Electron finding with ePIC

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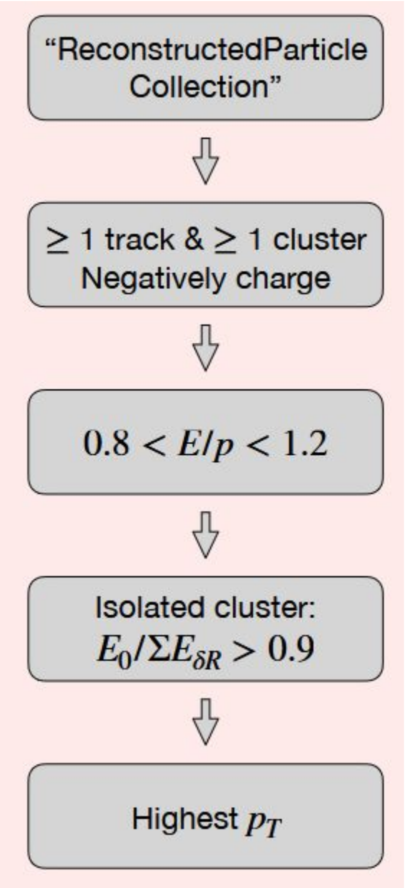
Joint Inclusive/EW+BSM PWG Meeting, 2026/06/17

Outline

- Start from “standard” eID algorithm
- Consider other quantities that could be used
    - Implement E/(E+H)
    - Benchmark using PID from look-up tables
- Systematically consider impact of each cut
- Suggest updated selection based on these findings

Methodology



- "Conventional" electron finding algorithm uses a series of selection criteria to find candidates.
- Started from the selection described in snippets/ElectronID, then explored these cuts and alternative selections.

- See Win's talk from 2026/04/07.

Methodology

- Considered single dataset containing ~42k events from the 26.02.0 campaign, NC DIS only, 18x275, min $Q^2 = 10\ GeV^2$
  - **No beam induced/physics backgrounds included**
  - **Minimum Q^2 ensures scattered electrons scatter into central detector**
- Use reconstructed particle information, compare to truth-level information.

$$Efficiency = \frac{Number\ of\ events\ with\ candidates}{Number\ of\ events}$$

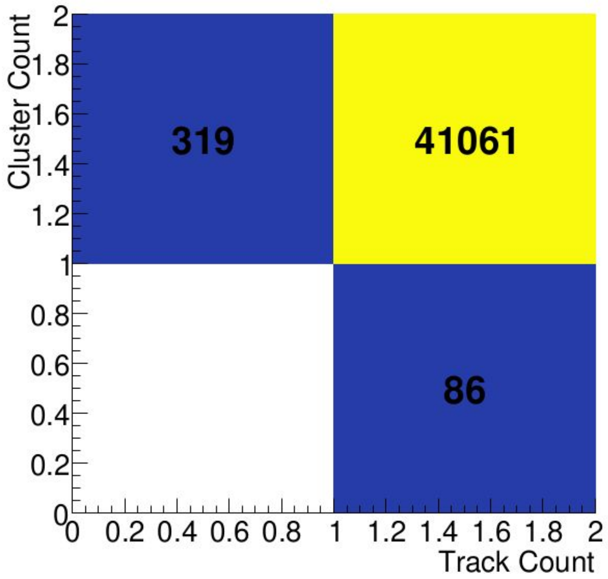
$$Purity = \frac{Number\ of\ correctly\ identified\ scattered\ electrons}{Number\ of\ events\ with\ candidates}$$

Note: Mostly show these as a function of p_T -> strongly correlated with Q^2 (and y)

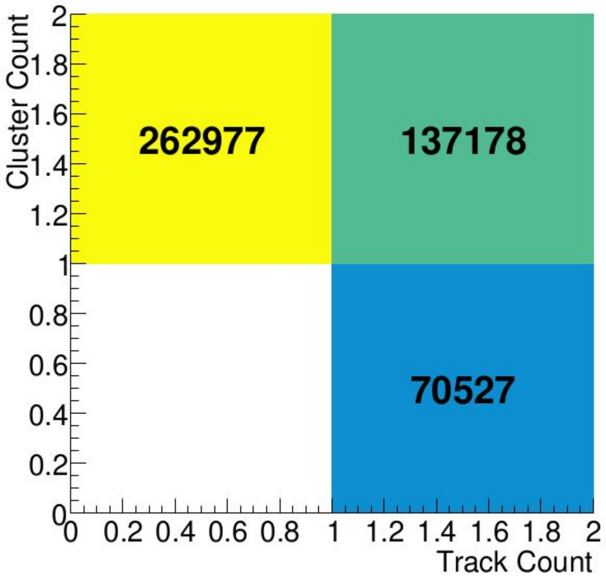
$Q^2 \sim p_T^2$ (low y)

Matching of Tracks and Clusters

- Scattered electrons almost always have a matched track and ECAL cluster.
- Other reconstructed particles only have a matched track and cluster 1/3rd of the time.
  - **Less than ½ of ReconstructedParticles have a track? Mostly neutral particles?**



