PFA (Particle Flow Algorithm) at University of Iowa

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Outline

1. PFA overview
    - Photon, Electron and Muon ID
    - Track and Seed cluster
    - Building charged shower
    - Reconstructing particles
2. Progress since Boulder workshop
3. Muon ID study

Photon ID & Electron ID & Muon ID

- Initial "photon" cluster obtained by Ron's Photon Finder
- Break down these into three categories
  - No track matched : Pure photon
  - Track matched & E/p ≈ 1 : Electron
  - Other : consider possibility of overlap as hadronic shower.
- Muon
  - Find MIP direction in Muon detector and match with the direction of extrapolated track from tracker.
  - Detail later
- These hits do not participate in building clusters except for the overlaps.

DirectedTree Cluster

Next step is running DTree clustering package

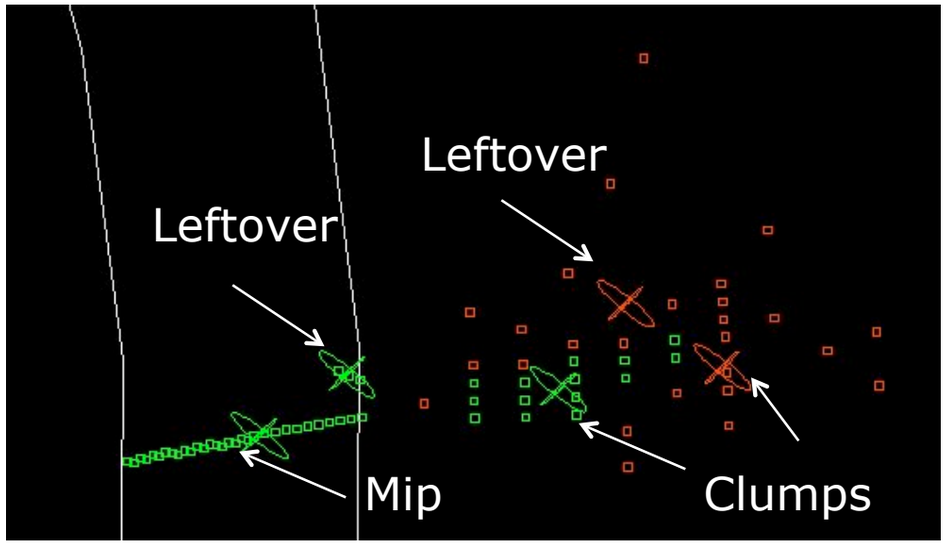
Ecal Digi Hits(Barrel, Endcap)			Hcal Digi Hits (Barrel, Endcap)		
Photon, Electron, Muon	DTree cluster (Ecal Barrel)	DTree cluster (Ecal Endcap)	Muon	DTree cluster (Hcal Barrel)	DTree cluster (Hcal Endcap)

DTree cluster

- MIPs: A continuous sequence of single hits
- Clumps: Group of hits with high density
- Blocks: No structure, if(>= 20hits in ECal, >=15 hits in HCal)
- Leftover: No structure, small number of hits (Share with others)

- Leakage

Some of high energy shower escapes Hcal, reaching Muon Detector. Adding the energy by using Muon Endcap as tail catcher give better resolution. (Currently not using Barrel)



