COMSOL Simulations and Electric Field Map generation

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COMSOL MultiPhysics

Software to study many physics process for engineering and research
-> Not free, Licence is very (very) expensive

-> CERN can provide one licence, upon request with justification
http://information-technology.web.cern.ch/services/software/comsol
It comes with one restriction : you have to be physically at cern to run it (no ssh tunneling would work).

Caveat : I've never used COMSOL up to last week, I was only handling the output given to me by someone else

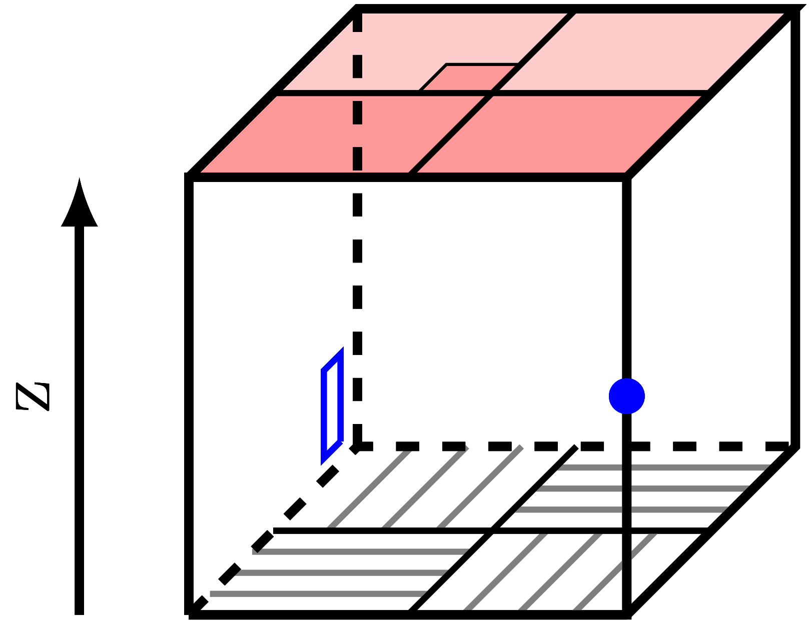
COMSOL for the 666

We have two sources of field distorsions :

1. The short
2. The Space charge effect

-> Studying effect 1. is fairly easy, effect 2. is a bit more complicated.

Filippo explained to me how to introduce the short in a simplified 666 geometry and compute stationary field computation.

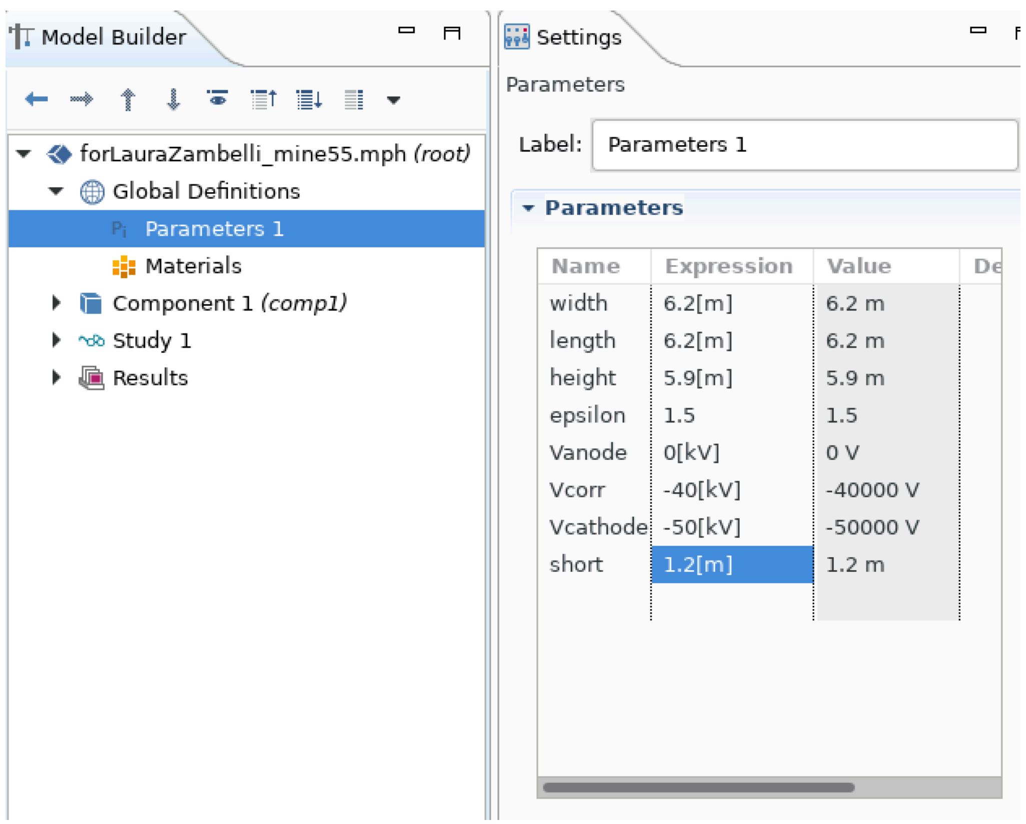


FYI : I'll be using the non-LArsoft coordinate where z is along the cathode->anode axis and the (0,0,0) is at the center of the detector

Drift field with short

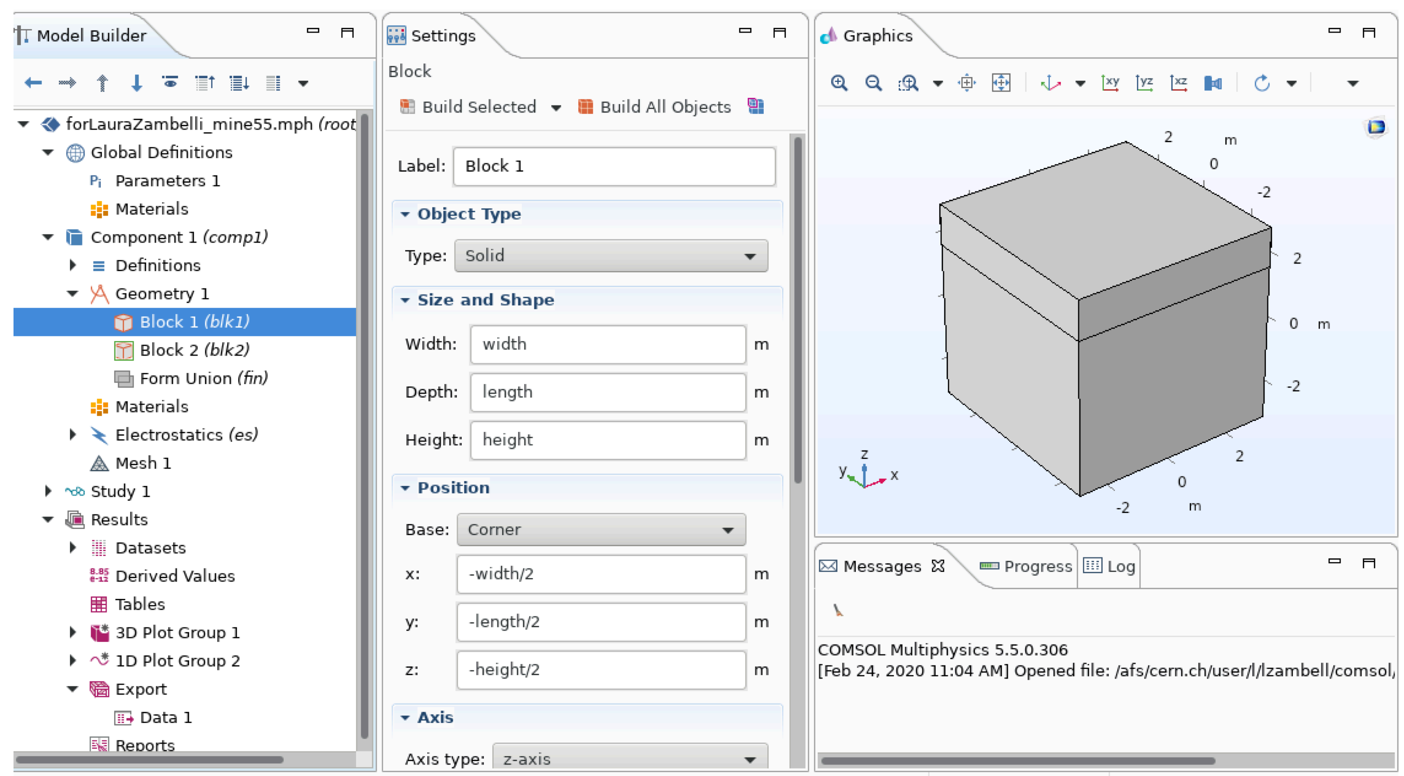
Open COMSOL > Wizard > 3D > AC/DC > Electric Fields & Current > Electrostatics > Stationary

