Spacer configuration optimization for the RPCs based on COMSOL Multiphysics simulation

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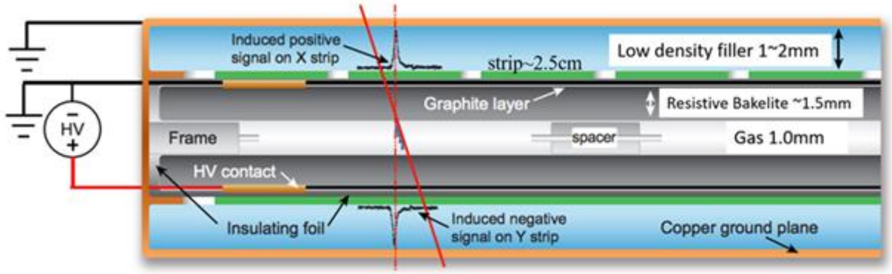
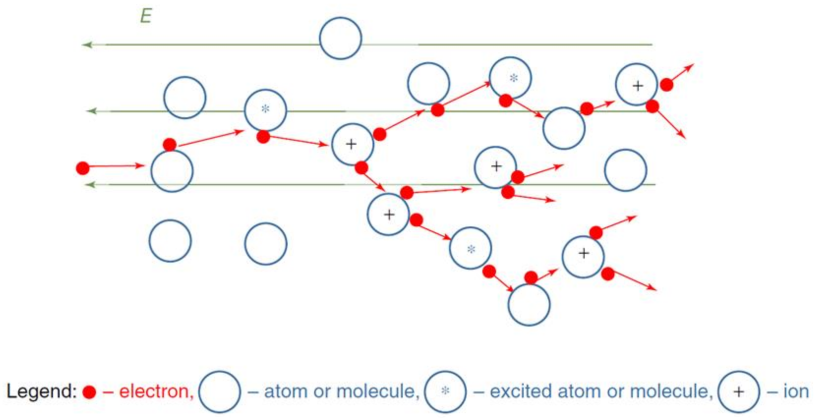
Brief introduction of the RPC

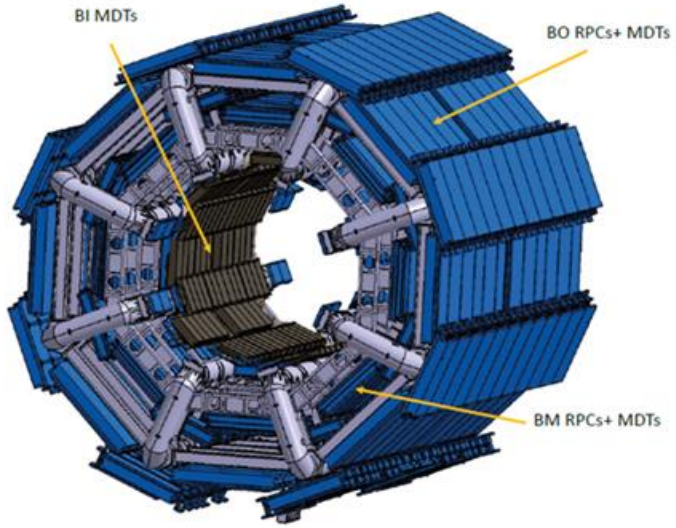
- RPC(Resistive Plate Chamber) is a gaseous detector based on avalanche mode.
- Which uses resistive material(glass, Bakelite) as electrodes.

- Advantages: Efficiency>95%, time resolution ~1 ns(single gap),
  easy to build, large area, quite cheap.

