COMSOL SIMULATIONS AND ELECTRIC FIELD MAP GENERATION

Laura Zambelli - LAPP/CNRS Wednesday February 26th 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 <u>http://information-technology.web.cern.ch/services/software/comsol</u> It comes with one restriction : you have to be physically at cern to run it (no ssh tunneling would work).

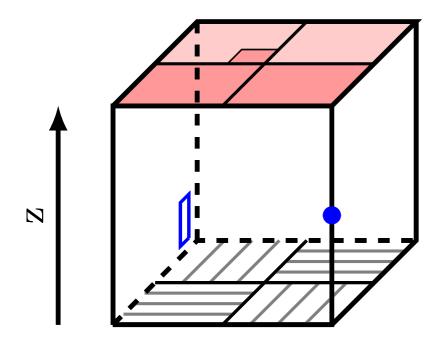
Caveat : I've never used COMSOL up to last week, I was only handling the output given to me by someone else

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

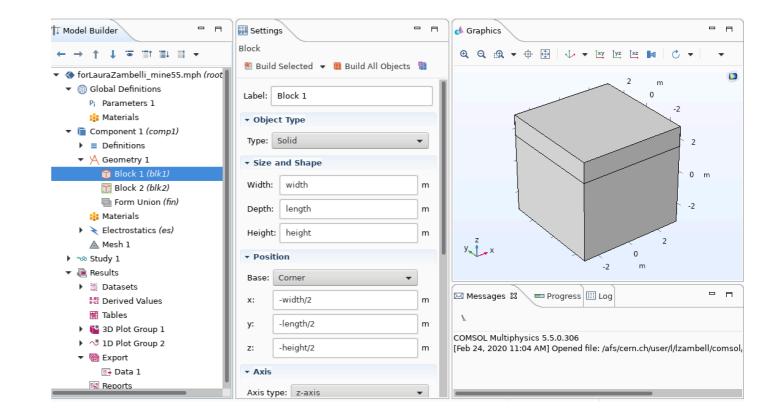
Open COMSOL > Wizard > 3D > AC/DC > Electric Fields & Current > Electrostatics > Stationary

1. Define a set of useful parameters

Model Builder 🗖 🗖	Settings	
← → ↑ ↓ ☜ ≣† ≣∔ ≣ ▼	Parameters	
 ✓ forLauraZambelli_mine55.mph (root) ✓ () Global Definitions 		
Pi Parameters 1	▼ Parameters	
🚦 Materials	Name Expression Value	De
Temponent 1 (comp1)	width 6.2[m] 6.2 m	
🕨 👒 Study 1	length 6.2[m] 6.2 m	
🕨 📠 Results	height 5.9[m] 5.9 m	
	epsilon 1.5 1.5	
	Vanode 0[kV] 0 V	
	Vcorr -40[kV] -40000 V	
	Vcathode -50[kV] -50000 V	
	short 1.2[m] 1.2 m	

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

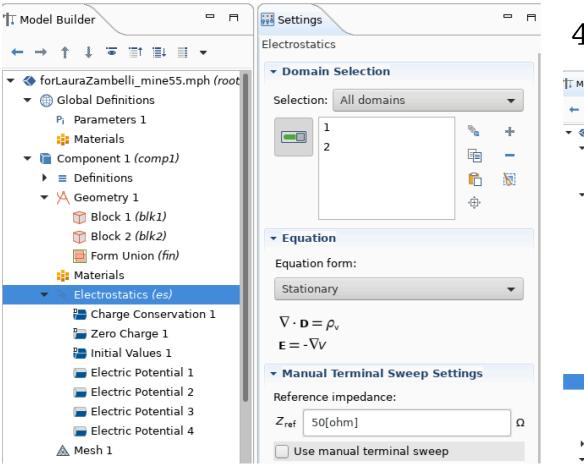
2. Define the geometry (in our case 2 cubes)

