

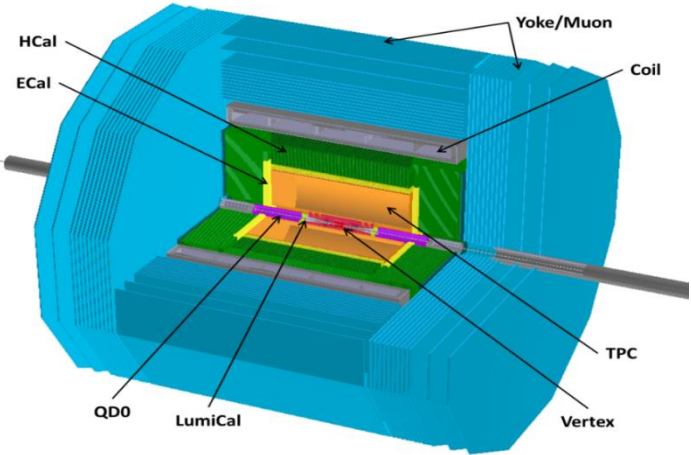
# Plastic scintillator ECAL and HCAL

Yunlong Zhang

University of Science and Technology of China



# Requirements of CEPC Calorimeter



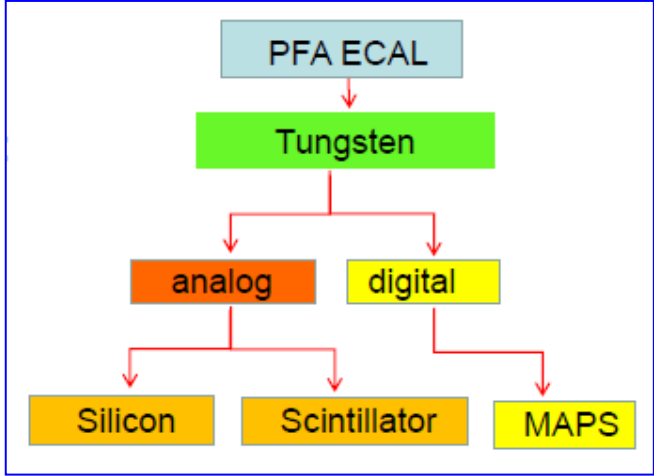
- **ILD-like detector with additional considerations.**

**Challenges:**

- **Momentum:**  $\sigma_{1/p} < 5 \times 10^{-5} \text{ GeV}^{-1}$
- **Impact parameter:**  $\sigma_{r\phi} = 5 \oplus 10 / (p \cdot \sin^2 \theta) \mu\text{m}$

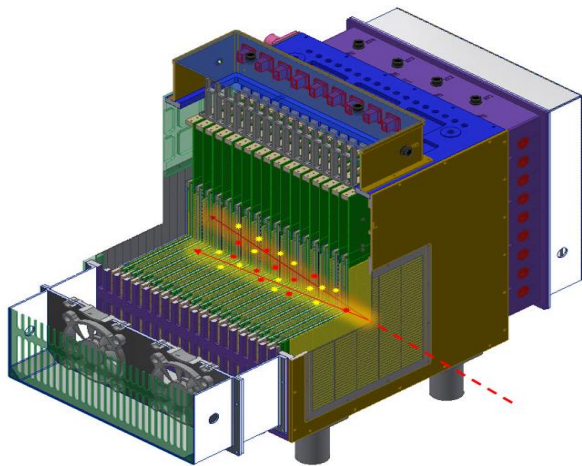
➤ **Jet energy:**  $\frac{\sigma_E}{E} \approx 3 - 4\%$

- The Particle Flow Algorithm (PFA) calorimeter concept was proposed
  - High granularity
  - Good track finding
  - Good energy resolution

