Backward Hadronic Calorimeter

Status and plans

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nHCal DSC meeting 15.1.2025

THE OHIO STATE UNIVERSITY

Outline

Status

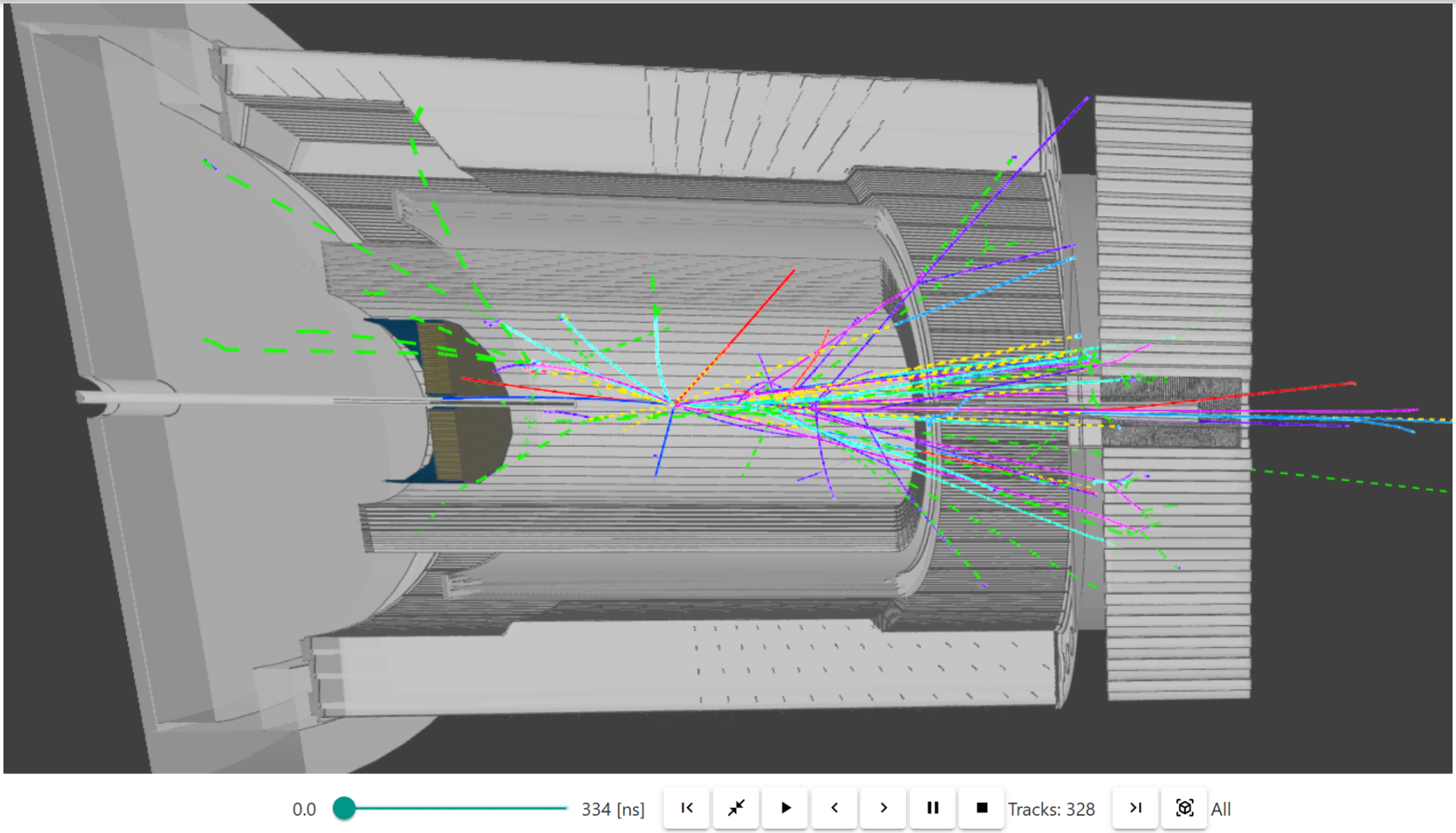
- Basic pre-TDR completed - Congratulations!
  - **Zenodo v1:** `https://doi.org/10.5281/zenodo.14328280`
  - **Review of v1:** `https://docs.google.com/spreadsheets/d/1mineH2breuoVui-uZm1ZYSraRquLjM9oOY4w2ASdvtA/edit?usp=sharing`
  - No feedback on nHCal yet
  - Please check repositories here and add your codes to reproduce the plots by the end of December
  - **Repositories located here:** `https://github.com/orgs/OSUNuclearPhysics/repositories`
  - Need to add you there to users - contact me
- **Created a links page (use it!):** `https://docs.google.com/spreadsheets/d/1m6NzPk4mfQI8YQE8cwO9sLJyKp5iH6pqttPGqYzTmZ8/edit?usp=sharing`

