Construction of an SiPM-on-tile ZDC prototype

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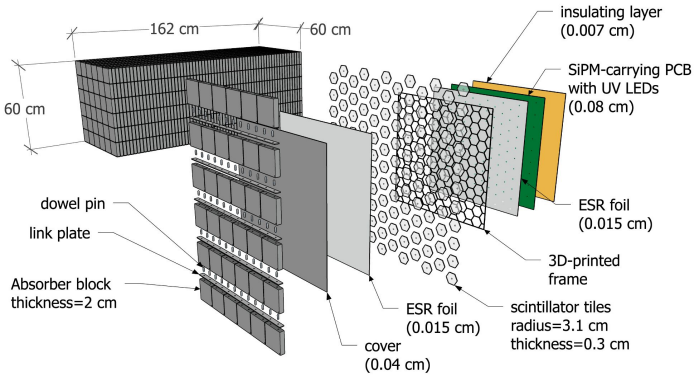
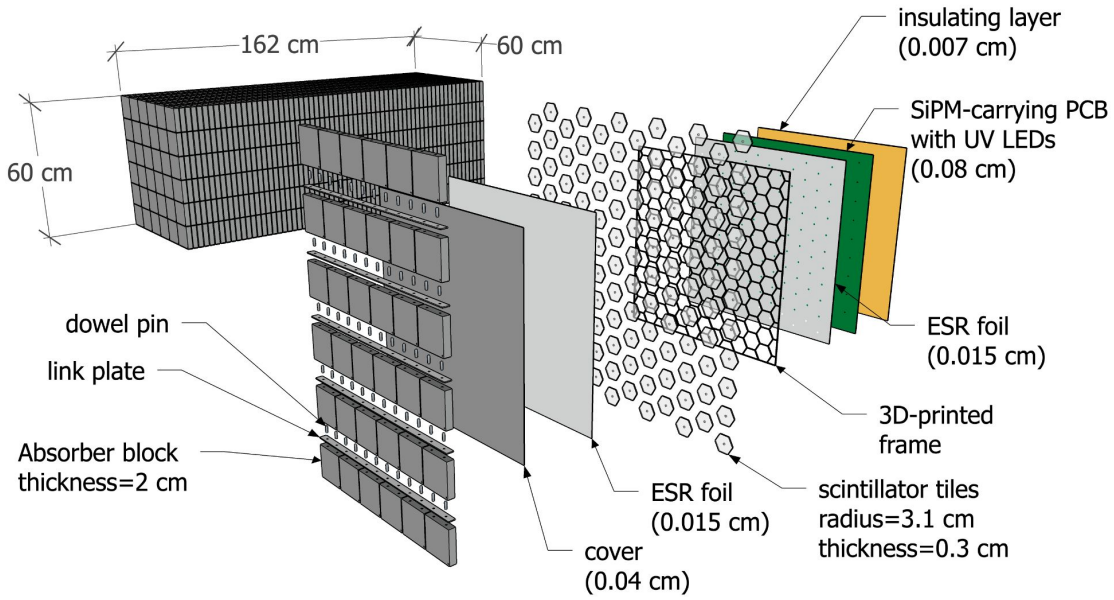


