Beam Tests of
the CEPC AHCAL Prototype

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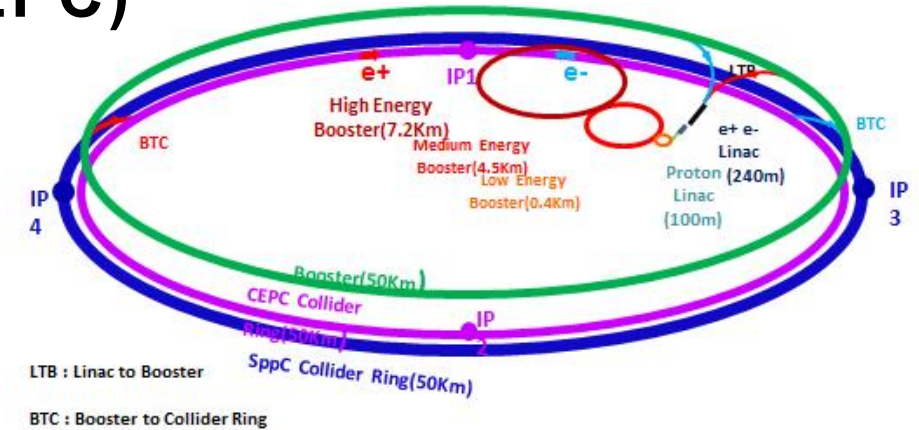
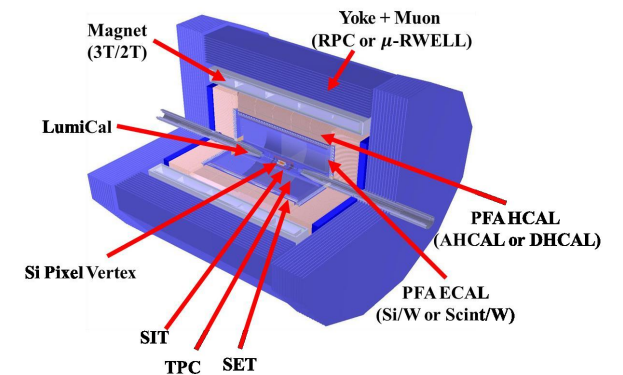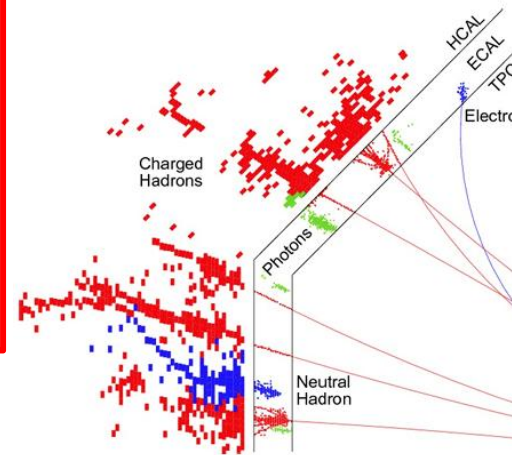**On behalf of CEPC Calorimeter working group**
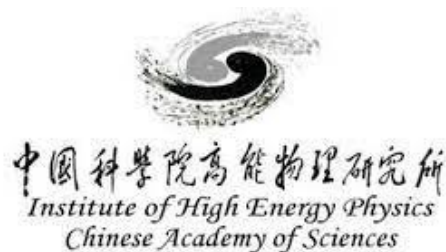
Introduction

➢**Circular Electron Positron Collider (CEPC)**

  ➢$E_{cm} \approx 240$ GeV (higgs mode)

  ➢luminosity ~ 8.3×10^{34} cm⁻²s⁻¹ (higgs mode)

  ➢challenges: jet energy resolution $< \dfrac{30\%}{\sqrt{E[GeV]}}$

LTB : Linac to Booster

BTC : Booster to Collider Ring

➢ **Particle Flow Algorithm (PFA)**

  ➢ High granularity

  ➢ Good track finding
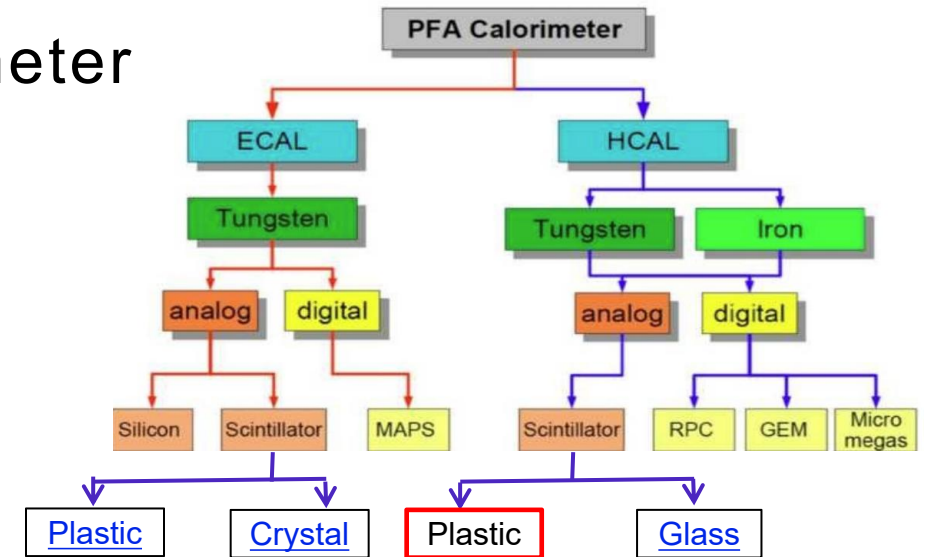
  ➢ Good energy resolution

AHCAL Prototype

➢ an Analogue readout Hadronic Calorimeter prototype has been developed

Total layers	40
Sensitive detector	PSD + SiPM
Sensitive area	72cm*72cm
Granularity	4cm*4cm*0.3cm
Total channels	12960
Absorber	Fe
Length	4.6 λ_I
Energy Resolution	<60%@ 1 GeV
Weight	5.0T

PFA Calorimeter

ECAL — Tungsten — analog / digital
- analog: Silicon, Scintillator
- digital: MAPS

HCAL — Tungsten / Iron — analog / digital
- analog: Scintillator
- digital: RPC, GEM, Micro megas

