# Leveraging Staggered Tessellation for Enhanced Spatial Resolution in High-Granularity Calorimeters

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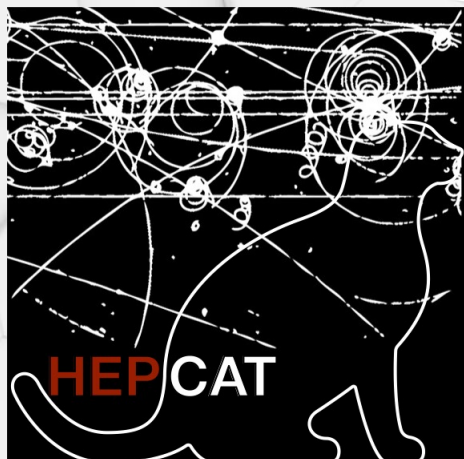
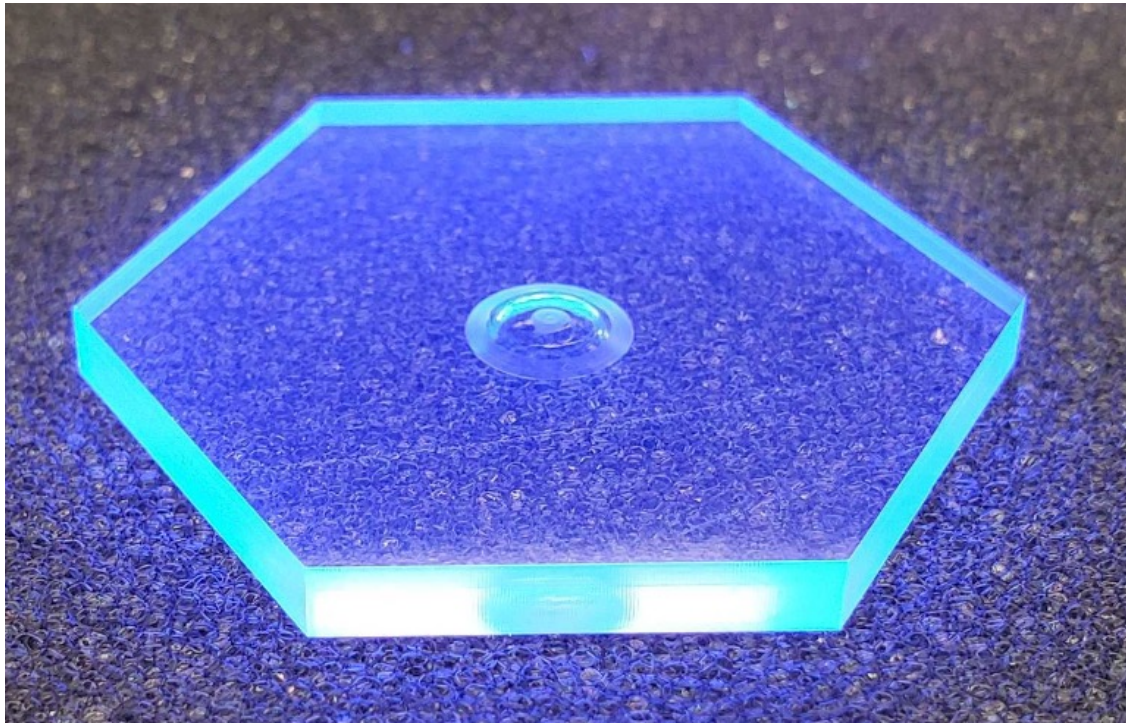
CPAD Workshop 2023





# Outline

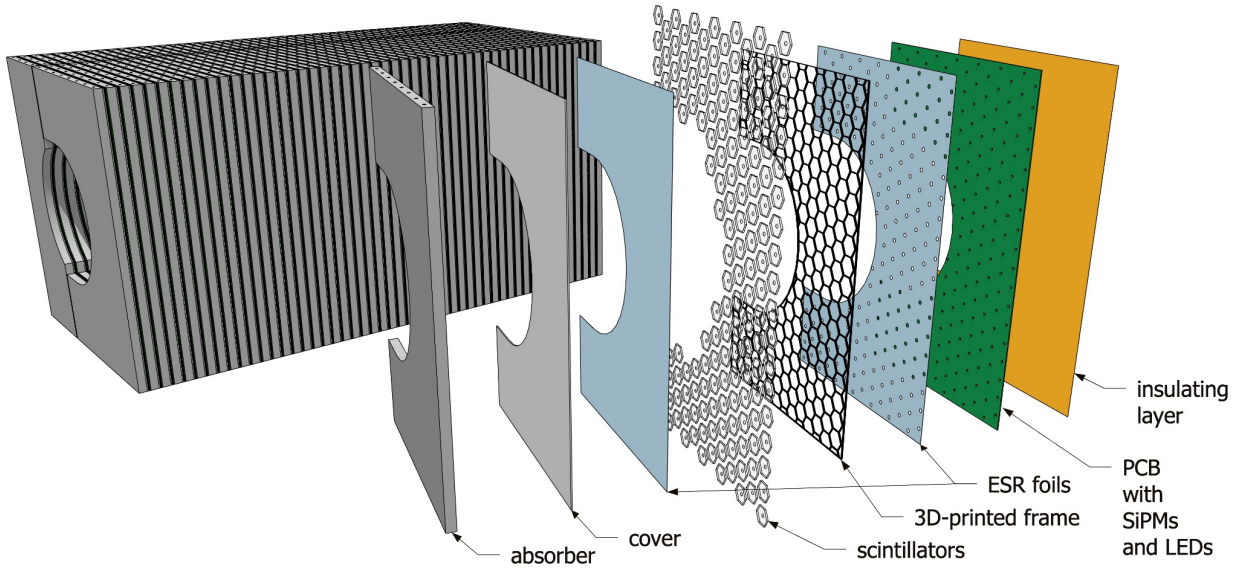
- Staggering layers in a high granularity calorimeter
- The HEXPLIT algorithm for shower reconstruction
- Neutron shower simulations
- Results for shower position resolution
- Summary

