Progress of CEPC AHCAL Prototype Development

Yanyun Duan (SJTU)
For the CEPC calorimeter working group

CALICE Collaboration Meeting

Sep. 9, 2021

Content

Content

CEPC physical goal and PFA

CEPC Physical Goal

- Precise measurement of the Higgs particle's properties
- Explores new physics beyond standard model
- Precise measurement of the electroweak interaction parameters related to W and Z.

Requirements of CEPC calorimeter: high granularity

- Energy resolution reach $30\%/\sqrt{E}$ at jet energy below 100GeV
- HCal: $60\%/\sqrt{E(GeV)} \oplus 4\%$

Particles in jets	Fraction of energy	Measured with	Resolution [σ^2]
Charged	65 %	Tracker	Negligible
Photons	25 %	ECAL with 15%/√E	$0.07^2\ E_{jet}$
Neutral Hadrons	10 %	ECAL + HCAL with 50%/√E	$0.16^2\ E_{jet}$
Confusion	Required for 30%/√E		$\leq 0.24^2\ E_{jet}$

18%/√E

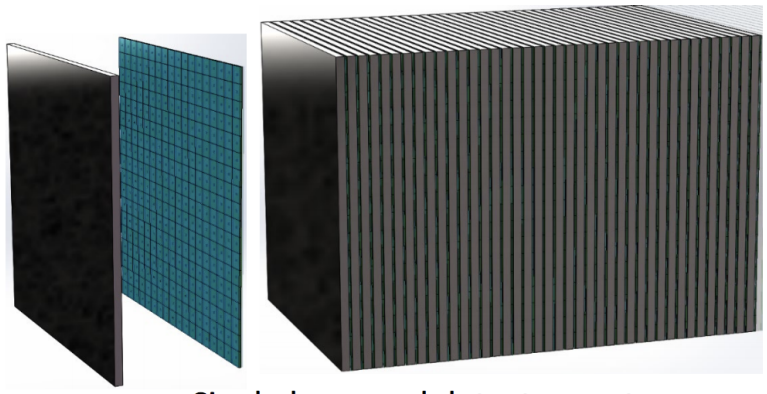
CEPC AHCAL prototype

The AHCAL task: based on PFA, $60\%/\sqrt{E(GeV)} \oplus 4\%$

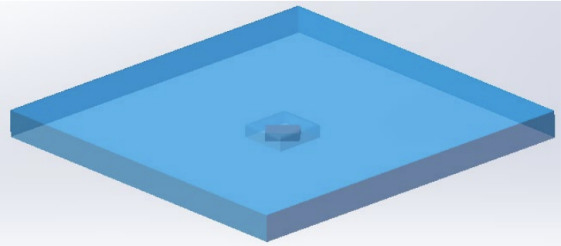
- Designing, building and testing a full AHCAL prototype.

CEPC AHCAL: SiPM-on-Tile configuration

- Prototype: 72cm×72cm×100cm with 40 layers
- PCB: 2mm, with SiPMs, temperature sensors and SPIROC2E based readout system
- Detector cell size: 40mm×40mm×3mm
- Detector cell: scintillator made of polystyrene and wrapped in enhanced specular reflector (ESR) films.
- Active layer: SiPMs + scintillators, 12,960 channel in total
- Absorber: steel (20mm Fe)



Single layer and detector part



Detector cell of
40mm ×40mm ×3mm

Overall progress

Participating institutes: USTC+IHEP+SJTU.
Overall Progress:

- PFA-based detector simulation tool and completed the design optimization of the AHCAL prototype. (Result from Yukun Shi.) (Finished)
  - Boson Mass Resolution: 4%.
  - The performance for the AHCAL prototype:
    - Linearity: $\pm 1.5\%$
    - Resolution: $\frac{48\%}{\sqrt{E(GeV)}} \otimes 3\%$
- Injection molding process to produce scintillator tiles. (Finished)
- Scintillator tiles batch testing system. (Finished, more than 14k scintillators qualified)
- SiPMs batch testing system (NDL finished, HAMAMATSU in progress.)
- HBU and DAQ system (in progress.)
- Design of the mechanical structure and cooling (in progress)

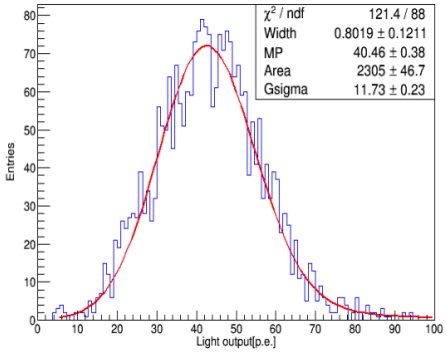
Content

Studies on AHCAL sensitive cells

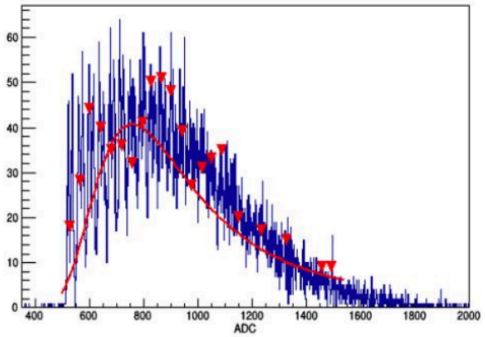
AHCAL sensitive cells progress: (Result from Jiechen Jiang)

- Structure of AHCAL tiles: 4cm × 4cm × 40 layers geometry
- Material of Scintillator: GNKD PS Tiles (injection molding scintillator)
- SiPMs: 35 layer + 5 layer backup HAMAMATSU (S14160-1315PS) + 5 layer NDL (22-1313-15-S)
- 40 sensitive layers, total readout channels: 12,960 (4cm×4cm), 5 backup layers.
- Uniformity testing of AHCAL scintillator tiles: light yield winthin 10% deviation
  - Expected the light yield of the scintillator is greater than 40p.e.
  - Expected light yield uniformity around ±10%.

