FPCCD digitization and reconstruction

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Requirements for vertex detector

- Impact parameter resolution
  - High IP resolution is needed for good flavor tagging.

$$\sigma_{r\varphi} = 5\ [\mu m] \oplus \frac{10\ [\mu m]}{p\beta sin^{3/2}\theta}$$

- Tolerance against beam background and RF noise
  - Pixel occupancy < few%
  - RF noise is induced by bunched beam.

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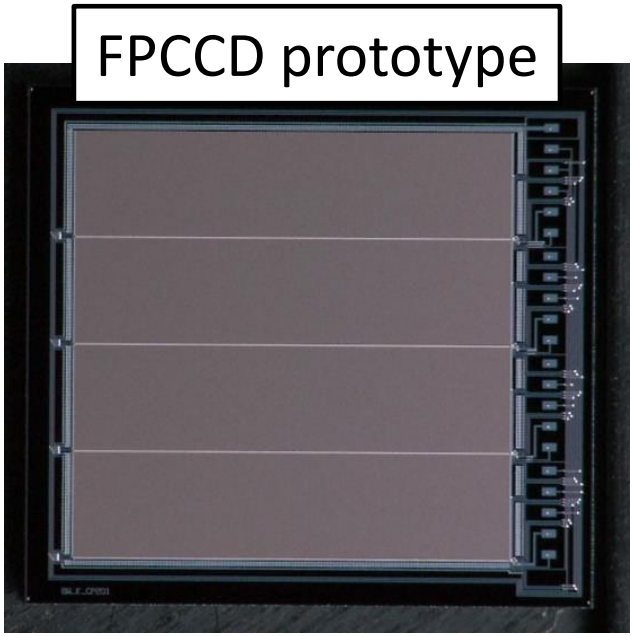
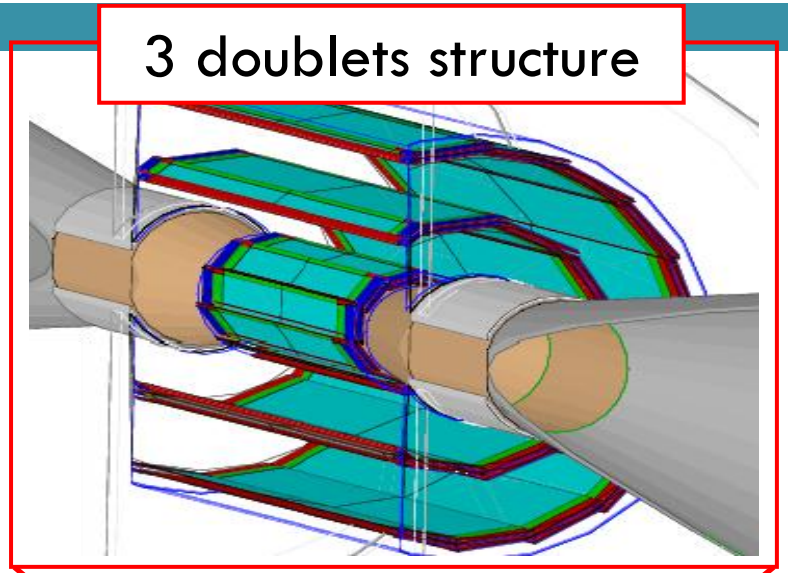
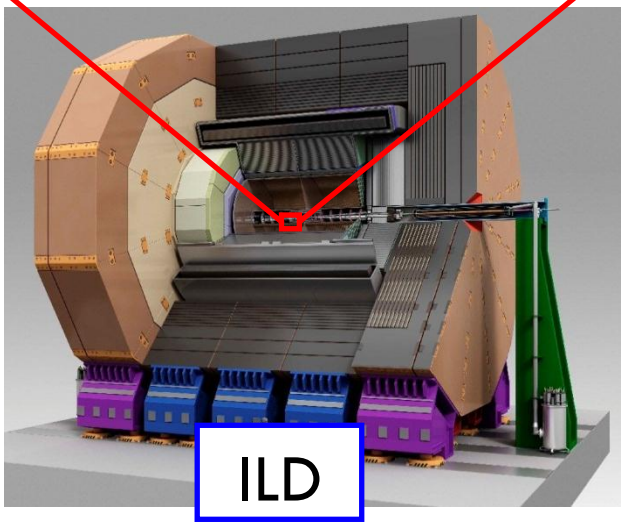
➡ One possible solution : FPCCD vertex detector

FPCCD vertex detector

- FinePixelCCD vertex detector
  - Pixel size : 5 x 5 um^2
  - Number of pixels : ~10^{10}
  - Read out time : Inter-train
  - Fully depleted sensor



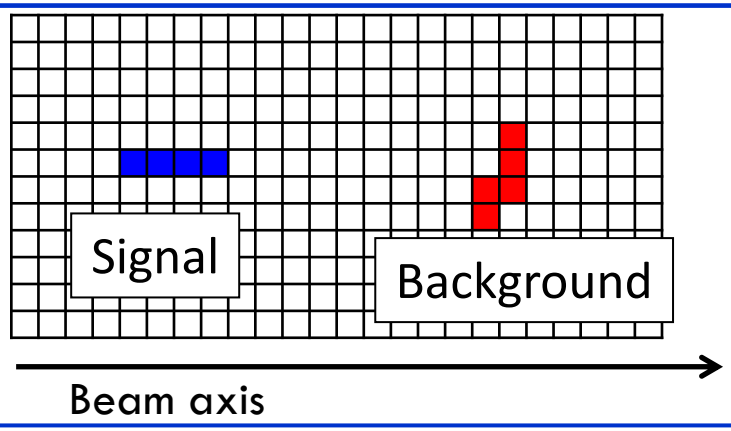


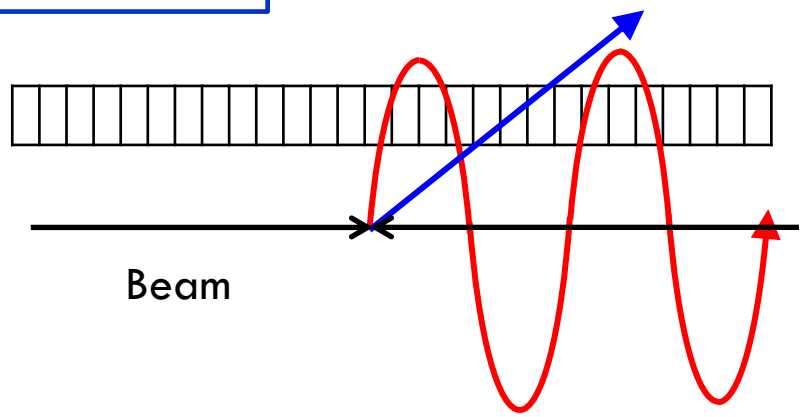


Advantage of FPCCD vertex detector

- FinePixelCCD vertex detector
  - Pixel size : 5 x 5 um^2 → High spatial resolution, High IP resolution
  - Number of pixels : ~10^{10} → Low pixel occupancy
  - Read out time : Inter-train → Not affected by RF noise
  - Fully depleted sensor → High 2track separation capability

