Perspective on BIC Beam Test Priorities

5th BIC In-person Workshop

Session: Beam Test and System Testing Goals and Priorities

June 17th 2026

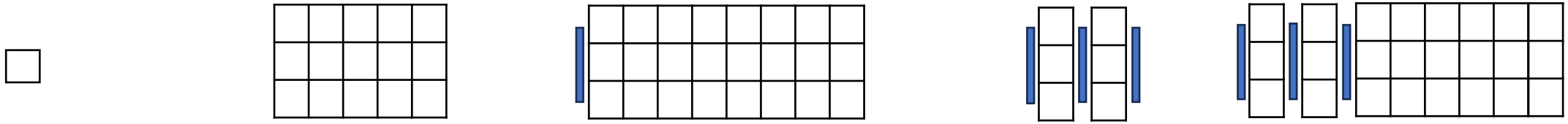
Jeongsu Bok (Pusan National University)

Outline

- Past: Achievements so far
- Future: Future goals and circumstances
- Now: Perspective on BIC Beam Test Priorities

Past: Achievements so far

Beam tests in recent years in Korean group

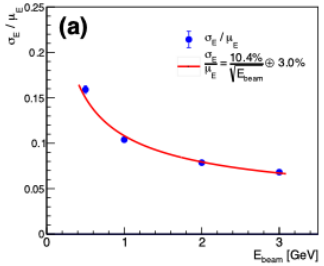


May 2024

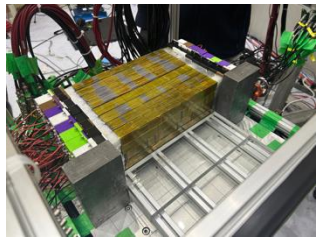
First piece

Aug 2024 CERN PS

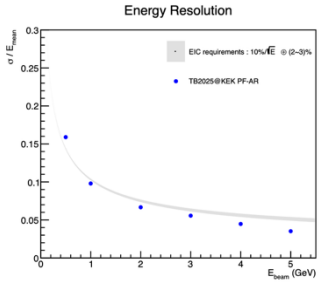
First Pb/SciFi prototype production in Korea
First beam test with ~10.9X_0 depth
Successful data taking



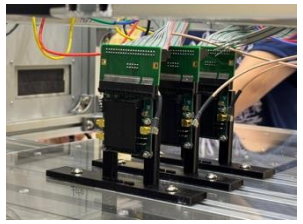
Mar 2025 KEK



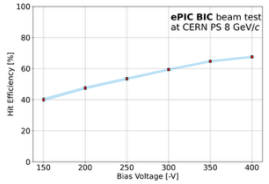
More (~15X_0) Pb/SciFi
Improved energy resolution
New DAQ, Trigger, Hodoscope, Calibration
Extension cable test

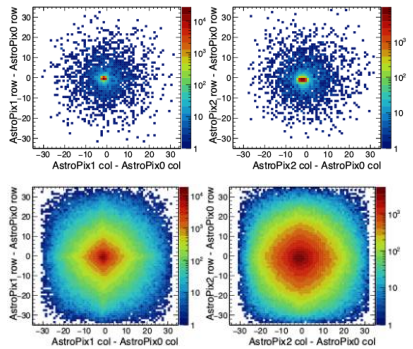


June 2025 KEK



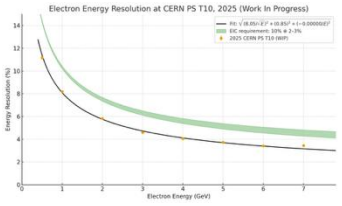
AstroPix synchronization with trigger time

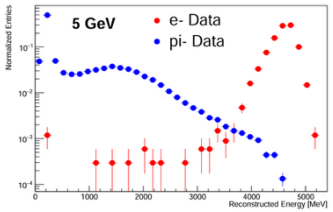




July 2025

synchronized data taking of AstroPix + Pb/SciFi
Proof-of-principle imaging of e/pi
Resolution fulfill the EIC requirement



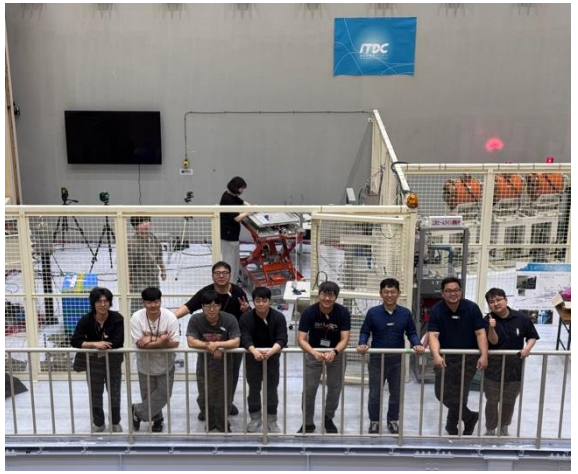


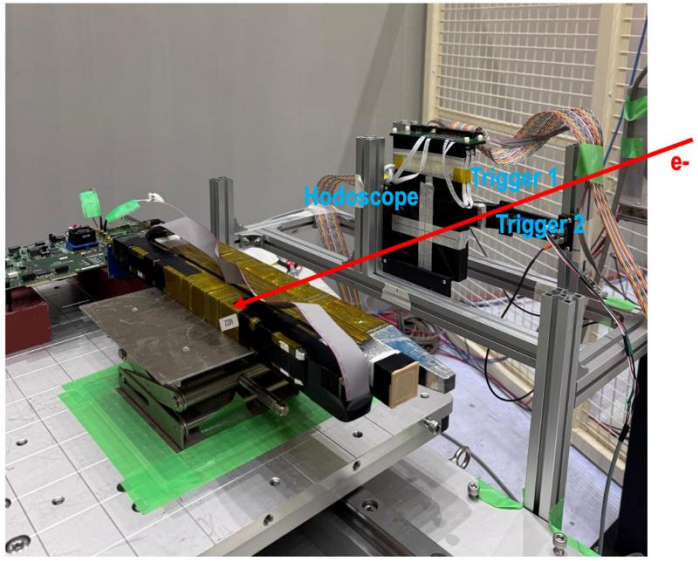
Achievements so far

- Achievements using 32x3x3 unit modules
  - Electron energy resolution fulfill the requirements with 32x9x24cm (~17.3X_0)
  - Timing resolution, Electron calibration
  - Synchronized data taking with AstroPix single chips
  - Electron/pion data taking
  - AstroPix-v3 single chip test: Efficiency using three single chips, e/pi shower between Pb/SciFi
- Limitation
  - Energy range: 0.5~about 7 GeV (baby-bcal 4~10 GeV)
  - Pb/SciFi: Dimension(32cm horizontal length), material composition
  - ESB: PMT instead of SiPM, no light guides
  - DAQ: No H2GCROC. Have been using a local solution.

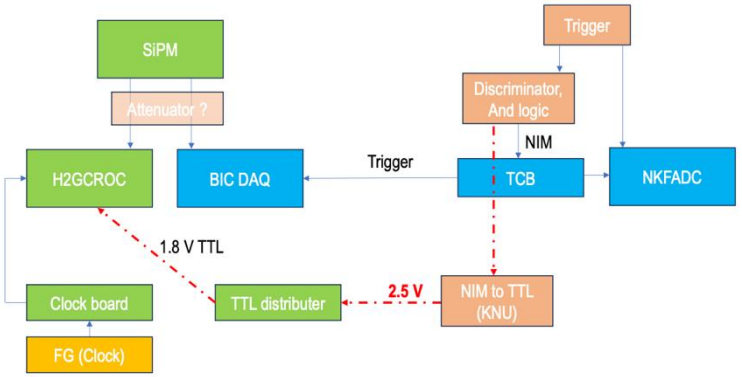
Beam Test at KEK in May 2026

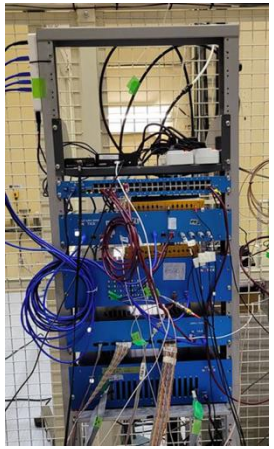
- Data acquisition for H2GCROC
- Data acquisition with analog signals
  - For auxiliary detectors in future beam test including Cherenkov counters at CERN
- Using electron beam at KEK PF-AR Test Beam Line
  - At 1st and 3rd rows in 1-5 GeV; dynamic ranges for the future beam test
- Test parameter settings under electron beam condition
  - Individual, summing board test
  - Cross check with Flash ADC which has been used in past beam tests
- Light Guide test
- AstroPix 9-chip standalone test

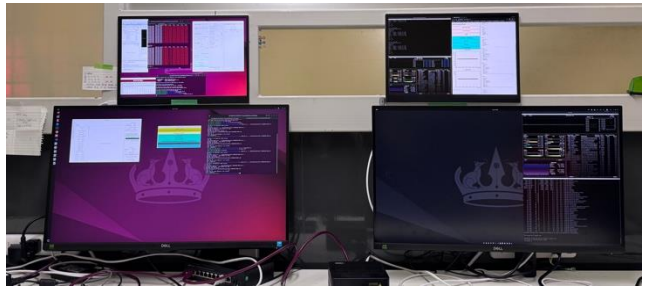




Beam Test Details

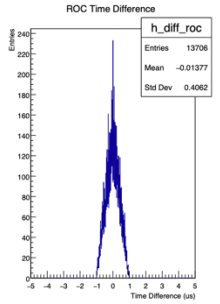




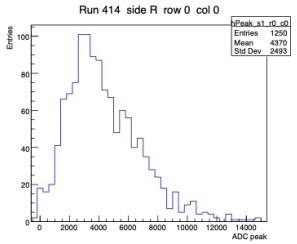


H2GCROC data taking with RCDAQ

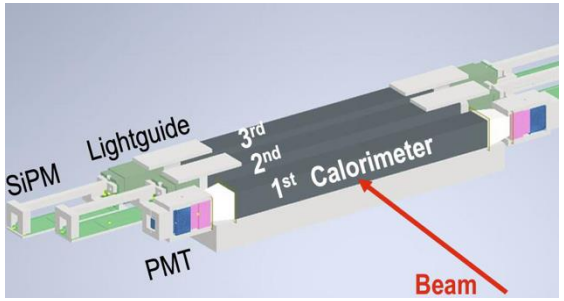
Integrated data acquisition of auxiliary detectors (Trigger, Hodoscope, Drift chamber)



Timestamp matching < μs



Crosscheck using FADC



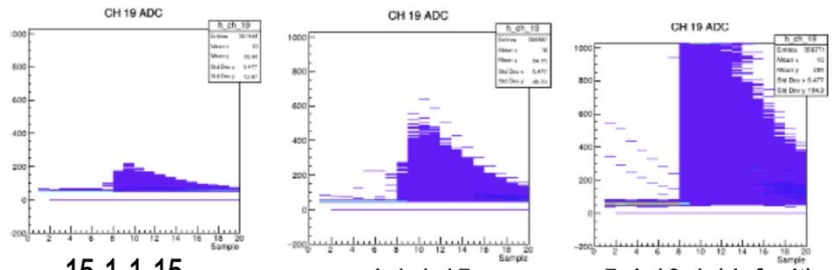
	MPV Npe per SiPM (9 cm²)		
e- (GeV)	1st	2nd	3rd
0.5	600	1100	700
1	700	1800	1500
2	1000	2800	3000
3	1100	3800	4500
4	1150	4500	6000
5	1300	5500	7500

Checked signal for ranges at 1st and 3rd Pb/SciFi layers for 1-5 GeV electrons

Summing board was tested

SiPM bias voltage controlled using an external module

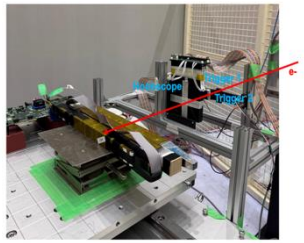
Hybrid, 1st, 3GeV



Future: Future goals and circumstances

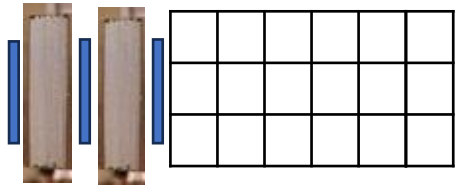
Future Tasks in beam test

May 2026 KEK



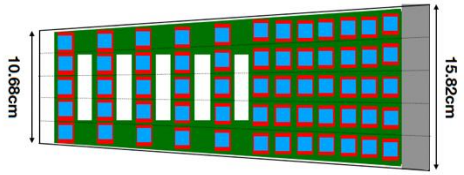
SiPM+LG
H2GCROC data taking
AstroPix 9-chip standalone

Aug 2026 CERN PS

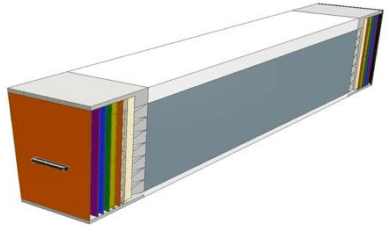


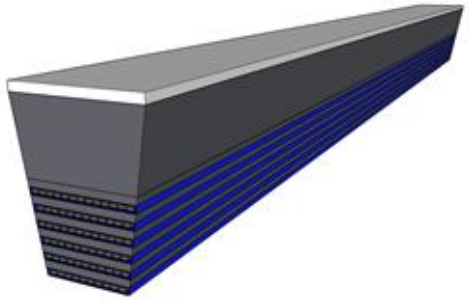
70cm SFIL, AstroPix 9-chip module, H2GCROC