Plastic   Crystal   Plastic   Glass

this talk

Scintillator and PCB   absorber

Steel cassette
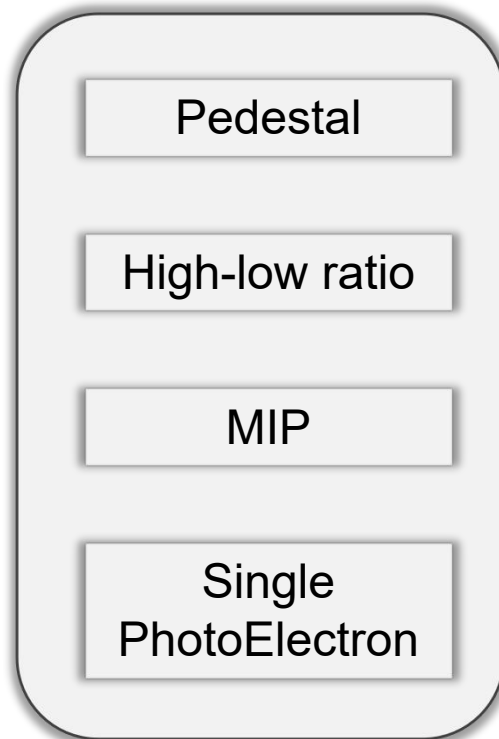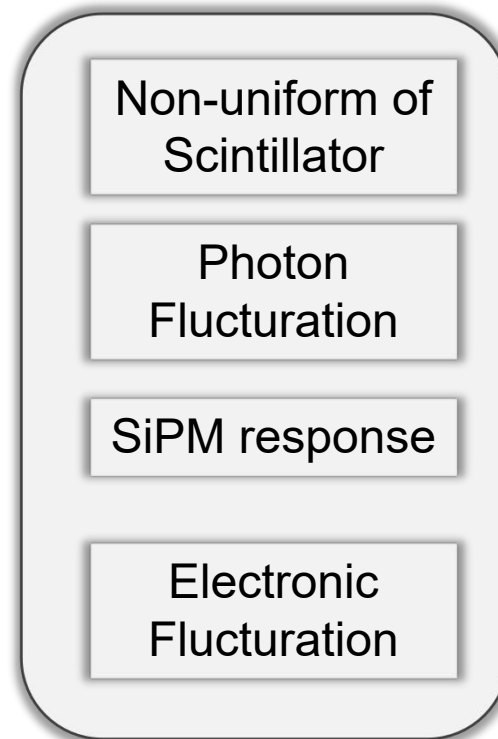
AHCAL
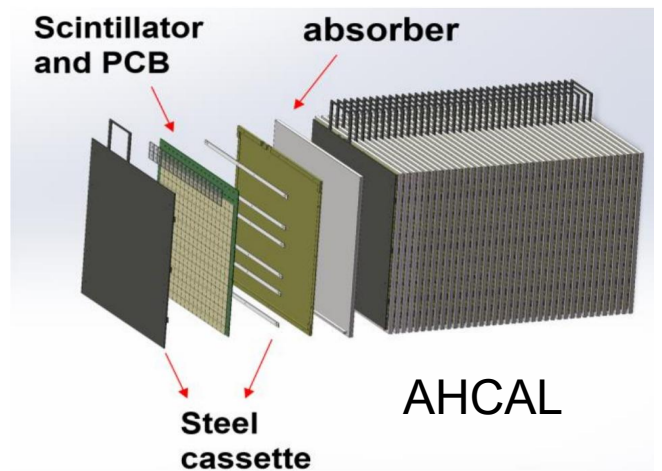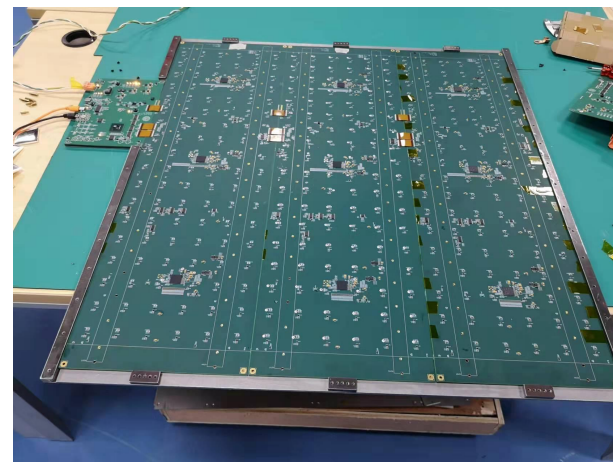
Beam Tests

➢ 3 beam tests have been done at CERN

   ➢ muon position scan(100GeV/c)

   ➢ pion (1-120GeV/c)

      ➢ w/wo ECAL in front

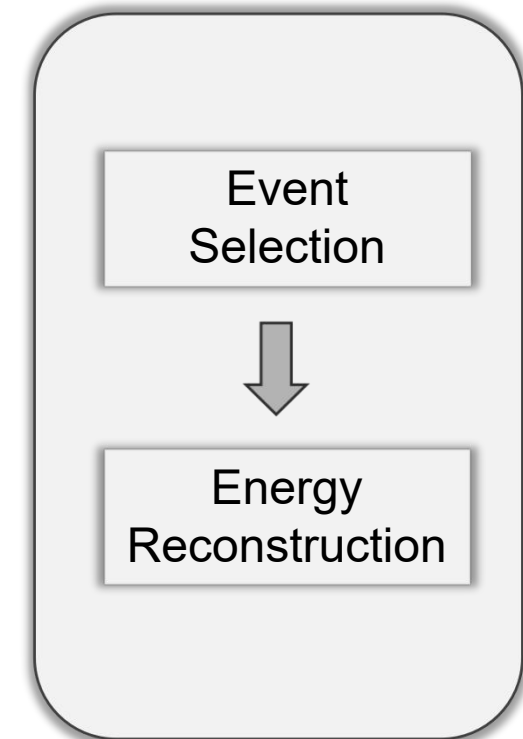   ➢ electron (1-120GeV/c)

      ➢ wo ECAL in front
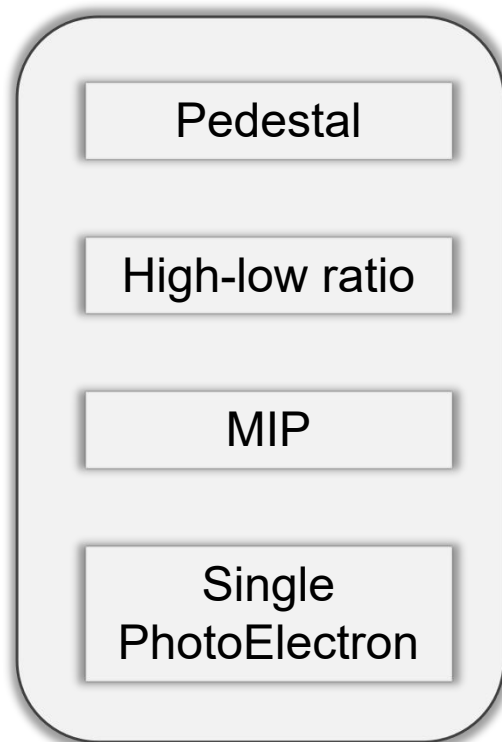
Outline

Parameters Calibration

- Pedestal
- High-low ratio
- MIP
- Single PhotoElectron

Simulation & Digitization

- Non-uniform of Scintillator
- Photon Flucturation
- SiPM response
- Electronic Flucturation

