Gas flow simulations, cooling system and chamber construction at SJTU

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On behalf of SDHCAL Study Group

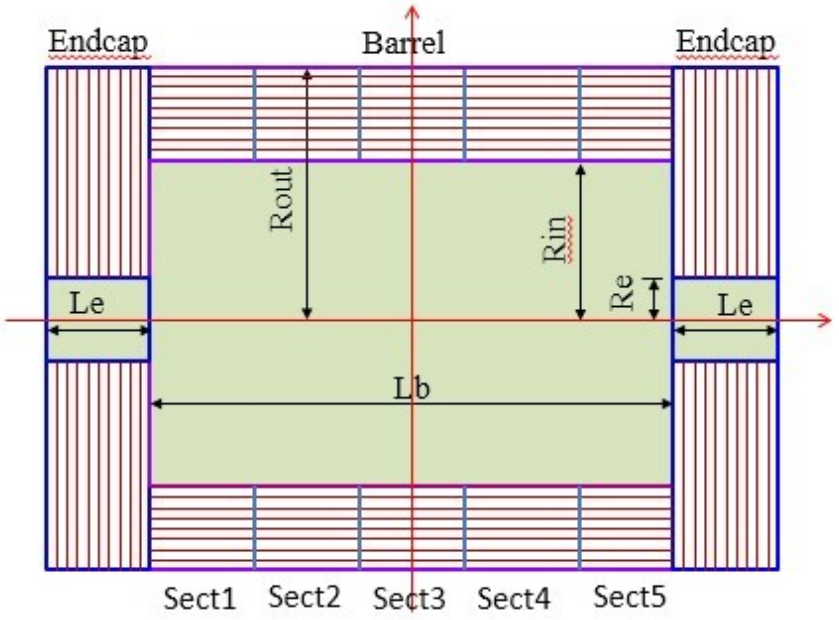
CALICE collaboration meeting 2021/03/25

Outline

- Introduction
- Gas flow simulation for GRPC
- Cooling system for a SDHCAL at CEPC
- GRPC performance tests
- Summary

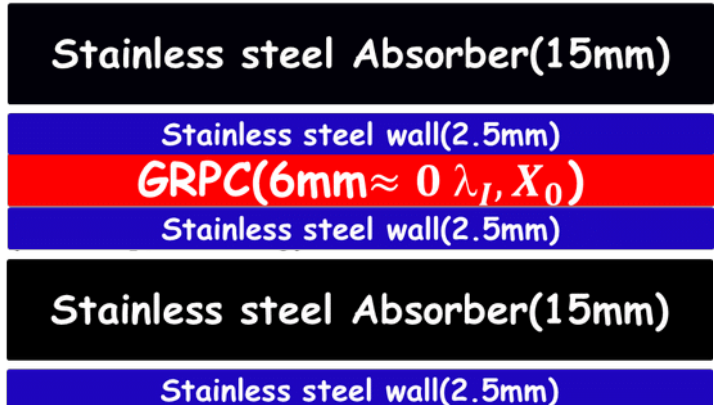
Introduction

- Futur Electron-Positron Collider (CEPC,ILC,FCC)
  → Higgs boson factory

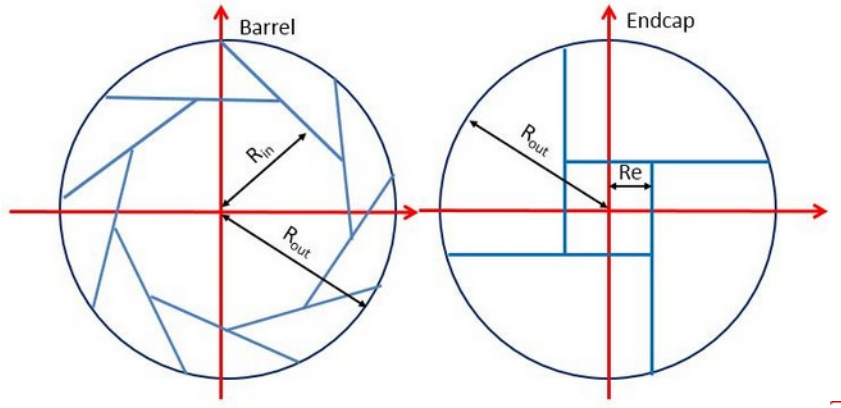


- CEPC SDHCAL(Semi-Digital Hadron Calorimeter
  - Area of the active layers:
    - ~3800m² (barrel)
    - ~2800m² (endcap)

$(0.12\lambda_I, 1.14X_0)$



→ 3 mm GRPC
1.2 ↔ 1.4 mm PCB
1.6 mm ASIC

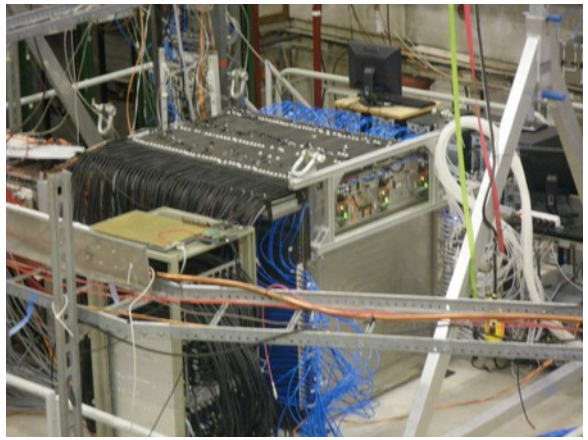


Introduction

Why do we need a cooling system for CEPC SDHCAL ?

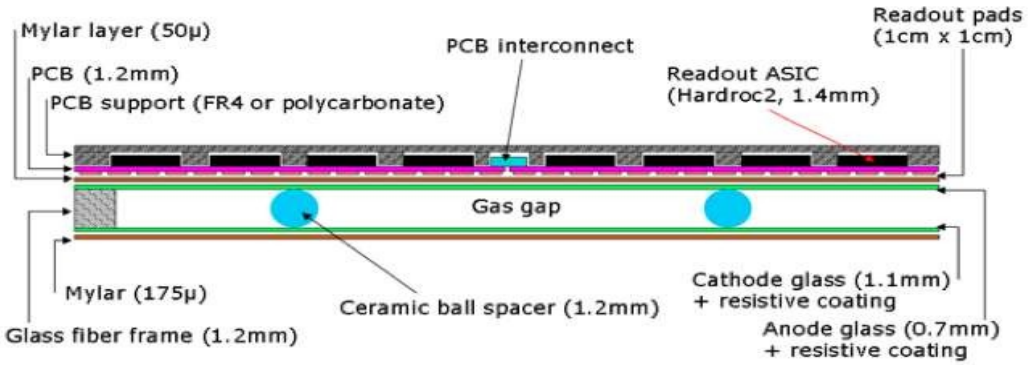
- The new generation of detetector will fully exploit the Particle Flow Algorithm :
  → Need high granularity detectors.
- → Avoid cracks in the detectors.

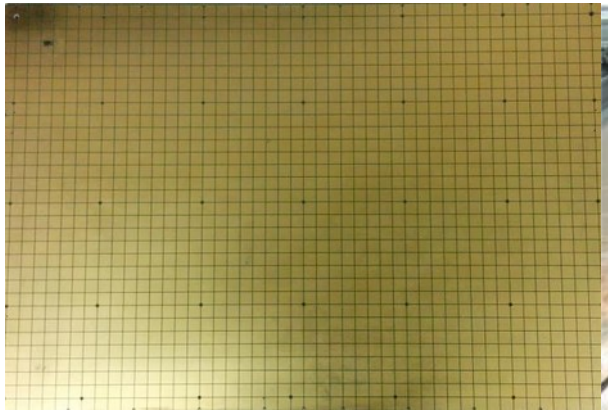
- For SDHCAL :
  → 1×1cm²cm pads → Over 60M channels → HEAT !
  ASIC chips : ~1mW/ch → 60kW +Readout board ...



