Small Visible Energy Scalar Top

Iterative Discriminant Analysis

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Many thanks: LCFI Colleagues

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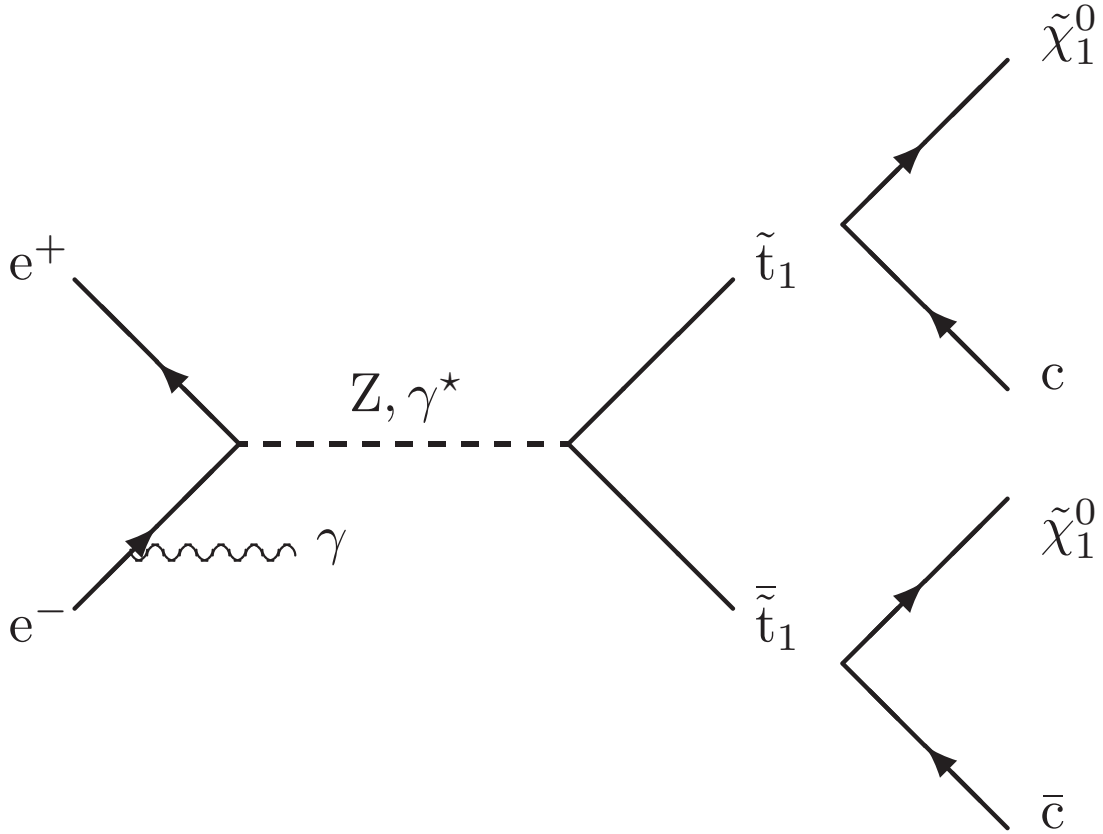
Introduction



Signal: Two charm jets and missing energy.

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

Small Stop-Neutralino Mass Studies

Motivations:

- Challenge for Vertex Detector
- Dark Matter (Carena, Balázs, Wagner, PRD70:015007,2004): $\tilde{\chi}_1^0$ is Cold Dark Matter (CDM) candidate. Correct CDM rate for small $\tilde{t}_1 - \tilde{\chi}_1^0$ mass difference (co-annihilation).
- Dark Matter Determination at LC possible (Carena, Finch, Freitas, Milsténe, Nowak, Sopczak, PRD72:115008,2005). Sequential cut based analysis.
- Expected Dark Matter precision depends much on scalar top mass determination.
- Optimization of signal over background ratio with an Iterative Discriminant Analysis (IDA).

Signal and Background $\sqrt{s} = 260$ GeV

Process	Cross-section [pb]
$P(\mathrm{e}^-)/P(\mathrm{e}^+)$	0/0
$\tilde{\mathrm{t}}_1\bar{\tilde{\mathrm{t}}}_1 \quad m_{\tilde{\mathrm{t}}_1} = 122.5$ GeV	0.0225
$\mathrm{q\bar{q}}$, $\mathrm{q} \neq \mathrm{t}$	49.5
$\mathrm{W^+W^-}$	16.9
$\mathrm{We}\nu$	1.73
2-photon, $p_\mathrm{t} > 5$ GeV	786
ZZ	5.05
eeZ	1.12