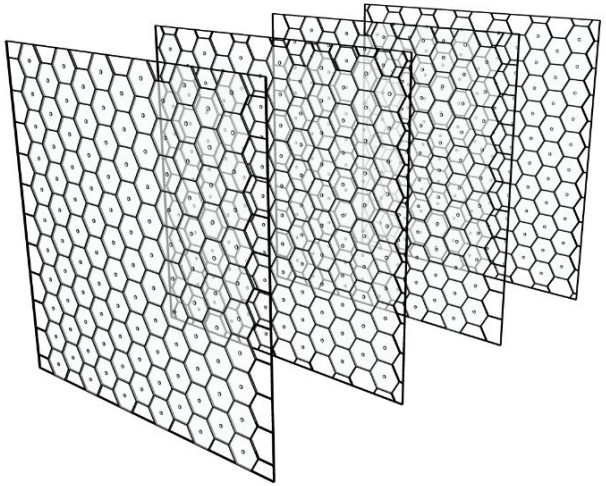
Zero-degree calorimeter

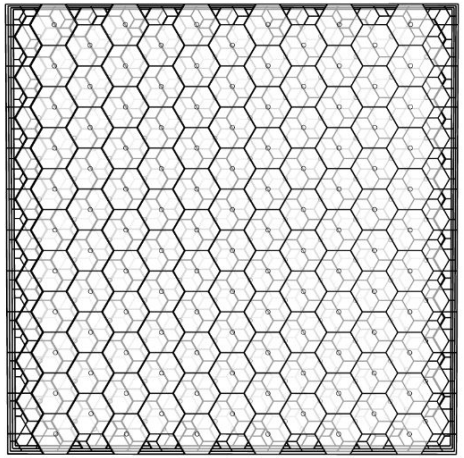
- Located ~35 m downstream of target along proton-beam direction
- Detects neutral particles
- Uses SiPM-on-tile technology similar to forward Hcal insert
- Self-supporting structure with stainless steel absorbers, repurposed from STAR experiment



Staggered design

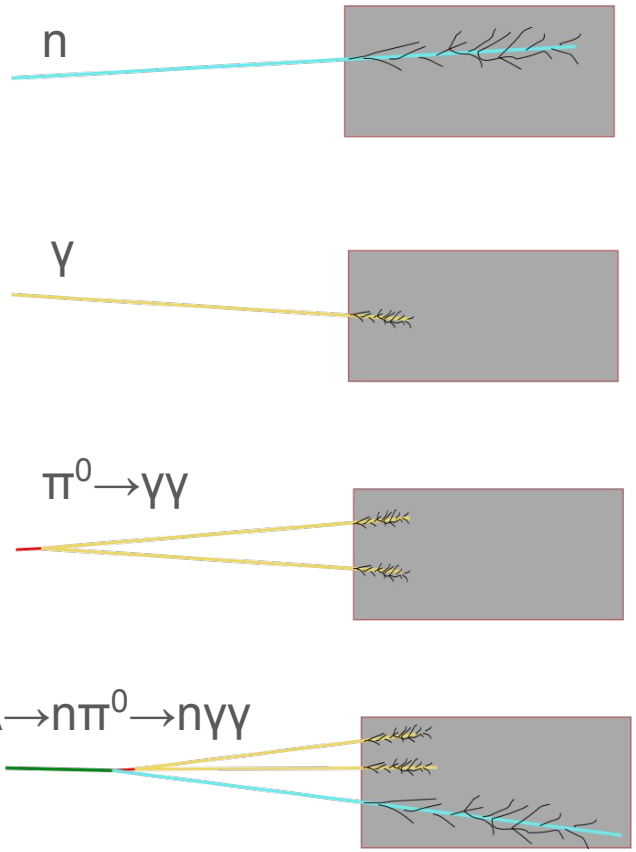
- Cycles through four layouts of hexagonal tessellations
- Improves position resolution of detector through overlapping the cells in one layer with those of another.
- “Subcells” defined by overlap provide higher granularity.





What can we measure with the ZDC?

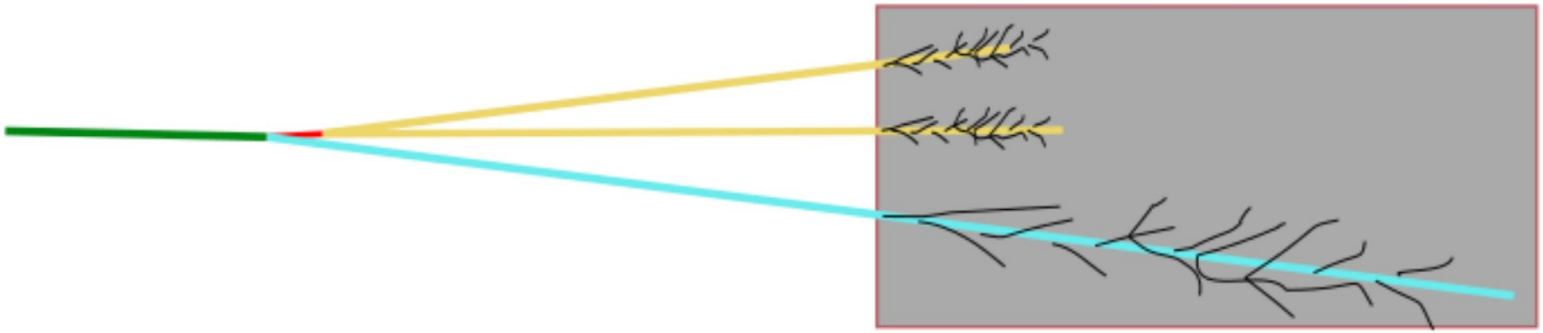
- Neutrons
- Photons
  - Can be reconstructed well at mid to high energy with this detector despite it being designed as an HCAL
- π^0 through decay to $\gamma\gamma$
- Λ^0 through decay to $n\pi^0 \rightarrow n\gamma\gamma$
  - An excellent benchmark for the ZDC performance, since it requires all of the techniques used in the other channels



