Another method for measuring masses

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Abstract

In [1], I give a general description of how to measure selectron masses taking into account the fact that $e^+e^- \to \tilde{e}_R^+\tilde{e}_R^-$ production is symmetric. This method was based on work done by Jonathan Feng [2] on squark mass measurements. In this paper, I elaborate on the method and show some results using data from point 2.

1 Theory

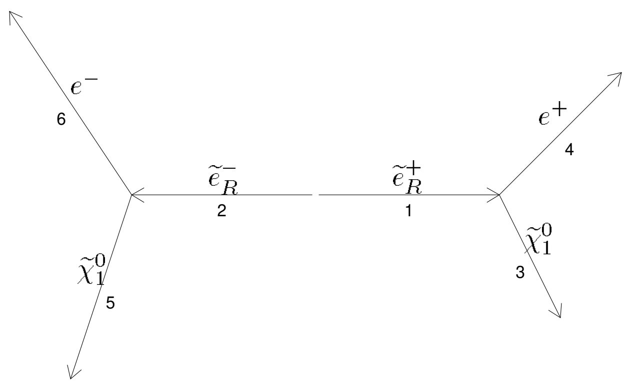

Figure 1: The momentum vectors in a selectron-pair event.

Let's assume that we know the mass of the neutralino from previous measurements (say, from $\tilde{\chi}_1^+$decays). Consider Figure 1, which is a diagram of $e^+e^- \to \tilde{e}_R^+\tilde{e}_R^-$ production with the subsequent decay $\tilde{e}_R^\pm \to \tilde{\chi}_1^0 e^\pm$. Let us begin the analysis by writing down all the quantities we know *a priori*. For the selectrons, we know the quantities e_1 and e_2 (these must be equal to the beam energy) but not $\mathbf{p}_1$, $\mathbf{p}_2$, nor $M_{\tilde{e}_R}$ (although we do know that $\mathbf{p}_1 = -\mathbf{p}_2$). We know everything about the electrons, since we measure them: $\mathbf{p}_4$, $\mathbf{p}_6$, e_4, e_6 and M_e.

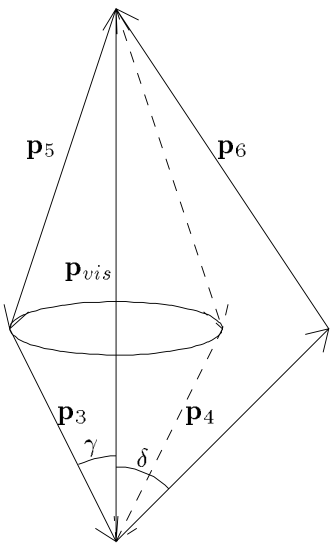

Figure 2: The vectors $\mathbf{p}_4$ and $\mathbf{p}_6$ are known. If the $\tilde{\chi}_1^0$ mass is also known, then the vectors $\mathbf{p}_3$ and $\mathbf{p}_6$ are constrained to lie on the indicated circle.

From these quantities, we can calculate a few more. In Figure 2, the vectors $\mathbf{p}_4$ and $\mathbf{p}_6$ are known. If the $\tilde{\chi}_1^0$ mass is also known, then the vectors $\mathbf{p}_3$ and $\mathbf{p}_6$ are constrained to lie on the indicated circle. We know $e_3 = e_1 - e_4$ and $e_5 = e_2 - e_6$. Therefore, we know:

$$|\mathbf{p}_3| = \sqrt{e_3^2 - M_{\tilde{\chi}_1^0}^2}$$

$$|\mathbf{p}_5| = \sqrt{e_5^2 - M_{\tilde{\chi}_1^0}^2}$$

and

$$\delta = \cos^{-1}\left(\frac{\mathbf{p}_{vis}\cdot\mathbf{p}_4}{p_{vis}\,p_4}\right)$$
$$\gamma = \cos^{-1}\left(\frac{p_3^2+p_{vis}^2-p_5^2}{2p_3\,p_{vis}}\right)$$

The maximum possible momentum for the $\tilde{e}_R^+$ occurs when $\mathbf{p}_3+\mathbf{p}_4$ is maximal, which is when then angle between these two vectors is $\gamma+\delta$:

$$(p_1^{max})^2 = p_3^2+p_4^2-2p_3p_4\cos(\gamma+\delta)$$

Thus we can construct a quantity $M_{\tilde{e}_R}^{min}$ which is:

$$(M_{\tilde{e}_R}^{min})^2 = E_{beam}^2-(p_1^{max})^2$$

2 Experiment

Let's take point 2 data (50 fb^{-1} of both SUSY signal and standard model background at $\sqrt{s}=$ 500 GeV with 80% right-polarized electrons) and make the following cuts to ensure a good sample of $e^+e^-\to\tilde{e}_R^+\tilde{e}_R^-$ events:

- exactly one e^+, one e^- and no other particles
- $-0.80<\cos\theta_{e^-}<0.80$ (Figure 3 shows the distribution of $\cos\theta_{e^-}$)
- 4 GeV $<E_{e^\pm}<$ 180 GeV

With these cuts, we can then plot the distribution of the quantity $M_{\tilde{e}_R}^{min}$ on an event-by-event basis, and produce the histogram shown in Figure 4.

As can be seen, the peak of the distribution is at 156.3 GeV, which is 0.4% from the true generated selectron mass of 157.0 GeV. Thus, this method seems to produce an extremely precise measurement of the selectron mass (and it should be easily adapted to other measurements).

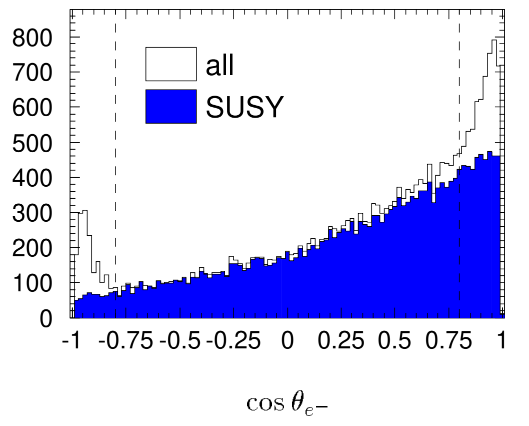

Figure 3: The direction of the negative electron.

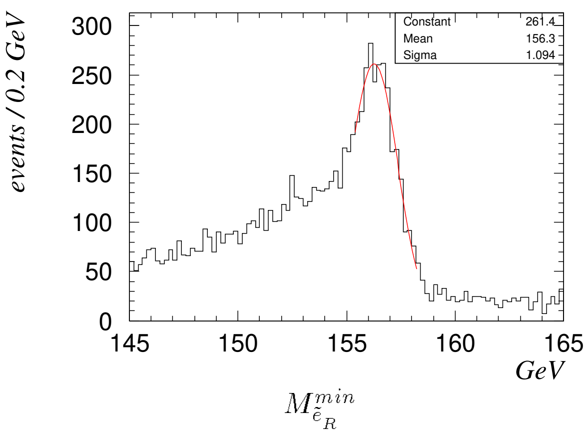

Figure 4: The distribution of the quantity $M_{\tilde{e}_R}^{min}$ for selectron-pair events.

References

[1] D. L. Wagner, Measuring masses using correlations, 1997.

[2] J. L. Feng and D. E. Finnell, Phys. Rev. D **49**, 2369 (1994), hep-ph/9310211.