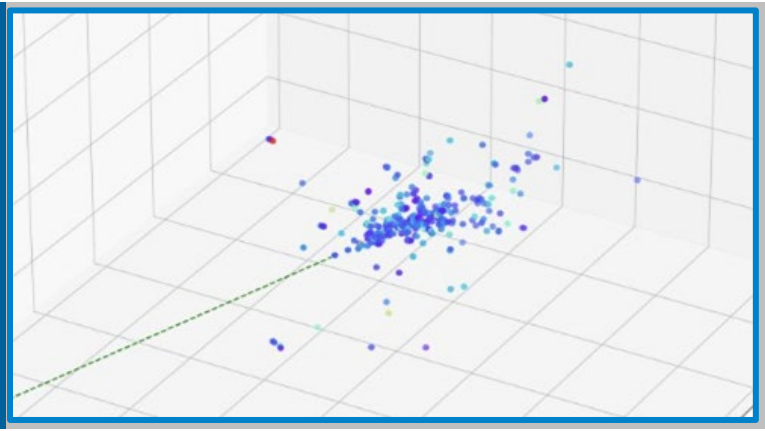
Pion Rejection Study with Imaging Calorimeter for EPIC



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Argonne National Laboratory

EPIC Calorimetry Weekly Meeting, 11/16/2021

Simulation for e/pi Separation

EPIC Brycecanyon configuration (with cladding to fibers that lower sampling fraction to 9.3%)

