FPCCD reconstruction

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KILC 12

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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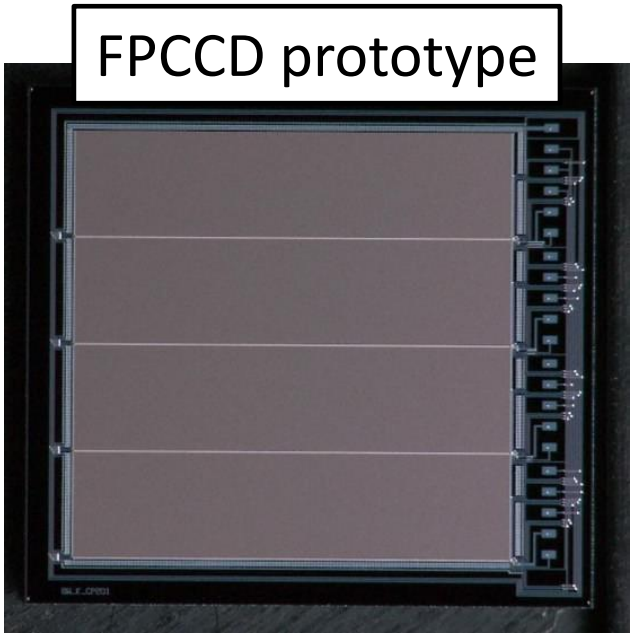
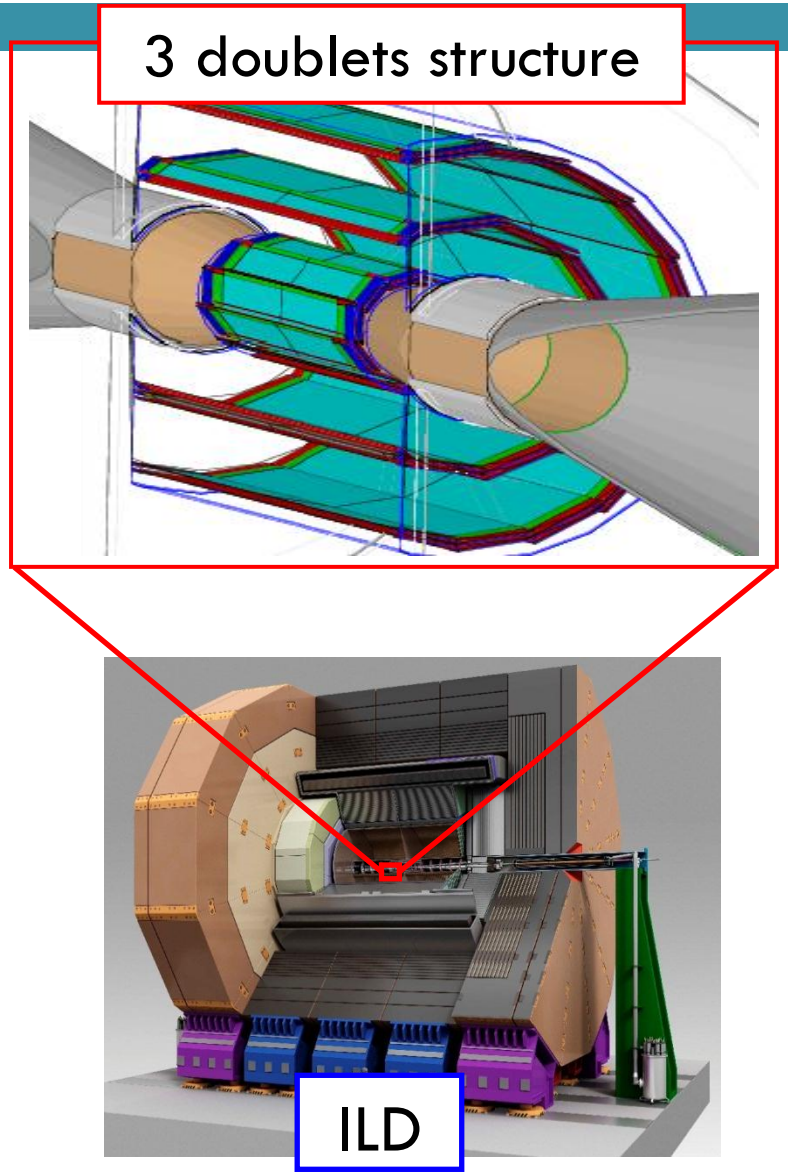
➡ One possible solution : FPCCD vertex detector

