PFA Development at NIU

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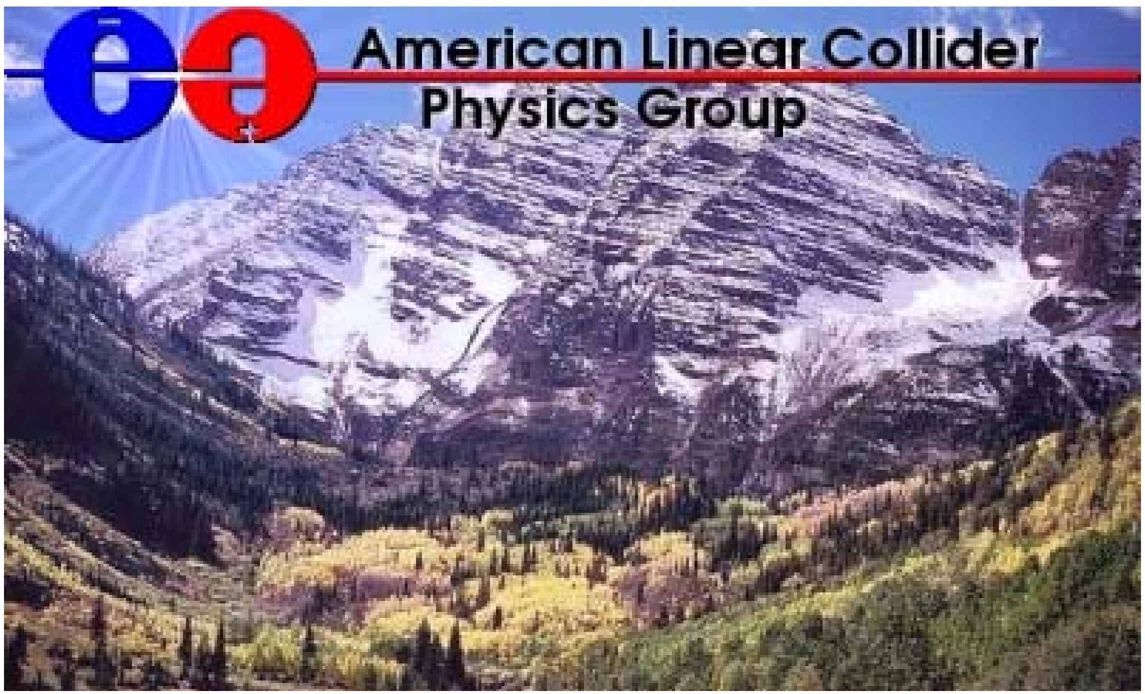


2005 International Linear Collider Physics and Detector Workshop
and Second ILC Accelerator Workshop
Snowmass, Colorado, August 14-27, 2005

Outline

- Introduction
- The Basic Algorithm
  - Density-weighted Clustering in Calorimeter
    - Calorimeter-only (no track-seeding)
    - Same for ECal (e, γ), and HCal (h^+, h^0).
  - Replace cal clusters with matching (MC) tracks, if any.
- The Directed Tree Algorithm
  - Association of isolated “fragment”s or “satellite”s.
- Work in Progress

Introduction

- Primarily interested in exploring the digital hadron calorimeter option in general, with scintillator as the active material in particular.
- For digital algorithms and results for single particles, Refer to talks given at the LDC meeting (Paris, Jan 2005).
- Results are preliminary.

The "SD" calorimeter

- ECal:
  - 30 layers, silicon-tungsten.
  - 5mm x 5mm transverse segmentation.
- HCal:
  - 34 layers, scintillator-steel
  - 1 cm x 1 cm transverse segmentation.
- Magnetic field: 5T
- Support structures, cracks, noise, x-talk, attenuation, inefficiencies,… not modelled.

Clustering (reported in past)

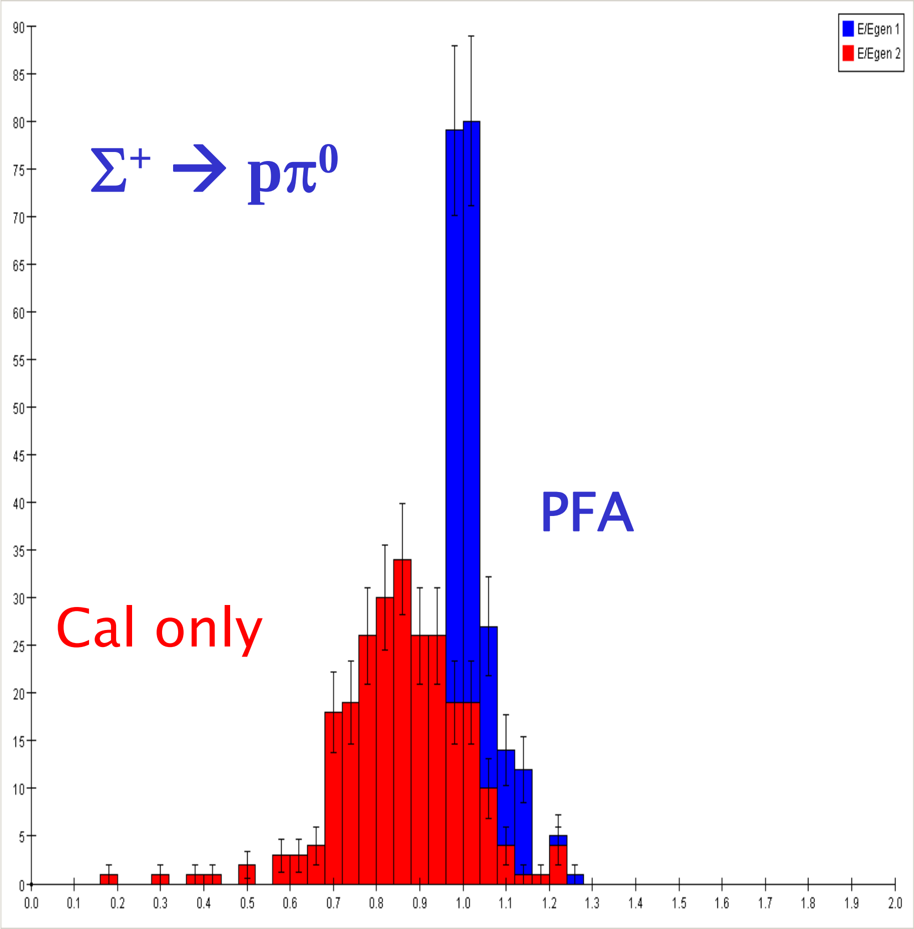
- Seeds: maxima in local density:

$$d_i = \Sigma\ (1/R_{ij})$$

- Membership of each cell in the seed clusters decided with a distance function.
- Only unique membership considered.
- Calculate centroids.
- Iterate till stable within tolerance.