ZDC performance benchmark

- Select 3-cluster events
- Cluster with largest eigenvalue in moment matrix is identified as neutron, the other two are identified as photons from the π^0
- Correct the neutron energy for hadronic/EM scale differences

$$E_n^{\mathrm{corr}} = \frac{E_n^{\mathrm{uncorr}}}{1 + A + B/\sqrt{E_n^{\mathrm{uncorr}}} + C/E_n^{\mathrm{uncorr}}}$$



ZDC performance benchmark

- Determine momenta of *n* and *γ*'s:

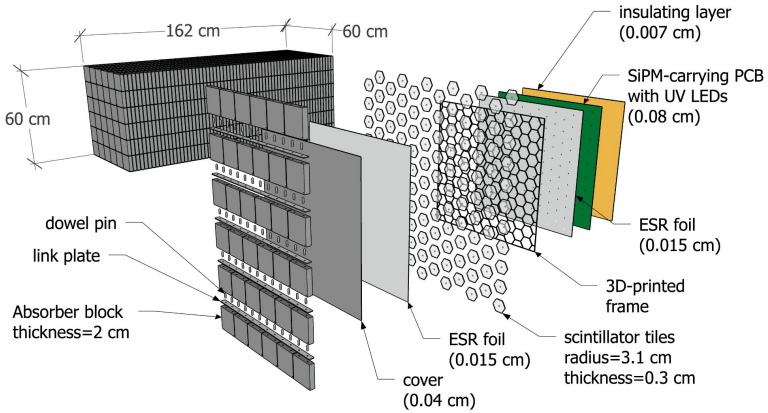
$$\vec{p}_n = \sqrt{E_n^2 - m_n^2}\,\frac{\vec{x}_n}{|\vec{x}_n|}, \quad |\vec{p}_{\gamma_i}| = E_{\gamma_i}\,\frac{\vec{x}_{\gamma_i}}{|\vec{x}_{\gamma_i}|}$$

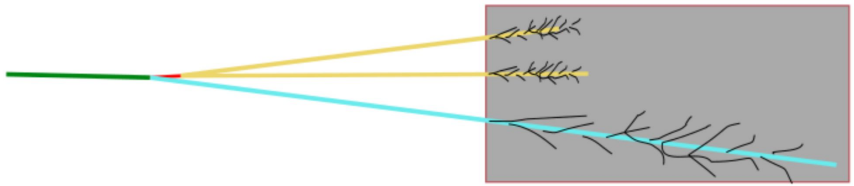
- Determine θ^*_Λ, m_Λ, and $m_{\pi 0}$:

$$\theta^*_\Lambda = \vec{p}_p^{\,\text{beam}} \angle (\vec{p}_n + \vec{p}_{\gamma_1} + \vec{p}_{\gamma_2})$$

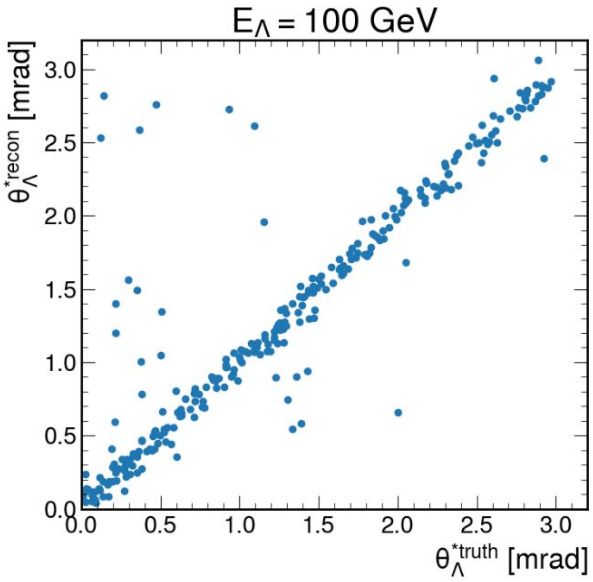
$$m_\Lambda = \sqrt{(E_n + E_{\gamma_1} + E_{\gamma_2})^2 - |\vec{p}_n + \vec{p}_{\gamma_1} + \vec{p}_{\gamma_2}|^2}$$

