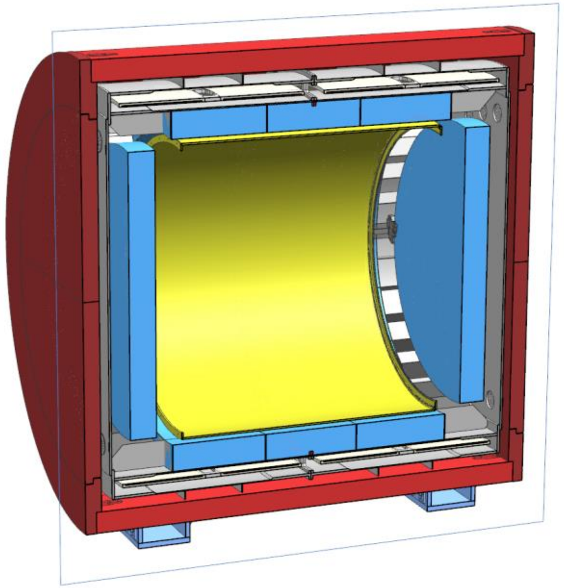
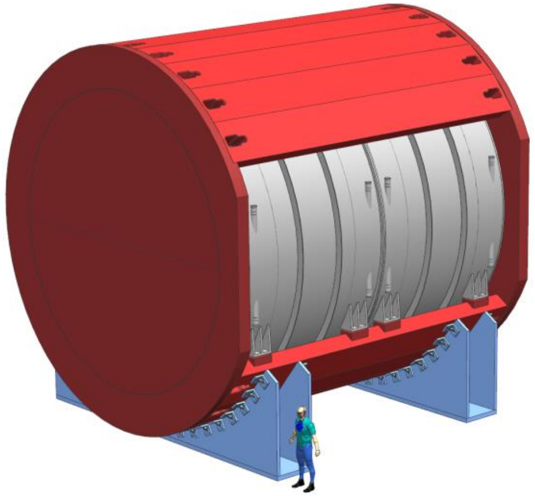
Electrostatic Simulations For the New ND-GAr Detector



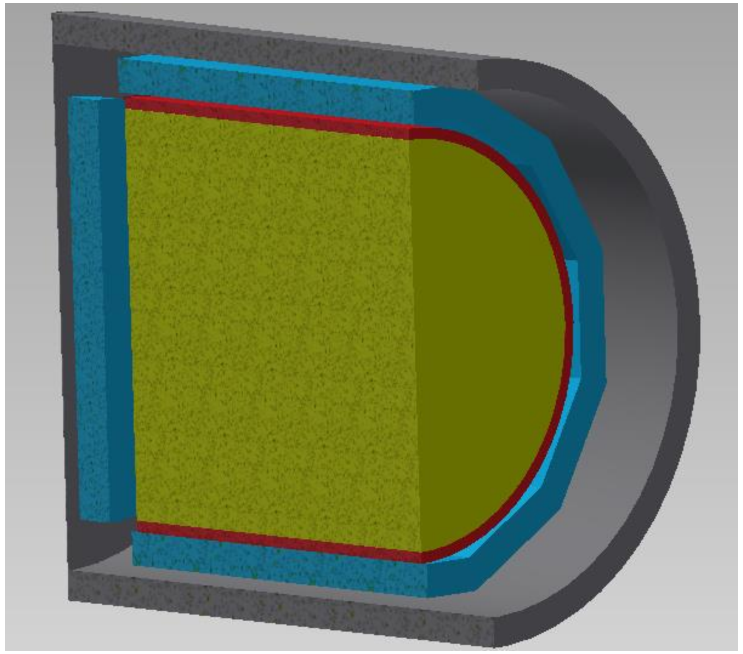


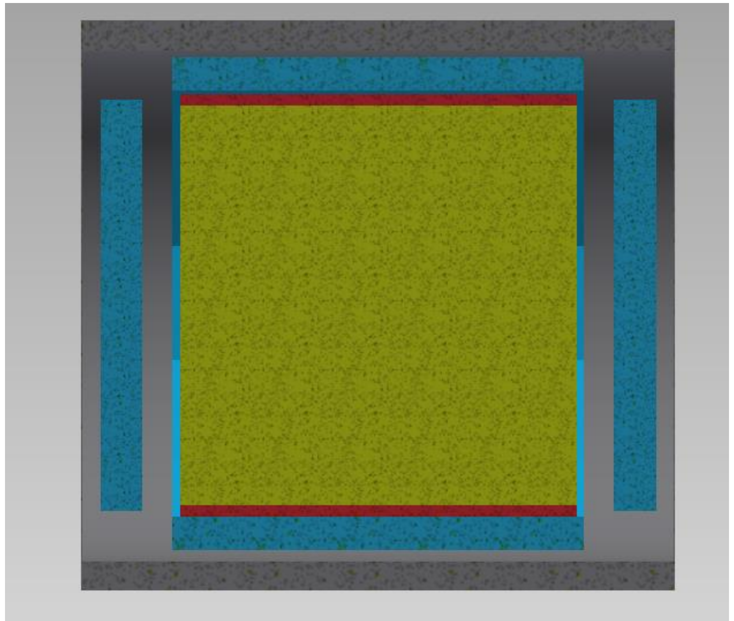
Christopher Hayes
Indiana University
3/1/2021

Calculation of Volumes Inside Pressure Vessel using Autodesk Inventor

Diameter of PV interior	6.725 m
Length of PV	7.788 m
Diameter of ALICE TPC + insulation layer	5.56 m
Length of ALICE TPC	5.20 m
Diameter of endcap ECAL	5.40 m
Thickness of endcap ECAL	0.55 m
Length of Barrel ECAL	5.40 m
Thickness of Barrel ECAL	0.436 m

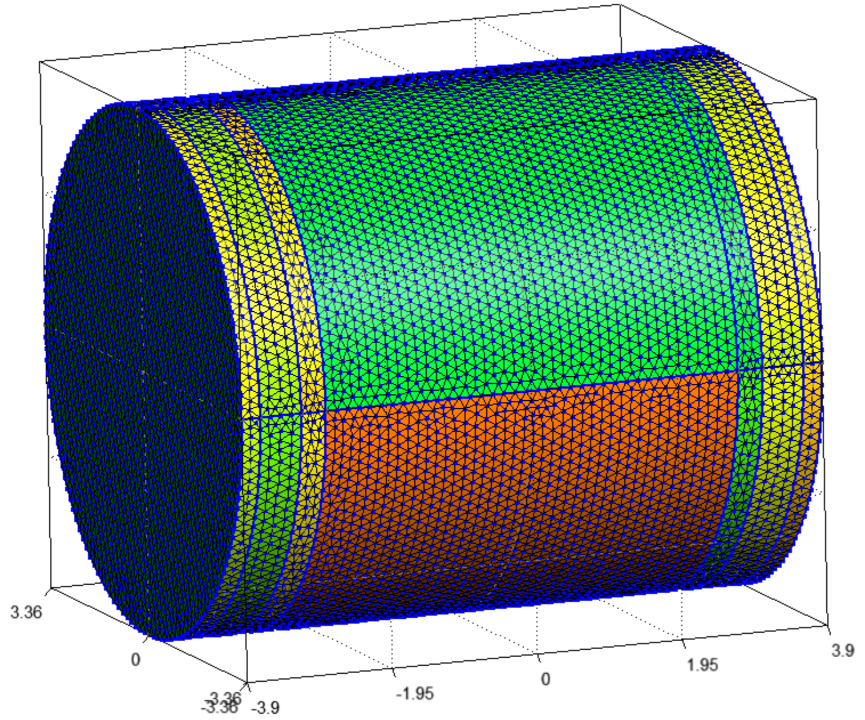
Total Volume inside Pressure Vessel:	276.63 m^3
Volume of TPC with insulation Layer:	-126.25 m^3
Volume of Barrel ECAL:	-45.68 m^3
Volume of two end cap ECAL:	- 2 x 12.59 m^3
Extra unused volume inside PV:	79.51 m^3

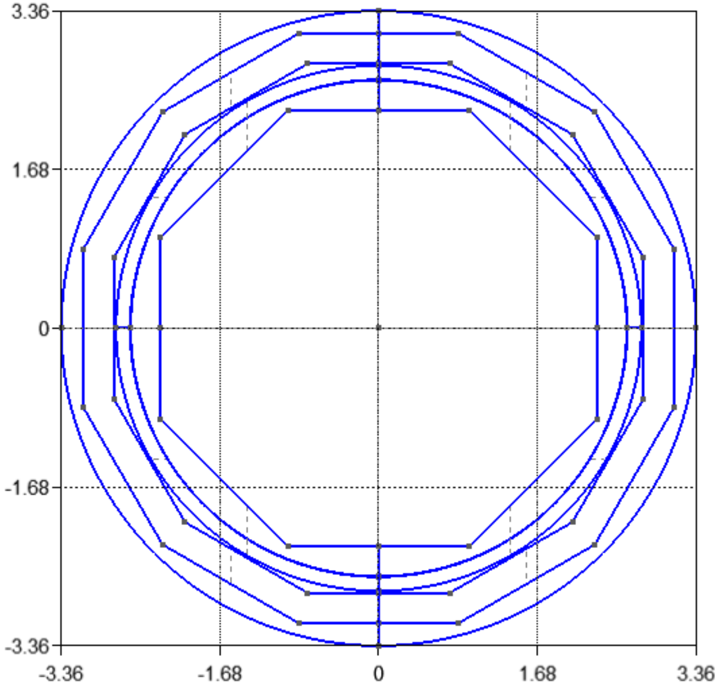


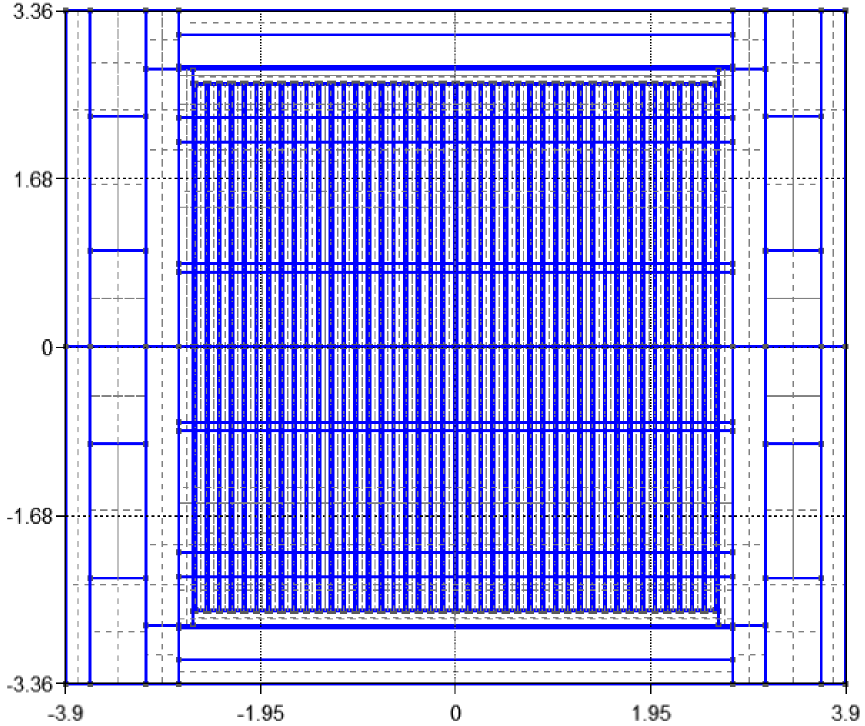


Mesh for the New Simulation

- ***New mesh includes the entire pressurized region of the ND-GAr detector.***
- ***Mesh prepared using the Gmsh finite element meshing software***
- ***Outer dimensions: R=6.72 m L=7.8 m***





