CCD Vertex Detector Charm-Tagging Performance in Studies of Scalar Quarks

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Introduction

Large challenge to develop a vertex detector for a future LC.

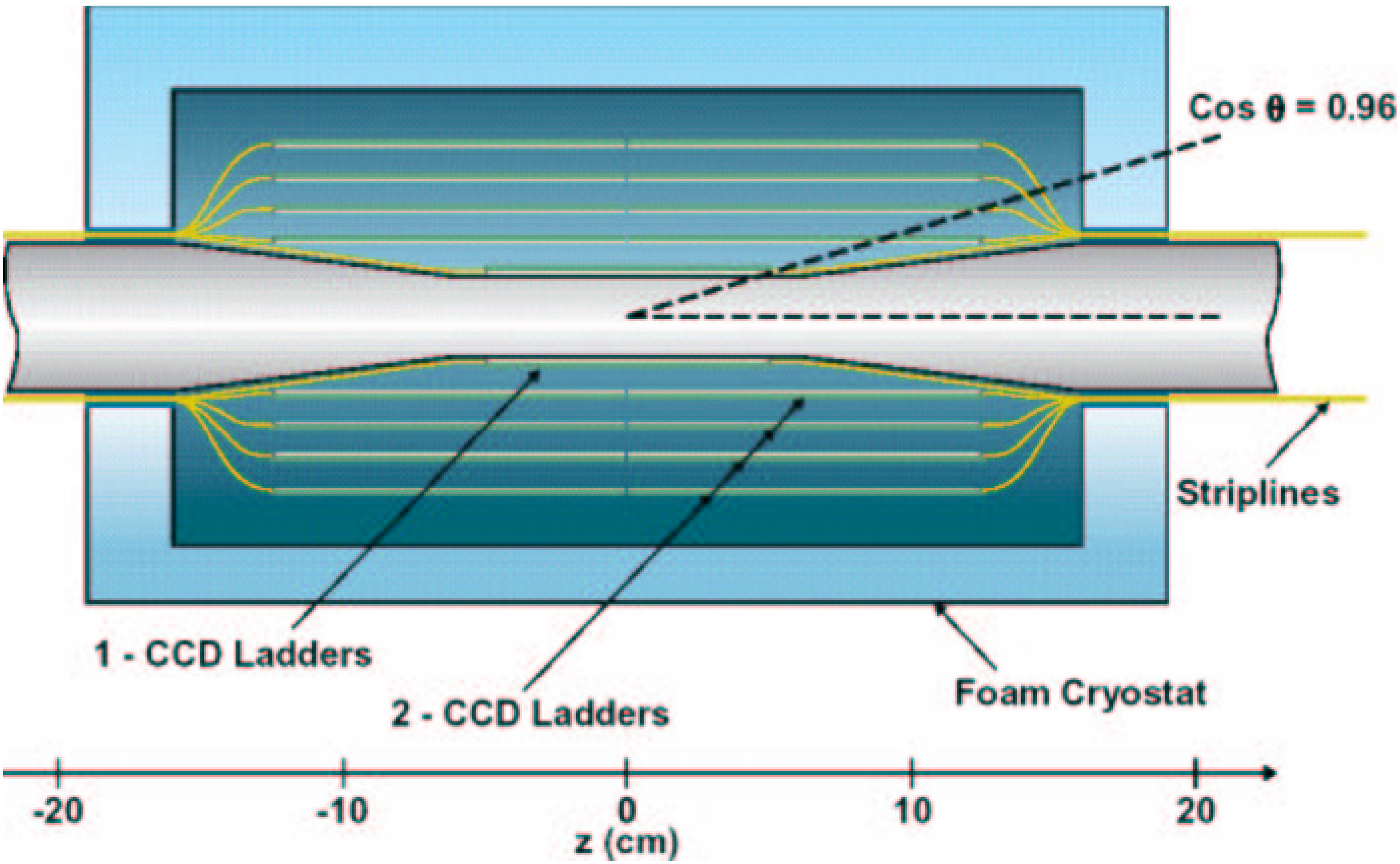
Key aspects:

- Distance to interaction point of innermost layer (radiation hardness, beam background).
- Material absorption length (multiple scattering).
- 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.

