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Status of CEPC ECAL R&D

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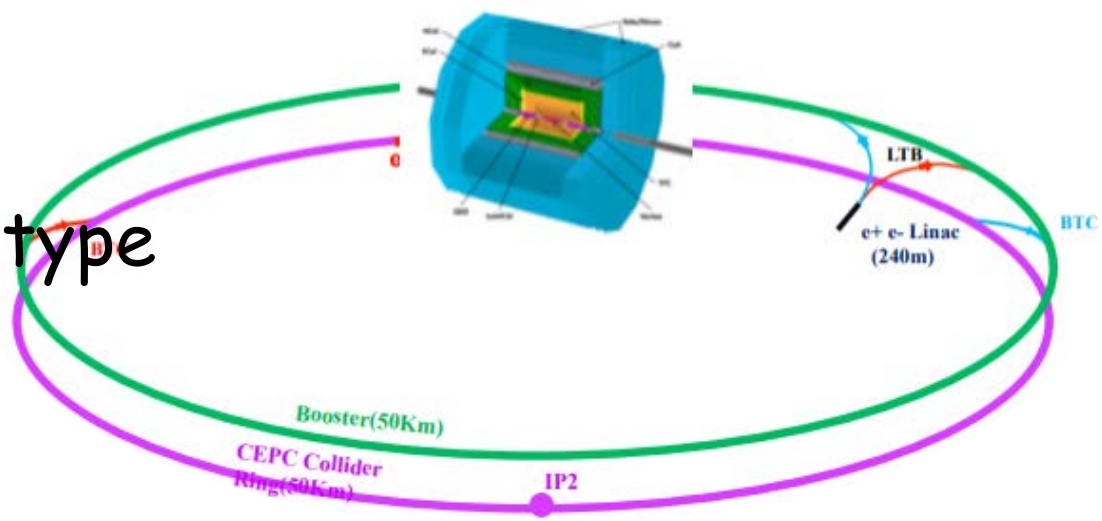
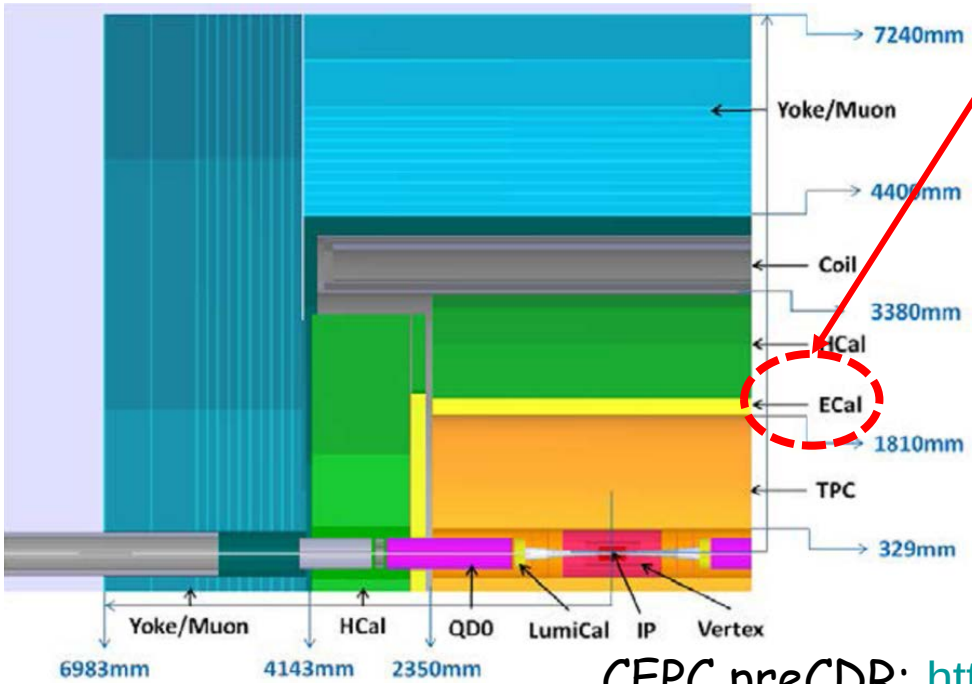
Outline

- Motivation : PFA and Imaging Calorimetry
- ECAL Unit Study and Optimization
  - Simulation and Optimization
  - Photon sensor
  - Scintillator strip
  - Readout Electronics
- Single Layer Prototype
- Summary



Motivation



Requirements for CEPC ECAL:

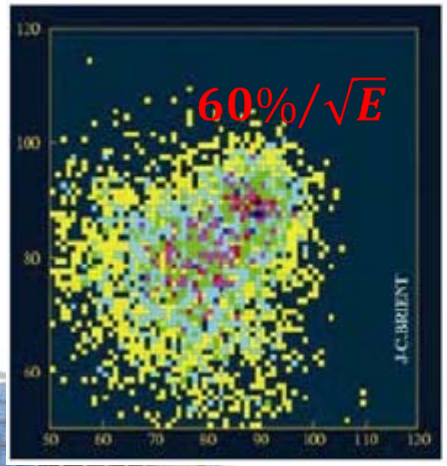
- Energy resolution of γ:

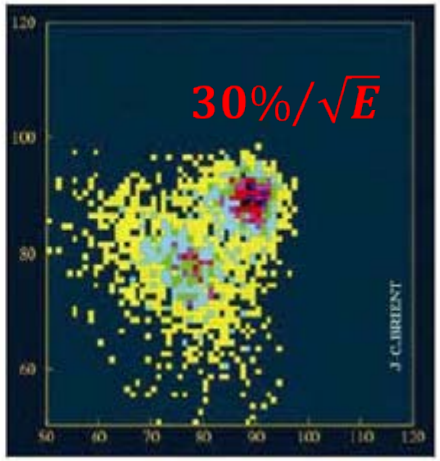
$$\sigma_E/E \approx 16\%/\sqrt{E} \oplus 1\%$$

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

$$\sigma_E/E \approx (3\%\sim4\%)@100GeV$$

CEPC preCDR: http://cepc.ihep.ac.cn/preCDR/volume.html



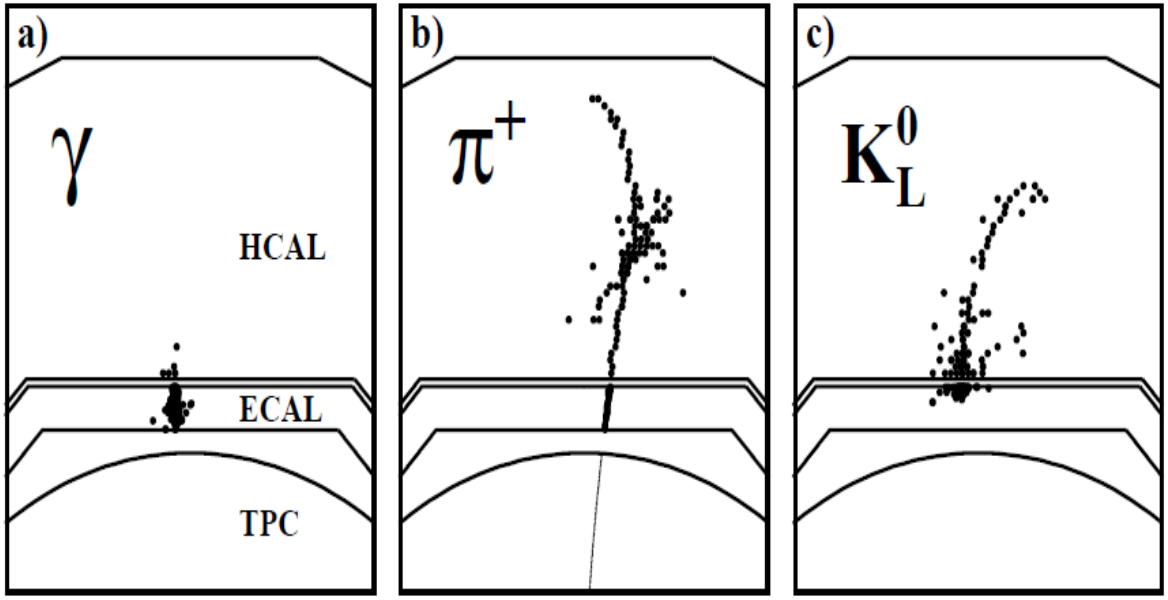


- Simulation of WW and ZZ separation for the events in 4jets

PFA and Imaging Calorimetry

Particle Flow Algorithm(PFA) calorimetry concept proposed: Reconstruct each individual final state particle in the most suitable sub-detector