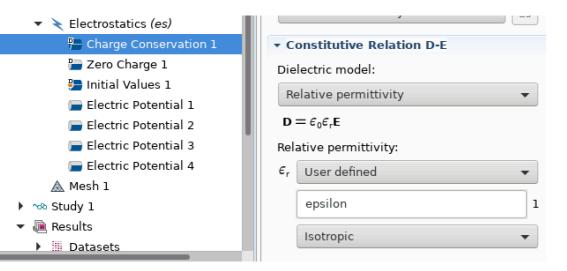


-> Above short ; Below short

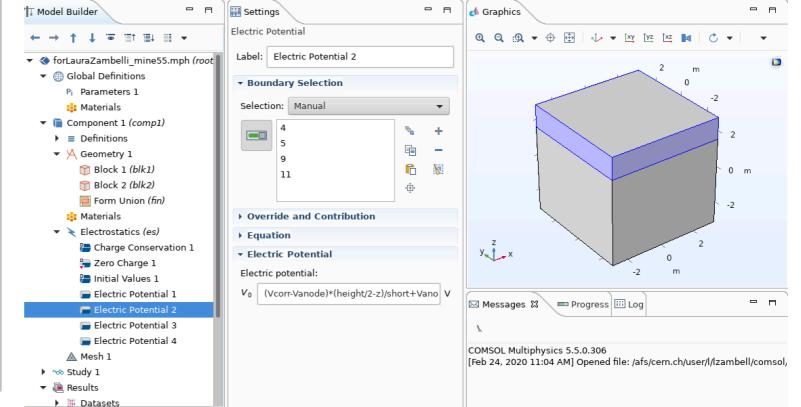
Drift field with short

3. Define the physics





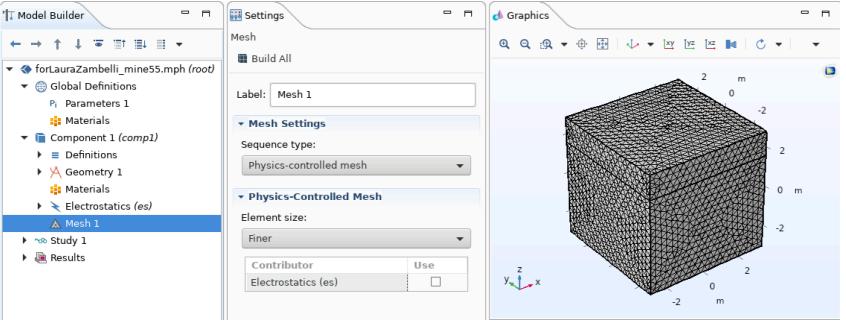
4. Define the electric potentials



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

'† Model Builder 🗧 🗖	Settings 🗖 🗖
 ← → ↑ ↓ ✓ forLauraZambelli_mine55.mph (root) ✓ ⊕ Global Definitions Pi Parameters 1 ⋮ Materials ✓ ● Component 1 (comp1) ▷ ■ Definitions ▷ ▲ Geometry 1 ⋮ Materials ▷ ▲ Electrostatics (es) ▲ Mesh 1 	Study C Update Solution Label: Study 1 Study Settings Generate default plots Generate convergence plots Store solution for all intermediate study steps Plot the location of undefined values
 Study 1 Step 1: Stationary Solver Configurations Results Datasets Derived Values Tables 3D Plot Group 1 1D Plot Group 2 Export Reports 	 Information Last computation time: 9 s

7. Get the results

'∏ Model Builder □ 🗖	🖬 Settings 📃 🗖	📣 Graphics 🔥 Convergence Plot 1 🗖 🗖
	3D Plot Group	Q, Q, :,Q, ▼ ∰ ↓ ▼ № № № № № Č ▼ € ▼
 ✓ § forLauraZambelli_mine55.mph (root) ✓ ⊕ Global Definitions 	Label: 3D Plot Group 1	Slice: Electric field norm (V/m) Streamtine: Electric field Contour: Electric potential (V) 0
Pi Parameters 1 :: Materials • Component 1 (comp1)	▼ Data	10 ⁴² ×10 ⁴
 Definitions A Geometry 1 	Dataset: Study 1/Solution 1 (sol1) 🔻	
 Materials Electrostatics (es) 	Selection Title	
▲ Mesh 1 ▼ → Study 1 ▷ Step 1: Stationary	✓ Plot Settings View: Automatic ✓	
 Solver Configurations Results 	Show hidden entities	y x 0 -2.38 1 0.5
 Datasets Derived Values 	Propagate hiding to lower dimensions Plot dataset edges	
III Tables	Color: Black Frame: Material (x, y, z)	Messages X Progress III Log
 ID Plot Group 2 Image Export Reports 	Color Legend	COMSOL Multiphysics 5.5.0.306 [Feb 24, 2020 4:19 PM] Number of degrees of freedom solved for: 12954 [Feb 24, 2020 4:20 PM] Solution time (Study 1): 11 s.
	ſ 🖌 Show legends	

