Reconstruction Methods for semi-digital HCAL

Minimum Spanning Tree and Hough Transform

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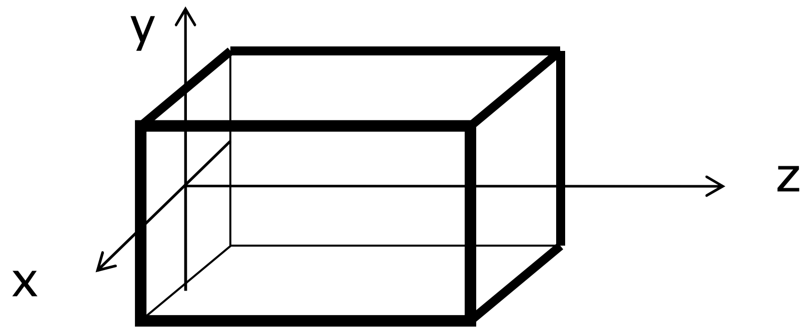
I – Minimum Spanning Tree

Electron – Hadron separation

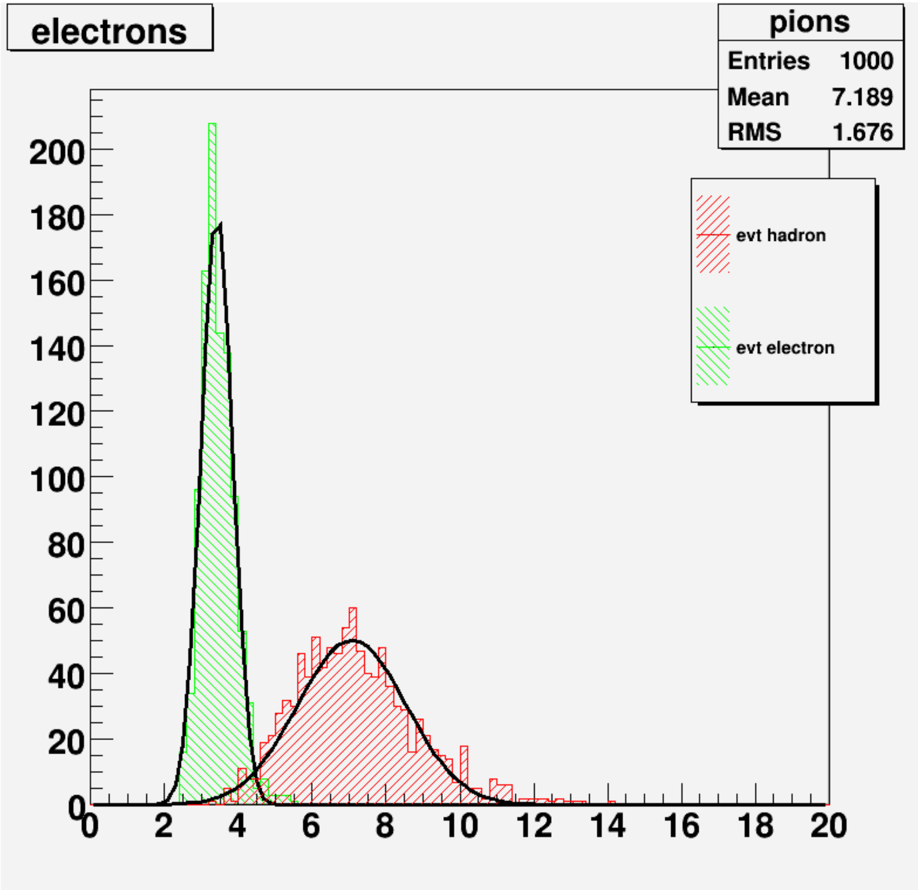
Minimum Spanning Tree (MST) – Principle :

- Find the best way to link N points
- Defining a metric from the geometry
- Weighting each link (λ_{ij}) and selecting the shortest
- In our case we distinguish both longitudinal and transversal directions (electromagnetic and hadronic shower development)
- $\lambda_{ij} = a|z_i - z_j| + b(|x_i - x_j| + |y_i - y_j|)$



- Hits are simulated with Geant4 and the positions data are recorded (1000 pions and 1000 electrons)
- The whole set of links is computed for the N(N-1)/2 links
- Search for (N-1) minimizing links, then hits are associated by pair
- Average link length indicates the shower complexity
  - Event by event
  - Separation within the same shower

- Studying average link length distribution, considering incoming particle (CHARM II)



