An Unusual Signal for Supersymmetry at the Tevatron

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Abstract

We propose a new scenario in which the dominant signal for supersymmetry at the Tevatron are the events having two or three $\tau$ leptons with high $p_T$ accompanied by large missing transverse energy. This signal is very different from the multijet or multileptons (involving $e$ and/or $\mu$ only) or the photonic signals that have been extensively investigated both theoretically and experimentally. A large region of the GMSB parameter space with the lighter stau as the NLSP allow this possibility. Such a signal may be present in the past Tevatron data to be analyzed.

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Over the past two decades, there has been a great deal of experimental effort to discover the supersymmetric (SUSY) particles at the Tevatron. The searches have concentrated mainly in two fronts. One is to look for the SUSY partners of the strongly interacting quarks and gluons, namely the squarks and the gluinos \[1\]. In this case, the signals are multijets and/or multileptons with high $p_T$ plus large missing transverse energy ($E_T$). The other is to look for the SUSY partners of the leptons and the electroweak (EW) gauge bosons namely the sleptons, charginos and the neutralinos. The signals looked for in this case are high $p_T$ multileptons, namely dileptons and trileptons (involving $e$ and/or $\mu$) \[2\] accompanied by large $E_T$. Both types of the signals have been motivated by the gravity mediated SUSY breaking theories where the lightest neutralino is mostly the lightest SUSY particle (LSP) to which all the produced SUSY particles eventually decay. LSP escapes detectors giving rise to the $E_T$ signal. In the last two years gauge mediated SUSY breaking (GMSB) models have become very popular \[3,4\]. In these theories, gravitino is the LSP, and most of the experimental searches have concentrated on the regions of the theory in which the lightest neutralino $\chi_0$ is the next to lightest SUSY particle (NLSP). $\chi_0$ decays to a photon and a gravitino within the detector. The signal in this case is photons with high $p_T$ and large $E_T$ \[3\]. Inspite of the extensive searches no SUSY signal in any of the considered modes has yet been observed either at the Tevatron \[6\] or at the LEP2 \[7\], except for one possible $e^+e^-\gamma\gamma$ plus missing energy event at the Tevatron \[8\]. The object of this work is point out that in the GMSB theories the dominant signal for the SUSY can be two to three high $p_T$ $\tau$ leptons plus large $E_T$. This happens when the lighter of the scalar tau (\(\tilde{\tau}_1\)) is the NLSP. In that case all the produced SUSY particles will eventually decay to $\tilde{\tau}_1$ which subsequently decays to a $\tau$ and a gravitino. The gravitino escapes the detector giving rise to $E_T$. Such a signal occurs for a large region of the GMSB parameter space. In this case, discovery of SUSY will crucially depend on the ability of the detectors to detect high $p_T$ $\tau$ leptons with good efficiency.

The dominant processes that give rise to our signal at the Tevatron are the productions of chargino pairs ($\chi^+\chi^-$) and the chargino and the second neutralino pairs ($\chi^\pm\chi_2^0$).
(σχ±χ0, where χ0 is the lightest neutralino is very small compared to σχ±χ0). The chain of decays of χ± and χ0 lead to the observable high \( p_T \) τ’s and the missing neutrinos and the gravitinos. There are several mass hierarchies of these superparticles, (involving χ±, χ2, \( \tilde{\nu} \), \( \tilde{\ell} \)) leading to the inclusive high \( p_T \) 2τ or 3τ final states plus \( E_T \). Below we first briefly discuss the GMSB parameter space giving rise to \( \tilde{\tau} \) as the NLSP and our desired scenario.

