Development of RPC for ATLAS Phase-II muon upgrade

Lagarde François
On behalf the SJTU-RPC group, **INPAC**

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Outline

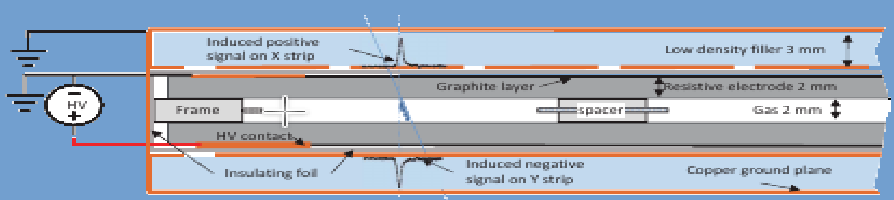
- Introduction
- RPC Laboratory setting up at SJTU
- Glass RPC construction
- Gas Flow simulation
- Conclusion

Introduction

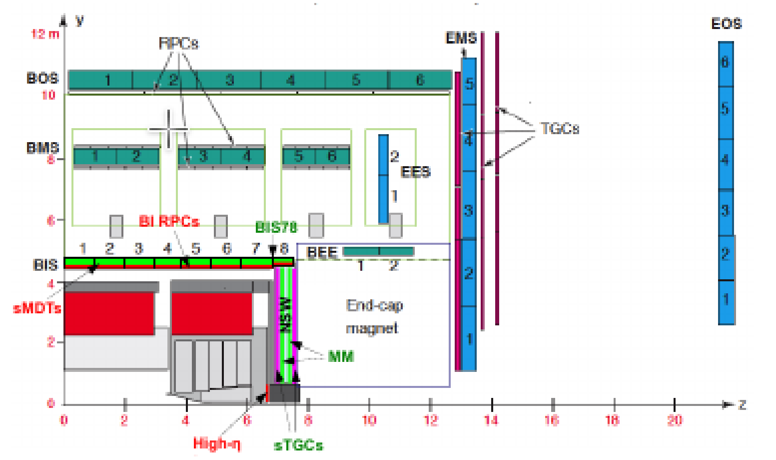
Hight Luminosity-LHC (2023-~2035)

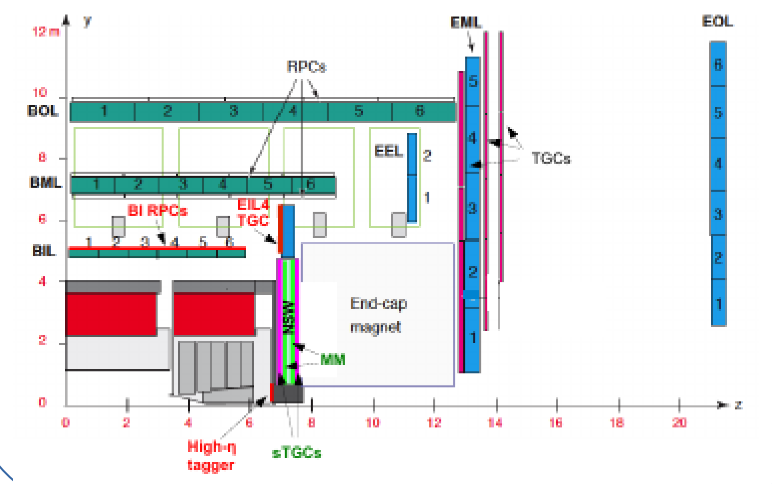
Increase the luminosity L(t) (X5-7)
Increase the pile-up (~200)
particles fluxes
Need to upgrade ATLAS !

The current ATLAS RPC chambers :



→ Certified for 10 years of operation at LHC.
→ Integrated charge up to 0.3 C/cm².
→ 10 years at a counting rate of 100Hz/cm².
→ Can only work under lower voltage with detection efficiency lost of 15%-35%



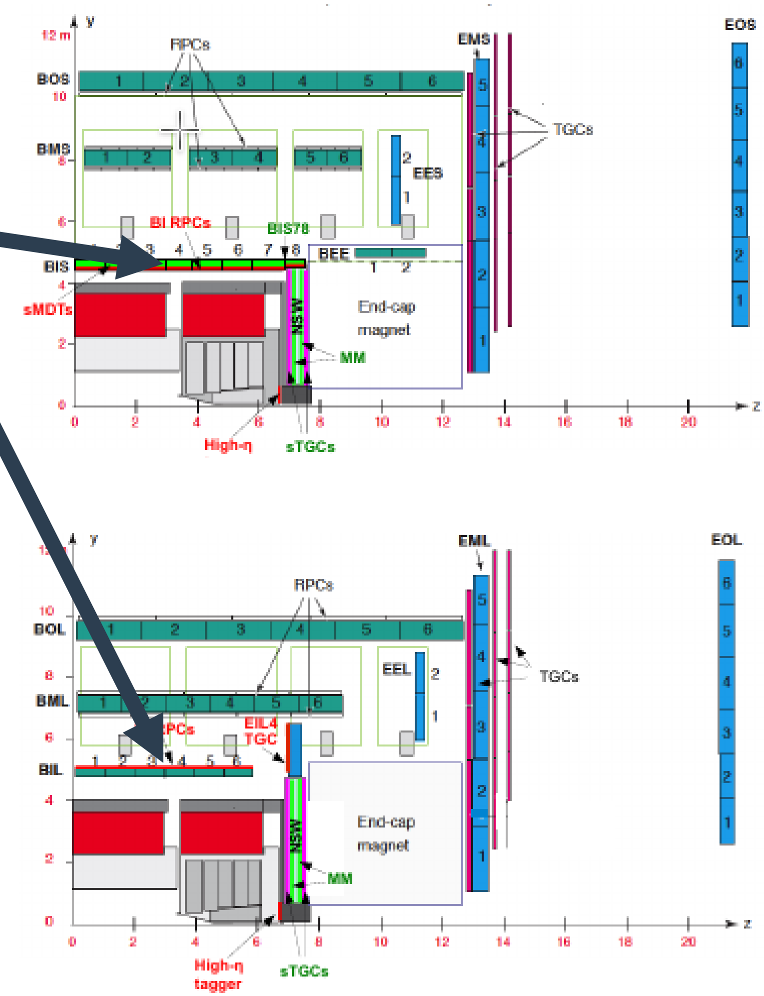


Introduction

Install 3 BI RPC layers during the Phase II Upgrade (2024-2026)

→ High rate capability RPCs (~ kHz/cm2),
→ 10 years of operation at HL-LHC
→ Higher spatial and time resolution
→ Restore high trigger efficiency.
→ Increase the redundancy.
→ Increase the geometrical acceptance.

Expected max rate in new inner layer ~1 kHz/cm²
→ Improve the rate capability to sustain the Phase-II LHC luminosity.
Limited space available for the installation ~5cm
Reduced gas gain : gap 1 mm, electrodes 1.2 mm
→ Increased amplification in front-end electronics.



