Arbor, a new approach of the Particle Flow Algorithm

Manqi RUAN

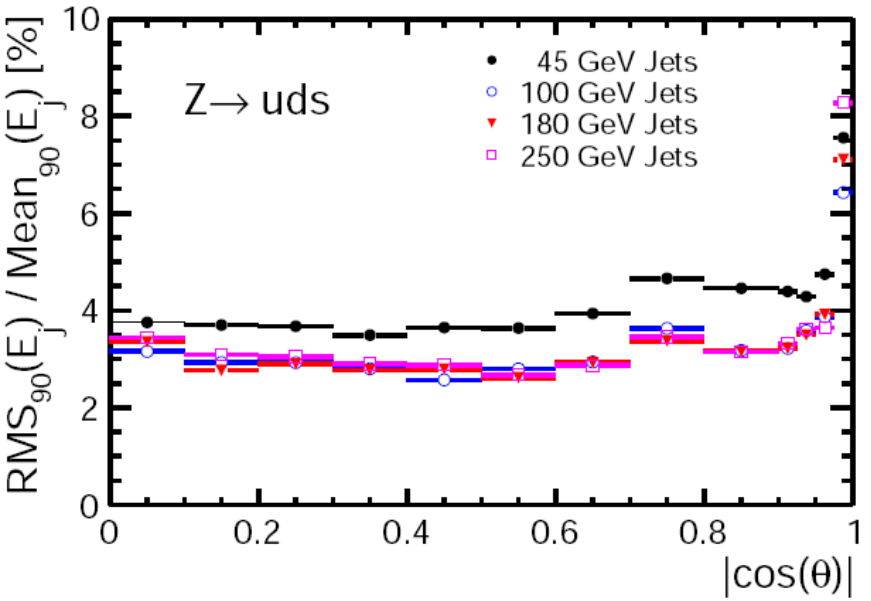
Laboratoire Leprince-Ringuet (LLR)
Ecole Polytechnique
91128, Palaiseau

Particle Flow Algorithm (PFA)

- LC detector: precisely identify and measure final state particles (*visible*)
  - Calorimeter: jet energy, PID

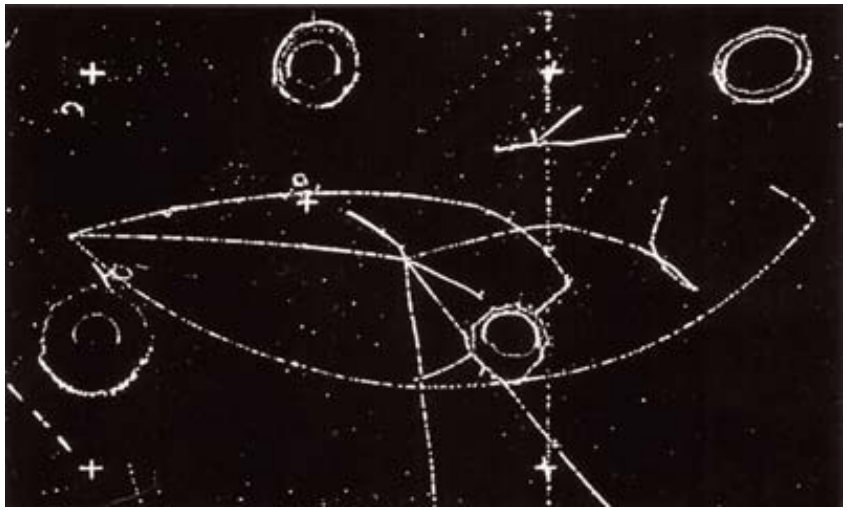
Multi bosons	Multifermions + Boson(s)
ZH	e^+e^- H , e^+e^- Z
WW	νν H , νν Z
ZZ	ttH
ZHH	e ν W
ZZZ	νν WW, νν ZZ
ZWW	ttbar

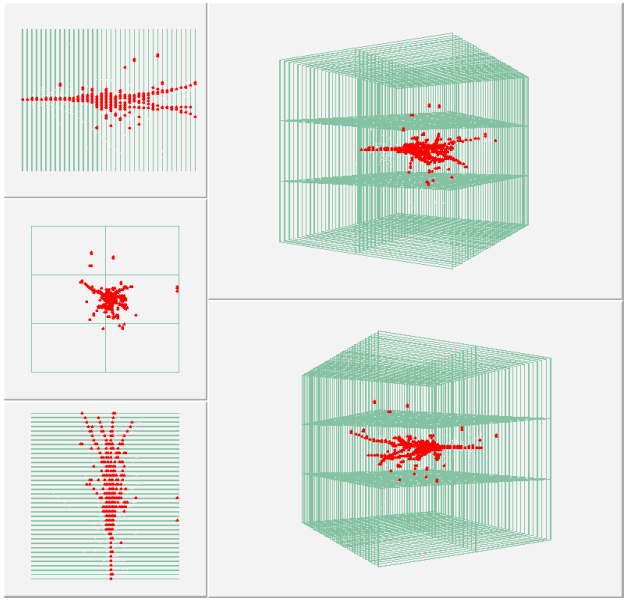
- PFA: Measure every jet particle in the most suited sub detector(s)
  - *Pflow, SiD-IowaPFA, Trackwise Clustering...*
  - **PandoraPFA**: achieves the Benchmark requirement: δE/E ~ 3%

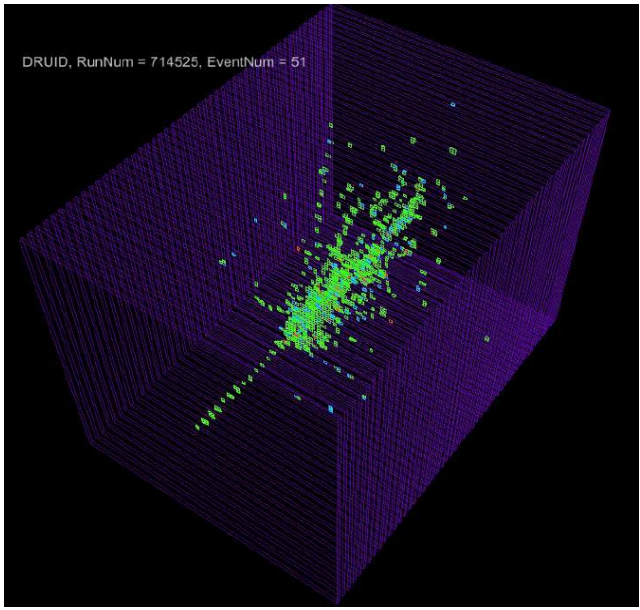


- Another PFA?
  - Re-validate PFA principle
  - Fully draw the reconstruction potential from detector

Ultra-high granularity





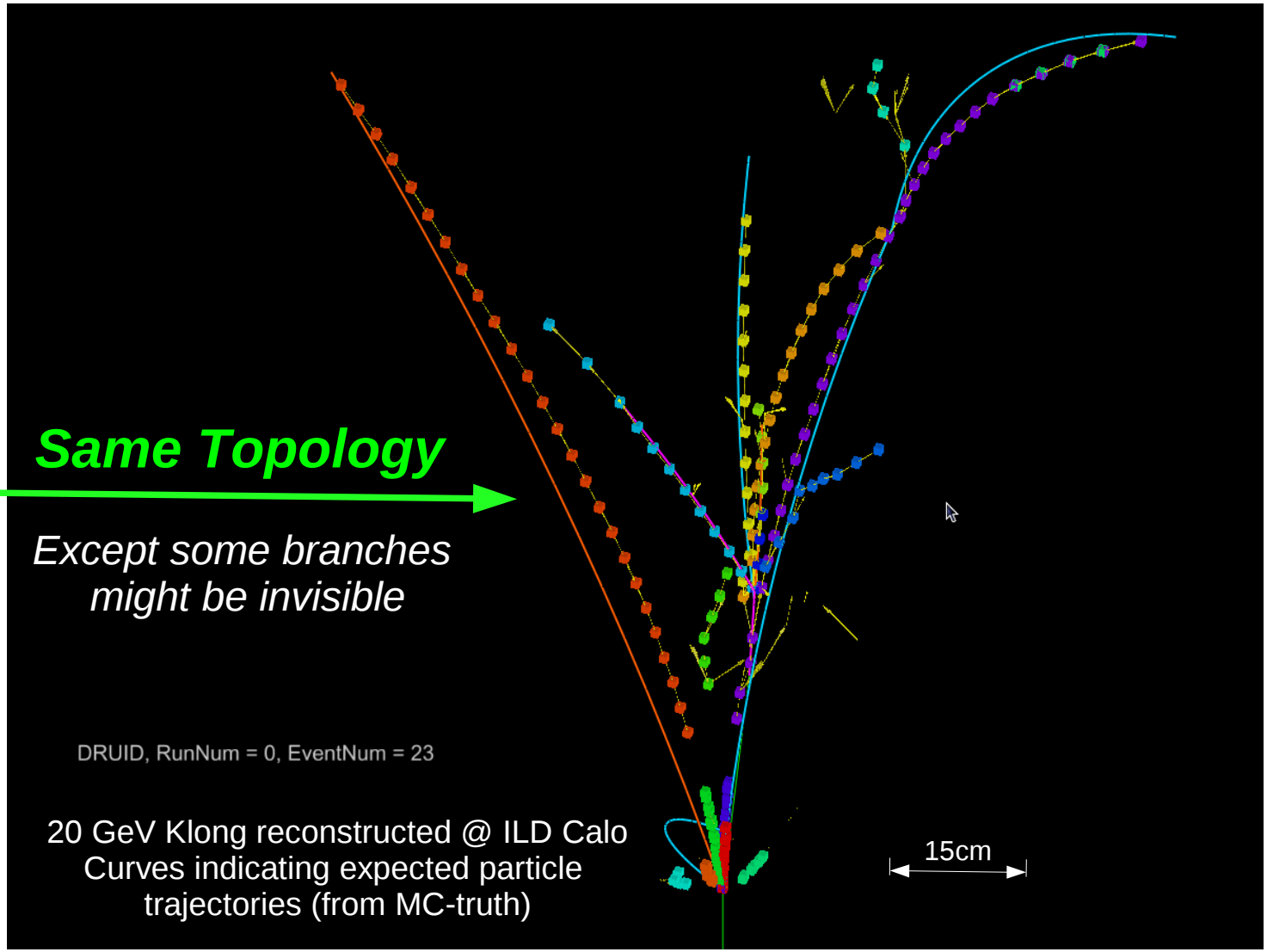


Granularity ~ 1 cm^{-3}. 3d - 5d(spatial + energy & tme) image...
properly understand/use these information...