In GMSB models, with radiative EW symmetry breaking, all the sparticle masses and the mixing angles depend on five parameters, \( M, \Lambda, n, \tan \beta, \) and sign of \( \mu \). \( M \) is the messenger scale, and \( \Lambda \) is equal to \( \langle F_s \rangle / \langle s \rangle \), where \( \langle s \rangle \) is the VEV of the hidden sector field \( S \), and \( \langle F_s \rangle \) is the VEV of the auxiliary component of \( S \). The parameter \( n \) is fixed by the choice of the vector like messenger sector. For example, for 5 + \( \bar{5} \) of \( SU(5) \), \( n \) can take the values 1, 2, 3 or 4. The parameter \( \tan \beta \) is the usual ratio of the up \( (H_u) \) and down \( (H_d) \) type Higgs VEVs. The parameter \( \mu \) is the coefficient in the bilinear term, \( \mu H_u H_d \) in the superpotential. We demand that the electroweak symmetry be broken radiatively which then determines the magnitude of \( \mu \) and another parameter \( B \) (in \( B \mu H_u H_d \) term in the potential) in terms of the other parameters of the theory. The constraints coming from \( b \rightarrow s \gamma \) demands \( \mu \) to be mostly negative \[9\]. The soft SUSY breaking gaugino and the scalar masses at the messenger scale \( M \) are given by \[3,10\]

\[
\tilde{M}_i(M) = n \, g \left( \frac{\Lambda}{M} \right) \frac{\alpha_i(M)}{4\pi} \Lambda. \tag{1}
\]

and

\[
\tilde{m}^2(M) = 2 \, n \, f \left( \frac{\Lambda}{M} \right) \sum_{i=1}^{3} k_i \, C_i \left( \frac{\alpha_i(M)}{4\pi} \right)^2 \Lambda^2. \tag{2}
\]

where \( \alpha_i, i = 1, 2, 3 \) are the three SM gauge couplings and \( k_i = 1, 1, 3/5 \) for SU(3), SU(2), and U(1), respectively. The \( C_i \) are zero for gauge singlets, and 4/3, 3/4, and \( (Y/2)^2 \) for the fundamental representations of \( SU(3) \) and \( SU(2) \) and \( U(1)_Y \) respectively (with \( Y \) defined by \( Q = I_3 + Y/2 \)). Here \( n \) corresponds to \( n(5 + \bar{5}) \). \( g(x) \) and \( f(x) \) are messenger scale threshold functions with \( x = \Lambda/M \). We have studied in great detail the super partner mass spectrum

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in the \((M, \Lambda, n, \tan \beta)\) parameter space for negative \(\mu\). We have calculated the SUSY mass spectrum using the appropriate RGE equations \([11]\) with the boundary conditions given by the equations above. In the scenarios where \(\chi_0\) is the NLSP, one obtains high \(p_T\) photon signal and these scenarios have been studied in great detail both theoretically \([12, 13]\) and experimentally \([14]\). In the GMSB parameter space, this occurs for \(n = 1\) and low values \(\tan \beta\) (\(\tan \beta \leq 25\)) \([12]\). However, as \(\tan \beta\) increases, \(\tilde{\tau}_1\) becomes the NLSP for most of the parameter space with lower values of \(\Lambda\). For \(n \geq 2\), \(\tilde{\tau}_1\) is the NLSP even for the low values of \(\tan \beta\) (for example, \(\tan \beta \gtrsim 2\)), and for \(n \geq 3\), \(\tilde{\tau}_1\) is again naturally the NLSP for most of the parameter space. The parameter space where \(\tilde{\tau}_1\) is the NLSP give rise to our proposed high \(p_T\) \(\tau\) signals. The next question we ask is the following: can \(\chi^\pm\) and \(\chi_2^0\) be light enough to be produced at the Tevatron energy? Some examples of the mass spectrum, appropriate for exploration at the Tevatron energy is shown in Table 1 and 2. All of the superpartner masses satisfy the current experimental limits applicable for this scenario.

