

Beam Test Results for a SiPM-on-Tile ZDC Prototype

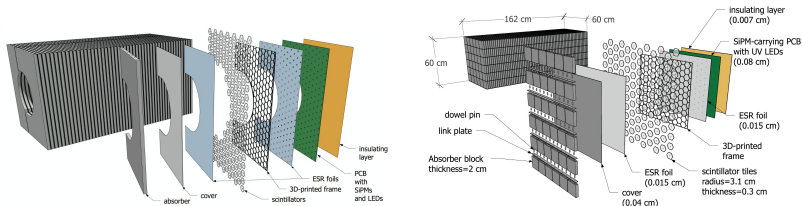
Weibin Zhang

EICUG Early Career Workshop
2025-07-12



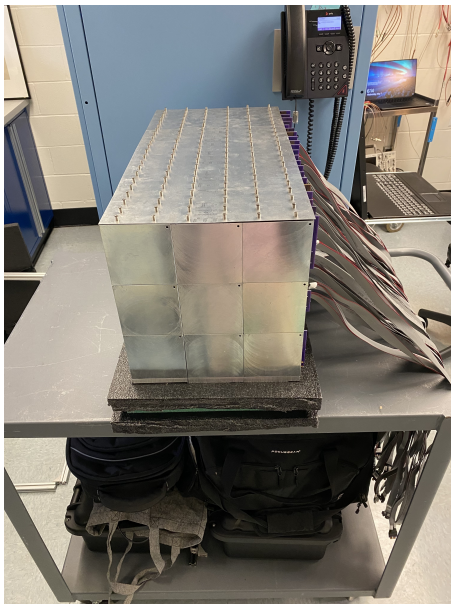
CALIFORNIA EIC
CONSORTIUM

SiPM-on-Tile Calorimetry



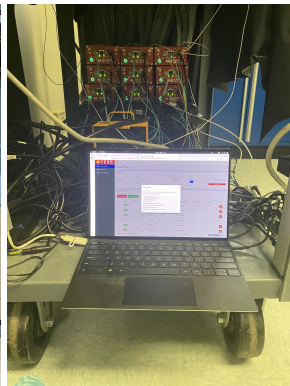
- Developed by the CALICE Collaboration for e^+e^- colliders
- Deployed at scale at the LHC and the EIC
- Chosen for the Longitudinally-segmented Forward Hadronic Calorimeter (LFHCAL), High Granularity Calorimeter Insert (CALI), Zero Degree Calorimeter (ZDC) and possible Few Degree Calorimeter (FDC) for the ePIC detector

The ZDC Prototype

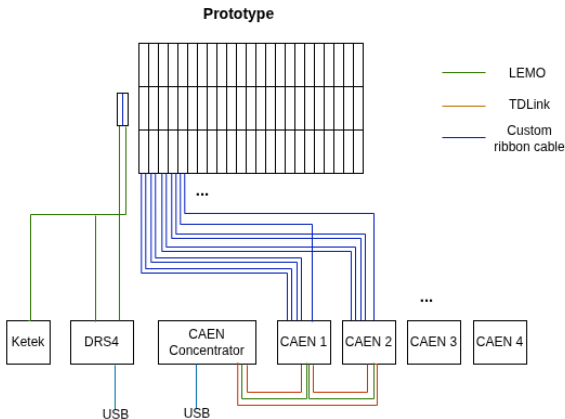


- $30\text{cm} \times 30\text{cm} \times 60\text{cm}$
- 23 layers: 2 cm iron absorbers + scintillator tiles + PCB, SiPM air coupled to scintillator
- 25 channels per layer, 5×5 square scintillator tiles, shifted diagonally every other layer³

Setup



- Prototype held in a dark box
- 1 m long custom ribbon cable
- Electronics beneath the prototype



- Two scintillator tiles in front of the prototype as external trigger
- 9 CAEN units + 1 CAEN concentrator
- 4 Daisy chains with 2 CAEN units in each chain + 1 single
- Same configurations for trigger connections