Preselection: Reduction of Background

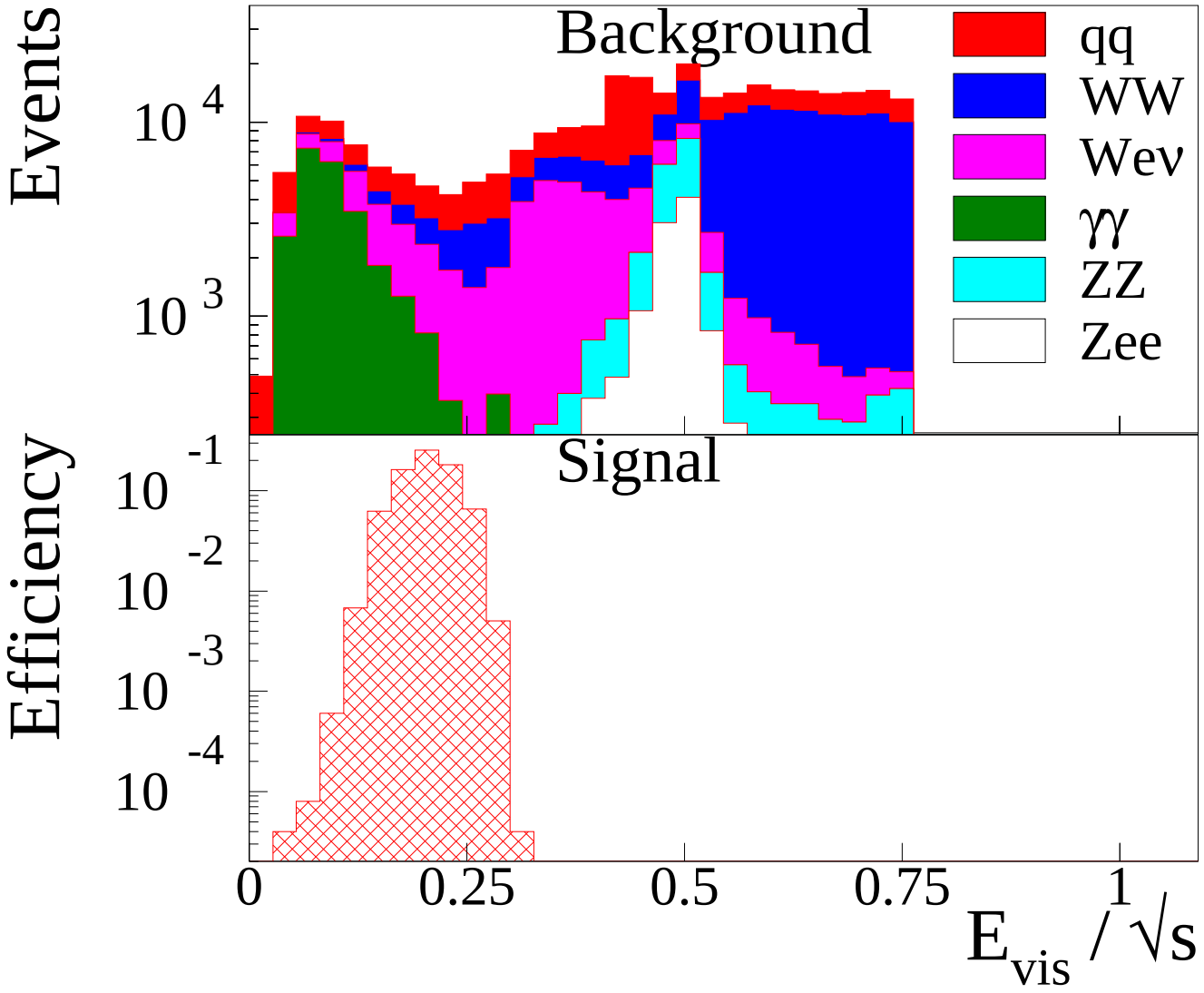
1. $0.1 < E_{\rm vis}/\sqrt{s} < 0.3$ to reduce $e^+e^- \to W^+W^-$, ZZ, $q\bar{q}$ and $\gamma\gamma \to q\bar{q}$
2. Remaining two-photon background is almost completely removed by $p_{\rm t}({\rm event}) > 15$ GeV.
3. $4 <$ number of tracks < 50, mostly very low multiplicity background is removed.

Expected Events after Preselection

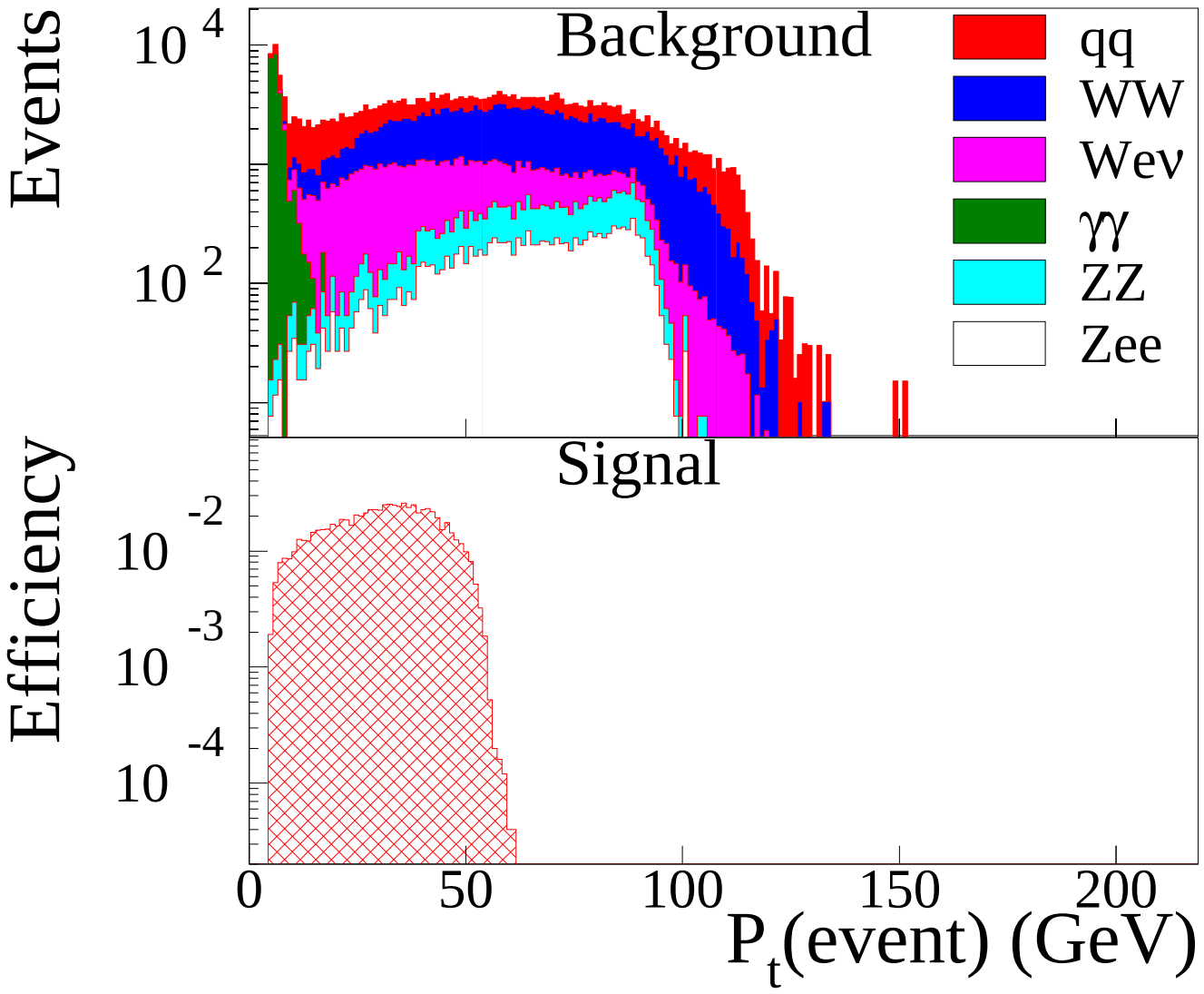
Process	Total ×1000	50% training	After preselection	σ (pb)	Factor per 50 fb^{-1}	Expected events
signal	50	25	13113	0.0225	0.0450	590
$q\bar{q}$, $q \neq t$	350	175	55	49.5	14.14	778
W^+W^-	180	90	49	16.9	9.300	456
Weν	210	105	914	1.73	0.824	753
2-photon	1600	800	3	786	49.13	147
ZZ	30	15	13	5.05	18.33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