2026-2027



70cm and longer test article corresponding to a sector





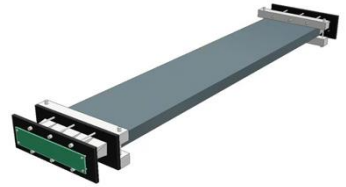
Full sector

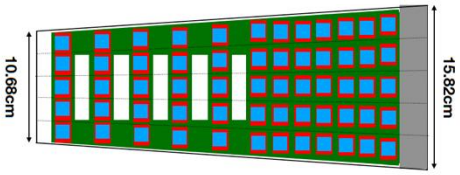
Future tasks of beam test

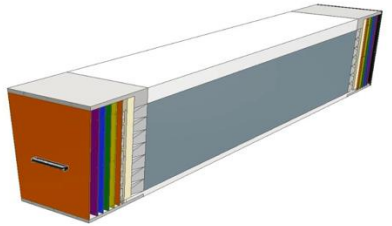
Data taking with H2GCROC.
Long test article production and ESB test
Performance of imaging layers. (More coverage, new AstroPix …)

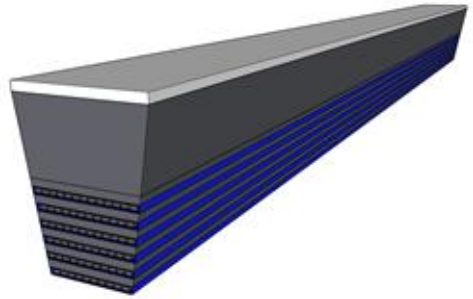
Beam opportunities in near future

- CERN PS T09 beam test Aug 24-31 2026
  - Electron/pion mixed beam up to 15 GeV
    - At T10, pid using Cherenkov was not effective above ~7GeV
- KEK PF-AR test beam line
  - 0.5~5.8 GeV electrons
  - Oct-Dec, Feb-Mar, May-June
- Plan after the beam test at CERN (Korean)
  - Build a 70cm-long test article corresponding to a sector with 5 SFILs + bulk using single-clad fiber
    - Fibers, SiPM, LG are ready.
  - Larger test article
  - Integrate details (e.g. readout box option toward final ESB) with BIC group
  - Prepare beam tests at KEK when we get ready.
    - e.g. If AstroPix v5 comes in October, we can try next May-June.



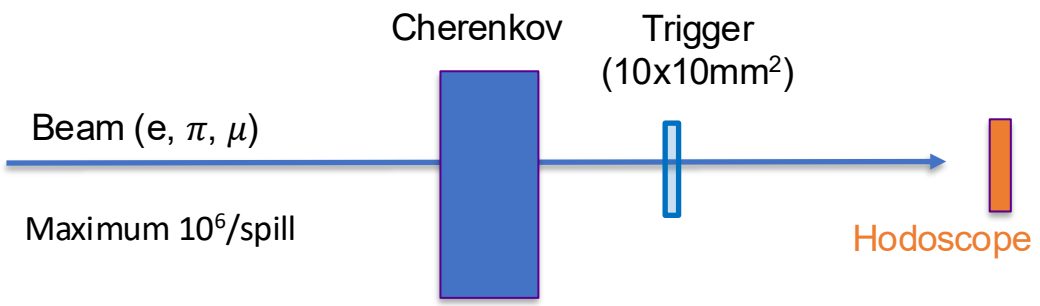




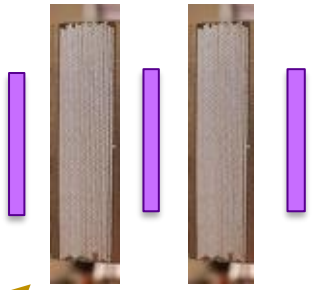


Now: Perspective on BIC Beam Test Priorities

CERN Beam test: detector setup



Possible AstroPix ?

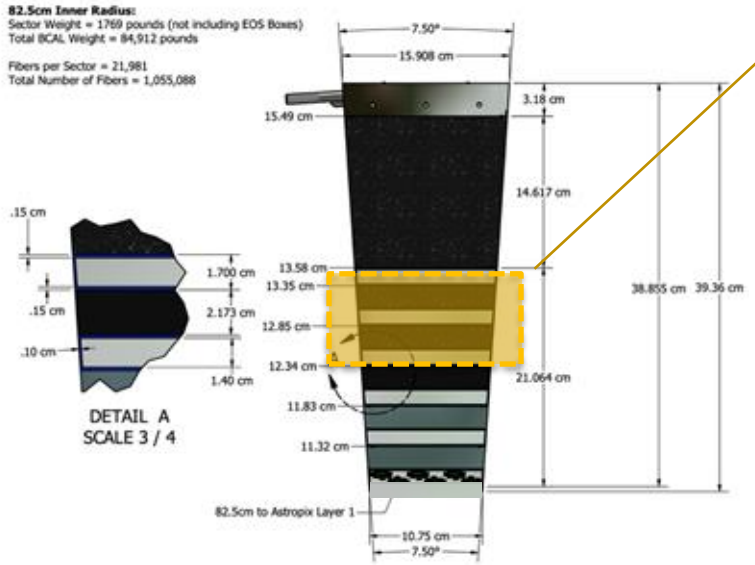


70cm SFILs

Bulk sector using
32x3x3 cm³ modules
~32x9x15 cm³

AstroPix quad chip modules

50cm-long SFIL at ANL



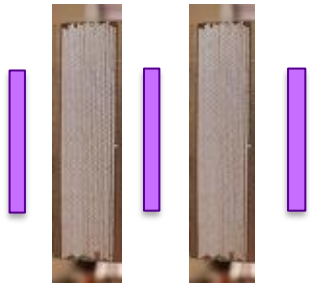
BIC sector dimension

- Conservative plan for Pb/SciFi production in Korea for CERN TB
  - 32x9x15cm³ bulk region (~10.9X_0)
  - 2 SFILS (~3.0X_0)
  - Decision for possible option for more SFILs or bulk will be made on Friday (order schedule related)

Possible goals with this setup

- Ideal scientific goals
  - Energy/Timing resolution of near-full-sector geometry.
  - 3D shower imaging validation and e/pi separation using both AstroPix and Pb/SciFi
- Possible goal:
  - Energy/time/position resolution with H2GCROC
  - **Response and Npe for single-clad SFIL (requires simulation)**
- Technical goals considering situation
  - H2GCROC data taking
    - Performance comparison with FADC
    - Integrated data taking with other detectors (Cherenkov, Hodoscope, …)
    - Measurements for wide dynamic range (electrons, pions, muons)
  - Electron/pion data taking and calibration
  - More tests with SFILs
    - Align the beam with an angle for SFILs
    - Beam position scan: time and position resolution

AstroPix case



- AstroPix cases
  - IF one or more 9-chip(quad) chip modules are provided, we will try
    - Integrated data taking (but requires preparation) with AstroPix
    - e/pi shower measurement with large acceptance
    - One module case: move location from front → behind 1-SFIL→ 2-SFILs
      - In order to observe e/pi shower shape, we may use very small trigger, or hodoscope
      - We need to calculate the limit for data acquisition limit and reduce beam rate to take data behind SFIL.
    - Pixel calibration data. (but it is repetition)
  - If we focus on JLab: So far, we have done things we could do with three v3 single chips.
    - We don't think testing single chip modules is worthy this time.
- It is almost last chance for e/pi mixed beam before production. However, is there something to achieve this time, considering preparation?

Lets go for it!

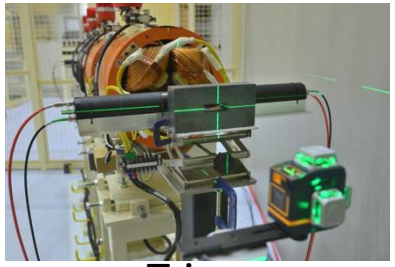
Backup: KEK PF-AR Test Beam Line

Counting Room

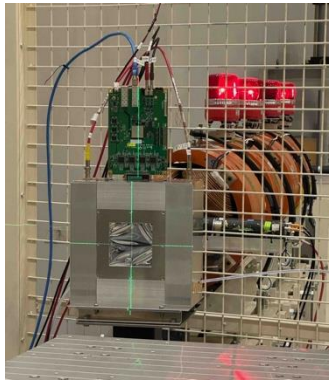
Extract electron from Photon Factory
Momentum up to 5.8 GeV/c

Beam Shutter

Sensor stage

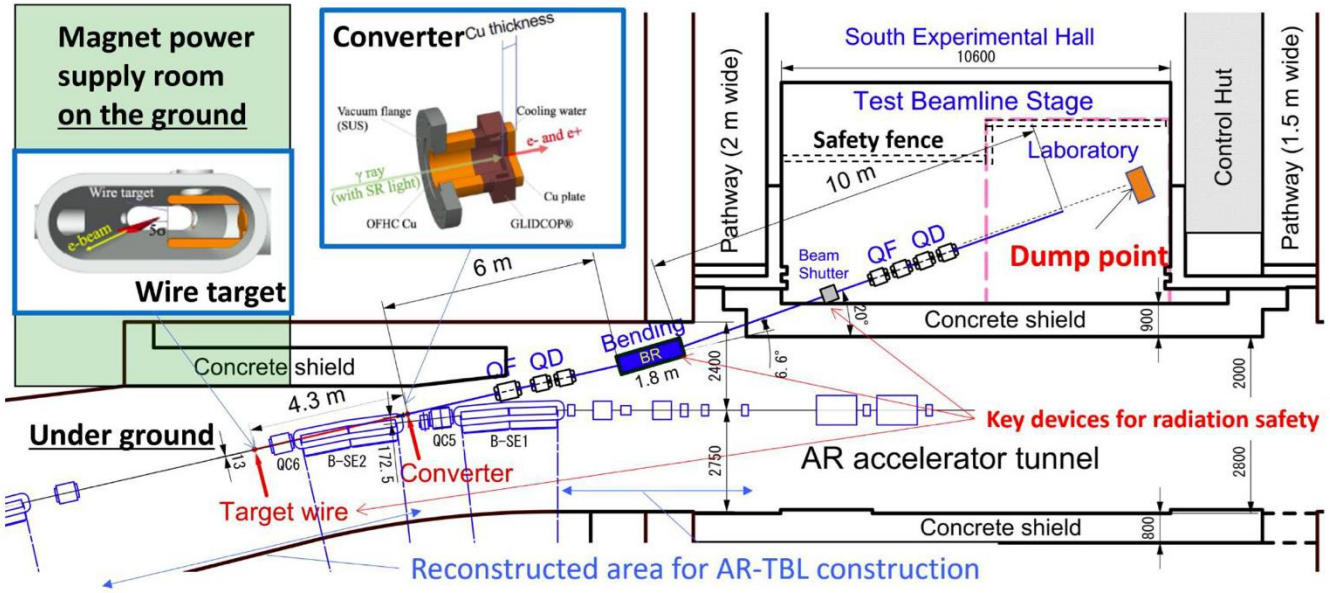


Trigger



Drift Chamber
(upstream, downstream)

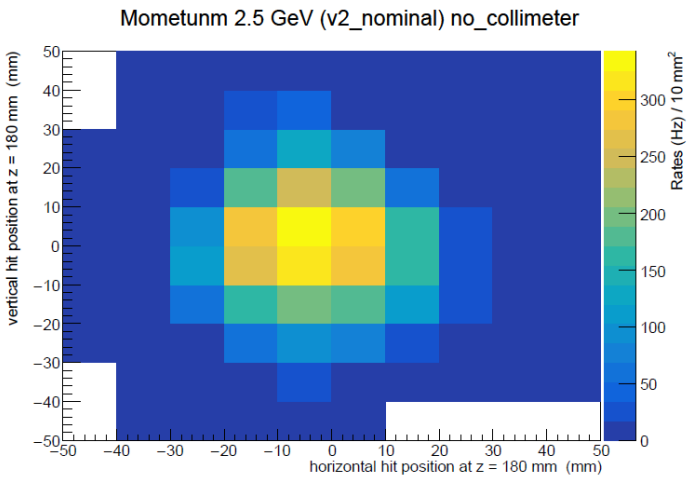
Backup: KEK PF-AR Test Beam Line



PF-AR electron beam line single bunch, rev. 795 kHz	
Beam energy	< 5.8 GeV/c
Δp/p	~ 8 %
Beam rate@ 2.5 GeV/c	
20 mm x 30 mm	7 kHz
10 mm x 10 mm	~350 Hz
5 mm x 5 mm	~100 Hz

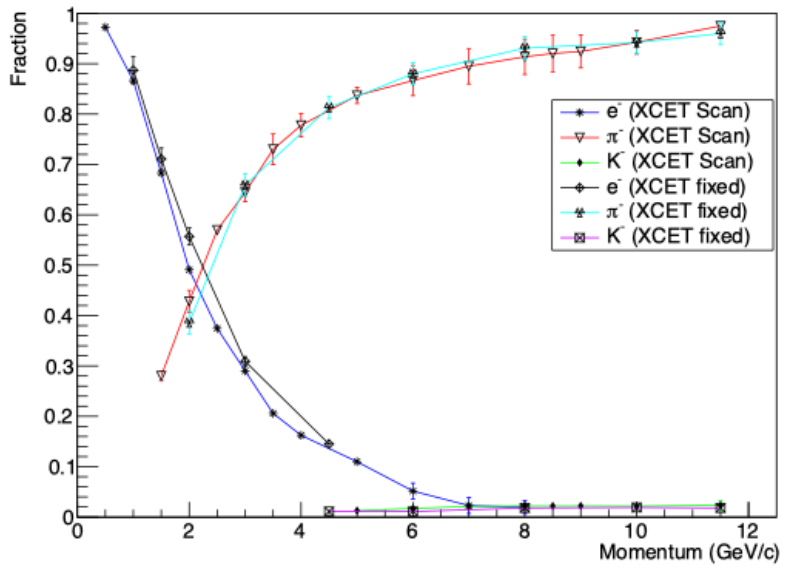
Photon emission by wire target (Graphene, two wires system)
Inject photon to a converter (16 mm Cupper plate) to make pair creation.
Transfer electron with Di-pole and Quadra-pole magnets to the test stage.