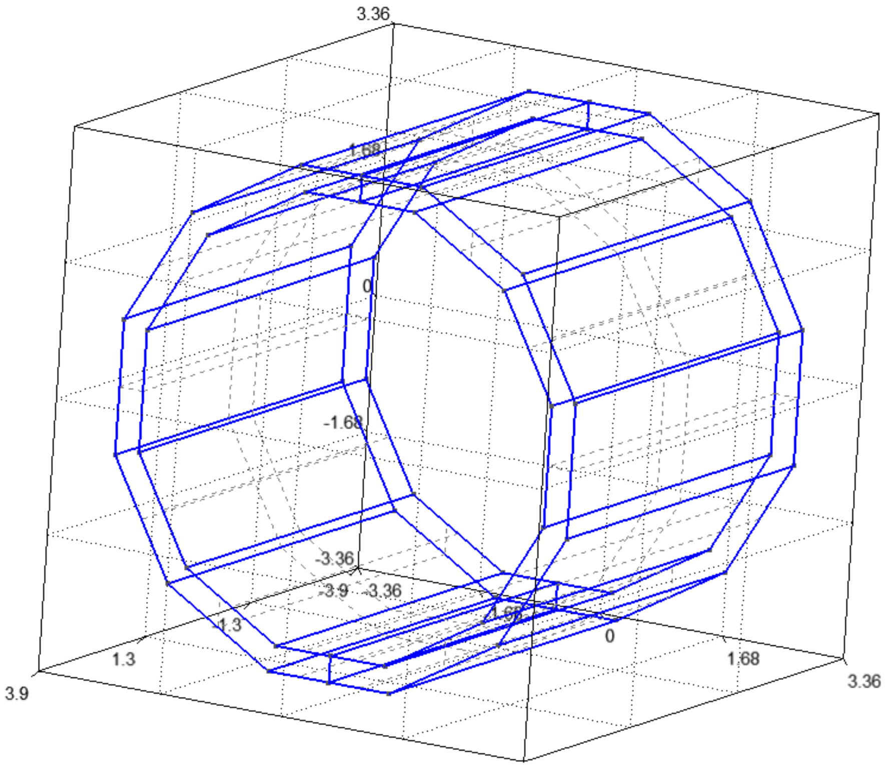


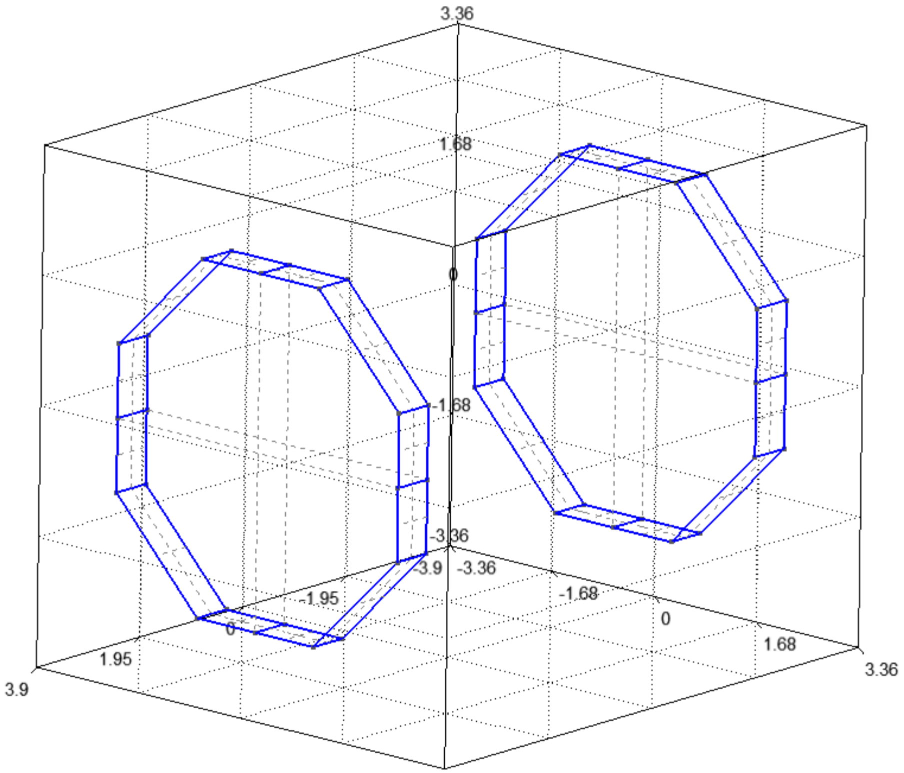
Mesh contains:

- ***TPC with 42 voltage strips***
- ***High voltage Insulation layer surrounding the TPC***
- ***Barrel ECAL and End Cap ECAL***

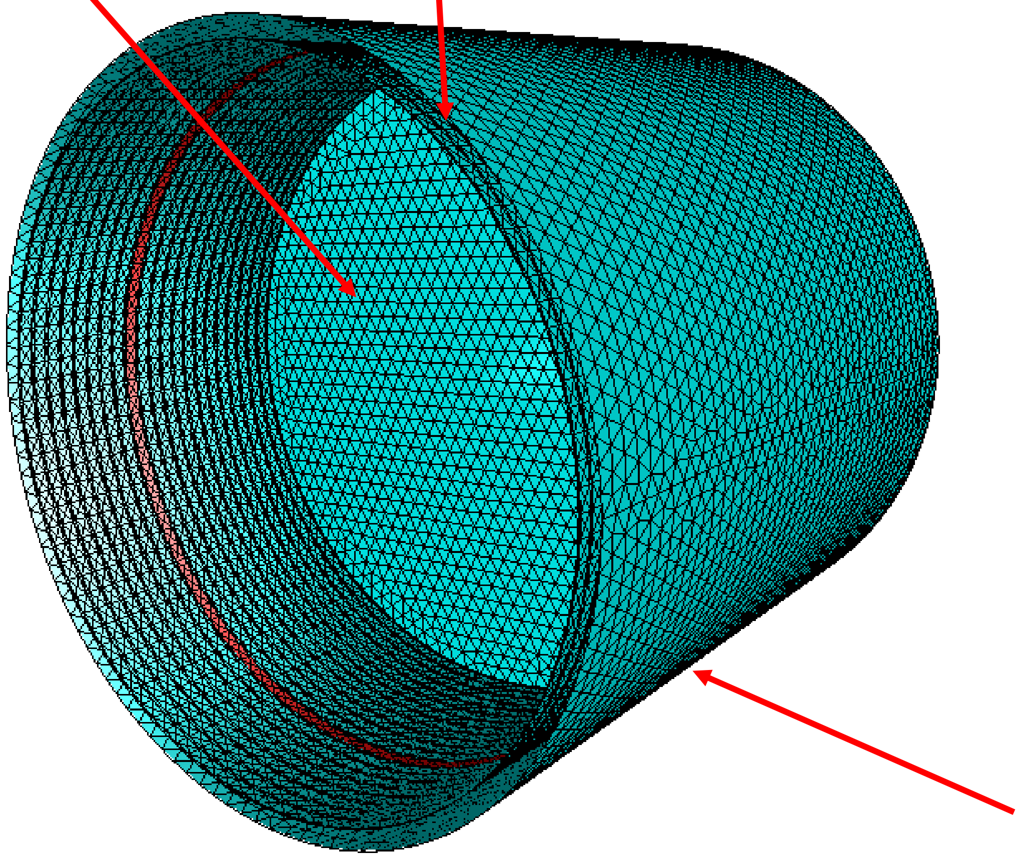
Details of Barrel ECAL and End Cap ECAL for the Mesh

- 8-sided End Cap ECAL with thickness of 55 cm
- 12-sided Barrel ECAL with thickness of 33 cm
- Both ECAL approximated as slabs of polystyrene plastic with dielectric constant $\varepsilon = 2.55$
- All other volumes are filled with gas





Outline For 2 Simulations



I. Central Cathode Design with grounded insulation layer

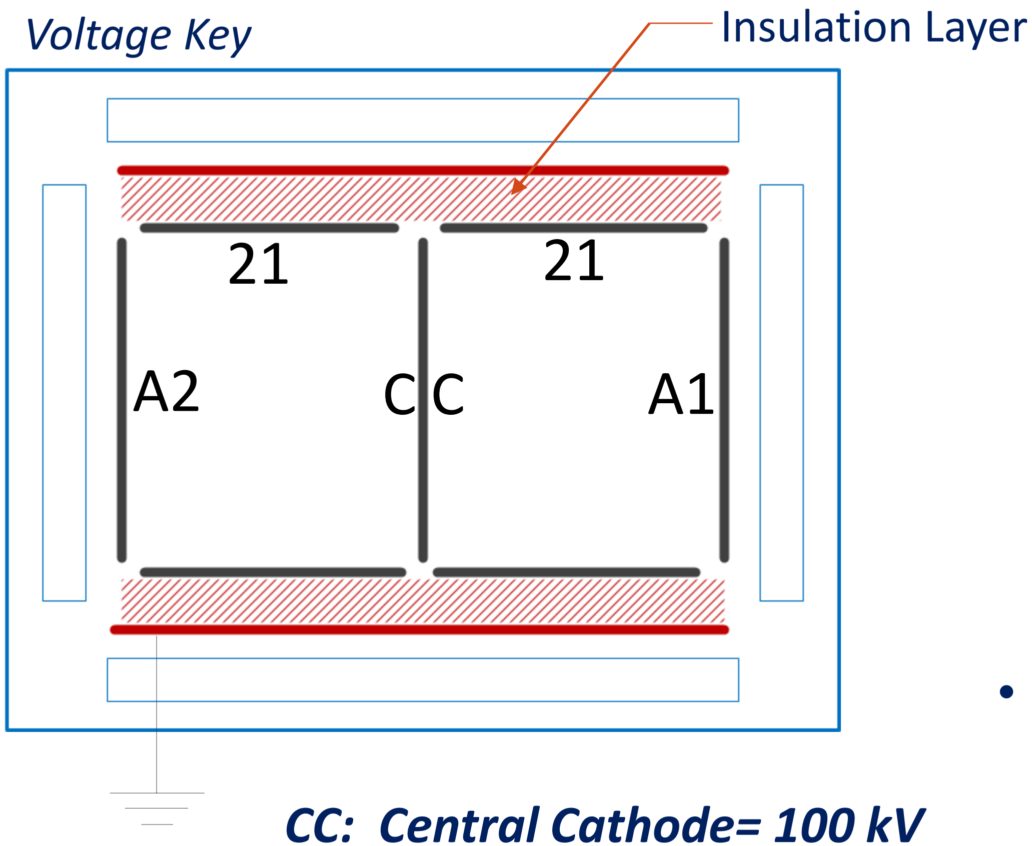
II. Single Anode Design with grounded insulation layer

