# Status of GRPC, gas flow simulation and active cooling R&D

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Joint workshop of the CEPC physics, software and new detector concept
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# Outline

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

# Introduction

- ILD CEPC Detector
- CEPC SDHCAL(Semi-Digital Hadron Calorimeter):
  - Total area ~100m3
  - 4-40 millions channels

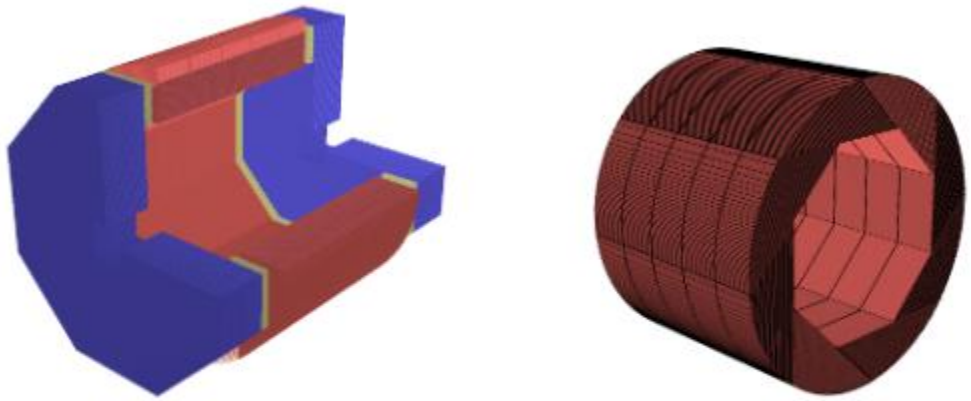
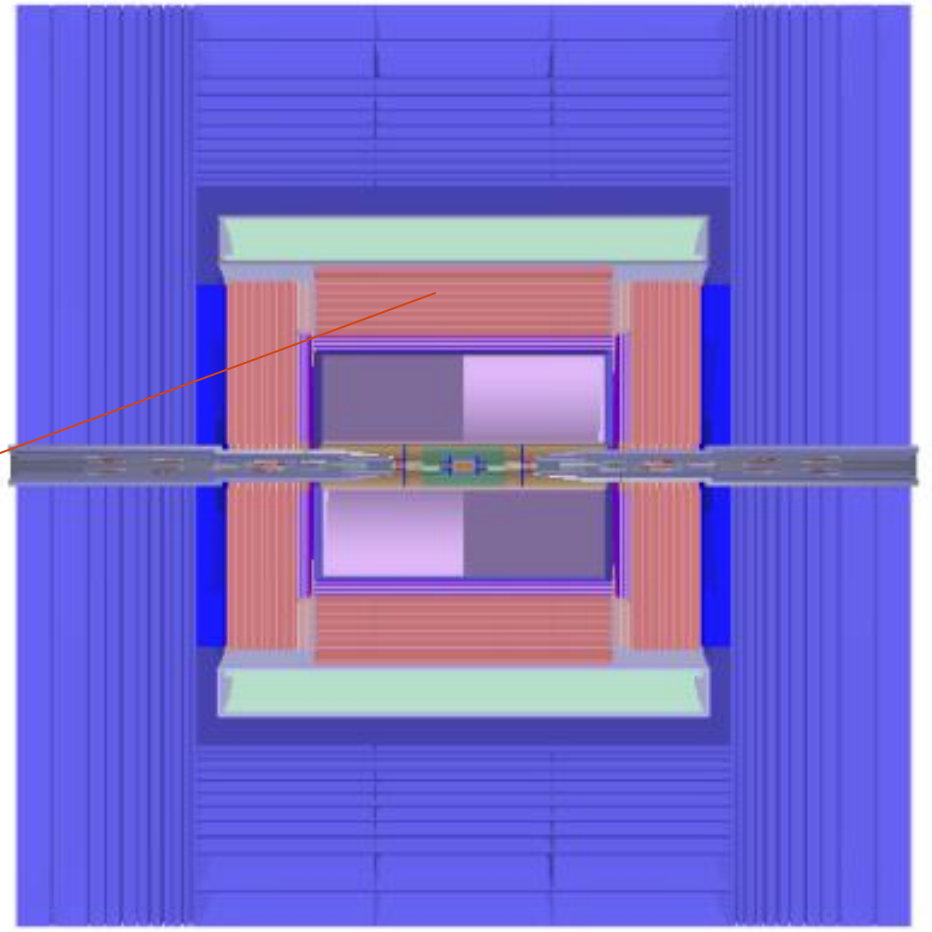


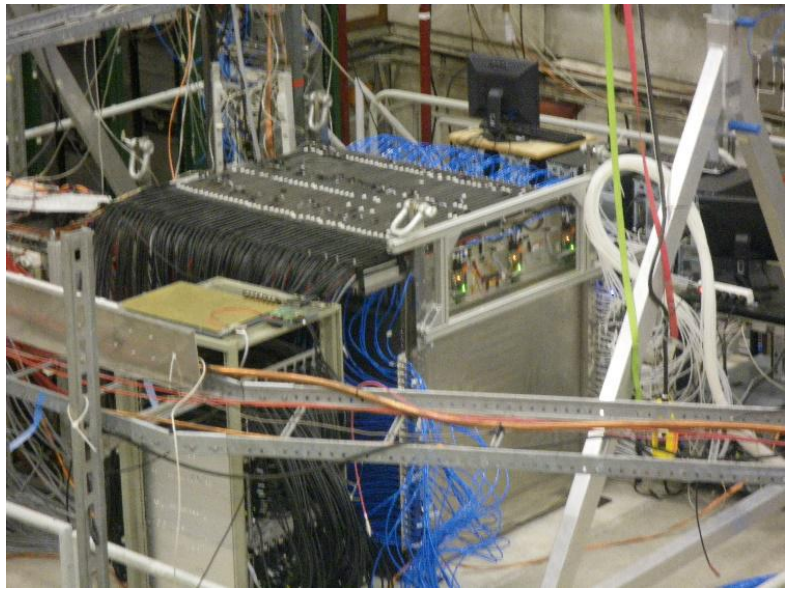
**Figure 5.16:** Schematic of the CEPC HCAL layout in its baseline design (left) consisting of one cylindrical barrel (red) spanning from 2058 mm to 3144 mm radially and two endcaps (blue) between 2650 mm and 3736 mm in $|z|$. An isometric view of the barrel HCAL is shown on the right.

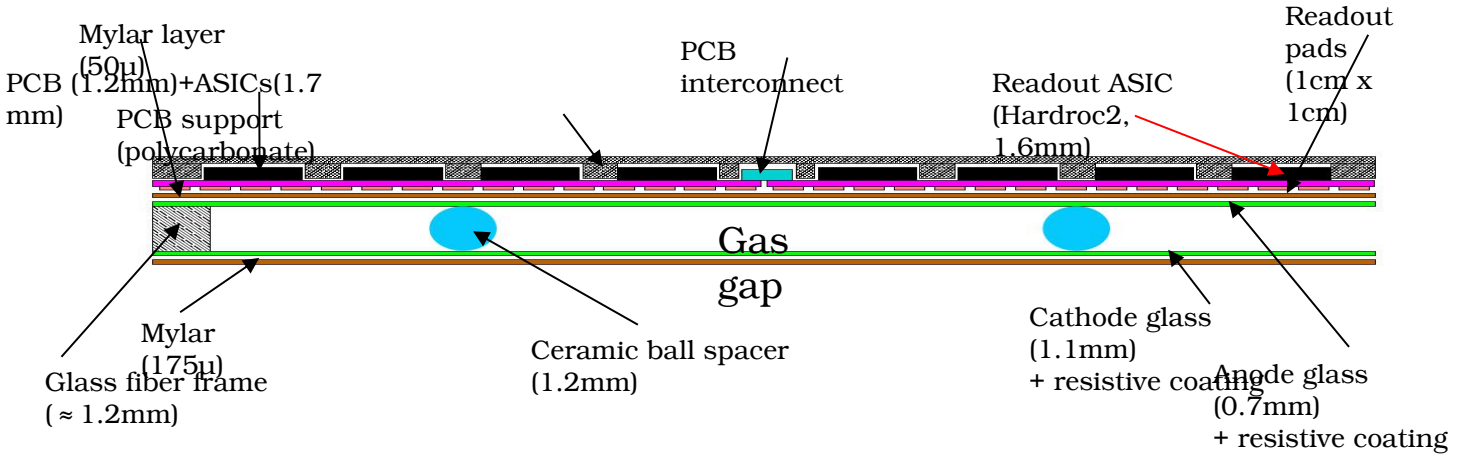


Baseline detector

# SDHCAL prototype

Size : 1m*1m*1.3m
Nbr layers : 48 of RPC
Cell Size : 1cm*1cm







$(0.12\lambda_I, 1.14X_0)$

Stainless steel Absorber(15mm)
Stainless steel wall(2.5mm)
GRPC(6mm≈ $0\ \lambda_I, X_0$)
Stainless steel wall(2.5mm)

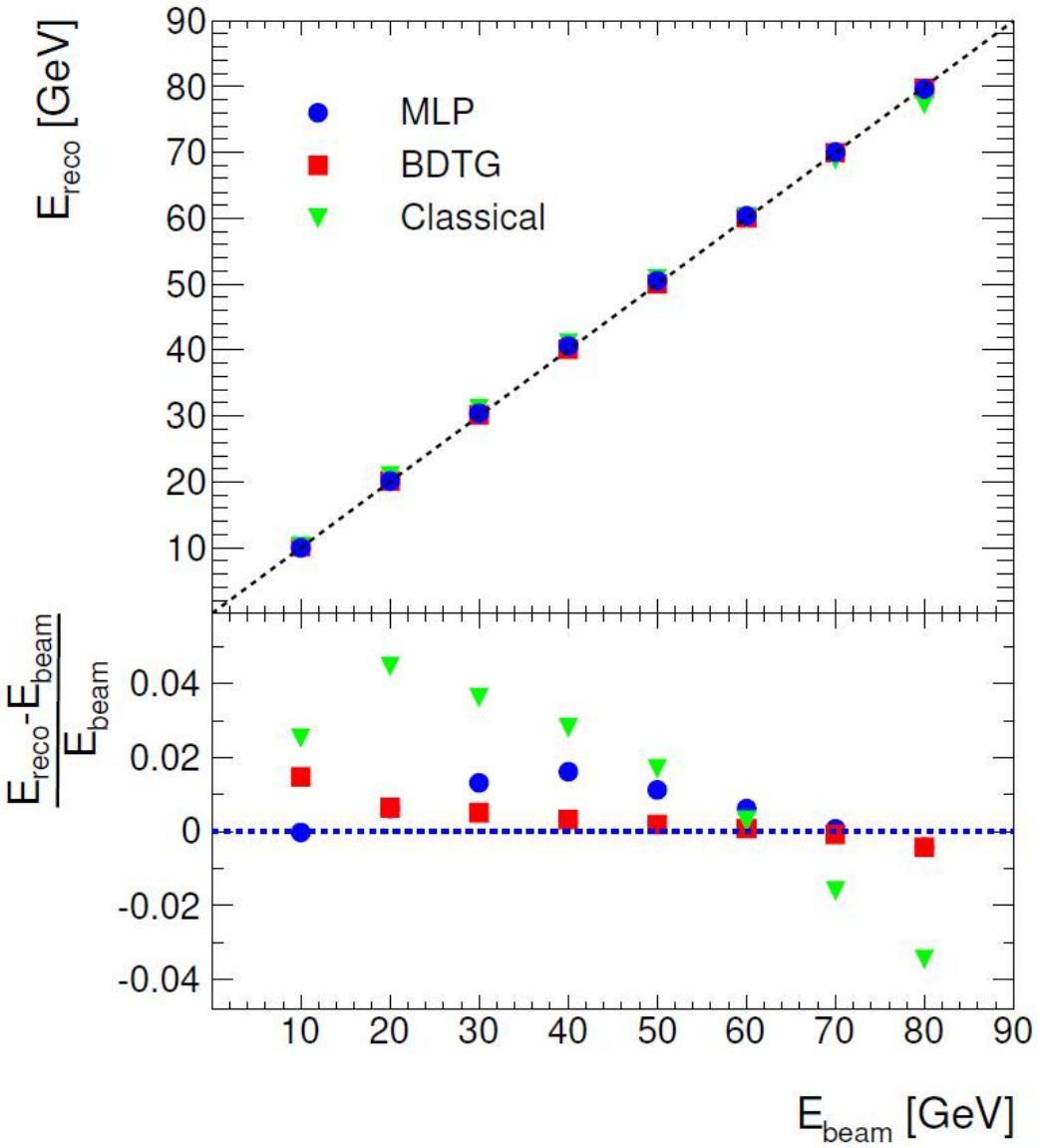
3 mm RPC (glass)
1.2 - 1.4 mm PCB
1.6 mm ASIC

