GTS gun COMSOL simulations

Field maps review.

Gabriel Palacios

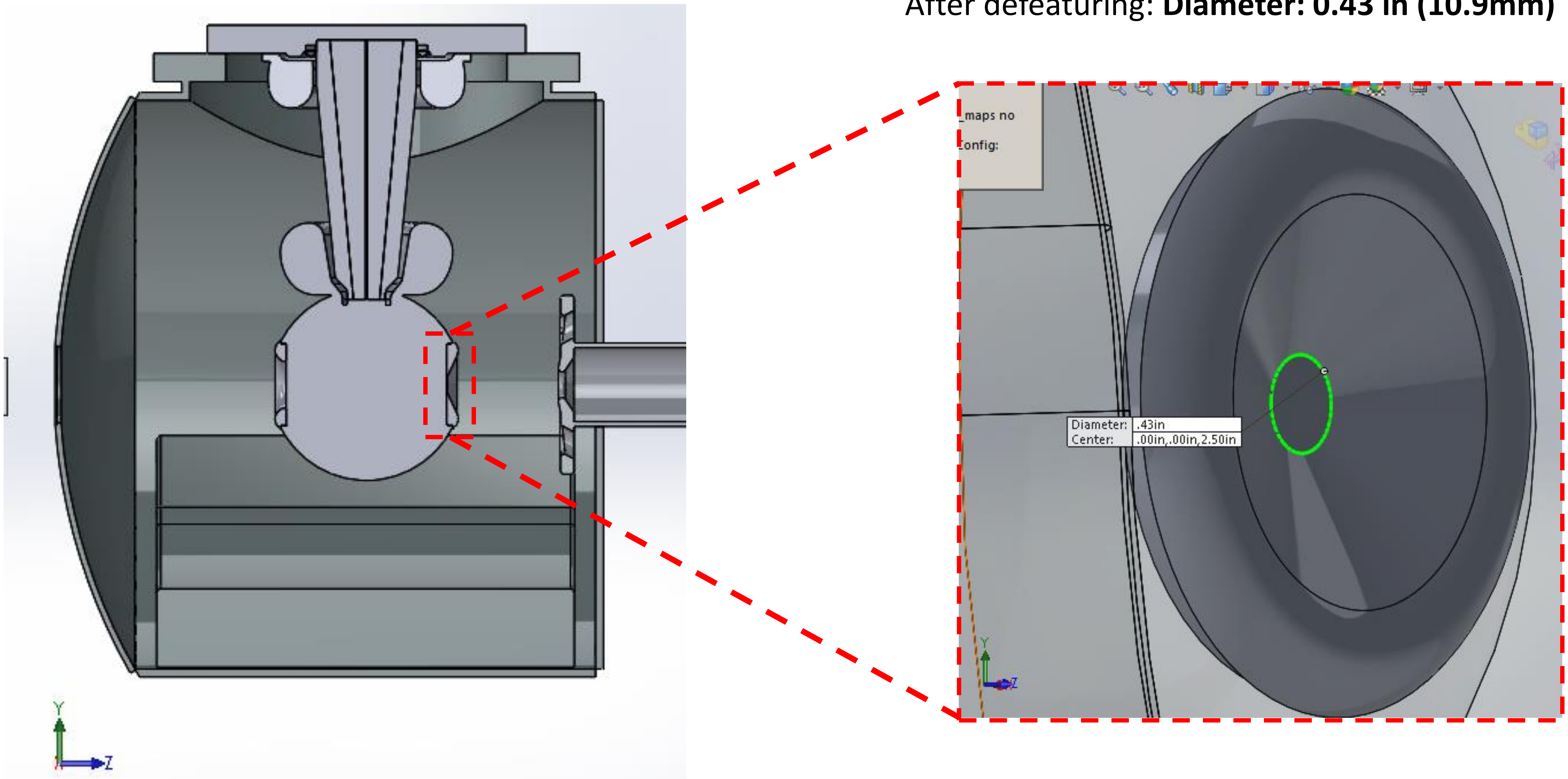
gpala001@odu.edu
04/03/17

Summary

- Solidworks
  - Geometry modifications
- COMSOL
  - Details of simulation
  - Gnuplot plots
  - COMSOL plots
- Additional slides

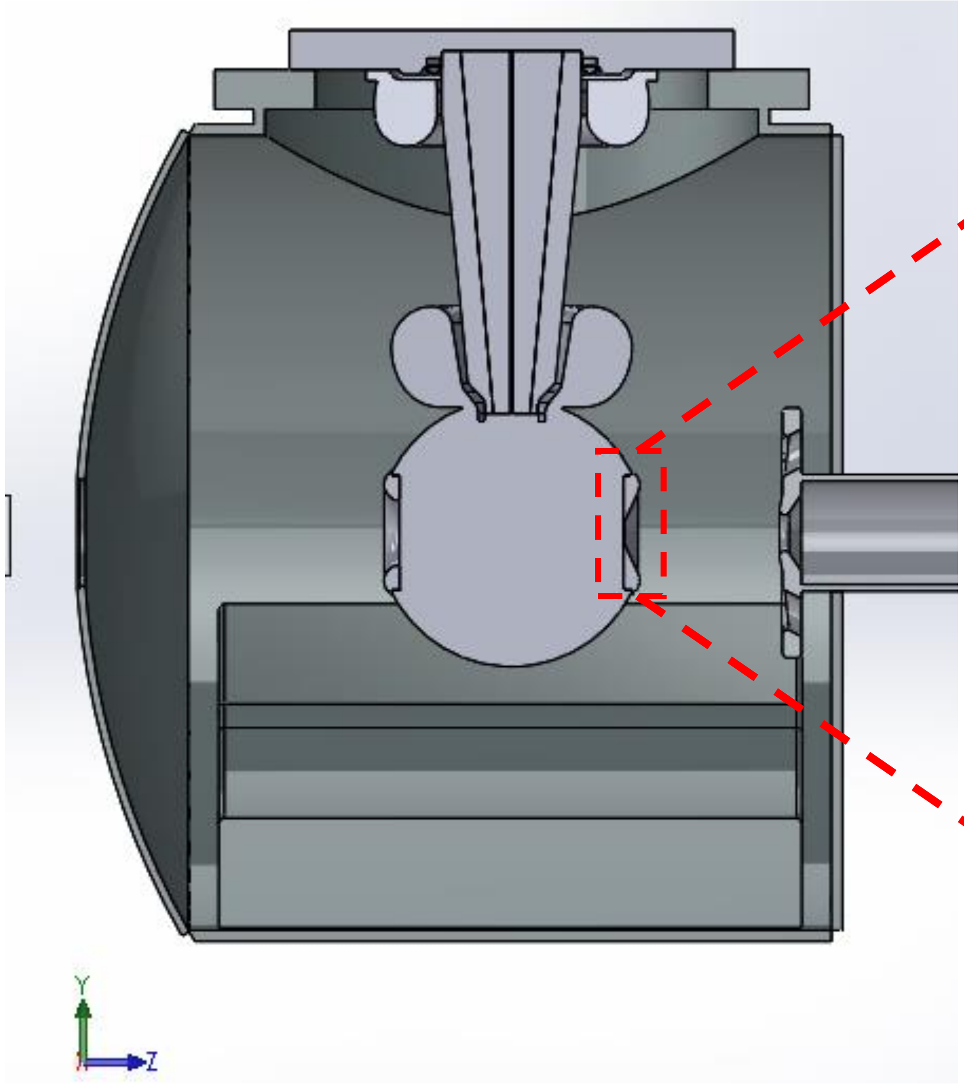
Solidworks geometry modifications:

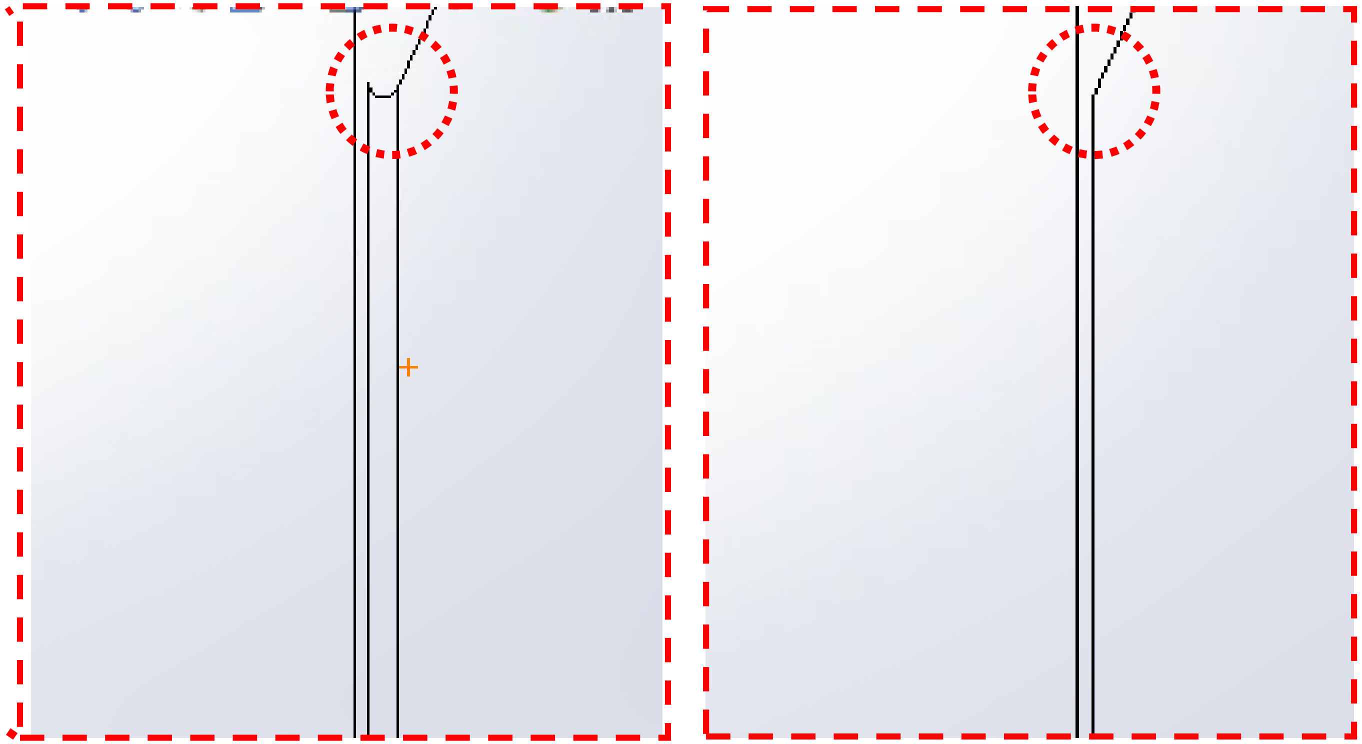
Before defeaturing: Diameter 0.48 in (12.1 mm)
After defeaturing: **Diameter: 0.43 in (10.9mm)**



Solidworks geometry modifications:

What do you mean by “defeaturing”?
These snippets are not to scale.

