CEPC AHCAL Progress

Yunlong Zhang

State Key Laboratory of Particle Detection and Electronics, China

University of Science and Technology of China

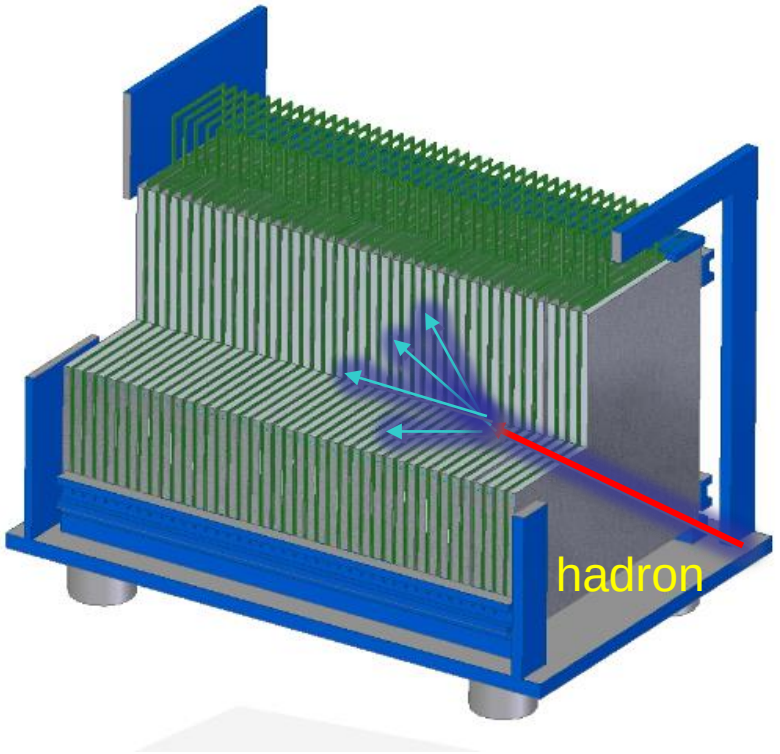
On behalf of CEPC Calorimeter working group

Outline

- CEPC AHCAL Brief Introduction
- AHCAL Progress
  - Electronics Board Design
  - AHCAL Basic-Unit (HBU) Assembly
  - HBU Cosmic Ray Test
  - Mechanical Design
  - Cooling simulation
- Summary and outlook

AHCAL Prototype

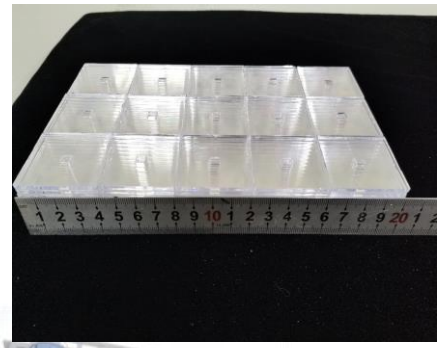
- Sampling Calorimeter
  - 40 layers, ~ 5 N.I.L
  - 72 cm×72 cm
- Absorber
  - Iron，2 cm thickness
- Sensitive Detector
  - Scintillator+SiPM，Number:13,960
  - Cell size：40 mm×40 mm×3mm
  - SiPM：HPK and NDL
- Electronics
  - SPIROC2E ASIC Chip

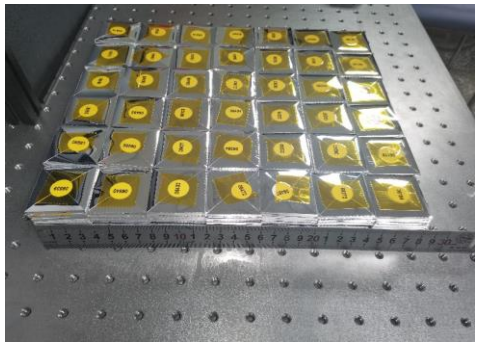


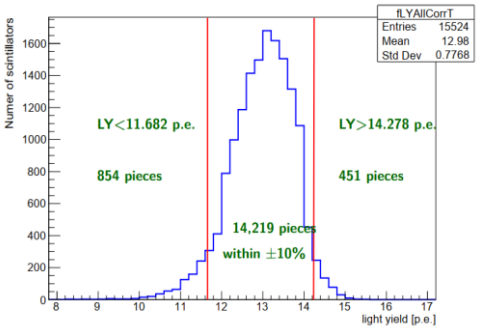
AHCAL Structure

Previous Results

- More than 15000 scintillators were produced based on ejection molding and packaging using ESR film in August
- All the packaged scintillators have been tested, 14,219 pieces within 10% of 15,524 pieces in total. About 91.6% of scintillators are qualified (within 10% of LY window).
- Two different types SiPM were selected in this prototype, of which NDL models were tested one by one







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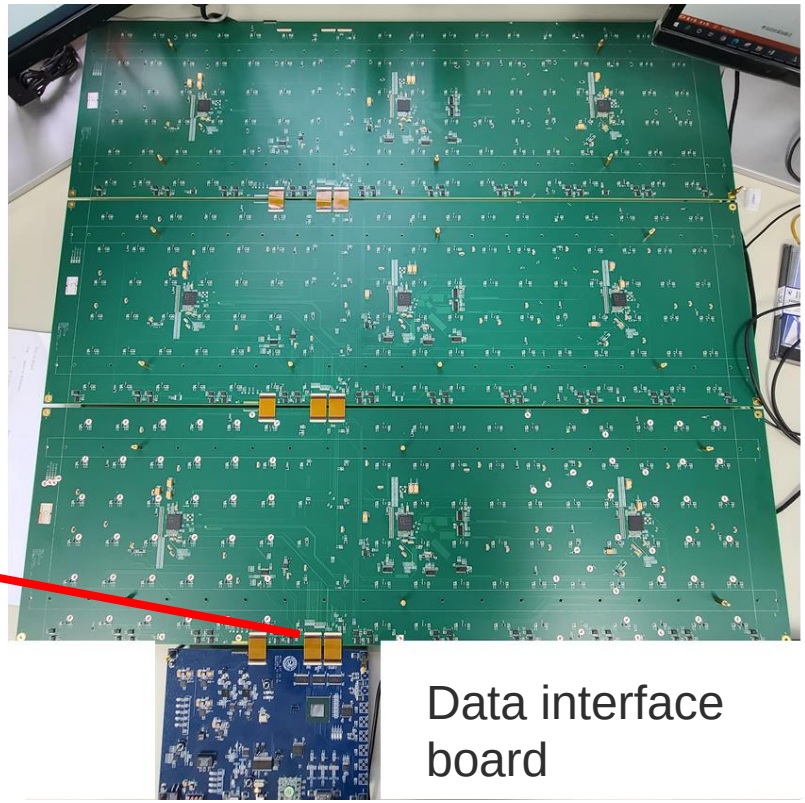
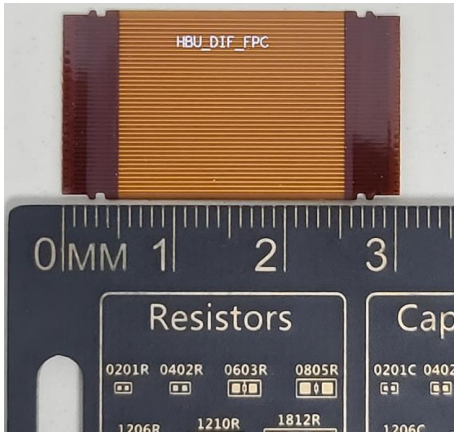
Electronics Board Design — V1

- Design
  - Divide sensitive area to 3 PCB (785mm x 240mm)
  - FPC is used to transmit signal and current
- Verification
  - PCB physical stability
  - Soldering
  - Long term signal transmission
- Power consumption
  - 2.13A @ 6.2V=13.2W per layer

