

18" CEBAF gun "a la GTS"

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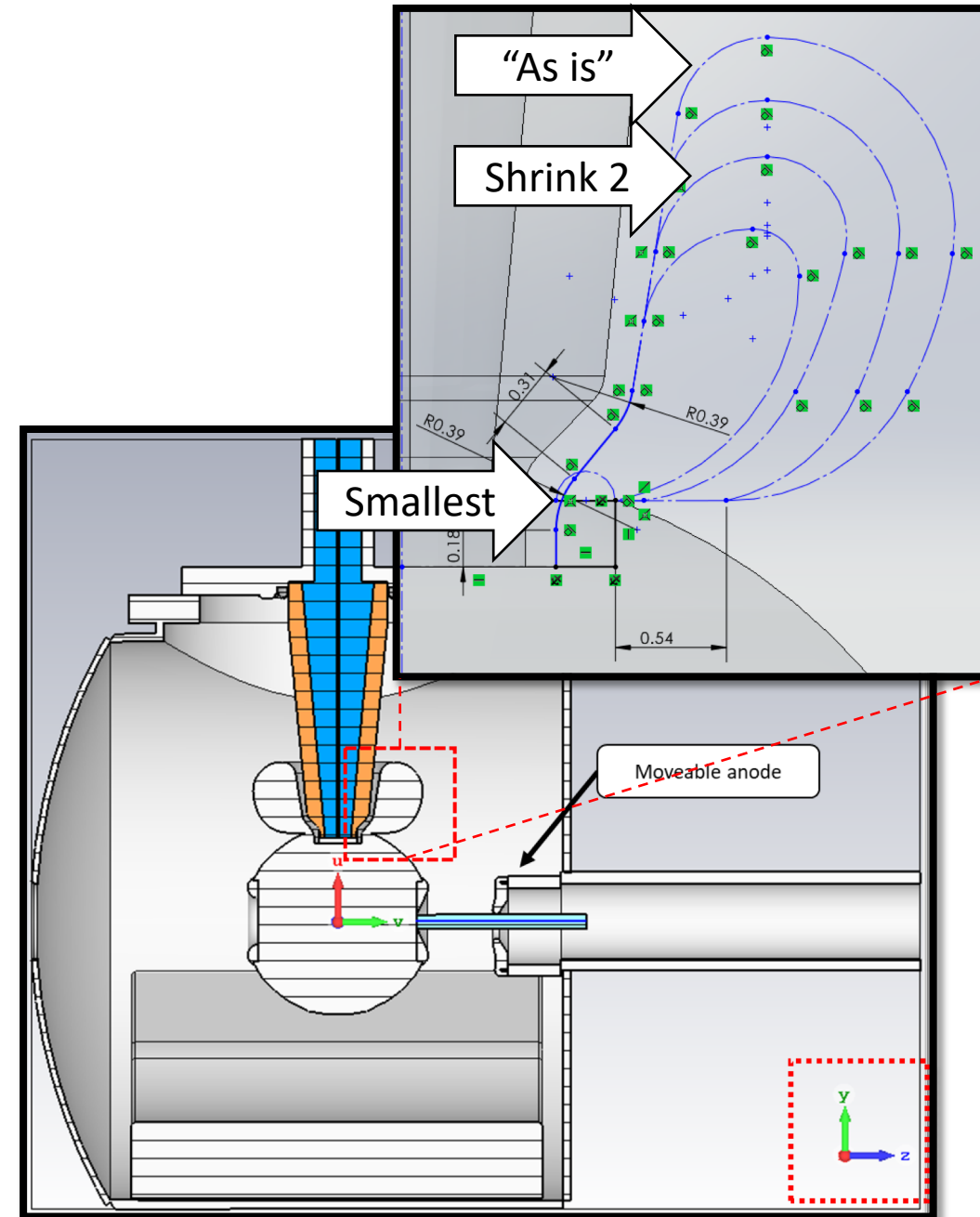
09/21/2021

Overview

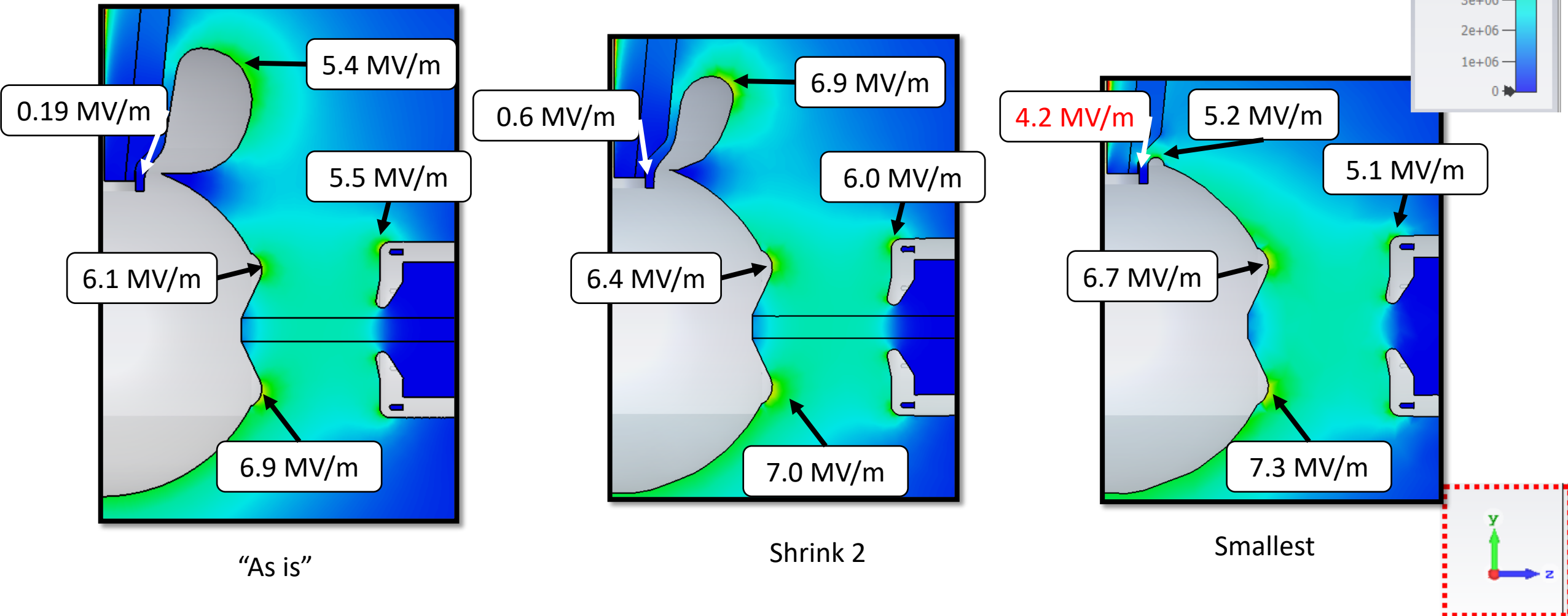
- Can we use a smaller shield?
 - For “As is”, Shrink 2, and Smallest Shield:
 - Electrostatics at operational (-200kV) and processing (-320 kV) voltages
 - Beam dynamics at -200 kV
- How does the 18” CEBAF gun a la GTS perform “As is”?
 - Response to anode **shifts and tilts**
 - Electrostatics at operational (-200kV) and processing (-320 kV) voltages
 - Beam dynamics at -200 kV
 - Dynamics response to anode shifts and tilts

Comparing shields:

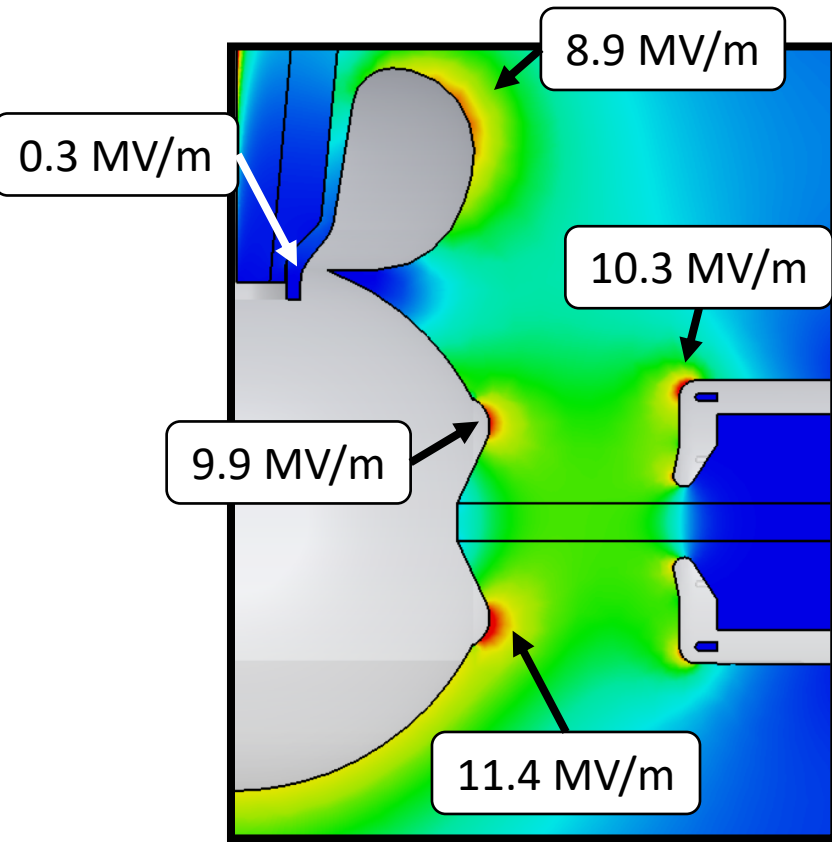
“As is”, Shrink 2, and Smallest Shield



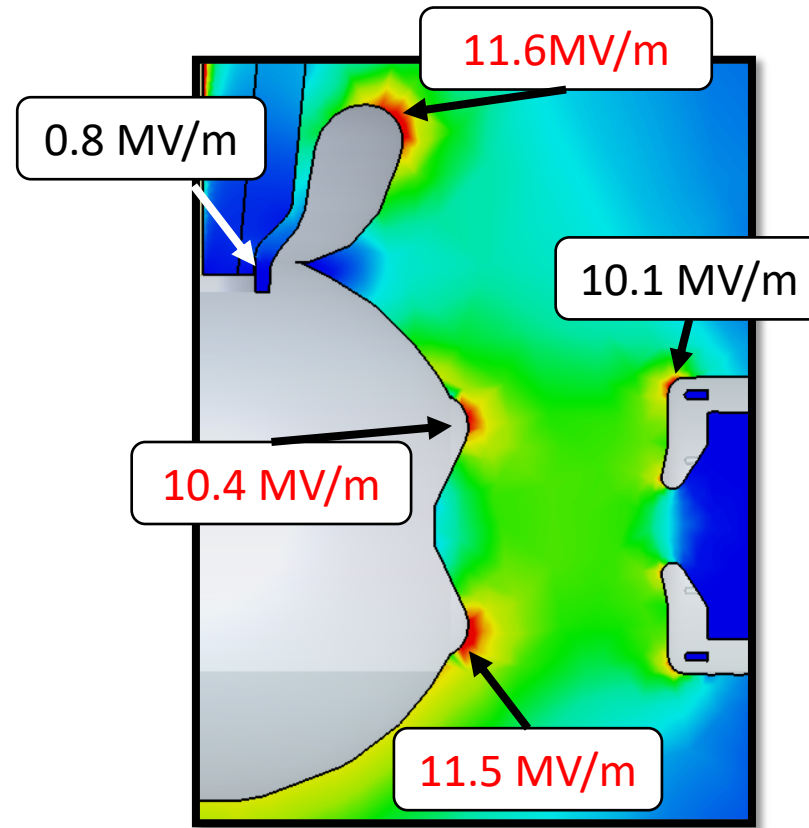
For operation at -200 kV



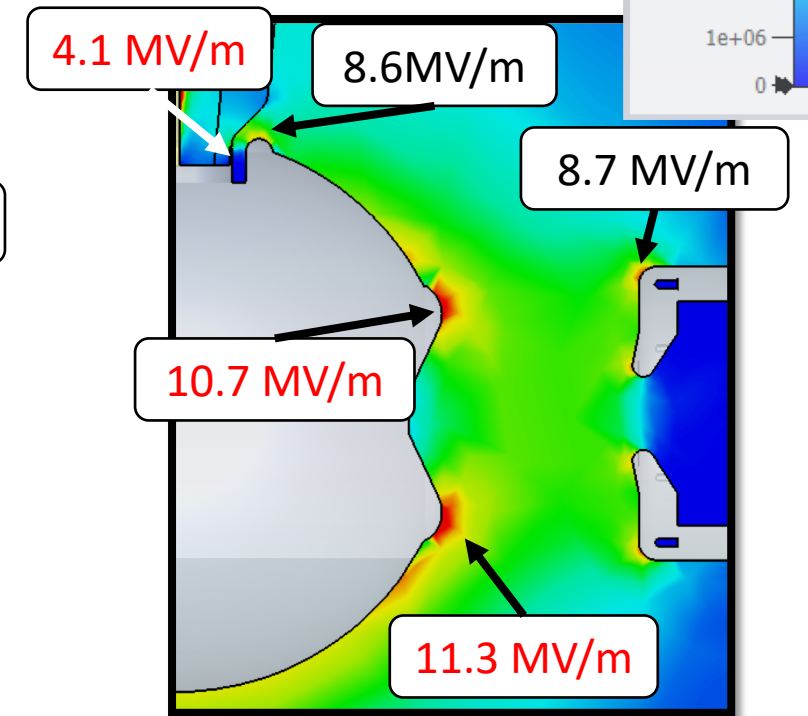
For HV processing at -320 kV



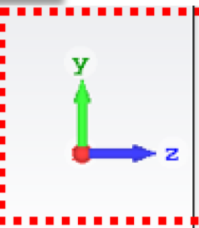
"As is"

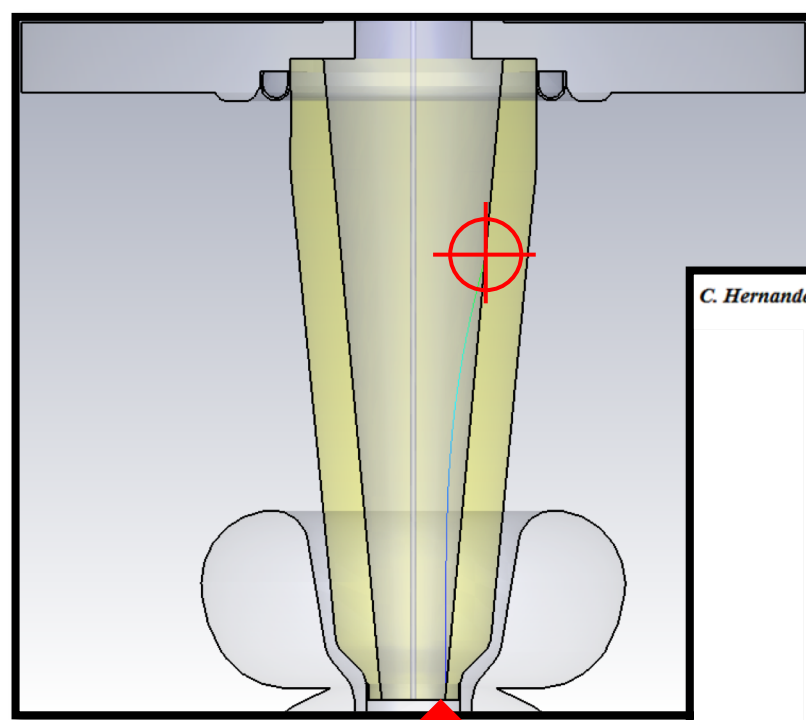


Shrink 2

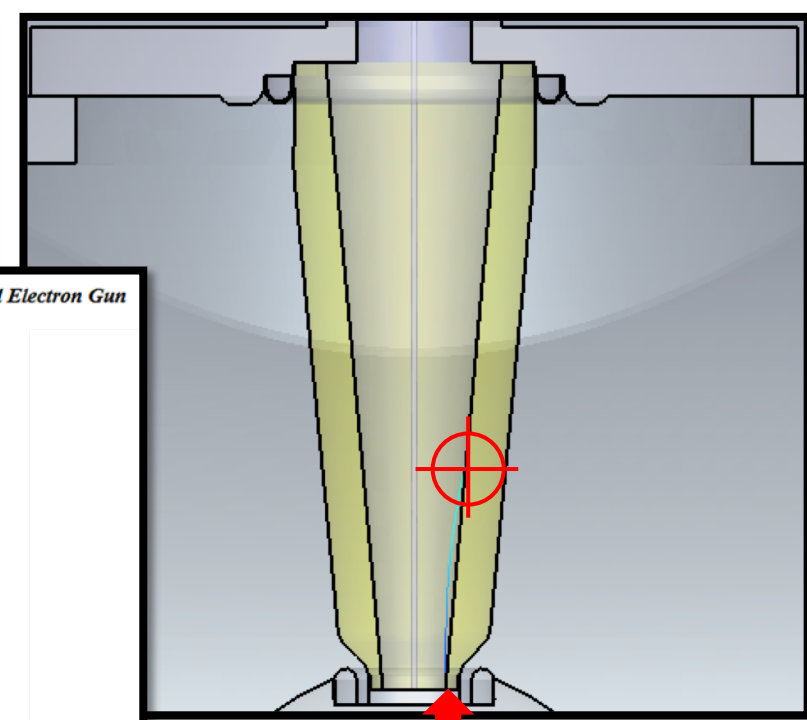
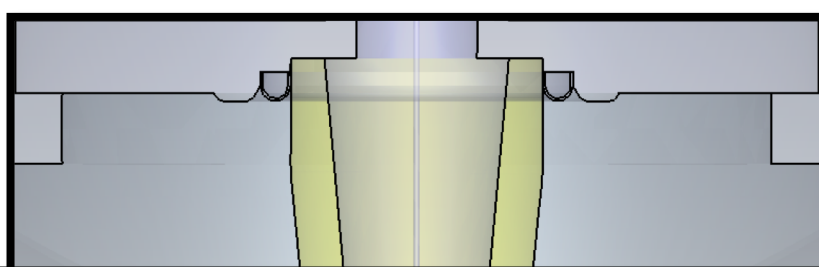