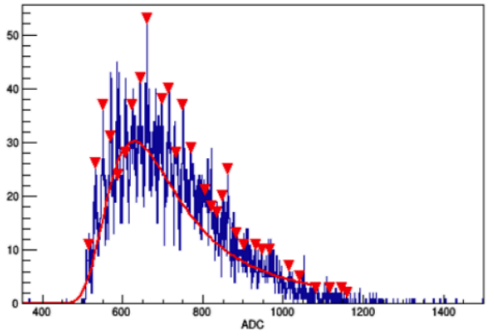
NDL
40 pe/MIP



S13360-1315PE
13 pe/MIP



S14160-1315PS
16 pe/MIP

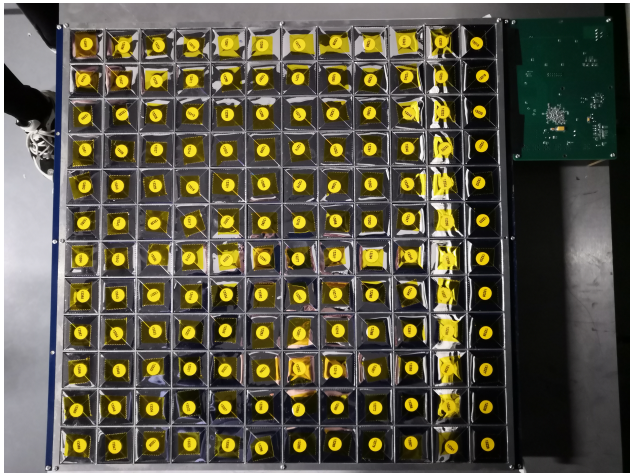


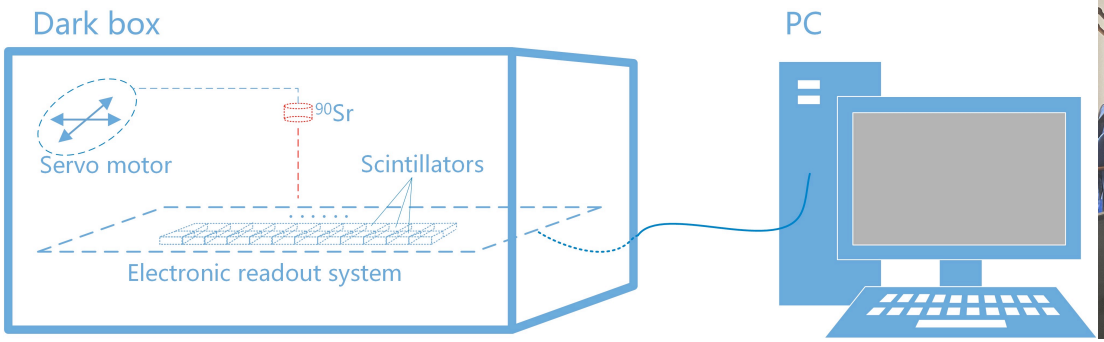
Reference about "Study of SiPM for CEPC-AHCAL", NIMA 980 (2020) 164481

Scintillator tiles batch testing system

- 3 batch test system in total, USTC + SJTU + IHEP.
- Sr90 (2.28 MeV electron)
- 4 SPIROC2E+ 144 SiPMs (S13360-1325PEs)+FPGA in DIF
- Calibration and light yield measured by batch test system:

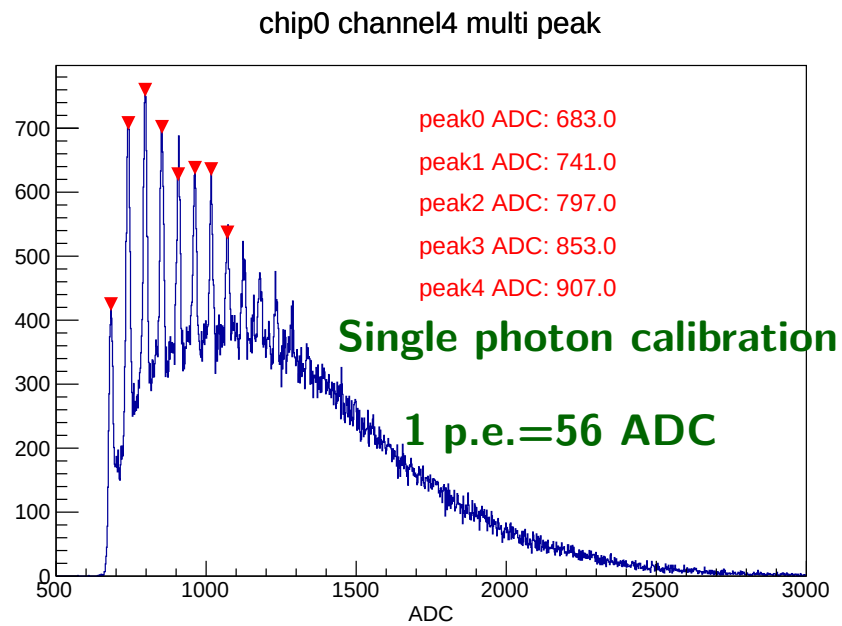
$$LY = \frac{ADC_{MIP} - ADC_{baseline}}{Gain_{SinglePhoton}} (perMIP) \quad (1)$$

