The R&D progress of CEPC HCAL

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ICHEP2018, 5 July 2018,Seoul

Outline

—CEPC Detector Concept(s)

—The options of CEPC-HCAL;

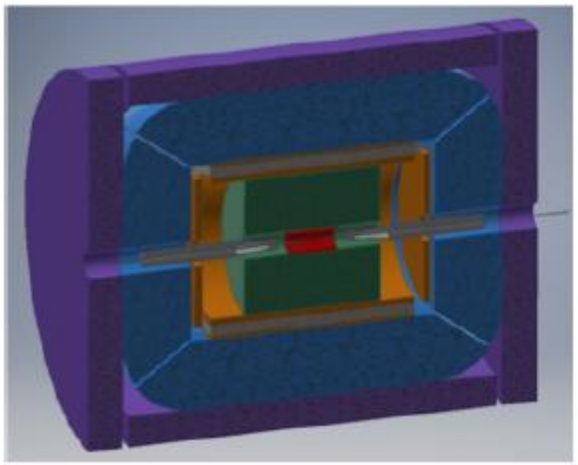
—The progress of two option of HCAL

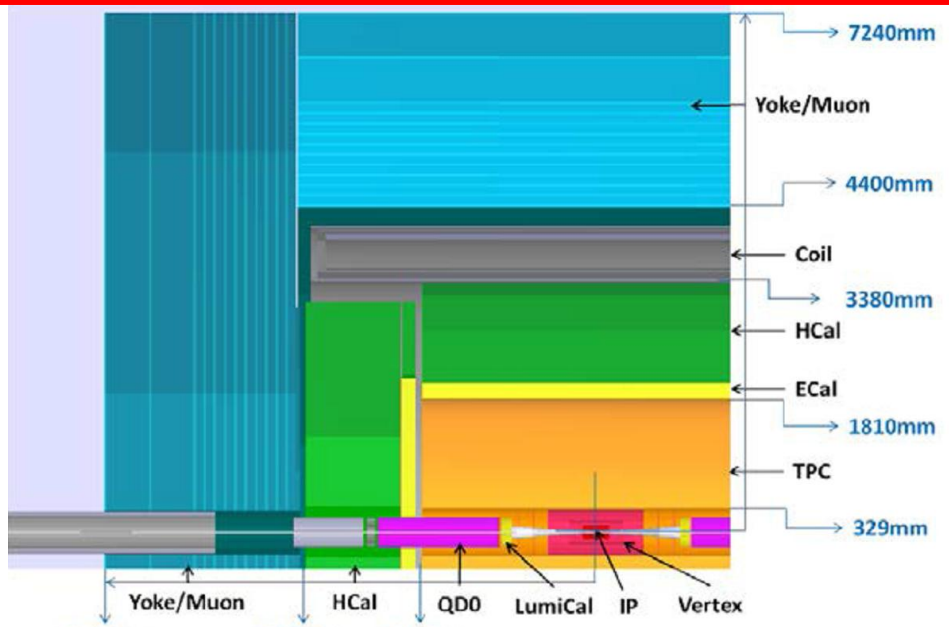
- DHCAL based on RPC and MPGD(THGEM/GEM);
- AHCAL based on scintillator;

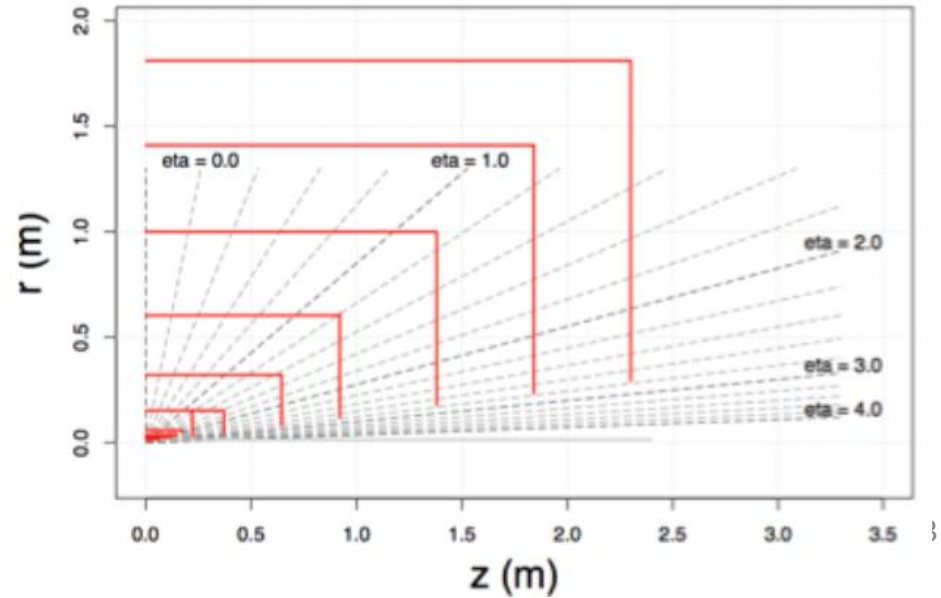
—Summary

CEPC Detector Concept(s)

- Baseline: ILD-like
  - TPC tracking + Imaging calorimetry (ECAL+HCAL)
  - PFA-oriented
- Alternatives
  - Low-field concept
  - Full-silicon concept



