

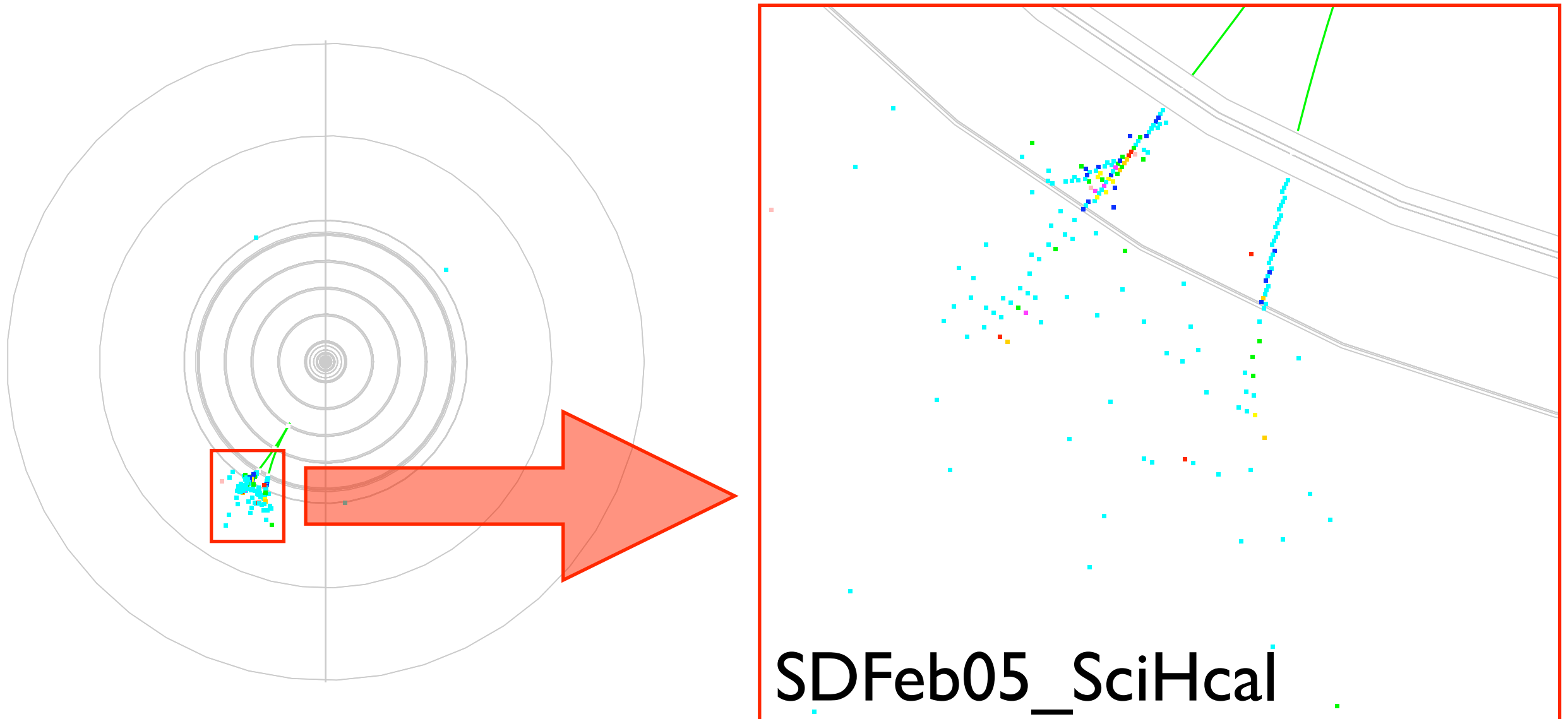
Dissecting the Structure of Hadronic Clusters

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The University of Iowa

Introduction, MST recap

- MST algorithm combines hits into clusters if $\text{metric}(\text{hit1}, \text{hit2}) < \text{threshold}$.
- Default metric: simple geometrical distance (similar to nearest-neighbour approach)
- Very effective at picking up contiguous clusters (incl. tendrils that cone algorithms miss)
- ... but doesn't handle close/overlapping clusters gracefully

Example: $K_s \rightarrow \pi^+ \pi^-$



- Clusters are clearly separated by eye...
- But with intermediate hits, they're close enough that MST merges them.

Cluster structure

- Hadronic showers are mostly composed of a few building blocks:
 - Charged track segments
 - Dense clumps following a hard interaction
 - A “halo” of fragments from secondary neutrals, soft tracks, etc.
- Approach:
 - Break cluster down into these pieces
 - See if they should really be linked.

Proof-of-concept algorithm

- Find MIPs that start/end at calorimeter edges MIPClusterBuilder
- Find large-scale clusters MSTClusterBuilder
- Within cluster, look for skeleton components:
 - MIPs, track segments MIPClusterBuilder
 - Dense clumps MSTClusterBuilder
 - Halo hits (i.e. everything else)
- Link skeleton together
 - Track-clump, with cuts on distance of closest approach (DOCA) and distance between nearest hits
 - Track-track, with cuts on DOCA and distance from nearest hits to point of closest approach (POCA)
- Merge halo hits into nearest clump/MIP

... + details (omitted here)

Example: $K_s \rightarrow \pi^+ \pi^-$

4 clumps:

1) 15 hits

2) 14 hits

3) 8 hits

4) 9 hits

7 track segments:

A) 28 hits

B) 4 hits

C) 6 hits

D) 6 hits

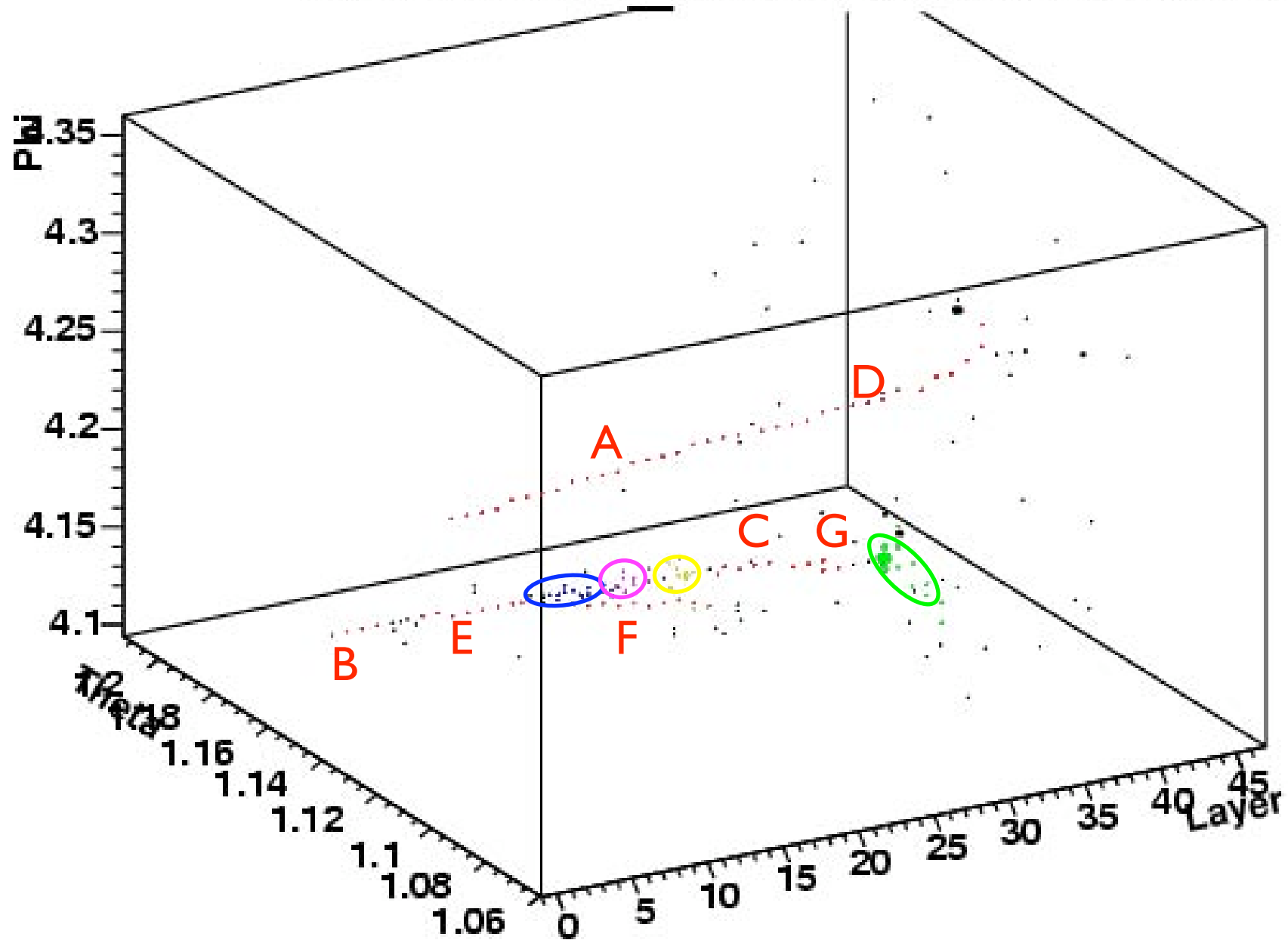
E) 9 hits

F) 9 hits

G) 5 hits

Same event as before.