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

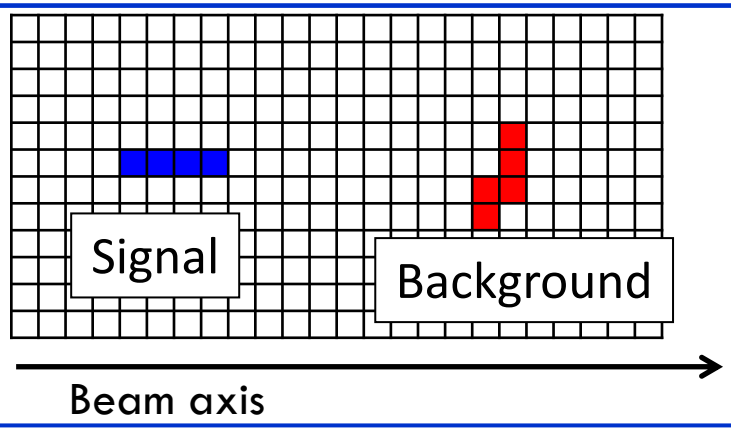


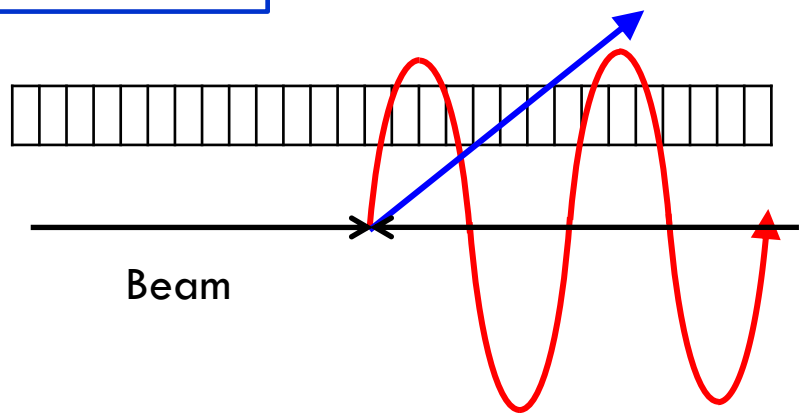


Advantage of FPCCD vertex detector

- 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

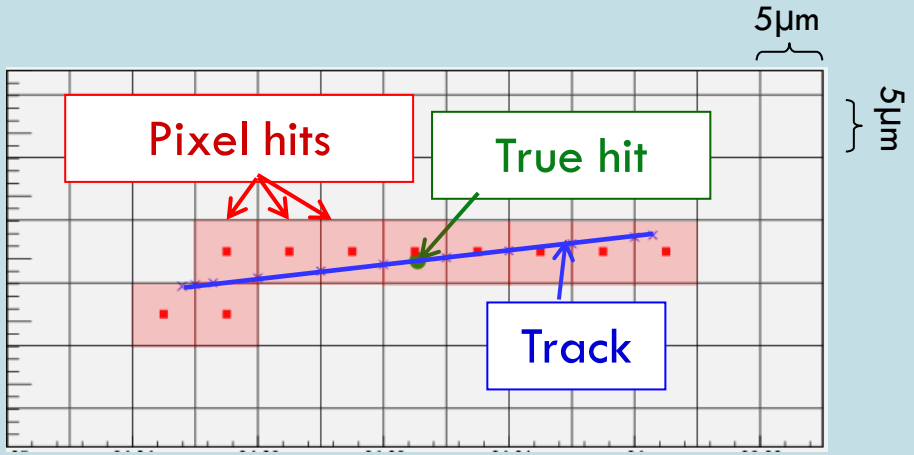
- To evaluate the performance of FPCCD vertex detector, FPCCD software has been developed.

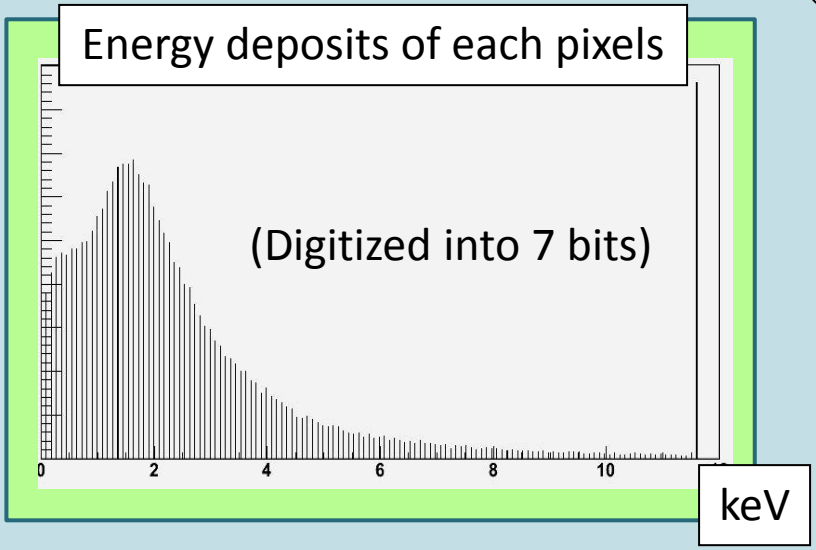
- Software for FPCCD simulation
  - FPCCDDigitizer
  - FPCCDClustering
  - FPCCDOverlayBX (merge background into physics event)

  These software has been developed and installed into MarlinReco.

