ML Studies on Λ^0 decay for ZDC

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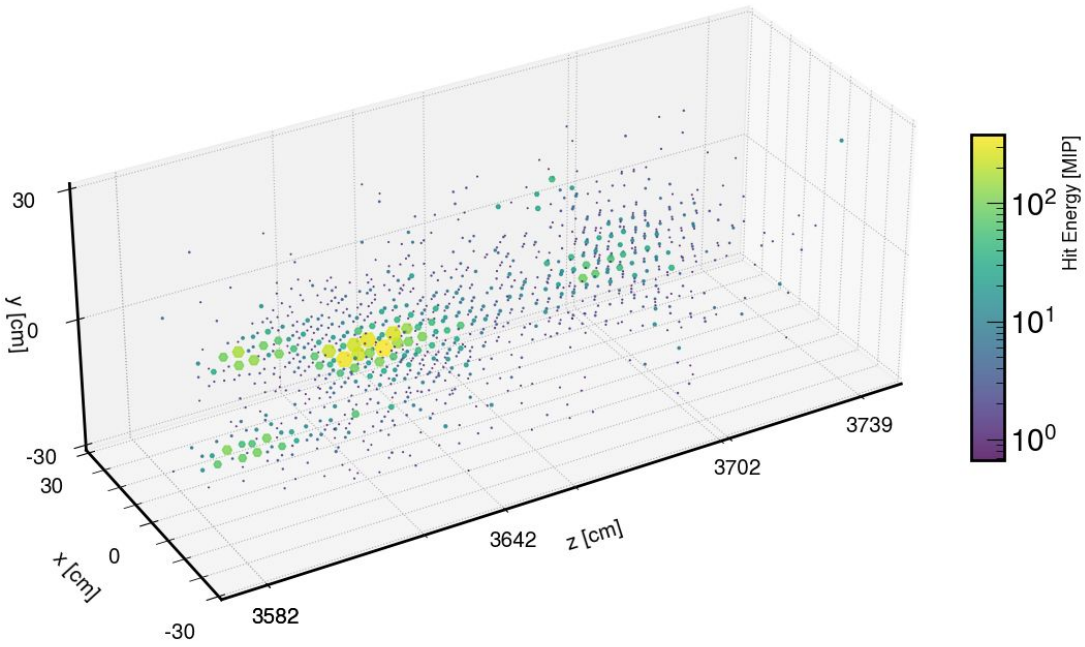
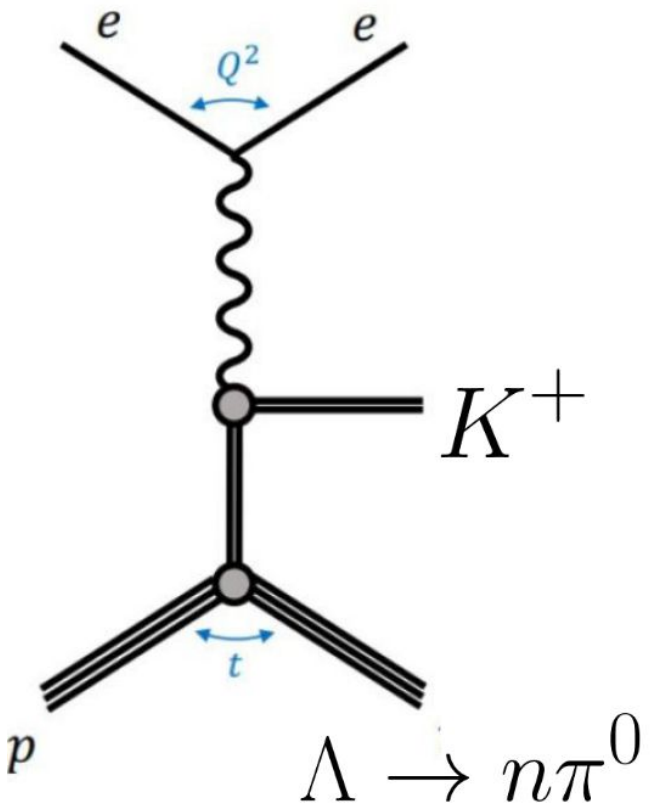


Λ decay

- e + p →e’ + X + Λ / e + p →e’ + K^+ + Λ
- Two possible decays:
  - Λ →p + π^+
  - Λ →n + π^0
- Motivation: Meson structure
  - What are the quark and gluon energy contributions to the kaon mass? (EIC YR Table 7.1)



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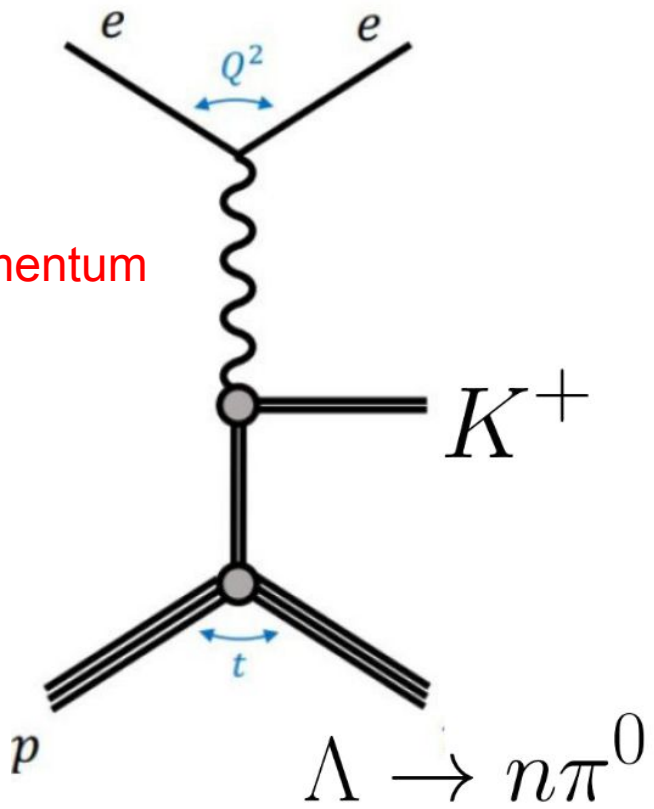

