

ePIC
Barrel Imaging Calorimeter (BIC)
Parasitic Beam Test in Hall D

Maria Zurek for the test beam team

ePIC TIC Meeting, Sep 15, 2026

Beam Test Goals

March (low energy):

- Commission for the first time the readout with HGCROC.
- Test synchronization between AstroPix and HGCROC readout.
- Benchmark low-energy response (~ 0.5 GeV) within the nominal and August Beam-Test dynamic range, at different energy points.

August (high energy):

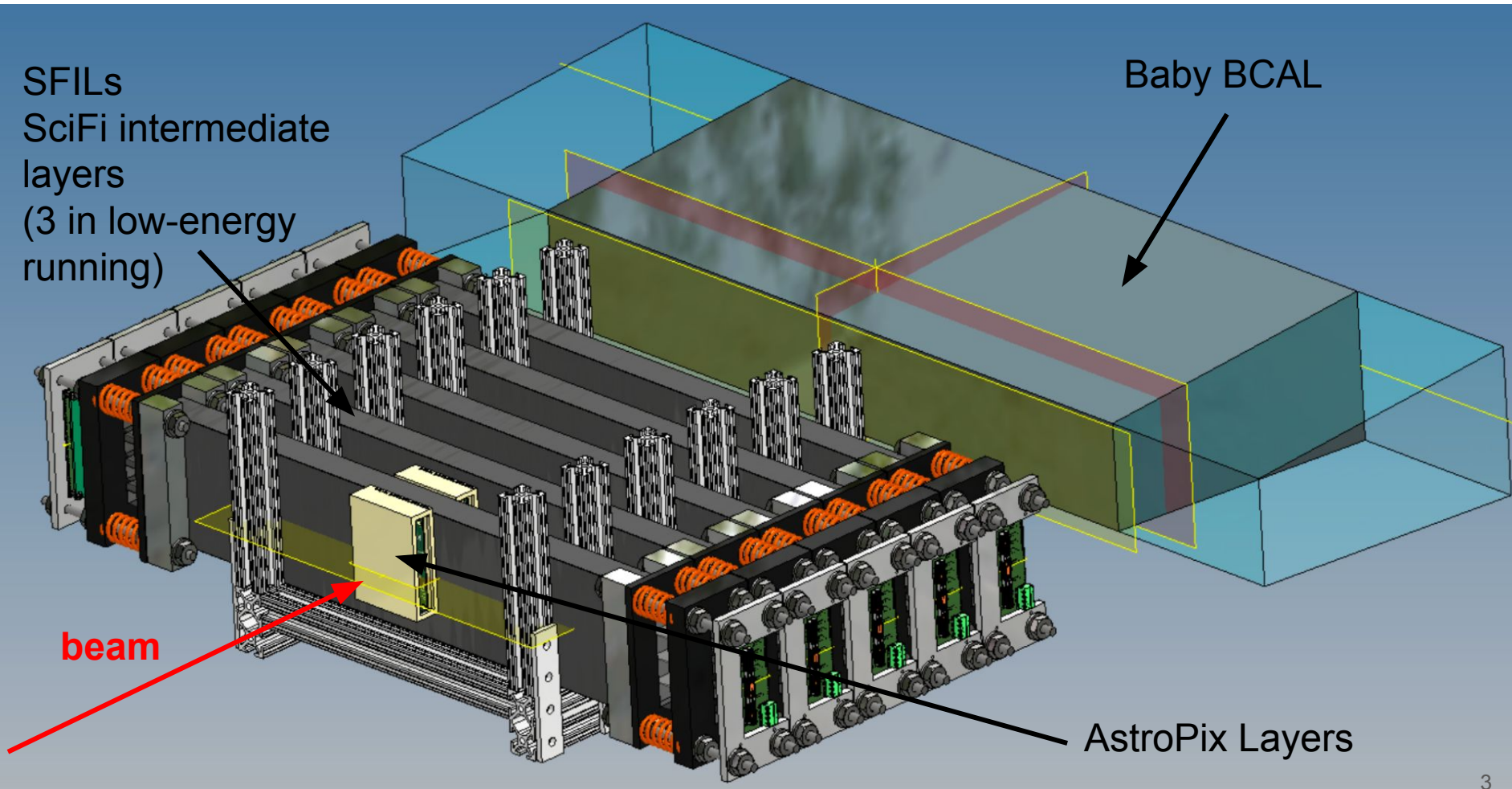
- Commission readout with summing boards for SFILs and Baby BCAL
- Benchmark energy and timing resolution within 3-6 GeV energy of positrons (Hall D) and 0.5~10 GeV electron-pion mixed beam (CERN) range with full HGCROC readout and show shower imaging event by event.

SFILs
SciFi intermediate
layers
(3 in low-energy
running)

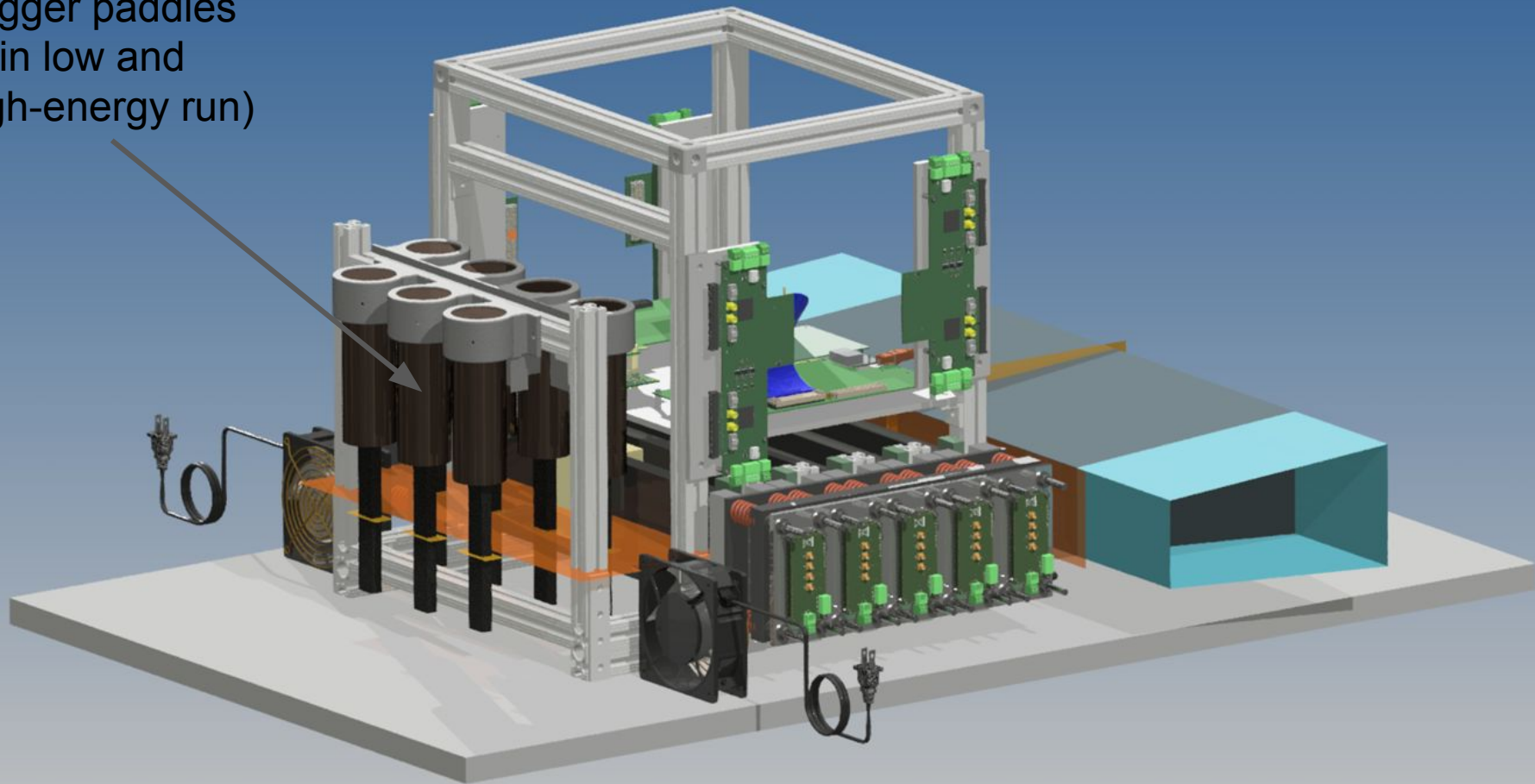
Baby BCAL

beam

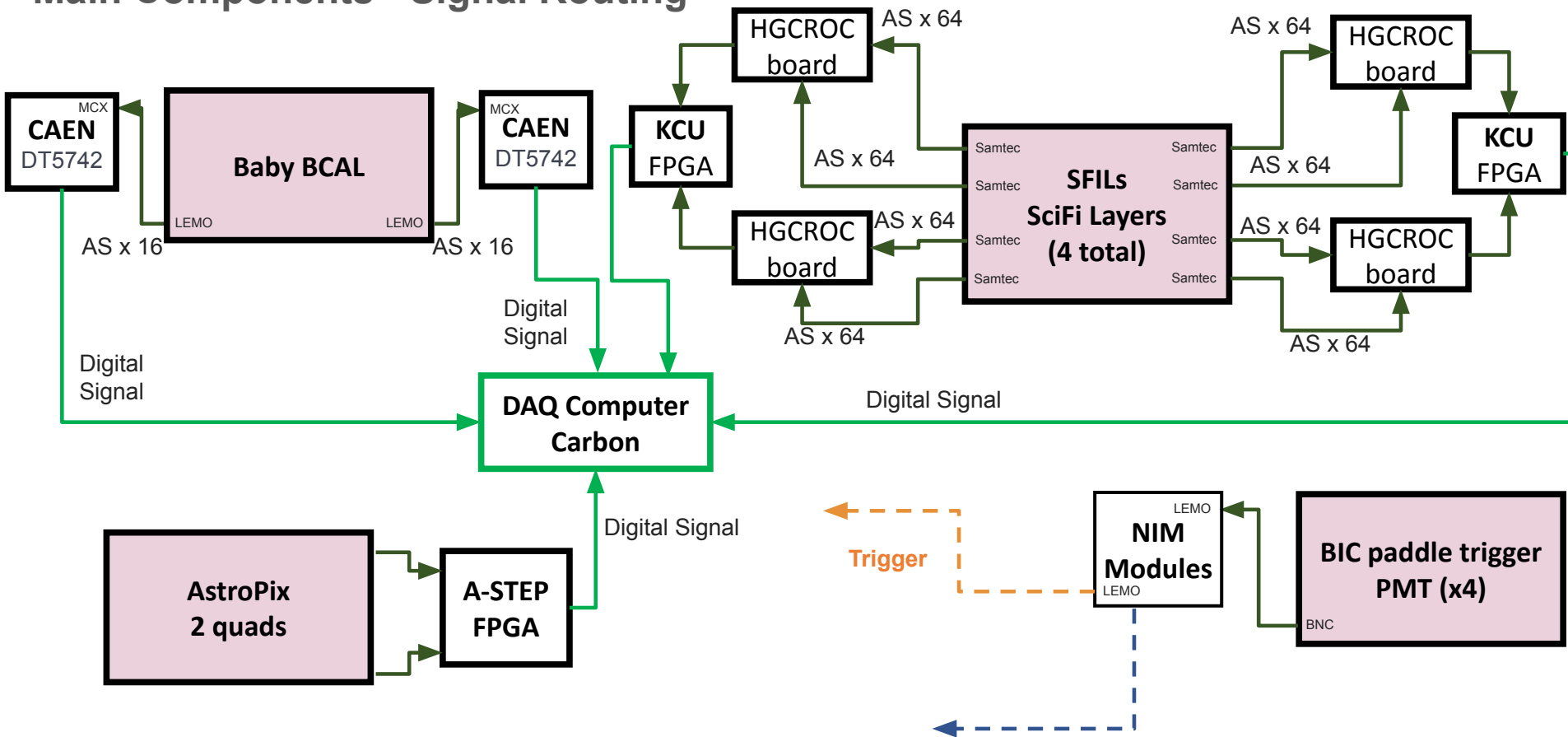
AstroPix Layers



Trigger paddles
(4 in low and
high-energy run)



Main Components - Signal Routing

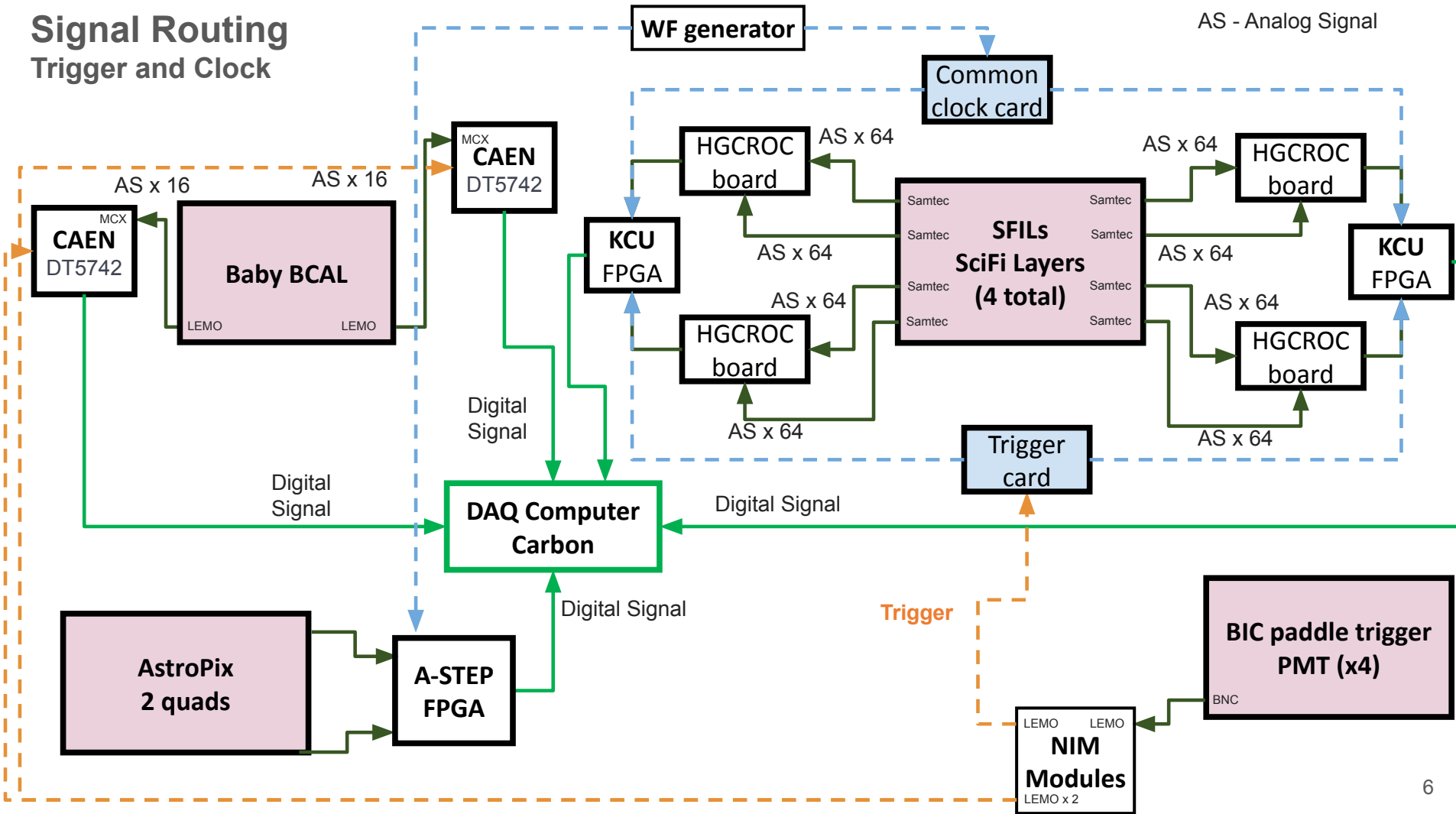


AS - Analog Signal
DS - Digital Signal

To be calibrated vs PS paddles

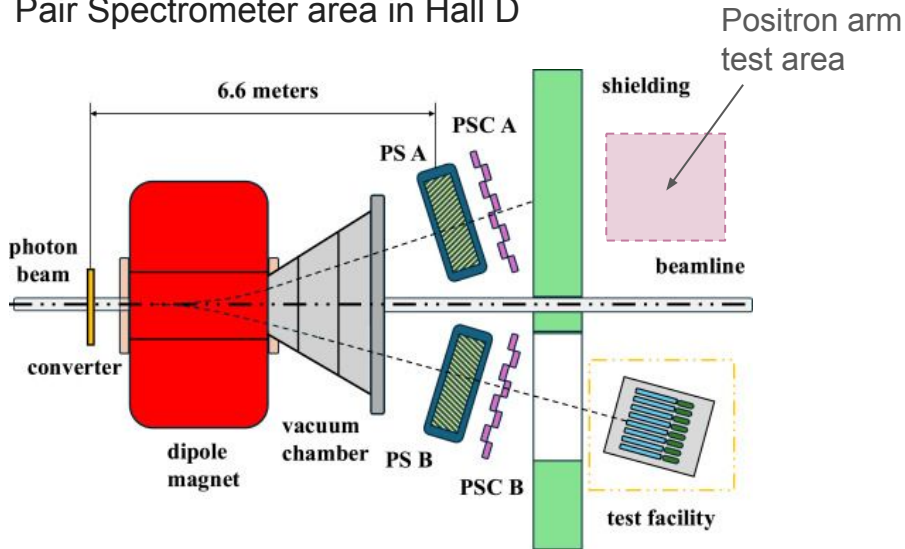
Signal Routing

Trigger and Clock



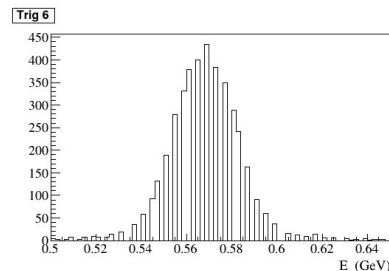
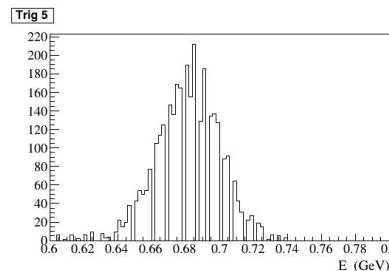
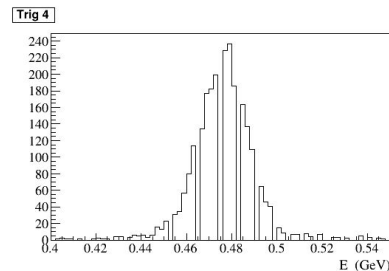
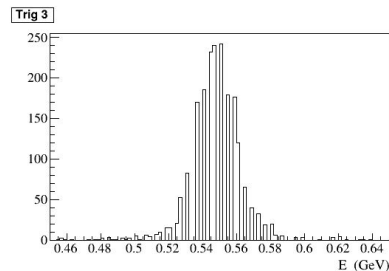
Running Conditions

Pair Spectrometer area in Hall D



Our trigger paddles energy ranges (low energy run)

In August we didn't get help is calibrating paddles.
No direct energy measurement, unfortunately.