- Applications: muon system for ATLAS and CMS, SDHCAL(Calorimetry) …

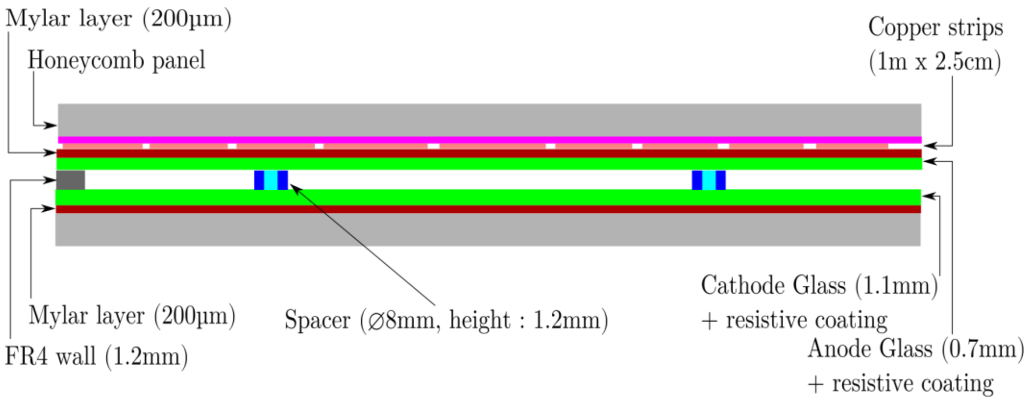


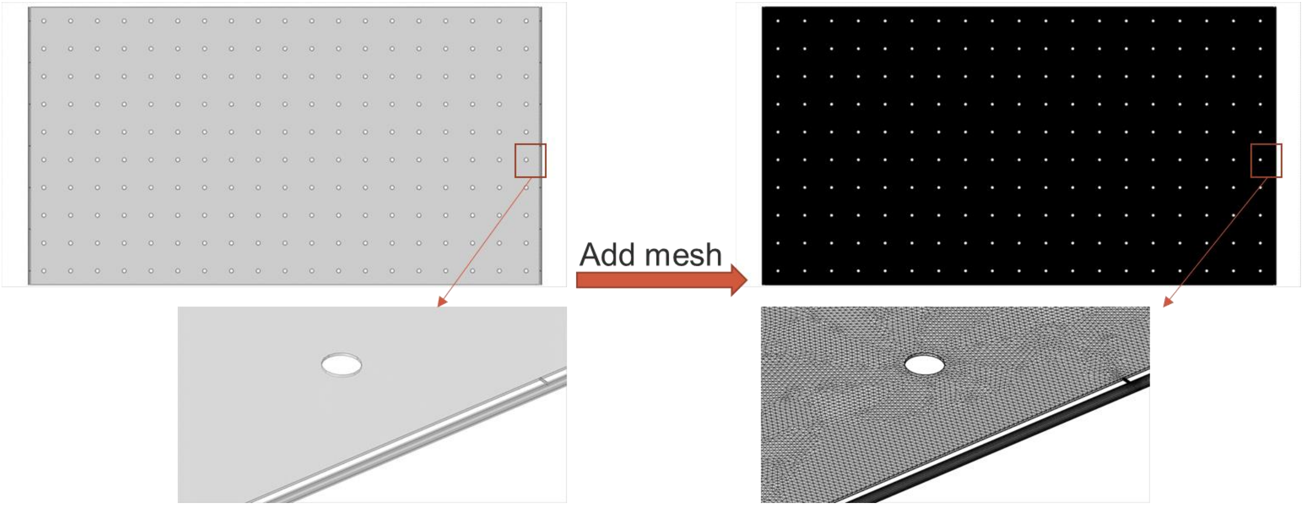




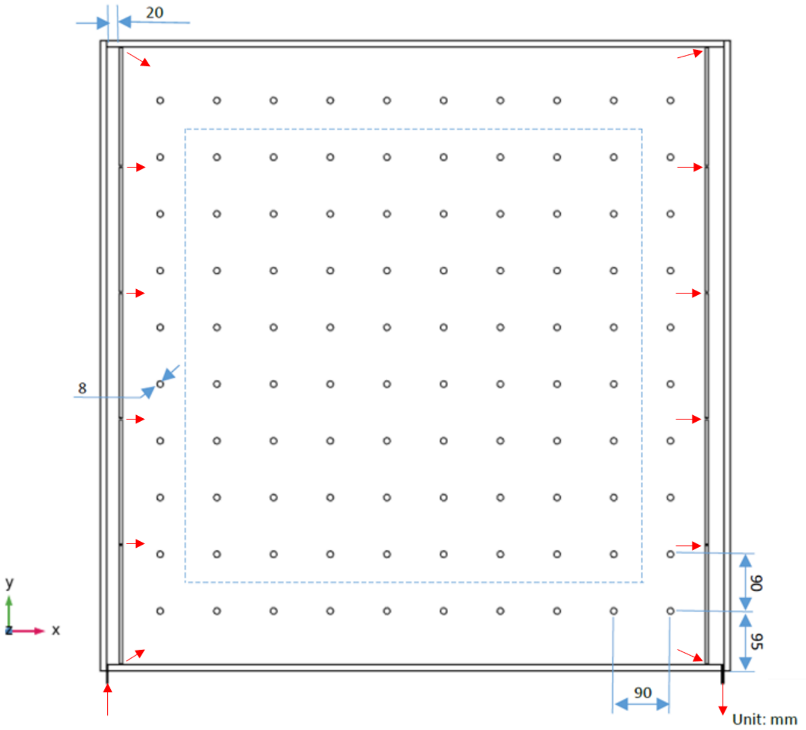
Introduction

- The uniformity of the gas flow in the chamber and the deformation of the electrode plates are critical to the performance and/or aging of RPC.
- During the course of making a RPC, we need spacers to keep the thickness of gas gap uniform. Also, the spacers will affect the gas flow.
- Here a software named COMSOL Multiphysics® is used to simulate the gas flow and deformation of the electrodes for RPCs with different spacer configuration by finite element method.

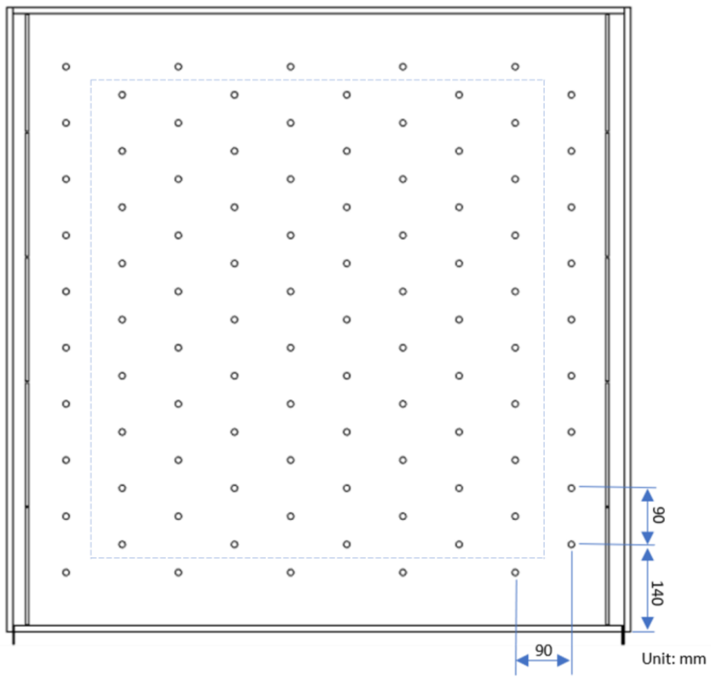




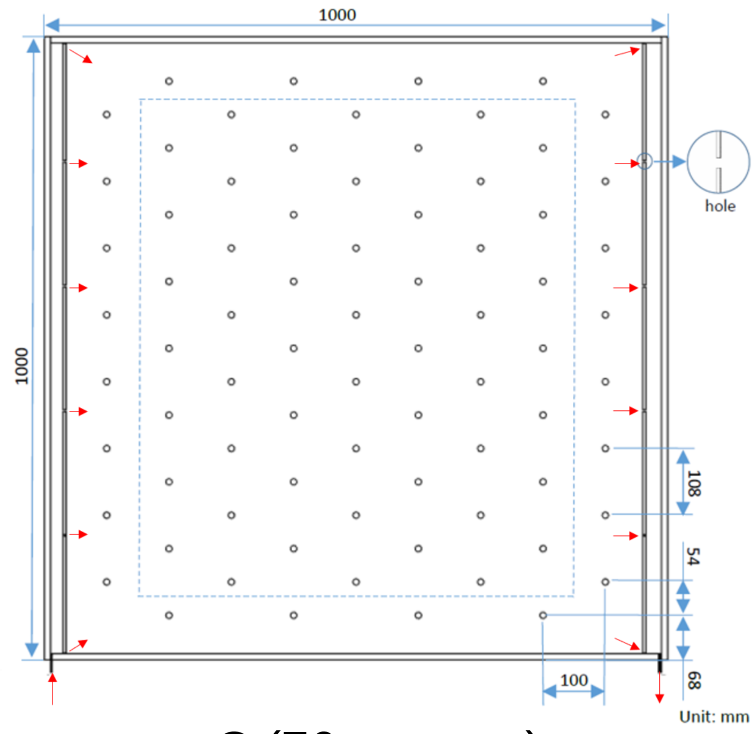
Geometry of RPC models



A (10×10 spacers)



B (95 spacers)

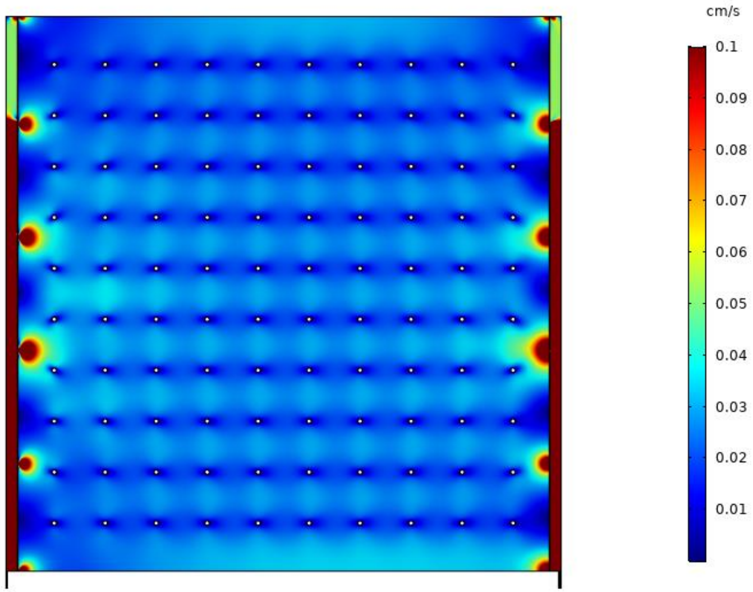


C (76 spacers)