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  - Λ →n + π^0 ZDC!
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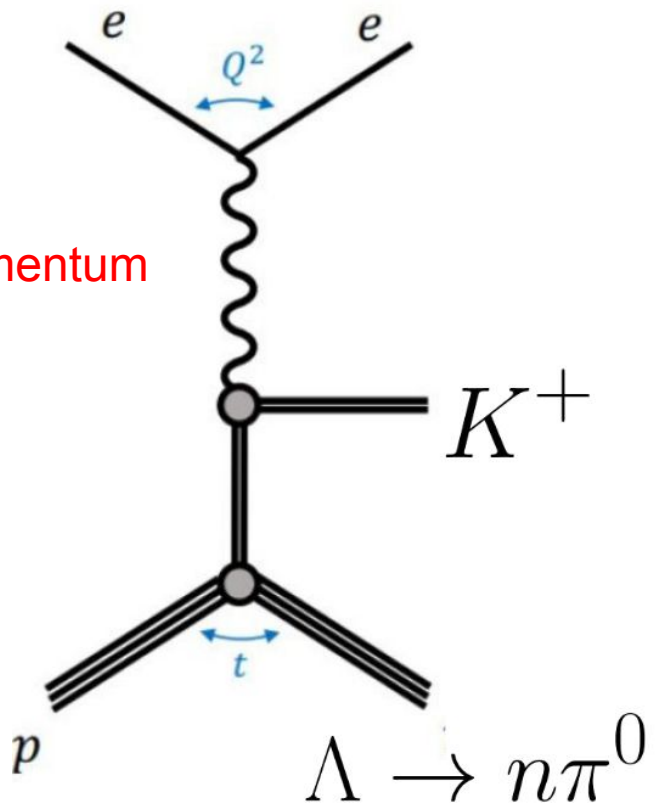
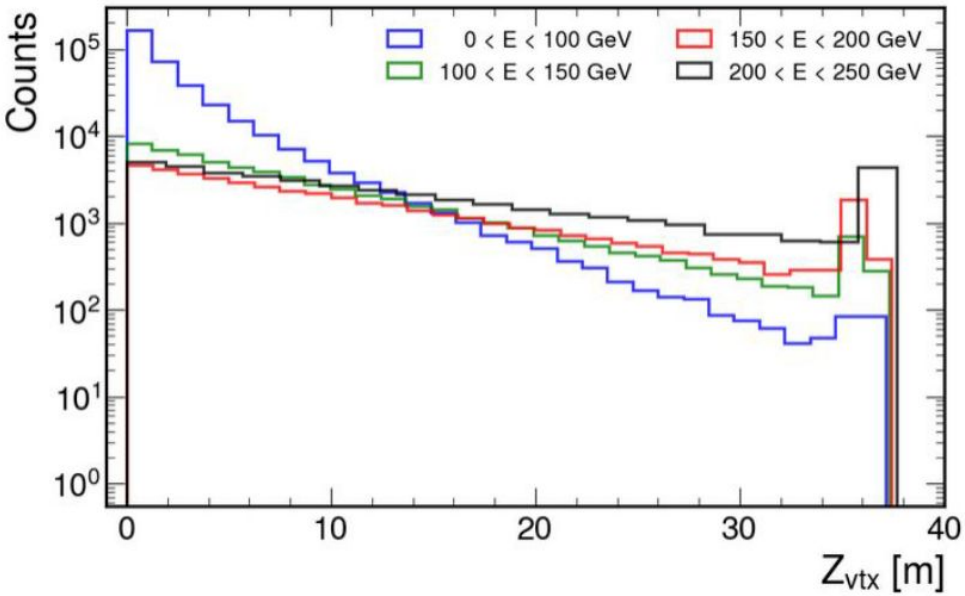


$\Lambda \rightarrow n + \pi^0$ Challenge

- Resolution of Λ^0 p_T depends on angular resolution of ZDC
- Need to know Z_{vertex} to properly measure θ
- ZDC is at 35.8 m



$\Lambda \rightarrow n + \pi^0$ Challenge

- Resolution of Λ^0 p_T depends on angular resolution of ZDC
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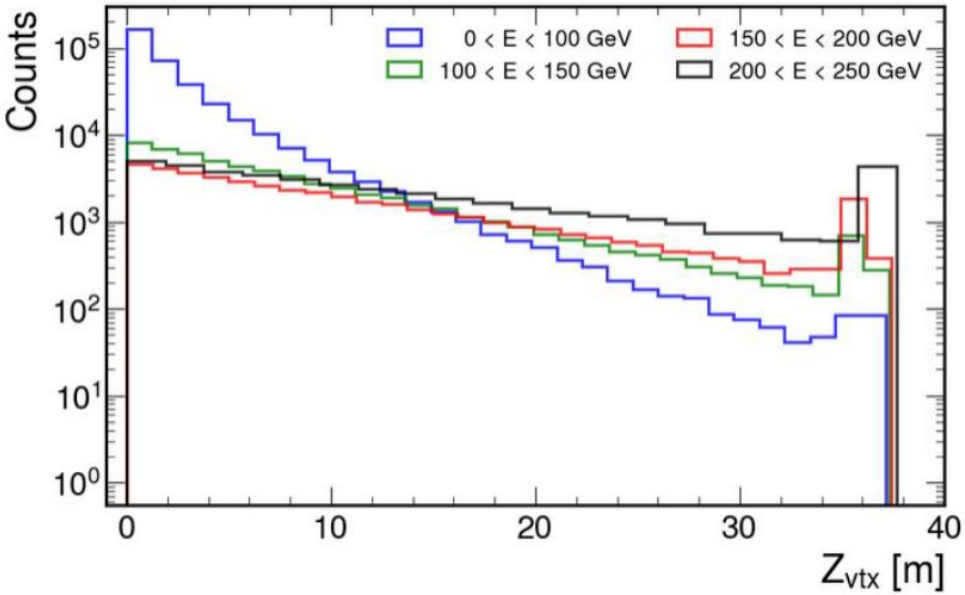
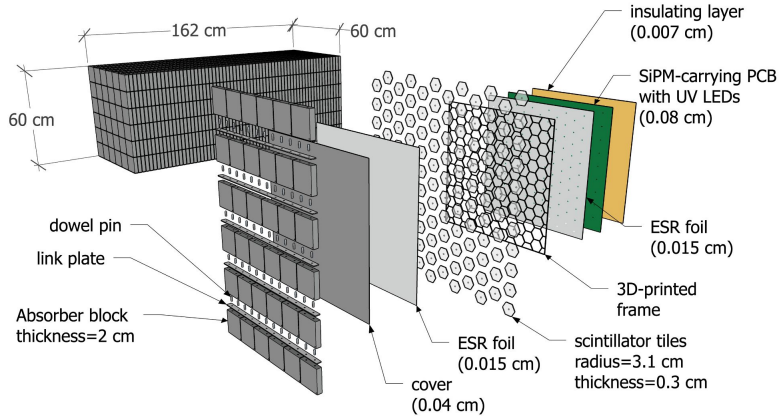
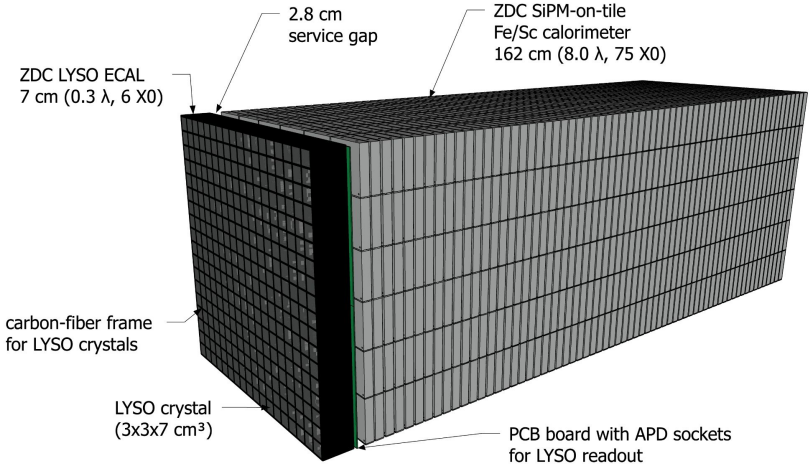
- ZDC is at 35.8 m
- “The reconstruction of the Λ event in the far-forward detection area is one of the most challenging tasks.” - EIC YR



How to detect this?