HBU sub board



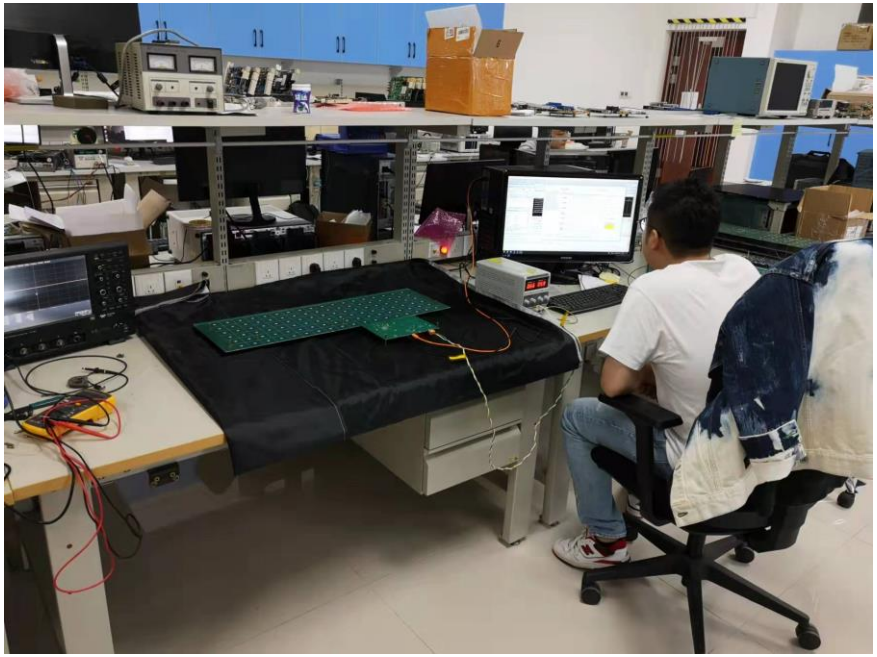


Flexible Printed Circuit connection is adopted between the three sub-HBUs and between DIF board and HBU

Electronics Board Design – V2

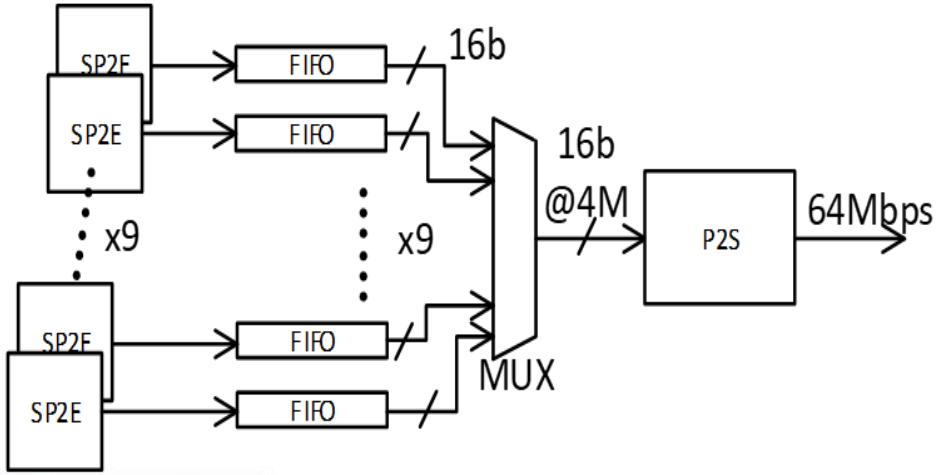
- In order to decrease the power consumption, V2 was designed
- Optimization
  - Reduce buffer quantity to 18
  - Power consumption reduced to 9.7 W (V1 ~ 13.2 W)

Device	Power consumption	quantity
FPGA	990mW	1
LDO group	1172mW	1
SPIROC2E	187mW	9
buffers	150mW	54(HBU Version 1)

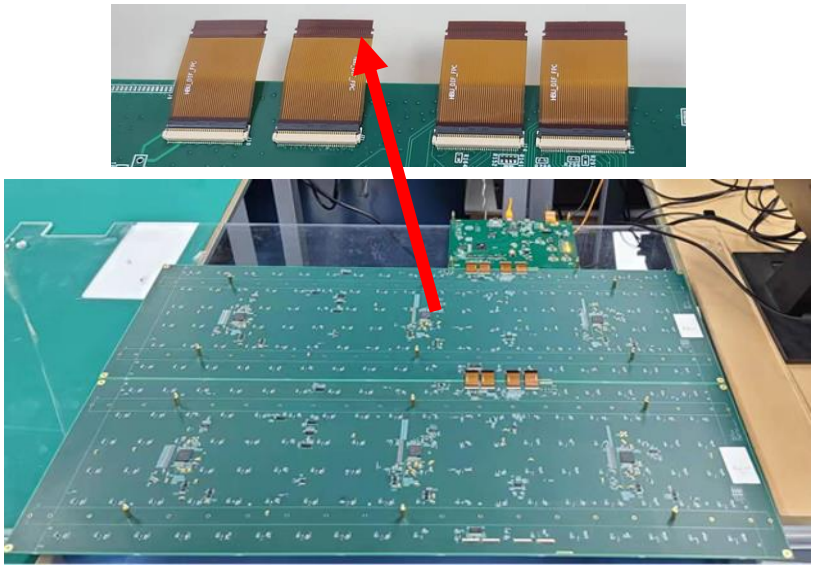


Electronics Board Design — V3

- Maximum event rate of HBU_V2 is only ~100Hz
  - The data transmission speed is mainly limited by the serial readout of the chip
- Event rate increased to 3 kHz by parallel readout strategy of HBU_V3



More signal need to be transmitted
Another FPC is added



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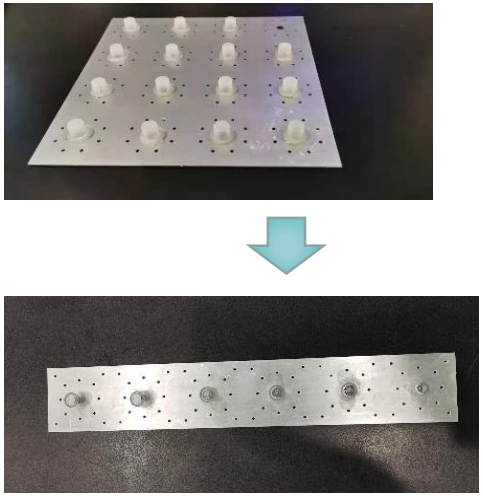
HBU assembly

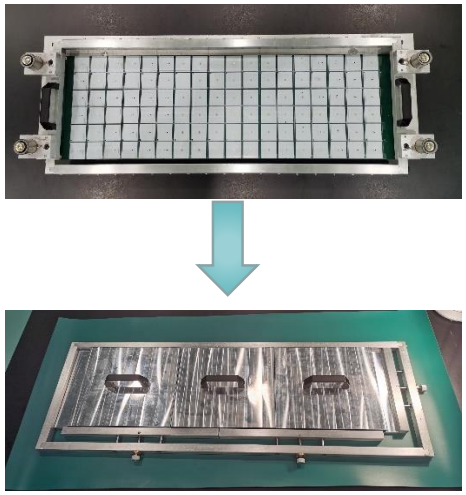
- After HBU welding and performance testing, an important work is to assemble the scintillators
- This work is carried out in Shang Institute of Ceramic
- They improved the assembly process of scintillator on the basis of previous research

Rubber brush plate update



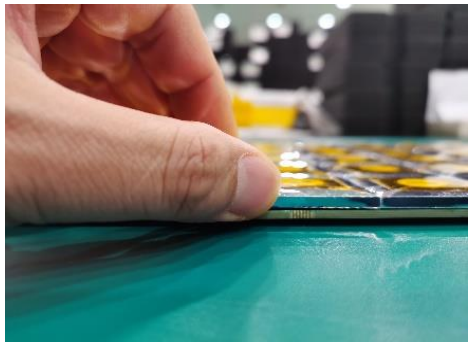
➢ **Glue coating is more uniform**

Limit of scintillator position



➢ **More accurate location**

Specially designed for the bonding of edge scintillators

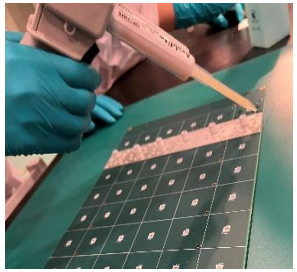
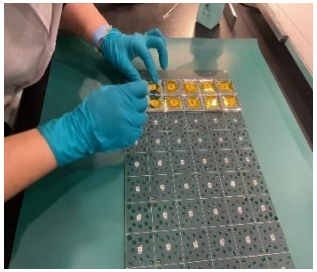
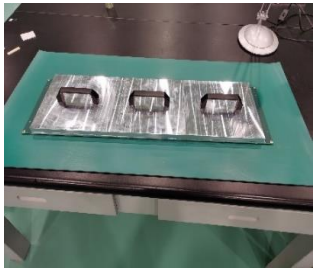
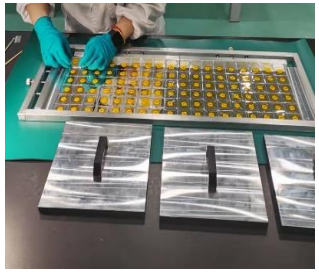