Plans

1. Complete ongoing studies
   - Diffractive dijets
   - Position resolution
   - Jets with neutrals
   - Vector meson reconstruction
   - Scattered electron ID
   - Tile tests
2. ePIC Collabration meeting 2025.1.20-24
   - `https://agenda.infn.it/event/43344/`
   - None from the OSU or UIUC plans to participate
   - Did CTU schedule any presentations?
   - **Interesting workfests:** `https://agenda.infn.it/event/43344/page/9444-workfest-descriptions`
     - Integration
     - Tracking Projections/Resolution at hpDIRC
     - Exclusive, Diffraction and Tagging WG
     - Jets and Heavy Flavor Workfest
3. Preliminary design review planned for summer time
4. Organize construction of prototype and beam tests
   - LFHCAL group plans to organize a readout electronics and testbeam workshop at ORNL sometime in spring
   - We should participate
5. Start working on the remaining topics
6. Check alternative KLM-type design

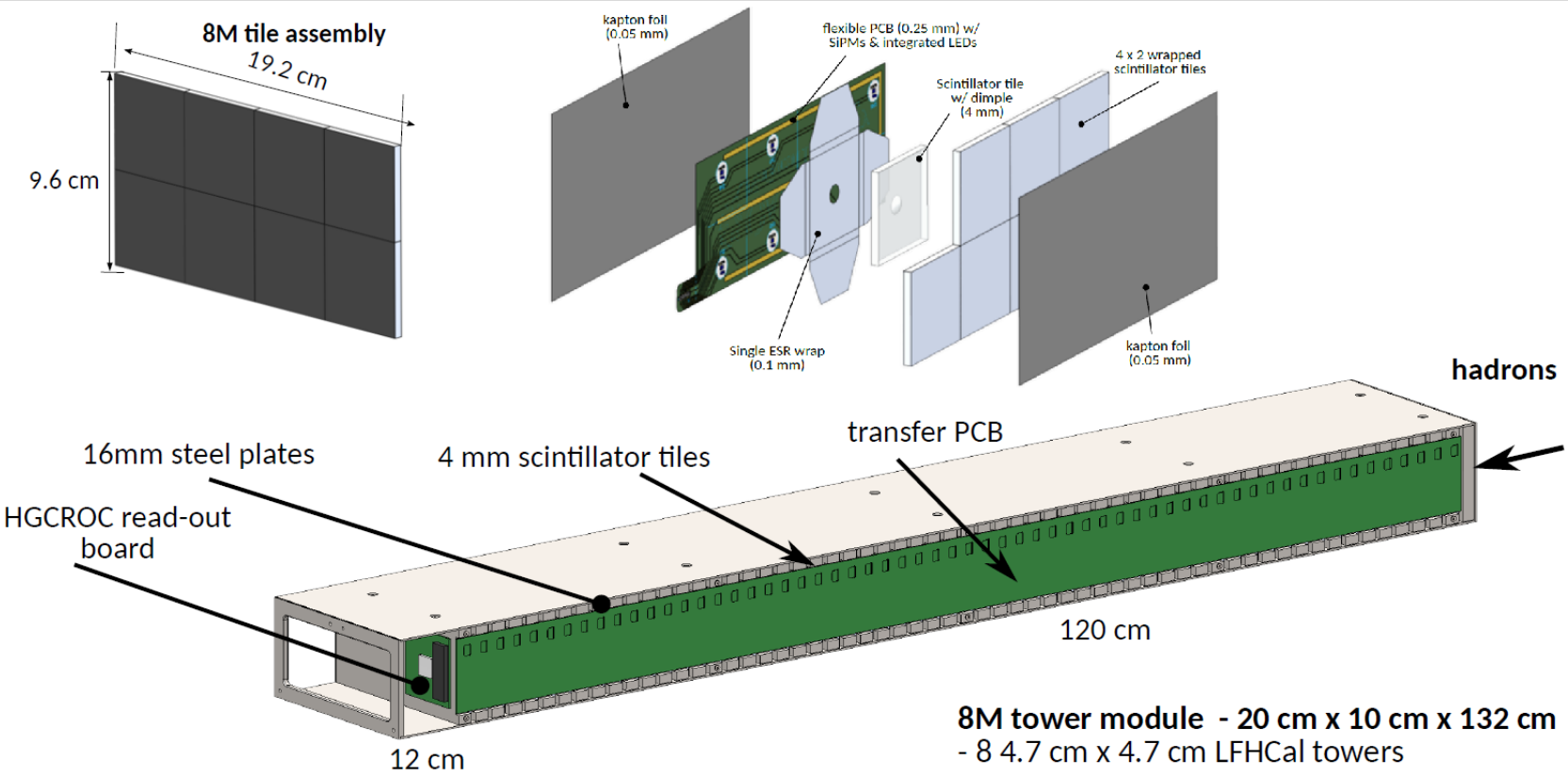
- Preliminary design review planned for summer time

