Measurement of chargino and neutralino production at CLIC

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Introduction

SUSY model (mSUGRA):

$m_{1/2}$ = 800 GeV, A_0 = 0,

m_0 = 966 GeV, tanβ = 51, μ > 0

$M(\tilde{\chi}_1^0)$ = 340.3 GeV

$M(\tilde{\chi}_2^0)$ = 643.1 GeV

$M(\tilde{\chi}_1^+)$ = 643.2 GeV

$M(h^0)$ = 118.5 GeV

Signal processes:

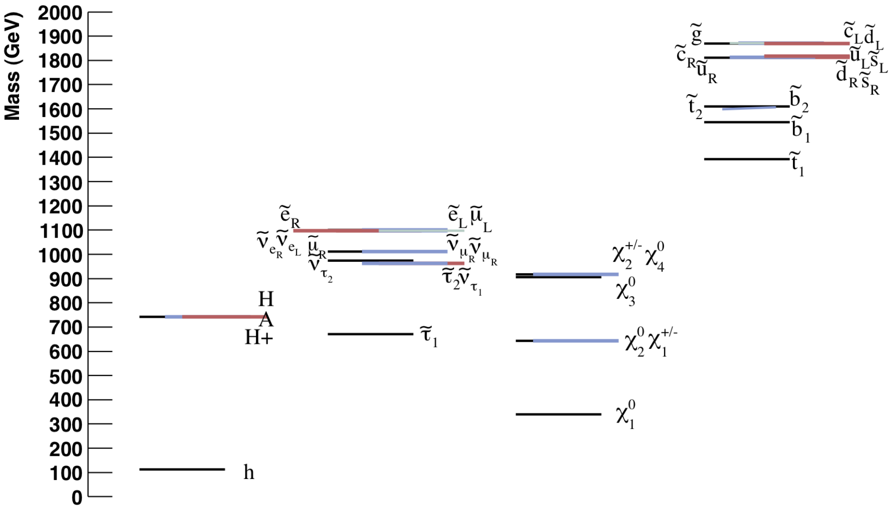
$$e^+e^- \to \tilde{\chi}_1^+\tilde{\chi}_1^- \to W^+W^-\tilde{\chi}_1^0\tilde{\chi}_1^0$$

$$e^+e^- \to \tilde{\chi}_2^0\tilde{\chi}_2^0 \to h(Z)h(Z)\tilde{\chi}_1^0\tilde{\chi}_1^0$$

h: 90.6% Z: 9.4%

Looking at hadronic $W^\pm/h^0/Z^0$ decays

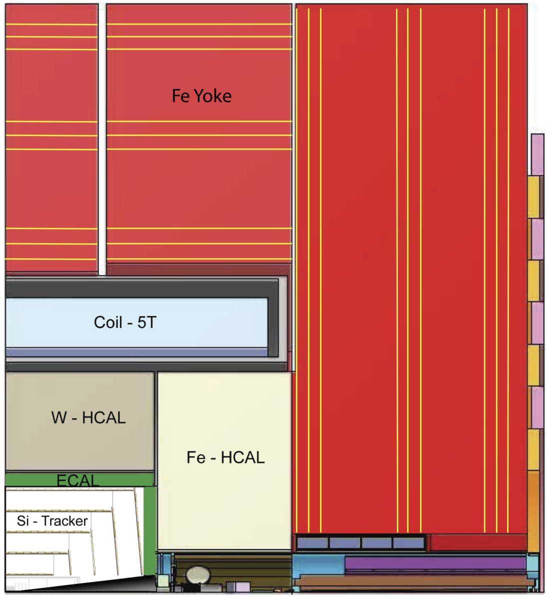
→ 4 jets + MET in final state



Motivation

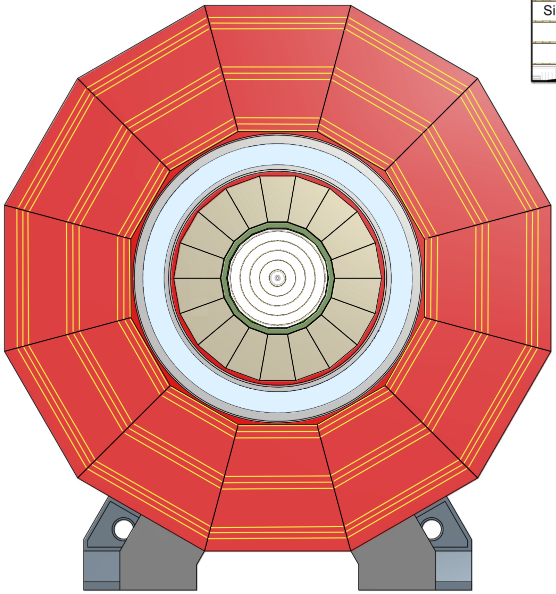
The study presented in this talk was performed for the CLIC CDR (http://lcd.web.cern.ch/lcd/CDR/CDR.html)