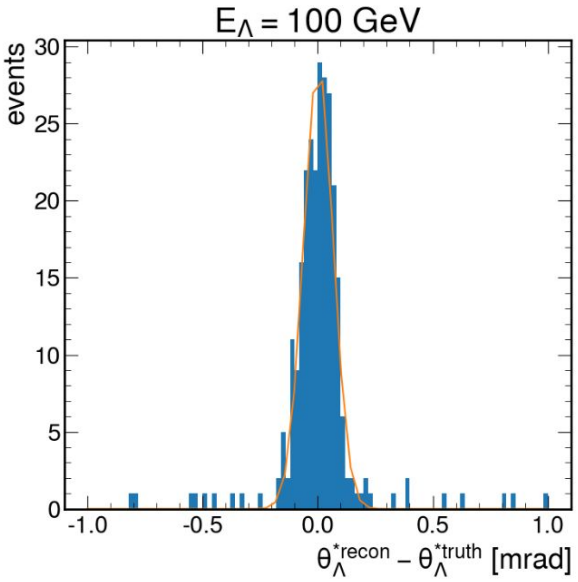
$$m_\pi^0 = \sqrt{(E_{\gamma_1} + E_{\gamma_2})^2 - |\vec{p}_{\gamma_1} + \vec{p}_{\gamma_2}|^2}$$