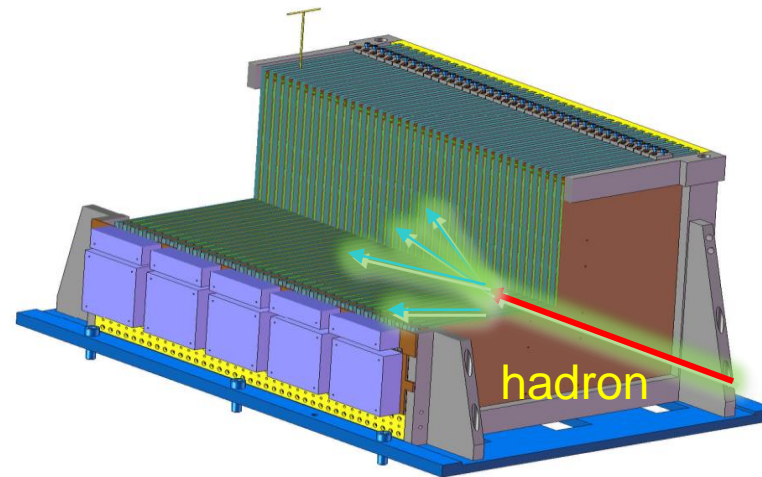


## Sampling Calorimeter

Calo	Sampling No.	Sensitive detector	Absorber	Granularity	Electronics	Absorb length	Energy Resolution	weight
Sci-W ECAL	32	PSD+SiPM	W-Cu	5mm×5mm	SP-2E	22 $X_0$	16%@ 1 GeV	0.3 T
AHCAL	40	PSD+SiPM	Fe	40mm×40mm	SP-2E	4.6 NIL	60%@ 1 GeV	5.0 T



Sci-W ECAL

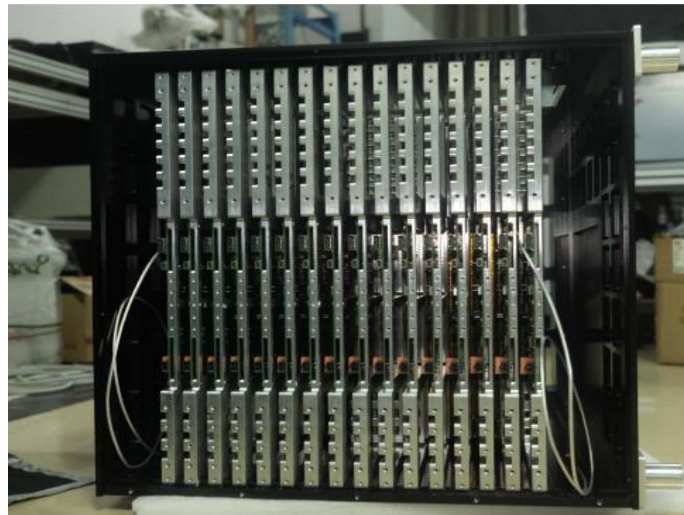
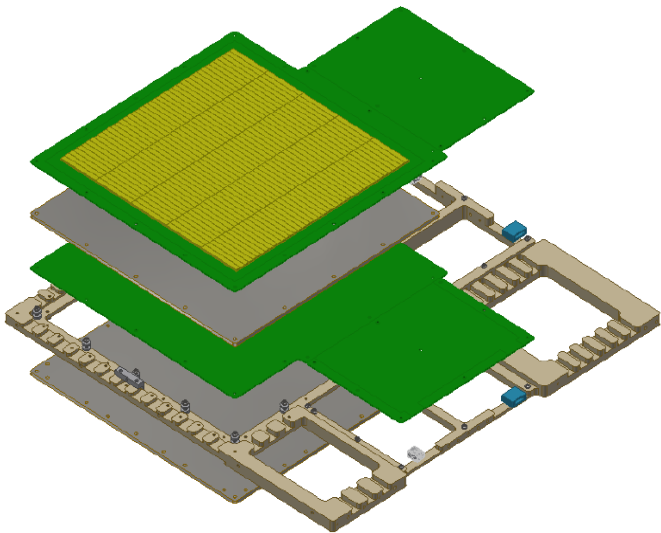
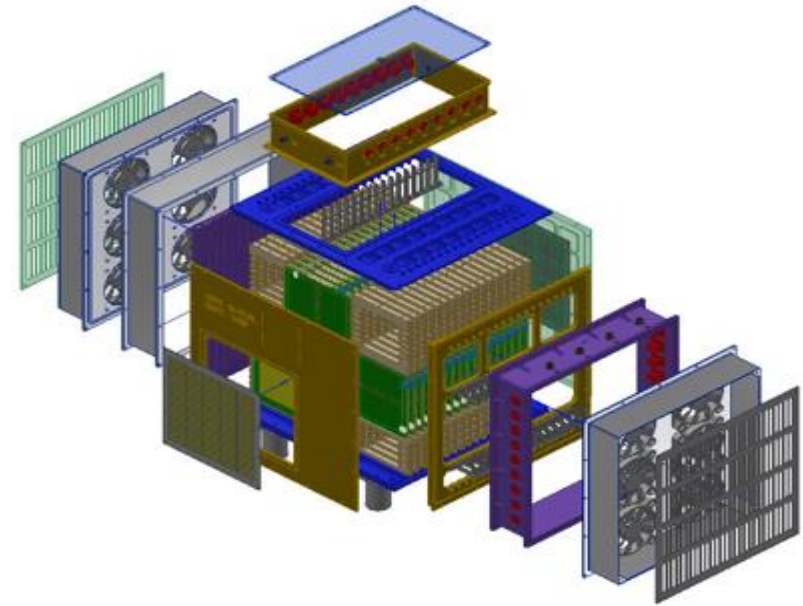


