Design and Performance of Insert-like ZDC

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California EIC Consortium Collaboration Meeting
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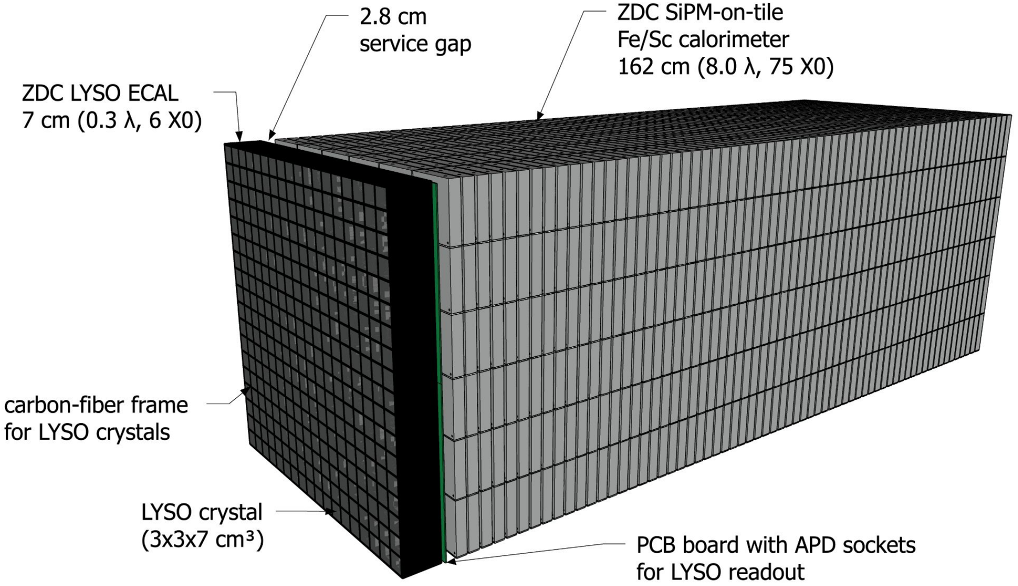

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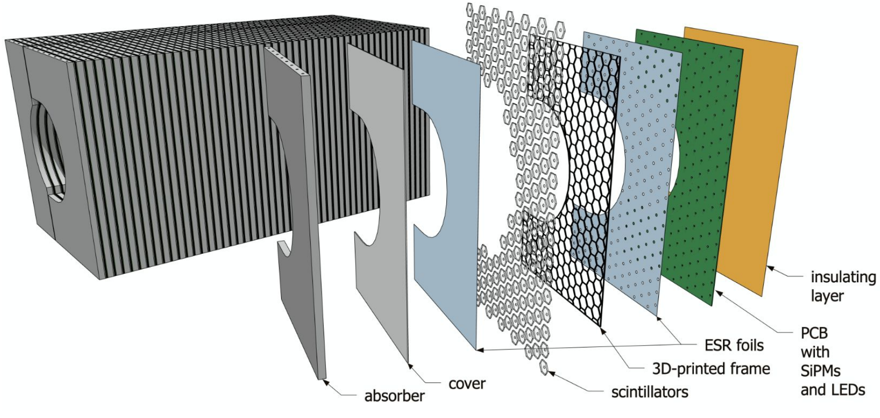
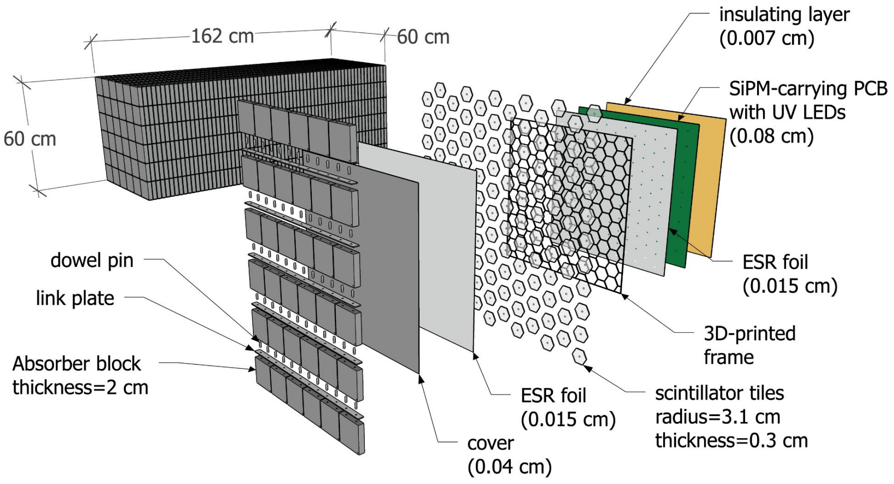
Design

- SiPM-on-tile design, similar to insert
- Steel/Scintillator sampling calorimeter
  - Reuse STAR FCS steel blocks
  - 64 layers, 2.0/0.3 cm Steel/Sc