After preselection: 52.45% signal efficiency and 2379 background events.

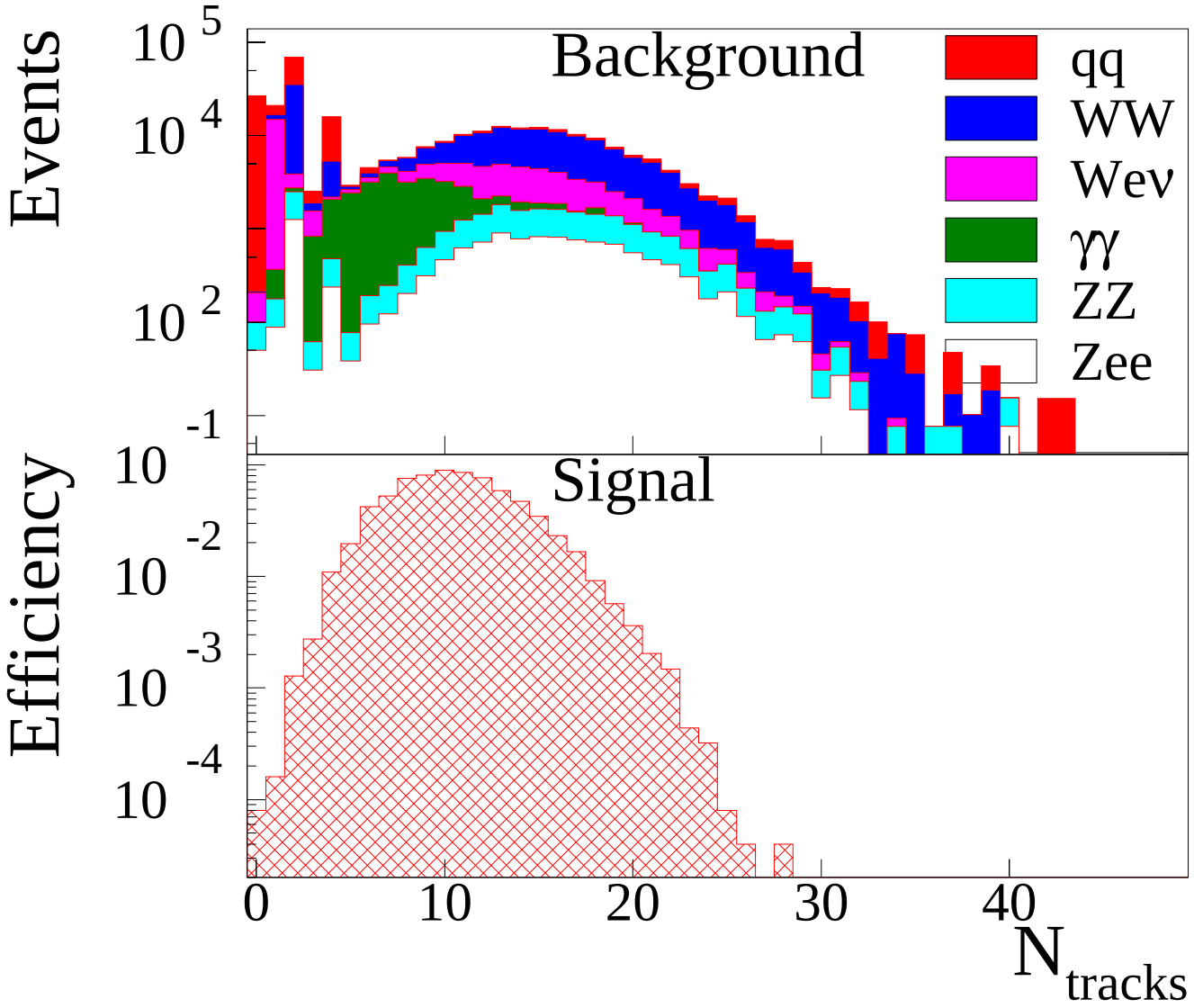
Preselection



Preselection



Preselection



Iterative Discriminant Analysis Method

A method to weight each event to optimize signal / background separation using n discriminant variables.