Introduction

Challenges

Due to the decrease of the gas gain :
→ A more sensitive, fast, low power electronics.
→ Increase the signal-to-noise ratio by optimizing the gas gap and readout panel structure,

Due to the limited space available :
→ A thinner and more rigid structure for the chamber is necessary.

Other issues :
→ Improve the spatial and time resolution
→ Look and test eco-friendly gas mixtures.

Introduction

Semi-Digital Hadronic Calorimeter (SDHCAL) is one of the baseline for the CEPC Hadronic Calorimeter.

LYON SDHCAL prototype

- Designed for the ILC project
- ~1m*1m*1m
- Stainsteel absorber.
- 48 layers of GRPC
- Pad electronics.
- ~500 000 channels

RPC Laboratory setting up at SJTU

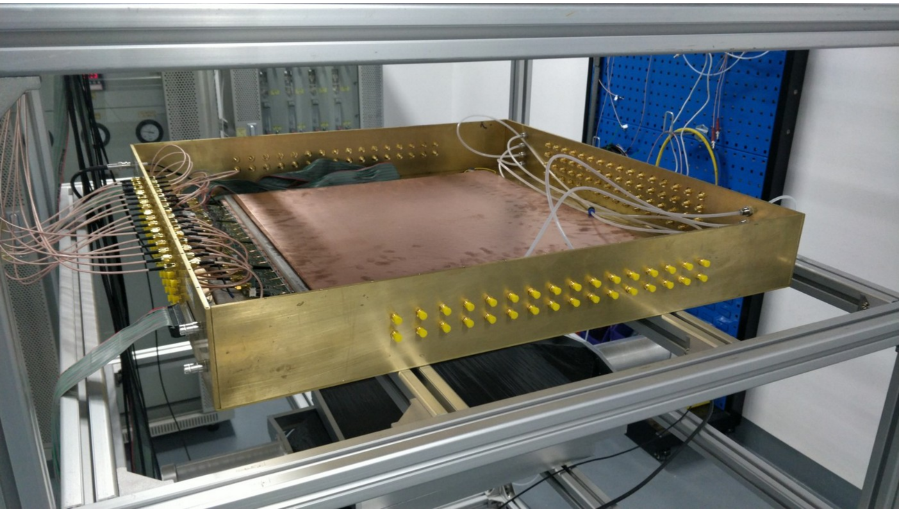
Goals :

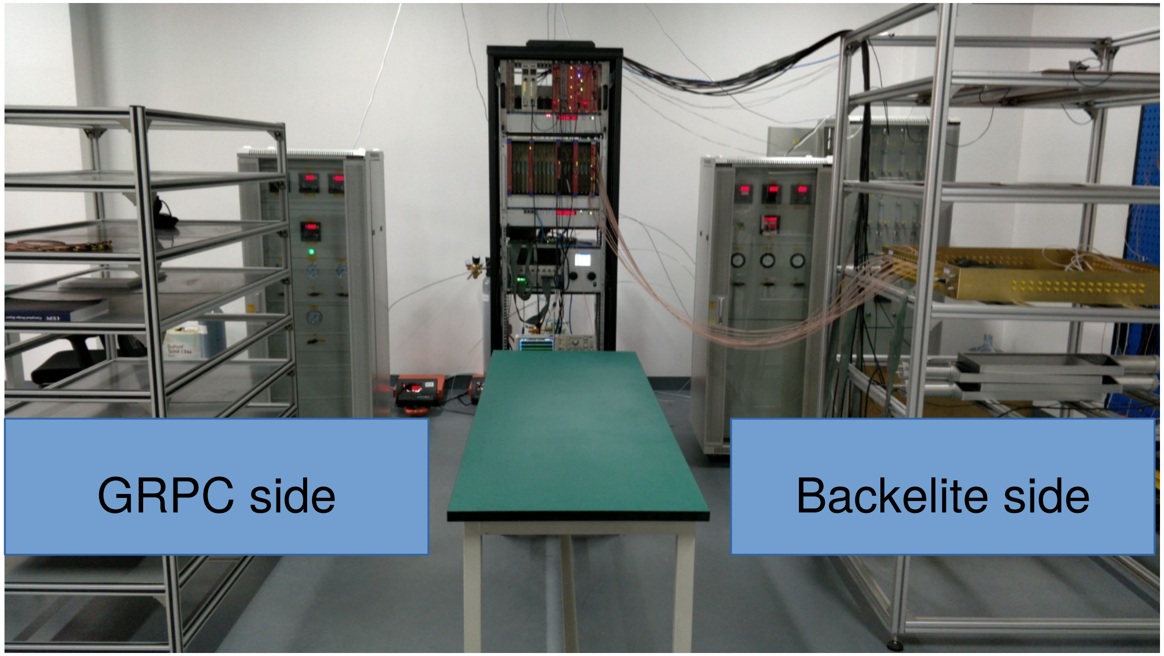
→ Test new electrode material.
→ Test different gas gap , readout material and structures.
→ Characterize chambers.
→ Test electronics.
→ Simulation.
→ Design RPC.
→ Build and test RPC chambers.
→ Establish the assembly and test procedure, quality control.
→ Get ready for the mass production.

RPC Laboratory setting up at SJTU

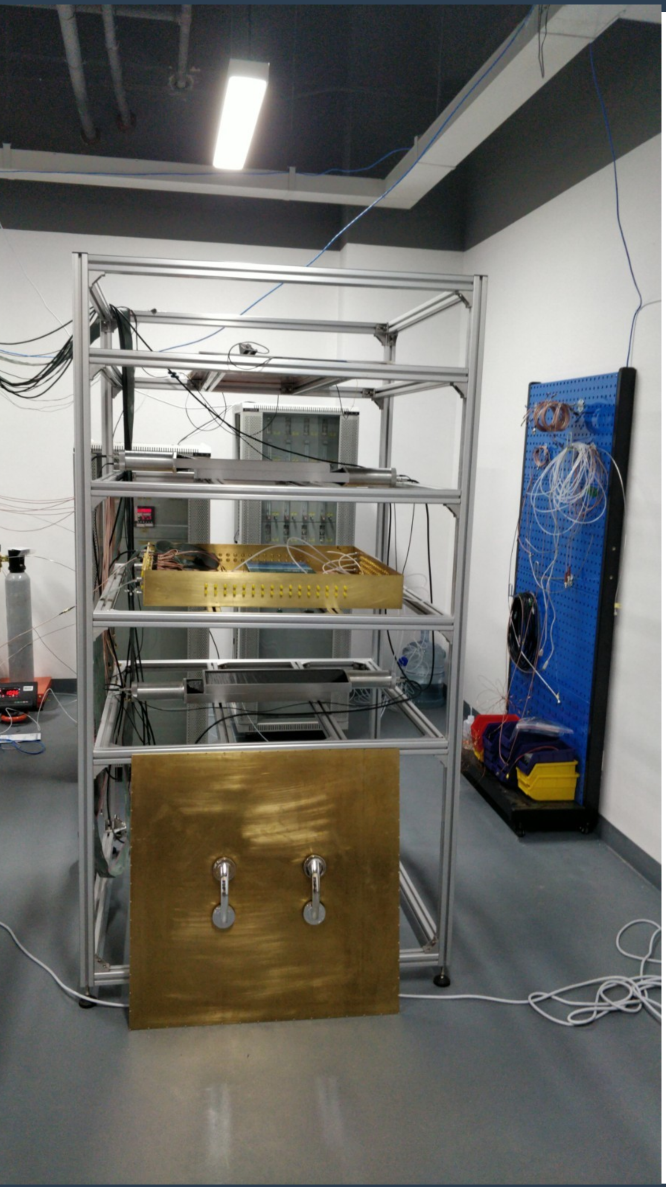
Two different gas mixer :

