

RECONSTRUCTING SLEPTONS IN CASCADE-DECAYS AT THE LINEAR COLLIDER

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A method to reconstruct sleptons in cascade-decays at the FLC is presented. It is shown that experimental mass-resolutions as low as $8.7 \text{ MeV}/c^2$ are attainable.

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I have studied the cascade process $e^+e^- \rightarrow \tilde{\chi}_2^0\tilde{\chi}_2^0 \rightarrow \tilde{\ell}\tilde{\ell}ll \rightarrow \tilde{\chi}_1^0\tilde{\chi}_1^0lll'l'$ at a number of SPS points[1,2]. Simulated events were processed by the fast detector simulation SGV[3-5]. Events that did not contain other charged particles than the four leptons, and had clear signs of undetected particles were further analysed. The $\tilde{\chi}^0$:s were reconstructed using the seen leptons and conservation laws. E and $|p|$ of the $\tilde{\chi}_2^0$:s follow from energy conservation and their direction is found the way p_W in $e^+e^- \rightarrow W^+W^- \rightarrow l\nu l\nu$ is found, yielding two possible solutions[6]. The momentum of the $\tilde{\chi}_1^0$ was obtained from $P_{\ell\ell}$ and each of the two $\tilde{\chi}_2^0$ solutions, and $P_{\tilde{\ell}}$ by adding the momentum of $\tilde{\chi}_1^0$ to the appropriate $P_{\tilde{\ell}}$. As there is no way to determine which lepton came from the slepton decay, and there are two possible values for the momentum of $\tilde{\chi}_1^0$, there will be four possible solutions for each slepton (or eight in $4e$ or 4μ events). ^a

Slepton mass determination in SPS1a. In SPS1a, at $E_{\text{cms}} = 500 \text{ GeV}$, and $\mathcal{L} = 500 \text{ fb}^{-1}$, 800 events of this type are expected. There are no other cascades open, but one expects 10^6 other SUSY events. Events were selected as above: There should nothing but four charged leptons seen, $\not{p}_t > 10 \text{ GeV}/c$, $M_{\text{vis}} \in [100, 300] \text{ GeV}/c^2$, $E_{\text{seen}}(E_{\text{seen,neut}}) < 300$ (150) GeV . The thrust-axis should be above 0.3 Rad , and $E_{\text{calo,below}30^\circ} < 150 \text{ GeV}$ (the last two cuts removes the $\gamma\gamma$ background). For all eight (or 16) possible values of $P_{\tilde{\ell}}$ the invariant mass was calculated. A narrow peak at the right mass corresponds to the correct solutions (two per event). The decay of the $\tilde{\chi}_2^0$ is a three-body decay ($\ell\ell \tilde{\chi}_1^0$), so the tail from the wrong solutions can be suppressed by demanding that they should be in the Dalitz-triangle, and be within the narrow bands corresponding to the right combination (fig 1a). One can often reject the

^aSimilar ideas have been applied by other workers for background rejection in SUSY searches at LEP[7], to cascades at LHC[8] and to \tilde{e} -production in e^+e^+ -collisions[9].

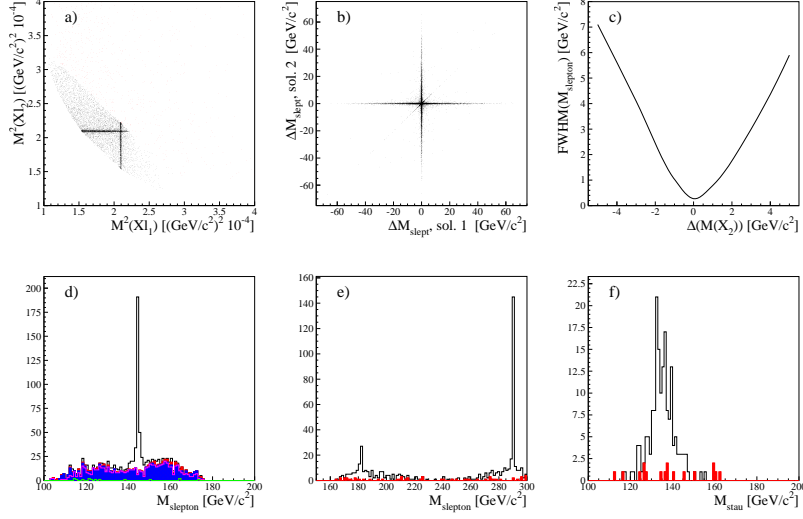


Figure 1: Various kinematic distributions, for $\tilde{\mu}$ in SPS1a, if nothing else is mentioned. a) Dalitz plot. b) Difference between the two reconstructed $M_{\tilde{\mu}}$ for each of the solutions. c) FWHM of the peak as a function of $M_{\tilde{\chi}_2^0} - M_{\tilde{\chi}_2^0}^{input}$. d) $M_{\tilde{\mu}}$. e) $M_{\tilde{\mu}}$ in SPS3. f) $M_{\tilde{\tau}}$.

