Scintillator-tungsten ECAL R&D progress

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On behalf of CEPC calorimetry working group and in collaboration with the Japanese Sci-ECAL group

Outline

- Performance Requirements of scintillator-tungsten ECAL
- Scintillator module test and optimization
- Single active layer construction and test
- Collaboration with Japanese group
- Summary

Performance Requirements of ECAL

- Precise measurements of electrons and photons with energy resolution of :

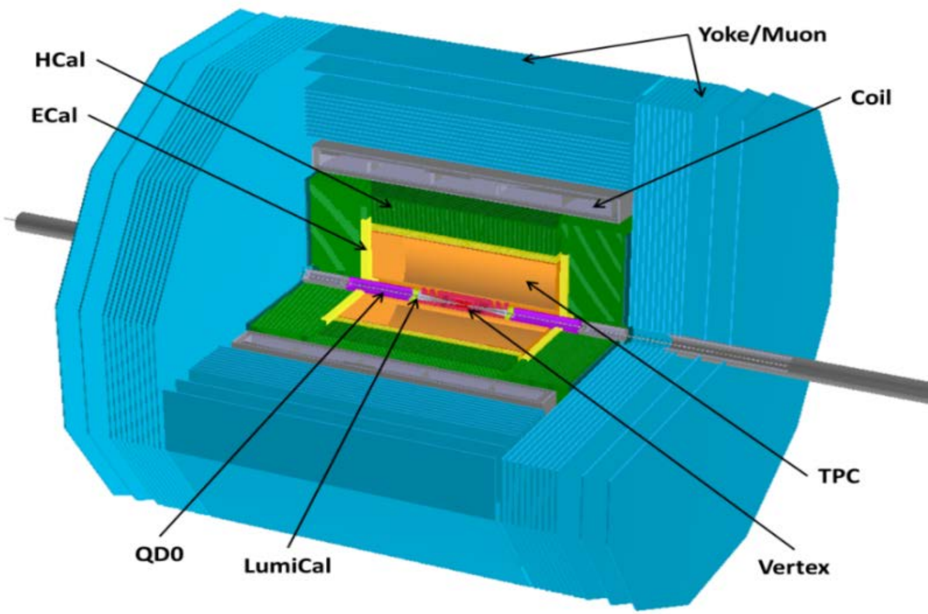
  $\sigma_E/E \approx 16\%/\sqrt{E} \oplus 1\,\%$

- Jet energy resolution (ECAL combined with HCAL and tracker):

  $\sigma_E/E \approx (3\% - 4\%)$

- Can give detailed information of showers:

  high granularity



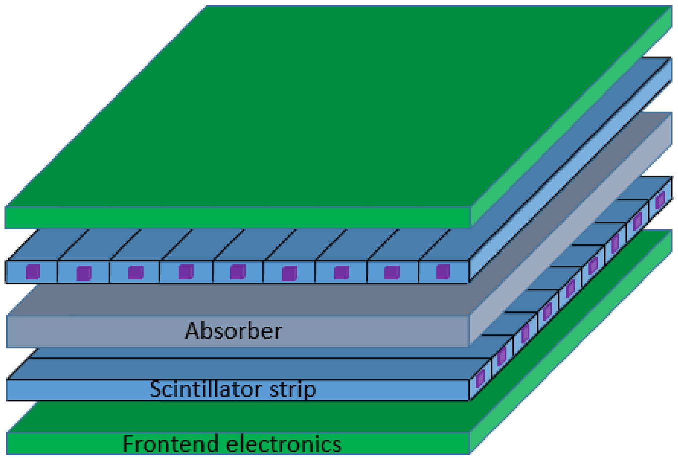
Particle Flow Algorithm (PFA) calorimetry system is considered

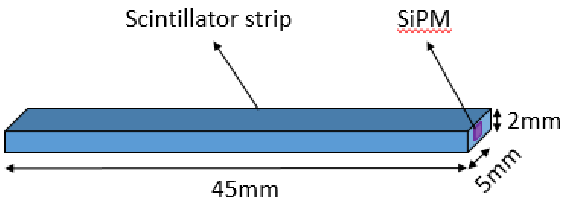
- A sampling calorimeter with scintillator-tungsten sandwich structure (ScW) is one of the ECAL options
- Good energy resolution
- High granularity and minimum dead materials
- Compact showers(small radiation length X_0, and small Moliere radius R_M)

Technological Prototype

- A technological prototype will be constructed and tested
- The key parameters were determined by simulation
  - 30 layers, Sandwich structure
  - Each layer has a sensitive dimension of about 200mm ×200mm
  - Each layer includes
    - Tungsten absorber (2.8mm)
    - Scintillator module (2mm): scintillator + SiPM
    - Readout electronics (PCB)