Plots by Sasha Somov

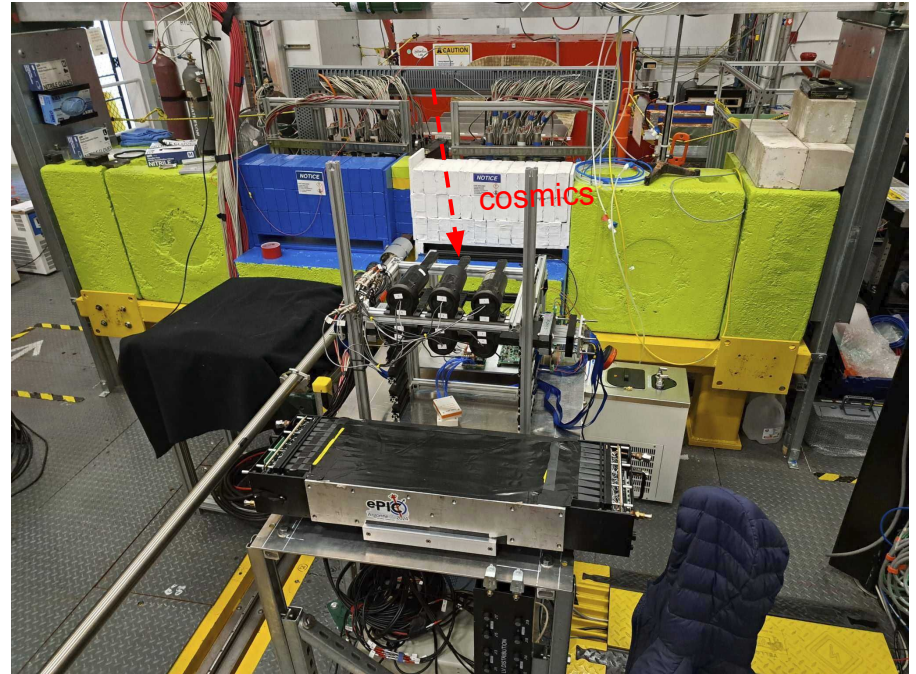
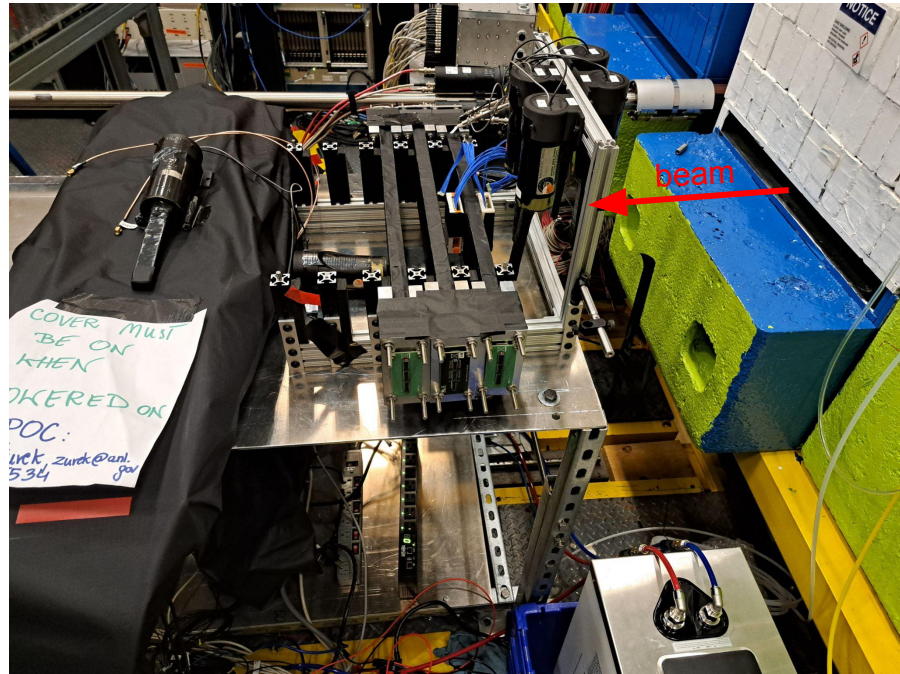
- Parasitic running with GlueX
- With lots of delays in CEBAF beam delivery to Hall D
 - May: No scheduled maintenance days, no planned opportunities for the hall entry
 - August: Significant beam down times + ended run after about 1.5 weeks
 - Relaying on remote operations and opportunistic entries with the personnel we had on site

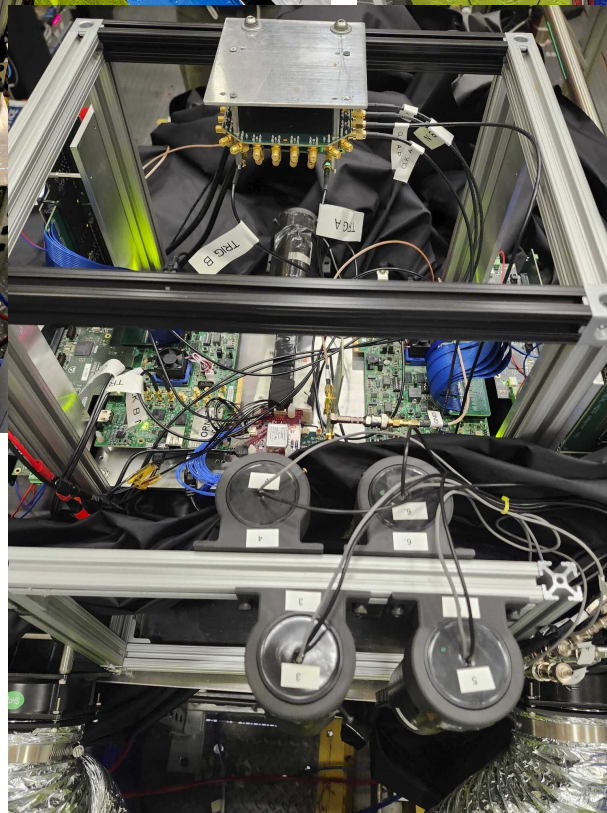
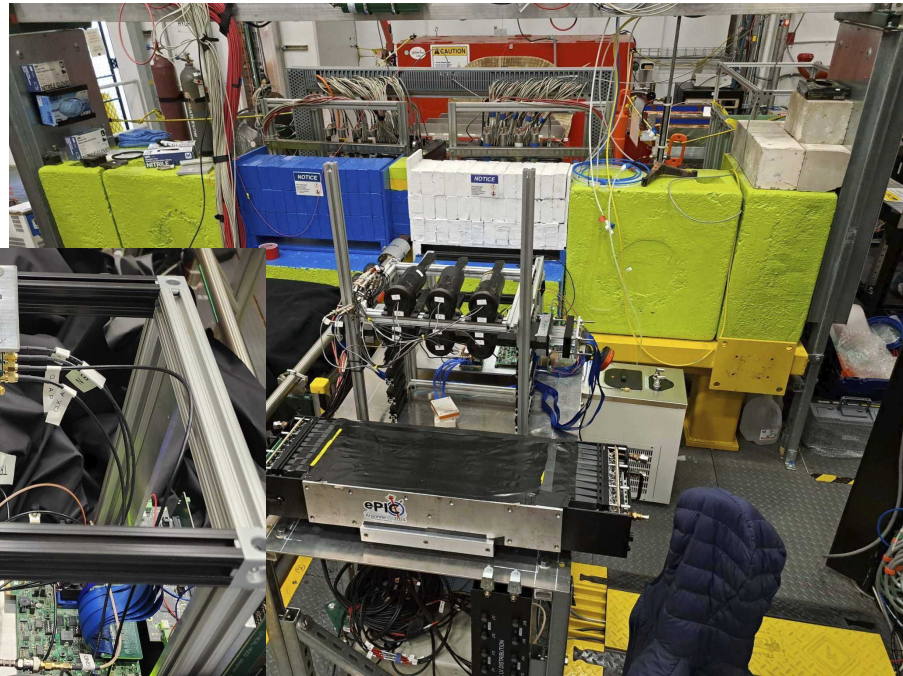
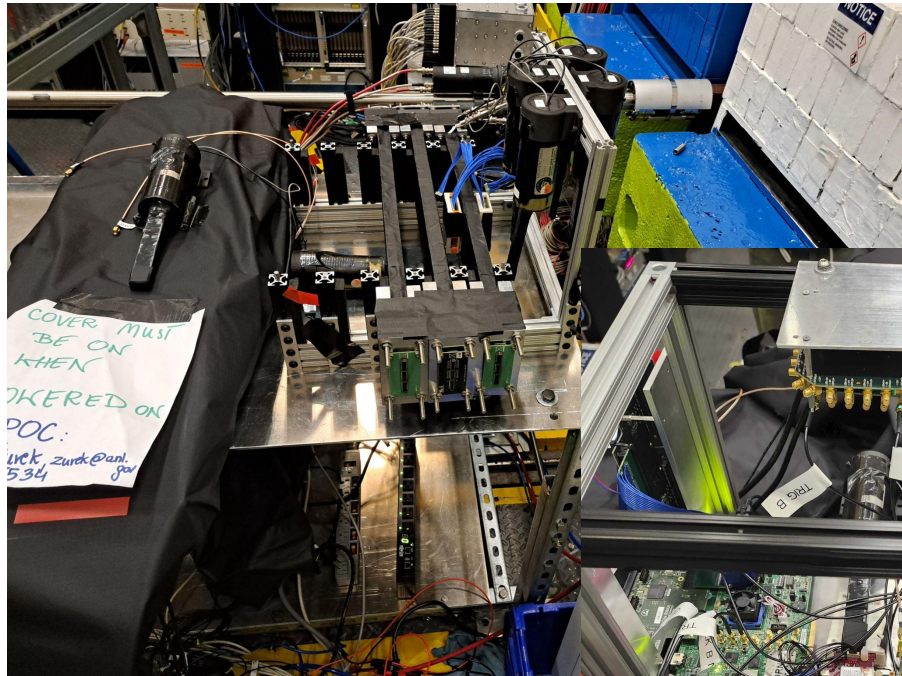
May

All 3 SFILs on single-SiPM boards, each end (north/south) on one KCU

Baby BCAL on CAEN

AstroPix on ASTEP FPGA - 2-quad chips layer 1 and 2





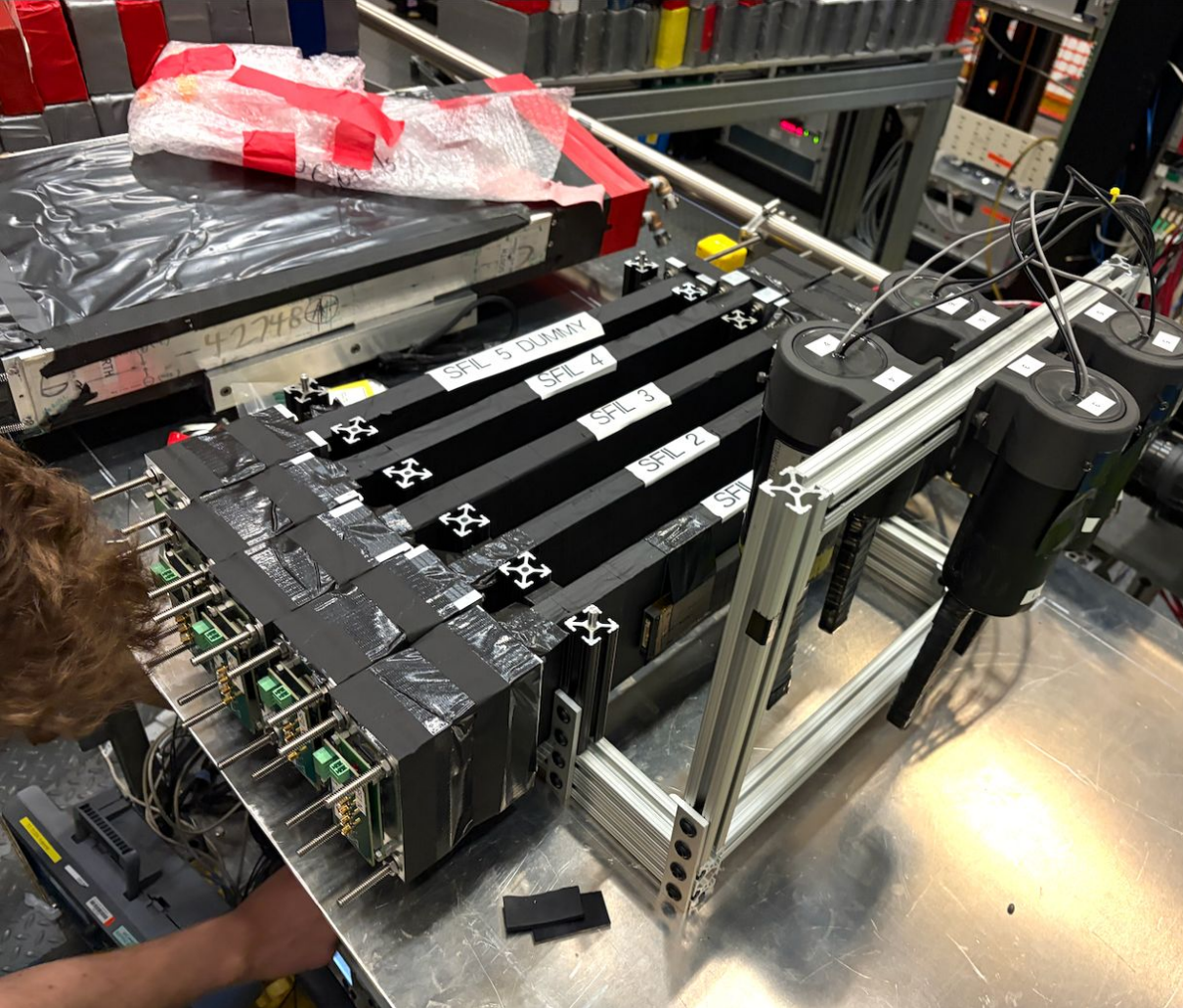
August

5 SFIL

- 5th on single-SiPM board (KCU1)
- 1-4 on summing boards (KCU0)
 - Week 1: North side on Active boards, South on Passive
 - Week 2: Both sides on Passive boards

Baby BCAL on CAEN one side and on URegina SiPM boards

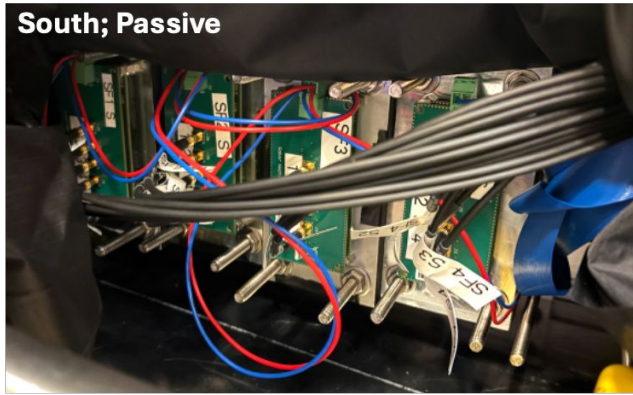
AstroPix on ASTEP FPGA - one 9 chip pcb



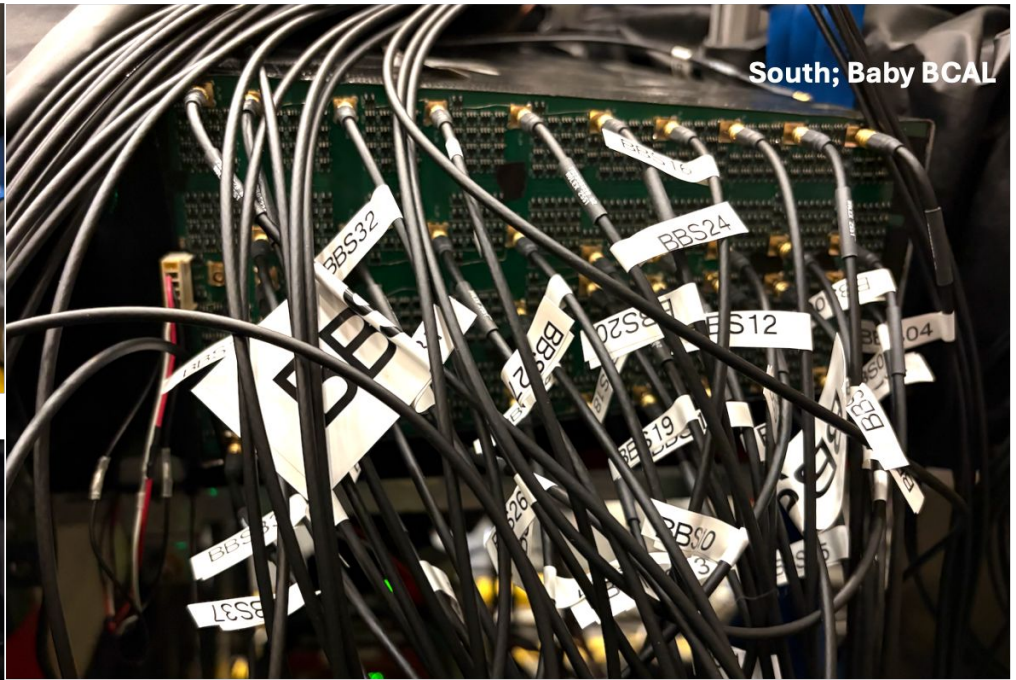
Week 1: 5th layer dummy
Week 2: All active SFILs

8 cm LGs
SFIL 5 South: no LGs

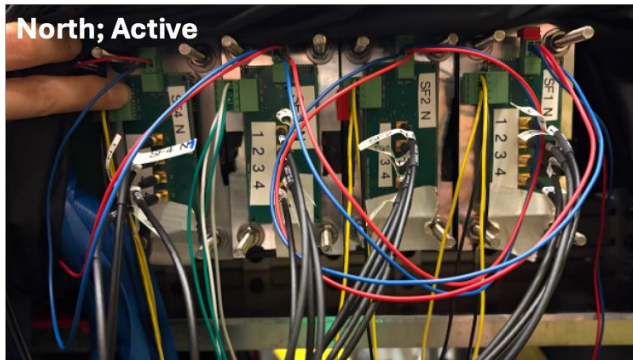
South; Passive

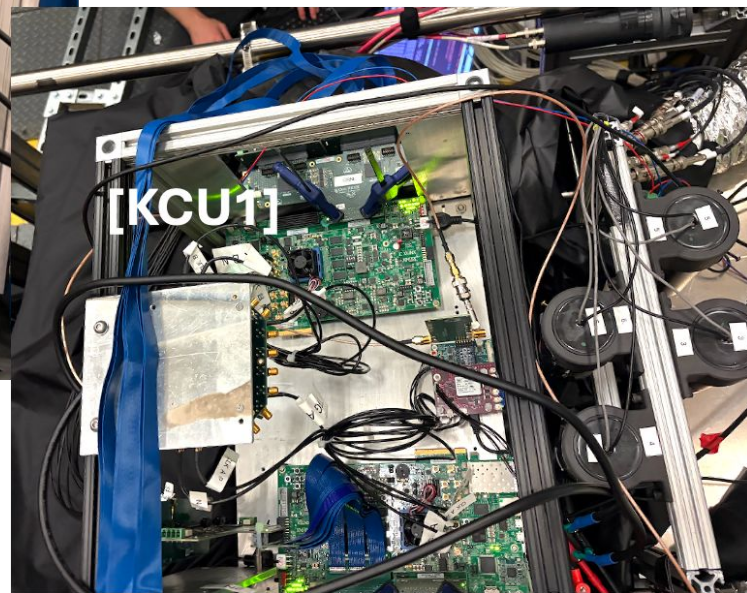
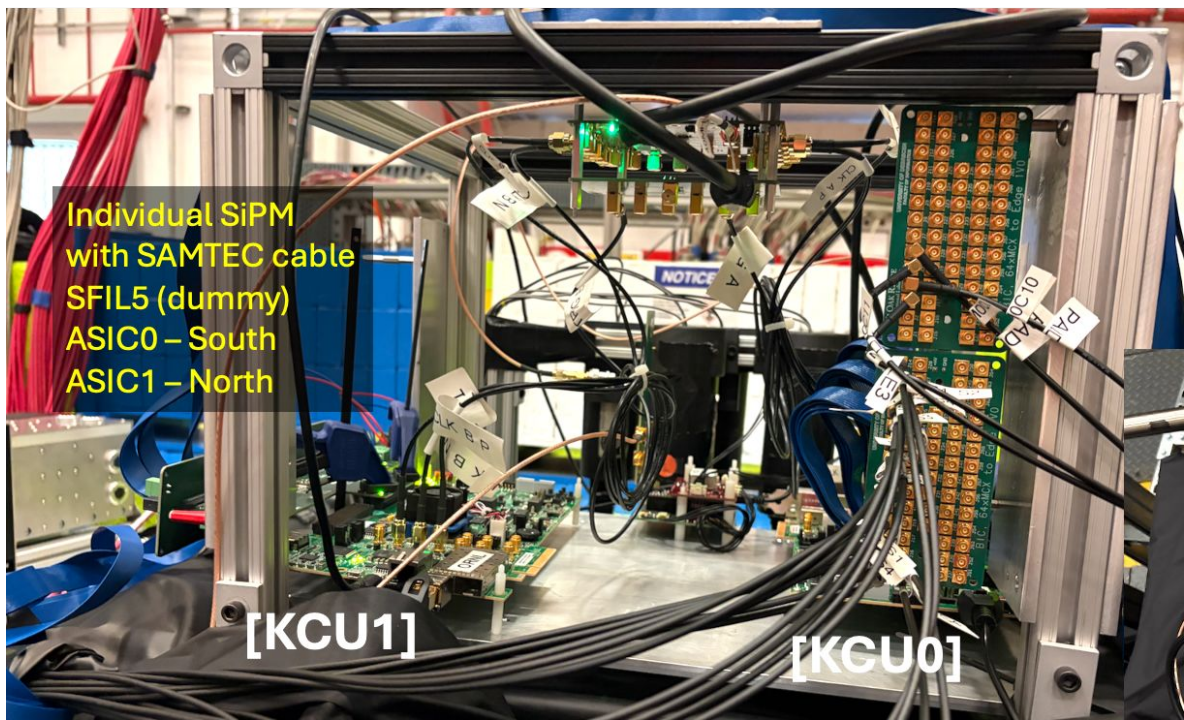