Beam Test in HalID at JLab



- 2.5 GeV positron beams, 370 read out channels
- Evaluate the performance of the ZDC engineering test module
- Assess the scalability
- Validate new features: staggered scintillator tiles for the use of the **HEXPLIT** clustering algorithm

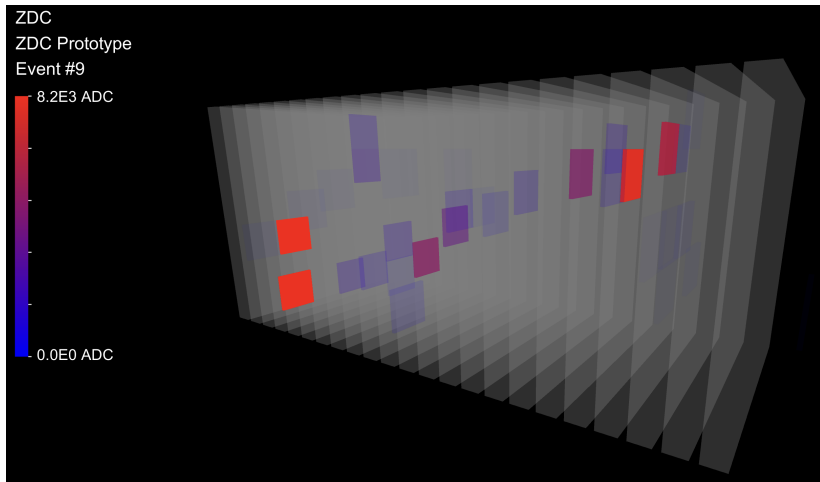
Parasitic Beam Test at Beam Dump at NSRL



Ion	Count
P	1.14E13
He	1.59E10
O	2.98E10
Si	6.82E8
Fe	1.59E10

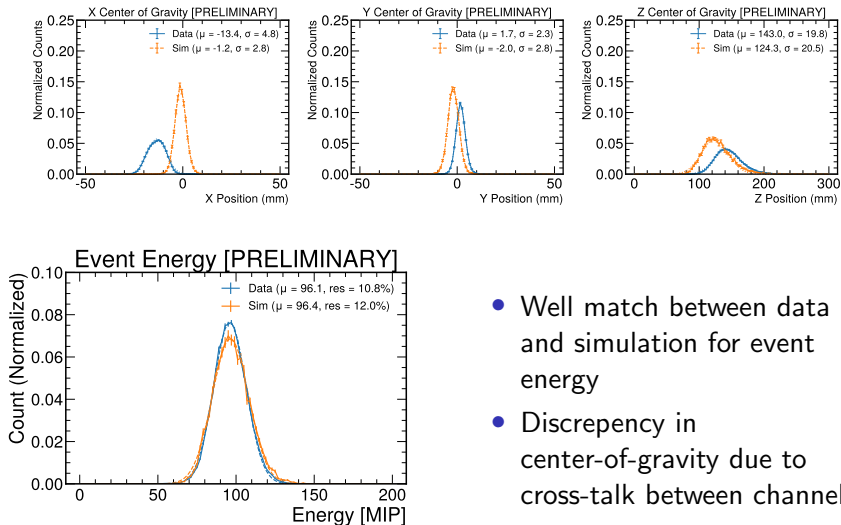
- Unplanned irradiation test
- Response to low energy ions (1 GeV/u)

Event Display with VIRTUE



- VIRTUE: <https://zenodo.org/records/14934340>

JLab Test Results



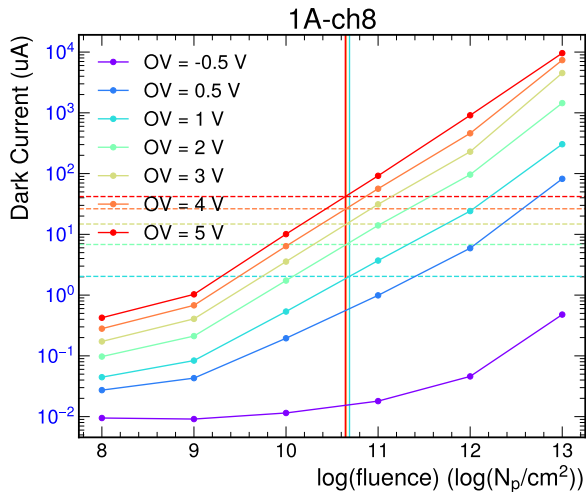
- Well match between data and simulation for event energy
- Discrepancy in center-of-gravity due to cross-talk between channels