Energy Reconstruction

- Event Selection
  ↓
- Energy Reconstruction

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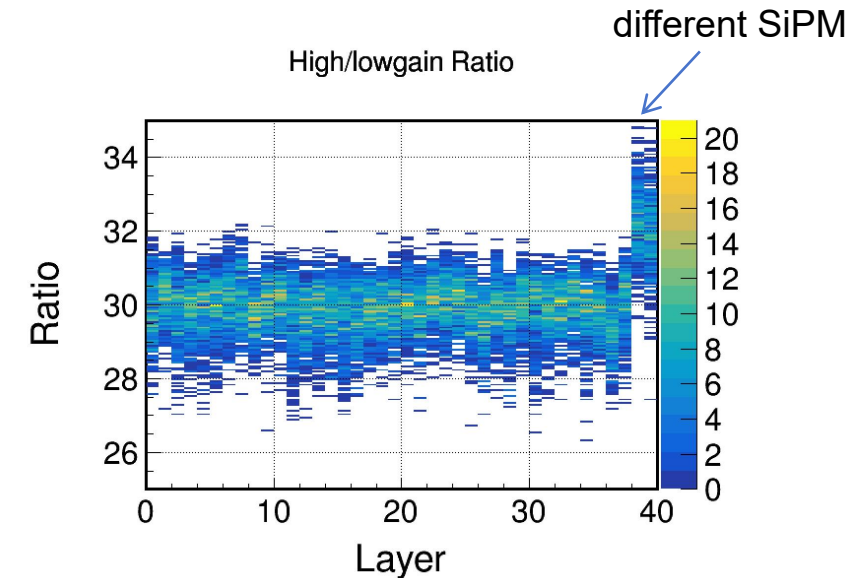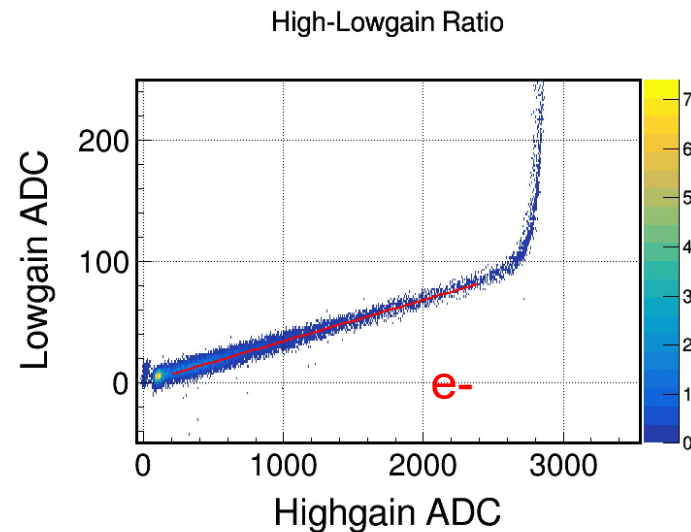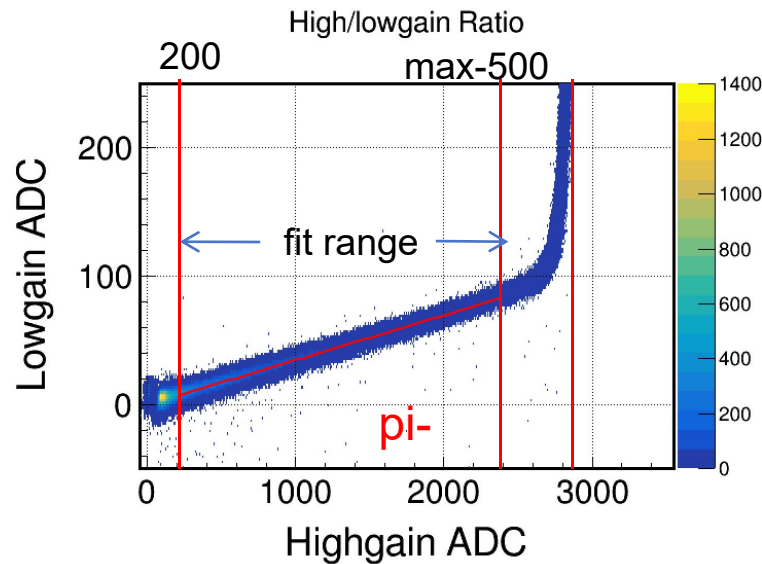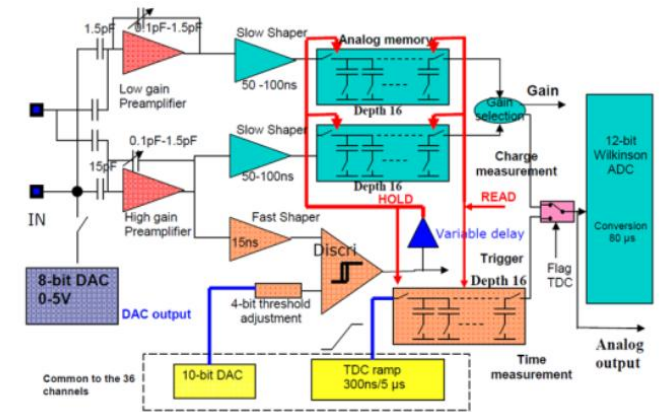- Energy Reconstruction
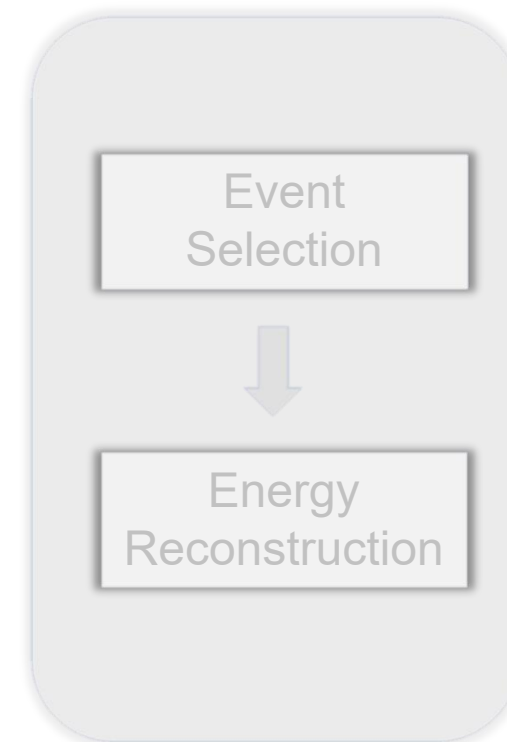
Pedestal Calibration

