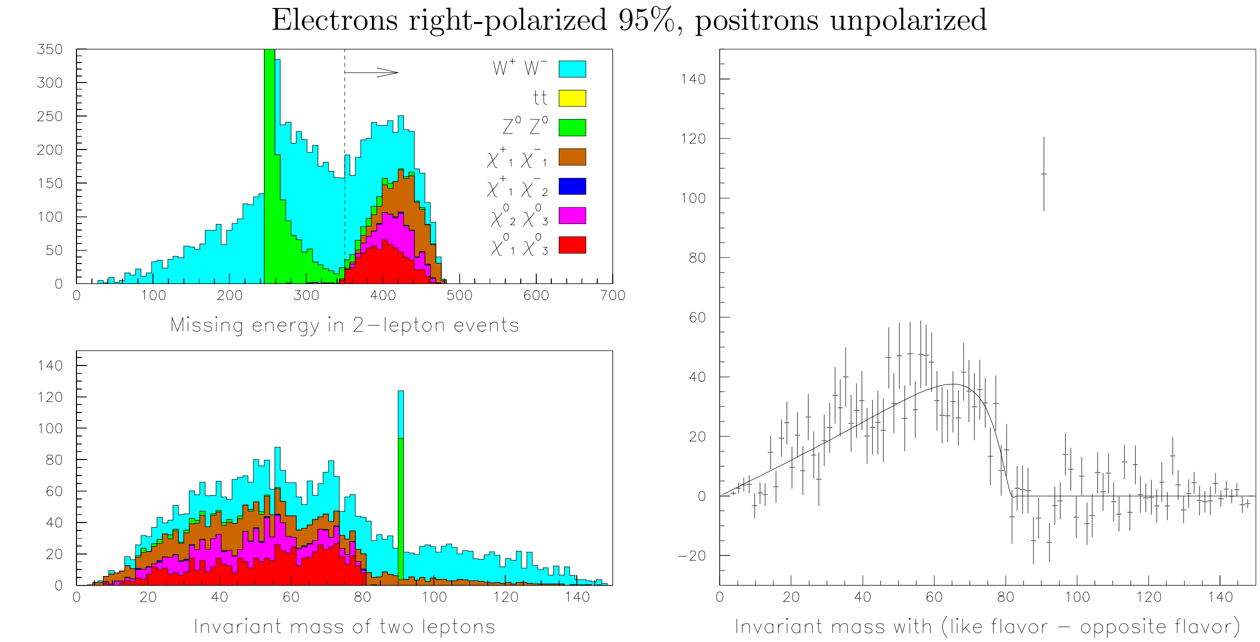

Figure 1: Analysis of neutralinos from 250 fb^{-1} of e^+e^- collisions: electrons 95% right-polarized, positrons unpolarized. Left-top: Missing energy for events with zero jets and two tracks identified as leptons. Left-bottom: Invariant mass of the two leptons with $>$ 350 GeV missing energy. Right: Invariant mass with opposite-flavor leptons subtracted and fit to a threshold function. (All Z-pair events are in the high bin at 91 GeV.)

1 Neutralinos to Two Leptons

$$\begin{array}{llll} e^+e^- \to \tilde{\chi}^0_1 & \tilde{\chi}^0_3 & & \\ & \tilde{\chi}^0_3 \to \tilde{\chi}^0_1 & Z^* & \\ & & Z^* \to \ell^+\ell^- & \end{array}$$

and

$$\begin{array}{lllllll} e^+e^- \to & \tilde{\chi}^0_2 & & & \tilde{\chi}^0_3 & & \\ & \tilde{\chi}^0_2 \to \tilde{\chi}^0_1 & Z^* & & \tilde{\chi}^0_3 \to \tilde{\chi}^0_1 & Z^* & \\ & & Z^* \to \nu\bar{\nu} & & & Z^* \to \ell^+\ell^- & \end{array}$$

Both neutralino modes, $\tilde{\chi}^0_1\tilde{\chi}^0_3$ and $\tilde{\chi}^0_2\tilde{\chi}^0_3$, can be identified by selecting events with two oppositely-charged tracks and missing energy. This lets the $\tilde{\chi}^0_3$ decay into a $Z^0 \to \ell^+\ell^-$ (two electrons or muons) and $\tilde{\chi}^0_1$ (missing energy). (The prompt $\tilde{\chi}^0_1$ also contributes to missing energy.) While the neutralino signals can be cleanly distinguished from Standard Model and chargino backgrounds, it is difficult to separate the two signals from each other because $\tilde{\chi}^0_2$ can decay invisibly into $\tilde{\chi}^0_1$ with a $Z^0 \to \nu\bar{\nu}$. Consequently, the two-lepton final state can only be used to measure a weighted sum of the two modes, to be disambiguated later by the two jet, two lepton measurement of $\tilde{\chi}^0_2\tilde{\chi}^0_3$ alone (see section **??**). One measurement that

