Identification Performance of Leptons in Jets

Online mini-workshop on a detector concept with a crystal ECAL

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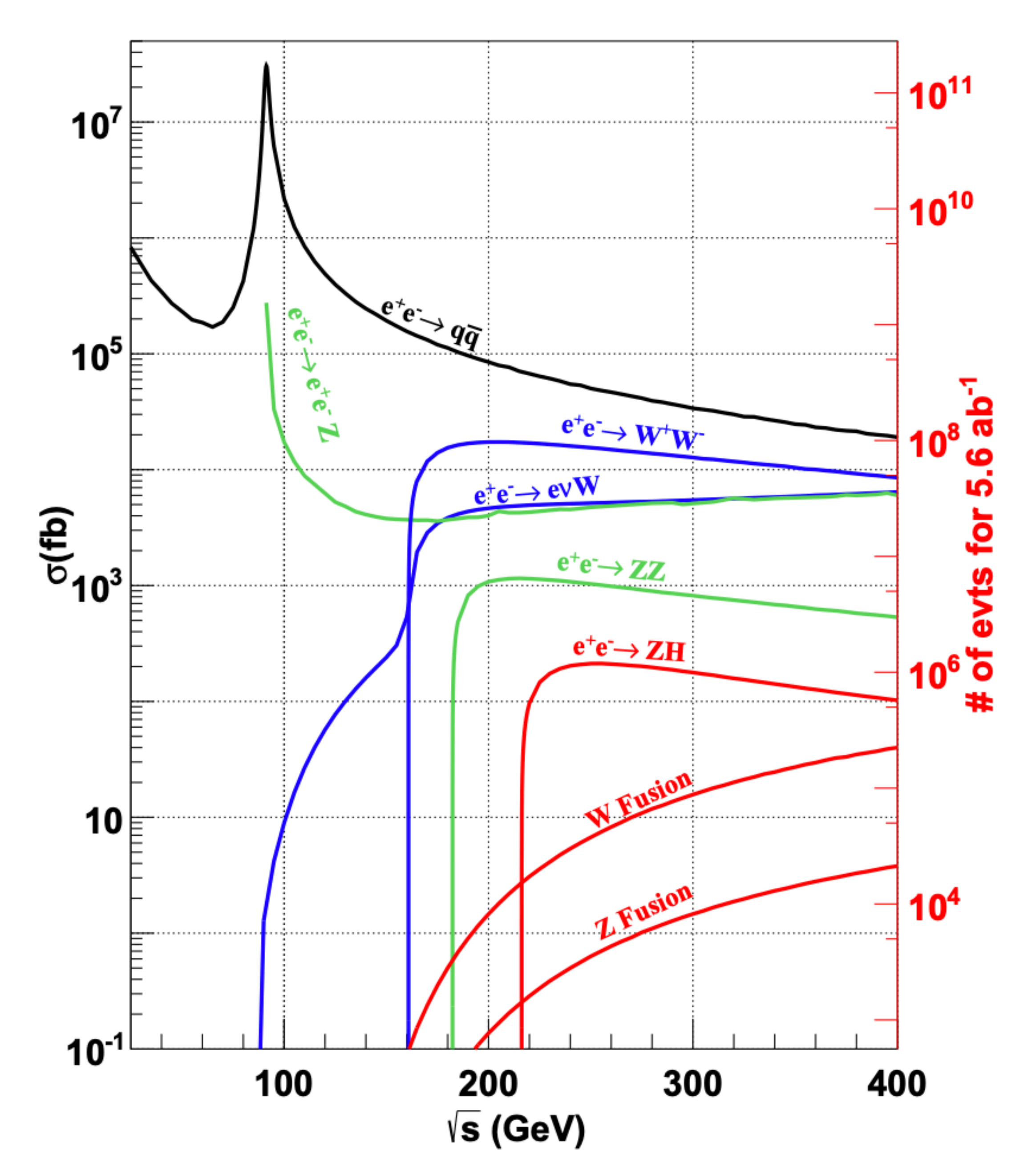
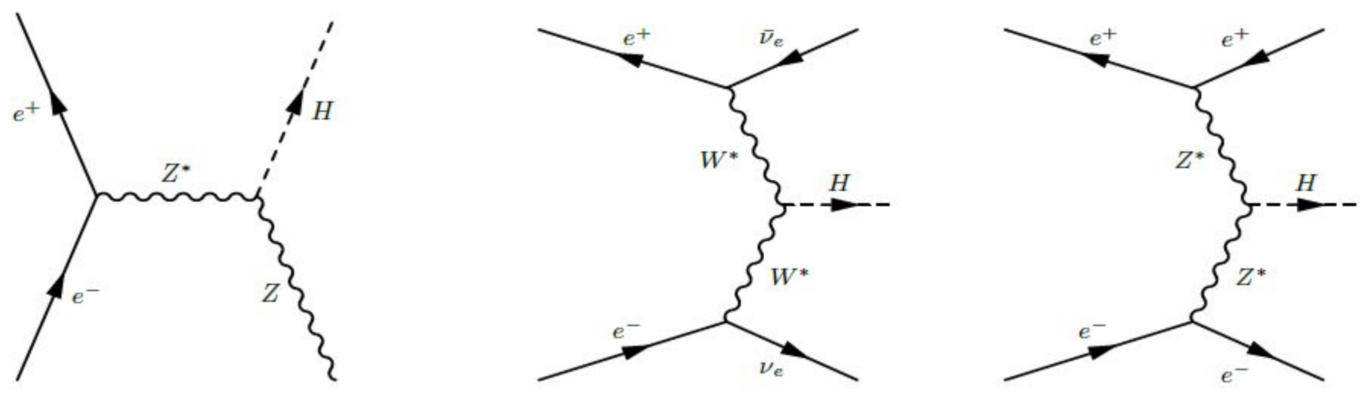
CEPC

Plan

- Introduction
- Lepton Identification
    - Single lepton
    - Lepton in jets
- τ Identification
- Summary

CEPC

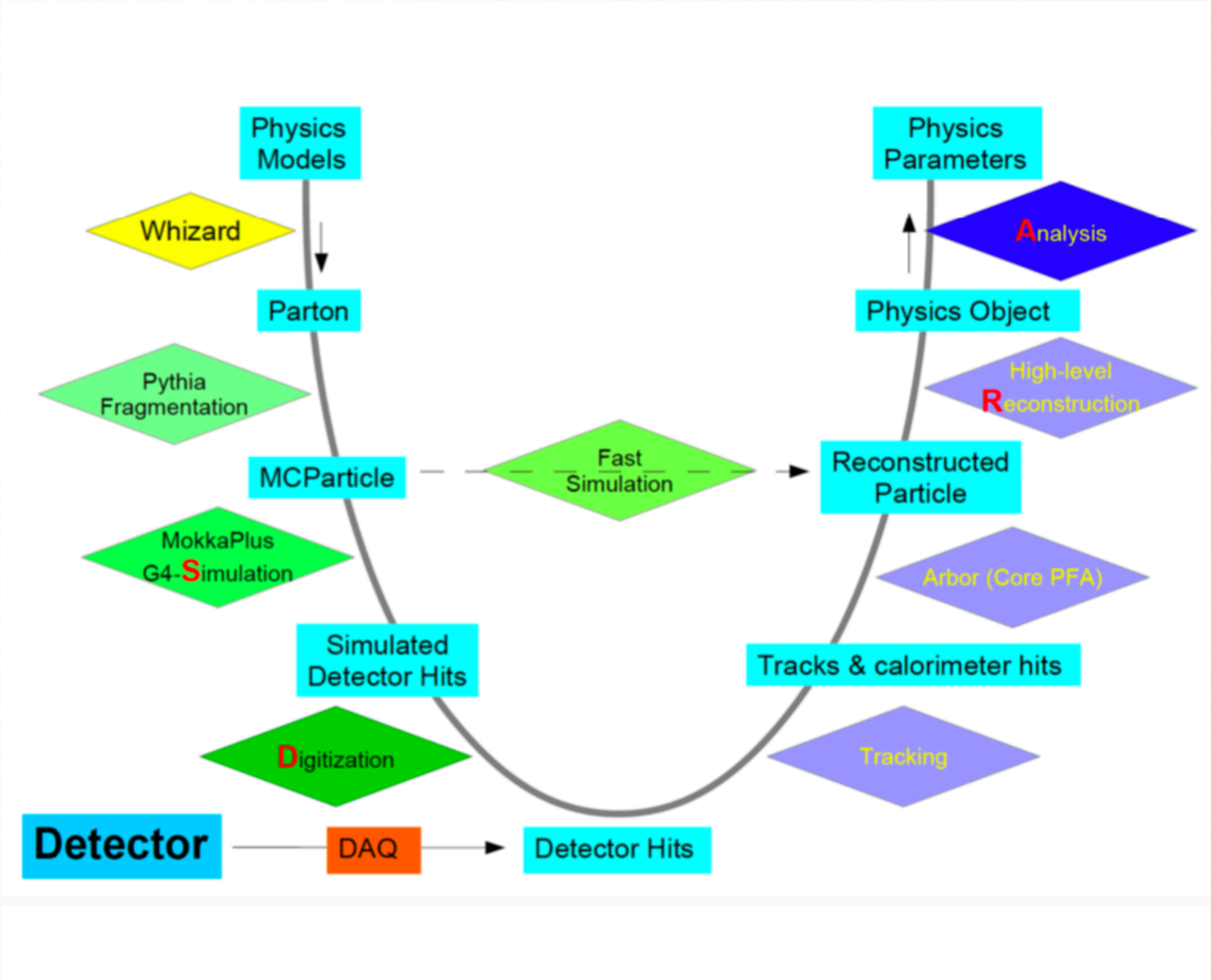




- Higgs factory: 240 GeV, 10^6 Higgs,
  - Advantage: Clean, Known initial states
  - Measurements: Higgs boson mass, cross section, decay modes, branching ratio
- Z factory: 91 GeV, 6×10^{11}
  - EW precision physics
- WW threshold runs, ~160GeV, 10^8
  - W mass/width measurement
- PFA Oriented detector
- Lepton identification is essential to the precise Higgs measurements/jet flavor tagging and the jet charge measurement
- Flavor physics in Z factory

