A SiPM-on-tile ZDC

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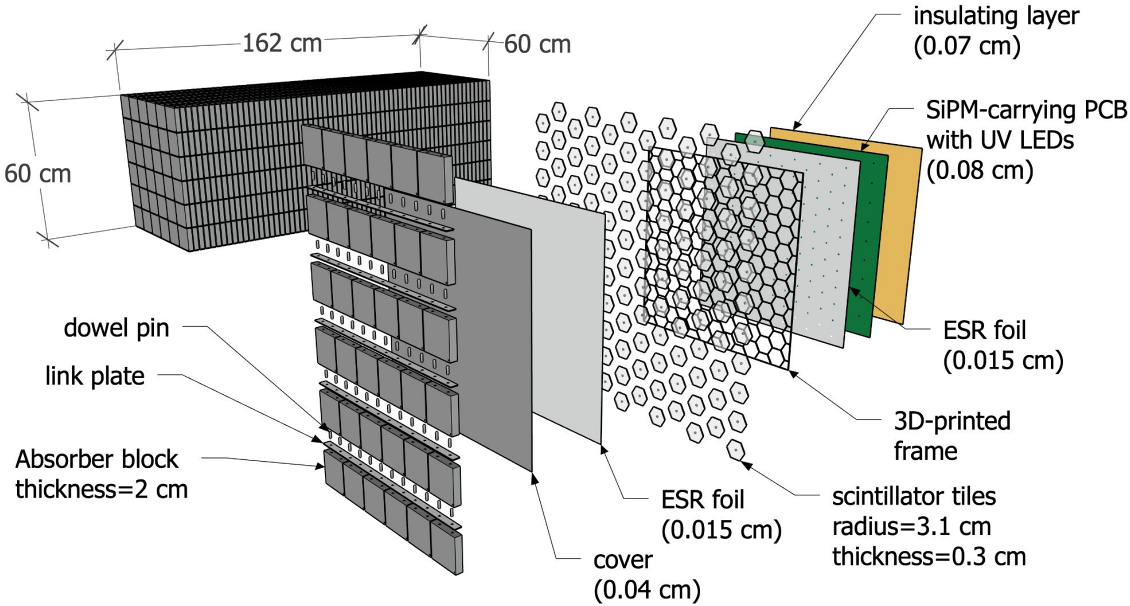
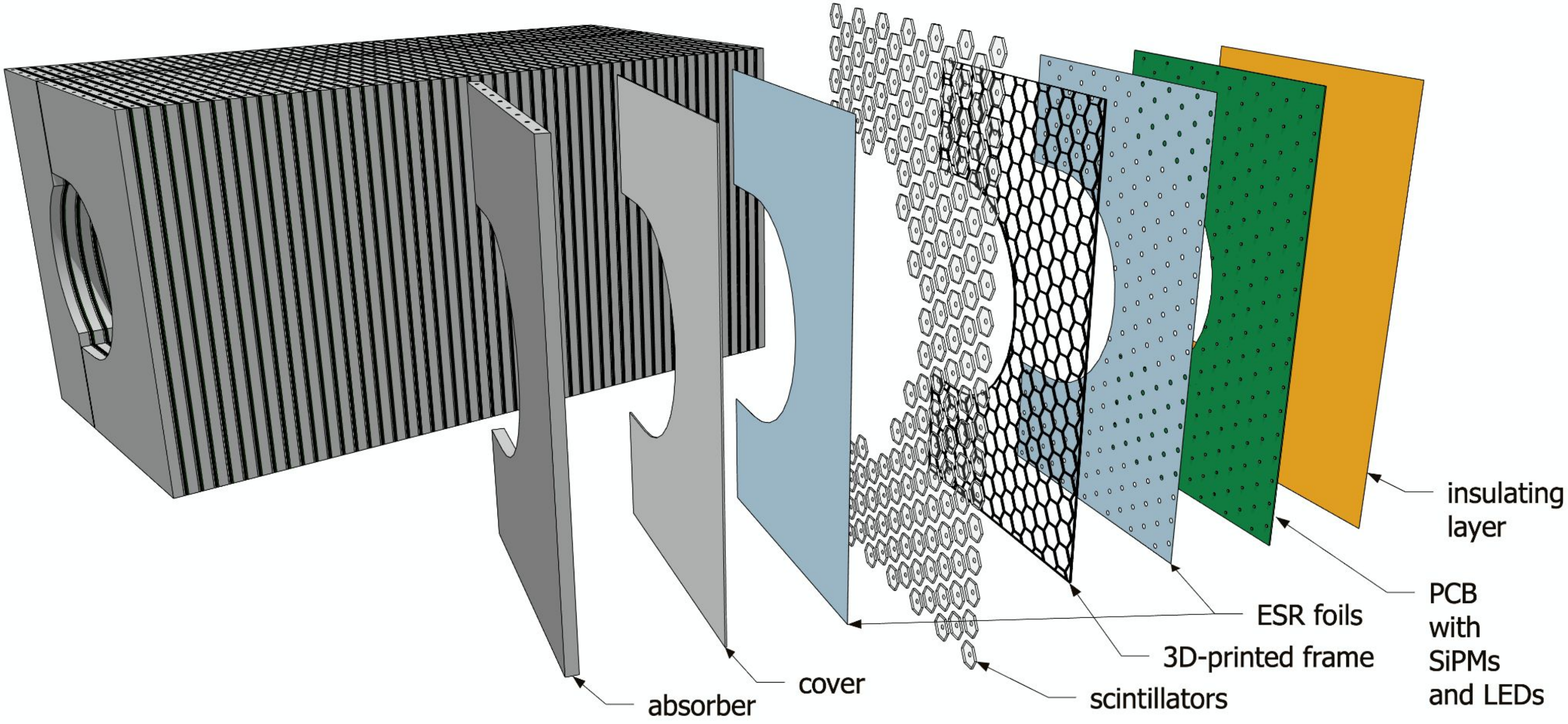


