

The ePIC Barrel Imaging Calorimeter

System Testing and Simulation

Maria Żurek for the System Testing and Simulation Team
Argonne National Laboratory

BIC General Meeting
June 16, 2025



Updates since the BIC Workshop



Joined System Testing and ESB Meetings:

- May 13 <https://indico.bnl.gov/event/27548/>
- May 27 <https://indico.bnl.gov/event/27549/>
- June 10 <https://indico.bnl.gov/event/27550/>

Planned

- June 24: ESB Meeting
- July 1: System Testing - KEK Beam Test - first results discussion

News Brief



Pb/ScFi testing front

- FTBF Beam Test results on the Baby BCAL response to electron and pions accepted for publication

AstroPix testing front

- Multilayer, multi-chip tests (quad, 9-chip PCB) tests ongoing, towards future integrations

Integrations news

- SFILs at ANL, integration with AstroPix accomplished
- First look at HGCROC at ANL, KNU
- Ongoing integrations at the KEK Beam Test

Simulations front

- Work on implementation of digitization in ePIC Framework
- Update on simulation studies for SiPMs

Beam Test Front

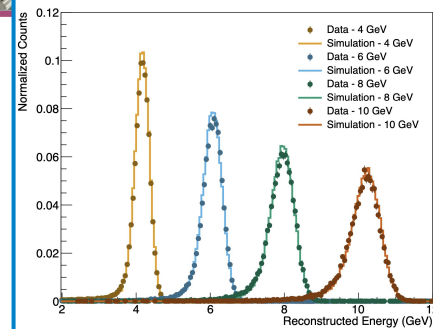
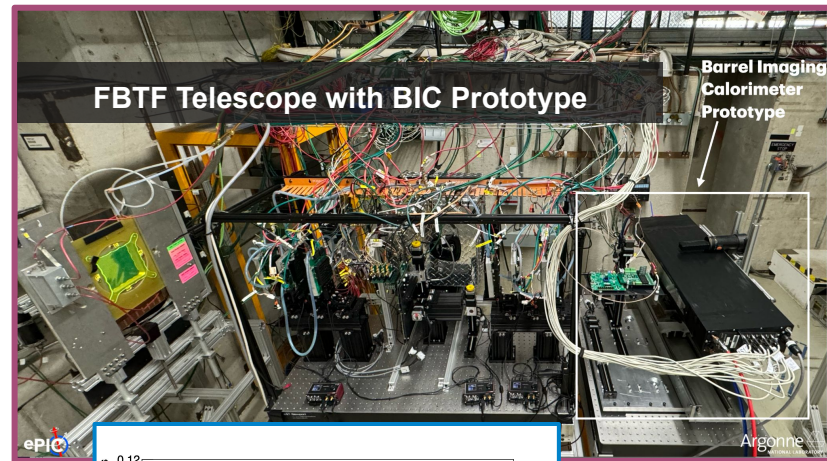
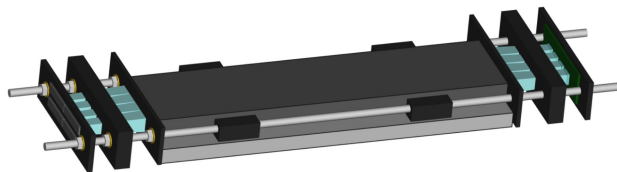
- KEK Beam Test by BIC-Korea Team finished last week

Conclusion of the R&D Phase

Project R&D Phase Completed: See 2025 [R&D Day Presentation](#)

- GlueX Baby BCal tested at FTBF in FY24 with mixed e/π beams & MIPs, despite limited beam time.
- Data **analyzed for e and π response** and separation in SciFi/Pb section. Simulations benchmarked.
- AstroPix v3 performance validated against design requirements.
- **Proof-of-principle AstroPix integration demonstrated** in beam and on bench.
- **Thin ScFi/Pb layers** with new SiPMs and optical cookies **commissioned** on bench.
- Large-scale readout integration now pursued under PED program.