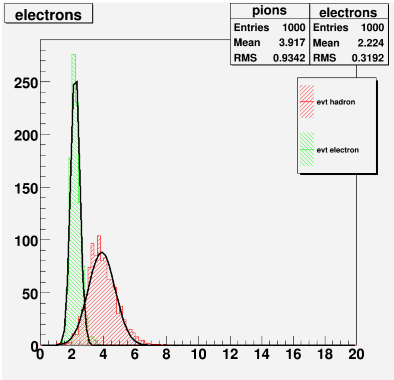
# of events vs. mean link length

- Electromagnetic shower:
  - Contained in a small volume mainly situated around the shower axis

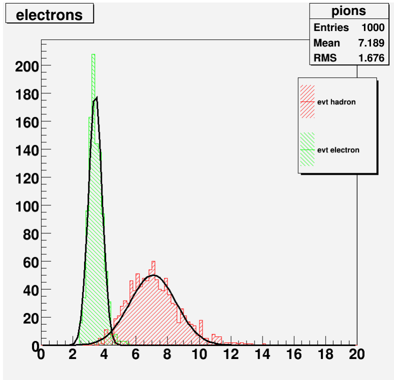
  => smaller average link length
- Hadronic shower :
  - More complex processes, less similarity between events, transversal development

  => superior and widespread average link length value

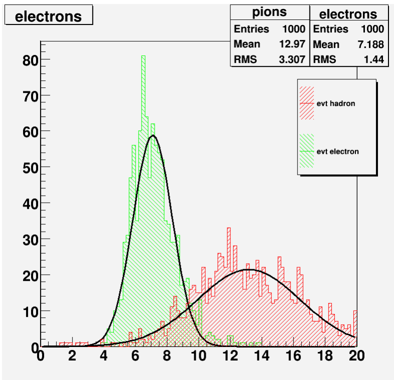
- Using different metrics leads to more or less separation efficiency



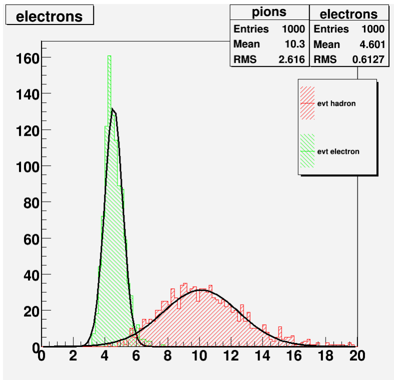
(a,b) = (1,1)



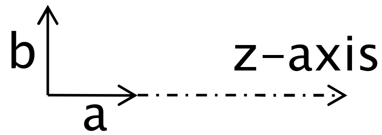
(a,b) = (5,1)



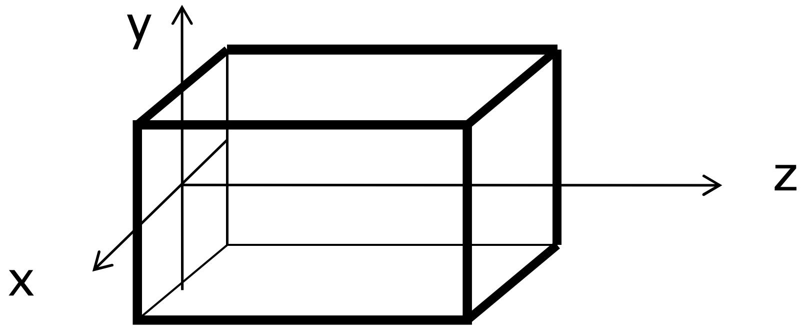
(a,b) = (1,5)



(a,b) = (10,1)