The SDHCAL has been design for ILC and use the particular beam structure (collision rate ~5Hz) to swich off part of the his electronics.

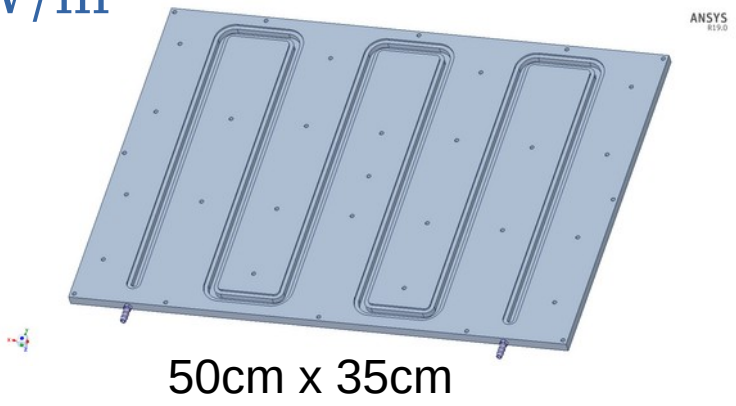
For CEPC the collision rate ~1.5MHz (Higgs configuration)
→ Active cooling system.

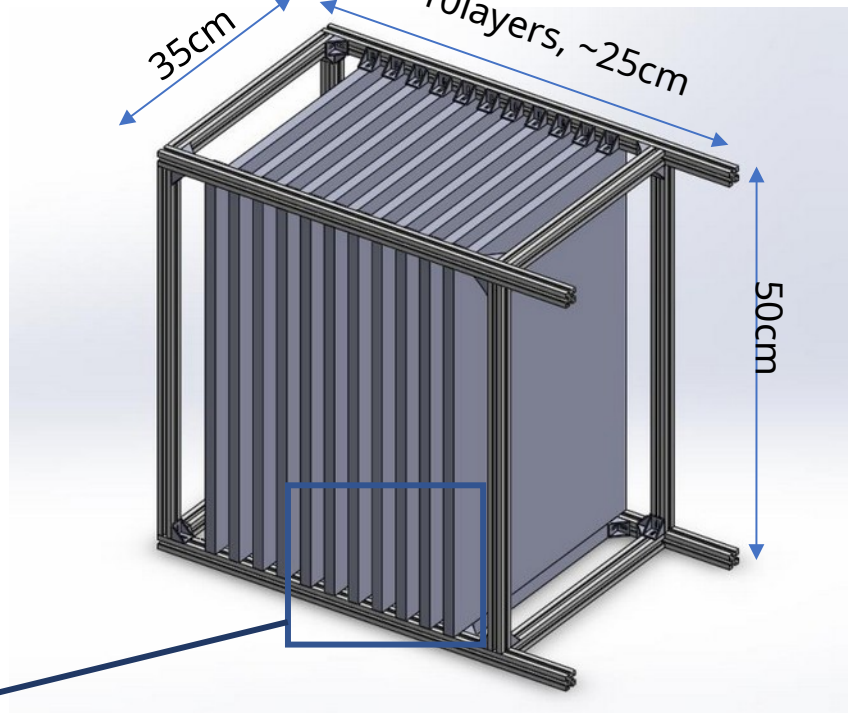


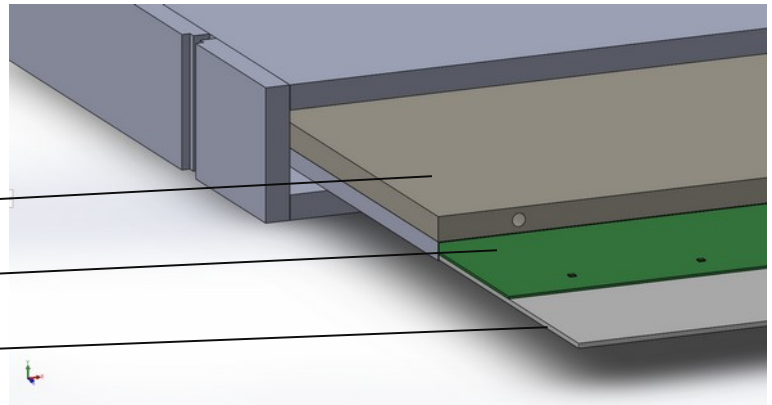


Cooling system : cooling plates

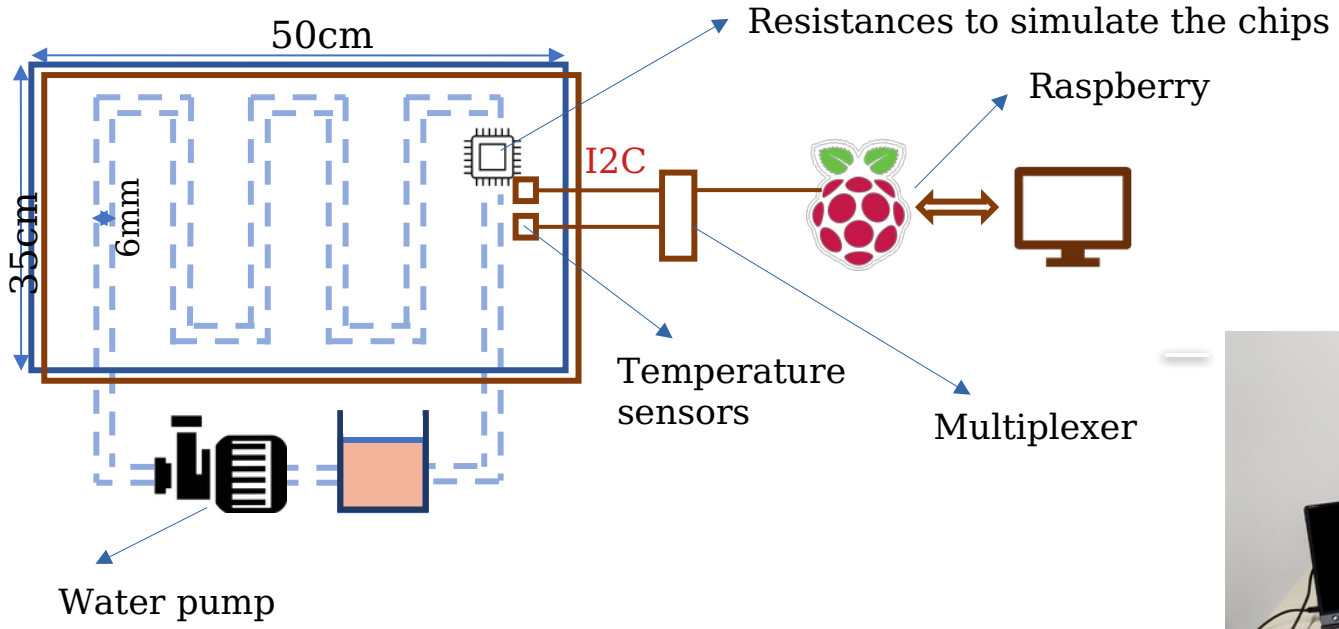
- Cooling plates: water pipes imbedded in metal plates
  - Cooling ability: ~kW/m^2
  - Using water
  - Price
  - Compactness
  - Maintenance
- Flexible framework