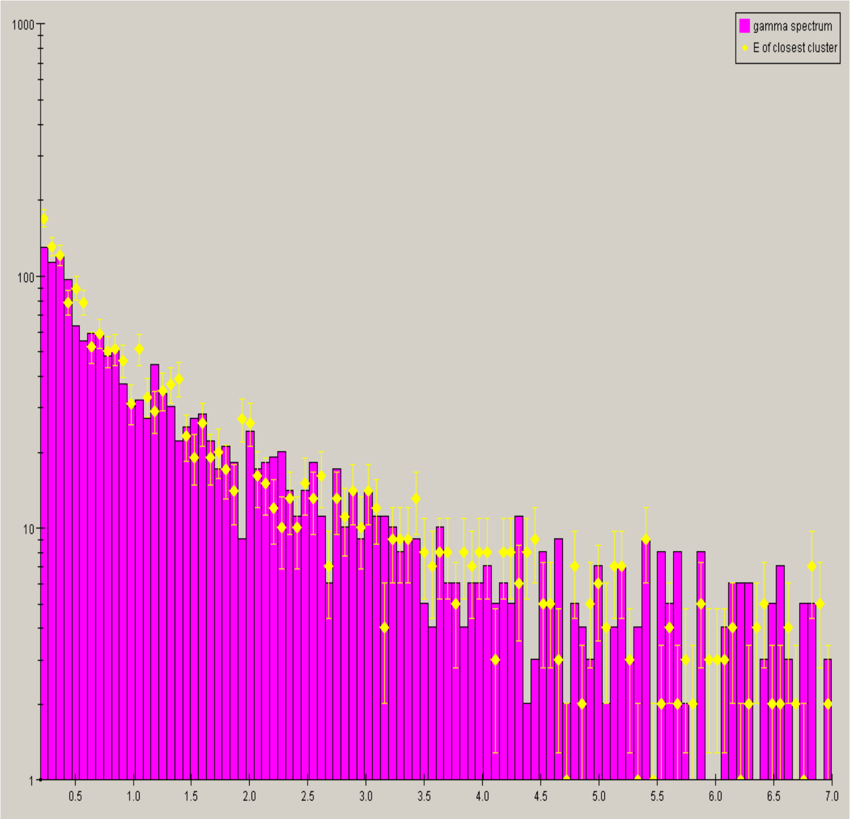
DHCal: Particle-flow algorithm (NIU)

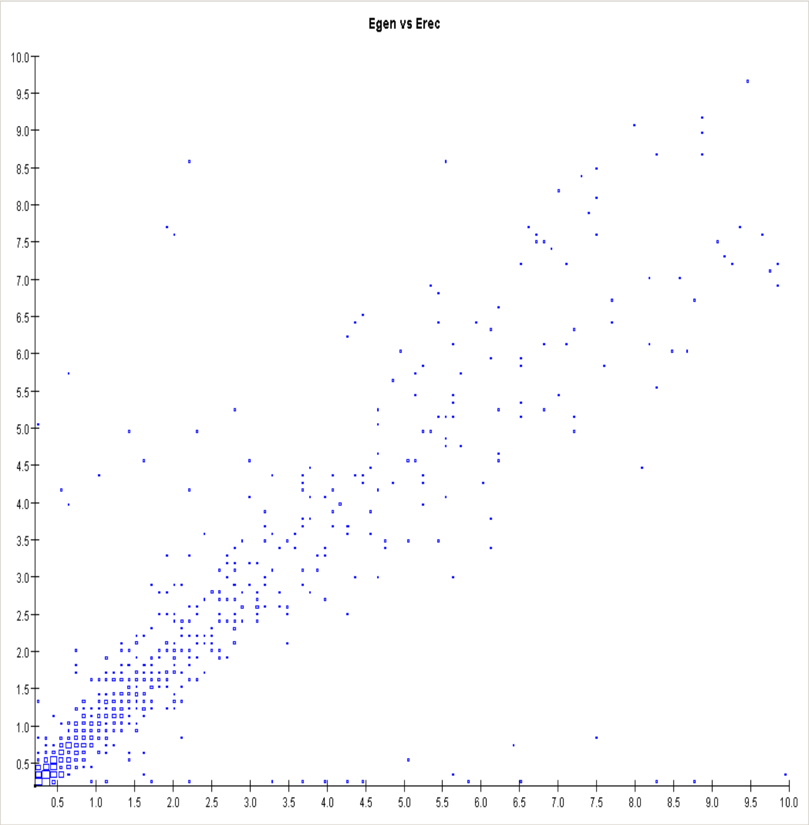
- Nominal SD geometry.
- Density-weighted clustering.
- Track momentum for charged,
- Calorimeter E for neutral particles.



