CEPC HCAL Progress

Yunlong Zhang

State Key Laboratory of Particle Detection and Electronics, China

University of Science and Technology of China

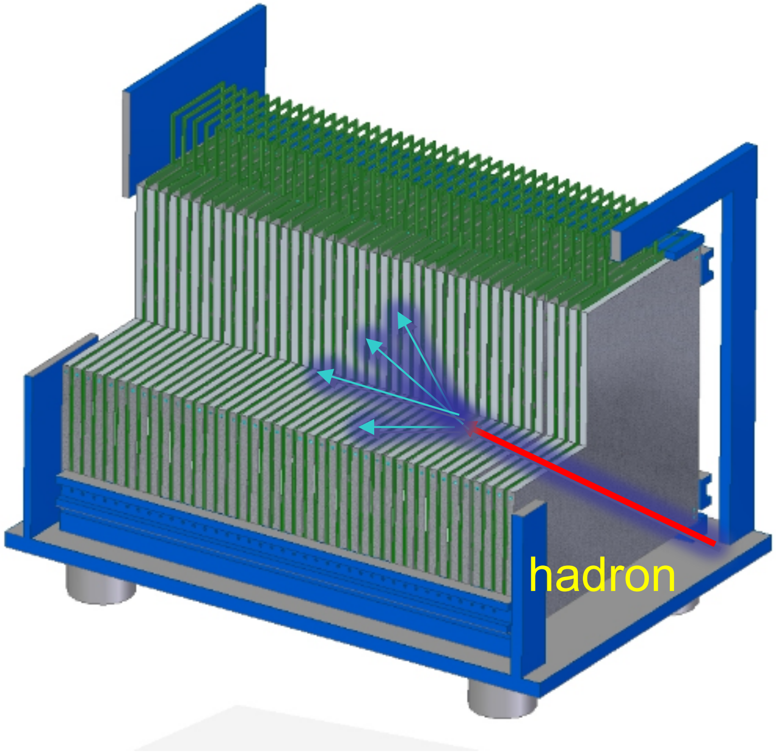
On behalf of CEPC Calorimeter working group

Outline

- CEPC AHCAL Status
  - Scintillators mass production and test
  - SiPM batch test
  - HBU design
  - Cooling simulation and Mechanical Design
- CEPC DHCAL
  - RPC
  - RWELL
- Summary and outlook

AHCAL Prototype

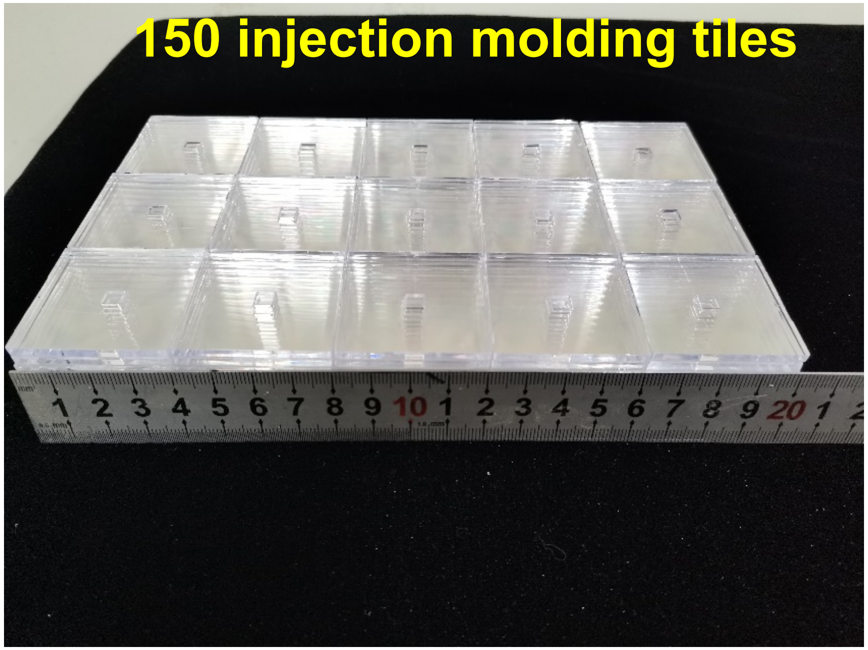
- Sampling Calorimeter
  - 40 layers, ~ 5 N.I.L
  - 72 cm×72 cm
- Absorber
  - Iron，2 cm thickness
- Sensitive Detector
  - Scintillator+SiPM，Number:13,960
  - Cell size：40 mm×40 mm×3mm
  - SiPM：HPK and NDL
- Electronics
  - SPIROC2E ASIC Chip

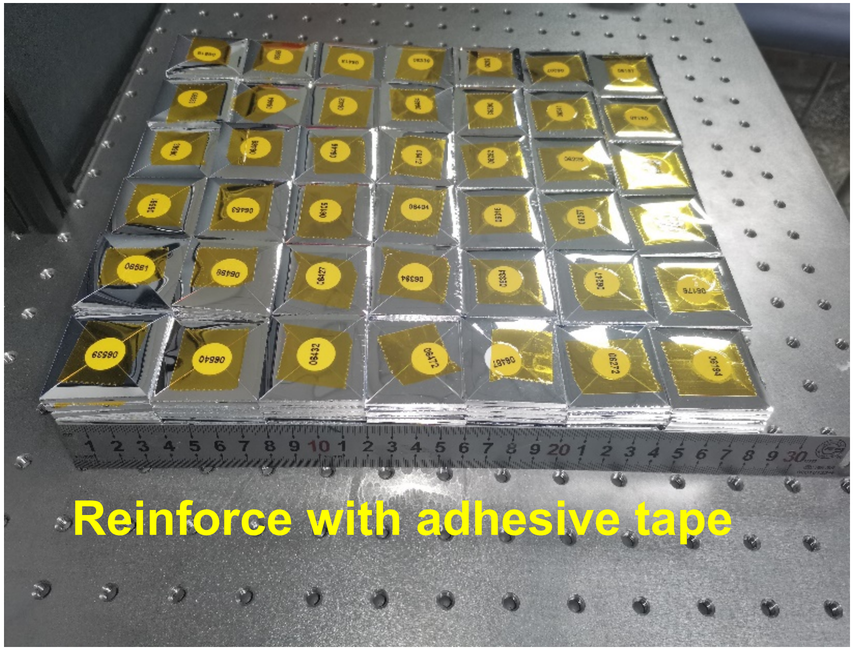


AHCAL Structure

Scintillator mass production and packaging

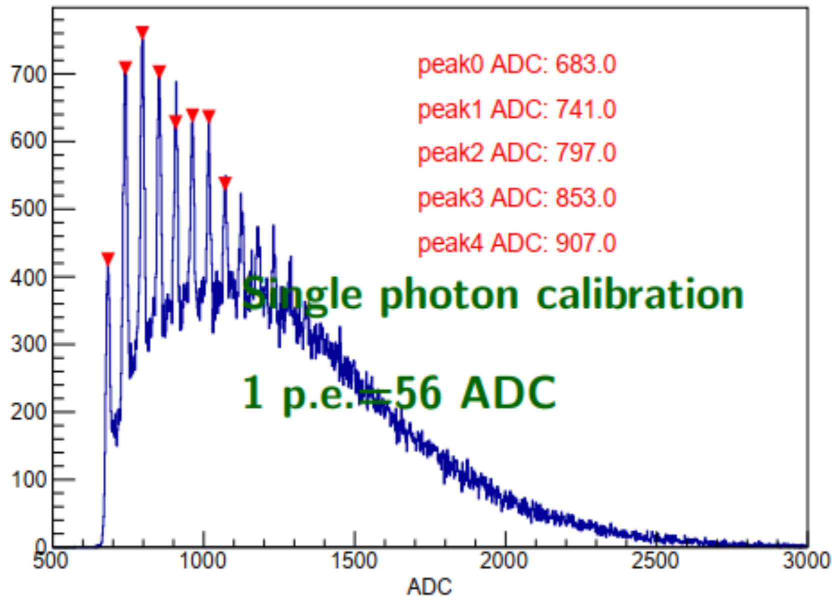
◆More than 15000 scintillators were produced based on ejection molding and packaging using ESR film in August





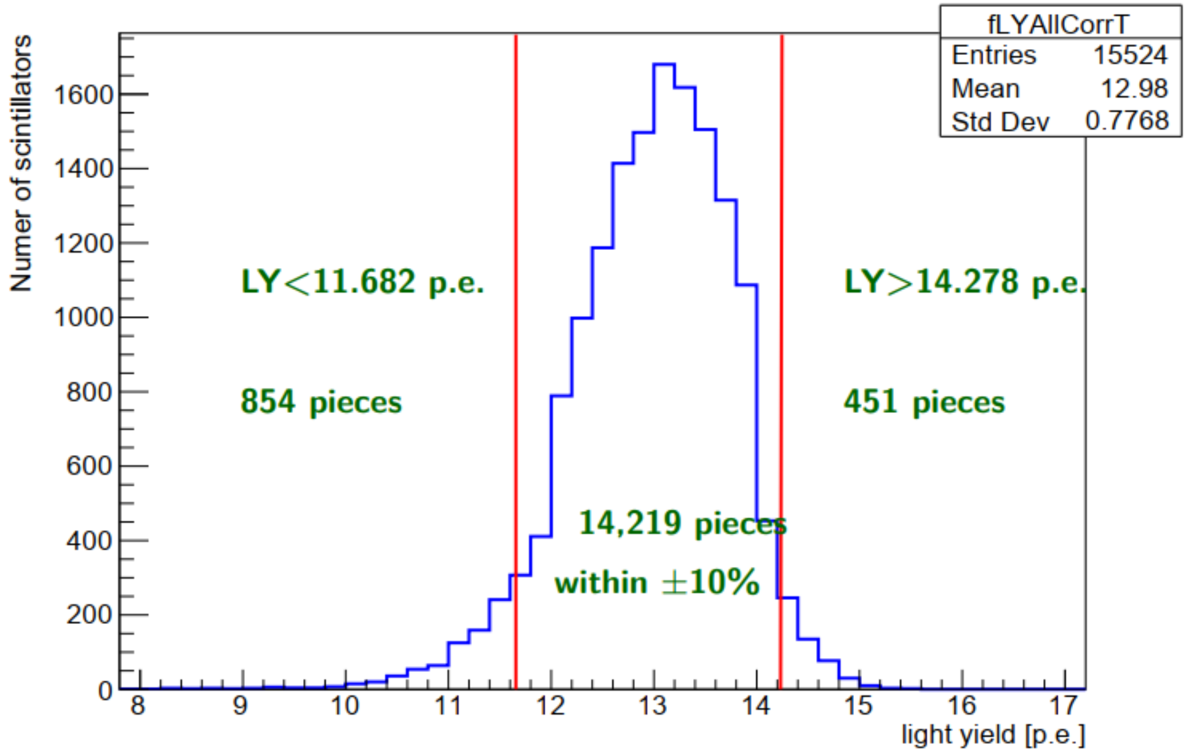
Scintillator batch test

- All the packaged scintillators (~15000) have been tested using Sr-90 β-ray source
  - SJTU, USTC
- The automatic displacement platform controls the movement of radioactive source and tests the scintillator one by one