ePIC Calorimetry Meeting, July 12, 2023

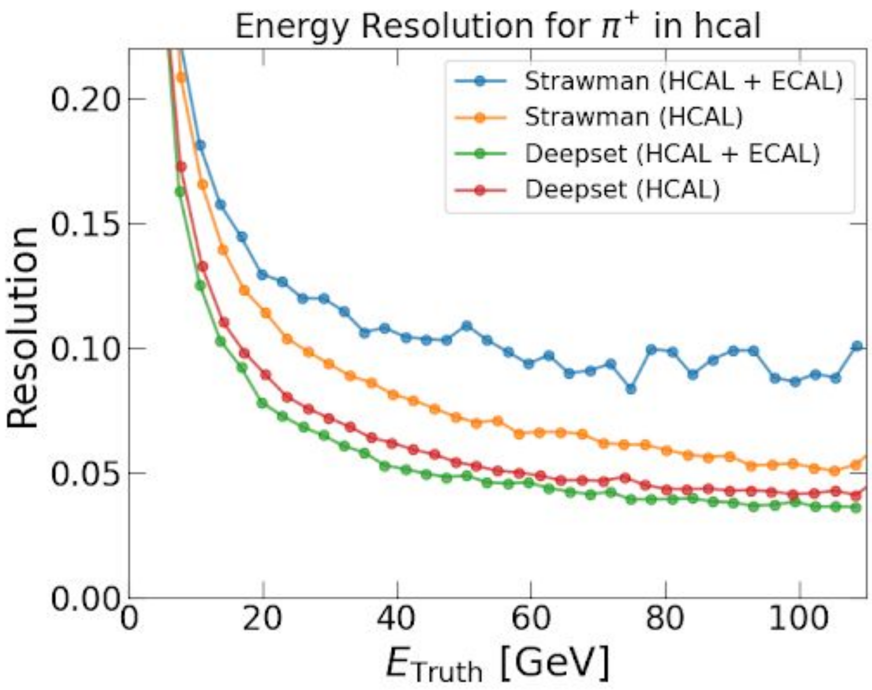
Outline

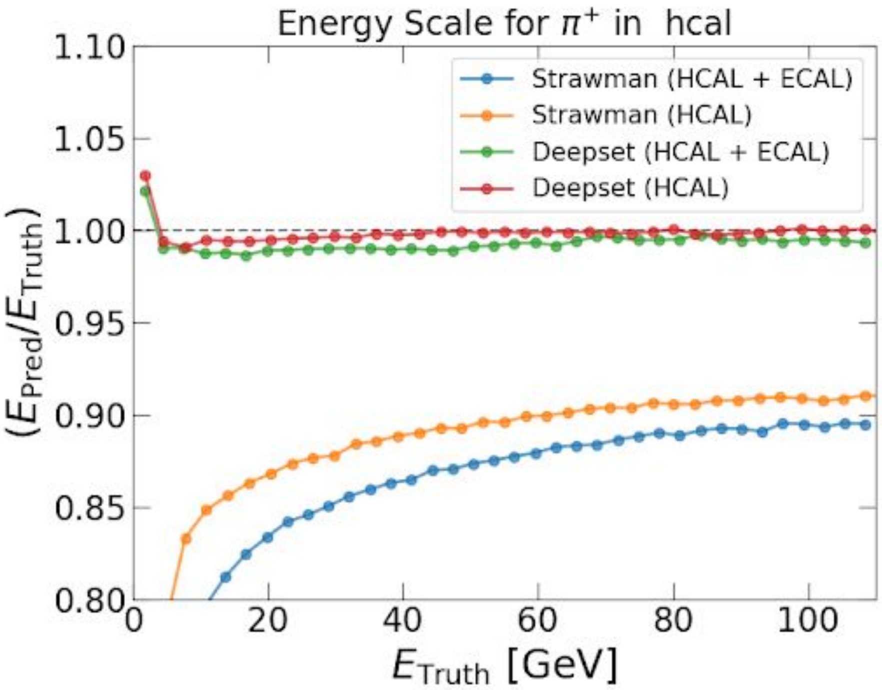
- Brief summary of Calorimeter Insert design and performance
- ZDC ala Calorimeter Insert