1. Define a set of useful parameters



-> Voltage at short is 10kV lower than cathode (?)

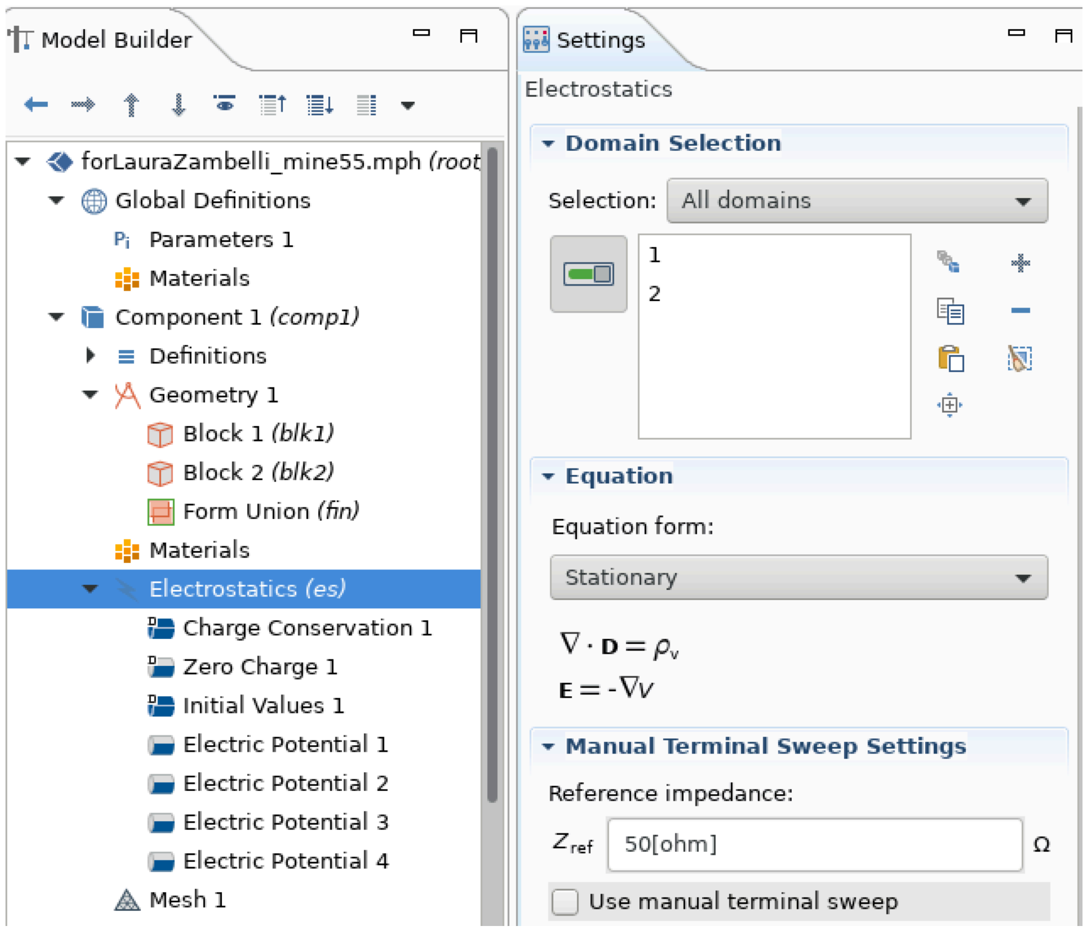
2. Define the geometry (in our case 2 cubes)