**ASIC HARDROC (64 ch)**
**3-threshold: 110fC, 5pC, 15pC**

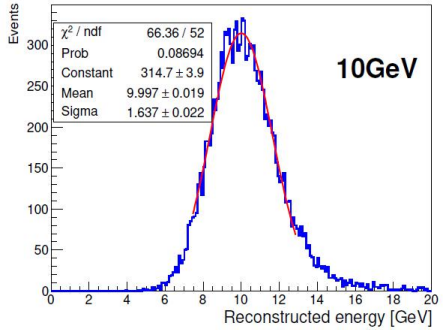
# Performances with MVA

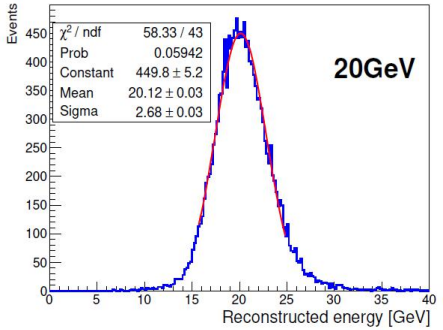
**Energy linearity :**

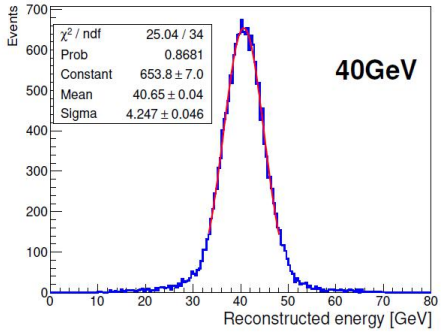
**SJTU+IPNL JINST 14, P10034 (2019)**

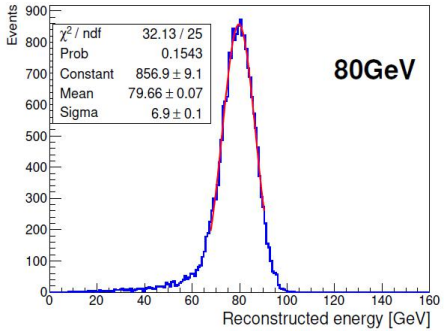



**Energy linearity improves from 3-4% to 1-2% level using MVA**



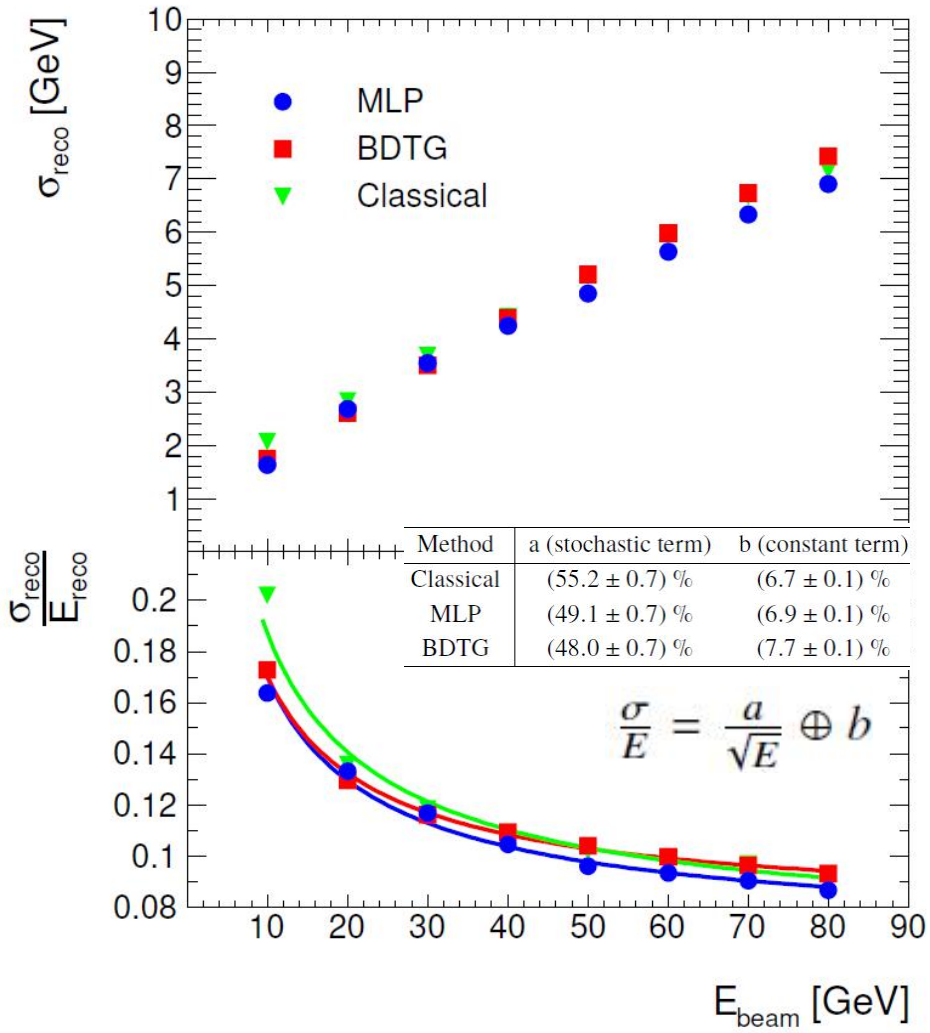



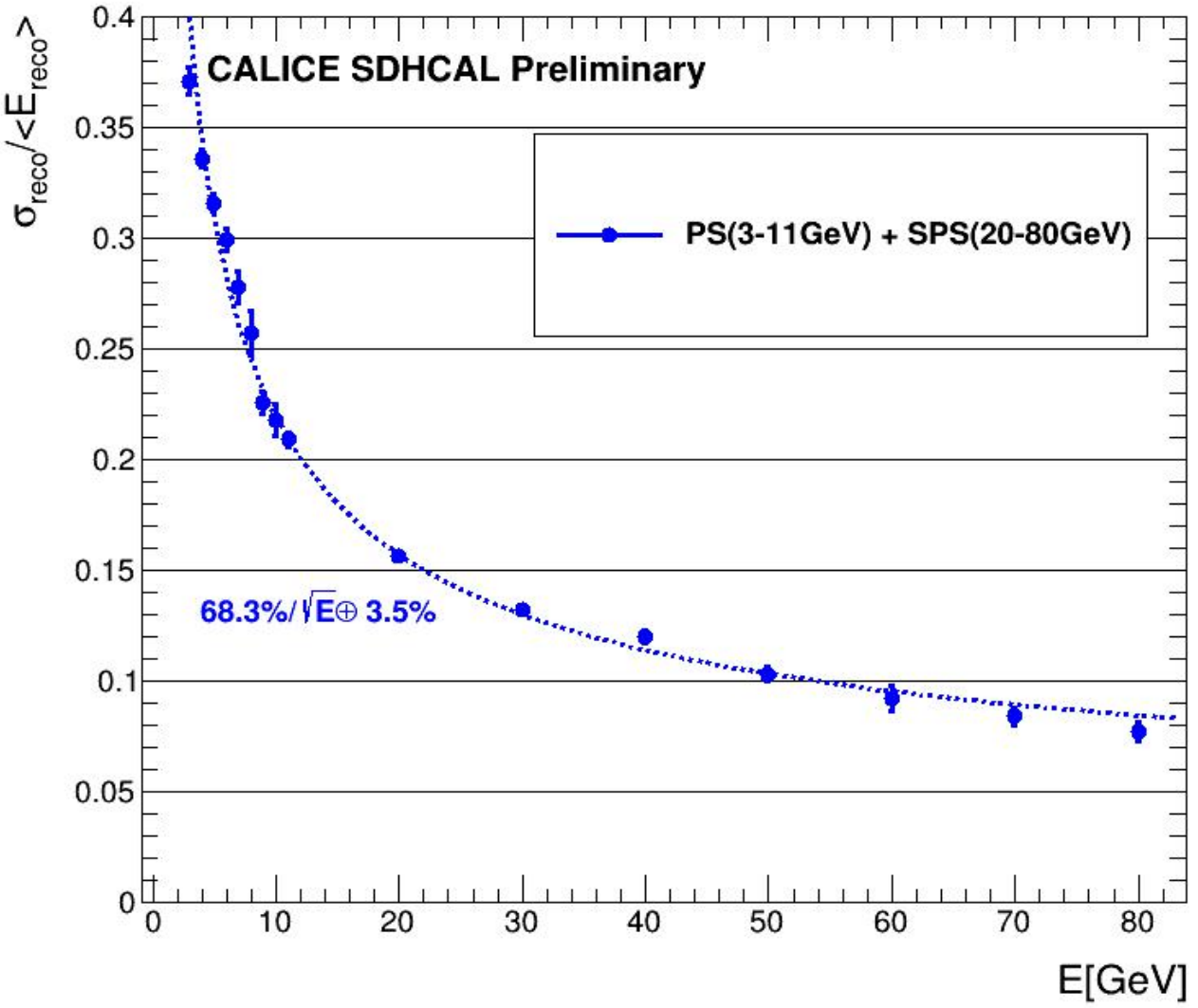
# Performances with MVA

**SJTU+IPNL JINST 14, P10034 (2019)**

**Energy resolution :**



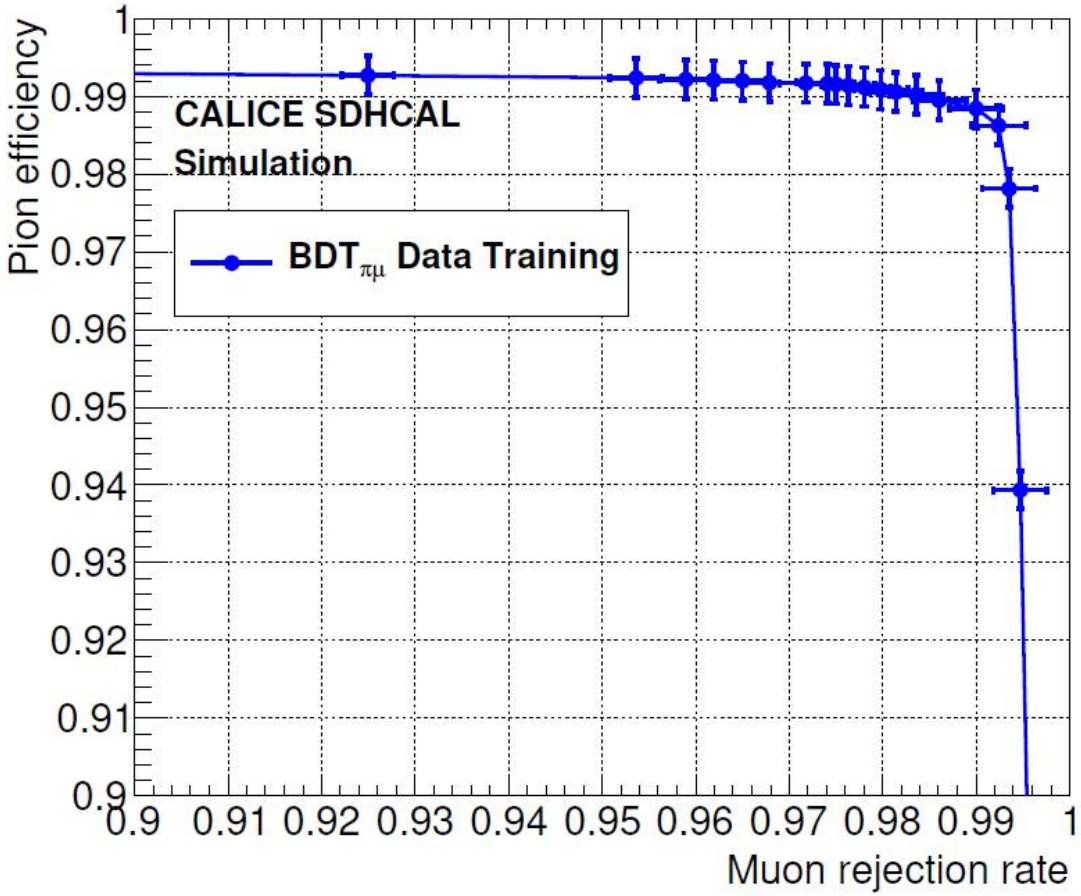

| Method | a (stochastic term) | b (constant term) |
|---|---|---|
| Classical | (55.2 ± 0.7) % | (6.7 ± 0.1) % |
| MLP | (49.1 ± 0.7) % | (6.9 ± 0.1) % |
| BDTG | (48.0 ± 0.7) % | (7.7 ± 0.1) % |

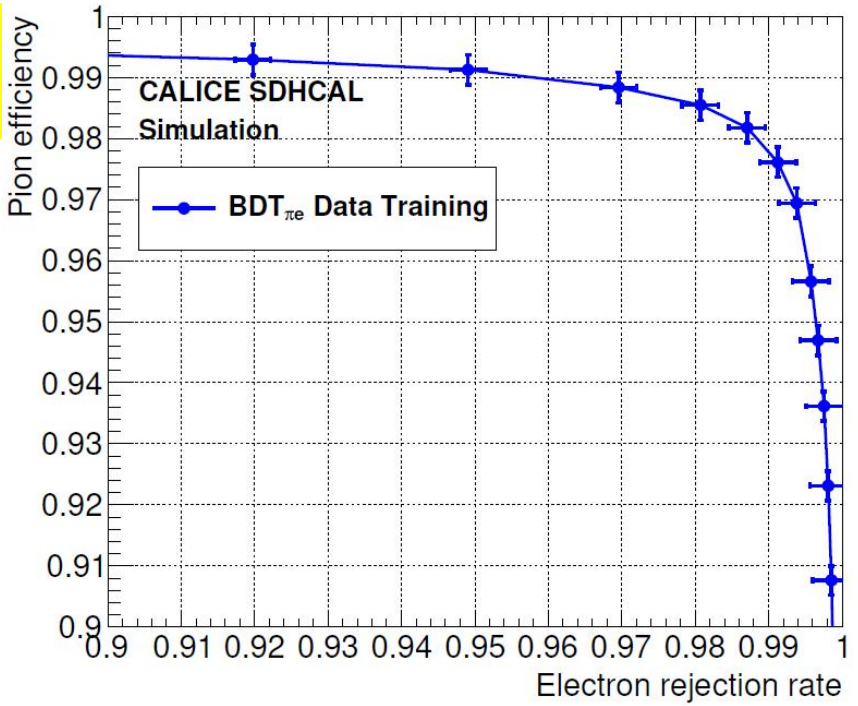


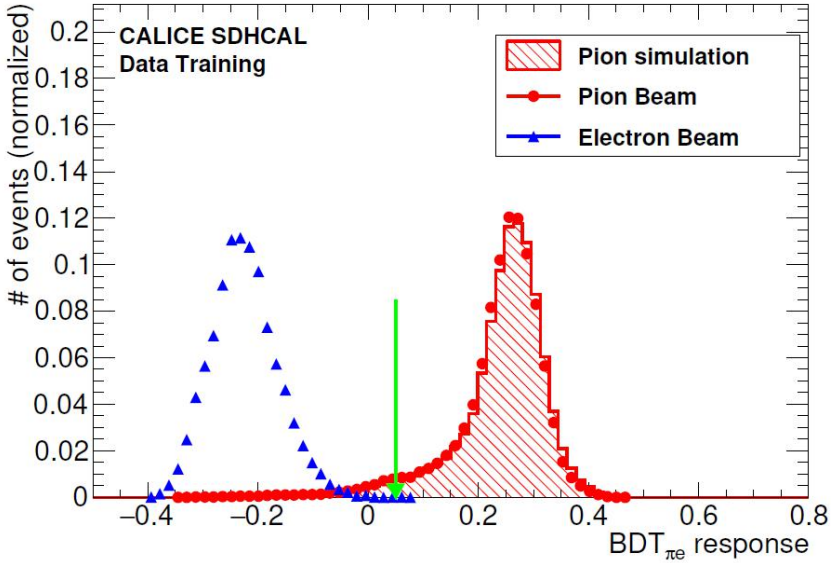
# Performances

**SJTU+IPNL**
**JINST 15, P10009 (2020)**

**PID :**



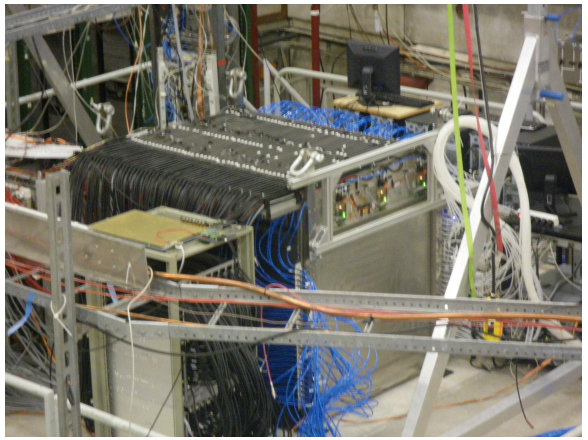



# Introduction

## Why do we need a cooling system for CEPC SDHCAL ?

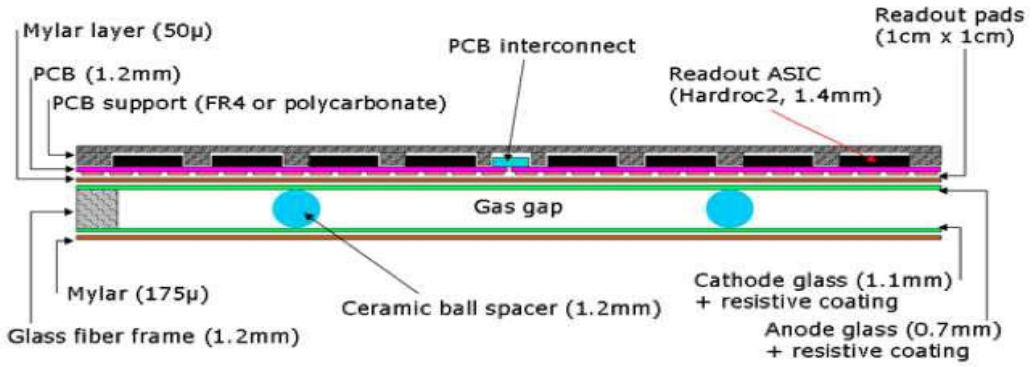
- The new generation of detector will fully exploit the Particle Flow Algorithm :
  - → Need high granularity detectors.
  - → Avoid cracks in the detectors.

- For SDHCAL :
  - → 1×1cm$^2$ pads → Over 60M channels → HEAT !



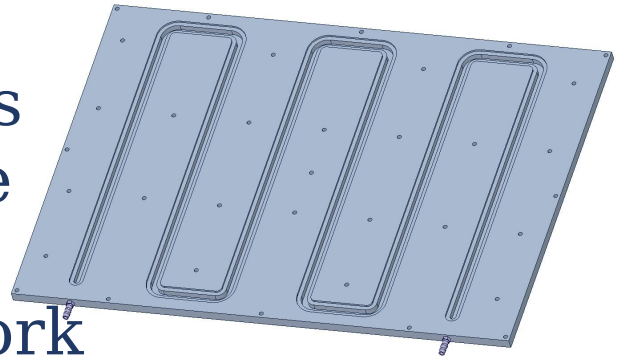
The SDHCAL has been design for ILC and use the particular beam structure (collision rate ~5Hz) to switch off part of the its electronics.

