Hadronic Shower Reconstruction Algorithms

Semi-Digital Hadronic Calorimeter

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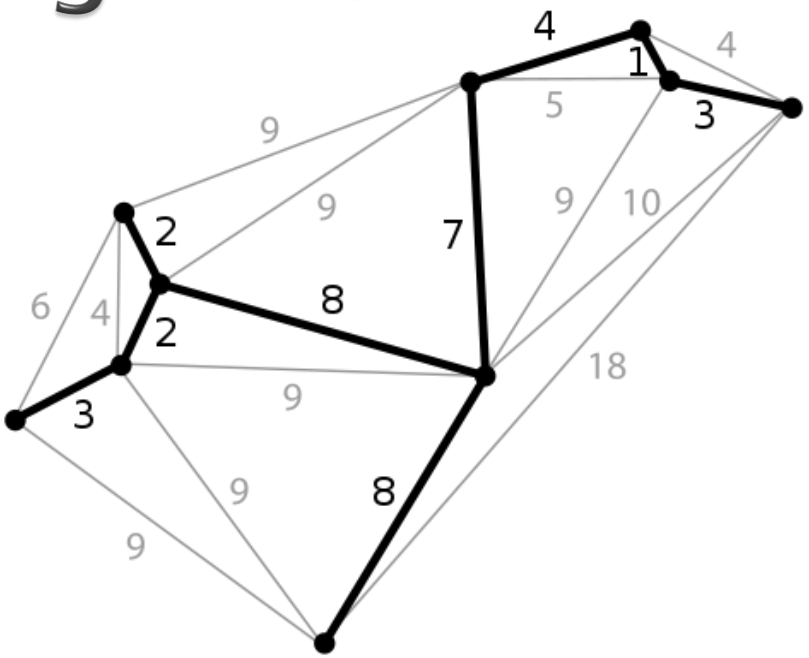
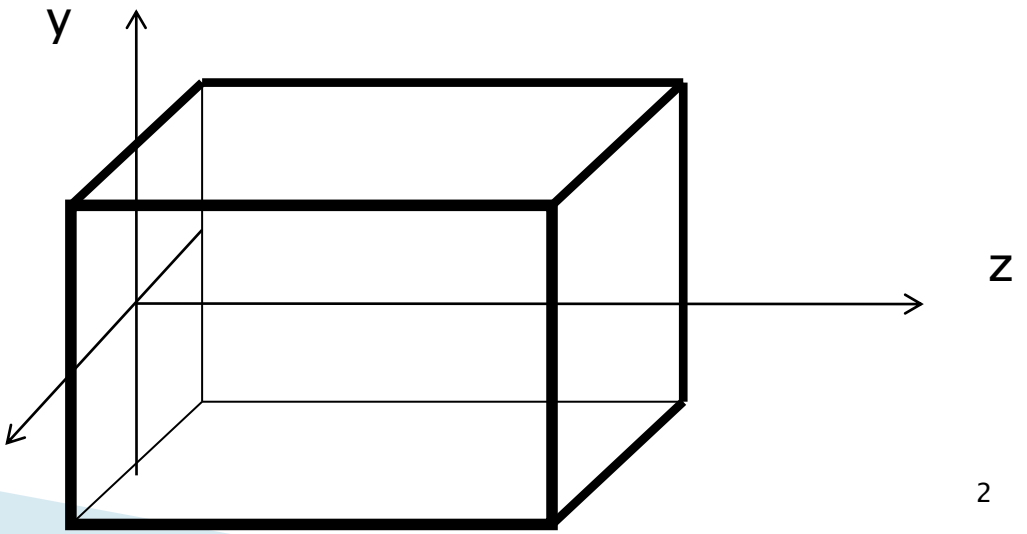
Minimum Spanning Tree

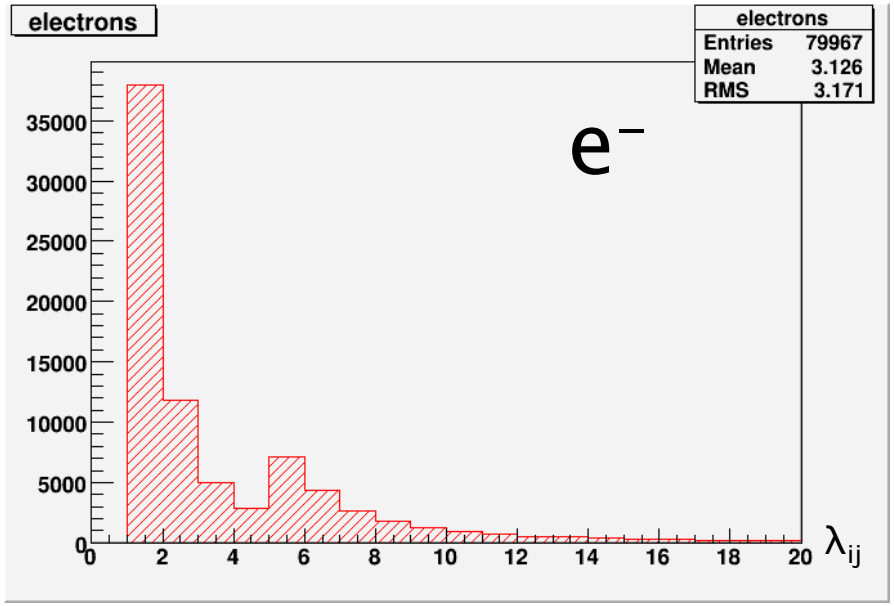
- Principle:
  - Method to link N dots
    - N(N−1)/2 weighted links λ_{ij}
  - For each node i, one minimal link
    - N−1 links λ_{imin}
  - Weighting according to a specific metric (a,b)
  - $\lambda_{ij} = a|z_i - z_j| + b(|x_i - x_j| + |y_i - y_j|)$
    x,y : pad number (0−96),
    z : layer number (0−40)
  - Highlight shower development differences