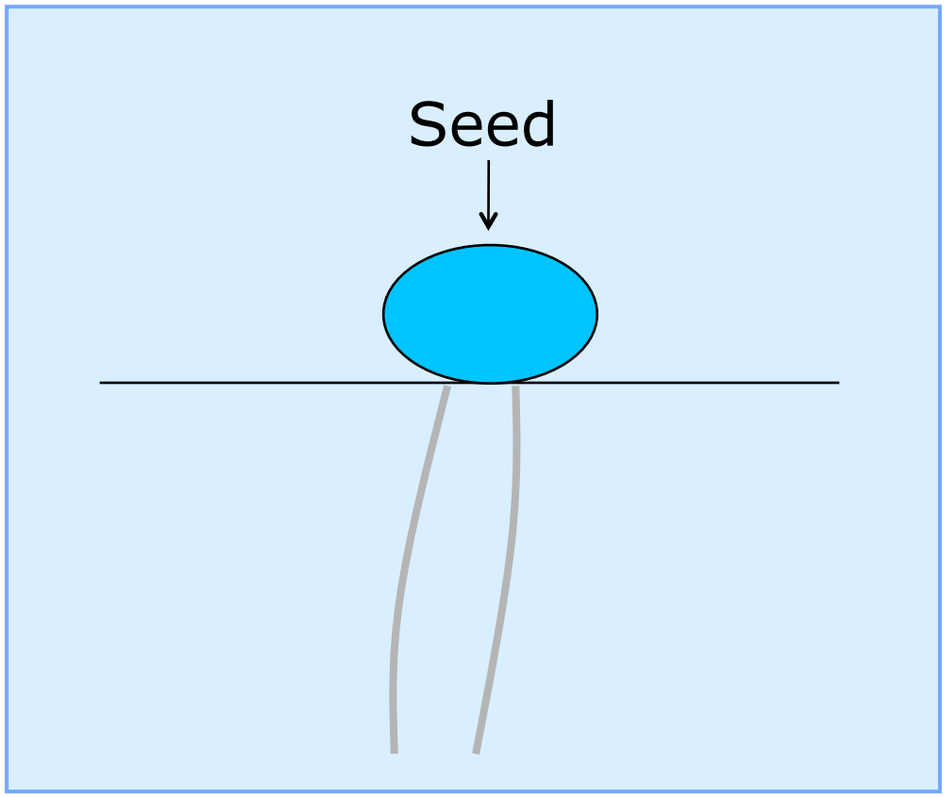
Track and Seed

- For production version Full propagation track is used
  - Cheater track for development
- Of course the resolution is better for cheater track.

- Start building shower from seed
- Seed: Cluster directly connected to extrapolated track.
- Each track has one seed typically.
- Handle special cases
  - Track doesn’t reach calorimeter
  - Track reach calorimeter but no seed found

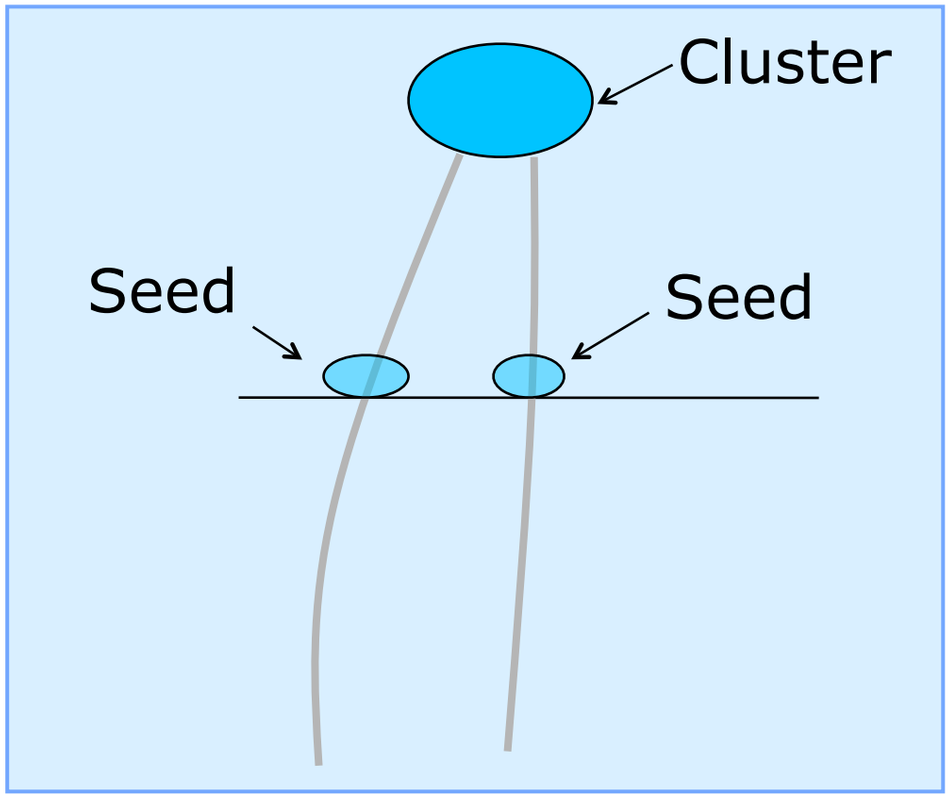
Merging track case

Case 1



Make “multiple track” for E/p check. Written out as 2 separate charged particles in the end.

