上海交通大學
SHANGHAI JIAO TONG UNIVERSITY

SJTU

Status of GRPC, gas flow simulation R&D

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On behalf of SDHCAL Study Group

CEPC Meeting
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Outline

- Introduction
- Gas flow simulation for GRPC
- GRPC performance tests
- Summary

Introduction

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

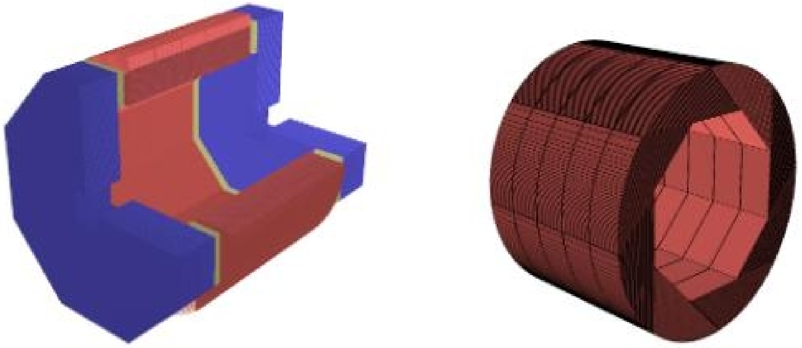
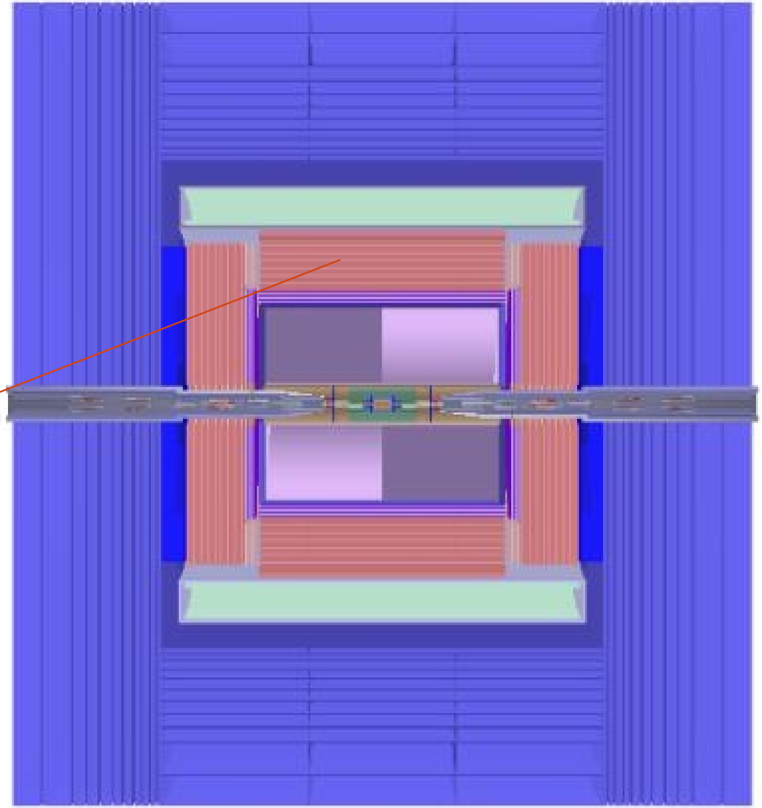


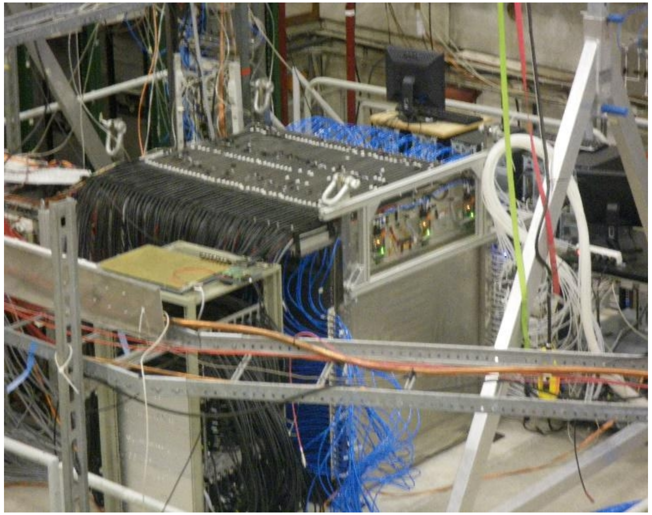
Figure 5.16: Schematic of the CEPC HCAL layout in its baseline design (left) consisting of one cylindrical barrel (red) spanning from 2058 mm to 3144 mm radially and two endcaps (blue) between 2650 mm and 3736 mm in $|z|$. An isometric view of the barrel HCAL is shown on the right.

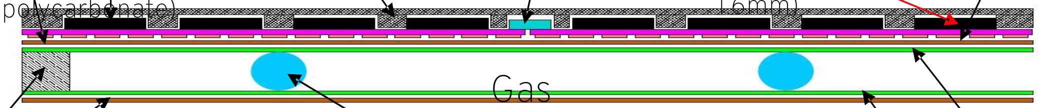


Baseline detector

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)

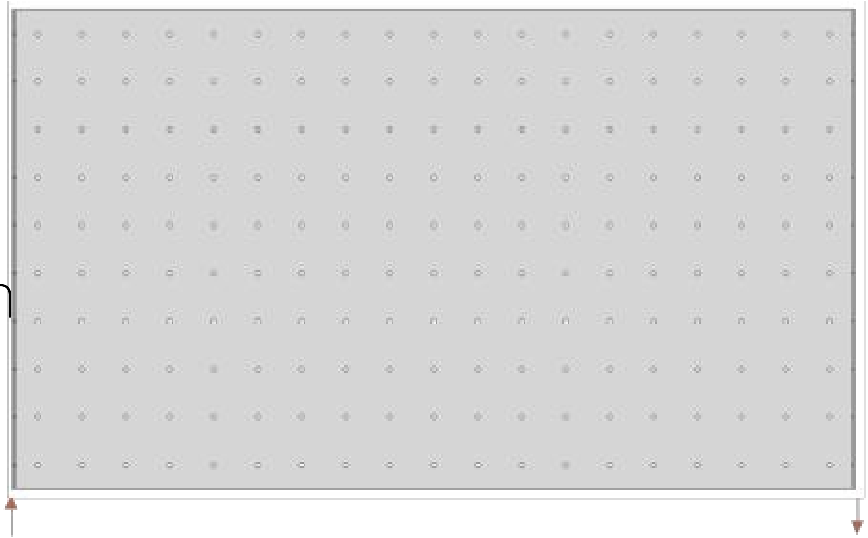
3 mm RPC (glass)
1.2 - 1.4 mm PCB
1.6 mm ASIC

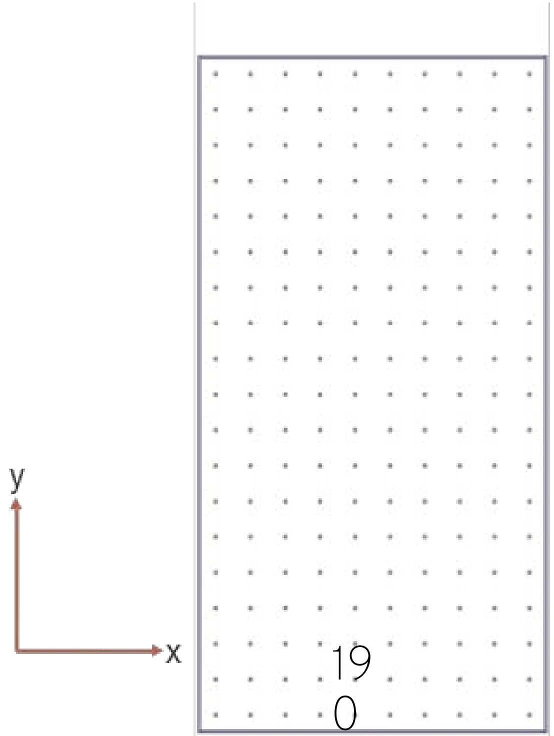
ASIC HARDROC (64 ch)
3-threshold: 110fC, 5pC, 15pC

Gas flow simulatio for GRPC

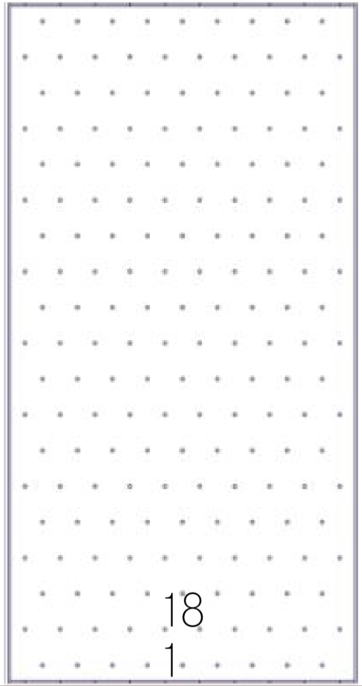
Gas flow has a strong impact on the homogeneity, efficiency of the RPC.
→ The biggest the chamber, the most critical it's become.
→ For large GRPC 1820mm x 990mm.
→ Using COMSOL Multiphysics 5.4 to simulate gas flow/electric field.

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)	
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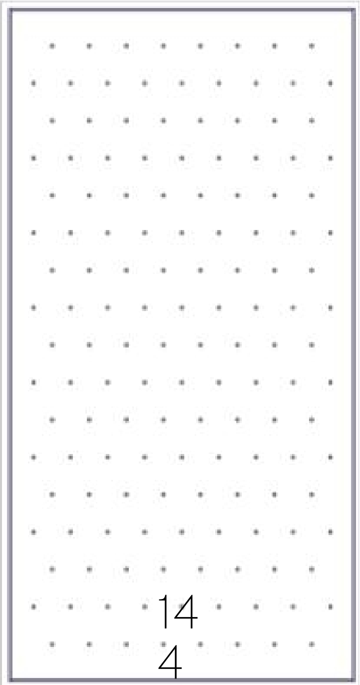
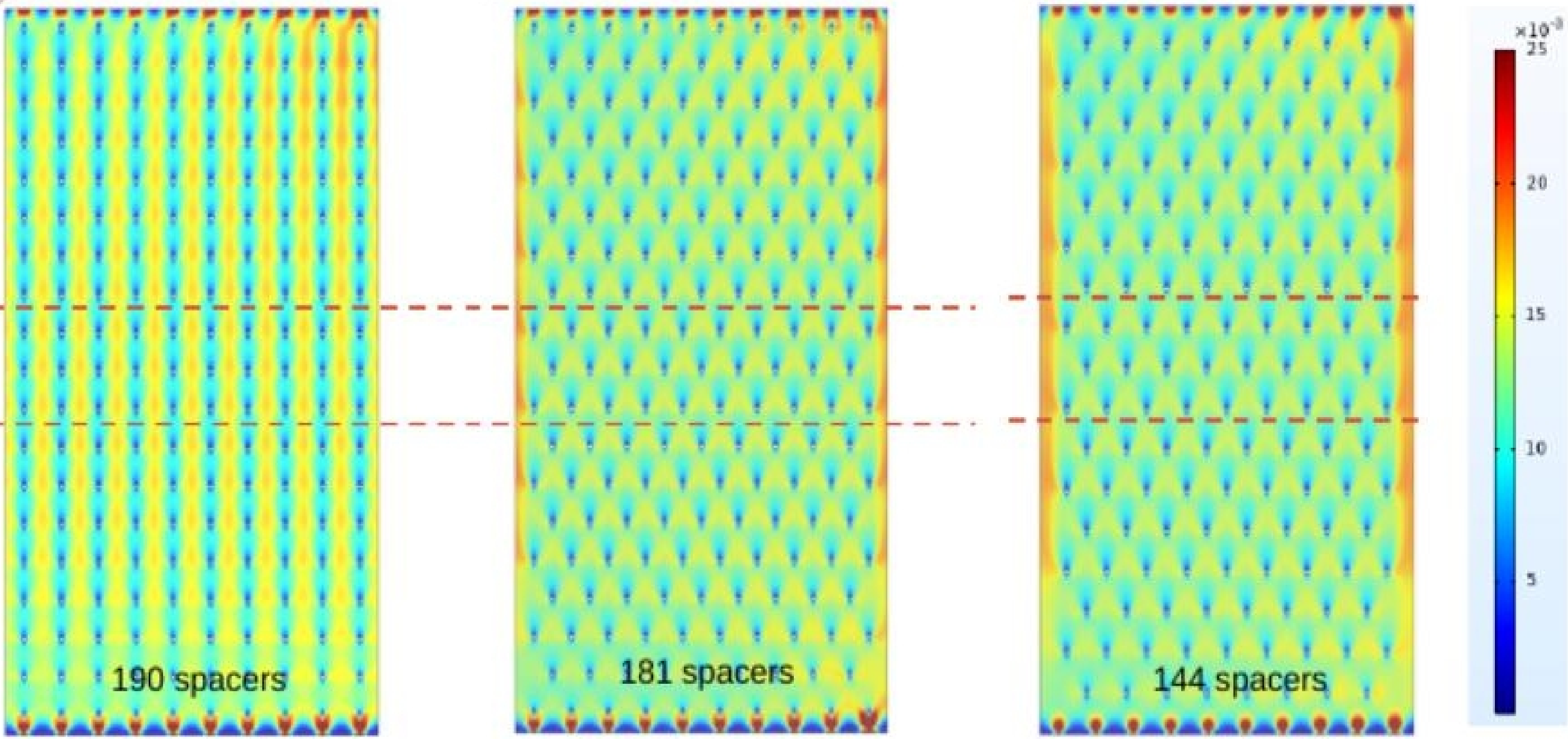