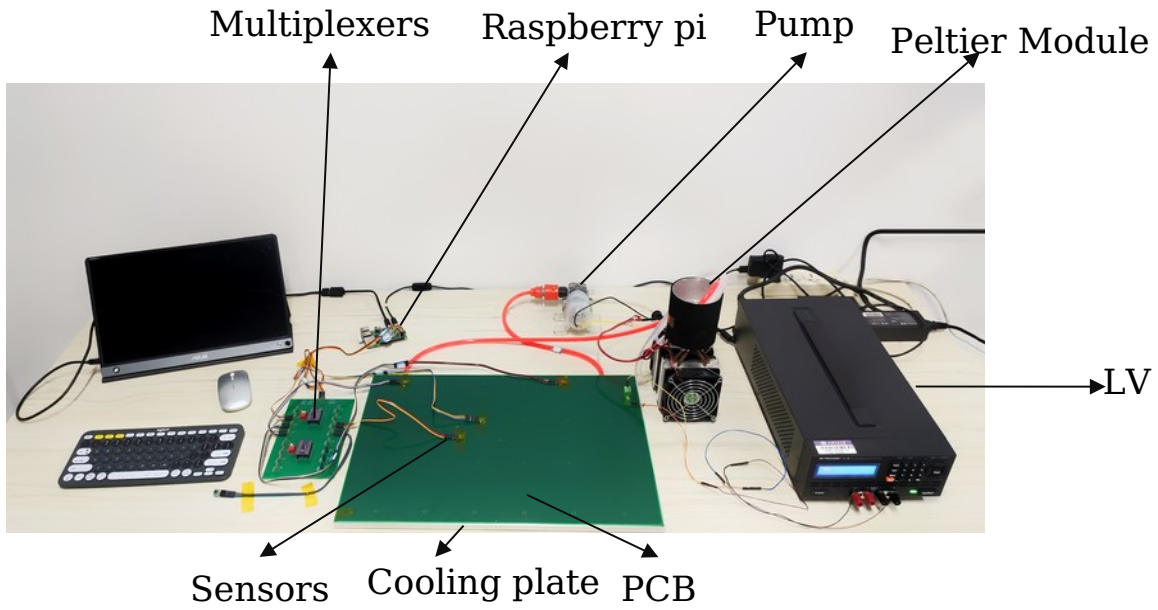






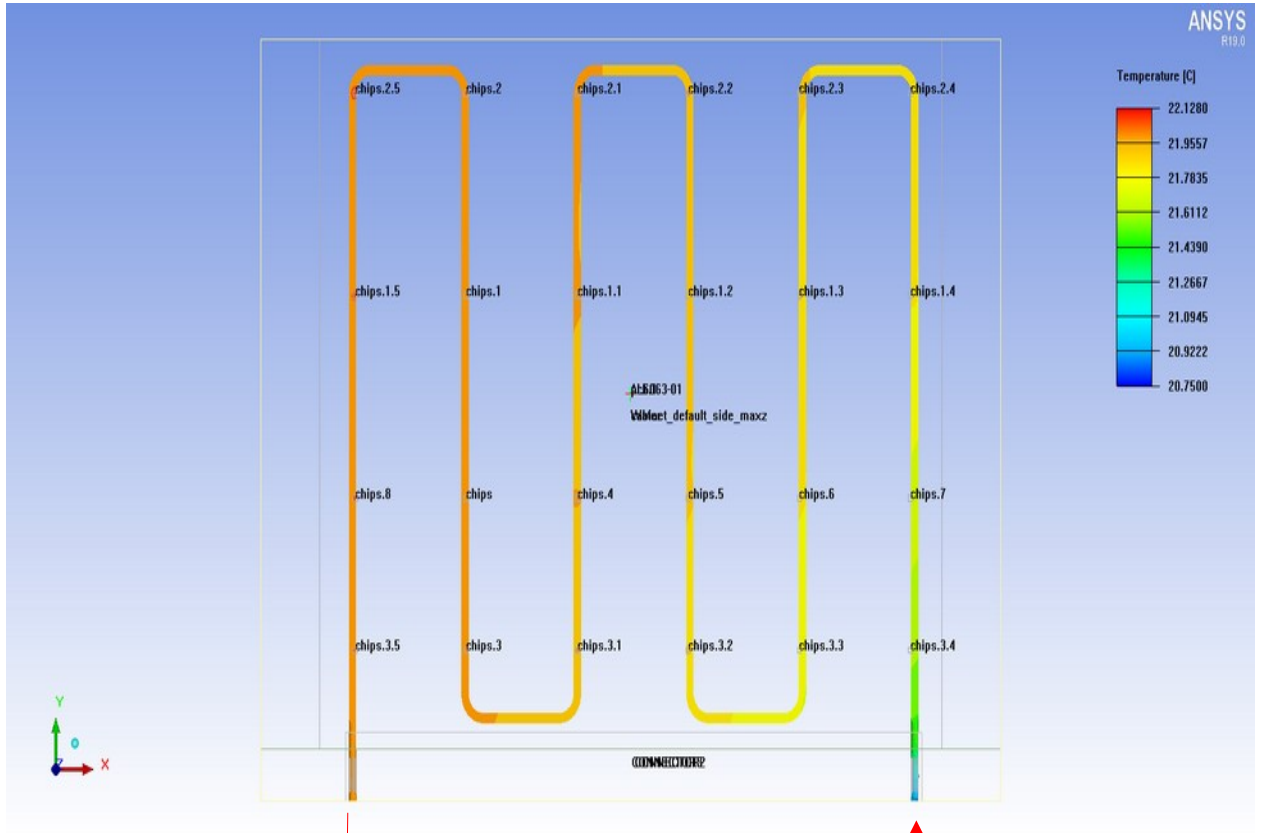
Test of the cooling plates



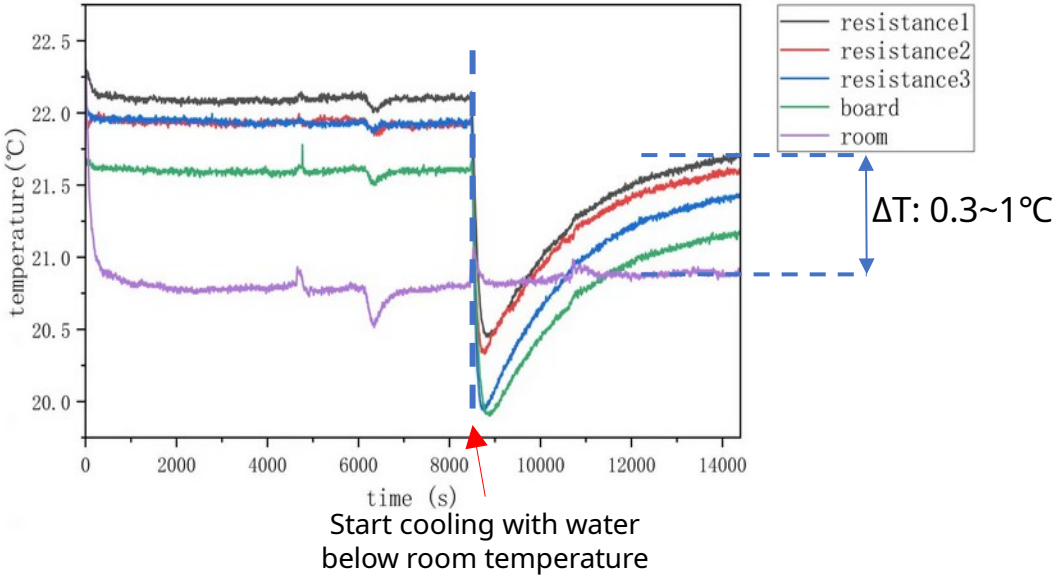


Test of the cooling plates

Simulation

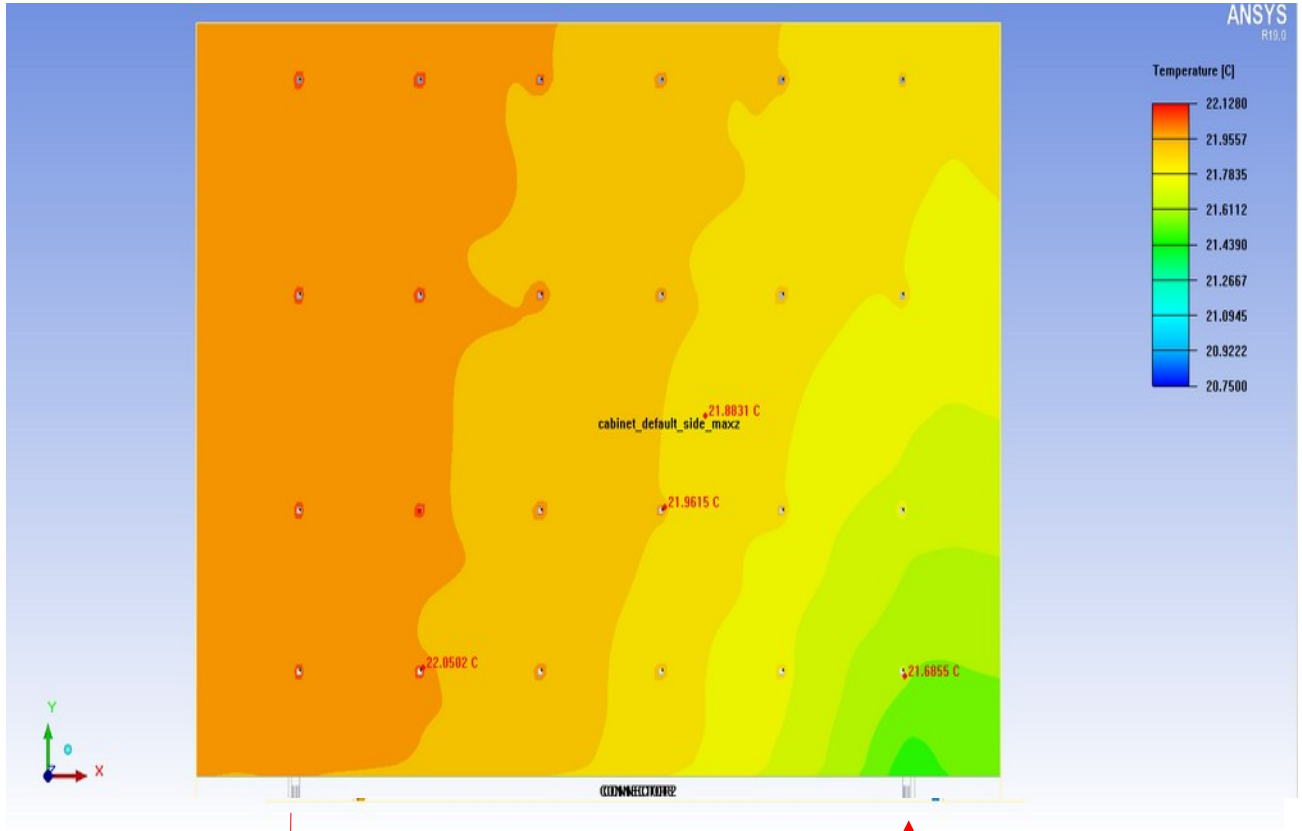


Temperature measurements



Test of the cooling plates

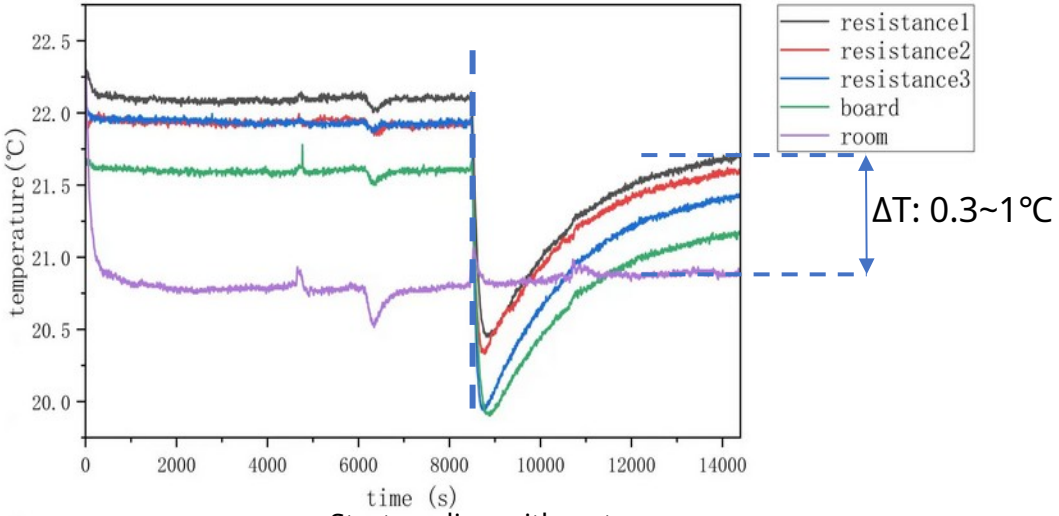
Simulation



