A PFA used by SiD

by

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A short overview

Goal: To obtain dijet mass resolution $\Delta M/M < 3\text{-}4\%$ (Z width)

➔ $\Delta E(cm)/E(cm) < 3\text{-}4\%$ for $e^+e^- \rightarrow qq$ (q=u,d,s)

Resolution for PFA :

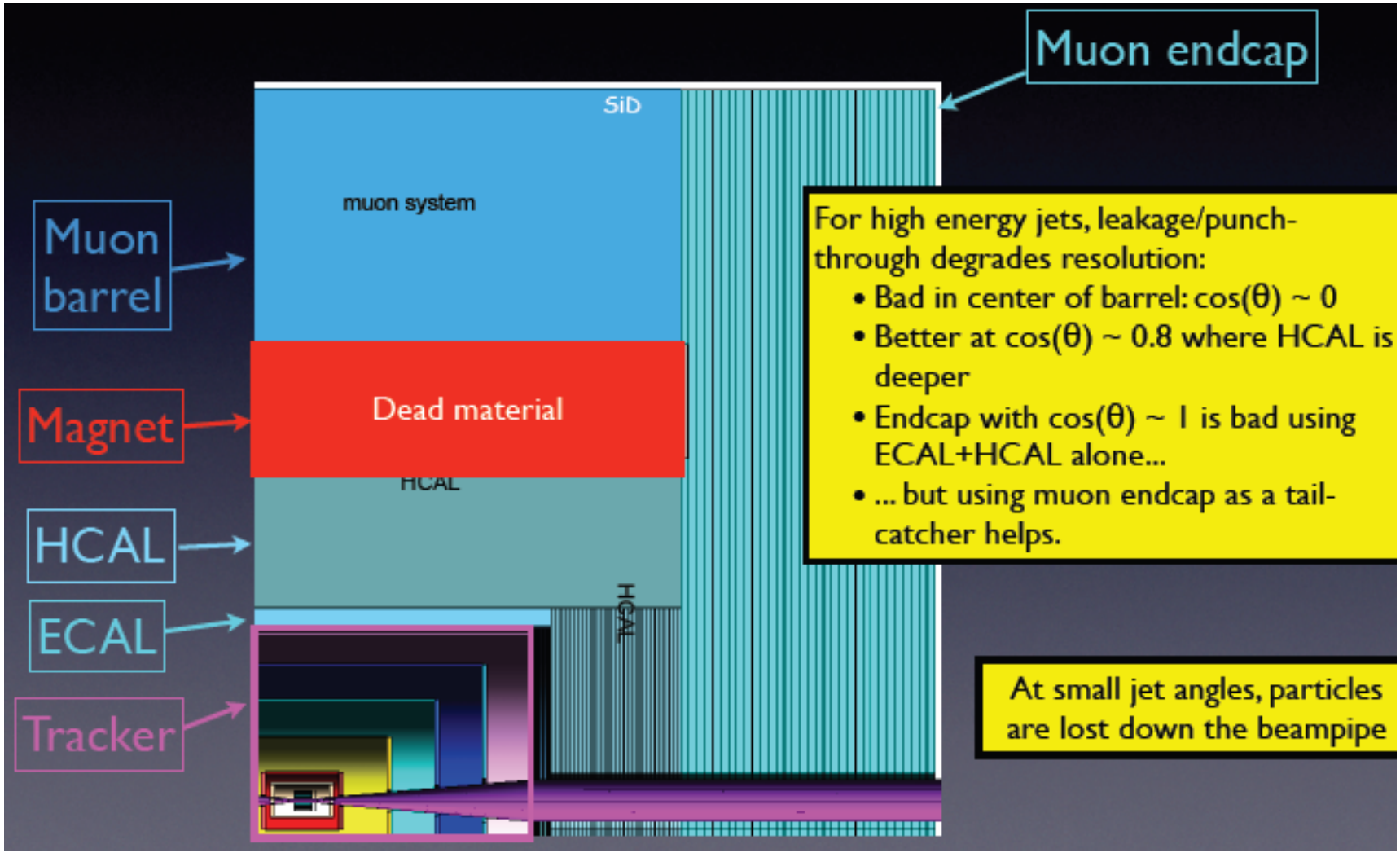
$$\sigma = \sigma_{EM} \oplus \sigma_{neu.had} \oplus \sigma_{conf}$$