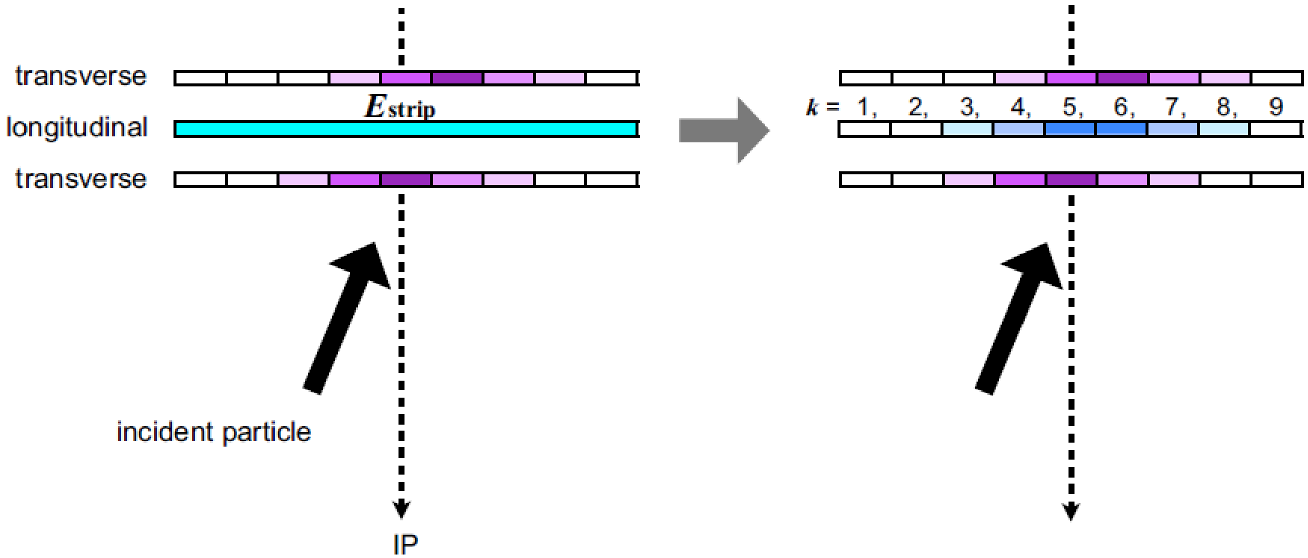
Scintillator module



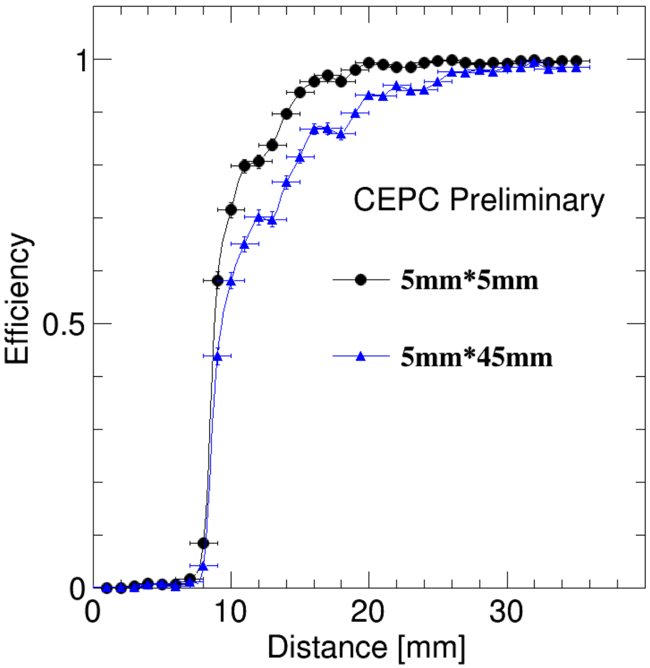


- The scintillator module : Scintillator wrapped with reflector+ SiPM
- The key parameters: Granularity, Light output, Homogeneity, Dynamic range, Dead material /area
- Scintillator dimension : 5mm×45mm×2mm
- Cross arrangement of neighboring layers → a transverse readout cell size of 5×5 mm^2
- Reduction of the readout channels → low cost
- SiPM coupled at the side or the bottom of the scintillator strip → few or negligible dead area

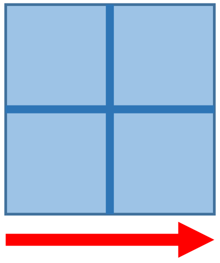
Algorithm

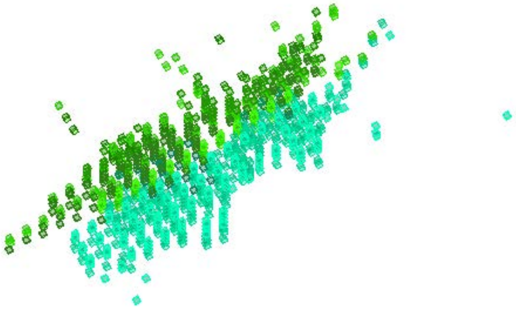


5×45mm Cell -> 5×5mm Cell
Energies of Neighbor Layer Strips (2×9) are used to calculate the splitting weights