Scattered electrons



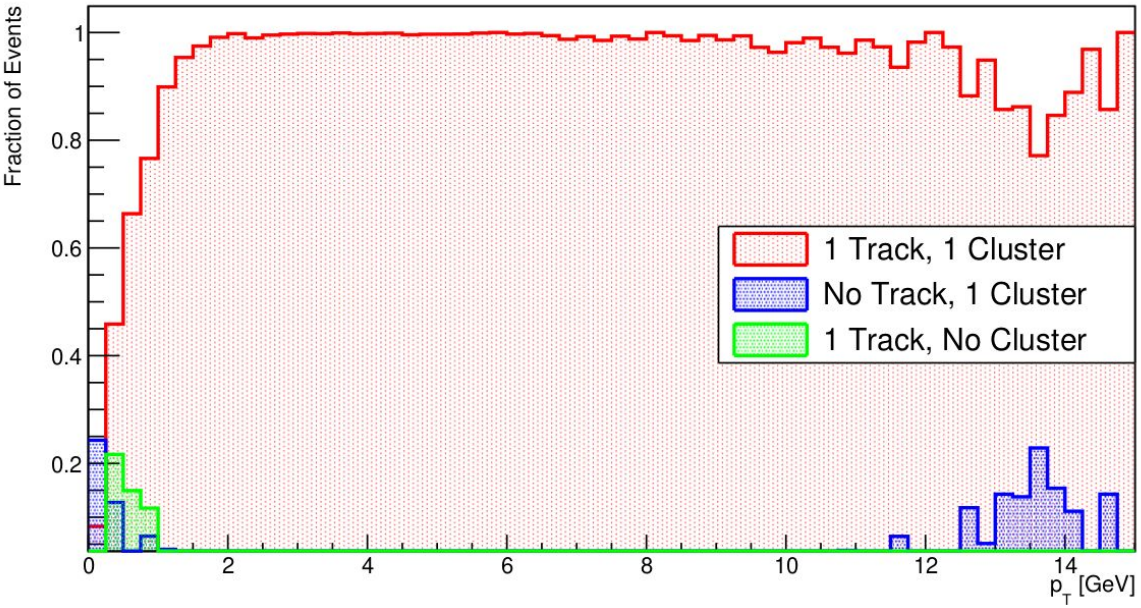
All other particles

26.02.0
Pythia8
18x275 GeV
$Q^2 > 10$ GeV^2

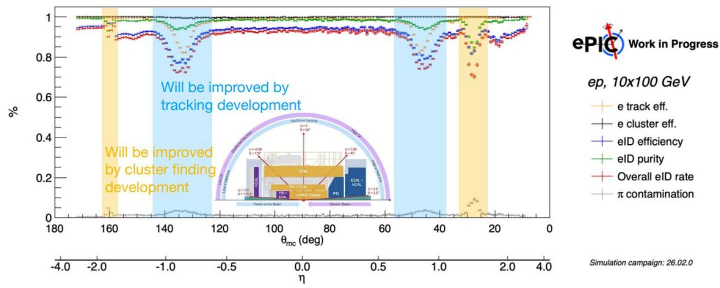
Matching of Tracks and Clusters

- Electrons with missing track typically have p_T~13.5 GeV -> Q^2~180GeV^2 -> 135 degrees.
  - Silicon Tracker service cone
- ...And low p_T -> lower tracking efficiency
- Missing clusters at lower p_T -> less likely to reach calorimeters

$$Q^2 = 2E_e E'_e (1 + \cos(\theta_e))$$



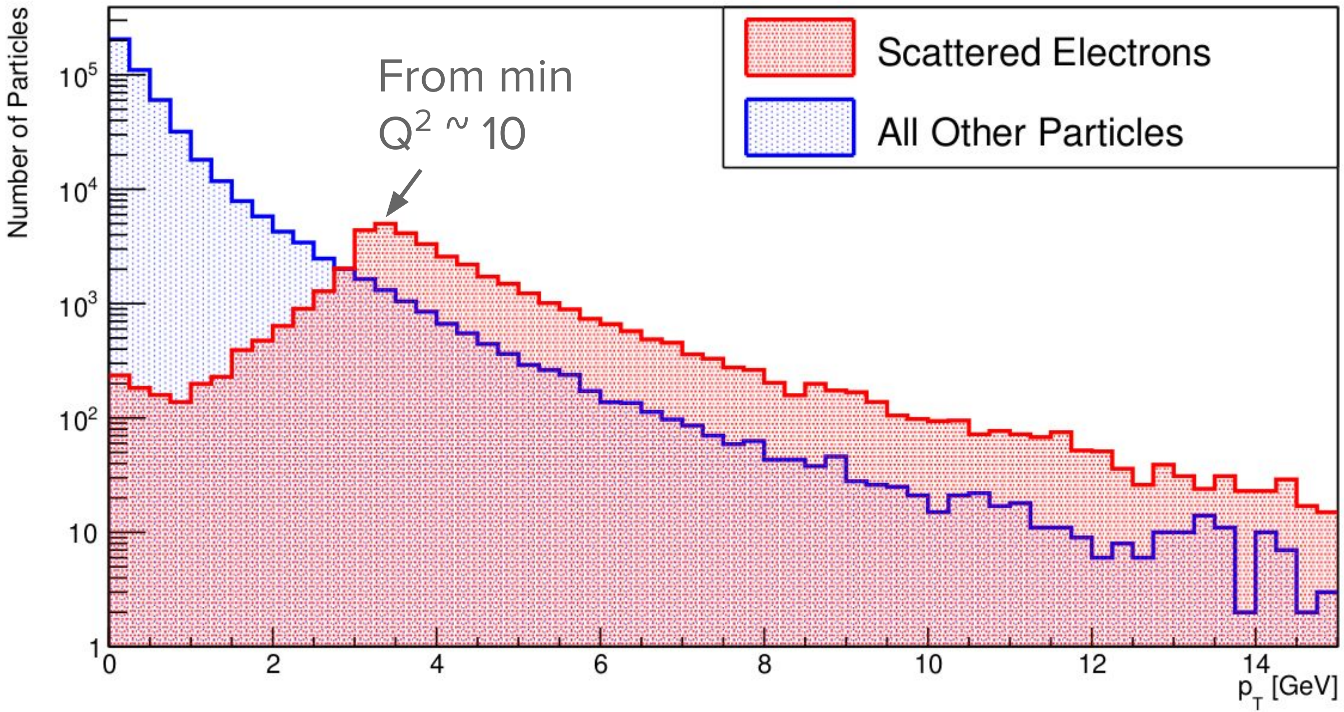
26.02.0 Pythia8 18x275 GeV
$Q^2 > 10$ GeV^2