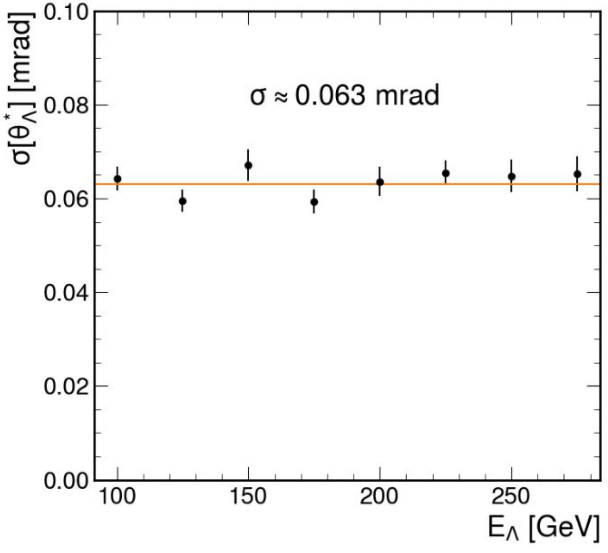




Results of benchmark: θ*

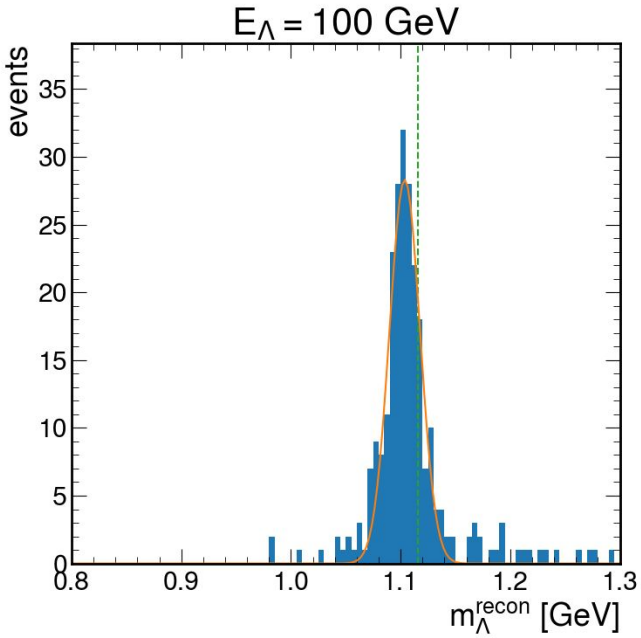


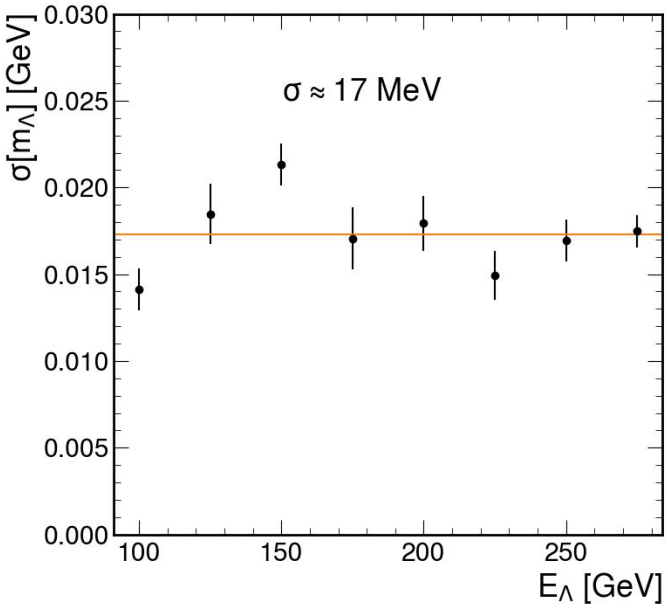




Results of benchmark: reconstructed lambda mass

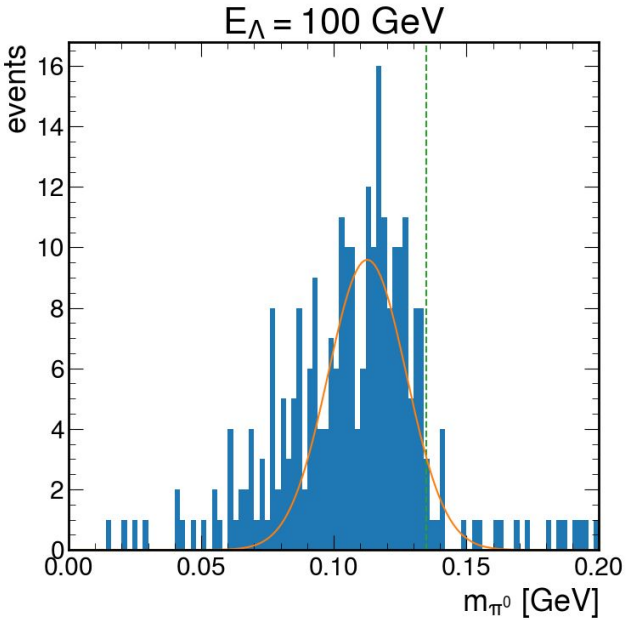
- Surprisingly good resolution
- Particle directions assume they come from origin (causes some bias)