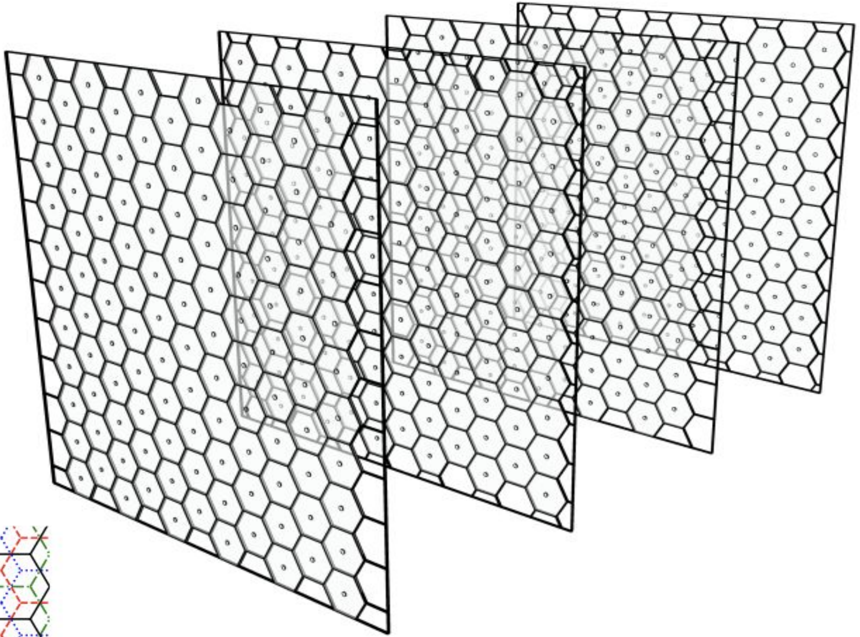
Insert

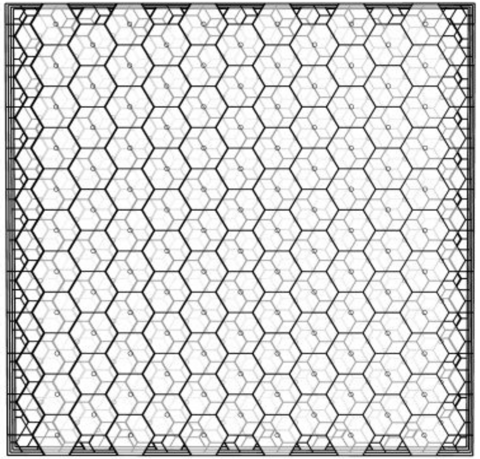


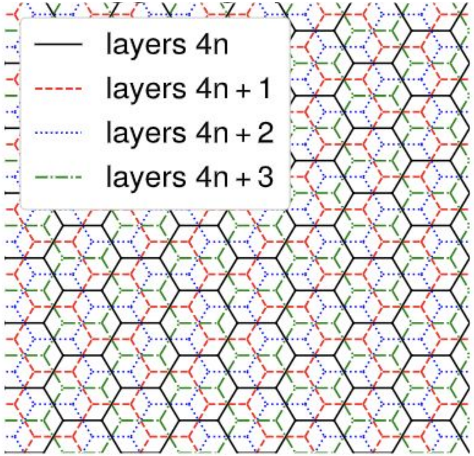
ZDC

Scintillator staggering

- Layers cycle through four different scintillator layouts
- Enhances the position resolution
- NIM A 1060 (2024) 169044