Link



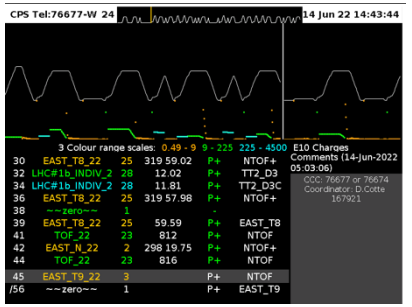
CERN PS: Beam Characteristics

Parameter	T09 Target	T10/T11 Target	
Beam Line	T09	T10	T11
Secondary beam Max Momentum (GeV/c)	15	11.5	3.5
Δp/p (%)	±0.7 to ± 15.0	±0.7 to ± 15.0	±0.7 to ± 15.0
Maximum intensity/spill (hadrons/electrons)	~10^6	~10^6	~10^6
Available particle types	Pure electrons (T09) or mixed/pure hadrons or pure muons		

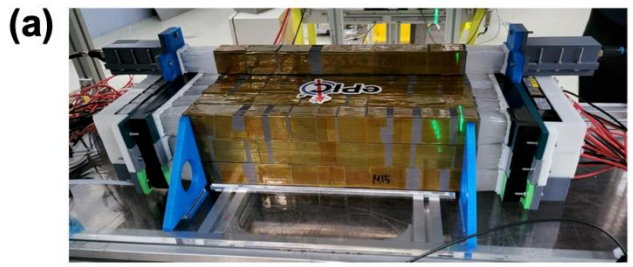


T10 (neg) beam composition (arXiv: 2507.02567)

Mixture of electron,pion, etc. fraction changes in momentum
Muon beam available.
Particle identification with two Cherenkov Counters
Expert can adjust focus and rate.
At T10 in July 2025, trigger(10x10mm) rate was 2.7kHz for BIC beamtest.
Spill duration: 0.4 second flat top. Usually, 1-2 cycles per minute per destination



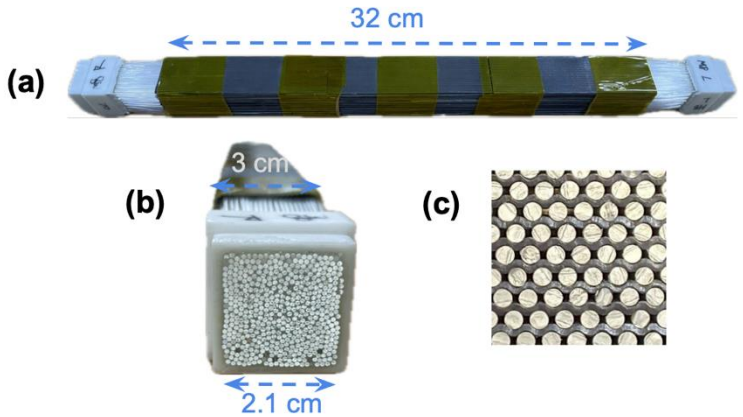
First beam test at CERN PS T10 in Aug 2024



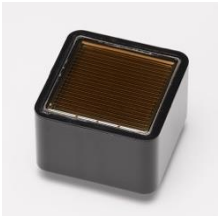
(c)

				M16
M5	M4	M3	M2	M1
M10	M9	M8	M7	M6
M15	M14	M13	M12	M11

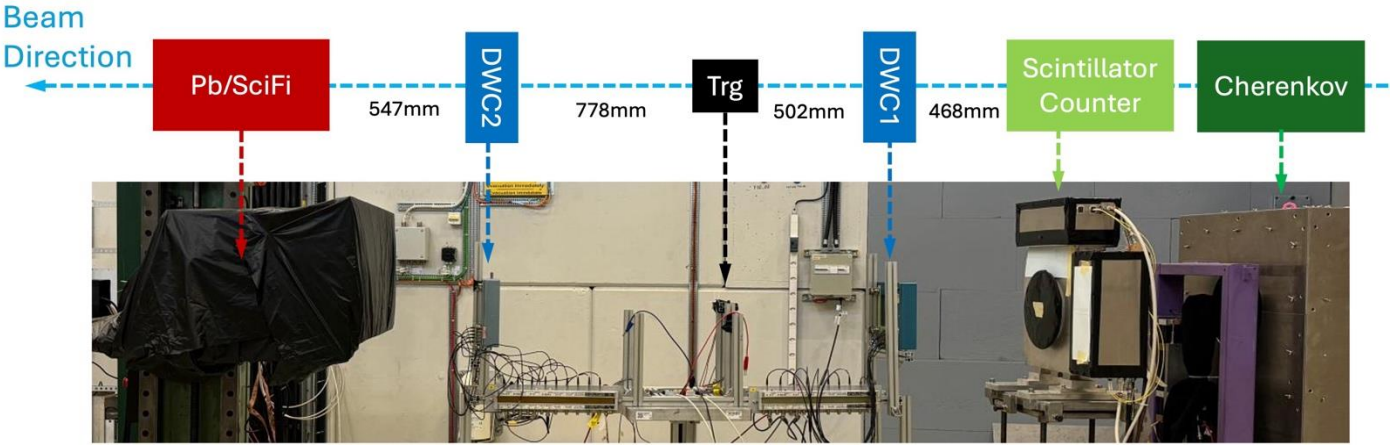
Beam



A Pb/SciFi prototype which is not identical to the final design



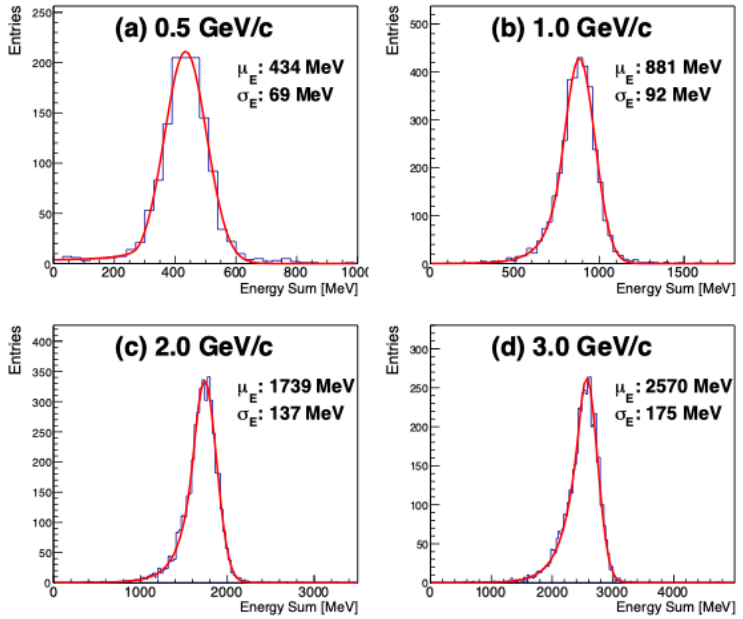
Glass PMT
Hamamatsu
R11265U-100



Achievement

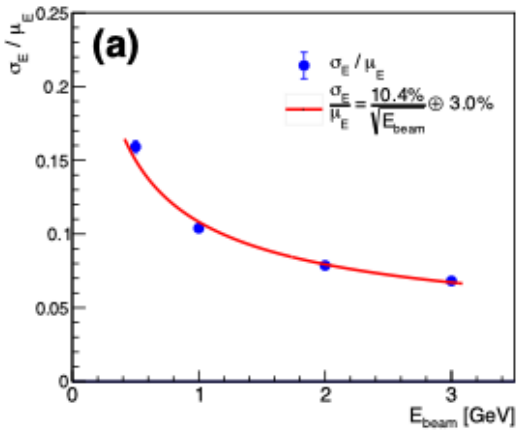
Successfully collected data from the Pb/SciFi calorimeter prototype (32x9x15 cm^3) produced in Korea using 0.5,1,2,3 GeV electron beams

Results at CERN PS in Aug 2024

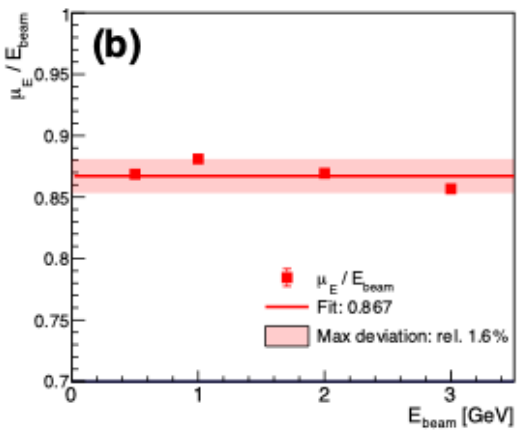


arXiv:2604.22647

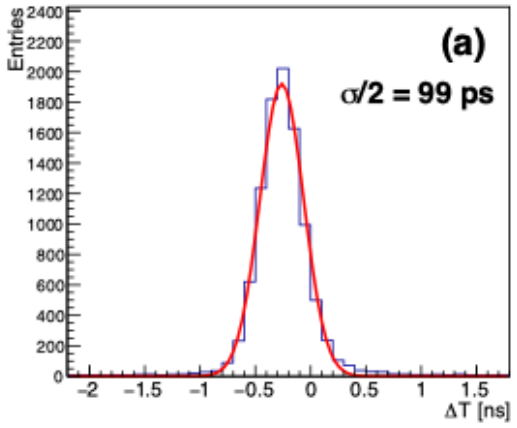
Response of 32x9x15 cm^3 (~$10.9X_0$) using 0.5,1,2,3 GeV electrons
Electron calibration was used.

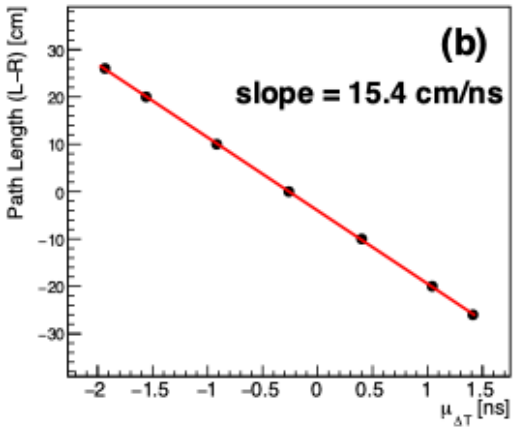


Energy resolution



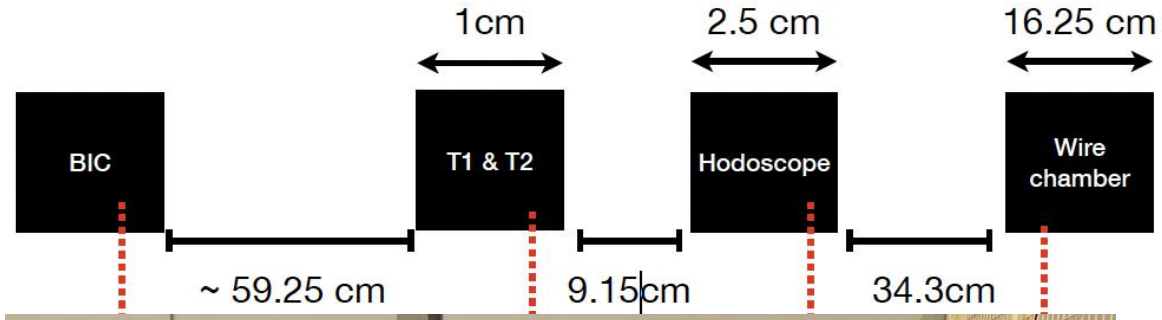
Ratio of the measured energy to the beam energy

