Pion rejection factor in SciGlass ECal

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Outline

Scintillation quenching

Erratum for last presentation

Pion rejection in the negative endcap

Proto-clustering in SciGlass for pion rejection

Machine learning

Setup

All studies in this presentation are conducted with DD4hep simulation using ePIC 22.11.1 geometry

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Scintillation quenching

Scintillation quenching without optical simulations in G4

When measuring deposited energy one does not expect to be sensitive to scintillation effects, yet:

- Birks' law correction is enabled by DD4hep for detectors processed with `Geant4ScintillatorCalorimeterAction`: see Geant4SDActions.cpp of DD4hep
  – This uses optional Geant4 facilities
- Log message "`### Birks coefficients for Geant4 materials`" should be a good indicator that Birks' constants are applied
  see Geant4StepHandler.cpp of DD4hep, see G4EmSaturation.cc of G4
- Calorimeters are `Geant4ScintillatorCalorimeterAction` by default
  `DDG4 INFO +++ EcalBarrel type:calorimeter --> Sensitive type: Geant4ScintillatorCalorimeterAction`
- Official production log have those messages ⇒ Birks' law is applied to SciGlass!
- Constant value of 0.0333 mm/MeV is not measured, taken from PbWO4

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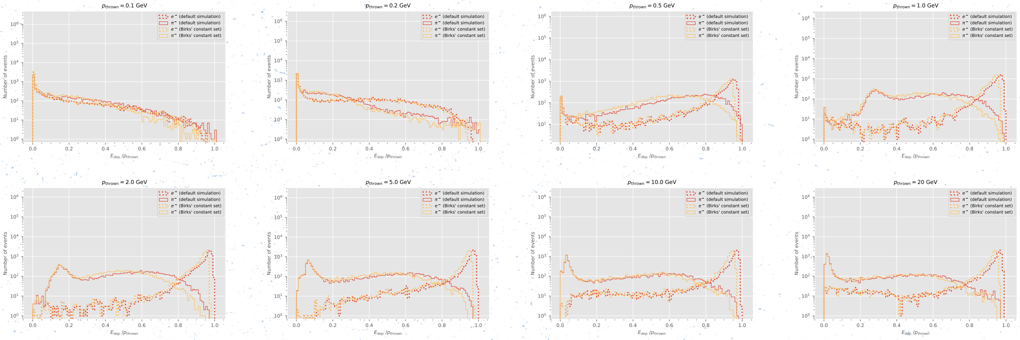
Birks's law effect on E/p



Quenching significantly reduces high-end energy tail for pions.

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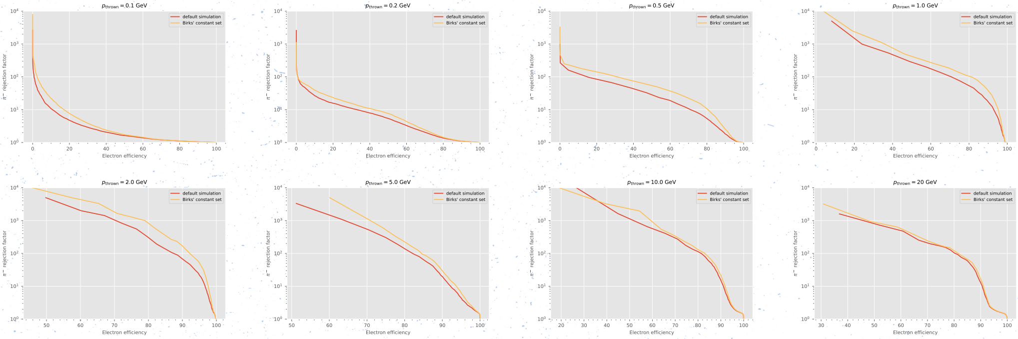
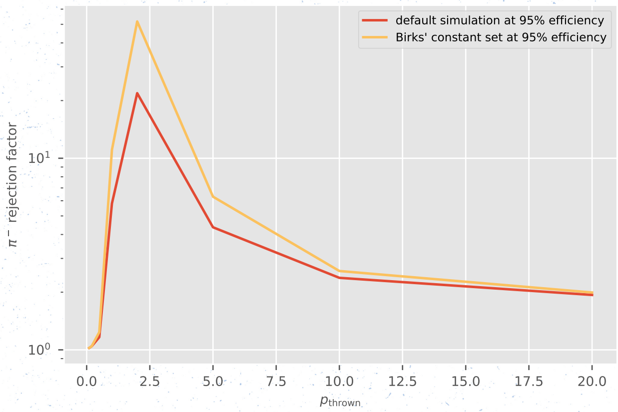
Birks's law effect on pion rejection



Quenching somewhat improves the pion rejection.

