AstroPix3 Beam Test at KEK using Integrated DAQ System

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BIC System Testing Meeting, 2025.07.01

Contents

1. Integrated DAQ
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3. Limitations

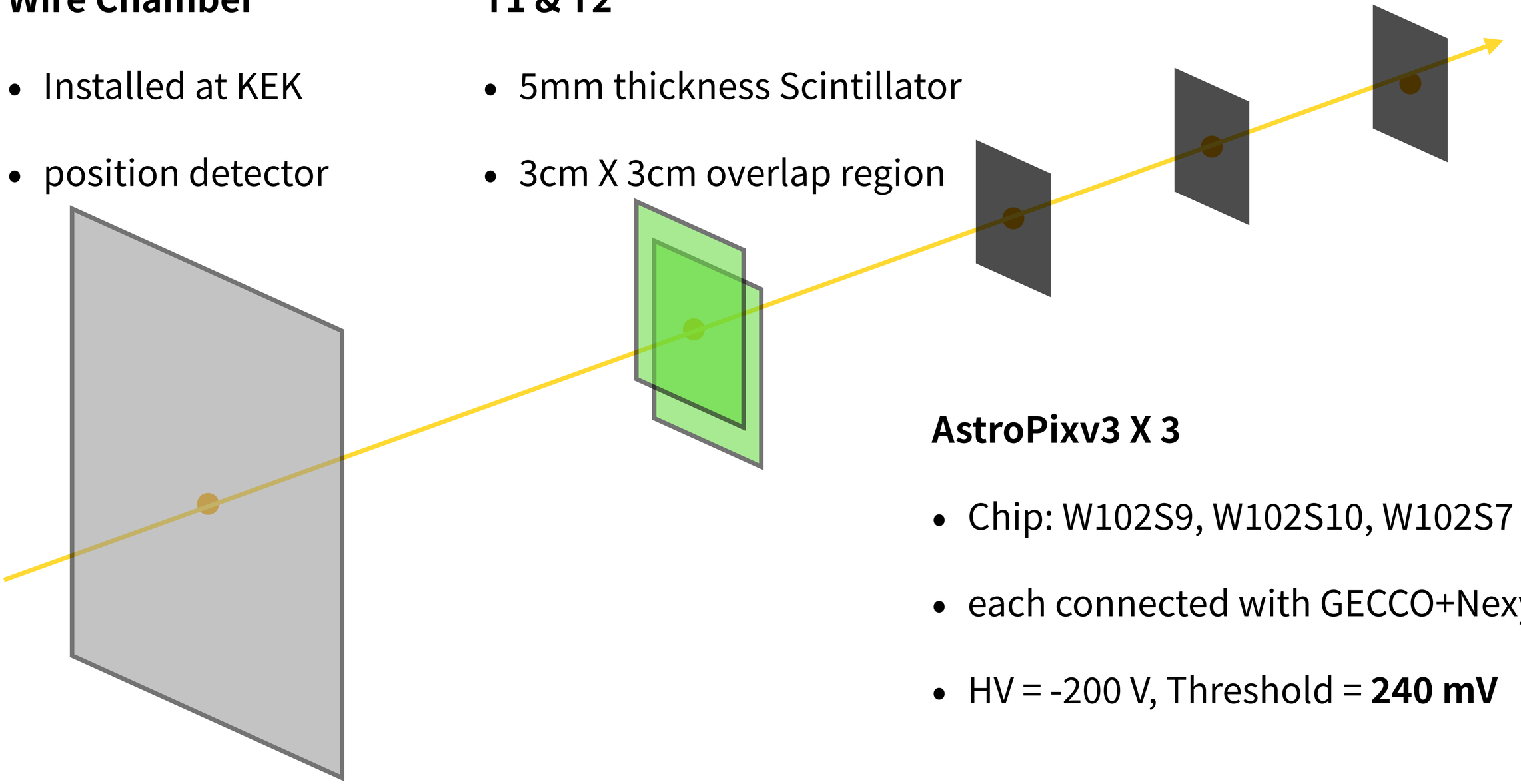
Set-up

Wire Chamber

- Installed at KEK
- position detector

T1 & T2

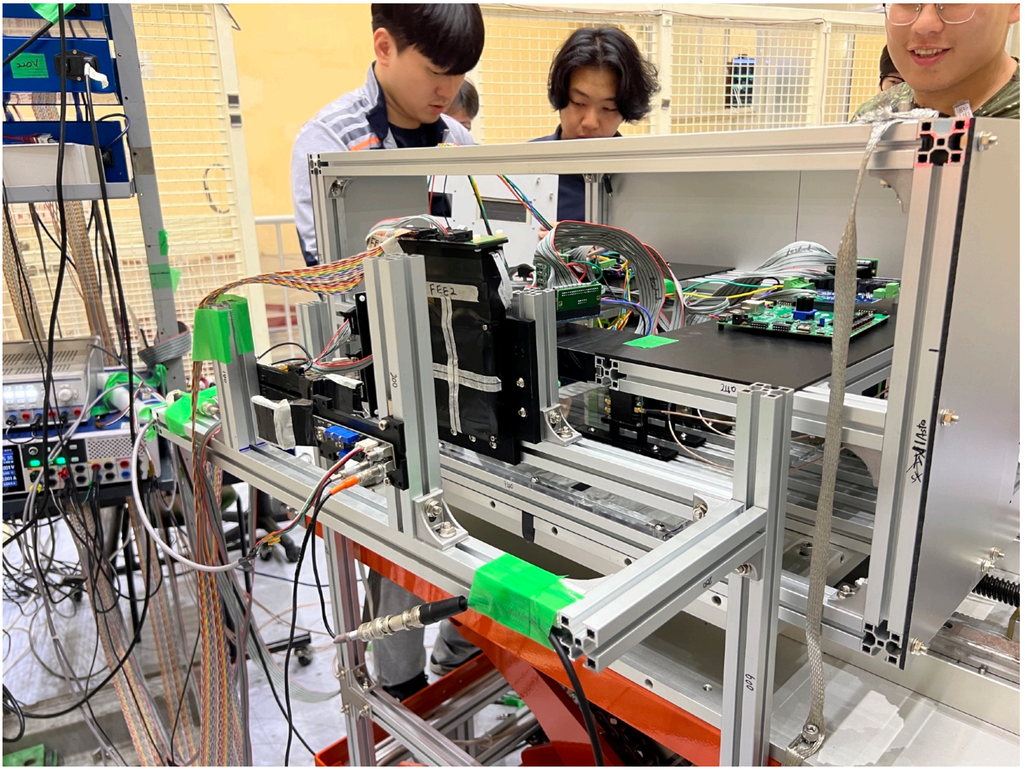
- 5mm thickness Scintillator
- 3cm X 3cm overlap region

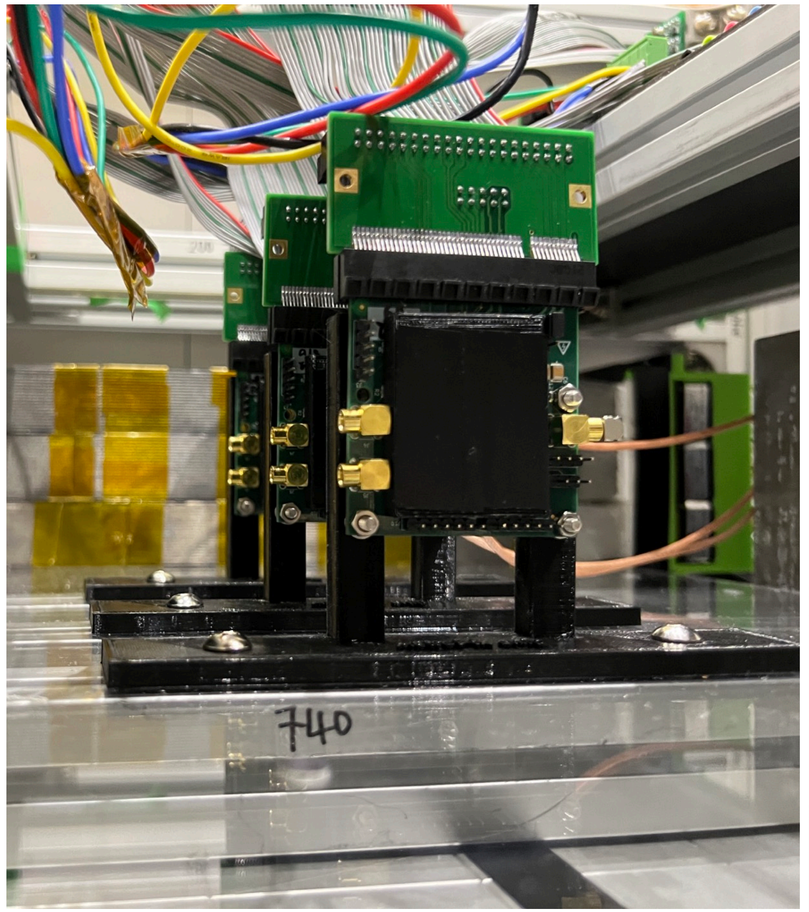


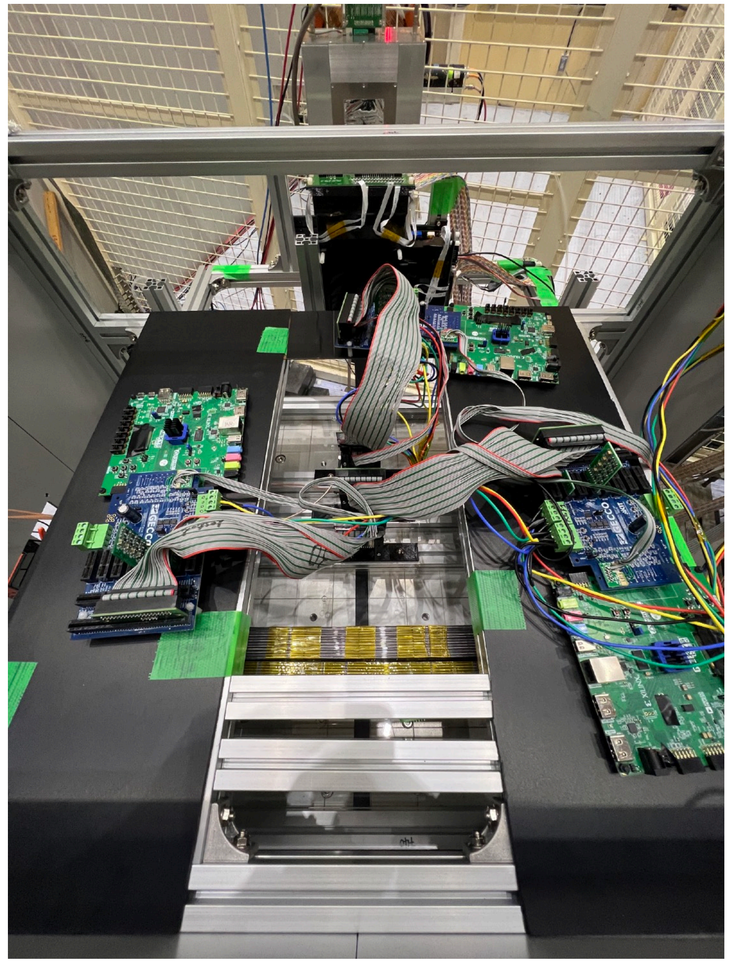
AstroPixv3 X 3

- Chip: W102S9, W102S10, W102S7
- each connected with GECCO+Nexys
- HV = -200 V, Threshold = **240 mV**

