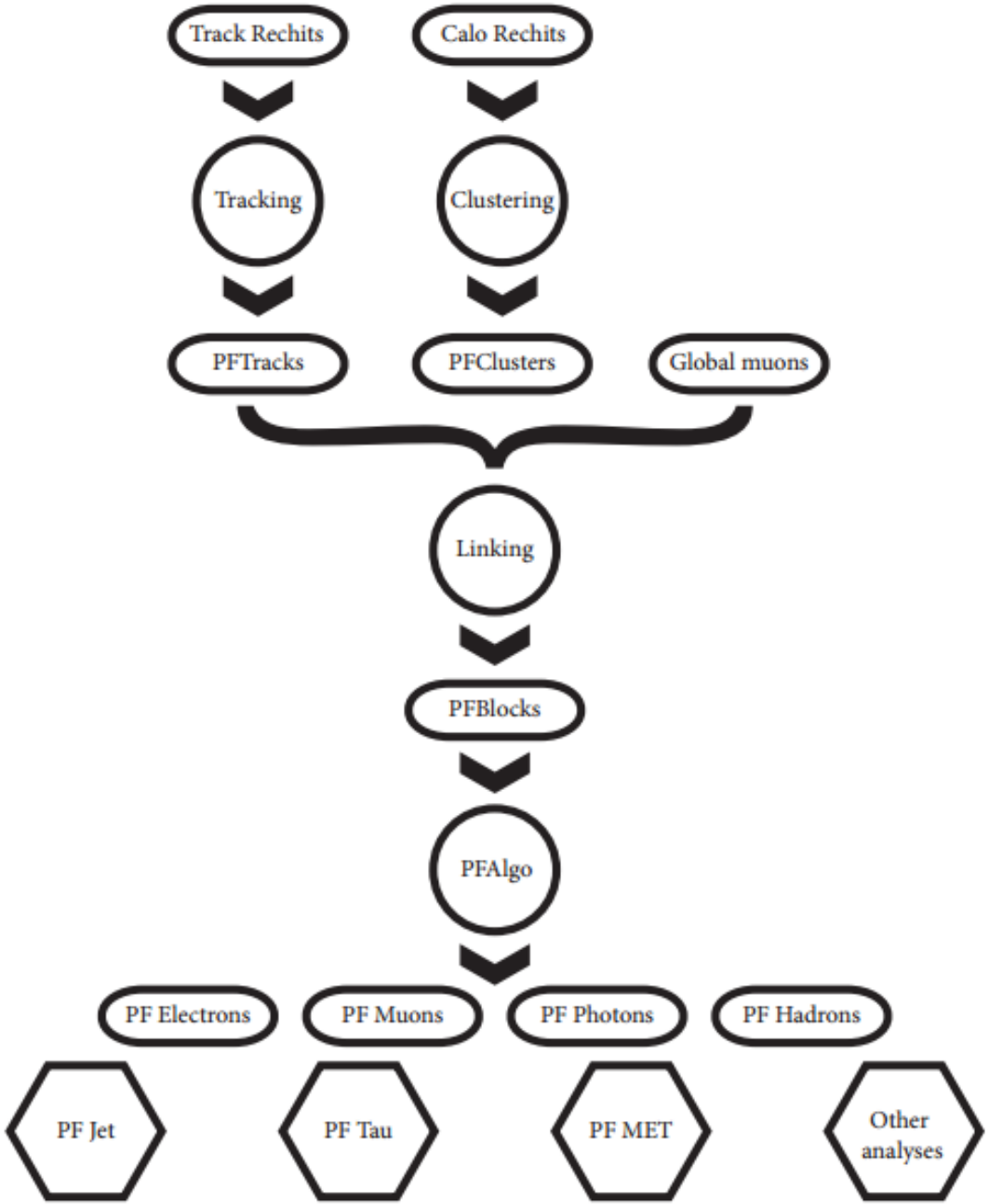
Particle-flow

Particle flow reconstruction
Various terms used in the diagram are explained in the text.