Distance(cm)	
Spacer to spacer(x)	10.1
Spacer to spacer(y)	10.6
Spacer to wall(x)	10.1
Spacer to wall(y)	10.6

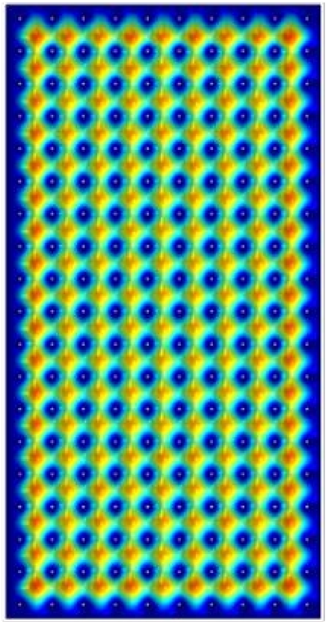
Gas flow velocity **input:1m/s~10L/h**

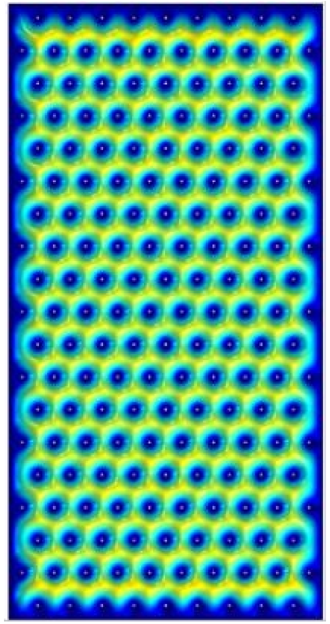


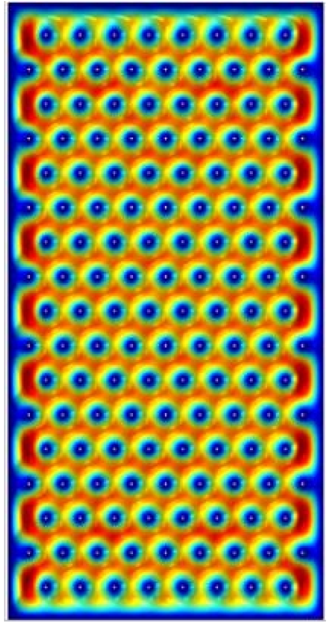
	190 spacers	181 spacers	144 spacers
Ave(m/s)	0.012184	0.012319	0.012329
Dev(m/s)	0.003631	0.002994	0.003080

- 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%

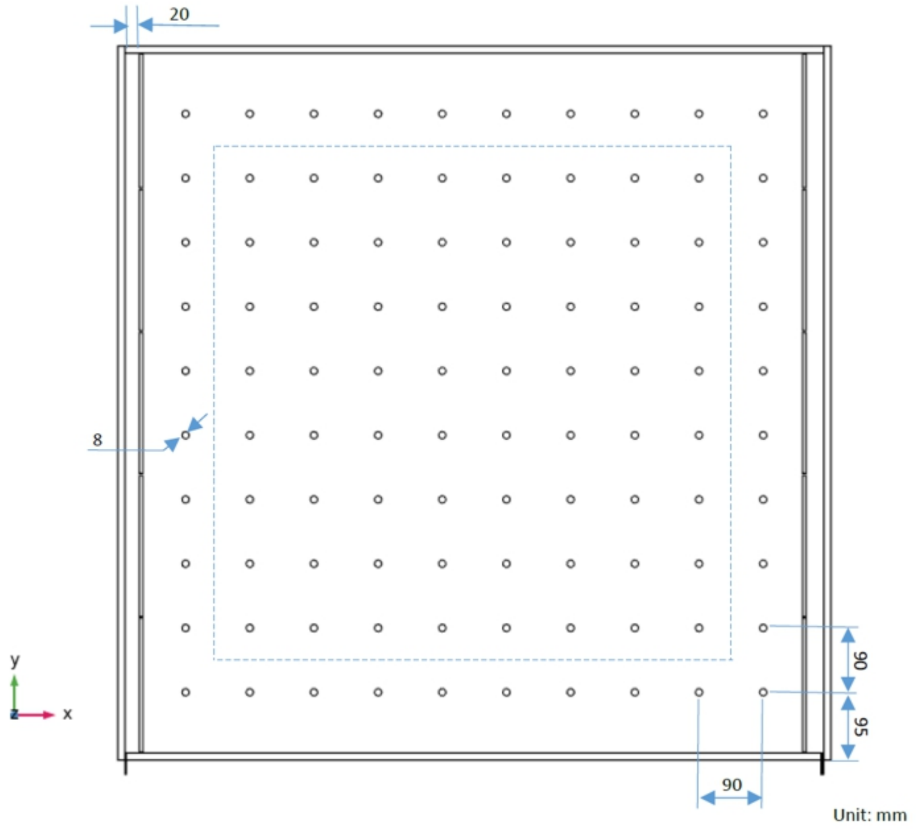
Thickness of gas gap: 1mm

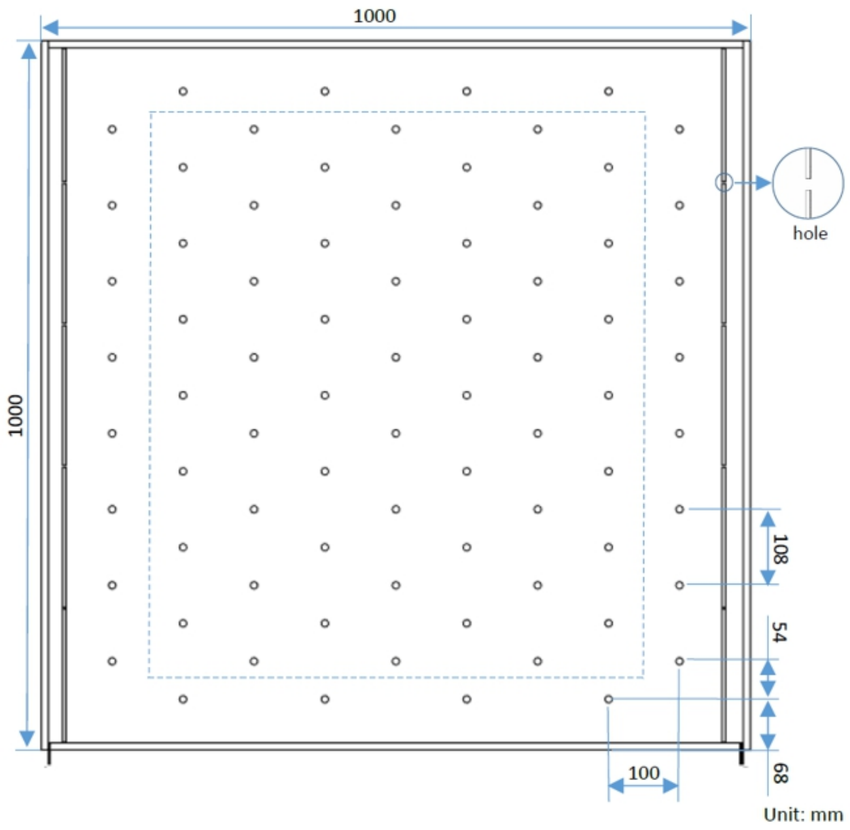
By shifting the spacers and trying to keep the same deformation :

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

1m*1m gas flow simulation

Compare «Reference» and «shifted» spacers configuration.

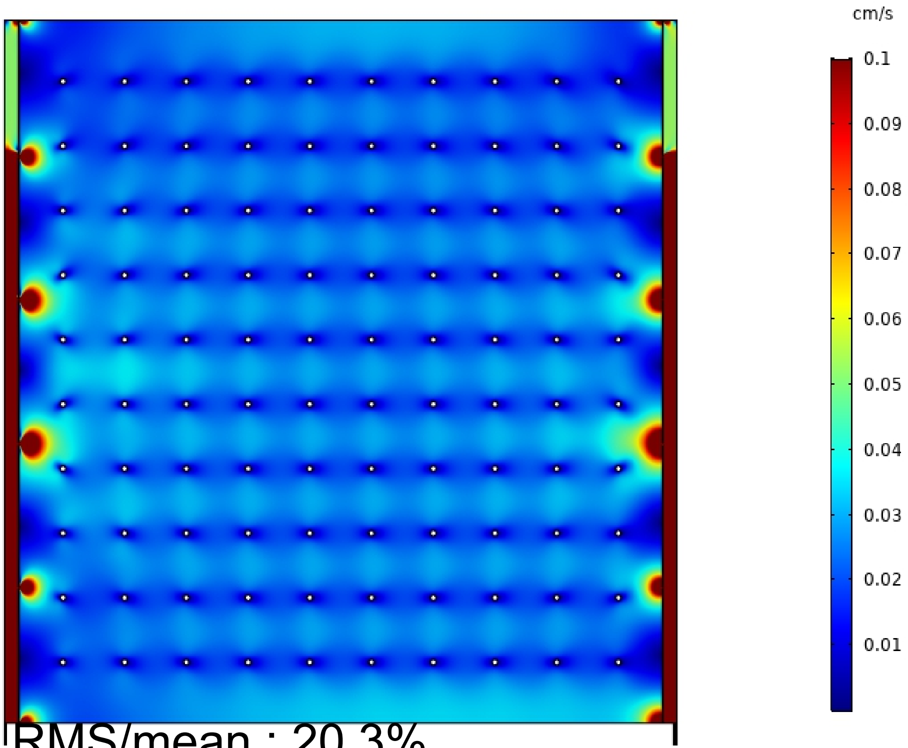




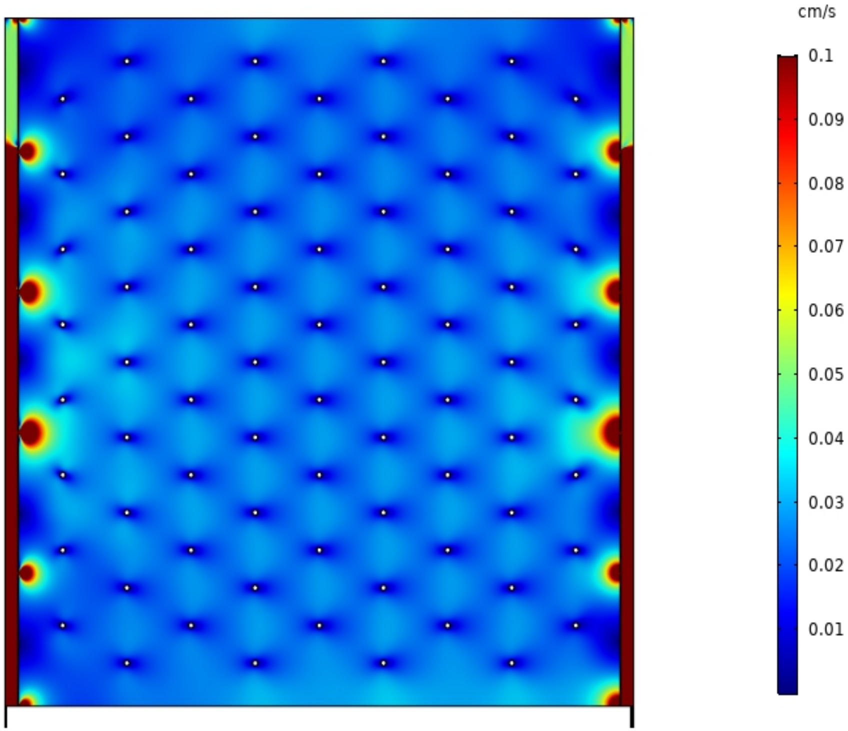
1m*1m gas flow simulation

Compare «Reference» and «shifted» spacers configuration.

