Status of SiD-Iowa PFA

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Status at Granada

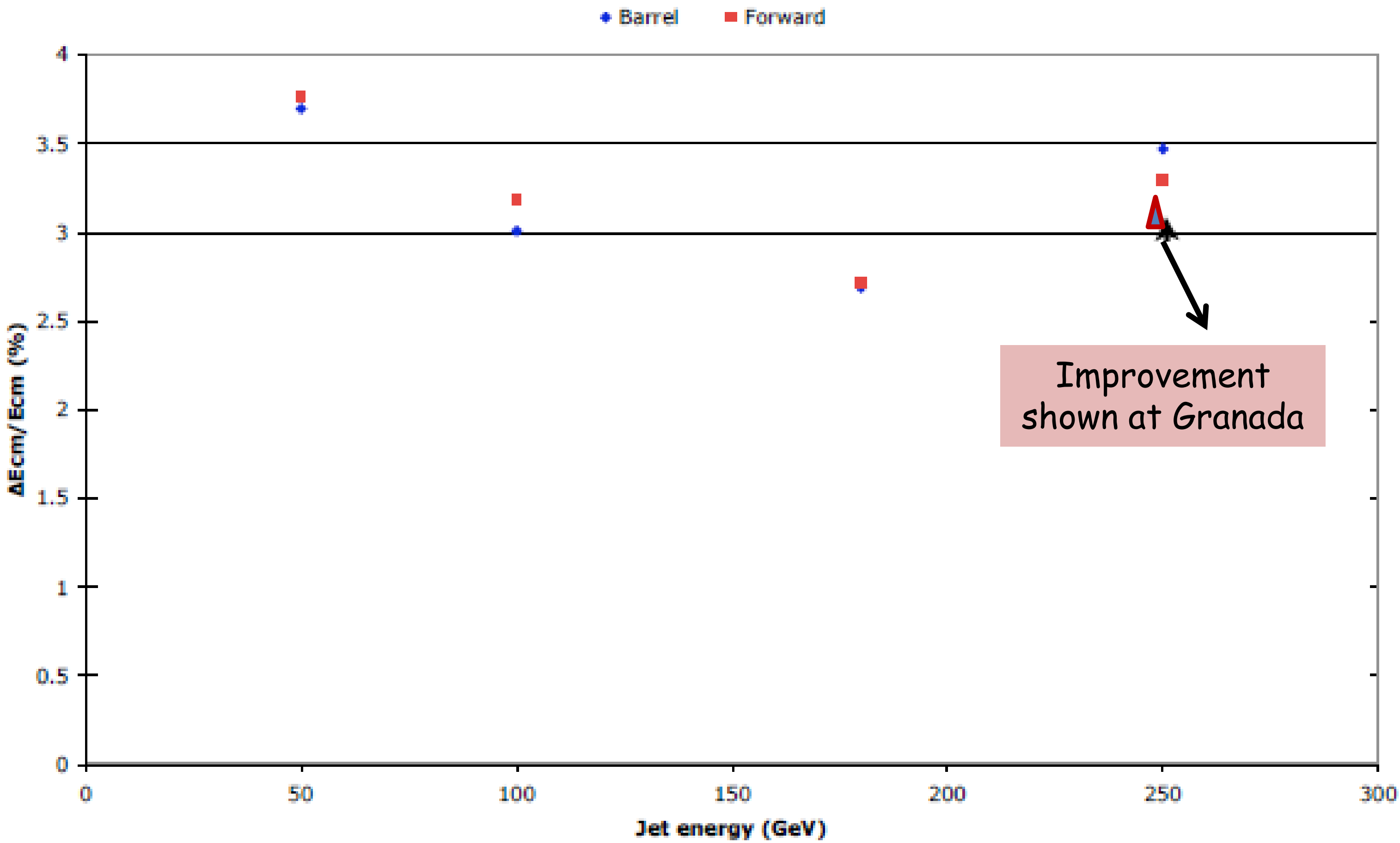
Several improvements prior to shower reconstruction

- Smaller clump formation → increased purity (90%)
  - K-mean algorithm
- Improved photon purity (90%)
  - By treating a reconstructed photon cluster as a hadronic clump if within 3 degrees of a track
  - Still 10% inefficiency and 10% contamination
- Improved track-seed matching
  - When a photon overlapped hadronic track and the photon was reconstructed (15% of tracks), the hits were removed
  - By helical extrapolation of the track to the closest sub-cluster, 80% of the problems fixed
- Improved linking of immediate neighbor sub-clusters with better likelihood

Performance at LOI

SiD02 geometry

$$e^+e^- \rightarrow q\bar{q}(q = u, d, s) \text{ at } \sqrt{s} = 500 \text{ GeV}$$



Resolution improved from 3.5% to 3.1% using baseline shower reconstruction with improvements mentioned earlier