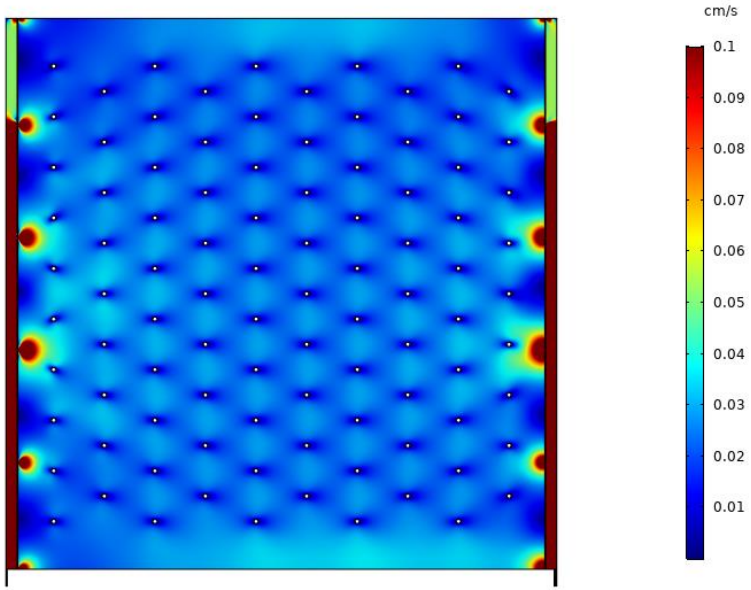
· Red arrows show the routine of the gas flow

· The center part of the chamber marked by the dashed lines is used for result comparison

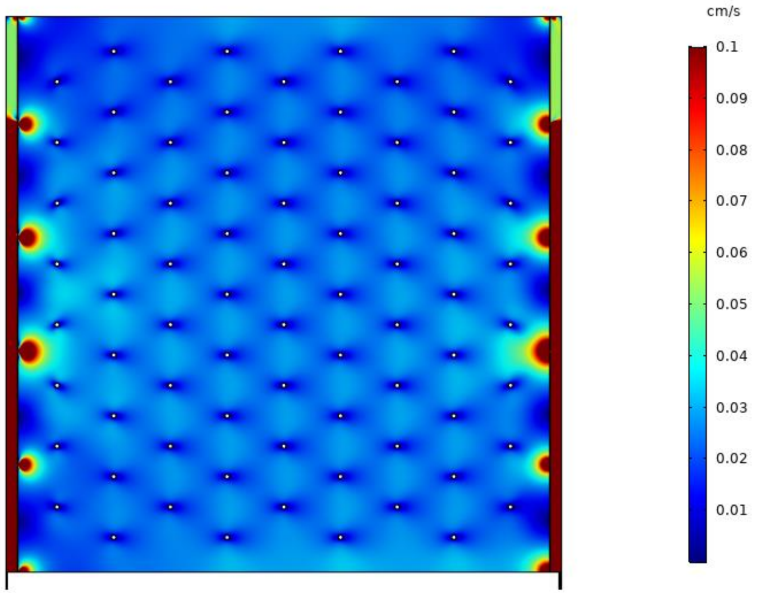
Velocity inside the chamber(Input: 1L/h)



A



B



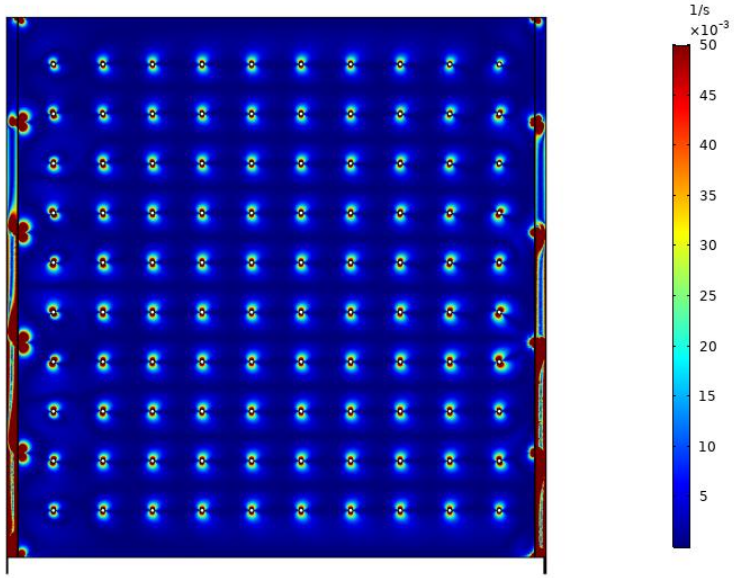
C

Model	A	B	C
Mean velocity(mm/s)	0.238	0.234	0.241
RMS of velocity(cm/s)	0.049	0.045	0.042
RMS/mean	20.3%	19.3%	17.5%

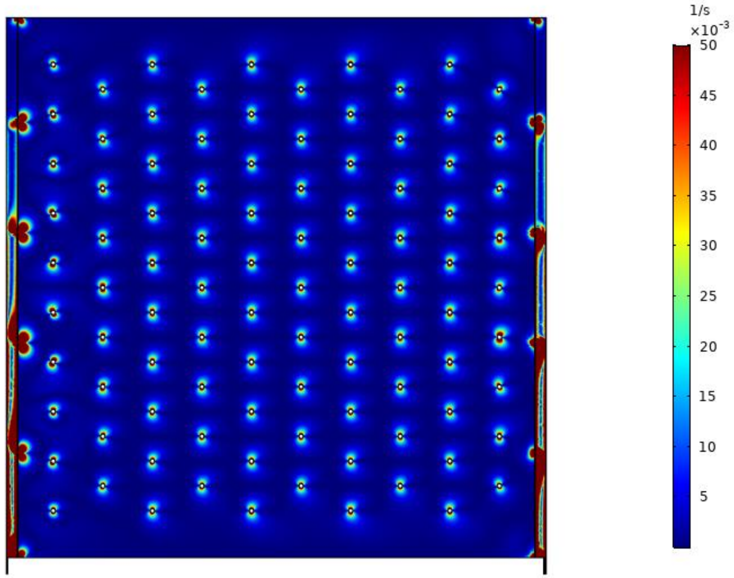
· Shifting the spacers helps to make the distribution of velocity more uniform

· The distribution of velocity gets more uniform after reducing the number of the spacers

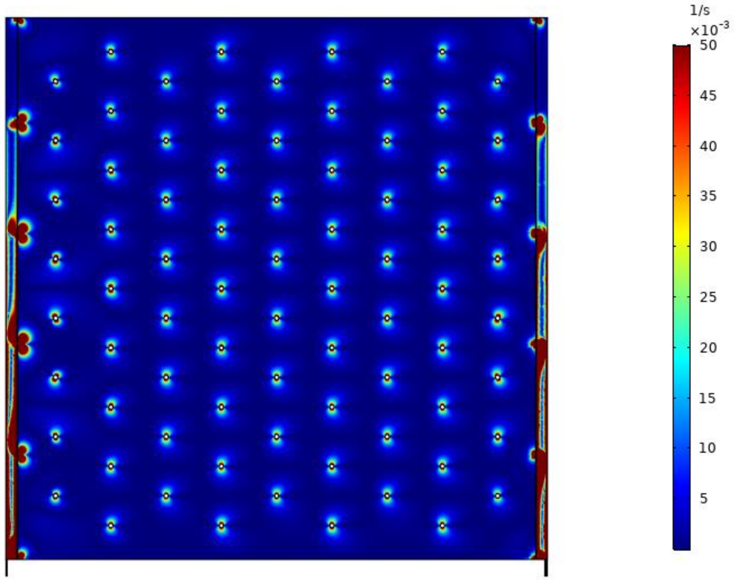
Vorticity inside the chamber(∇ ×v)