Scintillator batch test

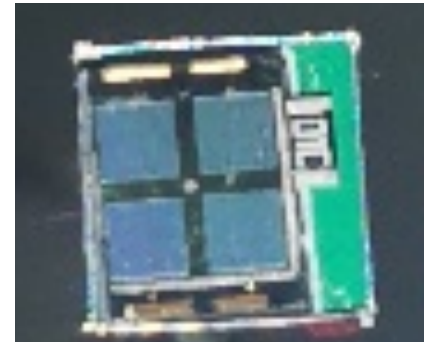
- 14,219 pieces within 10% of 15,524 pieces in total. About 91.6% of scintillators are qualified (within 10% of LY window).



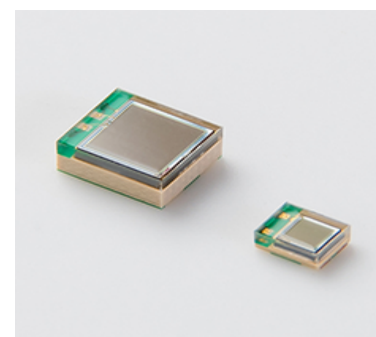
SiPM Procurement and testing

- ◆Two different types SiPM were selected in this prototype
  - ◆NDL, 1700 pieces
  - ◆HAMAMATSU, ~13000 pieces

Company	NDL	HPK
Type	22-15	S14160-1315PS
Sensitive area (mm^2)	1.6*4	1.69
PDE (%)	40	32
Gain ($*10^5$)	2.4	3.6
Pixel No.	7400*4	7284
Breakdown Voltage (V)	28	38
OverVoltage (V)	4	4
Dark Count (kHz)	330*4	120
Cross Talk (%)	8.5	1.0



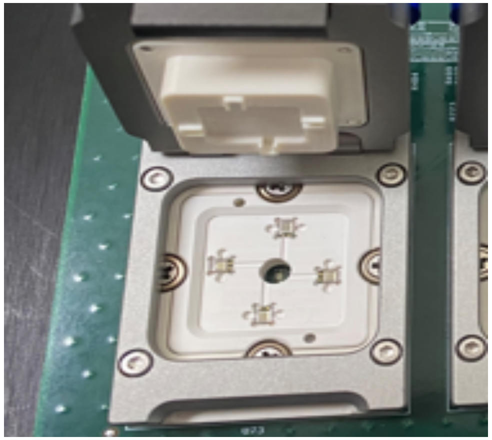
NDL



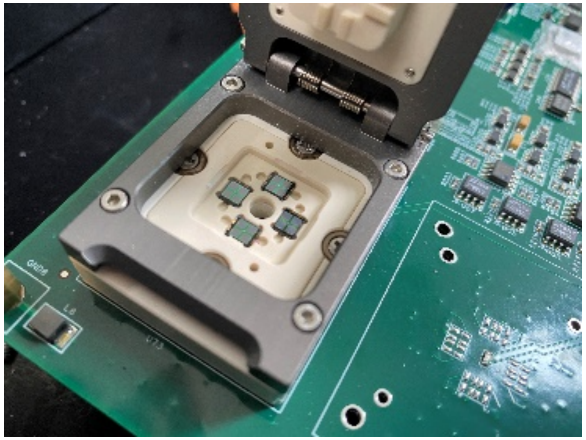
S14160-1315PS

SiPM bench test system

- Two sets of SiPM batch test systems were developed
  - NDL SiPM
  - HPK SiPM

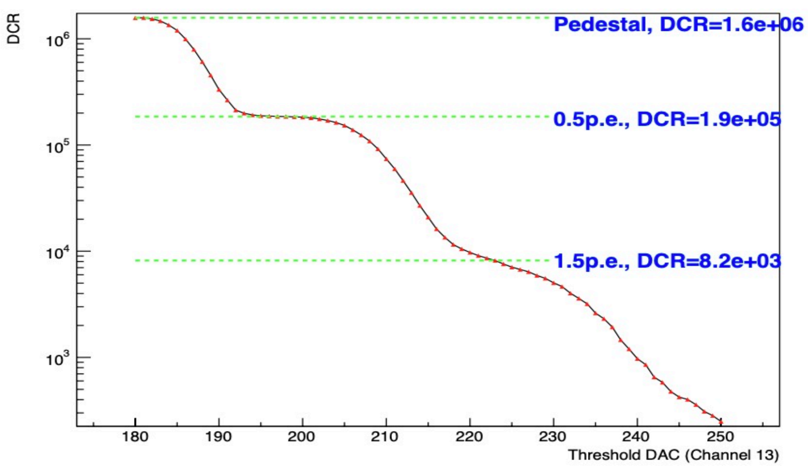


HPK

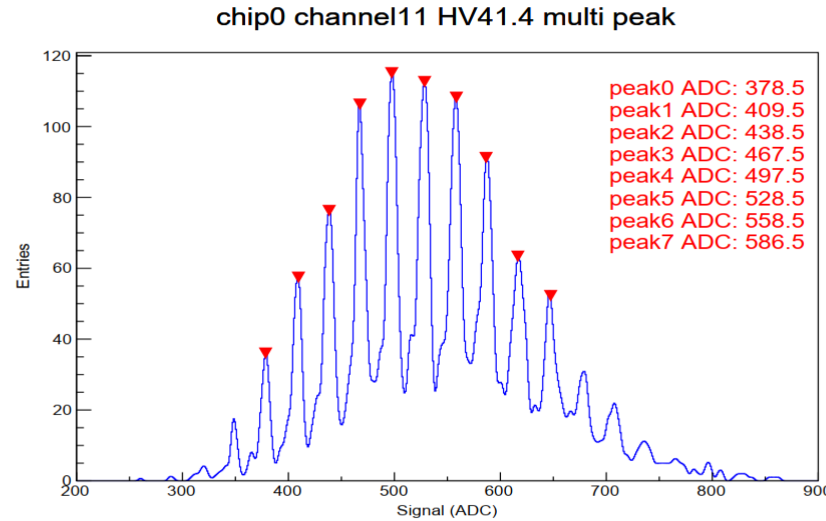


NDL

HPK SiPM Test



Dark Counting Rate



Photon-electron peak

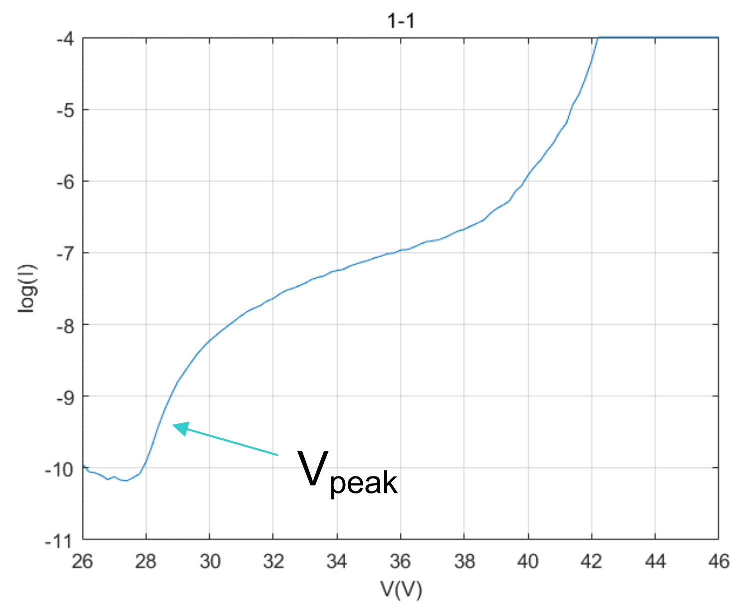
Electrical and optical characteristics (Typ. Ta=25 °C, VR=Vop, unless otherwise noted)

Parameter		Symbol	S14160 -1310PS	S14160 -3010PS	S14160 -1315PS	S14160 -3015PS	Unit
Spectral response range		λ	290 to 900				nm
Peak sensitivity wavelength		λp	460				nm
Photon detection efficiency at λp*3		PDE	18		32		%
Breakdown voltage*4		VBR	38±3				V
Recommended operating voltage*4		Vop	VBR + 5		VBR + 4		V
Vop variation within a reel		-	±0.1				V
Dark count rate*5	typ.	DCR	120	700	120	700	kcps
	max.		360	2100	360	2100	
Direct crosstalk probability		Pct	< 1				%
Terminal capacitance at Vop		Ct	100	530	100	530	pF
Gain		M	1.8×10^5		3.6×10^5		-
Temperature coefficient of Vop		ΔTVop	34				mV/°C

*3: Photon detection efficiency does not include crosstalk and afterpulses.

