Barrel Imaging Calorimeter TB2025 overview

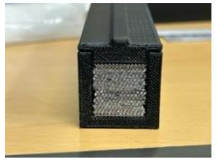
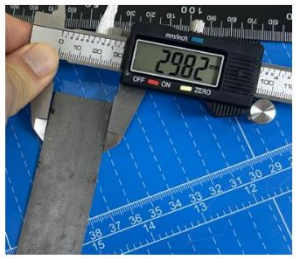
EPIC calorimetry bi-weekly meeting – TB2025 overview

2025.05.07

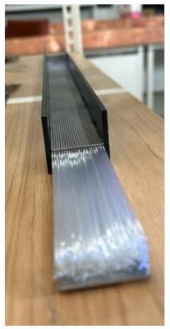
Jeongsu Bok (Pusan National University)

Pb/SciFi Prototype Module Production in Korea

1) Pb plate preparation

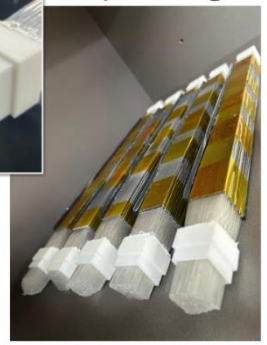




2) Stacking with fiber

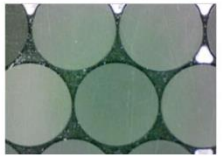


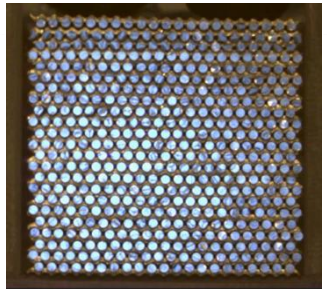

3) Cutting fiber

4) curing

5) polishing

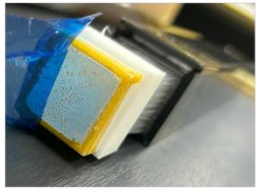
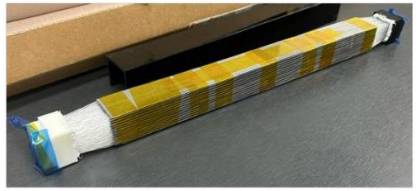




Pb : Fiber : Air = 40 : 43 : 17

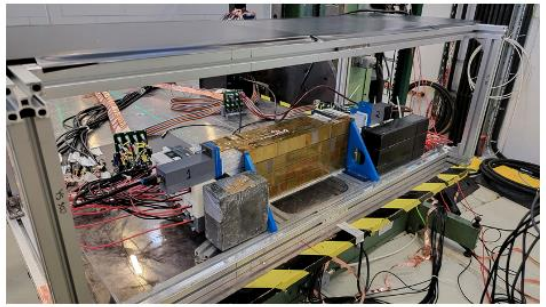
Produced 16 unit modules
(32x3x3cm^3) in 2024,
16 more in 2025.

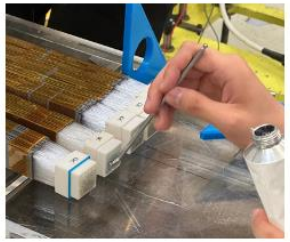
완성본

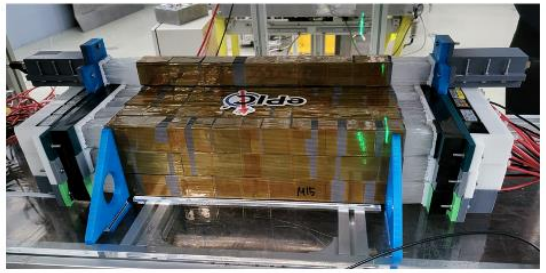



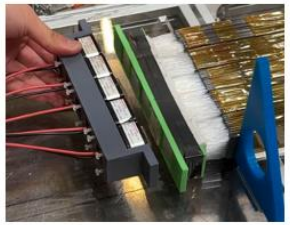

6) Connect with PMT

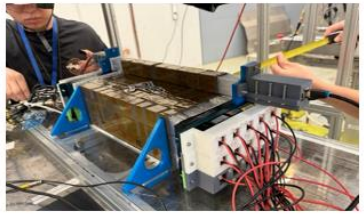
TB2024 at CERN PS T10 recap

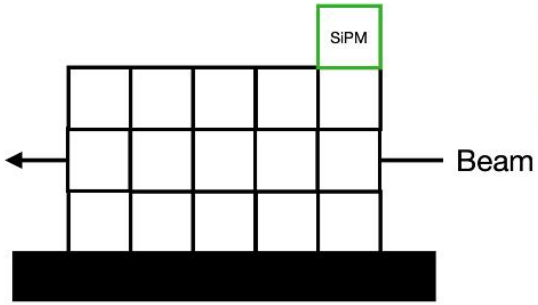




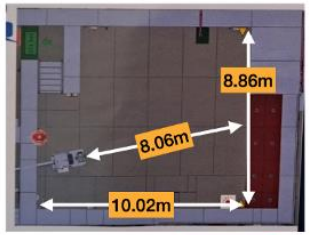


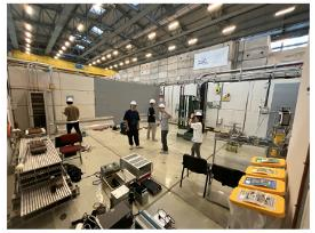


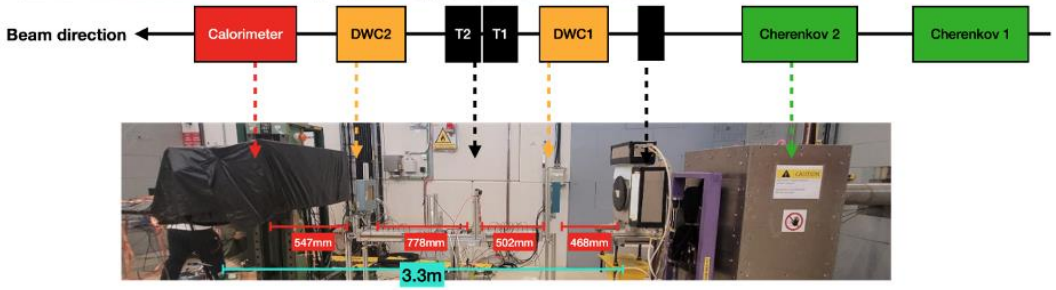




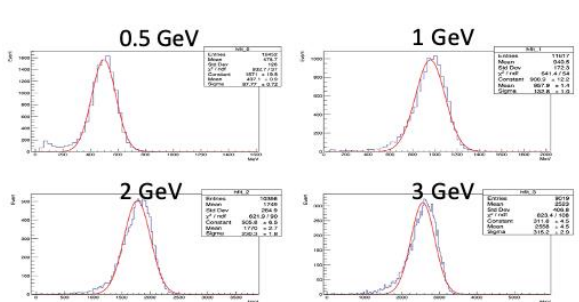
15 unit modules (32x3x3cm^3): 32x9x15 cm^3 Pb/SciFi

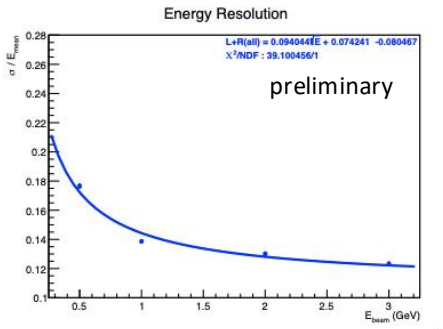






Collected data from 0.5,1,2,3 GeV electron beams

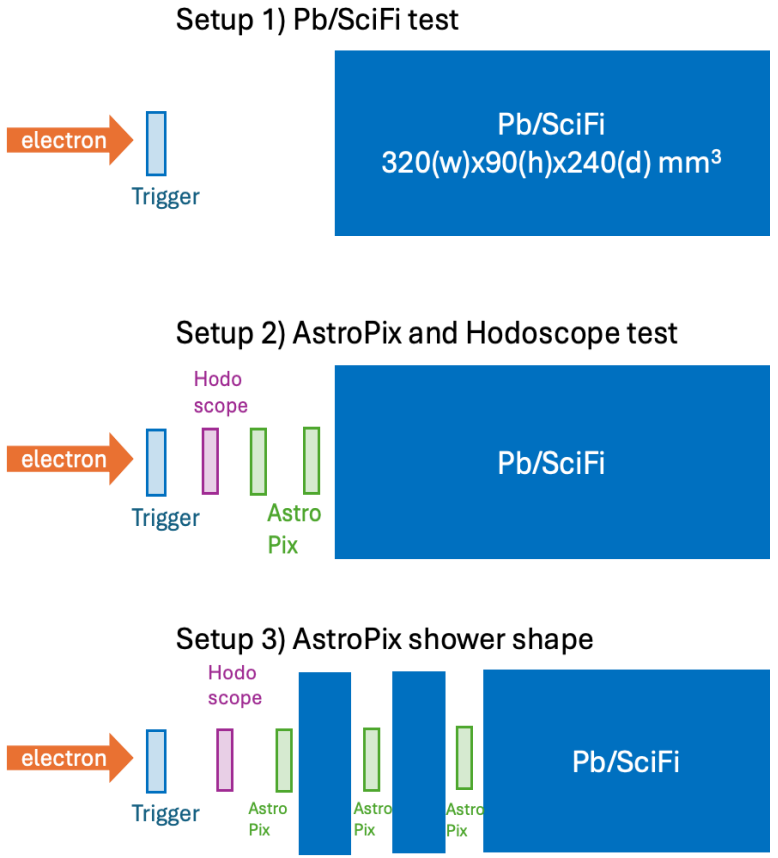




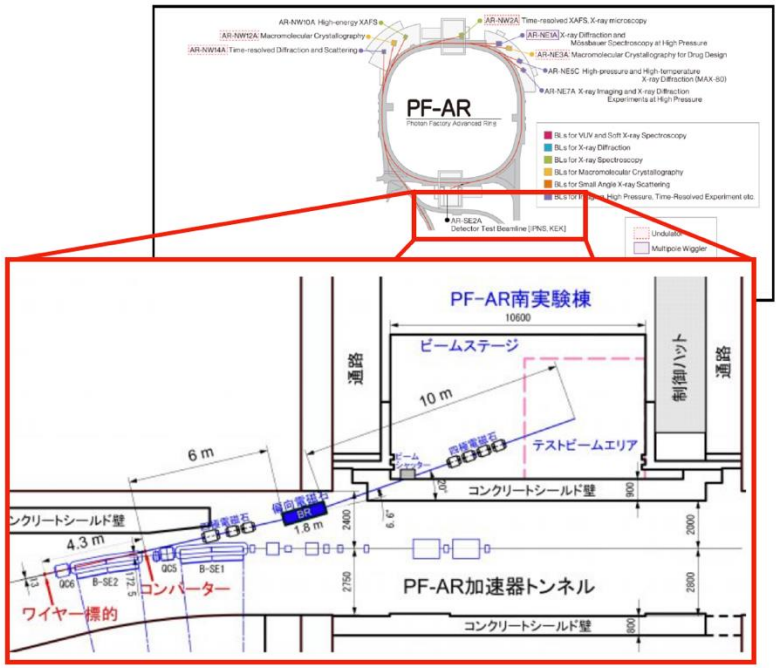
August 2024
17 participants from 5 institutions

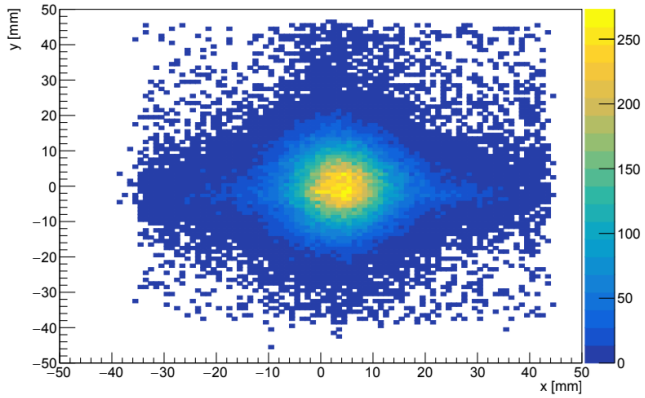
Experimental Program at KEK in March 2025