8. Save results

'∏ Model Builder □ 🗖	🖼 Settings 📃 🗖
	Data
 forLauraZambelli_mine55.mph (root) Global Definitions Pi Parameters 1 Materials Component 1 (comp1) Definitions Geometry 1 Materials 	Expressions
 Electrostatics (es) Mesh 1 Study 1 Step 1: Stationary Solver Configurations Results Datasets 	Expression Unit Description es.normE V/cm Electric field i es.Ex V/cm Electric field, es.Ey V/cm Electric field, es.Ez V/cm Electric field,
Image: Series of Control of Contro of Contro of Control of Control of Control of Control	↑ ↓ ≔ ∖ ► ⊟ ঊ ▼ Expression:

Drift field with short - things to be improved

To be improved :

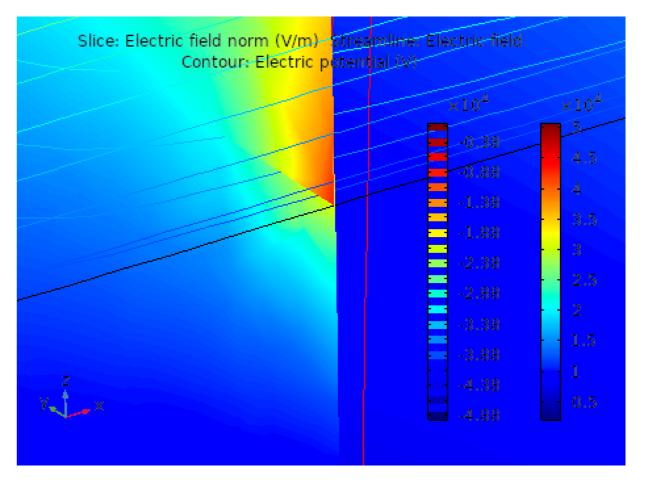
 more precise values of detector geometry (h×w×l), short position

• 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_mi	ine55.mph				
% Version:	COMSOL 5.5.0.306					
% Date:	Feb 21 2020, 10:32					
<pre>% Dimension:</pre>	3					
% Nodes:	8000					
<pre>% Expressions:</pre>	4					
<pre>% Description:</pre>	Electric field norm	m, Electric field, x compo	nent, Electric field, y componer	nt, Electric field, z compon	ent	
<pre>% Length unit:</pre>	m					
% X	У	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 :