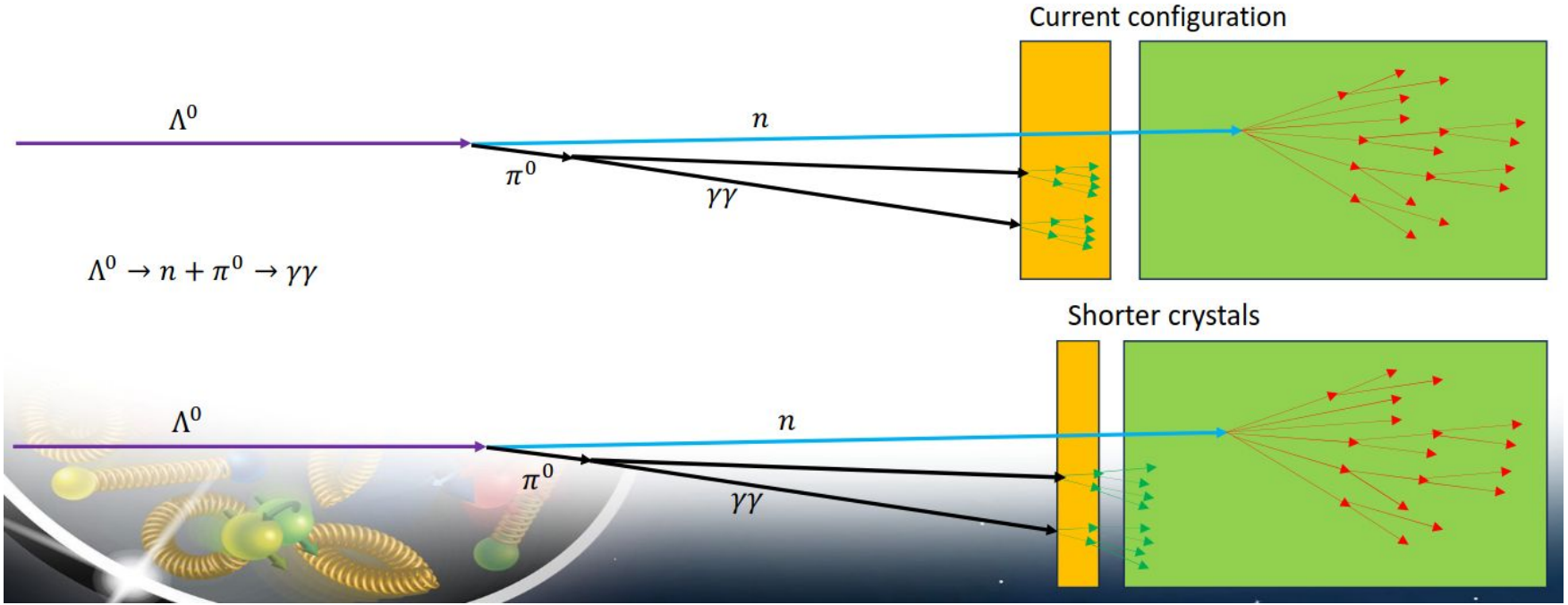
- HCal: SiPM-on-tile ZDC
- ECal: Multiple options
  - 6.4 X0 LYSO
  - 6.4 X0 PbWO4
  - 22.5 X0 PbWO4
- ECal used to capture photons from $\pi^0 \rightarrow \gamma+\gamma$





ECal considerations

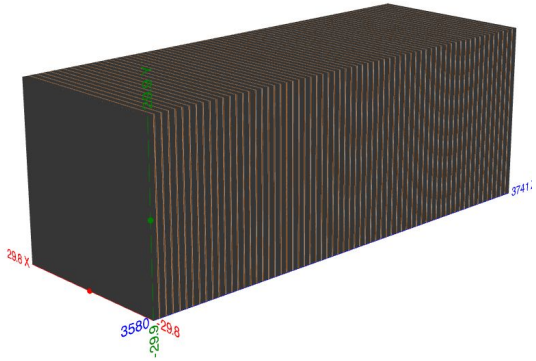
Yellow = ECal, Green = HCal

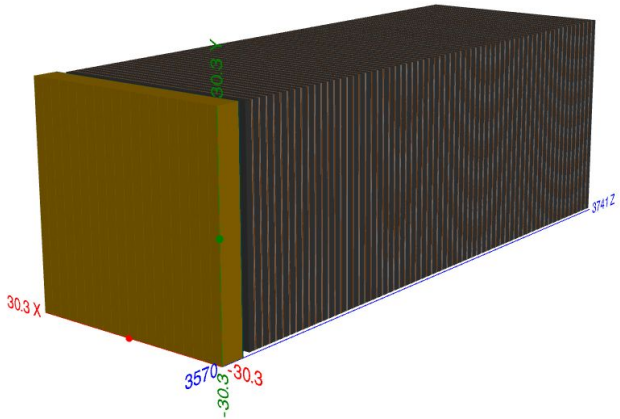


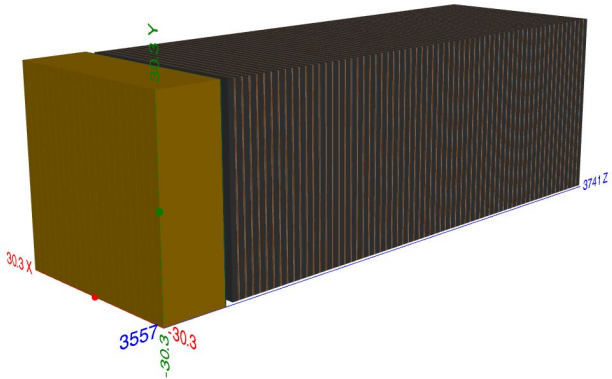
Images courtesy of A. Jentsch from [CFNS Summer School 2024]

Simulation

- 10-250 GeV $\Lambda \rightarrow n + \pi^0$, $0 < \theta < 4$ mrad
- 4 standalone detector configurations:
  - SiPM-on-tile only
  - 6.4 X0 LYSO + SiPM-on-tile
  - 6.4 X0 PbWO4 + SiPM-on-tile
  - 22.5 X0 PbWO4 + SiPM-on-tile