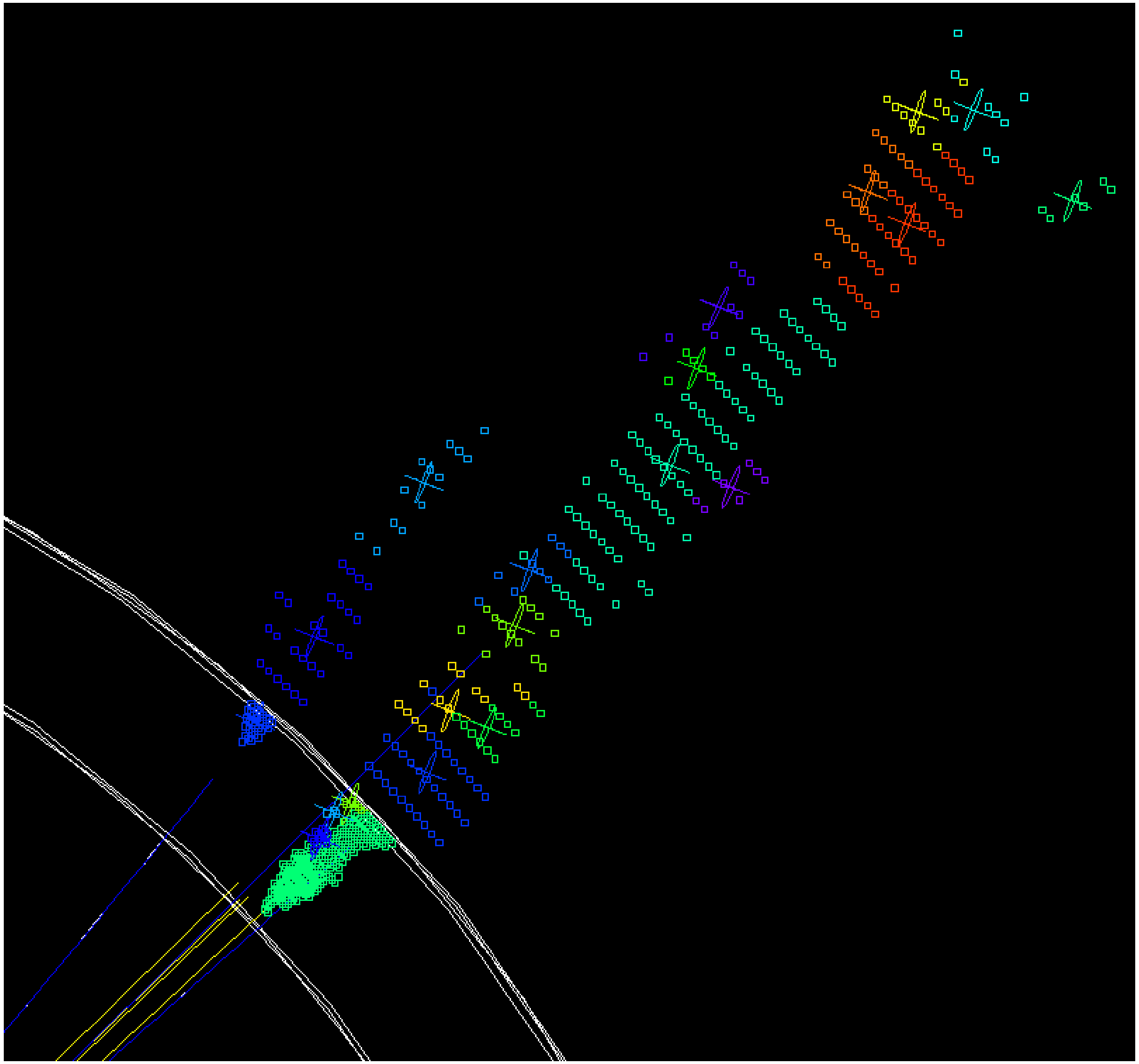
Shower Reconstruction

- To be scalable at higher energies
- Iterative reconstruction with several passes
- First pass: High purity shower core reconstruction with charged hadron primary showers
- Second pass: Identify primary neutrals and add smaller pieces to the core
- Third pass: Divide up groups of closely bunched tracks and use E/p balance for each bunch/region

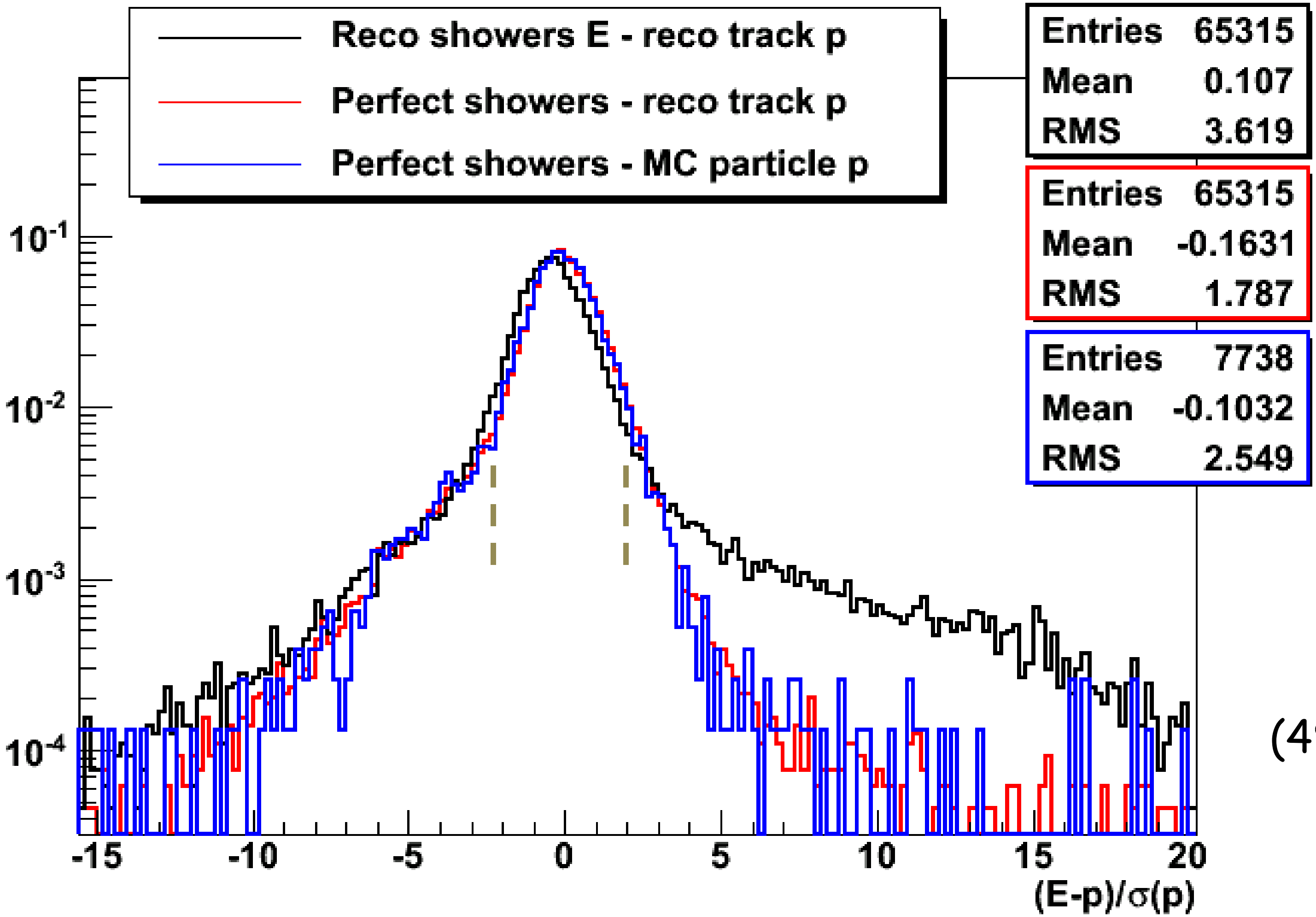
Optimization of the cone size for track bunching

The optimal cone size for bunching turns out to be 4° or 5°

For each cone size the energy deposited by a track inside the cone compared with the E deposited by the track altogether from MC was checked. For very small cone size the energy ratio is less than 100%, for very large cone size the ratio is always 100%, the cone size approaching 100% was used.