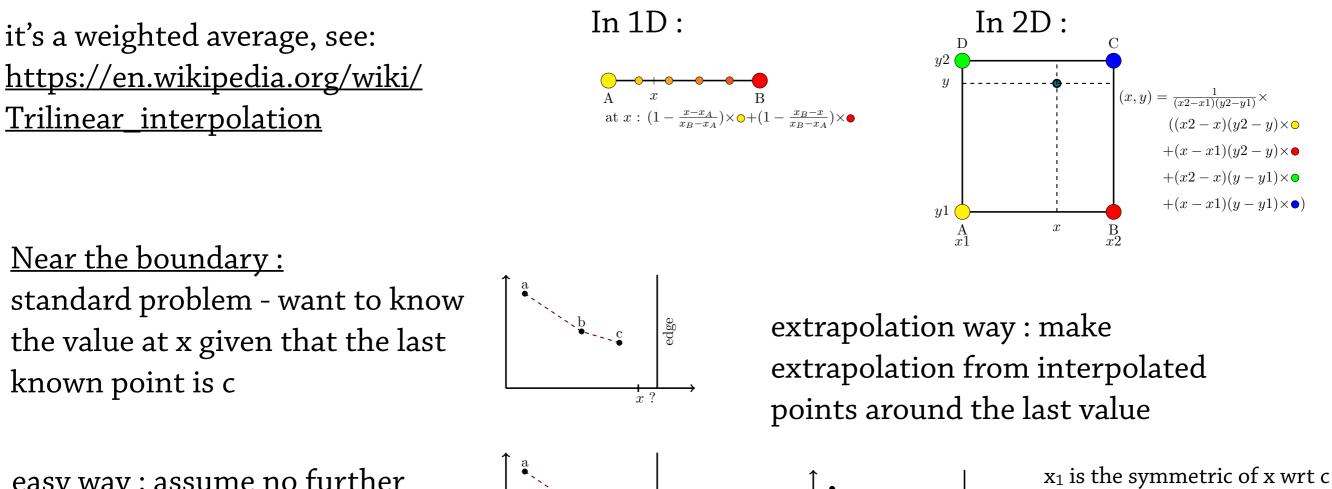
- store x and y displacement

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) mm³ The choice of the binning is a trade between precision (esp. in region with rapid change), CPU time and output file size

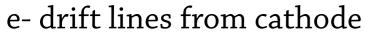
In the simulation, when electrons are produced at (x,y,z) coordinate, their arrival time and position on the anode are determined from a 3D interpolation from the 8-nearby point stored in the maps