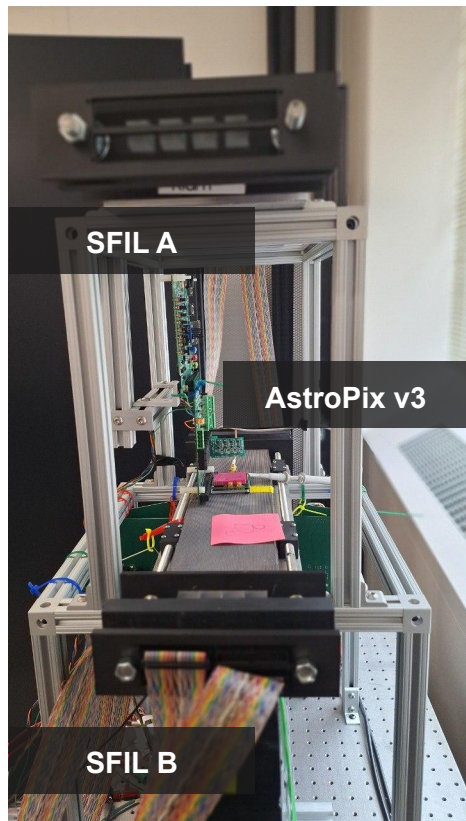
Thin ScFi/Pb layer



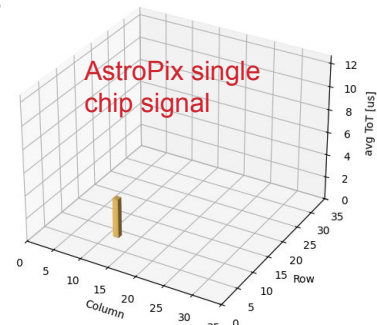
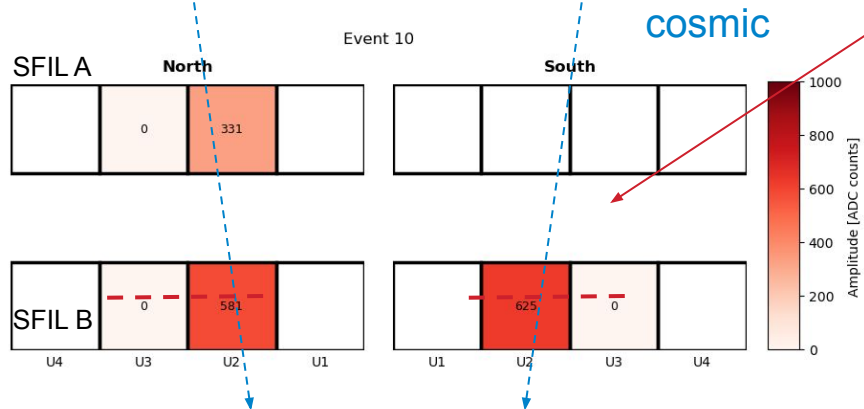
Comparison of reconstructed e^- energy in Baby BCal for data and simulation measured at FBTF.

Results accepted for publication in JINST <https://arxiv.org/abs/2504.03079>

System Testing - AstroPix/SFILs Integrations



- Synchronization (AstroPix-SFILs) Plan A: LVDS MISO0/1 signals that generated from Astropix used as trigger IN for Baby BCAL
- SFILs: new S14 SiPM arrays, optical cookies, 8 cm machined light-guides
 - Test station for optical coupling and improvements
- Setup successfully commissioned at bench with cosmics