➤the mean of electronic offset is pedestal, its width is noise level

➤normally(HitTag=0), pedestal have multiple peaks due to crosstalk

➤use force-trigger-mode now to prevent this problem

  ➤force trigger mode file collect signal even if hittag of all channels equals to 0
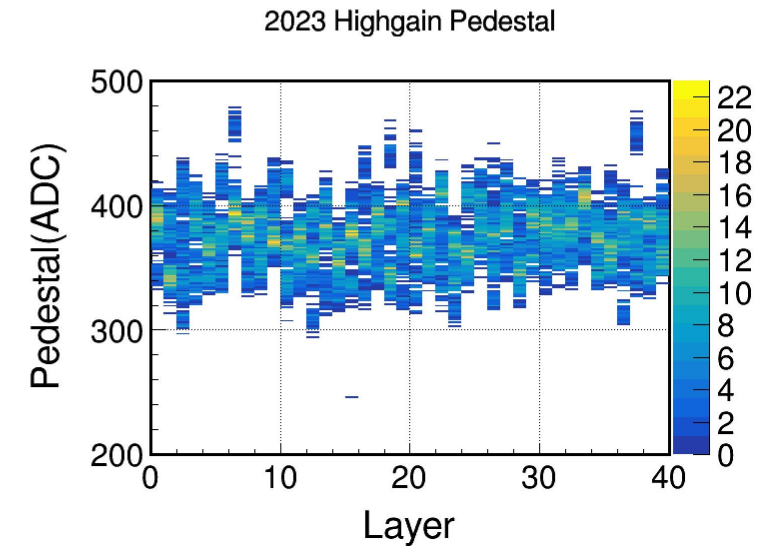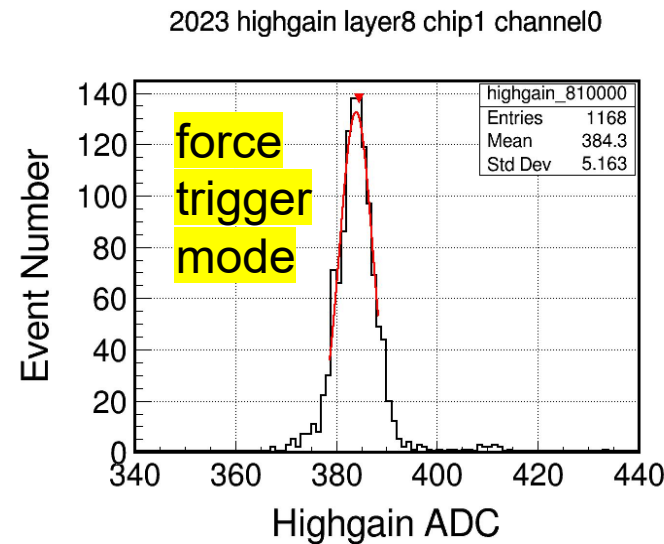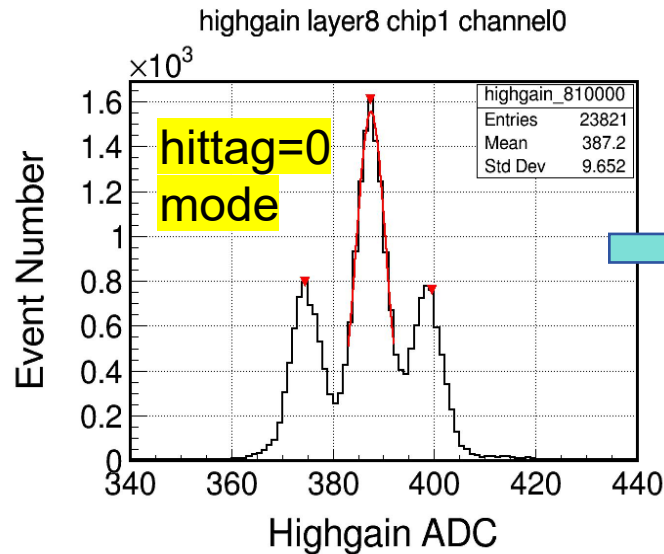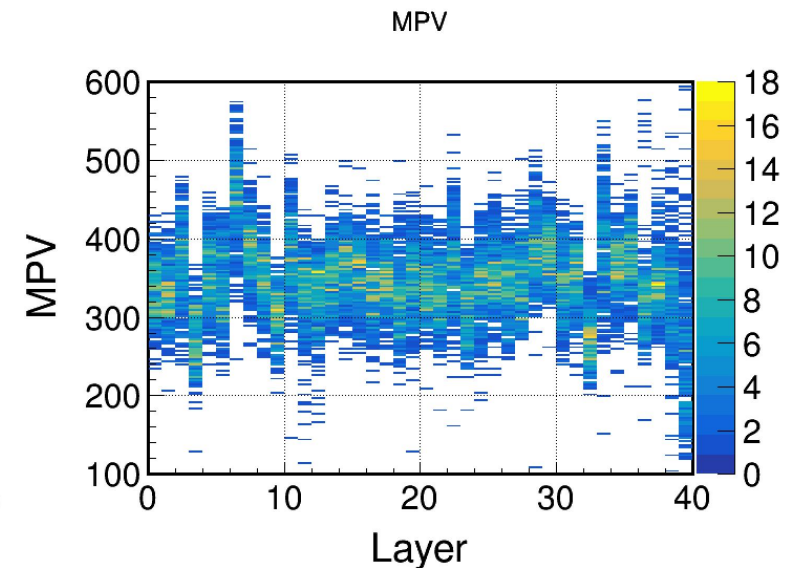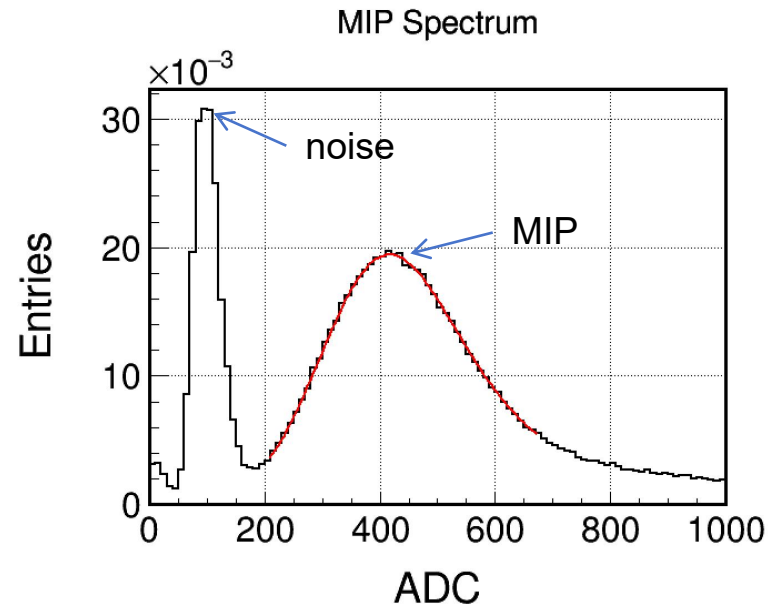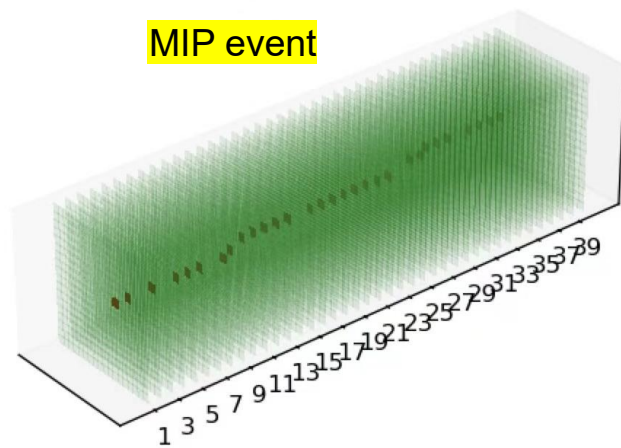
High-Lowgain Calibration