$$\lambda_{ij} = a|z_i-z_j| + b(|x_i-x_j|+|y_i-y_j|)$$

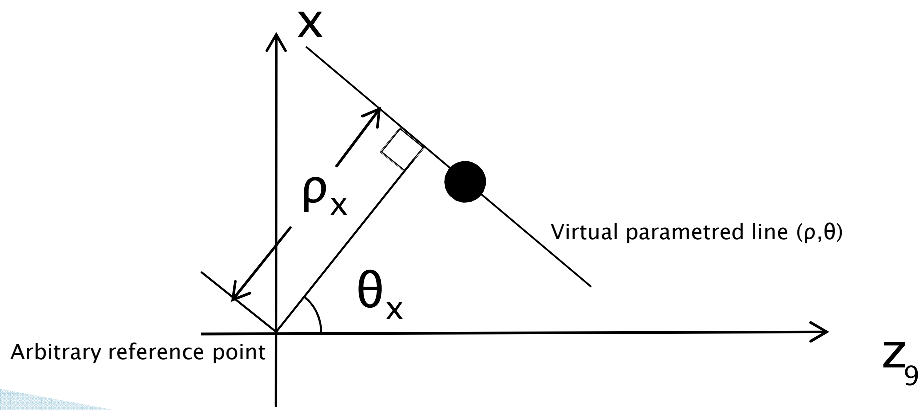


- Further works :
  - Try to isolate the electromagnetic contribution in a hadronic shower (Daniel Forster)
  - Use minimum spanning tree to distinguish a multi-particle event and associate a specific hit to its primary particle (detailed in part III)

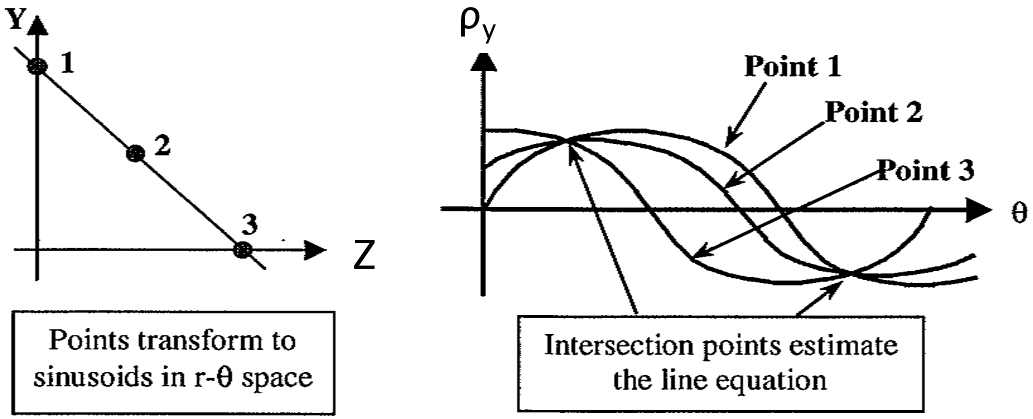
II – Hough Transform

M.I.P tracks detection

- Why are we interested in MIP tracks?
  - Be able to proceed to online detector calibration
  - Check the RPC's efficiency
  - Check the detector alignment
- Hough Transform – Principle :
  - Detect geometrical objects in a picture
  - Hough space = space containing geometrical parameters of wanted objects
  - For each hit we consider all lines which pass through, projected in the xOz and yOz planes (influence of binning)
  - $\rho_x = x.\sin(\theta_x) + z.\cos(\theta_x)$ $\theta_x, \theta_y \in [-\pi/2; \pi/2]$
  - $\rho_y = y.\sin(\theta_y) + z.\cos(\theta_y)$



- We obtain a Hough space matrix containing ρ_x, ρ_y values for each hit and each value of θ
- This Hough space is replaced with 4D histogram
- Then we keep bins (θ_x, ρ_x, θ_y, ρ_y) wich contain a maximum number of intersections
- The hits associated to those bins are considered as mip track candidates