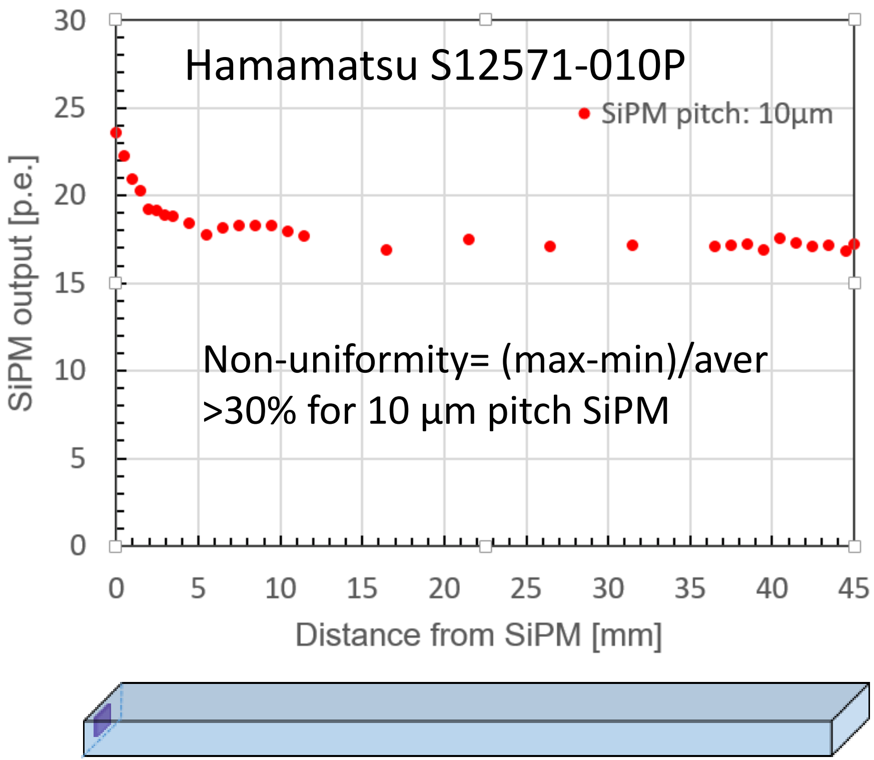
Di-photon Separation

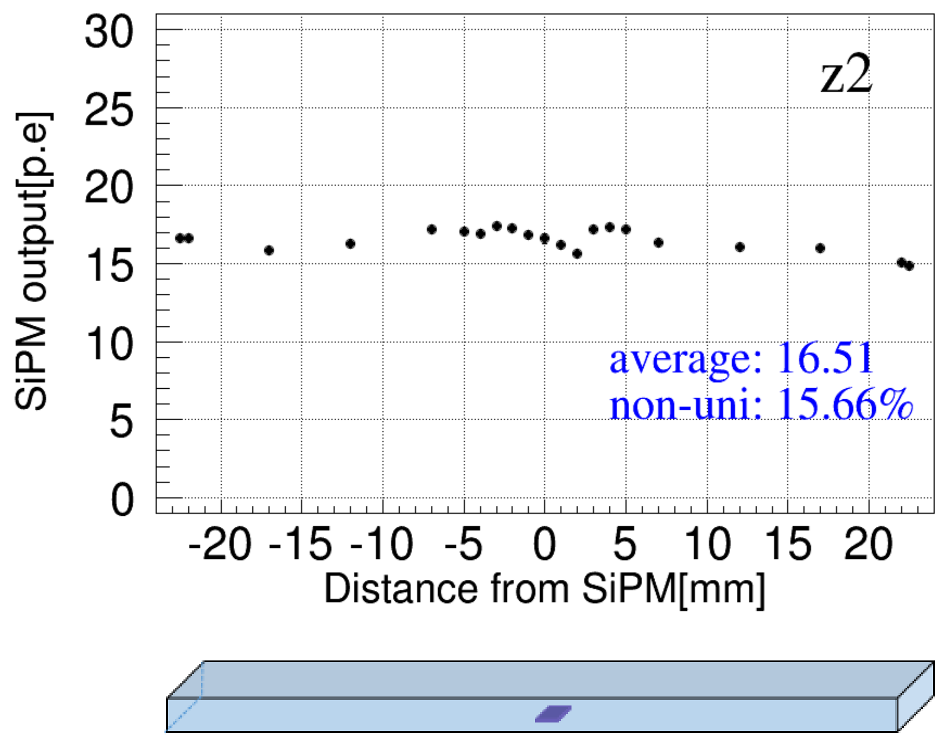




Distance = 15mm

Module test and optimization





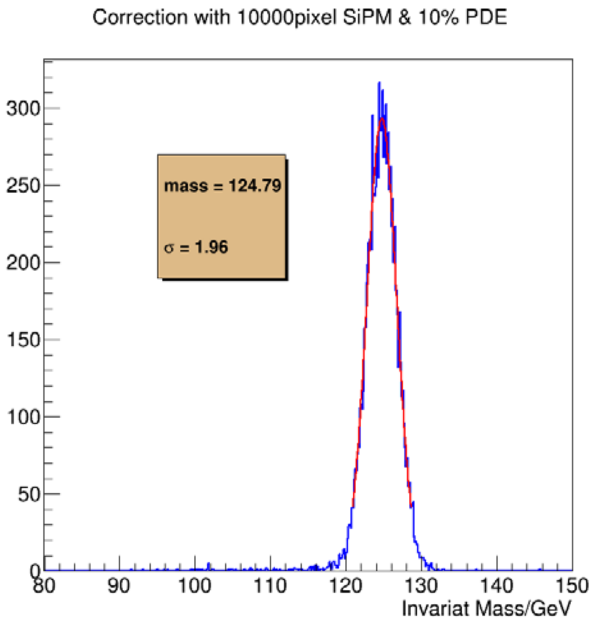
- SiPM (Hamamatsu S12571-010P) coupled at the side-end of the scintillator → bad uniformity
- Change the coupling mode: SiPM embedded at bottom-center of the strip
- Uniformity of light output is improved significantly

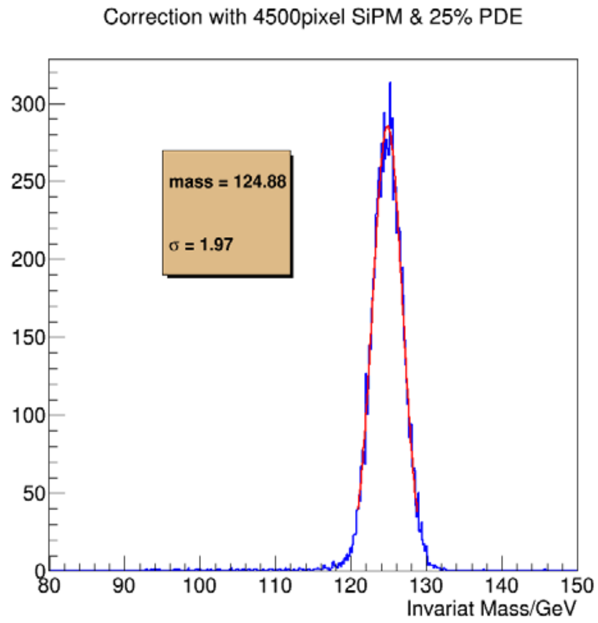
SiPM bottom-center embedded coupling

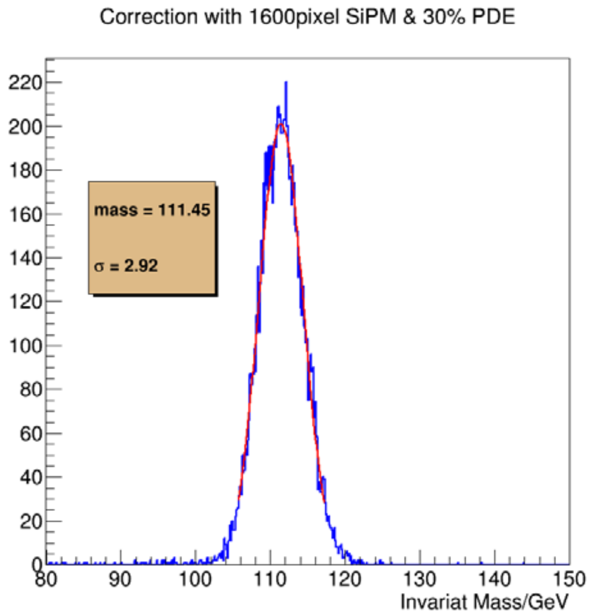
SiPM bottom-center embedded coupling mode will be adopted in the construction of the ScW ECAL prototype

- Improve the uniformity → The non-uniformity can reach about 15%
- No gap between the scintillators → Avoid the dead area
- Easy to operation in the prototype construction
- Enabling to extend the SiPM area with more pixels and extend the dynamic range of the SiPM if it is required

SiPMs with different pixel number



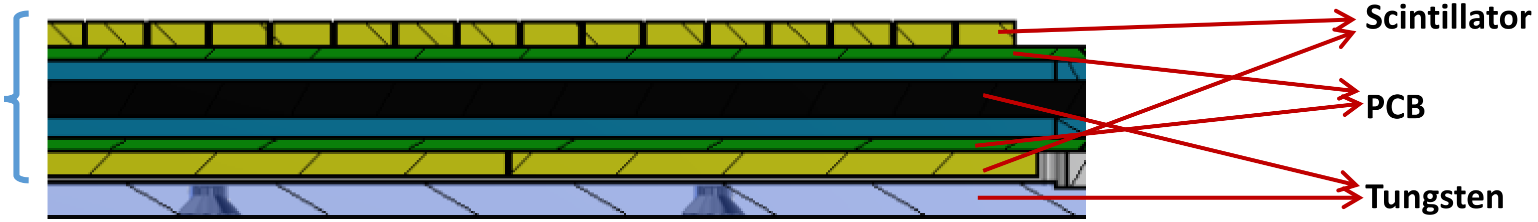




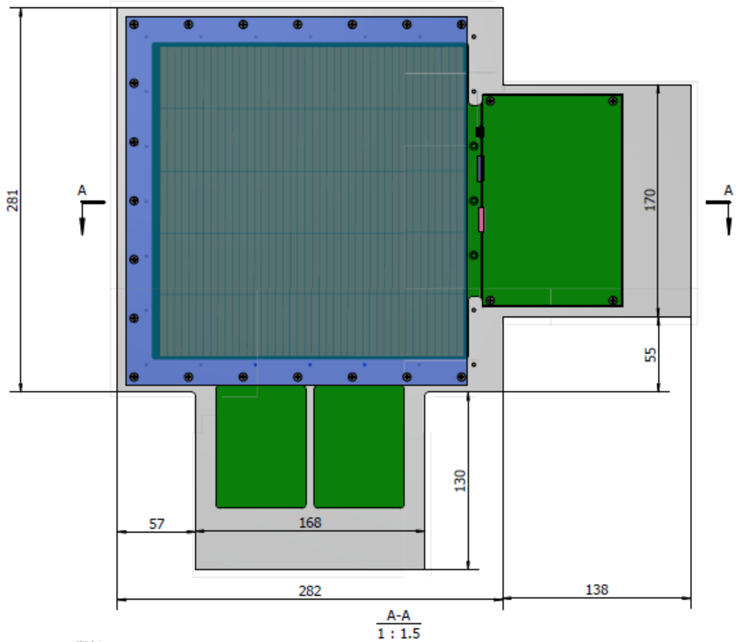
Pixel number	10000	4500	1600
Pitch size	10μm×10μm	15μm×15μm	25μm×25μm
PDE / %	10	25	30
MIP LY / p.e.	20	50	60
Mean / GeV	124.79	124.88	111.45
$\sigma/Mean$	1.57%	1.58%	2.62%