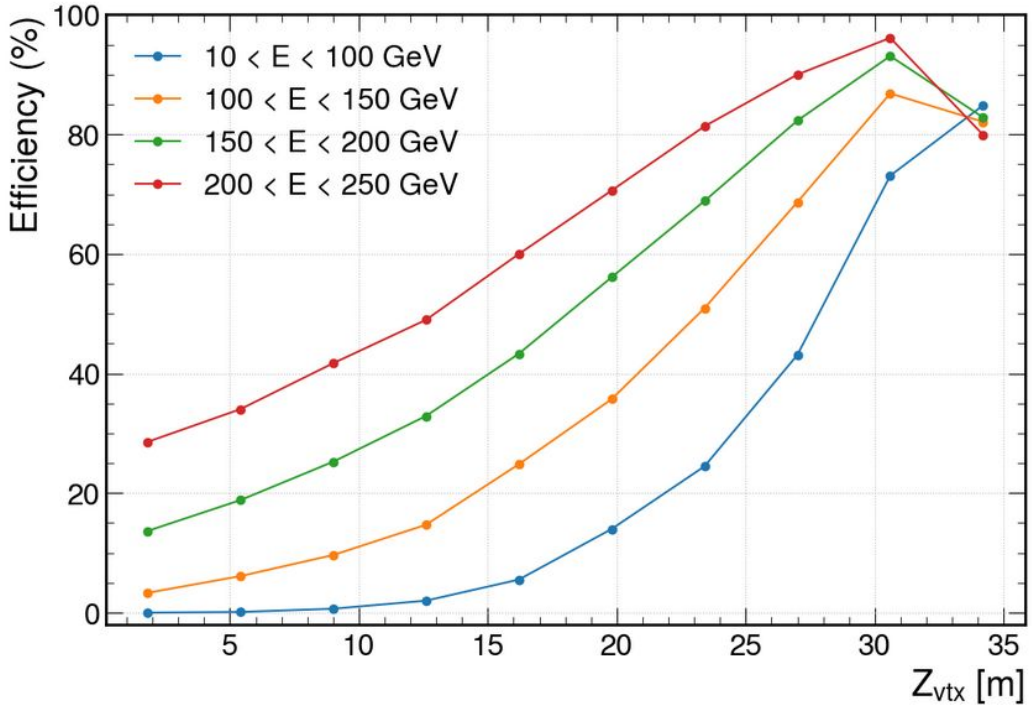






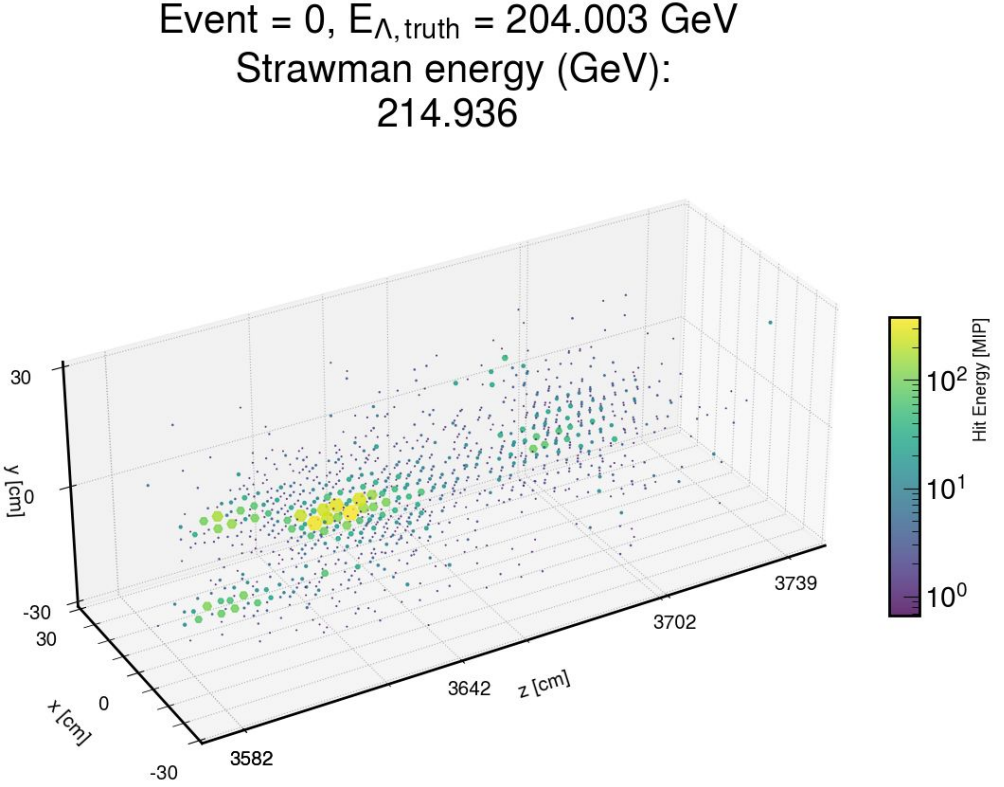
Event selection

- Only select events where all three particles (n, 2γ) are within ZDC acceptance
- Low energy decays detected in central detector



