

Status of ECAL calorimeter R&D

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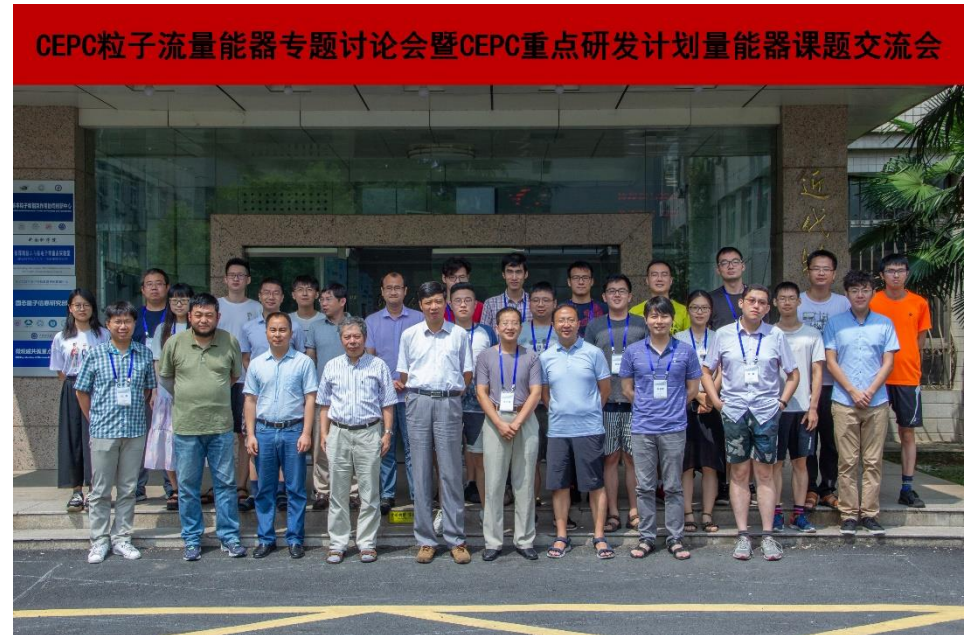
State Key Laboratory of Particle Detection and
Electronics

On behalf of the CEPC calorimeter working group



CEPC粒子流量能器专题讨论会暨CEPC重点研发计划量能器课题交流会

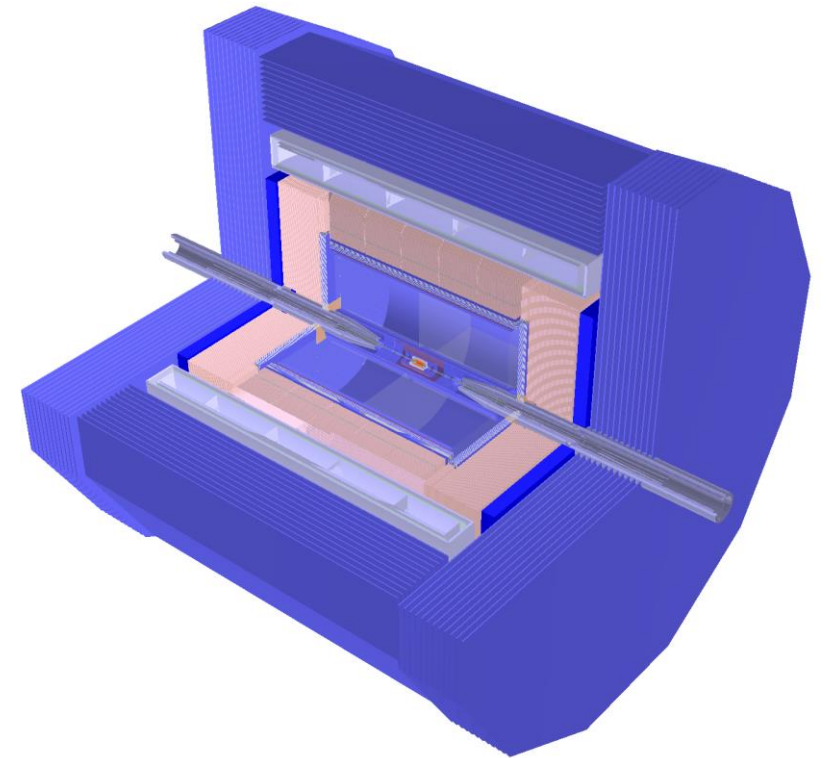
- 2 days CEPC calorimetry symposium @Hefei, 8-9 August
 - > ECAL crucial parameters optimization
 - > Introduction of CEPC ECAL R&D project
 - > ECAL unit study and optimization
 - > Electronics(EBU, DIF & DAQ) study of ECAL
 - > Mechanical structure study of ECAL prototype
 - > ECAL prototype progress



<http://cicpi.ustc.edu.cn/indico/conferenceOtherViews.py?confId=2131&view=standard>

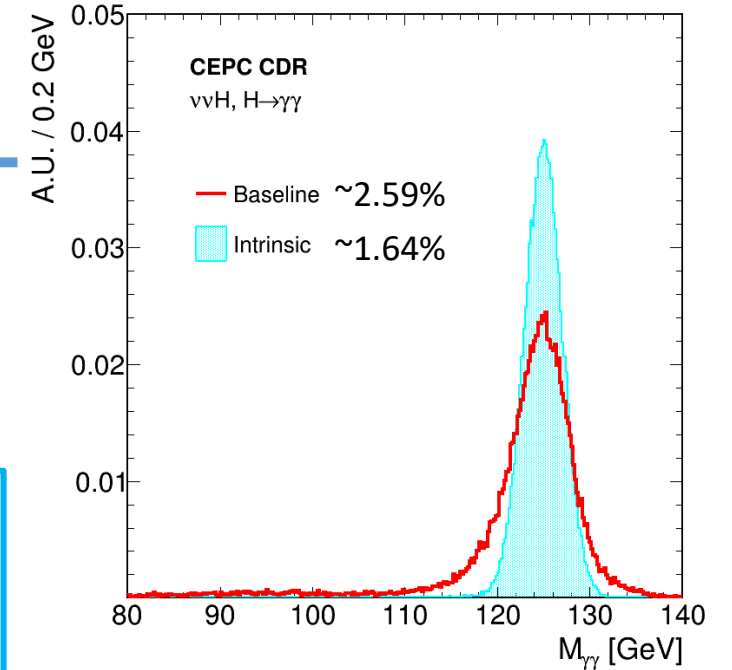
Outline

- Introduction: requirements of ECAL performance and prototype
- ECAL Optimization and Unit study
 - Simulation and Optimization
 - Photon sensor
 - Scintillator strip
 - Readout Electronics
- Prototype progress and schedule until BT
- Conclusion



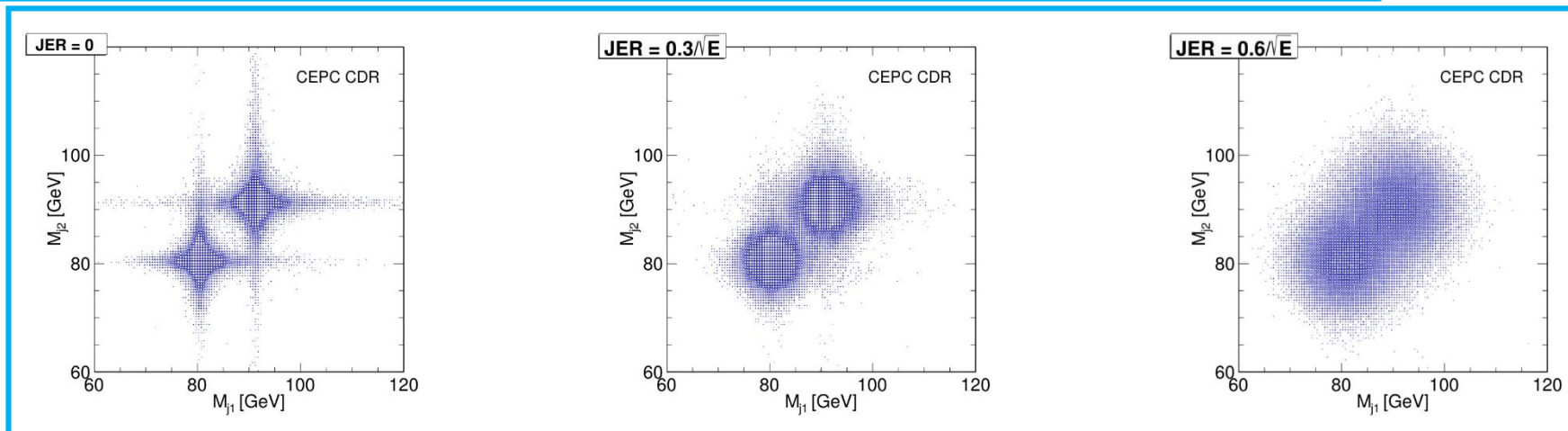
Performance requirements

$H \rightarrow q\bar{q}, WW^*, ZZ^*$	$\text{BR}(H \rightarrow q\bar{q}, WW^*, ZZ^*)$	ECAL HCAL	$\sigma_E^{\text{jet}}/E =$ $3 \sim 4\% \text{ at } 100 \text{ GeV}$
$H \rightarrow \gamma\gamma$	$\text{BR}(H \rightarrow \gamma\gamma)$	ECAL	$\Delta E/E =$ $\frac{0.20}{\sqrt{E(\text{GeV})}} \oplus 0.01$