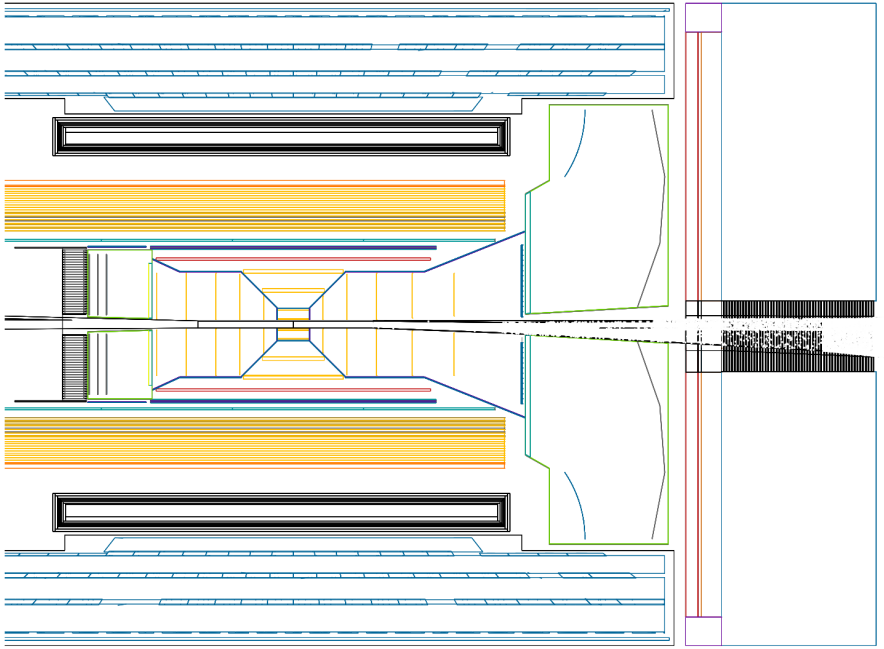
Single particles of e^- and π^-

Momenta around 1 GeV/c and 2 GeV/c

Polar angle from 75 to 105 degree

Two-step e/pi separation

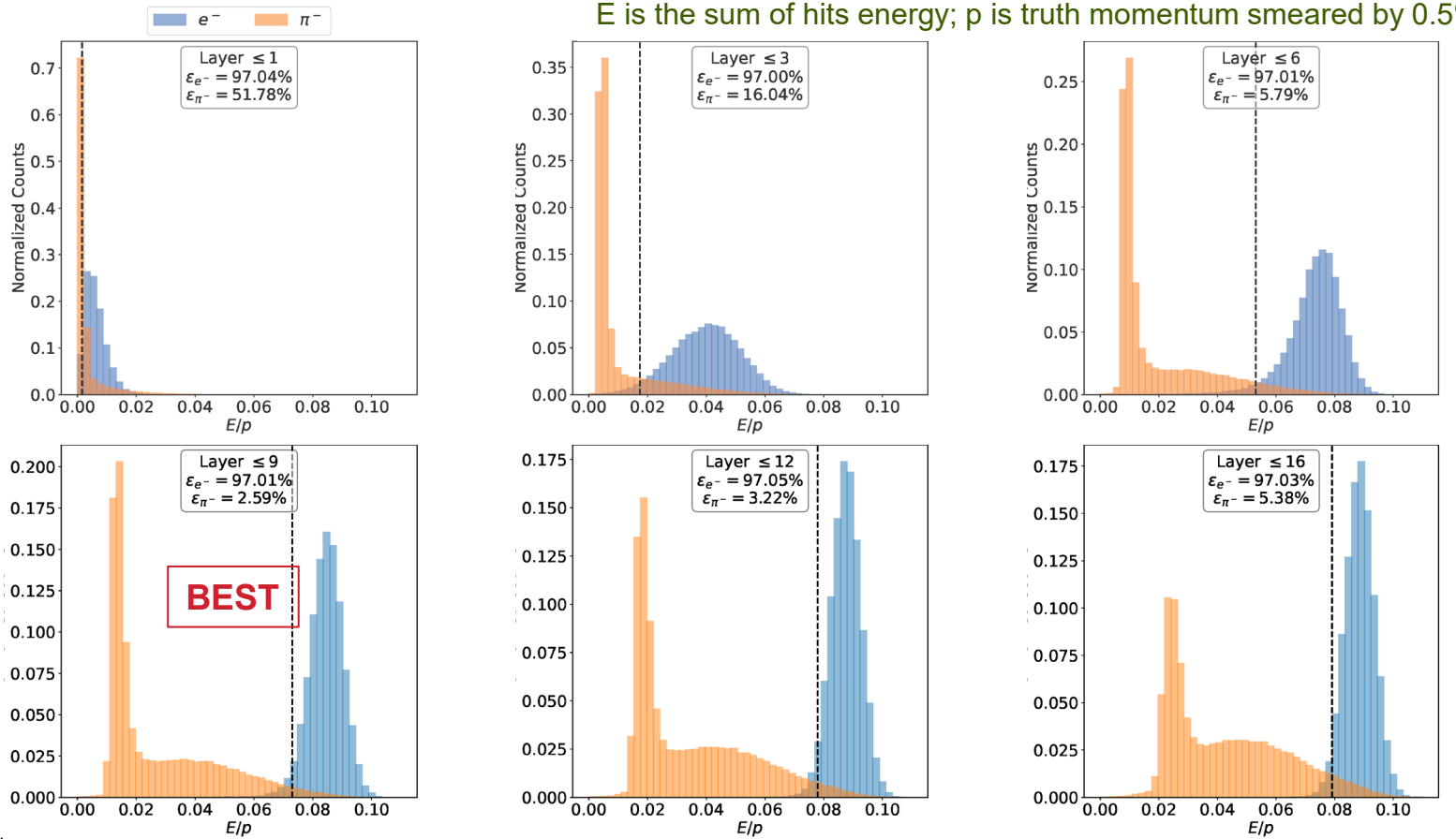
- E/p cut
- ML classification



Benchmark code available at:
https://eicweb.phy.anl.gov/EIC/benchmarks/reconstruction_benchmarks/-/tree/master/benchmarks/imaging_shower_ML