A



B



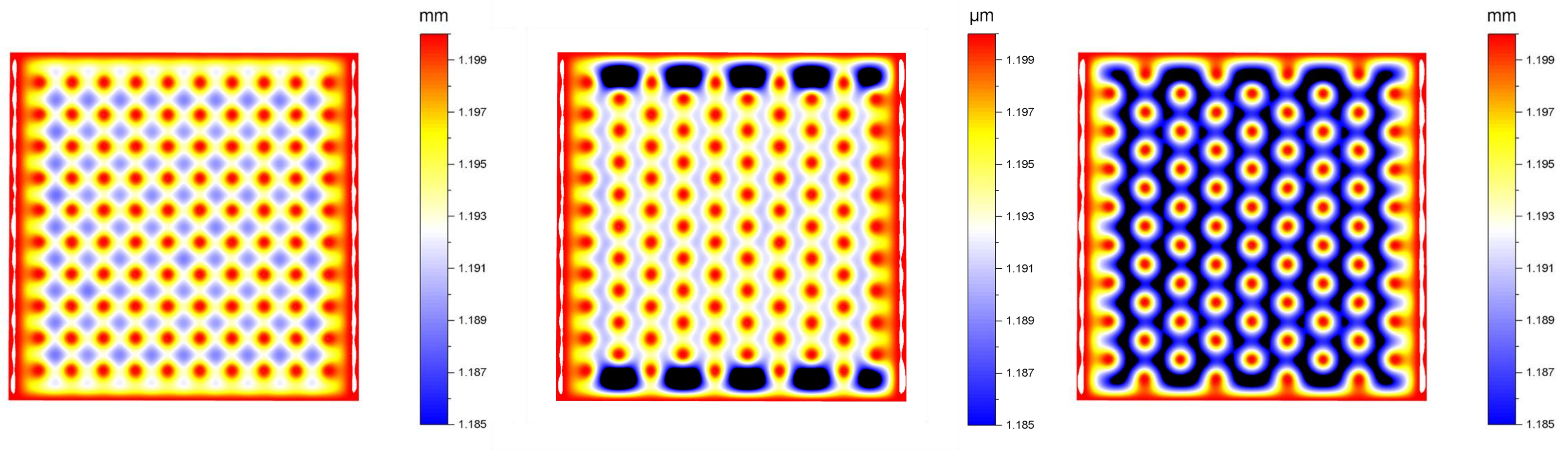
C

Model	A	B	C
Mean vorticity near spacers region(1/s)	0.0199	0.0198	0.0196
RMS of vorticity near spacers region(1/s)	0.0129	0.0129	0.0127
Mean vorticity excluding the vicinity of spacers(1/s)	0.0022	0.0021	0.0018
RMS of vorticity excluding the vicinity of spacers(1/s)	0.0028	0.0029	0.0026

· Shifting the spacers and reducing the number of spacers can reduce the vorticity inside the gas gap (less vortex region)

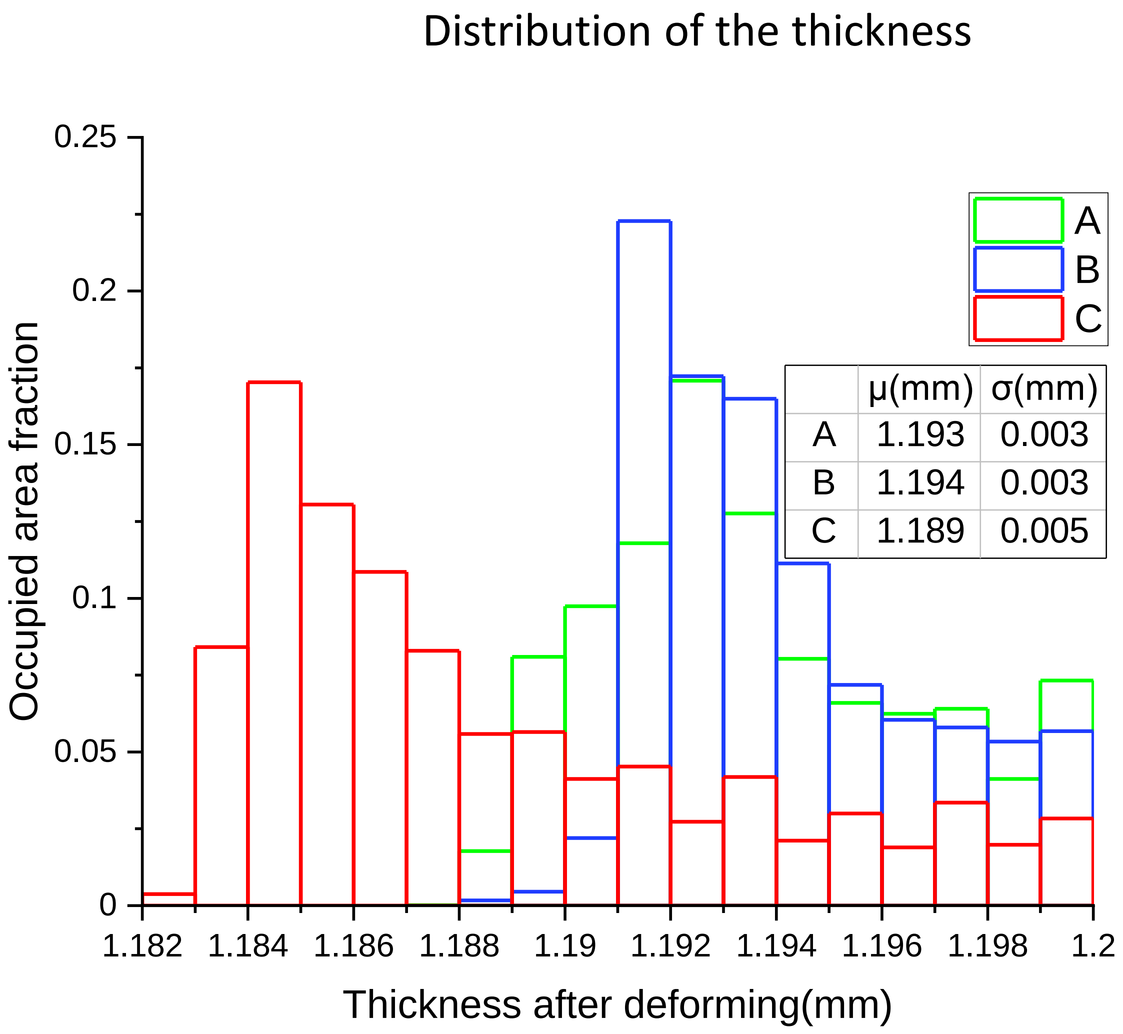
Deformation of the glass electrodes

The simulation of chamber deformation on the electrodes is carried out by using pressure of gas flow and an electric field between two electrodes which is applied at 6.6 kV (working voltage of our RPC).