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

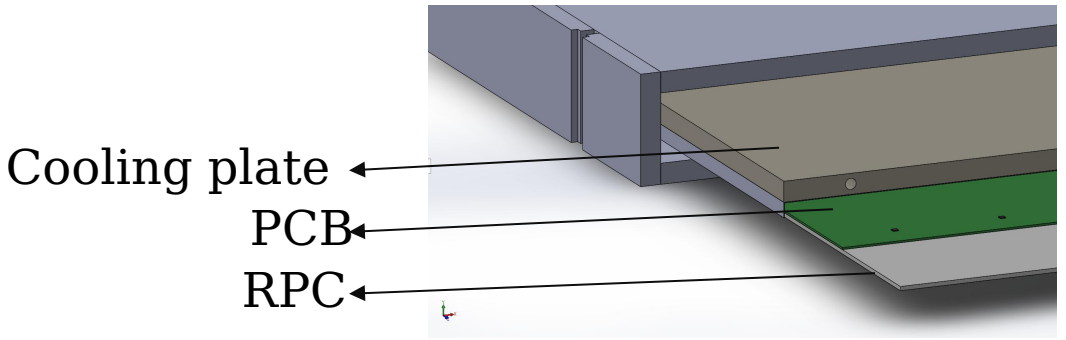


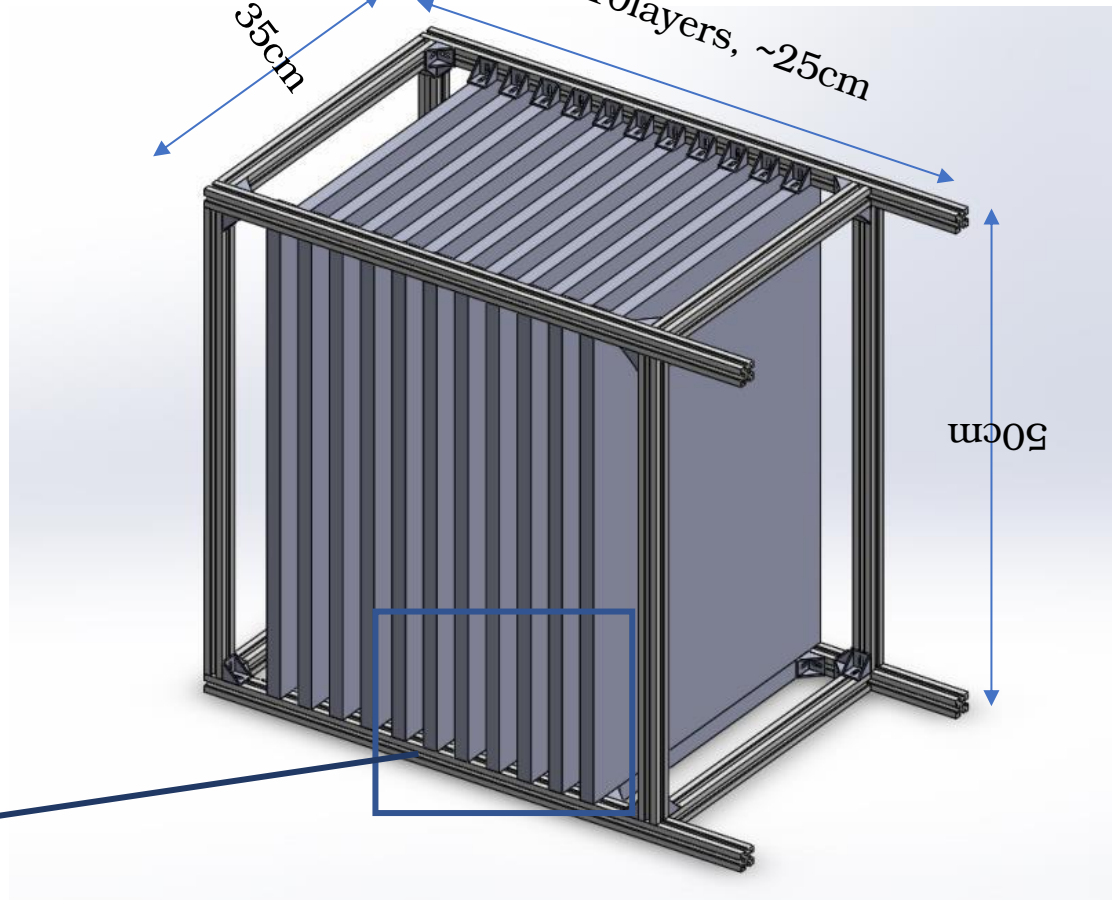
# Cooling system : cooling plates

- Cooling plates: water pipes imbedded in metal plates
  - Cooling ability: ~kW/m2
  - Using water
  - Price
  - Compactness
  - Maintenance