- Pb/SciFi calorimeter prototype test
  - Calibration, Energy resolution
  - 3x5(CERN)→4x8(KEK) setup
- AstroPix and Hodoscope test
- AstroPix + Pb/SciFi calorimeter combined setup
  - Integrated data acquisition of calorimeter and AstroPix
  - Shower profile
- Additional test
  - A module with light guide
  - Test of the new DAQ
  - Integration of different detectors
    - Trigger, Hodoscope, Wire Chamber, AstroPix, Pb/SciFi



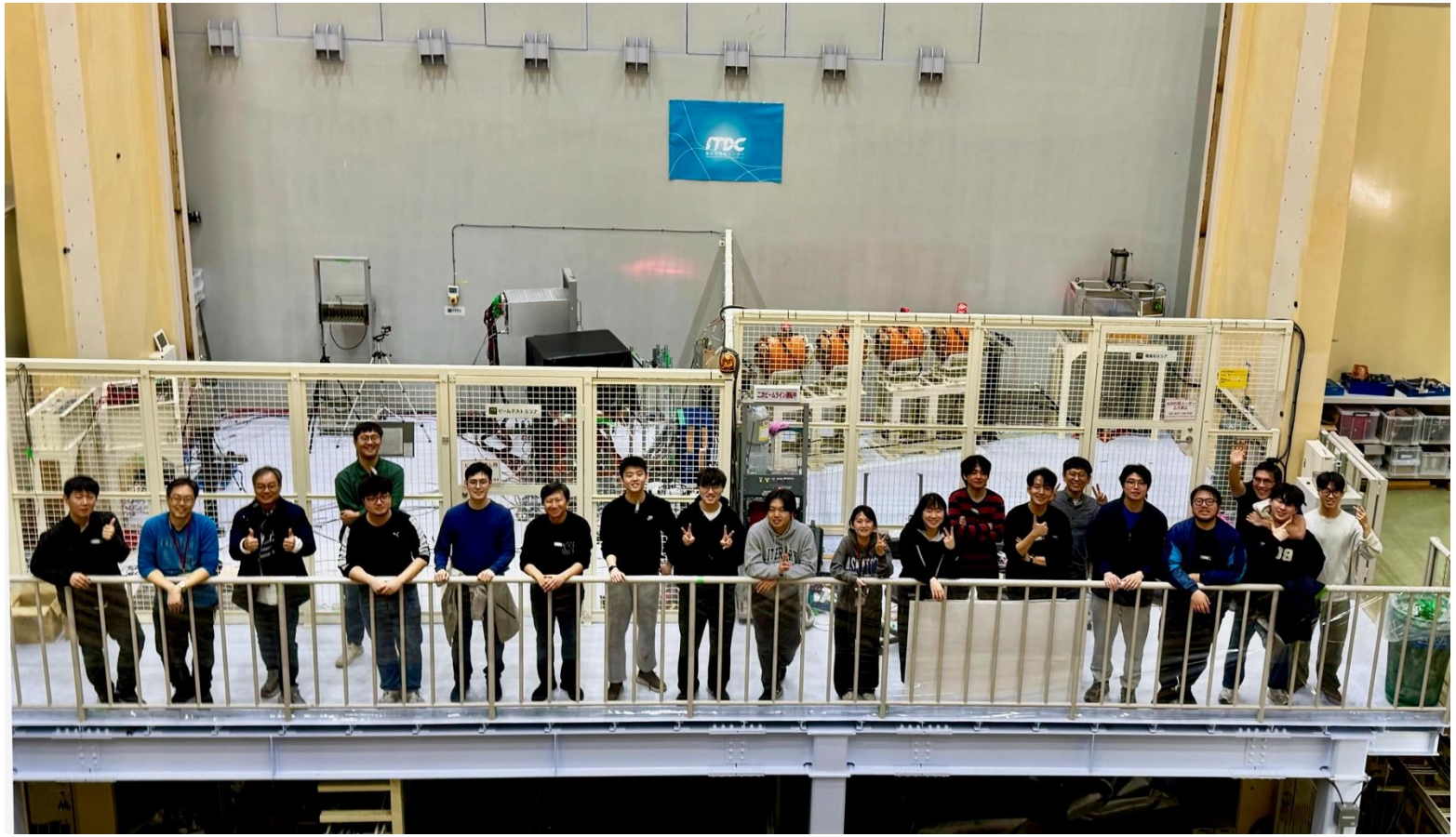
KEK PF-AR Testbeam





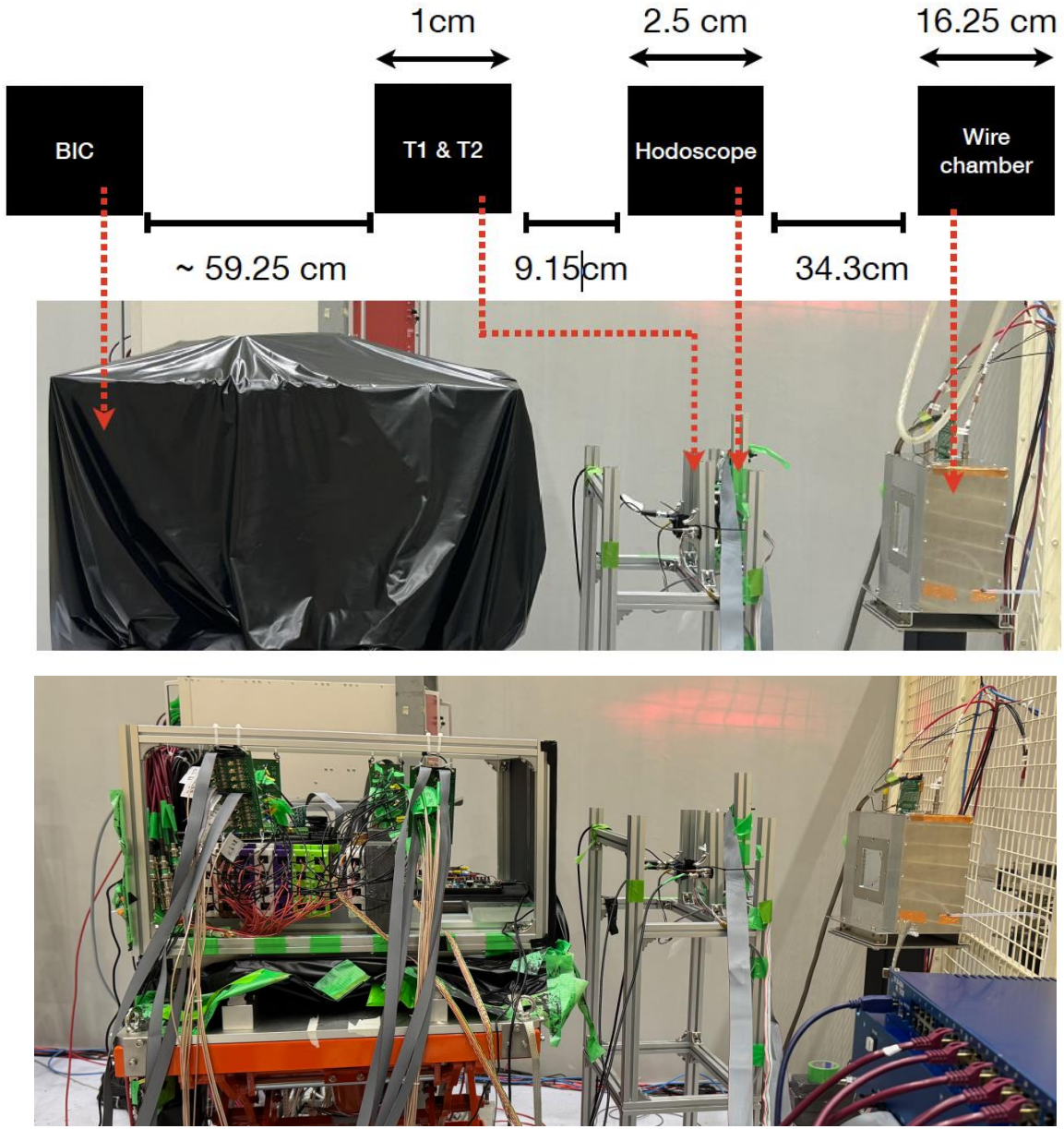
Electron from 0.5 to 5 GeV
Δp/p~10%
~350Hz in 8x8mm^2

Team for the beam test at KEK in March



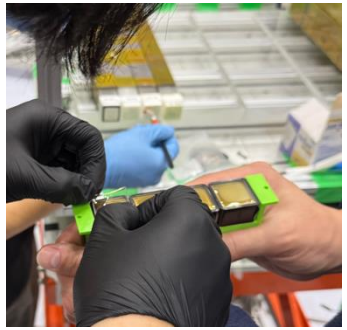
20 members from 6 institutions
Kyungpook National University
University of Seoul
Yonsei University
Sungkyunkwan University
Pusan National University
Chung-Ang University
Contact person: Taku Gunji, Yuji Goto

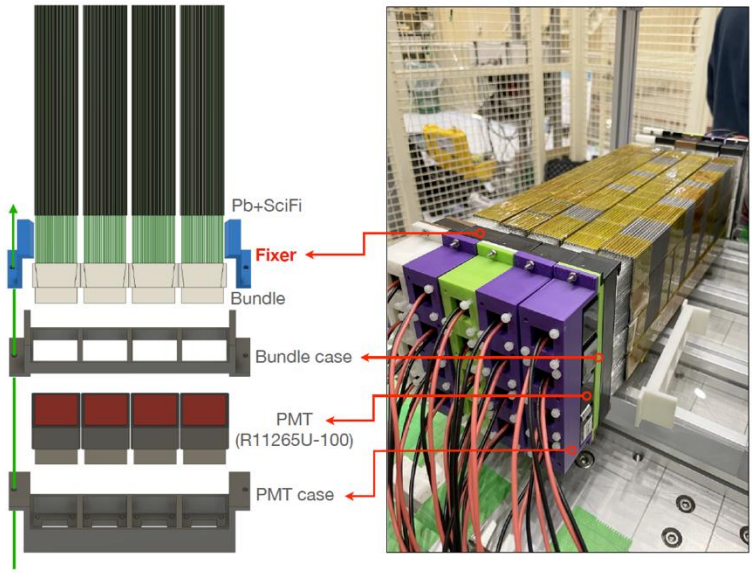
Experimental Setup for Pb/SciFi

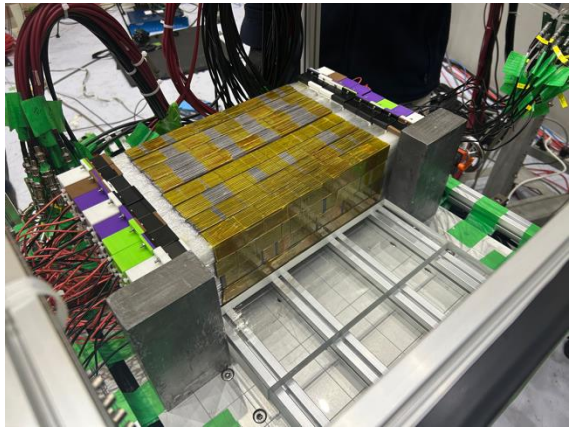


- Detector setup
  - Wire Chamber
  - Hodoscope, Trigger
  - Pb/SciFi Calorimeter
- Program
  - Horizontal, vertical position scan.
  - Calibration
  - Energy response
  - Position dependent energy response.
  - Longitudinal (transverse) shower profile along modules
  - Time (position) resolution by horizontal positions scan