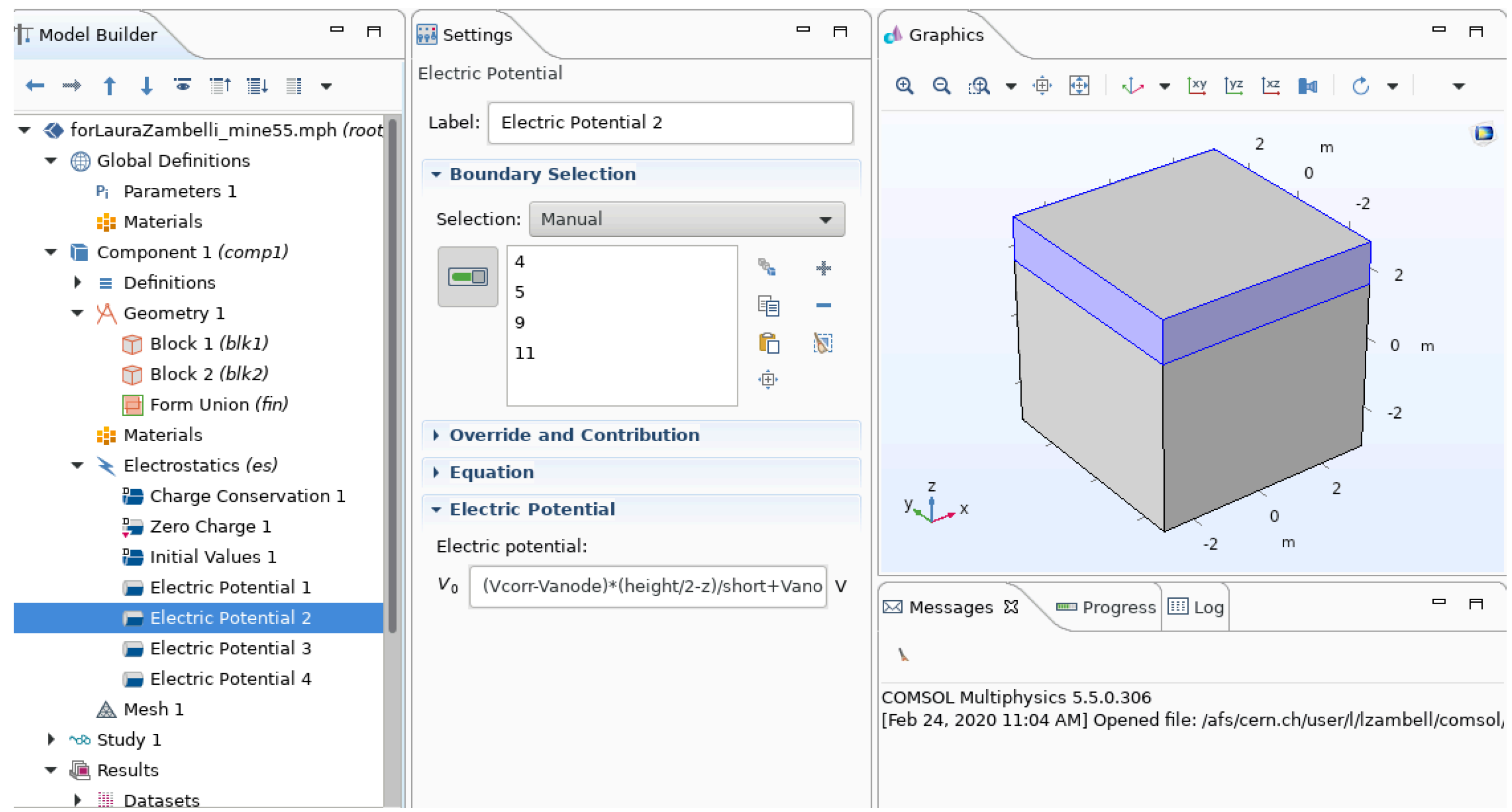
-> Above short ; Below short

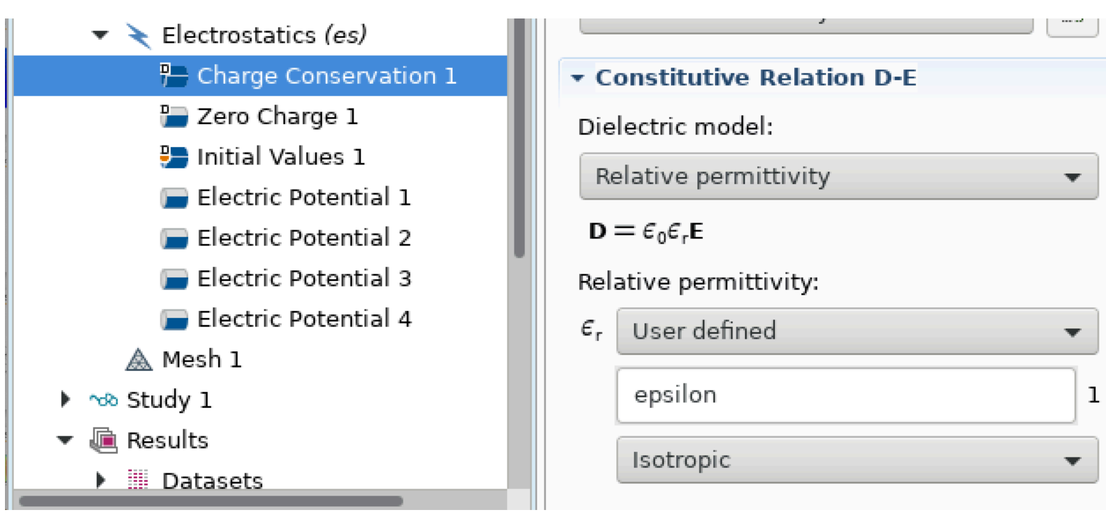
Drift field with short

3. Define the physics



4. Define the electric potentials

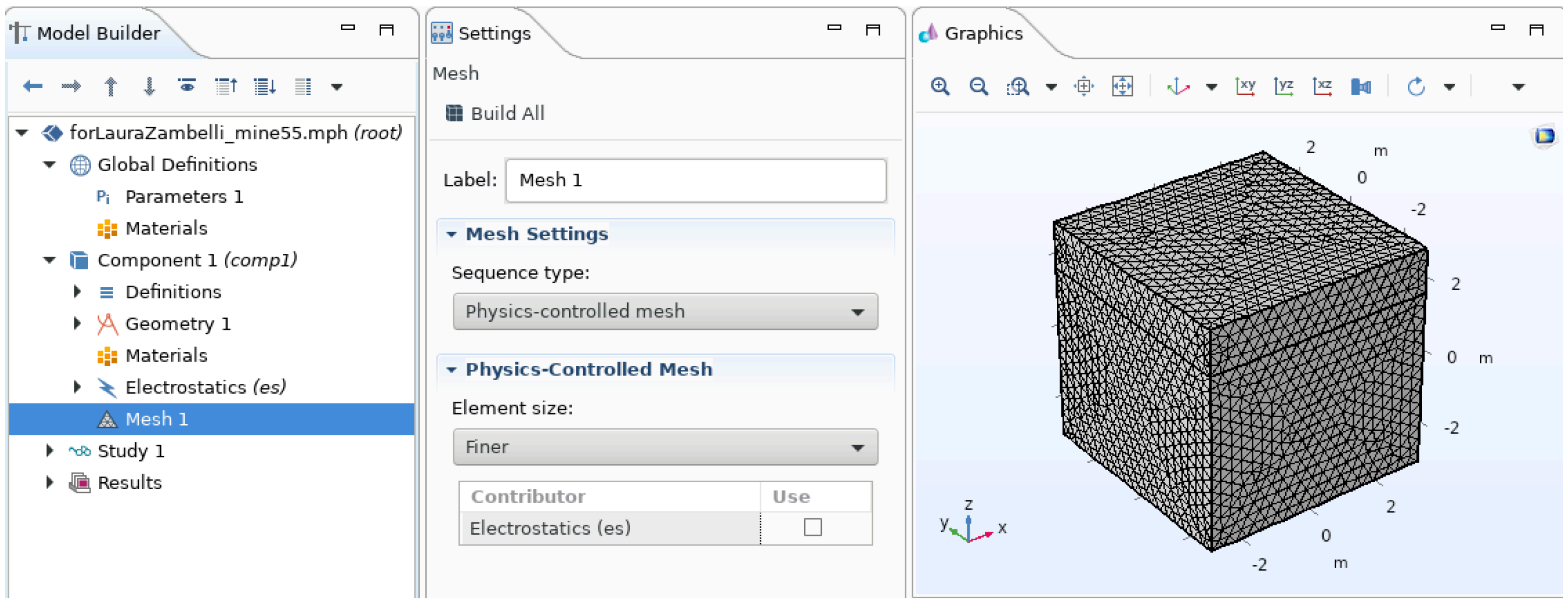




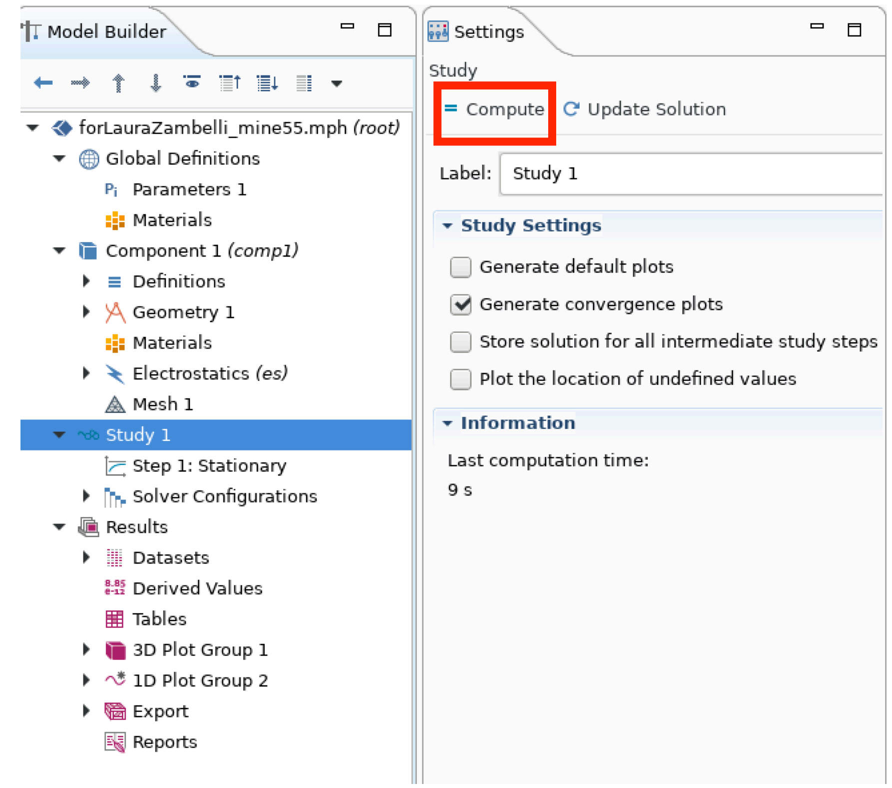
a plane for the anode & cathode