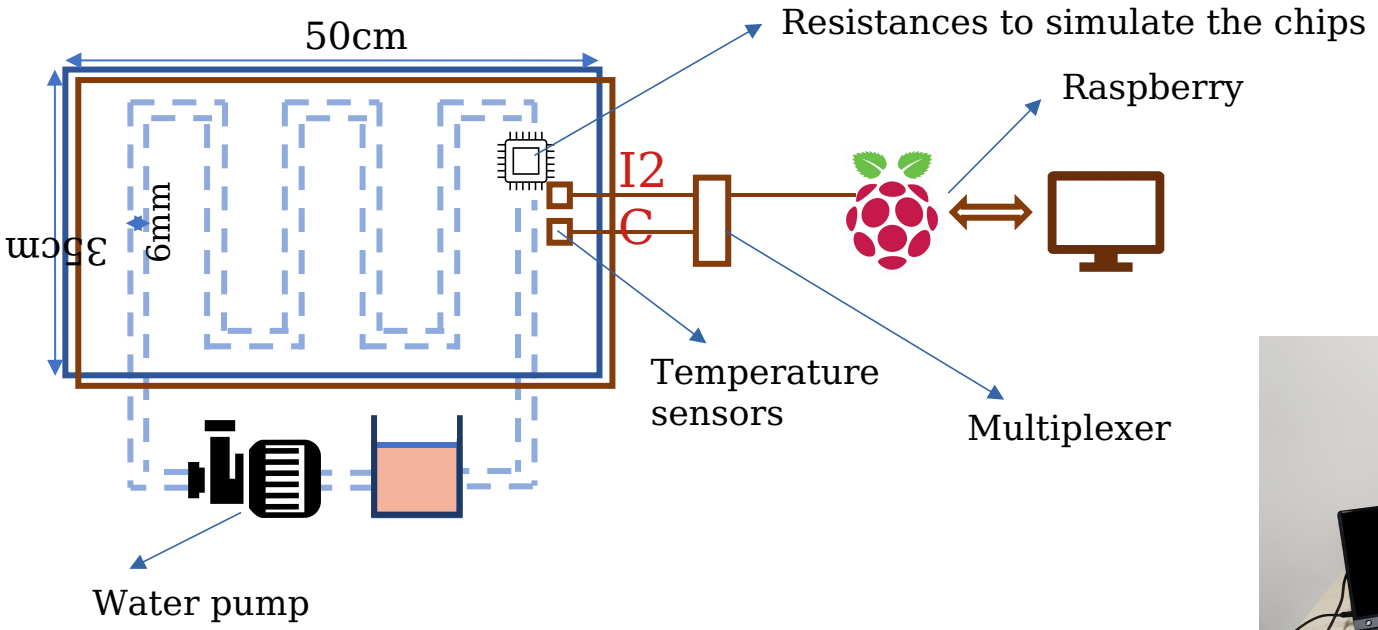


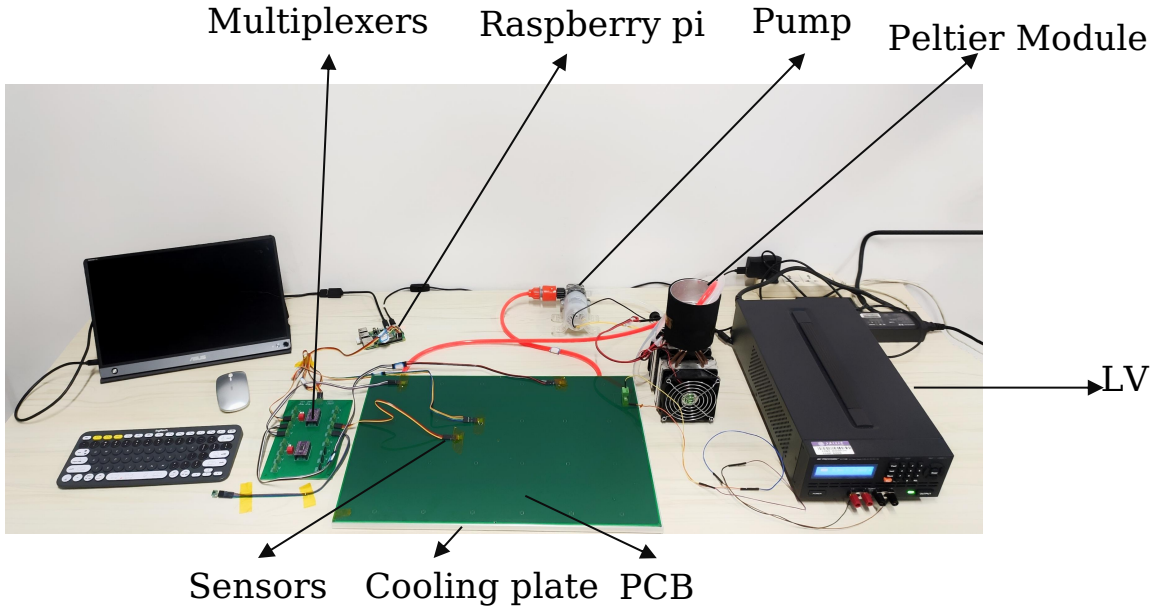

- Flexible framework



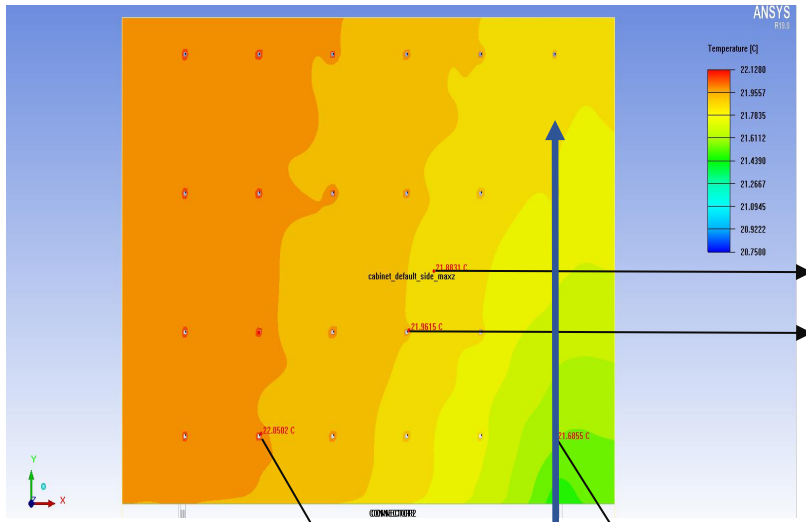
# Test of the cooling plates



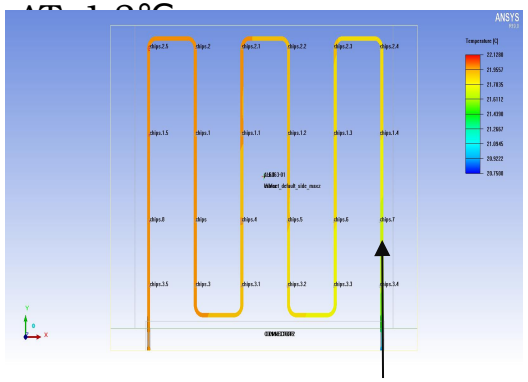
# Test of the cooling plates

## Simulation




21.88℃, ΔT~1.1℃

21.96℃,



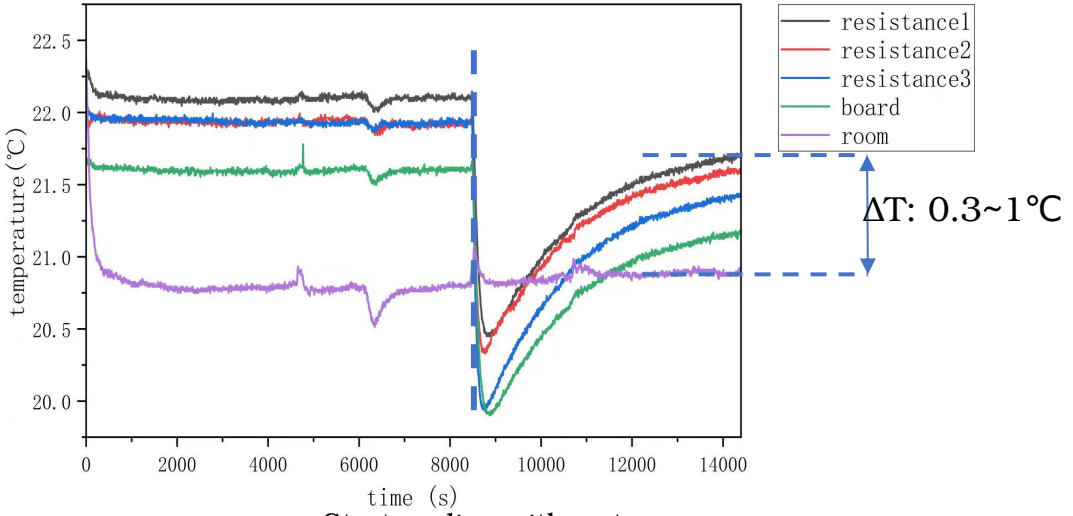

water flow

22.05℃,
ΔT~1.3℃

21.69℃ ,
ΔT~0.9℃

water flow

## Prototype



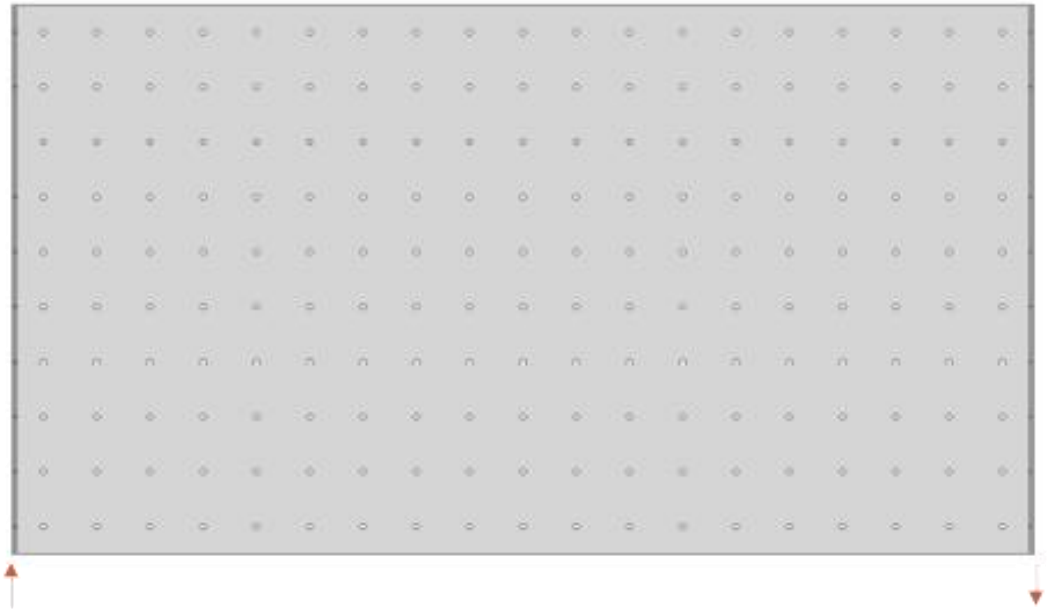

ΔT: 0.3~1℃

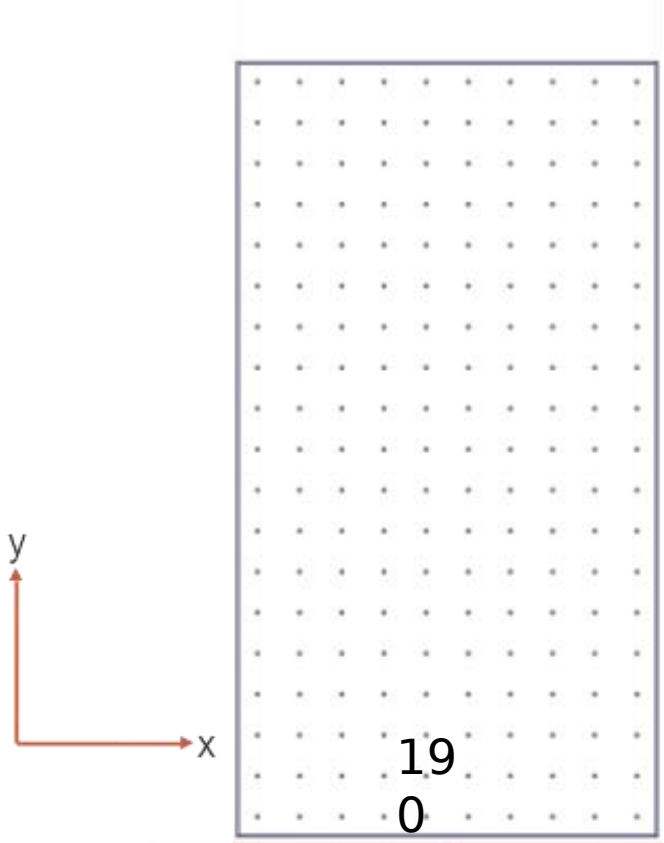
Start cooling with water
below room temperature

# Gas flow simulatio for GRPC

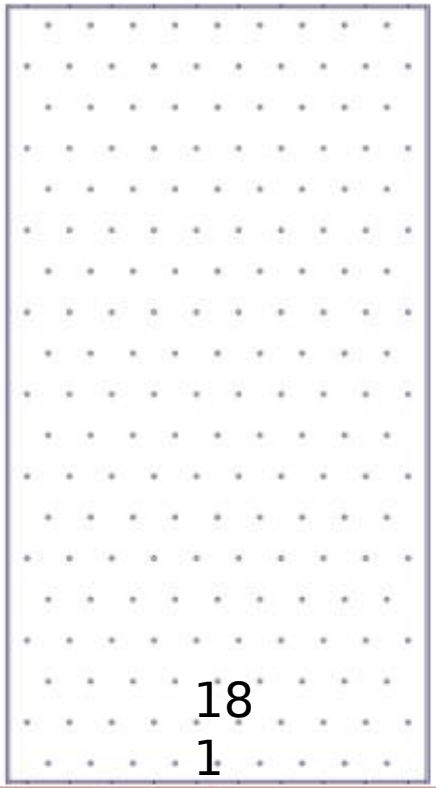