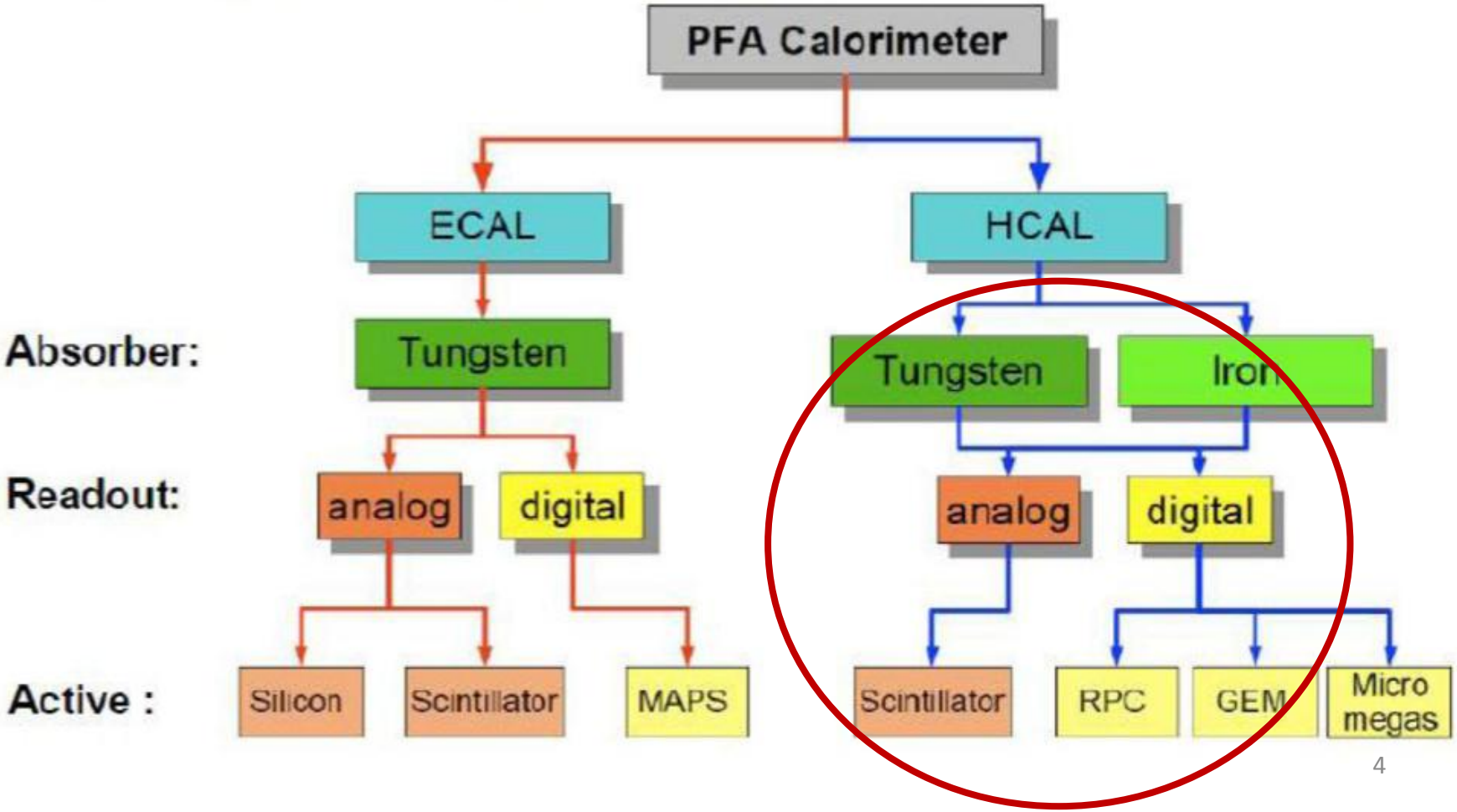




The options of CEPC-HCAL;

Two options:

1. Digital HCAL (DHCAL): Gas detector, RPC & MPGD
2. Analog HCAl (AHCAL): Plastic scintillator



PFA HCAL R&D for CEPC

- Initiated by the CEPC MOST-1 R&D project in 2016

  PFA HCAL R&D topics that started initially (Digital HCAL)

  –RPC technology

  –MPGD（GEM/THGEM）technology

- Initiated by the CEPC MOST-2 R&D project in 2018

  –Analog option of scintillator entered the game later

- Now R&D ongoing for the two options

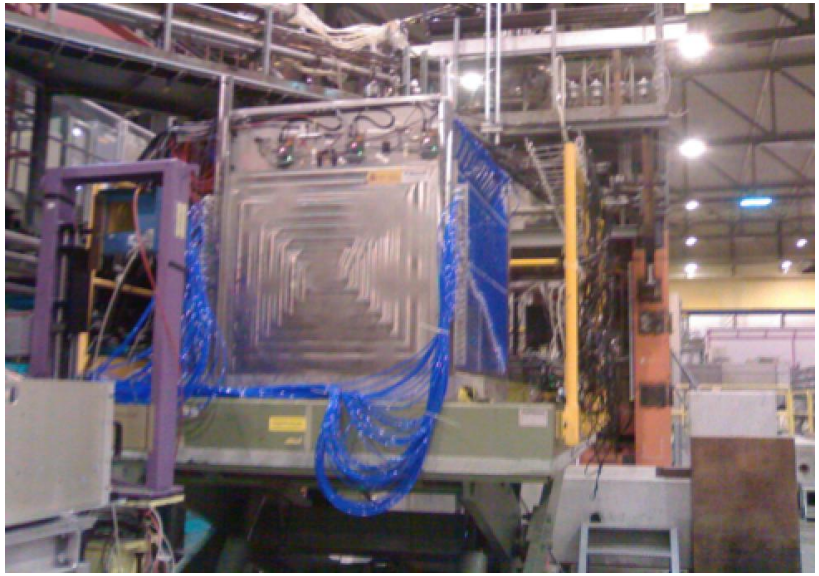
SDHCAL Based on RPC（IPNL+SJTU within CALICE）

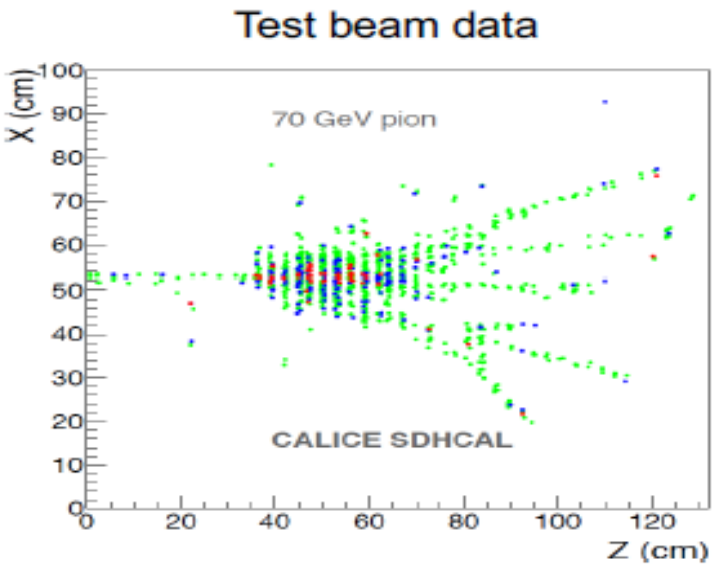
SDHCAL Prototype

- SJTU is working with IPNL, Tsinghua and several other groups within CALICE on RPC-SDHCAL as part of CEPC detector R&D effort

- Total Size:1.0x1.0x1.4m^3
- Total Layers: 48
- Total Channel(pads):440000
- Power consumption:$10\mu W/channel$

(Power pulsing)