Velocity distribution



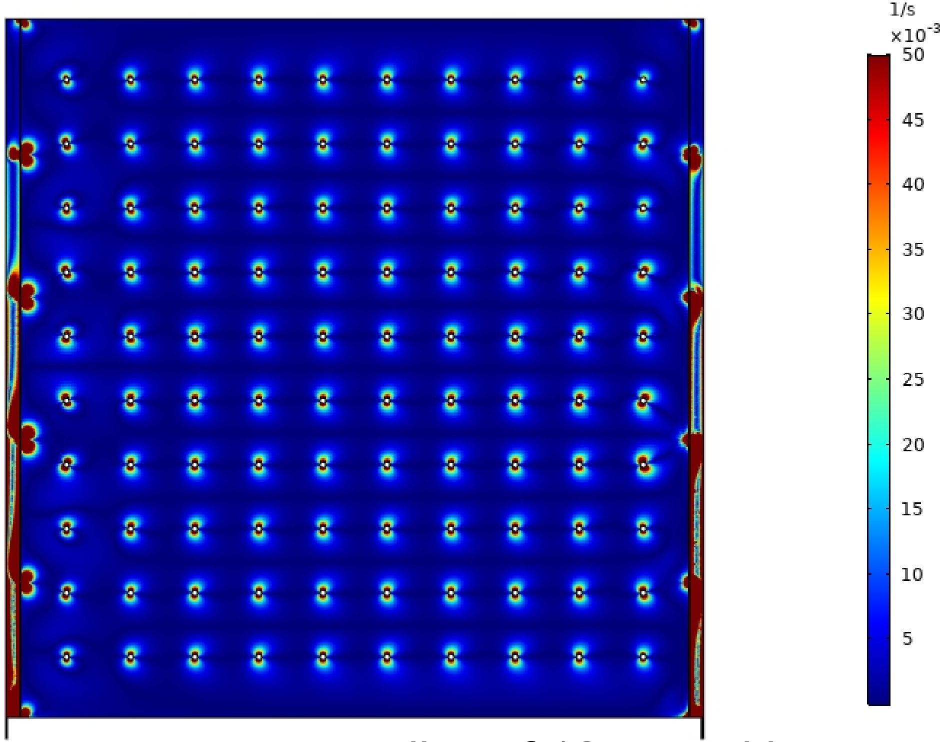
RMS/mean : 20.3%

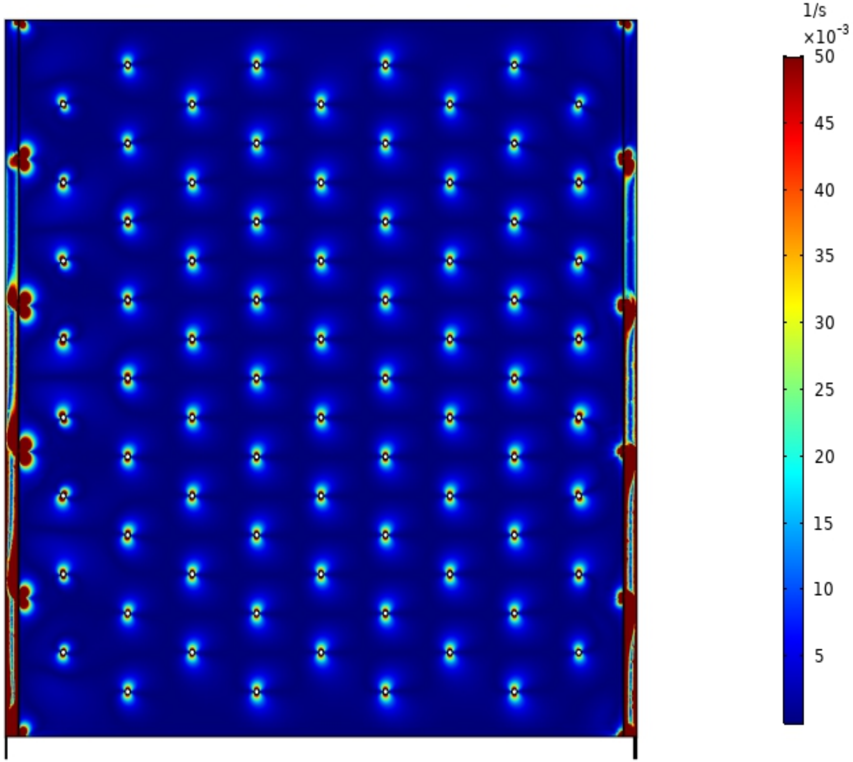


RMS/mean : 17.5%

The velocity is more uniform with the «shifted» design

Vorticity





radius of 12 mm with respect to the spacer center

Mean vorticity around the spacer : 0.0199s^{-1}

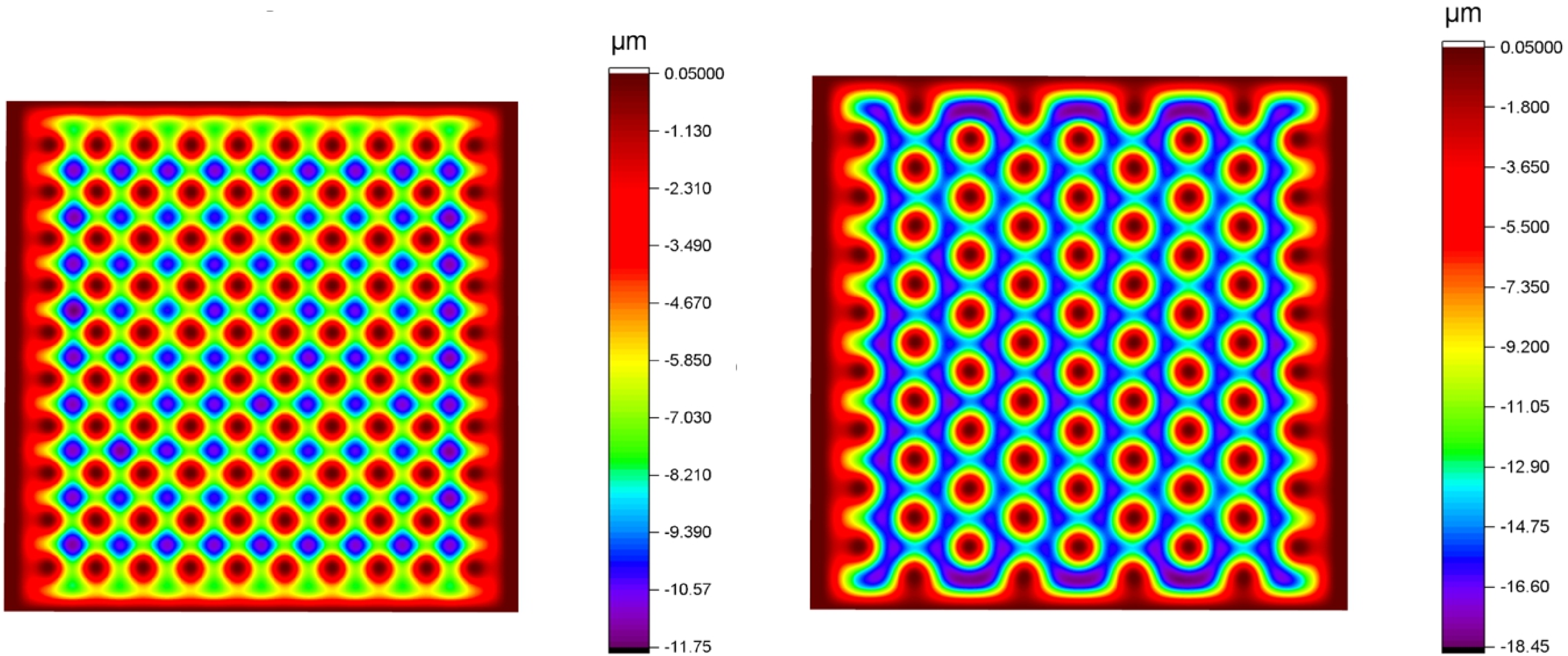
Mean vorticity remaining area : 0.0022s^{-1}

Mean vorticity around the spacer : 0.0196s^{-1}

Mean vorticity remaining area : 0.0018s^{-1}

The vorticity is decreased in both area

Deformation of the gas gap



Mean deformation: 6.5 ±1.9 μm
Mean/sigma : 29.0%

Mean deformation: 11.6 ±3.2 μm
Mean/sigma : 27.6%

Better deformation uniformity

Summary for the simulations :

Model	"Reference spacers" RPC	"Shifted spacers" RPC
Mean velocity $\bar{v}$	0.0238 ($cm\,s^{-1}$)	0.0241 ($cm\,s^{-1}$)
RMS of velocity σ_v	0.0049 ($cm\,s^{-1}$)	0.0042 ($cm\,s^{-1}$)
$\sigma_v/\bar{v}$	20.3 (%)	17.5 (%)
Mean vorticity near spacers region	0.0199 (s^{-1})	0.0196 (s^{-1})
Mean vorticity excluding the vicinity of spacers	0.0022 (s^{-1})	0.0018 (s^{-1})
Mean deformation between gas gap $\bar{d}$	6.5 (μm)	11.6 (μm)
RMS of deformation σ_d	1.9 (μm)	3.2 (μm)
$\sigma_d/\bar{d}$	29.0 (%)	27.6 (%)

Table 1: Results from simulation.

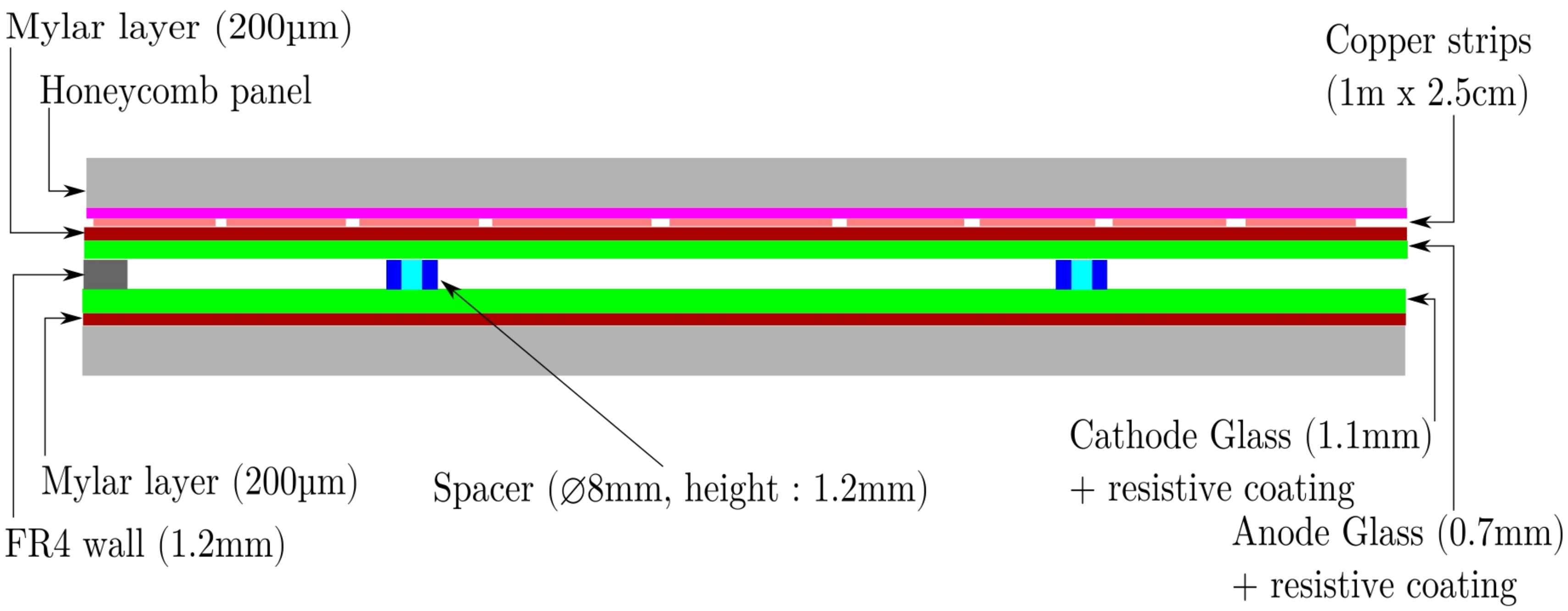
There is improvement on all the parameters :

- Increase on the mean velocity
- More uniform velocity
- More uniform deformation
- More active region
- Less vorticity
- More uniform vorticity

From construction perspective:

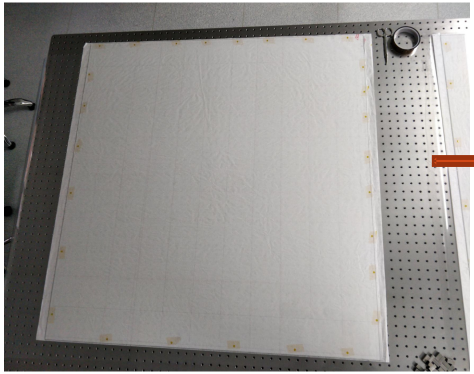
- Easier to build
- 25% less spacers

GRPC scheme

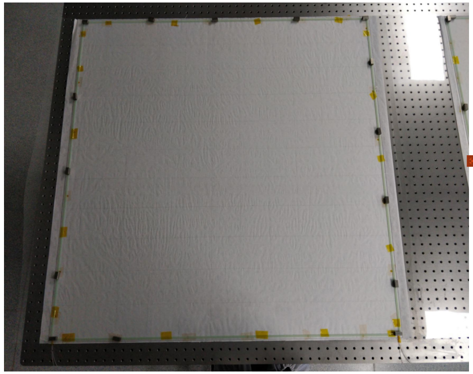

Mylar layer (200µm)
Honeycomb panel
Copper strips
(1m x 2.5cm)
Cathode Glass (1.1mm)
+ resistive coating
Mylar layer (200µm)
Spacer (∅8mm, height : 1.2mm)
Anode Glass (0.7mm)
+ resistive coating
FR4 wall (1.2mm)

