CCD Vertex Detector Charm-Tagging Performance in Studies of Scalar Top Quark Decays

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The importance of the vertex detector performance for c-quark tagging in scalar top quark decays is discussed for a Linear Collider (LC). The quality of the c-quark tagging in this benchmark reaction depends on the detector design. The influence of the material thickness of the detector layers, and the number of sensitive layers has been considered.

It is a challenge to develop a vertex detector for a future LC. Key aspects are the distance to the interaction point of the innermost layer (radiation hardness, beam background), the material absorption length (multiple scattering) and the tagging performance. While at previous and current accelerators (e.g. SLC, LEP, Tevatron) b-quark tagging has revolutionized many searches and measurements, c-quark tagging will be a very important tool at a future LC. A CCD detector for a future LC (Fig. 1), being developed in the LCFI Collaboration [1], is considered. The benchmark reaction $e^+e^- \to \tilde{t}_1\bar{\tilde{t}}_1 \to c\tilde{\chi}_1^0\bar{c}\tilde{\chi}_1^0$ is studied in the framework of the Supersymmetric extension of the Standard Model. The expected signal consists of two charm jets and missing energy.

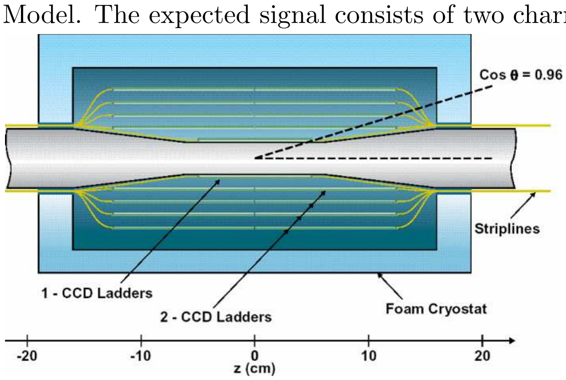

Figure 1: Five CCD layers at 15, 26, 37, 48 and 60 mm. Each layer contributes less than 0.1% radiation length. The CCD clocking speed is up to 50 MHz. The detector is characterized by a low power consumption and good radiation hardness.

1 Signal and Background Cross Section

Two scenarios are considered: 1) for comparison with previous 'SGV' studies [2] $m_{\tilde{t}_1} = 180$ GeV, $m_{\chi_1^0} = 100$ GeV, and 2) for 'SPS-5 SUSY' parameters [2] $m_{\tilde{t}_1} = 220.7$ GeV, $m_{\chi_1^0} = 120$ GeV. For this study no beam polarization is considered, however, beam polarization is very important for mass and mixing angle determination [2]. The signal and background cross sections (in pb) are:

$\tilde{t}_1\bar{\tilde{t}}_1$(180/220.7)	Weν	WW	q$\bar{q}$	t$\bar{t}$	ZZ	eeZ
CALVIN32	GRACE	WOPPER	HERWIG	HERWIG	COMPHEP	PYTHIA
0.0532/0.0164	5.59	7.86	12.1	0.574	0.864	0.6

2 Preselection Comparison with Previous SGV Simulation

Signal and background events have been generated for $\sqrt{s} = 500$ GeV and passed through the SIMDET 4.03 detector simulation [2]. The 1000 fb^{-1} simulation is compared to a previous SGV simulation in regard to signal efficiency and numbers of expected background events for $m_{\tilde{t}_1} = 180$ GeV:

Channel	Generated events	Preselection/500 fb^{-1}	Previous SGV
c$\tilde{\chi}^0_1\bar{c}\tilde{\chi}^0_1$	50 k	48%	47%
q$\bar{q}$	12169 k	64963	46788
t$\bar{t}$	620 k	32715	43759
eeZ	5740 k	24864	4069
ZZ	560 k	3100	4027
Weν	4859 k	252367	252189
WW	6800 k	122621	115243
Total backgr.		500631	466075

After additional cuts, $E_{\rm vis}/\sqrt{s} < 0.52$ and $P_{\rm t}/E_{\rm vis} > 0.05$, the following numbers of events are obtained:

Channel	q$\bar{q}$	WW	Weν	t$\bar{t}$	ZZ	eeZ	Total
Total background	6801	23278	226070	5267	125	2147	263691

The total number of background events agrees well with the previous 278377 events for the SGV simulation.