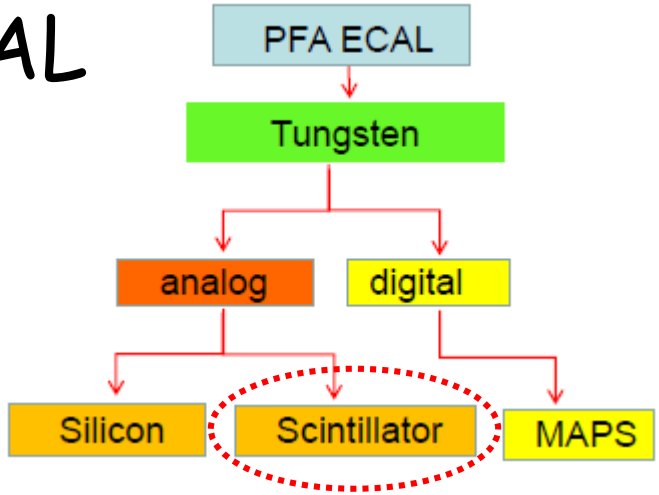
- High granularity
- Good shower separation
- Good energy resolution

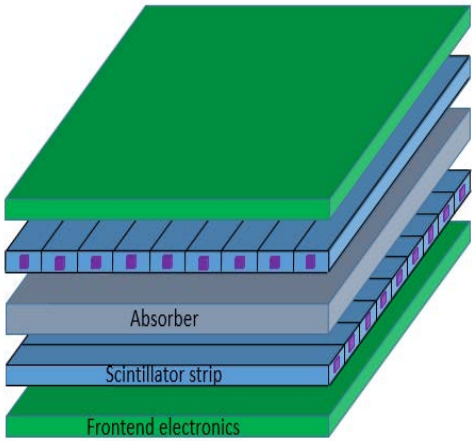


ECAL Options

✓ Scintillator-tungsten ECAL

- Larger detector PFA
  - Sandwich structure
  - Absorber + SD + Electronics
- Smaller Moliere radius
  - Tungsten
- Larger dynamic ranger
  - Scintillator + SiPM
  - SPIROC Chip



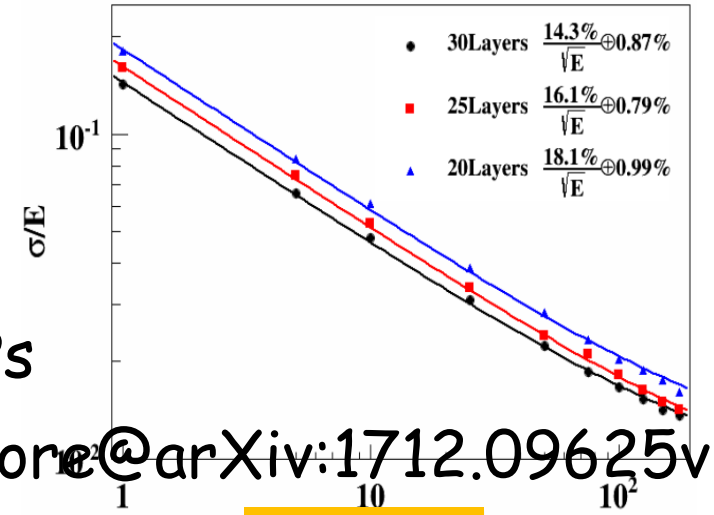


ECAL Optimization

ECAL crucial parameters:

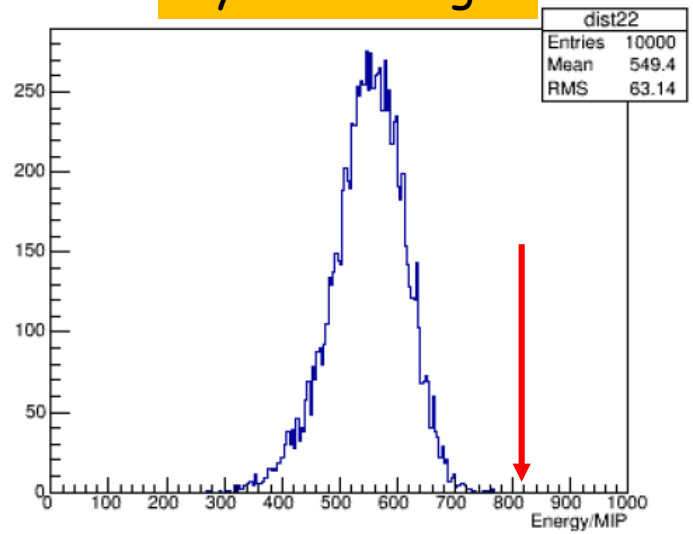
- Absorber thickness: 24 X_0
- Layers number: 30 layers
- Cell size: <10mm*10mm
- Dynamic range: 1 MIP~800 MIPs