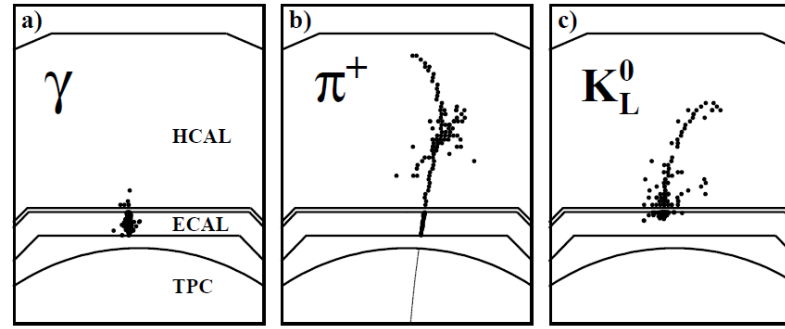
- Energy resolution of γ :
 - $\sigma_E/E \approx 16\%/\sqrt{E} \oplus 1\%$
- Jet energy resolution (combined tracker, ECAL and HCAL)
 - $\sigma_E/E \approx (3\% \sim 4\%) @ 100 \text{ GeV}$

CEPC CDR : http://cepc.ihep.ac.cn/CEPC_CDR_Vol2_Physics-Detector.pdf



$WW \rightarrow 4j$ and $ZZ \rightarrow 4j$

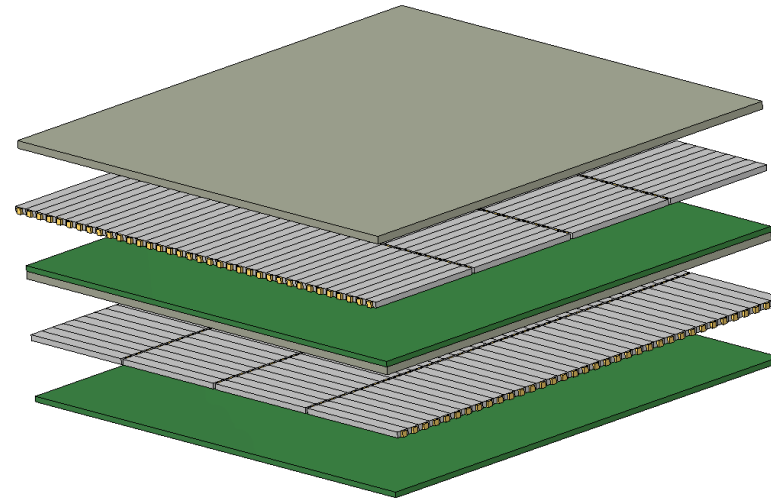
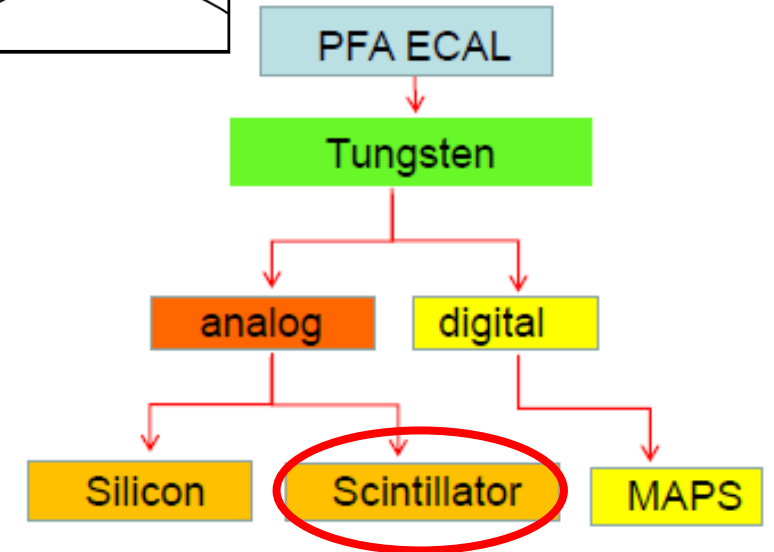
ECAL prototype



- PFA oriented electromagnetic calorimeter

✓ Scintillator-tungsten ECAL

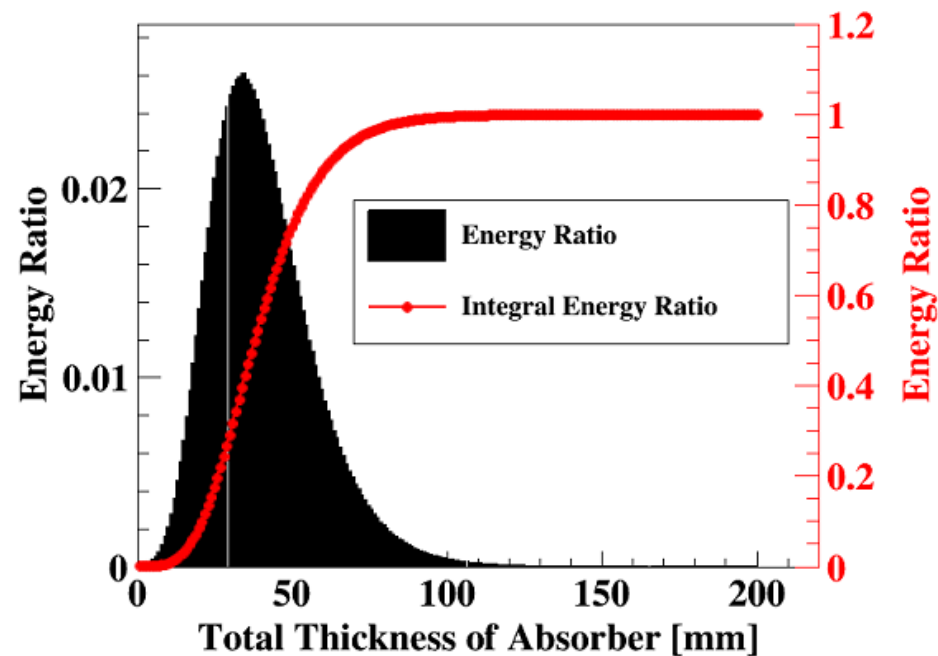
- Sandwich structure
 - Absorber + SD + Electronics
- High granularity
 - $5\text{mm} \times 45\text{mm}$ scintillator strip
- Larger dynamic range
 - Scintillator + SiPM
 - SPIROC Chip



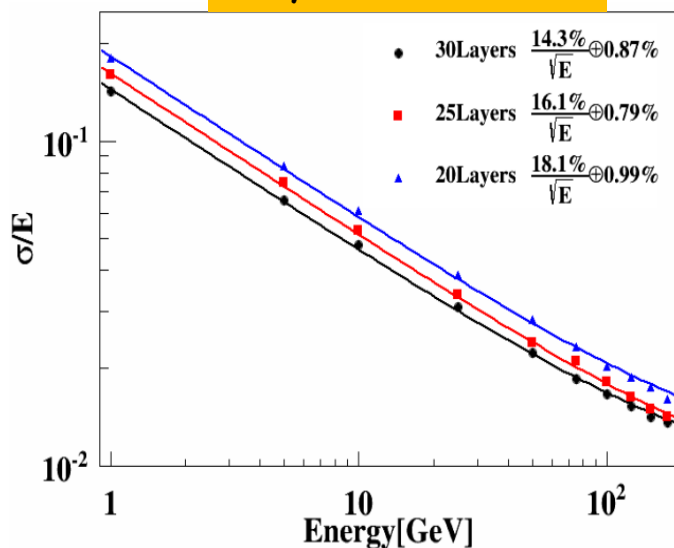
ECAL optimization

ECAL crucial parameters:

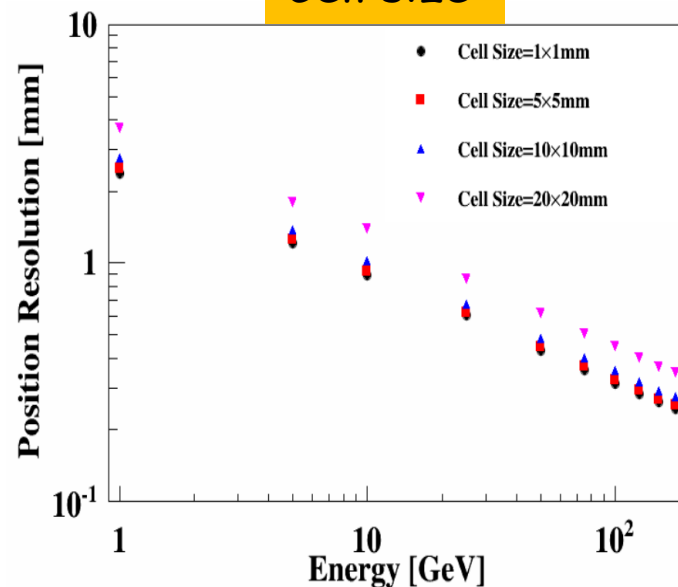
- Absorber thickness: $24X_0$
- Layer number: 30 Layers
- Cell size: $< 10\text{mm} \times 10\text{mm}$
- Dynamic ranger: $1\text{MIP} \sim 800\text{MIPs}$