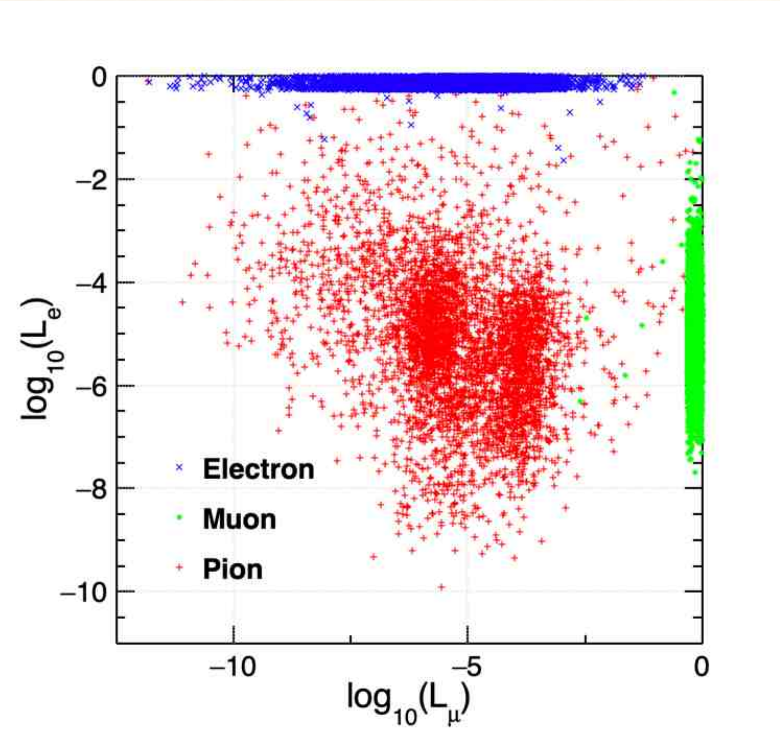
CEPC Full Simulation

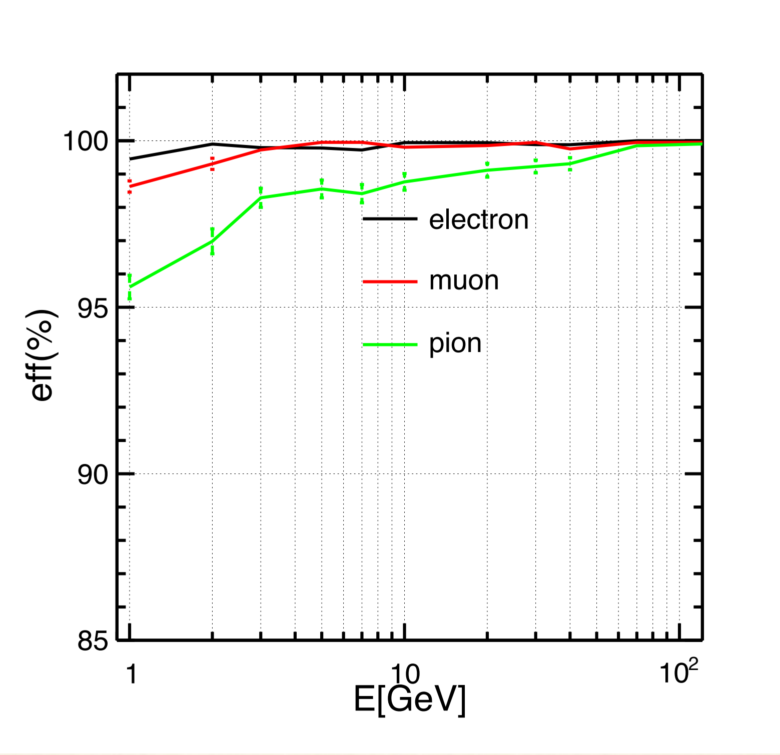
- Software chain
- CDR Samples:
  - Full simulated Higgs signal
  - small cross-section(<20 fb): simulated to a minimal statistic of 100k
  - 4 fermion background Full simulated
  - 2 fermion background: 20% simulated

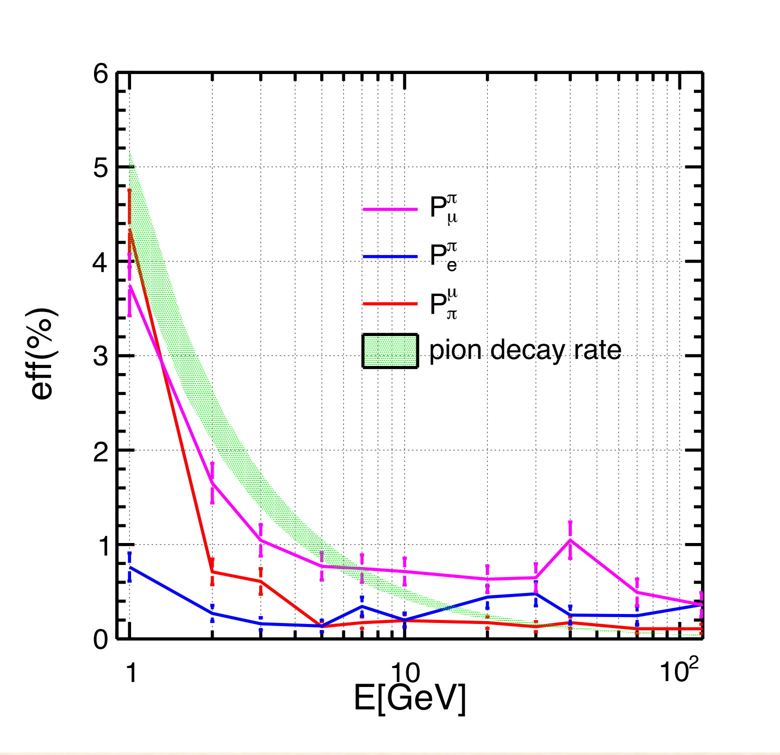


Isolate Leptons

- LICH uses TMVA methods to summarize 24 input variables into two likelihoods, corresponding to electrons and muons.
- The efficiency for electron and muon is higher than 99.5% (E>2 GeV). Pion efficiency ~ 98%.







Migration Matrix at 40GeV (LICH)

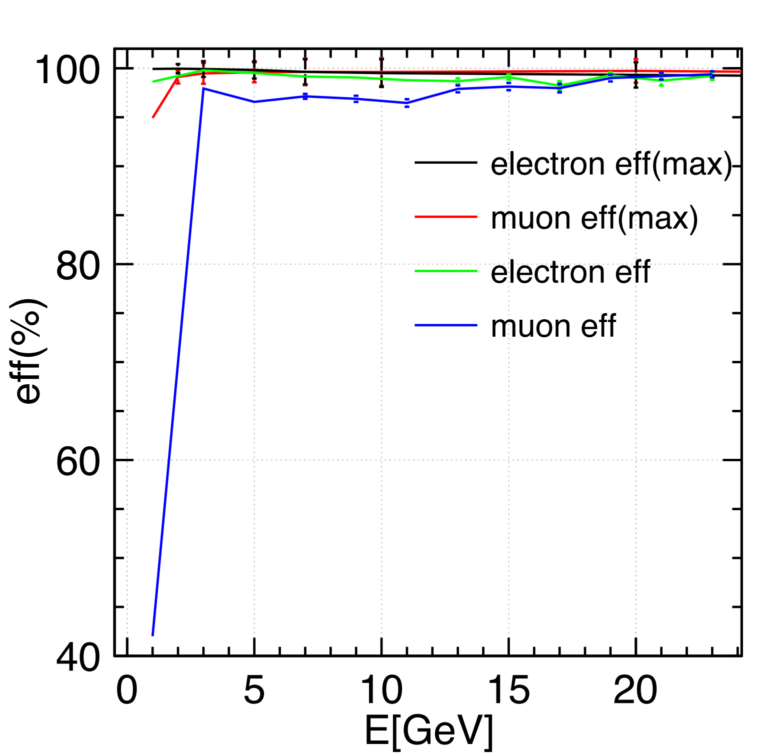
Type	e^- *like*	μ^- *like*	π^+ *like*
e^-	99.71 ± 0.08	< 0.07	0.21 ± 0.07
μ^-	< 0.07	99.87 ± 0.08	0.05 ± 0.05
π^+	0.14 ± 0.05	0.35 ± 0.08	99.26 ± 0.12

