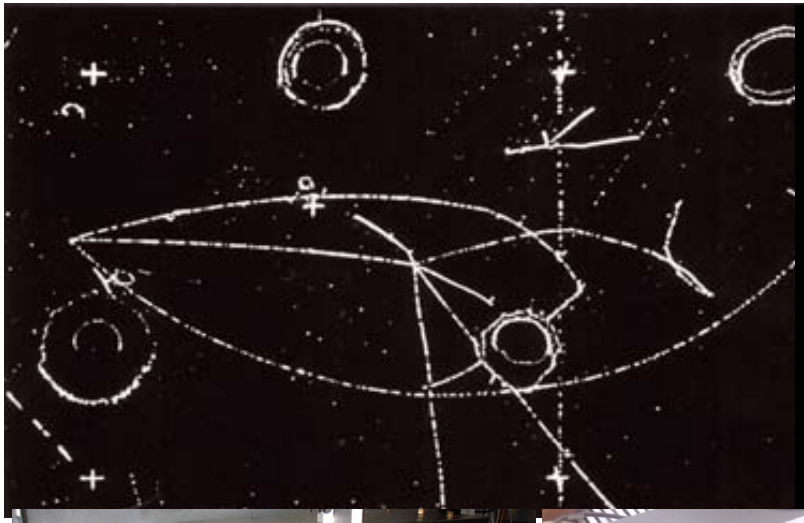
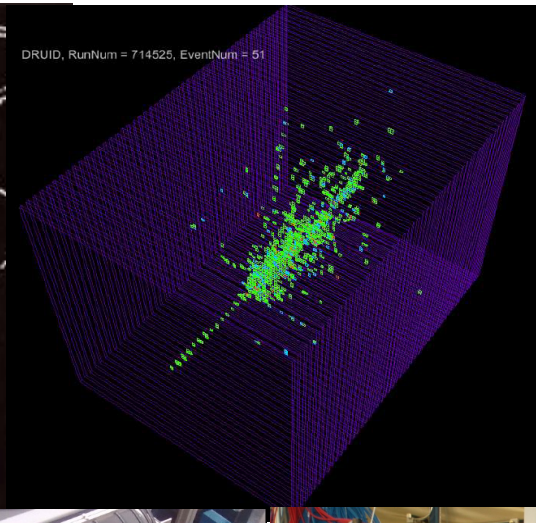
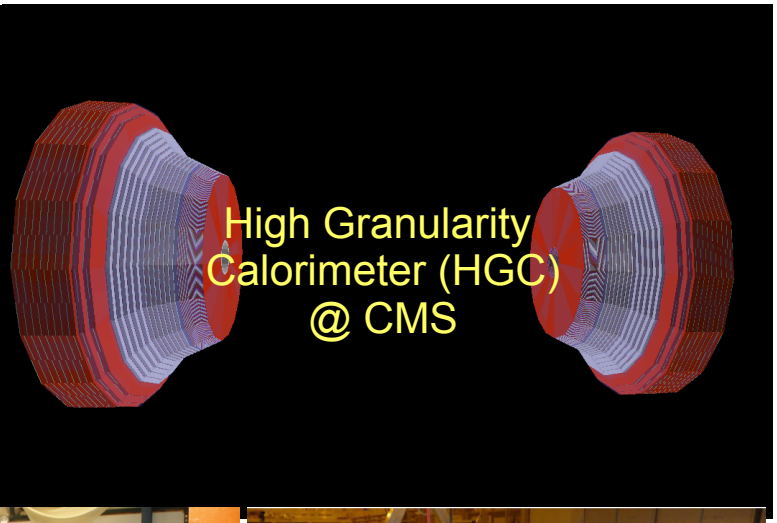
# Arbor: status & plan

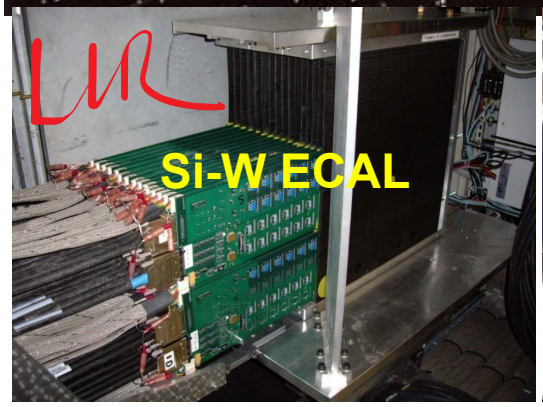
Manqi RUAN

# Ultra-high granularity

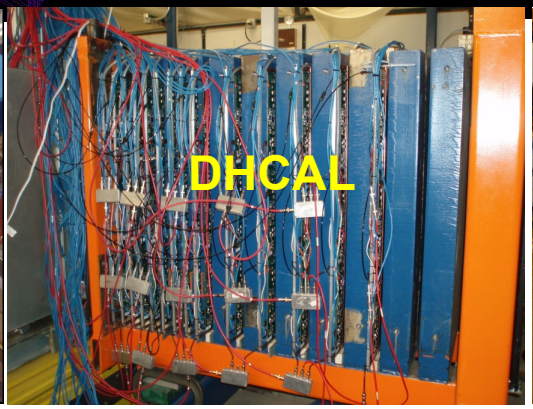




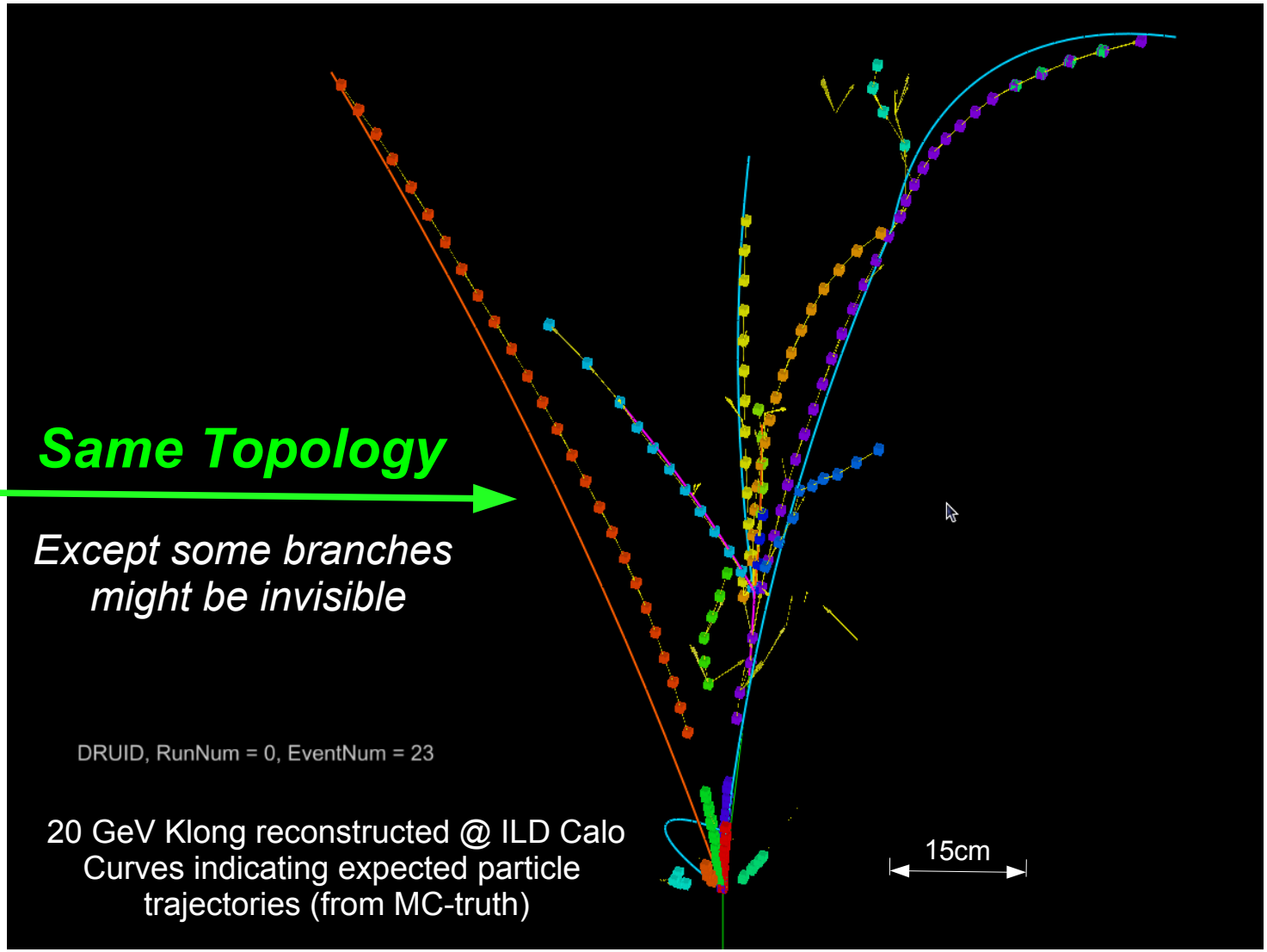






Granularity ~ 1 $cm^{-3}$. 3d - 5d(spatial + energy & tme) image...
**properly** understand/use these information...