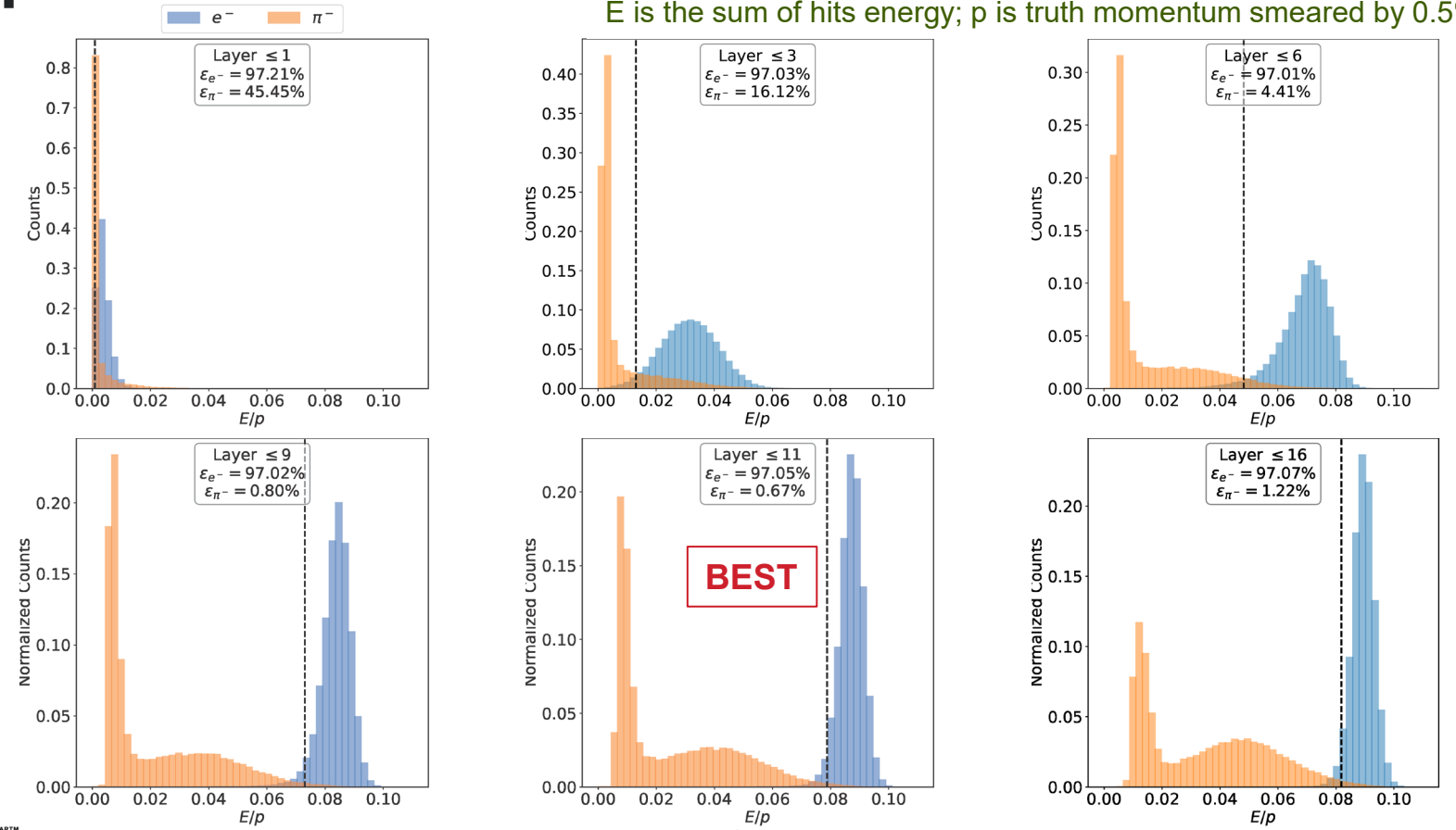
E/p Distributions

Particles with p = **0.8 – 1.2** GeV/c, E/p cut at $\varepsilon_e \geq 0.97$
E is the sum of hits energy; p is truth momentum smeared by 0.5%



E/p Distributions

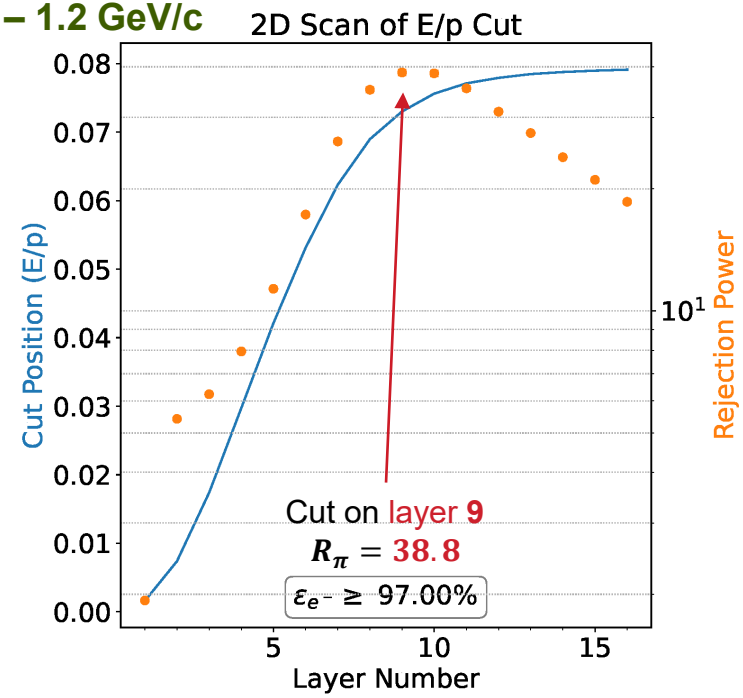
Particles with p = **1.5 – 2.5** GeV/c, E/p cut at $\varepsilon_e \geq 0.97$
E is the sum of hits energy; p is truth momentum smeared by 0.5%