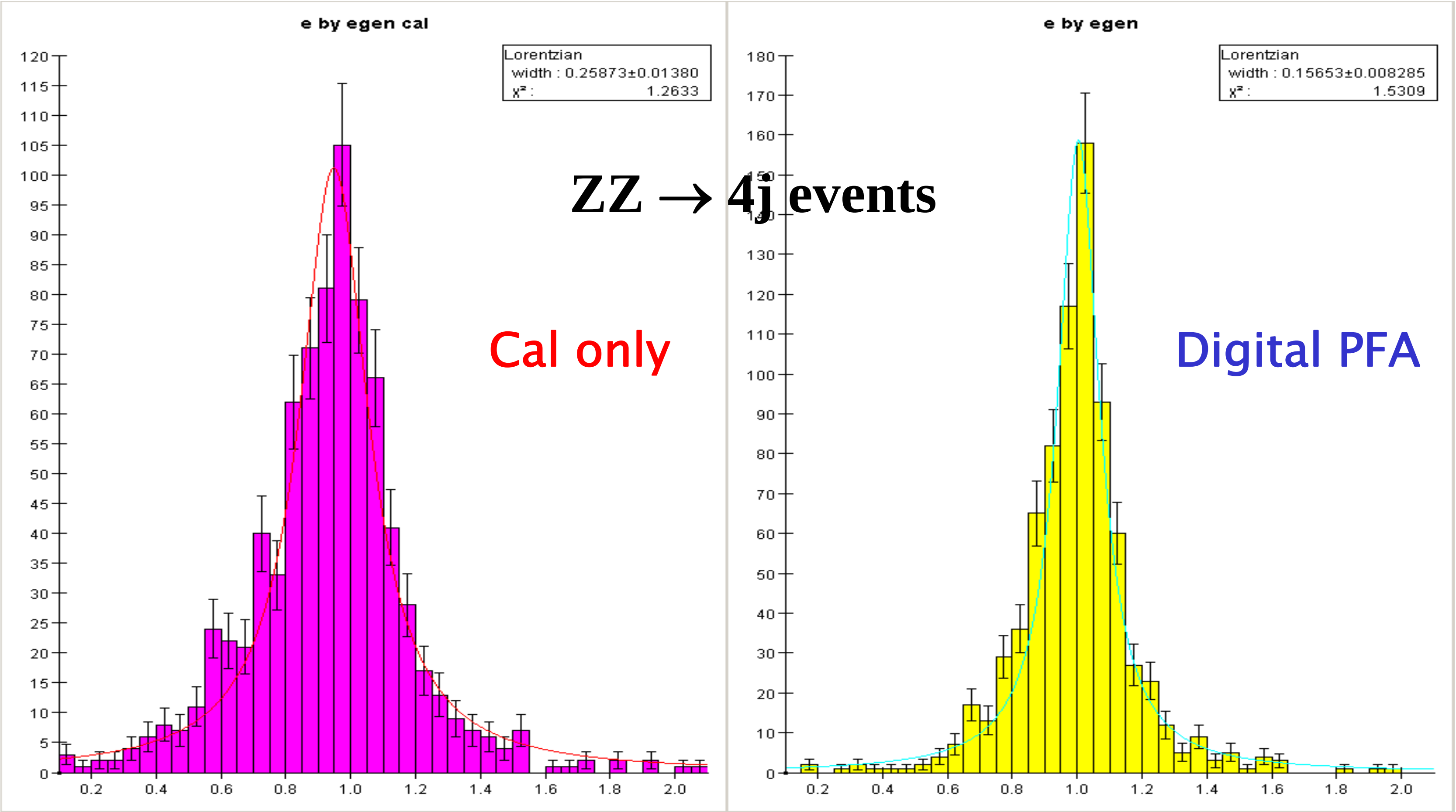
DHCal: Particle-flow algorithm (NIU) Photon Reconstruction inside jets

Excellent agreement with Monte Carlo truth:





DHCal: Particle-flow algorithm (NIU) Reconstructed jet resolution



The Directed Tree Algorithm

- Define neighborhood for a cell
- Discard cells below threshold (0.25 MIP)
- Calculate density for each cell i
- If(density==0) ?

  else

  calculate $(D_j - D_i)/d_{ij}$

  where j is in the neighborhood

  find max []

The Directed Tree Algorithm (contd.)