Birks's law effect on pion rejection: Summary



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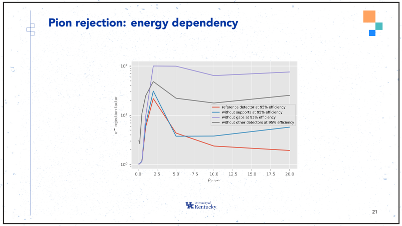
Erratum for last presentation

Bug in previously shown results



Corrected slides uploaded back to Indico: `https://indico.bnl.gov/event/17706/`

Minor issue with the "without other detectors" curve:

- Was supposed to remove all detectors other than calorimeter and keep the magnetic field
- Configuration files from "no gaps" were used by accident with the intended "`epic_sciglass_only`" configuration
- As a result, detectors were removed, but calorimeter was simulated without gaps and without magnetic field

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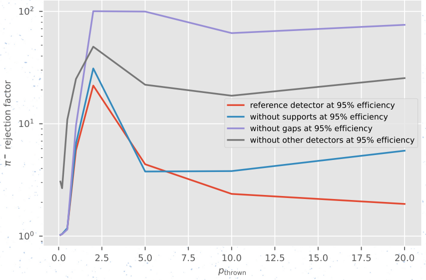
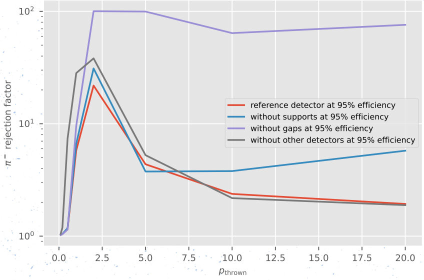
Pion rejection: energy dependency

With bug:



Without bug:



Curves on the left and right, by construction, are identical except for the "no gaps" one that was affected by the bug.

Pion rejection in the negative endcap

EcalEndcapN

- A question was raised during GD/I regarding apparent difference to endcap
- A consistent comparison to SciGlass has to use an identical analysis procedure
- A chance to compare PbWO4 vs SciGlass for calorimeter material
- Electrons and negative pions thrown uniformly with $2.82 < \theta < 3.08$ at the geometry of EcalEndcapN with modified material and tower length (45 cm for SciGlass to accomodate for radiation length scaling)

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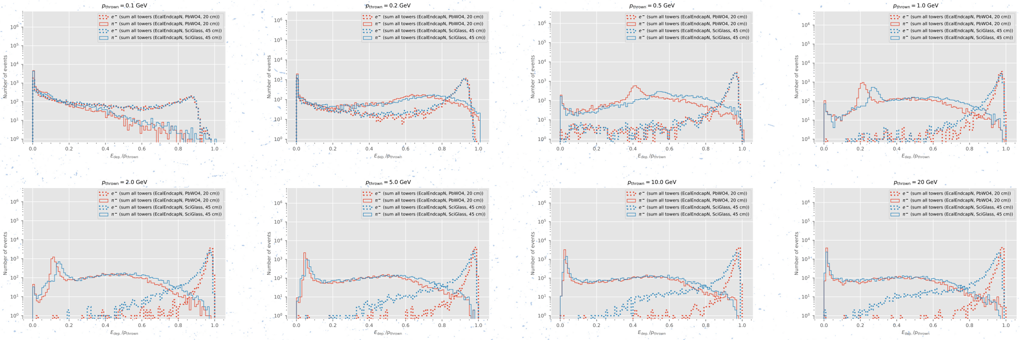
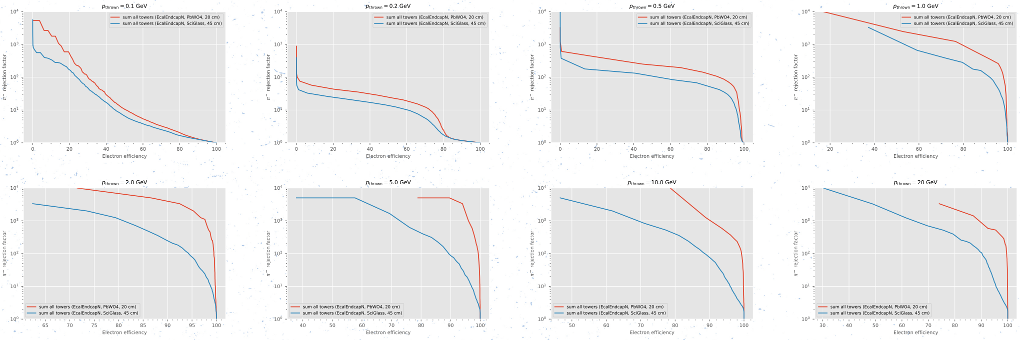
E/p for EcalEndcapN



