Status of ZDC ECal Development EIC-Asia Meeting@20241031

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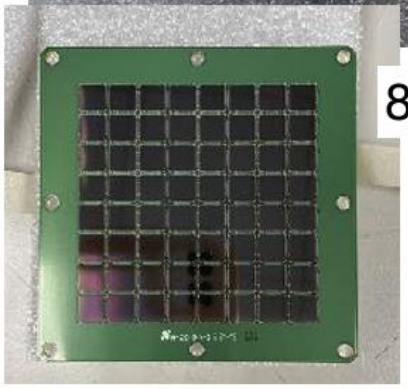
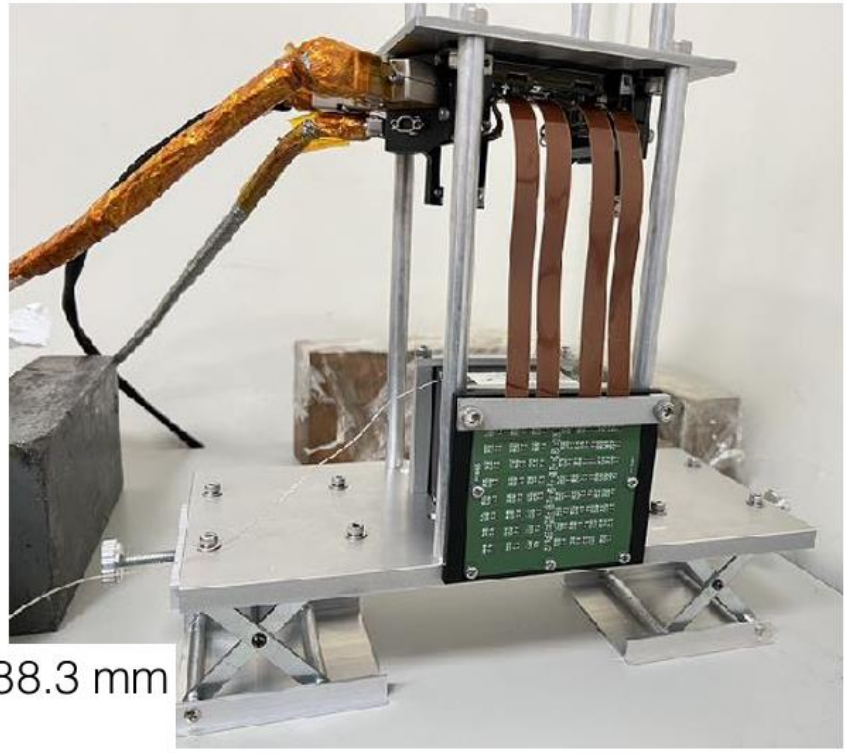
1st ZDC ECal Prototype with LYSO and SiPM