See Win's talk

Input variables - transverse momentum

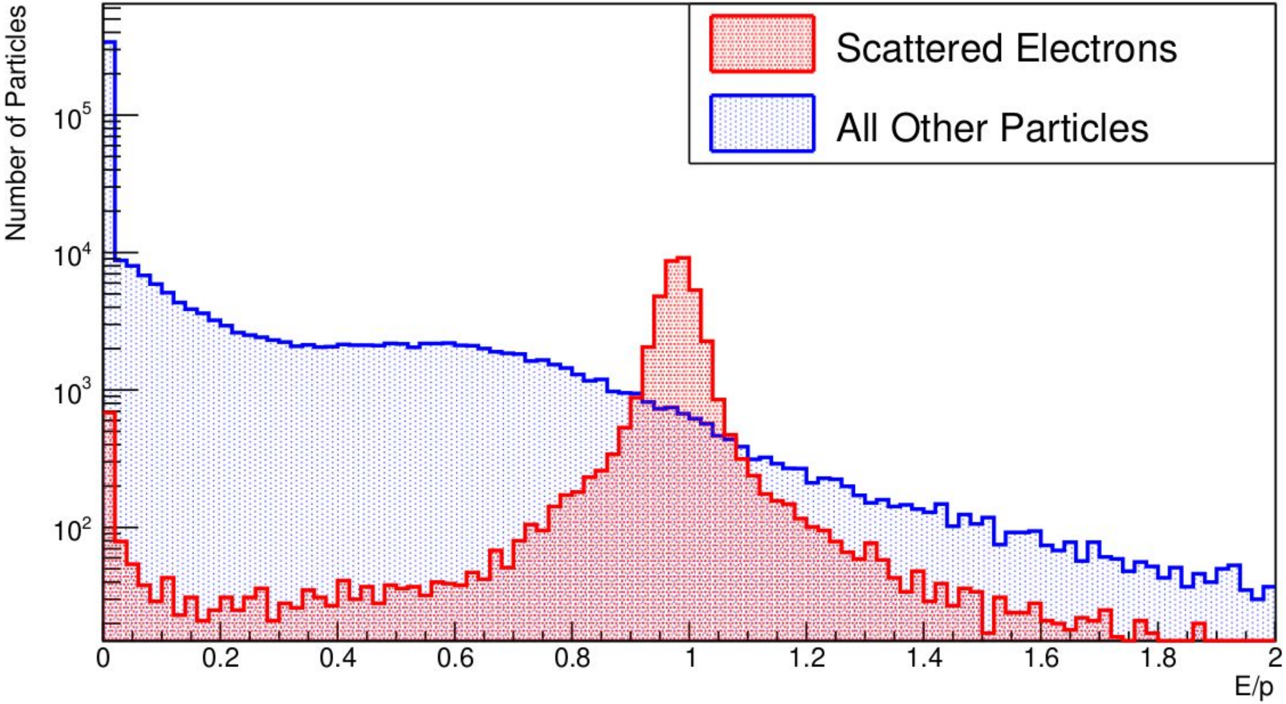
- For Q^2 larger than ~1 GeV^2 the scattered electron is usually the highest-p_T object in the event



26.02.0
Pythia8
18x275 GeV
$Q^2 > 10$ GeV^2

Input variables - E/p

- Electron energy/momentum should be completely measured by the ECAL/tracker
  - E/p ~ 1
- Hadronic particles usually deposit only part of their energy in the ECAL -> E/p < 1



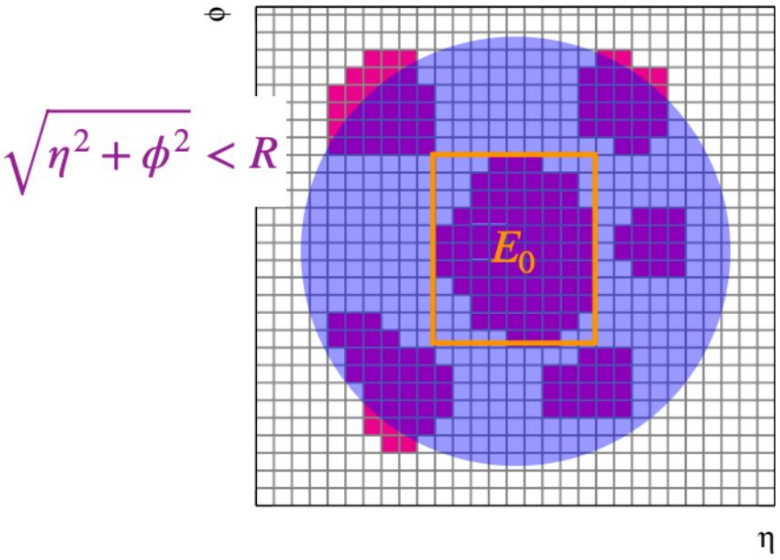
0.8 < E/p < 1.2

For track with matched ECAL cluster:
-> E/p is cluster energy divided by track momentum

26.02.0 Pythia8
18x275 GeV
$Q^2 > 10$ GeV^2

Input variables - Isolation

$$Isolation = \frac{Primary\ cluster\ energy}{Energy\ deposited\ within\ \Delta R_{Iso}\ of\ primary\ cluster},$$