z-dependent potentials for anode->short
and short->cathode

Drift field with short

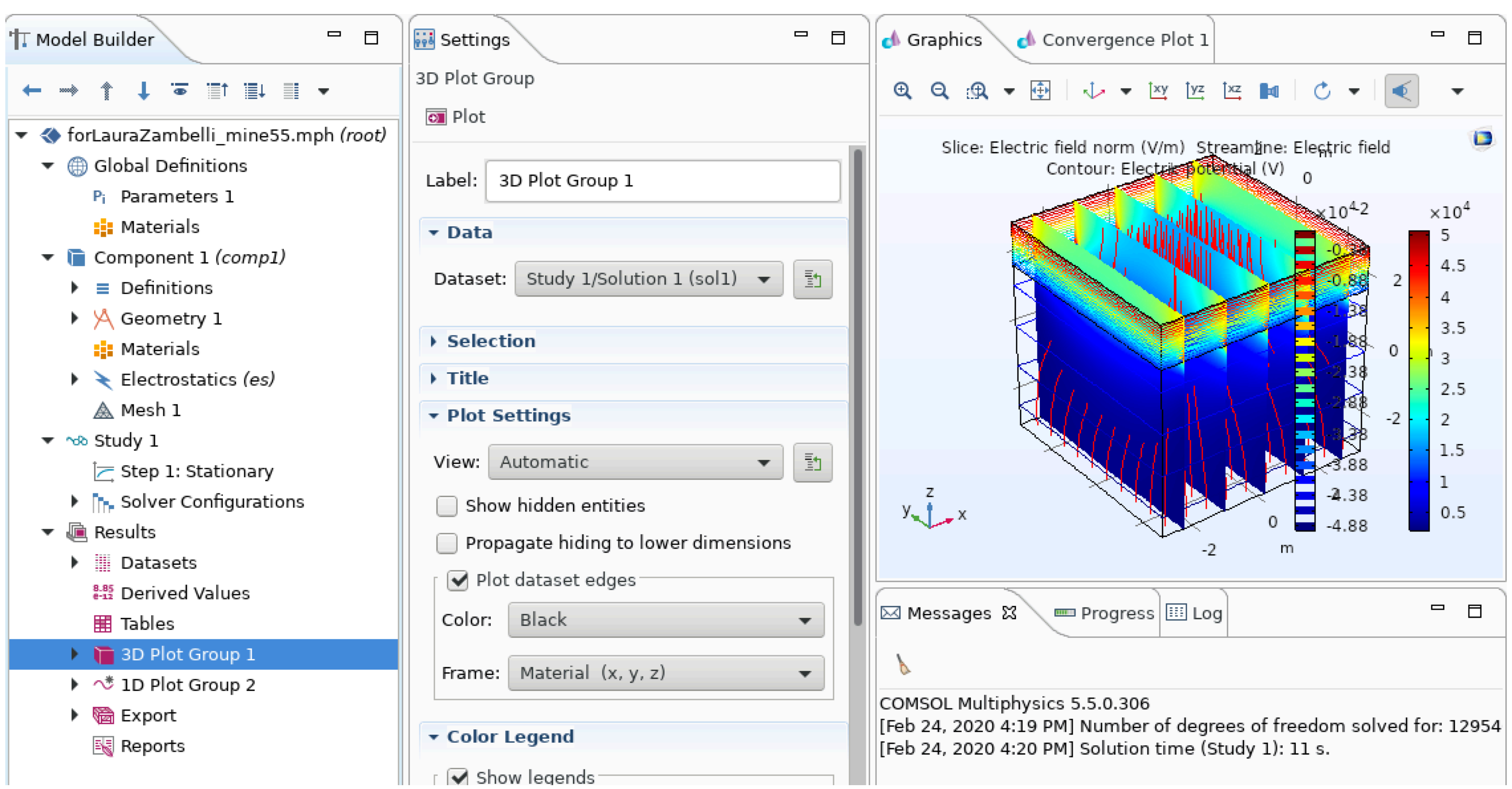
5. Discretize the volumes



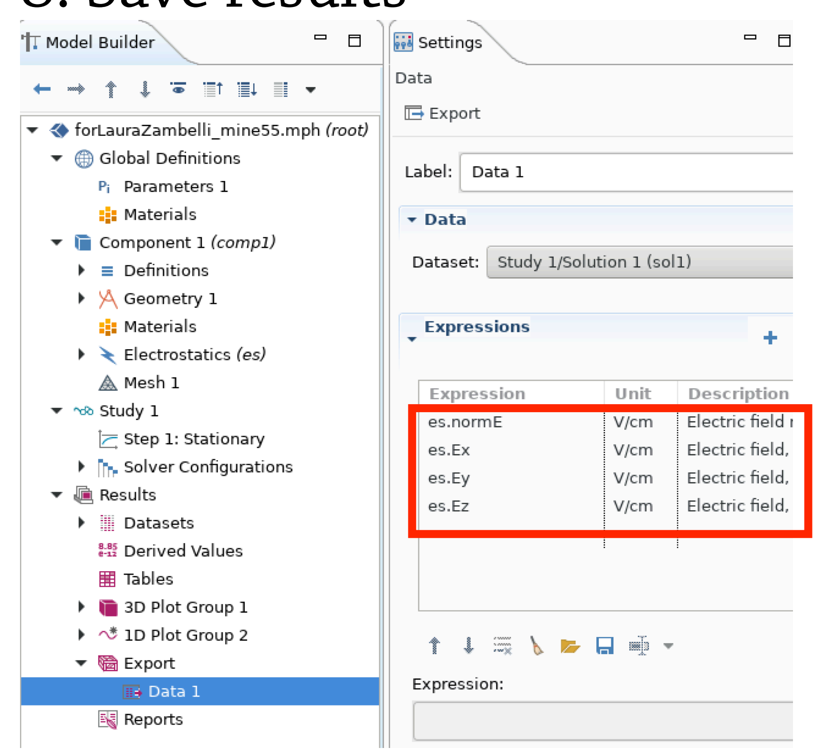
6. Compute solution



7. Get the results



8. Save results



Drift field with short - things to be improved

To be improved :