Smallest

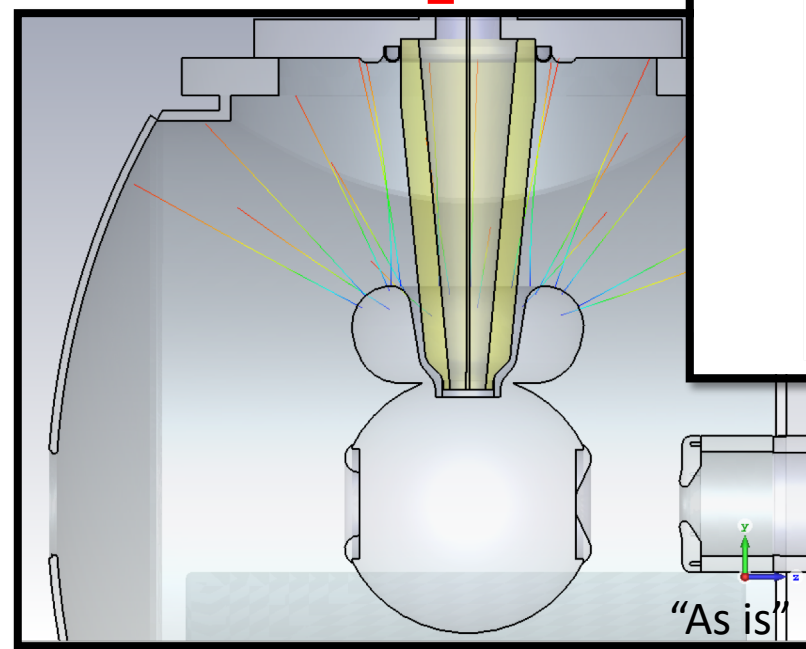
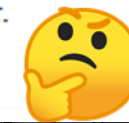
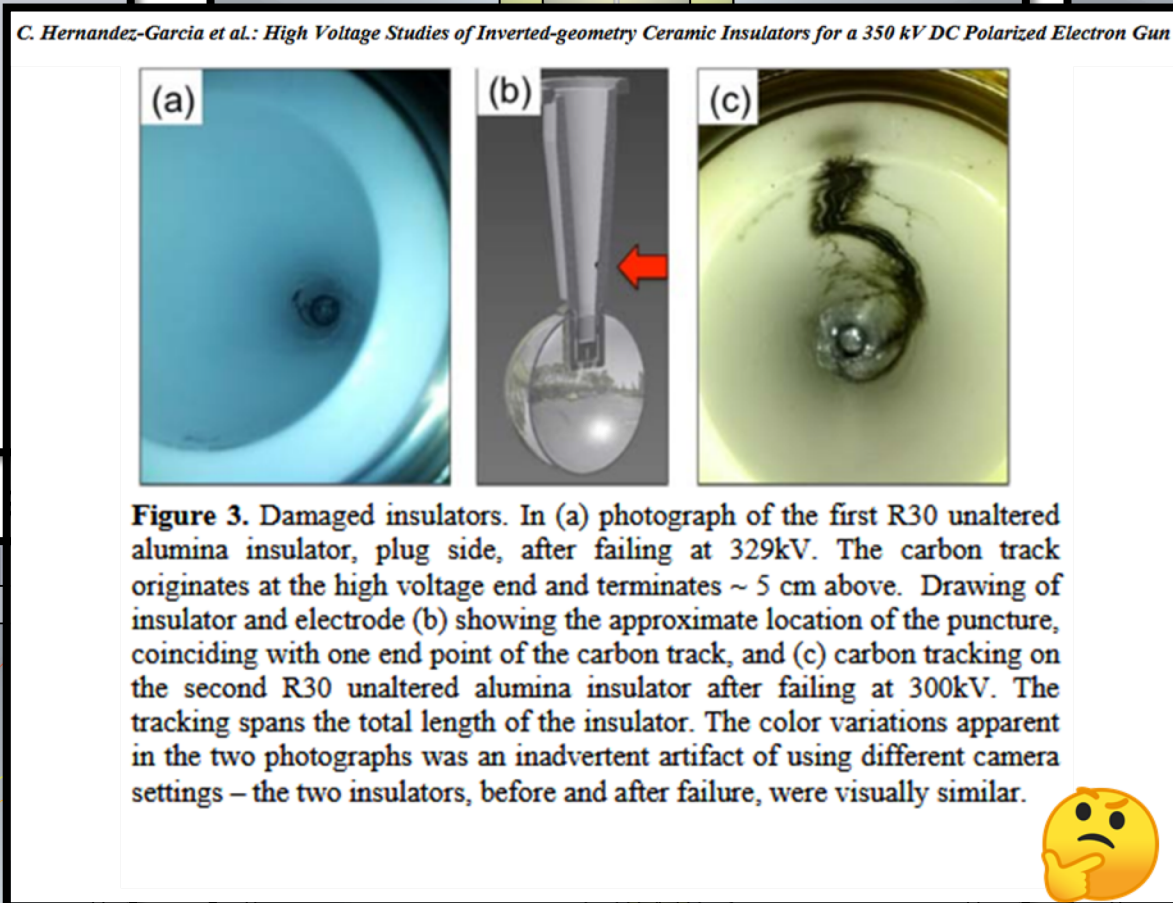




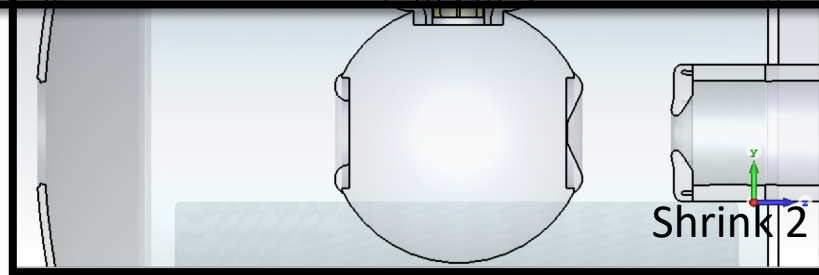
Potential



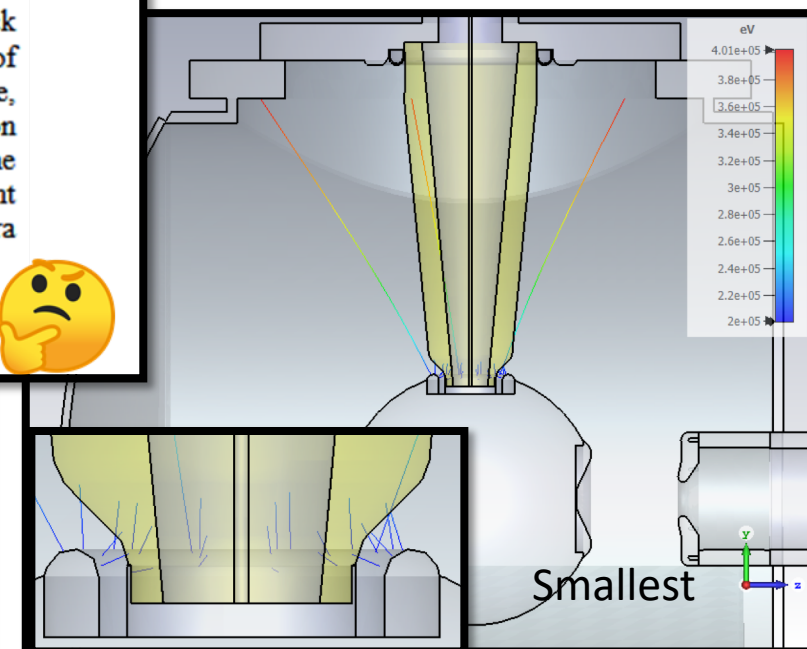
with solids



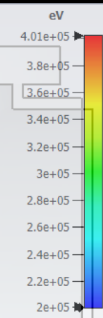
“As is”



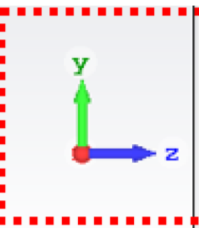
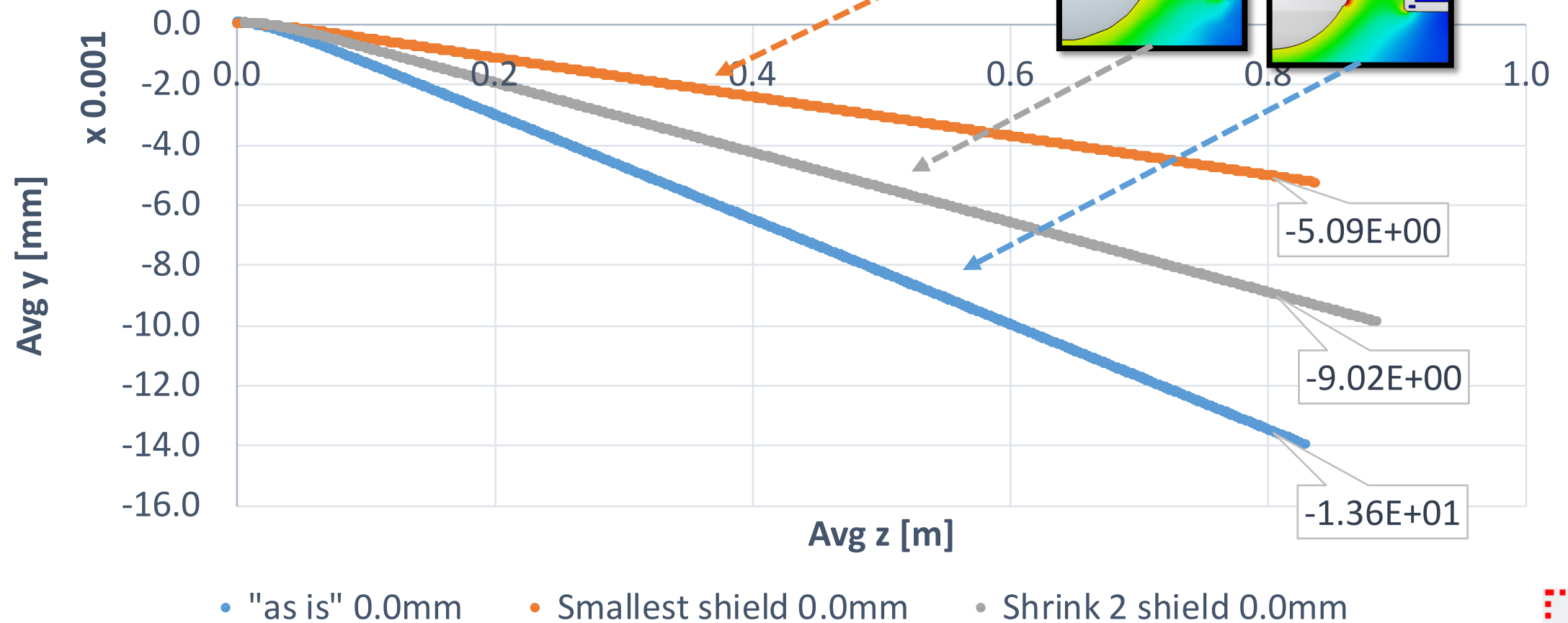
Shrink 2