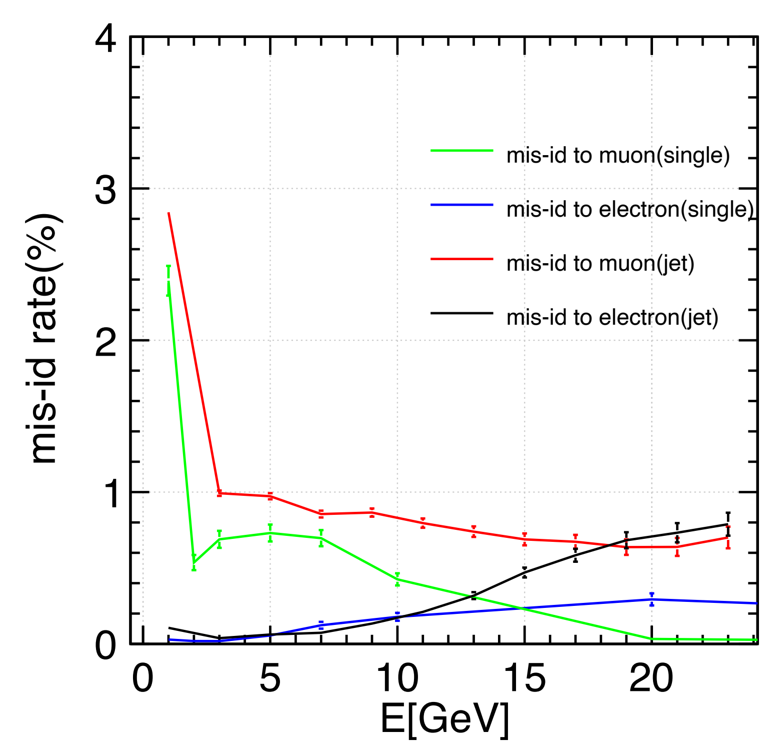
Migration Matrix for ALEPH PID ($> 2GeV$)(*Eur.Phys.J.C20:401-430,2001*)

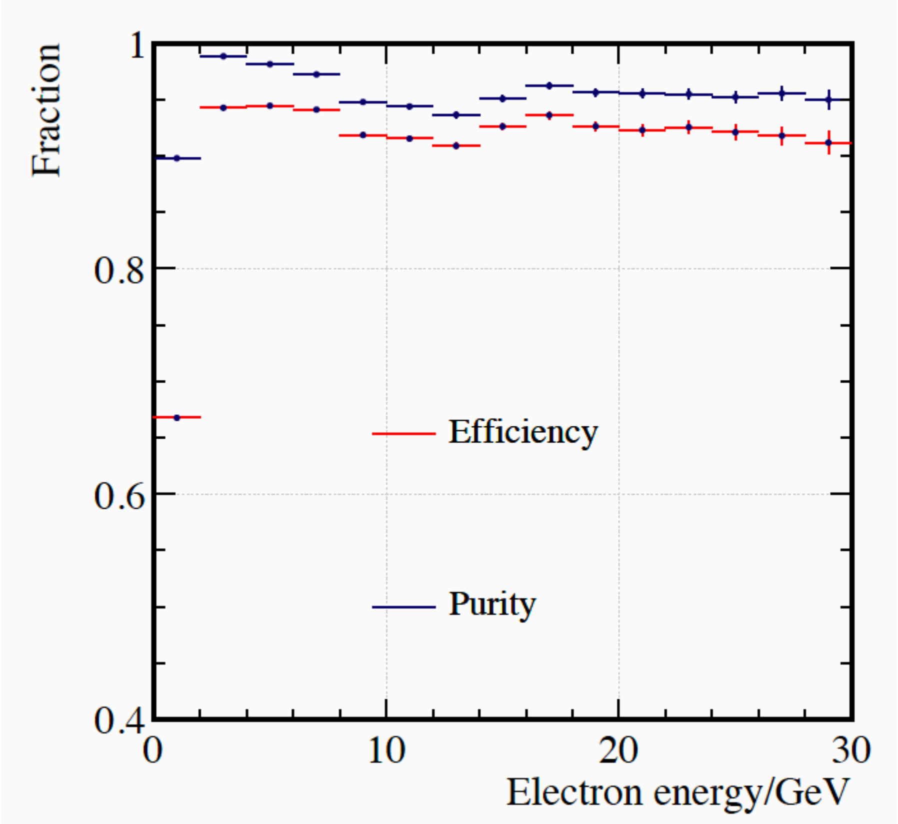
Type	e^- *like*	μ^- *like*	π^+ *like*	undefined
e^-	99.57 ± 0.07	< 0.01	0.32 ± 0.0	0.09 ± 0.04
μ^-	< 0.01	99.11 ± 0.08	0.88 ± 0.08	0.01 ± 0.01
π^+	0.71 ± 0.04	0.72 ± 0.04	98.45 ± 0.06	0.12 ± 0.03

Lepton in jets

- The performance for lepton in jets degrades comparing to the single particle results
- Application: Bc→τν



