



FPCCD reconstruction

Daisuke Kamai (Tohoku university)

Y.Sugimoto, K.Fujii, A.Miyamoto,
Y.takubo, H.Sato, H.Yamamoto

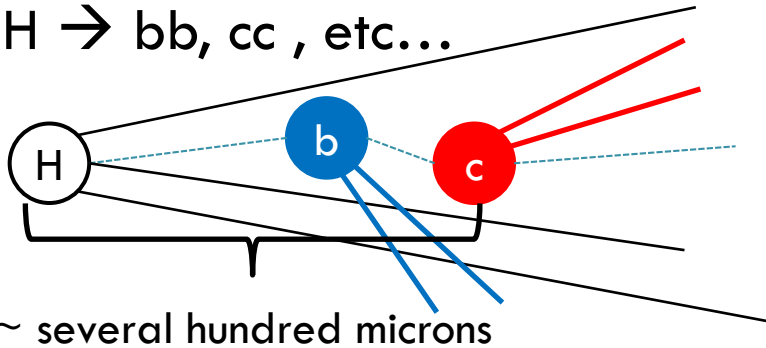
2011/9/14

Kick-Off Meeting 2011 at Tohoku university

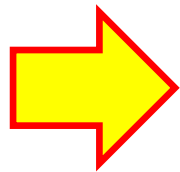
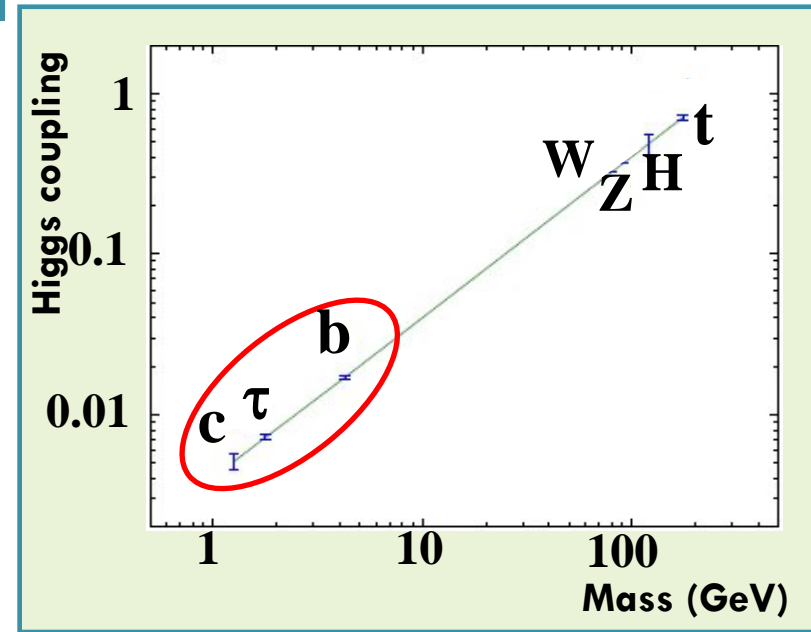
Vertex detector for ILC

1

- The physics aim of ILC
 - ▣ Validation of new physics
 - ▣ Precision measurement of Higgs
 - $H \rightarrow bb, cc, \text{etc...}$



Identify b, c quark correctly.



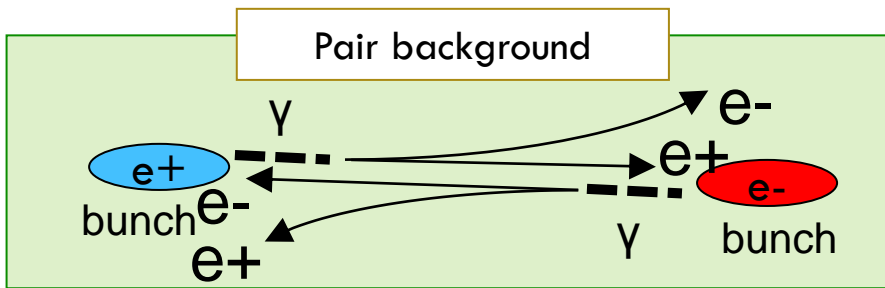
Required
impact parameter
resolution

$$\sigma = 5 \oplus \frac{10}{p\beta \sin^{3/2} \theta} (\mu m)$$

Challenge for Vertex detector

2

- The challenge for vertex detector
 - ▣ The vertex detector is installed in the nearest point by IP.($R=1.6\text{cm}$)

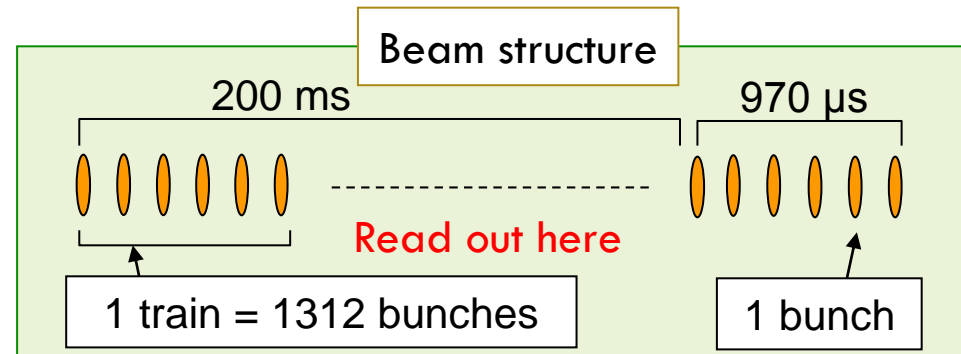
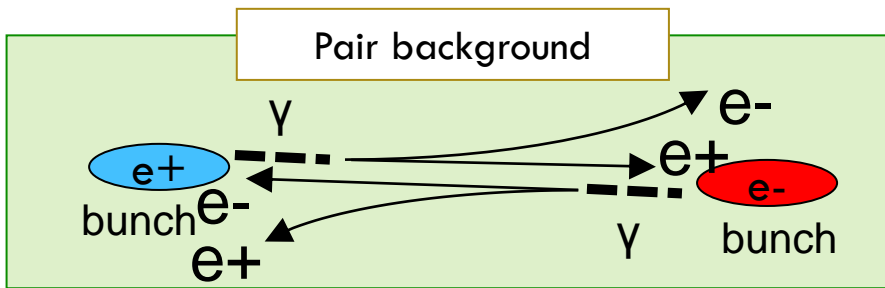


Challenge for Vertex detector

3

■ The challenge for vertex detector

- The vertex detector is installed in the nearest point by IP.($R=1.6\text{cm}$)
- The data for 1 train is accumulated and read out.