Set-up

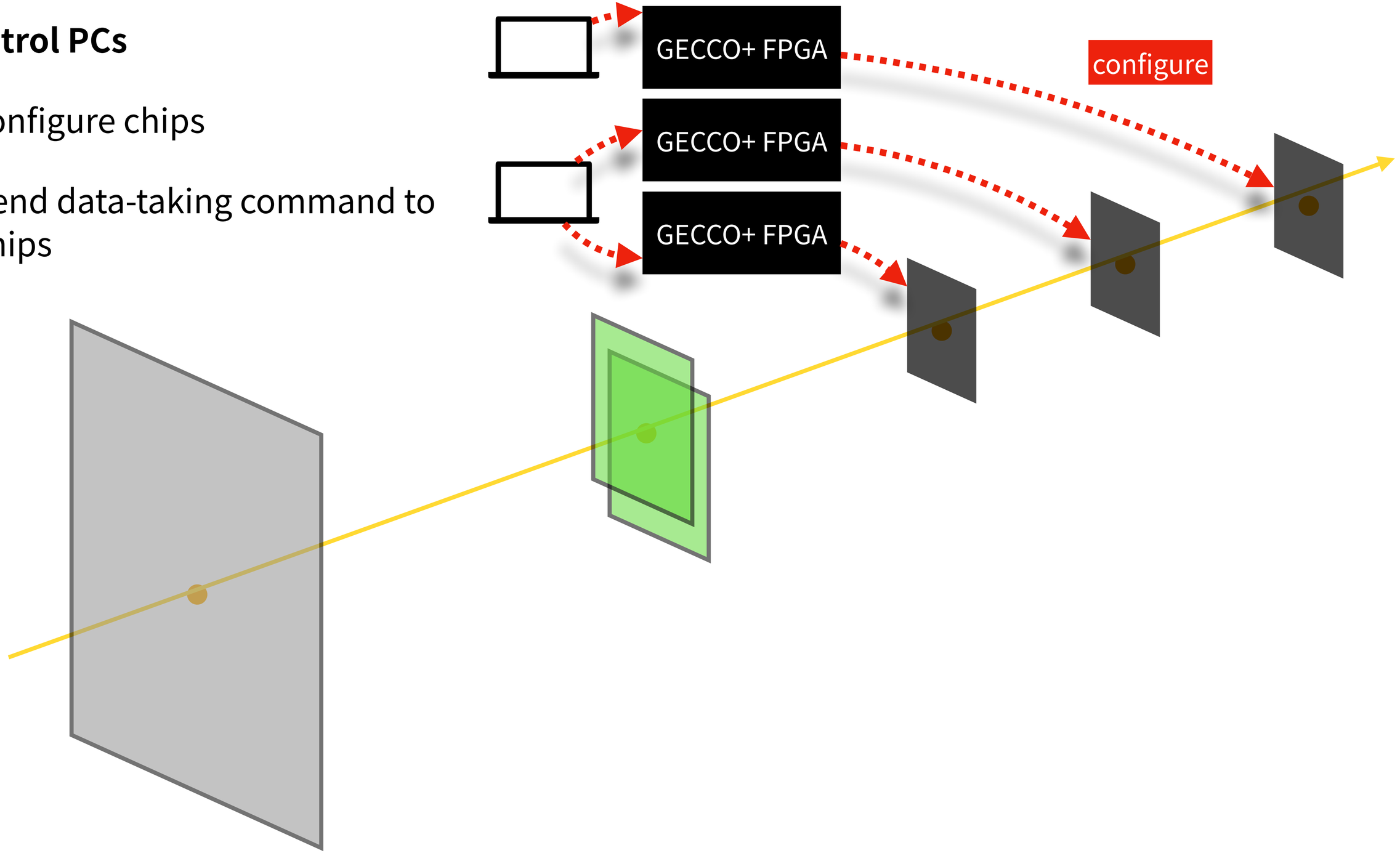




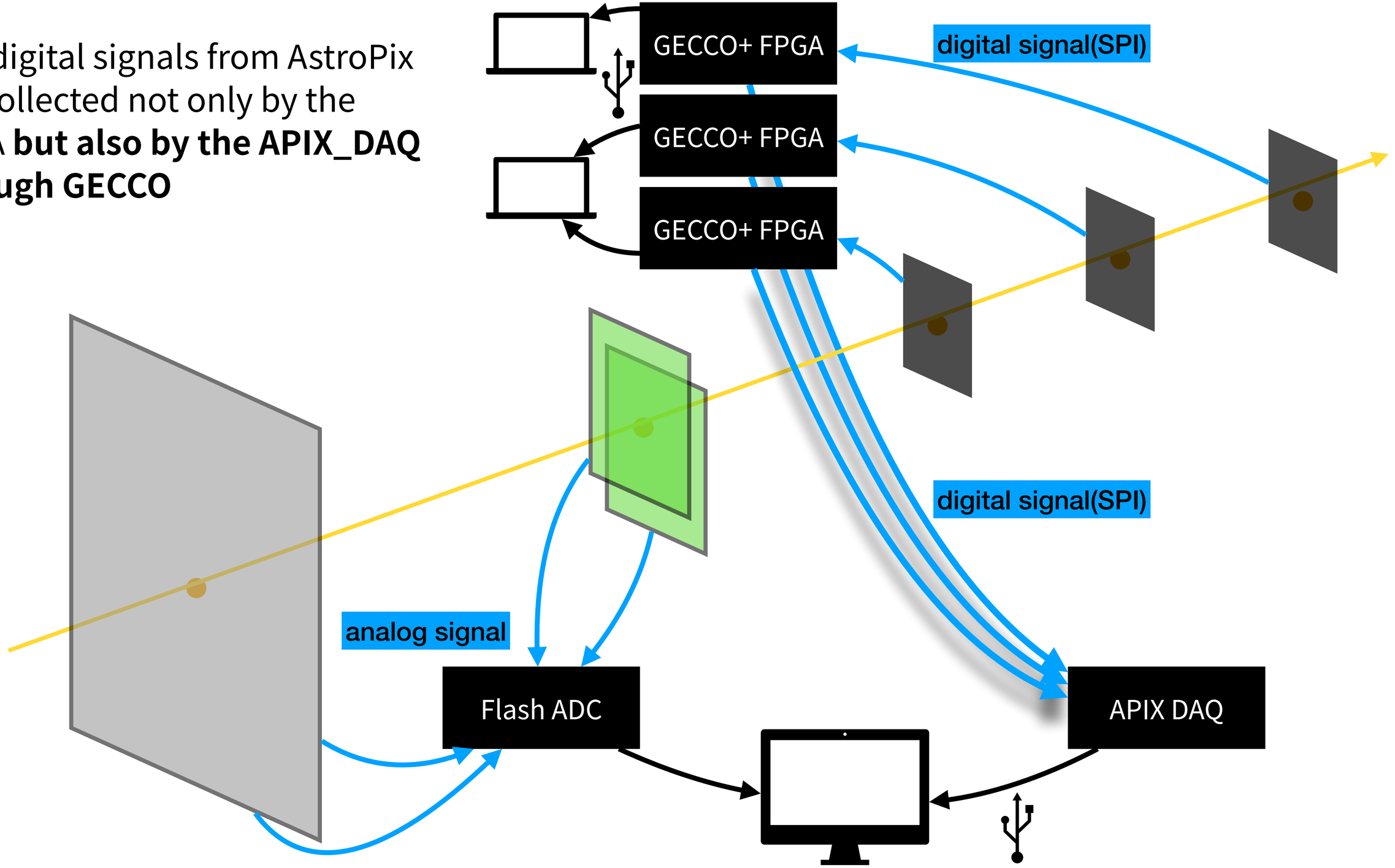


Control PCs

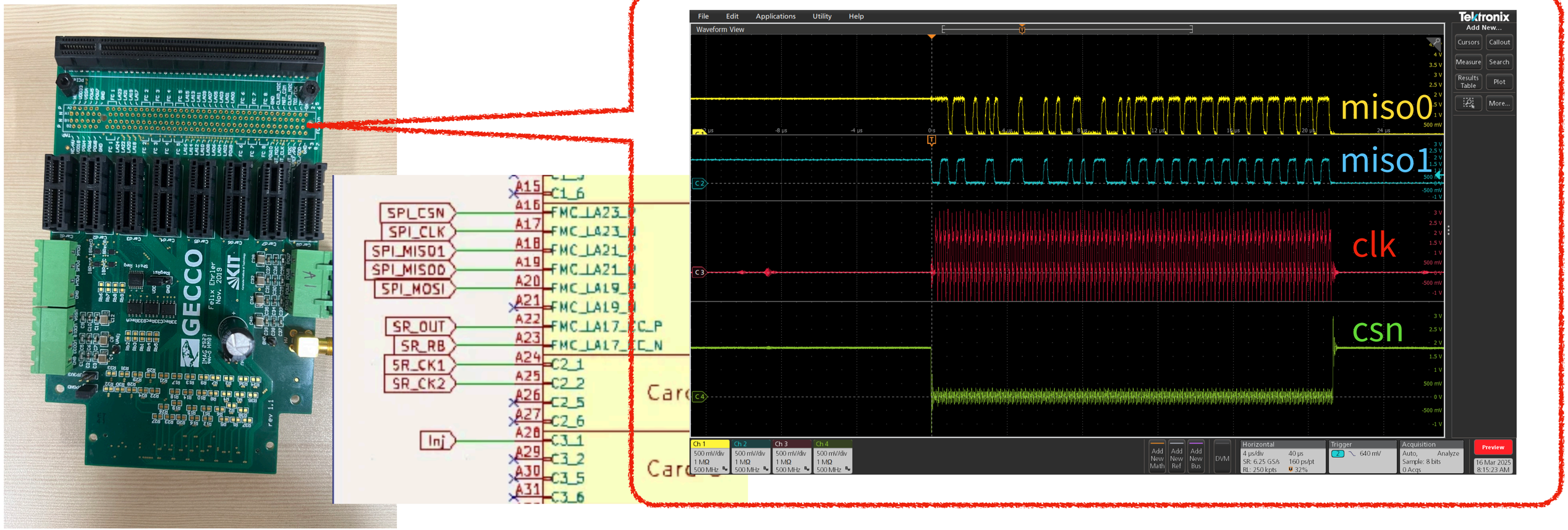
- configure chips
- Send data-taking command to chips



The digital signals from AstroPix are collected not only by the FPGA **but also by the APIX_DAQ through GECCO**



SPI signal?



When a hits is recorded, **csn gets low**, clock(clk) gets started

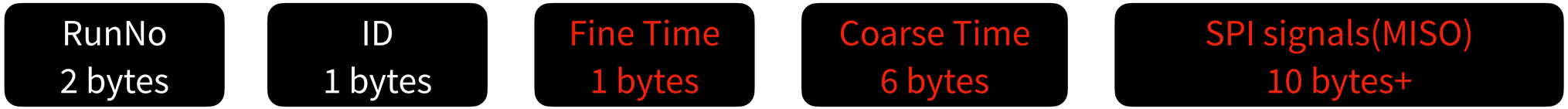
MISO = **MISO0+1 in bitwise,** contains hit location, ToT, Timestamp

➡Hijack the data to APIX_DAQ using the A16–A20 pins on the GECCO board

Integrated DAQ

APIX DAQ

When the **CSN line goes low** for each AstroPix, the SPI signals are recorded along with prepended metadata such as the global clock information

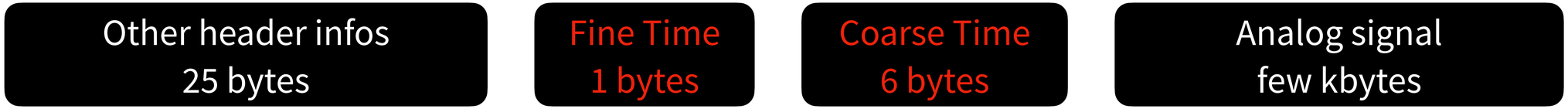


1 clk = 8 ns

1 clk = 1 us

Flash ADC

When a **coincidence signal from T1 & T2 is detected**, the analog signals from the connected auxiliary detectors are recorded, with global clock information and other metadata added