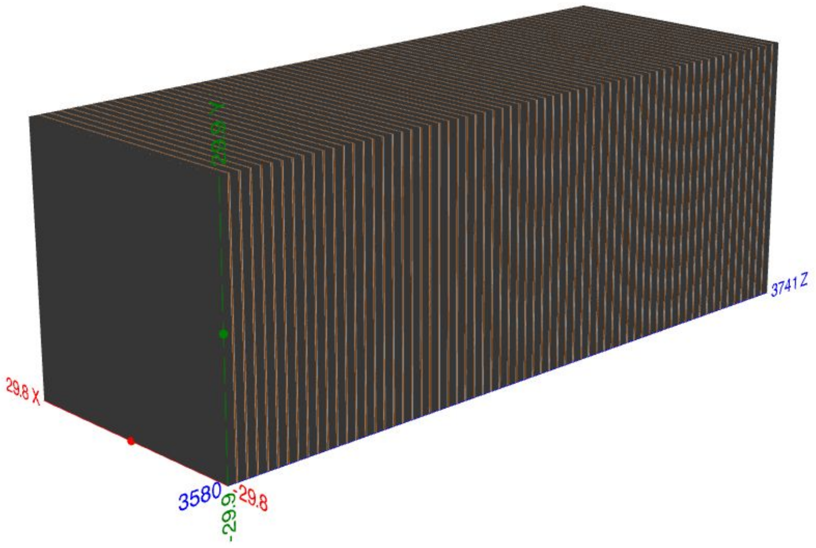




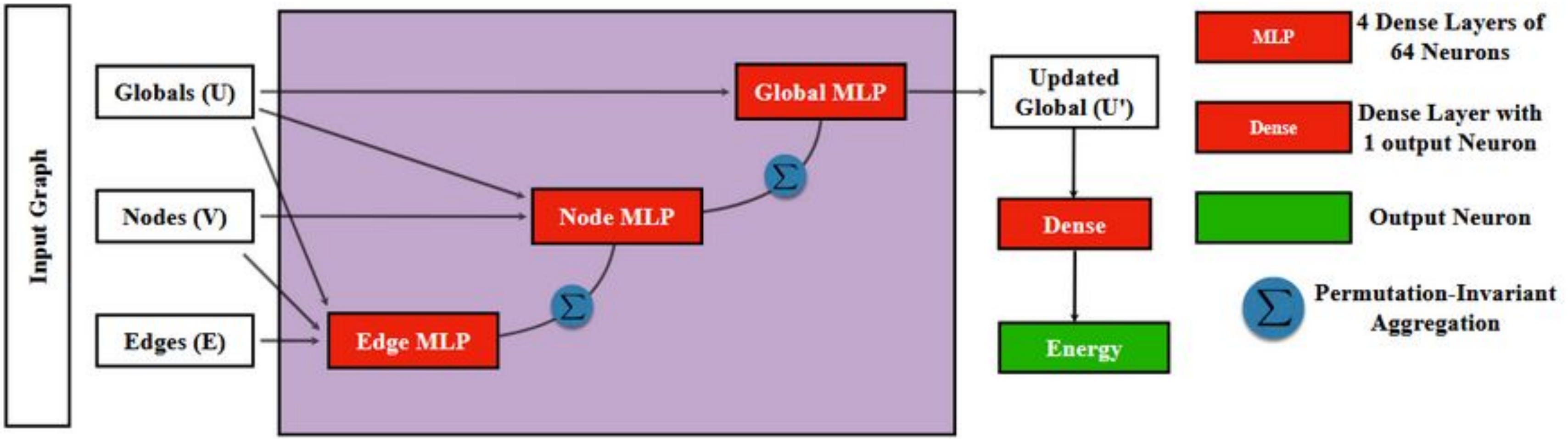


Simulation & procedure

- Goal: To measure angle and energy of neutrons at small angles, $\eta>6$
- Standalone simulation of ZDC (no LYSO Ecal)
- Investigate energy and angular resolutions in neutron events
  - $10 < E < 300$ GeV, $0 < \theta < 0.5$
- Employ graph neural networks (GNNs) for regression on E, θ

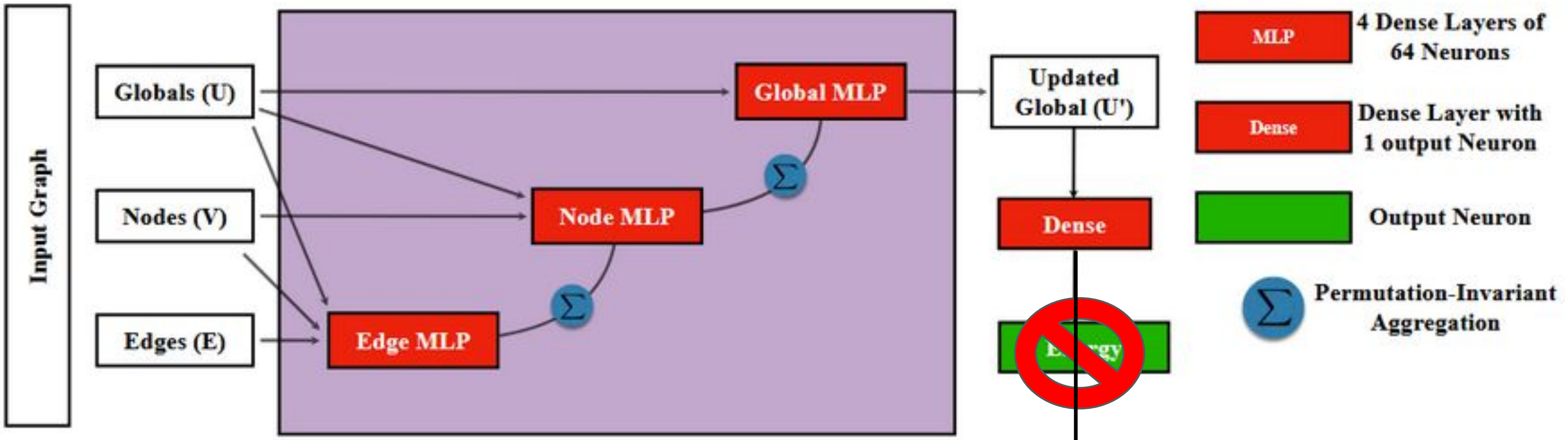


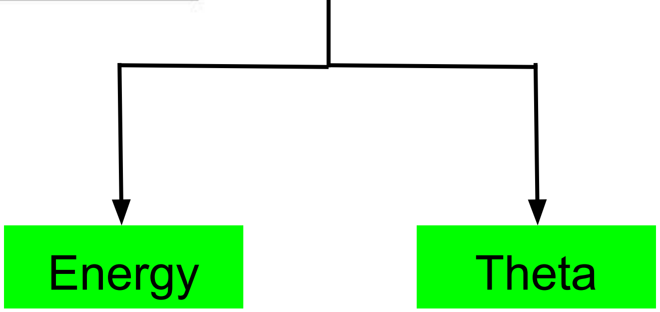
1D Model schematic



- Model in previous paper outputs E_{gen}
  - arXiv:2310.04442
- Provide model with cell (E, x, y, z), event energy, and info of neighboring cells