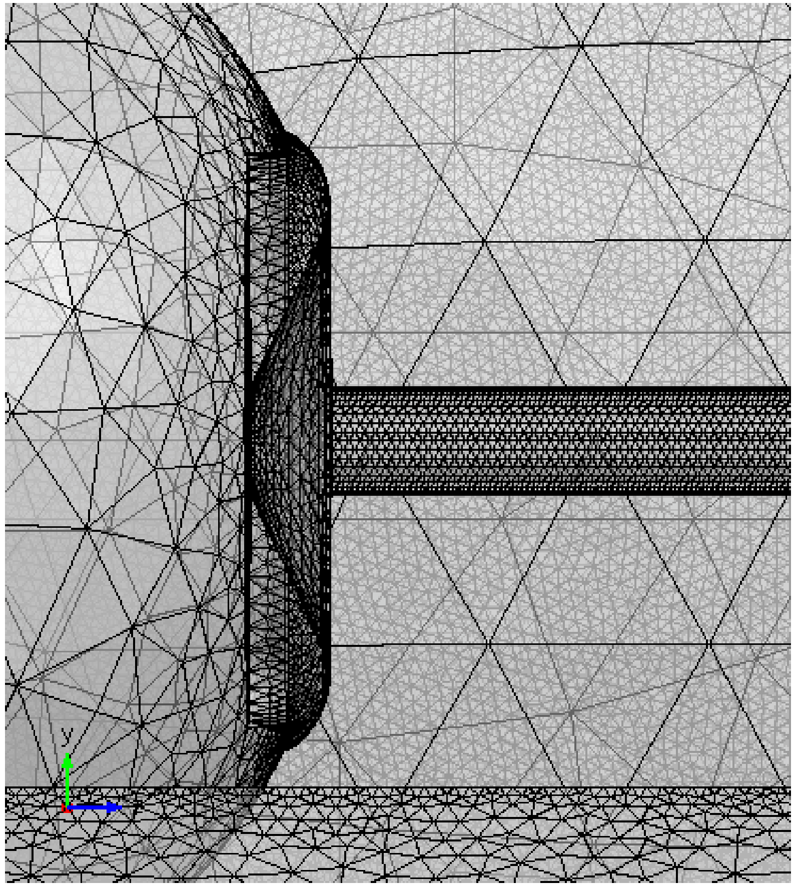




Perfection is a harsh mistress.

Solidworks geometry modifications:

Perfection is a harsh mistress.



Big features like flanges, chamber and pipes **vs** tinny features like pierce geometry, anode details, insulator details are **hard to mesh together (fixing the photocathode region will brake the mesh at the bigger parts)**.

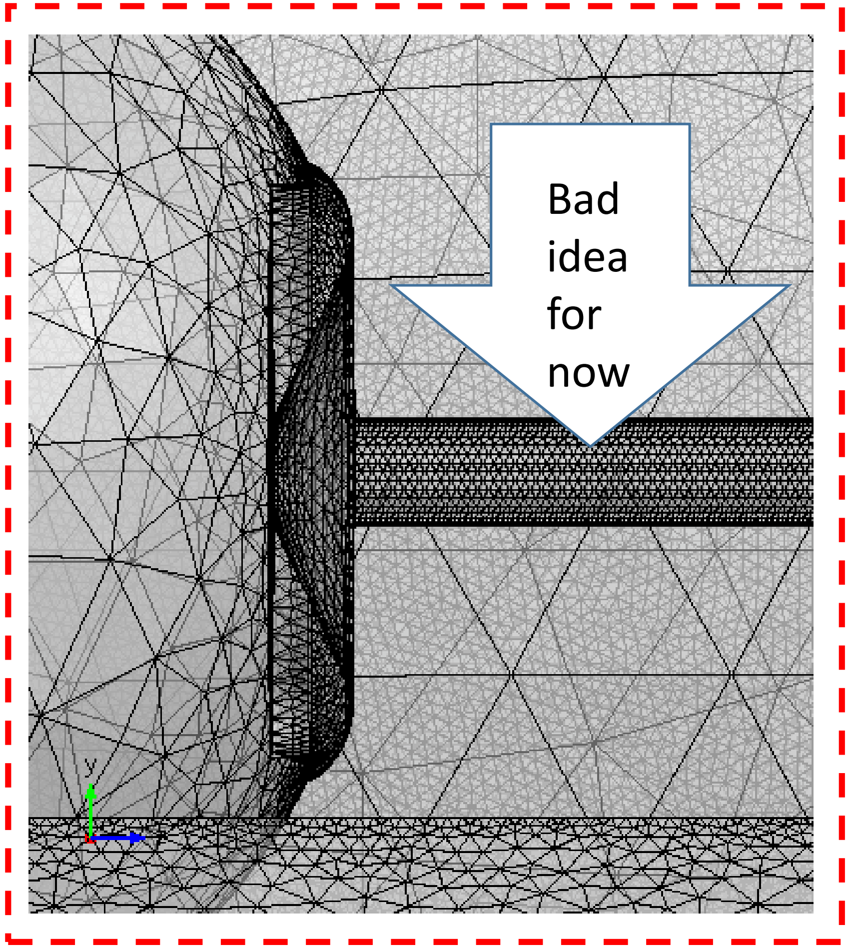
Walter Frei (COMSOL specialist): *"…It is relatively easy to come up with a geometry that no meshing algorithm will ever be able to mesh in a reasonable amount of time…"*

I thought you said COMSOL was the bomb?
Well, it is, but one has to think about time-benefit of the meshing refinement process.

Perfect results at photocathode = perfect mesh for big & small = perfect 3D model with exact measures and no small gaps

Solidworks geometry modifications:

Perfection is a harsh mistress.



Then what!?

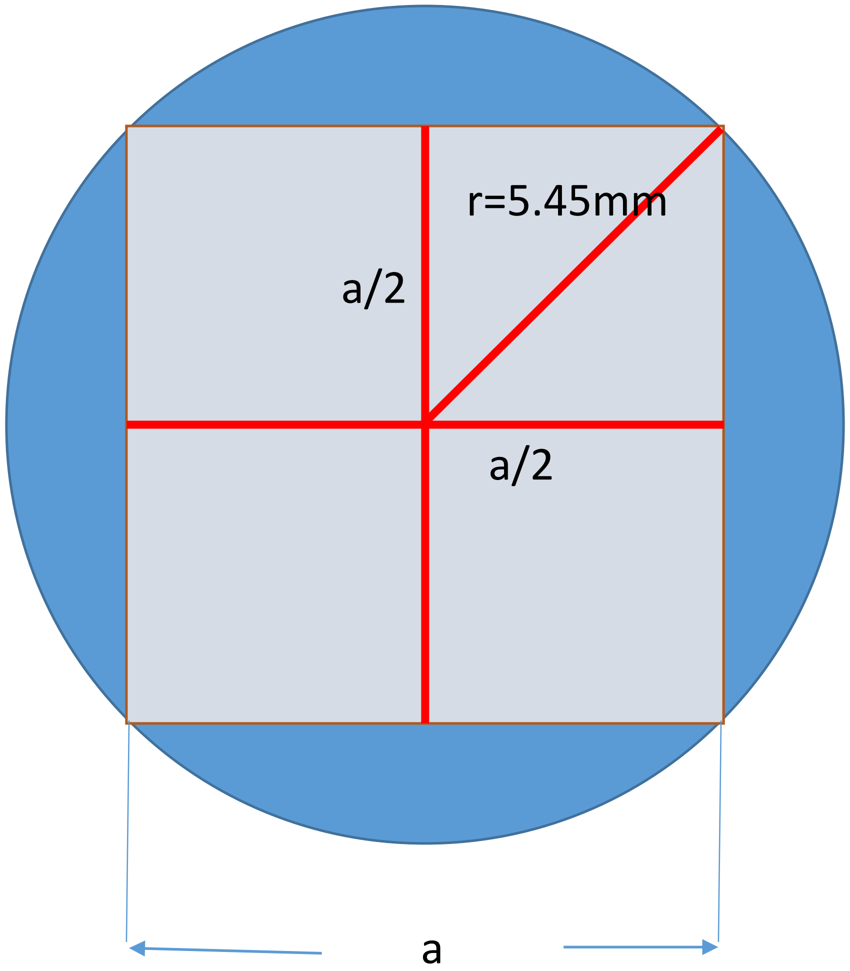
Besides noting that the **cylinder was introducing problems so it had to be removed.**

In other business, for the photocathode there is a trade off:

- If I am on the **photocathode surface** (z=2.50”=**63.5 mm**) I can only show:
  - **-3.85mm < x < 3.85mm**
  - **-3.85mm < y < 3.85mm**
- If I am **separated from the surface** by ~1mm (z=**64.5 mm**) I can show:
  - **-5.5mm < x < 5.5mm**
  - **-5.5mm < y < 5.5mm**

Solidworks geometry modifications:

What does that mean?



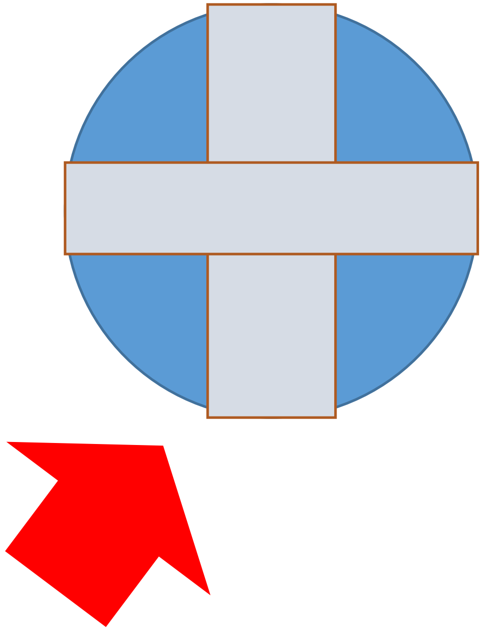
Trade off:

- If I am on the **photocathode surface** (z=2.50"=**63.5 mm**) I can only show:
  -3.85mm < x < 3.85mm
  -3.85mm < y < 3.85mm
- Or we could do **narrow vertical or wide horizontal** scans to catch details near the top and bottom, or more complicated mapping that **requires coding**.

$$2\left(\frac{a}{2}\right)^2 = r^2$$

$$a = \frac{2}{\sqrt{2}} r = \frac{2}{\sqrt{2}}(5.45) = 7.70 \text{ mm}$$

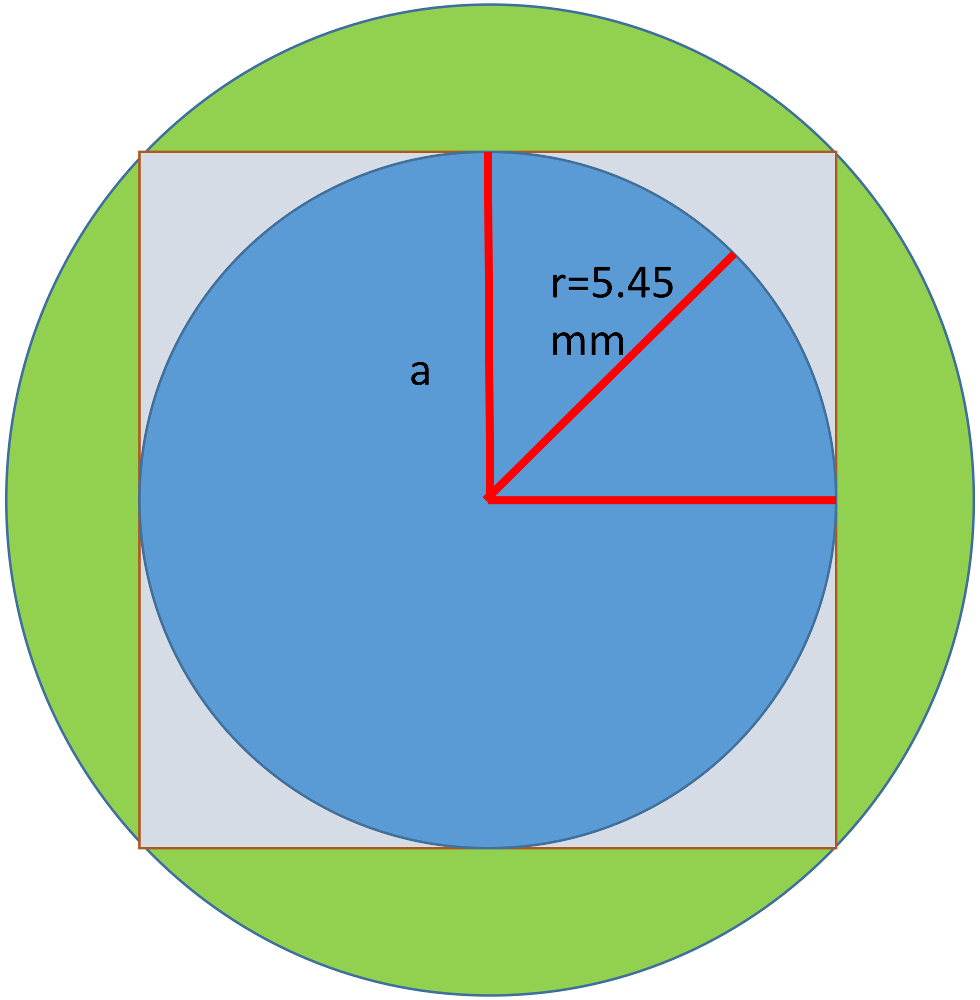
$$a/2 = \mathbf{3.85\ mm}$$



Best way to do it, in my opinion.