GRPC construction

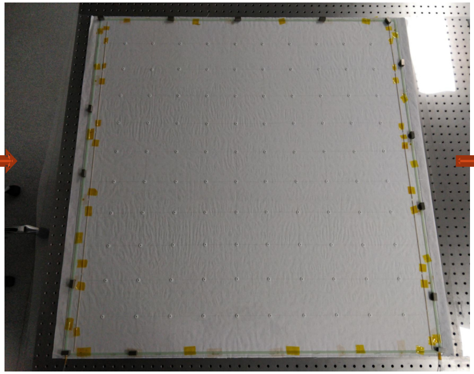
Cleaning



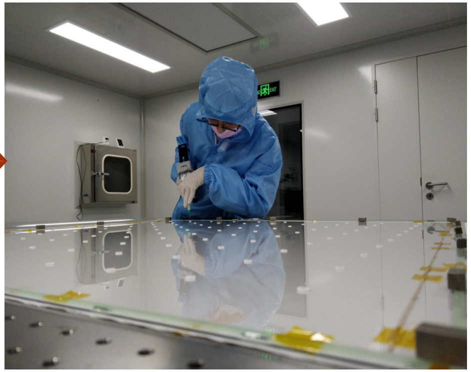
Walls positionning



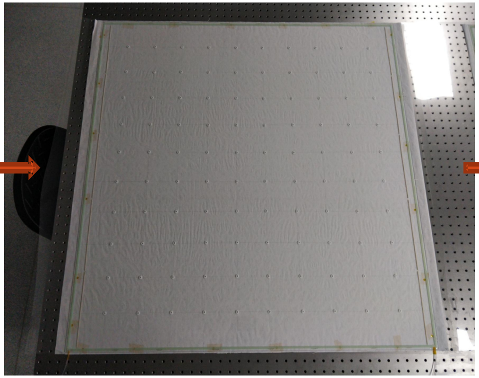
Spacers positionning



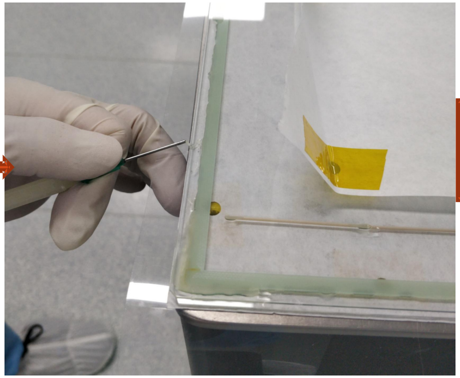
Walls/spacers gluing

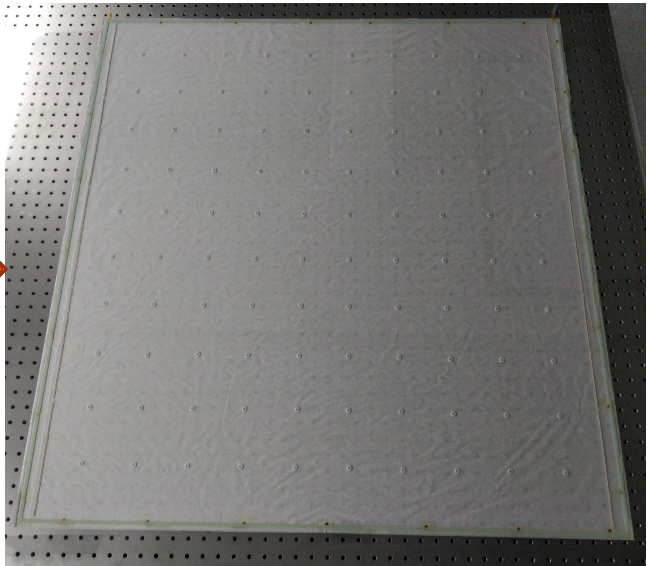


Flipping and 2nd glass positionning

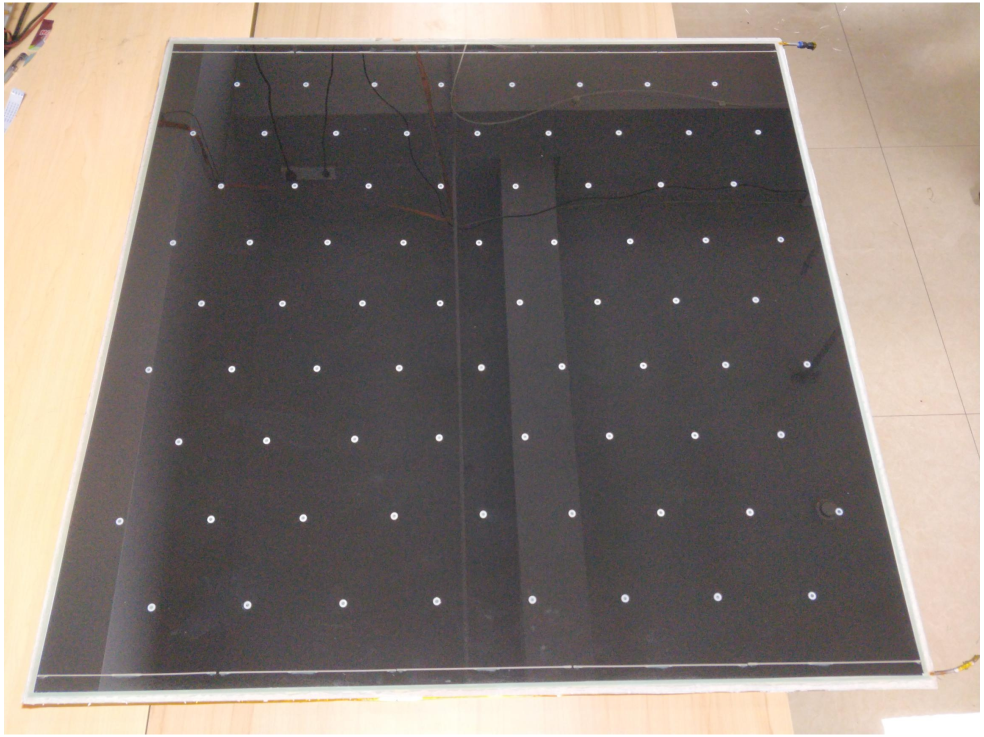


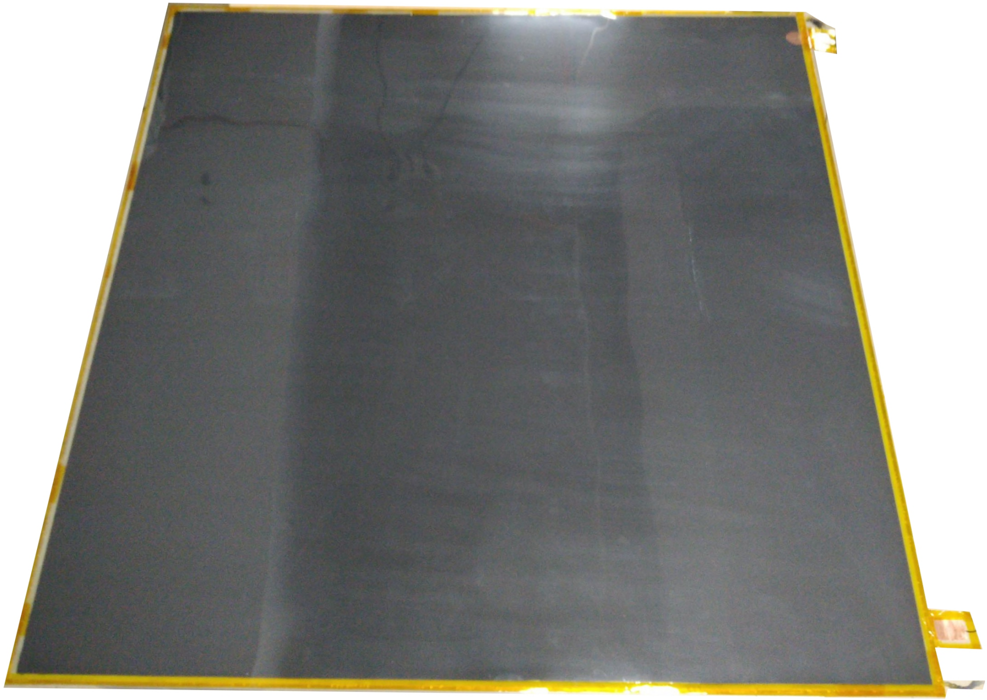
2nd glass gluing
gas tightning



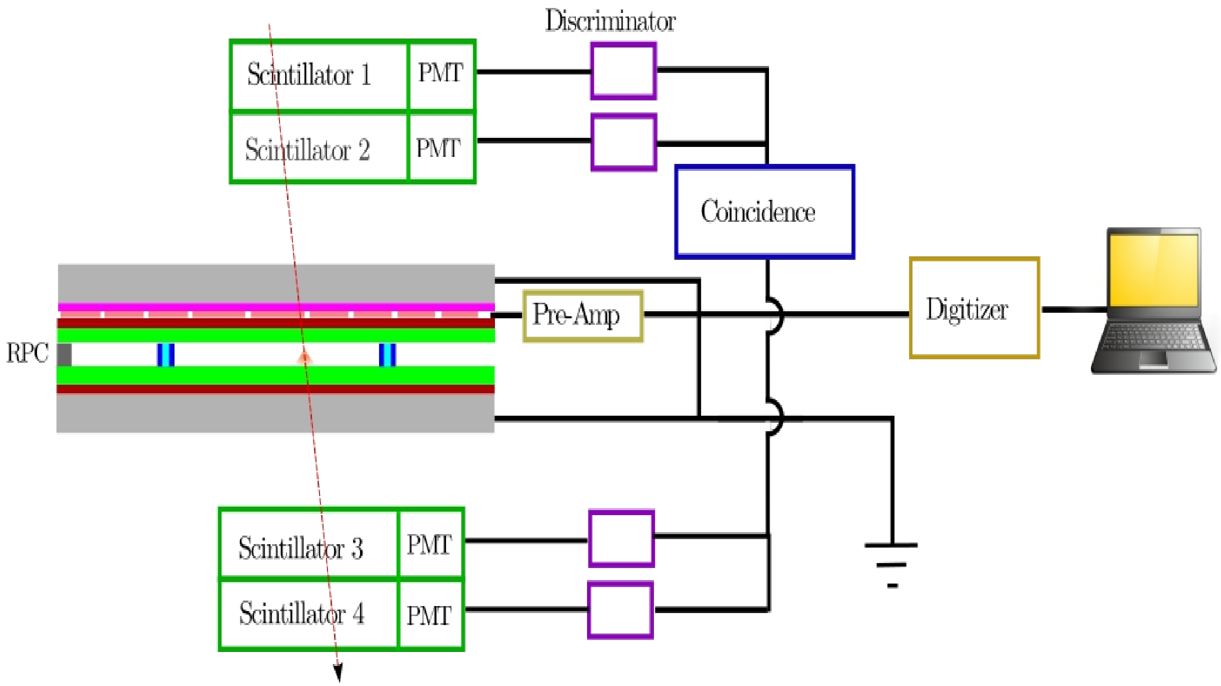


GRPC construction



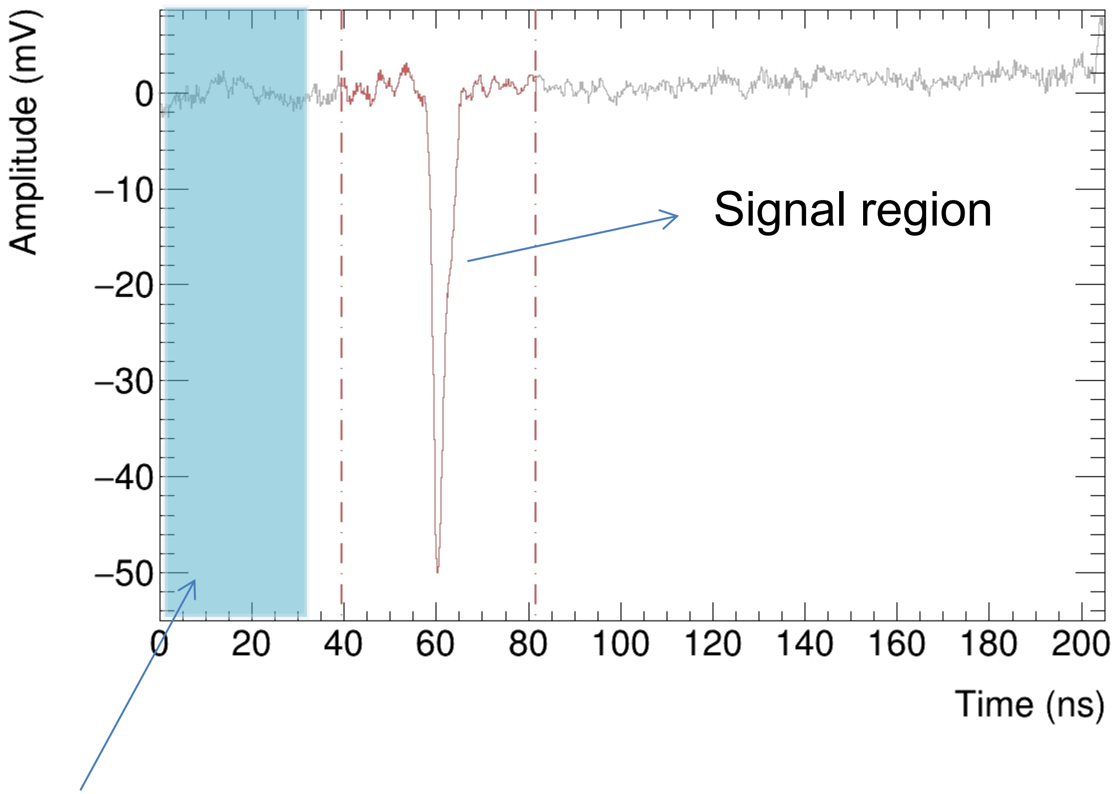


Data taking



Digitizer : CAEN V1712 5Gs/s

Data taking

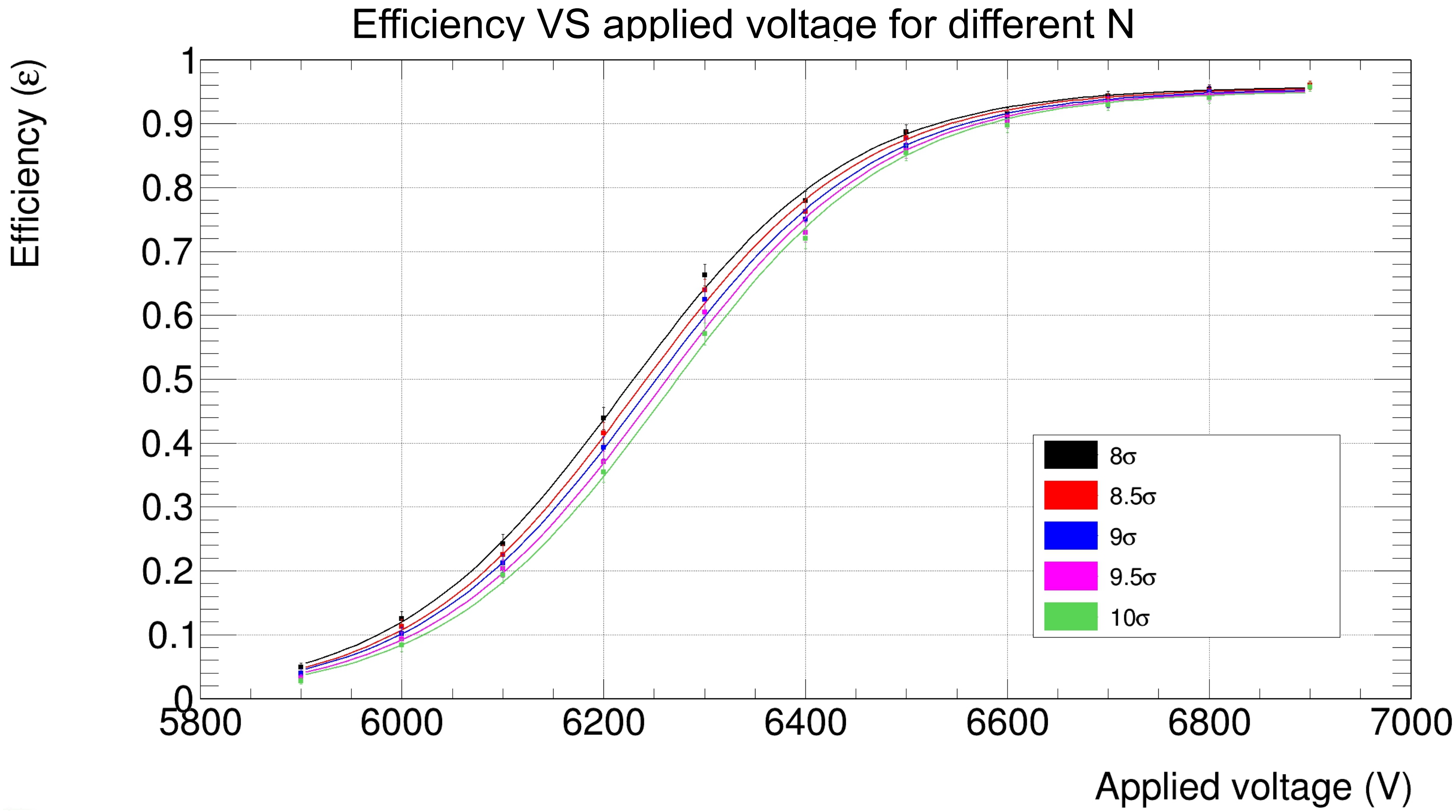


Signal from one channel

Compare the amplitude of the signal to the baseline and RMS of the Reference region