- If max[] is –ve

  i starts a new cluster

  if max[] is +ve

  j is the parent of I

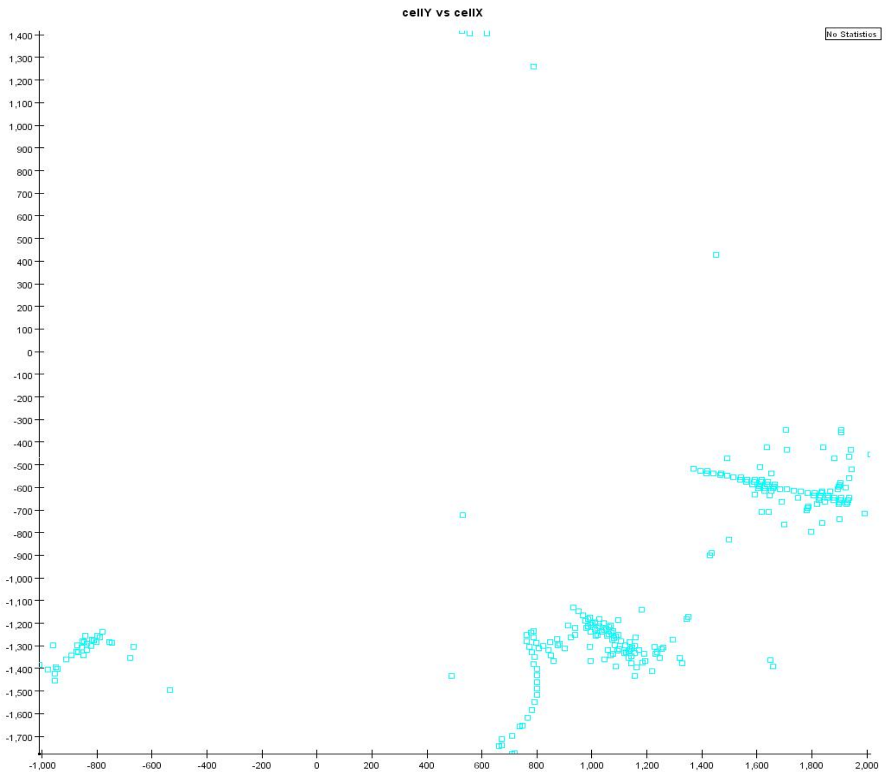
  if max[] == 0

  avoid circular loop

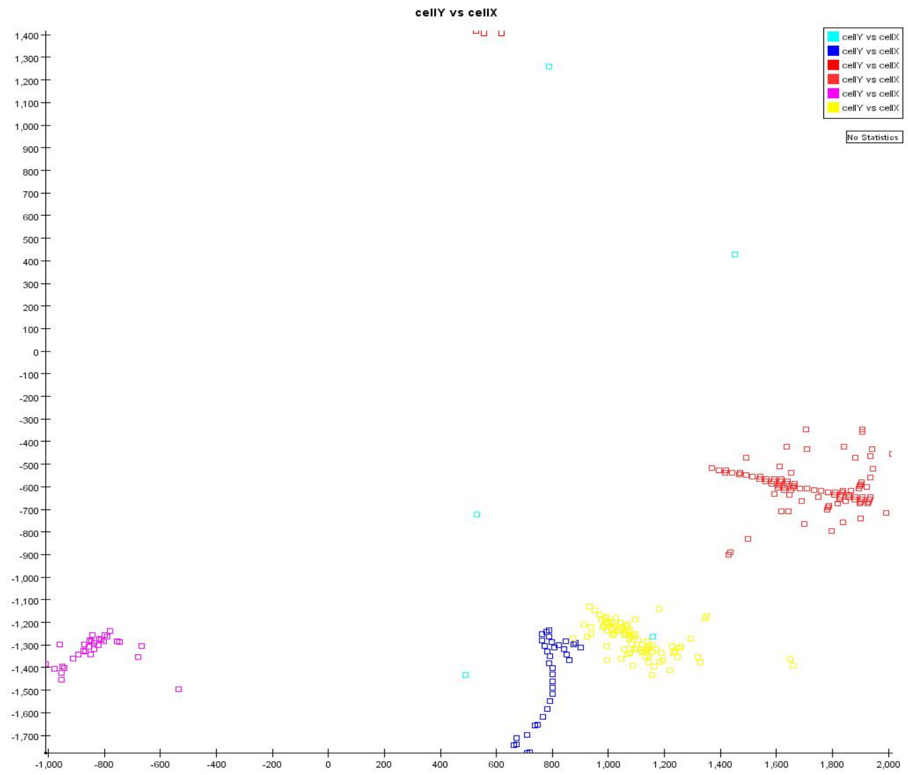
  attach to nearest

Single hadrons in the ECal

Generated clusters



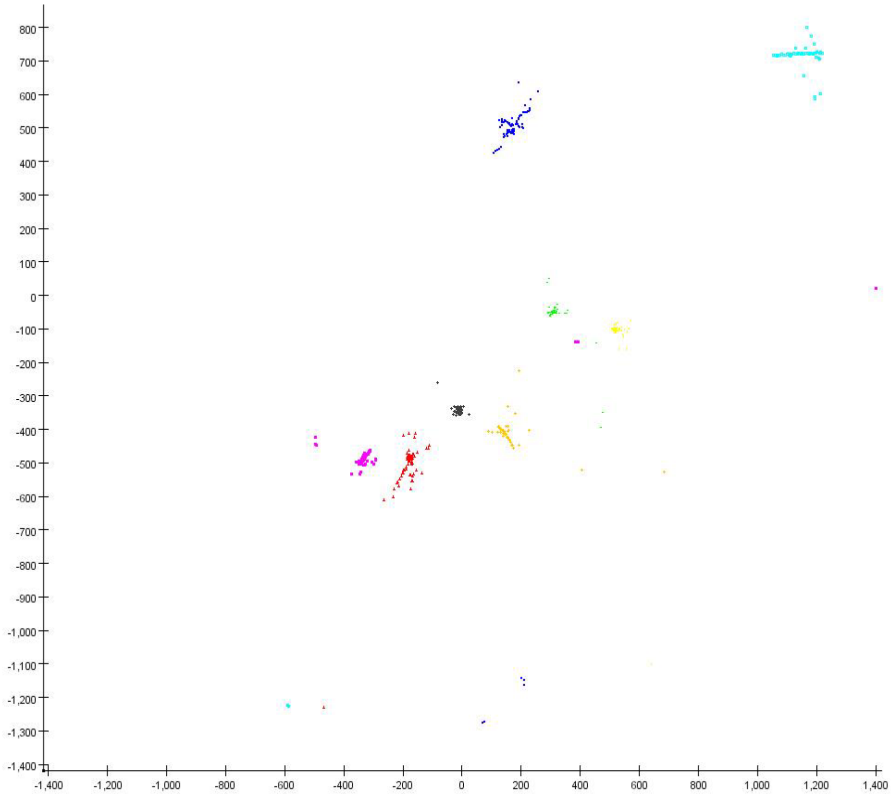
Reconstructed clusters



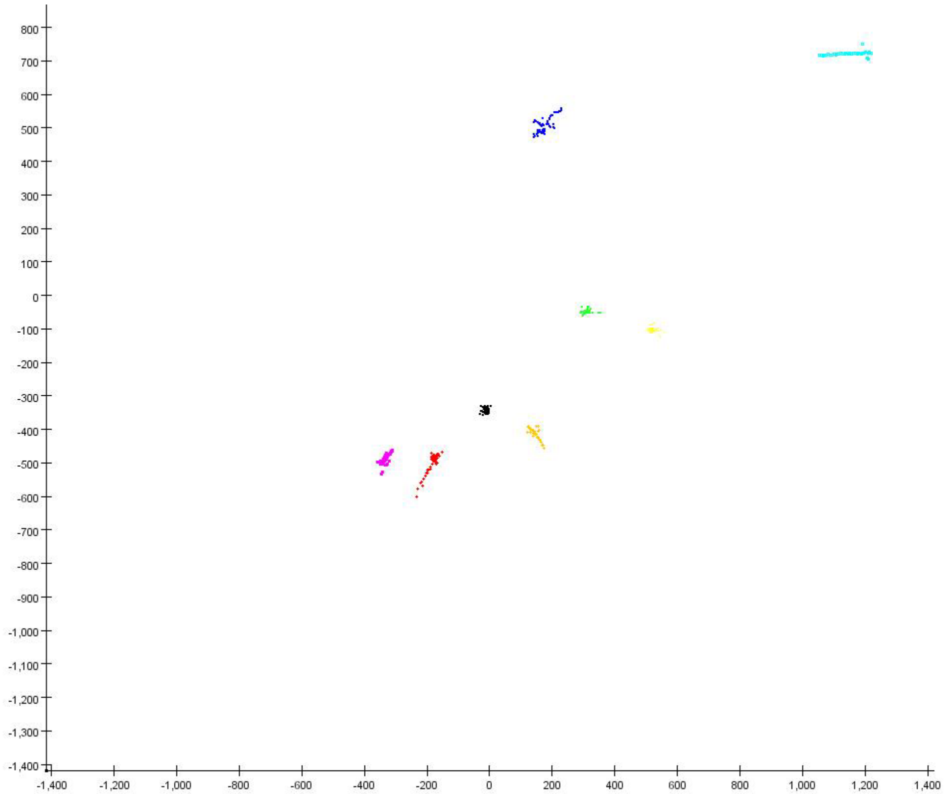
Clusters from single hadrons are reconstructed well.
Some “fragment”s or “satellite”s remain unassociated.