The well measured and the poorly measured showers

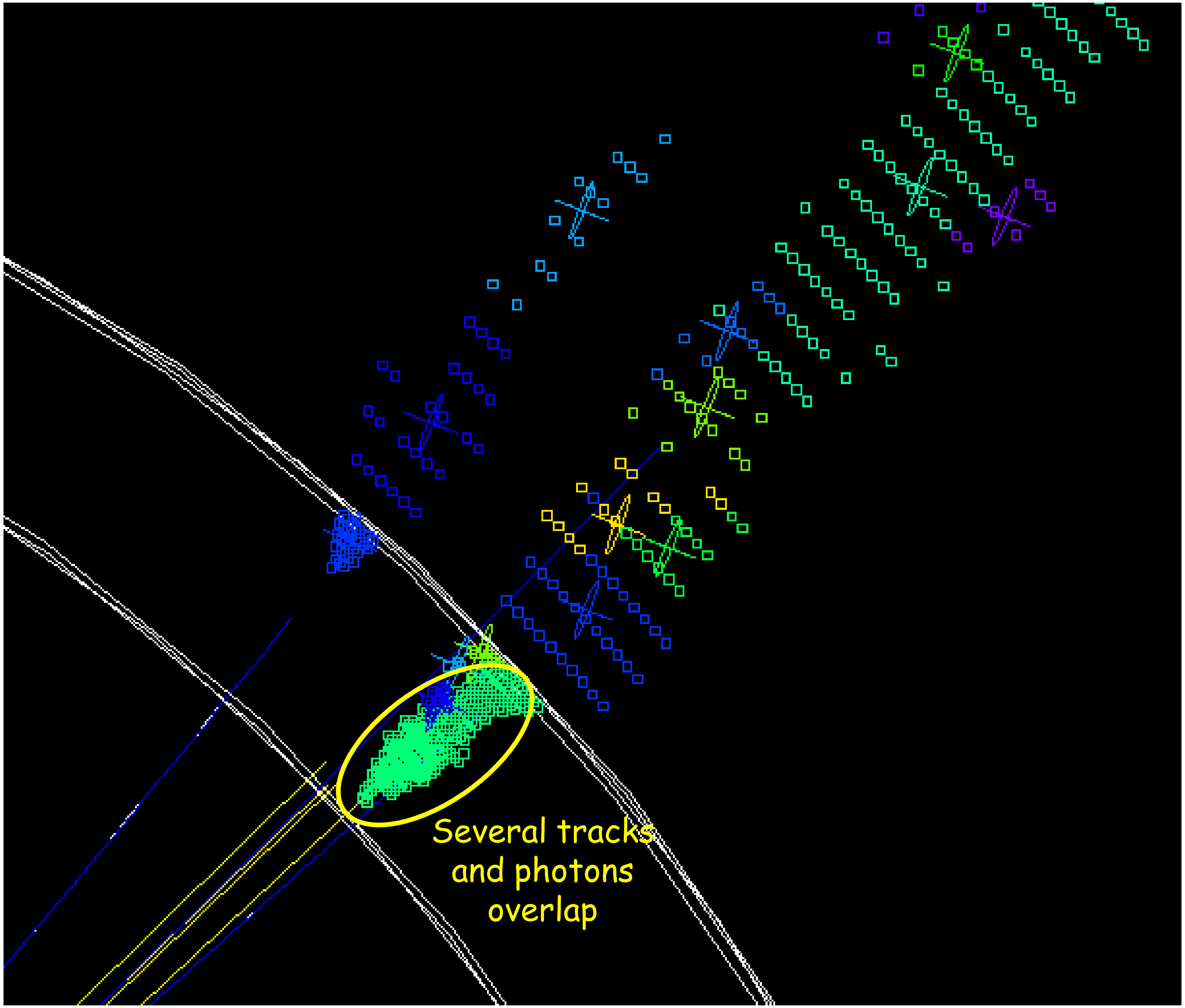


5° cone

(4° also works)