Construct: vector x containing the n variables and
$(n^2 - n)/2$ products of those variables.

Calculate:

V	Variance matrix
$\Delta\mu$	Difference in the mean values between signal and background
$a = V^{-1}\Delta\mu$	
$D^0 = x^T \cdot a \cdot x$	Provides the maximum separation between signal and background.

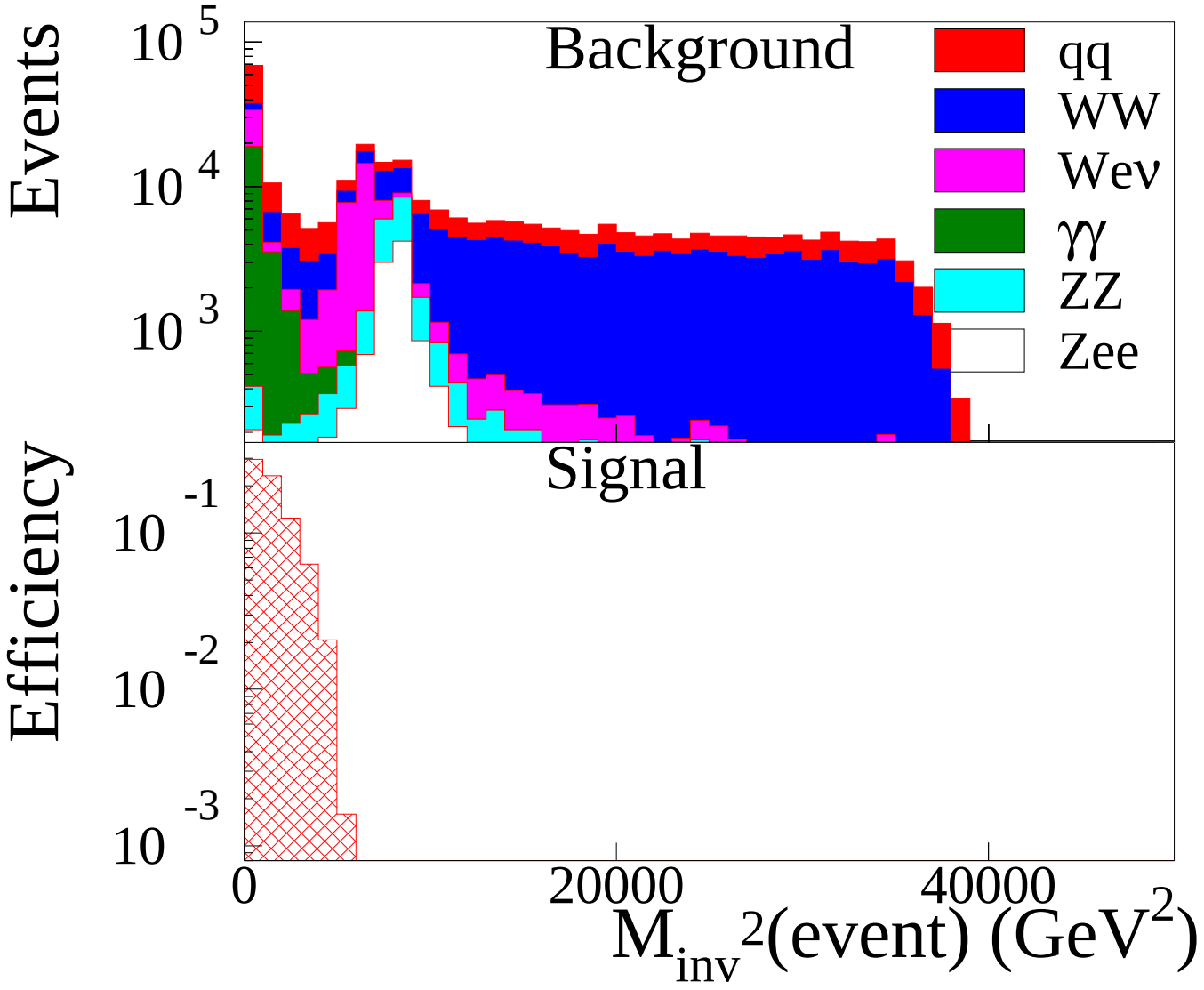
Weighted such that signal and background have equal importance.

Find the value of D^0 which selects a predetermined fraction of the signal (e.g. 50%), and cut on it. Do this process once again for events passing the cut.