Gas flow has a strong impact on the homogeneity, efficiency of the RPC.
→ The biggest the chamber, the most critical it’s become.
→ For large GRPC 1820mm x 990mm.
→ Using COMSOL Multiphysics 5.4 to simulate gas flow/electric field.

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

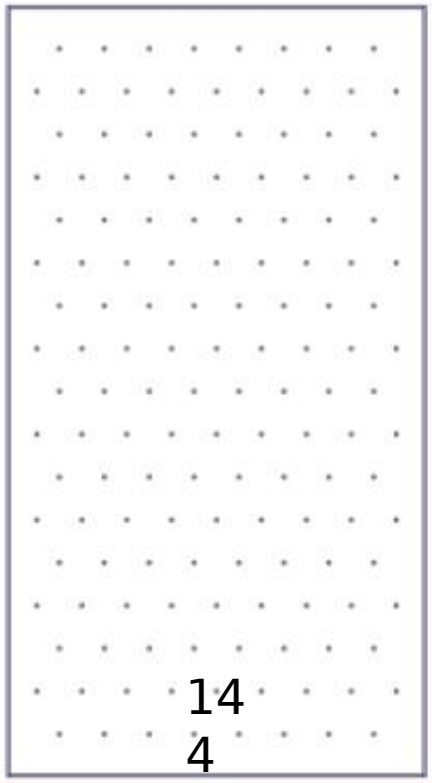





| Distance(cm) | |
|---|---|
| Spacer to spacer(x) | 9.9 |
| Spacer to spacer(y) | 9.96 |
| Spacer to wall(x) | 9.9/2 |
| Spacer to wall(y) | 9.96/2 |

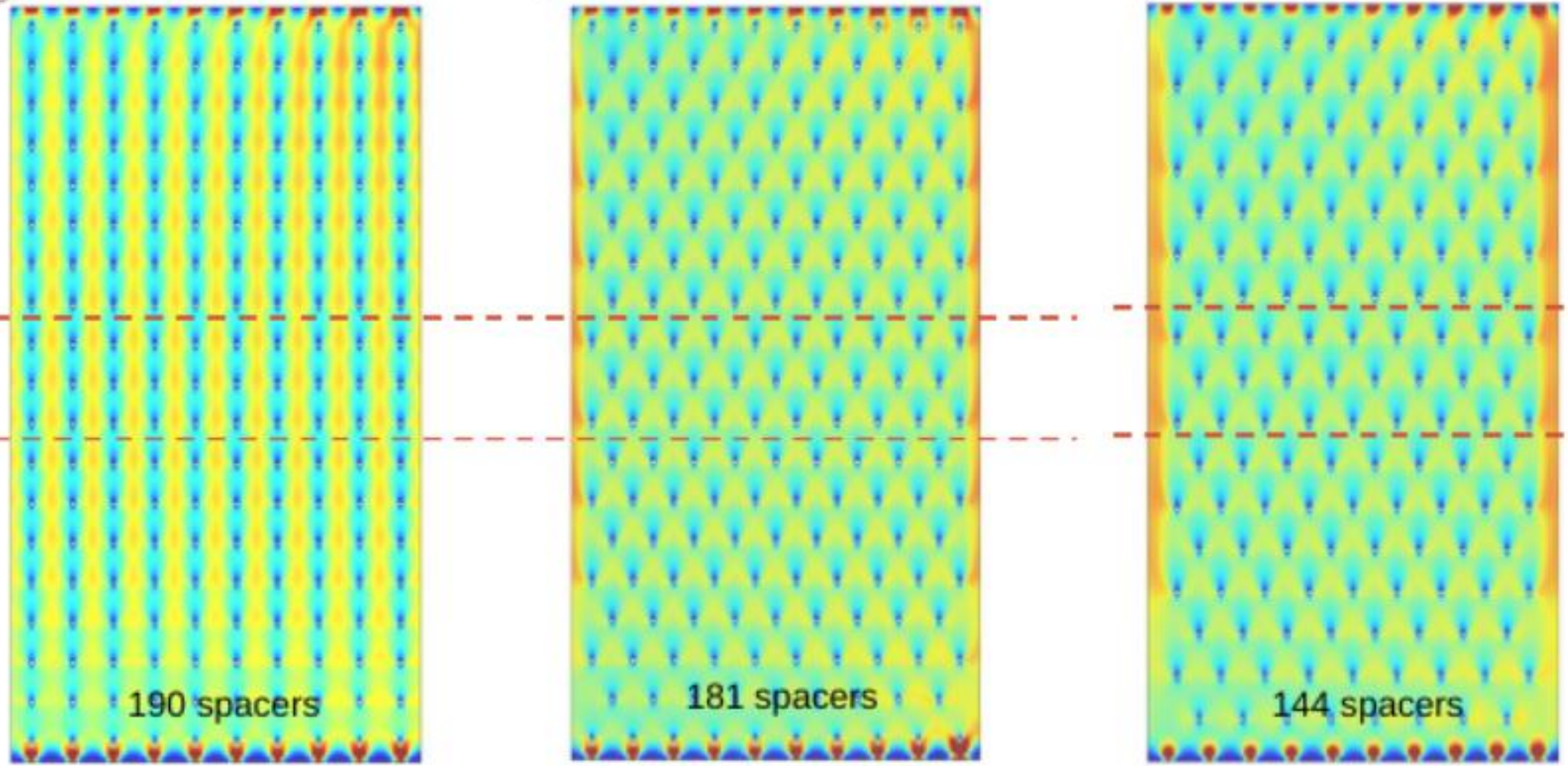



| Distance(cm) | |
|---|---|
| Spacer to spacer(x) | 9.9 |
| Spacer to spacer(y) | 9.96 |
| Spacer to wall(x) | 9.9/2 |
| Spacer to wall(y) | 9.96/2 |