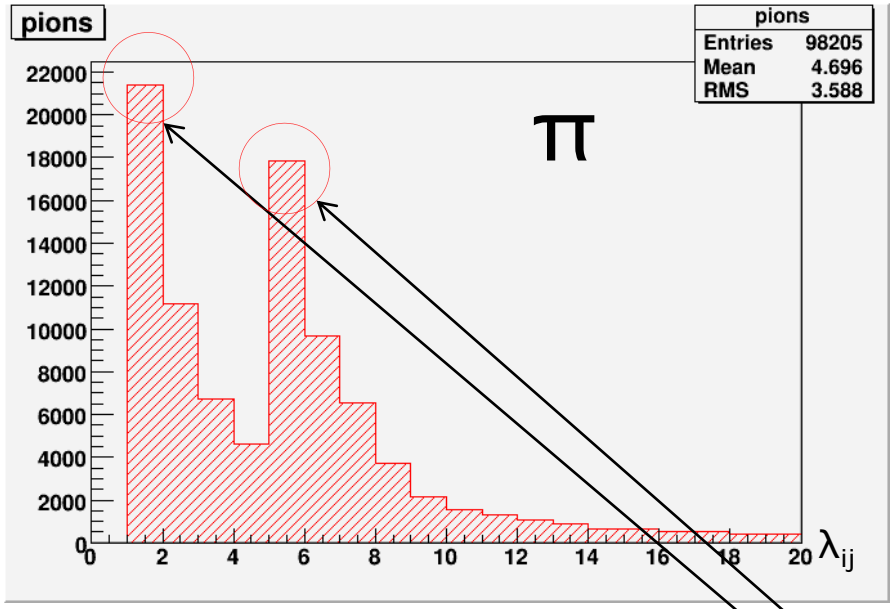




Minimum Spanning Tree

- Differentiation EM and hadronic showers :



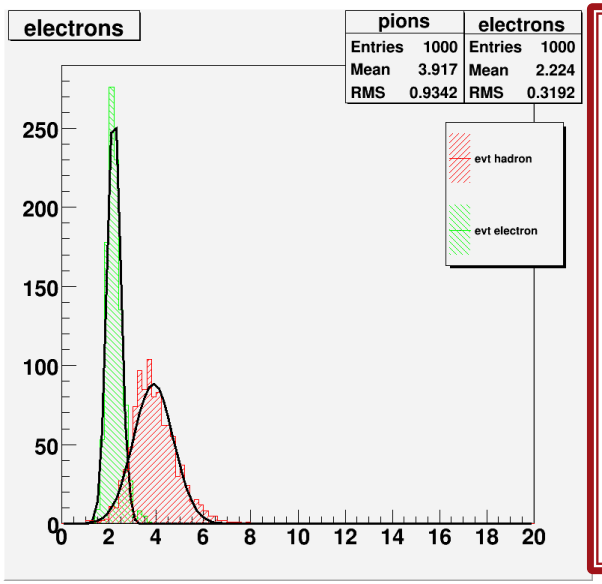


Minimal link (λ_{imin}) distribution with metric (a,b)= (1,5)

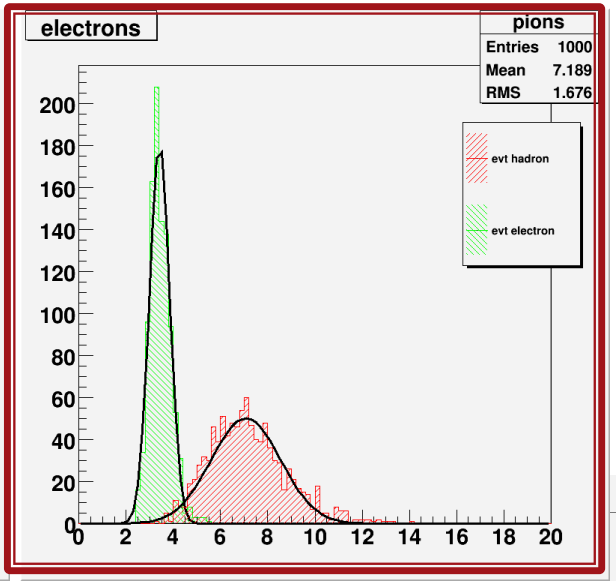
Minimum Spanning Tree

- Metric influence on mean link length

  Mean link length per event distribution $\Lambda_{\text{moy}} = \frac{1}{N}\sum_i \lambda_{i\min}$

