Backward Hadronic Calorimeter

Work plan and priorities

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nHCal DSC meeting 18.3.2025

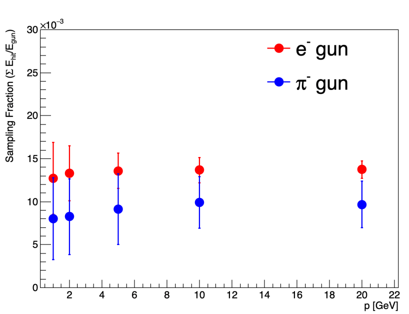
Outline

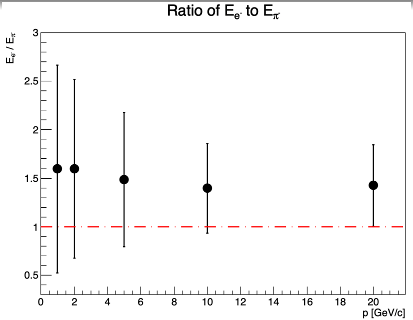
Work plan priorities

1. Determine detector geometry: tile, absorber and overall thickness - **high priority**
2. Tile tests in different configurations: SiPM on tile, WLS fibers etc.
3. Finalize jet/diffractive dijet reconstruction study to optimize the tiles for these measurements - **priority**
4. Study of muon track identification with nHCal - **priority**
5. Study of K_L identification with nHCal
6. Re-check position resolution study with full ePIC geometry with clustering bug fixed - **medium priority**
7. Investigate shower reconstruction in high material region - **medium priority**
8. Prototype construction - on hold until geometry fixed
9. Prepare for beam tests

`https://docs.google.com/document/d/1SSqGlWChuWoEM8sNb0CyXTGGEHa-pAdBQc0MXvHJgLw/edit?usp=sharing`

Sampling fraction



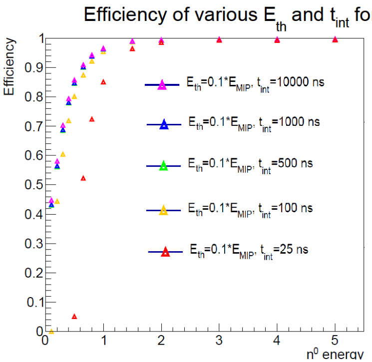


- Sampling fraction 0.95% for pions, but needs to be revisited
  - Used pion energy instead of energy deposits as a reference
- $e/h \approx 1$ ratio suggests compensation
- May need more frequent sampling to better measure low energy neutrons eg. below $E_k = 1\,\mathrm{GeV}$
- Baseline: tile thickness 4 mm, steel absorber 4 cm, total 45 cm
- Check a few different configurations and optimize:
  - e/h response
  - energy resolution
  - neutron detection efficiency
- Switch from stainless steel to steel in epic repository

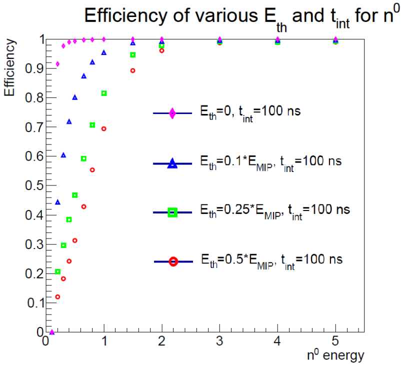
`https://docs.google.com/document/d/1p9QSd1E2REgA7cfunoBBrwUadJ3kUskcXm0GAKWCxcE/edit?usp=sharing`

Neutron detection efficiency check

Integration time dependence



Threshold dependence

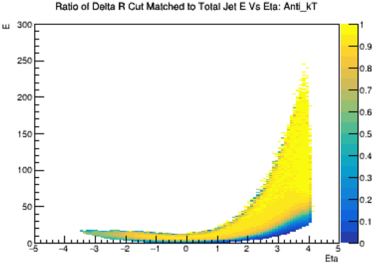


Sam Corey, OSU

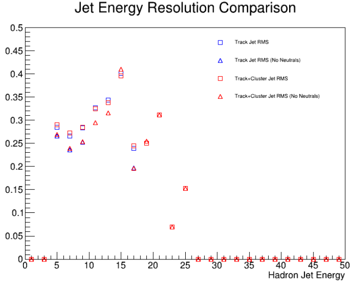
- Revisit for different configurations during sampling fraction study
- Efficiency of requiring a hit with a sum of hit contributions energy integrated up to t_{int} and passing a threshold E_{th}, $t_0 = 0$
- Checked with simulation only - no digitization
- E_{MIP} is 0.75 MeV per layer
- E_{th} has the biggest impact
- 100 ns is good enough, but lower energy neutrons may need longer times
- 60% efficiency for $E = 300\ \mathrm{MeV}$ neutrons $E_{th} = 0.1 \times E_{MIP} = 75\ \mathrm{keV}$ and 100 ns

