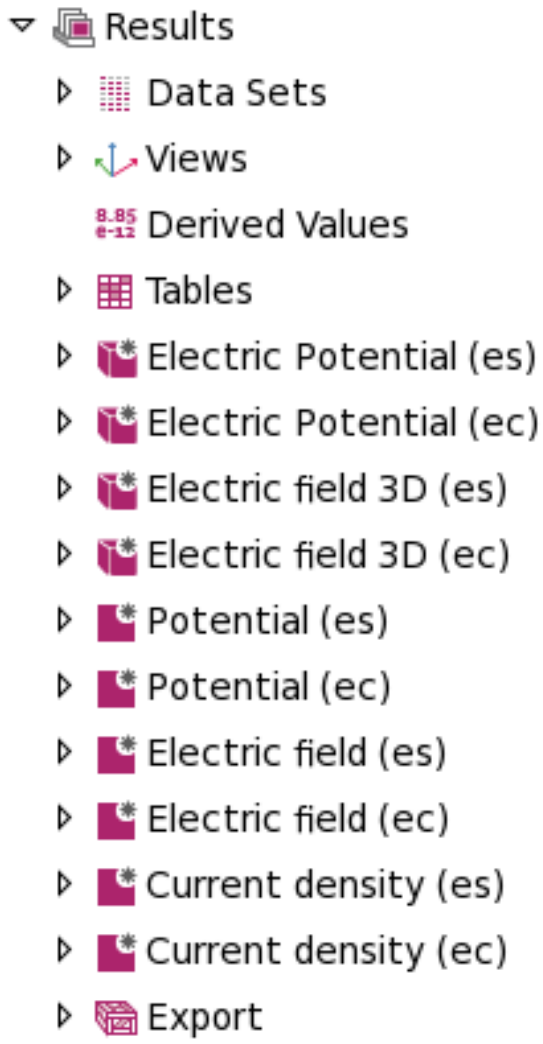
Physics and Variables Selection

☐ Modify physics tree and variables for study step

	Physics interface	Solve for
	Electrostatics (es)	☑
	Electric Currents (ec)	☑

COMSOL results:

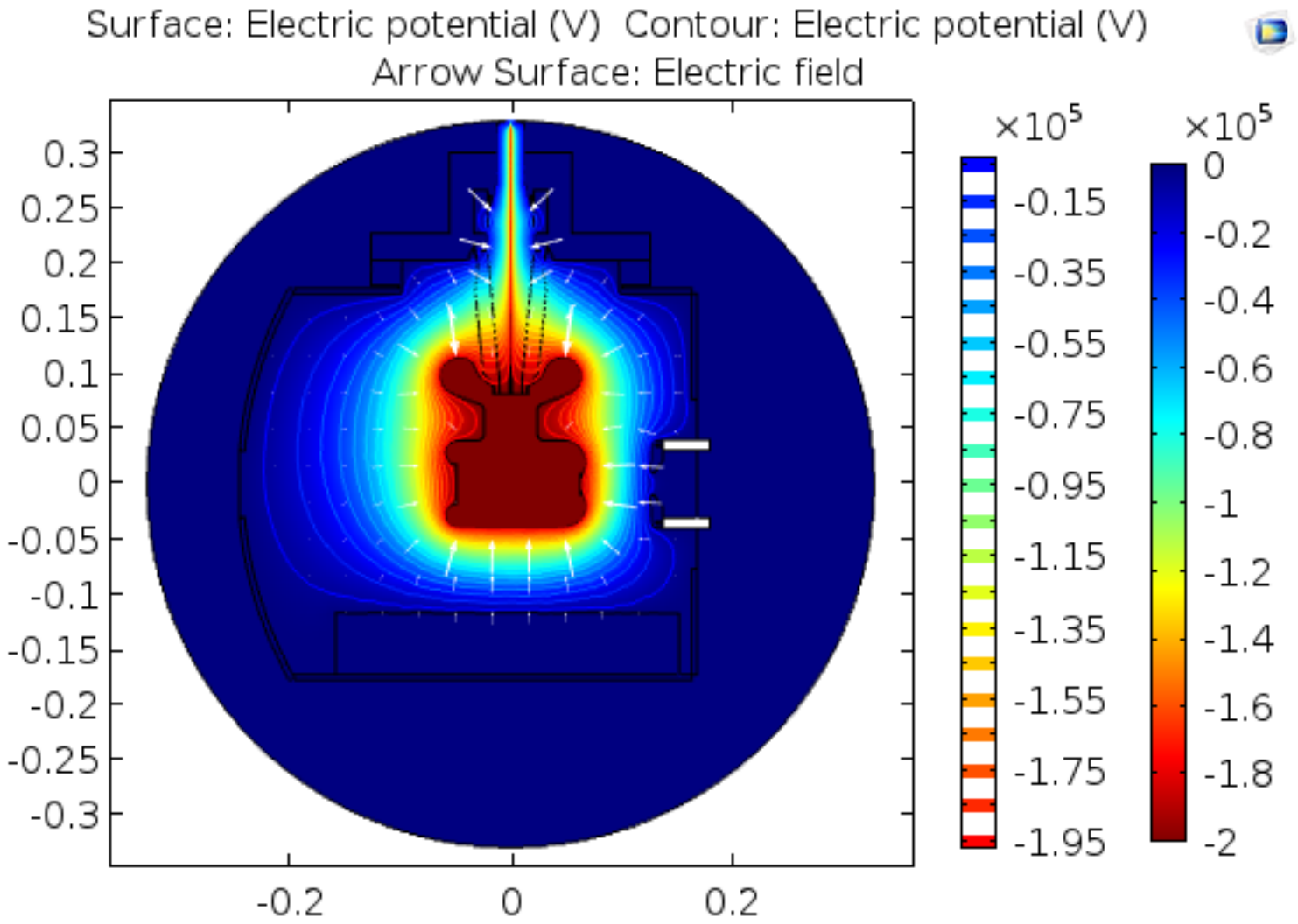
- After the solver finished obtaining the solutions, I produced a group of plots that show the potential and electric field in different cases as a visual aid. Then using the data sets, I extracted the information from a line parallel to the ceramic insulator - rubber plug boundary and plotted the potential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



No conductivity vs White insulator conductivity

- Conductivity of 2E-14 S/m

COMSOL Potential:

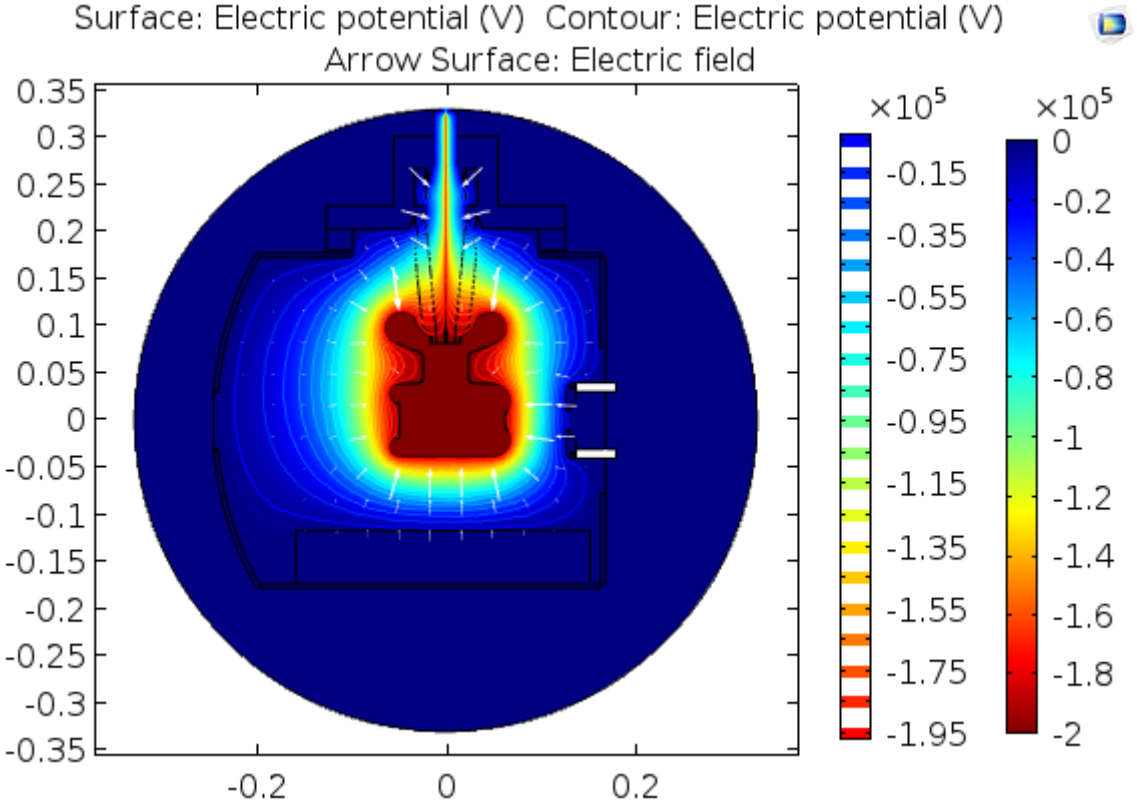


- This image shows the potential as color intensity (with equipotential lines). The white arrows size is proportional to the intensity of the electric field norm at the arrow tip. The axis are coordinates in meters.

COMSOL Potential:

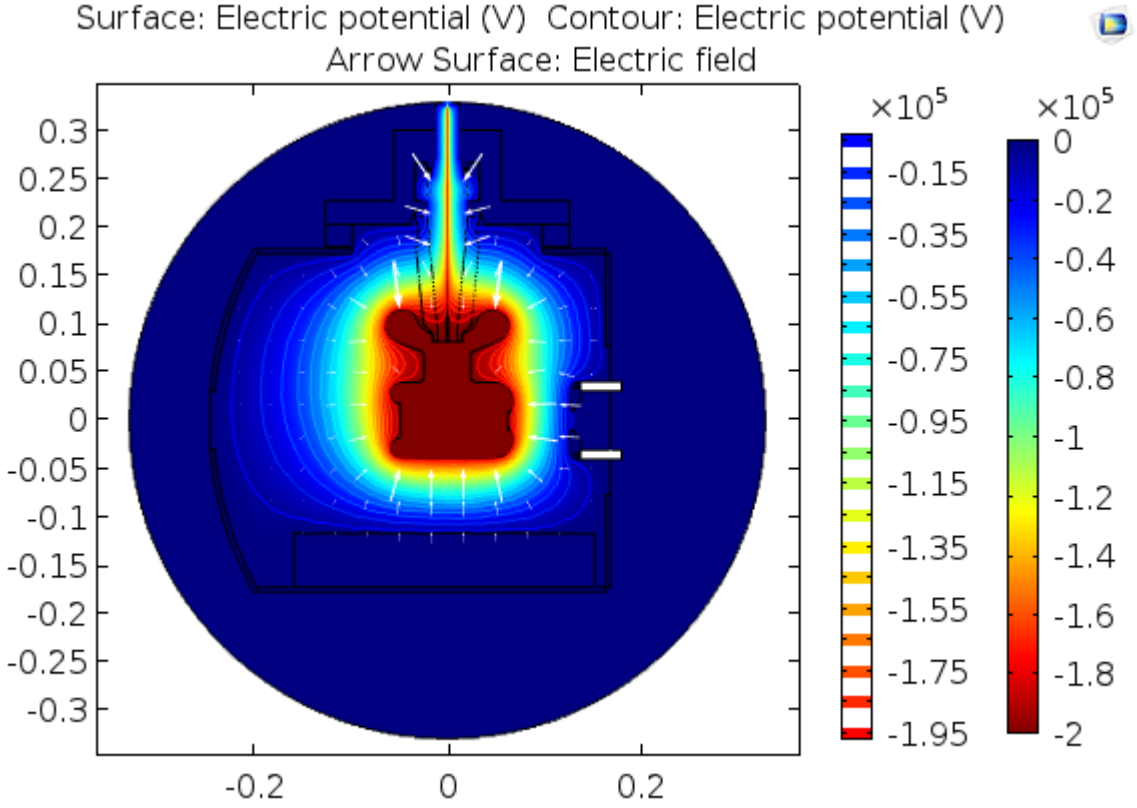
- This image shows the potential as color intensity (with equipotential lines). The white arrows size is proportional to the intensity of the electric field at the arrow tip. The axis are coordinates in meters.

Without solving for conductivity



With white alumina conductivity

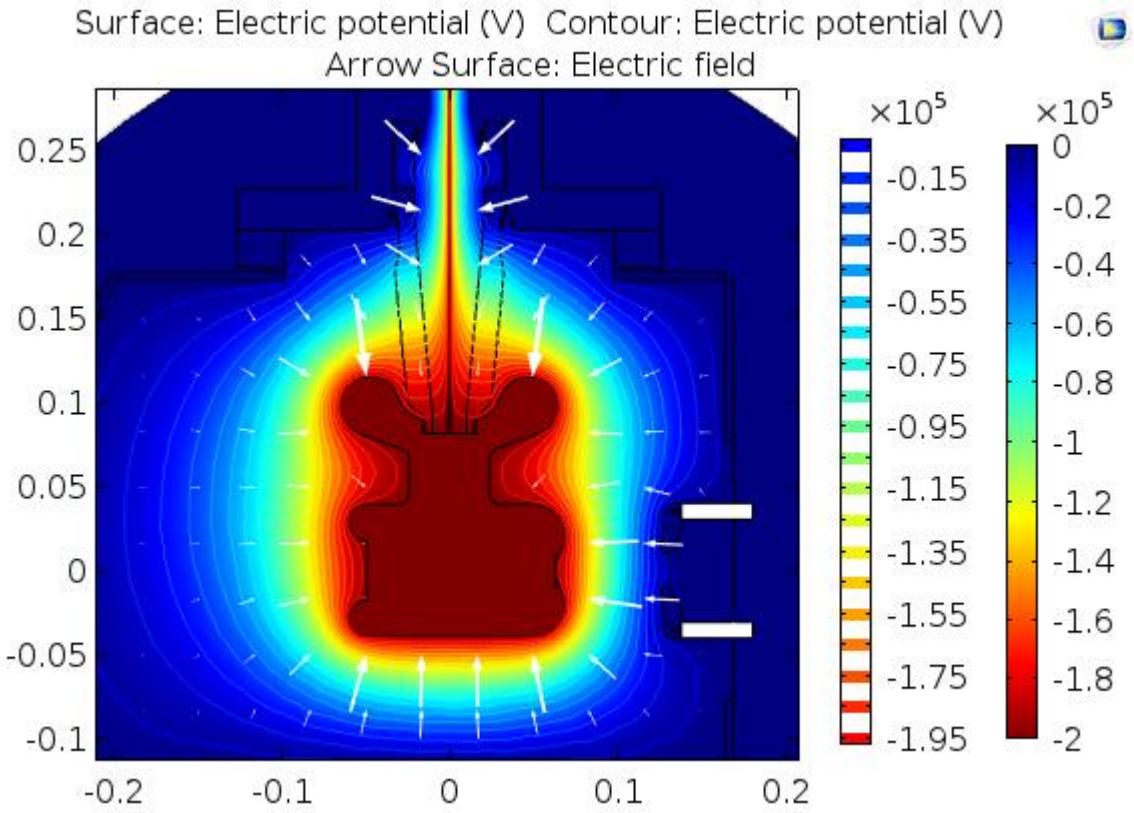
Conductivity of 2E-14 S/m



COMSOL Potential:

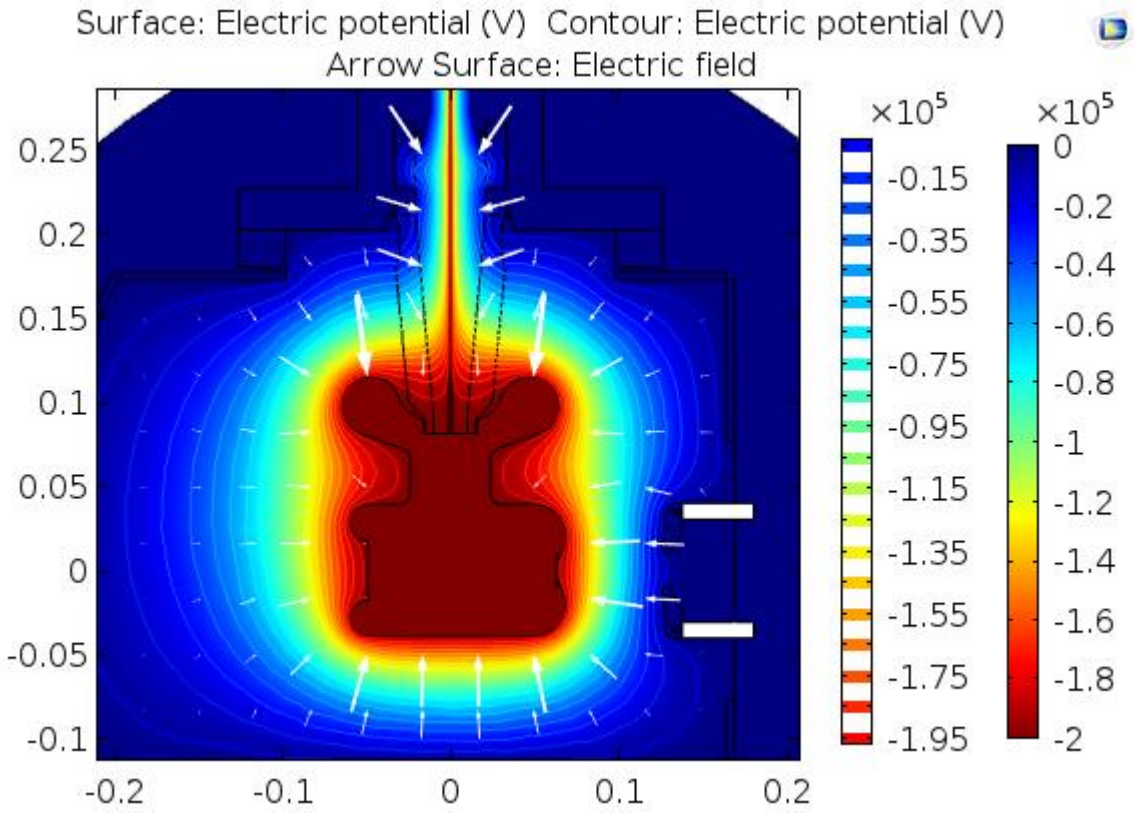
- This image shows the potential as color intensity (with equipotential lines) closer to the cathode electrode. The white arrows size is proportional to the intensity of the electric field at the arrow tip. The axis are coordinates in meters.