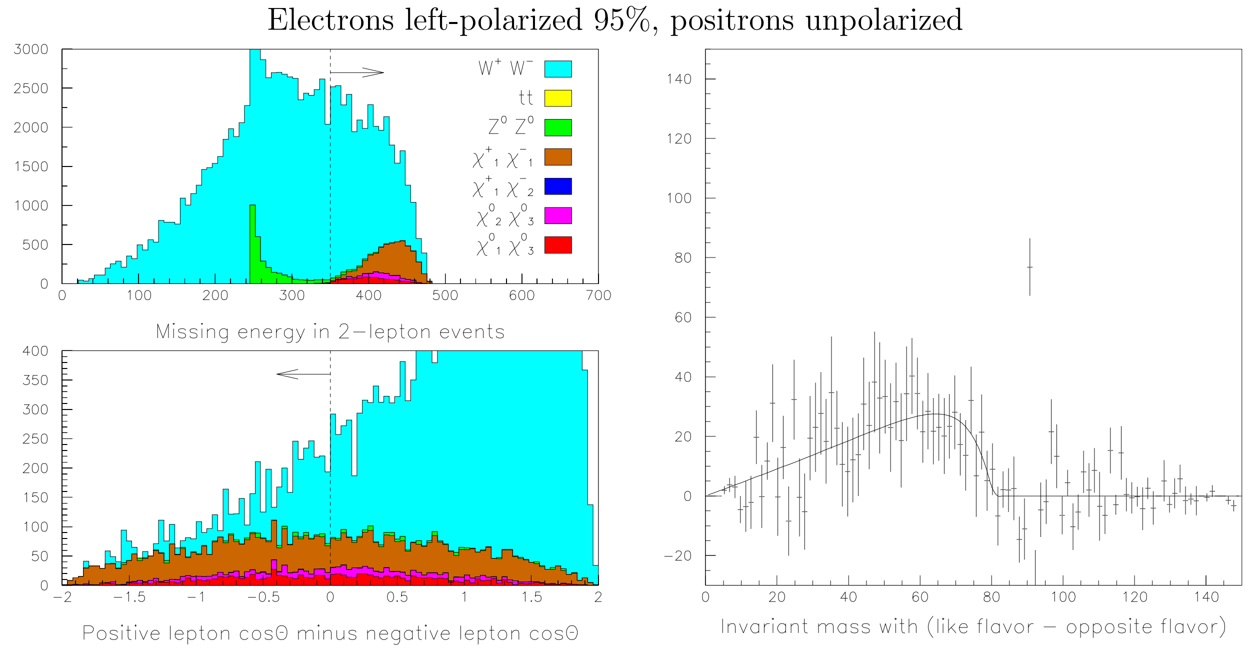

Figure 2: Analysis of neutralinos from 250 fb^{-1} of e^+e^- collisions: electrons 95% left-polarized, positrons unpolarized. Left-top: Missing energy for events with zero jets and two tracks identified as leptons. Left-bottom: Cosine of the polar angle of the positive track from the positron beam-line minus that of the negative track, with > 350 GeV missing energy. The cut at zero divides the signal symmetrically and avoids the region where $W^\pm$ is correlated in direction with the incident $e^\pm$. Right: Invariant mass with opposite-flavor leptons subtracted and fit to a threshold function, with missing energy and angle cuts applied. (All Z-pair events are in the high bin at 91 GeV.)

is actually aided by the overlapping modes is the mass difference between $\tilde{\chi}^0_3$ and $\tilde{\chi}^0_1$; both neutralinos have an upper limit in invariant mass at this mass difference.

The most effective means of background suppression comes from the availability of polarized beams: if only the electron beam is 95% right-polarized, W-pair events in the signal region (missing energy) are supressed by a factor of nine over unpolarized beams. Although the right-polarization will yield by far the most significant results, we also consider the left-polarization, in which the W-pair background is actually enhanced.