- SiPM with pixel number larger than 10000 is not required
- Need further study

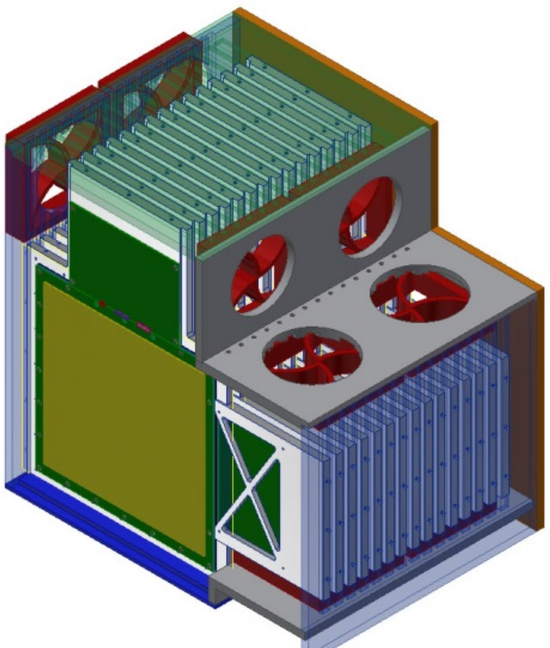
Prototype structure design



Two active layers and a absorber layer merged into a pluggable layer, each active layer includes about 5×45 scintillator modules and a embedded readout electronics board



PCB with scintillator strips and SiPM fixed by sporting structure



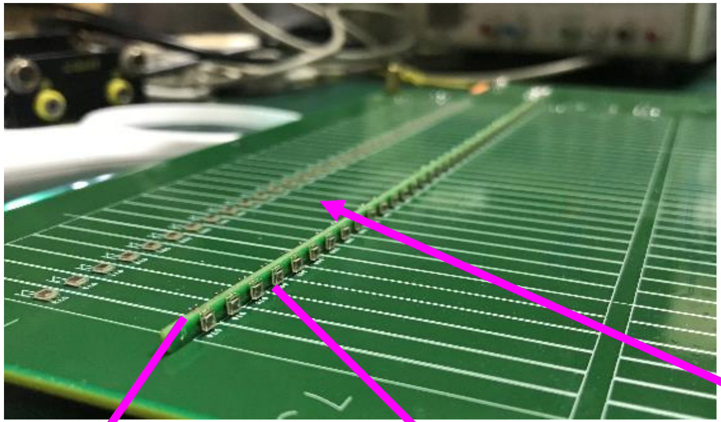
Fans are arranged for air cooling

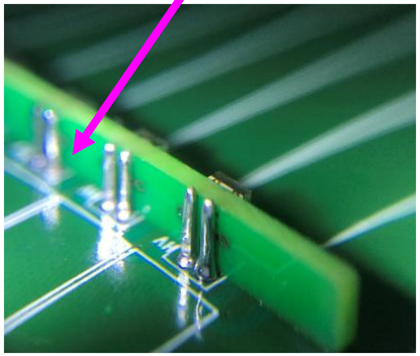
Cooling study is under progress, see Bing Liu's talk

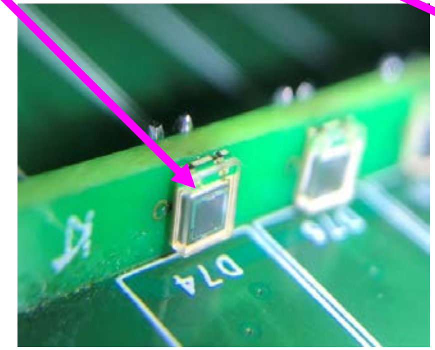
Single active layer

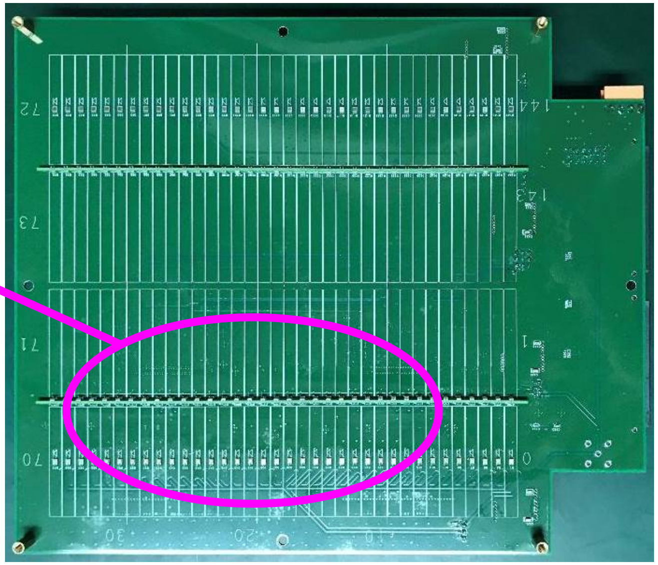
- Single active layer for the study of module layout, integration, preliminary performance
- 4 SPIROC2b chips, 144 modules
- Half : side-end coupling mode, another half : bottom-center embedded coupling mode