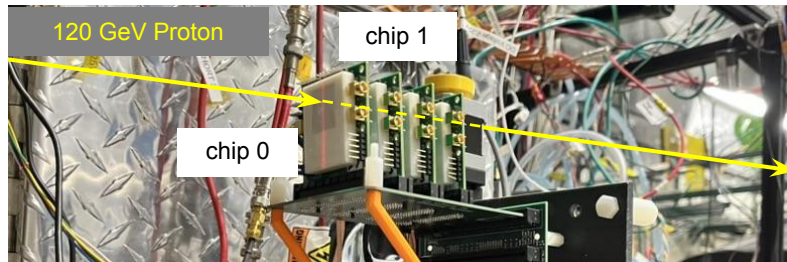


Plan B (for HGCROC) - preparations in progress

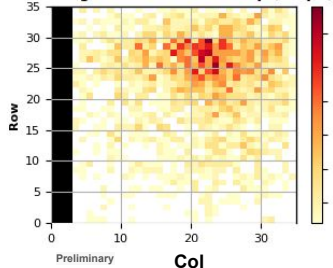
- Provide up to 10 MHz LVDS external clock to Astropix chip via PMOD

System Testing - AstroPix/BCAL Integrations

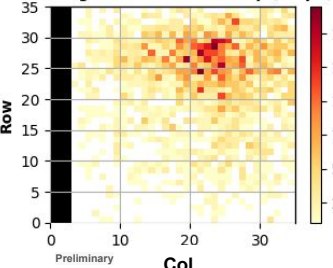
AstroPix v3 integration tests: first proof-of-concept demonstration of the integration of two daisy-chained AstroPix layers and Baby BCal and AstroPix in a beam-like environment.



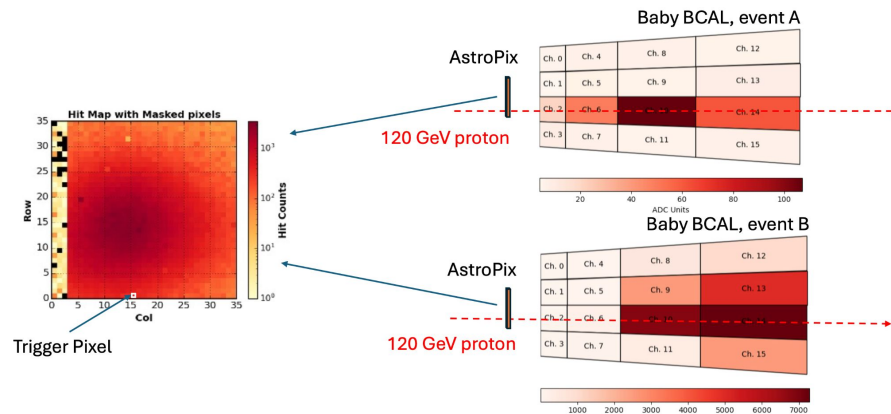
Matching Coincidence Hit Map (Chip0)



Matching Coincidence Hit Map (Chip1)



The multilayer AstroPix v3 setup which we tested at FTBF, and an example of the recorded **120 GeV proton beam events from the first two layers, read in coincidence**



Baby BCal event triggered on AstroPix signal from 120 GeV proton. Event A shows MIP-like behavior, event B shows hadronic shower behavior.