SDFeb05 SciHcal structure



Example: $K_s \rightarrow \pi^+ \pi^-$

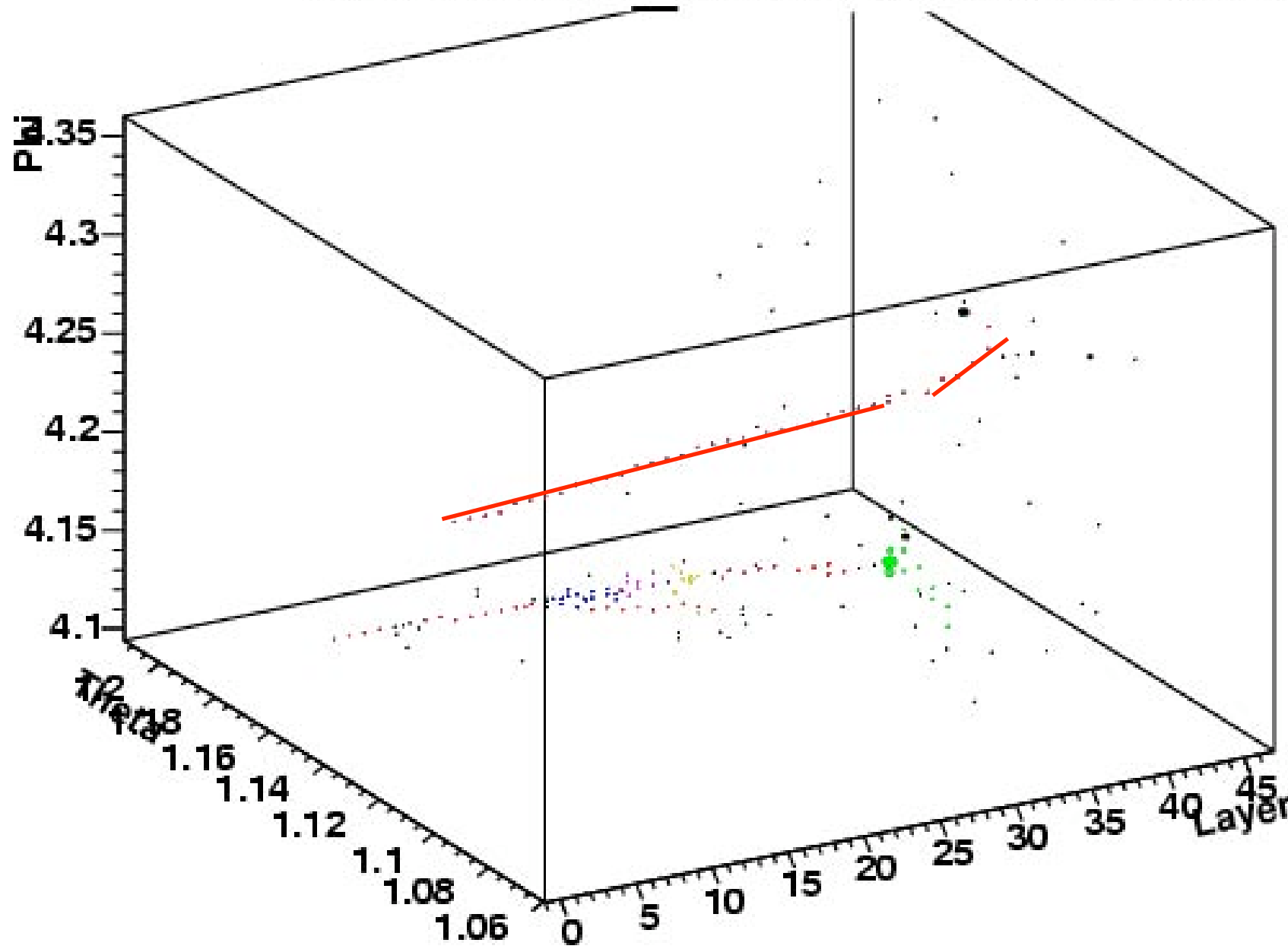
4 clumps:

- 1) 15 hits
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7 MIP segments:

- | | |
|------------|-----------|
| A) 28 hits | E) 9 hits |
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SDFeb05_SciHcal structure



DOCA $\sim 4.0\text{mm}$
Hit-hit distance $\sim 2.6\text{cm}$
 $\Rightarrow$ Strong link

Example: $K_s \rightarrow \pi^+ \pi^-$

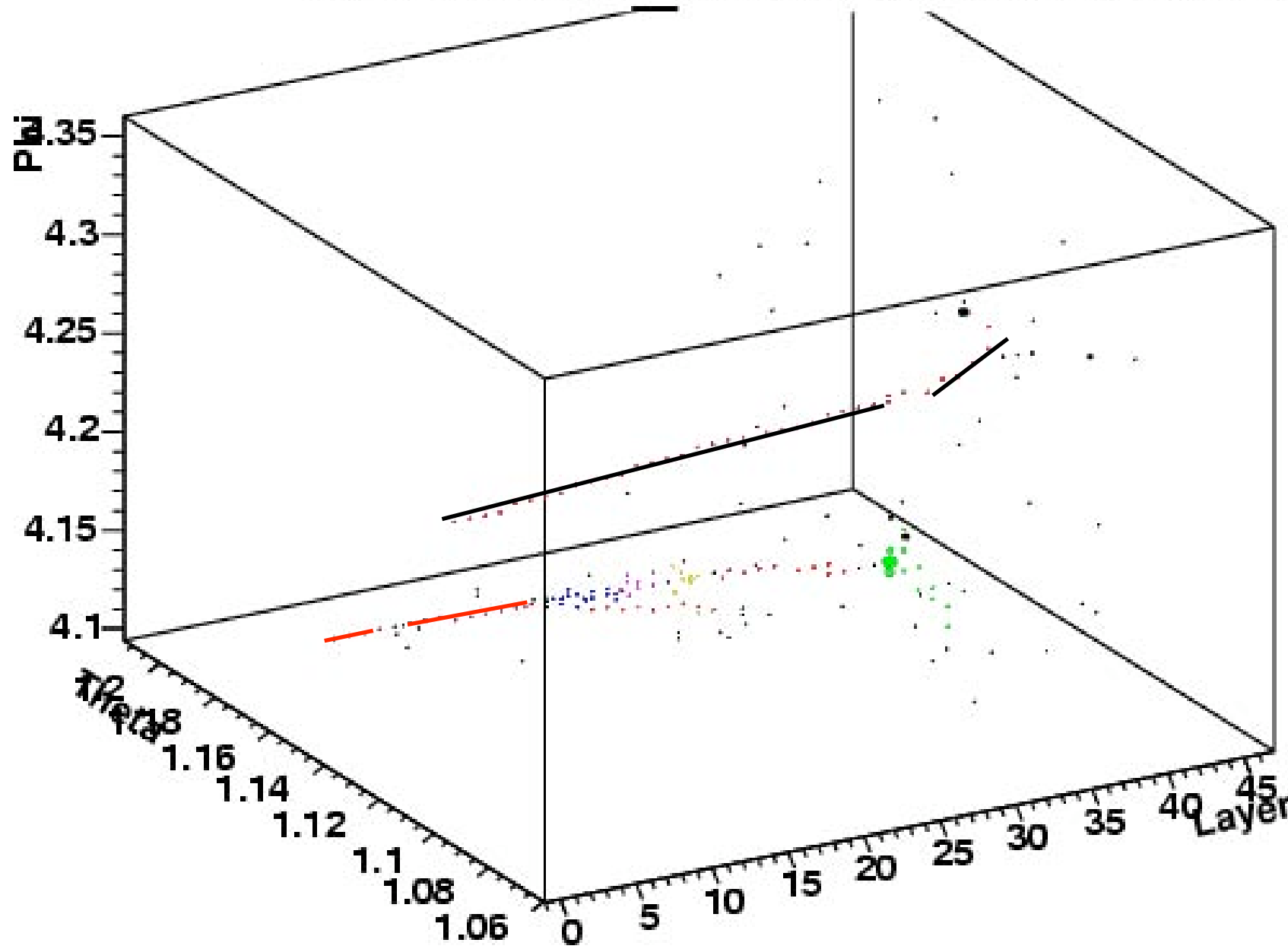
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SDFeb05_SciHcal structure



DOCA $\sim 2.4\text{mm}$
Hit-hit distance $\sim 1.2\text{cm}$
 $\Rightarrow$ Strong link

Example: $K_s \rightarrow \pi^+ \pi^-$

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7 MIP segments:

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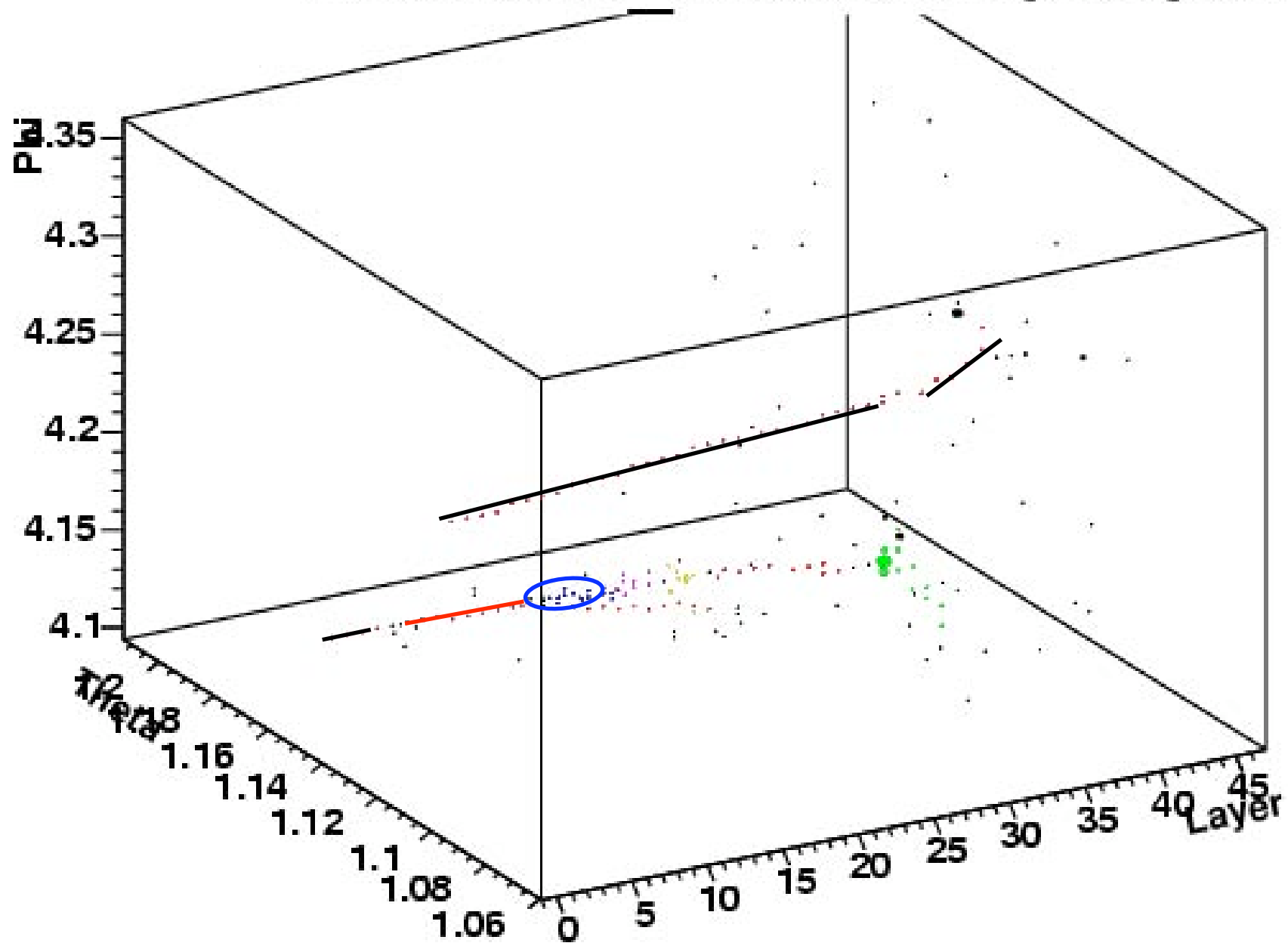
D) 6 hits