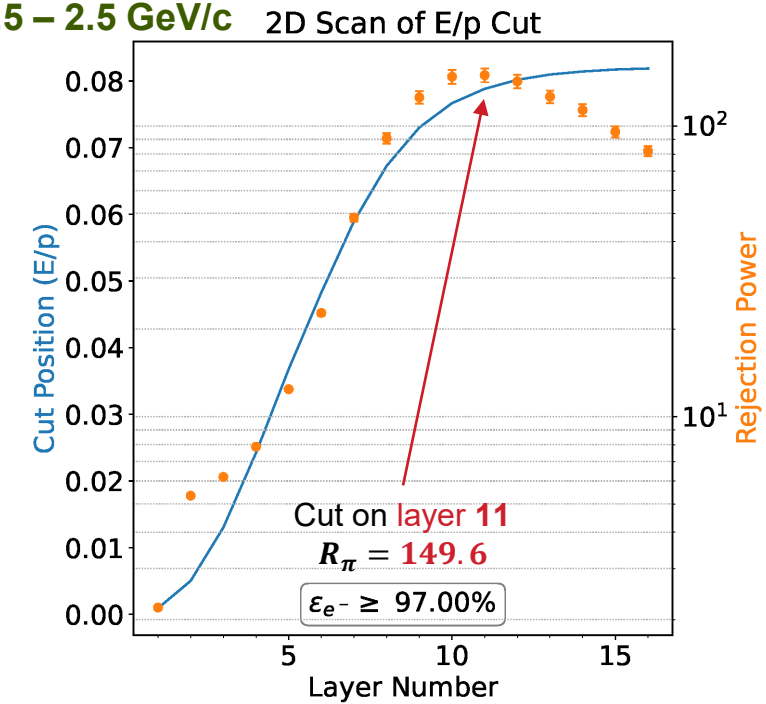
2D E/p Cut

- Scan of the best cut over E/p and layer

0.8 – 1.2 GeV/c



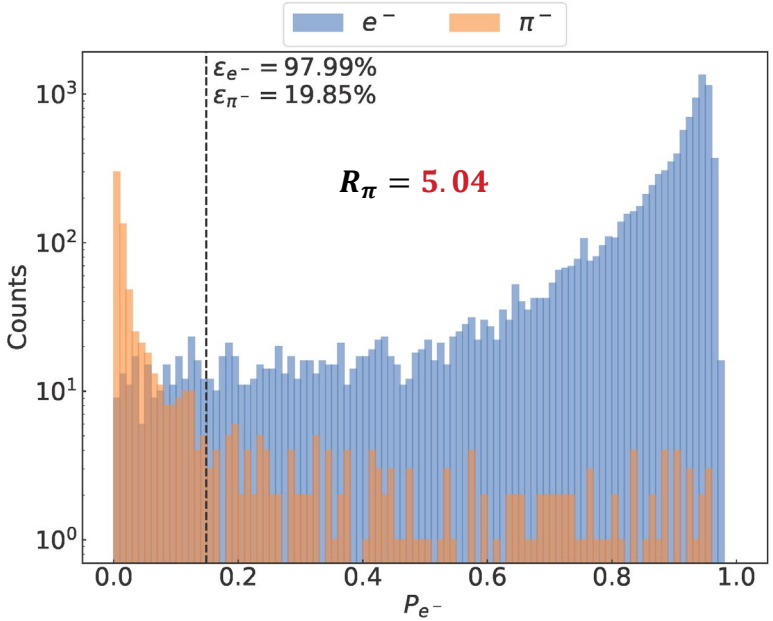
1.5 – 2.5 GeV/c



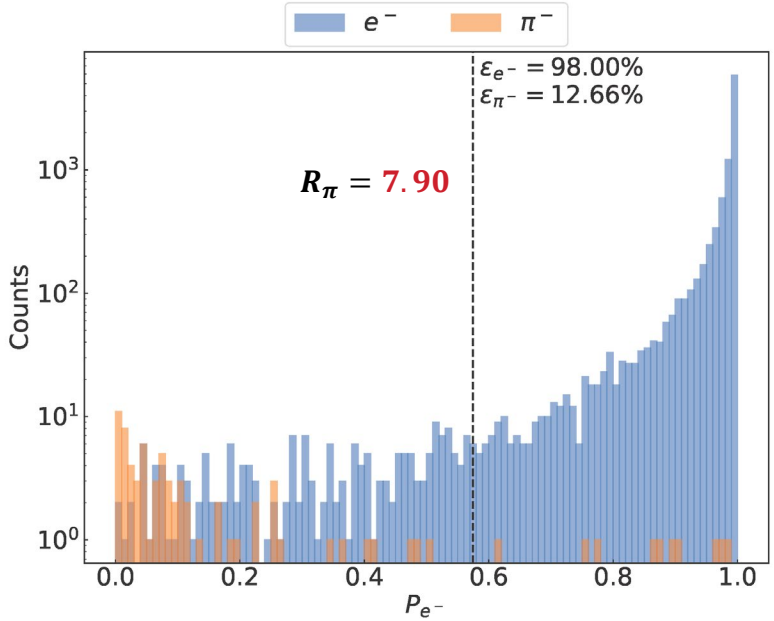
ML Classification

- ML model trained with samples after the best E/p cut

0.8 – 1.2 GeV/c



1.5 – 2.5 GeV/c



Two-step Separation

EPIC Results (materials & fields in Brycecanyon + cladding + eff. > 95%)

P (GeV/c)	E/p Cut		ML Classification		Combined	
	efficiency	rejection	efficiency	rejection	efficiency	rejection
0.8-1.2	97.01%	38.75	97.99%	5.04	**95.06%**	**195.28**
1.5-2.5	97.05%	149.59	98.00%	7.90	**95.11%**	**1181.78**

A factor of **2-3** improvement from ATHENA for **eff. > 95%**

Previous ATHENA Results (materials & fields + eff. > 95%)

6 layers (maintaining 95%+ eff.)

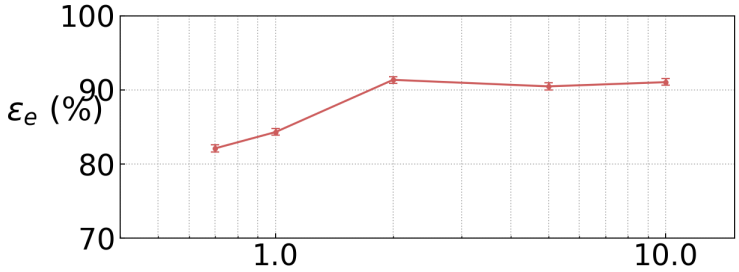
p (GeV)	Edep/p cut			ML			Combined	
	Cut	e Eff.	pion Rej.	e:pion Weighting	e Eff.	pion Rej.	e Eff.	pion Rej.
0.7	> 0.04 @ $7X_0$	97.53%	1.98	1:2	97.53%	28.50	**95.12%**	**56**
1	> 0.065 @ $7X_0$	96.40%	12.75	1:2	98.57%	7.28	**95.02%**	**93**
2	> 0.085 @ $12X_0$	95.50%	68.86	1:2	99.57%	5.89	**95.09%**	**405**
5	> 0.090 @ $12X_0$	95.25%	137.49	1:1	99.73%	3.22	**95.00%**	**443**
10	> 0.091 @ $12X_0$	95.11%	168.87	1:1	99.94%	2.48	**95.05%**	**419**