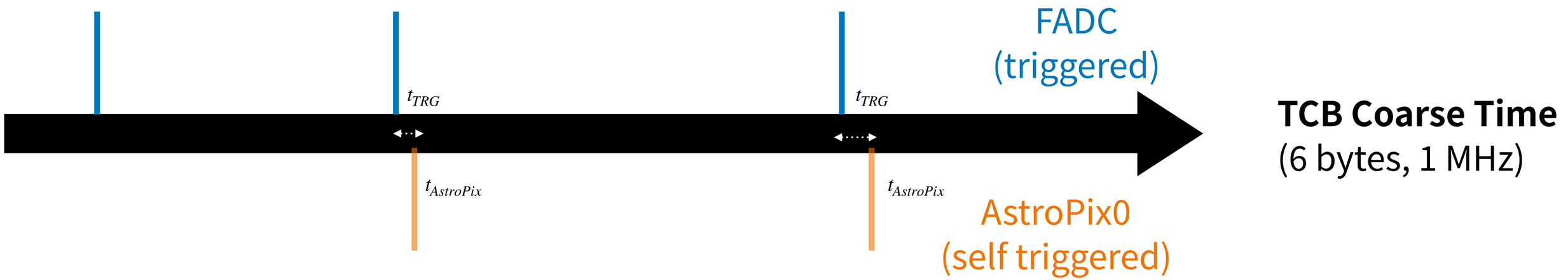


Both DAQ systems **share the global clock** issued by the TCB,

enabling synchronization not only between the AstroPix and the calorimeter+auxilary system (triggered by T1 & T2), but also among multiple AstroPix chips.

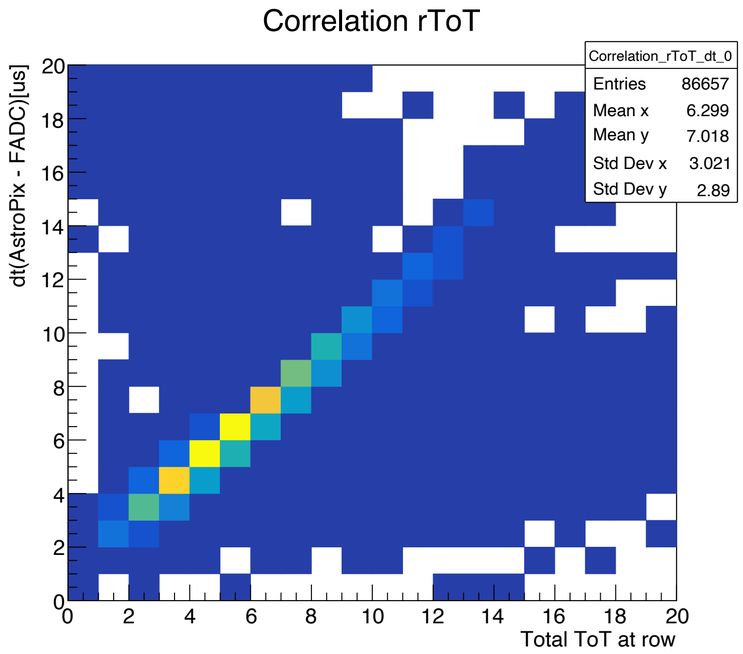
Results

Event Building

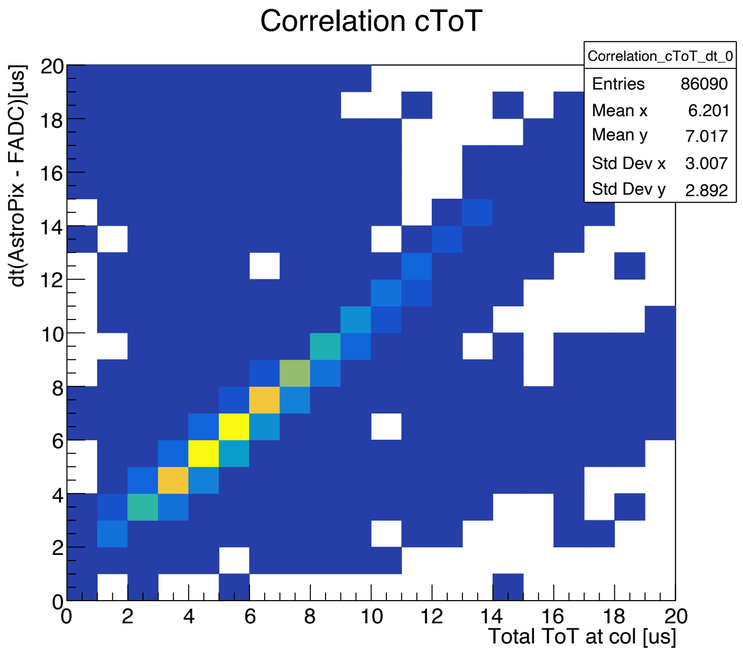


- For each FADC event(trigger by T1 & T2), the TCB coarse time is compared with that of the AstroPix
- Events with closely matching times are synced as a single event
  - $dt = t_{AstroPix} - t_{TRG}$, Synced as a same event if $dt < 20\ us$
- For AstroPix, each event(csn low state) can contain multiple hits

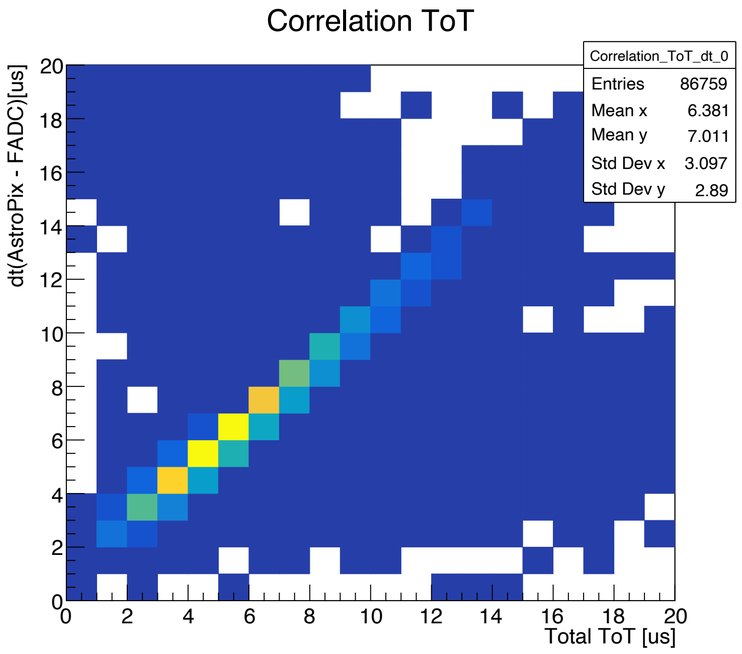
Dead Time due to ToT measurement



x-axis : $\Sigma\ ToT_{row}$



x-axis = $\Sigma\ ToT_{col}$



x-axis : $\max\left(\Sigma\ ToT_{col}\ ,\ \Sigma\ ToT_{row}\right)$

- The SPI signal is issued after the completion of ToT measurement (i.e., after the falling edge), resulting in a **dead time equivalent to the measured ToT** duration