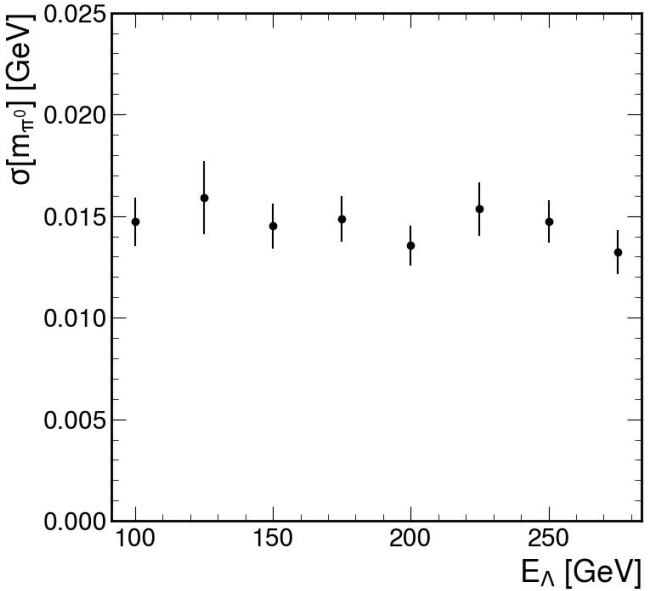




Results of benchmark: reconstructed π^0 mass

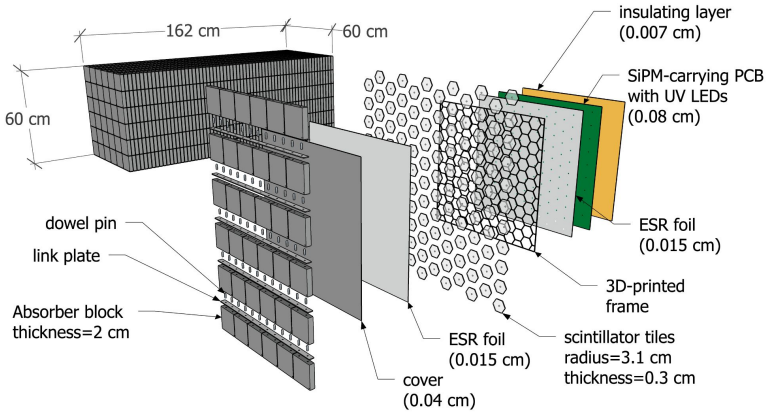
- Not quite as good recon for Λ mass
- Could be improved with reconstruction of the vertex position?

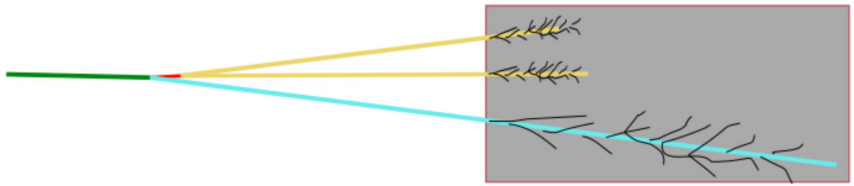




ZDC performance benchmark

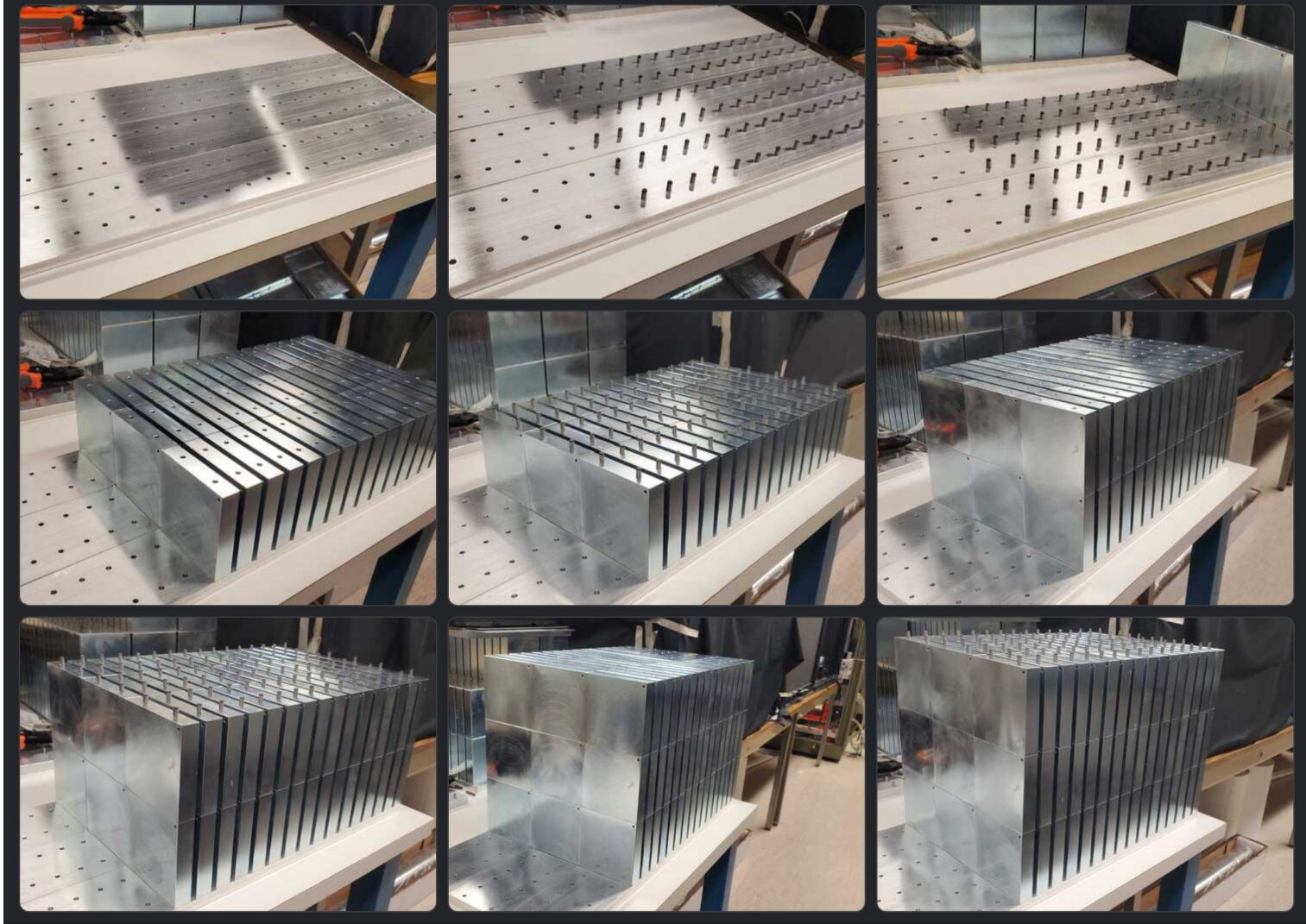
- Overall, a success for this design, showing that it can perform not only hadronic calorimetry, but also