- Based on the CLIC_SiD detector model
- Overlay of 60 BX of $\gamma\gamma \rightarrow$ hadrons



Motivations for the study:

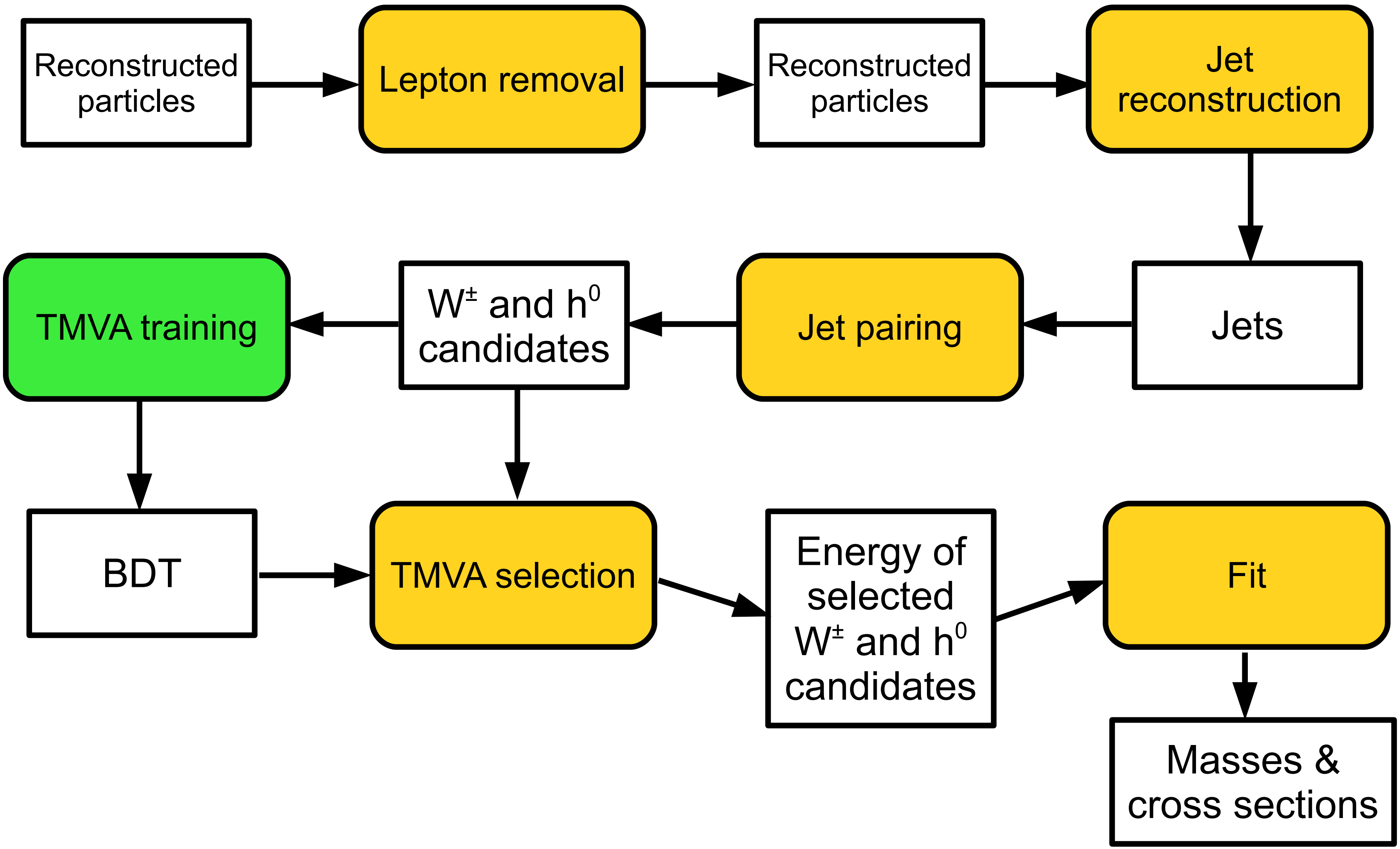
- Demonstrate reconstruction of fully hadronic final state in the presence of background
- Benchmark performance of $W^{\pm}/Z^0/h^0$ reconstruction