Background rejection by using cluster shapes





Software for FPCCD

- To evaluate the performance of FPCCD vertex detector, FPCCD software are being developed.

- Software for FPCCD simulation
  - FPCCDDigitizer
  - FPCCDClustering
  - FPCCDOverlayBX (merge background into physics event)

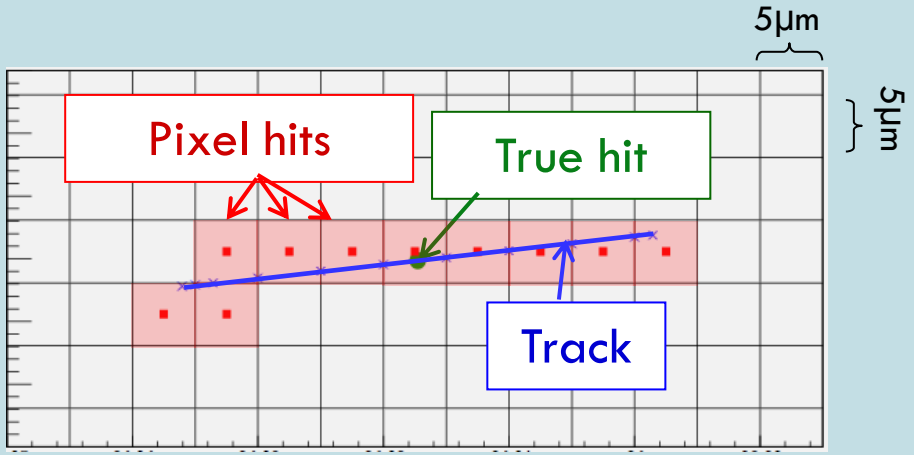
  These software were developed and installed into ilcsoft.

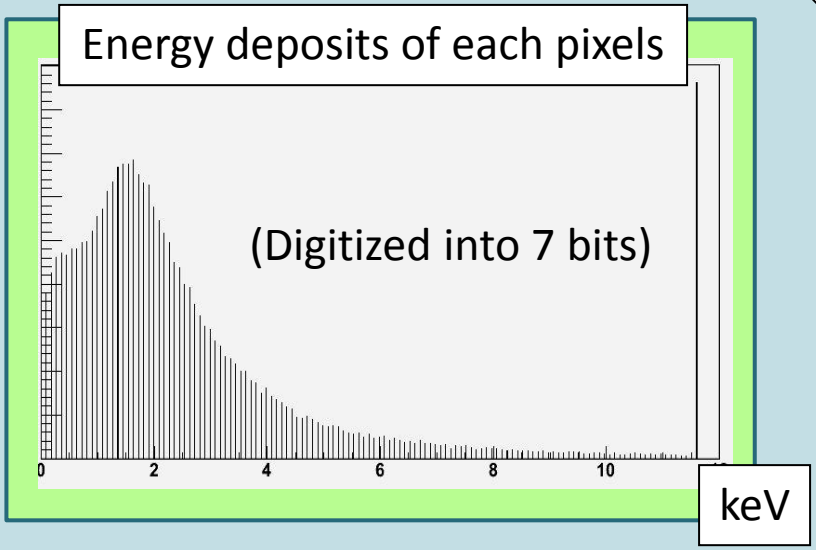
  - VTracking processor ← Being developed.

    (utilizing the features of FPCCD)

FPCCDDigitizer

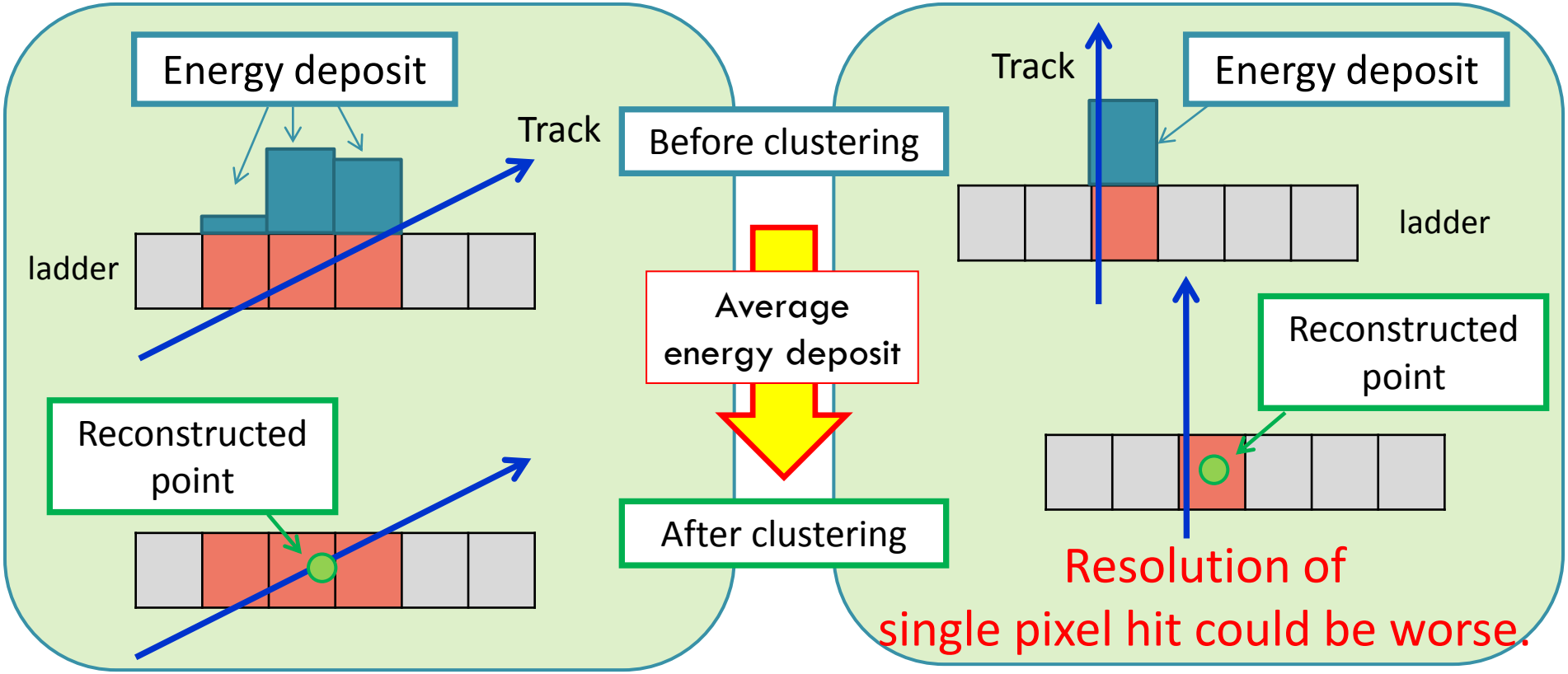
- The hit point and track momentum are obtained from Mokka.
- The trajectory is calculated by hit point and momentum.
- The pixel hit is identified by the intersection of track and boundaries of pixels.
- The energy deposit of hit is divided into pixels as proportional to path length then smeared by Landau distribution.