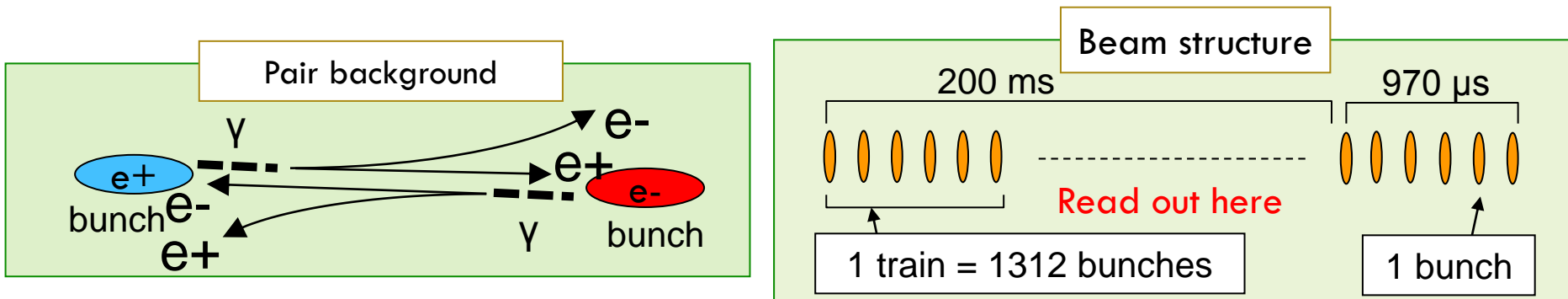


Challenge for Vertex detector

4

■ The challenge for vertex detector

- ▣ The vertex detector is installed in the nearest point by IP.($R=1.6\text{cm}$)
- ▣ The data for 1 train is accumulated and read out.



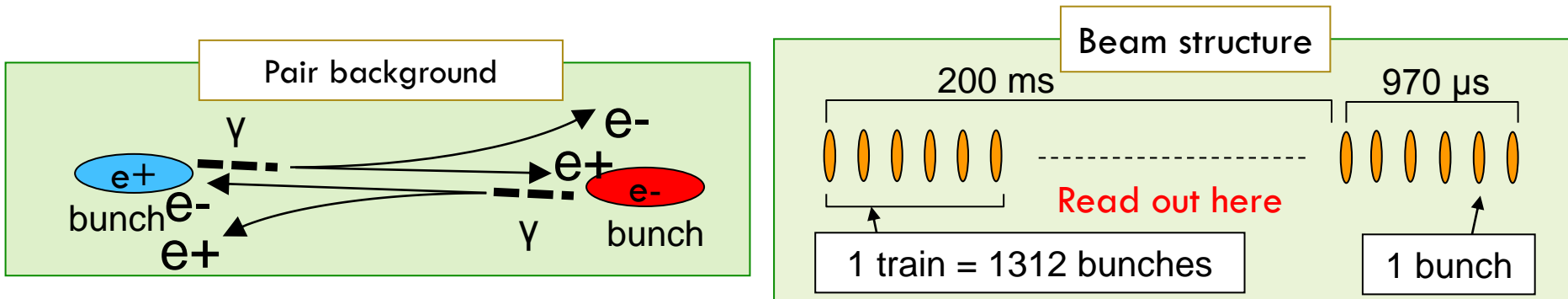
➔ The pixel occupancy of pair background becomes problem.

- $20 \times 20 \text{ } \mu\text{m}^2$ CCD : $> 40\% \rightarrow \sim 1\%$ is required.

Challenge for Vertex detector

5

- The challenge for vertex detector
 - ▣ The vertex detector is installed in the nearest point by IP.($R=1.6\text{cm}$)
 - ▣ The data for 1 train is accumulated and read out.



- ➔ The pixel occupancy of pair background becomes problem.
- $20 \times 20 \mu\text{m}^2$ CCD : $> 40\% \rightarrow \sim 1\%$ is required.

The solution : Smaller pixel \rightarrow **FinePixelCCD!!**

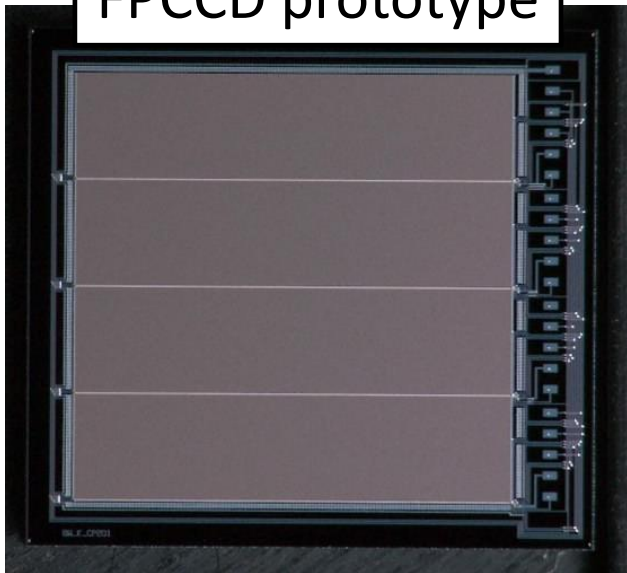
FPCCD vertex detector

6

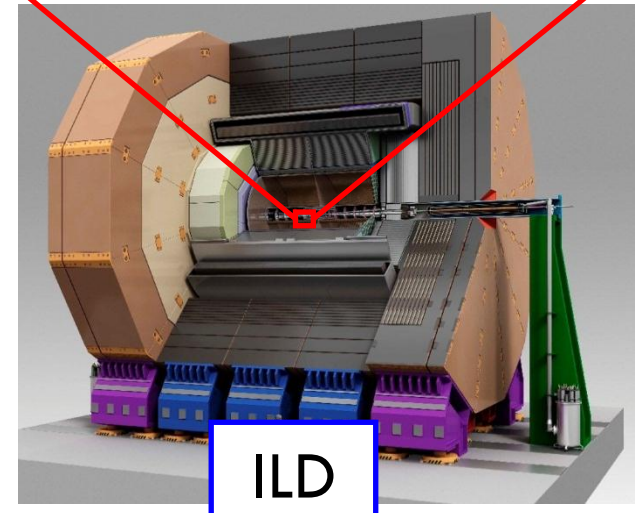
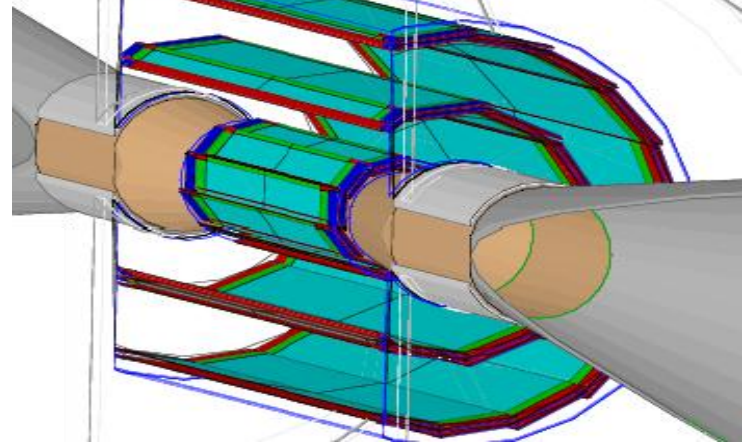
FinePixelCCD vertex detector