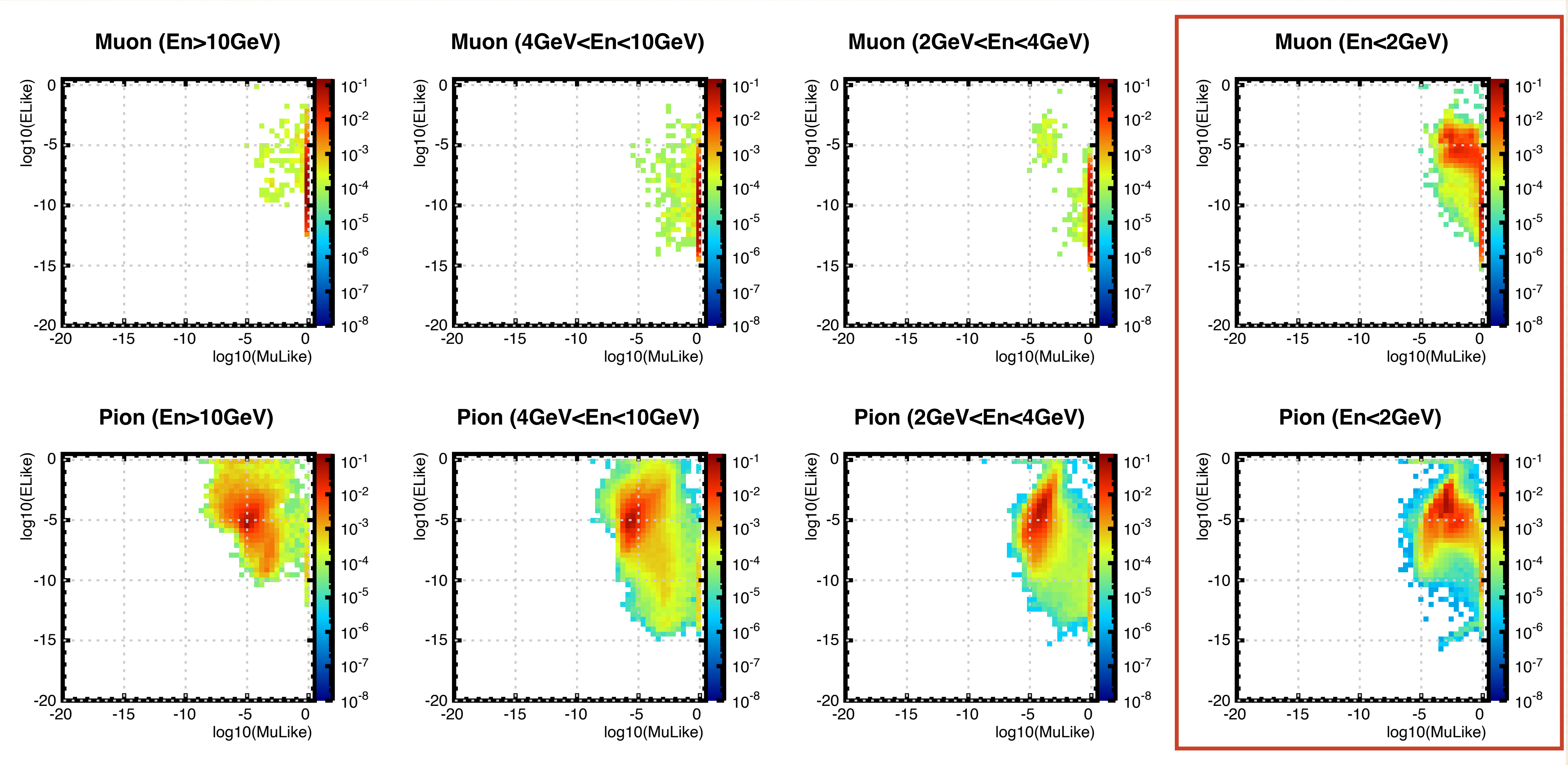




arxiv:2007.08234 by Taifan ZHENG

Likelihood vs Energy

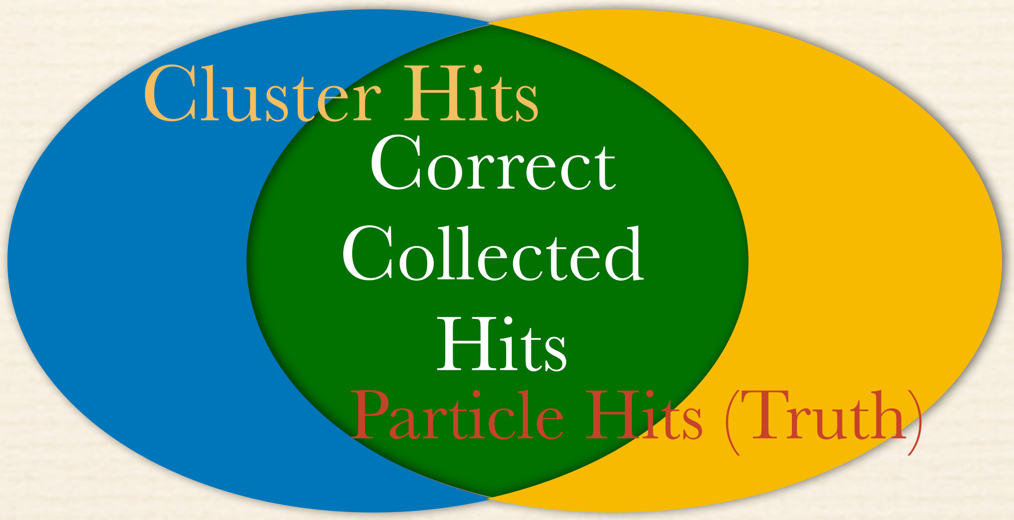
- For higher energy, still nice separation
- For lower energy, pion mixed with muon



Clustering Performance

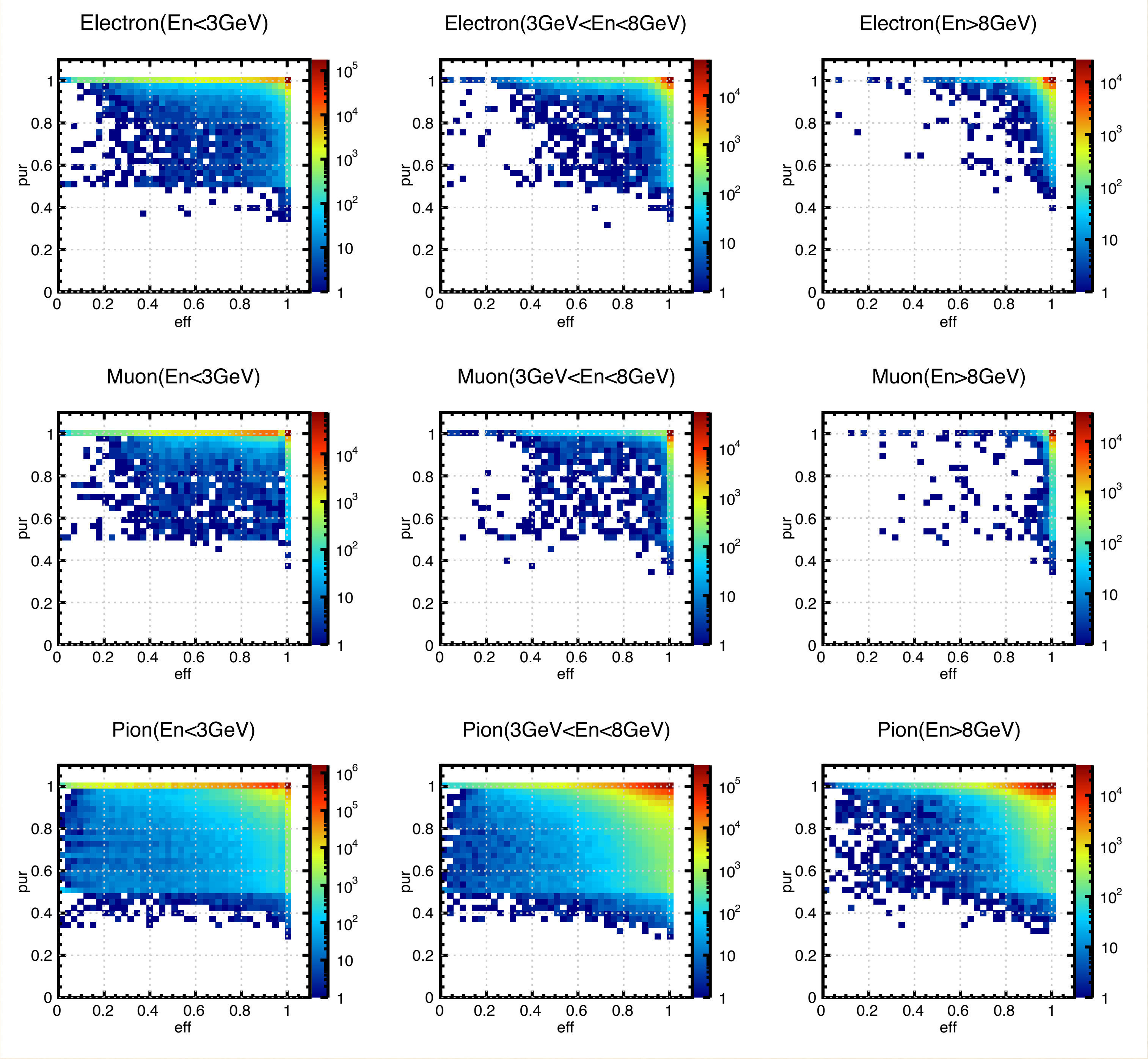
- Use clustering
  - efficiency (correct collected hits/particle hits)
  - purity (correct collected hits/cluster hits)