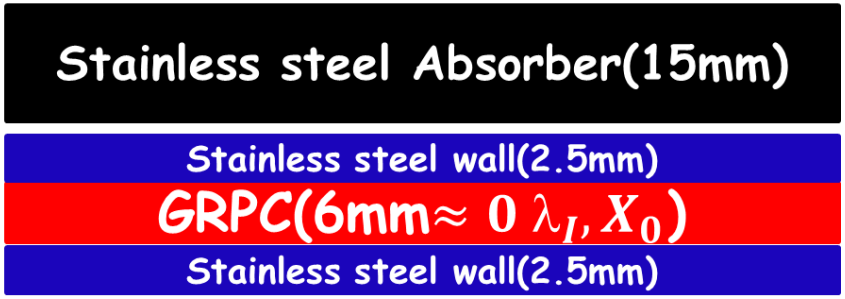


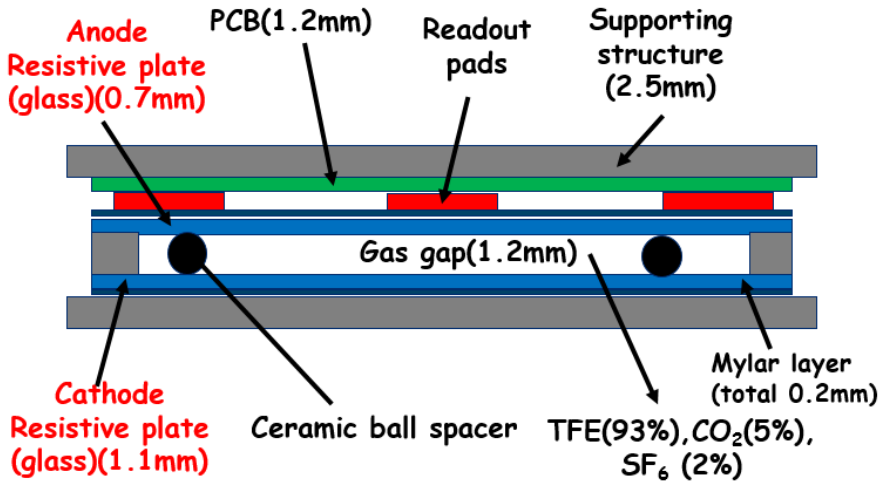


Developed by the CALICE collaboration

Structure of sampling layer

$(0.12\lambda_I, 1.14X_0)$

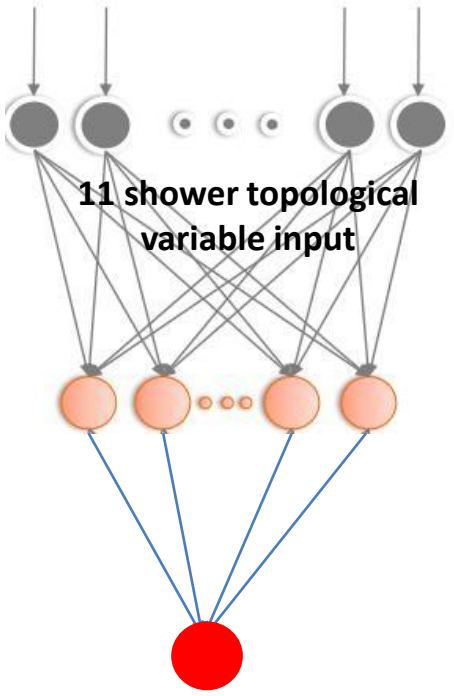




ASIC HARDROC(64 channel)
three-threshold (Semi-digital)
110fC,5pC,15pC

Analysis of test beam data： Energy reconstruction using MLP and BDT

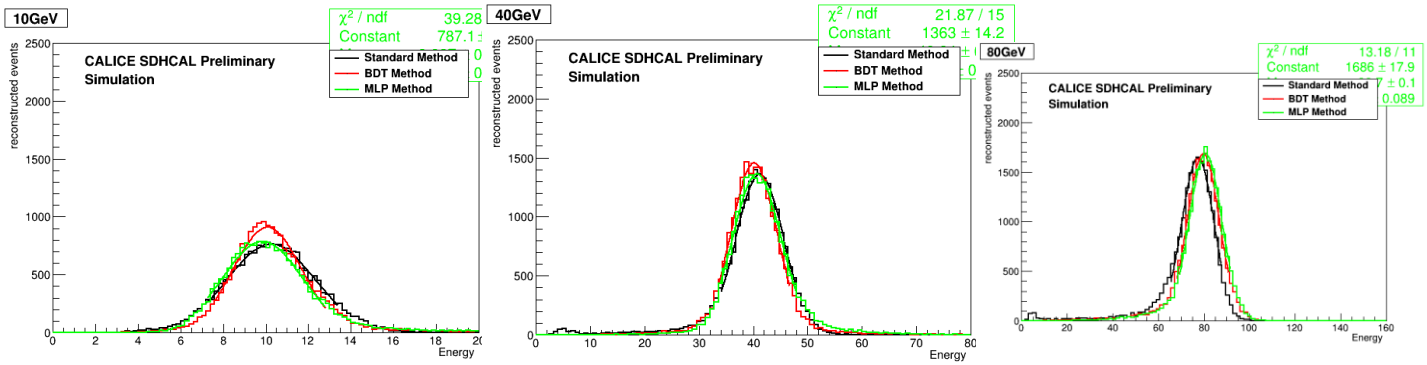
MLP Structure

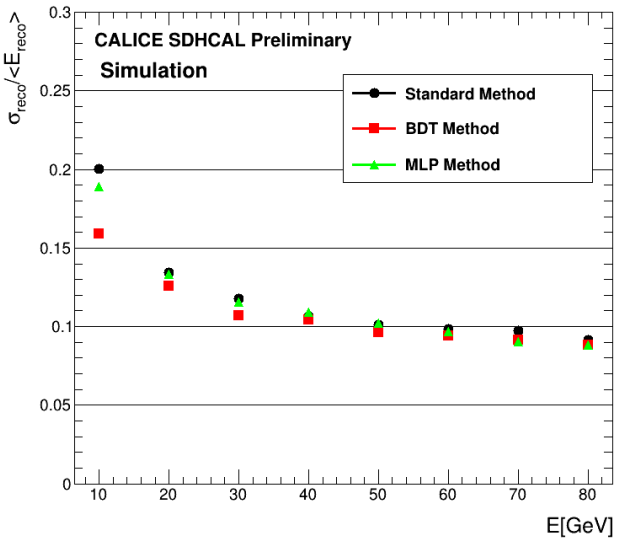


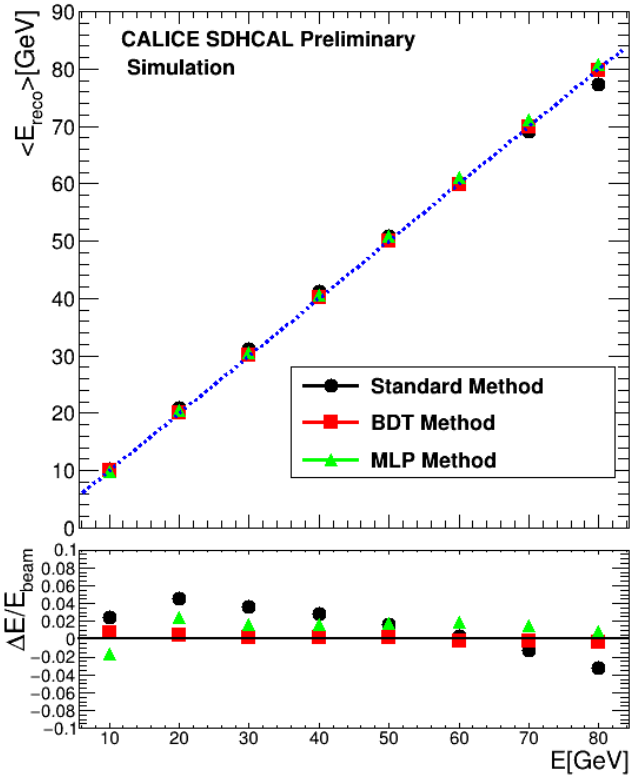
11 shower topological variable input

One hidden layer

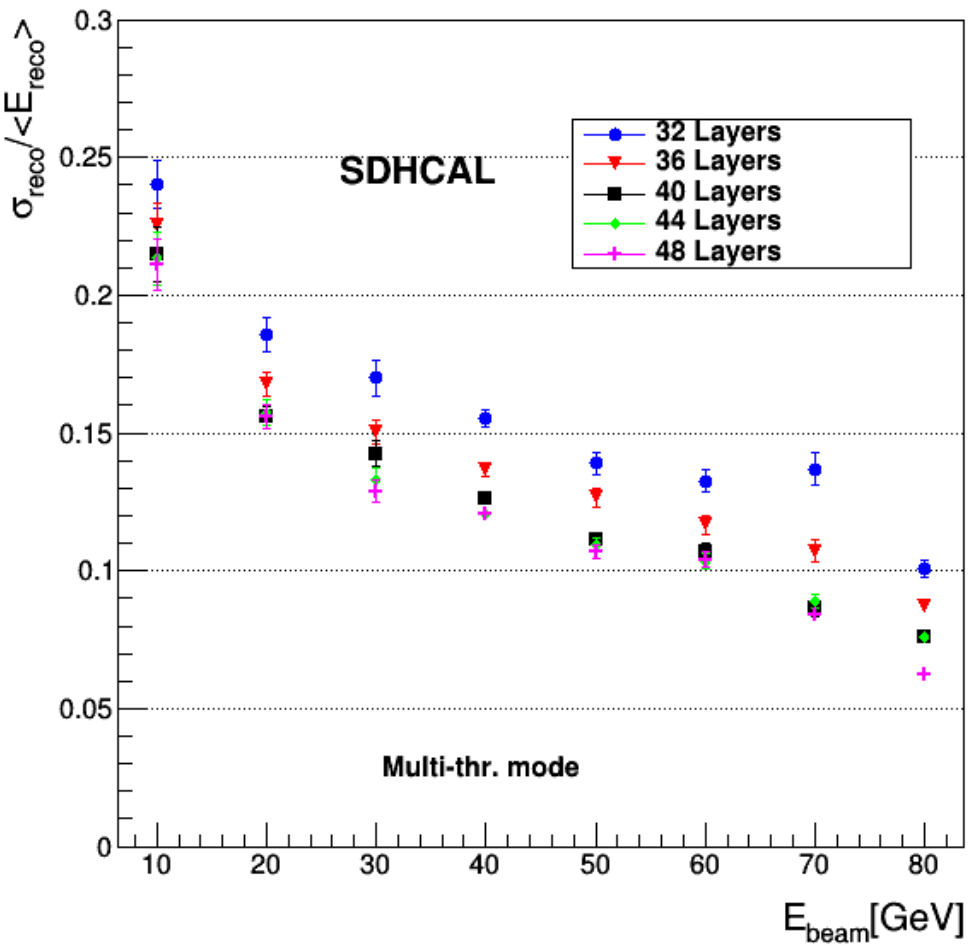
Energy reconstruction







Optimization of SDHCAL Layers



$(0.12\lambda_I, 1.14X_0)$

Stainless steel Absorber(15mm)