The Insert is a Fe/Sc SiPM-on-tile calorimeter



Current performance of Calorimeter Insert

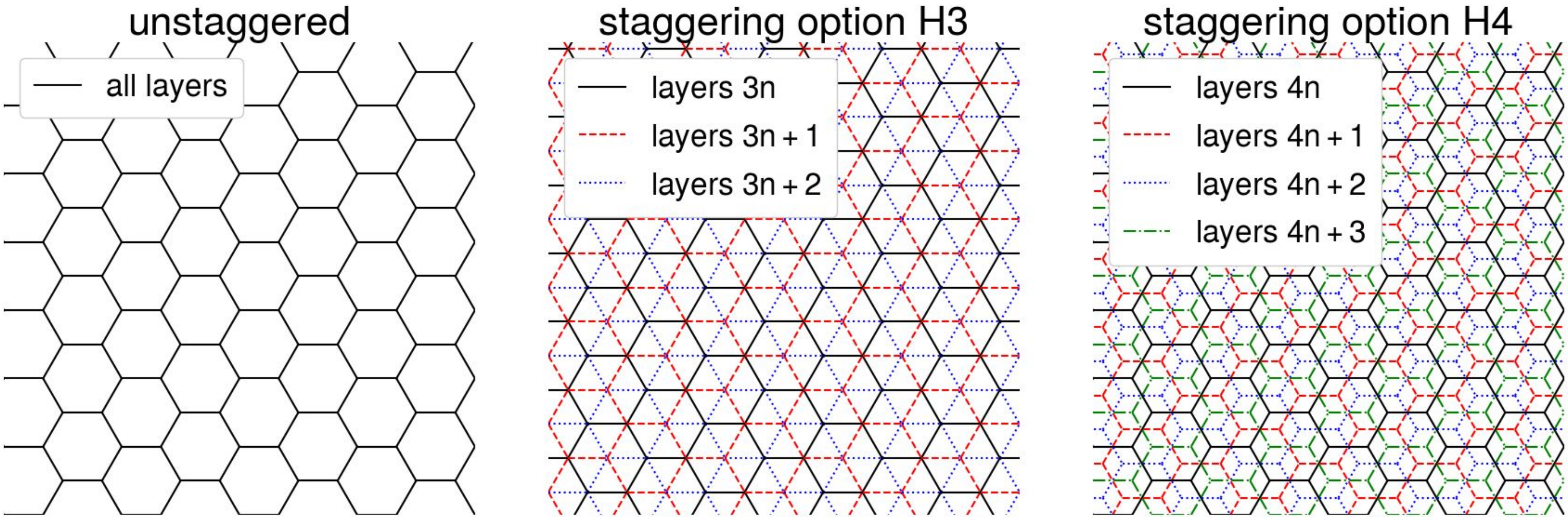




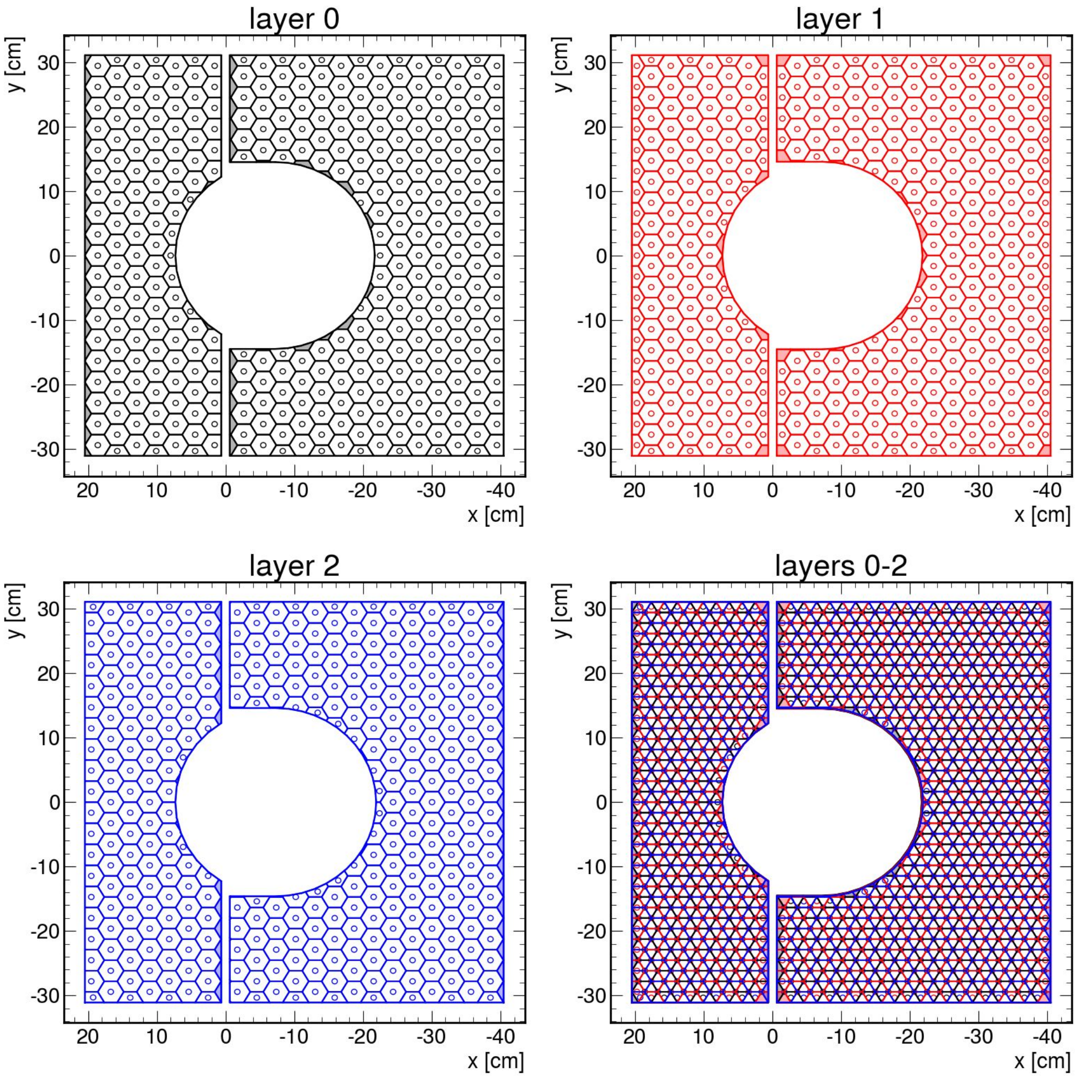
- Non-compensated response can be corrected via reweighting. Can be done “manually” a la CALICE, or with neural networks
- Works with W/SciFi ECAL as well.