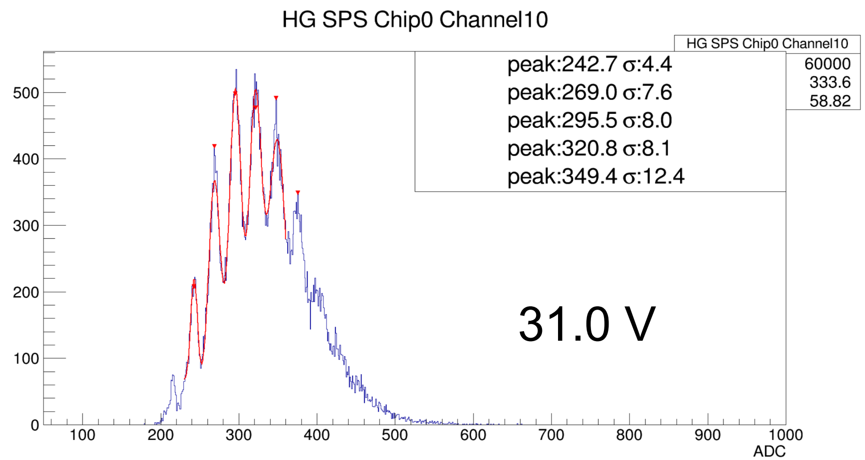
NDL SiPM

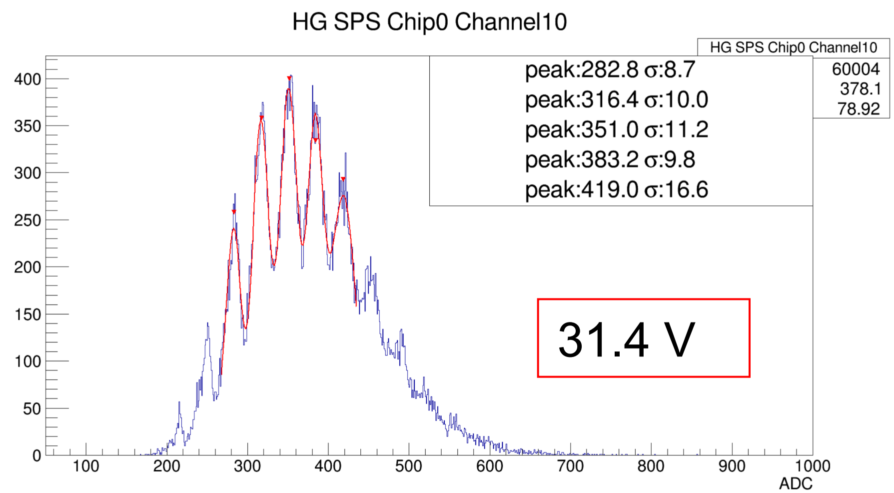
NDL SiPM

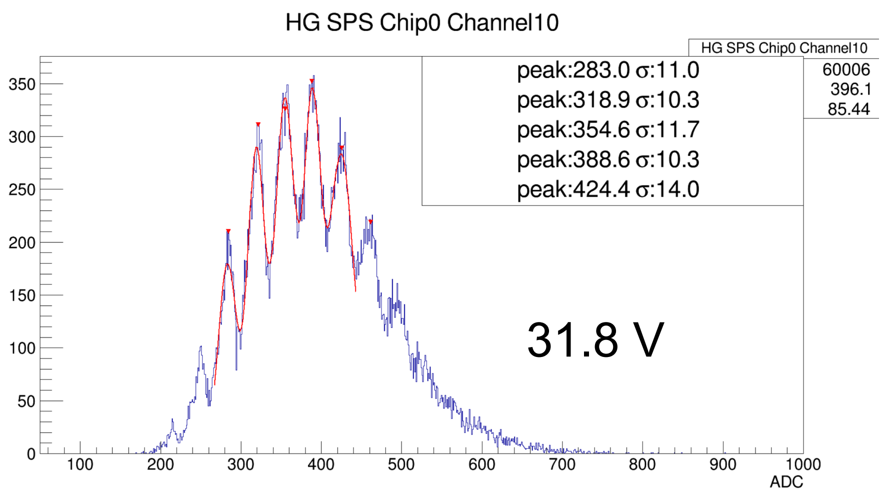


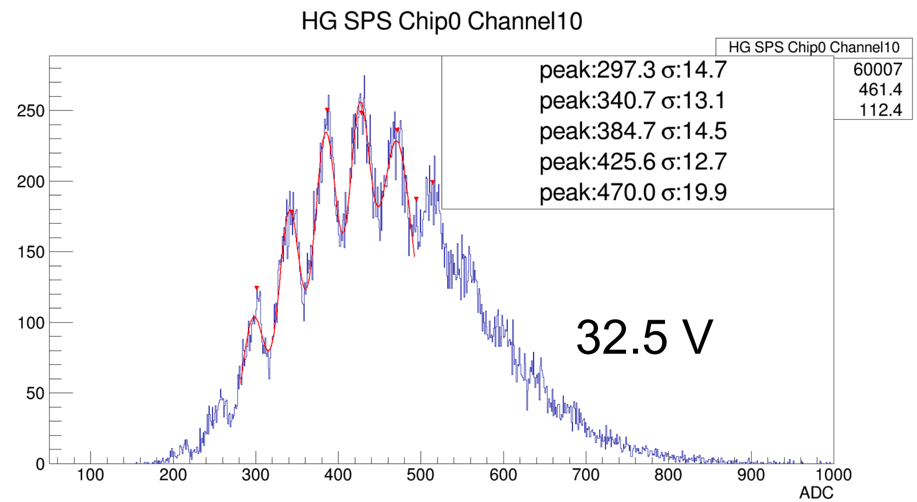
I-V curve

NDL SiPM photon electron spectrum



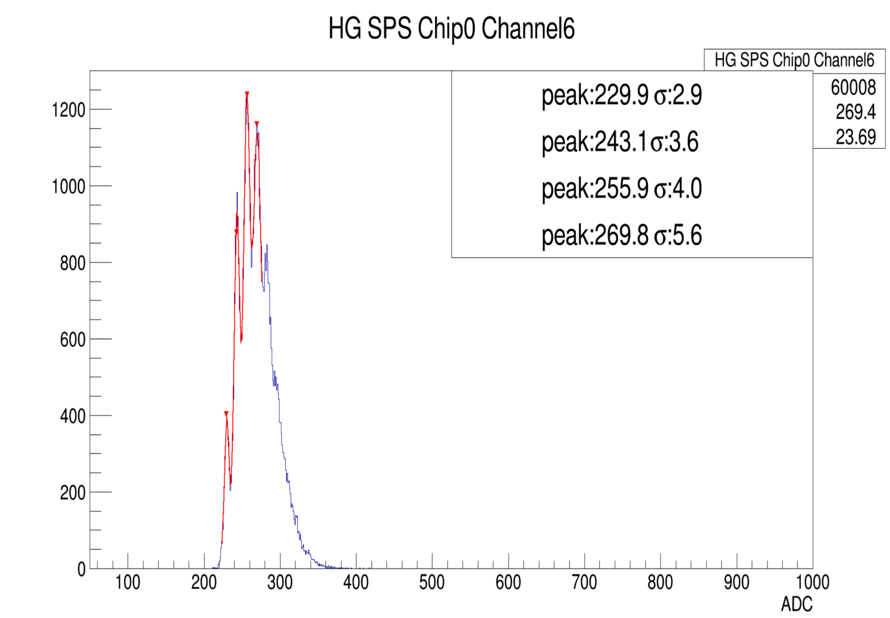


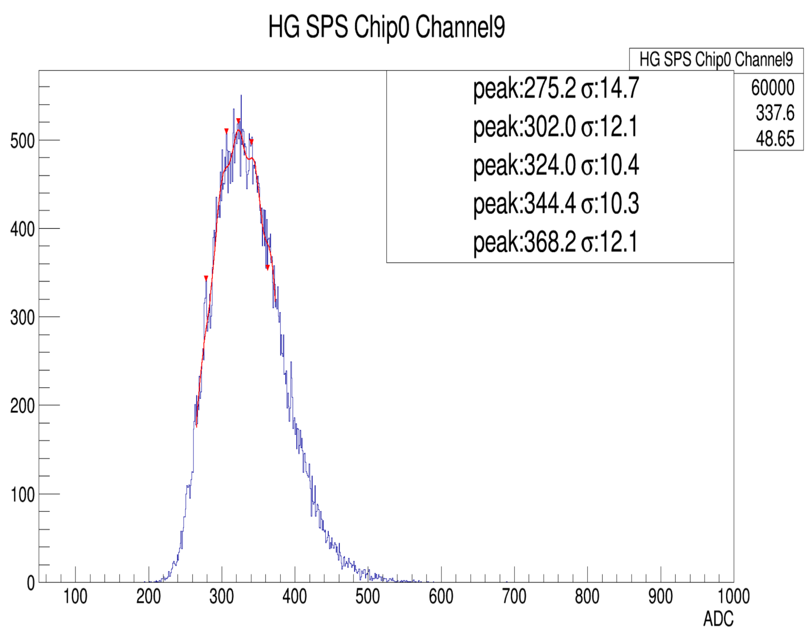




NDL SiPM photon electron spectrum

- we found that the SNR of a few SiPM was very small
- the photoelectric peaks disappeared with the increase of voltage