Tracking

- Approximately two-thirds of the particles produced in collisions are charged so it is imperative that these particles are correctly reconstructed.
- The cms tracker's resolution outperforms the calorimeters for charged hadrons up to transverse momenta (pT) of O(300 GeV/c).
- It also gives the direction of the charged particles emanating from the collision vertex
- Particle flow uses an iterative tracking strategy that creates tracks using very strict quality criteria which are subsequently loosened to increase efficiency while maintaining a negligible fake rate.

Electrons and muons

- electrons radiate 50% of their energy in the tracker, so much effort is devoted to ensuring these electrons are accurately and precisely reconstructed
- Muons receive a specialized treatment combining information from the tracking and muon systems, giving rise to the jargon of 'global muons'

Clustering-Algorithm

1. Find all rechits greater than the seed threshold. Neighbouring rechits exceeding the threshold contest each other for seed status; the rechit with the greatest energy becomes the seed. In the ecal, crystals which share a corner qualify as 'neighbouring'; in the hcal the towers must share an edge. In other words, cells must be a local maximum above the seed threshold to qualify for seed status.
   - The seed and cell thresholds are based on hcal noise values derived from testbeam data

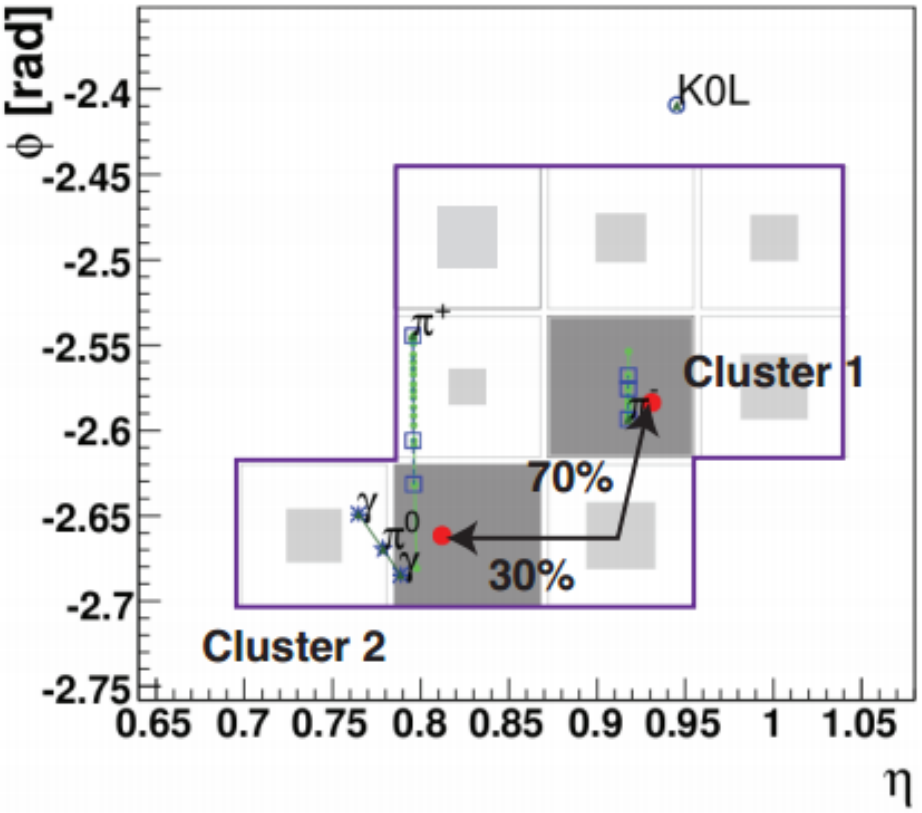
PF Clustering parameters

Reproduced from [41]. No clustering is applied in the HF. Components are: EB, EE – ECAL barrel & endcap; HB, HE – HCAL barrel & endcap; PS – preshower.