Staggering layers can Improve Angular Resolution

This idea, while not new, can optimize performance



Staggered Insert



Staggered Hex Grid class defining a “DD4HEP segmentation” was created by Sebouh

https://github.com/sebouh137/staggered_tesselations/blob/main/dd4hep/src/HexGrid.cpp

Shower-Position Reconstruction

No sub-cell weighting:

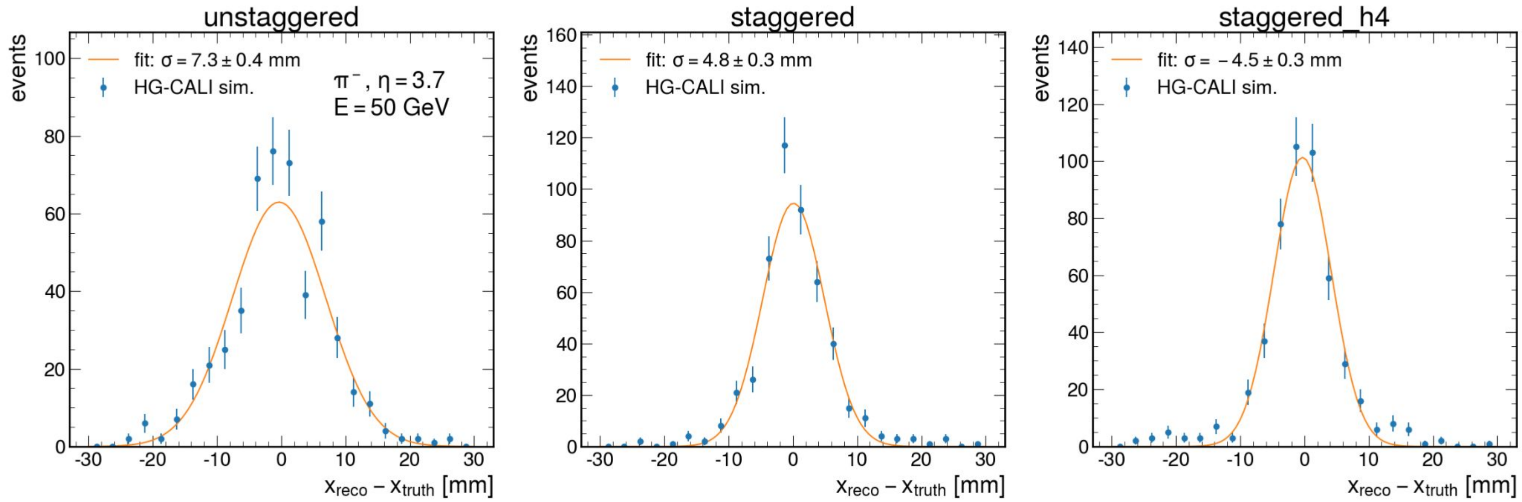
$$\vec{x} = \sum_{i \in \text{hits}} \vec{x}_i w_i,$$

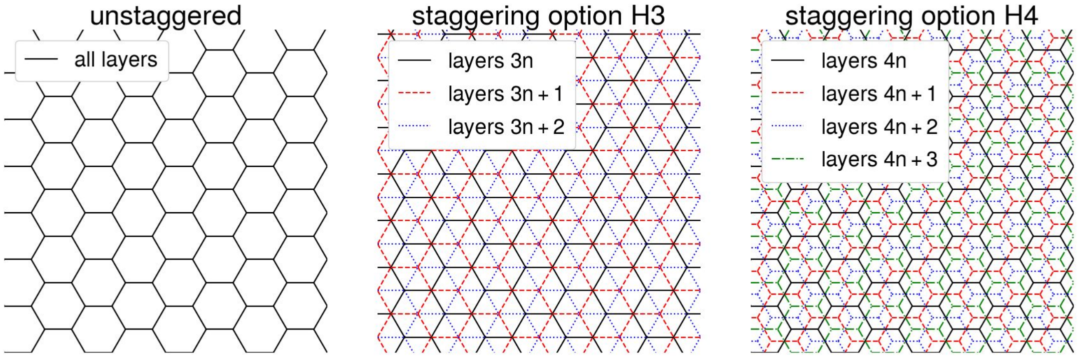
$$\text{where } \; w_i = \max\left(0, w_0 + \ln \frac{E_i}{E_{\text{tot}}}\right)$$

$$\text{using } \; w_0 = 4.0$$

- Traditional method, using just using cell-energy logarithmic weighting
- Picked 4.0 but not really optimized for neutrons yet

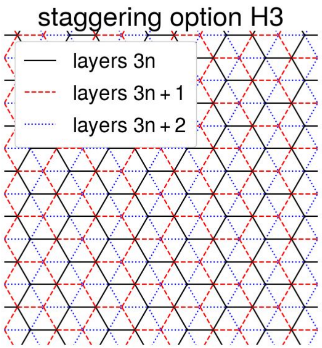
Insert Position Resolution with and without staggering





Significant improvements with staggering, even using a very simple algorithm

Shower-Position Reconstruction
With sub-cell weighting



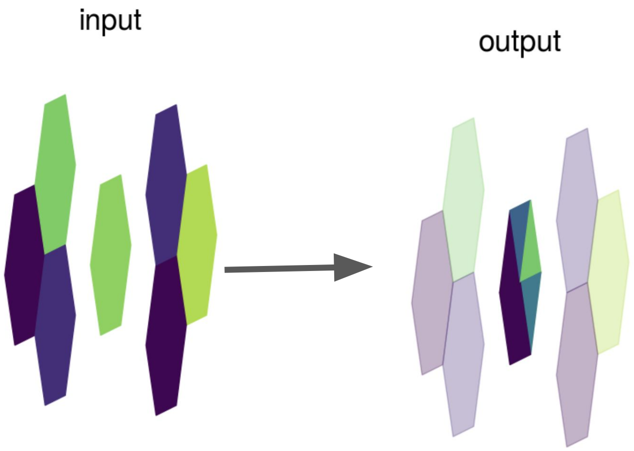
$$\vec{x} = \sum_{i \in \text{subcells}} \vec{x}_i w_i,$$

$$\text{where} \quad w_i = \max\left(0, w_0 + \ln \frac{E_i^{\text{rwt}}}{E_{\text{tot}}}\right)$$

