Report on GEM Standalone Simulation Studies

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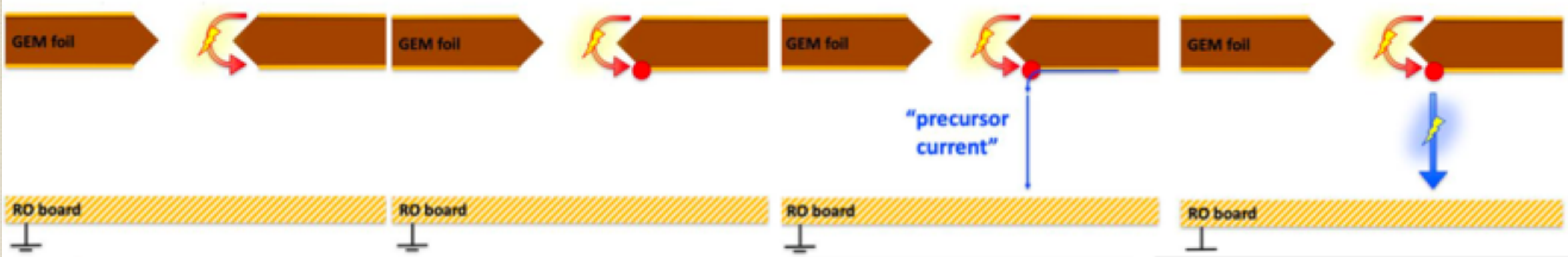
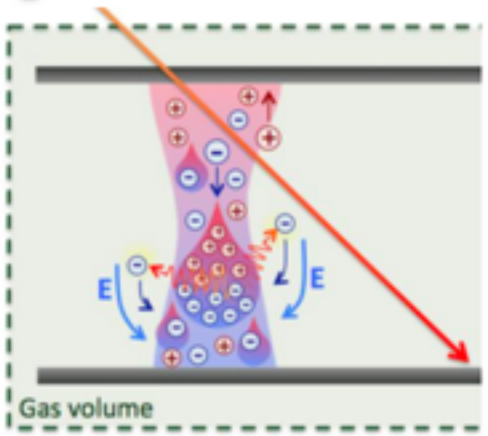
GEM Detector Simulation group

GEM Workshop, Sep 30 - Oct 4, 2019

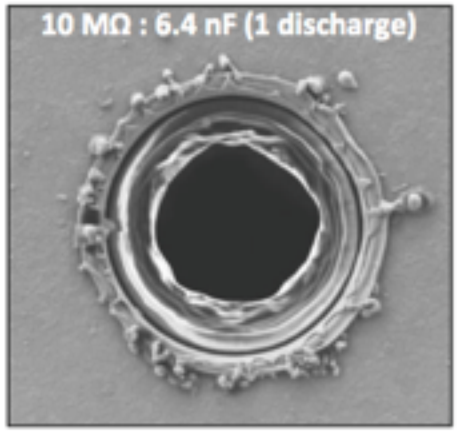
GE1/1 Operation

Discharge Propagation Principle



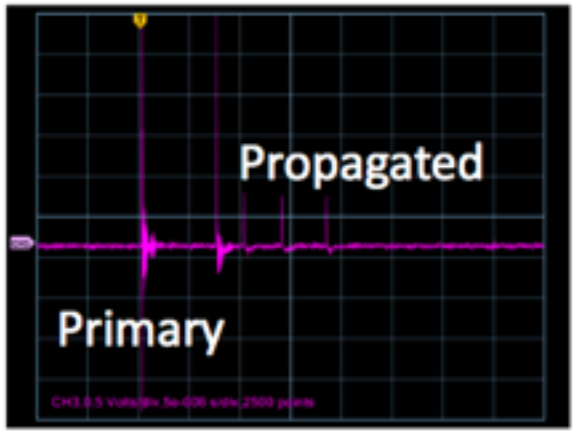


Typical development of avalanche into a streamer



SEM picture of a GEM hole (bottom) after one discharge with an energy of 2.0 mJ

A. Utrobičić et al. (University of Zagreb), MPGD Stability Workshop June 2018



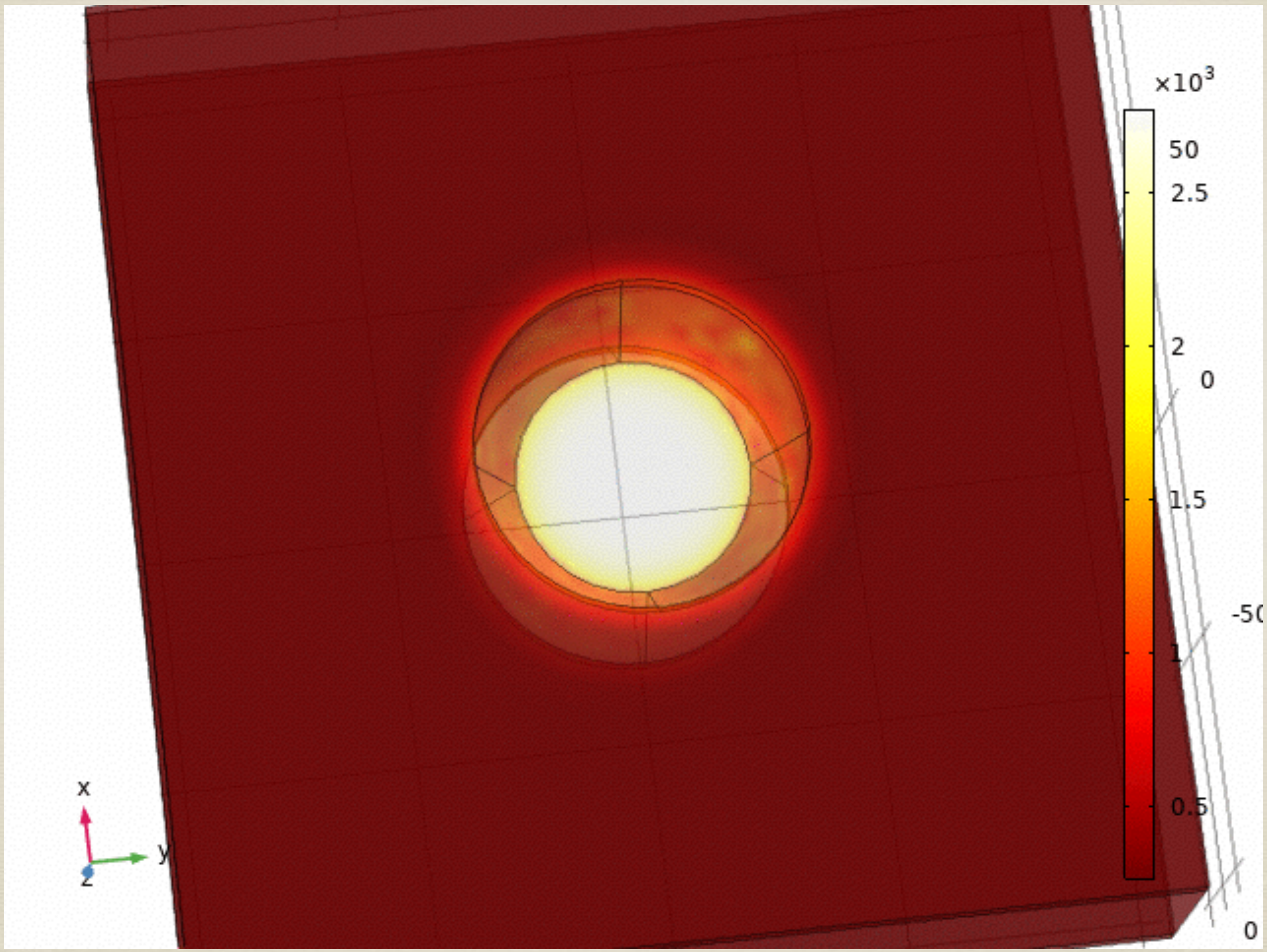
Typical EM interferences caused by propagating discharges in GEM detectors

- **Step 1:**
  Primary discharged caused by the increase of the space charge density in the avalanche
- **Step 2:**
  Creation of a hot spot on the copper near the hole rim >2500 °C
- **Step 3:**
  Thermionic emission of electrons in the gas, enhanced by local electric field (Schottky effect)
- **Step 4:**
  Development of the precursor current into a streamer causing a second discharge

Extensive study initiated by Alice and RD51 communities (Technical University of Munich, University of Zagreb et al.)