Smallest



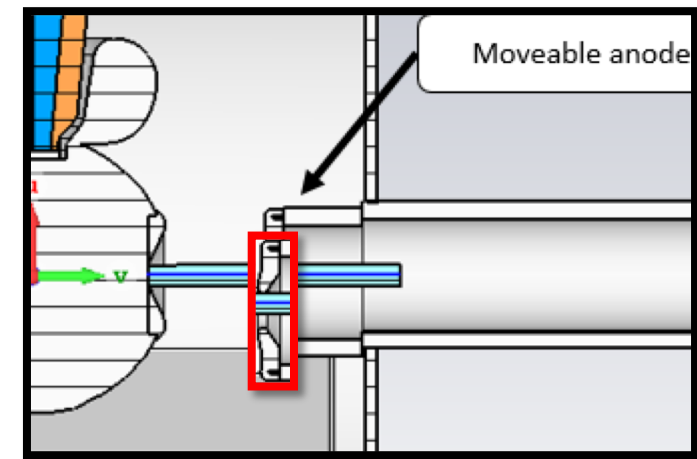
Dynamics at -200 kV



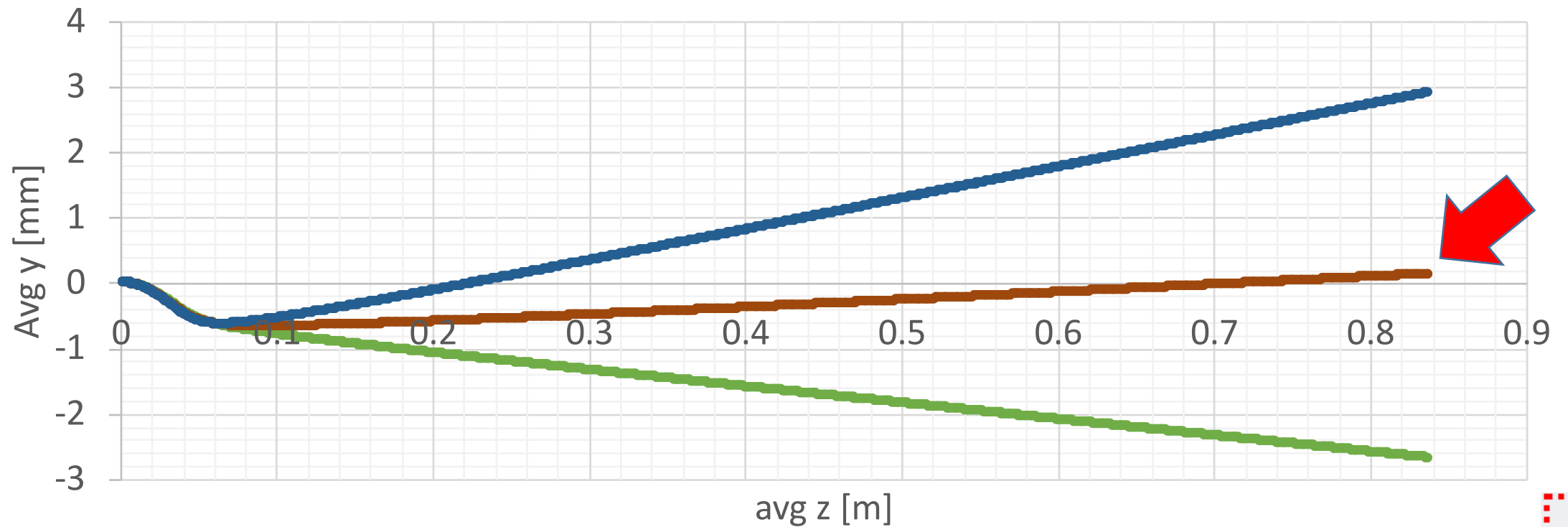
“As is” gun at -200 kV

Beam dynamics behavior subjected to anode **shifts and tilts**

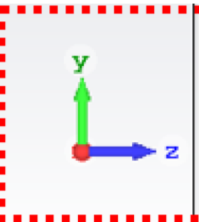
Anode shifts: Average position



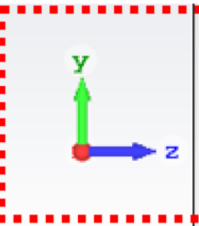
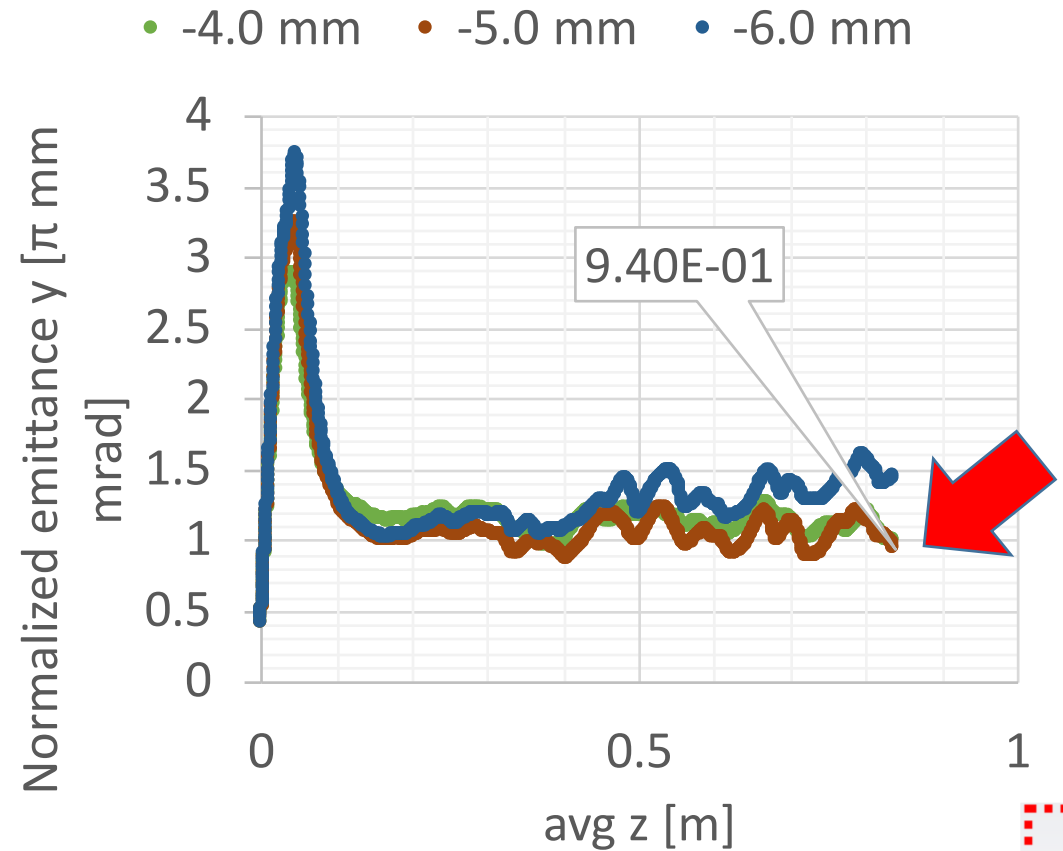
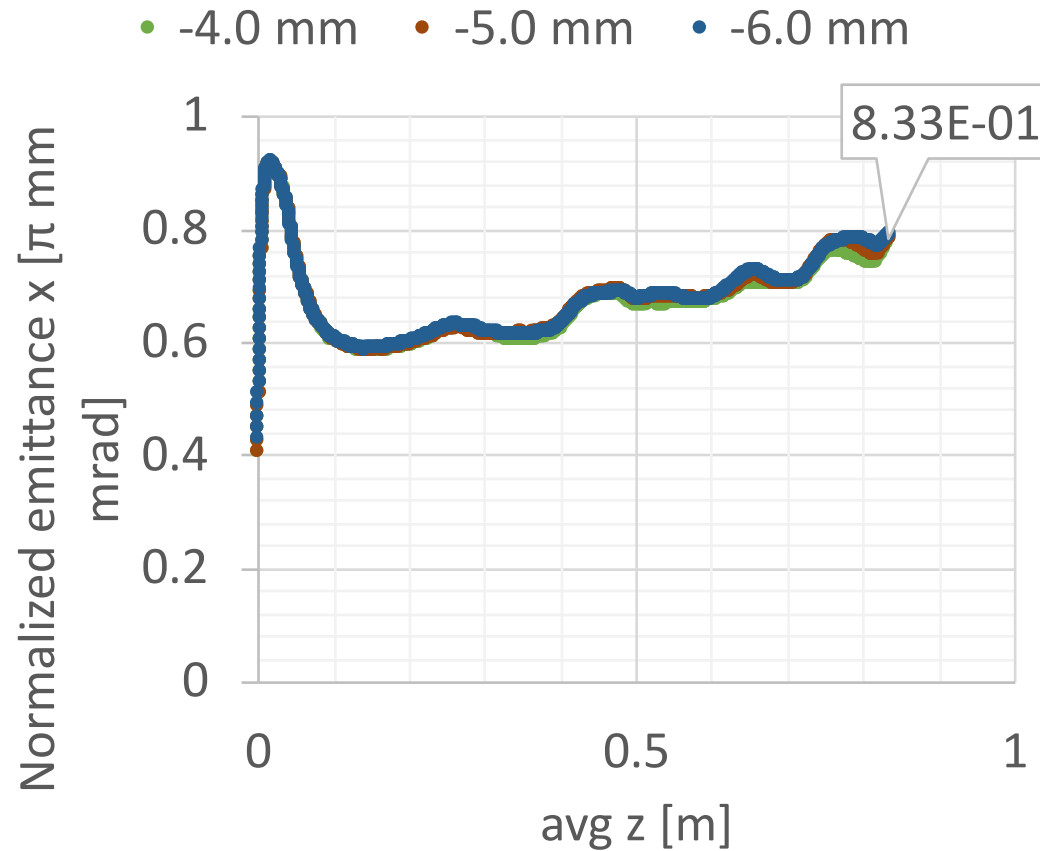
• -4.0mm • -5.0mm • -6.0mm



At -200 kV

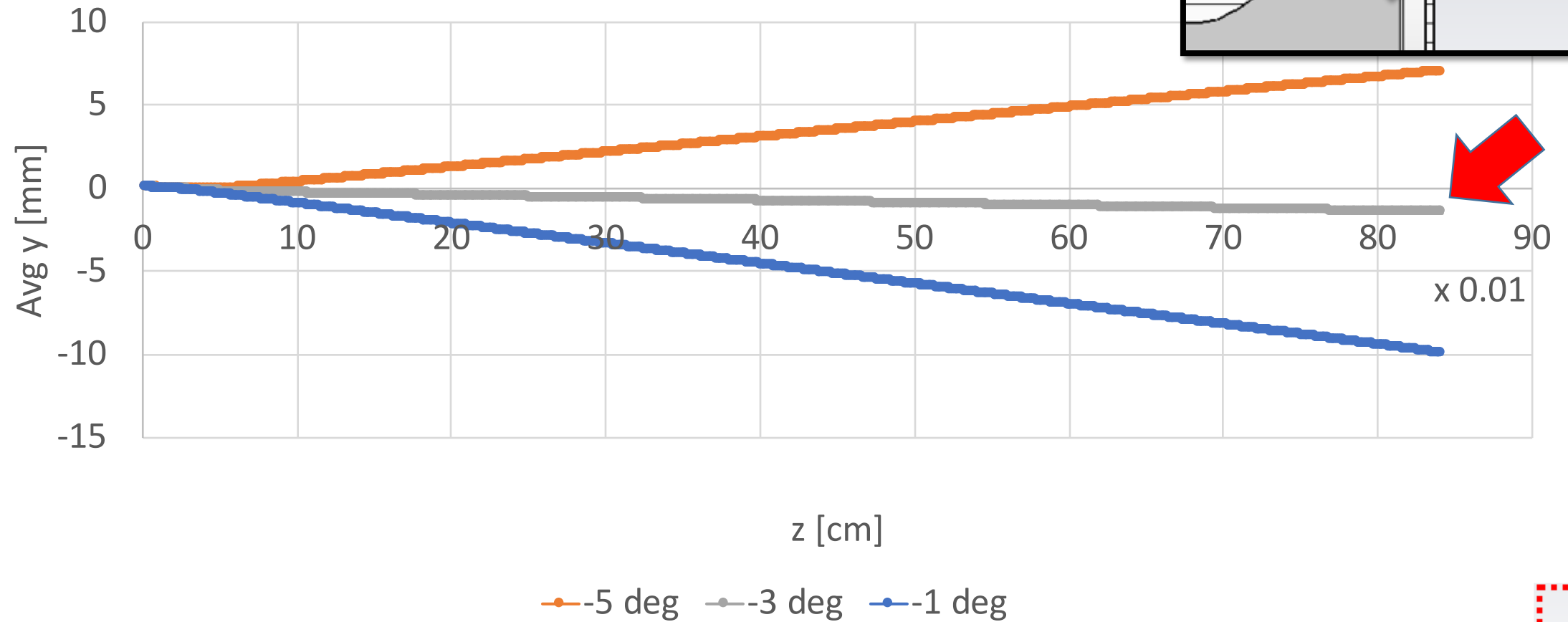
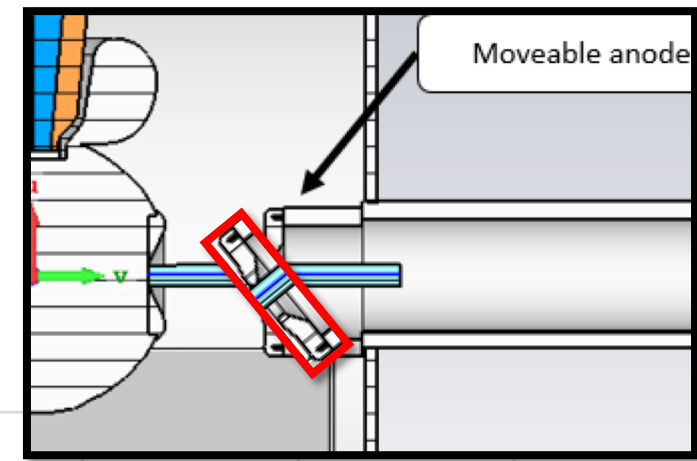


Anode shifts: Emittance

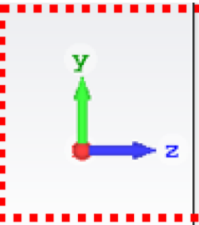


At -200 kV

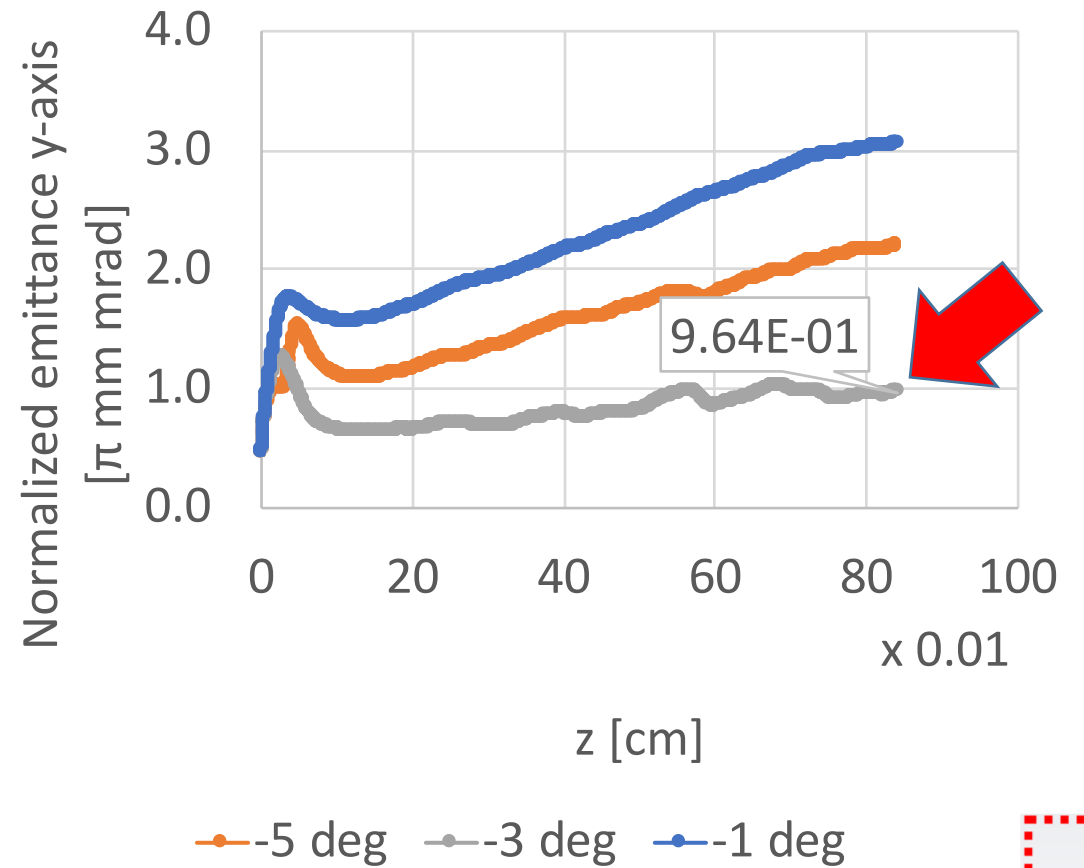
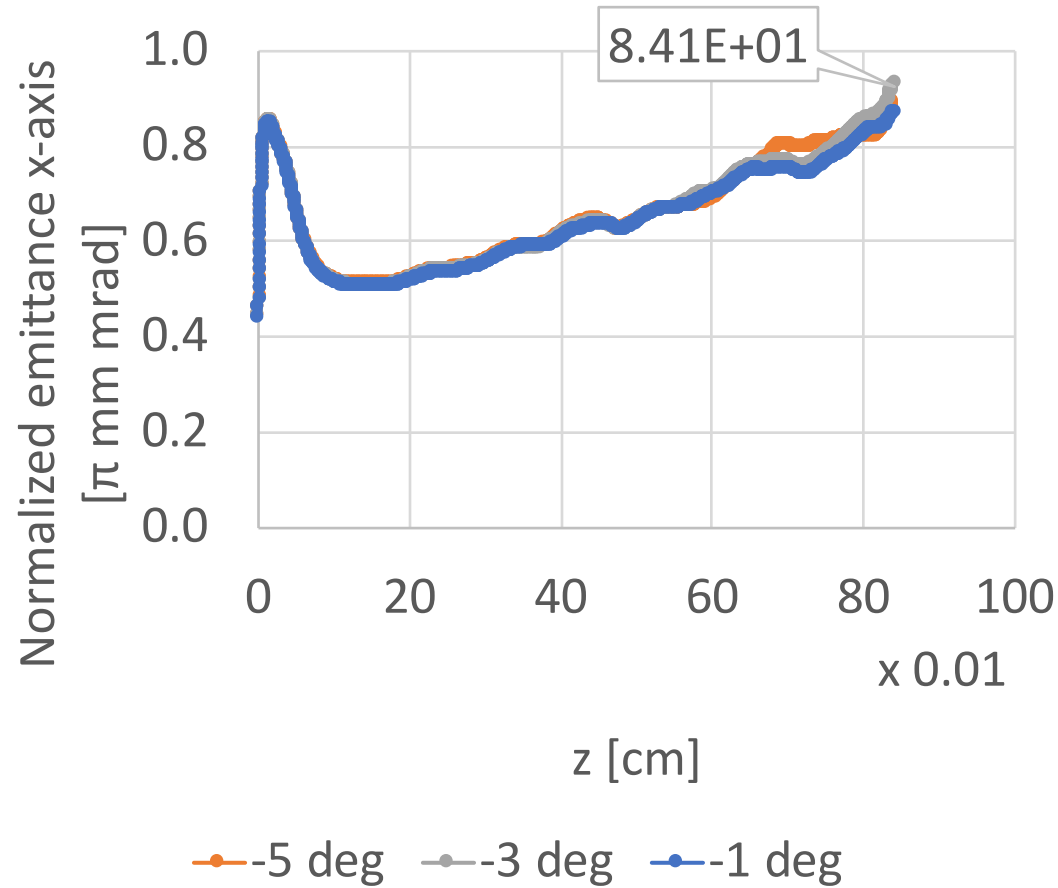
Anode tilts: Average position



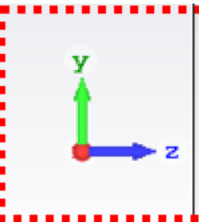
At -200 kV



Anode tilts: Emittance



At -200 kV



FIN

Extras

HV Design of Vacuum Components

J. M. Wetzer and P. A. A. F. Wouters

High Voltage and EMC Group,
Department of Electrical Engineering,
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Wetzer et al.: HV Design of Vacuum Components

symbols +, +/-, - or ---. From Table 2 the following conclusions are drawn:

1. if the cathode triple junction field is low, and electrons do not interact with the insulator surface (group I), the insulator performance is excellent;
2. if electrons do interact with the insulator surface, but are trapped by the insulator geometry (group II), the insulator performs reasonably well, but is in all respects inferior to those of group I;
3. if electrons do interact with the insulator surface, and are not trapped by the insulator geometry (group III and IV), the insulator performance is bad in particular with respect to unconditioned breakdown voltage and conditioning speed.