- Pixel size : $5 \times 5 \text{ um}^2$
- Number of pixels : $\sim 10^{10}$
- Read out time : Inter-train
- Fully depleted sensor

FPCCD prototype



3 doublets structure



ILD

Advantage of FPCCD vertex detector

7

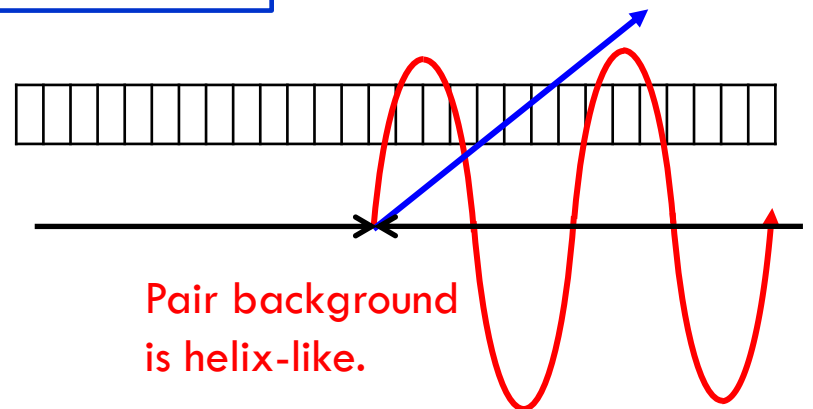
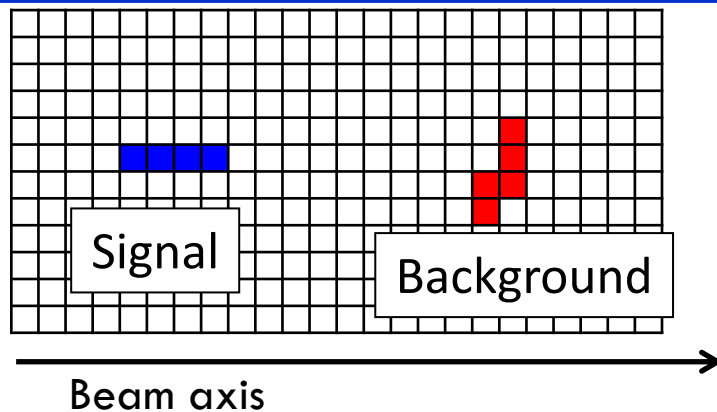
■ FinePixelCCD vertex detector

- Pixel size : $5 \times 5 \text{ um}^2$
- Number of pixels : $\sim 10^{10}$
- Read out time : Inter-train
- Fully depleted sensor



- High spatial resolution
- High IP resolution
- Low pixel occupancy
- Not affected by RF noise
- High 2track separation capability

Background rejection by using cluster shapes



Software for FPCCD

8

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

- Software for FPCCD simulation

- ▣ FPCCD Digitizer (generate signals)
- ▣ FPCCD Clustering (reconstruct the hit point from signal)
- ▣ FPCCD Overlay (merge background into physics event)

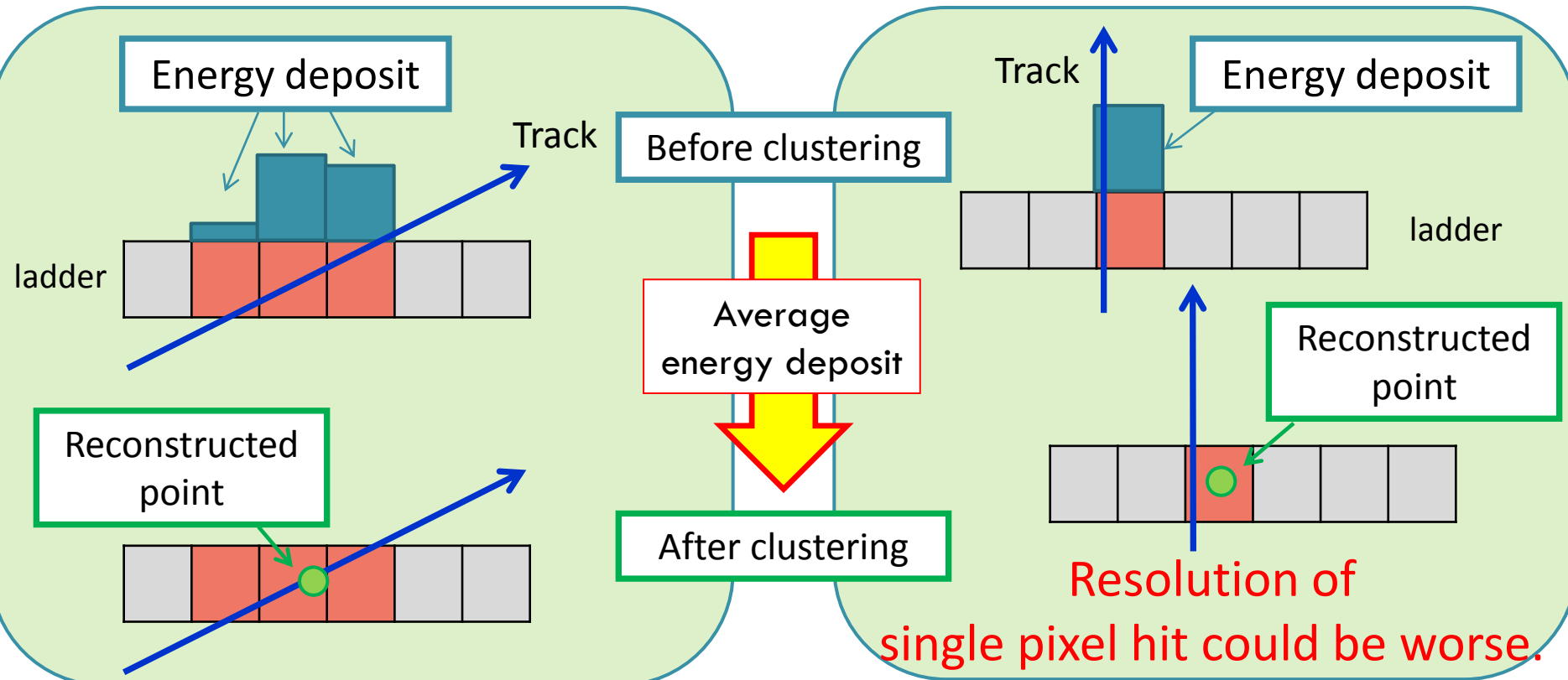
These software were developed and installed in MarlinReco.