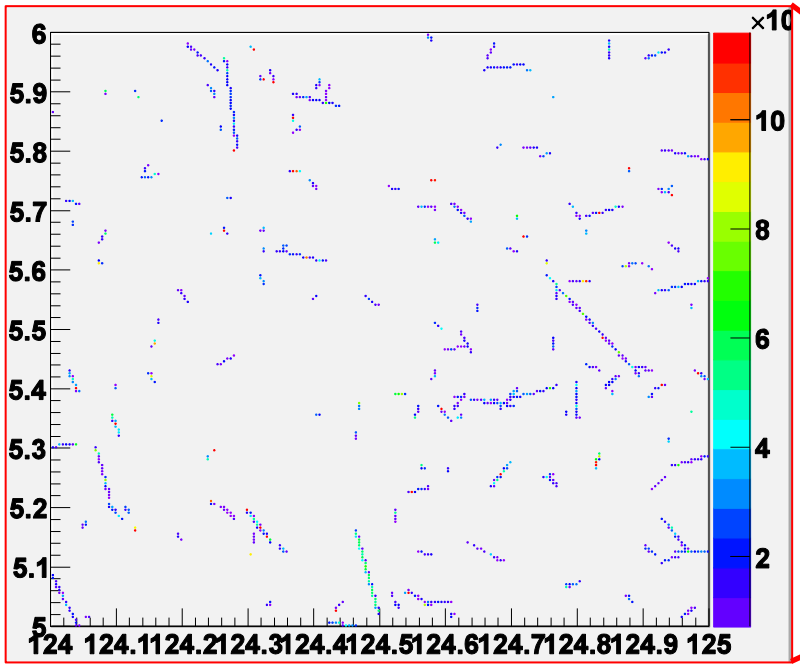
FPCCDClustering

- The neighboring pixels are recognized as a cluster.
- The hit coordinate is calculated by an energy weighted average.

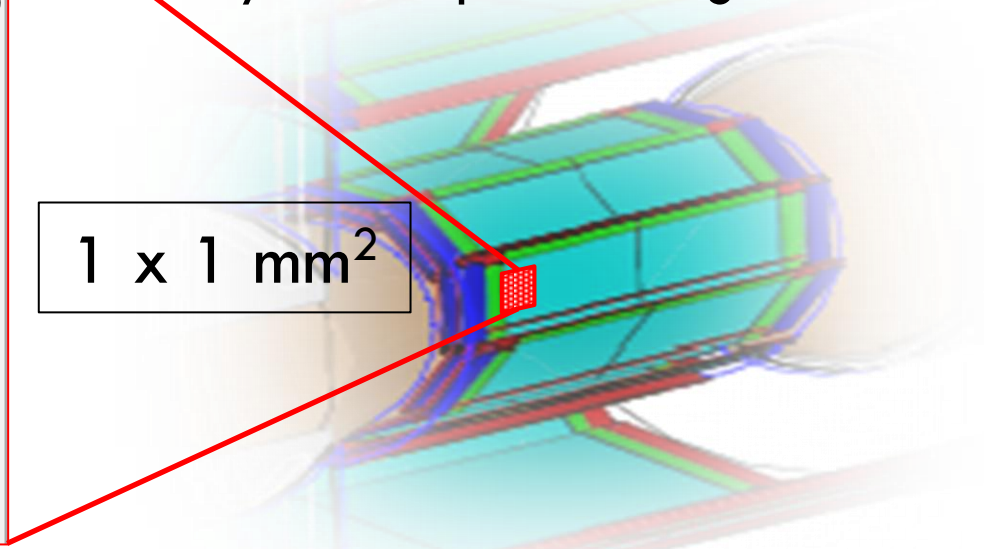


FPCCDOverlayBX

- If there are more than 2 hits in the same pixel, the processor adds the energy deposit of both hits.
- The hit quality (signal, background, overlap) is updated for background rejection analysis.



Pixel hits in the innermost layer by 1train pair background.



The simulation results

Spatial resolution

Impact parameter resolution

Pixel occupancy

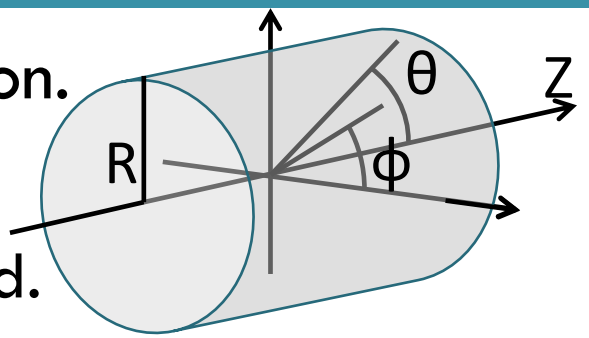
σ_{noise} : 50 e^-/pixel, Threshold : 200 e^-/pixel

The energy deposits were digitized into 7 bits.