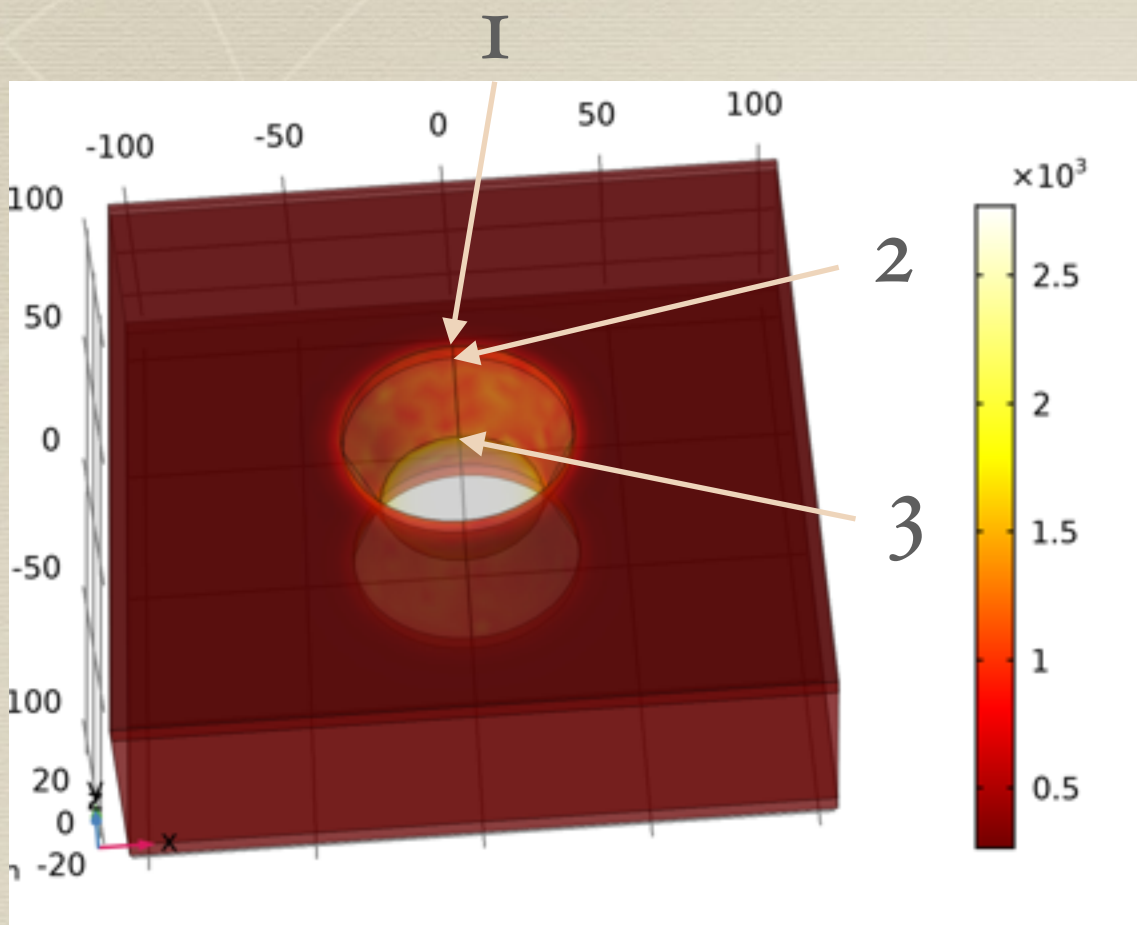
Heat Transfer Study

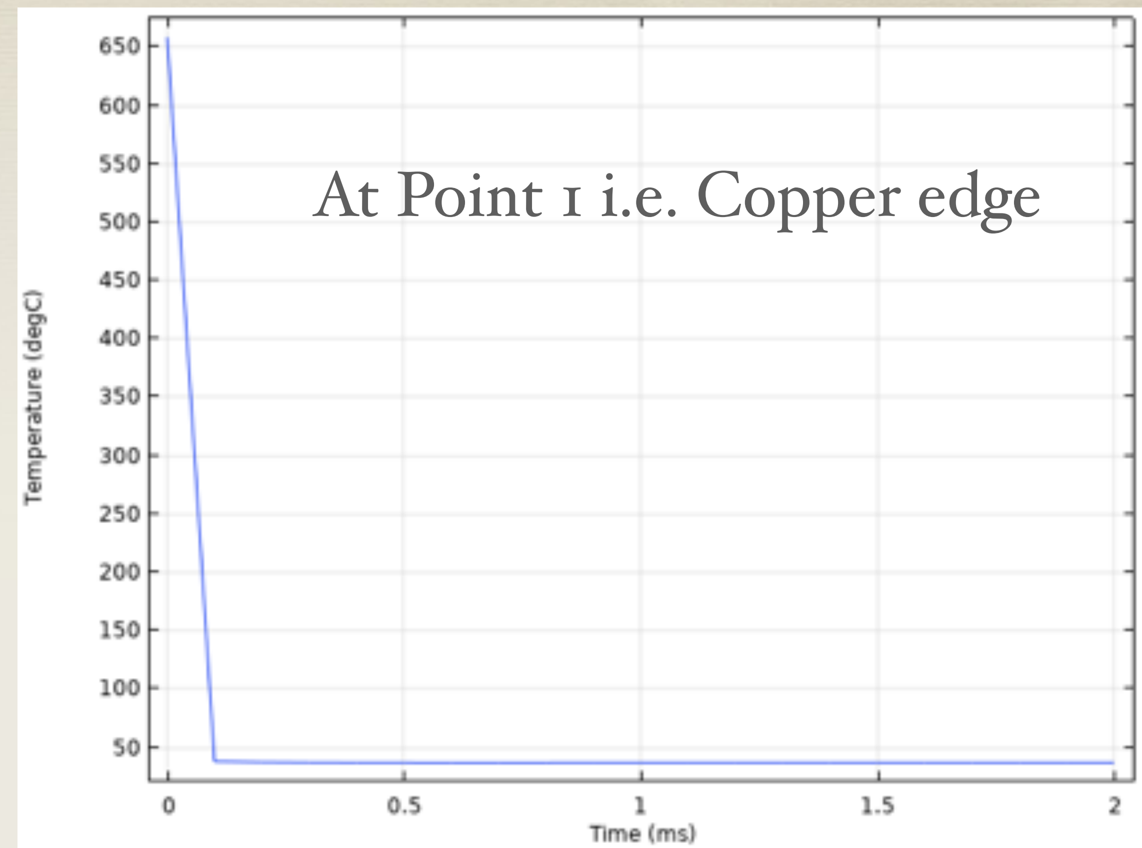
3-D Model of a single hole GEM foil with 2500 °C inside hole

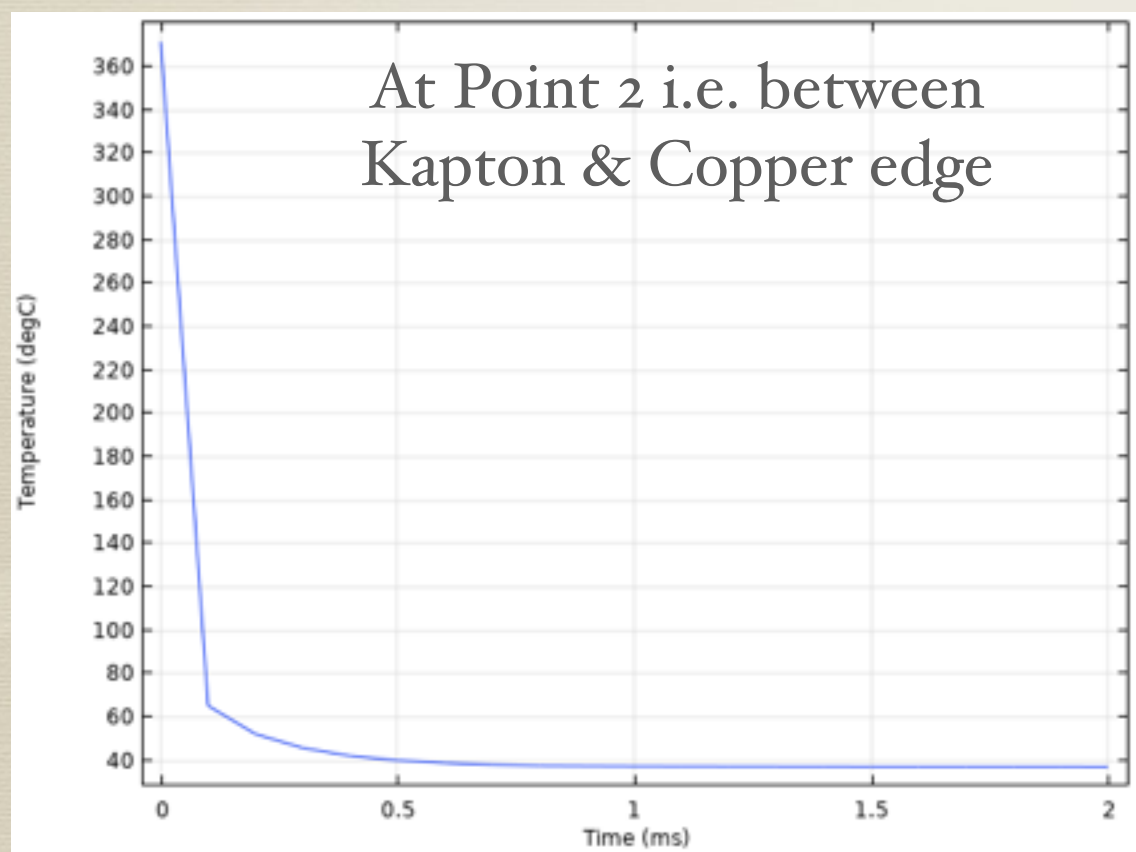


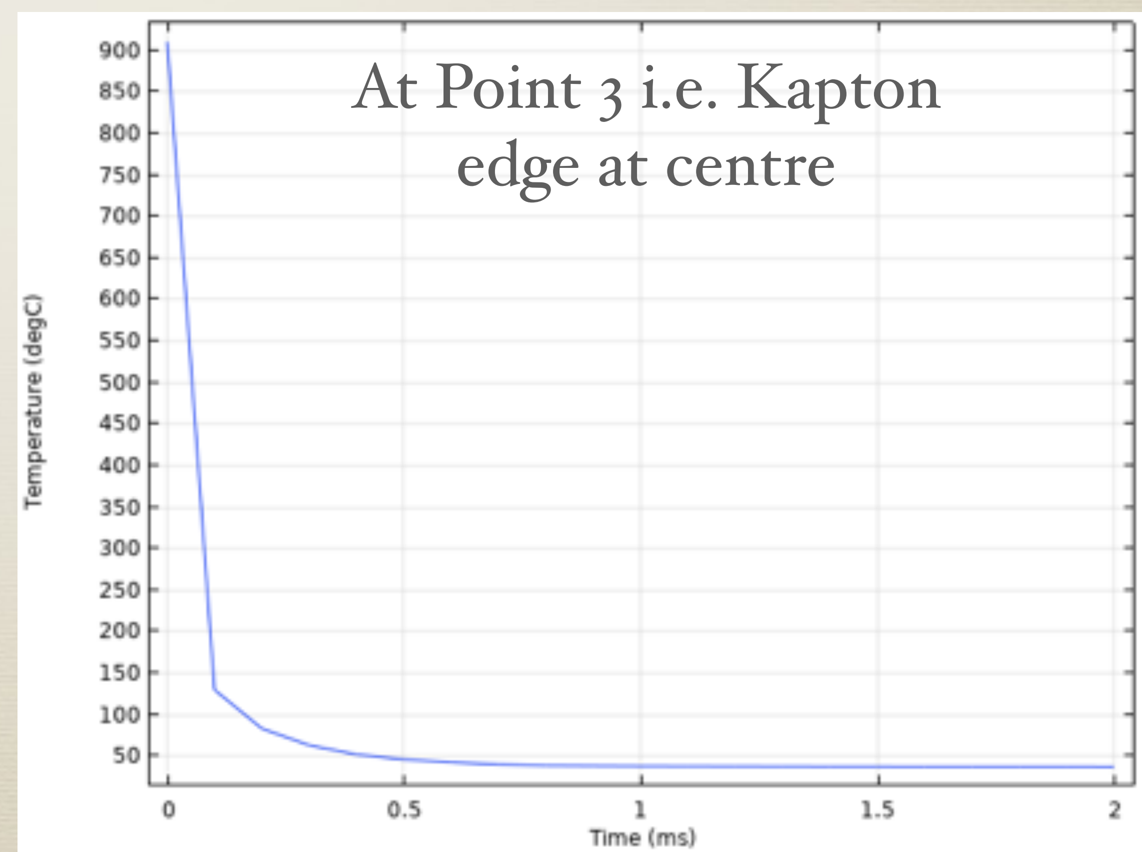
Time dependent solution using COMSOL Multi physics