Without solving for conductivity



With white alumina conductivity

Conductivity of 2E-14 S/m



COMSOL Potential:

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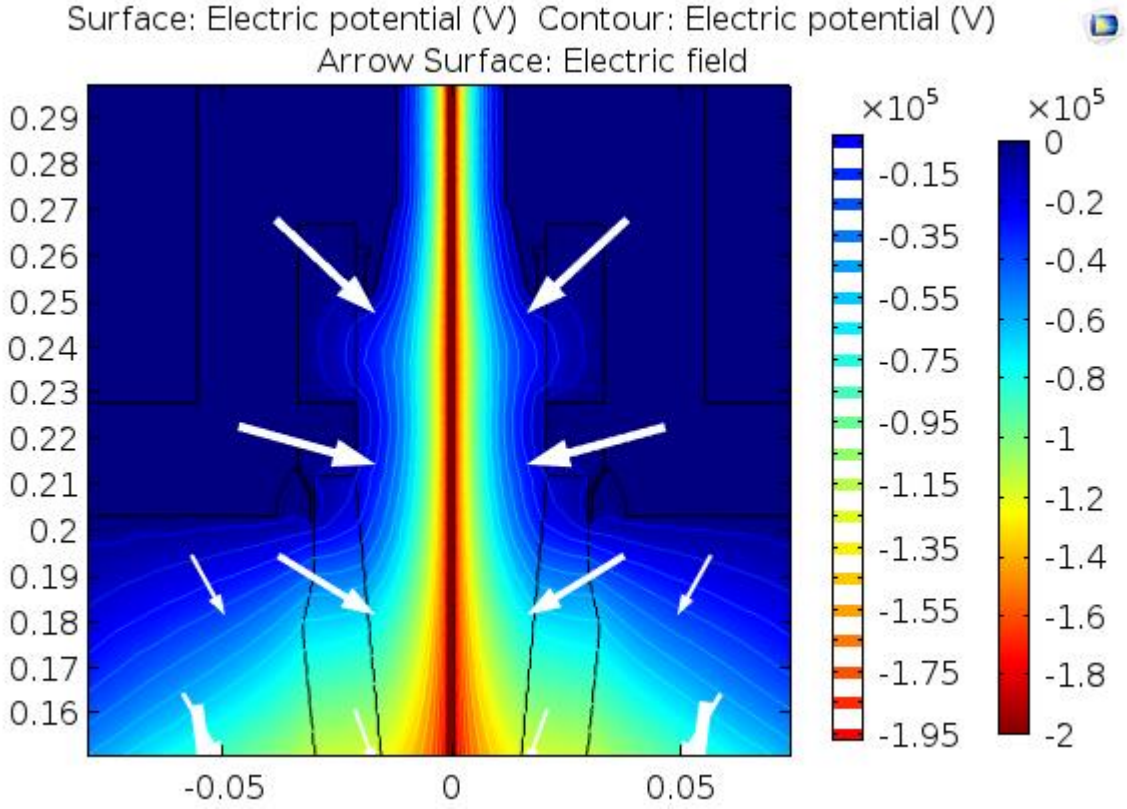
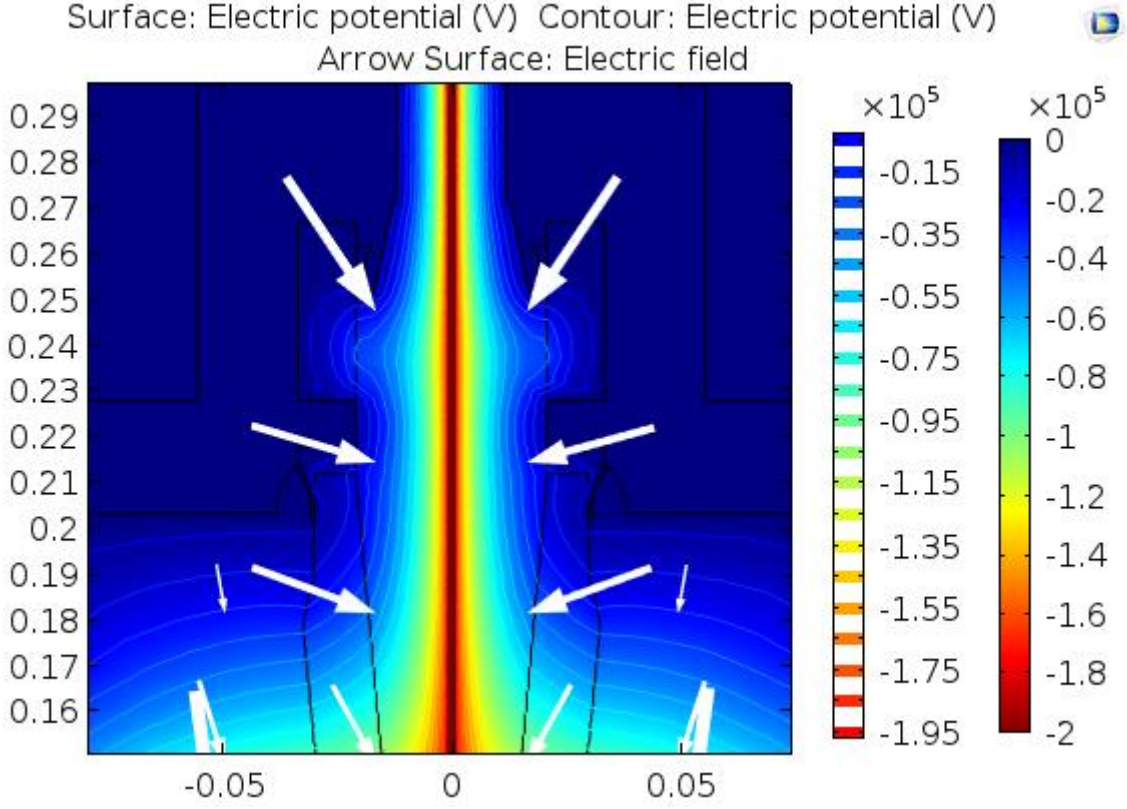
Without solving for conductivity



With white alumina conductivity

Conductivity of 2E-14 S/m



No conductivity vs Black insulator conductivity

- Conductivity of 2E-12 S/m

COMSOL Potential:

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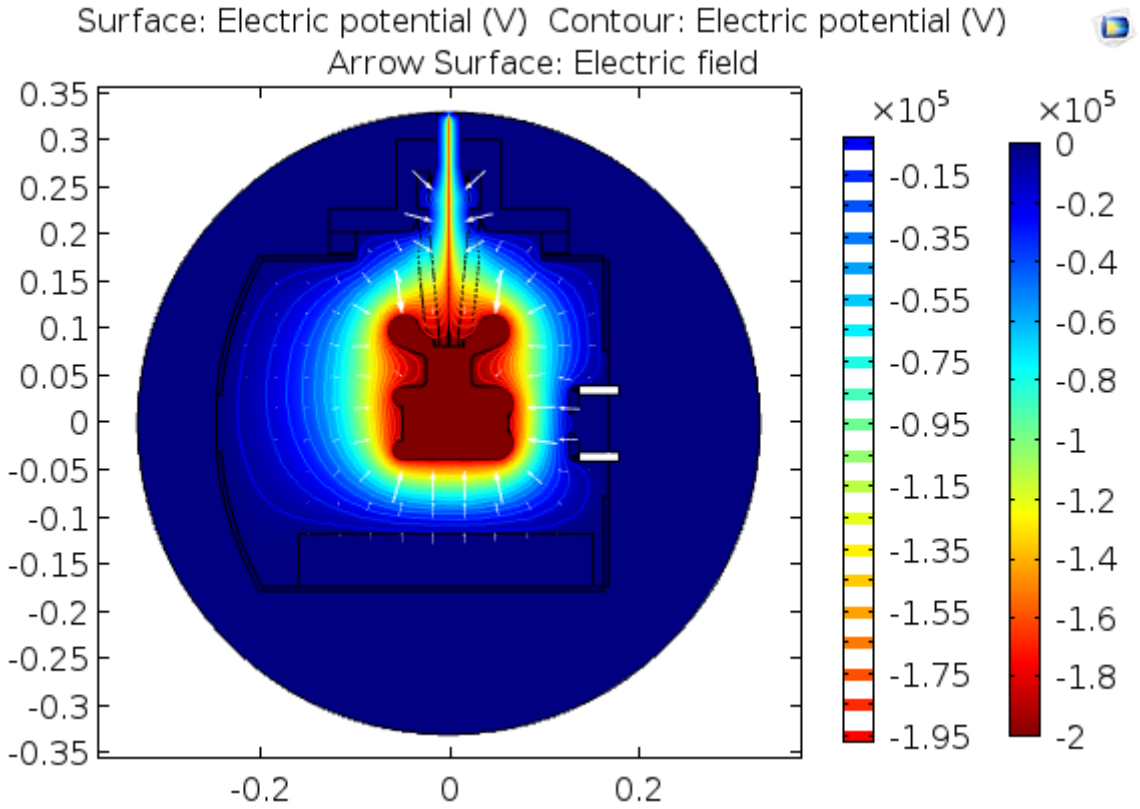
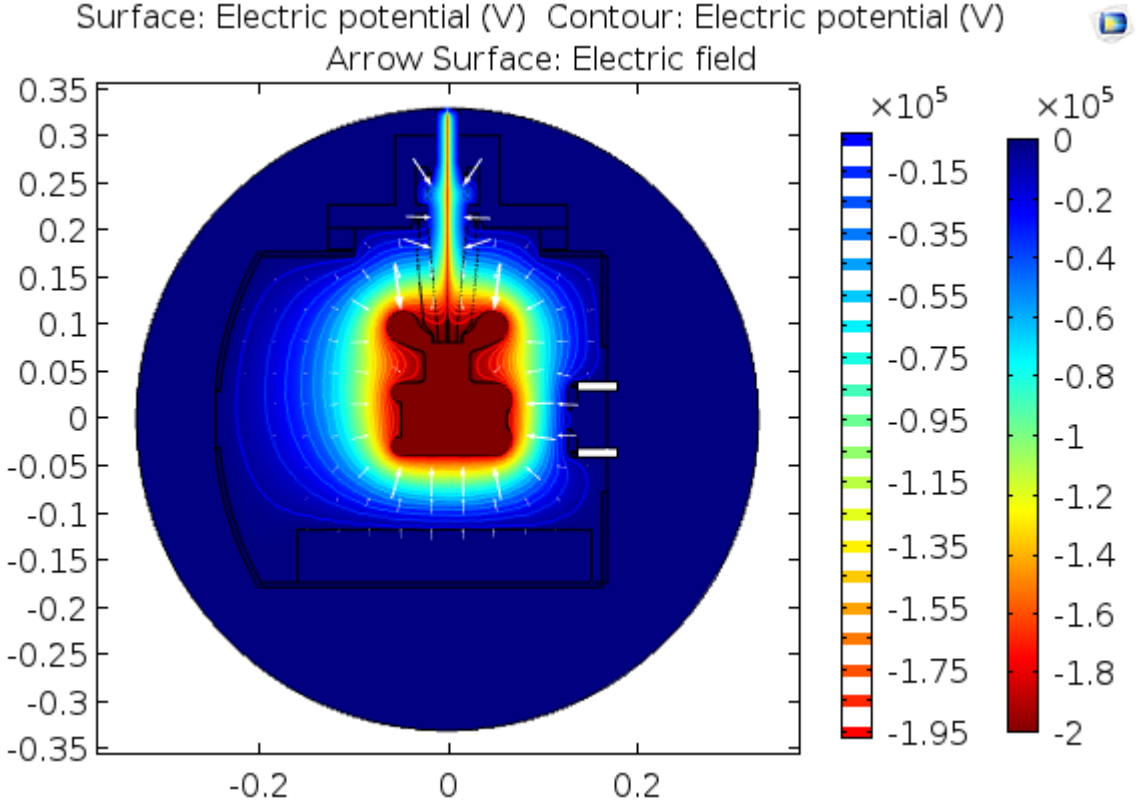
Without solving for conductivity



With black alumina conductivity

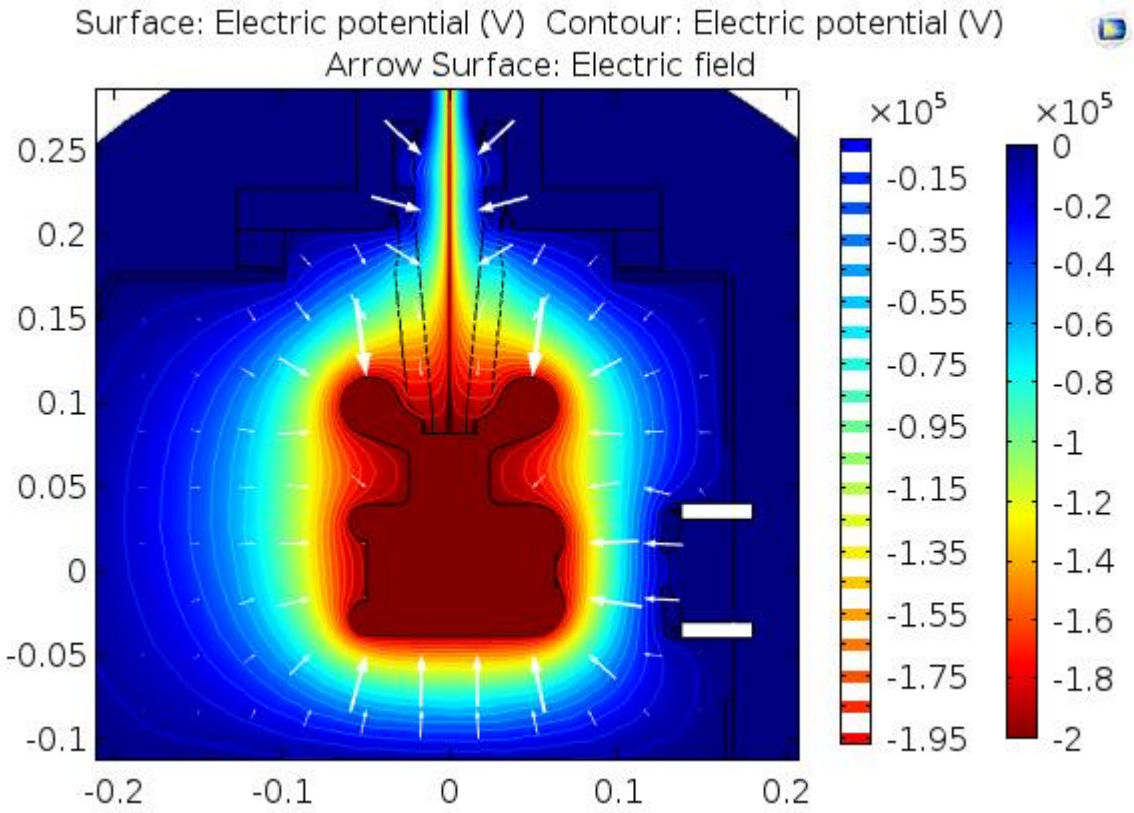
conductivity of 2E-12 S/m



COMSOL Potential:

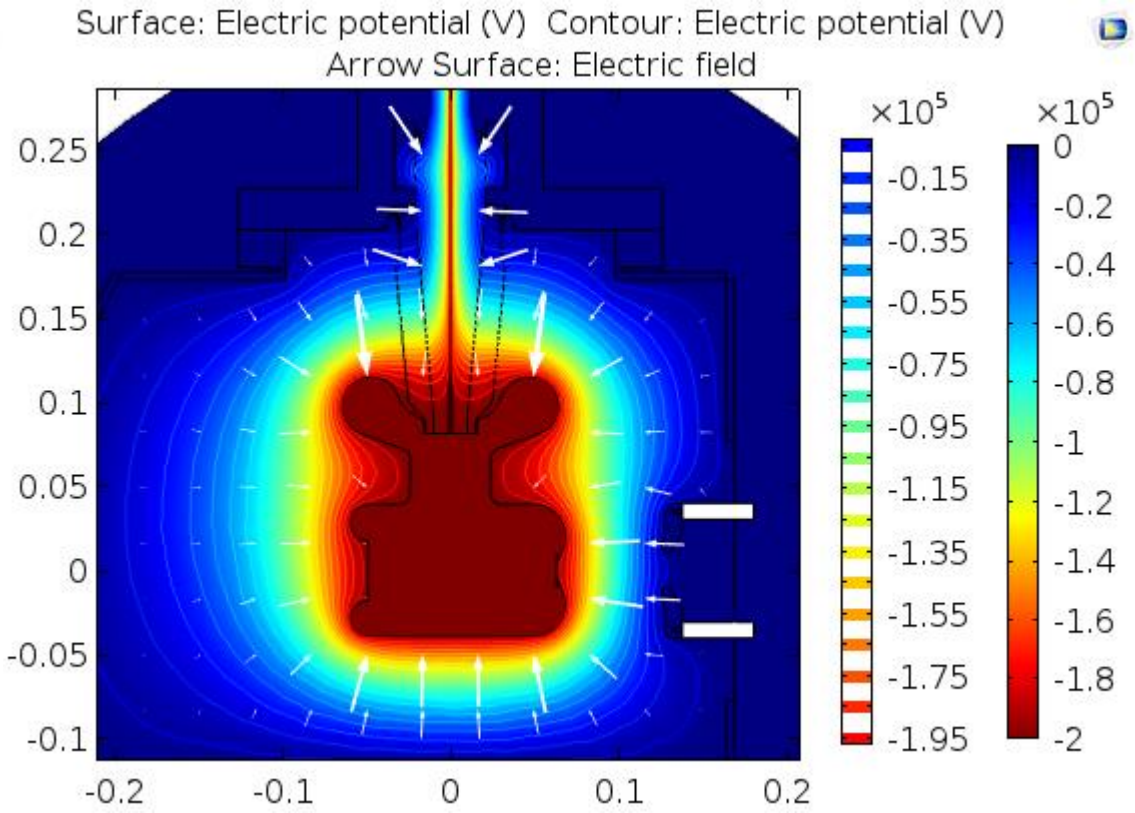
- This image shows the potential as color intensity (with equipotential lines) closer to the cathode electrode. The white arrows size is proportional to the intensity of the electric field at the arrow tip. The axis are coordinates in meters.

Without solving for conductivity



With black alumina conductivity

conductivity of 2E-12 S/m



COMSOL Potential:

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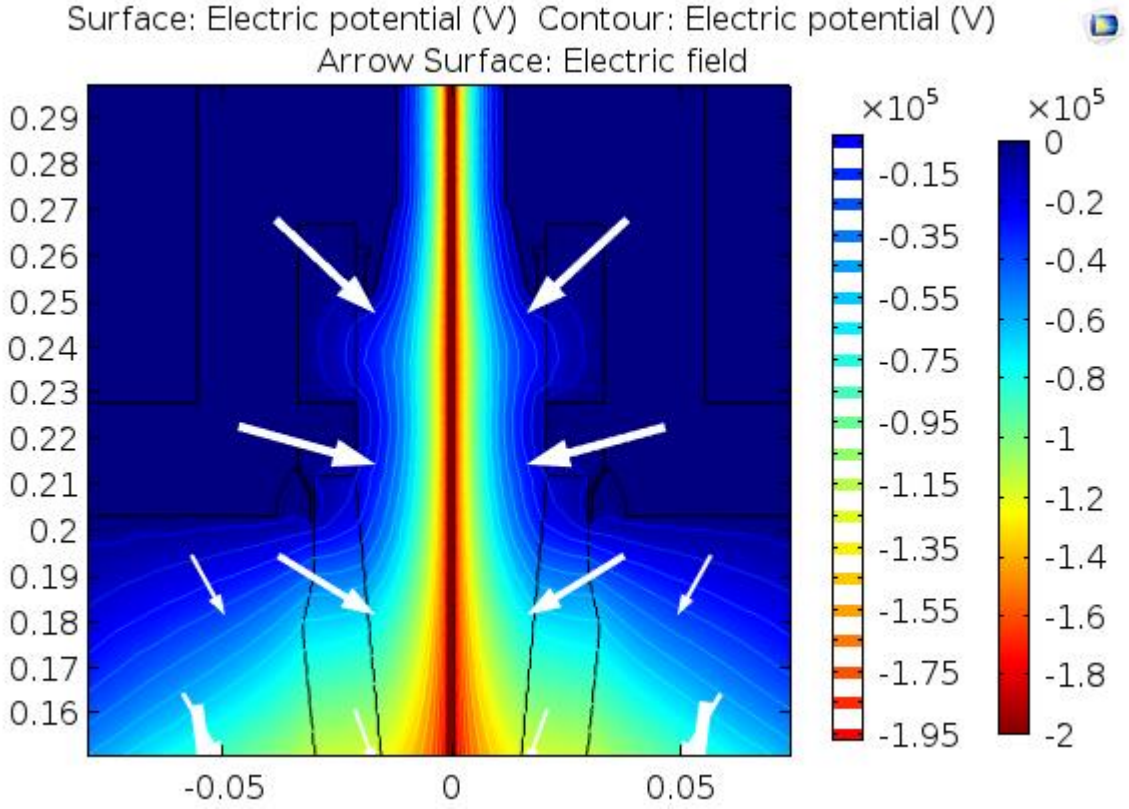
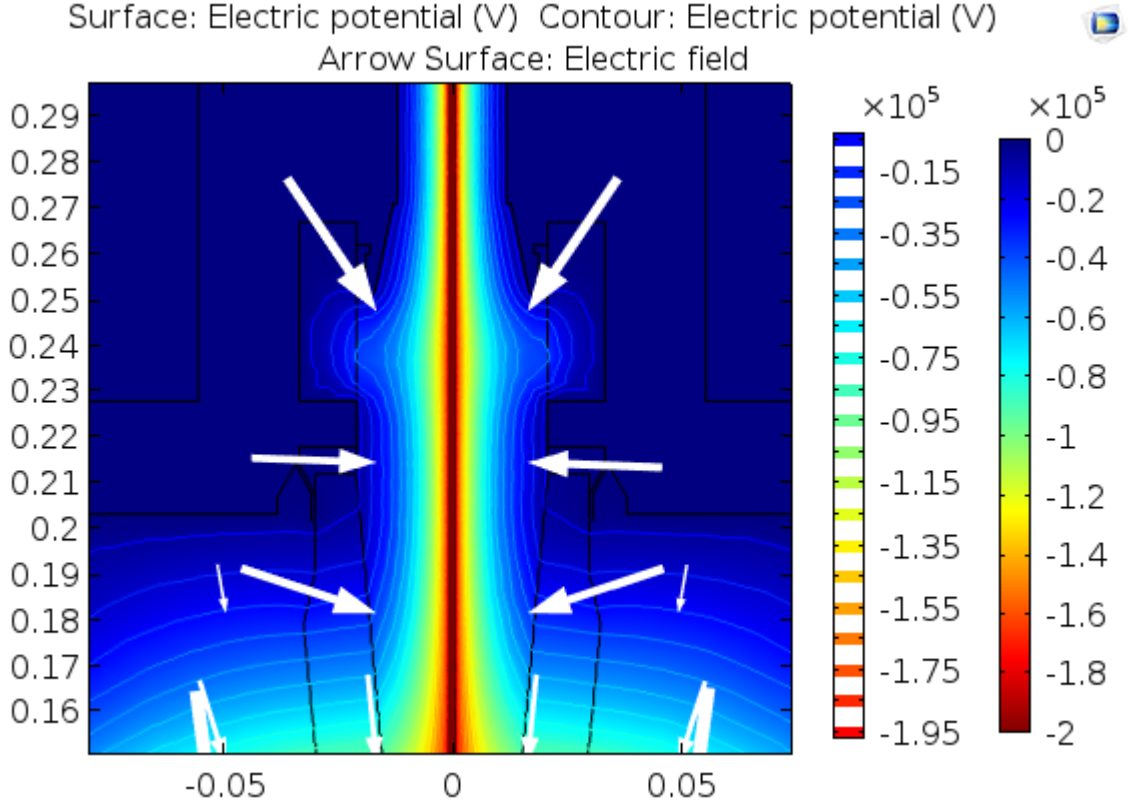
Without solving for conductivity



With black alumina conductivity

conductivity of 2E-12 S/m



White insulator vs Black insulator

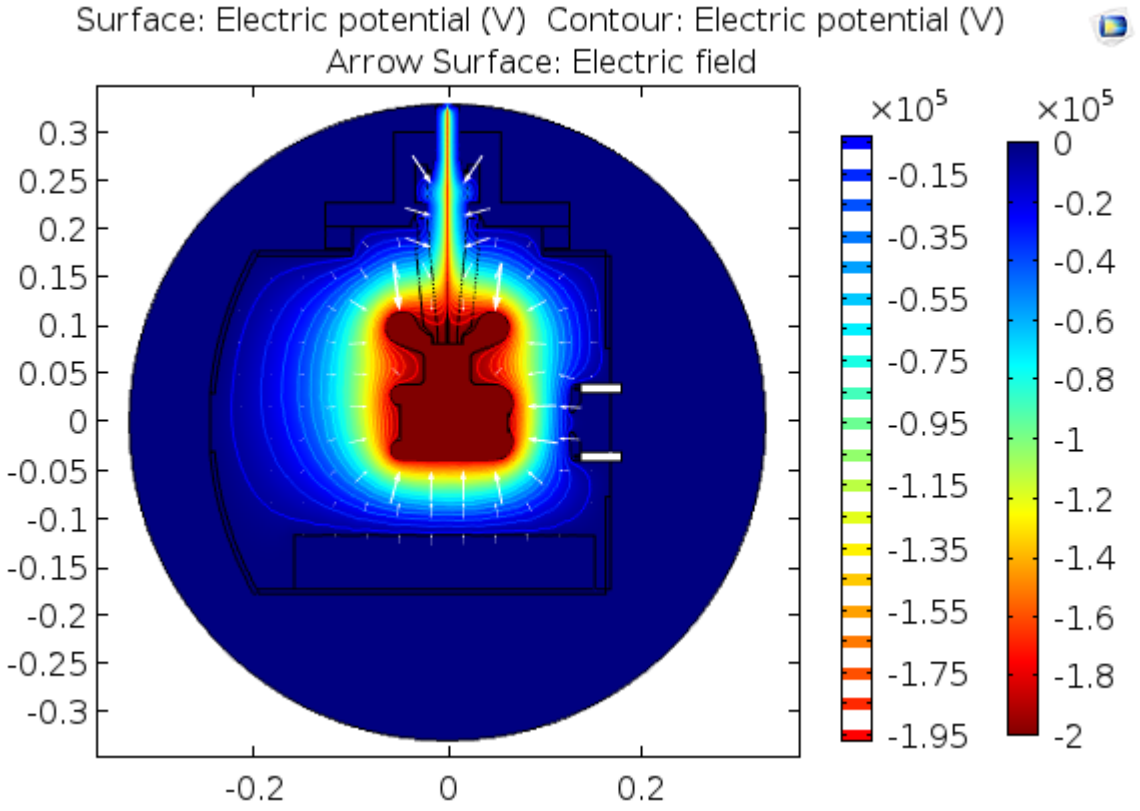
- White alumina conductivity of 2E-14 S/m
- Black alumina conductivity of 2E-12 S/m

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.