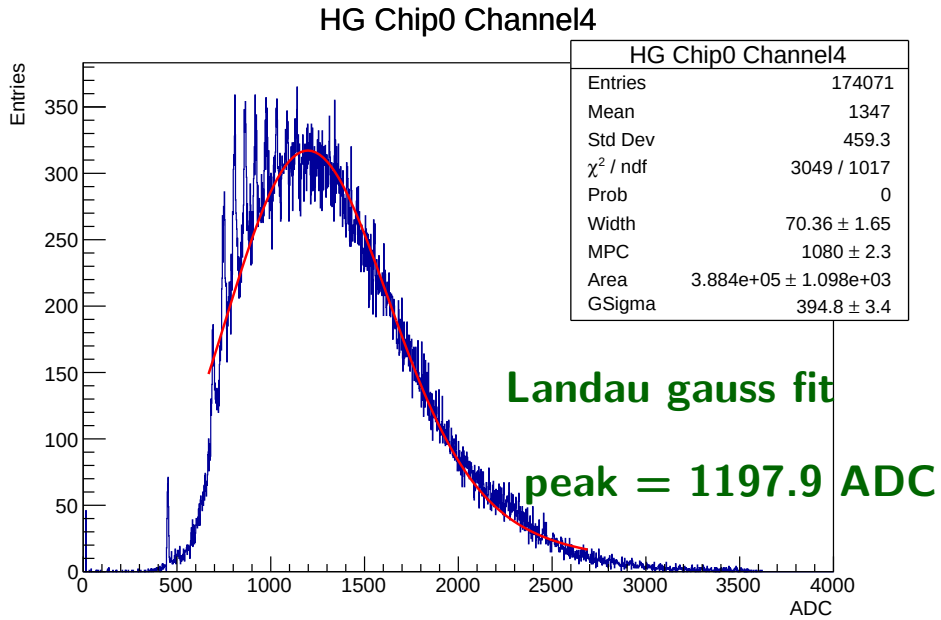


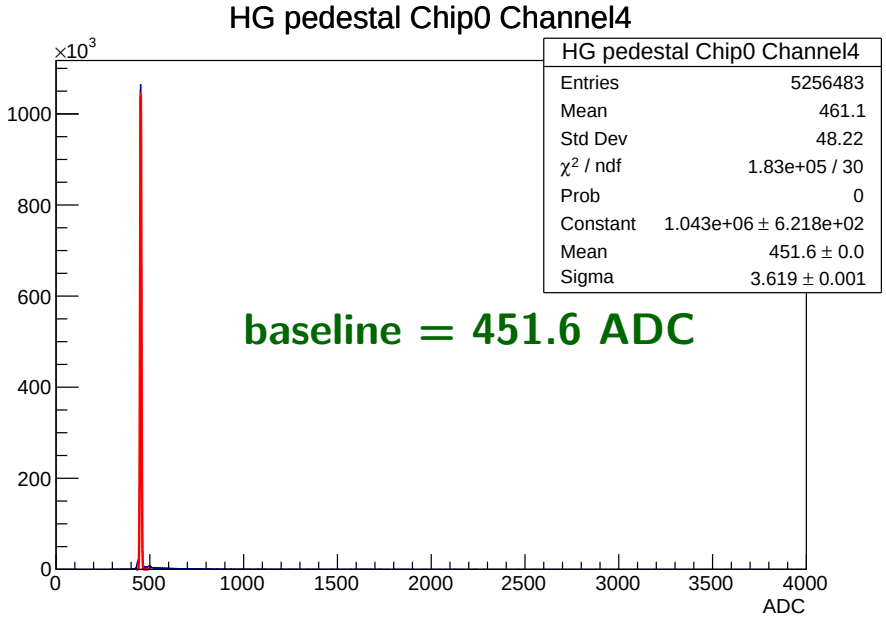


Reference: JINST15 C10006 (2020)

Batch test result - light yield



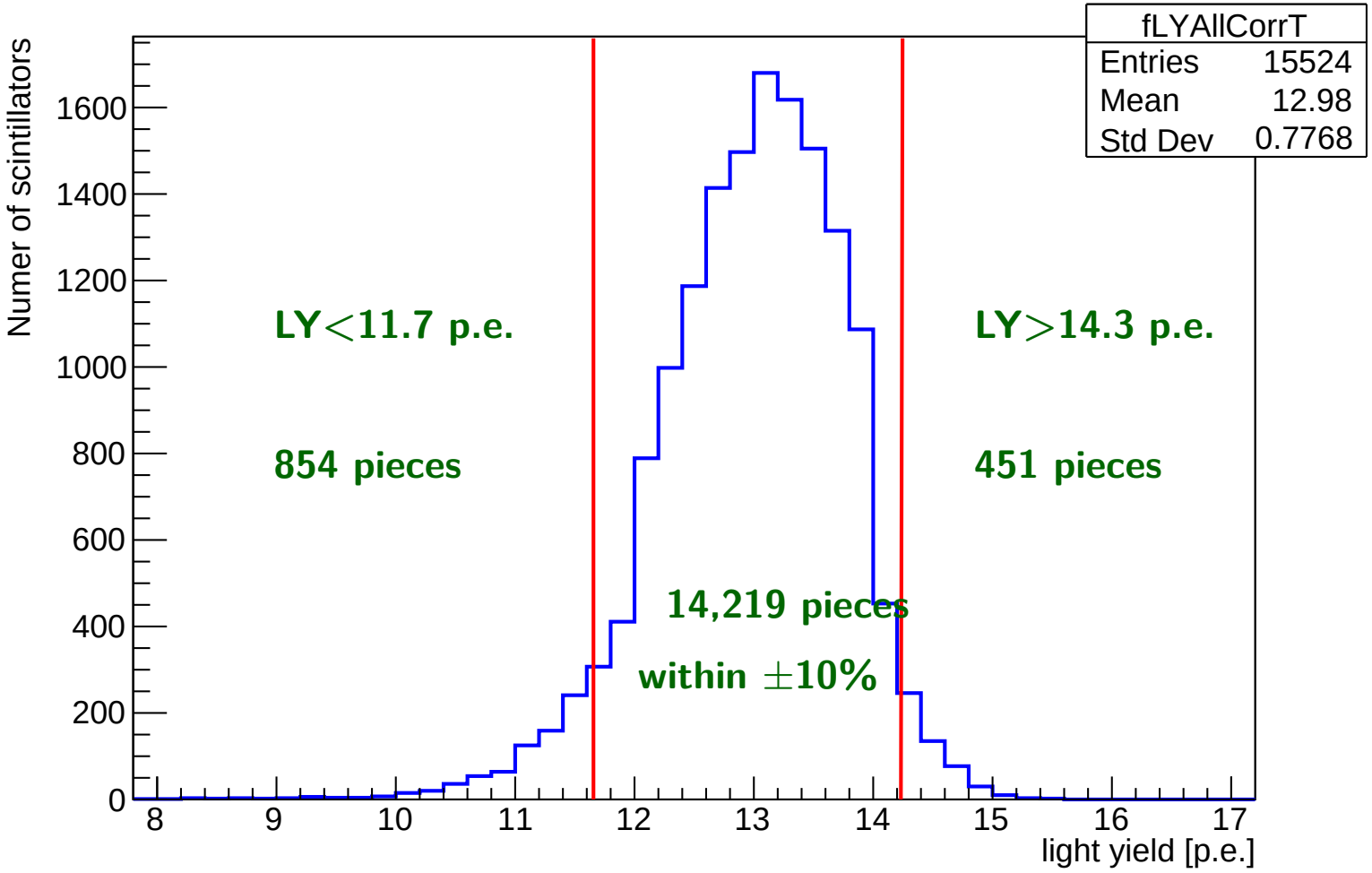




$$LY = \frac{ADC_{MIP} - ADC_{baseline}}{Gain_{SinglePhoton}} (perMIP) \quad (2)$$

LY=(1197.9-451.6)/56=13.33p.e.