Attempt to minimize σ_{conf} in the PFA

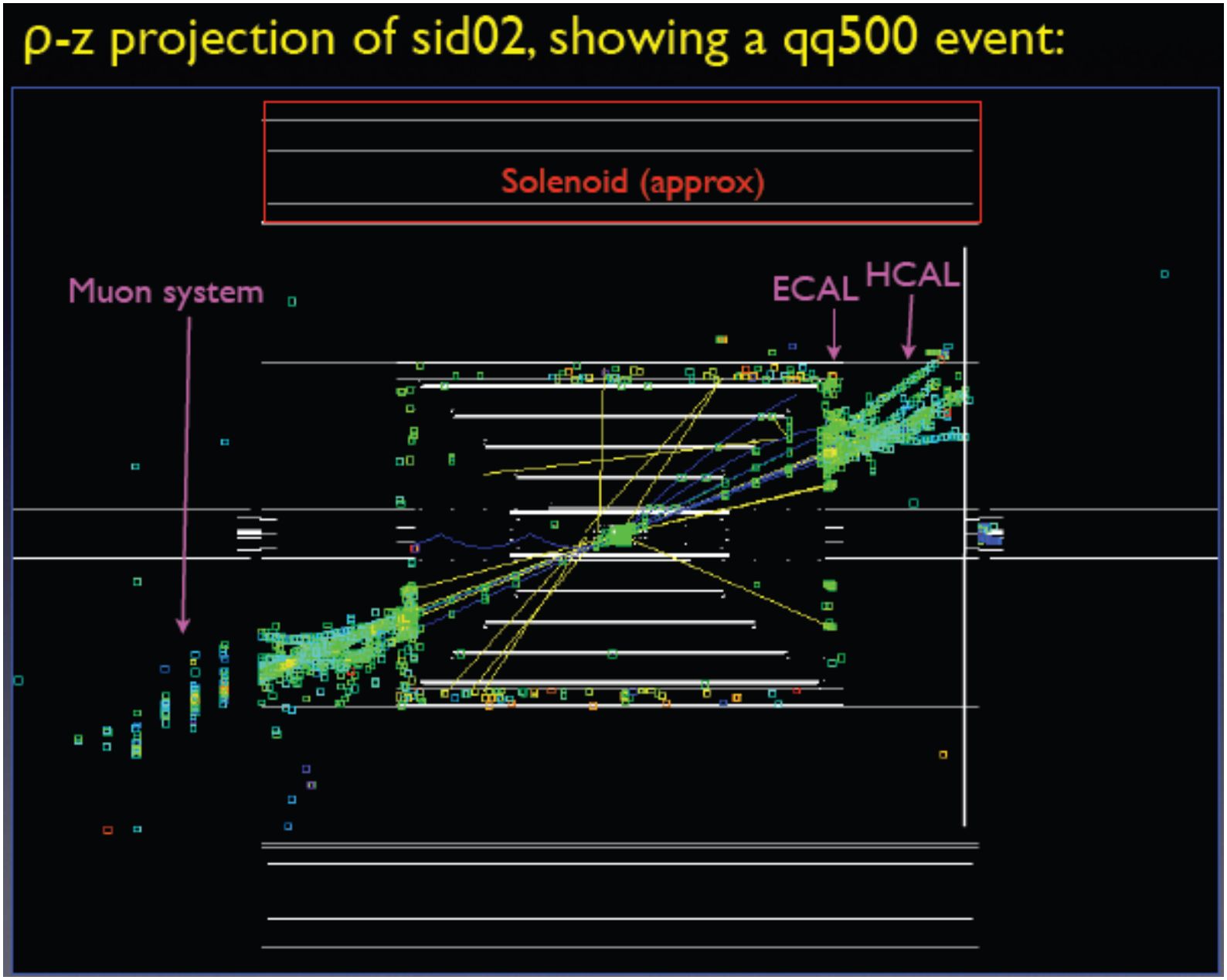
In calorimetry $\sigma/E \propto 1/\sqrt{E}$…
… but in a PFA the confusion increases with E
At high energies leakage is also important

Generally σ_{PFA} ~ between $\sqrt{E}$ and E

The Detector (SiD02)