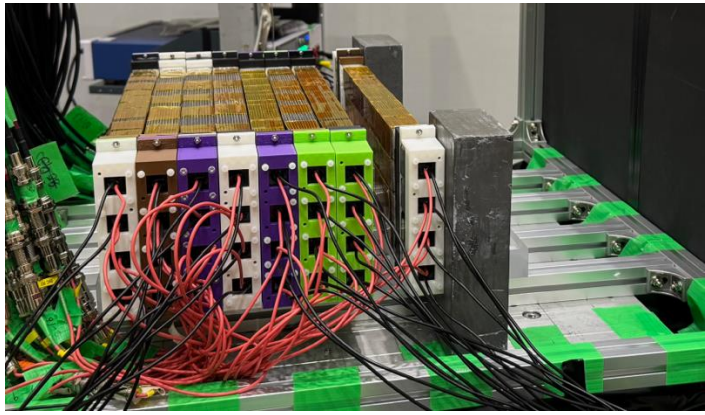
Pb/SciFi Module Assembly



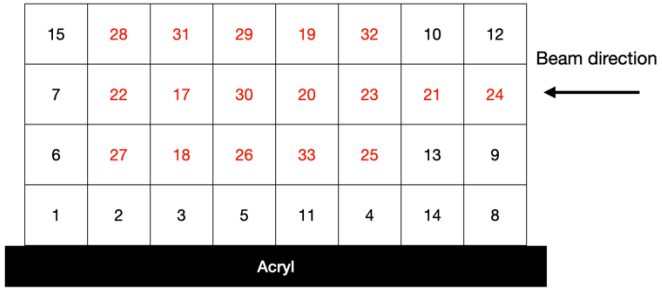




Setup for calibration with 5GeV and energy scan



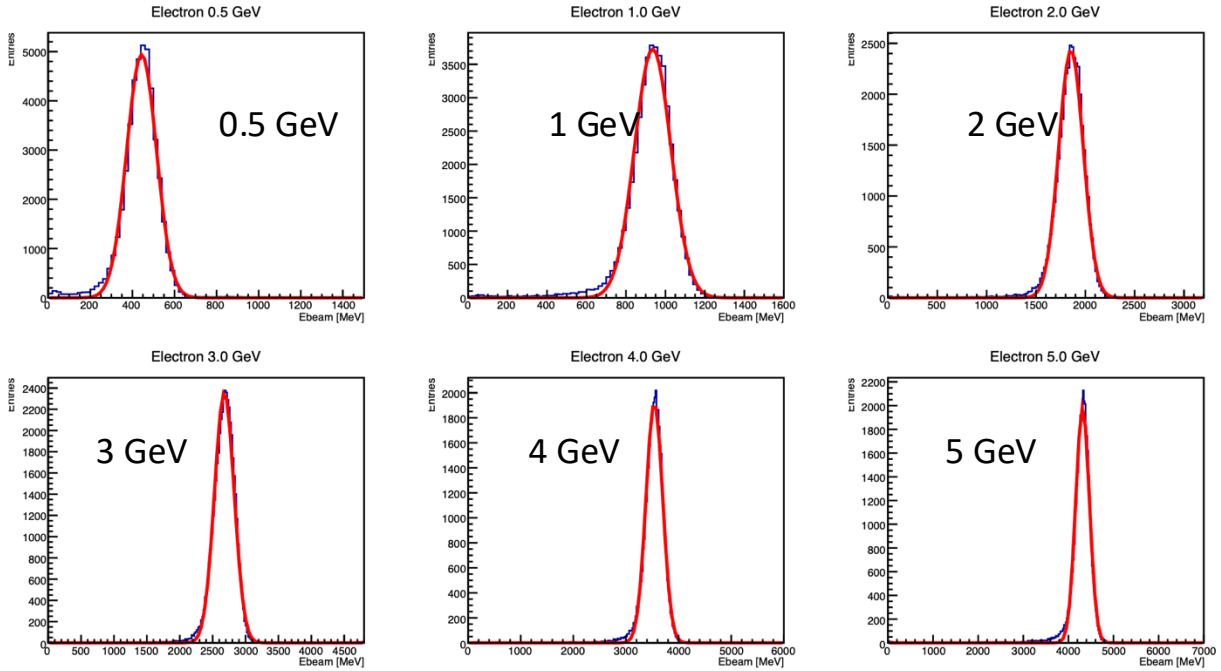
Setup for AstroPix layer between Pb/SciFi

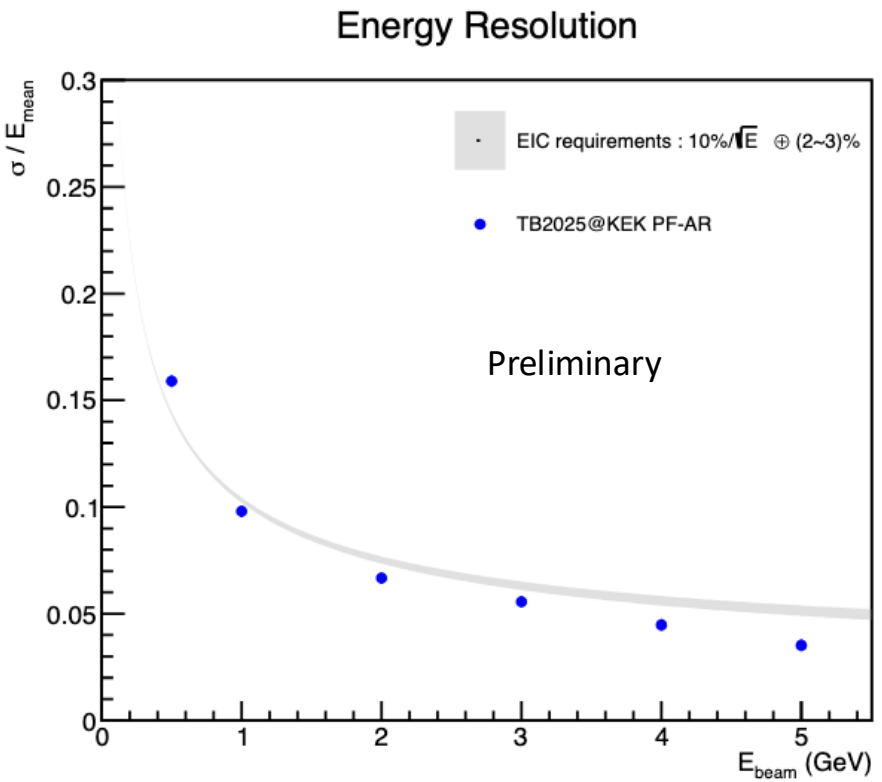


Module distribution

- 4x8 setup of 32x3x3 cm^3 unit modules: 32x12x24 cm^3
- Depth comparable with the actual BIC
  - The number of channels were limited to 4x7 in new DAQ in March.

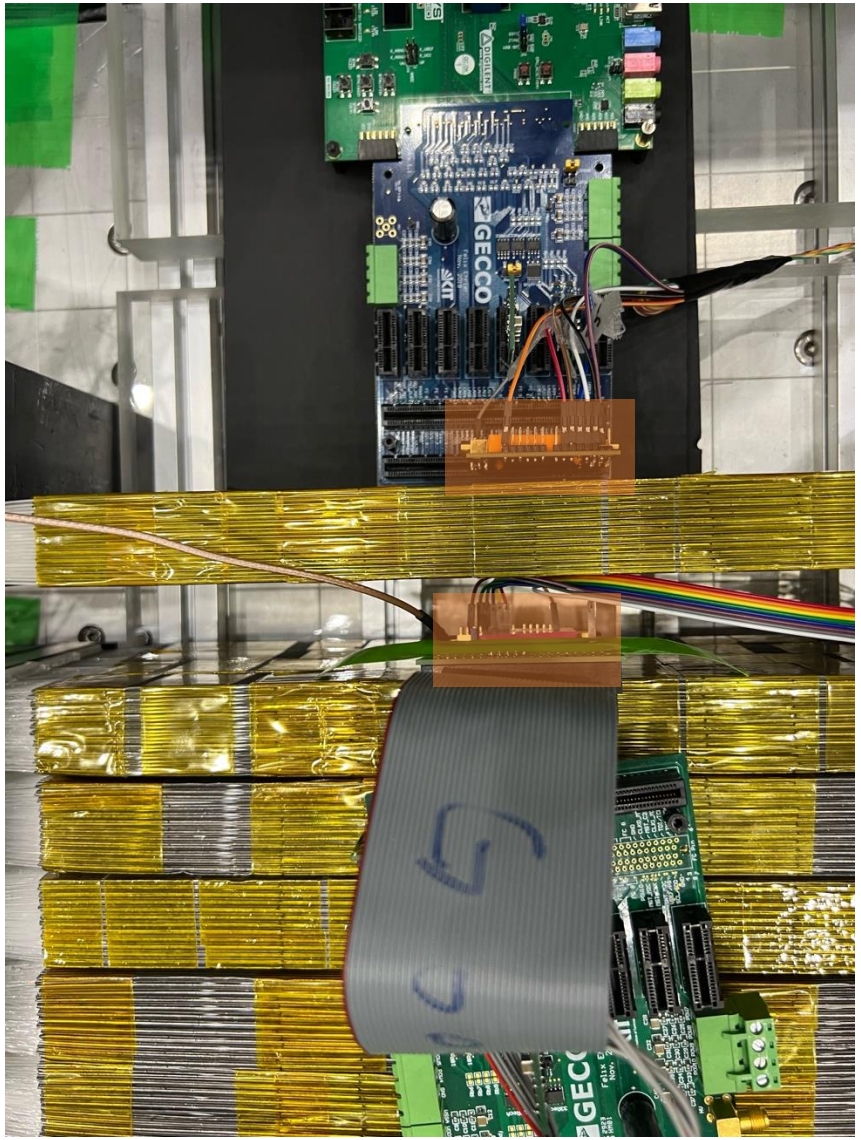
Pb/SciFi results from TB2025 at KEK

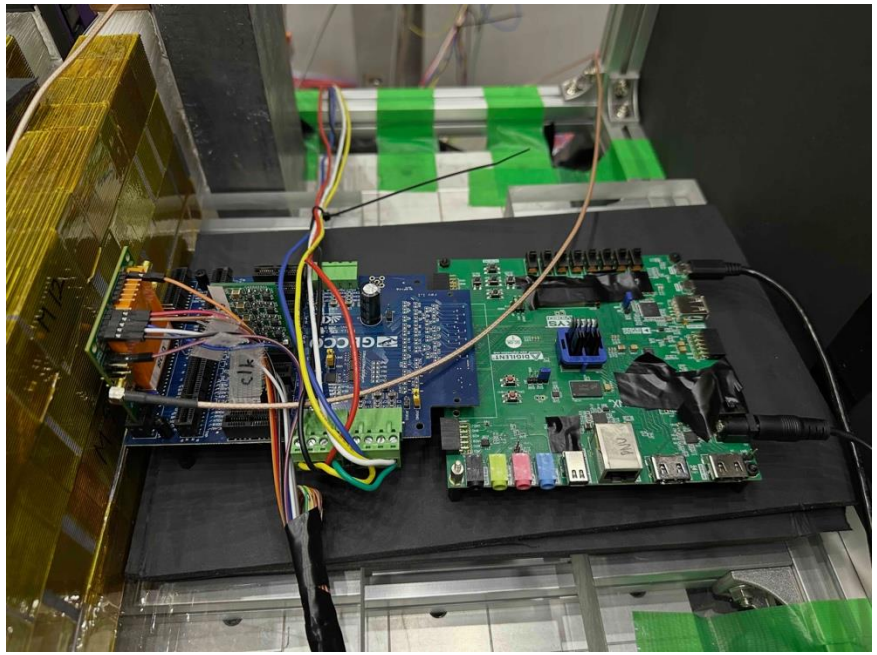




4x7 setup of 32x3x3cm^3 unit modules: 32x12x21cm^3 ~ 15.2X_0
Energy resolution below 10%⊕2~3% from 1 GeV
Comparable with baby-bcal result at 4 GeV