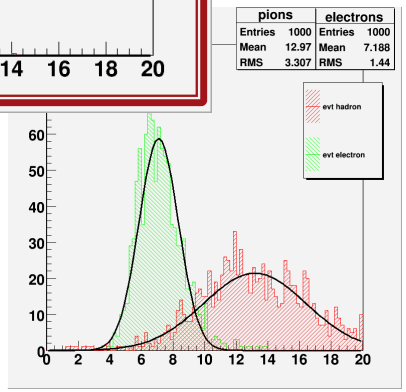


(a,b) = (1,1)

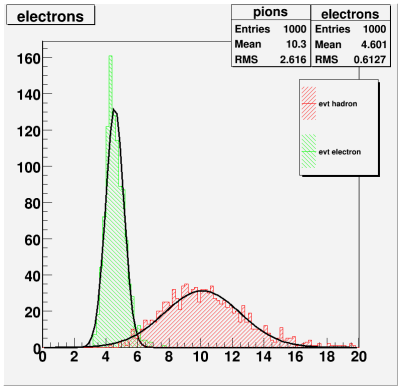


(a,b) = (1,5)

Metric used next



(a,b) = (5,1)

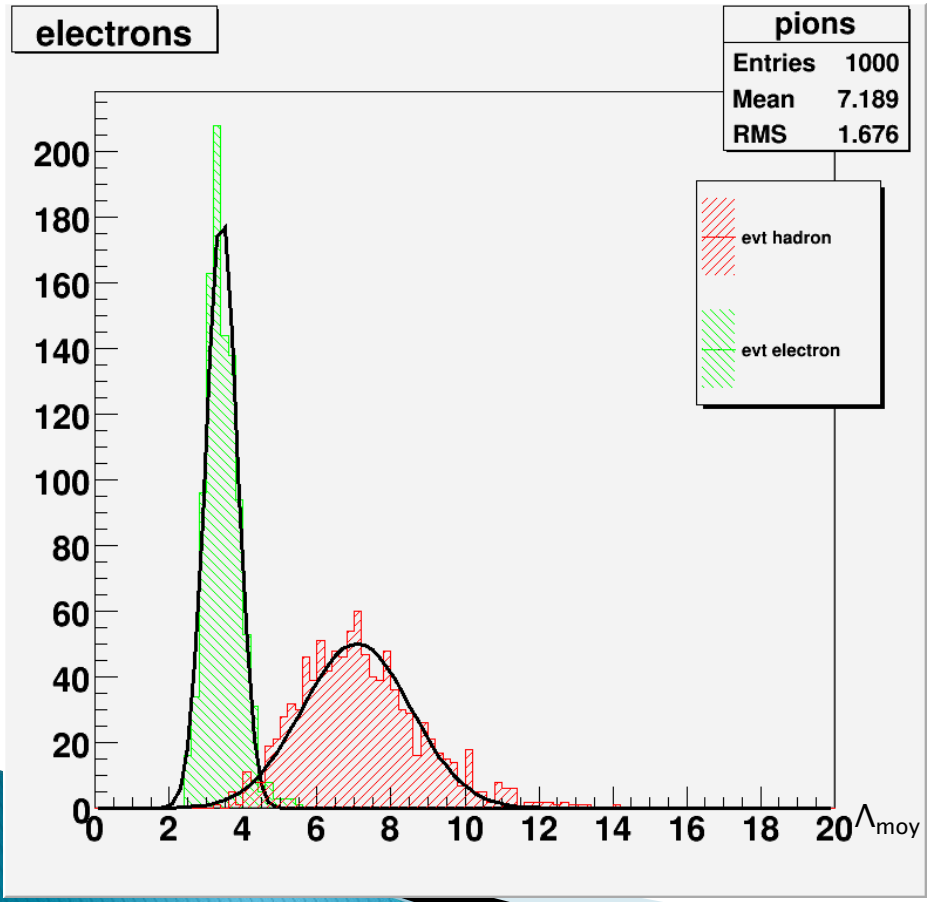


(a,b) = (1,10)

1000 evt. @ 10GeV

Minimum Spanning Tree

- Mean link length study – metric (a,b)=(1,5)



- Purely EM shower (green) :
  - Contained in a smalll volume along longitudinal axis

  => Small mean link length
- Hadronic shower (red):
  - More complex processes
  - Transversal development, variable from a shower to an other