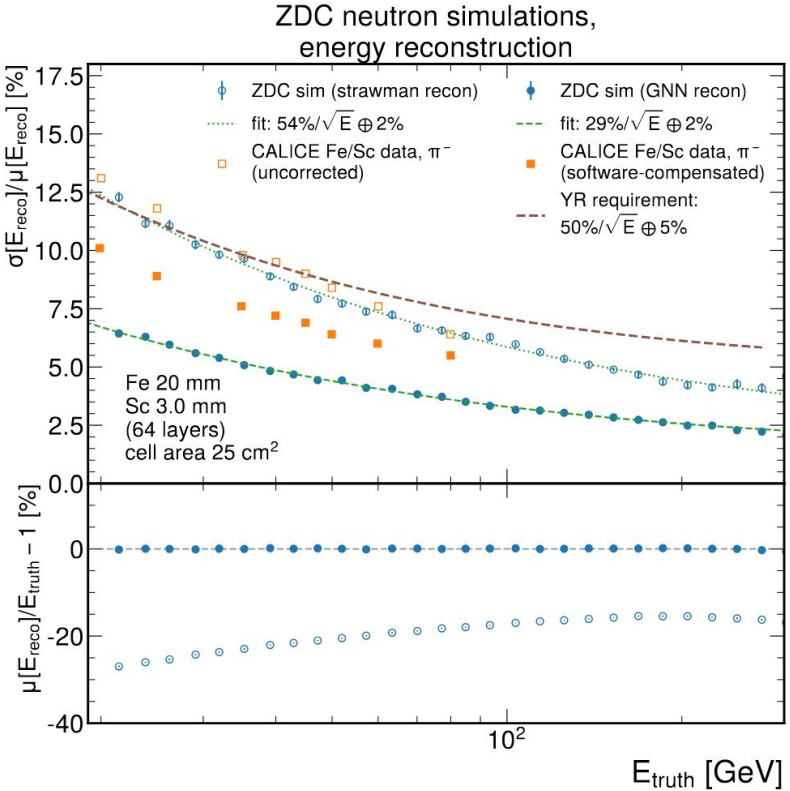
GNNs for reconstruction

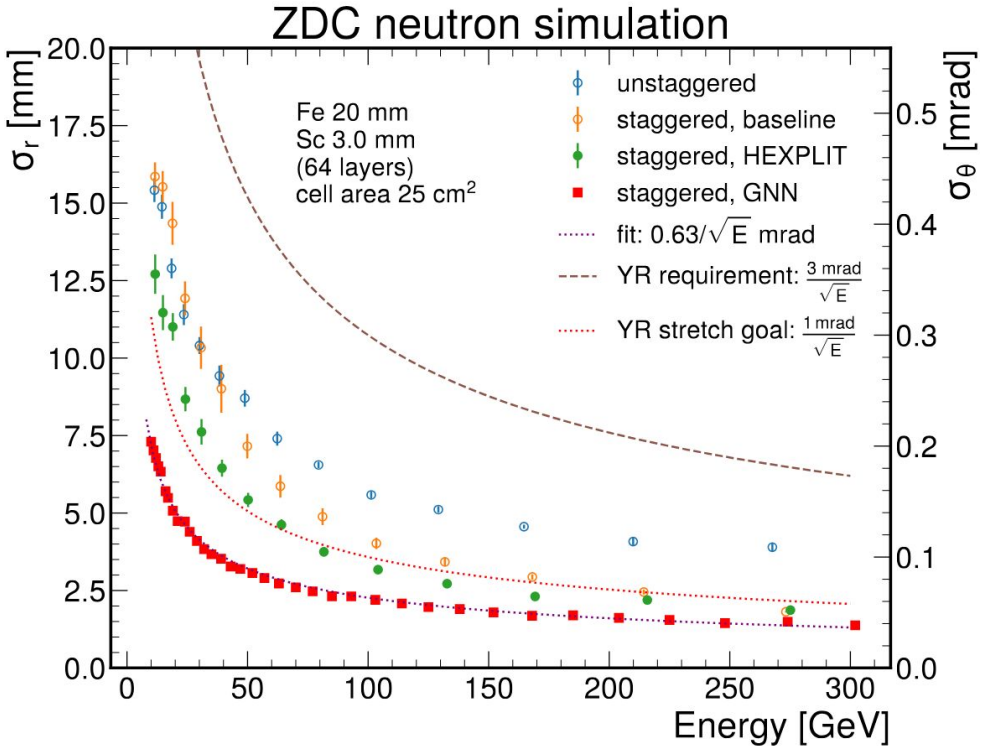
- Use graph neural networks (GNN) to regress on Λ energy, θ, ϕ
- GNN details:
  - Nodes - Cell (E, x, y, z)
  - Edges - (E, x, y, z) of ten neighboring cells
  - Globals - Total deposited energy
  - Loss - Mean absolute error



Why use ML/GNNs?

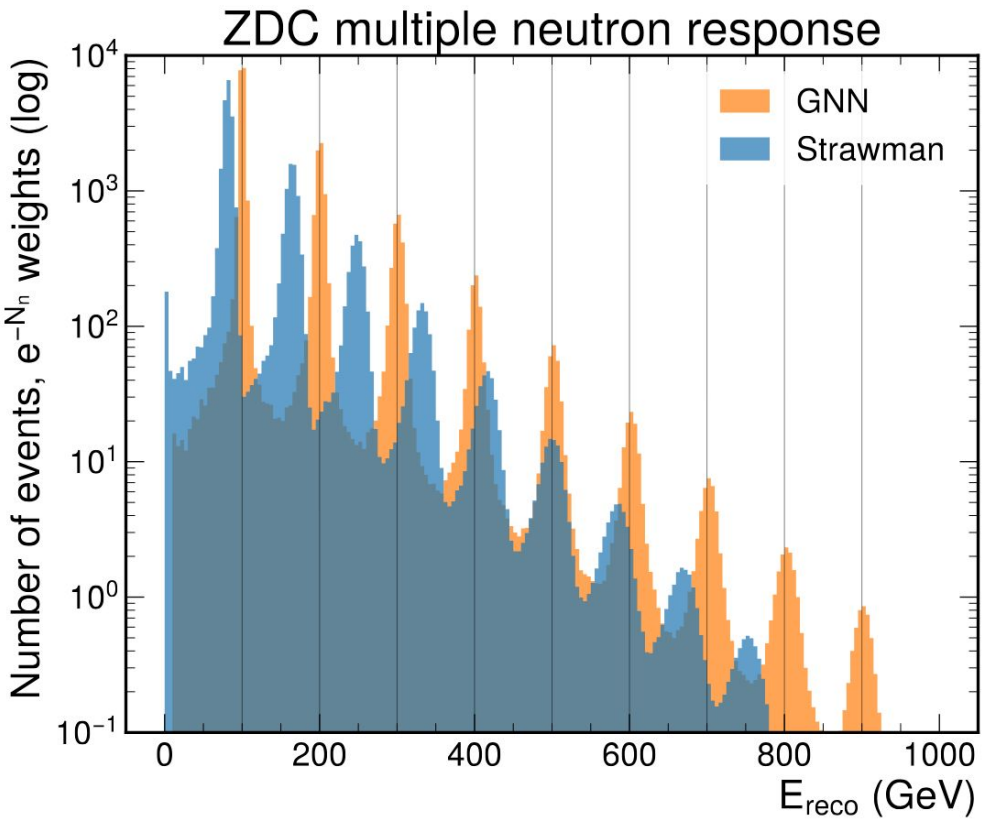
- F.T. Acosta *et al* 2024 *JINST* **19** P06002 , arXiv:2406.12877