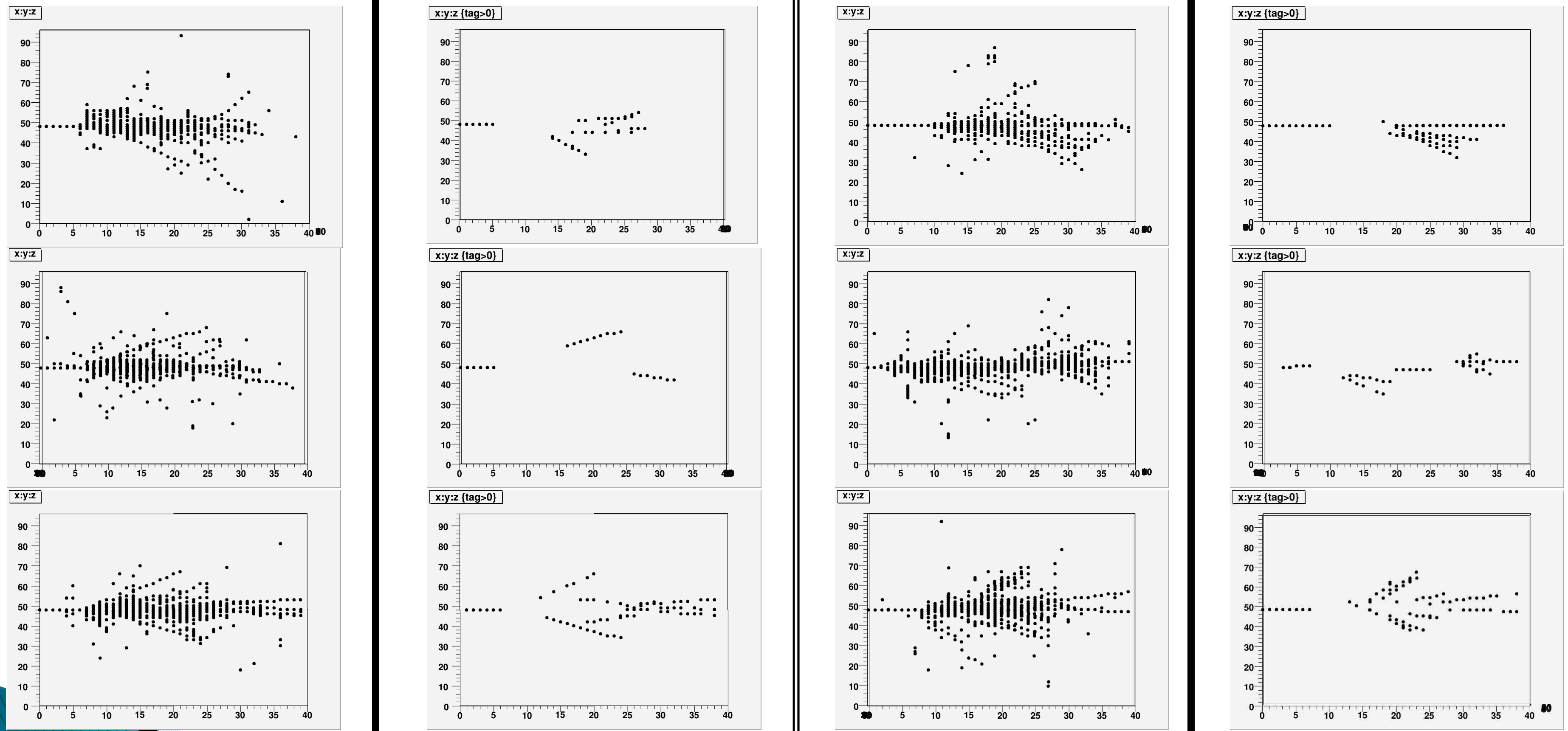
- To reduce computing time, some hits are simply ignored :
  - Density cut : Hits which belong to the heart of the shower and isolated hits are ignored (to avoid computing insignificant lines)
  - As we have a semi-digital calorimeter (3 threshold : 0,2 ; 5 ; 10 mip), I also apply a cut on hit threshold
    - Hits which trig the third threshold are ignored, the energy deposition is too high to correspond to a mip

- Once main lines are obtained, an extra step is performed to check the availability of these lines
  - They must include a significant number of hits
  - They must be continuous no more than few missing hits

- To ensure the tracks continuity, I used the minimum spanning tree (MST) technique
  - Each hit belonging to a mip track candidate is tagged (i.e. with the track ID number)
  - Then I apply the MST algorithm on these specific hits
  - If there is a “hole” in this track I divide it into some secondary tracks and check if they are compatible in terms of length and continuity criteria

- Results :
  - After computing, tagged hits are displayed
  - Here showers are presented for 100GeV incoming pion

untagged | tagged | untagged | tagged



- Further work :
  - Use simulation information on particles ID to check the method efficiency (muon detection)
  - Use different parameterizations to identify curved tracks
  - Study the effect of binning on the method efficiency

III – Multiparticle separation

- Still based on Geant4 simulation
  - Building a multiparticle event from different simulation files : different incoming particles at different energies
  - Combining two of the previous independent events as one event
  - Studying effects of proximity and incidence angle of the showers on efficiency of the method

- Main steps of the algorithm :
  - Find shower thrusts :
    - Cut on low energy deposition and low hit density
    - Apply Hough transform on remaining hits and keep parameters of main shower axes
    - Create virtual hits corresponding to shower thrusts
  - Reconstruct events :
    - thrust axis chosen as Z axis, X & Y perpendicular to Z, forming a right-handed coordinate system.
    - A minimum spanning tree is computed for each projection
  - Minimum spanning tree :
    - Same principle with few changes