- Allow to test different ratio at the same time
- Glass RPC and Backelite in parallel (with humidity)
- Slowcontrol (Pressure, temperature, humidity) monitoring

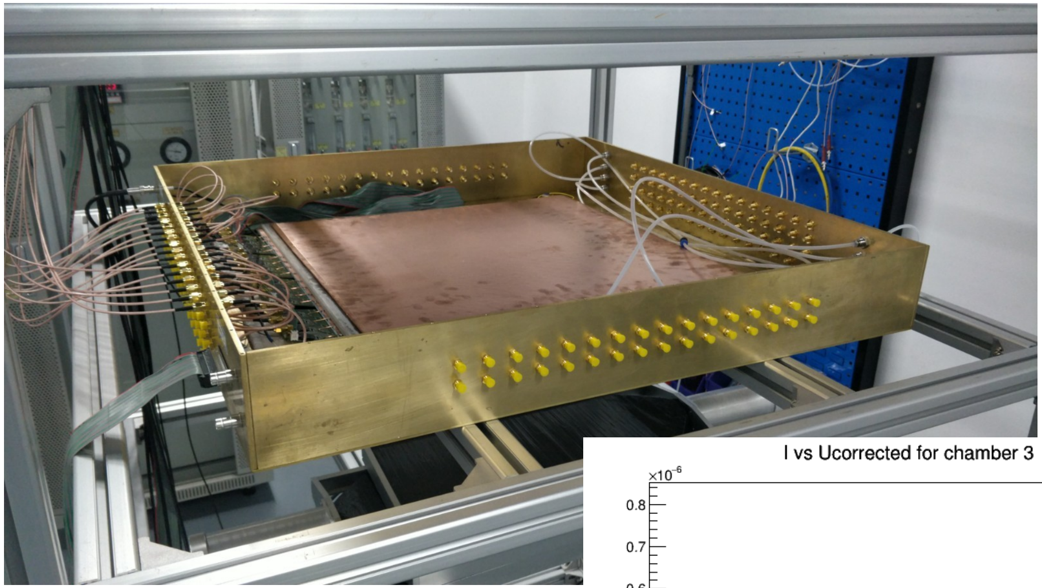


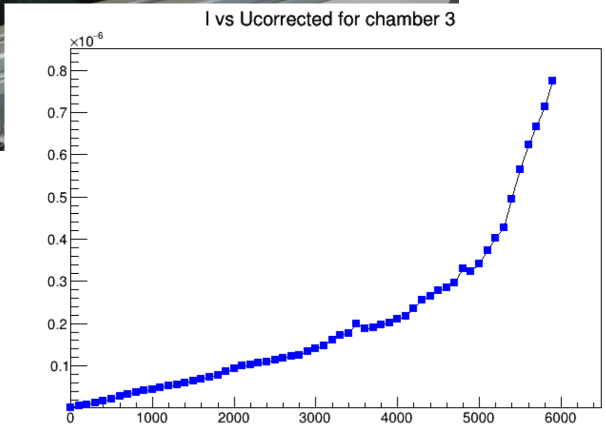


RPC Laboratory setting up at SJTU



- Cosmic stand has been build to test the Phase-II ATLAS RPC.
- Basic test of the ATLAS RPC has been started





Glass RPC construction

We started building small 200 x 120 x 1 mm³ ATLAS-like GRPC (helped by USTC)

“ATLAS-like” (G)RPC chambers.

Glass RPC construction

We created a tools and procedure to test RPC :

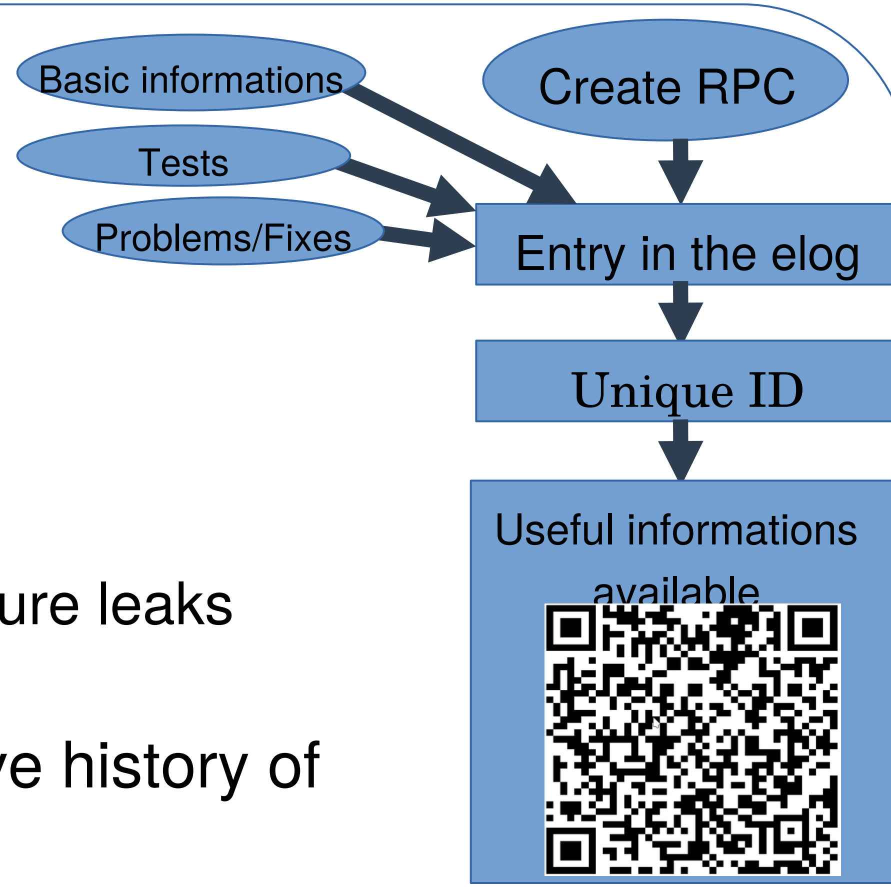
- Volumic resistivity of electrodes
- Surface Resistivity of the coating