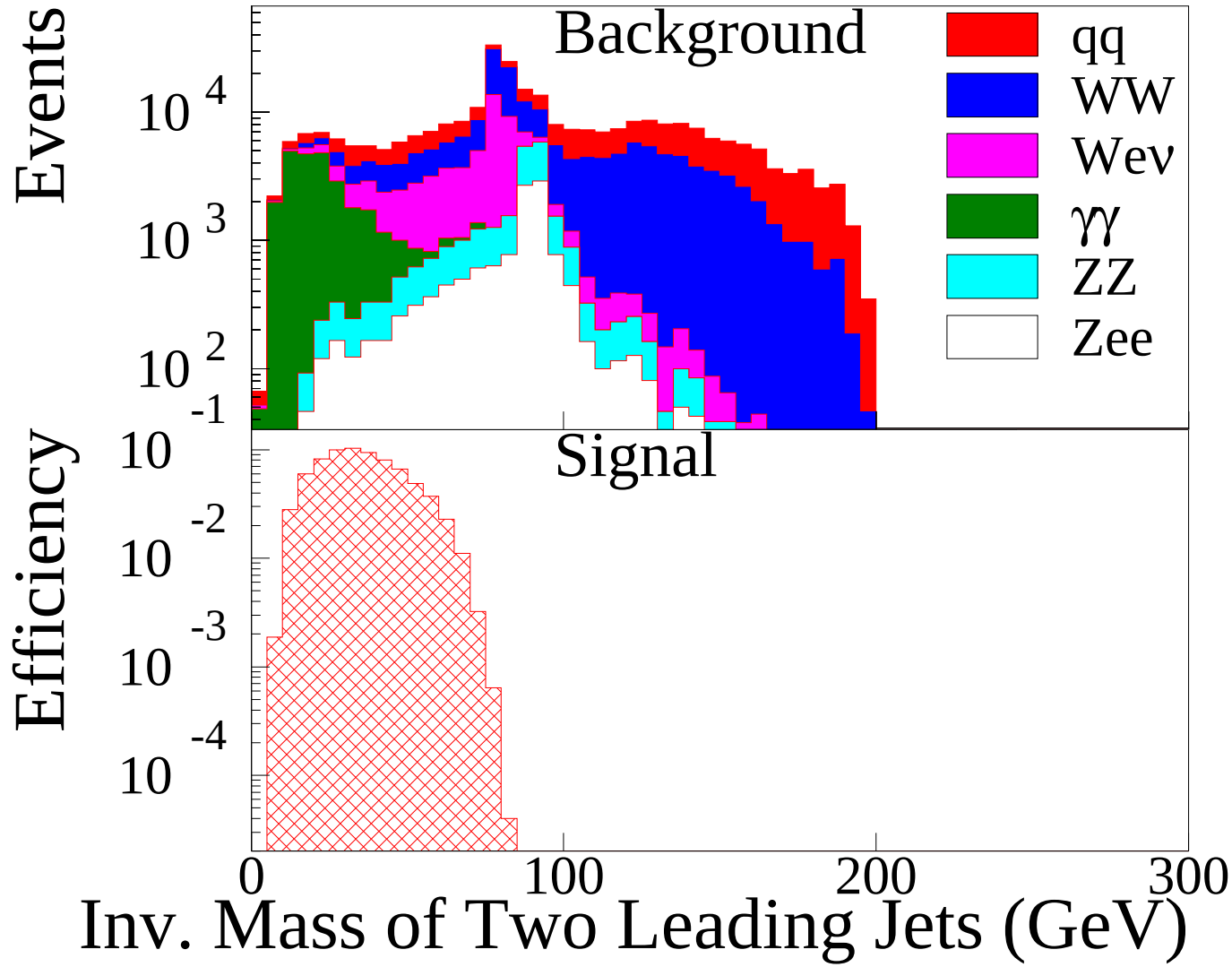
Leading IDA Input Variables

1. E_{vis}
2. p_{t}(event)
3. Number of tracks
4. Event invariant mass
5. Invariant mass of the two jets
6. c-quark tagging (Neural Network optimized for small Δm).
   - Leading jet
   - Subleading jet