| 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 |

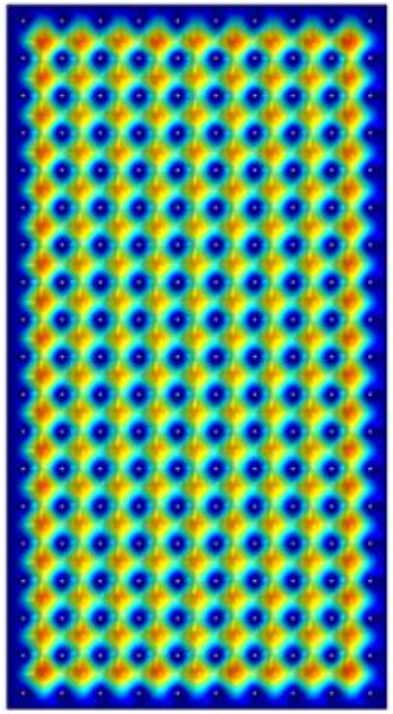
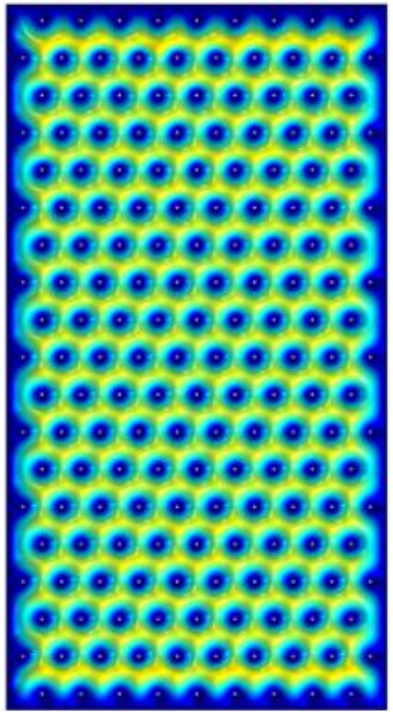
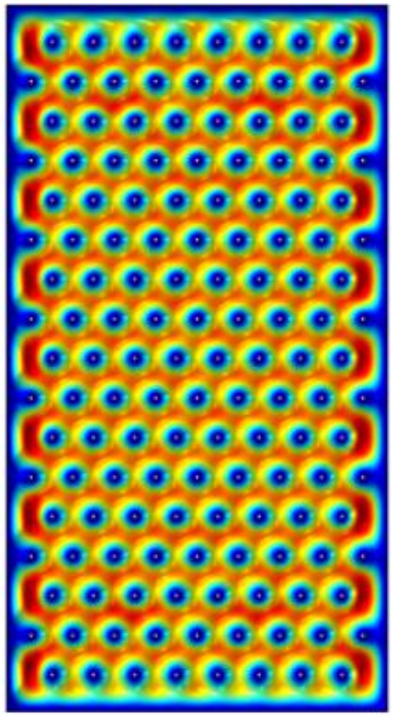
# Gas flow velocity **input:1m/s~10L/h**




| 190 spacers | | 181 spacers | | 144 spacers | |
|---|---|---|---|---|---|
| Ave(m/s) | 0.012184 | Ave(m/s) | 0.012319 | Ave(m/s) | 0.012329 |
| Dev(m/s) | 0.003631 | Dev(m/s) | 0.002994 | Dev(m/s) | 0.003080 |

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

# Deformation due to pressure and electric field

| 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% |

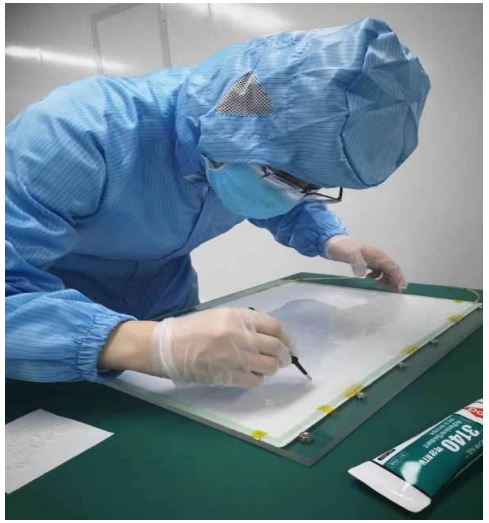
Thickness of gas gap: 1mm

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

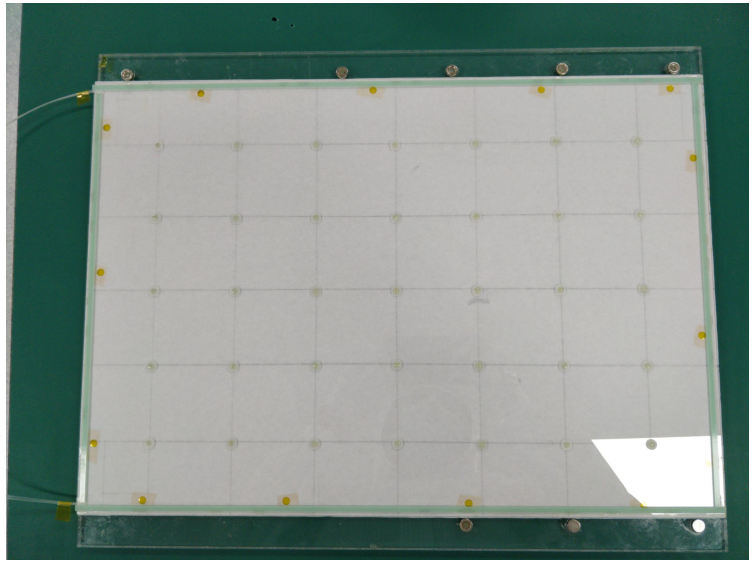
- Decrease the spacer number 190 → 181 → 144 (-25%)
- More active region
- Easier to build
- Improve homogeneity