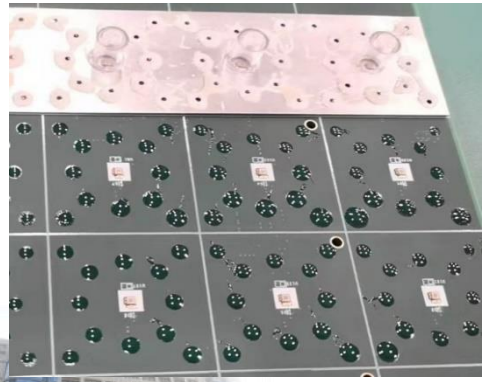
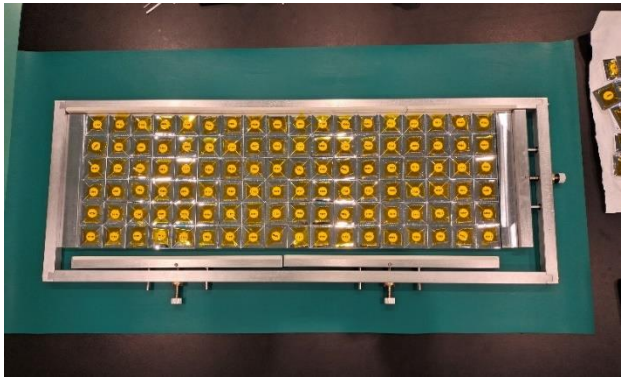
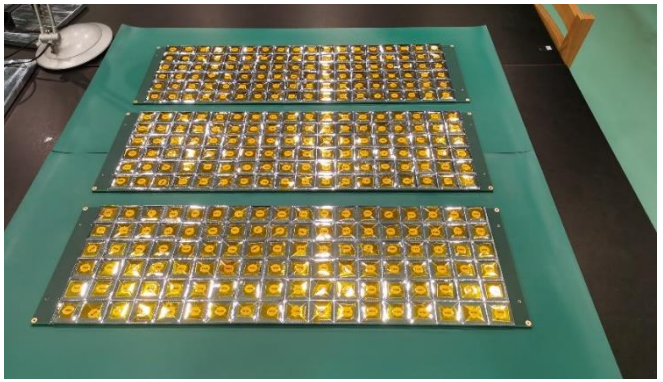
➢ **Enhance the adhesion between scintillator and PCB**

HBU assembly

◆Assembly Process

Scintillator visual inspection → Gluing → assembly → Glue curing → Visual inspection

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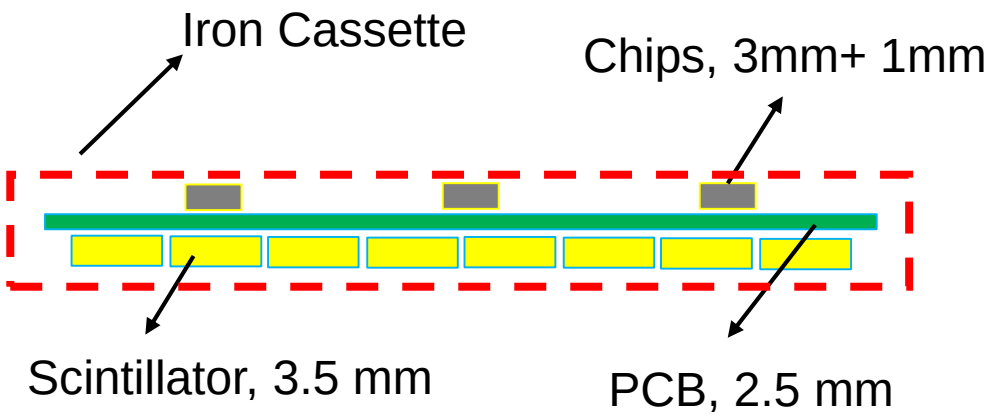
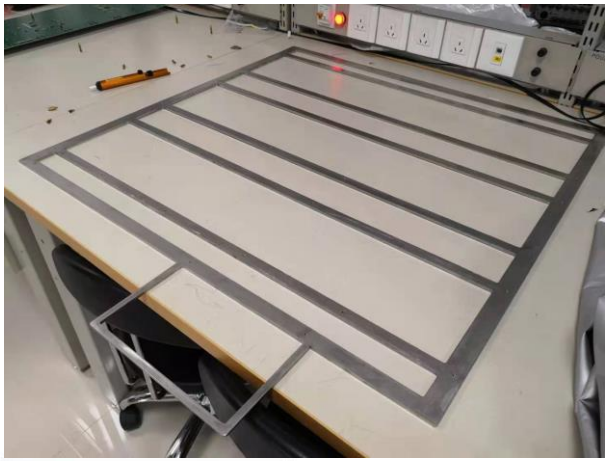
HBU Cassette

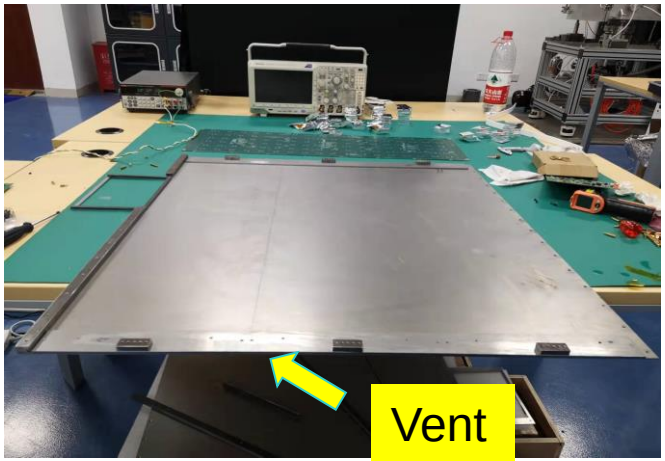
- In order to facilitate testing and transportation, each HBU has a cassette
- We choose iron as the material of the box, and the mass of this part is directly deducted from the absorber





v1

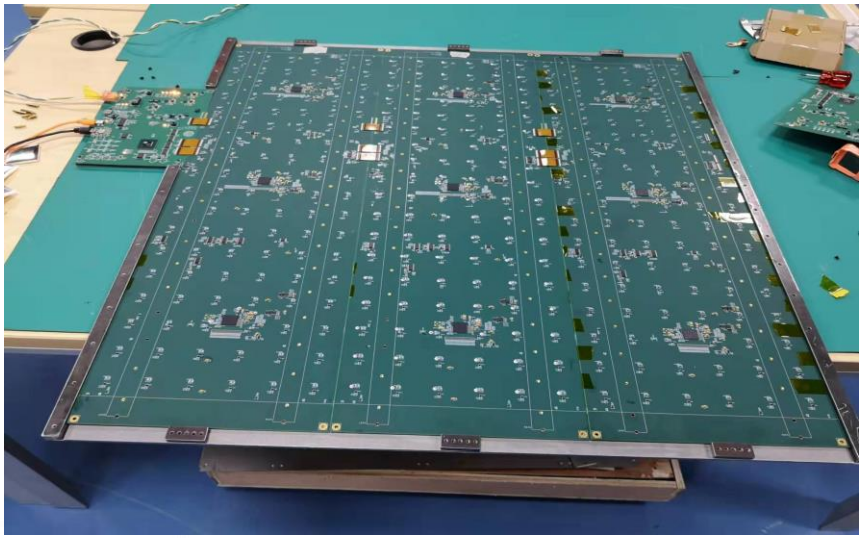
v2



v3

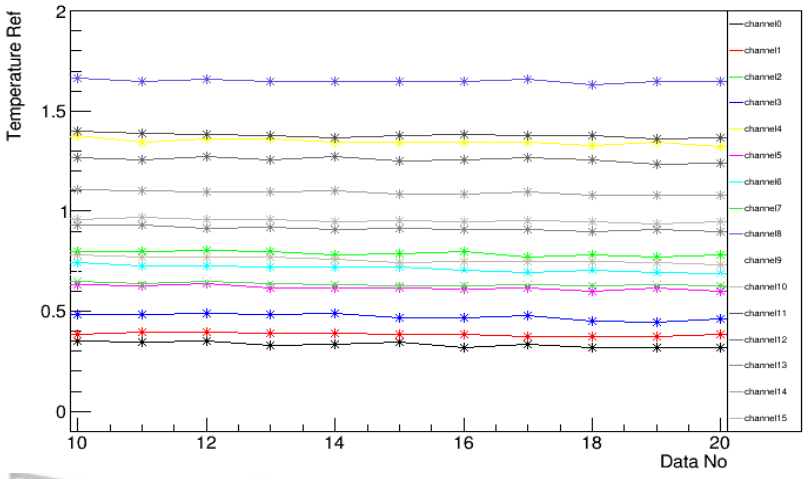
HBU Cassette

- Assemble the HBU into the cassette
  - The scintillation detector faces down and the electronic components face up
  - Some rubber strips will be used to support the cover plate on the box to prevent the cover plate from contacting the chip