Variation of Temperature with Time

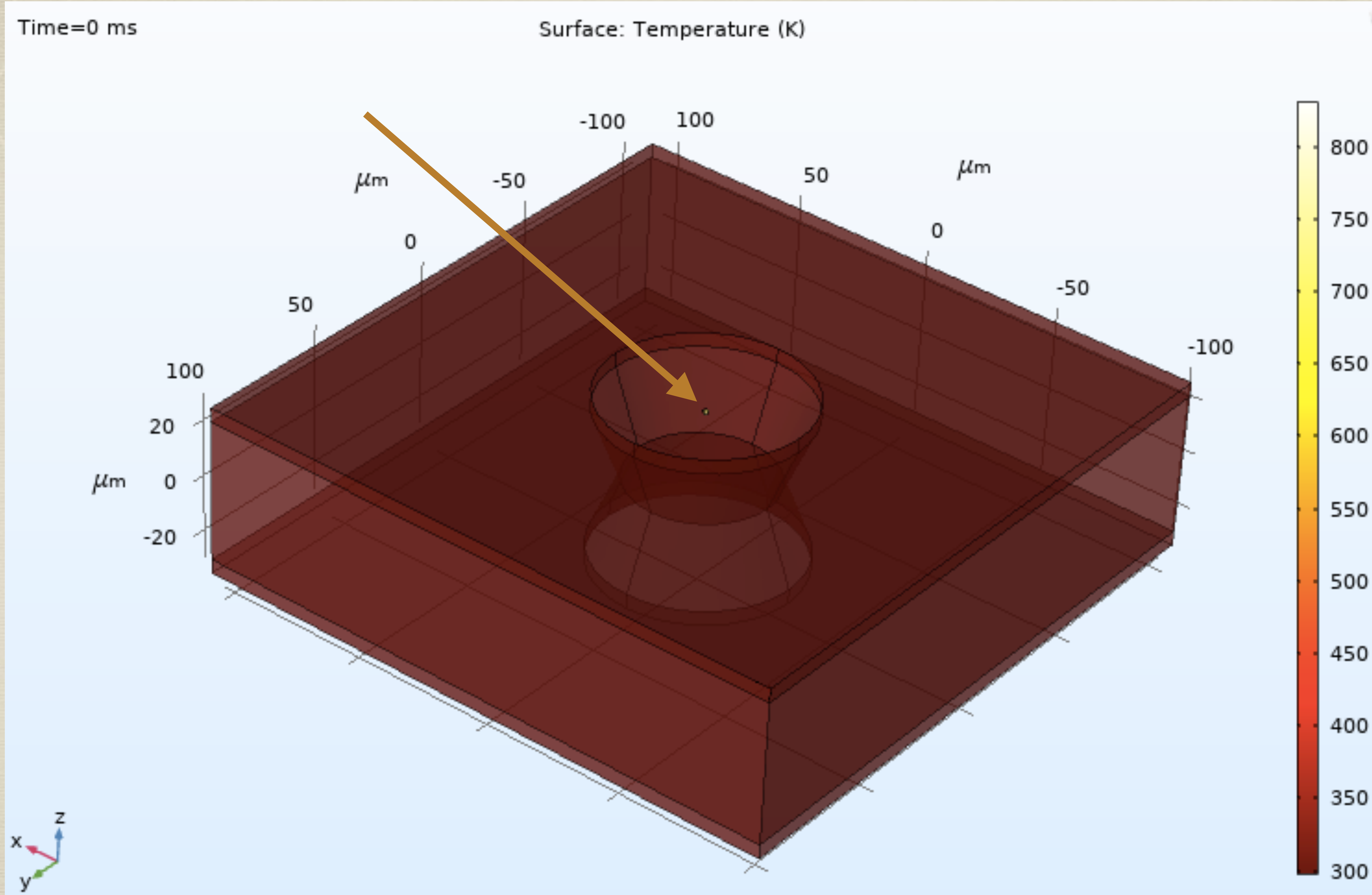








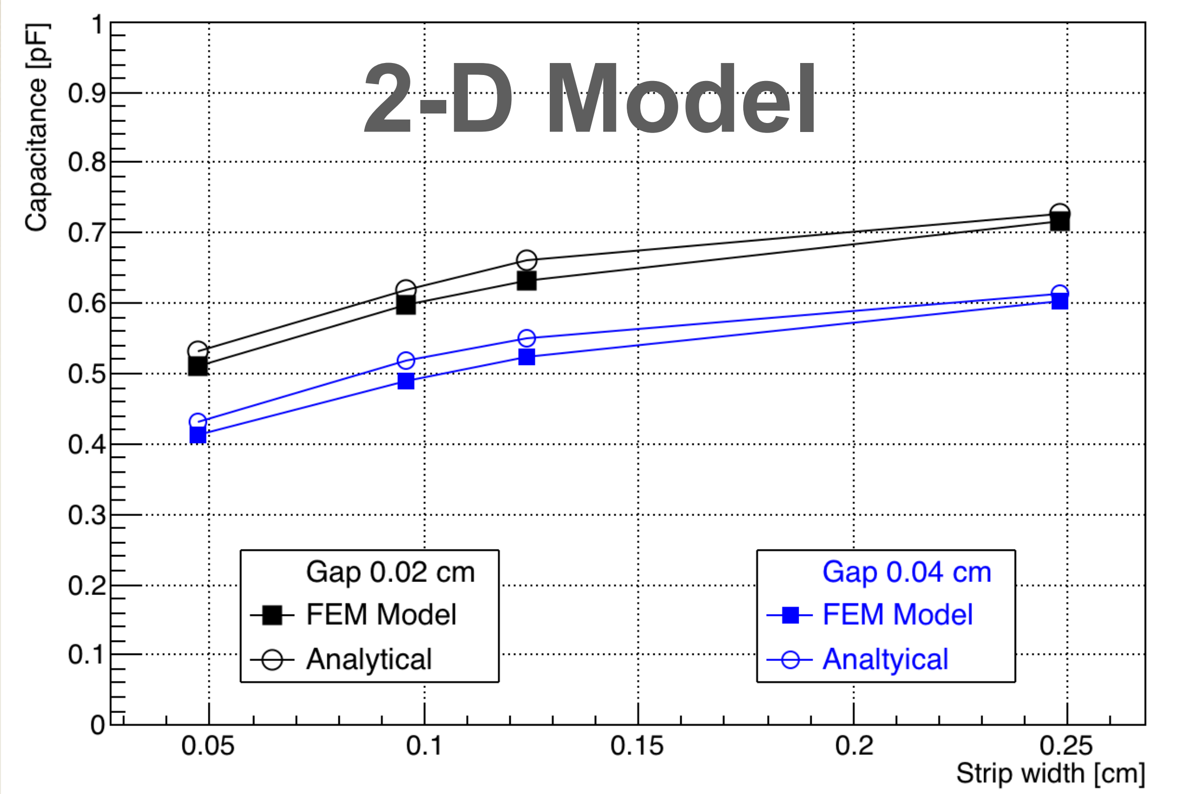
Temperature with Point Source

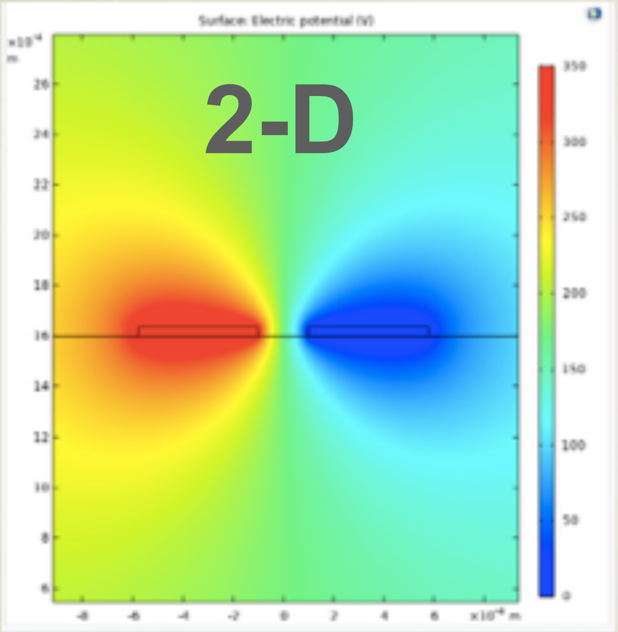


Made an initial condition of heat coming from a point source at 2500 ºC but acc. to the simulation it shows only 550 ºC.

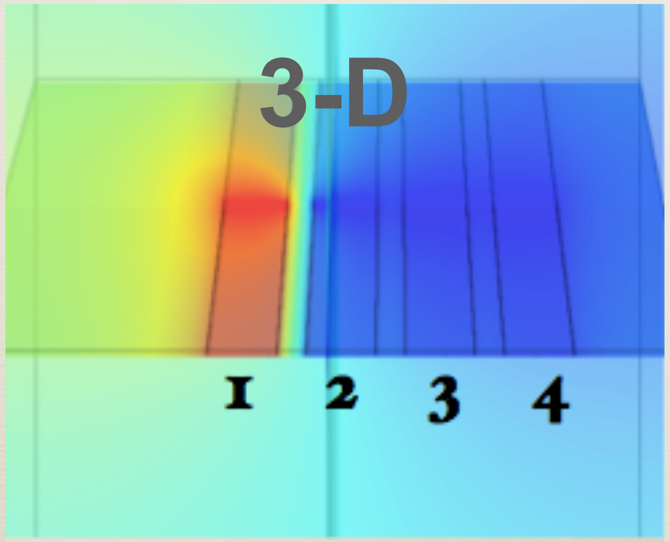
Interstrip Capacitance (GE2/1)

- Build a FEM for two strips
- First using MATLAB and now COMSOL for multi-strips
- Compared results for M1 & M4 size strips with analytical calculations (CMS IN-2018/006)
- Extended 2-D model to 3-D with 2, 3 and 4 strips using COMSOL