Arbor: principle

Same Topology

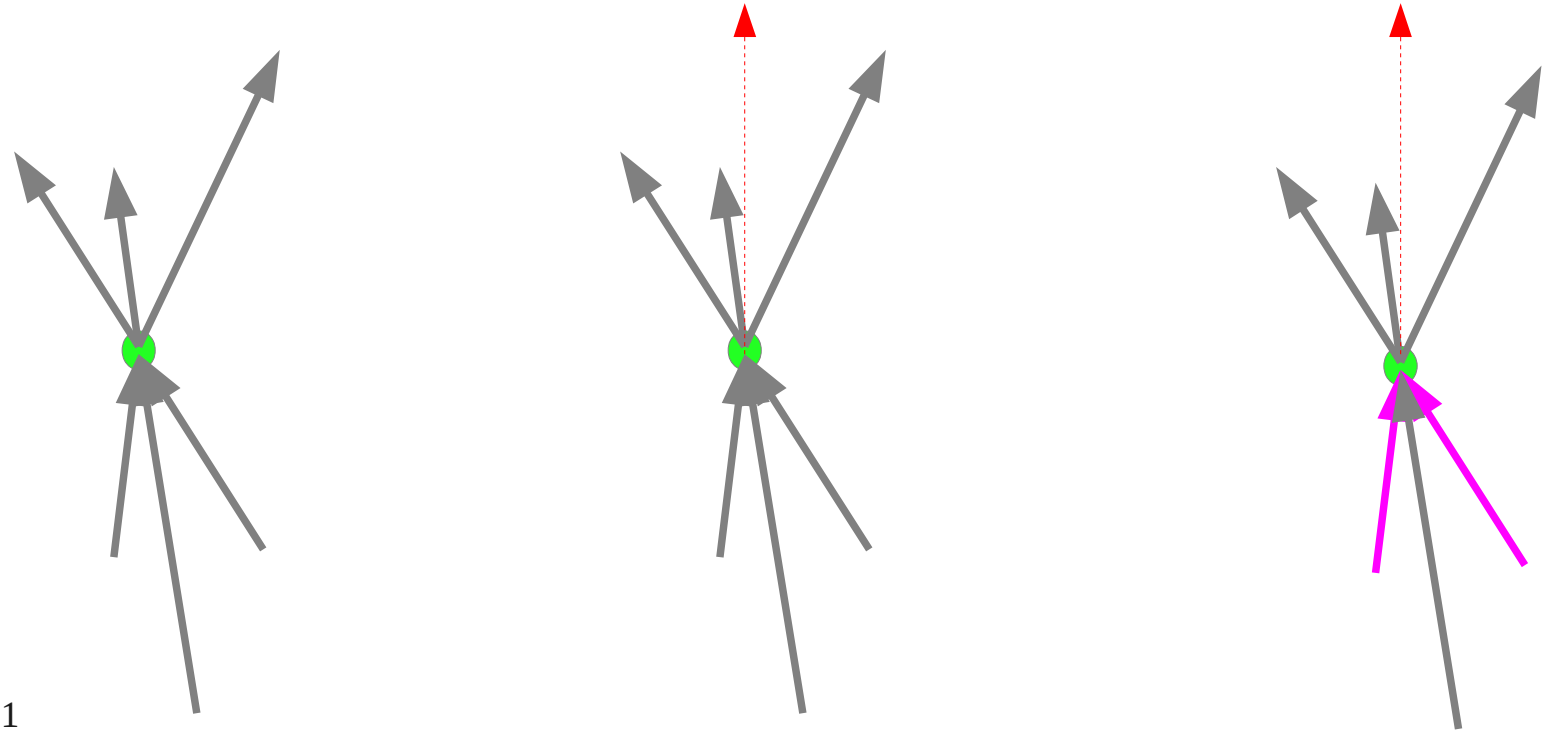
Except some branches might be invisible



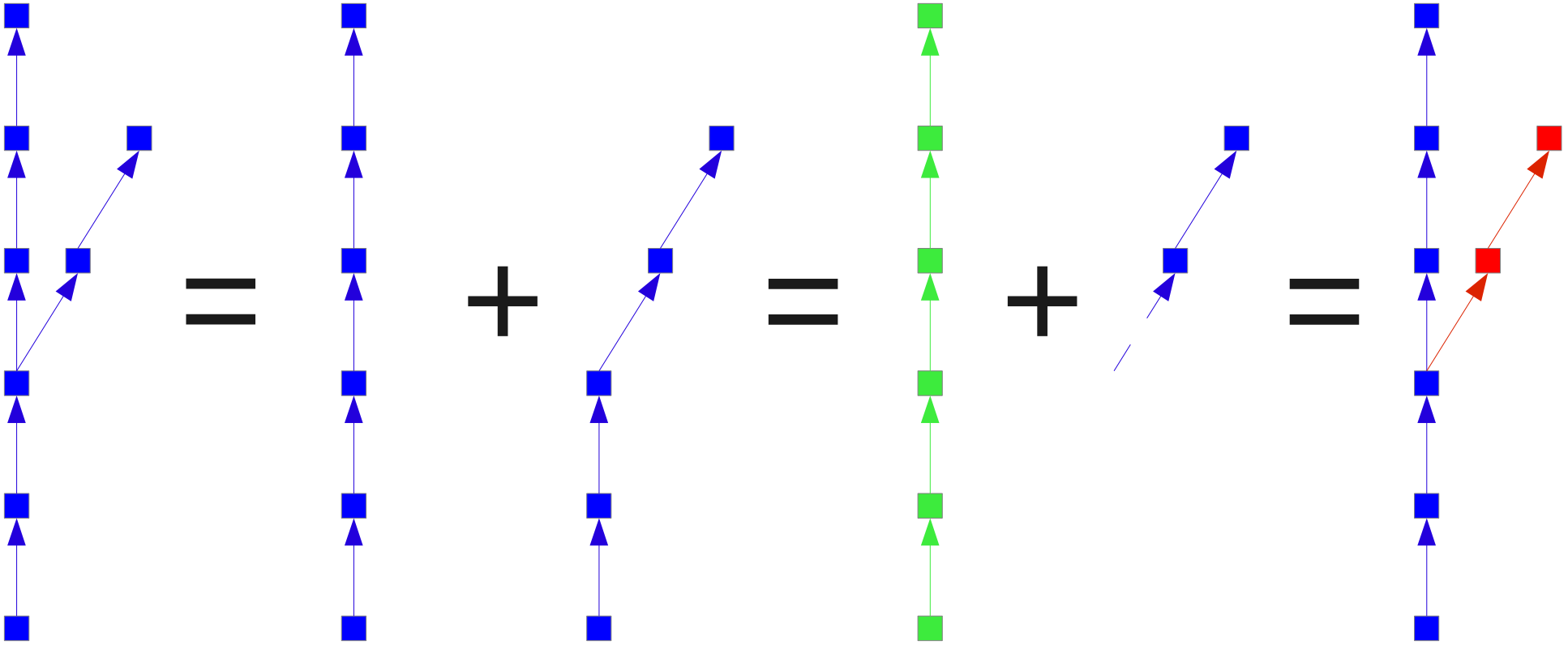
- Original idea from Henri Videau

Algorithm: hits → connector set

- Preparation: hits cleaning, pre-clustering, etc
- Create connector set between hits
  - Create all possible connectors (according to geometry constrains)
  - Clean: keep at most one connector end at a given hit
  - Iterate: change geometry constrain, add new connectors, and clean