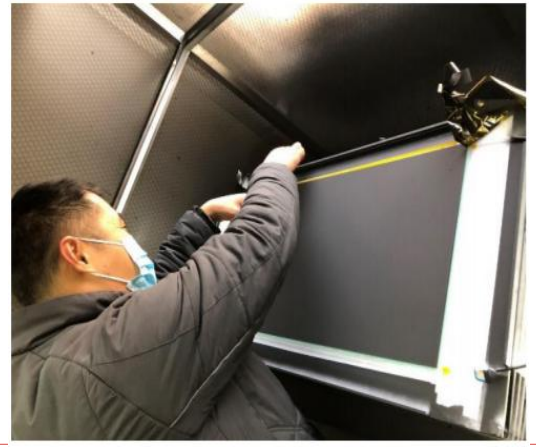
# GRPC construction

30cm x 50cm Chambers

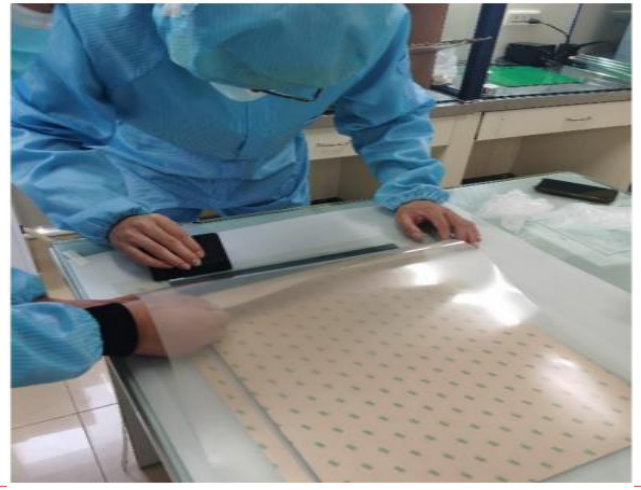


Placing spacers

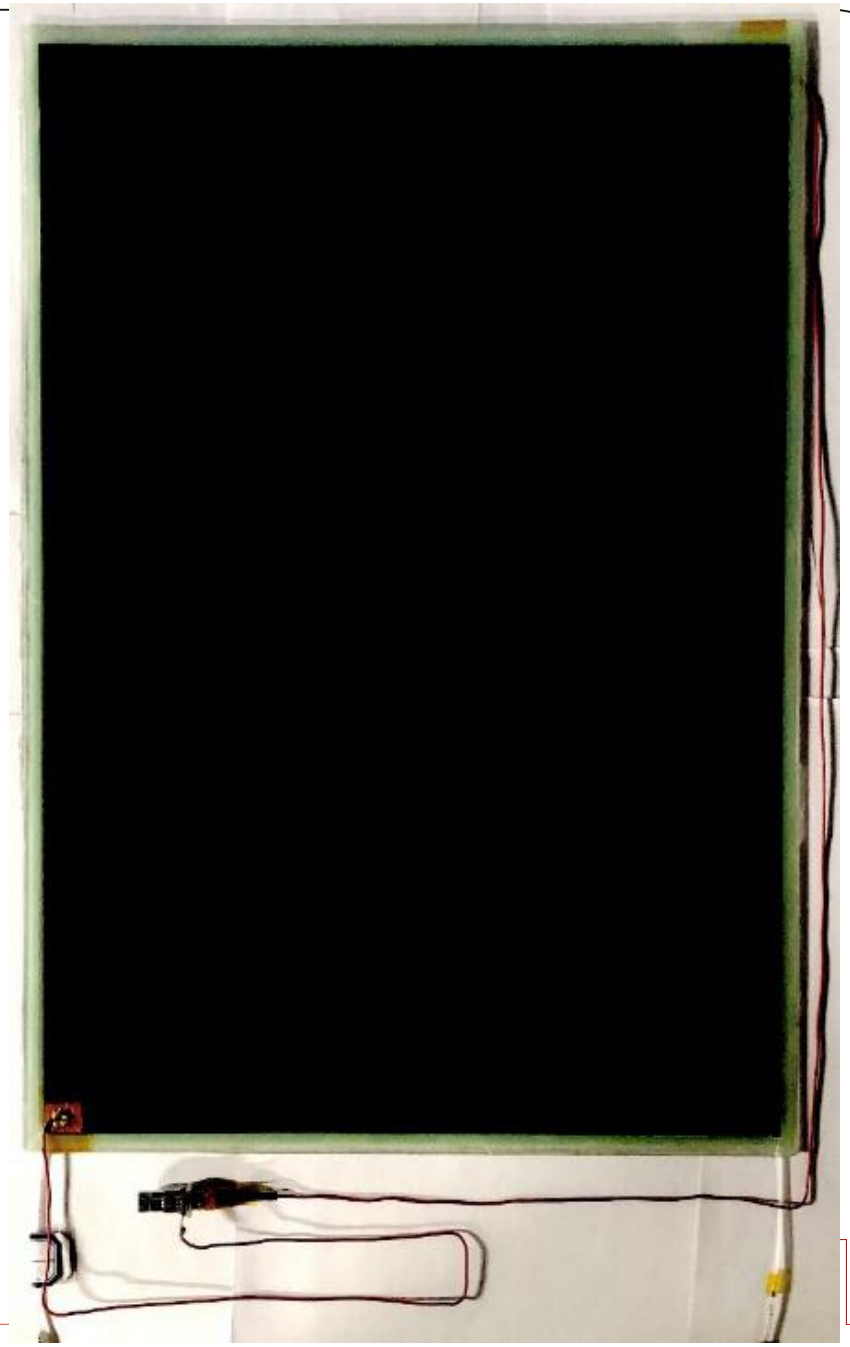




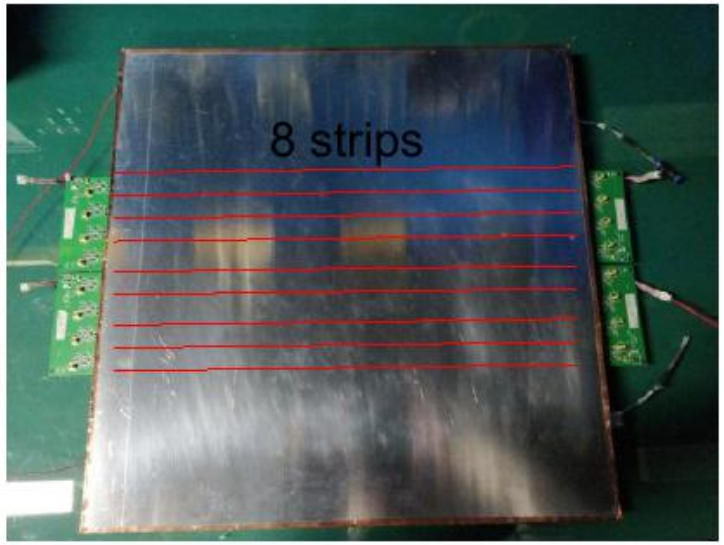
Printing



Mylar gluing



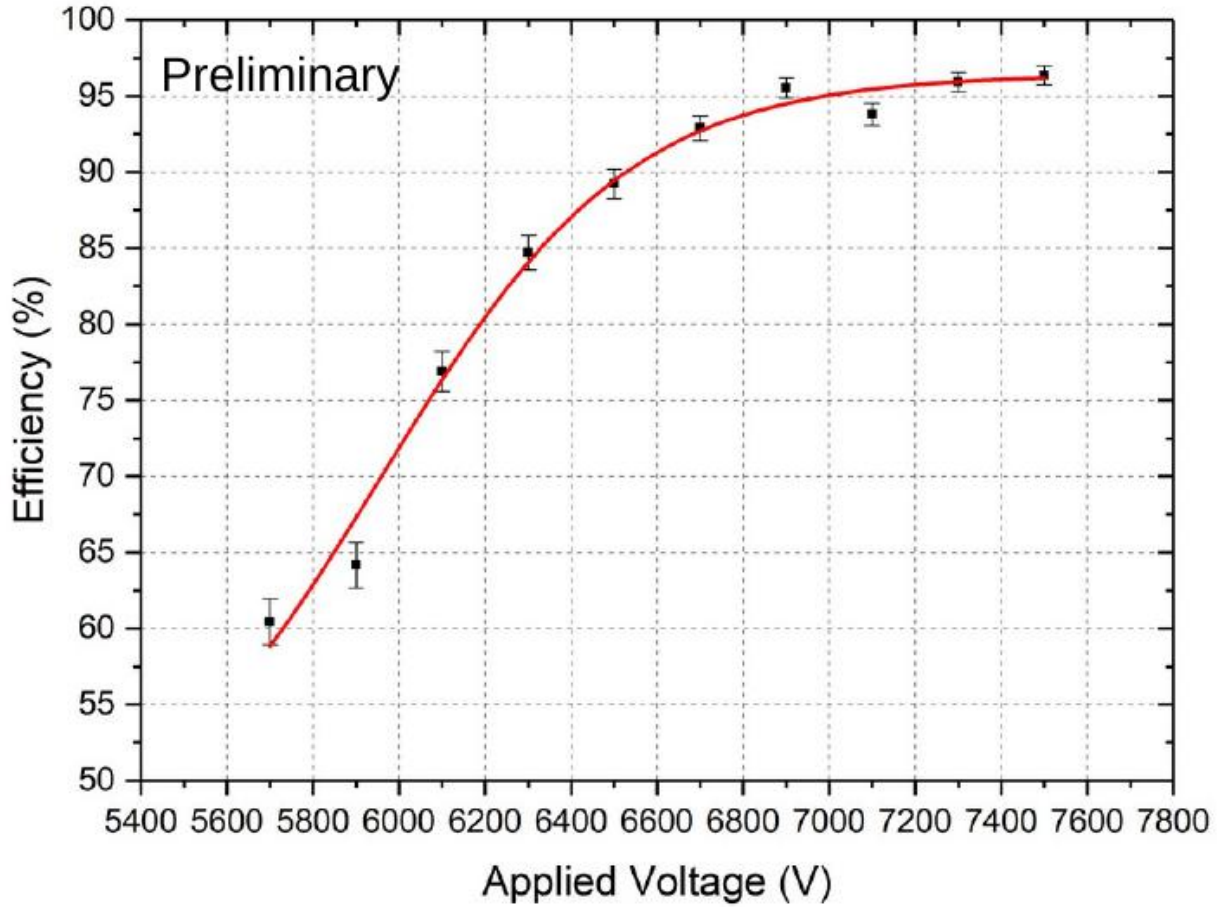
# Cosmic stand



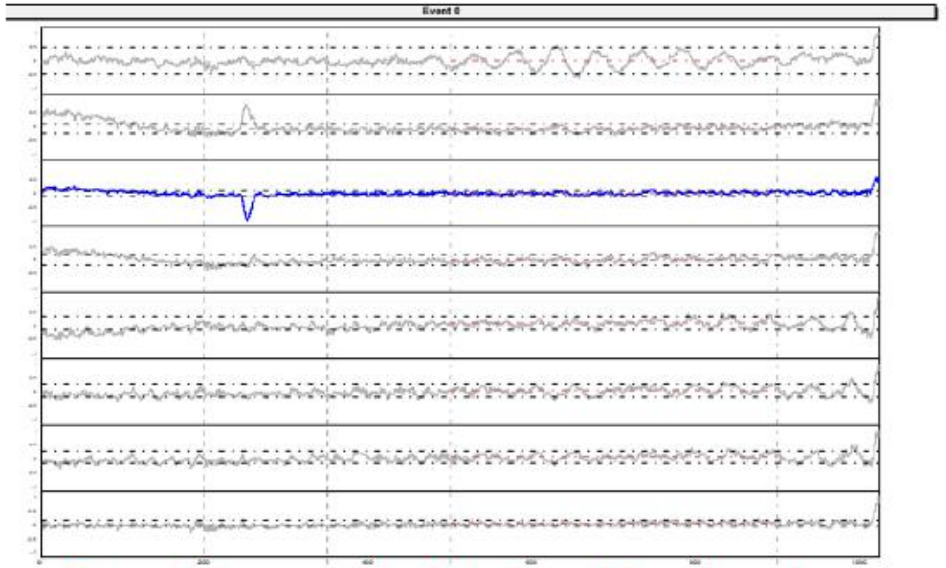

Testing the 50cm x 30cm chambers

USTC reference chamber

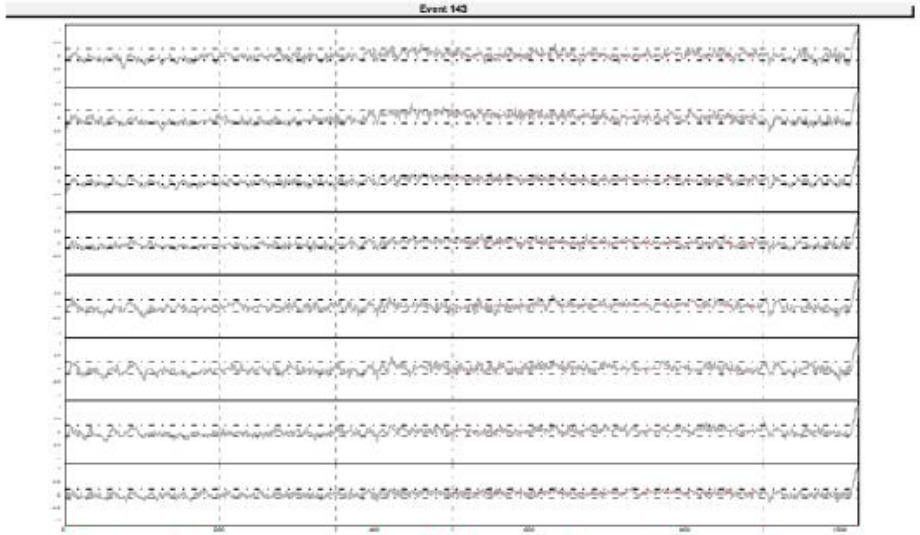
# GRPC efficency using cosmic muons



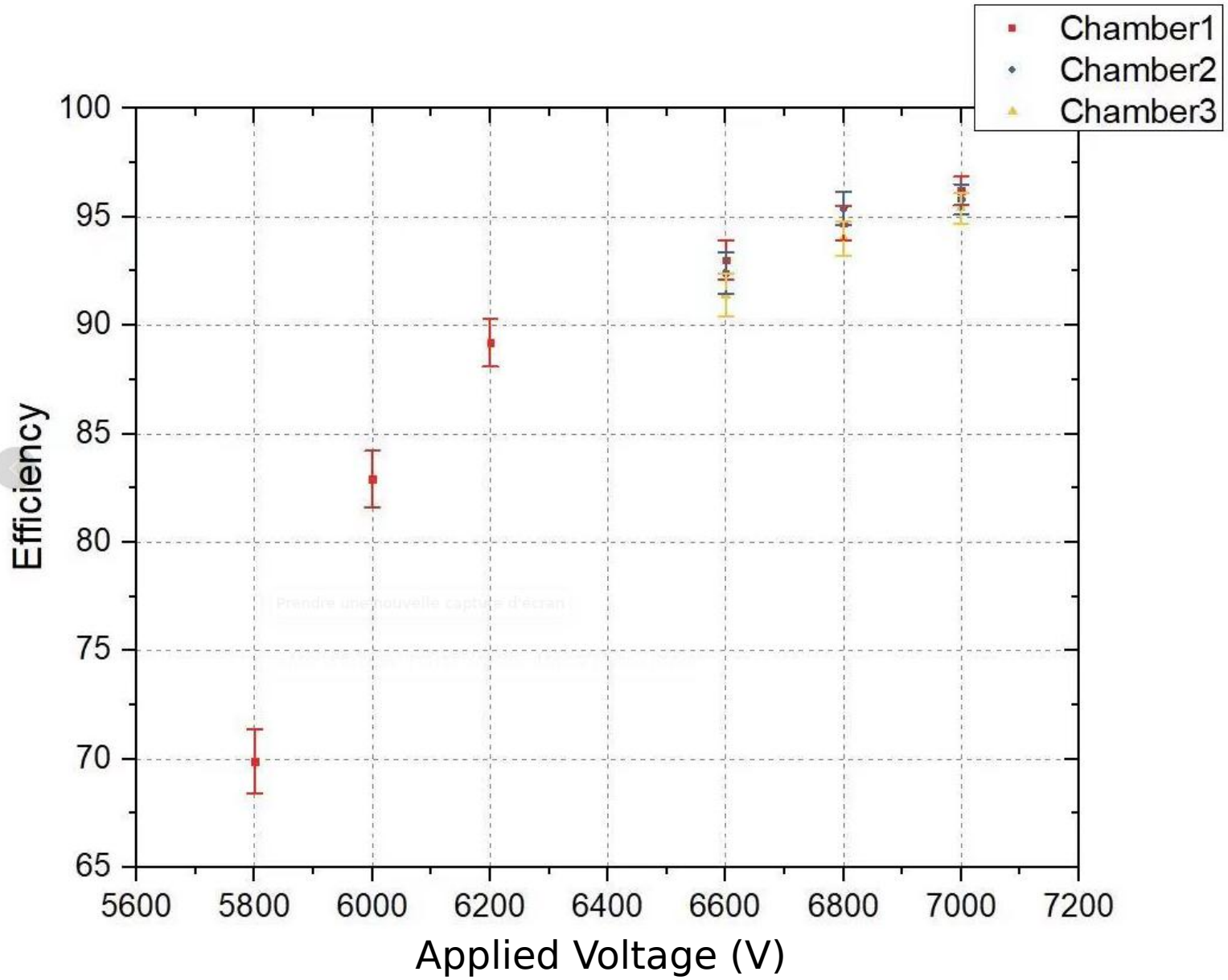

- RPC efficiency reachs 95% at ~7000V
- ~1000 muons / HV point.



Even triggered with signal in chamber



Even triggered with no signal in chamber



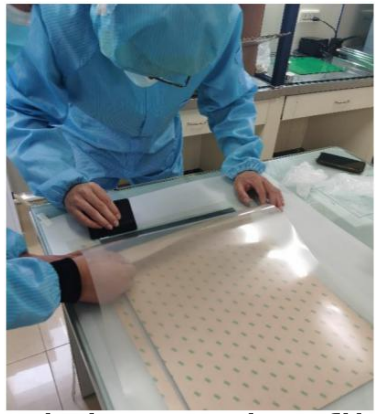

Efficiency is compatible for all chambers

# GRPC construction

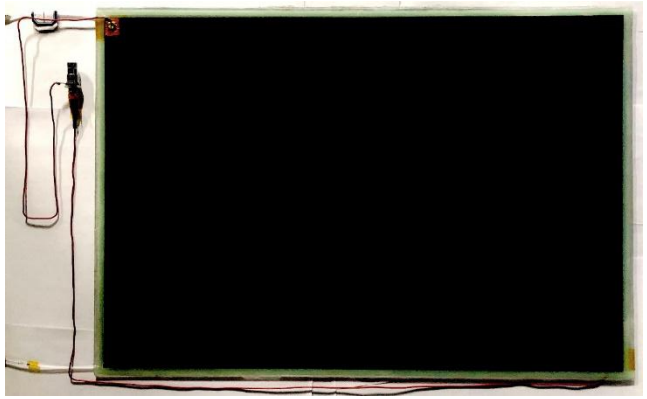