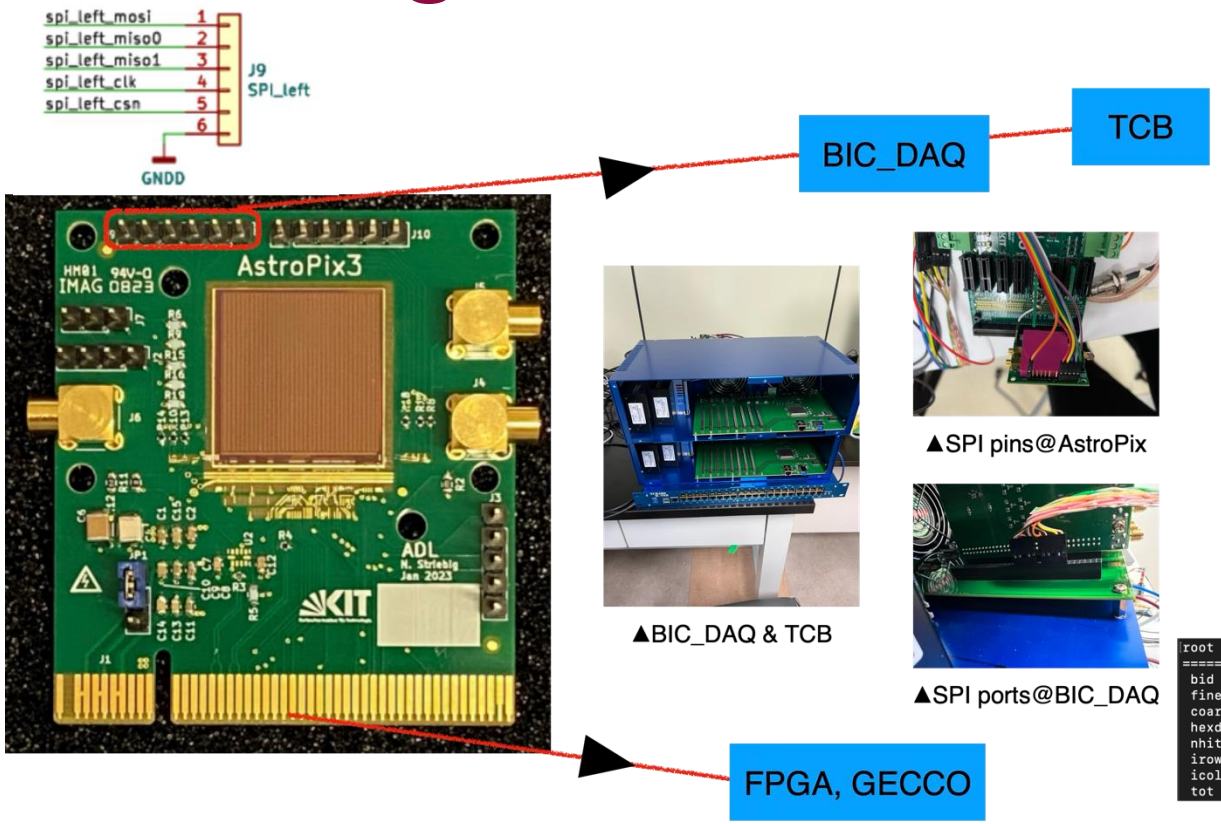
Setup with AstroPix





- DAQ: signal from pins
  - Temporary, but easier implementation to our DAQ
- Unfortunately, only one setup worked
- 1,3,5 GeV/c data in front of or between Pb/SciFi

Signal from AstroPix to DAQ, FPGA

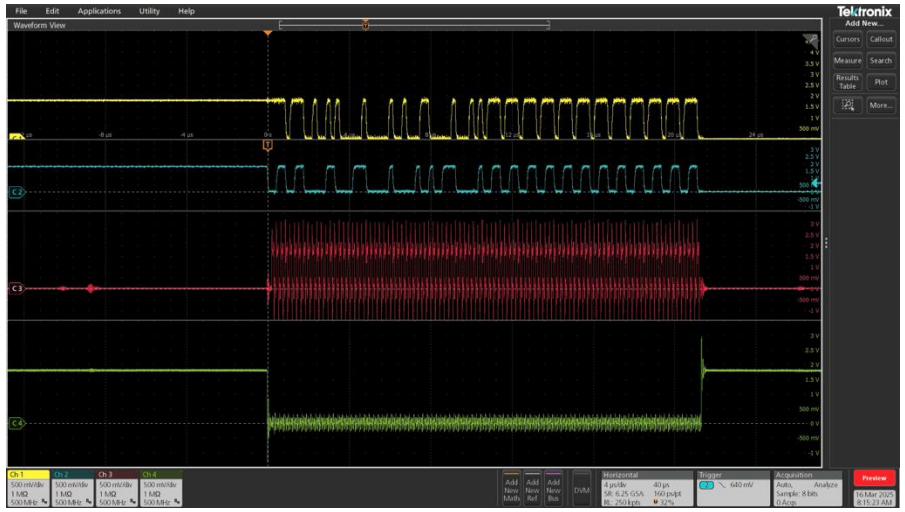


▲BIC_DAQ & TCB

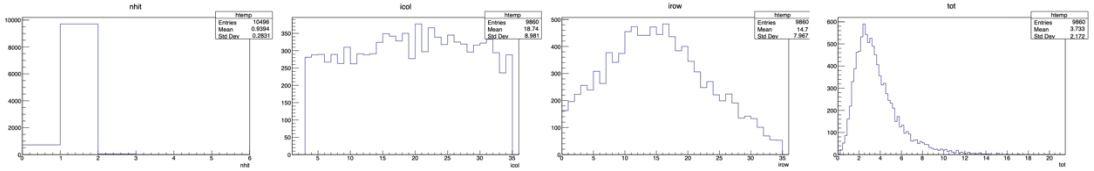
▲SPI pins@AstroPix

▲SPI ports@BIC_DAQ

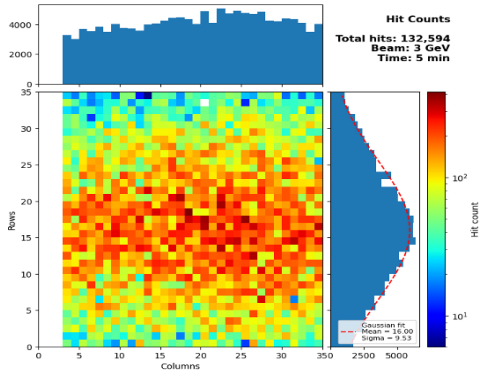
```
root [3] apix2->Show(16)
======> EVENT:16
 bid              = 162
 finetime         = 16
 coarsetime       = 110116
 hexdata          = 0000000
 nhit             = 1
 irow             = 25
 icol             = 25
 tot              = 4.905
```



Hits in the DAQ from the pins after matching

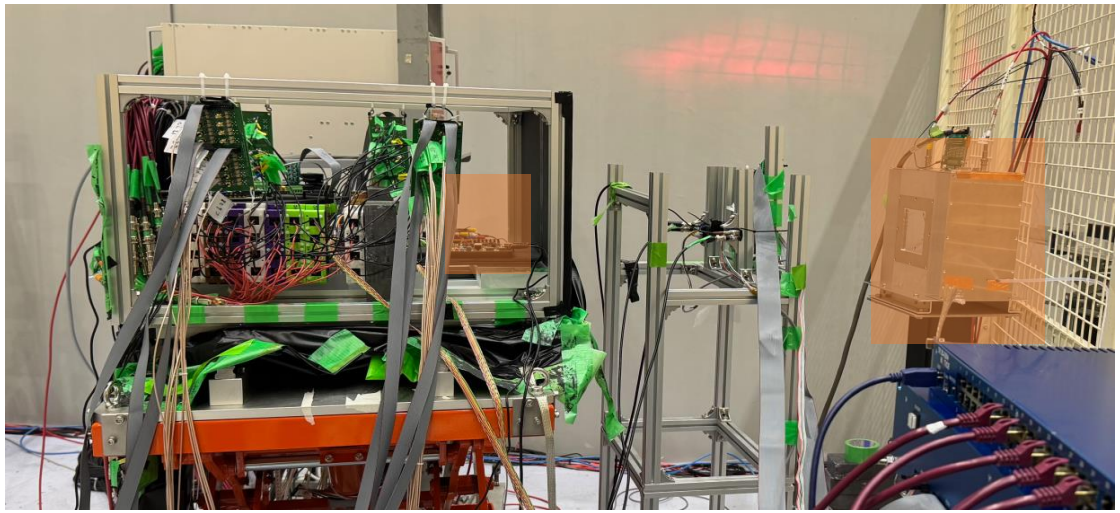


- When a hits is recorded, interrupt(csn) gets low, clock(clk) gets started
  - 10 bytes MISO signal contains hit location, ToT, Timestamp
- In the DAQ,
  - 8 analog channels to receive SPI signals from each 4 pins of a AstroPix
  - SPI signals are recorded when csn is low & clk is enabled
  - It records these signals along with the TCB clock, sharing it with the Pb/SciFi signal

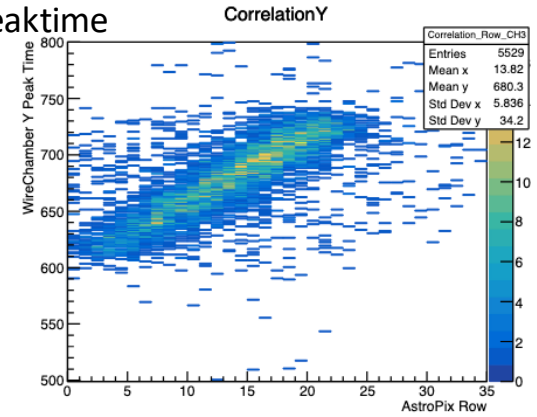


Signal in the FPGA (in front of Pb/SciFi)

AstroPix signal through DAQ



Wire Chamber peaktime

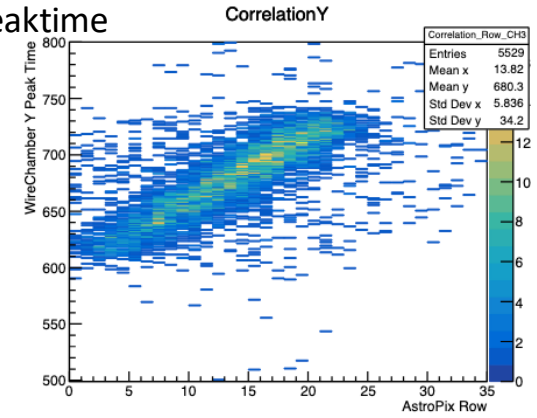


AstroPix row

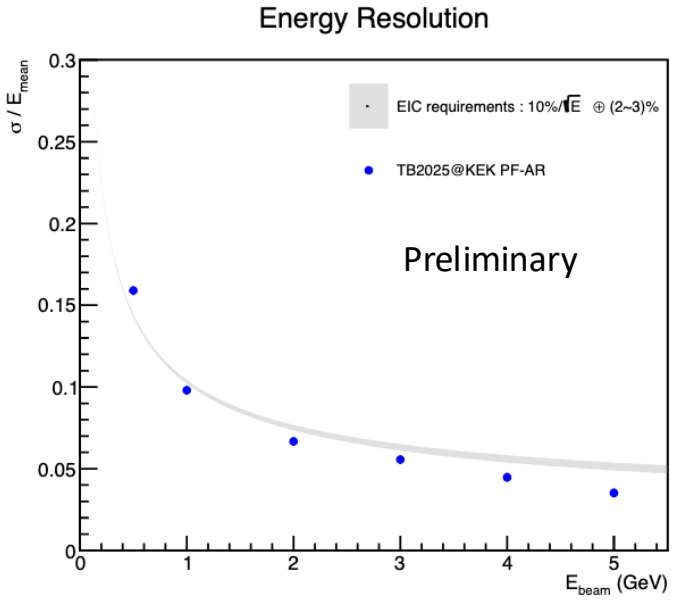
- We see a correlation between the wire chamber and AstroPix.
- But need improvement in DAQ: items for next Testbeam
  - Multi-hit
  - Higher rate