At the Tevatron, the chargino pair \((\chi^+\chi^-)\) production takes place through the s-channel \(Z\) and \(\gamma\) exchange; while the \(\chi_2^0\chi^\pm\) production is via the s channel \(W\) exchange. Squark exchange via the t-channel will also contribute to both processes. Since the squark masses are large in the GMSB models these contributions are negligible. The inclusive final states arising from both of processes are either \(2\tau\) or \(3\tau\) with high \(p_T\) plus \(E_T\) (due to the undetected neutrinos and gravitinos). The \(2\tau\) mode will be mostly of opposite sign charges, but a significant fraction will also have the same sign of charges. The details of the decays for the \(\chi^\pm\) and \(\chi_2^0\) depend on the hierarchies of the superparticle masses, which in turn depend on the GMSB parameter space. In most of the parameter space we looked at, the mass of \(\chi_2^0\) is approximately equal to that of \(\chi^\pm\) (within a few GeV). The sneutrinos \(\tilde{\nu}_l\) (\(l = e, \mu, \tau\)) can be heavier or lighter than the \(\chi^\pm\). (The sneutrinos are always heavier than the righthanded sleptons because of the SU(2) gauge interactions.) Also, \(\chi_0\) can be heavier or lighter than the right handed \(\tilde{e}, \tilde{\mu}\). Thus there are four possible cases for the mass hierarchies:

\[
\text{case1 : } M_{\chi_2^0} \geq M_{\chi^\pm} > m_{\tilde{e}, \tilde{\mu}} > M_{\chi_1^0} > m_{\tilde{\tau}_1}\]  \(\text{(3)}\)
case 2: $M_{\chi_2^0} \geq M_{\chi^\pm} > m_{\tilde{\nu}} > M_{\chi^0} > m_{\tilde{e}, \tilde{\mu}} > m_{\tilde{\tau}_1}$

case 3: $m_{\tilde{\nu}} > M_{\chi_2^0} \geq M_{\chi^\pm} > m_{\tilde{e}, \tilde{\mu}} > M_{\chi^0} > m_{\tilde{\tau}_1}$

case 4: $m_{\tilde{\nu}} > M_{\chi_2^0} \geq M_{\chi^\pm} > M_{\chi^0} > m_{\tilde{e}, \tilde{\mu}} > m_{\tilde{\tau}_1}$

All three sneutrino masses are essentially the same. The scalars $\tilde{e}$ and $\tilde{\mu}$ are essentially right handed and get the same masses. In table 1, we give four scenarios for case 1. The scenarios occur mostly for $n=3$. The reason is that the gaugino masses are proportional to $n$ while the scalar masses are proportional to $\sqrt{n}$. Thus for higher values of $n$, the scalar masses get reduced compared to the gaugino masses resulting in $m_{\tilde{\nu}}, m_{\tilde{e}, \tilde{\mu}} < M_{\chi^\pm}$. Increasing $n$ further ($n=4$), $\tilde{e}, \tilde{\mu}$ masses get even smaller than $m_{\chi^0}$ producing case 2. Two scenarios for case 2 is shown in Table 2. Case 3 occurs for smaller values of $n$ in order to have $m_{\tilde{\nu}}$ larger than $M_{\chi_2^0}$. Two scenarios for case 3 are also shown in table 2. We have not found a scenario for case 4. In table 1 and 2, we also give the production cross-sections of the chargino pair and for the chargino -second neutralino at the Tevatron for two center of mass energies, $\sqrt{s} = 1.8$ TeV and $\sqrt{s} = 2.0$ TeV. $\sigma(\chi^\pm \chi^0)$ is always somewhat bigger than $\sigma(\chi^+ \chi^-)$.