Extra: Designs with grounded pressure vessel

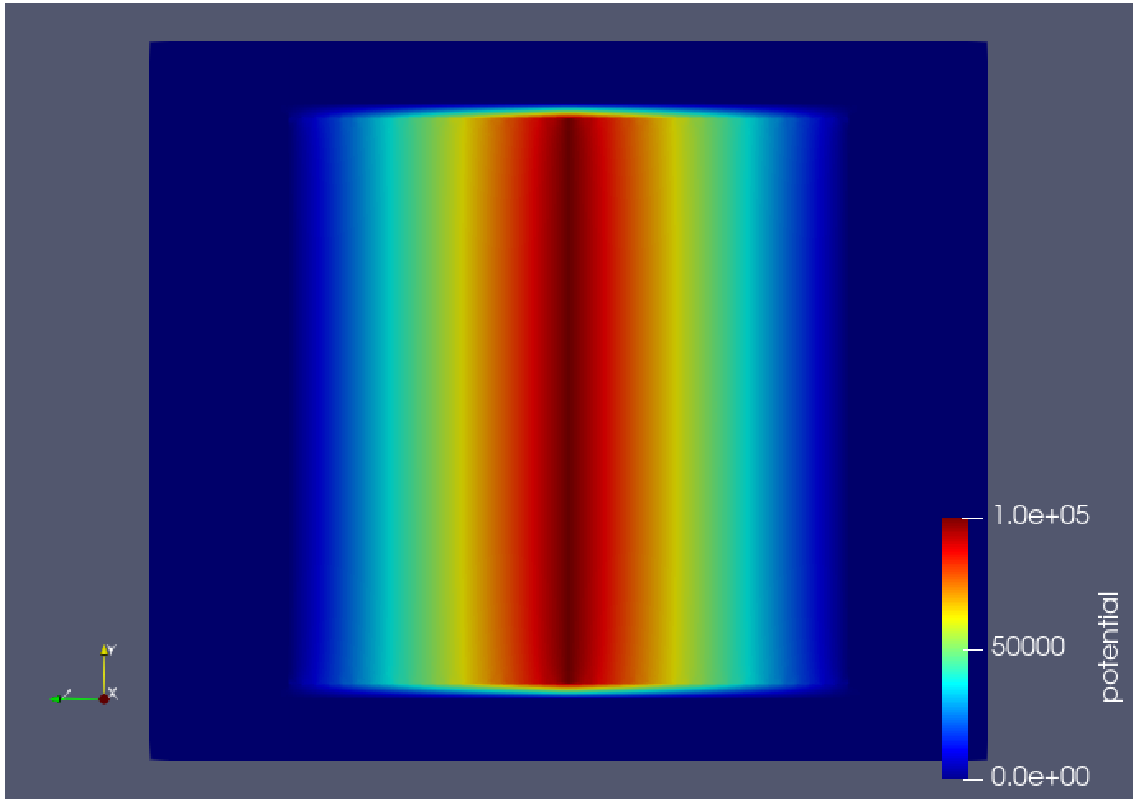
- ***Schematic generated by ElmerGUI shows the TPC in the new design with 15 cm thick insulation layer surrounding it.***
- ***Schematic shows one voltage strips selected***
- ***Grounding the insulation layer means only grounding the outside surface of the layer***

I. Central Cathode Design with grounded Insulation layer

Voltage Key



Voltage Profile



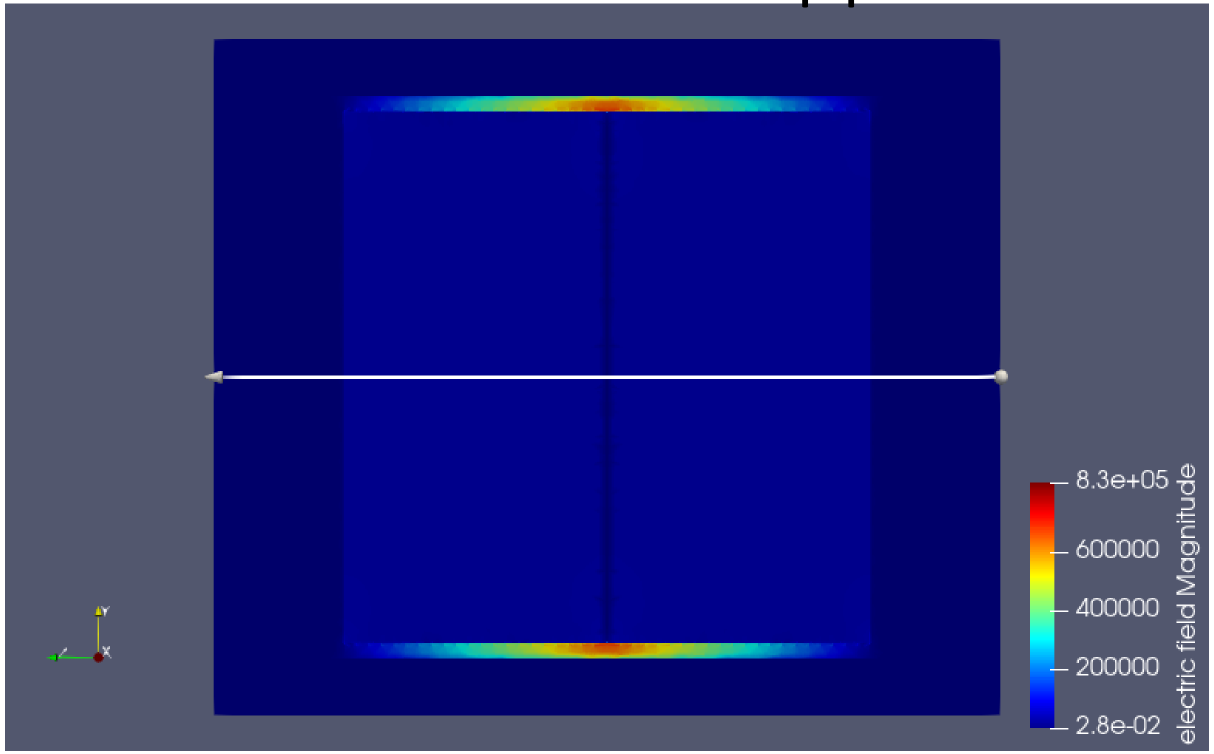
CC: Central Cathode= 100 kV
A1 and A2: Anodes = 0 kV

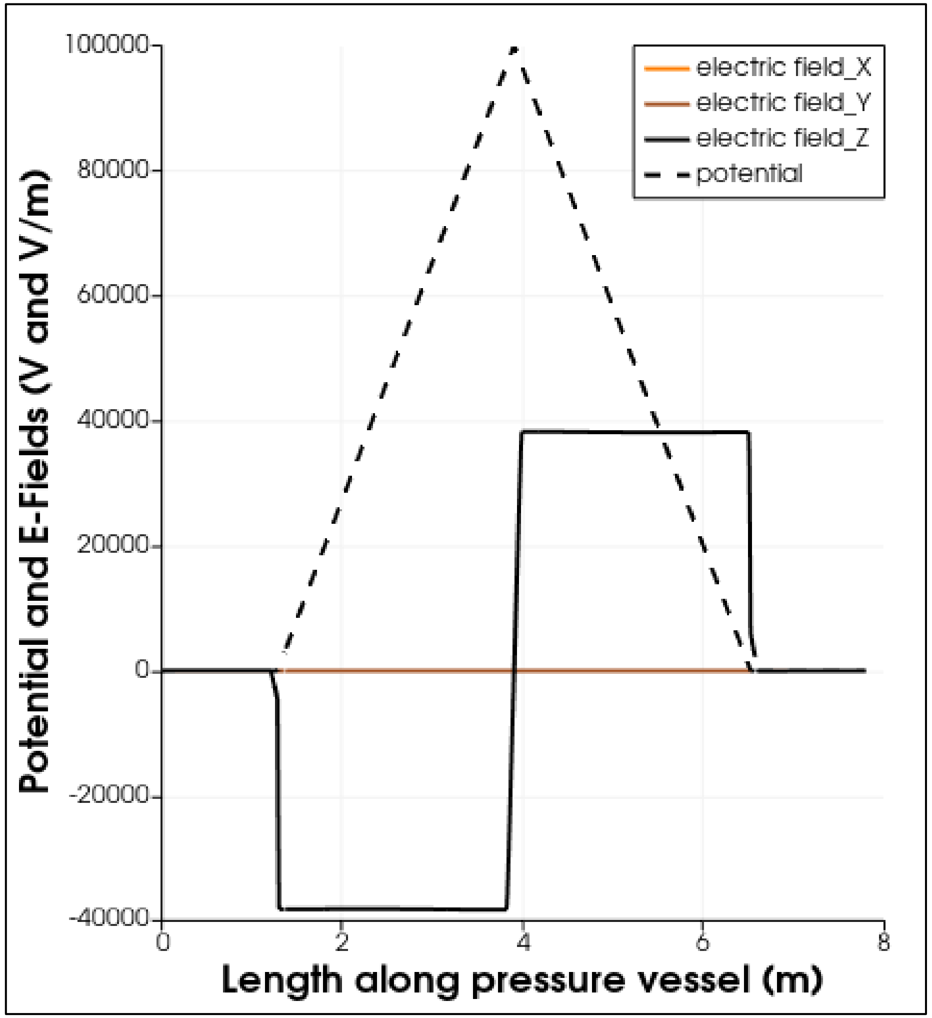
- ***21 Voltage strips: Increasing voltages toward central cathode***
- ***Only outer surface of insulation layer is grounded***

Central Cathode Design with Grounded Insulation Layer

- ***Barrel and end cap ECAL are unaffected by the grounding scheme***
- ***Large voltage drop cross insulation layer***