Scintillators batch testing result

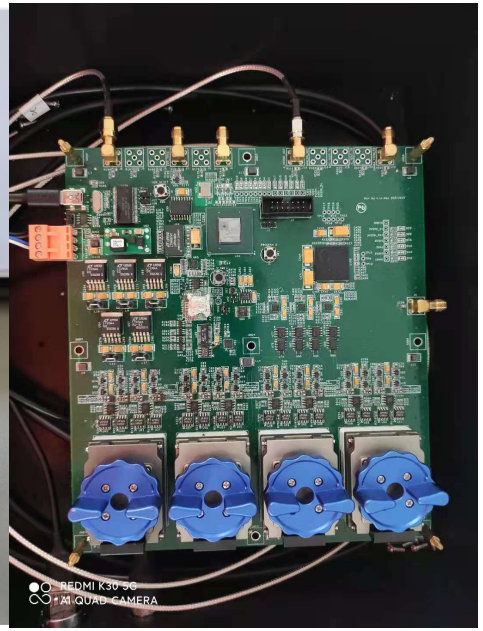


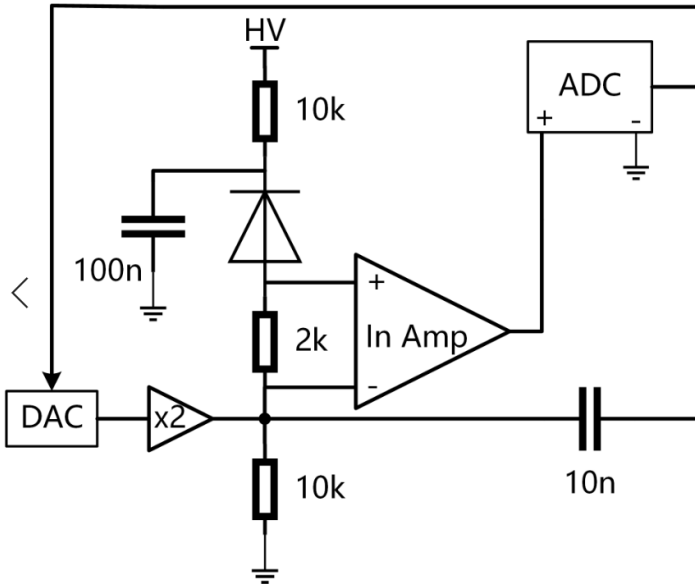
- About 91.6% of scintillators are qualified within 10% of LY window.

SiPM Batch Test

SiPM Batch Test: (Result from Yukun Shi)

- 16 channels, SKIROC + discrete-circuit readout.
- One LED for 4 SiPMs calibration.
- Determine working voltage:
  - Single photon separation with LED
  - Operating at best SNR
- DCR and gain control
  - SiPM with too high DCR should be abandoned
  - Uniformity of SiPMs' gain should be controlled
- NDL SiPMs test finished, HAMAMATSU SiPMs in progress.

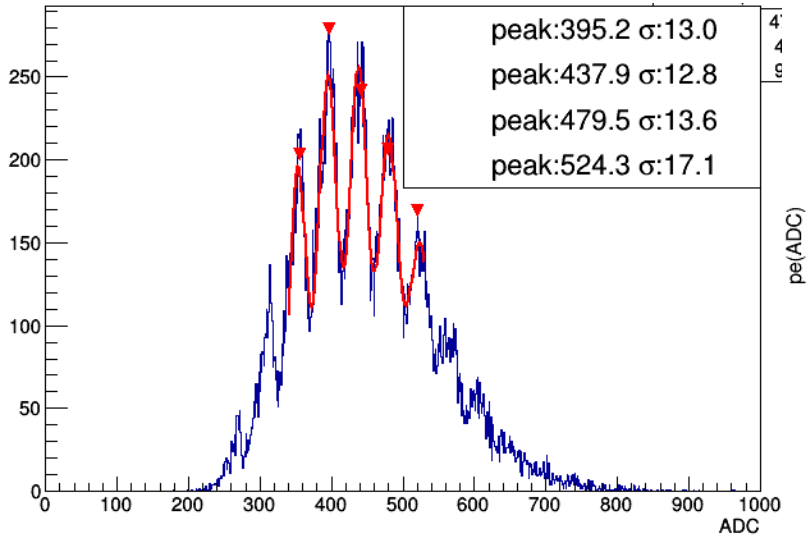


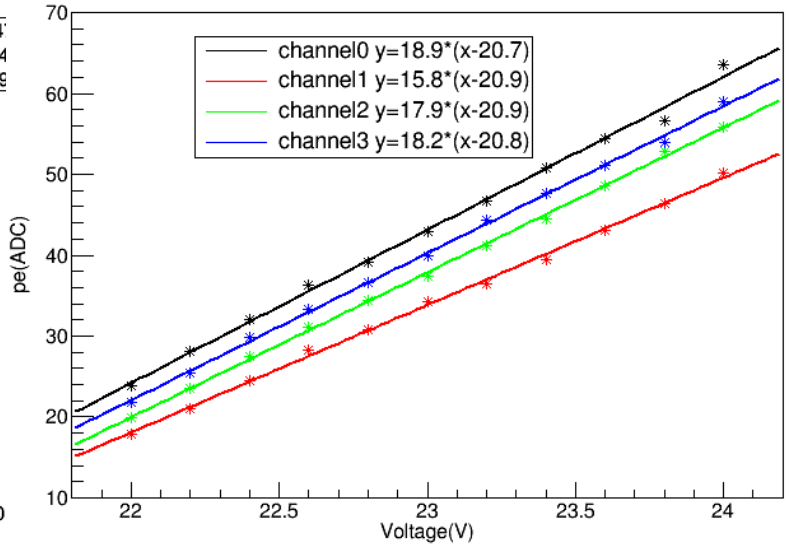


LED spectrum

NDL SiPM test: (Result from Yukun Shi)