30cm x 50cm Chambers

Placing spacers

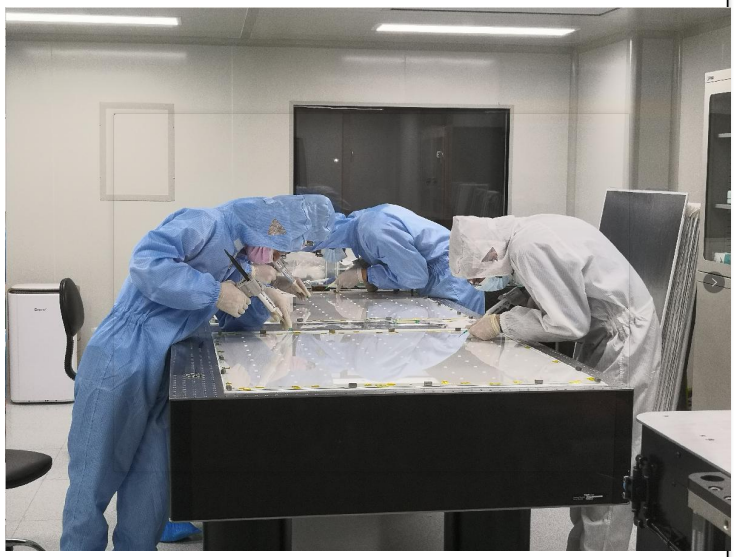
Painting



Gluing Mylar film

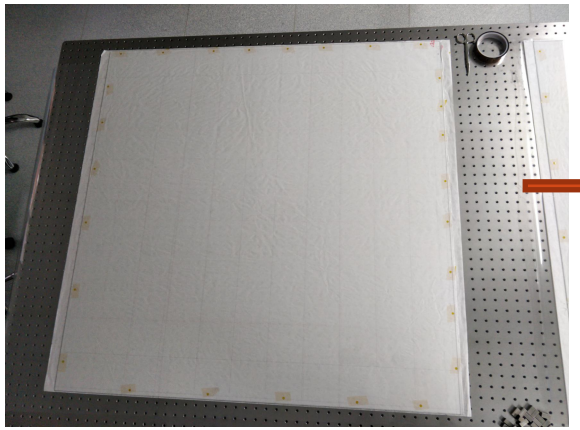


Building 1m x 1m GRPC

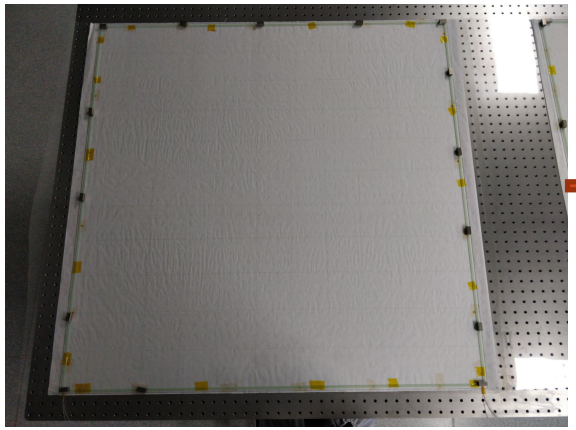


# GRPC construction

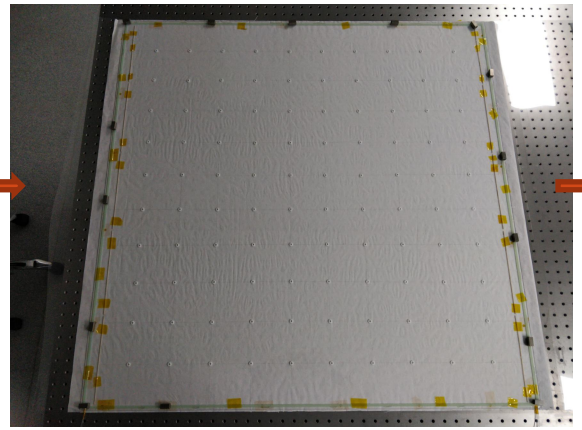
Cleaning



Walls positionning

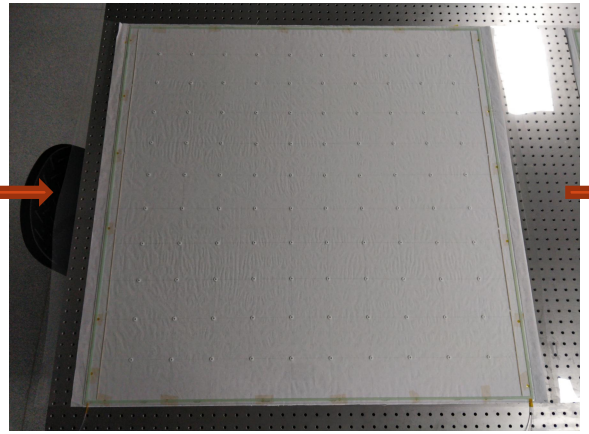


Spacers positionning

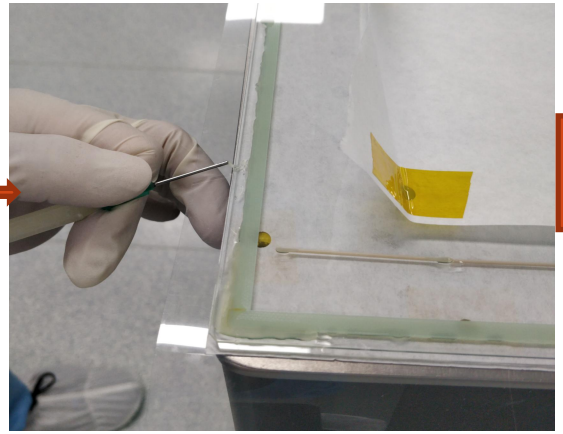


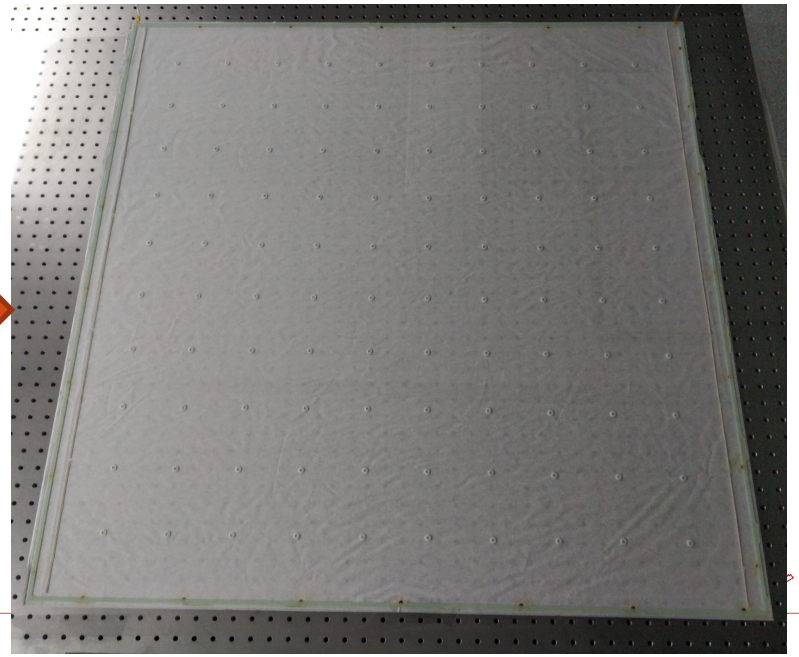
Walls/spacers gluing

Flipping and 2nd glass positionning



2nd glass gluing gas tightning





# Summary

Gas flow simulation has been performed to improve the GRPC layout.

Cooling system studies has started

Construction of GRPCs has been done on small (50cm*30cm) size and big size (1m*1m).

The chambers fullfil the requirements for efficiency (>95%)

# *Thanks for your attention!*