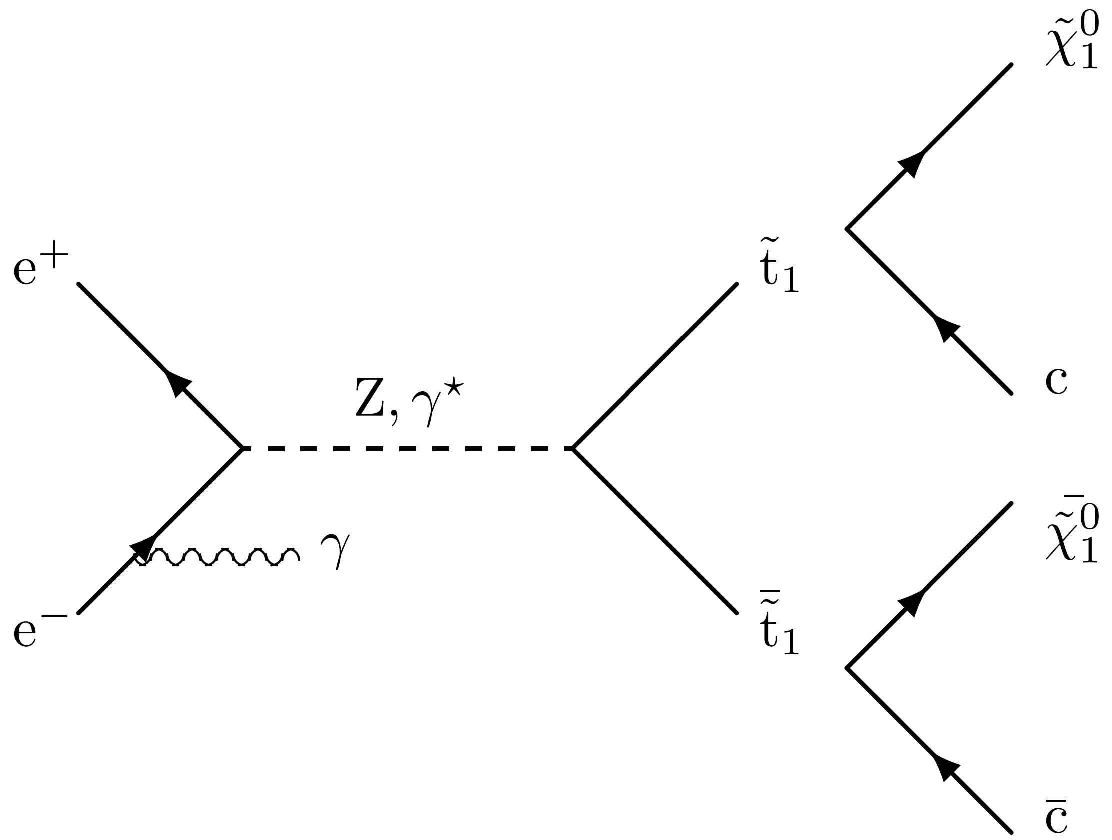
CDD Vertex Detector

LCFI Collaboration: Development of a CCD detector for a future LC.



5 CCD layers at 15, 26, 37, 48 and 60 mm. Each layer $< 0.1\%\ X_0$.

c-Quark Tagging: a Benchmark Reaction



Signal: Two charm jets and missing energy.

Benchmark reaction in the Supersymmetry framework: $e^+e^- \to \tilde{t}_1\bar{\tilde{t}}_1 \to c\tilde{\chi}_1^0\bar{c}\tilde{\chi}_1^0$

(Other benchmark reactions, e.g. in Higgs sector, $H \to c\bar{c}$)

Signal and Background Cross Section

Two scenarios:

1. Comparison previous SGV study: $m_{\tilde{t}_1} = 180\,\text{GeV}$, $m_{\tilde{\chi}_1^0} = 100\,\text{GeV}$
2. SPS-5 SUSY parameters: $m_{\tilde{t}_1} = 220.7$ GeV, $m_{\tilde{\chi}_1^0} = 120$ GeV

Decays mode (kinematics) $\tilde{t}_1 \to \tilde{\chi}_1^0 c$.