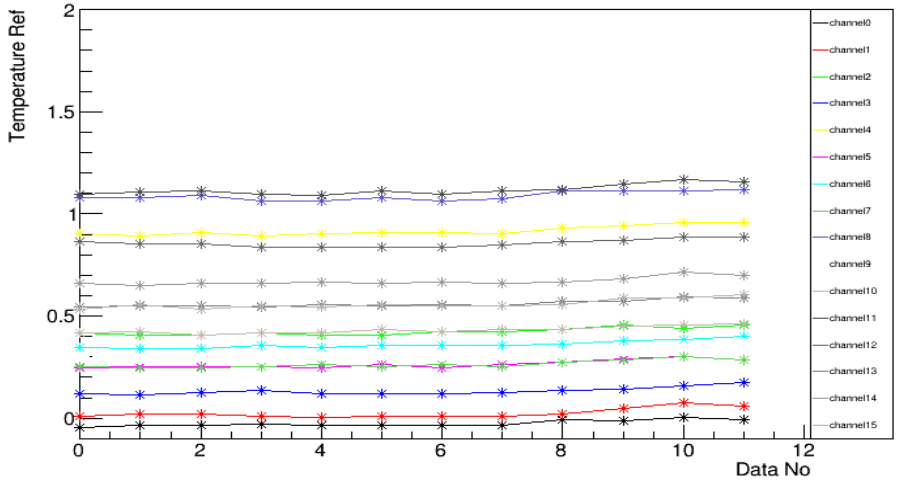


HBU Temperature

- Each HBU has16 temperature sensors which are the same with Sc-ECAL
  - We tried to place the thermal conductive rubber pads at the position of HBU chips to export heat
  - Before placing the thermal conductive rubber pads, the temperature of HBU will be ~ 1 degree higher than the room temperature. After placement, it is found that the temperature on HBU is closer to the room temperature



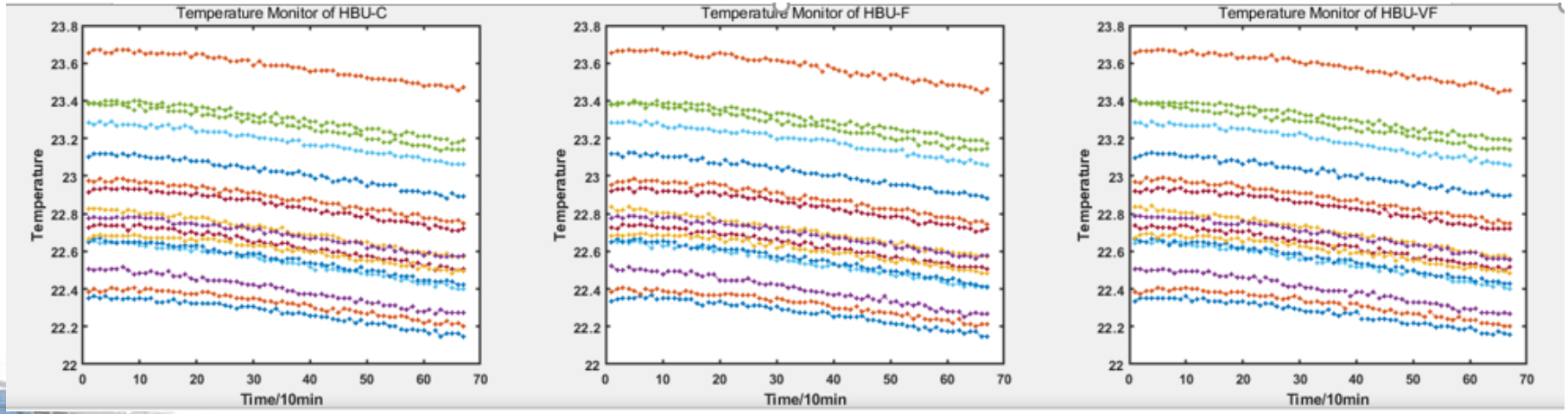
Before place thermal rubber



after place thermal rubber

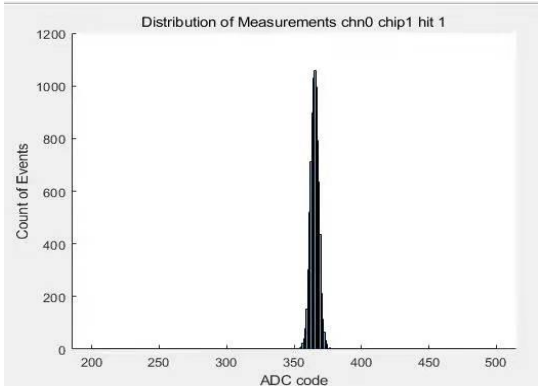
HBU temperature

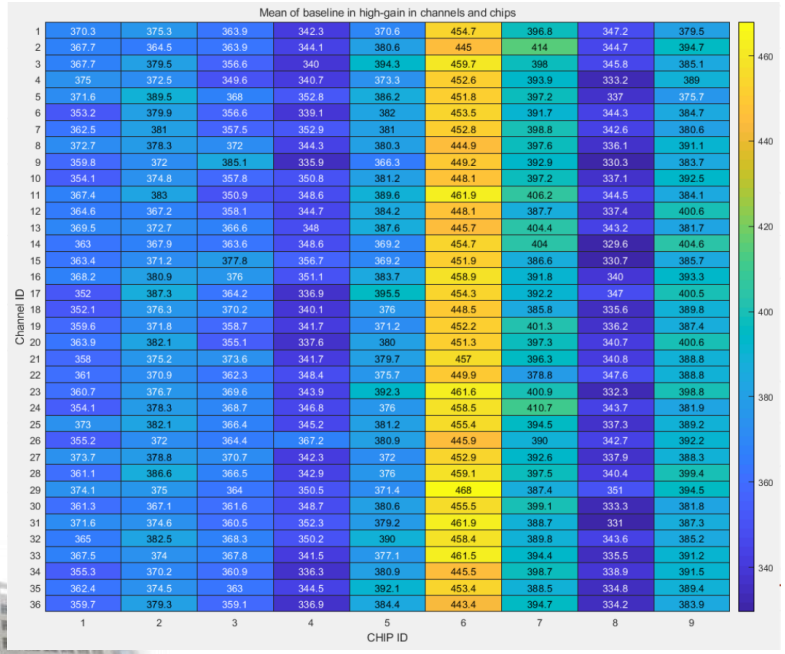
- We tracked the temperature stability of the HBU assembled in the cassette
  - The test lasted for ~ 12 hours, the temperature is relatively stable and changes with the room temperature
  - The temperature of three sub-HBUs are almost the same, and the temperature at the same position on different sub-HBU is basically the same
  - The relative temperature at different positions on the HBU is stable