EM clusters in Z→qq Events

Generated clusters



Reconstructed clusters



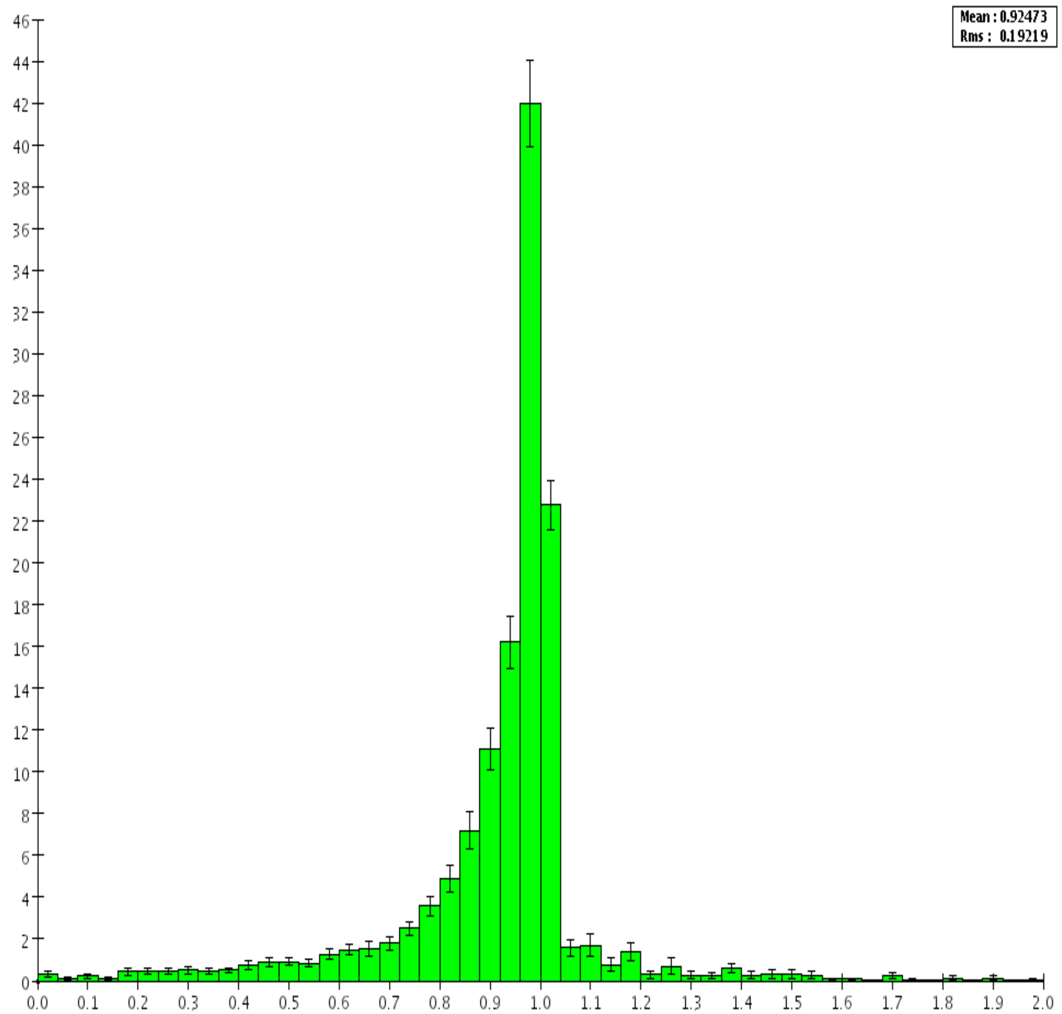
Only a few highest E clusters shown.

The confusion term

- Internal to calorimeter.
- Reconstruct “gen” and “rec” clusters,
- A “gen” cluster is a collection of cells which are attached to a particular MCparticle. All detector effects are included in this cluster.
- Find centroids and match to nearest “rec” cluster, making sure that no cluster gets associated twice.
- Somewhat conservative.

Z→qq Events

- Calculate E_{rec}/E_{gen} for each generated cluster
- Enter into histogram with weight E_{gen}/E_{total}.

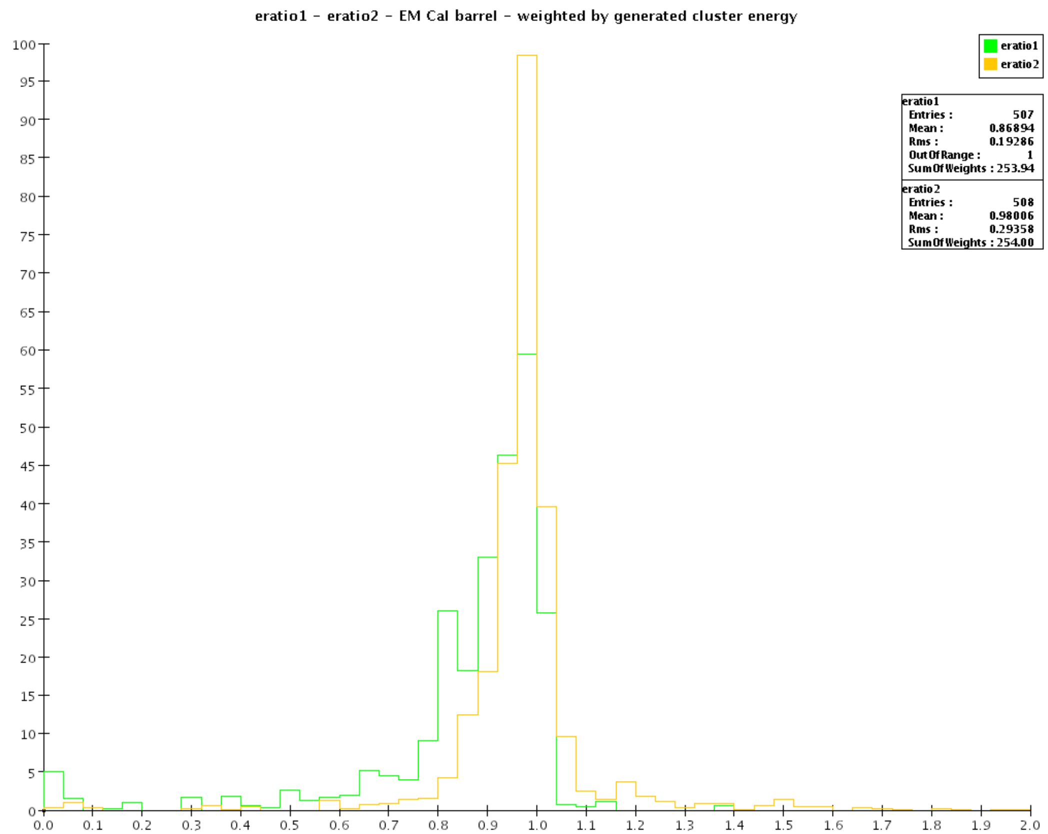


Cluster Matching and Merging

- Stage 1: one-to-one gen-reco matching based on distances (3D or angular)
  $\rightarrow$ unassociated clusters ("satellites")
- Stage 2: attach satellites to reco clusters based on angular distances: possible cuts on angular separation, satellite energies, number of hits,...