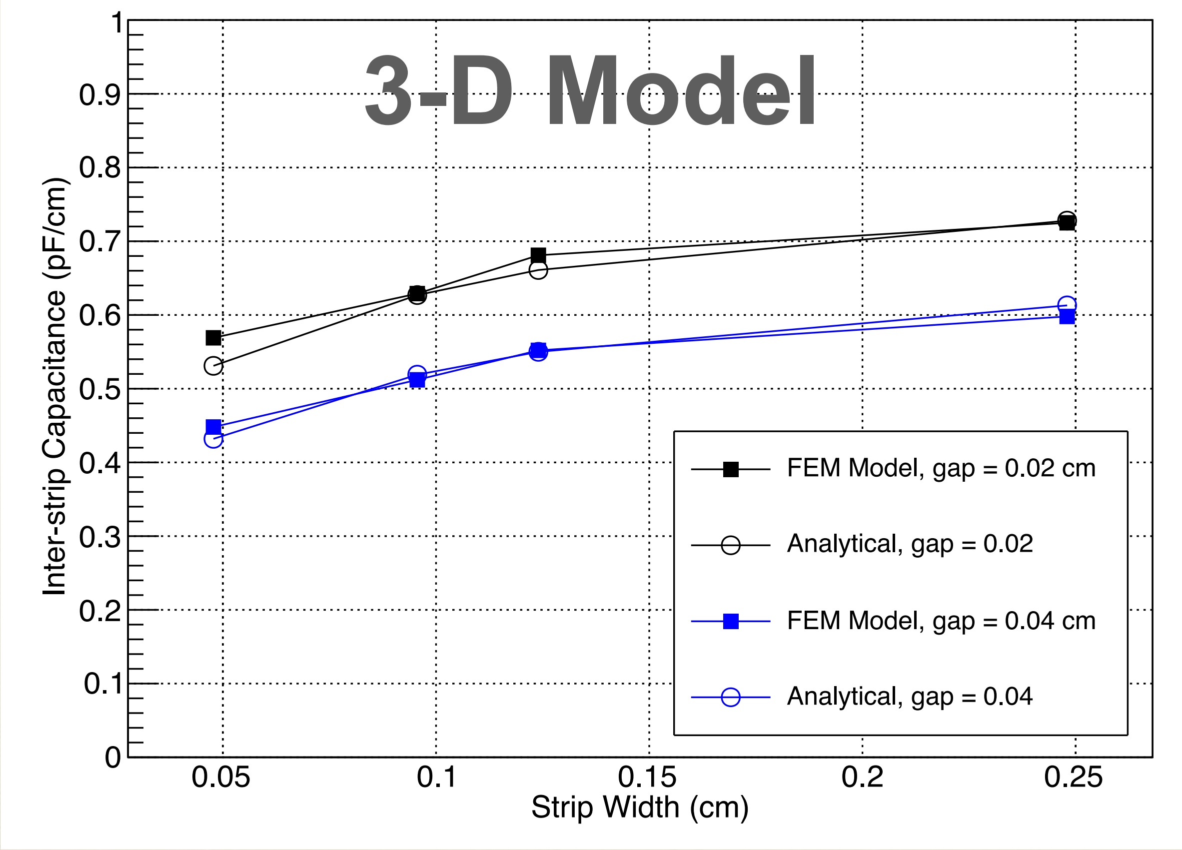




C_{21} = 0.5108 pF
Strip width = 0.0478 cm
Gap width = 0.02 cm

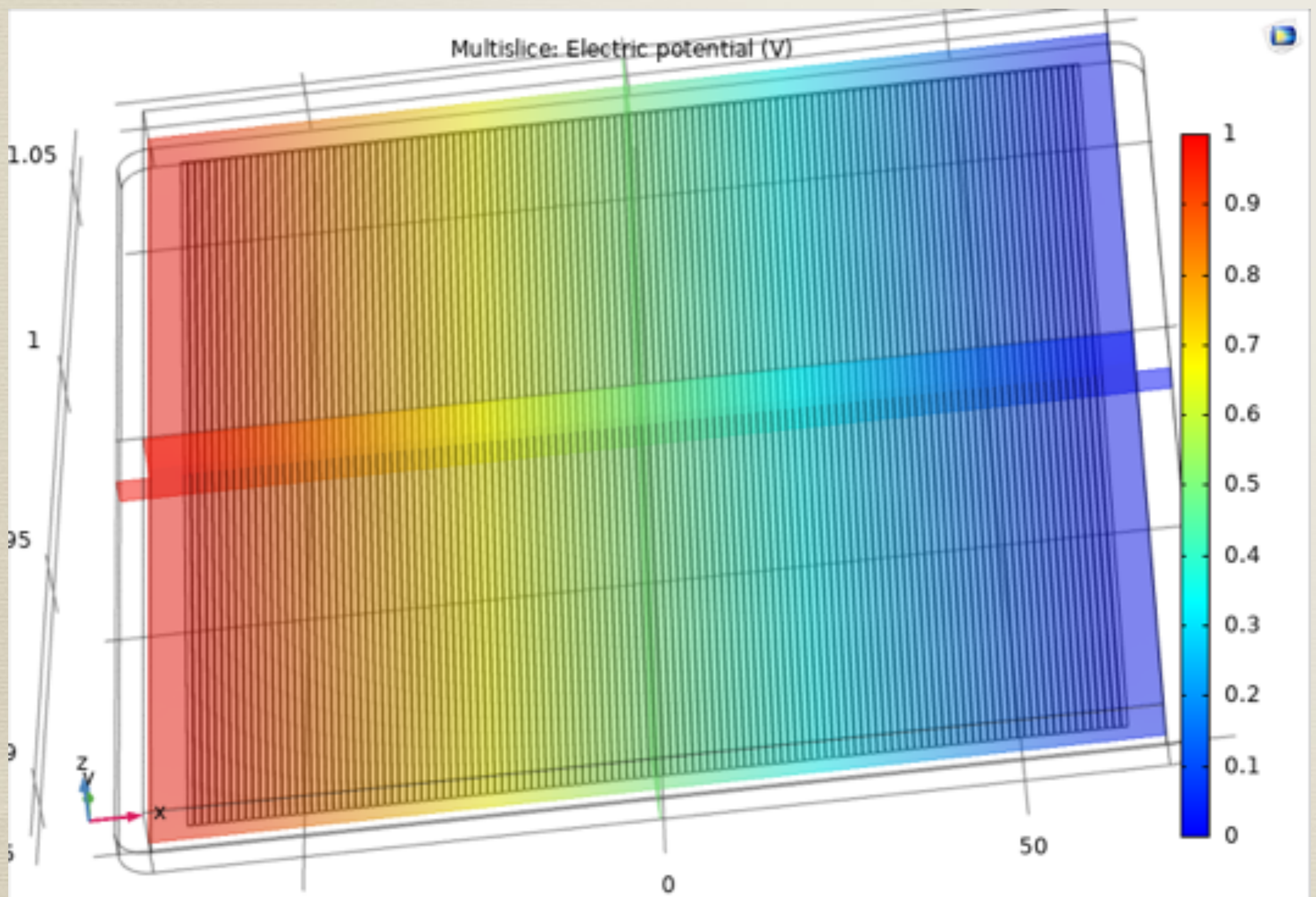


C_{21} = 0.401 pF/cm
C_{31} = 0.093 pF/cm
C_{41} = 0.085 pF/cm



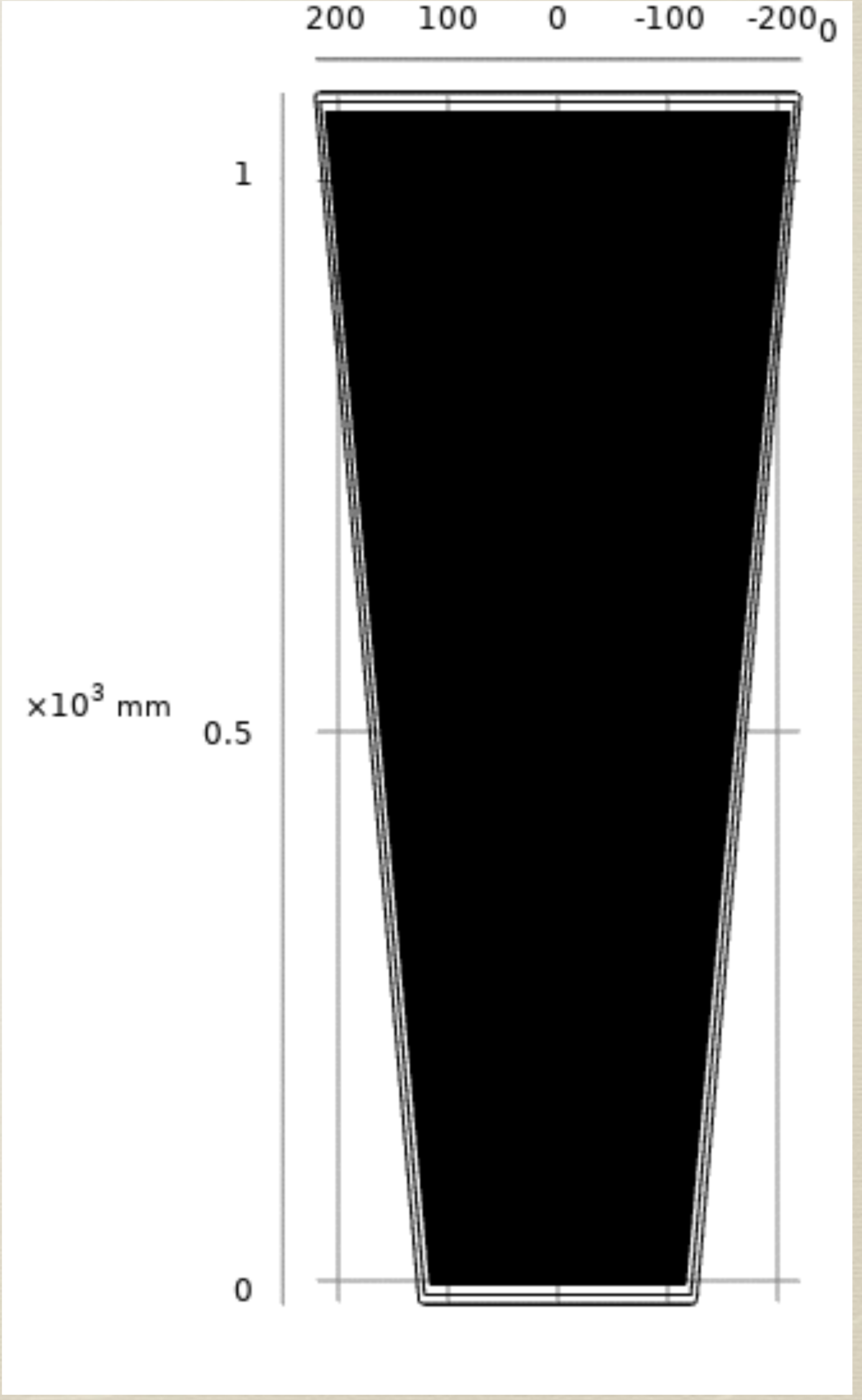
Interstrip Capacitance

- Impossible to do meshing of whole GE1/1 readout board
- Tried to do scan for each eta sector but still required more computing power
- Decided to use only 128 strips model



Sector 1 with 128 strips

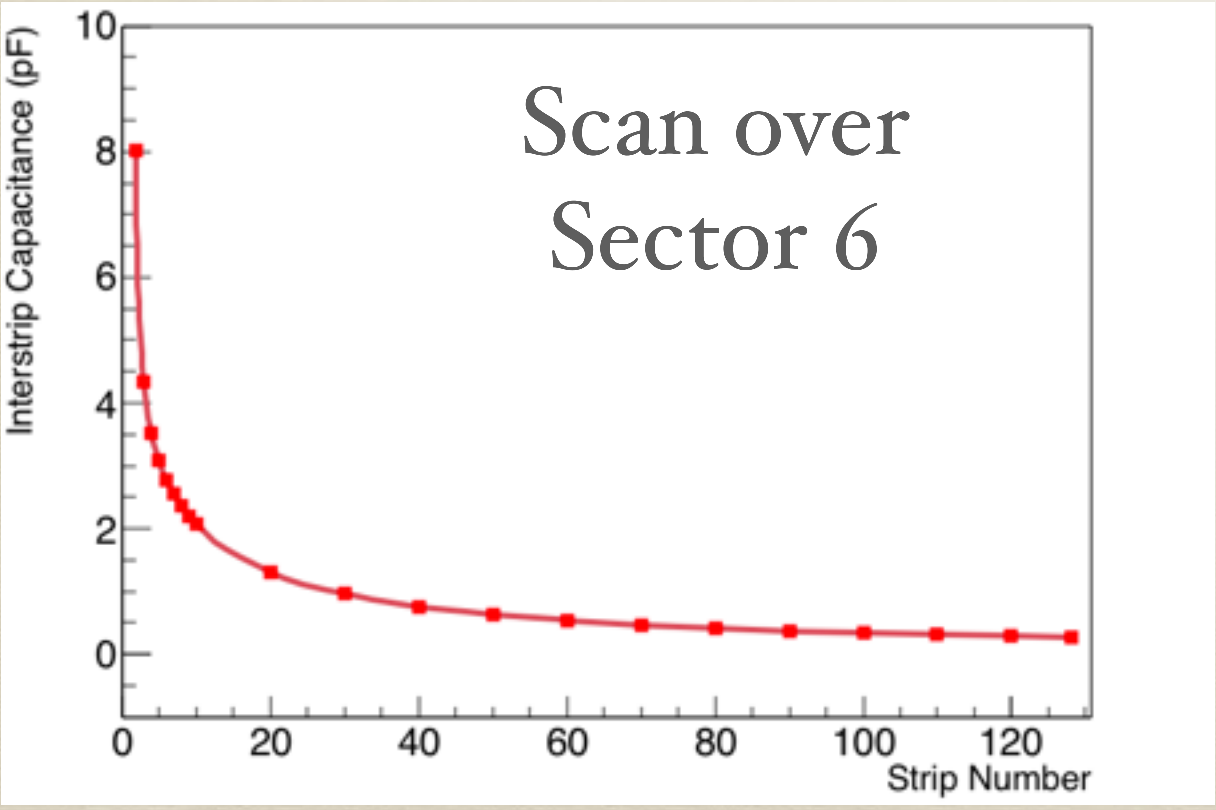
GE1/1 RO Board

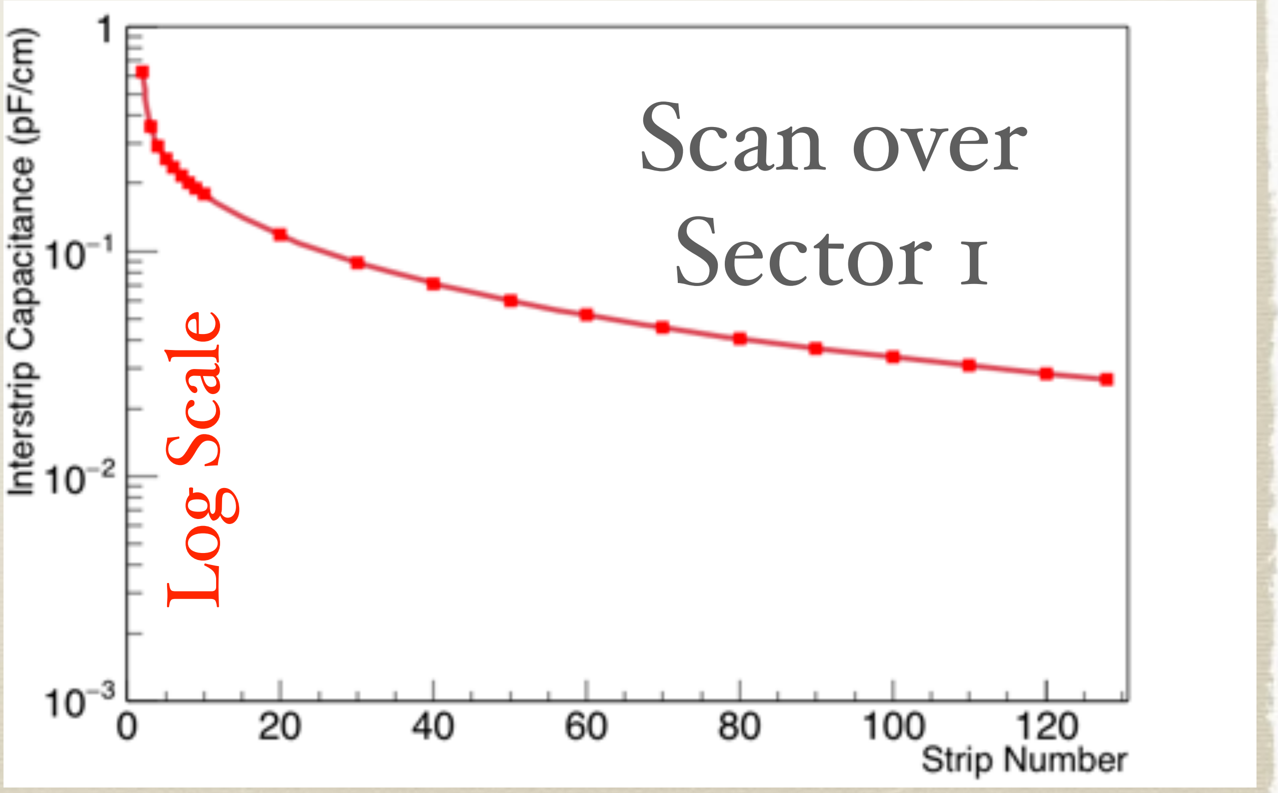


Interstrip Capacitance (GE1/1)

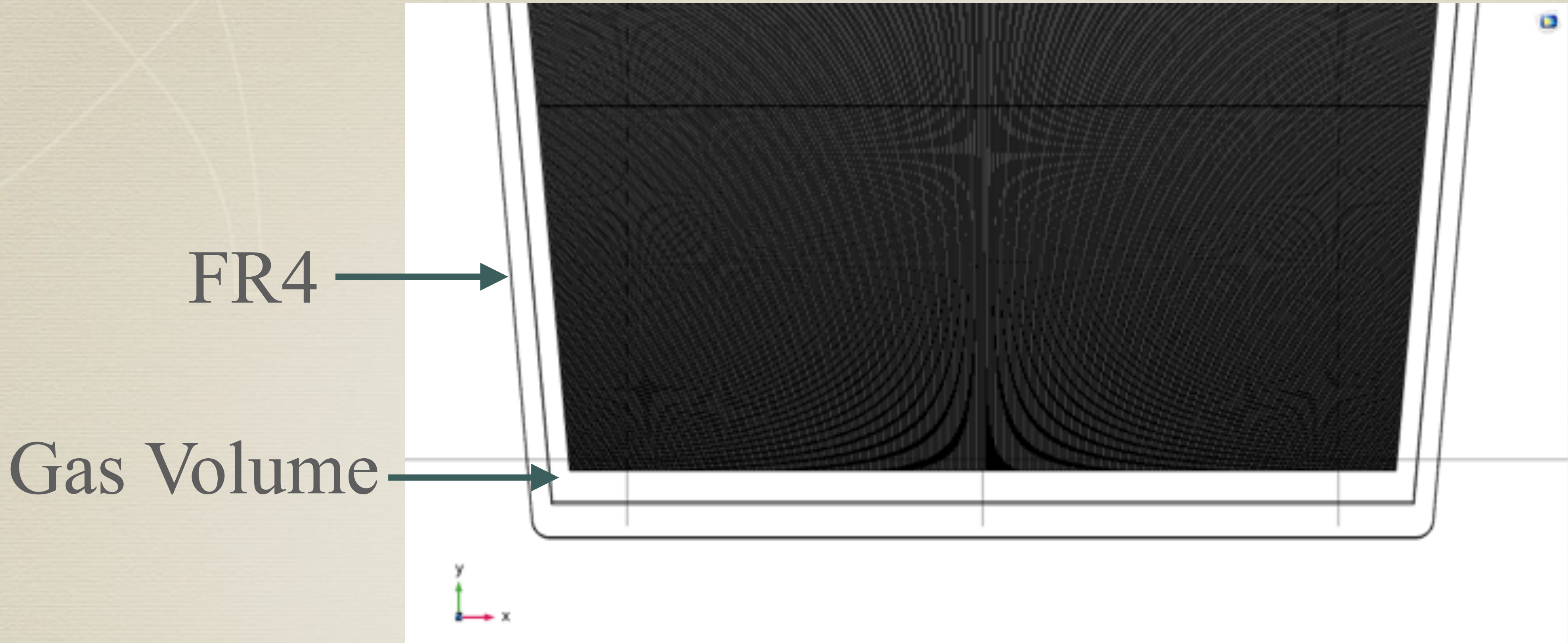
Calculated and experimentally measured values of Interstrip capacitance of GE1/1-X-S RO Board (from CMS IN-2018/006)