$$\text{using} \quad w_0 = 5.0$$

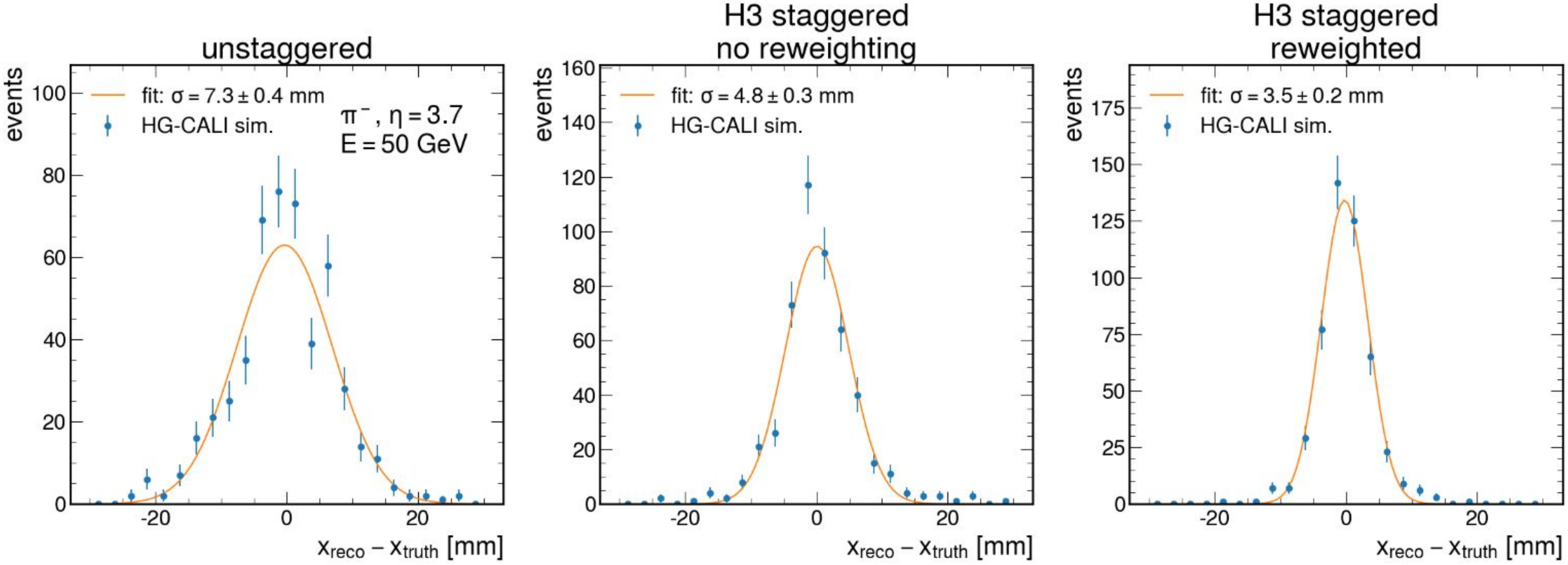
$$E_i^{\text{rwt}} = E_{\text{hit}} w_i^{\text{rwt}}$$

$$w_{\text{rwt}}^i \propto (E_i^{\text{up}} + \epsilon)(E_i^{\text{down}} + \epsilon)$$



$E_i^{\text{up}}, E_i^{\text{down}}$ are energies of overlapping cells in the immediately upstream or downstream layers

Staggering and subcell reweighting improves resolution by factor of 2!