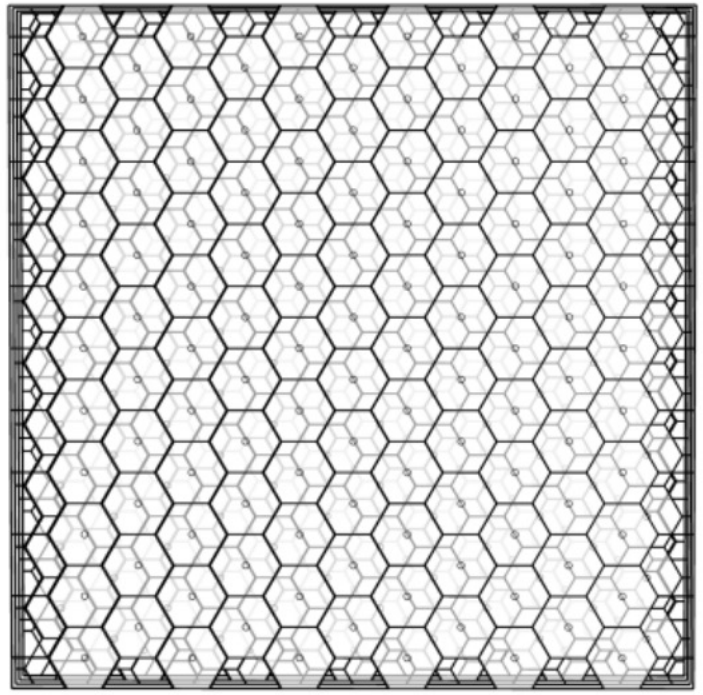


- The ePIC Calorimeter Insert is a high granularity sampling calorimeter
- Between absorbers, each layer is populated with identical scintillating cells

    Position of each layer is unconstrained

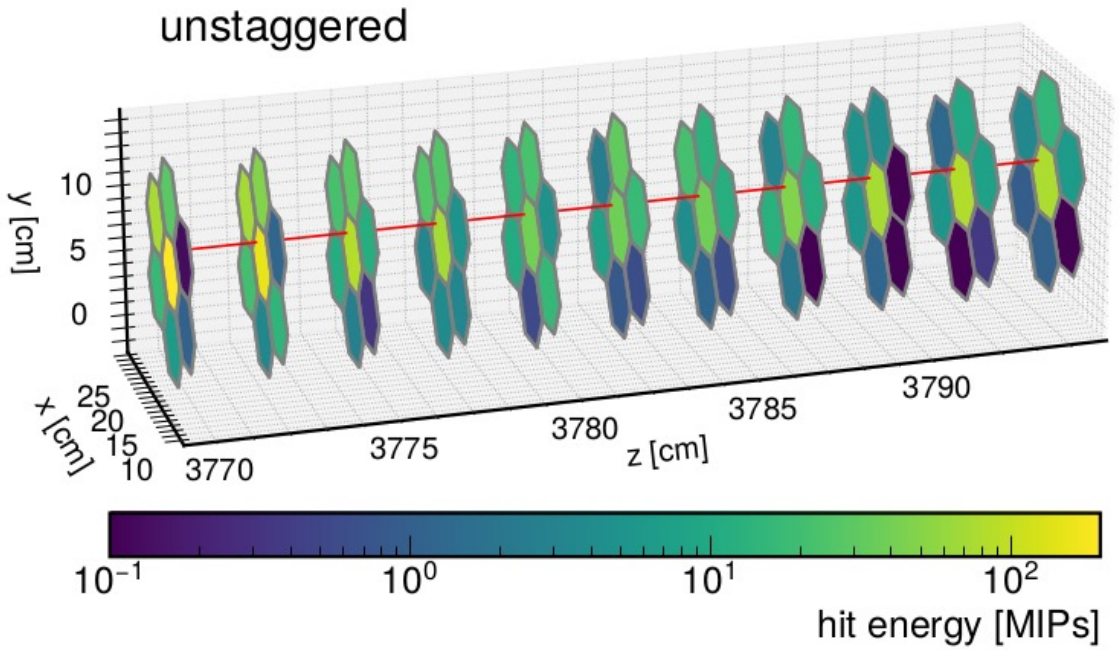
How should the layers be oriented to maximize position resolution?



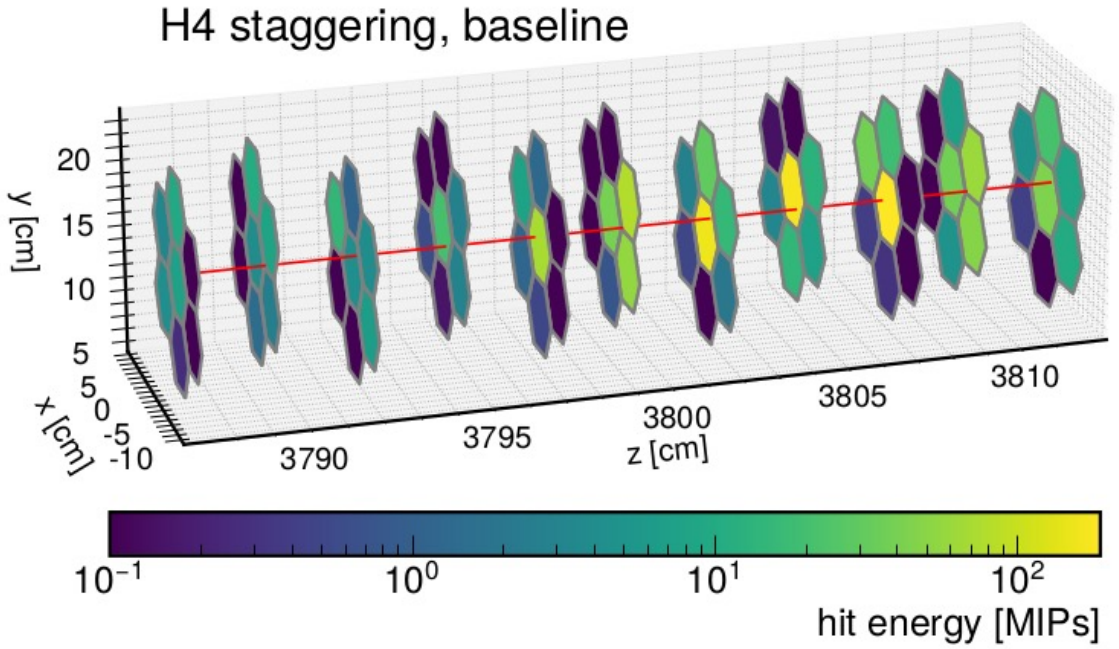
- If the core of a shower passes through two cells with the same transverse positions, the second cell adds little information