8x8 LYSO crystal array



8x8 SiPM array

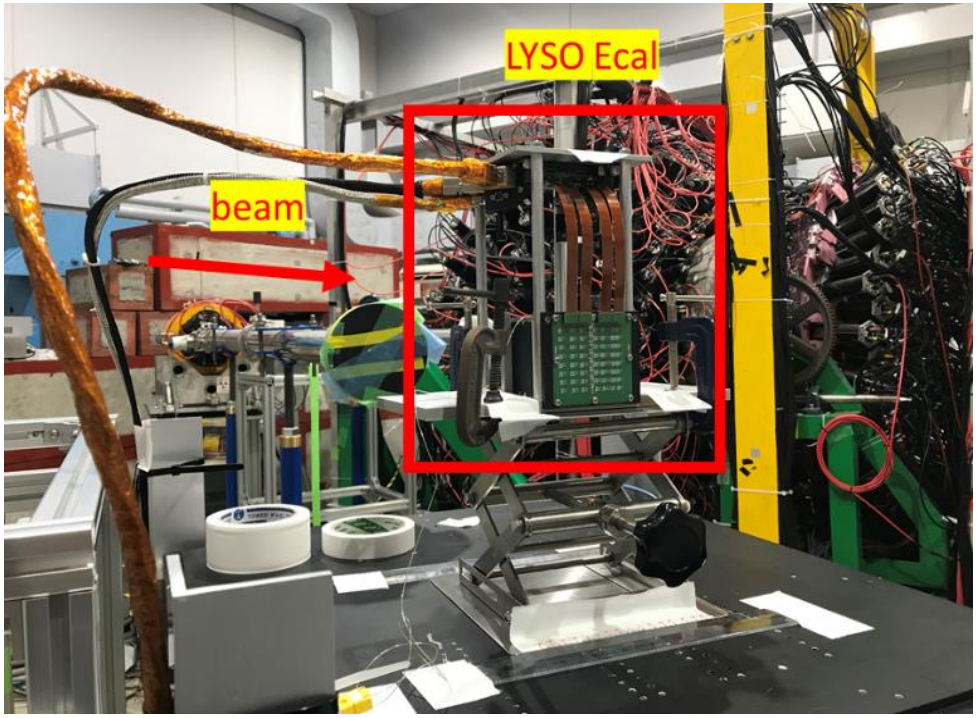
LYSO calorimeter prototype



One crystal: 7.12 mm x 7.12 mm x 88.3 mm
8x8 array: 56.96 mm x 56.96 mm

- 1st ZDC ECal prototype is composed by LYSO and SiPM.
- Geometry is 8x8 crystal array with around 5.5cm*5.5cm active area.

Beam Test



- **Time**

2024 Feb. 15th to Feb. 21th

- **Location**

ELPH@Tohoku, Japan

- **Beam**

positron beam
from 47.18 MeV to 823.36 MeV

- **Scan list**

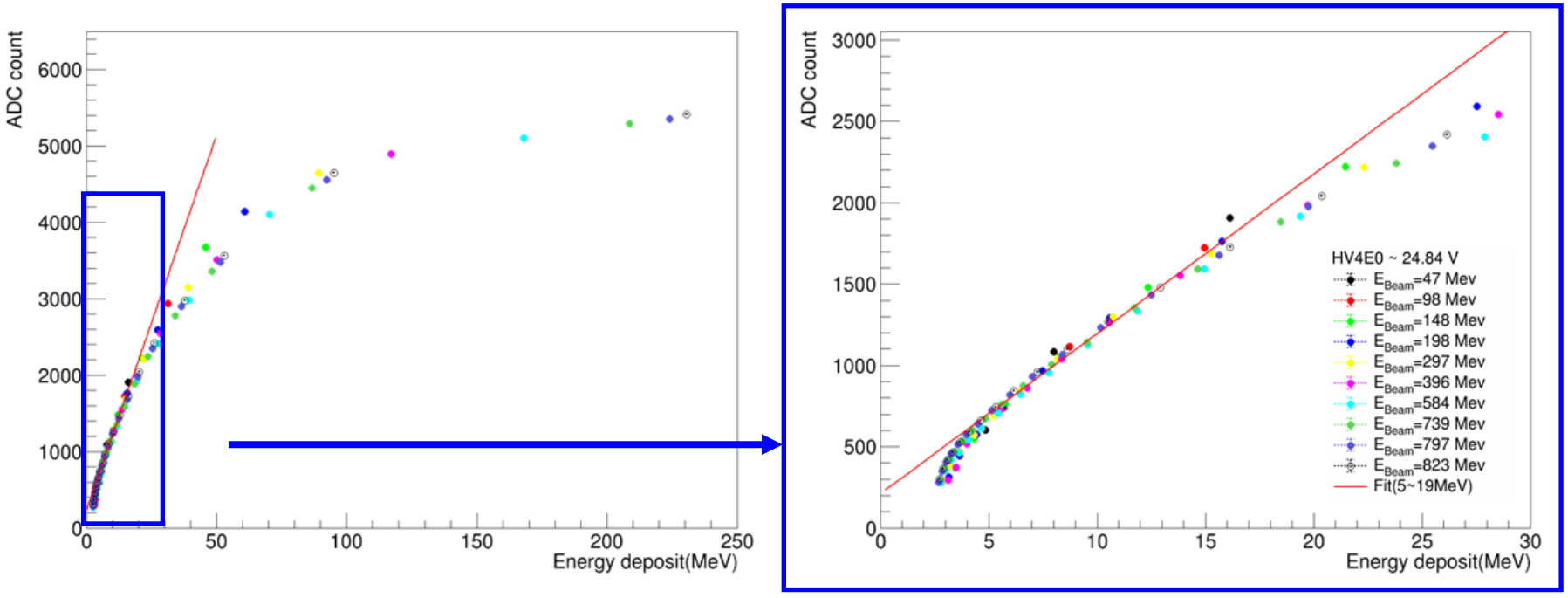
SiPM HV Scan, Beam energy scan, detector rotation, etc.