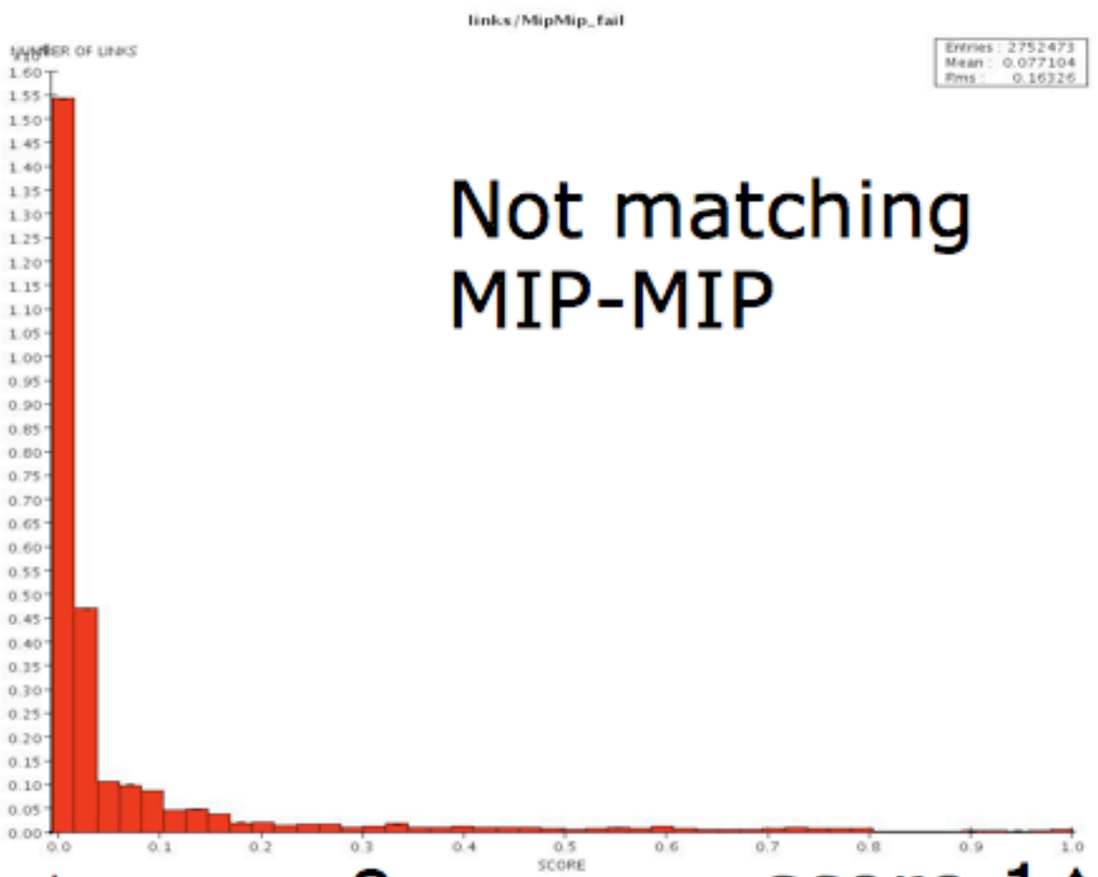
Case 2

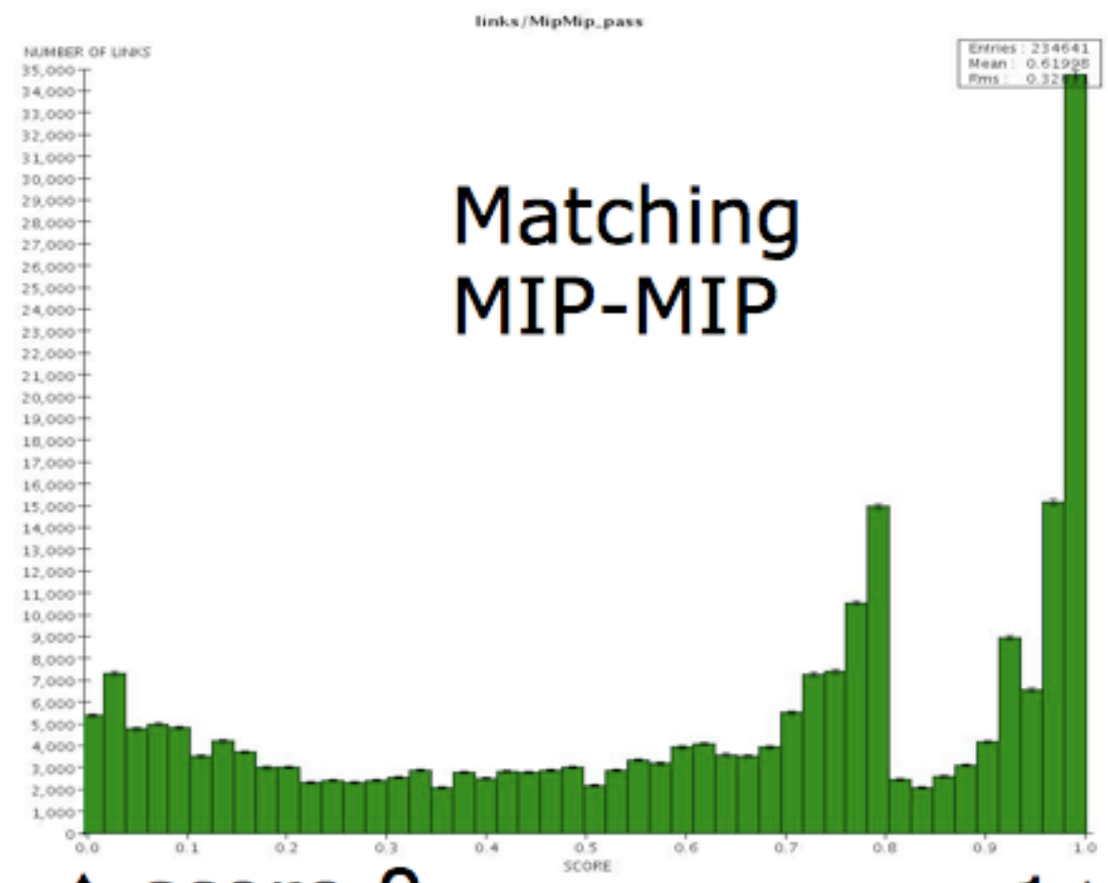


Going into same cluster leading to connecting seed. Put it together for E/p check