- Staggering layers gives more information per layer that constrains the trajectory!

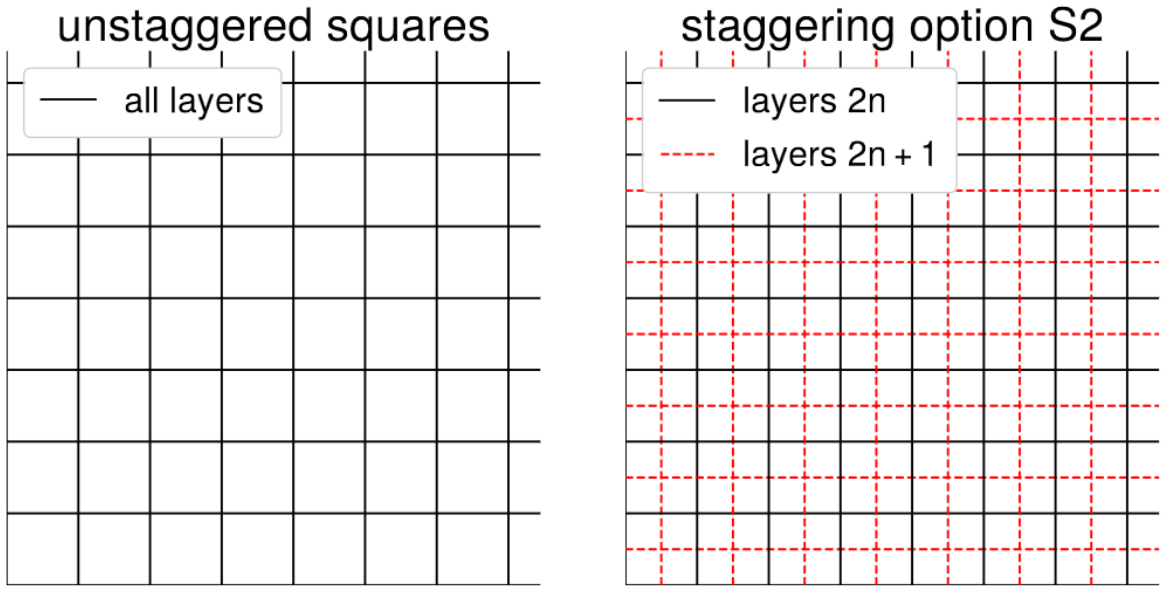


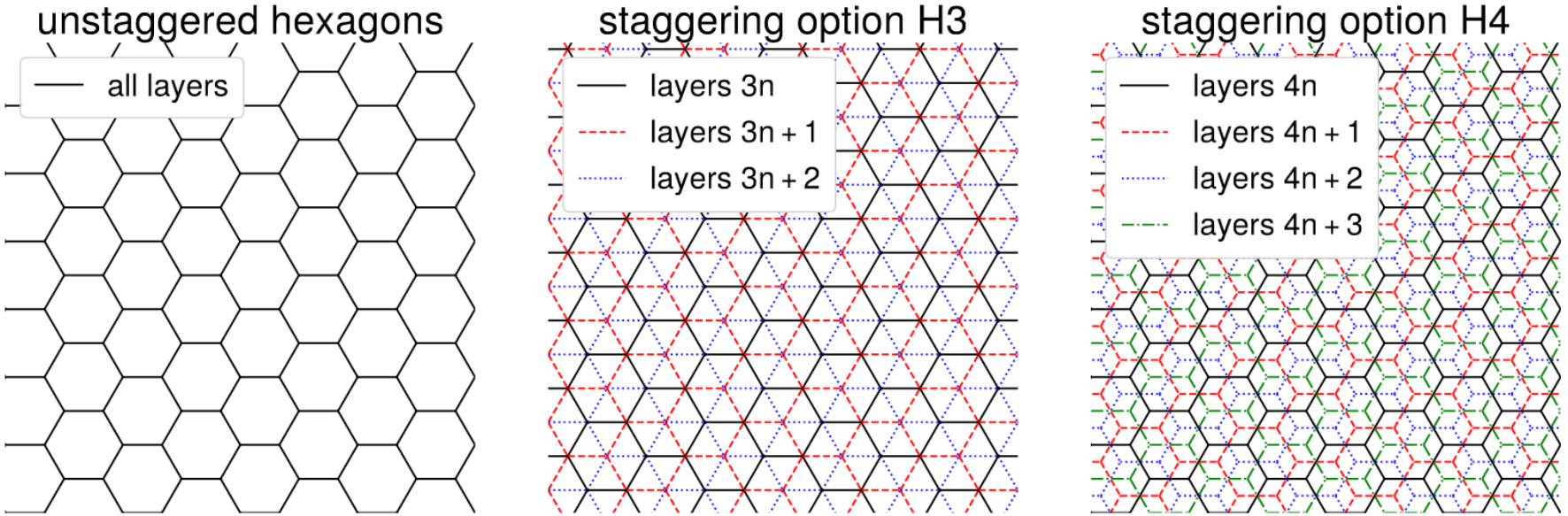

Truth trajectory of neutron

Core of a neutron shower



- Staggering creates overlapping “subcell” regions smaller than the tile
- We consider staggering patterns for hexagonal and square cells