AHCAL

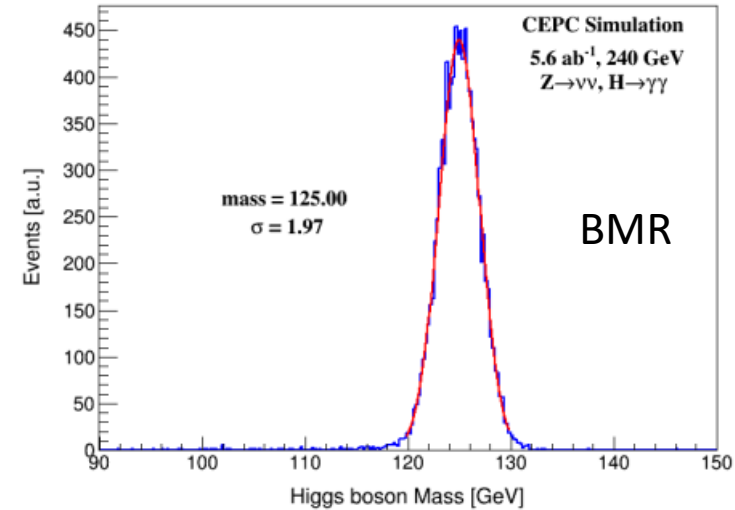
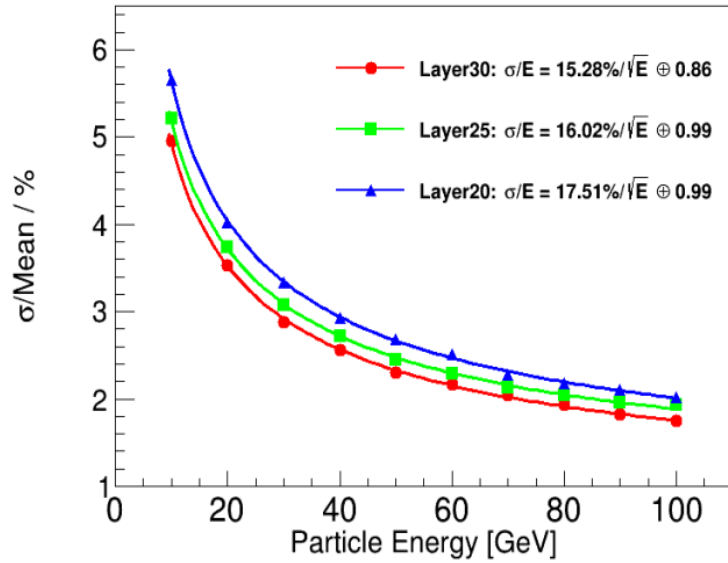
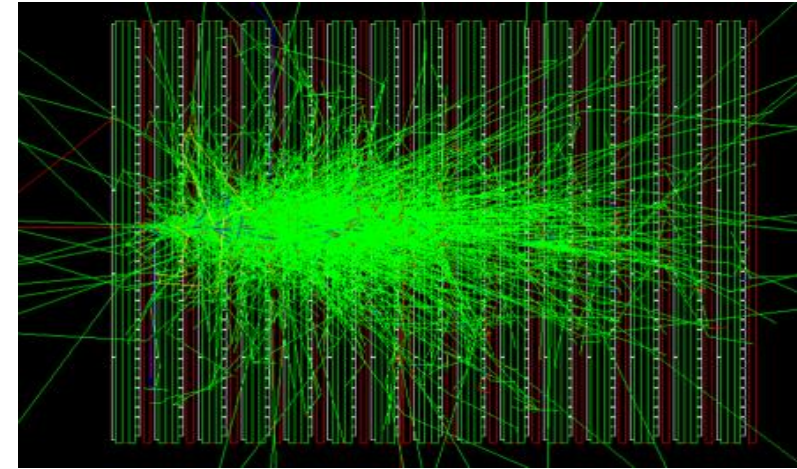


# Sci-W ECAL

- Sci-W ECAL
  - 32 layers, 16 super-layers
  - 210 channels of each layer, total channels:6720
  - Sensitive area:  $22\text{cm} \times 22\text{cm}$