What we have achieved from beam test in Mar 2025

Wire Chamber peaktime



AstroPix row



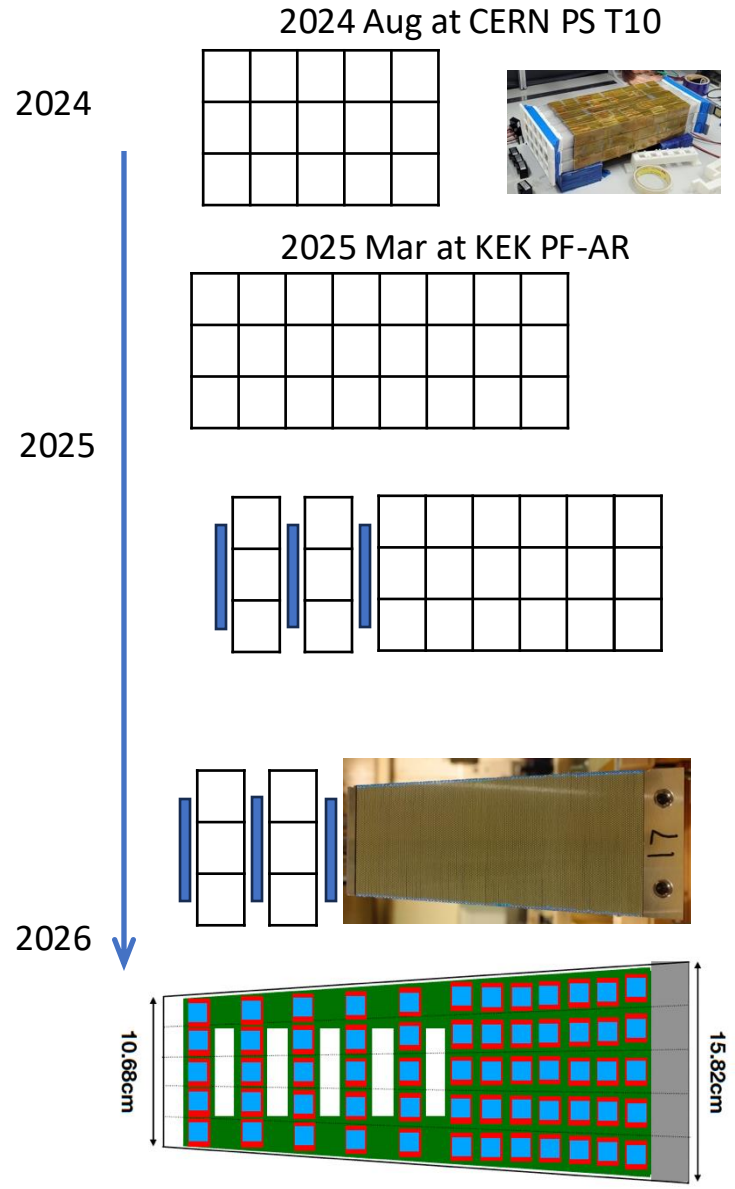
Electron energy resolution below EIC requirement (10%⊕2~3%) except for 0.5GeV, comparable with baby-bcal at 4GeV

Personpower with beam test & production experience

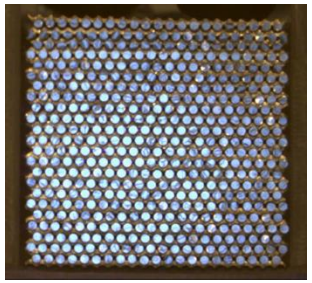
Synchronized data taking of AstroPix and calorimeter (will be improved): The first data of AstroPix between Pb/SciFi

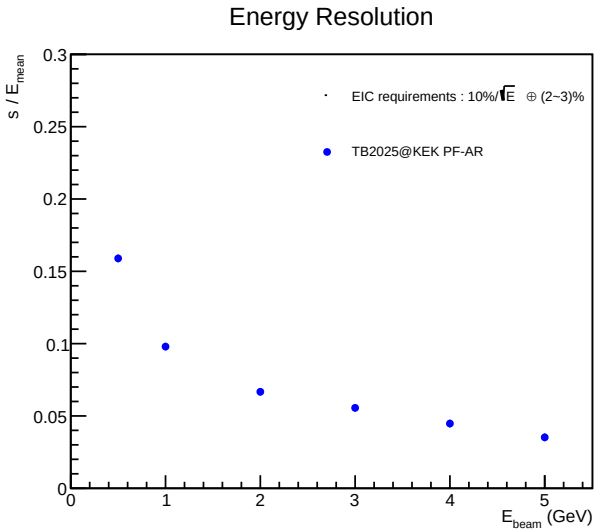
Plan for the next beam test

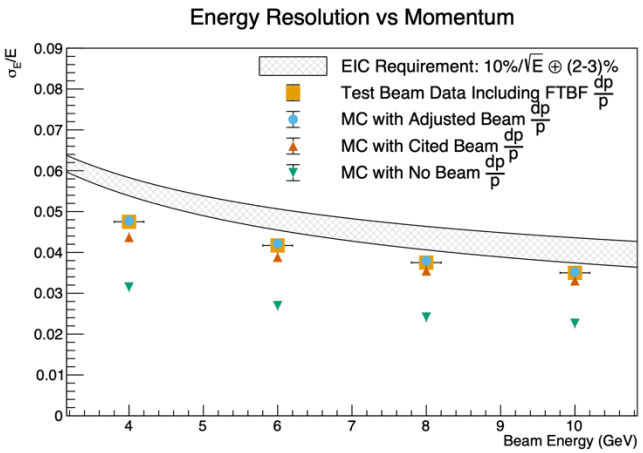
- June 11th~19th at KEK
  - Preparation of CERN beam test, especially for the AstroPix part.
  - Confirm the standing order for the team
  - Improvement in DAQ
- July 23th~30th at CERN PS T10
  - Pion and electron discrimination using Pb/SciFi and AstroPix
  - Muon beam calibration
  - Response of Pb/SciFi in separated setup
  - SiPM + LG module test
  - HGCROC
- Near Future
  - In 2025, we will build a short prototype corresponding to a sector.
  - 3D shower profile using AstroPix and Pb/SciFi



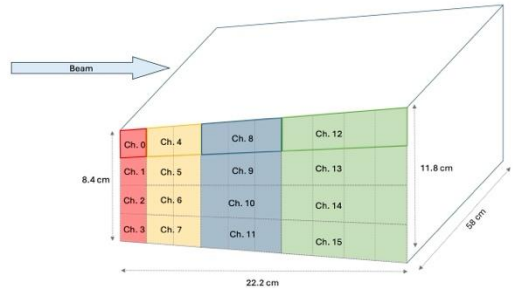
Backup: energy resolution

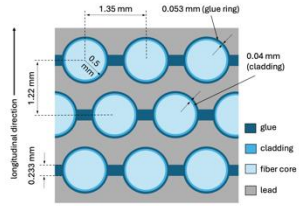






arXiv:2504.03079

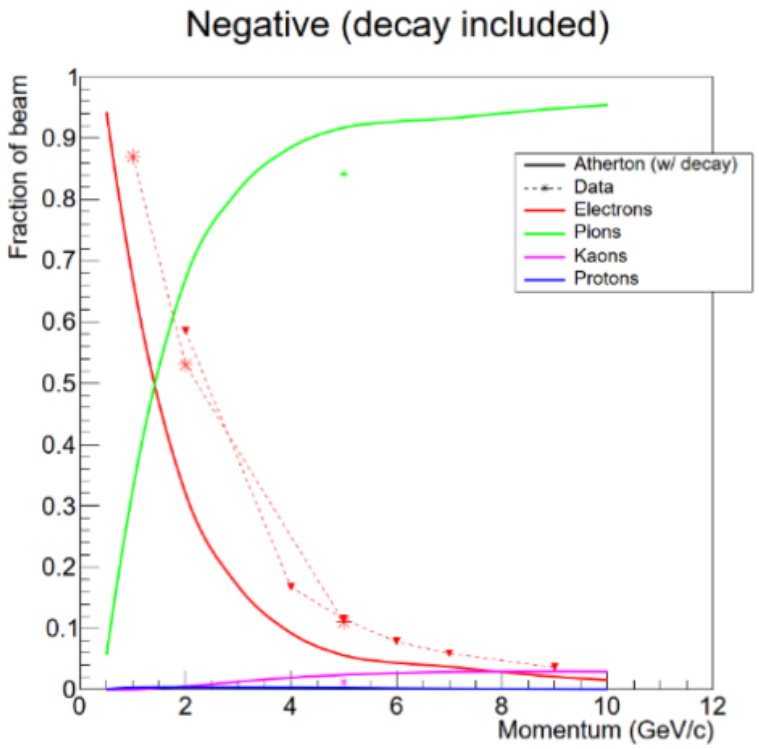


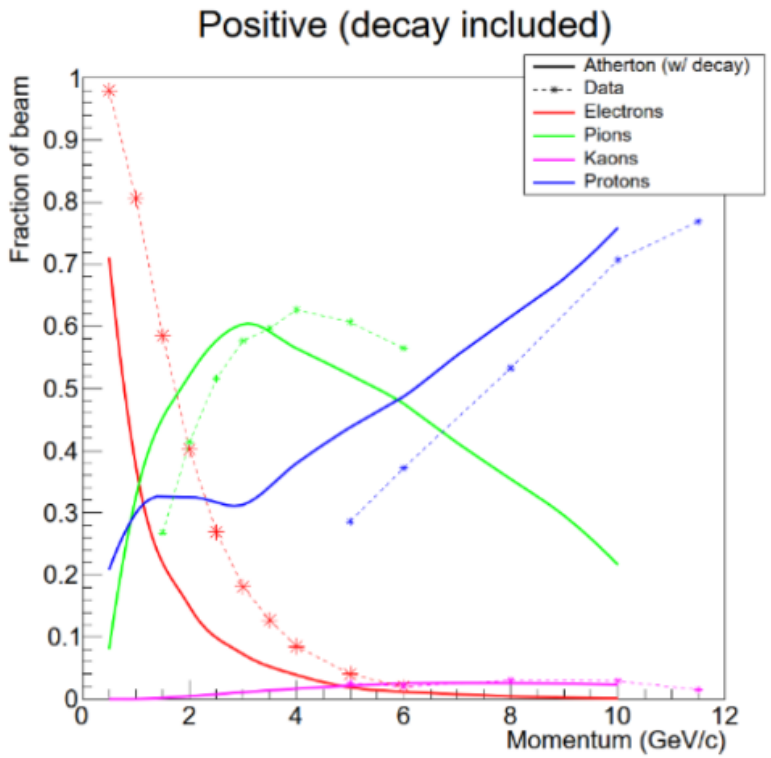


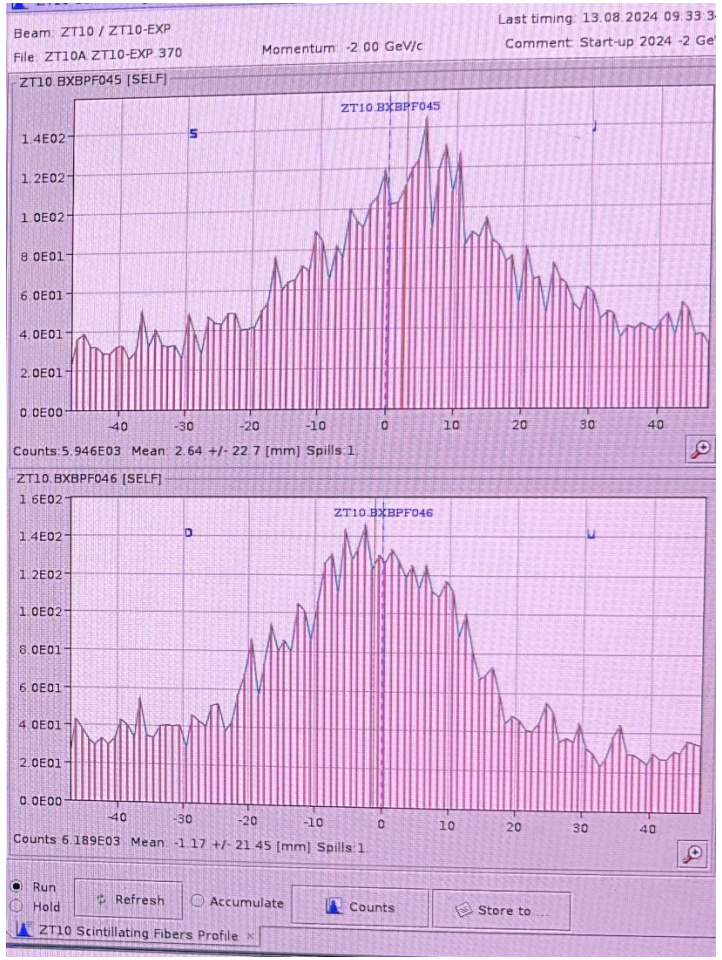
4x7 setup of 32x3x3cm^3 unit modules:
32x12x21cm^3 ~ 15.2X_0
Pb : Fiber : Air = 40 : 43 : 17
X_0 ~ 1.38 cm
PMT readout
CERN PS T10 0.5~3 GeV
KEK 0.5~5 GeV electron