Solidworks geometry modifications:

What does that mean?



Or even:

- If I am 1 or 2 mm away from **photocathode surface** (z=**64.5 - 65.5 mm**)

I could show:

-5.5mm < x < 5.5mm

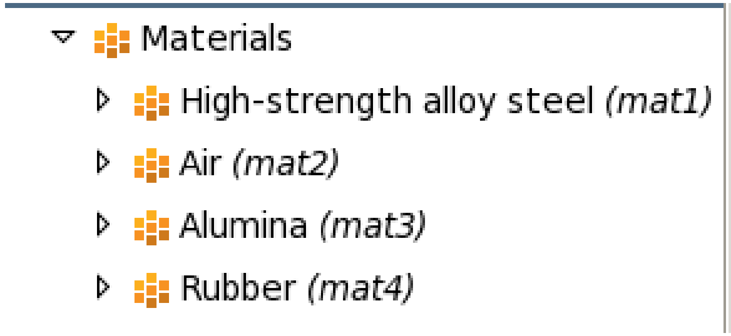
-5.5mm < y < 5.5mm

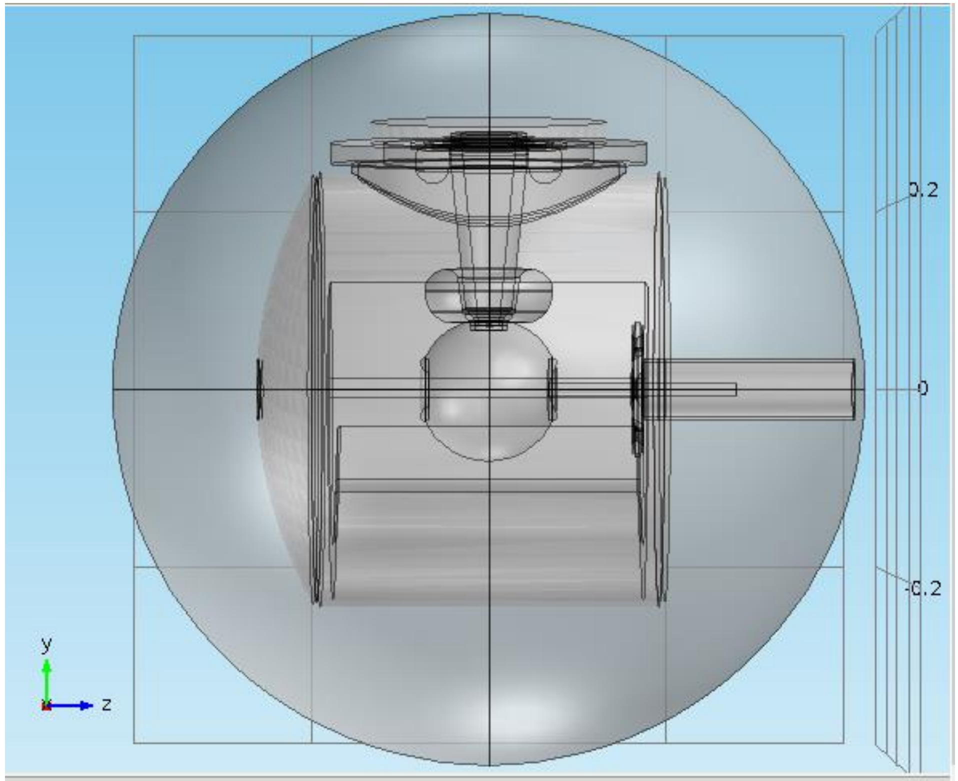
Any points inside the metal will probably cause GPT to loose particles.

COMSOL materials:

- Stainless steel for all metal components with ε_r=1 and σ of 1.1E6 S/m
- Air for the vacuum surroundings.
- Alumina for the ceramic.
  - ε_r=8.4 and σ of 2E-12 S/m for the black.
- Rubber for the HV cable plug with ε_r=2.37 and σ of 1E-14 S/m .

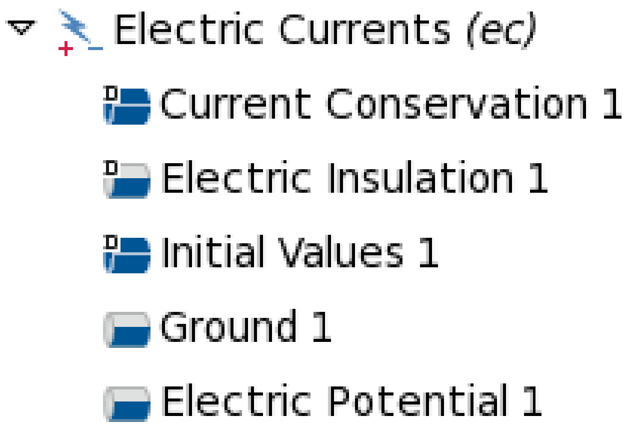
Used the Physics AC/DC module to implement electrostatics: Grounded the chamber, anode, flanges and V=-300kV to the cathode assembly. The rest of the options are automatically setup by COMSOL.

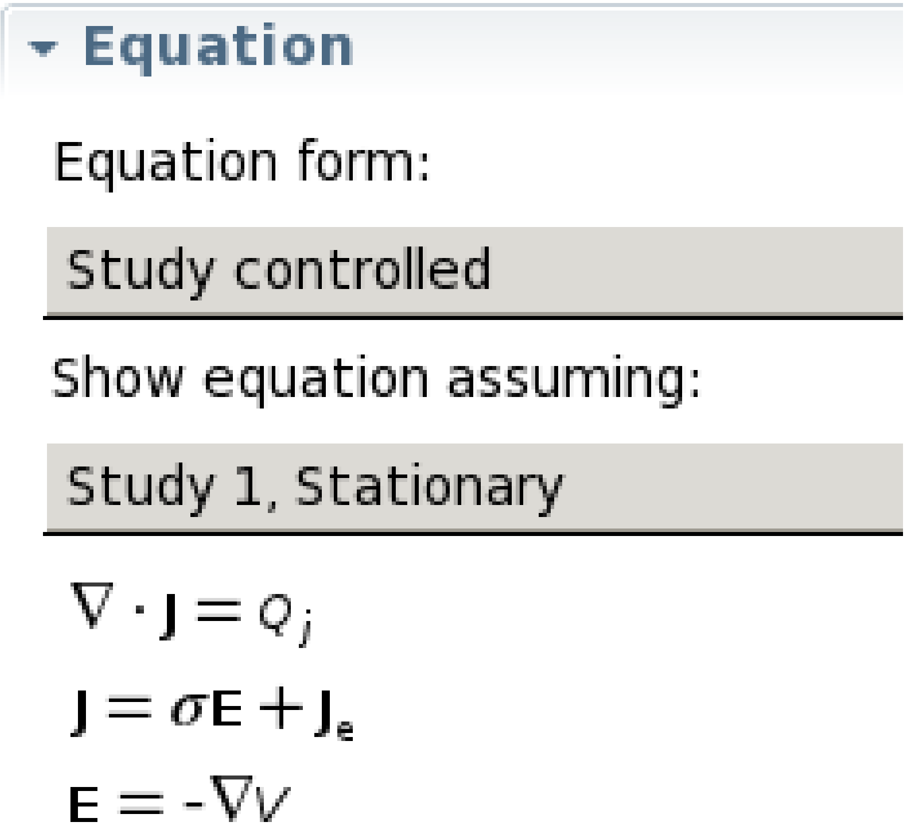




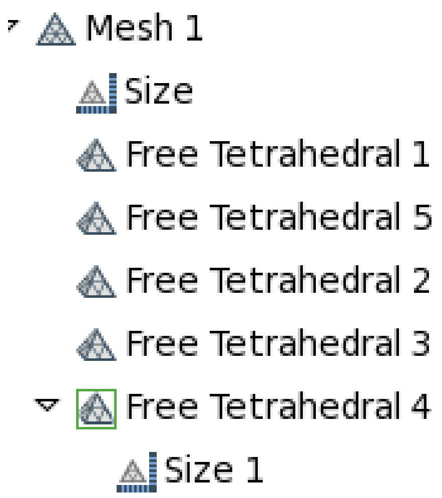
COMSOL electric currents:

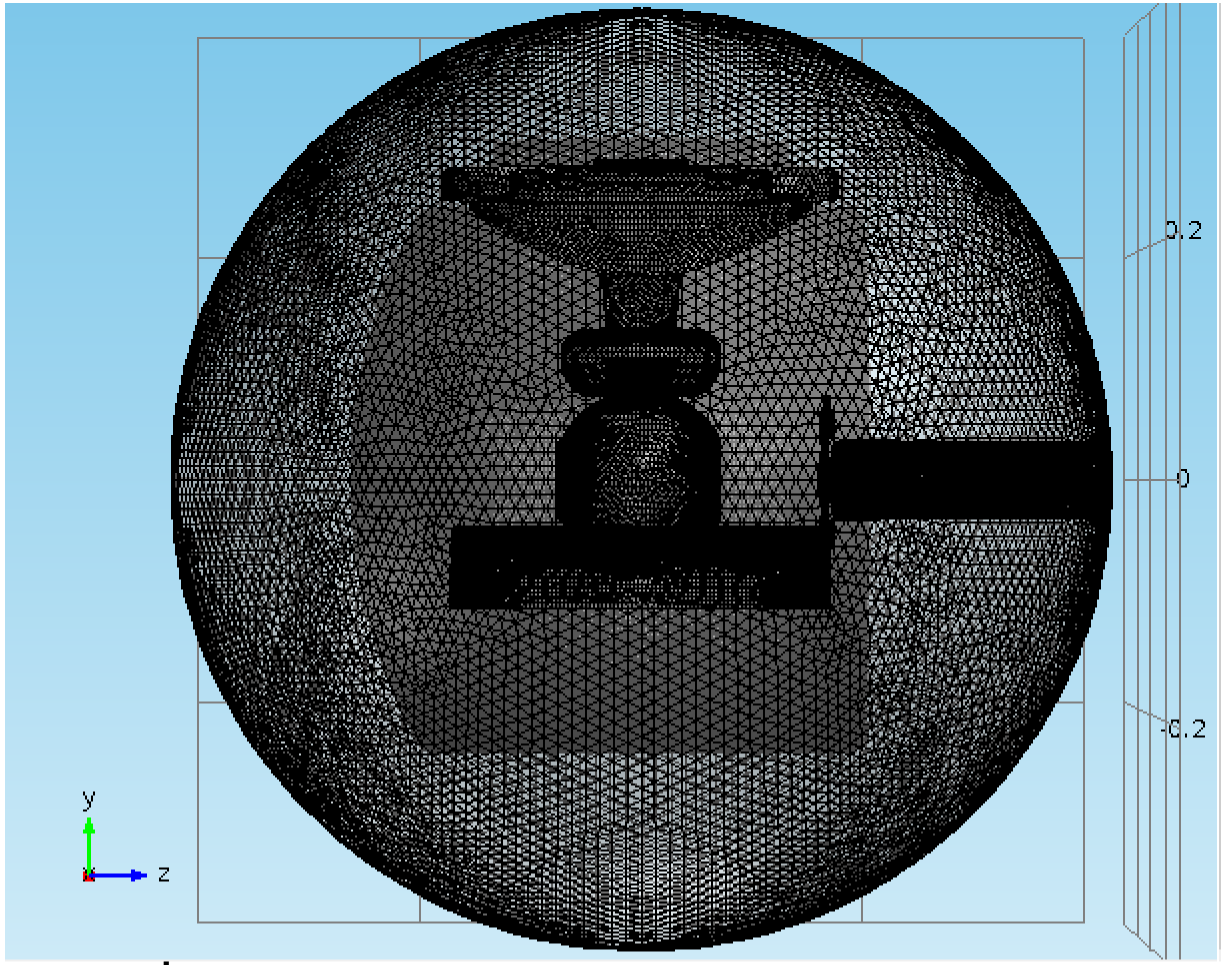
- Current conservation in all domains.
- Electric insulation at the outer air boundary.
- Initial value (of potential) set to zero by default.
- Ground 1 at vacuum chamber, NEGs, anode, flanges, upper shed.
- Electric potential at -300kV at the cathode, cathode shed and HV cable.