FPCCDDigitizer

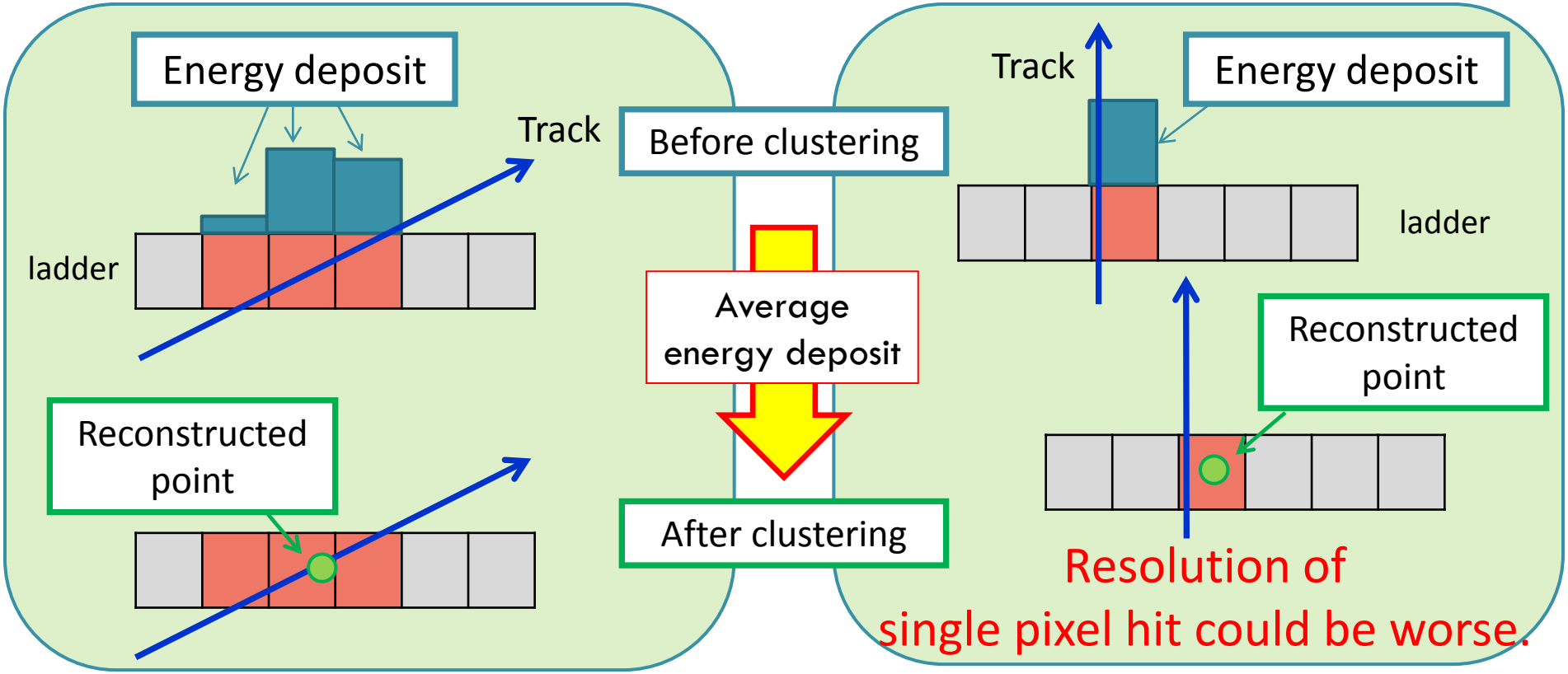
- The hit point and track momentum are obtained from Mokka.
- The trajectory is calculated by hit point and momentum.
- The pixel hit is identified by the intersection of track and boundaries of pixels.
- The energy deposit of hit is divided into pixels as proportional to path length then smeared by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