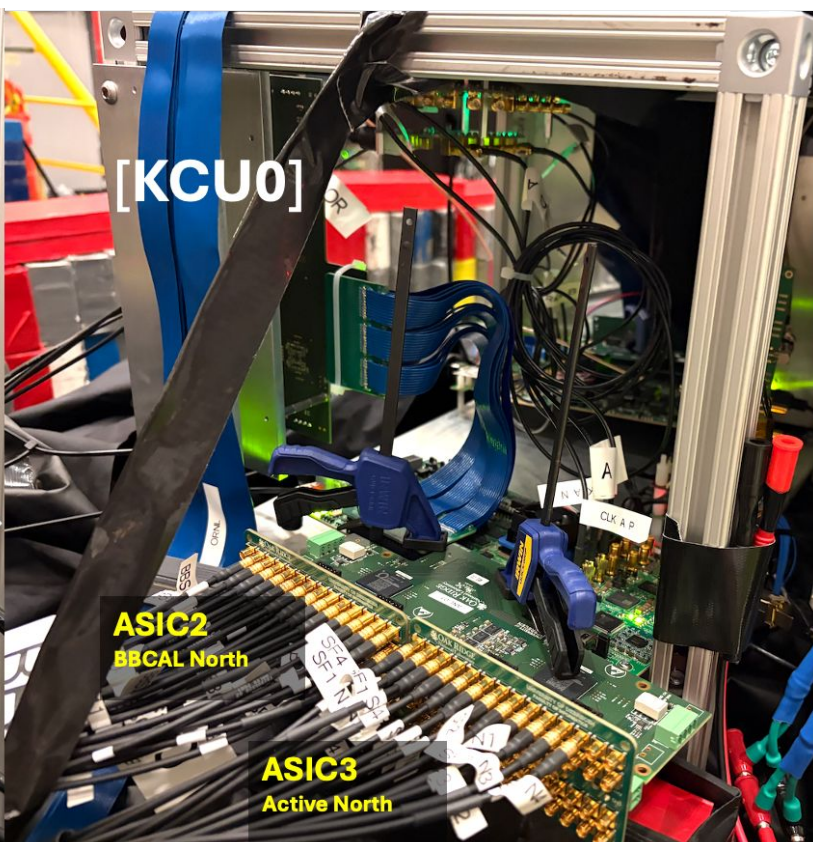
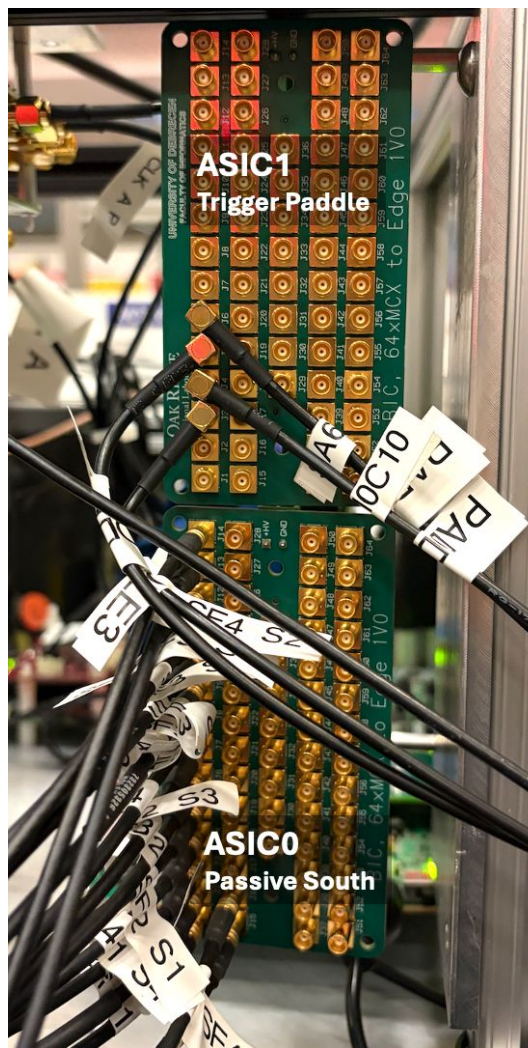
South; Baby BCAL



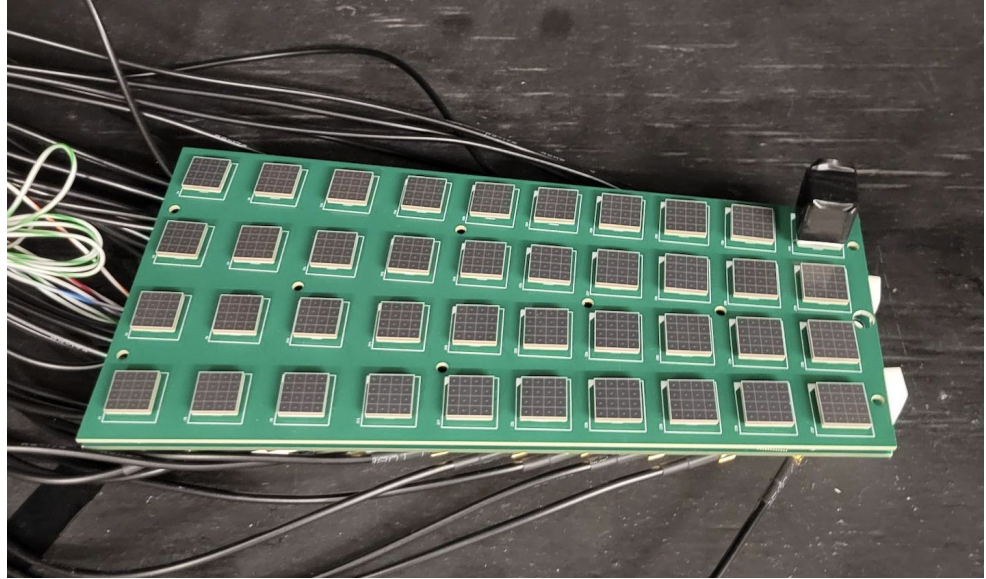
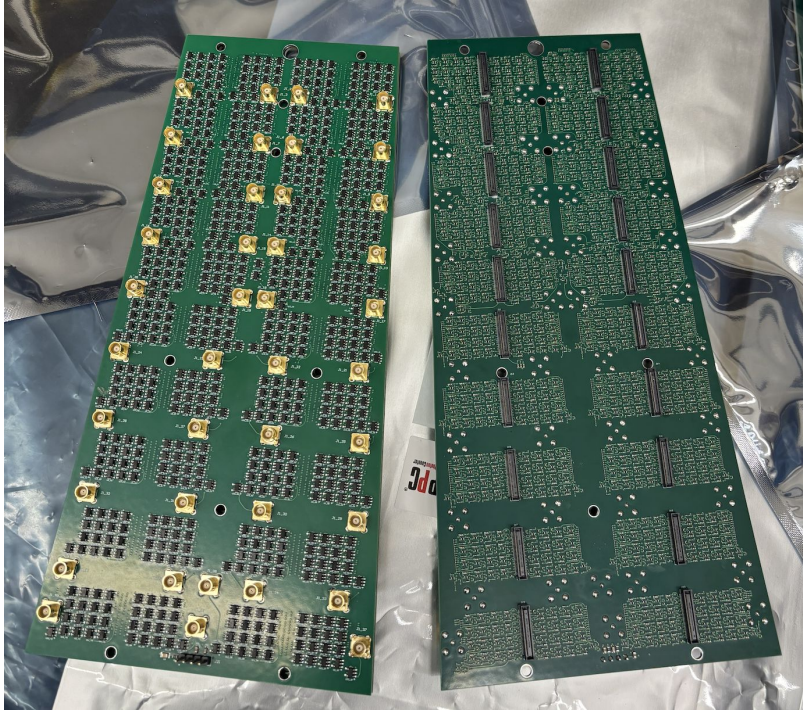
North; Active







New Baby BCAL boards (URegina)



Status of signals from the boards (week 1)

Passive Boards - Signals Visible on HGCROC

Paddles - Signals Visible on HGCROC

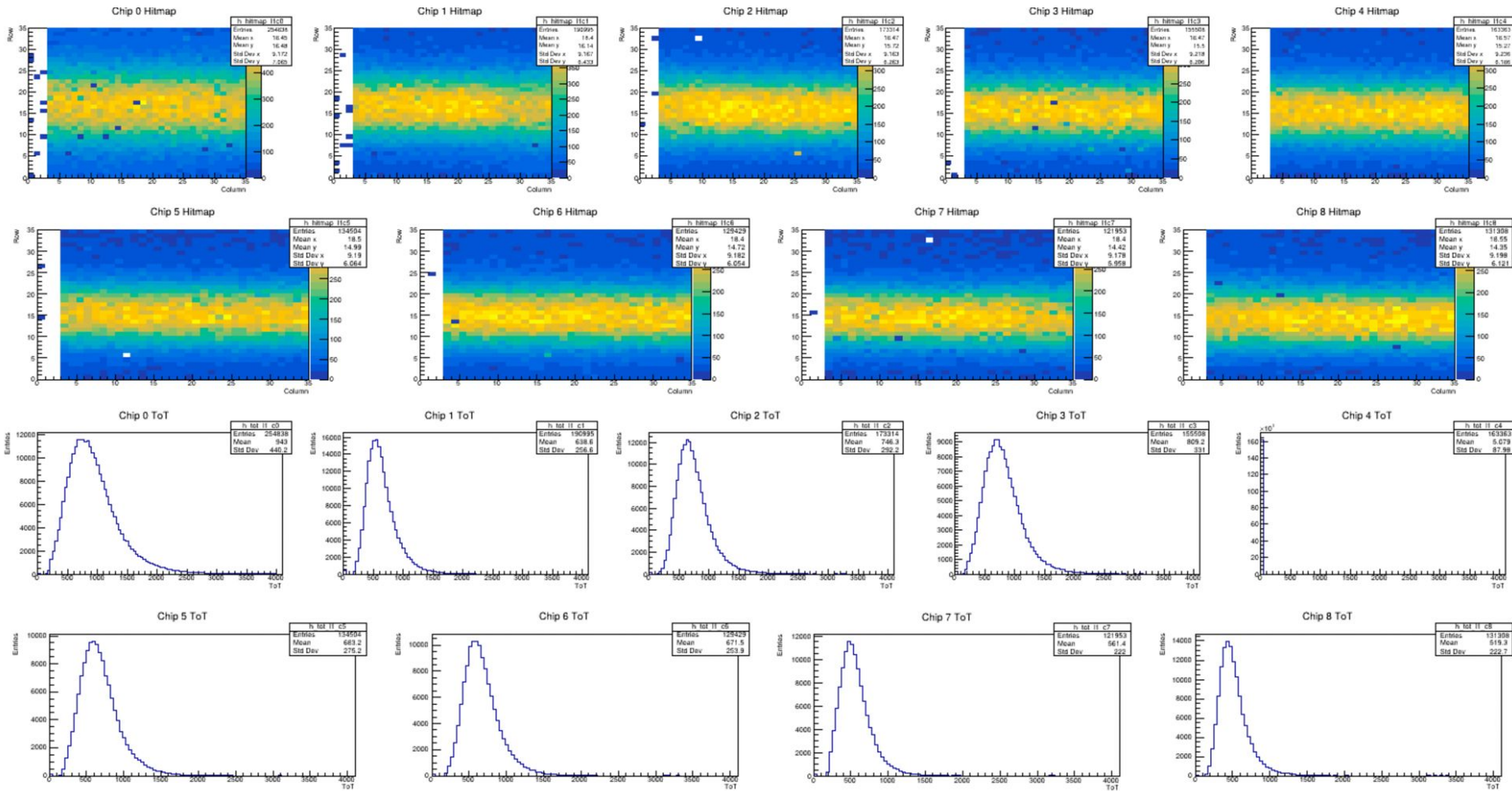
Baby BCAL - Noise only -> Added CAEN on South Side

Active Boards - No Signals -> Switched to Passive boards

Dummy boards - Individual SIPM read out, signals visible

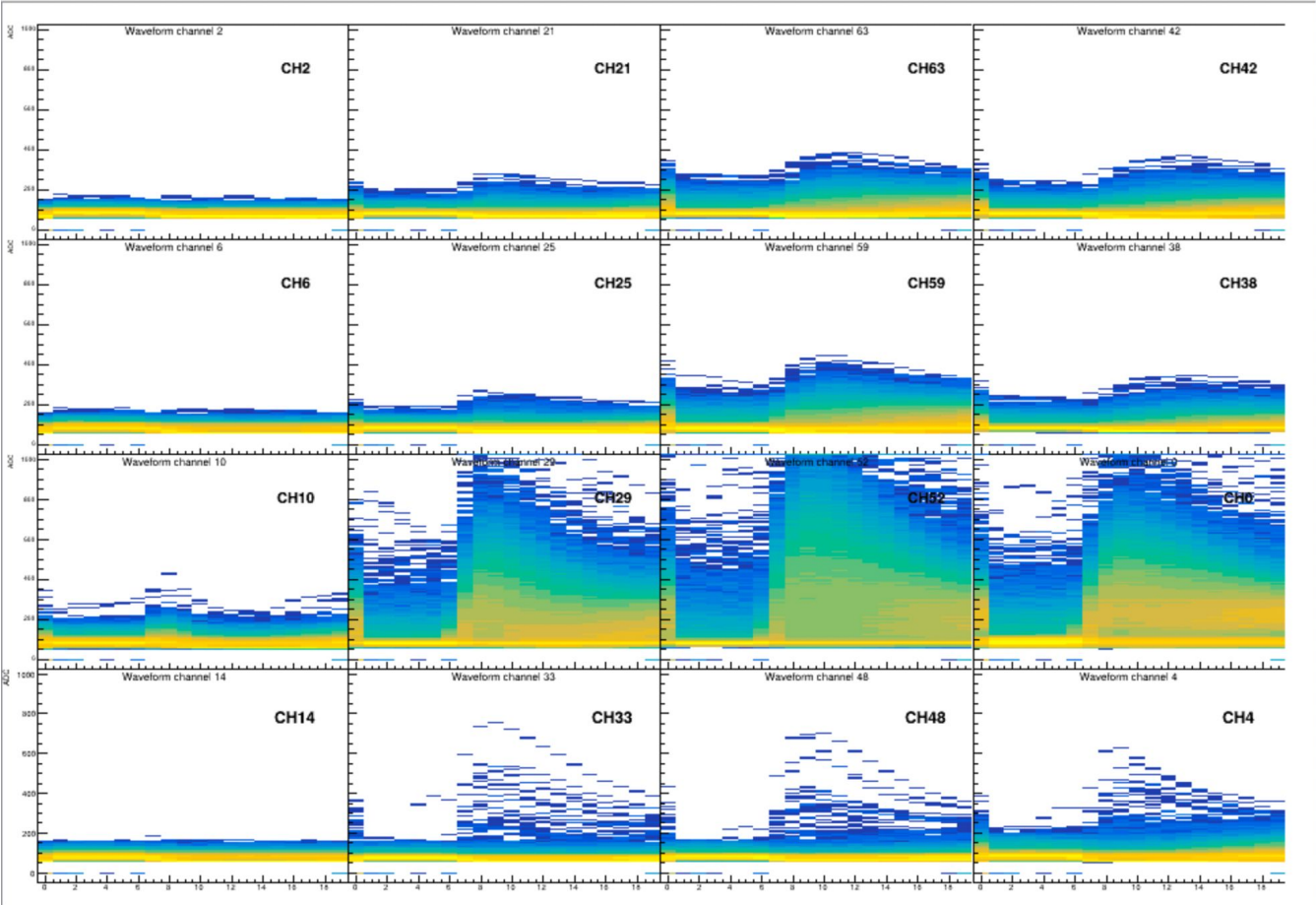
AstroPix - Signals visible

Astropix, 9-pcb board

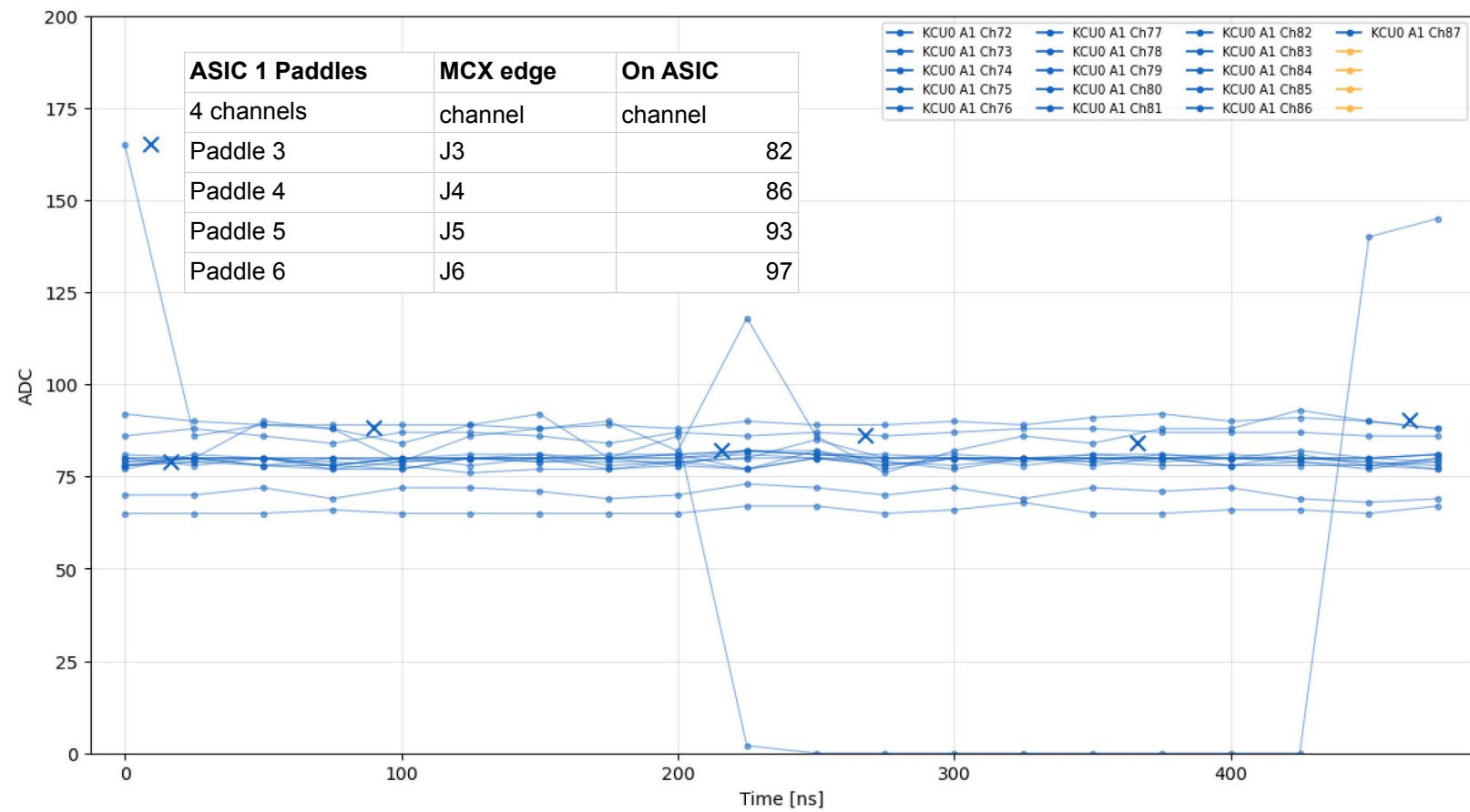


Passive boards

beam



Paddles



Analysis Strategy

Run log:

https://docs.google.com/spreadsheets/d/1A1WHqhv_xlBiuXv_9bHU0ouF-x_MO-xO1tQLETT0LFM/edit?gid=0#gid=0