Signal and background samples

Type	Process	Cross section (fb)	Referenced with
Signal	$\tilde{\chi}_1^+\tilde{\chi}_1^-$	10.6	Chargino
	$\tilde{\chi}_2^0\tilde{\chi}_2^0$	3.3	Neutralino
Background	$\tilde{\chi}_2^+\tilde{\chi}_2^-$	10.5	SUSY
	$\tilde{\chi}_1^+\tilde{\chi}_2^-$	0.8	
	$\tilde{\chi}_1^+\tilde{\chi}_1^-\nu\bar{\nu}$	1.4	
	$\tilde{\chi}_2^0\tilde{\chi}_2^0\nu\bar{\nu}$	1.2	
	$q\bar{q}q\bar{q}\,\nu\bar{\nu}$	95.4	SM
	$q\bar{q}\,h\nu\bar{\nu}$	3.1	
	$h\,h\,\nu\bar{\nu}$	0.6	

Analysis overview



Event reconstruction

1.) Consider only events with at least four reconstructed particles with p_T > 250 MeV

2.) Reject events with at least one identified electron or muon with p_T > 20 GeV

3.) Reconstruct jets using the k_t algorithm its exclusive mode with four jets and R = 0.7

4.) Rejects events if at least one jet contains only one PFO

5.) Form $W^{\pm}$ or h^0 candidates from jet pairs minimising:

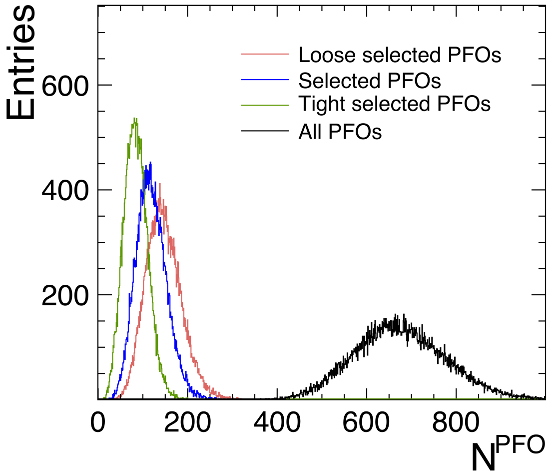
$$(M_{jj,1} - M_{W,h})^2 + (M_{jj,2} - M_{W,h})^2$$

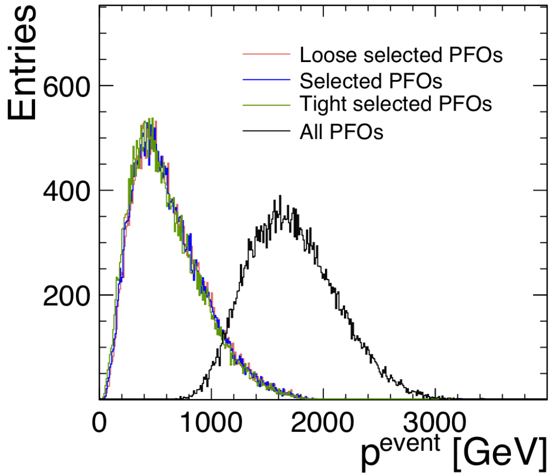
Effect of pileup from γγ → hadrons

Overlay of chargino signal events with pileup from 60 bunch crossings of γγ → hadr. interactions:

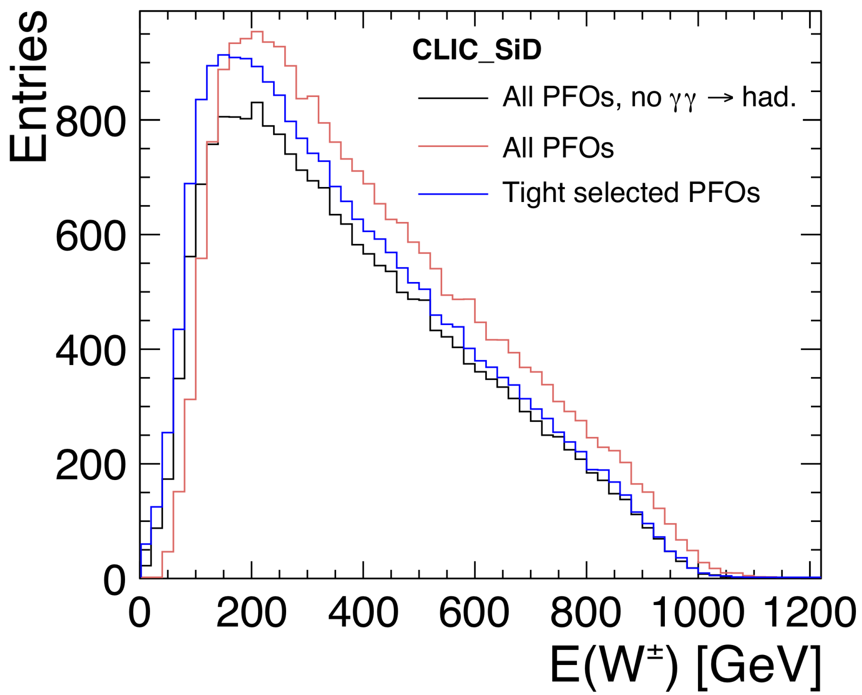
- The number of reconstructed particles per event increases by a factor 10
- The visible momentum increases by a factor 4