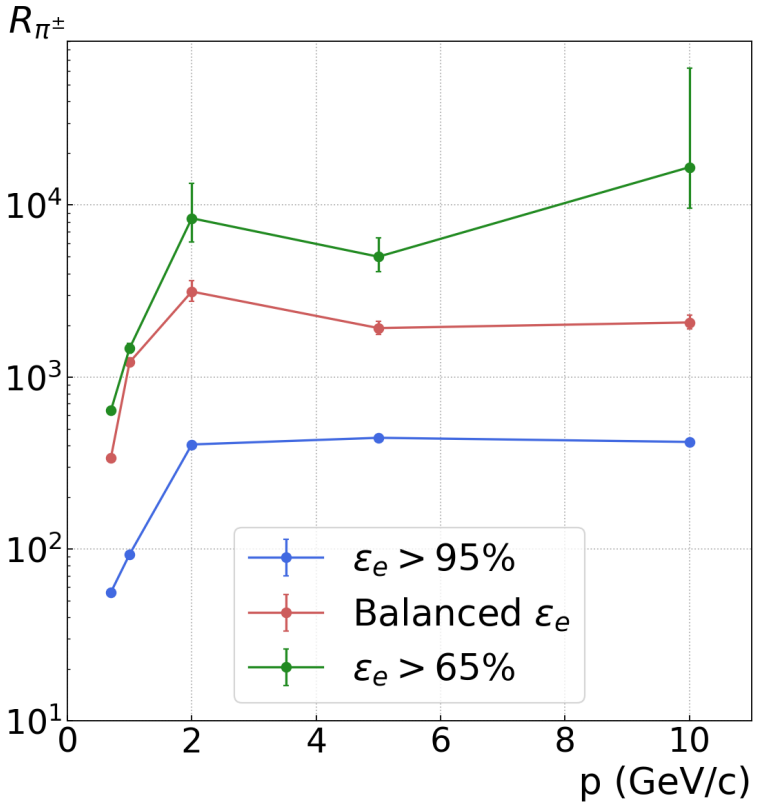
Trade-off for Rejection Power

Previous ATHENA Results

Trade efficiency for rejection power

- Achieved R > 1000 at P > 1 GeV/c with **84% - 92%** efficiency
- Similar study for EPIC is ongoing





Summary

Two-steps discrimination of e/π is studied for imaging calorimeter at EPIC Brycecanyon configuration

- Added cladding to fibers (lower sampling fraction from about 12% to 9.3%)

Results for eff. > 95% is better than what we observed before for ATHENA

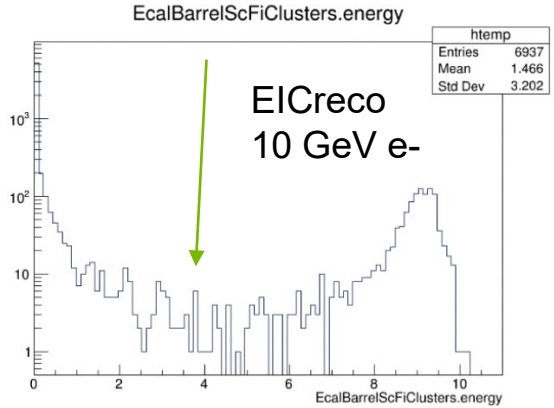
- Probably due to less materials and weaker fields (easier to achieve higher efficiency)

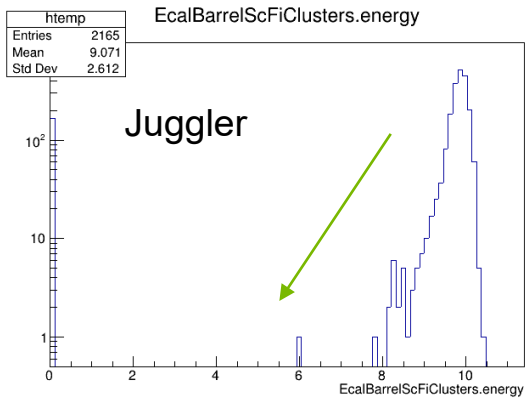
More studies are ongoing

- Trade-off of efficiency for rejection power
- More momentum points
- Benchmark with simulation campaign data (no cladding)

Imaging calorimetry reconstruction - EICreco production

- **Issue with wrong reconstructed** hit energy from AstroPix layers **solved (yay!)**
  - Problem: the dynamic range units were not passed to the reco algorithm (assumed GeV, should have been MeV)
- **Issue with topological clusters** form imaging layers
  - Issue is being worked on, clusters are reconstructed, but found that the min cluster energy was not adjusted (this has to be corrected): https://github.com/eic/EICrecon/issues/351
- **Open issue: Example SciFi Cluster energy plots from EICreco show much more low-energy outliers:**