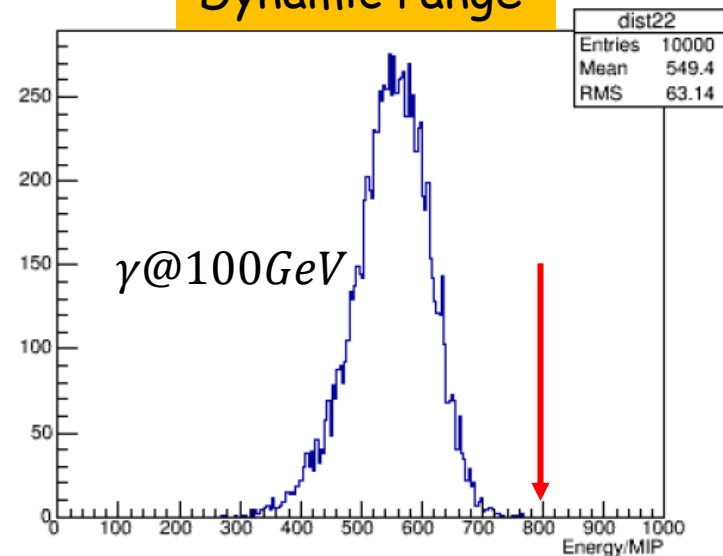
Layers number



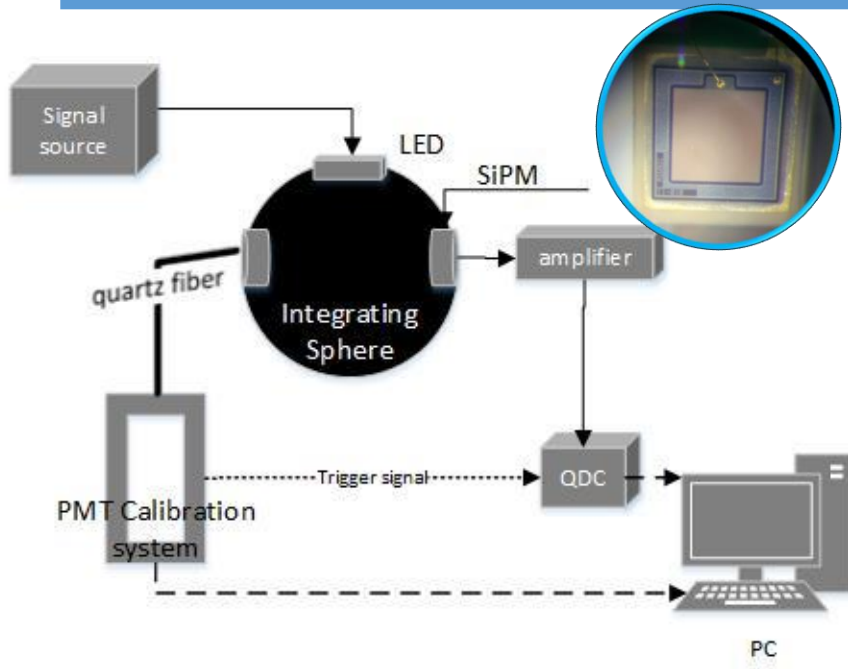
Cell size



Dynamic range

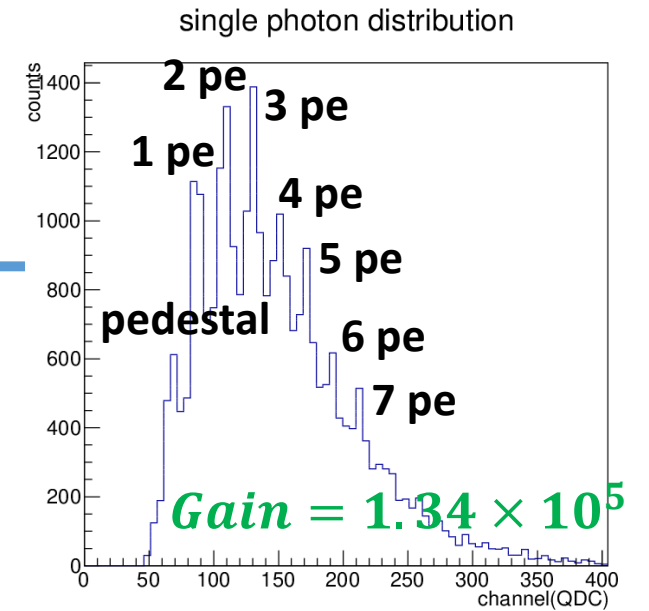


SiPM study

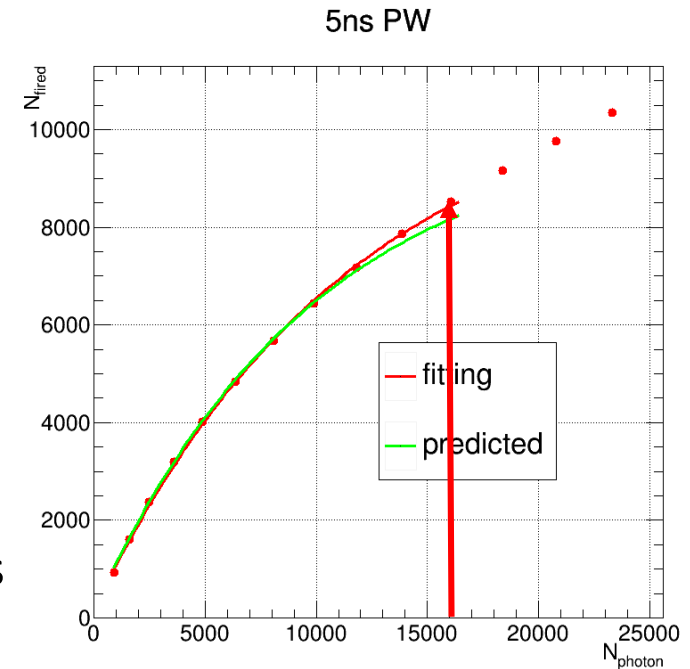


Hamamatsu S12571-010P

- Area: $1\text{mm} \times 1\text{mm}$
- Size: $10\mu\text{m}$
- Pixels: 10K

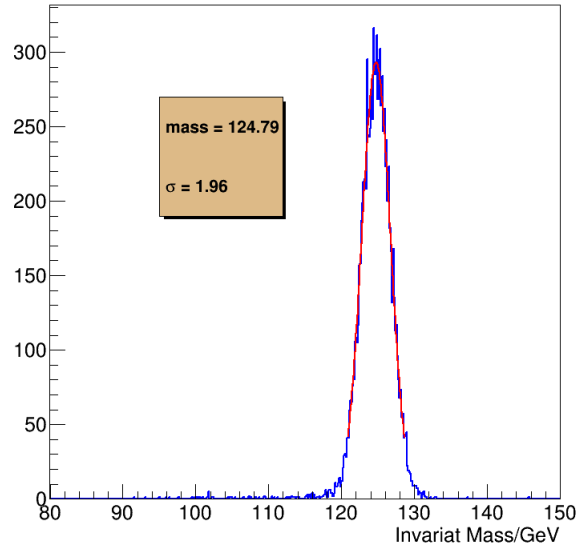


- > SiPM gain calibrated by SPS, 1.3×10^5
- > SiPM effective pixels increase with the photon width
- > SiPM response can be described well with the theoretic formula
- > Through correction SiPM dynamic range can up to 16,000 photons with less than 1% error with 10k pixles

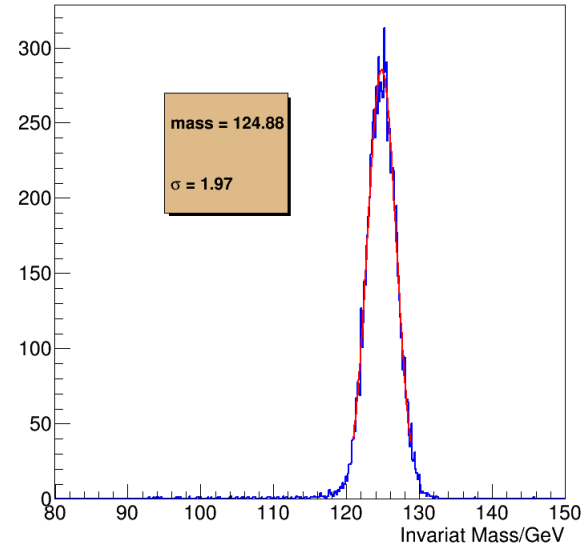


SiPM study

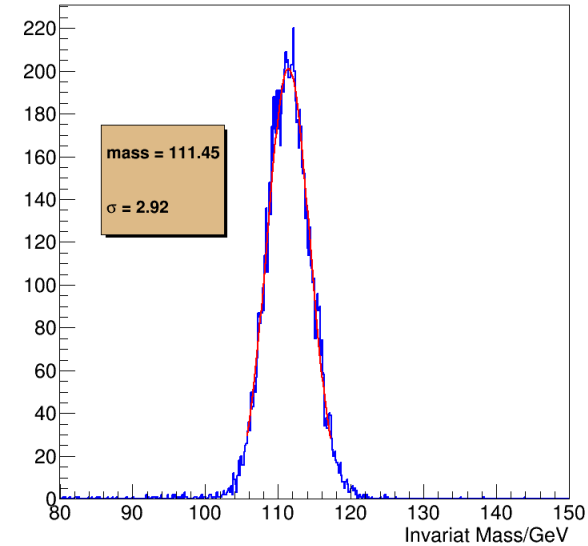
Correction with 10000pixel SiPM & 10% PDE



Correction with 4500pixel SiPM & 25% PDE



Correction with 1600pixel SiPM & 30% PDE

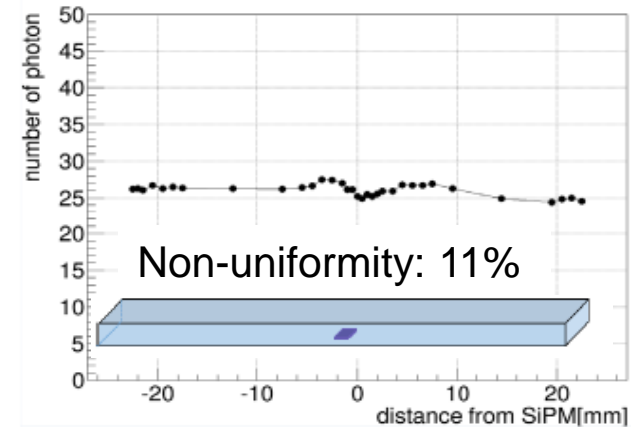
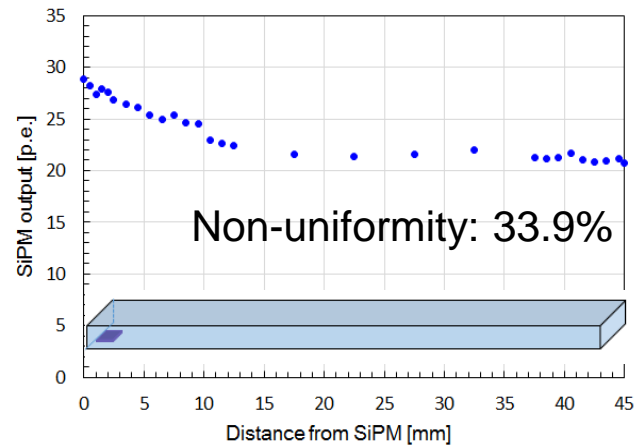
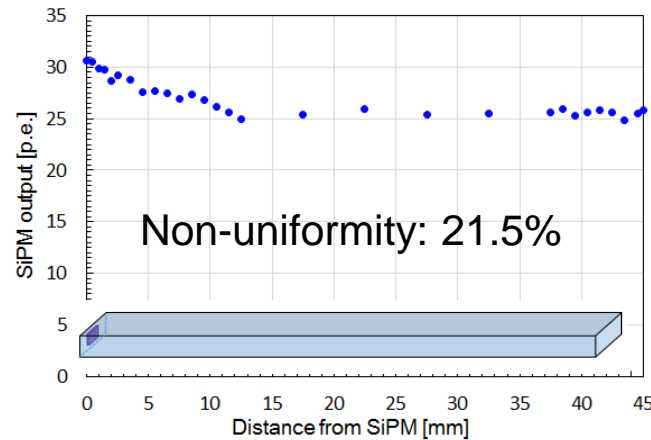