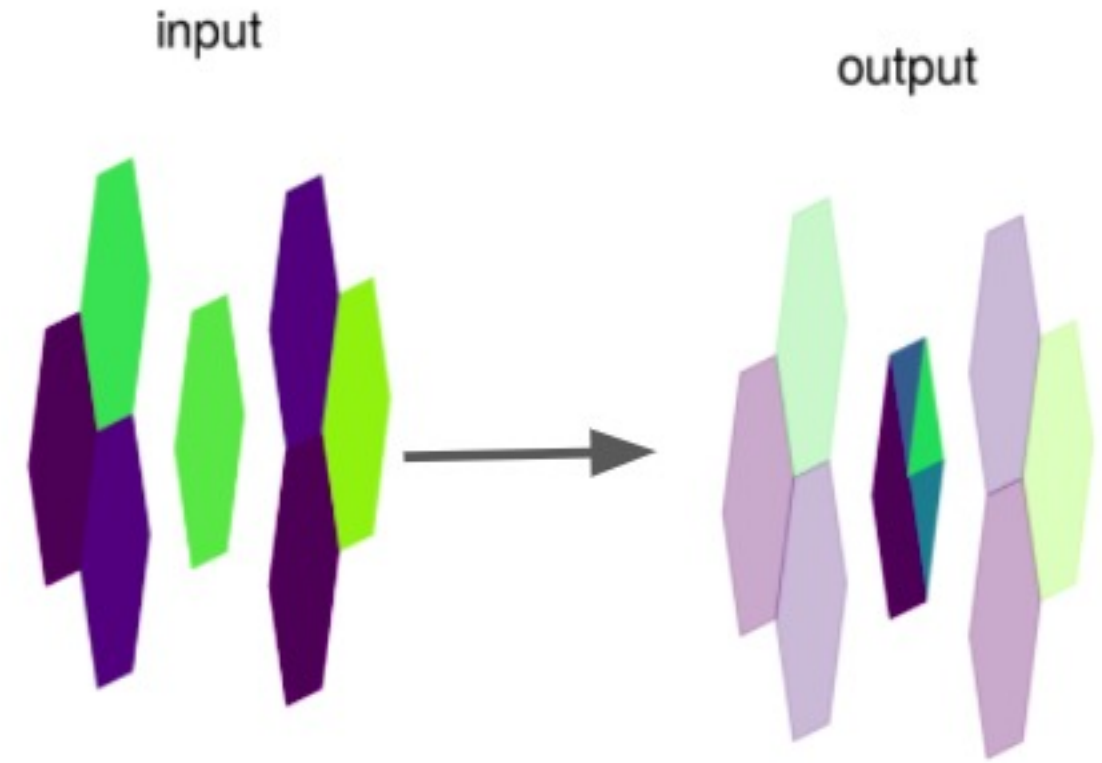
# HEXPLIT Algorithm

- HEXPLIT reweights the energy of a cell into subcells, given the energies of overlapping cells in neighboring layers

- Reweighting is determined by

$$W_{subcell} = \prod_{j=overlap\ cell} max(E_j, \delta)$$

H3 staggering




arXiV paper: https://arxiv.org/pdf/2308.06939.pdf

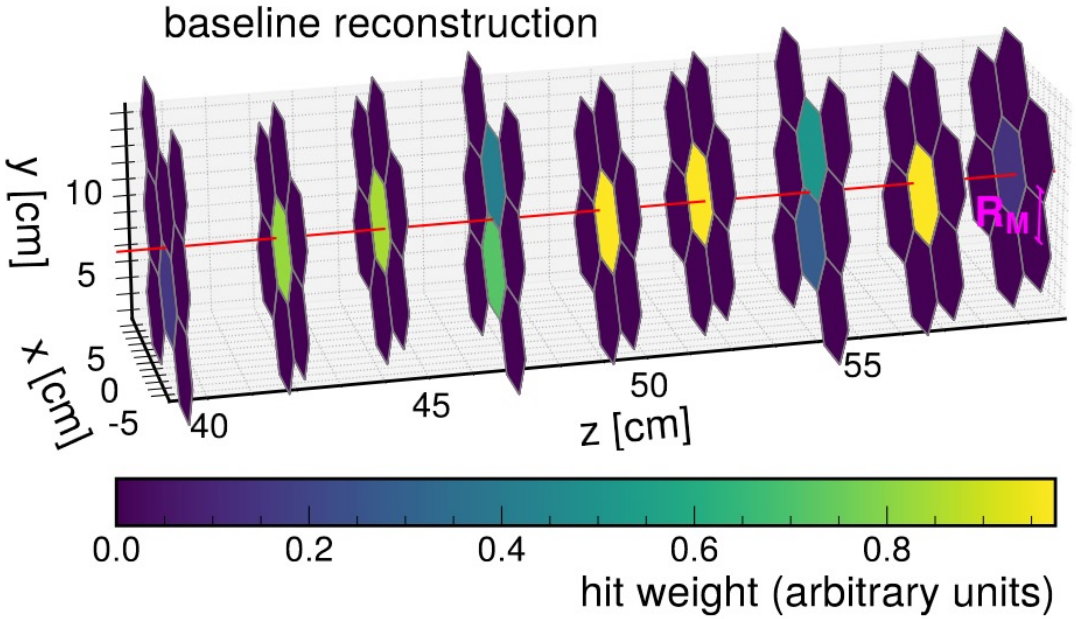
- For the baseline shower reconstruction, the shower position is given by

