Studies of time resolution, light yield, and crosstalk using SiPM-on-tile calorimetry for the future EIC

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PAPER

Studies of time resolution, light yield, and crosstalk using SiPM-on-tile calorimetry for the future Electron-Ion Collider

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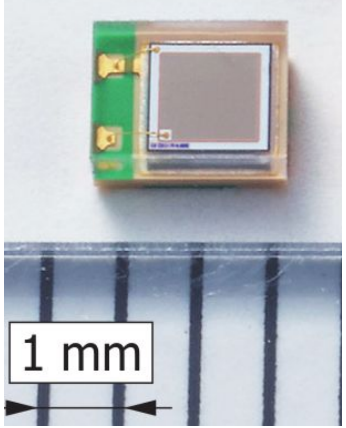
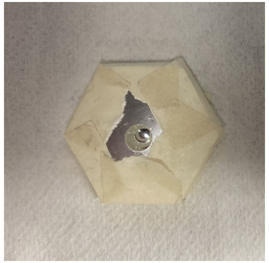
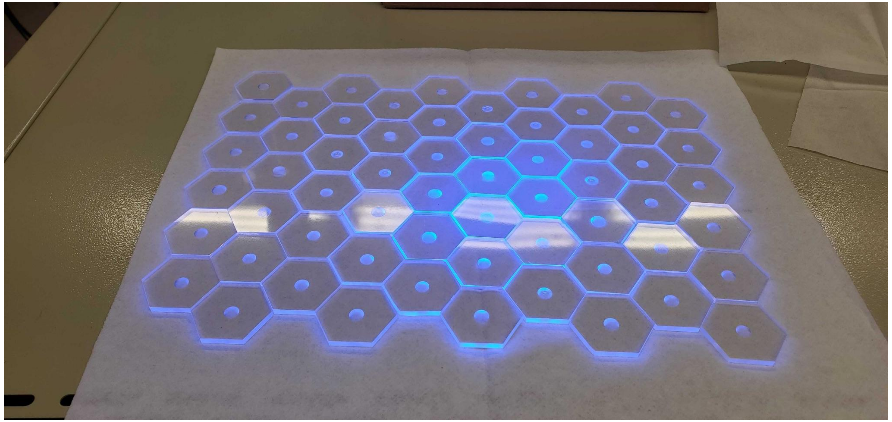
SiPM-on-tile technology

SiPM is a Silicon Photomultiplier
used to detect light.

Scintillating tiles are a doped plastic material that will emit light when ionized