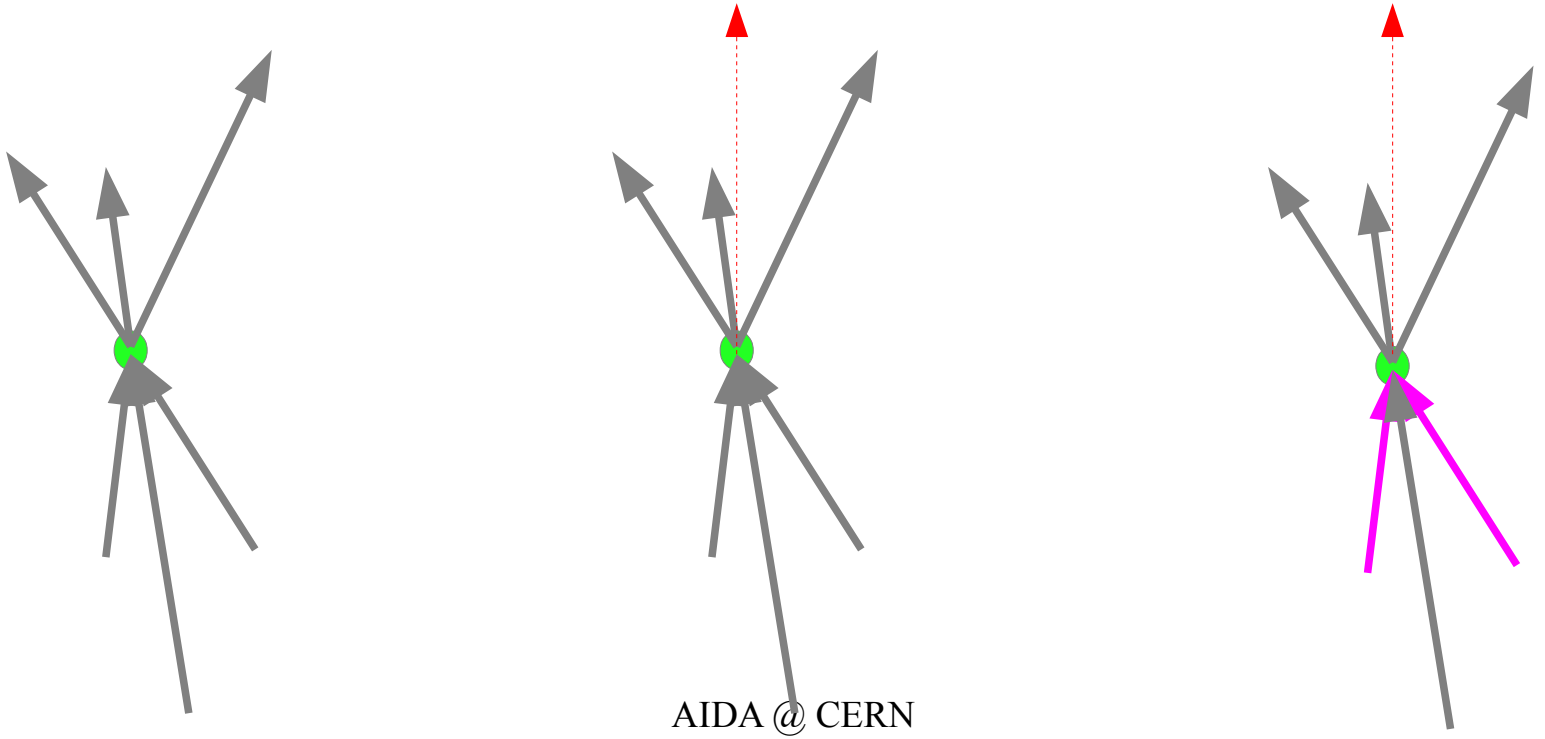
# Arbor: principle



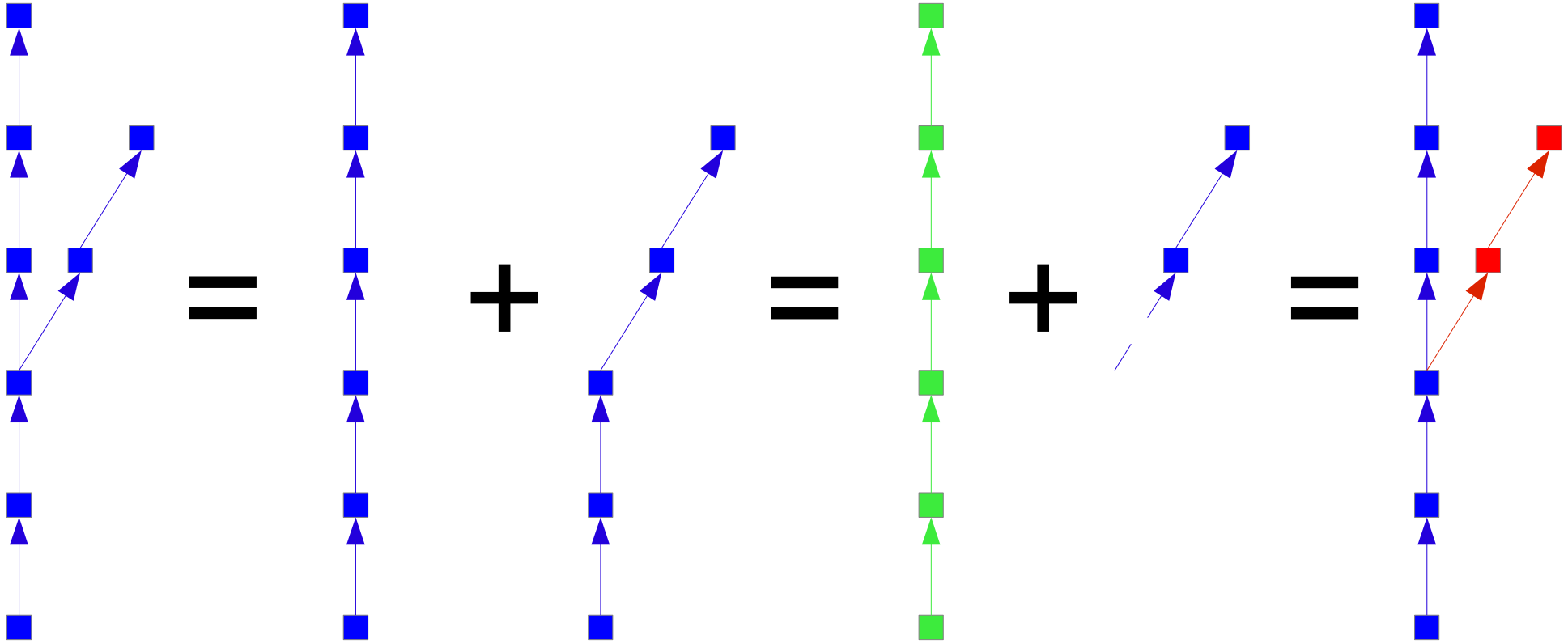

- Original idea from Henri Videau, in the ALEPH studies

# 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

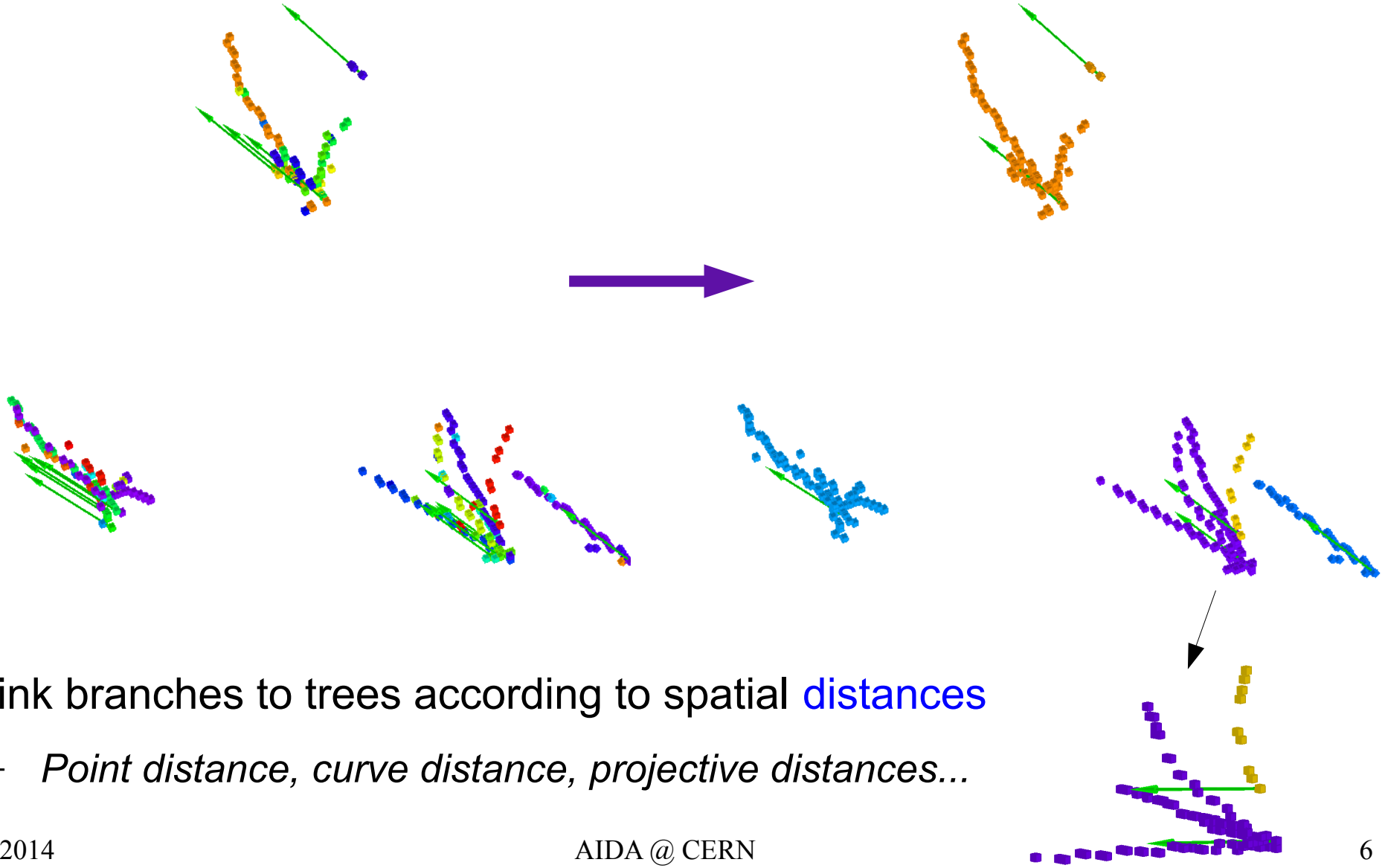


# Algorithm: connector → branch



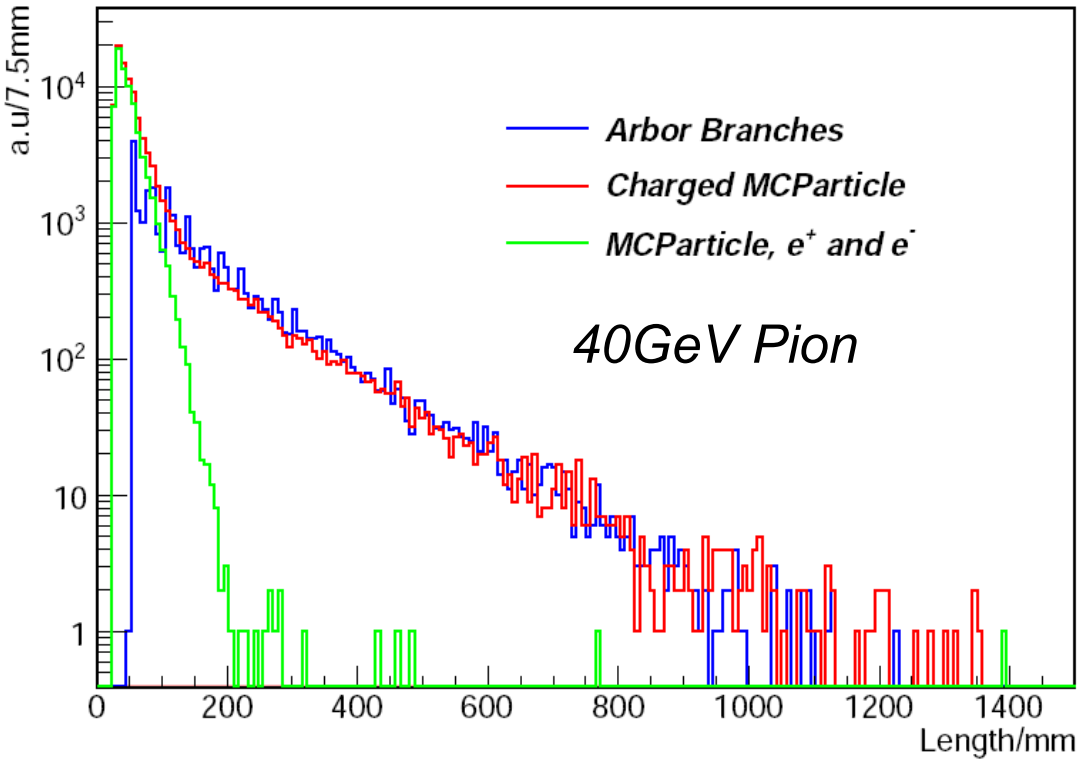
- Tag the unique branch set from connectors
  - Create all the possible branches (*from leaves to seed*)
  - Loop the branches with length order, flag hit, end the branch at the flagged hits...