- Bottom line we have one overnight run with 4.5 SFILs and Baby BCAL

Detailed discussions on analysis: <https://indico.bnl.gov/event/34143/>

Energy Proxy extraction (template fitting) and Synchronization focus now

Golden runs

Run Number	RCDQ Run Type	Date	Start Time	End Time	KCU0	KCU1	AstroPix	CAEN	Settings	KCU0 N Events	KCU1 N Events	AstroPix N Events	CAEN N Events	Hall D average Beam Current, PS field, Radiator	Notes
3060	beam	08-13-2026	16:16	20:17	ON	OFF	ON	ON	SiPM HV: 41.70 V SiPM I: 119 μ A T1: NO DATA T2: NO DATA	12398 97	1	1423	91099 06	<I> = 92.92 nA PS field: 1.662 T (~300A setting) Rad: NO RADIATOR PSrad: HOME (out of beam) @ 0.000 mm TPOL: B (Be ~75 μ m?) @ 70.000 mm	Run with SFIL1-4 North and South IN, KCU1 was taken out (no SFIL 5)
3061	beam	08-13-2026	20:31	20:32	ON	OFF	OFF	ON	SiPM HV: 41.70 V SiPM I: 125 μ A T1: NO DATA T2: NO DATA	121	1	1	1000	<I> = 0.29 nA PS field: 1.662 T (~300A setting) Rad: JD80-213 80um 45/135 deg PSrad: HOME (out of beam) @ 0.000 mm TPOL: B (Be ~75 μ m?) @ 70.000 mm	Run with SFIL1-4 North and South IN, KCU1 was taken out (no SFIL 5)
3062	beam	08-13-2026	23:44	00:09 (8/14)	ON	ON	ON	ON	SiPM HV: 41.70 V SiPM I: 343 μ A T1: NO DATA T2: NO DATA	40459 3	16290 5	12148	15074 61	<I> = 191.11 nA PS field: 1.662 T (~300A setting) Rad: JD80-213 80um 45/135 deg PSrad: HOME (out of beam) @ 0.000 mm TPOL: B (Be ~75 μ m?) @ 70.000 mm	Run with SFIL1-4 North and South IN, and half of SFIL 5

Golden runs

Run Number	RCDA Q Run Type	Date	Start Time	End Time	KCU0	KCU1	AstroPix	CAEN	Settings	KCU0 N Events	KCU1 N Events	AstroPix N Events	CAEN N Events	Hall D average Beam Current, PS field, Radiator	Notes
3063	beam	08-14-2026	0:09	0:11	ON	ON	ON	ON	SiPM HV: 41.70 V SiPM I: 326 μ A T1: NO DATA T2: NO DATA	25298	10514	713	103188	<I> = 145.71 nA PS field: 1.662 T (~300A setting) Rad: JD80-213 80um 45/135 deg PSrad: HOME (out of beam) @ 0.000 mm TPOL: B (Be ~75 μ m?) @ 70.000 mm	Run with SFIL1-4 North and South IN, and half of SFIL 5
3064	beam	08-14-2026	0:12	12:30	ON	ON	ON	ON	SiPM HV: 41.70 V SiPM I: 164 μ A T1: NO DATA T2: NO DATA	7450472	3035004	7466	28732556	<I> = 127.85 nA PS field: 1.662 T (~300A setting) Rad: UNDEFINED PSrad: HOME (out of beam) @ 0.000 mm TPOL: C (Be ~750 μ m?) @ 101.667 mm	Low current TAC run began during this run, Run with SFIL1-4 North and South IN, and half of SFIL 5

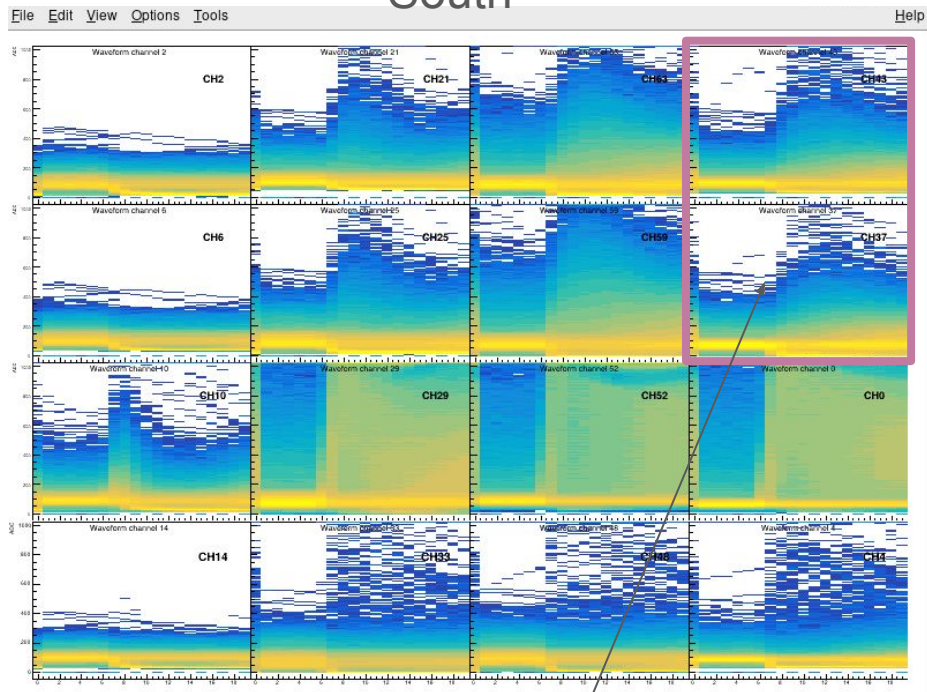
Lessons Learned

We have challenges with:

- Active summing boards (Baby BCAL and SFILs), need more look on the bench
- We have observed issues with HGCROC channels (half of channels, i.e. 36-group channels were having very high pedestal, or were not responding)
 - Not clear what was the reason: grounding? MCX edge boards? Problem with boards itself?
- Confirmation of the mapping -> see Bobae's slides

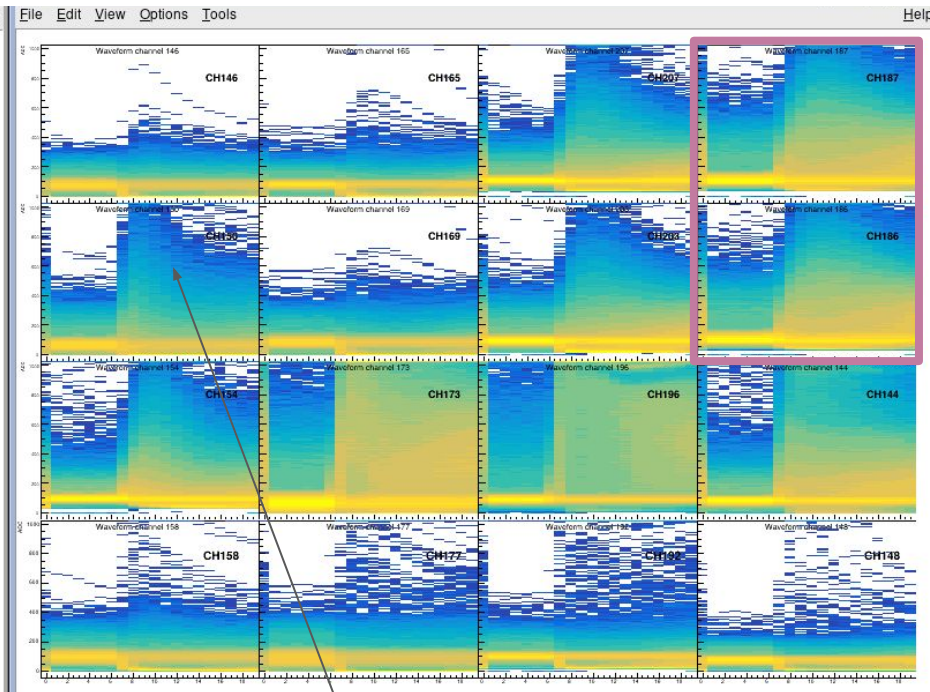
SFILs South and North

South



Those two look smaller on South wrt North.
Maybe the edge board. They are on J63 and
J64, and others on J1-J15

North



Norbert is pointing that ch150 might
be swapped with 165(?)

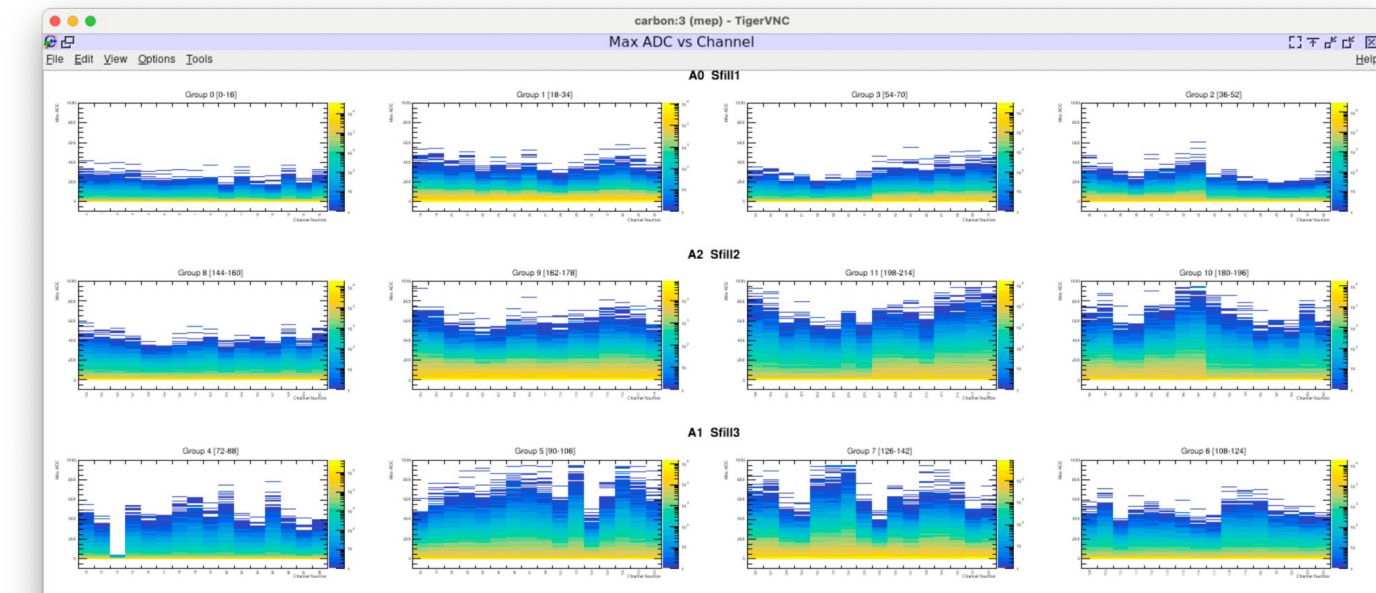
Backup

First look into the data

HGCROC - SFILs with beam

Akshaya Vijay (online monitoring)

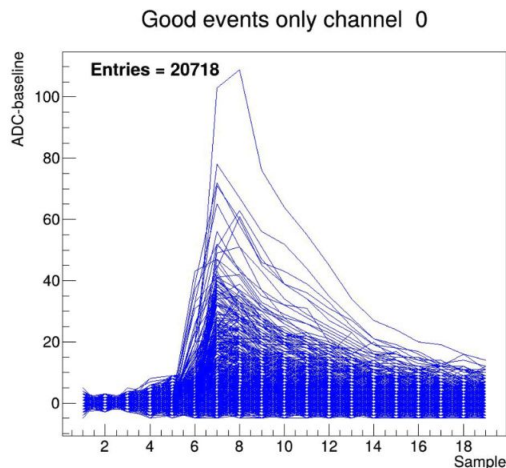
beam



First look into the data

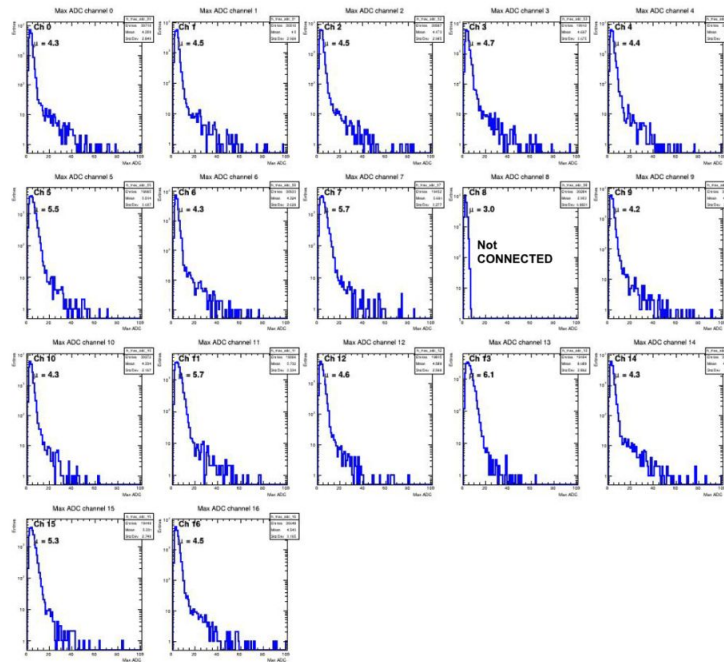
HGCROC - SFILs with cosmics (beam geometry trigger paddles)

Run # : 530,597,636,685,686,687



Events quality cut:

- a positive pulse amplitude (max ADC ≥ 0),
- no large negative ADC (min ADC ≥ -5),
- and a pulse peak occurring within ($5 \leq s_max \leq 17$).



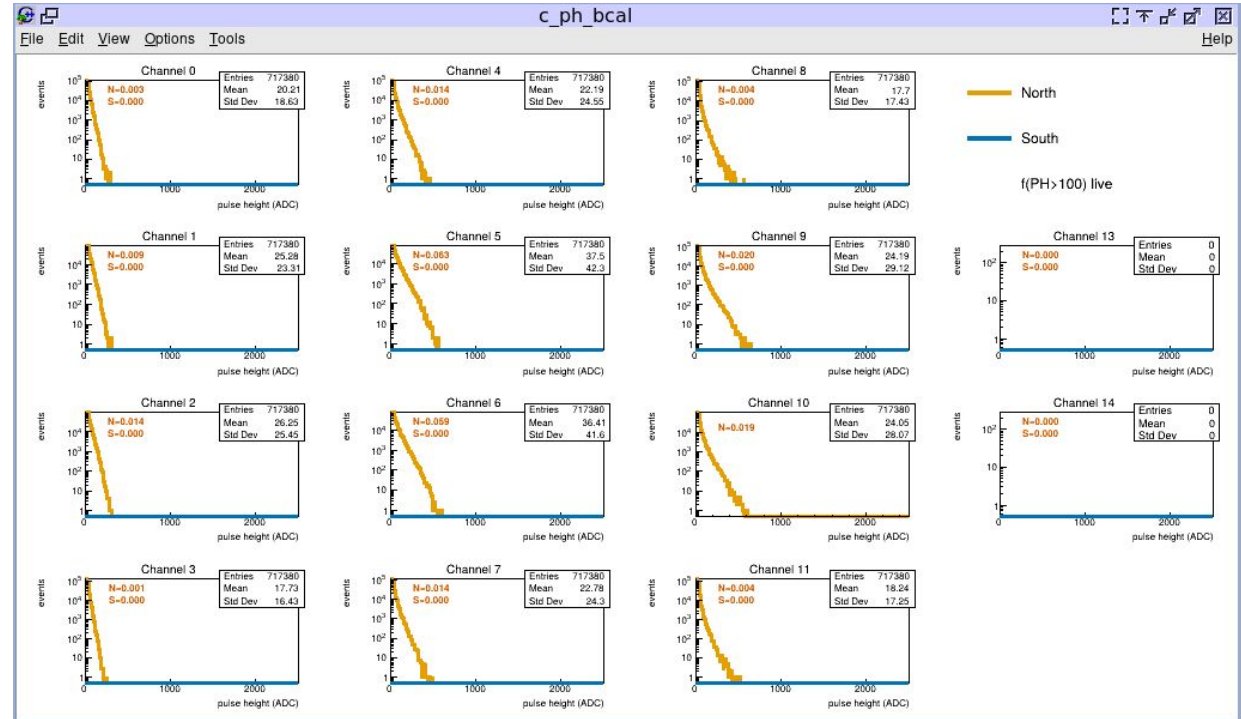
1 SiPM array example, SFIL 1, close to the trigger paddle

First look into the data

Baby BCAL

Henry Klest (online monitoring)

beam

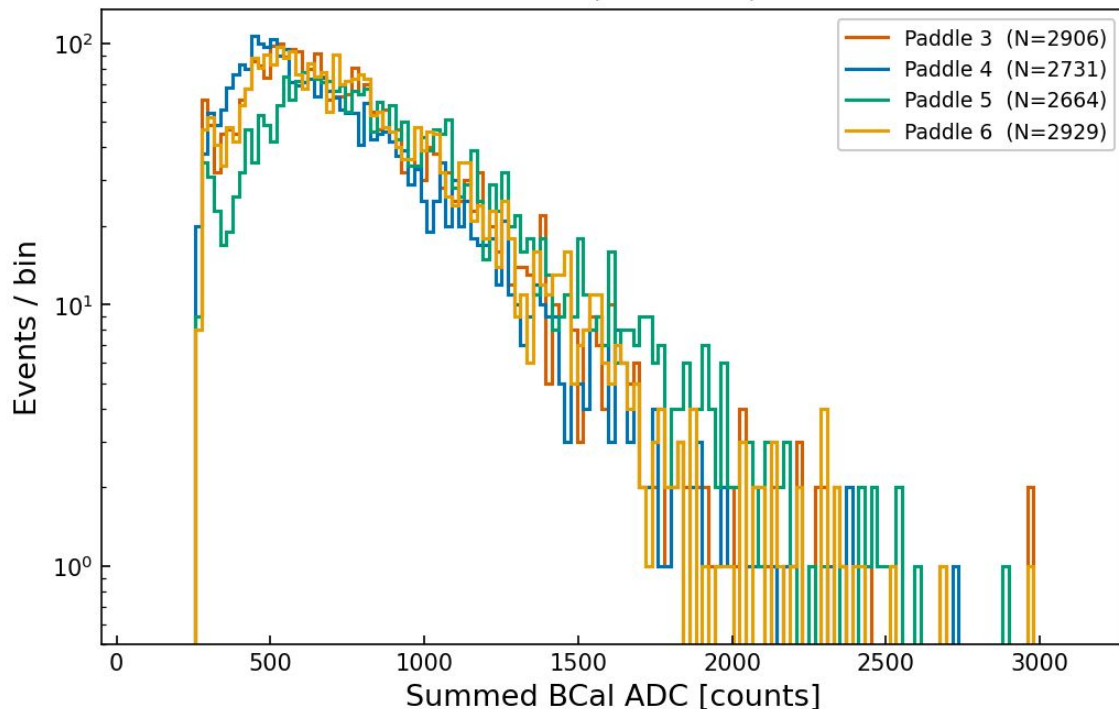


First look into the data

Baby BCAL

Henry Klest

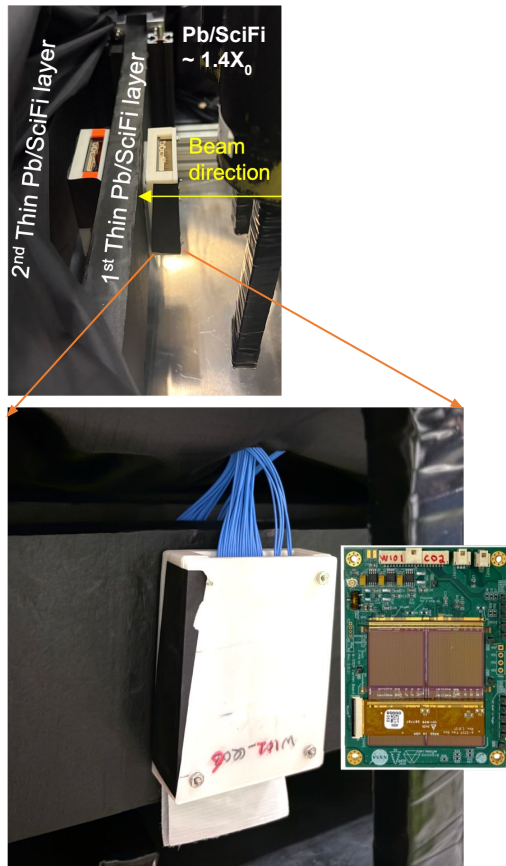
BCal Summed ADC — All Paddles Overlay
Run 596 (PS 0.563 T)