2D Model schematic

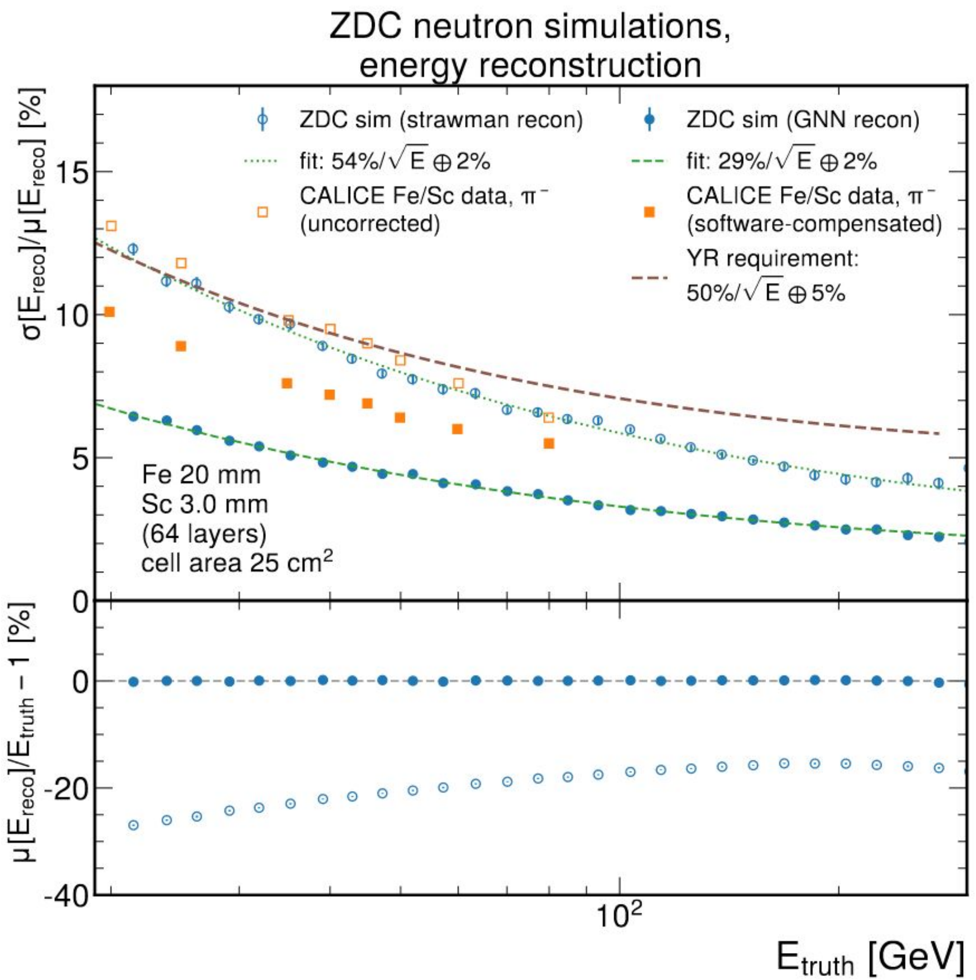




- Graph structure:
  - Nodes - Cell (E, x, y, z)
  - Edges - (E, x, y, z) of ten neighboring cells
  - Globals - Total deposited energy
- Loss = Mean absolute error

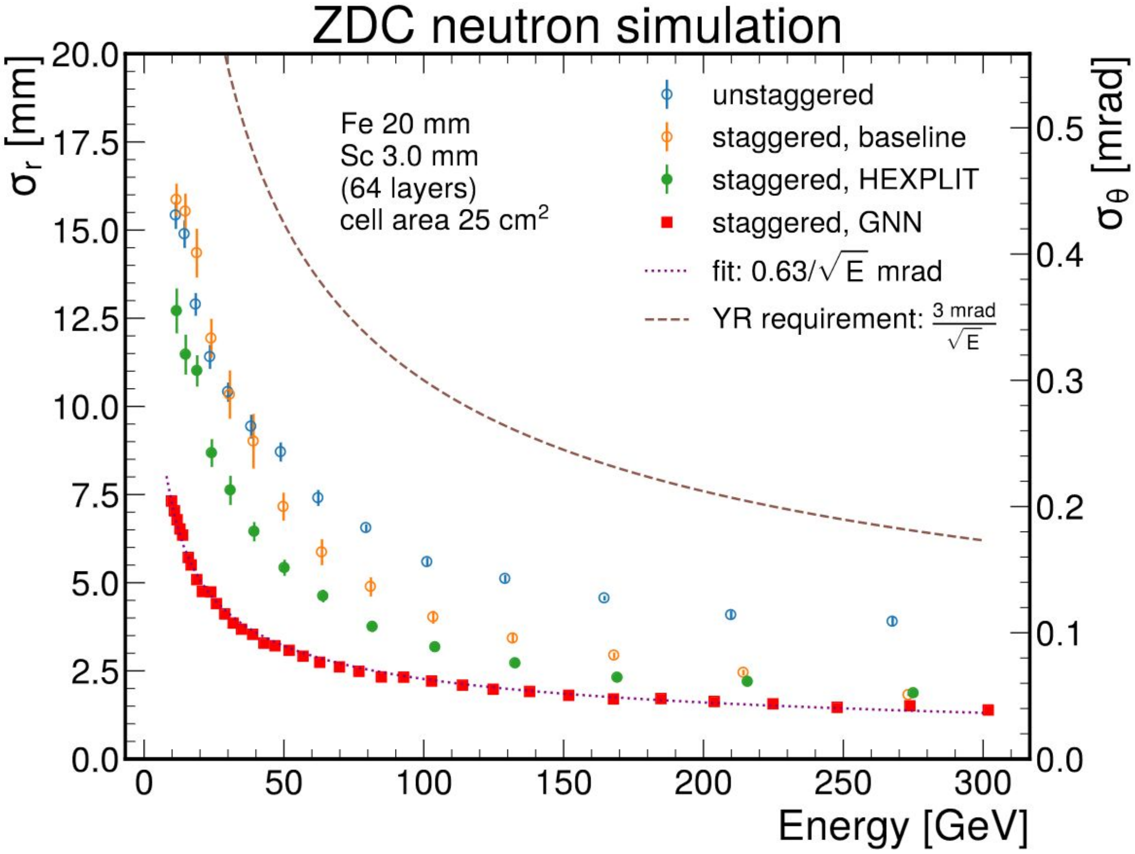
Energy resolution

- GNN significantly improves energy resolution
- Strawman is simple sum of cell energies
- Outperforms CALICE beamtest results