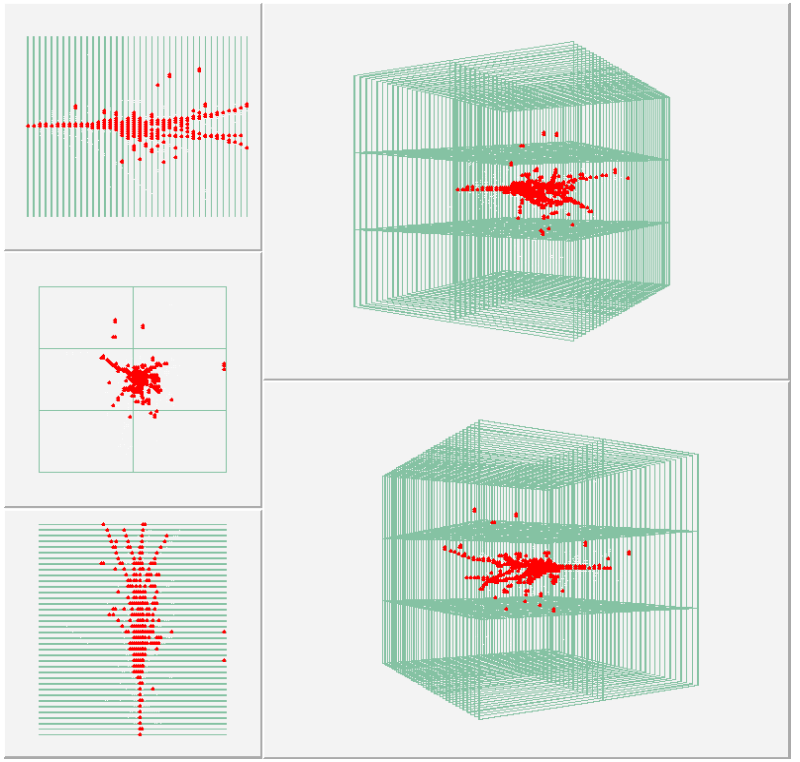
# Algorithm: branch→tree



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

# Validation: Arbor Branch Length

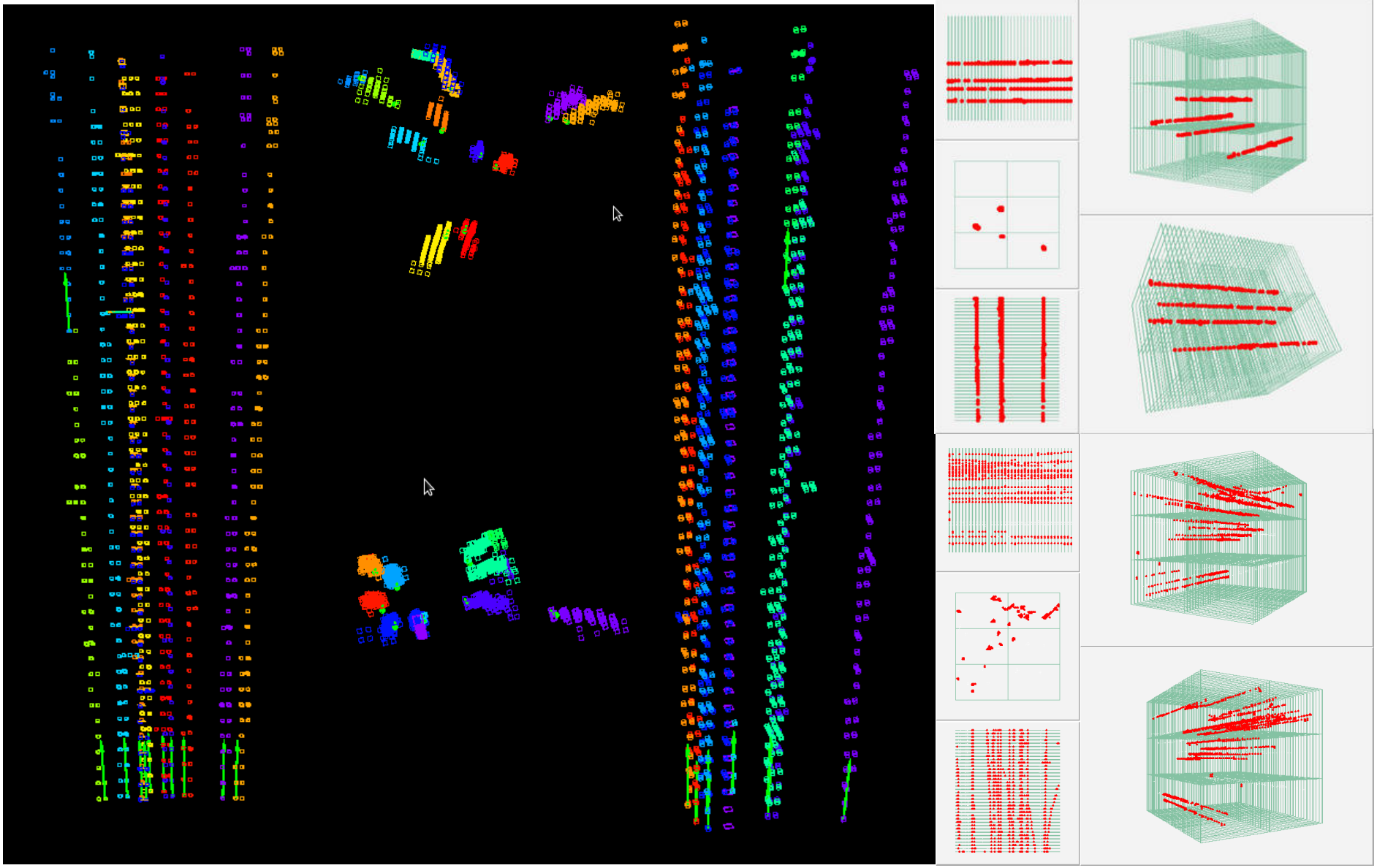


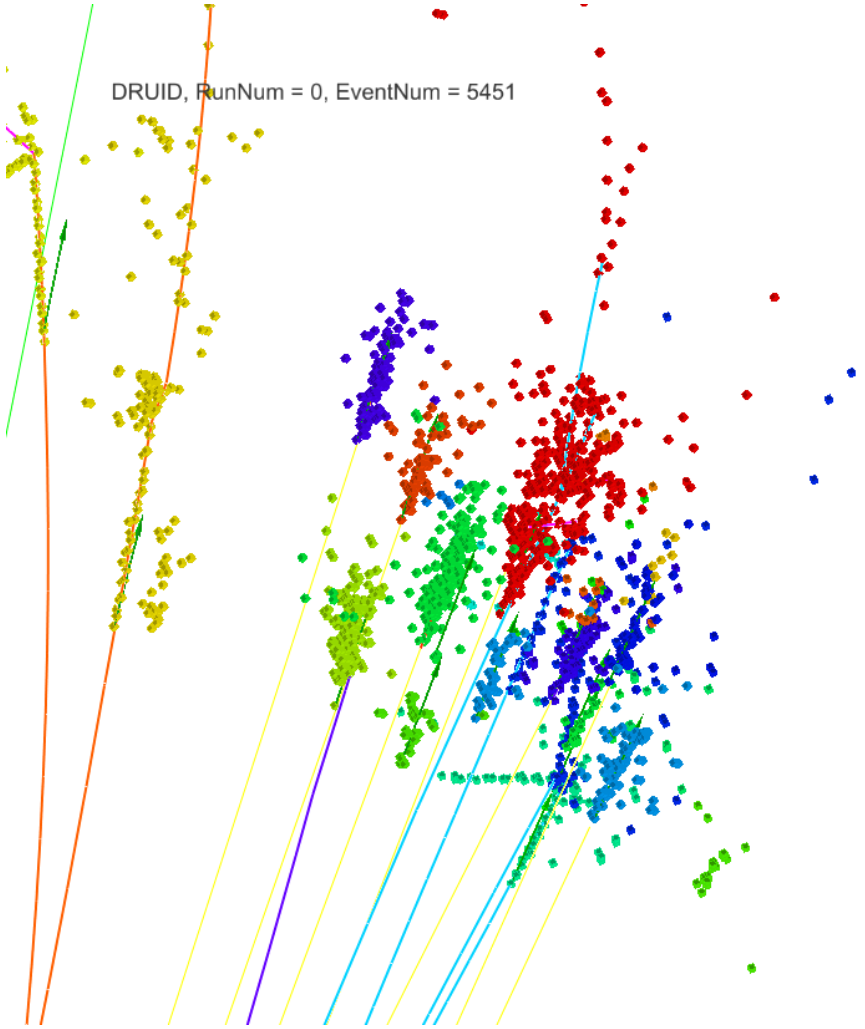
Arbor: successfully tag sub-shower structure

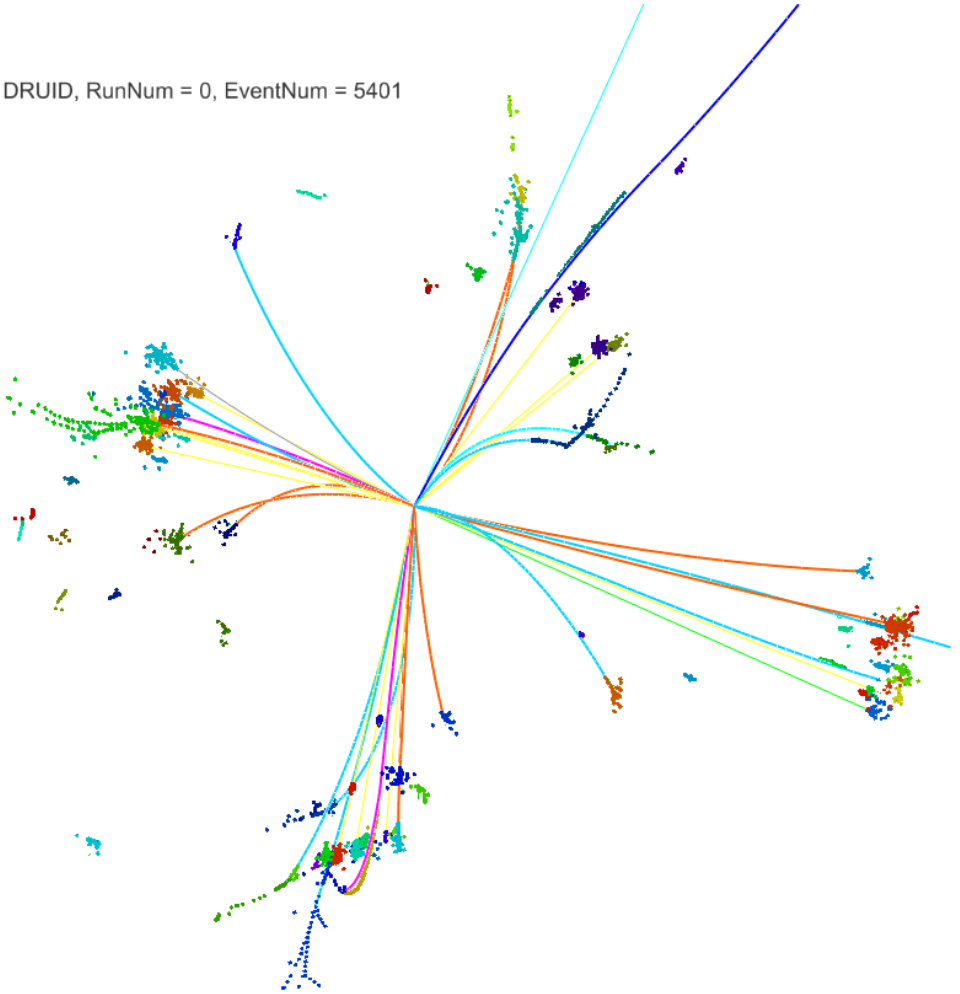
*Samples: Particle gun event at ILD HCAL (readout granularity 1cm$^2$ & layer thickness 2.65cm)*
*Length:*
*Charged MCParticle: spatial distance between generation/end points*
*Arbor branch: sum of distance between neighbor hits*