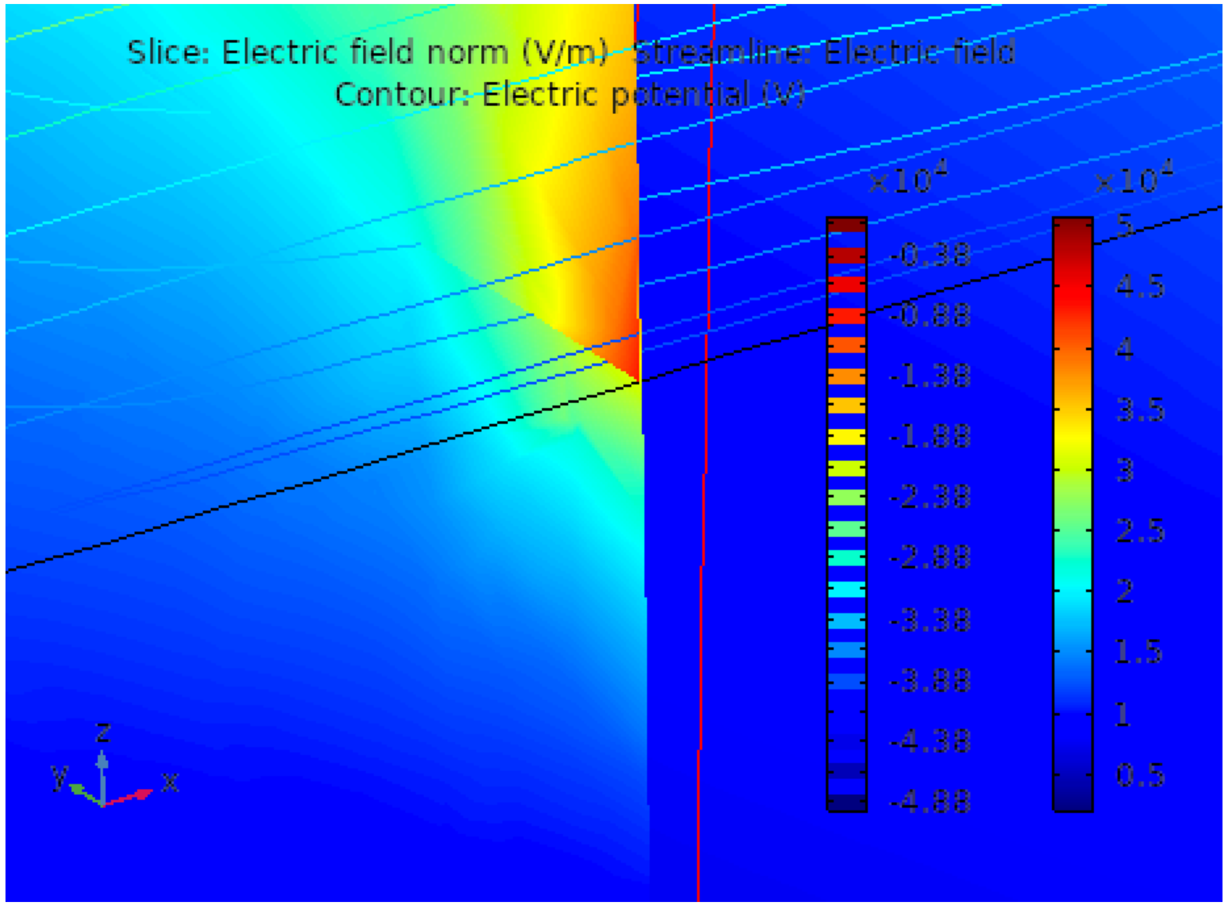
- more precise values of detector geometry (h×w×l), short position

- Do we include the field cage rings ? (there is a possibility to import CAD drawings - don't know how though) the FFS ?

- There is a field discontinuity at z = short : this is a problem with the interpolation : shall we build 2 maps ?

- For the light analysis, it is also important to take into account the field below the cathode (which is reversed and much higher than inside the charge fiducial volume) -> there will be an other discontinuity (at z = cathode) : shall we build 3 maps ?

ZOOM AROUND SHORT POSITION



COMSOL output and map maker

From the COMSOL output

```
% Model:              forLauraZambelli_mine55.mph
% Version:            COMSOL 5.5.0.306
% Date:               Feb 21 2020, 10:32
% Dimension:          3
% Nodes:              8000
% Expressions:        4
% Description:        Electric field norm, Electric field, x component, Electric field, y component, Electric field, z component
% Length unit:        m
% x                      y                         z                         es.normE (V/cm)           es.Ex (V/cm)              es.Ey (V/cm)              es.Ez (V/cm)
-3.1                     -3.1                      -2.95                     21.27659574468044         -1.9498071709883244E-13   -2.1996135564251026E-13   -21.27659574468044
-2.7736842105263158      -3.1                      -2.95                     21.276595744679113        2.2637891561316792E-13    5.345768272491114E-13     -21.276595744679113
-2.447368421052632       -3.1                      -2.95                     21.276595744681426        1.224090135811613E-13     4.3298958059227405E-13    -21.276595744681426
```

From each of these points, "electrons" are "transported" to the detector boundary, by steps of 1mm:
- start at (x0,y0,z0), field is (Ex0,Ey0,Ez0)
- next point will be at (x1,y1,z1) = (x0+Ex0/Etot, y0 + Ey0/Etot, z0 + Ez0/Etot)
- etc

At each step :
- increment distance travelled
- increment drifting time(+= step/vdrift(Etot))
- increment the transverse and longitudinal diffusion (field dependent, see here for more details)

Once boundary is reached :
- store x and y displacement

All these parameters (plus field value) are then stored in 3D histograms -> the field maps
An 3D interpolation is used to "propagate" the "electrons"

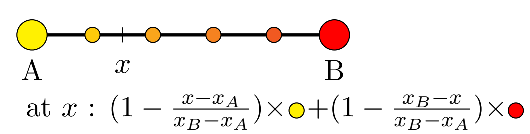
Interpolation

So far, I've generated maps with 20 bins/axis <-> a precision of (326.3×326.3×310.5) mm^3
The choice of the binning is a trade between precision (esp. in region with rapid change) , CPU time and output file size

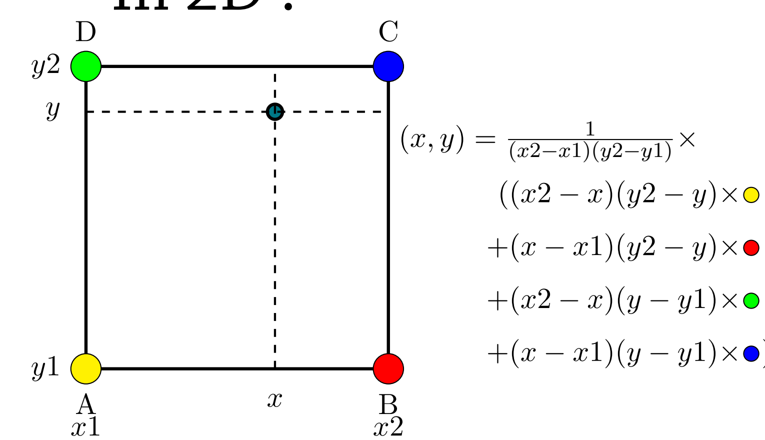
In the simulation, when electrons are produced at (x,y,z) coordinate, their arrival time and position on the anode are determined from a 3D interpolation from the 8-nearby point stored in the maps

it's a weighted average, see:
https://en.wikipedia.org/wiki/Trilinear_interpolation