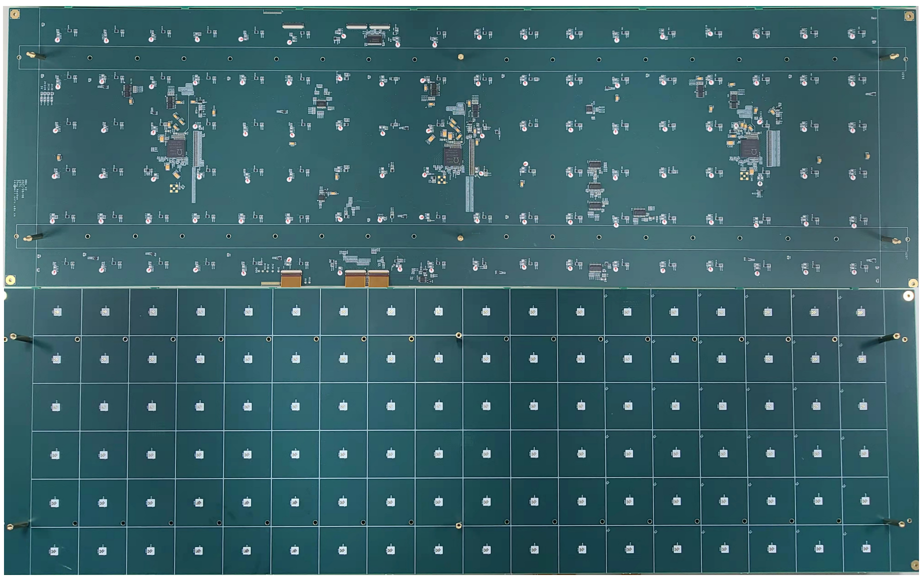


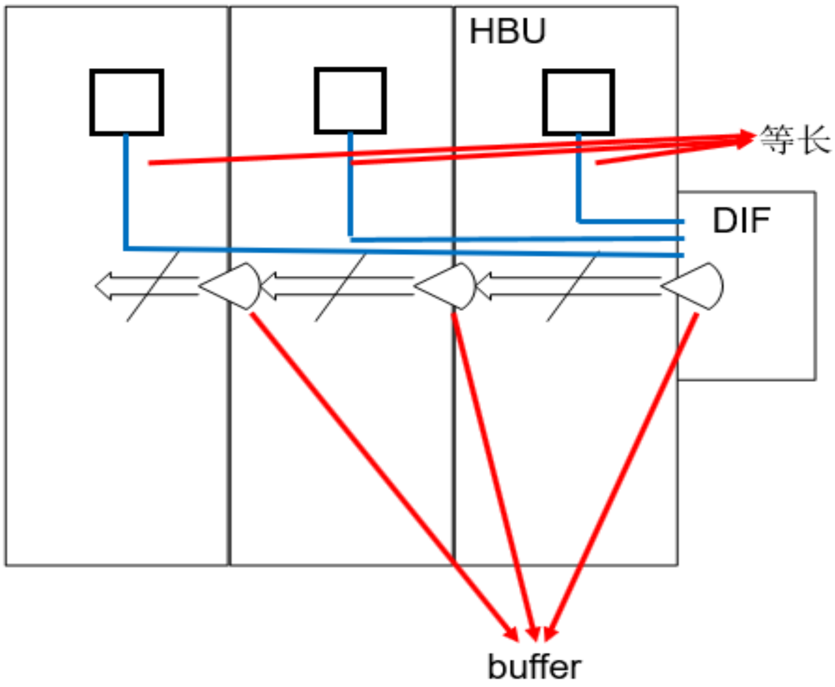


At present, these SiPMs account for 7% of the total

HBU-v2 update

- Optimize HBU size and Type-C interface
- Add additional buffer to the sub-board to ensure the signal integrity
- Keep real-time control signal among SP2e equaling to ensure all the SP2e in a same condition

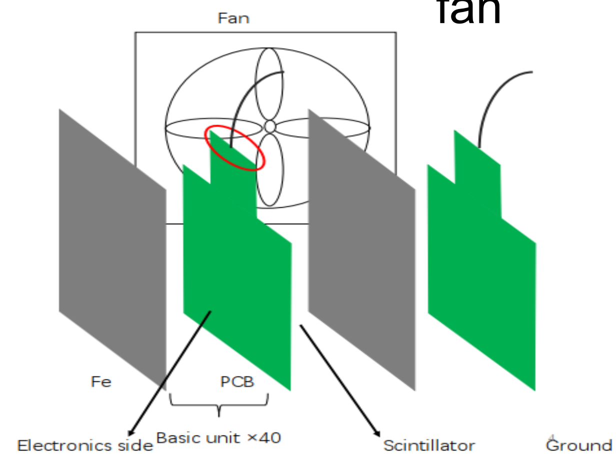




Cooling simulation

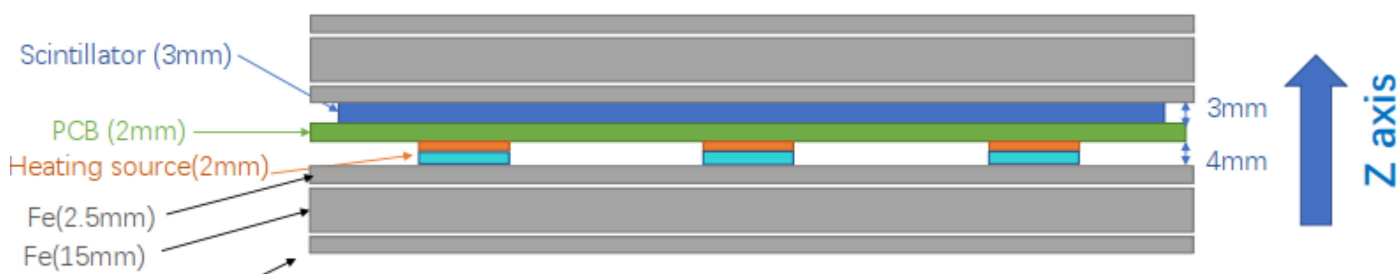
- The power consumption of each layer of HBU is about 4 W
- The main heat sources are electronic chips
- In order to reduce the influence of temperature, we add some fans next to the AHCAL

fan

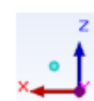


Fe-Heating source-PCB-Scintillator-Fe

(Fe-Heating source-PCB-Scintillator)*n-Fe



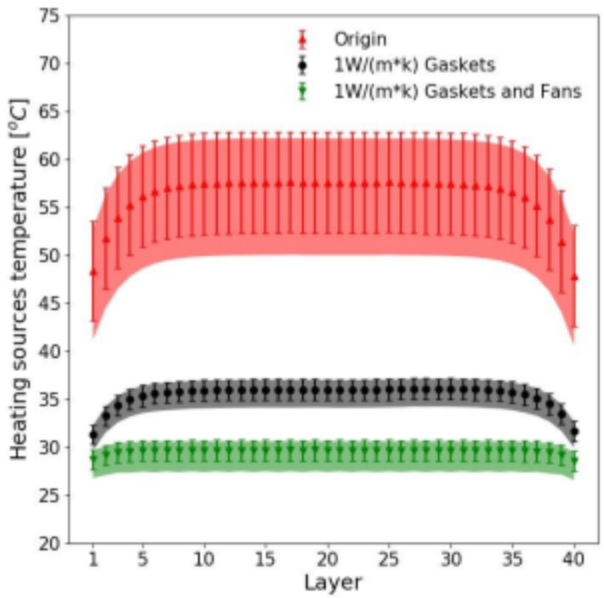
- Connect heat source and absorber with silicone base thermal grease



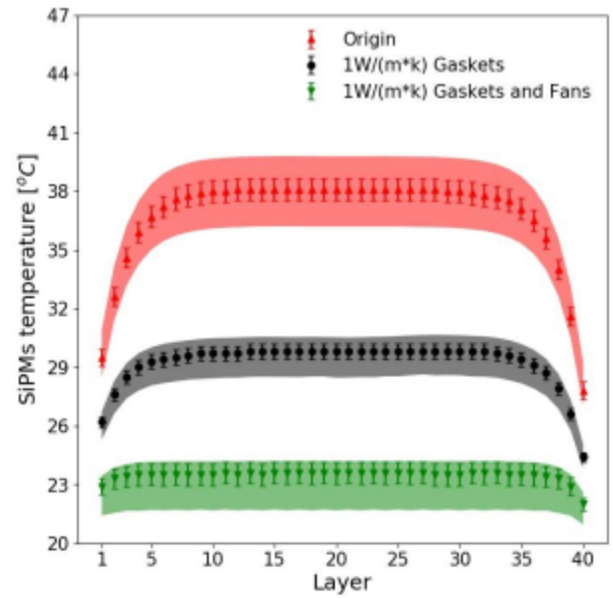
Conductivity
1W/m-K

6

Cooling simulation



Heating sources

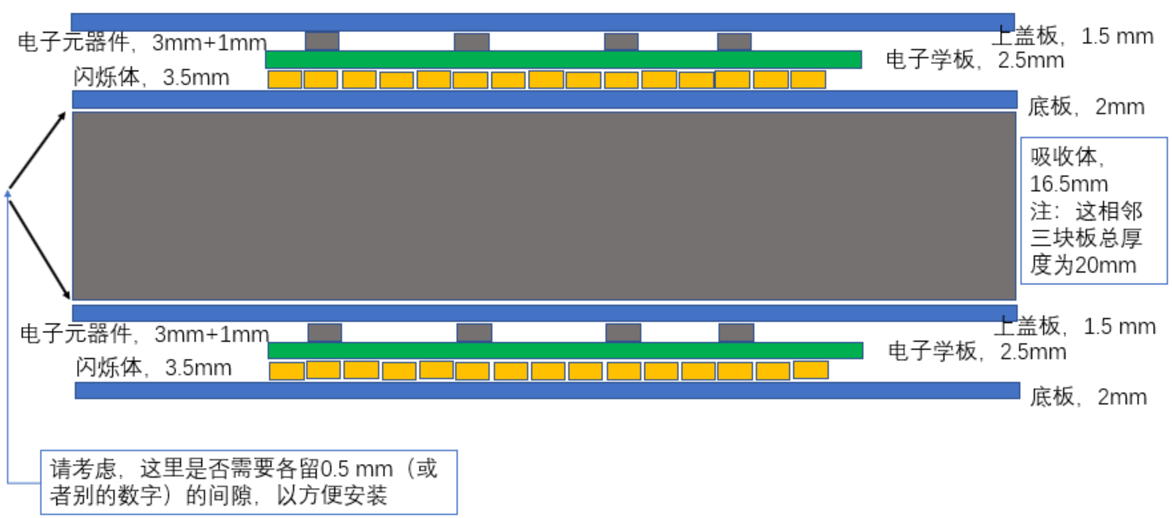


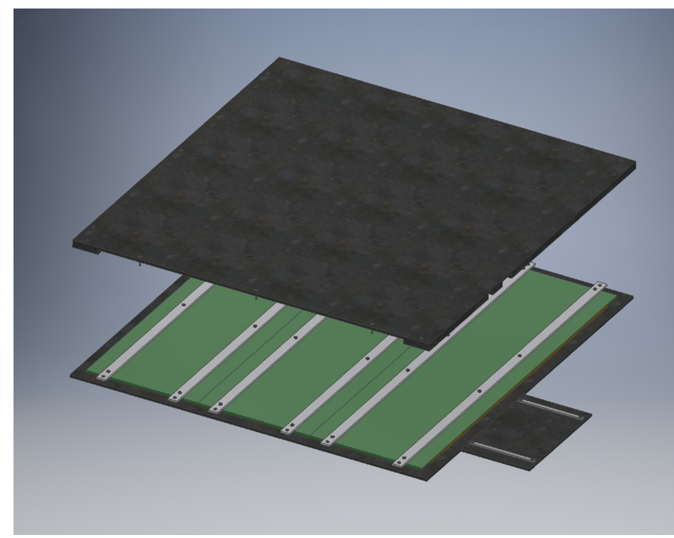
SiPMs

- For heating sources: The mean temperature of the origin: 48℃ to 58℃. Thermal conductive rubbers reduce the mean temperature by about 20℃. Fans further reduce the average temperature by about 6℃.
- For SiPMs: The mean temperature of the origin: 28℃ to 38℃. Thermal conductive rubbers reduce the mean temperature by about 8℃. Fans further reduce the average temperature by about 6℃.

