Linear Collider Vertex Detector Optimization for Higgs Branching Ratio Measurements [1]

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Abstract. The Higgs branching ratio measurement is a premier goal of the next Linear Collider physics program. Variations of a CCD vertex detector have been studied to assess the impact of inner radius and hit precision on the measurement of the Higgs branching ratios. A small dependence is found when the beampipe radius is varied between 1.2 cm and 2.4 cm, and the hit precision between 3 μm and 5μm.

INTRODUCTION

Vertex detection played an essential role at LEP and SLC. We can expect the next electron positron collider to see even better performance, as the physics program calls for it. [1] The best performance to date was achieved by the SLD final vertex detector, VXD3 [2], based on CCDs. The linear collider environment is ideally suited for the use of CCDs, with the low collision rate, and modest backgrounds. This study investigates the sensitivity of the Higgs branching ratio measurements to variations in parameters of the CCD vertex detector.

CCD VERTEX DETECTOR

Figure 1 displays the layout for a 5 barrel CCD vertex detector proposed for the future high energy linear collider. [3] It builds on the experience of the SLD VXD3, with improved performance coming with the increase from 3 barrels to 5, the reduction of the radius of the inner barrel from 2.8 cm to 1.2 cm, thinning of the ladders from 0.4% X_0 to 0.12%, and other advances. Table 1 summarizes some of these improvements.

The choice of a specific configuration, such as that illustrated in Figure 1 involves the compromise and optimal trade-offs between many parameters. Some of these

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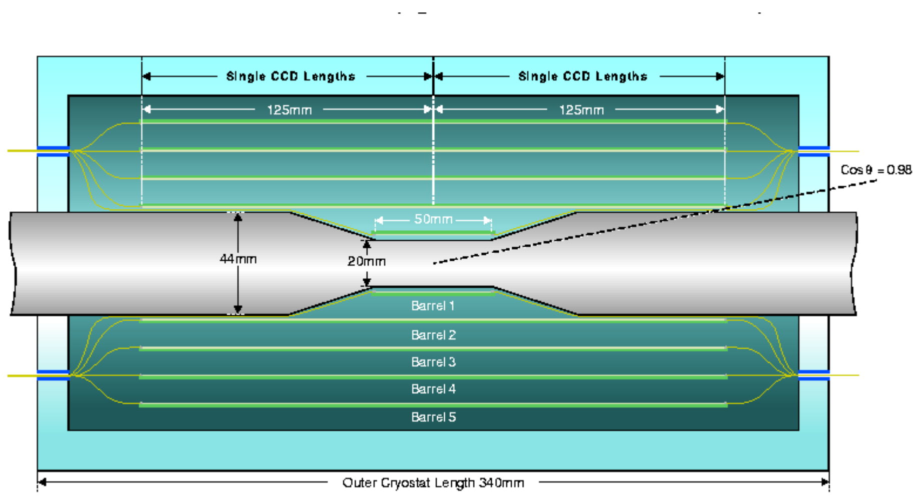

FIGURE 1. Proposed CCD vertex detector for a future high energy linear collider.

are the inner radius of the vertex detector, the number of barrels in the detector, the angular coverage of the detector, the hit resolution, and the thickness of the detector layers. An example of how these choices determine performance is shown in Figure 2, where we display the impact parameter resolution for several possible parameter choices at a high energy linear collider, along with the resolution of VXD3 [4]. Ultimately, the best test is the impact on the measurement of specific physics processes. As a gauge of this, we have investigated the precision of the Higgs branching ratio measurements. Our analysis of this is presented in more detail in the companion paper to this conference. [5]

These results are sensitive to the design of the outer detector, specifically the tracking and calorimeter performance. For the purposes of this study, we have assumed the large detector of the American Linear Collider Working Groups. [6]

Two key detector parameters have been varied: the inner barrel radius and the hit resolution. The 140 GeV/c^2 Higgs branching ratio measurements from the reaction $e^+e^- \to Z^0h$ are presented here. (Results for $m_H = 120MeV/c^2$ are presented in [5].) Table 2 lists the values for the parameters assumed for each configuration, c1-c5. The outer barrel is fixed at a radius of 6 cm, and the five barrels are equally spaced. The integrated luminosity is assumed to be 500 fb^{-1}, equally divided between 80% right-handed and 80% left-handed electron polarization. Vertex reconstruction was done with the ZVTOP algorithm developed by SLD [7].