Layers number

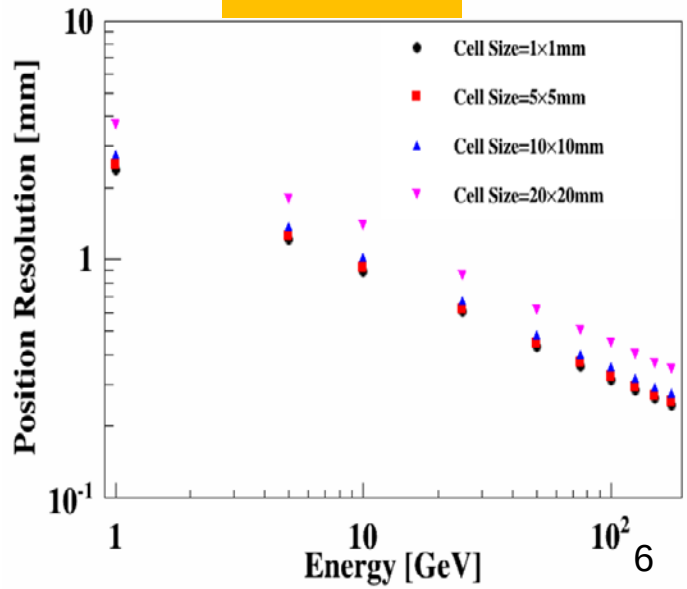


see more@arXiv:1712.09625v3

Dynamic range

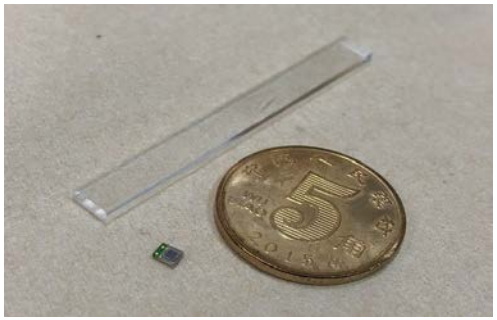


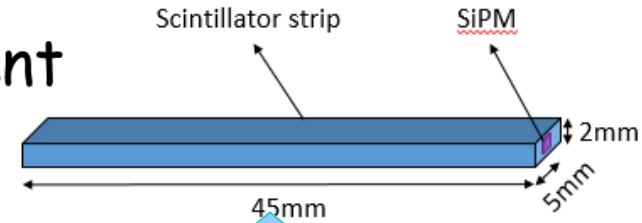
Cell size

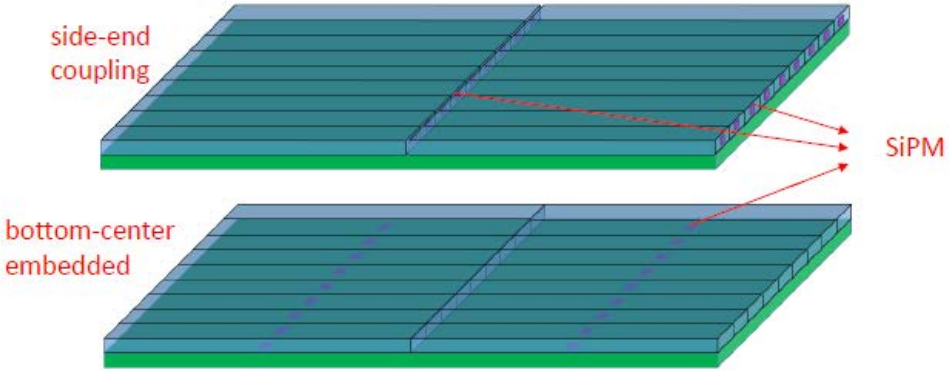


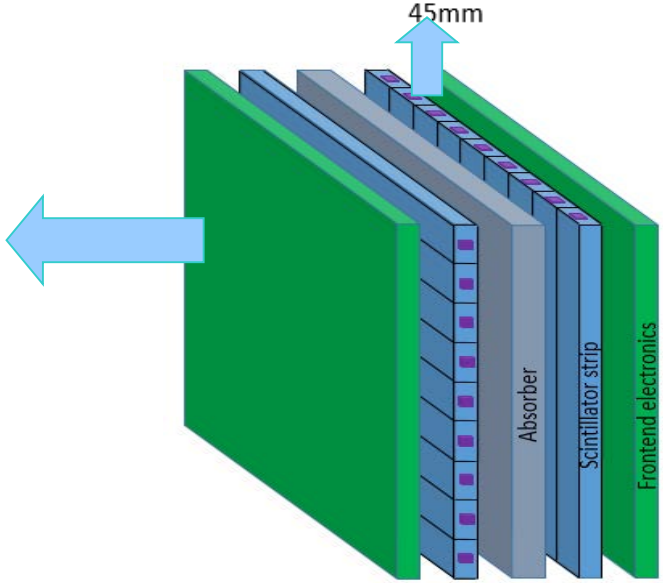
Structure overview of ECAL

- Scintillator strip: $45mm \times 5mm \times 2mm$
- High pixel SiPM: 10k
- Frontend electronics chip: SPIROC
- Assemble scintillator module in the other side of EBU
- Orthogonal arrangement of adjacent layers: achieve $5mm \times 5mm$ cell





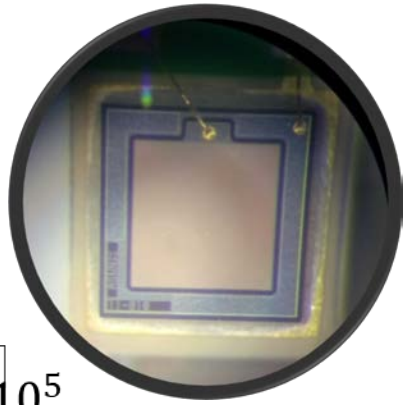


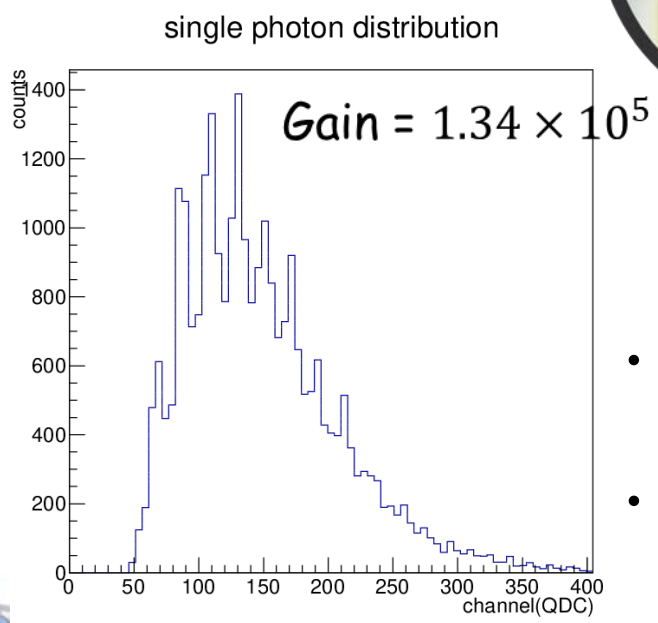


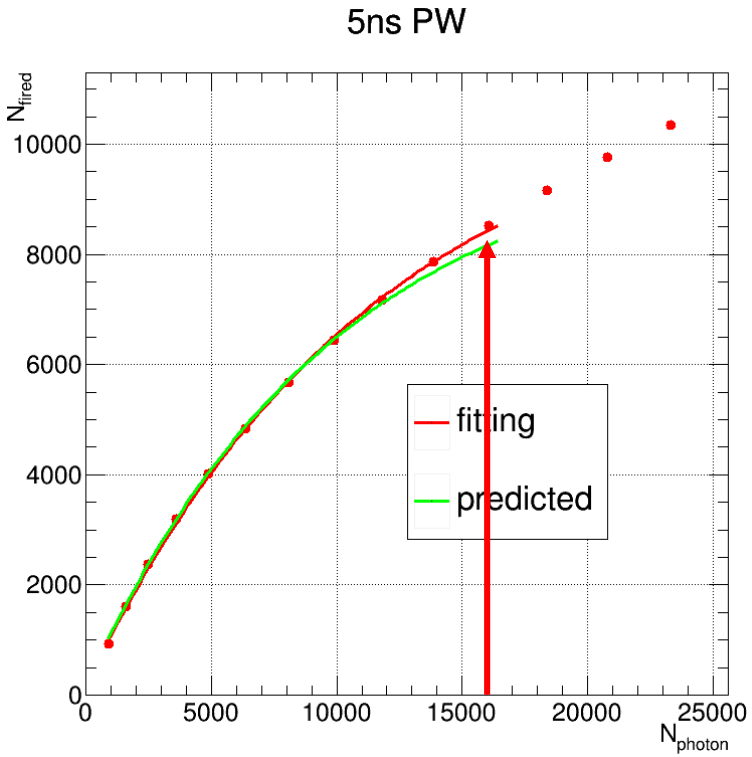
SiPM Study

Hamamatsu S12571-010P

- Area: $1mm \times 1mm$
- Size: $10\ um$
- Pixels: 10 k

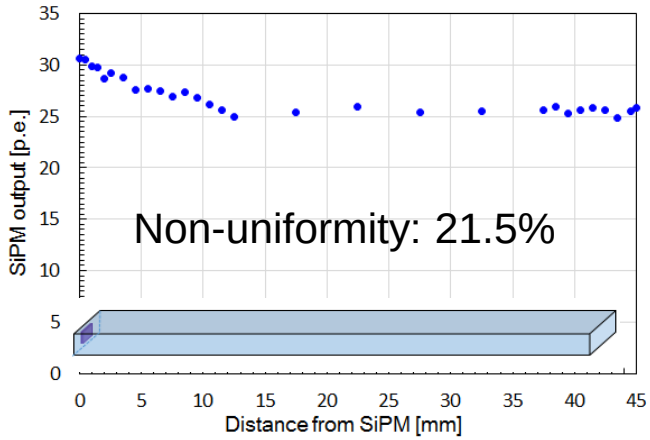


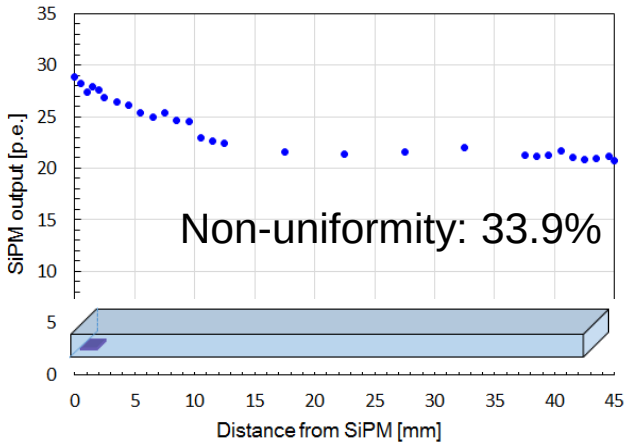


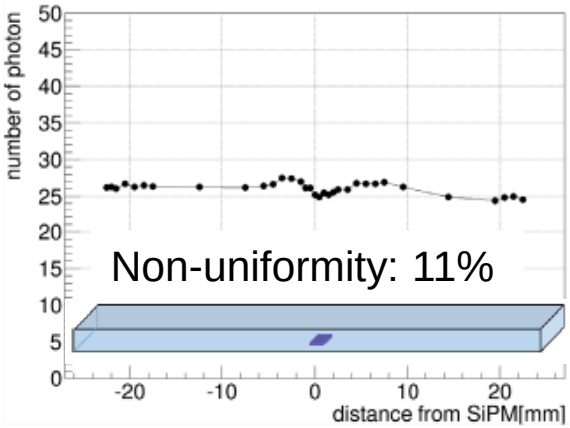


- SiPM response can be described well with the theoretic formula
- Enabling dynamic range larger than 16,000 photons through correction

