#### **ATEHNA EIC Inclusive Group Meeting**



#### **Barrel ECal Calorimetry Performance Studies**



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## ScFi + Imaging Calorimeter



- Imaging layer: 0.155 cm + 1 cm of air = **1.155 cm**
- Imaging layers separated with 13\*1.22 mm = 1.586 cm wide layers of ScFi (13 layers of fibers)

| [cm]                              | 9 Img layers | 6 Img layers |
|-----------------------------------|--------------|--------------|
| thickness of SiFi with Img lavers | 13.09        | 8.18         |
| thickness of SiFi w/o Img layers  | 19.63        | 24.54        |
| total SiFi                        | 32.72        | 32.72        |
| thickness of Img layers           | 9.40         | 5.93         |
| total thickness                   | 42.12        | 38.65        |

Currently in simulation:

- ECal Barrel r min = 103 cm
- Solenoid r min = 160 cm
- 57 cm for ECal + support (5 cm)





#### **Pion Background in Inclusive DIS**

https://indico.bnl.gov/event/8231/contributions/37820/attachments/28257/43445/EIC EMCal Pavia 21may20 v2.pdf





## **Pion Suppression Plot in YR**

 $\pi\pm$  rejection 10<sup>4</sup> PbWO<sub>4</sub> simulation  $10^{3}$ PbWO<sub>4</sub> W/ScFi simul [1519] 10<sup>2</sup> E 1523] Pb/Sc [1522] 10눝 10 p (GeV/c)

Simulation and Data

Standalone Ecal

E/p cut only

95% electron efficiency





- 50k electrons and 50k pions for each momentum point, 80% used for training, 20% for validating.
  - 100k events for benchmarking
- Apply E/p cut first to "clean up" samples
- Combine imaging layer hits and ScFi layer hits
  - 20 hits per layer, sorted by energy deposit, zero padding
  - 5 features per hit (layer\_type [0, 1], Edep, Rc, eta, phi)
- Adjust e:pi weighting in cost function to balance efficiency and rejection power





#### **Event Sample**

#### Electron Shower Sample



#### Pion Shower Sample







- Simple model
  - Sequential CNN + MLP
- 20 epochs of training
- e-pi classification
  - label with the highest probability is picked
- Final results may be improved
  - More epochs
  - More layers

Model: "sequential\_75"

Non-trainable params: 0

| Layer (type)                                       | Output Shape       | Param # |
|--|--------------------|---------|
|  |                    |         |
| conv2d_225 (Conv2D)                                | (None, 29, 20, 48) | 1008    |
| max_pooling2d_225 (MaxPoolin                       | (None, 14, 10, 48) | 0       |
| dropout_225 (Dropout)                              | (None, 14, 10, 48) | 0       |
| conv2d_226 (Conv2D)                                | (None, 14, 10, 96) | 41568   |
| <pre>max_pooling2d_226 (MaxPoolin</pre>            | (None, 7, 5, 96)   | 0       |
| dropout_226 (Dropout)                              | (None, 7, 5, 96)   | 0       |
| conv2d_227 (Conv2D)                                | (None, 7, 5, 48)   | 41520   |
| max_pooling2d_227 (MaxPoolin                       | (None, 3, 2, 48)   | 0       |
| flatten_75 (Flatten)                               | (None, 288)        | 0       |
| dense_225 (Dense)                                  | (None, 128)        | 36992   |
| dropout_227 (Dropout)                              | (None, 128)        | 0       |
| dense_226 (Dense)                                  | (None, 32)         | 4128    |
| dense_227 (Dense)                                  | (None, 2)          | 66      |
| Total params: 125,282<br>Trainable params: 125,282 |                    |         |