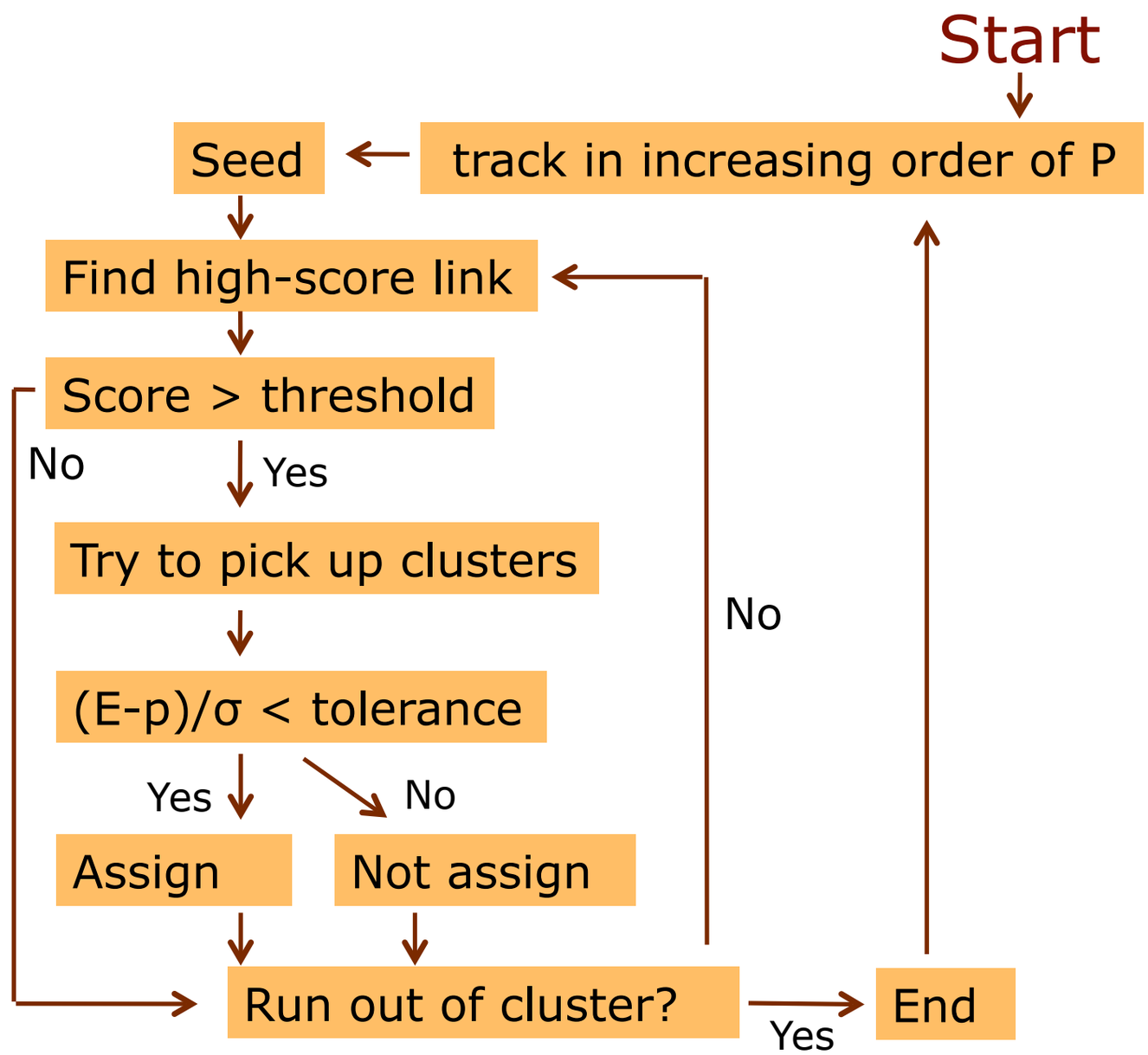
Scoring

- We assigned "Score" to the link based on how closely two clusters are related.
- It is based on the geometric quantities.
- Score ranges from 0 to 1





Finally building shower



If incomplete track(E<<p),
adjust tolerance/threshold and go back to the whole iterating.

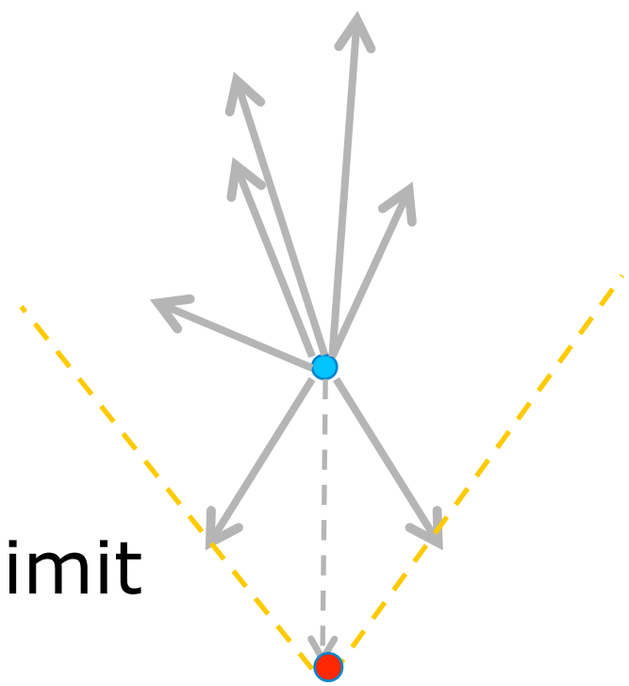
Fixing Mistakes

1. Override

Find high score link to the unassigned cluster.
Check if the corresponding cluster has track matched.
Add this cluster as long as E/p is low.

2. Reassignment

Make unassigned cluster list
Get an angle for each cluster with track
Veto if score < 0.7
Add clusters in angular order
Add clusters subject to tight E/p upper limit
Veto if the cluster is too huge (E>>p)



Neutral hadron shower

- The remaining cluster after assigning as charged and photon cluster are going to be neutral hadron clusters.
- Make neutral shower by looping over unassigned clusters in the same way we did for charged clusters.(But neither E/p cut or any adjusting threshold for score)
- Each set of shower clusters becomes one neutral particle.
- If the whole shower is deposited in ECAL, treat it as photon.