Better electron resolution in PbWO4 compared to SciGlass.

Pion rejection in EcalEndcapN



Better electron resolution in PbWO4 compared to SciGlass results in better pion rejection at a fixed efficiency.

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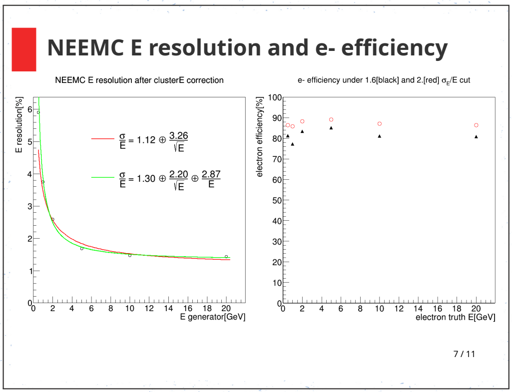
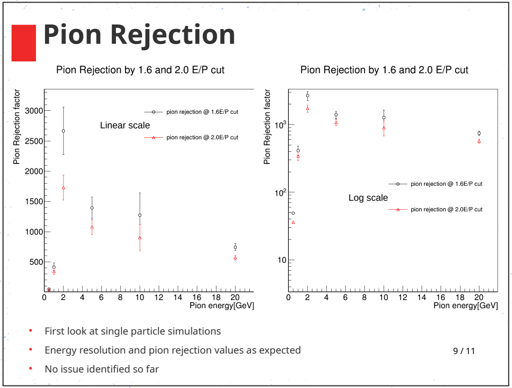
Pion rejection in PbWO4





https://indico.bnl.gov/event/17705/contributions/70651/attachments/44403/74927/NEEMC_single_particle_first_look.pdf

Pion rejection of 10^3 is achieved at $\approx 85\%$ efficiency

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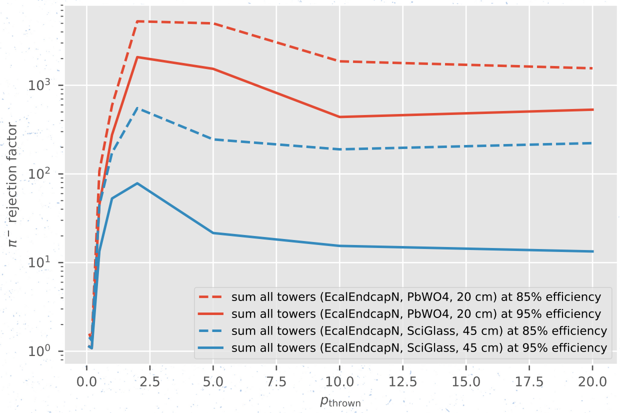
Pion rejection in EcalEndcapN: Summary



Better electron resolution in PbWO4 compared to SciGlass results in better pion rejection at a fixed efficiency.