Jet and diffractive dijet study

Reconstruction performance

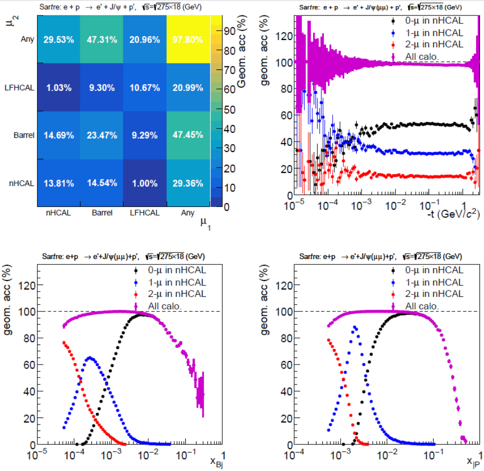


Energy resolution



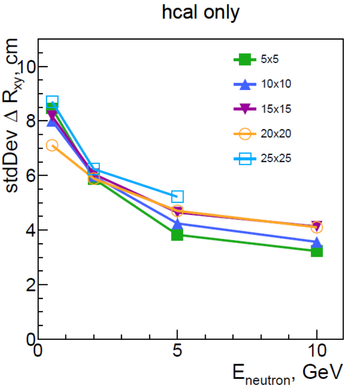
- Optimize tiles for neutron identification vs. charged hadron identification
  - Preliminary studies show that 10 cm x 10 cm tiles are good enough - based on cluster distances
- Use realistic track/cluster matching (coming soon from reco software group)
  - In the meantime look at MC truth clusters
- This is my focus in coordination with Brian

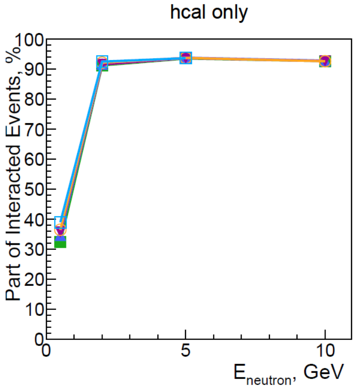
Muon identification study for VM reconstruction



- Study of VM meson reconstruction complete: https://doi.org/10.5281/zenodo.14200156
- Need to optimize tiles for the muon detection
- Study muon identification efficiency and purity
- Similar study for decays containing K_L (part of it started)

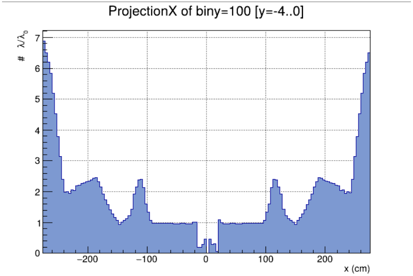
Alexandr Prozorov, CTU

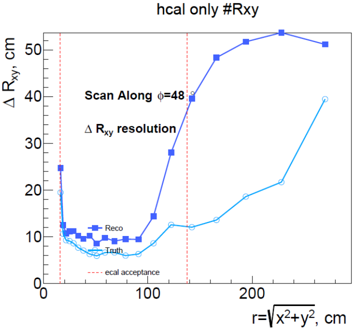




- Shoot single neutrons and compare ideal projections to RECO clusters
- Vary energy and tile size to obtain scaling
- Even large tiles up to 25 cm seem to be OK
- Need track projections and cluster matching in realistic DIS events - next steps