HBU box mechanical design

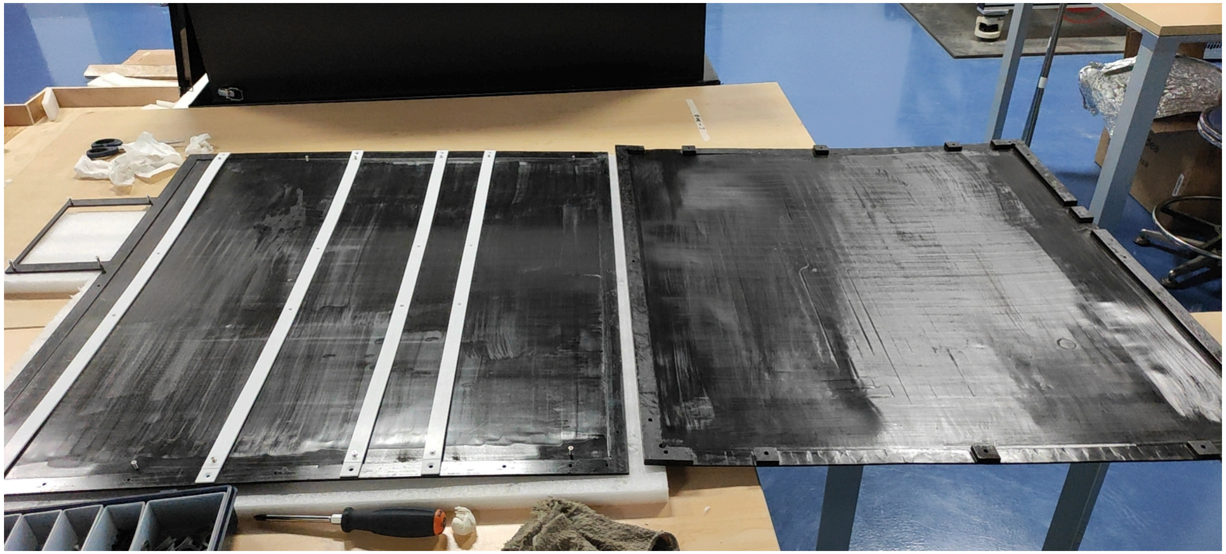
- In order to facilitate testing and transportation, each HBU has a cassette
- We choose iron as the material of the box, and the mass of this part is directly deducted from the absorber





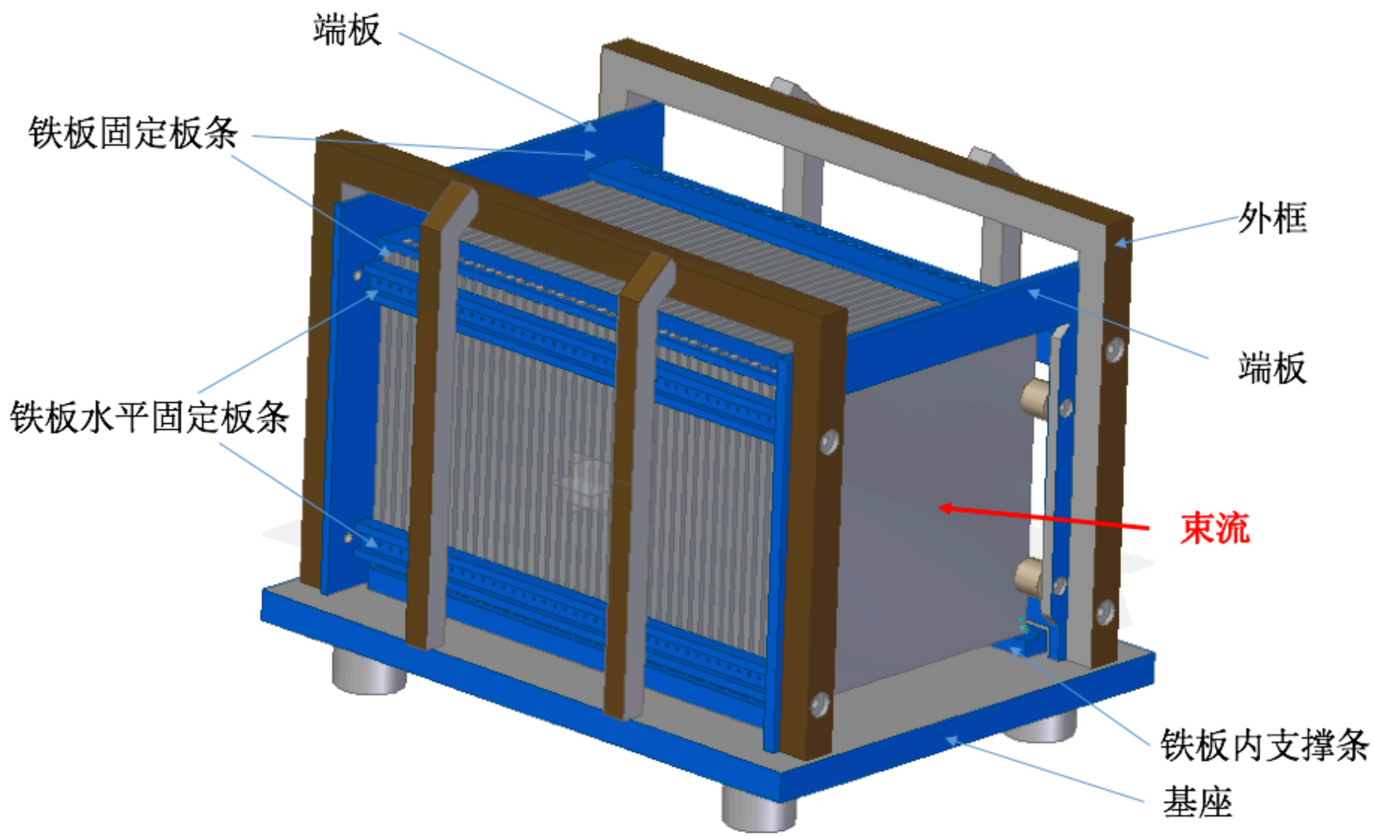
HBU box mechanical design

- The first version has been processed and is being trial assembled with HBU
- Heat dissipation test shall be carried out after welding of HBU

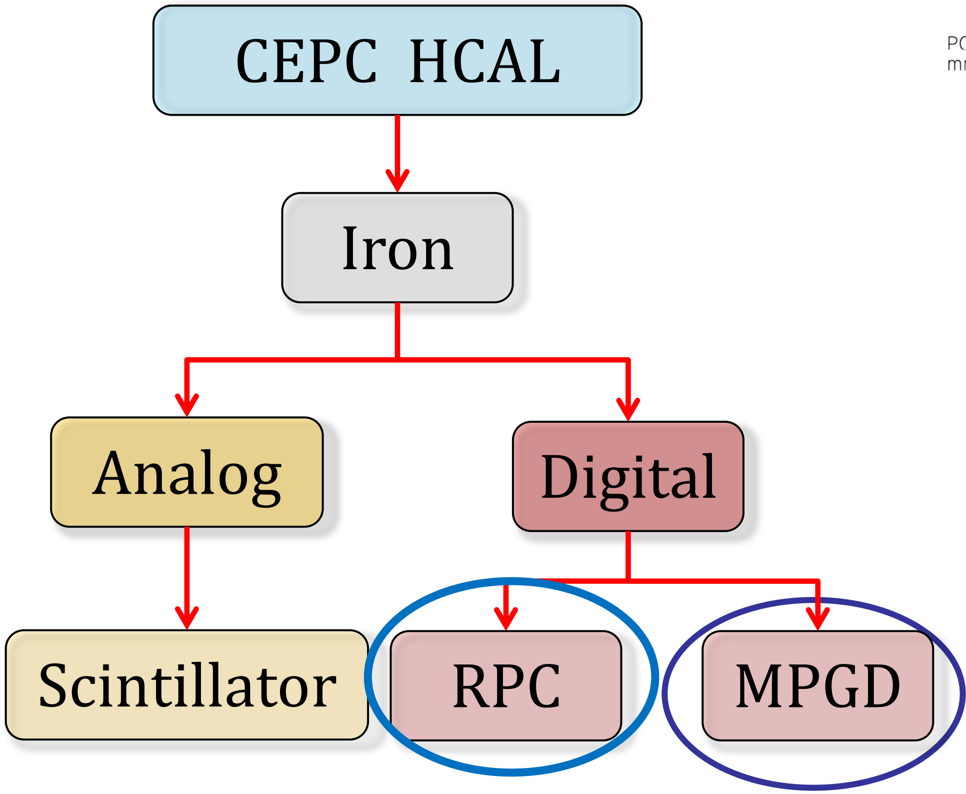


HBU box mechanical design

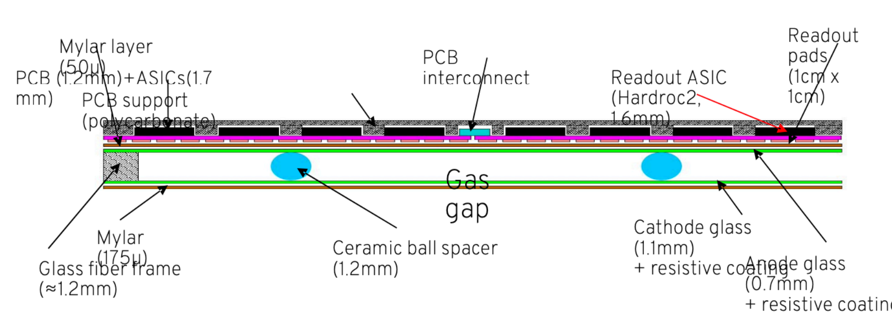
Then we can install these cassettes directly into the supporting structure of the prototype