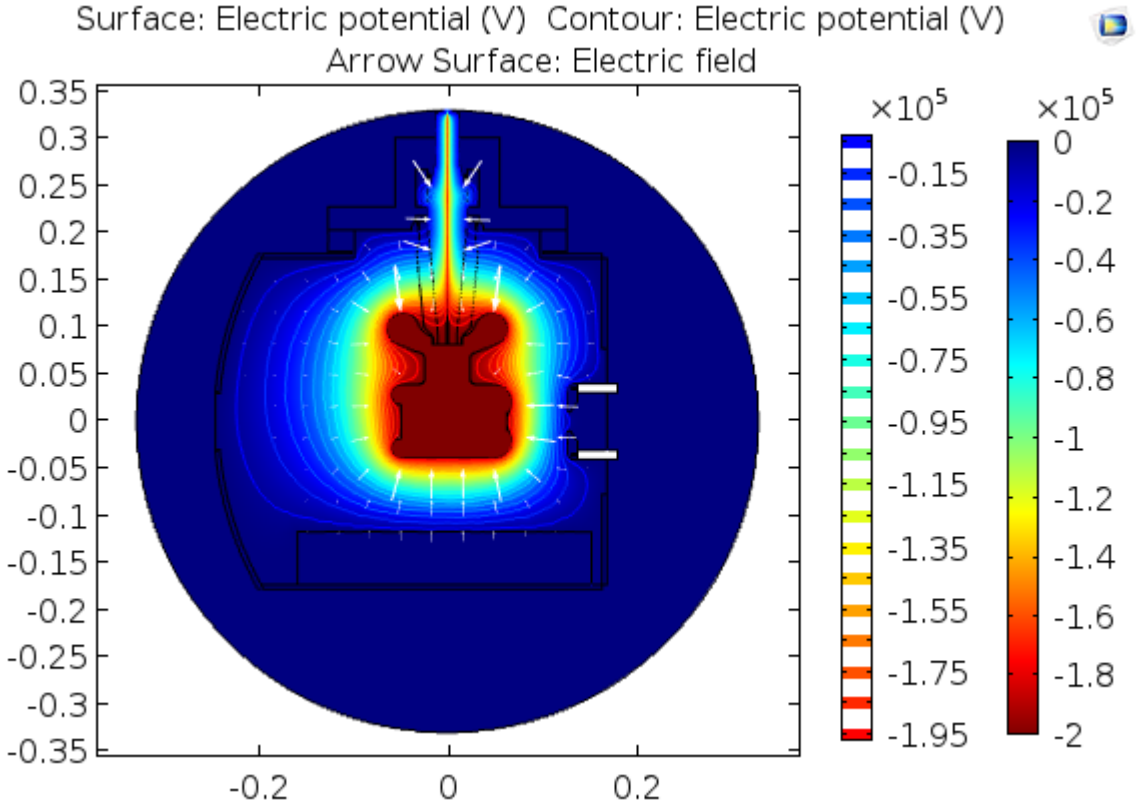
With white alumina conductivity

Conductivity of 2E-14 S/m



With black alumina conductivity

conductivity of 2E-12 S/m



COMSOL Potential:

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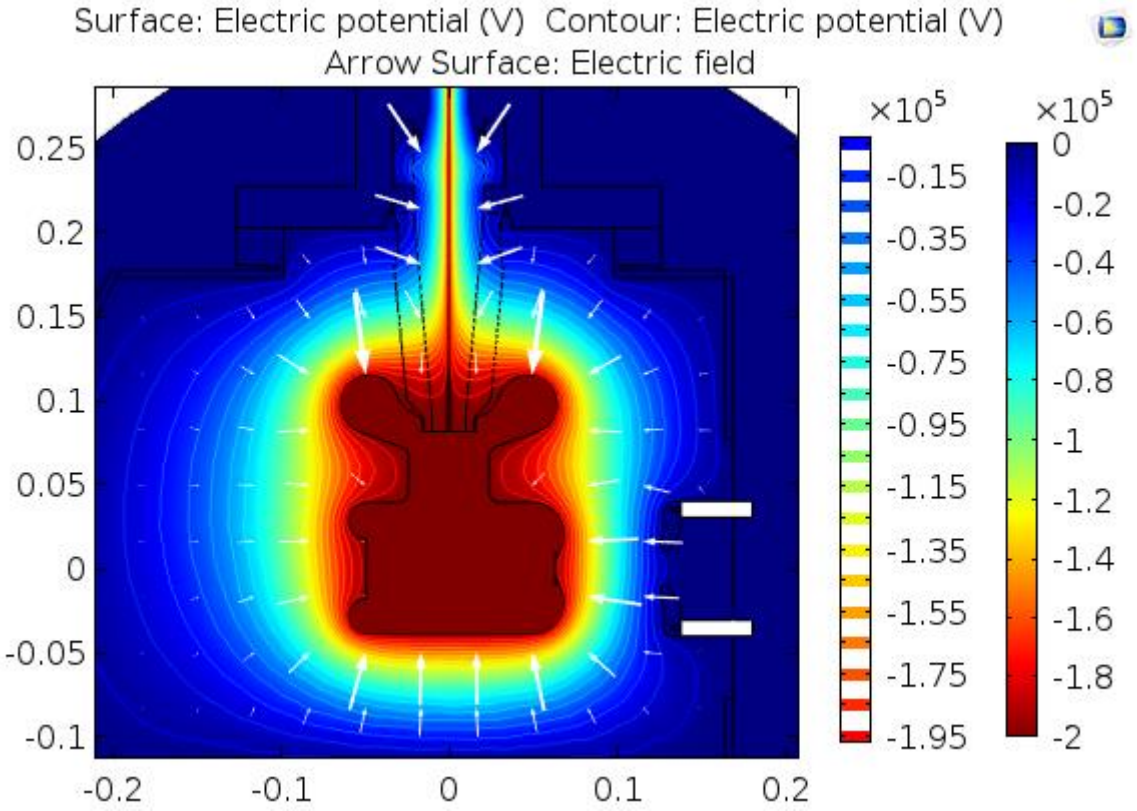
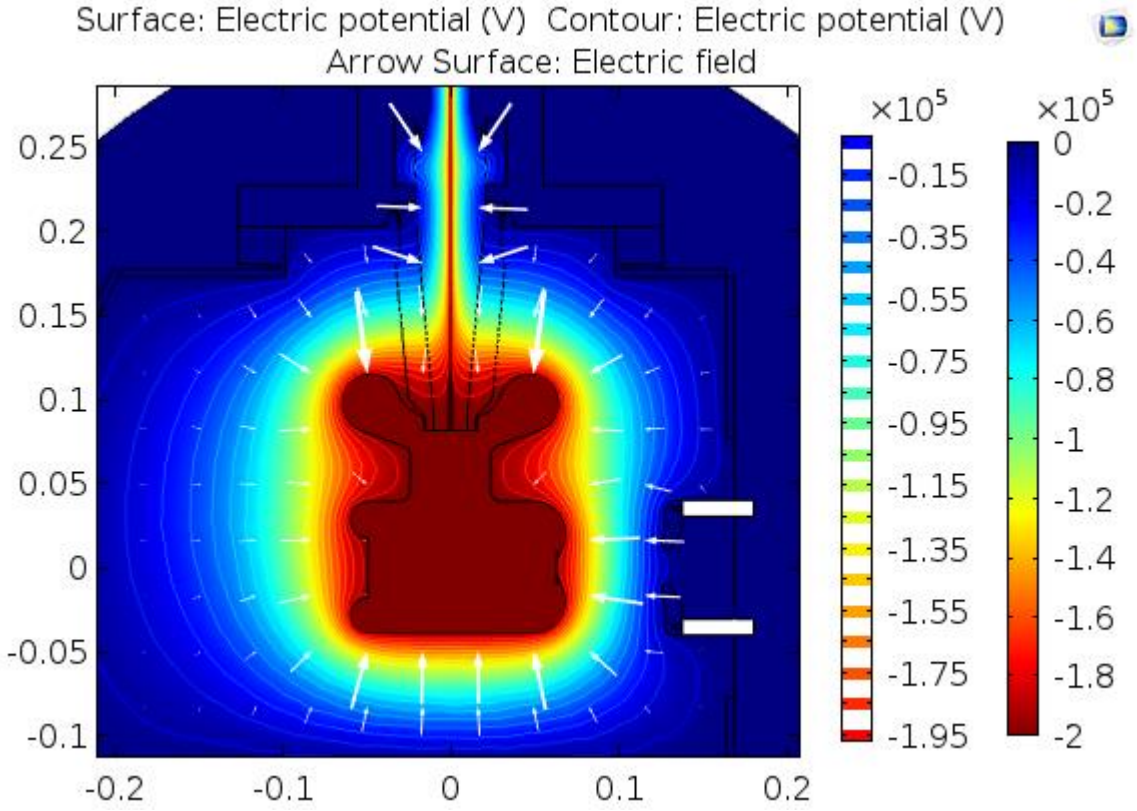
With white alumina conductivity

Conductivity of 2E-14 S/m



With black alumina conductivity

conductivity of 2E-12 S/m



COMSOL Potential:

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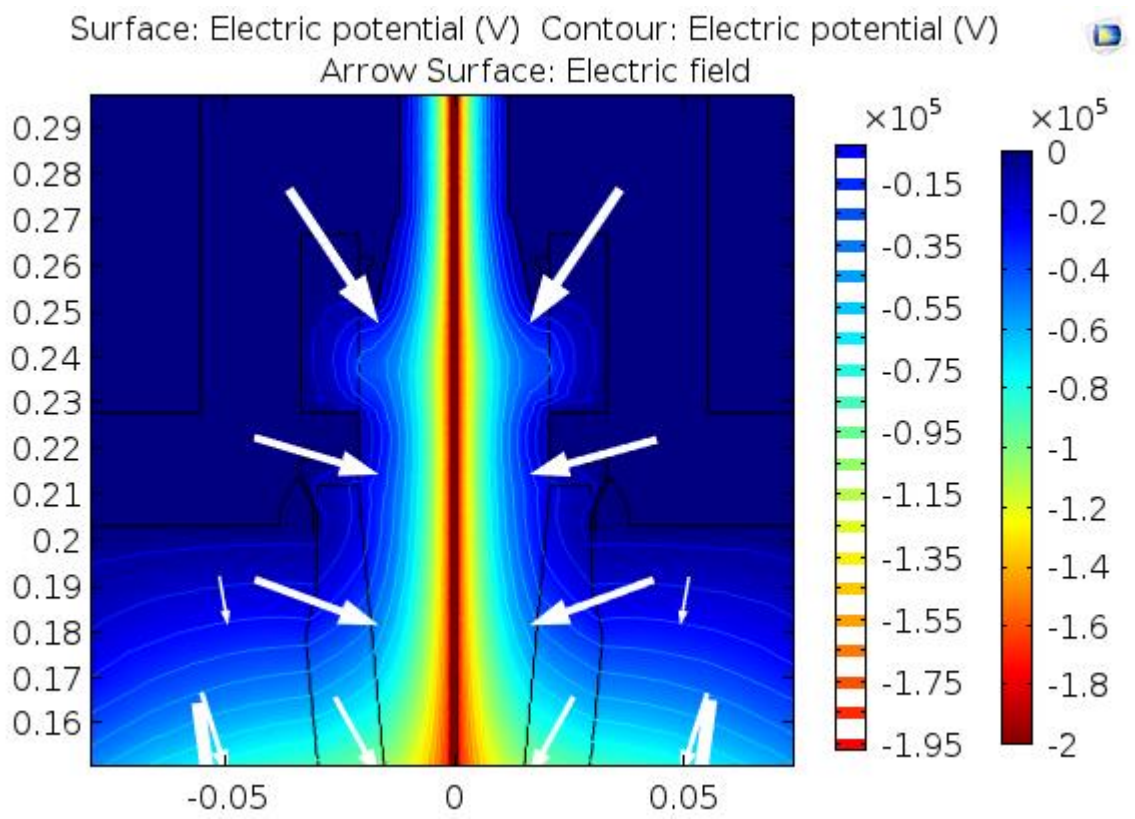
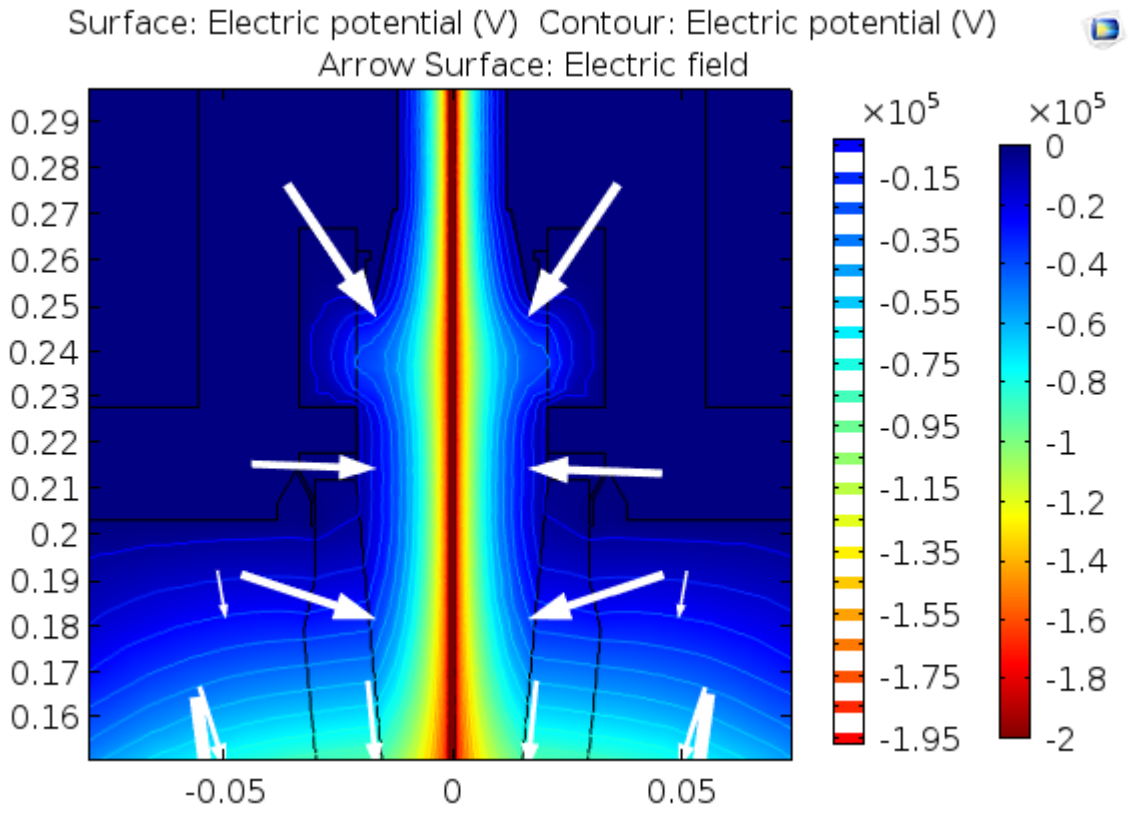
With white alumina conductivity

Conductivity of 2E-14 S/m



With black alumina conductivity

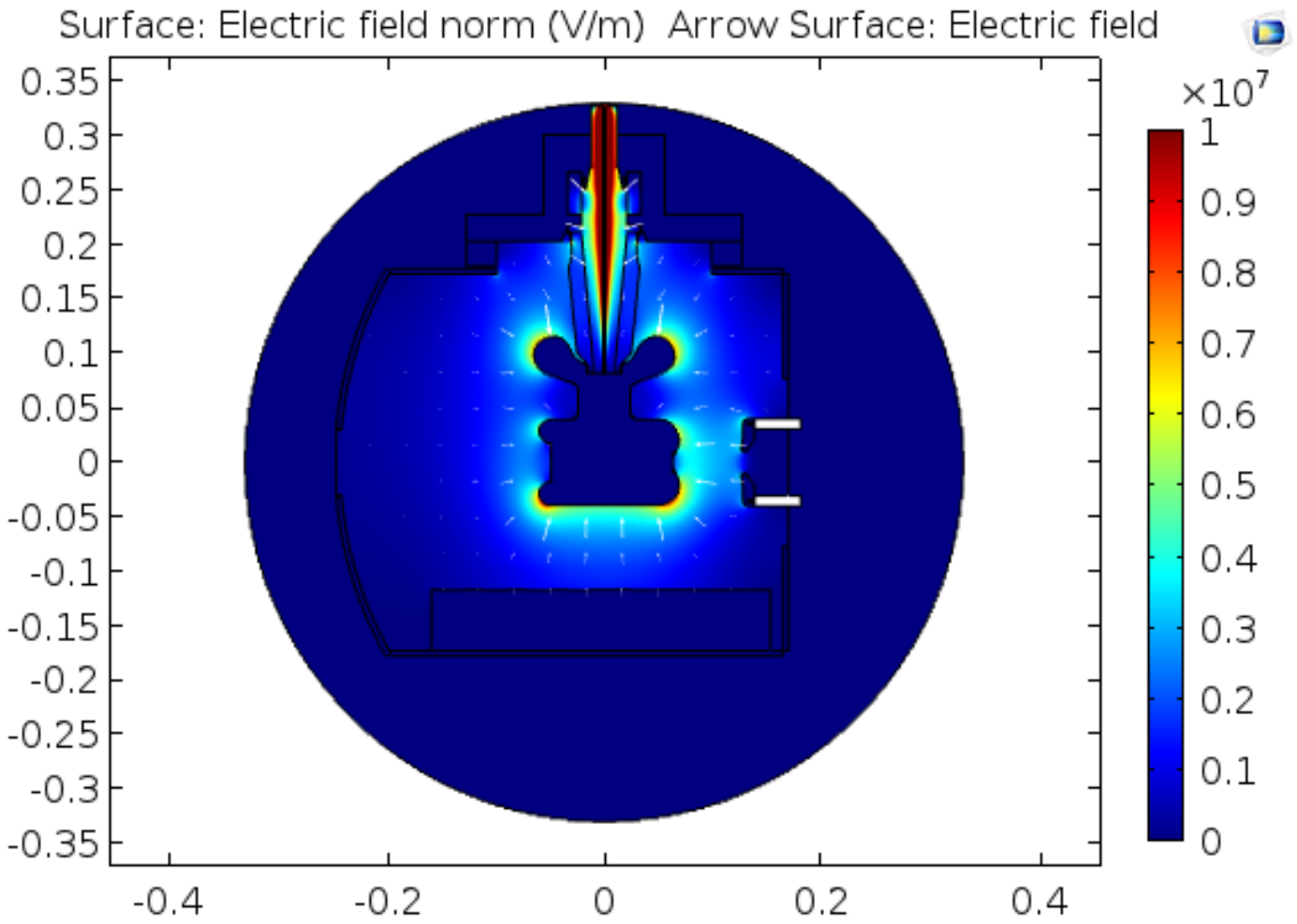
conductivity of 2E-12 S/m



No conductivity vs White insulator conductivity

- Conductivity of 2E-14 S/m

COMSOL Electric field Norm:



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COMSOL Electric field Norm :

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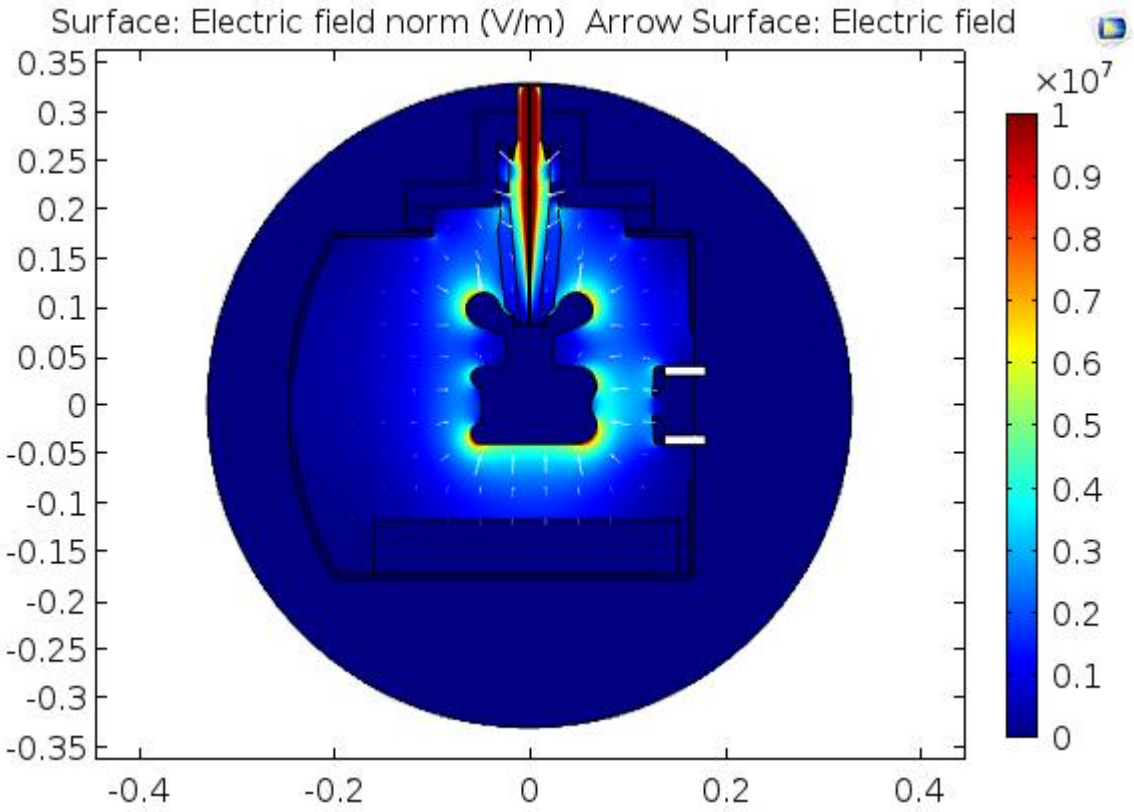
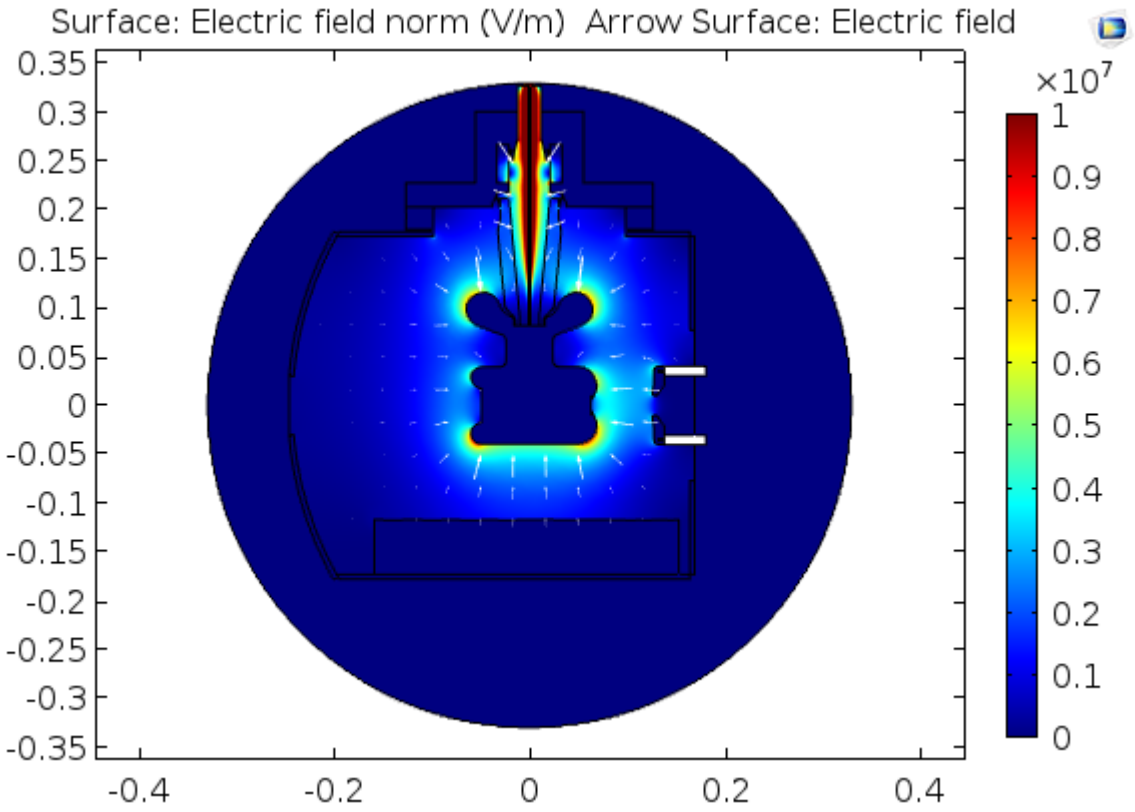
Without solving for conductivity



With white alumina conductivity

Conductivity of 2E-14 S/m



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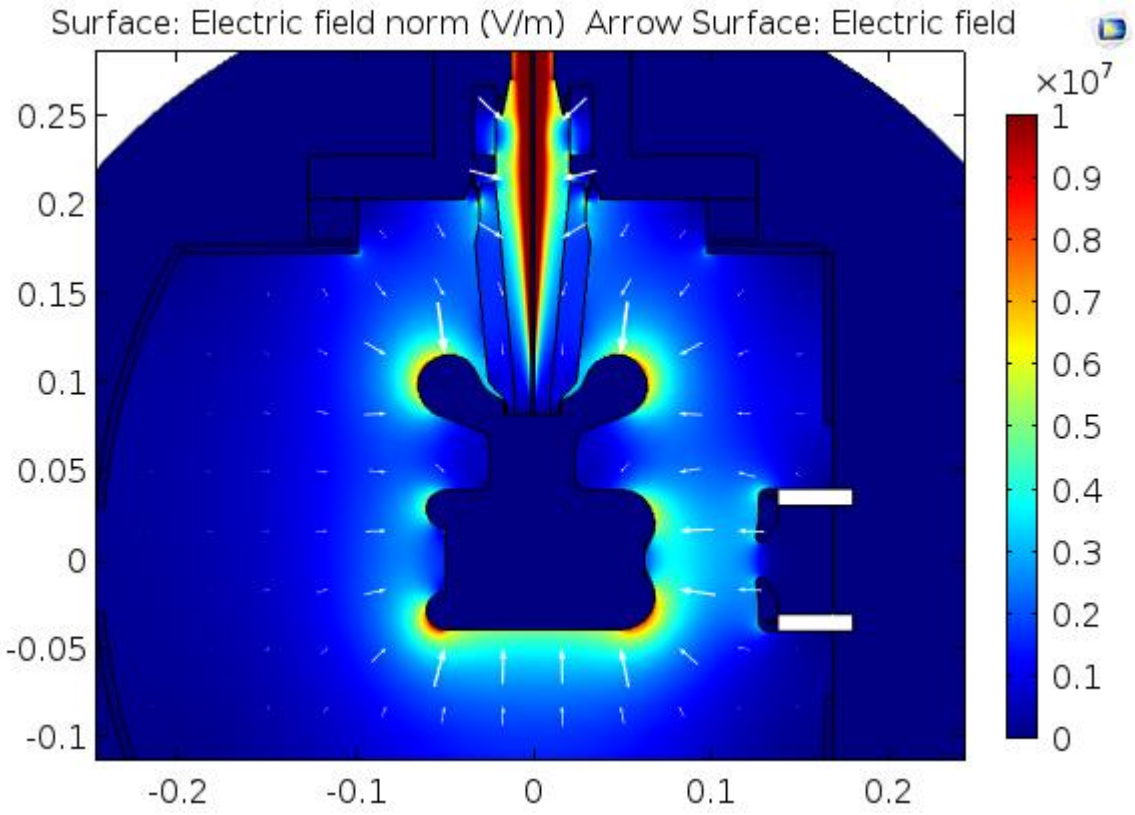
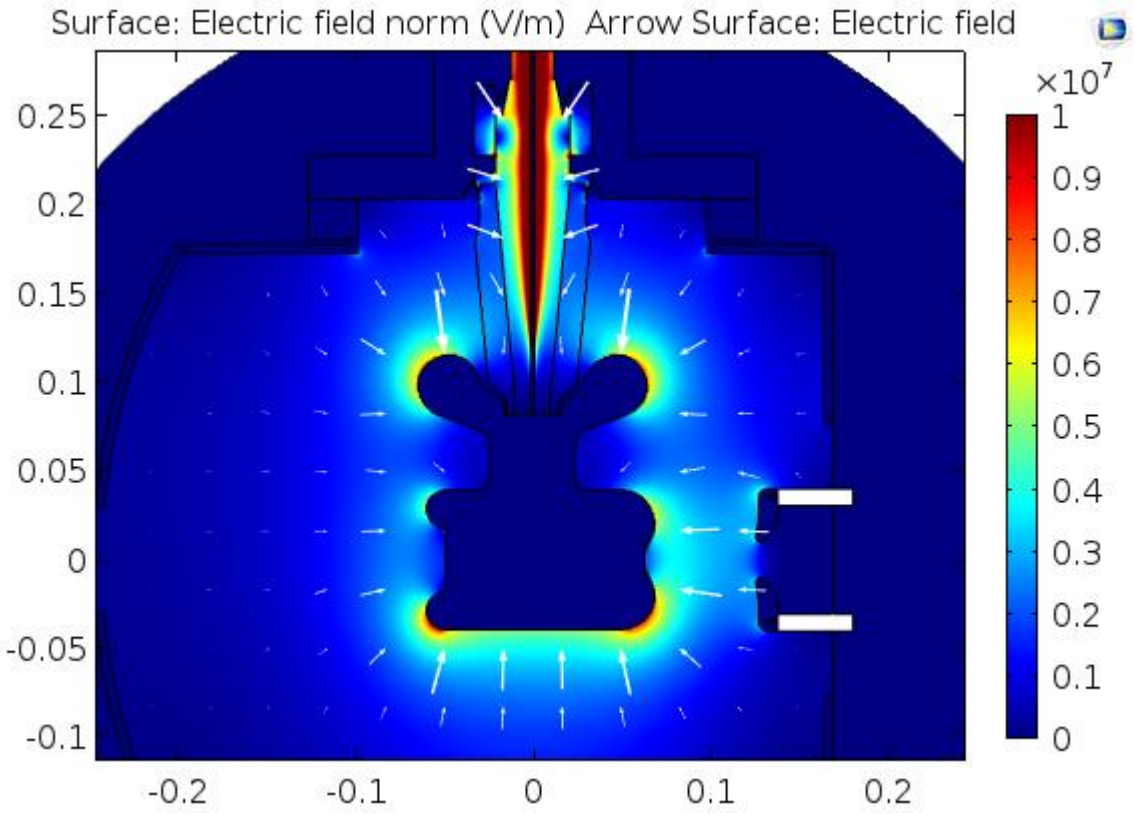
Without solving for conductivity



With white alumina conductivity

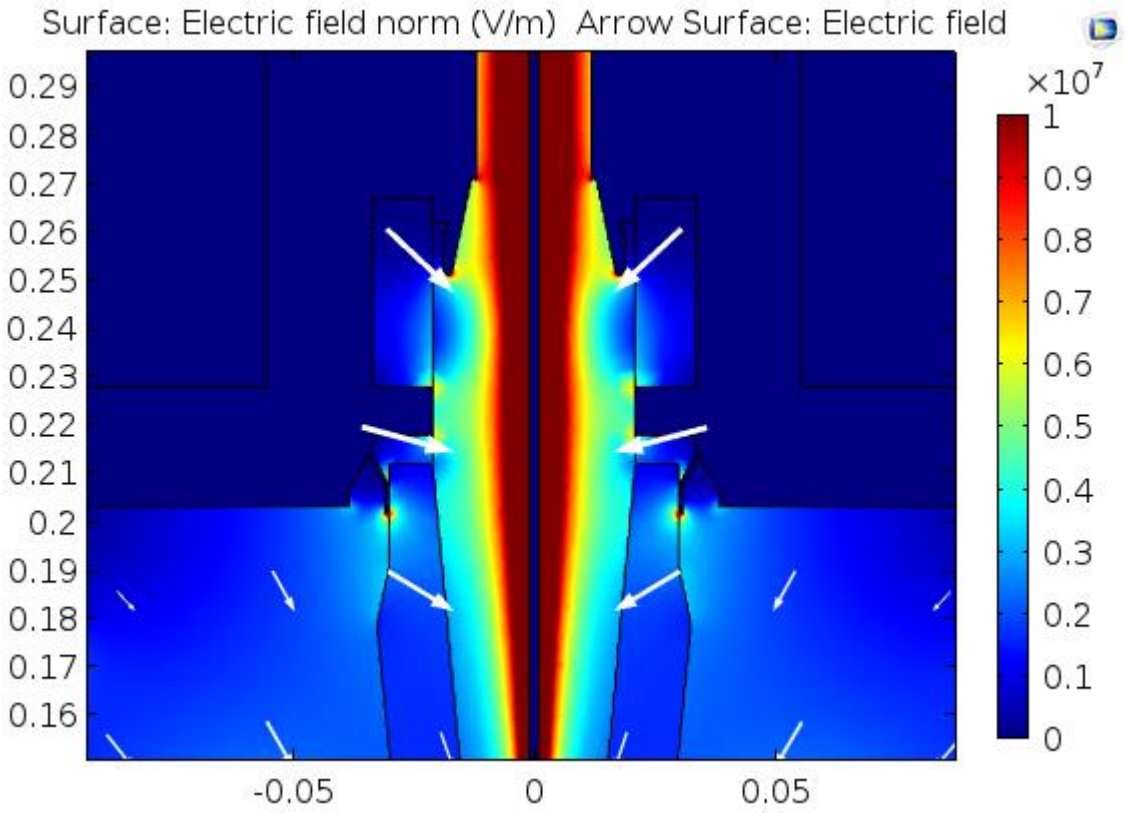
Conductivity of 2E-14 S/m



COMSOL Electric field Norm :

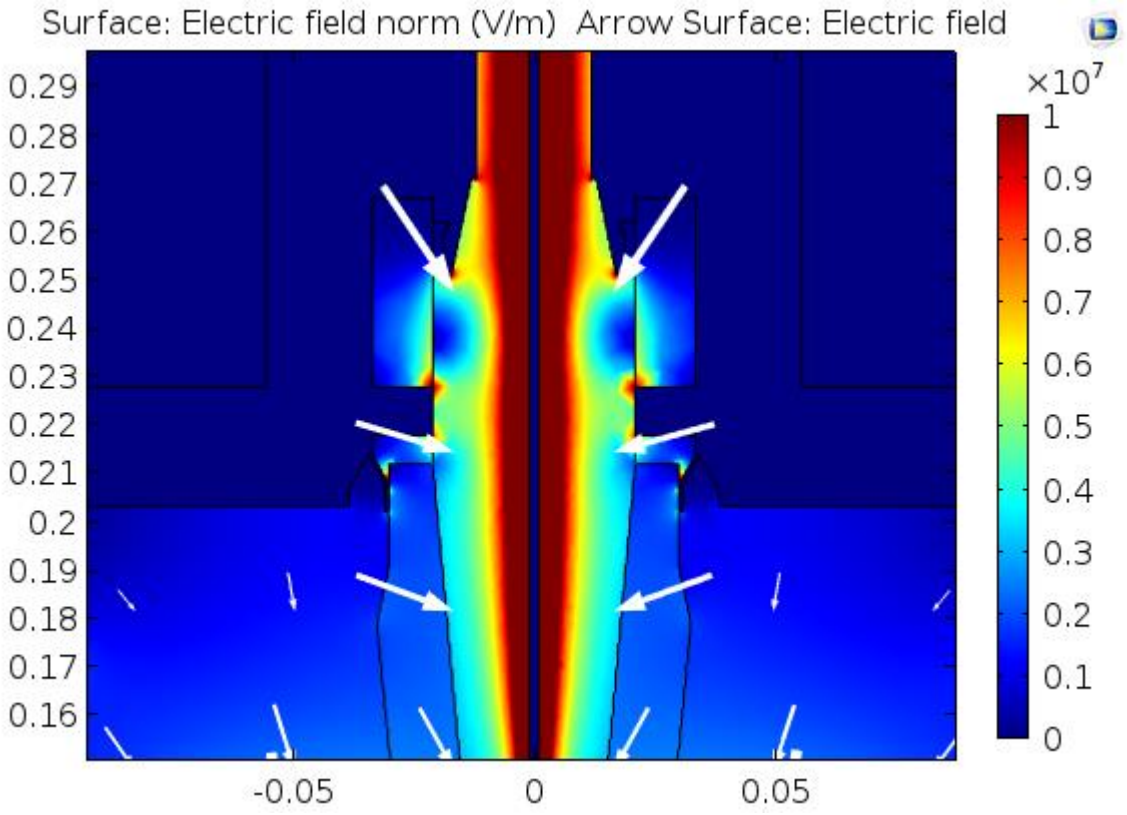
- This image shows the electric field norm |E| in MV/m as color intensity closer to the upper flange. The white arrows size is proportional to the intensity of the electric field at the arrow tip. The axis are coordinates in meters.