Scintillator coupling mode



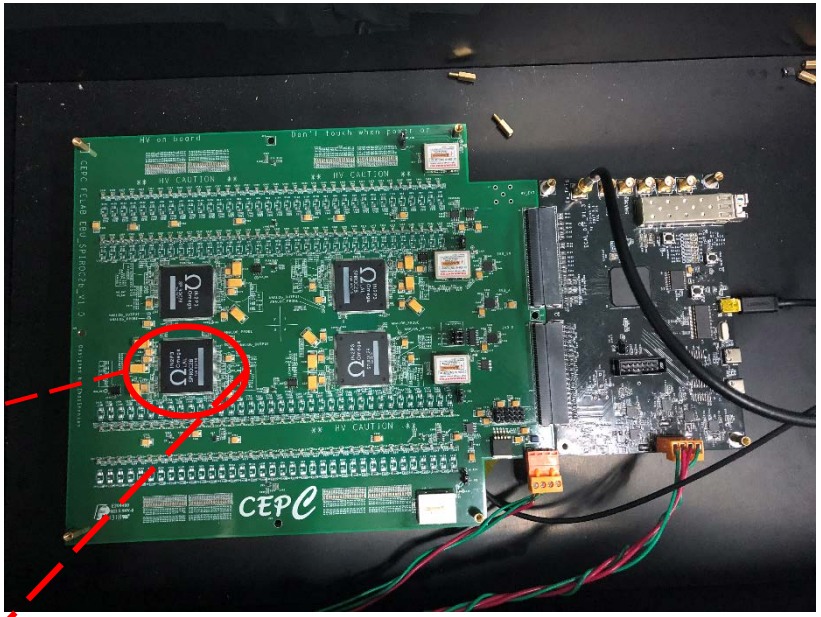


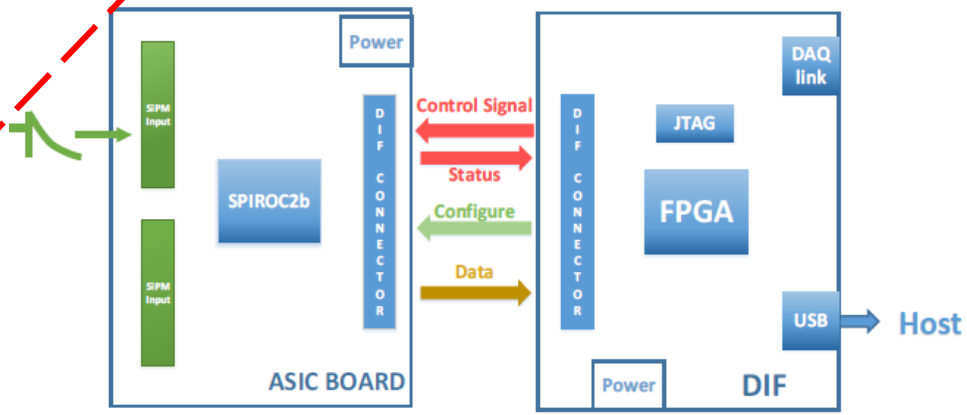


- Three classes coupling mode i.e. side-end, bottom-end and bottom-center
- Light outputs along the length of the scintillator strip is non-uniformity, degrades the energy resolution
- Bottom-center coupling have the minimum non-uniformity
  - Avoiding the dead area between scintillators
  - Simplifying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

Readout Electronics

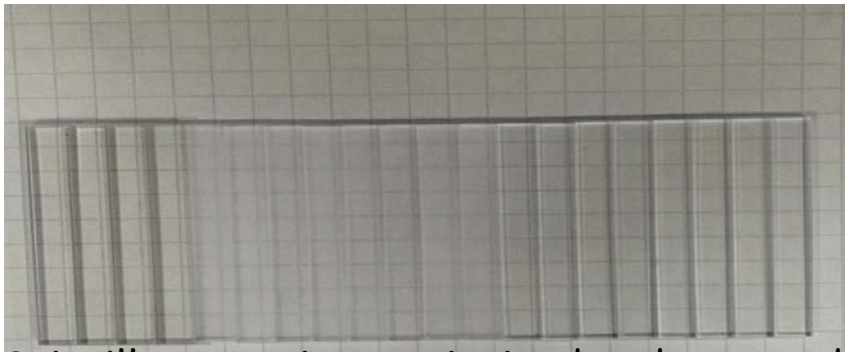
- Measurement is also relative with not only Q_{inject}, but also waveform
- $\tau_{fall} = C_t * R_{load}$ same to $\boldsymbol{\tau_{SiPM}}$~$\mathbf{3.5ns}$ (S12571-010P)
- $Q_{inject} = \Delta V * C_t$ (@ τ_{SiPM}~$3.5ns$)
- $R_{load} = \mathbf{200\Omega}$, $C_t = \mathbf{18pF}$
- High Gain 92fC – 19pC (3% INL, S/N ~ 2)
- Low Gain ~ 350pC (2% INL)