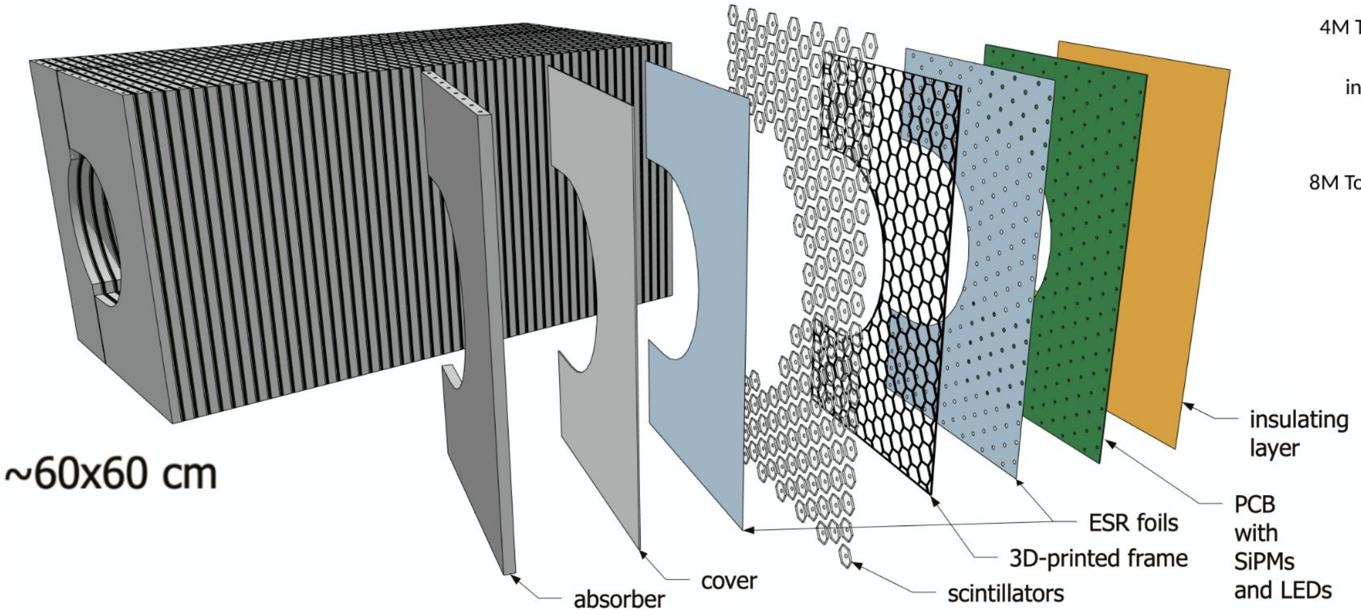


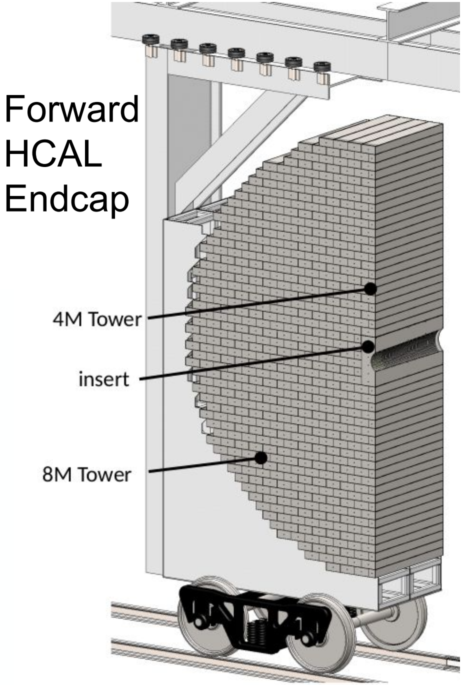




Developed as unit cell for highly granular calorimeter by CALICE for e+e- colliders, now being deployed at scale at the LHC and EIC

The Calorimeter Insert (CALI)





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M. Arratia et al. NIMA 1047 (2023) 167866

What were we trying to test?

Light Yield: How much much light yield would be read by the SiPMs with the Scintillators we were using.

Cross-talk: How much of our light signals in a cell will leak into the the neighboring cells, and what is the best way to reduce this.

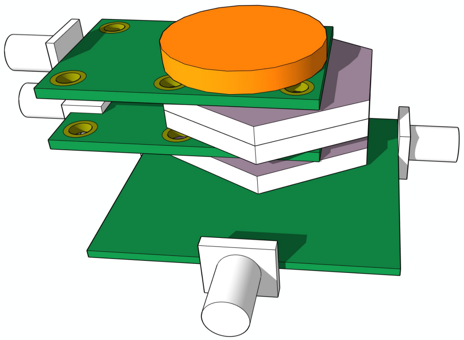
Timing resolution: What is the time difference and timing resolution for our set up.

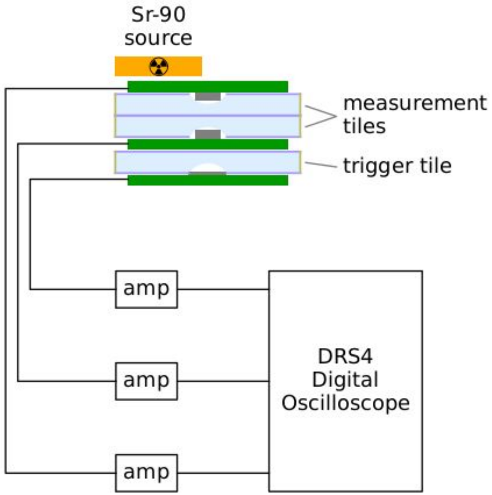
Our SiPM Configuration and Materials: 3x3 mm^2, SiPMs from Hamamatsu (model S14160-3015) at +2V Overvoltage

Experimental Light Yield Setup using Strontium-90

Radioactive Source was placed above three SiPMs. The bottom most SiPM would act as the trigger.

Data was collected with full-waveform digitizer (DRS4) from the two uppermost SiPMs and analyzed.



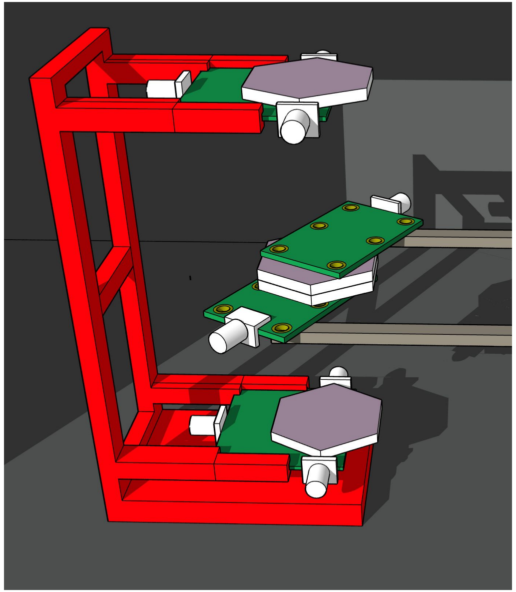


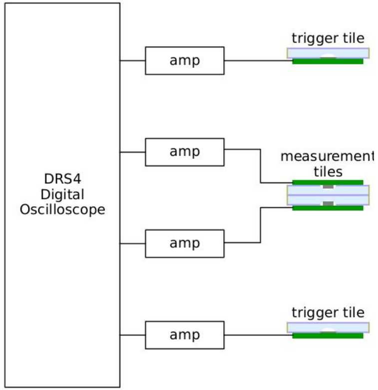
Experimental Light Yield Setup for Cosmic Rays

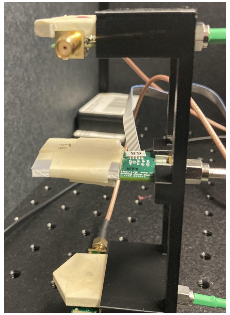
Two SiPMs were placed directly between two other SiPMs separated by a distance that would act as the trigger.