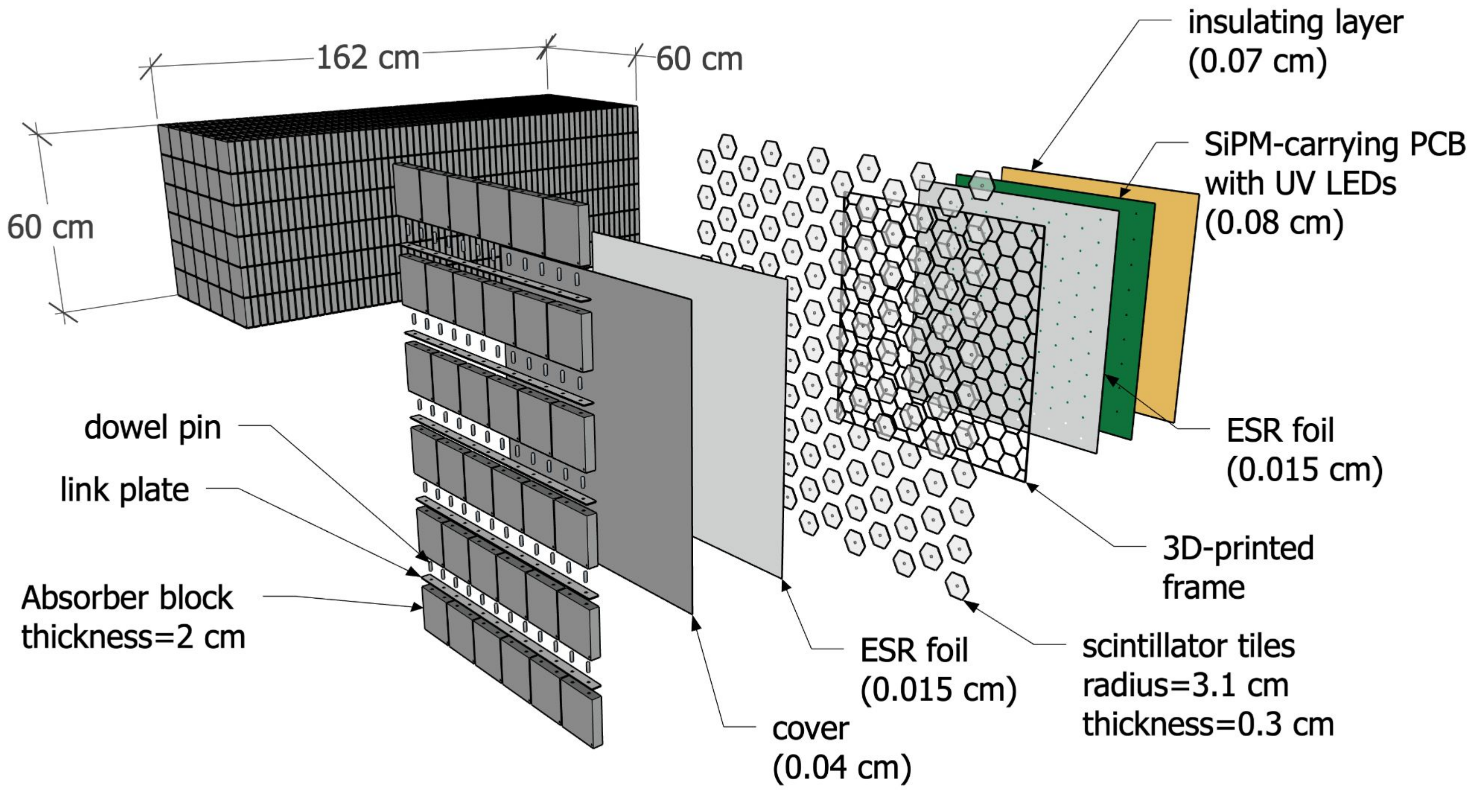


A SiPM-on-tile ZDC

Reused STAR-HCAL Fe blocks.

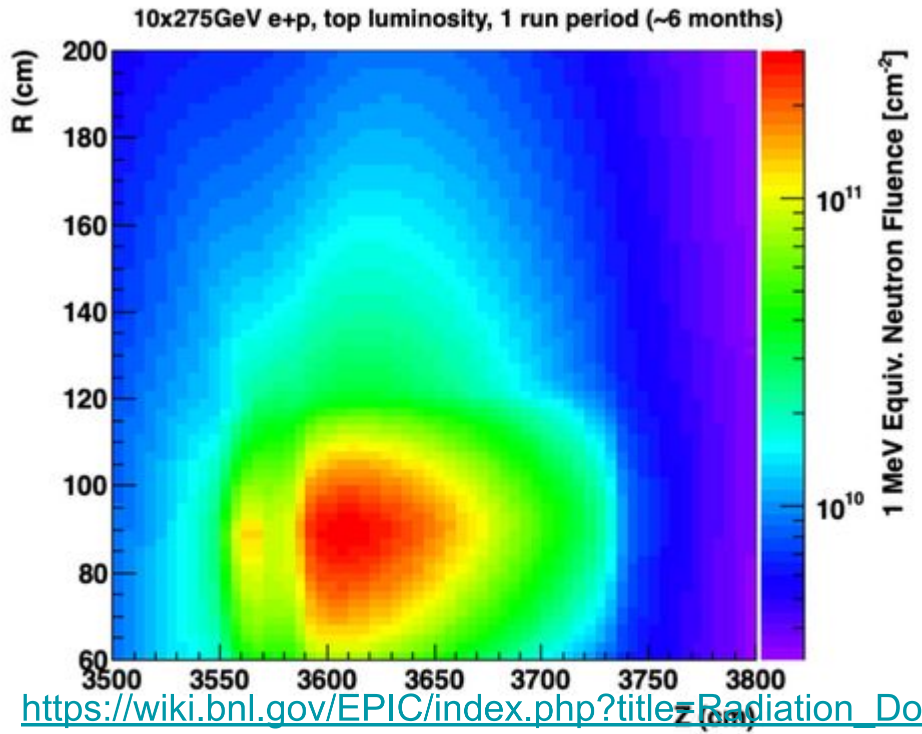
SiPM-on-tile design similar to calorimeter insert

Hexagon cell size with area eq. To~ 5x5 cm2



Neutron flux expected in ZDC Area

Figure 12: 1 MeV equivalent neutron fluence for minimum-bias PYTHIA e+p events at 10x275 GeV @ top machine luminosity for 6 months of running at 100% machine and detector efficiency. ROOT files can be found here.