# Separation: multiple muon



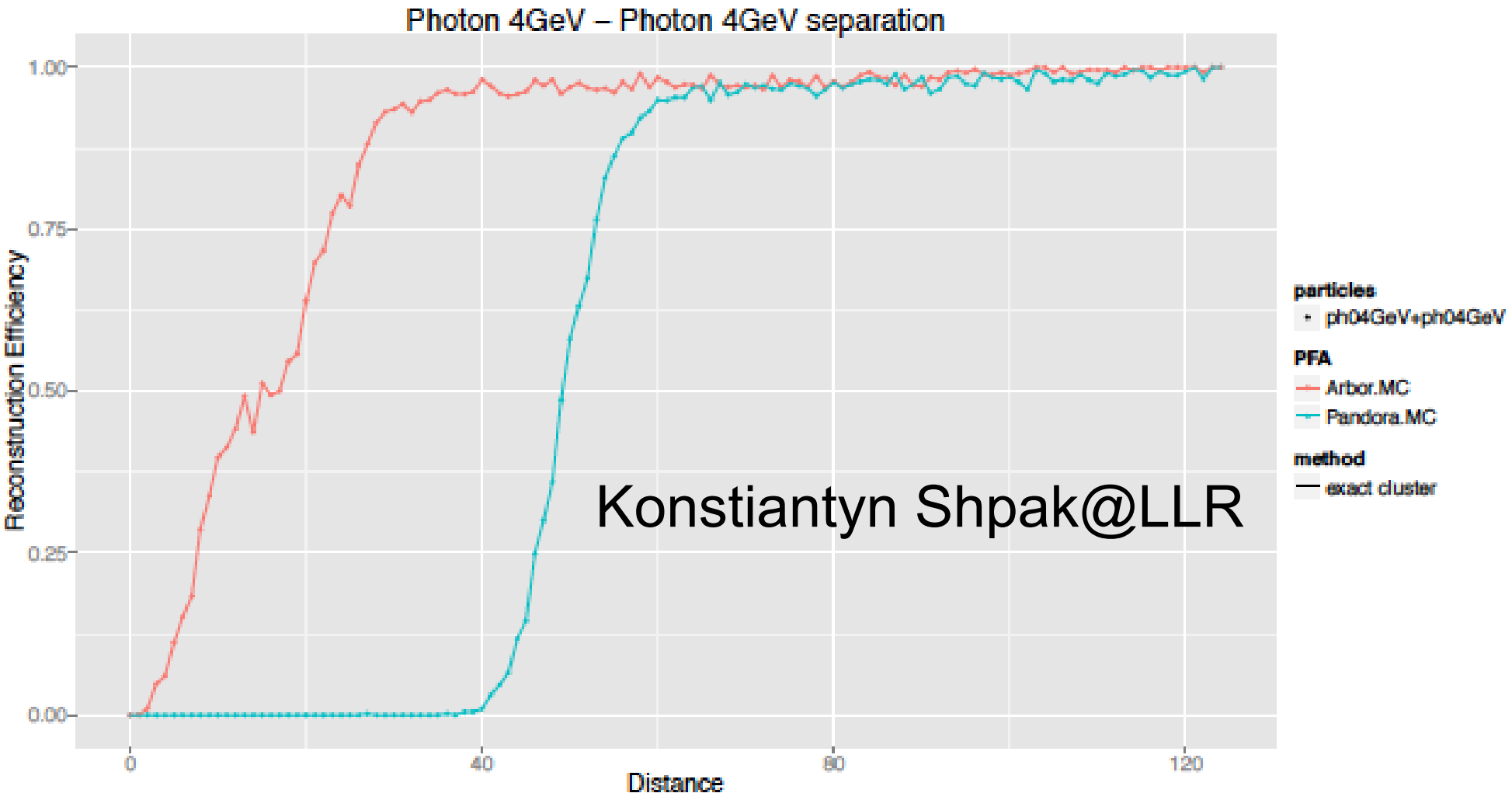
# Separation: Jets



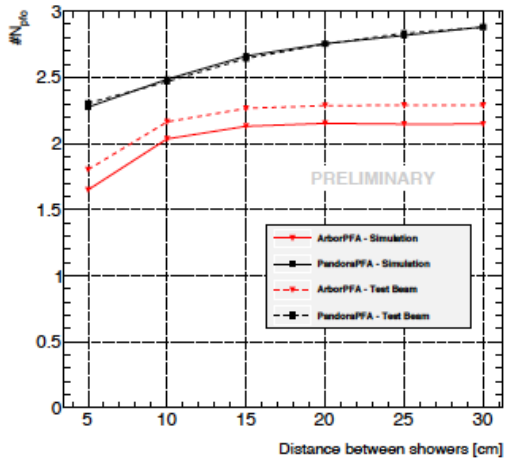

***Separation: Key for PFA***

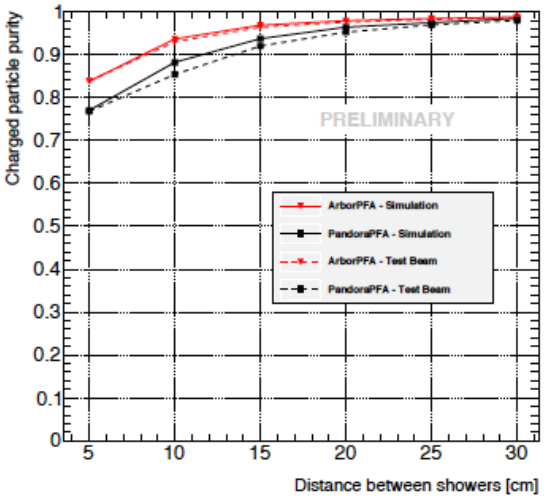
# Separation: di-photon

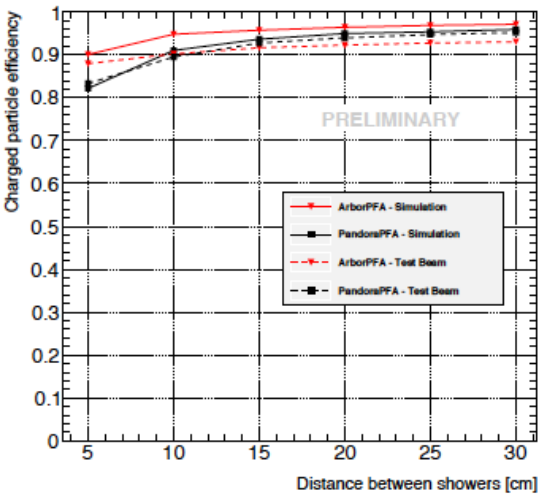


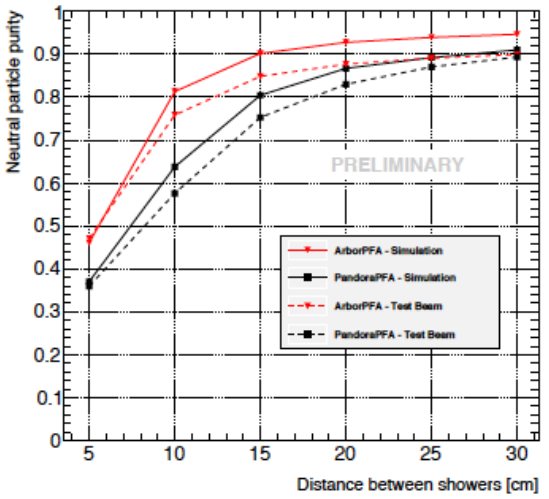
# Pfo analysis

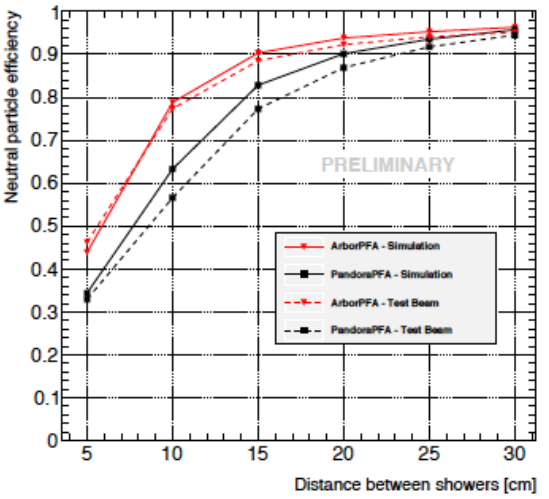
Overlay study. 10 GeV neutral pi + 30 GeV charged pi-



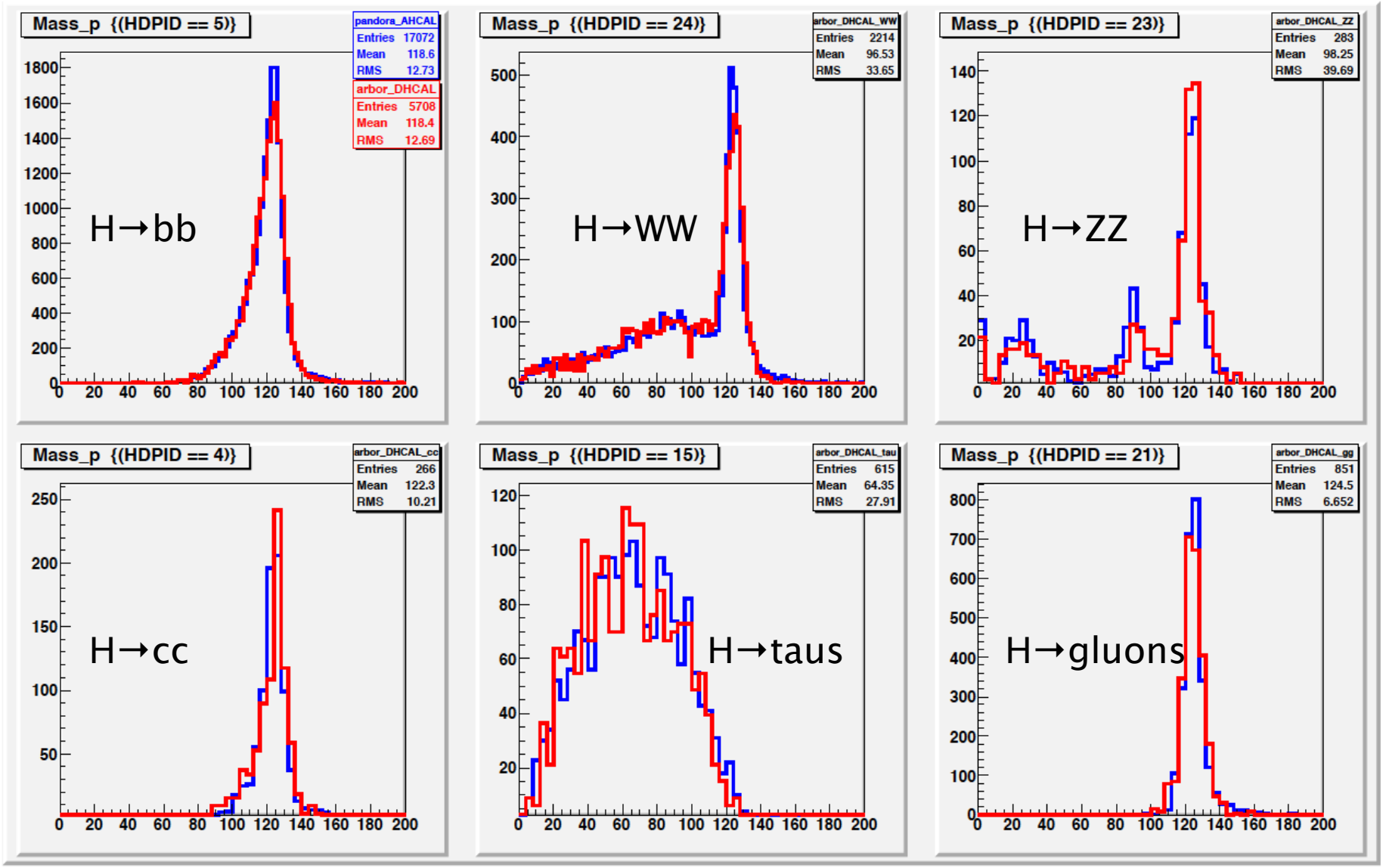



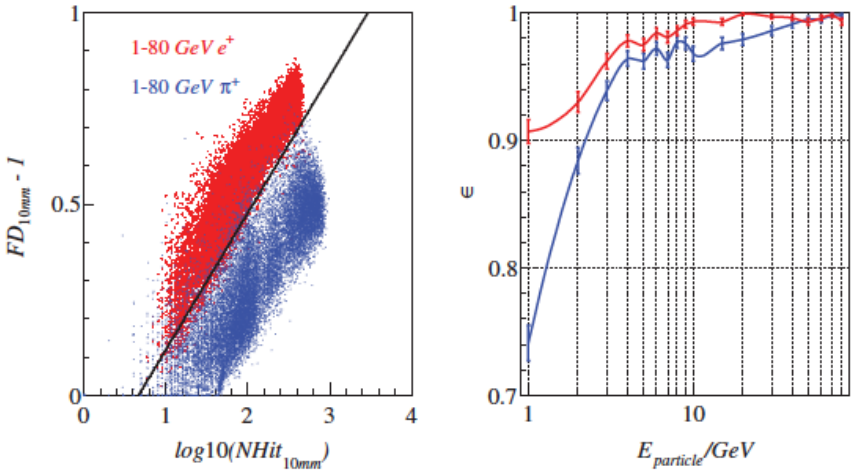

R. Ete @ INPL

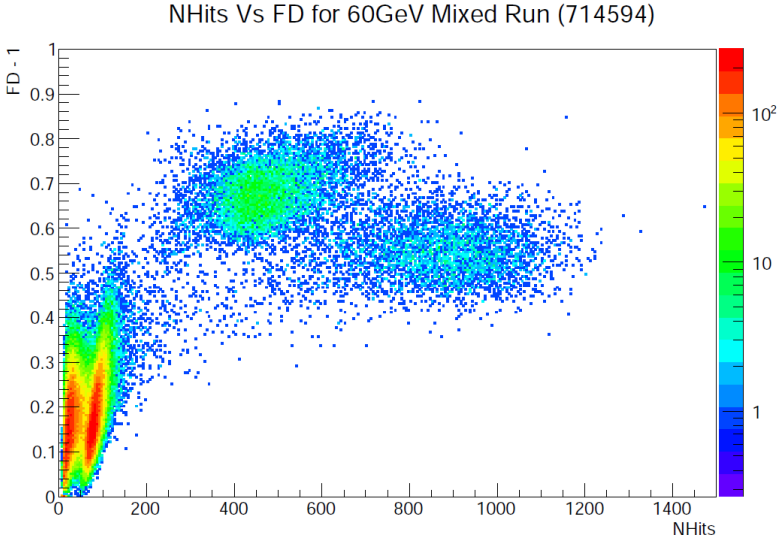
# At Higgs invariant mass




*Arbor Uses GRPC Hadron Calorimeter, whose intrinsic resolution – based on current energy estimator is worse than that Pandora Used (Scintillator Tile Analogy HCAL).*