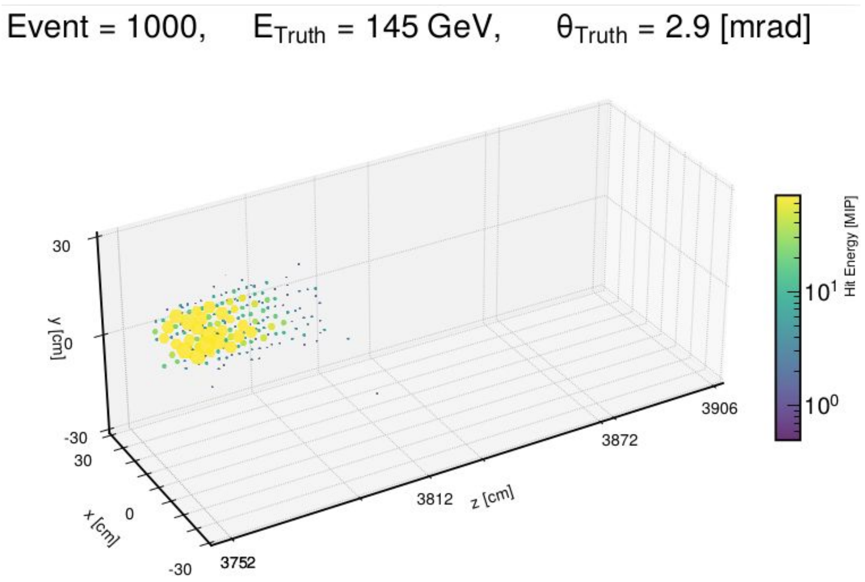
Angular resolution

- Defined as the sigma of a Gaussian fit of $\Delta r = r_{reco} - r_{truth}$
- See improvements with staggered design
- HEXPLIT & GNNs improve even further
  - HEXPLIT is a reweighting procedure detailed in [NIM A 106 (2024) 169044]

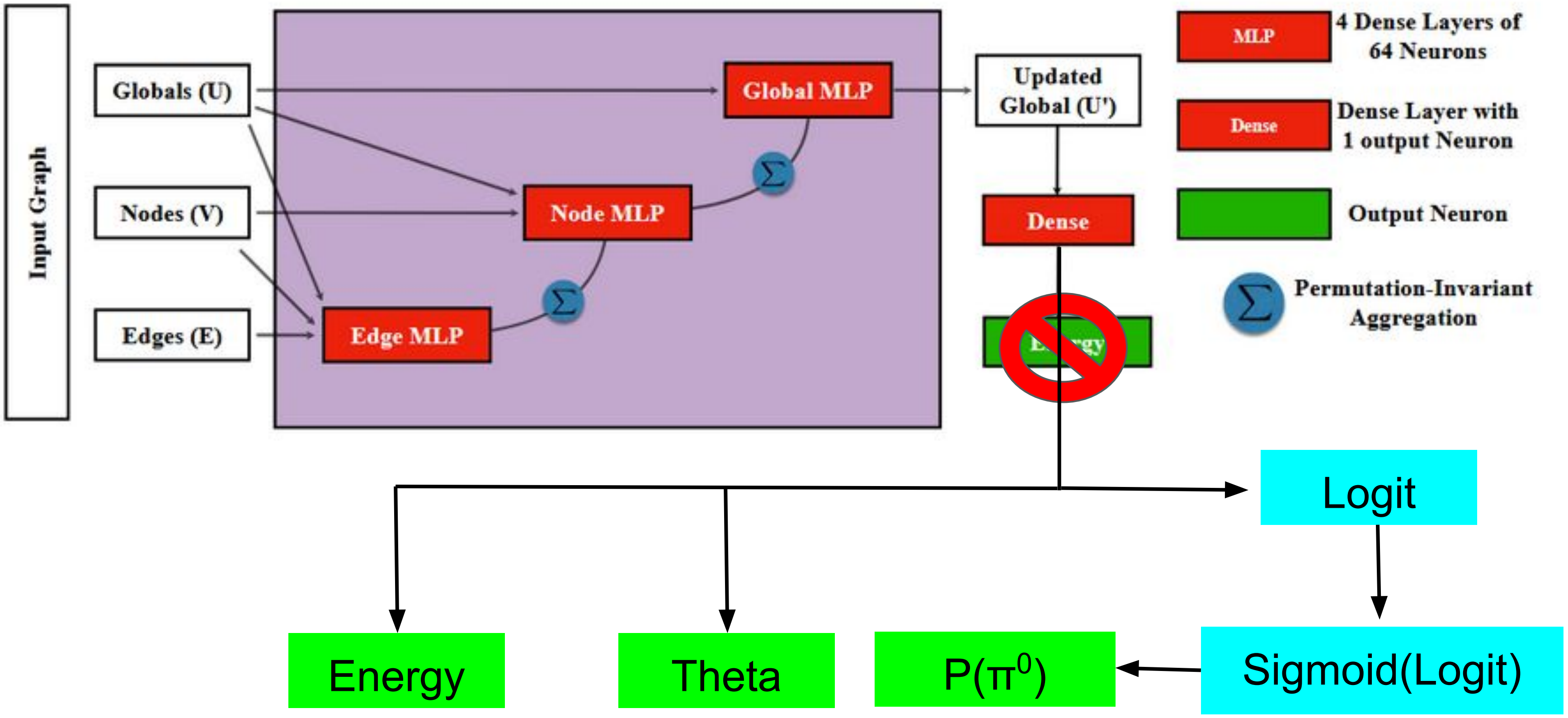


π^0/γ separation

- ZDC granularity must be capable of distinguishing π^0 and γ in u-channel backward reactions
- Implement particle type classification into GNN