From these observations and from our discussion on conditioning we can derive the following design rules:

Design Rule 1

Minimize the cathode triple junction field.

Design Rule 2

Keep electrons away from the insulator surface.

Design Rule 3

If electrons hit the insulator surface, make sure they are trapped.

Design Rule 4

Tailor the design of an insulator to the way it is conditioned or operated.

For most cylindrical insulators (Figure 7 B) the distance between electrodes is large, and the cathode field is not effectively reduced by enhancing the anode field. Because of the distance, however, the situation is not critical, and it is sufficient to shield triple junctions.

Example C in Figure 7, shows a recommended design for insulating concentric conductors. The arguments for the optimization are similar to those for the insulator between parallel electrodes (example A). The rod type spacers often used for easy alignment can only be applied safely at low voltages: breakdown voltage and conditioning speed are low, and the conditioning stability is poor.

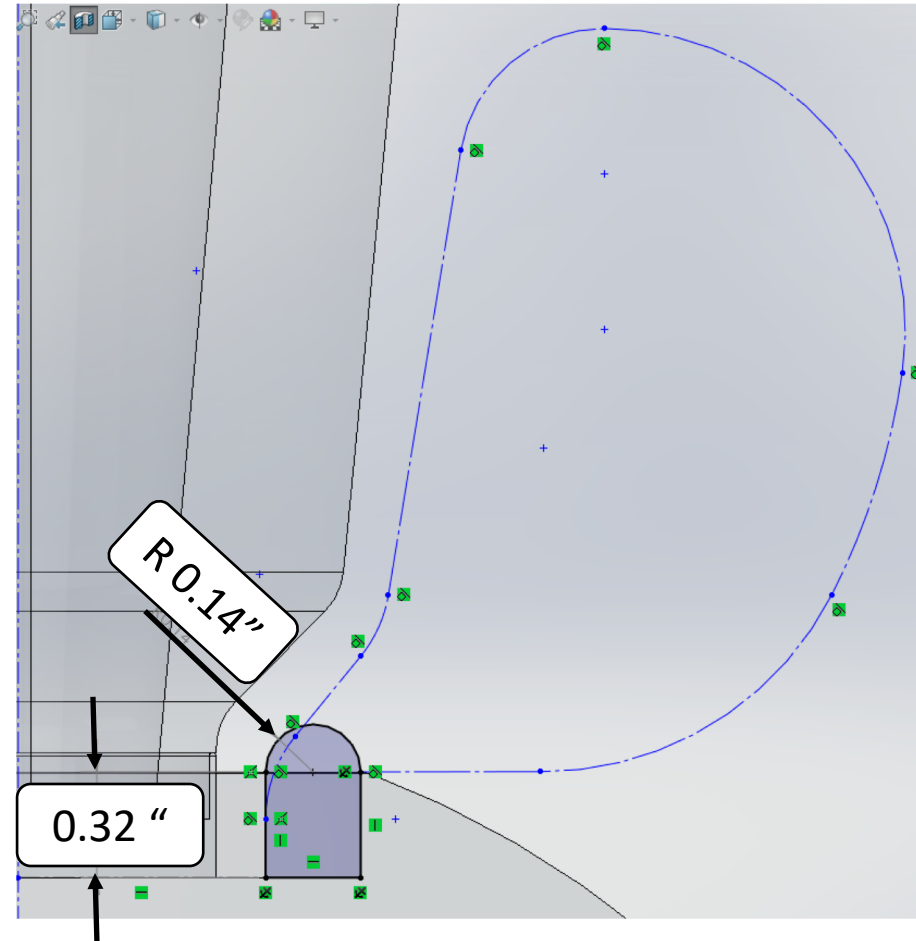
Two examples of optimized vacuum tube feedthroughs for space applications are shown in Figure 7 D. The feedthroughs have one side in the tube vacuum, and the other side in vacuum (satellite) or in air (terrestrial). Inside the tube the cathode field is kept low by choosing a large conductor radius and conductor/insulator separation (right), or by shaping the insulator and shielding the triple junction (left). The inside of the insulator tube may be metalized but for dc the same effect is achieved by charging processes. A cathode recess could be used as in (A). Inside the tube the anode field is not harmful. Outside, different pressures may occur, and the field is controlled at both cathode and anode side.

negative electrode, across the barrier of the work function [9]. This emission starts at microscopic protrusions or imperfections, either metallic, semiconducting or insulating [10–12]. Secondary emission is caused by energetic electrons impinging on the insulator surface. The field components perpendicular and parallel to the insulator surface both contribute to the collision energy. Secondary electrons are harmful if they hit the surface again with increased energy [14]. The creepage distance argument is not a valid design principle in vacuum.

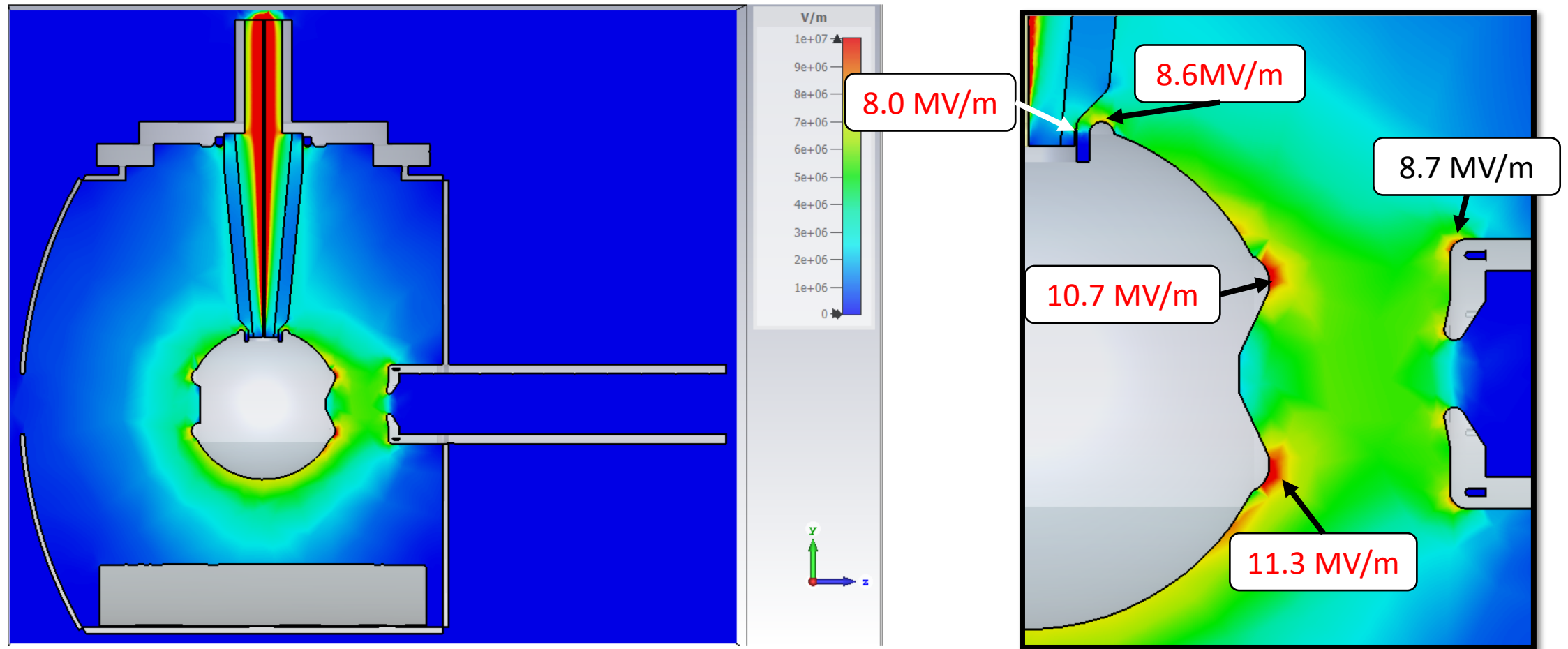
The differences between vacuum and air breakdown are summarized in Table 3. Figure 8 shows the breakdown voltage vs. electrode distance for vacuum [9], and

5.2. VACUUM AND AIR OPERATION

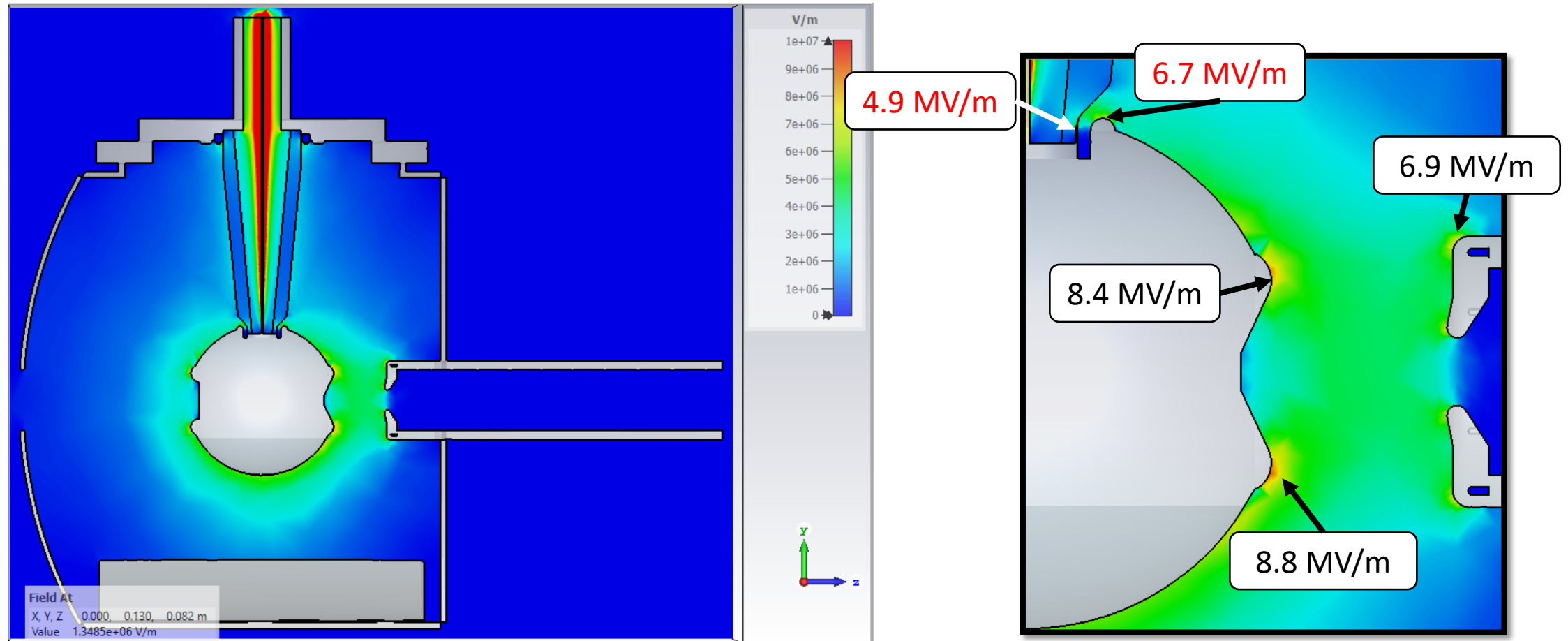
My smallest shield model



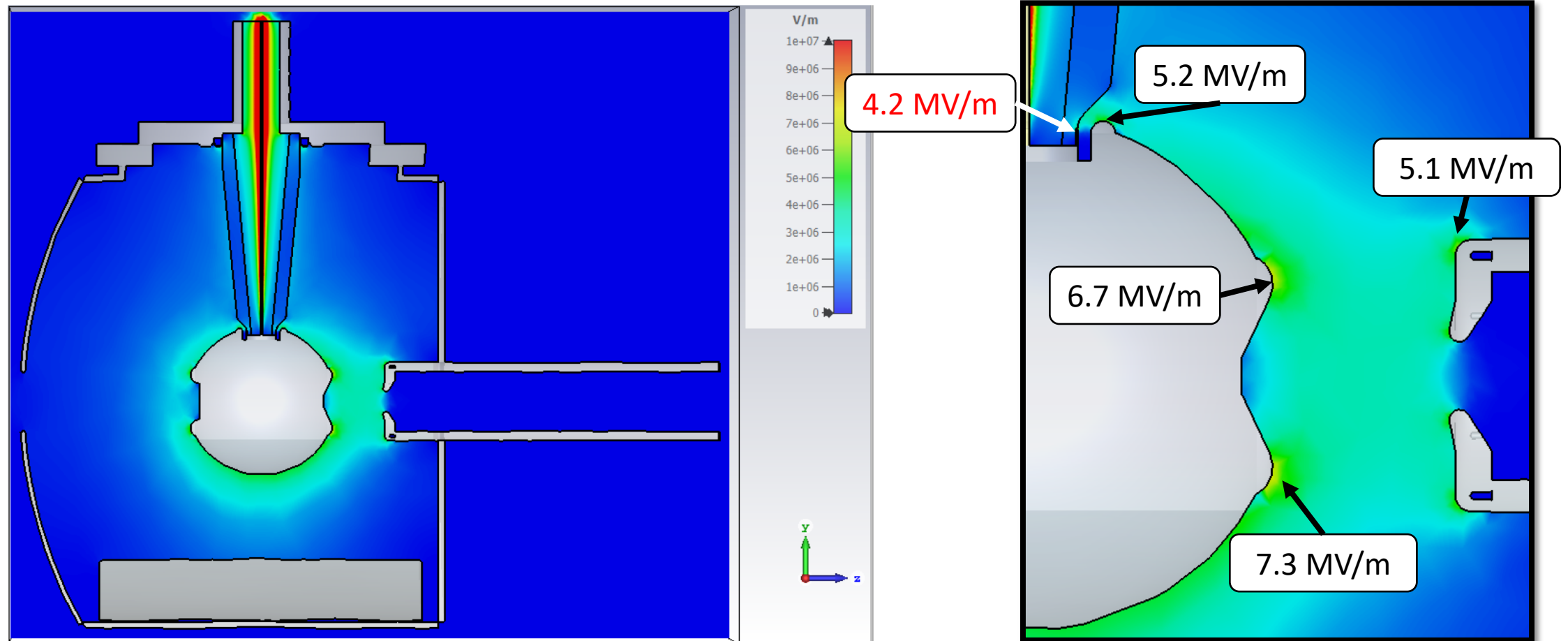
Electrostatics: operational voltage -320 kV