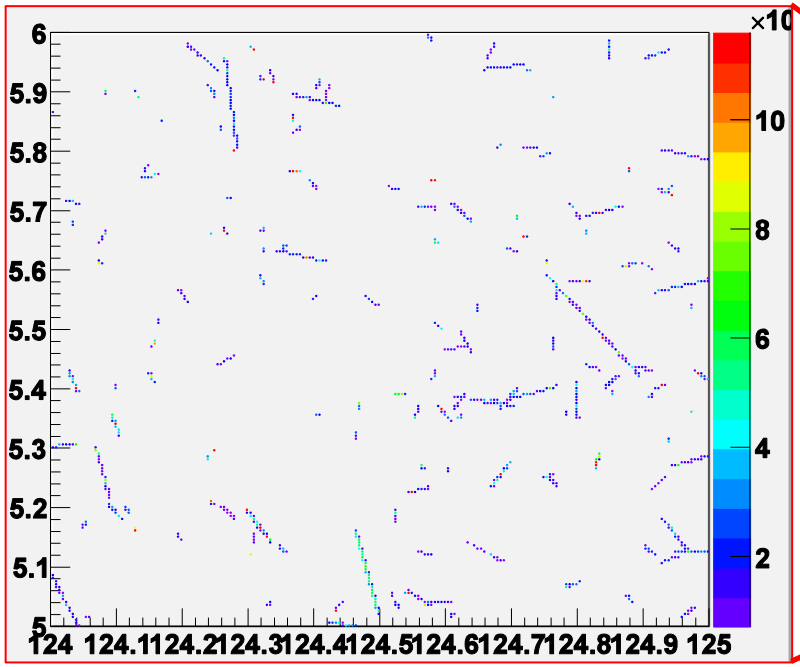
FPCCDClustering

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

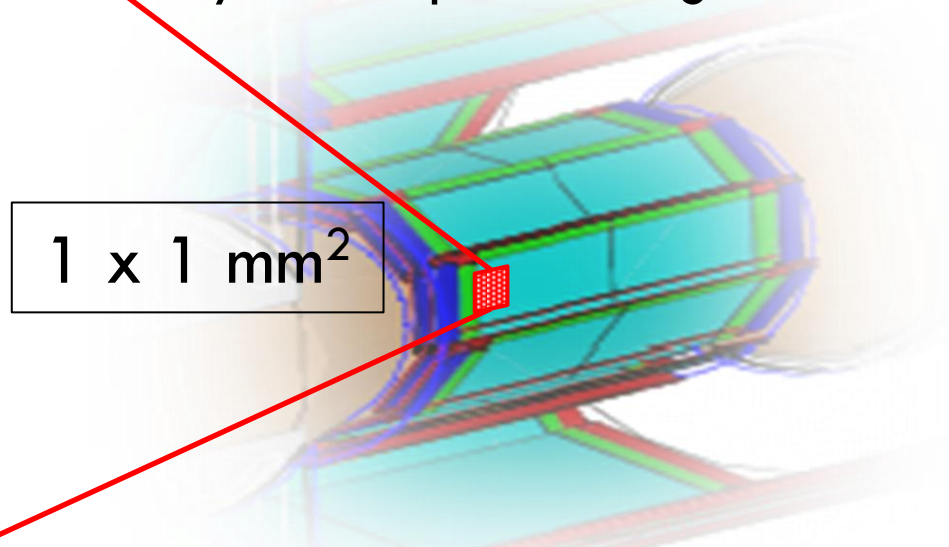


FPCCDOverlayBX

- 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

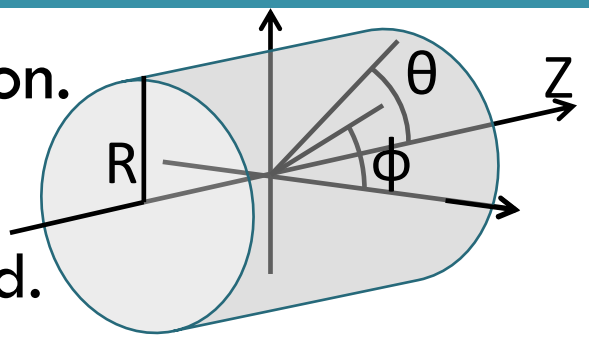
ilcsoft v01-13-05, ILD_O1_v02

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