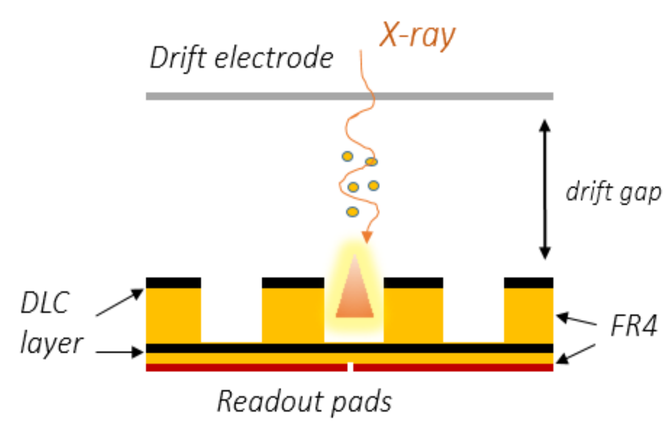
CEPC DHCAL



- Resistive Plate Chamber

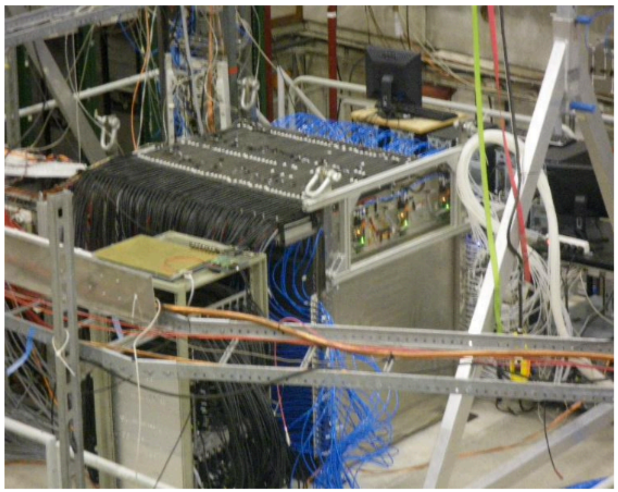


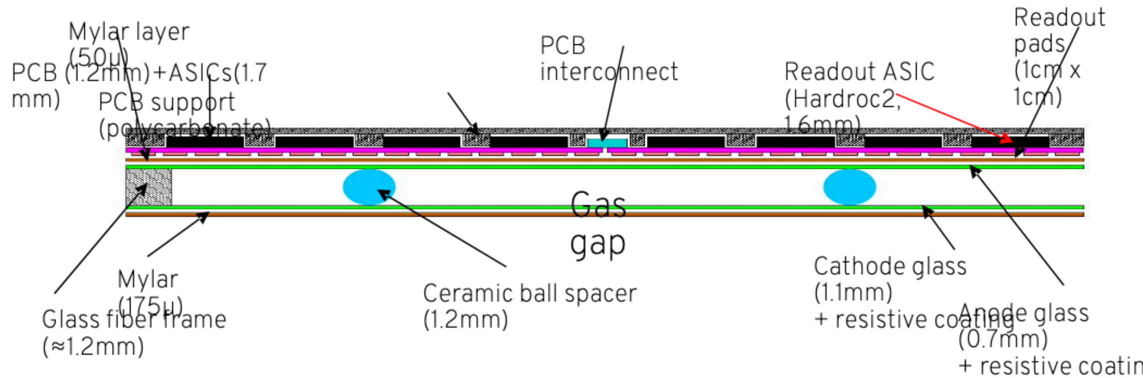
- Resistive WELL detector (RWELL):

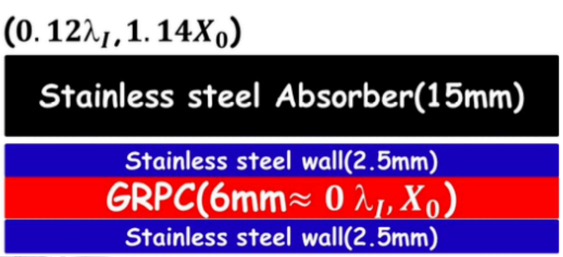


DHCAL Based on GRPC

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





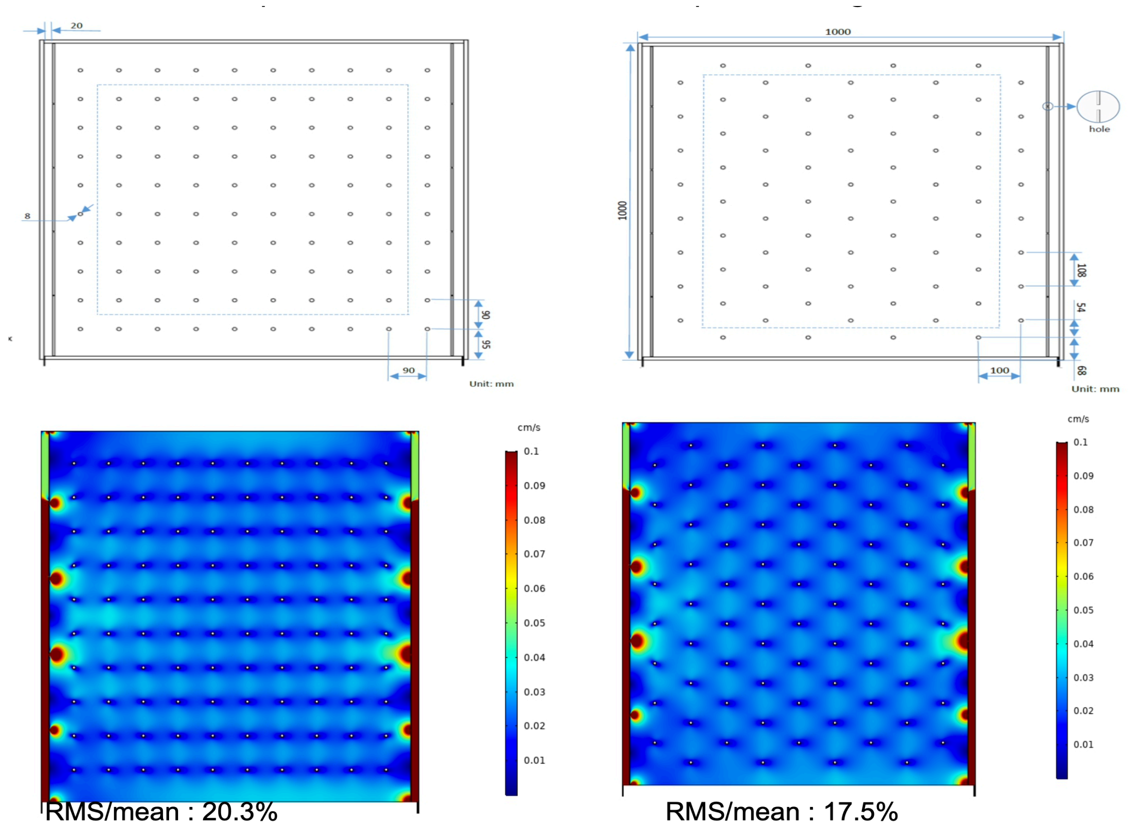


3 mm RPC (glass)
1.2 - 1.4 mm PCB
1.6 mm ASIC

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

Gas flow simulation for GRPC

- Gas flow has a strong impact on the uniformity, efficiency of GRPC
  - The bigger chamber, the more critical it's become
  - For large GRPC 1820✖990 mm， simulate the gas flow impact
  - Compare the spacer position, the velocity is more uniform with the shifted design