Front End Board



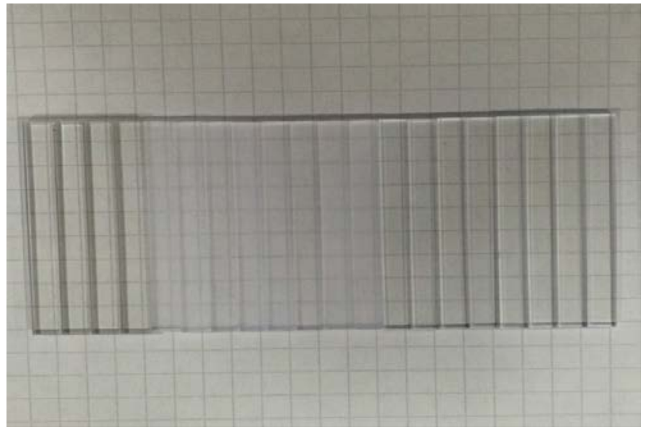


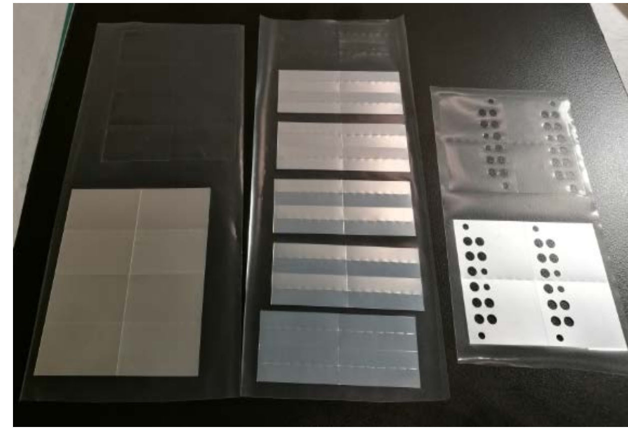


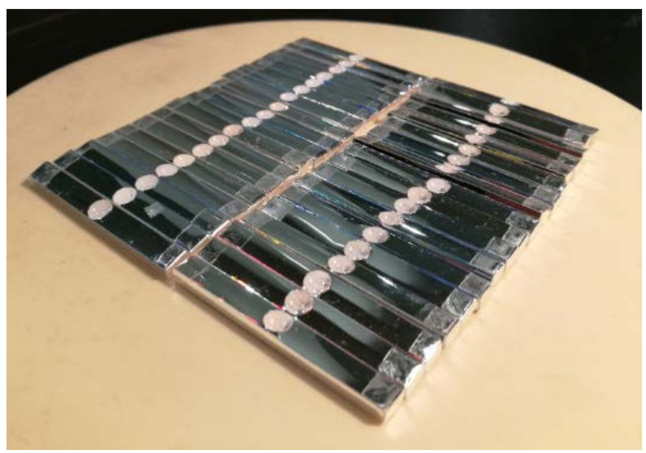


Scintillator modules

Cutting → Grooving → Polishing → Annealing → Cleaning → Packing



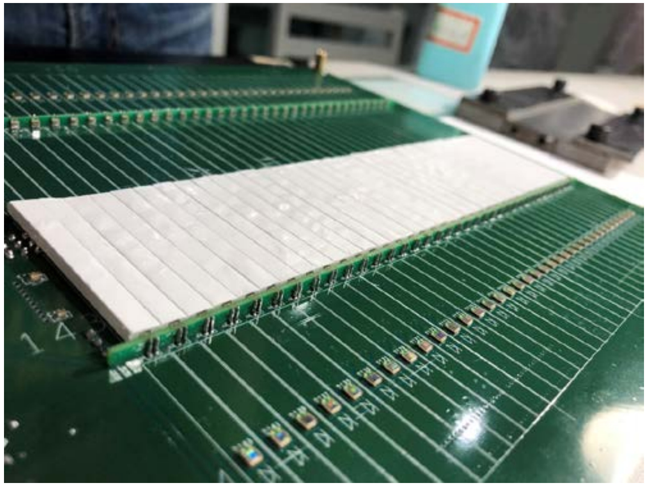


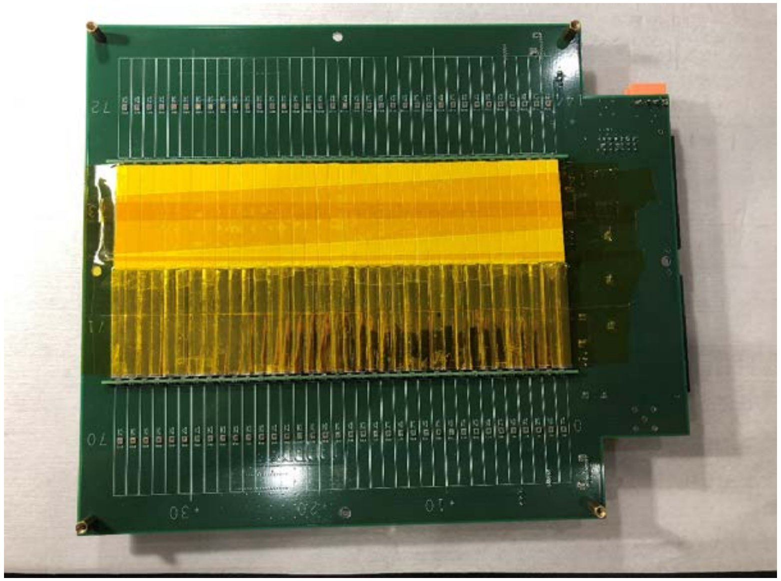


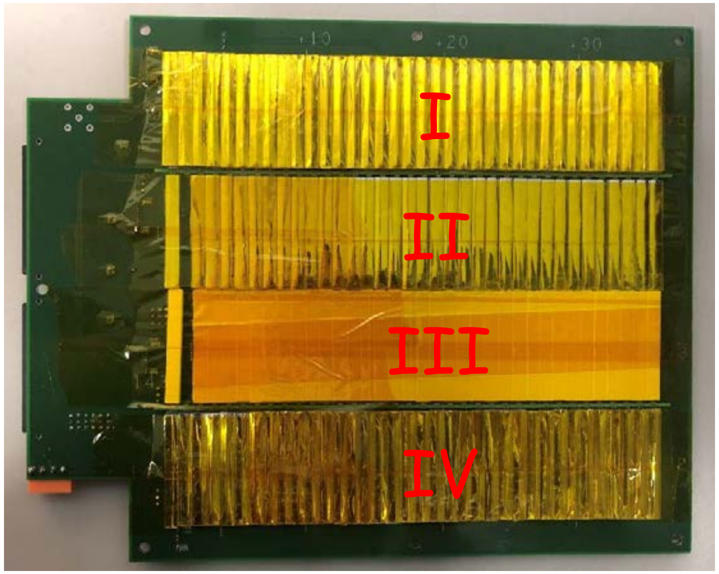
Scintillator strips are incised and wrapped in the SIC (Shanghai Institute of Ceramics)

Assembly

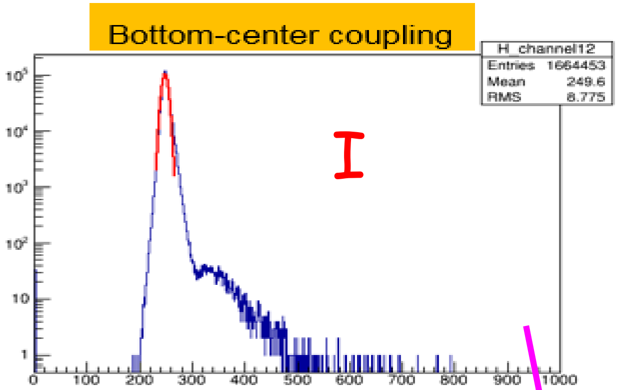
- 144 modules of scintillator strip coupling with SiPM (S12571-010P)
- I and IV: bottom-center embedded coupling mode, wrapped with ESR
- II: Side-end coupling mode scintillators wrapped with ESR
- III: Side-end coupling mode scintillators wrapped with Teflon