COMSOL mesh:



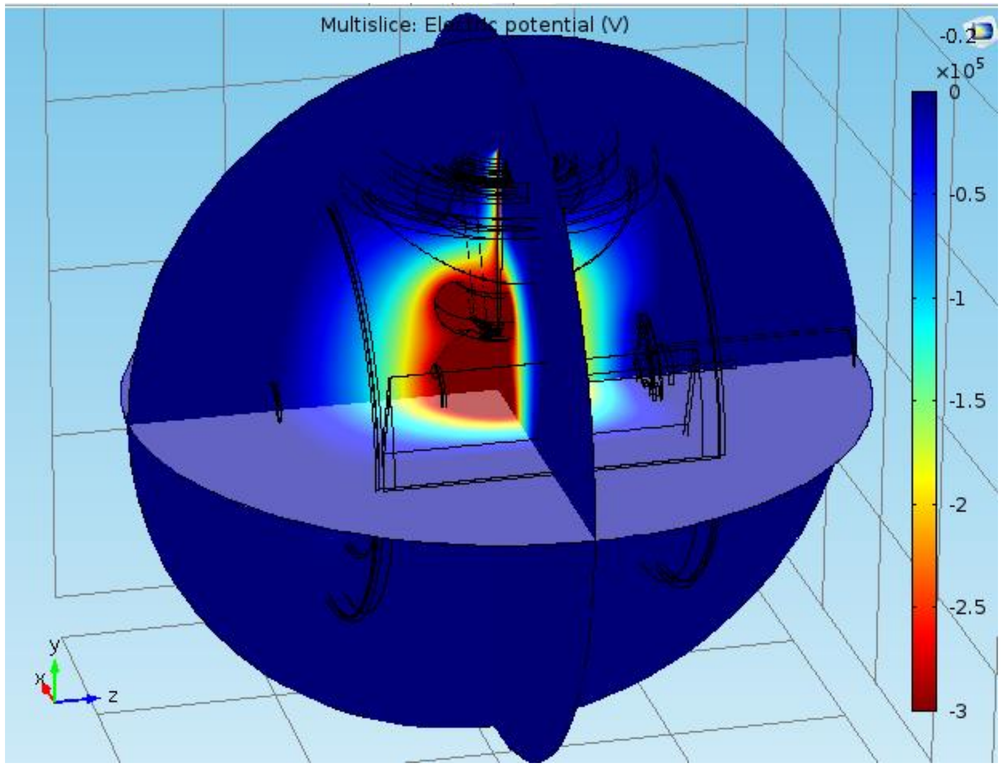


- The mesh was separated into 5 pieces.
  - A general physics extra fine mesh was used. (min element size 1.2mm)
  - Except for the air (vacuum) sphere, where an extremely fine semiconductor mesh was used. (min element size 1.5mm)

COMSOL Study:

- Study 1
  - Step 1: Stationary
  - Solver Configurations

- The study solves for the electric field and potential including the effect of the conductivity of the materials using the currents module.



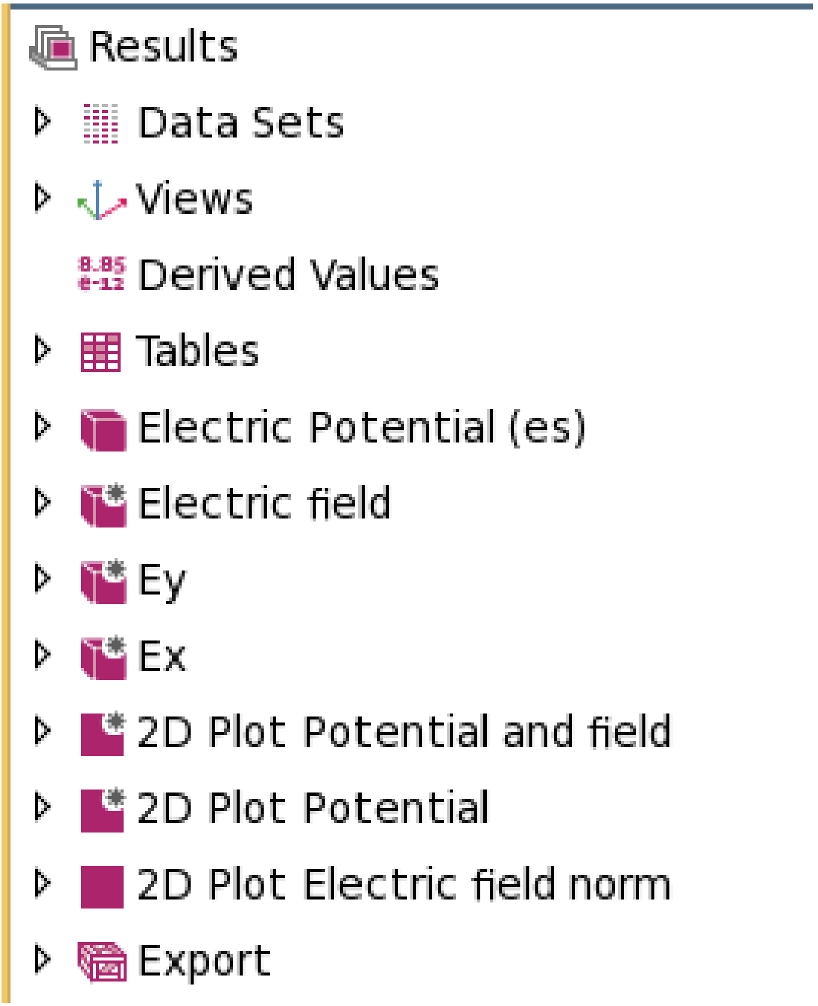
Physics and Variables Selection

☐ Modify physics tree and variables for study step

	Physics interface	Solve for
	Electrostatics (es)	✔

COMSOL results:

- The results for the electric field components Ex, Ey, Ez where plotted along a line from the photocathode center to the anode center as a function of **z-coordinate.** The plot showed as **a field map 2D projection** sometimes called a ‘shadow’.
- Also COMSOL color maps of Ey component is shown for detail.



COMSOL results:

- **But wait, why is the file that big?**

Let us take **100µm** step.

Length in x-axis: $\frac{7.7mm}{0.1mm} = (7.7)(10) = 77$

Times the same in the y-axis: $77^2 = 5929$

Times the length in the z-axis:

$(5929)\left(\frac{116.5mm}{0.1mm}\right) = (5929)(116.5)(10) = 6907285\ data\ points$

Noticed the cubic dependence on the resolution?

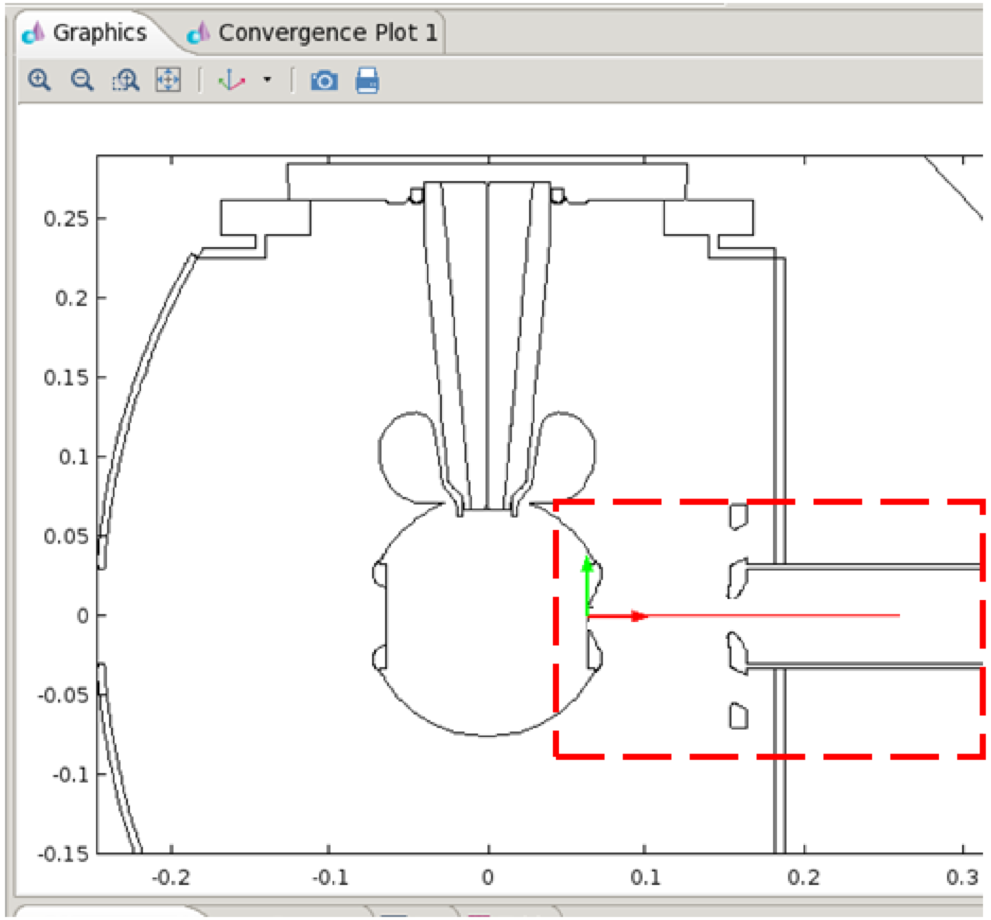
* If I take a square of 11mm length:

~$16456000\ data\ points$

* If we take 10 **µm step** the node on the cluster runs out of memory ☺. That is, the powerful computer at ODU is unable to handle the enormous amount of data for the file. (This could be for many reasons, restrictions, etc.)

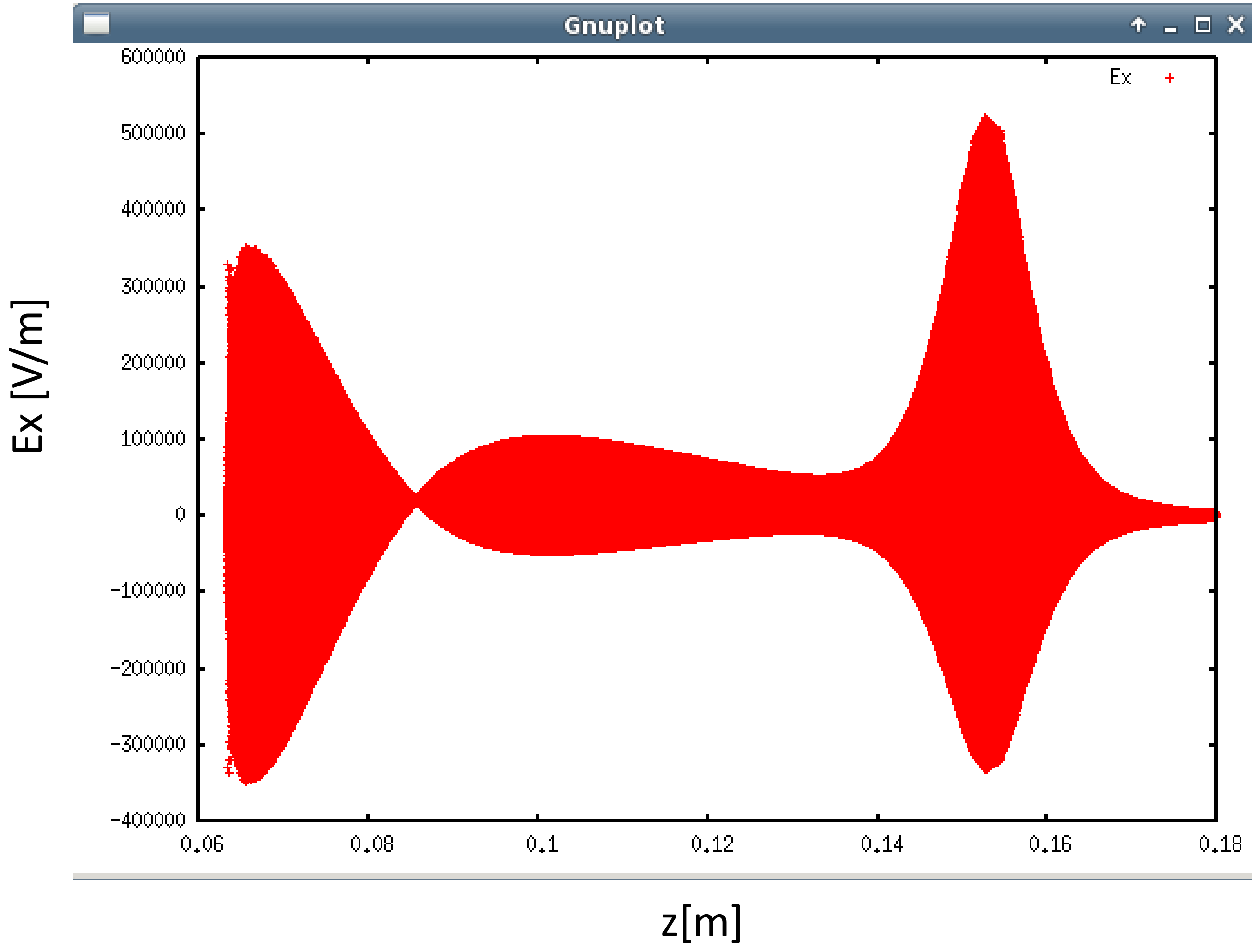
Photocathode-anode line:

The data for the following plots was taken along a horizontal line from the center of the photocathode to the back of the chamber passing through the anode center of 18cm as shown in the red line



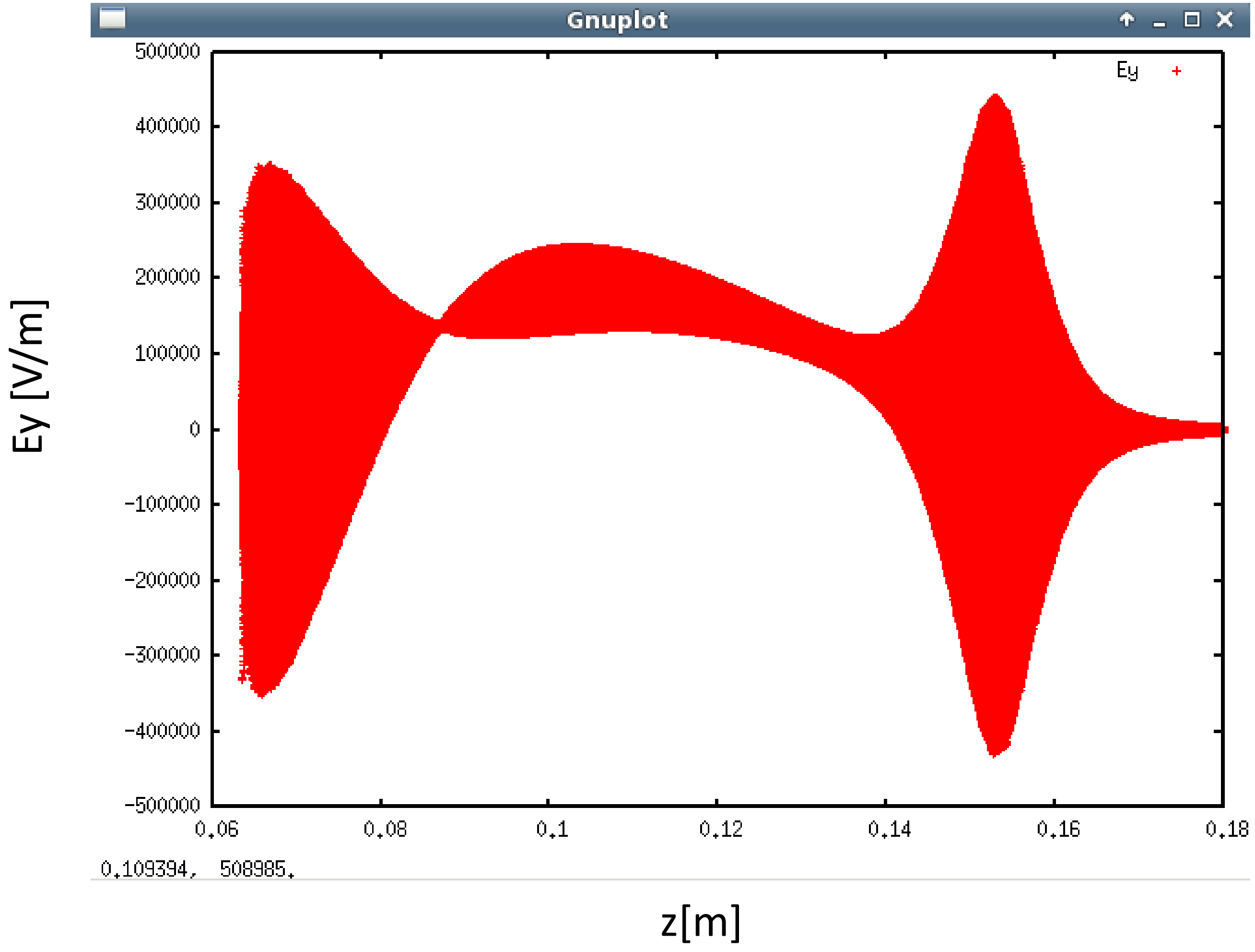
Photocathode-anode line :

- This image shows the electric field Ex component in V/m as a function of position on the z axis.



Photocathode-anode line :

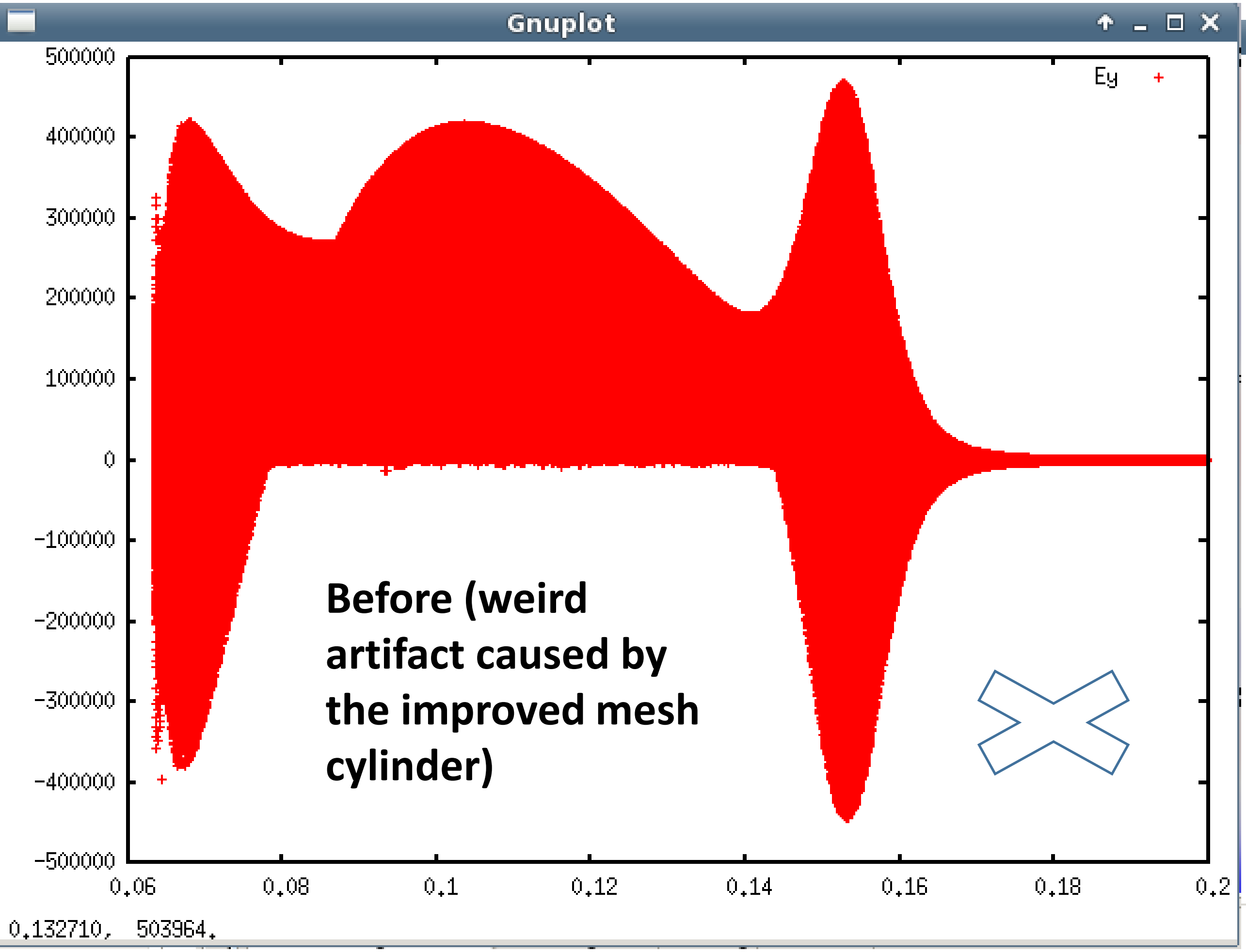
- This image shows the electric field Ey component in V/m as a function of position on the z axis.

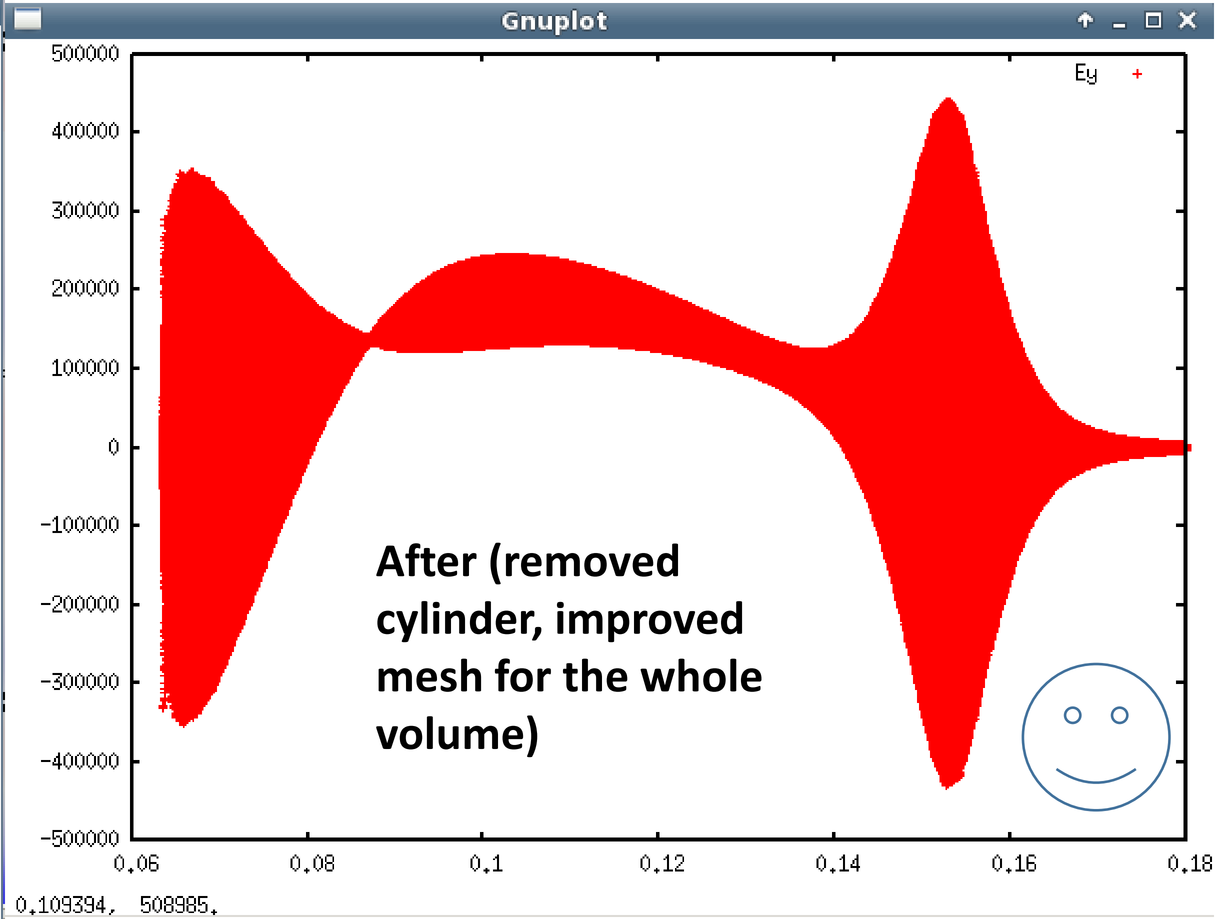


- **Yay!**
- The negative part of Ey is there. It is not missing data. The field **is positive** in that gap.