Distribution of the thickness of the gas gap after deformation

Thickness of the gas gap after electrodes’ deformation



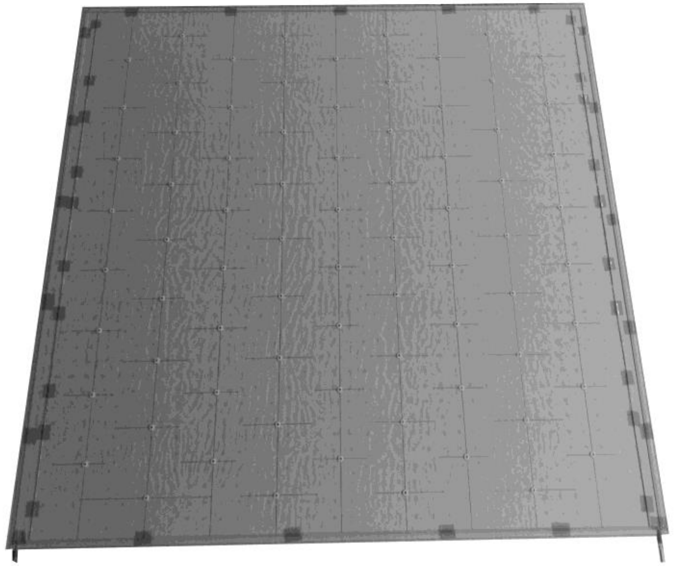
Model	A	B	C
RMS/mean	0.25%	0.25%	0.34%

· Shifting the spacers can slightly lower the deformation

· The increase of the distance between spacers would cause more deformation on both electrodes, but still within 1%

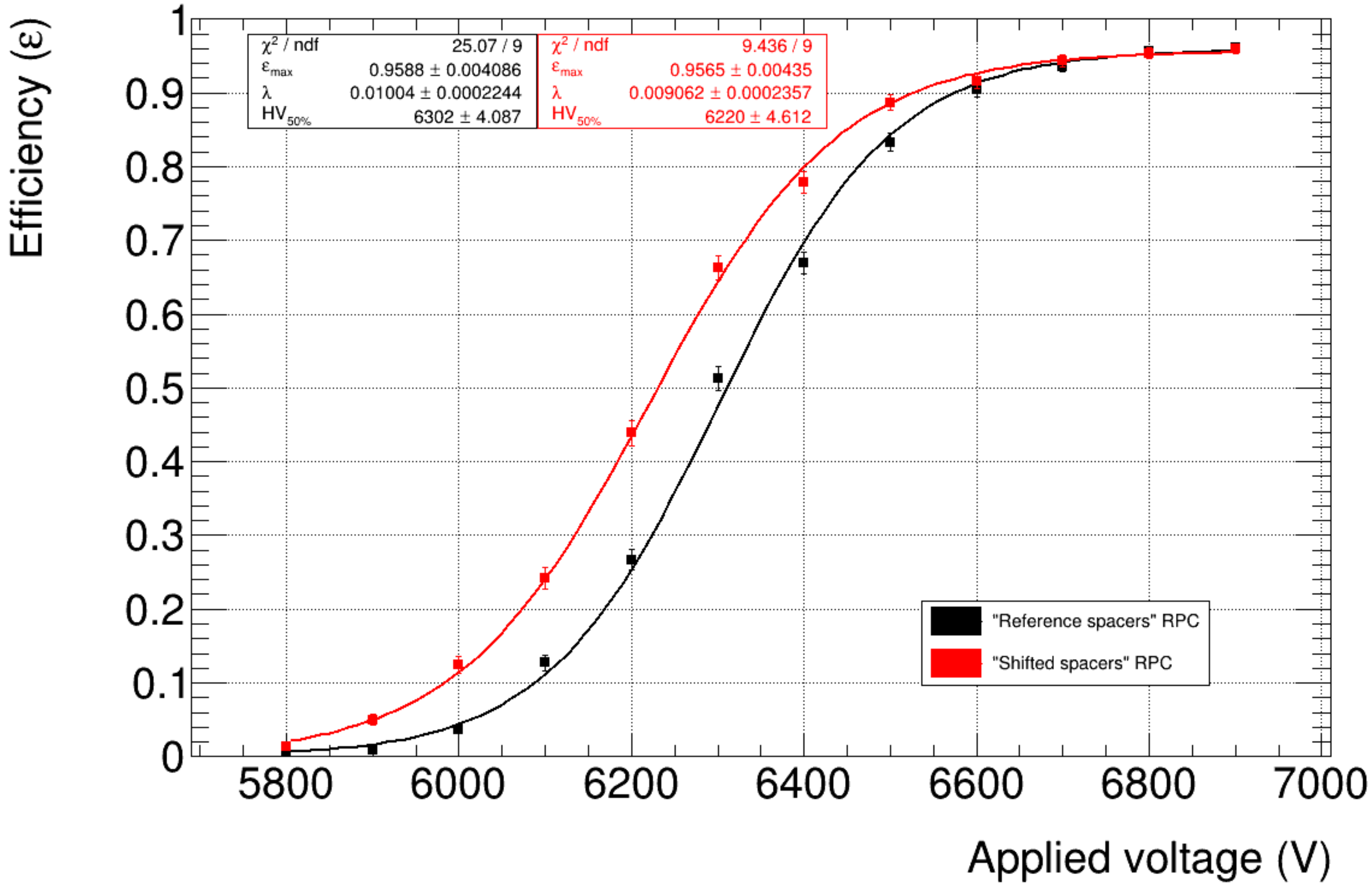
· The uniformity of deformation maintains similar level

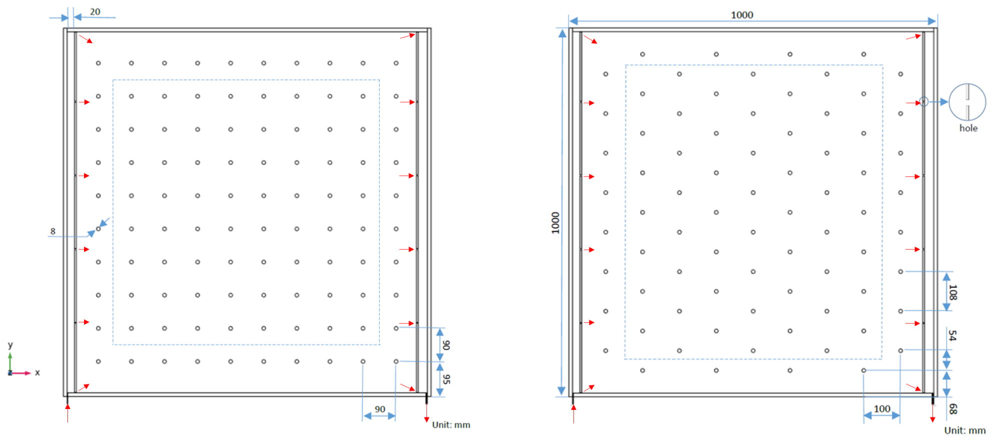
Construction and test of the RPCs



· Chambers built in the lab and test under the cosmic ray

Construction and test of the RPCs





· The efficiency plateaus are comparable for the two chambers are both greater than 95%