Complications from overlaps

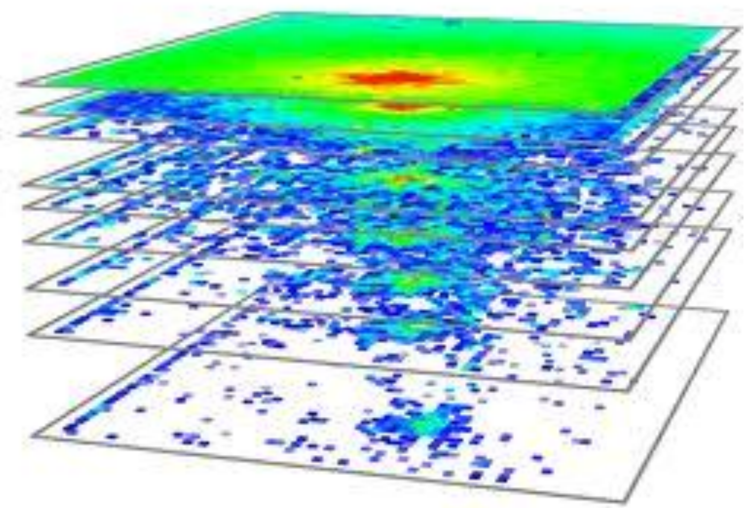
MIPs not shown



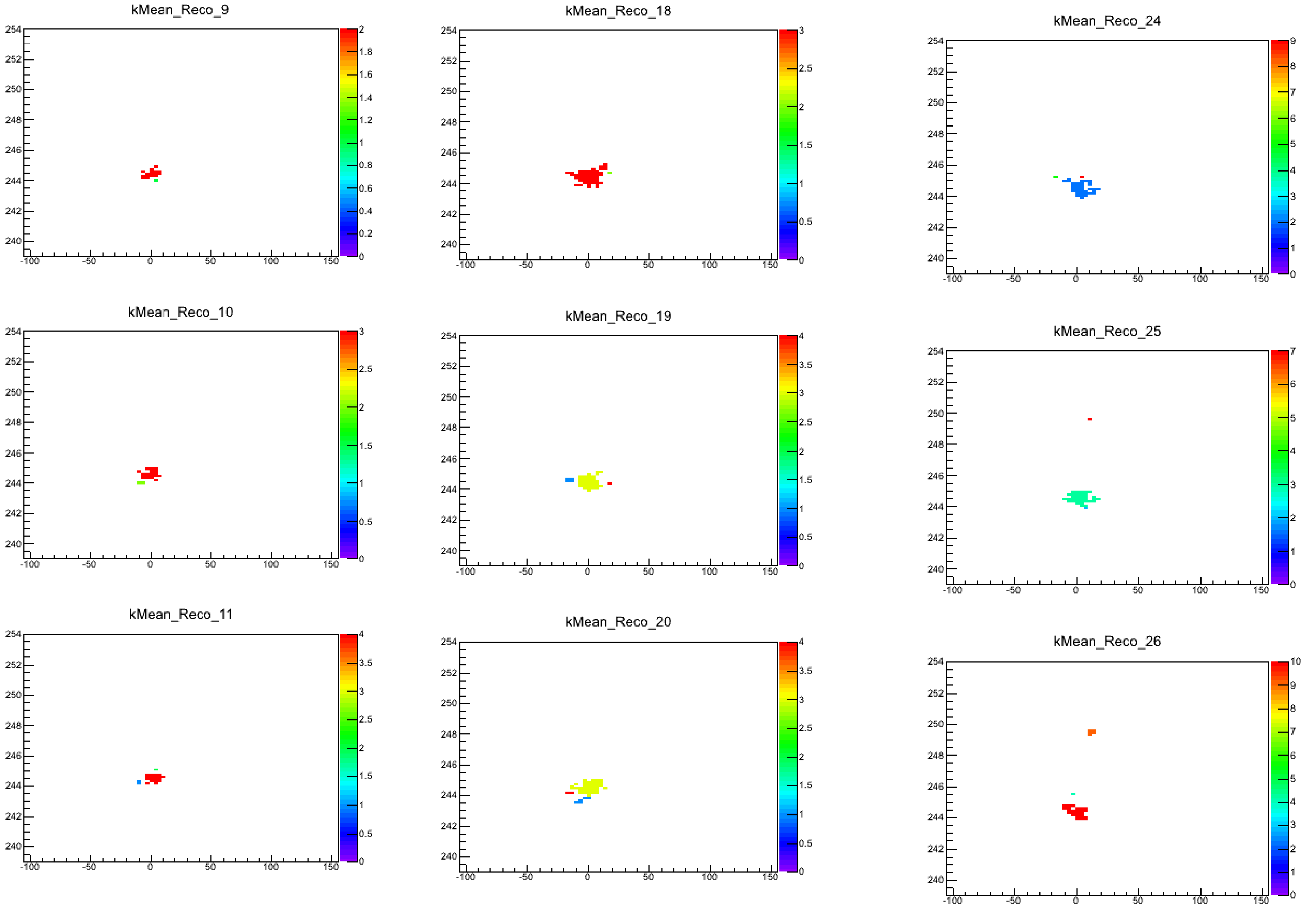
Development of each shower in profile

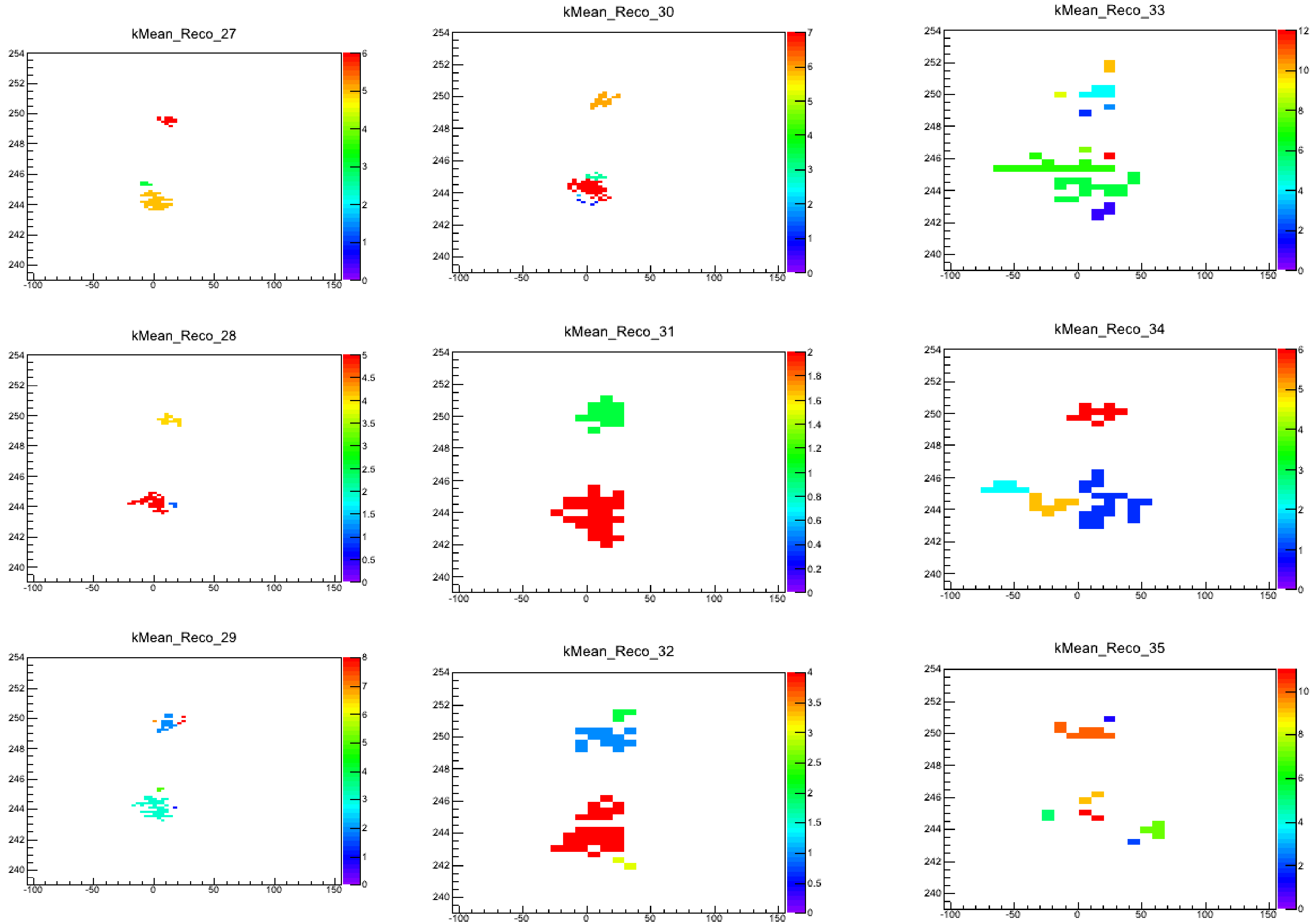
- For each ECAL/HCAL layer form local 2D clusters
- Follow each local 2D hit/cluster of hits
- Reconstruct each one through successive layers by its geometric and energy profile

2D projections of the hits on each CAL layer as the shower develops (cylinder surfaces)