to characterize clustering performance



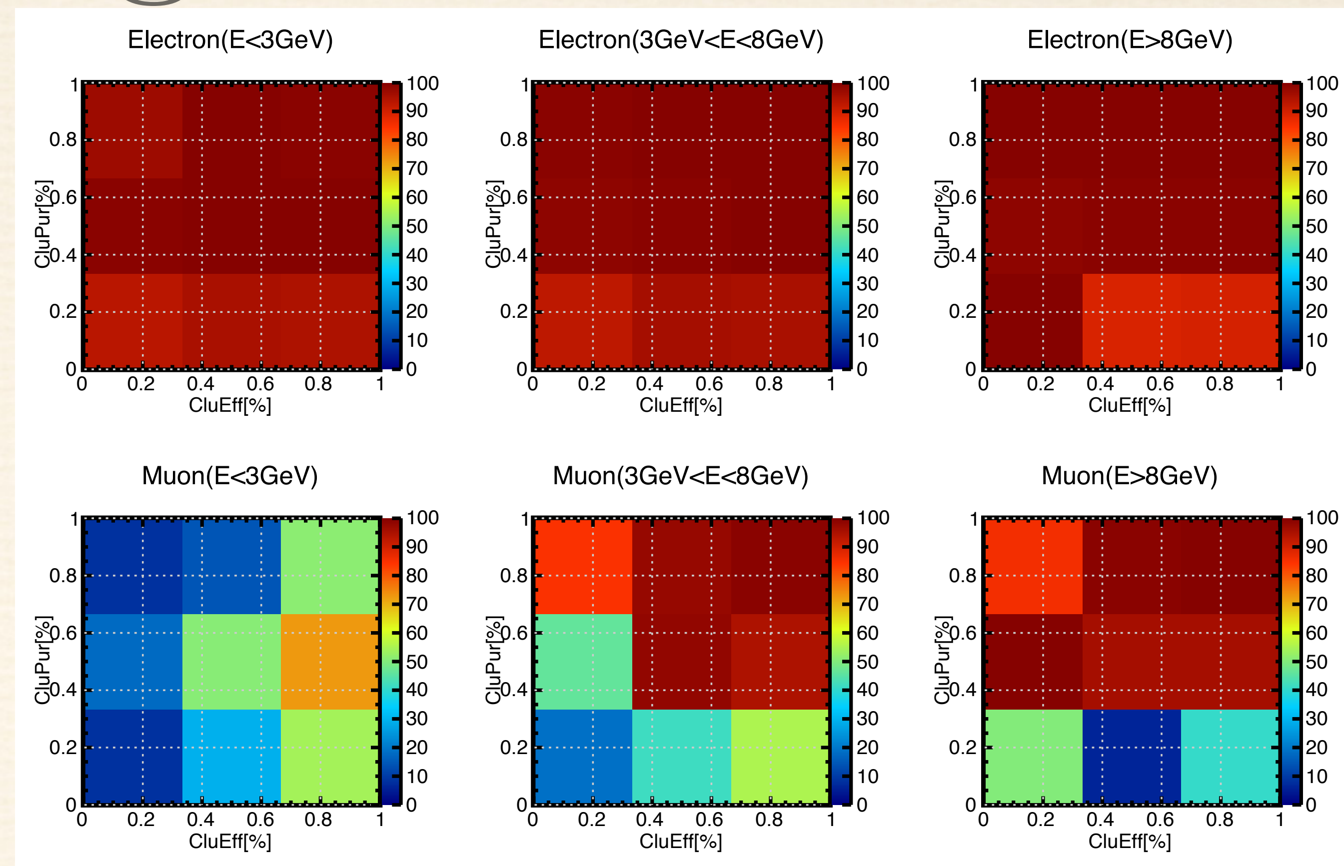
Clustering Performance

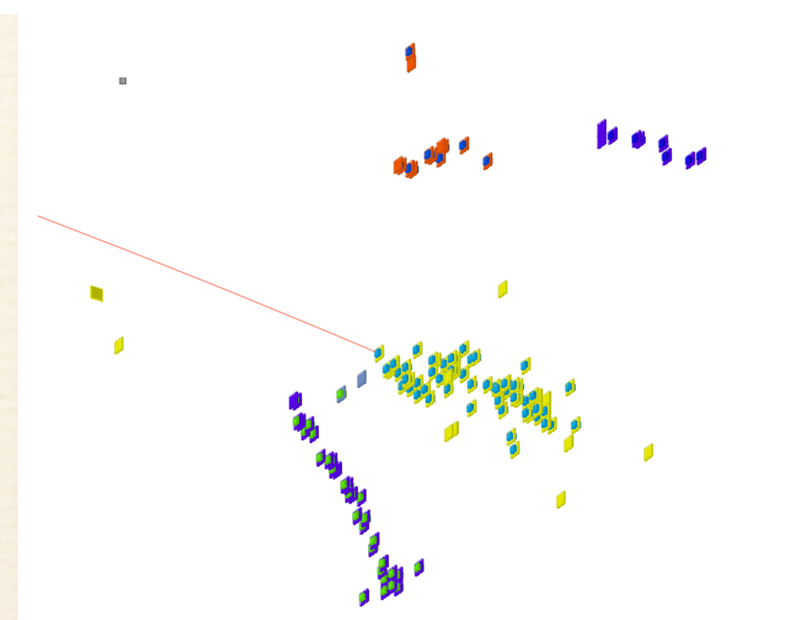
- Higher energy, better clustering performance
- Muon:
  - 85% perfect
  - 5% eff*pur< 0.9
- Electron:
  - 64% perfect
  - 22% eff*pur<0.9
- Pion:
  - 52% perfect
  - 24% eff*pur<0.9



Clustering vs PID

- Electrons:
  - low energy: dE/dx dominate
  - clusters are compact, the splitting clusters still electron-like
- Muon:
  - cluster is not MIP-like if mixed with other hits
  - muon likeliness is lost when the muon cluster splits into small pieces
- Pion:
  - likely to be a EM cluster with some branches
  - more likely to be mis-identified as an electron for lower clustering efficiency





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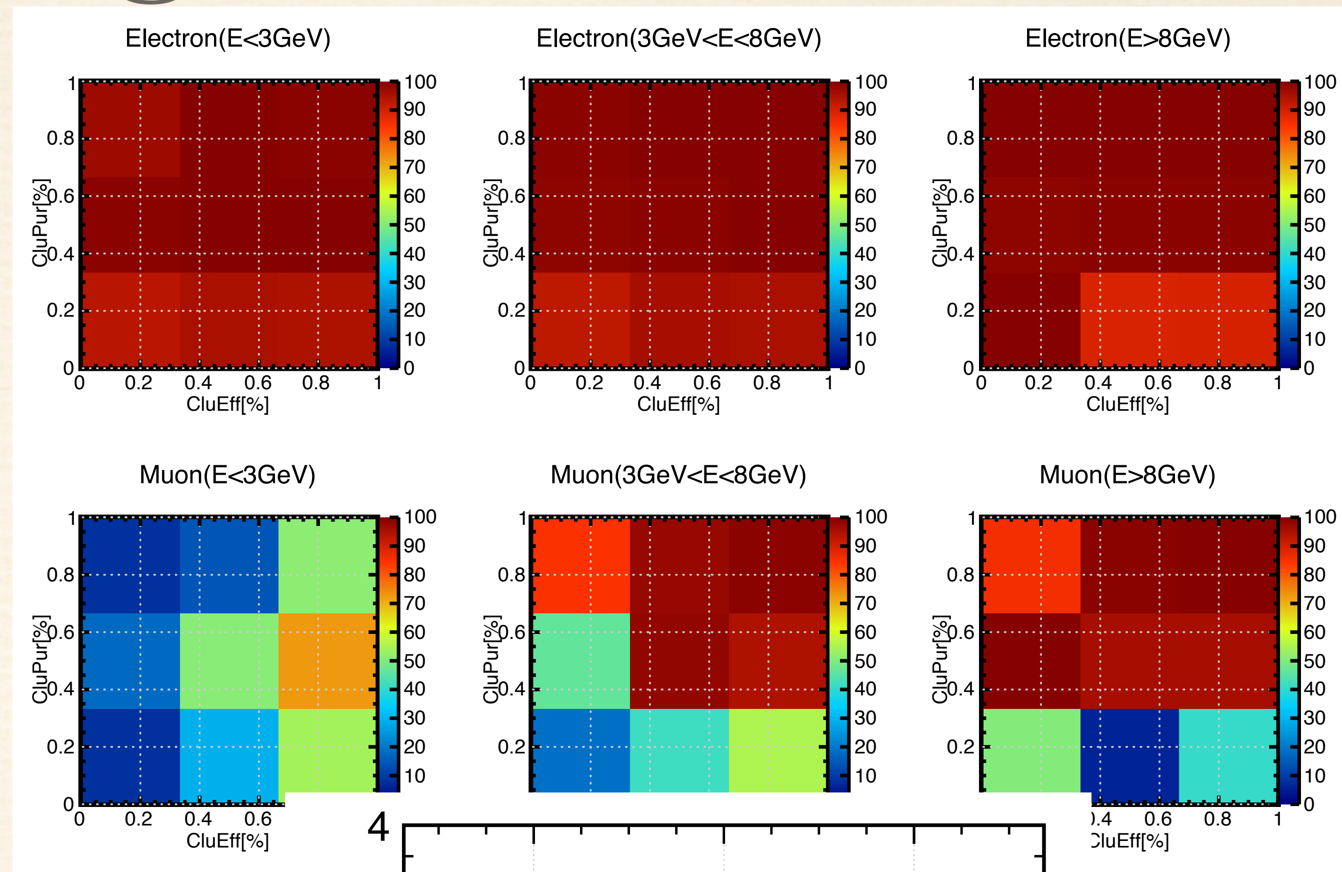
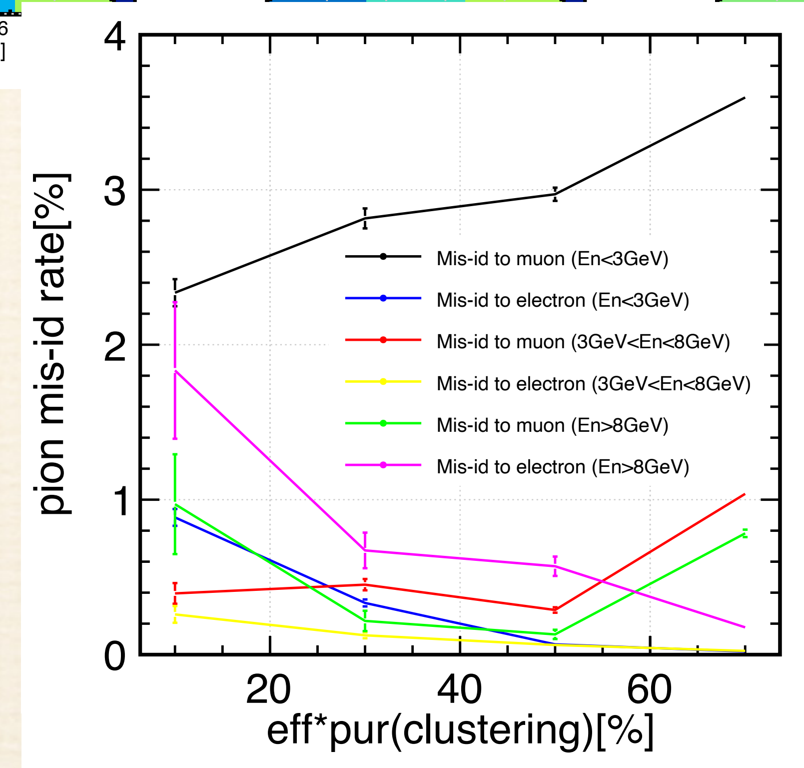
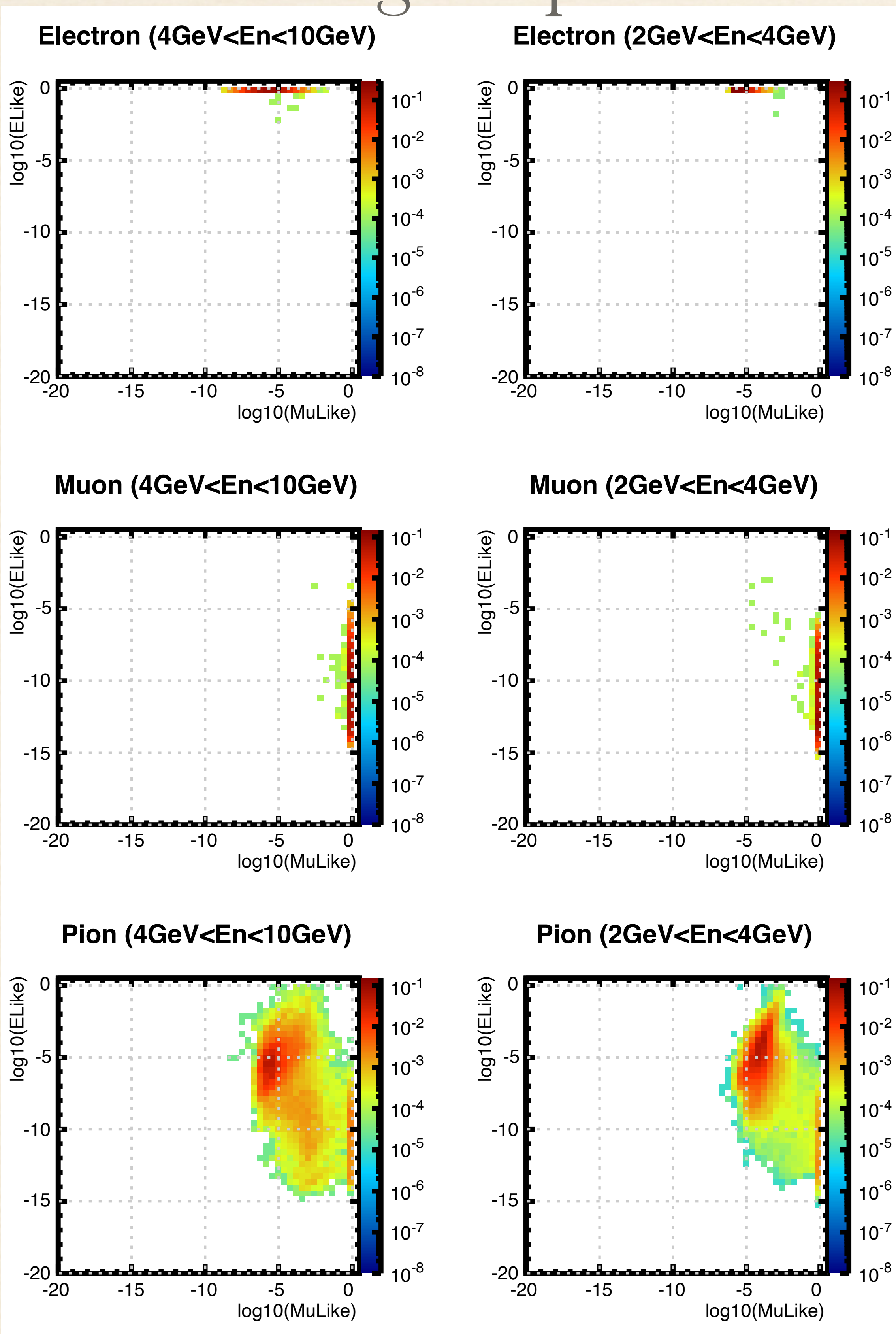
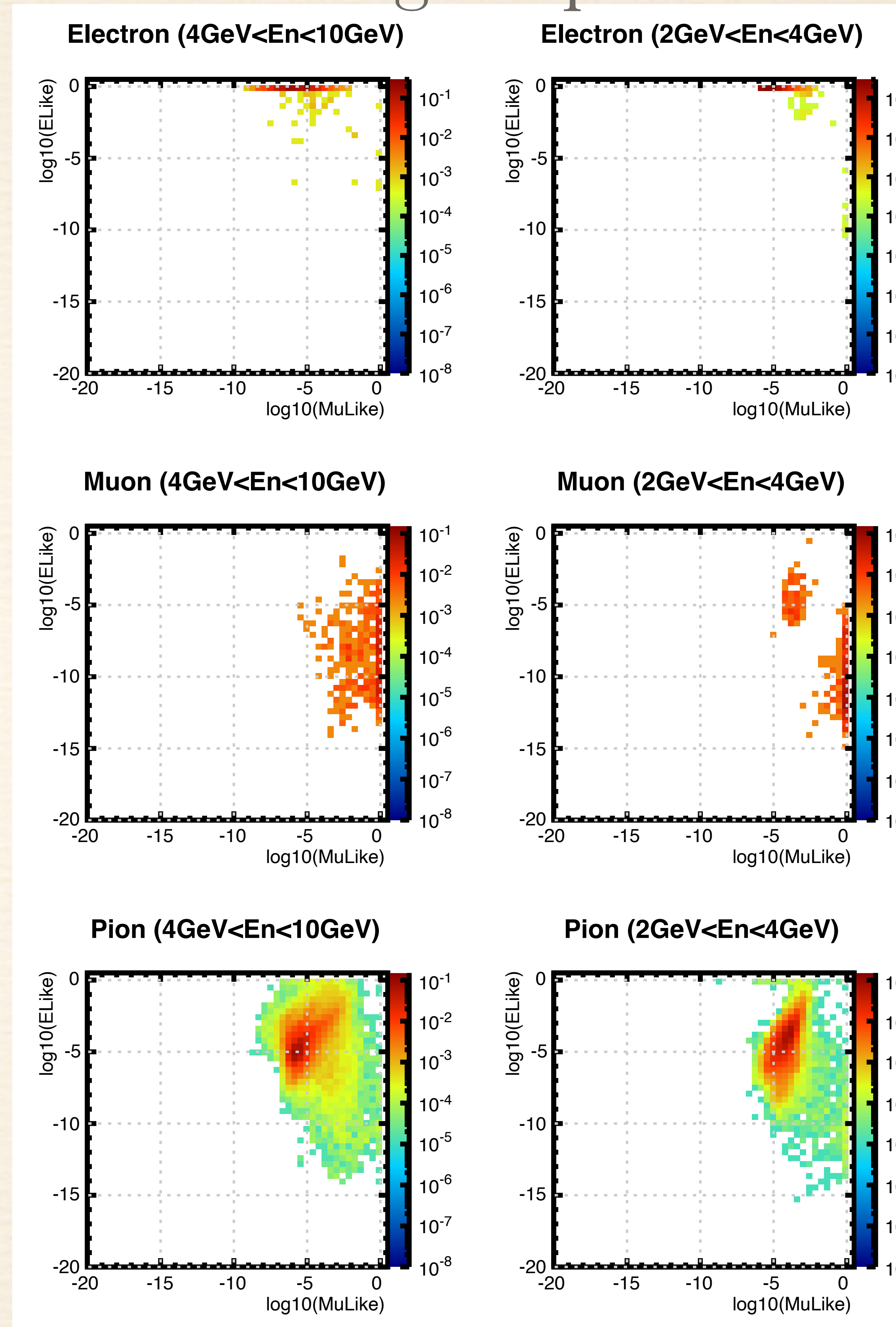