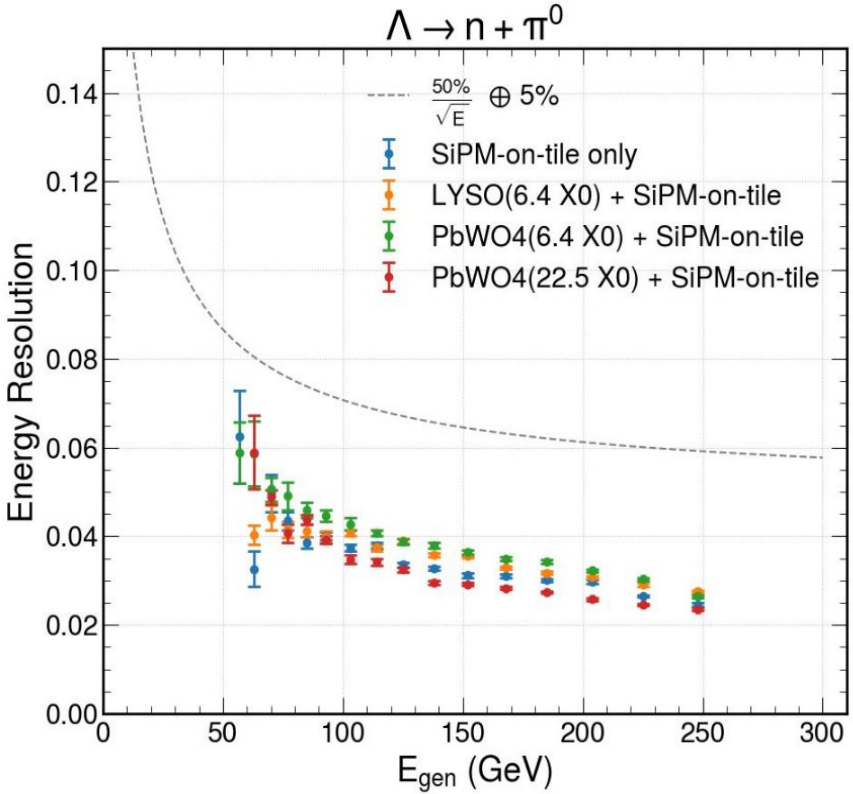


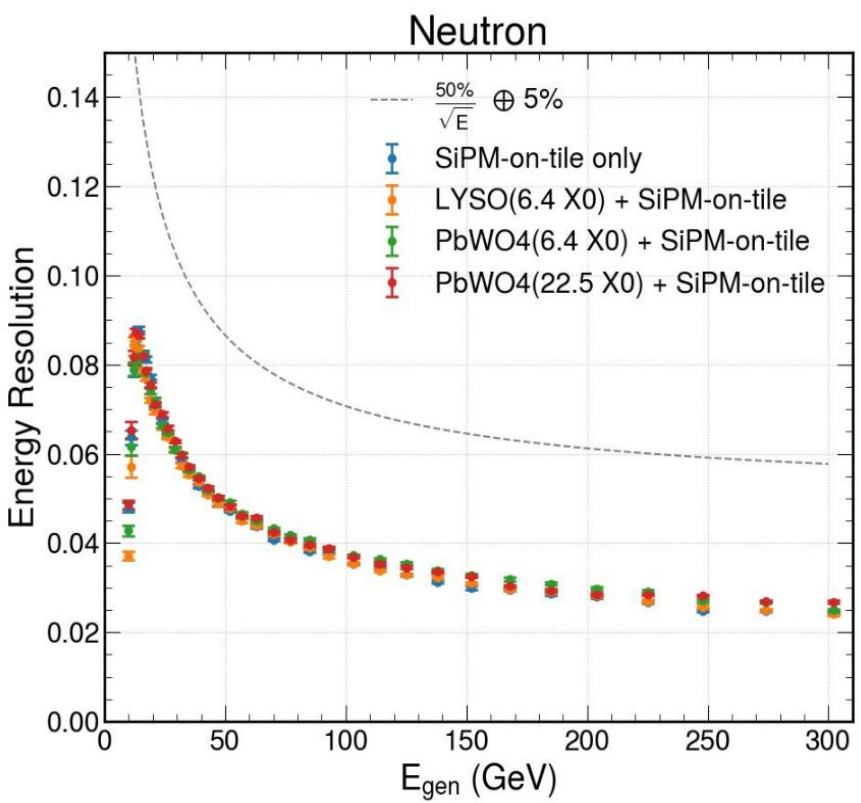
Why use ML/GNNs?

- Even with multiple showers!
- F.T. Acosta *et al* 2024 *JINST* **19** P06002 , arXiv:2406.12877