Reconstruct Particle

- **Photon** has one cluster and no mass. 4-vector is based on position and energy of the cluster.
- **Electron** has one cluster and one track. 4-vector is based on the track momentum and electron mass.
- **Muon** has one cluster and one track. 4-vector is based on the track momentum and muon mass.
- **Charged particle** is reconstructed with 4-vector based on the track momentum and pion mass.
- **Neutral particle** is reconstructed with 4-vector based on the position and energy of the cluster and kaon mass.

Update since Boulder

- Rearrangement by Mat
  - Take photon, electron and muon out of the main code.
  - Easy to maintain, code simpler
  - Reduce mistake in bookkeeping
- Muon ID study
  - Identified as Muon, no need to build shower. (reduce confusion from misidentification as hadron)
  - Focus on high momentum track. (reaching Muon detector)

Muon ID Study

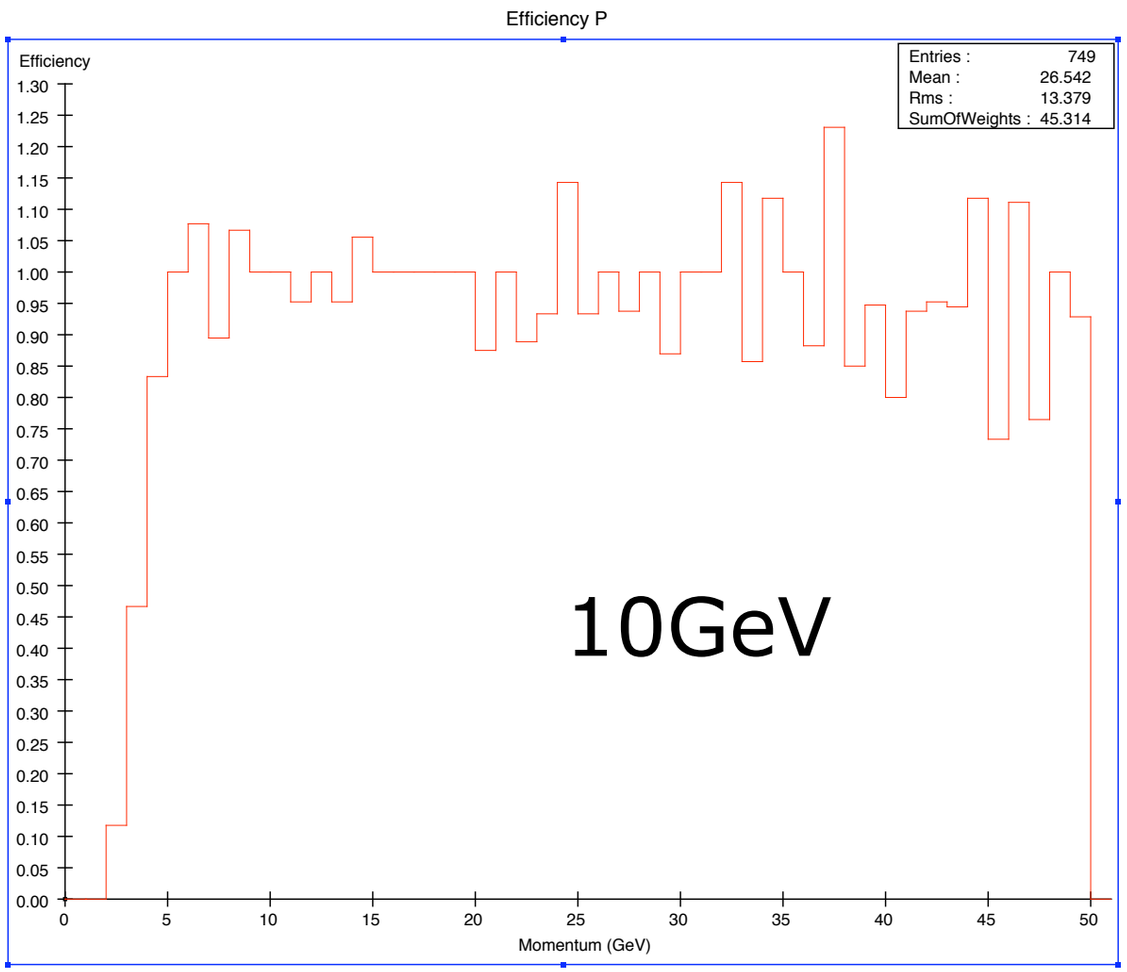
- How to identify high momentum muon (Simple way)
  - Using Digi hits (Endcap and Barrel)
  - Compare the direction of MIP in Muon detector and tangent direction of extrapolated track at the surface of calorimeter.