- $dt_{corrected} = t_{AstroPix} - t_{TRG} - \max\left(\Sigma\ ToT_{col}\ ,\ \Sigma\ ToT_{row}\right)$

Event Building

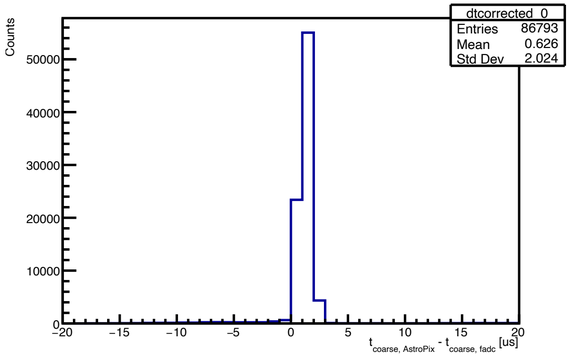
TCB Coarse Time
(6 bytes, 1 MHz)

dead time

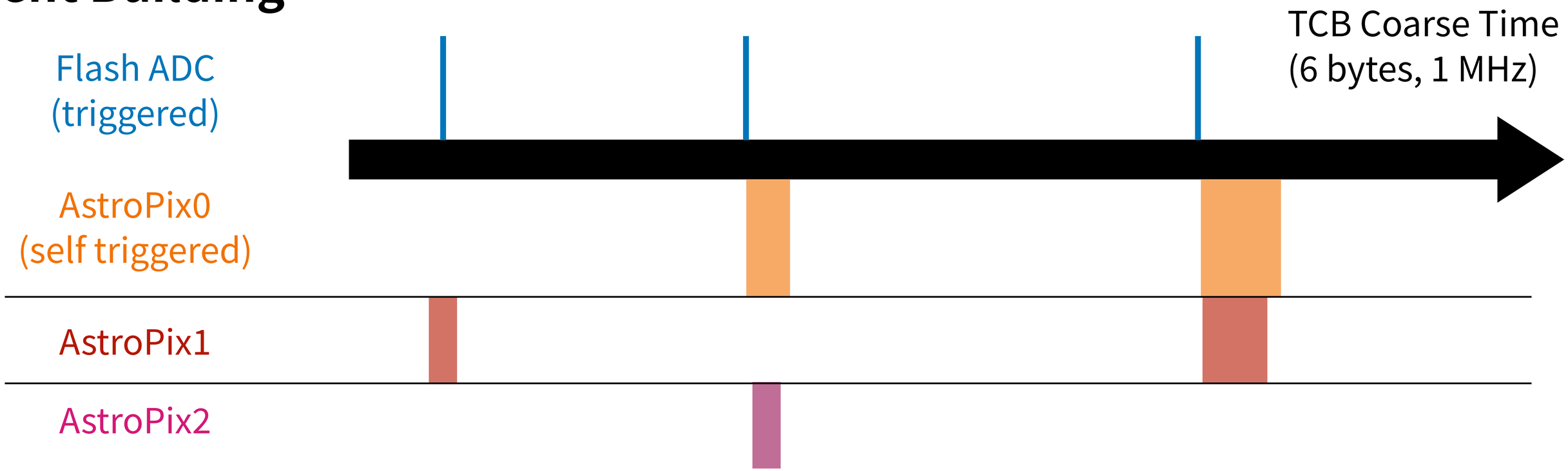
- due to ToT measurement
- ToT range = 0-10 us for AstroPix v3

Event Building

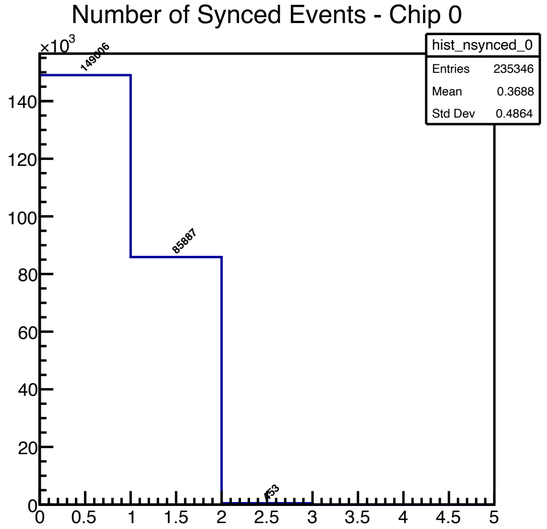
- $dt_{corrected} = t_{AstroPix} - t_{TRG} - deadtime$
- Saved as a same event if $dt_{corrected} < 20\ us$
- Each Event can contain multi-hits

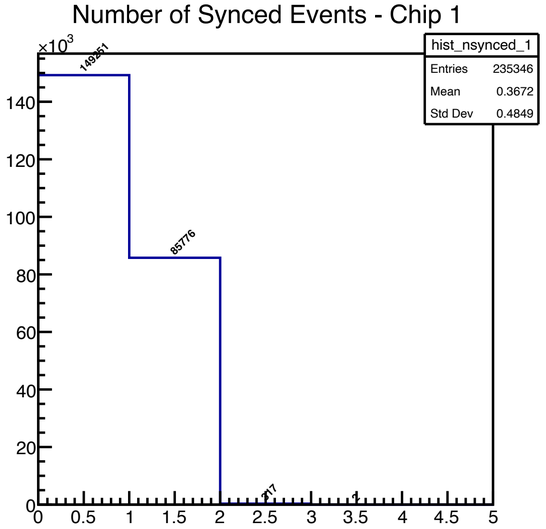


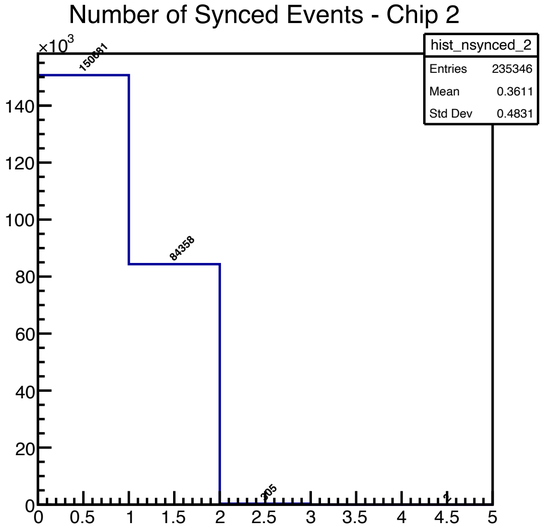
Event Building



AstroPixs only, 4.5 GeV/c:
(no scattering material)