Baby-Bcal 56x[8.4-11.8]x22.2cm^3 ~ 15.5X_0
Pb : Fiber : Glue = 37 : 49 : 14
X_0 ~ 1.45 cm
SiPM+Light Guide readout
FTBF 4~10 GeV electron

Backup: CERN PS Beam info



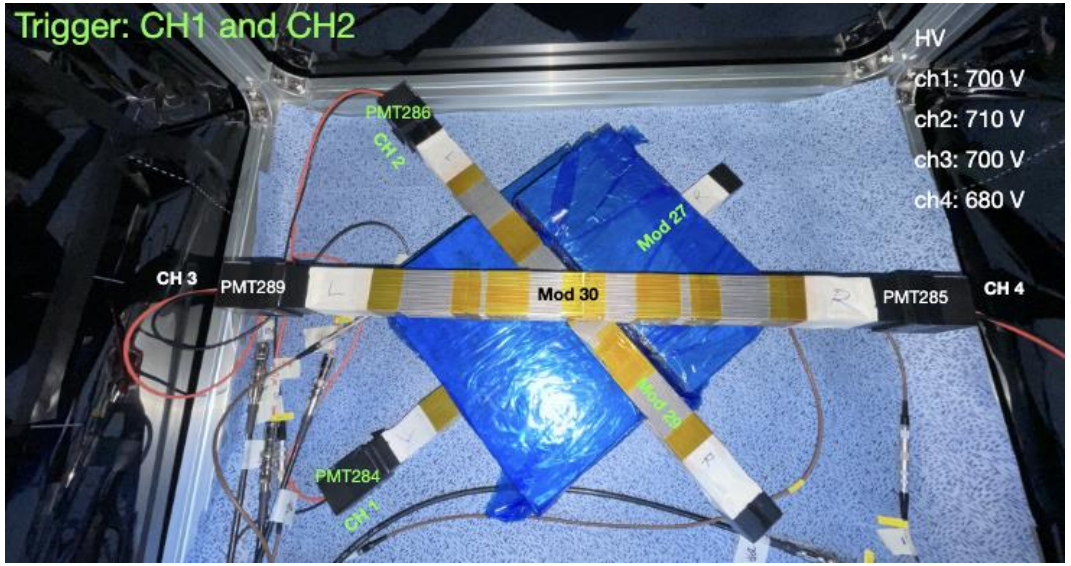


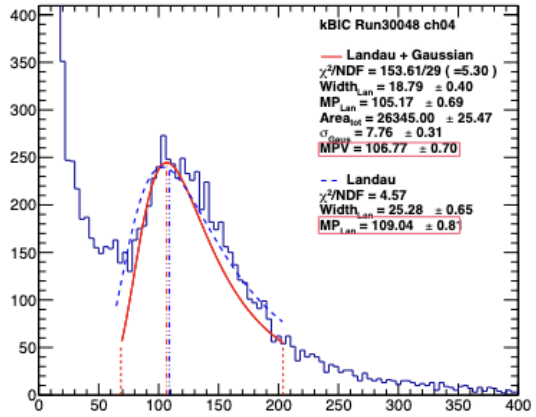


Characteristics of the beams

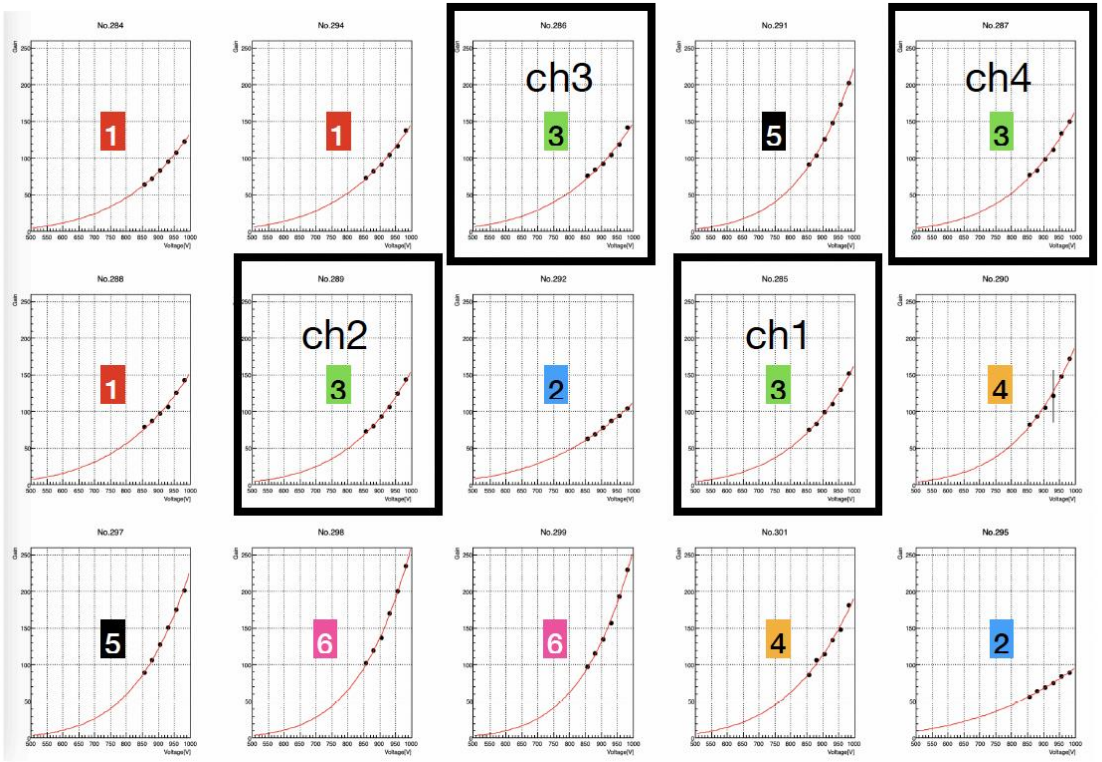
Parameter	T09	T10	T11
p_{max} of secondary beam in $^{GeV}/_{c}$	16	12	3.5
$\Delta p/p$ in %		± 0.7 to ± 15	
Maximum intensity/spill (hadrons/electrons)		10^6	
Available particle types	Pure electrons (T09 only) or mixed electrons (T10) or mixed/pure hadrons or pure muons		

Backup: Pb/SciFi module, PMT test





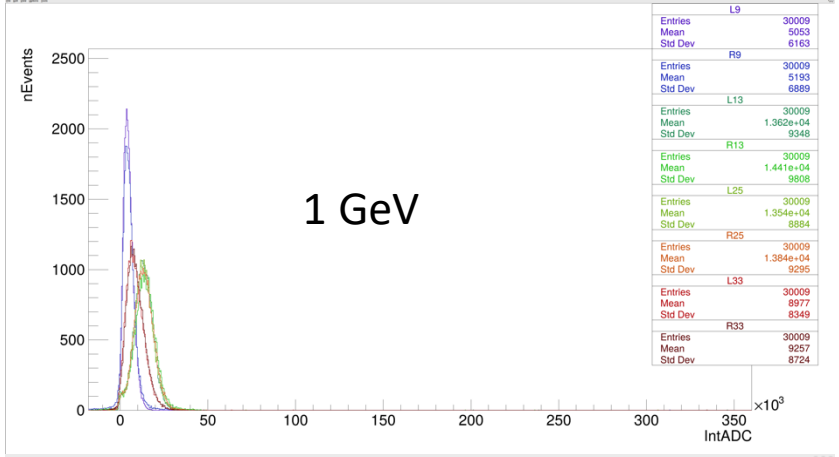
Checked module response for cosmic using the same PMTs

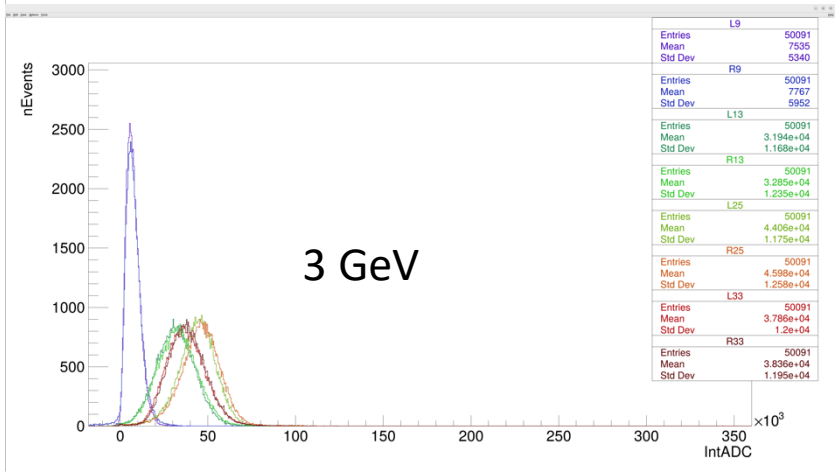


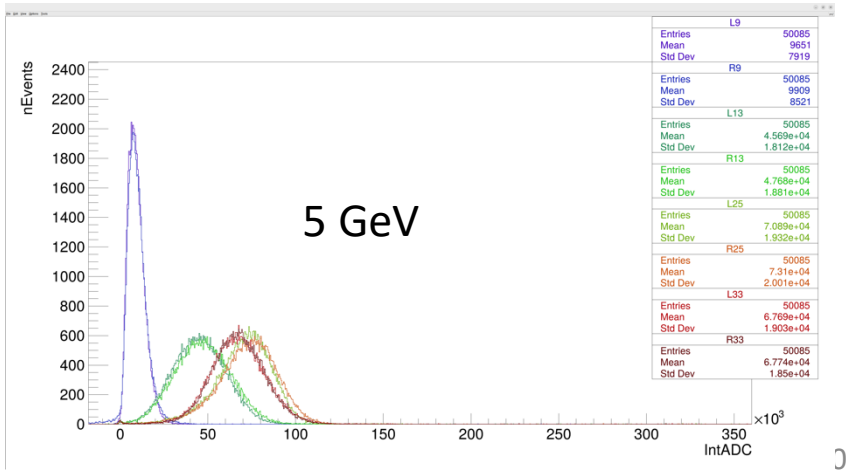
LED test for PMT

Backup: Pb/SciFi calibration

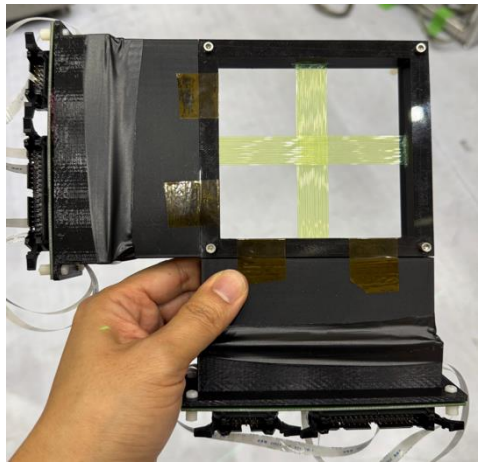
- Channel equalization for uniform response
  - Optimize operation voltage of each channel, considering dynamic range and saturation of pulse height.
  - Voltage scan to get starting point, then adjust voltage for each channel until it reaches the expected integrated ADC value for the location of module
- Calibration
  - Energy deposit in simulation / Integrated ADC
  - Obtain calibration constant for each channel using 5 GeV electron to ensure enough energy is delivered to downstream.
- Energy response
  - 0.5, 1, 2, 3, 4, 5 GeV electron