- ▣ VTracking processor ← Being developed.
(utilizing the features of FPCCD)

FPCCD Clustering

9

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



The simulation results

Existing tracking processor was used.

Spatial resolution

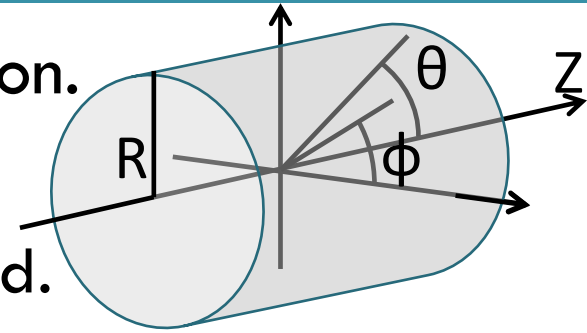
Impact parameter resolution

Pixel occupancy

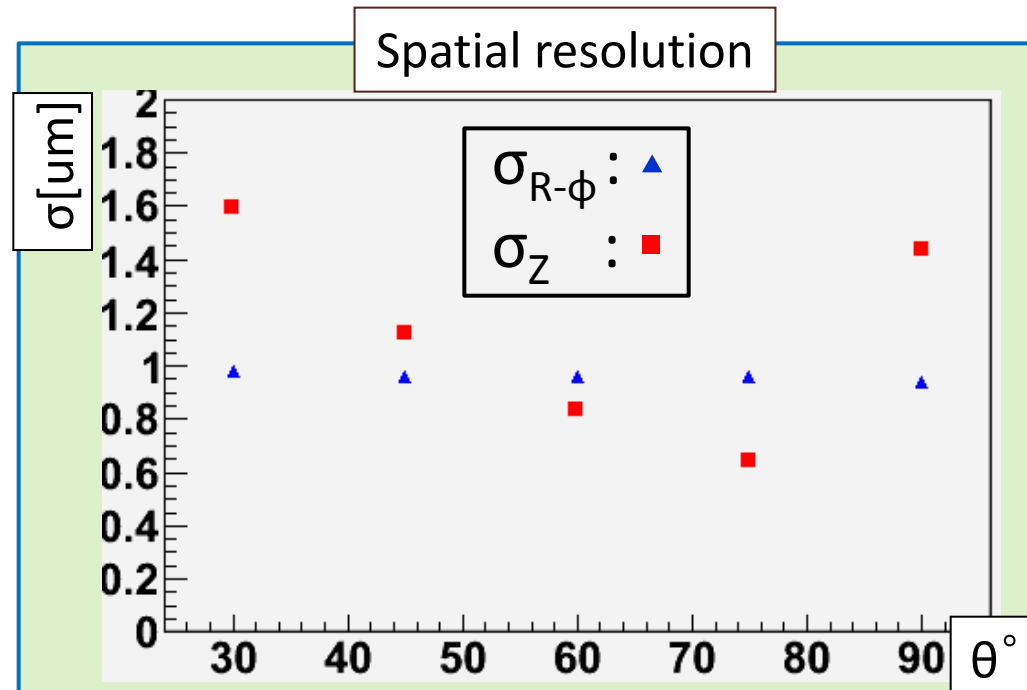
Spatial resolution

11

- 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 1 μm .**



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

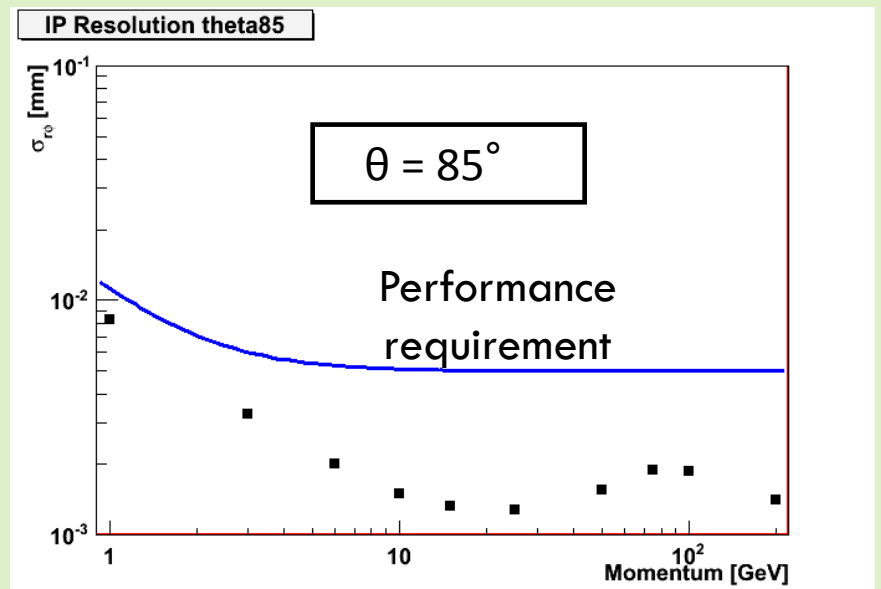
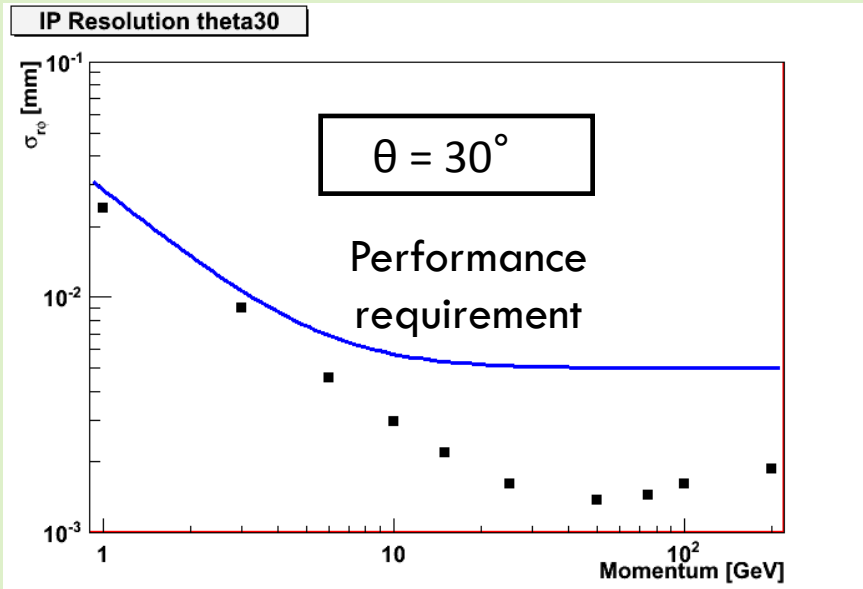