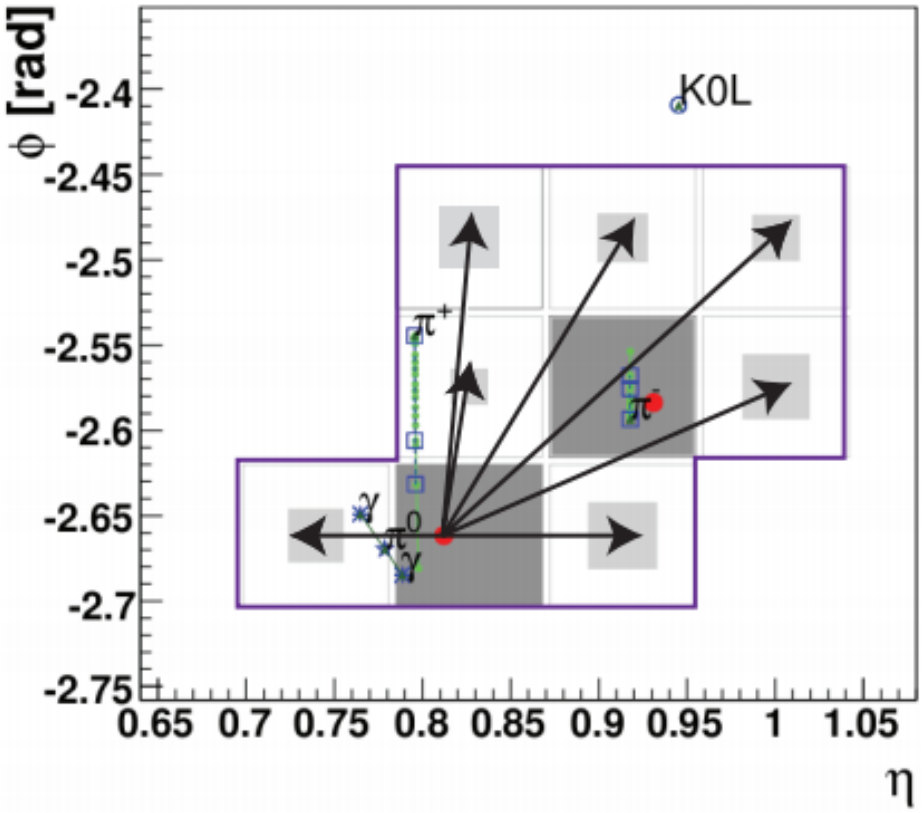
	EB	EE	HB	HE	PS
Cell threshold (GeV)	0.08	0.30	0.80	1.10	7×10^{-6}
Seed threshold (GeV)	0.23	0.80	0.80	0.80	5×10^{-4}
# cells to compare to candidate seed	8	8	4	4	8
R (cm) (Eq. 4.1)	5.0	5.0	10.0	10.0	0.2
# cells for position calculation	9	9	5	5	all

2. Grow clusters: connect the remaining rechits with energies greater than the cell threshold to the seeds, where the proposed rechit and any of the seed and already connected cells are neighbours (according to the definition above). Cells may belong to more than one cluster. Note, however, that in practice clusters do not grow larger than 2 or 3 cells across even in the most dense environments.

3. Determine the energy and position of the clusters with an iterative procedure.First, each cluster is assigned a position equal to that of its original seed. Second,each rechit contributes energy to each of its parent clusters with a weight, $w_{ij} \exp(-d_{ij}^2/R^2)$
where di j is the distance between the cluster i and cell j, R is given by Table 4.1, and wi j is a normalization to prevent double-counting of energy. ❒The position of each cluster is then re-computed as the average position of its rechits, weighted by a factor log(Ej/Ecell). ❒The energy of the cluster is then re-evaluated. ❒This position/energy reassignment is repeated until the cluster's position does not move more than a small fraction of that subdetector's position resolution