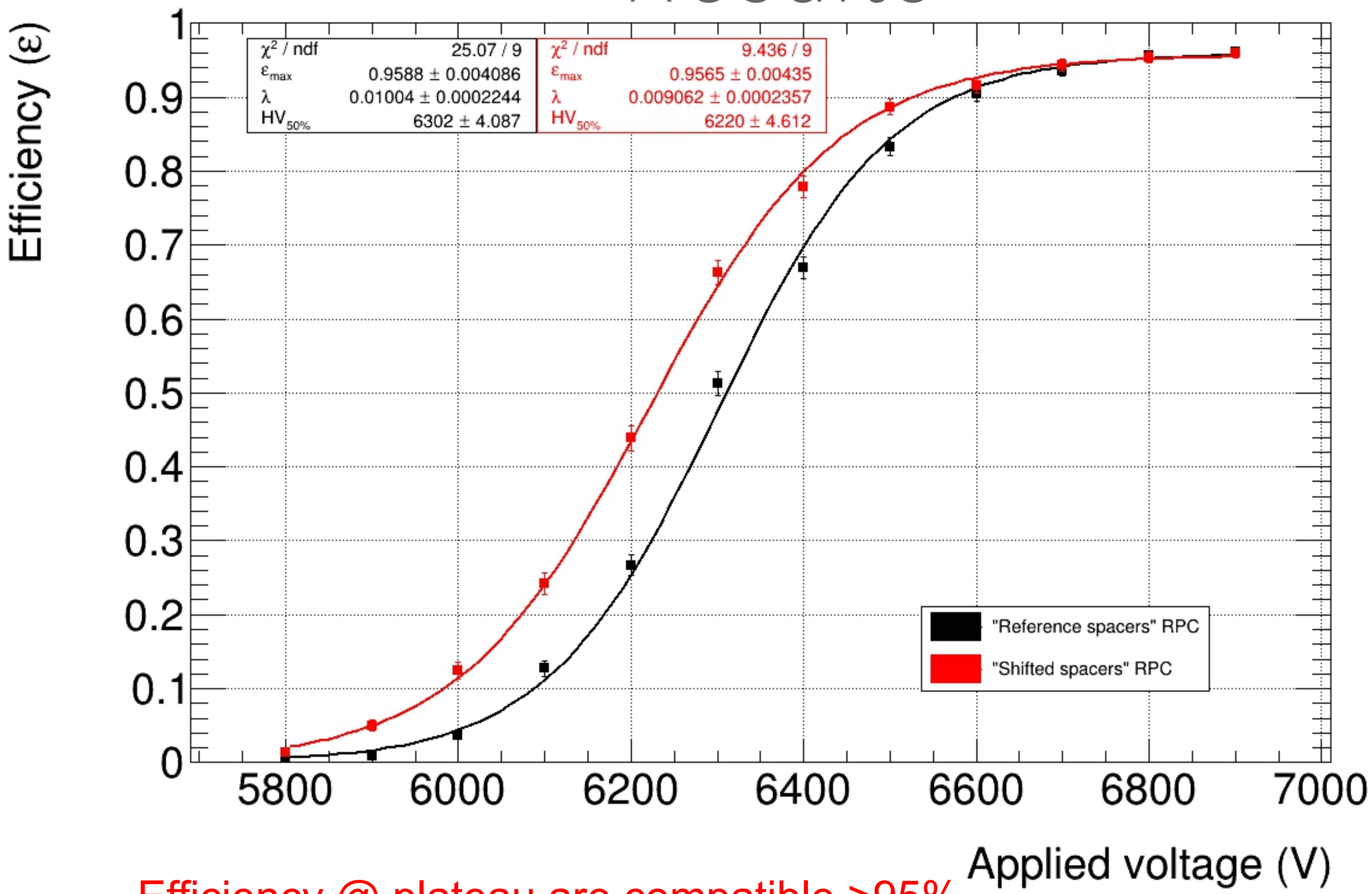
The chamber is considered as efficient on this event if at least one channel has an amplitude greater than N* σ

After study (cf. next slide) we chose N=8.



The efficiency (efficiency plateau) is quite similar for all the tested N.
-> robustness of the muon detection against noise

Results



Efficiency @ plateau are compatible >95%

Summary

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

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

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

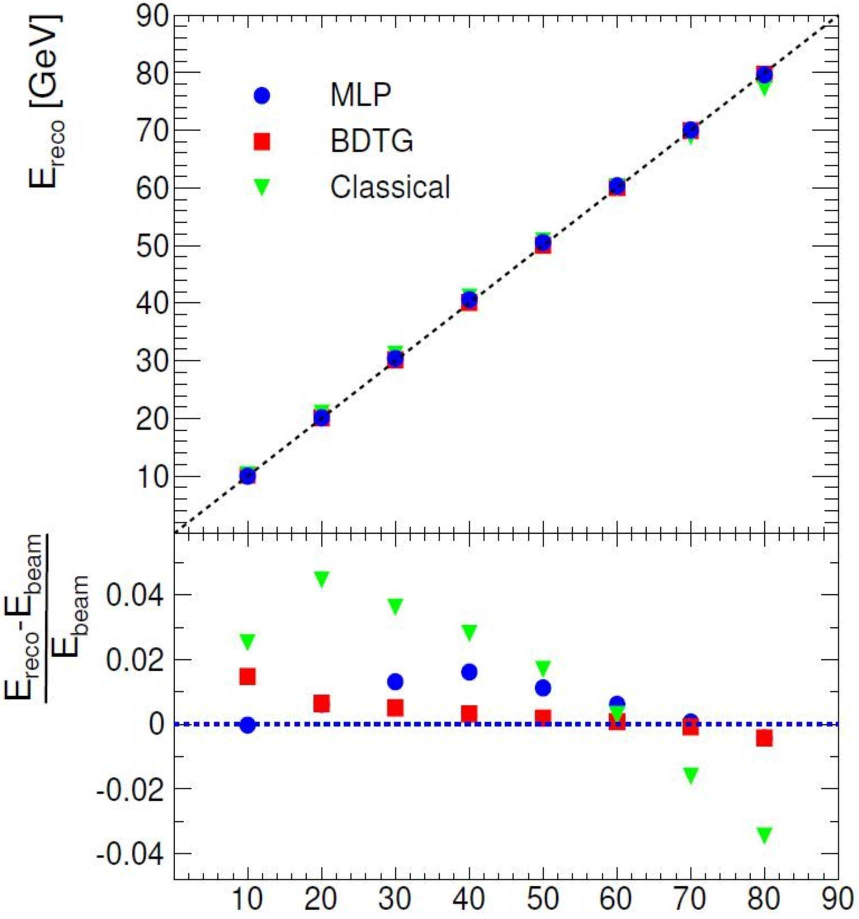
Thanks for your attention!

Backup

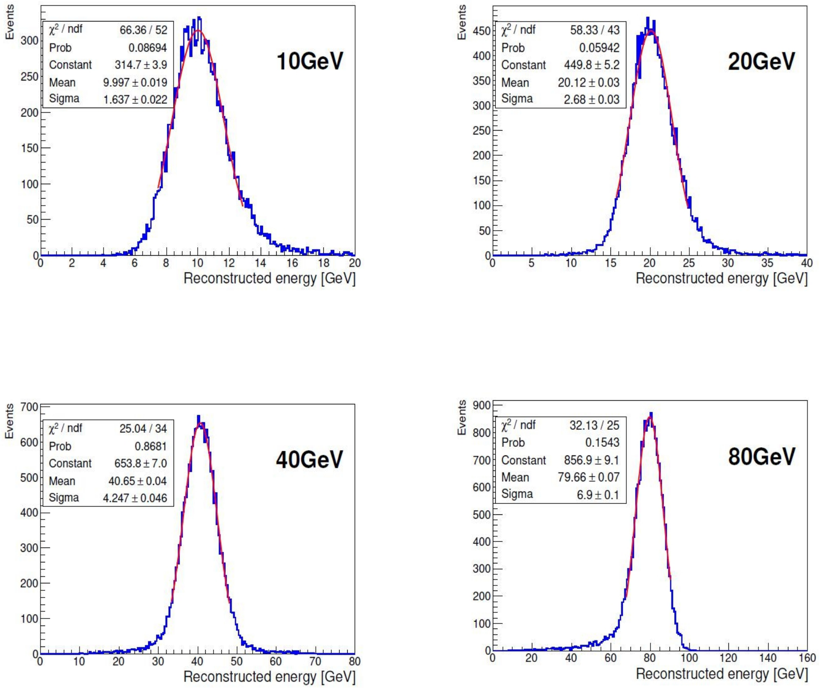
Performances with MVA

Energy linearity :

SJTU+IPNL JINST 14, P10034 (2019)