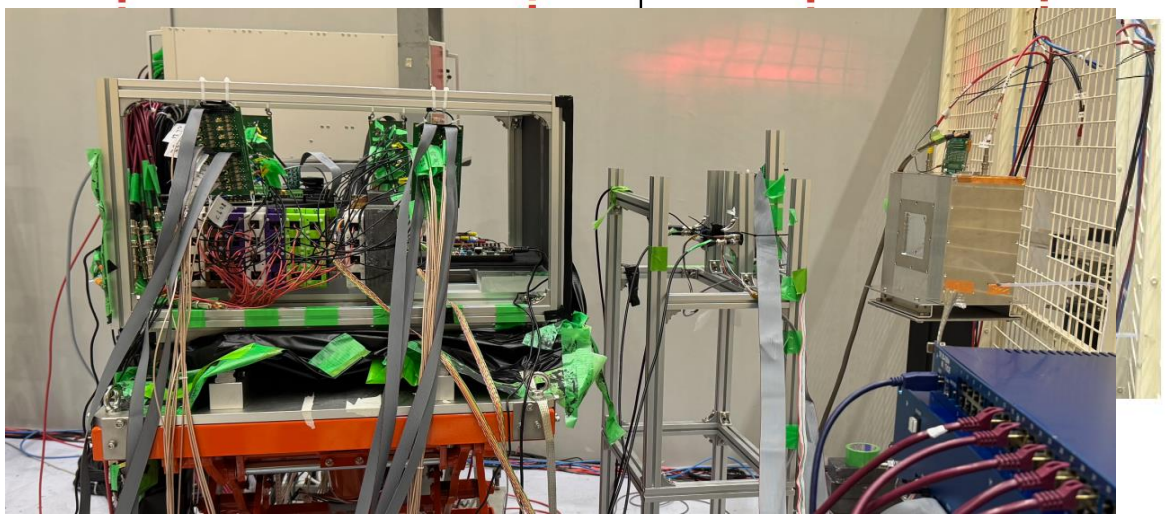


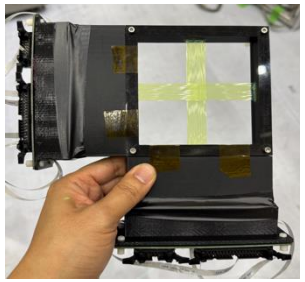


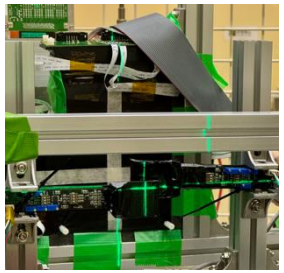
Timing resolution ΔT/2 from left & right side readout.
Effective propagation speed from horizontal position scan

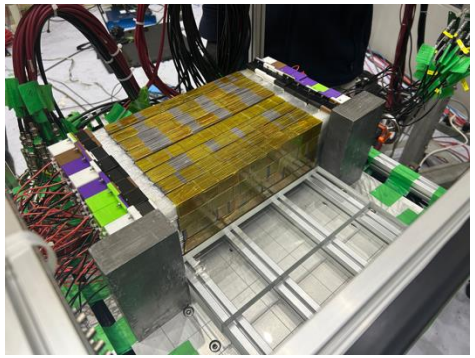
Second beam test at KEK PF-AR in Mar 2025





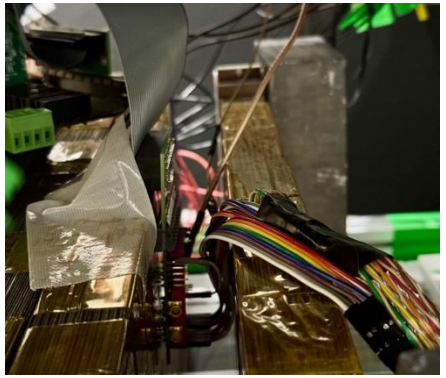


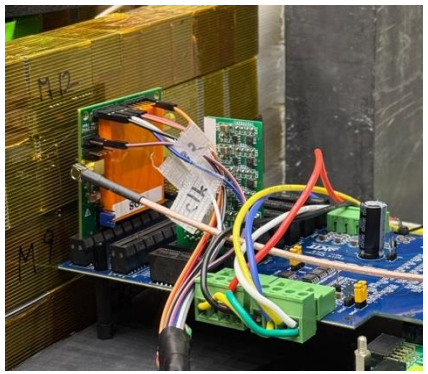


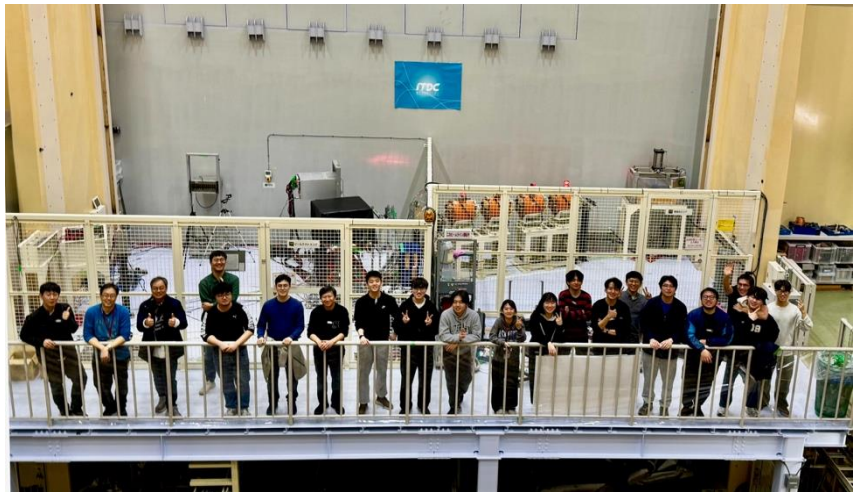


Achievement

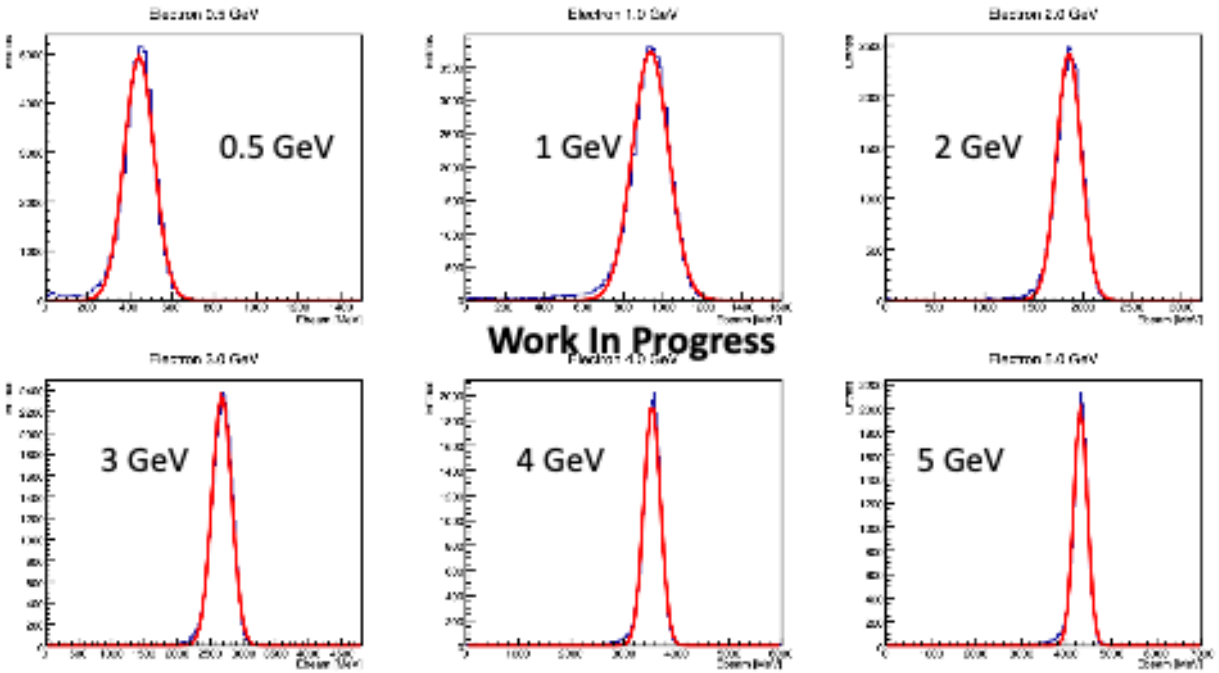
- Bigger, Deeper Pb/SciFi setup: 32x12x21cm^3 ~15X_0
- Refine calibration procedure
- Stable operation with new DAQ
- Operation of auxiliary detectors: Hodoscope, Trigger
- Test of extension cable for test between calorimeter.



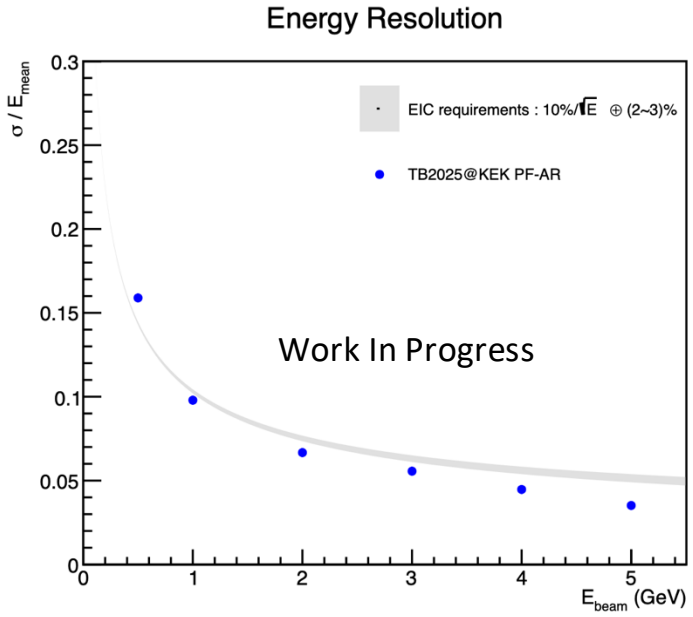




Results at KEK in March 2025

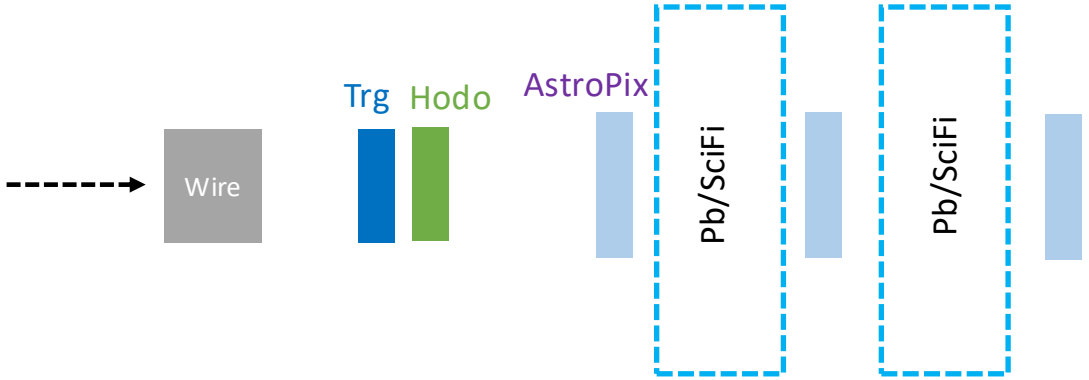


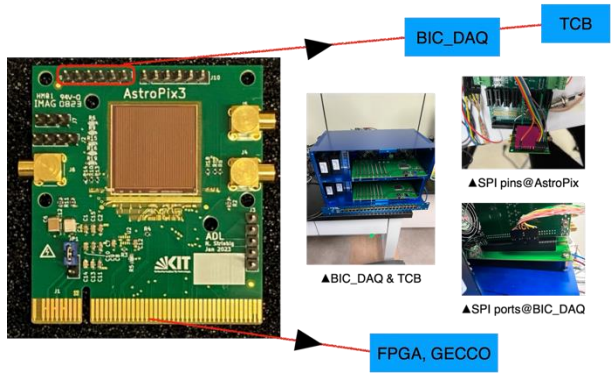
Response for 0.5-5 GeV electron beams

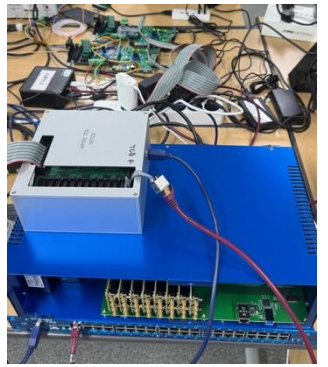


Energy resolution

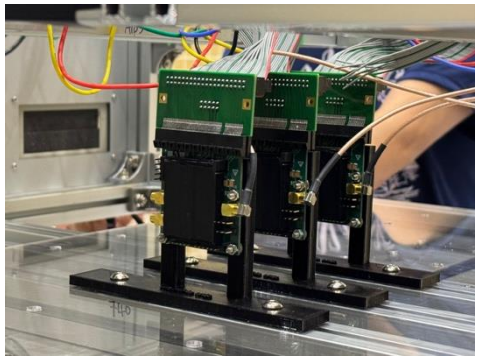
Third beam test at KEK PF-AR in June 2025

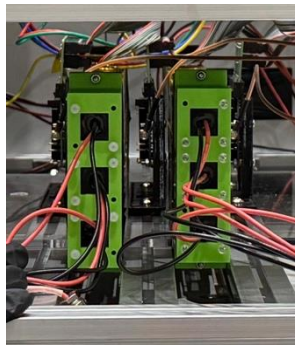




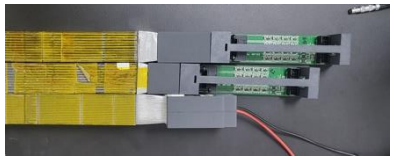


3 AstroPix Layers to be synchronized





3 AstroPix Layers between Pb/SciFi



S13,S14 SiPM with LG

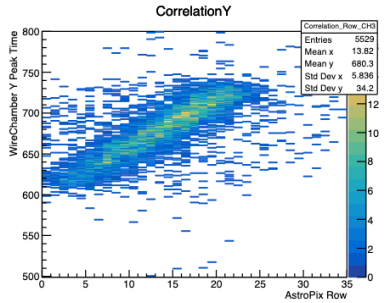
Hit distribution from electron beam in GEANT4 simulation

Achievement

Synchronization between AstroPix's and other detectors in the DAQ made in Korea

Preparation of shower profile study.

