A Study of VTX Detector Geometry for Flavour Tagging

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This study was aimed at discovering the influence of Vertex Detector (VTX) geometry on results of flavour tagging in International Linear Collider (ILC), basing on fast simulation. Flavour tagging was tested in $e^+e^- \to hZ \to 4jets$ @ 500 GeV in presence of standard model background. Both SM and MSSM higgs bosons were simulated. Precision of measurement of higgs boson branching ratio $\Gamma(h \to c\bar{c})$, $\Gamma(h \to b\bar{b})$ was determined for different sets of VTX parameters. VTX detector parameters taken into account included thickness of detector layer, spatial resolution of a single layer, position of innermost layer. The rest of the detector was described according to TESLA TDR [1] which is very similar to Large Detector Concept (LDC).

1. SIMULATION

Performance of the VTX detector for flavour tagging was tested on $e^+e^- \to hZ, (h \to c\bar{c}, b\bar{b})(Z \to 2jets)$ events at 500 GeV centre of mass energy assuming 500 fb^{-1}. The SM background processes : $e^+e^- \to W^+W^-$, $e^+e^- \to q\bar{q}$, $e^+e^- \to ZZ$ and other higgs decay modes were taken into account. Both signal and background events were generated using PYTHIA [2], assuming the SM higgs boson mass $\mathrm{M}_h = 127$ GeV. In the MSSM, masses, widths and branching ratios of the higgs bosons were calculated using HDECAY [3] for: $\mathrm{M}_A = 350$ GeV, $\mathrm{M}_2 = 200$ GeV, $\mathrm{A}_{\tilde{f}} = 2450$ GeV and the lightest higgs boson ($\mathrm{M}_h = 127$ GeV) was used in simulations. Detector response was modelled using Simulation á Grande Vitesse 2.30 (SGV), a fast simulation program allowing simplified definition of the entire detector geometry. A 5 layer, long - barrel VTX detector with geometry shown in Figure 1 and layer radii listed in Table I was simulated. A beryllium beampipe of 0.25 mm thickness and 14 mm radius was assumed. Simulations were made for detector layer thickness 50, 150, 300 μm, track spatial resolution 2, 5, 10 μm for all five layers or with the innermost layer removed [1]. Except for the VTX, entire detector was described as in the TESLA TDR.

2. ANALYSIS

The $e^+e^- \to hZ, (h \to c\bar{c}, b\bar{b})(Z \to 2jets)$ events were selected using cuts: $E_{vis} > 0.8\, E_{cms}$, $|p_t| < 20$ GeV, $|p_z| < 30$ GeV, $|cos(\theta_{thrust})| < 0.7$. Jets were identified using the JADE algorithm. Jet energies were rescaled to achieve energy and momentum conservation, keeping jet velocities fixed. From all pairs of jets the one with invariant mass ($\mathcal{M}_{ij}$) closest to the mass of Z was chosen. The remaining pair was assumed to originate from the higgs boson decay and selections $|\mathcal{M}_{ij} - M_Z| < 10$ GeV, $|\mathcal{M}_{other\ pair} - M_h| < 10$ GeV gave a good rejection of background from processes other than higgs boson production.

To distinguish between different higgs decay modes a neural network (NN) based jet tagging algorithm was used. Number of secondary vertices in each jet was determined using ZVTOP [4]. Number of these vertices along with

[1] In some accelerator designs the beampipe radius is higher than 14 mm which may cause the need to remove the innermost layer or redesign the detector.

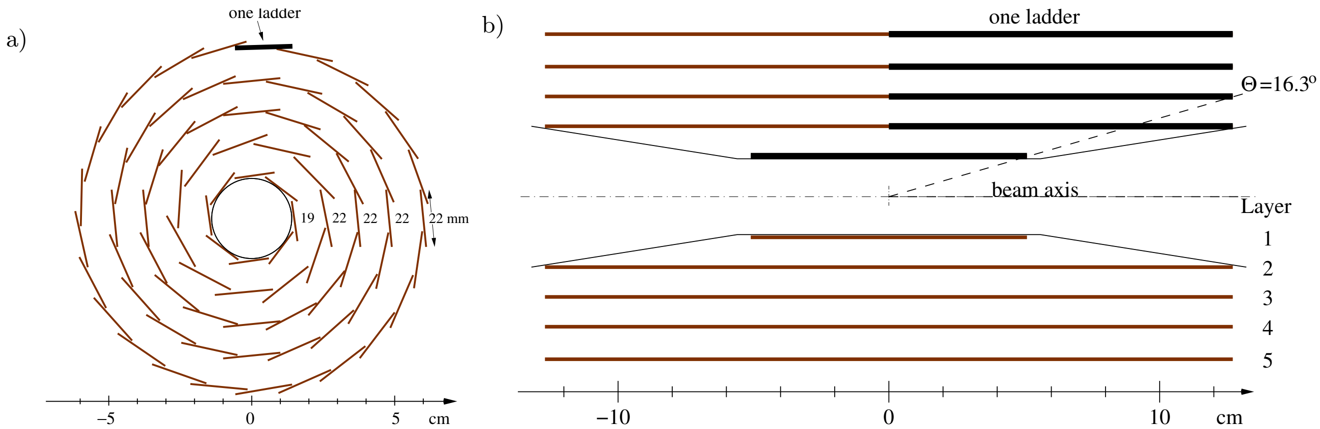

Figure 1: VTX detector geometry a) XY view, b) RZ view.