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Proto-clustering in SciGlass for pion rejection

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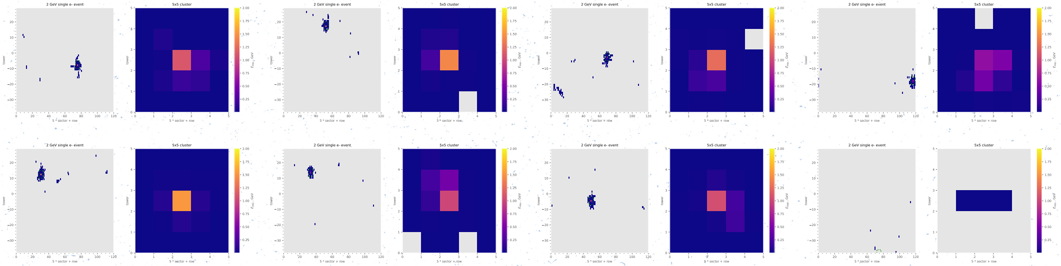
Single particle event and clustering

No proper clustering for SciGlass in EICrecon or Juggler – adjacency using decoded cellID is not implemented yet (see discussion on Mattermost).
A crude clustering was implemented by selecting an $N \times N$ region around the leading tower.

Example e^- events and corresponding 5×5 clusters



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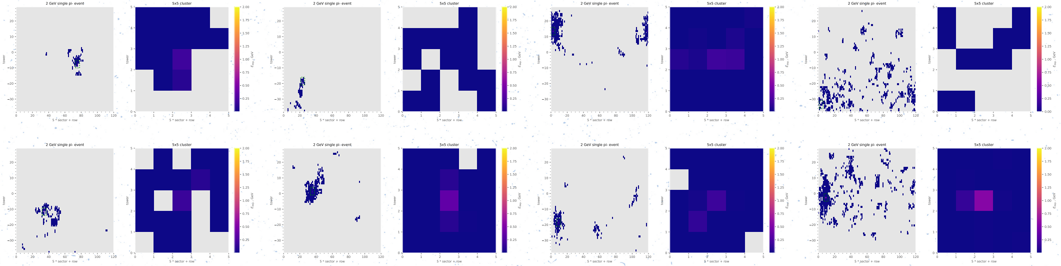
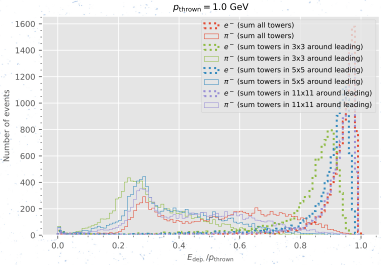
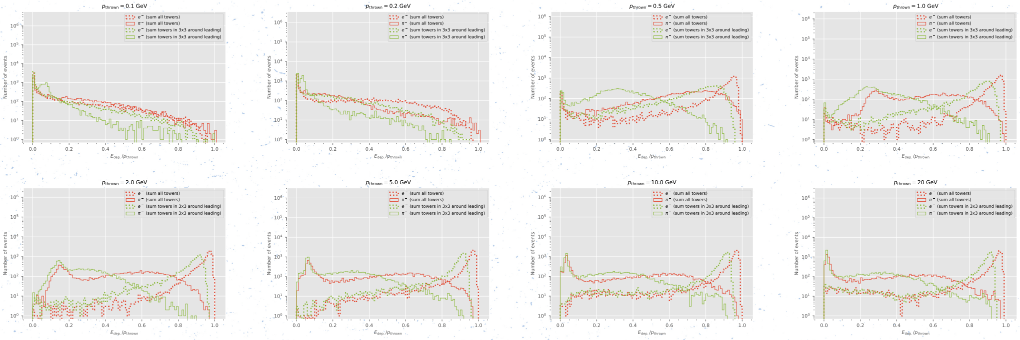


Cluster energy vs cluster size



Will now focus on 3x3 clustering (see backup for others).