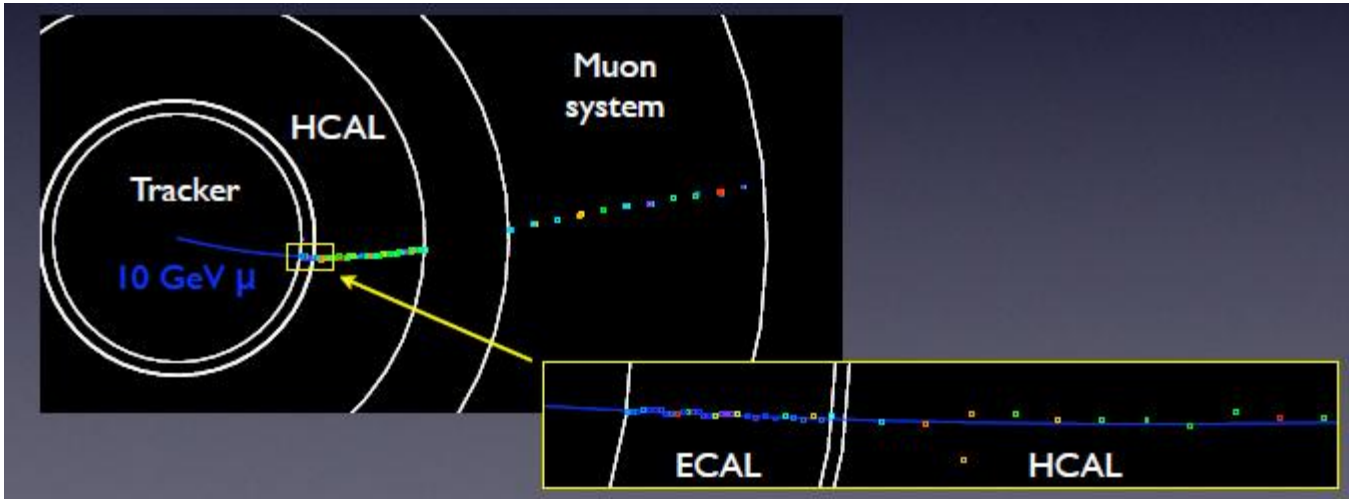


An Event Display

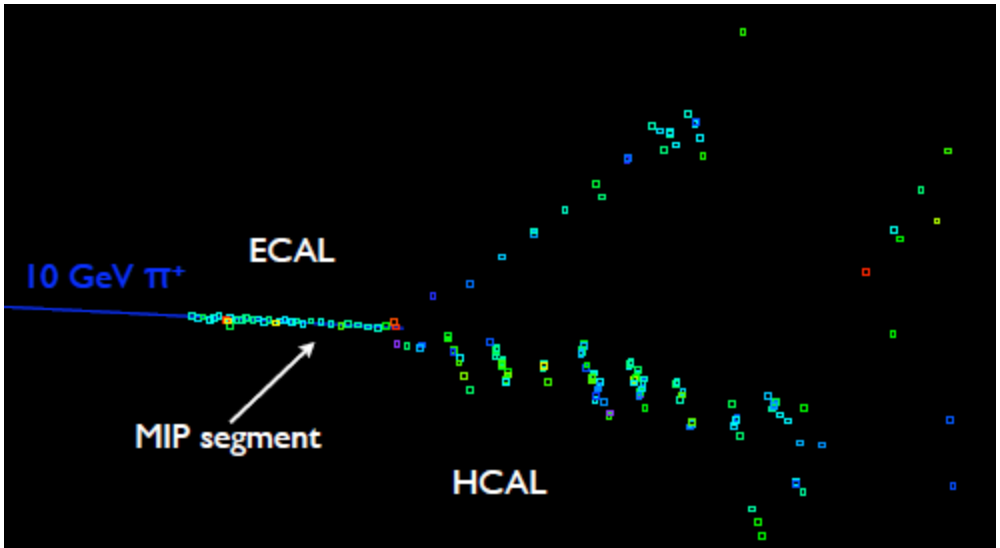


Shower Characteristics: MIP

MC hits are digitized within 100 ns of the primary interaction
Start with easier ones, isolating muons

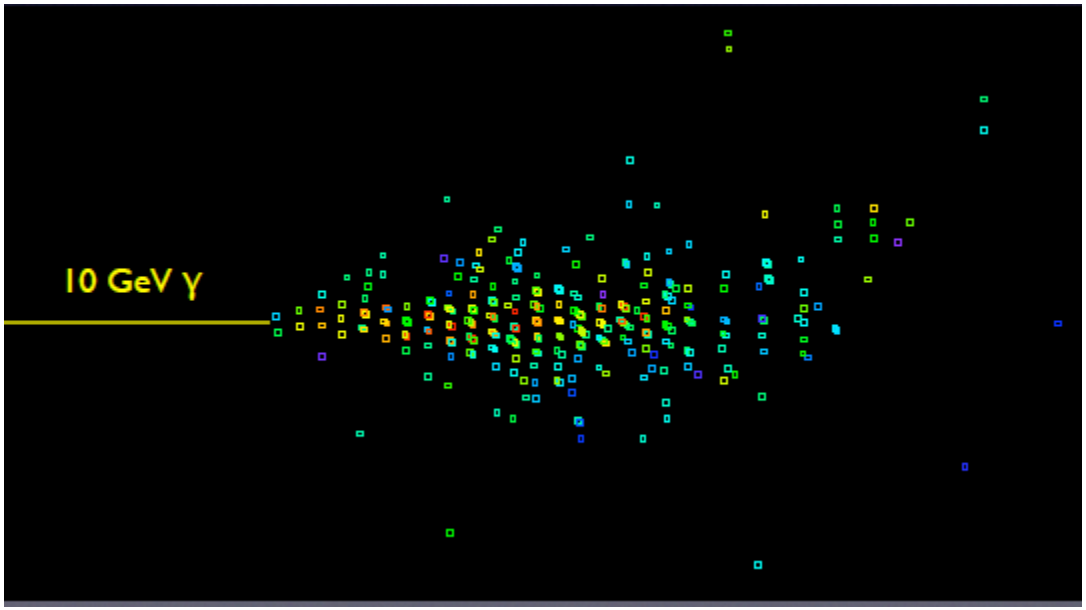


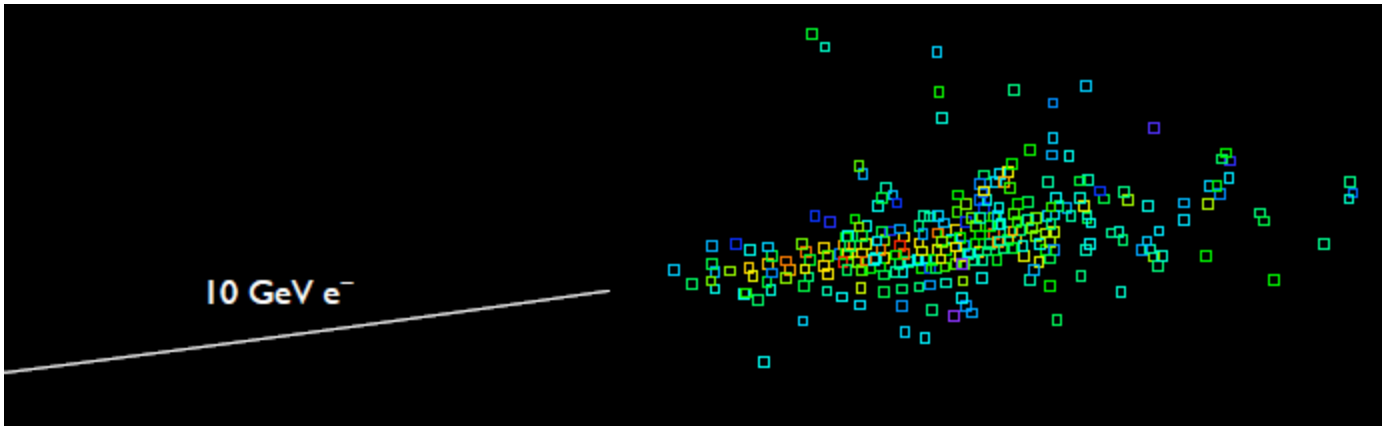
Of course, charged hadrons behave the same way before showering



