

Small visible energy scalar top iterative discriminant analysis

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Abstract. Light scalar top quarks with a small mass difference with respect to the neutralino mass are of particular cosmological interest. This study uses an iterative discriminant analysis method to optimize the expected selection efficiency at the international linear collider (ILC).

Keywords. Supersymmetry; scalar top quarks; CCD detector; vertex detector; linear collider flavour identification; linear collider.

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1. Introduction

The search for scalar top quarks and the determination of their parameters in the framework of supersymmetric models are important aspects of the linear collider physics programme. The lightest neutralino with a small mass difference (Δm) to the scalar top quark is a candidate for dark matter in the Universe [1]. The dark matter rate could be measured at a linear collider [2,3]. This study applies an iterative discriminant analysis (IDA) [4] to a scenario involving a 122.5 GeV scalar top and a 107.2 GeV neutralino at $\sqrt{s} = 260$ GeV which is near threshold. This center-of-mass energy will be used for the scanning phase of the ILC operation and a luminosity of 50 fb^{-1} is assumed. The event generation and detector simulation has been performed with unpolarised beams as for a sequential-cut-based analysis [2]. In particular, the vertex detector concept of the linear collider flavour identification (LCFI) collaboration [5], which studies pixel detectors for heavy quark flavour identification, has been implemented in simulations for c -quark tagging in scalar top studies.

Table 1. Generated events, events used for the IDA training, events after the preselection, $\sqrt{s} = 260$ GeV cross-section, scaling factor, and expected number of events.

Process	Total $\times 1000$	50% training	After preselection	σ (pb)	Factor per 50 fb $^{-1}$	Expected events
Signal	50	25	13113	0.0225	0.0450	590
$q\bar{q}, q \neq t$	350	175	55	49.5	14.14	778
W^+W^-	180	90	49	16.9	9.300	456
$W e \nu$	210	105	914	1.73	0.824	753
2-photon	1600	800	3	786	49.13	147
ZZ	30	15	13	5.05	18.33	238
eeZ	210	105	12	1.12	0.533	6.4

2. Preselection

Only two c -quarks and missing energy (from undetected neutralinos) are expected from the reaction $e^+e^- \rightarrow \tilde{t}_1\tilde{t}_1^* \rightarrow c\tilde{\chi}_1^0\bar{c}\tilde{\chi}_1^0$. After a simple event preselection, the expected remaining signal and background events are given in table 1. The requirement $0.1 < E_{\text{vis}}/\sqrt{s} < 0.3$ reduces the $e^+e^- \rightarrow W^+W^-$, ZZ , $q\bar{q}$ and $\gamma\gamma \rightarrow q\bar{q}$ backgrounds. Remaining two-photon events are almost completely removed by the cut $p_t(\text{event}) > 15$ GeV. Requiring at least four but no more than 50 tracks removes mostly very low multiplicity background.

The distributions of visible energy, transverse momentum and charged track multiplicity before preselection are shown in figure 1. After the preselection 52.5% signal efficiency and 2379 background events remain per 50 fb $^{-1}$.

3. IDA event selection

Figure 2 shows additional input variables used in the IDA: the event invariant mass and the invariant mass of the two jets. Further input variables are the c -quark tagging of the leading (most energetic) and subleading jets (figure 3). The c -quark jet tagging has been performed with a neural network [6] optimized for small Δm .

The IDA has been applied in two steps in order to optimize the performance, as shown in figure 4. In the first step, a cut was applied on the IDA_1 output variable such that 99.5% of the signal events remain. This leads to 52% signal efficiency and 490 background events per 50 fb $^{-1}$. These remaining signal and background events have been passed to the second IDA step. A cut on the IDA_2 output variable determines the final selection efficiency and the corresponding expected background. The resulting performance is shown in figure 5.