Impact parameter resolution

12

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

Impact parameter resolution



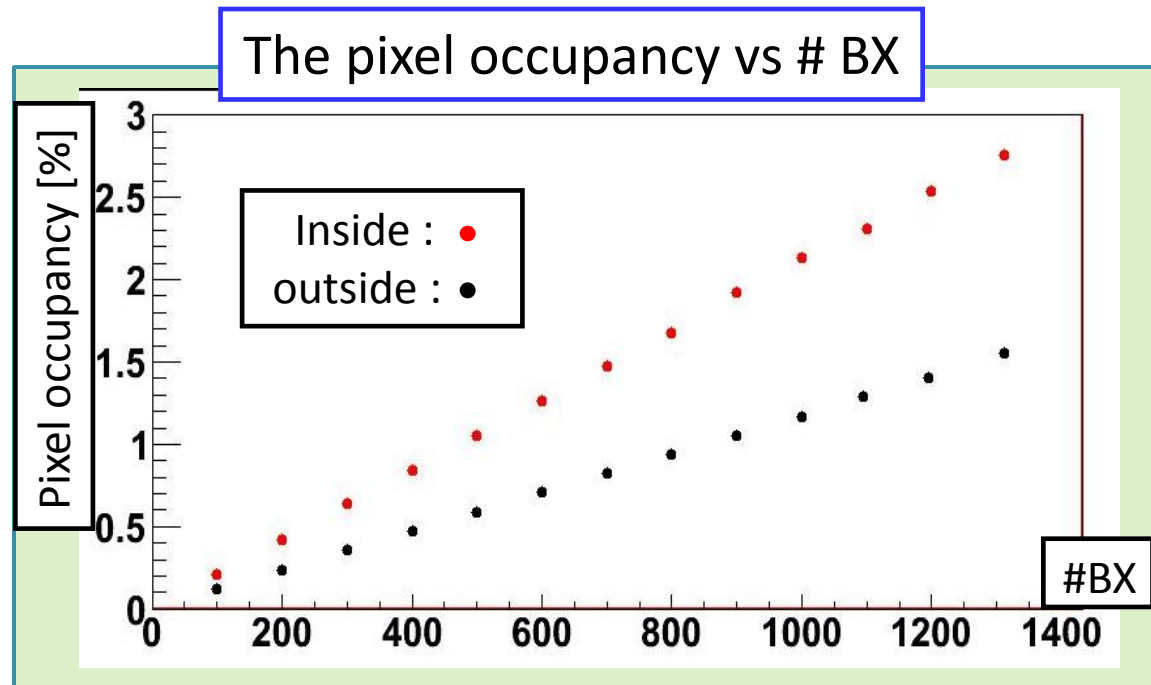
Pixel occupancy

13

- 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 : SB2009_w/TF
- CM energy : 500 GeV
- Range cut : 100 um



14

Software under development

Tracking software

Tracking software

15

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

1 . Track finding
Finding the hit points
that make up the track.

2 . Track fitting
Fitting the track parameter

■ Old :

Standard track finding

χ^2 fitting

■ New :

Track finding utilizing the
features of FPCCD

Kalman Filter

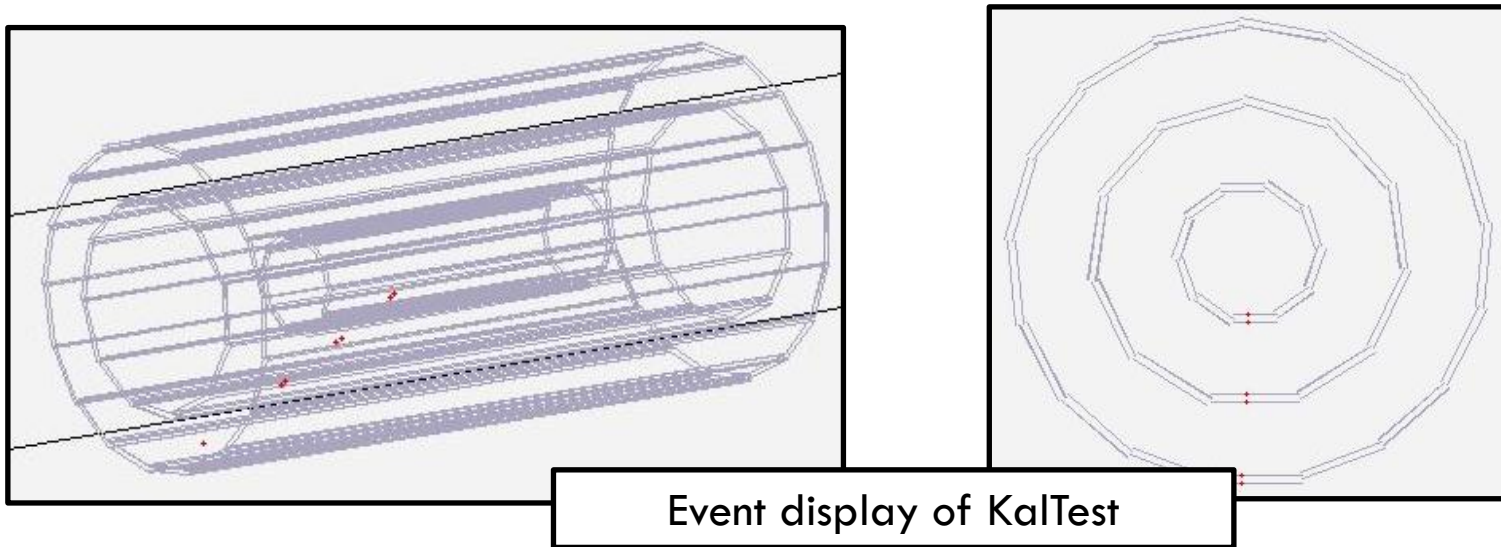
↑
Under development

↑
Installation is completed.

Track fitting

16

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

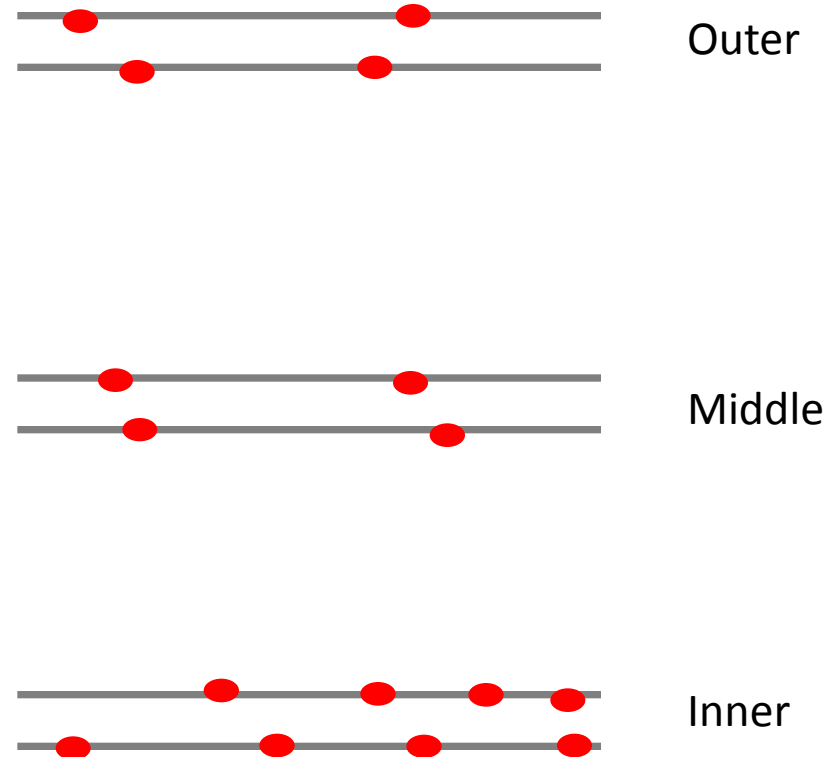


- The Kalman filter fitting on FPCCD is available.