Electromagnetic Showers

Starts early in ECAL with a tight core and longitudinal profile





Basic Building Blocks of the (Iowa) PFA

An Overview :

- Photon, Muon and Electron ID

EM reconstruction – R. Cassell (SLAC)

- Track and Seed Cluster
- Building Charged Hadron Shower

DirectedTree – NIU

- Neutral Hadrons
- Reconstructing Particles (four-vectors)

Photon, Muon and Electron ID

- Initial "EM Cluster"

  No track matched – photon
  Track matched with E/p $\approx$ 1 , electron
  Possibility of overlap with other showers

- Muon

  Find MIP direction in Muon detector, match extrapolated track

These hits removed from the hit list for clustering algorithm

Categorizing: DirectedTree Clustering

Now use DirectedTree Cluster for classification into sub-cluster types

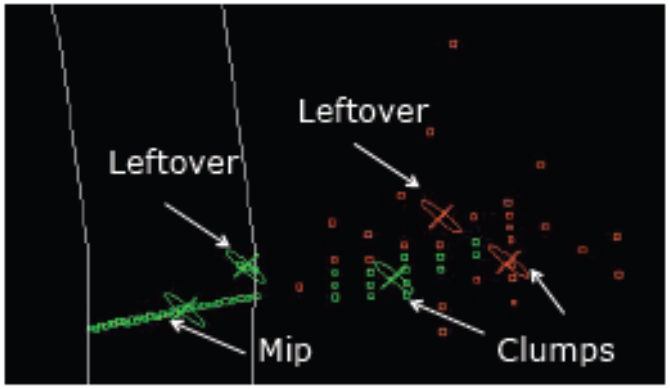
Ecal Digi Hits(Barrel, Endcap)			Hcal Digi Hits (Barrel, Endcap)		
Photon, Electron, Muon	DTree cluster (Ecal Barrel)	DTree cluster (Ecal Endcap)	Muon	DTree cluster (Hcal Barrel)	DTree cluster (Hcal Endcap)

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)



Cluster Building 1

- Extrapolate (each) track to the ECAL surface
- Find Seed: sub-cluster directly connected to extrapolated track
- Each track typically has one seed

(Special cases: track without seed, or does not reach calorimeter)

- Now start connecting other sub-clusters to the seed of each track
- Start with lowest and then progressively higher momentum tracks

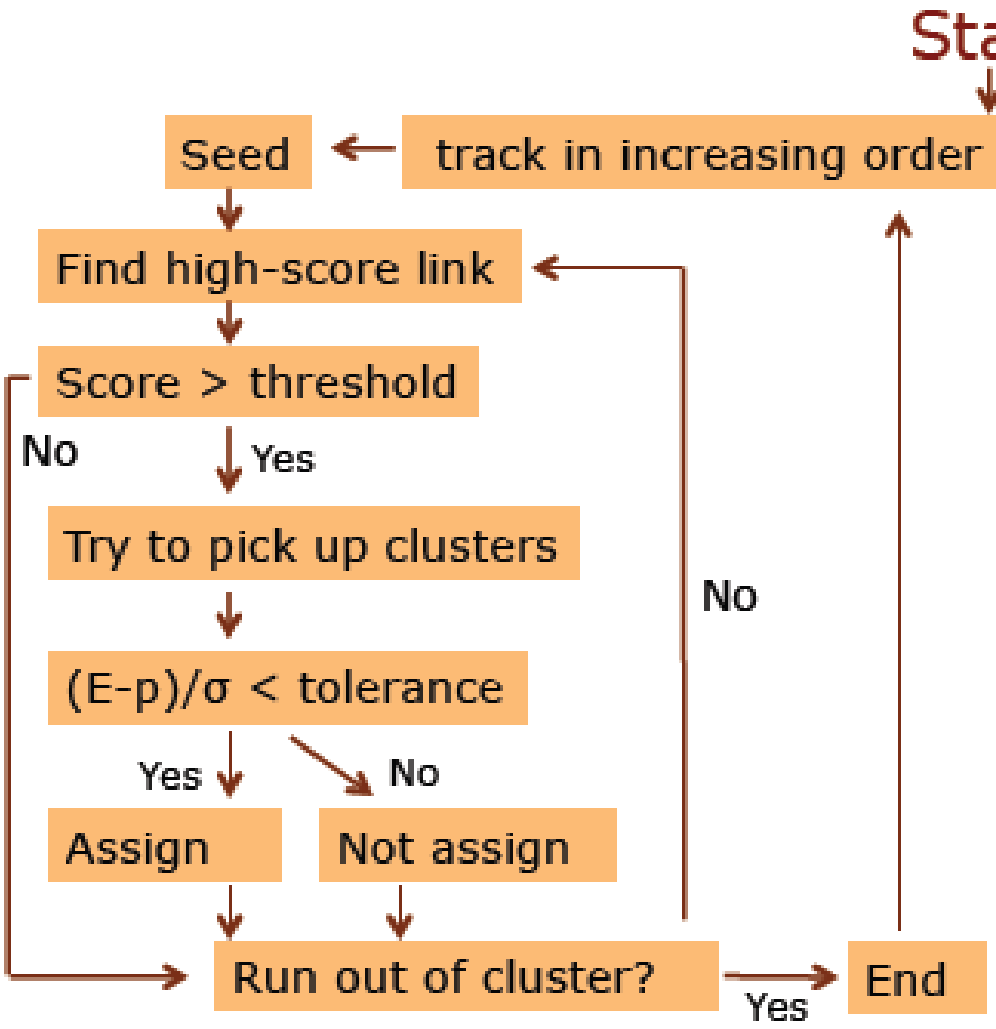
Scoring : (a poor man's) Probability of a link

