Simulation Study of the FPCCD Vertex Detector for the ILC

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Performance of the FPCCD based vertex detector for the ILC has been studied using Geant4 based simulation program developed for GLD. We present impact parameter resolutions, impact on track-hit matching efficiencies at the inner most layers by high background rates, performance of pair background rejection using cluster sizes.

1 Introduction

We have studied a vertex detector design based on CCD with very small pixels, FPCCD, using a Geant4 based simulation program developed for the GLD detector concept [2]. In the ILC, very large amount of pairs of e^+ and e^- are produced in collisions of very small beams, those pairs are expected to be very severe background in the vertex detector. From the study based on beam interaction simulation program, CAIN, a hit rate in an inner most layer of the vertex detector is estimated to be more then 50 hits / mm^2/train. Since FPCCD accumulate signals during a whole beam train, those pixels have to be as small as 5μm by 5μm to lower the background occupancy less than 1% level. Since those pairs have low transverse momentum, thus large incident angle tracks, FPCCD have to be 15μm thick fully depleted sensitive layers to reduce the background cluster sizes. Another feature of the vertex detector is that every two adjacent layers are put close together, gaps of those pair of layers are 2 mm. Here we show some geometrical configuration of the vertex detector in this simulation study in the Table 1. The thickness of each layer is 50 μm with 30 μm Si which is equivalent to materials of ladder supports, total material budget per layer is 80 μm Si or 0.09 % of X_0. We assume Be beam pipe with 250 μm thick and 18 mm radius. Details of the FPCCD vertex detector and other sub-detectors in GLD detector concept is described in GLD Detector Outline Document [2].

2 Expected Impact Parameter Resolutions

We use a Kalman filter based track fit program to study the impact parameter resolutions. In the track fitting procedure, only true hits of tracks in TPC, SIT and the vertex detector are used for the track fits. Using helix parameters of the fitted tracks, the impact parameters are calculated for muons with momentum between 0.5 GeV/c through 100 GeV/c. The impact parameters in the R-ϕ plane are show in Figure 1.As seen in the figure, the resolutions over momentum of 1GeV/c are comparable to that shown in [2], which is expressed as $\sigma_b \leq 5 \pm \frac{10}{p\beta \sin^{3/2}\theta}$ (μm).

Layer #	1	2	3	4	5	6
Radius (mm)	20	22	32	34	48	50
Length (mm)	65	65	100	100	100	100

Table 1: Radius and Length of the layers

3 Effects of Background in Track Finding

To evaluate track finding capability in very high background rate, which are expected more then 50 hits/mm^2/track in the two inner most layers, Layer 1 and Layer 2. Due to lack of a track finding program in software tool we used currently, we follow a procedure described below. In this procedure, we assume sizes of the clusters are negligible.

1. Perform track fitting with true hits of TPC, SIT and the vertex detector except for the hits of the two inner layers, Layer 1 and Layer 2.

2. Extrapolate the track onto Layer 2.

3. Calculate a distant between the extrapolated hit point and the true hit on Layer 2 and make a probability distribution function(PDF).

4. Generate true hit according to the PDF and background hits uniformly at 50, 100 and 200 hits/mm^2/train.

5. Accept that track fit successful if a distance of the true hit is less background hits from the expected hit point.

The procedure are carried out for tracks at $\cos\theta = 0$ and momentum between 0.5 through 4.0 GeV/c to evaluate the efficiencies to find true hits of the tracks. The results are show in Figure 3. As seen in the figure, inefficiencies are less than 10% below momentum of 0.5 GeV/s at background rate at 100 hits/mm^2/train. Since Layer 1 is very close to Layer 2, efficiencies of Layer 1 is almost same as ones of Layer 2. Thus, requiring two hits that one on Layer 1 and the other on Layer 2 are close enough to the track, inefficiency caused by background hits is reduced. Since in this study, cluster size and cluster overlaps are not taken into account yet, more detailed study is necessary.

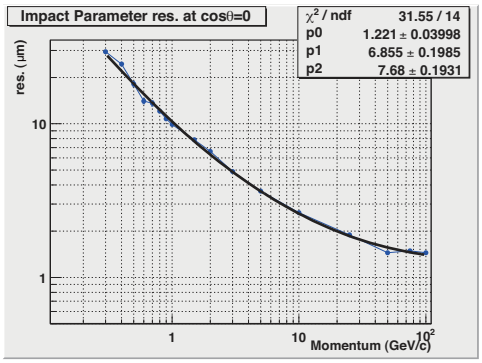

Figure 1: The momentum dependence of the mpact parameter resolution.

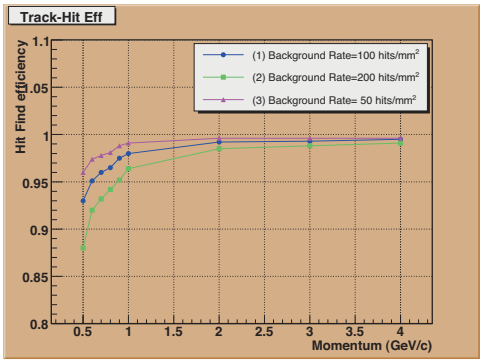

Figure 2: Efficiencies on Layer 2 under the background levels at 50, 100 and 200 hits/mm^2/train.

4 Rejection of Pair Background Clusters

Since the pair background tracks have large curvatures, those traverse several pixels as many as 8 pixels in the ϕ direction and as many as 6 in the z direction. And those numbers of traversed pixels are independent of the hit positions. On the other hand, the incident angles of the high momentum tracks to the vertex detector layers in R-ϕ plane are close to normal and traverse one or two pixels in the ϕ direction. Numbers of pixels traversed in the z directions depend on polar angles of tracks and are proportional to z positions from the interaction point. Using these differences of the cluster sizes, we can discriminate clusters of the pair background. Figure 3 shows the results after the rejection using cluster sizes. The figure shows that rejection factor for the pair background at large Z position is about 20, while the losses of the efficiencies for high momentum tracks are at level of 1%.

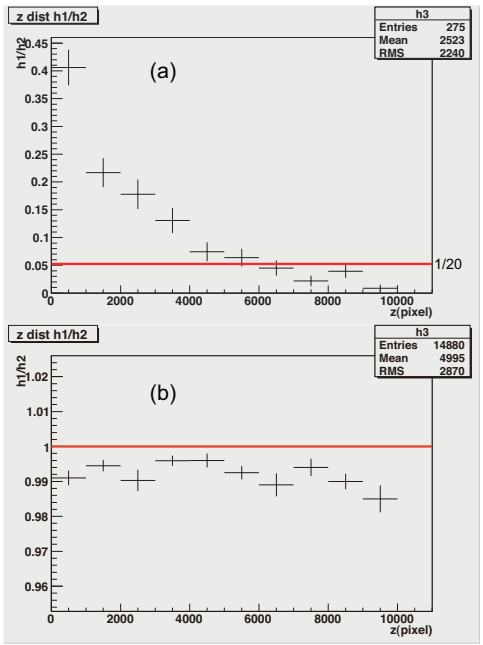

Figure 3: Z-dependent of Rejection factor for the pair background (a), and 1 GeV/c muon tracks (b), where unit of horizontal axis is a pixel.

5 Conclusions

We have studied the performances the vertex detector design sing the FPCCD sensor technology. The impact parameter resolutions are close to the requirements in GLD. The impact on tracking by very high level of background hits has been studied and is small enough at high momentum and tolerable at low momentum. The discrimination using cluster sizes is found to be very useful.

6 Acknowledgements

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7 Bibliography

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