This trigger setup would ensure that a muon would directly hit the two in the middle.

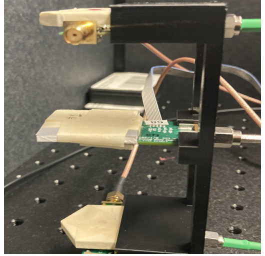
Data would be collected from the two in between.

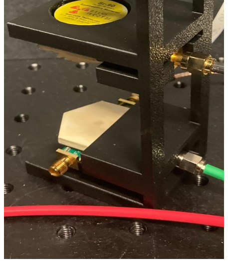






Light yield results



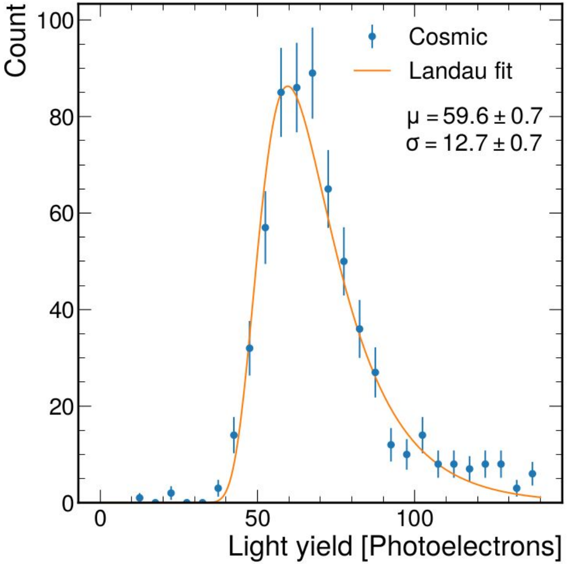


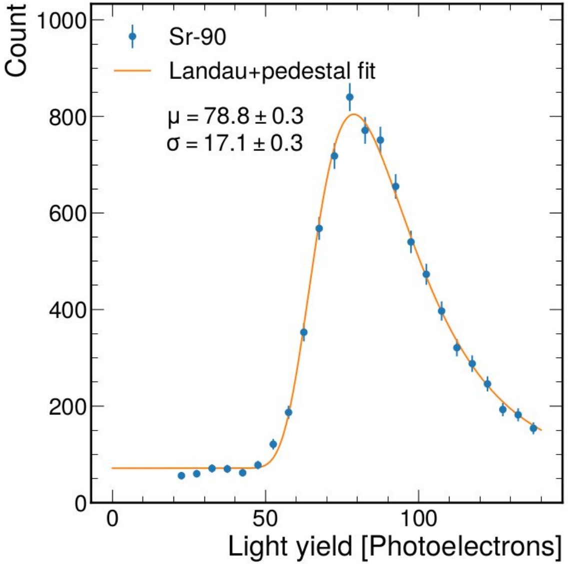
Light yield from cosmic rays is analyzed to be 60PE

Light yield from the Sr-90 source is analyzed to be 80PE.

Both results compatible once energy loss of electron is considered

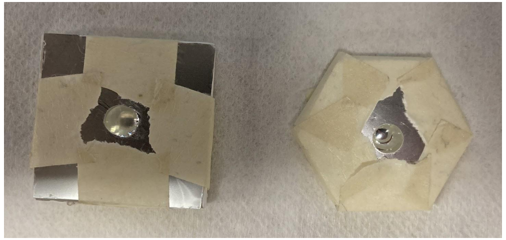
3x3 mm², SiPMs +2V overvoltage



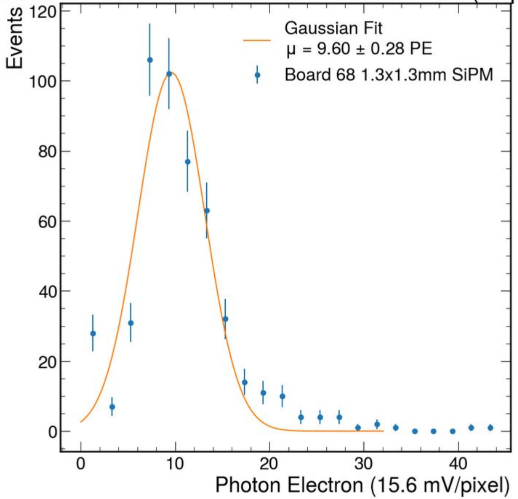


High light yield at low operating voltage is beneficial to buffer expected radiation damage