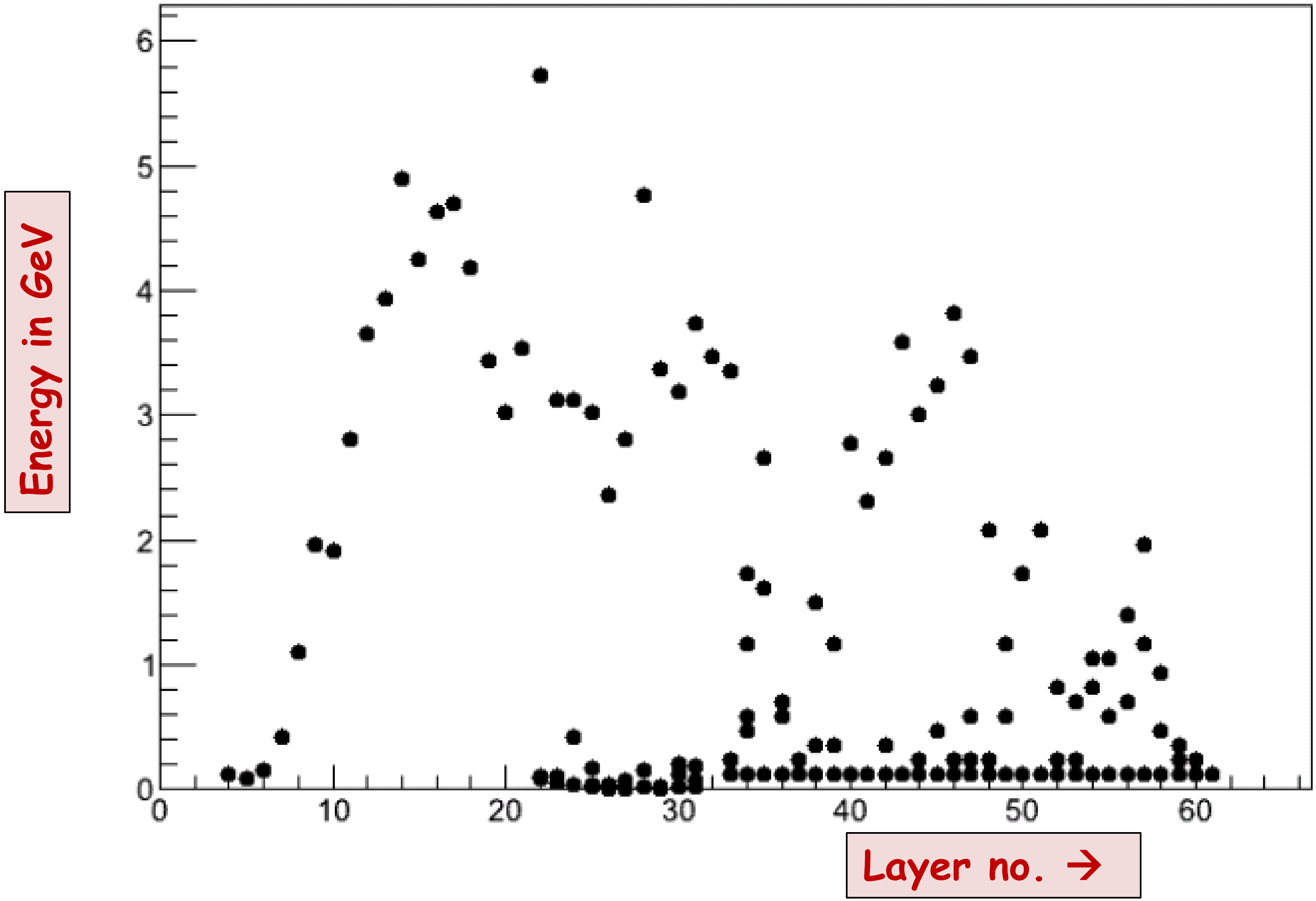


Reconstructed 2D shower profile




kMean_Reco_27
kMean_Reco_30
kMean_Reco_33
kMean_Reco_28
kMean_Reco_31
kMean_Reco_34
kMean_Reco_29
kMean_Reco_32
kMean_Reco_35

An energy profile of a shower with a photon overlapping a charged particle



Shower development

- Start from the innermost layer from the “seeds” attached to the track, follow through each subsequent layer (geometry and energy)
- After a few layers observe the beginning of a shower development for charged hadrons
- In case of overlap of an energetic photon, the energy profile shows a quick increase, drop off, and later development in addition to $E \gg p$
- If a hadronic shower starts to develop unattached to a MIP, beginning of a neutral shower
- In case of two showers merging into one as they progress an arbitration is made checking the next layers whether one stops and the other progresses or they simply cross paths
- Identify and connect secondary showers (developing in later layers)
- Finally share the “leftover” hits as before

Current Status

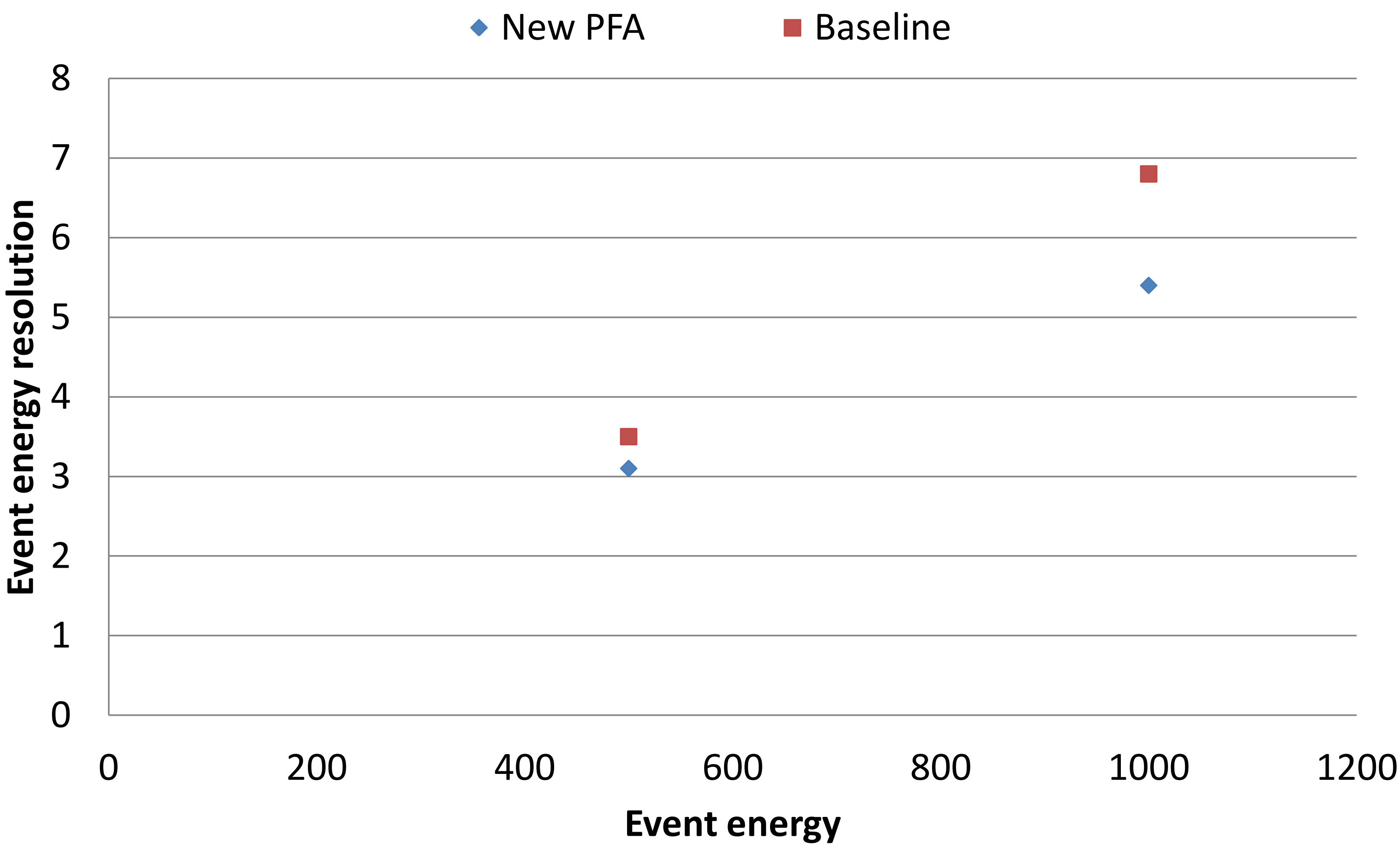
- Coding completed
- Debugging and testing started with single pion and qqbar events
- In parallel cross-checks put in place with bunched E/p balance for 500 GeV and 1 TeV qqbar events