Summary

· By shifting the spacers, then increase the distance

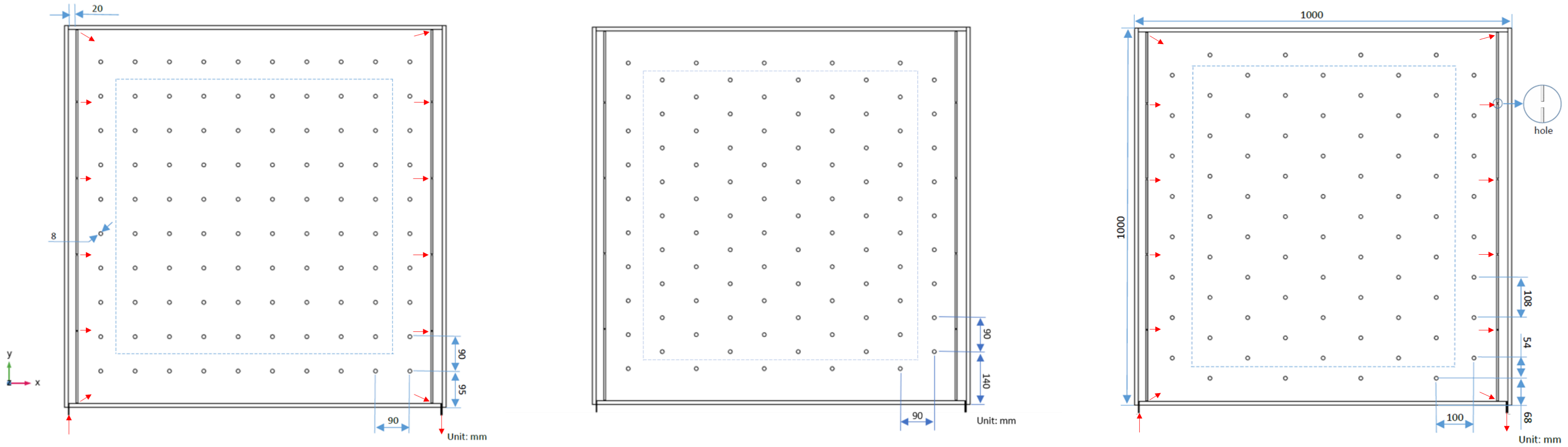
(1) Decrease the spacer number(100 → 95→ 76)， at last a 24% decrease

(2) More active region($1-\frac{spaces' space}{chamber's\ space}$), 99.487% to 99.512% to 99.610%.

(3) Making the gas to move more uniformly

(4) Lower vorticity inside the chamber

(5) Maintaining similar deformation uniformity of the electrodes



arXiv:2108.12843

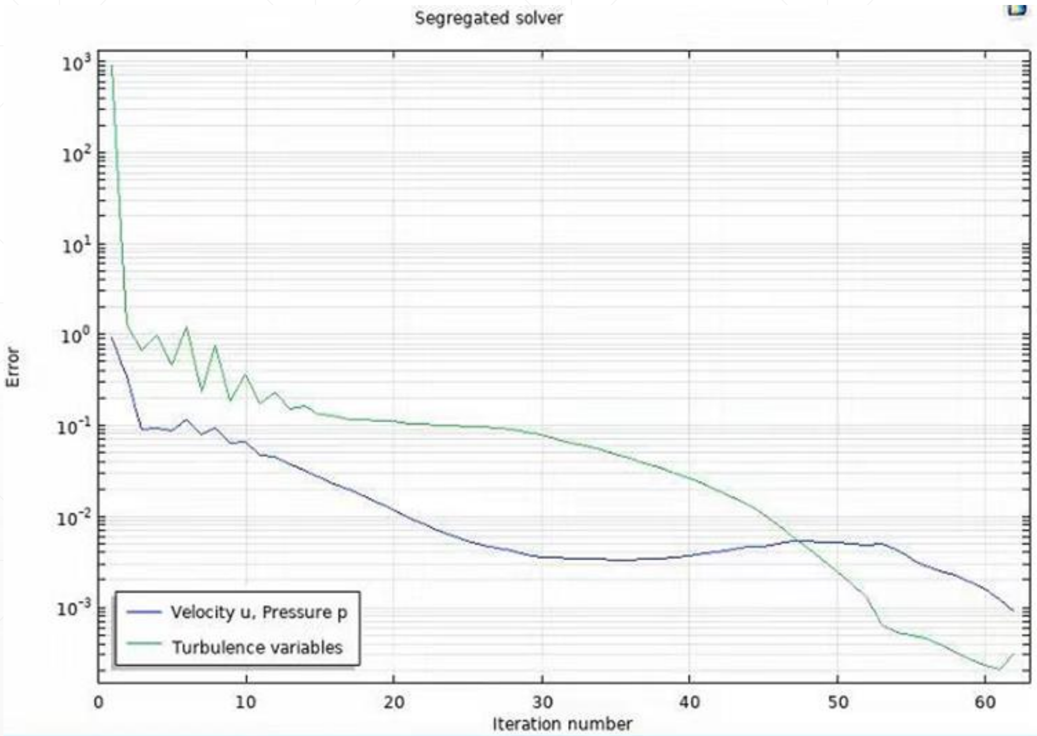
THANKS!

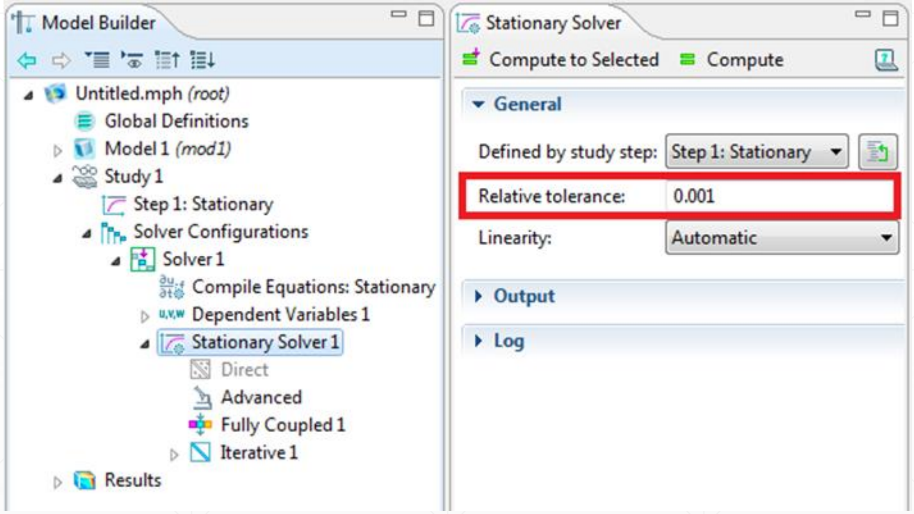
BACKUP

Testing for error

4 times for running(deformation), get the maximum value(μm)