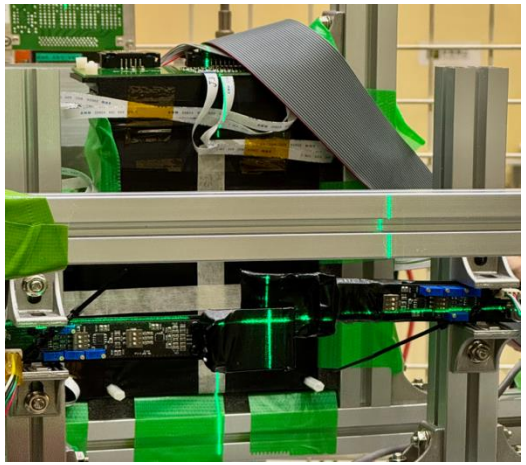


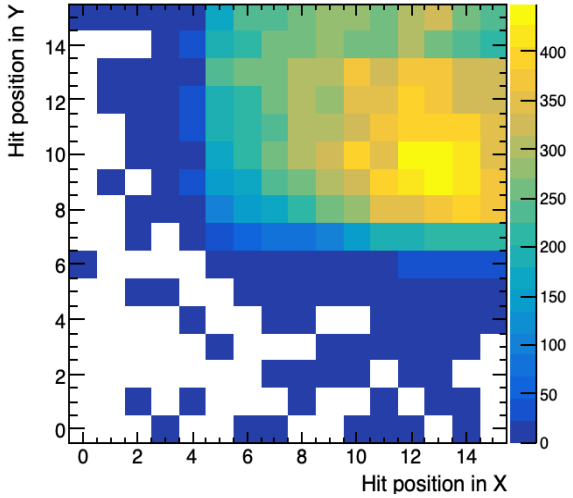


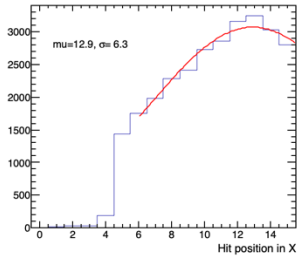


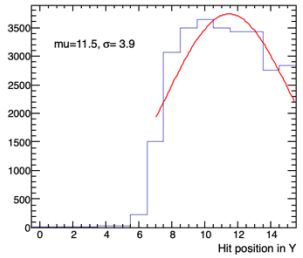
Backup: Trigger, Hodoscope





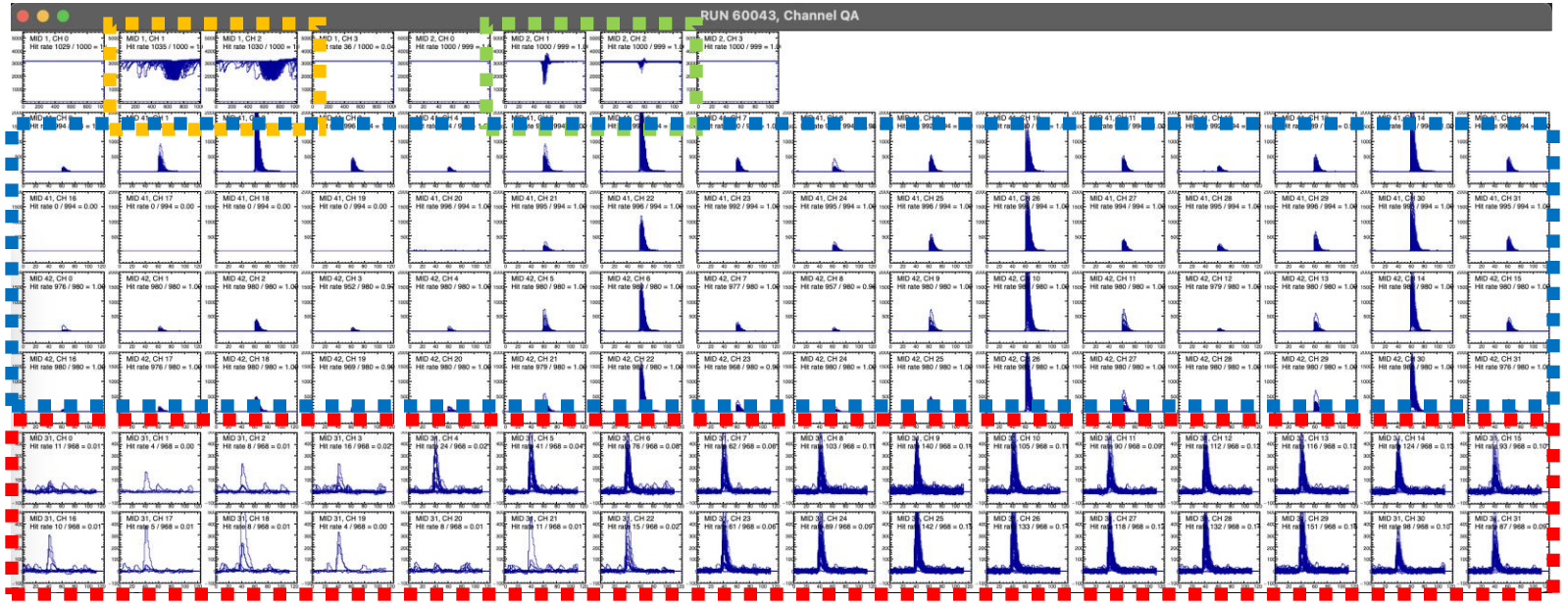


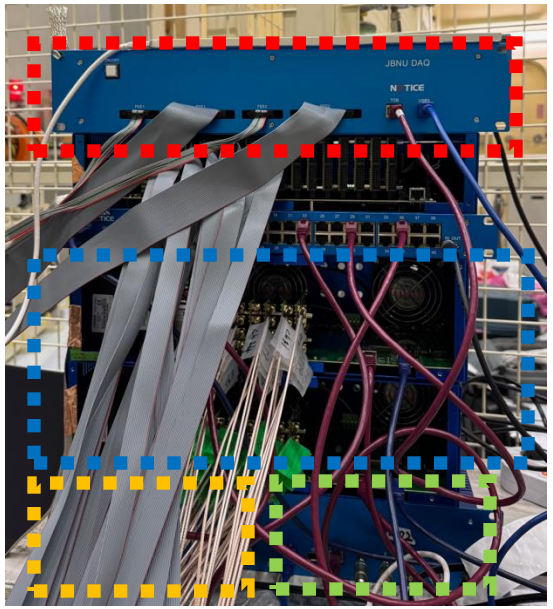




- Trigger: plastic scintillator + SiPM
  - Overlapping region ~10x10 mm^2 from two scintillators of 30x30x2 mm^3
- Hodoscope: SciFi(1mm) 16(x)+16(y) with 32 SiPMs
  - Overlapping region: 16x16 mm^2
  - Not centered perfectly, but it shows trigger shape.

Backup: new DAQ test

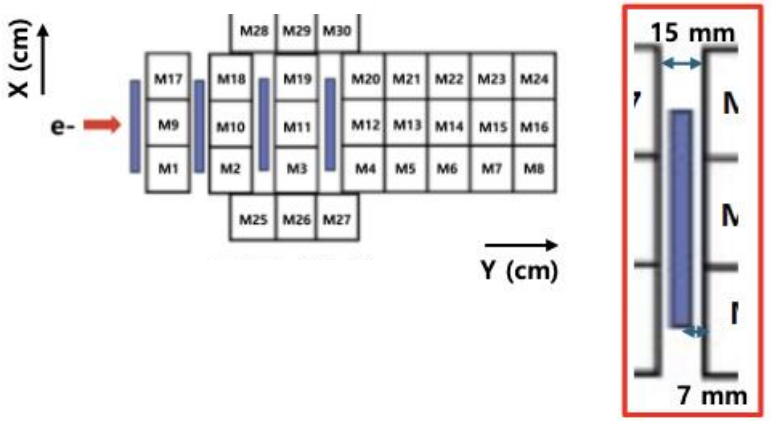




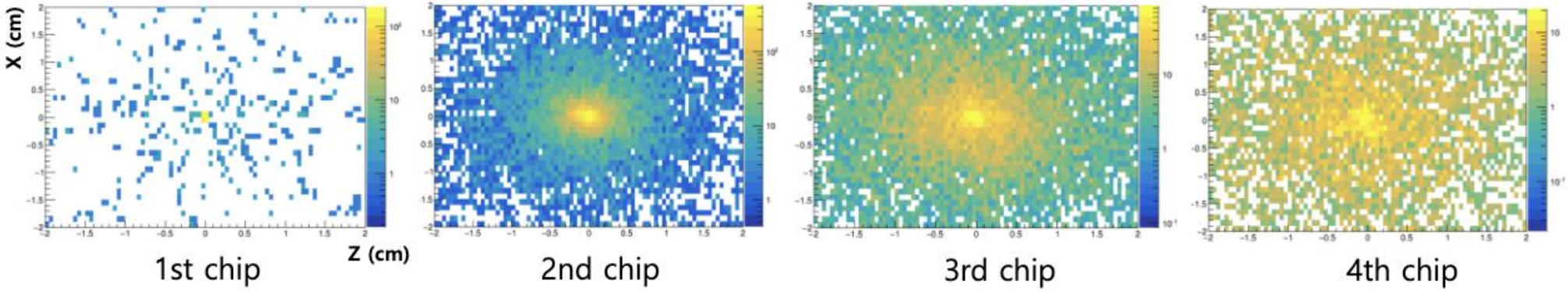
- Using coaxial cable for calorimeter.
- Integrated various detectors
  - Wire Chamber, Trigger: 8ch BNC
  - Hodoscope: 32ch (flat cable), Calorimeter: 56ch (lemo-sma) via same trigger board
  - AstroPix added

Backup: simulation for silicon + Pb/SciFi

- **Energy Deposit for 3x8+6 modules**
  - Hit position (transport, Energy doposit)
  - Particle (e-, photon, e+ .. etc.)