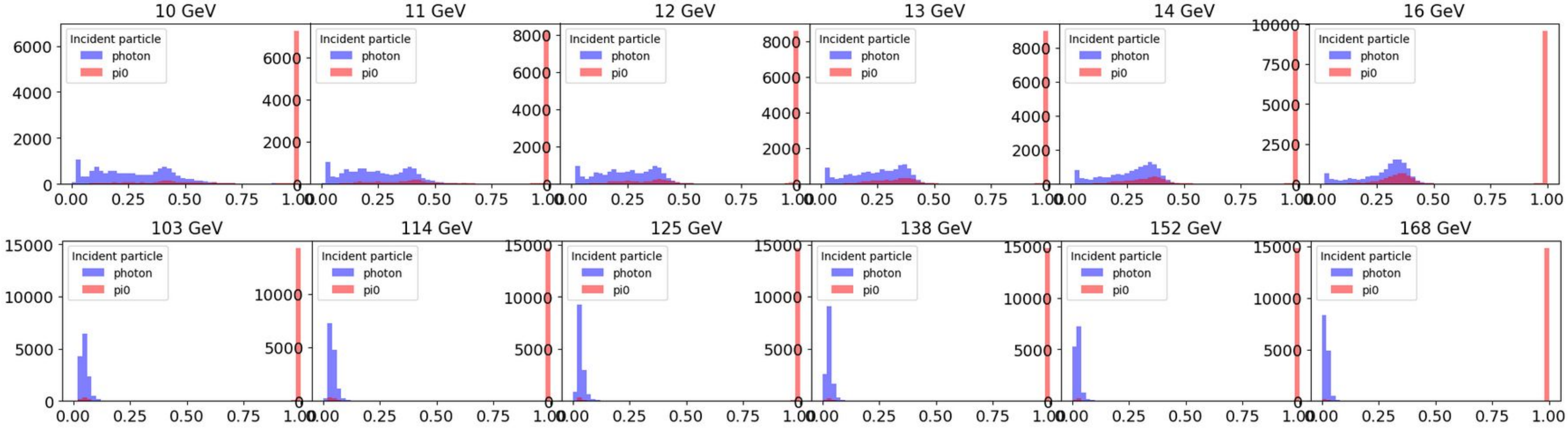


Amended Model schematic



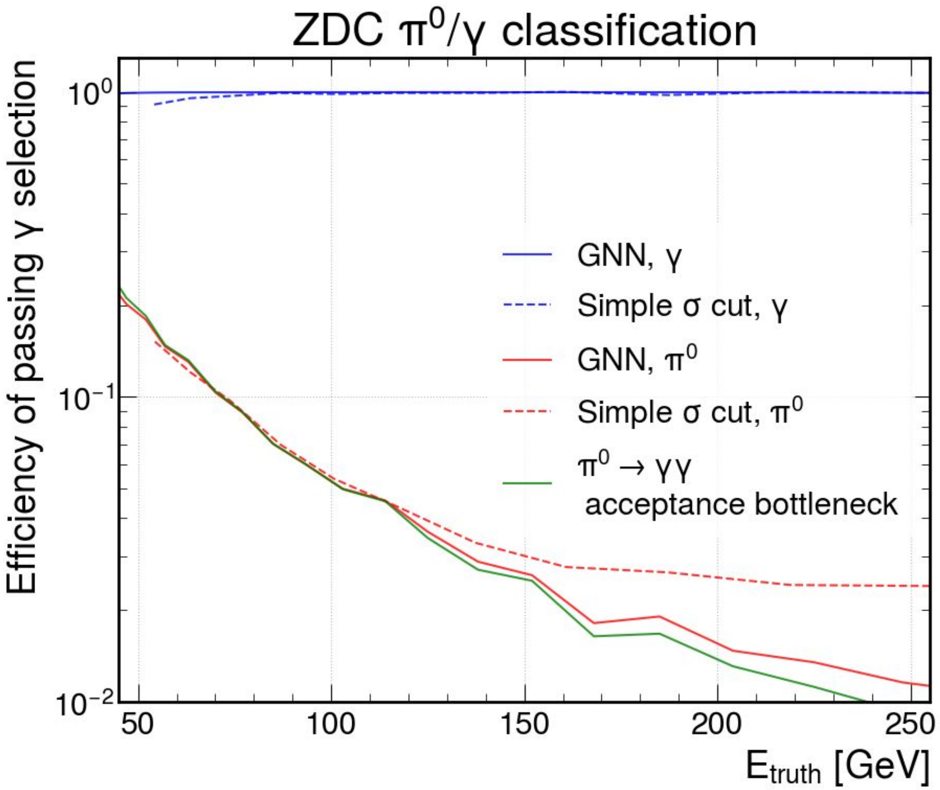
Classification strategy

- Loss $=\alpha * L_{regression} + (1-\alpha) * L_{classification}$
  - $\alpha = 0.75$
  - $L_{regression}$ = MAE, $L_{classification}$ = Binary cross entropy
- Model gives probability event is π^0
  - If model output is > 0.3, call it π^0, otherwise γ