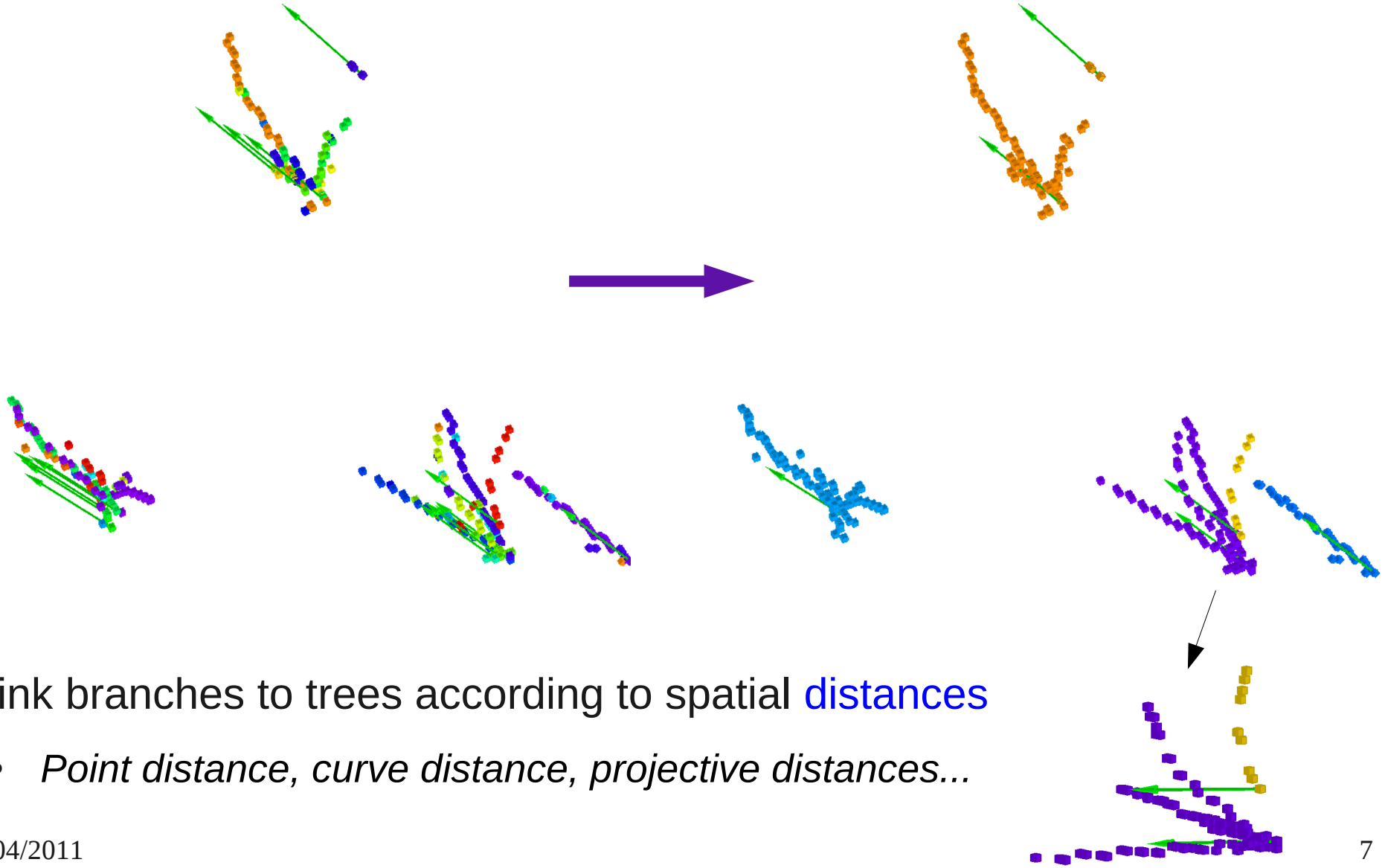


Algorithm: connector → branch



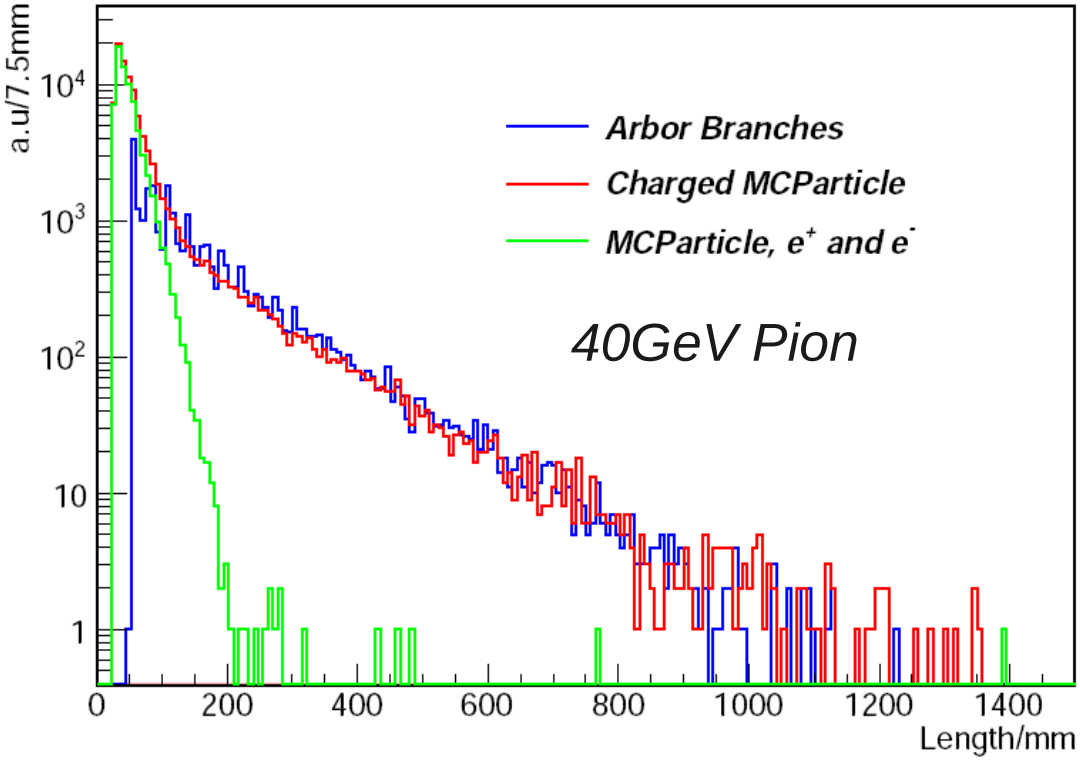
- Tag the unique branch set from connectors
  - Create all the possible branches (*from leaves to seed*)
  - Loop the branches with length order, flag hit, end the branch at the flagged hits

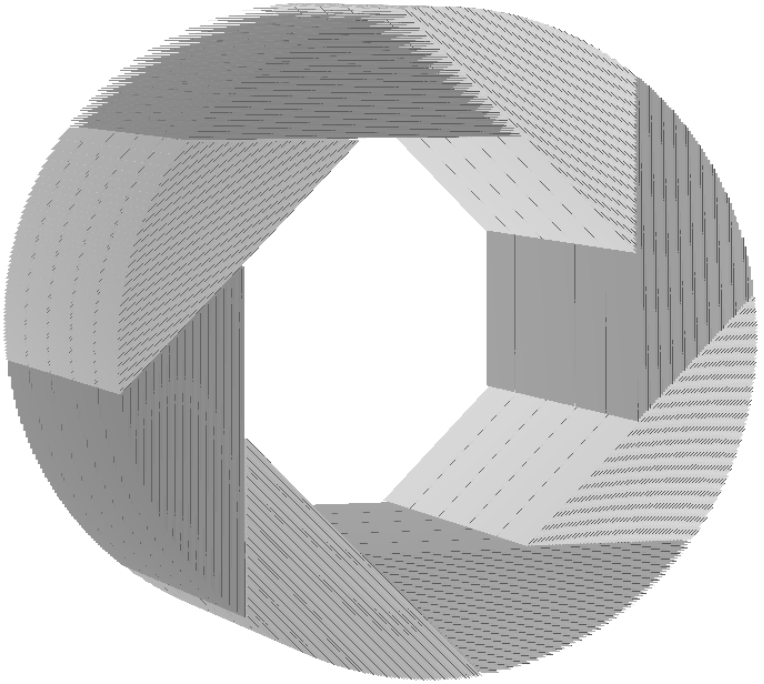
Algorithm: branch → tree



- Link branches to trees according to spatial distances
  - *Point distance, curve distance, projective distances...*

Validation: Arbor Branch Length (ABL) Vs MC Truth

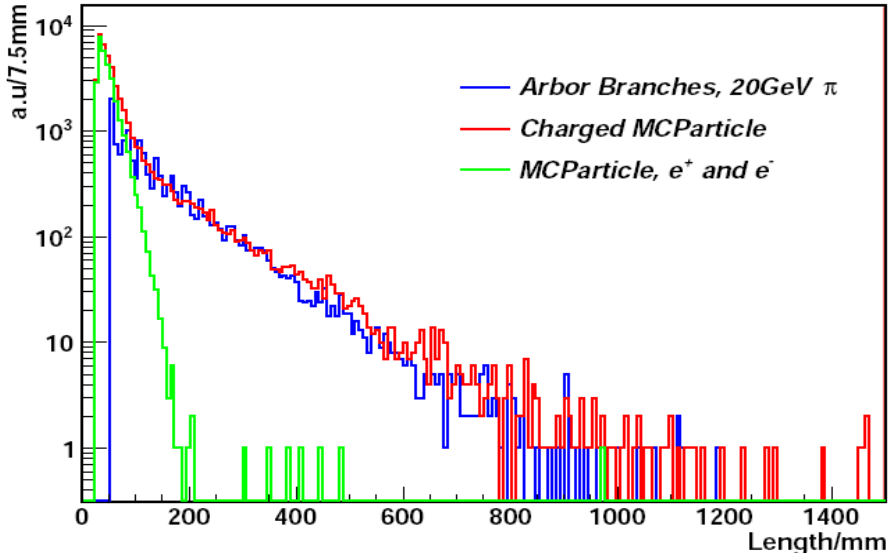




Arbor: successfully tag sub-shower structure

Samples: Particle gun event at ILD HCAL (readout granularity 1cm^2 & layer thickness 2.65cm)
Length:
Charged MCParticle: spatial distance between generation/end points
Arbor branch: sum of distance between neighbouring cells

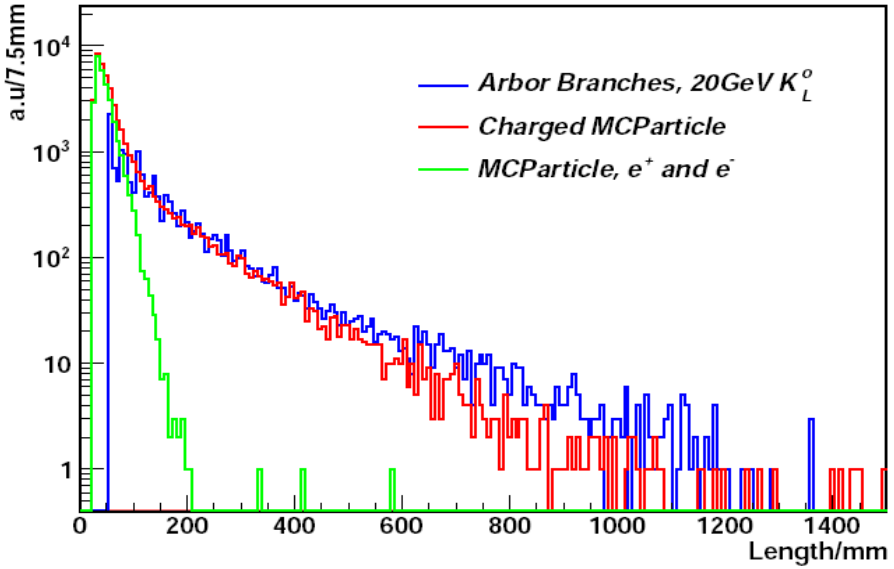
ABL @ different energy

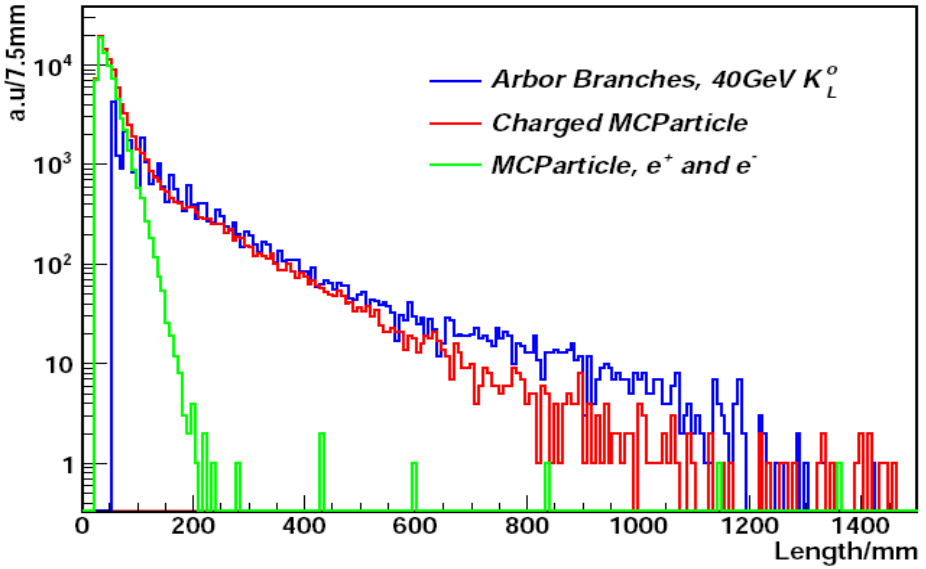


Arbor leading branches (geometrically allowed longest branch):