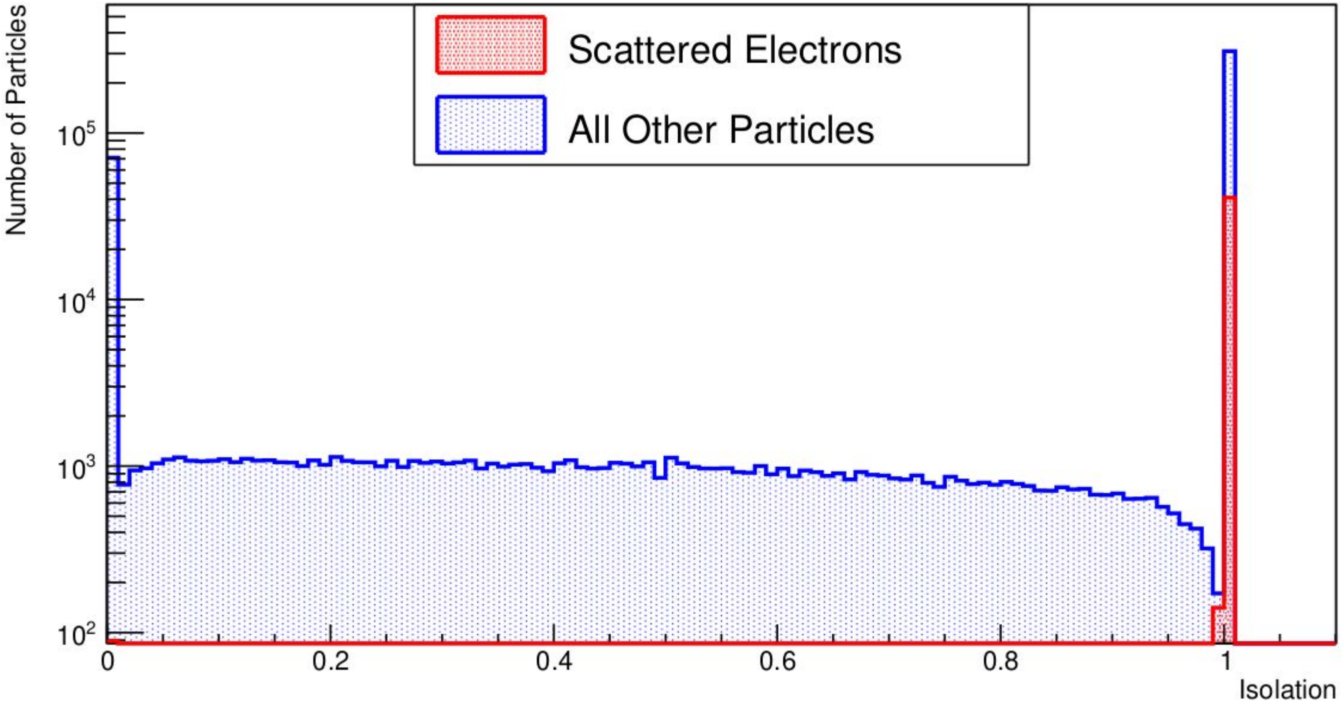


$$\Delta R_{Iso} = \sqrt{\Delta\eta^2 + \Delta\phi^2},$$

- Scattered electrons should be isolated compared to particles in e.g. a jet

Input variables - Isolation

- Isolation > 0.9 (ΔR = 0.4 rad.)
- Note: many "other" particles also have isolation ~1

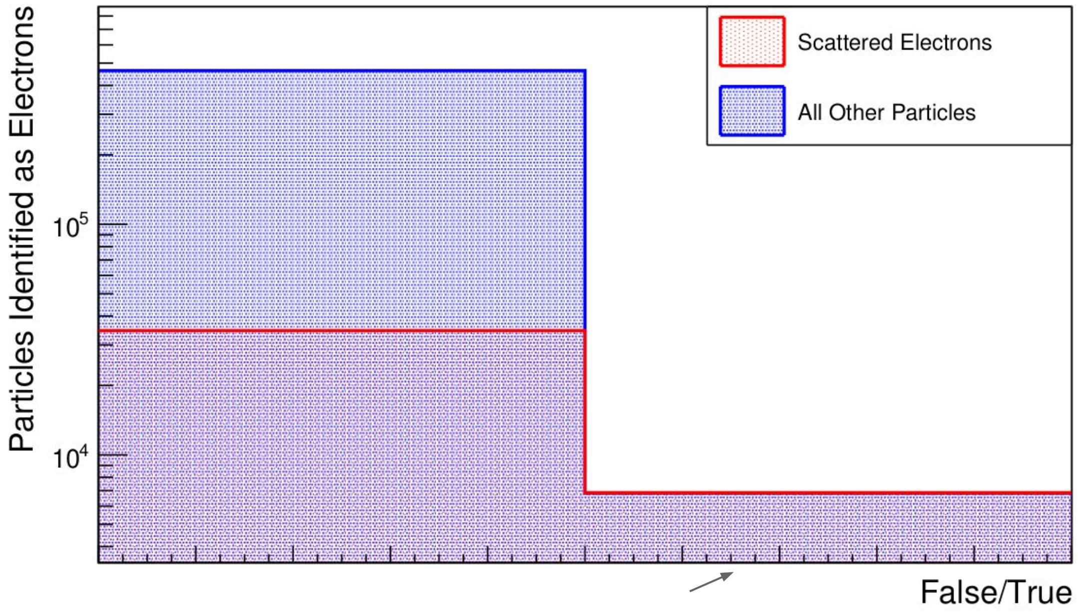


26.02.0 Pythia8
18x275 GeV
$Q^2 > 10$ GeV^2

Might be more impactful with backgrounds included?

Input variables - PID from look-up tables

- PID from Cherenkov detectors currently available through ReconstructedParticles.PDG
    - [PID through look-up tables]
- Low efficiency (even for real electrons) -> but might be good at low momenta?