Stainless steel wall(2.5mm)

GRPC(6mm$\approx 0\ \lambda_I, X_0$)

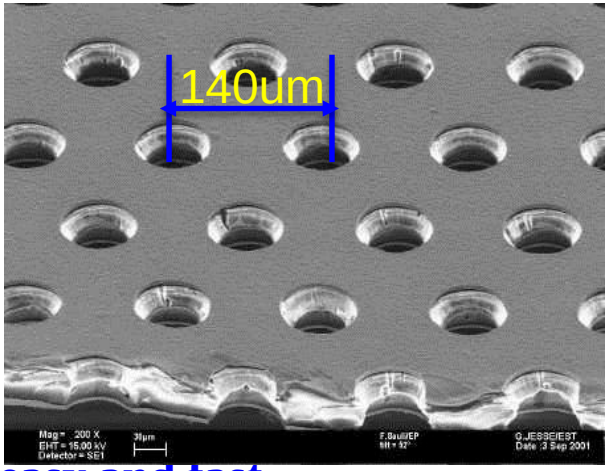
Stainless steel wall(2.5mm)

➔SDHCAL has 48 layers which aims for ILC Detector
- 6mm RPC+20mm absorber

➔Optimization no. of layers for CEPC at 240GeV

➔40-layer SDHCAL yields decent energy resolution.

DHCAL based on MPGD(GEM)



Typical parameters

Cu : t = 5μm

Kapton: T = 50μm

Diameter: d = 60μm

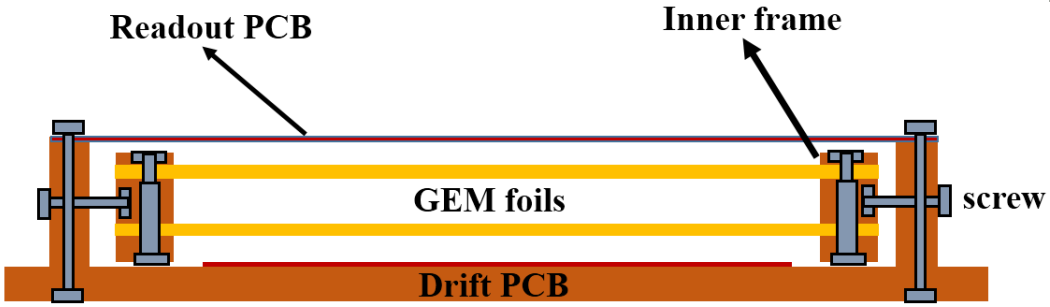
D = 80μm

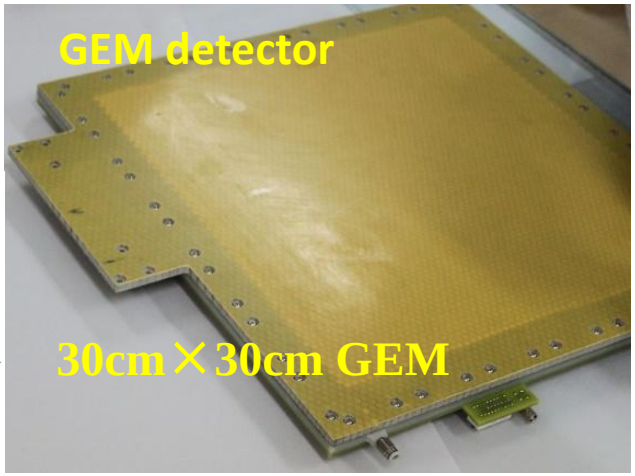
pitch: 140μm

➢ **Advantages:**

1. assembling process is easy and fast
2. no dead area inside the active area
3. uniform gas flow
4. detachable

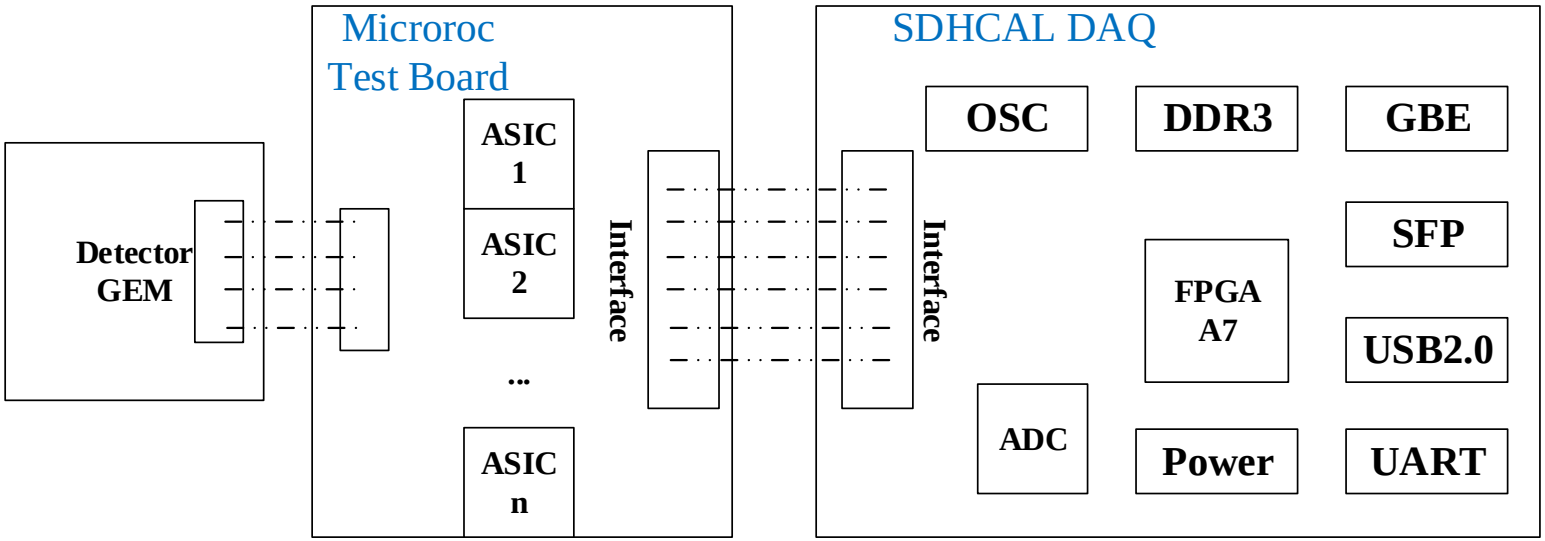
Self-stretching technique (from CERN)