- **Participants**

RIKEN, Tsukuba University, Tsukuba University of Technology, Sejong University, EIC-Taiwan

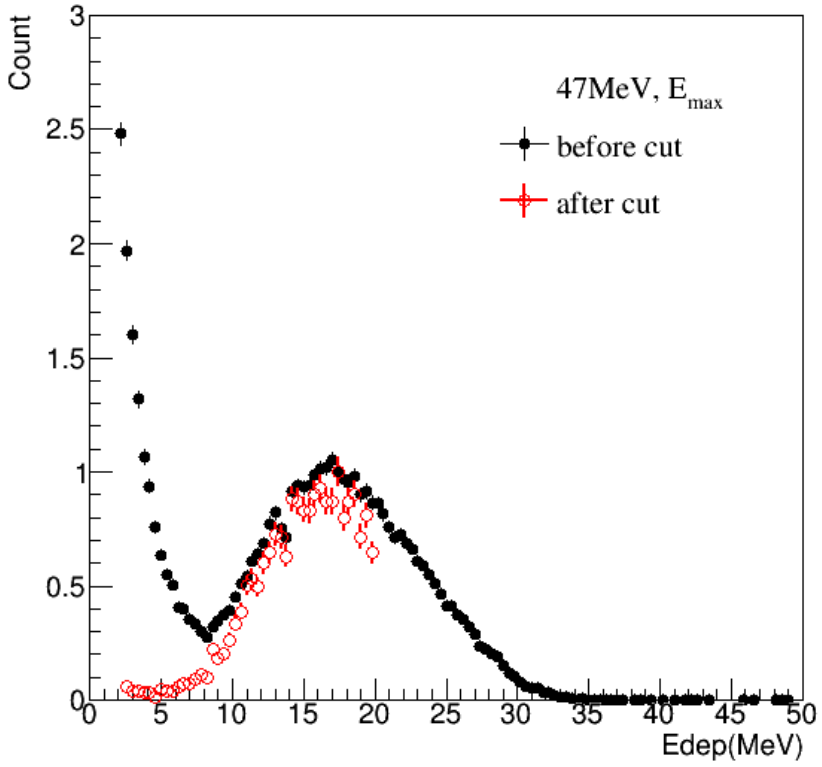
Beam test was performed at ELPH, Japan with around 50MeV to 820MeV positron beam.

SiPM Saturation



- Most of the data fall within the saturated range, except for the 47 MeV data. Approximately 60% of the data from the 47 MeV positron beam remain in the linear range, and we first focus on these data.

Selection Criteria



We chose the 47MeV data only in linear range and remove the possible low energy photon and noise contributions.