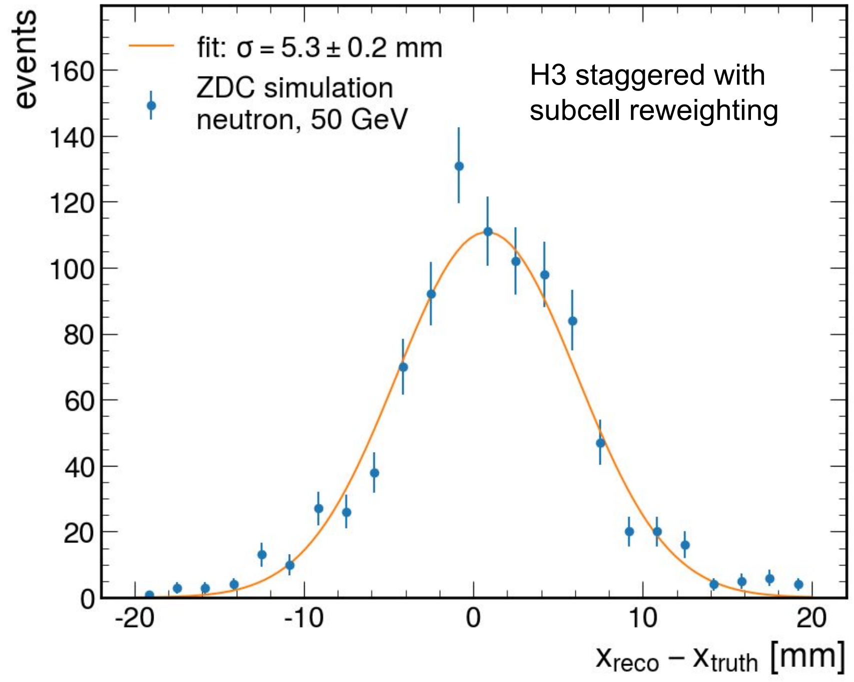


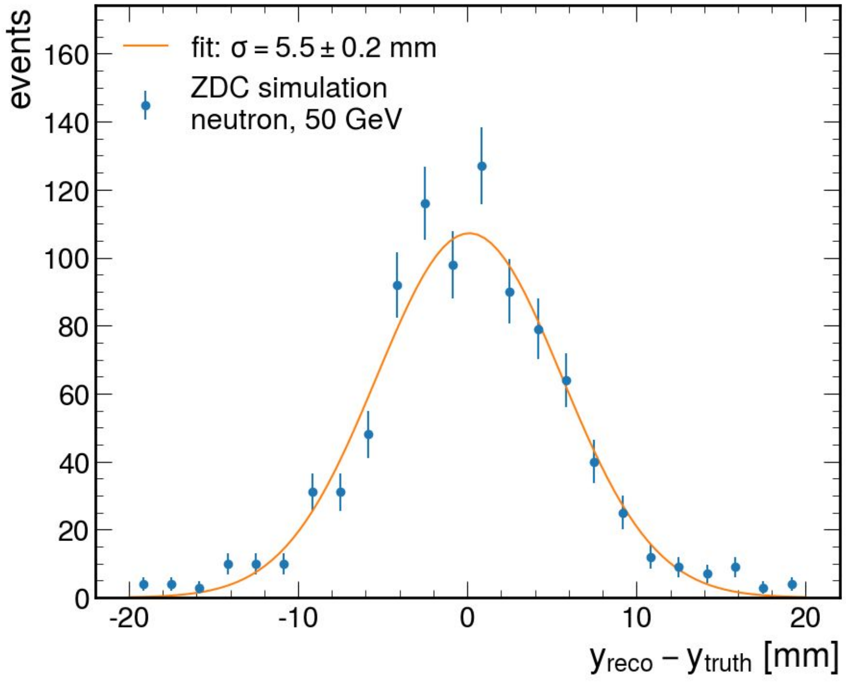
SiPMs will survive this rate.