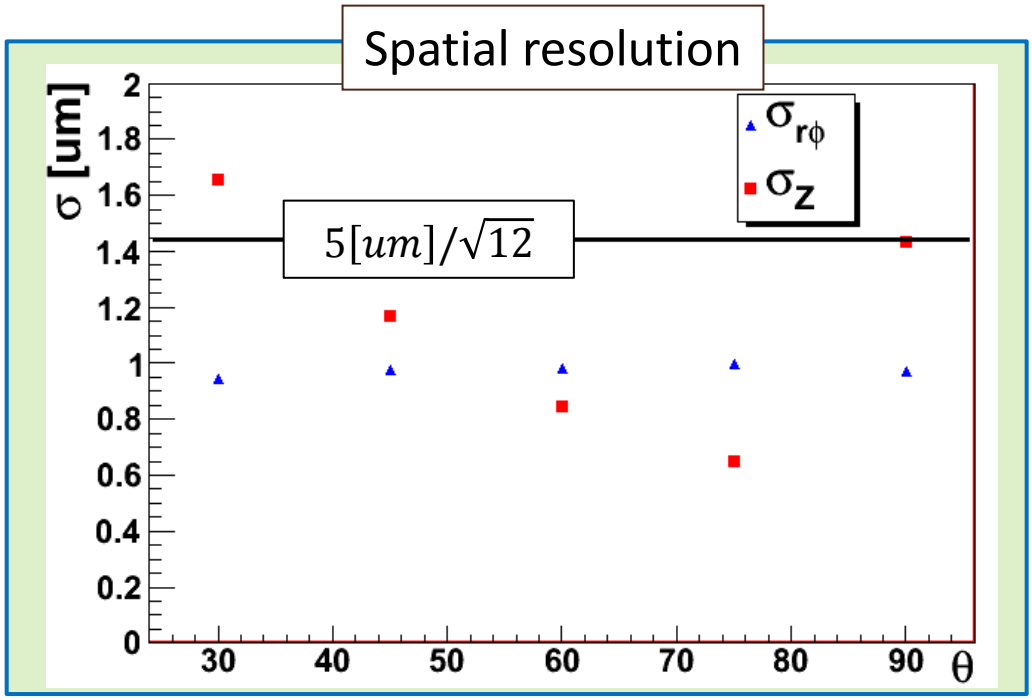
The energy deposits were digitized into 7 bits.

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.



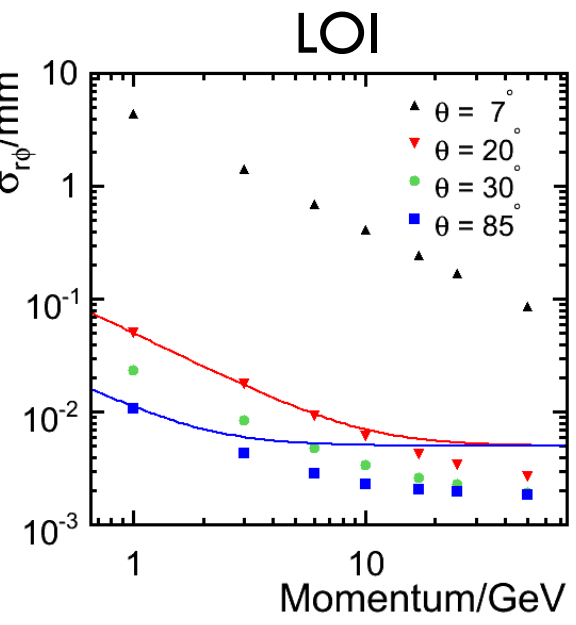
θ	σ_Z	$\sigma_{R\text{-}\phi}$
90°	1.5 um	0.94 um
75°	0.64 um	0.96 um
60°	0.83 um	0.96 um
45°	1.2 um	0.96 um
30°	1.6 um	0.98 um
LOI	2.8 um	2.8 um