# Lepton identification (Preliminary)




| 10GeV | P_PID_e(%) | P_PID_mu(%) | P_PID_pi(%) |
|---|---|---|---|
| e | 99.02 | 0.09 | 0.89 |
| mu | 0.02 | 98.24 | 1.74 |
| pi | 5.34 | 4.14 | 90.66 |

| 20GeV | P_PID_e(%) | P_PID_mu(%) | P_PID_pi(%) |
|---|---|---|---|
| e | 99.47 | 0.06 | 0.47 |
| mu | 0.09 | 99.11 | 0.80 |
| pi | 5.56 | 1.99 | 92.45 |

| 30GeV | P_PID_e(%) | P_PID_mu(%) | P_PID_pi(%) |
|---|---|---|---|
| e | 99.47 | 0.03 | 0.50 |
| mu | 0.06 | 99.20 | 0.74 |
| pi | 5.28 | 1.84 | 92.88 |

| 40GeV | P_PID_e(%) | P_PID_mu(%) | P_PID_pi(%) |
|---|---|---|---|
| e | 99.43 | 0.13 | 0.44 |
| mu | 0.13 | 99.45 | 0.41 |
| pi | 5.38 | 1.71 | 92.91 |

| 50GeV | P_PID_e(%) | P_PID_mu(%) | P_PID_pi(%) |
|---|---|---|---|
| e | 99.70 | 0.09 | 0.21 |
| mu | 0.20 | 99.35 | 0.45 |
| pi | 6.28 | 1.37 | 92.35 |

| 60GeV | P_PID_e(%) | P_PID_mu(%) | P_PID_pi(%) |
|---|---|---|---|
| e | 99.71 | 0.09 | 0.20 |
| mu | 0.24 | 99.56 | 0.20 |
| pi | 5.84 | 1.63 | 92.53 |

| 70GeV | P_PID_e(%) | P_PID_mu(%) | P_PID_pi(%) |
|---|---|---|---|
| e | 99.62 | 0.09 | 0.29 |
| mu | 0.25 | 99.58 | 0.17 |
| pi | 5.06 | 1.78 | 93.26 |

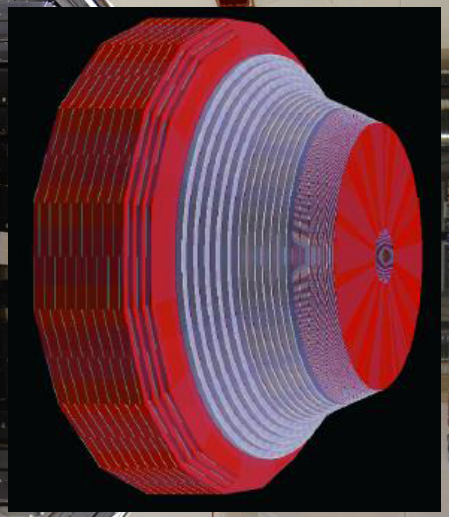
| 80GeV | P_PID_e(%) | P_PID_mu(%) | P_PID_pi(%) |
|---|---|---|---|
| e | 99.47 | 0.09 | 0.44 |
| mu | 0.22 | 99.68 | 0.10 |
| pi | 5.00 | 2.49 | 92.51 |

| 90GeV | P_PID_e(%) | P_PID_mu(%) | P_PID_pi(%) |
|---|---|---|---|
| e | 99.46 | 0.05 | 0.49 |
| mu | 0.25 | 99.69 | 0.06 |
| pi | 5.00 | 2.34 | 92.76 |

| 100GeV | P_PID_e(%) | P_PID_mu(%) | P_PID_pi(%) |
|---|---|---|---|
| e | 99.28 | 0.03 | 0.69 |
| mu | 0.43 | 99.56 | 0.01 |
| pi | 4.24 | 2.59 | 93.17 |

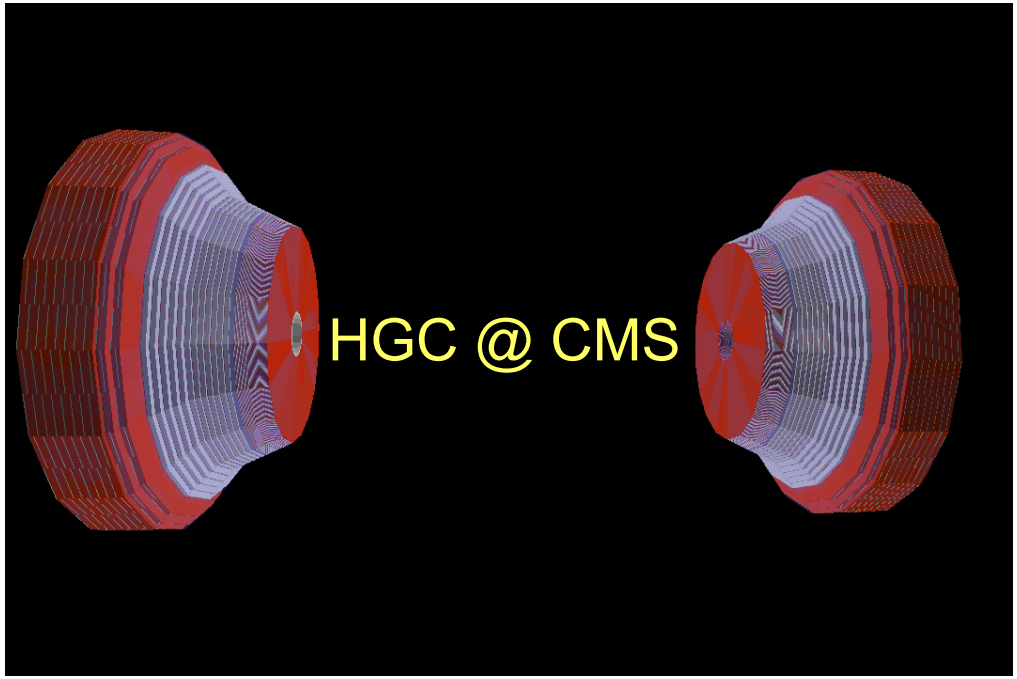
Binsong MA @ IHEP: Arbor Clusters:
Efficiency > 99% is achieved for muon/electron:
On going activity: understand the pion mis-id case...
Push to low energy cases

# A Silicon based High luminosity Calorimeter for HL-LHC...



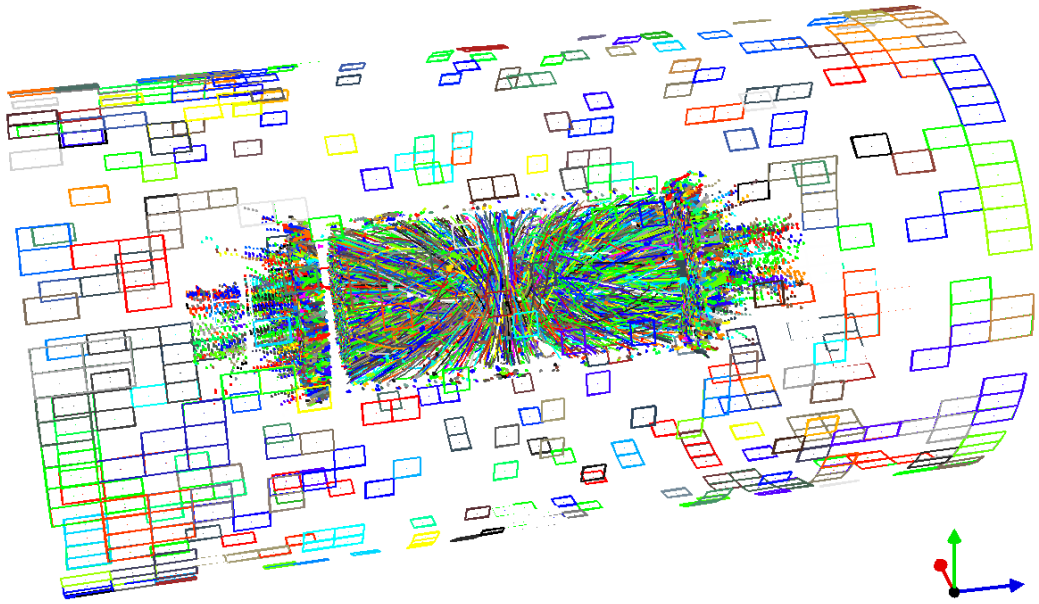
# ...Pile ups...

***140 PU: 100 k hits ~ o(100 TeV) energy deposition at each EndCap...***





CMS Experiment at LHC, CERN
Data recorded: Thu Jan 1 01:00:00 1970 CEST
Run/Event: 1 / 1
Lumi section: 1



CMS Experiment at LHC, CERN
Data recorded: Thu Jan 1 01:00:00 1970 CEST
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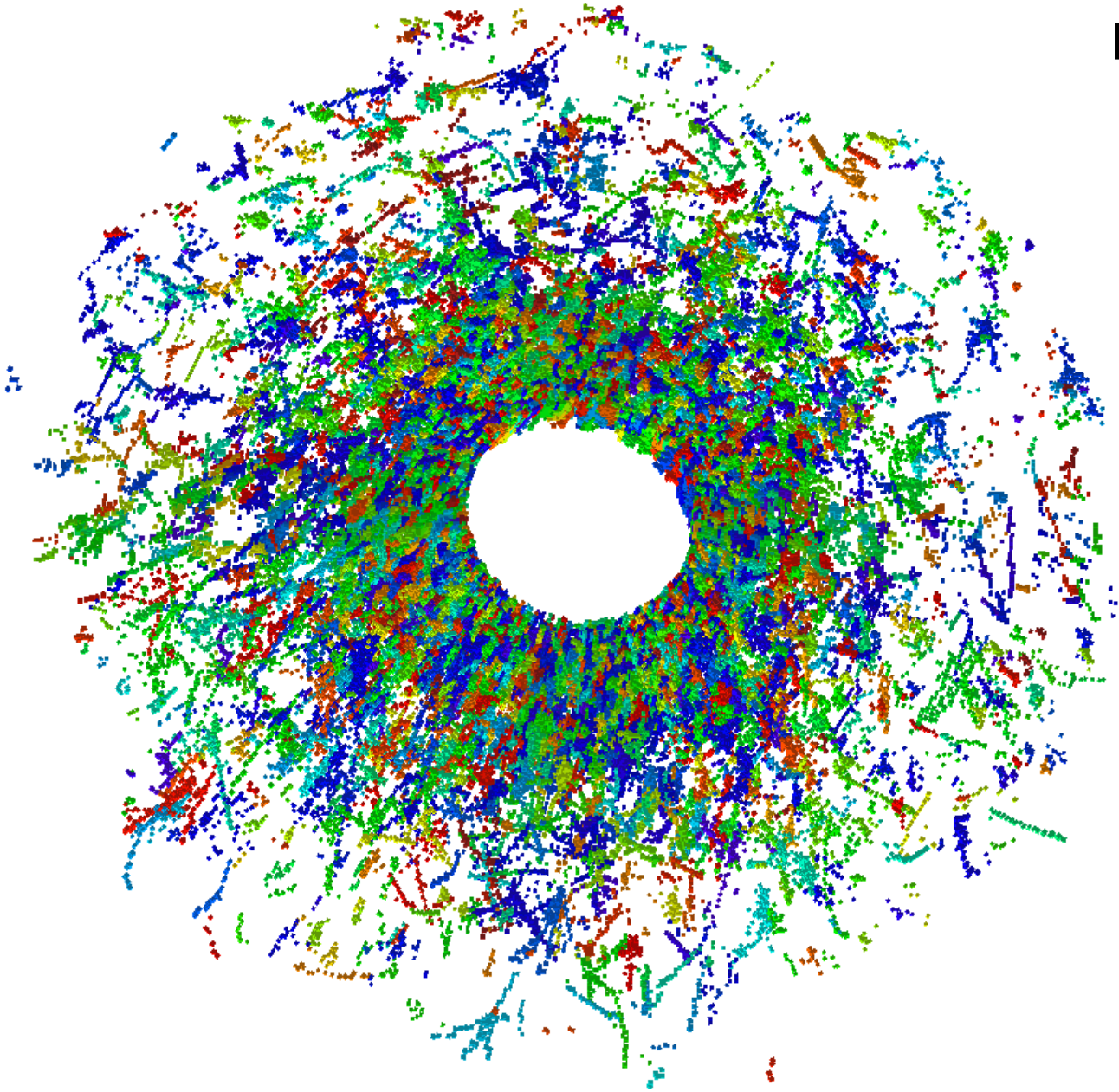
Lumi section: 1

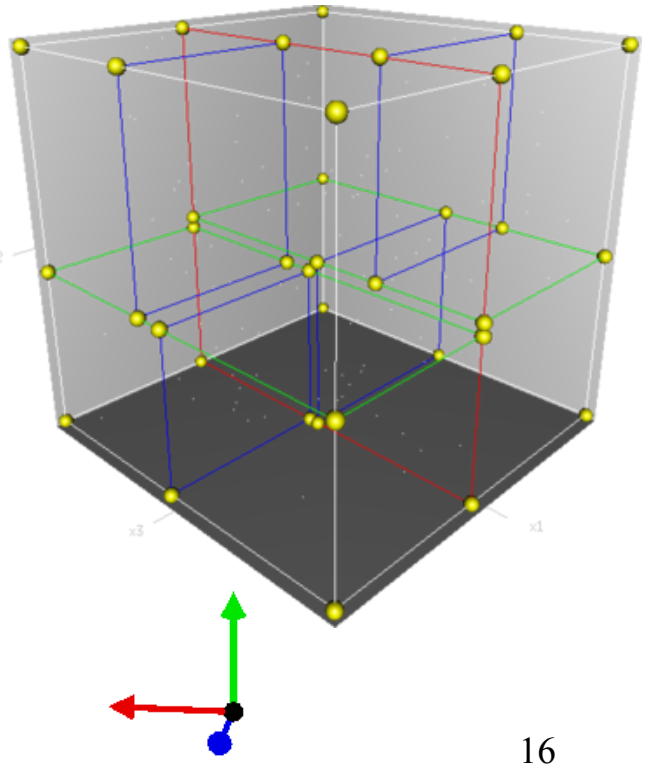
# Lindsey Gray



KD-Tree implemented:

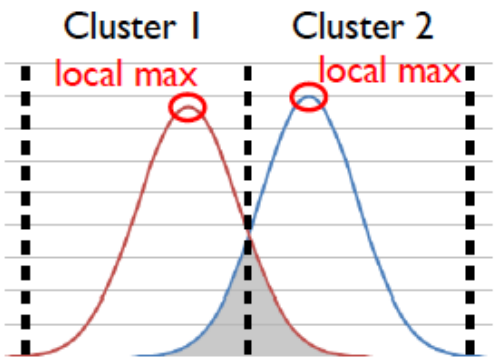
$N^2 \rightarrow N\log(N)$

One event ~ 40 sec...