Firebird event display



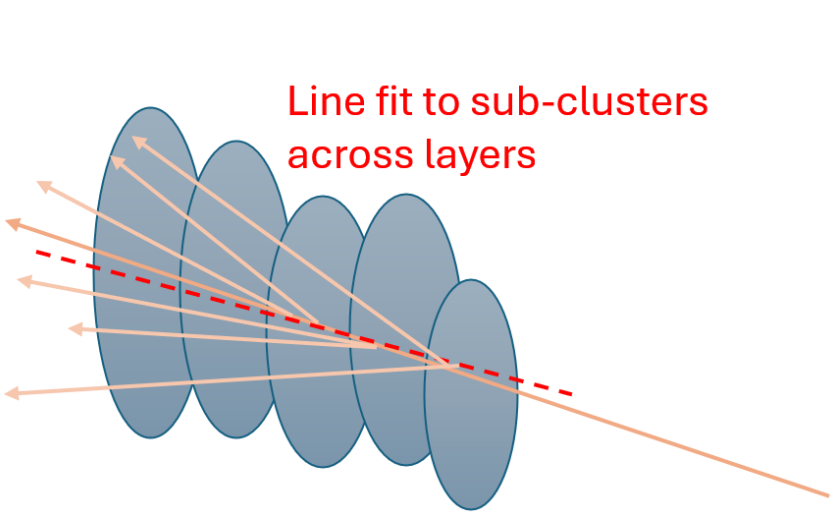
- Web-based: `https://eic.github.io/firebird/display`
- Seems to be able to visualize MCparticle trajectories
- Uses *EDM4EIC* files
- Allows cool animations
- Good for visually investigating simulated events

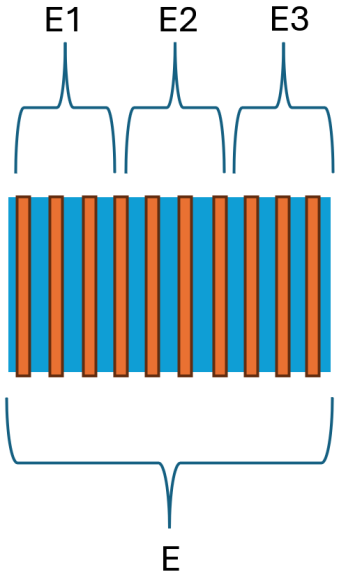
Prototype construction



- 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.
  - The absorber plates have different thickness and are fixed, so we have to fill the gaps with steel.
  - Modules produced with electron beam welding in a vacuum.
- Produce our own module? Most likely.

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?