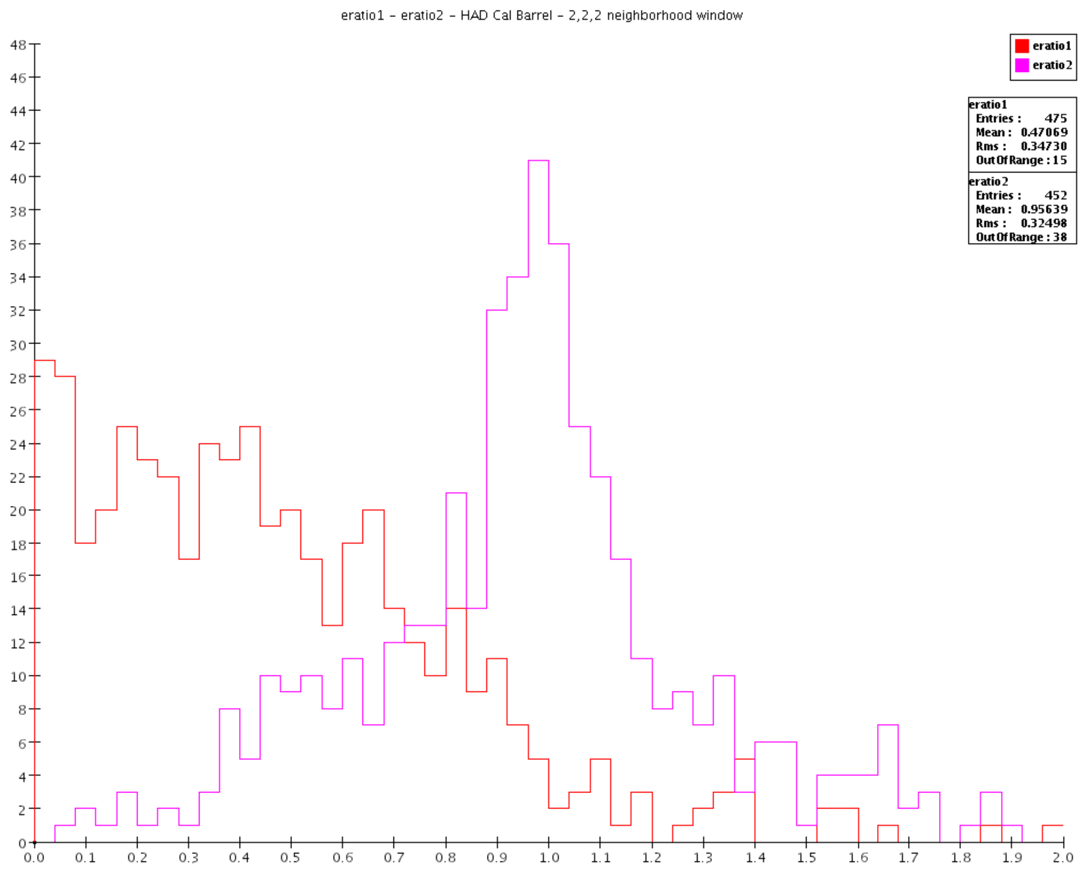
Preliminary ECal Analysis

- 500 events, with 2-pions 10 cm apart at ECal face, using SDNPHOct04 detector
- neighborhood definition: ($d\phi=5$, $dz=5$, $dlayer=9$)
- discard events with decays or interactions before Ecal
- Look at:
  - eratio1: E_{rec}/E_{gen} after stage 1 (matching)
  - eratio2: E_{rec}/E_{gen} after stage 2 (merge satellites)



Preliminary HCal Analysis

- 500 events, with 2-pions 10cm apart at Ecal face, using SDNPHOct04 detector
- neighborhood definition: (dϕ=2, dz=2, dlayer=2)
- discard events with decays or interactions before Ecal
- Look at:
  - eratio1: E_{rec}/E_{gen} after stage 1 (matching)
  - eratio2: E_{rec}/E_{gen} after stage 2 (merge satellites)