Outlet

Inlet

Temperature measurements



Start cooling with water below room temperature

- Maximum ΔT for simulation (~1.3℃) is coherent with experiment ΔT (~1℃).

→ First checks look promising

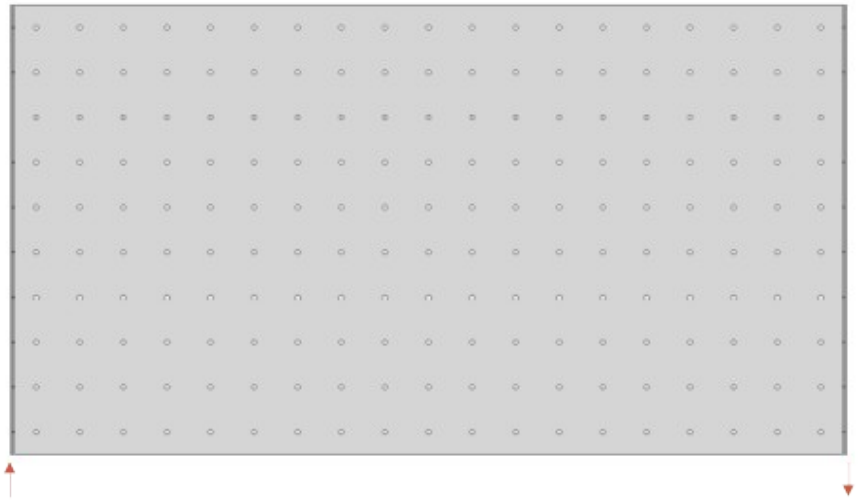
Gas flow simulation for GRPC

Gas flow has a strong impact on the homogeneity, efficiency of the RPC.