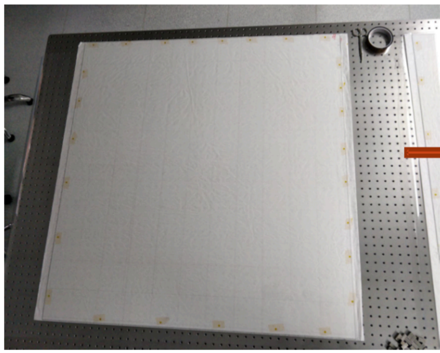


RMS/mean : 20.3%

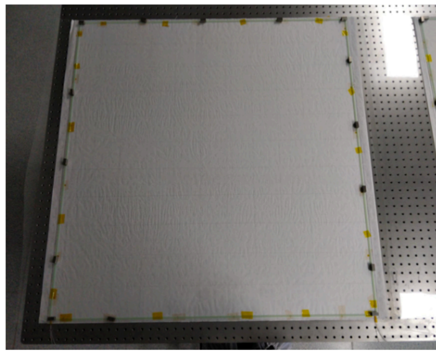
RMS/mean : 17.5%

GRPC construction

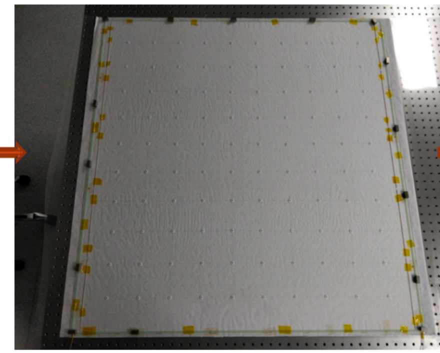
Cleaning



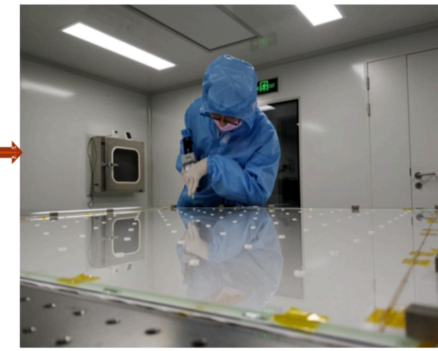
Walls positionning



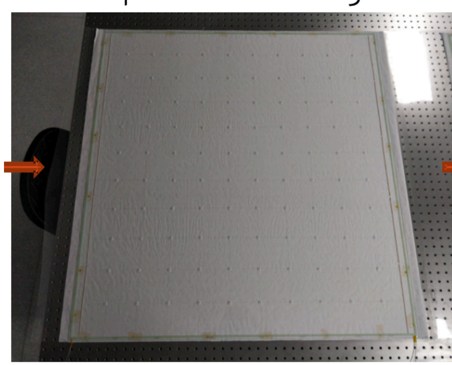
Spacers positionning



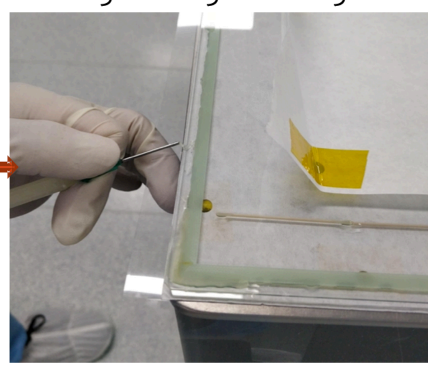
Walls/spacers gluing

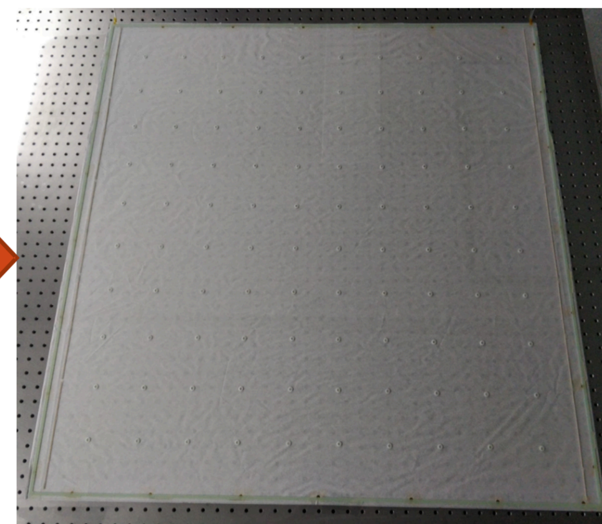


Flipping and 2nd glass positionning



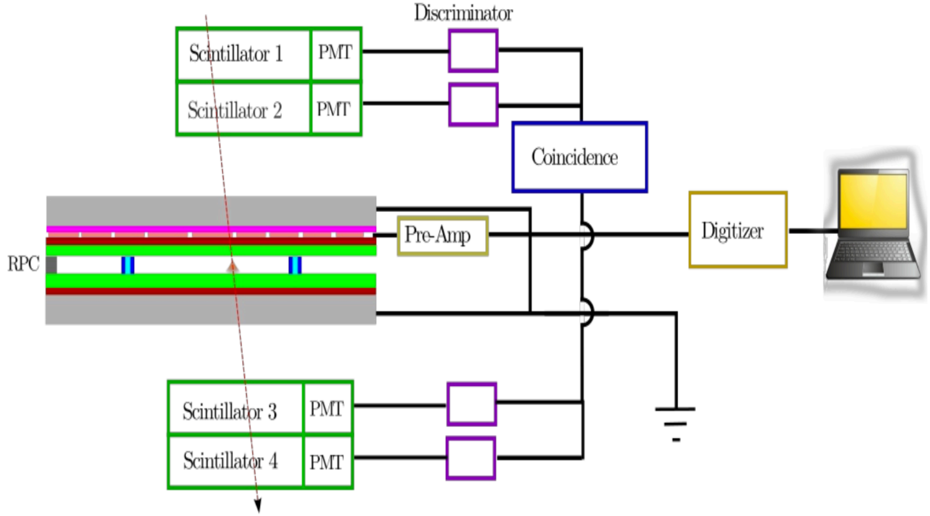
2nd glass gluing gas tightning



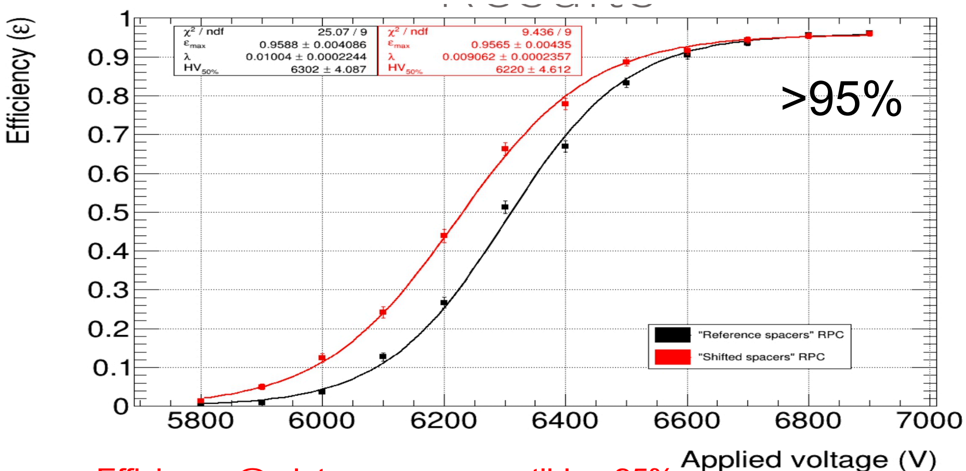


GRPC test

Cosmic ray test



efficiency

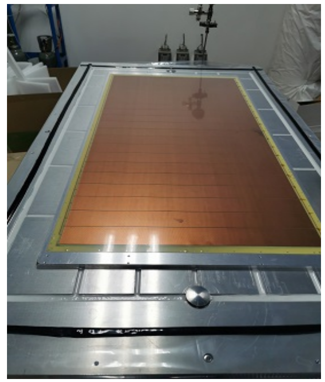


Efficiency @ plateau are compatible >95%

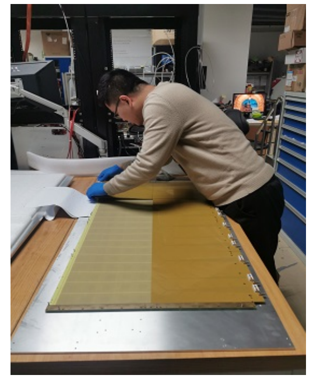
Fabrication of RWELL detector

100cm×50cm RWELL:

Painting the glue



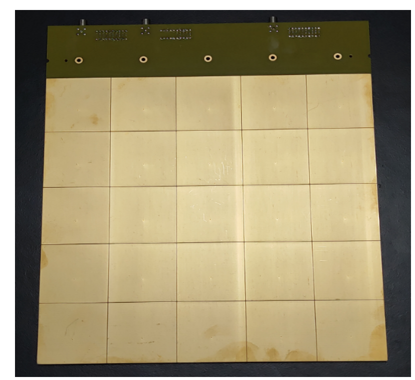
Pumping and drying



Assembling

100cm×50cm RWELL detector

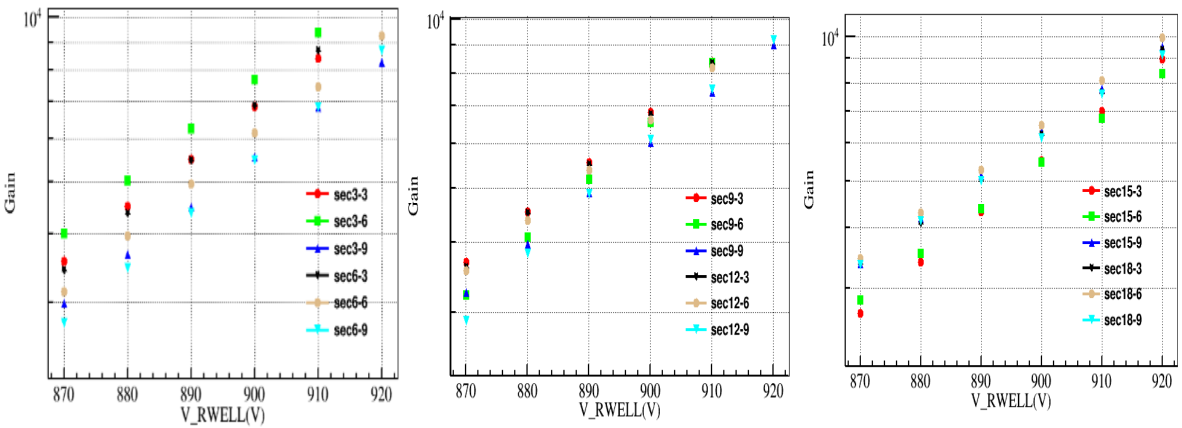
- We make a special PCB and use it as the gluing mask;
- We put glue on both resistive layer PCB and THGEM PCB;
- A vacuum platform was used for gluing;
- 8 pieces of readout PCB are used, there are 25 pad(Pad size 5cm×5cm) on each pcb