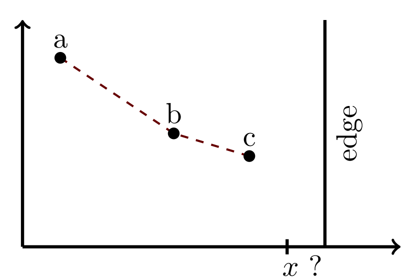
In 1D :



In 2D :

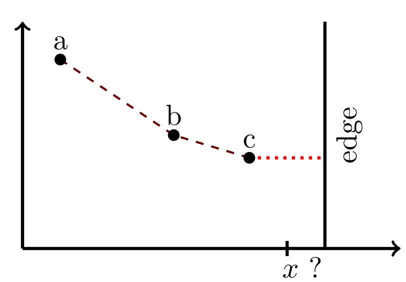


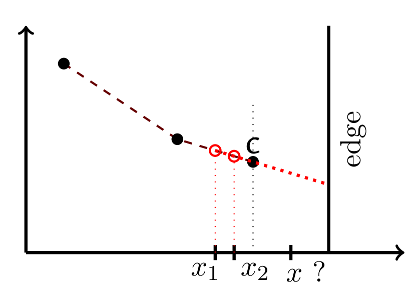
Near the boundary :
standard problem - want to know the value at x given that the last known point is c



extrapolation way : make extrapolation from interpolated points around the last value

easy way : assume no further variation from the last point



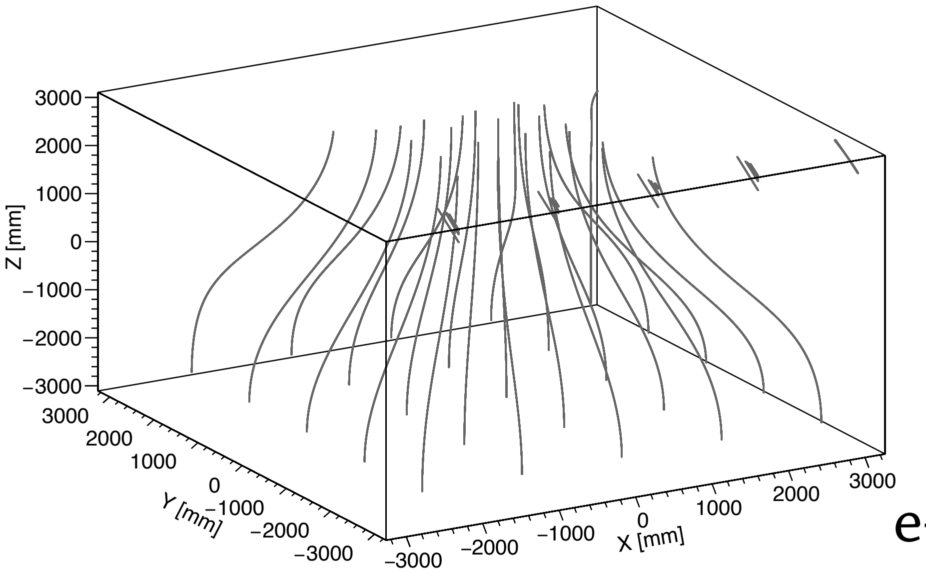


x_1 is the symmetric of x wrt c
x_2 is in between x_1 and c

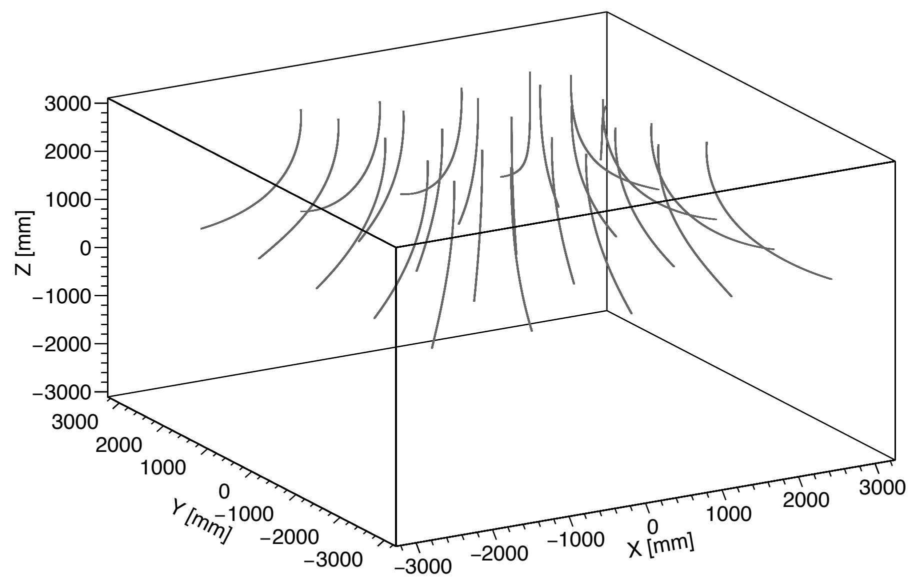
$$y = \frac{y_1 - y_2}{x_1 - x_2}x + \frac{x_1 y_2 - y_2 y_1}{x_1 - x2}$$