➡ Electrometer + probes
(circular ring and 4 points method probes
under installation and testing)

- Gas Leak test

➡ We are designing a leakage box to measure leaks

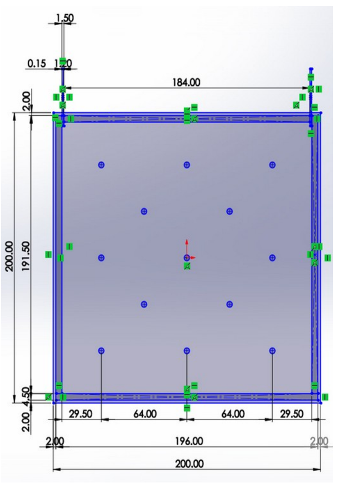
- I vs U scan test
- We are developping logbook to conserve history of each chamber and tag them

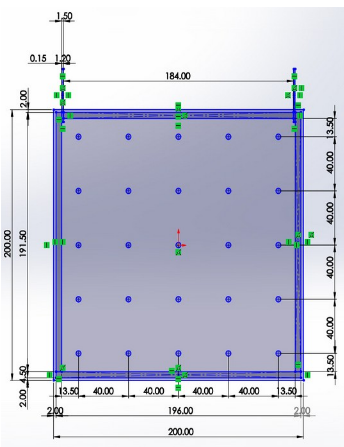


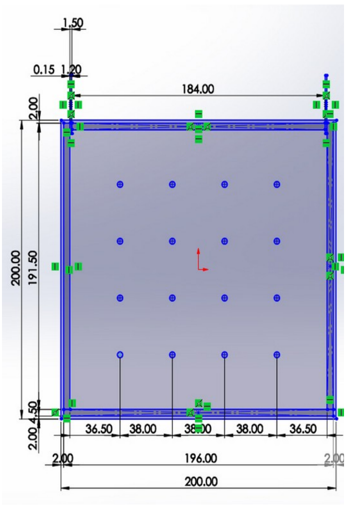
➡ Detect and point conception, material problems in the future.

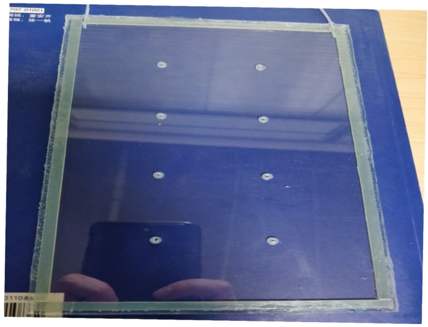
Glass RPC construction

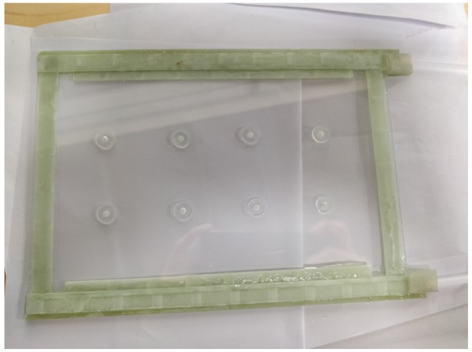
For our first production we decide to build (20*20cm2) SDHCAL like GRPC :







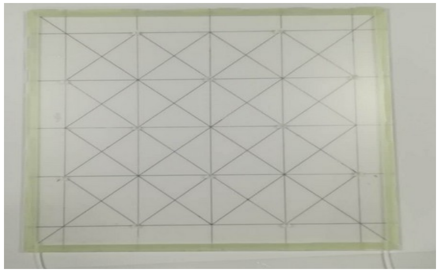




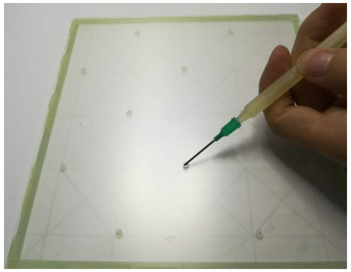
Glass RPC construction

1.Position the walls and pipes

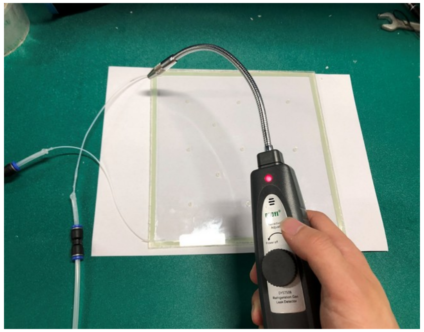
3.Draw the spacer position sketch



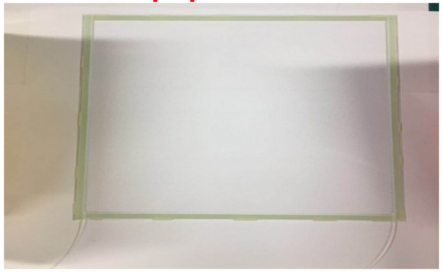
5.Glue the spacers



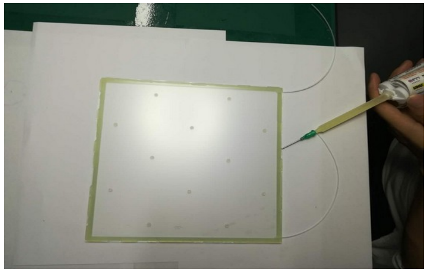
7. Gas tight with silicon and test leaks



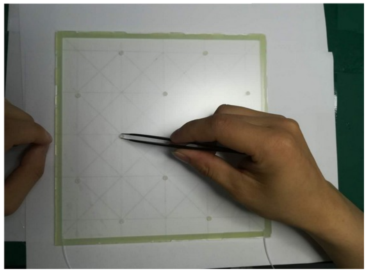
2.Glue walls and pipes.