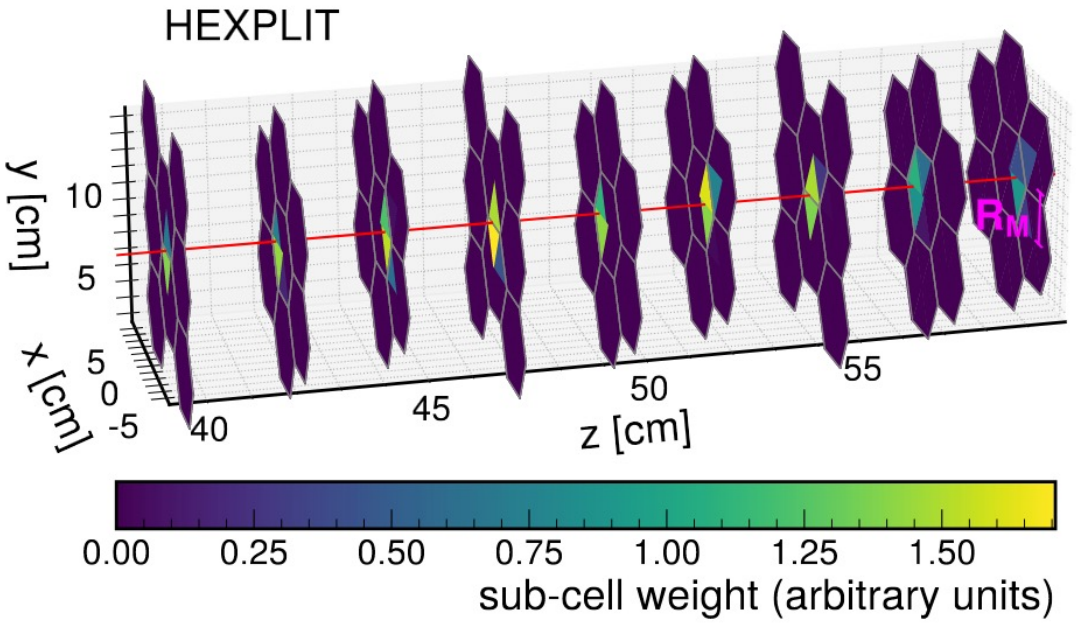
$$\vec{x}_{\text{recon}} = \frac{\sum_{i \in \text{hits}} \vec{x}_i w_i}{\sum_{i \in \text{hits}} w_i}$$

where the weights are determined from a logarithmic weighting:

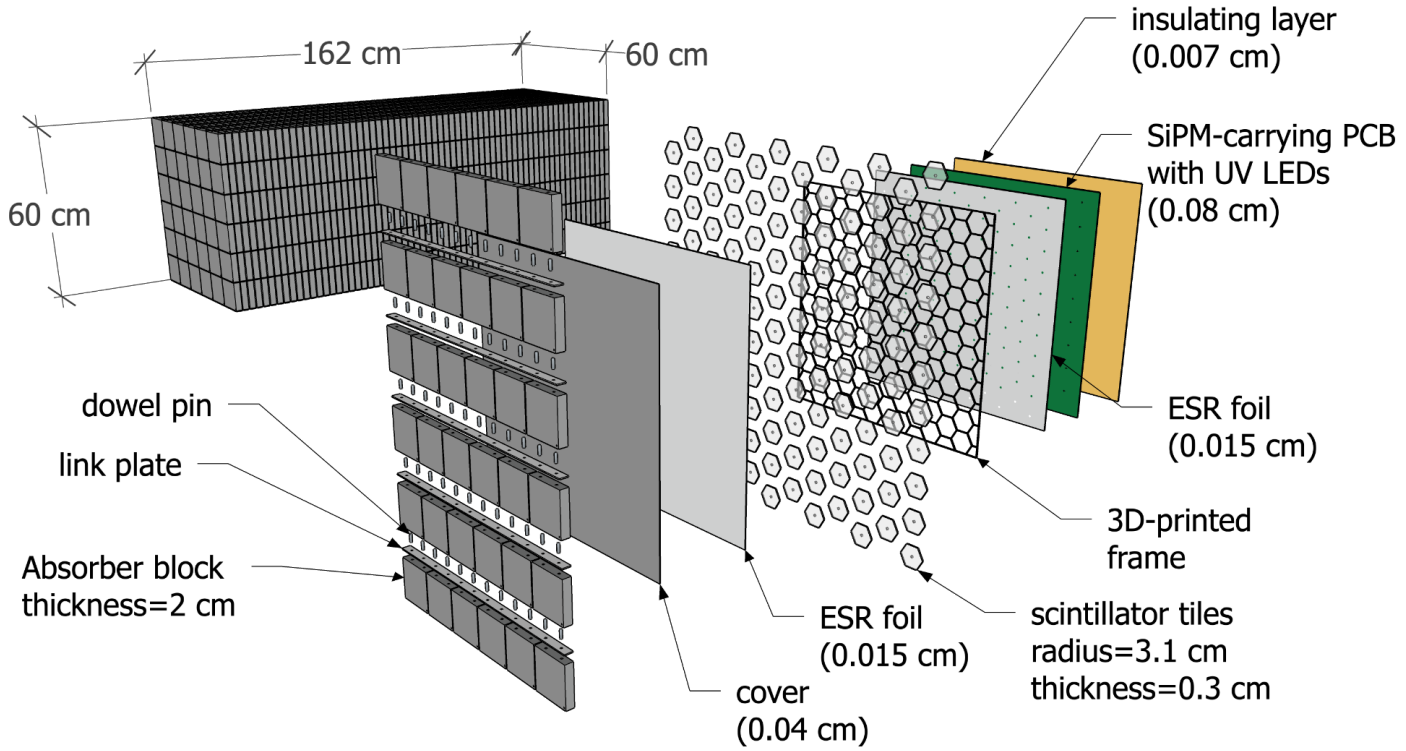
$$w_i = \max\left(0, w_0 + \ln \frac{E_i}{E_{\text{tot}}}\right)$$