ΔE/E = 3.1% at 500 GeV
ΔE/E = 5.4% at 1 TeV
cpu is not too different

$$for$$

$$e^{+}e^{-} \rightarrow q\overline{q}(q = u, d, s)$$

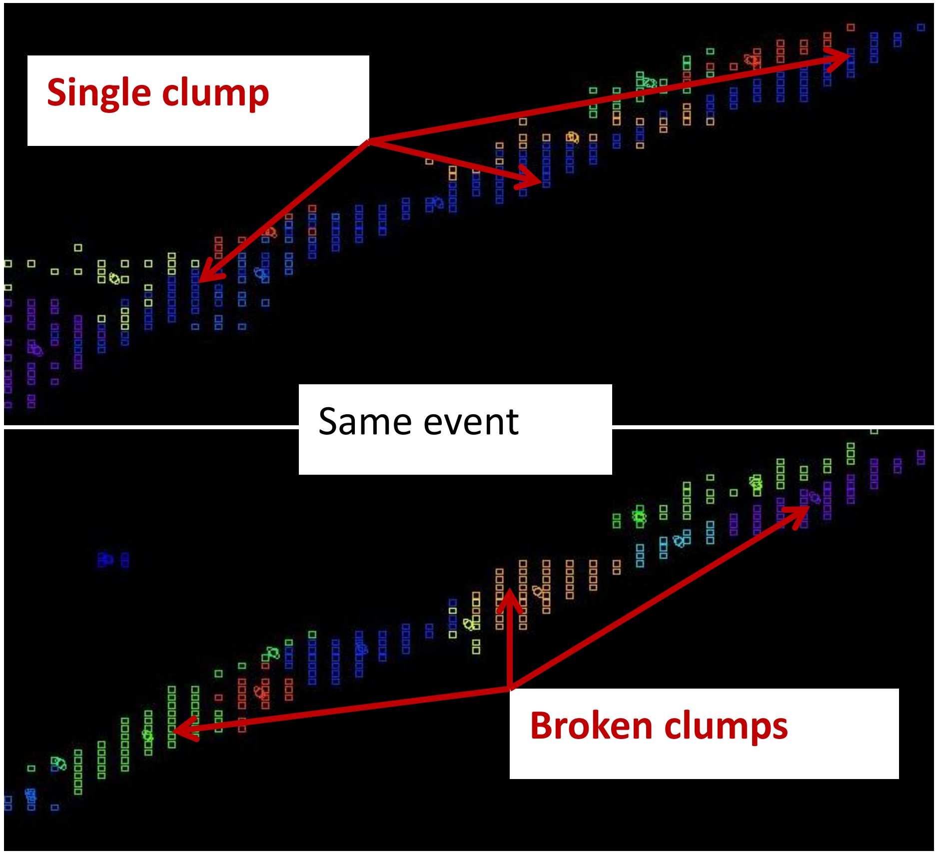
Intermediate results with SiD02



Back-ups

Subcluster improvements

Sub-cluster categories: Clumps, Blocks, leftovers, redefined

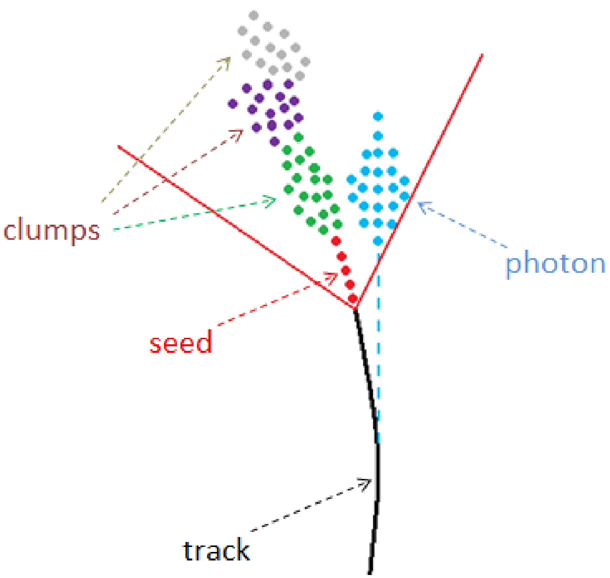


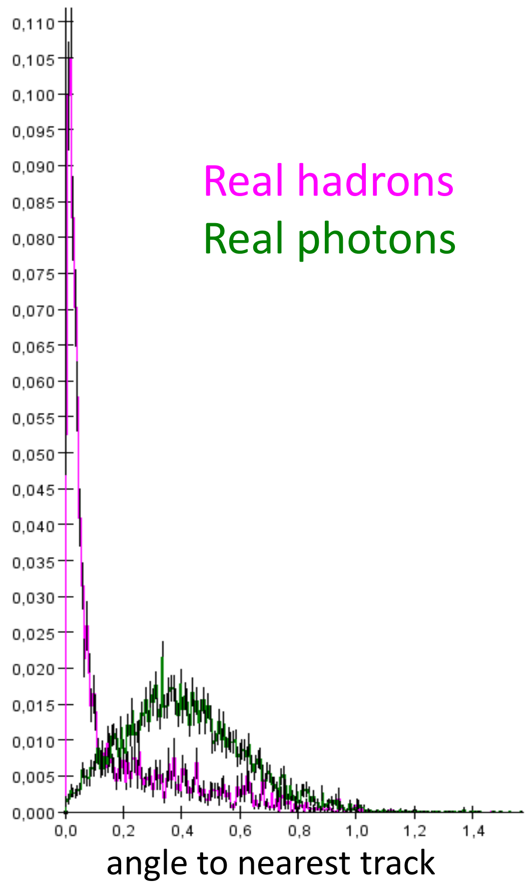
Energy weighted distribution:
Clumps ~46%
MIPs ~ 12%
Left-overs~ 23%
Photons~19%
Blocks ~ <1%

Improved clump purity
83% → 90%

Photon veto

- Improved photon purity:
  - Try to treat a reconstructed photon cluster as a hadronic clump if within 3 degrees of a track
  - Still have a 10% inefficiency and 10% contamination .