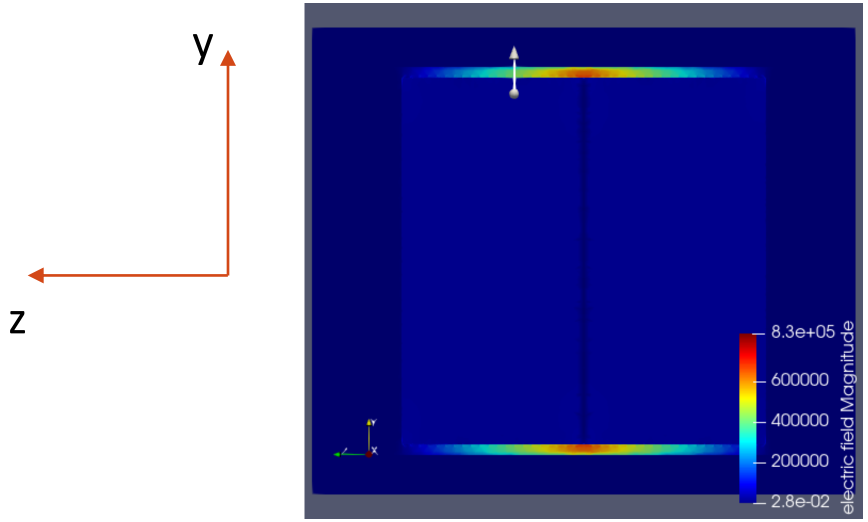
|E|-field Profile

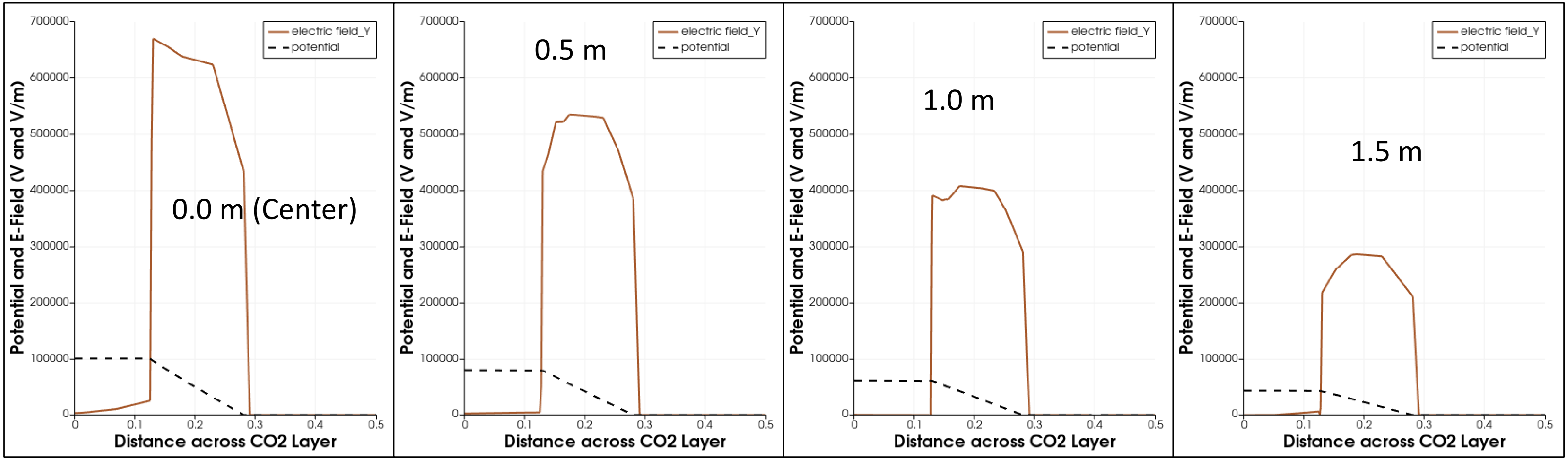




Electric Field Across Insulation Gap

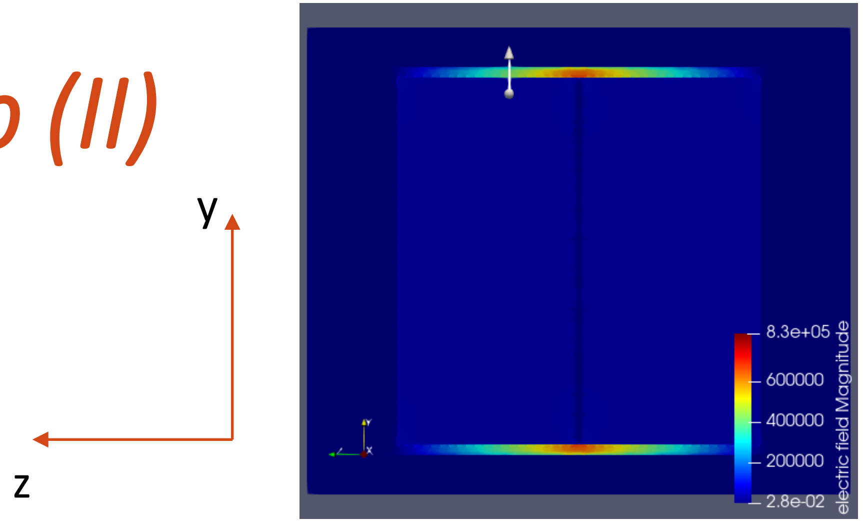
- ***Plots show detailed behavior of fields in the interior of the insulation layer***
- ***Electric fields approaching 700,000 V/m near the central Cathode***

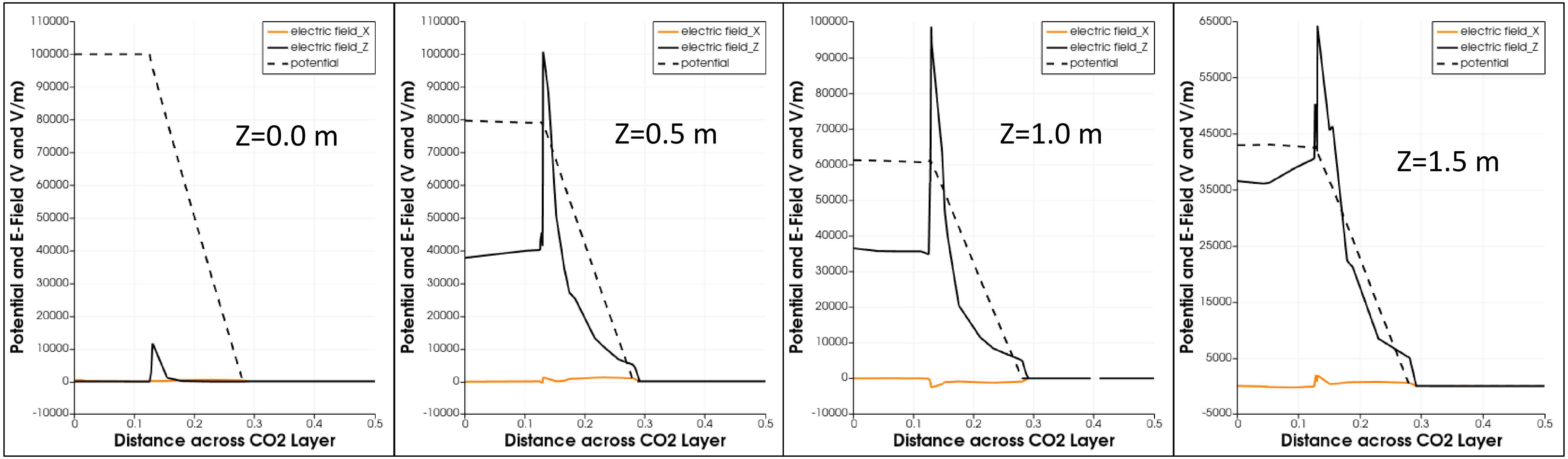




Electric Field Across Insulation Gap (II)

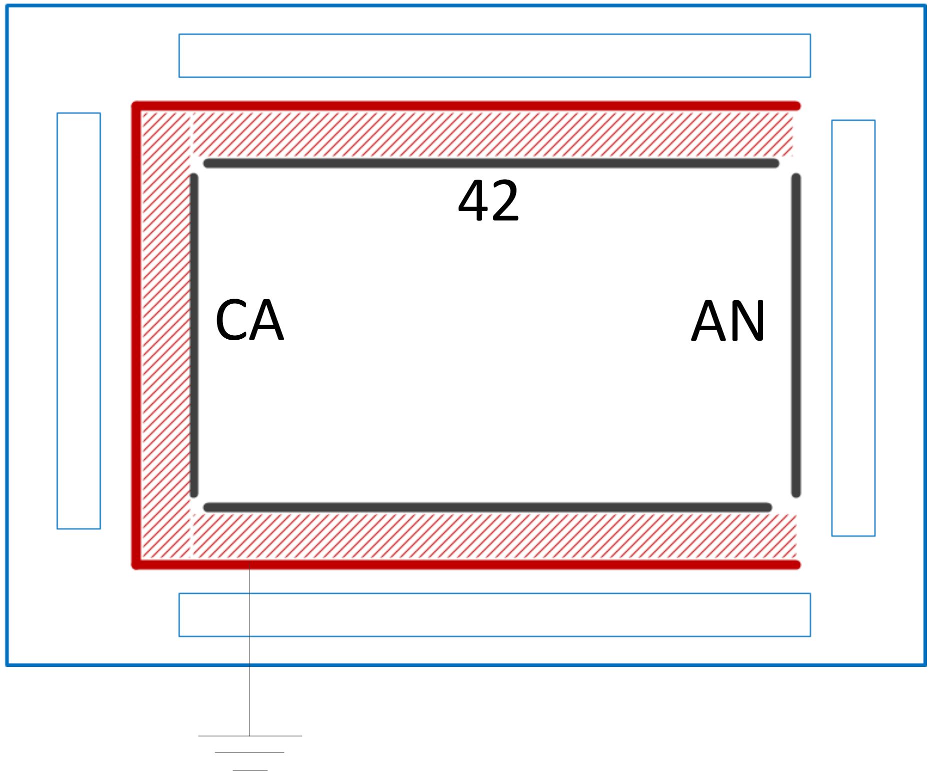
- ***Z-component of electric field in the insulation gap is also significant.***





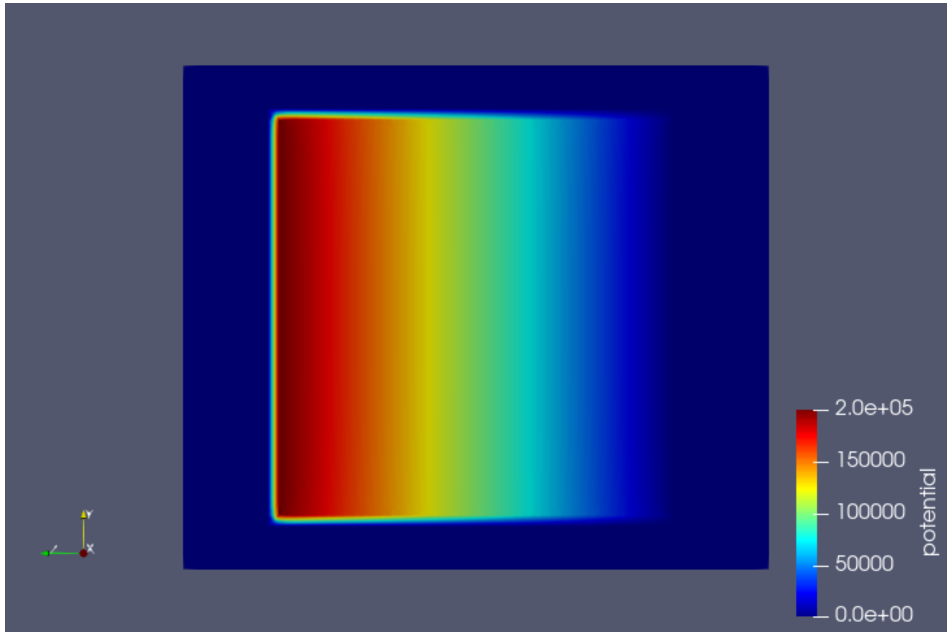
II. *Single Anode Design with Grounded Insulation Layer*