→ The biggest the chamber, the most critical it's become.

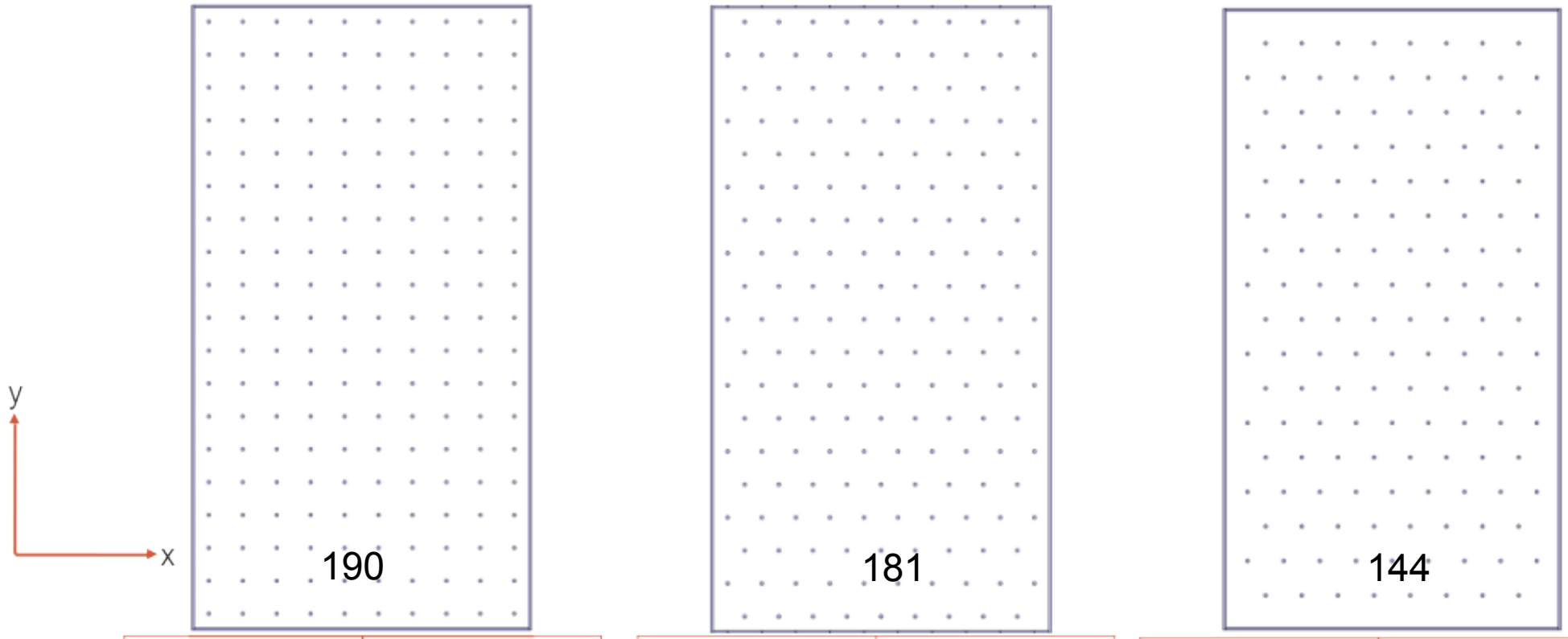
→ For large GRPC 1820mm x 990mm.

→ Using COMSOL Multiphysics 5.4 to simulate gas flow/electric field.



Total size : 1820mm x 990mm x 1mm
Number of spacers : 19 x 10
Spacer radius 5mm

GRPC with different number of spacers

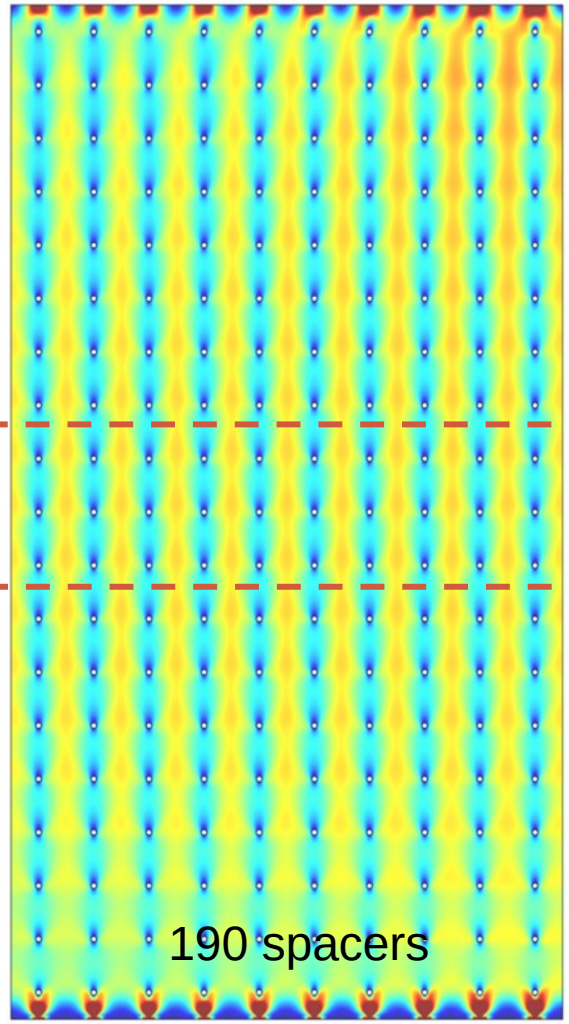


Distance(cm)	
Spacer to spacer(x)	9.9
Spacer to spacer(y)	9.96
Spacer to wall(x)	9.9/2
Spacer to wall(y)	9.96/2

Distance(cm)	
Spacer to spacer(x)	9.9
Spacer to spacer(y)	9.96
Spacer to wall(x)	9.9/2
Spacer to wall(y)	9.96/2

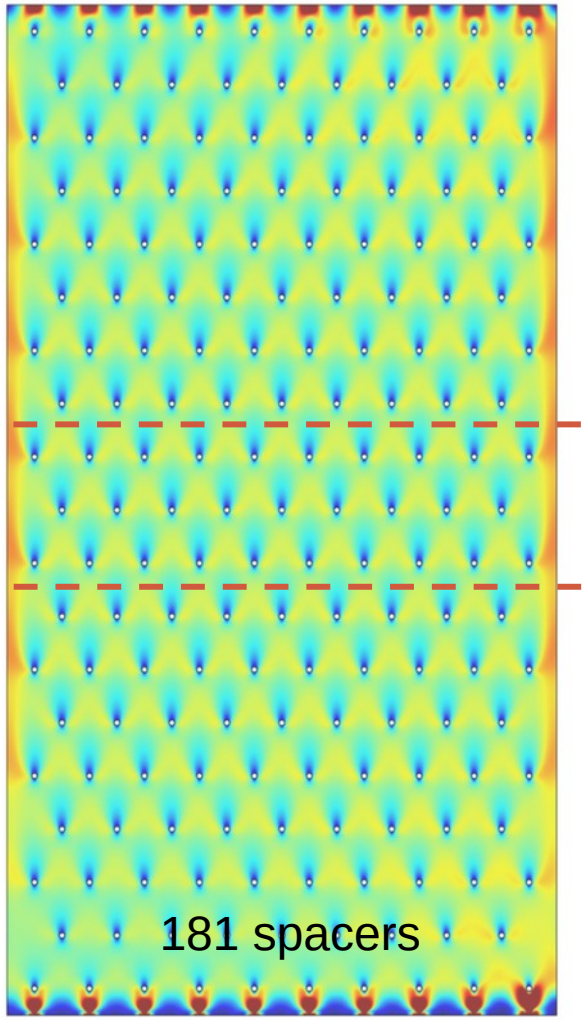
Distance(cm)	
Spacer to spacer(x)	10.1
Spacer to spacer(y)	10.6
Spacer to wall(x)	10.1
Spacer to wall(y)	10.6