Based on the sub-cluster type and geometric proximity a score between 0 and 1 is assigned between any two sub-clusters starting with the cluster in consideration

The higher the score the higher the probability of a link

A cut-off threshold is obtained for an energy by studying events

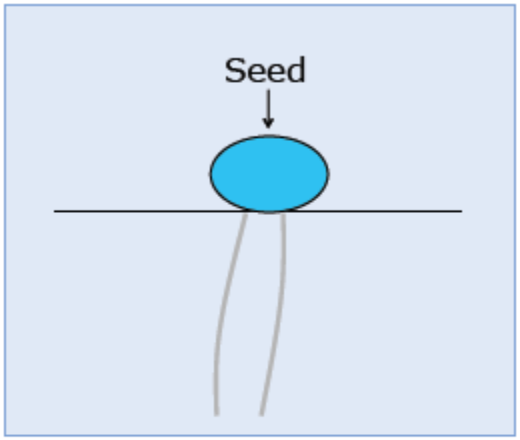
Final Clustering : a flow for each track



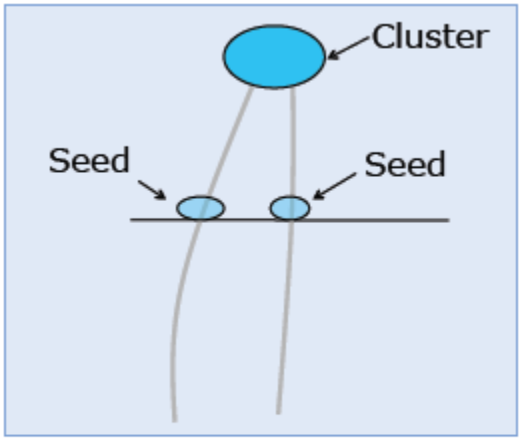
If incomplete track(E<<p),
adjust tolerance/threshold and go back to the whole iterating.

Special Cases

Merged Clusters



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



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

Override

If a high score link to an unassigned cluster which is not `assigned' to a track is found, added after checking E/p

Reassignment

Hoping to pick up secondary neutrals: make a conical path from the shower starting point and pick up high score sub-clusters in angular order, keeping E/p in mind; reassign score

Neutral Hadrons and output

- Once all charged tracks are matched with clusters, the remaining clusters are assigned to neutral hadrons
- Neutral clusters are constructed from sub-clusters the same way as the clusters associated with charged tracks, except E/p match
- Each such reconstructed cluster set is a neutral hadron
- If the complete (neutral) shower is in ECAL, treated as a photon

- A charged particle four-vector written with the track momentum with the mass of a charged pion
- A neutral particle four-vector is written out with the position and energy of the cluster and a neutral Kaon mass
- A muon (electron) four-vector is written out with the momentum and the muon (electron) mass
- A photon four-vector is written out with the position and energy of the cluster

Performance and Plans

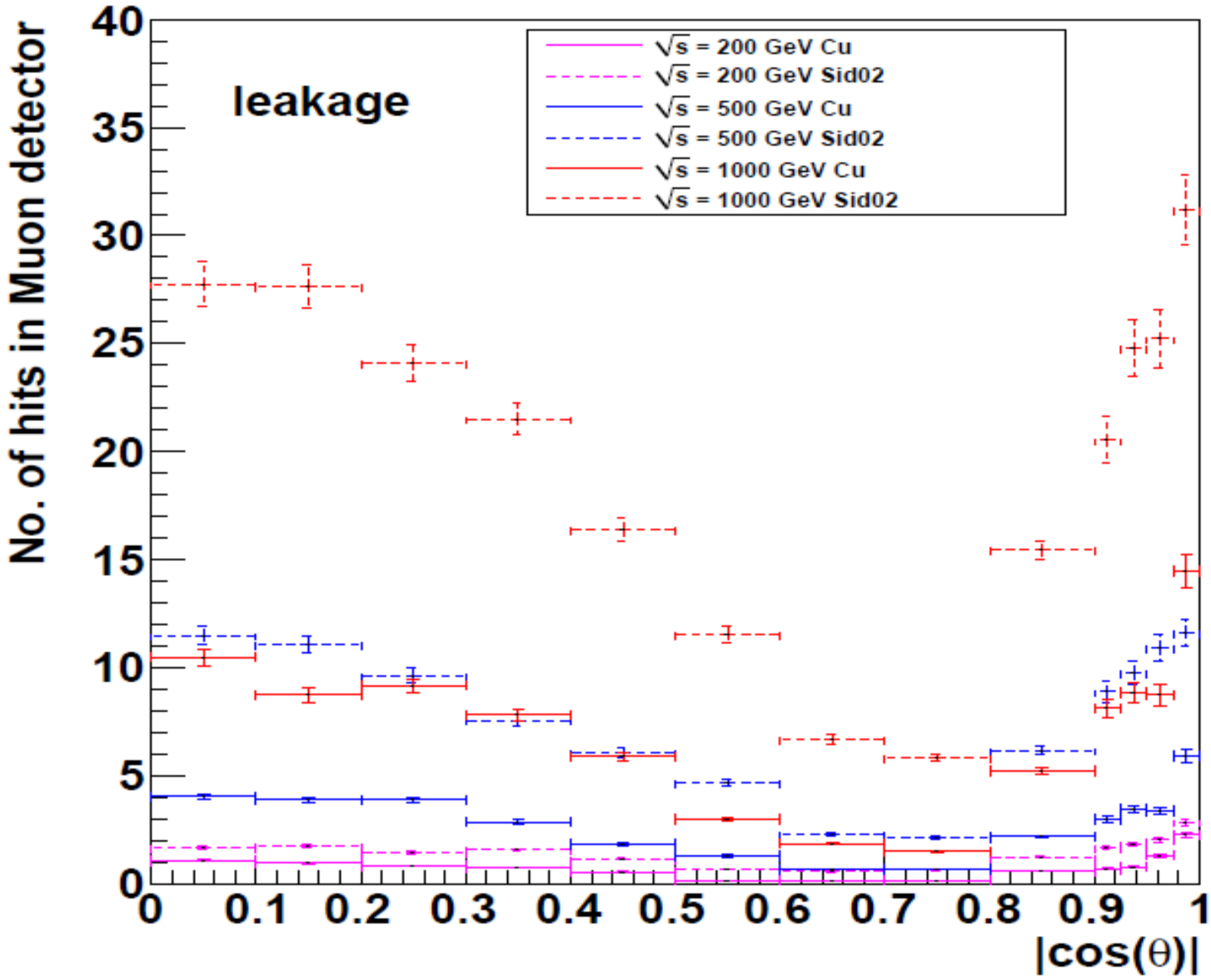
- At LOI, the current PFA met the threshold criteria
- However, a lot of catching up to do with PANDORA
- Studied leakage since LOI, a real issue at 500 GeV, huge at 1 TeV