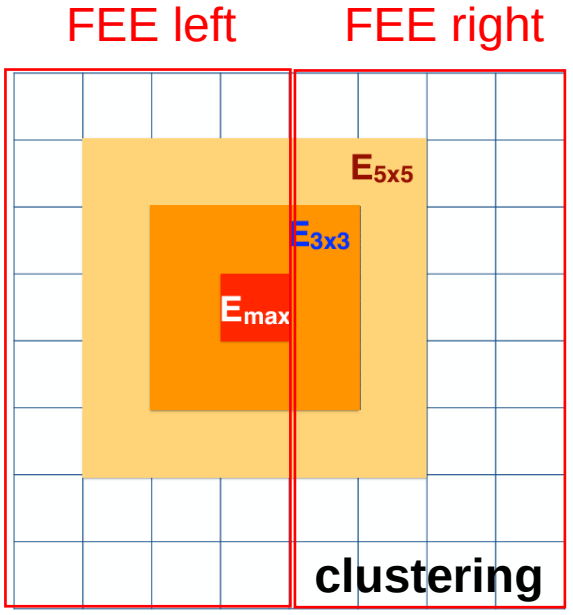
- **Two cut criteria**

(1) 2.5MeV<Emax<20 MeV

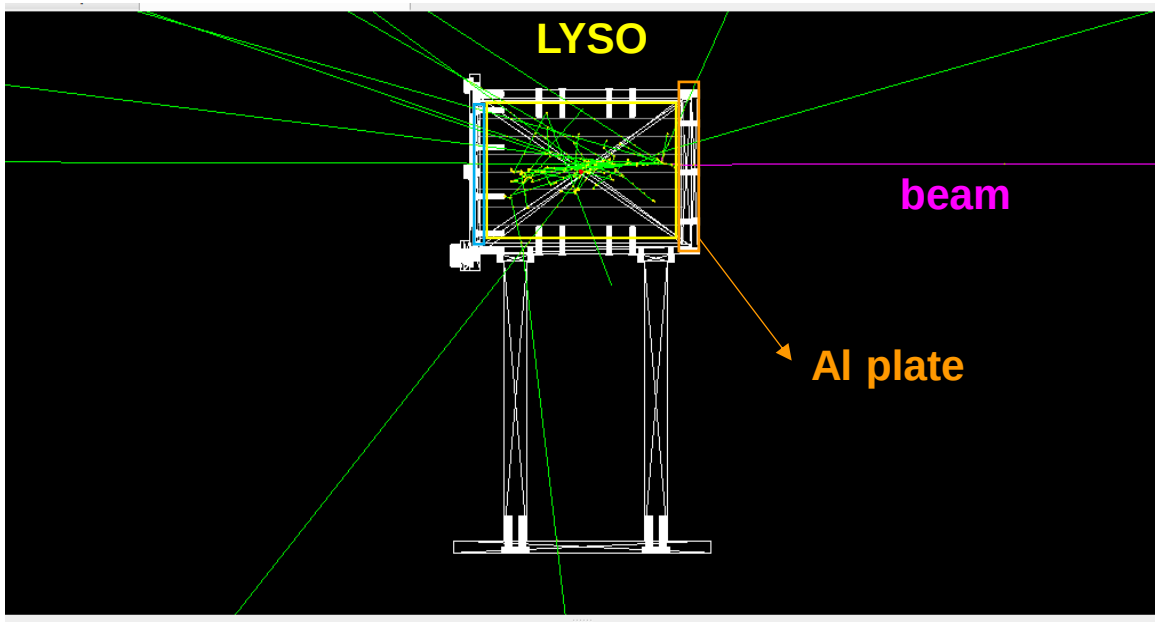
To focus data only in linear range and remove the low momentum photons coming from beam.

(2)Fire both left and right crystals

Ask hits from both FEE left and FEE right to remove events only contains noise.



MC Simulation



- **MC implementation**

① Detector geometry and material
② Beam momentum with resolution
③ Beam profile (center, sigma)
④ Beam angle 90 degree

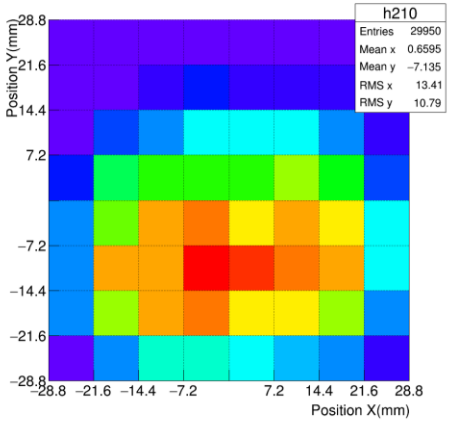
- **SiPM MC is not implement.**
  It should be fine for linear range data.

- **Beam Mom. w/ Res.**

I (A)	x_{PS} 制限なし		
	μ_P (MeV/c)	σ_P (MeV/c)	σ_P/μ_P (%)
025	47.18(2)	5.48(1)	11.63(3)
050	98.19(4)	4.92(3)	5.01(3)
075	148.22(4)	4.77(2)	3.22(2)
100	197.94(3)	4.91(2)	2.48(1)
125	247.79(3)	5.00(2)	2.02(0)
150	297.30(2)	5.29(2)	1.78(0)
175	346.81(2)	5.31(1)	1.53(0)

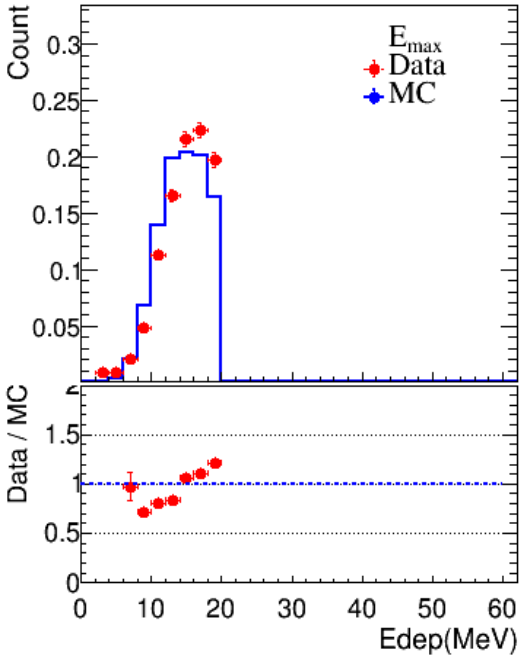
Energy resolution of 47MeV positron beam ~ 11.6%