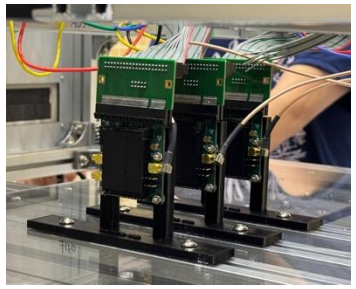
SiPM and Light Guide test



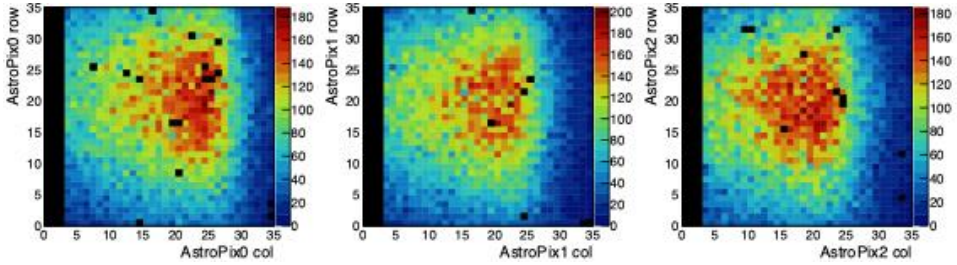
correlation of beam position at AstroPix and drift time at Wire Chamber

Results at KEK in June 2025

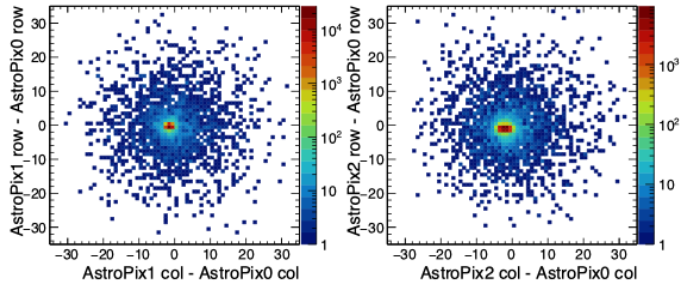
AstroPix only



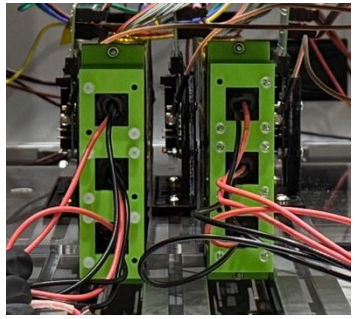
Hitmap for 4.5 GeV electrons.

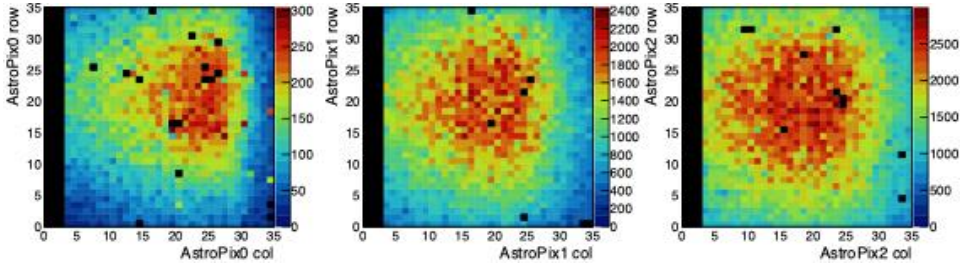


Position corrected to the upstream AstroPix

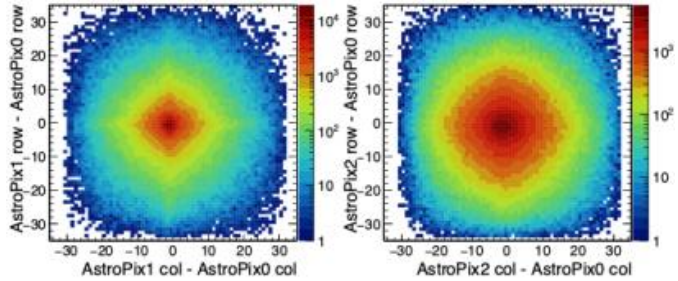


AstroPix interleaved with Pb/SciFi

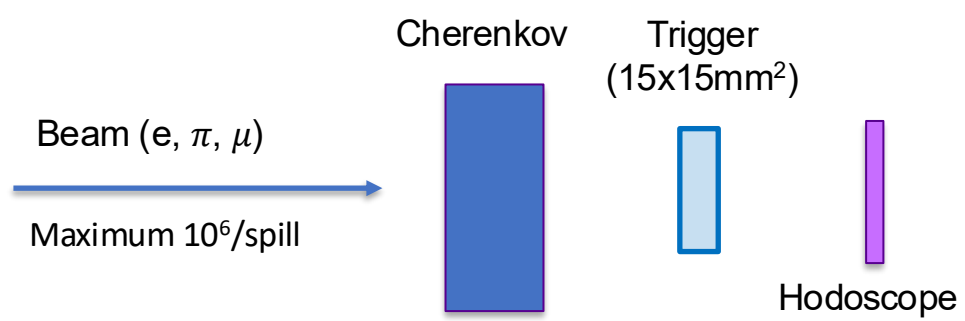


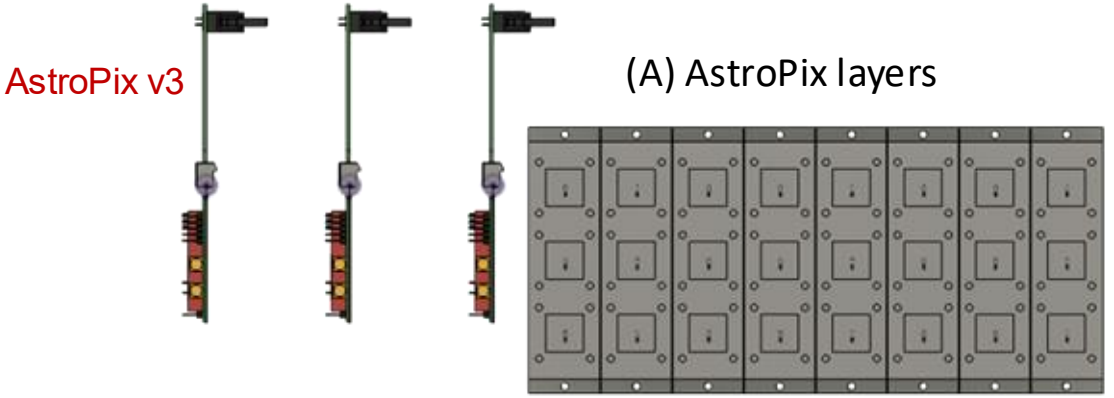


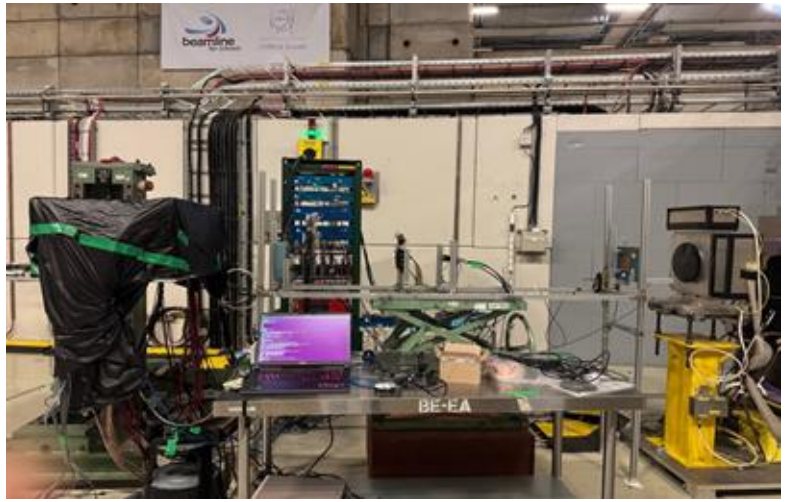
2nd Layer 3rd Layer



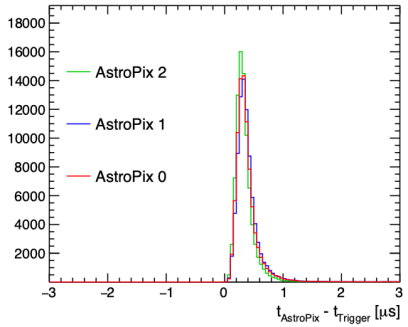
4th beam test at CERN PS T10 in July 2025

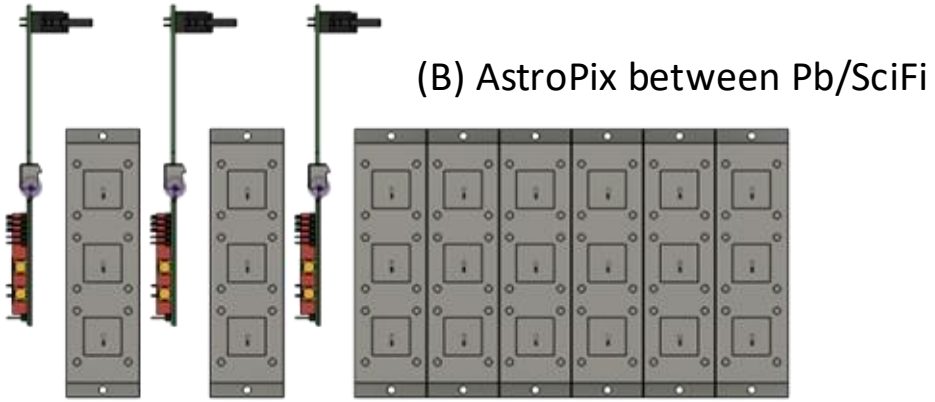






Time between AstroPix and Trigger

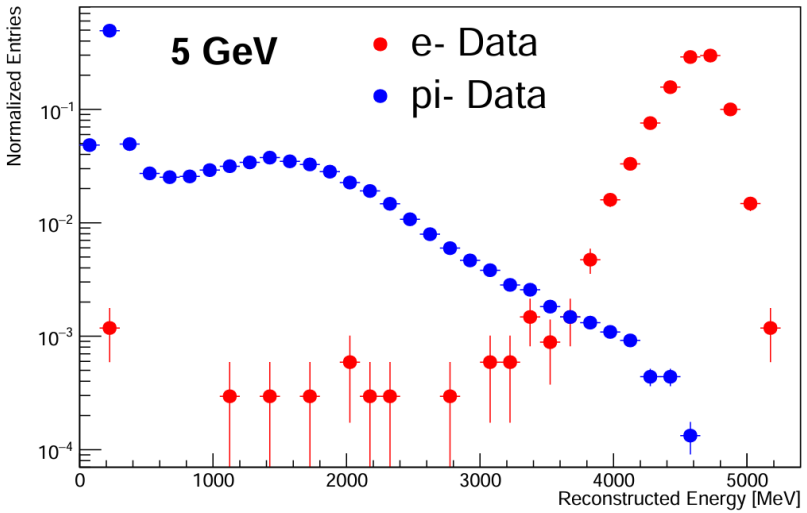




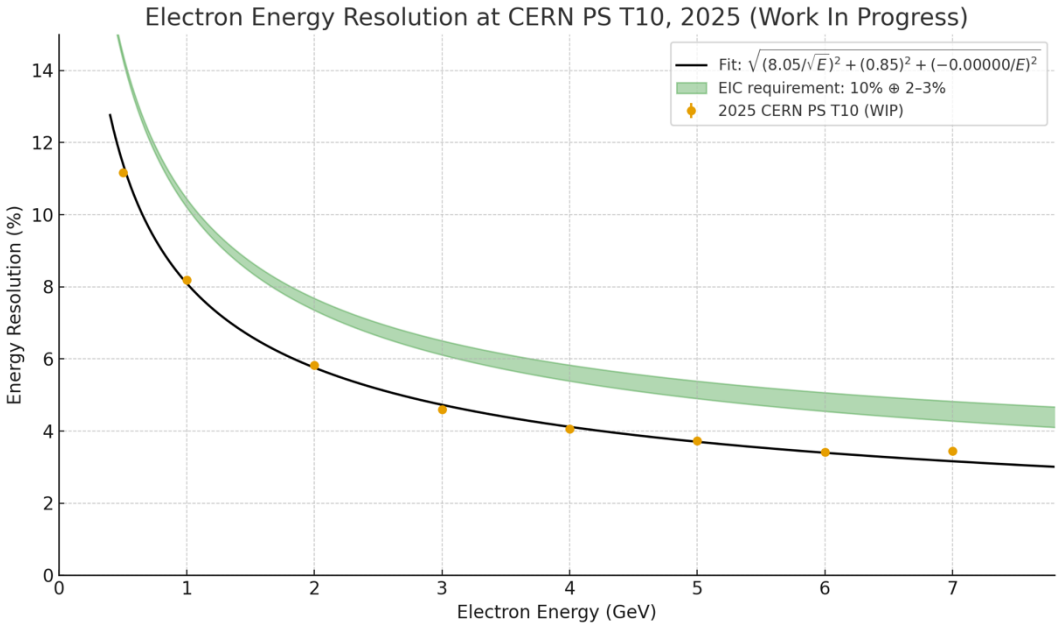
Goal: Proof-of-principle imaging of electrons and pions using synchronized setup of AstroPix in beam environment using synchronized data taking between AstroPix's and Pb/SciFi