# Recent development: Lindsey, using energy information

Step 1: EM-Like Clustering




Step 2: Track-Assisted Clustering

Use clusters, with axes and positions calculated, and remaining free RecHits.

Attach RecHits along track, merge clusters with axes tangent to track direction in nearest layer.

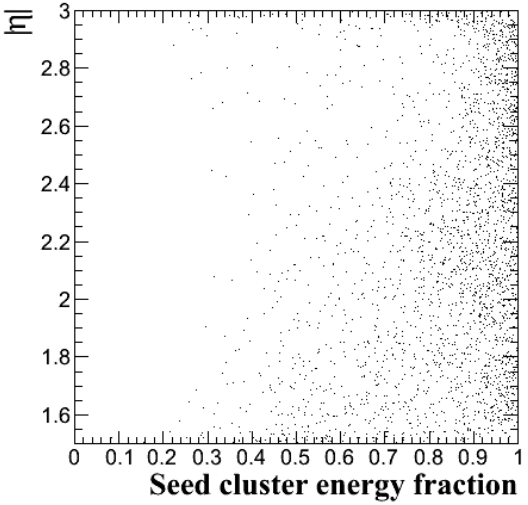
Step 3: Clean-up

Use resulting set of clusters and RecHits to perform a final clustering step, exploiting position and pointing information where possible.

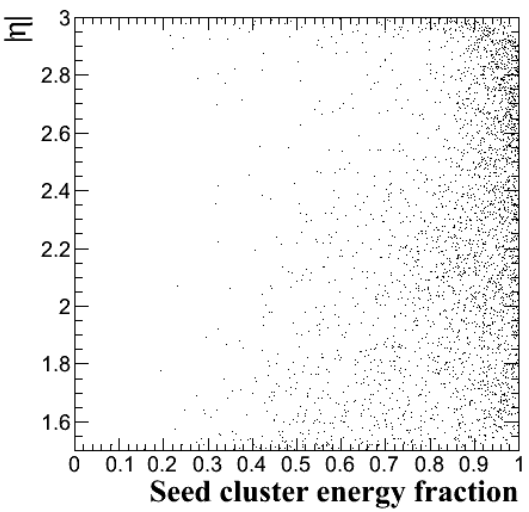
- *1st: per layer clustering*
- *2nd: inter layer clustering based on Arbor*

# Tagging/reconstruct EM object

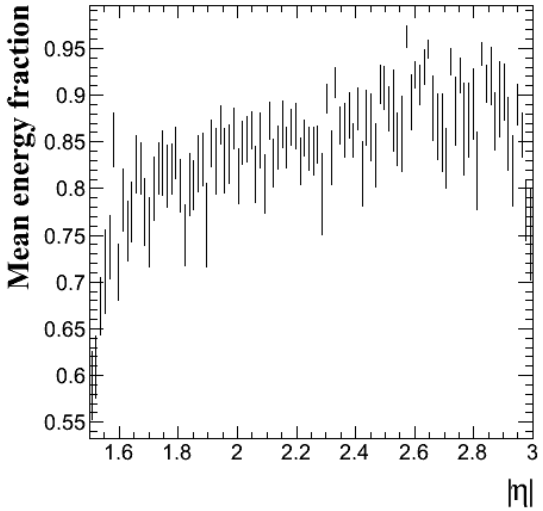
140 PU

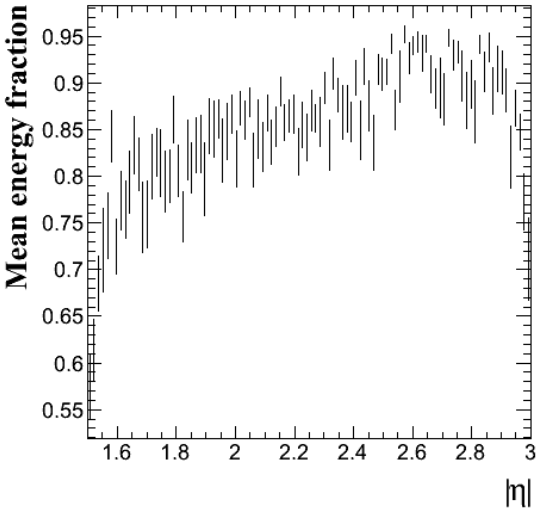



No PU

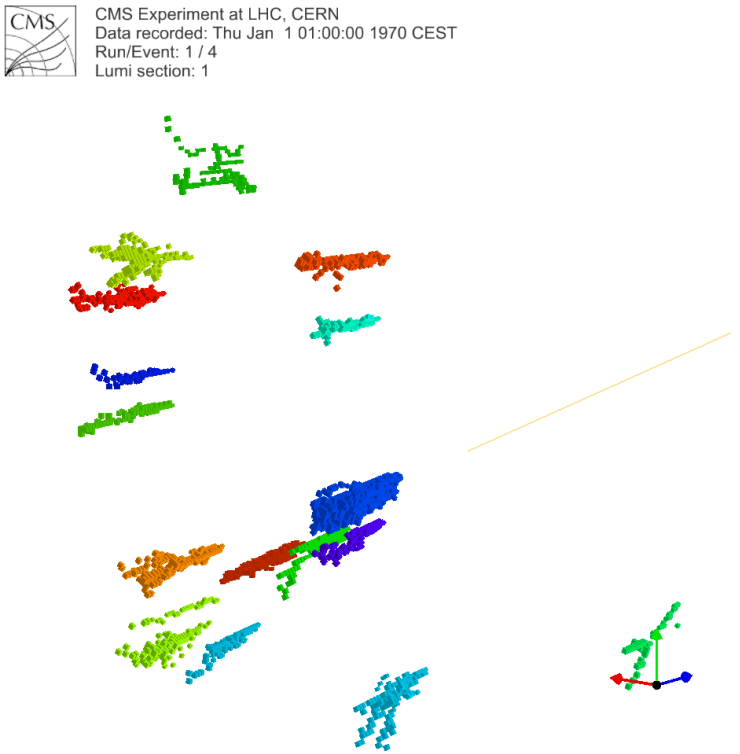



From C-Charlot (LLR)




Photons with 35 GeV tagged
At 140 PU background...

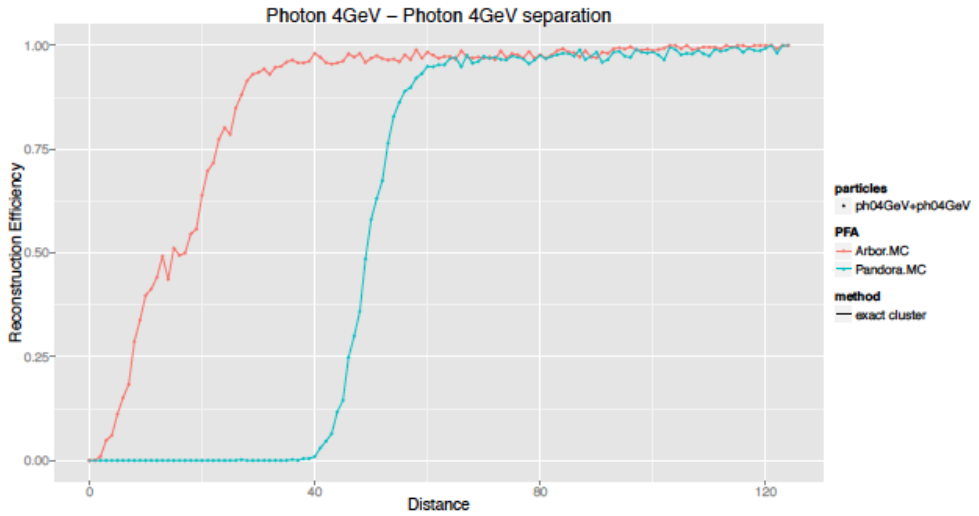


# Summary

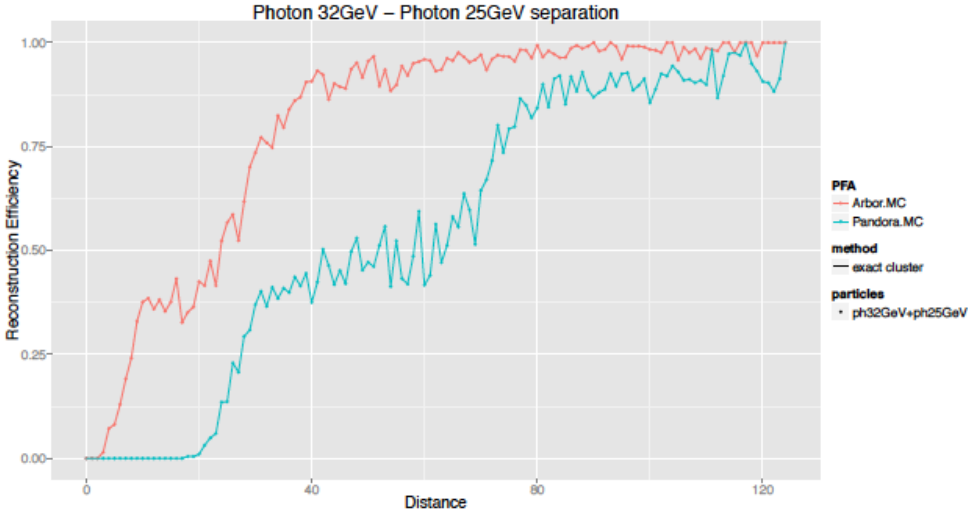
- Arbor: key to shower/sub-shower structure
  - Simple, generic, clear physics interpretation (Core part: 1k lines)
  - Many active studies on going
- Reasonable performance on
  - Separation, Pattern tagging, lepton id, Jet.
  - Electron-positron collision/hadron collisions
- HGC:
  - Some key issues solved (speed, EM-object tagging)
  - More results are expected
- Lot's of new ideas & fun...