Prototype construction

- 30x30 cm2 (¼ transverse area of full detector)
- 15 layers (full detector uses 60)
- Constructed similar to the full detector
- Staggered square cell pattern

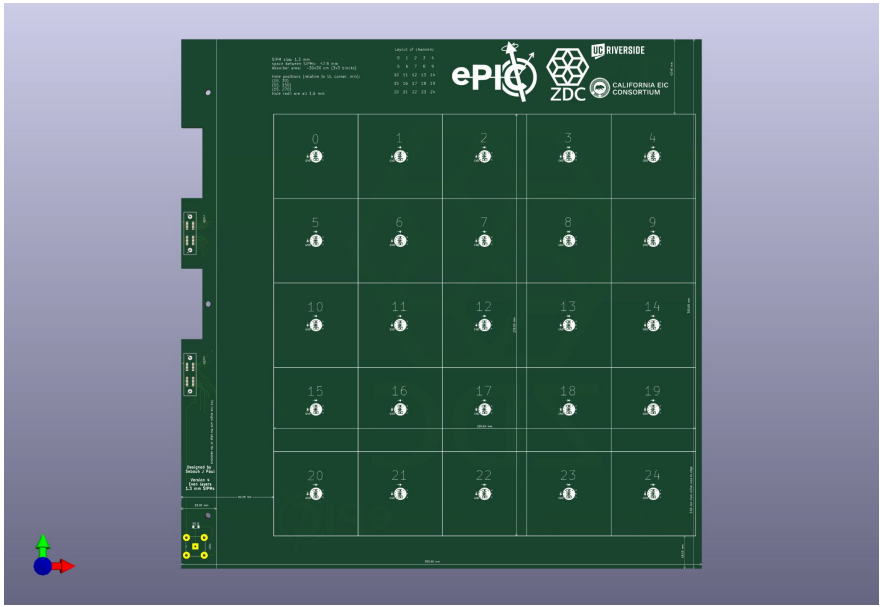


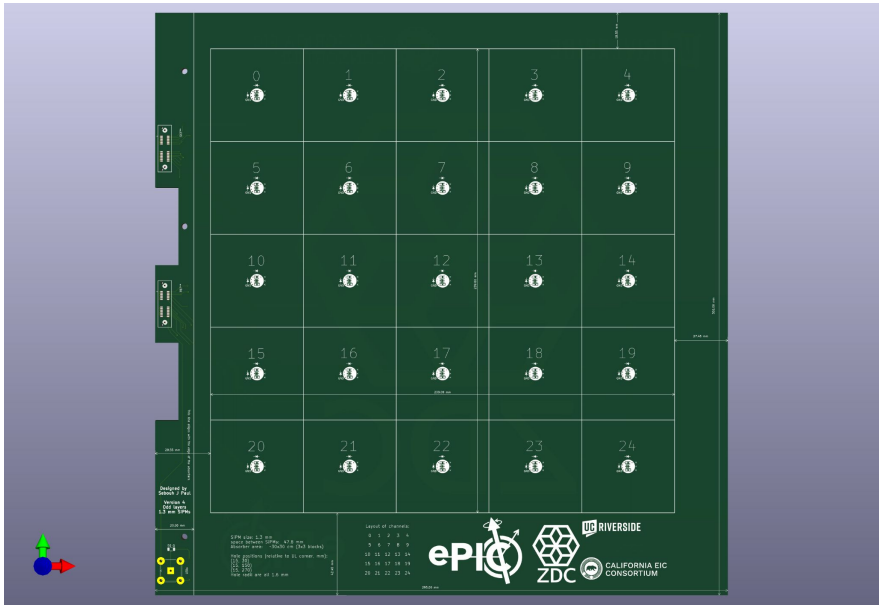
PCB assemblies slide into the gaps between absorbers