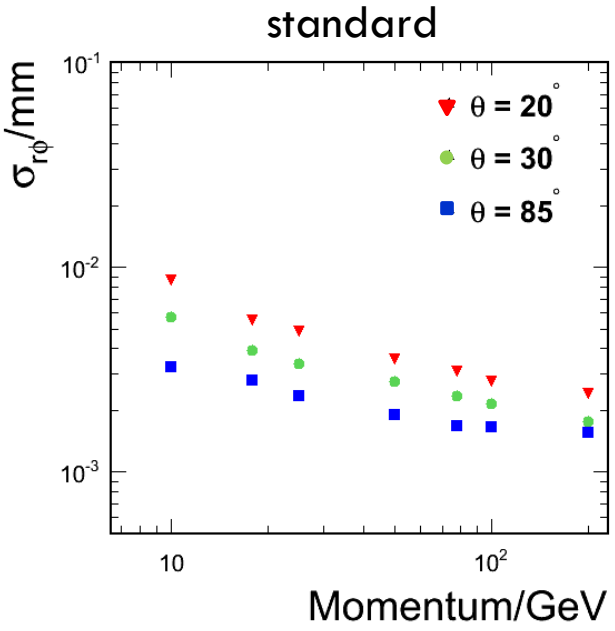


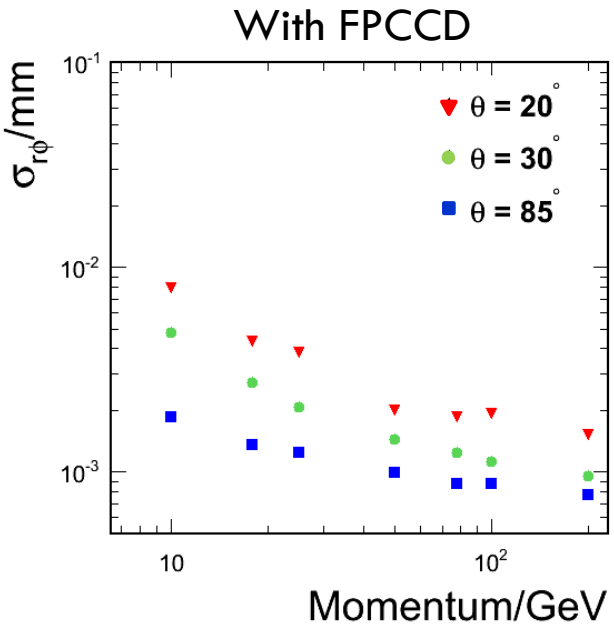
Impact parameter resolution

- Impact parameter resolution in R-Φ direction.
  - FPCCD can improve the IP resolution.

This study







Pair background study

- Pixel occupancy of pair background were checked by using FPCCD software.

- E_{CM} : 500 GeV
- Detector Model : ILD_01pre02
- data statistics : 1600 BX
- 1312 BX/train

Previous study

- E_{CM} : 1 TeV
- Detector Model : ILD_O1_v02
- data statistics : 20BX
- 2450 BX/train

This study

Pixel occupancy

- Pixel occupancy for 1train.
  - cut : signal e- > 200 e- /pixel
  - ~5 times greater than sb2009wTF-500 (# BX is different)

Layer	1TeV Without cut	1TeV With Cut	Sb2009wTF-500 w/ cut
1	20.1 %	15.5 %	3.079 %
2	10.1 %	7.79 %	1.74 %
3	0.854 %	0.674 %	0.0919 %
4	0.458 %	0.363 %	0.0731 %
5	0.145 %	0.116 %	0.017 %
6	0.116 %	0.094 %	0.015 %

This study

Summery / Plan

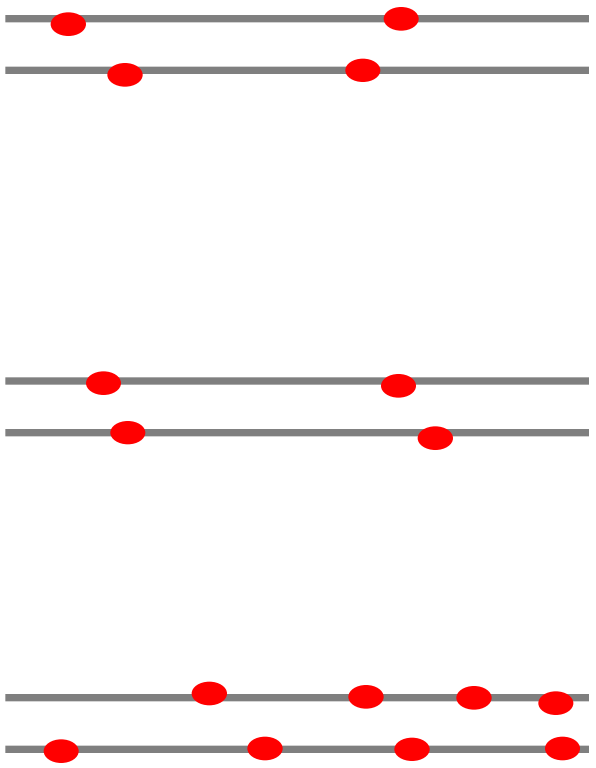
- FPCCD software has been developed. These are working correctly with latest version ilcsoft.
- FPCCD can improve the IP resolution.
- Pixel occupancy
  - 1 TeV occupancy is ~ 5times greater than sb2009wTF-500.

- Plan
  - Estimation of background effect.
  - Evaluate the performance of flavor tagging.
  - New tracking software utilizing the features of FPCCD vertex detector.