NSRL Test: Dark Current After Irradiation

Date	B0	B1	B2	B3	B4	B5	B6	B7	B8 (mA)
20250521 20:45	1.09	1.24	1.10	1.04	0.73	0.64	0.38	0.37	0.16
20250522 12:35	0.94	1.03	0.94	0.87	0.62	0.54	0.33	0.32	0.13
20250523 16:45	0.85	0.92	0.85	0.80	0.56	0.51	0.30	0.30	0.12
20250524 21:45	0.82	0.88	0.81	0.75	0.53	0.47	0.28	0.28	0.12
20250525 18:35	0.79	0.85	0.78	0.73	0.51	0.45	0.27	0.27	0.11
20250526 15:45	0.76	0.82	0.76	0.70	0.49	0.44	0.27	0.26	0.11
20250527 12:12	0.73	0.79	0.73	0.68	0.48	0.42	0.26	0.26	0.11
20250530 18:20	0.58	0.62	0.64	0.54	0.35	0.37	0.21	0.23	0.07

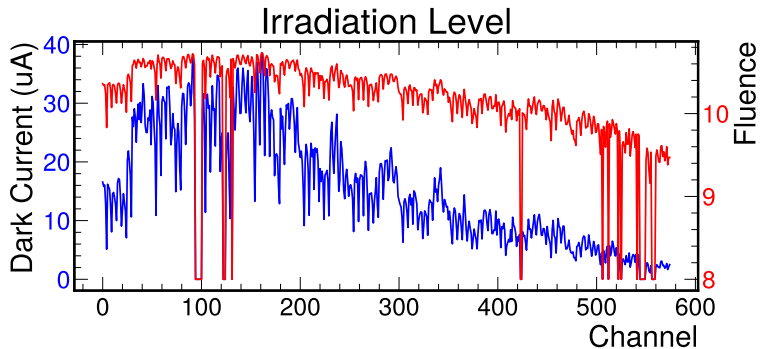
- Dark currents drop to half after 9 days
- Cooling of activated radiation and annealing effect

IV Measurement



- 1 week after the irradiation, annealing effect included

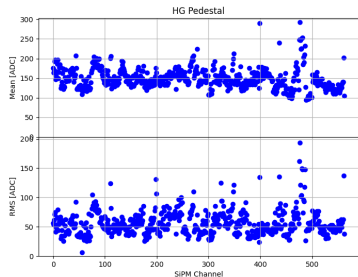
IV Measurement



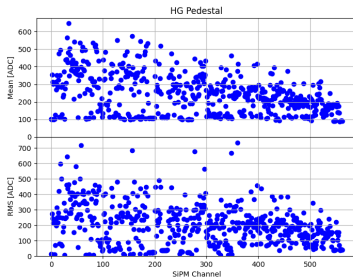
- Highest irradiation level at $10^{10.7}$ 1 MeV P^+ /cm²

Irradiation Effect on Pedestal: HG

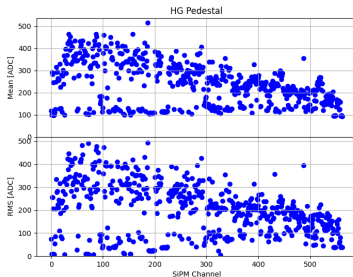
Run 1: 2025.05.16



Run 169: 2025.06.03



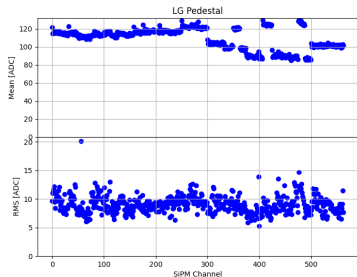
Run 507: 2025.07.08



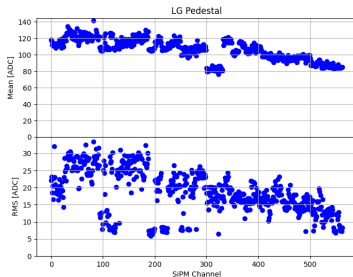
- Significant shift in both pedestal mean and width