$H \rightarrow \gamma\gamma$

Pixel	10000	4500	1600
MIP LY / p.e.	20	50	60
PDE / %	10	25	30
Mean / GeV	124.79	124.88	111.45
$\sigma/Mean$	1.57%	1.58%	2.62%

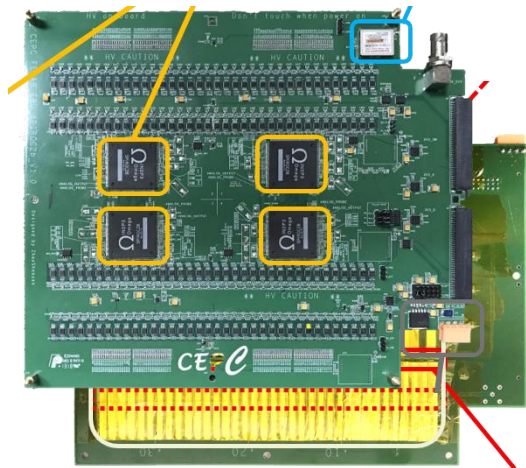
- SiPM with more pixel larger than 10000 is not required

Scintillator strips study

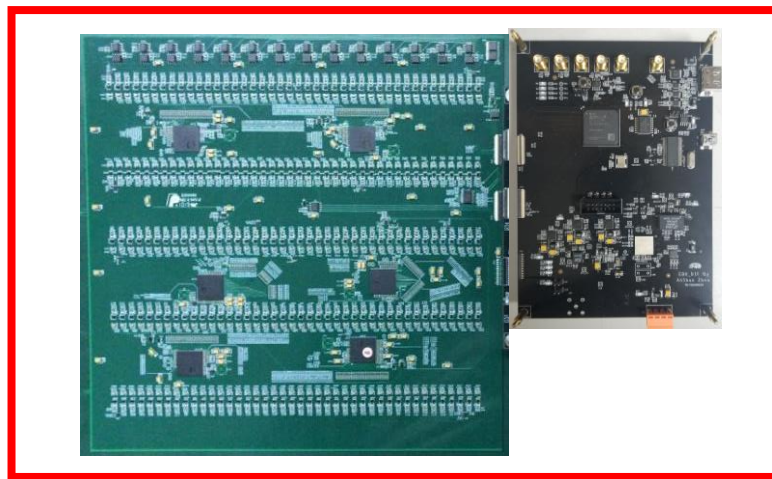
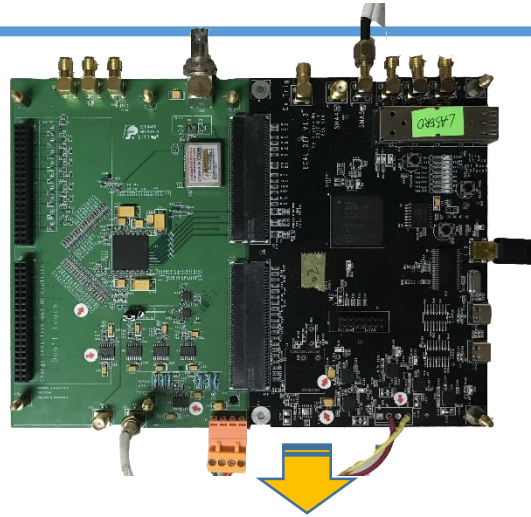


- > Three classes coupling mode i.e. side-end, bottom-end and bottom-center
- > Light outputs along the length of the scintillator strip is non-uniformity, degrades the energy resolution
- > Bottom-center coupling have the minimum non-uniformity
 - Avoiding the dead area between scintillators
 - Simplifying scintillators assembling process
 - Enabling to extend the SiPM area with more pixels

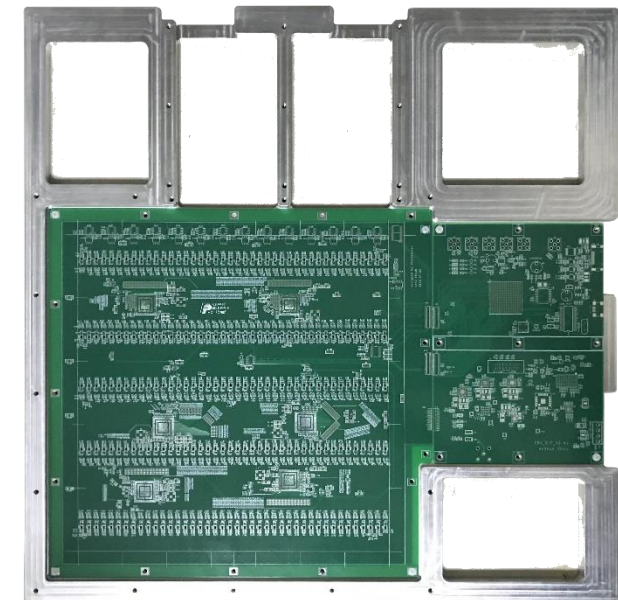
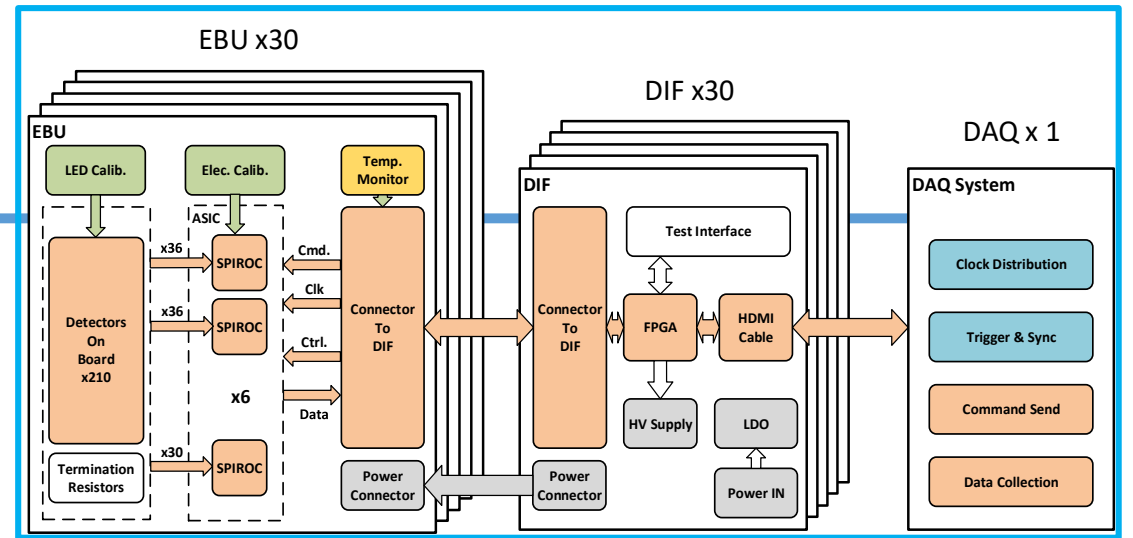
Electronics study