Table I: VTX detector layer specifications.

Layer	Radius	# of ladders
1	15 mm	8
2	26 mm	22
3	37 mm	32
4	48 mm	40
5	60 mm	50

other jet properties (number of charged particles at secondary vertices, raw momentum of a jet, invariant mass of a jet corrected for invisible particles, distance between vertices, impact parameters of tracks in a jet and other) were used as an input for NN [2] which returned probabilities, c-tag and b-tag, of jets originating from a "c" or "b" quarks.

Events of higgs decays $h \to c\bar{c}, h \to b\bar{b}$ were selected using c-tag and b-tag values respectively. Cuts on the values of c-tag and b-tag were optimised to achieve the best statistical accuracy of measurement of the corresponding branching ratio.

Similar analysis was performed and precision of measurement of branching ratios was calculated for every set of detector parameters. Results for both SM and MSSM higgs bosons are shown in Figure 2.

Acknowledgments

This work was partially supported by the Polish Committee for Scientific Research, grants no. 1 P03B 040 26 and 115/E - 343/SPB/DESY/P-03/DWM 517/2003-2005. The authors greatly acknowledge the support of DESY.

References

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[2] In fact there were several neural networks to choose from depending on number of secondary vertices.

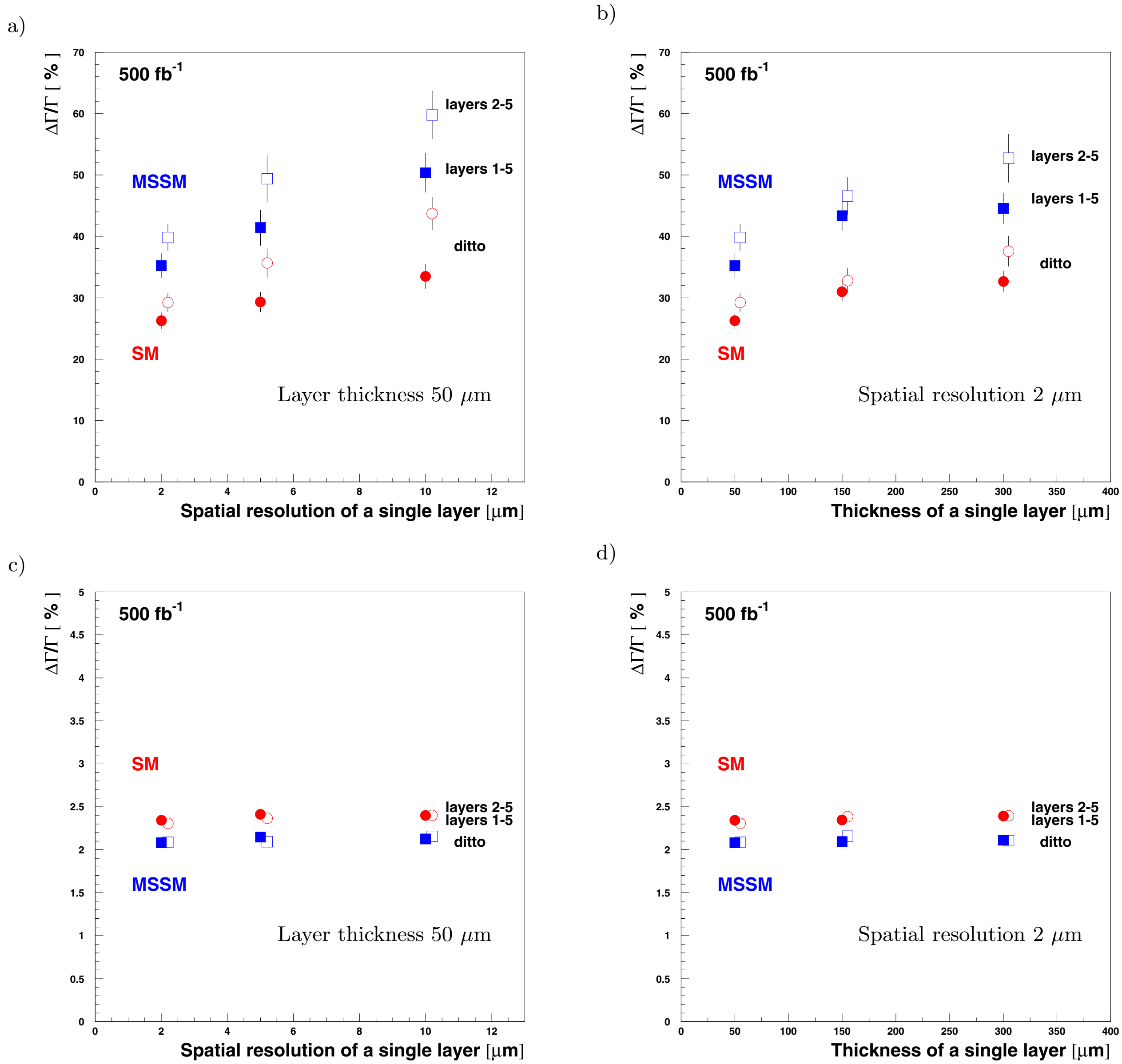

Figure 2: Precision of measurement of SM and MSSM higgs boson branching ratio. a) $\Delta\Gamma/\Gamma$ $(h \to c\bar{c})$ as a function of spatial resolution and b) layer thickness. c) $\Delta\Gamma/\Gamma$ $(h \to b\bar{b})$ as a function of spatial resolution and d) layer thickness.

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