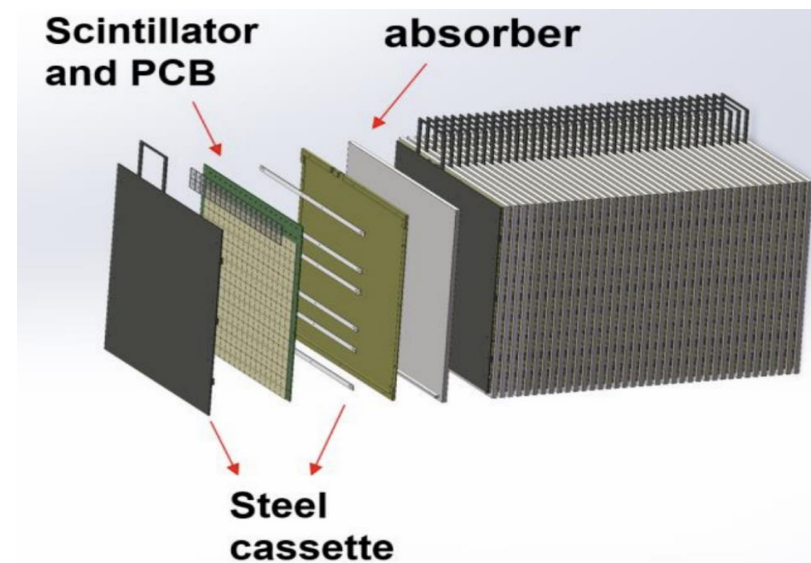
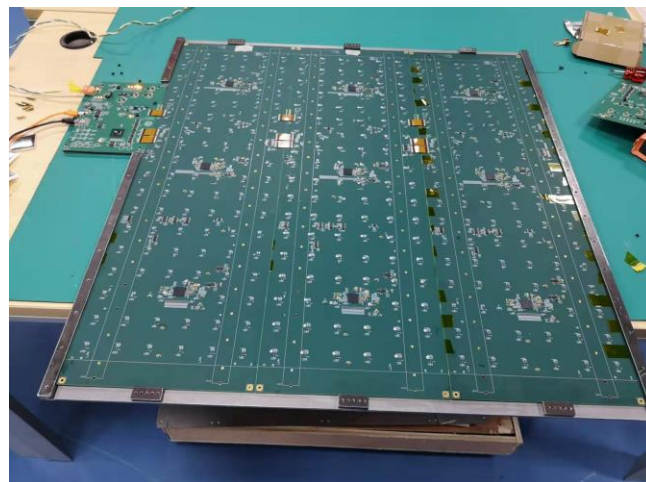
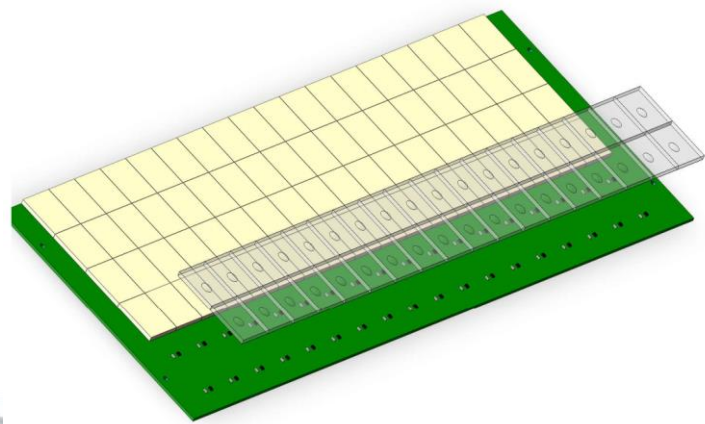


- ◆ 能量分辨率 16% @ 1 GeV
- ◆ BMR: 1.97% ( $H \rightarrow \gamma\gamma$ )