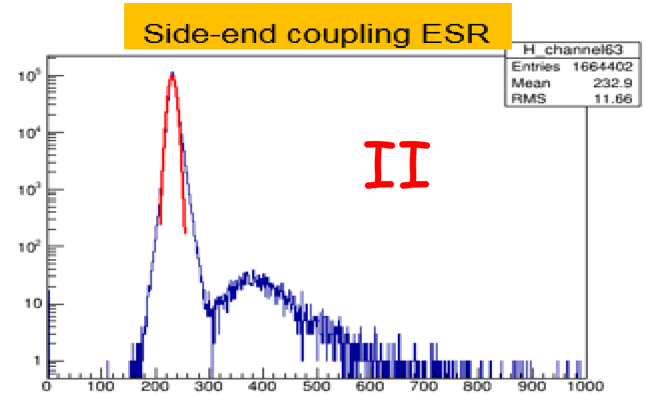


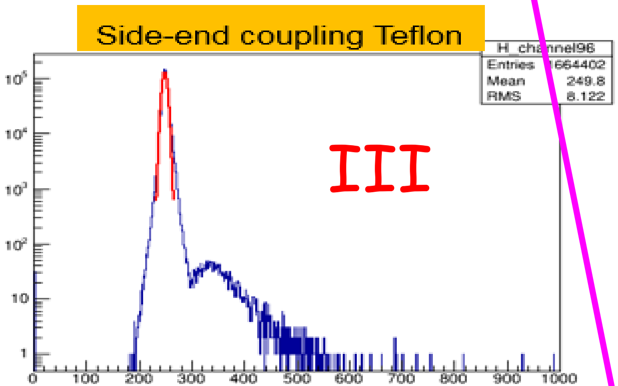


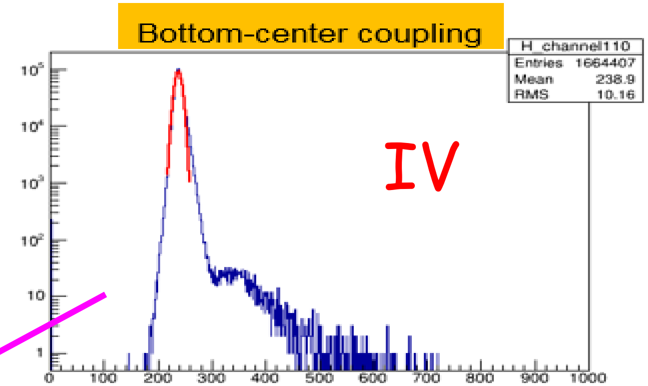


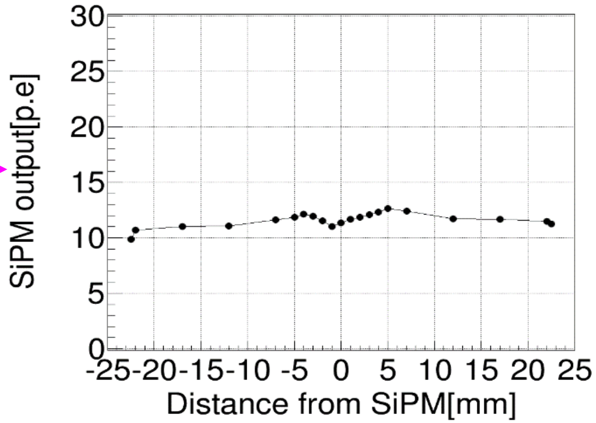
Cosmic-ray test







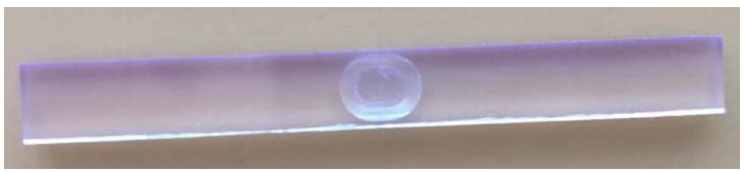


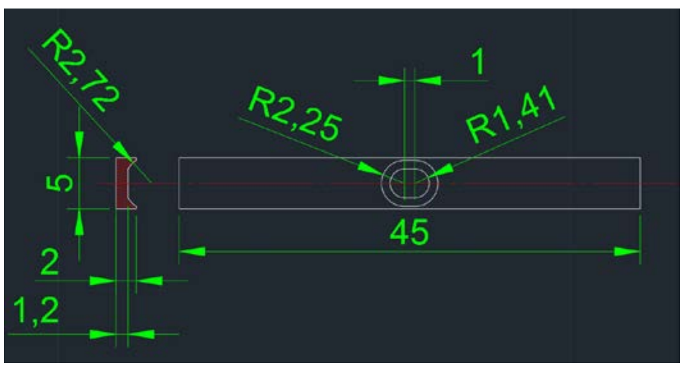


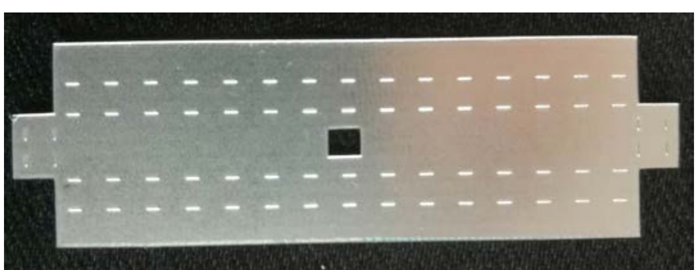
- Small cracks lead to low light output

New scintillator strips

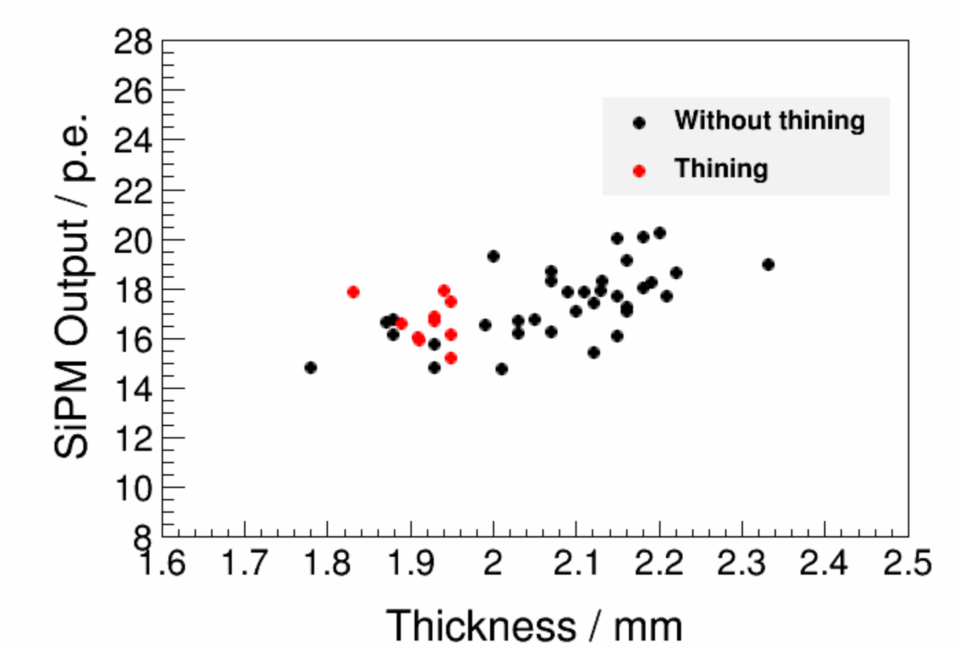
- New BC408 scintillator strips were cut with a runaway-shaped groove (without polishing)
- The thickness of the scintillator plate is non uniform (1.8mm-2.5mm). Strips with thickness larger than 2.3mm were thinned to 2mm