- The HEXPLIT version of shower reconstruction is identical, but summed over subcell hits instead of cell hits



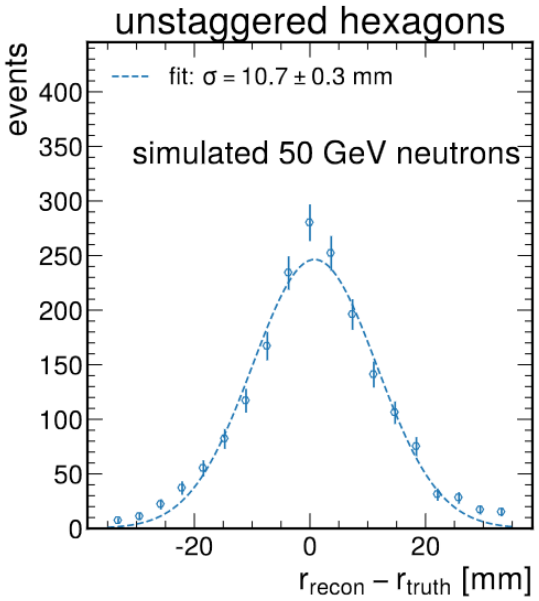
- Simulated single neutron showers with DD4HEP in a proposed ZDC calorimeter, similar to the ePIC calorimeter insert
- Alternating layers of 20 mm Fe absorbers and 3 mm scintillator tiles
- 64 layers, cell circumradius of 1 Molière radius
- Versions of this detector were tested with square tiles, hexagonal tiles, and different staggering patterns

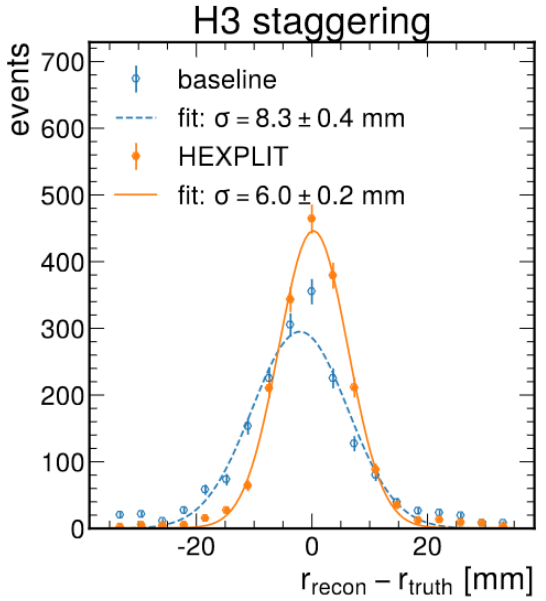


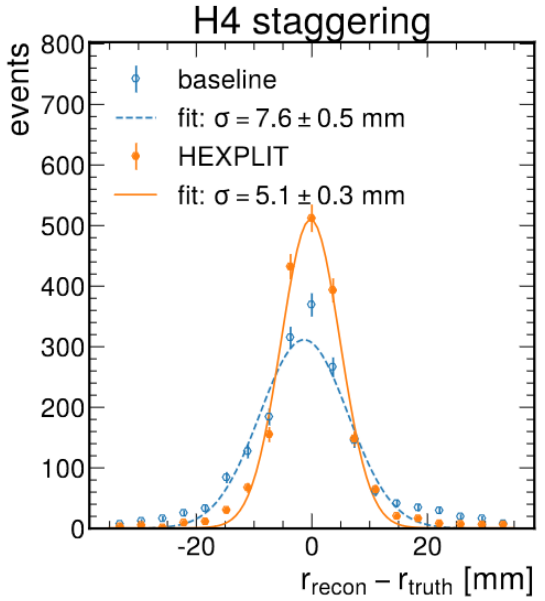
# Results

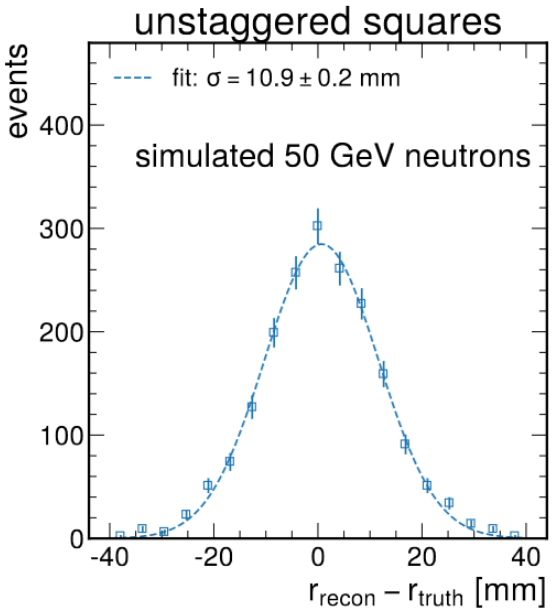
- For 50 GeV neutrons, staggering alone improves position resolution from ~11 mm to ~8.5 mm
- HEXPLIT improves this further in H4 all the way to 5.1 mm

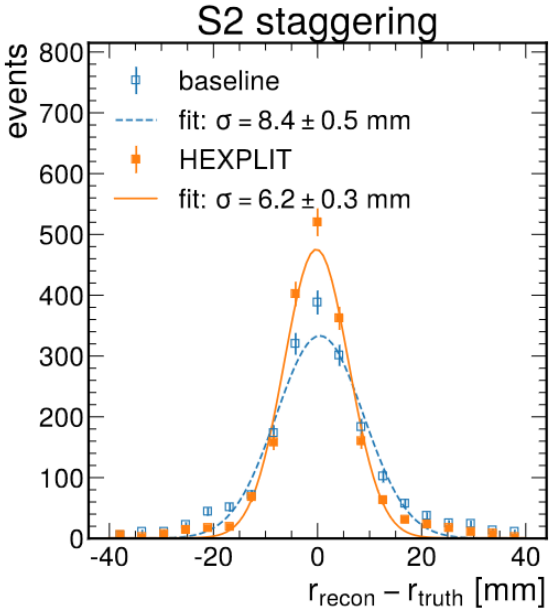
50% improvement!