Track finding – Vector hit

17

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

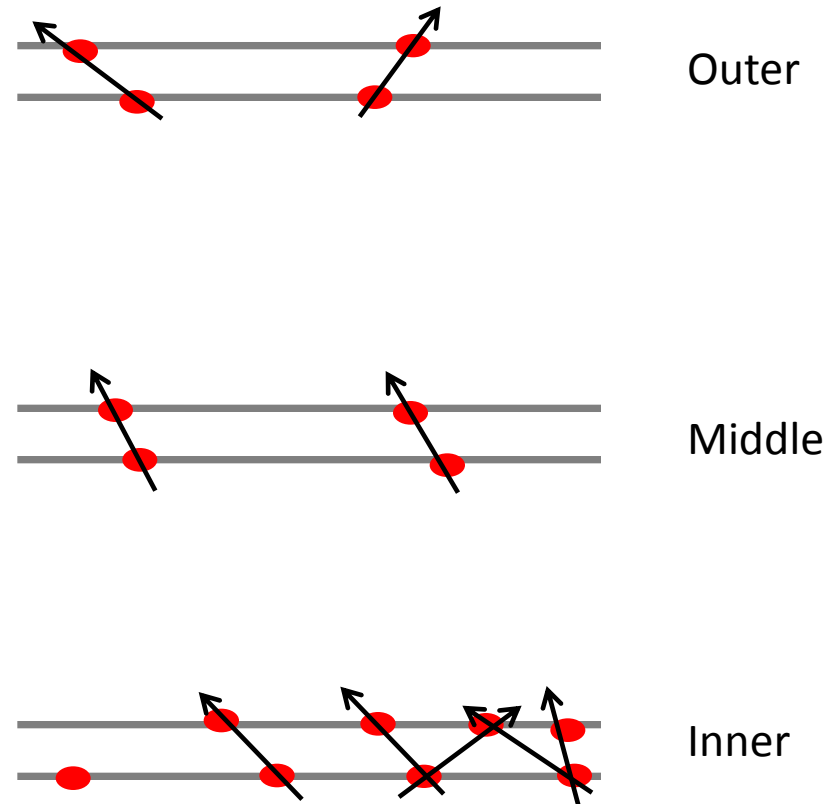
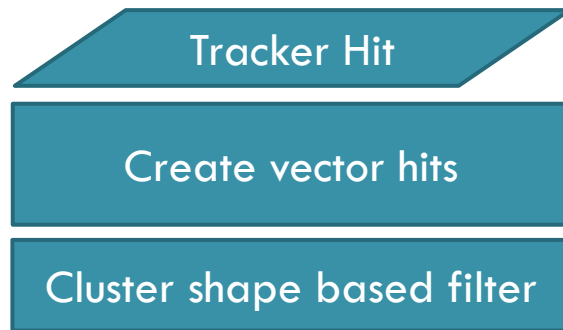


Track finding – Vector hit

18

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

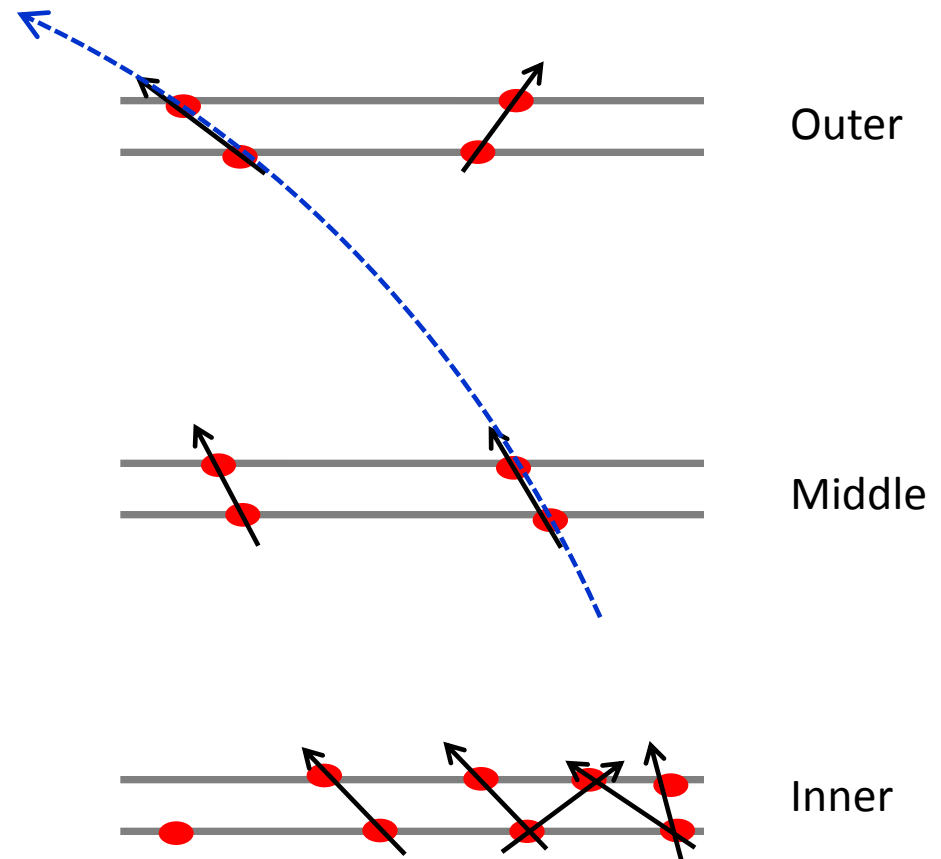
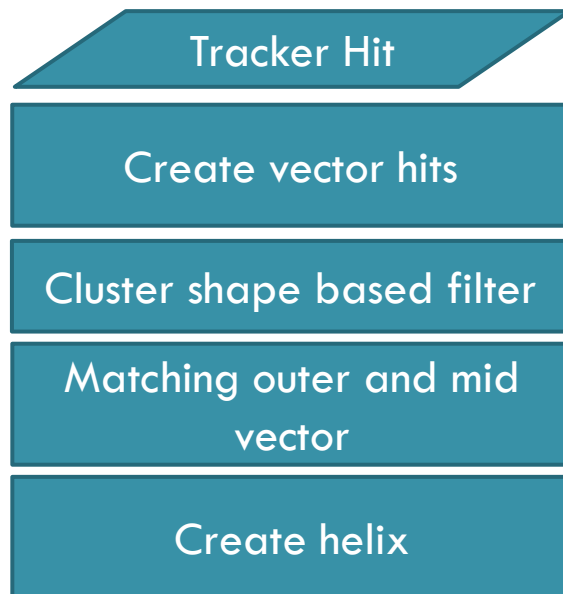
Vector hit : ↑