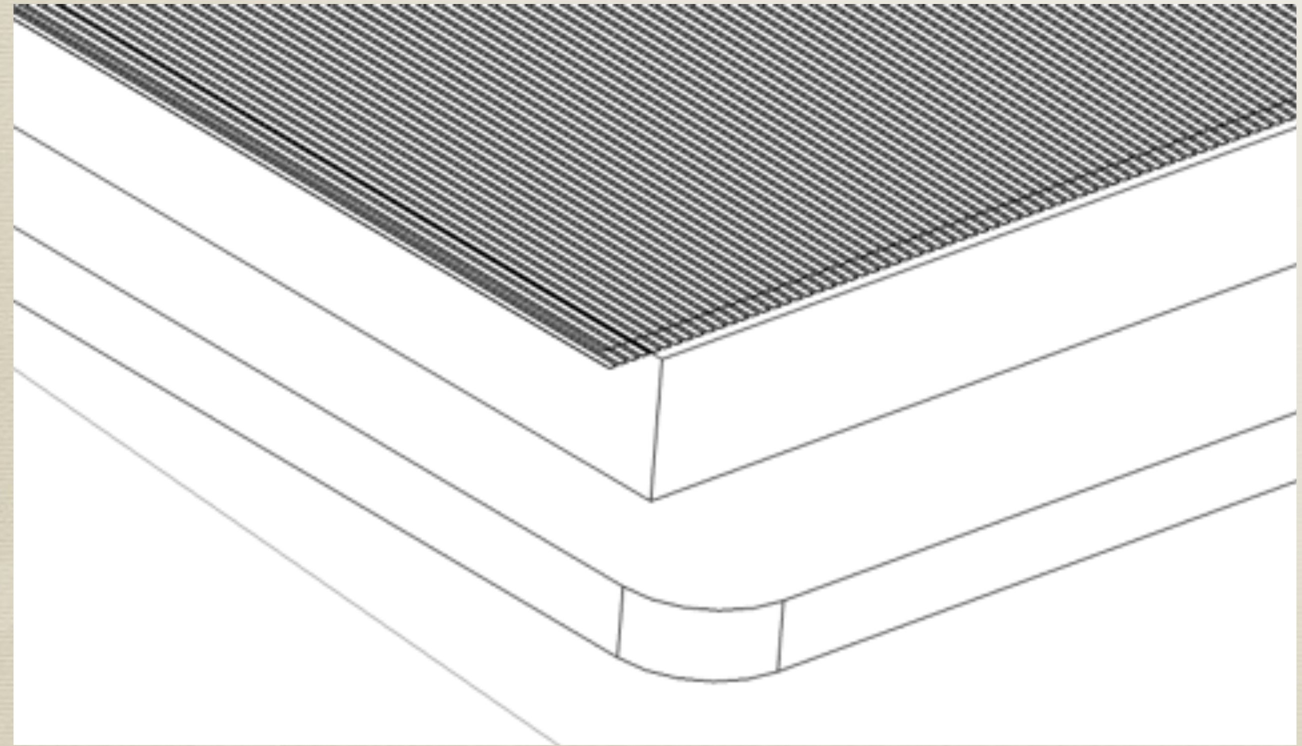
Eta Sector	1	2	3	4	5	6	7	8
Calc. Cap./cm (pF/cm)	0.624	0.598	0.585	0.571	0.555	0.545	0.529	0.515
Avg. Meas. (pF/cm)	1.02	0.946	0.942	1.01	1.04	1.00	0.909	0.952
Meas. Error (pF/cm)	±0.08	±0.084	±0.086	±0.10	±0.16	±0.11	±0.128	±0.187
Ratio (Calc./Avg. Meas.)	0.61	0.63	0.62	0.57	0.54	0.54	0.58	0.54
Using COMSOL (pF/cm)	0.769			0.710		0.668		0.631

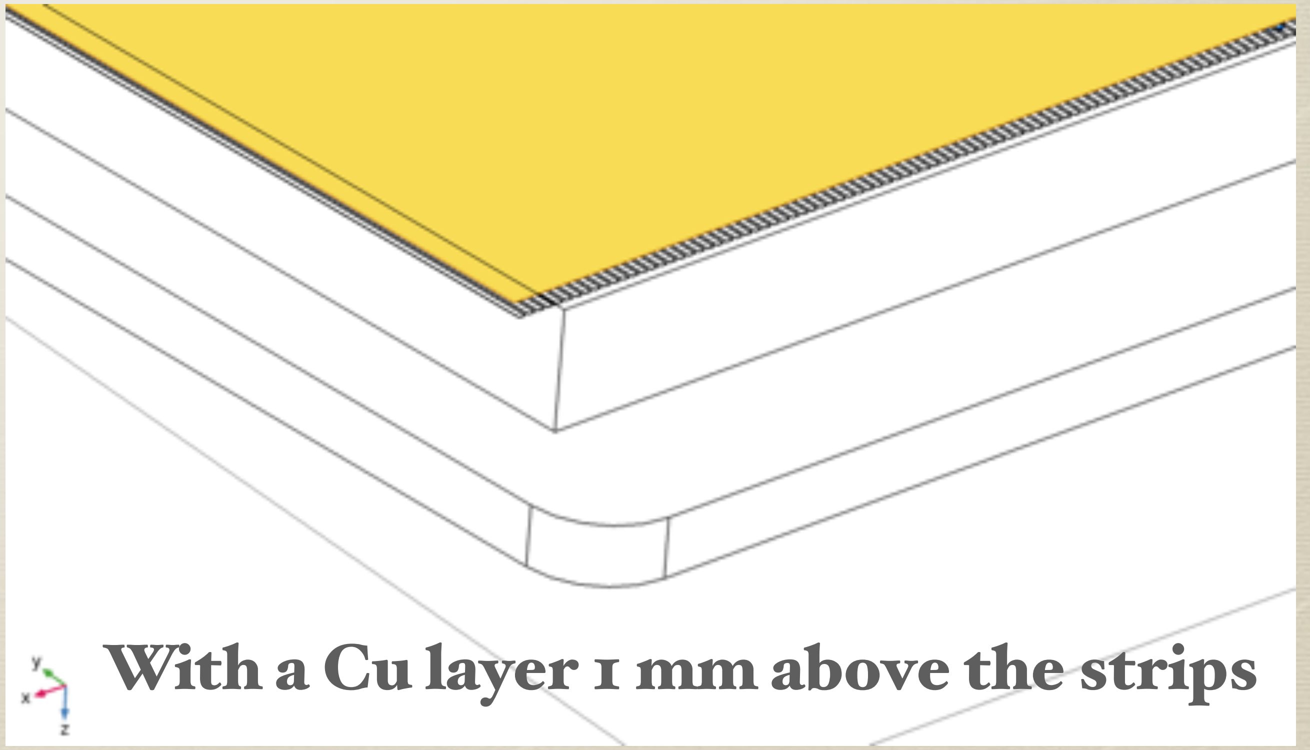




Interstrip Capacitance (GE2/1)

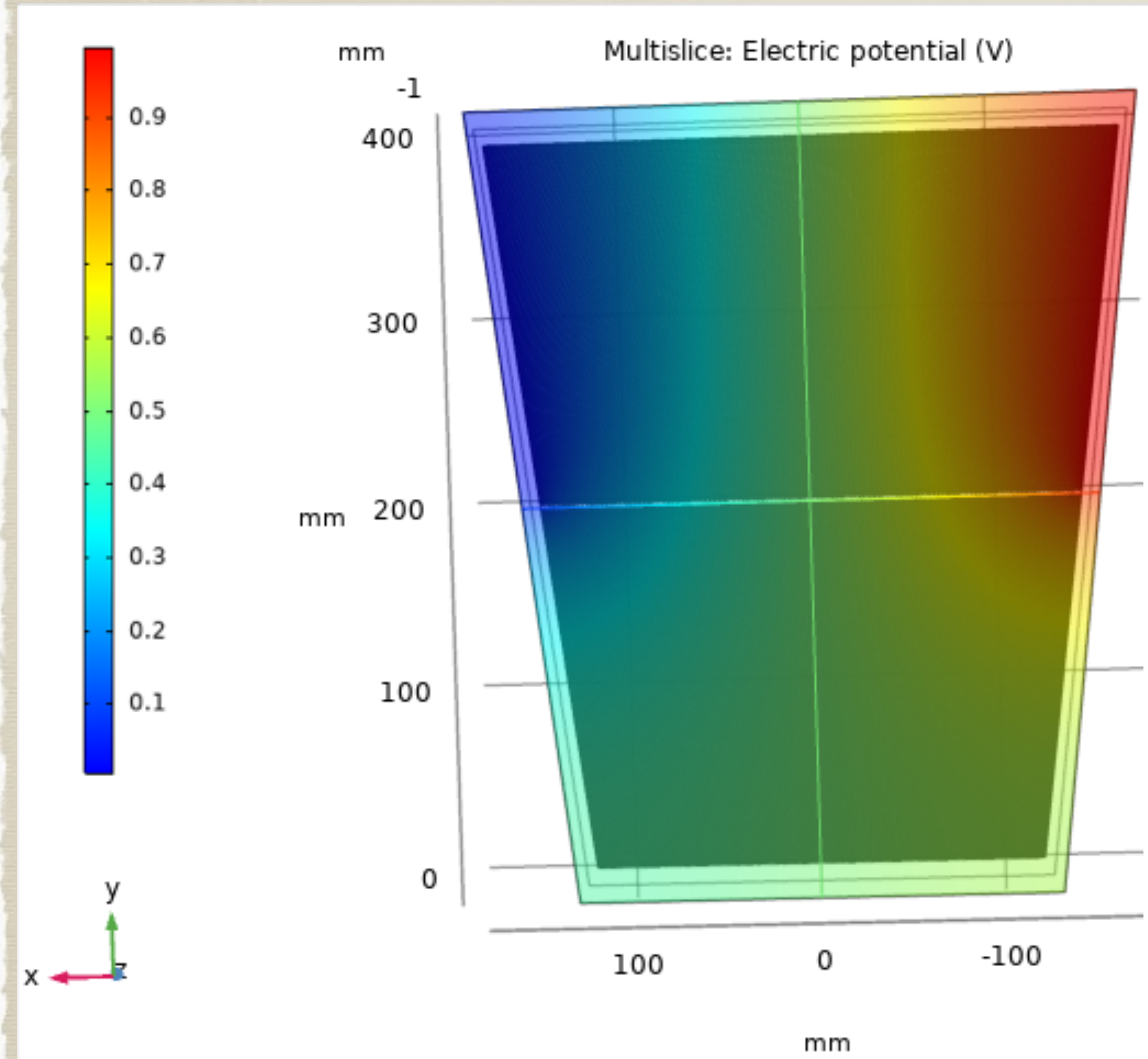






Interstrip Capacitance (GE2/1)