  SiD02 with cu replacing steel and 54 layers instead of 40 in HCAL
- Algorithm improvement is needed

  SiD02(cu) resolution does not scale as leakage

Punch-through muon hits

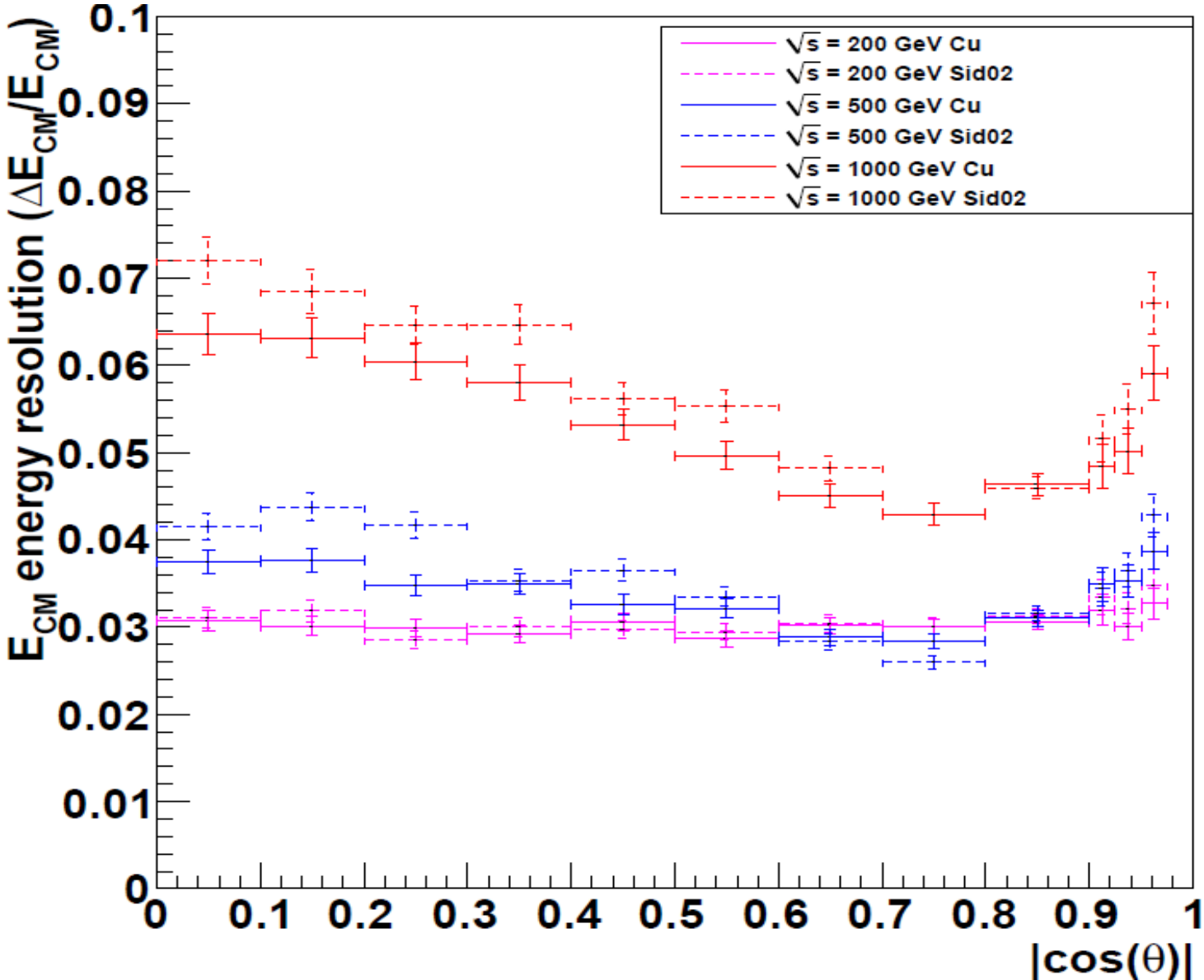
SiD02-Cu
SiD02



Resolution study (SiD02-Cu comparison)