Signal and background cross section (pb):

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

For this performance study: no beam polarization.

However, beam polarization is very important for mass and mixing angle determination.

Analysis Strategy

- Signal and Background generated for 500 fb^{-1} and $\sqrt{s} = 500$GeV
- Detector Simulation: SIMDET 4.03 (J. Schreiber et al.)
- b/c tagging algorithm (T. Kuhl et al.)
- Iterative Discriminant Analysis (IDA) for selection optimization
- Different Vertex Detector configurations

SIMDET Detector Simulation (cf. SGV)

$\tilde{t}_1 \rightarrow c\tilde{\chi}^0_1$ and 1000 fb $^{-1}$ Standard Model background simulated (180 GeV).

Channel	Generated	Preselection/500 fb^{-1}	Previous SGV
$c\tilde{\chi}^0_1$	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
$We\nu$	4859 k	252367	252189
WW	6800 k	122621	115243
Total bg		500631	466075

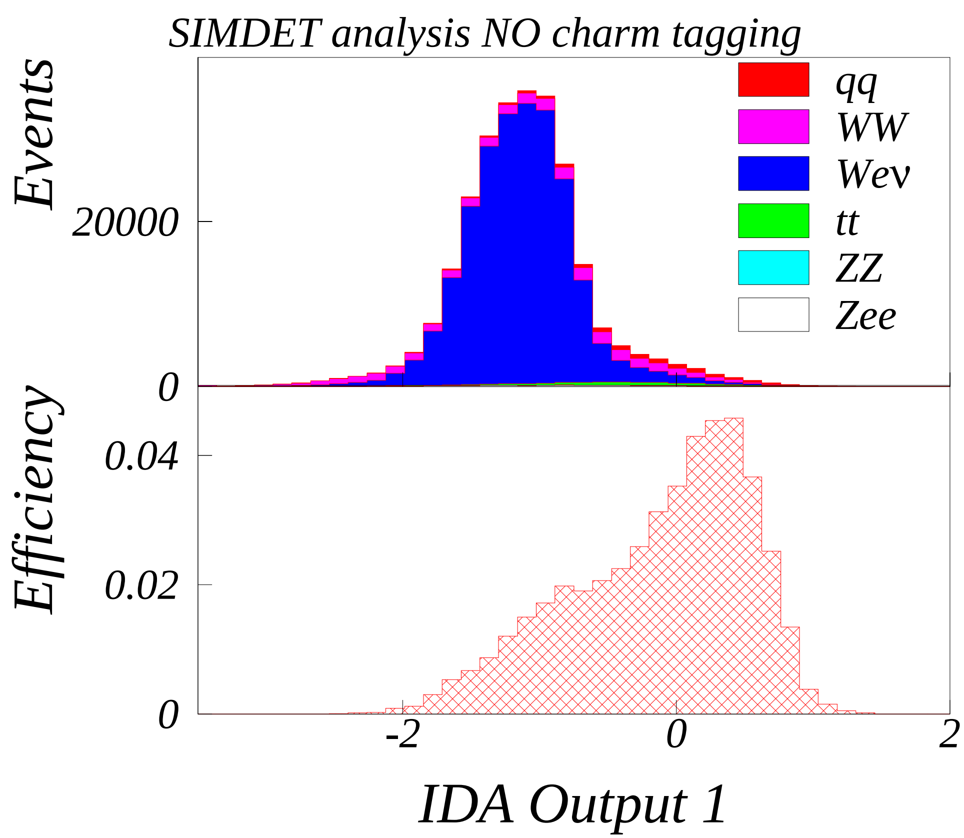
After additional preselection ($E_{\rm vis}/E_{\rm cms} < 0.52$, $P_{\rm t}/E_{\rm vis} > 0.05$):