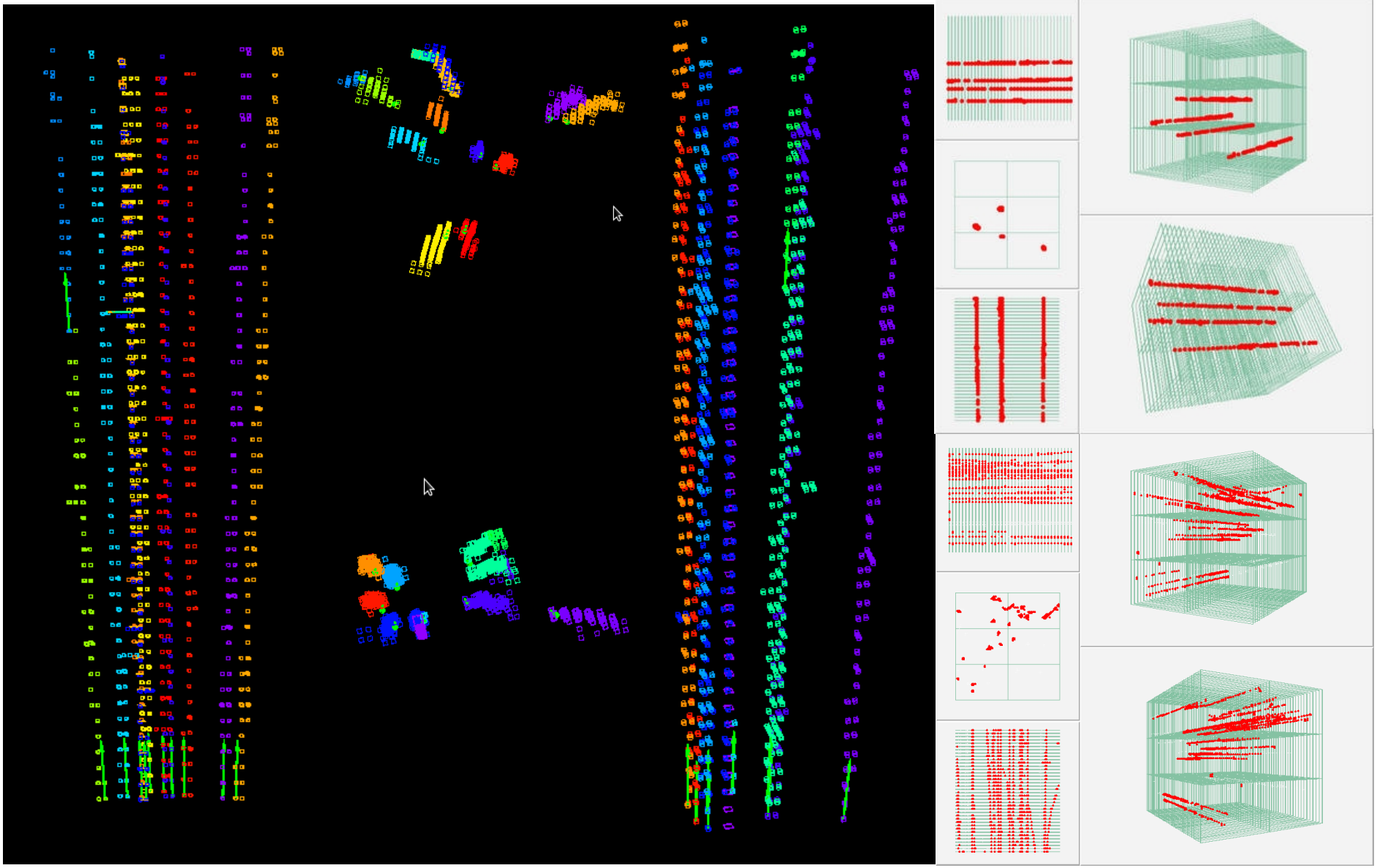
vetoed for pion shower (identified as the branch start at first layer)