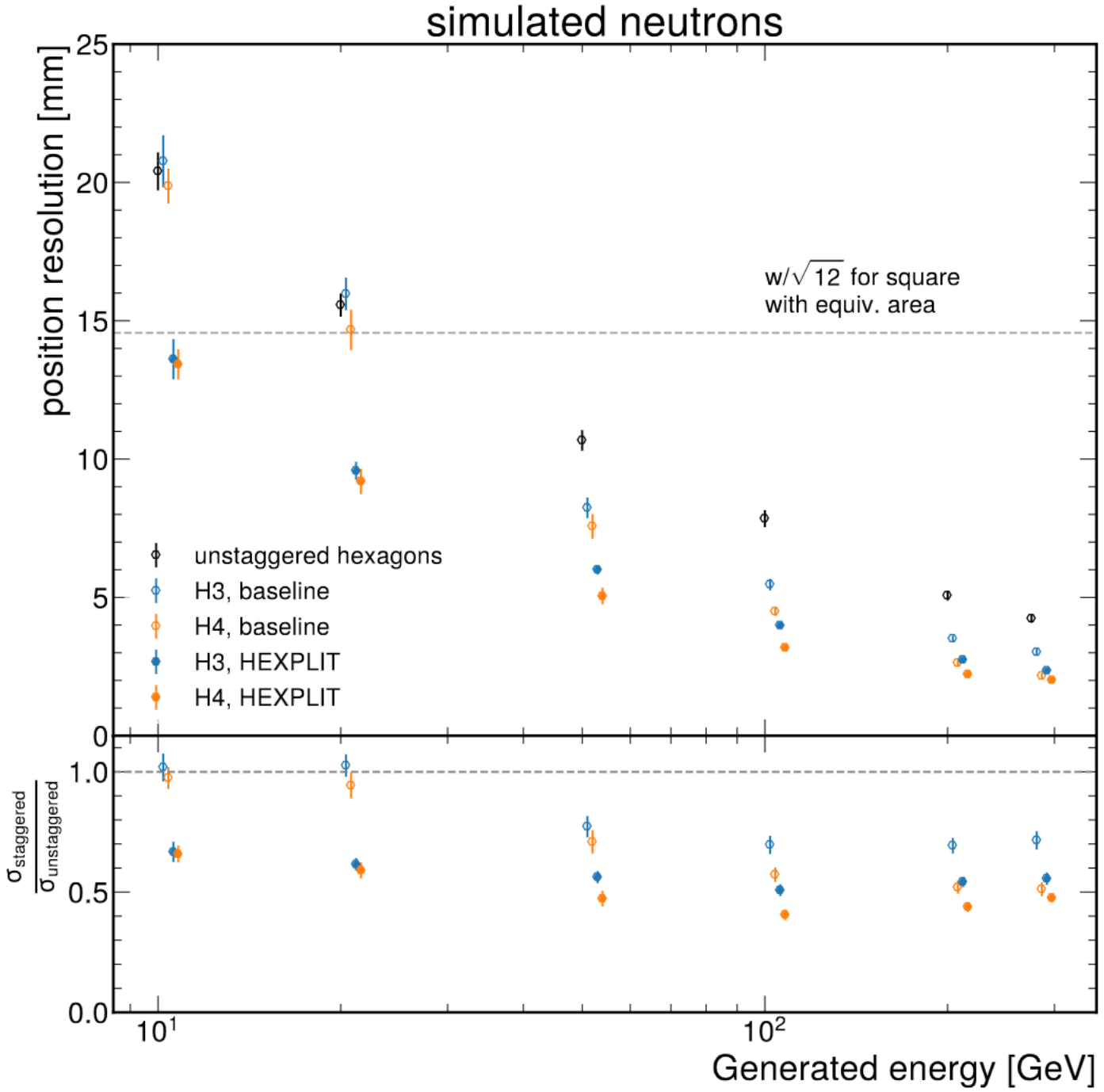



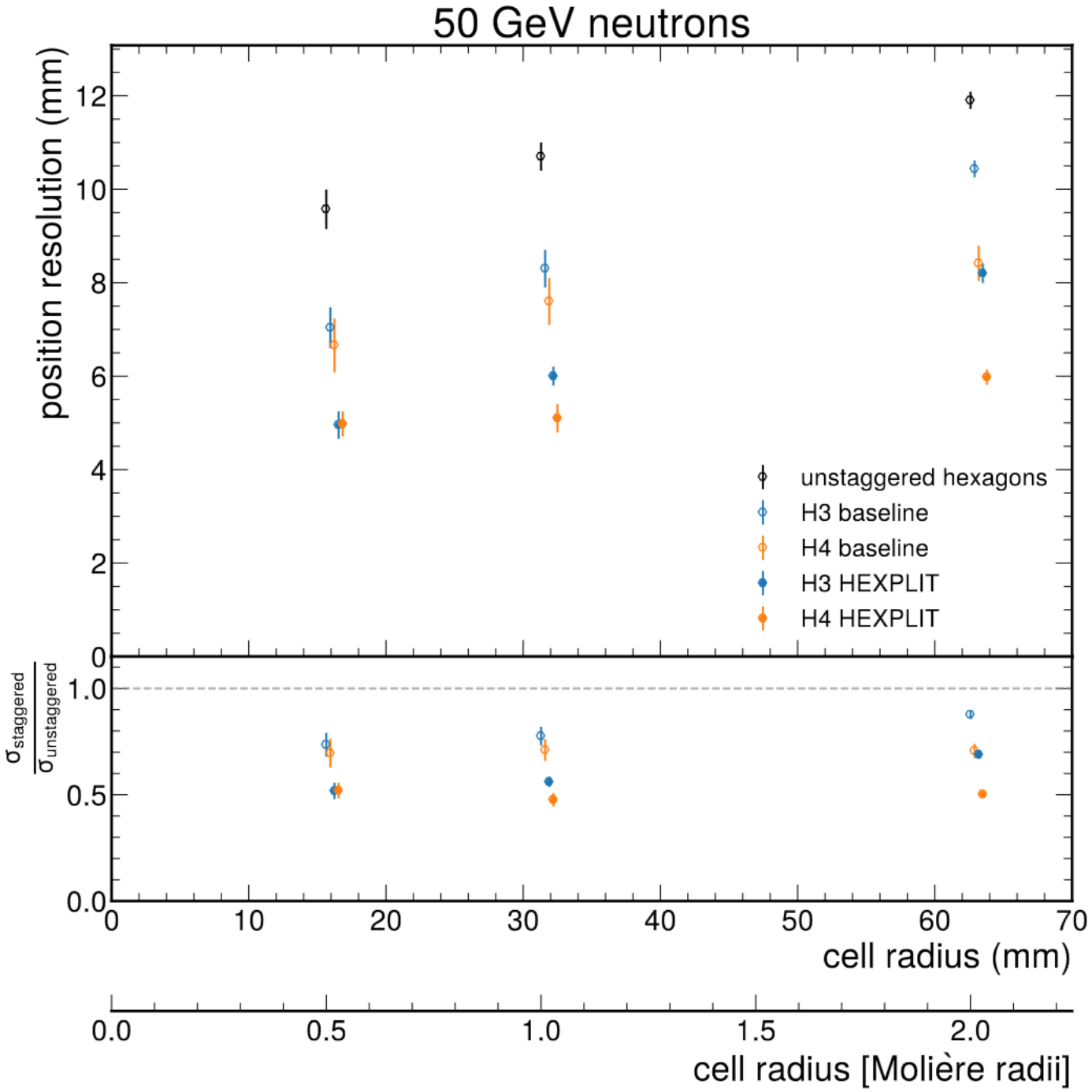
# Results

- Staggering improves spatial resolution across the spectrum from 10 GeV to 300 GeV
- Using HEXPLIT with H4 yields best performance



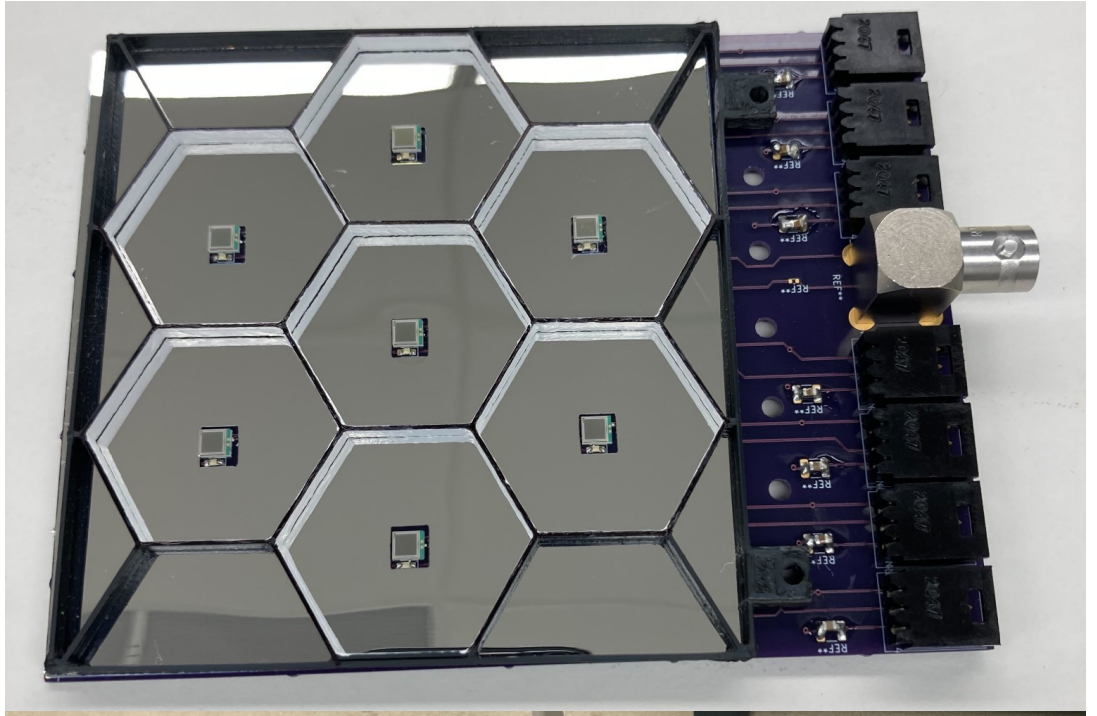
# Results

- For 50 GeV neutrons, we tested the impact of reducing and increasing the cell radius by a factor of two
- H4 staggering with HEXPLIT consistently improved spatial resolution twofold relative to unstaggered hexagons



# Summary

- Staggering layers of a high granularity calorimeter, along with the HEXPLIT algorithm, can significantly improve hadronic shower position resolution
- Of the patterns tested, hexagonal tiling with a four-fold cycling pattern yield the best results for single neutron showers
- These studies will inform our development of the ePIC Calorimeter Insert and beyond



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# Thank you!