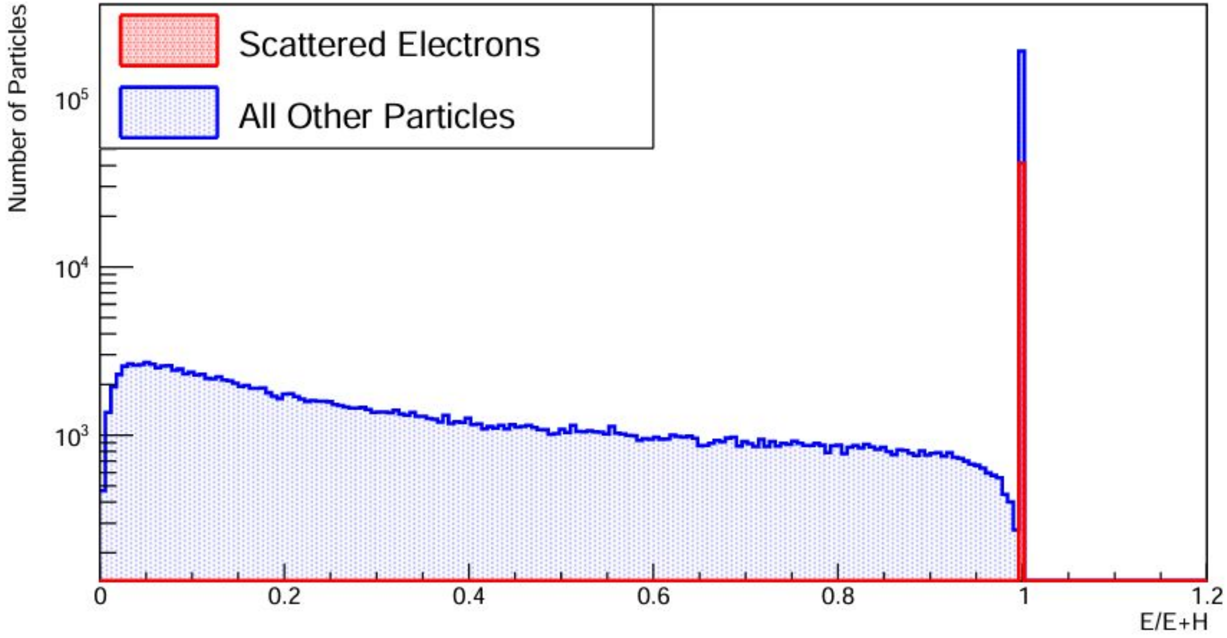


Needs double-checking

26.02.0 Pythia8
18x275 GeV
$Q^2 > 10$ GeV^2

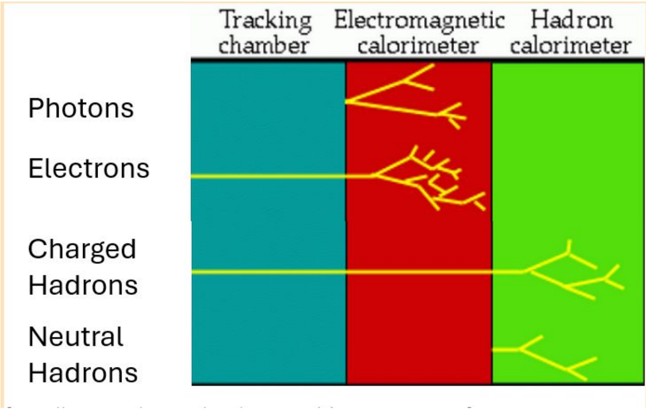
Input variables - ECAL / (ECAL + HCAL)

- Ratio of ECAL cluster energy to energy total energy from ECAL+HCAL in a cone around the cluster
  - Electrons should be well contained by ECAL, while hadronic particles will split energy between ECAL and HCAL



E/(E+H) > 0.99

26.02.0 Pythia8 18x275 GeV
$Q^2 > 10$ GeV^2



“Basic” Selection

- At least 1 track & 1 cluster
- Negatively charged
- Highest p_T object

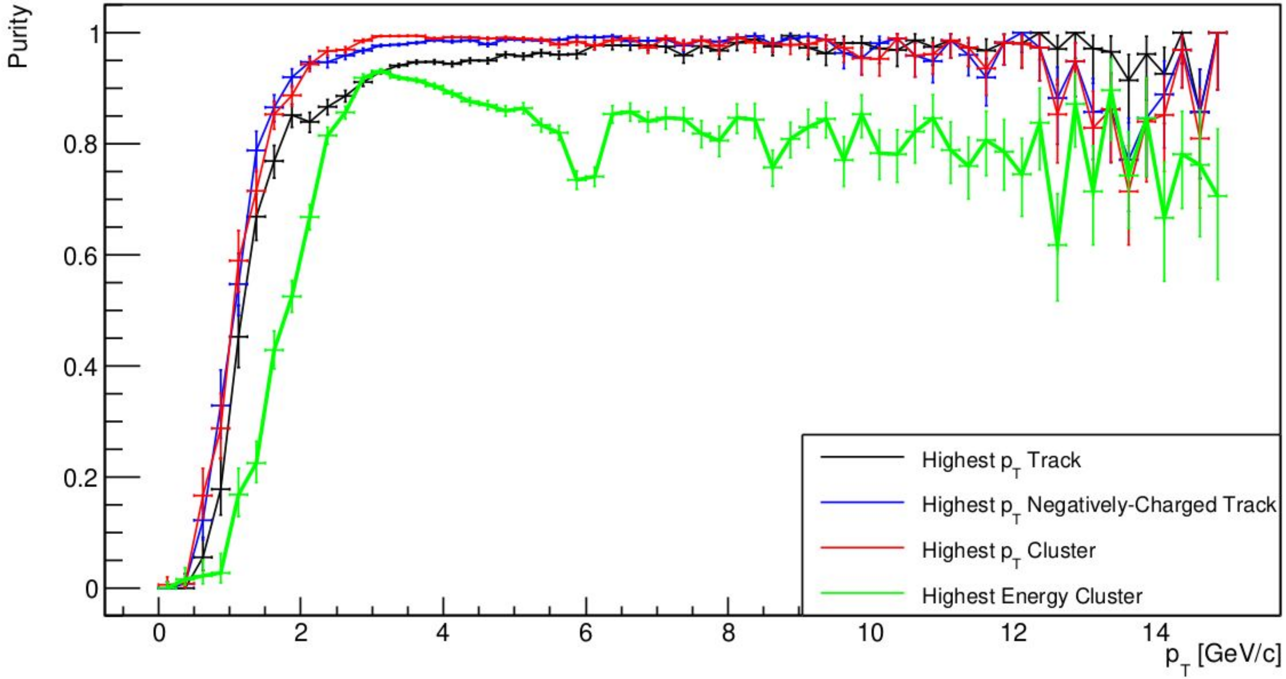
Additional Criteria

- ParticleID
- E/p
- Isolation
- E/(E+H)

- Start from a simple initial selection
- Gradually add in other criteria
  - Assess improvement in purity relative to loss in efficiency

Purity with each criterion (individually)