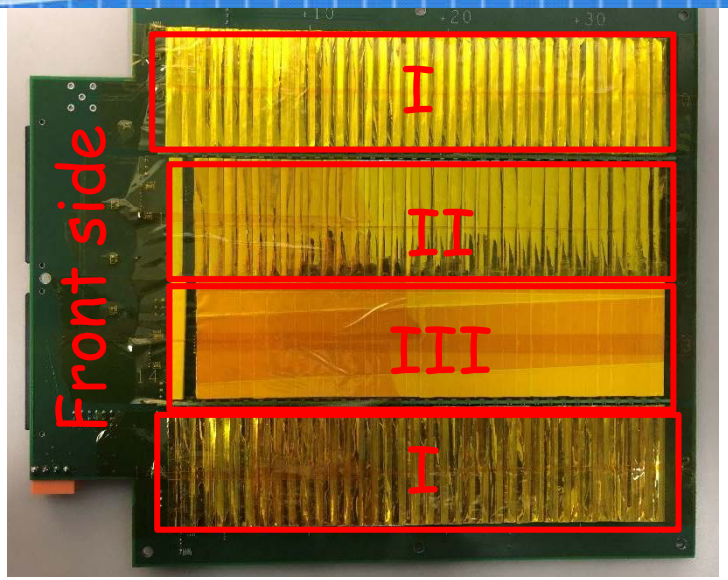


System schematic

Single layer prototype



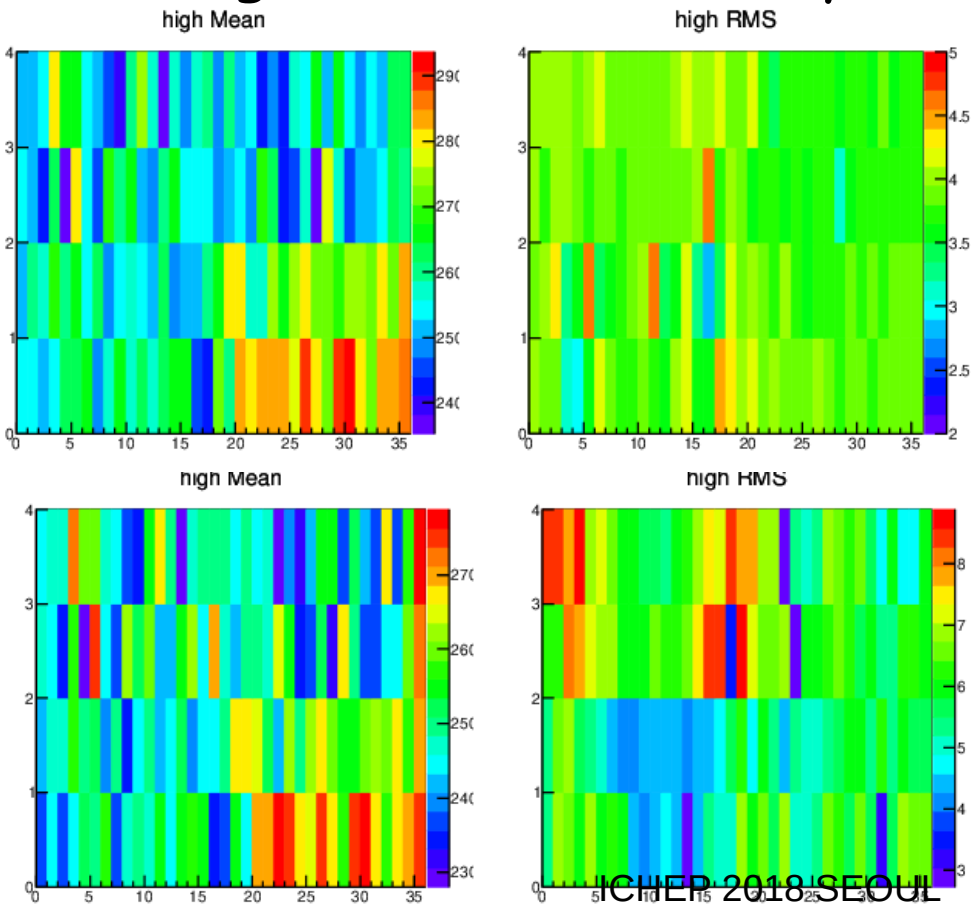
Scintillator strips are incised and wrapped in the Shanghai institute of Ceramics(SIC)

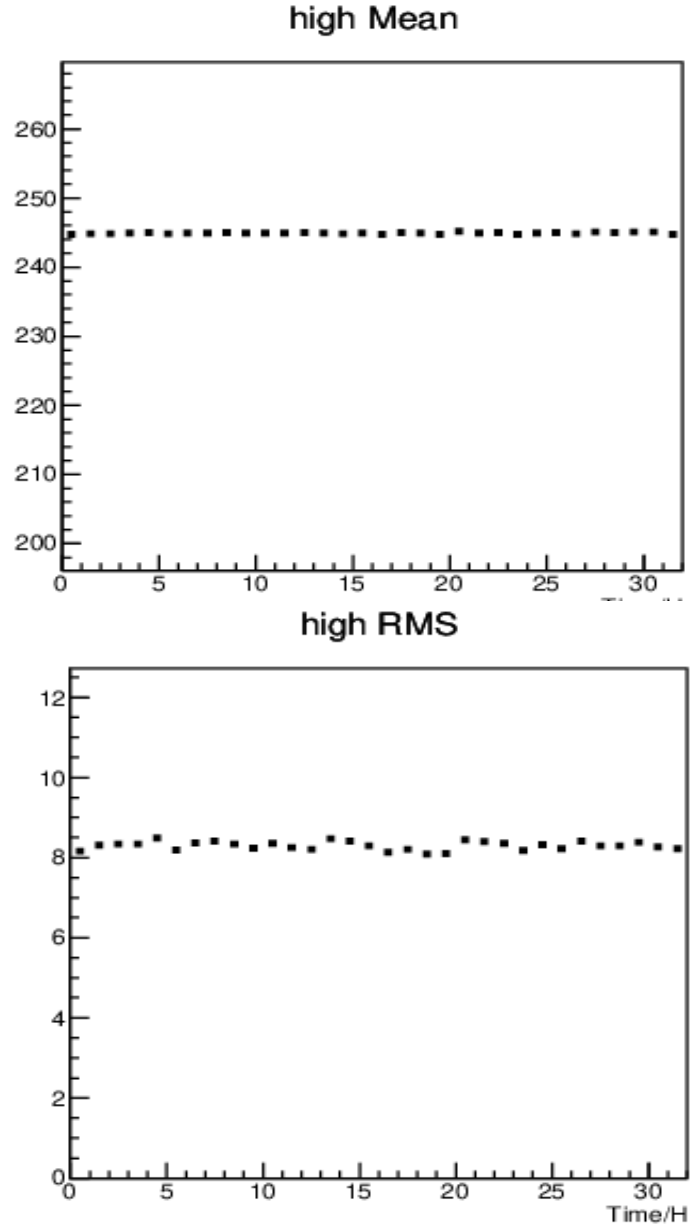


- Single layer prototype for the study of modules layout, integration, preliminary performance
- 144 modules of scintillator strip coupling with SiPM(S12571-010P)
- Half are side-end coupling mode, the other half are bottom-center embedded coupling mode(I)
- Side-end coupling mode scintillators wrapped with ESR(II) or Teflon(III)

Electronics performance

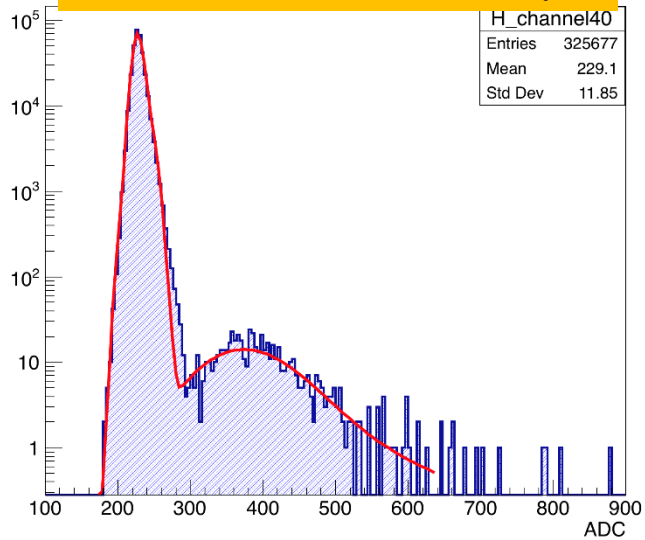
- Working in high gain mode
- SiPM without H.V.
- SiPM with H.V.
- Long time work stability



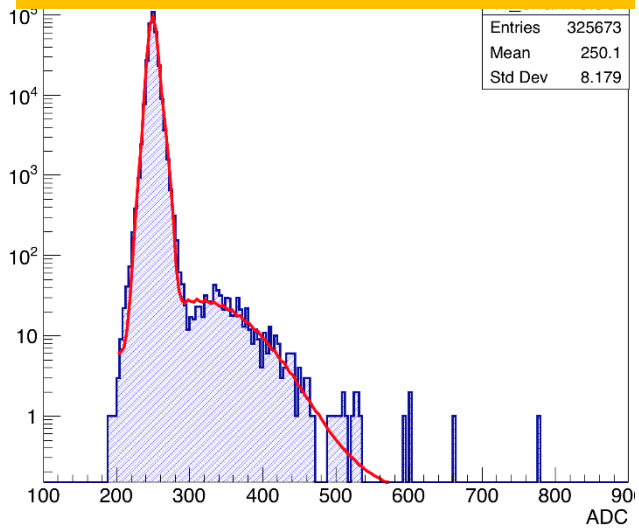


Cosmic Ray Preliminary performance

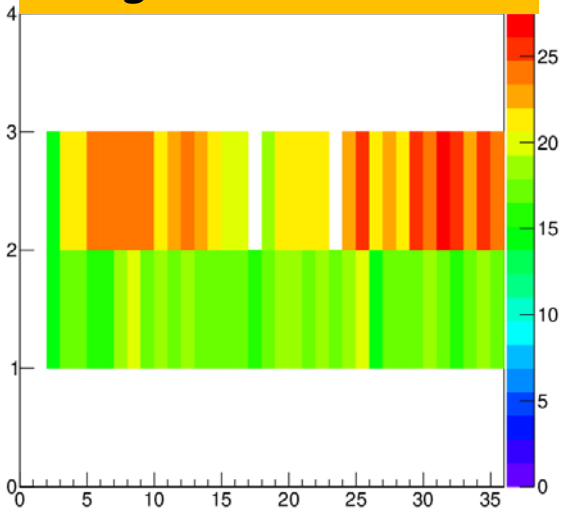
Side-end ESR wrap



Side-end Teflon wrap



Signal noise ratio



- For side-end coupling mode, almost all channels separate pedestal and MIP peak well except two
- Signal noise ratio are all larger than 10
- Wrapped with ESR signal larger than wrapped with Teflon
- Bottom-center coupling mode strips test is ongoing……