EBU SP2b 144channels

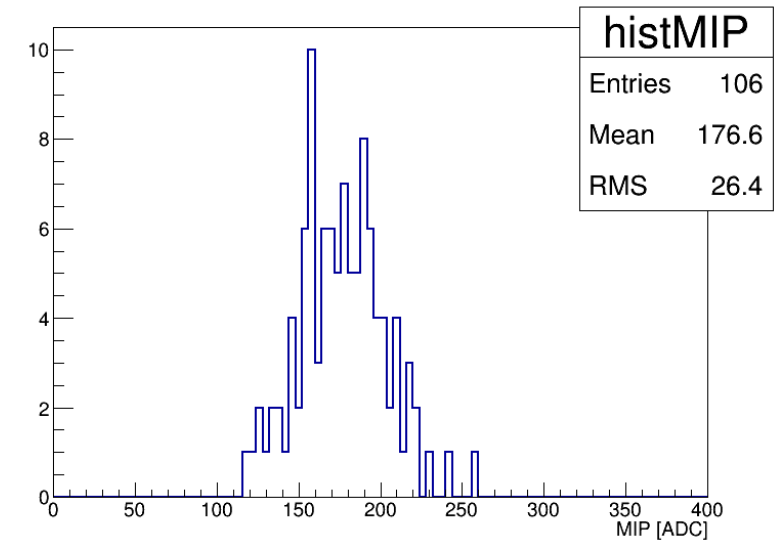
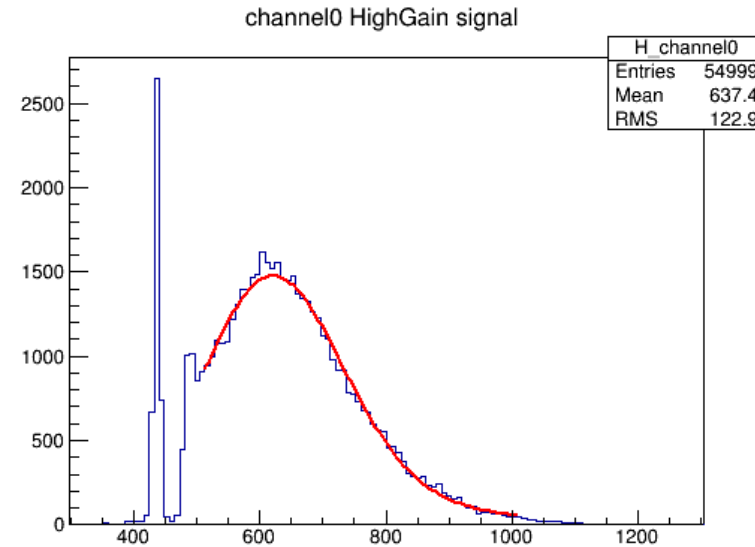
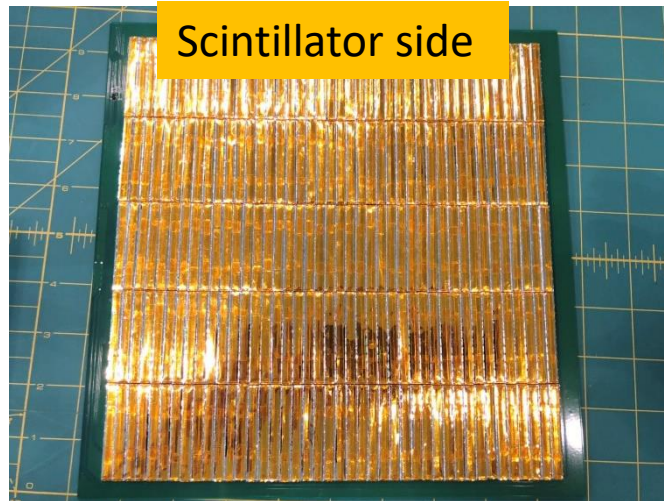
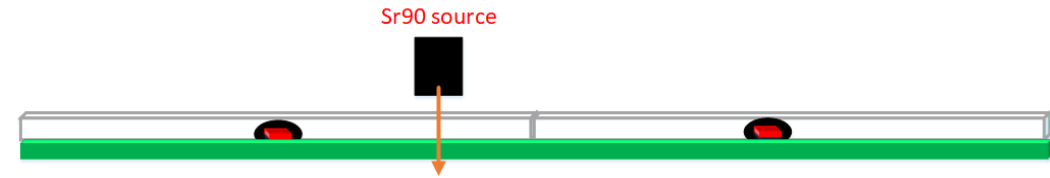


EBU SP2e 210channels



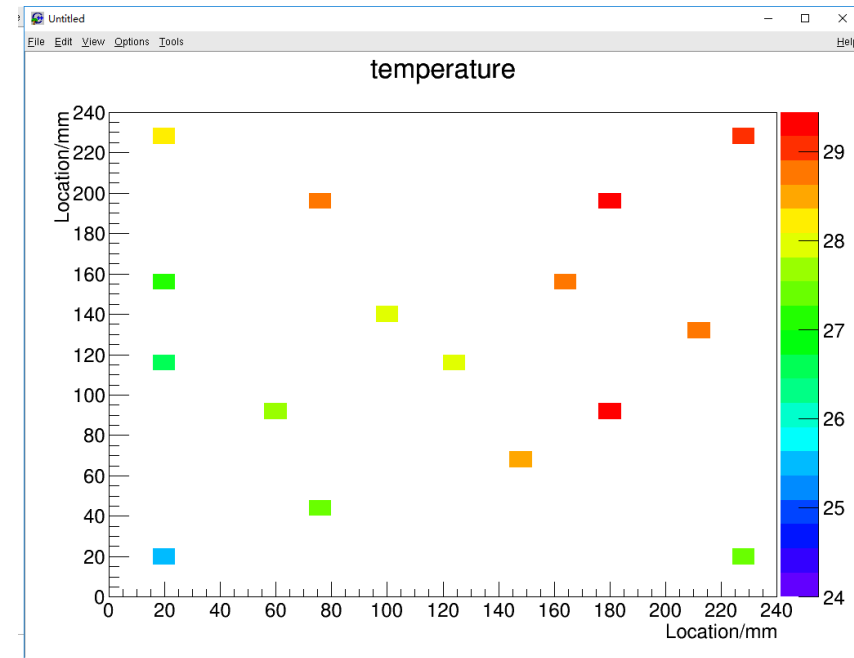
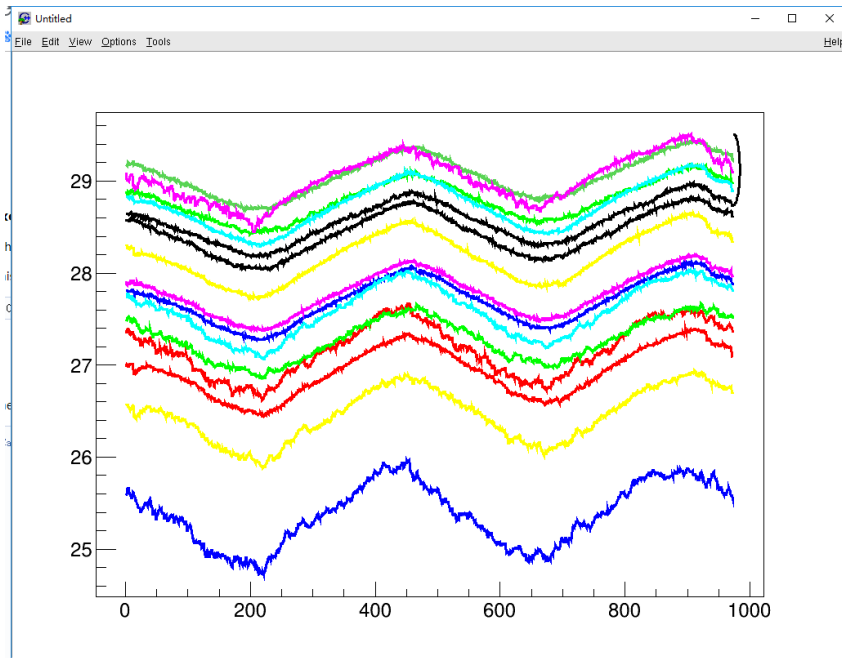
EBU SP2e technological board

EBU2e single layer



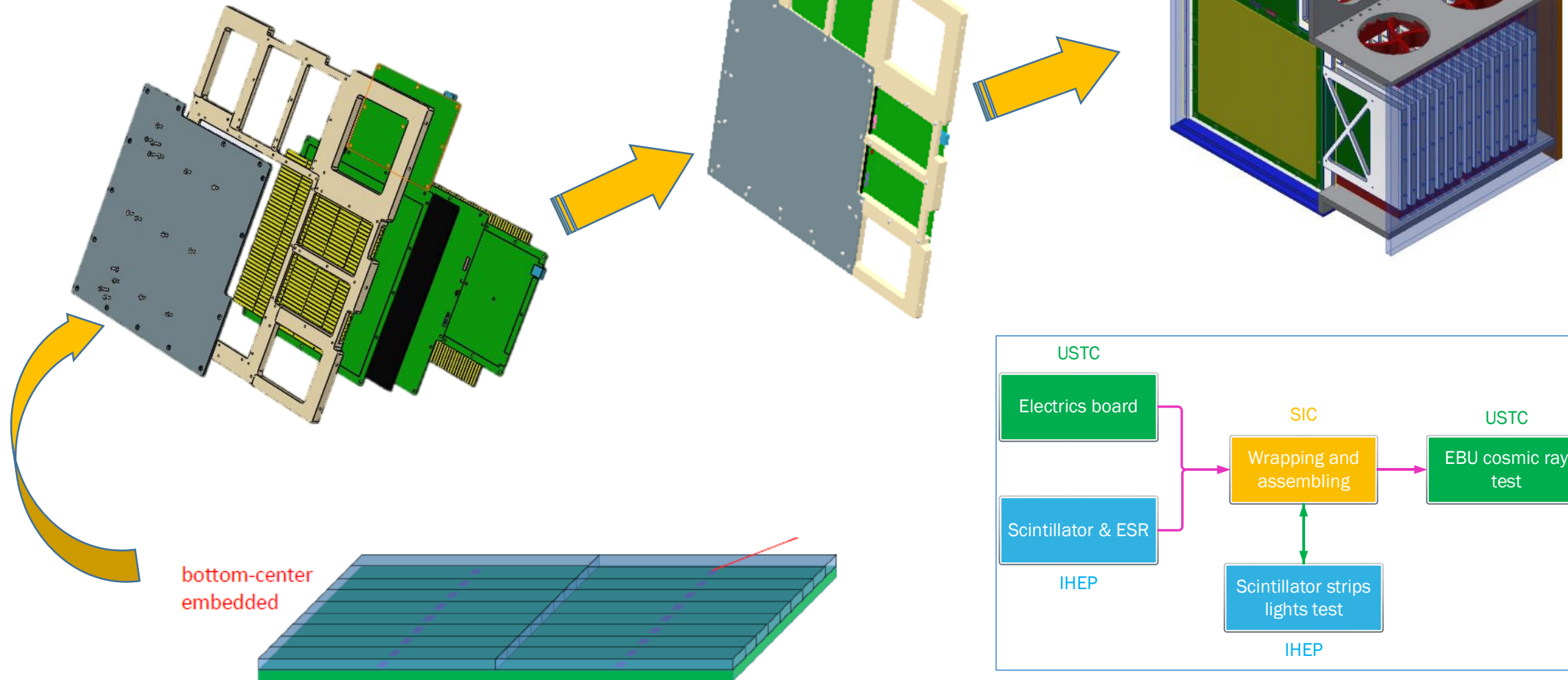
- > 210 channels readout with 6 SP2E chips divided into 5 rows and 42 columns
- > Total thickness is controlled under 6mm (< 1mm deviation) excluding DIF
- > LED calibration and temperature monitor can achieve
- > 106/108 channels can distinguish MIP signal successful