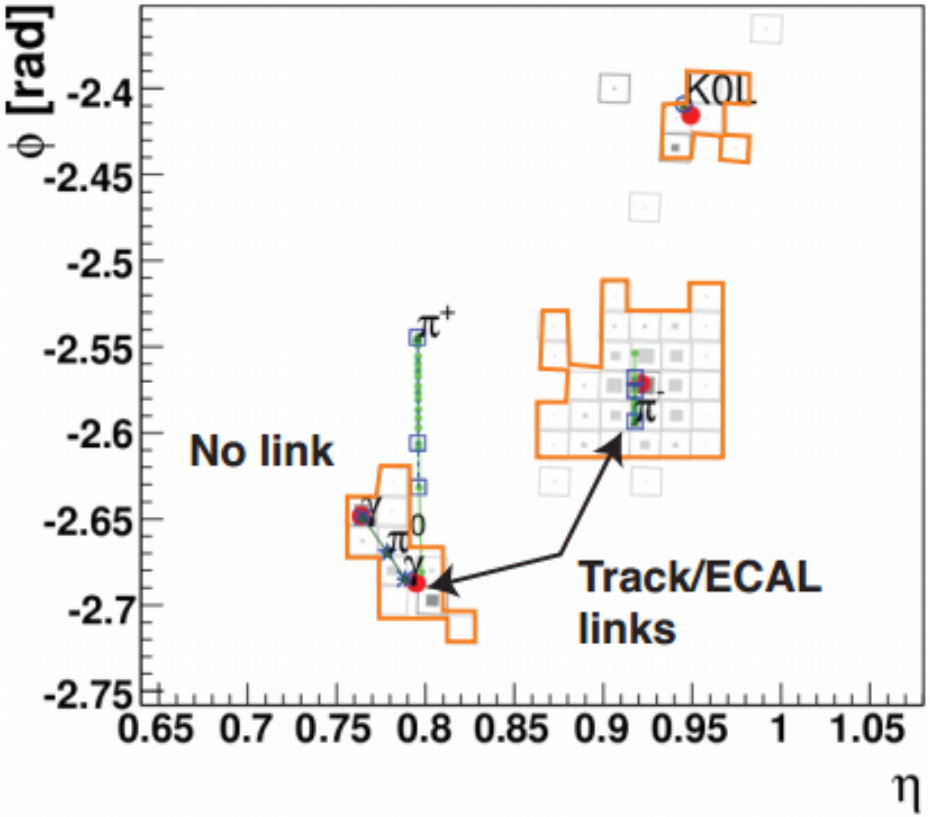
(a) Finding the seeds in the HCAL. Two clusters overlap with an envelope shown in purple. The bottom right rechit contributes its energy to the two seeds with a weight according to Eq. 4.1.