Ideal case to compare with YR plot

**no materials** in front of barrel Ecal, **no magnetic field** eta scan from -1 to 1

|         | Edep/p cut (9 + 9 layers) |        | ML        |                     | Combined |           |        |           |
|---------|---------------------------|--------|-----------|---------------------|----------|-----------|--------|-----------|
| p (GeV) | Cut                       | e Eff. | pion Rej. | e:pion<br>Weighting | e Eff.   | pion Rej. | e Eff. | pion Rej. |
| 0.1     | > 0.05                    | 99.94% | 1.05      | 1:10                | 95.55%   | 489.85    | 95.49% | 514       |
| 0.2     | > 0.06                    | 99.87% | 1.04      | 1:20                | 95.36%   | 590.72    | 95.24% | 614       |
| 0.5     | > 0.085                   | 98.48% | 3.45      | 1:30                | 96.47%   | 479.63    | 95.00% | 1655      |
| 1       | > 0.085                   | 98.67% | 4.72      | 1:80                | 97.18%   | 505.95    | 95.89% | 2388      |
| 2       | > 0.085                   | 98.08% | 6.72      | 1:100               | 98.42%   | 746.00    | 96.53% | 5013      |
| 5       | > 0.08                    | 98.17% | 8.27      | 1:40                | 96.77%   | 678.86    | 95.01% | 5613      |
| 10      | > 0.0925                  | 97.70% | 23.33     | 1:100               | 97.78%   | 305.86    | 95.53% | 7134      |









#### E/p Cut with Current Simulation

Hadron response is being studied, results on E/p cut will change (likely improve) Simple E/p cut for the accumulative Edep over 9+9 layers (sandwich layers)

**1 GeV/c particles** 









electrons

0.030

pions

0.025

#### 0.1 GeV/c







#### 0.2 GeV/c







#### 0.5 GeV/c





#### 1.0 GeV/c







#### 2.0 GeV/c







#### 5.0 GeV/c







# Numbers of Imaging Layers

Disable signals of latter layers (they are still in simulation)

E/p cut is the same, weighting was adjusted to maintain > 95%

Both eff. and rej. are worse with less number of layers

| p (GeV) | Pion Rejection Power (e Eff. >= 95%) |                   |                   |  |  |
|---------|--------------------------------------|-------------------|-------------------|--|--|
|         | 2 AstroPix layers                    | 6 AstroPix Layers | 9 AstroPix Layers |  |  |
| 0.1     | 147                                  | 344               | 514               |  |  |
| 0.2     | 113                                  | 366               | 614               |  |  |
| 0.5     | 410                                  | 699               | 1655              |  |  |
| 1       | 983                                  | 1393              | 2388              |  |  |
| 2       | 1567                                 | 3135              | 5013              |  |  |
| 5       | 2098                                 | 4578              | 5613              |  |  |



#### **Numbers of Imaging Layers**







## Summary

- ML with imaging layers in Barrel region significantly improves pion rejection
  - Additional rejection based upon traditional methods like E/p
- Realistic simulation is ongoing
- Inputs from inclusive group is important for detector optimization
  - Balance of cost/performance
  - Satisfy the physics requirement
- Possible future improvements
  - 2D cuts on dE/dx
  - Multi-views classification (More complicated NN structure)





#### Backup





#### Cut of Energy deposit from ScFi layers

All particles generated for **eta = 0, no MF,** energies: 0.1, 0.2, 0.5, 1, 2, 5, 10 GeV Plots for all scanned energies in the backup slides







Plots: deposited energy summed up to the particular layer

Example for 2 GeV

Plots for all scanned energies in the backup slides

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0.3 Energy Dep











Left: **Pion suppression** vs the layer that the deposited energy is summed up to Right: **Electron efficiency** for the cut on the deposited energy up to the particular layer



For 2 GeV electrons/pions, cut on energy summed up to 6th or 7th layer.