E) 9 hits

F) 9 hits

G) 5 hits

SDFeb05 SciHcal structure



DOCA ~ 3 mm

Hit-hit distance ~ 0.8 cm

$\Rightarrow$ Strong link

Example: $K_s \rightarrow \pi^+ \pi^-$

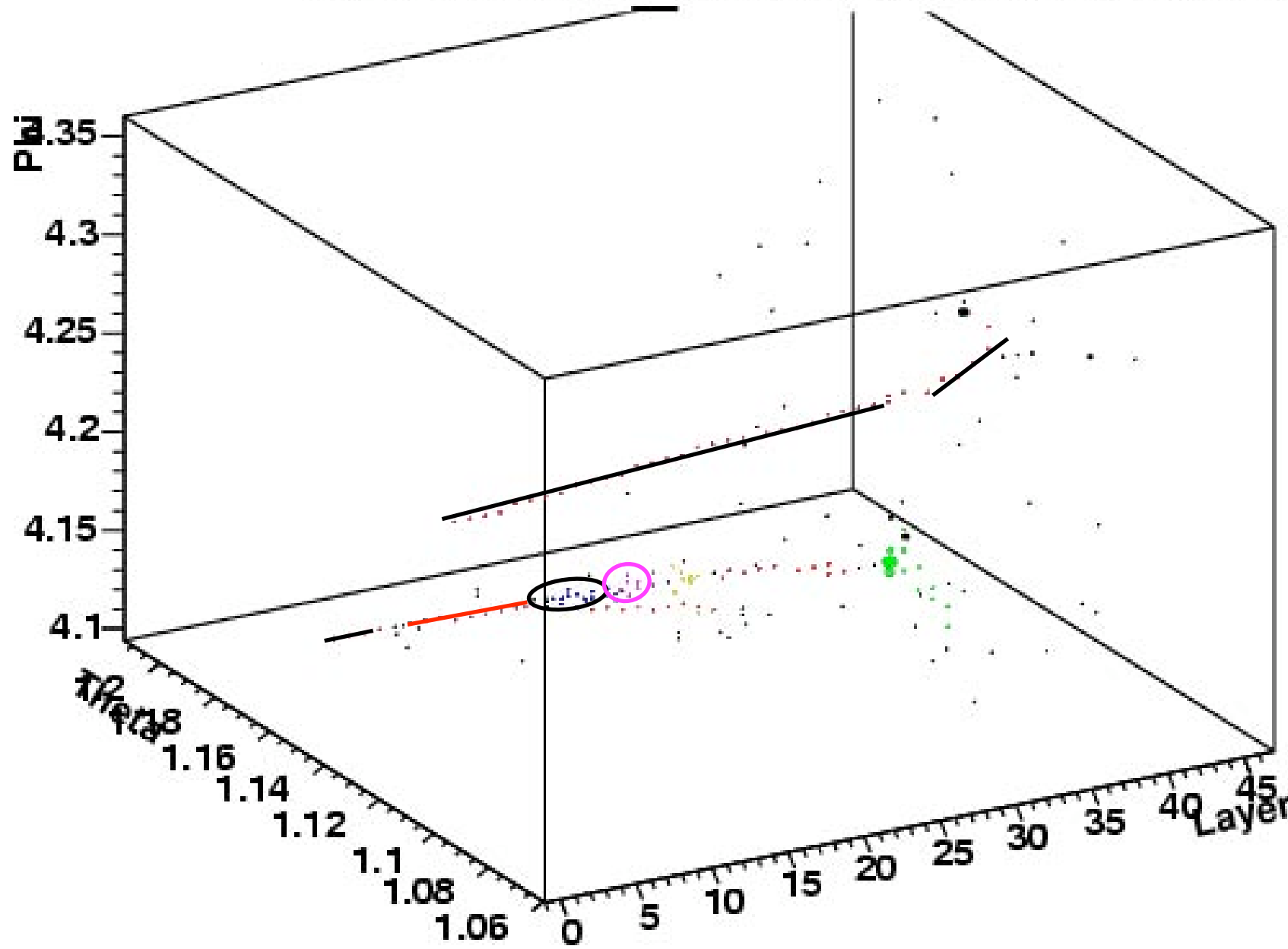
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7 MIP segments:

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- G) 5 hits

SDFeb05 SciHcal structure



DOCA ~ 10 mm
Hit-hit distance ~ 2.9cm
⇒ Strong link

Example: $K_s \rightarrow \pi^+ \pi^-$

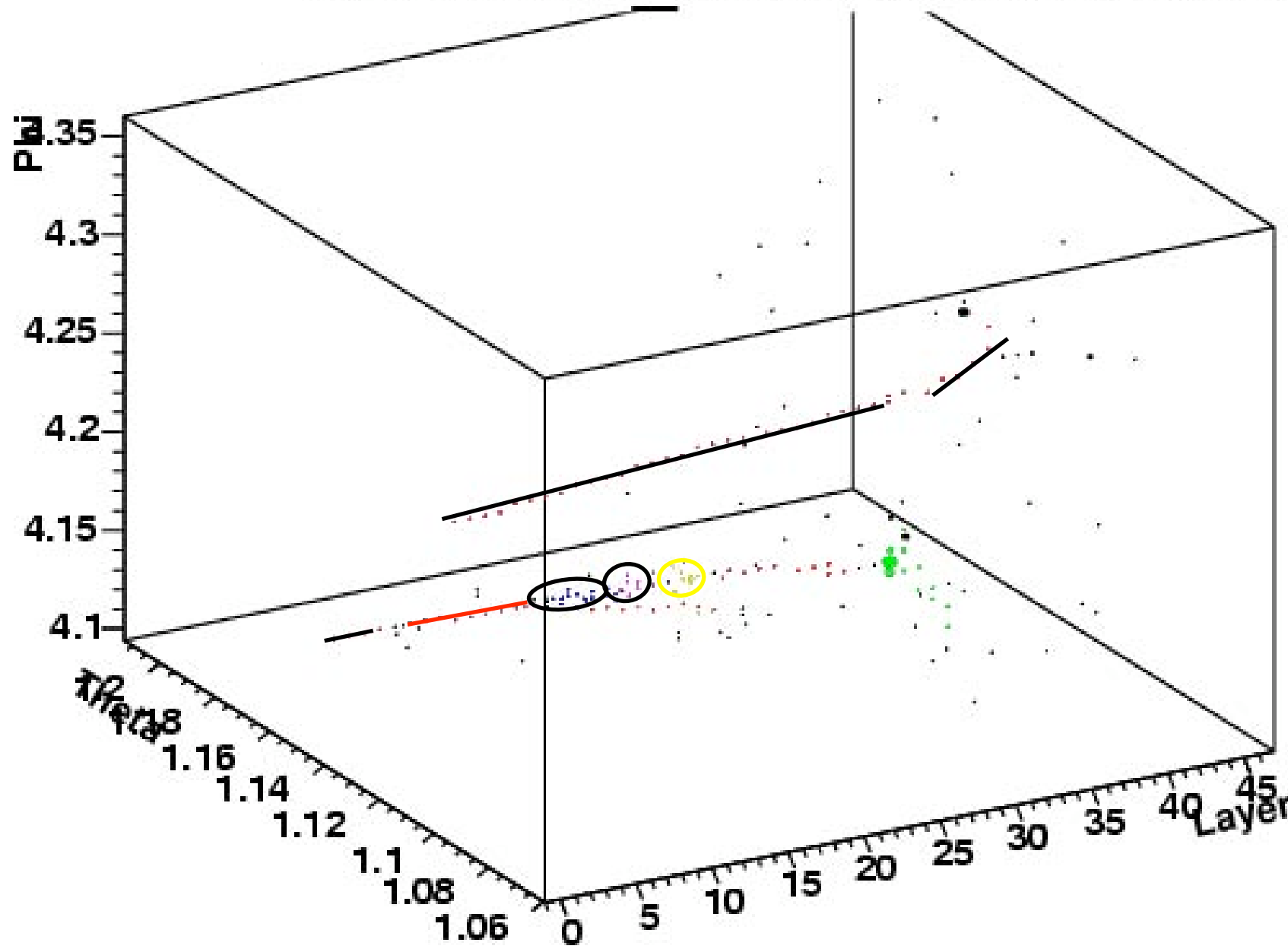
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SDFeb05 SciHcal structure