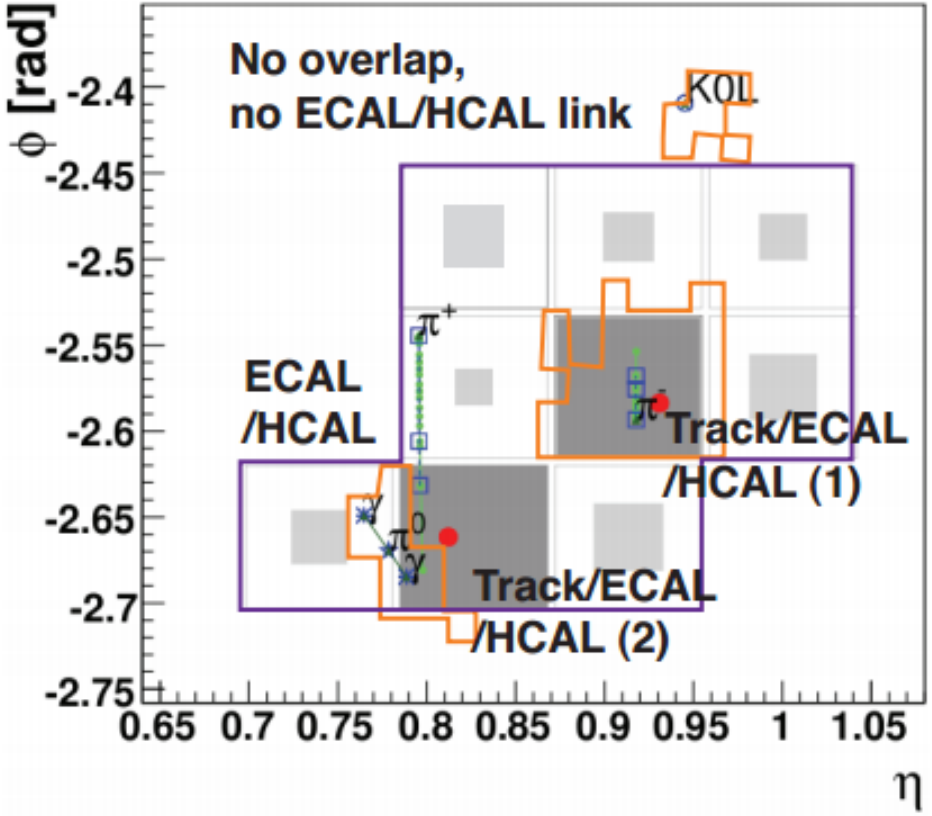
(b) Sharing energy. Seeds do not contribute to other cluster's energies. This stabilizes the algorithm in highly asymmetric cases.

Commissioning of the link algorithm-Track-cluster link

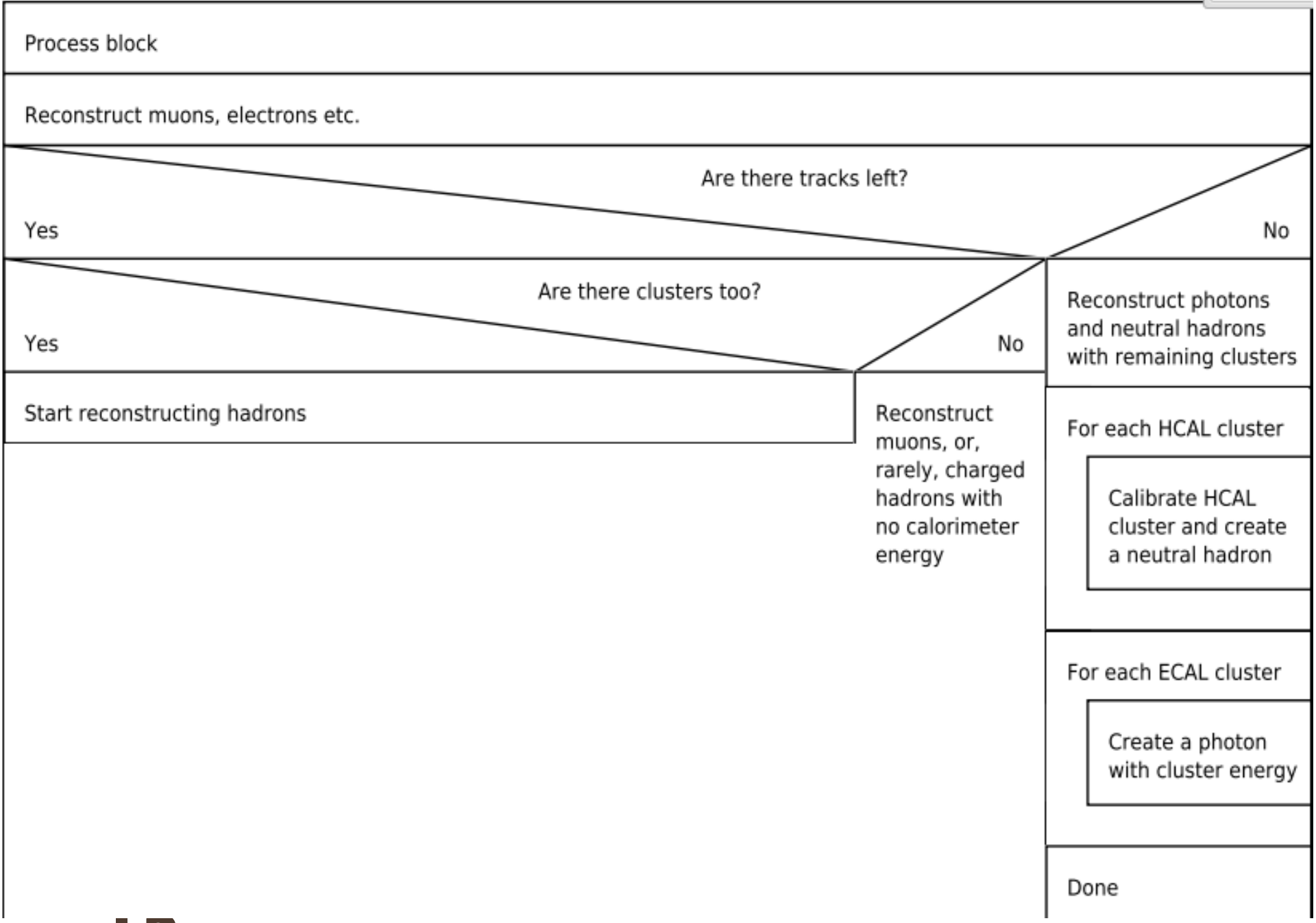
- The track is first extrapolated from its last measured hit in the tracker to
  - the two layers of the preshower detector
  - the ECAL, at a depth corresponding to the expected maximum of a typical longitudinal electron shower profile
  - the HCAL, at a depth corresponding to one interaction length, typical of a hadron shower
- The track is linked to a given cluster if the extrapolated position in the corresponding calorimeter is within the cluster boundaries.