Results: Electron energy resolution for Pb/SciFi

Electron/pion response

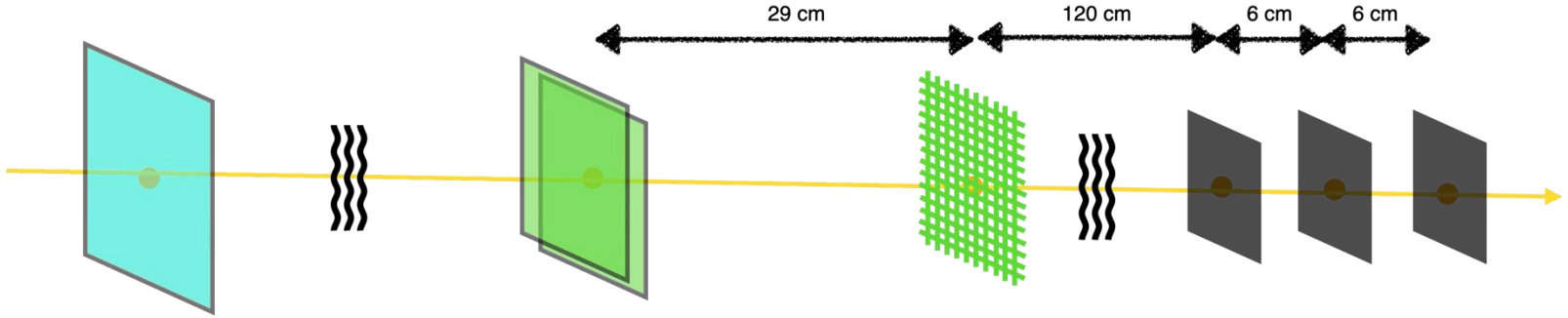


Electron energy resolution (work in progress)



All datapoints are below 10%⊕2-3%

Setup for AstroPix at CERN PS T10 in July 2025

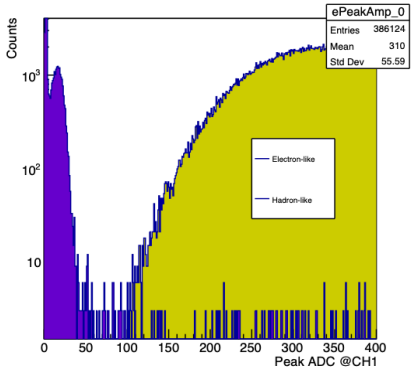


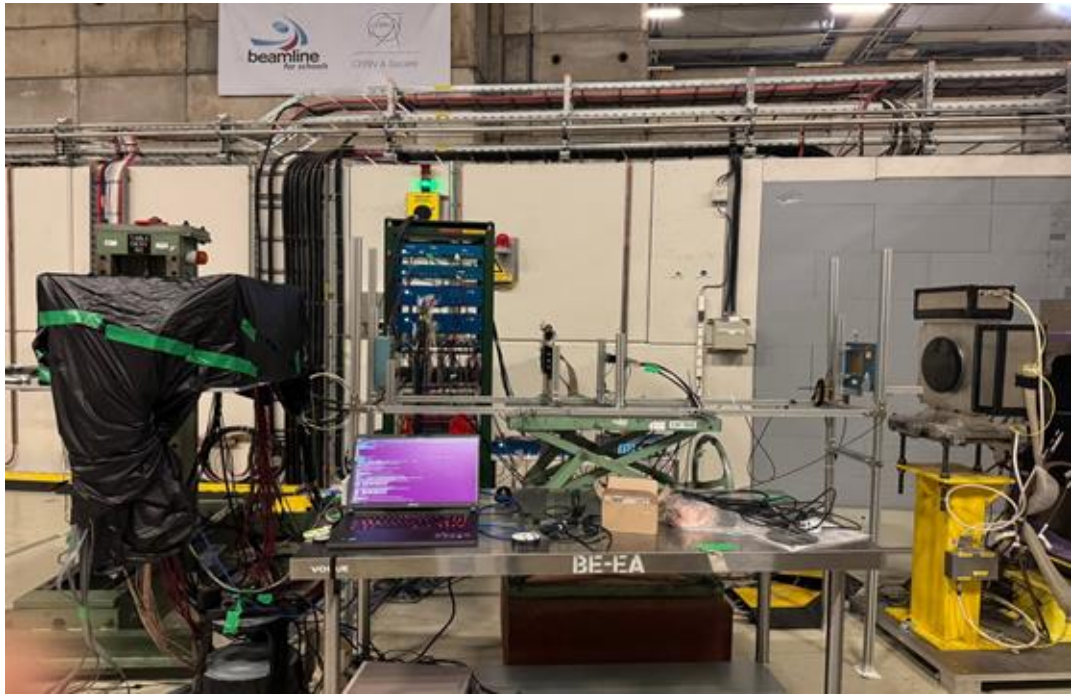
Cherenkov detector :C1, C2

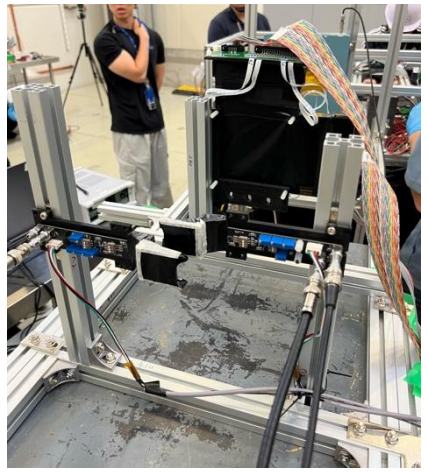
Scintillator Trigger :T1 ,T2

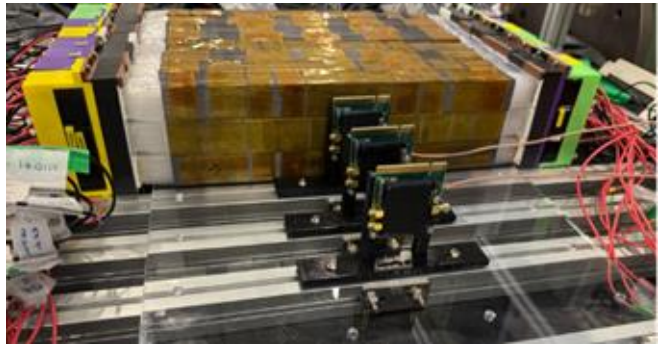
Hodoscope

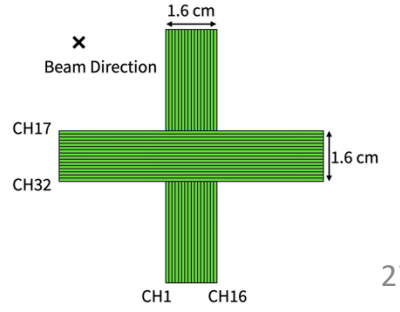
AstroPix3s (& BIC prototype)



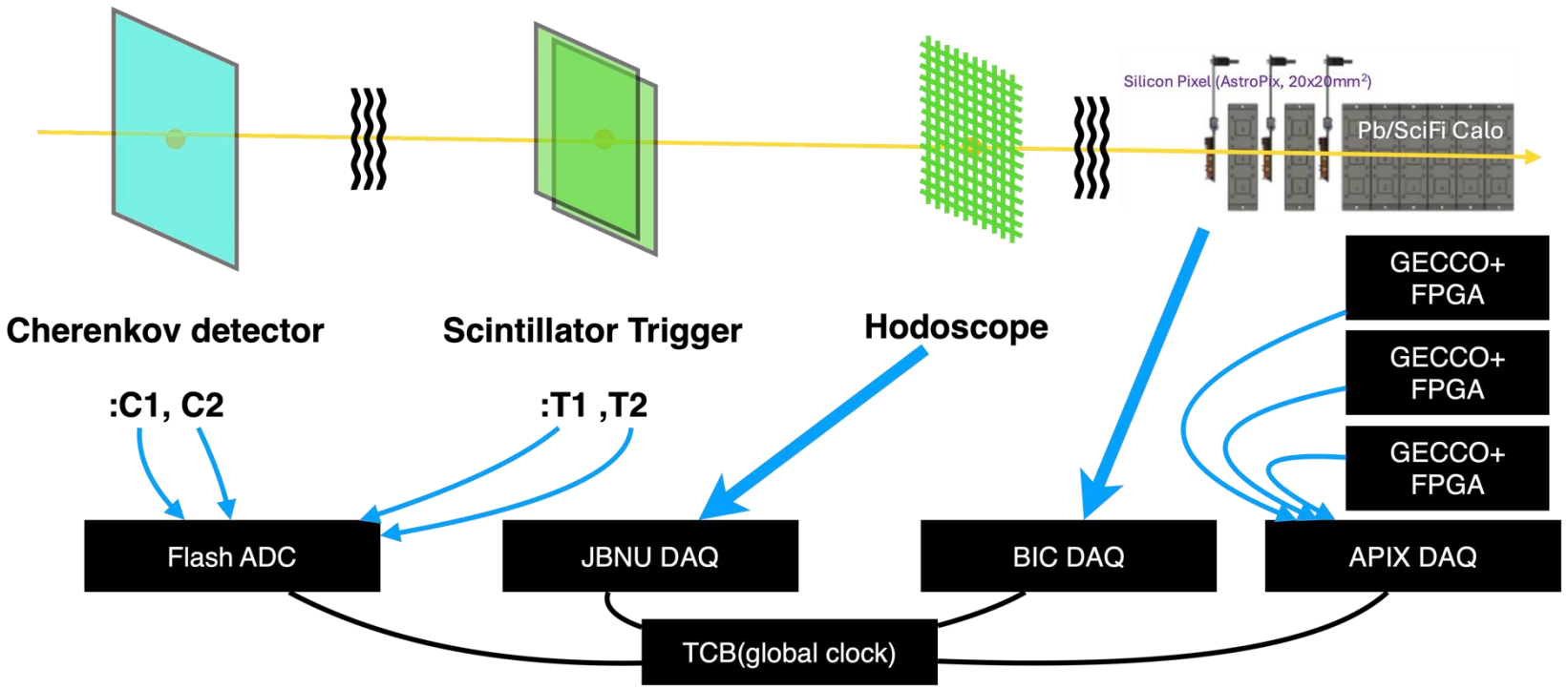


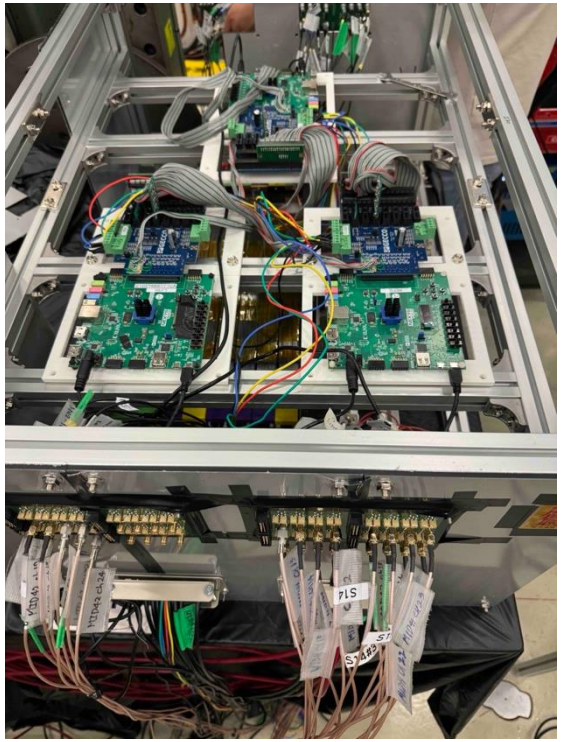




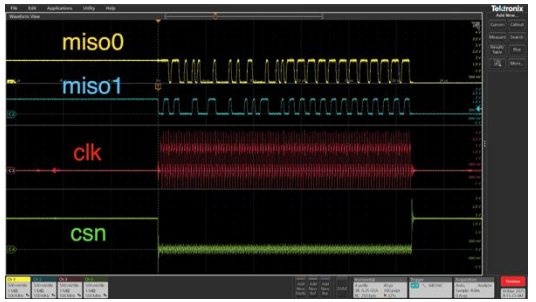


DAQ integration in July 2025



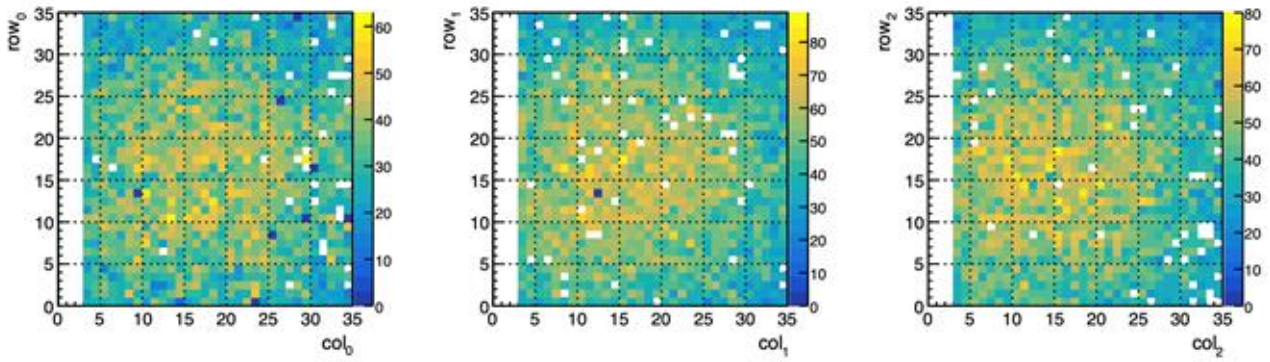


Lab setup for AstroPix readout does not require external trigger.
TCB provides the global clock for the multiple DAQ machines
Trigger signal initiates for three DAQs to record their analog signals & clock.
Custom DAQ device to collect data from AstroPixs with their external timestamp