Shower reconstruction with machine learning

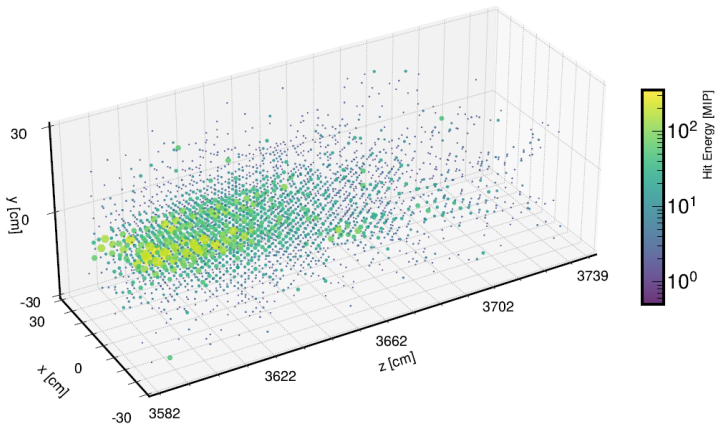
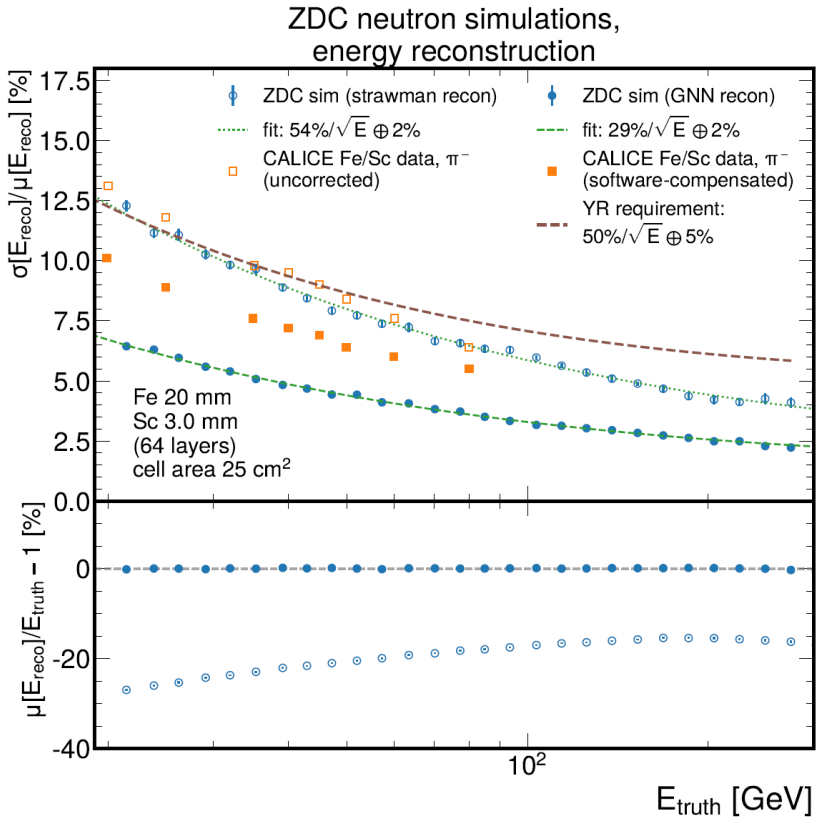
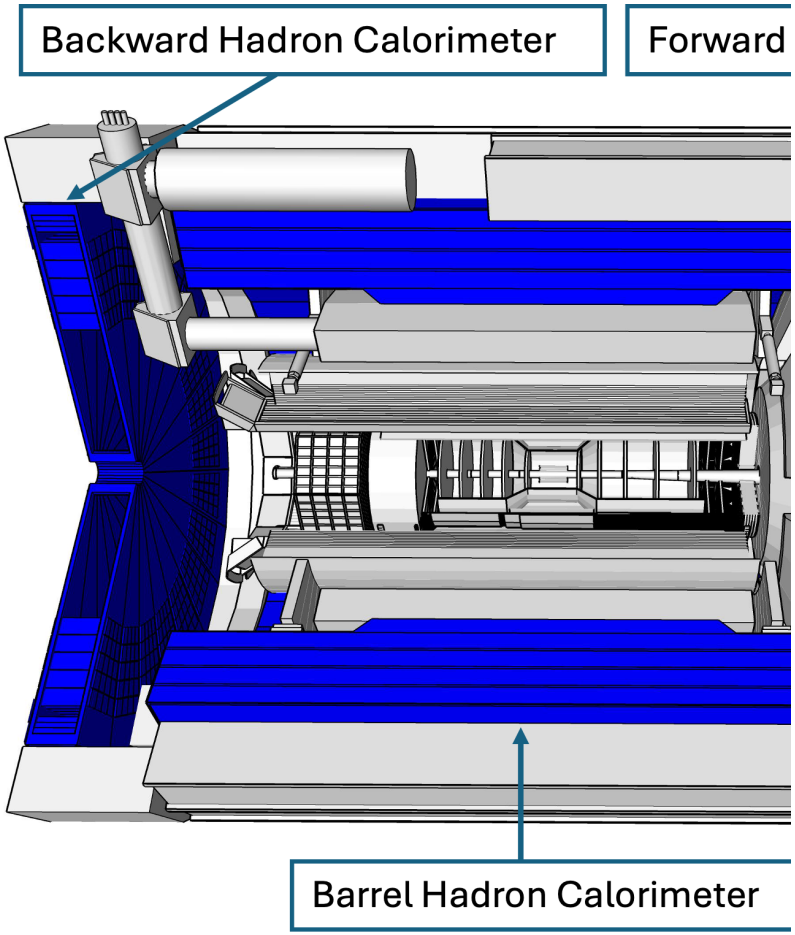