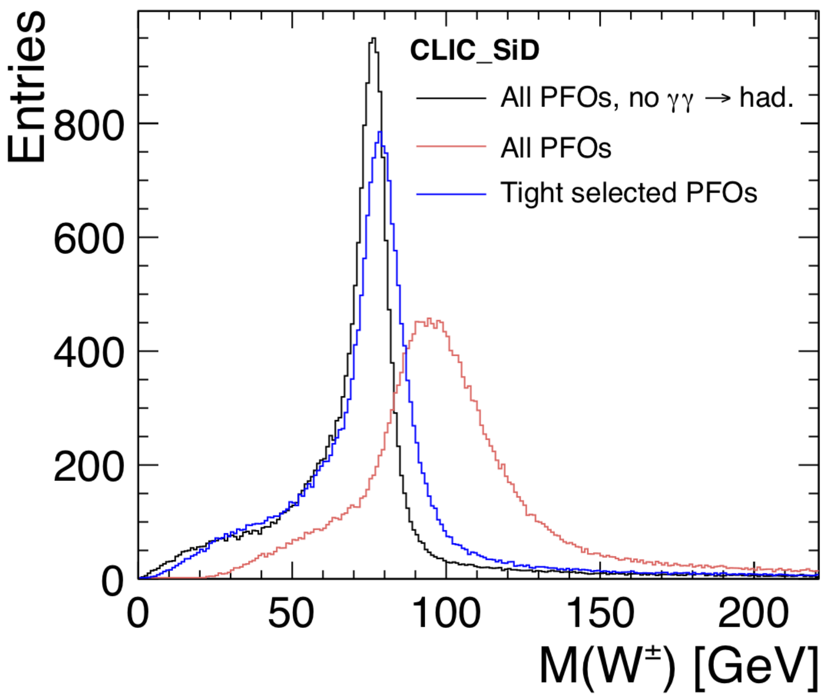
→ Suppression of background crucial for this measurement