Readout Scheme

- Schematic of the System

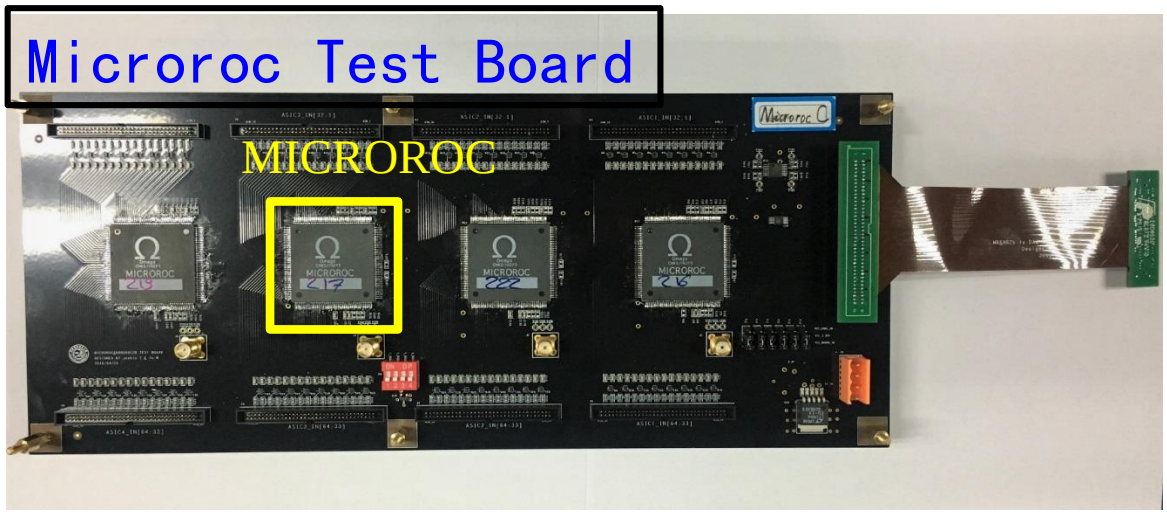


- Readout Board: GEM detector Readout composed by 900 $1cm^2$ pads.
- MICROROC Test Board: Mounted 4 Microroc ASICs, controlled by daisy chain.
- DIF Board: Microroc control, test and data acquisition

Readout ASIC

Readout ASIC	Channels	Dynamic Range	Threshold	Consumption
GASTONE	64	200fC	Single	2.4mW/ch
VFAT2	128	18.5fC	Single	1.5mW/ch
DIRAC	64	200fC for MPGD	Multiple	1mW/ch, 10μW/ch(ILC)
DCAL	64	20fC~200fC	Single	——
HARDROC2	64	10fC~10pC	Multiple	1.42mW/ch,10μW/ch(ILC)
MICROROC	64	1fC~500fC	Multiple	335μW/ch, 10μW/ch (ILC)

Considered the multi-thresholds readout, dynamic range and power consumption, MICROROC is an appropriate readout ASIC

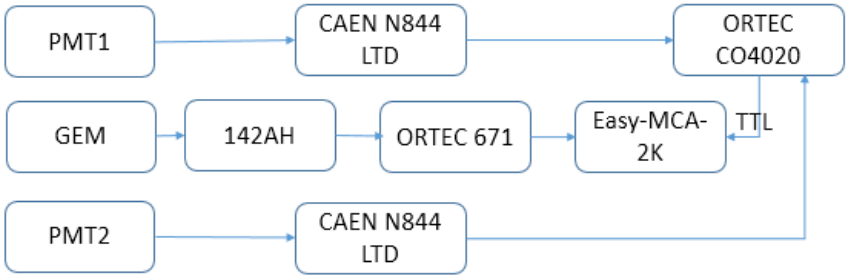


MICROROC Parameters

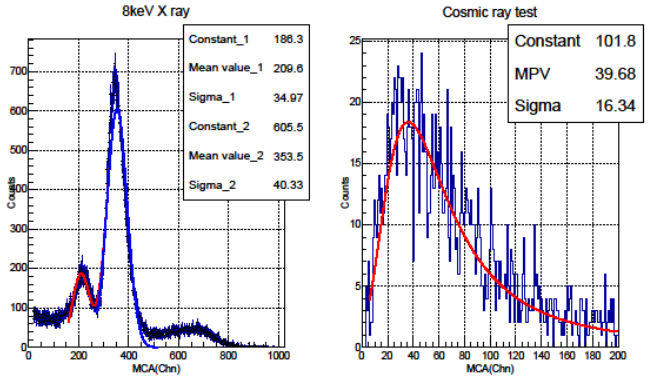
- Thickness: 1.4mm
- 64 Channels
- 3 threshold per channel
- 128 hit storage depth
- Minimum distinguishable charge:2fC