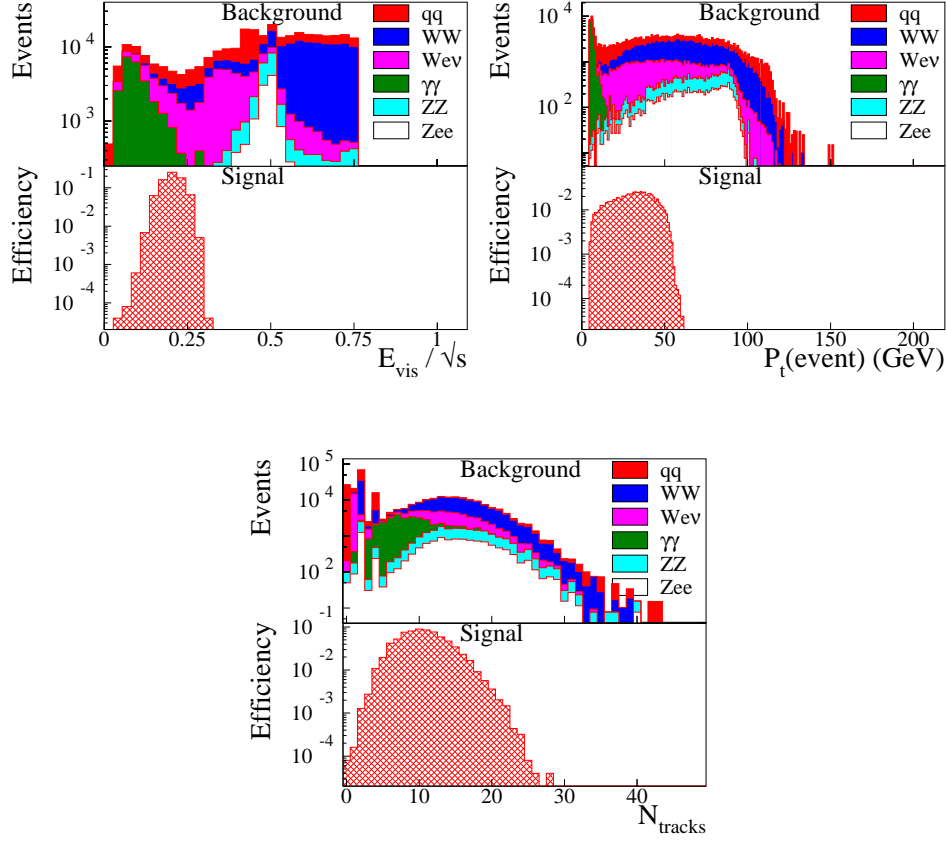


Figure 1. Event distributions before preselection.

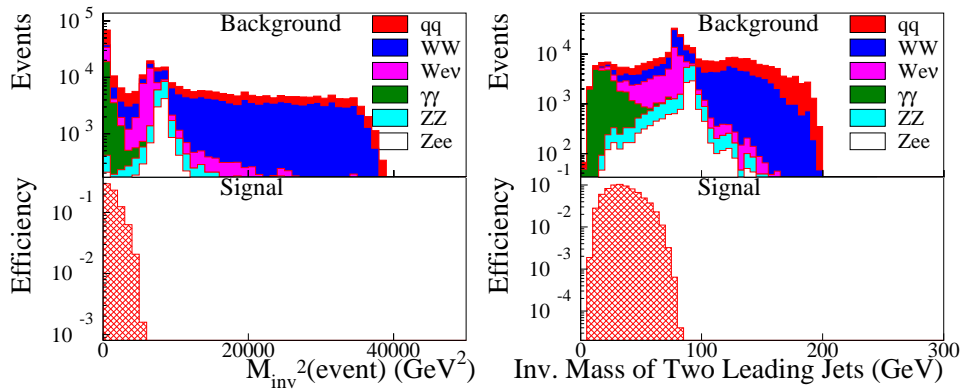


Figure 2. Distributions of IDA inputs after preselection.