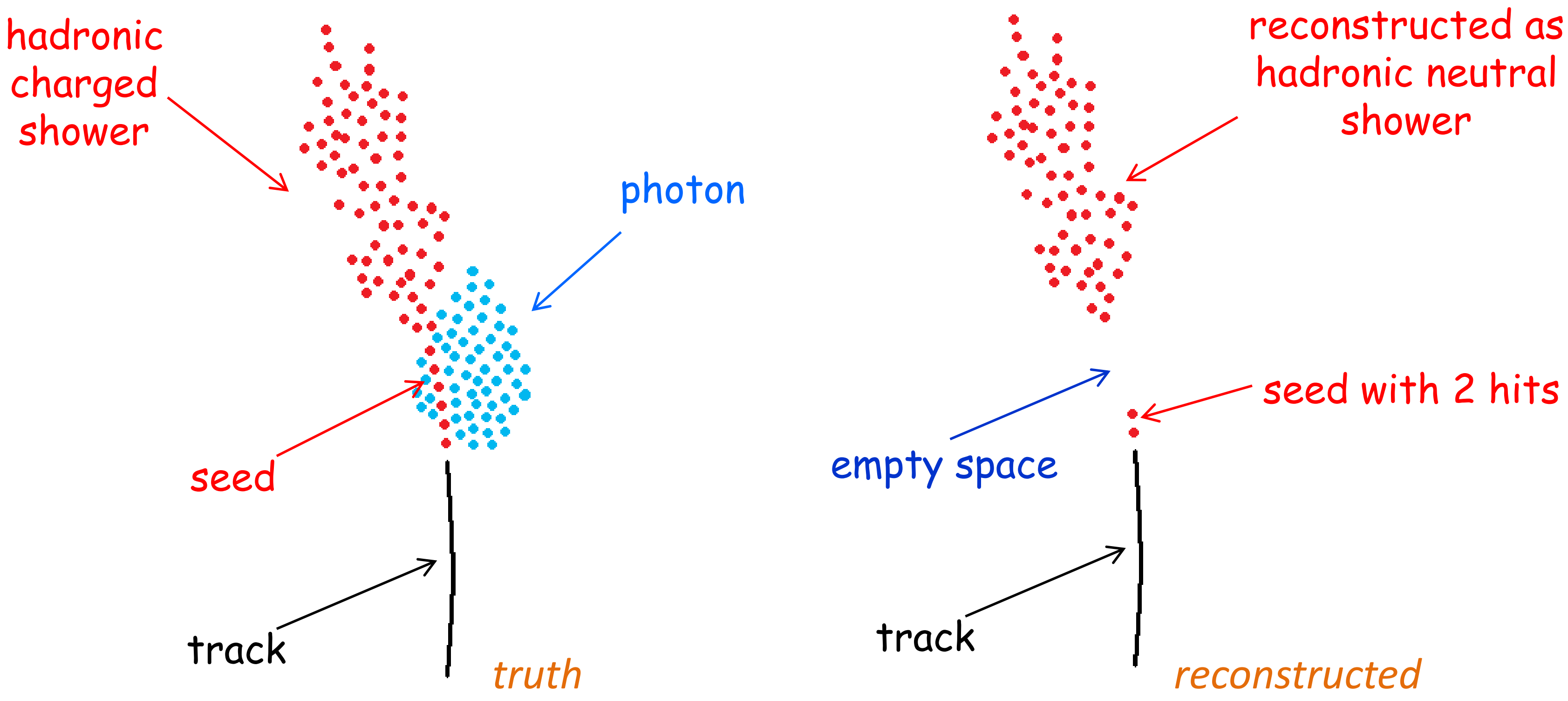




Energy weighted Purity:
83% → 90%
Energy weighted Efficiency:
92% → 90%

Track-seed matching, problems

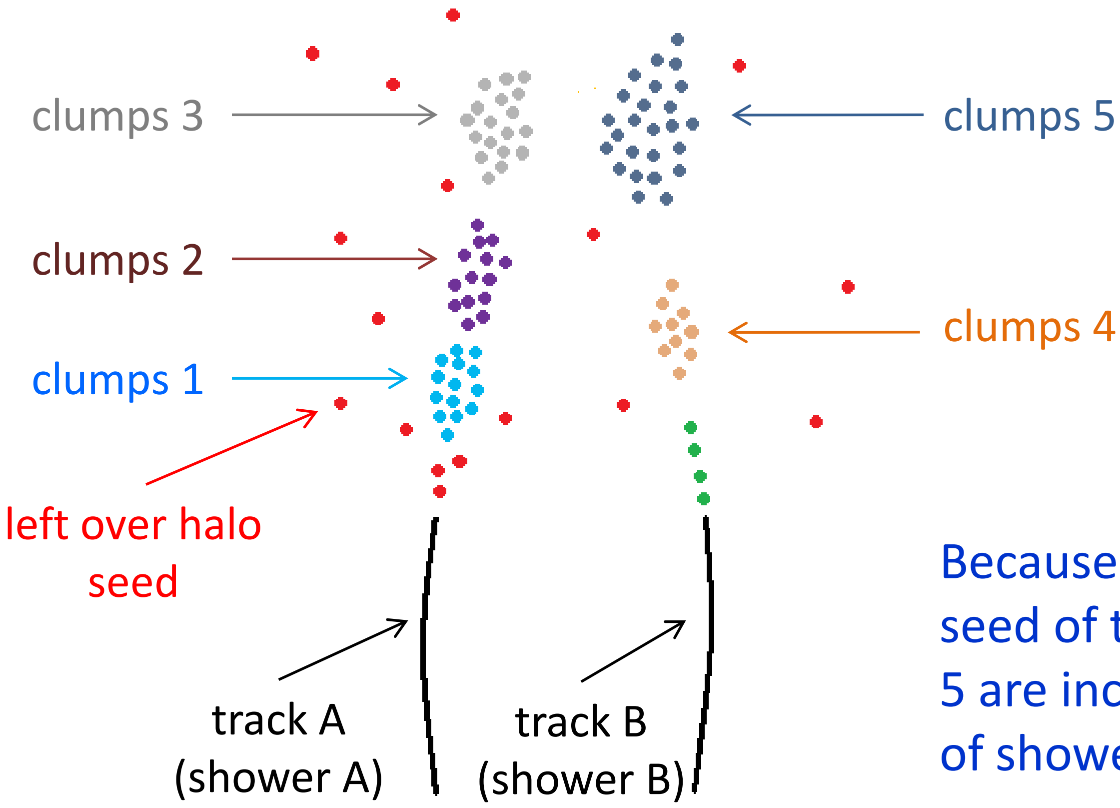
- Two problematic cases are identified:
  - Case 1: Photon close to a track



8% of tracks have this problem.

Track-seed matching, problems

- Two problematic cases are identified:
  - Case 2: Track seed is made from left-over hits.



Because of the leftover halo (the seed of the track A), the clumps 4 & 5 are included in shower A instead of shower B

7% of tracks have this problem.