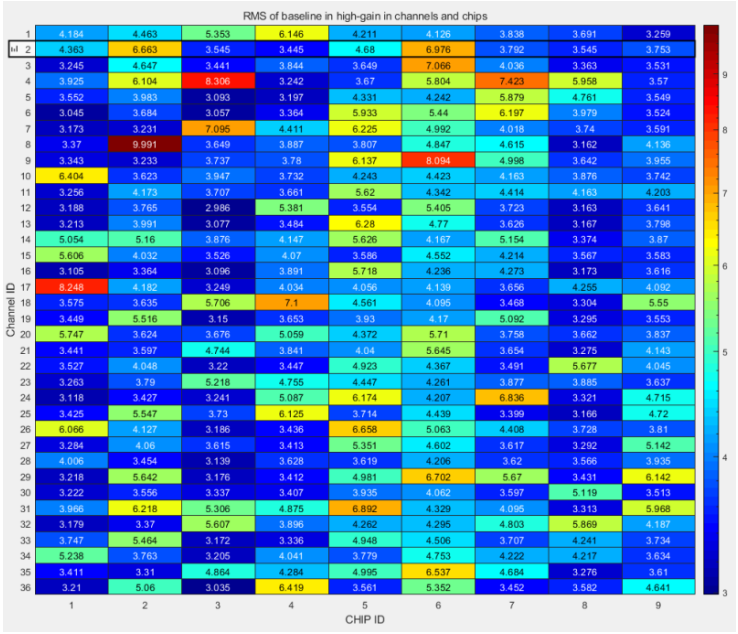


HBU readout channel noise

- Results of electronic test
  - The pedestals are around 300-400 ADC
  - The rms of pedestals are about 4
  - Different chips have different pedestal positions, but the same chip is more consistent

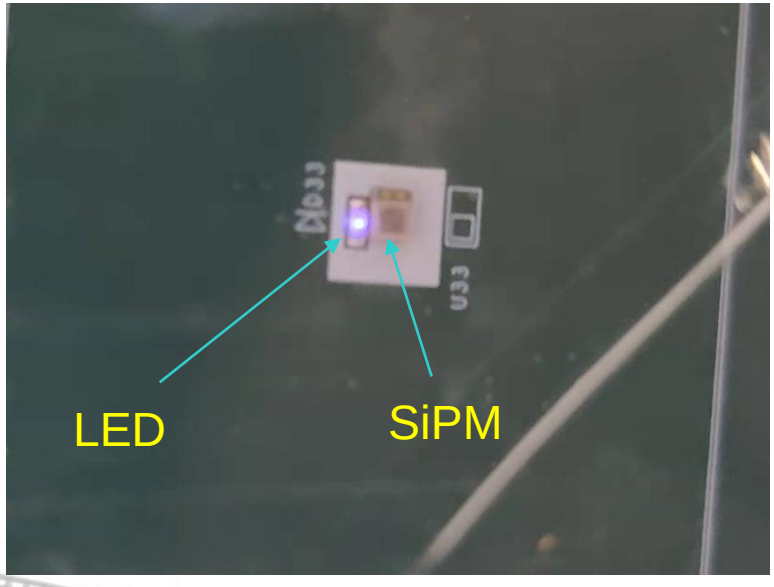


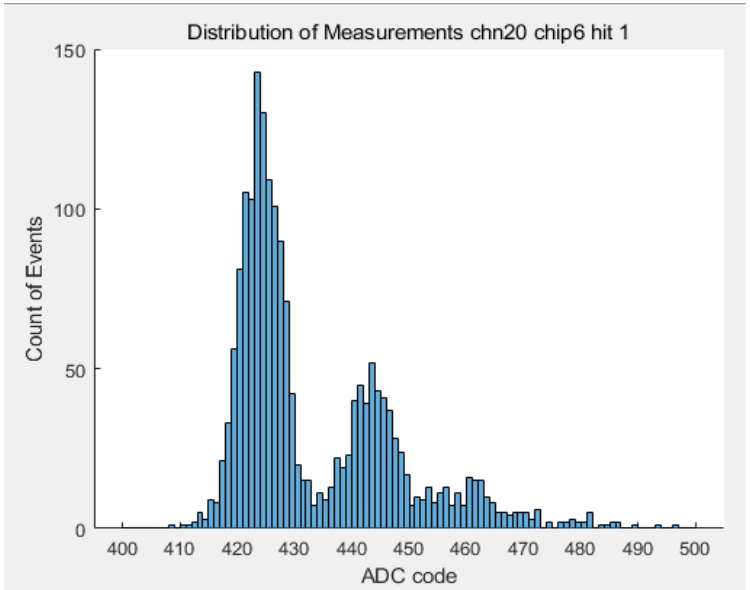




HBU LED Test

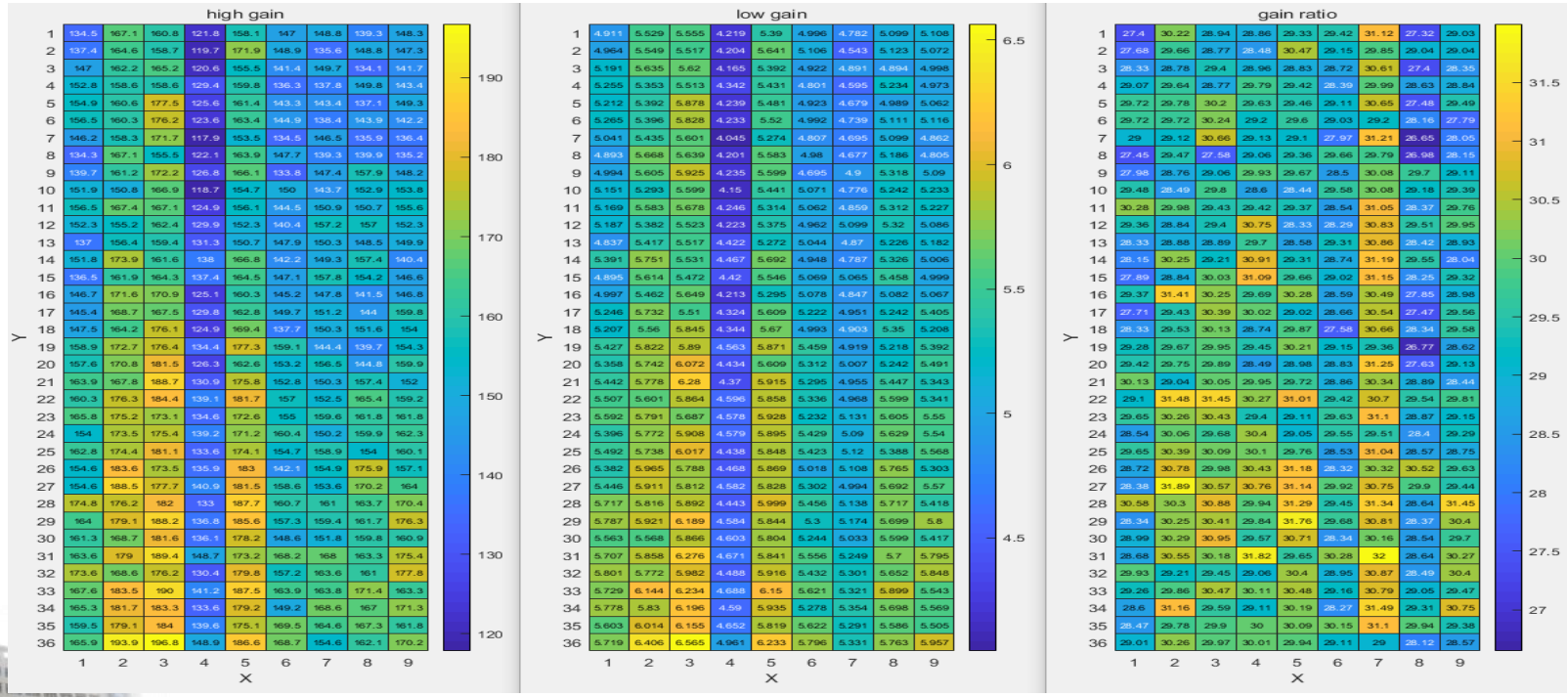
- Similar to the Sc-ECAL design, the LED is also added to calibrate the single photoelectronic (SPE) peak of SiPM to track the stability of SiPM gain
- The position of LED is placed near SiPM
- The test result shows that the SPE could be seen clearly