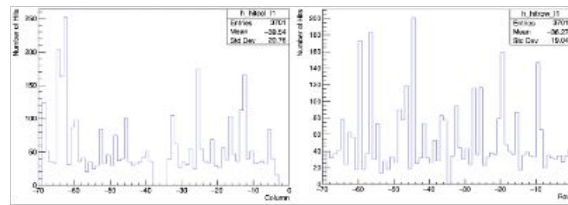
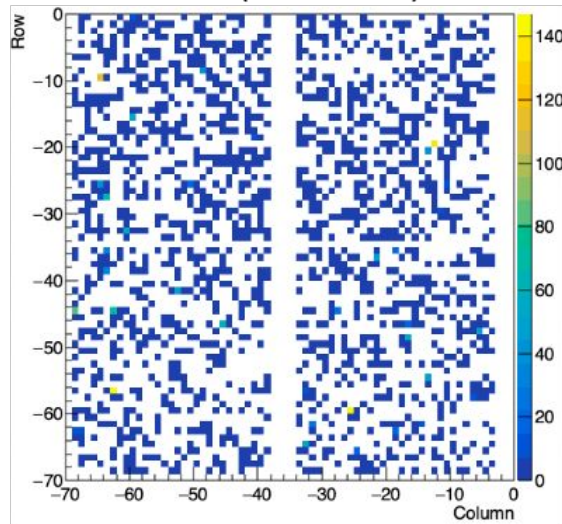
Trig 3	0.55 ± 0.01 GeV
Trig 4	0.48 ± 0.01 GeV
Trig 5	0.68 ± 0.02 GeV
Trig 6	0.57 ± 0.01 GeV

First look into the data

AstroPix: 1st layer of Astropix quad-chip



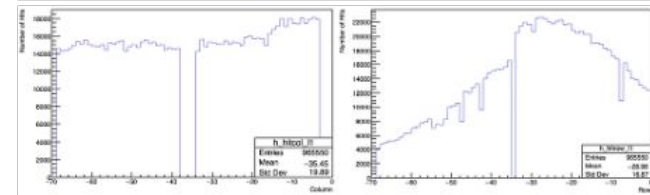
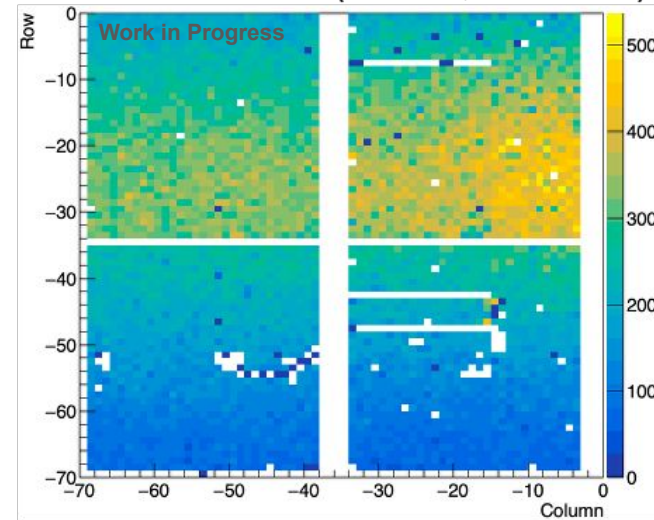
No beam (cosmic run)



Bobae Kim (online monitoring)

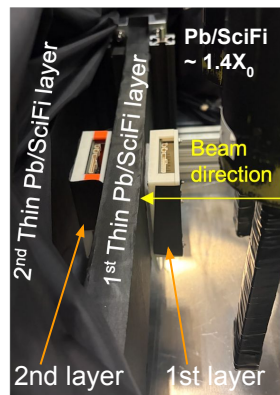
- Two Quad-chips + A-STEP (Astropix multichip/multilayer prototype readout system)
 - confirmed the stable operation up to ~ 1.2 kHz beam rate at KEK beam test last year; **promising stable operation under Hall D beam conditions.**

Run1318 – 1324 (Total 61,416 events)



First look into the data

AstroPix: Two-layer of Astropix quad-chips

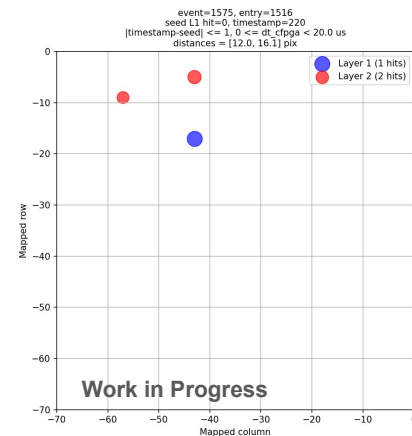
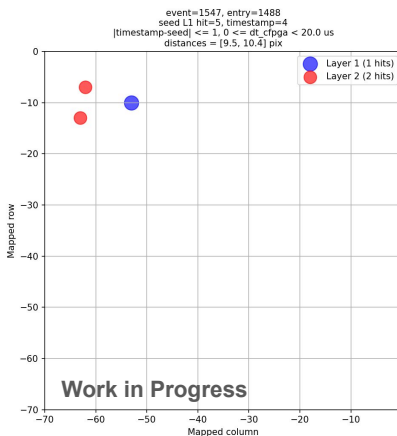
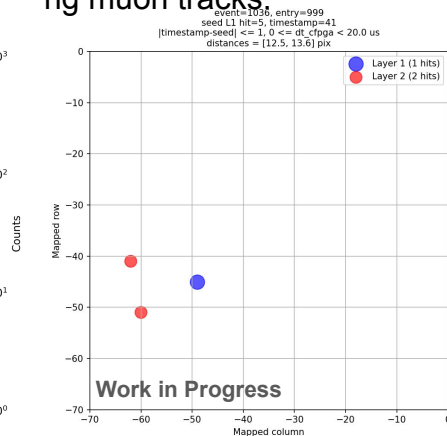
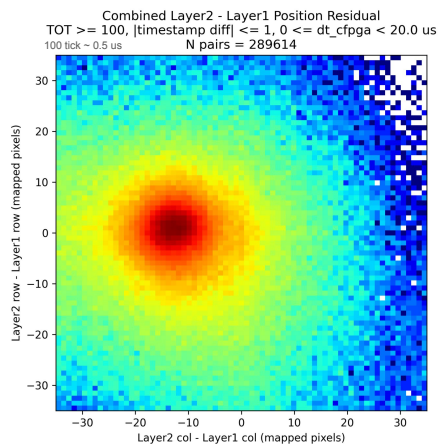


Applied cut

- Selected Layer-1 seed hits with $\text{ToT} > 0.5 \mu\text{s}$ (100 tick) due to reduce noise
- Matched Layer-2 hits with $|\Delta\text{AstroPix timestamp}| \leq 1$ (sharing AstroPix timestamp clock among all AstroPix layers)
- Required $0 \leq \Delta\text{FPGA timestamp} < 20 \mu\text{s}$

Example position residual plot and event display plots

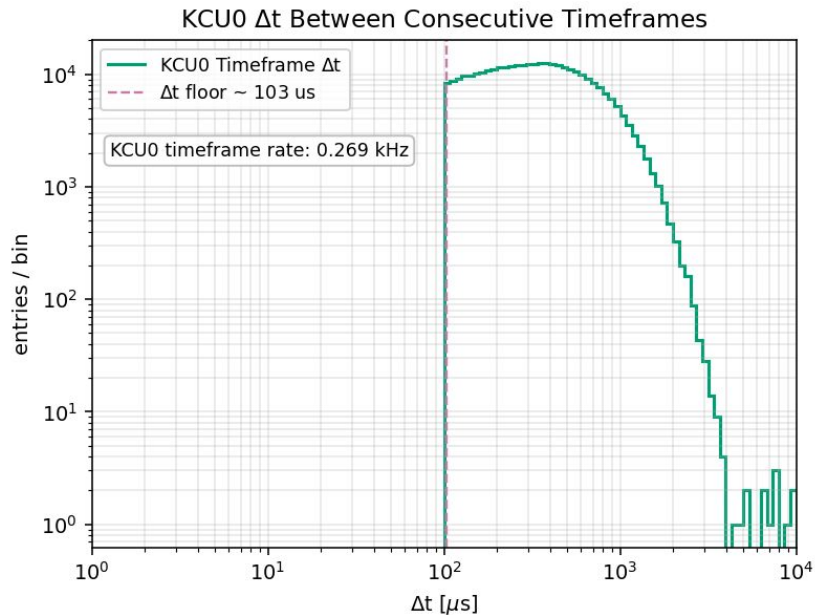
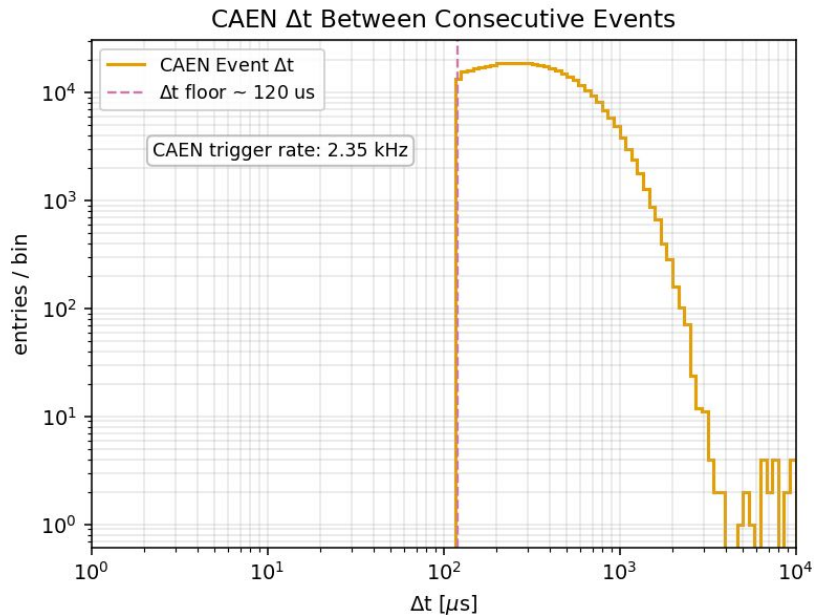
- The observed **~6 mm offset of col** is attributed to both the parasitic beam trajectory and the relative misalignment of the AstroPix layers.
 - The relative misalignment between the AstroPix layers can be corrected through software alignment using muon tracks.



First look into the data

Synchronization

Operating in a region with non-negligible deadtime, so cannot match events using pure event number



First look into the data

Synchronization

Operating in a region with non-negligible deadtime, so cannot match events using pure event number

Information available to assist with cross-system matching:

- CAEN, KCU0, KCU1, AstroPix FPGA timestamps
- “Real-time” clock corresponding to event arrival time at PC (large jitter)
- Precise 10 Hz pulser triggering CAEN and KCU readout (empty event signature)
- Energy deposit patterns and total deposited energy (as cross-checks)

Need to do a fit of “shifting” and “squeezing” event timelines to maximize the number of matching events, output from the fit is ratio of FPGA clock speeds and initial run-start offsets

First look into the data

Synchronization

Candidate matched event display, shower in SFIL and tail in Baby BCal

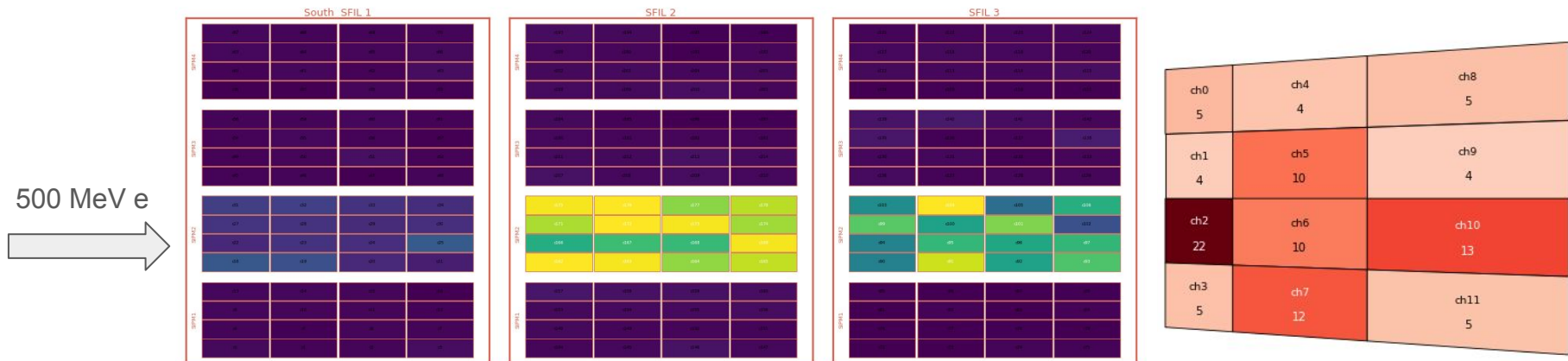


SFIL SiPMs are summed together in this display, but all 16 sub-array channels are available

First look into the data

Synchronization

Candidate matched event display, shower in SFIL and tail in Baby BCal



First look into the data

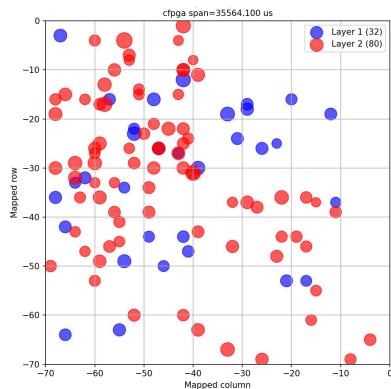
AstroPix Sync

- Key Considerations for Synchronization

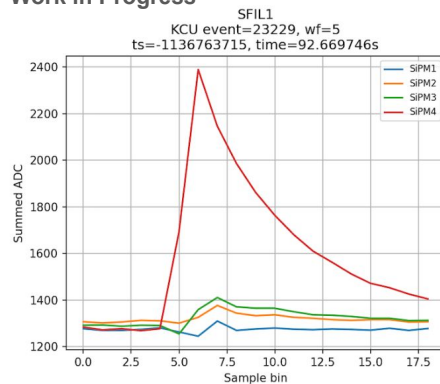
- FPGA timestamp clocks: 160 MHz for H2GCROC (6.25 ns/tick) and 40 MHz for AstroPix (25 ns/tick)
- Common 40 MHz external clock distributed to both independent DAQ systems
- Different readout architectures
 - SFIL + H2GCROC: external-triggered event-based readout
 - AstroPix: self-triggered streaming readout
- Time alignment between DAQ systems
 - FPGA timestamp offset
 - Trigger and buffering latency differences

- FPGA timestamps converted to acquisition time and validated against the overall data-taking duration
- Example plots: Candidate AstroPix event block (~35 ms) and a selected KCU0 waveform from three SFILs
- Ongoing work: timing corrections for true event coincidence matching

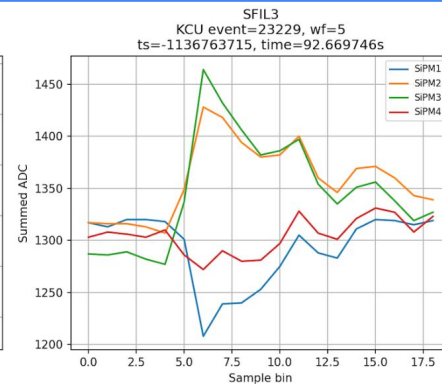
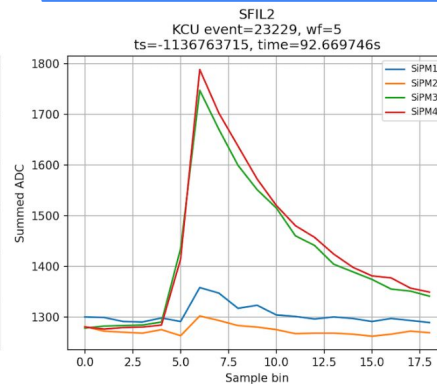
Work in Progress



Work in Progress

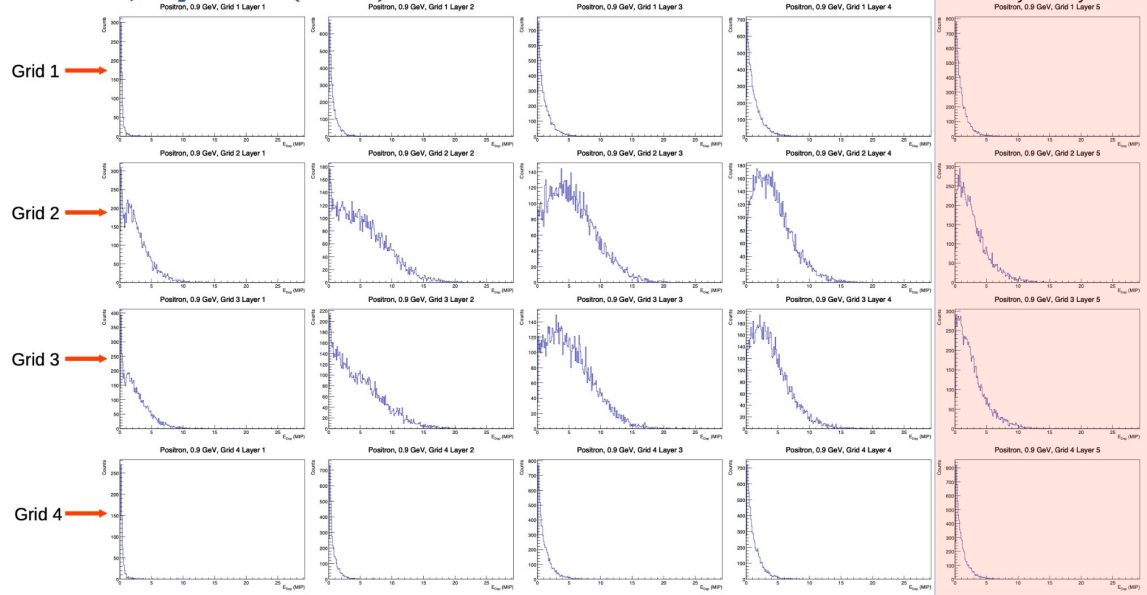


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Simulations

Positrons, Layers 1-4 (SFILs): 0.9 GeV e^+ in MIP Units



Jared Richards, UConn

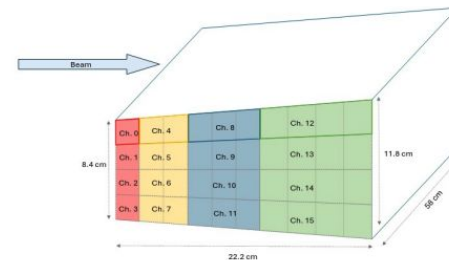
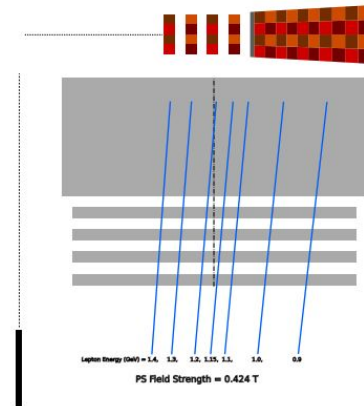
Hall D Beam Test Simulations

March 6, 2026

5/27

Adjustments ongoing based on detailed setup metrology

Layout for generating .hepmc file



Summary and next steps

- A major logistics and integration push was completed for the Hall D beam-test setup and readout commissioning
- The setup is substantially new compared to previous tests:
 - mechanically, it is a completely new configuration
 - from the readout point of view: first beam tests of HGCROC with BIC test articles
 - DAQ fully independent from the GlueX DAQ
 - all readout components integrated into RCDAQ
- The setup has been successfully assembled, commissioned, and is now stored in Hall D until the August beam test
- The electronics are back at ANL and ORNL for SiPM summing-board tests before August
- The SFIL-related electronics are in hand and available for these tests
- The Baby BCAL SiPM board is also expected to be available for the August beam test
- Overall, the key infrastructure and commissioning steps are in place, positioning us well for the August run