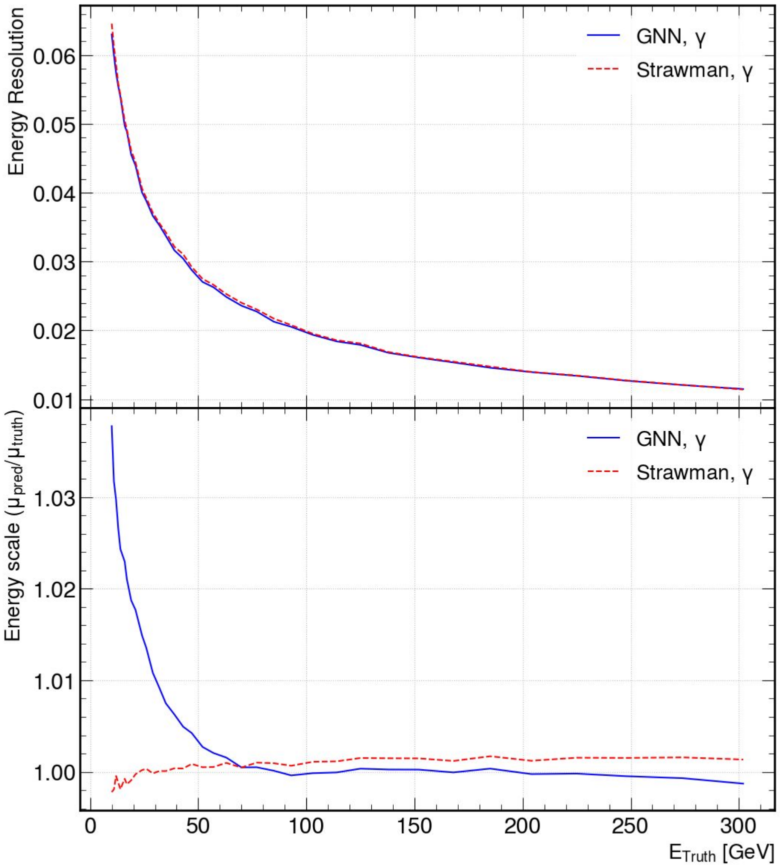


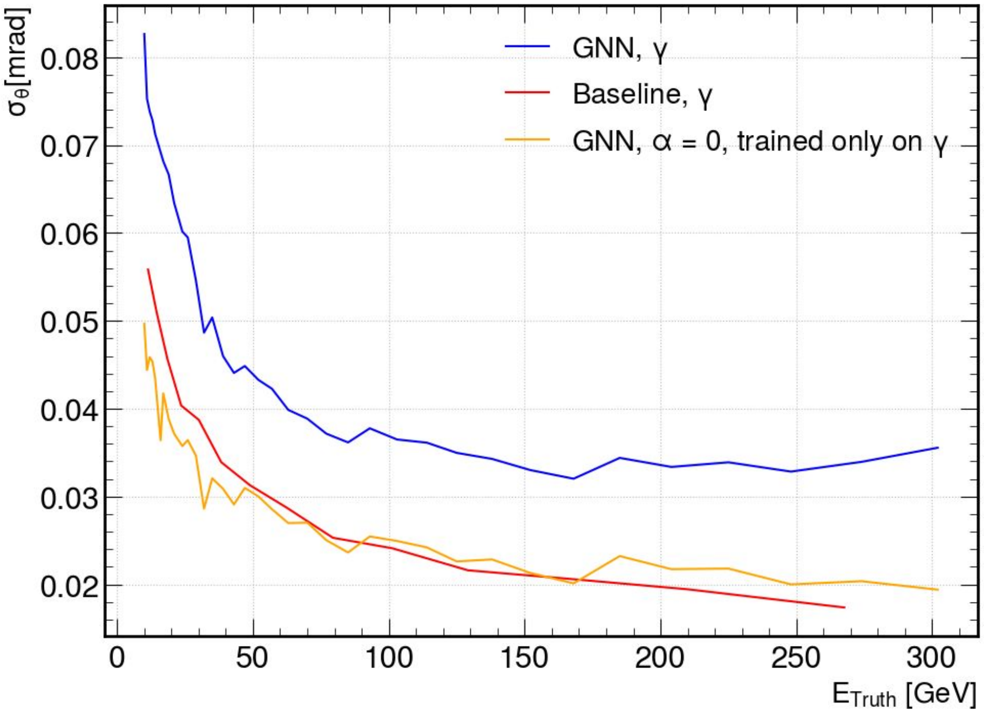
Classification efficiency

- Fraction of photon & π^0 events classified as photons
- Performs similarly to a simple cut on shower width
- Bottleneck of whether both π^0 decay photons reach the ZDC



Regression results





Summary & Future work

- ZDC is a novel design that is enhanced with machine learning
- Future work:
  - Investigate impact of α on results
  - Extend regression to include Φ
  - Include neutrons in classification
  - Studies of $\Lambda \rightarrow n + \pi^0 \rightarrow n + \gamma + \gamma$

Design of a SiPM-on-Tile ZDC for the future EIC, and Its Performance with Graph Neural Networks