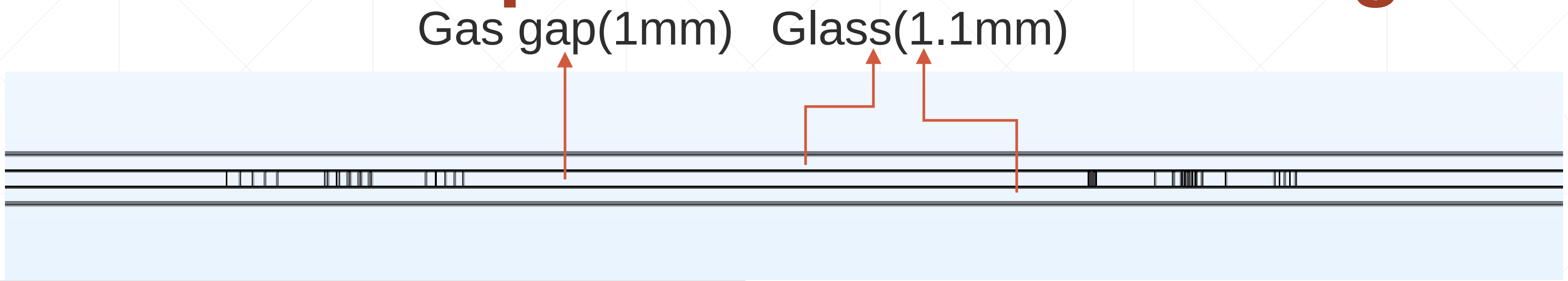
1	2	3	4
3.14241452818821017	3.14241452818804603	3.14241452818806086	3.14241452818811824
0	-5.22337E-13	-4.75144E-13	-2.92546E-13