M1 module with a 5um Cu layer 1 mm above the strips

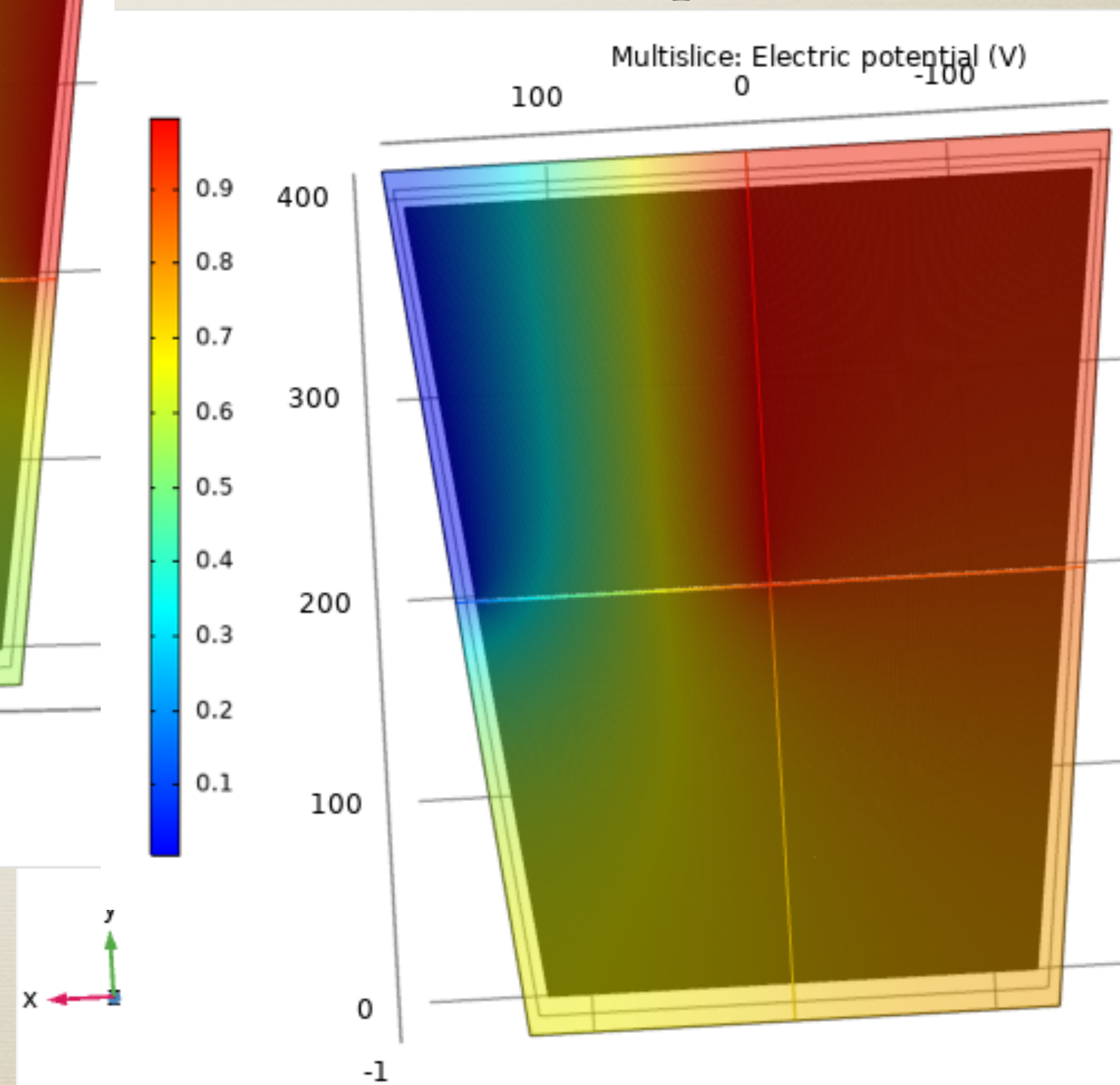


Between strip 1 to 384

0.00838 pF/cm

Between strip 192 to 384

0.0154 pF/cm



Interstrip Capacitance (GE2/1)

Table 4: GE2/1 ROB Interstrip Capacitance With and Without Grounding Plate

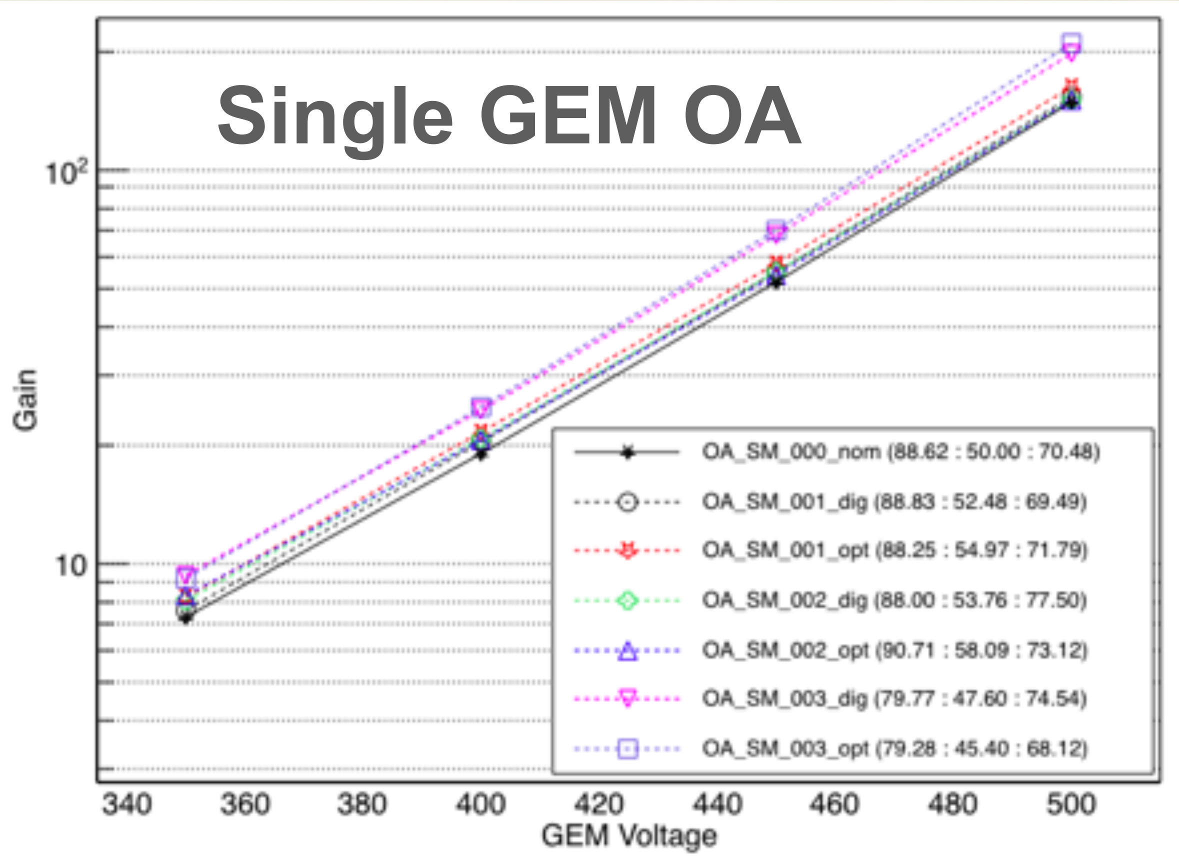
Sector	Module	Parameters	Avg. Meas. Cap. w/o plate (pF)	Avg. Meas. Cap. w/plate (pF)	$(C_w/C_{w/o})$
1	M4	Original TDR design (Strip Gap: 0.2 mm)	21.69±0.05	25.85±0.27	1.192±0.013
2	M4	Gap: 0.3 mm	19.98±0.12	20.98±0.03	1.050±0.006
3	M4	2×Width, 0.5×Length	15.33±0.03	20.16±0.04	1.315±0.004
4	M4	Long traces	27.87±0.06	28.43±0.07	1.020±0.003
5	M1	Original TDR design (Strip Gap: 0.2 mm)	16.27±0.04	19.04±0.21	1.170±0.013
6	M1	Gap: 0.3 mm	14.65±0.07	18.26±0.06	1.246±0.007
7	M1	Gap: 0.4 mm	13.17±0.04	14.85±0.08	1.128±0.007
8	M1	2×Width, 0.5×Length	11.82±0.06	15.82±0.32	1.338±0.028
9	M1	0.5×Length	9.32±0.05	9.17±0.10	0.984±0.012
10	M1	Original TDR Design, Long traces	20.58±0.06	26.80±0.14	1.302±0.008
11	M1	Original TDR Design, Minimal traces	14.02±0.02	14.82±0.03	1.057±0.003
12	M1	Original TDR Design, Minimal traces, 0.5×Length, 2×Width	10.39±0.07	10.33±0.11	0.994±0.013

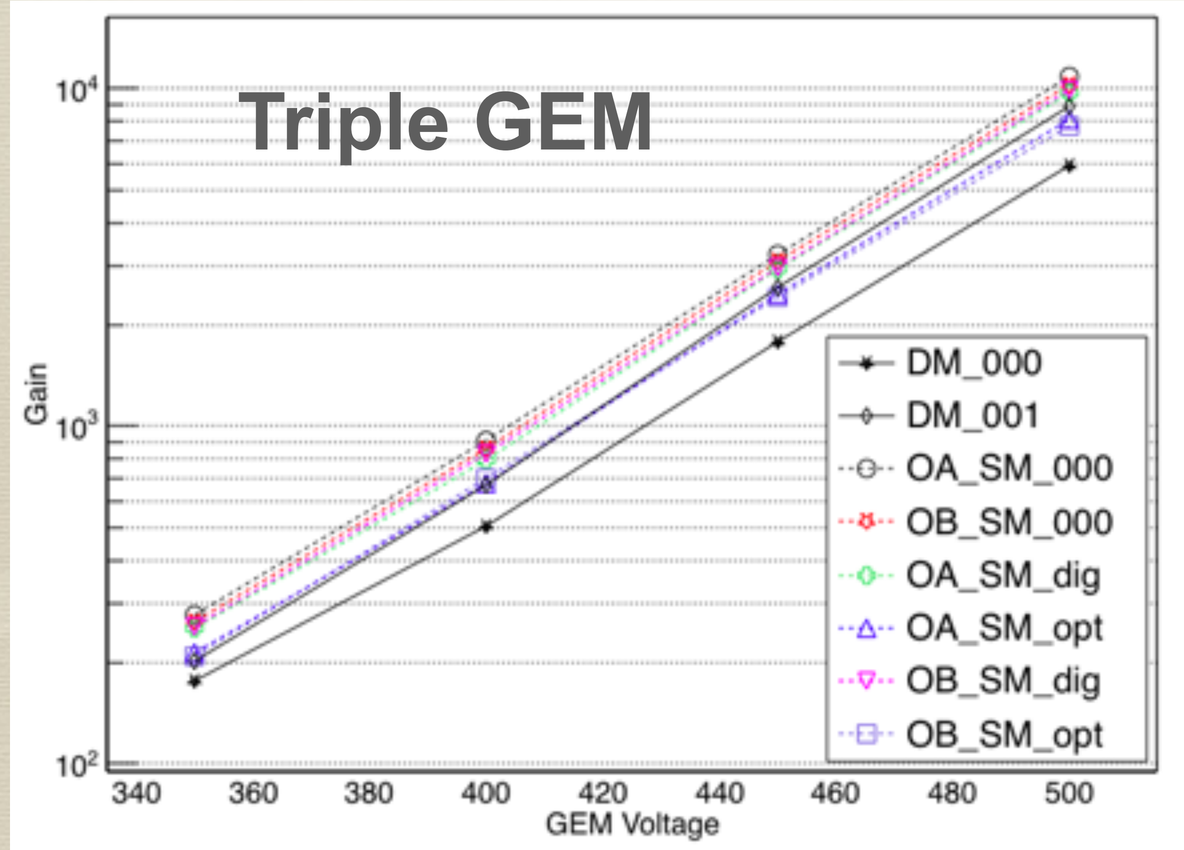
Module	Parameters	Cap. w/o plate (pF)	Cap. with plate (pF)	C
M4	Strip Gap: 0.2mm	16.119	16.252	1.008
M4	2 x Width, 0.5 x Length	12.635	12.691	1.004
M1	Strip Gap: 0.2mm	13.159	13.607	1.034
M1	0.5 x Length	7.0076	7.1788	1.024