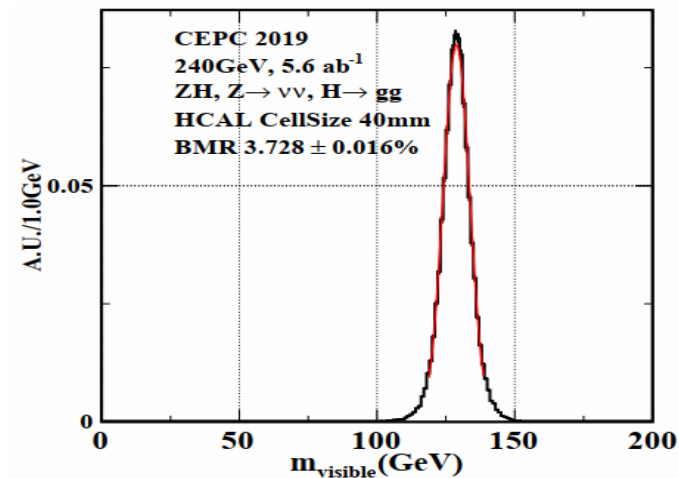
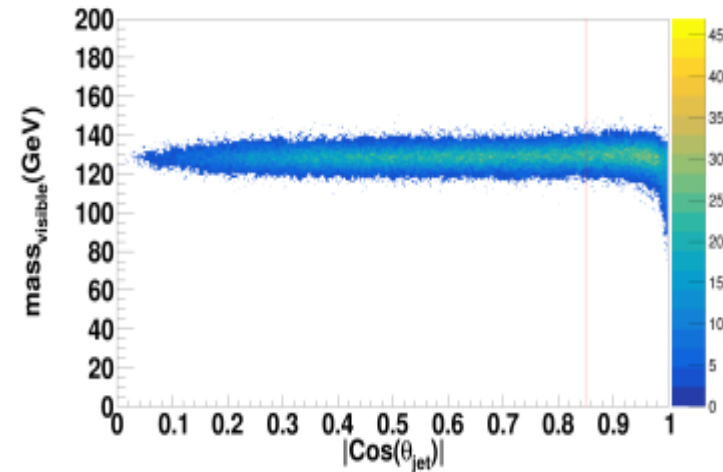
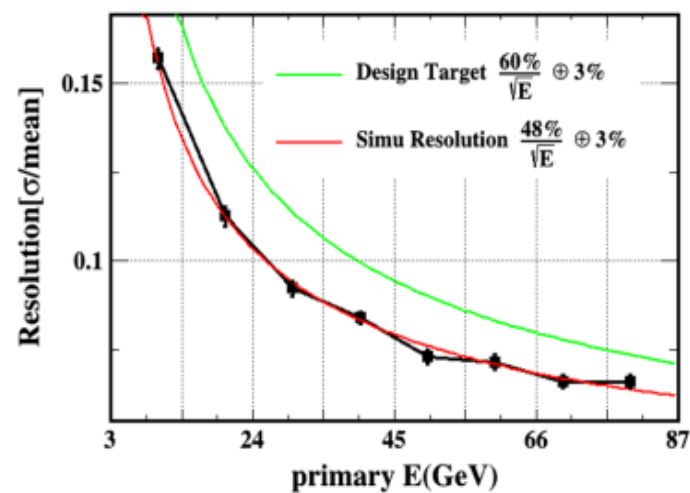
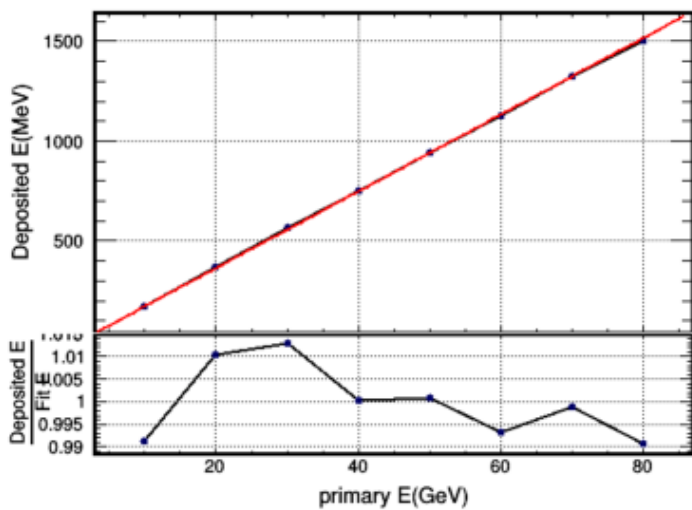
# AHCAL

- ◆ The AHCAL was assembled this summer
  - ◆ 40 sensitive layers, and sensitive area is ~ 72 cm x 72 cm
    - ◆ Each layer has 324 sensitive cells
    - ◆ Total number is 12960