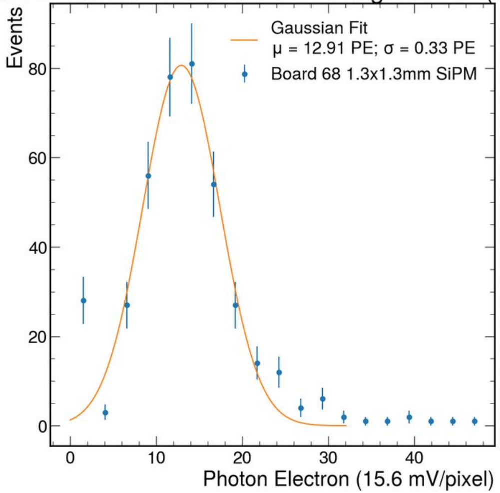
Hexagons Vs Squares



Board 68 at +2 Cosmic ReTest with UCR Tile #1 (Super Painted)

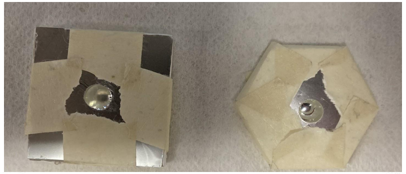


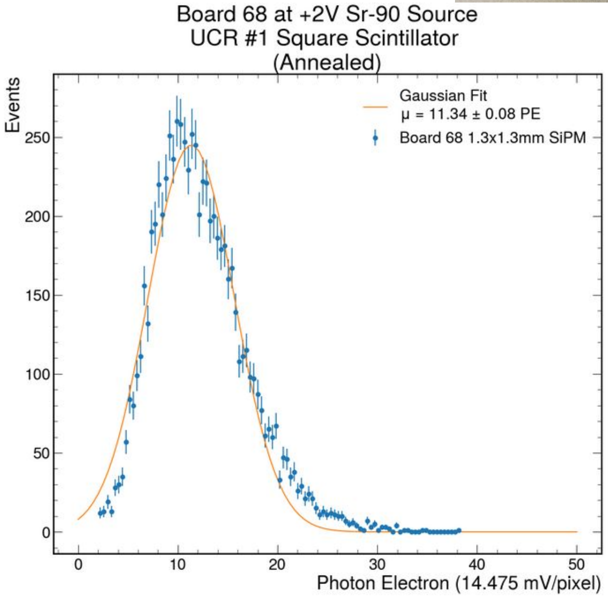
Board 68 at +2 Cosmic Test with UCR Hexagonal Tile (Super Painted)