DOCA ~ 10 mm
Hit-hit distance ~ 2.9cm
⇒ Strong link

Example: $K_s \rightarrow \pi^+ \pi^-$

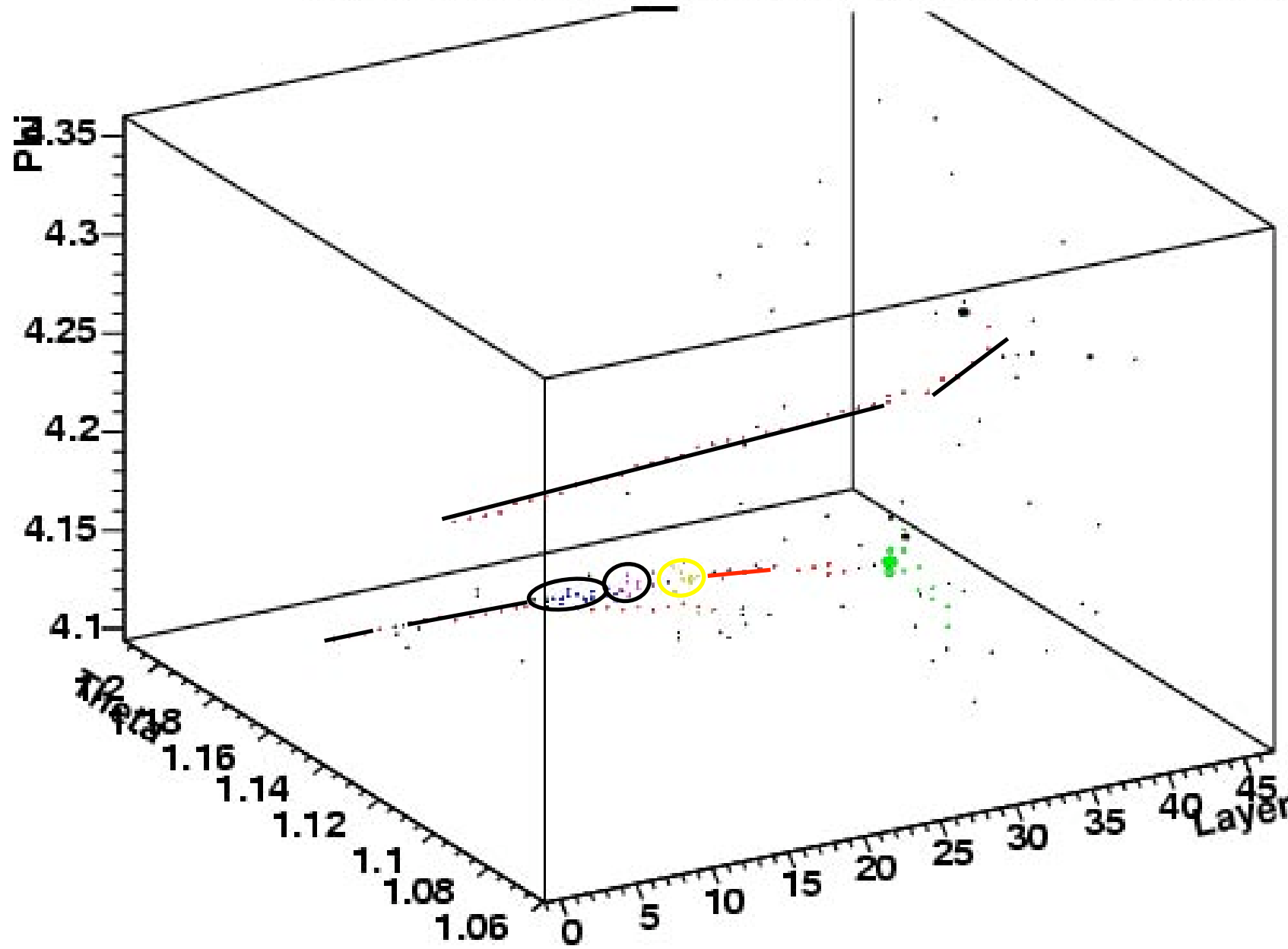
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SDFeb05_SciHcal structure



DOCA ~ 12 mm
Hit-hit distance ~ 0.4cm
⇒ Strong link

Example: $K_s \rightarrow \pi^+ \pi^-$

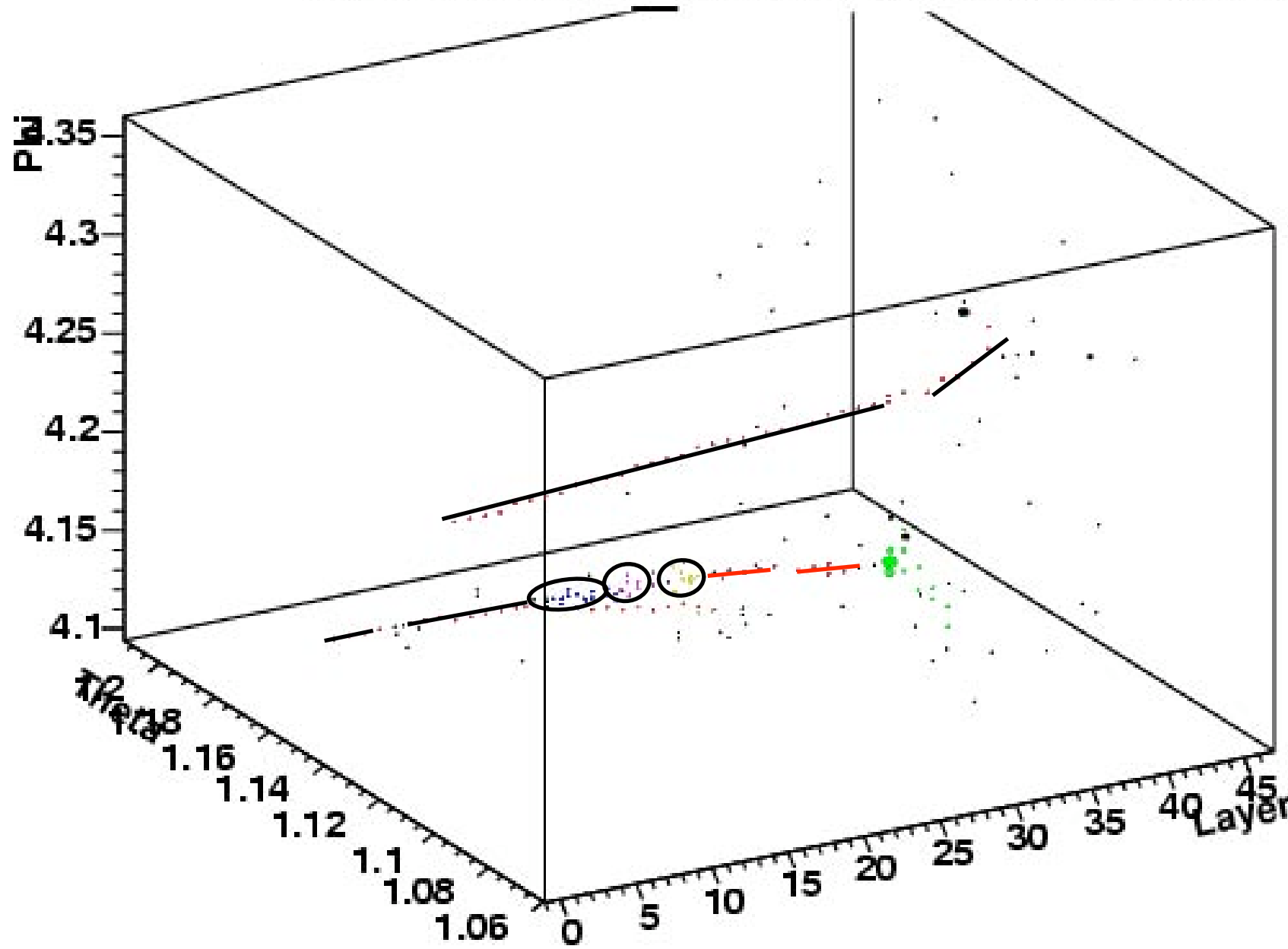
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SDFeb05_SciHcal structure



DOCA ~ 1.0 mm
Hit-hit distance ~ 1.6 cm
 $\Rightarrow$ Strong link

Example: $K_s \rightarrow \pi^+ \pi^-$

4 clumps:

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2) 14 hits

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7 MIP segments:

A) 28 hits

B) 4 hits

C) 6 hits

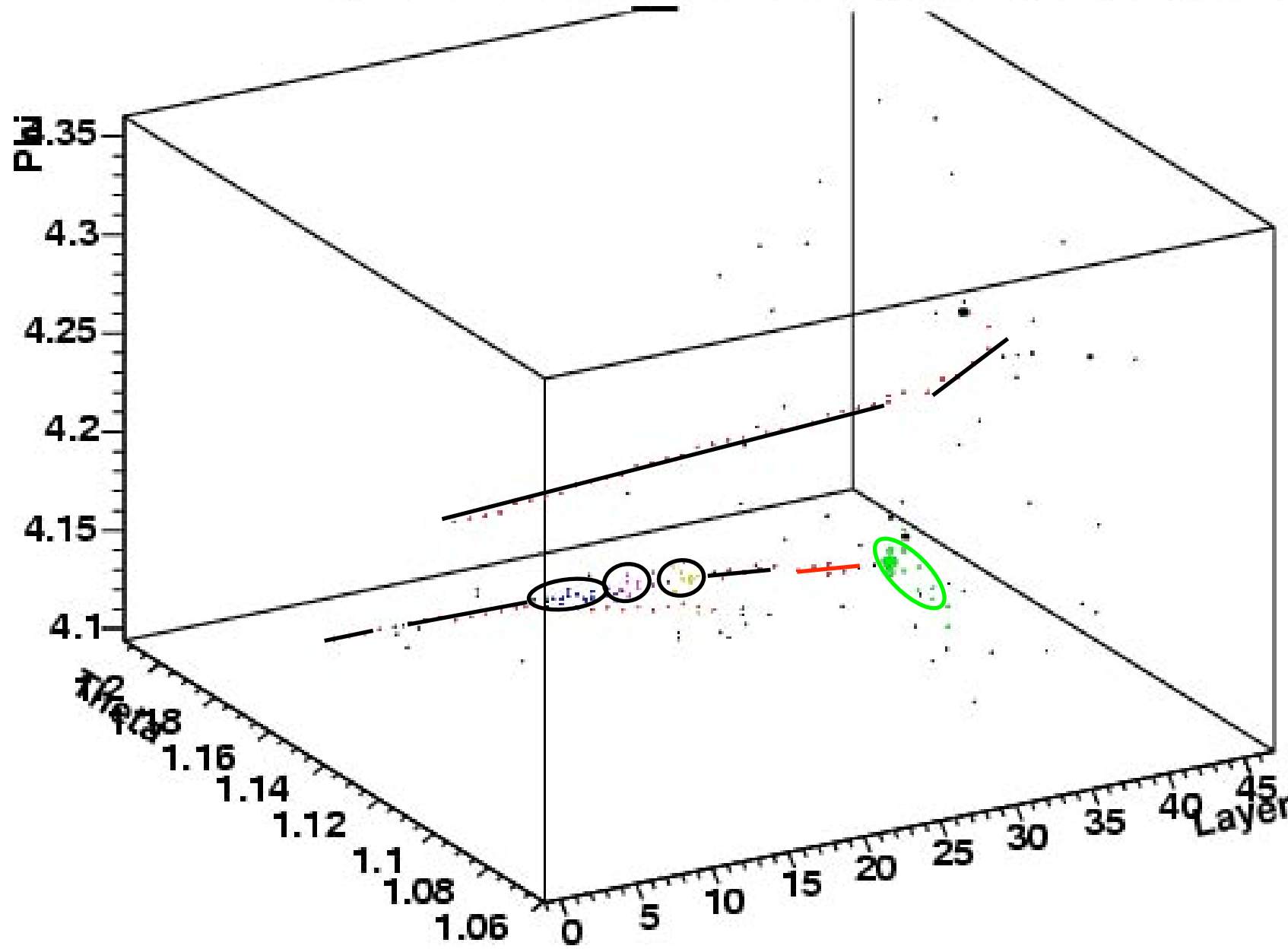
D) 6 hits

E) 9 hits

F) 9 hits

G) 5 hits

SDFeb05 SciHcal structure



DOCA ~ 5 mm

Hit-hit distance ~ 5.0cm

⇒ Strong link

Example: $K_s \rightarrow \pi^+ \pi^-$

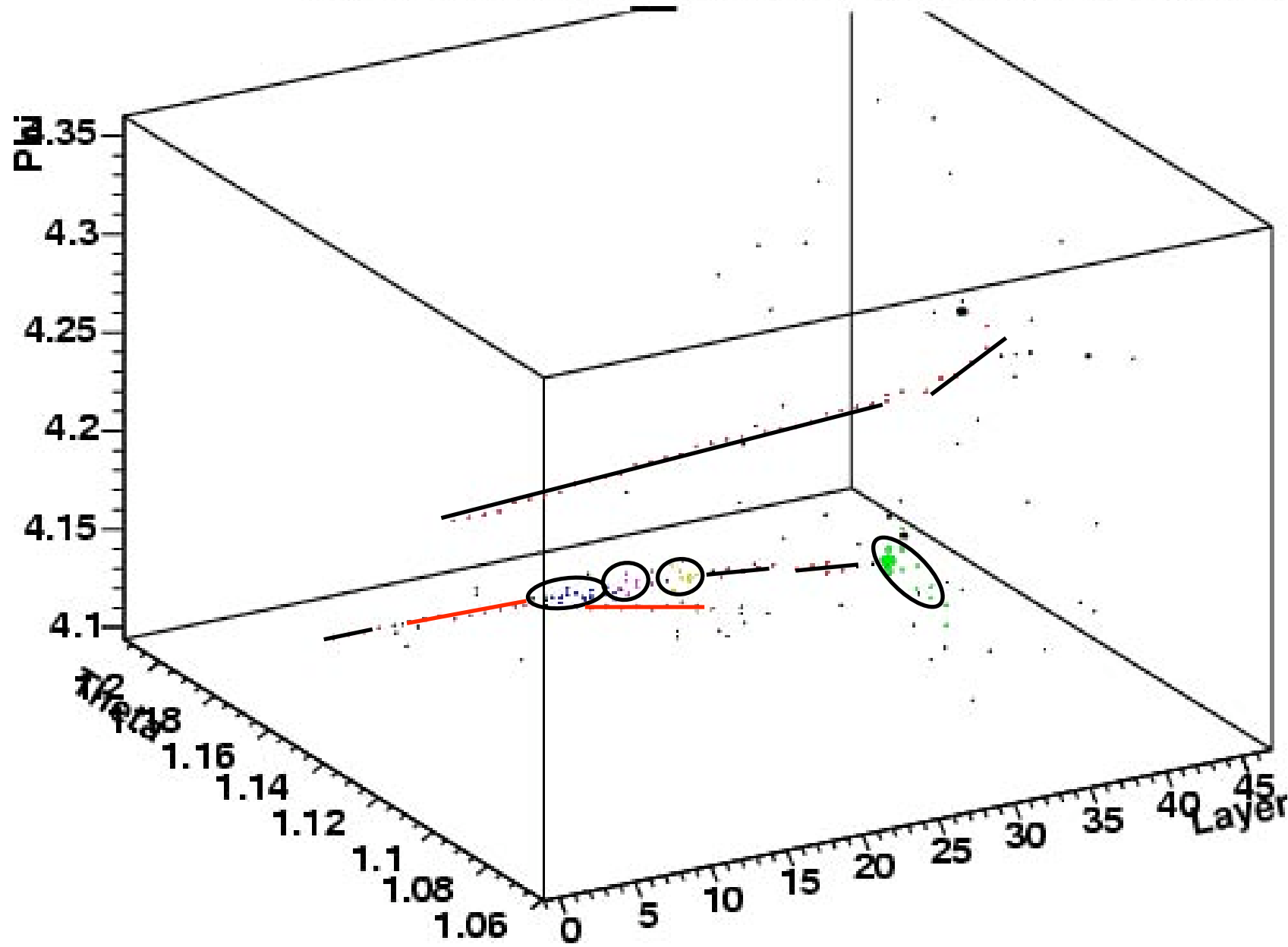
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SDFeb05 SciHcal structure



DOCA ~ 0.6 mm
Hit-hit distance ~ 2.1 cm
 $\Rightarrow$ Strong link

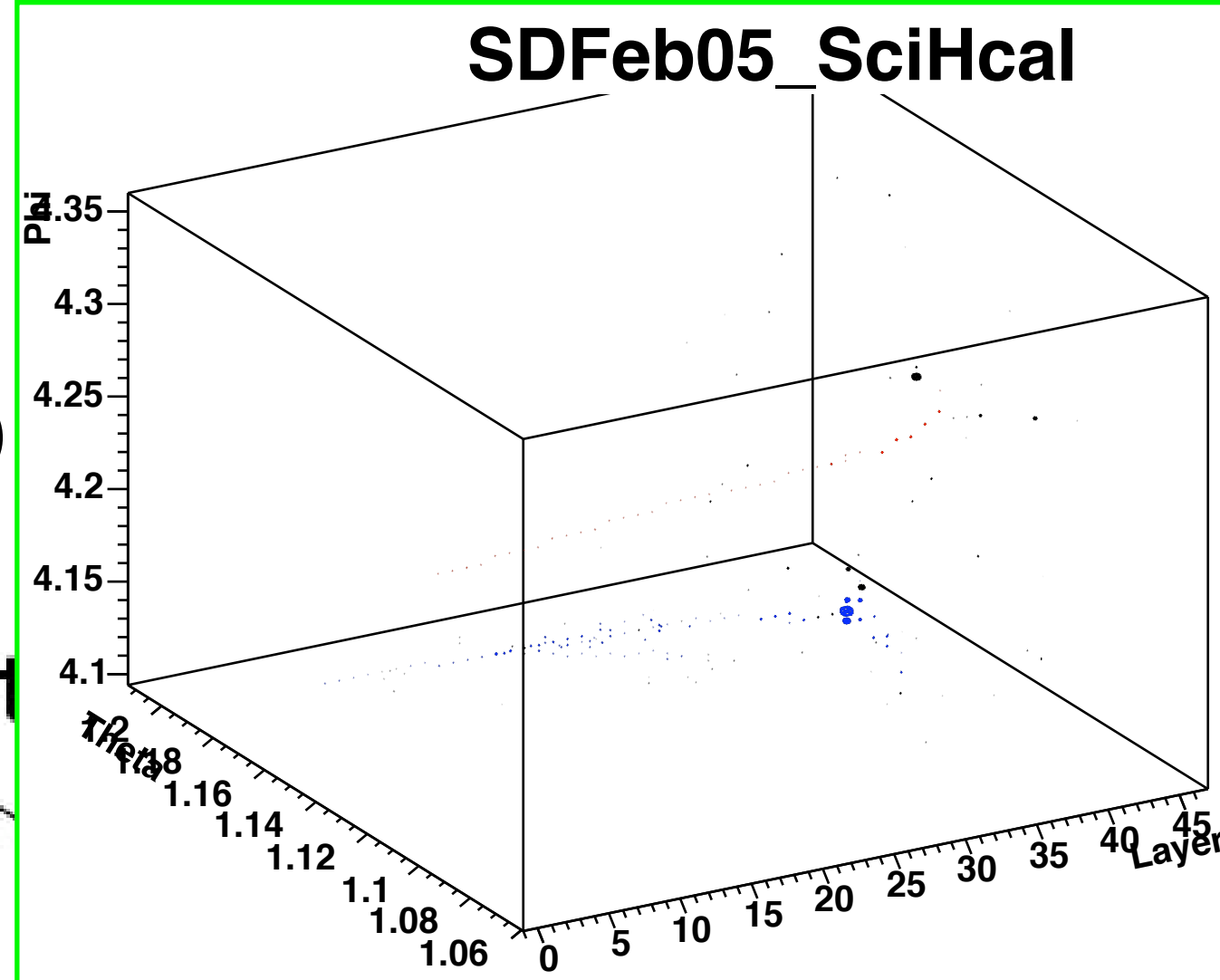
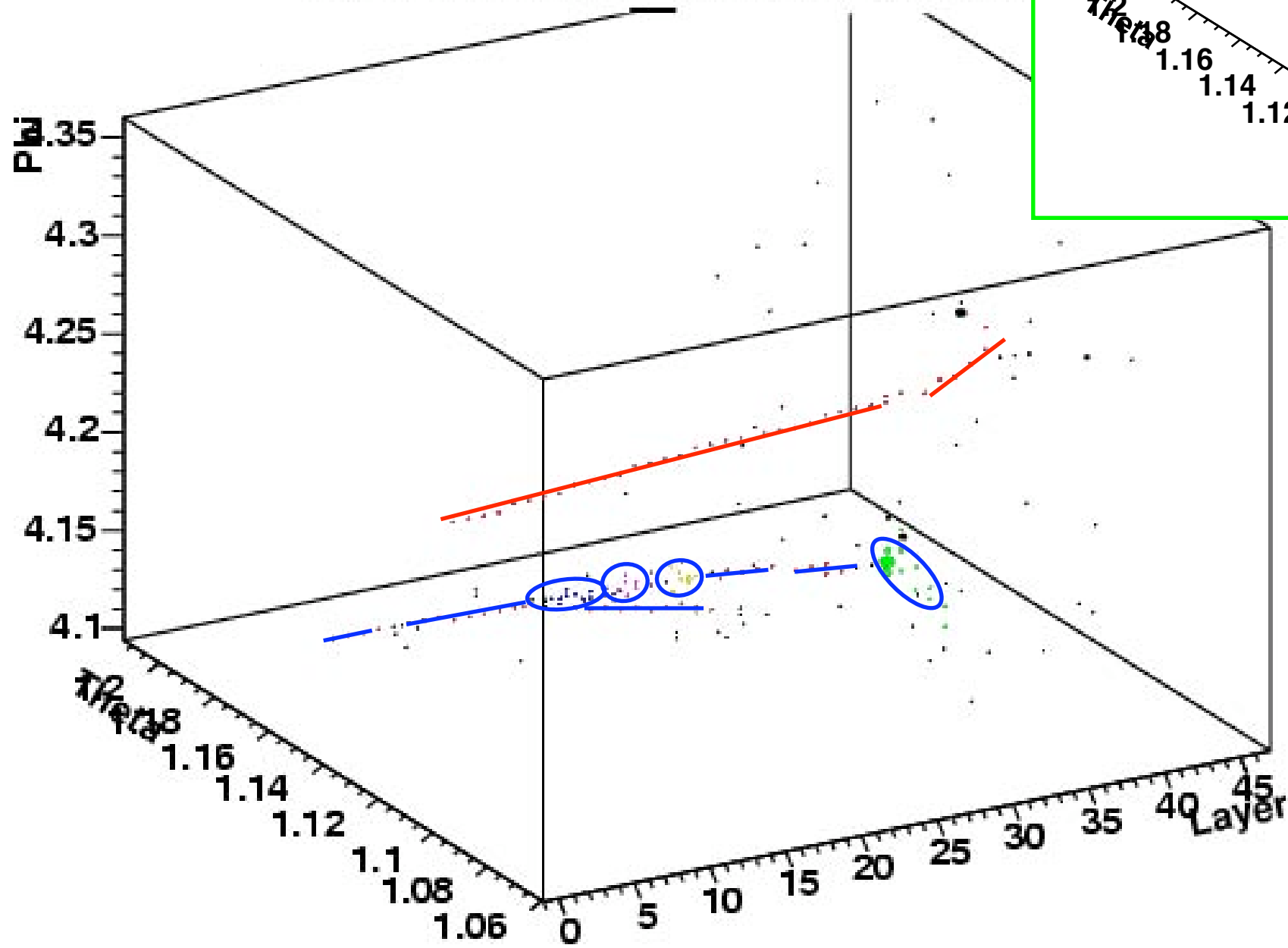
Example: $K_s \rightarrow \pi^+ \pi^-$