Temperature monitor

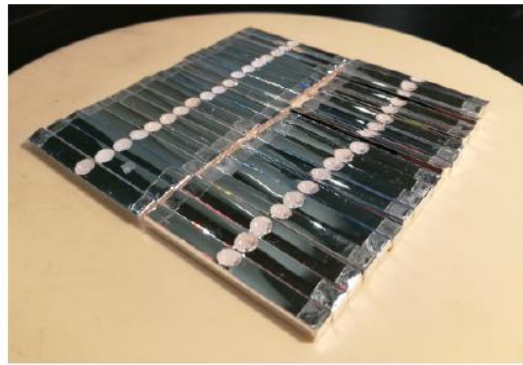
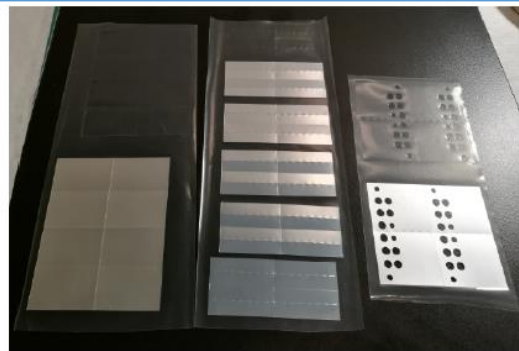
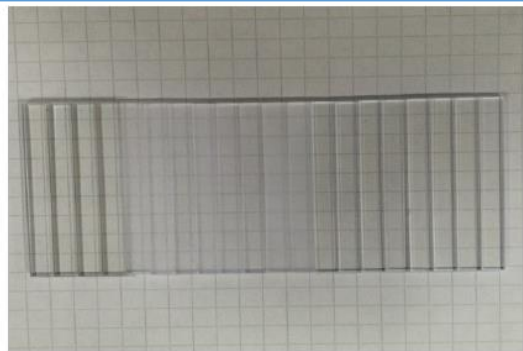
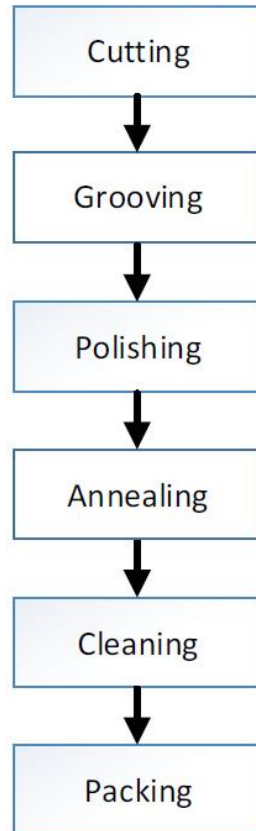


- 16 temperature sensor distribution on the EBU
- Normalized calibration is needed
- 0.1 °C temperature precision can be achieved
- Temperature feedback and DAC compensation **online inaccessible**

ECAL prototype



Wrapped and assembled in SIC



Visual inspection



Size measurement



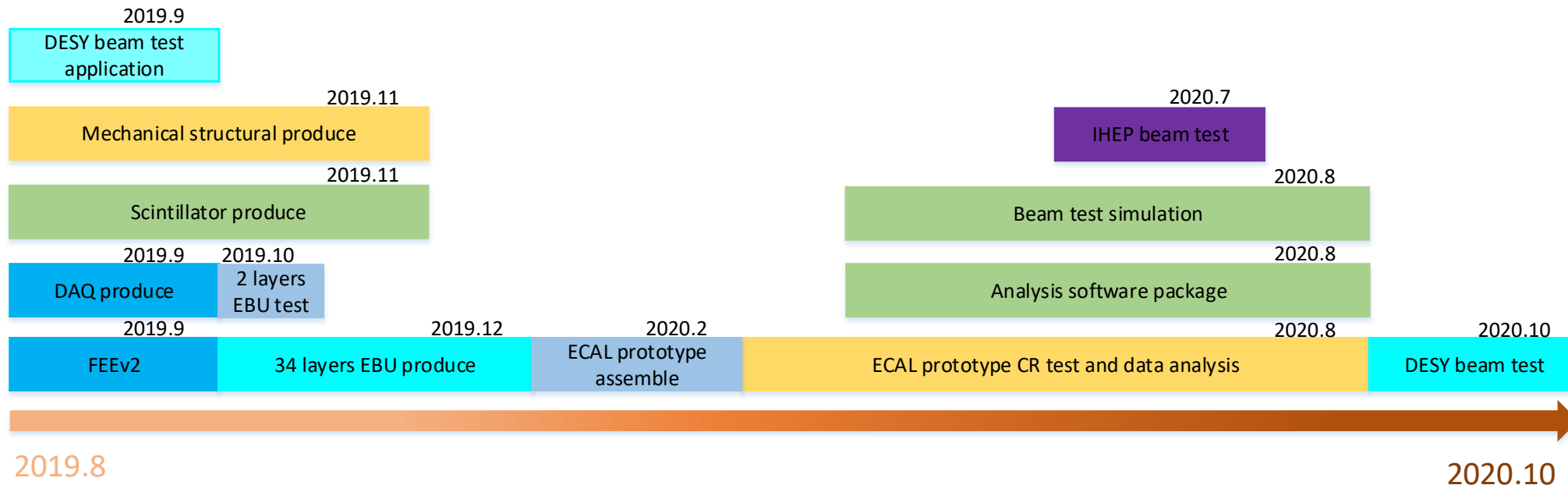
cleaning



assembling

Status and schedule

- ✓ EBU single layer prototype produce and test
- ✓ DIF single layer produce and DAQ system
- ✓ Mechanical structure design and single layer produce
- ✓ SiPMs and scintillators study and purchase



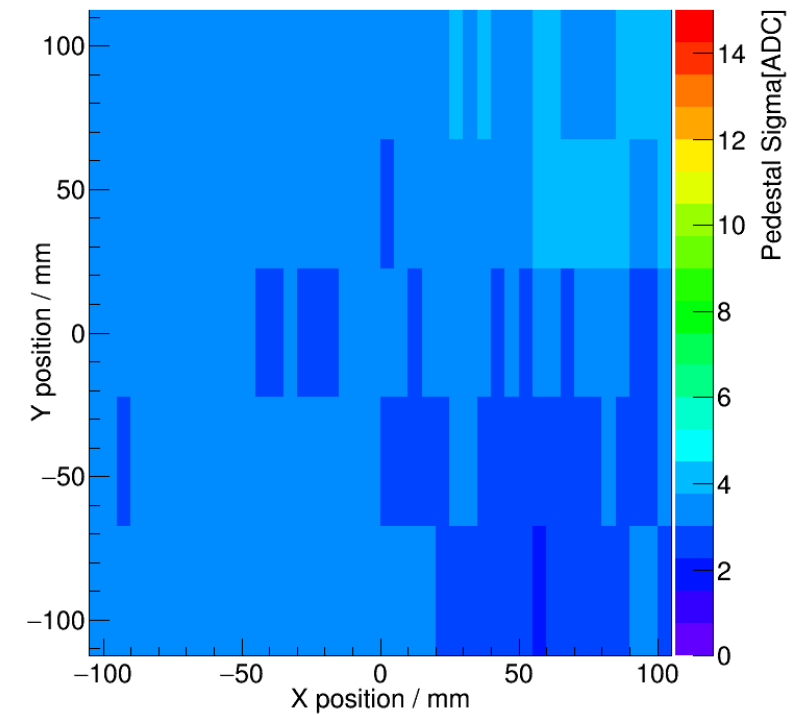
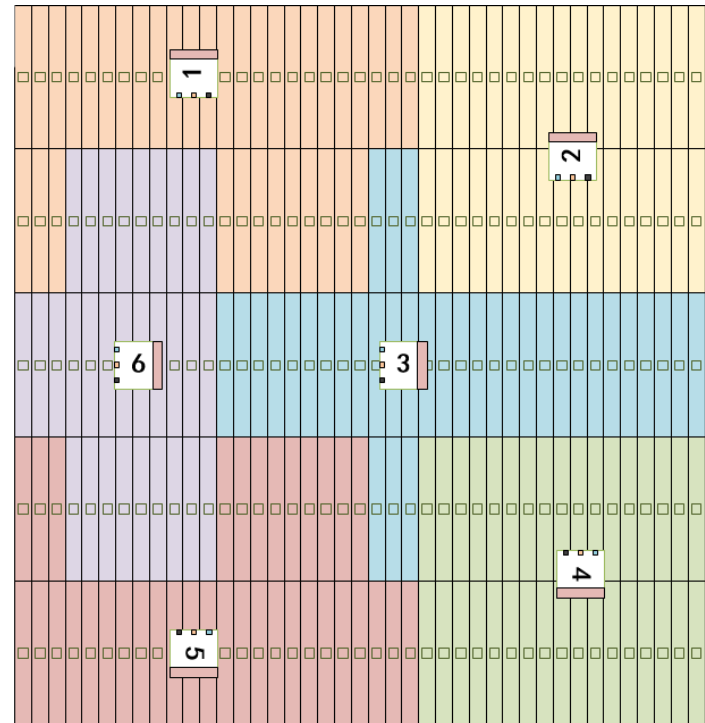
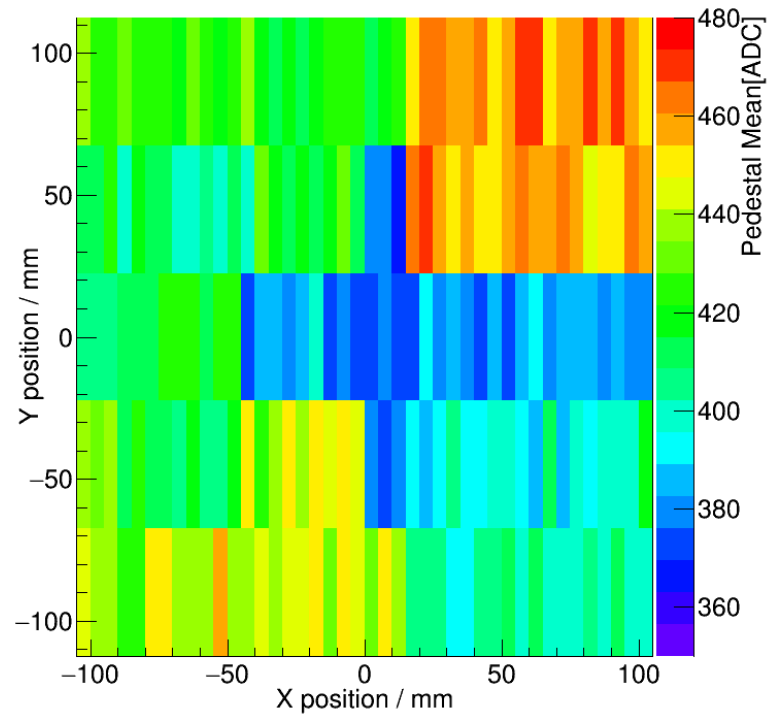
Conclusion