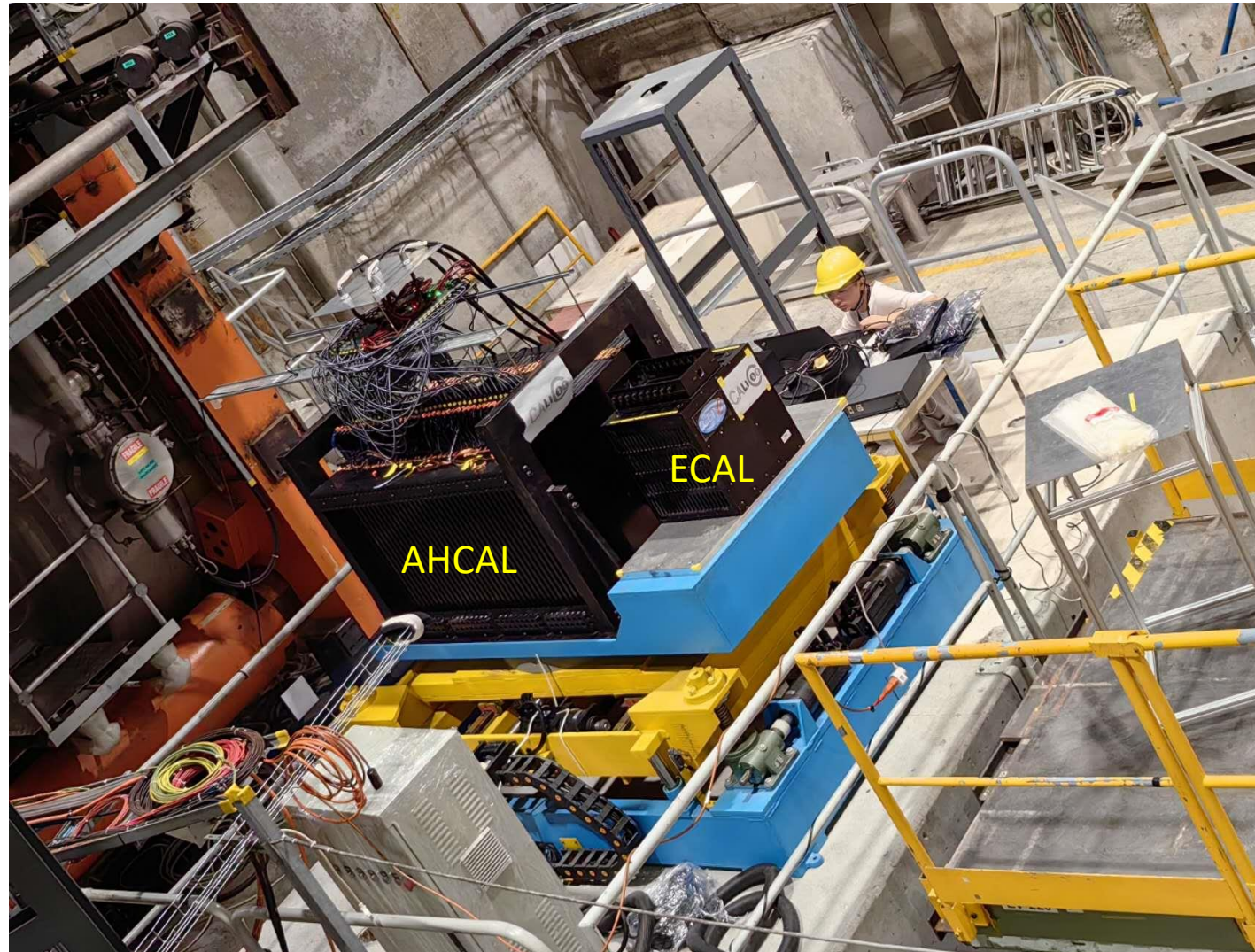


2024/3/14

- ◆ 能量线性优于1%
- ◆ 能量分辨率~48%@1 GeV
- ◆ BMR ~3.7% (H->gg)