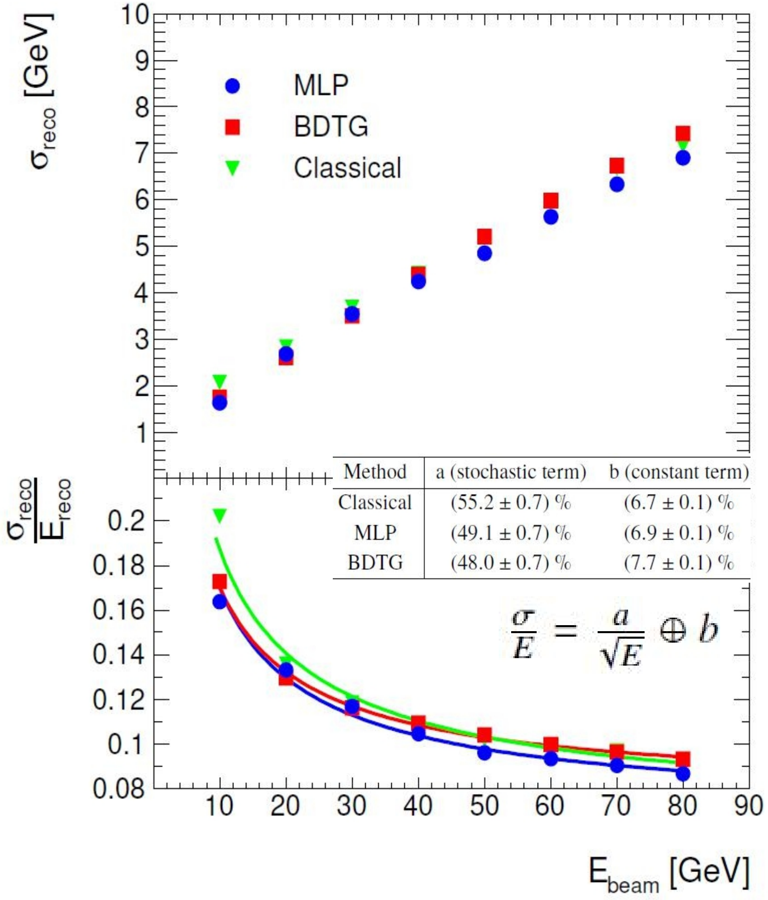
Energy linearity improves from 3-4% to 1-2% level using MVA



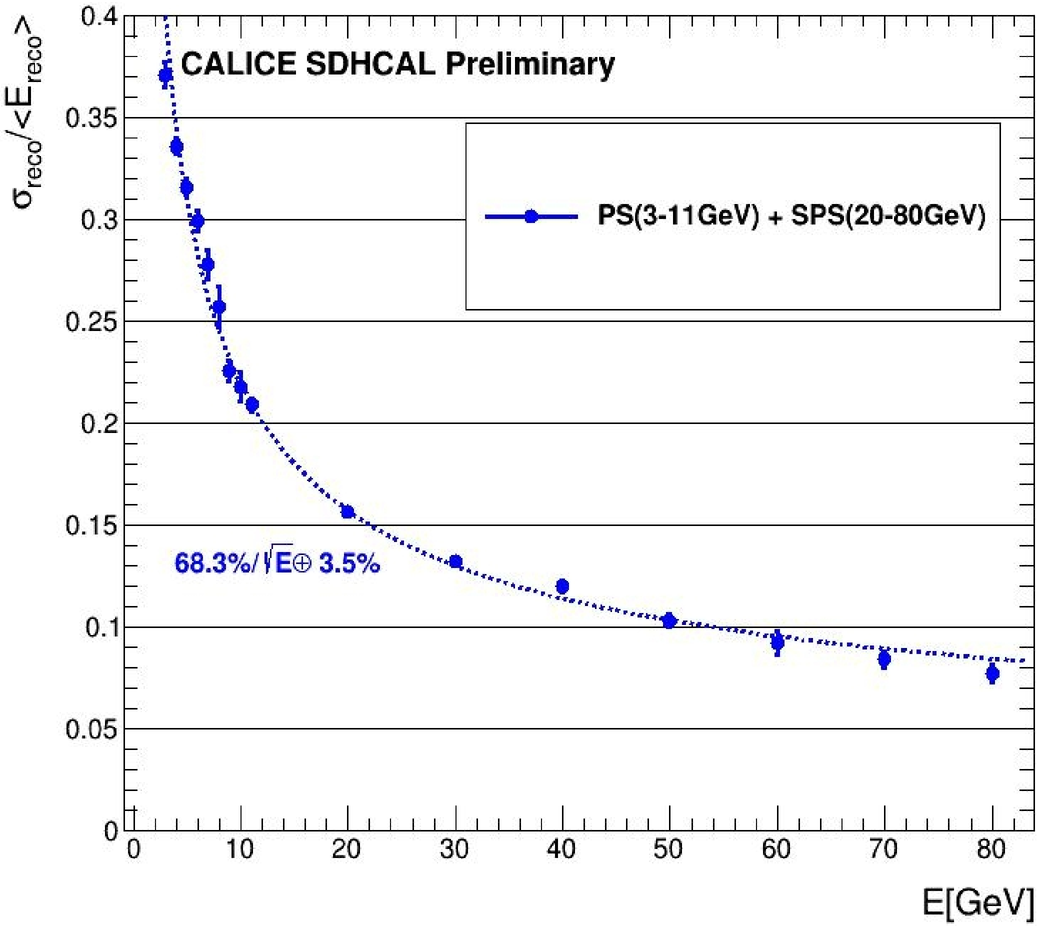
Performances with MVA

SJTU+IPNL JINST 14, P10034 (2019)

Energy resolution :



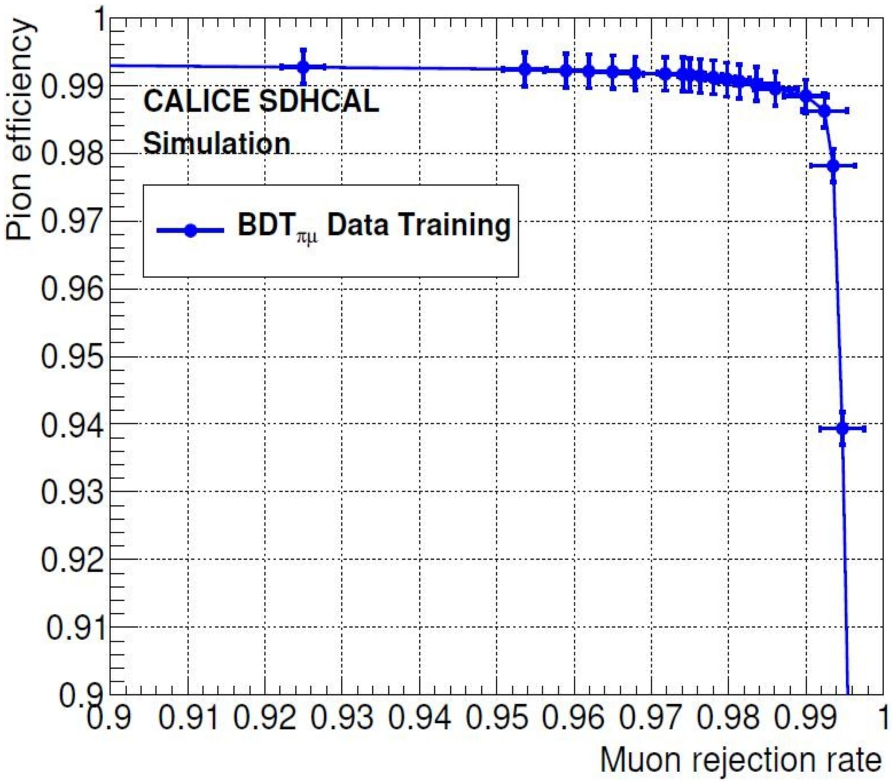
Method	a (stochastic term)	b (constant term)
Classical	(55.2 ± 0.7) %	(6.7 ± 0.1) %
MLP	(49.1 ± 0.7) %	(6.9 ± 0.1) %
BDTG	(48.0 ± 0.7) %	(7.7 ± 0.1) %

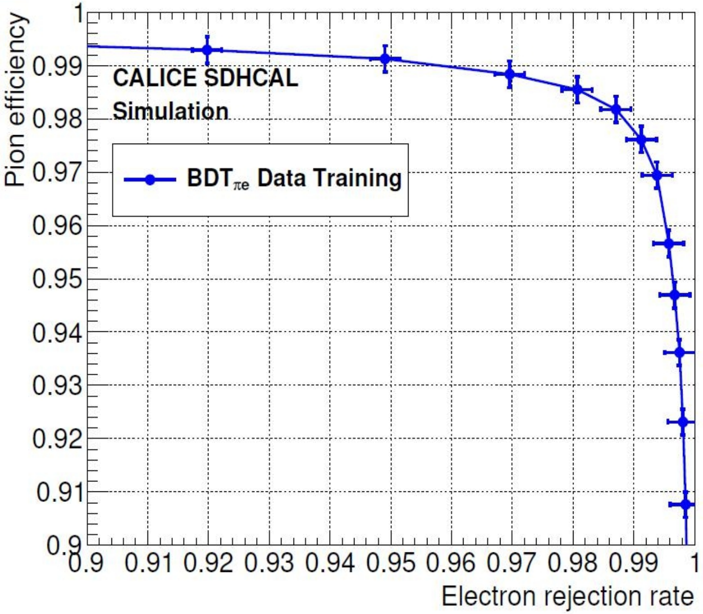


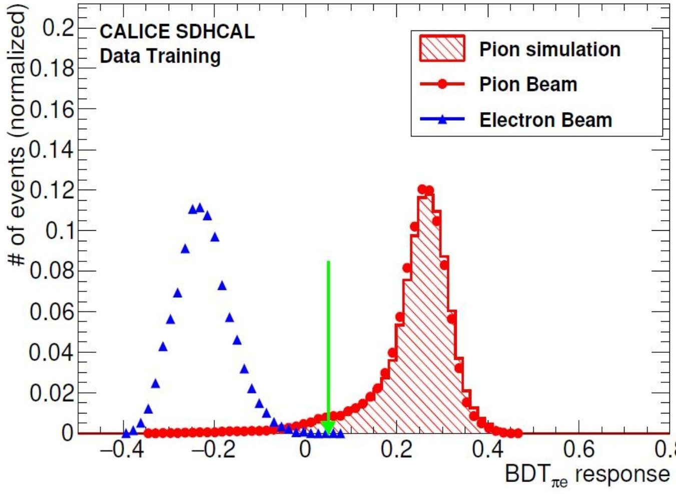
Performances

SJTU+IPNL
JINST 15, P10009 (2020)

PID :







Introduction

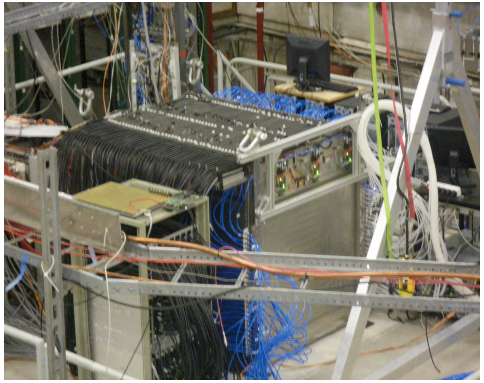
Why do we need a cooling system for CEPC SDHCAL ?

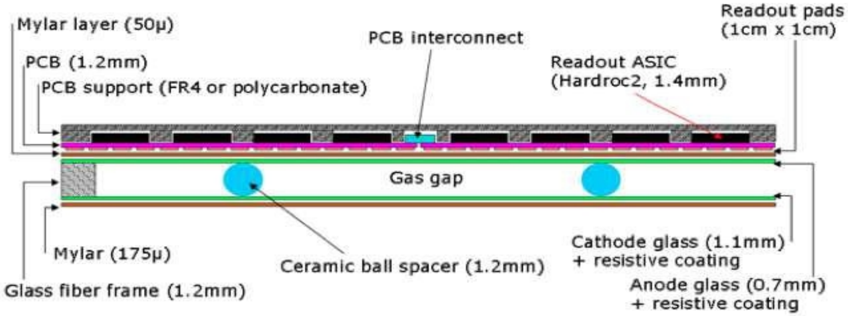
- The new generation of detector will fully exploit the Particle Flow Algorithm :
  - → Need high granularity detectors.
  - → Avoid cracks in the detectors.

- 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.

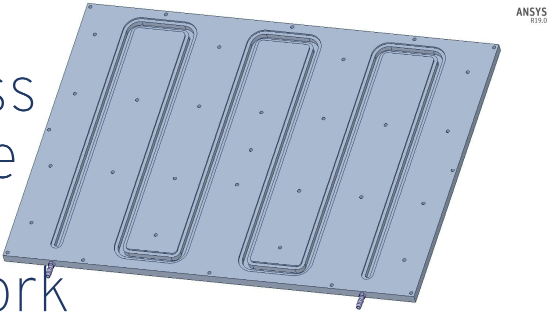
For CEPC the collision rate ~1.5MHz (Higgs configuration)
→ Active cooling system.