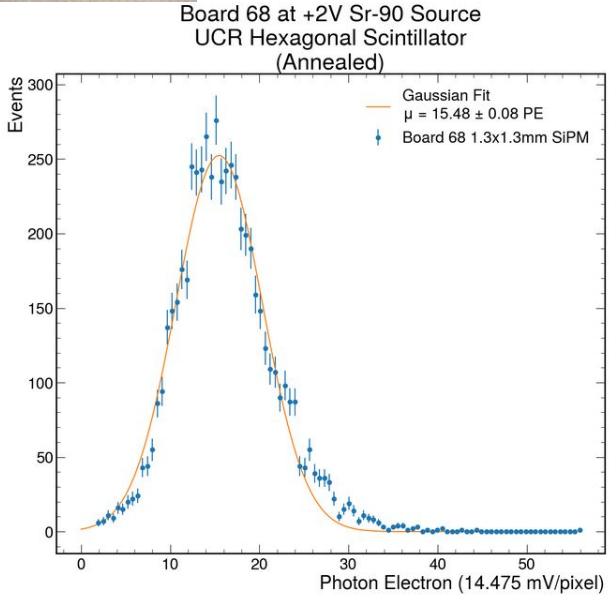


Hexagon ~34% higher light yield

Hexagons Vs Squares

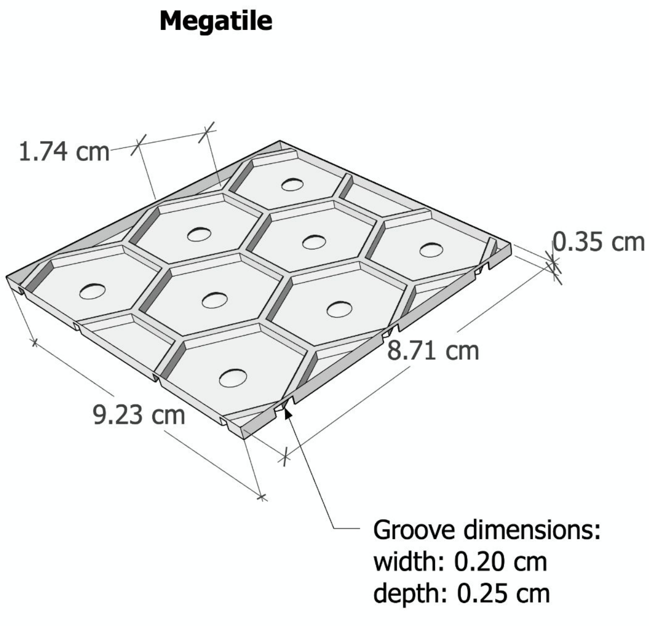


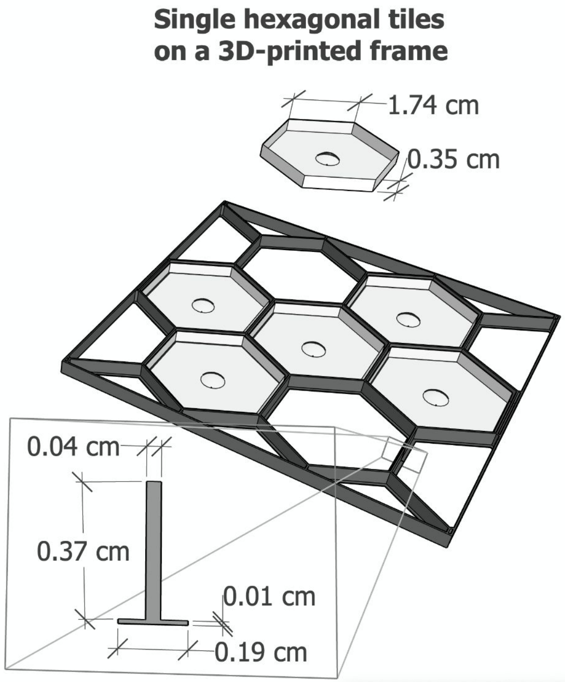




Hexagon ~37% higher light yield, statistically compatible cosmic ray results

Two Methods Used When Testing Crosstalk





The "Megatile" is a single scintillating plastic piece that was machined to have grooves in the shape of hexagons.

The grooves were painted white.

Using a 3D printed frame.

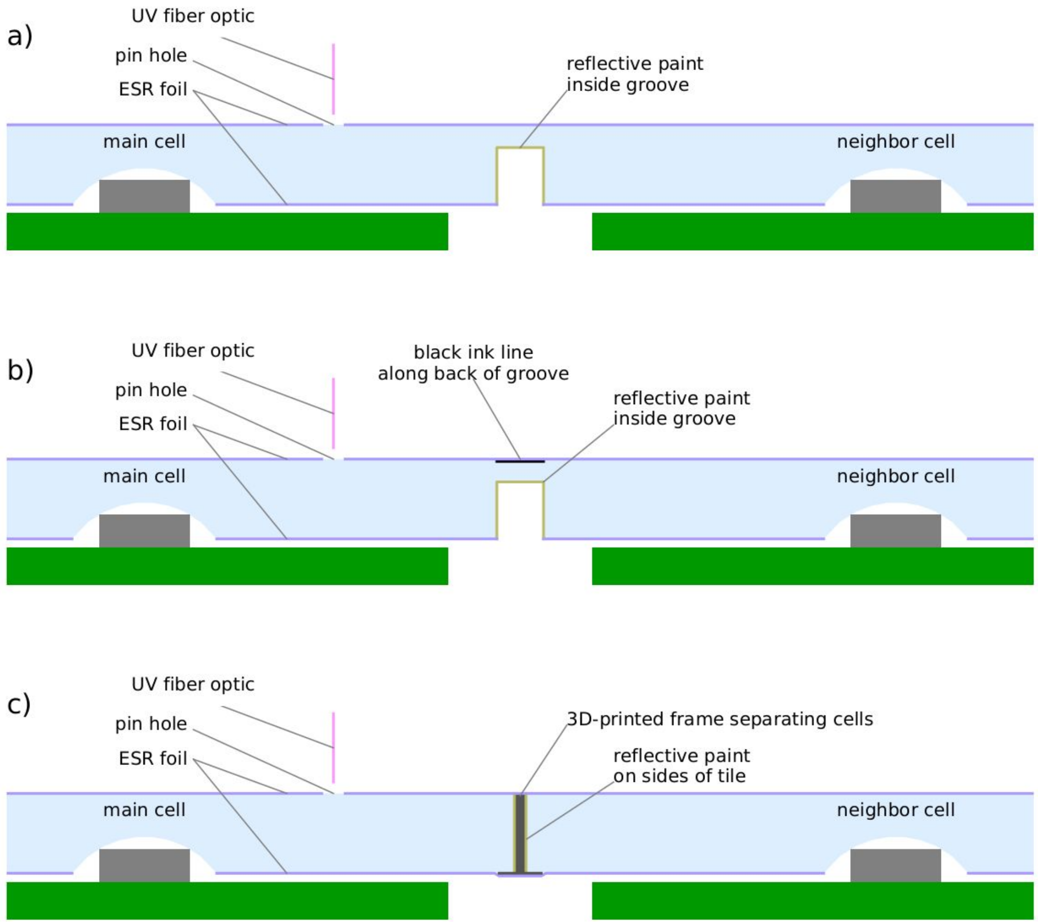
Dimensions of a single hexagons were 0.35mm thick, with each side being 1.74cm.