Gas flow velocity **input:1m/s~10L/h**



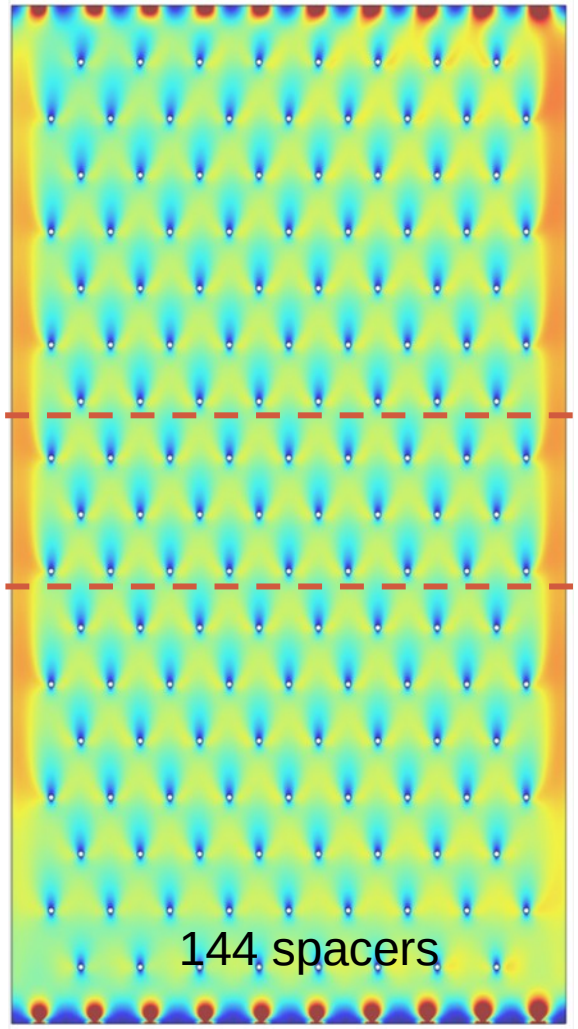
Ave(m/s) 0.012184

Dev(m/s) 0.003631



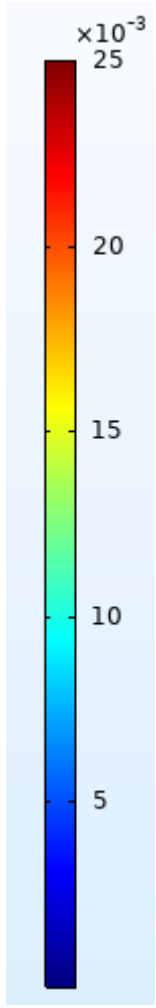
Ave(m/s) 0.012319

Dev(m/s) 0.002994



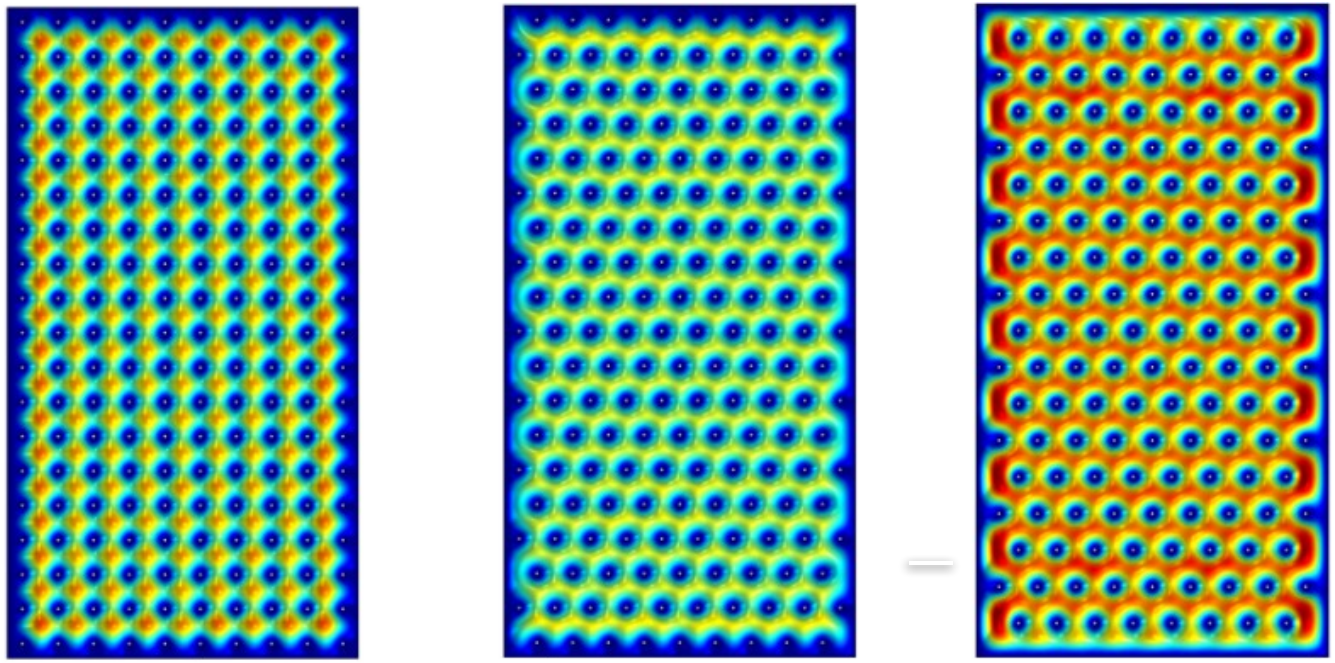
Ave(m/s) 0.012329

Dev(m/s) 0.003080



- Slightly better velocity uniformity while reducing the number of spacers by ~25%

Deformation due to pressure and electric field



Applied voltage : 6600V

Maximum/gap*100%	Non-shifted	Shifted	Less spacers
Fluid(1 vol/h)+electrical	-0.245655%	-0.196048%	-0.296364%
Electrical force	-0.248539%	-0.198346%	-0.300121%
Fluid(1 vol/h)	0.002298%	0.002884%	0.003757%
Fluid(10 vol/h)	0.044475%	0.035548%	0.056712%

Thickness of gas gap: 1mm

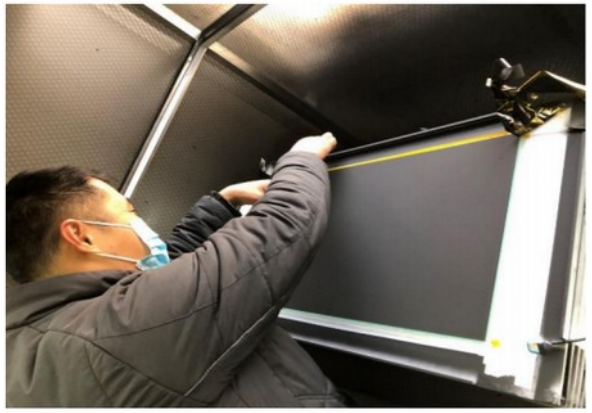
By shifting the spacers and trying to keep the same deformation :