E/p for sum in cluster vs full sum



- sum all towers - sum of raw $E_{dep.}$ for all 8 160 towers
- sum towers in 3x3 around leading - sum of raw $E_{dep.}$ 9 towers around the one with the highest energy

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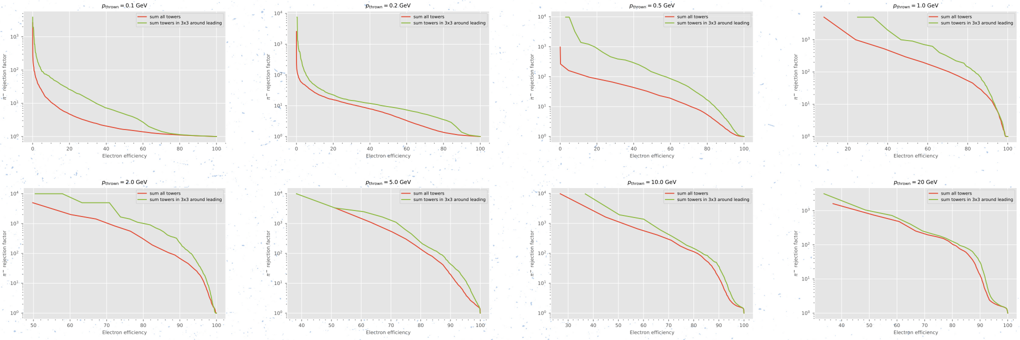
Pion rejection using sum in cluster vs full sum



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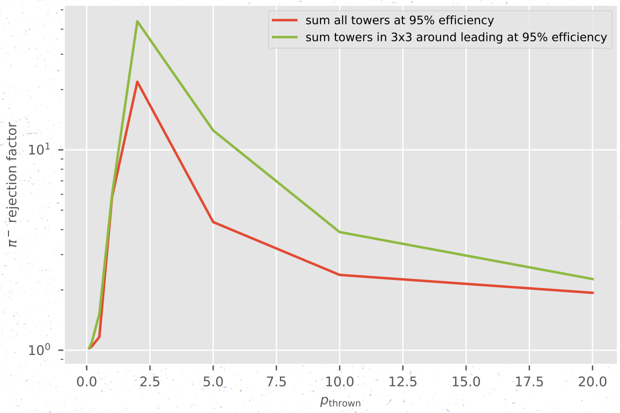
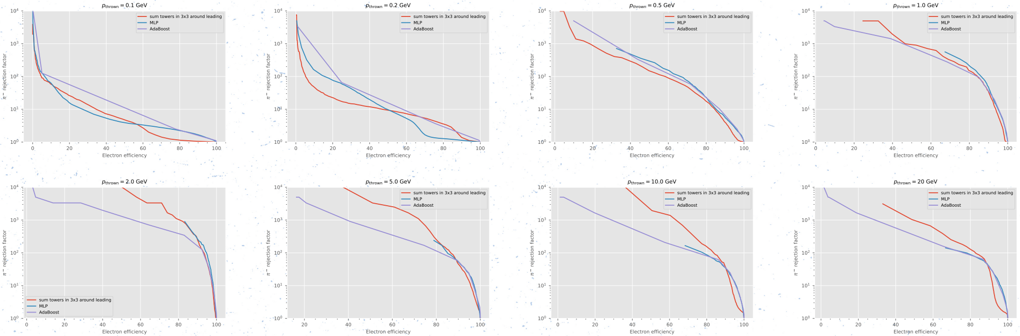
Pion rejection using sum in cluster vs full sum: Summary



A significant improvement when using clustering!

Machine learning

Pion rejection using Machine Learning



Three methods to implement 3x3 cluster (9 inputs):

» *E / p* classifier

» Multi-layer Perceptron (default settings from sklearn, tuned a bit)

» Adaptive Boosting (default settings from sklearn, untuned)

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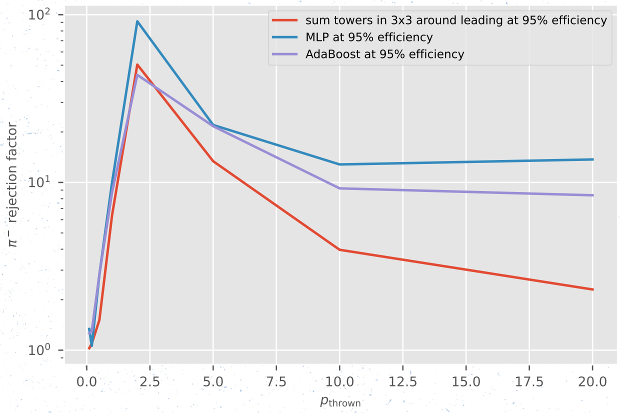
Pion rejection using Machine Learning: Summary