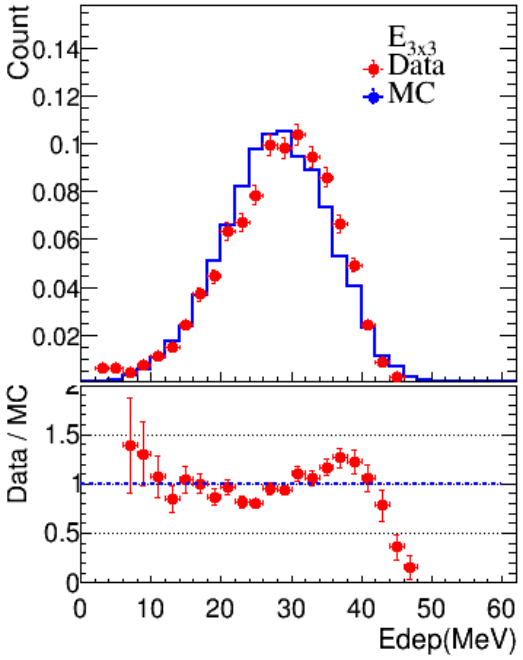
- **Beam profile @ 47MeV**

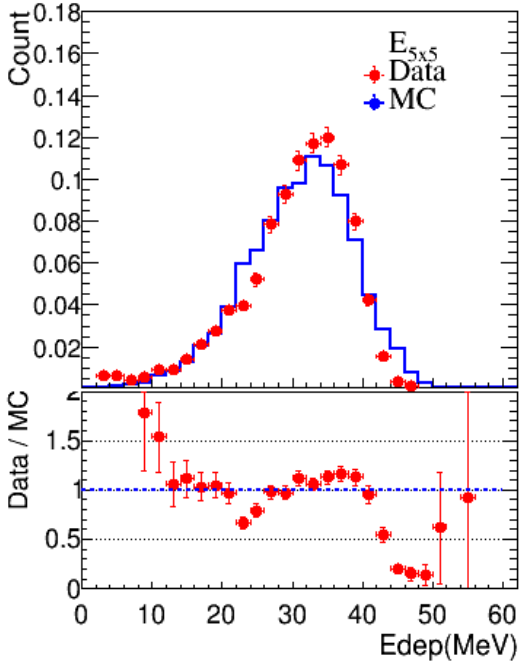


Beam is ellipse shape and not well centered.