Voltage Key

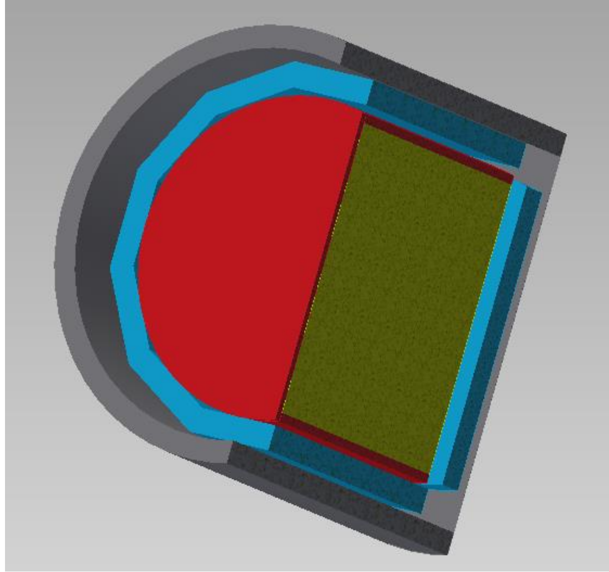


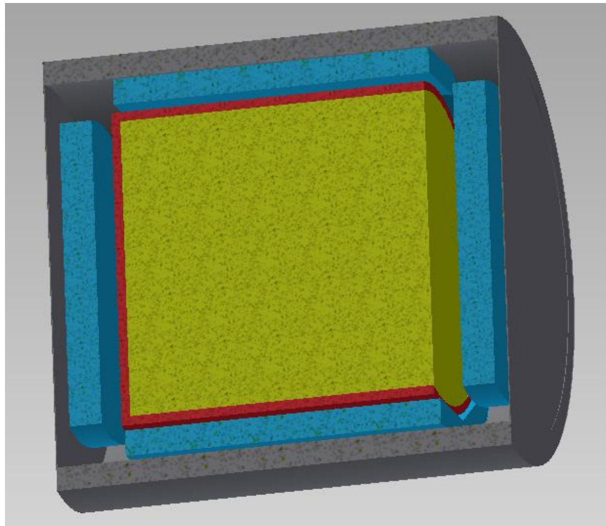
CA: Cathode= 200 kV
AN: Anode = 0 kV

Voltage Profile



- ***42 Voltage strips: Increasing voltages toward cathode***
- ***Insulation layer extended to cover the region outside the cathode***

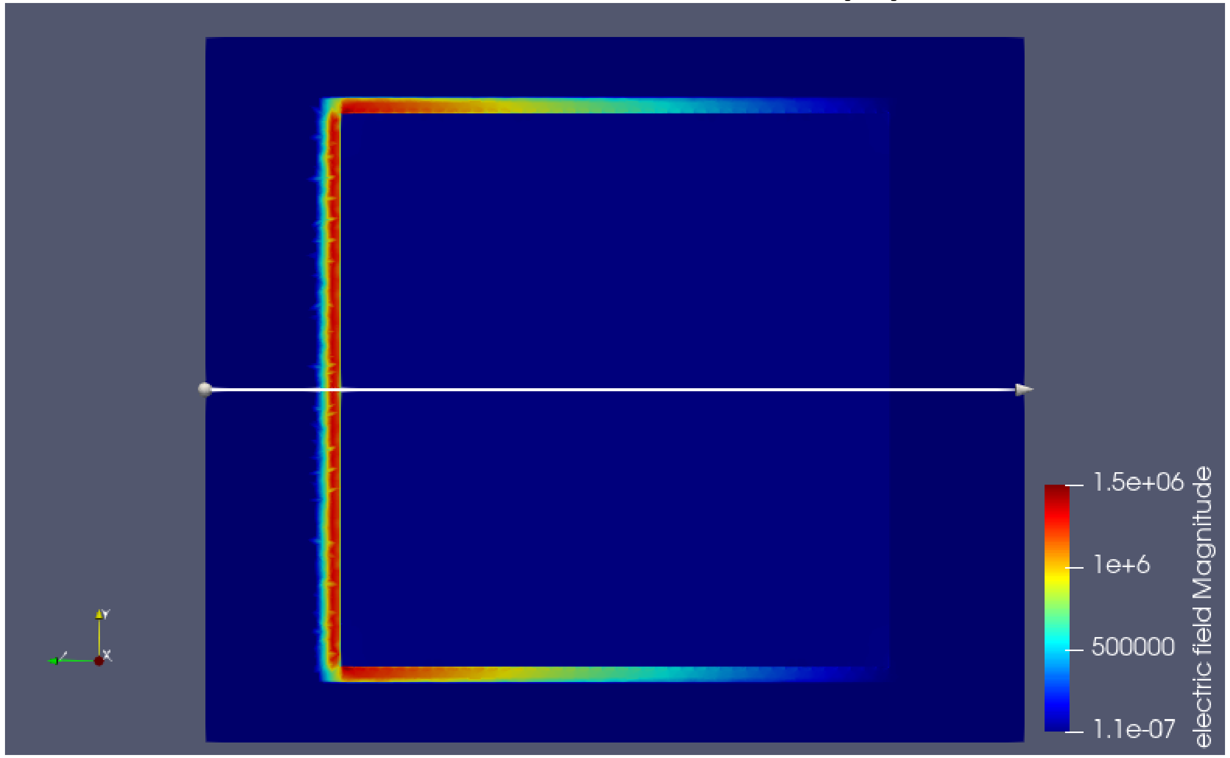


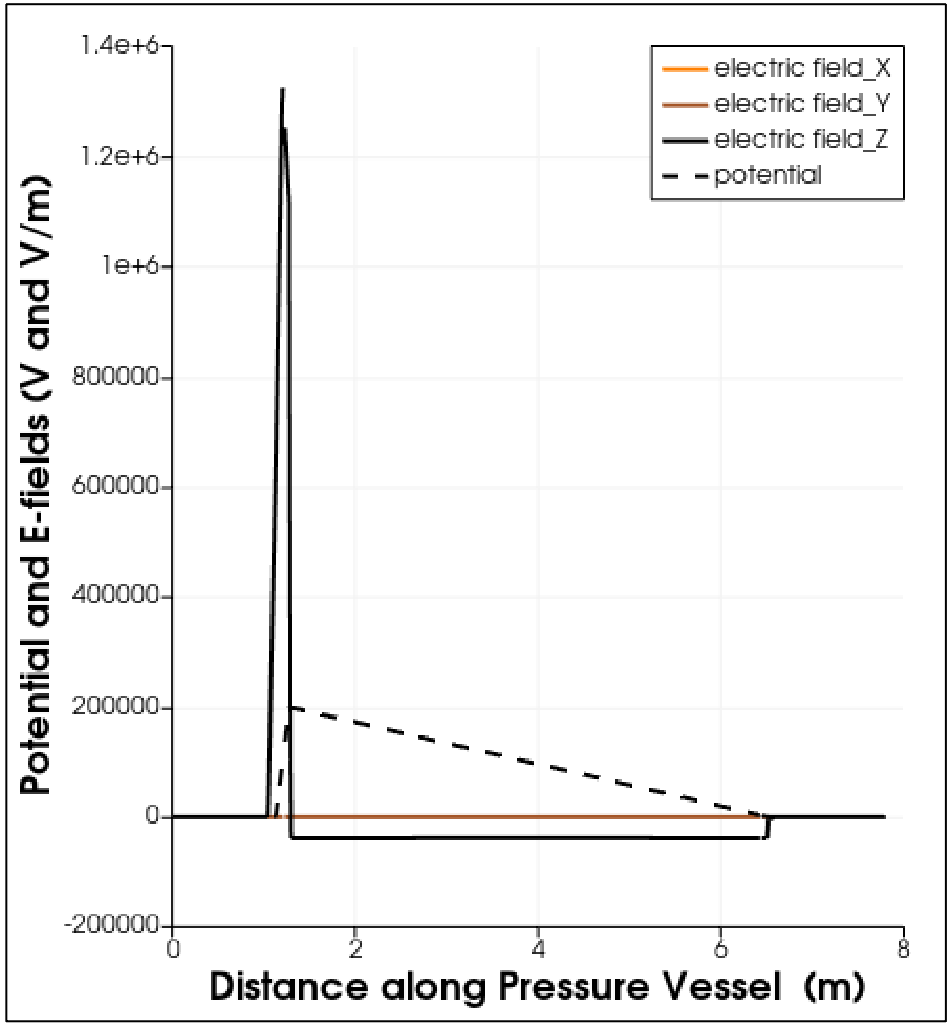


Single Anode Design with Grounded Insulation Layer

- ***Design produces large peaks in all components of the electric field vector inside the insulation layer***
- ***Barrel and End Cap ECAL unaffected by grounding of insulation layer.***