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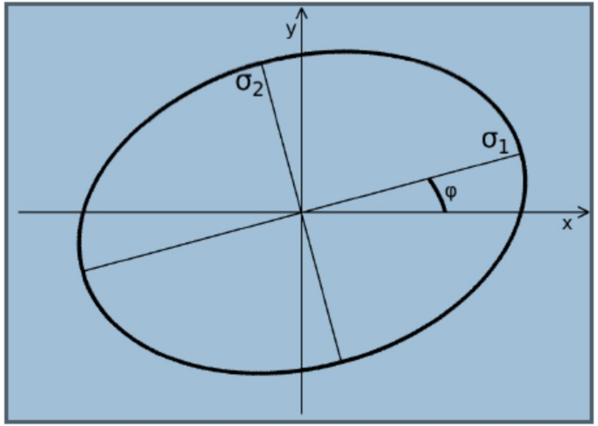
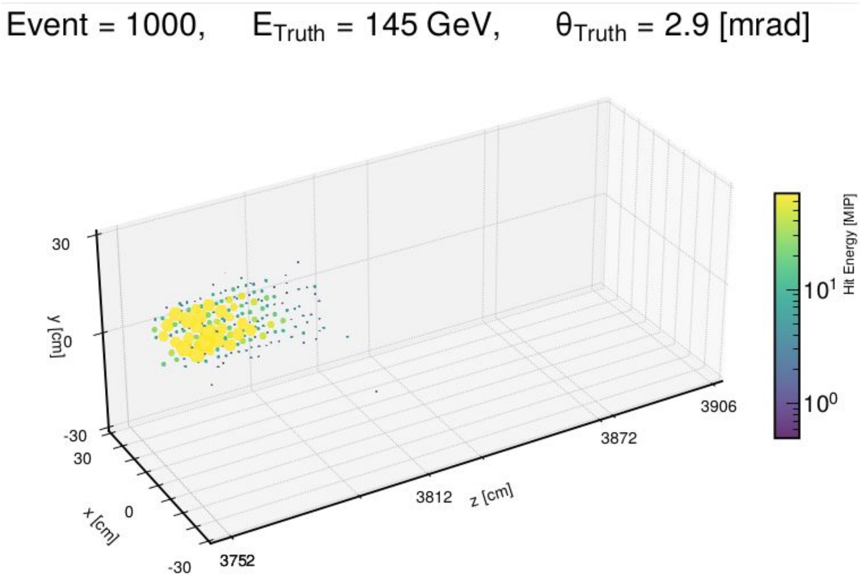
Backup

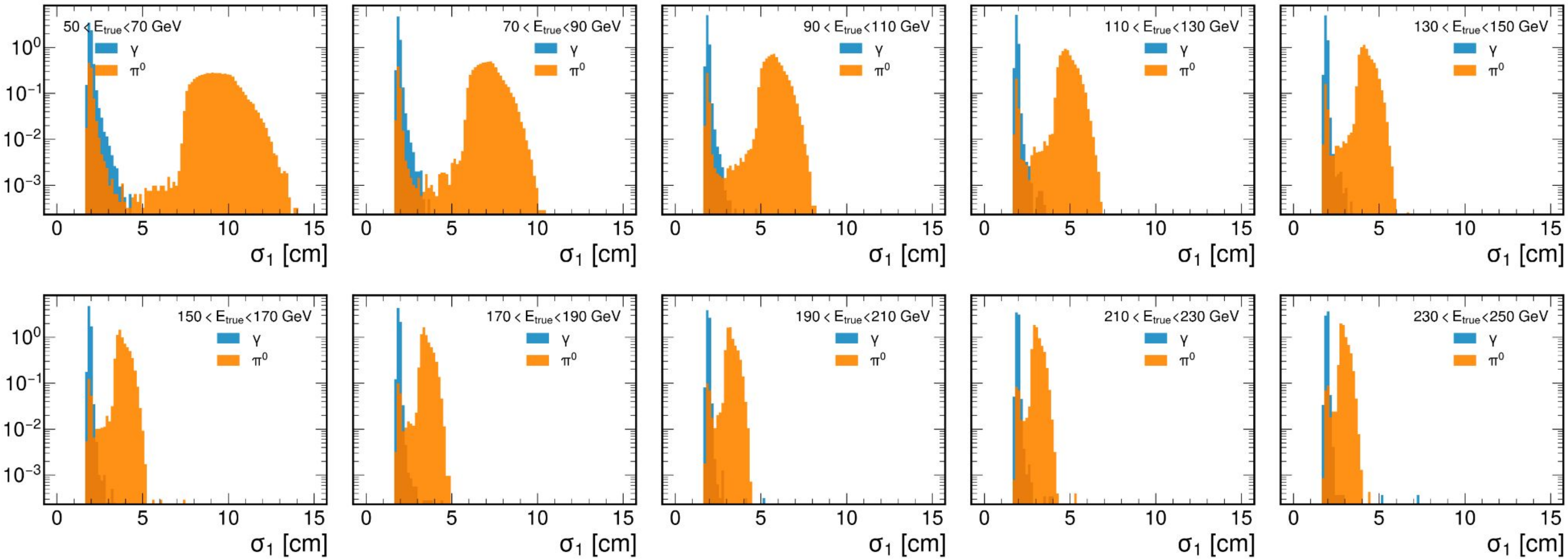
Fe/Sc π0 rejection

- π0 in u-backward channel lead to two backgrounds: reducible: 2 ɣ hit ZDC. "irreducible": 1 ɣ hit ZDC. See Zach's paper for details.
- Estimating rejection power based on simple shower shape analysis and GNN





Preliminary performance plots for γ/π0 identification



Single photon peak well separated from diphoton distribution.

The single photon peak in pi0 (other photon missing ZDC acceptance) is “irreducible” with shower shape only

Demonstration of low energy predictions

- Model is struggling to get the correct energy for π^0 at low energies