We can anneal SiPMs after each run

https://wiki.bnl.gov/EPIC/index.php?title=Radiation_Doses

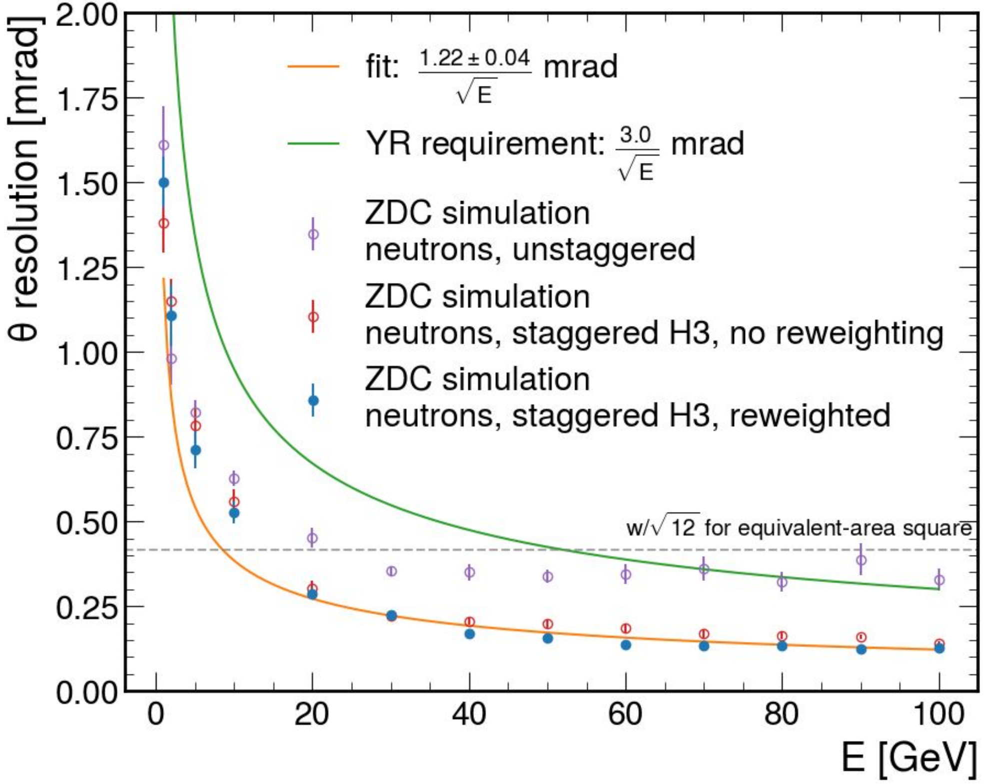
Position resolution for 50 GeV neutron





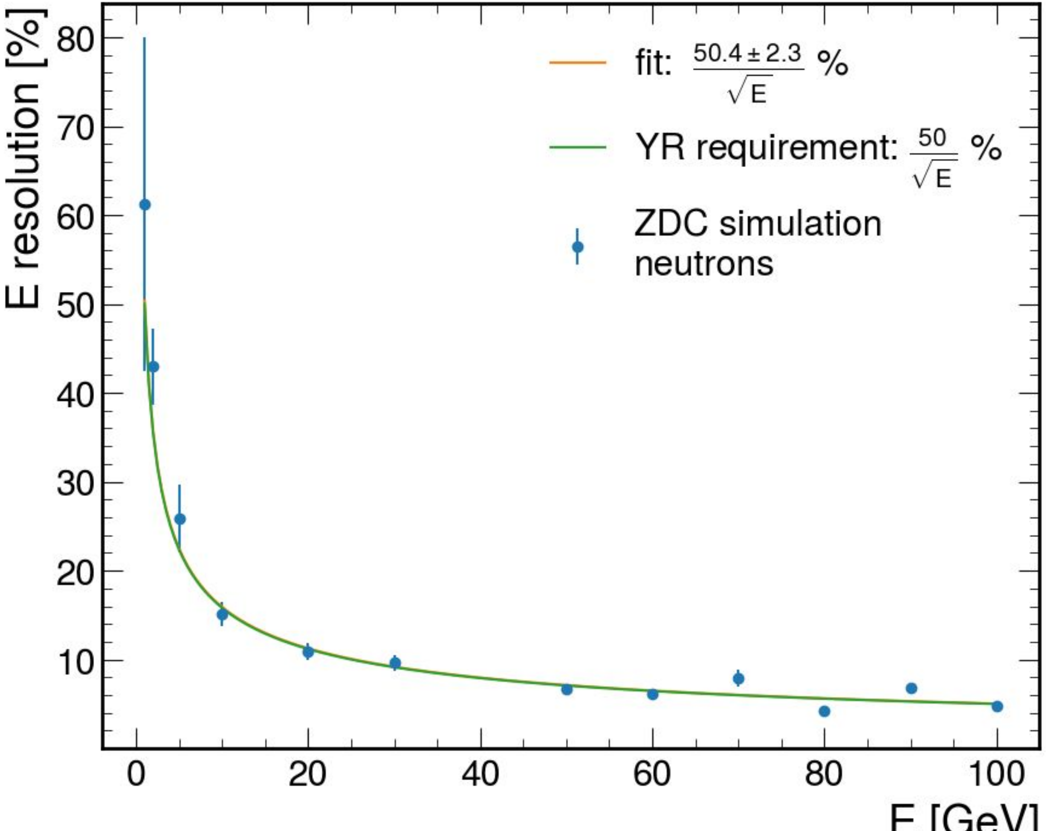
~5.5 mm at 35 m yields 0.16 mrad, whereas requirement at 50 GeV is 3mrad/sqrt(50) =0.42 mrad

SiPM-on-tile ZDC position resolution



- Exceeds YR requirements.
- This is obtained with human-made algorithm, which has not been optimized yet.
- So far, sub-cell reweighting algo yields O(10%) improvements
- Performance can be tuned with cell size, currently set to hexagons with area of ~27 cm2

Energy resolution before software compensation

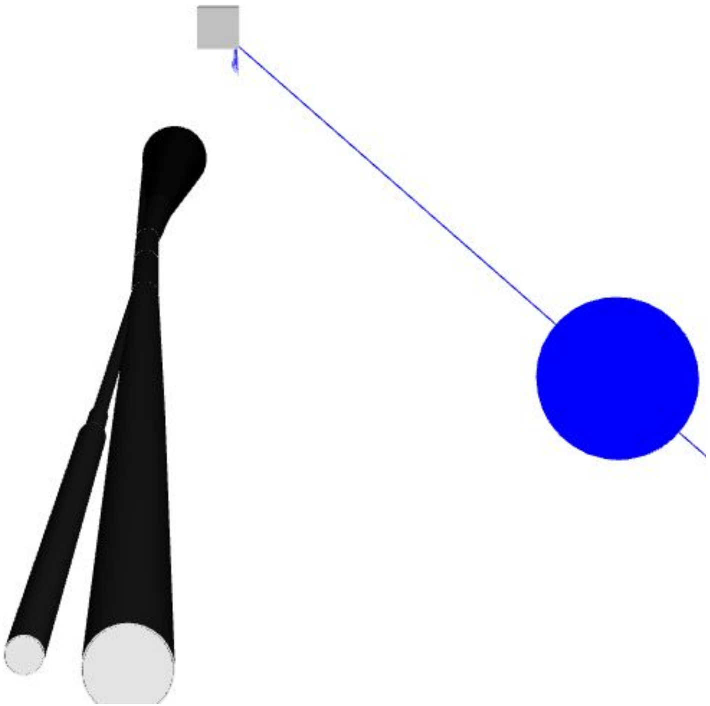


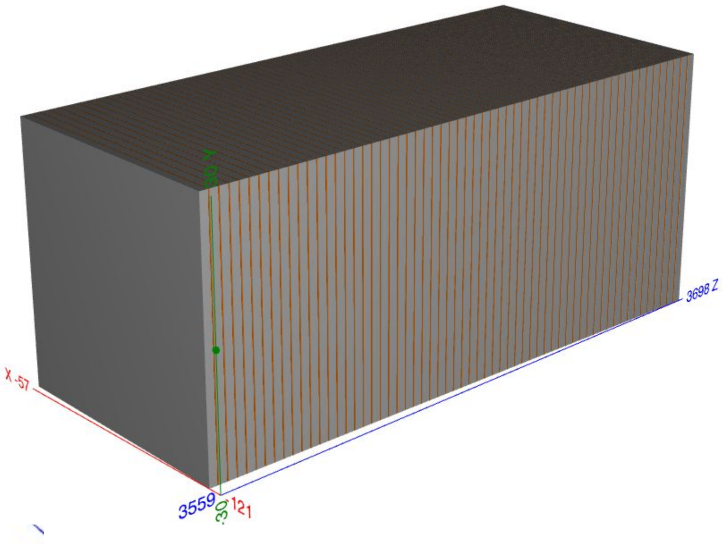
- "Strawman" approach without any compensation is 50%/sqrt(E), i.e. the YR requirement

- Performance can be improved with software reweighting to somewhere between 40-45%/sqrt(E), even with ECAL in front

- We are carrying out compensation studies similar to what we did with Insert

SiPM-on-tile ZDC, ready to go in ePIC DD4HEP





By Ryan Milton

Summary

- A SiPM-on-tile ZDC ala Insert (i.e CALICE-style) **meets YR requirements**
  (thank Elke for suggestion to explore this)
- **Compensation via reweighting** exploiting high-granularity. Done via point-cloud networks
- Fe blocks from STAR can be **reused to save $$$,** make **construction straightforward.**
- Proposed design is **easy to build, and cheap**
  Likely ~0.1M cost of materials: SiPM, scintillator cells, HGROC, etc for ~9k channels
- Only one technology, **easy to calibrate** (MIP cell-by-cell) **and monitor** (cell-by-cell with LED)
- Design allows for access SiPM boards for high-temperature annealing
  → **radiation damage not a showstopper.**