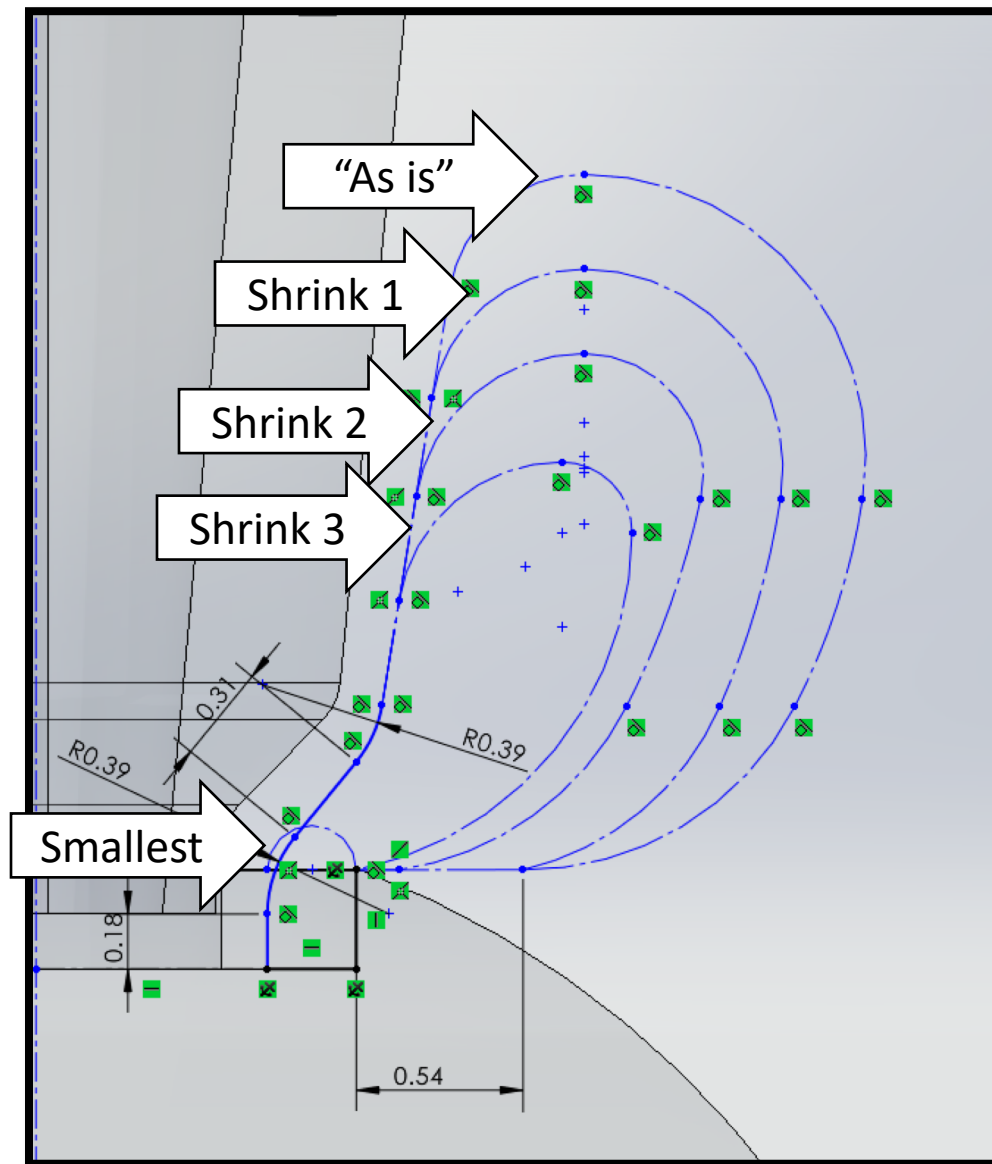
Electrostatics: operational voltage -250 kV



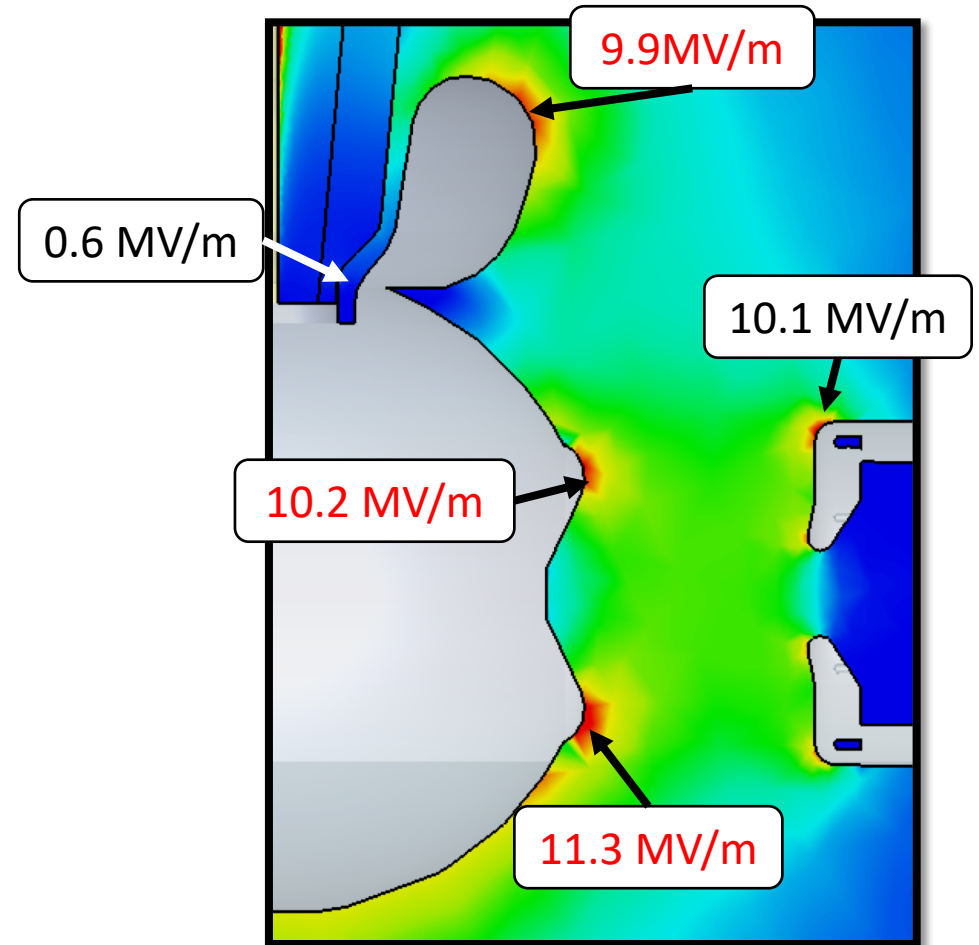
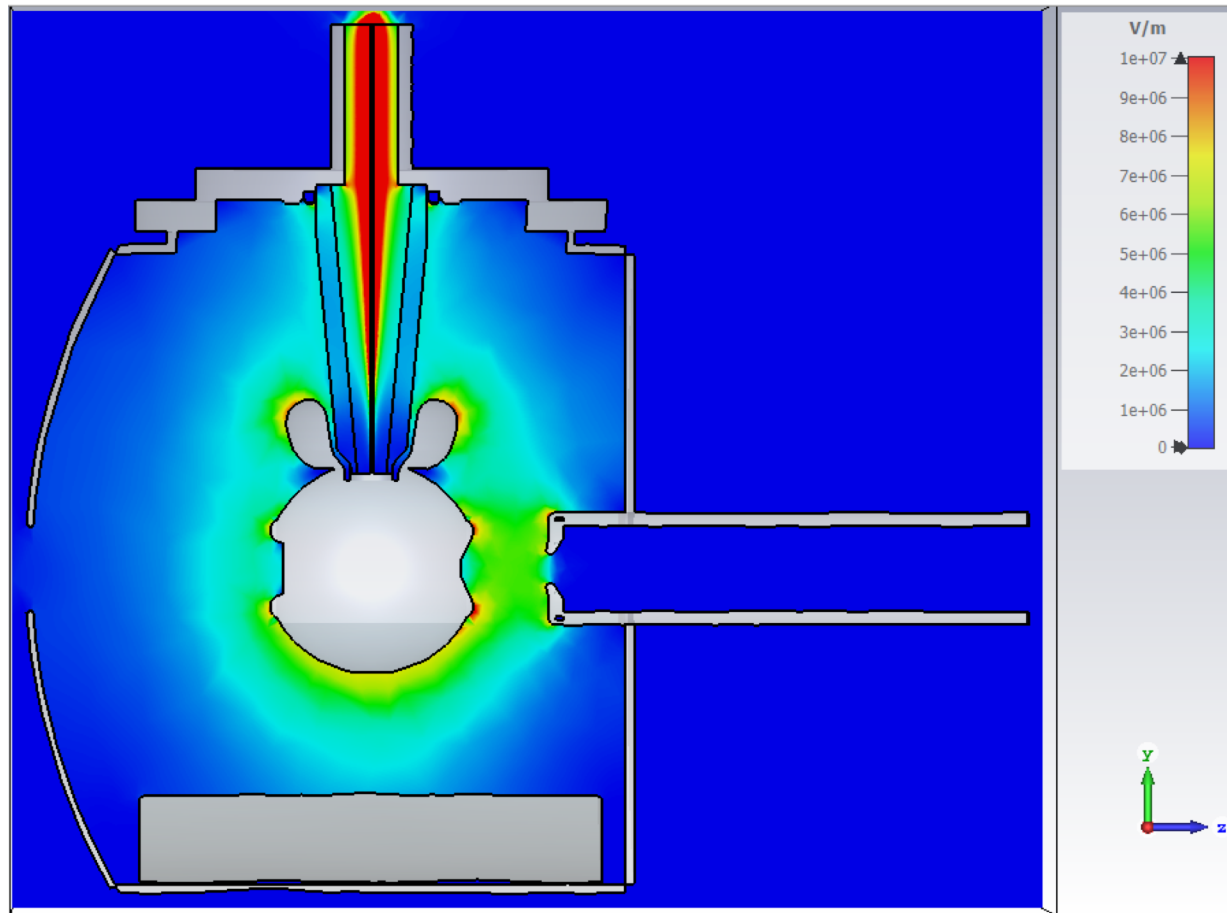
Electrostatics: operational voltage -200 kV



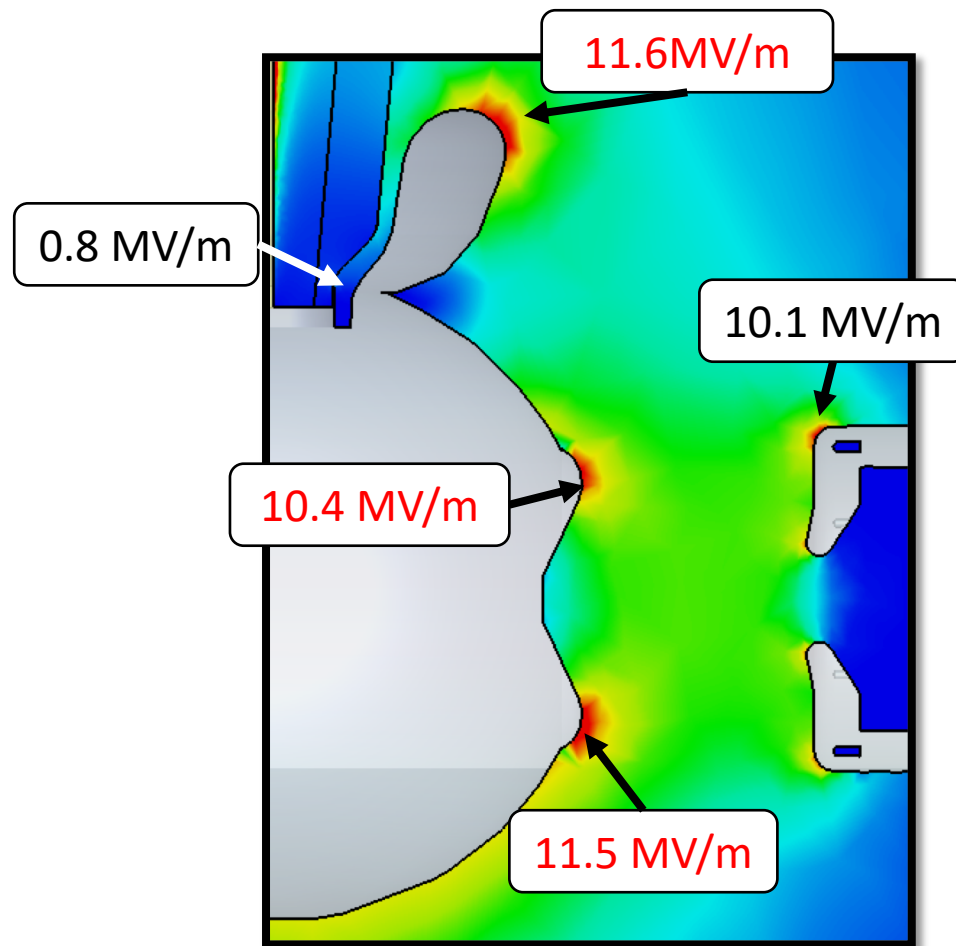
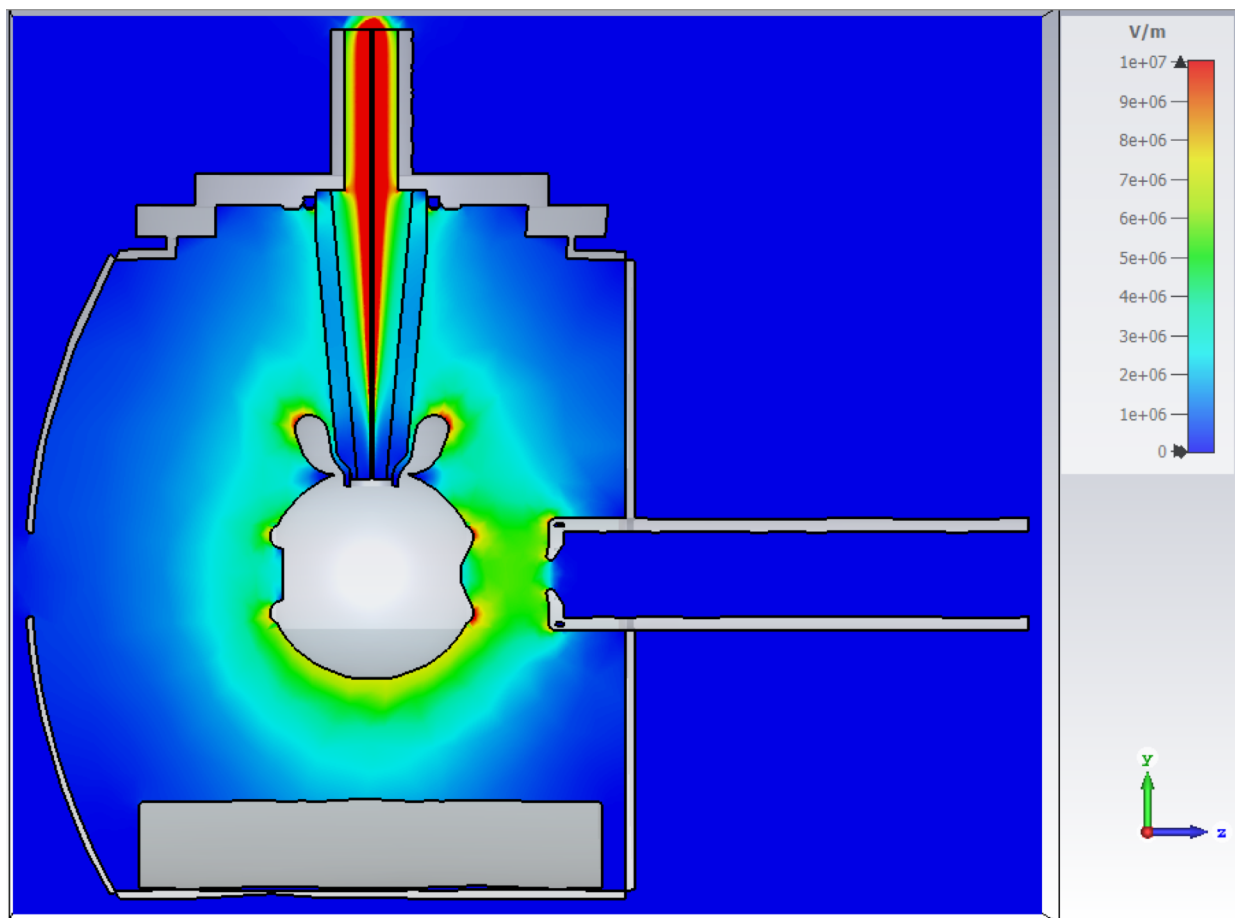
Shrinking the “As is” shield