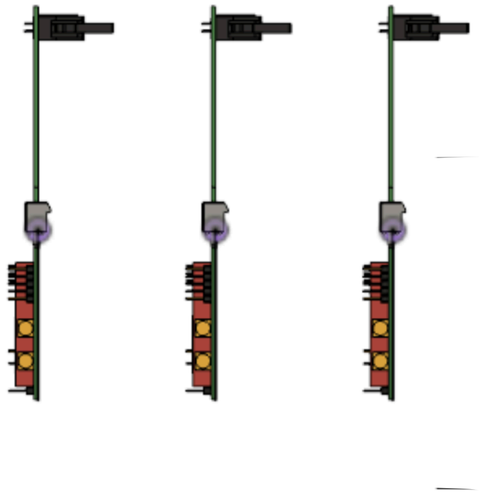




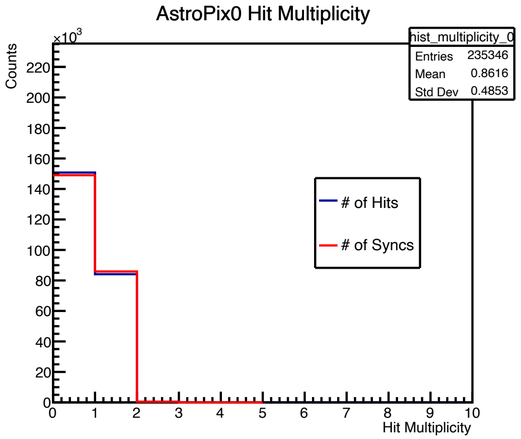


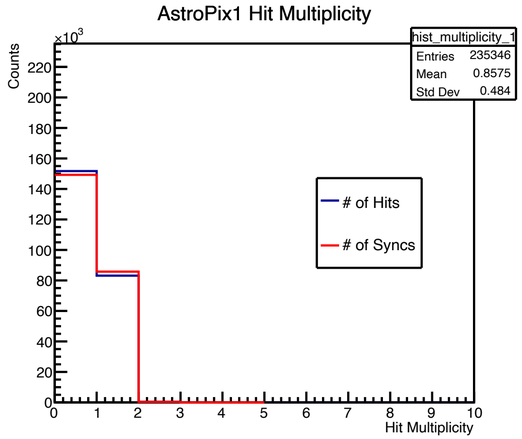
Position correlation

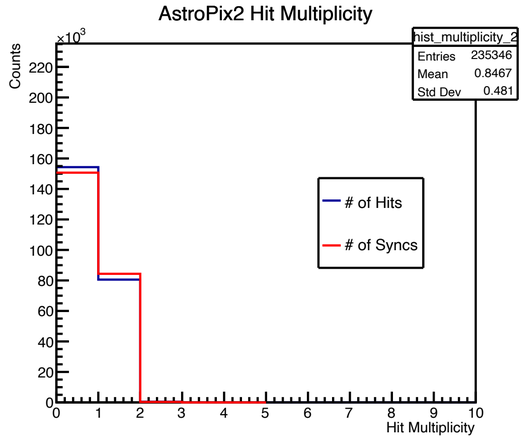
AstroPixs only, 4.5 GeV/c

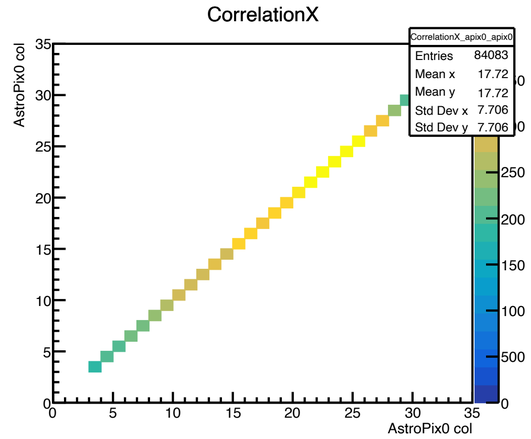


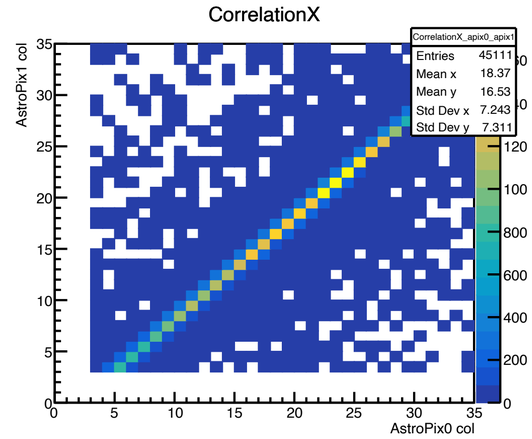
- correlation drawn only if each chip has single hit

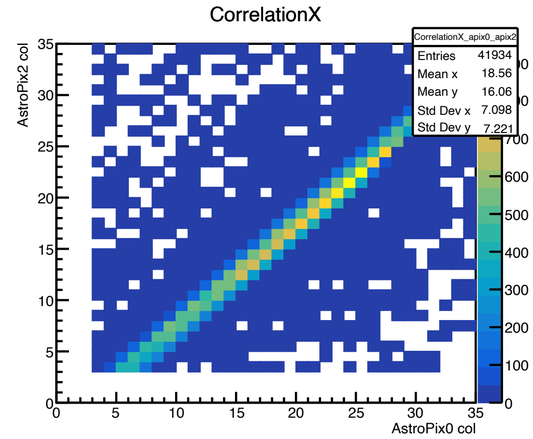


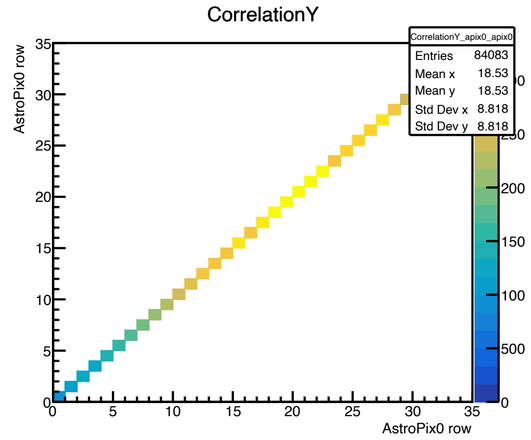


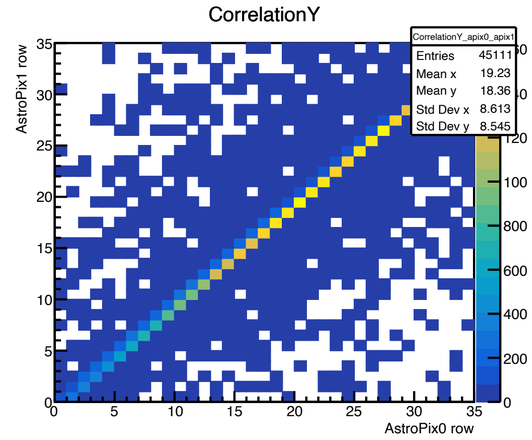


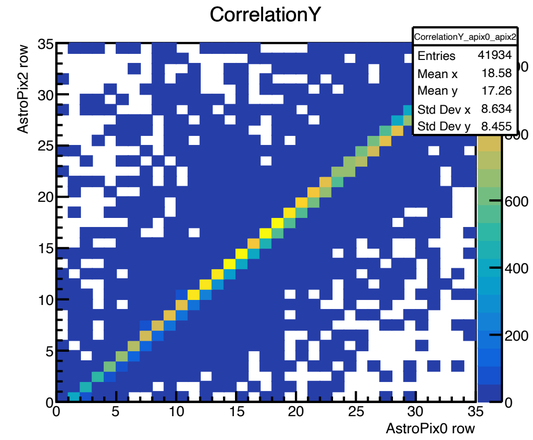






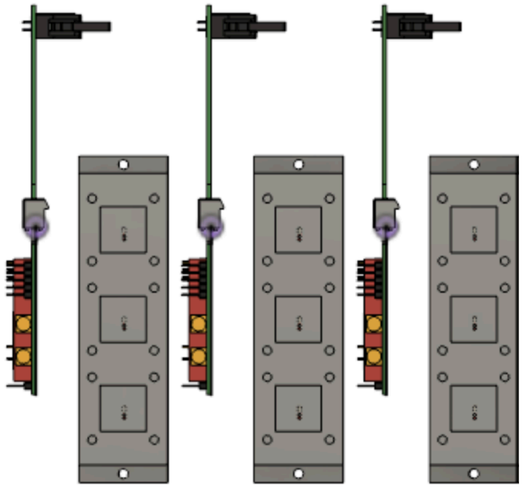




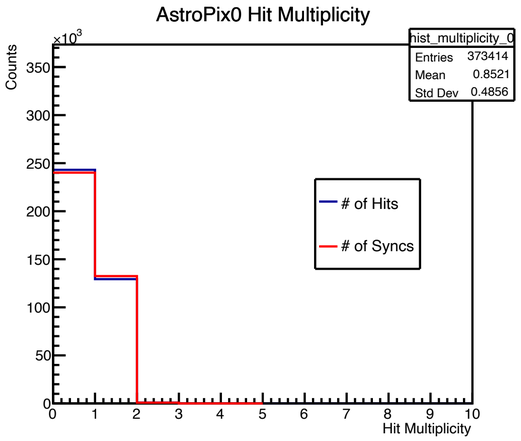


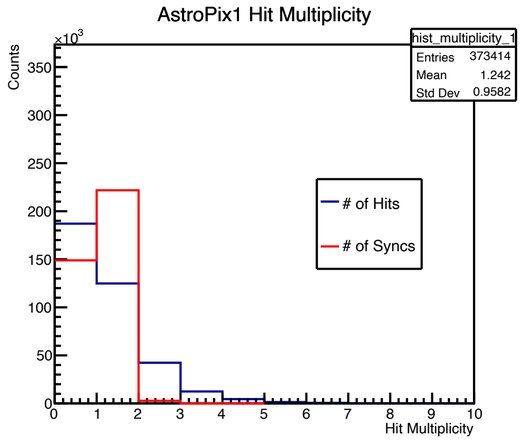
Position correlation

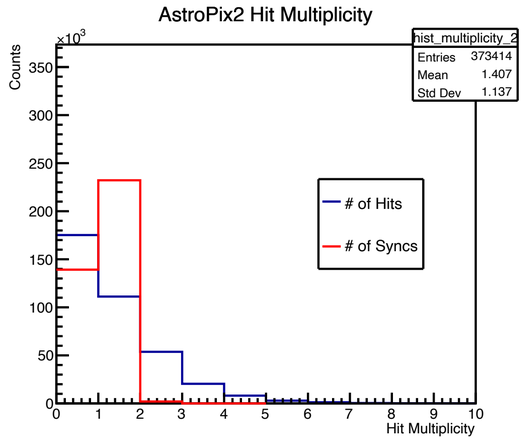
AstroPixs+3 Calorimeter, 4.5 GeV/c

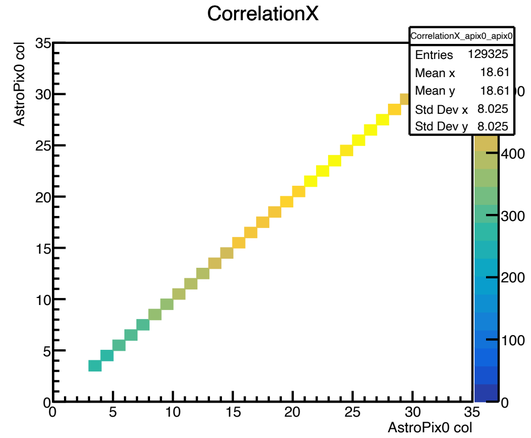


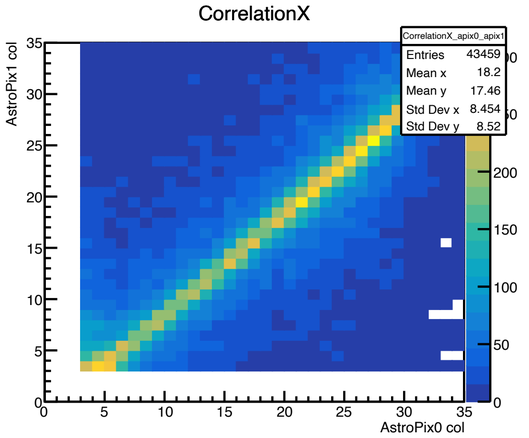
- correlation drawn only if each chip has single hit