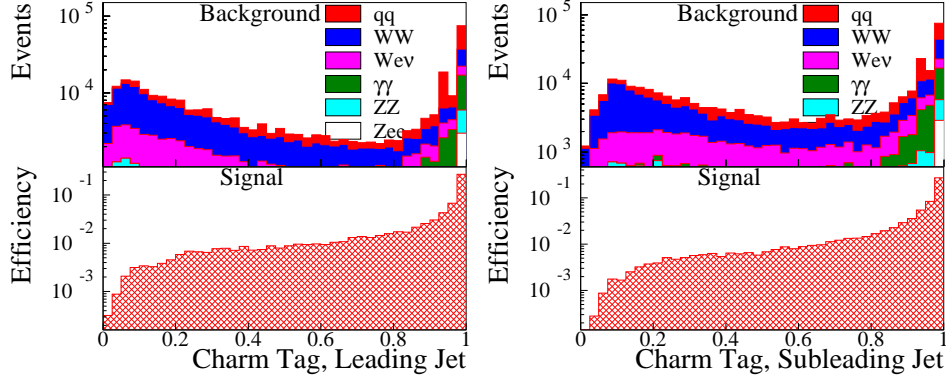


Figure 3. Distributions of IDA inputs after preselection.

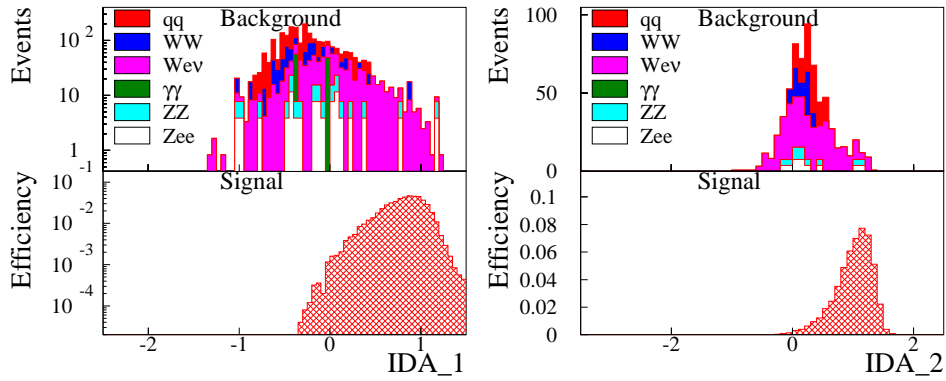


Figure 4. IDA output for steps 1 and 2. In the first IDA step, a cut on IDA_1 is applied at zero, retaining 99.5% of the simulated signal input events.

4. Conclusions

The iterative discriminant analysis leads to a good signal over background ratio for the investigated supersymmetric scenario with a scalar top mass of 122.5 GeV and a neutralino mass of 107.2 GeV (figure 5). For 50% signal efficiency (560 signal events) about 200 background events (mostly Wev) are expected per 50 fb^{-1} . The analysis is a step towards a precise scalar top mass determination. The expected uncertainty in the light scalar top mass measurement dominates the uncertainty in the dark matter prediction from the co-annihilation process [2,3]. A further study will also include a systematic error analysis. While this study has focused on $\sqrt{s} = 260 \text{ GeV}$, an IDA study for this small Δm scenario at $\sqrt{s} = 500 \text{ GeV}$ is in progress [7] and a much improved determination of the dark matter prediction is expected [8]. Further plans are to focus on the vertex detector design, including the implementation of a new LCFI [5] c -quark tagging.

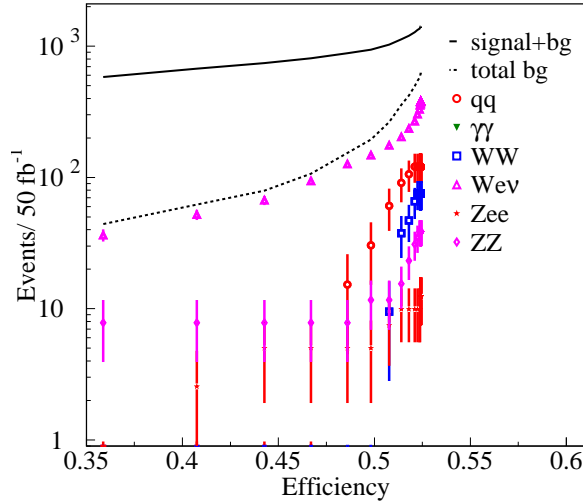


Figure 5. Expected background events as a function of the signal efficiency.

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