Track-seed matching, solutions

- Two problems shown on previous slides:

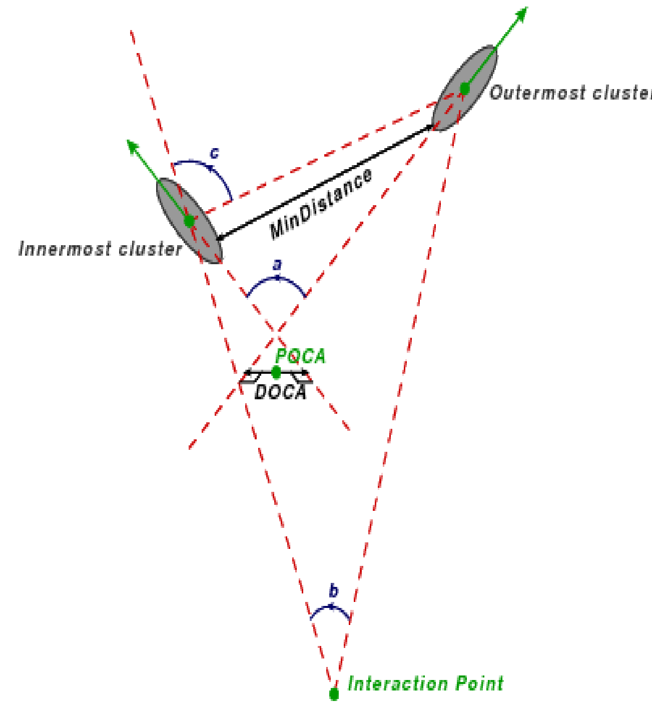
- 1) Photon steals most early hits, hard to extrapolate to main part of shower (8% of tracks)
  - Fix: helix extrapolation of the track to the closest sub-cluster

- 2) Seed is a sparse "leftover" cluster with poor geometrical information (7% of tracks)
  - Fix: helix extrapolation of the track to the closest sub-cluster

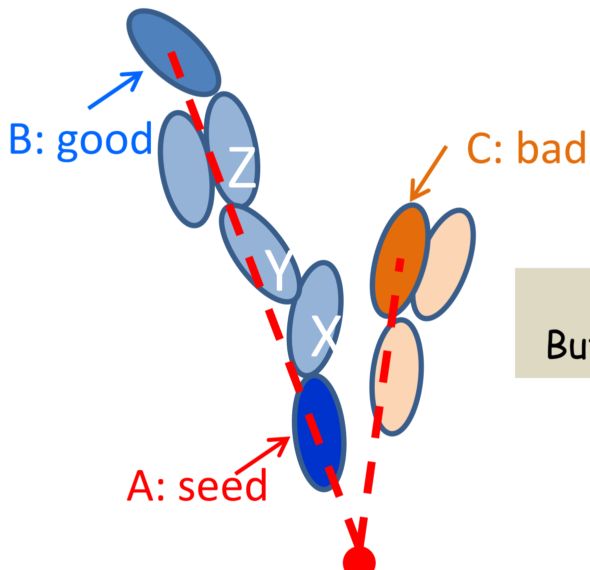
Performance : 80% of the 15% are fixed

Linking with Maximum Likelihood

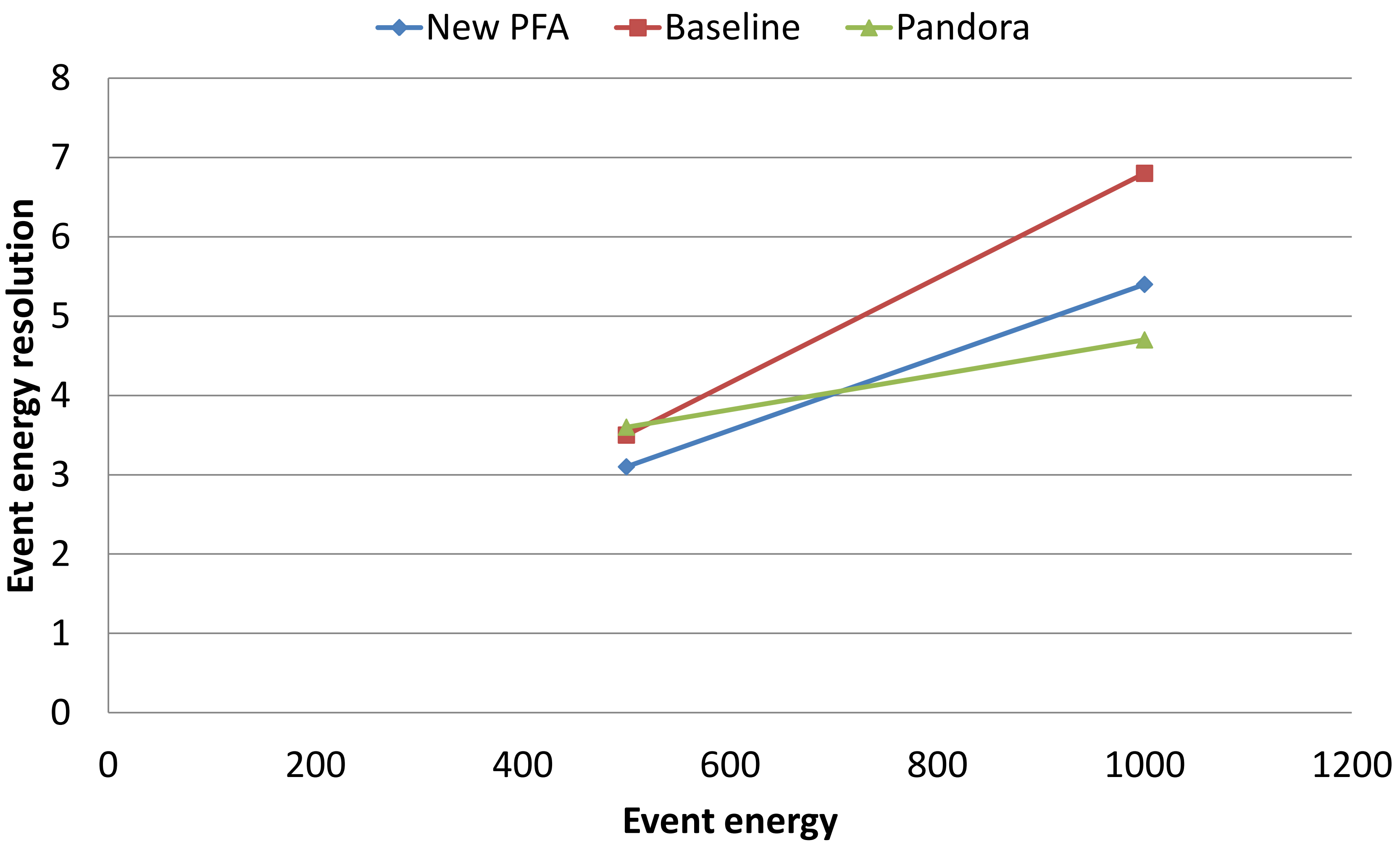
- New and effective discriminating variables
- Correlations taken into account
- Individual likelihood for each sub-detector like ECAL, HCAL (different precision)



- **Train likelihood to link immediate neighbors**



Link A to B via X,Y,Z
But no direct link from A to C



New PFA
Baseline
Pandora
8
7
6
5
4
3
2
1
0
Event energy resolution
0
200
400
600
800
1000
1200
Event energy