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Please ignore point (0,0)

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# Energy resolution photons

5%/√E + 0.36%





# Spatial resolution

generated with eta=0, phi=(0,360) deg





#### electron/pion energy loss in all ScFi layers



27



Plots: deposited energy **summed up to** the particular layer

Example for 0.1 GeV













































#### electron/pion PID - cut investigation



Electron efficiency



Example for 0.1 GeV



Plots: deposited energy summed up to the particular layer

Example for 0.2 GeV



Sum of energy deposit up to layer 5

Sum of energy deposit up to layer 9

Sum of energy deposit up to layer 13

Sum of energy deposit up to layer 17



Mean 0.01585 5td Dev 0.003345

5000

Mean 0.01787

Std Dev 0.003121

Entries 5000 Mean 0.01817

Std Dev 0.00311

Sum of energy deposit up to layer 2



Mean 0.008825 Std Dev 0.003397









Minchando#jayer\_jakottor Entries 5000

Mean 0.01732 Std Dev 0.00315

5000 Entries 5000 Mean 0.01808 Std Dev 0.003111

Entries 5000 Mean 0.01821 Std Dev 0.003115

Entries 5000 Mean 0.01824 Std Dev 0.003119

Sum of energy deposit up to layer 7

Sum of energy deposit up to layer 11

Sum of energy deposit up to layer 15

Sum of energy deposit up to layer 19

















#### electron/pion PID - cut investigation





Example for 0.2 GeV





Plots: deposited energy summed up to the particular layer

Example for 0.5 GeV





Std Dev 0.006562

5000

5000 0.04762

Entries 5000 Mean 0.04762 Std Dev 0.005349

Mean 0.04643



Mean 0.01632

Std Dev 0.00624









Mean 0.04427 Std Dev 0.005743

Entries 5000 Mean 0.04787 Std Dev 0.005328

Sum of energy deposit up to layer 7















Sum of energy deposit up to layer 9

Sum of energy deposit up to layer 13







Sum of energy deposit up to layer 19

#### electron/pion PID - cut investigation



Electron efficiency



Example for 0.5 GeV



Plots: deposited energy summed up to the particular layer

Example for 1 GeV



0.14 0.16 0.18

0.08 0.12













Sum of energy deposit up to layer 7

Sum of energy deposit up to layer 11

Sum of energy deposit up to layer 15

Sum of energy deposit up to layer 19

Entries 1000

Mean 0.08762 Std Dev 0.009292

Entries 10000 Mean 0.09567 Std Dev 0.007835

Entries 10000 Mean 0.09707 Std Dev 0.007744

Montantial Juy 1, rivers Entries 10000 Mean 0.09733 Std Dev 0.007754

0.12 0.14 0.16 0.18 0

0.1 0.12 0.14 0.16 0.18 0.

10000















Sum of energy deposit up to layer 13



#### electron/pion PID - cut investigation



Electron efficiency



Example for 1 GeV



Plots: deposited energy summed up to the particular layer

Example for 5GeV



Sum of energy deposit up to layer 9

Sum of energy deposit up to layer 13

Sum of energy deposit up to layer 17



Sandoff Japan Burkett 5000

5000 0.4893

Entries 5000 Mean 0.4893 Std Dev 0.01836

Entries 5000 Mean 0.495 Std Dev 0.01771

0.8

Entries

Mean 0.4593

Std Dev 0.02637



Sum of energy deposit up to layer 2

clundel layer 2 electron

Mean 0.06127

Std Dev 0.03207

Machandra Jayor A sheet

Mean 0.3637 Std Dev 0.04719

Entries 5000

5000







Sum of energy deposit up to layer 7

















texturdof()ayer/)\_state

Mean 0.409 Std Dev 0.03918





#### electron/pion PID - cut investigation



Example for 5 GeV



Plots: deposited energy summed up to the particular layer

Example for 10 GeV





Entries 10000

Mean 0.2143 Std Dev 0.0833

htechundofijkyer,)\_elector Entries 10000

Mean 0.7779 Std Dev 0.08532

Entries 10000 Mean 0.9531 Std Dev 0.03838

Entries 10000 Mean 0.9874 Std Dev 0.02758

Entries 10000 Mean 0.994 Std Dev 0.02564

10000











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#### electron/pion PID - cut investigation



#### Electron efficiency



Example for 10 GeV