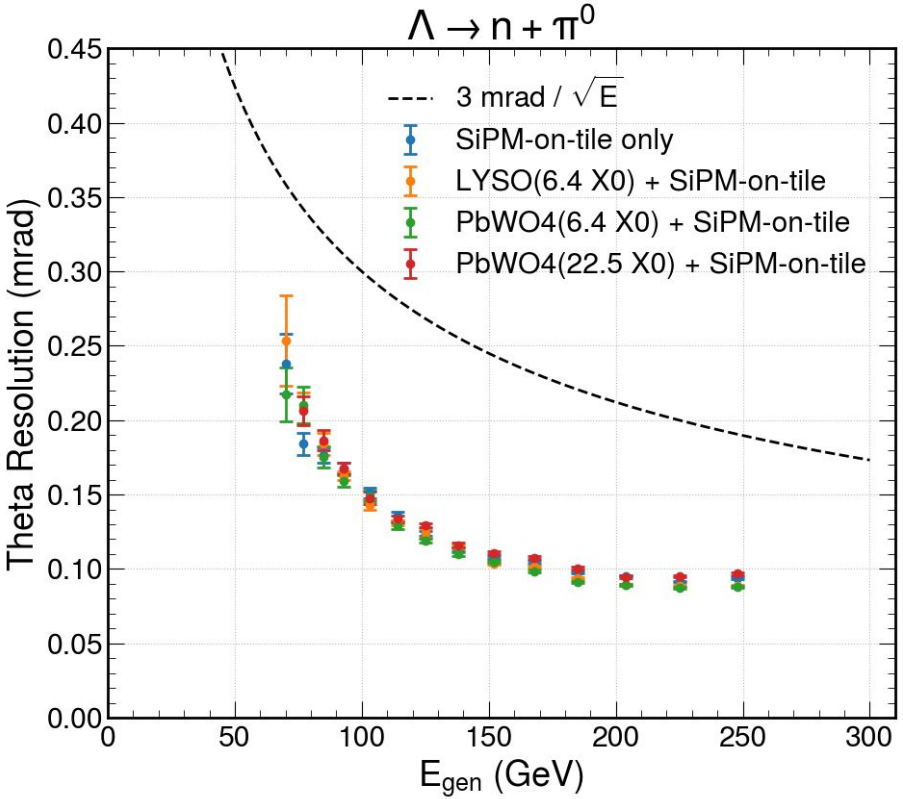


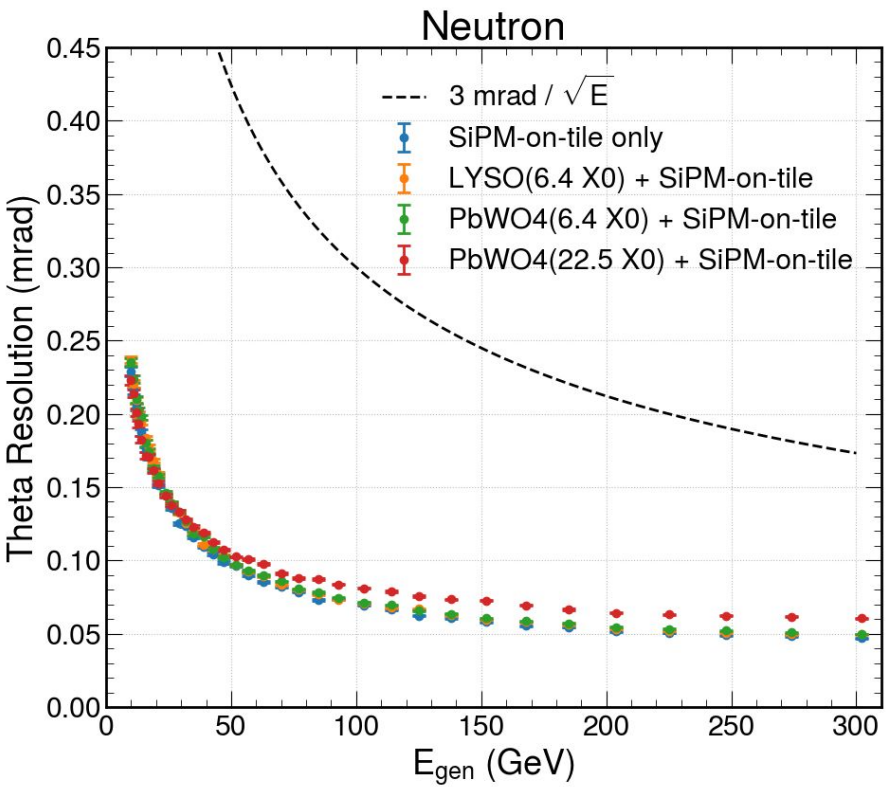
GNN Energy resolution





GNN Angular resolution





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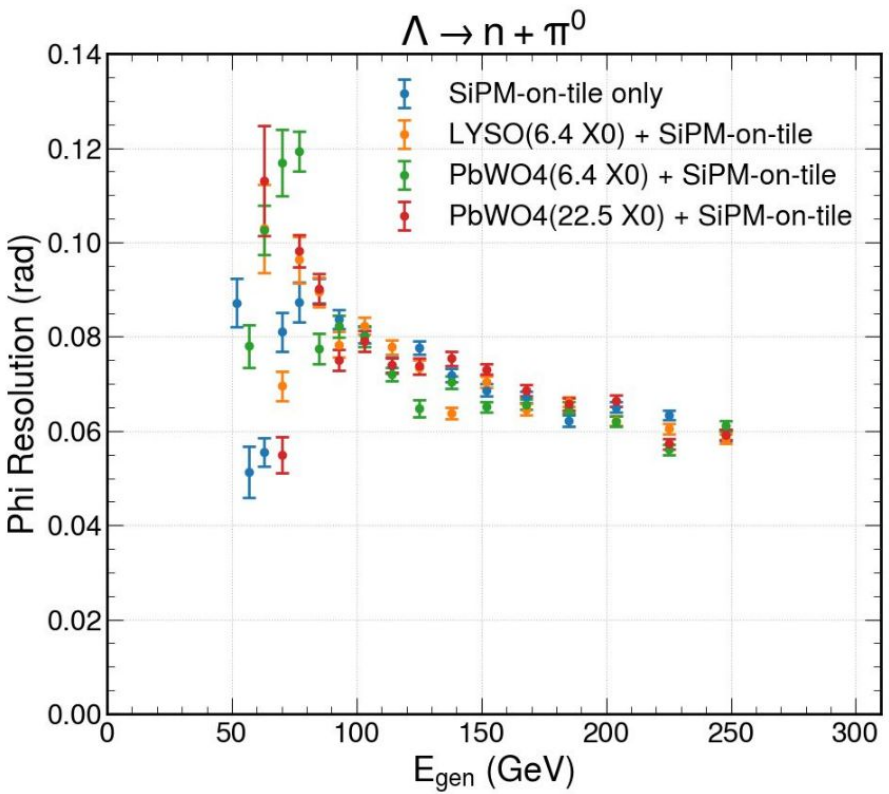
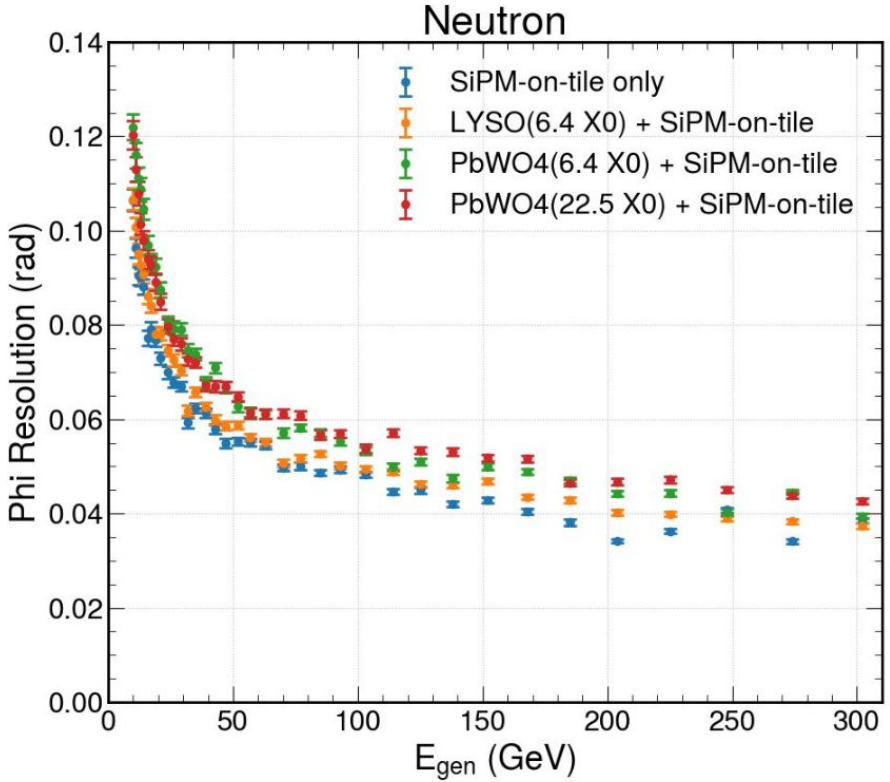
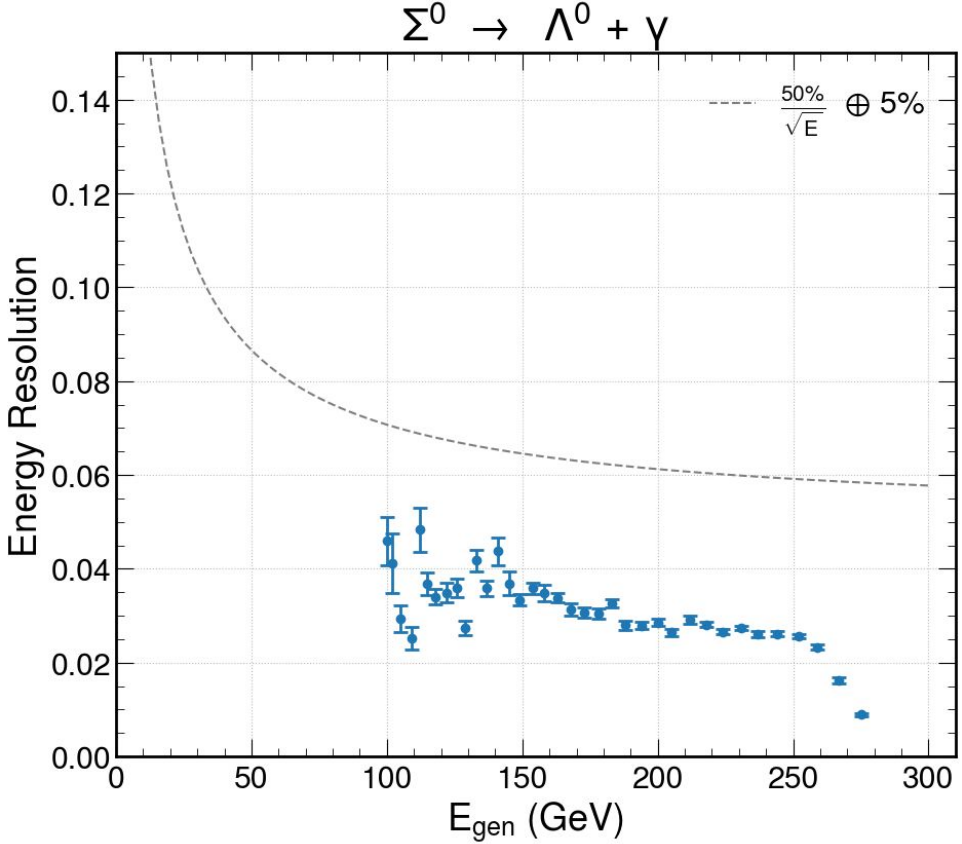