# Back up

# Separation: di-photon





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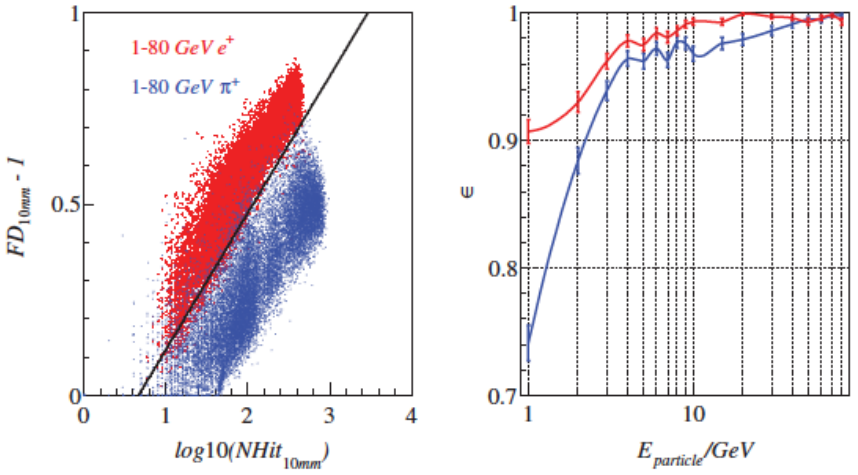


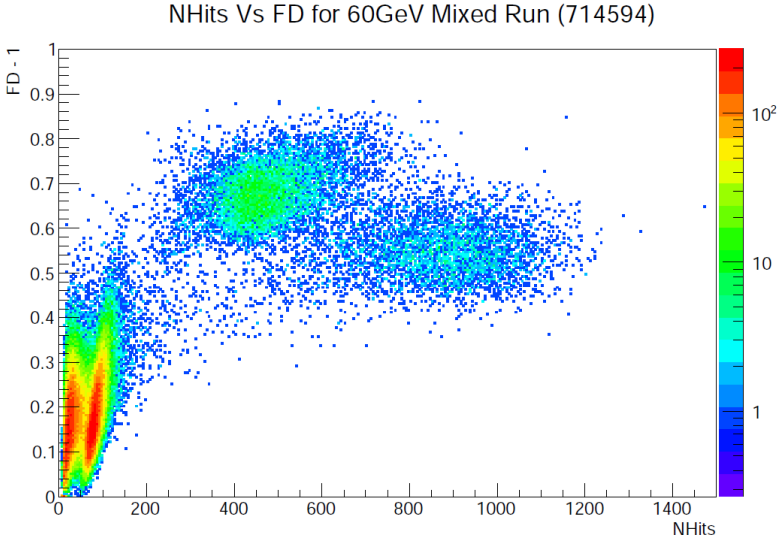


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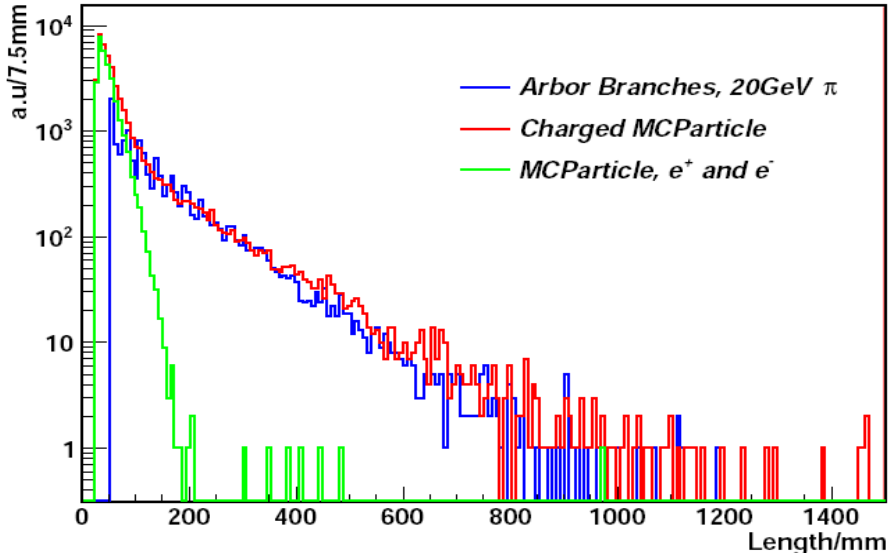
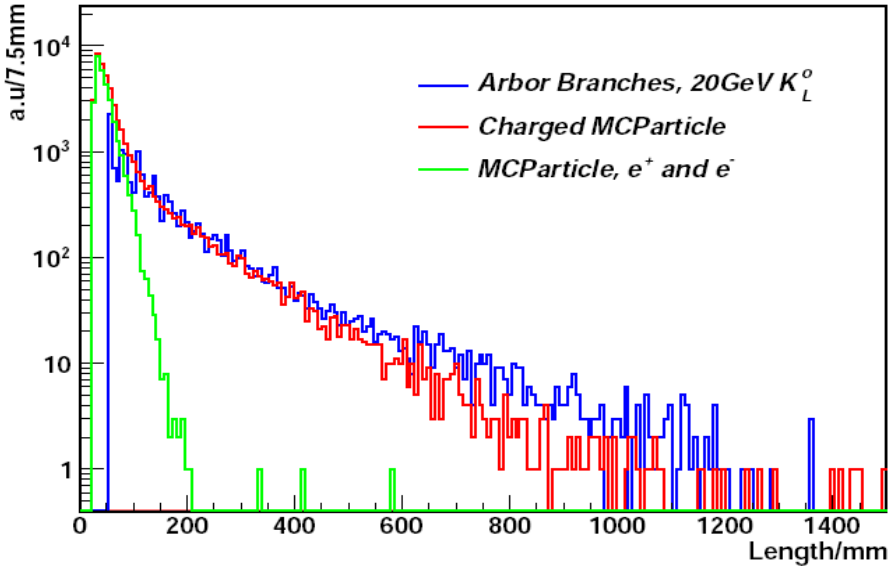
# ABL @ different energy

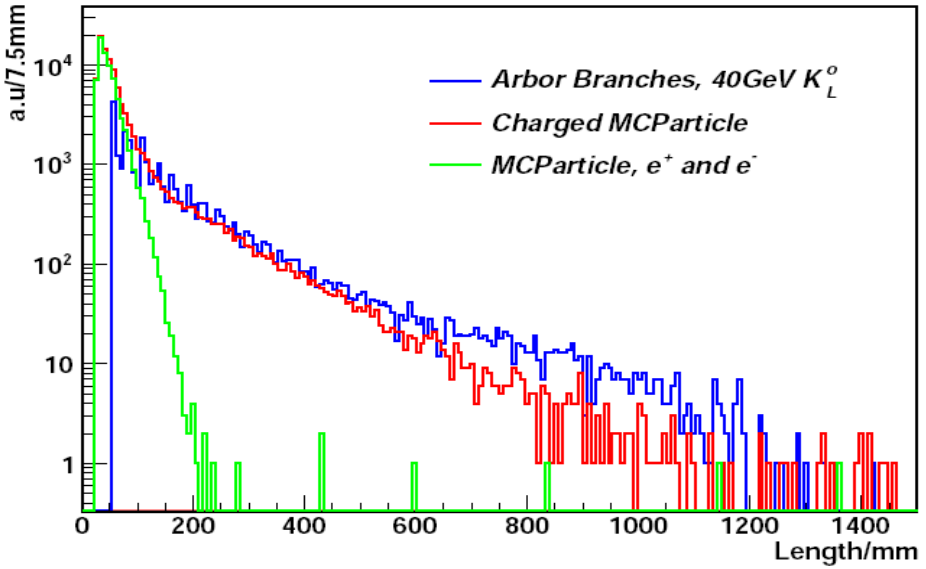



*Arbor leading branches (geometrically allowed longest branch):*

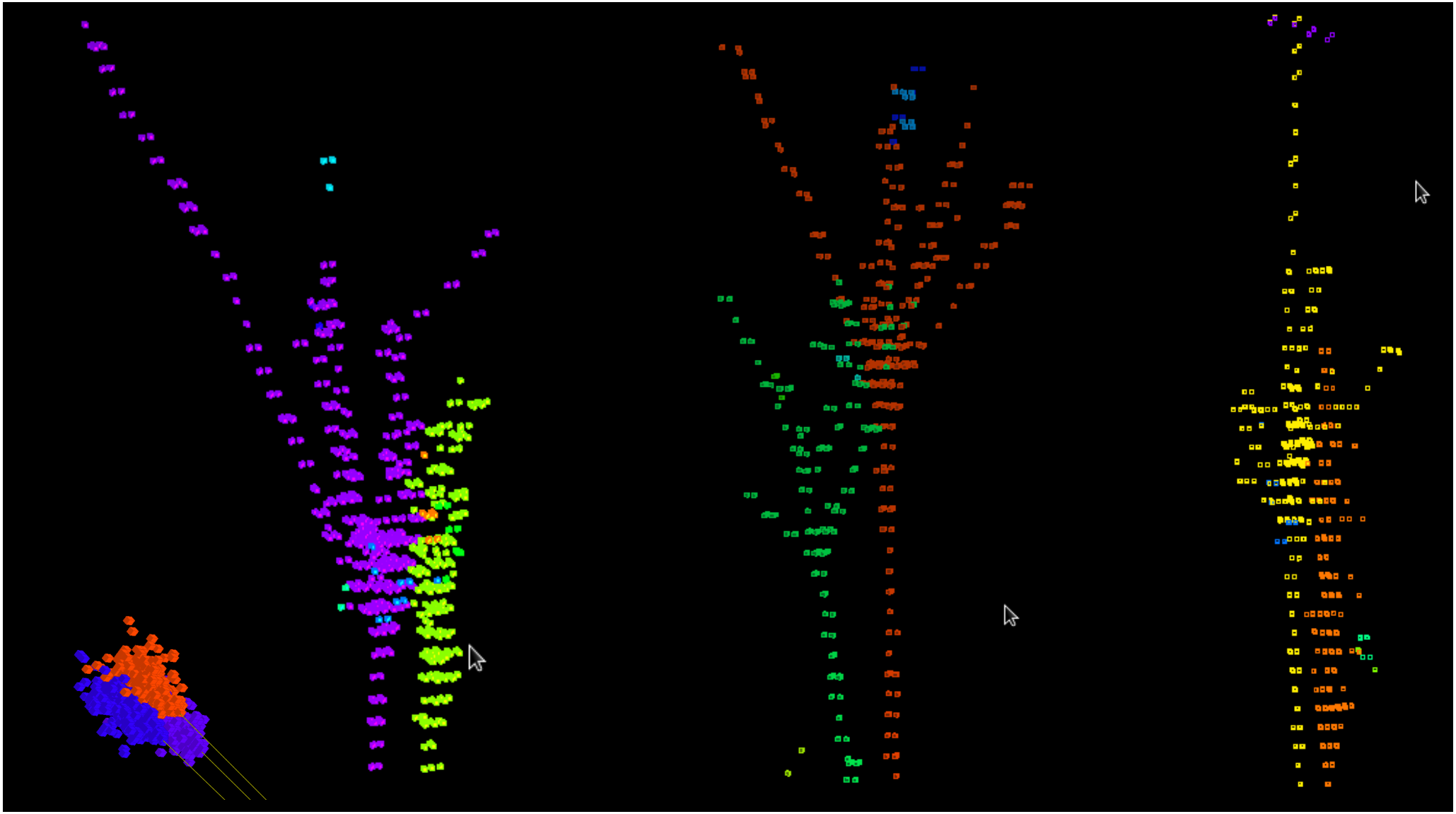
*vetoed for pion shower (identified as the branch start at first layer)*