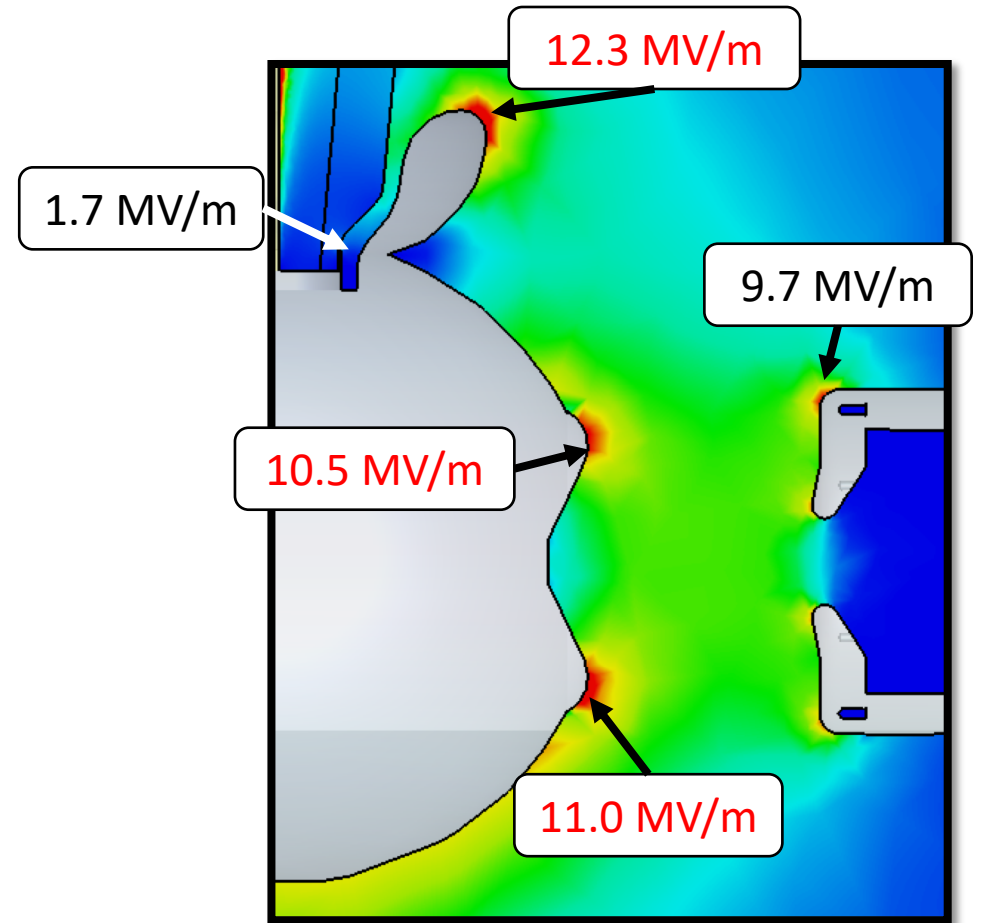
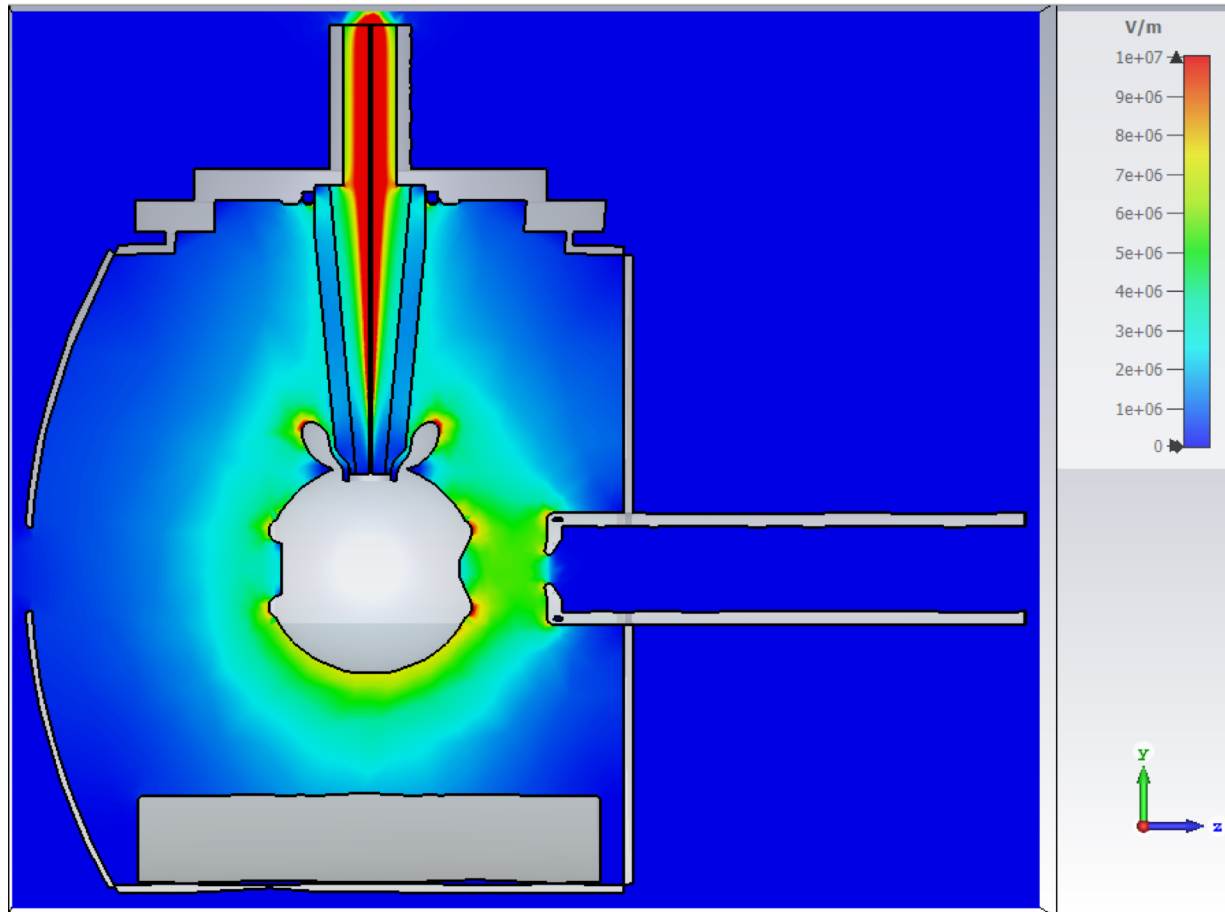
Shrink 1 at -320 kV



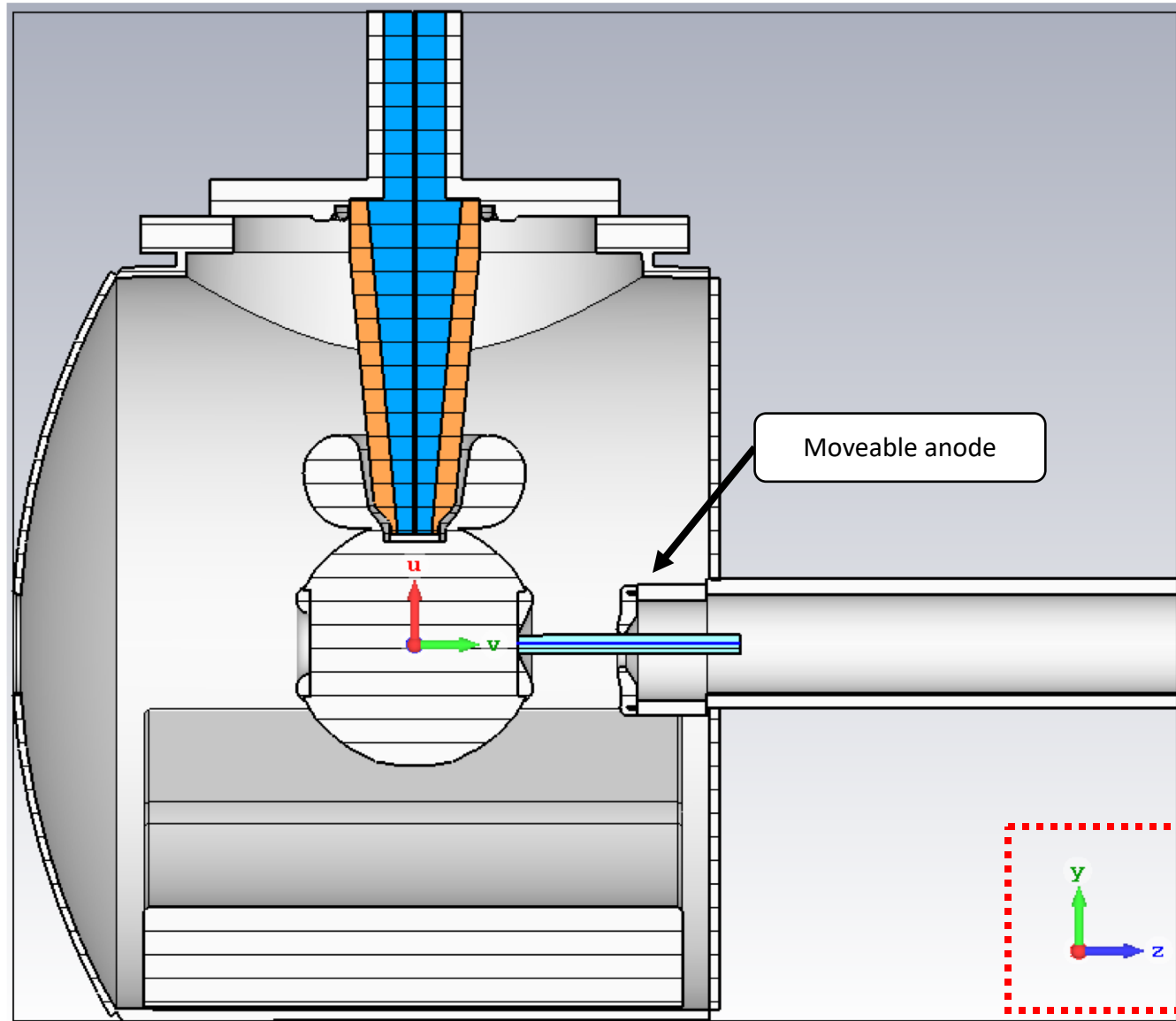
Shrink 2 at -320 kV



Shrink 3 at -320 kV

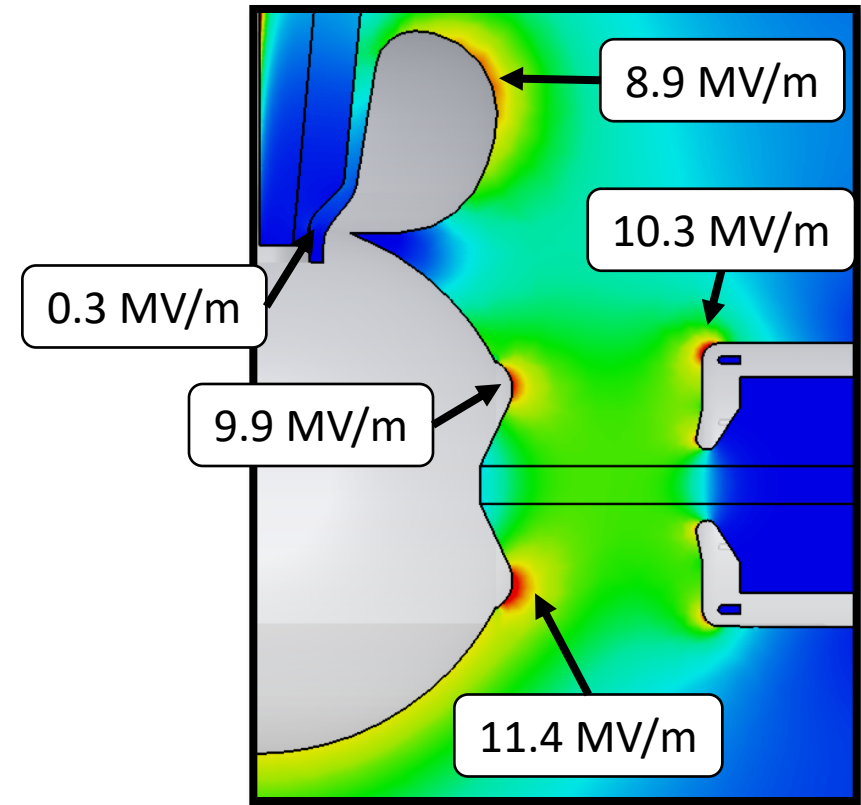
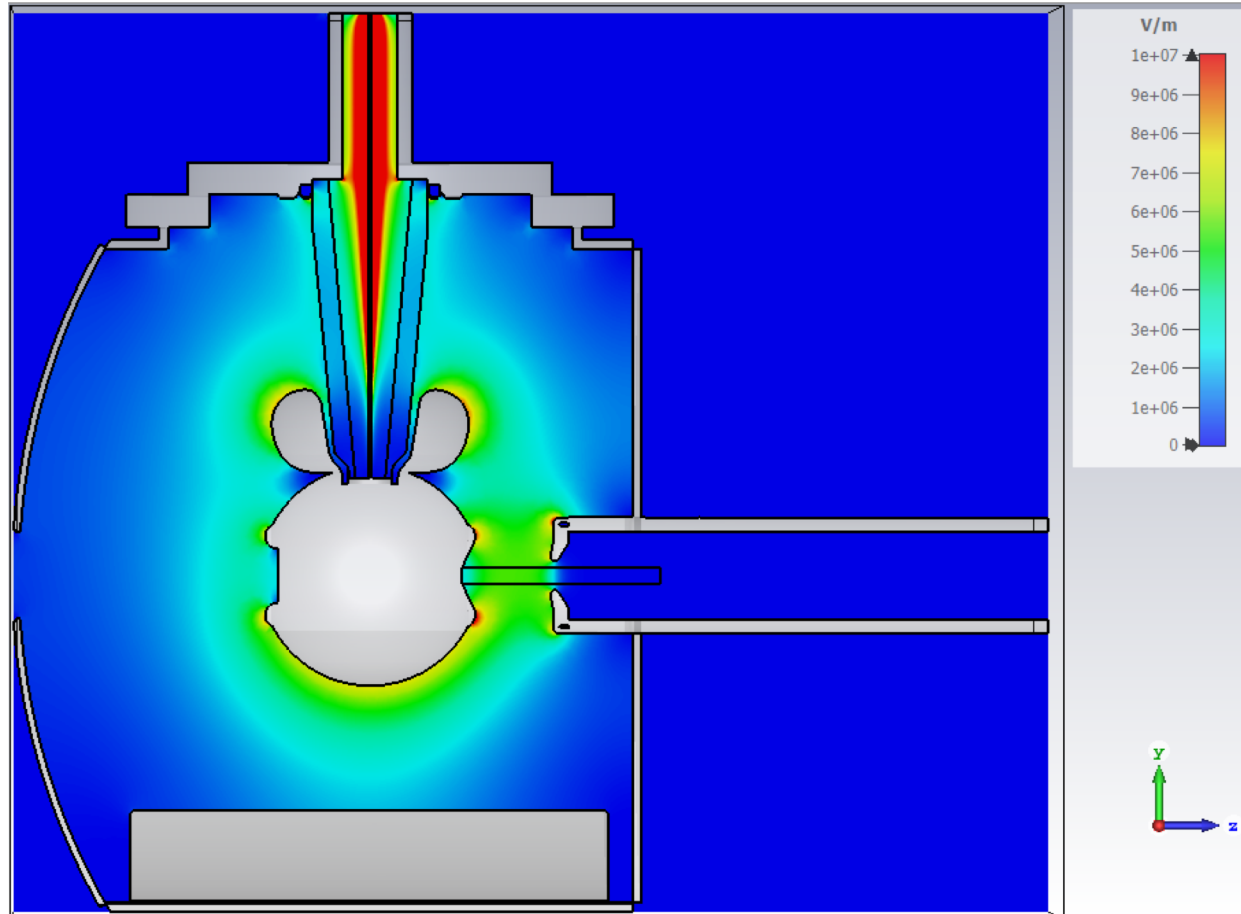