Without solving for conductivity



With white alumina conductivity

Conductivity of 2E-14 S/m



No conductivity vs Black insulator conductivity

- Conductivity of 2E-12 S/m

COMSOL Electric field Norm :

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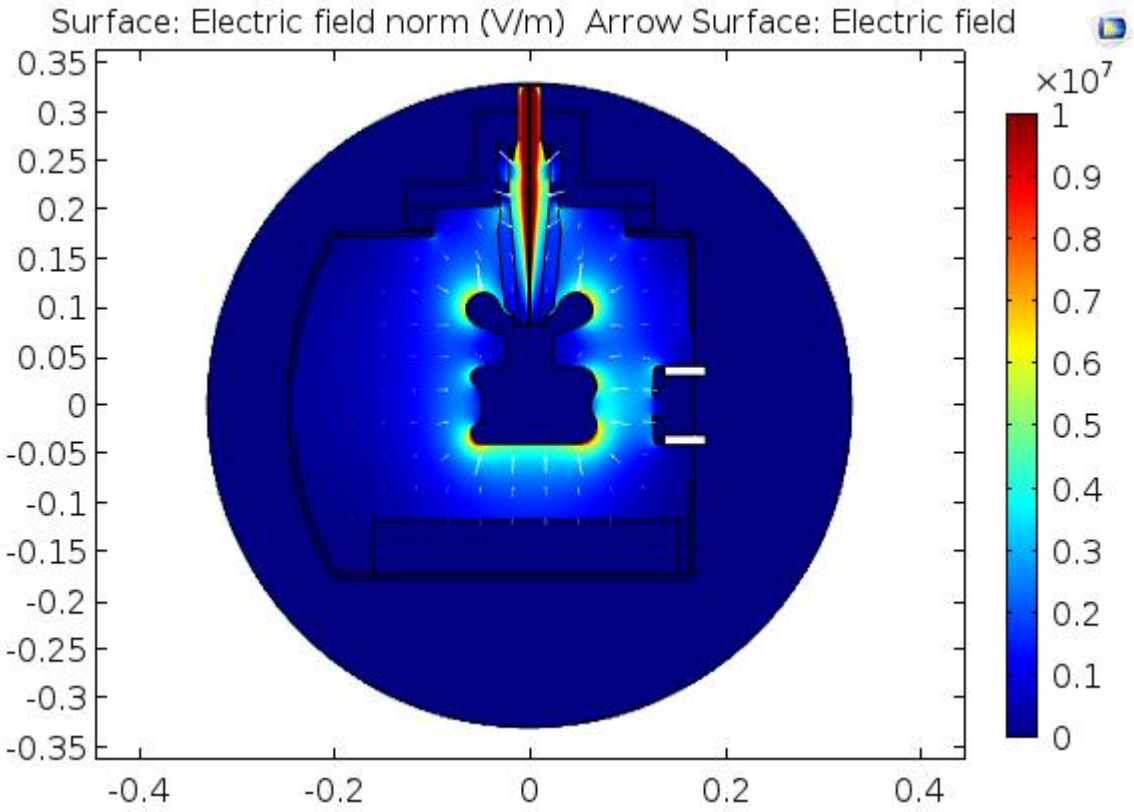
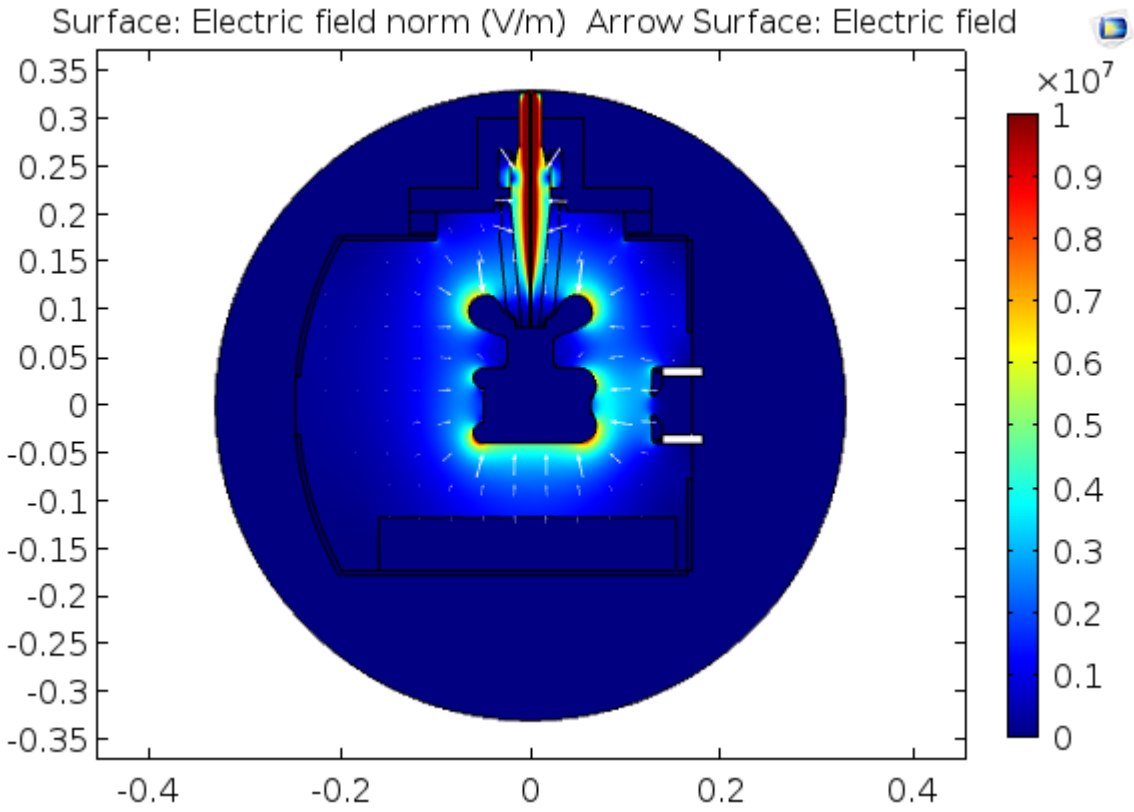
Without solving for conductivity



With black alumina conductivity

conductivity of 2E-12 S/m



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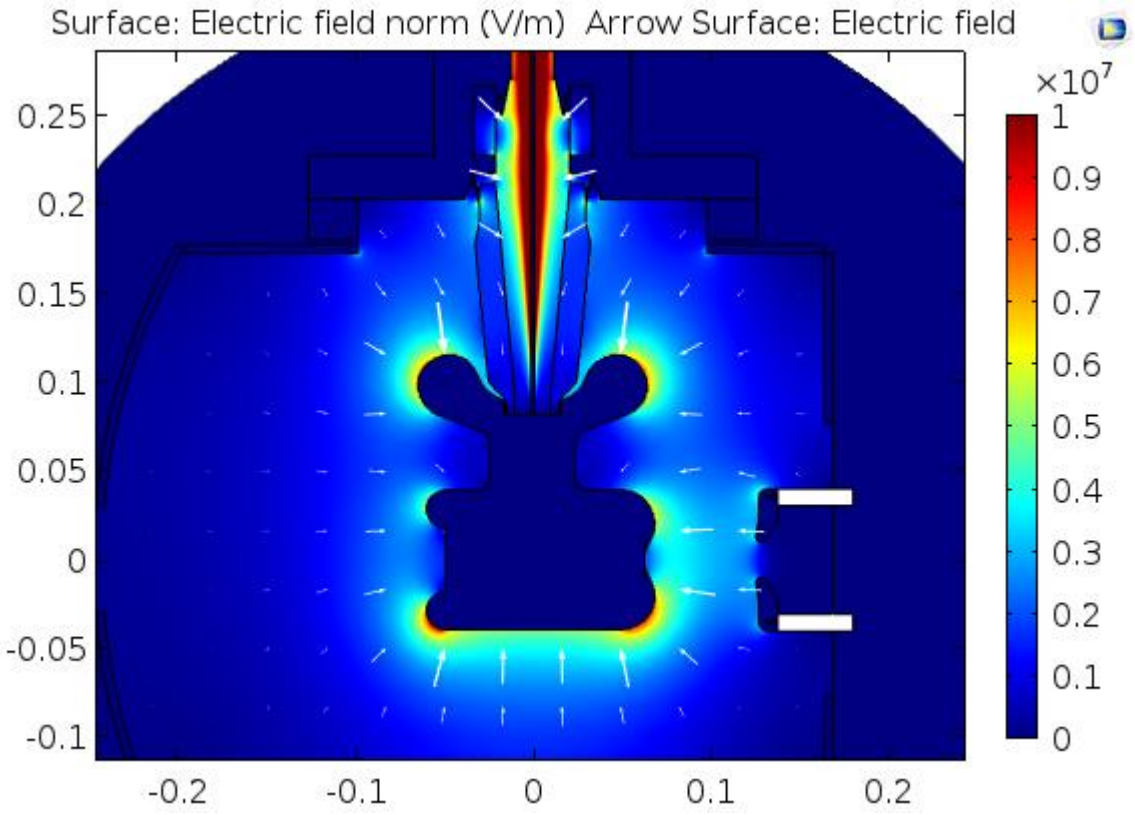
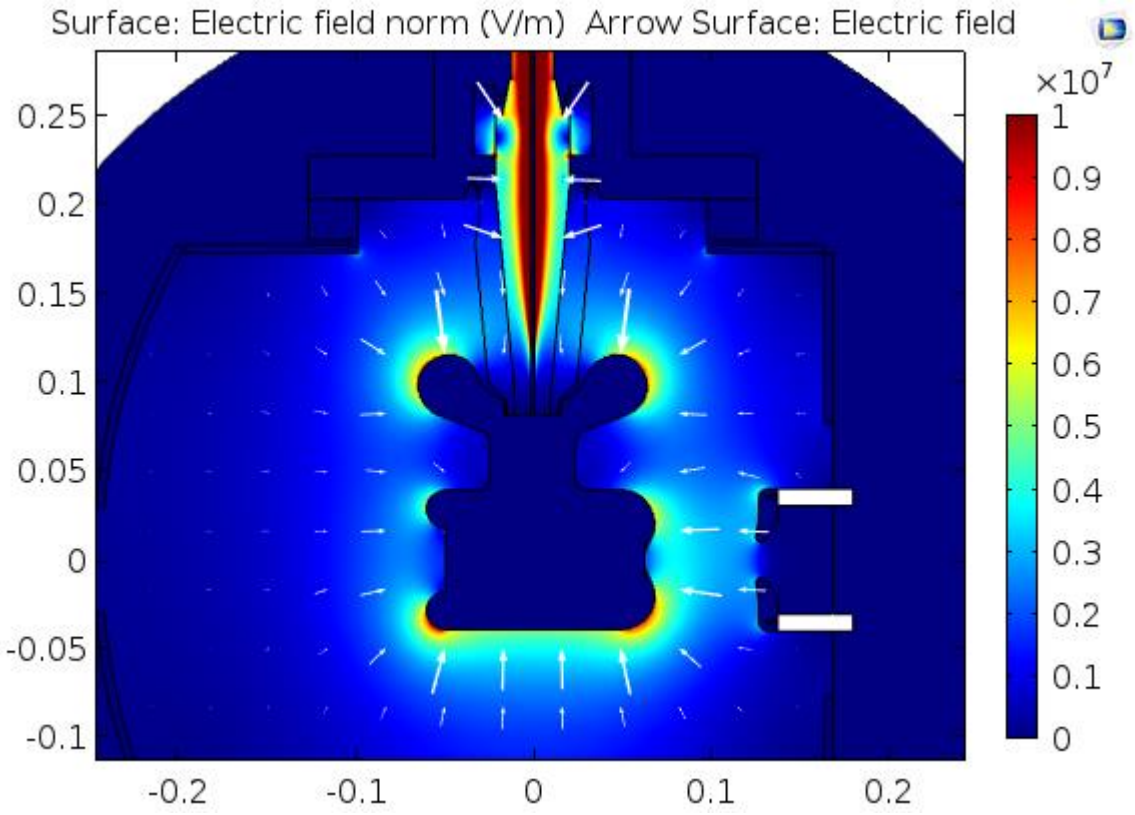
Without solving for conductivity



With black alumina conductivity
conductivity of 2E-12 S/m



COMSOL Electric field Norm :

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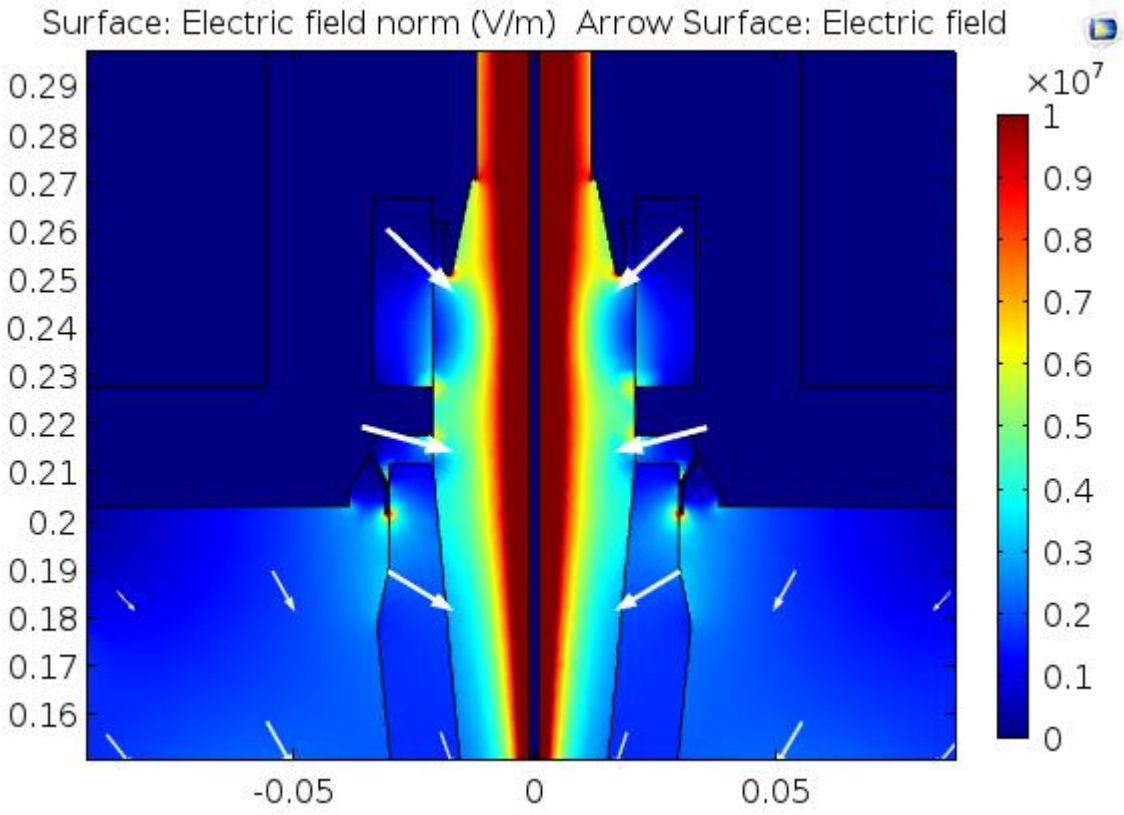
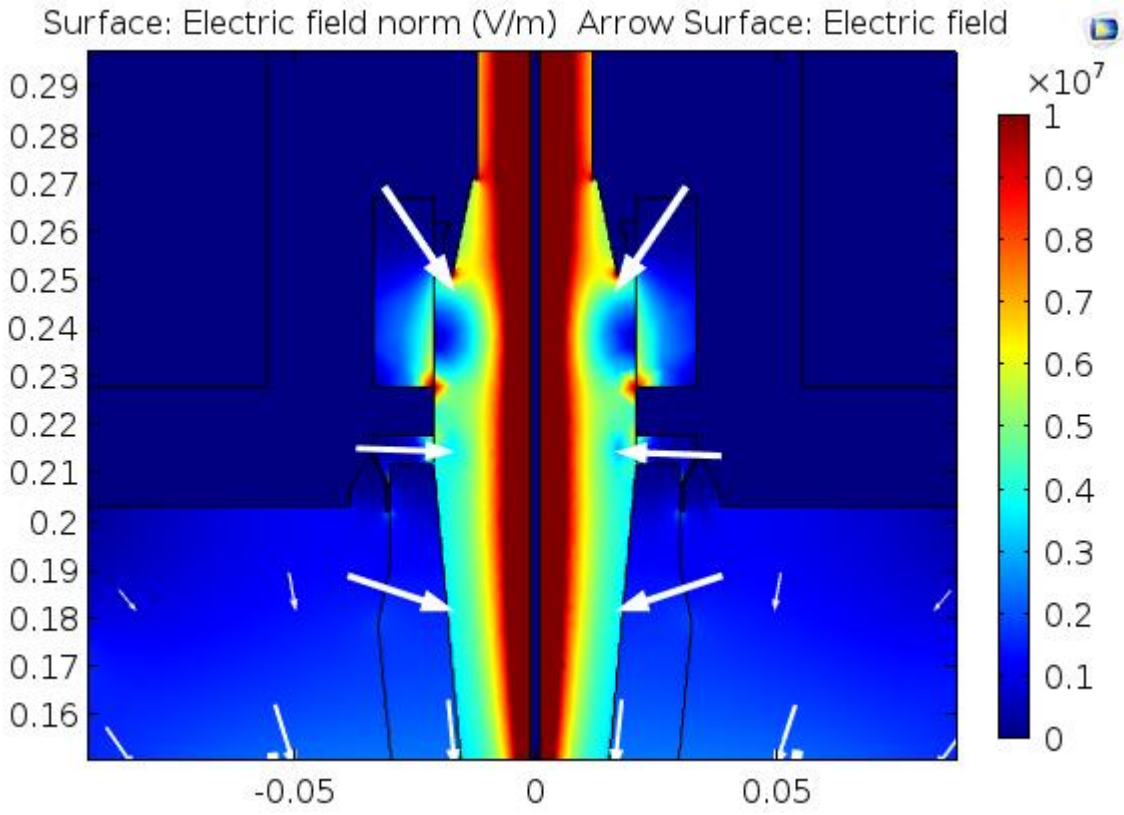
Without solving for conductivity



With black alumina conductivity

conductivity of 2E-12 S/m



White insulator vs Black insulator

- White alumina conductivity of 2E-14 S/m
- Black alumina conductivity of 2E-12 S/m

COMSOL Electric field Norm :

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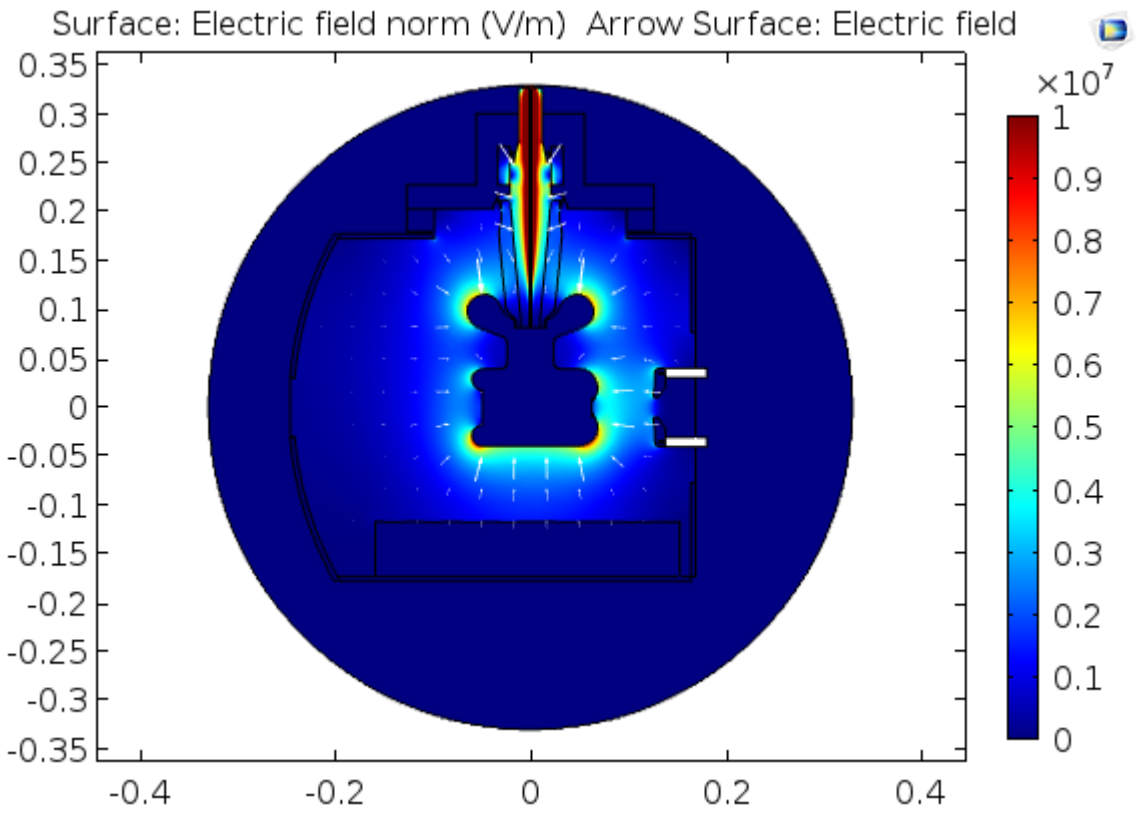
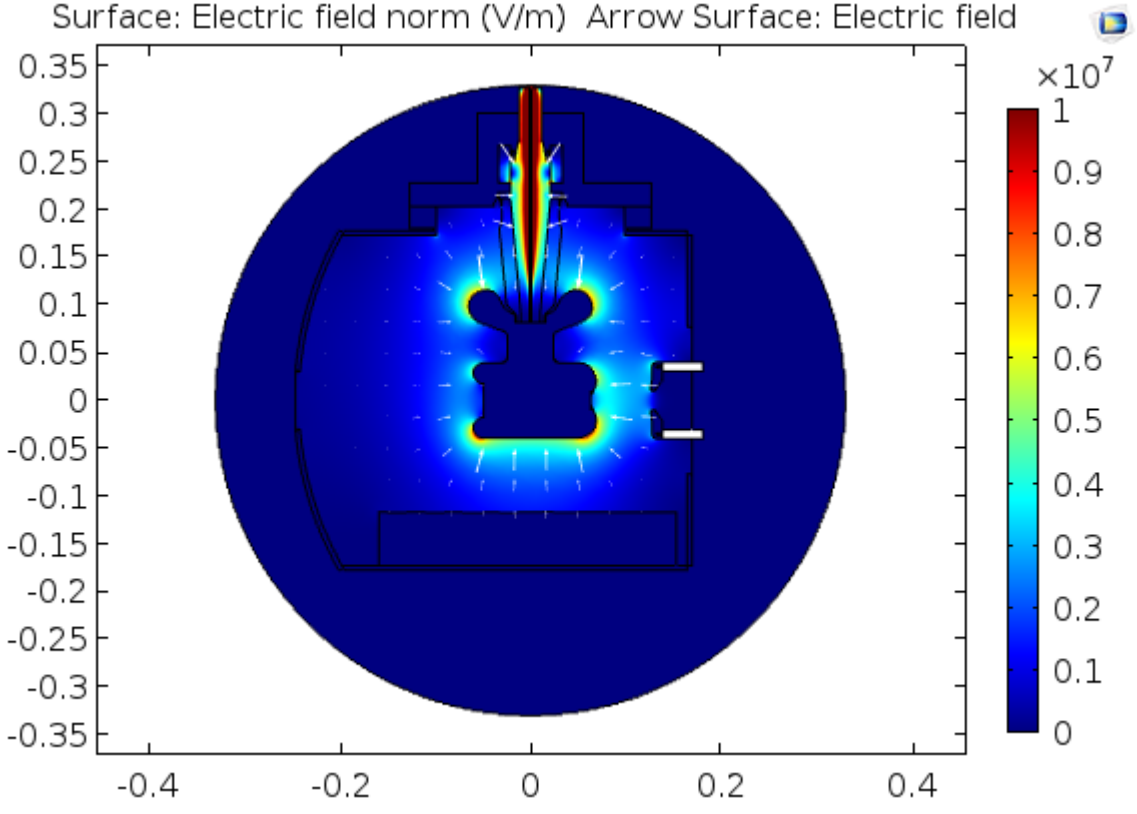
With white alumina conductivity
Conductivity of 2E-14 S/m