*cause bump at large length for klong shower*

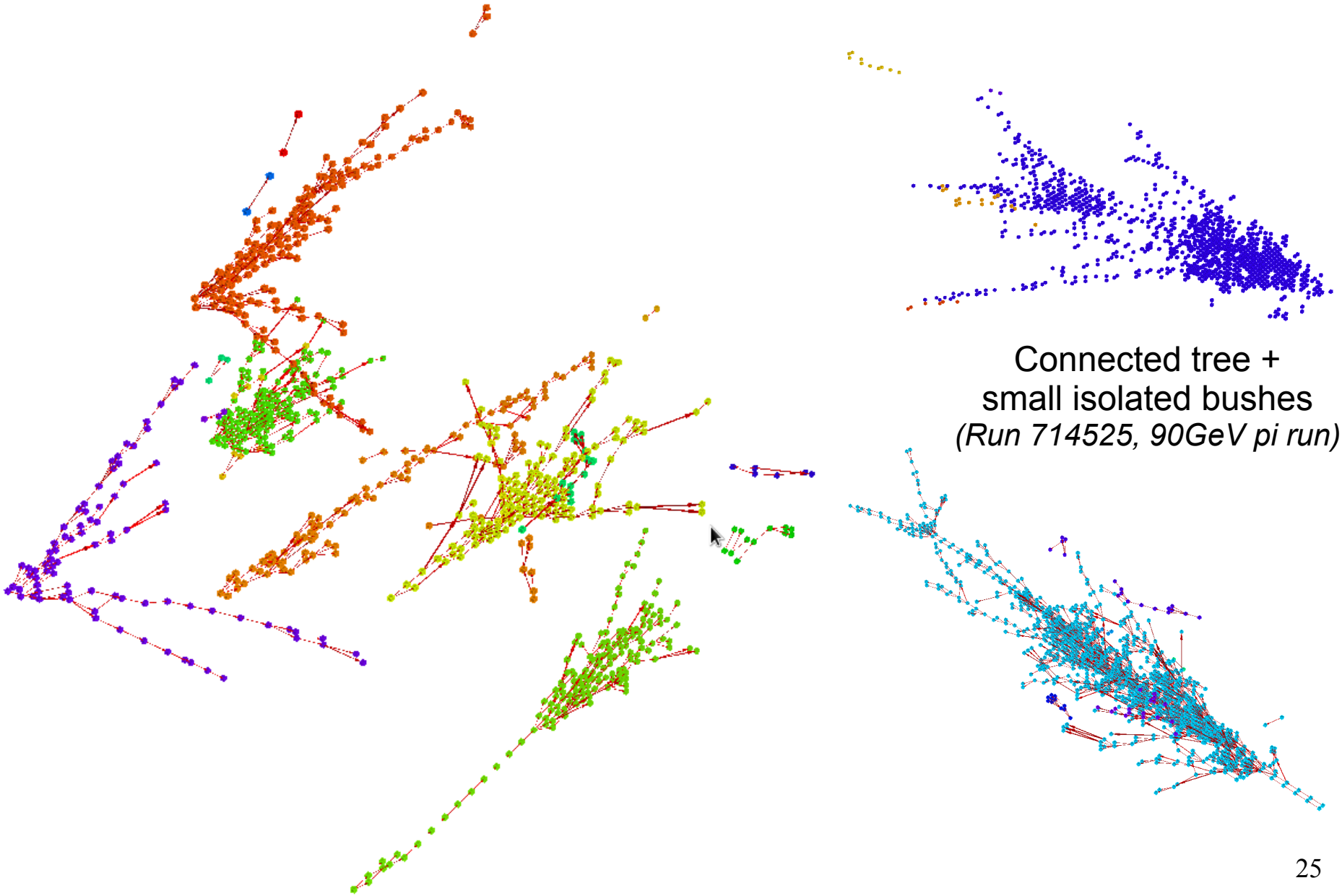


# Separation: overlay showers



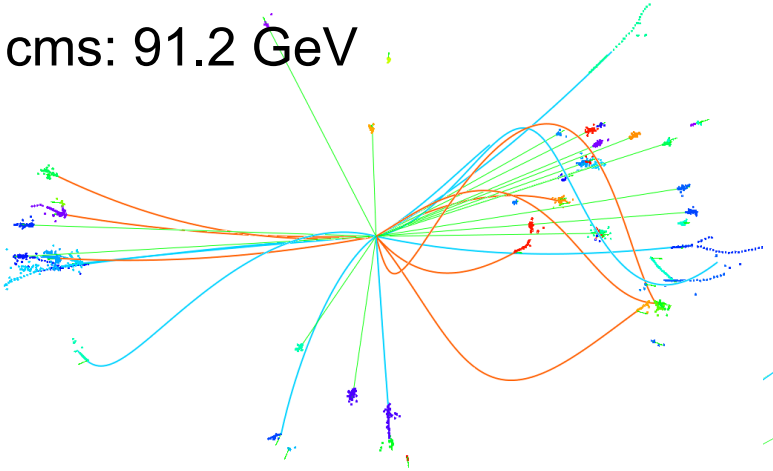
# Test beam data

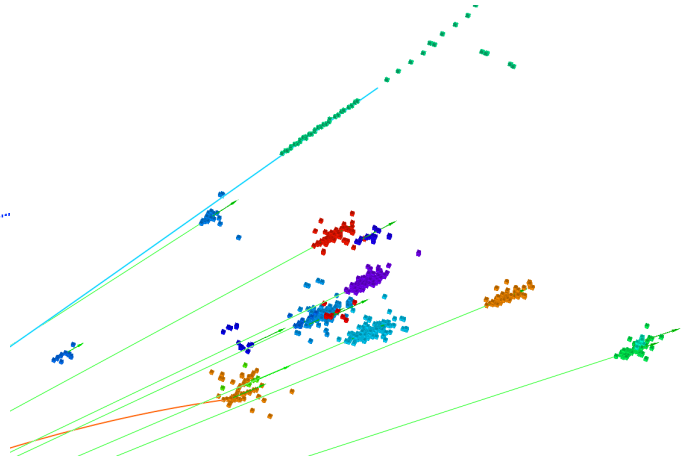


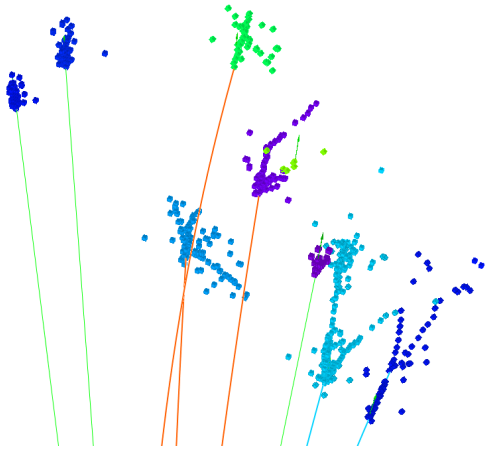
Connected tree +
small isolated bushes
*(Run 714525, 90GeV pi run)*

# At CEPC

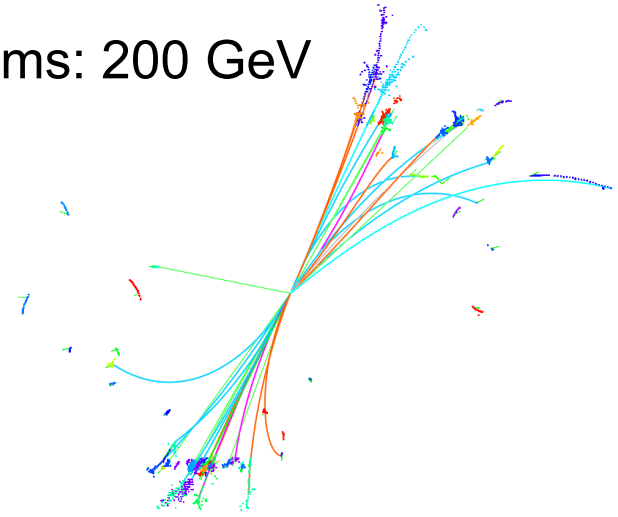
cms: 91.2 GeV

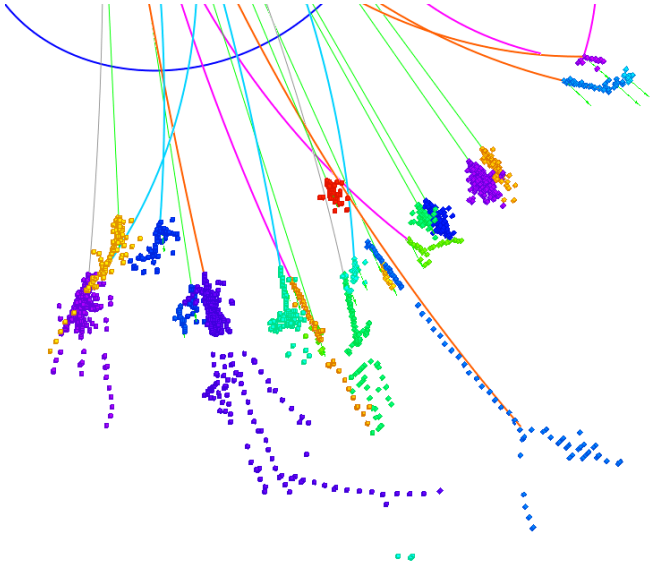


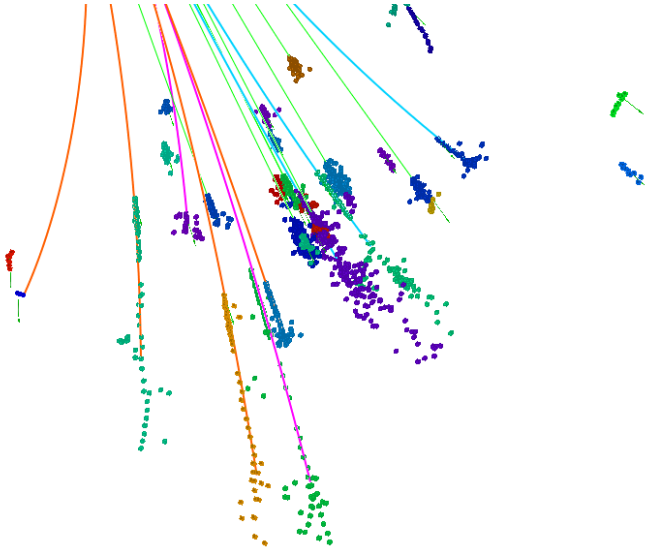




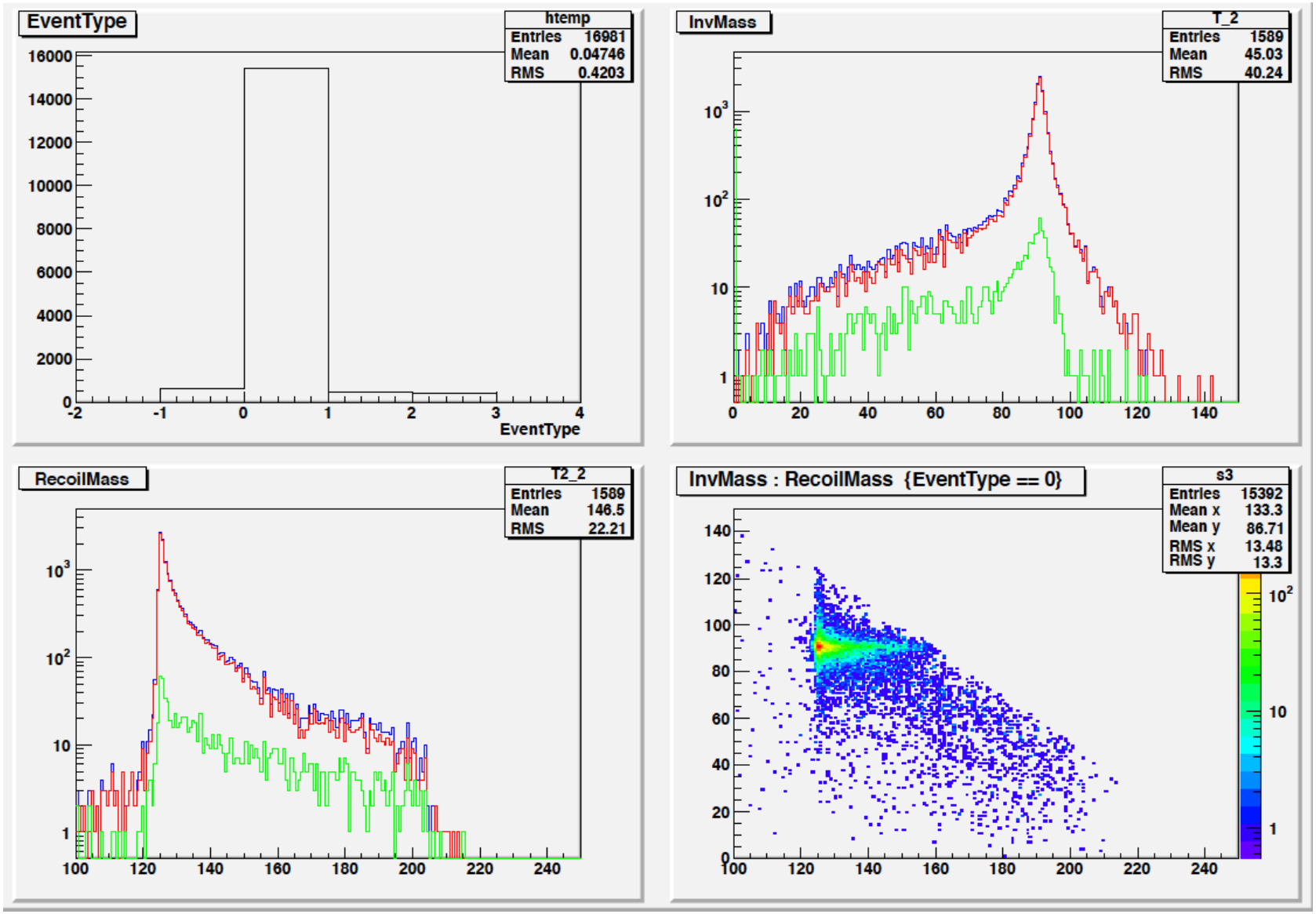
cms: 200 GeV







# Arbor Full Simulation at ILD




Single Muon Tagging efficiency (including acceptance) ~ sqrt(15932./16980) = 97%

# Example: Bremsstrhlung photon