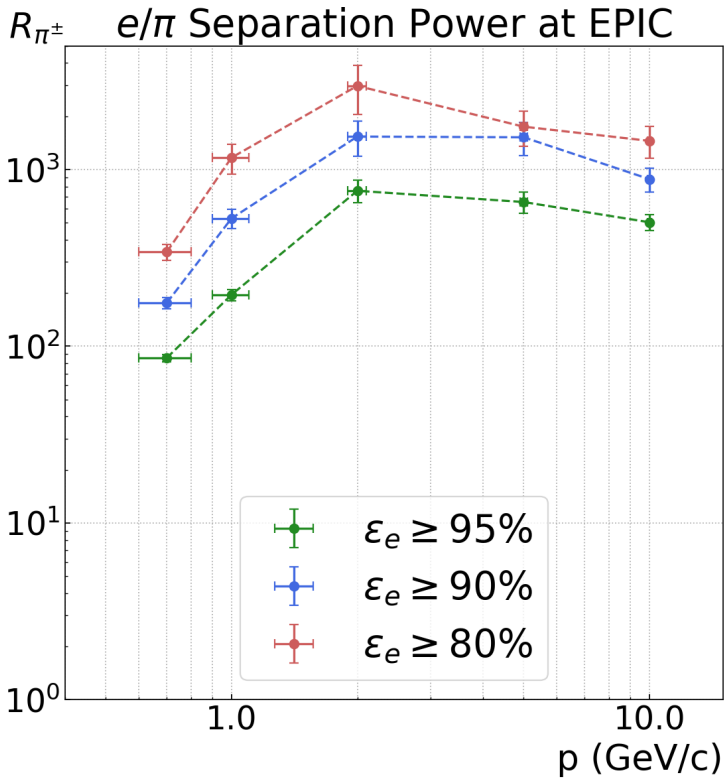
Cluster thresholds quite low (for both reconstructions):

minClusterHitEdep: 1.0*MeV
minClusterCenterEdep: 10.0*MeV

Update on 2022/12/08

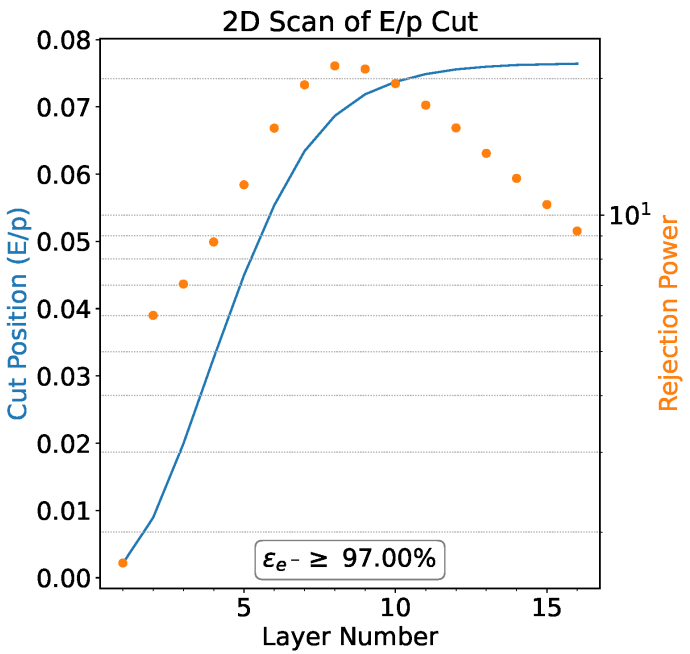
e/pi Separation Power Curve

- Two-steps separation
  - Assumed 0.5% momentum res.
  - Efficiency from E/p cut: **97%**
  - Efficiency from ML: **98%**, **93%**, **82.5%**
- 5 data points over momenta
  - 0.6 – 0.8 GeV/c
  - 0.9 – 1.1 GeV/c
  - 1.9 – 2.1 GeV/c
  - 4.9 – 5.1 GeV/c
  - 9.9 – 10.1 GeV/c
- Full simulation
  - 22.11.1 with fiber cladding