  => Larger and more widespread mean link length value

Minimum Spanning Tree

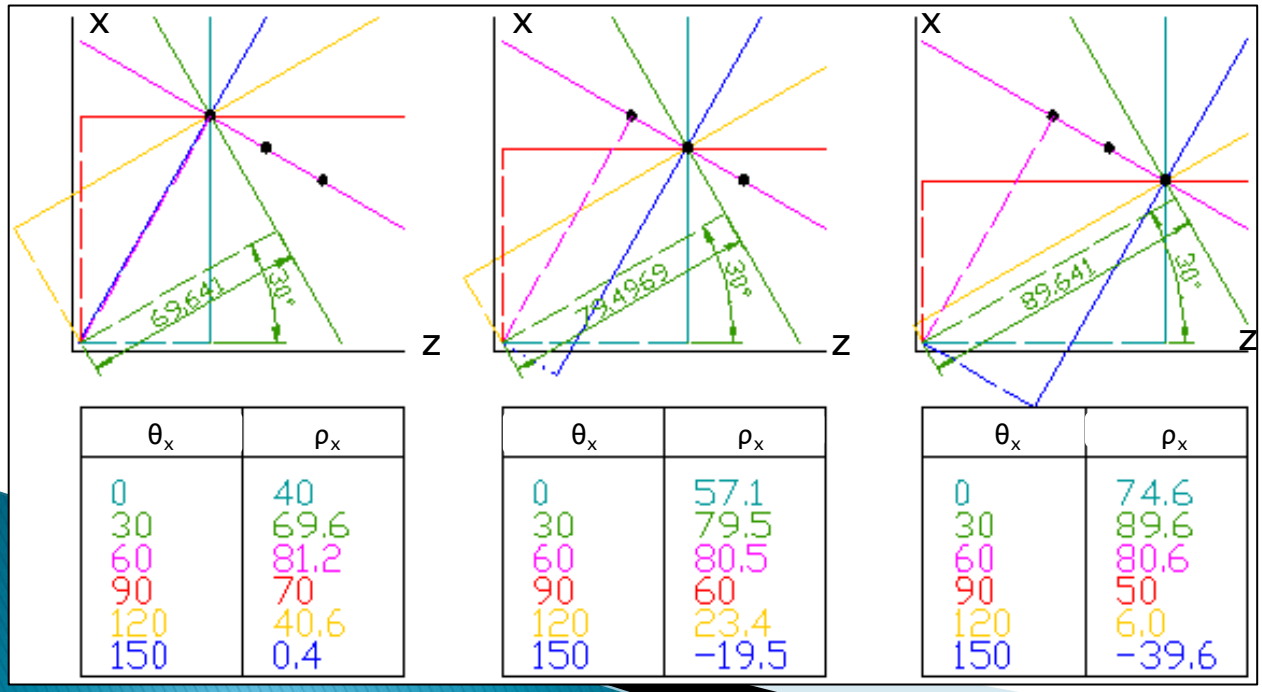
- Results :
  - Highlighting difference behavior EM/H
  - Estimating about particle tracks
- Improvements :
  - Neutral/charged hadrons separation
  - EM contribution estimation within a single hadronic shower
  - General method used next for reconstruction (geometrical dispersion, track continuity…)

Hough Transform (HT)

- Isolated tracks detection (muons !):
  - Linear tracks without magnetic field
  - On-Line calibration
  - Check detection efficiency
  - Check cells alignment
  - First tagging for spotting heavy hadrons semi leptonic decays
- Application : Shower thrusts identification
- Principle of HT:
  - Detect geometrical shapes in a “noisy picture”
  - Based on shape geometrical parameters
    => Hough Space (HS)
  - HS interest points used to find main tracks of the picture

Hough Transform (HT)

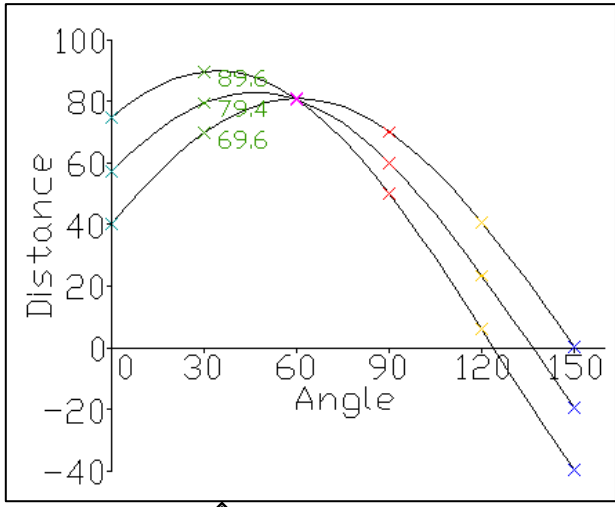
- Building the Hough Space:
  - Hit (x,y,z) ⇔ 2 Sinus (HS) : $(\rho_x,\rho_y,\theta_x,\theta_y)$
  - $\rho_x = x.\sin(\theta_x) + z.\cos(\theta_x)$ $\quad \theta_x, \theta_y \in [-\pi/2; \pi/2]$
  - $\rho_y = y.\sin(\theta_y) + z.\cos(\theta_y)$
  - Certain number of lines (discrete Hough Space) per hit