With black alumina conductivity
conductivity of 2E-12 S/m



COMSOL Electric field Norm :

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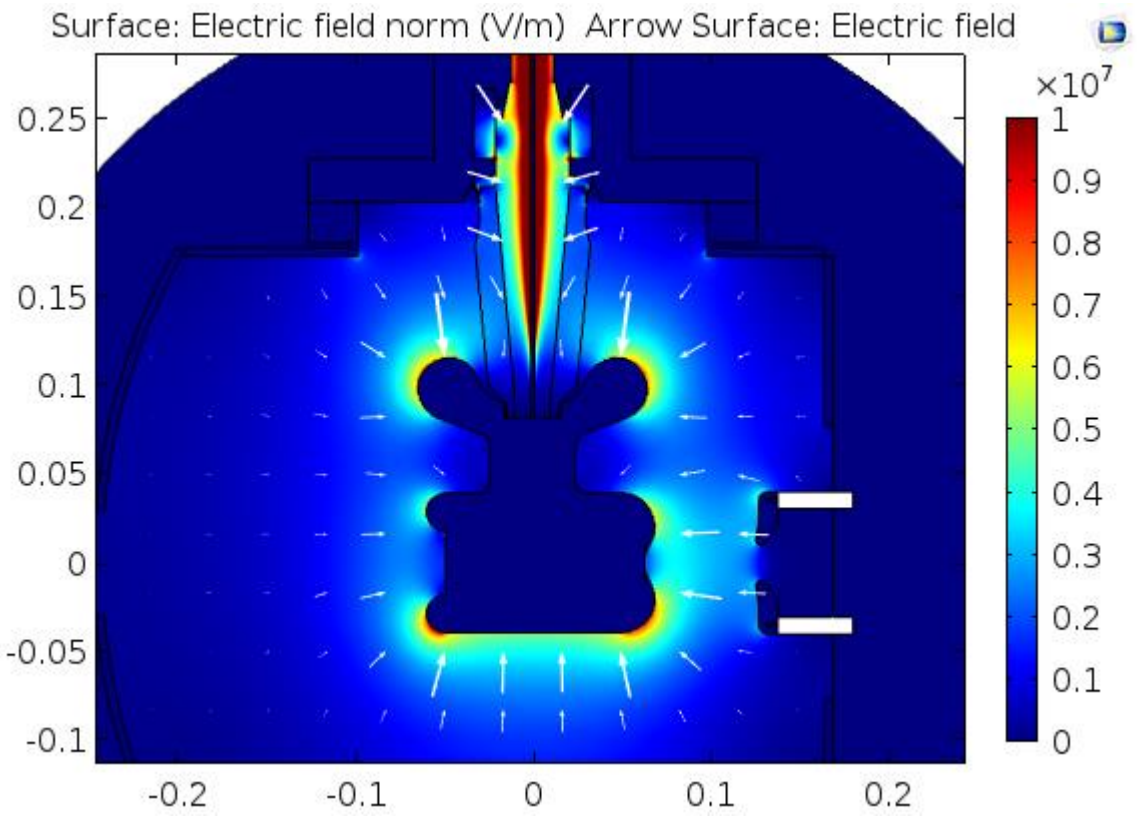
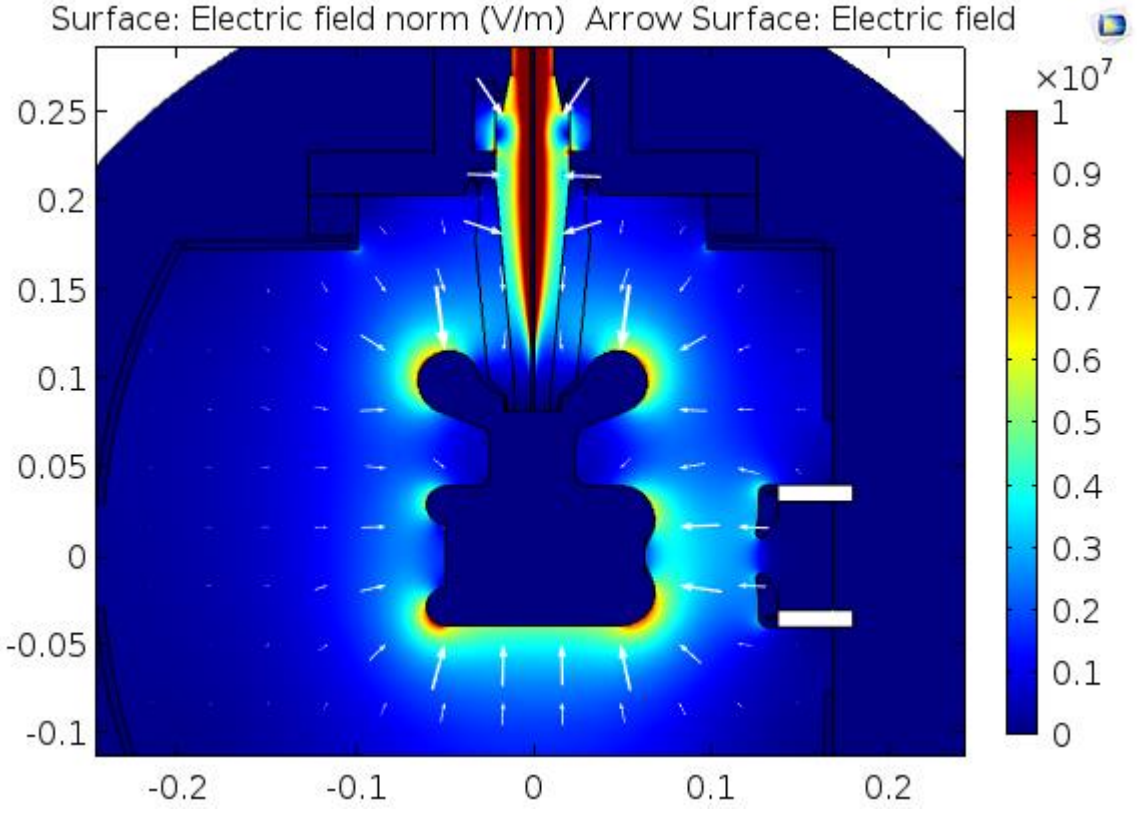
With white alumina conductivity
Conductivity of 2E-14 S/m



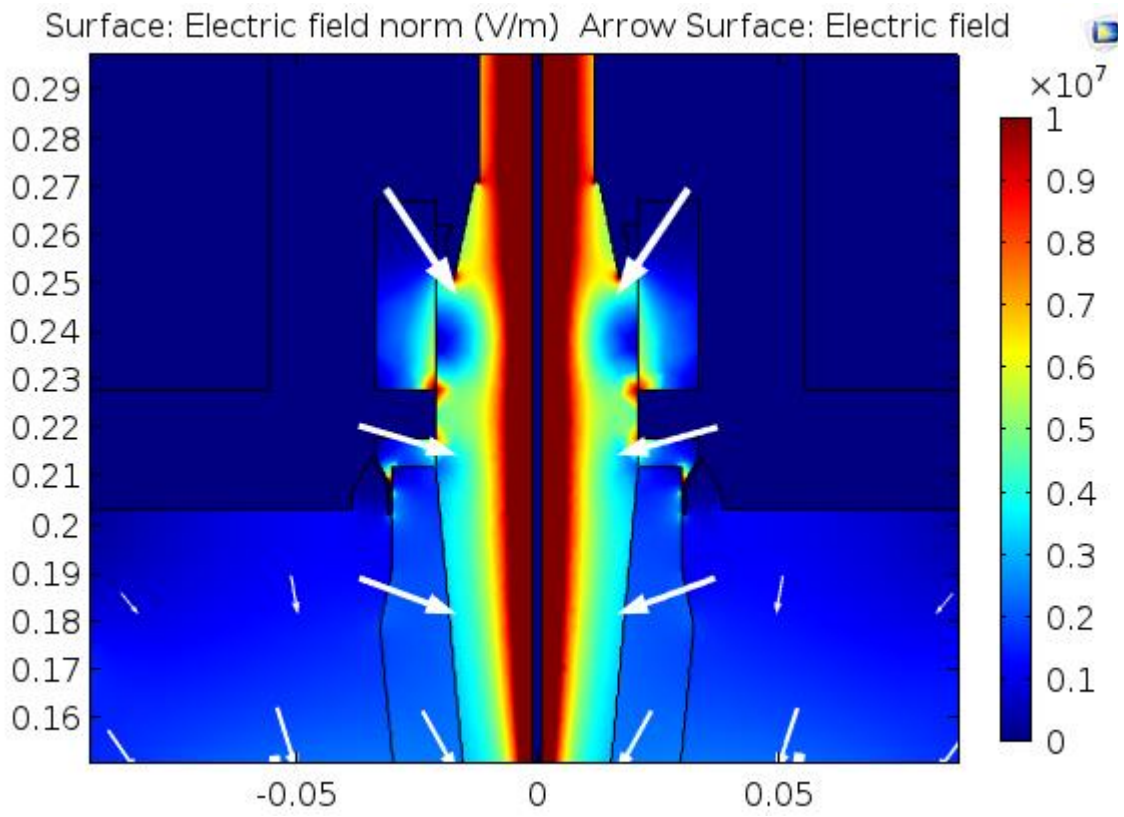
With black alumina conductivity
conductivity of 2E-12 S/m



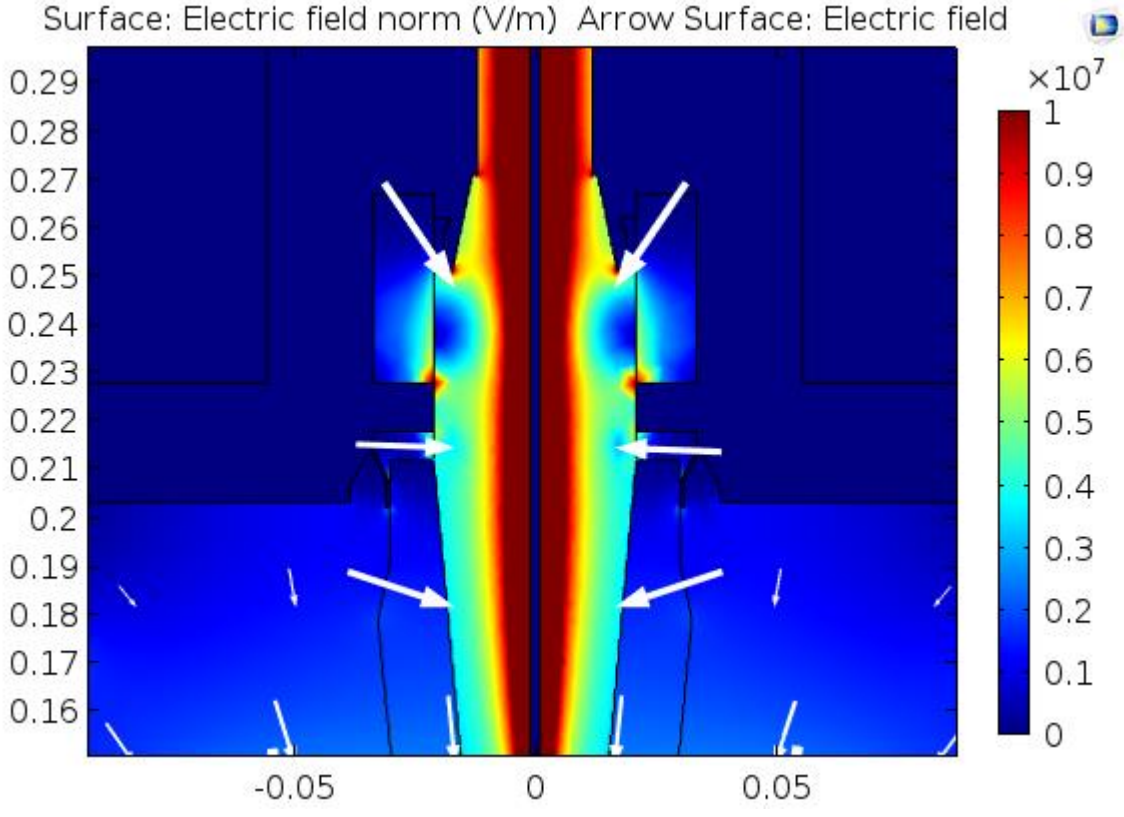
COMSOL Electric field Norm :

- This image shows the electric field norm |E| in MV/m as color intensity 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.

With white alumina conductivity
Conductivity of 2E-14 S/m

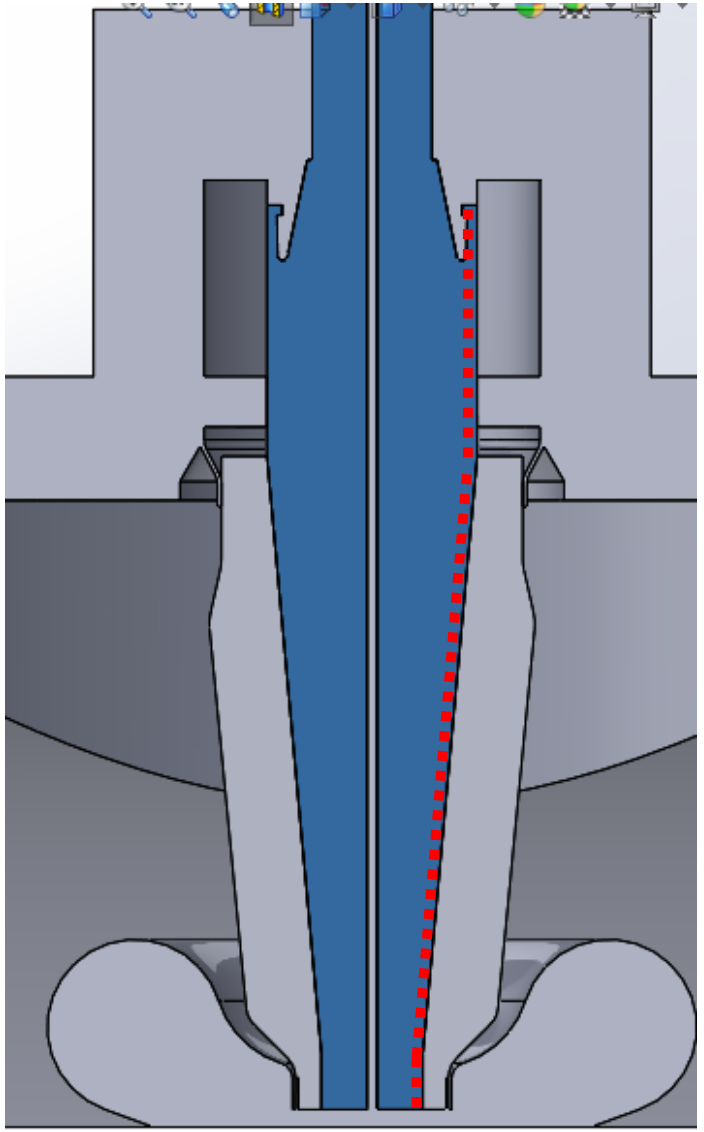


With black alumina conductivity
conductivity of 2E-12 S/m

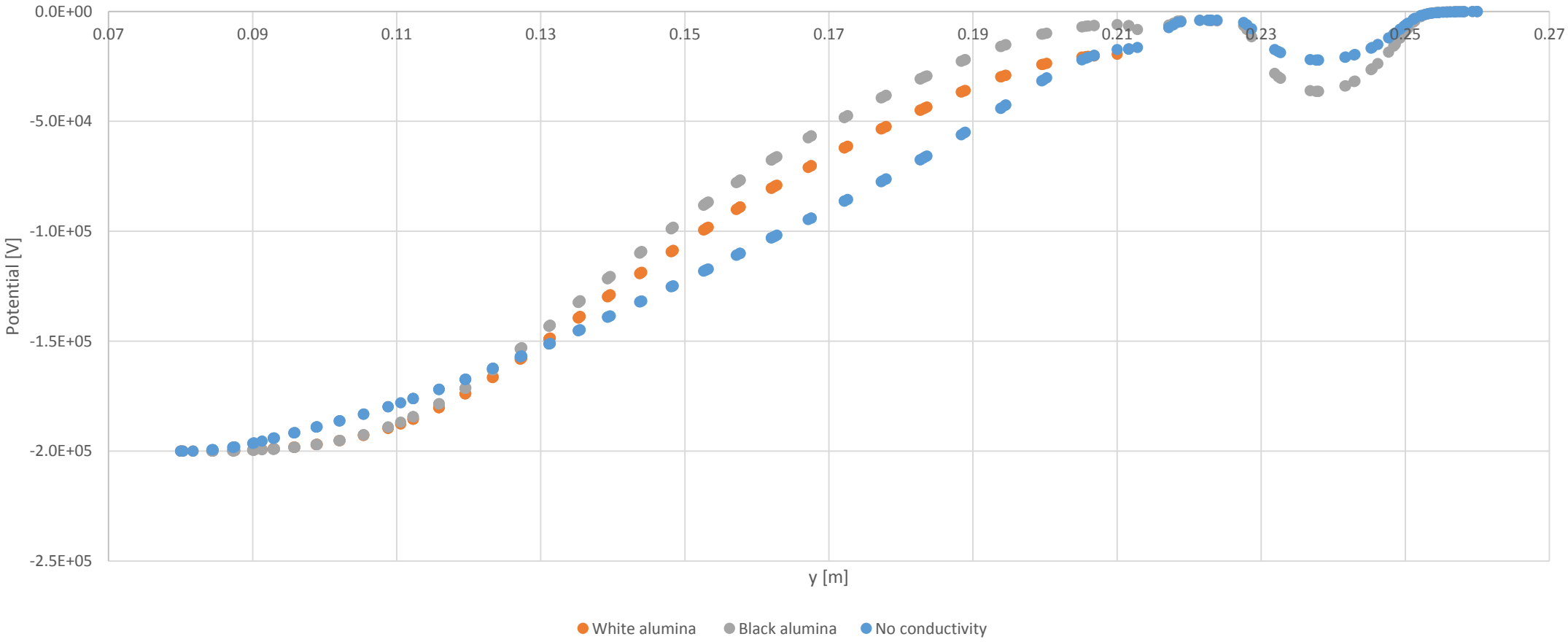


Potential and electric field:

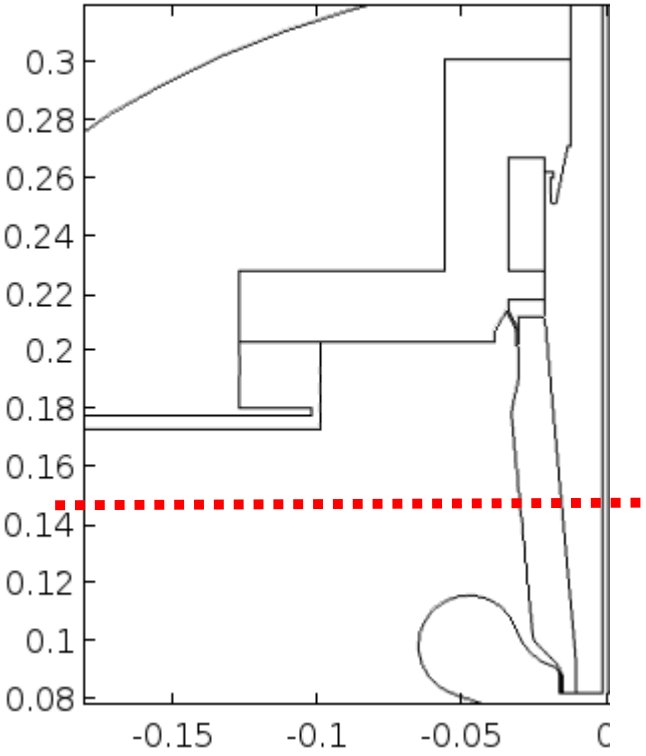
- Then the information about the potential and electric field along the rubber plug – ceramic insulator interface was obtained (as shown in the red dotted line), plotted as a function of the height (y-coordinate) and compared for three cases:
  - Without solving for the conductivity.
  - Solving for white alumina conductivity.
  - Solving for black alumina conductivity.