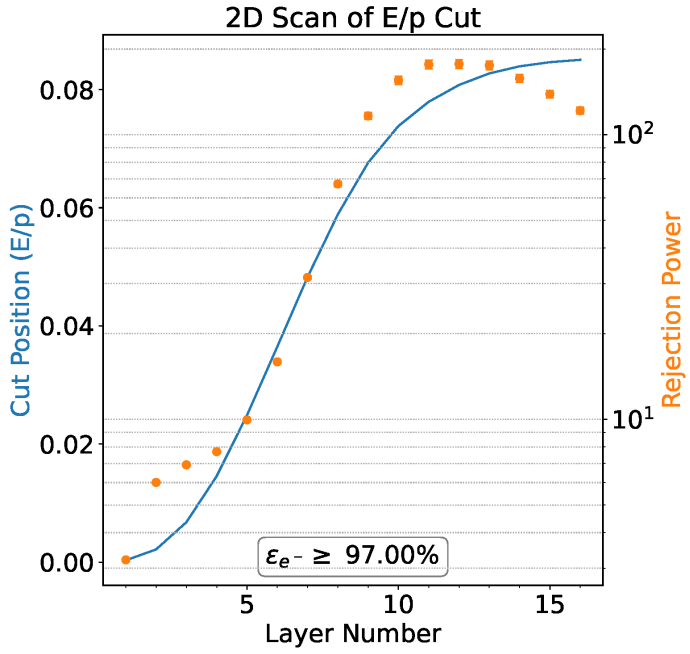


E/p Cuts

0.6-0.8 GeV/c

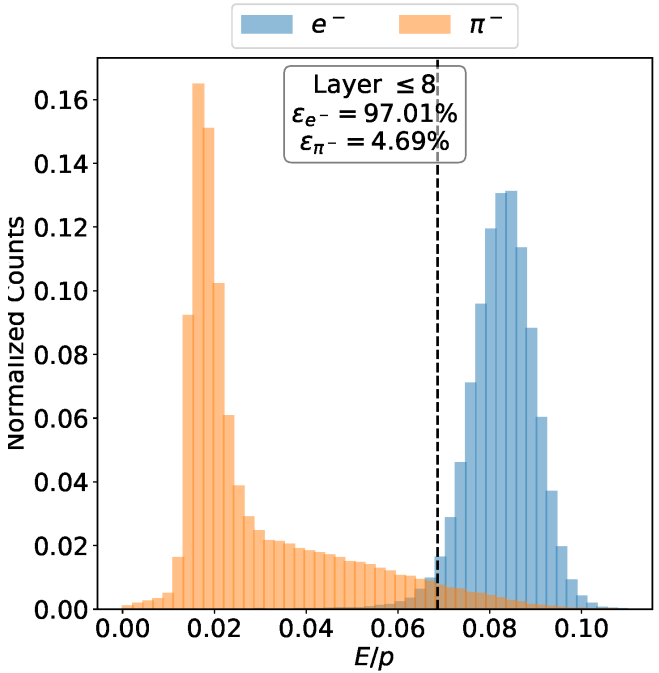


9.9-10.1 GeV/c

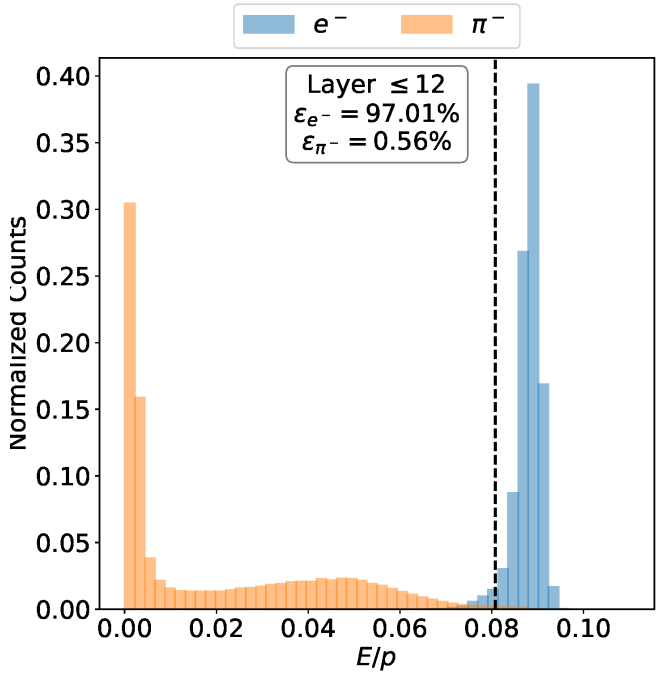


E/p Cuts

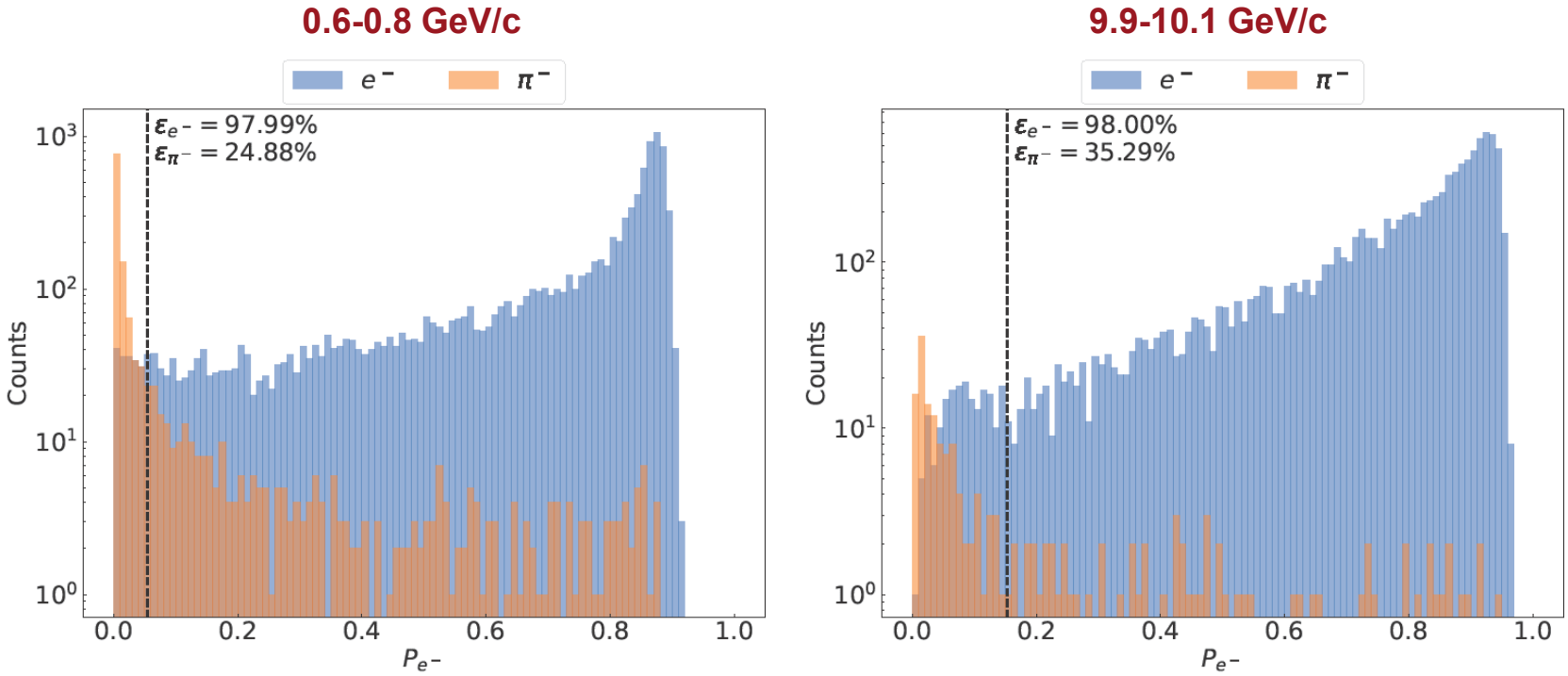
0.6-0.8 GeV/c



9.9-10.1 GeV/c

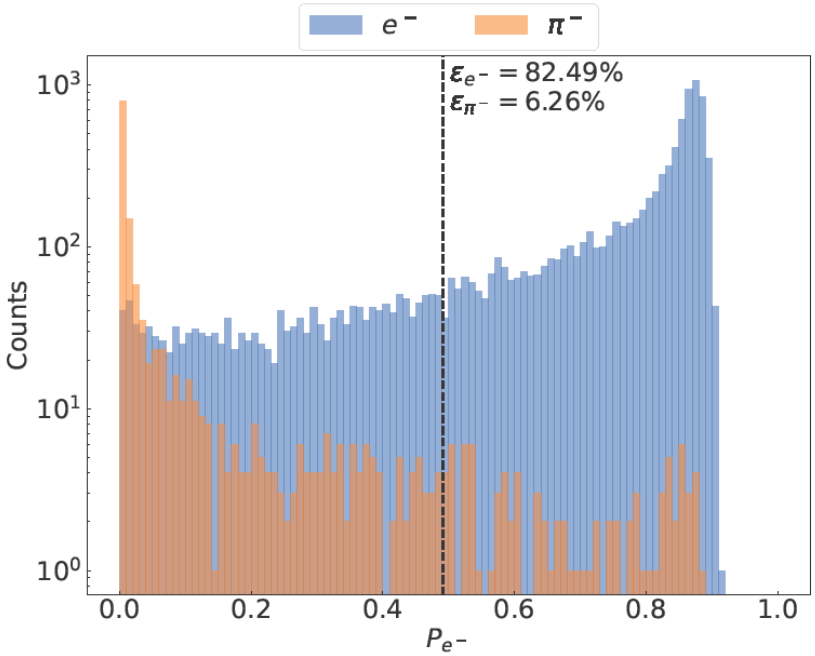


ML Classification – 98% Cut

