Chargino and Neutralino Mass Reconstruction for Small Mass Difference Non-Universal Sugra Points

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A study of $\chi^+\chi^- \rightarrow qq\chi^o + \ell\nu\chi^o$ events from various points in the non-universal SUGRA model where the mass difference between the lightest chargino and neutralino is significantly smaller than the W mass is presented. The parameters of the points correspond to Model Line B (a.k.a. Slope B) established at the 2001 Snowmass workshop. The analysis demonstrates the effectiveness of the two currently considered detector designs for a 500 GeV e^+e^- linear collider to deal with the lost W mass constraint, low energy tracks and high backgrounds. In addition, a unique modification of the energy end-point technique is used to extract the masses of the $\chi^\pm$ and χ^o.

1. Introduction

The study presented here was started at the 2001 Snowmass Workshop as part of the Direct SUSY working group. The objective is to test the ability to measure the chargino and neutralino masses at a 500 GeV e^+e^- linear collider when the mass difference between the lightest chargino and neutralino is very small relative to the W mass. Such signals are theoretically possible in non-universal SUGRA models. A line of points in this model was chosen by imposing simple relations between the gaugino mass parameters (M_1, M_2 and M_3) at the GUT scale. This line has been named Model Line B or Slope B. Three points along this line are used in this analysis. The events at these points have been simulated with $\pm 80\%$ electron beam polarization and no positron beam polarization. The large and small detector models conceived by the american linear collider group are used and their performance in analyzing the signals is compared [1]. The large model is a close approximation of the detector currently being considered by the TESLA group.

The decay mode $\chi^+\chi^- \rightarrow qq\chi^o + \ell\nu\chi^o$ has been chosen for this analysis because of its clean signature and because one of the chargino decays in the event can be fully reconstructed. The standard technique for determining the masses of the charginos and neutralinos in such events is to use end-points of the energy spectrum of the W reconstructed from the qq jets in the $\chi^+ \rightarrow W\chi^o$ decay [2]. When the mass difference between the chargino and neutralino is larger than the W mass then one expects an approximately box shaped distribution for the energy distribution of the W. Furthermore, the constraints on the detector design are minimal because the energy of the jets can be corrected by using a constraint to the W mass. When the mass difference is smaller this constraint is lost and the reconstruction of the energy-flow in the event because much more important. For small mass differences, additional complications arise: more lower momentum particles are present and harder to reconstruct and the signal signature is harder to resolve from the backgrounds.

The technique has been reformulated in terms of the minimum and maximum observed boost of the W ($\gamma_W = E_W^{recon.}/M_W^{recon.}$). This results in the canceling of some of the detector resolution effects. The chargino and neutralino masses in terms of the maximum and minimum boost (γ_{max} and γ_{min}) are given by:

$$m_{\chi^\pm} = \sqrt{\frac{(1+\gamma_{max}*\gamma_{min})-\sqrt{(1-\gamma_{max}^2)\times(1-\gamma_{min}^2)}}{2(\gamma_{max}+\gamma_{min})^2/E_{COM}^2}},\ m_{\chi^o} = \sqrt{m_{\chi^+}^2 \times (1-2\frac{E_{max}+E_{min}}{E_{COM}}) + m_W^2}$$

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Set	M_o	M_1	$M_{2,3}$	A_o	$tan(\beta)$	$sgn(\mu)$	$m_{\chi}^{\pm}$	m_{χ}^{o}
P0	150	480	300	0	10	+1	215.8	182.1
P1	125	400	250	0	10	+1	174.8	153.6
P2	100	320	200	0	10	+1	133.7	117.7

Table I The non-universal SUGRA points used for the analysis. Events at each of these points are produced for +80% and -80% electron beam polarization. No positron beam polarization is used.

Set	cross-section (fb)	# events	$sign(P_e)$
P0	8.82	100000	-
P0	81.3	100000	+
P1	28.4	100000	-
P1	248.0	100000	+
P2	55.1	100000	-
W^+W^-	1160.0	400000	-
W^+W^-	10120.0	400000	+
two-photon($\gamma\gamma$)	1256.0	180000	

Table II List of signal and background samples used for the analysis.

2. Analysis

The analysis proceeds by applying kinematic cuts to obtain a useable signal to background ratio and then fitting a box function convoluted with a Gaussian resolution function to the γ_W distribution to determine the end-points.

The tools for this study were the ISAJET 7.51 generator for the SUSY signals and the W^+W^- background [4]. The signal points that were analyzed are shown in Table I. PYTHIA was used for the two-photon background generation [5]. The fast Monte Carlo simulation package (LCDROOT V3.2) along with Root 3.00 was used for the detector modelling, event reconstruction and analysis [1]. The samples used for the analysis are shown in Table II.