Track finding – Vector hit

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

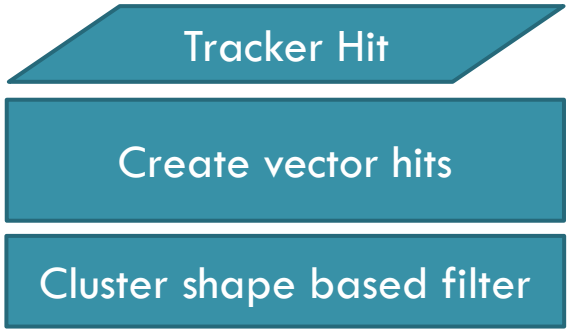
Tracker Hit

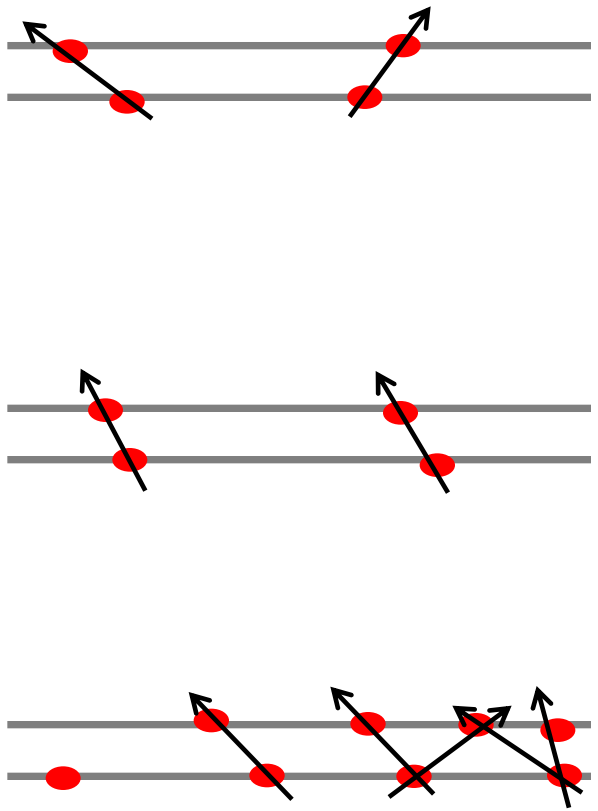


Track finding – Vector hit

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

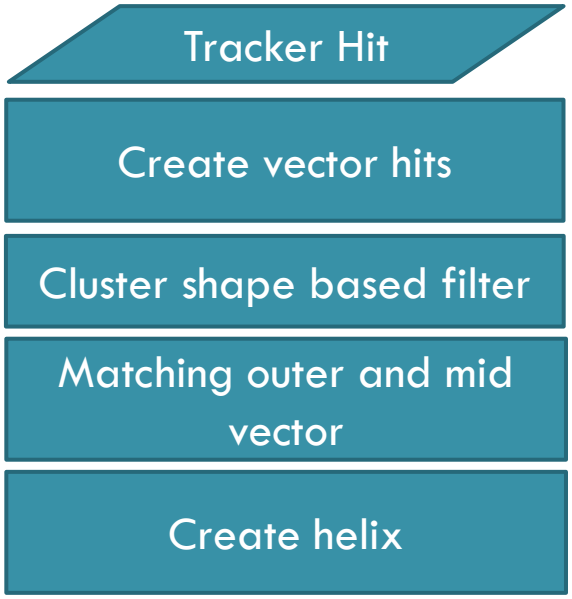
Vector hit : ↑