- Different working voltage has been scanned
- Linear fit is used for the V-gain plots
- V break down is defined as the x intercept

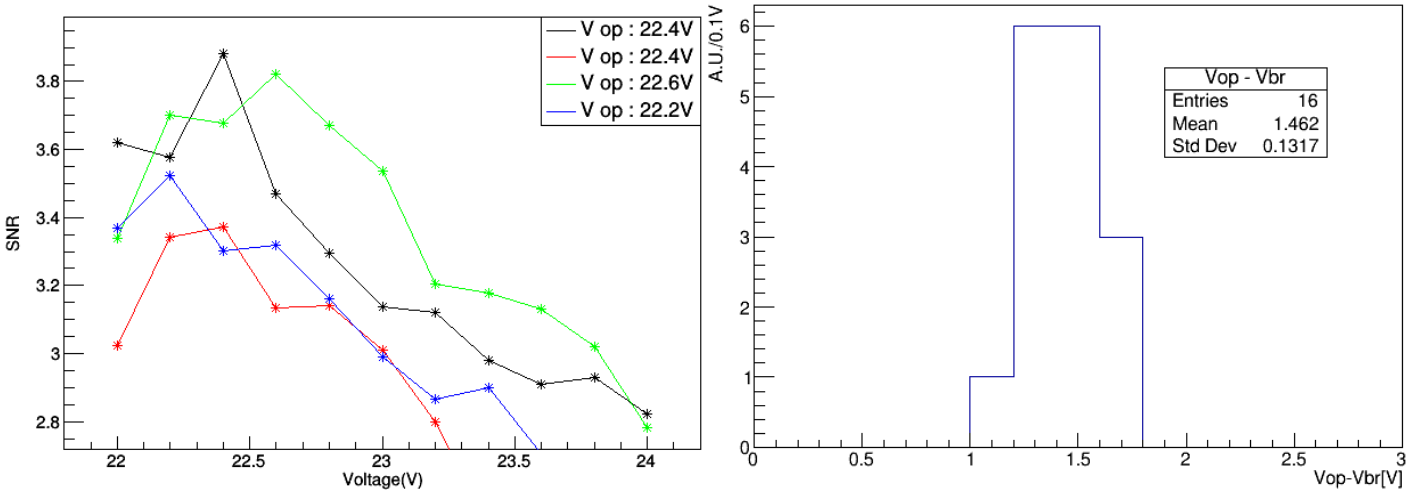




V operation

NDL SiPM test: (Result from Yukun Shi)

- The SNR is defined as peak/σ
- The V operation is the working voltage with best SNR
- The Vop is generally 1.5V larger than Vbr



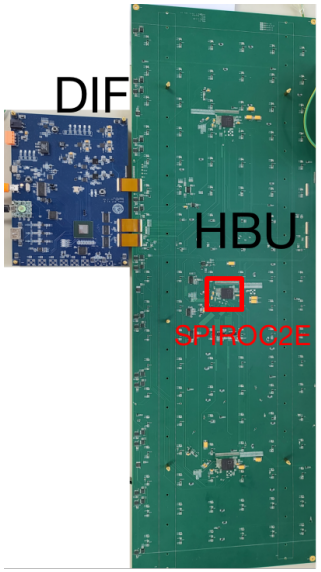
In progress...

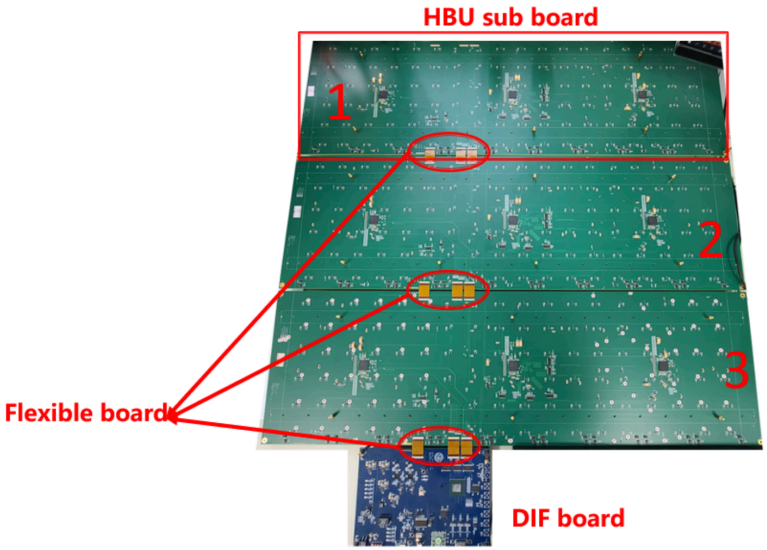
Content

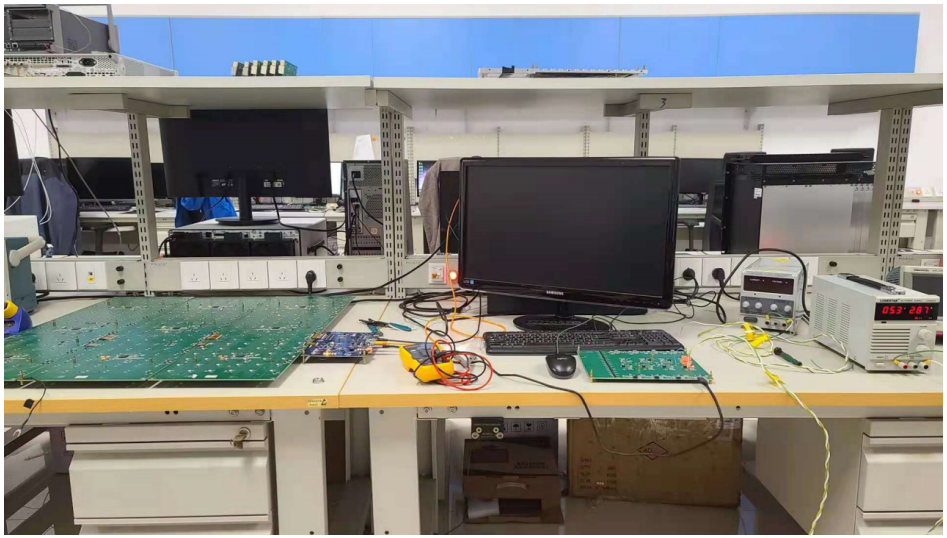
AHCAL readout electronics and DAQ

Result from Zhongtao Shen.