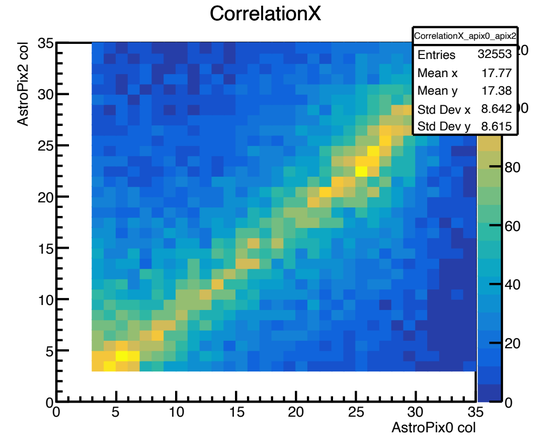


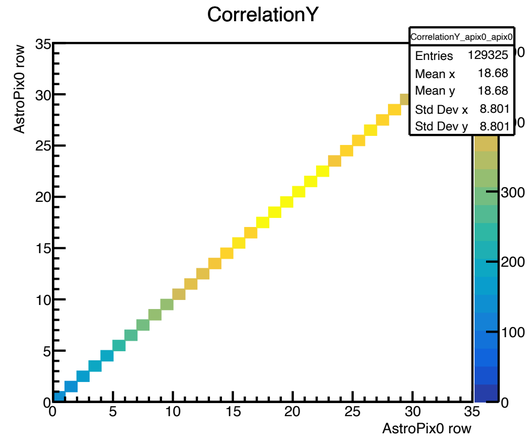


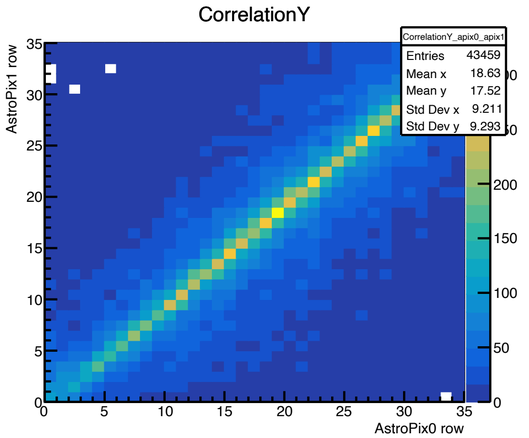


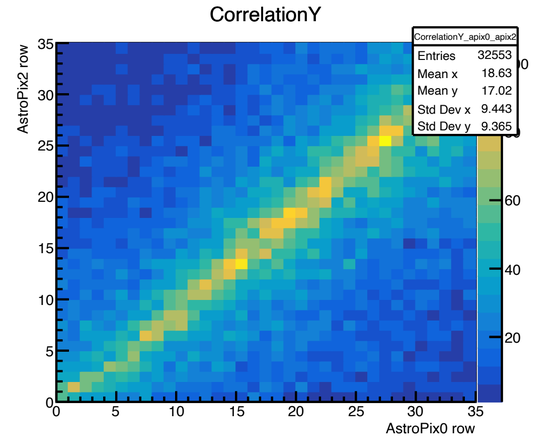






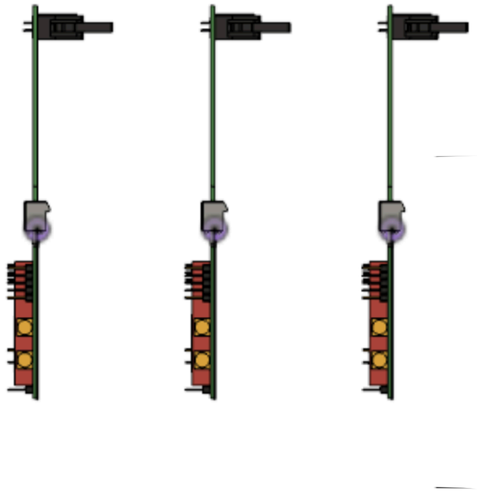




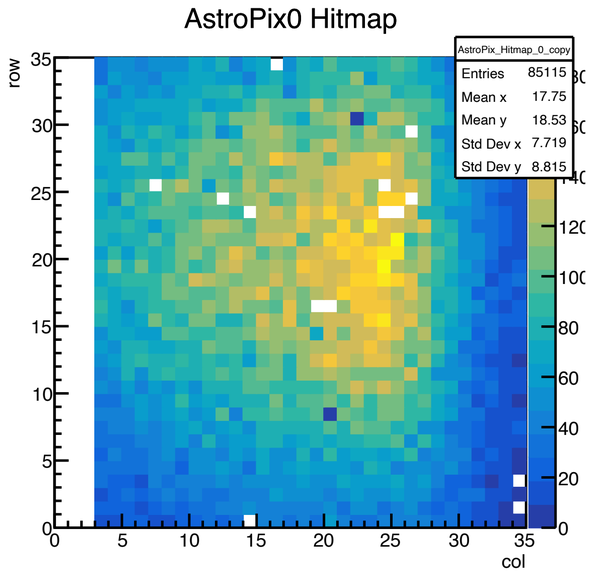


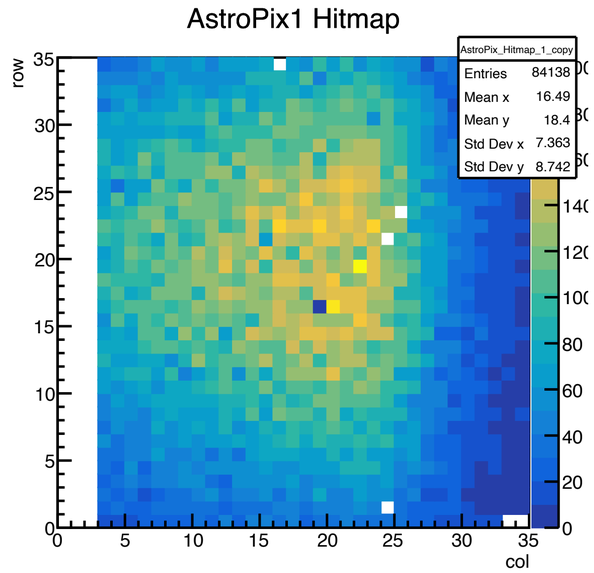
Hitmaps

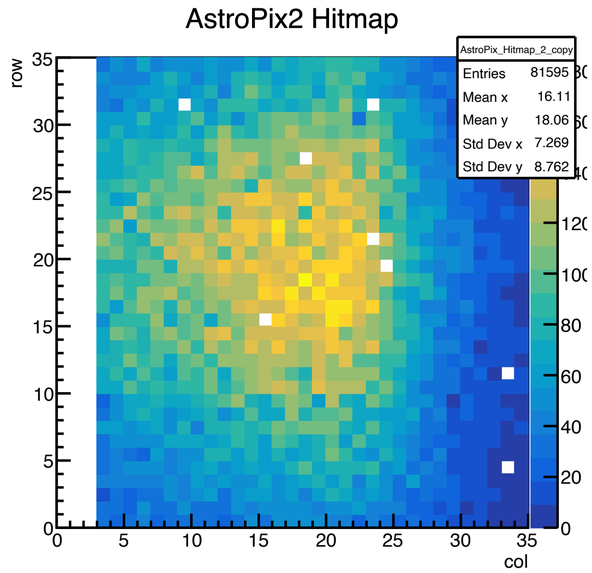
AstroPixs only, 4.5 GeV/c

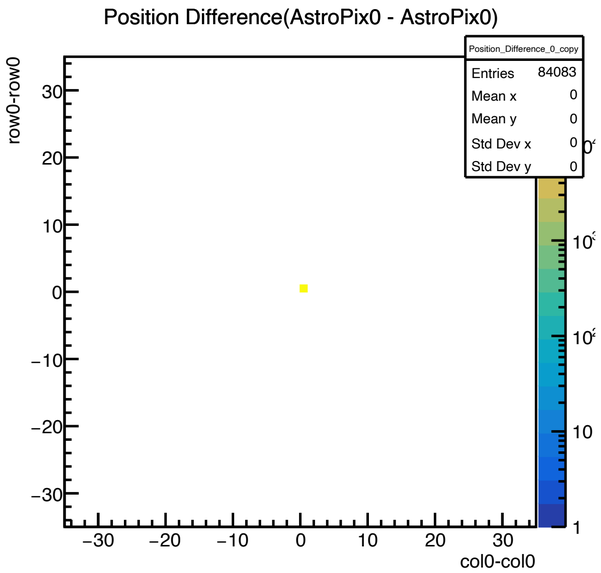


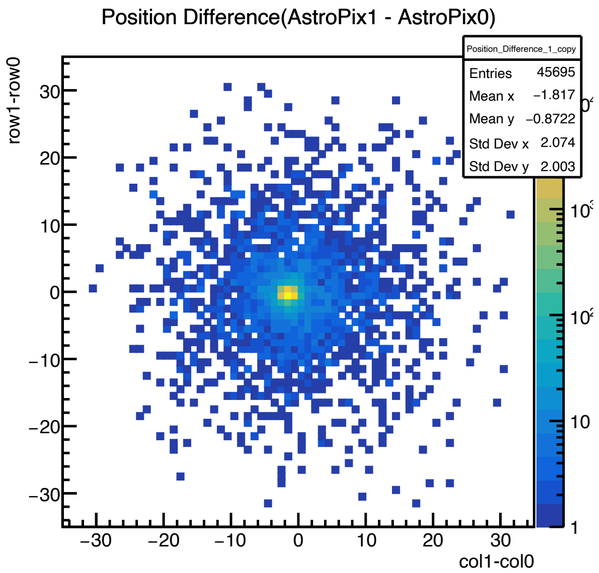
- position difference drawn if chip0 has a single hit