wrong $\tilde{\chi}_2^0$ -solution by demanding that the masses are equal: in the vertical band in fig 1b, solution 1 is likely to be correct, in the horizontal, solution 2. In fig 1c, the width of the peak is shown as a function of $M_{\tilde{\chi}_2^0}$: the clear minimum shows that $M_{\tilde{\chi}_2^0}$ can also be extracted from the data. Fig 1d shows the observed distribution of the reconstructed $M_{\tilde{\mu}}$ with background, ISR and beam-strahlung included (the two latter do not effect σ , but migrates events to the tails, reducing ϵ). The background, dominated by $\tilde{e}_R\tilde{e}_L \rightarrow e\tilde{\chi}_1^0 e\tilde{\chi}_2^0 \rightarrow e\tilde{\chi}_1^0 e\tilde{\ell} \rightarrow e\tilde{\chi}_1^0 e\ell\ell' \tilde{\chi}_1^0$, is flat. The width of the reconstructed mass peak is 83 MeV/ c^2 (experimental resolution: the generated natural width is 0). There are 90 events in the peak ($\epsilon = 11\%$). The error on the mass ($= \frac{\sigma}{\sqrt{N}}$) is 8.7 MeV/ c^2 (0.05%). The fitted mass (true mass) is 174.74 (174.73) GeV/ c^2 .

Multiple cascades. In SPS3, both \tilde{e}_R and \tilde{e}_L have masses below $M_{\tilde{\chi}_2^0}$, yielding cascades that cannot be separated by the identity of the leptons. Still, with minor modifications, the same method can be used to extract both $M_{\tilde{\ell}}$. The Dalitz-triangle does not depend on $M_{\tilde{\ell}}$, but the presence of several particles will show up as more bands. To analyse the events, the position of one peak is determined, then events with masses close to this value in one Dalitz-projection

are cut out, which enables to find the smaller peak in the *other* projection (fig 1e). There is little SUSY background in SPS3, since both \tilde{e}_R and \tilde{e}_L have masses below $M_{\tilde{\chi}_2^0}$: The $\tilde{e}_R\tilde{e}_L$ channel cannot be confused with the signal. The fit to the two peaks yields $\sigma_{L(R)} = 103(176)\text{MeV}/c^2$. At $E_{\text{cms}} = 800$ GeV and with $\mathcal{L} = 500 \text{ pb}^{-1}$, 50(18) events are found in the peak, yielding $\delta(M_{\tilde{\mu}}) = 14.5$ (41.4) MeV/c^2 (0.05 (0.2)%). The fitted mass is 290.0(181.9) GeV/c^2 , while the true value is 289.96 (181.83) GeV/c^2 .

Stau channels. Because of the ν :s in the τ -decays, the method will not work for $\tilde{\tau}$:s. However, in channels where only one $\tilde{\chi}_2^0$ decays to a $\tilde{\tau}$, an approximation can be found, if $M_{\tilde{\mu}}$ (or $M_{\tilde{e}}$) is known: using the known masses (including M_τ), the events can be reconstructed, except for two unknowns. One - the azimuthal angle between the τ and the τ -jet - has a minor effect on the reconstructed $M_{\tilde{\tau}}$. The other is E_τ in the $\tilde{\chi}_2^0$ decay, which can be estimated using all available information, and an initial guess on $M_{\tilde{\tau}}$. At certain combinations of E_{jet} and M_{jet} , E_τ can only vary within a quite limited range, and - under very general assumptions - the p.d.f. of E_τ can be determined. Therefore, for any E_{jet} and M_{jet} , $E(E_\tau)$ and $V(E_\tau)$ can be found, and one can select events with low variance estimates. The cuts used are the same as for \tilde{e} and $\tilde{\mu}$ except that the topology should be two leptons and two τ -jets[10], and that the $\tilde{e}_R\tilde{e}_L$ background must be removed by selecting events without electrons. In fig 1f, the final mass plot for SPS1a is shown. One finds $\sigma = 5.07 \text{ GeV}/c^2$, and 176 events in the peak ($\epsilon = 7 \%$). This leads to $\delta(M_{\tilde{\tau}}) = 380 \text{ MeV}/c^2$ (3 %), comparable to other methods[11]. The fitted mass (true mass) is 135.3 (135.4) GeV/c^2 . $M_{\tilde{\tau}}$ is one input to the E_τ estimation; it was verified that the fitted value was not sensitive to the input. By varying the $\tilde{\tau}$ mixing, it was also verified that the peak indeed moves with $M_{\tilde{\tau}}$.

Conclusions. By reconstructing $\tilde{\chi}_2^0$ cascades when the cascade passes a $\tilde{\ell}$, I show that $\delta(M_{\tilde{\ell}})$ as low as 8.7 MeV/c^2 ($\tilde{\mu}$ in SPS1a) can be obtained, with ISR, beam-strahlung, detector-resolution, background and ambiguities taken into account. An approximate method to treat $\tilde{\tau}$ -channels was presented.

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