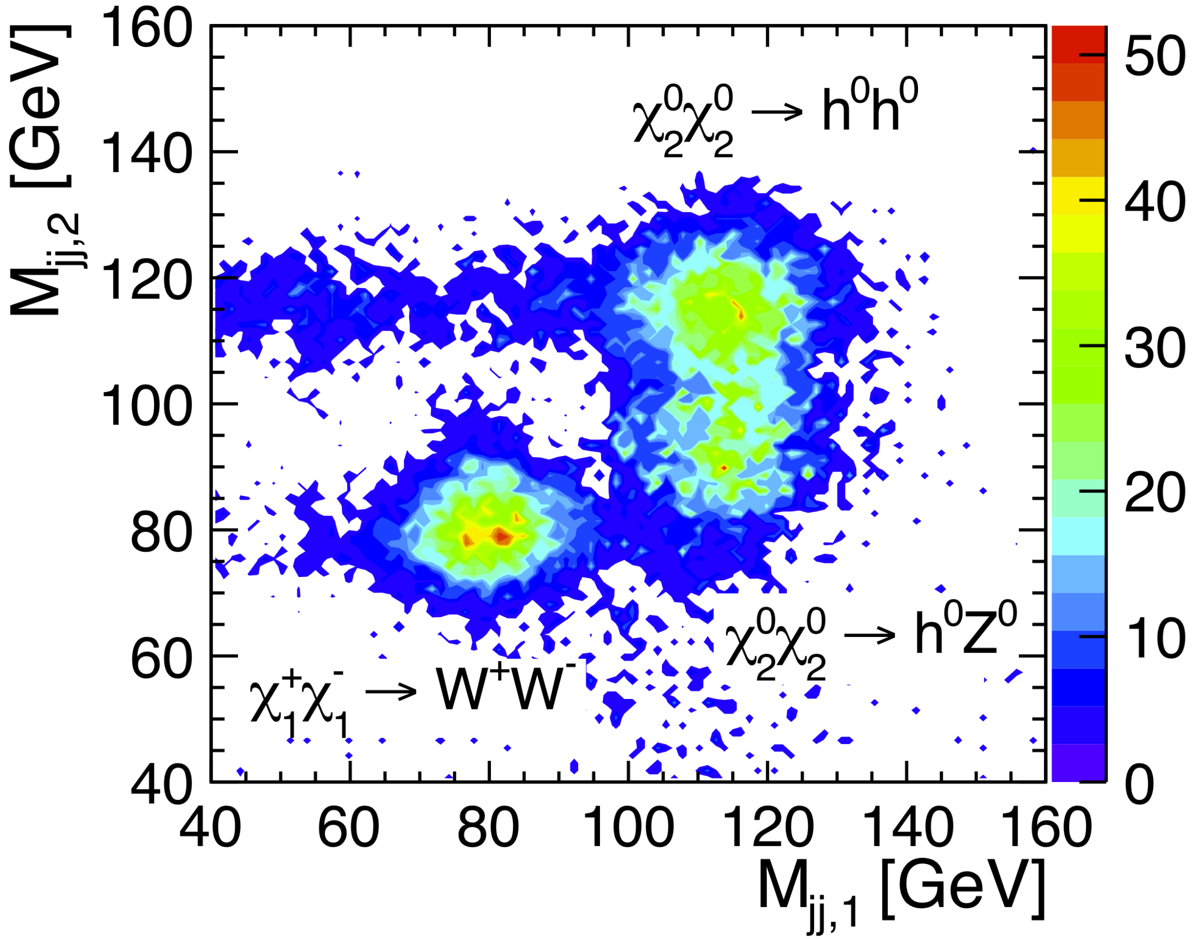
Example: $W^{\pm}$ reconstruction





Good reconstruction of $W^{\pm}$ bosons achieved if combined timing and momentum cuts are applied to select the PFOs used as input to the jet reconstruction

Separation of Chargino and Neutralino events



Marginal overlap between the different contributions

→ The Neutralino background to the chargino analysis is small and vice versa

Event selection

Pre-selection:

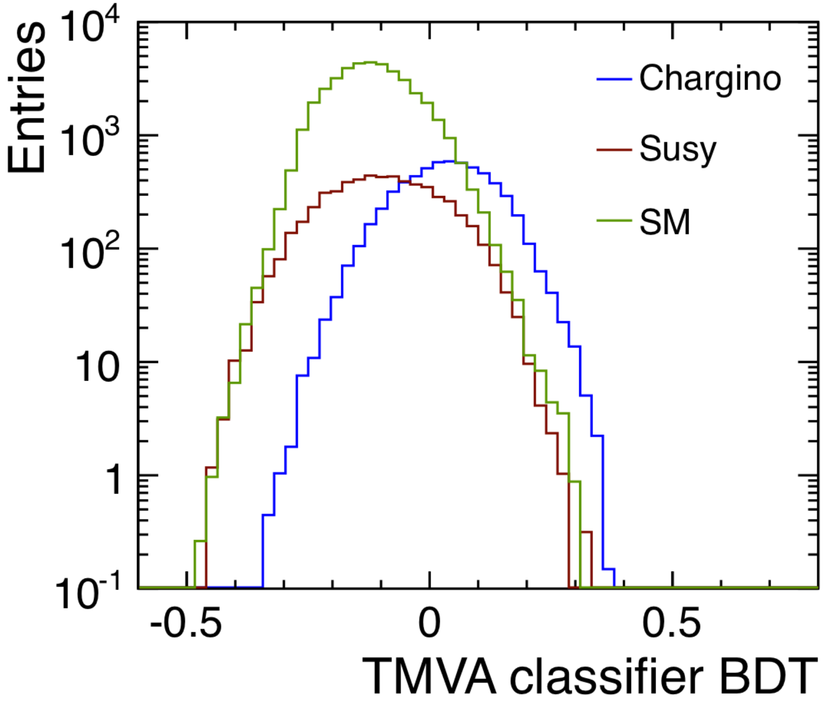
- $40 < M_{jj,1} < 160$ GeV and $40 < M_{jj,2} < 160$ GeV
- $|\cos\theta^{miss}| < 0.95$
- Angle between $W^{\pm}$ or h^{0} candidates > 1 radian
- $|\cos\theta^{jj,1}| < 0.95$ and $|\cos\theta^{jj,2}| < 0.95$

Event selection:

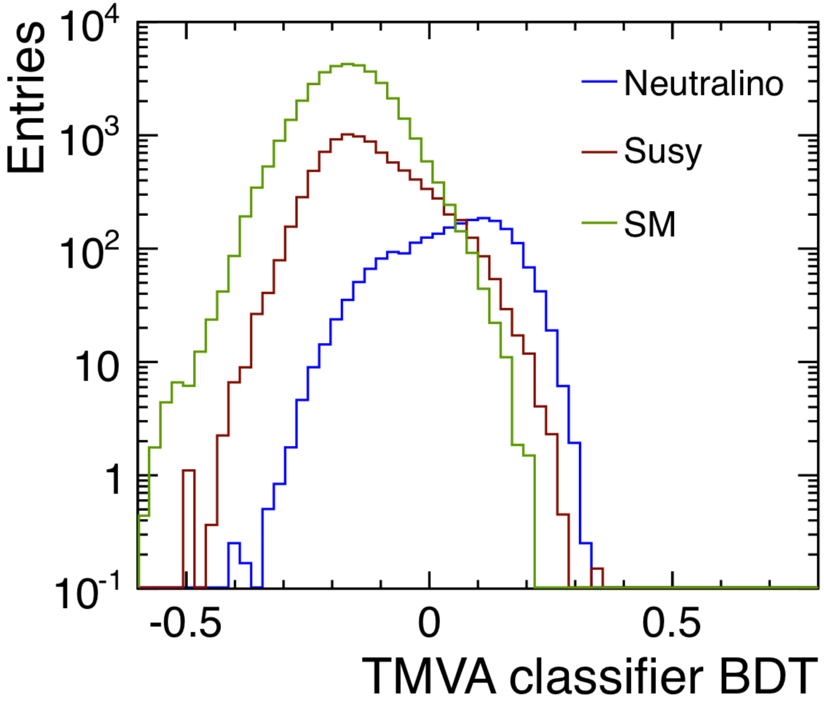
- Based on Boosted Decision Trees (BDTs) as implemented in TMVA
- The BDTs were trained using 15 variables describing kinematic properties of the reconstructed $W^{\pm}$ and h^{0} candidates as well as the event topology

BDT responses

Chargino



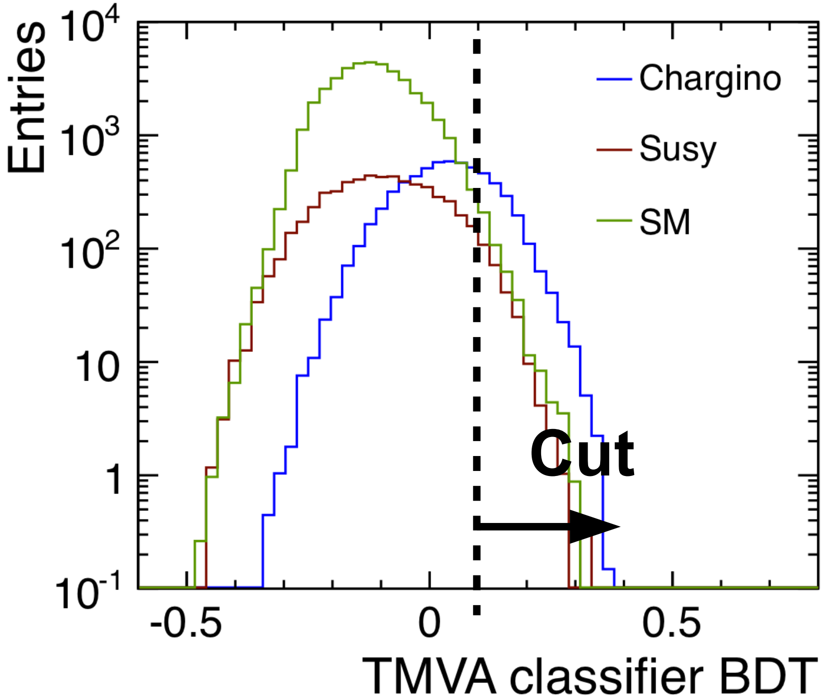
Neutralino



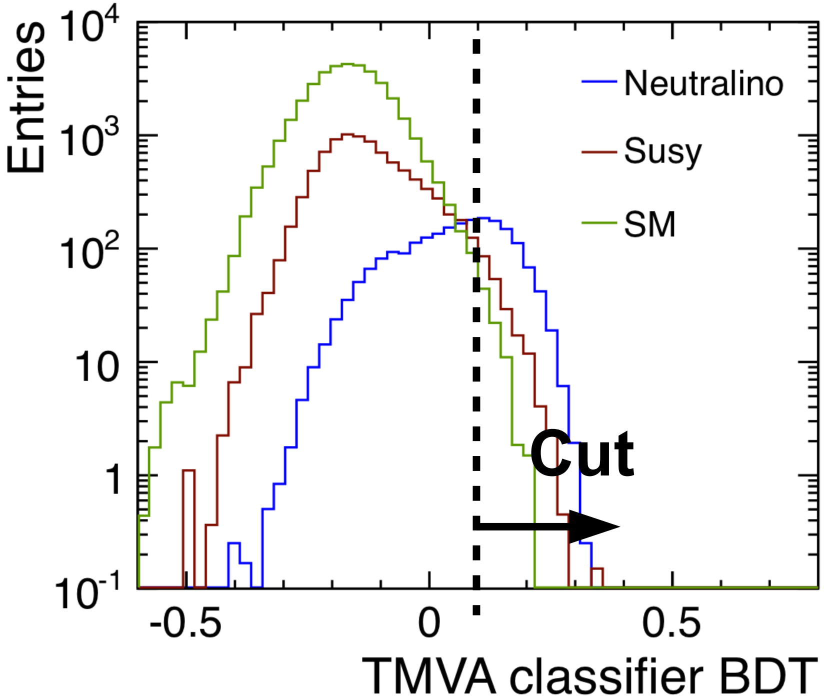
The signal distributions peak at larger values than the backgrounds