Figure 7: Examples of 4 reconstructed 3D shower shapes in the ZDC for events with 1 neutron ($N_n = 1$), 2 neutrons ($N_n = 2$), 4 neutrons ($N_n = 4$), and 9 neutrons ($N_n = 9$). The color code represents hit energy in terms of E_{MIP}. The marker size is displayed proportionally to hit energy for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



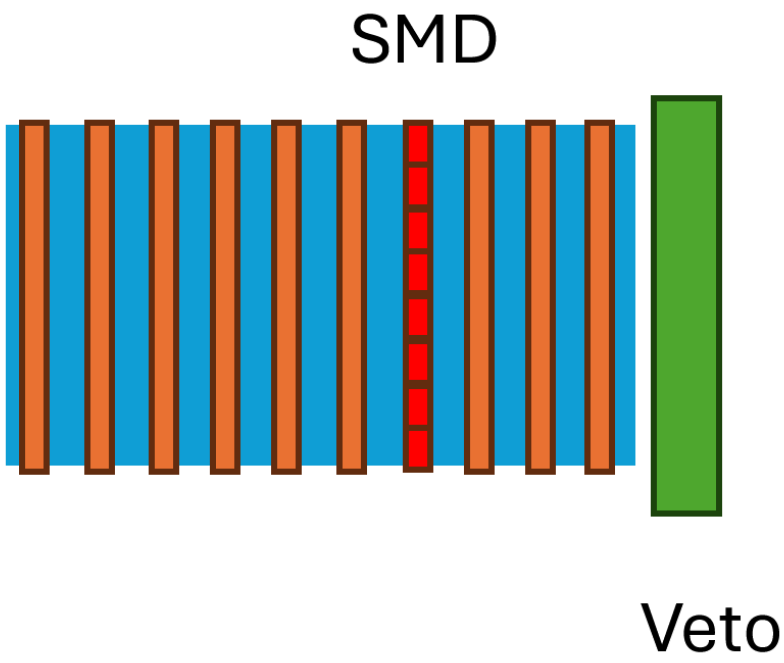
- Potential to use machine learning to improve shower reconstruction
- Studies done by LFHCAL Insert/ZDC group (UC Riverside)
  - Applied Graph Neural Networks (GNN): `https://arxiv.org/abs/2406.12877`
  - [Nucl.Instrum.Meth.A 1047 (2023) 167866]
- Revisit later

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?