AstroPix testing front



697	System Demonstration	Apr 9, 2025	Mar 27, 2026	
700	Procure items needed for the setup in B102 to run the HGCROC Board	Apr 9, 2025	May 20, 2025	2 weeks
701	Test HGCROC with S14 SiPMs on SFIL: Make it work + Tune readout parameters for our SiPMs	May 21, 2025	July 1, 2025	15 days
702	REQD: Prototyping Box with new BabyBCAL SiPM Board that can connect to HGCROC readout and JLAB Coda	Jun 30, 2025	Jun 30, 2025	
704	Milestone: BabyBCAL with new SiPMs and HGCROC tested and benchmarked	Aug 26, 2025	Aug 26, 2025	
705	REQD: 9-chip board available (4-chip would be ok)	July 28, 2025	July 28, 2025	
706	Sync AstroPix multi-chip board with HGCROC readout	Jul 29, 2025	Aug 25, 2025	3 weeks
707	REQD: 3 9-chip boards available (4-chip would be ok)	Aug 25, 2025	Aug 25, 2025	
708	Sync AstroPix 9-chip boards with HGCROC readout	Aug 26, 2025	Sep 8, 2025	
709	Milestone: AstroPix 9-chip board can be read in sync with SciFi HGCROC readout	Sep 8, 2025	Sep 8, 2025	
710	Full electrical test of 3 AstroPix 9chip pcb read out by the ASTEP board: data transfer, calibration, noise, etc.	Sep 9, 2025	Oct 20, 2025	
711	Milestone: 3 AstroPix 9-chip boards can be read in sync with SciFi HGCROC readout	Oct 20, 2025	Oct 20, 2025	
712	Development of the Calibration Procedure for chips based on v4 single chip	Oct 21, 2025	Dec 1, 2025	

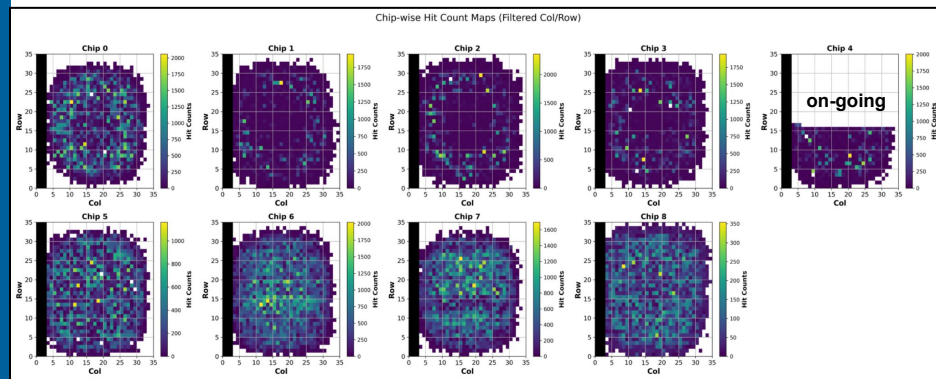
708 Sync with HGCROC

- Generating the bit file for the external clock with the current setup (ASTEP HW) : on-going