real tracking

SiD02-Cu
SiD02



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  SiD02(cu) resolution does not scale as leakage
- Also found problems with reassignment part of the algorithm
  - Immediate plan is to replace with a more sophisticated algorithm to do what it should without breaking others
- Make assignment of hits among neighboring tracks flexible
  - Deal more gracefully with overlaps (sharing)

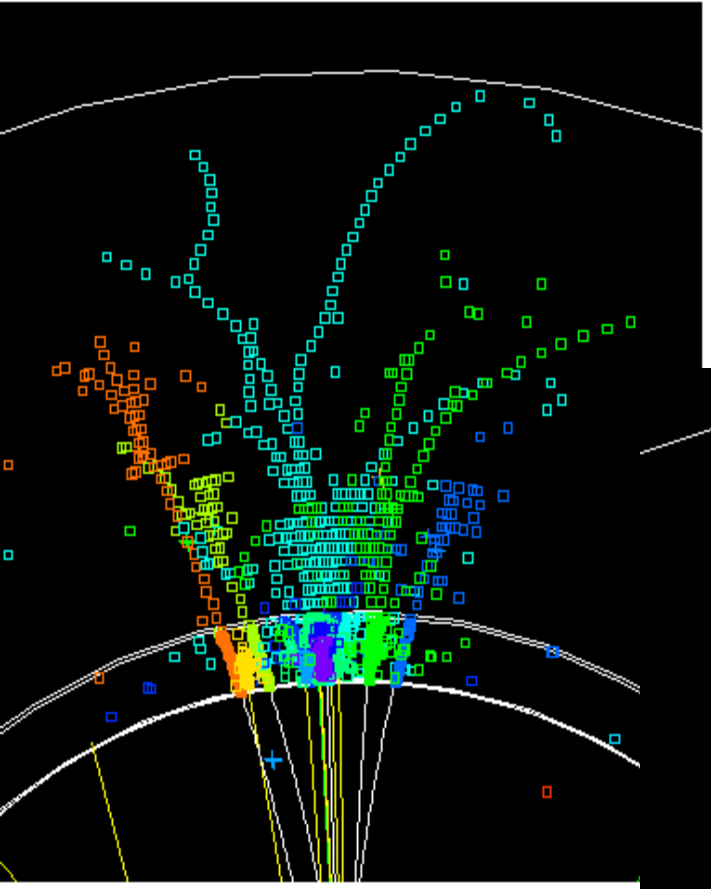
Conclusion

- Much better understanding of weak points of algorithm
- Hitting our stride in aftermath of LOI
- Clear path to improve pattern recognition
- Lots of work to do!

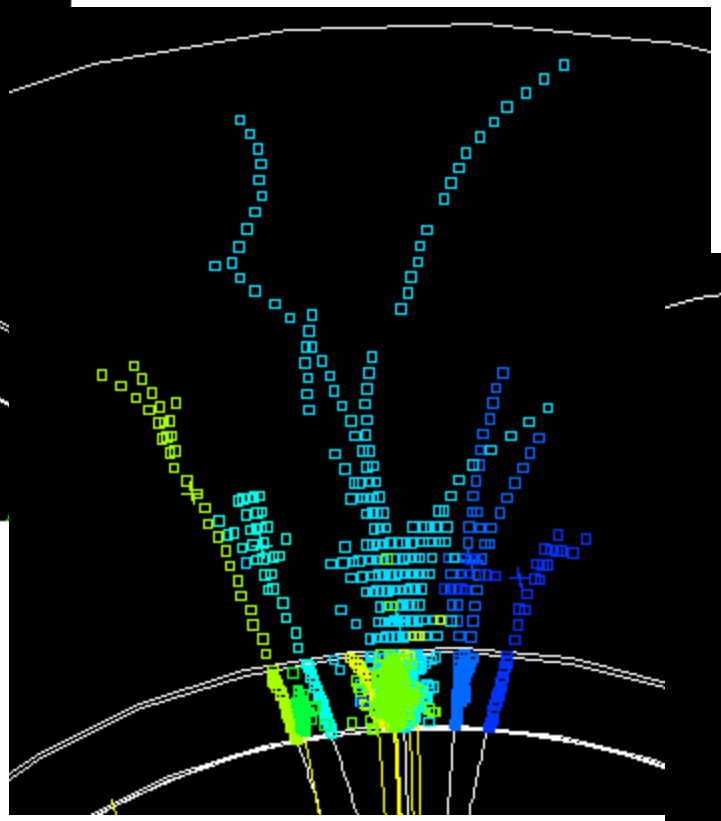
Backups

has a low energy 12 GeV neutral hadron and several photons present in the ECAL; interaction of charged hadron