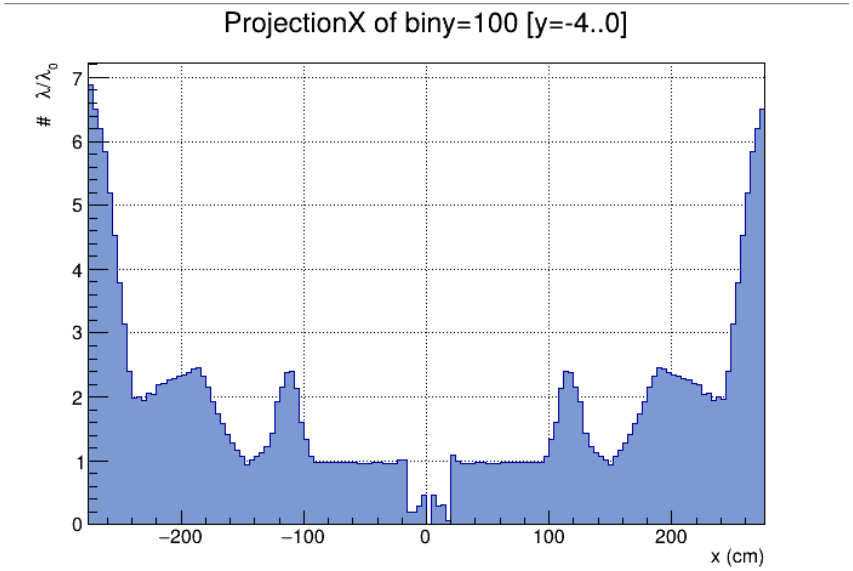
Additional charged veto and SMD layer

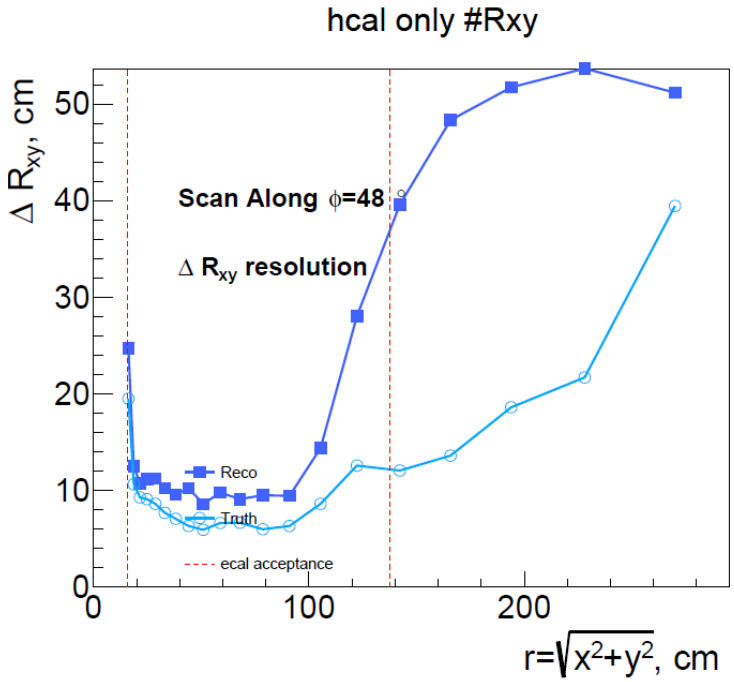


1. Investigate if adding extra scintillator layer as a charged veto helps isolate neutral showers
2. This extra layer needs to be thicker eg. $2\,\mathrm{cm}$ to leave enough signal
3. Can have better granularity than standard tiles

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

High material impact on shower reco

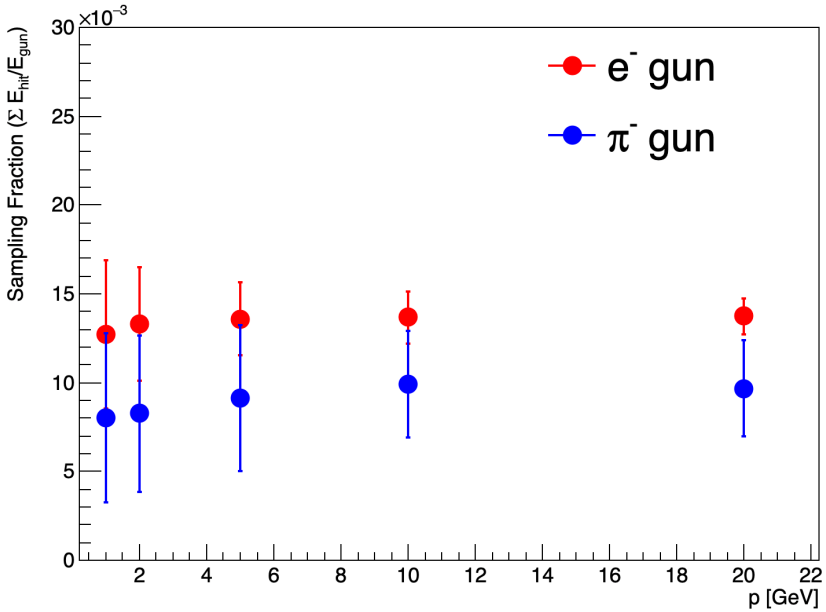




full epic

- 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
- If needed revisit position resolution study with full geometry