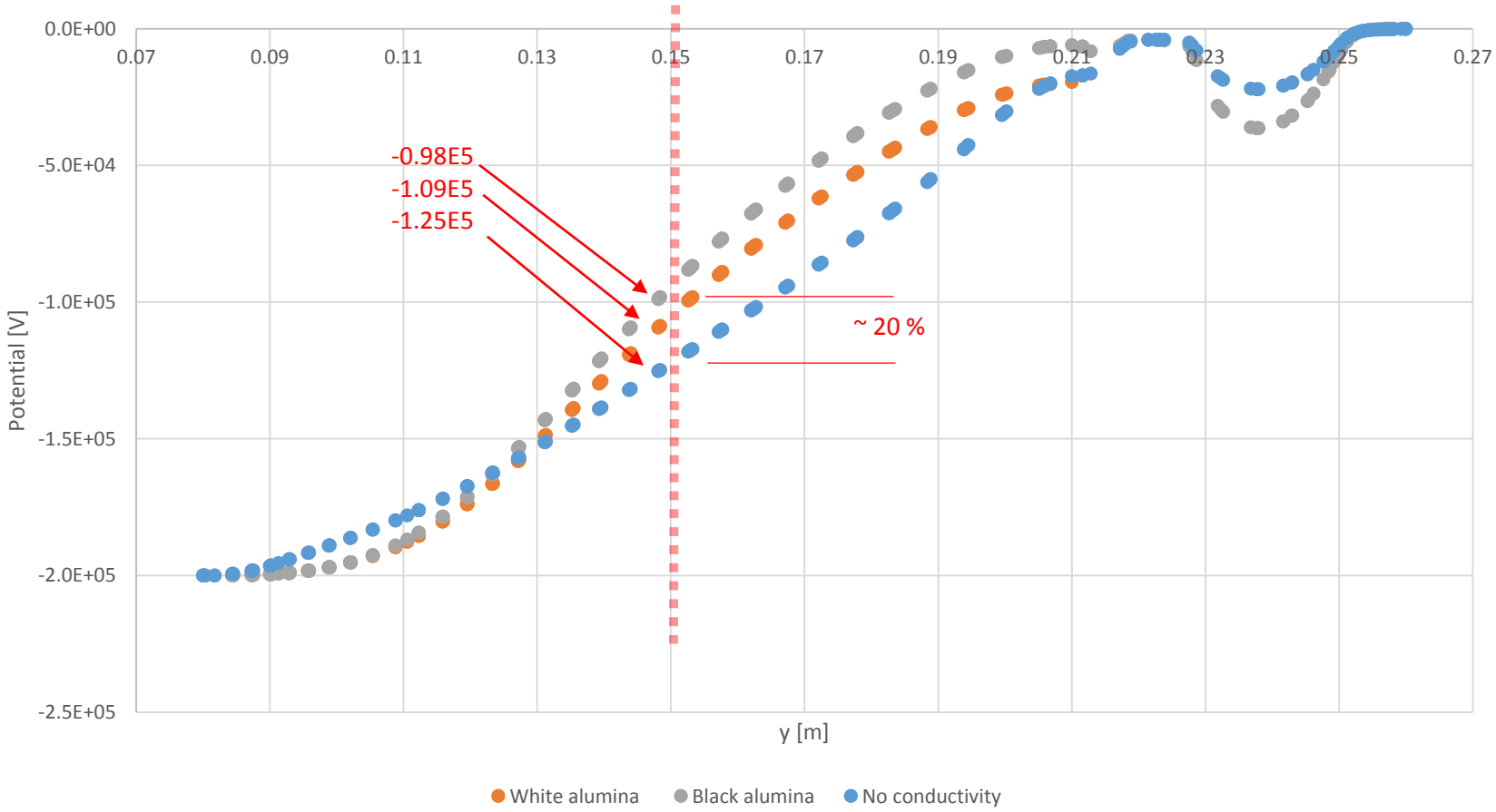
Potential:


0.0E+00
-5.0E+04
-1.0E+05
-1.5E+05
-2.0E+05
-2.5E+05
Potential [V]
0.07
0.09
0.11
0.13
0.15
0.17
0.19
0.21
0.23
0.25
0.27
y [m]
White alumina
Black alumina
No conductivity

Potential near the middle of insulator:

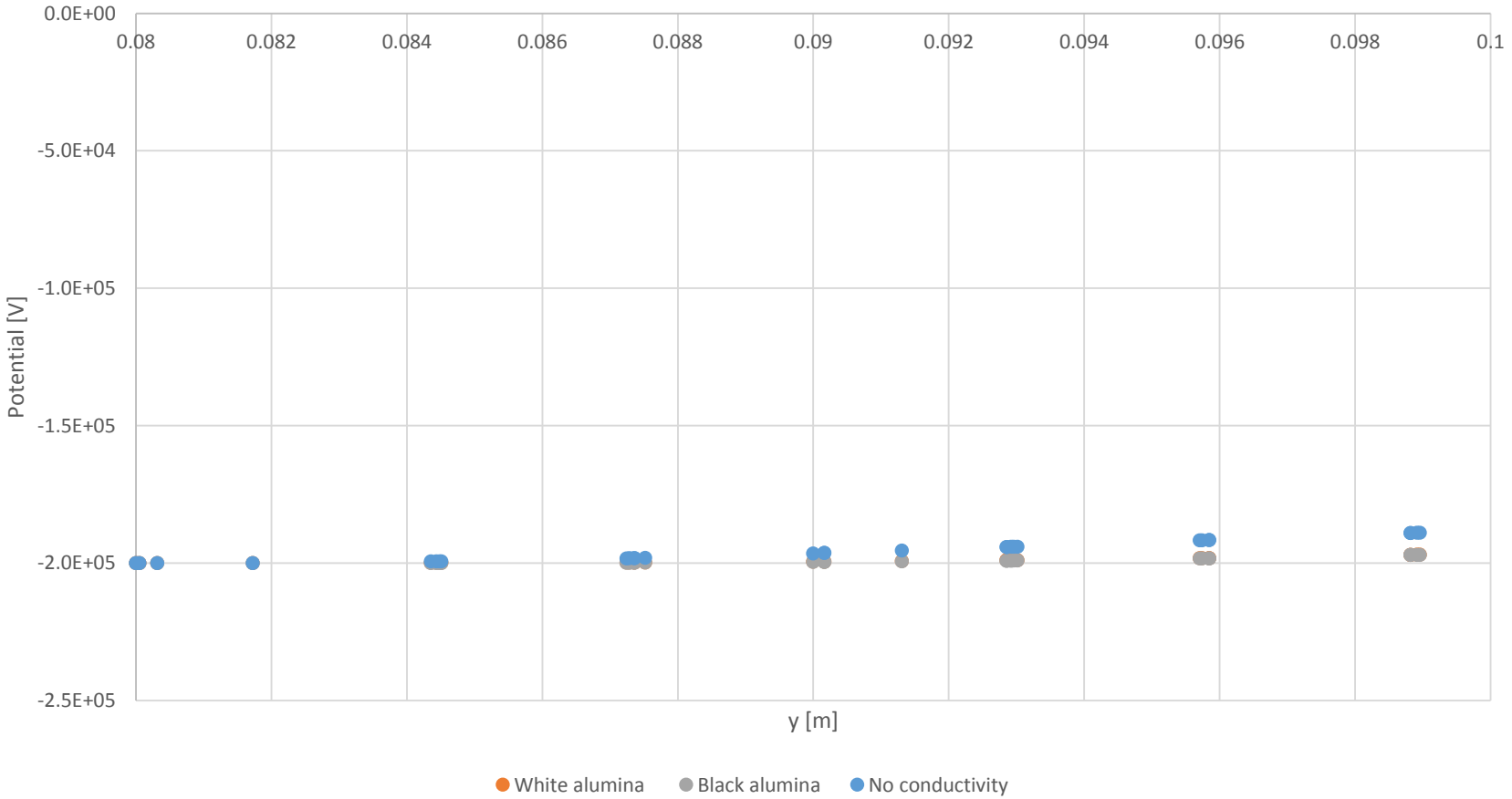


The height is ~0.14m



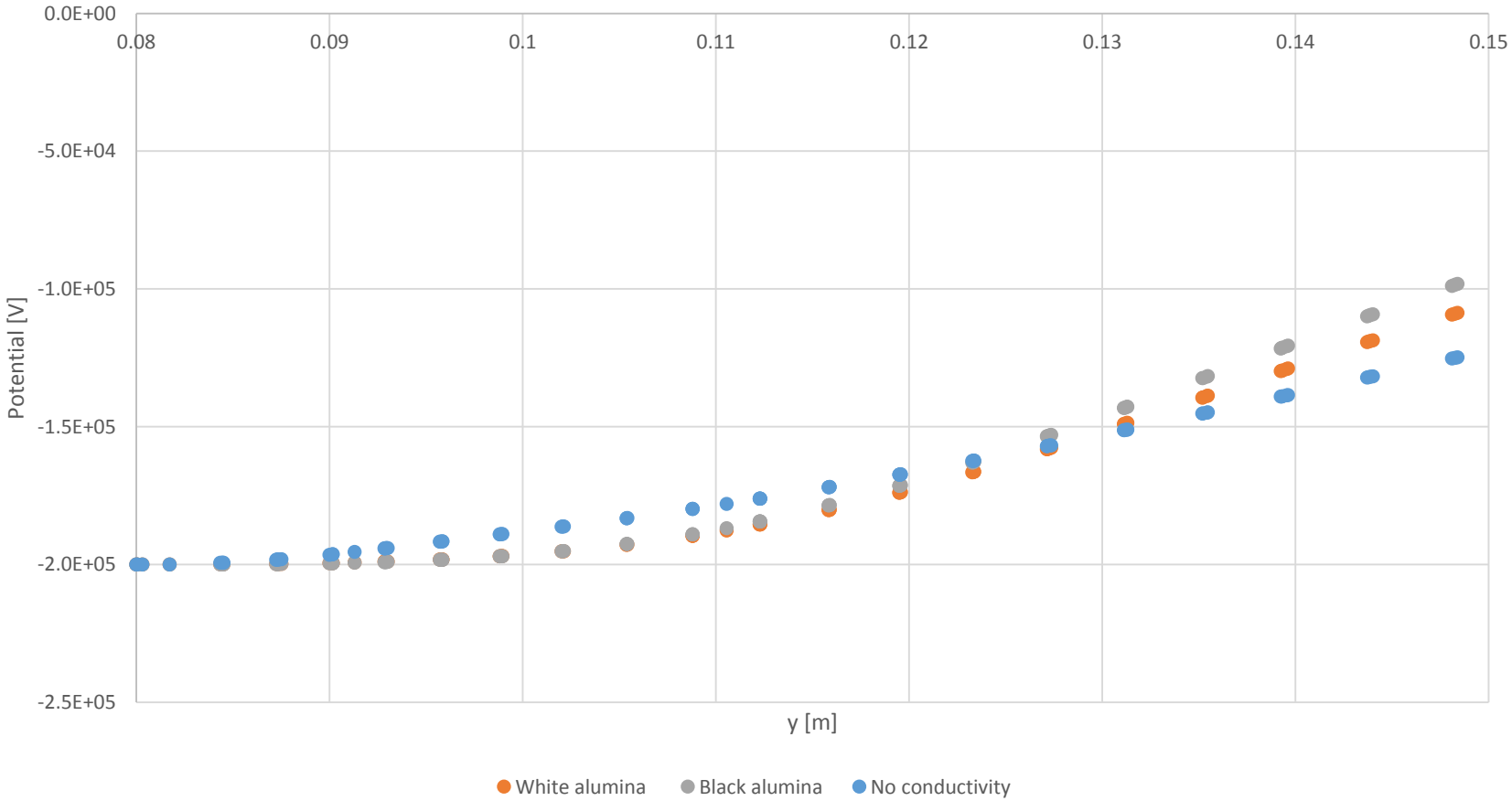
Potential near triple point:

The height is ~0.14m



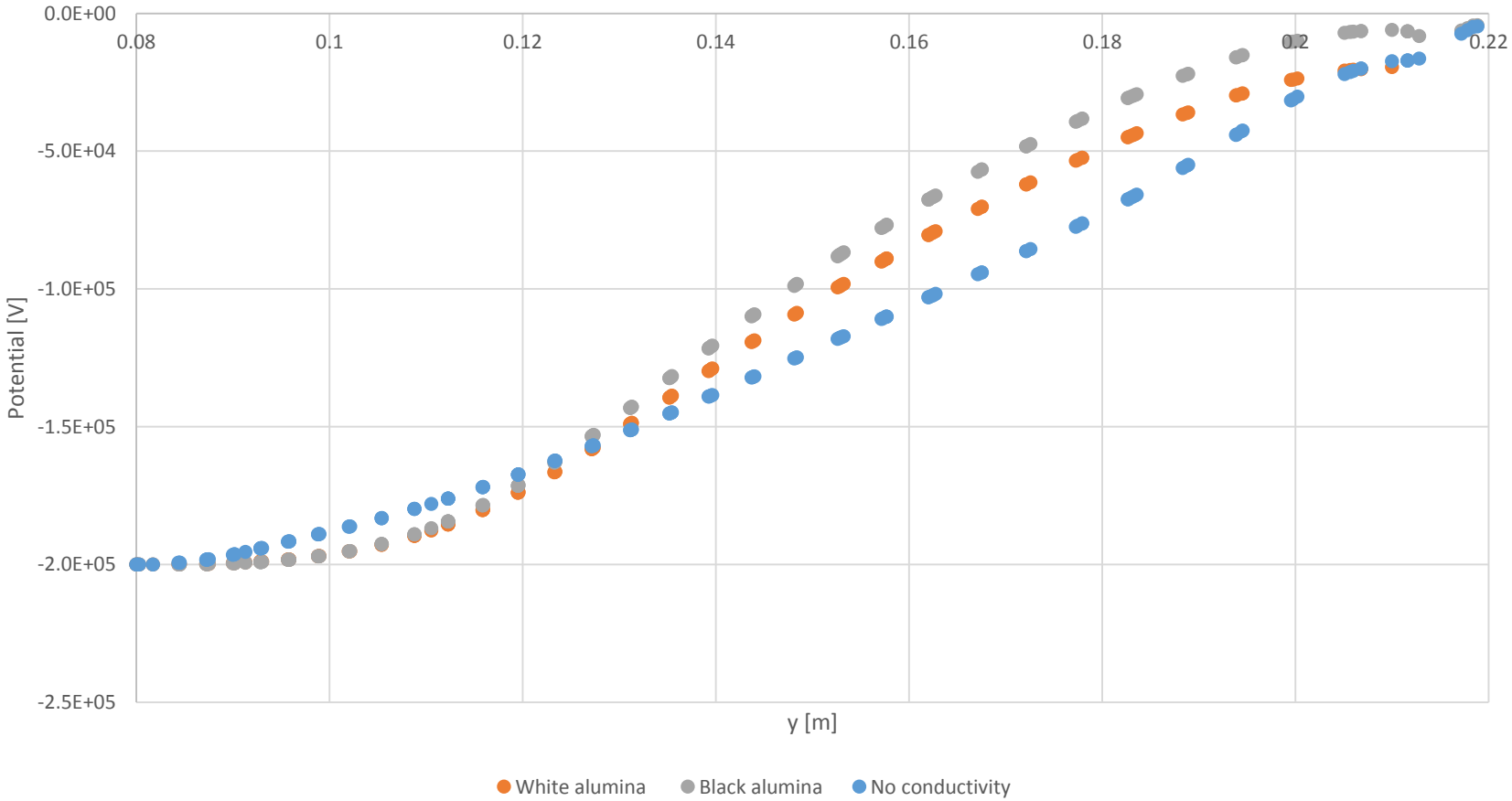
Potential up to the middle of insulator:

The height is ~0.14m

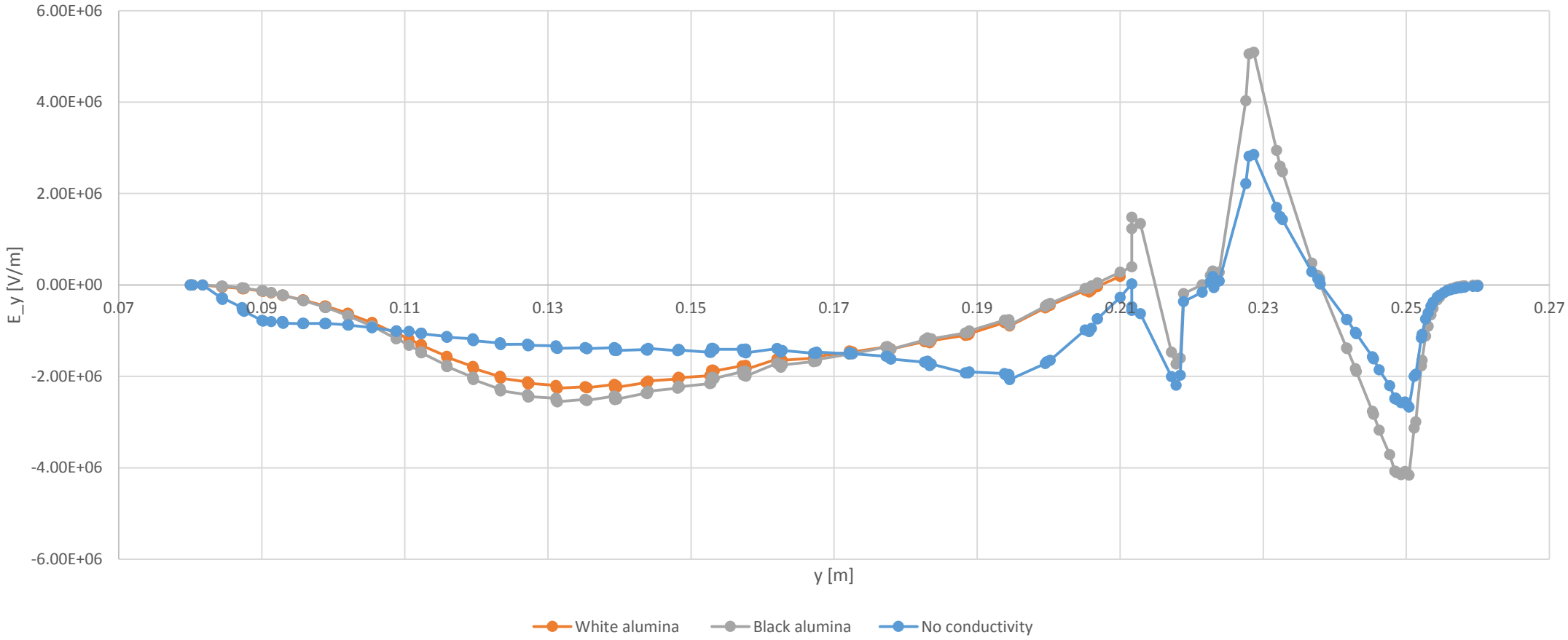


Potential along the insulator length:

The height is ~0.14m

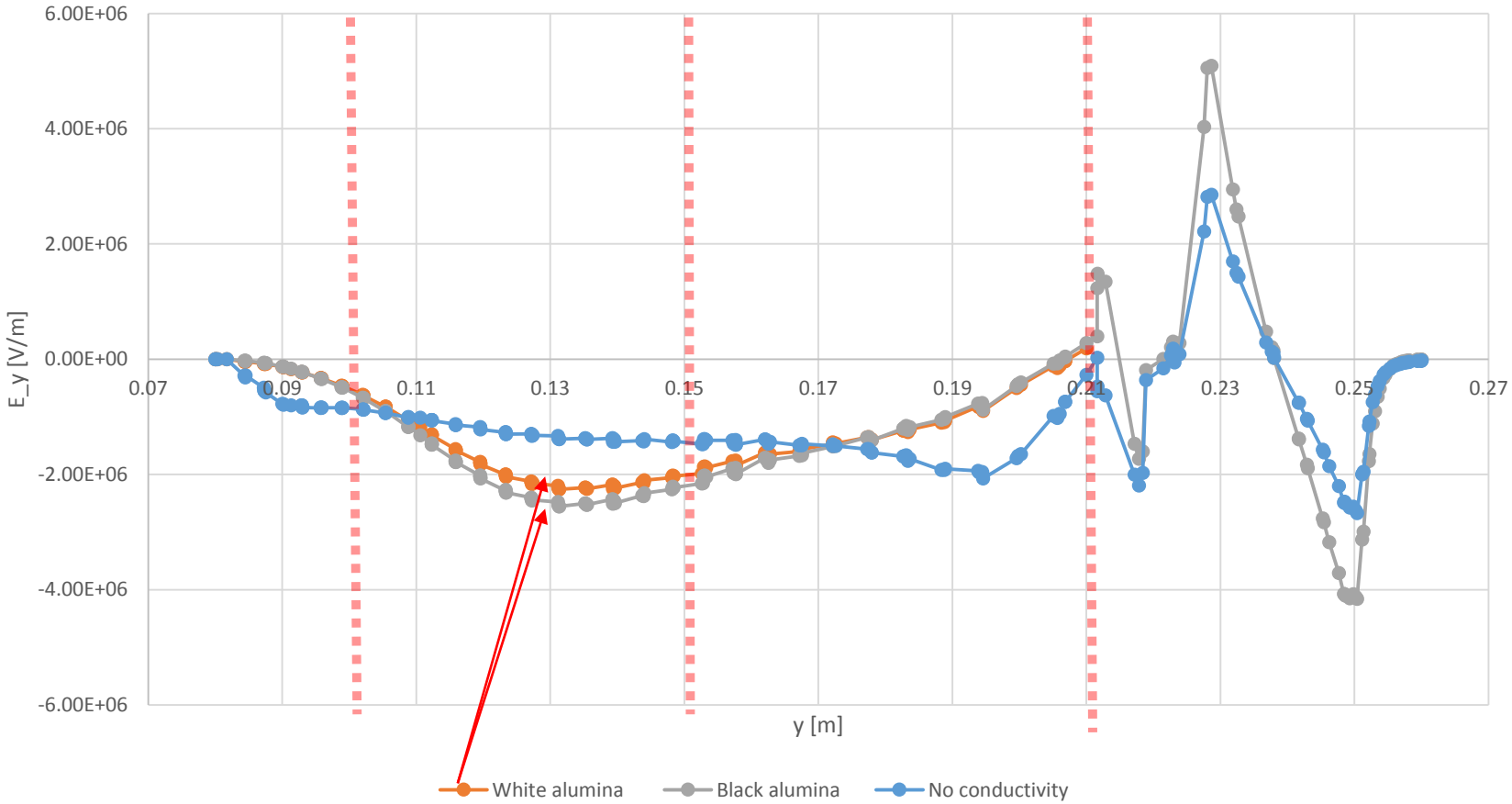


Electric field in the y-direction:



E_y field component near the middle of insulator:

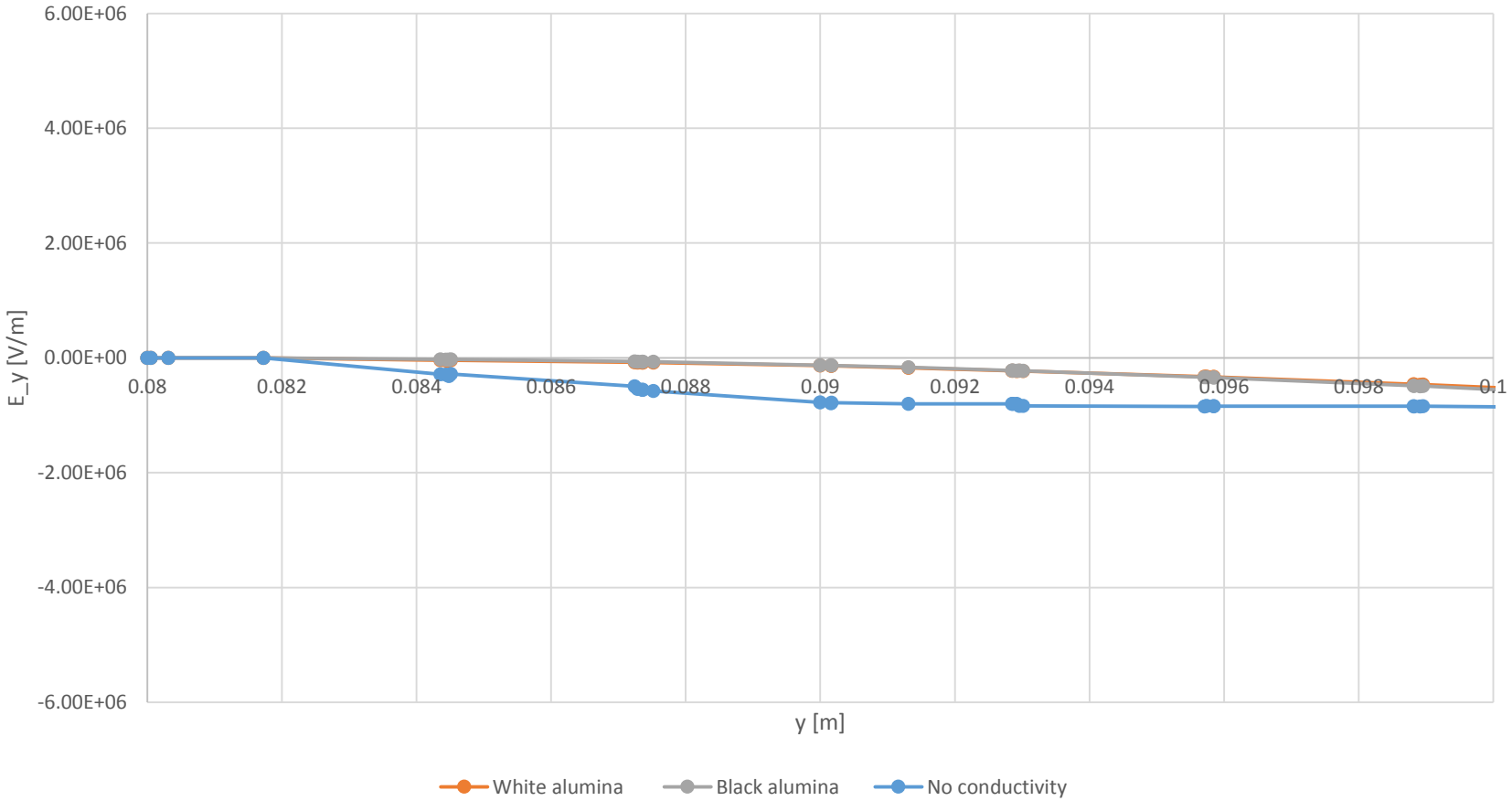
The height is ~0.14m



~20% difference

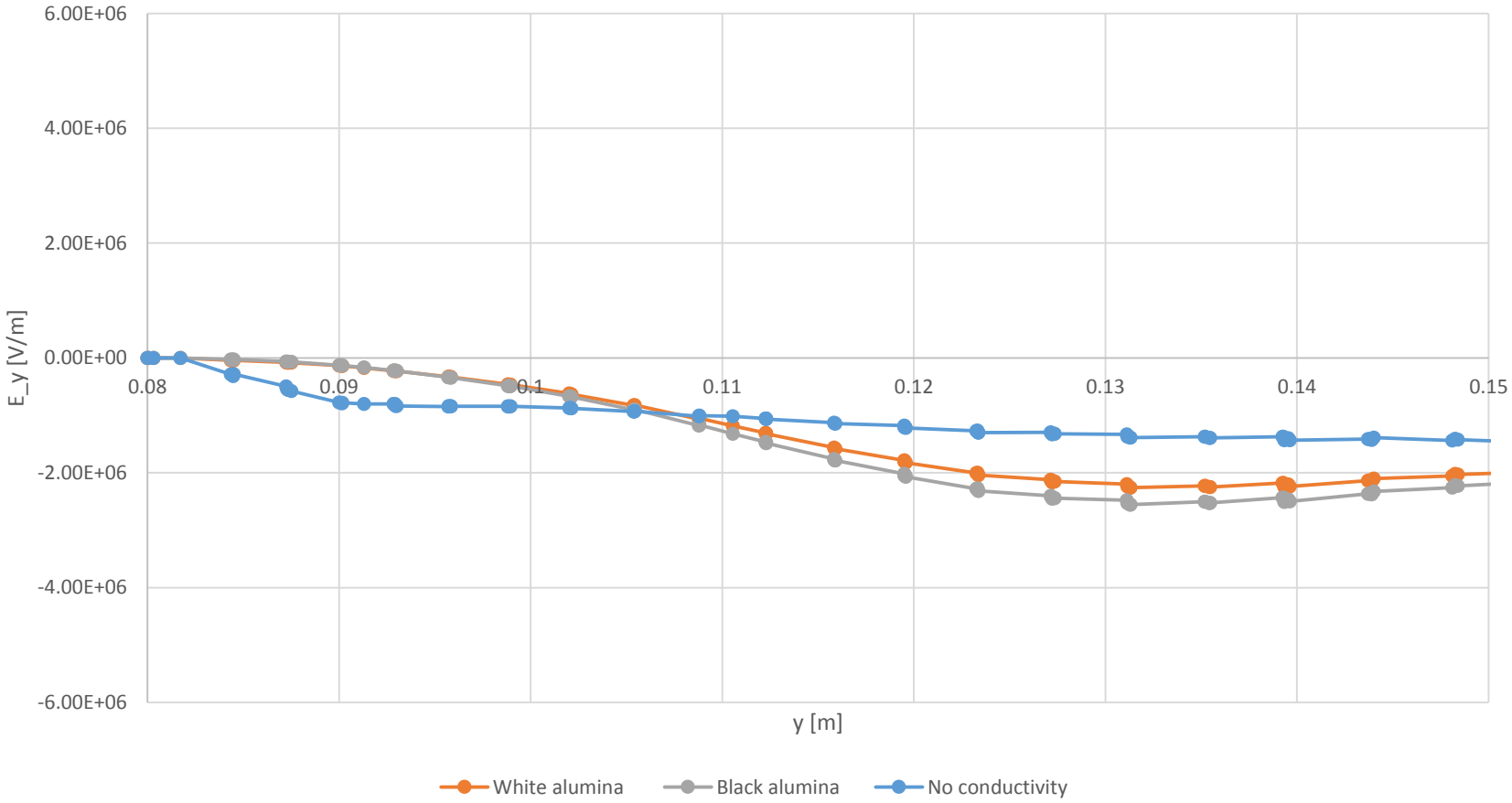
E_y near triple point:

The height is ~0.14m



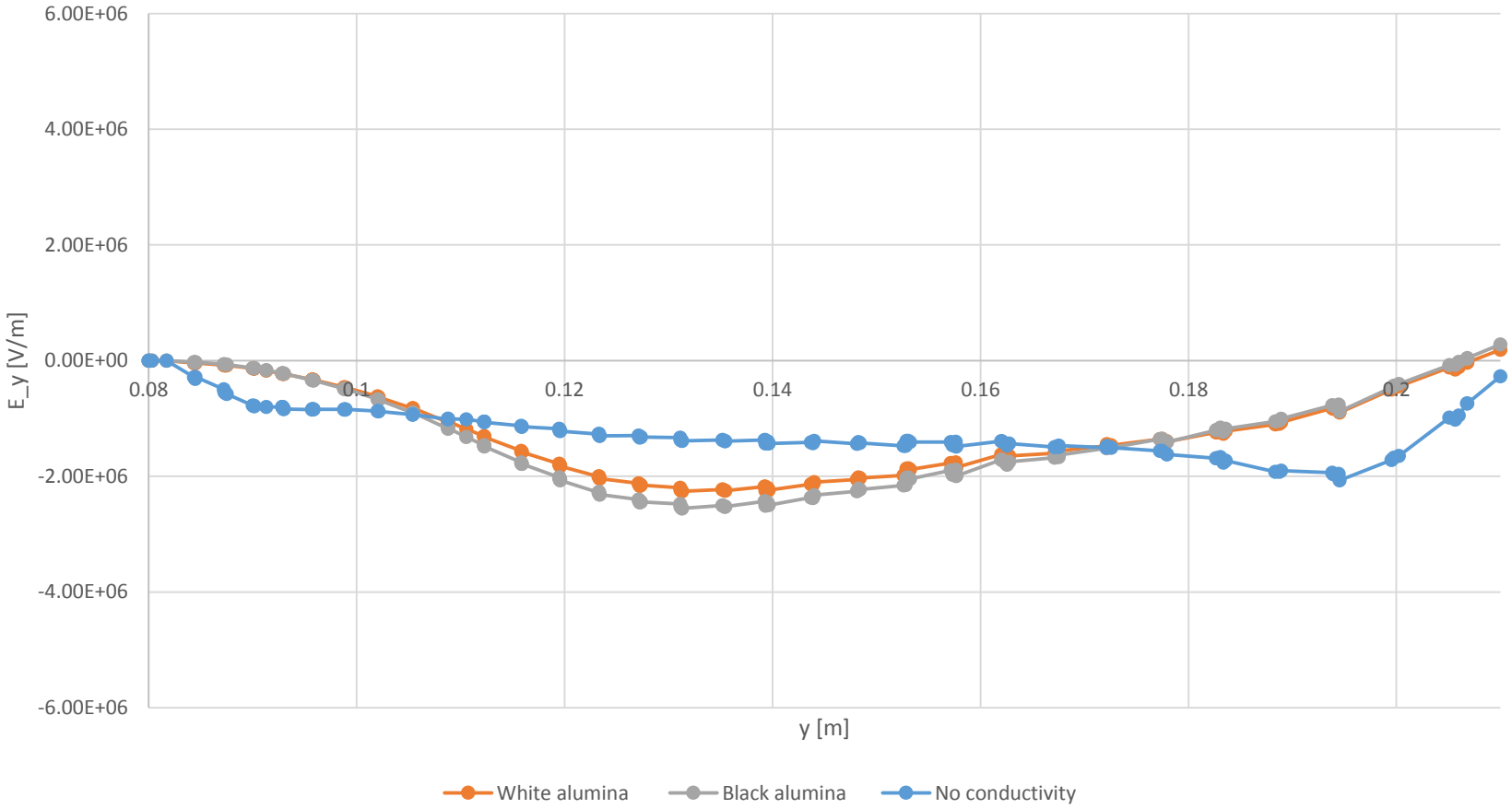
E_y up to the middle of insulator:

The height is ~0.14m

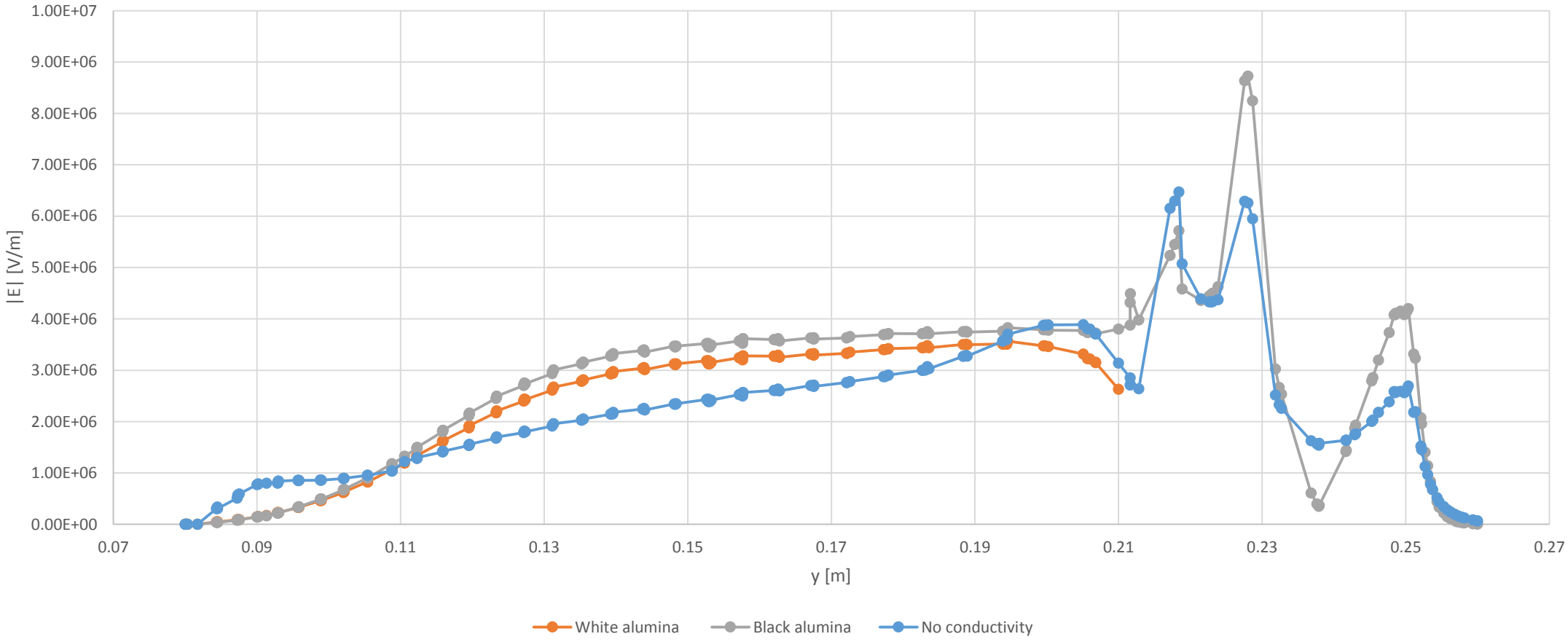


E_y along the insulator lenght:

The height is ~0.14m



Electric field norm |E|:



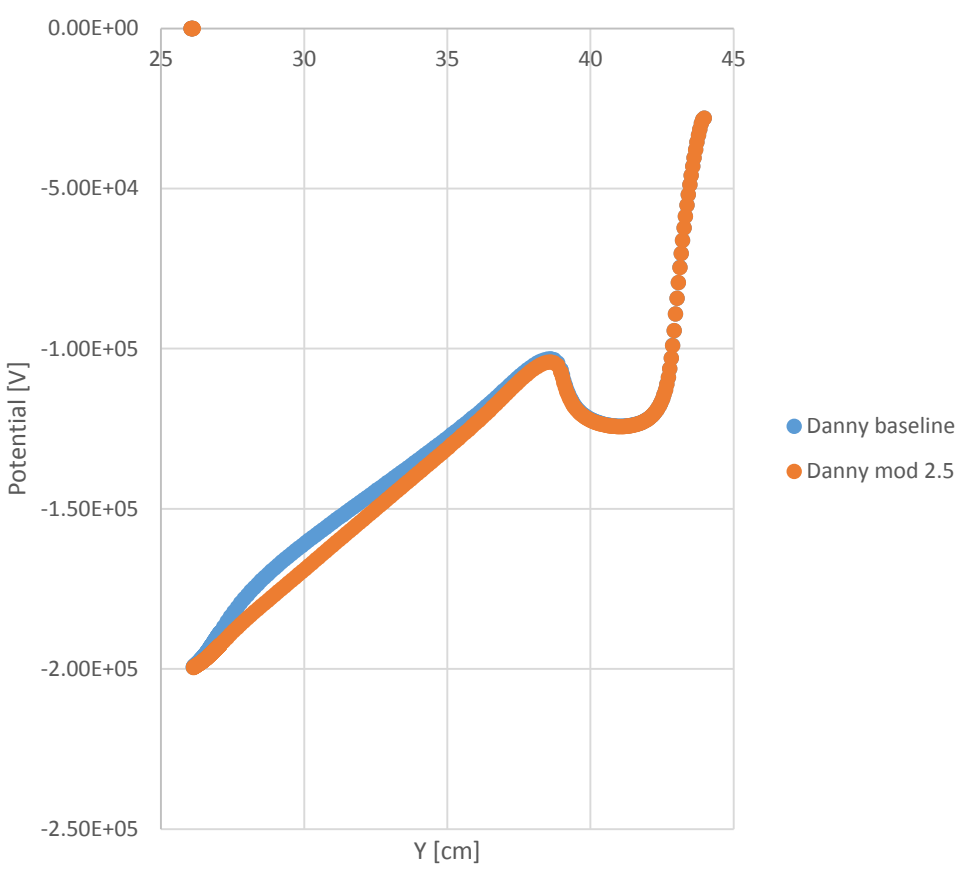
Preliminary conclusions

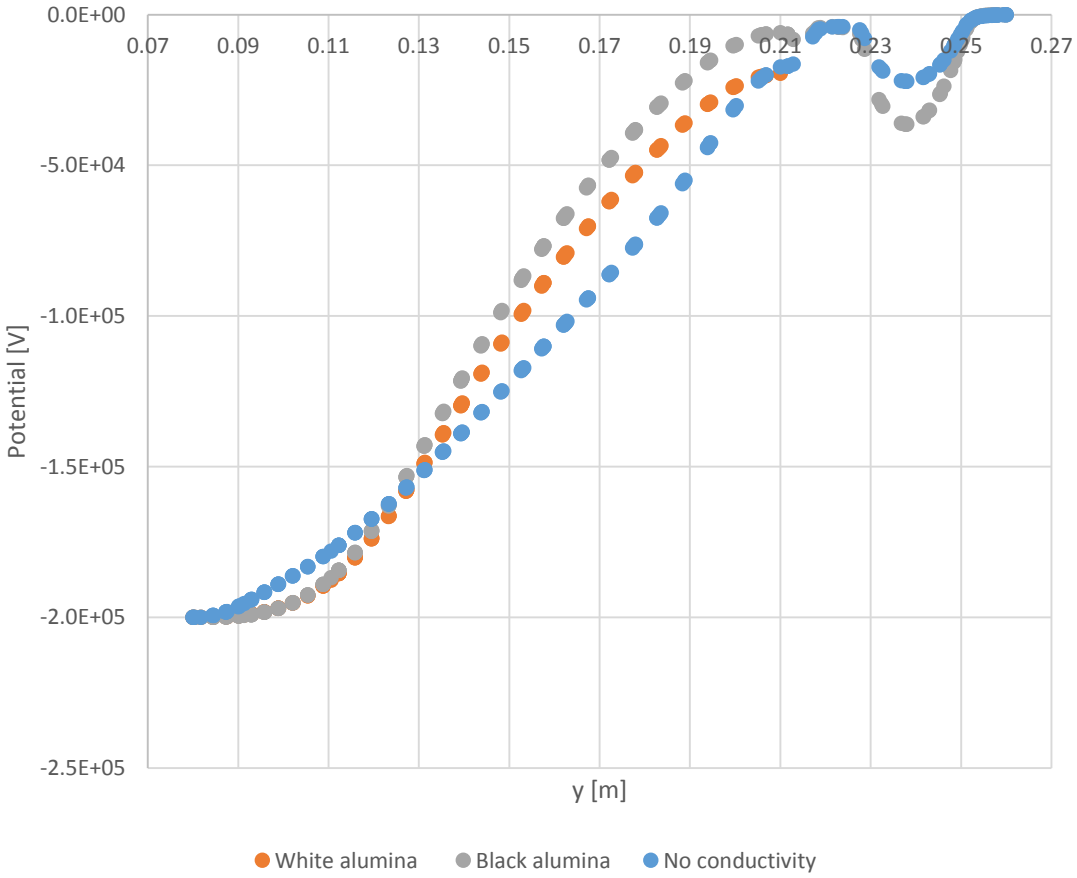
- Adding the conductivity produces a similar potential and electric field shape, but with regions of marked differences between the three models. The differences are more noticeable between the model that does not account for the conductivity and the two models that account for conductivity.
- Both cases that include conductivity seem to produce a less linear potential along the insulator-rubber plug interface.

Next steps.

- Add this to the COMSOL Technote.
- Explore the use of another shed near ground because of the existence of another triple point where the top flange meets the insulator.
- Charge accumulation?

Fin.


0.00E+00
-5.00E+04
-1.00E+05
-1.50E+05
-2.00E+05
-2.50E+05
Potential [V]
25
30
35
40
45
Y [cm]
Danny baseline
Danny mod 2.5


0.0E+00
-5.0E+04
-1.0E+05
-1.5E+05
-2.0E+05
-2.5E+05
Potential [V]
0.07
0.09
0.11
0.13
0.15
0.17
0.19
0.21
0.23
0.25
0.27
y [m]
White alumina
Black alumina
No conductivity