cause bump at large length for klong shower

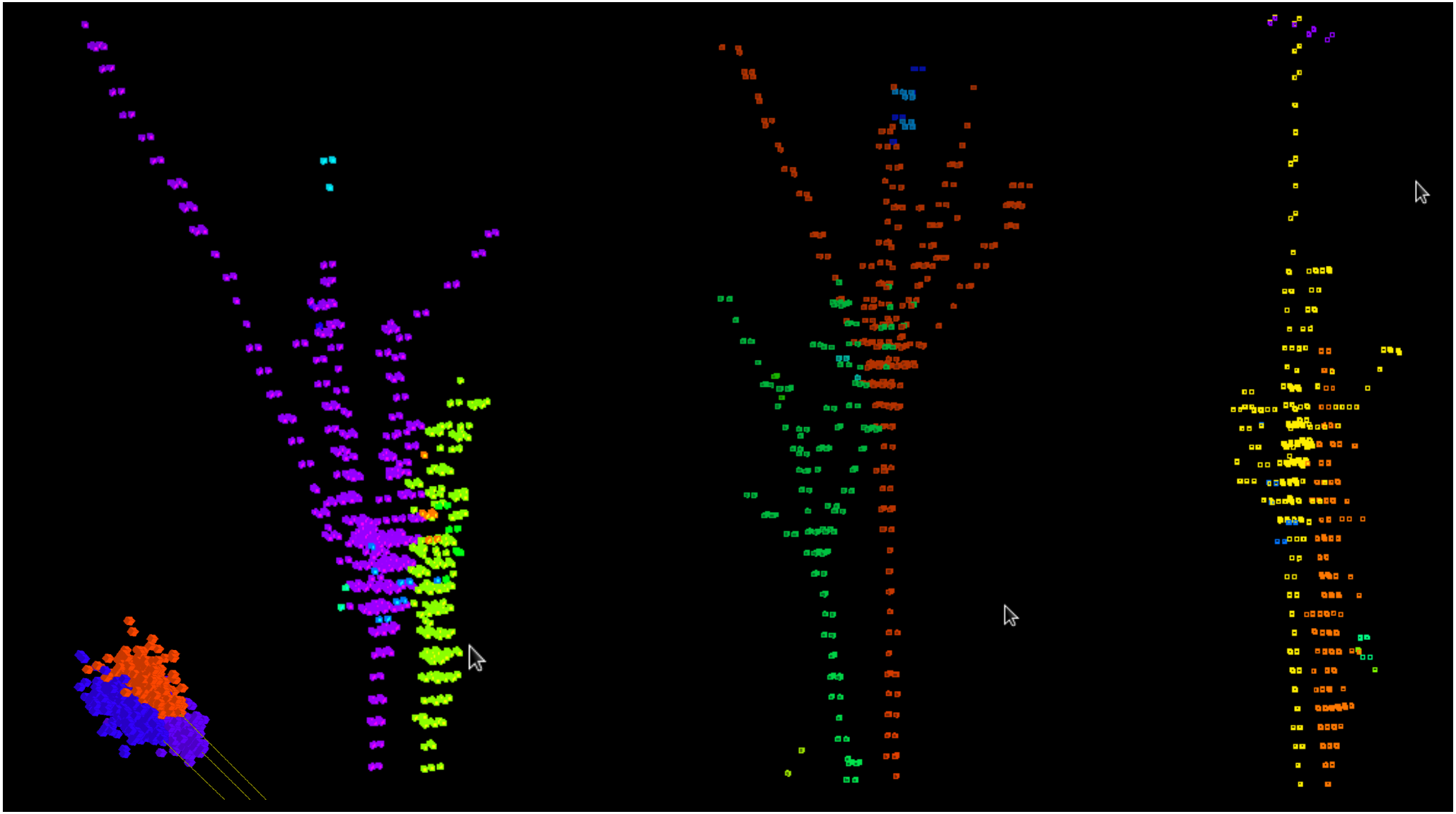




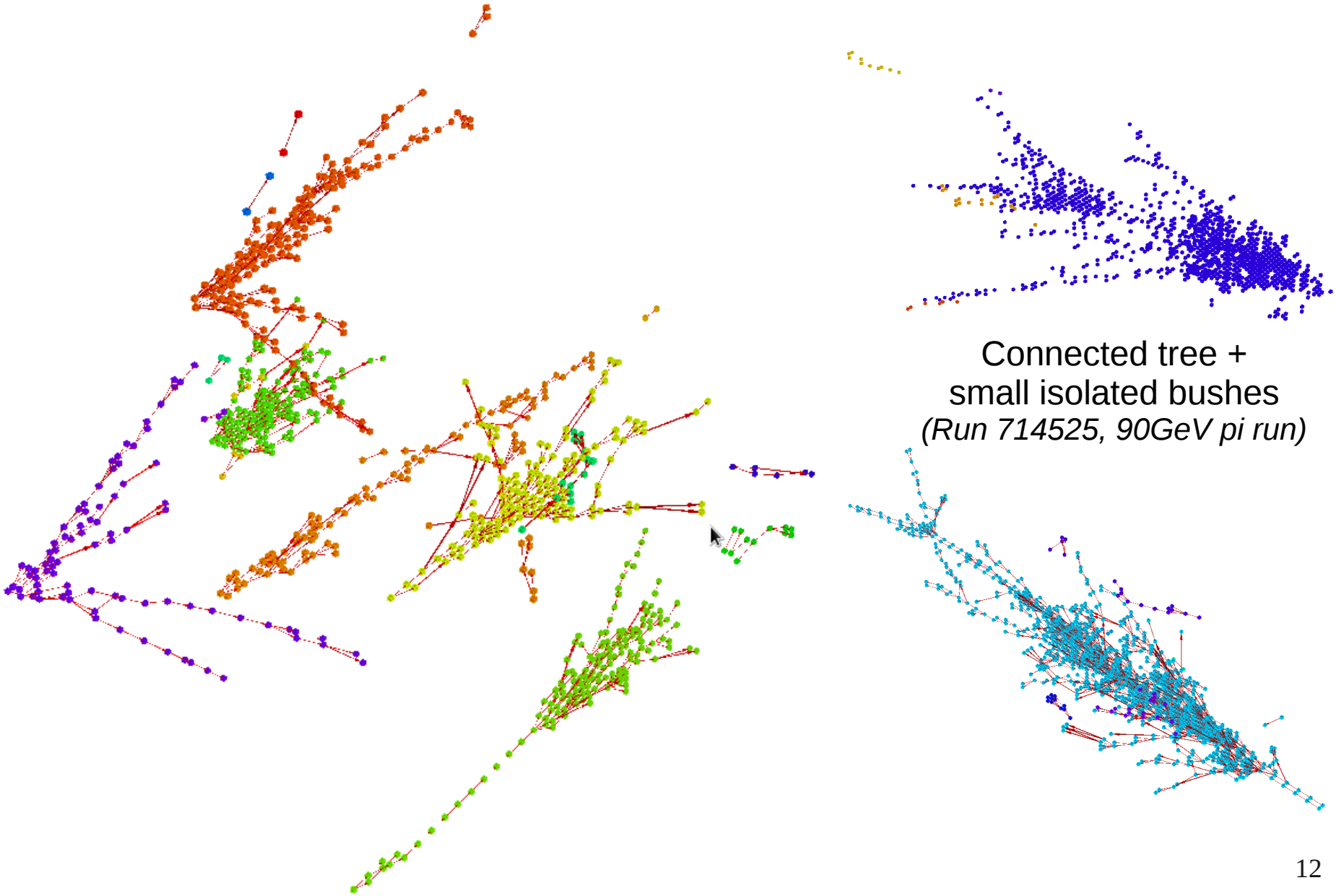
Separation: multiple muon



Separation: overlay showers

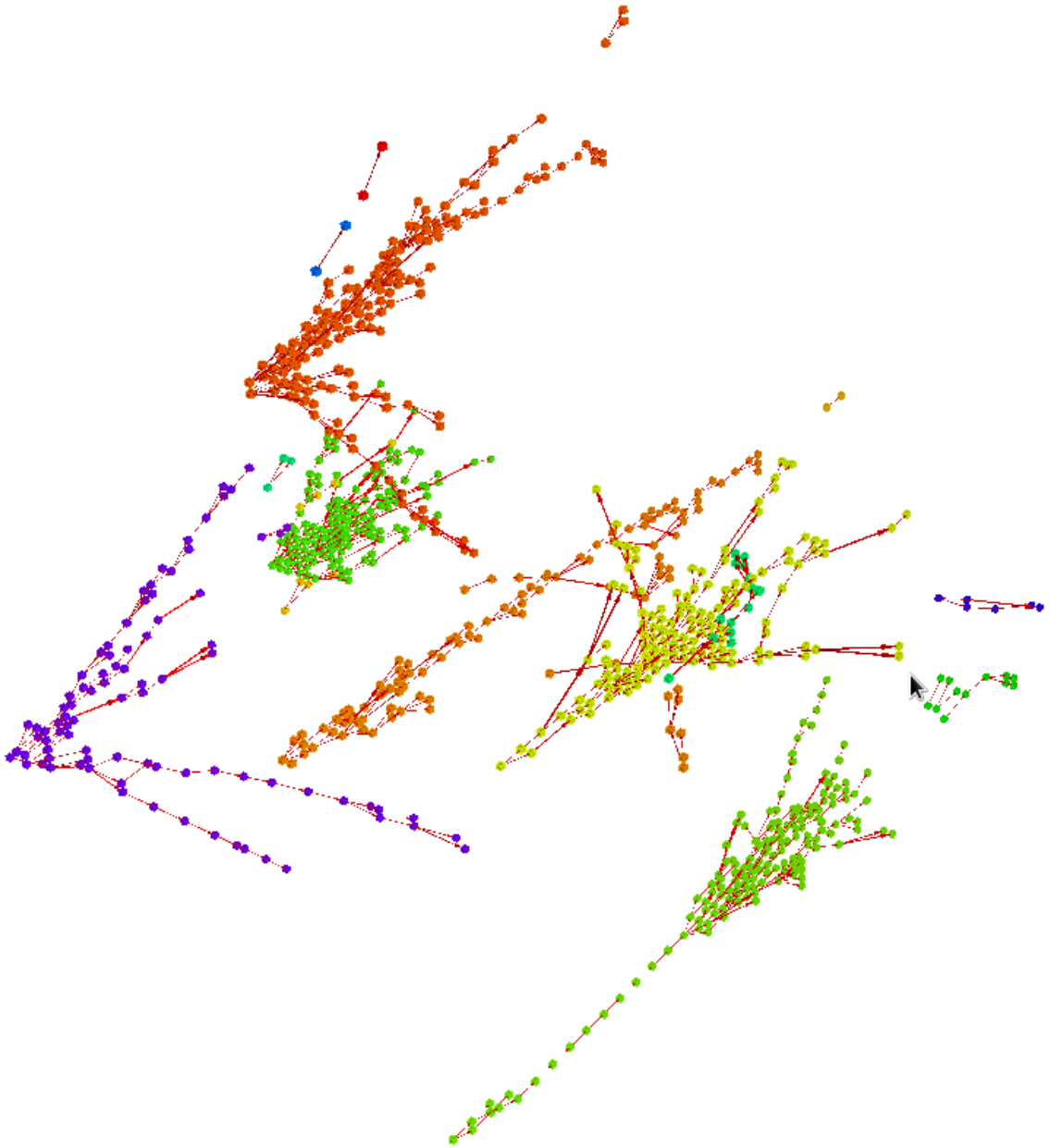


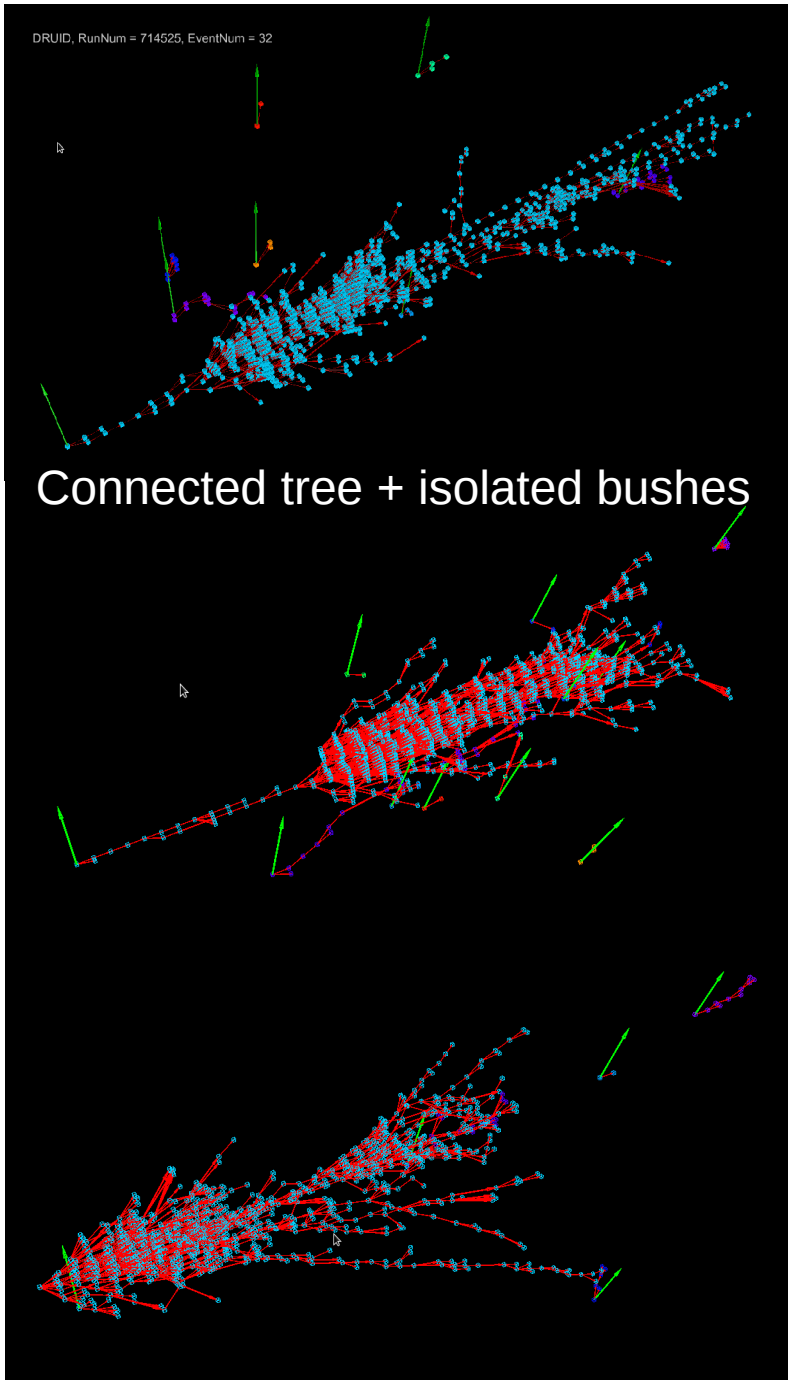
Test beam data



Connected tree +
small isolated bushes
(Run 714525, 90GeV pi run)