- Tracks generally better than clusters
- p_T better than energy



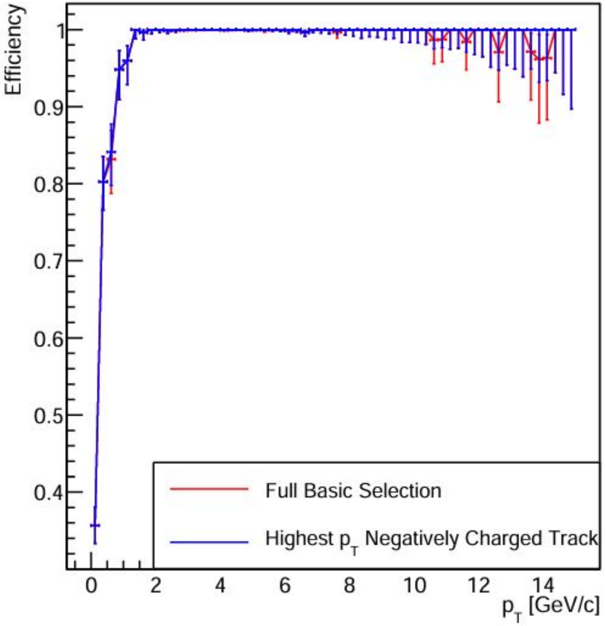
26.02.0 Pythia8
18x275 GeV
$Q^2 > 10$ GeV^2

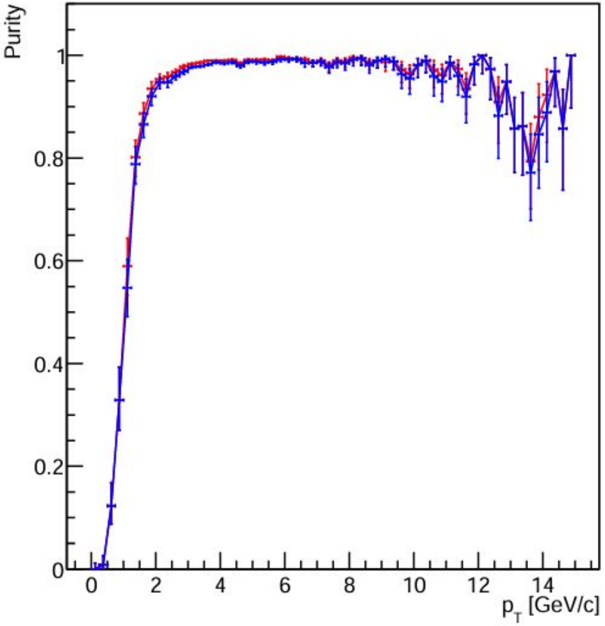
Note: criteria applied individually

Purity/Efficiency for simple selections

- At least 1 track & 1 cluster
- Negatively charged
- Highest p_T track

- Don't lose much efficiency by requiring cluster
- Don't gain in purity either





26.02.0 Pythia8
18x275 GeV
$Q^2 > 10$ GeV^2

Blue: highest p_T -ve track in event

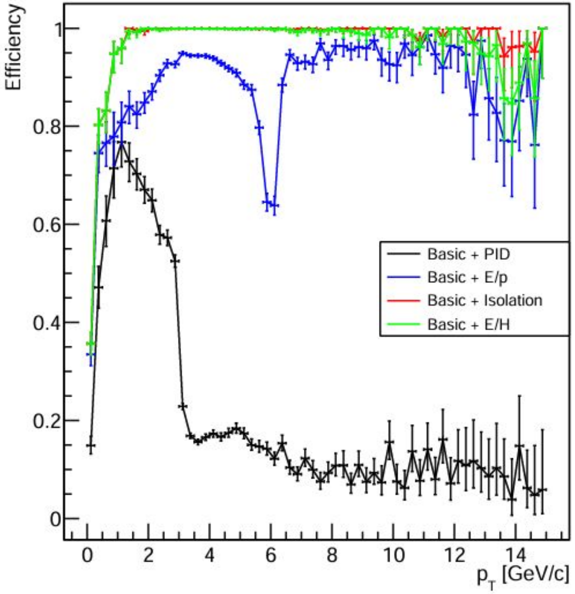
Red: highest p_T -ve track with a matched cluster -> note: **no E/p requirement**

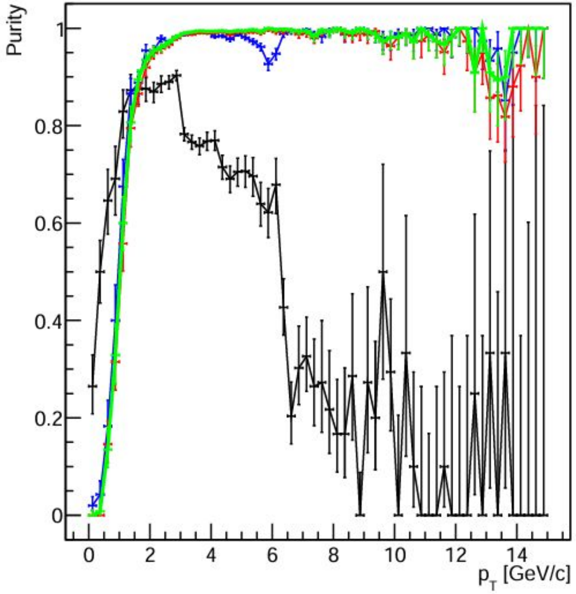
Probably because 99% of electron tracks have a matched cluster!

Purity/Efficiency for basic selection + 1 criterion

Basic selection: -**ve track with matched cluster**
-> take highest p_T track at end of selection