Two Methods Used When Testing Crosstalk

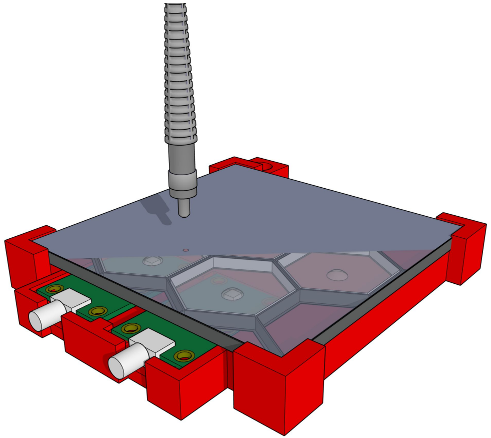
First iteration was to paint the inside of the grooves with a white reflective paint.

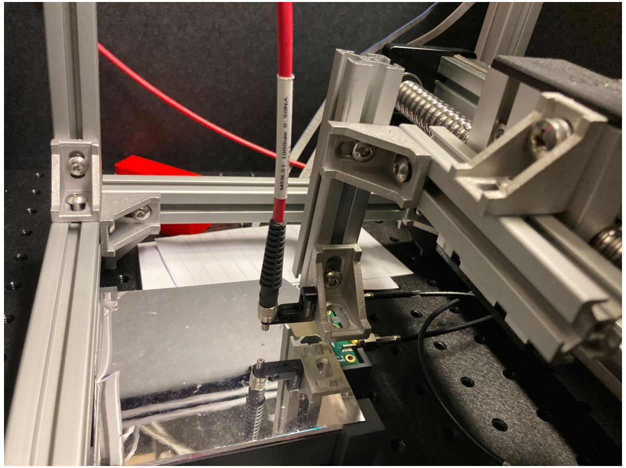
The second iteration involved drawing a black ink line along the back of the groove. This would cause any light passing to the other cell to be absorbed.

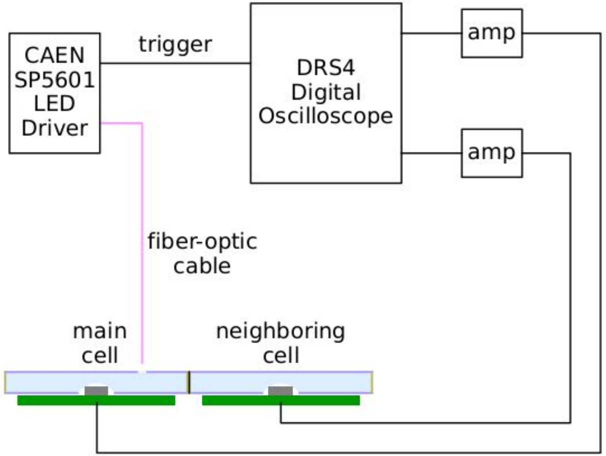
3D printed frame would create a wall to stop all light.



Experimental Procedures Used to Test Crosstalk



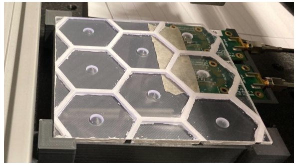


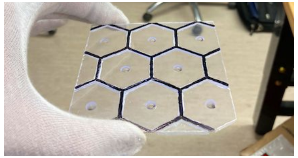


Using two SiPMs placed under the Scintillator(s), one cell would be chosen as the main cell and the other would be named the neighboring cell.

A pinhole was made in the foil above the main cell. A UV LED was shined directly into the pinhole of the main cell.