p (orange) = 119 GeV, E/p match, enough hits (green) = 17 GeV



RefinedCheatCluster

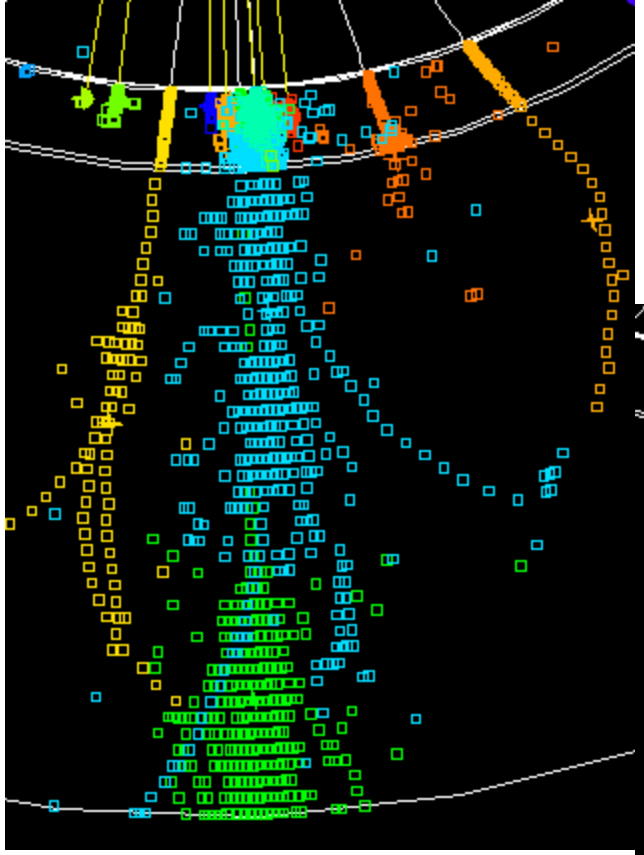


RefinedCluster - sharedhits

reconstructed

$e^+e^- \rightarrow qq$ at 500 GeV

p(left) = 105 GeV, p(right) = 97 GeV
Angle < 1 degree, connected `seeds'



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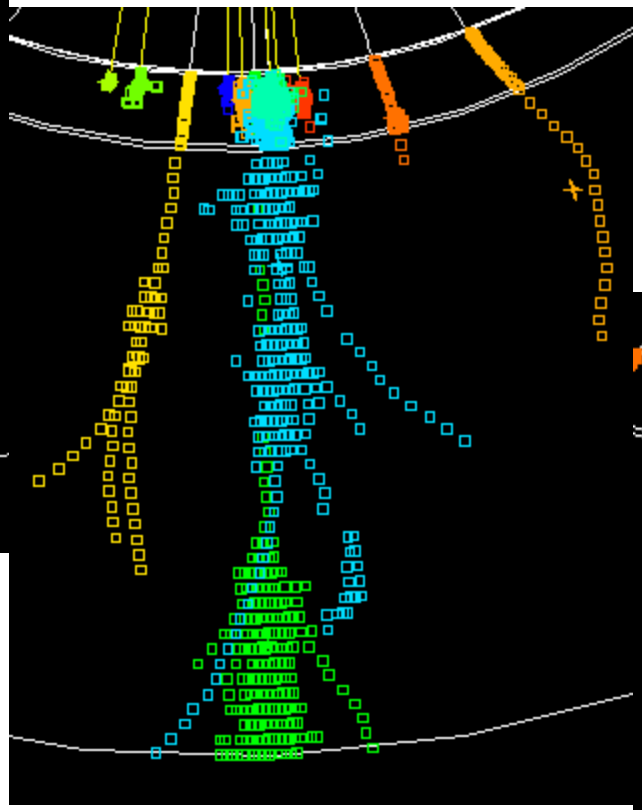
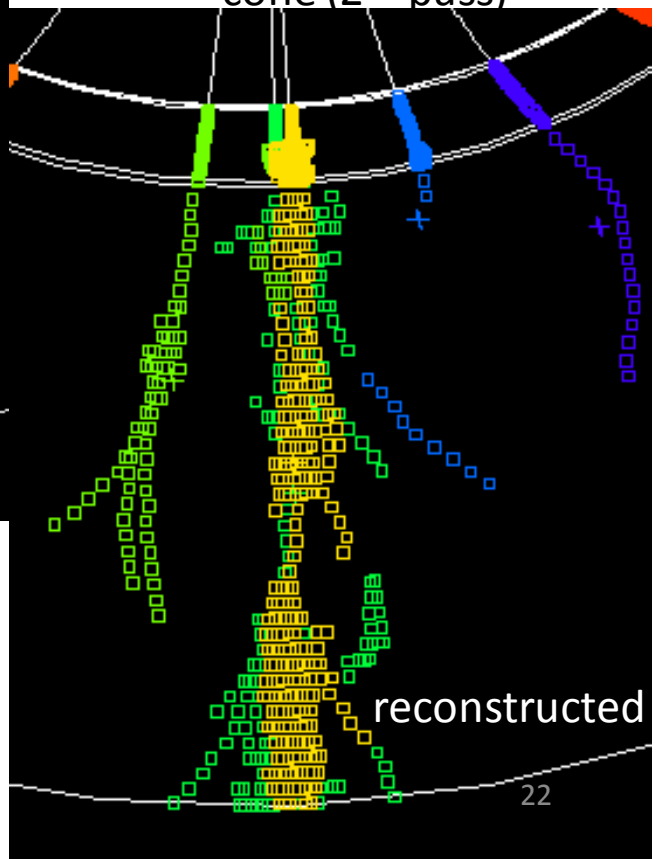


RefinedCluster - sharedhits

p = 7.7 GeV, blue piece picked up by cone (2nd pass)



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$e^+e^- \rightarrow qq$ at 500 GeV