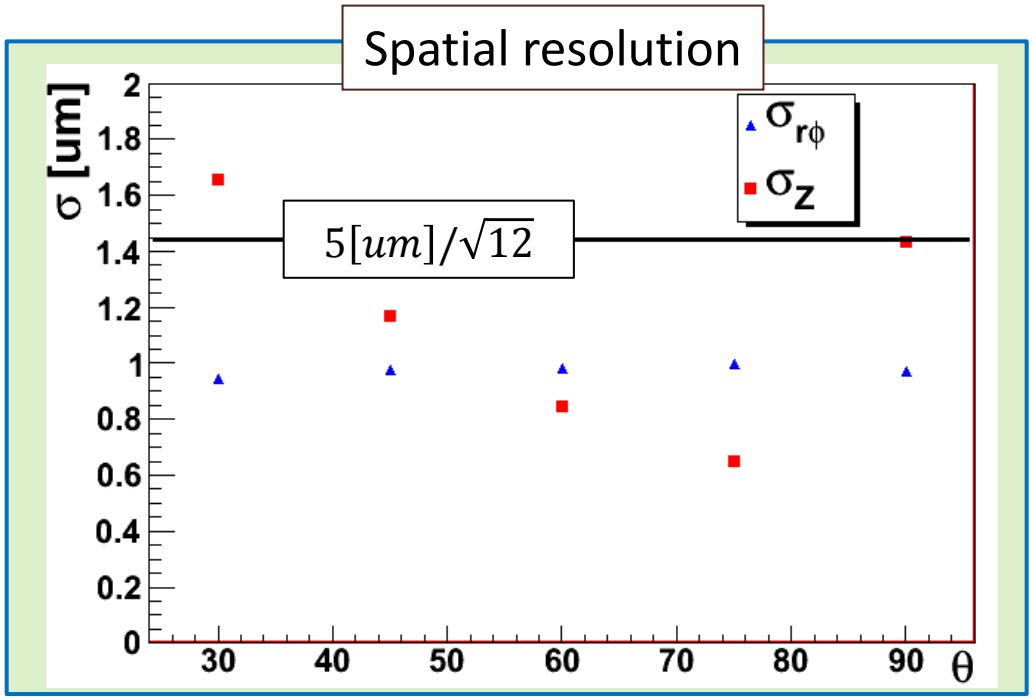
Existing tacking processor was used.

Spatial resolution

- The θ dependency of the spatial resolution.
  - The Z resolution is worse at forward.
  - The Z resolution of the vertical track is bad.
  - The R-Φ resolution is better than 1um.



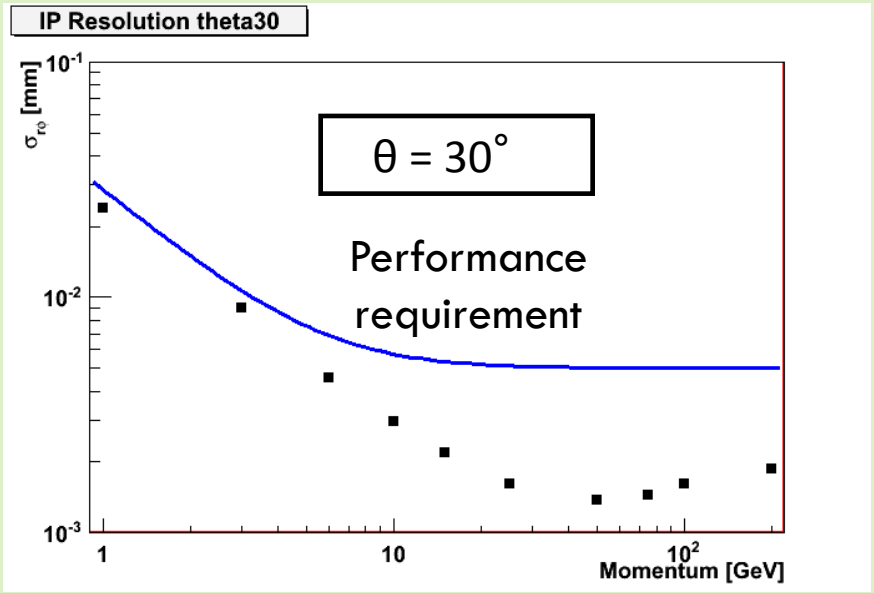
θ	σ_Z	$\sigma_{R\text{-}\phi}$
90°	1.5 um	0.94 um
75°	0.64 um	0.96 um
60°	0.83 um	0.96 um
45°	1.2 um	0.96 um
30°	1.6 um	0.98 um
LOI	2.8 um	2.8 um

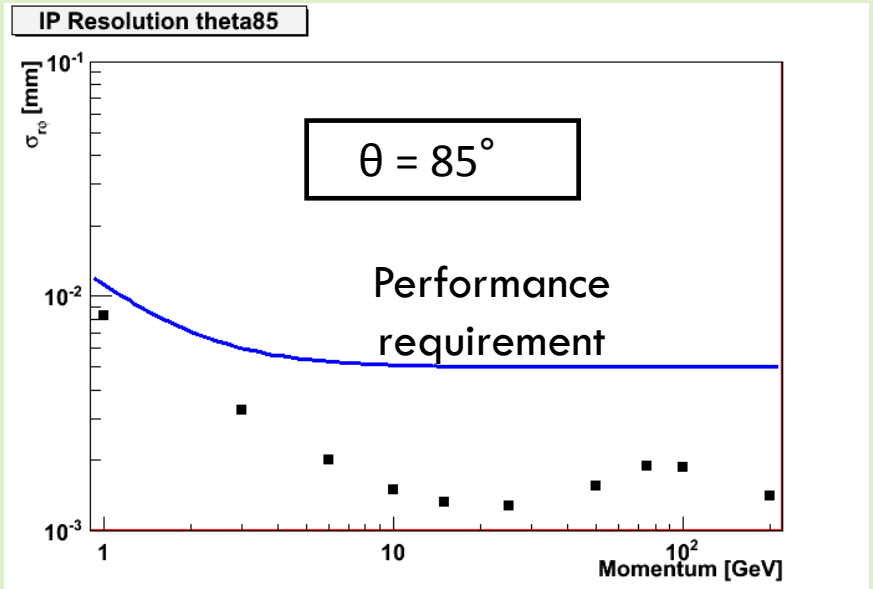


Impact parameter resolution

- Impact parameter resolution in R-Φ direction.
  - FPCCD can satisfy the performance requirements.