- ASIC design: 9 SPIROC2E
- HBU design: 18×18 =324 readout channel per layer
  - The function of signal readout, electronics calibration, light calibration and temperature monitor.
- DAQ system development: FELIX card+DAQ board+DIF (Data Interface) boards+HBU

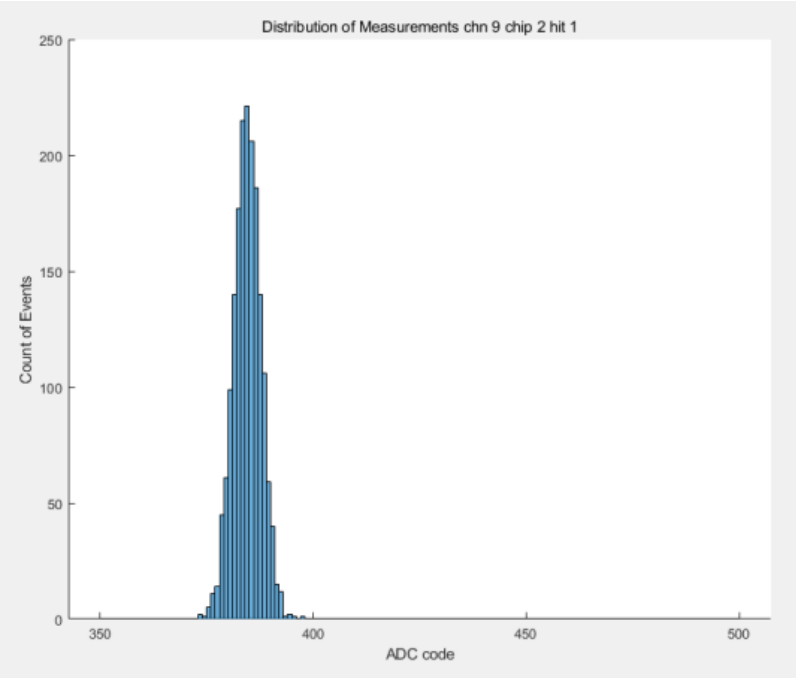


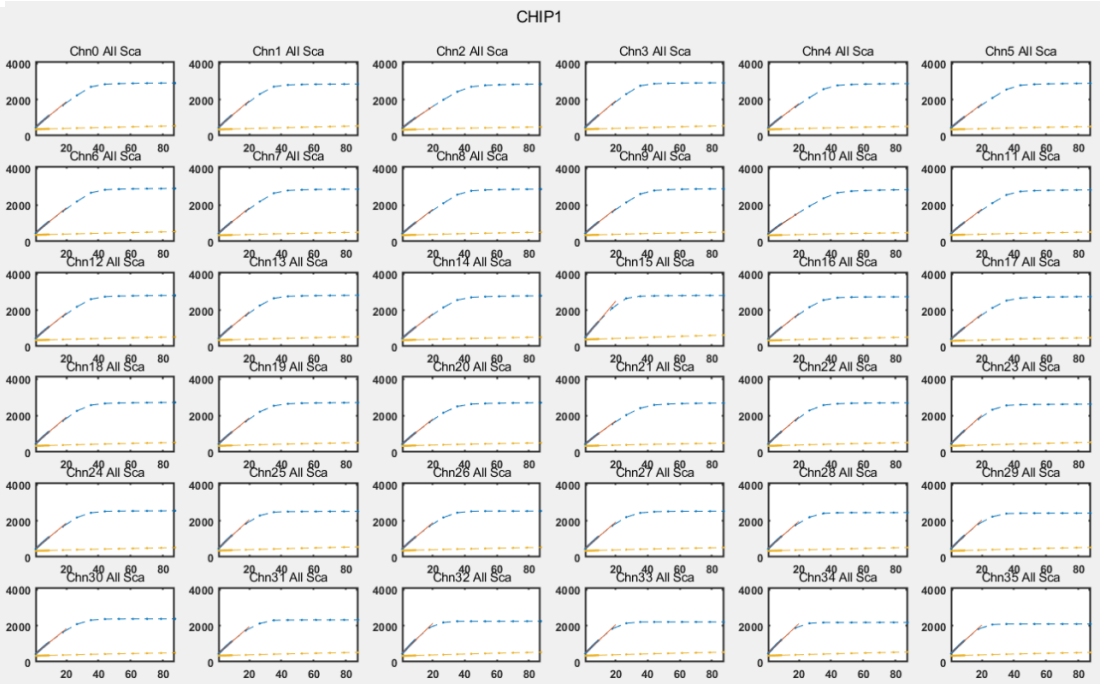




HBU Electronic test

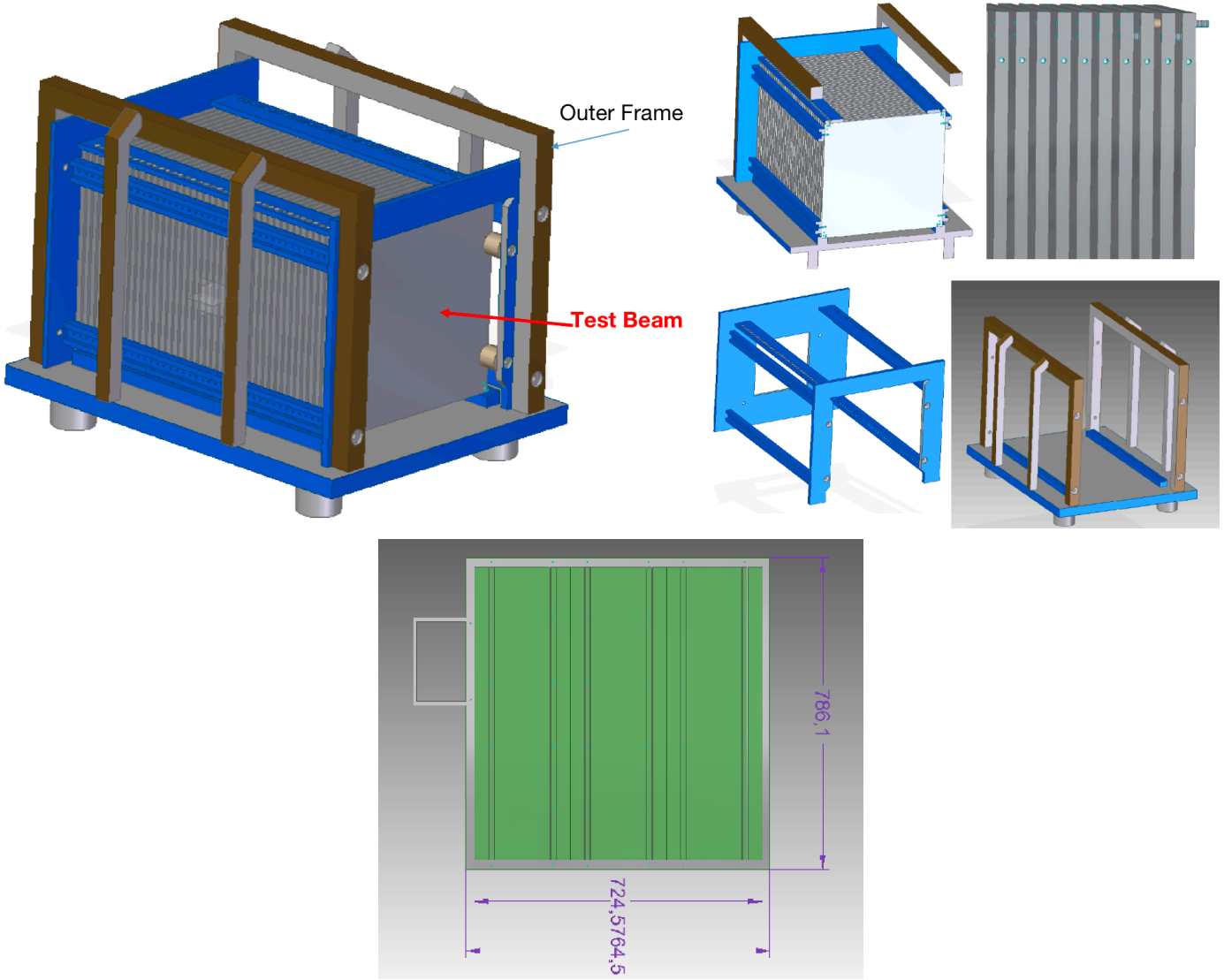
The pedestal and charge calibration results mean that the chips are working normally.