# ECAL & AHCAL Beam Test



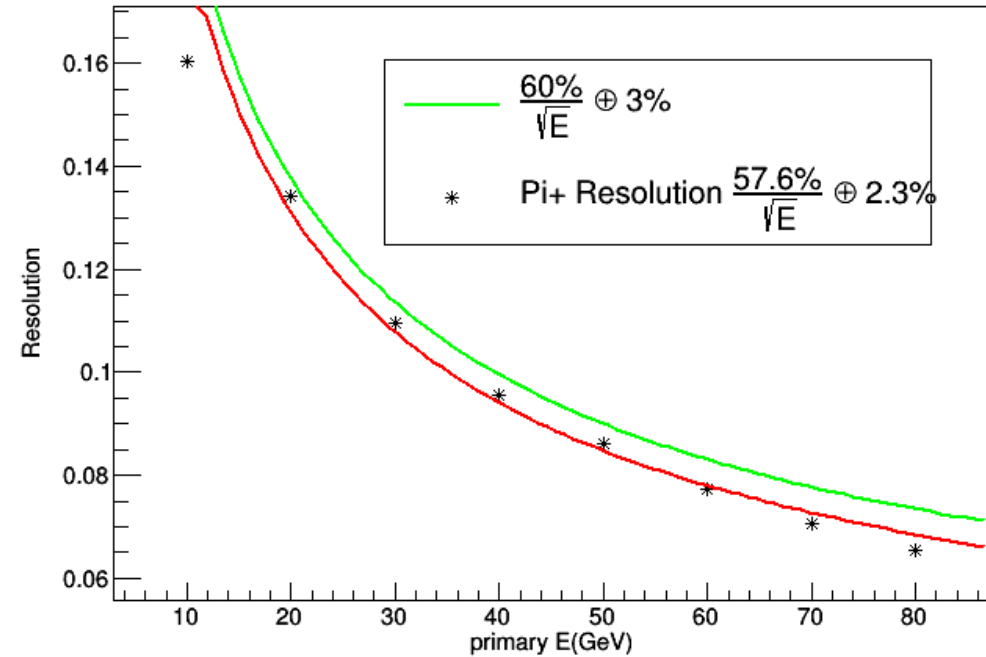
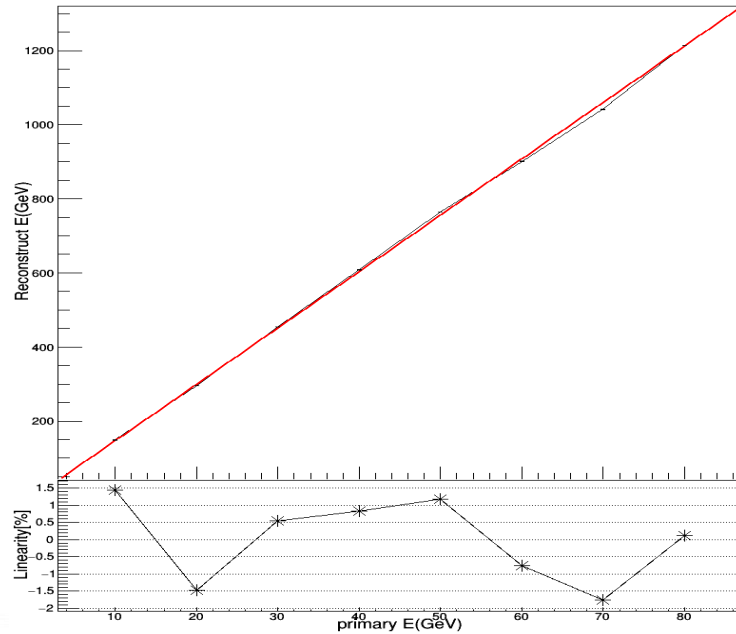
2024/3/14



# ECAL & AHCAL Beam Test

- Energy linearity better than 2%
- Energy resolution is  $\frac{57.6\%}{\sqrt{E}} \oplus 2.3\%$

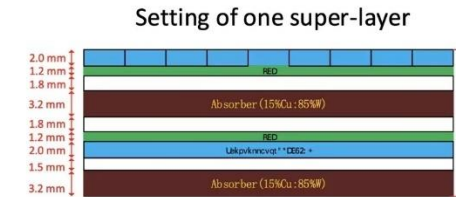
10 – 80 GeV



# 计算依据

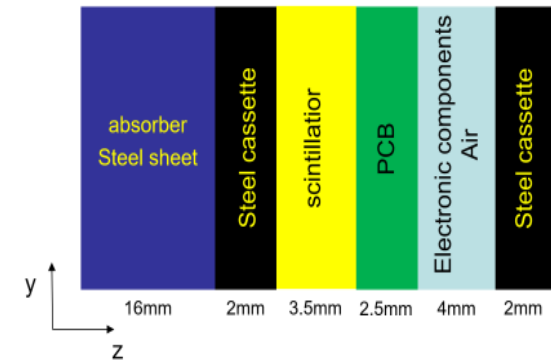
ECAL Barrel Inner radius  $R1 = 1.90\text{m}$ , Outer radius  $R2 = 2.14\text{m}$ , length  $L = 6.0\text{m}$ ,  $N_{\text{layers}} = 30$  Area of Barrel =  $2 * \text{PI} * [(R1+R2)/2] * L * N_{\text{Layer}} = 2284.6 \text{ m}^2$

ECAL Endcap Inner radius  $r1 = 0.35\text{m}$ , Outer radius  $r2 = 2.14\text{m}$ ,  $N_{\text{layers}} = 30$  Area of Endcap =  $2 * \text{PI} * (r2 * r2 - r1 * r1) * N_{\text{Layer}} = 840.2 \text{ m}^2$



HCAL Barrel Inner radius  $R1 = 2.25 \text{ m}$ , Outer radius  $R2 = 3.69\text{m}$ , length  $L = 6.7\text{m}$ ,  $N_{\text{layers}} = 48$ , Area of Barrel =  $2 * \text{PI} * [(R1+R2)/2] * L * N_{\text{Layer}} = 6001.4 \text{ m}^2$

HCAL Endcap Inner radius  $r1 = 0.4\text{m}$ , Outer radius  $r2 = 3.69\text{m}$ ,  $N_{\text{layers}} = 48$ , Area of Endcap =  $2 * \text{PI} * (r2 * r2 - r1 * r1) * N_{\text{Layer}} = 4058.3 \text{ m}^2$