Clustering eff*pur=1

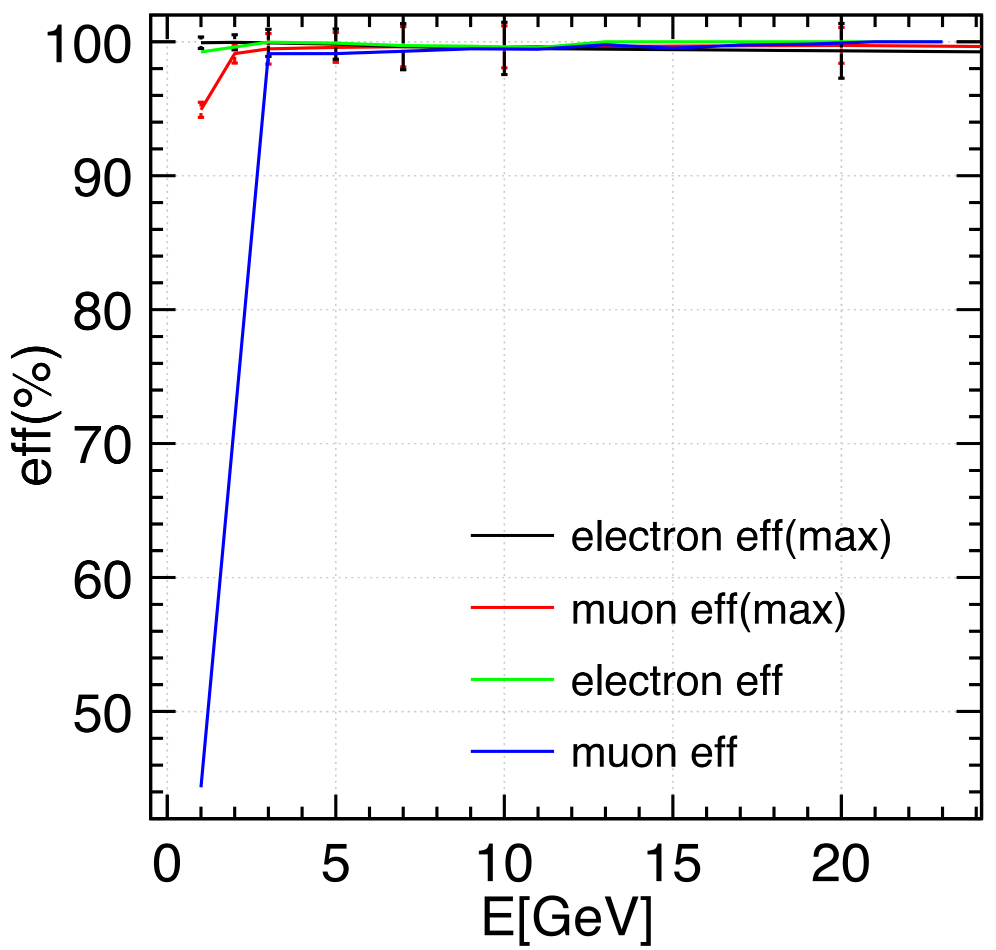


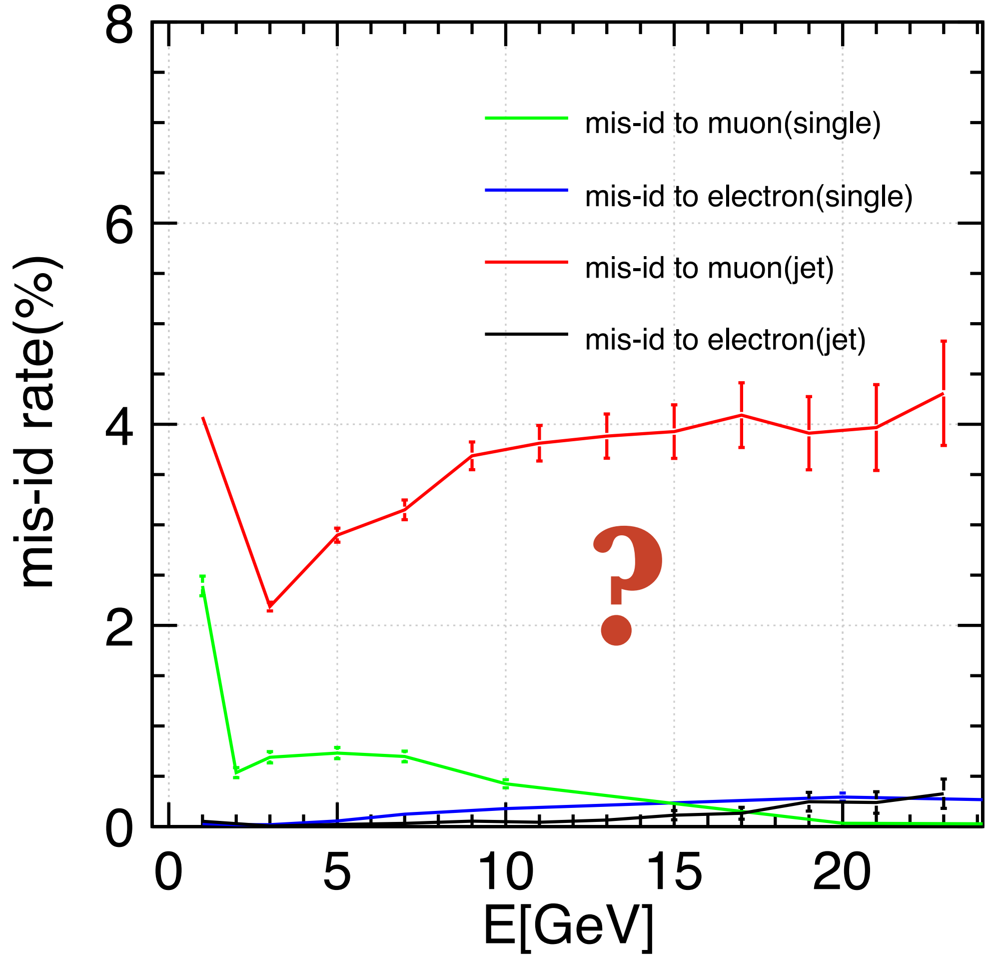
Clustering eff*pur<0.9



Comparison

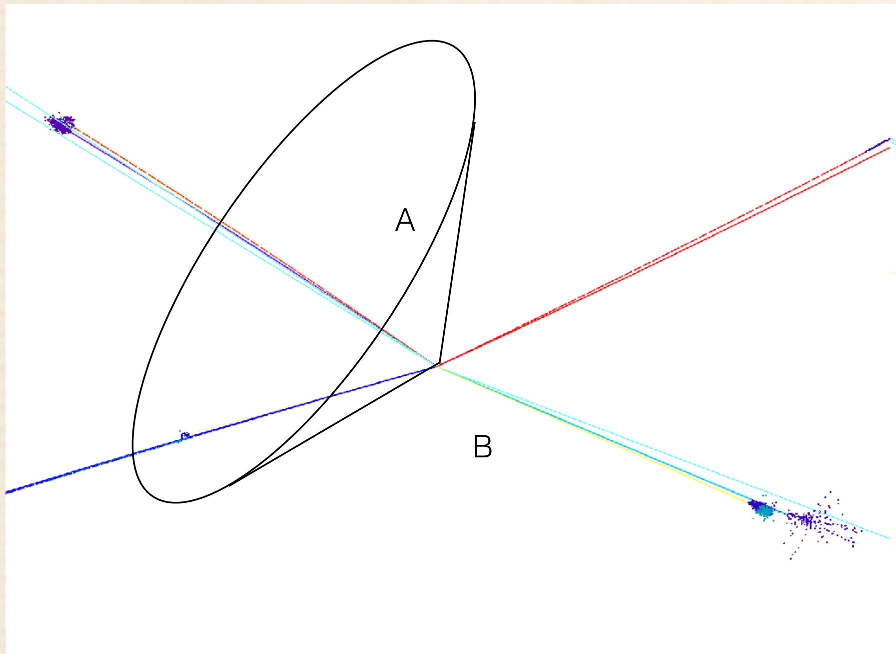
- Comparison of lepton identification performance for perfect clusters and the performance of single particle
- Pion in jets more likely to be mu-like





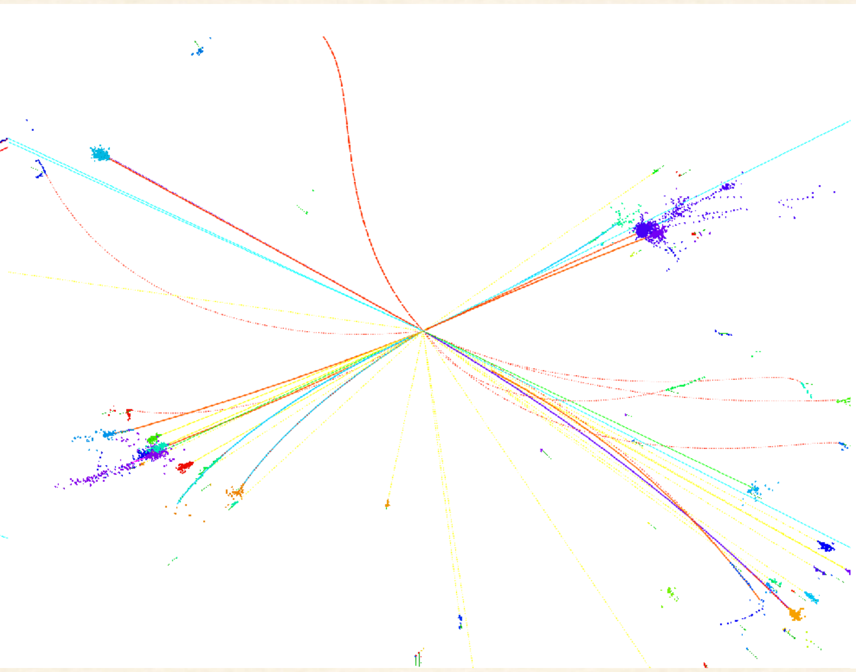
Tau event topology

- llH channel / $Z \to \tau\tau$



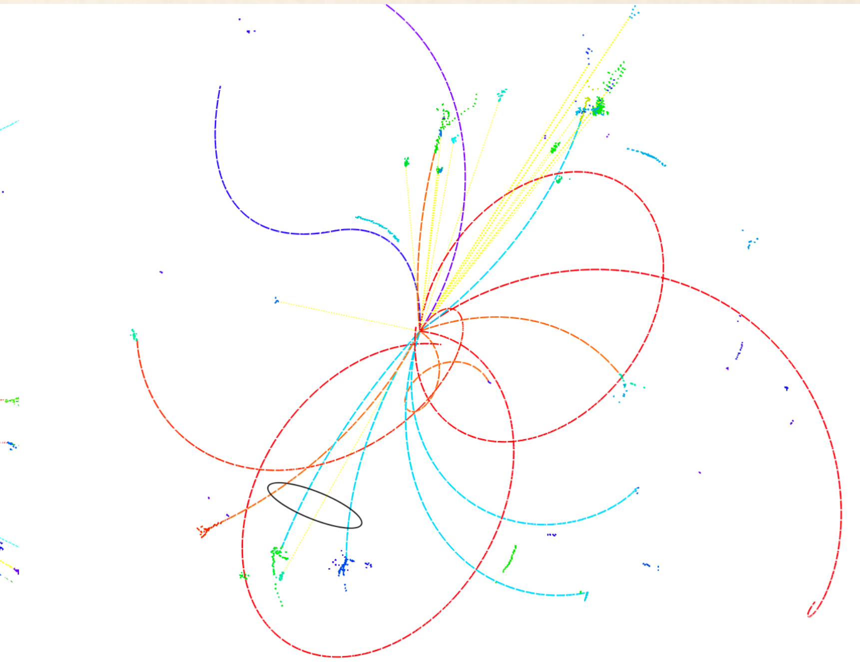
- (Veto the two isolate lepton)
- Divide the whole space into 2 part
- Multiplicity & Impact parameter