Detection efficiency for MIPs

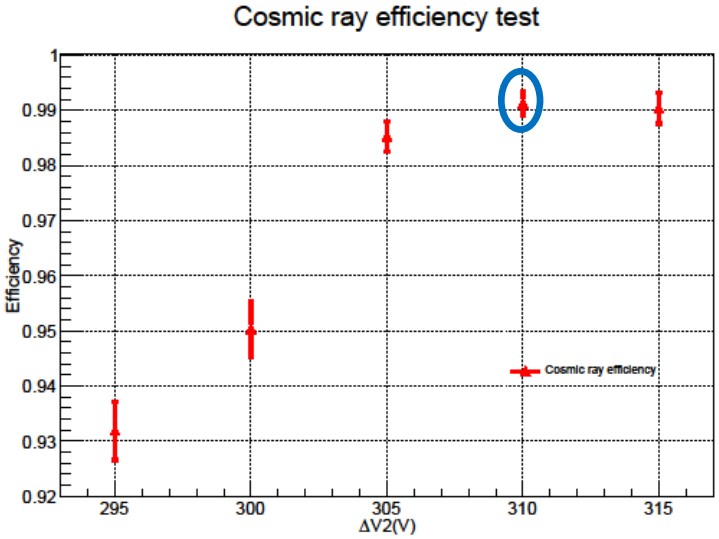
Electronic system

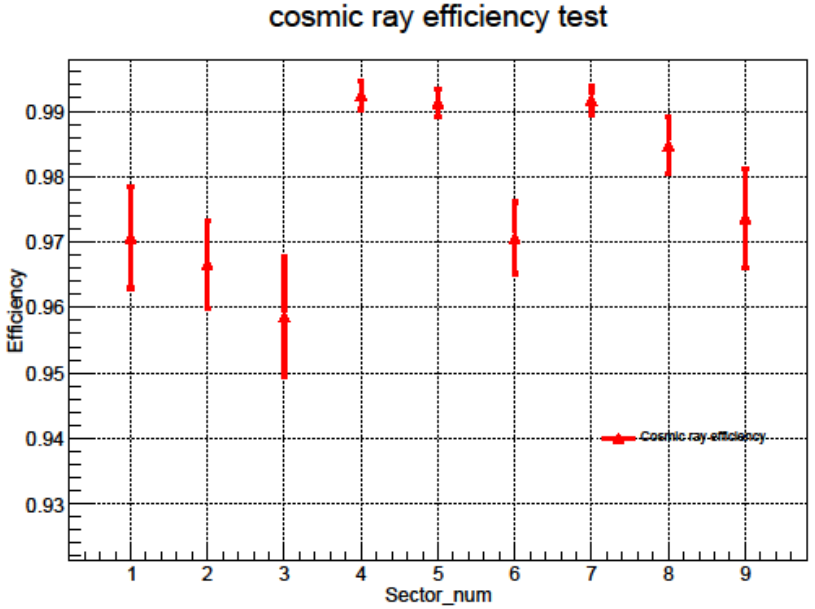


Spectra of X ray and cosmic ray



Detection efficiency vary with voltage



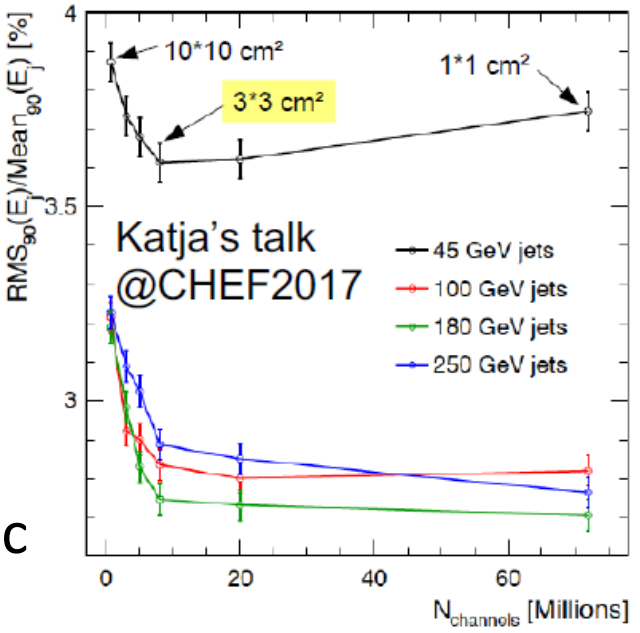


Detection efficiency in different area of GEM detector

The R&D progress of scintillator AHCAL

— Analog hadron calorimeter for CEPC:

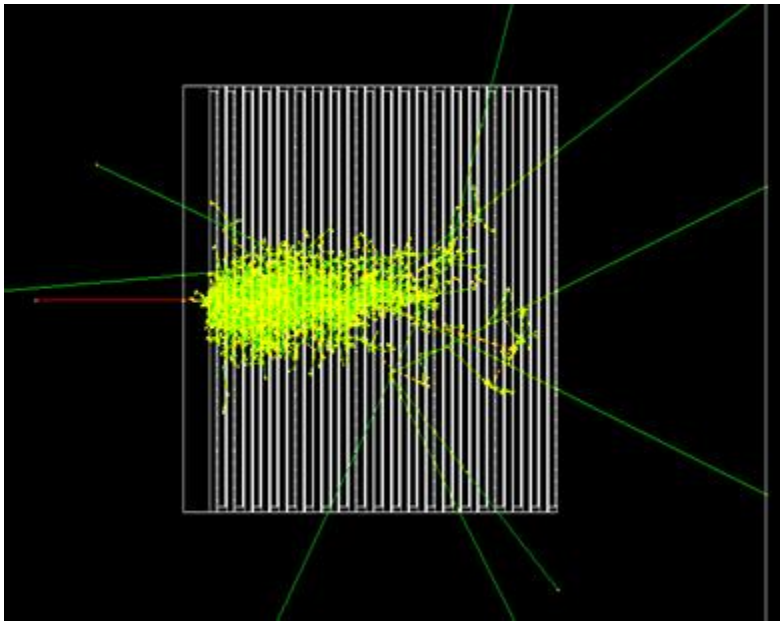
- The absorber: 2cm Stainless steel;
- Detector cell size: 3cm × 3cm (baseline) , 4cm × 4cm, 5cm × 5cm ;
- Readout chip: ASIC SPIROC2E
- The sensitive detector : Scintillator(organic scintillator);
- 40 sensitive layers, total readout channel: ≈6 Million (3cm × 3cm)

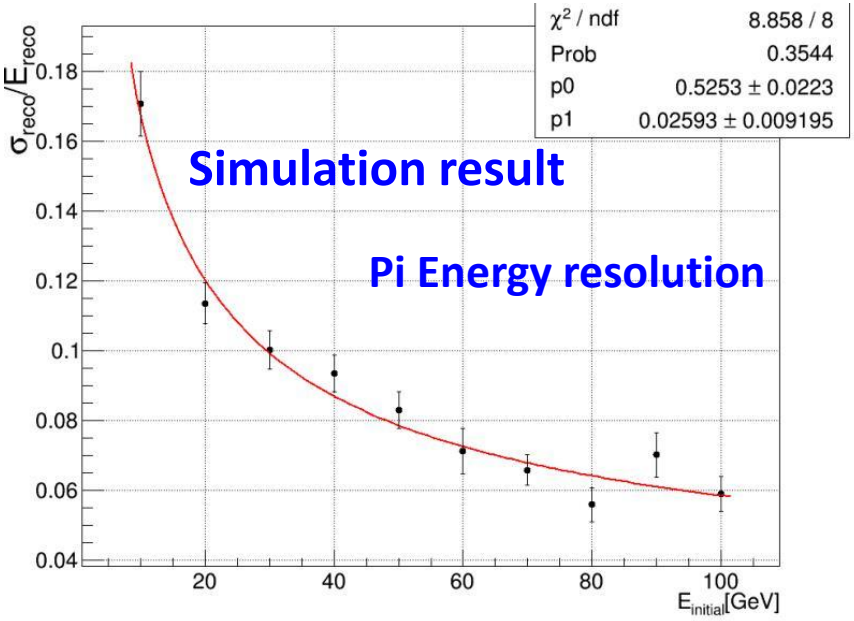


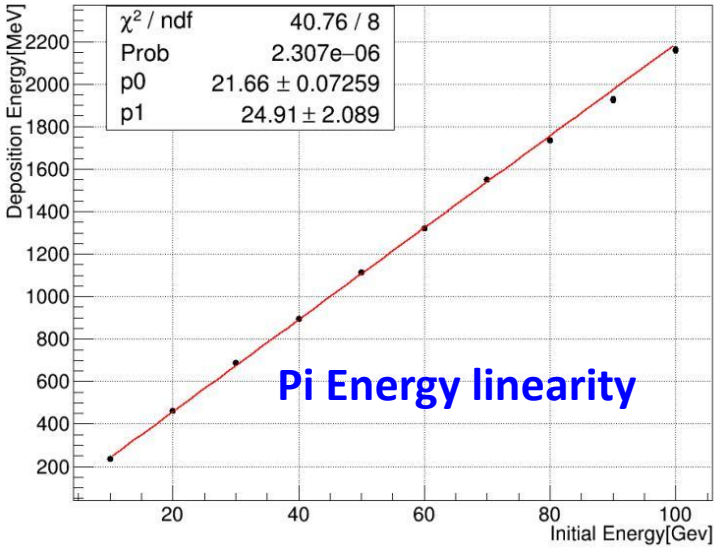
AHCAL prototype Plan（MOST2 funding Support）