Track finding – Vector hit

19

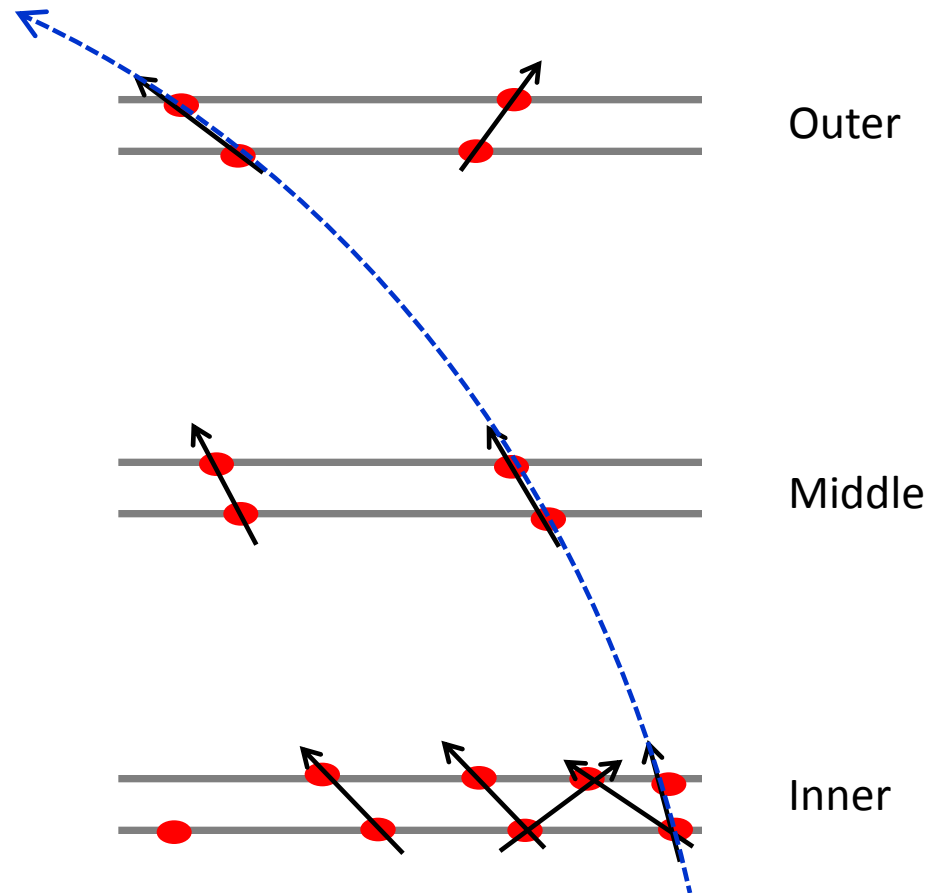
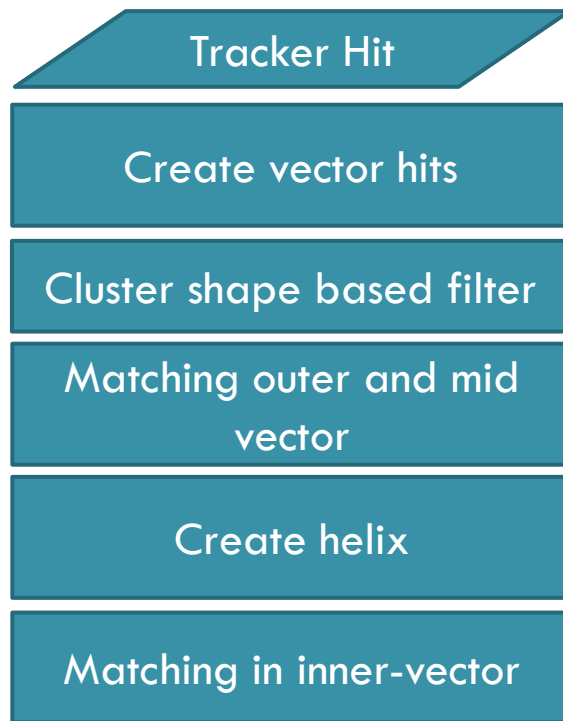
- Create helix by middle and outer layers. (Inner layers has heavy background.) → Speed-up will be expected.