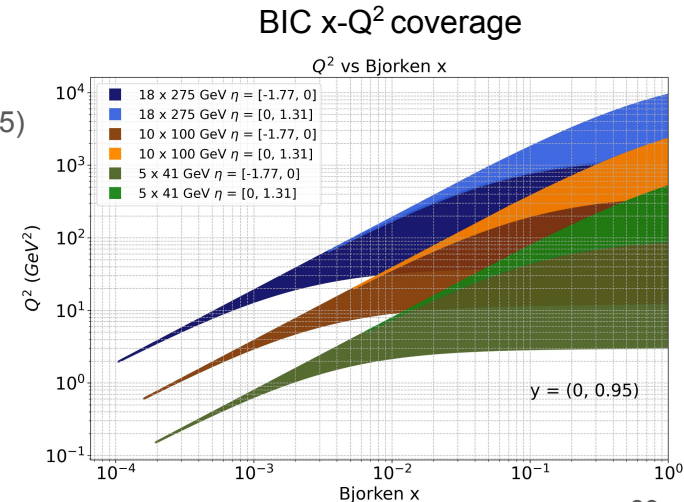
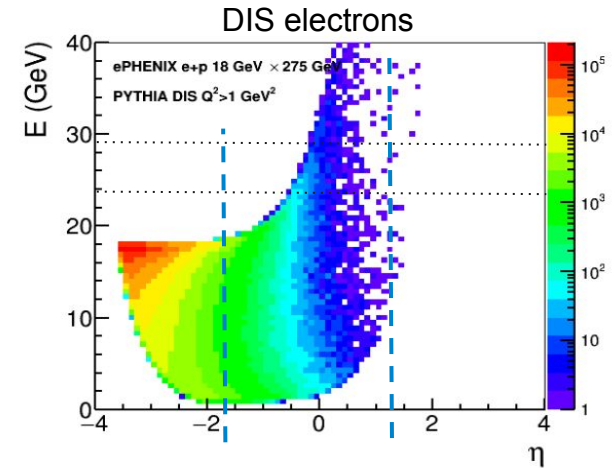
ePIC Requirements for BIC

Identify scattered electrons and measure their energy, in high Q^2 events, also decay electrons, e.g. from vector or heavy flavor meson decays, and to measure DVCS photons and decay photons (G-DET-ECAL-BAR.16.10.05)

- **Electron ID up to 50 GeV and down to 1 GeV** and below (F-DET-ECAL-BAR.16.10.05)
- Energy resolution $< 10\%/\sqrt{E} + (2-3)\%$ (P-DET-ECAL-BAR.16.10.05)
- High power for **e/π separation down to 1 GeV/c** (P-DET-ECAL-BAR.26.10.05)
- **Photon measurements up to 10 GeV** (F-DET-ECAL-BAR.26.10.05)
- **y/π^0 separation up to 10 GeV** (F-DET-ECAL-BAR.36.10.05)
 - Distinguishing two showers with opening angle down to 30 mrad (P-DET-ECAL-BAR.36.10.05)

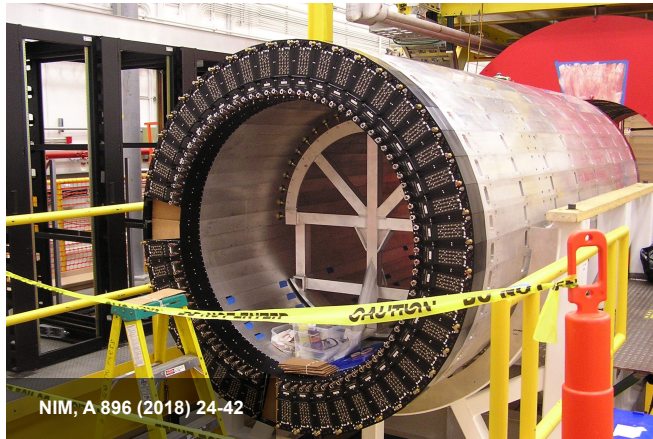
Assist with **muon identification** (G-DET-ECAL-BAR.36.10.05)

Sufficient dynamic range to **detect MIP** signals in all layers (P-DET-ECAL-BAR.56.10.05)

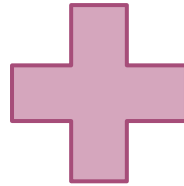


A Novel Hybrid Imaging Calorimeter

Combination of a high-performance sampling calorimeter with silicon sensors for shower profiling



Start from mature layered Pb/ScFi technology with side-readout (same as the GlueX calorimeter) for state-of-the-art sampling calorimeter performance

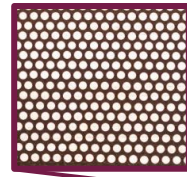
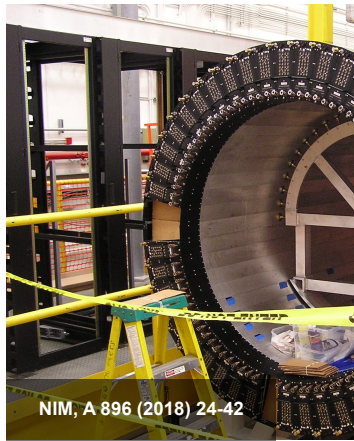


Insert layers of monolithic AstroPix sensors (ultra-low-power silicon sensor developed for NASA) in the first half of the calorimeter to capture a 3D image of the developing shower

455-cm long, 80-120cm radially, US\$23M, ~40 metric tons

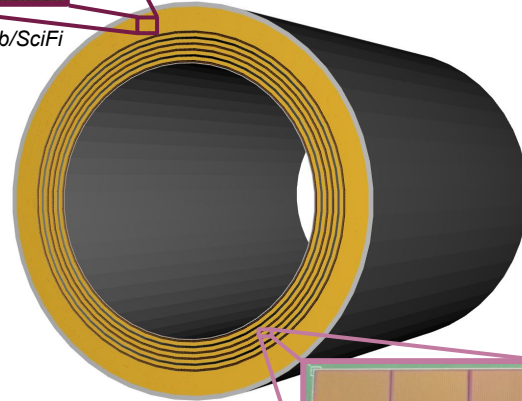
A Hybrid Imaging Calorimeter

Combination of a high-performance sampling calorimeter with silicon sensors for shower profiling

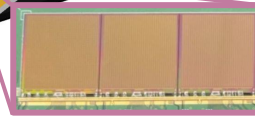


Pb/SciFi Layers ($\varnothing = 1\text{mm}$)
with **two-sided SiPM** readout

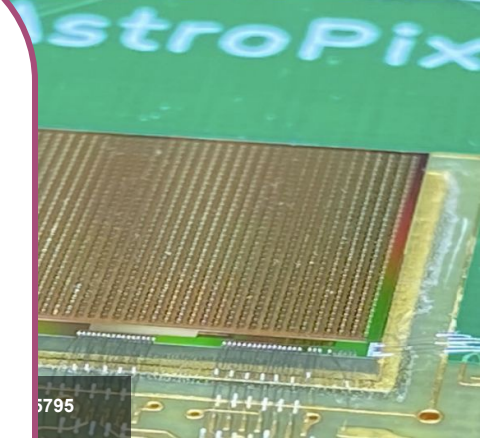
ANL-built Pb/SciFi
Matrix



AstroPix: silicon sensor
with $500 \times 500 \mu\text{m}^2$ pixel size



AstroPix Module Test Article



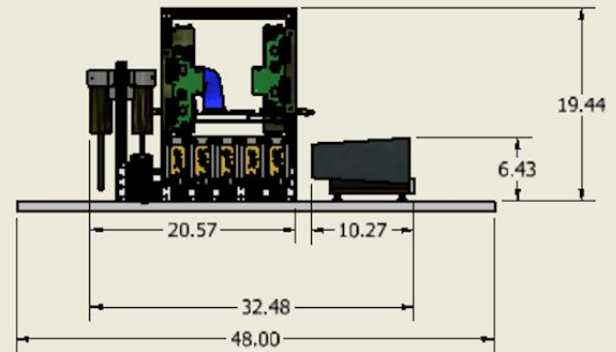
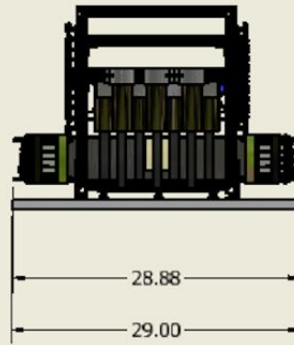
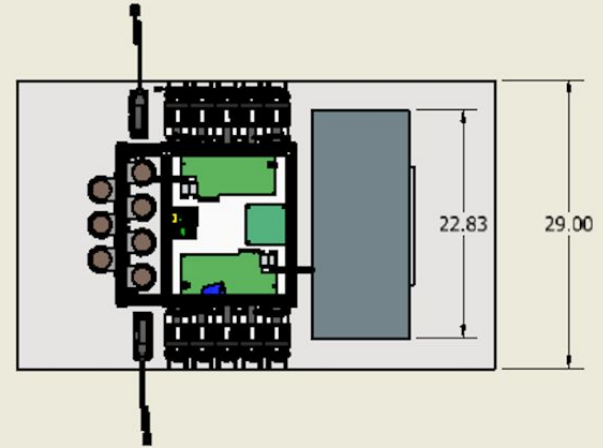
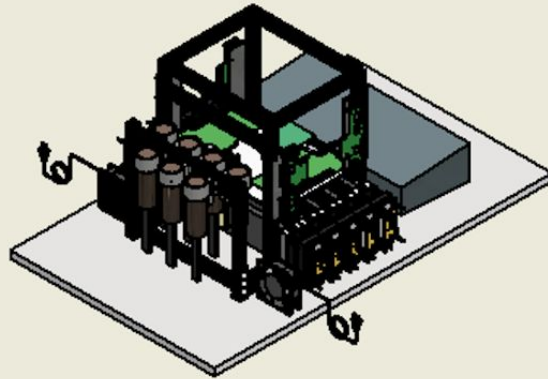
Barrel Imaging Calorimeter

Footprint

LxWxH
35"x30"x20"

Adjustable table
by JLab

Weight: < 300
pounds (fully
loaded)



Beam Test Schedule

Past beam tests with Baby BCAL: Hall D (2023), FNAL (2024)

Week	date	Energy	Left arm (tracking)	Right arm (CAL)
W1	March 30	Low	BIC	HALL-D HiCAL
W2	April 8	Low	BIC	HALL-D HiCAL
W3	April 15	Low	BIC	HALL-D HiCAL
W4	April 22	Low	MPGD	HALL-D HiCAL
W5	April 29	Low	MPGD	HALL-D HiCAL
W6	May 6	Low	MPGD	MOLLER
W7	May13	Low	TRD/ FPGA	MOLLER
W8	May 20	Low	Short week / SWITCH TO HIGH ENERGY	MOLLER
W9	May 27	Low	SWITCH TO HIGH ENERGY	SWITCH TO HIGH ENERGY
W10	June 3	Low	Short week/ SWITCH TO HIGH ENERGY	SWITCH TO HIGH ENERGY
W11	June 10	High	HALL-D TRD	HALL-D TAG-M
W12	June 17	High	HALL-D TRD	HALL-D TAG-M
W13	June 24	High	HALL-D TRD	HALL-D TAG-M
W14	July 1	High		CRYTOR
W15	July 8	High		CRYTOR
W16	July 15	High		CRYTOR
W17	July 22	High	LUMI	HALL-D HiCAL
W18	July 29	High	LUMI	EEECAL
W19	Aug 5	High	BIC	EEECAL
W20	Aug 12	High	BIC	EEECAL
W21	Aug 19	High	SVT/MPGD	EEECAL
W22	Aug 26-Aug 30	High	SVT/ MPGD	

Beam Test Goals

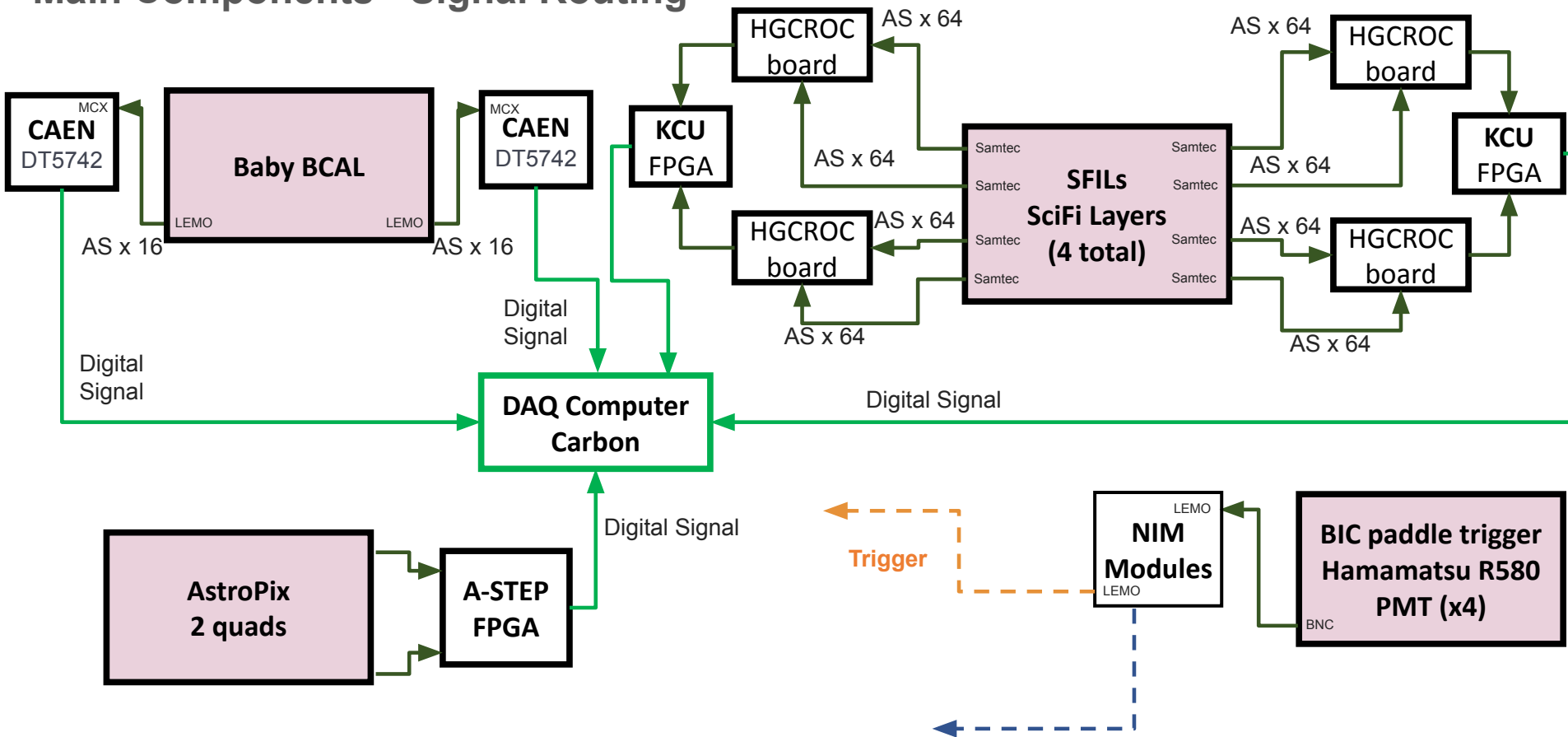
March (low energy):

- Commission for the first time the readout with HGCROC.
- Test synchronization between AstroPix and HGCROC readout.
- Benchmark low-energy response (~ 1 GeV) within the August Beam-Test dynamic range and full BIC Dynamic range.

August (high energy):

- Benchmark energy and timing resolution within 3-6 GeV energy range with full HGCROC readout and show shower imaging event by event.

Main Components - Signal Routing

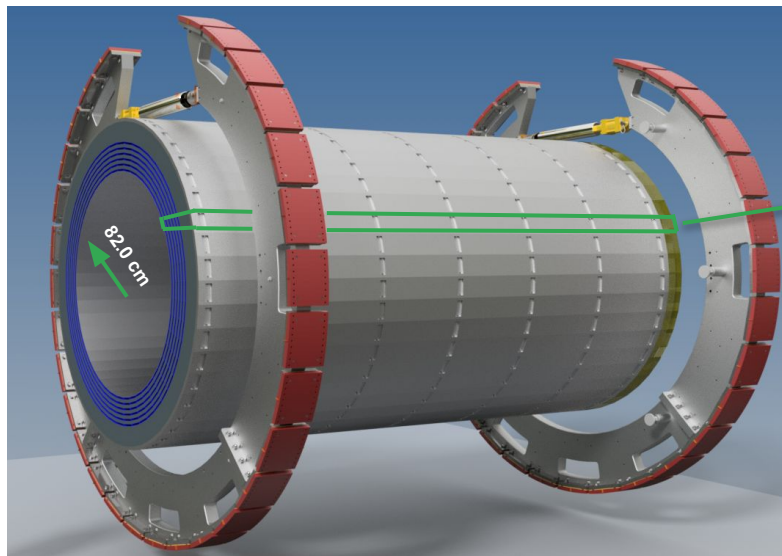


AS - Analog Signal
DS - Digital Signal

To be calibrated vs GlueX PS paddles

Barrel Imaging Calorimeter

Sector Mechanics

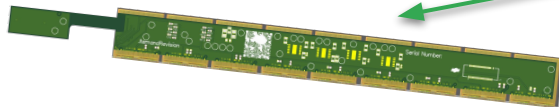


Total BIC weight ~42.5 US tons

AstroPix Module - Nine AstroPix sensors daisy-chained together on Flex PCB.

A stave consists of 12 modules.

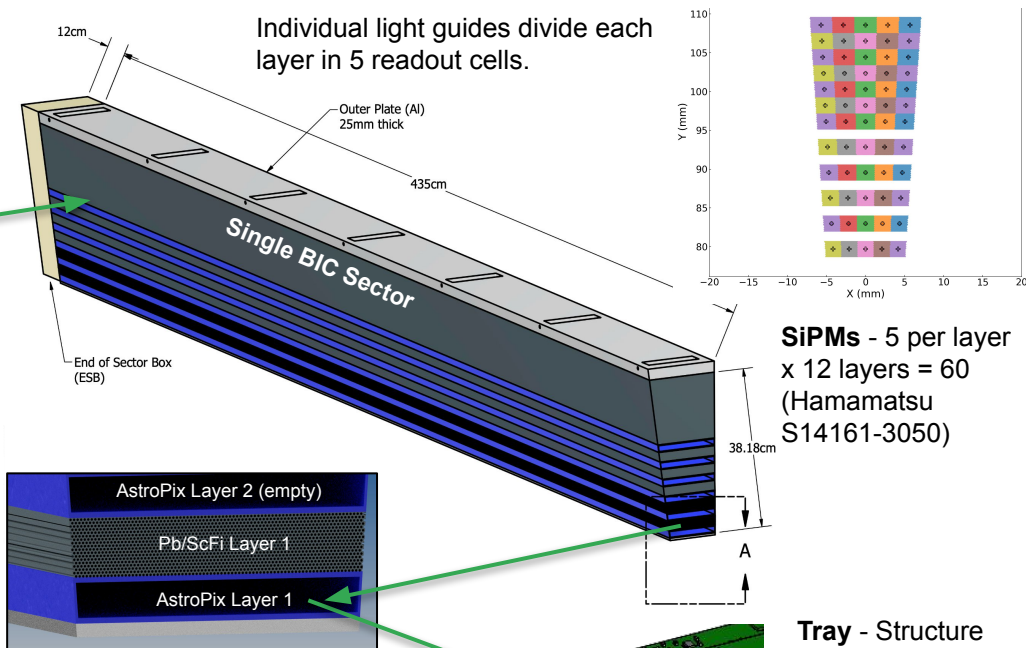
A tray contains of 6-8 staves.



Pb/SciFi Layers - 17 rows of fiber between corrugated lead.

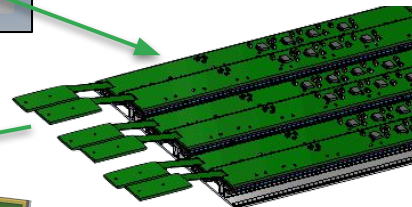
Each sector has 12 Pb/SciFi layers.

Individual light guides divide each layer in 5 readout cells.



SiPMs - 5 per layer
x 12 layers = 60
(Hamamatsu
S14161-3050)

Tray - Structure holding the AstroPix staves for a single layer (217.5 cm long).



Electrical Diagrams

Power supply channel and electrical outlets count

Summary of outlets, crates, etc

Crates/ Slots in Crates:

- Slots for 3 MPOD Modules (1 x ISEG 100 V power supply, 2 x Wiener 16 V power supplies) - close to the setup (platform). We can bring our own crate if needed.
- 1 Slot for the NIM Crate (NIM logic for trigger and HV supply for trigger paddles - HV Supply Bertan Model 365). We can bring our NIM crate or use the available one. Preferably upstairs.