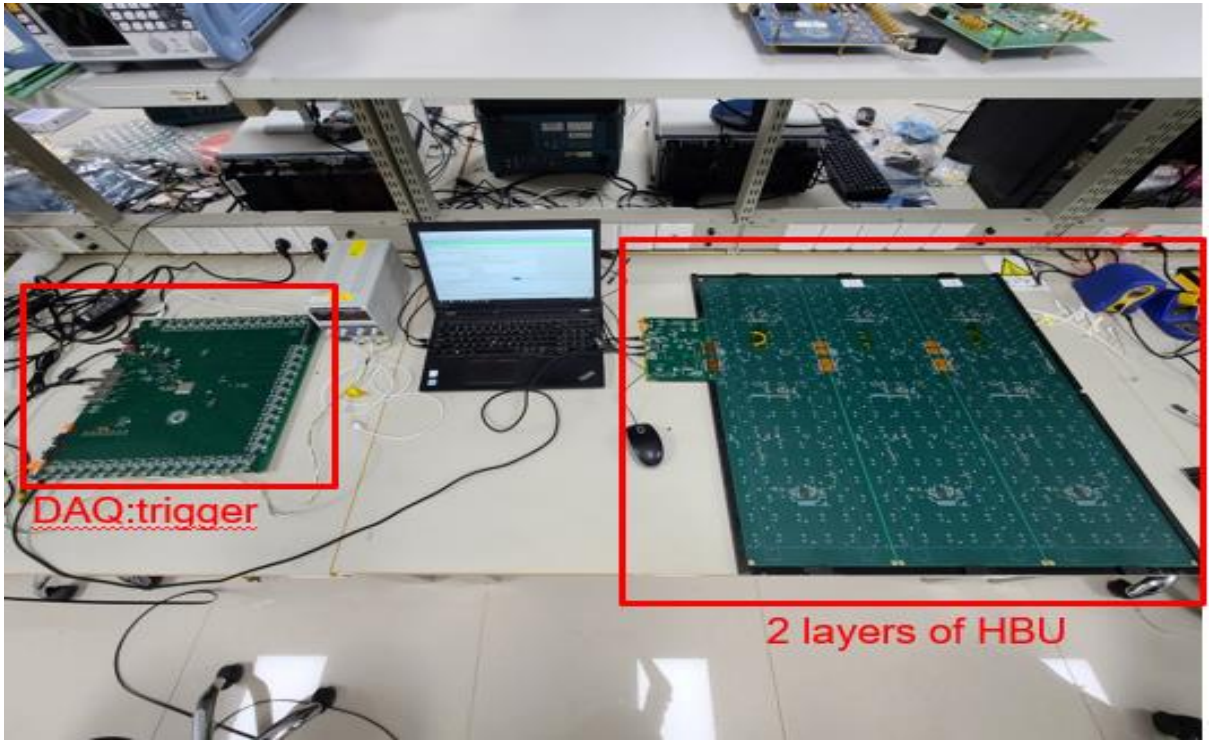
HBU low gain and high gain ratio

- The SPIROC2E has low gain and high gain channel to meet high dynamic range design
- The coefficient of each channel was tested using DAC. The coefficients of high and low gain are ~150 and ~5 respectively
- The ratio is about 30, which is close to the Sc-ECAL design



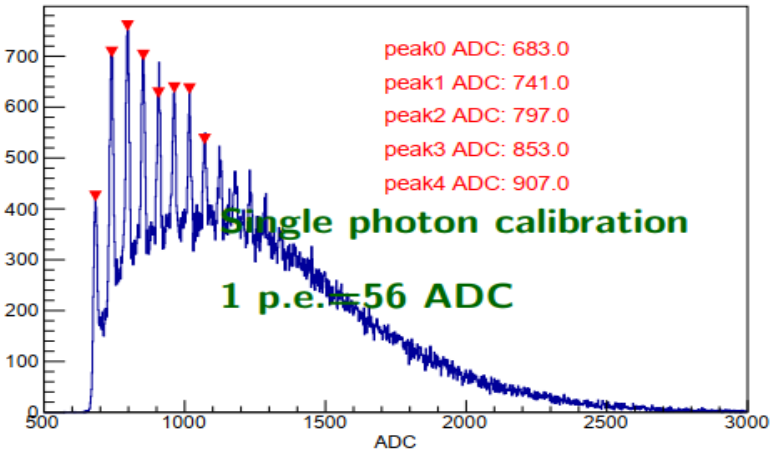
HBU Cosmic Ray Test

- The coincidence signals of the two layers of HBU is used as a trigger for the cosmic ray test
- The DAQ is also designed for AHCAL prototype, which could collect 40 layers signal

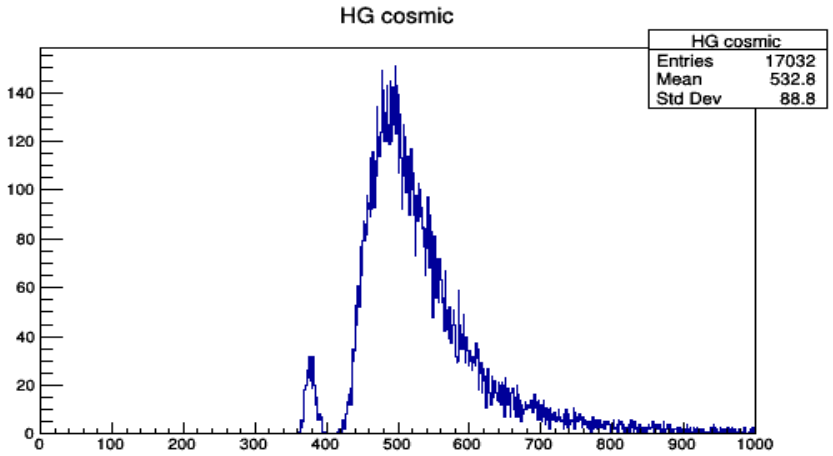


HBU Cosmic Ray Test

- After the two layers of signals are consistent, the MIPs signal could be seen clearly
  - In the previous batch test of scintillators, s13360-1325 (PDE ~ 25%, gain ~ 7e5) was used, and the light yield was ~13 pe/MIP.
  - The cosmic ray test adopts the new s14160-1315 (PDE ~ 32%, gain ~ 3.6e5)



Batch test



Cosmic test

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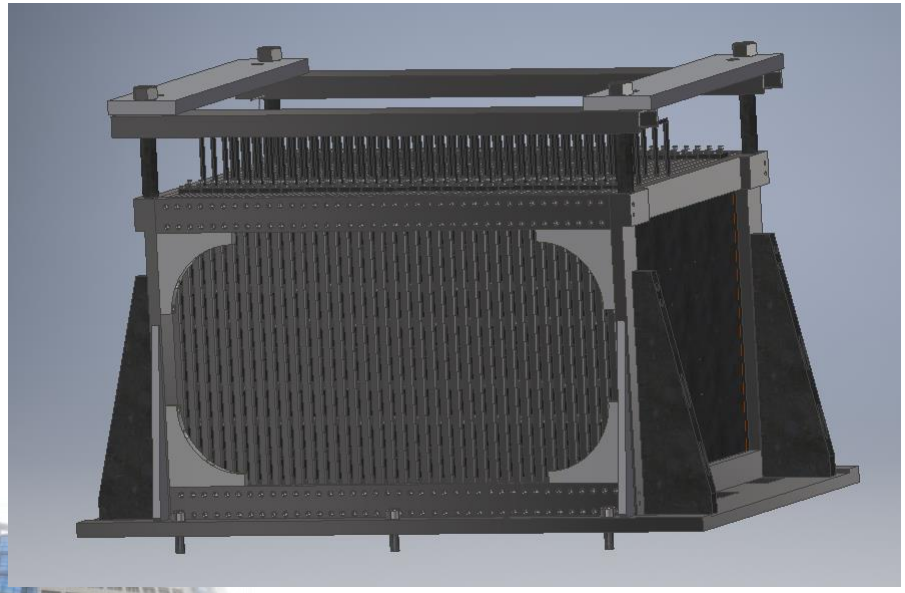
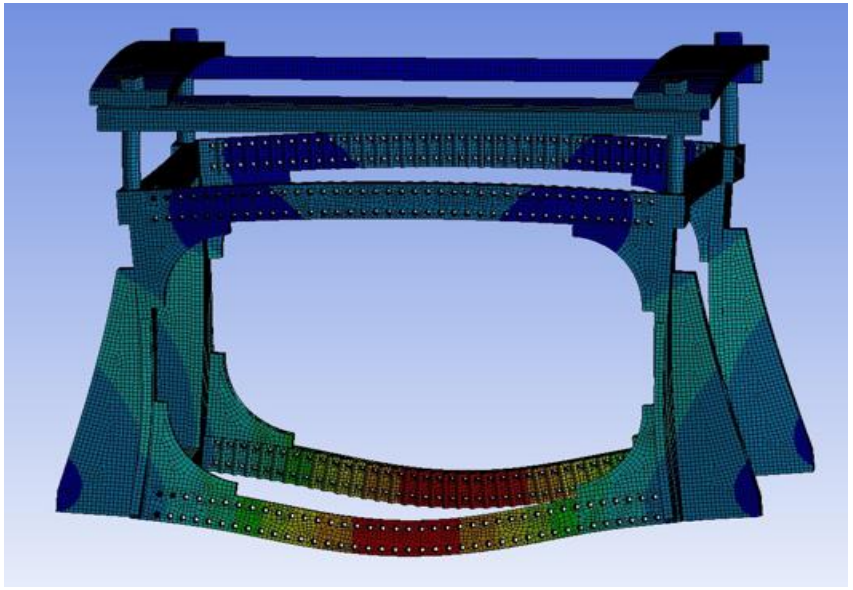
AHCAL mechanical design