Impact parameter resolution





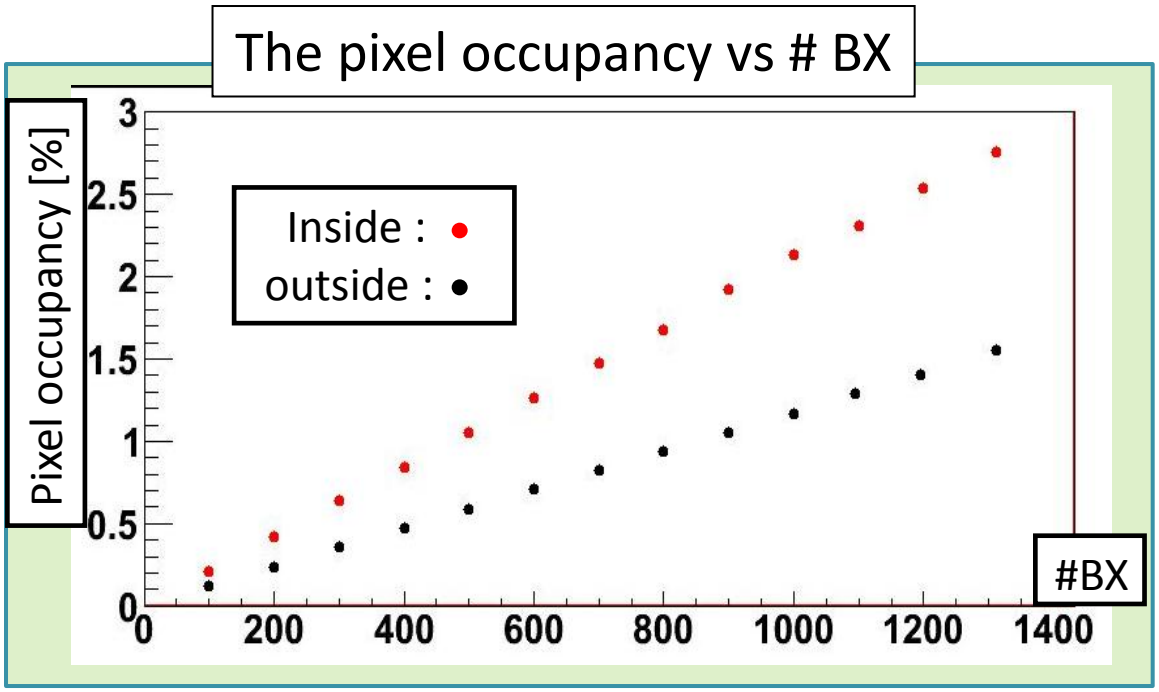
Pixel occupancy

- The Pixel occupancy of 1 train pair background.
  - Inside of innermost : 2.76 %, Outside of innermost : 1.55 %

Very low occupancy, compared with conventional CCD.

→ Check the performance under the background.

Background conditions
— Generator : Guinea Pig
— Beam parameter : SB2009w/TF
— CM energy : 500 GeV
— Range cut : 100 um



Software under development

VTracking processor

Tracking software

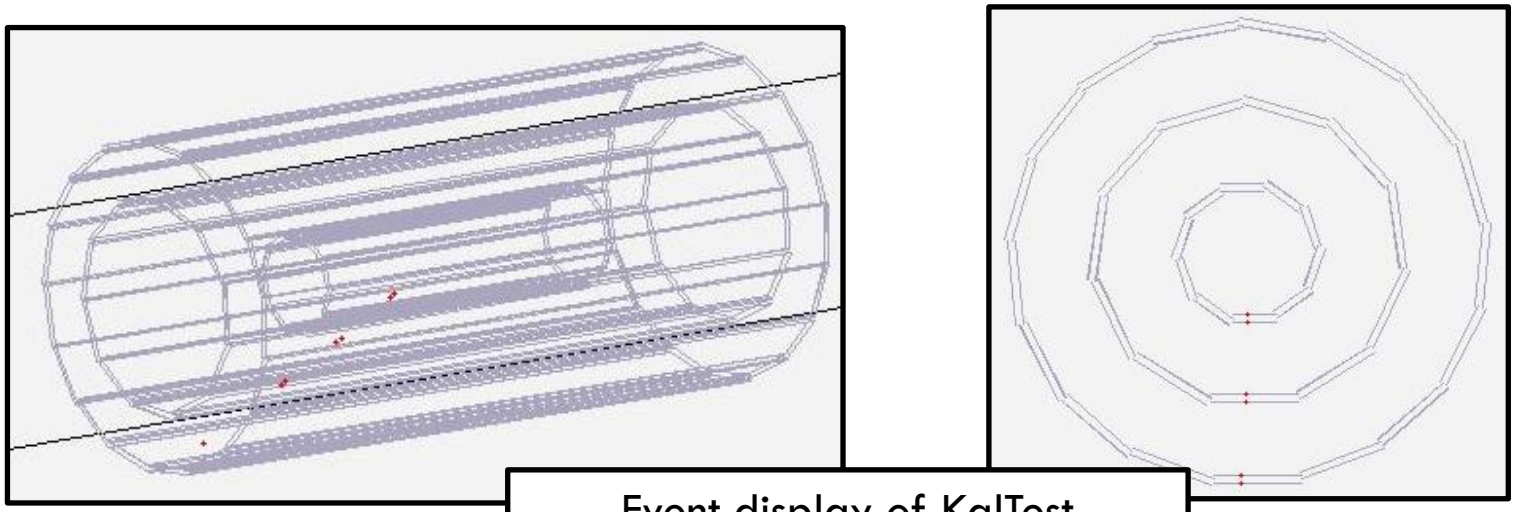
- The tracking software utilizing the features of FPCCD vertex detector is being developed.