BDT responses

Chargino



Neutralino



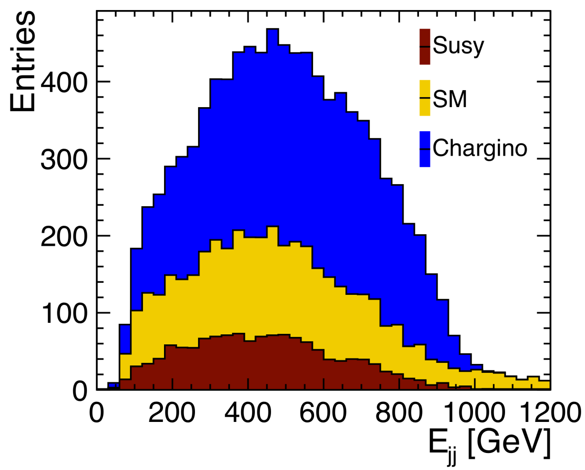
Efficiency: 25%
(Pre-selection cuts
+ event selection)

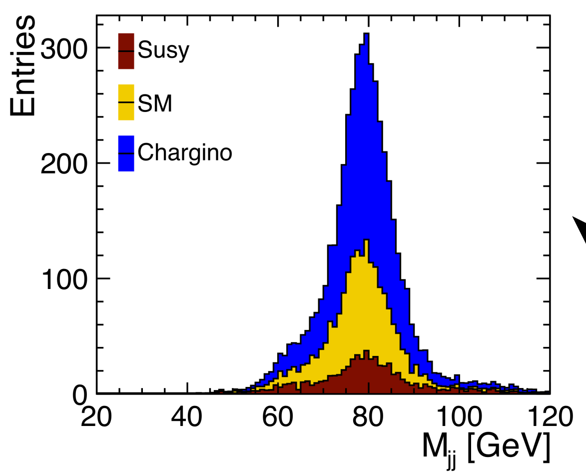
Efficiency: 33%

Selected $W^{\pm}$ and h^0 candidates

$L_{int} = 2\ ab^{-1}$

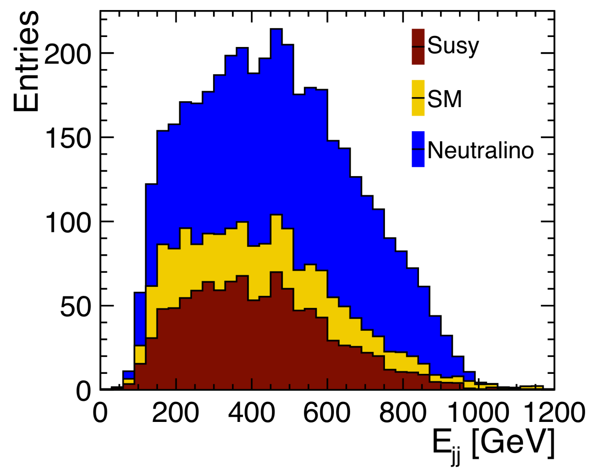
Chargino

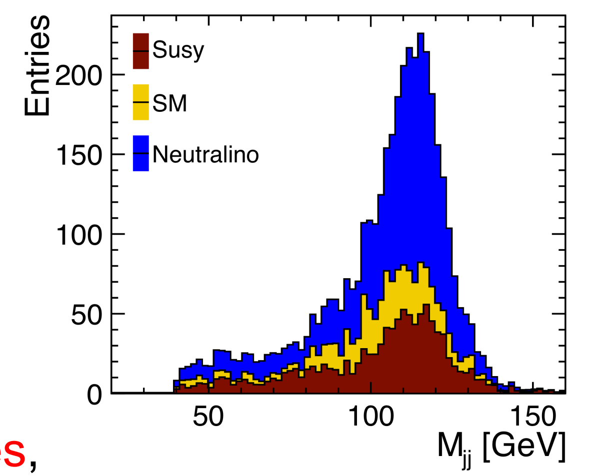




Purity: 57%

Neutralino





Purity: 55%

Average mass of both W± candidates, two entries per event in all other histograms