IsoR = 1
26.02.0 Pythia8
18x275 GeV
$Q^2 > 10$ GeV^2

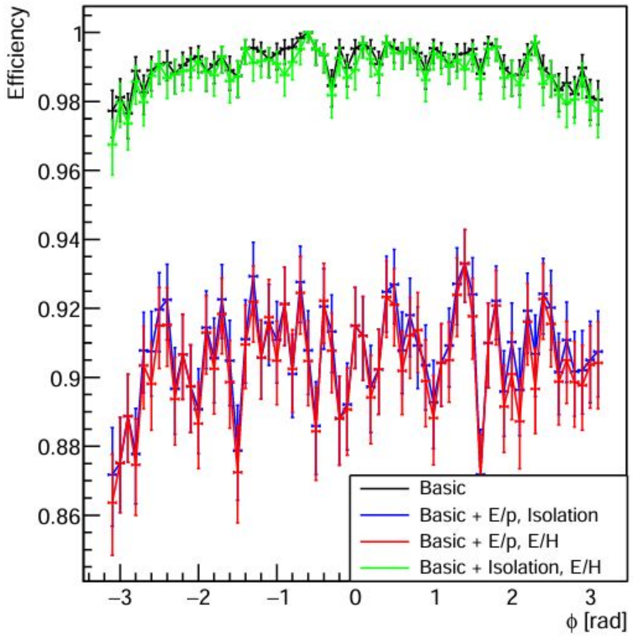


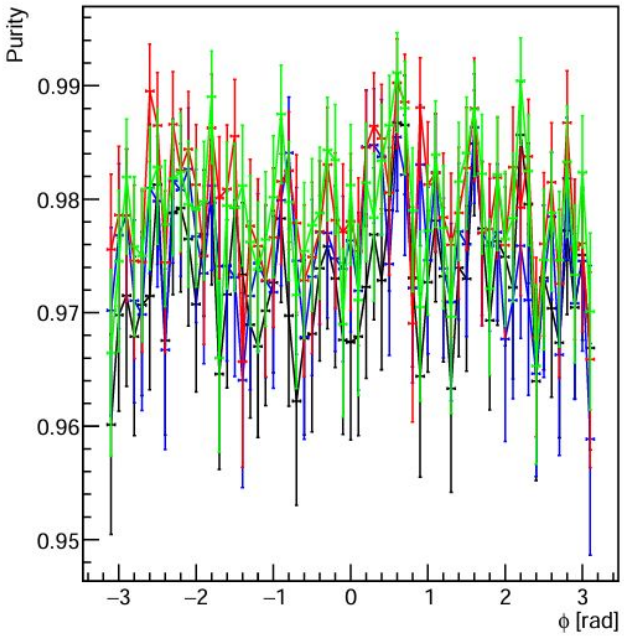


- Actually get very good performance with just basic selection **and/or** isolation or E/(E+H)
  - Additional criteria don't obviously improve purity
- E/p degrade purity at ~6GeV?
  - Barrel->Endcap
- Only criterion to actually improve purity somewhere is PID -> better at low p_T
  - Not great efficiency

Purity/Efficiency for basic selection + 2 criteria

Basic selection: -ve track with matched cluster
-> take highest p_T track at end of selection



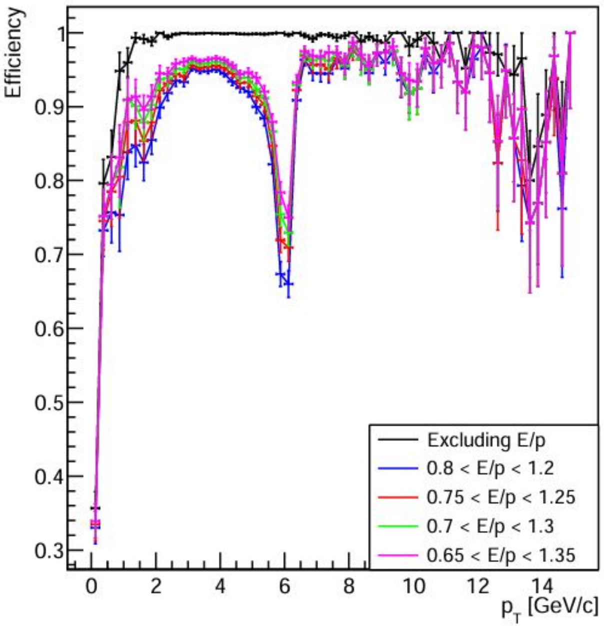


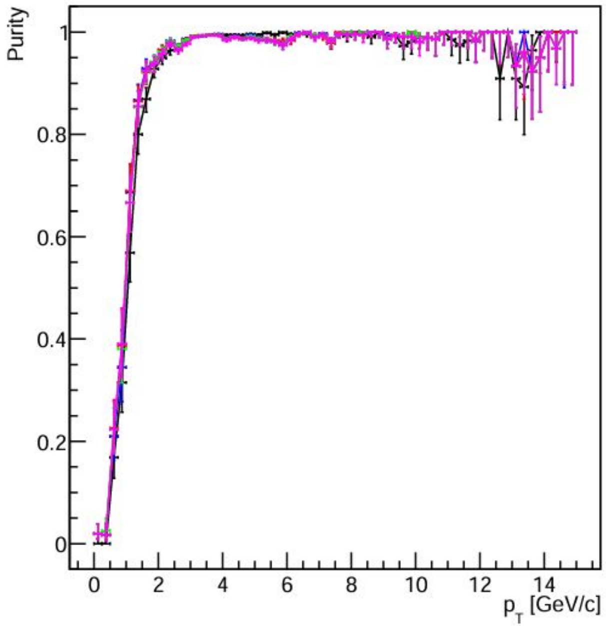
- Plot vs phi -> shows average
- E/p drops efficiency and doesn't massively improve purity
- Note: this is a pure DIS sample - E/p may impact more with backgrounds
- **Very high purity overall!**

Comparing E/p cuts

Basic selection: -ve track with matched cluster
-> take highest p_T track at end of selection