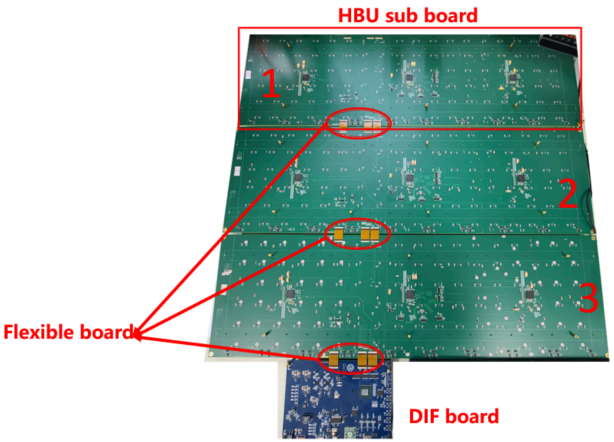


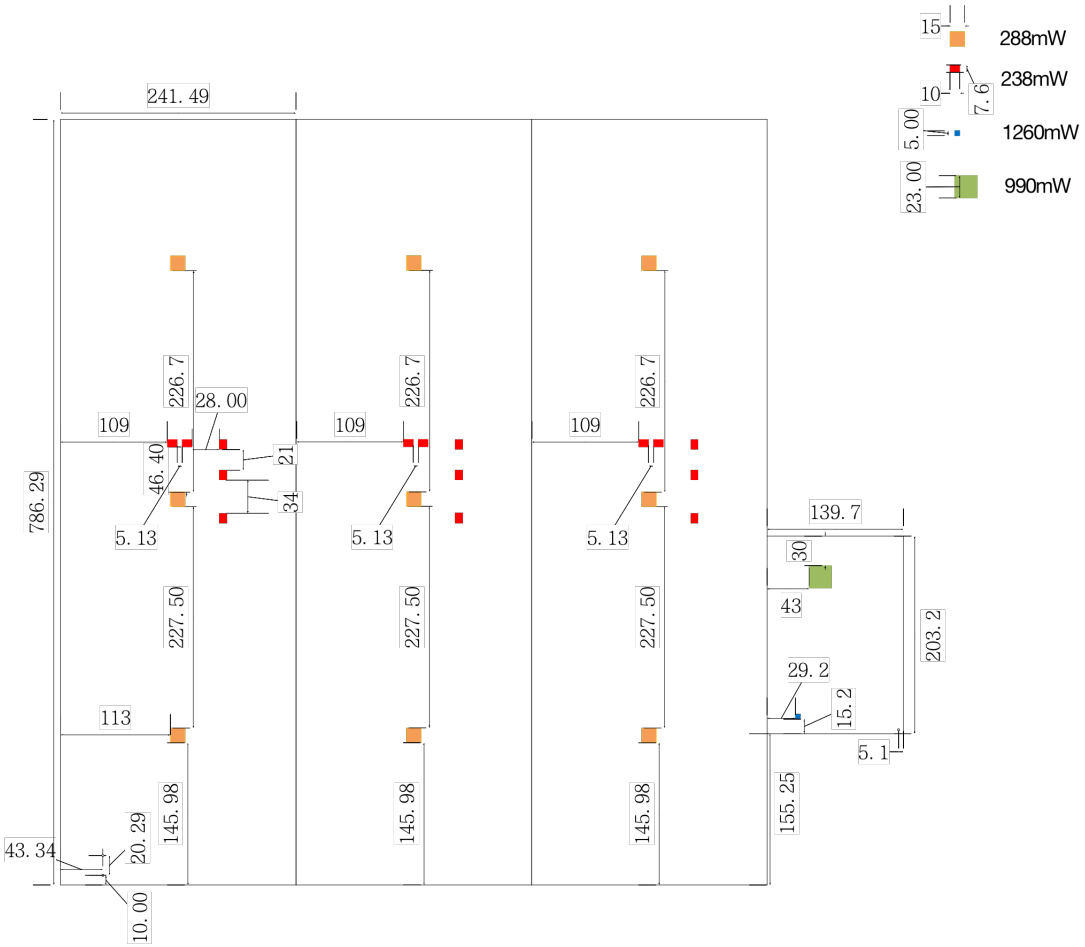
Content

Mechanic Structure



HBU consumption and cooling



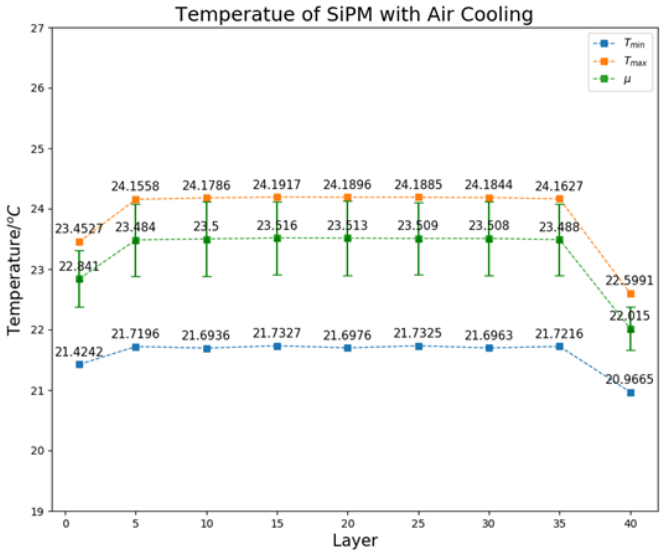


The power consumption of the current version of HBU is about 10W.

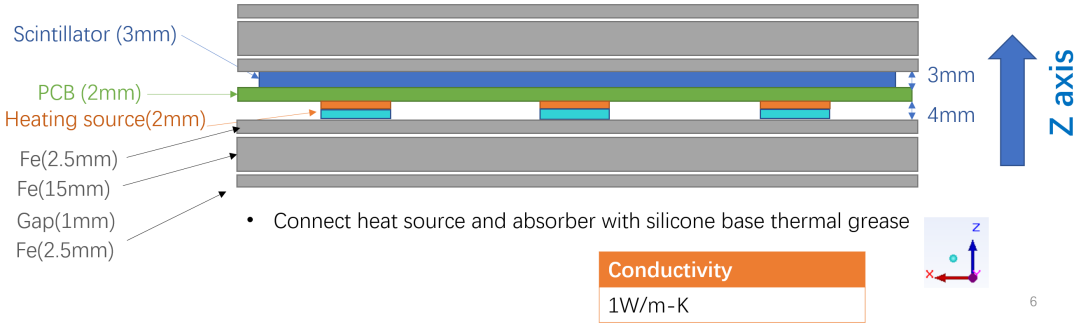
HBU consumption and cooling simulation

Result from Siyuan Song

- The thermal conductivity of Fe touch the heating source makes the temperature distribution more uniform.
- (Fe-Heating source-PCB-Scintillator)*n-Fe structure designed
- Performance of fans with air flow cooling simulated.
  - Reduce the overall temperature, but cause the non uniformity.
  - Multilayer, the inner layers have a relatively higher temperature.
  - The simulation effect of air cooling is not bad.



Room temperature: 20°, heating source highest: 30°, controlled blew 25°



Content

Summary and next plan

Sensitive cells and Detector:

- Scintillator tile: GNKD PS Tile, batch testing finish, 91.6% pieces are quanlified within 10% of LY window.
- SiPM: 35+5 layer HMAMMATSU (S14160-1315PS) batch testing in progress, 5 layer NDL (22-1313-15-S) batch testing finished.
- Design, assembling and production of sensitive layers in progress.

Electronics:

- Developed HBU.
- Production of HBU and DAQ boards in progress.

Mechanical part:

- Design of absorb layers and supporting structure.
- Design of cooling system based on simulation result.

AHCAL Prototype

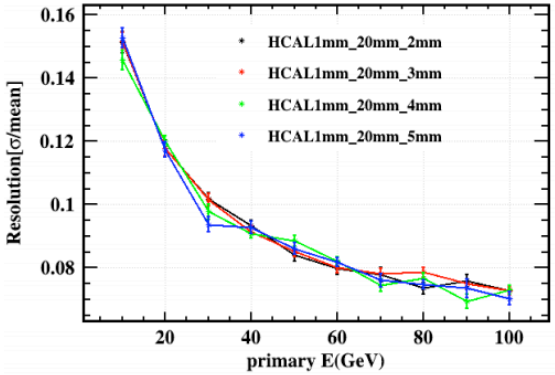
- The prototype construction will start from the end of this year.
- The cosmic and beam test is expected next year.

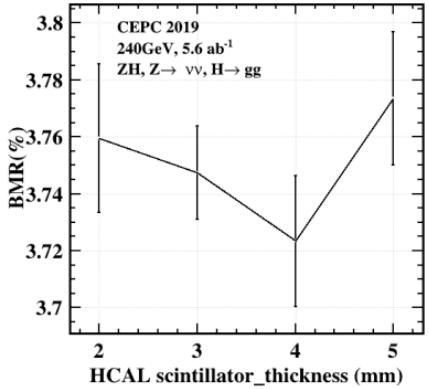
Thank You!.

Cell size simulation

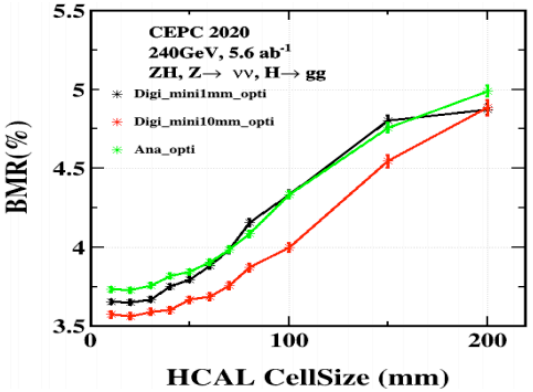
Result from Yukun Shi

Scintillator thickness





Cell size



Scintillator batch testing system