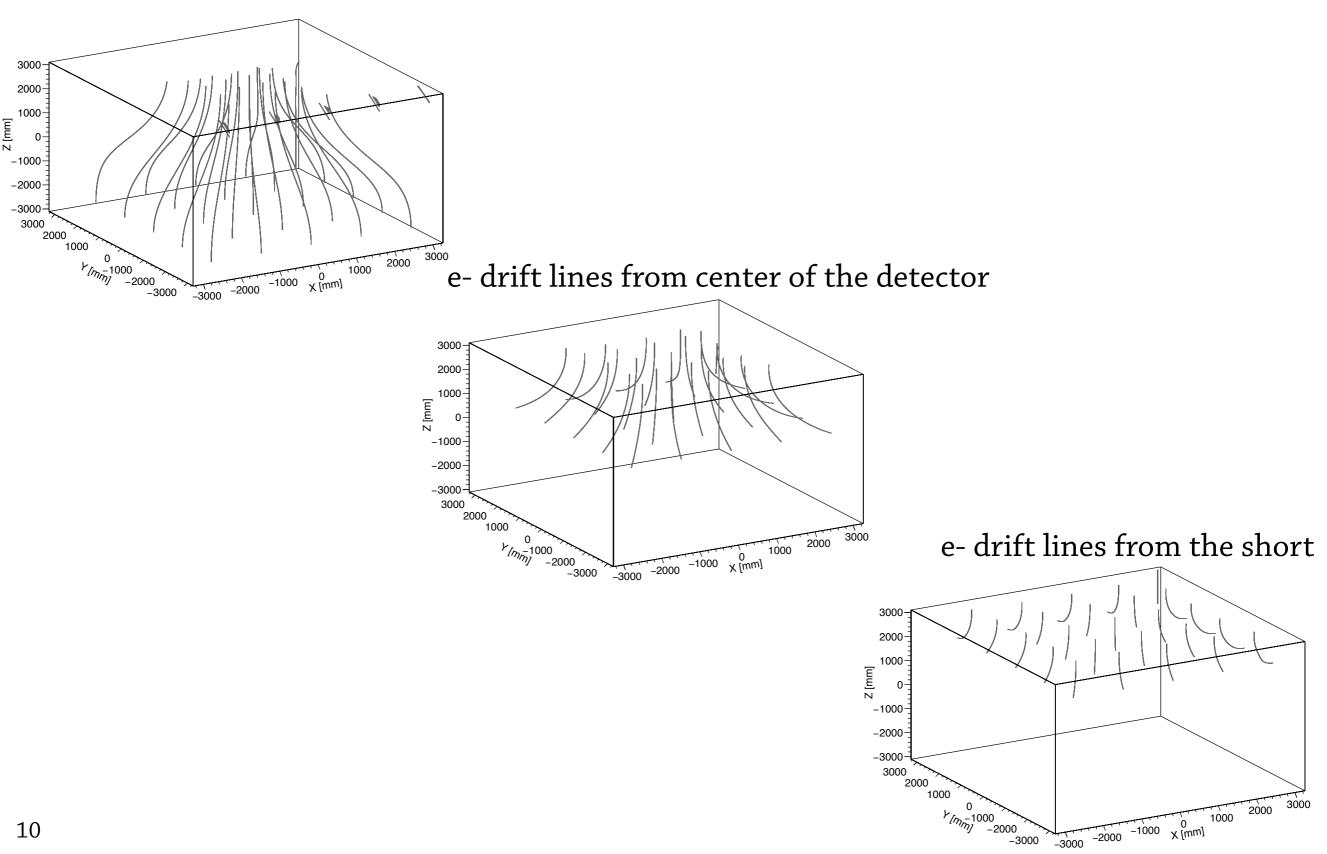


 x_2 is in between x_1 and c

 $y = \frac{y_1 - y_2}{x_1 - x_2}x + \frac{x_1y_2 - y_2y_1}{x_1 - x_2}$

easy way : assume no further variation from the last point

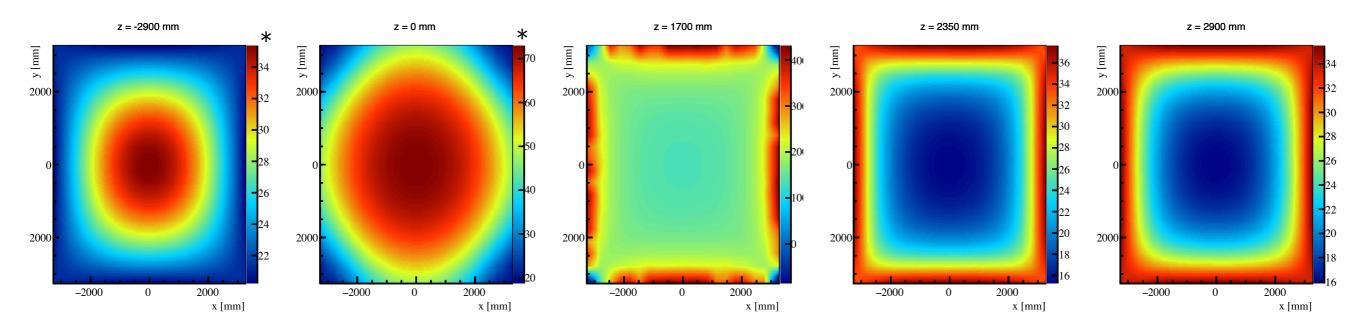




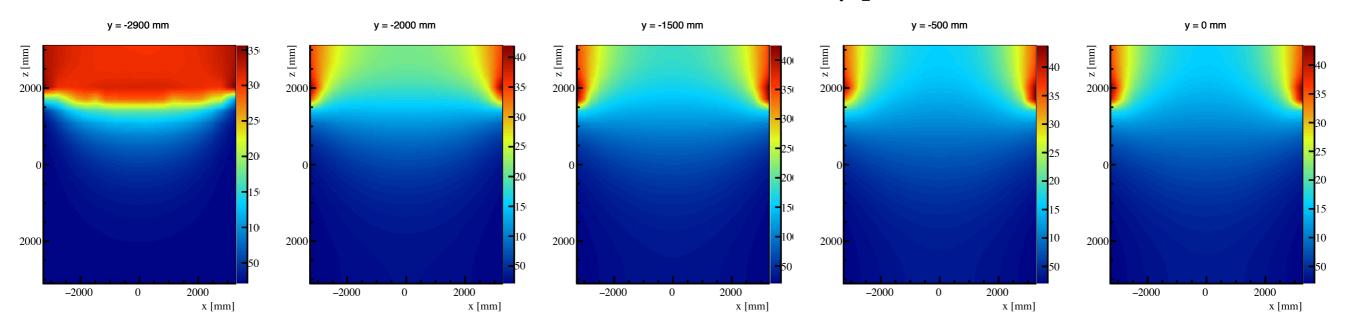
-3000

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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)