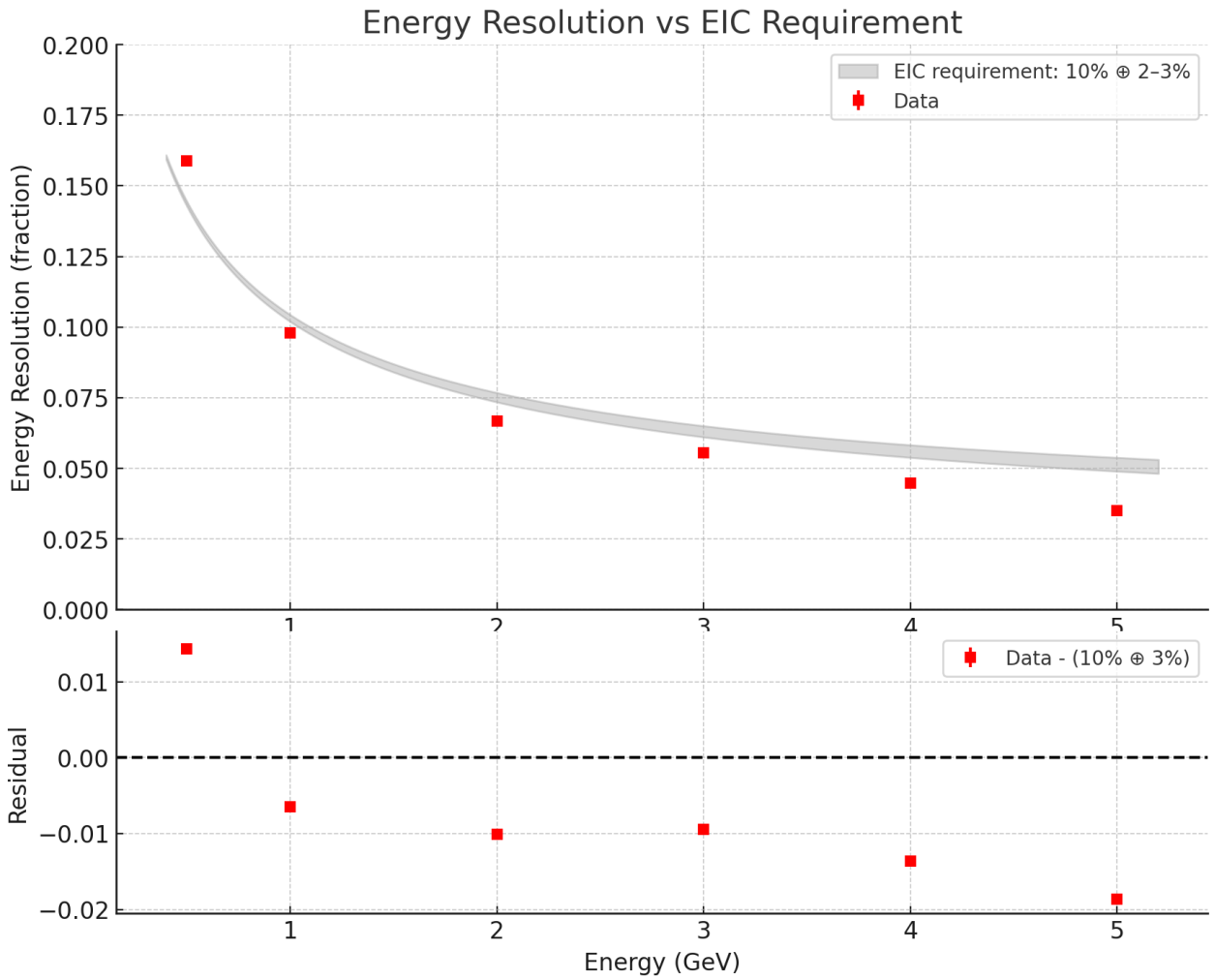


- **Transport position (500 MeV, All particles)**

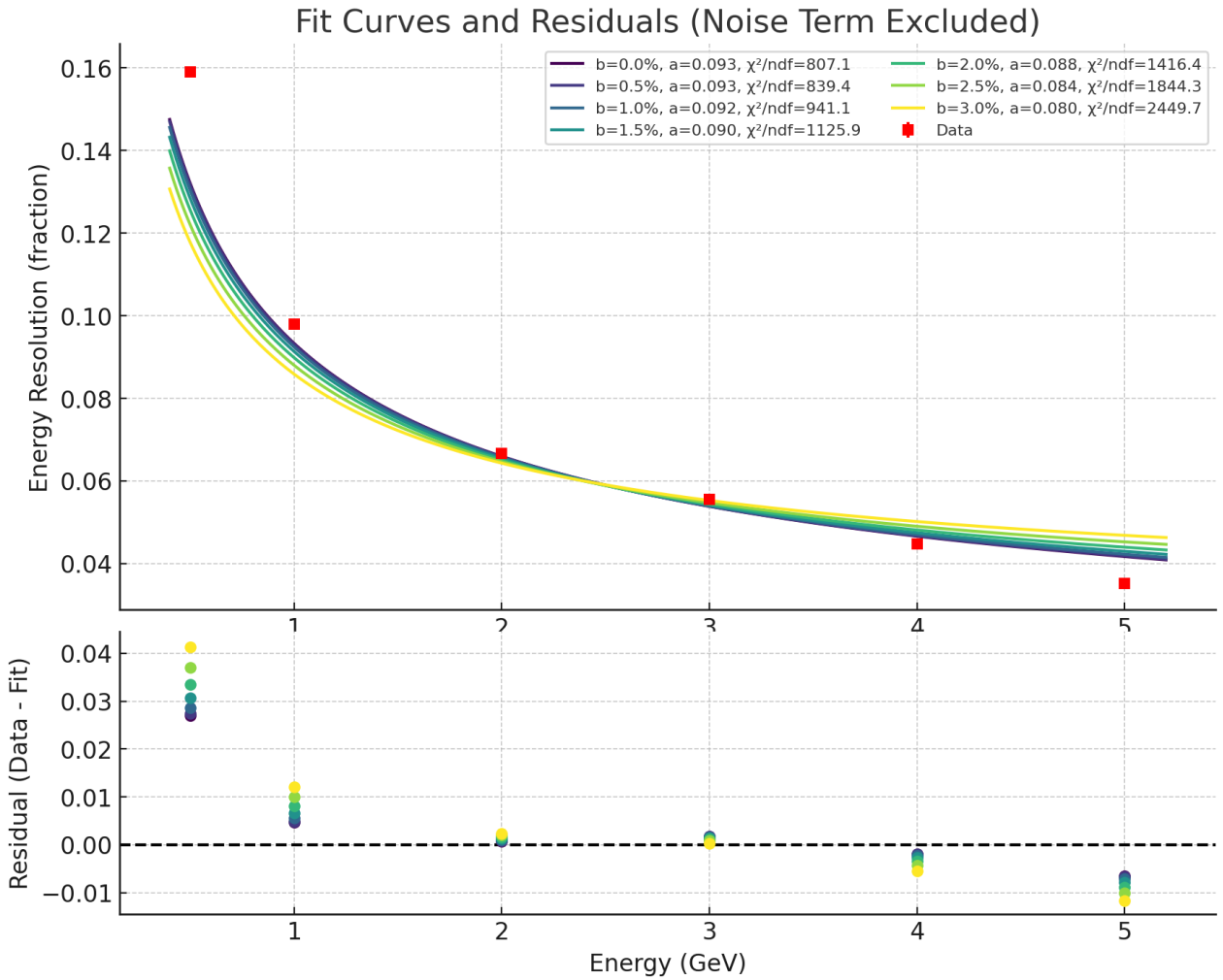


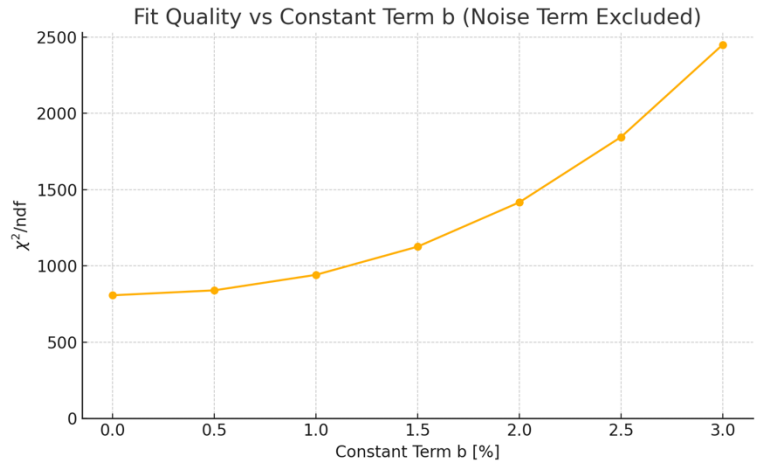
- Hit distribution on 4x4 cm^2 chips for pointlike beam position
- In progress toward July 2025 Testbeam at CERN

Backup: Result with EIC requirement: 10%+2~3%

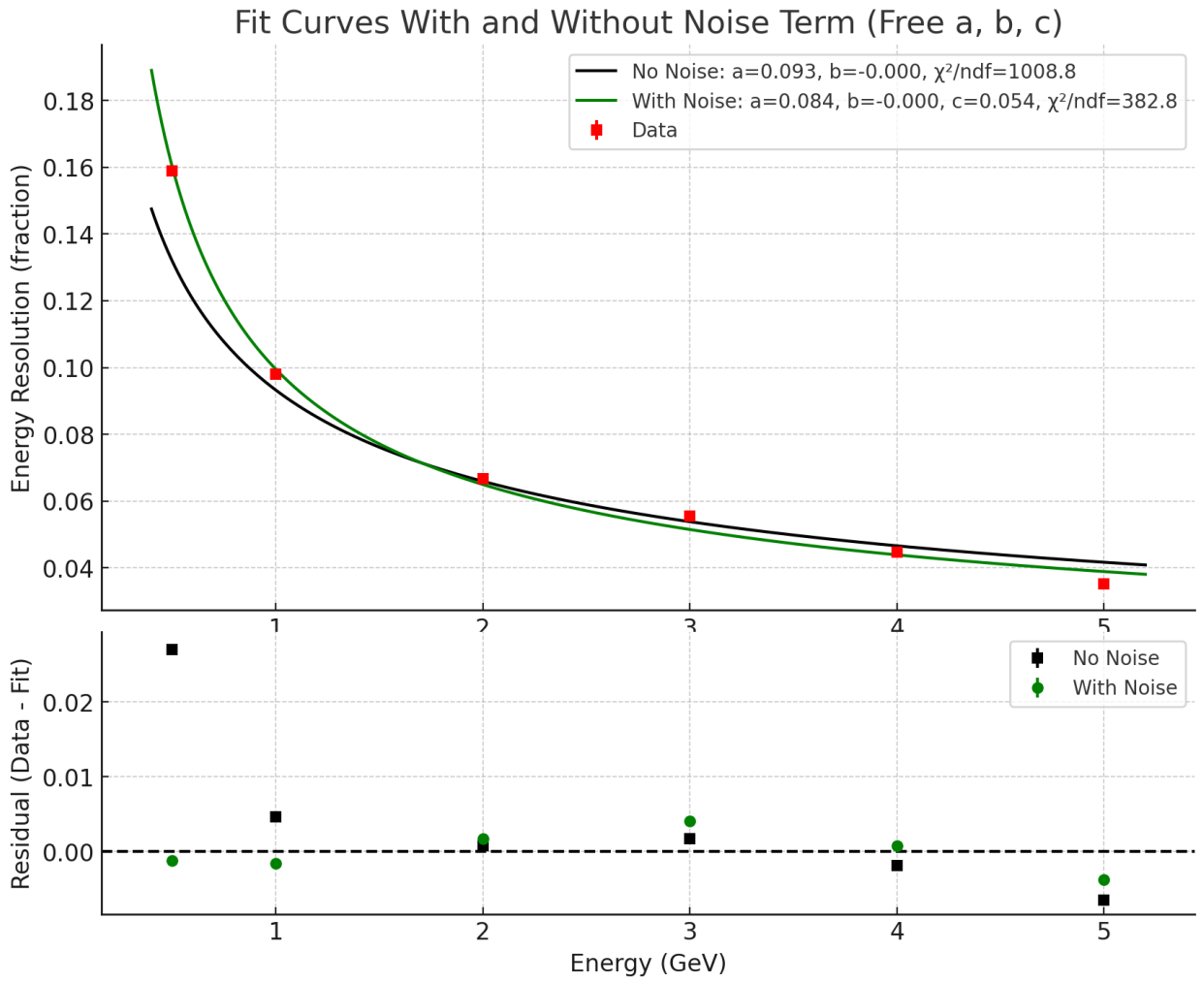


Backup: Fit with fixed constant term





Backup: With noise term



Backup: Constant term