The events are forced into a three jet topology using the Durham jet algorithm. The events must have one jet containing only one track and two others containing at least two tracks. The isolated track is taken to be the lepton. If the energy of clusters within a 20^o degree angle of the jet axis is greater than the track energy then the energy from the sum of the clusters is used instead. Clean-up cuts are applied to eliminate events with clearly mismeasured particles. The major physics backgrounds are from two-photon and W^+W^- events. Two photon events are typified by low acoplanarity, low visible mass, low transverse event momentum and energy loss near the beamline. The W events are typified by high jet-jet mass, high energy leptons, and occasionally very high acoplanarity. The cuts for the analysis reflect the rejections against these background topologies. For the event to be selected the following conditions must be satisfied: maximum track momentum $<$ 130% of beam energy, maximum cluster energy $<$ 130% of beam energy, event acoplanarity between 30. and 150. degrees, jet-jet mass between 5.0 and 50. GeV, missing event transverse momentum/beam energy between 0.05 and 0.10, cosine of event missing momentum direction relative to beamline $<$ 0.60 and cosine of jet and lepton directions relative to beamline $<$ 0.85.

The true W-boost distributions for events passing the selection are shown in Figure 1. The distributions for the various masses are clearly distinguishable. The results from the fits to the distributions which determine the W-boost end-points are marked on the plots.

The plots of the reconstructed W-distributions for the signals, W^+W^- and two-photon backgrounds for the various polarizations and detector models are shown in Figure 2. These results indicate that a positive polarization is necessary to get a sufficient signal above the two-photon background and also that the background levels are significantly less for the small detector model. The reason for the much smaller background level for the small detector is under study and may indicate a way of greatly reducing the background for the large detector. The cuts were tuned for the large detector.

Currently, fits with a background contribution included have not been performed. Doing this

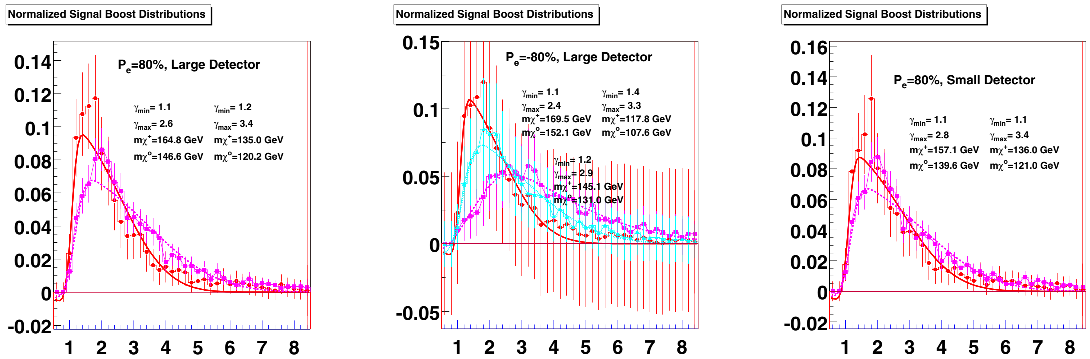

Figure 1: True W-boost distributions of the signals for the large detector and positive electron beam polarization (left), the large detector and negative electron beam polarization (middle), and the small detector and positive electron beam polarization (right). The left and right plots show signals P1 and P2. The middle plot shows signals P0, P1 and P2.

will allow the actual resolution for the masses of the lightest chargino and neutralino to be determined by comparing the results to the actual values for the various signals. The plots presented already indicate that resolutions at the level of a GeV (after rescaling the fit results) are likely achievable with a polarized electron beam.

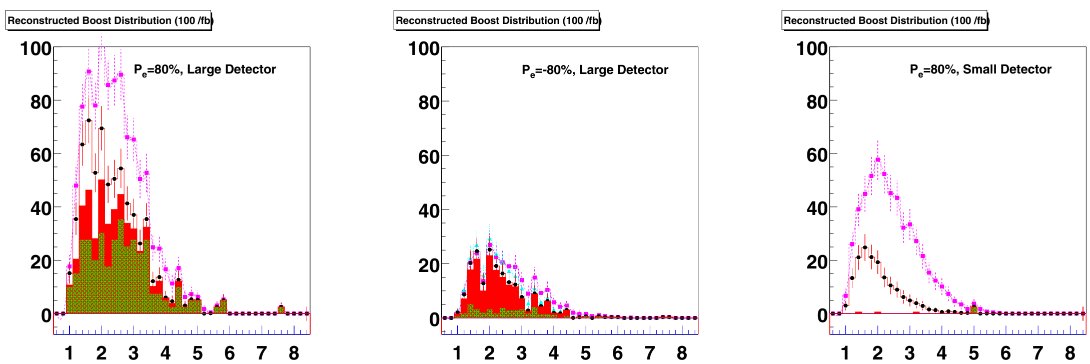

Figure 2: Reconstructed W-boost distributions of the signals, on top of the background expected from W^+W^- events (lower dark shaded region) and two-photon events (middle grey region). The left and right plots show signals P1 and P2. The middle plot shows signals P0, P1 and P2.

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