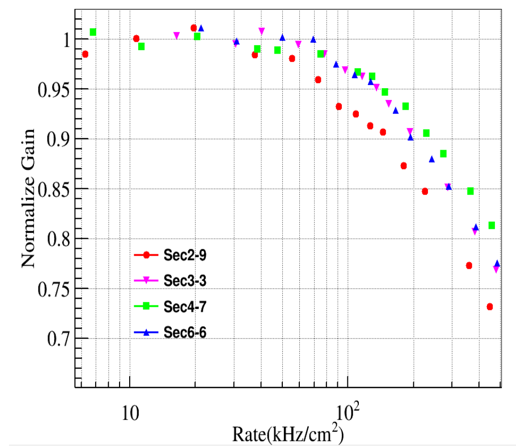
25 cm×25 cm Readout PCB

RWELL performance

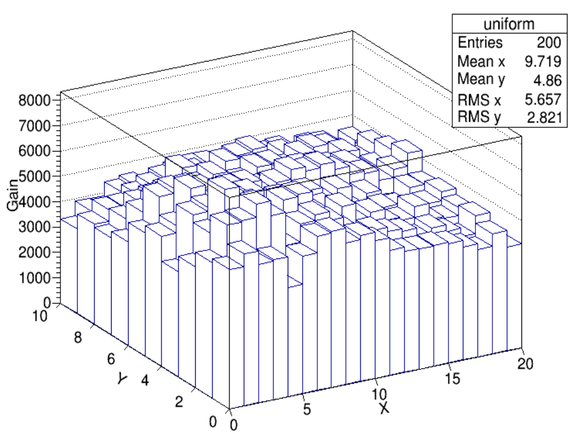
- **Gain vs HV:**

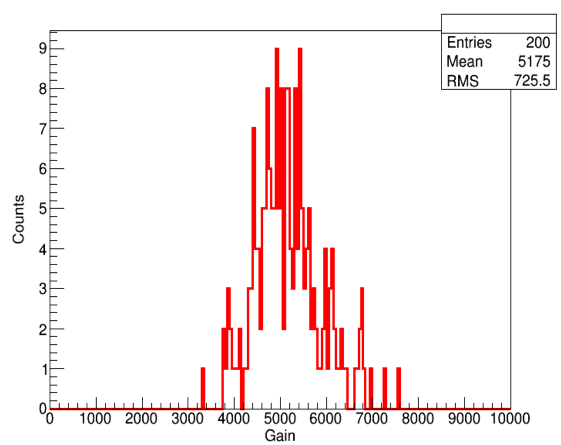


- **Rate capability： >100 kHz/cm²**

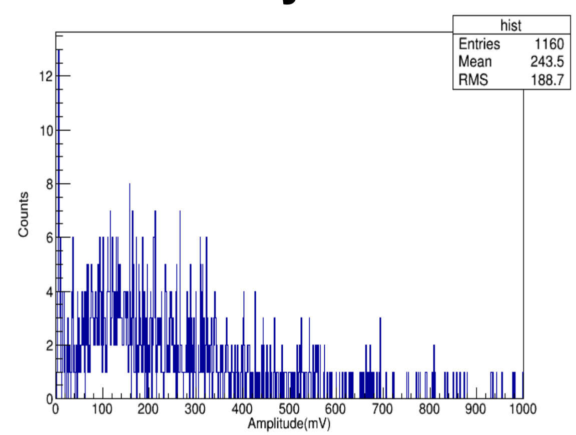


- **Gain Uniformity : RMS/Mean～14.0%@~5175 Gain**





- **Efficiency : ~95.9%**



Summary and outlook

- The light yield test of all scintillators has been completed.
  - A total of 14219 / 15524 scintillators meet our requirement (the prototype needs 13960)
- Two SiPM test systems are developed and applied to the test
  - One is for SiPM of HAMAMATSU, the other is for NDL
- The new HBU has been tested
- Under the existing power consumption, the influence of air cooling design of AHCAL was simulated
  - The design of fan + thermal conductive rubber pad can effectively reduce the temperature of the AHCAL
- HBU cassette handling is being carried out
- The DHCAL based on GRPC and RWELL are carried out in an orderly manner

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THANKS

backup

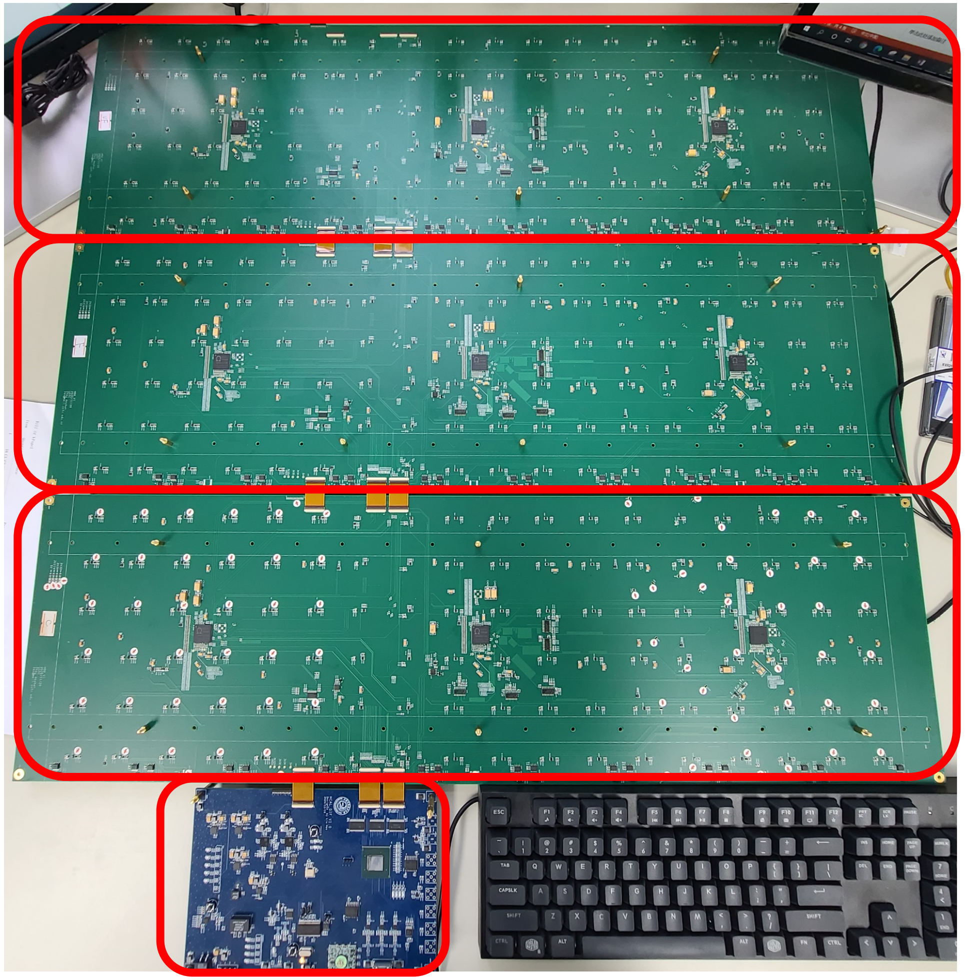
HCAL Baseboard Unit Status

- One layer has 3 sub-HBUs
- One sub-HBU is $78.5 \times 24\mathrm{cm}^2$
- Flexible boards are used to transmit power and signal between the 3 sub-HBUs and DIF
- Each sub-HBU has 3 SPIROC2E chips
  - The chips were packaged in China

ECAL

AHCAL

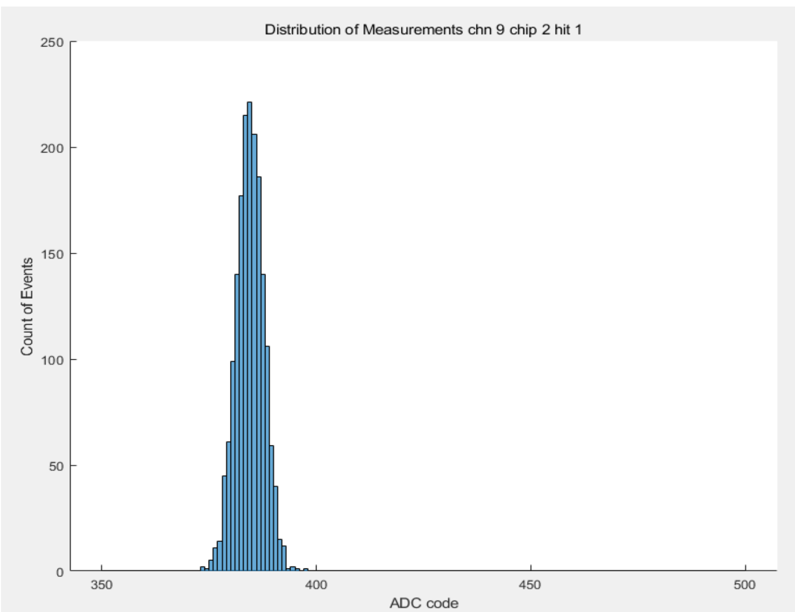
HBU



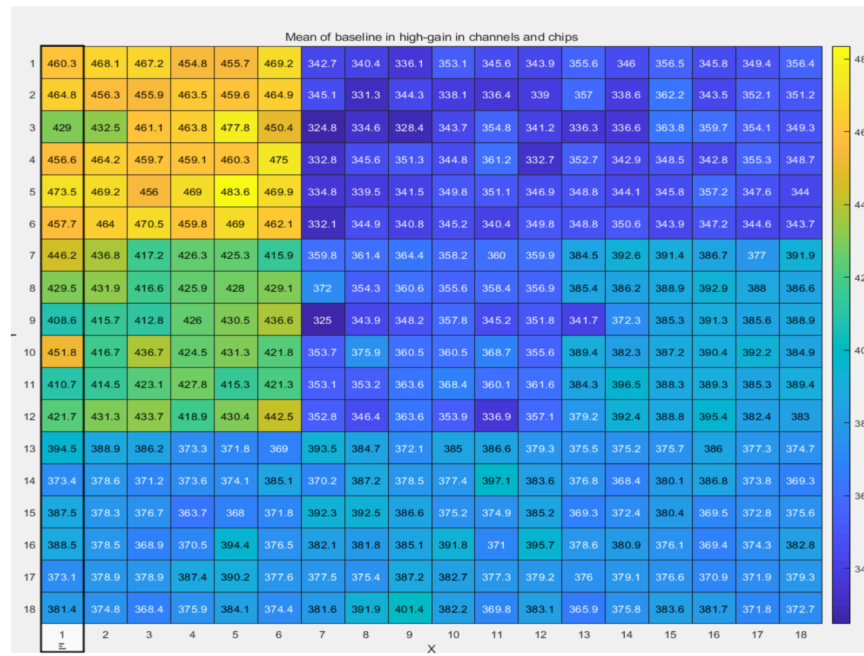
Data InterFace （DIF） board

Pedestal of HBU

- The pedestal of each channel was calibrated using random trigger
- The pedestal positions are differences between chips
- The channels of the same chip are relatively uniform
- The pedestal width has little to do with the chip



The pedestal of one channel



The pedestal of each channel in HBU

HBU Support Frame

- A 5mm thick Al support frame is machined for trial assembly and testing with HBU
- The optimization of the support frame will be discussed next step