Crosstalk results

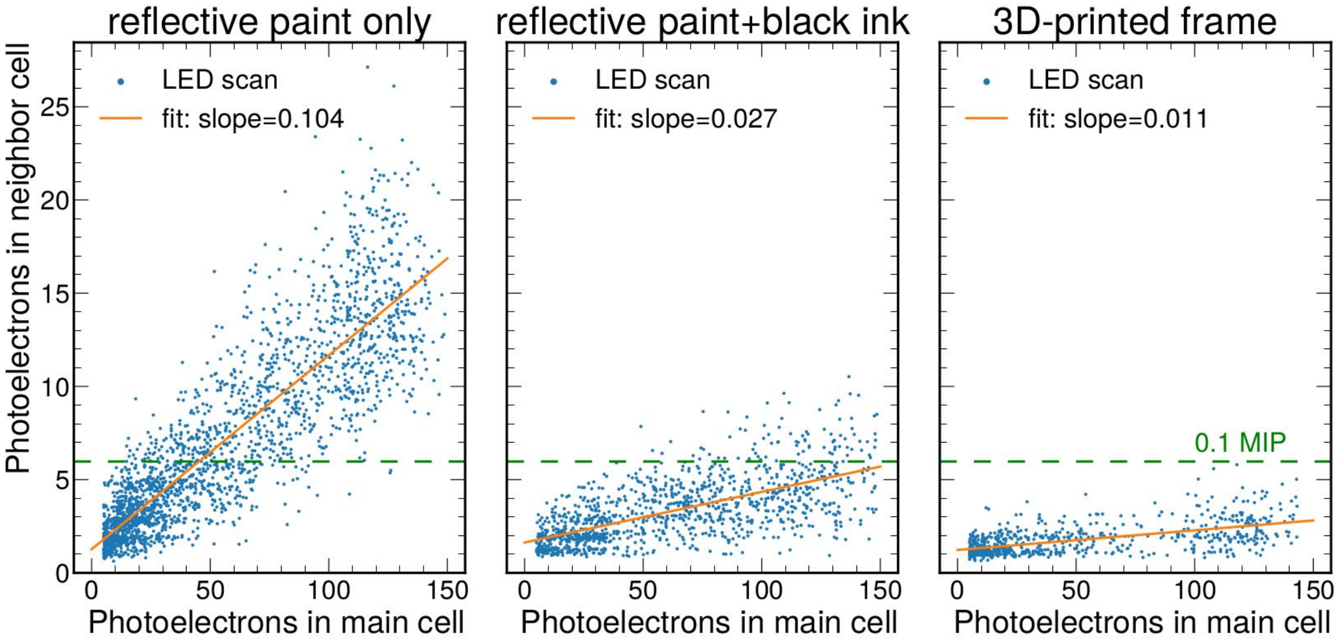




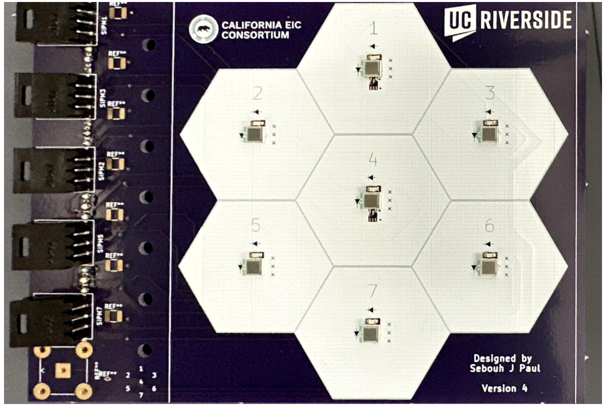
The results show reflective paint only is not effective at limiting the crosstalk between cells.

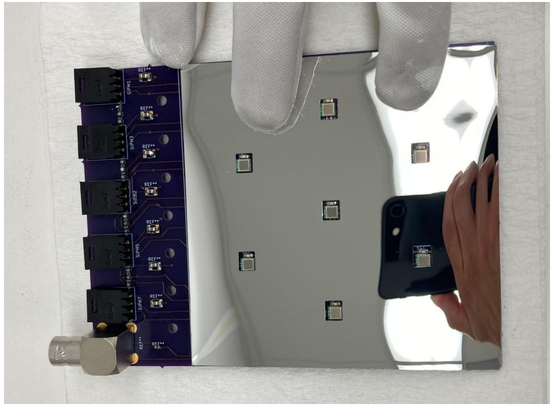
Adding black ink to the underside shows to greatly reduce the crosstalk.

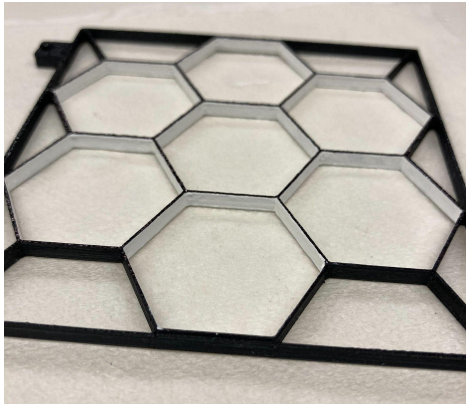
The 3D-printed frame is most effect at reducing the cross-talk.

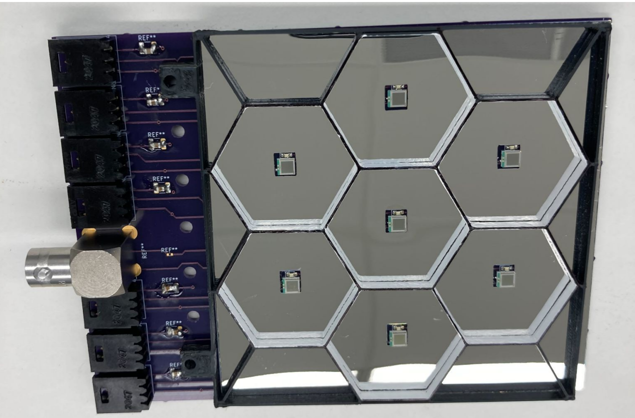


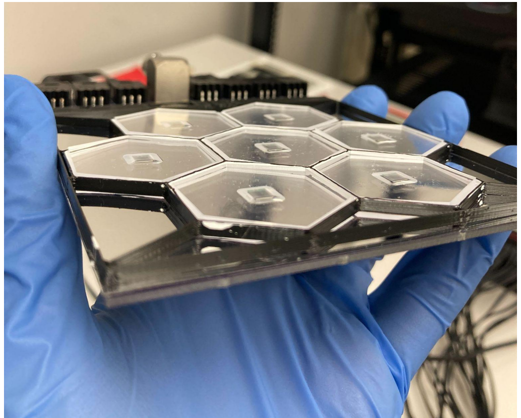
Plastic frame idea in practice:

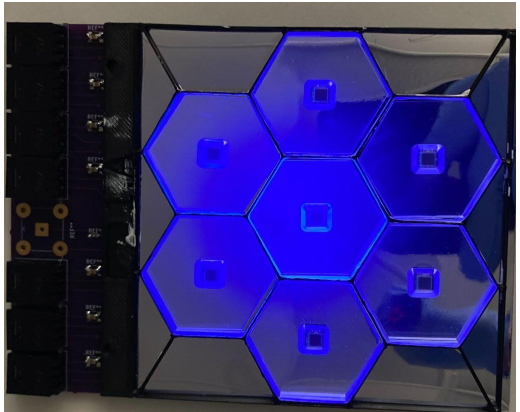






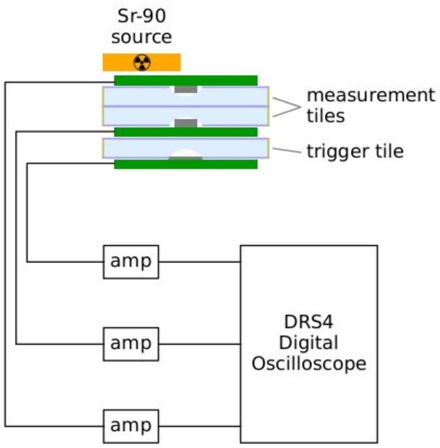


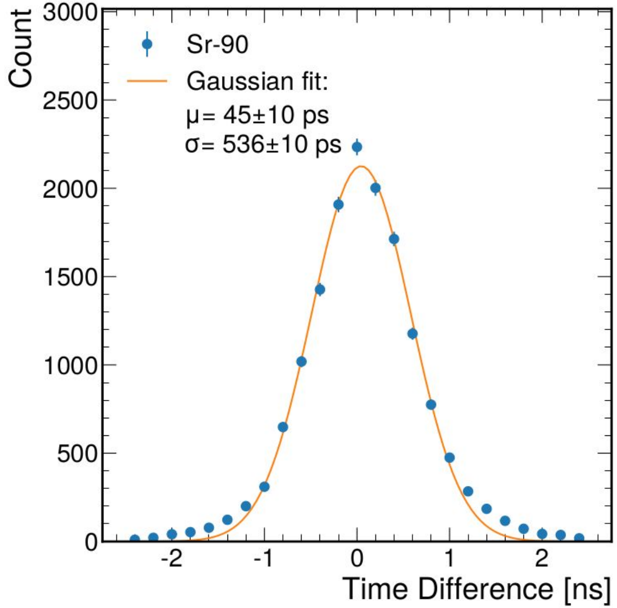


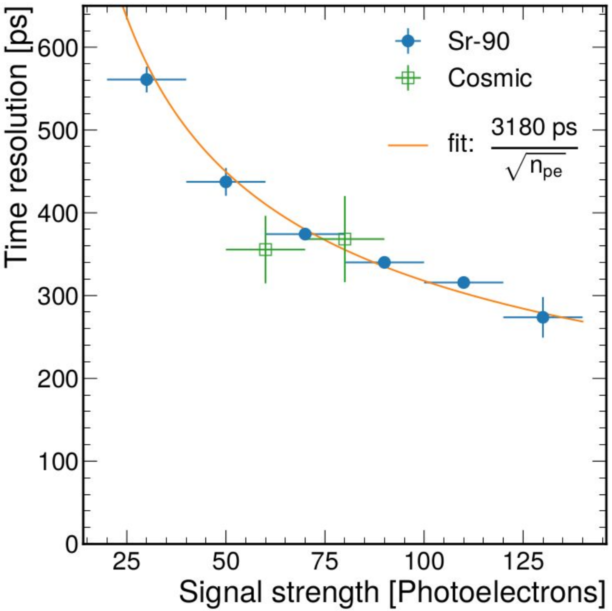


Time resolution result
(first measurement of SiPM-on-tile cell!)

We fit our data to a gaussian and found that our timing difference is μ =46 ± 9 ps and σ = 540 ps. The time resolution of a single SiPM is calculated by dividing this σ by √2 which calculates to 380 ps.







Time of arrival of pulse obtained with constant-fraction discriminator method reading out all waveform at 5 GHz.

The end result shows the data fits σ=3180/$\sqrt{n_{pe}}$

Summary and Conclusions

- Light-yield was measured to be 60PE with Cosmic Rays, and 80PE with the Strontium-90 with 3 mm SiPM + 2V.
  → Probably enough to survive radiation damage
- Crosstalk was found to decrease the most when the 3D printed frame was utilized to define cells
  → now baseline method for Calorimeter Insert
- Timing studies reveal time resolution of ~300 ps at 100 photoelectrons.
  → Can yield valuable time domain per cell

More details in:
https://iopscience.iop.org/article/10.1088/1748-0221/18/05/P05045/pdf