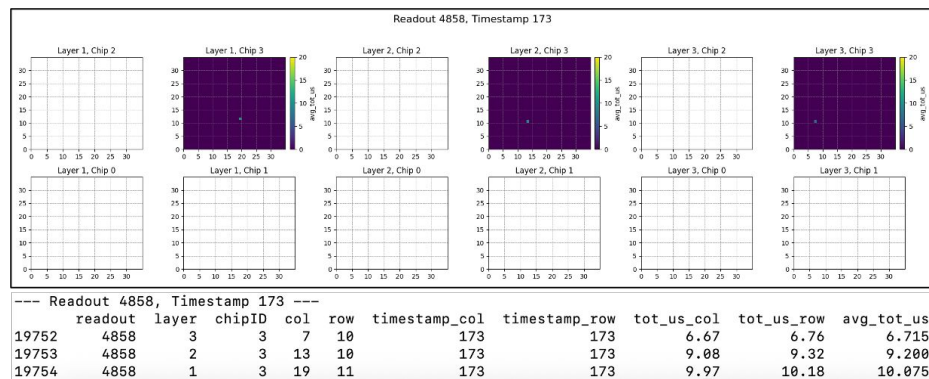
705 REQD: 9-chip board

- injection scan (on-going): Issue on the baseline fluctuation



707 REQD: 3 9-chip board (4-chip)

- Observed the coincident event matched three layers



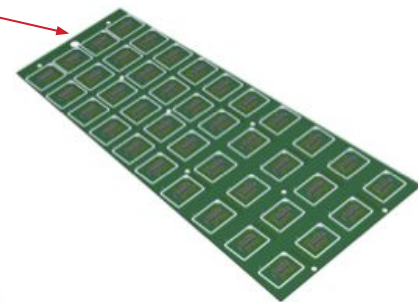
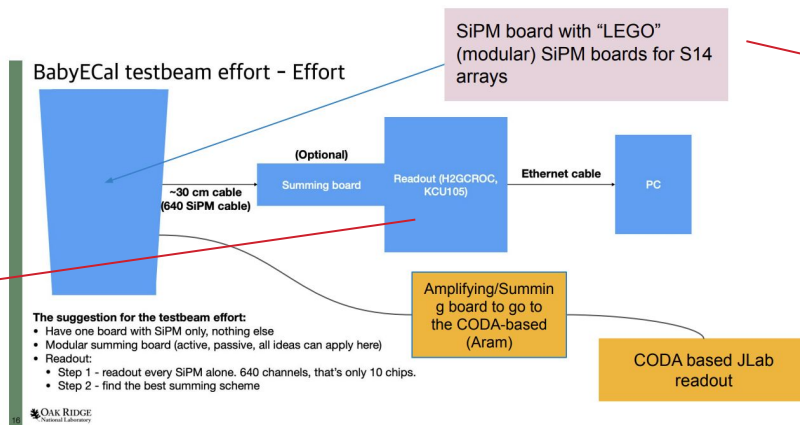
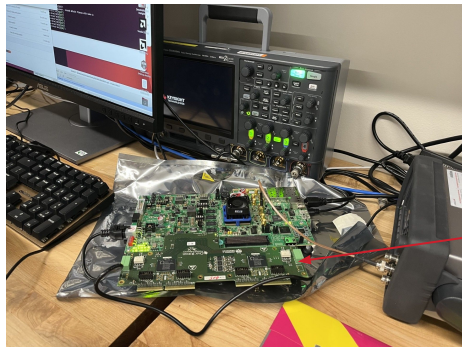
Next Steps

HGCROC integrations and test

- ANL Team ready to test SiPM arrays with HGCROC
 - Waiting on adapter for the current SFIL SiPM board from URegina
- Test stand at KNU under development

Baby BCAL SiPM board design in progress to test 40 x 2 channels with new S14 SiPM arrays and optical connection, and benchmark the HGCROC readout against the fADC