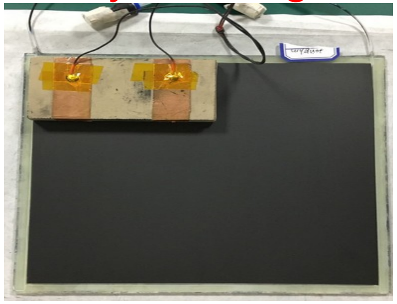
4.Put the spacers on the glass



6. Glue the second glass to the walls

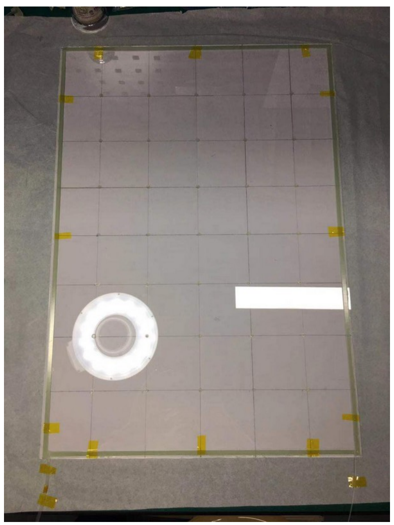


8. Graphite coating and mylar fixing



Glass RPC construction

First batches gave us the opportunity to test the procedure and find some problem on the materials, glass, pipes, walls and spacers. We then moved to bigger size GRPCs 50*50cm2



Use new spacers with better tolerances :

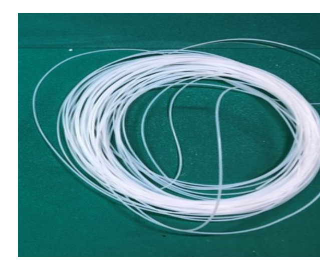
- Size:4mm*8mm*1.2mm with **±0.02mm**, the tolerance always **less than 0.05mm.**

New walls :

- thickness **1.2mm with better tolerance and better uniformity along the lengh.**

Use new pipes :

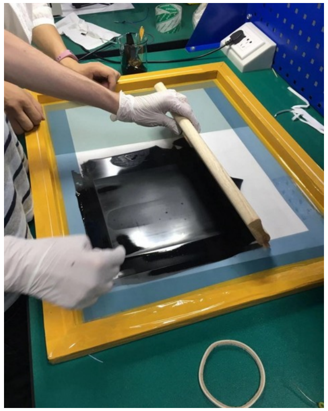
- Size: 0.8mm*1.2mm with diameter **±0.02mm** from PTFE material (**soft weak and easy to break**) to PPP material.

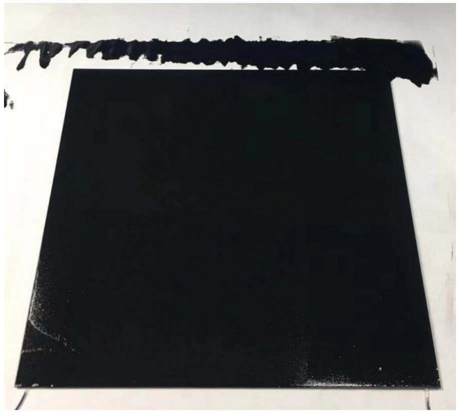


Silk Printing Method

RPCs need resistive layers to apply High Voltage on the Glass or Bakelite electrodes.

Based on the knowledge from Lyon's group, we decide to use the silk print method.
Basic test performed at SJTU confirmed the simplicity.
But it needs a heating process (80-90C)

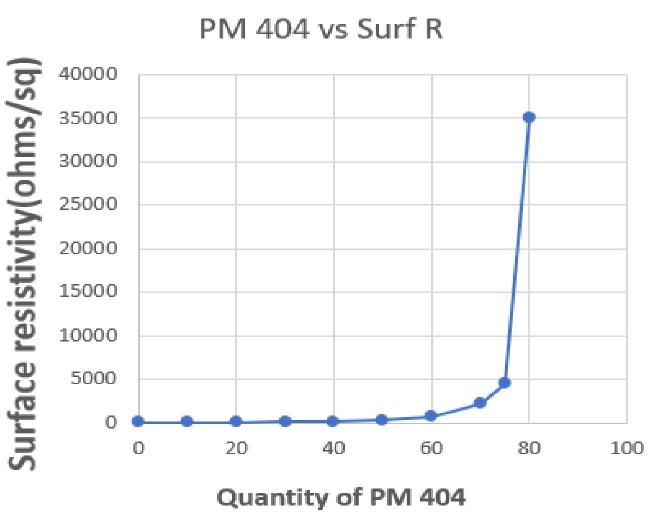




- **Easy way for graphite coating, very convenient and efficient ! Good surface thickness uniformity (surface resistance).**

Silk Printing Method

Graphite coating is formed mixing two different products. Different mixtures change drastically the resistivity of the coating.



We tested many mixture ratios in order to have a surface resistance ~1Mohm/□. The surface resistance depend on the thickness of the layers and then on the mesh size and process skill.

So we tested with different mesh sizes.

The heating process is one of the difficulties of such method.

The temperature should be maintained around 80-90 to avoid the peeling of the layers. Higher temperature could break the glass.

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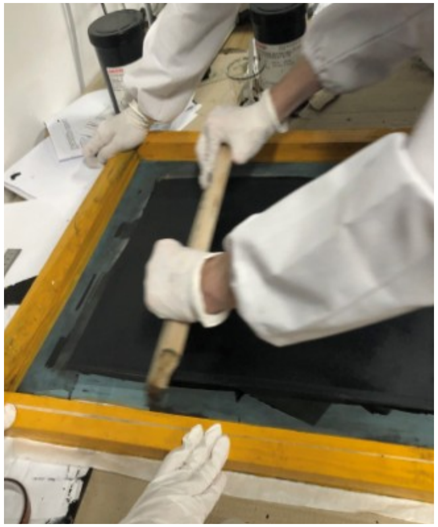
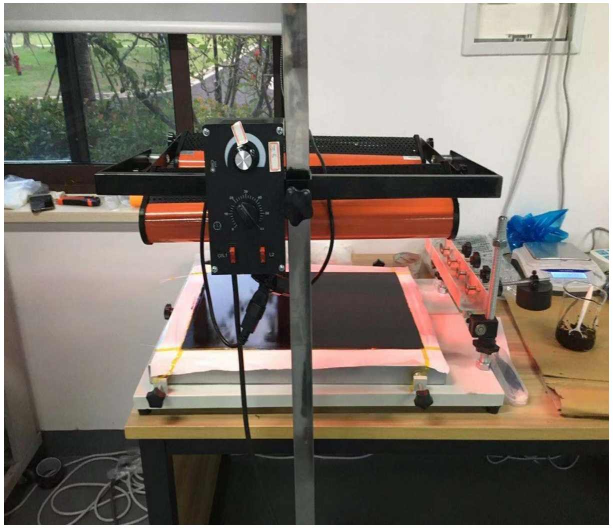
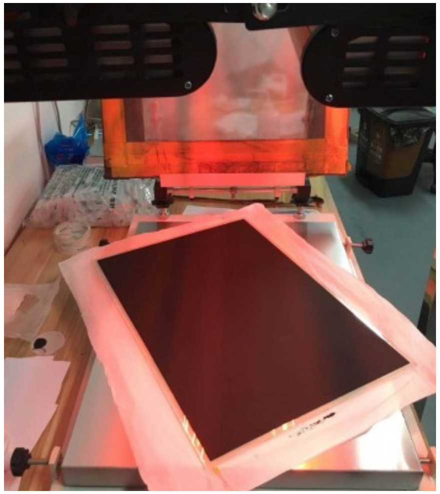
Silk Printing Method