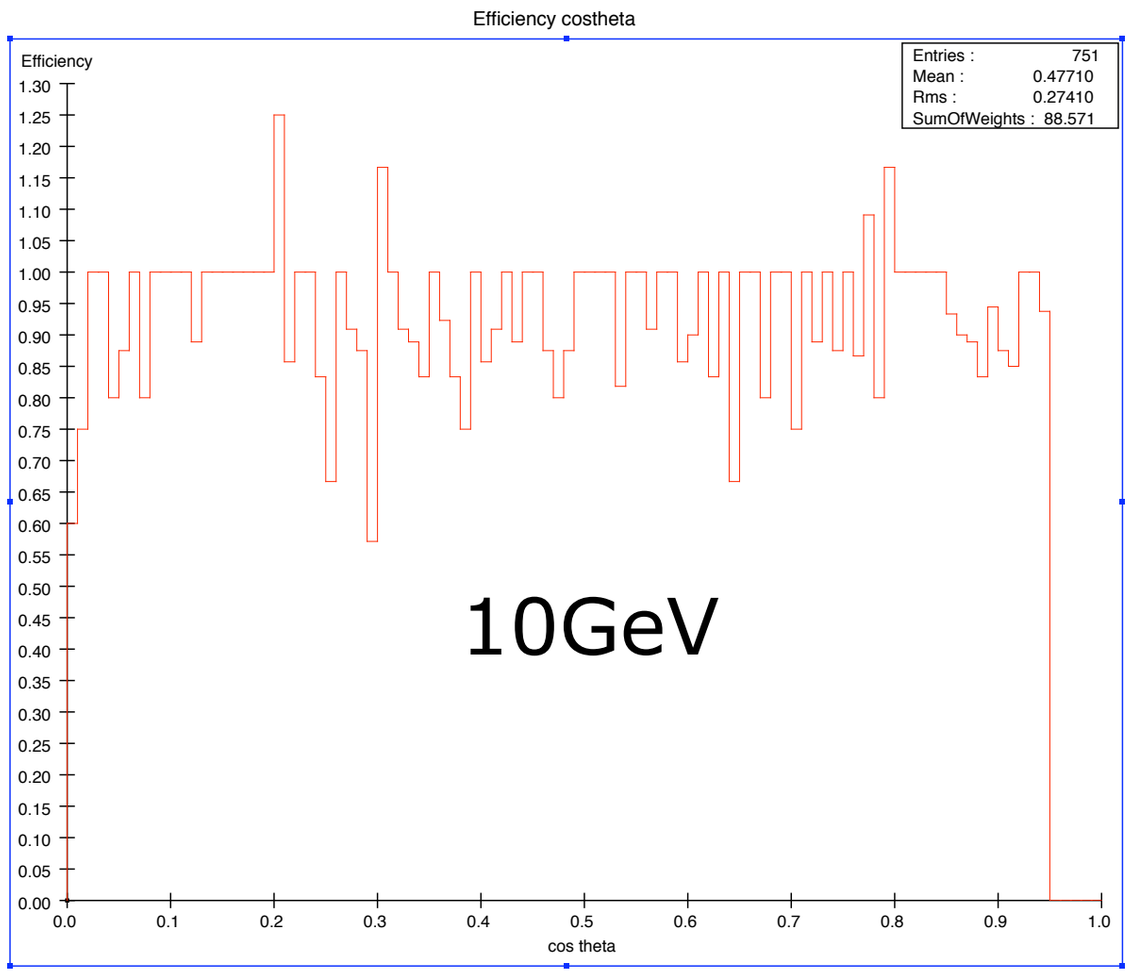
- Requirement
  - Muon MIP quality cut in the Muon detector. (at least 3 isolated hits)
  - Muon is supposed to behave like MIP going through out the detector without showering. We require a MIP-like behavior through the Ecal and the early layers in Hcal (allowing missing hits in the last 10 layers of Hcal).