Now, we are ready to discuss the decays of the chargino and the second neutralino and the resulting final states. We first consider the case 1. The four main decay modes for the chargino are: $\chi^+ \rightarrow (\nu_\tau \tilde{\tau}_1, \tau \tilde{\nu}_\tau, e\tilde{\nu}_e, \mu\tilde{\nu}_\mu)$. (Since the lighter $\tilde{e}$ and $\tilde{\mu}$ are essentially right handed the branching ratio to the other two kinematically allowed decay modes $\nu_e\tilde{e}$, $\nu_\mu\tilde{\mu}$ are essentially zero.) Subsequently $\tilde{\nu}_l (l = e, \mu, \tau)$ decays to $\nu_l\chi^0$, followed by the decay $\chi^0 \rightarrow \tau \tilde{\tau}_1$. Finally, $\tilde{\tau}_1$ decays to a $\tau$ and a gravitino. (The branching ratio for the decays of $\tilde{\nu}_l, \tilde{l}, \chi^0$ and $\tilde{\tau}_1$ is 100 %.) The possible final states from a chargino decays are: $(\tau, 3\tau, e\tau\tau, \mu\tau\tau)$ accompanied by the neutrinos and the gravitinos. Only one $\tau$ arising from the decay of $\tilde{\tau}_1 \rightarrow \tau \tilde{G}$ will have large $p_T$. The final states arising from the decays of the produced chargino pair are: $2\tau, 4\tau, 6\tau, (e, \mu) + 3\tau, (e, \mu) + 5\tau, (2e, 2\mu) + 4\tau, e\mu + 4\tau$, accompanied by the large $E_T$ due to the undetected gravitinos and the neutrinos. The branching ratios for these various final states for the scenarios in case 1 are given in table
3. Note that among the multileptons, only the two $\tau$’s coming from the decays of the $\tilde{\tau}_1$’s will have large $p_T$. This happens for all the final states. Thus, the inclusive final state to look for is two high $p_T$ $\tau$s accompanied by large $E_T$. These two high $p_T$ $\tau$’s can have both opposite as well as same sign of charges. For the large number of scenarios we looked at, the ratio $(\tau^- \tau^- + \tau^+ \tau^+)/ (\tau^+ \tau^-)$ lies between 0.5 to 0.7. Note that the values of $\sigma.B$, given in the upper half of Table 3, are for the final states having 2 high $p_T$ $\tau$’s accompanied by any number of soft charged leptons ($e$, $\mu$ or $\tau$). The inclusive cross-sections are given in table 1 and can be as large as almost half a picobarn at $\sqrt{s} = 1.8$ TeV at the Tevatron.

Next we discuss the decays of the second lightest neutralino, and the resulting final states when it is produced in association with a chargino. Again, we first consider case 1. The six decay modes of second neutralino are $\chi_2^0 \rightarrow \tau \tilde{\tau}_1$, $e\bar{e}$, $\mu\bar{\mu}$, $\nu_\tau \bar{\nu}_\tau$, $\nu_\mu \bar{\nu}_\mu$, $\nu_e \bar{\nu}_e$. Subsequently, $\tilde{l} \ (l=e, \mu)$ decays to $l\chi_1^0$, and $\chi_1^0$, $\bar{\nu}_l$ and $\tilde{\tau}_1$ decay as before. Thus the possible final states from a $\chi_2^0$ decay are $(\tau\tau, e\bar{e}\tau, \mu\mu\tau)$ accompanied by the neutrinos and gravitinos. The final states resulting from the $\chi_2^0\chi^\pm$ productions and their subsequent decays are:3$\tau$, 5 $\tau$, ($e, \mu) + 4\tau$, (2$e, 2\mu) + 3\tau$ (2$e, 2\mu) + 5\tau$, (2$e\mu, 2\mu e) + 4\tau$, (3$e, 3\mu) + 4\tau$, accompanied by the large $E_T$ due to the undetected gravitinos and the neutrinos. The branching ratios for the various final states for the scenarios in case 1 are given in table 3. Note that here we can have events with 2$\tau$’s having high $p_T$ or events with 3 $\tau$’s having high $p_T$. The latter happens when $\chi_2^0$ decays into $\tau$ and $\tilde{\tau}_1$. The ratio of the 2$\tau$ vs 3$\tau$ events are scenario dependent as can be seen from the values of $\sigma.B$ given in the lower part in the table 3. In the case of high $p_T$ 2$\tau$ events, we have equal number with the same or opposite sign charges. Again, note that the values for $\sigma.B$, given in the lower half of table 3, are for the final states having two or three high $p_T$ $\tau$’s accompanied by any number of soft charged leptons. The inclusive cross-sections are given in table 1 and can be more than half a picobarn at $\sqrt{s} = 1.8$ TeV at the Tevatron.