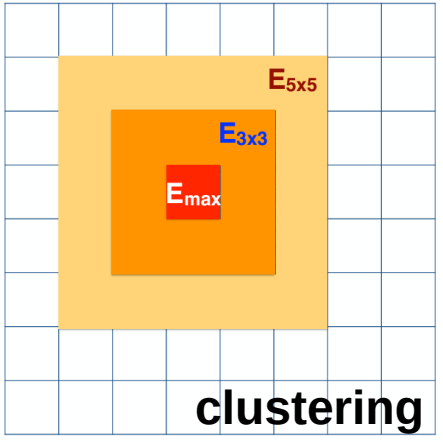
Data and MC Comparison



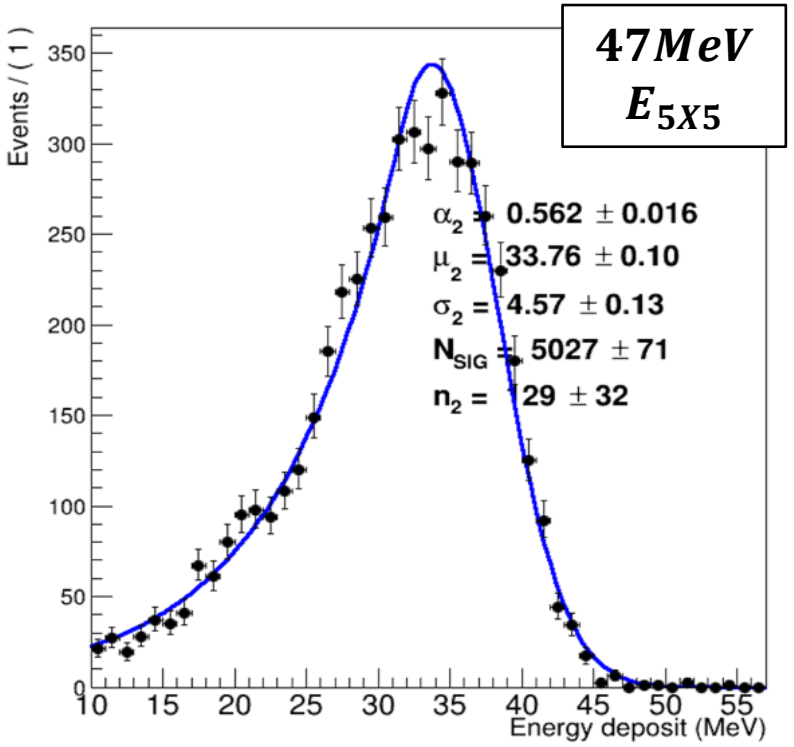




Reasonable agreement between data and MC for 47MeV positron beam data.