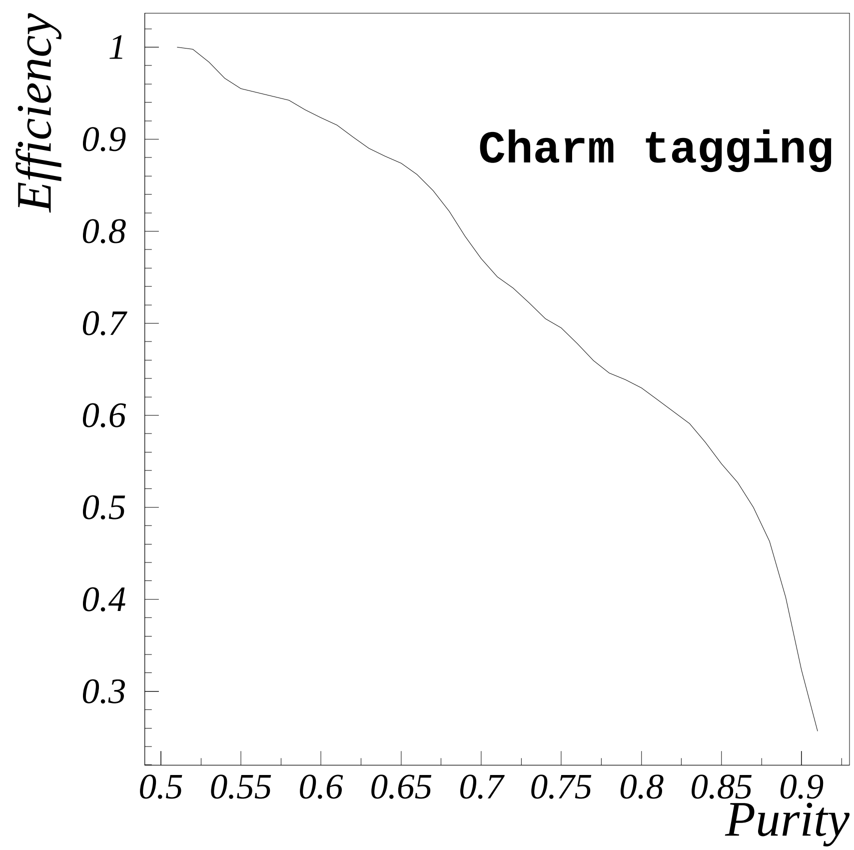
Channel	$q\bar{q}$	WW	$We\nu$	$t\bar{t}$	ZZ	eeZ	Total
	6801	23278	226070	5267	125	2147	263691

(cf. SGV: 278377 events).

Iterative Discriminant Analysis (IDA)