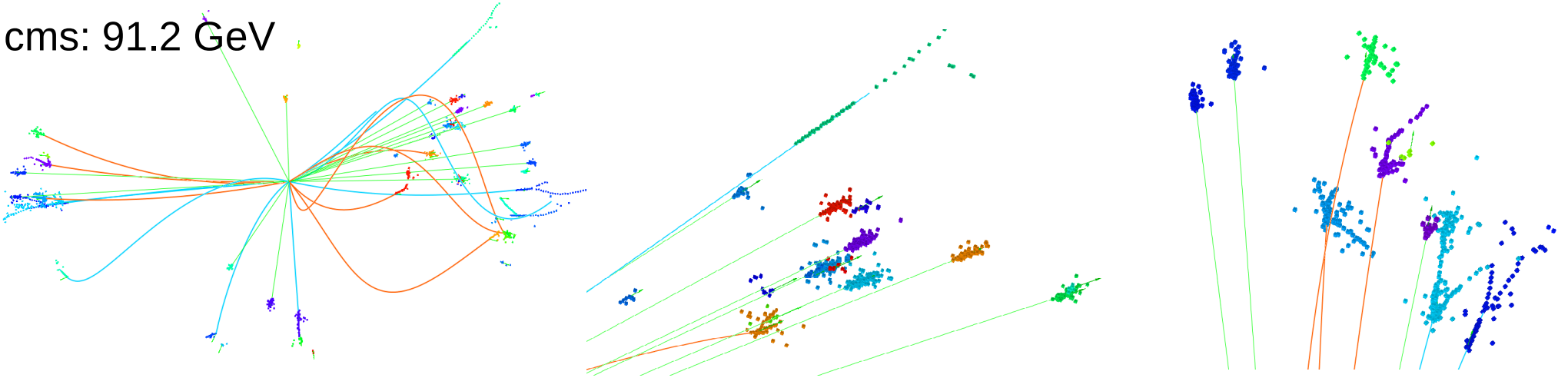
Test beam data



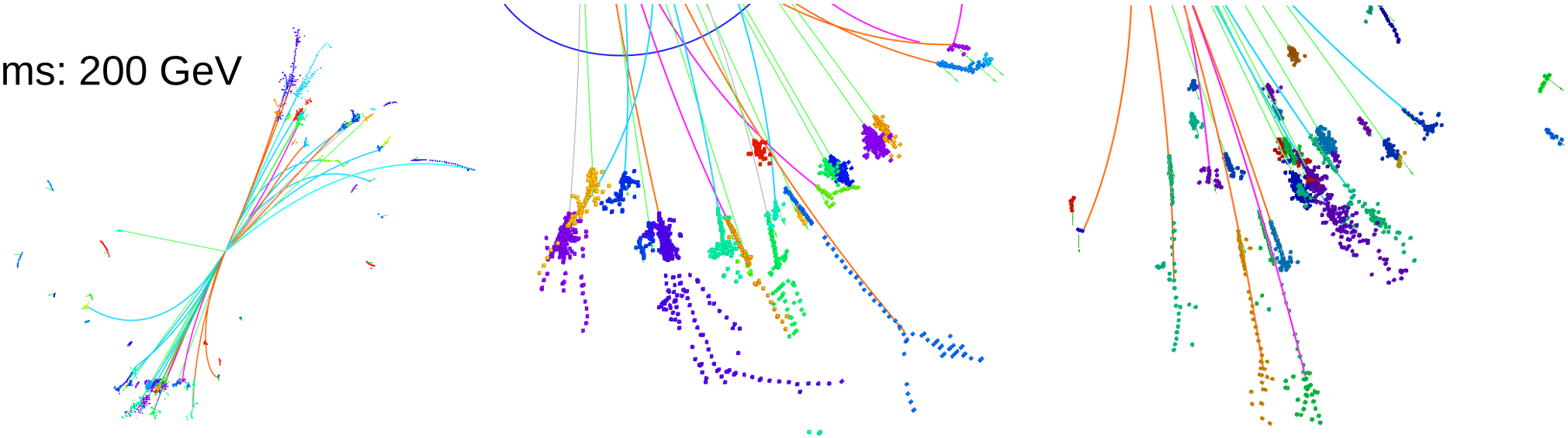


Jet: qq event

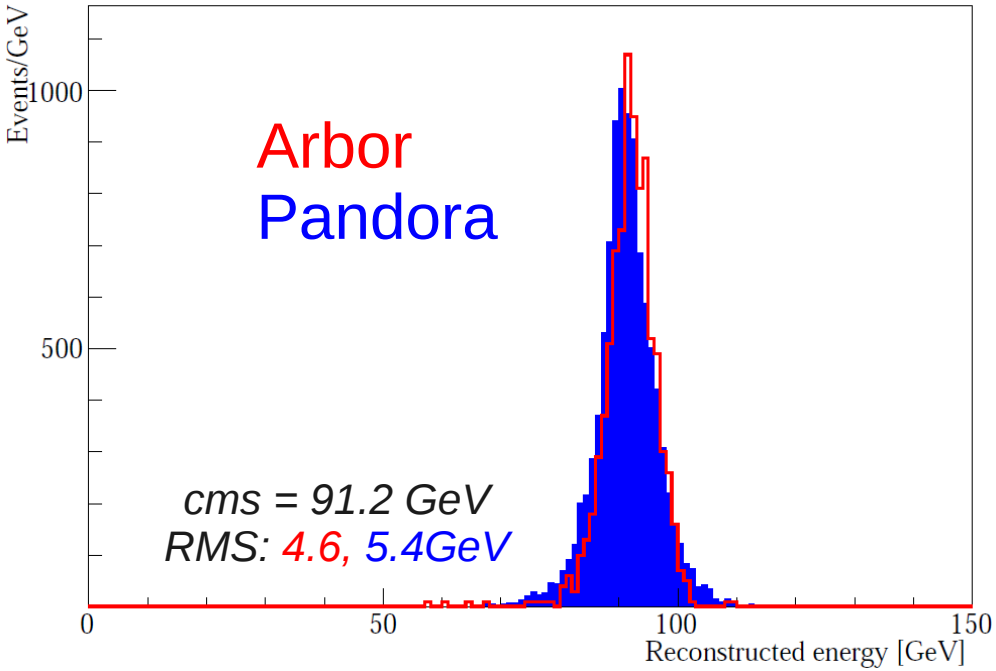
cms: 91.2 GeV

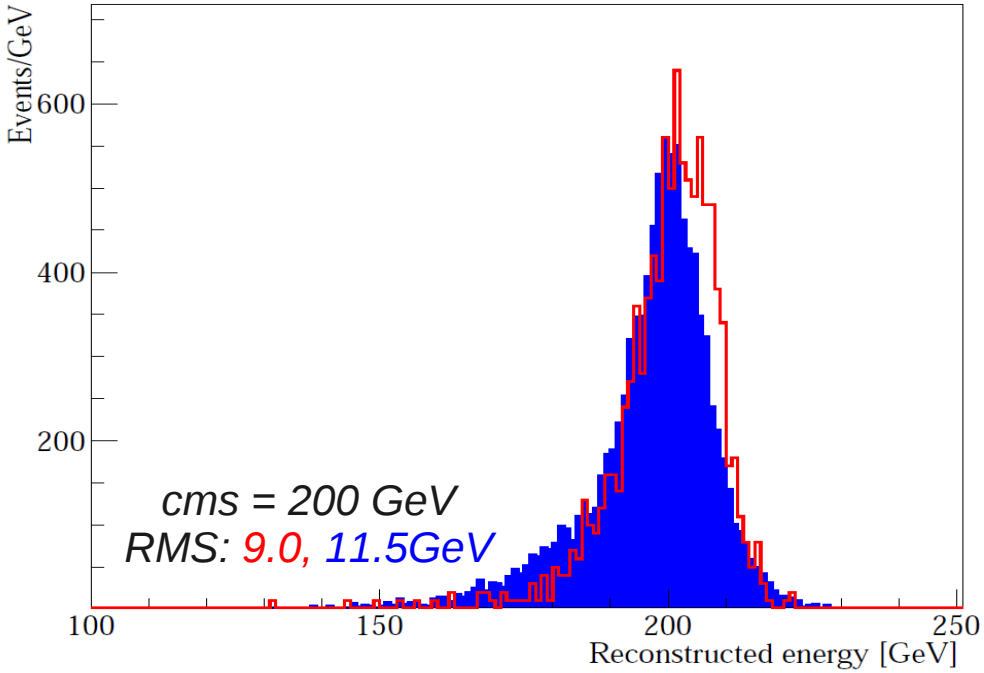


cms: 200 GeV



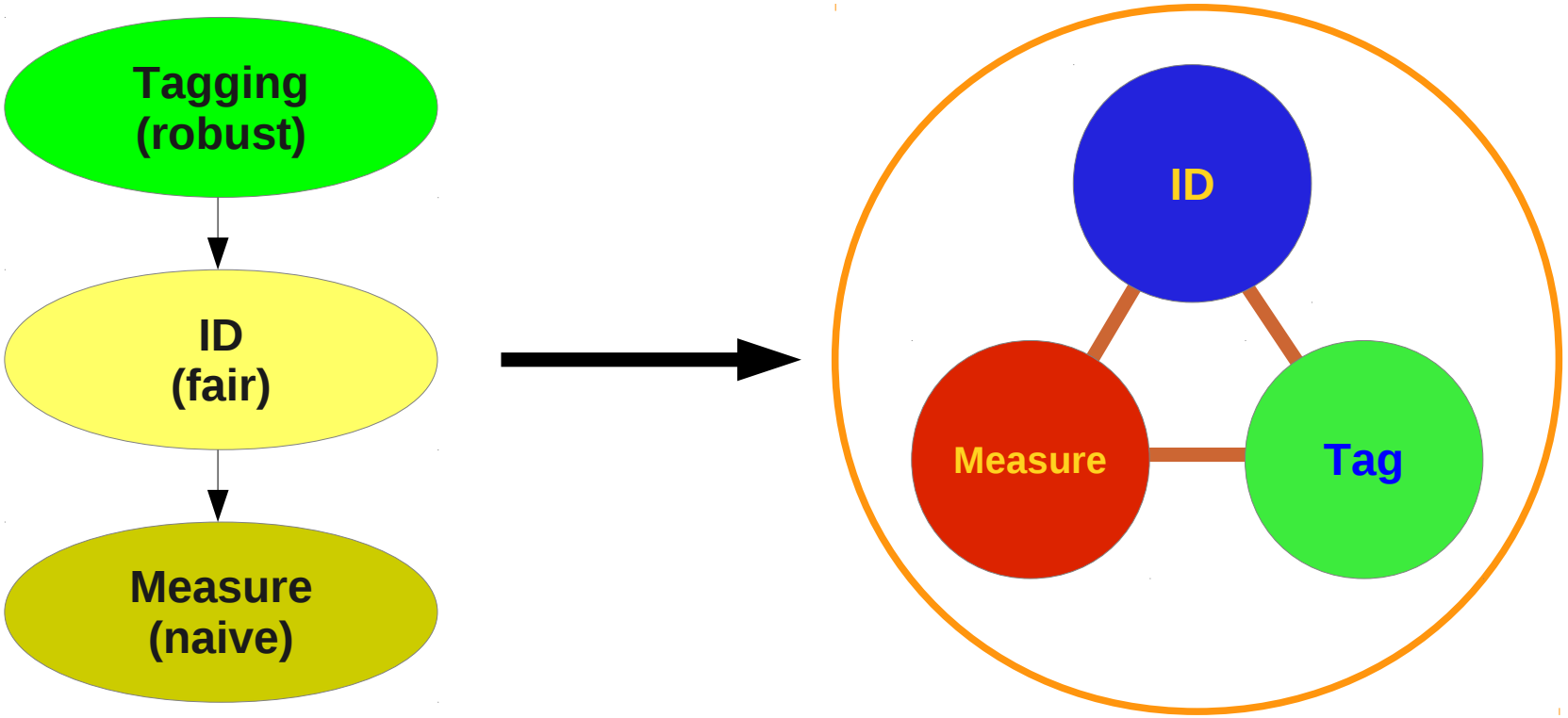
Total reconstructed energy at di-jet event





- Sample:
  - Pandora: simulated at Full ILD detector (10k events at each energy, at ILD_o2_v05)
  - Arbor: simulated with only ILD calorimeter system and magnetic field. To decouple the performance of tracking, clustering (1k events, normalized to 10k).
  - GRPC HCAL with binary readout: HCAL Cluster Energy ~ hit counts
- Performance: comparable*

Next step

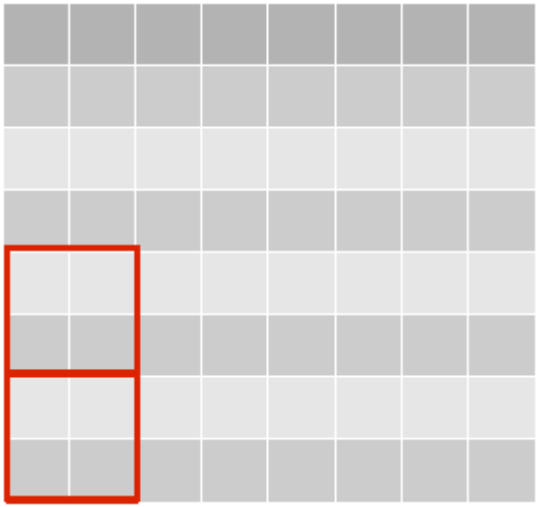


- Current focus: Pattern recognition
  - Cluster identification: electromagnetic, hadronic shower or fragments
  - Particle identification: lepton tagging
- Objective: PID & shower measurement in complex event

Fractal dimension of particle shower

$$FD_\beta = \left\langle \frac{\log(R_{\alpha,\beta})}{\log(\alpha)} \right\rangle + 1.$$

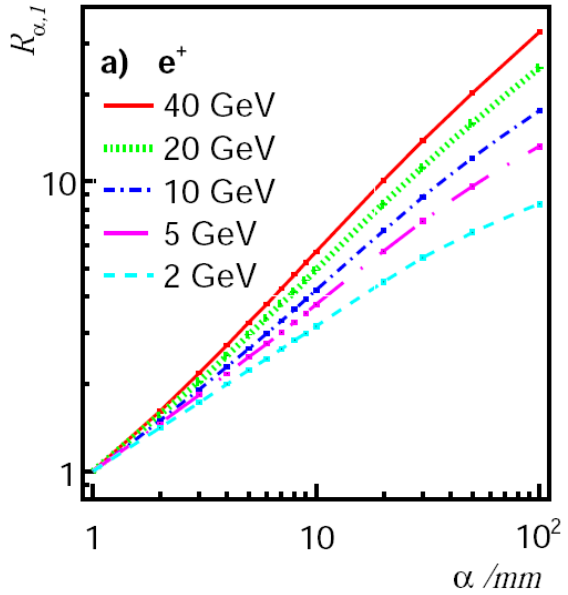
$$R_{\alpha,\beta} = N_\beta / N_\alpha.$$