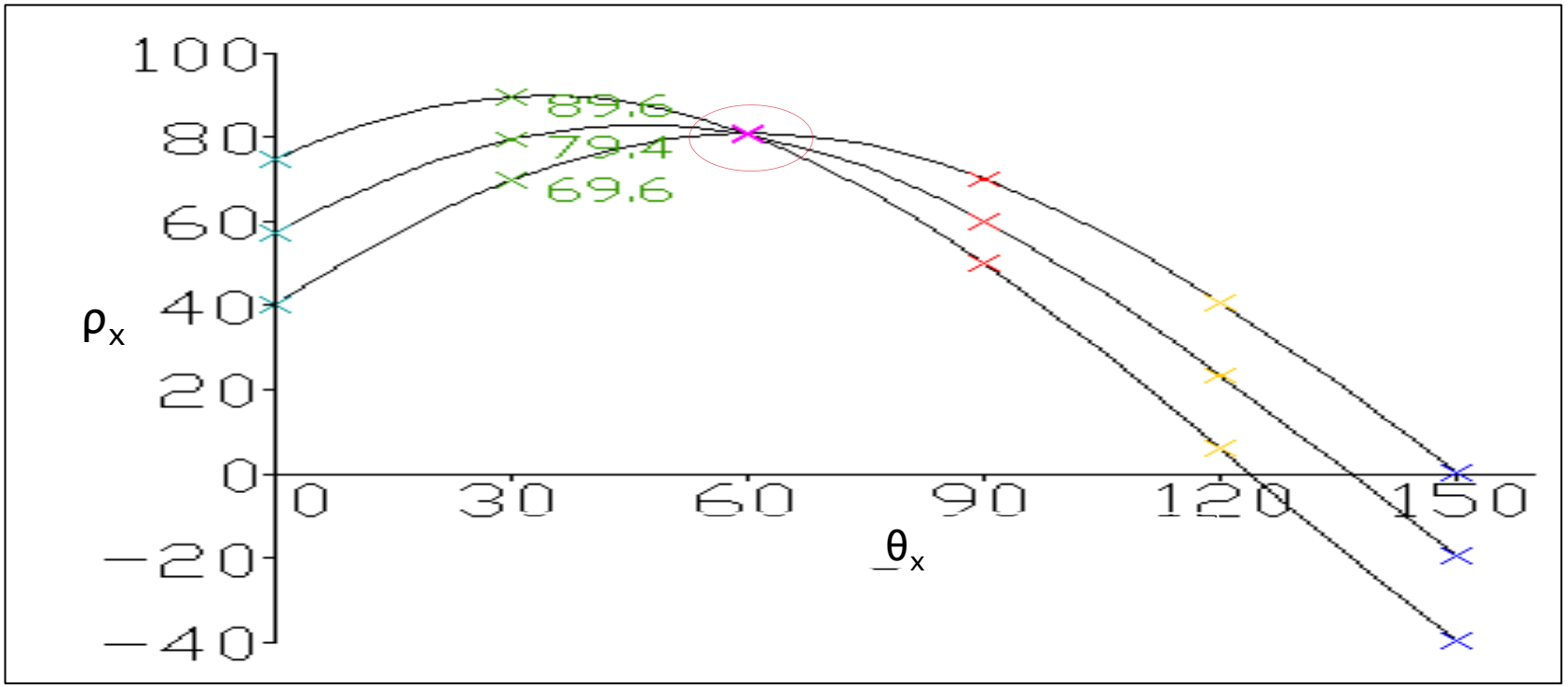
θ_x	ρ_x
0	40
30	69,6
60	81,2
90	70
120	40,6
150	0,4

θ_x	ρ_x
0	57,1
30	79,5
60	80,5
90	60
120	23,4
150	-19,5

θ_x	ρ_x
0	74,6
30	89,6
60	80,6
90	50
120	6,0
150	-39,6



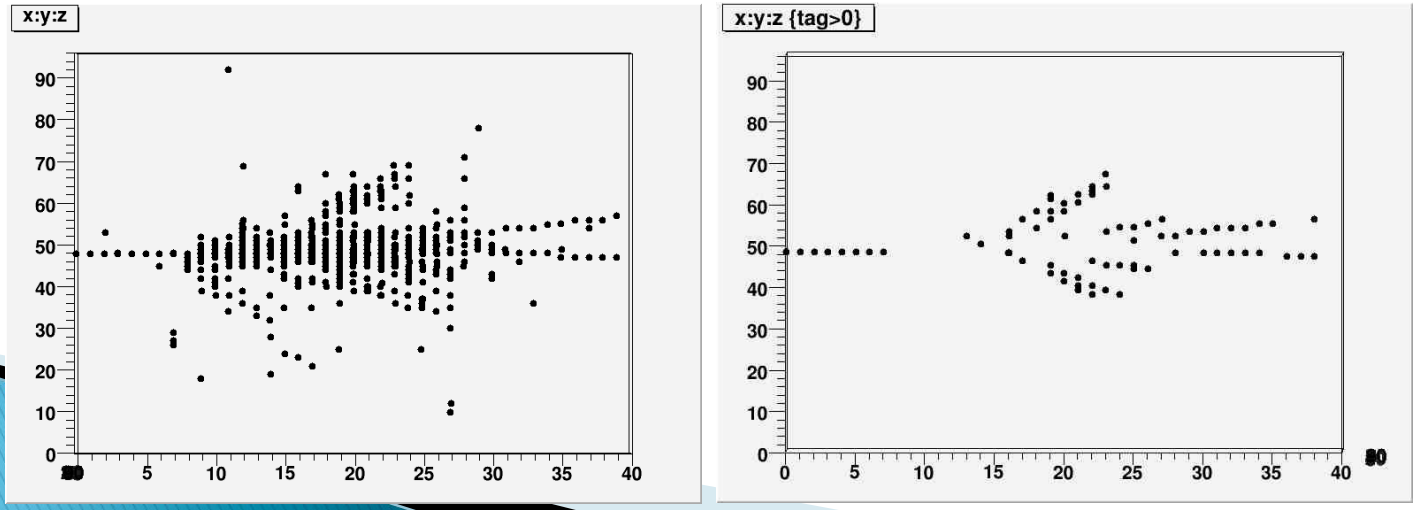
Hough Transform (HT)