- qqH (isolate τ with jets)



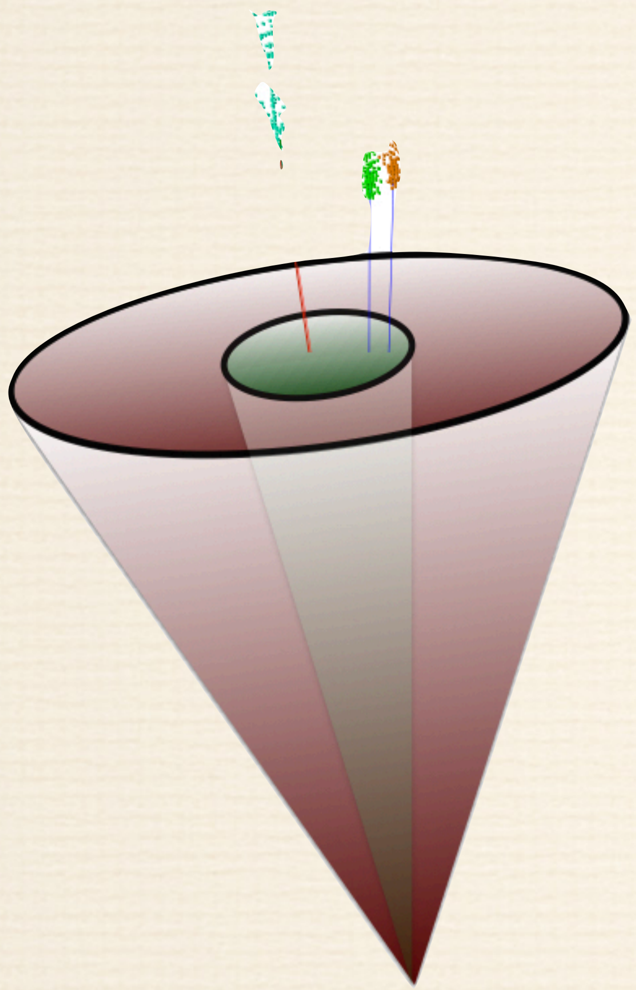
- Tau jet reconstruction package: TAURUS

- τ inside jets



- TAURUS with different parameters

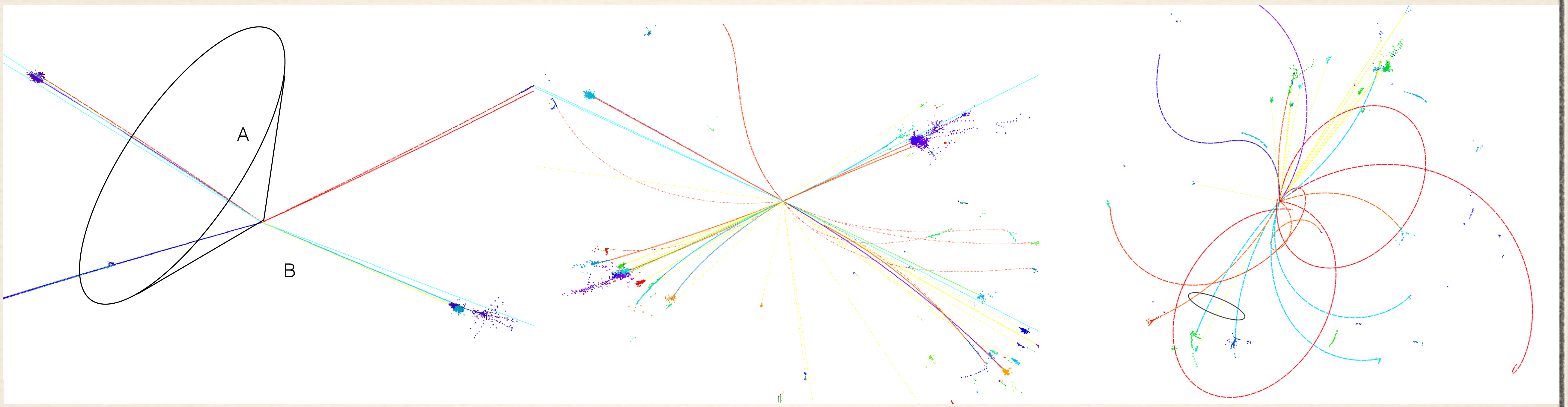
Taurus



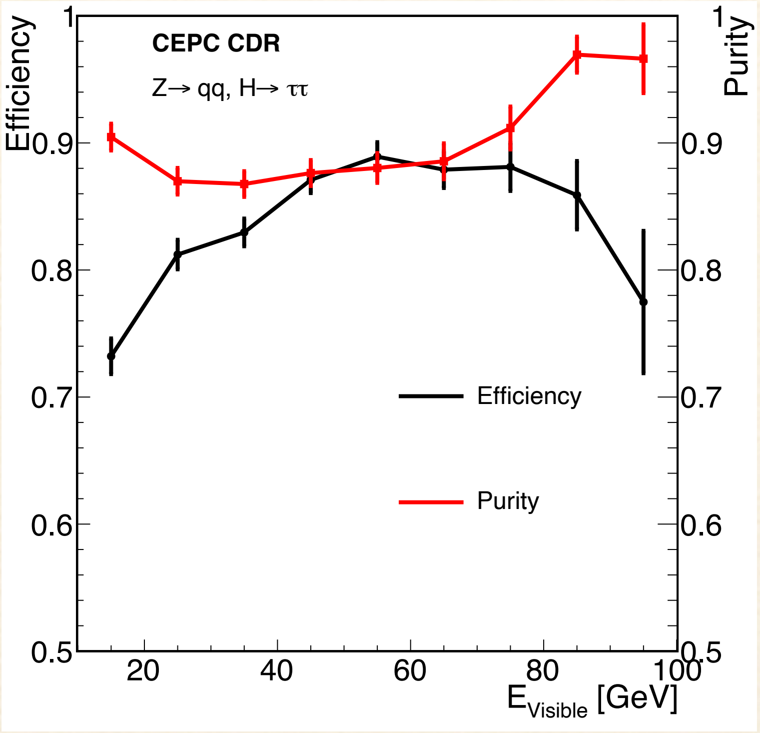
- Double cone based algorithm
  - Find seeds(Tracks with enough energy)
  - Collect particle in two cones
  - Use the multiplicity, energy ratio between two cones, invariant mass for τ tagging

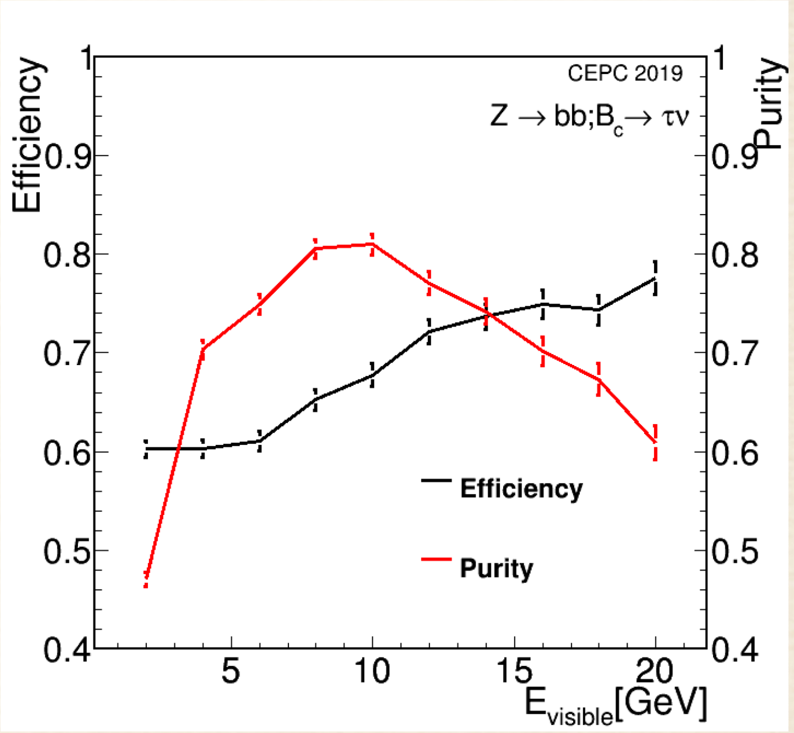
Event topology

- llH channel / Z→ττ
- qqH (isolate τ with jets)
- τ inside jets



- (Veto the two isolate lepton)
- Divide the whole space into 2 part
- Multiplicity & Impact parameter
- Efficiency > 90%





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Summary

- TMVA based lepton identification has been developed with high efficiency
  - For >2GeV isolate lepton: 99.5%
  - For leptons in jets, clustering performance defined (testbed)
  - At perfect clustering (eff*purity=1), identification performance converge to isolated lepton cases
- Inclusive τ identification developed
  - isolate τ efficiency/purity ~ 80%/90%
  - τ in jet efficiency/purity ~ 70%/70%
- Application
  - Flavor physics: Bc→τv
  - Flavor tag

Thank you for your attention!