# Performance Summary

Items	Priority	Results / Status		Remarks
Boson Mass Resolution	A	1.97% (H->γγ) 3.73% (vvH->vvgg)		BMR < 4%
Intrinsic EM/hadronic energy resolution	A	15.3% / $\sqrt{E}$ $\oplus$ 0.9% ; 48% / $\sqrt{E}$ $\oplus$ 3%	57.6% / $\sqrt{E}$ $\oplus$ 2.3%	
Separation power				gamma/gamma, gamma/hadron, hadron/hadron
Lepton ID in jets				
Timing capability				
$\pi^0$ reconstruction				
Pile-up at Z-pole				

- Priority/importance for performance requirements: (A) must-have; (B) plus; (C) not essential

# ECAL Cost Summary

Parameter Name	Barrel	Endcaps (x2)	Sum
Inner Radius for ECAL	1900 mm	350 mm	NA
Length for barrel; Outer radius for endcap	6000 mm	2200mm (1900 mm + $24X_0$ ) ; Sc-ECAL: 2140 mm	NA
Longitudinal Depth	$24X_0$ (Thickness depends on each option)		NA
Modularity	#modules in phi, #rings along Z	Assuming ideal geometry if no design?	NA
Material Volume (m <sup>3</sup> )	6.5	2.4	8.9m <sup>3</sup> 151 M
Readout channels	21.5M	7.9M	29.5M
Power dissipation (kW)	150.5	55.3	205.8
Cost: sensitive materials (Yuan)	245.1 M	90.1 M	335.2M
Cost: electronics	169.8 M	62.4 M	232.3 M
Total Cost			0.72 B

Please also consider to indicate in extra or supporting materials

- Unit cost for key components and materials
- References for unit cost or estimates
- Uncertainty or risks if applicable

闪烁体: 3.5元/channel  
SiPM: 7.9 元/片  
Ele: 7.9元/channel

# AHCAL Cost Summary

Parameter Name	Barrel	Endcaps (x2)	Sum
Inner Radius for HCAL	2250 mm	400 mm	NA
Length for barrel; Outer radius for endcap*	6700 mm	3690mm	NA
Longitudinal Depth	$6\lambda_I$ (Thickness depends on each option)		NA
Modularity	#modules in phi, #rings along Z	Assuming any ideal geometry if no design?	NA
Material Volume (m <sup>3</sup> )	112.2	80.9	193.1m3 15.1 M
Readout channels	3.7 M	2.5 M	6.2 M
Power dissipation (kW)	24.6	17.7	42.3
Cost: sensitive materials(Yuan)	57 M	38.5 M	95.5 M
Cost: electronics	29.2 M	19.8 M	49 M
Total Cost			159.6 M

\* Endcaps encompass barrel

Please also consider to indicate in extra or supporting materials

- Unit cost for key components and materials
- References for unit cost or estimates
- Uncertainty or risks if applicable

闪烁体: 7.5元/channel

SiPM: 7.9元/片

Ele: 7.9元/channel

Fe: 7.8万元/m<sup>3</sup> (样机: 4 times)



# Technical readiness level

- Status and plans of simulation studies and R&D (a table template)
- Person power

Category	Status	Design 1	Other Alternative Design (if any)
Technical Readiness Level	Full Simulation (system level)		
	Full Simulation (module level)		
	Prototyping R&D (common)		
	Prototyping R&D (modules, units)		



# ECAL and AHCAL

- ECAL (Scintillator + SiPM, Barrel 2323 + Endcap 840 = 3163 m<sup>2</sup>)
  - $P(\text{inside layer}) \sim 3.163 \times 10^7 \text{ (channels)} * 7 \text{ mW/ch (SPIROC)} = 221.4 \text{ kW (full load)}$
  - $P(\text{interface}) \sim 9 \text{ W /DIF/m}^2 * 3163 \text{ m}^2 = 28.5 \text{ kW}$
  - $P(\text{total}) \sim 250 \text{ kW}$
  
- AHCAL (Scintillator + SiPM, Barrel 5609.2 + Endcap 4045.3 = 9654.5 m<sup>2</sup>)
  - $P(\text{inside layer}) \sim 6.0341 \times 10^6 \text{ (channels)} * 7 \text{ mW/ch (SPIROC)} = 42.24 \text{ kW}$
  - $P(\text{interface}) \sim 9 \text{ W /DIF/m}^2 * 9654.5 \text{ m}^2 = 86.9 \text{ kW}$
  - $P(\text{total}) \sim 129.14 \text{ kW}$