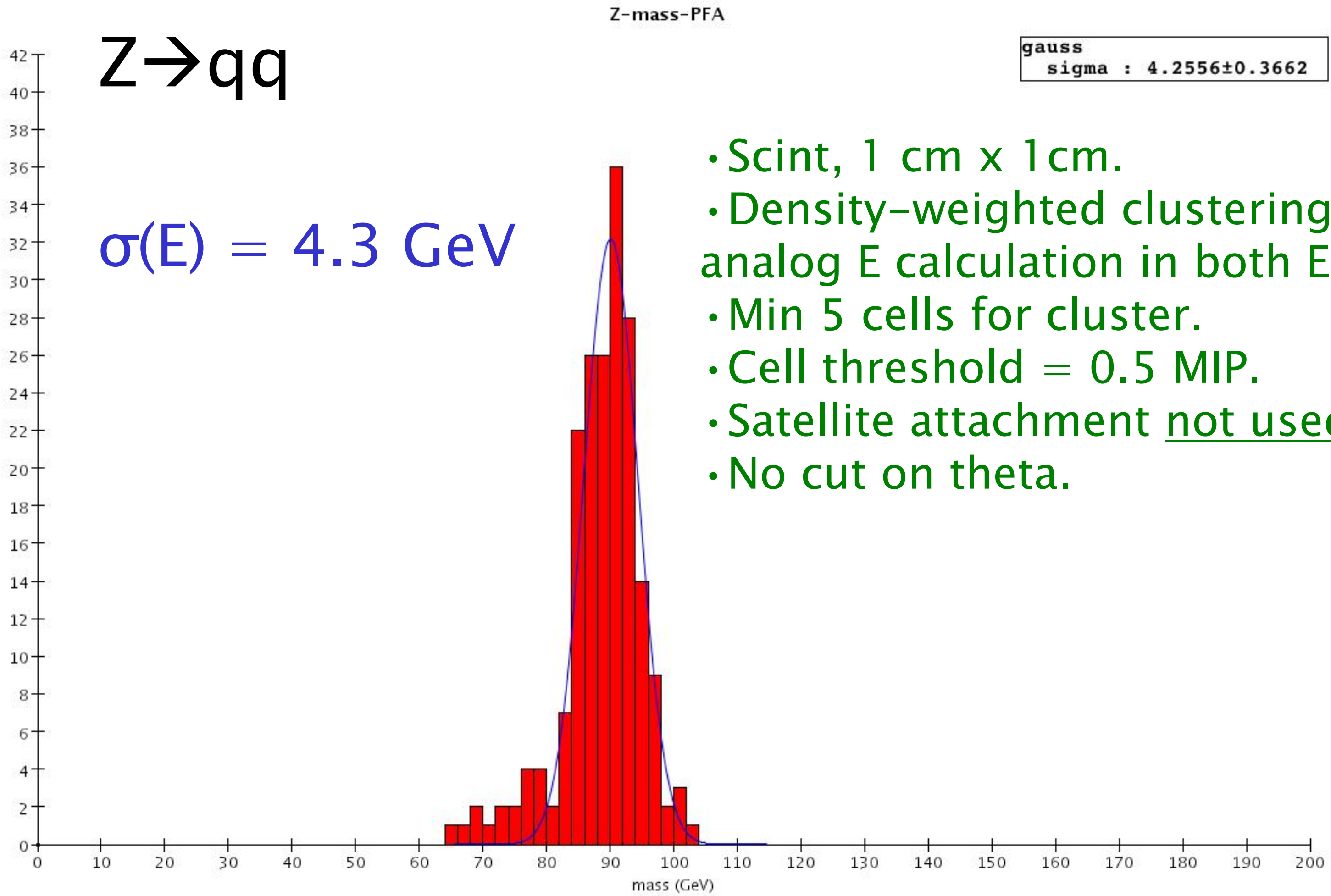
Current Status

- Analysis of complex events shows some problems with too many satellites – how to associate them with the right parent shower?
- Clustering algorithm ported to org.lcsim, to be certified. Committed to LCSim CVS repository.
- More manpower for the PFA development effort.
- Work in progress, a lot to do ...

Current Status (contd.)

Z→qq

$\sigma(E) = 4.3$ GeV

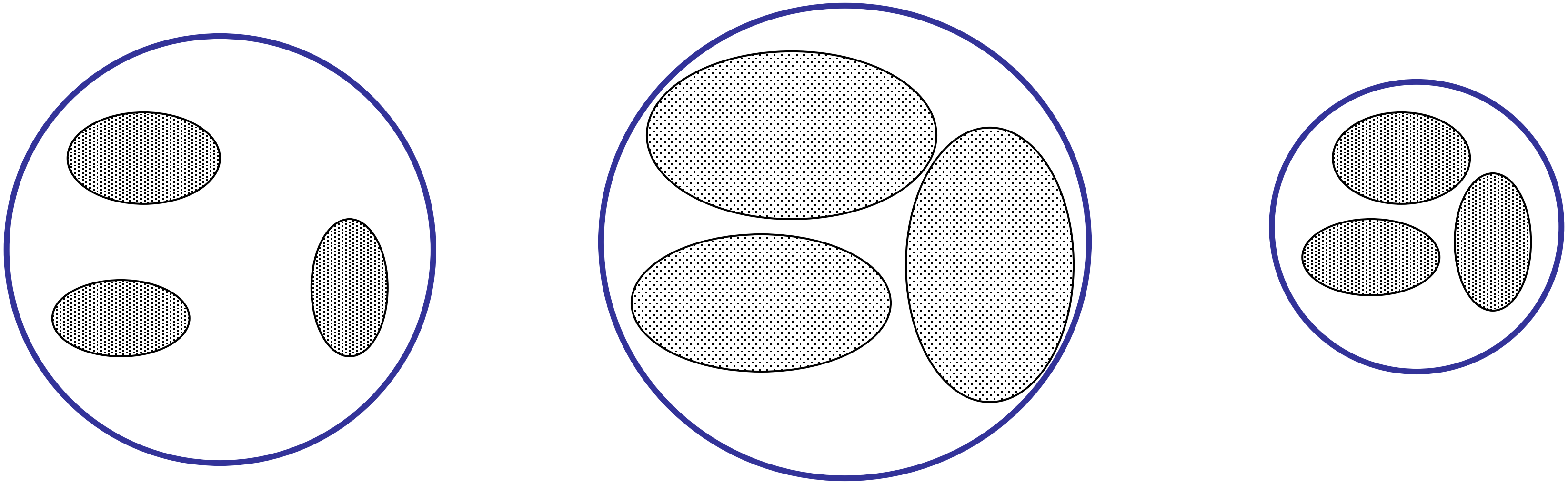


- Scint, 1 cm x 1cm.
- Density-weighted clustering, but analog E calculation in both ECal & HCal.
- Min 5 cells for cluster.
- Cell threshold = 0.5 MIP.
- Satellite attachment <u>not used</u>.
- No cut on theta.

With Perfect PFA (no confusion term), $\sigma(E) = 3.1$ GeV

Backup slides

Separability of clusters



Best separability is achieved when width of a cluster is small compared to distances between clusters.

$$J = \mathrm{Tr}\{S_w^{-1}\ S_m\}$$

Separability of clusters (contd.)