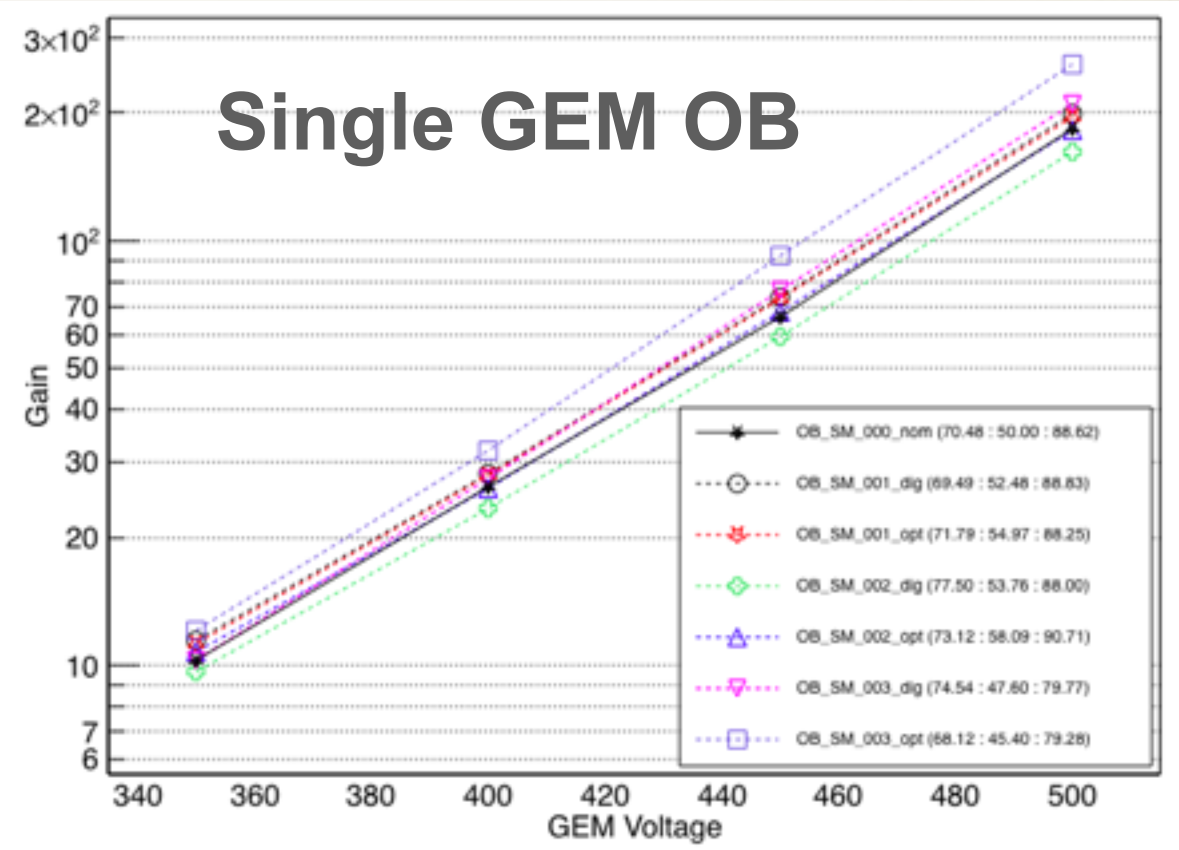
Working with other parameters

Hole size Variation

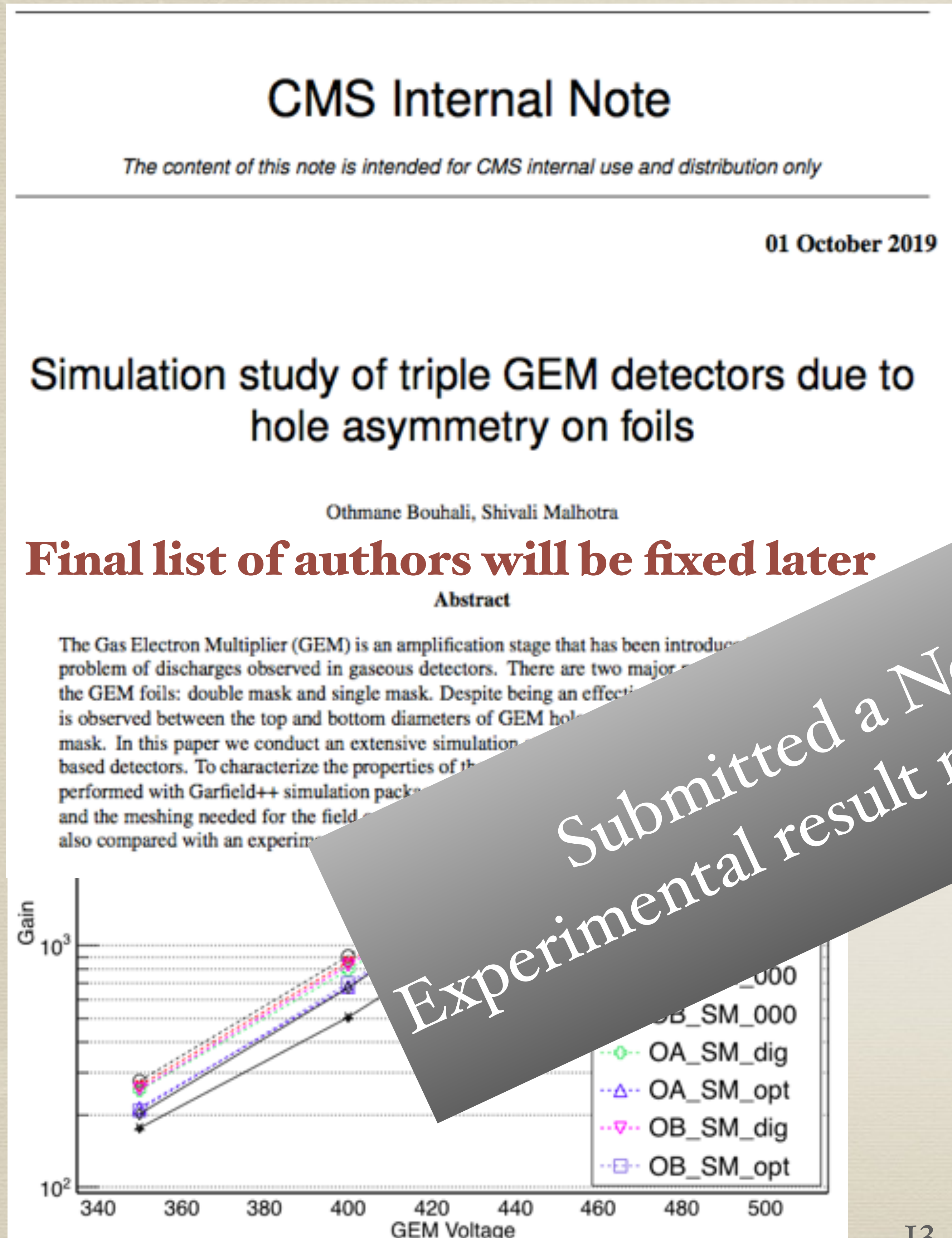
- Single and triple GEM with both single mask & double mask configuration
- Simulate & estimate the variation in gain due to different hole size
- Obtained different hole geometry from digital and optical microscopy from Jeremie







Hole size Variation


CMS Internal Note

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01 October 2019

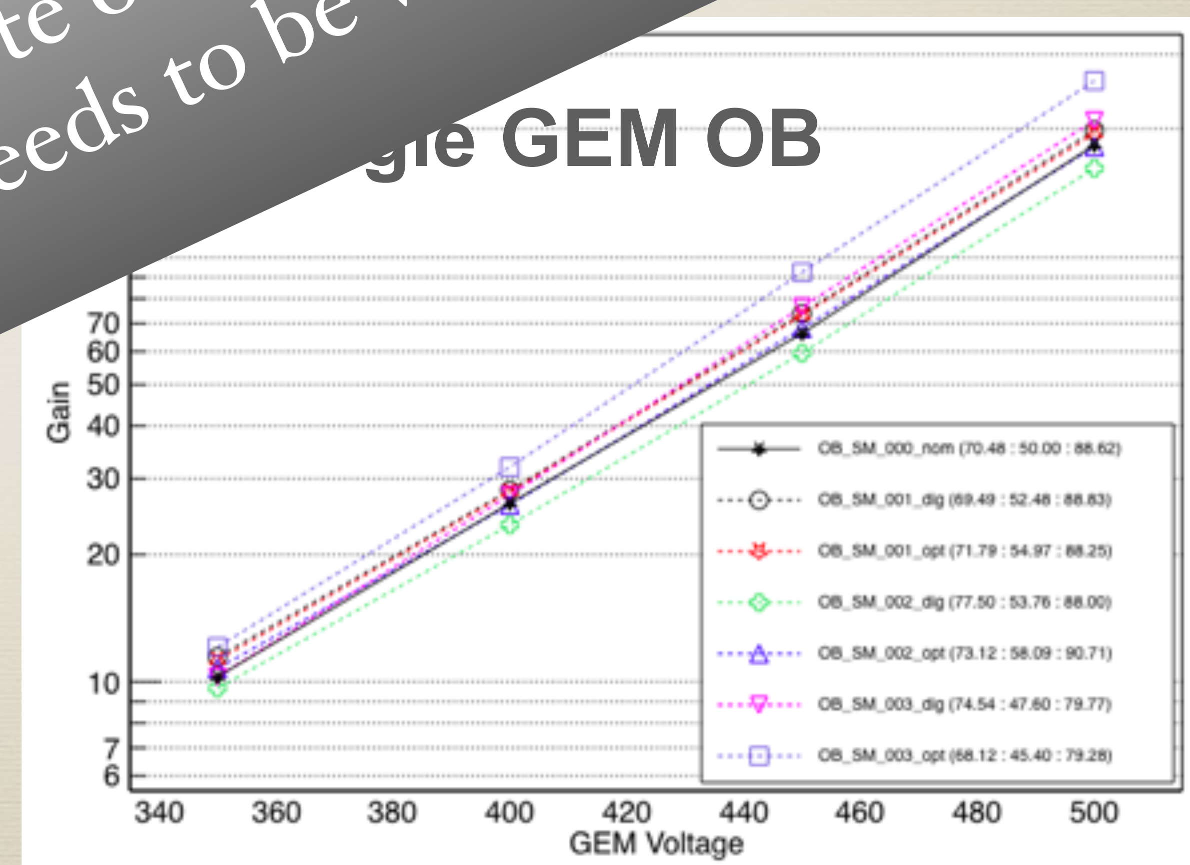
Simulation study of triple GEM detectors due to hole asymmetry on foils

Othmane Bouhali, Shivali Malhotra

Final list of authors will be fixed later

Abstract

The Gas Electron Multiplier (GEM) is an amplification stage that has been introduc… problem of discharges observed in gaseous detectors. There are two major … the GEM foils: double mask and single mask. Despite being an effecti… is observed between the top and bottom diameters of GEM hol… mask. In this paper we conduct an extensive simulation … based detectors. To characterize the properties of th… performed with Garfield++ simulation pack… and the meshing needed for the field … also compared with an experim…