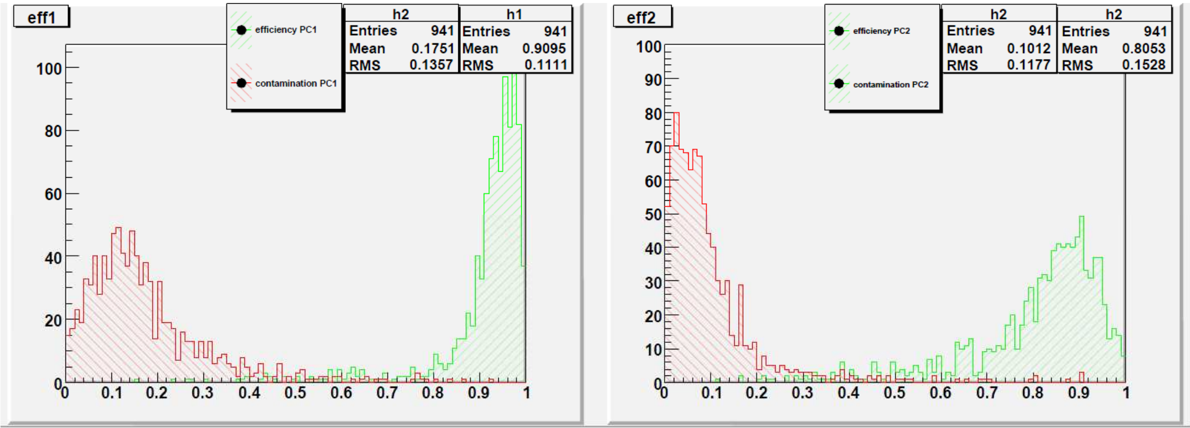
- The Minimum spanning tree is computed between the virtual hits of the thrust and the hits of the data, then
- A metric which gives more important contribution for longitudinal development is used
- The links are summed from one hit to an other (~distance from shower axis)
- Comparing the results of the different spanning trees computing associates hits to thrusts, so to events

First results

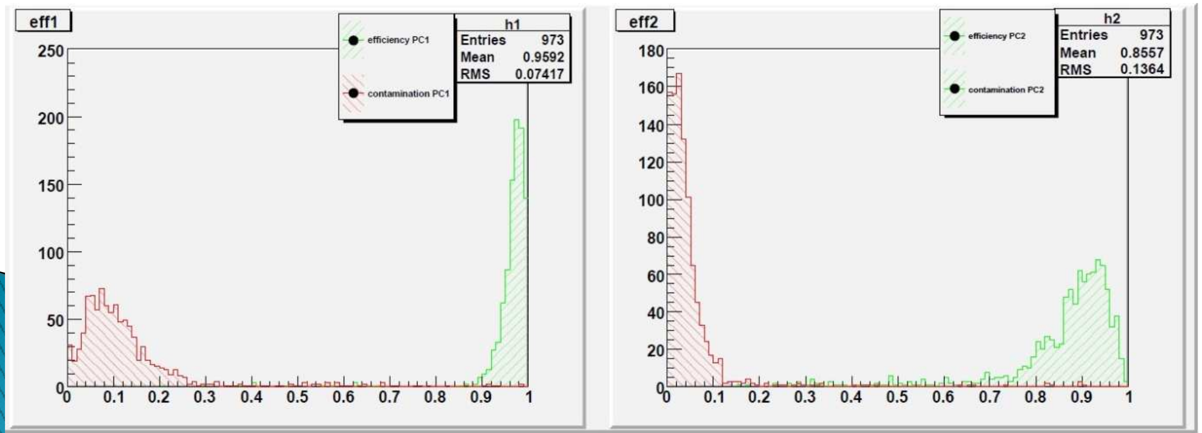
- For now, I just started to distinguish parallel events (π^- and K^0 @100GeV) for different separation distances
- I studied efficiency and contamination for 1000 randomly chosen π^- and K^0 events combinations
- Both efficiency and contamination are defined for each event/particle
- Efficiency = ratio between number of hits well tagged and total number of hits belonging to the event
- Contamination = ratio between number of hits wrongly tagged and number of hits belonging to the event

Efficiency and Contamination

- First results for 1000 random couples of kaons (PC1) and pions (PC2) at 100GeV, for different separation distances



Distance = 15cm



Distance = 20cm

Further works

- Study the effect of the angle between showers on the efficiency
- Apply this method for different energies and different incoming particles