3 Iterative Discriminant Analysis (IDA)

The signal to background ratio is optimized by the IDA method [2]. First, the signal efficiency is reduced by 50%, which removes most background events. Without c-quark tagging 7815 (cf. SGV 7265) background events remain, while with c-quark tagging this number is reduced to 3600 events. Second, the IDA method is repeated. Figure. 2 shows the background composition after IDA step 2 without c-quark tagging and the tagging performance after IDA step 1. For a 180 GeV signal and 12% detection efficiency 680 (cf. SGV 400) background events remain without c-quark tagging, while with c-quark tagging 165 background events are expected.

4 SPS-5 Results for a 220.7 GeV Scalar Top

For 25% (12%) efficiency 3800 (1800) signal events and 5400 (170) background events without c-quark tagging remain, while the background is reduced to 2300 (68) events with c-quark tagging.

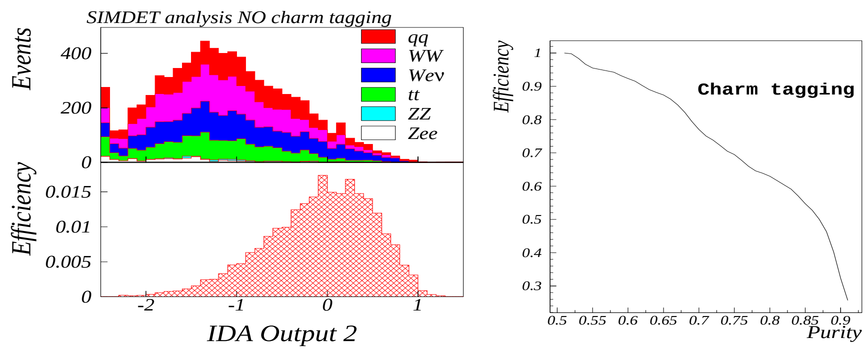

Figure 2: Left: IDA output. Right: Efficiency vs. purity of c-quark tagging after IDA step 1.

5 Varying Vertex Detector Design

The vertex detector absorption length is varied between normal thickness (TESLA TDR) and double thickness. In addition, the number of vertex detector layers is varied between 5 layers (innermost layer at 1.5 cm as in the TESLA TDR) and 4 layers (innermost layer at 2.6 cm). For SPS-5 parameters the following number of background events remain:

Thickness	Layers	12% Signal efficiency	25% Signal efficiency
Normal	5 (4)	68 (82)	2300 (2681)
Double	5 (4)	69 (92)	2332 (2765)

6 Conclusions

Scalar top quark production and decay at a Linear Collider are studied with a realistic detector simulation with focus on the c-tagging performance of a CCD vertex detector. The SIMDET simulation largely agrees with the previous SGV simulation in the kinematic distributions. In addition, the SIMDET simulation includes a CCD vertex detector (LCFI Collaboration). The tagging of c-quarks reduces the background by about a factor 3 in the $c\tilde{\chi}^0_1\bar{c}\tilde{\chi}^0_1$ channel. Thus, scalar top processes can serve well as a benchmark reaction for the vertex detector performance. Dedicated simulations with SPS-5 parameters are performed. The expected background depends significantly on the detector design, mostly on the radius of the inner layer, and with layer 1 removed, also on the thickness.

Acknowledgements

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References

1. LCFI Collaboration http://www.ppd.clrc.ac.uk/lcfi .
2. A. Finch, H. Nowak, A. Sopczak, "Determination of the Scalar Top Mass at a Linear e^+e^- Collider", these proceedings, and references therein.