Specification:

- 35 active layers;
- Detector cell:17*17*35=10115;
- Absorber: stainless steel;
- ASIC Chip： SPIROC-2E；
- Prototype size:51*51*87.5cm^3

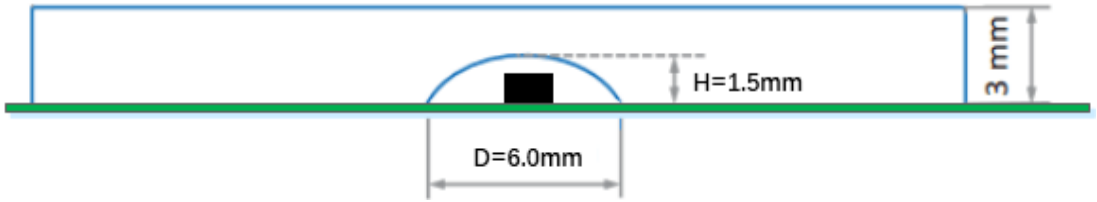




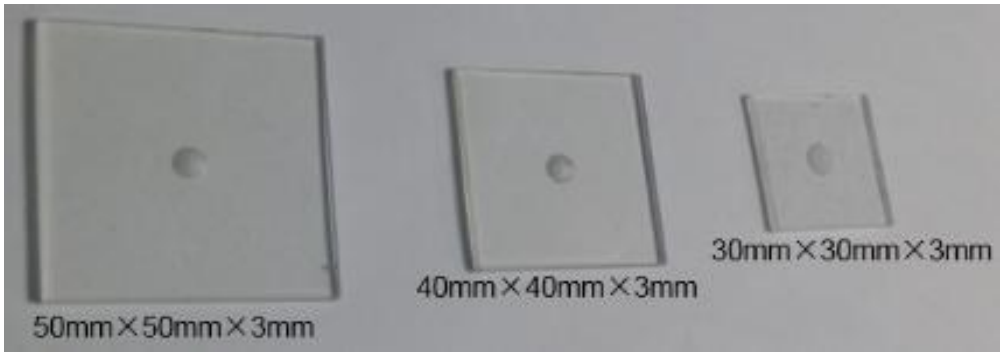


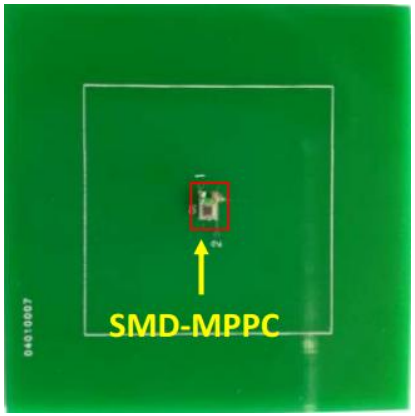
Detector Cells study

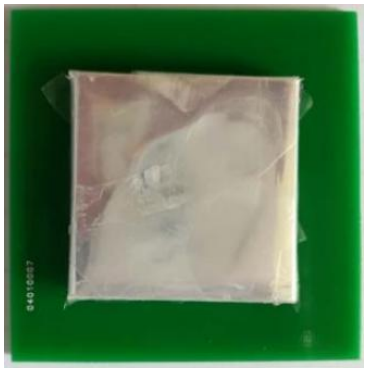
– The four sizes of 30×30×3mm^3,30×30×2mm^3 , 40×40×3mm^{3}and 50×50×3mm^3 were made.
– SiPM or MPPC(surface-mounted)
– Scintillator(BC408) were wrapped by ESR foil



Scintillator tile wrapped by ESR foil was glued on the PCB







Cosmic-rays measurement results

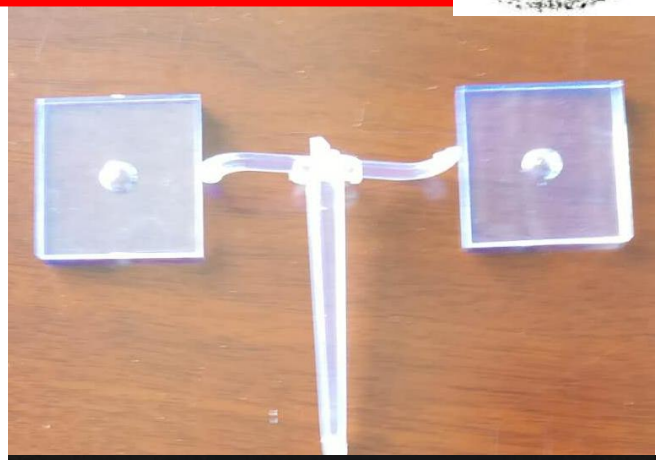
Table 1 Cosmic-ray measurement results of detector cells with different sizes

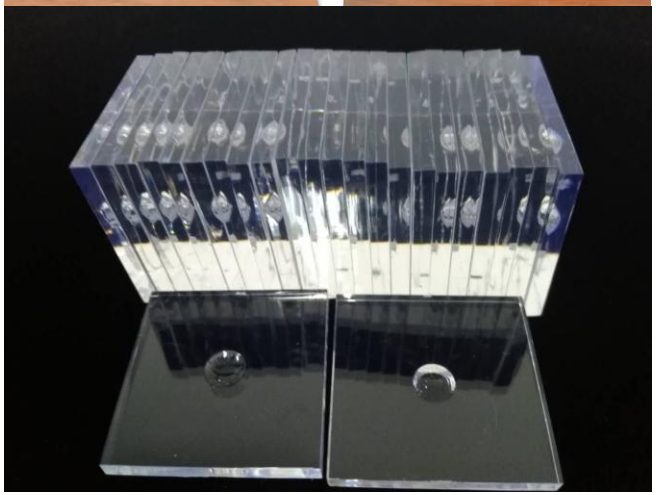
No.	Detector Cell	MPPC Type	Reflective Foil Type	Mean $N_{p.e.}$	Polishing Methods
1	$30\times30\times3mm^3$	S12571-025P	ESR	31.39±0.65	Ultra Precise Polishing
2	$30\times30\times3mm^3$	S12571-025P	ESR	22.55±0.7	Precise Polishing
3	$30\times30\times3mm^3$	S12571-025P	ESR	18.92±0.39	Rough Polishing
4	$30\times30\times3mm^3$	S12571-025P	TYVEK	13.63±0.33	Precise Polishing
5	$40\times40\times3mm^3$	S12571-025P	ESR	14.89±0.73	Precise Polishing
6	$50\times50\times3mm^3$	S12571-025P	ESR	9.87±0.43	Precise Polishing
7	$30\times30\times2mm^3$	S13360-1325PE	ESR	33.89±0.49	Precise Polishing

- For same size of detector cell， polishing method is very important;
- Different reflective foil: ESR is better than TYVEK;
- The bigger size detector cell， the less p.e. detected;

Injection moulded Scintillator tiles

- 3000 tiles polystyrene, PPO+BisMsb
  – injection moulded at Beijing
  – incl. dimple, no further surface treatment;
- Mechanical tolerances OK for assembly, the size error less than 50um;
- Scintillators Light yield fluctuation is <10%;