red = first cluster skeleton (π^-)

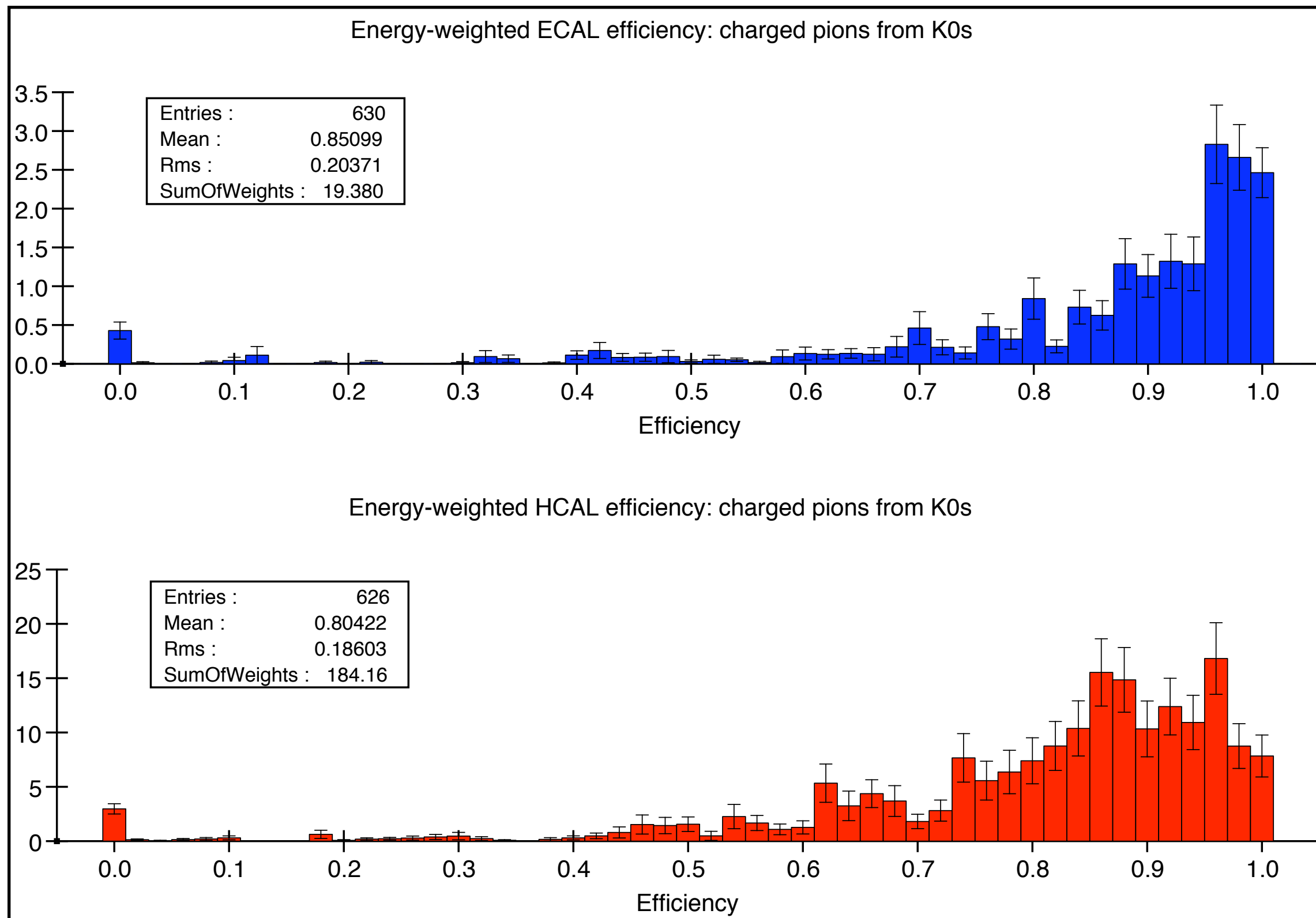
blue = second cluster skeleton (π^+)

black = halo

SDFeb05_SciHcal st

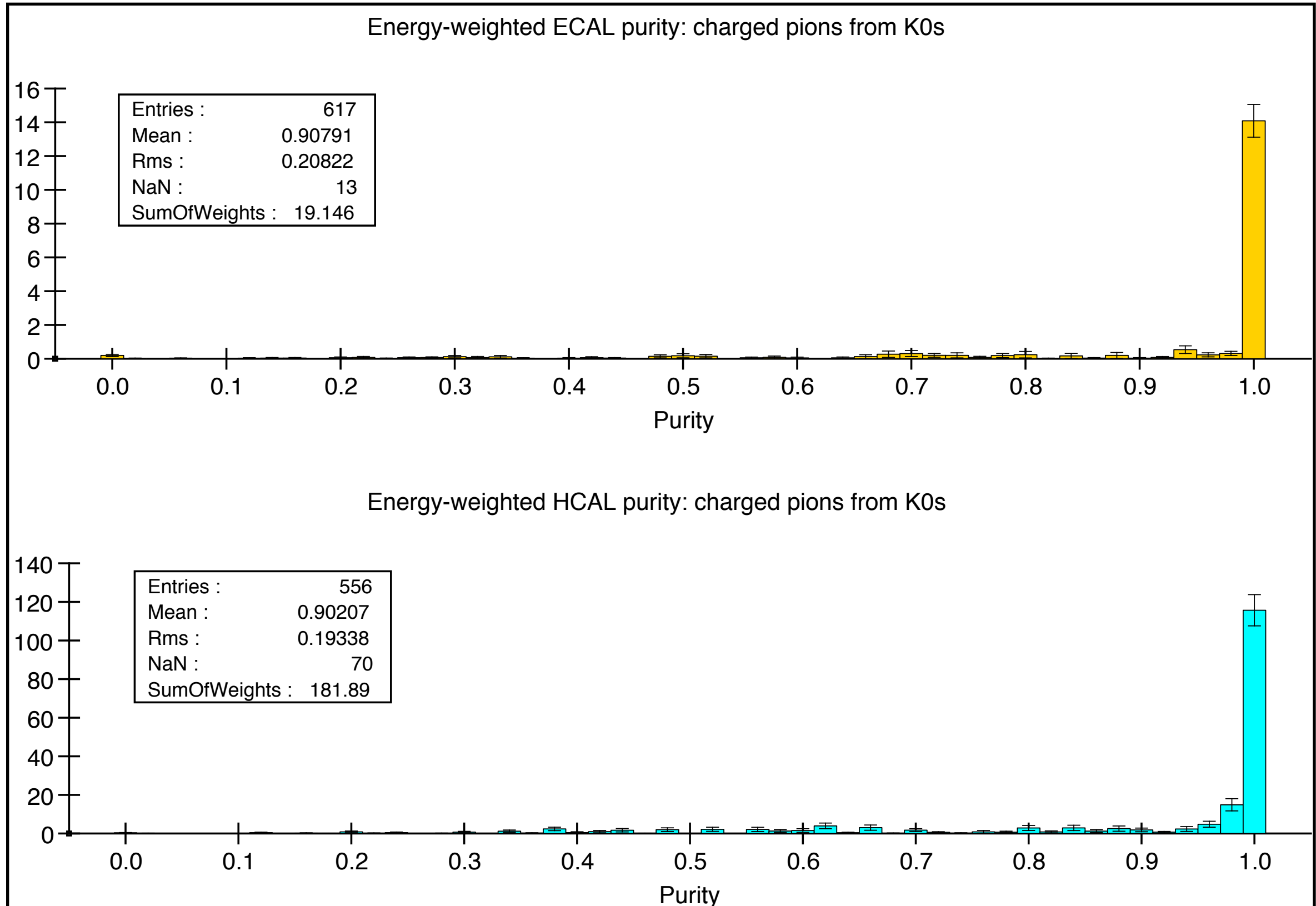


Current performance



Charged pions with $p > 0.2$ GeV/c, produced by K-short decaying at $r < 120$ cm
Source: ILC/singleParticle/SDFeb05_SciHcal/sio/lcdg4/K0S_pipi_Theta45-135_5-25Gev.sio