- > ECAL optimization and unit (SiPM, scintillator) study are finished
- > Readout electronics revision and finally for prototype are prepared
- > Components purchase finished: SiPMs and scintillators etc...
- > Mechanical structure and cooling design finished
- > EBU2e single layer 106/108 channels MIP test well
- > LED calibration and temperature monitor need more investment
- > **Currently, one and half months behind expected, everything's going in the right direction**

Additional

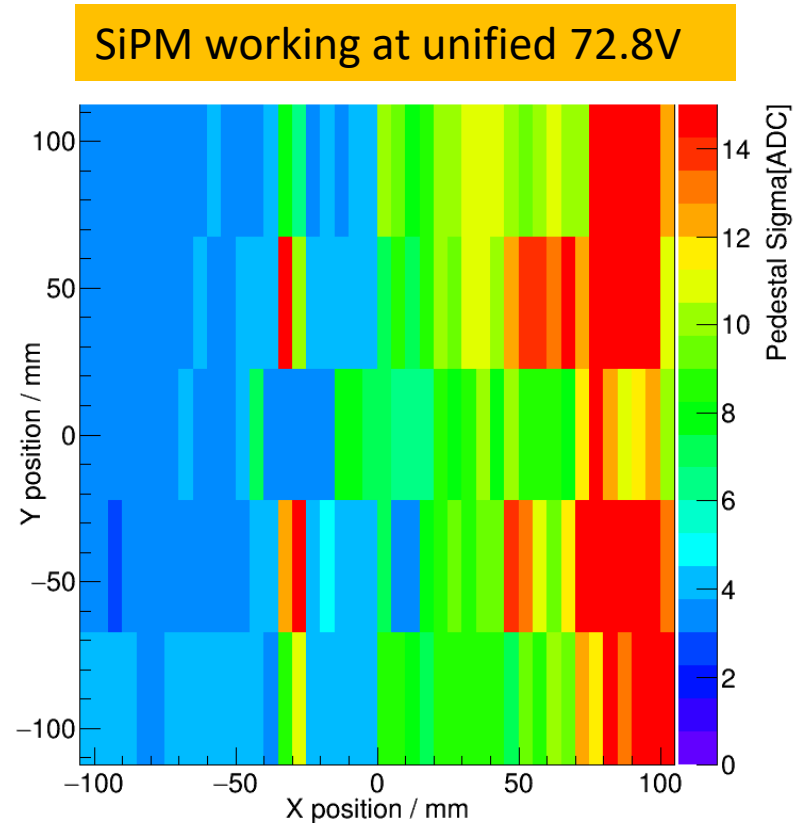
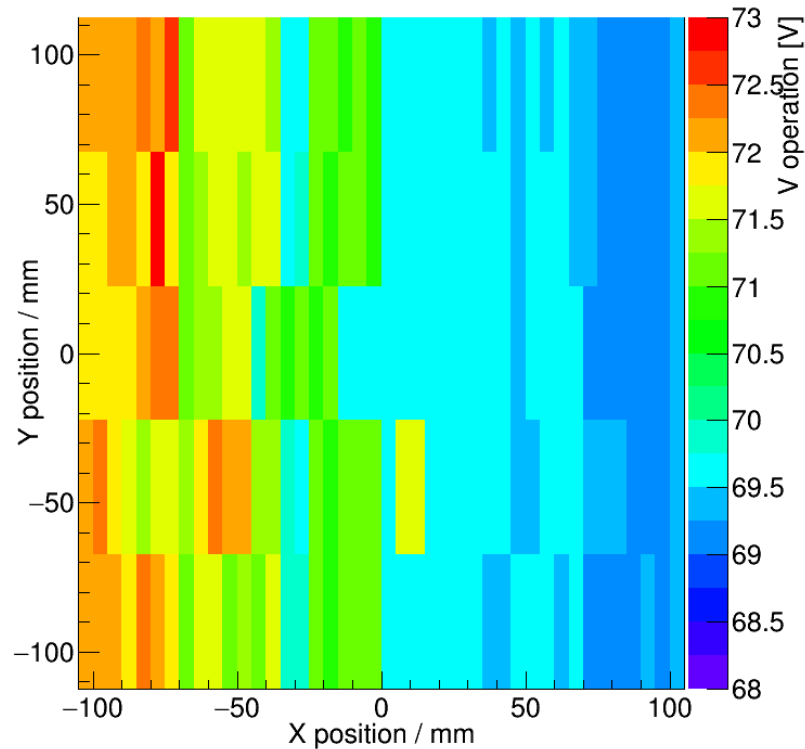
Electronics pedestal

SiPM w/o HV



- Pedestal mean various observable for different chips
- Pedestal sigma independent on the chips

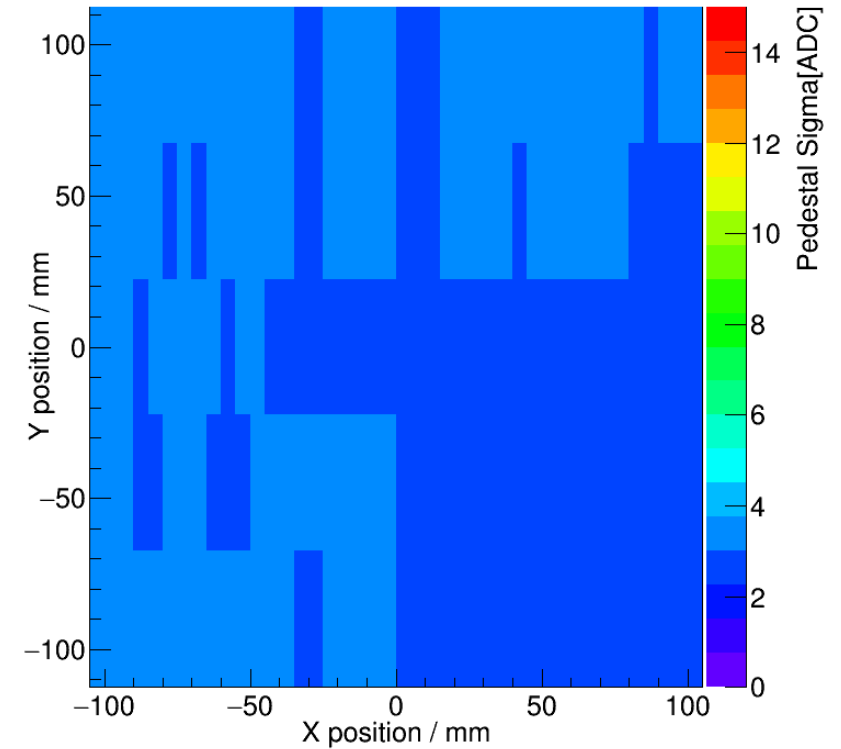
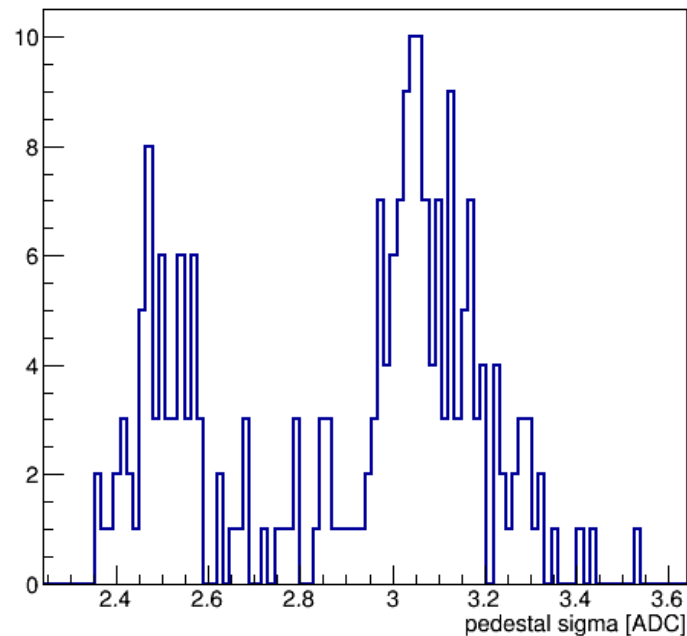
SiPM working voltage