Track finding – Vector hit

20

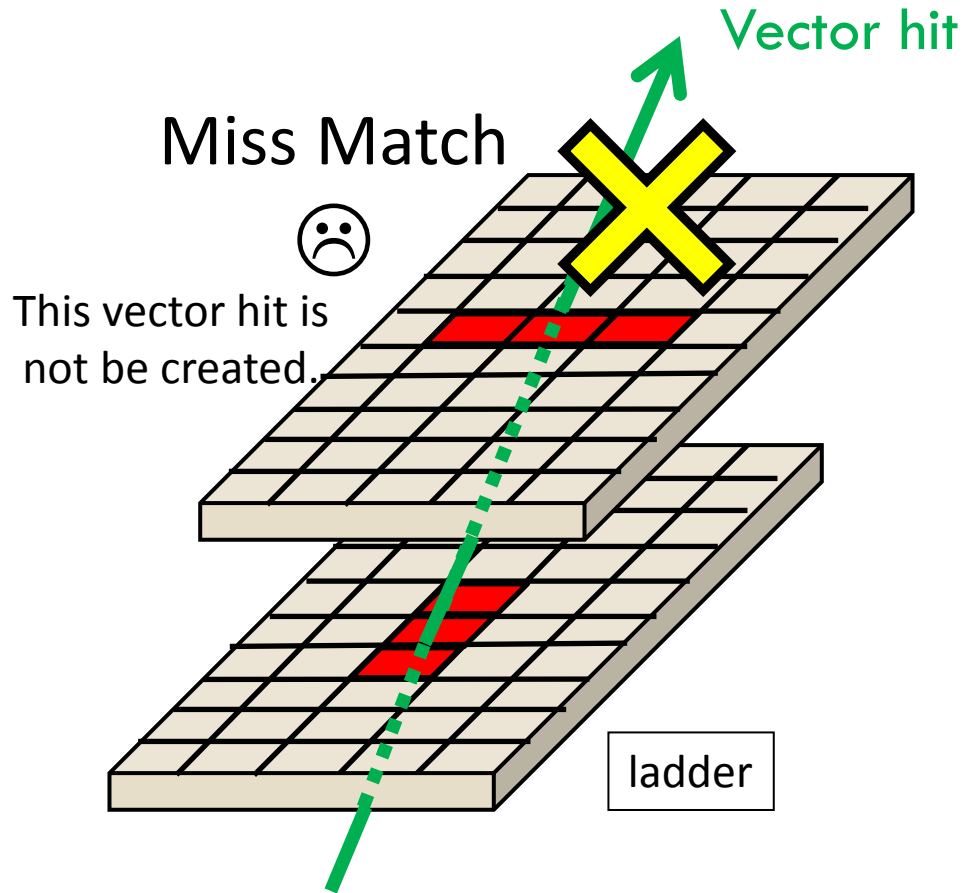
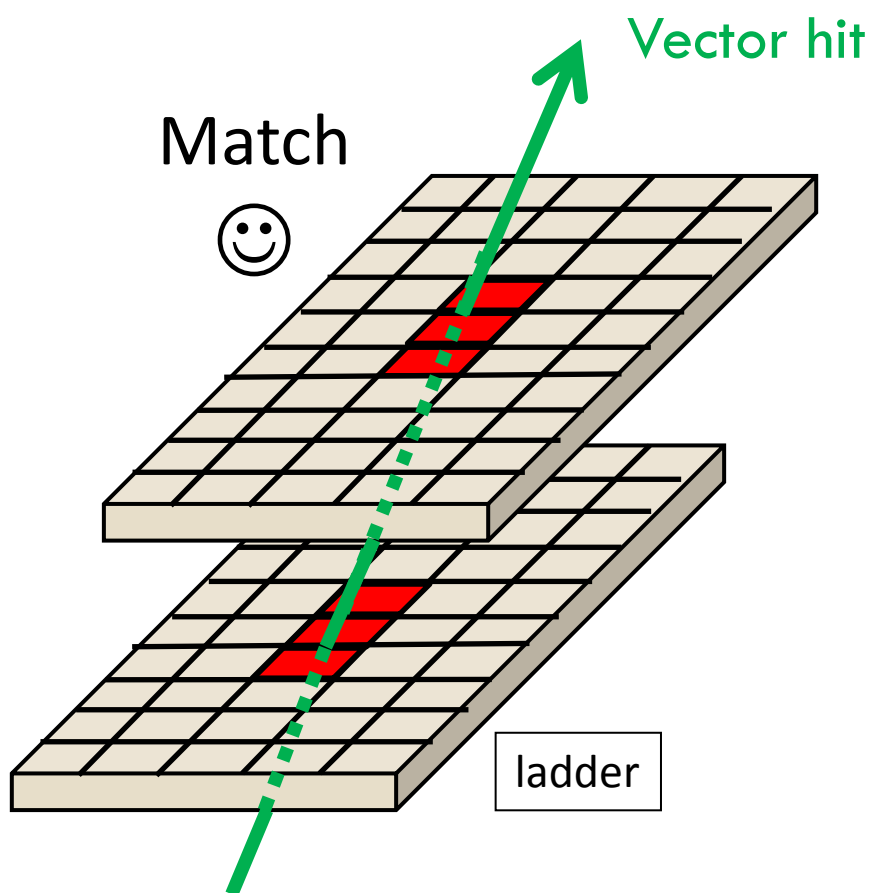
- Extrapolate the helix into inner layers and determine the track.



Track finding – Cluster shapes filtering

21

- Take consistency by cluster shapes in making vector hits.
 - More precise track finding can be expected.



Summery/Plan

22

- The simulation software for the performance study of FPCCD vertex detector were developed.
- FPCCD can **satisfy the IP resolution requirements.**
- **New tracking software** is being developed.

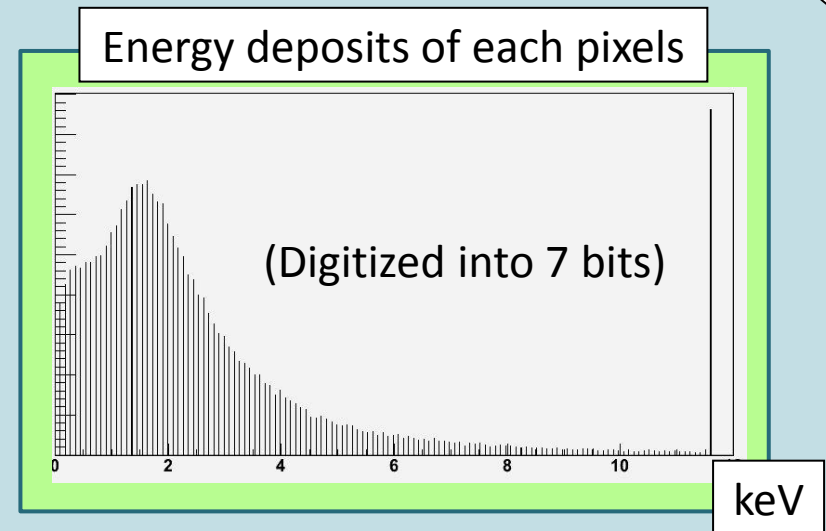
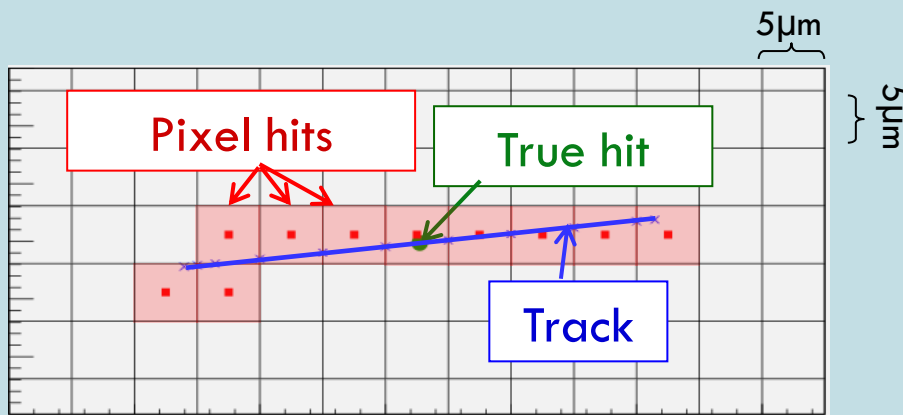
- Plan
 - ▣ Estimation of background effect.
 - ▣ Evaluate the performance of flavor tagging.

Back up

FPCCD Digitizer

24

- 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.



FPCCD Overlay

25

- FPCCD Overlay merge the data of background event into the data of physics event.
- If there are more than 2 hits in the same pixel, the processor adds the energy deposit of both hits.

Highest density region of innermost layer