- Decrease the spacer number 190 → 181 → 144 (-25%)
- More active region
- Easier to build
- Improve homgeneity

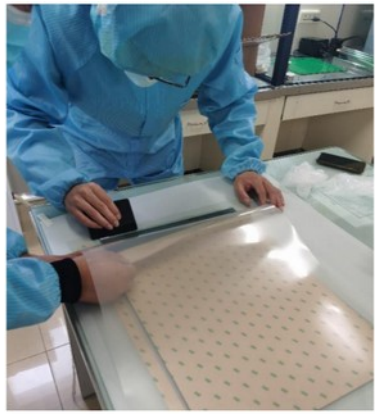
GRPC construction

30Cm x 50cm chambers

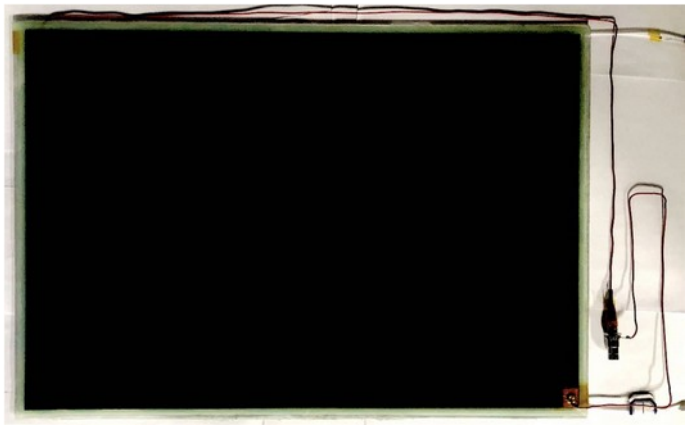
Placing spacers



Painting



Gluing Mylar film

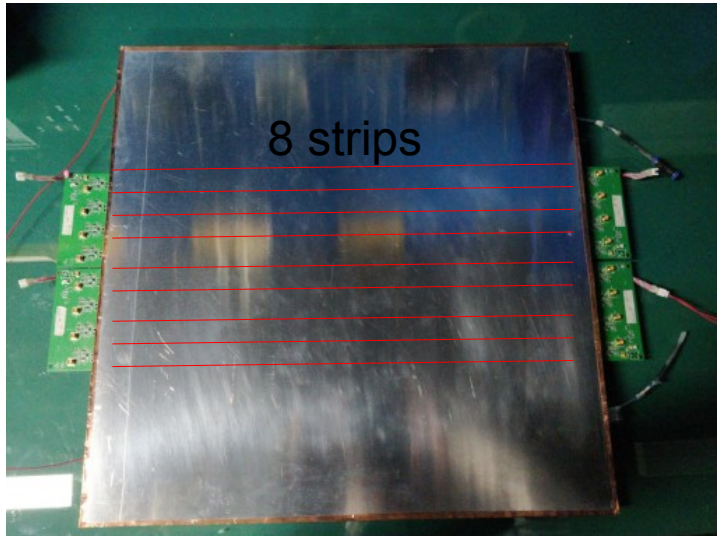


Building 1m x 1m GRPC

Placing spacers

Gluing spacers

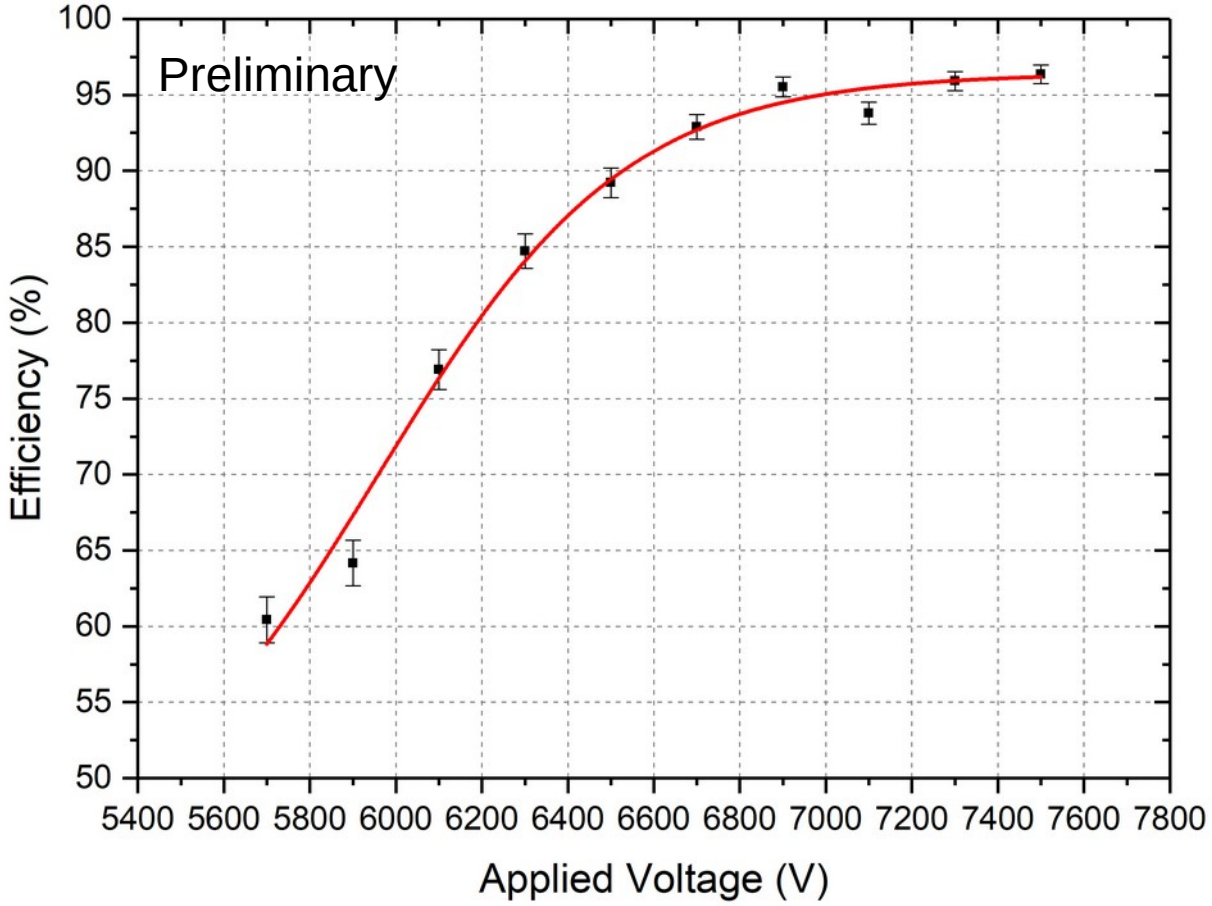
Cosmic stand



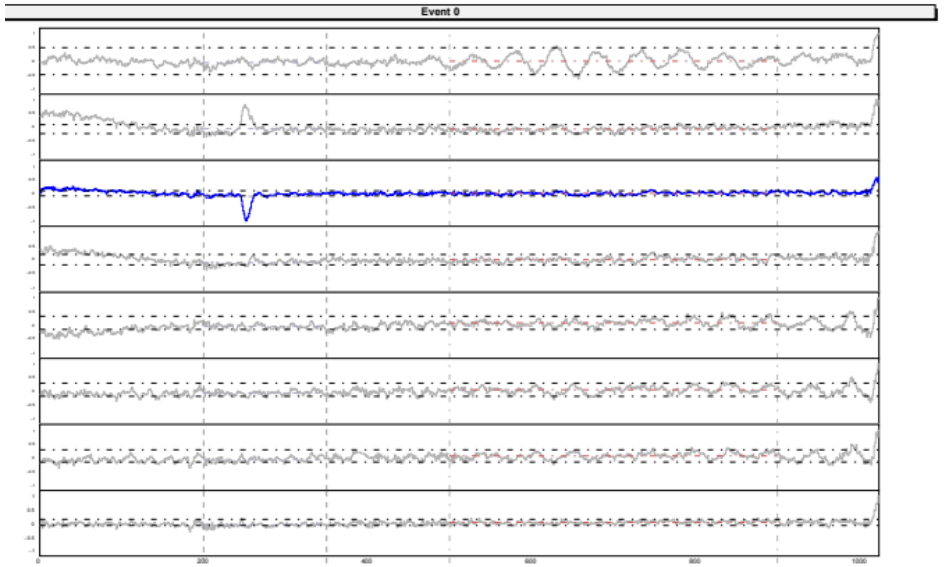