Improve sampling fraction calculation

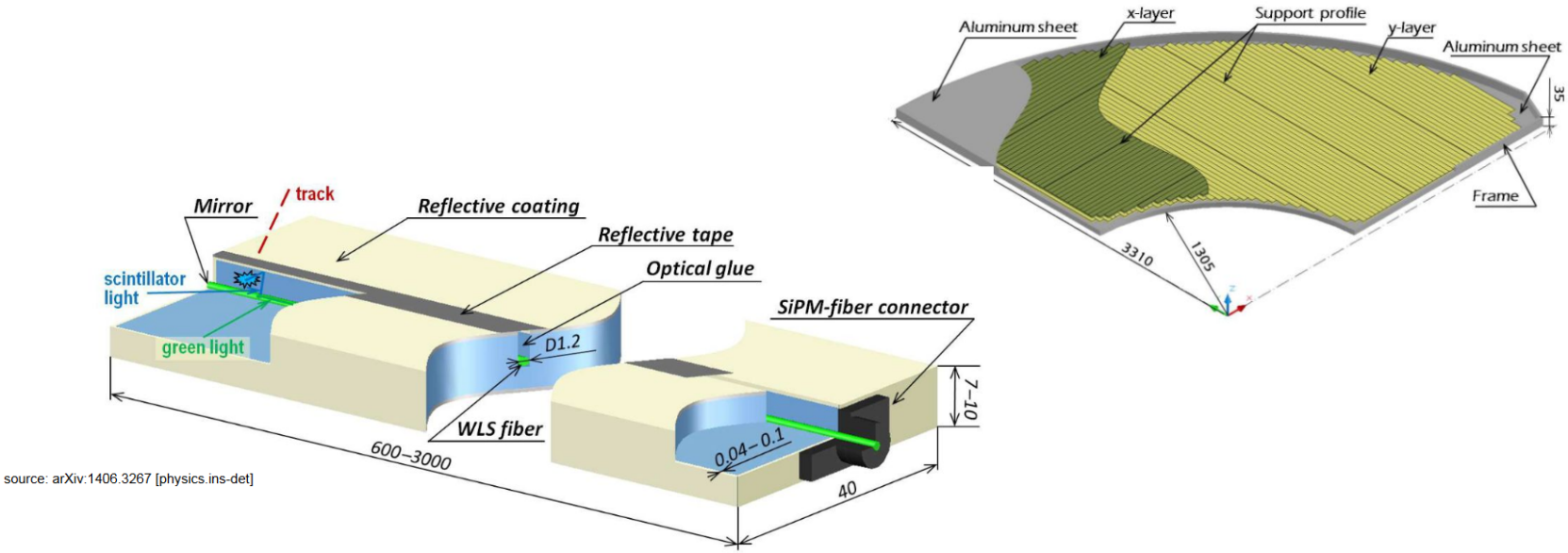


Particle	Momentum (GeV/c)	Sampling Fraction (%)	Uncertainty (%)
Electron	1.0	1.28	± 0.42
Electron	2.0	1.33	± 0.31
Electron	5.0	1.36	± 0.21
Electron	10.0	1.37	± 0.15
Electron	20.0	1.37	± 0.10
Pion	1.0	0.79	± 0.46
Pion	2.0	0.83	± 0.44
Pion	5.0	0.91	± 0.40
Pion	10.0	0.98	± 0.31
Pion	20.0	0.96	± 0.27
Neutron	1.0	N/A	N/A
Neutron	2.0	0.40	± 0.32
Neutron	5.0	0.67	± 0.30
Neutron	10.0	0.79	± 0.30
Neutron	20.0	0.84	± 0.39

Table 1: Sampling Fraction of nHCal for Different Particle Species

- IMPORTANT: Need to change absorber from *StainlessSteel* to *Steel* in simulation first
- Revise sampling fraction calculation using actual energy deposits in absorber and scintillators
- Looks like sampling fraction may decrease at lower energy
- Larger differences expected for pions and neutrons at lower energy
- Try to optimize it towards measurements of $\approx 1\,\mathrm{GeV}$ neutrons
- Add uncertainty on sampling fraction to eicrecon

Belle II KLM (K_L and muon detector)