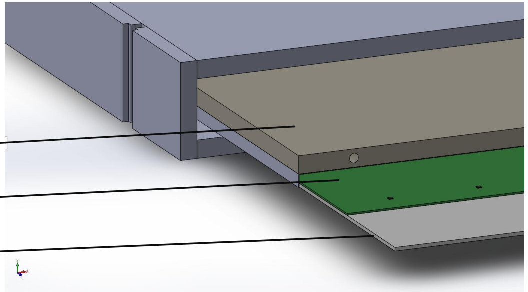


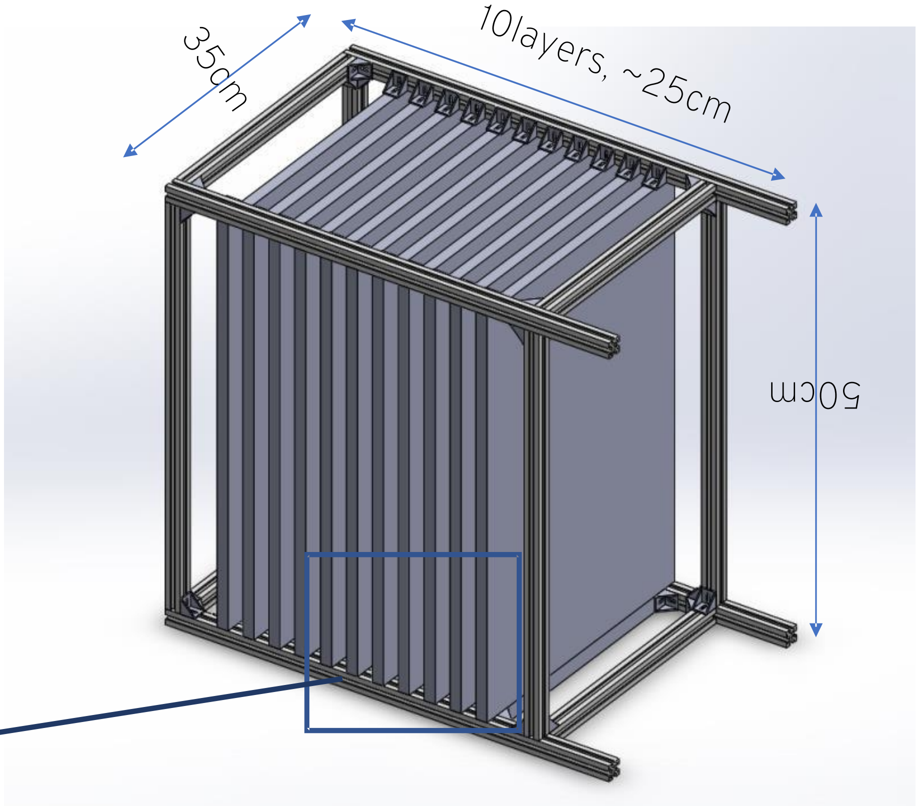
Cooling system : cooling plates

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

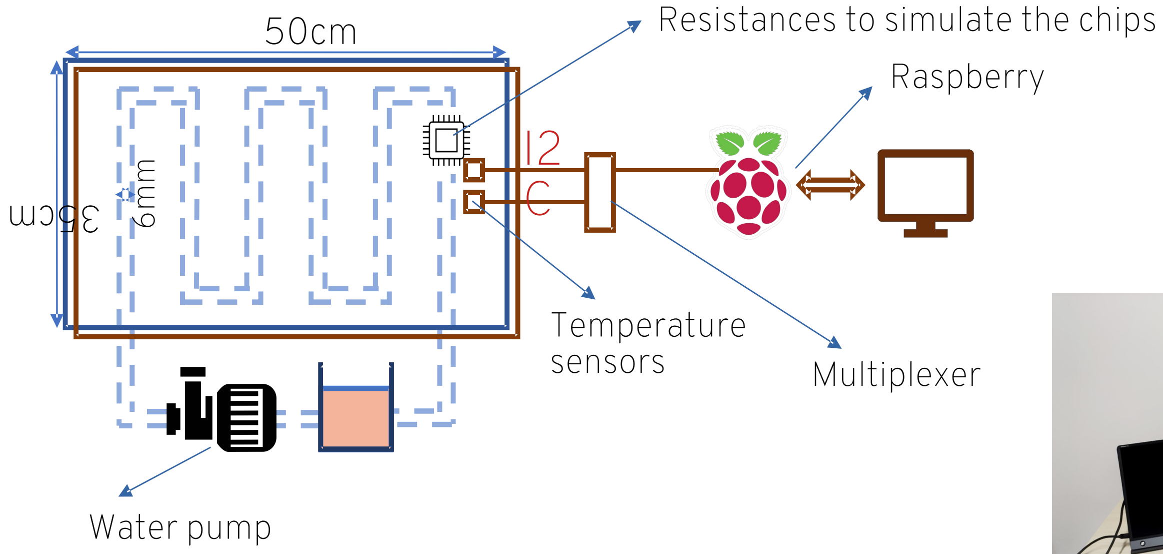


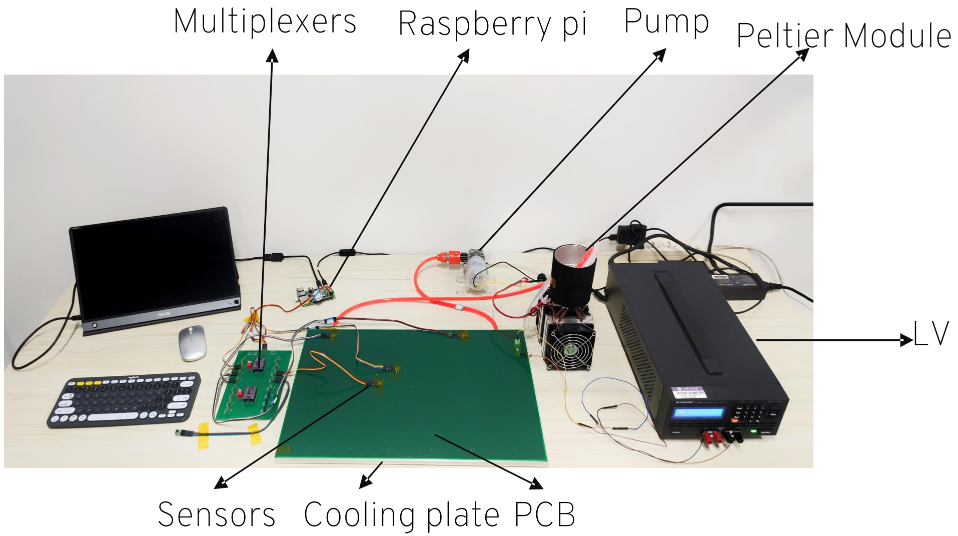
- Flexible framework





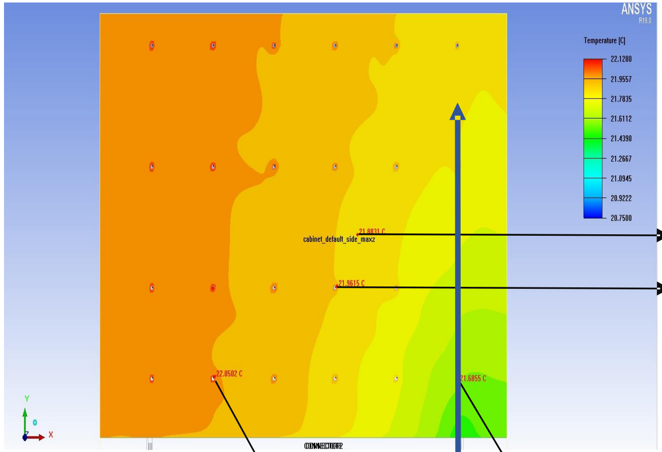
Test of the cooling plates





Test of the cooling plates

Simulation



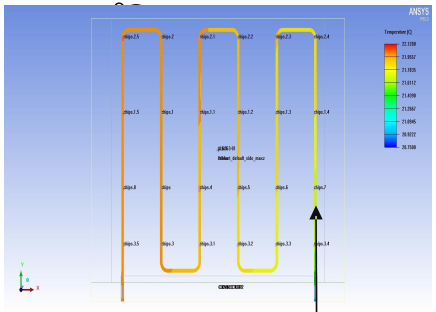
21.88℃, ΔT~1.1℃

21.96℃,

water flow

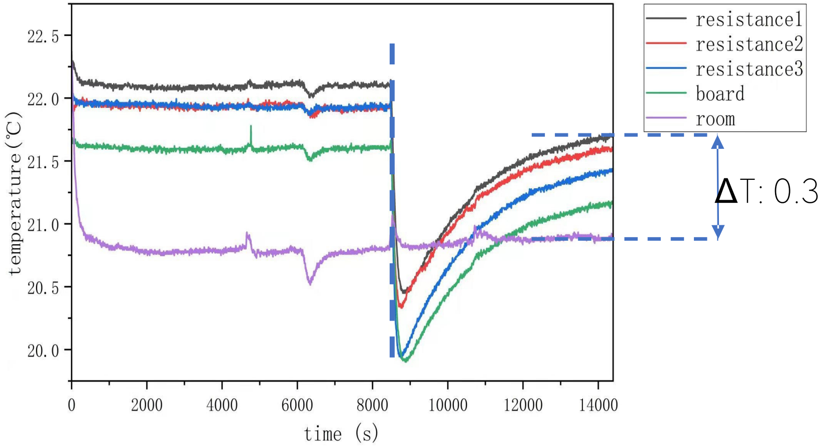
22.05℃,
ΔT~1.3℃

21.69℃,
ΔT~0.9℃



water flow

Prototype



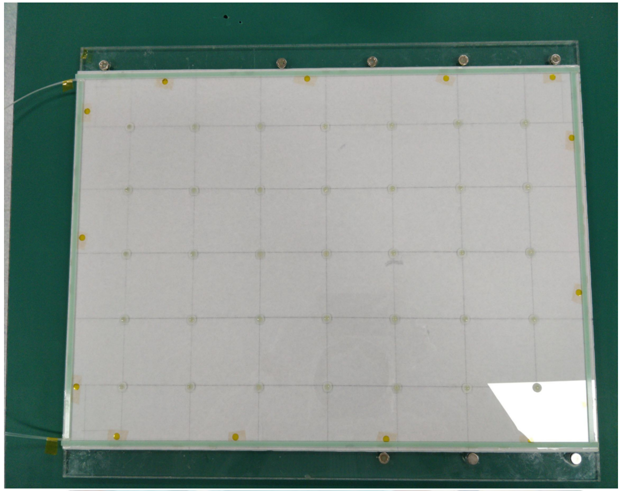
ΔT: 0.3~1℃

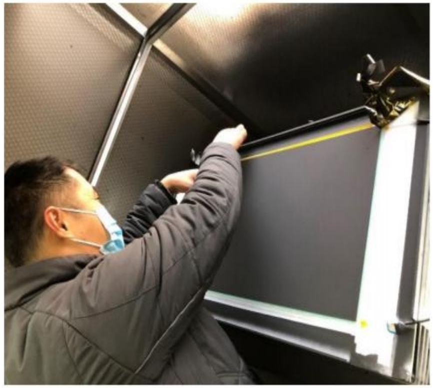
Start cooling with water
below room temperature