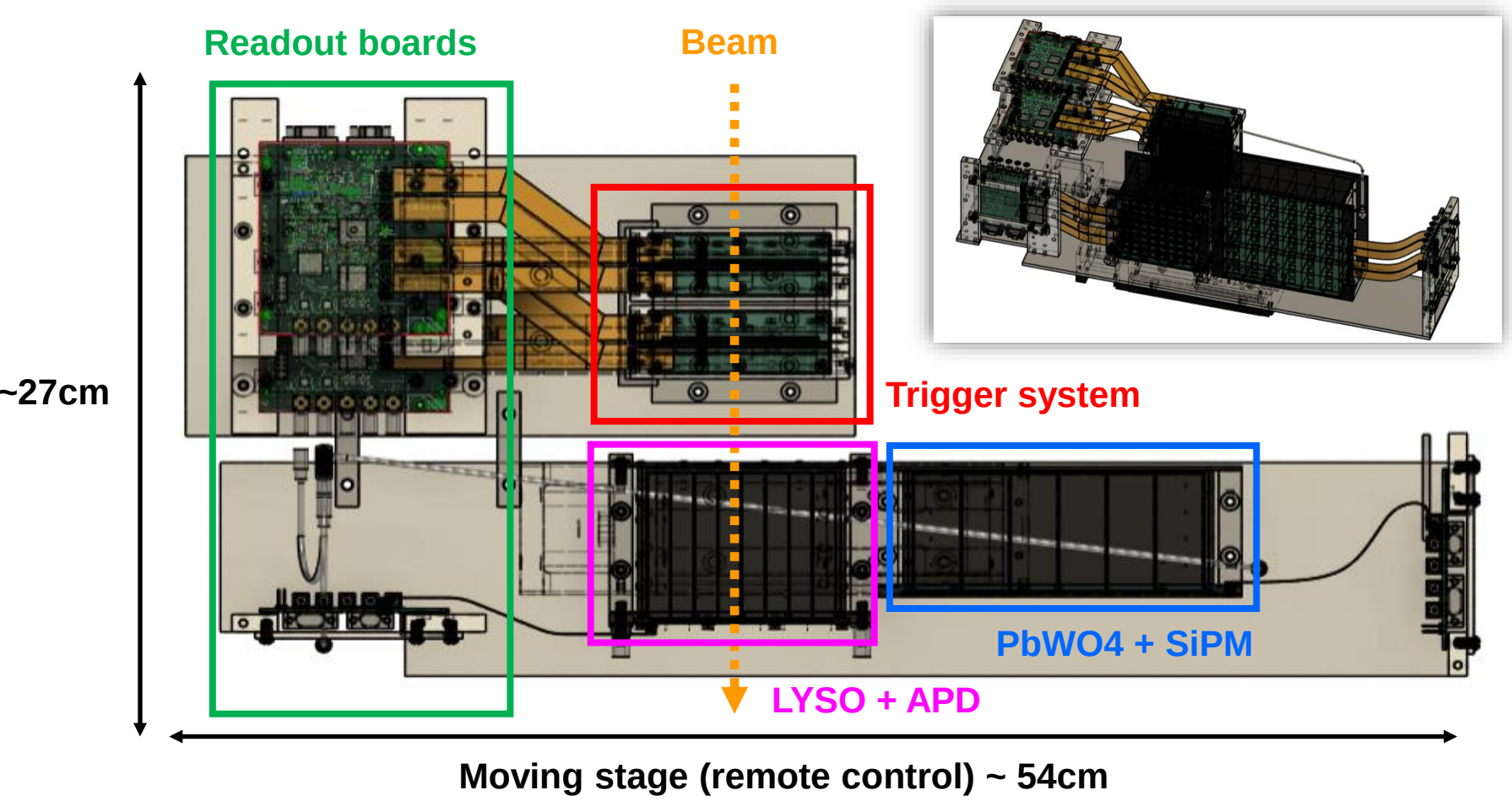


Energy Resolution



- Crystal ball fit : mean value of 33.76 ± 0.1 MeV and a sigma of 4.57 ± 0.13 MeV.
- The energy resolution is 13% for the 47 MeV electron beam including beam momentum resolution is ~11%.
- Energy regression practice will be implemented, and hopefully better result will be obtained.

2nd ZDC ECal Prototype



For the second prototype, we will test two configurations: LYSO with APD and $PbWO_4$ with SiPM, aiming to reduce gain and avoid saturation effects. A trigger system will also be set up to accurately determine the beam's position. We plan to complete all production by the end of the year, with the beam test at ELPH scheduled for February 2025.

Summary and To Do

- The first ZDC ECal prototype was constructed and tested with a positron beam spanning from 47 MeV to 823 MeV. Most of the test beam data falls within the SiPM saturation range, except for the 47 MeV data, which remains within the SiPM's linear range. We analyzed the 47 MeV data in this linear range, estimating an energy resolution of approximately 13%, factoring in an 11% beam momentum resolution. We anticipate improved results once energy regression is applied.

- For the second prototype, we will test two configurations: LYSO with APD and $PbWO_4$ with SiPM, aiming to reduce gain and avoid saturation effects. A trigger system will also be set up to accurately determine the beam's position. We plan to complete all production by the end of the year, with the beam test at ELPH scheduled for February 2025.

Backup

Estimation of ADC Value

- **Basic info**
  - SiPM gain = 1e6 ~ 5e6
  - APD gain = 1 ~ 100
  - LYSO PDE = 25e4-35e4 photons/MeV
  - PbO4 PDE = 1e2-2e2 photons/MeV
  - readout dynamic range = 11, 000 ADC
  - SiPM saturation ~ 3,000 ADC
- **LYSO + APD**
  - 50MeV electron , Emax = 21.5 , ADC = 19.18 => might be too low, close to noise level
  - 800MeV electron, Emax = 240.1, ADC = 213.689
  - 1GeV gamma , Emax = 248.6, ADC = 221.254
  - 40GeV gamma , Emax = 3190, ADC= 2839.1
- **PbWO4 + SiPM**
  - 50MeV electron , Emax = 22.43, ADC =997.8
  - 800MeV electron, Emax = 266.7, ADC = 11862.8 => out of linear range of SiPM
  - 1GeV gamma , Emax = 284.0, ADC = 12632.32 => out of ADC dynamic range
  - 40GeV gamma , Emax = 4198 , ADC = 186727 => out of ADC dynamic range

Production Status of 2nd ZDC ECal Prototype

- **LYSO + APD**
  - Radiation length : 6X0
  - Active area : 8cm*8cm
  - One crystal : 1cm*1cm
  - Num. of channels : 64
  - Crystal ready, APD PCB layout finished, wait for production
- **PbWO4 + SiPM**
  - Radiation length : 6X0
  - Active area : 12cm*12cm
  - One crystal : 2cm*2cm
  - Num. of channels : 36
  - Crystal ready, APD PCB layout finished, wait for production
- **Trigger System**
  - Plastic scintillator bar, EJ200
  - Active area : 64mm*64mm
  - One bar : 2mm*2mm (position resolution)
  - 32ch in X-dir and 32ch in Y-dir
  - Two stages coincidence (two layers in X and two layers in Y)
  - Crystal ready, PCB layout finished, wait for production
- **Readout** (design is similar to 1st prototype)
- **Mechanical structure** (design read, wait for production)
- **Moving stage** (ready)

Readout of 1st Prototype

- Designed by Chih-Hsun Lin of Academia Sinica
- 64 channels
- Trigger:
  - Self-triggered
  - Can accept external timing signal → needs to be studied
  - May accept external trigger → needs to be studied