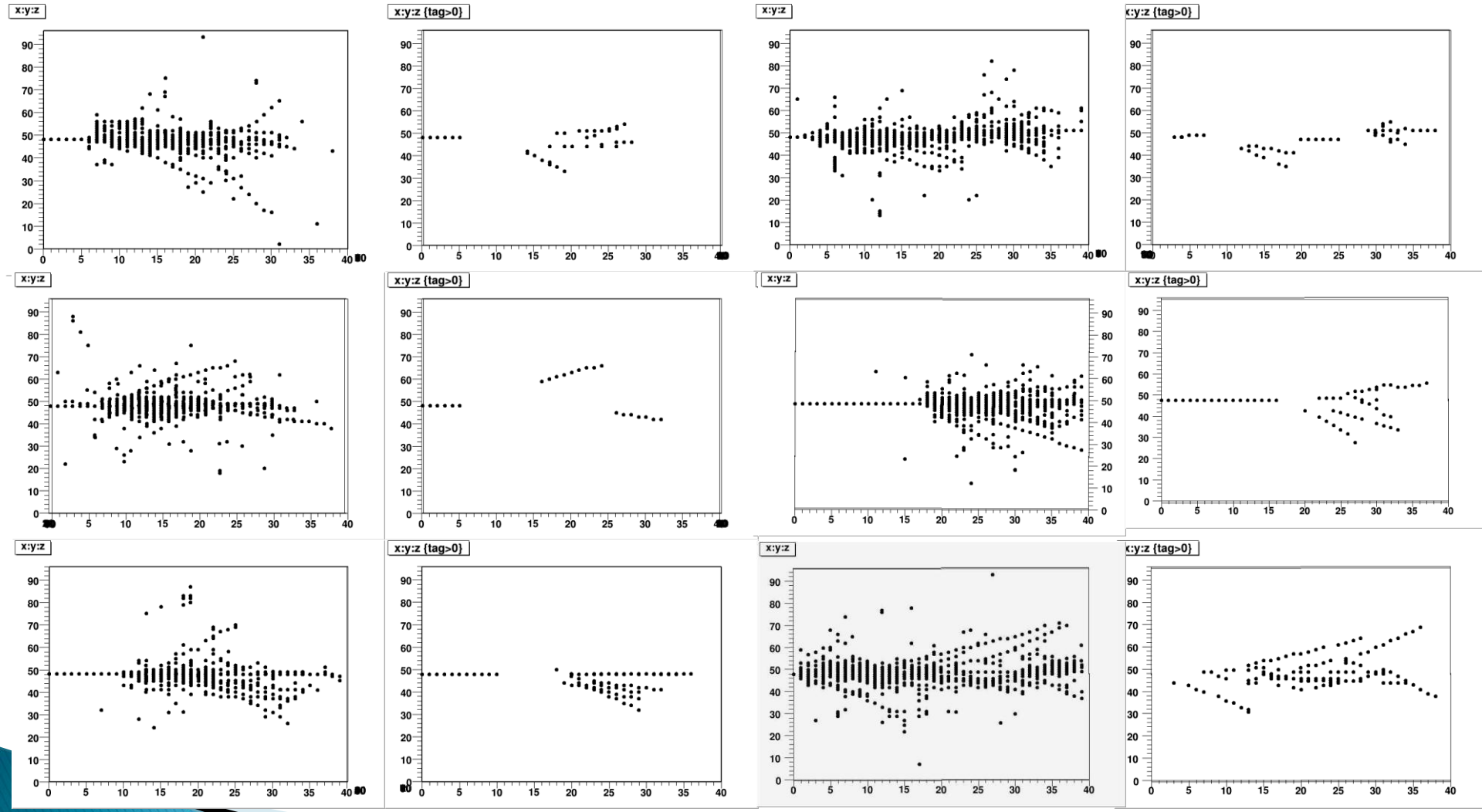
- Hough Space scan :
  - Spotting parameters (ρ_x,ρ_y,θ_x,θ_y) common to a maximum number of hits => main lines
  - Keep in memory these parameters
  - Scan stopped when number of hits associated to a track is too small (less than 10)