Photocathode-anode line :

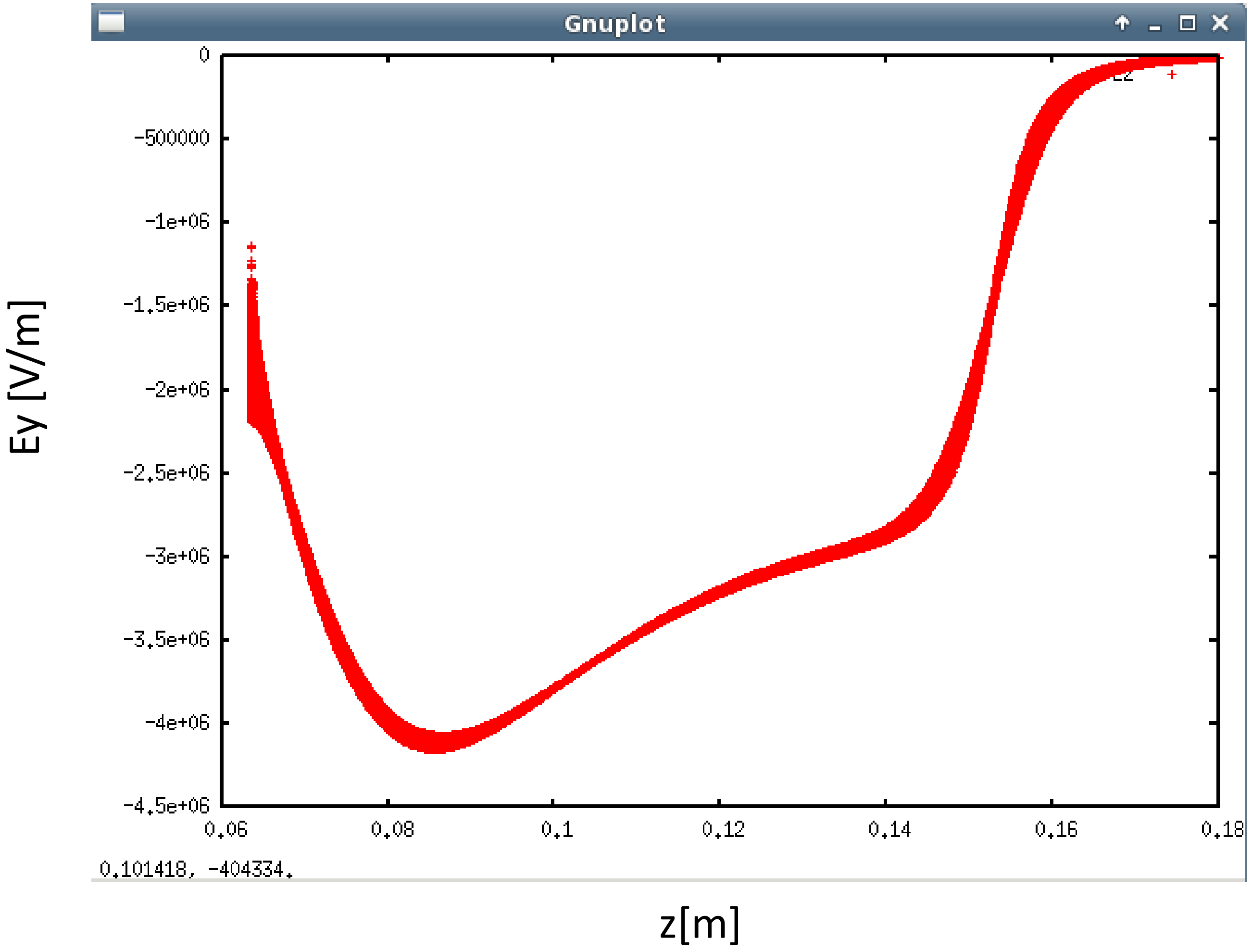
- This image shows the electric field Ey component in V/m as a function of position on the z axis.



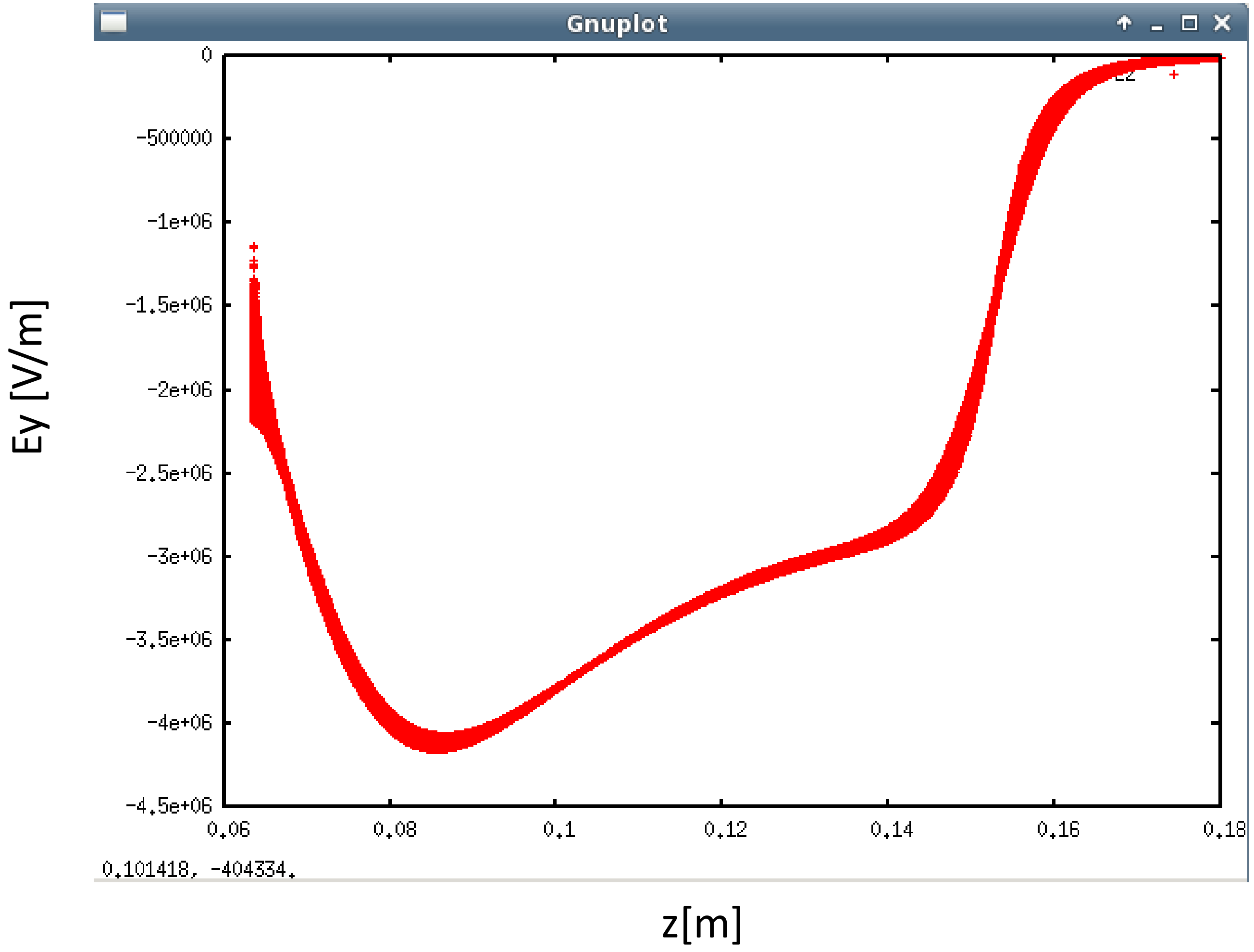


Photocathode-anode line :

- This image shows the electric field Ey component in V/m as a function of position on the z axis.



Photocathode-anode line :



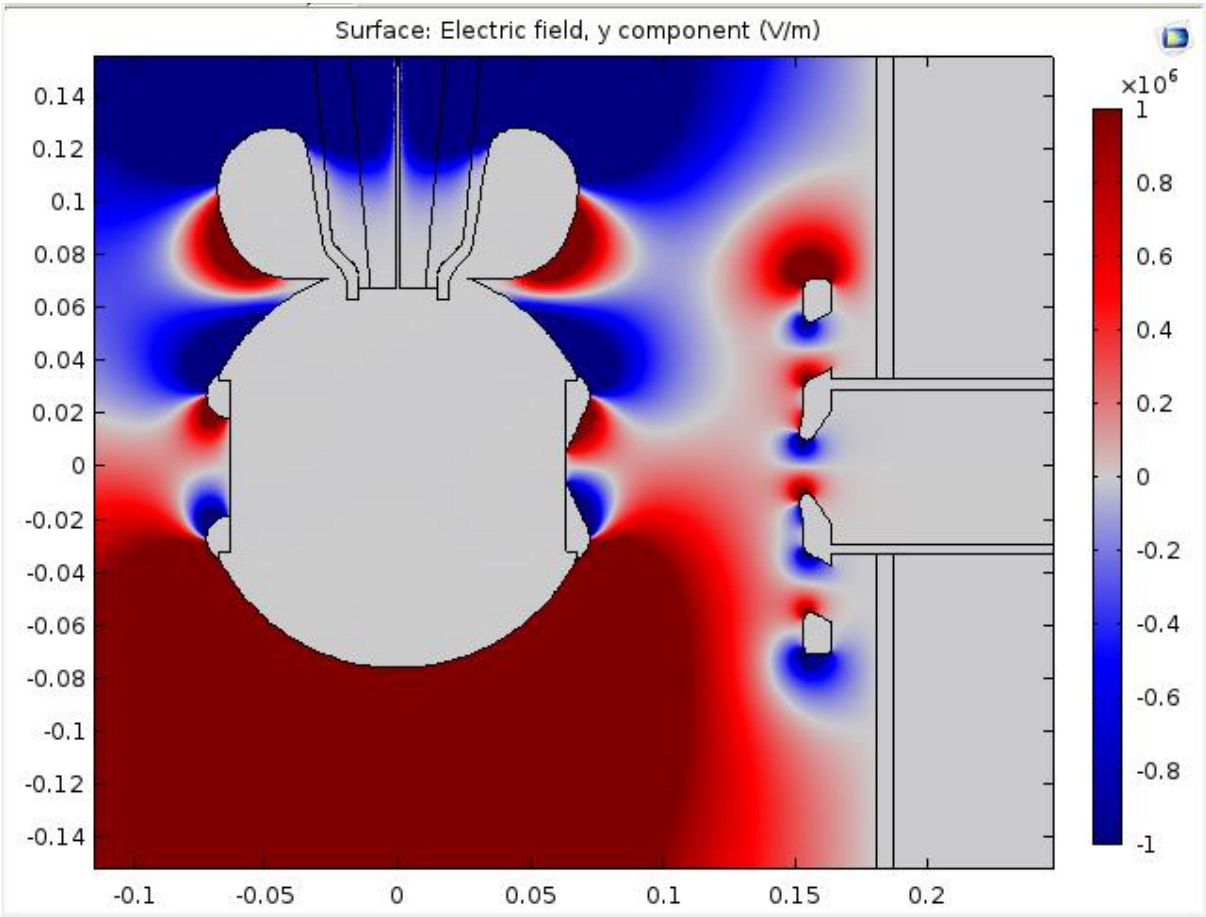
- **Wait, why is this line thick!?**

This is not a field map –*per se*. It is a direct plot of all the data points of Ez as a function of z-coordinate. Still a good tool to see what happens.