Model

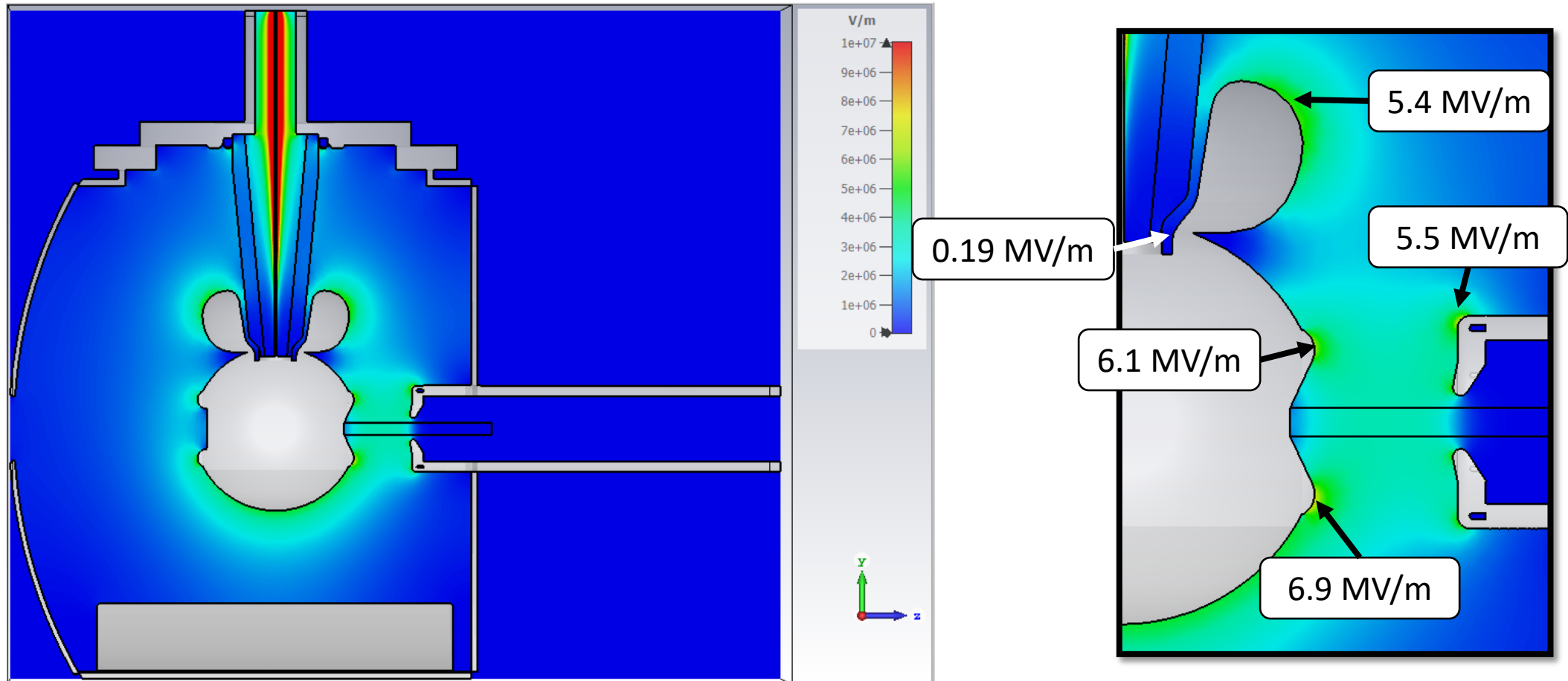


- This is the model with the so-called “CEBAF anode” and 6 cm cathode-anode gap.
- Material and settings are the same as before:
 - Closed boundaries everywhere except top and $z > 0$
 - Alumina for insulator and rubber for cable.

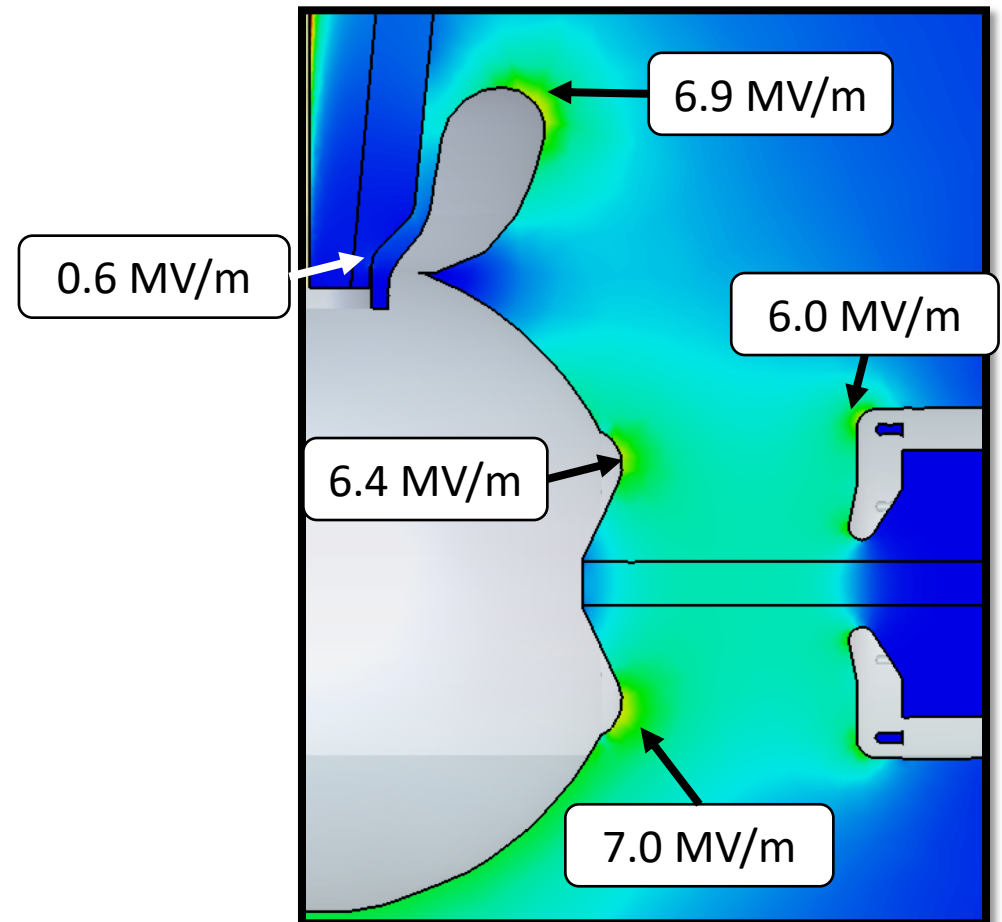
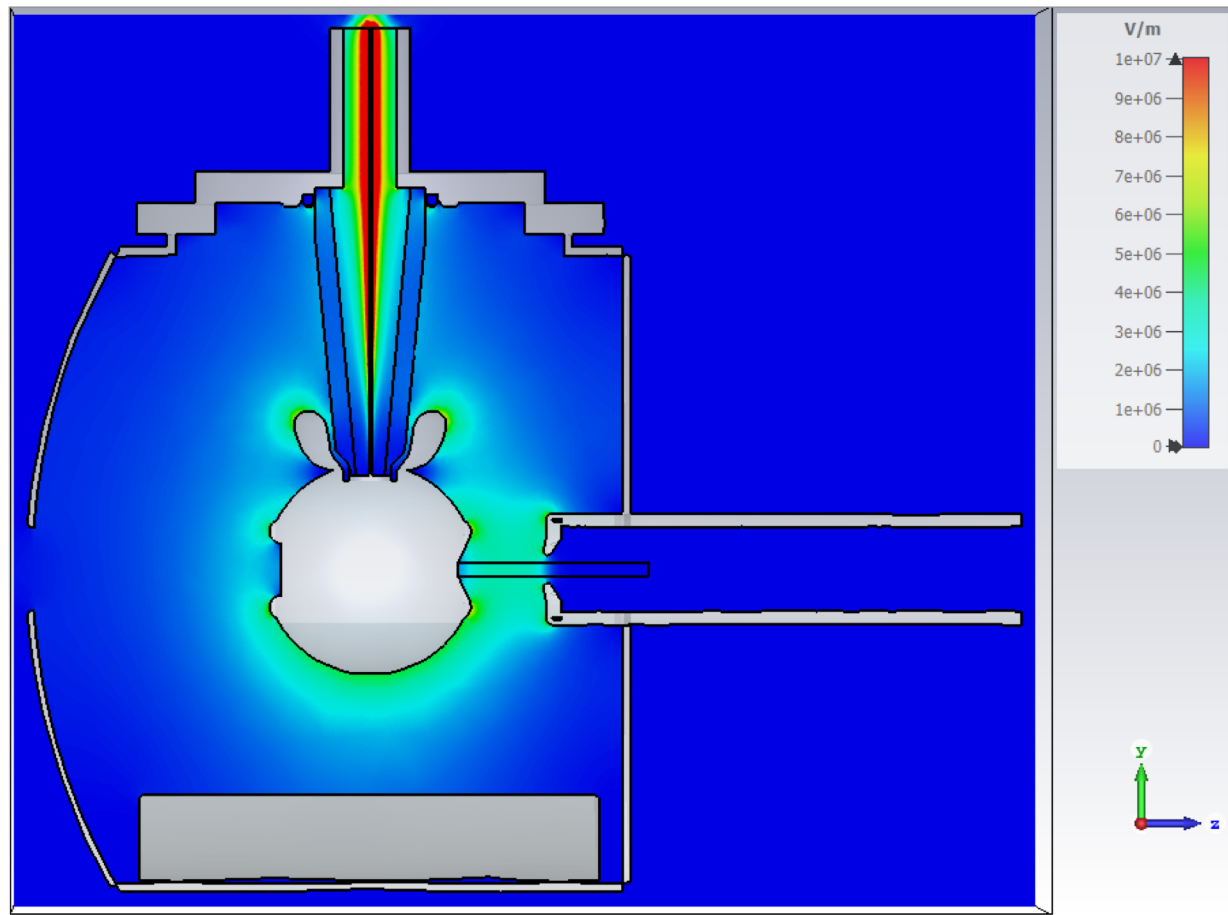
Electrostatics: processing voltage 320 kV



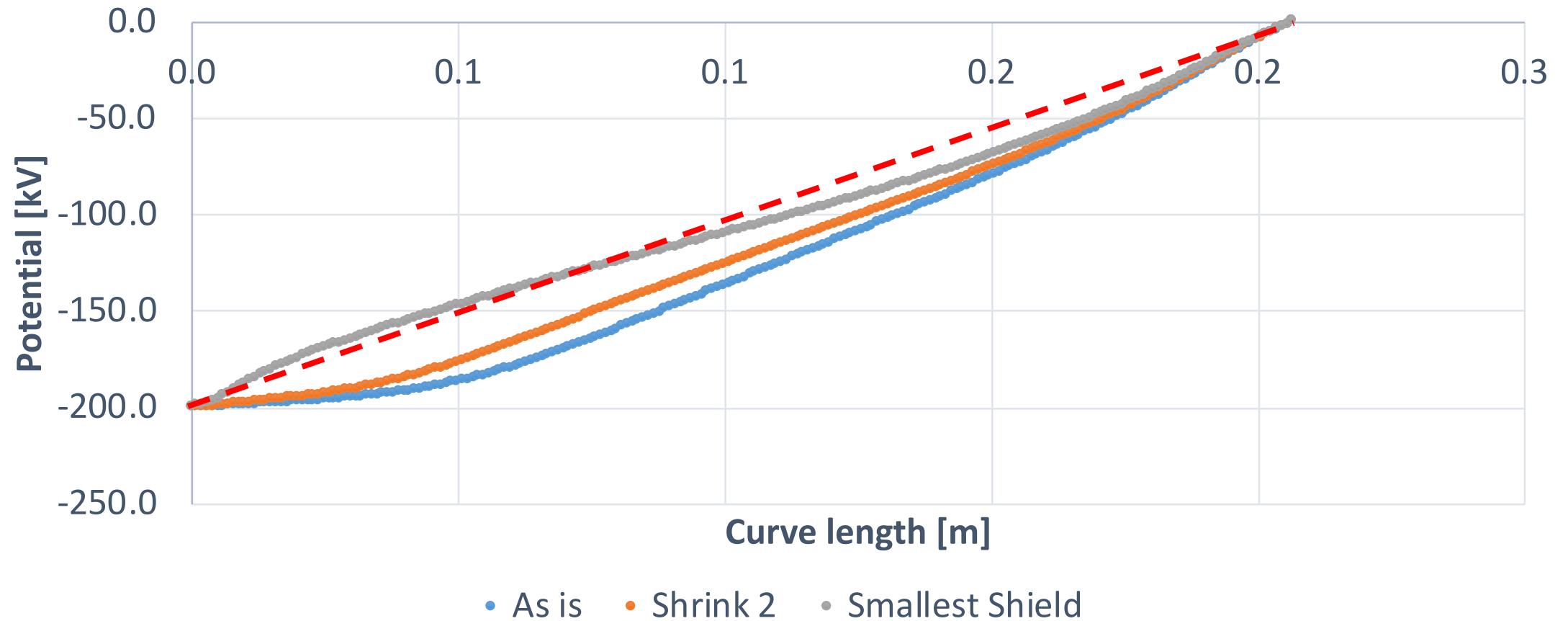
Electrostatics: operational voltage 200 kV