We select events with zero jets, two oppositely-charged tracks identified as electrons or muons, and more than 350 GeV of missing energy. For a right-polarized beam, these are our only requirements (Figure **??**). For a left-polarized beam, swamped with W-pair backgrounds, we also require that the polar angle of the positive lepton with respect to the incident positron beam be less than the polar angle of the negative lepton. This avoids the region in which the direction of the $W^\pm$ is correlated with the incident $e^\pm$, reducing this background by more than a factor of ten. The neutralino signal, being forward-backward symmetric, is only reduced by a factor of two (Figure **??**).

The primary backgrounds are W-pairs, Z-pairs, and light charginos. W-pairs are either suppressed by right-polarization or the angular cut described above, and Z-pairs have predictable missing energy outside the regions of interest, leaving charginos as the only irreducible background. W-pairs and charginos can be subtracted without model dependence by noting that signal neutralinos always decay to two leptons of the same flavor, while W-pairs and charginos decay to two uncorrelated lepton flavors. (Each chargino decays to $\tilde{\chi}_1^0$ with a $W^\pm$, which decays to a lepton and a neutrino.) If, therefore, we assume perfect flavor tagging and subtract opposite-flavor events from the invariant mass plot, we obtain a histogram with the two neutralino modes superimposed, W-pair and chargino backgrounds only contributing to statistical error, and all Z-pair events in one bin (91 GeV) above the maximum neutralino invariant mass ($\sim$80 GeV). These histograms are shown on the rights of Figures **??** and **??**.

The combined cross-sections of $\tilde{\chi}_1^0\tilde{\chi}_3^0$ and $\tilde{\chi}_2^0\tilde{\chi}_3^0$ can be determined by integrating this histogram up to about 85 GeV (to exclude bias from the Z-pairs and statistical error from the W-pair and chargino subtraction). For 250 fb^{-1}, this yields 1093 ± 65 for a right-polarized beam and 720 ± 91 for a left-polarized beam with the cuts described. The coefficients for the weighted sum of cross-sections are derived from branching fractions and efficiencies for each mode into the two detected leptons with all applied cuts. The branching fractions times efficiencies are given in Table **??**.

	electrons 95% left-polarized	electrons 95% right-polarized
$\tilde{\chi}_1^0\tilde{\chi}_3^0$	0.0308	0.0584
$\tilde{\chi}_2^0\tilde{\chi}_3^0$	0.0123	0.0254

Table 1: Branching fractions times efficiencies for left- and right-polarized electron beams.

Dividing these by the number of events seen and multiplying by 250 fb^{-1}, we obtain the constraints on the left- and right-handed cross-sections of $\tilde{\chi}_1^0\tilde{\chi}_3^0$ (σ_{13}^L and σ_{13}^R) and $\tilde{\chi}_2^0\tilde{\chi}_3^0$ (σ_{23}^L and σ_{23}^R).

$$0.0107\,\sigma_{13}^L + 0.00427\,\sigma_{23}^L = 1 \pm 0.13\sqrt{\frac{250\text{ fb}^{-1}}{\mathcal{L}}} \quad (1)$$

$$0.0133\,\sigma_{13}^R + 0.00580\,\sigma_{23}^R = 1 \pm 0.059\sqrt{\frac{250\text{ fb}^{-1}}{\mathcal{L}}} \quad (2)$$

where $\mathcal{L}$ is the total integrated luminosity.

Left- and right-polarized neutralino cross-sections are expected to differ by about 30%, but this difference will probably not be observable. Assuming a perfect σ_{23} subtraction, the difference between σ_{13}^L (56.8 fb) and σ_{13}^R (44.1 fb) can only be distinguished at the 3-σ level with 900 fb^{-1} of right-polarized collisions.

To measure the mass difference between $\tilde{\chi}_3^0$ and $\tilde{\chi}_1^0$, we fit our lepton invariant mass spectrum to the neutralino threshold function discussed in section **??**. The Z-pair bin contributes to the χ^2 of the fit, but not any of its derivatives near the minimum (since the fit function is exactly flat at 91 GeV). (It could just as easily be dropped from the fit.) While fits of this function to the histograms shown on the rights of Figures **??** and **??** converged, they yielded central values which depend linearly on the bin spacing for small variations, even with five times as many bins! For a different final state (section **??**), this pathology is avoided by employing an unbinned maximum likelihood fit, but such a technique would be hard to implement without giving up the model-independent background subtraction described above. Since statistical errors should be independent of the fitting technique, we report errors from our binned χ^2 minimization, which do not depend on bin spacing: ± 0.7 GeV from right-polarized electrons and ± 2 GeV from left-polarized electrons.