|E|-field Profile

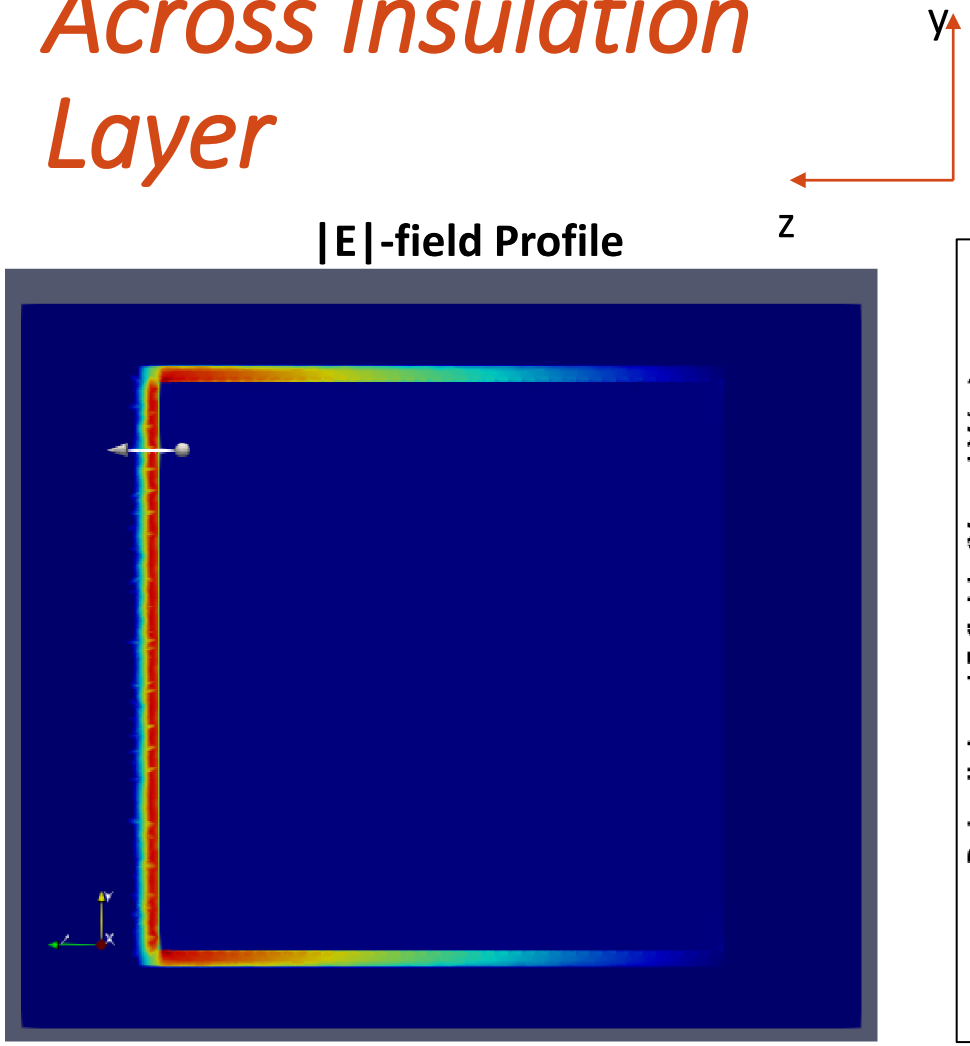


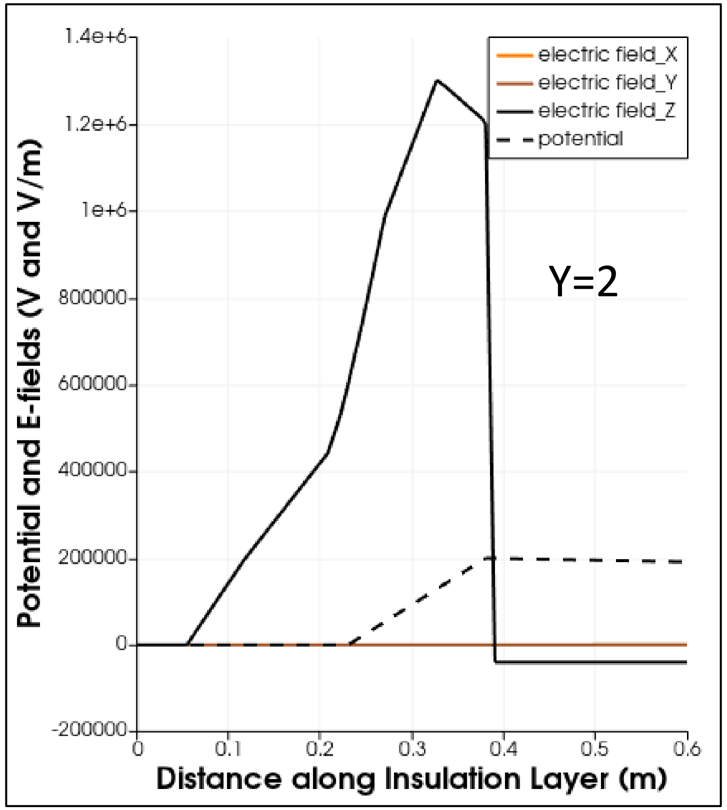


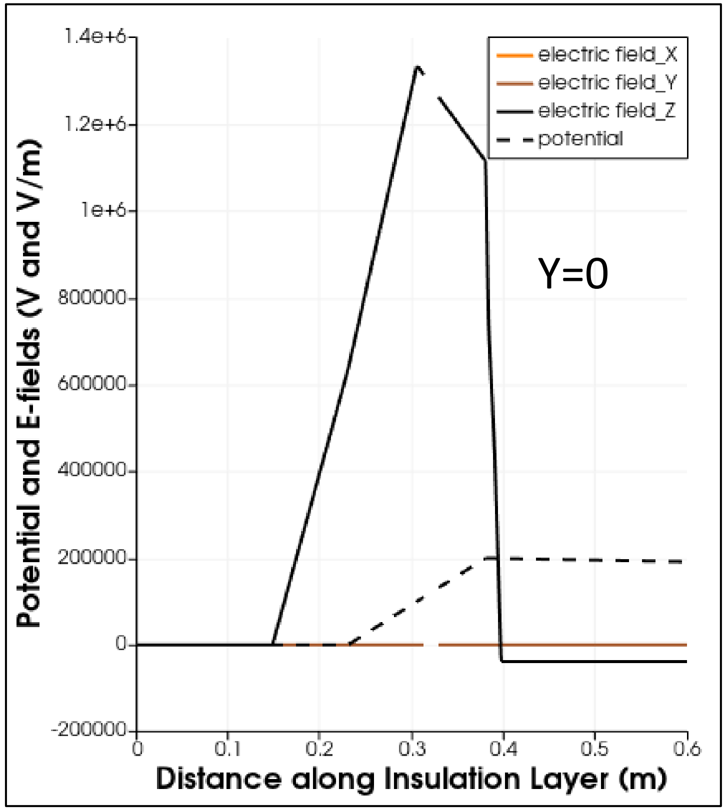
Voltage and Fields Across Insulation Layer

- ***Simulation shows fields extending well beyond the point on the insulation layer where the voltage is zero.***
- ***This is an unexpected result. Likely a problem associated with implementation of the simulation. We are investigating this.***

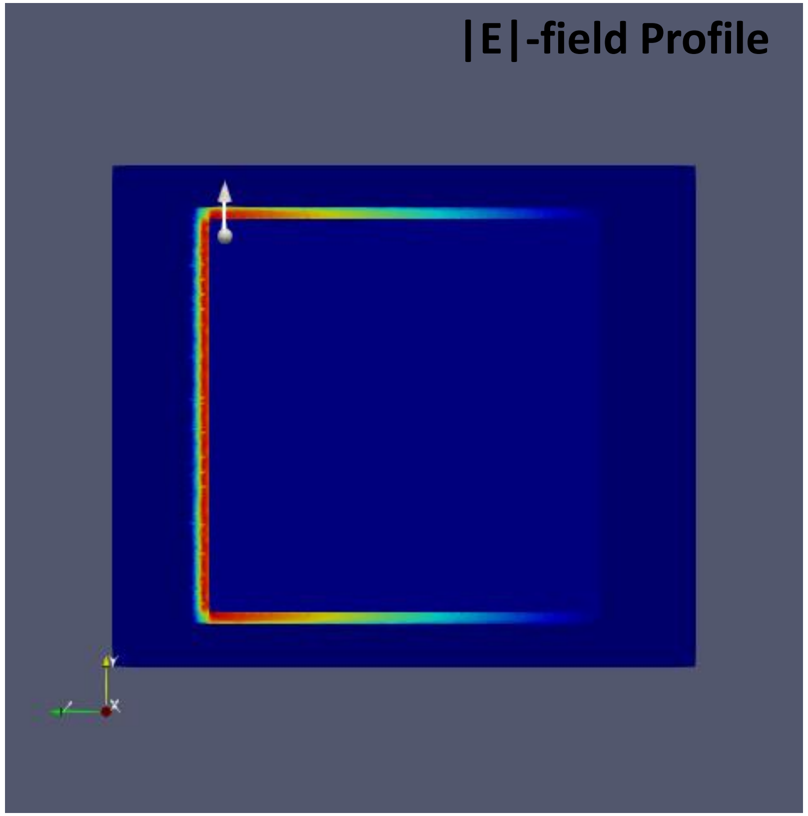
|E|-field Profile

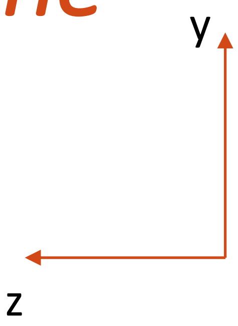


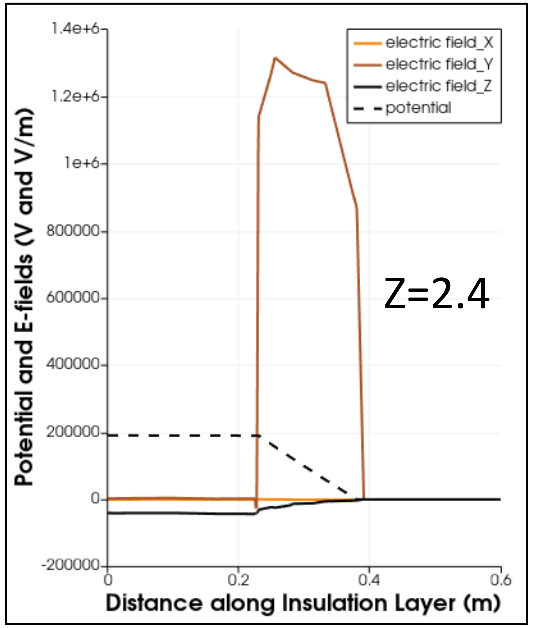


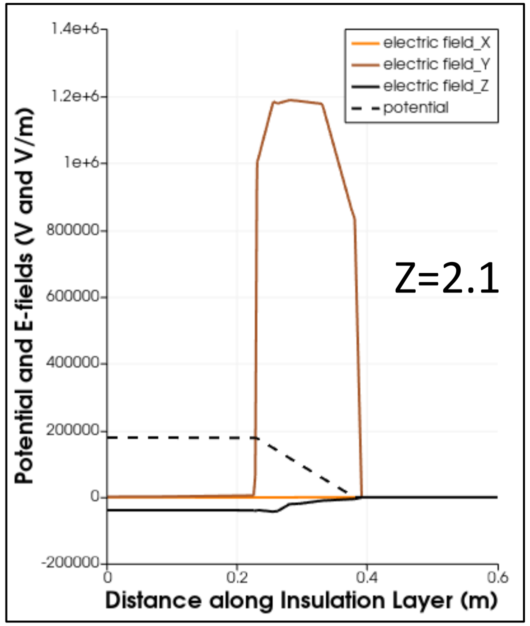


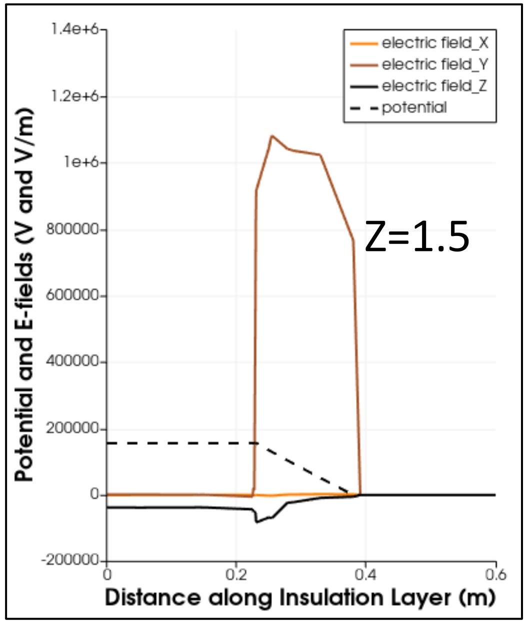
Voltage and Fields across cylindrical portion of the insulation layer