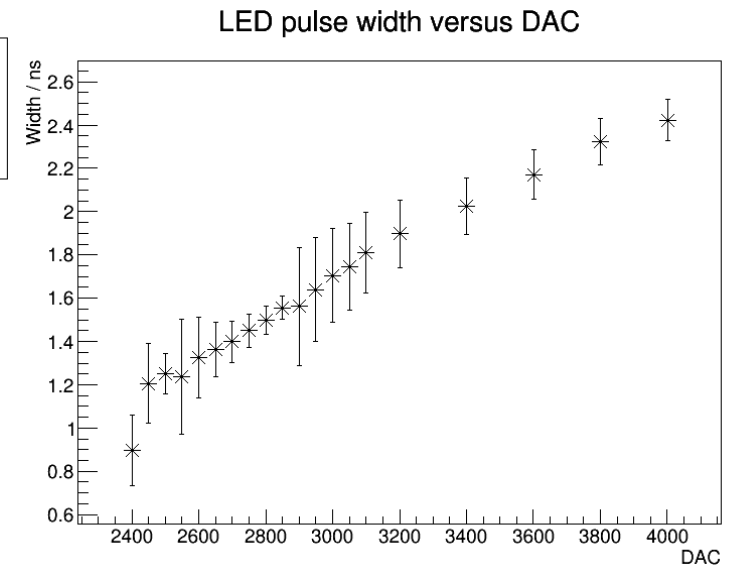
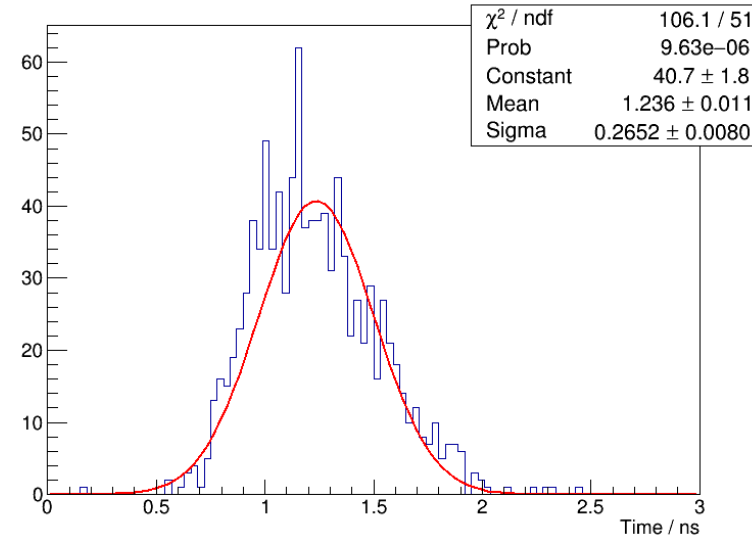
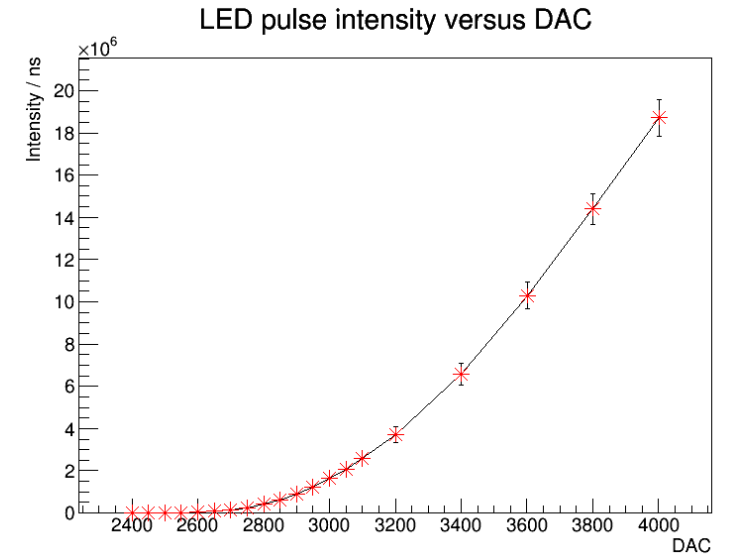
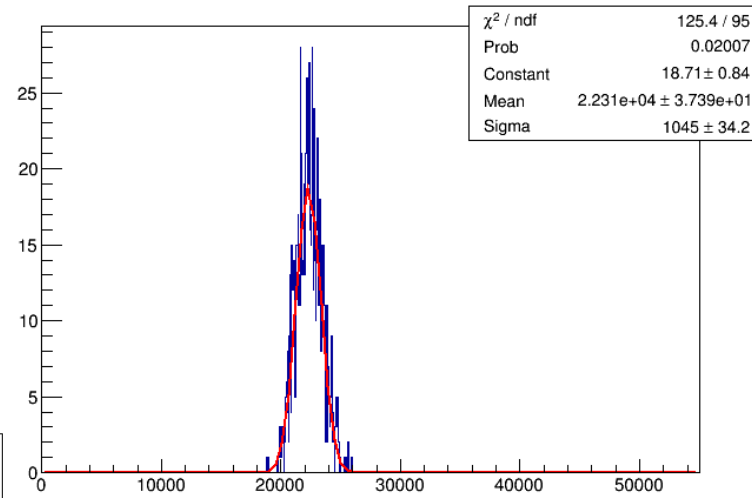
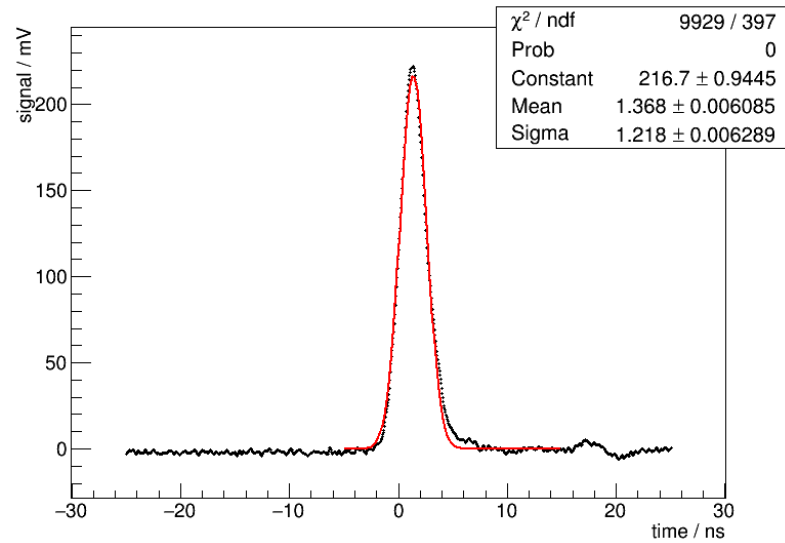
- SiPM V operation have almost 4V various, due to different batch production
- Pedestal sigma variance mostly dependent on the V operation of SiPM

SiPM working voltage

- DAC compensation SiPM bias voltage
- Configure SiPM working at operation voltage for each channel



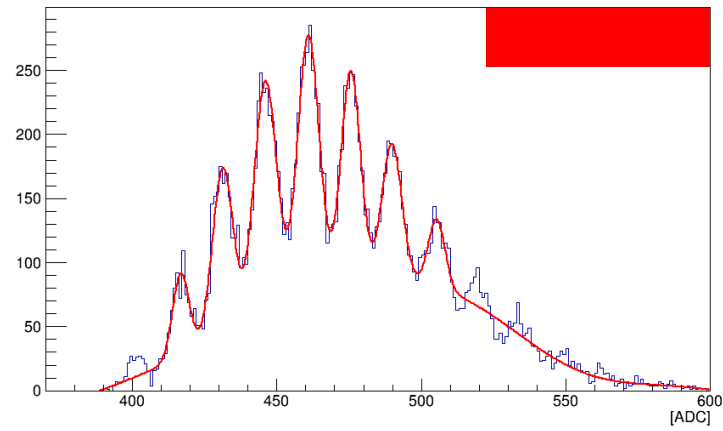
LED pulse



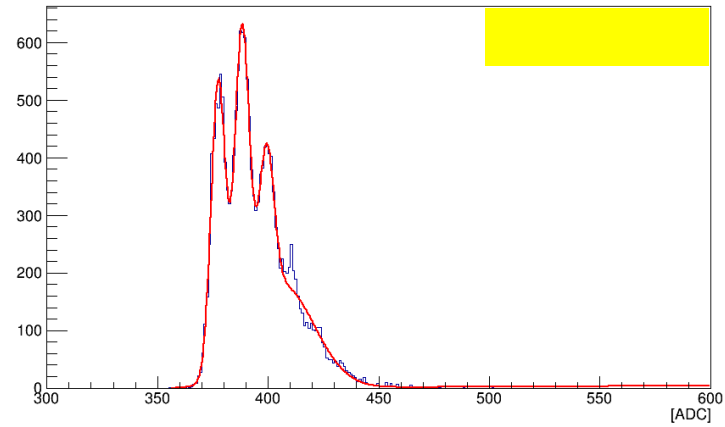
SPS

15	2400		
19	2700		
23	2800		
18	2600		great
22	2900		general
26	2750		bad
75	2850		failed
77	2850		
79	2850		
162	2500		
158	2670		
154	2850		
163	2400		
159	2430		
155	2420		

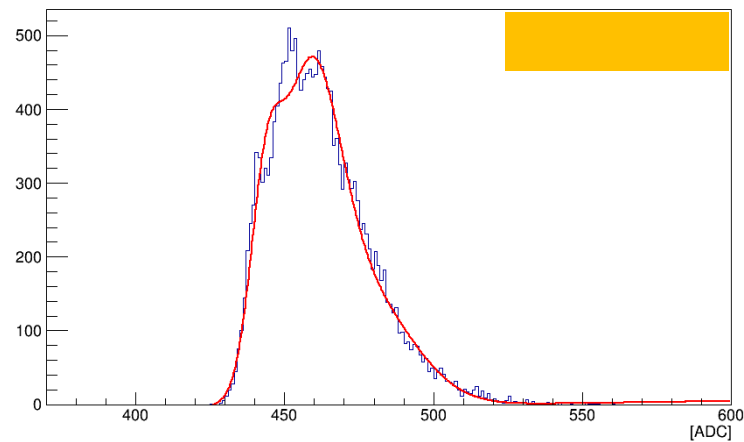
chip 0, channel 19



chip 2, channel 3



chip 4, channel 19



chip 0, channel 18