- Part of the PCB sticks out to make room for connectors
- Final design will use ribbon cables rather than single cables for each channel

Staggered design

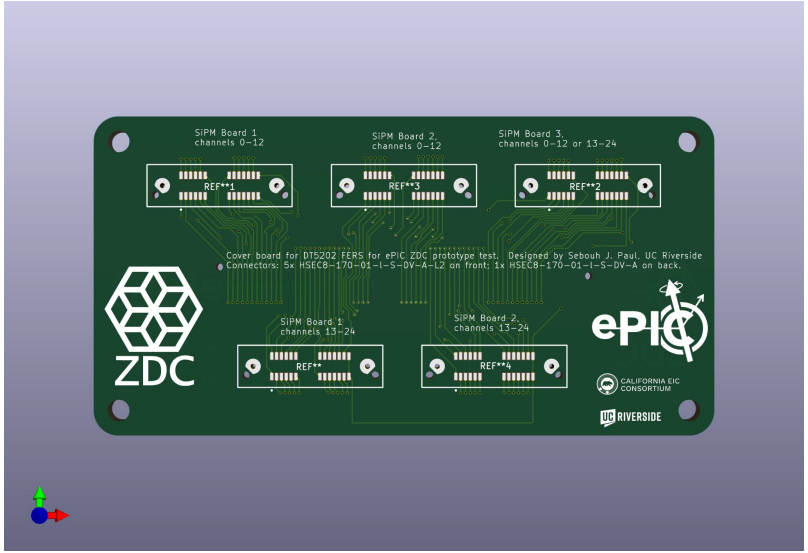
- Uses squares instead of hexagons
- Alternates between two layouts with different cell offsets





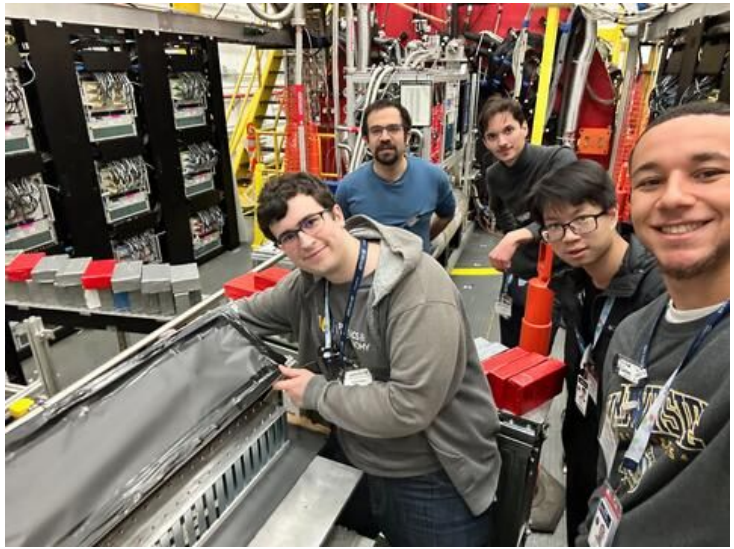
Readout system

- Uses CAEN DT5202s to digitize readout
- Each CAEN unit reads out from 2 ½ PCB boards, connected via ribbon cables
- 15 layers in prototype → 6 CAEN units



Planned beam test

- Hall D of JLab using e^+ beam
- Similar to 2023 beam test of CALI prototype
- Fall 2024 (exact dates TBD)



Conclusions/Summary

- The ZDC uses SiPM-on-tile technology to detect neutral particles (n, γ)
- A benchmark of reconstructing simulated $\Lambda \rightarrow n\pi^0 \rightarrow n\gamma\gamma$ events shows the promising potential of this detector
- A prototype of this detector is being constructed at UCR, to be used in a beam test this fall