Current performance



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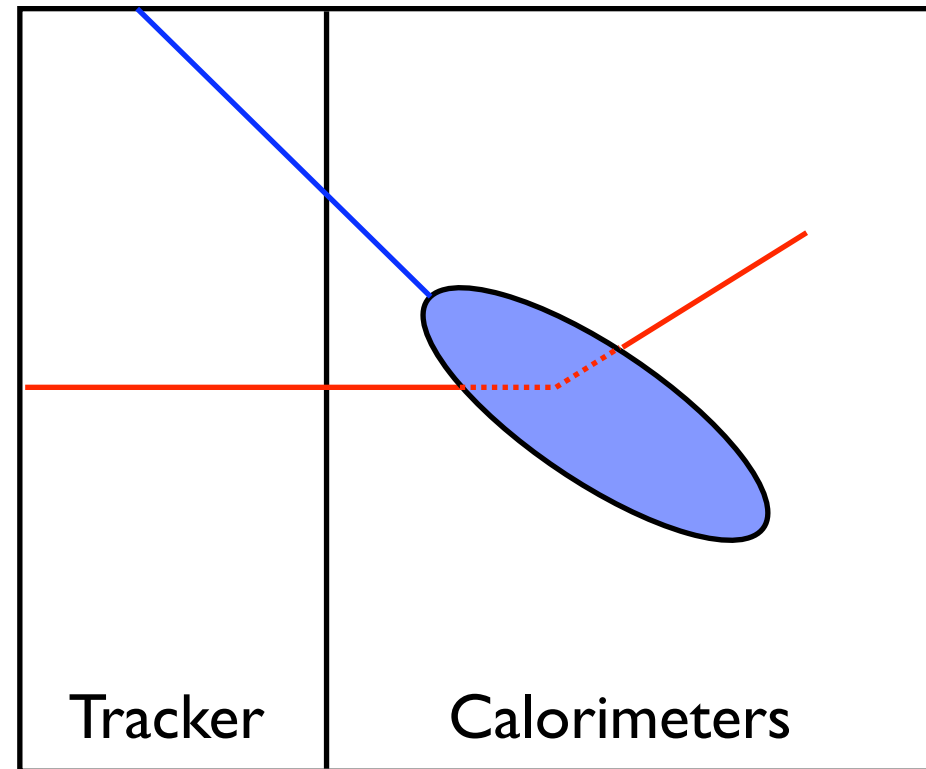
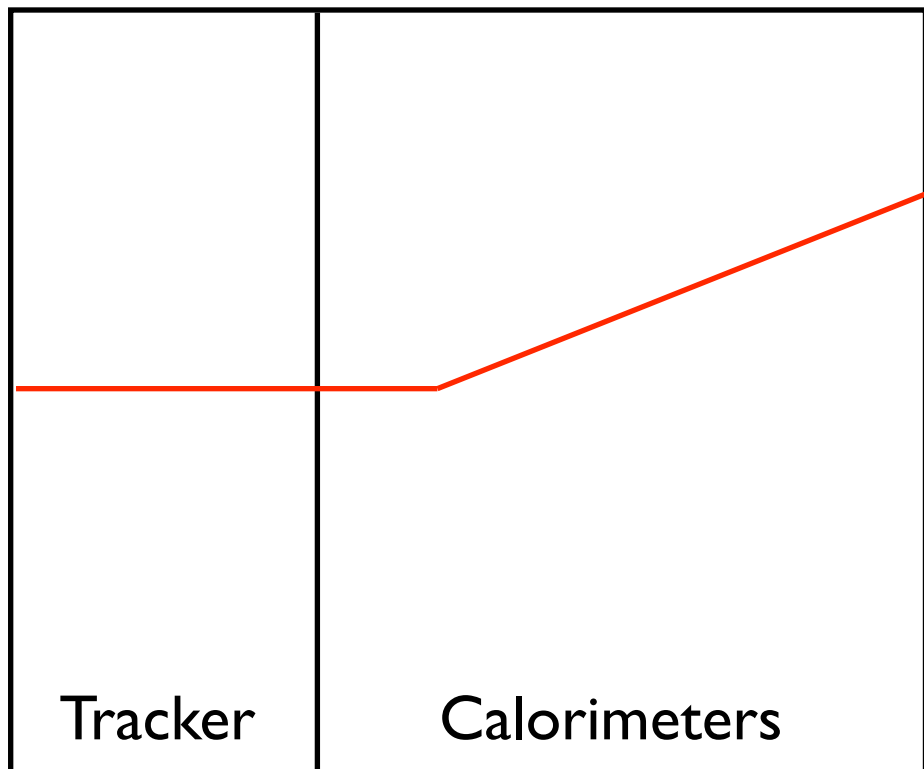
Source: ILC/singleParticle/SDFeb05_SciHcal/sio/lcdg4/K0S_pipi_Theta45-135_5-25Gev.sio

Patterns

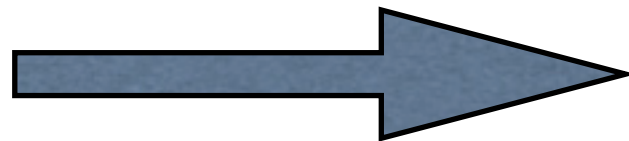
- Aggregate statistics are nice but don't tell the whole story.
- Quite often see certain classes of event which confuse the algorithm -- study these "typical events" in more detail.
- Iterative process (fixing one problem can break something else...)

Patterns: Linking tracks

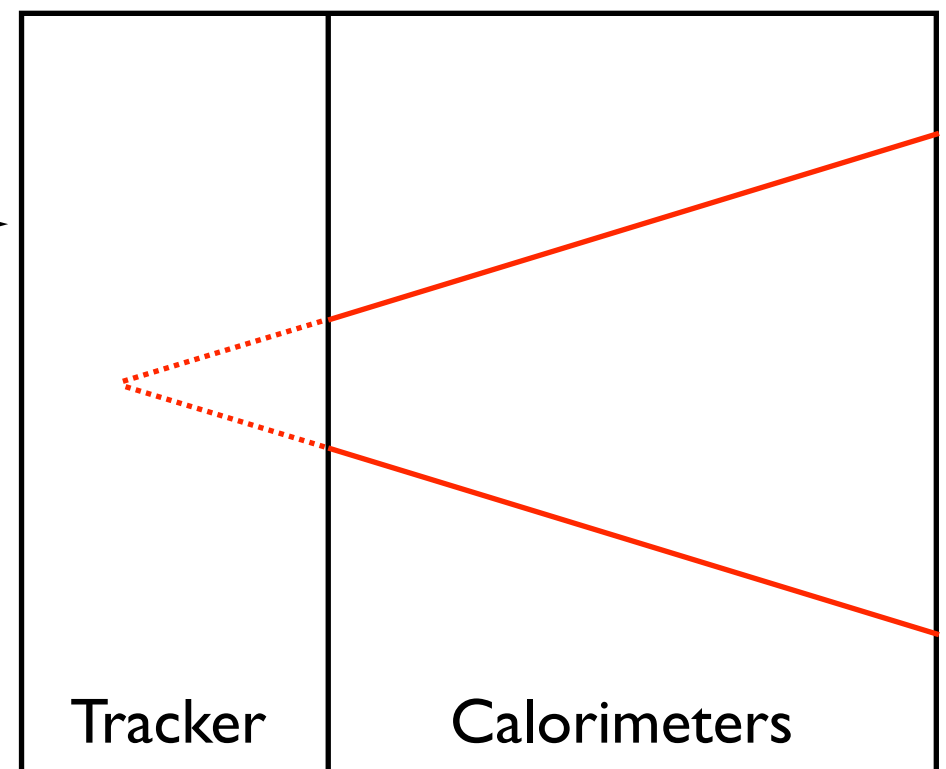
We want to link tracks in cases like these two:



But not in this case:

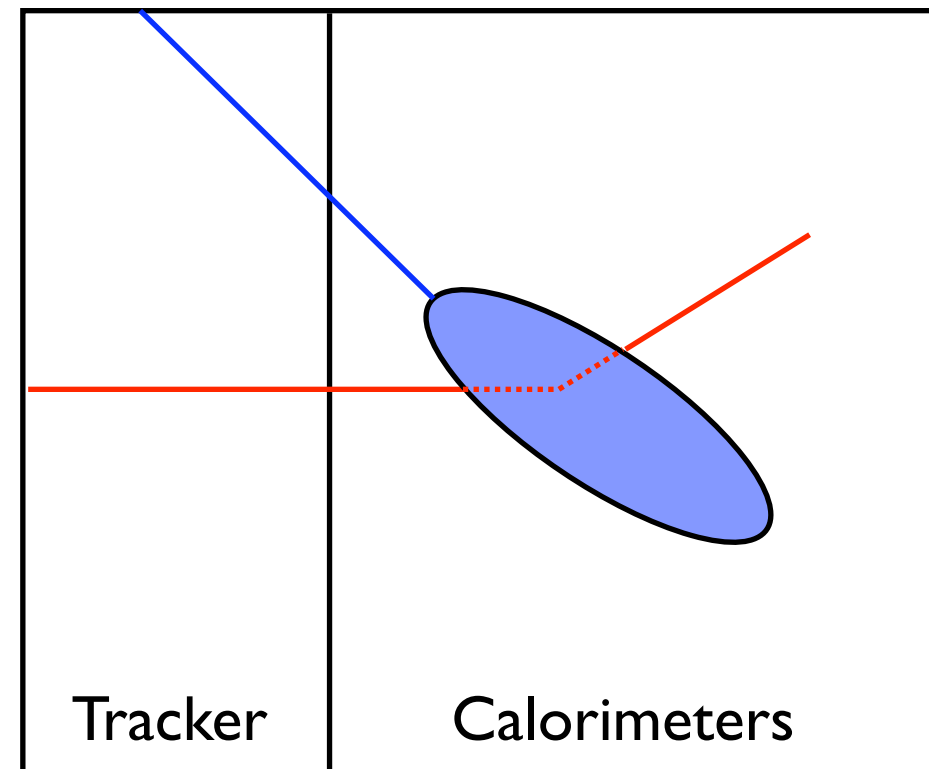
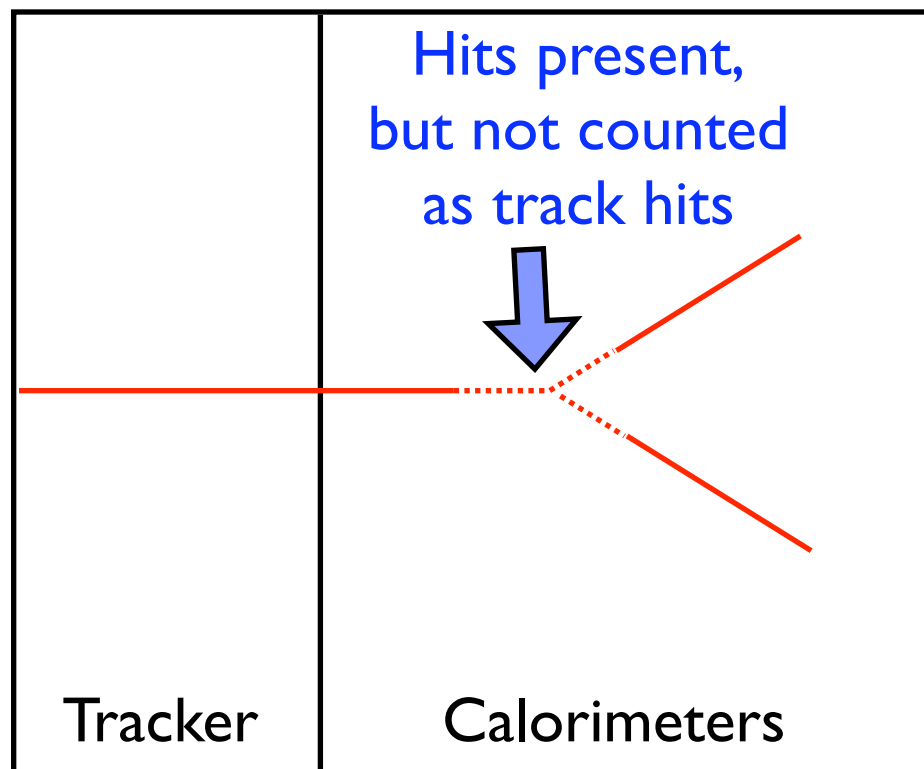