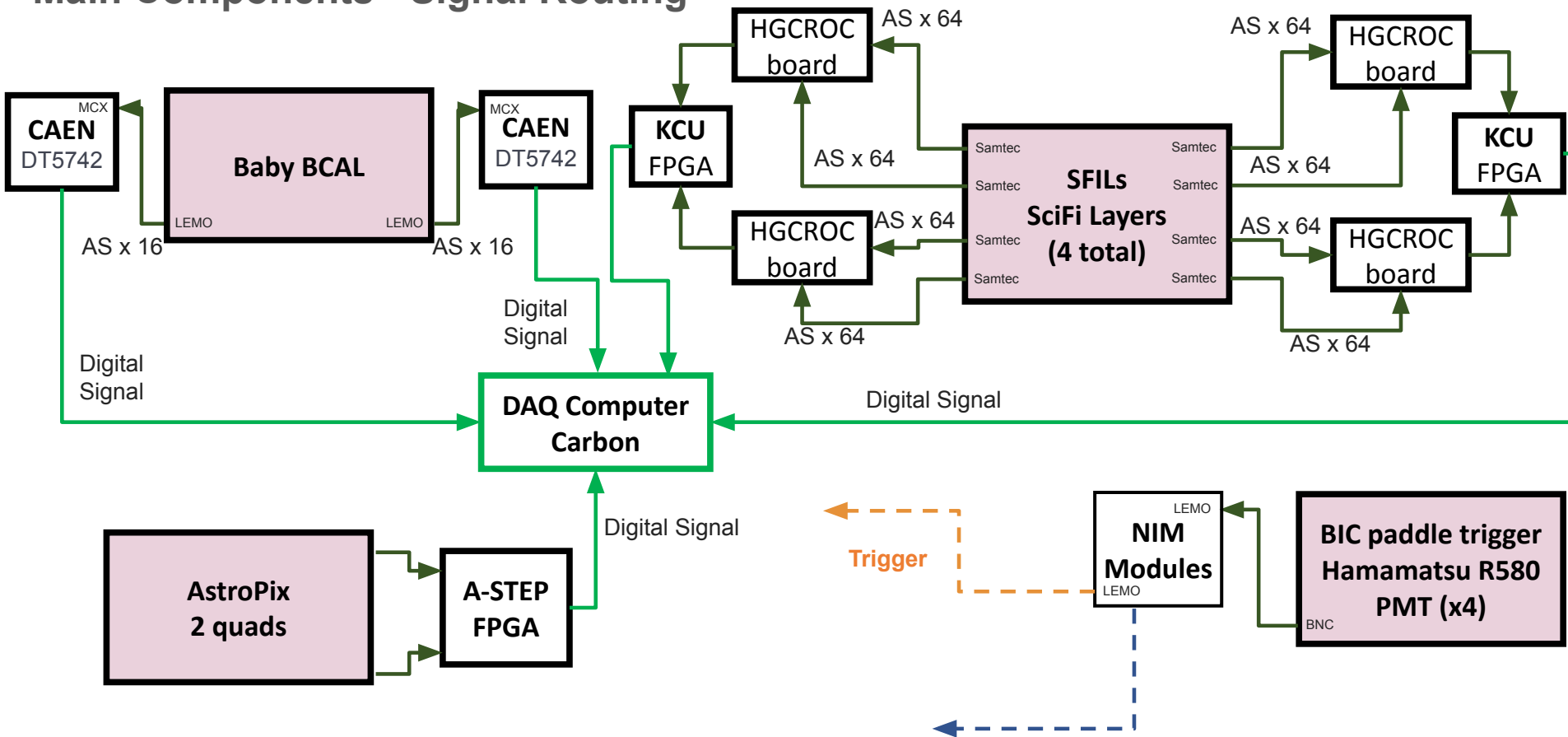
Remote controlled power strip slots:

- 2 outlets for CAEN DT5742 WF Digitizers
- 1 outlet for DAQ Computer
- 2 slots for KCU FPGA
- 1 outlet for WF Generator

Outlets/power strip slots:

- 1 for the chiller (cooling)
- 4 for fans (cooling)
- 2 outlets for R&S Power Supplies NGA142
- 2 outlets for R&S Power Supplies HMP4040

Main Components - Signal Routing

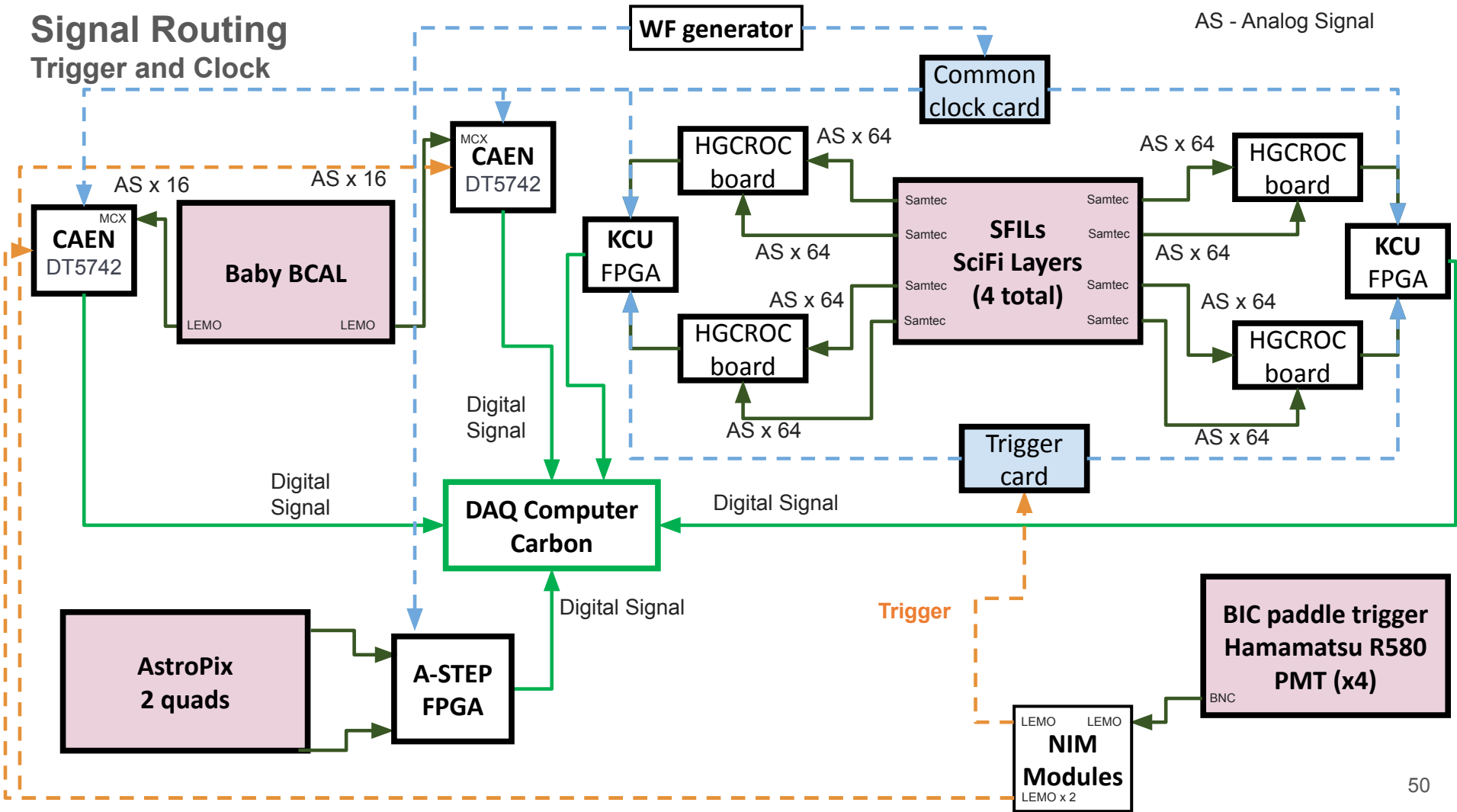


AS - Analog Signal
DS - Digital Signal

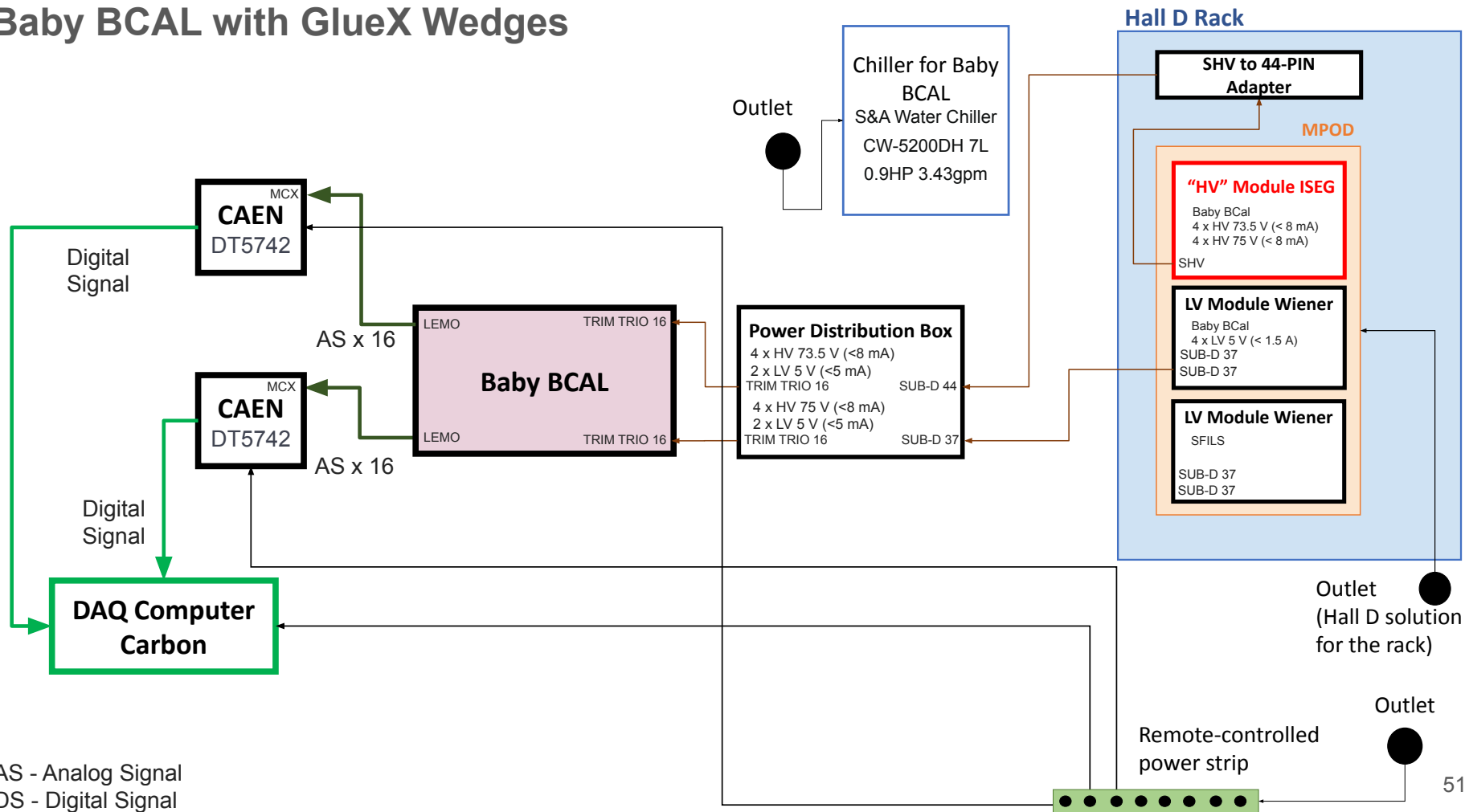
To be calibrated vs PS paddles

Signal Routing

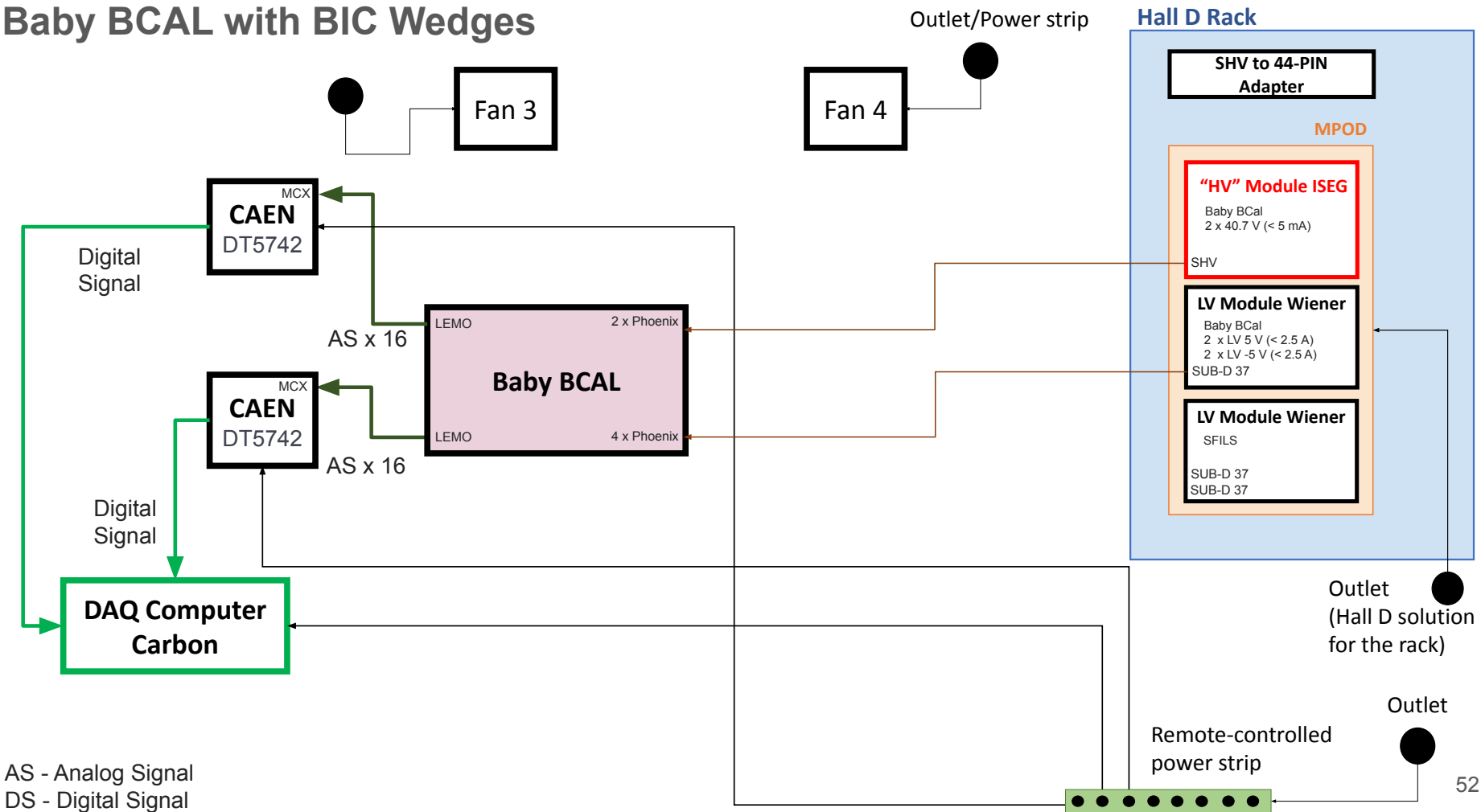
Trigger and Clock



Baby BCAL with GlueX Wedges



Baby BCAL with BIC Wedges



Total Count - Baby BCAL

Outlets:

- 2 outlets for CAEN DT5742 WF Digitizers (Remote-controlled power strip)
- 2 outlets for fans
- 1 outlet for DAQ Computer (Remote-controlled power strip)
- 1 outlet for the chiller (I expect this will need to be in the wall outlet)
- 2 slots in MPOD crate for power supply modules or we can bring our own crate if no space in the existing one. (platform, limited by the power cable lengths - they are borrowed from GlueX)

Question to Andrew: What needs to be the wall outlet and what the power strip?

Power line count: (see the diagram on previous page)

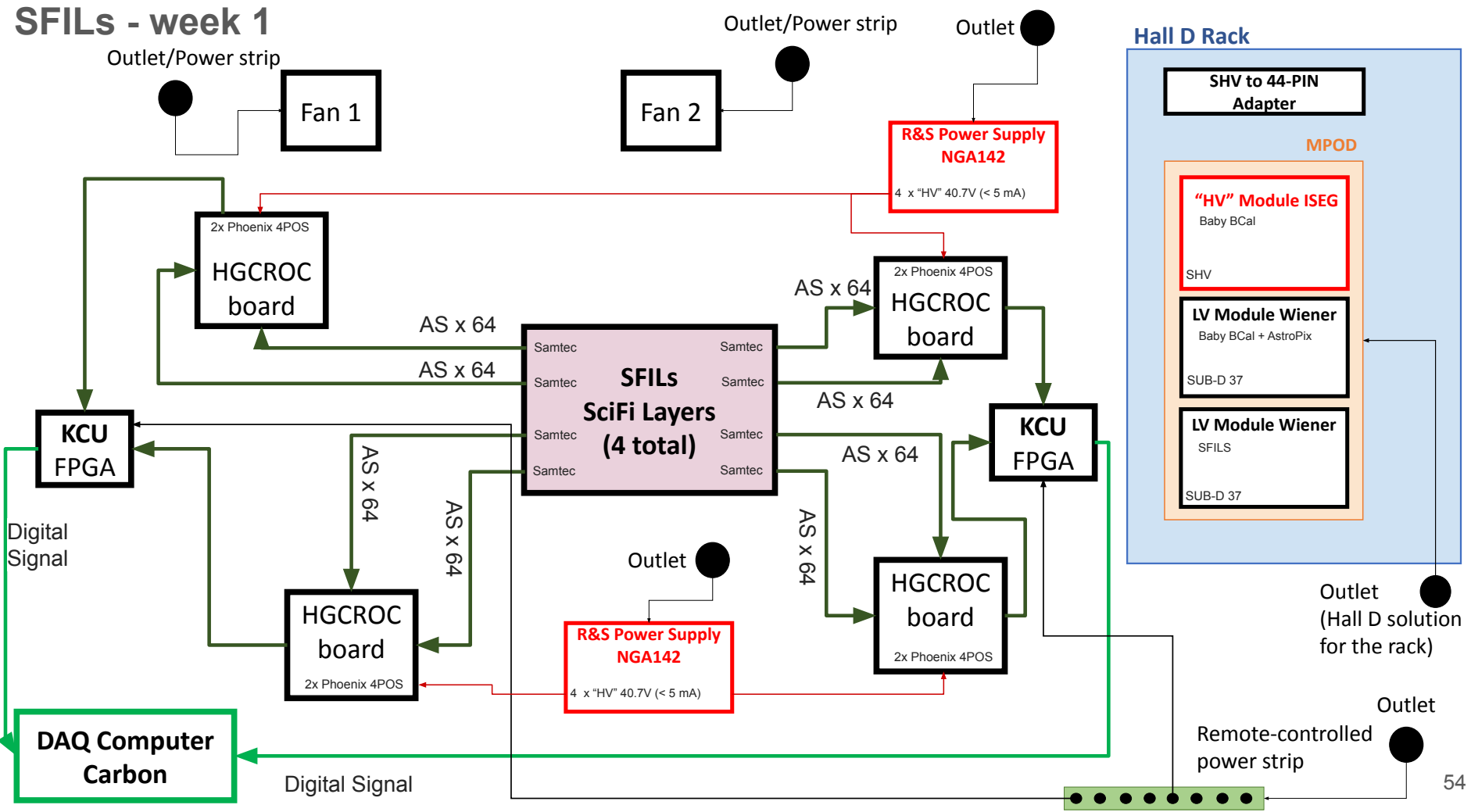
GlueX Wedges (March)