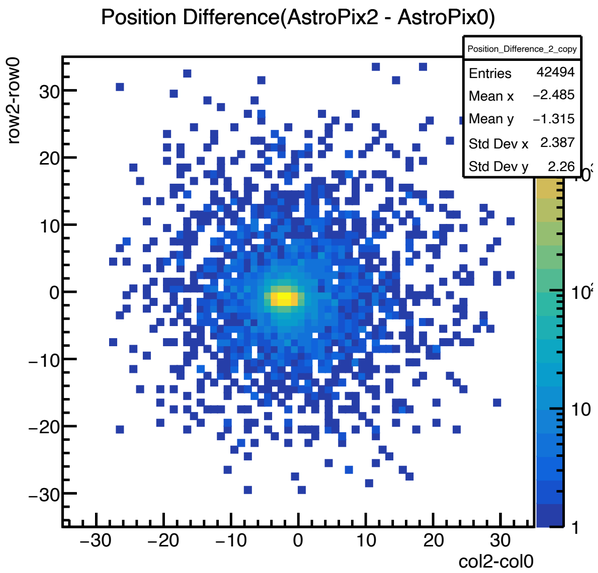






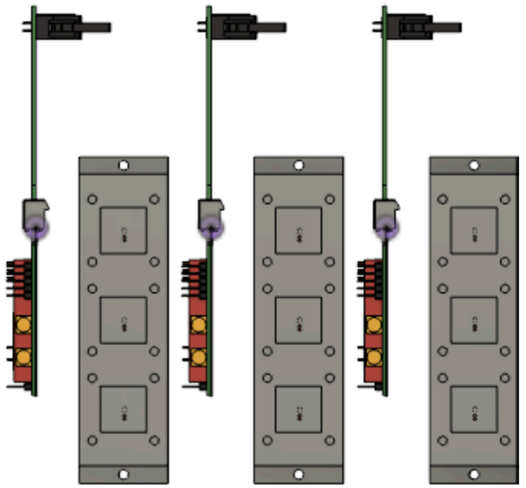




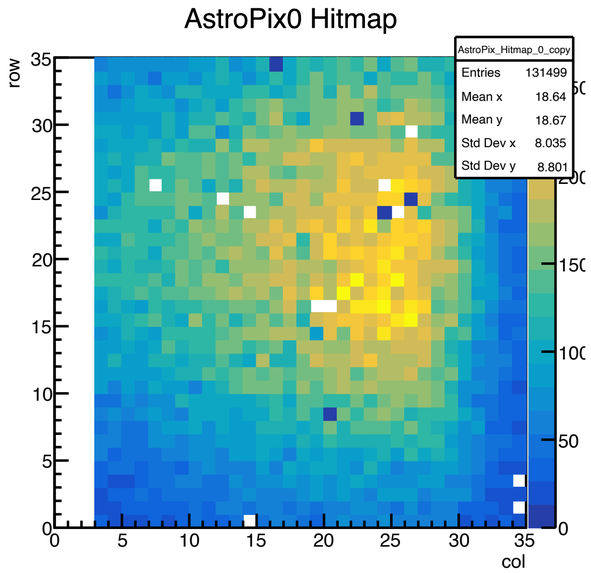


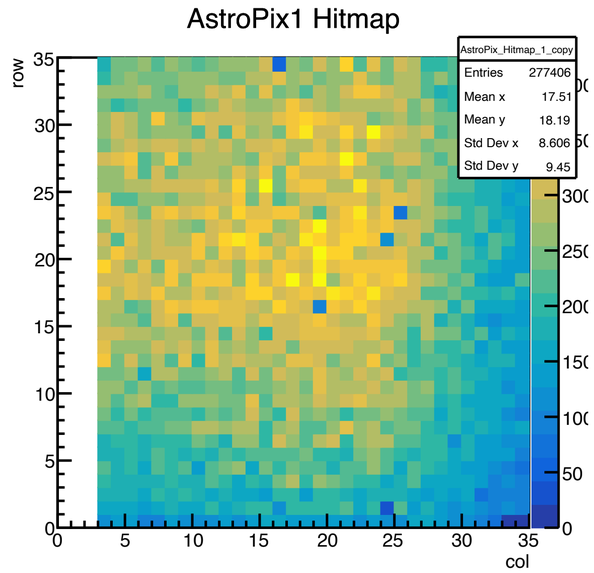
Hitmaps with Calorimeter modules

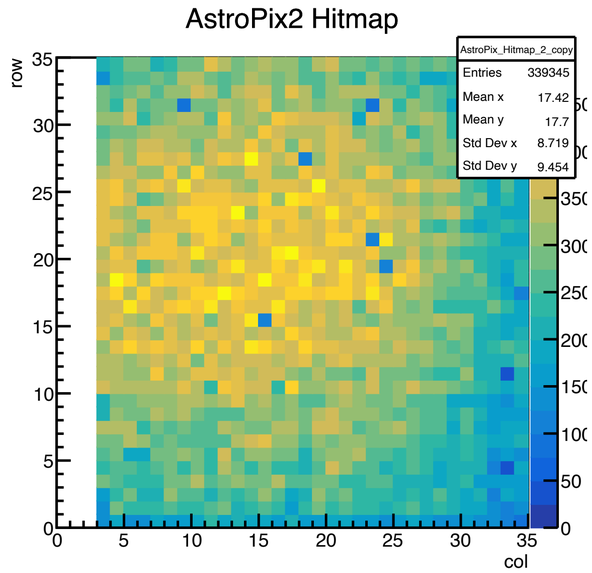
AstroPixs+3 Calorimeter, 4.5 GeV/c

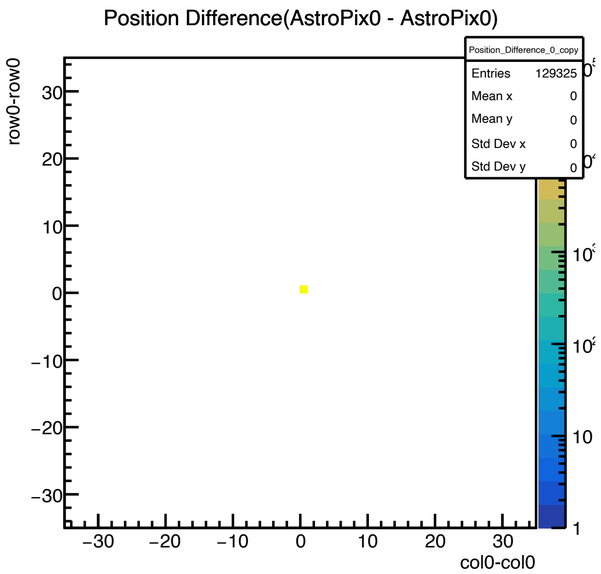


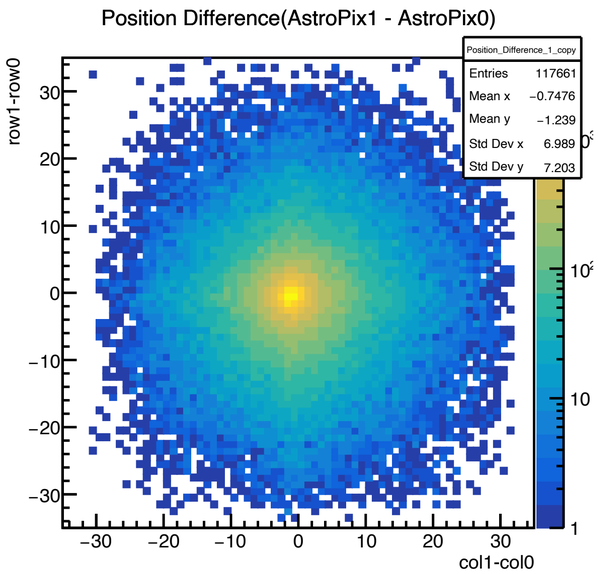
- position difference drawn if chip0 has a single hit

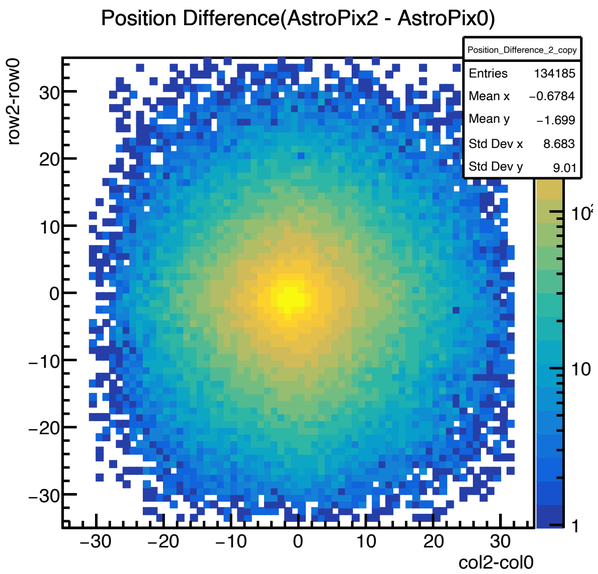






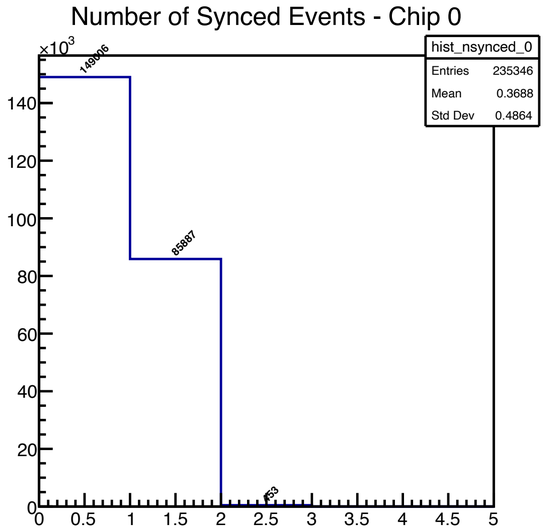


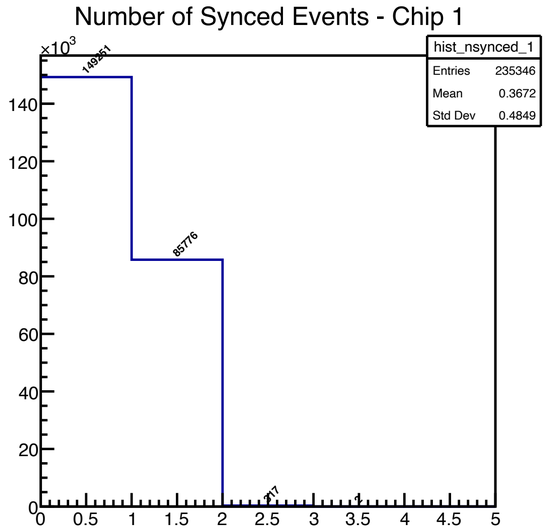


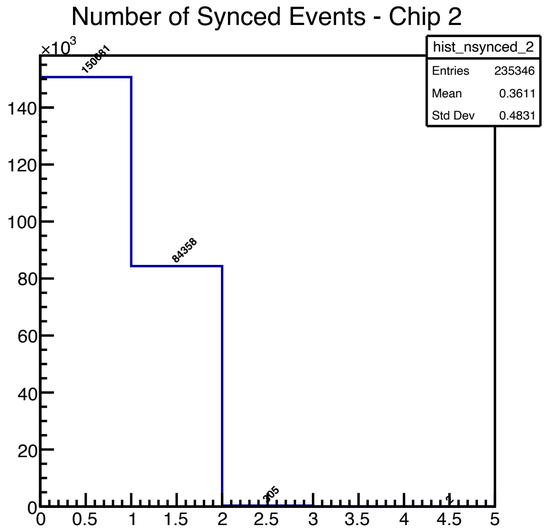


Limitations

Chip Efficiency?