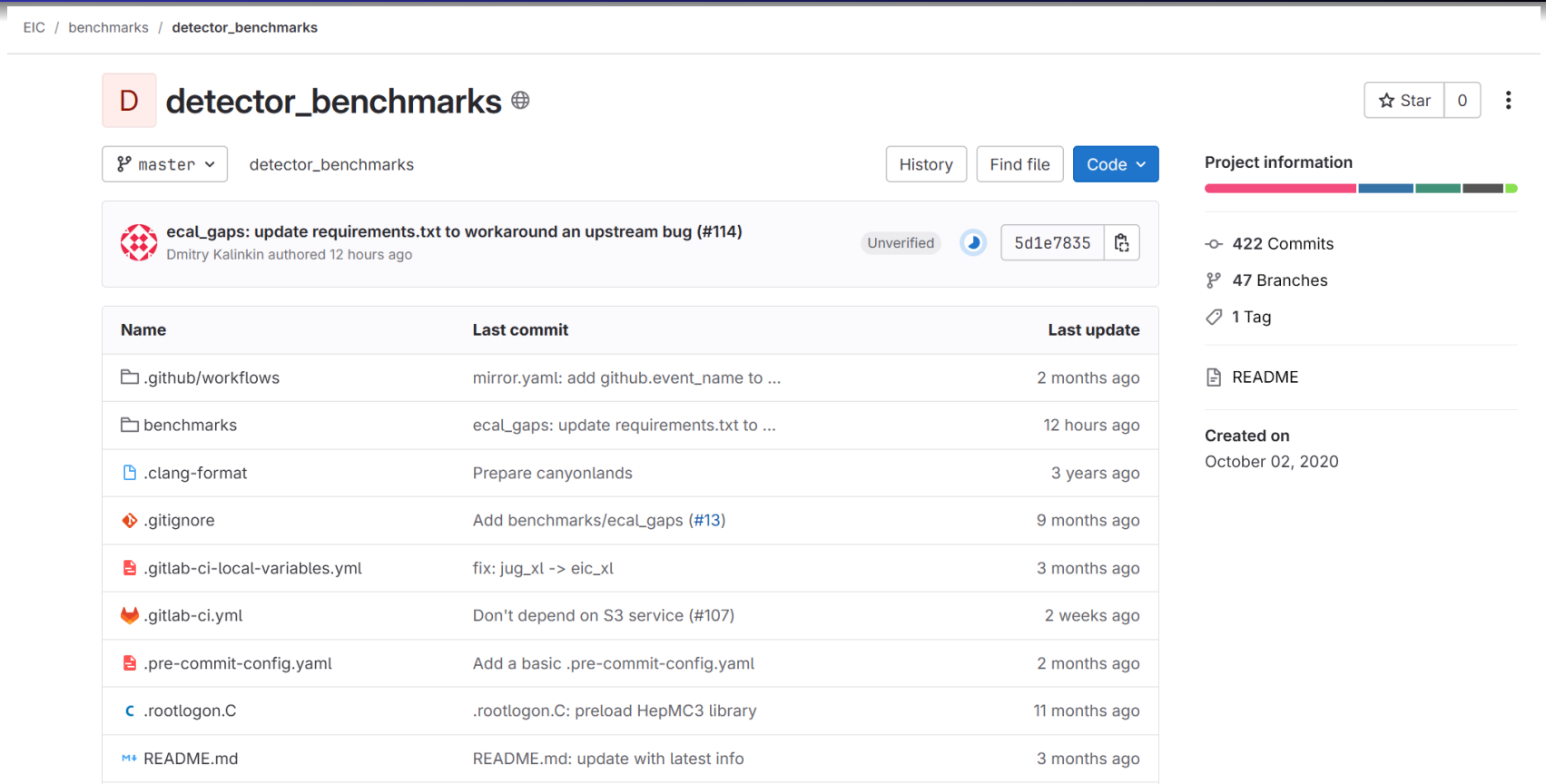
Schematic structure of the Belle II KLM scintillator setup

- Proposal of KLM-type detector for EIC Detector 2
- Advantages: cheaper, better position resolution
- Potential problems (to solve):
  - Long scintillator planks - signal attenuation in WLS may be a problem
  - Non-trivial clustering
- Links:
  - `https://indico.cern.ch/event/1238718/contributions/5485996/attachments/2693846/4675083/2nd%20Detector%20KLM%20Warszawa%202023.pdf`
  - `https://www.jlab.org/sites/default/files/eic_rd_prgm/files/2023_Proposals/EIC_KLM_R_D_Proposal_2023_EICGENRandD2023_18.pdf`

Light propagation simulation

- Perform light propagation simulation to check the tile design
- Use it to optimize SiPM mounting
- Use Tracepro or modified Geant4 from Jarda Adam
- `https://github.com/adamjaro/lmon/tree/master`

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

Publications

We need to start thinking about publications related to the nHCal development

- Model/Event generator based motivation and feasibility studies
  - eg.: Vector-meson reconstruction in the ePIC backward HCal `https://zenodo.org/records/14200156`
- Performance studies with simulations
- Performance studies with test beams
- Any other ideas? Journals?

Conclusions

- Presented status
- Discussed plans for the future
- Organized a list of tasks (to be updated)
  `https://docs.google.com/spreadsheets/d/1gsxpRqD6HY7lanvNzVA4v9_lZ6GizXsYzkj8fA7Kfhw/edit?usp=sharing`

BACKUP