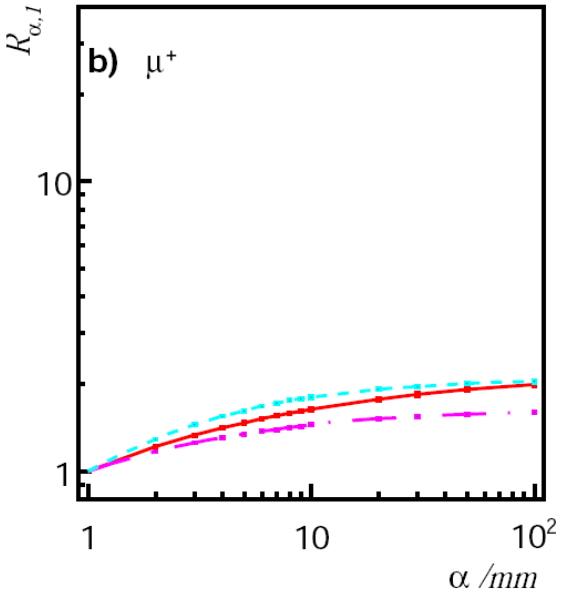


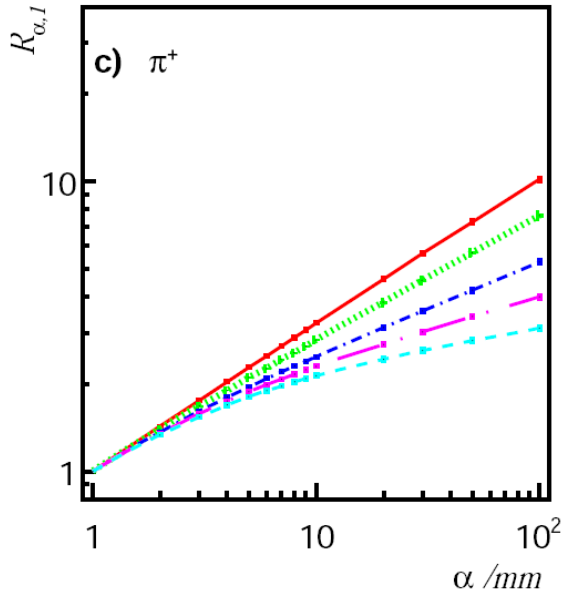
Ultimate cell size: 1mm

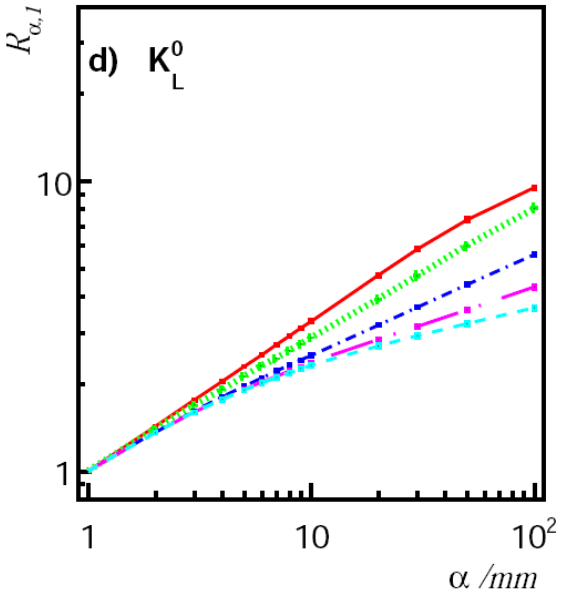
Resize cell: 2 – 10, 20, 30, 50, 60, 90, 120, 150 mm.