PM404 84% (16.8g)   S6017 16%(3.2g) for 350*500mm RPC

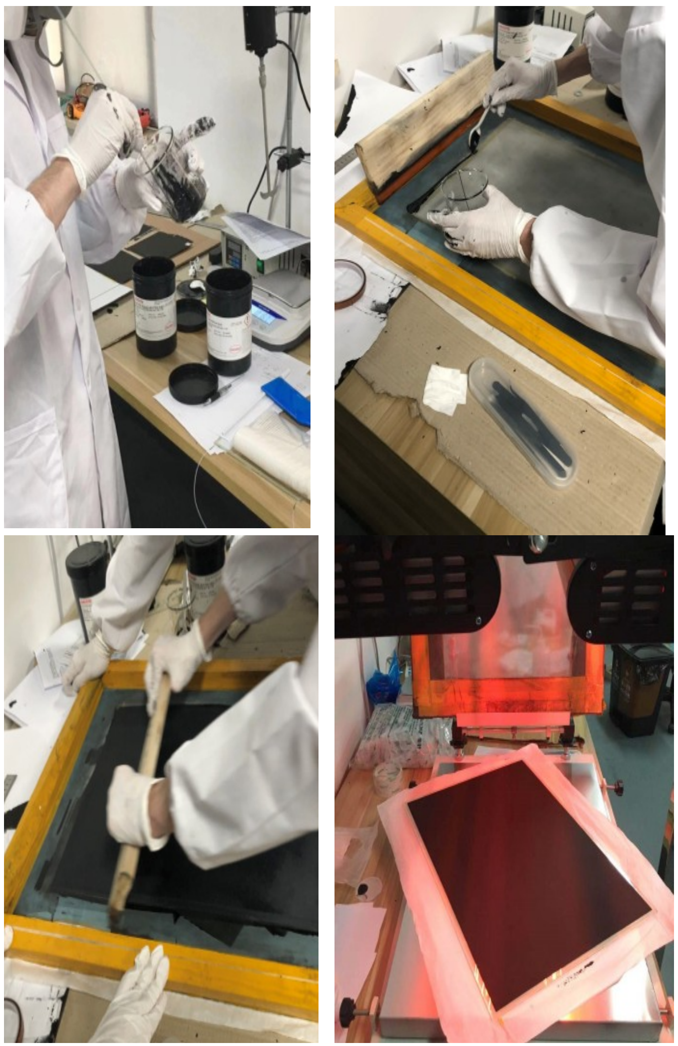
Stirring for 10mins to assure mixture uniformity.

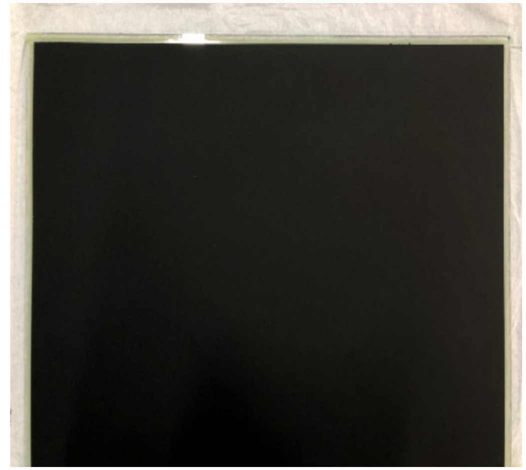
Silk screen parameters: 300 目 (grid density) 350*500 effective area

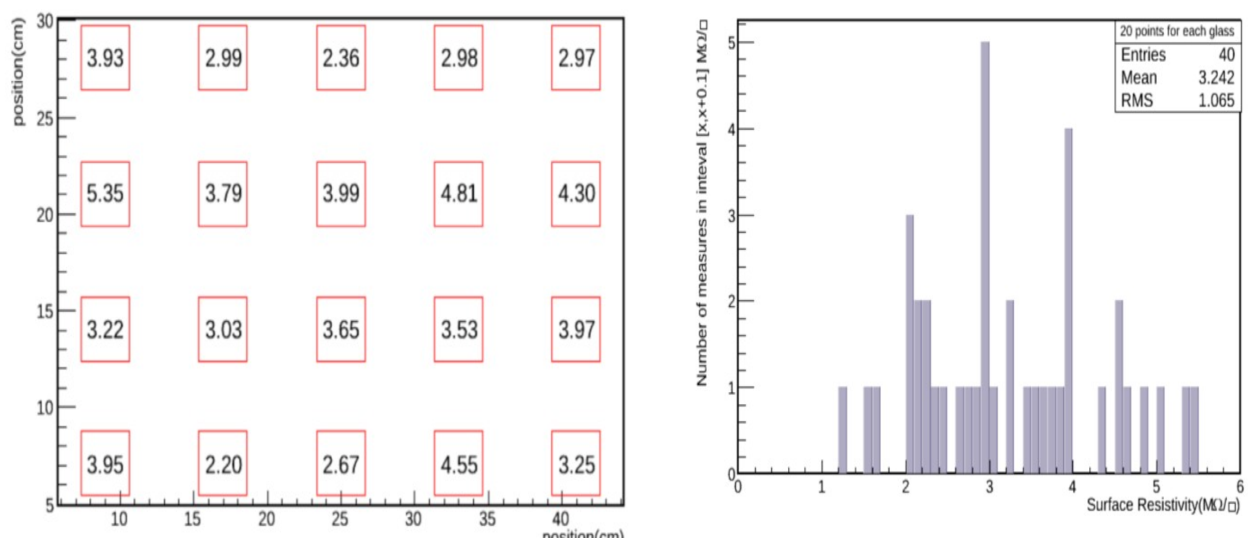
Cooking condition: one lamp, 80-90°C , 2 hours, diagonally cooking, more uniform and stable temperature for this size RPC.

Better quality of the layers.