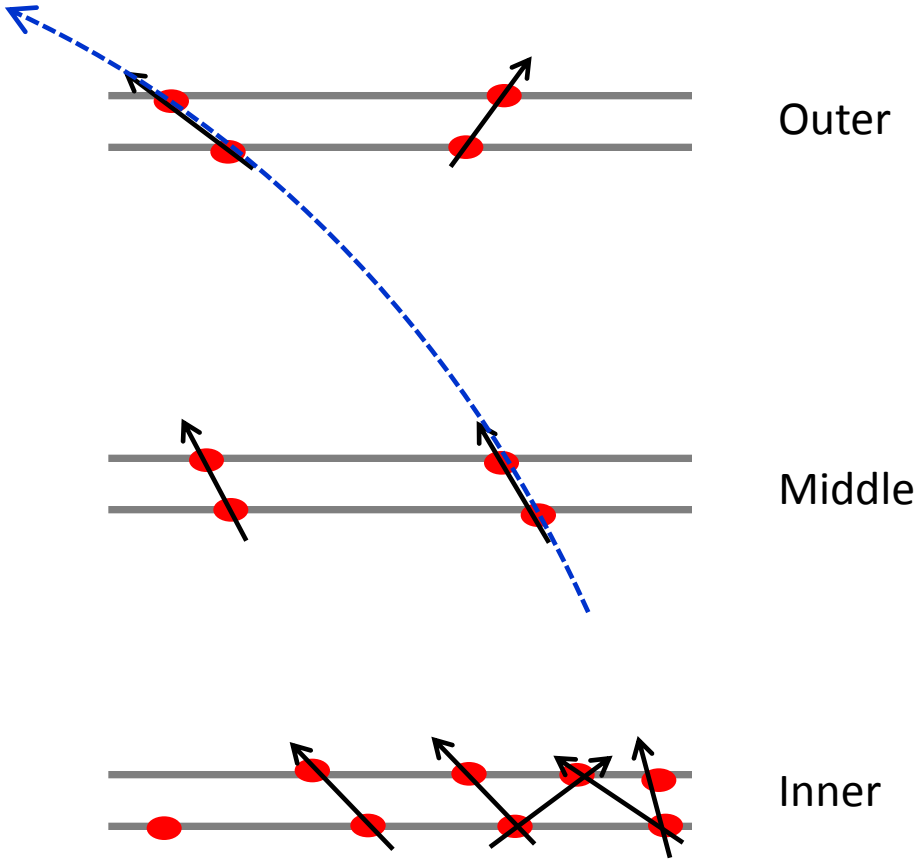




Track finding – Vector hit

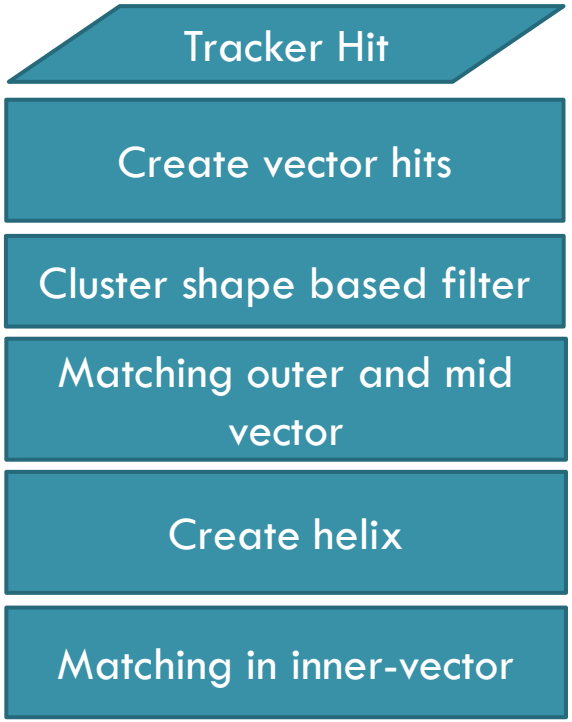
- Create helix by middle and outer layers. (Inner layers has heavy background.) → Speed-up will be expected.

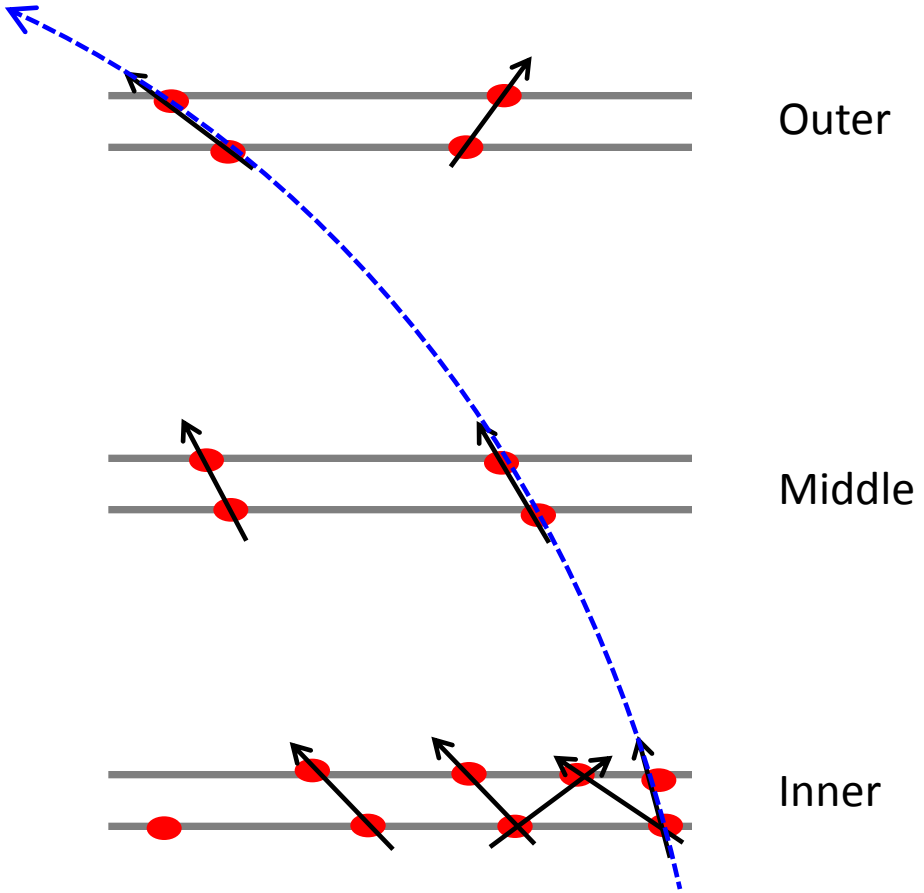




Track finding – Vector hit

- 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.