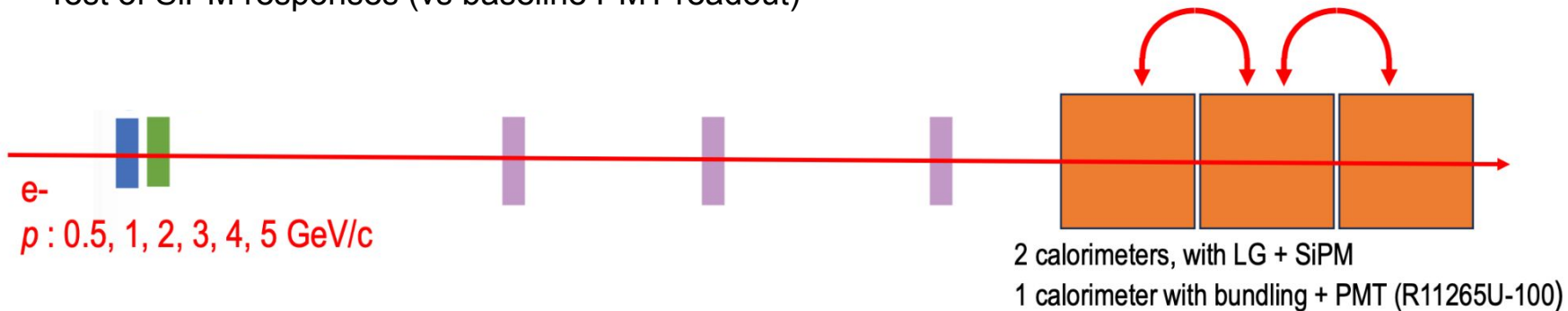
Tests of AstroPix - HGCROC Integration



BIC-Korea Beam Test in KEK

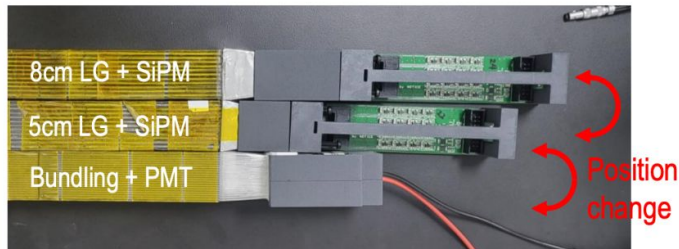
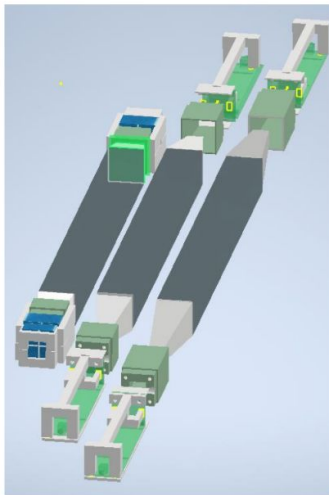
KEK (Japan)

- Dates: 11 June - 17 June , Beam: electron 0.5 - 5 GeV/c
- Main goal: AstroPix–FADC DAQ Integration Test
- Test of SiPM responses (vs baseline PMT readout)



BIC-Korea Beam Test in KEK

Bo Gyeong SEO, Jun Seop SHIN, Shin Hyung KIM, <https://indico.bnl.gov/event/27550/>, <https://indico.bnl.gov/event/27548/>



Bundling + PMT



LG + SiPM

Readout

3 sampling calorimeter

LG : 5cm, 8cm

SiPM: S14, S13

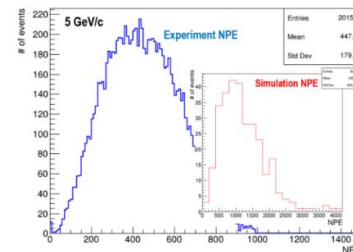
Different composition (LG length, Photon detector) for each beam test

Edep simulation (by C.H.LEE)