Muon Efficiency

Single Muon 1000 events, preselection : cos(θ) < 0.95

P	Cheater track	Full track	MC
1GeV	0	0	816
2GeV	0	0	816
5GeV	801(98%)	801(98%)	816
10GeV	801(98%)	803(98%)	816

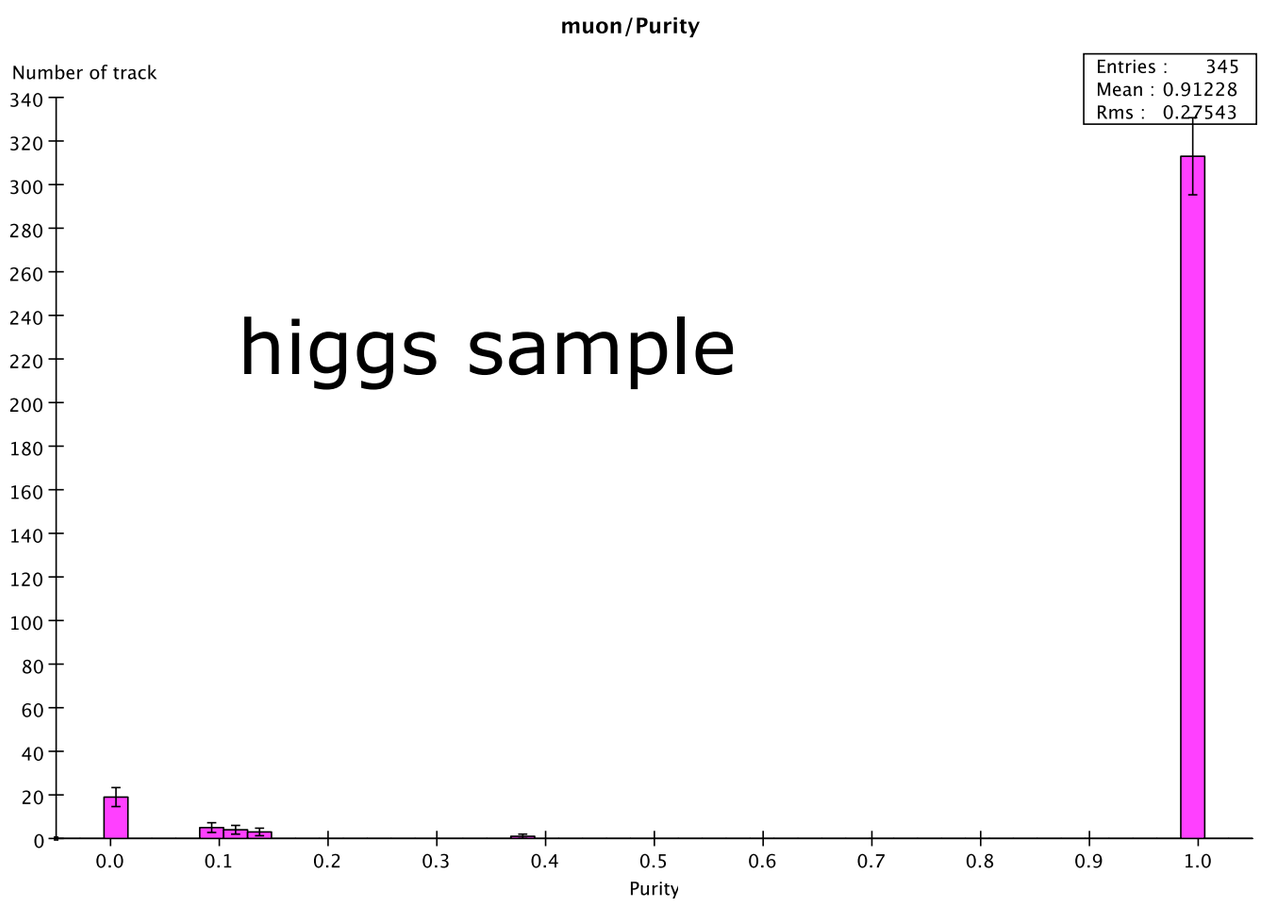




Muon Efficiency

Preselection : cos(θ) < 0.95 , P > 2GeV

Sample (1000events)	Cheater track		Full track		MC
	Purity	Efficiency	Purity	Efficiency	
ttbar (500GeV)	513(88%)	583(51%)	476(84%)	565(49%)	1143
higgs (250GeV)	327(93%)	350(57%)	313(91%)	345(56%)	615



Purity
= number of hits from muon divided by number of hits from tracks

Future Plan

- Continue to improve resolution
- Low momentum muon identification
- Energy dependent optimization for scoring
- Use Muon Barrel system as tail catcher
- Consider Energy Flow Algorithm for high energy jets.