Silk Printing Method

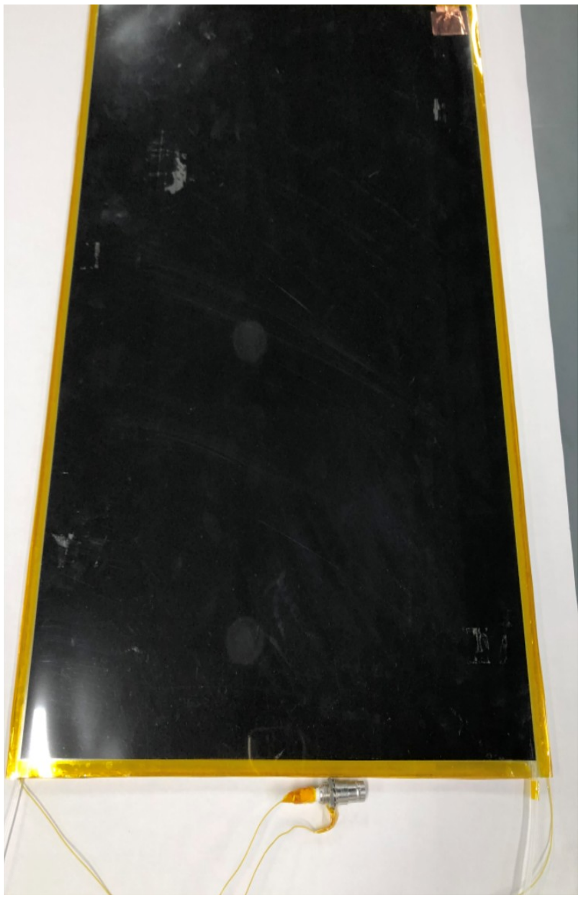


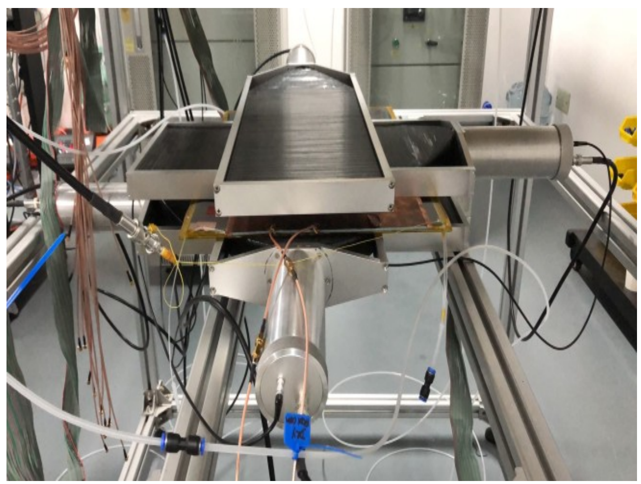




Test

We are able to detect cosmic muons with own-made RPC chambers at SJTU

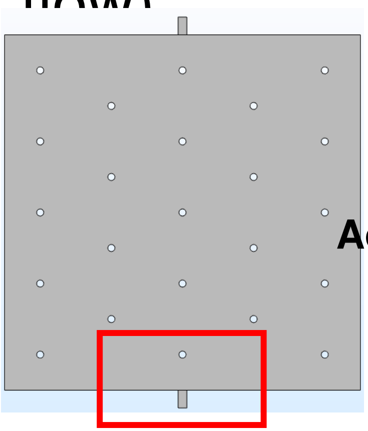




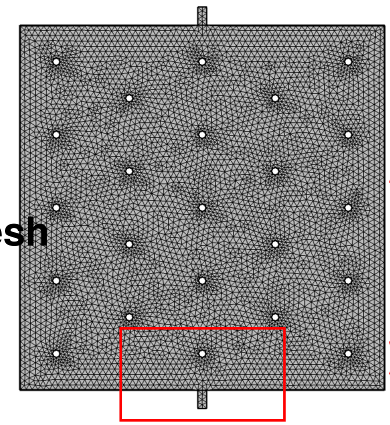
The efficiency is a bit too low. The elecrode glass material could be the reason → need to find a company with a glass fulfilling our needs.

Gas Flow Simulation

Find the best position of the spacers and its configuration to optimize the gas flow and avoid to stress chambers (avoid vorticity, uniform flow)

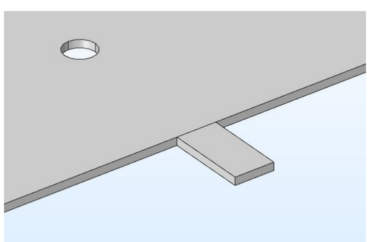


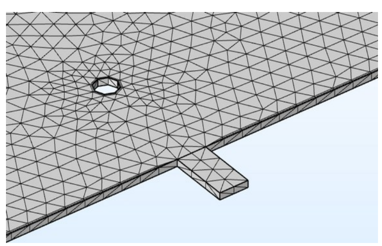
Add mesh



RPC size:
200mm*200mm*1mm

Nozzles size:
5mm*10mm*1mm





- Variance of velocity:

$$\sigma_u^2 = \frac{\sum_{i=1}^{n} (u_i - \bar{u})^2 V_i}{\sum_{i=1}^{n} V_i}$$

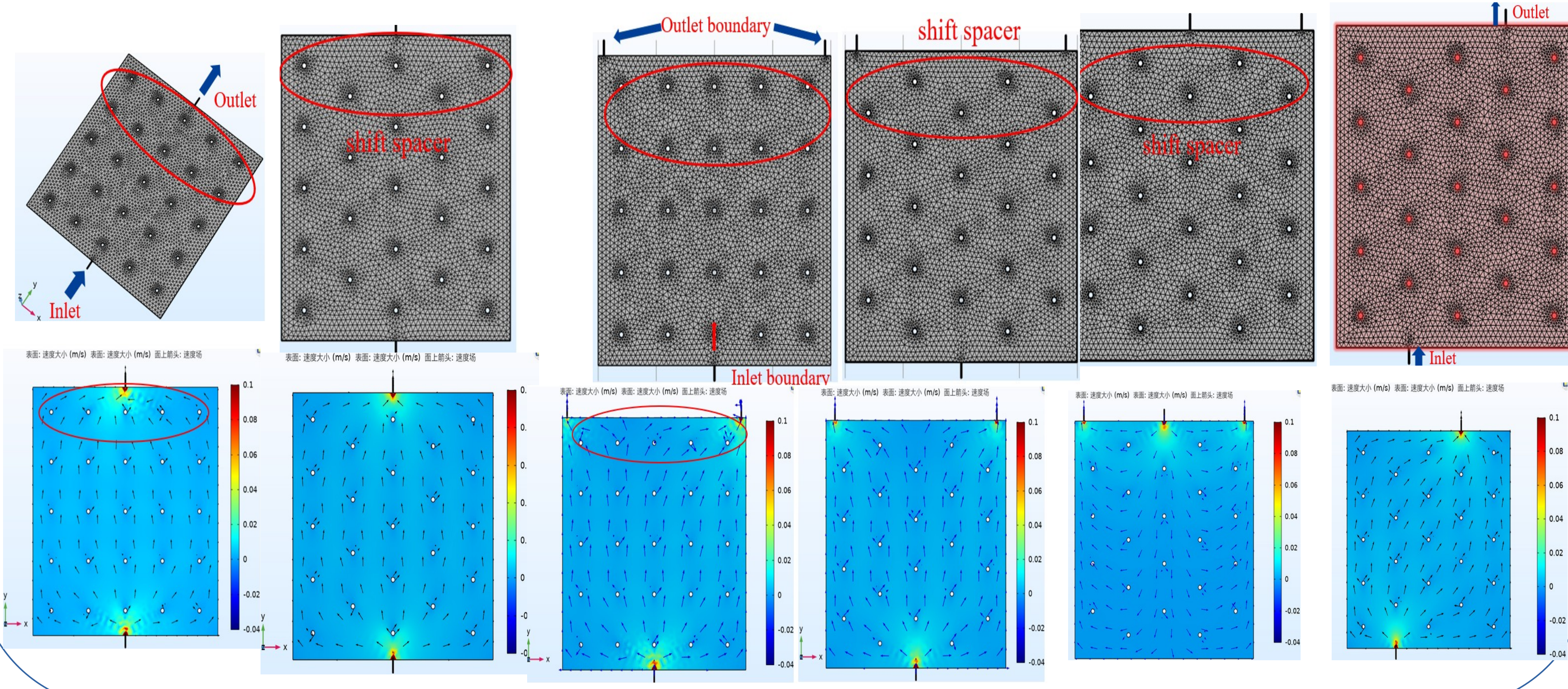
- Vorticity of velocity:

$$w = \nabla \times u \qquad \bar{w} = \frac{\sum_{i=1}^{n} w_i * V_i}{\sum_{i=1}^{n} V_i}$$