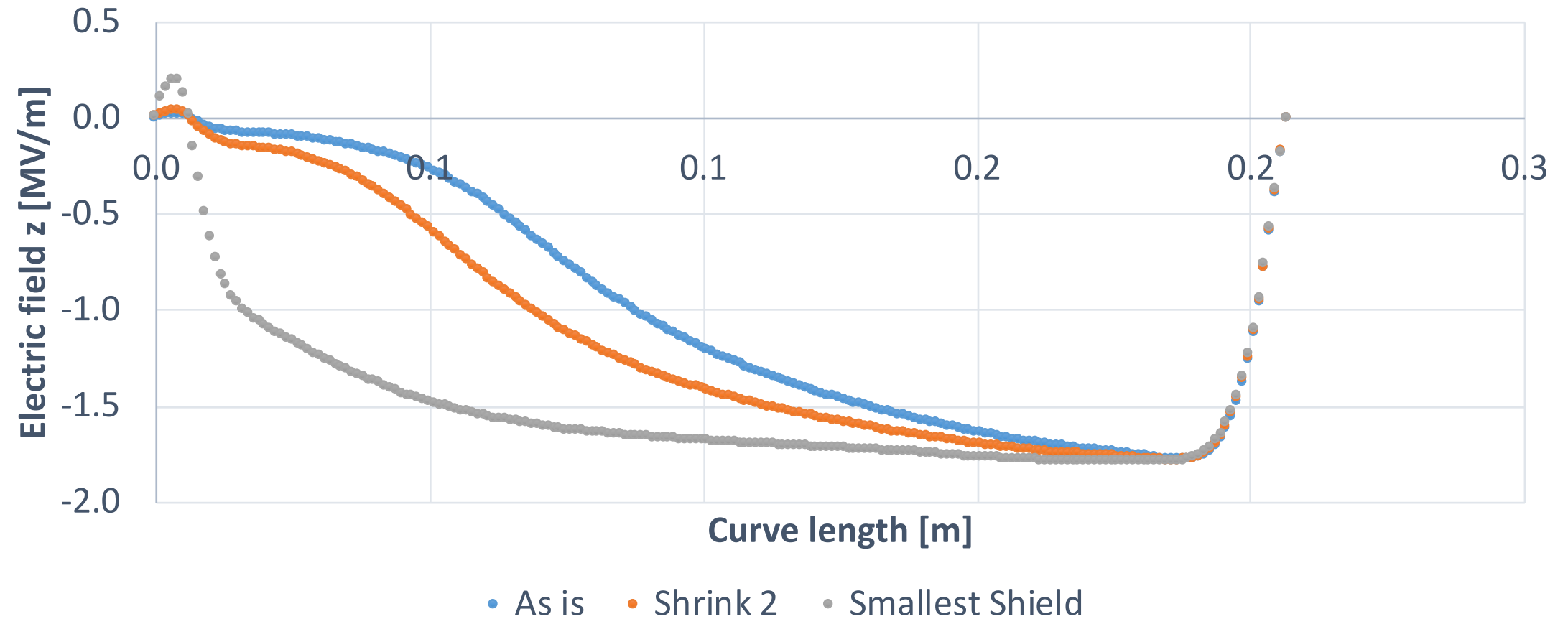
Shrink 2 at 200 kV



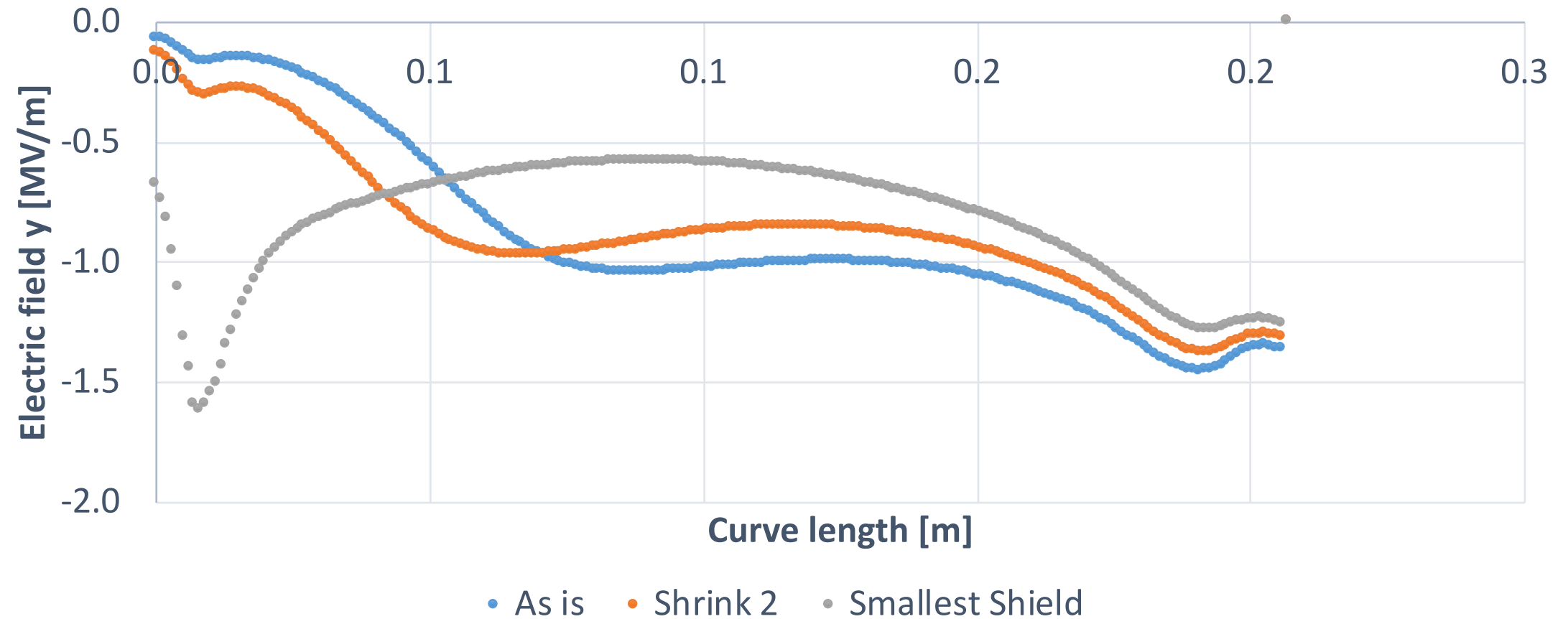
Potential along insulator length at -200 kV



E-field_z along insulator length at -200 kV



E-field_y along insulator length at -200 kV



GPT

I exported the field maps at **200 kV** and use them as inputs in the GPT deck for the GTS gun with **Dr. Sajini's parameters**, then obtained the dynamics

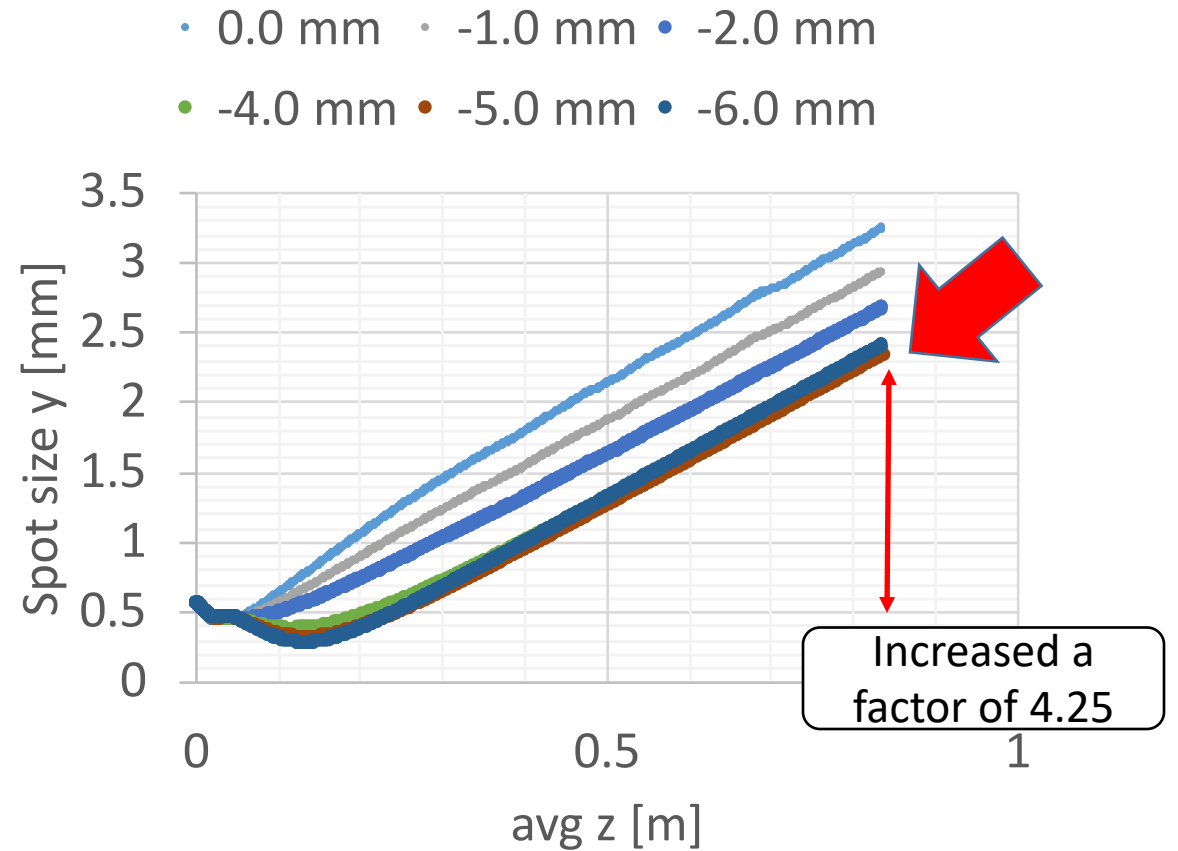
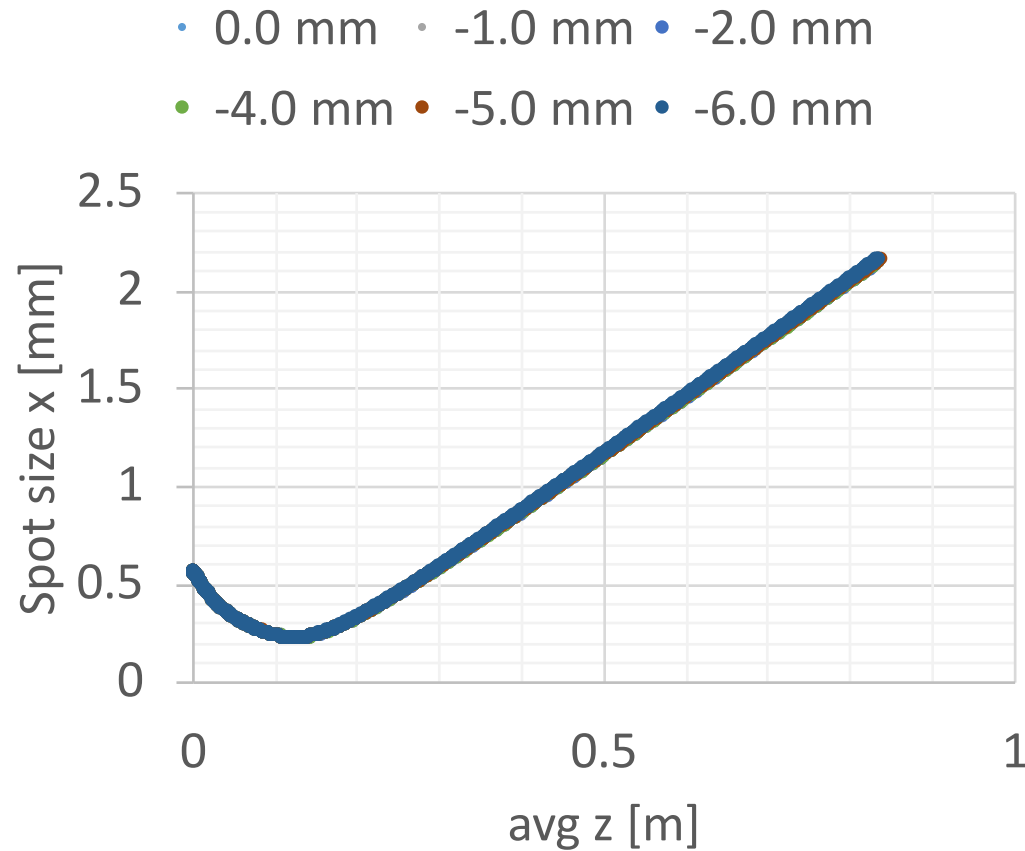
Parameters

- GPT parameters taken from Sajini's
 - Field map at **200 kV**
 - Qbunch $-1\text{e-}12$ # C
 - XYrms $0.5\text{e-}3$ # m
 - Space charge **ON**

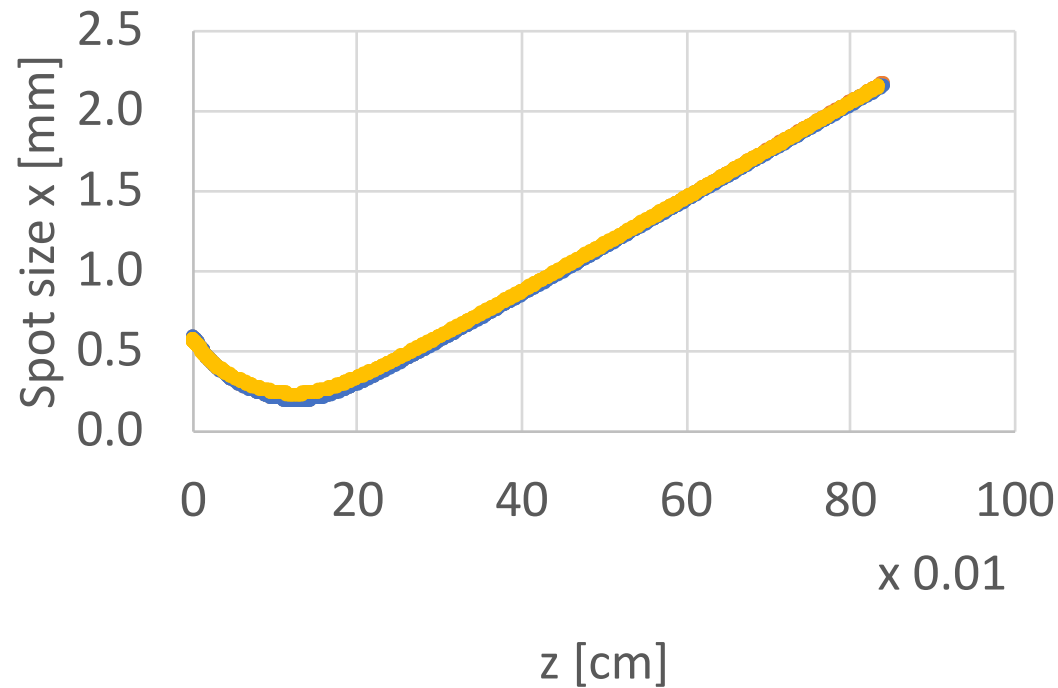
Simulation parameters

- Gun HV ~~350~~ **200** kV (3D E Field map CST)
- Charge 1 pC
- Gun solenoid off
- Pulse width 25 ps (rms)
- Laser spot size 1 mm (rms)
- Accuracy 6.5
- Space charge calculation off
- Focusing solenoids are off
- Correctors are off

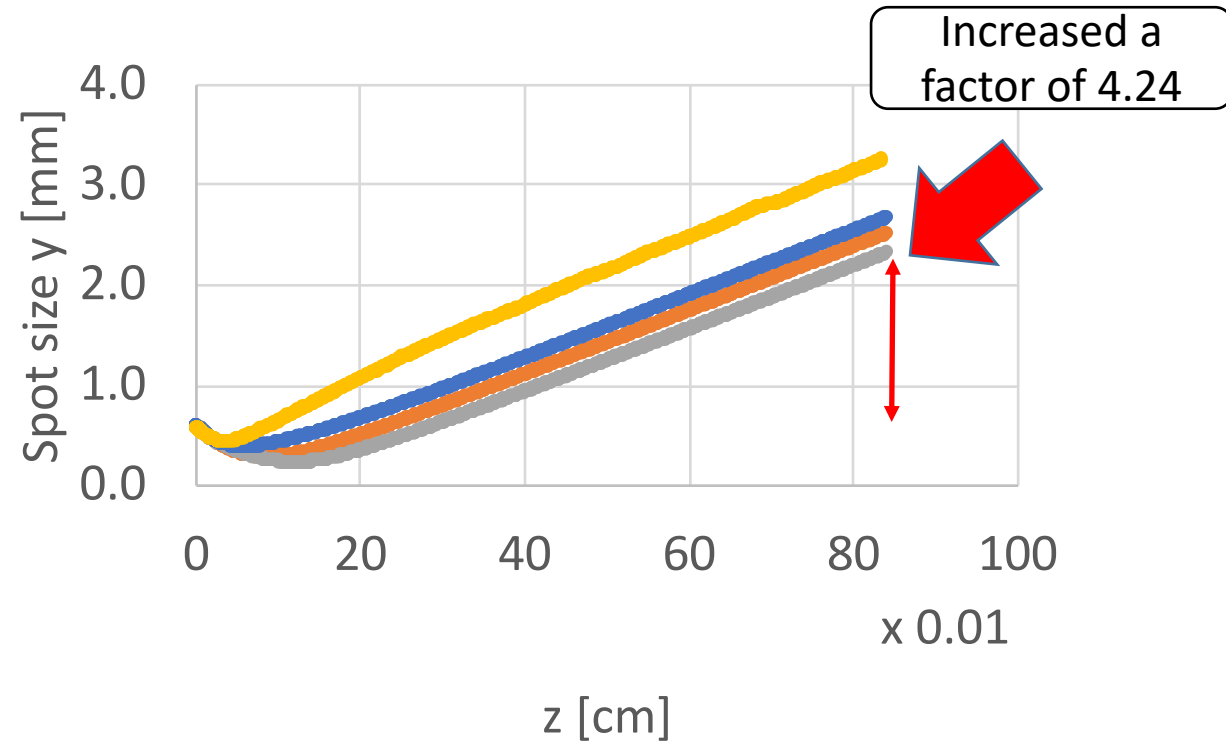
Anode shifts: Spot size



Anode tilts: Spot size



-10 deg -5 deg -3 deg -1 deg
0 deg 5 deg 10 deg



-10 deg -5 deg -3 deg -1 deg
0 deg 5 deg 10 deg