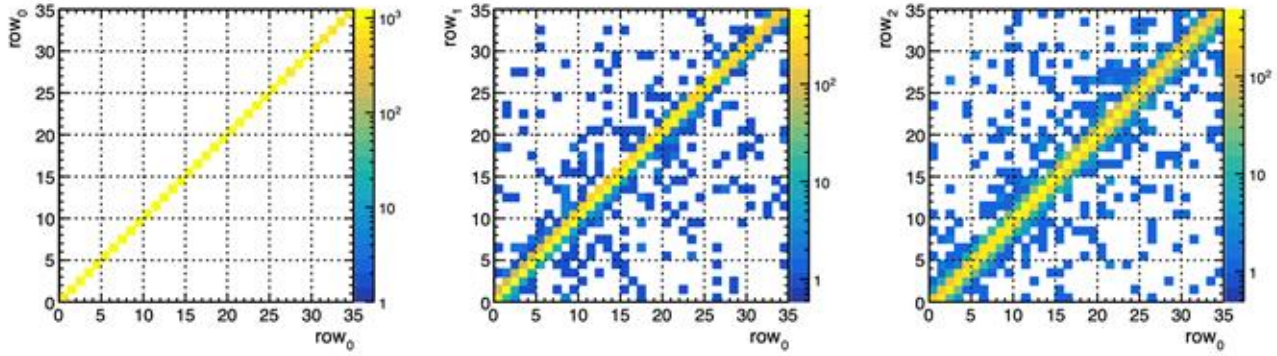


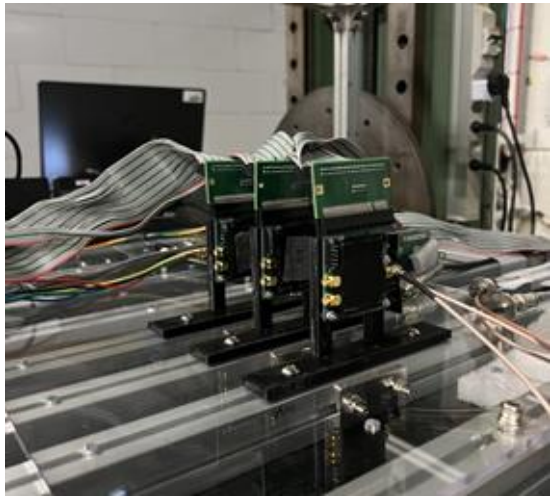
Synchronization of 3 layers of AstroPix v3

Hitmap



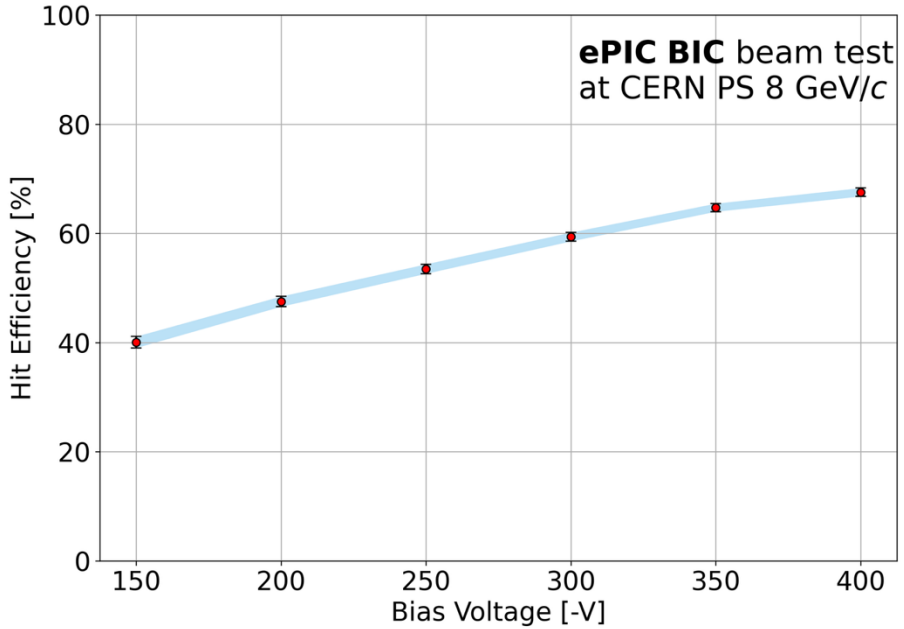
Correlation to the upstream chip





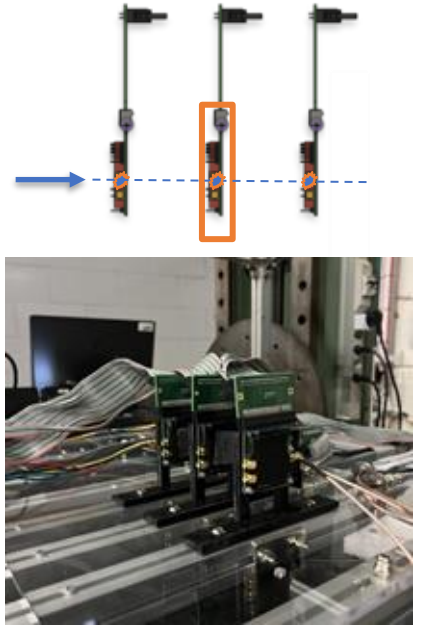
Three AstroPix v3 layers are tested using the electron/pion beam at CERN PS.
Correlations to the upstream show good alignment and data synchronization between AstroPix.
The integrated system works well in 2.7 kHz trigger rate on the beam. (BIC rate < 1 kHz/chip)

AstroPix v3 chip tracking efficiency (Shallow depletion)



Detection efficiency in percentage as a function of bias voltage

arXiv:2605.07681



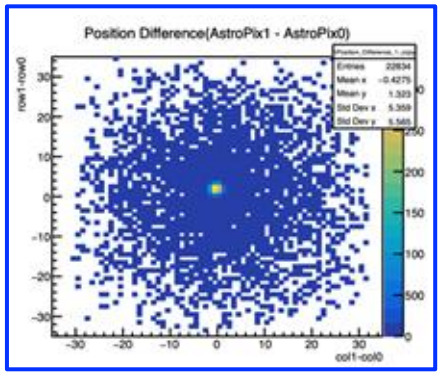
Proof-of-principle for a method to measure tracking efficiency of AstroPix v3 under beam condition.

It is calculated as probability of having a hit on the position estimated from hits on first & third chip.

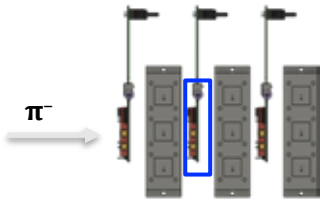
The shallow depletion of v3 was known and is addressed in v5 with increased depletion.

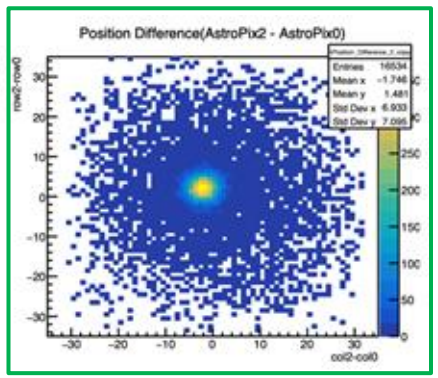
Different shower profiles of electrons and pions

Pions

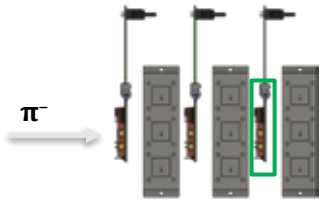


Position difference
between 1st-2nd layer

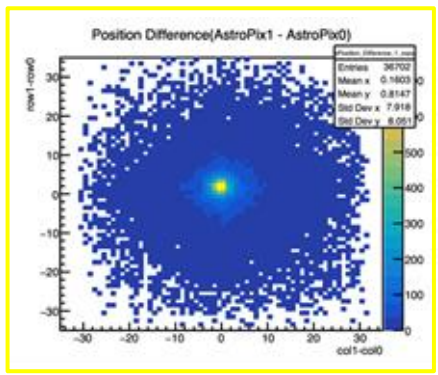




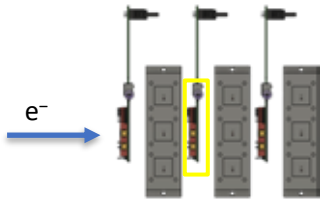
Position difference
between 1st-3rd layer

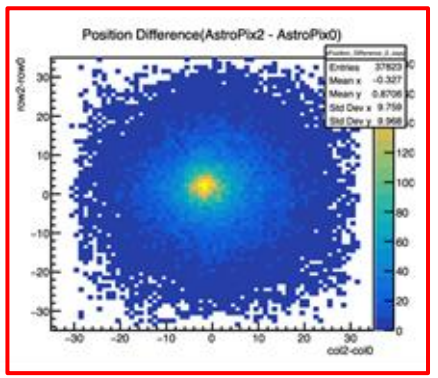


Electrons

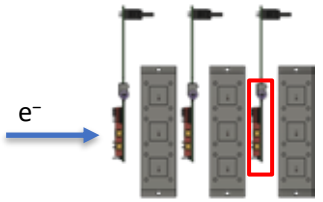


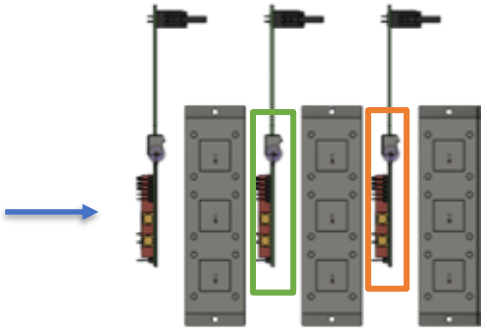
Position difference
between 1st-2nd layer

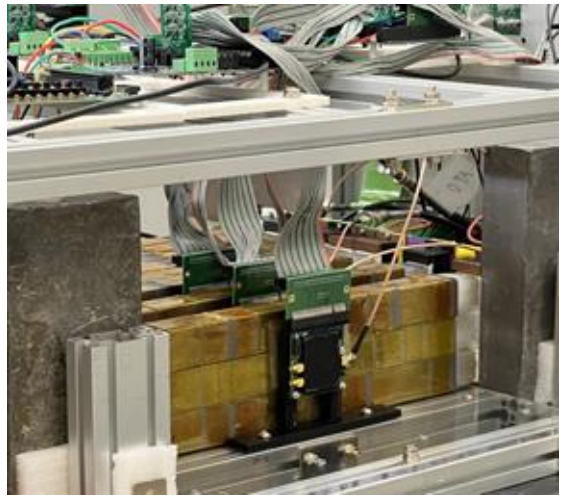




Position difference
between 1st-3rd layer





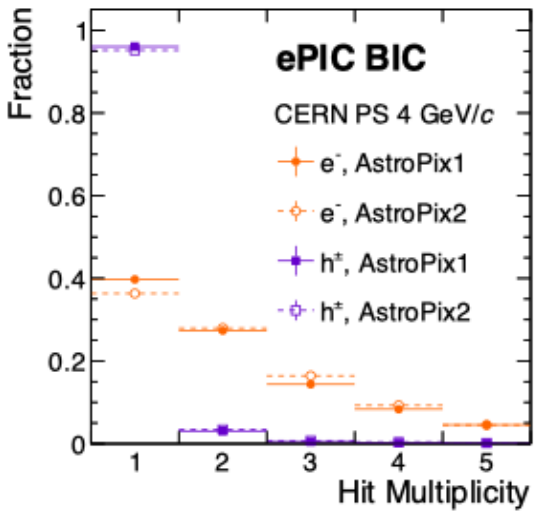


Proof-of-principle imaging of electrons and pions using synchronized setup of AstroPix in beam environment performed.