4GeV/c



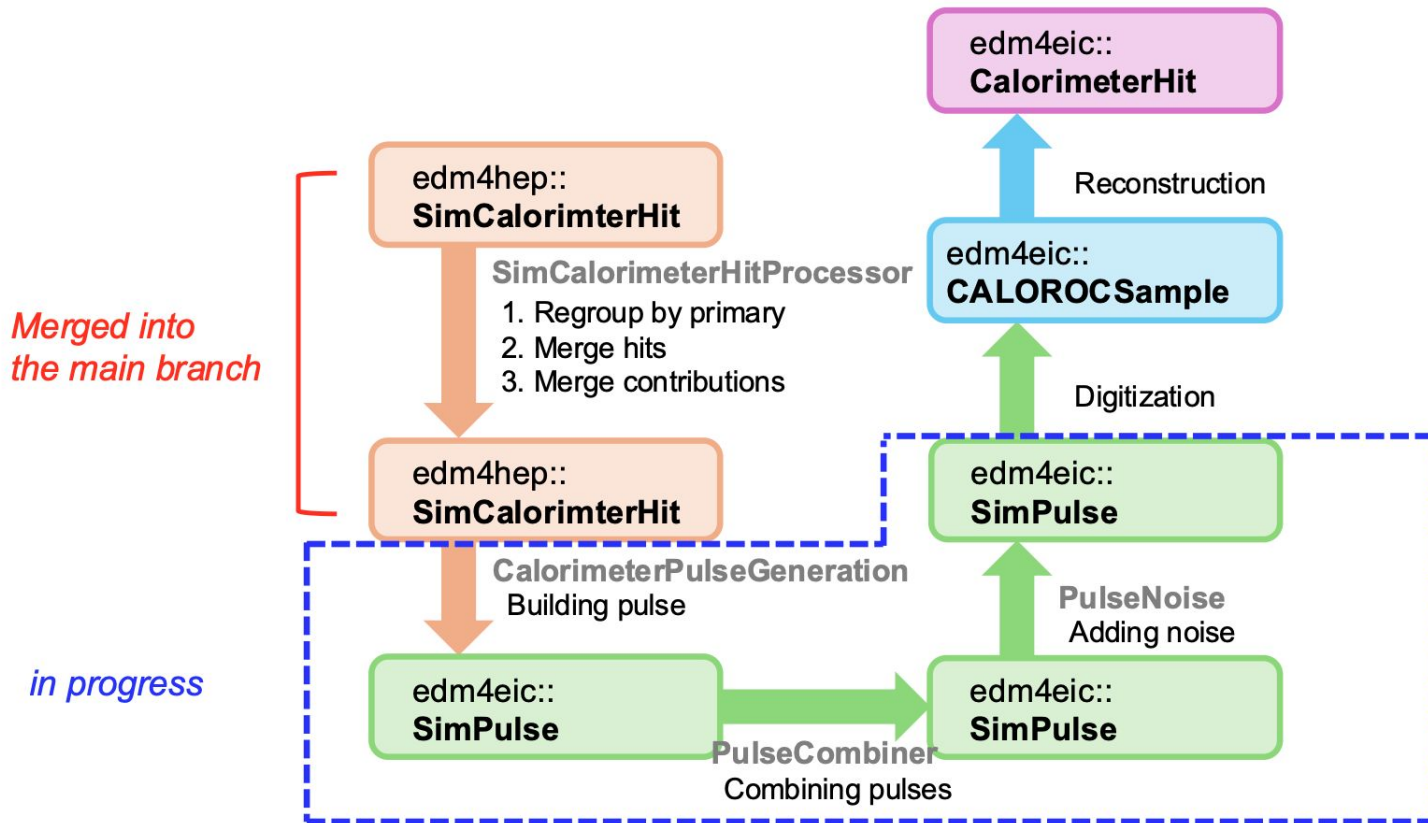
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3.79 %	15.7 7 %	22.0 1 %
0.11 %	0.45 %	1.02 %



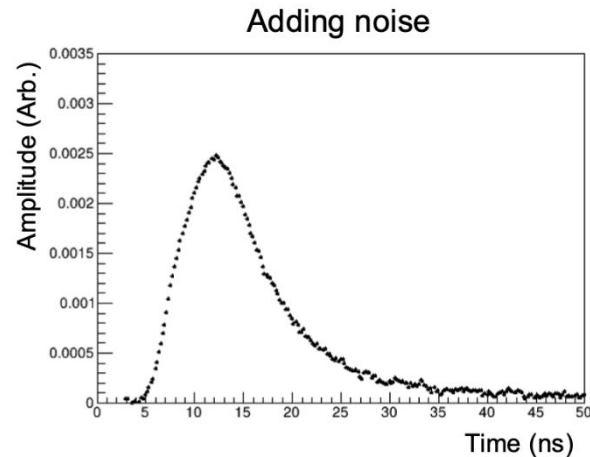
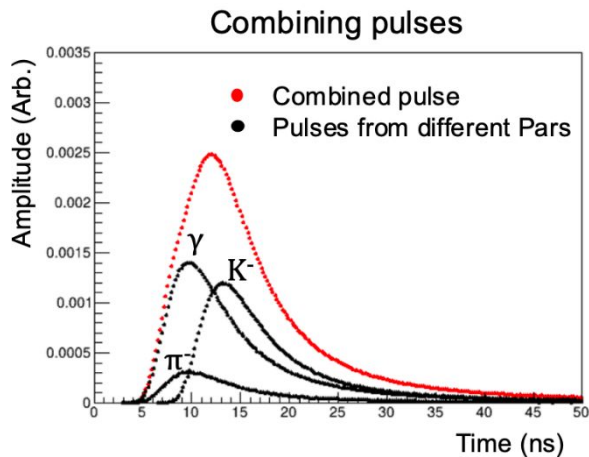
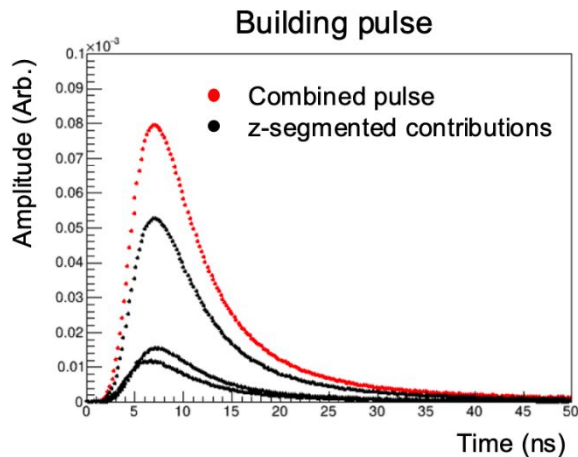
NPE comparison (sim. & exp.) was done for 8 cm LG & PMT with e- beam