➢ SPIROC2E chip has two gain modes to cover wider dynamic range

➢ using beam test data, calibrate high-lowgain ratio

➢ ratio is consistent in EM and hadronic shower

MIP Calibration

➤MIP is the key to reconstruct energy

➤MPV value is obtained by fitting 100GeV/c muon

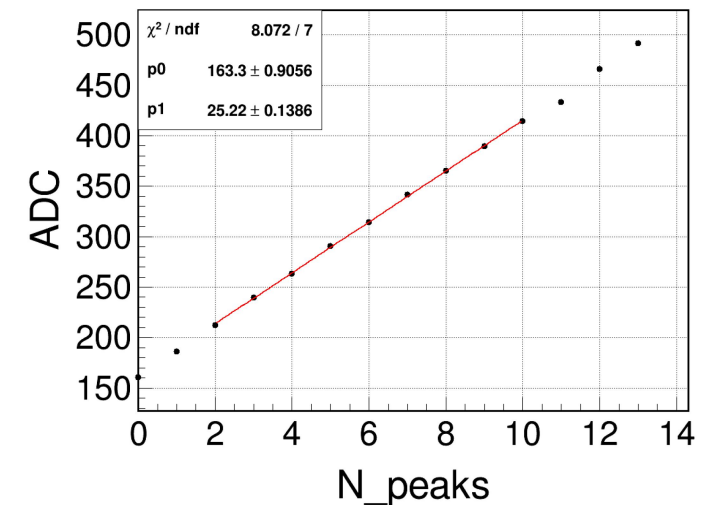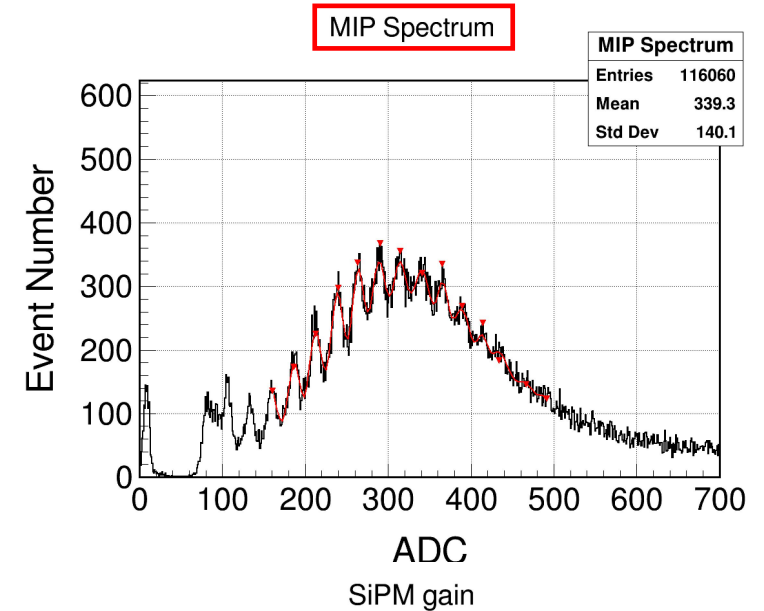➤93.3% channels can be calibrated successfully

➤need temperature correction

SPE Calibration

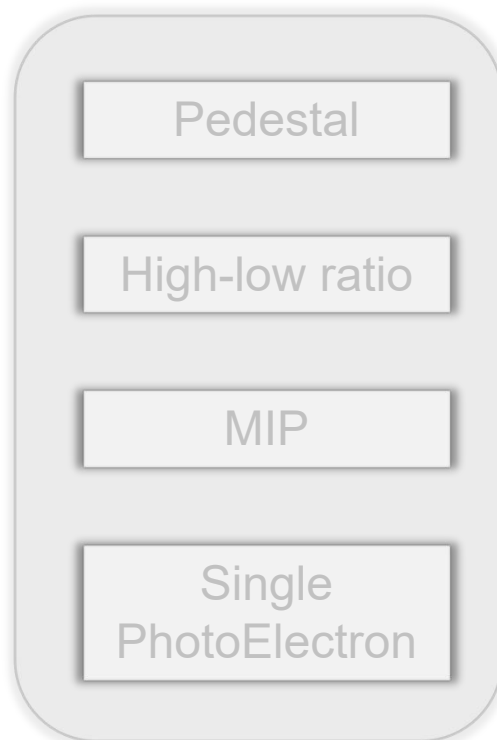➢SiPM is a photon-counting device using multiple APD pixels operating in Geiger mode

➢Its response is not linear strictly

$$N_{fired} = N_{pixel} \cdot (1 - e^{-\frac{N_{seed}}{N_{pixel}}}) \qquad , N_{seed} = N_{photon} \times PDE$$

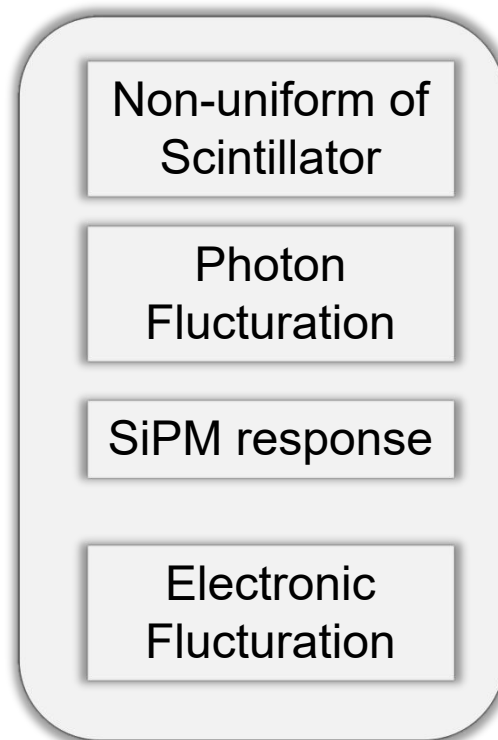➢to correct this effective, single photoelectron (SPE) calibration is necessary

➢muon data(MIP) are fitted with multi-gaussian to calculate SiPM gain for each channel

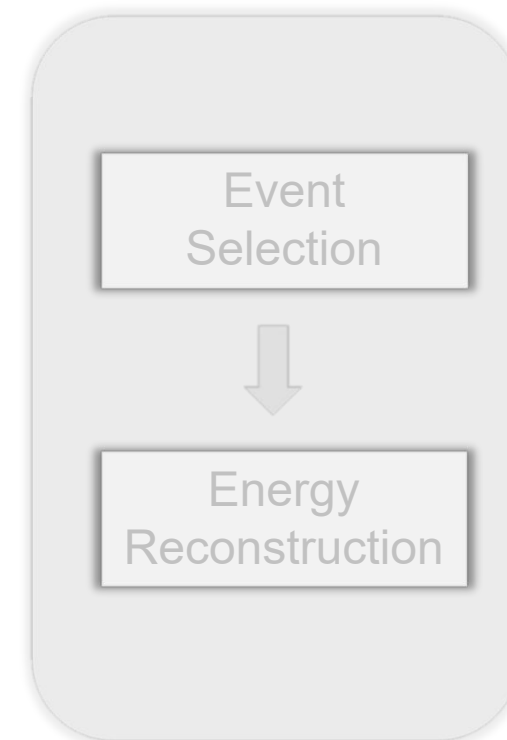➢65.4% channels can be calibrated successfully