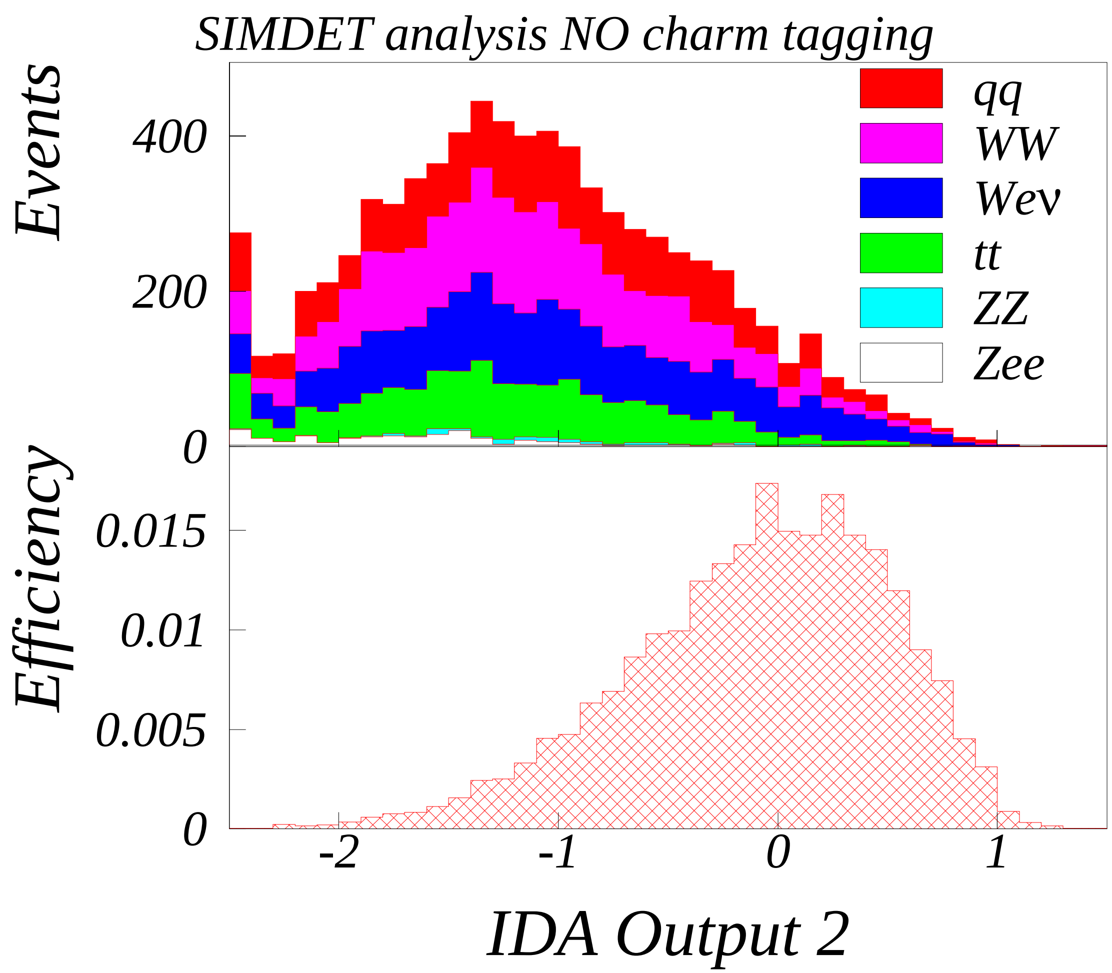
- First half-sample for training.
  Second part for signal efficiency and backgrund rate determination.
- Two step process: IDA 1: signal reduced to 50% efficiency; IDA 2: fine-tuning





Without charm tag 7815 (cf. SGV 7265). With charm tag 3600 background events.

Signal vs. Background: c-Quark Tagging



After second IDA step, remaining backgrounds for 12% efficiency (180 GeV):

Without charm tag 680
(cf. SGV 400 events),

With charm tag 165 events.

SPS-5 Results (220.7 GeV)

Events remaining after 1st Iteration of IDA (25% efficiency):

Signal	Background	Charm Tagging
3800	5400	No
3800	2500	Yes

Events remaining after 2nd Iteration of IDA (12% efficiency):

Signal	Background	Charm Tagging
1800	170	No
1800	50	Yes

Varying Vertex Detector Design

Vertex detector absorption length:

- Normal thickness (TESLA TDR)
- Double thickness

Number of vertex detector layers:

- 5 layers - innermost layer at 1.5 cm (like TDR)
- 4 layers - innermost layer at 2.0 cm (Layer 1 removed)

For SPS-5 parameters (220.7 GeV):

Thickness	Layers	Remaining background events (12% Signal)	(25% Signal)
Normal	5	50	2200
Normal	4	50	2600
Double	5	70	2300
Double	4	70	2600

Conclusions

- c-quark tagging as a benchmark for vertex detectors.
  In Supersymmetry: Scalar top quarks.
- SIMDET detector simulation includes vertex detector (CCD LCFI).
- About 31 million events simulated.
- SIMDET and previous SGV kinematic distributions largely agree.
- c-tagging reduces background by about a factor 4 in the $\tilde{\chi}^0_1 c \tilde{\chi}^0_1 \bar{c}$ channel.
- Dedicated simulation with SPS-5 parameters:
  Possibility to compare with other vertex detector projects.
- First indication on expected background variation depending on detector design.