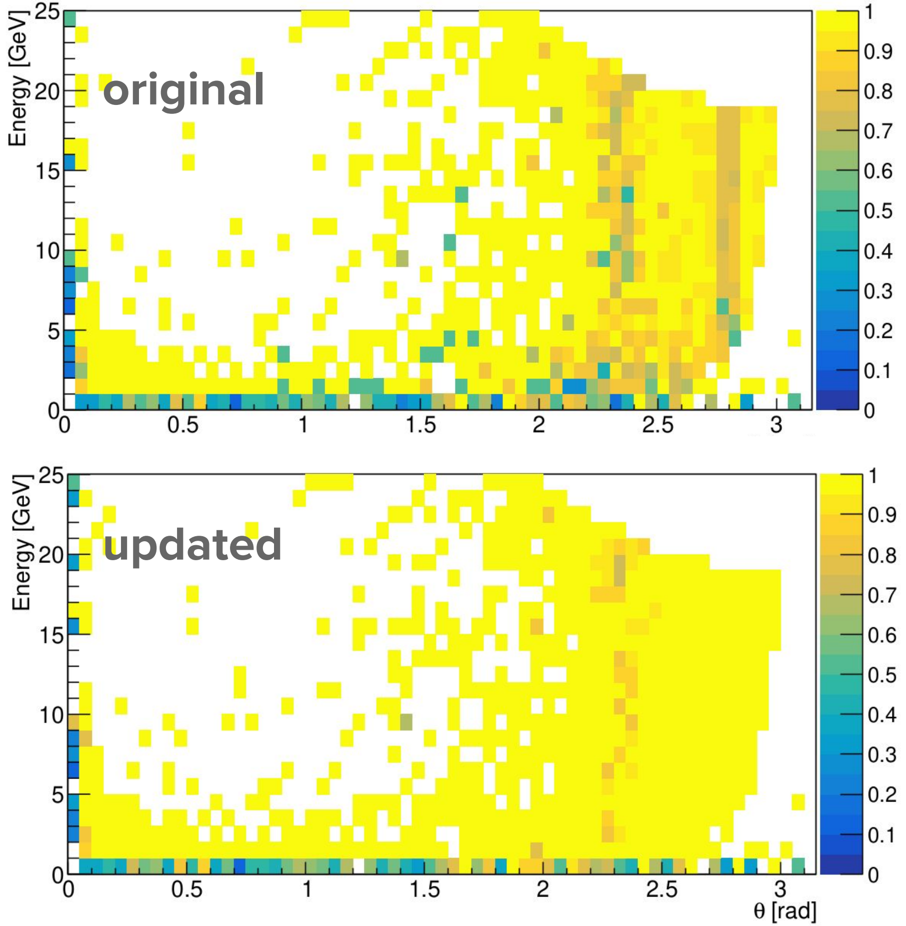
+E/p, Isolation, E/(E+H)





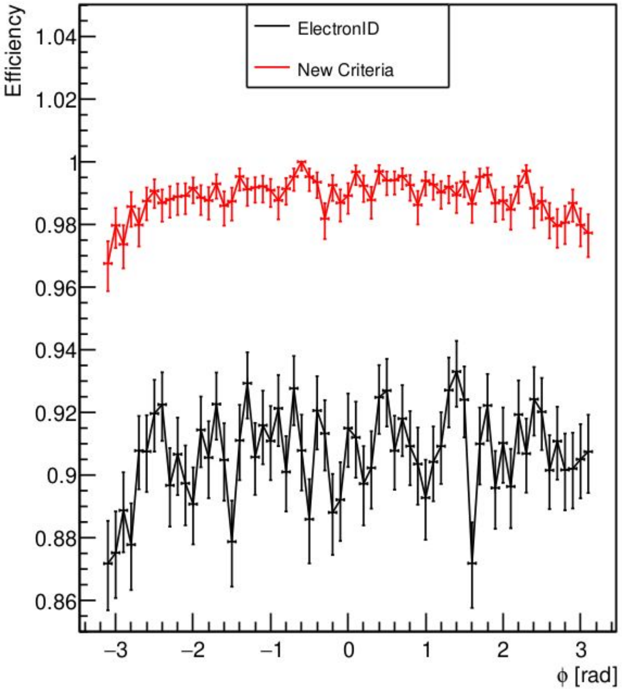
- Minimal difference between E/p cuts?
- Note: this is a pure DIS sample - E/p may impact more with backgrounds
- Dropping of E/p requirement (at least in ECAL transition region) may improve overall performance

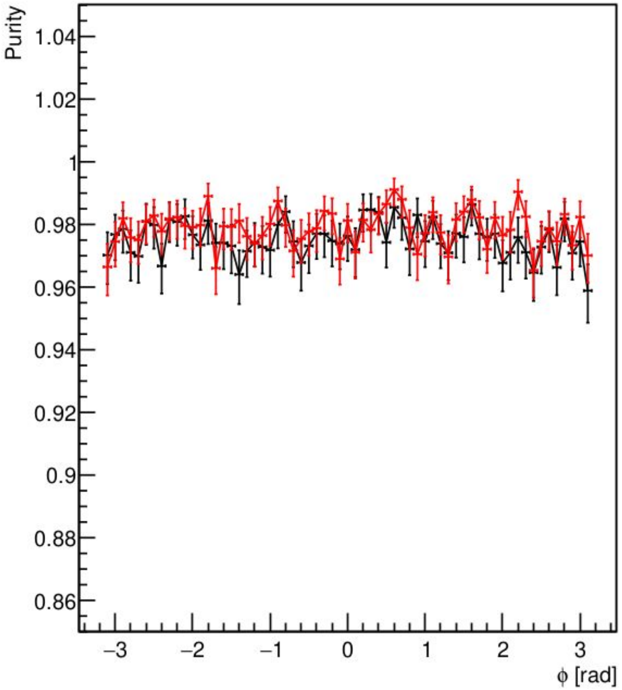
Updated eID algorithm (Efficiency vs E-θ)



- Updated algorithm removes E/p requirement from standard eID and adds E/(E+H) requirement, such that the algorithm becomes
  - Look for -ve tracks with a matched ECAL cluster
  - Isolation > 0.9
  - E/(E+H) > 0.99
  - Highest p_T candidate
- This significantly improves the efficiency, without losing purity
  - In these pure DIS samples only -> need further studies

Updated eID algorithm





- On average:
  - Updates improve efficiency from ~92->99%
  - No obvious loss in purity -> ~98% in both cases

Summary

- Took “standard” eID algorithm as a starting point
- Considered other quantities that could be used (E/(E+H) and PID)
- Efficiency drop from E/p cut not justified by improved purity
  - Removed this cut entirely for now -> may be better to keep cut except in transition regions
- E/(E+H) cut calculation implemented
  - doesn’t obviously improve purity, but doesn’t degrade efficiency either
- PID from look-up tables also considered
  - Low efficiency for eID, but can potentially improve purity at low momentum

Outlook

- **More detailed treatment required to optimally use E/p cut**
- Cone-based E/(E+H) calculation implemented -> could be added to standard algorithm
- PID from look-up tables could be useful at low momenta
  - Low efficiency so likelihood-based approach may be needed