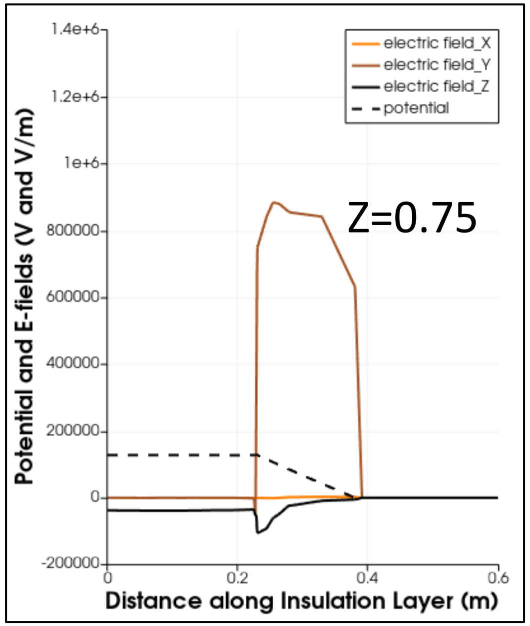


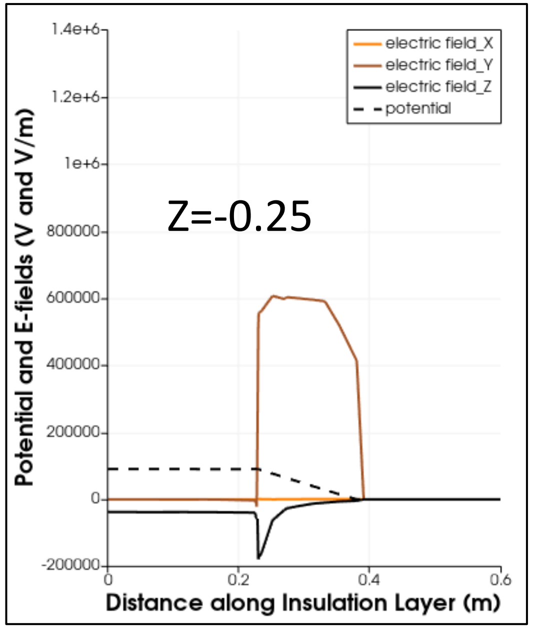








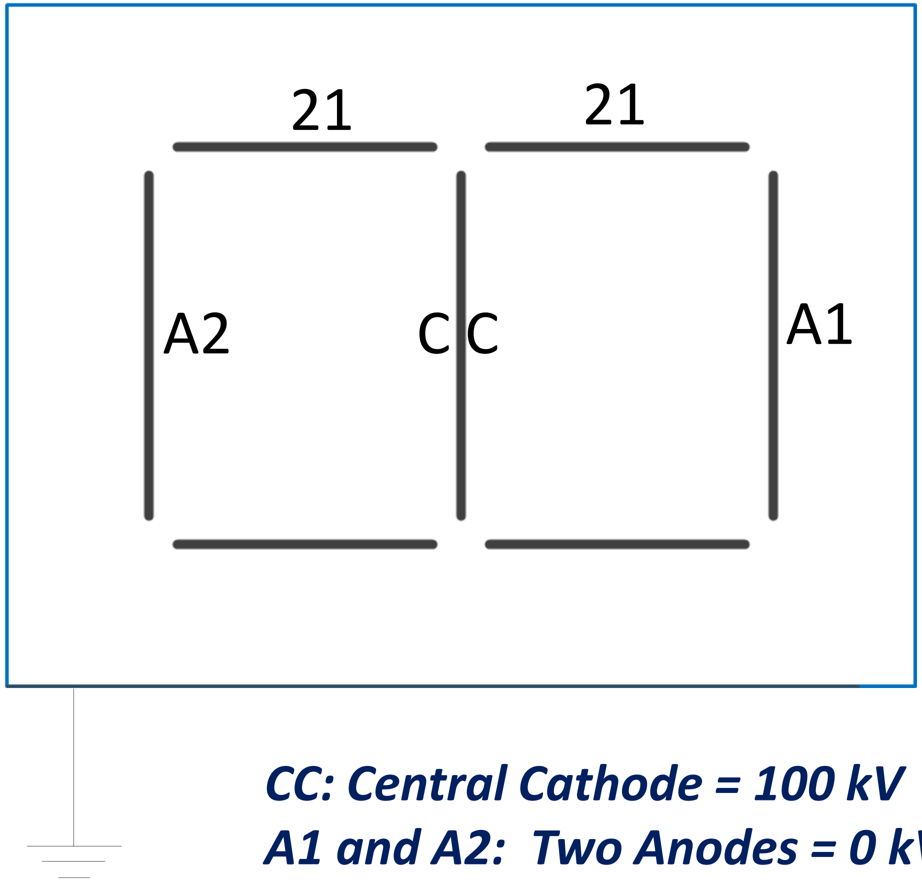




Extra: Designs with Grounded Pressure Vessel

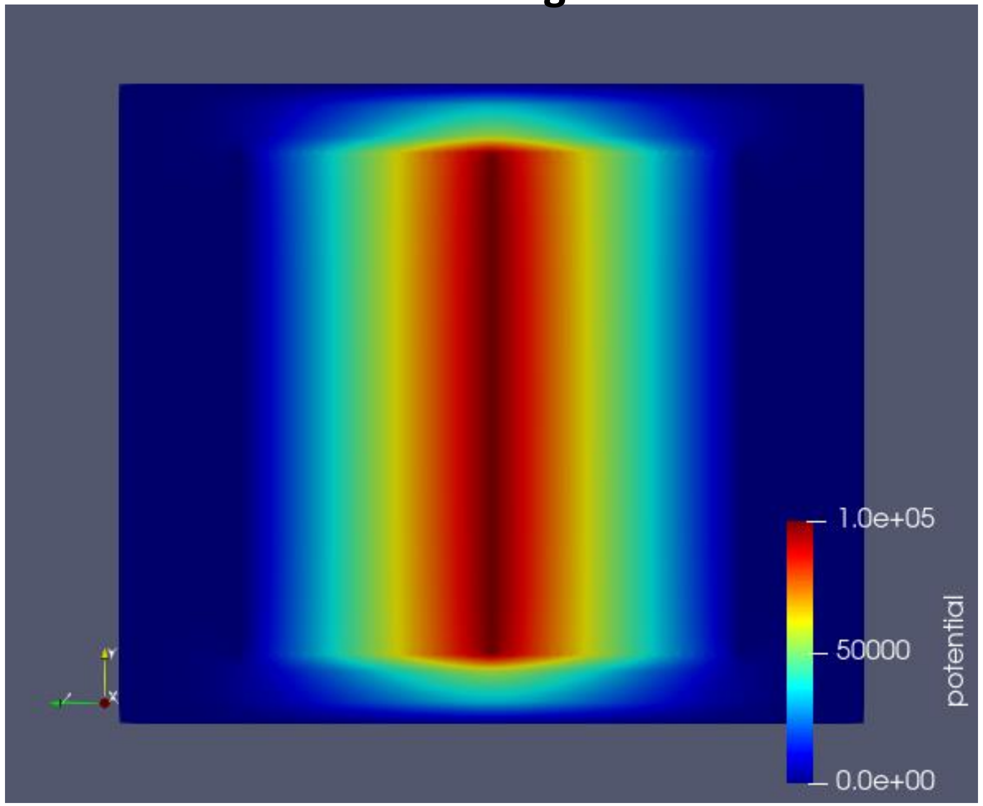
Central Cathode Design with Grounded Pressure Vessel

Voltage Key



CC: Central Cathode = 100 kV
A1 and A2: Two Anodes = 0 kV

Voltage Profile



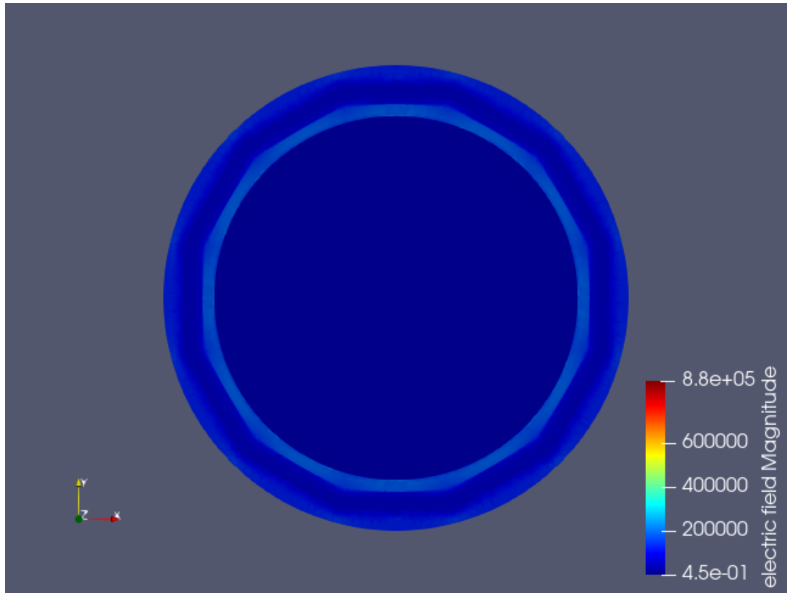
- ***21 Voltage strips: Increasing voltages toward central cathode***
- ***No need for an insulation layer***

Central Cathode Design with Grounded Pressure Vessel

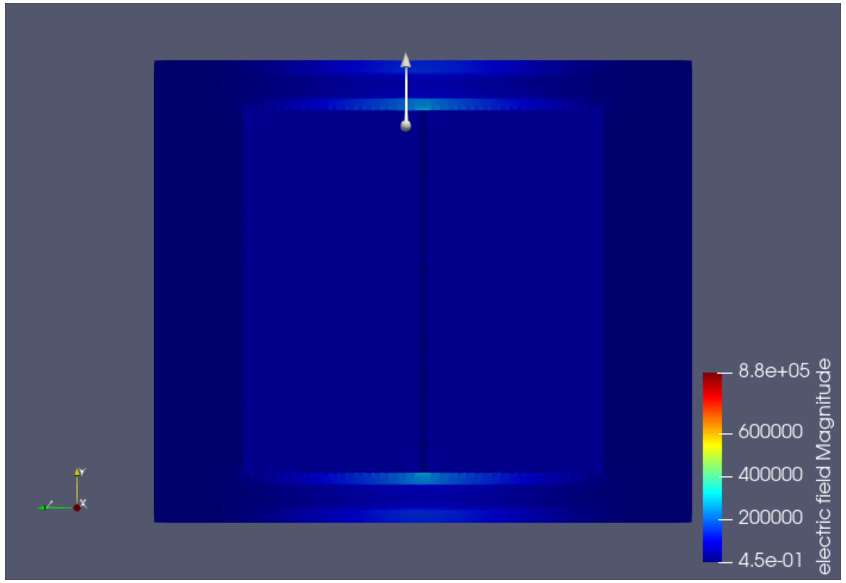
- ***Large voltage drops and radial electric fields crossing the barrel ECAL :***
  E=80,000 V/m

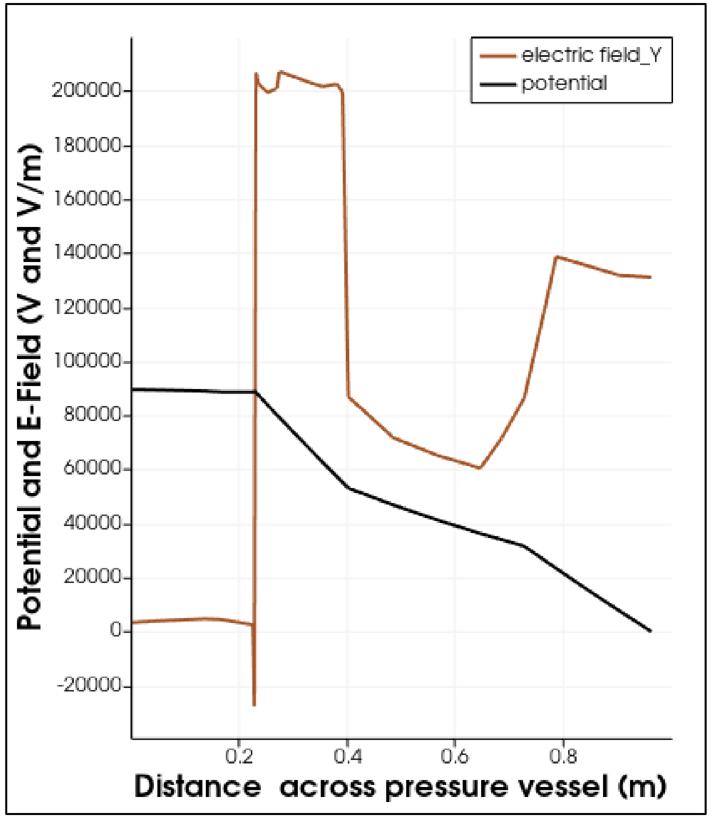
- ***Large Electric Fields terminate on the cylindrical wall of the pressure vessel :***
  E= 130,000 V/m