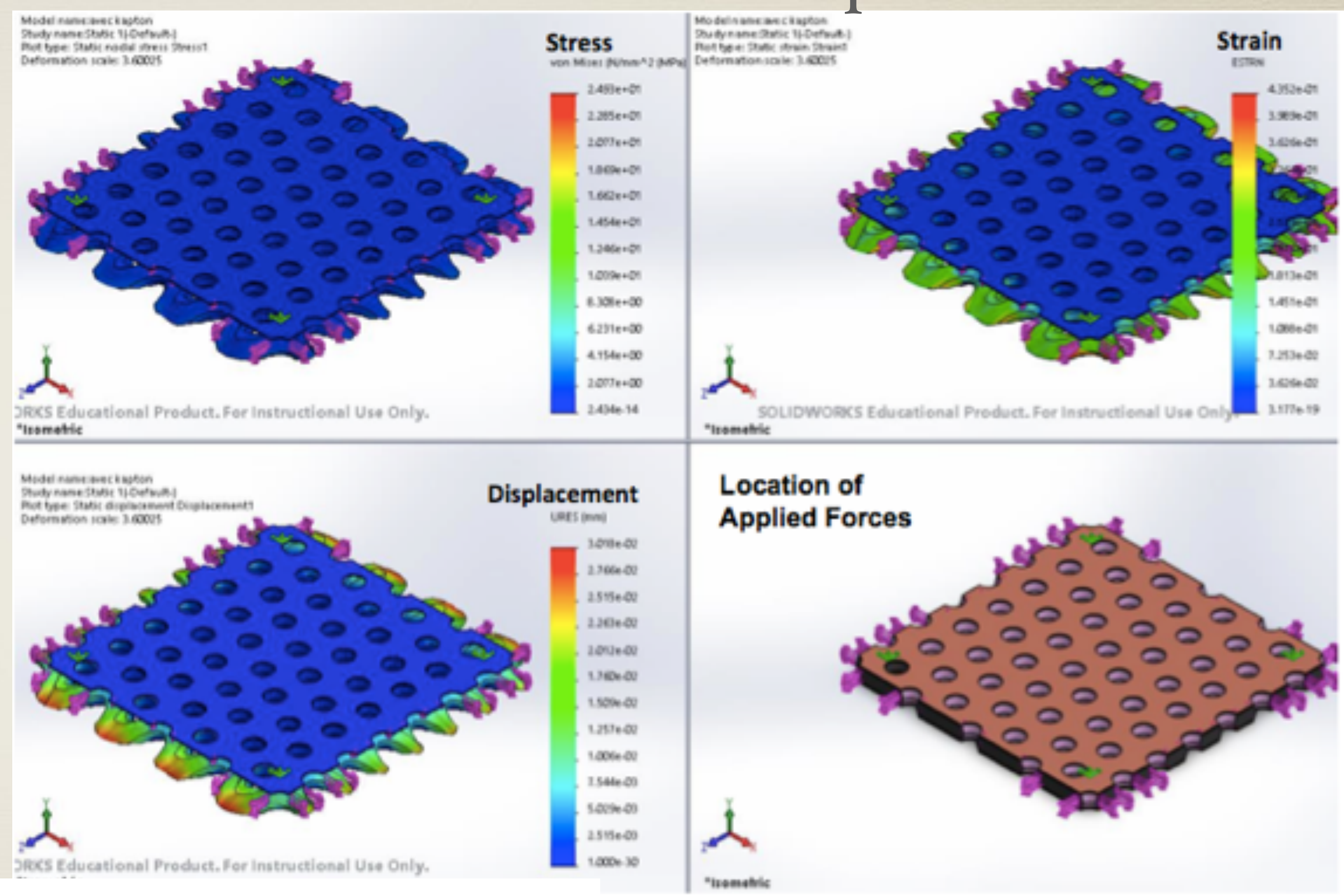


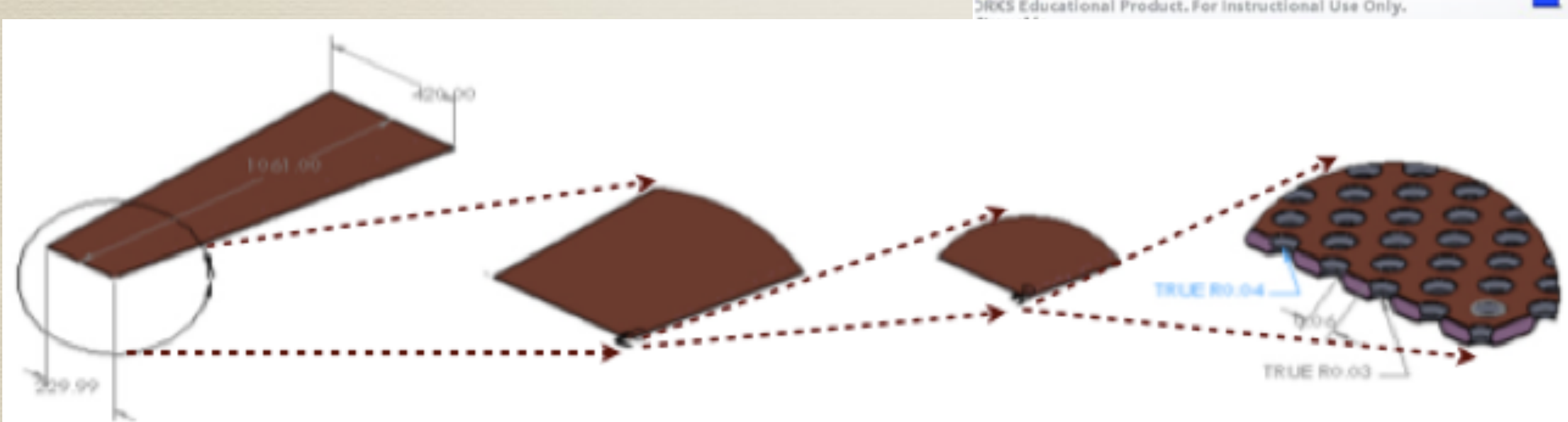
Submitted a Note on the results
Experimental result needs to be verified again!!

Deformation of Foil due to Stretching

- Build a Finite Element Model (FEM) for a small area GEM foil (done in SolidWorks)
- Estimate the deformation on the holes due to force applied in x & y directions
- Extrapolate the results to large area GEM foil

Stretching force applied on 1mm x 1mm GEM foil sample

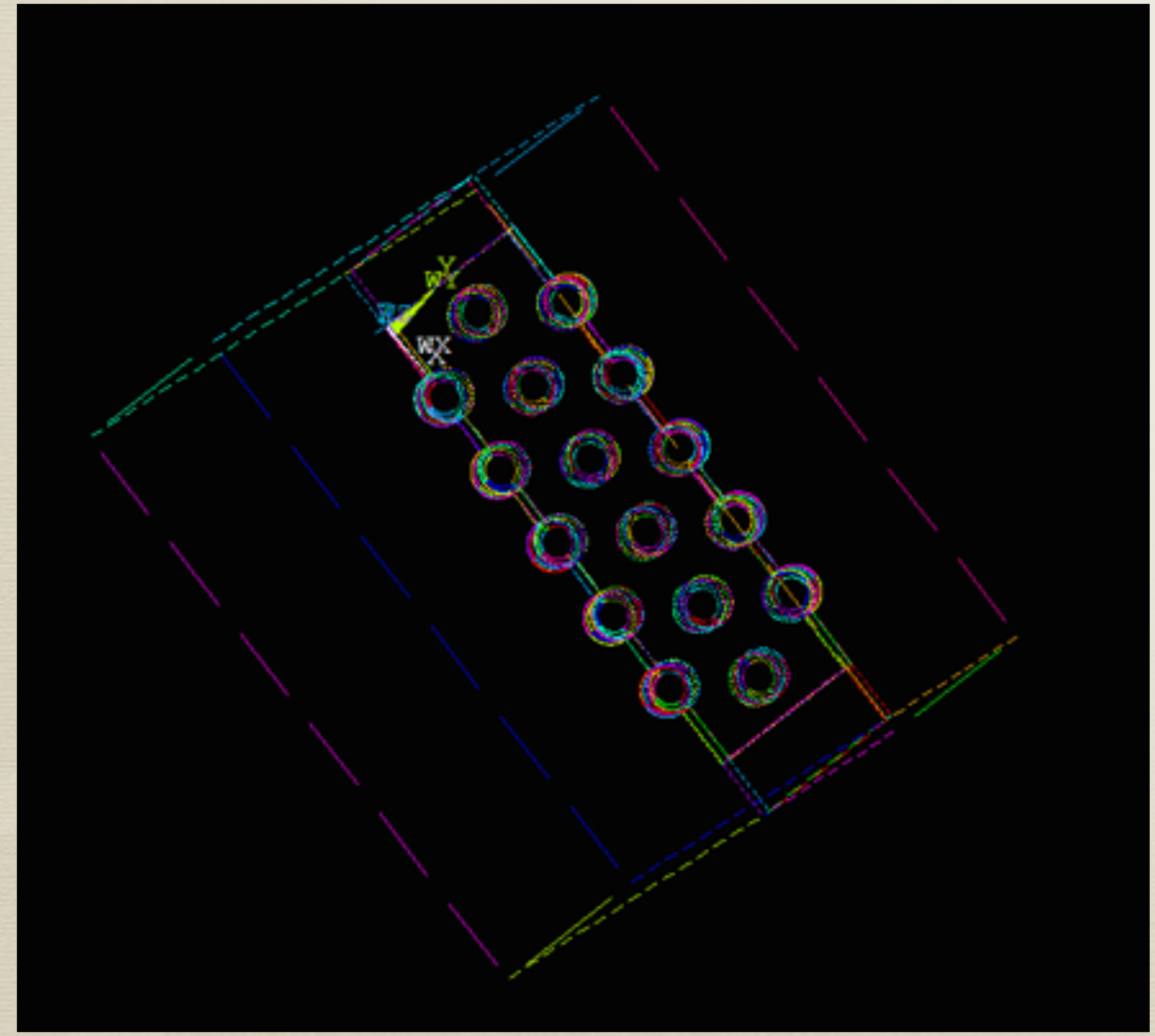


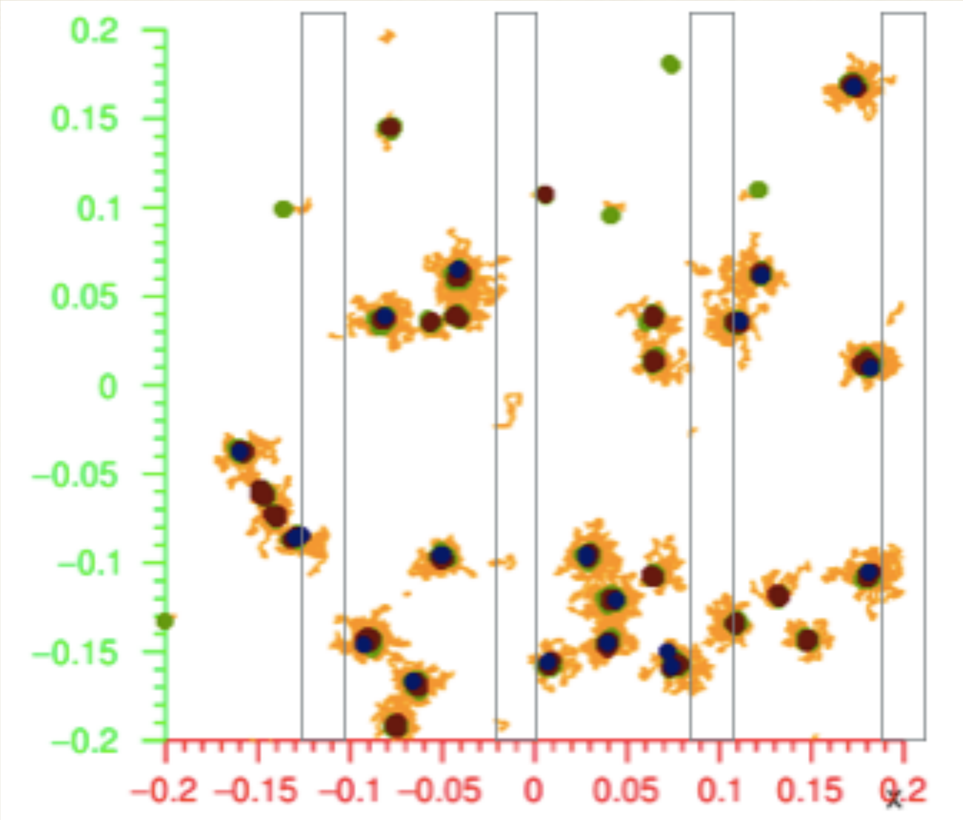


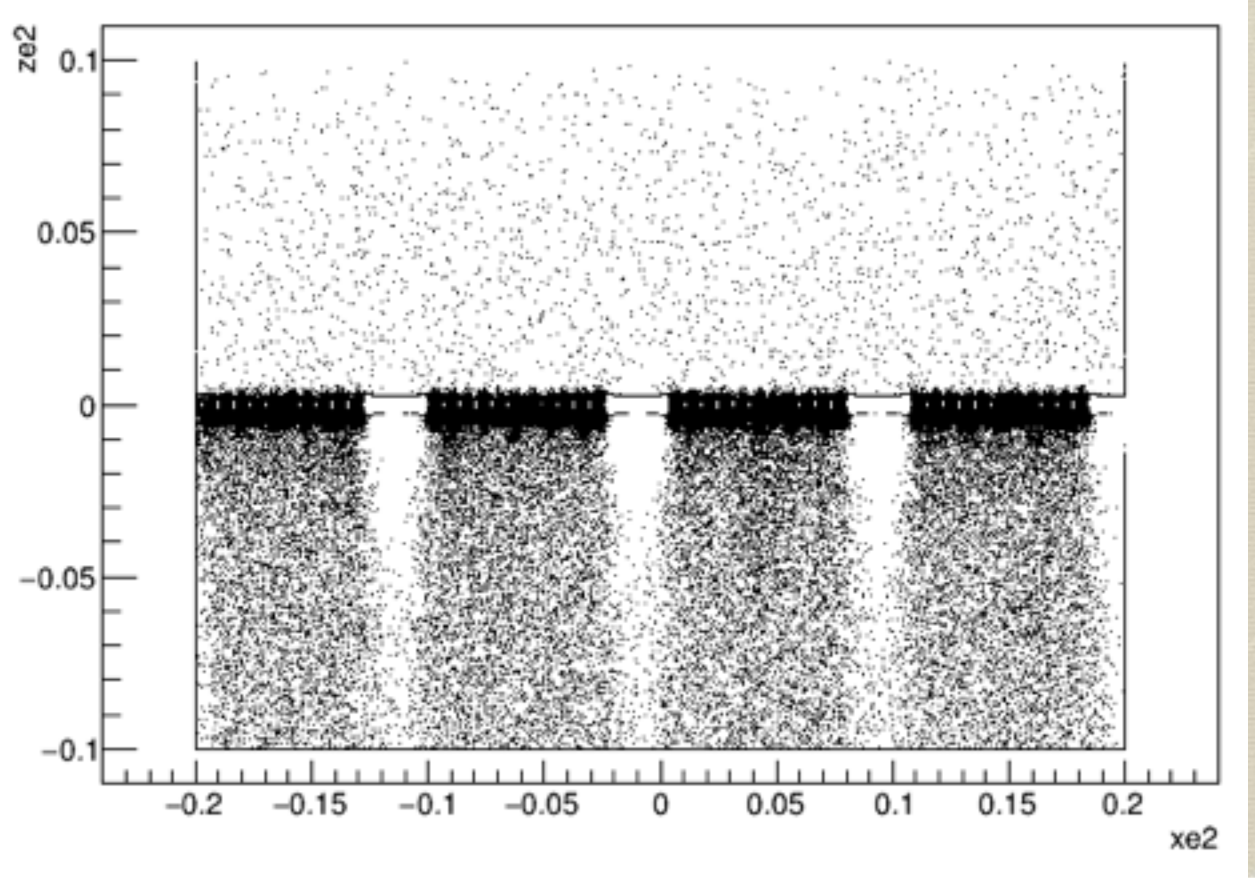
FEM was built for GE1/1 chambers

Dead Area Simulation

- Base element created in ANSYS
- Extended simulation area to 4mm x 4mm
- Dead Area: -0.124 to -0.104; -0.02 to 0 ; 0.084 to 0.104 and 0.188 to 0.2







Summary

- For GE1/1 Operation we are performing the simulation to understand the dissipation of heat from a discharge.
- Trying to debug the issue generated with a point source.
- Simulated values of Interstrip Capacitance are in good agreement with the measured values for both GE1/1 & GE2/1.
- Note has been submitted related to the study of gain variation due to asymmetry in hole size.

READY TO BE REVIEWED!!

- Other ongoing simulation studies have been reported