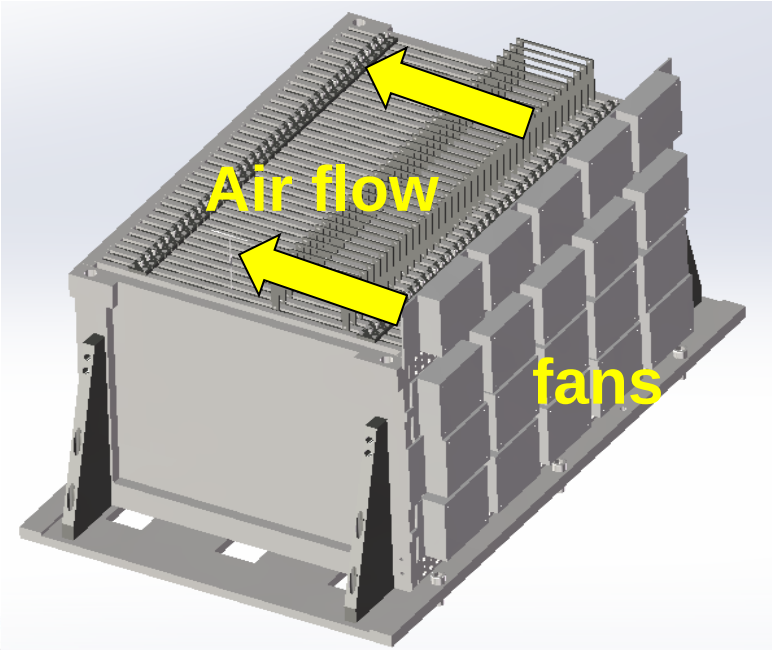
- With the help of Ji Quan and Zhang Junsong of IHEP, the supporting structure of AHCAL is designed
- The mechanical simulation is carried out. During hoisting, the maximum shape variable is 0.4 mm, the structural stress is basically within 33 MPa, and the maximum stress is less than 60 MPa

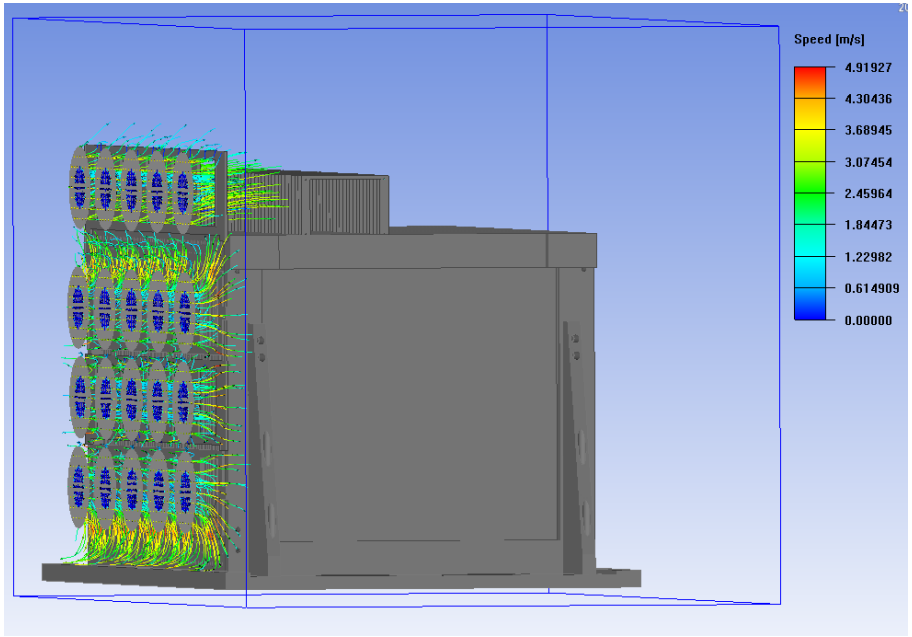




Cooling simulation

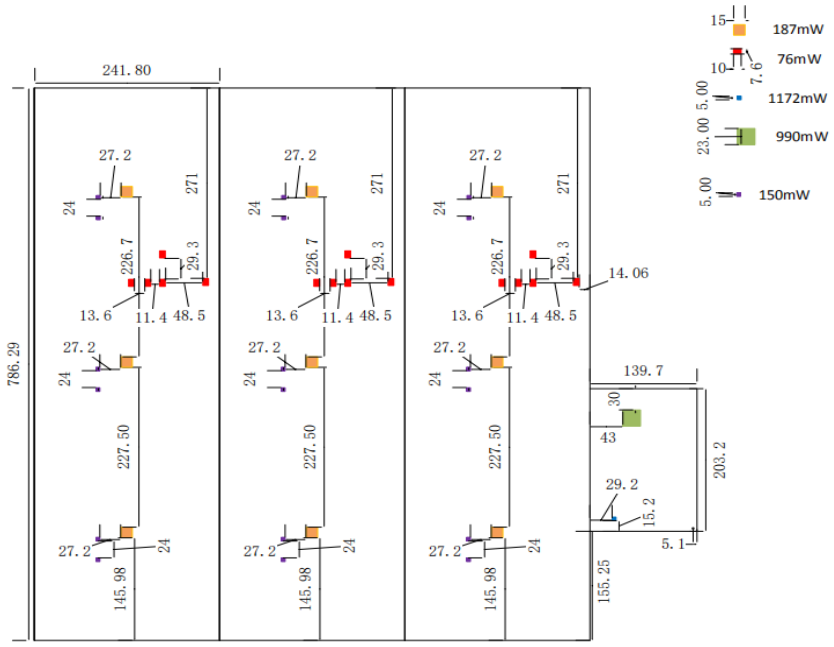
- Based on the same structural geometric design, the temperature simulation is carried out by Siyuan Song of SJTU
- The fans are placed on one side of the AHCAL



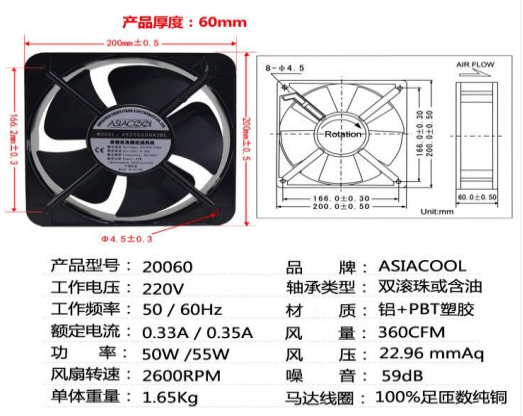


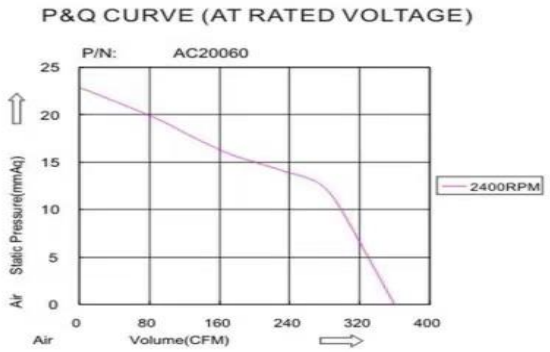
Cooling simulation

- The actual parameters are introduced into the simulation
- Total power of one layer except DIF board : $5523\ mW$
- The speed of the fan is 2600 RPM