MIP Spectrum

MIP Spectrum	
Entries	116060
Mean	339.3
Std Dev	140.1

SiPM gain

χ² / ndf	8.072 / 7
p0	163.3 ± 0.9056
p1	25.22 ± 0.1386

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- Energy Reconstruction
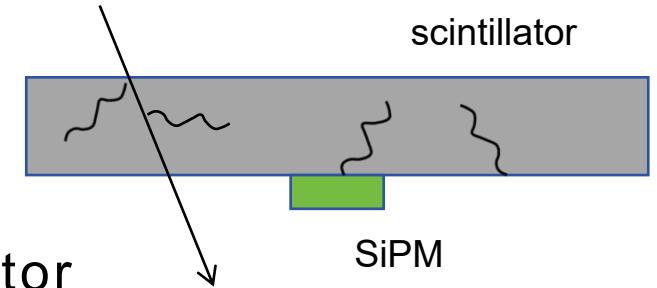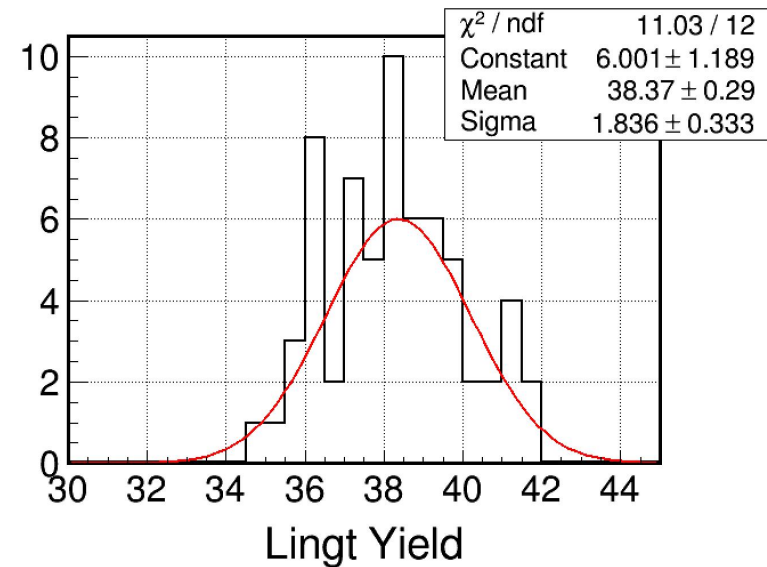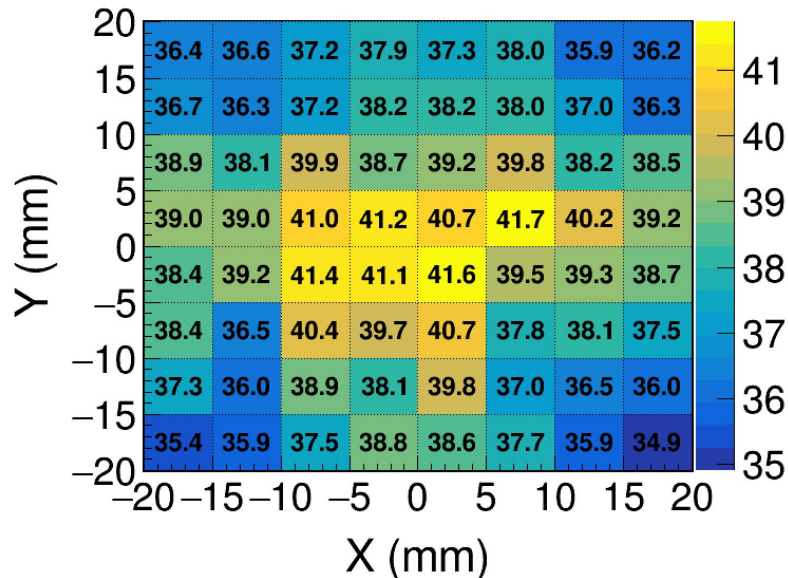
> **Scintillator**

> > energy to photon (poisson sampling)

> > 4.8% gaussian smear from non-uniformity of scintillator

> > photon electron conversion (binomial sampling)

scintillator

SiPM

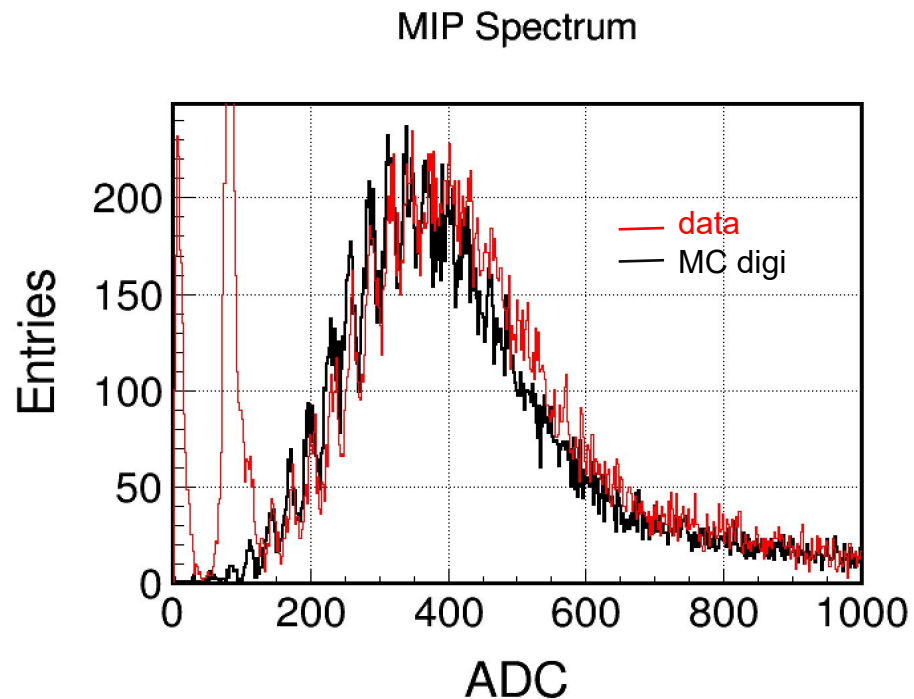light yield (p.e.) uniformity in one scintillator tile
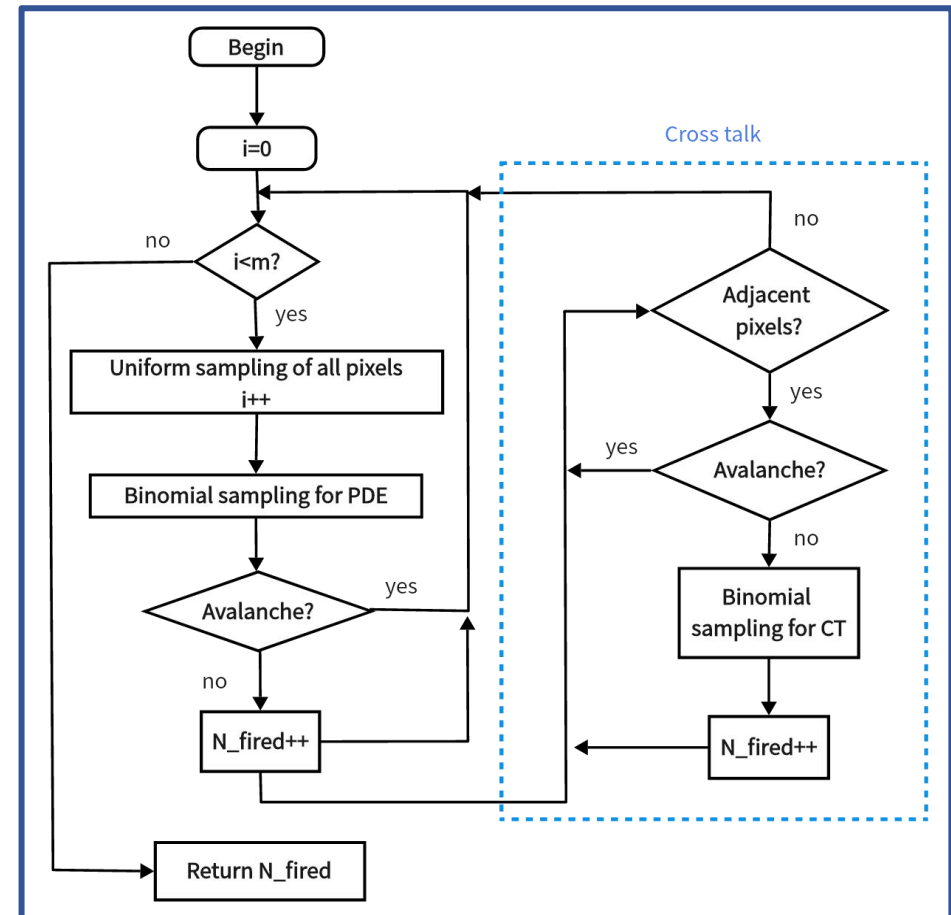
Digitization of Simulation II