Sample: particle gun events at ILD SDHCAL

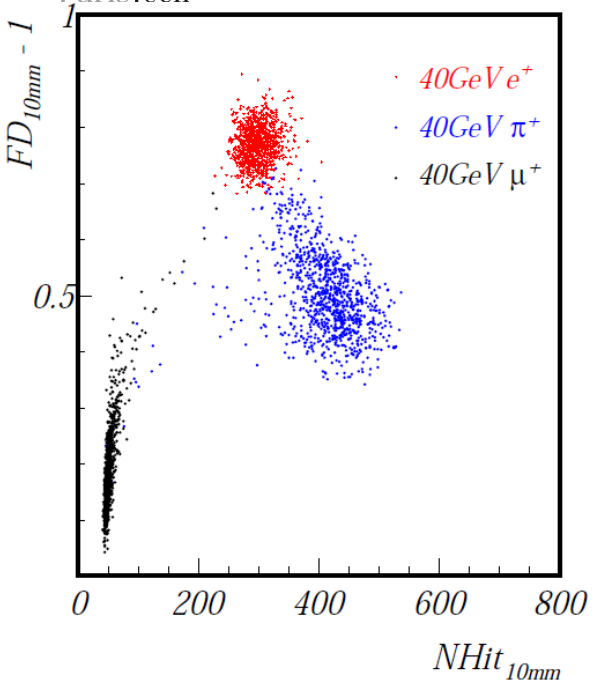


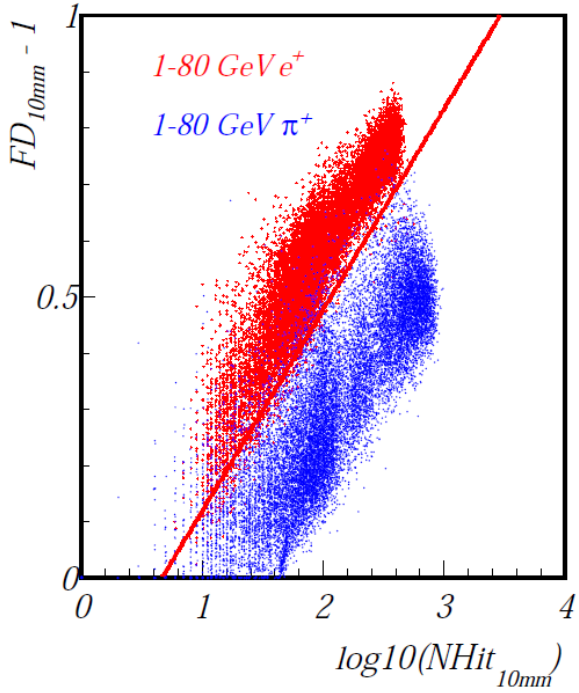


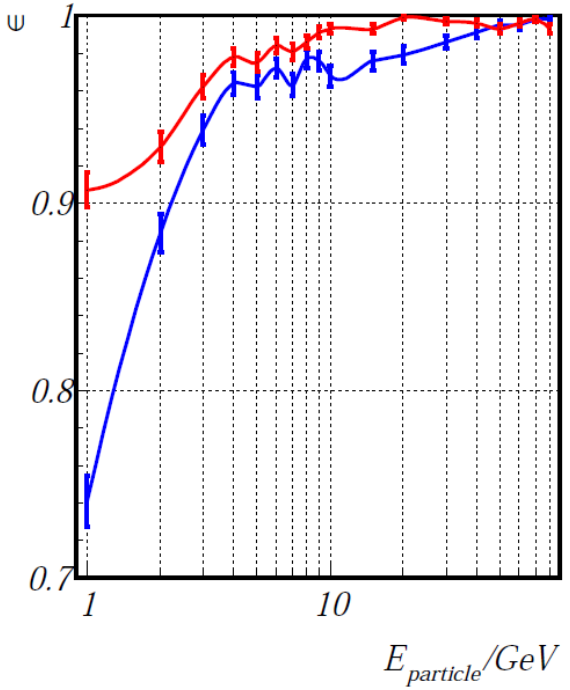


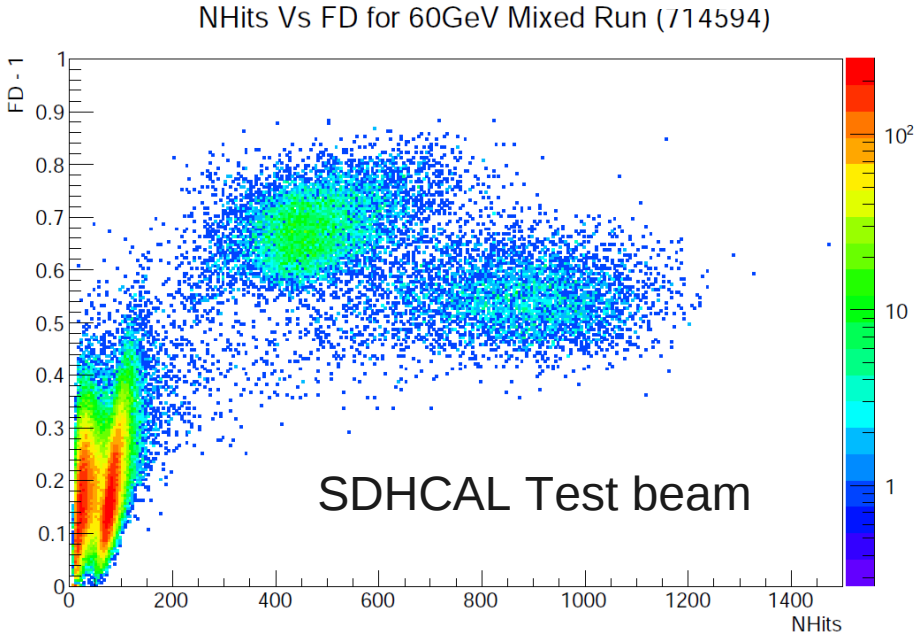


Application: PID, etc









	e^+	μ^+	π^+
e^+	100%	0	0
μ^+	0	99.5%	0.5%
π^+	1.7%	1.4%	96.9%

FD: transverse information

Promising PID over full energy range
Event classification at test beam

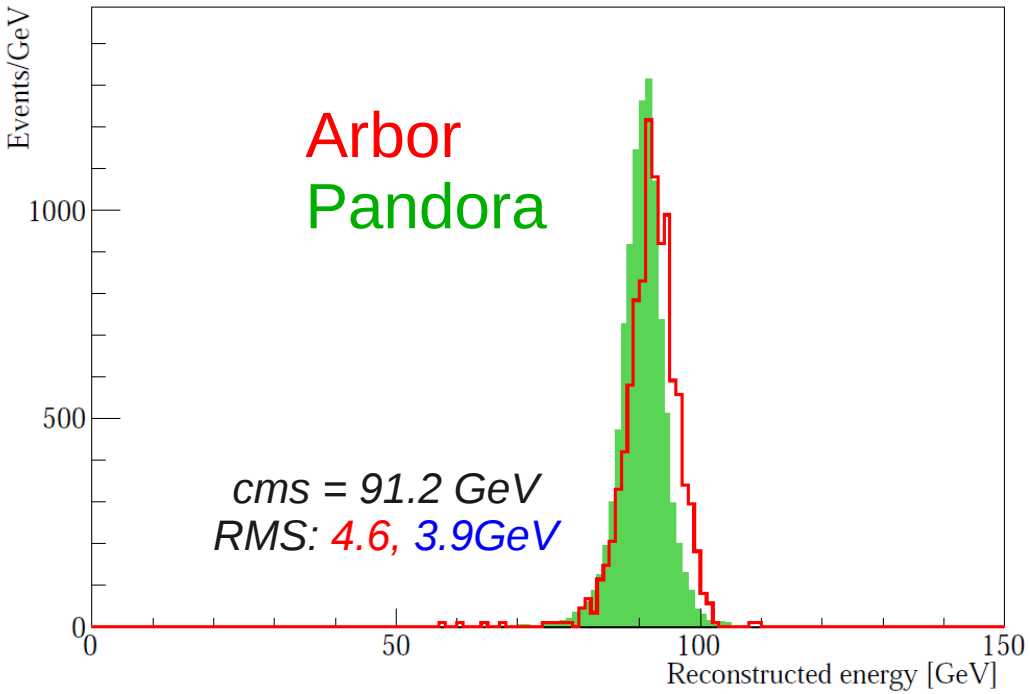
Arbor

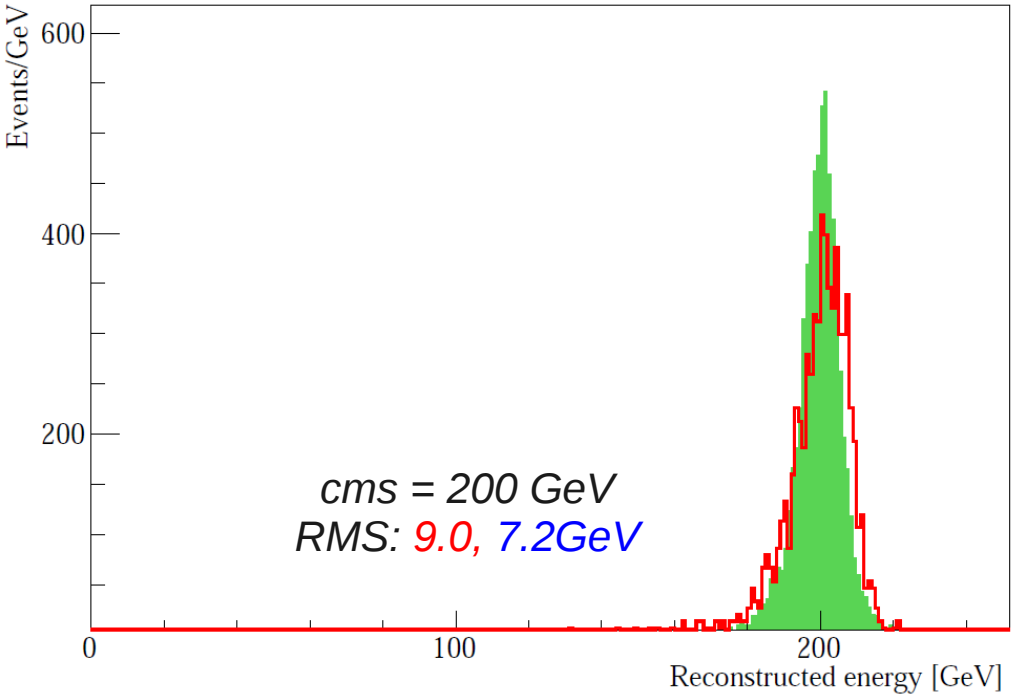
- Status:
  - Core algorithm: stable
  - Successful tagging of sub shower structure
  - Capable to separate showers even if they are overlapped
  - Jet energy performance ~ PandoraPFA
- Plan:
  - Current focus: pattern identification.
    - Advanced tools validated, needs adjusting & integration
  - Measurement, Iterations, optimizations
    - Foreseen lots of efforts

...Key to use high-granularity information...

Back up

Arbor @ DHCAL ~ Pandora @ AHCAL

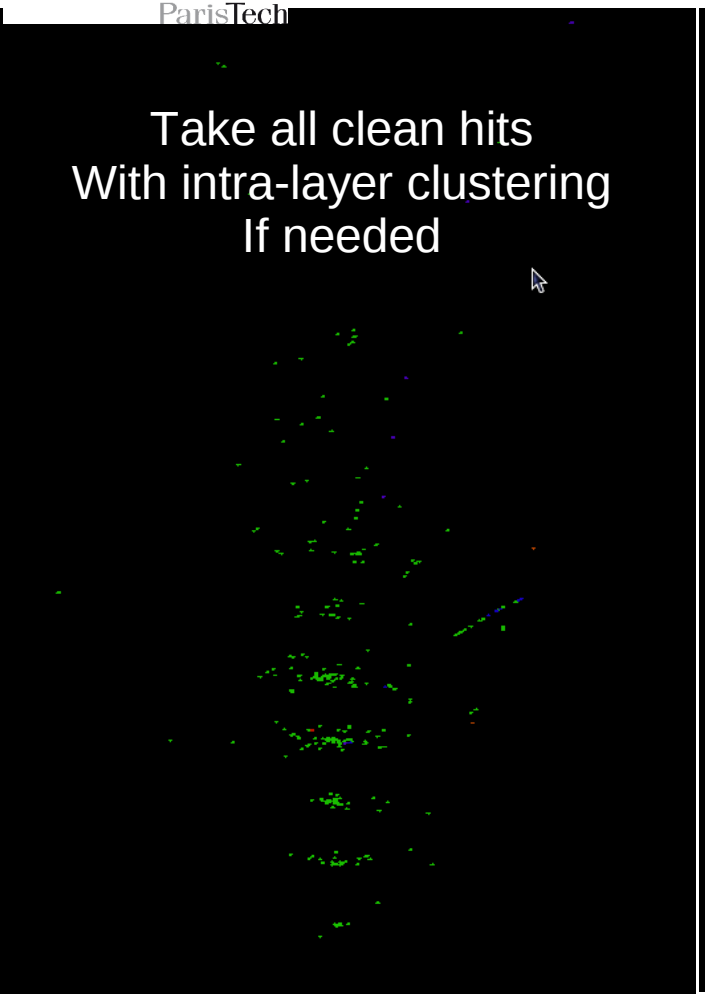




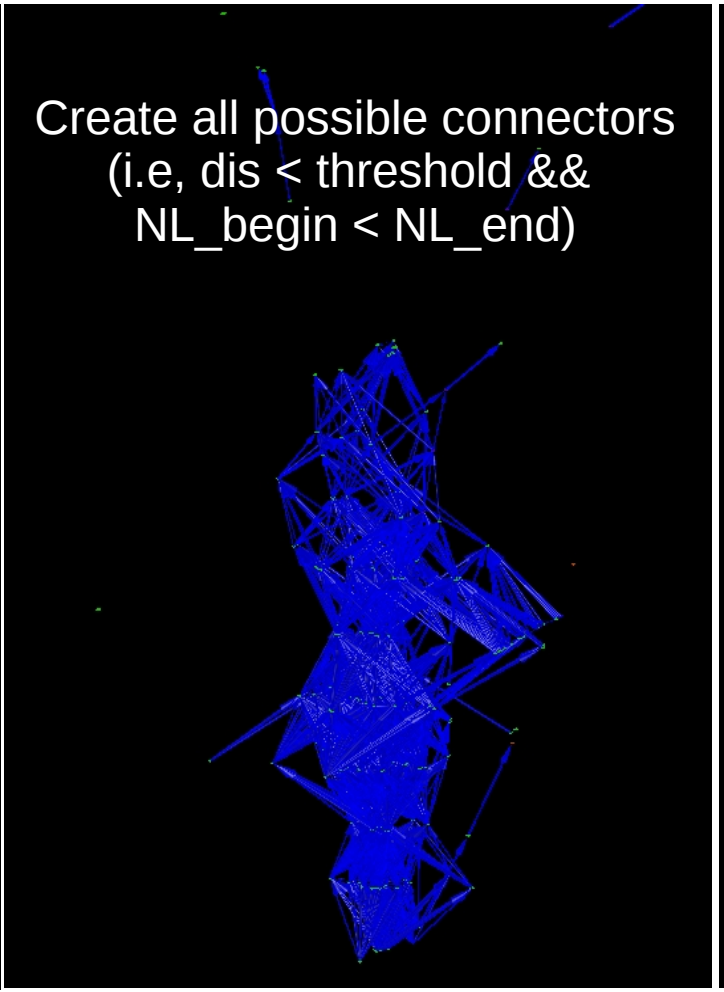
- Pandora, optimized at AHCAL (Scintillator with Analogy readout), not (S)DHCAL (GRPC with binary readout)
- Arbor, parameter tuned at cms 91.2GeV

Algorithm - I

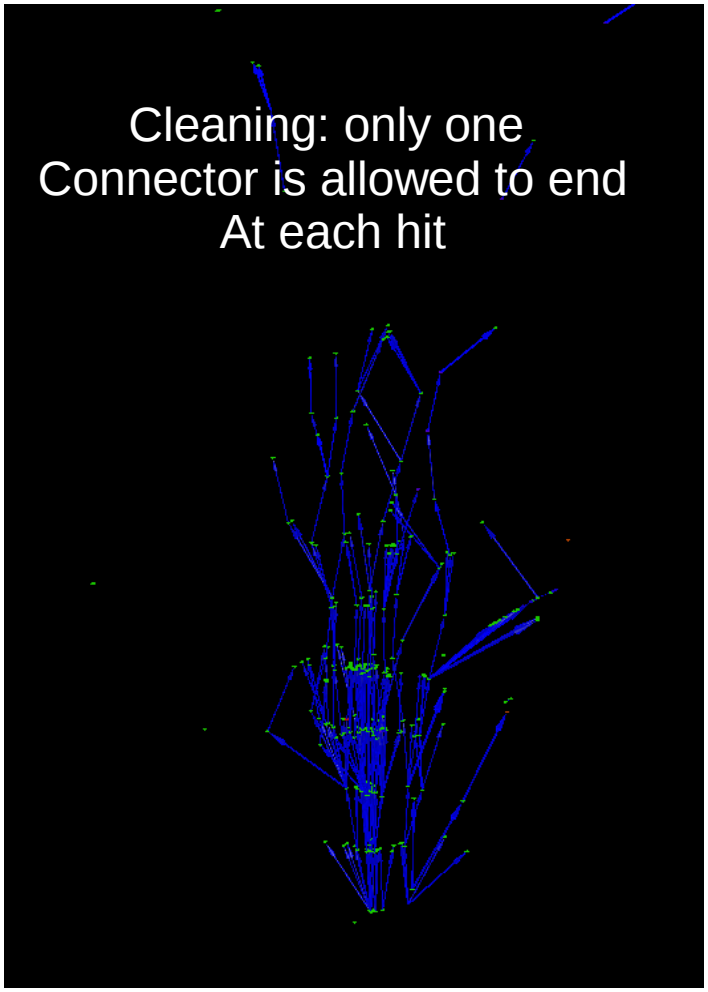
Take all clean hits
With intra-layer clustering
If needed



Create all possible connectors
(i.e, dis < threshold &&
NL_begin < NL_end)



Cleaning: only one
Connector is allowed to end
At each hit



- Clean
  - If a hit is the end of many connectors, keep the one with extreme order
  - Current Order parameter: Ang(P1, P2)*sqrt(Dis(P1, P2))

Algorithm - II

- Iteration the Connector Set (multiple times)
  - Create new possible connector
    - If hit found in the explored region, add new connector
    - Definition of the region (function to be optimized)
  - For each hit, get reference direction vector (function to be optimized)
    - Current function: mean of outgoing and hit position (Normalized vectors)
    - If only one outgoing link: connector direction