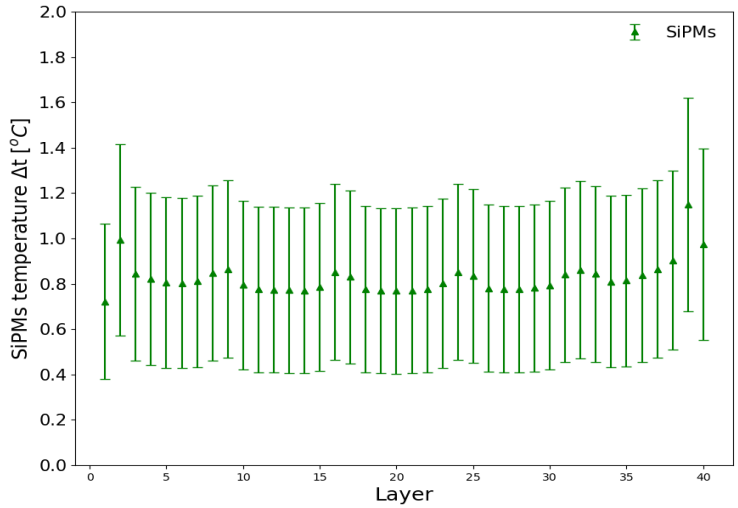
Position Distribution of high-power devices in HBU



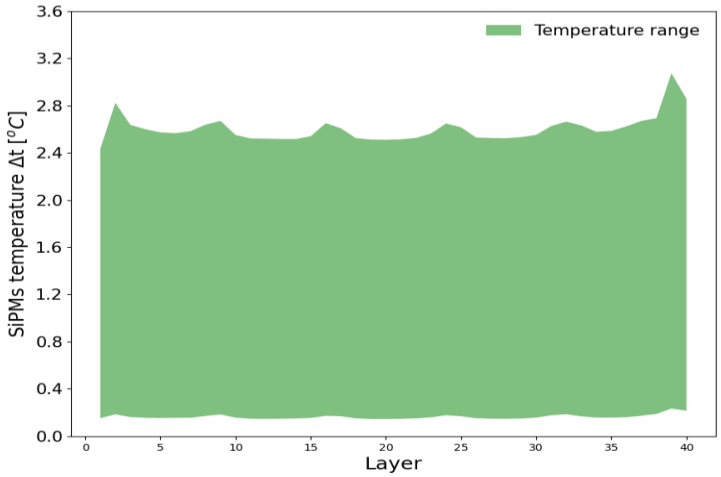


Cooling simulation

- The simulation results show that when the fan is running the average temperature (scintillator side) on the HBU is ~ 0.8 degrees higher than the room temperature.
- On the same layer, the temperature range of different positions is between ~ 0.2 - 2.8 degrees
- The temperature of different layers is basically the same, which is much better than the result without fan



Average temperature with standard deviation.



temperature range in each layer.

Summary and outlook

- The V3 board of HBU is designed
  - Its basic functions include LED test, DAC test, temperature monitor, etc. Now, two sensitive layers (6 sub -HBUs) have been welded.
- Two layers of HBU were assembled in SIC
  - Preliminary tests were carried out, and all properties were OK
- The overall structure of AHCAL and the cassette of HBU have also been determined
  - the temperature simulation under this geometric design shows that under the air-cooled design, the temperature of AHCAL is ok
- The second batch of HBU (4 layers) will be processed at the end of the month. It is planned to carry out scintillator assembly in early March.
- It is planned to complete the production, assembly and test of all HBU in April and cosmic ray test in May.
- The mechanical structure will also be processed in May, and the beam test will be arranged in autumn.

Summary and outlook

- The V3 board of HBU is finalized
  - Its basic functions include LED test, DAC test, temperature monitor, etc. Now, two sensitive layers (6 sub-HBUs) have been welded.
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- The second batch of HBU (4 layers) will be processed at the end of the month. It is planned to carry out scintillator assembly in early March.
- It is planned to complete the production, assembly and test of all HBU in April and cosmic ray test in May.
- The mechanical structure will also be processed in May, and the beam test will be arranged in autumn.

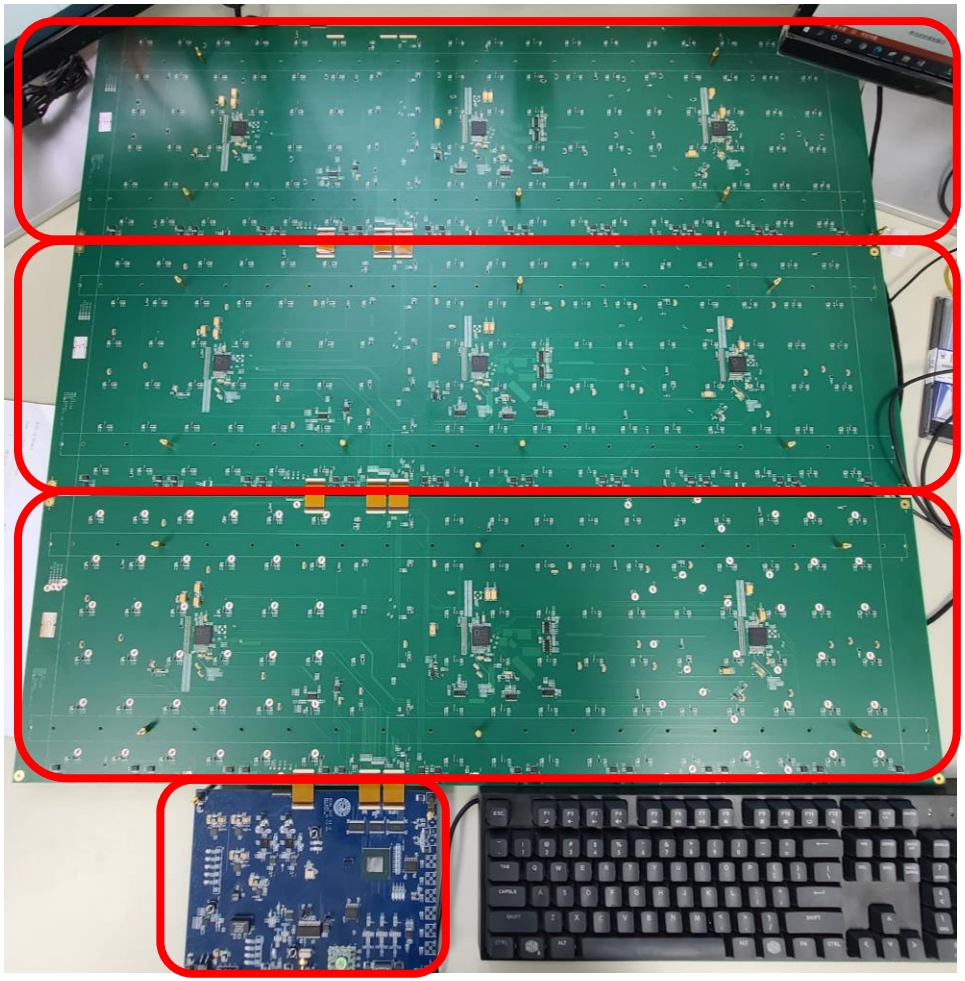
THANKS

backup

HCAL Baseboard Unit Status

- One layer has 3 sub-HBUs
- One sub-HBU is $78.5 \times 24 cm^2$
- 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

HBU



Data InterFace （DIF） board

ECAL

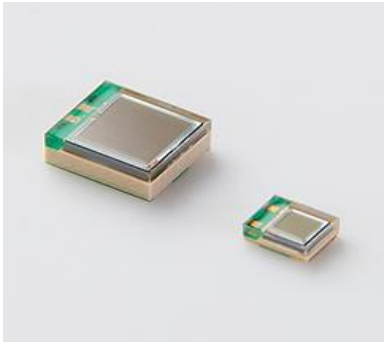
AHCAL

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

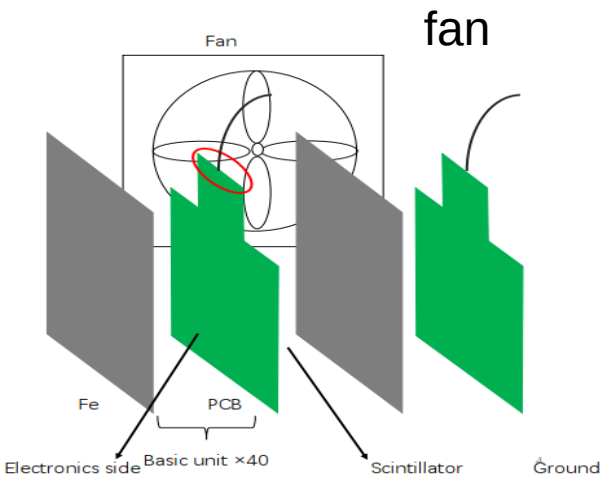
NDL



S14160-1315PS

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



Fe-Heating source-PCB-Scintillator-Fe

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