Further IDA Input Variables



Further IDA Input Variables



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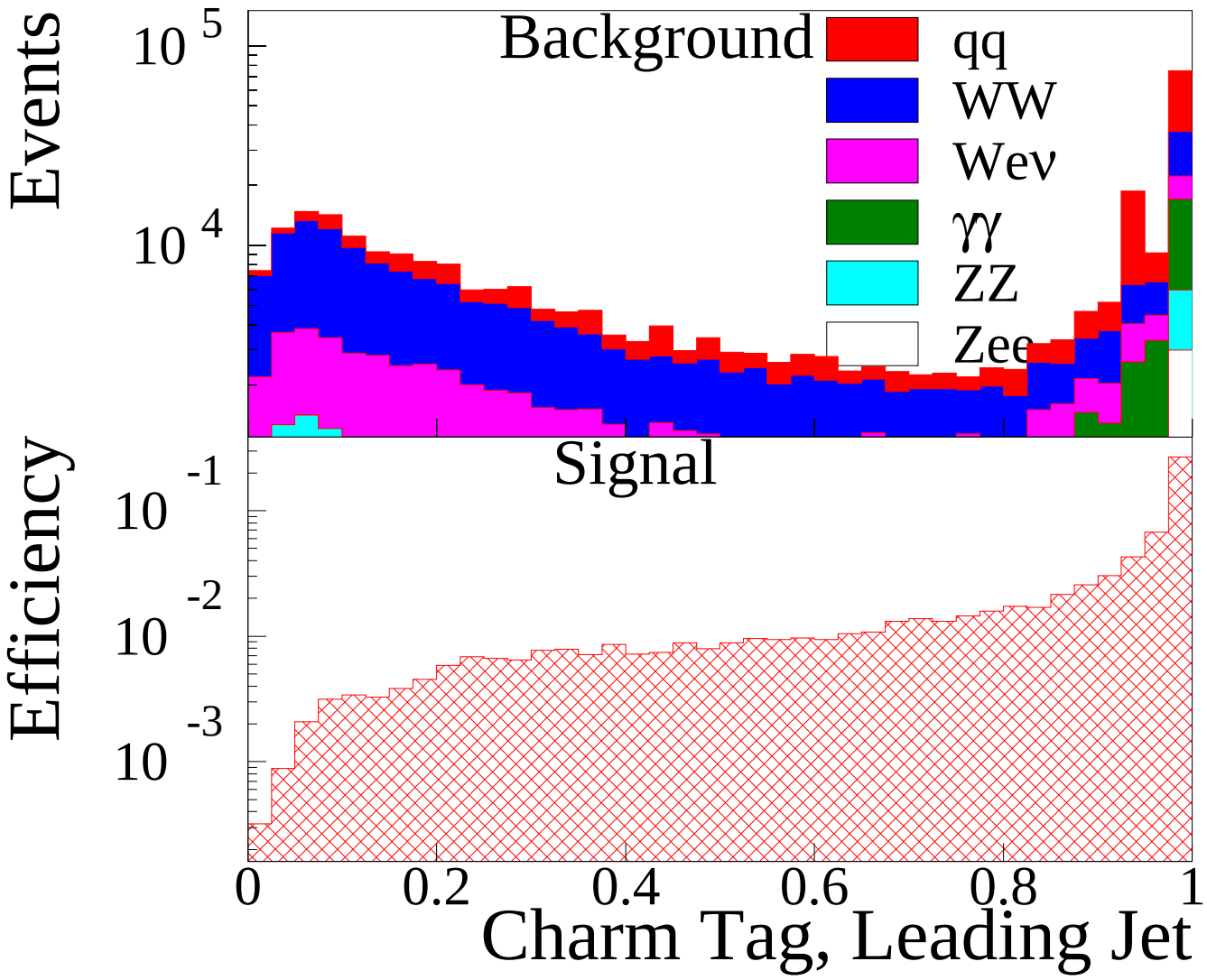
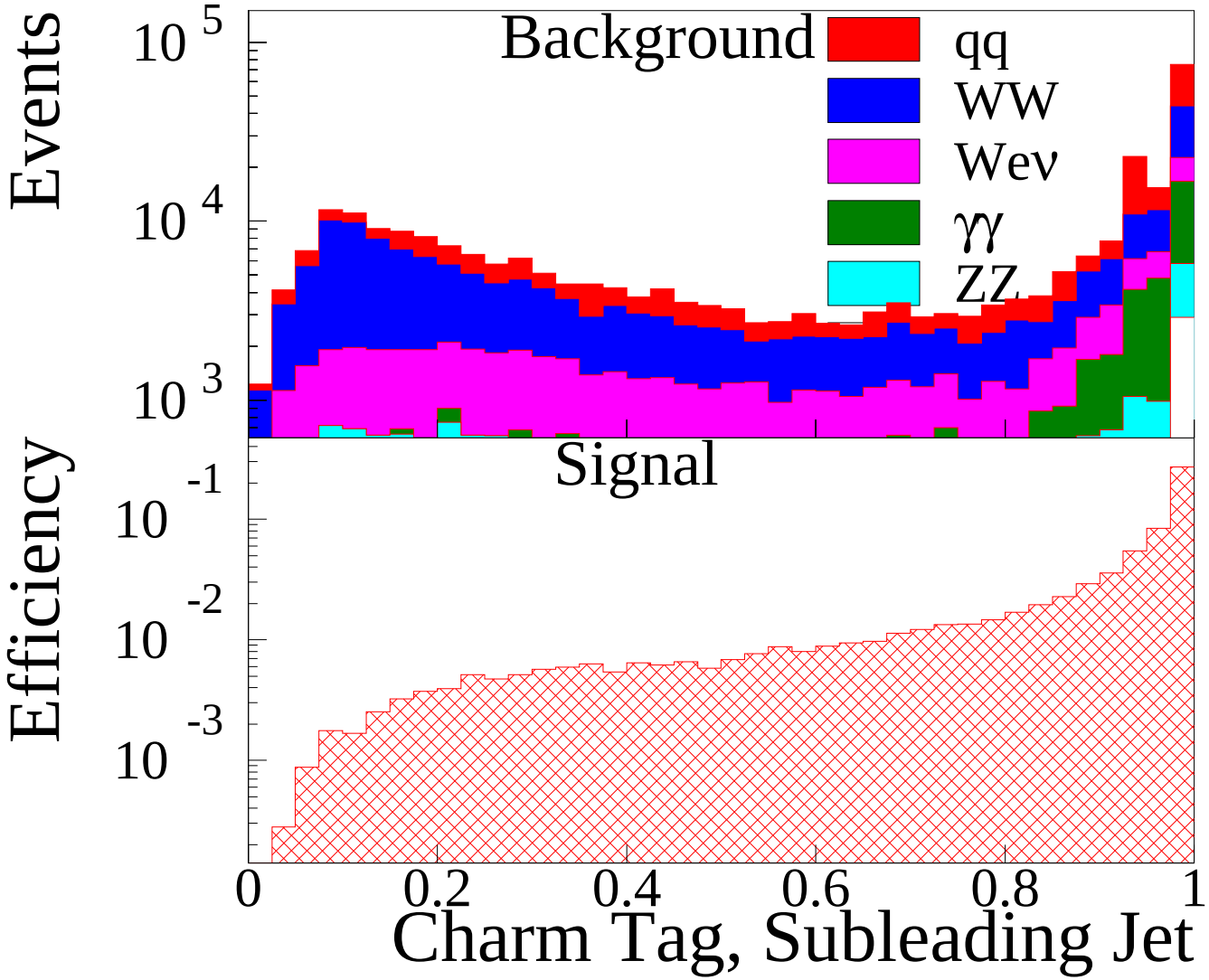
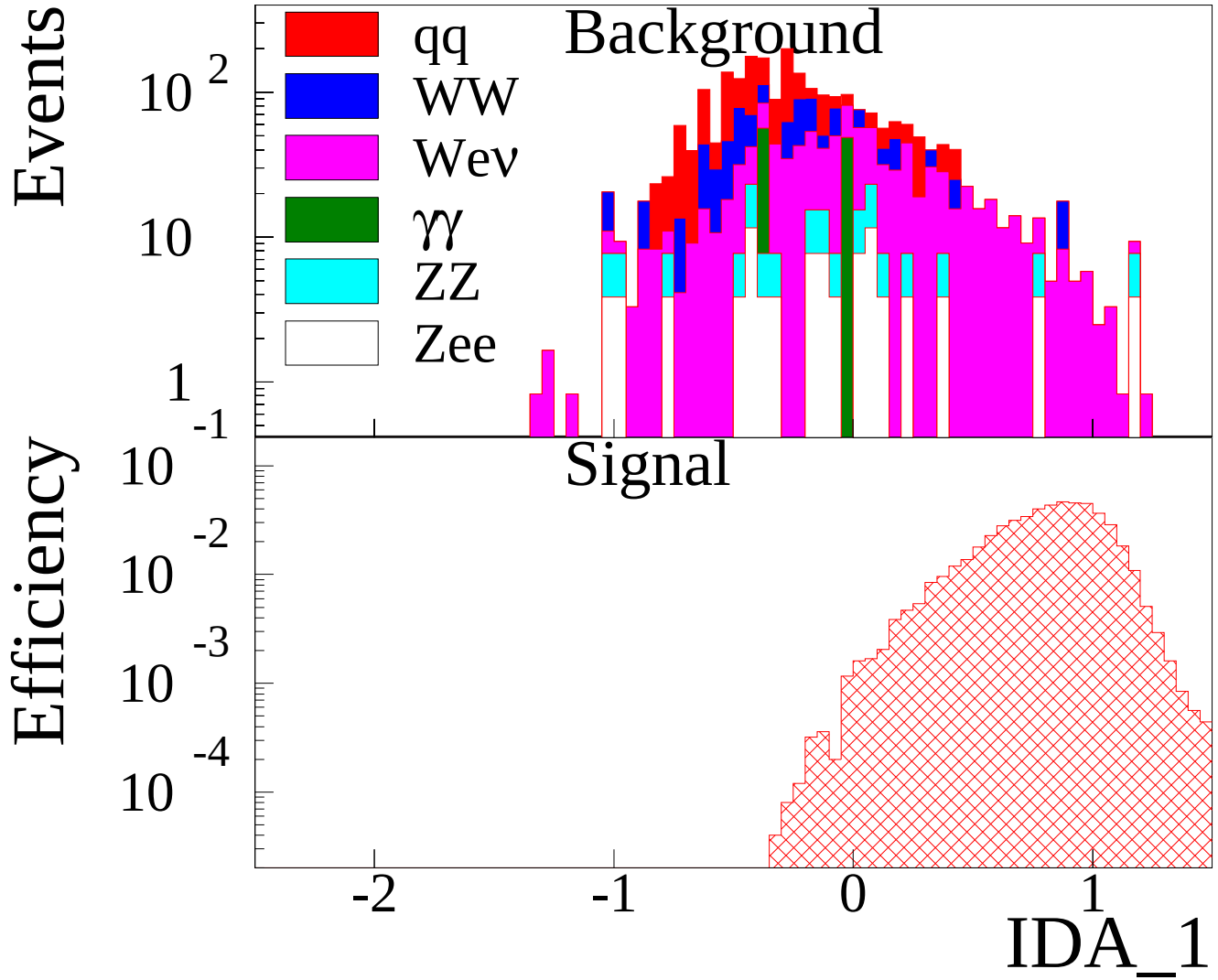