ANALYSIS

Event selection is described in Reference [5]. The final selection is based on a neural net analysis optimized for the separation of the individual Higgs decay modes. Following the selection of events with reconstructed Z's and recoil masses

TABLE 1. CCD Vertex Detector Parameters.

	VXD3	future
Number of Barrels	3	5
Beampipe radius	2.4 cm	1.0 cm
Beampipe thickness	0.35% X_0	0.16% X_0
Inner barrel radius	2.8 cm	1.2 cm
Inner barrel length	6.4 cm	5 cm
Outer barrel radius	4.8 cm	6 cm
Outer barrel length	6.4 cm	25 cm
3 hit coverage	$\cos\theta < 0.8$	$\cos\theta < 0.9$
Ladder thickness	0.4% X_0	0.12% X_0
Hit resolution	4 μm	<4 μm

consistent with the Higgs, the $h \to b\bar{b}$ efficiency is about 70%, and the $c\bar{c}$ efficiency is about 48%. Table 2 presents the results of the analysis for the five detector parameter sets studied. Increasing the inner barrel from 1.2 cm to 2.4 cm reduces the signal to background ratio in the charm channel by 9%, from a reduced charm efficiency and an increased background. This translates into the 5% variation in the $h \to c\bar{c}$ error. Since this measurement is not very sensitive to the separation of secondary and tertiary vertices, it is probably less constraining on the vertex detector parameters than some other physics studies might be.

TABLE 2. 140 GeV/c^2 Higgs branching ratio errors for each vertex detector configuration.

	BR(%)	c1	c2	c3	c4	c5
Inner barrel radius		1.2 cm	2.4 cm	1.2 cm	2.4 cm	1.2 cm
CCD hit resolution		5 μm	5 μm	3 μm	3 μm	4 μm
$h \to b\bar{b}$	34 %	±1.3 %	±1.3 %	±1.3 %	±1.3 %	±1.3 %
$h \to WW^*$	51 %	±1.9 %	±1.9 %	±1.9 %	±1.9 %	±1.9 %
$h \to c\bar{c}$	1.4%	±0.67%	±0.70%	±0.66%	±0.69%	±0.67%
$h \to gg$	3.5%	±2.4%	±2.4%	±2.4%	±2.4%	±2.4 %
$h \to \tau^+\tau^-$	3.6%	±0.6 %	±0.6 %	±0.6 %	±0.6 %	±0.6 %

CONCLUSIONS

This study shows that the precision of the Higgs branching ratio measurements based on a neural net analysis are weakly sensitive to the vertex detector param-

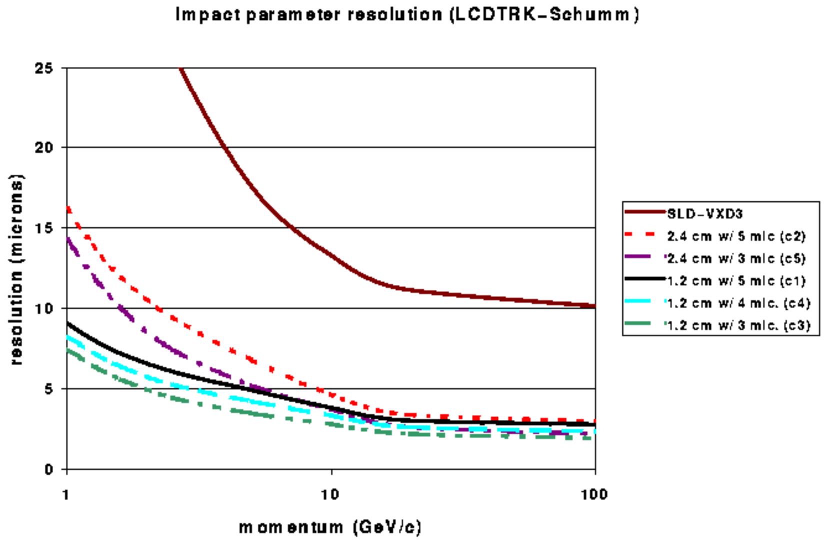

FIGURE 2. Vertex detector impact parameter resolution for several design choices: from top to bottom at low momentum a.) SLD-VXD3, b.-c.) 2.4 cm inner radius with 5 μm and 3 μm resolution, d.-f.) 1.2 cm inner radius with 5 μm, 4 μm, and 3 μm resolution.

eters, within the range being considered for the Next Linear Collider. The largest sensitivity appears in the $h \to c\bar{c}$ channel. Other physics goals of the next Linear Collider, namely those involving clear secondary/tertiary vertex reconstruction, may be more sensitive.

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