|E|-field Profile



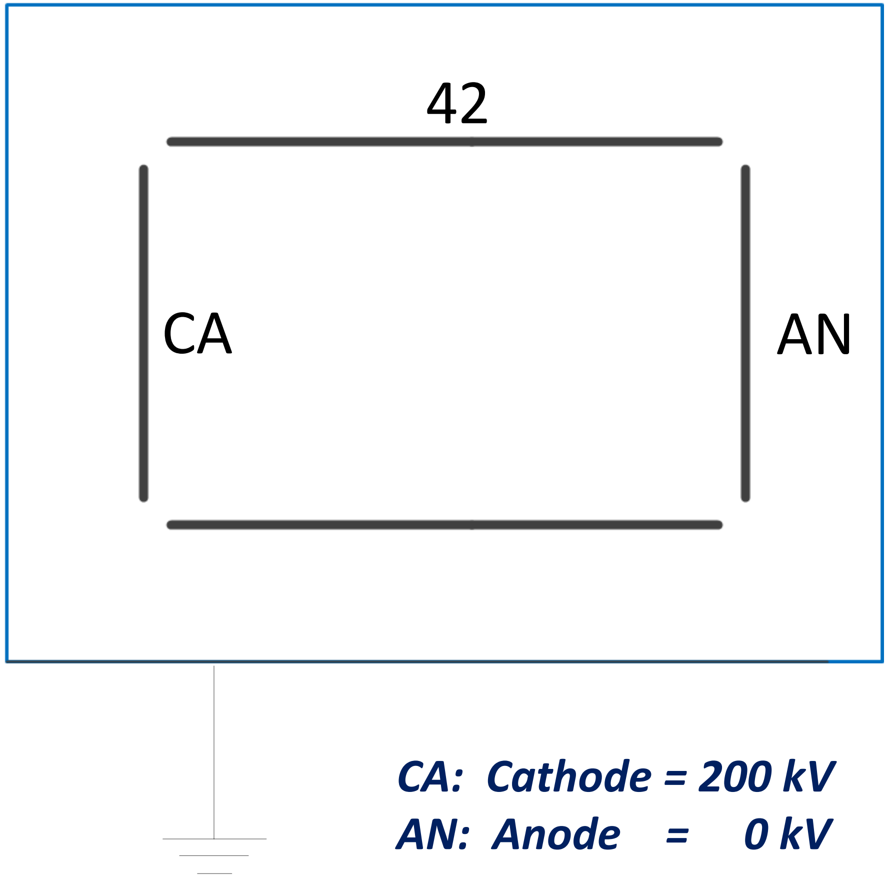
|E|-field Profile





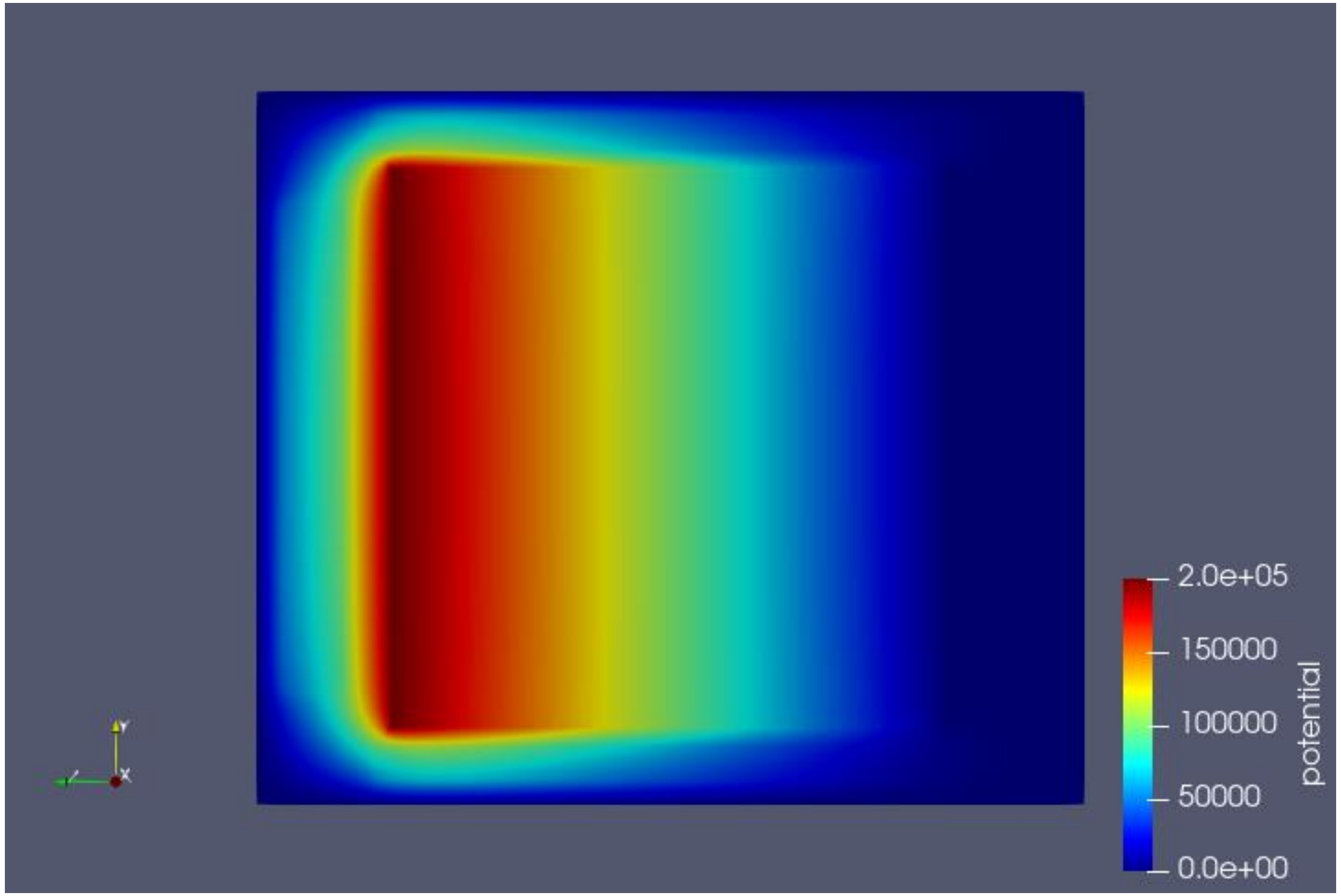
Single Anode Design with Grounded Pressure Vessel

Voltage Key



CA: Cathode = 200 kV
AN: Anode = 0 kV

Voltage Profile



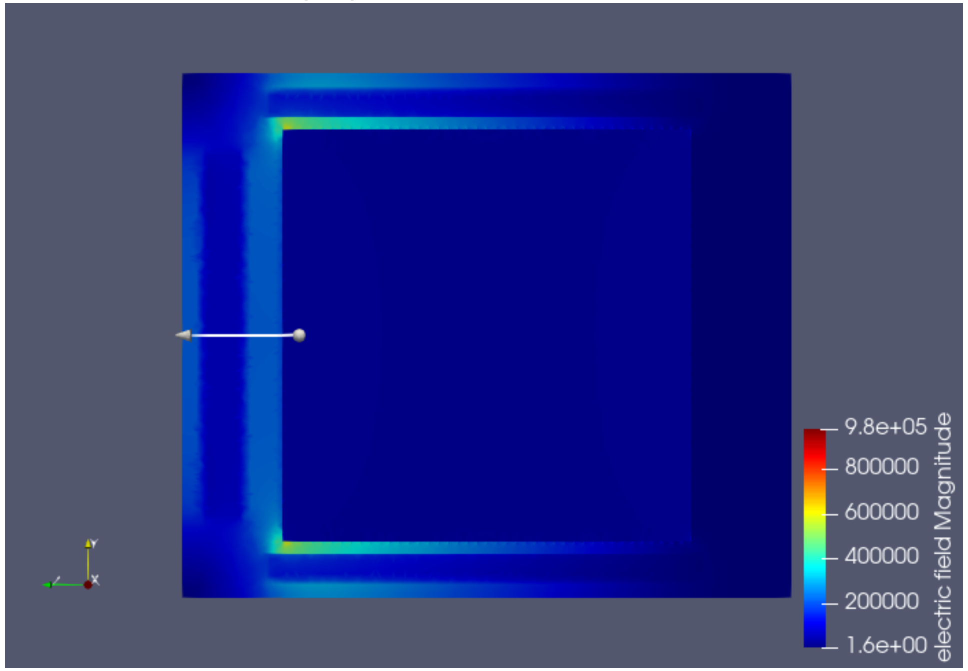
42 Voltage strips: Increasing voltages toward cathode

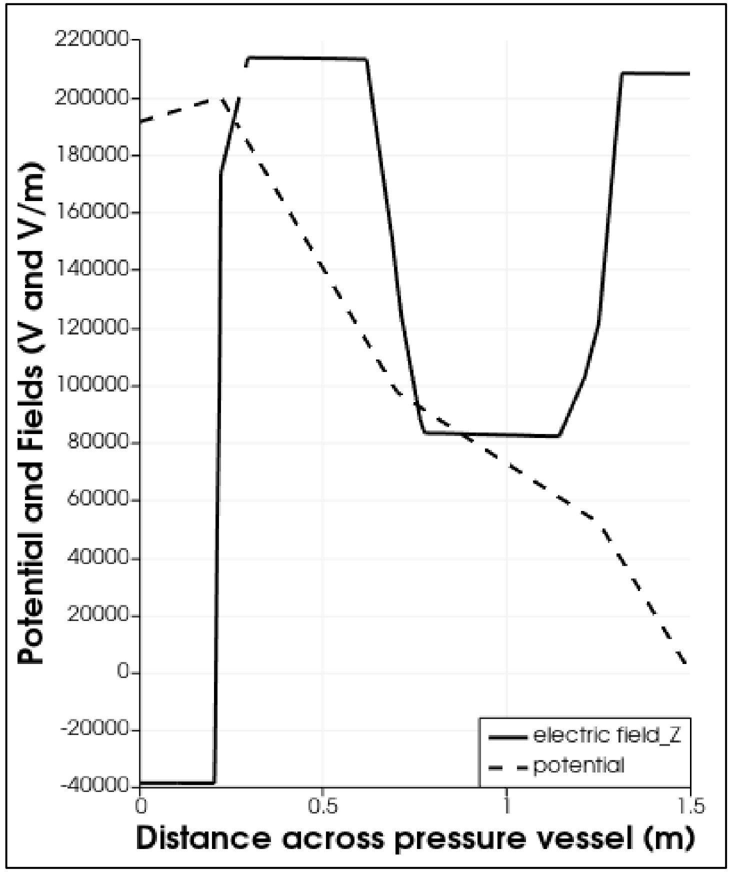
Single Anode Design with Grounded Pressure Vessel

Large voltage drops and large fields cross the barrel and end cap ECAL near cathode end

- ***E=80,000 V/m through the end cap ECAL at the cathode end***
- ***E=170,000 V/m through barrel ECAL at cathode end***
- ***E=250,000 V/m at cylindrical wall of pressure vessel***

|E|-field Profile





Summary

- *Placing ground on the outside of an electrical insulation layer for both single and double anode designs eliminates all electric fields in barrel and end cap ECAL*
- *To ensure absence of dielectric breakdown in the insulation layer, need a detailed Investigation into dielectric strengths of materials for single and double anode designs*
- *Current model allows for variation of parameters and introduction of additional complexity for future models*

Thank You for Listening