Hough Transform (HT)

- MIP/Muon track validation
  - Continuity test (« hole » has to be smaller than 2 pads/layers)
  - Length test (track must have more than 5 hits)
- Optimizing :
  - Cut on small and high density
  - Ignore hits « threshold3 » (0,2 ; 2 ; 10 mips)
- Results after Hough Transform :



Hough Transform (HT)



Reconstruction

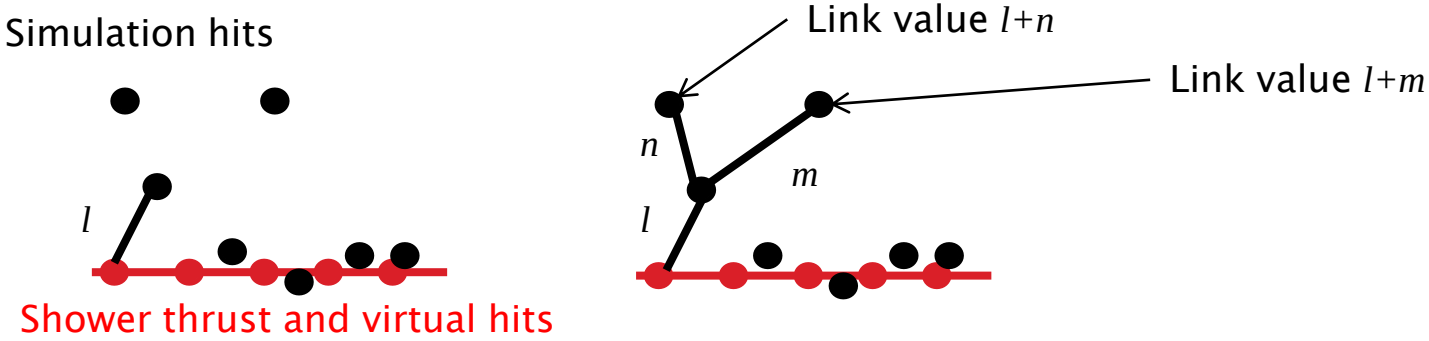
- Events separation :
  - Identify neutral and charged particles within jets
  - Separately identify showers for a better resolution (Neural Network)
- HT and MST combination
  - HT : Find shower thrusts
  - Minimum Spanning Tree : hits to shower association using these thrusts

Reconstruction

- Algorithm :
  - Random choice in the simulation data
  - HT : Find shower axis
  - Virtual hits corresponding to found thrusts added
  - Geometrical rotation : shower axis and detector axis (Oz) collinear
  - MST computing for each rotation (one per thrust found)

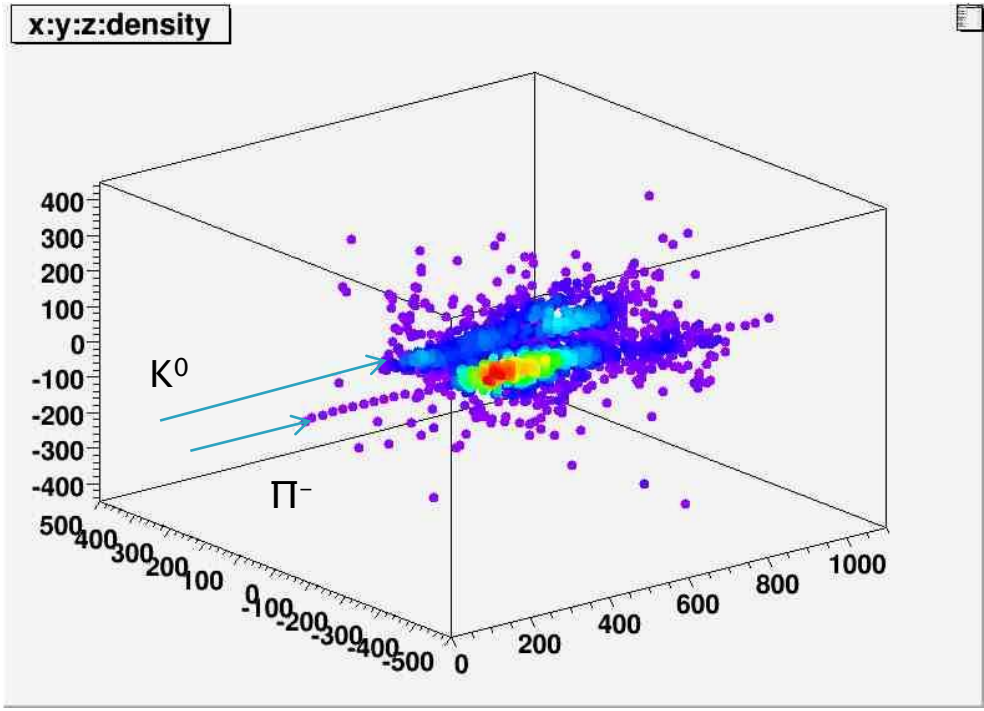
Reconstruction

- Used MST in details:
  - Computed considering virtual thrust hits and the whole set of simulation data
  - Using a longitudinal development metric
  - Summing links from one hit to another (≃hit–thrust distance)
  - Link length comparison considering previous projection
  - Association to the most favorable projection