➢**SiPM response**

   ➢ SiPM saturation and flacturation
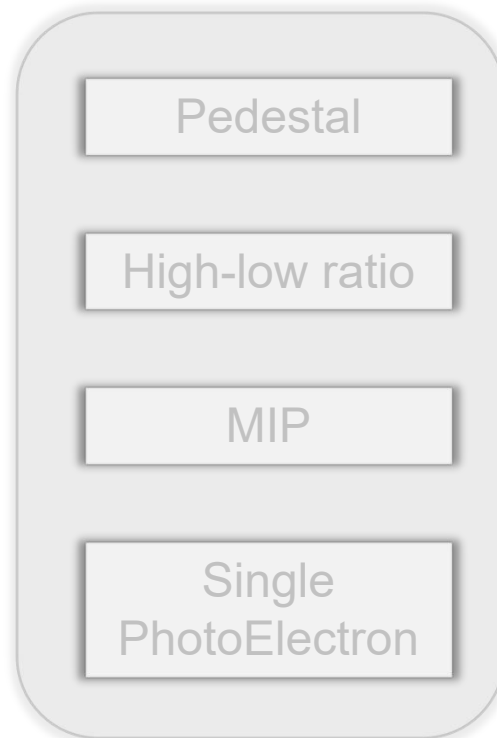
   ➢ SiPM gain smear

➢convert SiPM signal to data format ADC

SiPM simulation sampling diagram

MIP Spectrum

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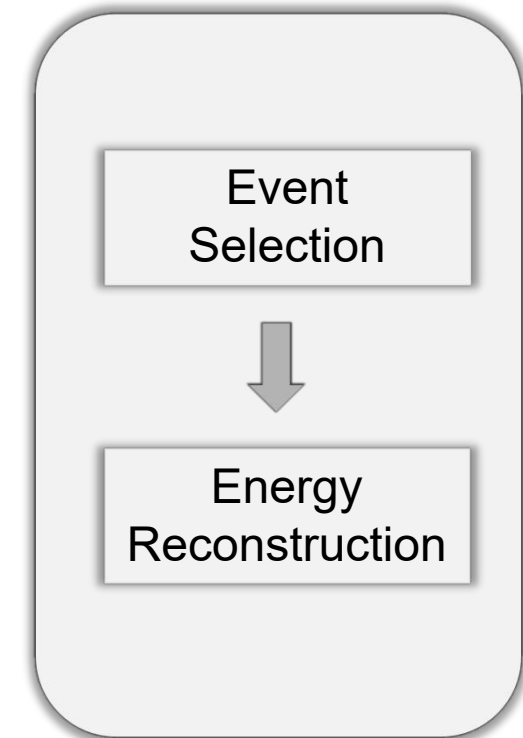
- Energy Reconstruction

➢ Beamtest data need to be selected to improve purity

(see poster of Xin,Siyuan)

 ➢ hit number

 ➢ shower start position
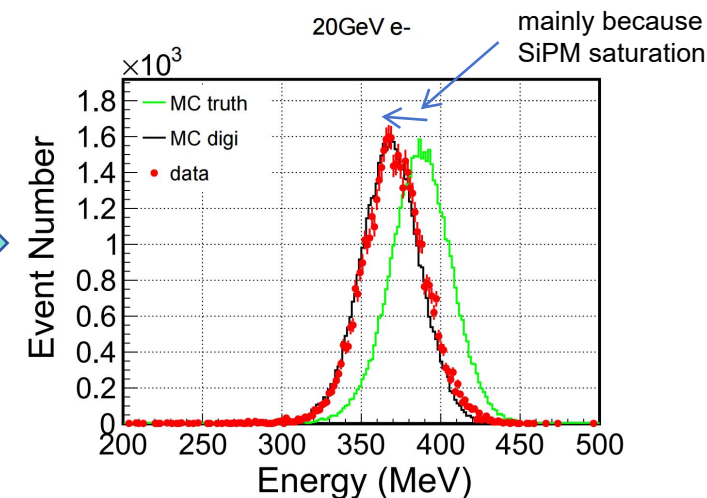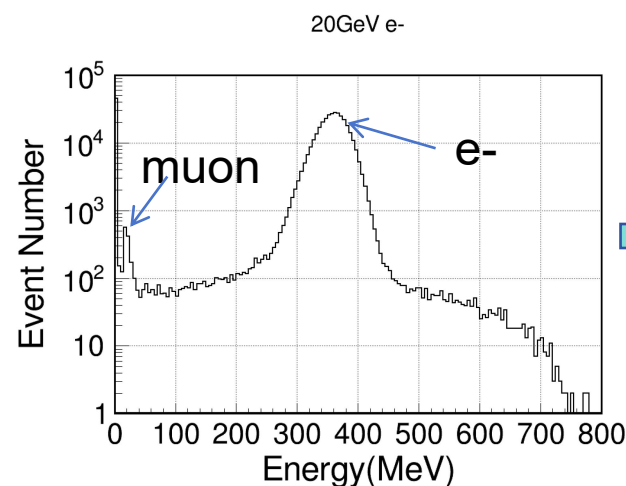
 ➢ ...