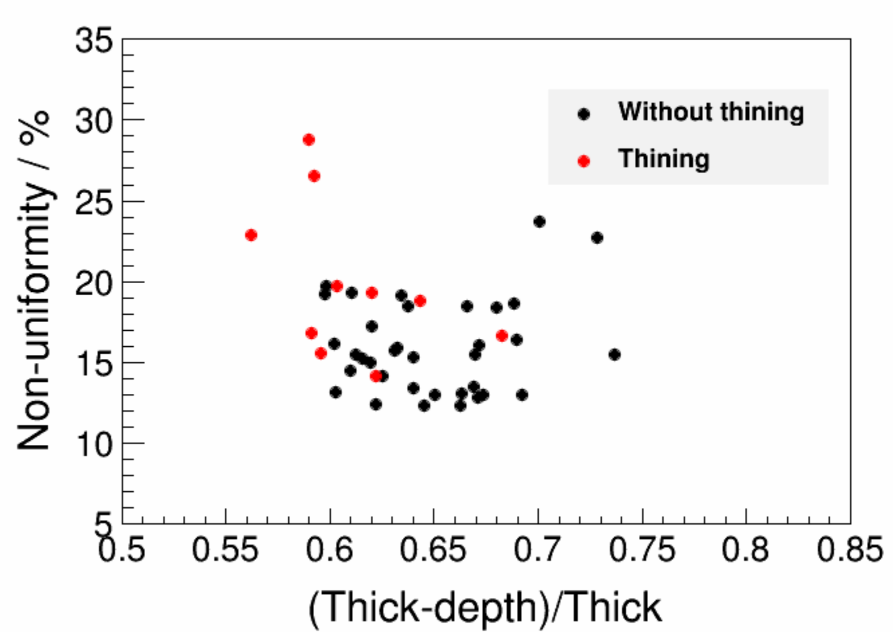






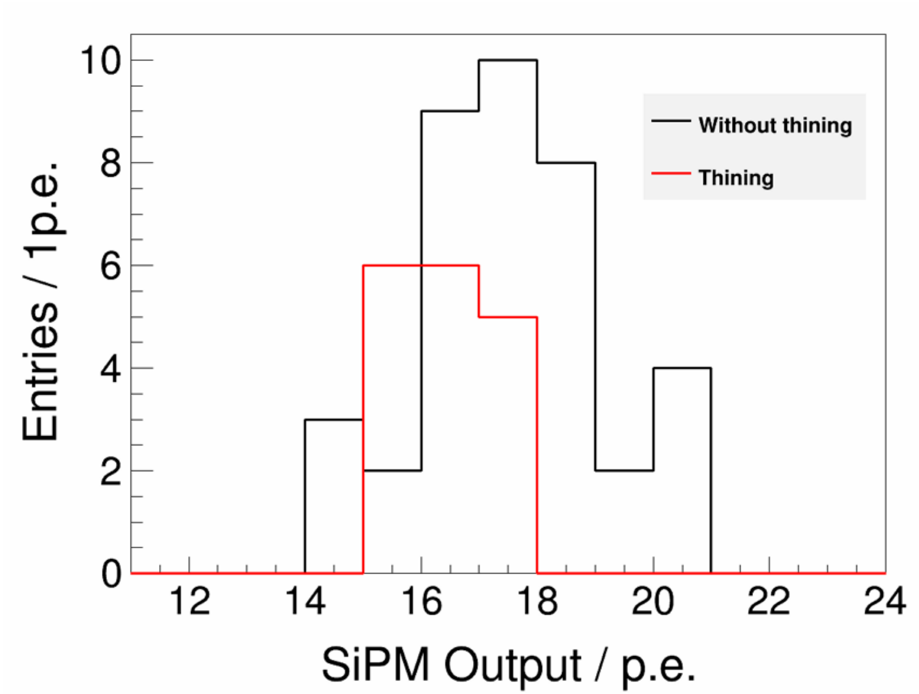
Light output and uniformity

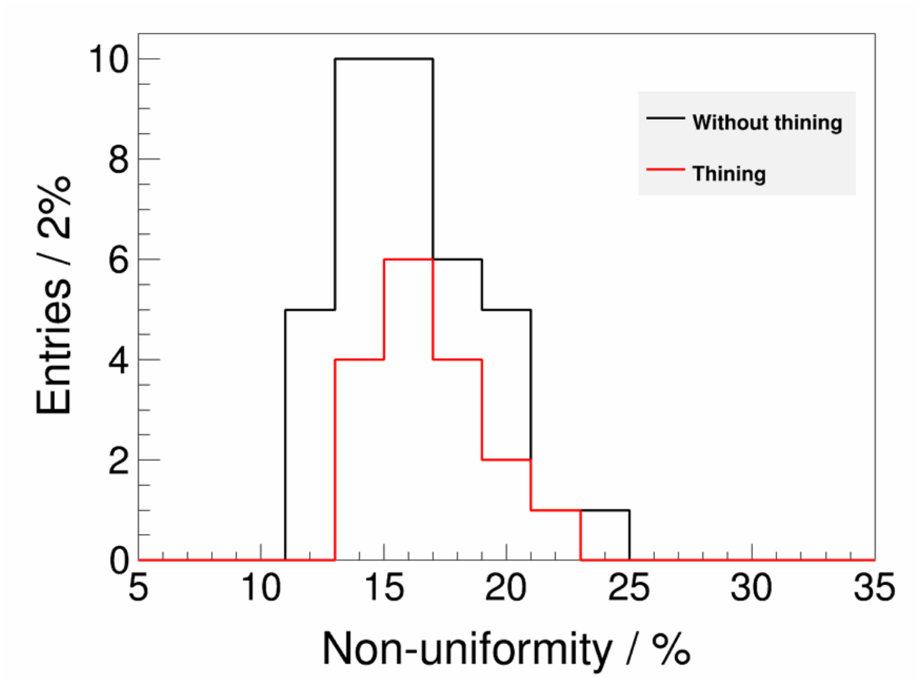




- The light output increases with the thickness of the scintillator strips
- The uniformity has a relationship with the ratio of the groove depth and the thickness of the strip.
- For the next mass production, the scintillator plates will be thinned to 2mm before cutting into strips.