NPE comparison for **LG + SiPM** will be done

Simulation workflow



Building-pulse algorithms



Build pulse for each particle by summing the z-segmented contributions.



Combine pulses for each SiPM if there is more than one particle.



Add noise.

Simulation front - SiPM noise studies



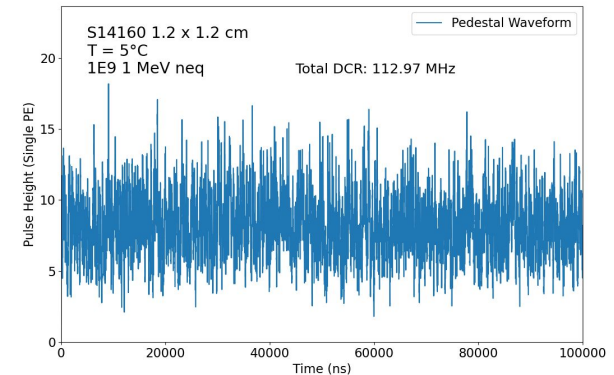
Requested to be discussed at the Calorimetry CC Meeting: <https://indico.bnl.gov/event/28287/>
Studies based on expected irradiation doses at ePIC and two irradiation campaigns

Bottom line: With S14 SiPM arrays at 7C we should be still able to see MIPs with 4σ separation radiation damage equivalent to $1\text{e}9$ 1-MeV neq (depends on the shape of the SiPM signal and relative pedestal to signal ratio)

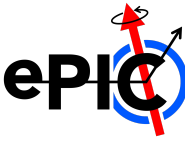
Baseline: We treat each channel separately in the DAQ using a threshold cut. Even in the worst case (irradiated sensor, MIP at $\eta = 0$), the MIP is well-separated

Mitigation: We can lower readout thresholds if desired (enough headroom in ASIC) and apply simple coincidence logic for zero suppression (e.g. in the DAM module)

	Forward SiPMs	Backward SiPMs
Dose from physics/ 1 fb^{-1}	$< 2 \times 10^7 / \text{cm}^2$	$< 5 \times 10^6 / \text{cm}^2$
Dose from hadron beam/ 1 fb^{-1}	$< 3 \times 10^6 / \text{cm}^2$	$< 5 \times 10^6 / \text{cm}^2$
Sum for 140 fb^{-1}	$3.2 \times 10^9 / \text{cm}^2$	$1.4 \times 10^9 / \text{cm}^2$



*Your BIC logo may
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Thank you!



Thank you!