⇒ Require POCA inside calorimeters

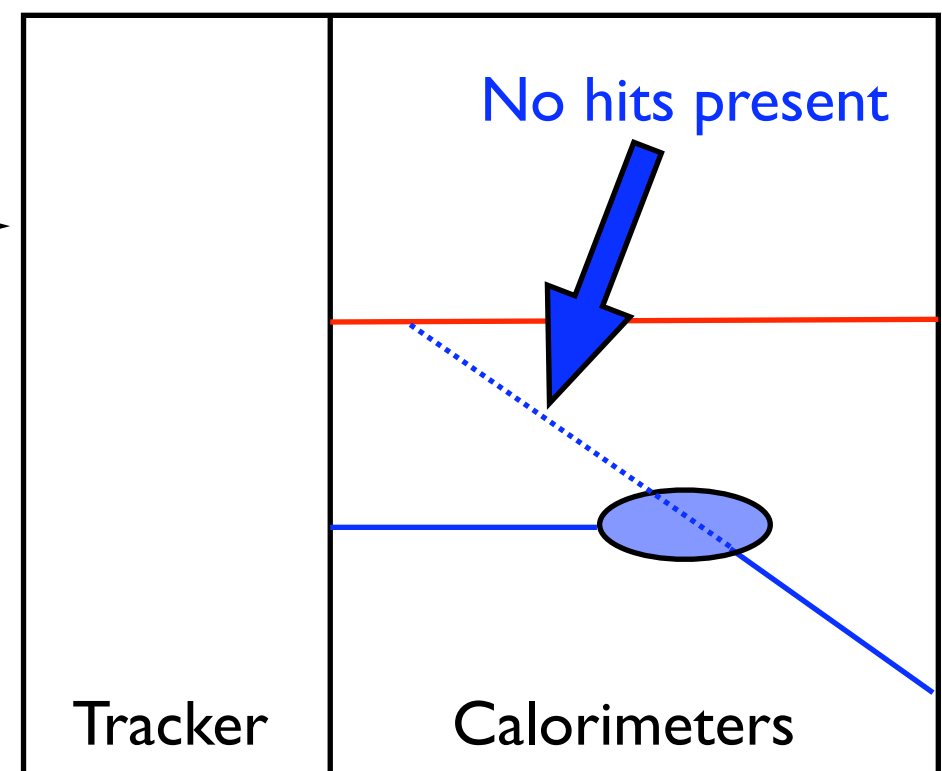


Patterns: Linking tracks

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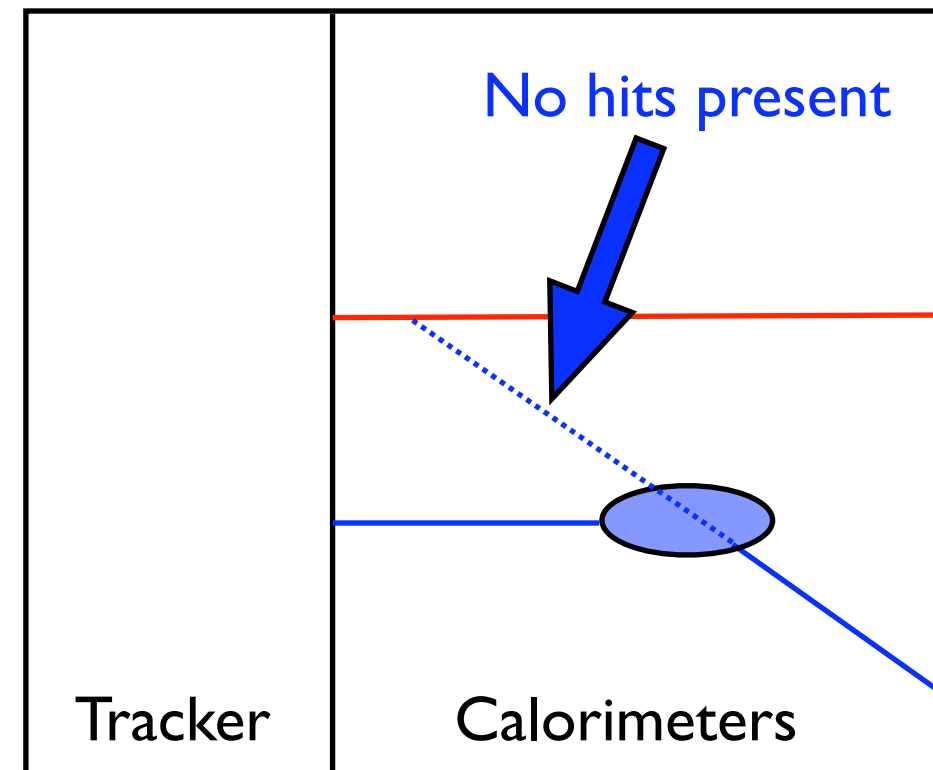
But not in this case:



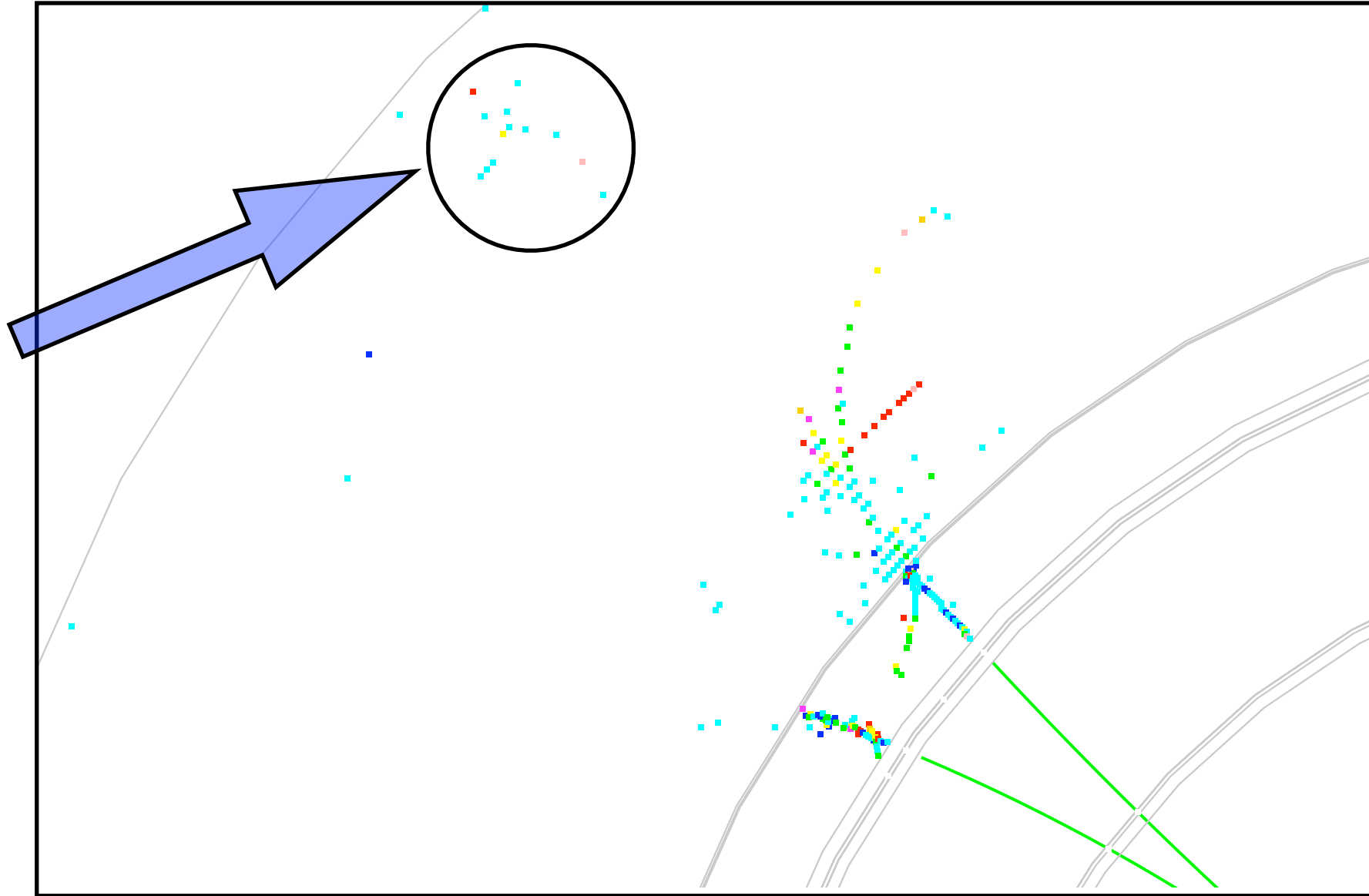
Patterns: Linking tracks

Solutions?

- Look for missing hits
 - Look at gap between track and POCA
 - Real link should have hits along trajectory
- Break apart clusters
 - Does cluster contain >1 primary MIPs?
 - If so, break weak links until one cluster per primary



Patterns: Isolated HCAL fragments



MST doesn't handle isolated fragments well
(HCAL threshold is 10cm here)

Lots to do...

- Test algorithm performance on more Ks events, taus, neutrons/K-longs, then Z0.
- Switch out or improve components (e.g. helix fit or swimming for tracks; find clumps better)
- Tune DOCA, POCA cuts
- Smarter handling of halo
- Move towards probabilistic approach
 - With likelihood-style tuning, could handle multiple detector designs
- Eventual goal: identifying & separating hadronic showers in calorimeters