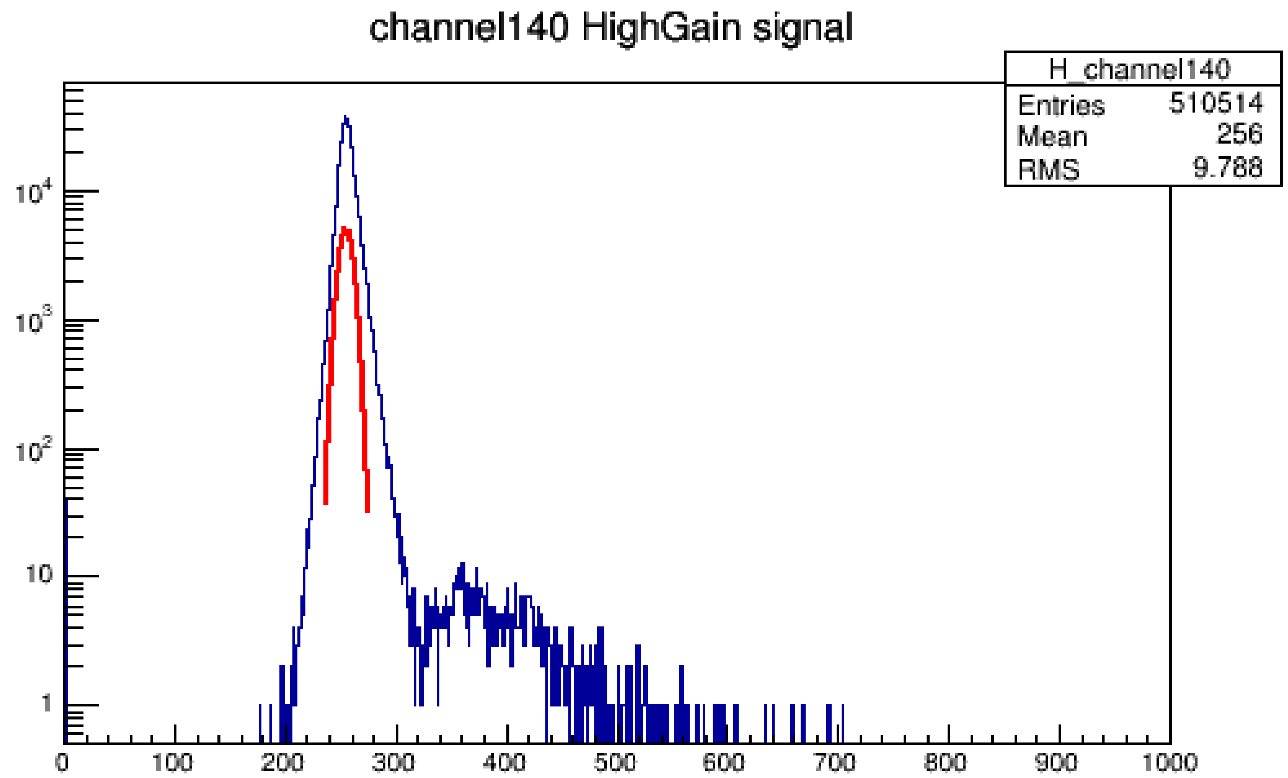
Light output and uniformity





- Light output of the strip after thinning is 15-18p.e./MIP , about 1p.e. smaller the strip without thinning
- A relative good uniformity can be achieved

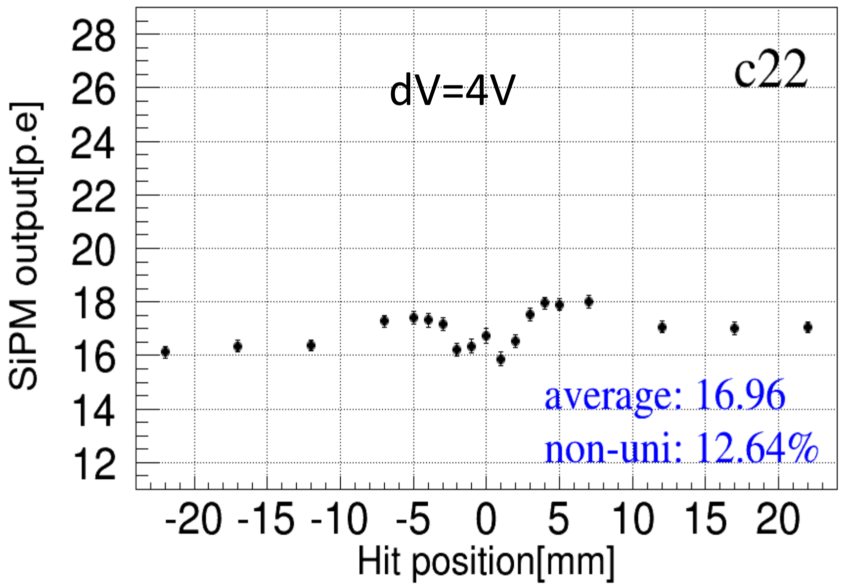
Cosmic-ray test of new strips



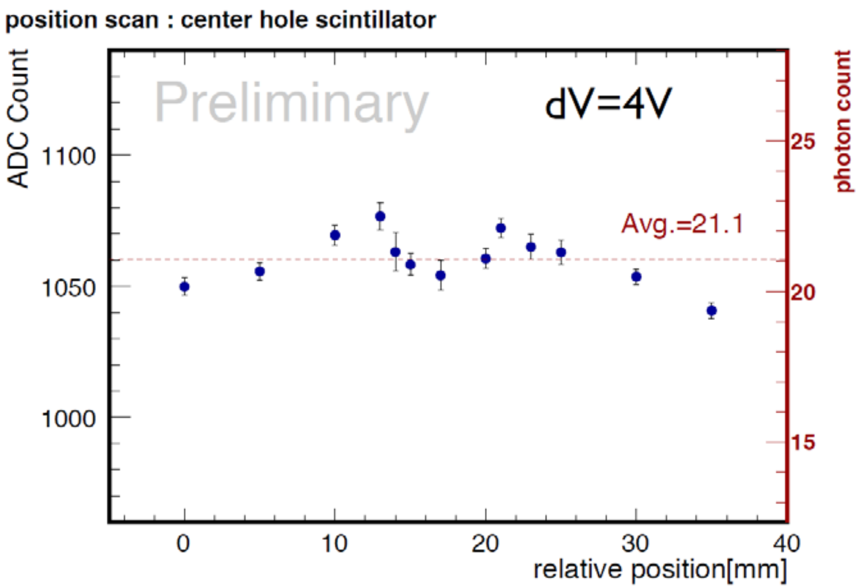
- 40 new scintillator strips was replaced the old ones on the single layer prototype and tested with cosmic-ray
- Preliminary results show the peak of the MIPs is well separated from the pedestal for most strips

Collaboration with Japanese group

- Monthly work meeting on Scintillator Ecal between Chinese group and Japanese group
- Application for CAS-JSPS Cooperative research project together with Tohru Takeshita from Shinshu University
- Joint effort to optimize the design of the sensitive unit (scintillator + SiPM)



Read out by Hamamatsu S12571-010P



Read out by Hamamatsu S12571-015P

Schedule in 2019

- ✓ 2019.1-4: development and test of new readout board with SPIROC2e chips
- 2019.4-5: construction and cosmic-ray test of a new single layer
- 2019.2-5: Mechanical structural design and manufacturing of a pluggable layer
- 2019.5-10: Mass production and test of the scintillator strips
- 2019.6-8: Manufacturing of the mechanical structural
- 2019.8-12: Mass production and test of the readout electronics, including the calibration system
- 2019.8-12: Assembly and test of the pluggable layers
- 2019: Application of the test beam for the prototype

Summary

- Scintillator strip modules were tested and optimized
- A single active layer was constructed and tested with cosmic-ray
- New scintillator module are prepared to replace the old ones on the single active layer
- Fruitful collaboration between Japanese and Chinese Sci-ECAL groups

Thanks for your attention !