where

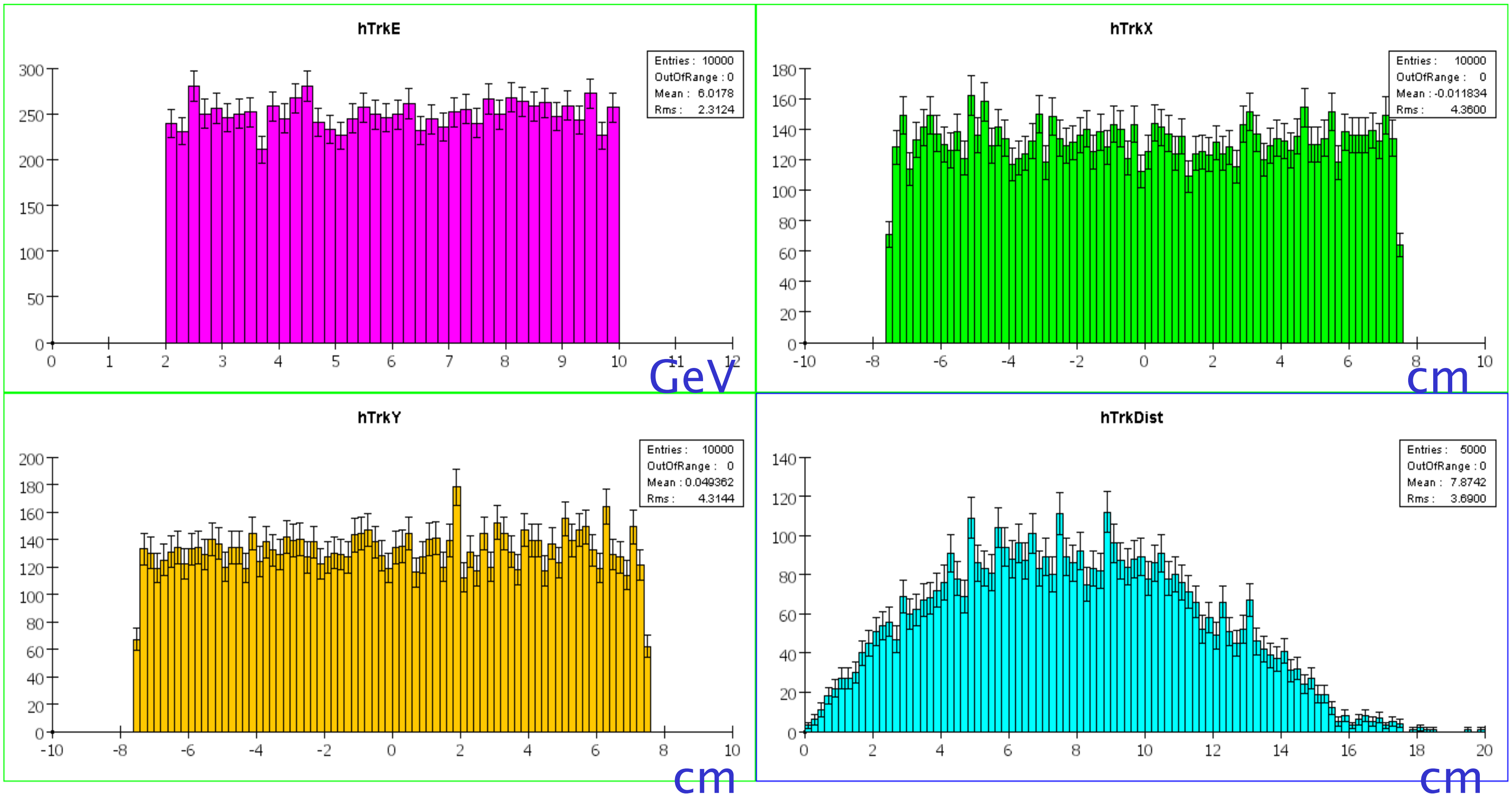
$S_w = S_i W_i S_i$

S_i = covariance matrix for cluster c_i (in x, y, z)

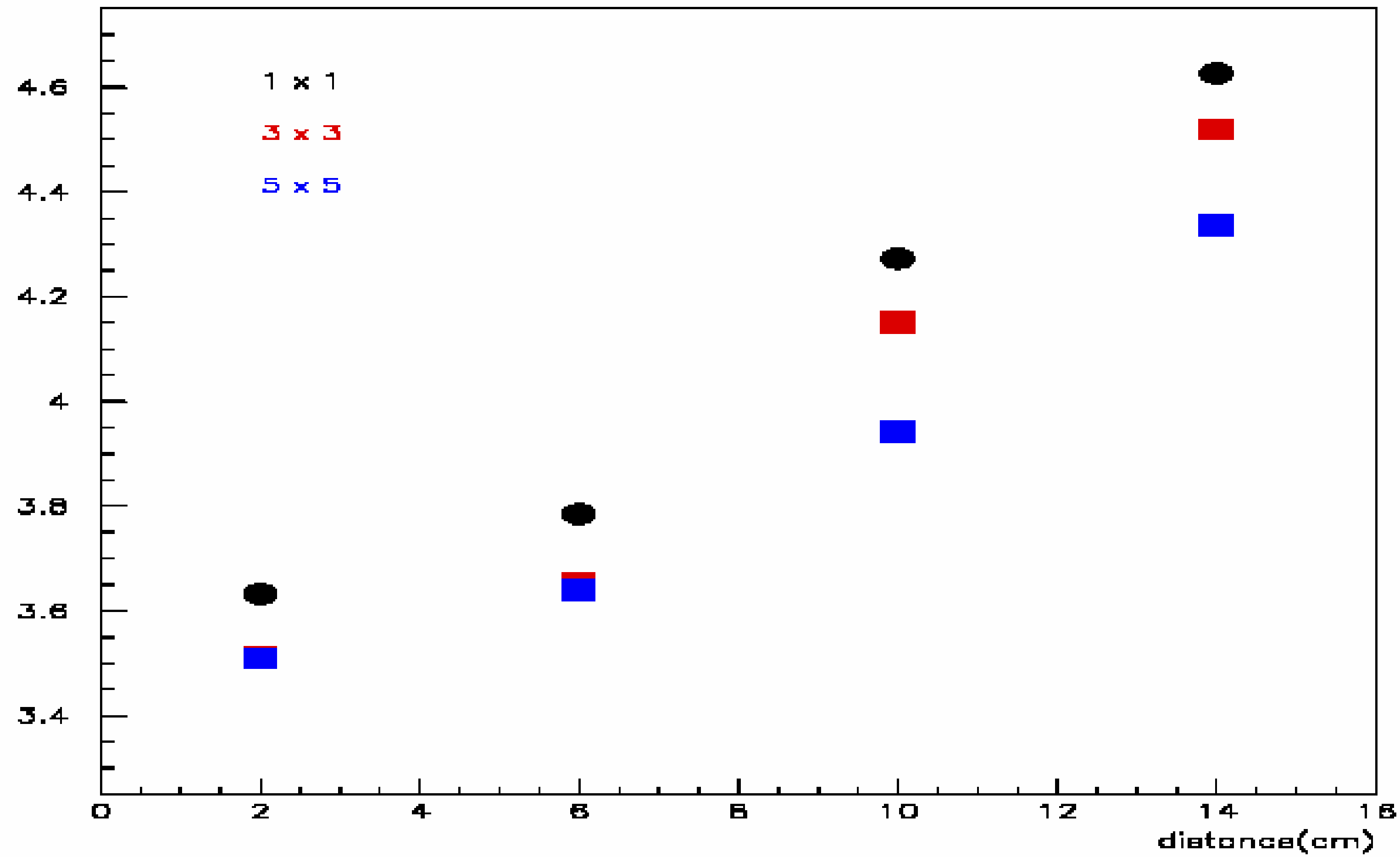
W_i = weight of c_i (choose your scheme)

S_m = covariance matrix w.r.t. global mean

Two (parallel) π^+'s in TB sim:



Two (parallel) π^+'s in TB prototype sim: separability (J) vs. track distance for different cell sizes



PFA Jet Reconstruction summary (past)

- Cone clustering in the calorimeters,
- Flexible definition of weight (energy- or density-based),
- Generalizable to form “proto-cluster” inputs for higher-level algorithms.
- Replace cal clusters with matching MC track, if any.
- Based on projective geometry.
- New clustering algorithms taking shape.