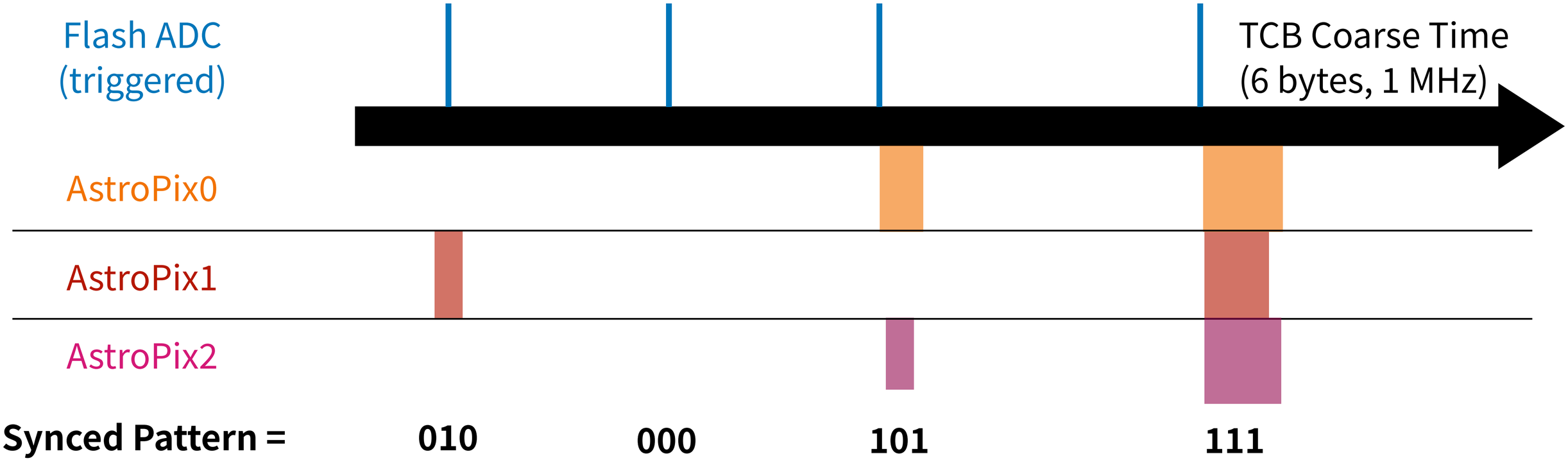


Zero-synced events:

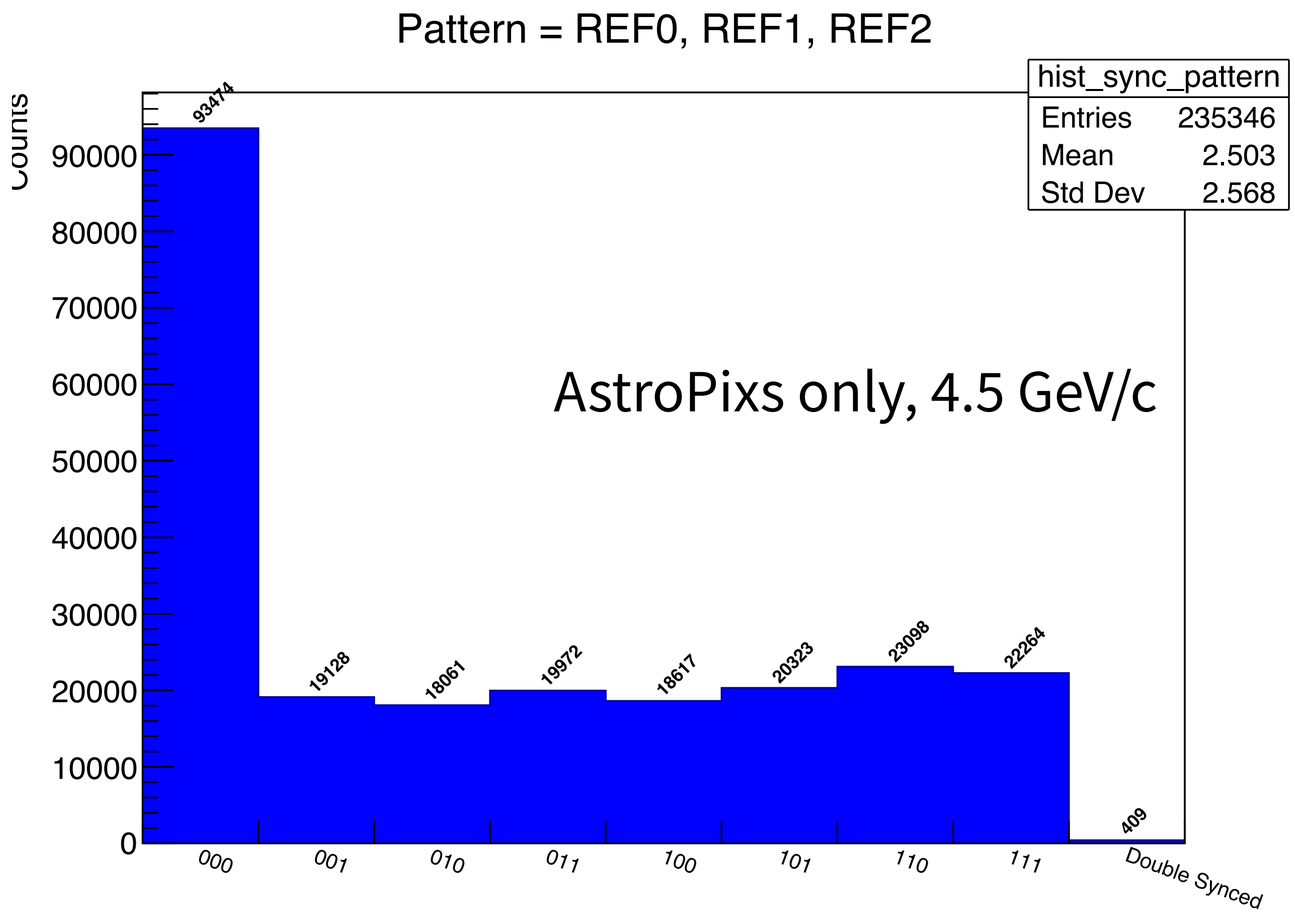
due to small acceptance?

or chip inefficiency?

Defined ‘Synced Pattern’



Chip Efficiency?



- let efficiency $\equiv x, y, z$
- let # of Events inside AstroPix $\equiv T$

$$(1-x)(1-y)z = 19128/T$$

$$(1-x)y(1-z) = 18061/T$$

$$\cdots$$

$$xy(1-z) = 23098/T$$

$$xyz = 22264/T$$

➡ $x = 0.532,\ y = 0.526,\ z = 0.514,\ T = 158{,}841$

‘000’ cases		Rejected by Inefficiency		Out of acceptance
93,474 Events	≈	17,124 Events $(1-x)(1-y)(1-z)T$	+	76,505 Events $235{,}346 - 158{,}841$

Multi-pixel injection

r5c10, r15c20:

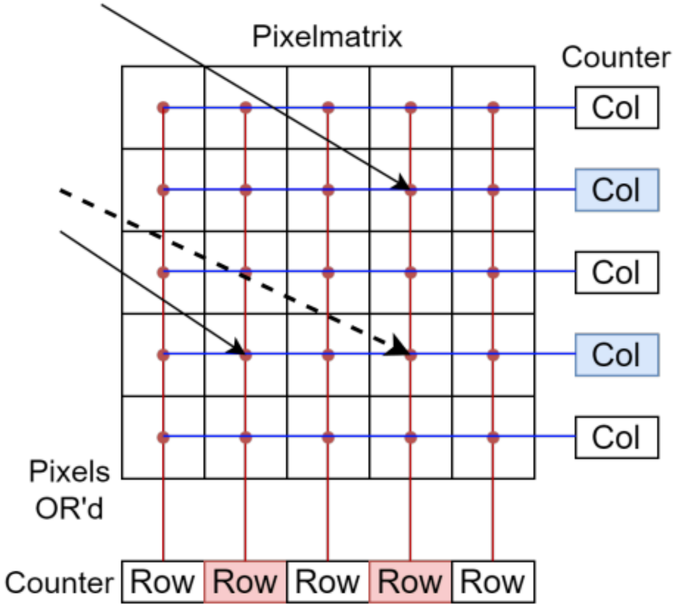
location	isCol	timestamp
5	0	178
15	0	178
10	1	178
20	1	178

r5c10, r15c10: (same col)

location	isCol	timestamp
5	0	58
15	0	58
10	1	57

r5c10, r5c20: (same row)

location	isCol	timestamp
10	1	52
5	0	52
20	1	52



When injecting multiple pixels in the same column (or row), **only one column (or row) is recorded**

➡Limitation of **AstroPix v3: Shared Buffer** for Same Column/Row

➡May not capture Multi-hit situations caused by EM showers

Summary

We established an integrated DAQ system using a global clock and validated its synchronization via position correlation

Plan1: In the July beam test@CERN PS, we plan to collect data from AstroPix, the calorimeter, and auxiliary detectors

Synchronization between multiple AstroPix chips allowed us to observe the macroscopic shape of EM showers

Plan2: We aim to measure shower shapes of electrons and pions using the data from the July beam test@CERN PS

By syncing triggered events with AstroPix data, we estimated the detection efficiency to be around 50%

Plan3: We also plan to take cosmic data to evaluate efficiency at low rates

Thanks to Test beam participants!

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