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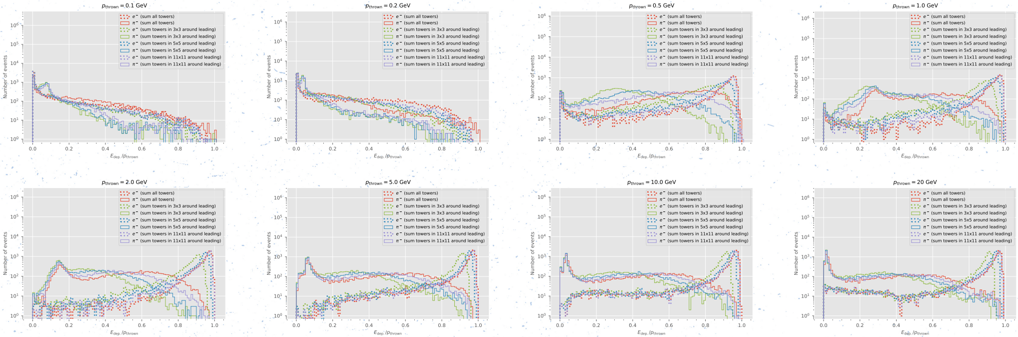
Ways to improve

- ML classifiers are trained for each energy separately
- Only 9 energy inputs are used – classifiers are not told where in the calorimeter the cluster is
- Introduction information from tracking (track φ and η) for even more precise hit position – might be possible to even recover some information lost due to the gaps
- Hyperparameter tuning
- Wild idea: Change of loss function to be sensitive specifically at high-efficiency?

Backup

E/p for sum in cluster vs full sum



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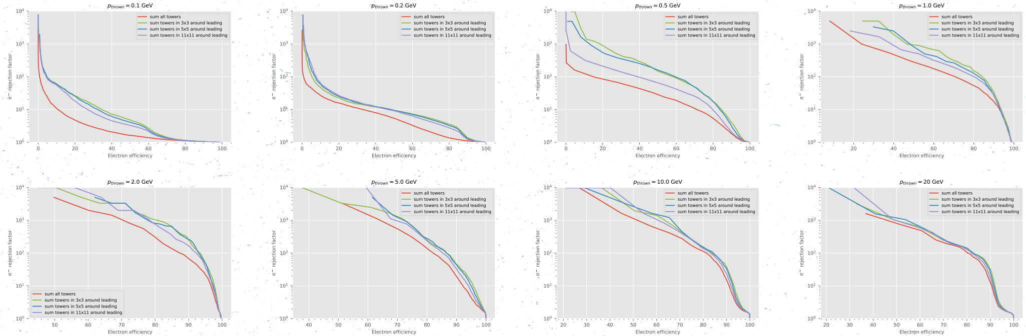
Pion rejection using sum in cluster vs full sum



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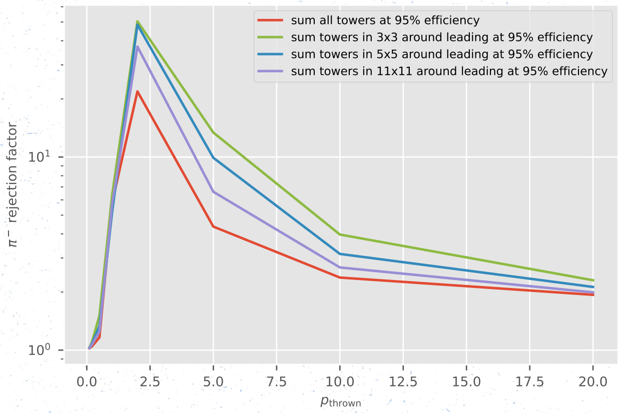
Pion rejection using sum in cluster vs full sum: Summary



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Binary classifier probability