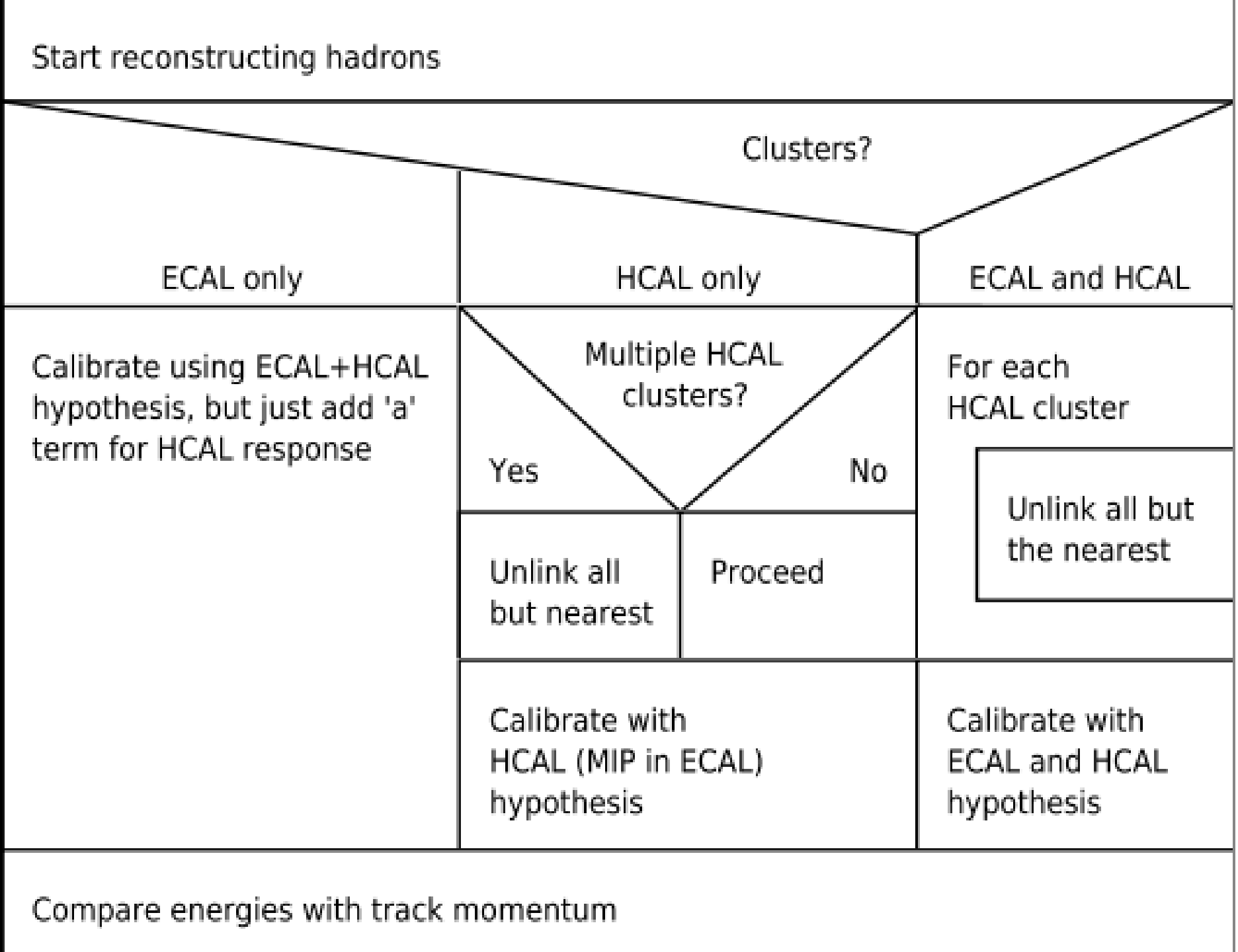


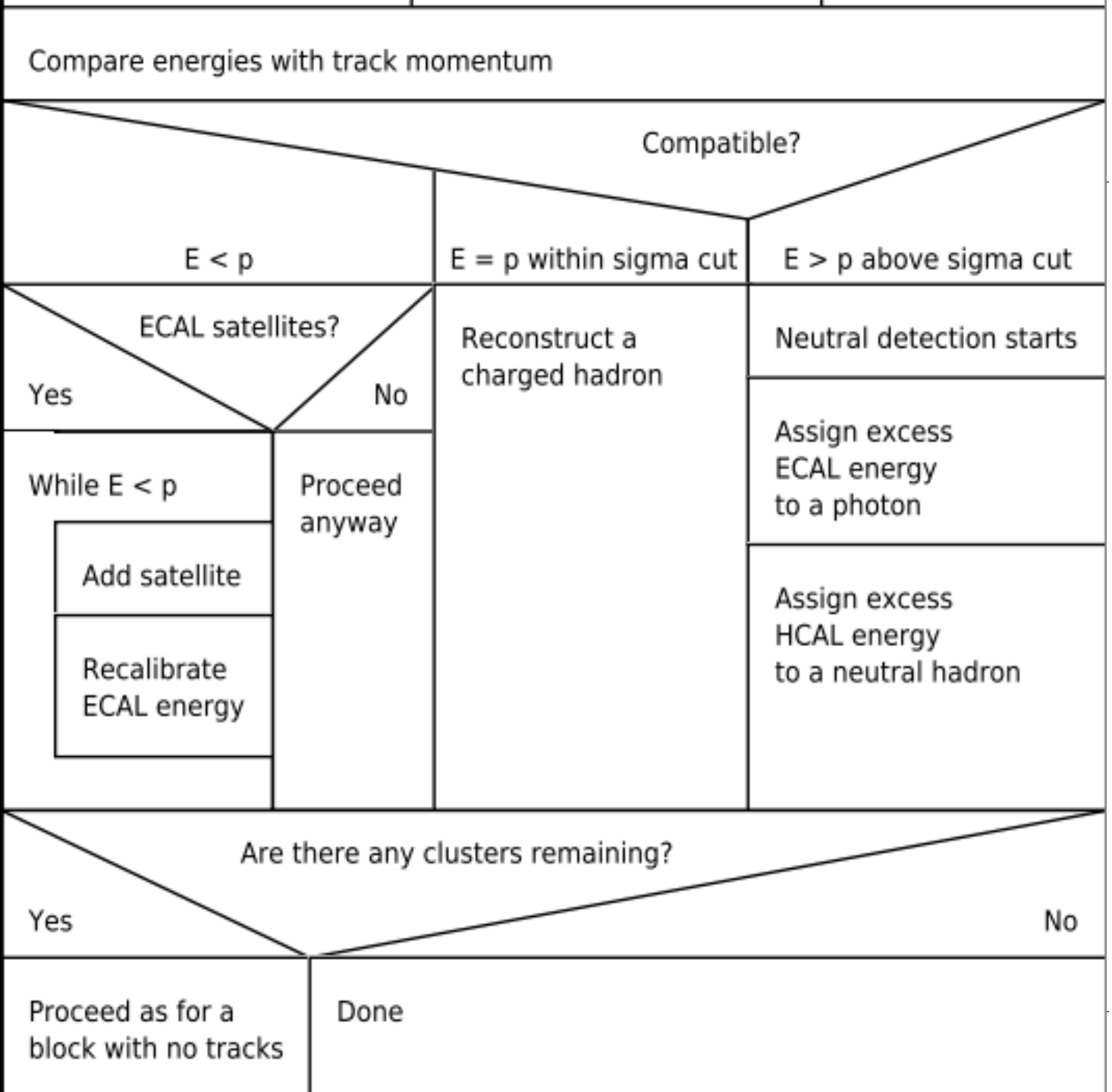
(a) *Four ECAL clusters have been found. The π^+ does not give rise to a cluster in the ECAL. ECAL clusters are linked to the track if the track intersects a rechit in a cluster.*



(b) *The left hand ECAL (2) and HCAL (2) clusters get associated with each other, and the HCAL cluster is associated with a track. The central clusters get associated with each other (1), but only the HCAL (1) cluster also gets associated to the track. The top-right ECAL cluster remains orphaned.*


Process block
Reconstruct muons, electrons etc.
Are there tracks left?
Yes
No
Are there clusters too?
Yes
No
Reconstruct photons and neutral hadrons with remaining clusters
Start reconstructing hadrons
Reconstruct muons, or, rarely, charged hadrons with no calorimeter energy
For each HCAL cluster
Calibrate HCAL cluster and create a neutral hadron
For each ECAL cluster
Create a photon with cluster energy
Done


Start reconstructing hadrons
Clusters?
ECAL only
HCAL only
ECAL and HCAL
Calibrate using ECAL+HCAL hypothesis, but just add 'a' term for HCAL response
Multiple HCAL clusters?
Yes
No
Unlink all but nearest
Proceed
For each HCAL cluster
Unlink all but the nearest
Calibrate with HCAL (MIP in ECAL) hypothesis
Calibrate with ECAL and HCAL hypothesis
Compare energies with track momentum


Compare energies with track momentum
Compatible?
E < p
E = p within sigma cut
E > p above sigma cut
ECAL satellites?
Yes
No
Reconstruct a charged hadron
Neutral detection starts
While E < p
Add satellite
Recalibrate ECAL energy
Proceed anyway
Assign excess ECAL energy to a photon
Assign excess HCAL energy to a neutral hadron
Are there any clusters remaining?
Yes
No
Proceed as for a block with no tracks
Done