Study issues of the vertex detector for GLD detector concept study

May 13, 2005

Abstract

In this document, we try to describe study issues of the vertex detector which is needed for the detector concept study of GLD, a large detector concept for ILC experiment. Questions on the vertex detector to be answered for the GLD concept study are listed. We show a list of tasks which is necessary to answer the questions. Those question/task list would not be a complete one. Feedback from any people interested in the GLD concept study is very welcome.

1. Introduction

Vertex detector is the most detector-concept independent sub-detector. One difference might be the requirement for self-tracking capability. For SiD, the self-tracking capability is mandatory. For large detector concepts (GLD and LDC), however, it is not necessarily so because track finding can be started from trackers outside the vertex detector, i.e., from TPC and Si inner tracker. As a consequence, a vertex detector option in which very high hit density is expected, such as fine pixel option described below, could be an attractive option for large detector concepts.

From a viewpoint of vertex detector concept (not technology), two options of sensors have been proposed for ILC vertex detector; standard pixel option and fine pixel option. In standard pixel option, the sensors have a typical pixel size of 20 μm and the signal is read out about 20 times per beam bunch train in order to reduce the pixel hit occupancy due to the beam background. In fine pixel option, the pixel size is as small as 5 μm and the signal for one bunch-train is accumulated and read out between trains. The study issues could be different between these two options.

2. Questions

2.1 Inner radius

Inner radius of the vertex detector is one of the key parameters which determines performance of the vertex detector. The following question should be answered to optimize the inner radius:

(1) What is the minimum radius of the beam pipe?

This question gives rise to new additional questions;

- How wide does synchrotron radiation (SR) spread? And what is the effect of the SR mask on the luminosity?
- What is the shape of the forward/backward dense core of the pair background? If the core hits the beam pipe, scattered electrons/positrons by the beam pipe cause a problem.

(2) How does physics output change as a function of inner radius and sensor thickness?

Impact on physics through b, c, and τ-tag efficiency and vertex-charge tagging efficiency would be the major concern.

2.2 Outer radius

Outer radius of the vertex detector and inner radius of Si inner tracker has to be determined based on the tracking efficiency and beam background level.

2.3 Angular coverage of the barrel region and need for forward disks

If the forward region is covered by the barrel part, the effective thickness of the detector becomes large and the impact parameter resolution is degraded due to multiple scattering. Merits and demerits of introducing forward disks should be investigated.

2.4 Support structure and readout electronics

Material budget of the vertex detector including sensors, support structure, and readout electronics affects the impact parameter resolution through multiple scattering. What is the allowable limit for the material and how can it be achieved?

2.5 Tracking efficiency under large beam background condition

At ILC experiment, hit density of the vertex detector due to the pair beam background is expected quite high. For the innermost layer put at R=20 mm in 3 T magnetic field, it is estimated 40 hits/mm^2 for the fine pixel option and 2 hits /mm^2 even for the standard pixel option (read out 20 times per bunch train). So it is not obvious whether we can get high track finding efficiency in such a high hit density.

In case of fine pixel option, however, we can expect background rejection using hit cluster shape because pair background particles have low pt (peak at around 20 MeV/c) and hit clusters are not parallel to z-axis.

2.6 Effect of other particle ID devices on flavor tagging

Vertex detector is the key component for jet flavor tagging, but actually the flavor tagging is done including information of other detectors. So far, particle ID capability (π/K separation) of the detector system has not been considered in the study of flavor tagging. Is it really useless?

3. Tasks

Tasks needed for answering the questions above are described bellow. The tasks with [priority 1] should be done as soon as possible, at least by the 8th ACFA Workshop in July, and the tasks with [priority 2] should be done by or at the Snowmass meeting in August.

3.1 Machine-related issues

(1) Design of SR mask and estimation of luminosity loss [priority 2]

(2) Pair background simulation [priority 1]

Those tasks are necessary to answer the questions 2.1(1) and we need help from accelerator people, particularly for (1). The pair background simulation includes the study of background rejection using hit-cluster shape mentioned in 2.5.

3.2 Detector simulation

(1) Study of tracking efficiency with beam background hits overlapped [priority 2]

This task is for questions 2.2 and 2.5. Full simulation study of tracking efficiency both for single track and for tracks in a jet should be done. This task is crucial for fine pixel option, but also necessary for standard pixel option.

(2) Simulation for flavor tagging efficiency using $e^+e^- \rightarrow ZH$, $H \rightarrow bb$, cc, $\tau\tau$

(3) Simulation for vertex-charge tagging efficiency using $e^+e^- \rightarrow W^+W^-$, tt, $\chi_1^+\chi_1^-$

These studies are relevant not only to the vertex detector but also to the total detector system, and give answer to questions 2.1(2) and 2.6.

3.3 Engineering design

(1) Study of wafer thinning

(2) Design of the support structure and readout electronics

These studies determine the material budget of ladders, and are relevant for questions 2.3 and 2.4.

4. Initial design parameters

Design parameters of the vertex detector which will be the initial input to the studies are listed in Table.1. for both standard pixel and fine pixel options. Some of the parameters are very aggressive and their feasibilities are not demonstrated yet.

Table. 1. Initial design parameters of the vertex detector.

		Fine Pixel Option	Standard Pixel Option
Pixel size		5 μm	20 μm
Point resolution		1.5 μm	3 μm
Number of layers		6 (2x3)	4
Radii of layers		20, 22, 32, 34, 48, 50 mm	20, 30, 40, 50 mm
Half length of ladders		65,65,100,100,100,100 mm	65, 100, 100, 100 mm
Wafer thickness		50 μm	
Epitaxial layer thickness		15 μm	
Forward disks	Z	120, 122 mm	120 mm
	R	40 – 58 mm (0.9<cosθ<0.95)	
Beam pipe	R	15 mm	
	thickness	250 μm (Be)	