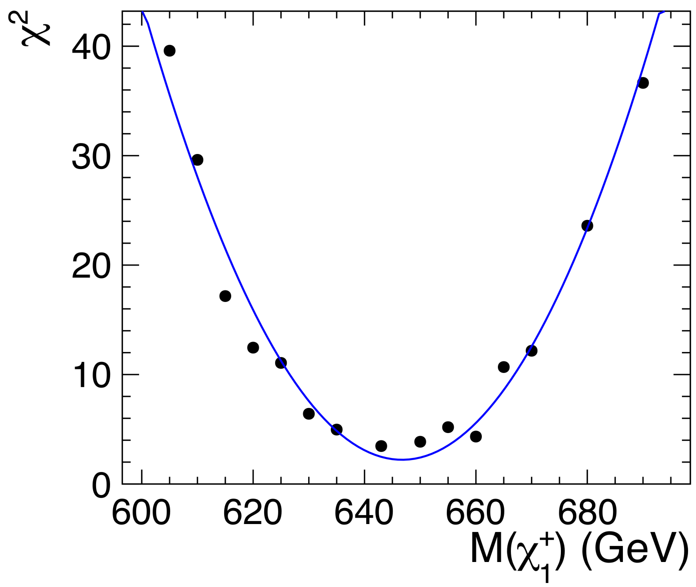
Signal extraction from reconstructed $W^{\pm}$ and h^0 energy distributions

Two independent methods

Template method:

• Generation of MC samples for different SUSY particle hypothesis

• Uncertainties from toy MC



Least squares fit:

• Each $W^{\pm}/Z^0/h^0$ reconstructed energy bin is expanded linearly about the nominal masses and cross sections

• The slopes are obtained by convoluting a map of true-to-reconstructed bin contents with the true energy distributions at different chargino and neutralino masses

Two parameter fits

Template method:

$L_{int} = 2\ ab^{-1}$

Parameter 1	Uncertainty	Parameter 2	Uncertainty
$M(\tilde{\chi}_1^\pm)$	6.3 GeV	$\sigma(\tilde{\chi}_1^+\tilde{\chi}_1^-)$	2.2%
$M(\tilde{\chi}_1^0)$	3.0 GeV	$\sigma(\tilde{\chi}_1^+\tilde{\chi}_1^-)$	1.8%
$M(\tilde{\chi}_2^0)$	7.3 GeV	$\sigma(\tilde{\chi}_2^0\tilde{\chi}_2^0)$	2.9%

Linear least squared fit:

Par. 1	Uncertainty	Par. 2	Uncertainty	$\rho(1,2)$
$M(\tilde{\chi}_1^\pm)$	5.7 GeV	$\sigma(\tilde{\chi}_1^+\tilde{\chi}_1^-)$	2.0 %	0.51
$M(\tilde{\chi}_1^0)$	3.3 GeV	$\sigma(\tilde{\chi}_1^+\tilde{\chi}_1^-)$	1.8 %	0.23
$M(\tilde{\chi}_2^0)$	8.5 GeV	$\sigma(\tilde{\chi}_2^0\tilde{\chi}_2^0)$	3.0 %	0.40

→ Reasonable agreement between both methods

Three parameter fit

• The two parameter fits implicitly assume that the other SUSY parameters are obtained through independent measurements

• Example: M($\tilde{\chi}_1^0$) will be measured with an accuracy of 3 GeV in Slepton events (see talk by Jean-Jacques Blaising)
→ Use as constraint in a three parameter least squares fit

Par. 1	Uncertainty	Par. 2	Uncertainty	Par. 3	Uncertainty	$\rho(1,2)$	$\rho(1,3)$	$\rho(2,3)$
$M(\tilde{\chi}_1^\pm)$	7.3 GeV	$M(\tilde{\chi}_1^0)$	2.9 GeV	$\sigma(\tilde{\chi}_1^+\tilde{\chi}_1^-)$	2.4 %	0.64	0.66	0.51
$M(\tilde{\chi}_2^0)$	9.9 GeV	$M(\tilde{\chi}_1^0)$	3.0 GeV	$\sigma(\tilde{\chi}_2^0\tilde{\chi}_2^0)$	3.2 %	0.52	0.49	0.33

→ Mass and cross section uncertainties up to 30% larger than before

• Also a simultaneous fit of all 5 parameters was performed
→ Results unchanged (due to good separation of both final states)

Summary

• Signals for the pair production of the next-to-lightest neutralino and of the chargino were extracted from fully hadronic final states with four jets and missing transverse energy

• The study was performed using full simulation and considering pileup from $\gamma\gamma \rightarrow$ hadrons

• Two different signal extraction procedures are in reasonable agreement

• The chargino and neutralino pair production cross sections are extracted with a precision of 2-3% while the masses of the $\tilde{\chi}_1^+$, $\tilde{\chi}_1^0$ and $\tilde{\chi}_2^0$ particles were determined with typical uncertainties of 1-1.5%

More information: LCD-Note-2011-037
(`https://edms.cern.ch/document/1160162/`)