Summary

- Thanks for the funded by MOST-1 CEPC R&D in 2016
- Optimized ECAL absorber thickness, active layers and cell size
- Improved uniformity of scintillator strip light output
- Achieved SiPM response function for nonlinearity correction
- Assembled single layer prototype and obtained preliminary cosmic ray test results
- Great progress has been made, but much more needs to be done ……

Summary

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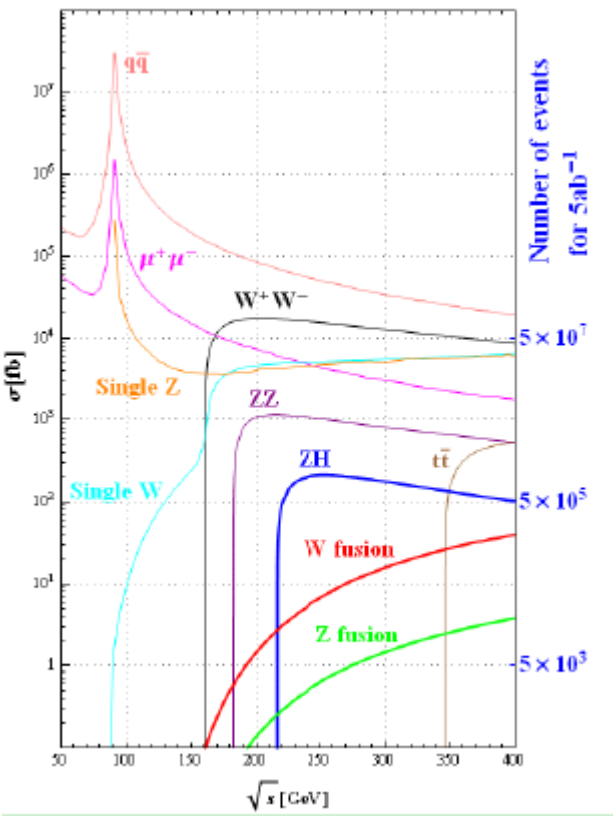
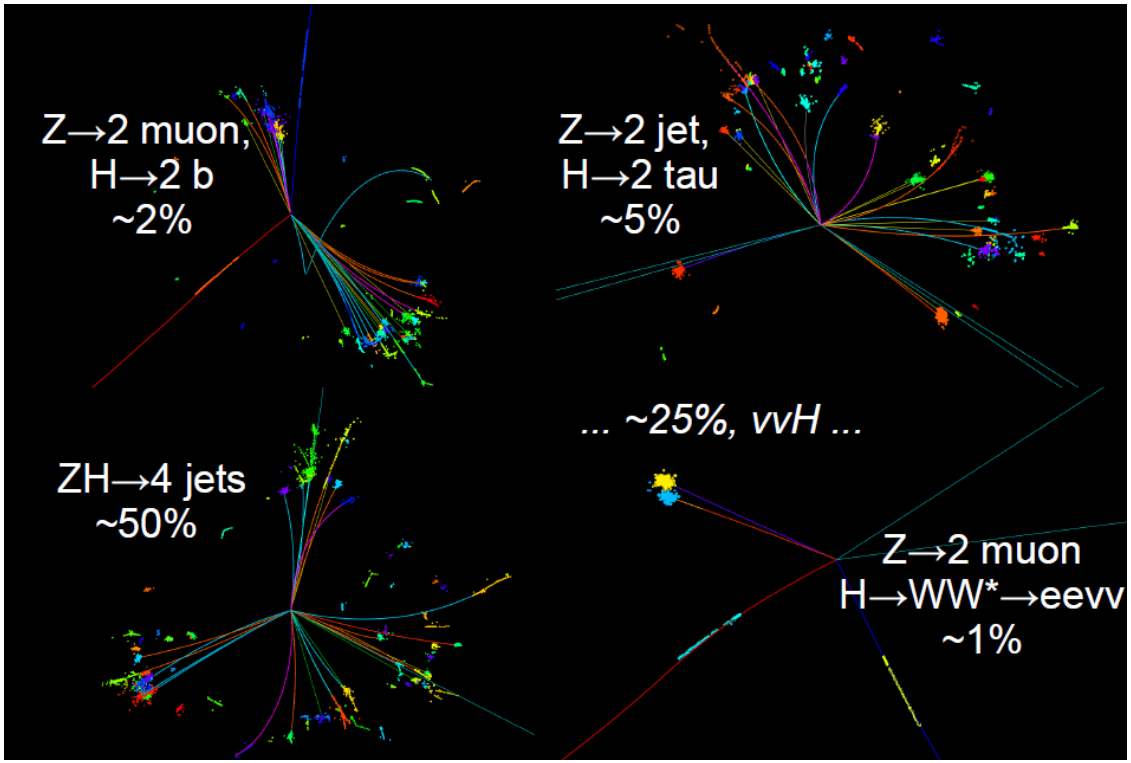
Thanks for your attention!

backup

Higgs production and decay

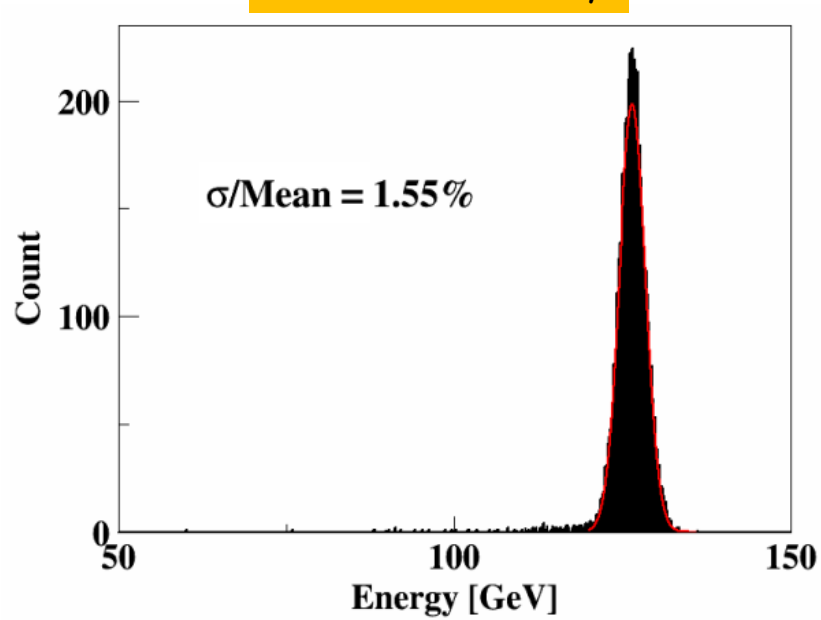




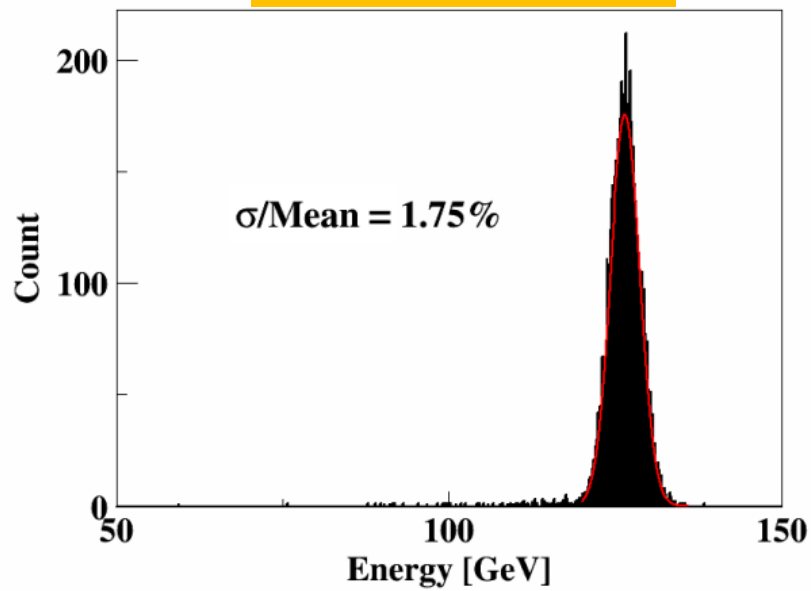
Scintillator non-Uniformity

How much is the effect of uniformity on energy reconstruction?