Irradiation Effect on Pedestal: LG

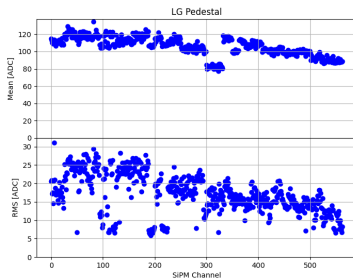
Run 1: 2025.05.16



Run 169: 2025.06.03

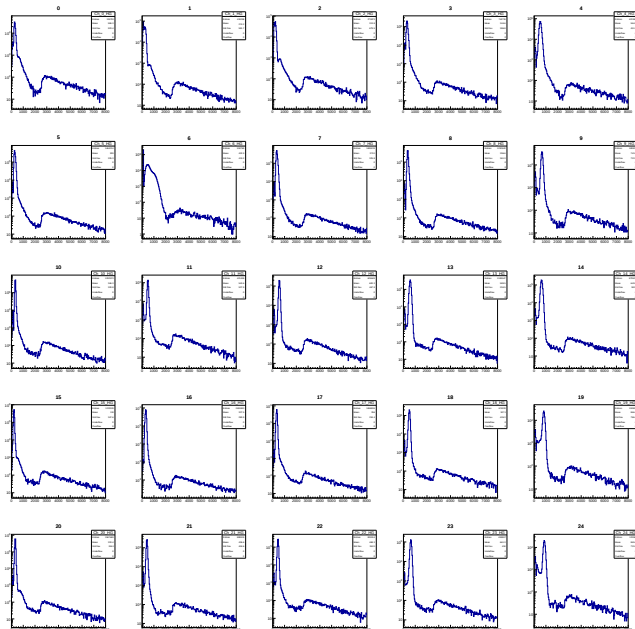


Run 507: 2025.07.08



- Stable pedestal mean and significantly shifted width

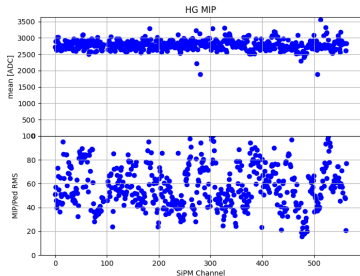
MIP Calibration



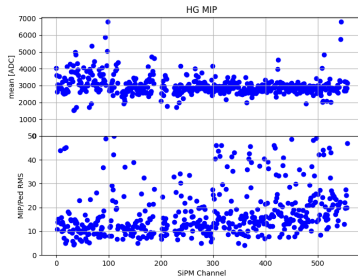
- TLogic mode, Majority of 2
- HG=63, LG=58
- Clear separation between the MIP peak and the pedestal peak

Irradiation Effect on MIP: HG

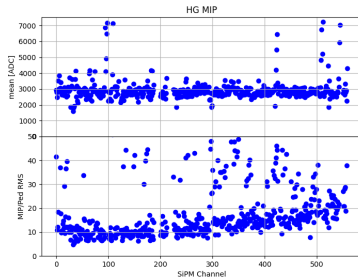
2025.05.16 - 2025.05.19



2025.05.06



2025.7.08 - 2025.07.10



- Relatively consistent MIP calibration
- MIP/Ped RMS stay above 5 after irradiation

Summary

- Successful beam tests at JLab and NSRL
- Demonstrate the scalability of the SiPM-on-tile design and key engineering features
- Cross-talk between channels need further investigation
- SiPMs survive up to 10^{11} 1 MeV P^+ /cm² irradiation
- 100k events of 1 GeV protons and 10k events of 2.5 GeV protons are under analysis

Acknowledgements We are grateful to the kind help of Yulia Furletova and Andrew Lumanog at JLab and Xiaodong Jiang and Mike Sivertz at NSRL