energy deposit in sensitive volume of 20GeV e-
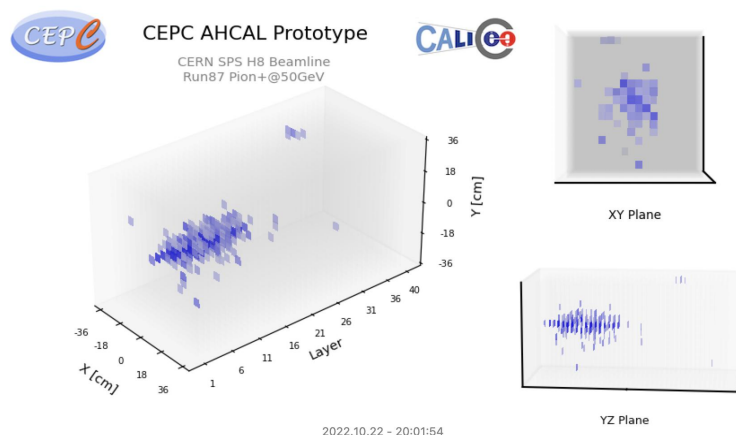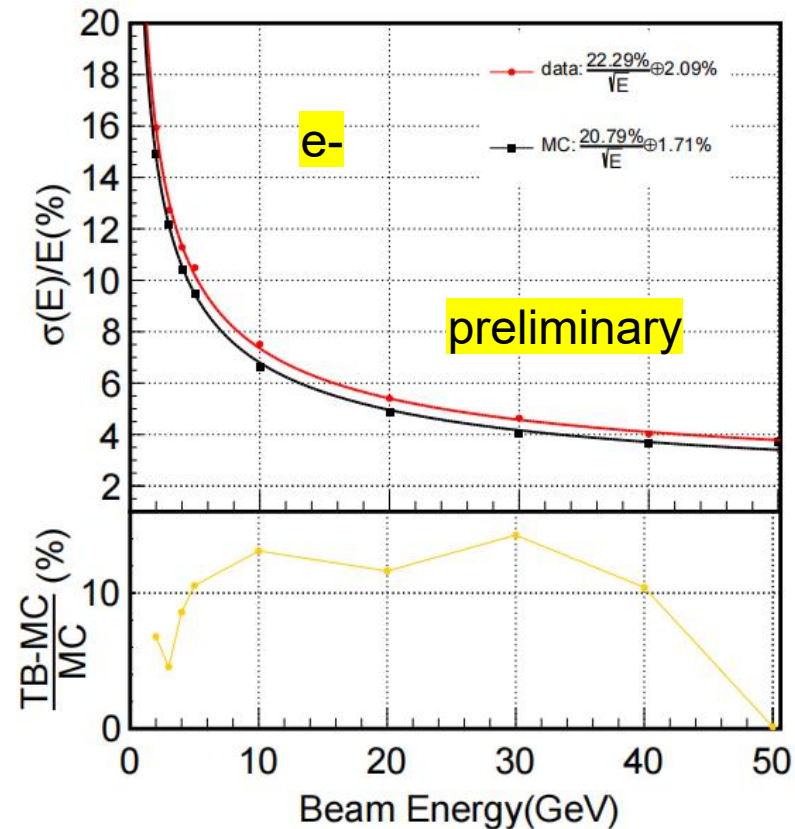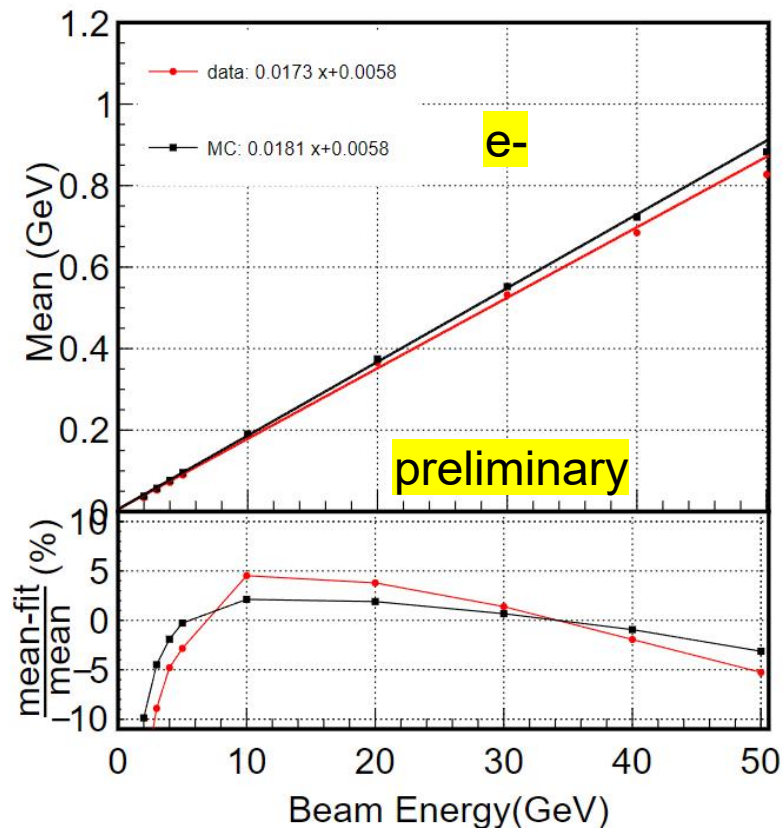
Energy Linearity and Resolution

➢ reconstruct energy mean v.s. beam energy

　➢ fitted with a linearity function

➢ energy resolution

- reconstruct energy mean v.s. beam energy
  - fitted with a linearity function
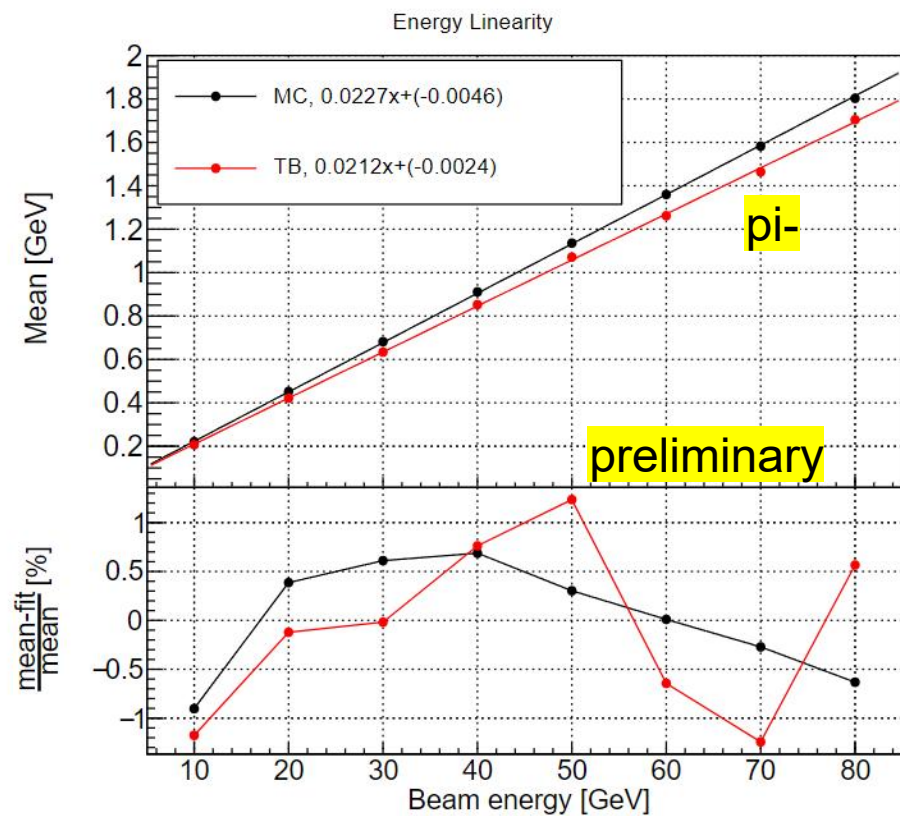
- energy resolution

Summary and Plan

- Summary:
  - based on the beam tests of AHCAL prototype
  - carry out full-process analysis on high energy particle
    - calibrate basic parameters
    - reconstruct energy
    - optimize MC simulation and digitization
  - preliminary results show, the agreement between beamtest and MC is well
- Plan:
  - analysis to electronic saturation
  - using the high granularity, carry out research on PFA method

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    ➢ using the high granularity, carry out research on PFA method

Thanks!

Backup

Simulation Based on Geant4

> code is based on Baohua(ihep colleague)

> incident particles: electron, pion, muon

> particle flow size: 20mm

incident particle

geometry construct

front trigger detector: polystyrene

gap: air, 1.5m

Absorber: steel: 2 mm

Scintillator: polystyrene: 3 mm

Cu

PCB: FR4

gap: air

Absorber: steel: 18 mm