666 Short with Vcathode = 50kV

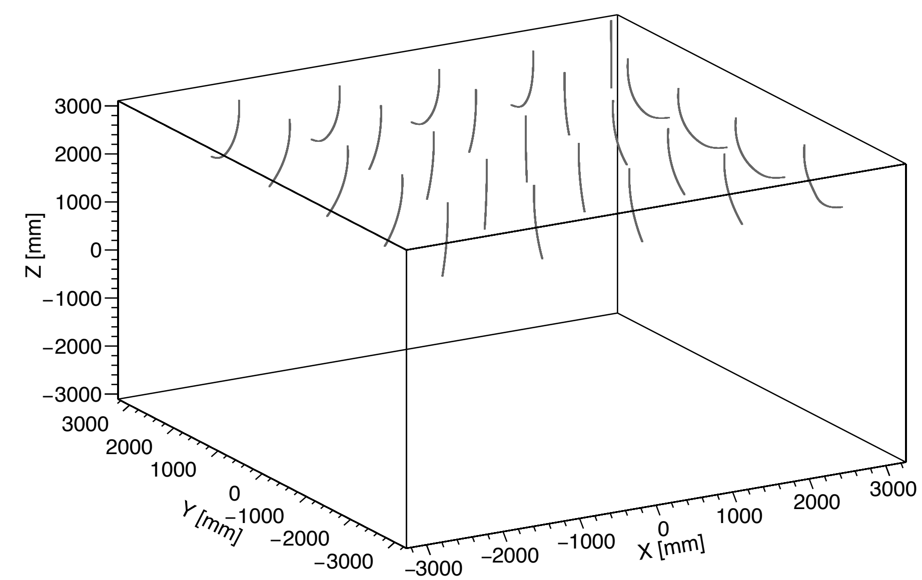
e- drift lines from cathode



e- drift lines from center of the detector

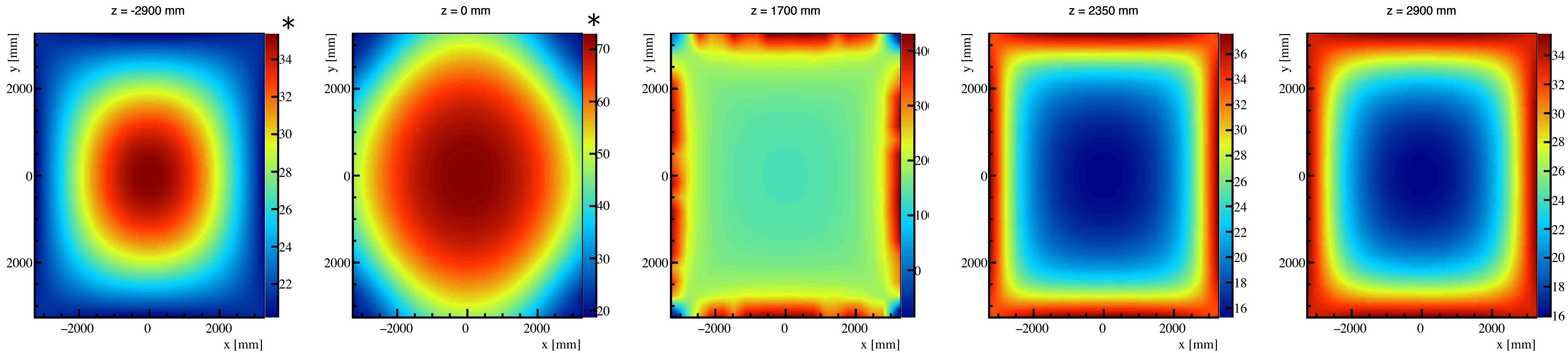


e- drift lines from the short

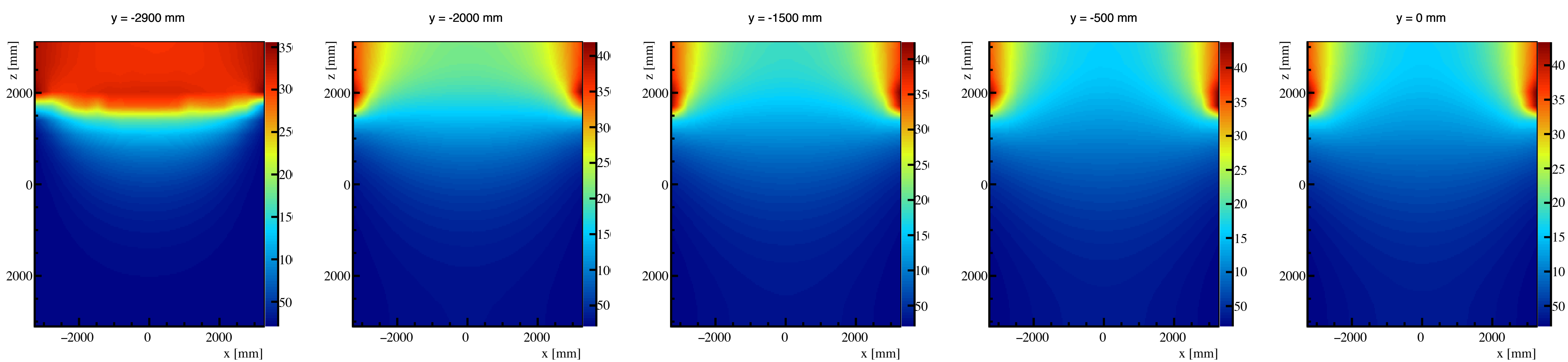


666 Short with Vcathode = 50kV

Values of the drift field at different z positions

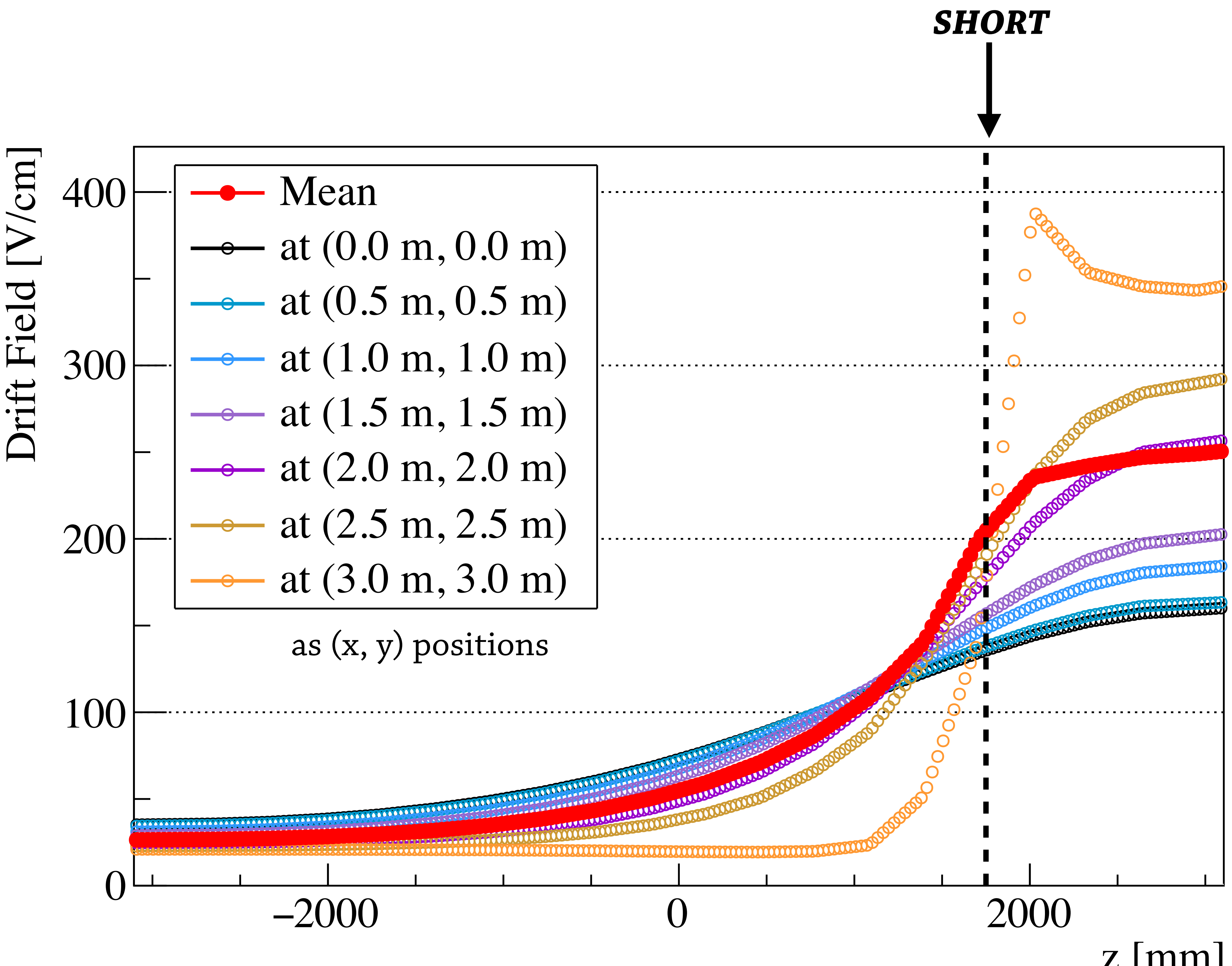