Tracking

	Track finding	Track fitting
Old :	Standard track finding	χ^2 fitting
New :	Track finding utilizing the features of FPCCD	Kalman Filter
	Under development	Installation is completed.

Track fitting

- The vertex detector which is 3 doublets structure is implemented into KalTest.

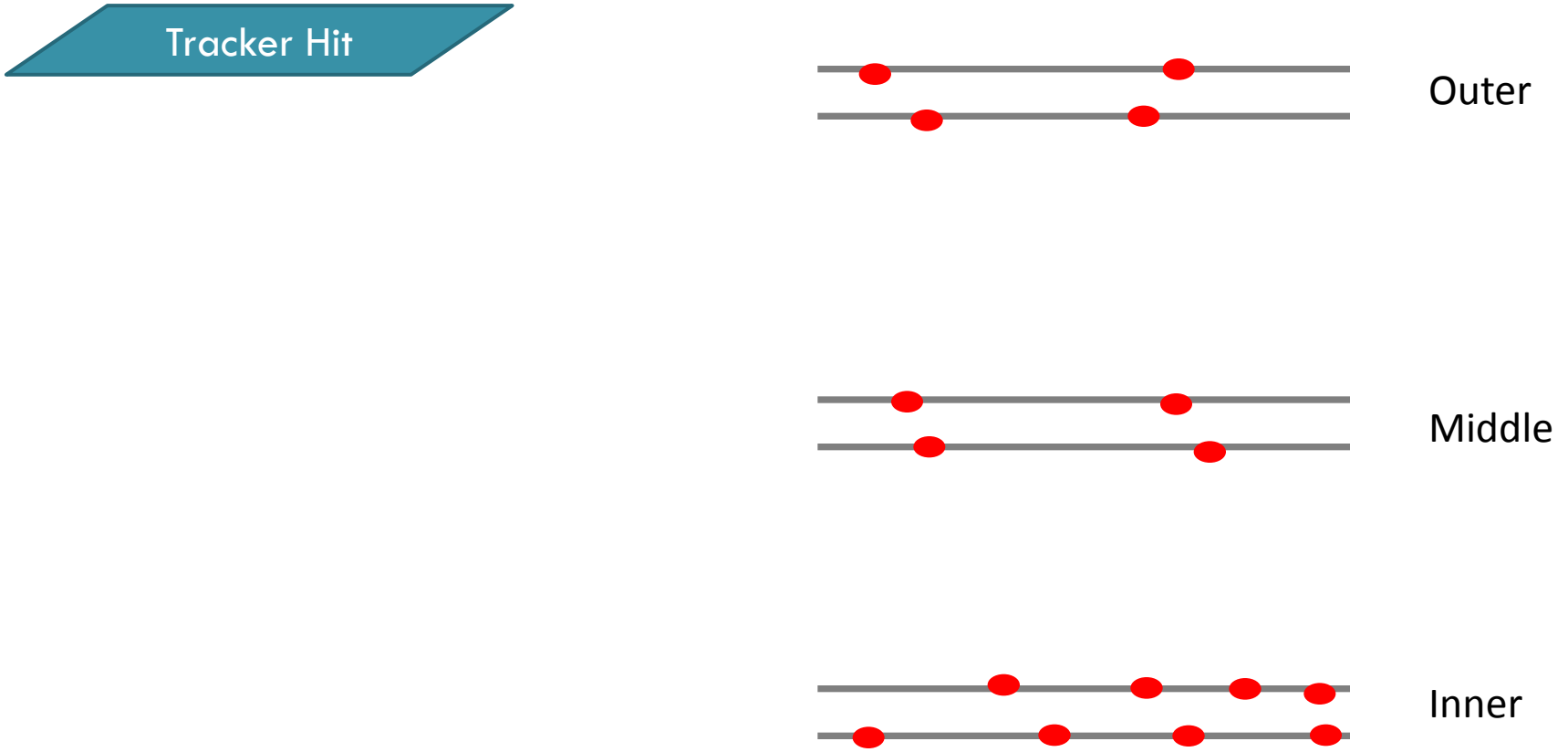


Event display of KalTest

- The Kalman filter fitting on FPCCD is available.

Track finding – Vector hit

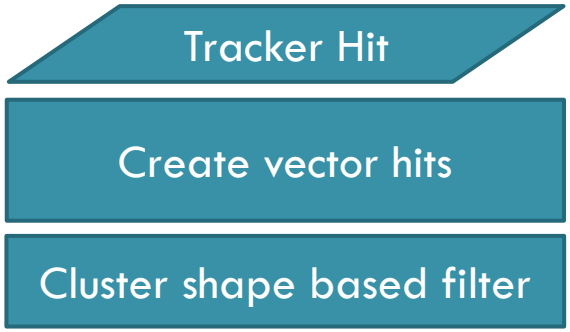
- Algorithm of track finding.
  - Find the track taking advantage of 3 doublets structure.

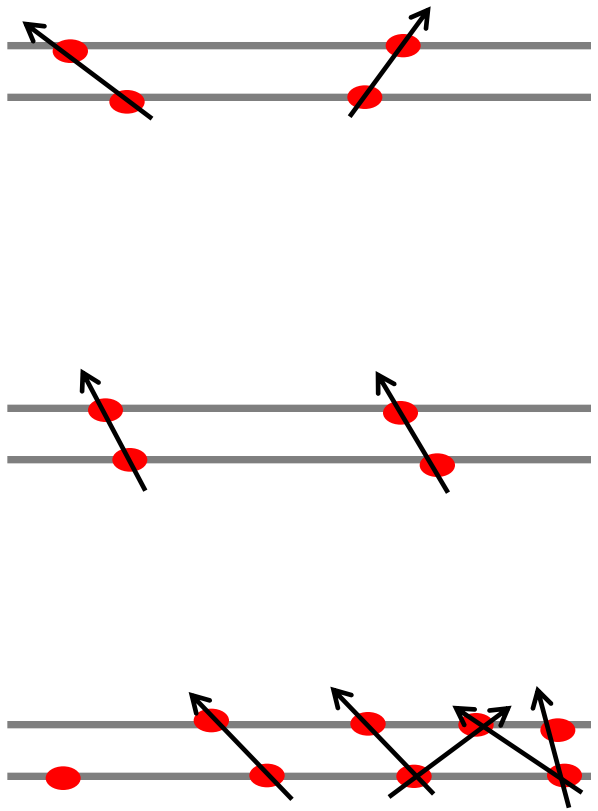


Track finding – Vector hit

- Create Vector hit by using doublet layer.
- Perform cluster shape based filter.