Gas Flow Simulation

RPC size 20cm*20cm*1.2mm

Spacer size: h=1.2mm, 2mm*4mm

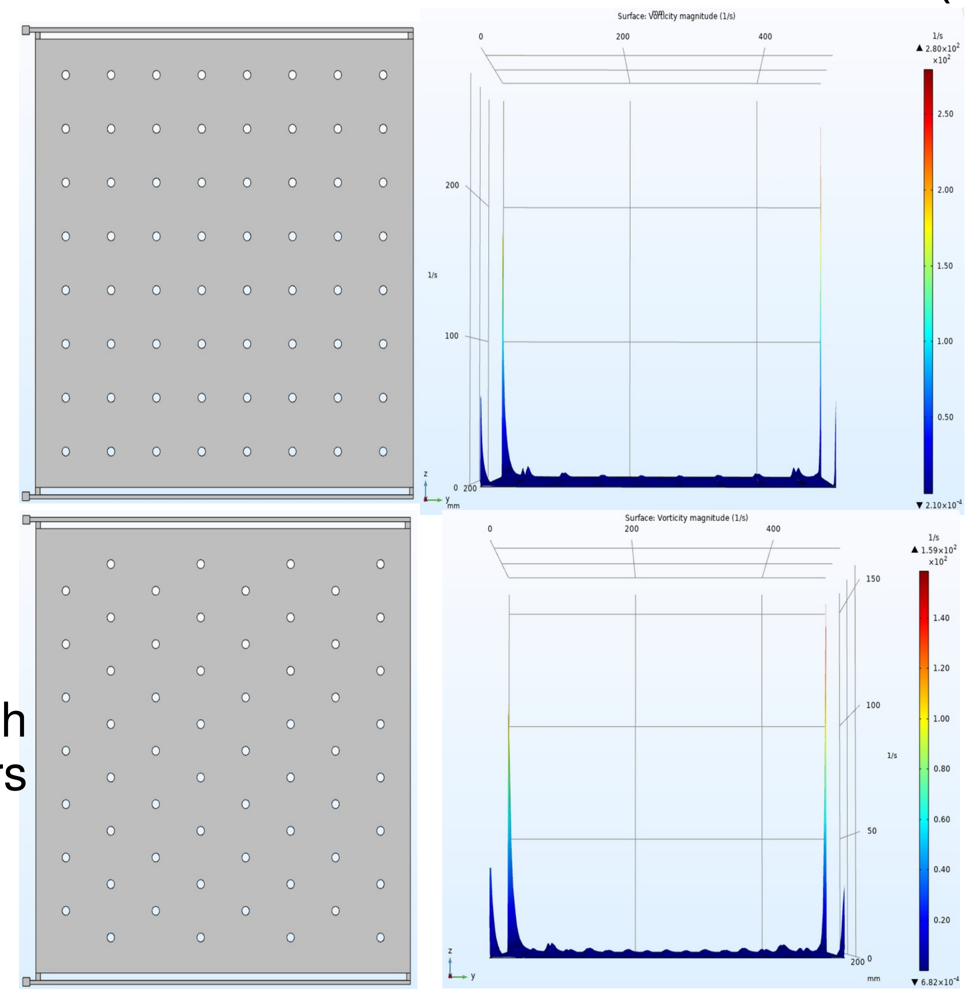


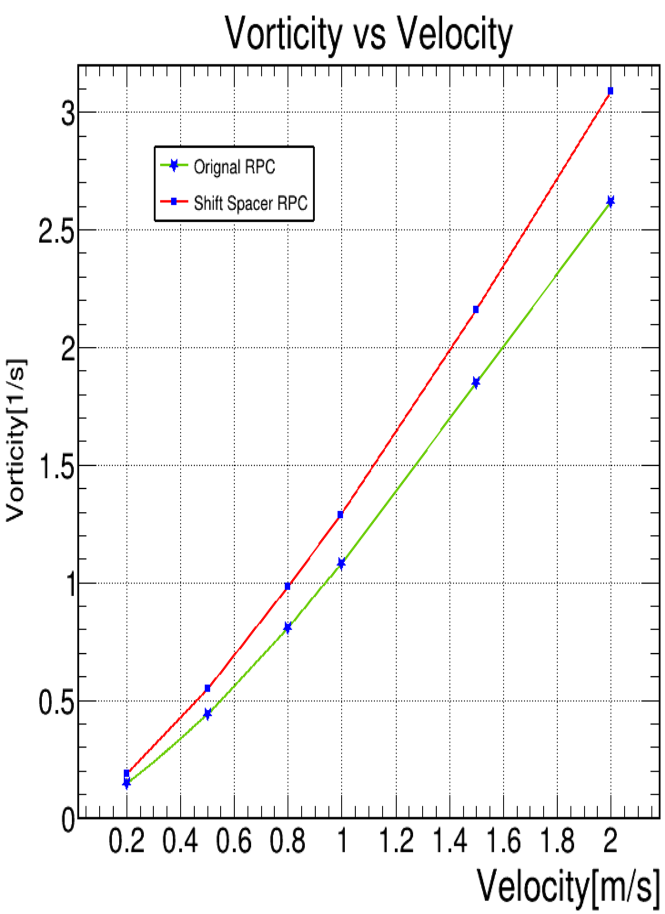
Gas Flow Simulation

RPC size 50cm*50cm*1mm (ATLAS-TYPE)

GT chambers

Simulation with shifted spacers





Conclusion and future plan

- A laboratory is beeing constructed and allow to test RPC chambers for ATLAS Phase II and CEPC projects.
- Simulations are performed in order to find the best design for the chambers
- We succeed to build our GRPC from scratch.
- We create tools to keep the construction parameters etc. of the chambers

Future plan :

- Continue to improve the design and the construction protocol.
- Improve the gas system.
- Perform gas flow simulation for the real size ATLAS Phase II chambers.
- Characterize our chambers and the ATLAS Phase II chambers.
- Build bigger chamber ~1m*1m.
- Test our chambers with the SDHCAL electronics,