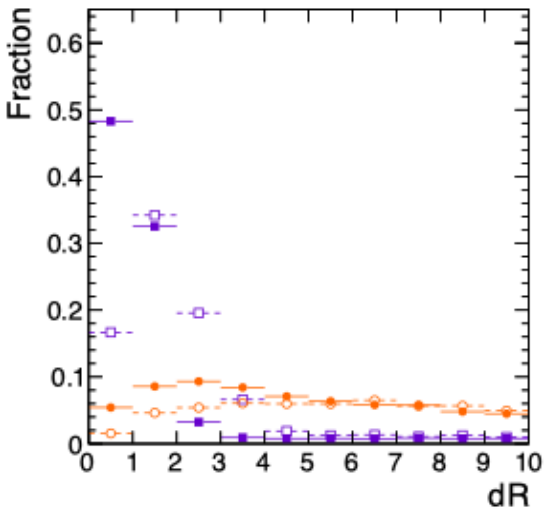
Different response on AstroPix between Pb/SciFi

arXiv:2605.07681

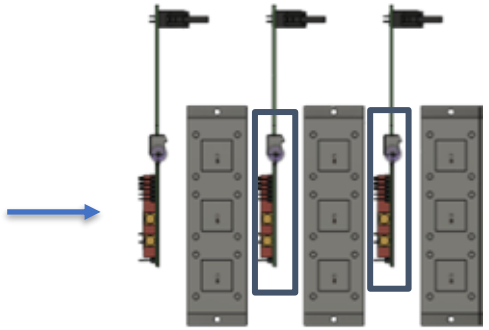
Hit Multiplicity at 2nd, 3rd layers

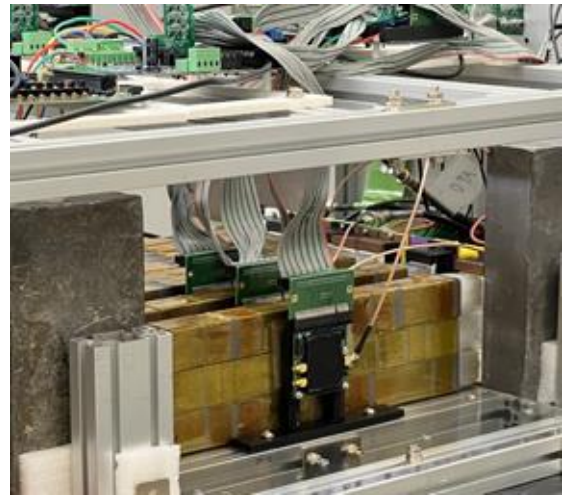


Distance from beam position



$$dR = \sqrt{(\Delta x)^2 + (\Delta y)^2}$$

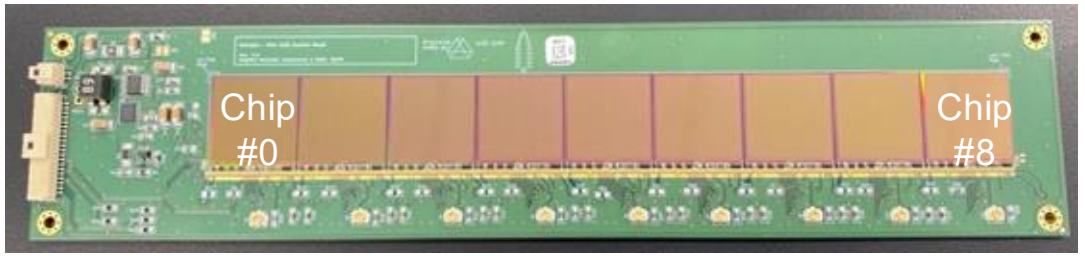


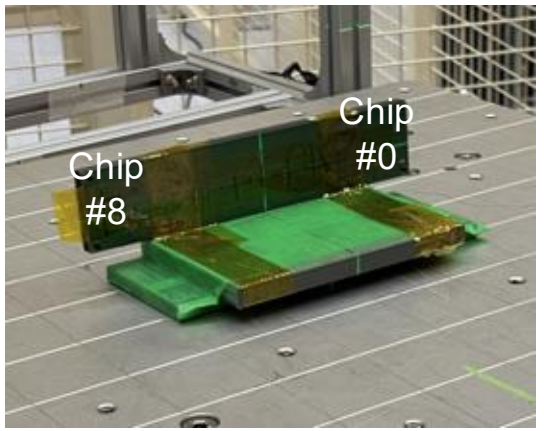


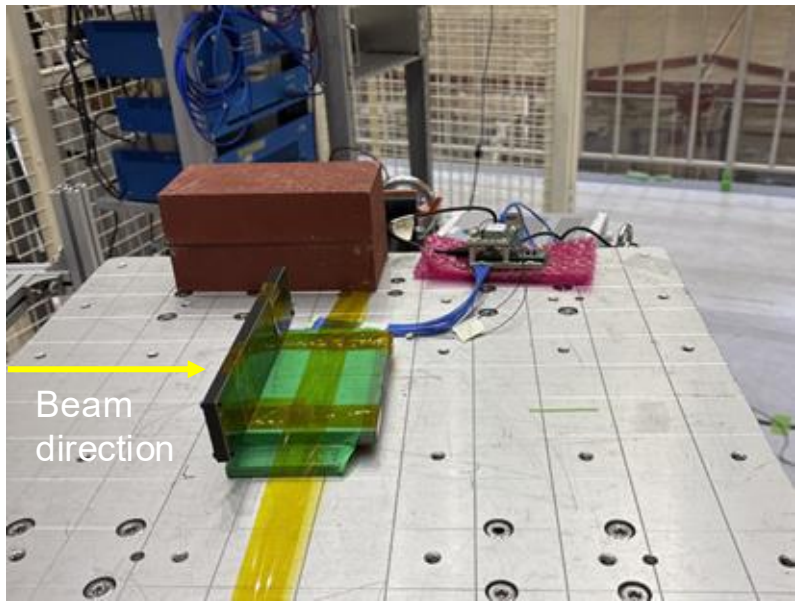
- Hit multiplicity and distance from the beam position at the second AstroPix v3 chip are different for electrons and pions.
- Data analysis using both Pb/SciFi and AstroPix is ongoing.
- The electron/pion separation power in the beam test condition will be enhanced by AstroPix information on shower shape.

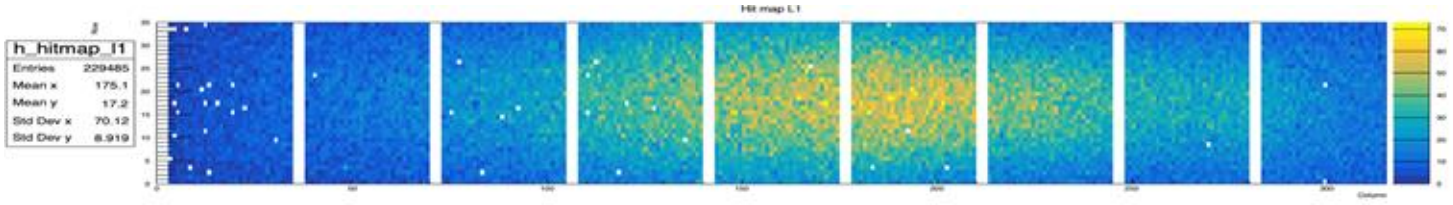
Beam on AstroPix 9-chip module

- First beam test using AstroPix 9-chip prototype module (v3 chips)
- Standalone test at KEK PF-AR
  - Operation of multiple quad chip modules at JLab by BIC group
- Worked at ~2.7kHz
  - (Trigger rate in the beam line)
- We have a plan to adjust the beam rate for AstroPix-Pb/SciFi integrated data acquisition at CERN PS T09 in August.



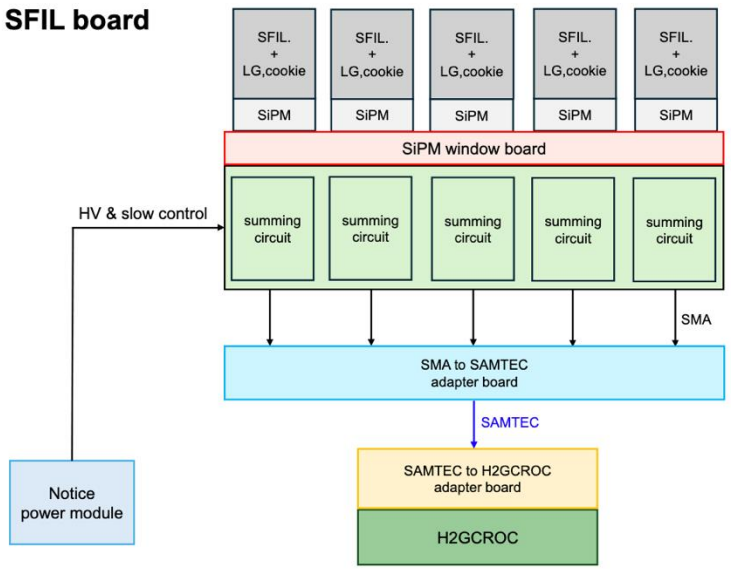


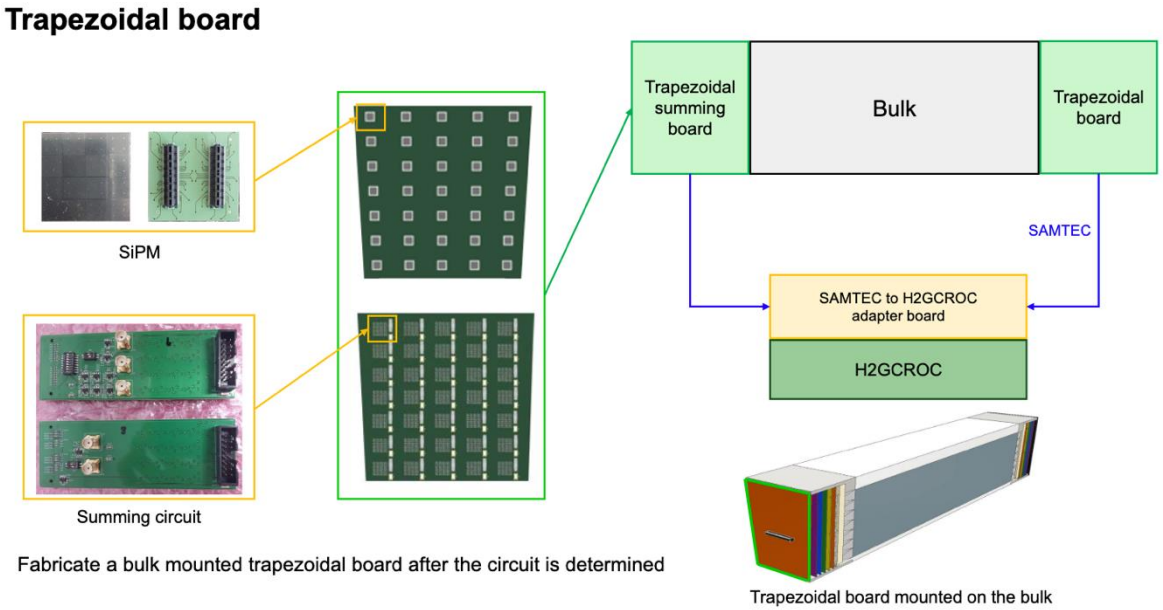




CALOR2026 presentation by Bobae Kim [Link]

Backup: Preparation for Larger Pb/SciFi

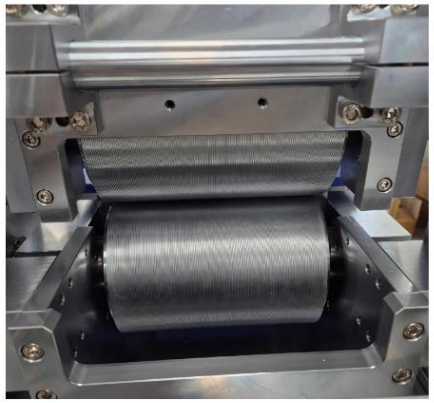




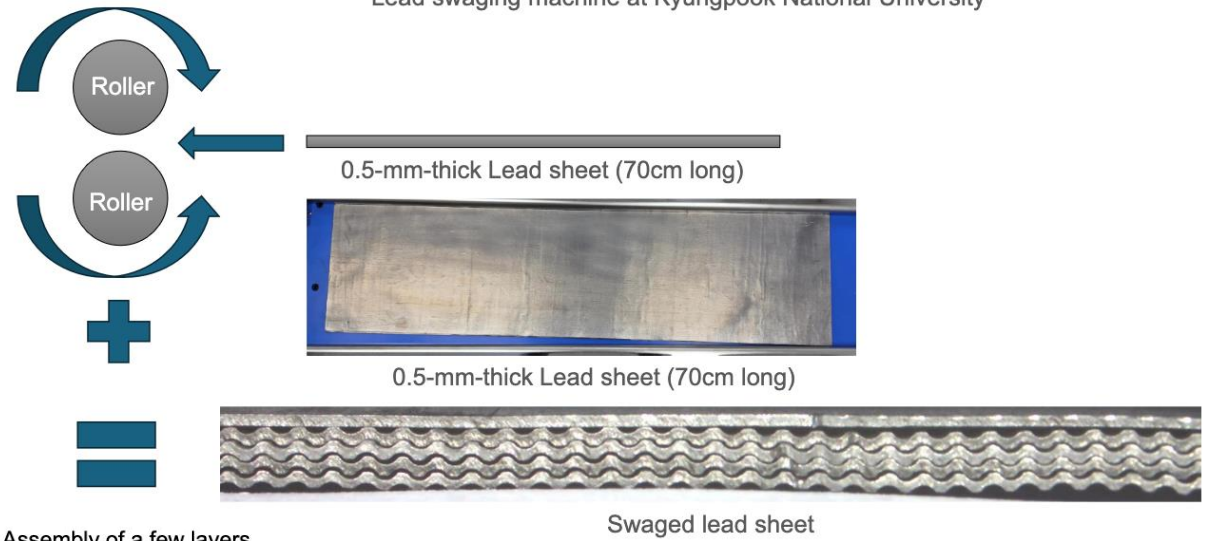
Preparation for Readout Box for Imaging Layers and Bulk section (70cm test article)

Backup: Preparation for Larger Pb/SciFi

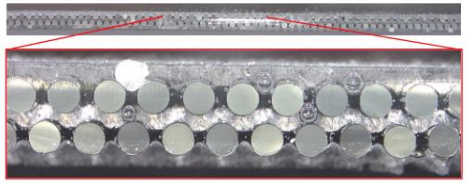
Lead swagging machine at KNU



Lead swaging machine at Kyungpook National University



Assembly of a few layers



Press to hold Pb and SciFi at KNU
Not a test with dummy fiber is ongoing to confirm dimension after stacking

Also, fiber test setup is ready for the production of the test articles, we started to see reasonable attenuation.