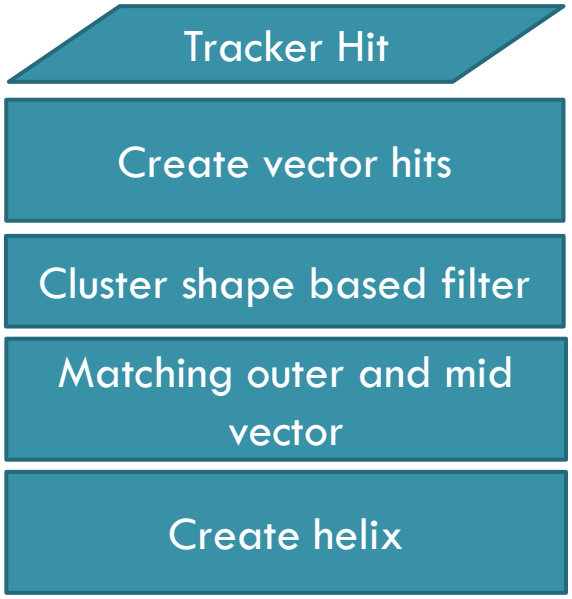
Vector hit : ↑

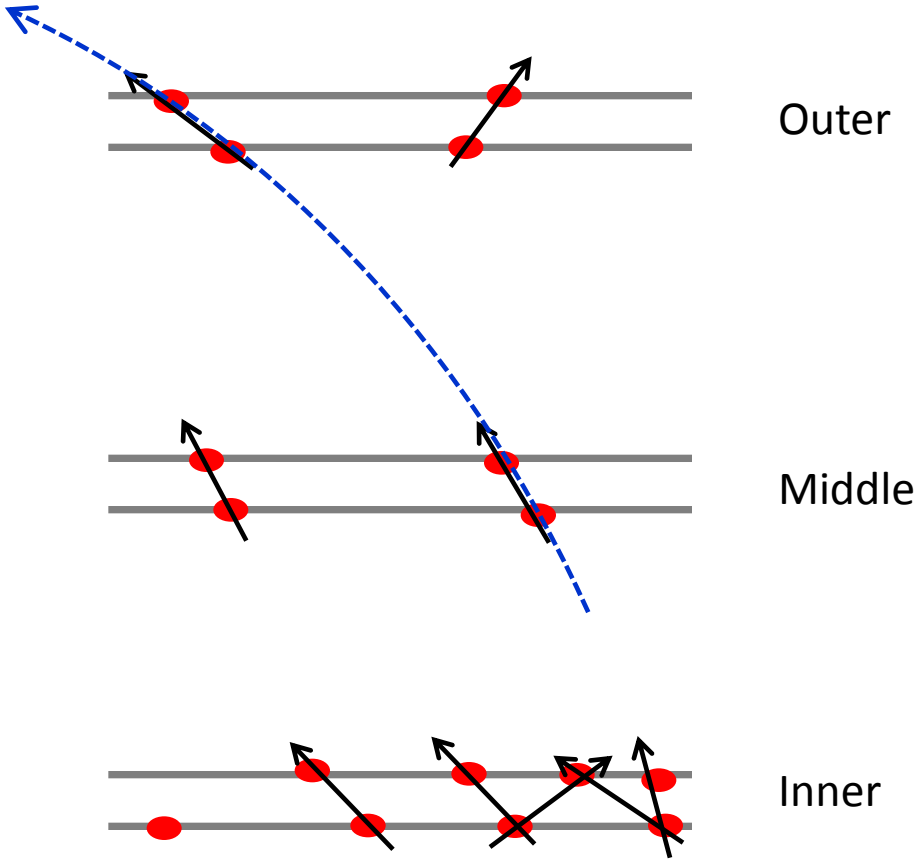




Track finding – Vector hit

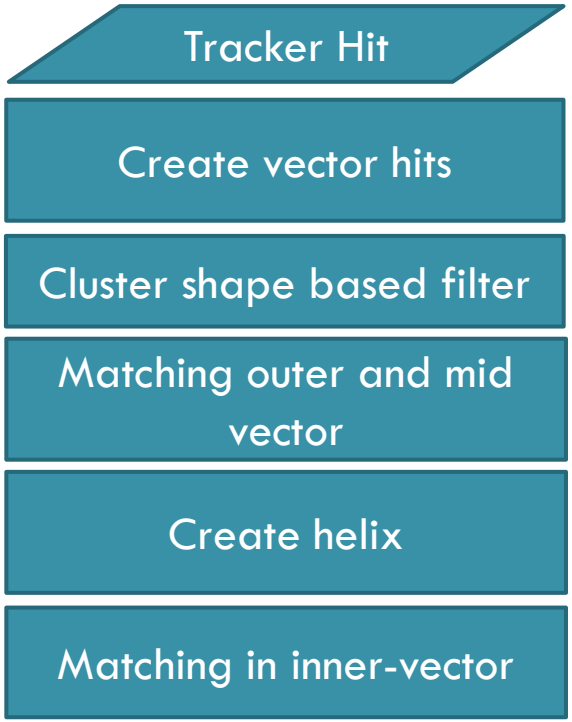
- Create helix by middle and outer layers. (Inner layers has heavy background.) → Speed-up will be expected.