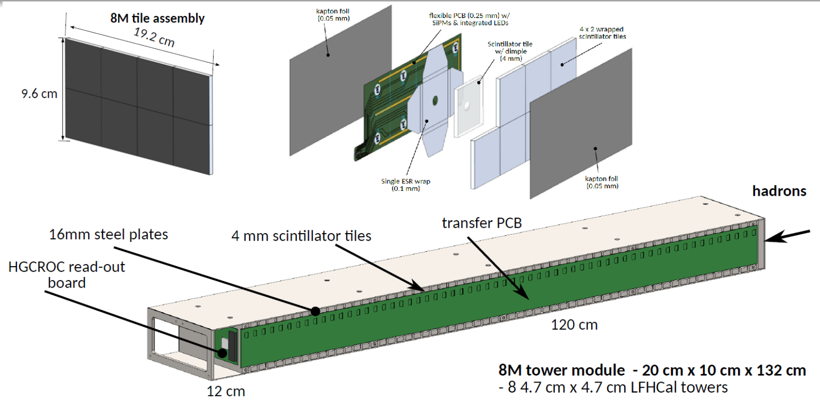
High material impact on shower reco





full epic

- Investigate impact in more details
  - Basic distributions, hits etc. vs. radial distance
  - Check the true stop vertex of MCparticle
- Try to determine optimal clustering parameters
- Revisit position resolution study with full geometry - previous one may be affected by the clustering bug



- LFHCAL module designs: `https://indico.bnl.gov/event/25021/`
  - Direct: `https://indico.bnl.gov/event/25021/attachments/57749/99174/8M%20Tower%20Assem_Combined_Oct1.pdf`
- Reuse spare LFHCAL module? Eg. place tiles at the beginning and ignore the rest.
  - Modules produced with electron beam welding in a vacuum.
- Produce our own module? Most likely.

`https://docs.google.com/spreadsheets/d/1Ow8v9TIoMQJZNTNtyoKcaHm0iRpucCt0eg8JCz44JwM/edit?usp=sharing`

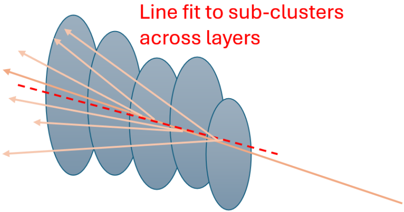
Summary

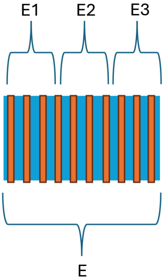
Summary

- Presented a work plan for most important tasks
- We need to discuss how the DSC will work on this

BACKUP

Position resolution improvement





1. Check if using max energy deposit in the first layer improves position resolution
2. Do 3D clustering
   - Store subclusters for every layer
   - Code for BIC from Sylvester: `https://eicweb.phy.anl.gov/EIC/juggler/-/blob/main/JugReco/src/components/ImagingClusterReco.cpp`
   - Fit a line through the clusters across the layers (and compare to a reco track)
3. Independent vs. integrated readout from layers
   - Affects 3D clustering etc.
   - If removed, most likely no effect on energy resolution
   - Can reduce channels by up to factor of 10
   - Any suggestions about which quantity may decide that?

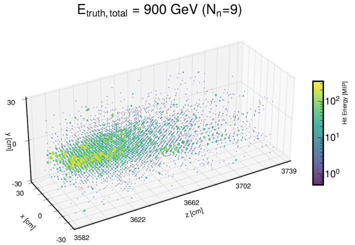
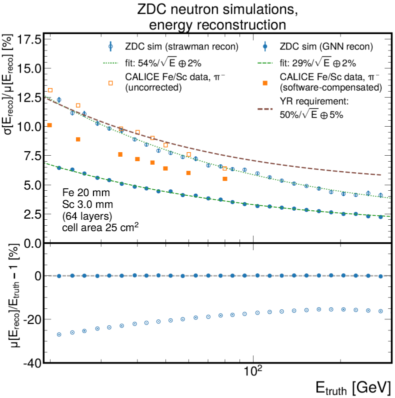
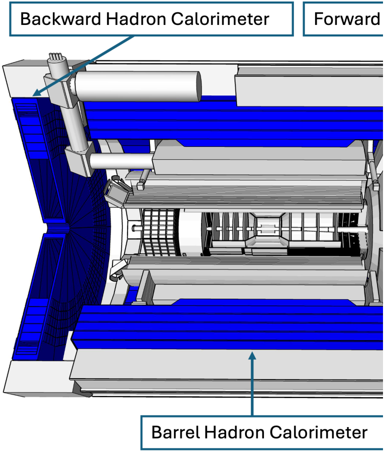


Figure 7: Examples of 4 reconstructed 3D shower shapes in the ZDC for events with 1 neutron (N_n = 1), 2 neutrons (N_n = 2), 4 neutrons (N_n = 4), and 9 neutrons (N_n = 9). The color code represents hit energy in terms of E_{MIP}. The marker size is displayed proportionally to hit energy for display purposes.