$\Sigma^0 \rightarrow \Lambda + \gamma$

- Using SiPM-on-tile HCal only
- Very preliminary results
- Comparable to Λ decay results



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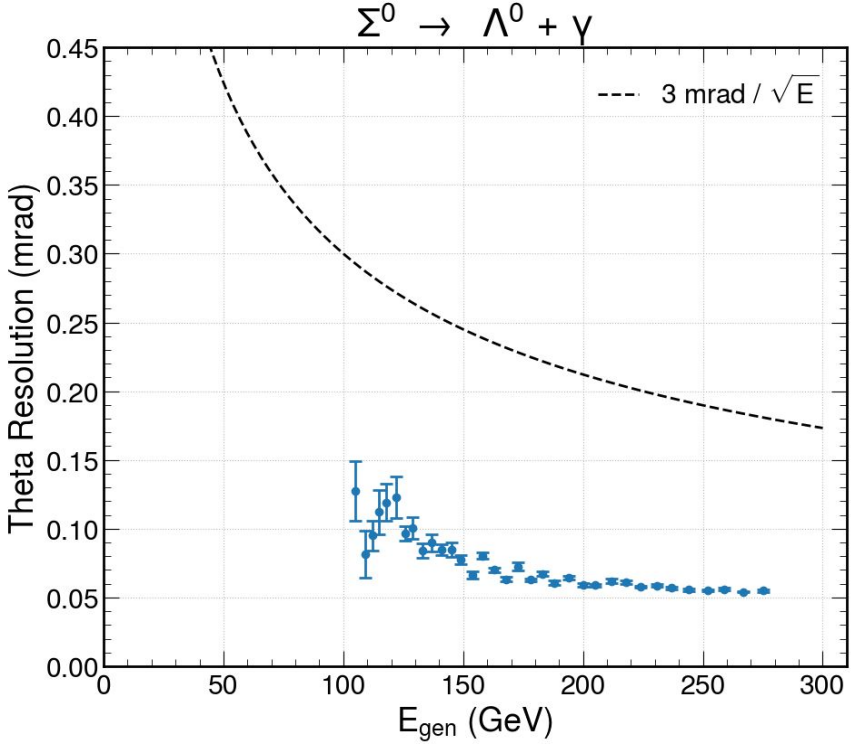
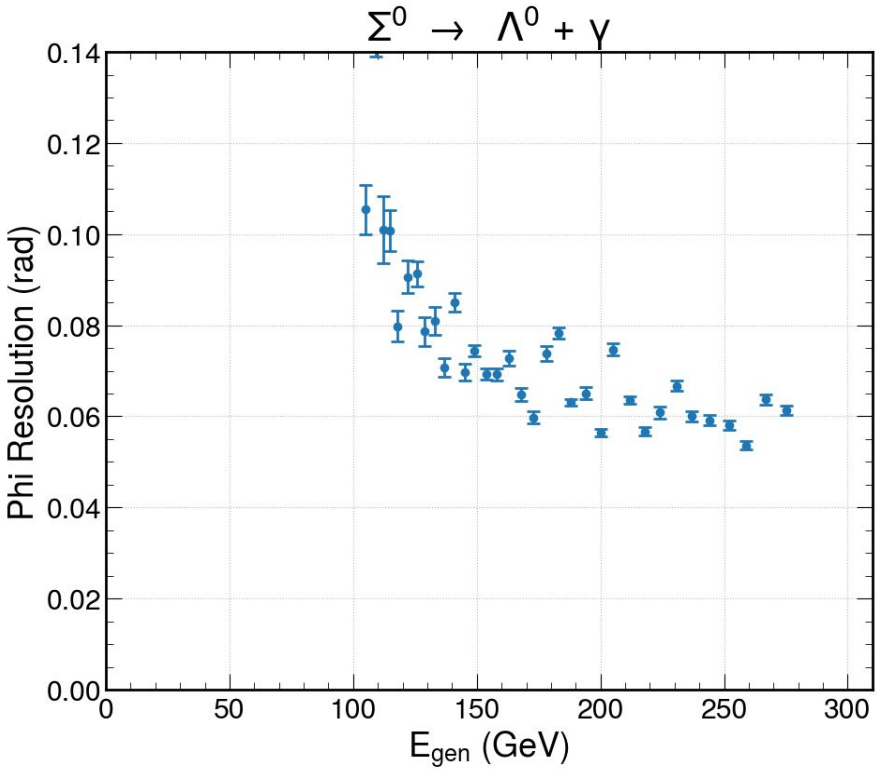


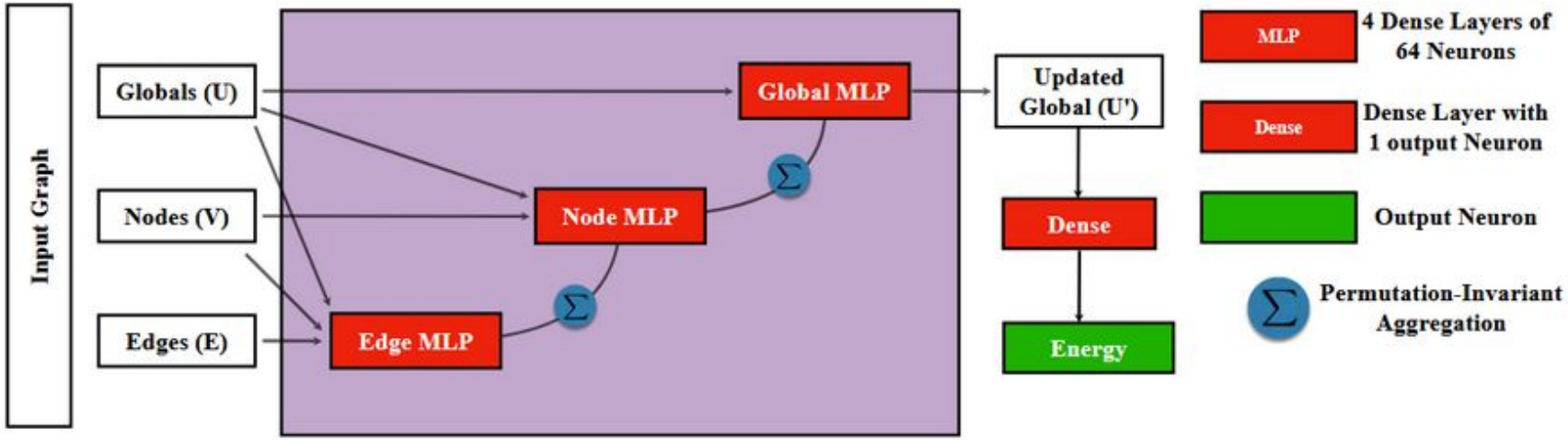


Takeaways

- All four detector configurations meet physics requirements using GNNs
  - Low-energy [1 MeV-O(1) GeV] γ→ LYSO
  - High-energy γ and π^0 → No reason for ECal
  - High-energy neutrons, Λ → No reason for ECal
- Promising results for Σ^0 decay using SiPM-on-tile ZDC

Thanks!

Backup:1D Model schematic



- Provide model with cell (E, x, y, z), event energy, and info of neighboring cells

Backup

- Z_{vertex} distribution for events that pass efficiency cut