Testing the 50cm x 30cm chambers

USTC reference chamber

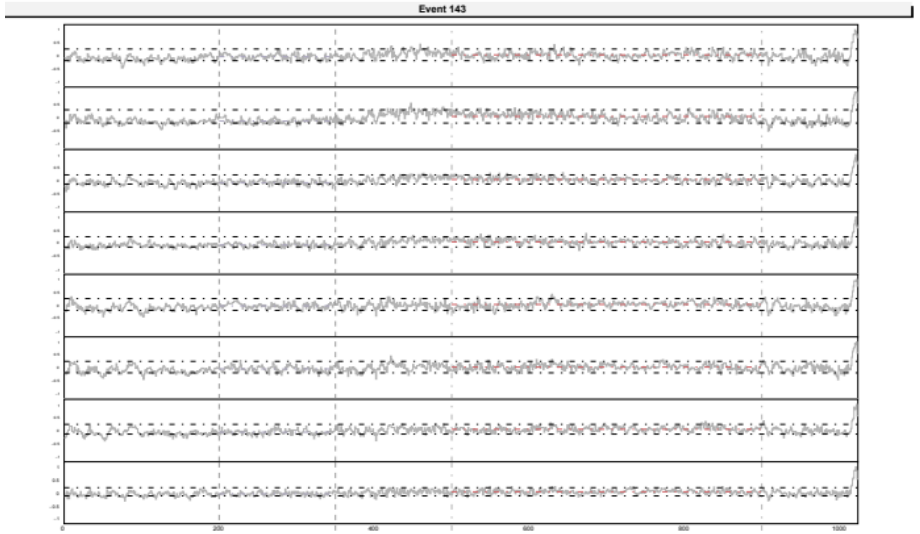
GRPC efficency using cosmic muons



- RPC efficiency reachs 95% at ~7000V
- ~1000 muons / HV point.



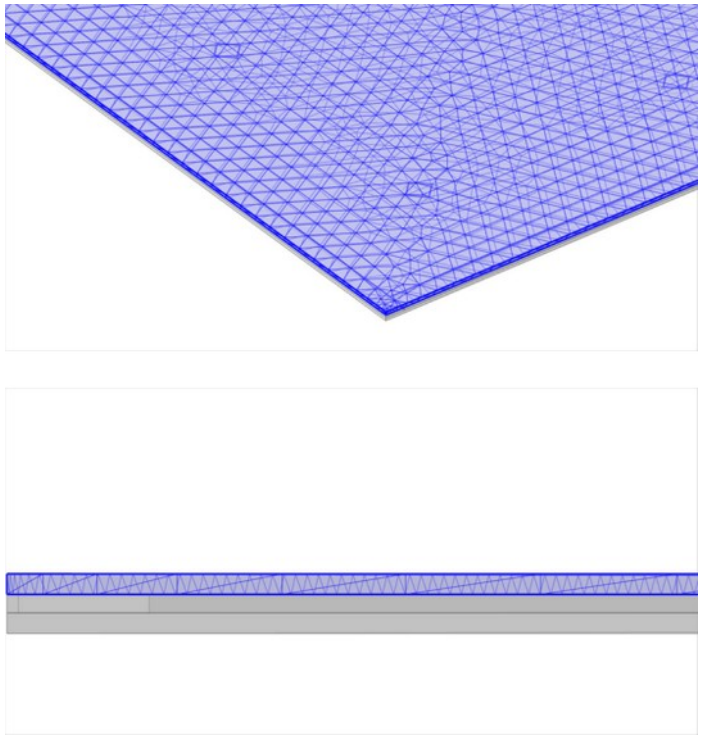
Even triggered with signal in chamber



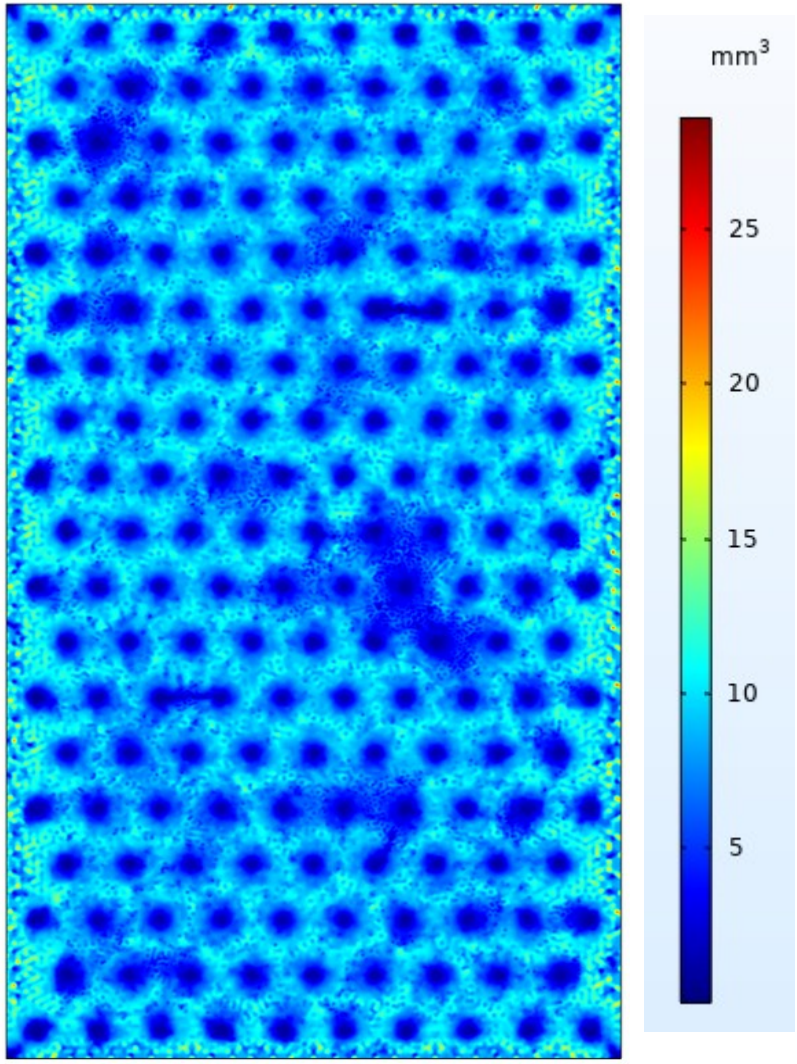
Even triggered with no signal in chamber

Thanks for your attention!

Sketch for the meshes



Volume of the meshes



- 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	