WO non-uniformity



W 25%non-uniformity

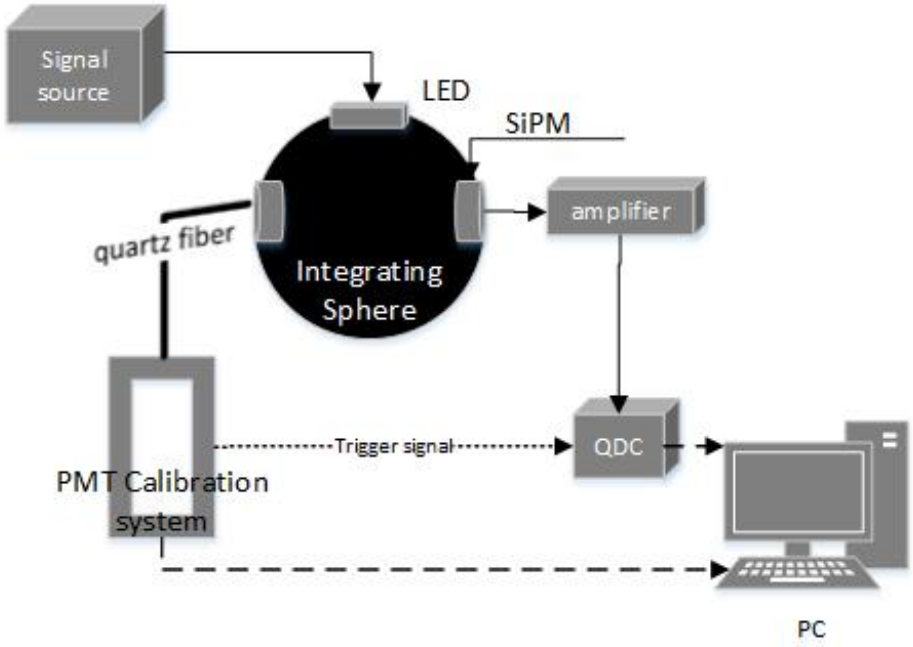


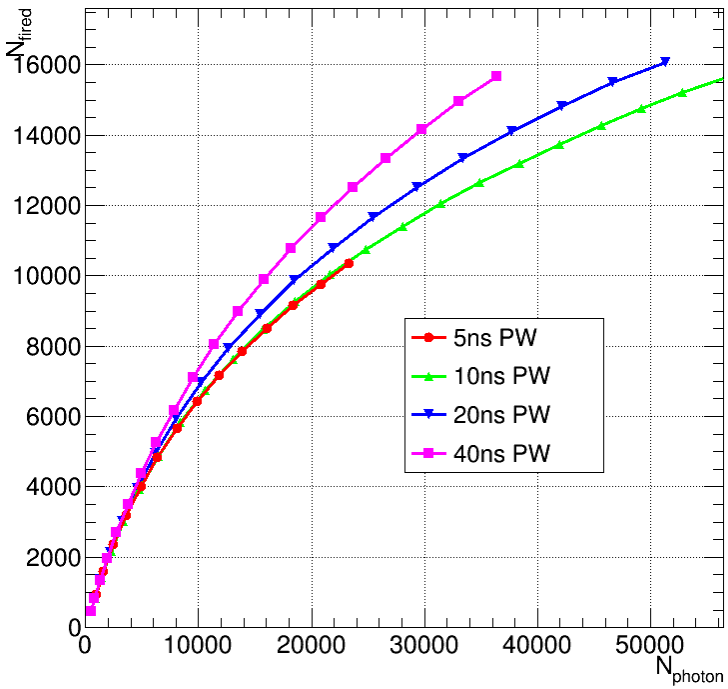
$$\nu\nu Higgs \rightarrow \gamma\gamma$$

SiPM Linearity

Test with different Photon Width(PW):

5ns, 10ns, 20ns and 40ns

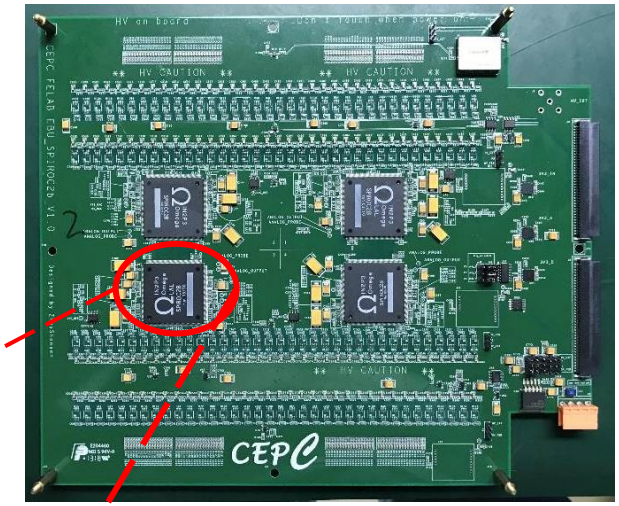




SPIROC2b chip

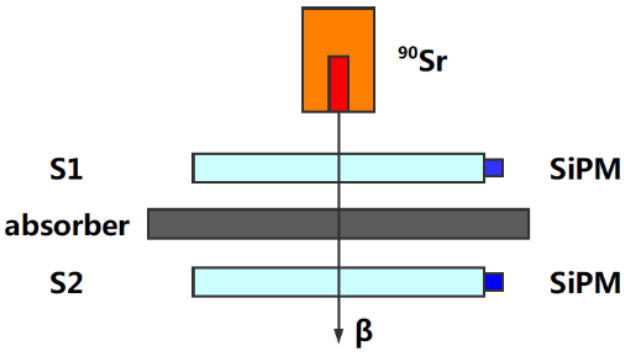
- SiPM front-end with **ASIC SPIROC2b** of 36 channels
- **FPGA** (Artix-7 200T)
- DIF is **compatible for FEB**
- USB for data upload & cmd sending
- USB for single DIF, and **serial port for DAQ** when using multiple DIF

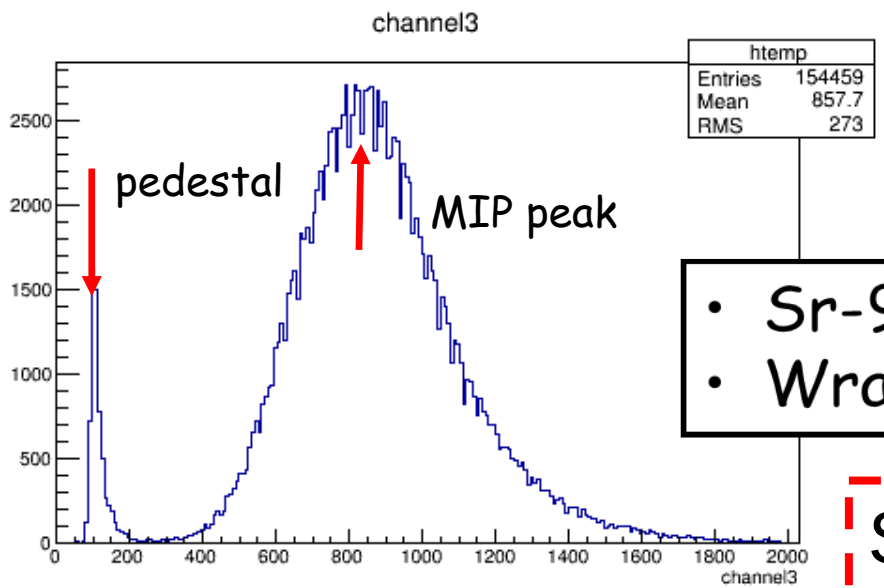
- Switched capacitor array store charge measurement
- 12 bits ADC conversion
- Variable Gain due to:
  - adjustable Cf of pre-amplifer
  - Rload on the board
  - Shaping time and delay