- 8 x 75V (MPOD ISEG) - GlueX Cable
- 4 x 5V (MPOD Wiener) - GlueX Cable

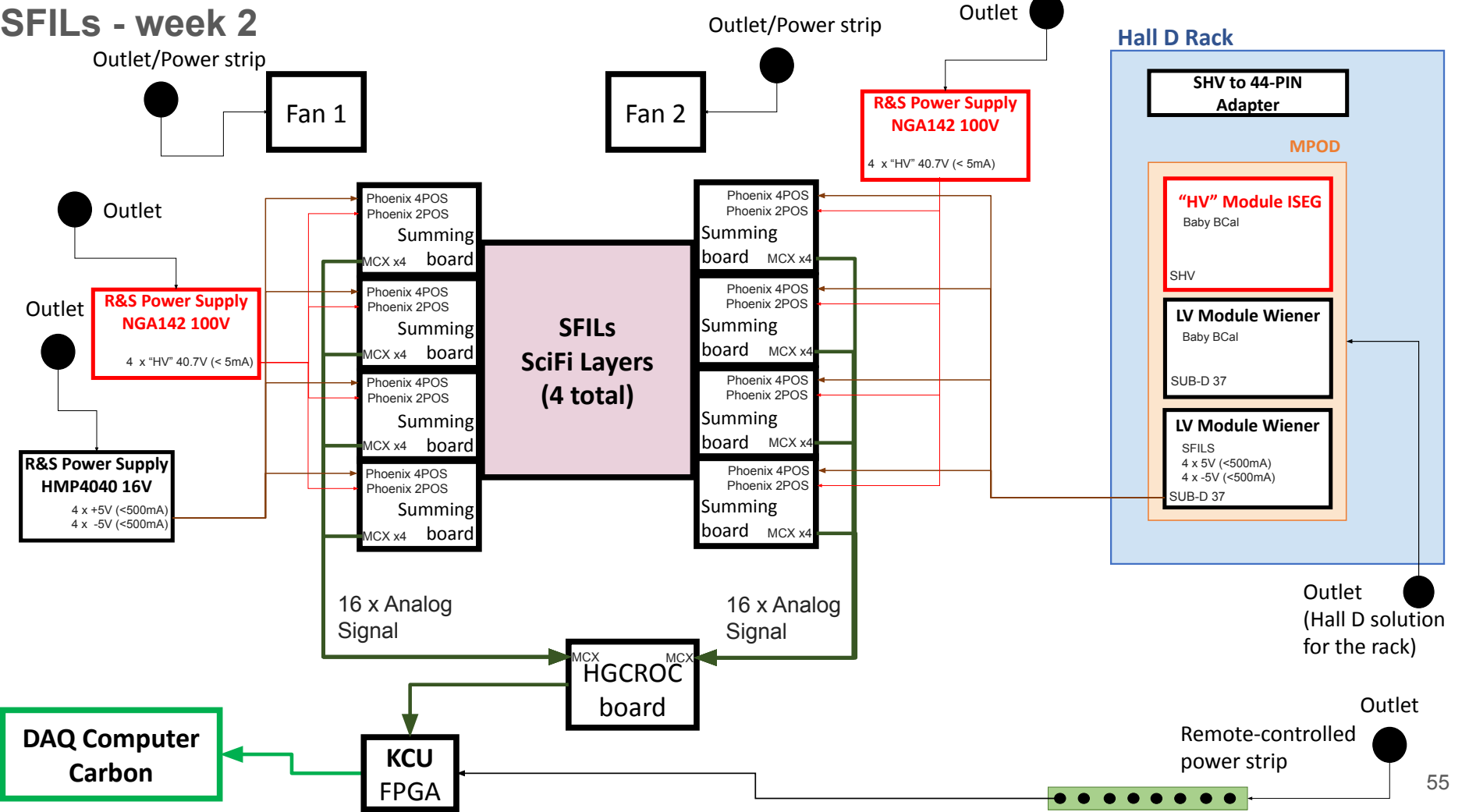
BIC Wedges (August)

- 2 x 40.7V (MPOD ISEG)
- 2 x 5V (MPOD Wiener)
- 2 x -5V (MPOD Wiener)

SFILs - week 1



SFILs - week 2



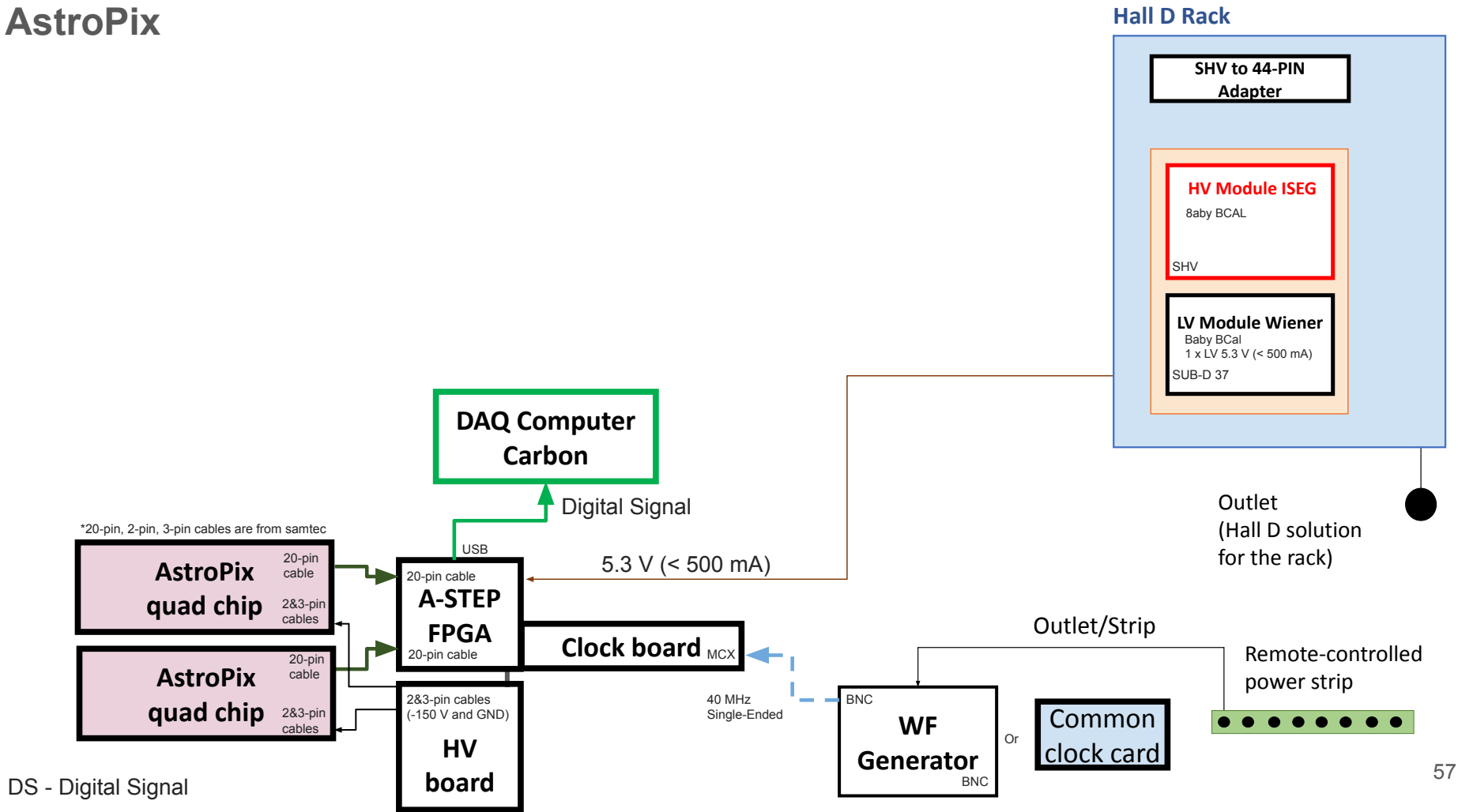
Total Count - SFILs

Outlets:

- 2 outlets/slots in power strip for 2 fans (cooling)
- 2 slots for KCU FPGA (remote controlled strip)
- 1 slot in MPOD crate for LV power supply modules or we can bring our own crate if no space in the existing one. (platform)
- 2 outlets for R&S Power Supplies NGA142
- 1 outlet for R&S Power Supply HMP4040

Power line count: (see the diagram on previous page, max from 2 setups is taken)

- 8 x +5V (MPOD Wiener, 8 ch power supply) - Summing boards
- 8 x -5V (R&S HMP4040, 4 ch power supply) - Summing boards
- 8 x 40.7V (2 x R&S NGA142, 2 ch power supply) - SiPM bias



Total Count - AstroPix

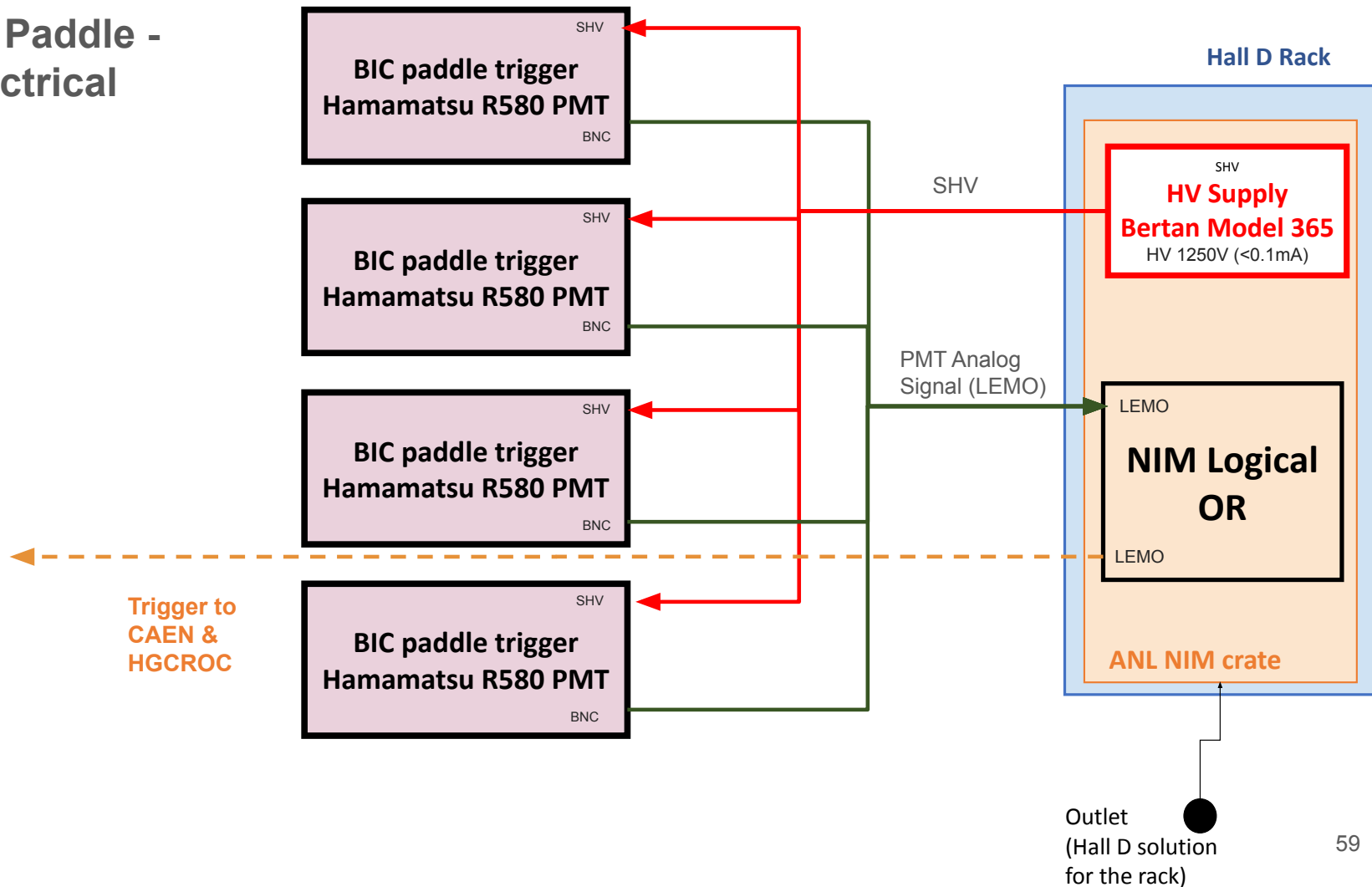
Outlets:

- 1 outlet for WF Generator (Remote-controlled power strip)
- Same MPOD LV Module as for Baby BCAL

Power line count: (see the diagram on previous page)

- 1 x 5.3V (MPOD Wiener)

Trigger Paddle - Full Electrical



Total Count - Trigger

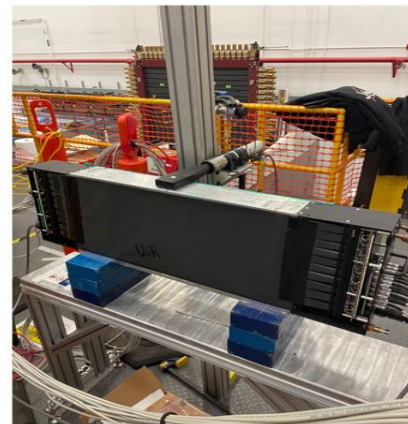
Crates/Outlets:

- 1 Slot for the NIM Crate (NIM logic for trigger and HV supply for paddles - HV Supply Bertan Model 365)

Power line count: (see the diagram on previous page)

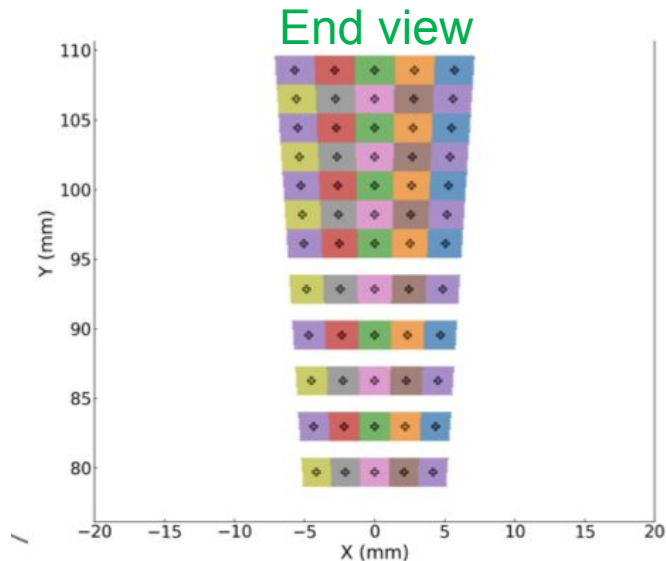
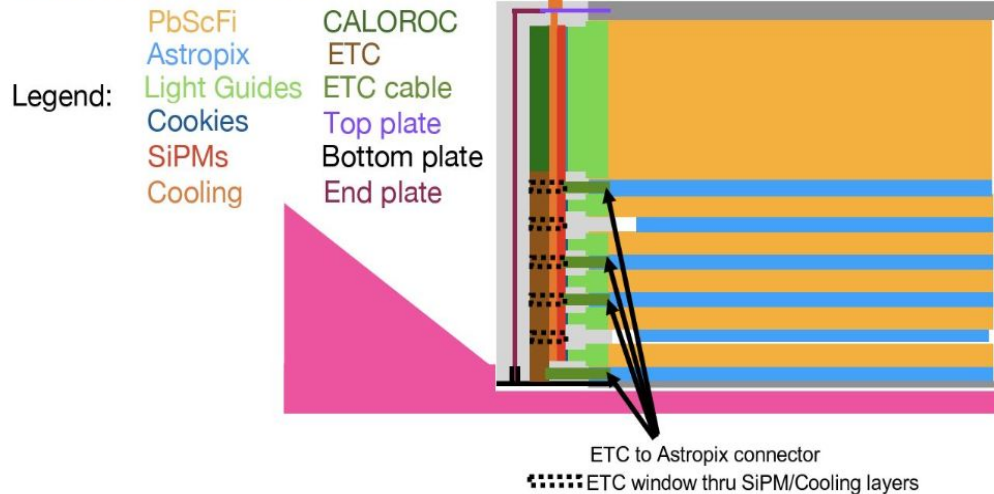
- 4 x HV 1250V ($<0.1\text{mA}$)

Hall D Setup - Beam Tests 2023



Overview of the BIC Sci/Fi readout

Sylvester & Zisis, March 4, 2025



The Sci/Fi layers have lightguides with a SiPM 4x4 arrays at the end.

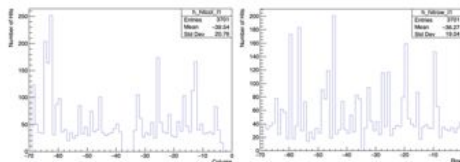
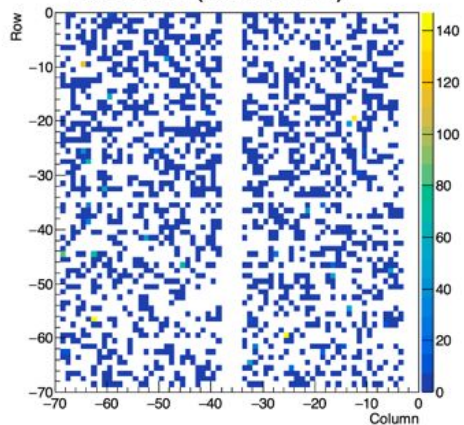
In one sector there are:

- 12 layers of SciFi; 5 columns; In total 60 x (4x4 3x3mm² array)
- Signals from individual SiPM's are summed

Design for Baby BCAL now, BIC design will follow

Hall D Beam Test: Beam profile measurement

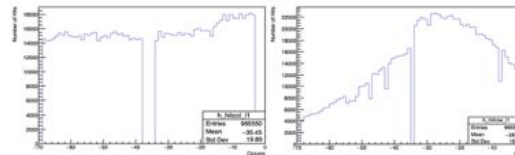
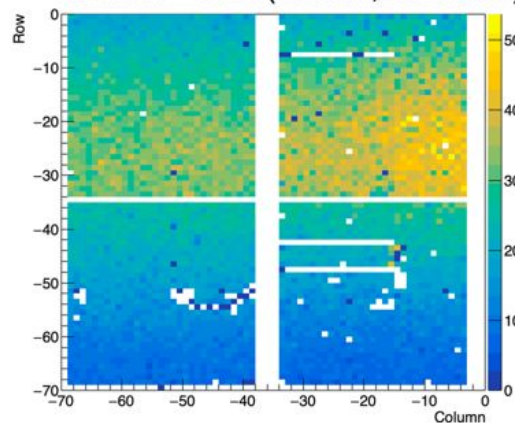
- No beam (cosmic run)



Run 1181-1191 (No beam (cosmic run))

- Expected cosmic-muon statistics: $\sim 1,300$ muons in a $4\text{ cm} \times 4\text{ cm}$ sensor over 2 h 44 min ($\sim 1\text{ cm}^{-2}\text{ min}^{-1}$, $\cos^2\theta$ distribution).

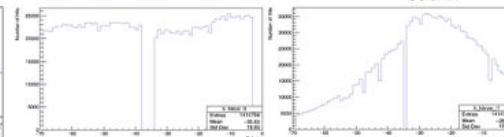
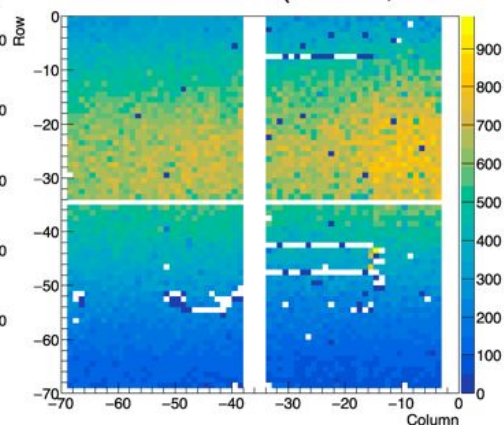
- Run 1318 – 1324 (Total 61,416 events)



Run 1318-1324

- Hit map over 2 hours 20 mins of data-taking (5/13 6:45~9:06 AM)
 - $\sim 100.6\text{ Hz}$ per matched hit
- $\langle I \rangle = 17.89\text{--}26.06\text{ nA}$
- PS field: 0.190 T ($\sim 100\text{A}$ setting)
- Rad: JD70-107 55um 45/135 deg
- PSrad: HOME (out of beam) @ 0.000 mm
- TPOL: C (Be $\sim 750\mu\text{m}$) @ 101.667 mm

- Run 2483 – 2489 (Total 23,520 events)



Run 2483-2489

- Hit map over 47 mins of data-taking (5/28 20:37~21:24)
 - $\sim 100.6\text{ Hz}$ per matched hit
- $\langle I \rangle = 27.97\text{--}35.56\text{ nA}$
- PS field: 0.244 T ($\sim 100\text{A}$ setting)
- Rad: JD70-107 55um 45/135 deg
- PSrad: HOME (out of beam) @ 0.000 mm
- TPOL: C (Be $\sim 750\mu\text{m}$) @ 101.667 mm