Reconstruction

- Type of events used :
  - Neutral kaon and charged pion induced showers (100GeV)
  - Normal incidence
  - Study considering different separation distances



- Identification efficiency and contamination
  - Efficiency = ratio correct tags/total number of hits of incoming particle
  - Contamination = ratio wrong tags/total number of hits of incoming particle

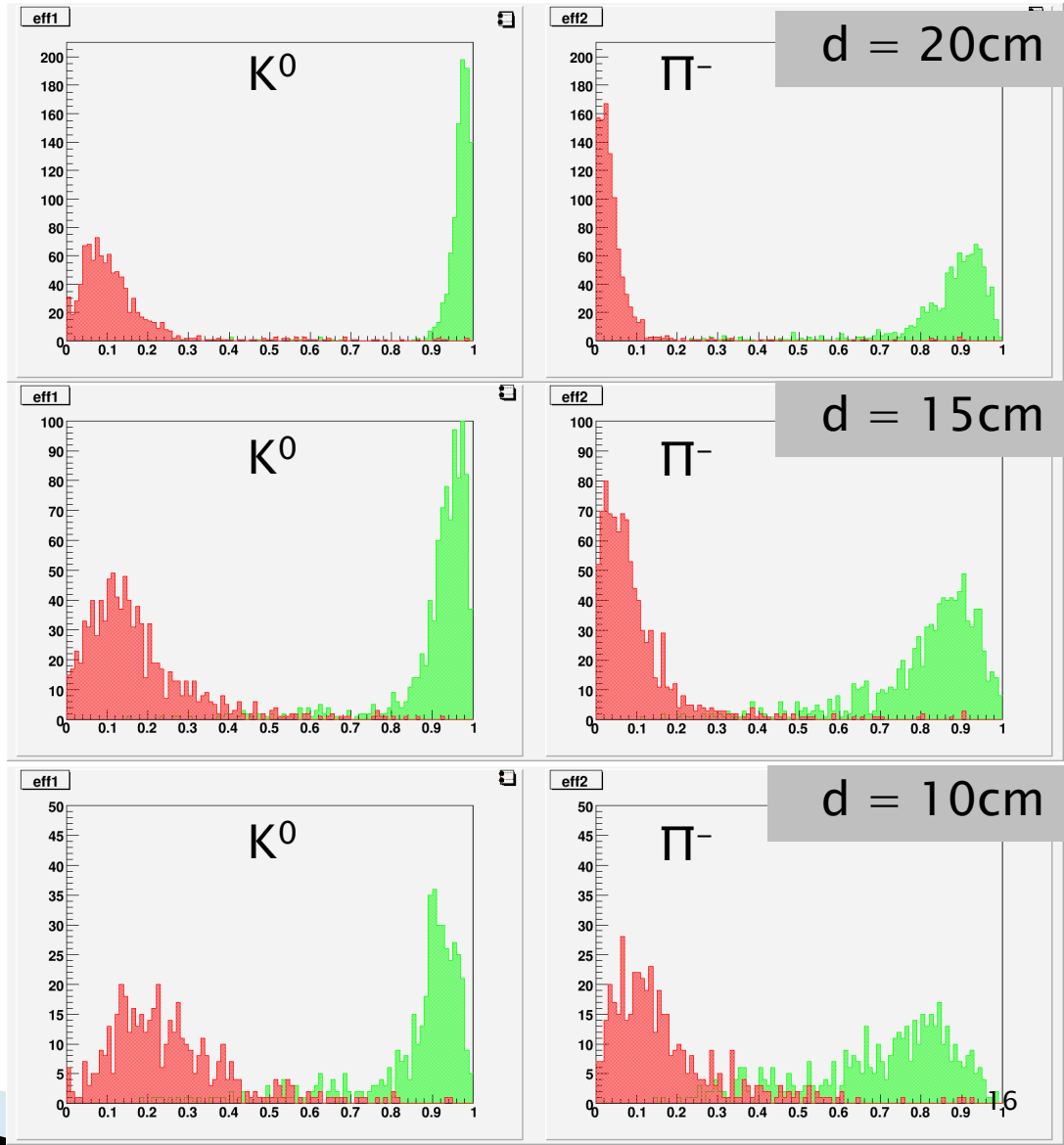
Results

- First results

Efficiency (green) – contamination (red)

Left plots :
- in red : pion hits recognized as kaon hits proportion
-in green : kaon hits recognized as kaon hits proportion

Right plots :
- in red : kaon hits recognized as pion hits proportion
-in green : pion hits recognized as pion hits proportion



Conclusions – Further work

- Minimum Spanning Tree
  - Development differentiation
  - Shower Separation
  - ➢ Future use in EM contribution proportion within a hadronic shower
- Hough Transform
  - Linear tracks recognizing
  - Shower thrusts identification
  - Muons detection
  - ➢ Hough Space parameters modification

  => detection in magnetic field