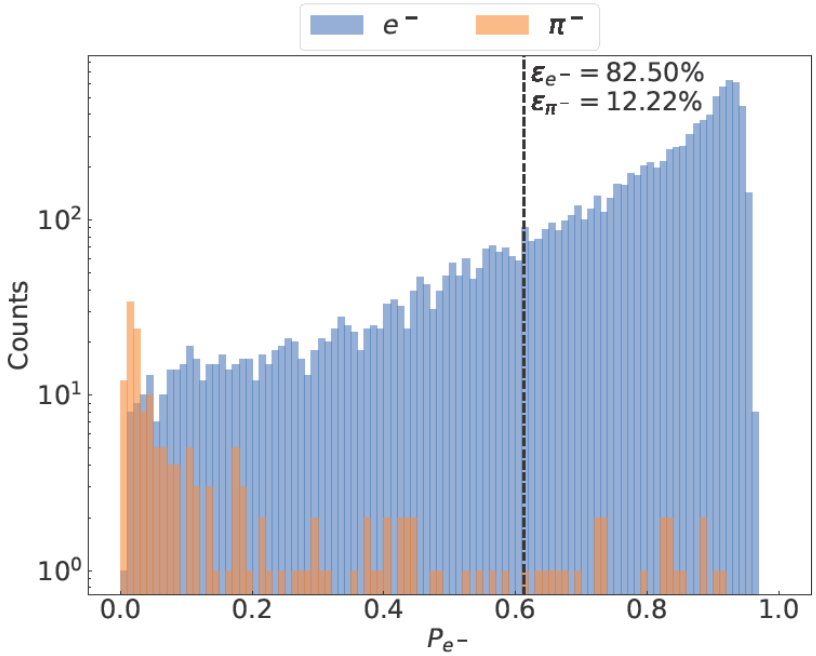


ML Classification – 82.5% Cut

0.6-0.8 GeV/c



9.9-10.1 GeV/c



Summary

Pion rejection power for momentum from 0.6 GeV/c to 10 GeV/c

Different electron efficiencies

- Only varied the cuts on ML classification
- More studies on going (varied cuts on E/p, and varied sample weights for ML training)