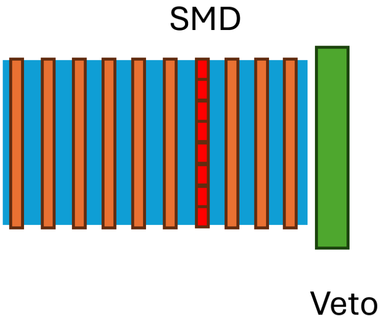
- Potential to use machine learning to improve shower reconstruction
- Studies done by LFHCAL Insert/ZDC group (UC Riverside)
  - Applied Graph Neural Networks (GNN): `https://arxiv.org/abs/2406.12877`
  - [Nucl.Instrum.Meth.A 1047 (2023) 167866]
- Revisit later

Detector thickness in z



1. Can we extend from 45 cm in z to eg. 70 cm?
   - Limited by oculus and room for electronics
   - Increases cost - estimate?
   - Improves energy resolution - quantify?
   - Other benefits?

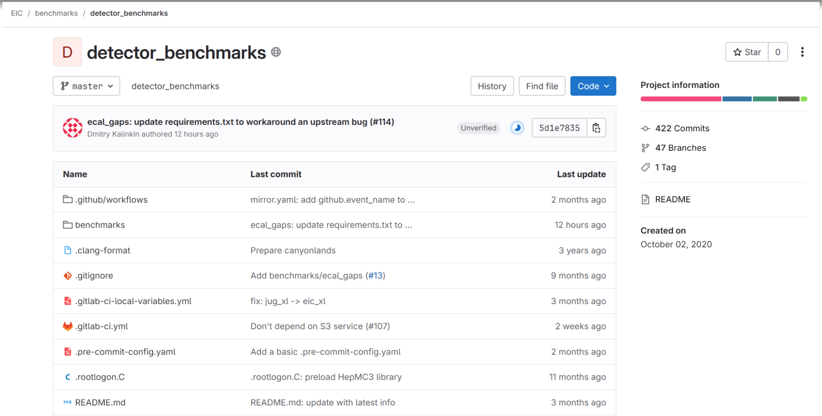
Additional charged veto and SMD layer



1. Investigate if adding extra scintillator layer as a charged veto helps isolate neutral showers
2. This extra layer needs to be thicker eg. $2\,\mathrm{cm}$ to leave enough signal
3. Can have better granularity than standard tiles

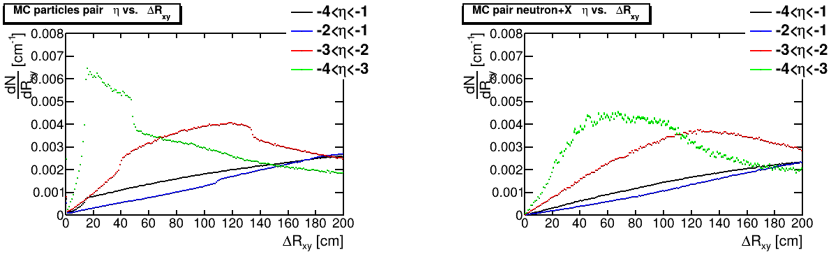
1. Revisit option of adding an SMD layer with high position resolution
2. Initially no plans to reuse STAR EEMC SMDs, because of too low light yield
   - `https://wiki.bnl.gov/athena/images/6/60/ATHENA_bnHCal_Notes_v1.pdf`
3. Similar idea to KLM
4. Another option to use smaller tiles

Benchmarks for CD/CI



- Develop benchamrks for CD/CI
- `https://eicweb.phy.anl.gov/EIC/benchmarks/detector_benchmarks`
- `https://indico.jlab.org/event/420/contributions/8307/attachments/6911/9434/20210504-Automated_workflows.pdf`
- Useful for automated checks: hit distributions, acceptance etc.
- Ideal task for bachelor and undergraduate students
- Submitted a thesis proposal at Warsaw University of Technology
    - May be piked up by a student around February-March 2025

MC particle projection distances in diffractive dijet events



- Neutron MC particle vs. charged MC particle separation
- 0.7% of charged MC particles are within 30 cm from a neutron