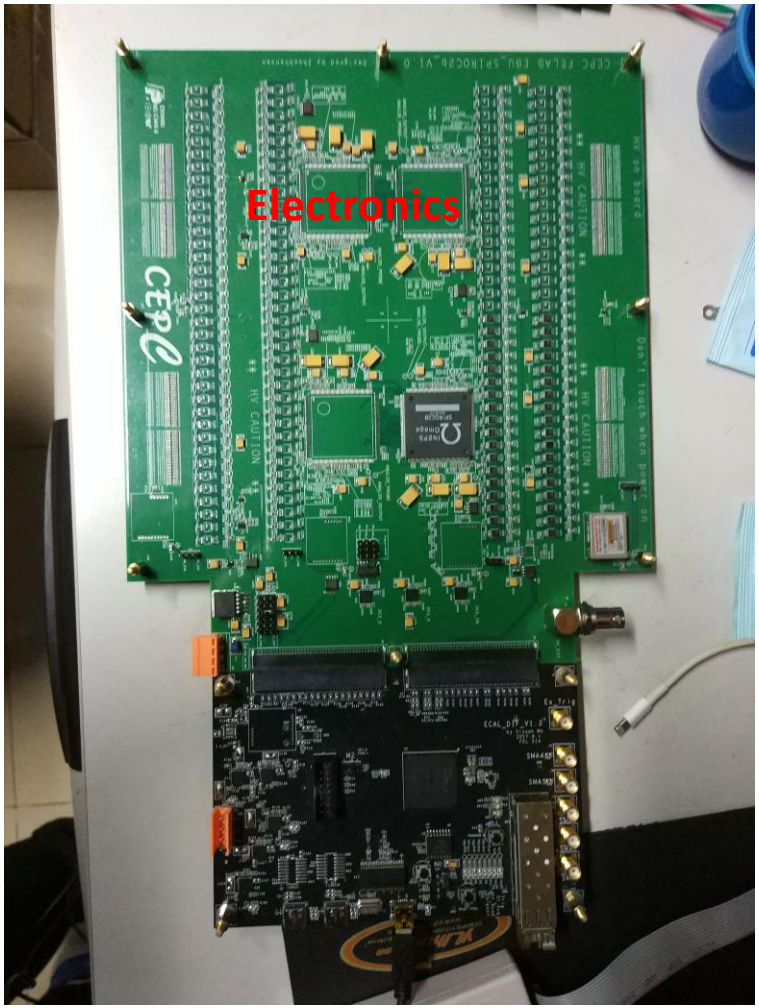


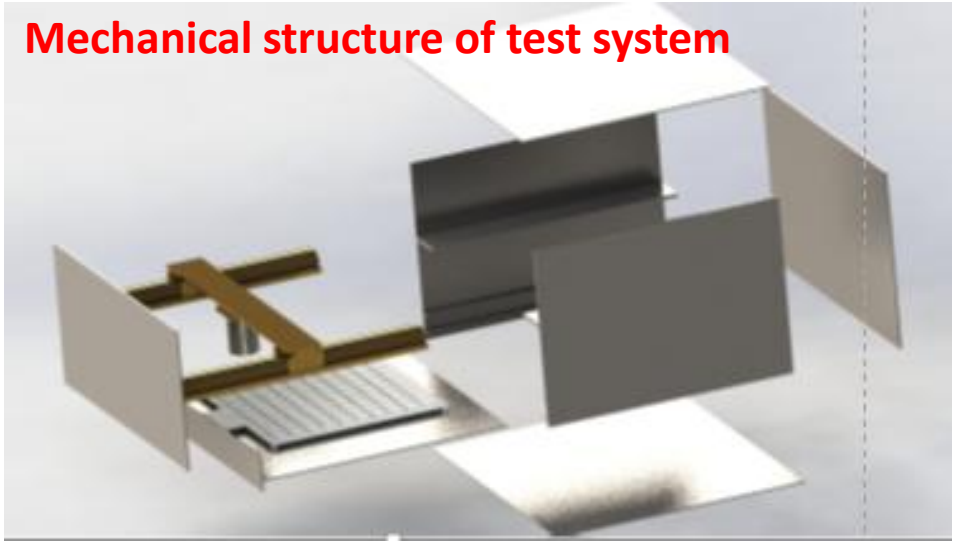


Tiles size(mm)	30.08x30.01 x3.08	30.07x30.04 x3.09	30.04x30.02 x3.09	30.09x30.09 x3.09	30.05x30.03 x3.09
Light yield(p.e.)	23.5	22.78	22.86	25.02	23.54

Detector cell test system design

- About 100 detector cells one batch;
- Electronics under design;
- Mechanical structure under design;

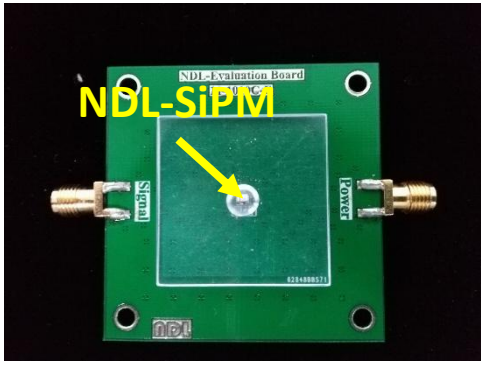




Chinese NDL-SiPM Test result (1mmx1mm 10umSiPM)

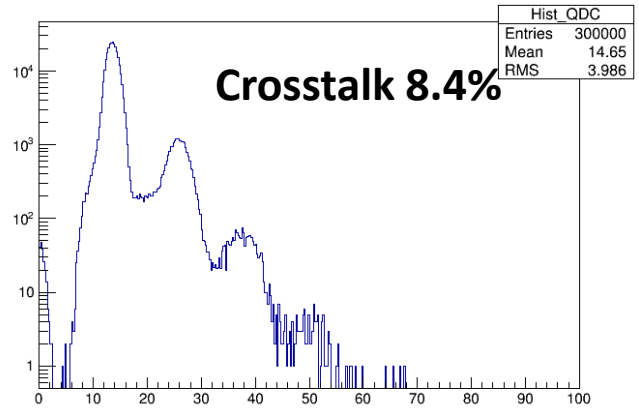
Six NDL-SiPMs was tested (electron-Sr90): 30mmx30mmx3mm with PL Scintillator

SiPM1	SiPM2	SiPM3	SiPM4	SiPM5	SiPM6
25.43p.e.	25.77p.e.	25.12p.e.	24.06p.e.	23.44p.e.	24.61p.e.



The light yield deviation smaller than 2p.e.

All SiPMs' high Voltage are 35V, each of which is measured after calibration.



Crosstalk spectrum

NDL-SiPM 11-1010C specification

Parameter	Value	Parameter	Value
Effective Active Area	1× 1mm^2	Peak PDE@420nm*	39%
Effective Pitch	10 μm	Dark Count Rate*	~500 kHz
Micro-cell Number	~10000	1 p.e. Pulse Width	5 ns
Operating Temperature	-196℃ - +40℃	Temperature Coefficient For V_b	25 mV/℃
Breakdown Voltage (V_b)	25.5±0.2 V	Gain	≥2×10^5
Max. Overvoltage (ΔV_{max})	8 V	Single Photon Time Resolution	≤ 70 ps

Summary and next

—The construction of CEPC-HCAL prototype based on scintillator is started;

—Some critical R&D items identified, which will be followed up.

—Our R&D work would be more and more integrated into international PFA calorimeter R&D activities.

Thanks for your attention!