Values of the drift field at different y positions

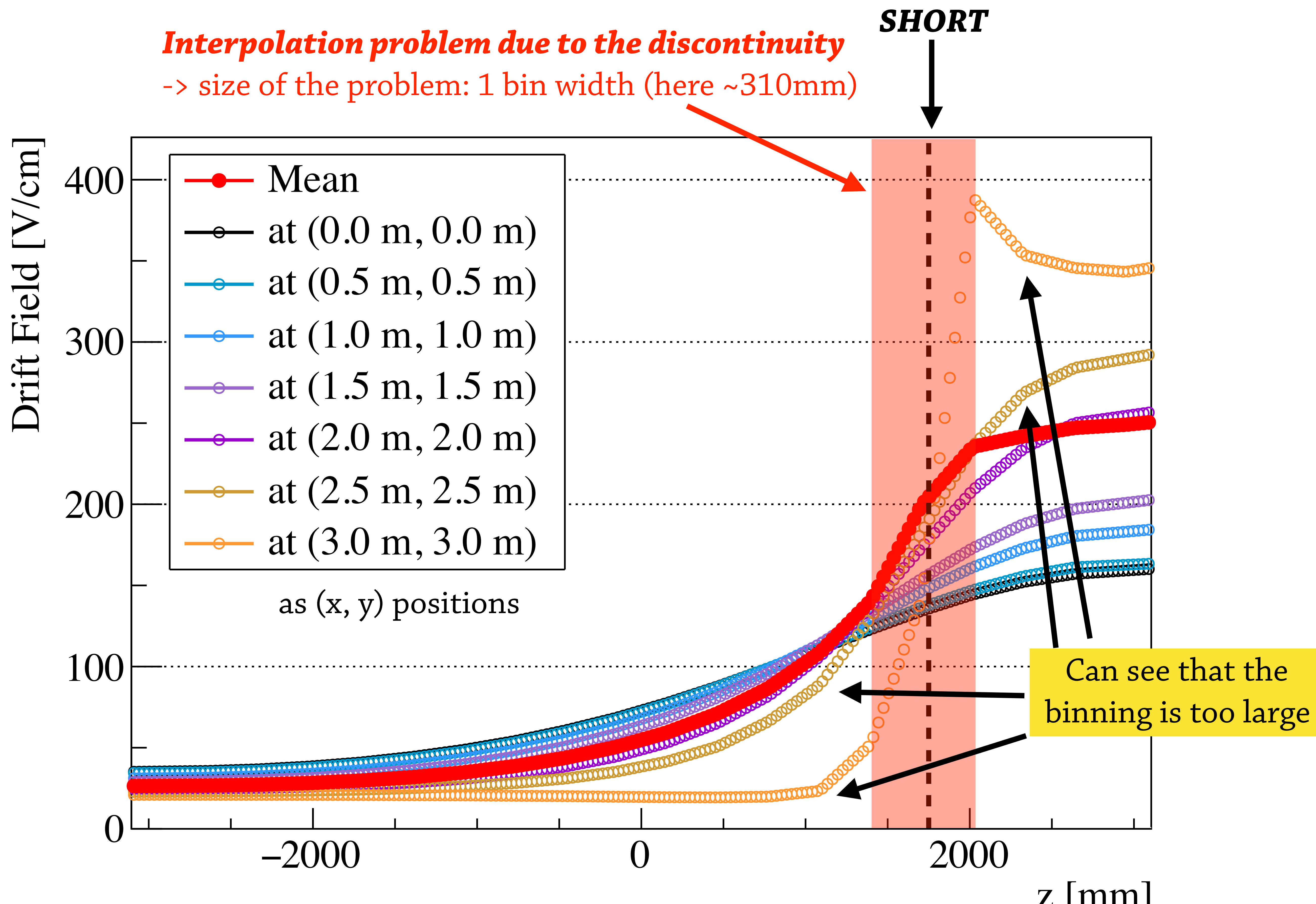


NB : apart from plots marked with *, the last digit on z-scale is cut (which is the field in V/cm)

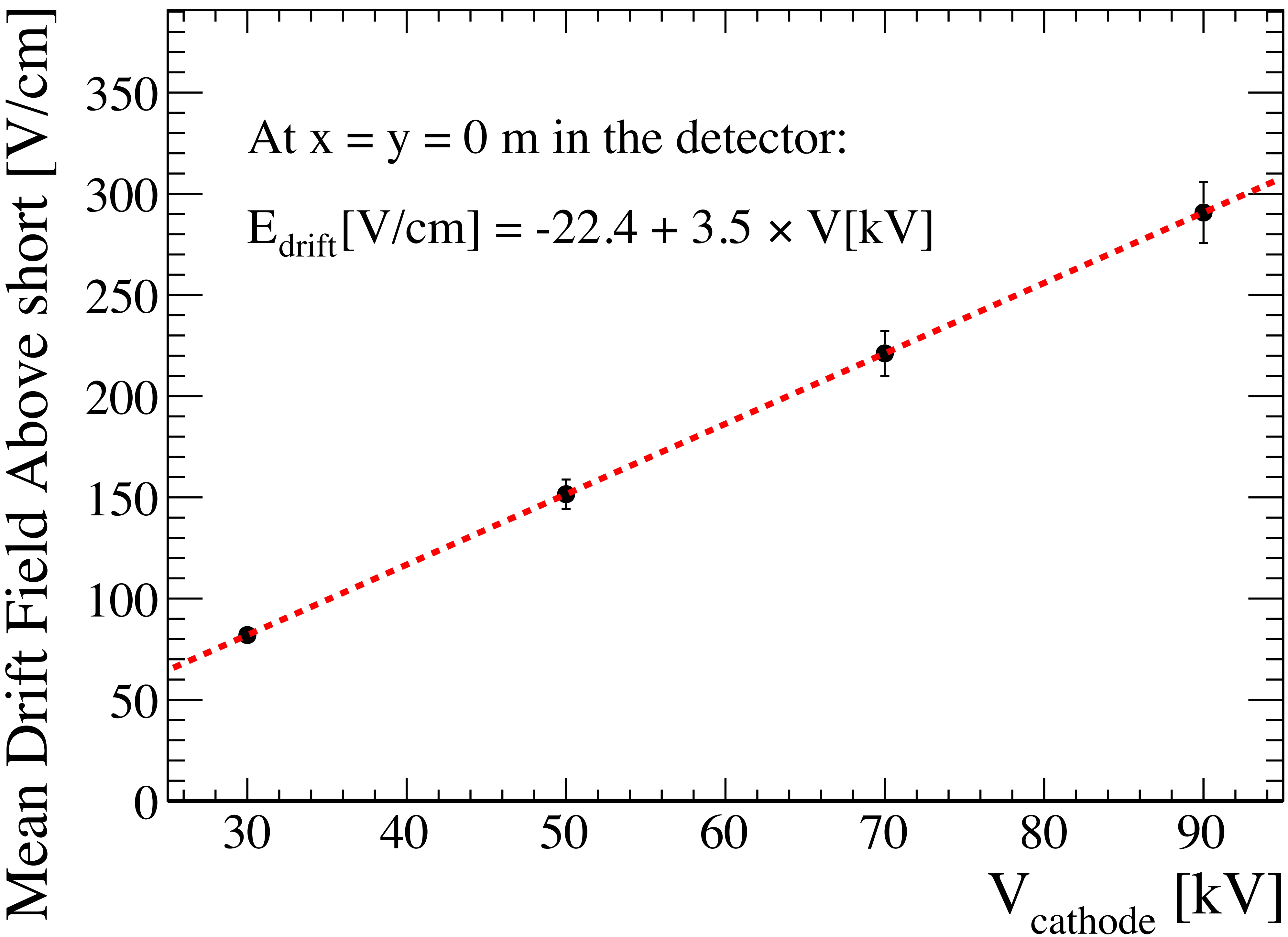
666 Short with Vcathode = 50kV



666 Short with Vcathode = 50kV



Drift Field with Vcathode



Drift Field with Vcathode