Further IDA Input Variables

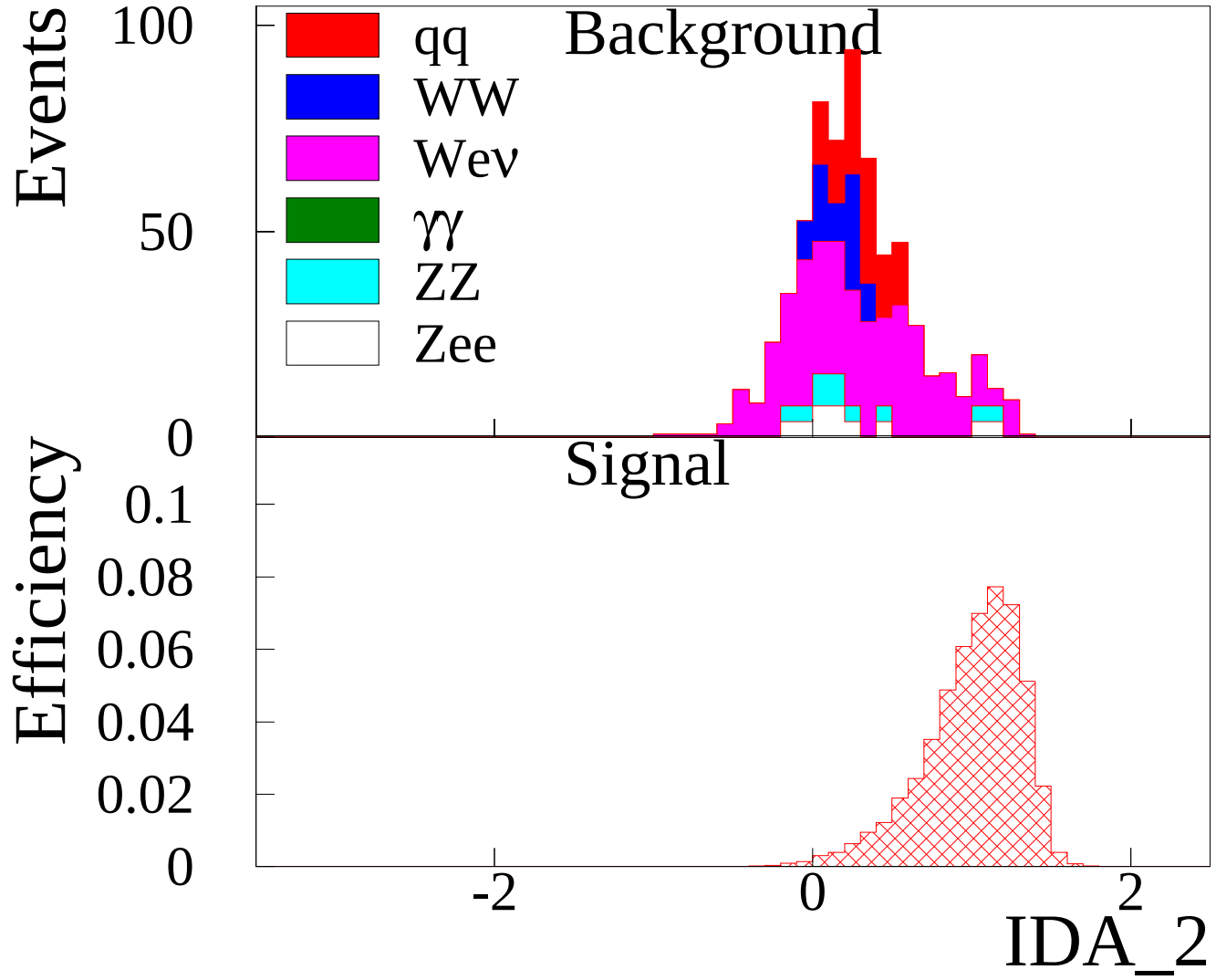


IDA Step 1: Cut at 0 (99.5% Remaining Signal)

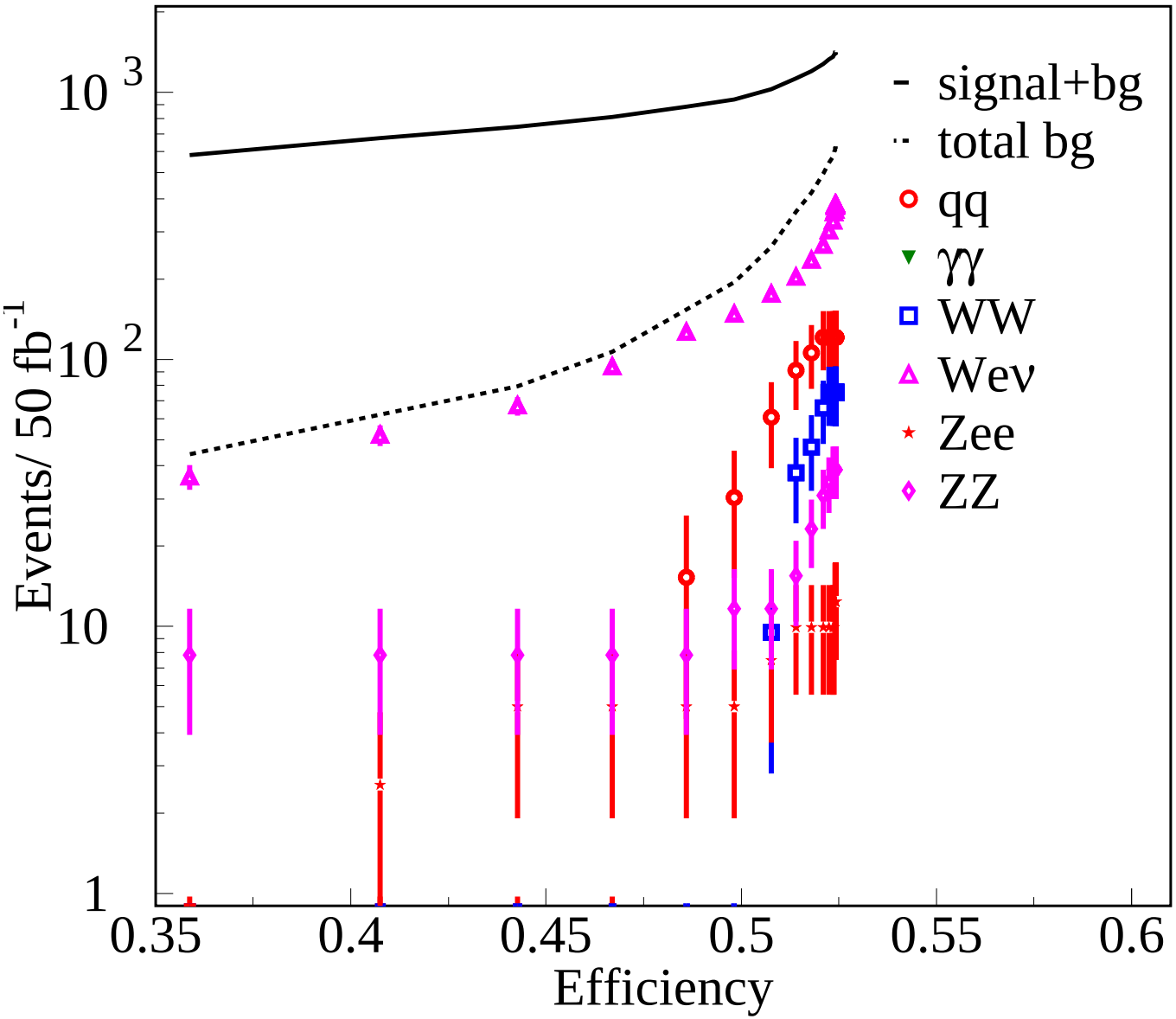


After IDA-1: 52.0% signal efficiency and 490 background events.

IDA Step 2


Events
100
50
0
qq
WW
Wev
γγ
ZZ
Zee
Background
Signal
Efficiency
0.1
0.08
0.06
0.04
0.02
0
-2
0
2
IDA_2

Performance



Conclusions

- New Iterative Discriminant Analysis leads to a good signal over background ratio.
- With 50% signal efficiency, about 200 background events (mostly Weν) for a 122.5 GeV stop and 107 GeV neutralino mass.
- For 50 fb^{-1} about 560 signal events are expected.
- Towards a precise stop mass determination.
- Plans: Small Δm analysis refinements.
- Systematic error analysis.
- Comparisons with sequential cuts analysis and $\sqrt{s} = 500$ GeV versus 260 GeV.
- Variations of the detector design.