- True field map should be 3D.

Photocathode-anode line :

- This image shows the electric field Ey component in V/m as a function of position on the z axis.



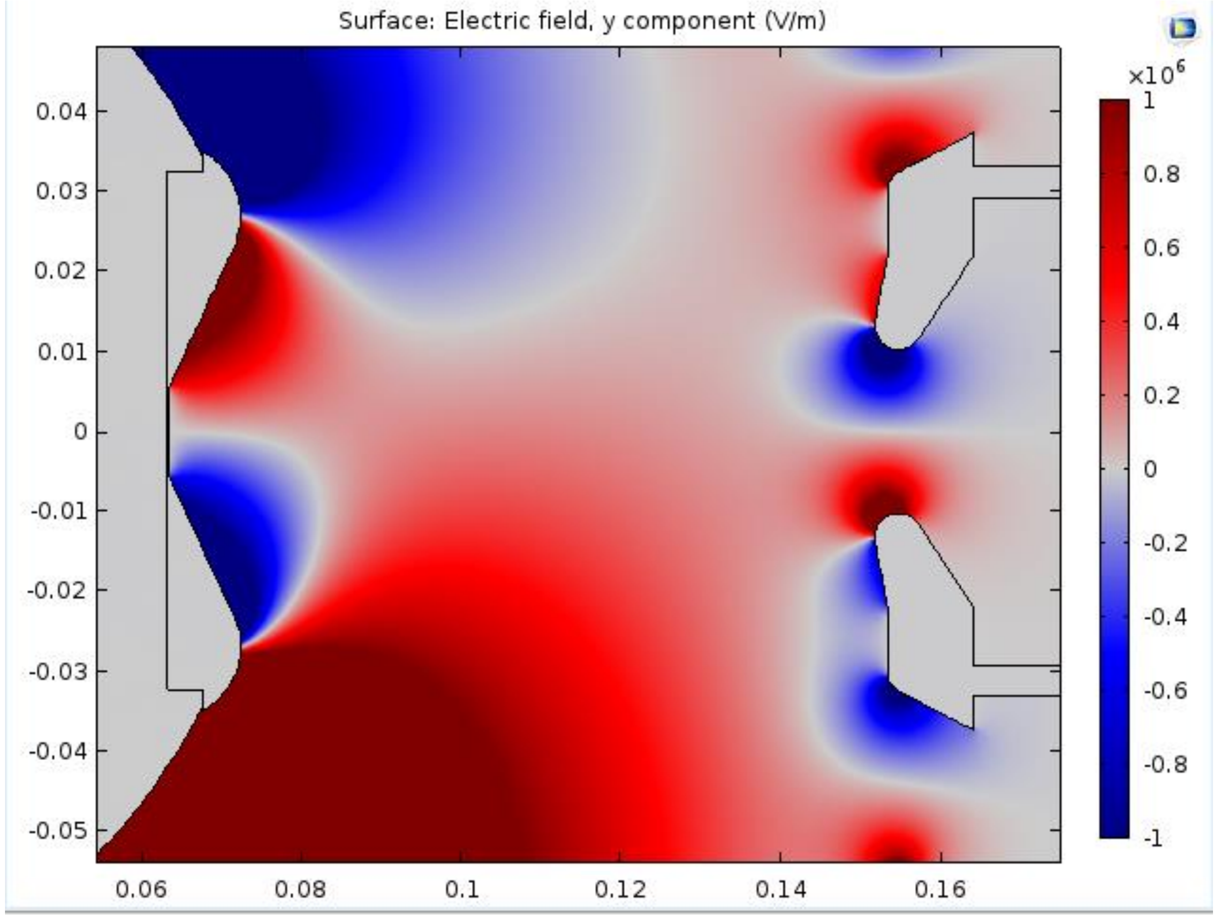
z[m]

The asymmetry of the field is related to the asymmetry of the geometry.
The gray line streams are regions of zero-field. In a perfectly symmetric gun, a gray stream should connect the photocathode center to the anode center.

Photocathode-anode line :

- This image shows the electric field Ey component in V/m as a function of position on the z axis.

If we set the color scale to **1MV/m** you can notice that the cathode-anode gap Ey field is dominated by a **positive** contribution



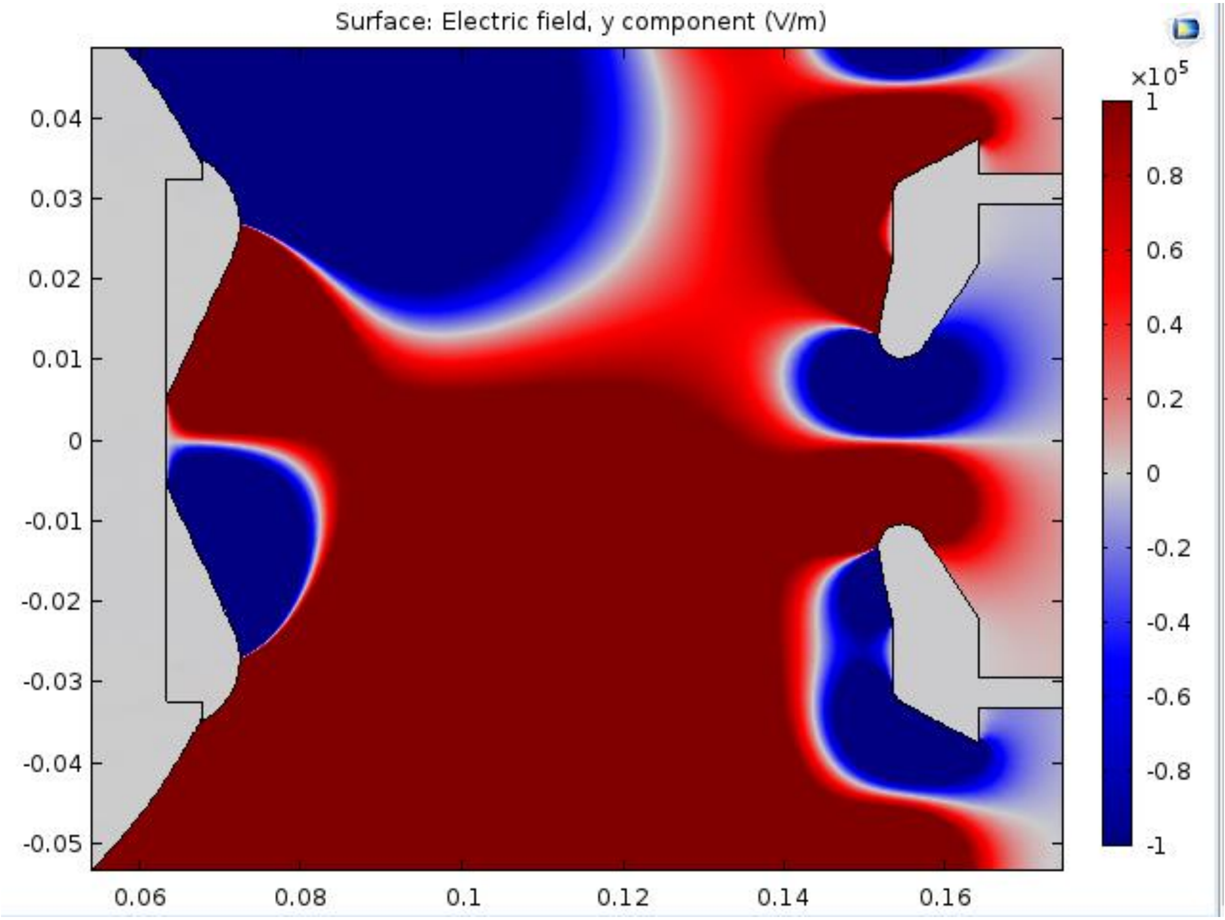
z[m]

Close

Photocathode-anode line :

- This image shows the electric field Ey component in V/m as a function of position on the z axis.

If we set the color scale to **100kV/m** you can notice that the cathode-anode gap Ey field is dominated by a **positive** contribution



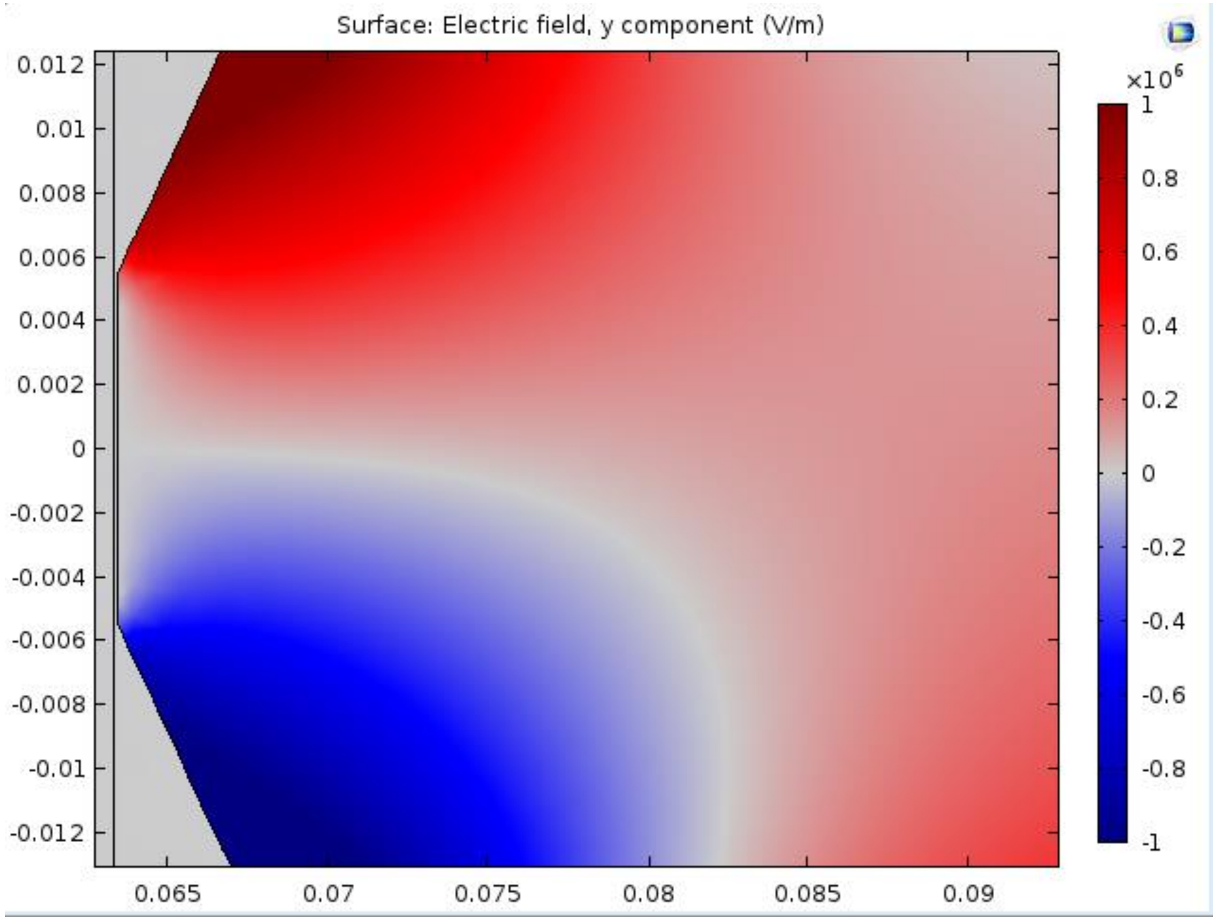
z[m]

Close

Photocathode-anode line :

- This image shows the electric field Ey component in V/m as a function of position on the z axis.