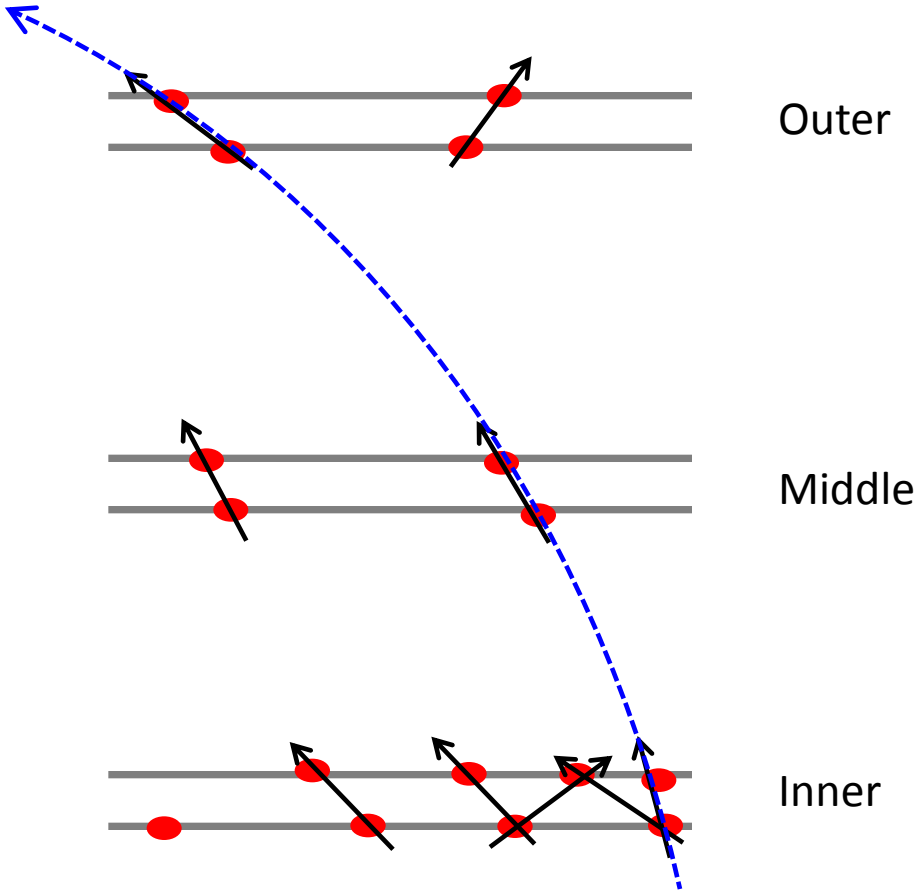




Track finding – Vector hit

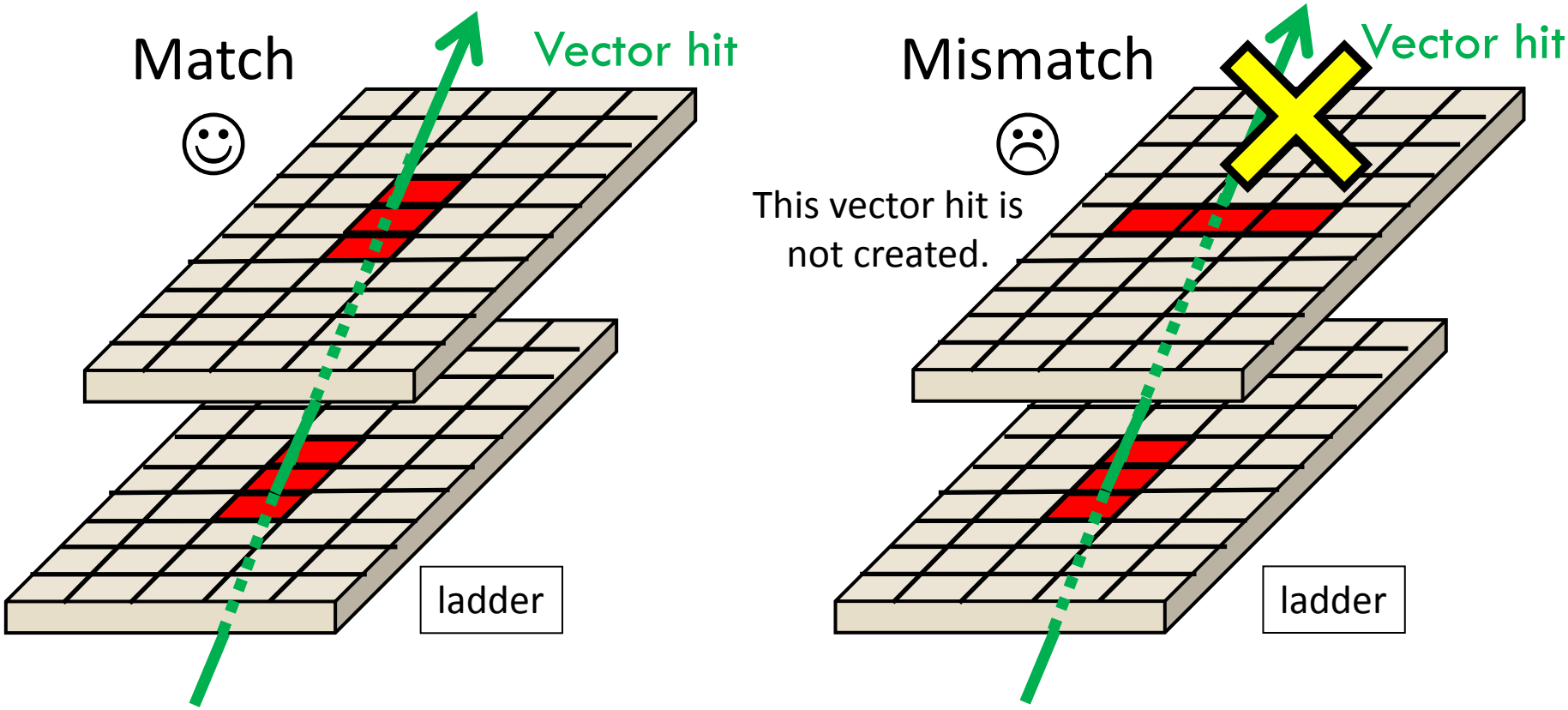
- Extrapolate the helix into inner layers and determine the track.





Track finding – Cluster shapes filtering

- Take consistency by cluster shapes in making vector hits.
  - More precise track finding can be expected.
  - Cluster shapes information is sorted into CellID1.



Summery/Plan

- The simulation software for the performance study of FPCCD vertex detector are being developed.
- FPCCD can satisfy the IP resolution requirements.
- Pixel occupancy
  - Innermost inside : 2.76 %, innermost outside : 1.55 %
- New tracking software is being developed.
  - Improve the efficiency and speed.
- Plan
  - Estimation of background effect.
  - Evaluate the performance of flavor tagging.