- Dynamic range: ~100fC~300pC
- channels: 36
- Dead time: 2ms
- Polar: positive
- power: 8mW/channel

Scintillator Light-Yield



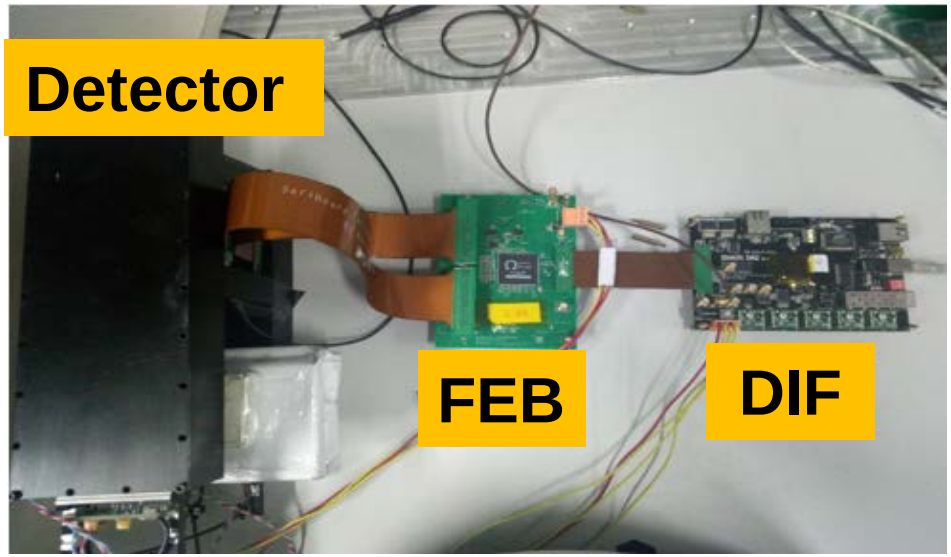


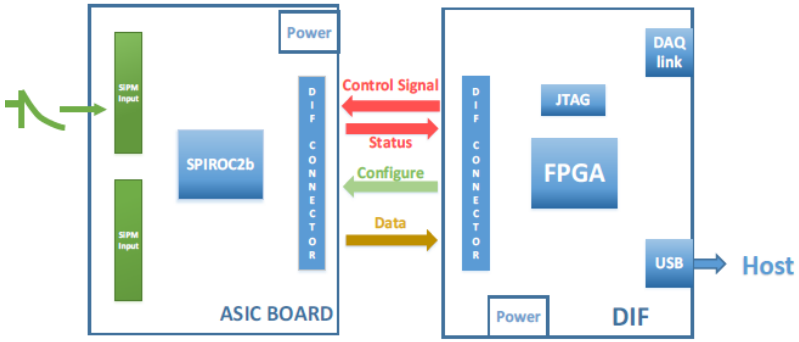
- Sr-90 source provide β ray as MIPs
- Wrapped with ESR or Teflon

Scintillator： BC-408
Light-Yield： ~25 p.e.
Dispersion: ~12%

Readout Electronics

- Test platform
  - Signal generator for electronic testing
  - Sci + SiPM detector with cosmic triggers
  - Power supply, oscilloscope and PC

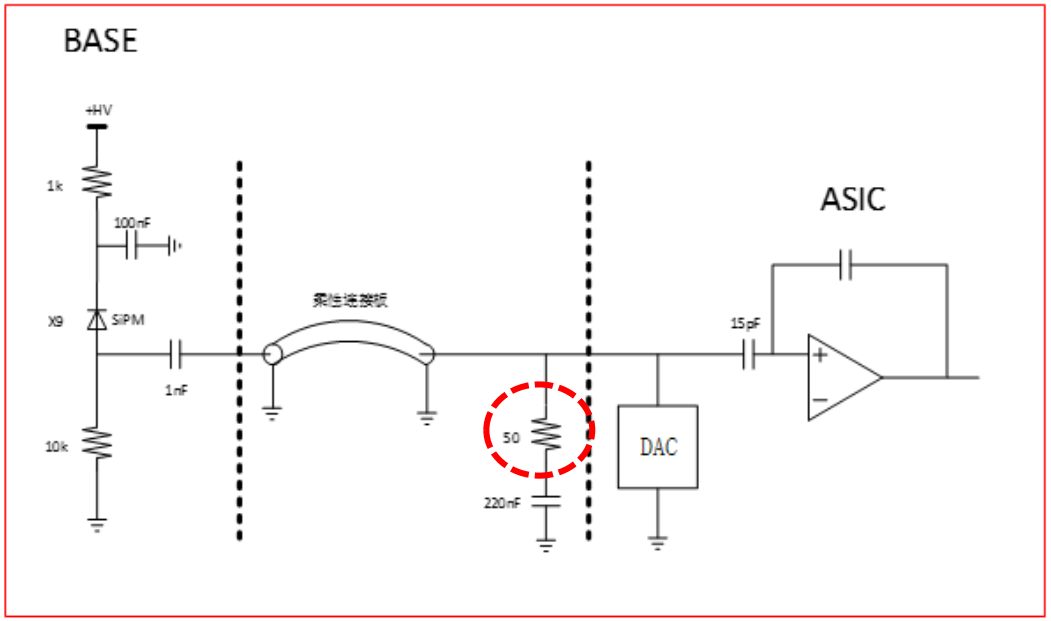




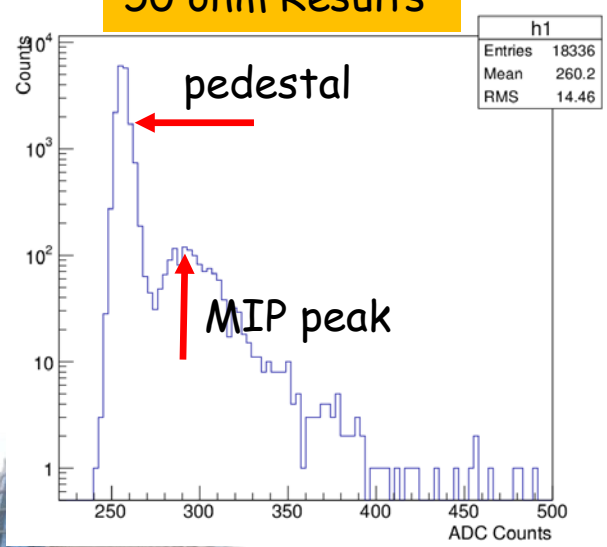
System schematic

Cosmic ray Results

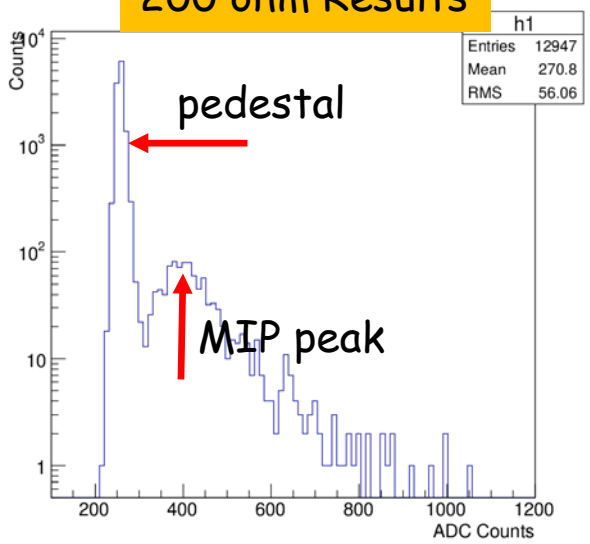
	sigma/ Ch	MIP/Ch	S/N
50ohm	2.7	35.7	13.2
200ohm	6.0	147.2	24.5
1kohm	24.7	389	15.7



50 ohm Results



200 ohm Results



1k ohm Results