If we set the color scale to **1MV/m** you can notice that the cathode-anode gap Ey field is dominated by a **positive** contribution



z[m]

Closer!

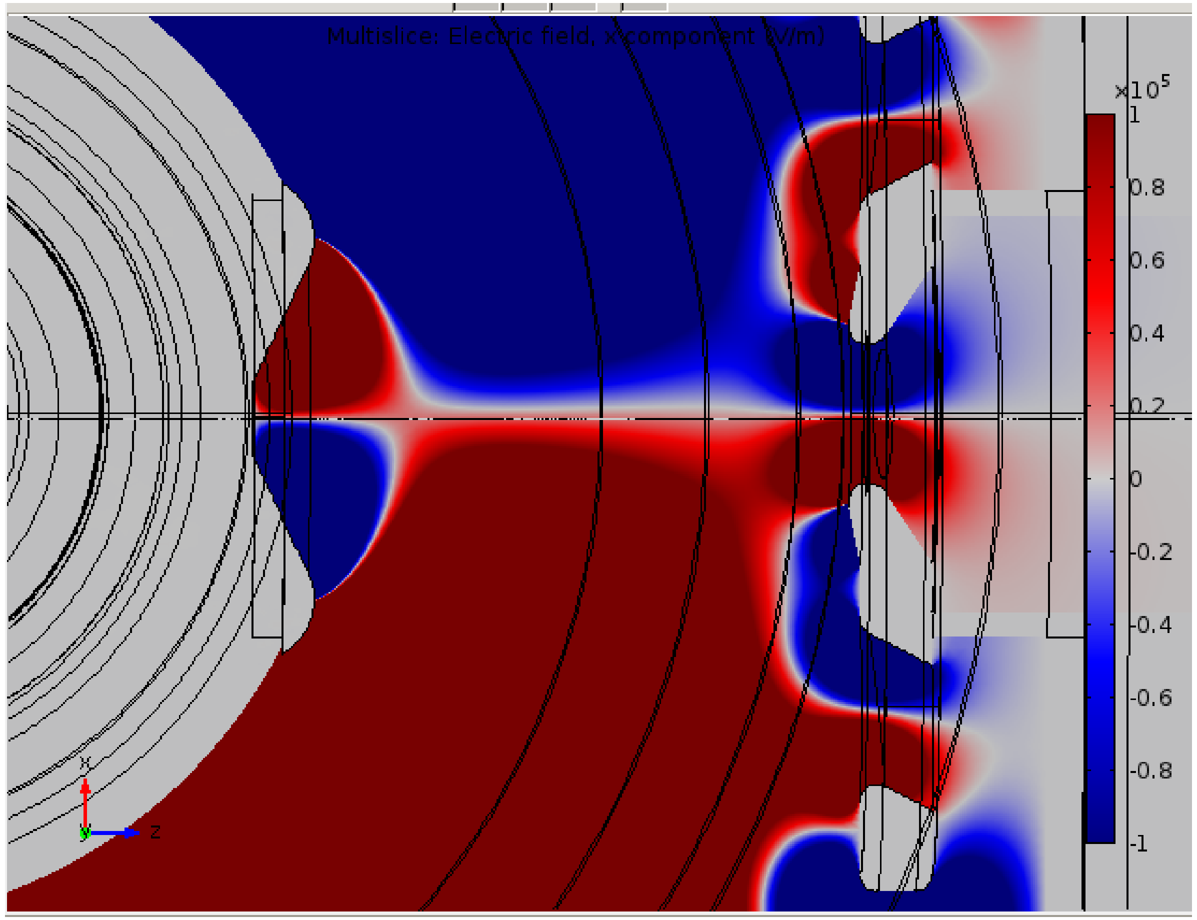
Near the photocathode surface the **pierce geometry dominates** the effect on the field.

Future steps.

- **Narrow vertical scan for catching the details near the top and bottom of the photocathode!**
- Adaptive mesh refinement?
- Coordinates of points in a circle with Python?
  - I can also take files with coordinate points and generate fields at them! You have?

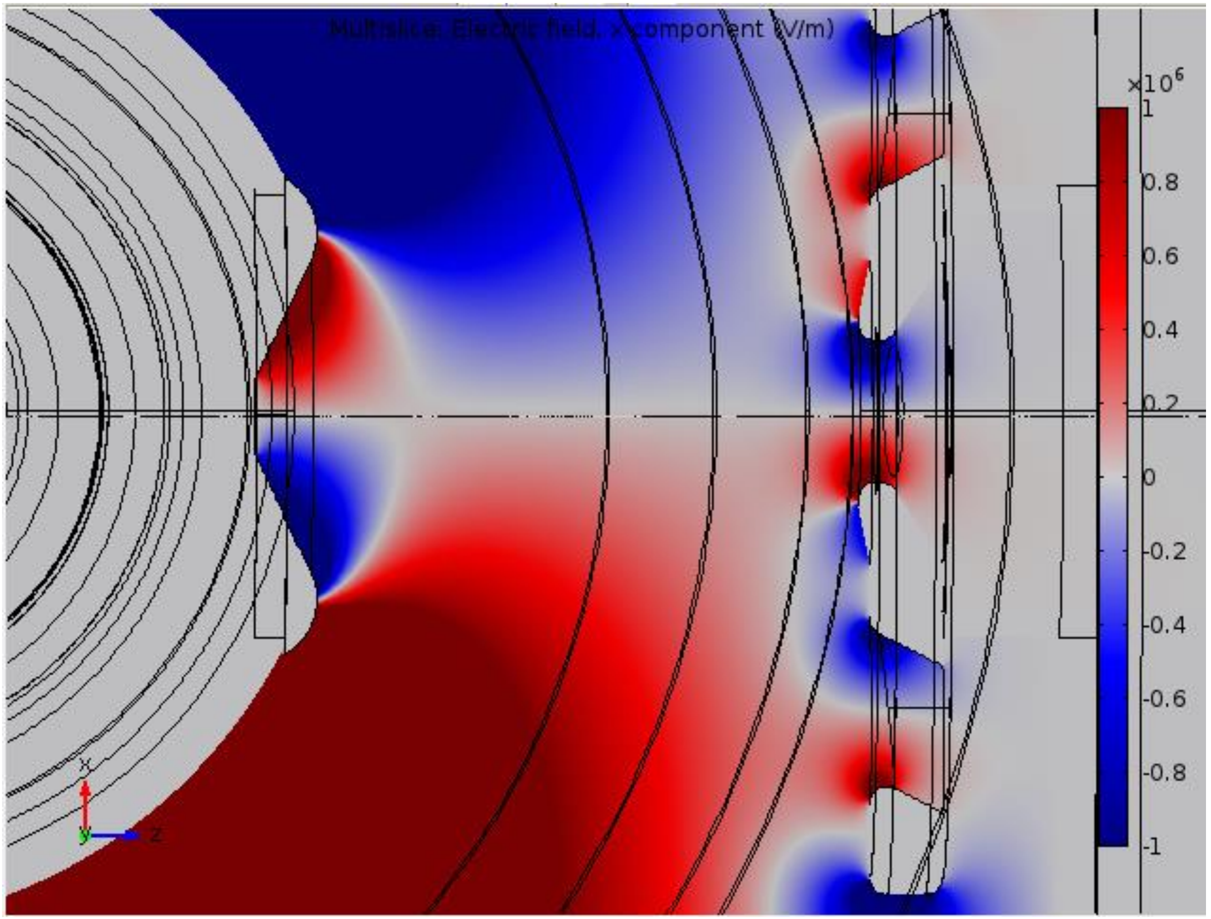
Fin.

Additional slides



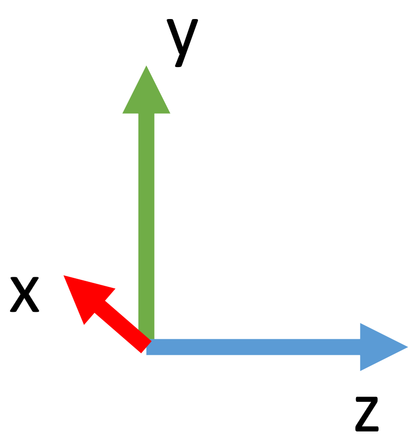
Top view Ex field

Additional slides

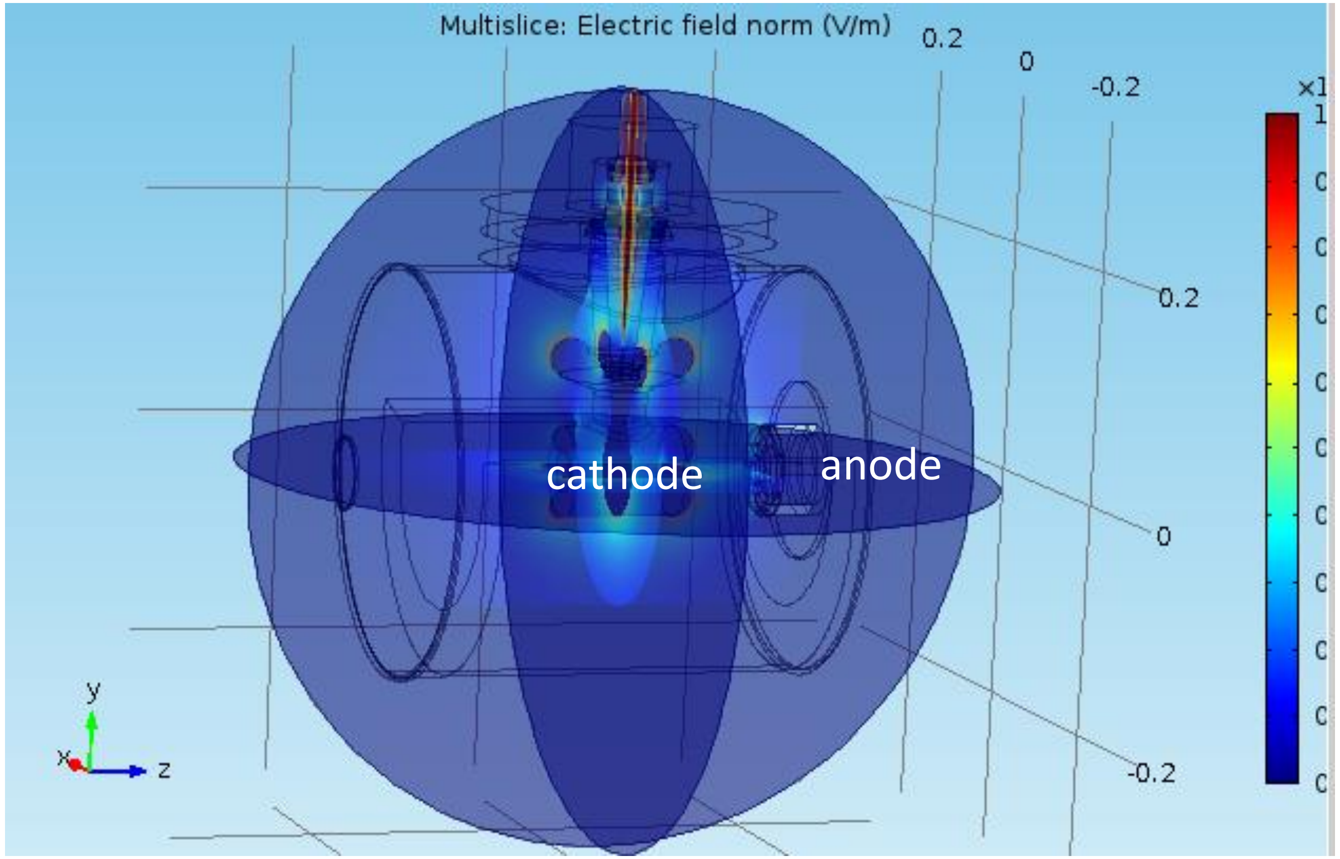


Top view Ex field

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)