GRPC construction

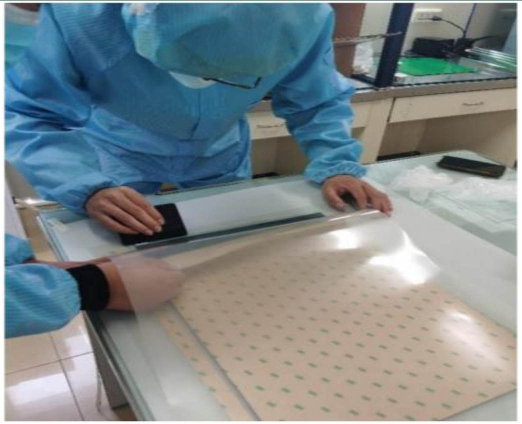
30cm x 50cm Chambers

Placing spacers

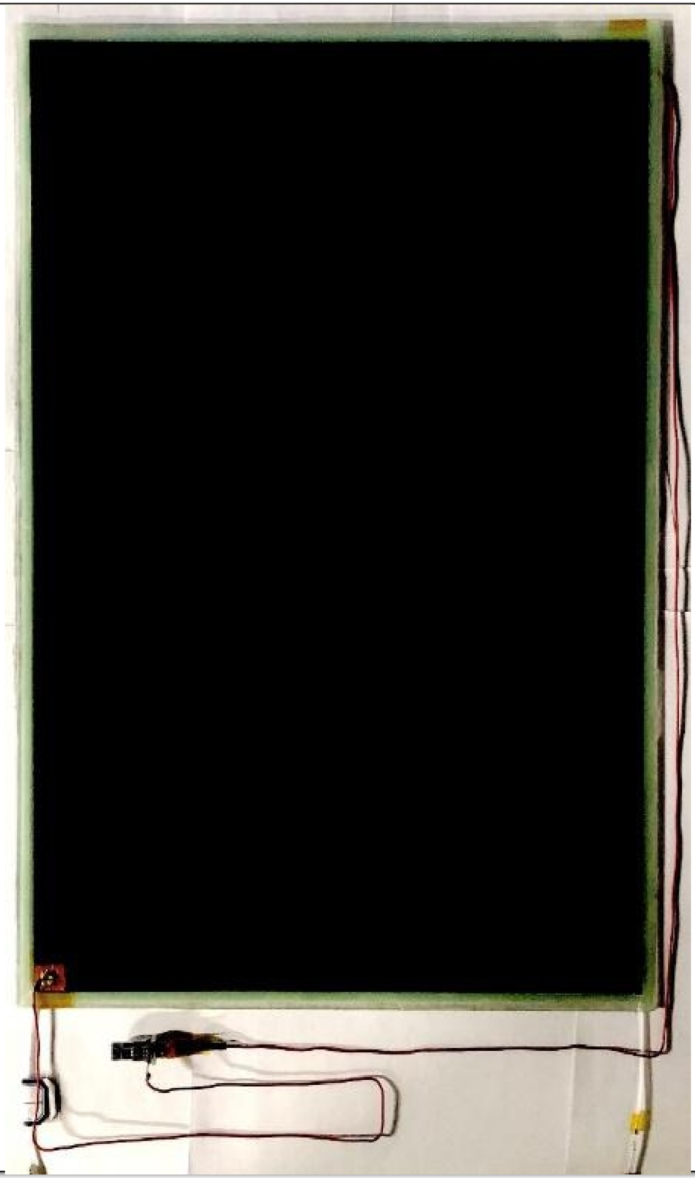


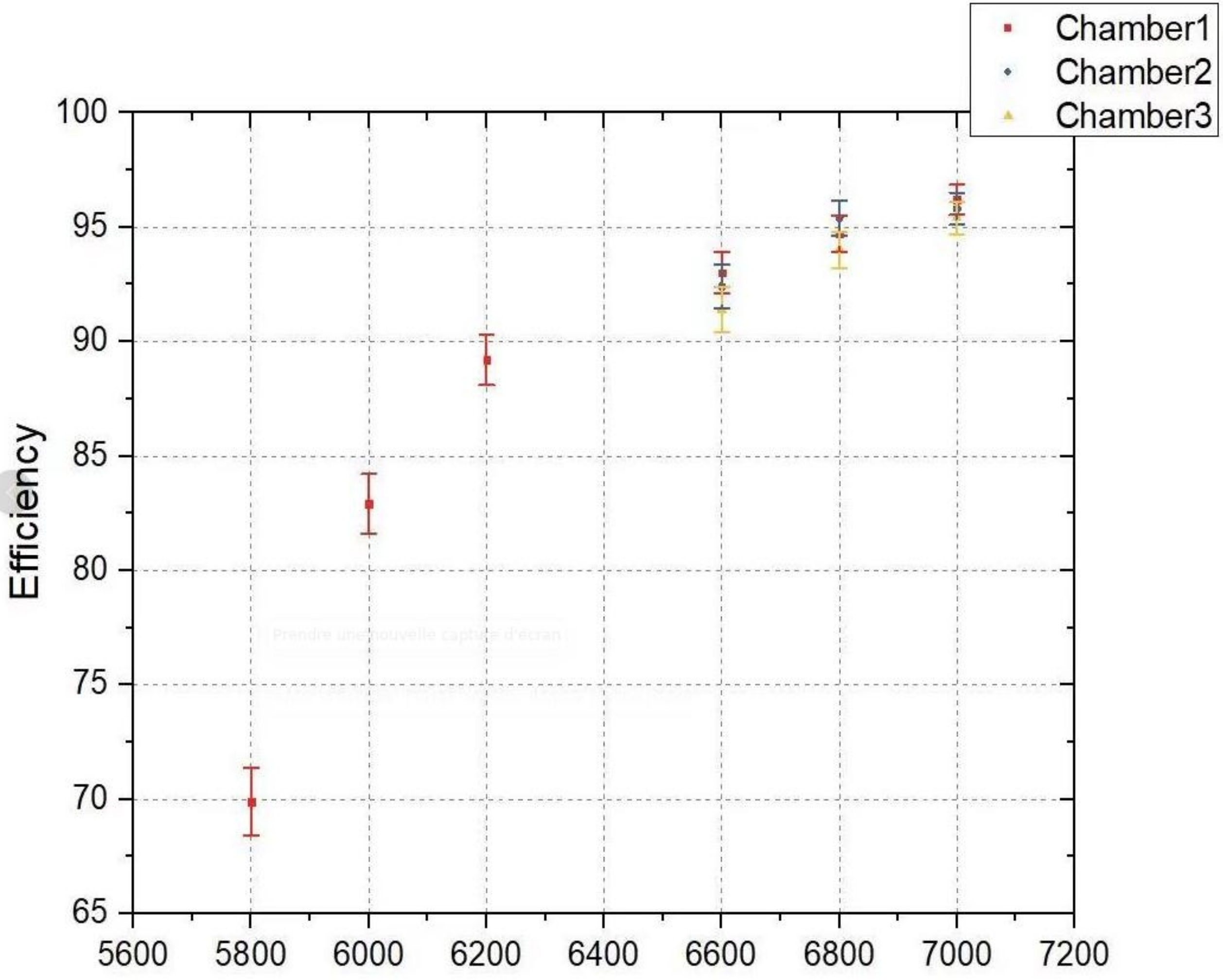


Printing



Mylar gluing



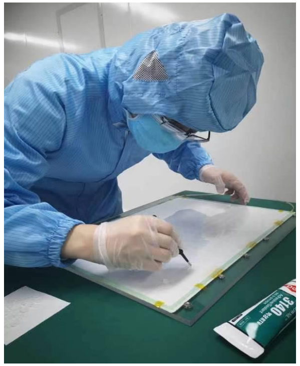


Applied Voltage (V)

Efficiency is compatible for all chambers

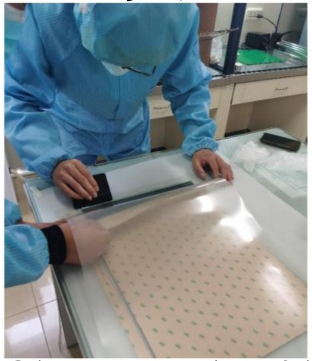
GRPC construction

30cm x 50cm Chambers

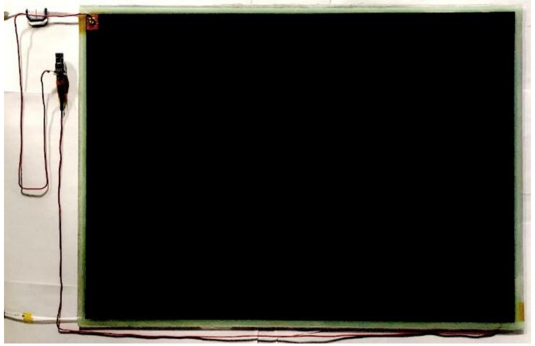


Placing spacers

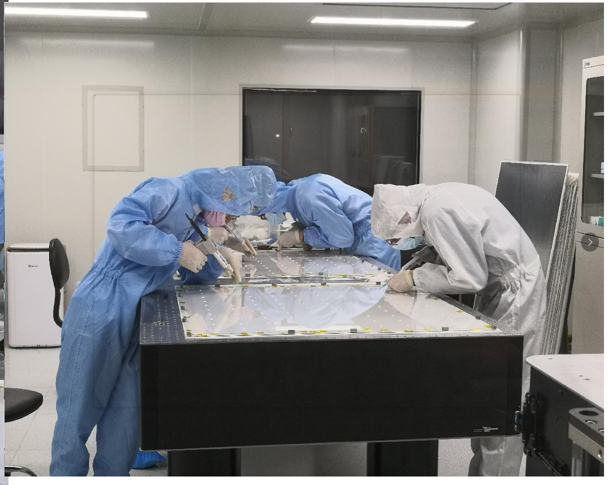
Painting



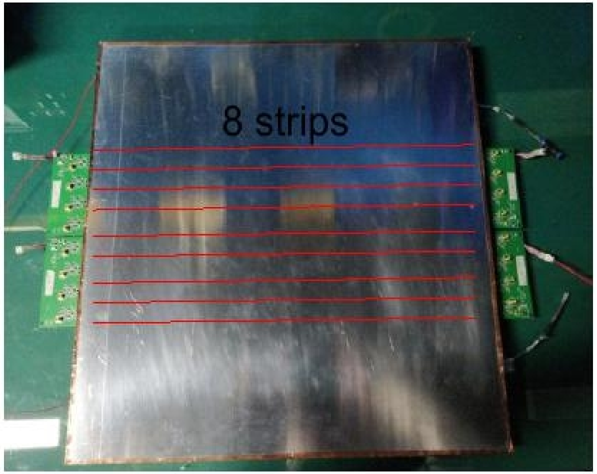
Gluing Mylar film



Building 1m x 1m GRPC



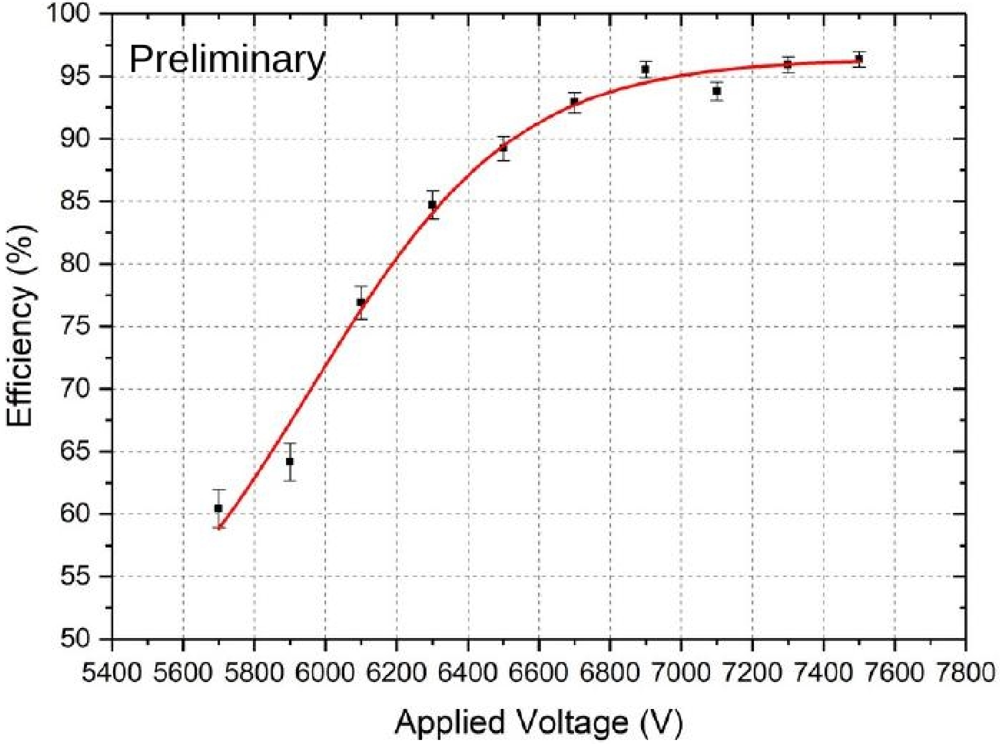
Cosmic stand



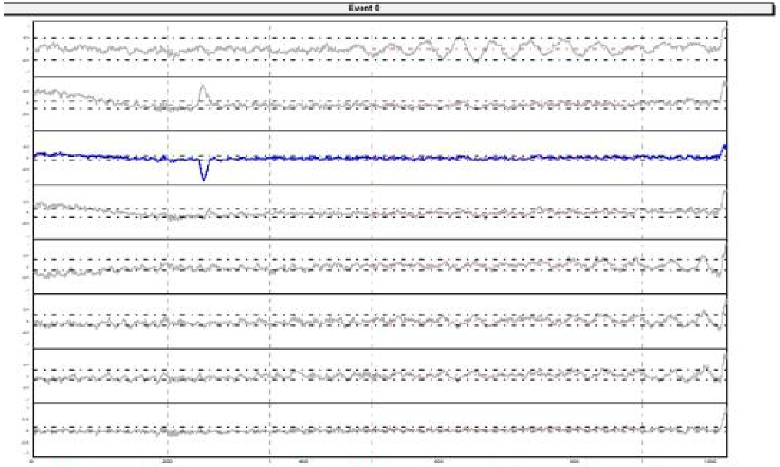
Testing the 50cm x 30cm chambers

USTC reference chamber

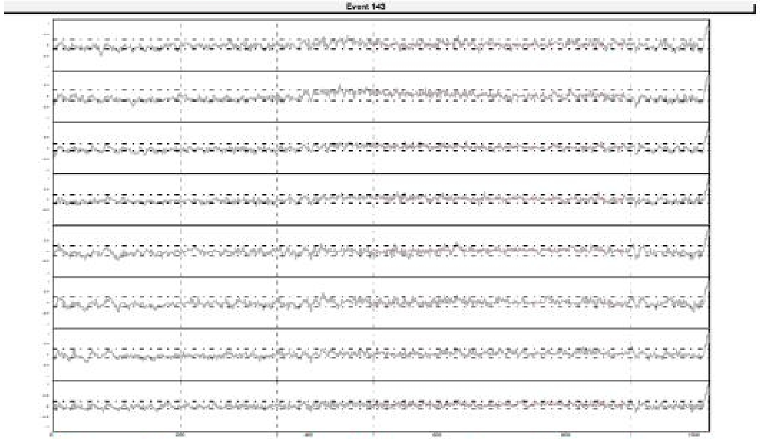
GRPC efficency using cosmic muons



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



Even triggered with signal in chamber



Even triggered with no signal in chamber