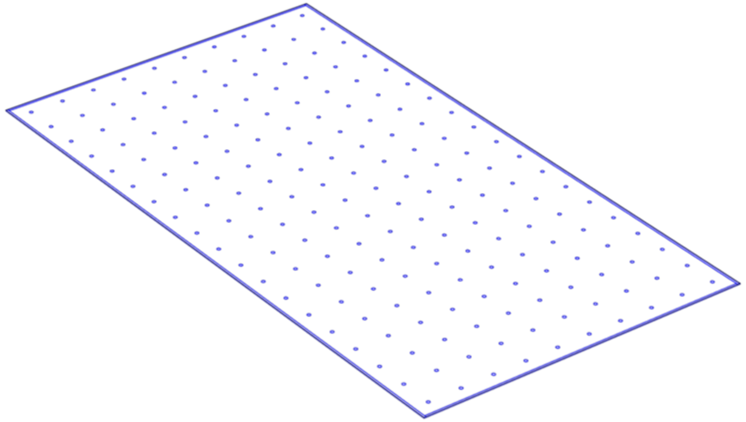


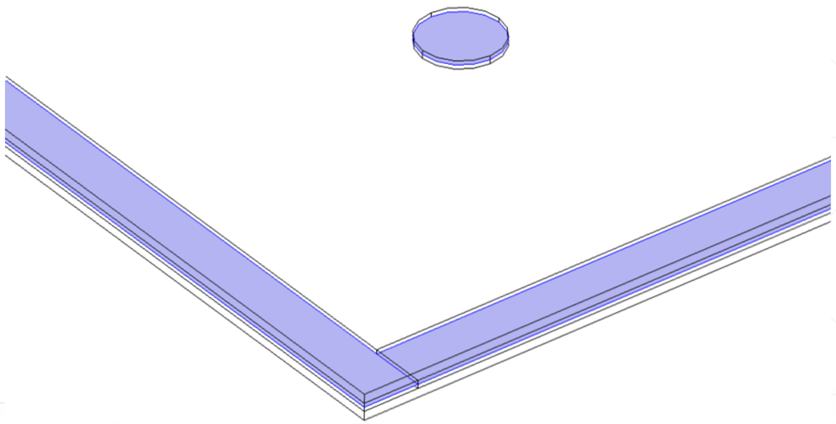


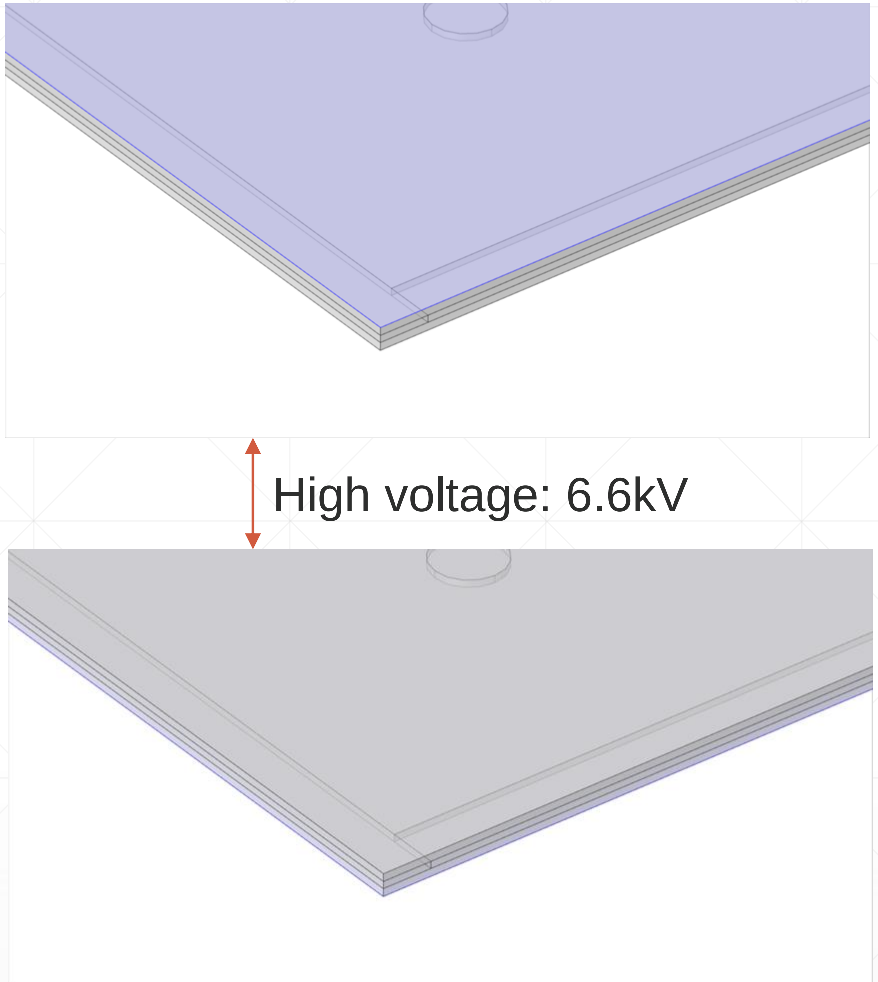
Threshold~10^-3

Work to couple electric field with glass









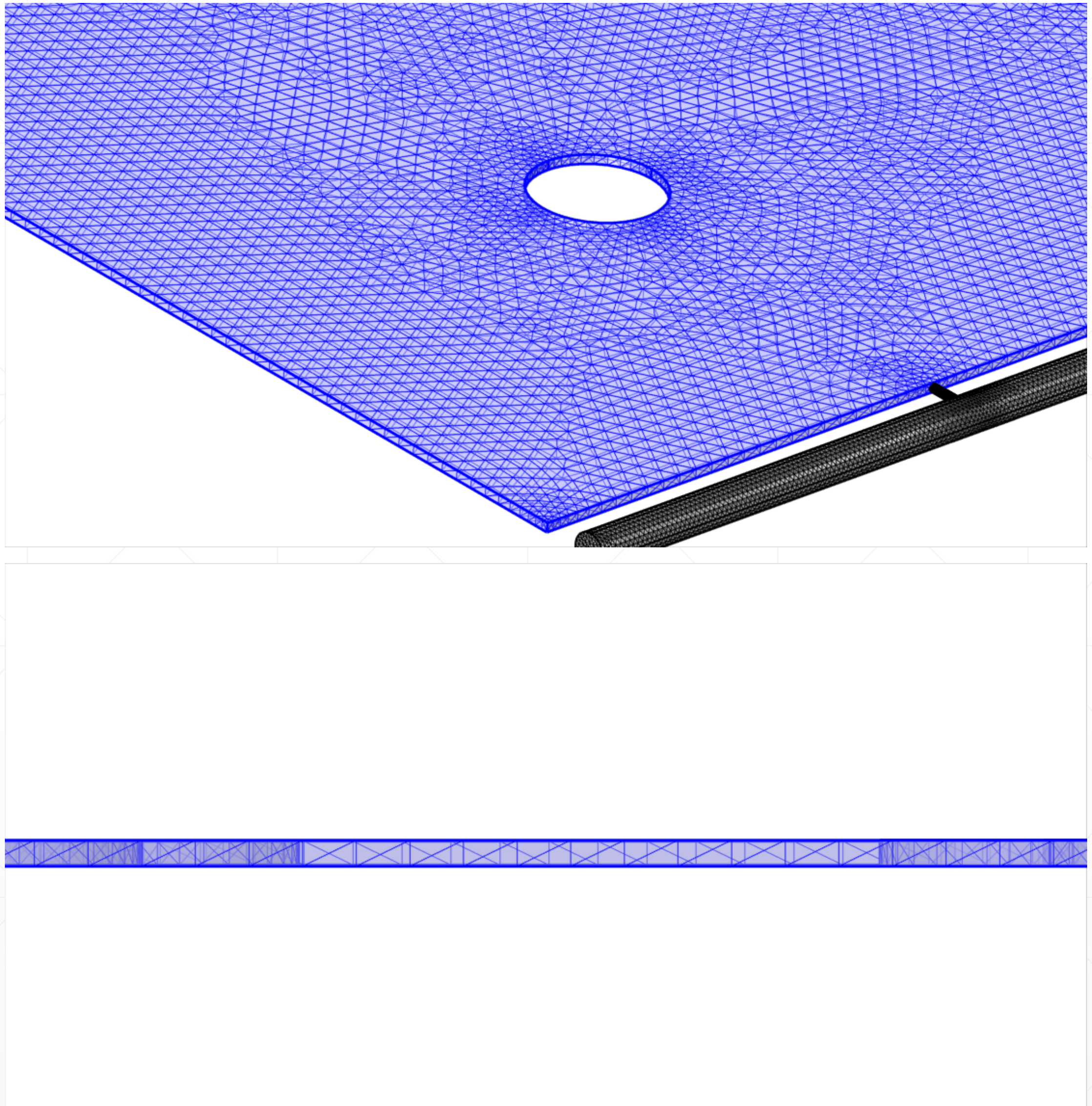
The middle of spacers/walls are fixed to avoid the chamber from moving.

- Other parameters:

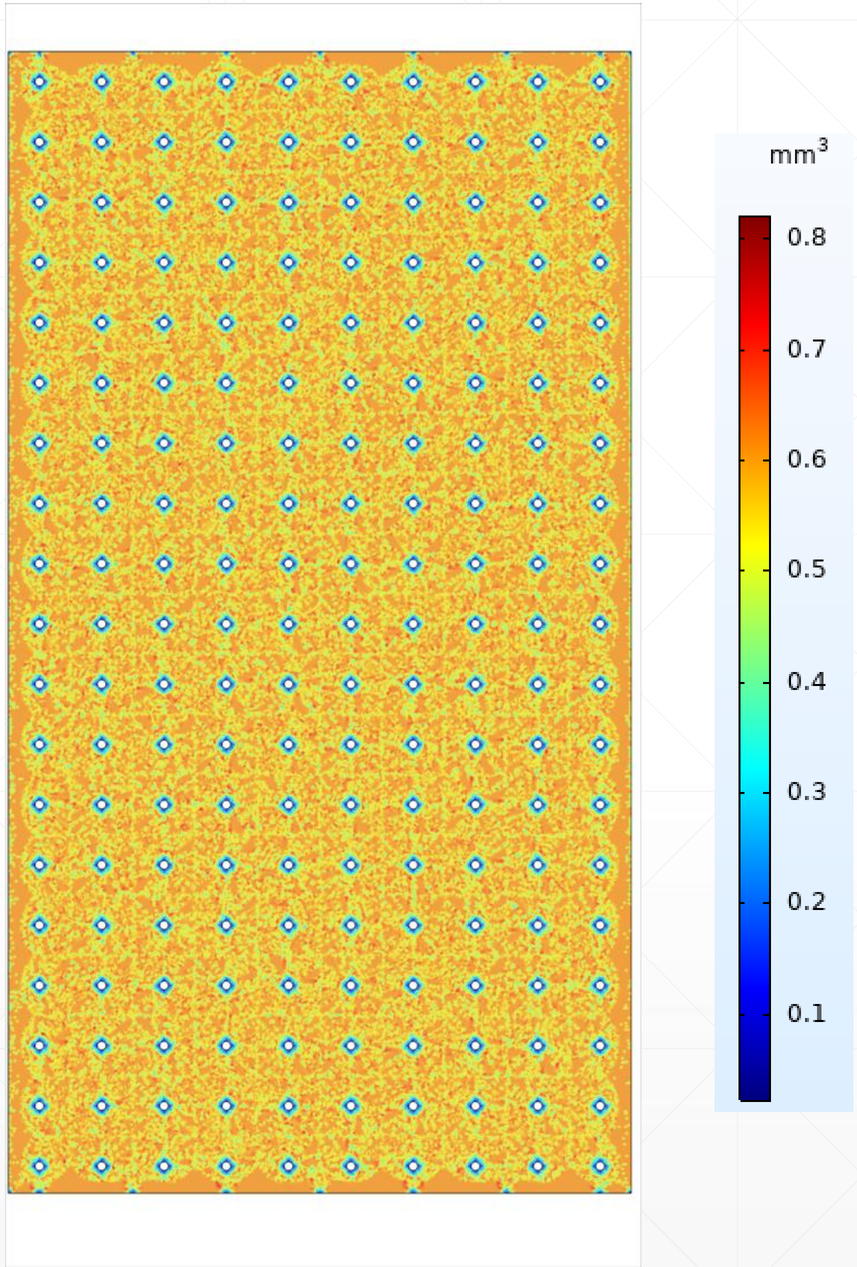
material	PA66(spacer)	FR4(wall)	Glass	Air
Relative permittivity[1]	4.5	4.5	4.2	10
Density[kg/m^3]	1140	1900	2210	
Young's modulus[GPa]	8.3	22	55	
Poisson's ratio[1]	0.28	0.15	0.25	

(all from website)

Adding the mesh



Sketch for the meshes



Volume of the meshes