We now briefly discuss case 2 and case 3. In table 2 we give two scenarios (5 and 6) for the case 2, and two scenarios (7 and 8) for the case 3. In case 2, there are two additional decay modes for $\chi_1^0$ ($\chi_1^0 \rightarrow e\bar{e}$, $\mu\bar{\mu}$) giving rise to more overall final states for the $\chi^+$ and
χ_2^0 decays. For the case 3, both χ^+ and χ_2^0 has less decay channels (since ˜ν_l’s (l=e, μ, τ) are heavier), and hence less final states. However, both cases give rise to inclusive 2τ and 3τ high p_T final states (accompanied by the missing transverse energy) with characteristics very similar to the case 1.

What is the prospect of detecting this signal in the past Tevatron data, in ongoing LEP2 experiments or in the upgraded Tevatron? CDF collaboration is capable of detecting τ leptons via their jet decay modes or via their e (or μ) decay modes. This requires high p_T for each τ and large E_T in the events. In our scenario, in the high p_T 2τ signal, both τ’s come from the decay ˜τ_1 → τG, while in the high p_T 3τ signal, 2τ’s come from the above decay while the third τ comes from the decay χ_2^0 → τ ˜τ_1. Since both ˜τ_1 and χ_2^0 are very heavy, these signal τ leptons are expected to be have high p_T. Since several neutrinos and the gravitinos escape detection in each event, large E_T is expected even after cancellations. No dedicated search for this signal has yet been carried out [14]. With a total (2τ +3 τ) high p_T inclusive cross-section as large as 1 pb (see table 1 and 2), few signal events should be found in the CDF 110 pb^{-1} data, even with an overall acceptance of few percent for these events. Upgraded Tevatron will see such events for much heavier charginos and second lightest neutralinos. We give results for the cross-sections for the χ^+χ^- and χ^±χ_2^0 pair productions in fig 1. These cross-sections have been calculated in a large region of the GMSB parameter space giving rise to our scenarios. For a given chargino mass, the cross-sections are approximately scenario independent. The dashed curves are for the case, √s=1.8 TeV, while the solid curves are for the case √s=2.0 TeV. In each case, the bottom ones are for σ(χ^+χ^-), the middle ones are for σ(χ^±χ_2^0) and the top ones are for the sum of the two. At LEP2, our scenarios will produce 4τ events with large missing energy from the production of a χ_0 pair and their subsequent decays [15]. Plans are underway to look for such a signal at LEP2 [16].

At Tevatron, the background for our high p_T 2τ or 3τ signal events could come from the WW, WZ, ZZ pair productions and Drell-Yan pairs, fake τ’s, W+jets. After appropriate cuts, the expected number of 2τ events from these background is about two [14]. The
expected background for $3\tau$ signal events is even much smaller. Charged Higgs or $\tilde{\tau}_1$ pair productions can also give $2\tau$ signal events, however these cross-sections are very low at the Tevatron.

We conclude summarizing our main points. We have proposed a scenario in which the dominant signal for supersymmetry at the Tevatron are the events with two or three high $p_T\tau$ leptons accompanied by large missing transverse energy. This happens in the GMSB models with $\tilde{\tau}_1$ as the NLSP for a wide region of the parameter space. The signal events are jet-less. There will be no high $p_T$ dileptons (involving electrons or muons) or photons in this scenario. In the $2\tau$ events, the $\tau$s can be of same sign as well as of opposite sign. Our signal events may already be present in the past Tevatron data. A dedicated “$2\tau$”, “$3\tau$” search will be needed to detect such a signal. Discovery of SUSY in such a scenario in the future Tevatron run will crucially depend on the ability of the detectors to detect high $p_T\tau$ leptons with good efficiency.

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TABLE CAPTIONS

Table 1: Mass spectrum for the superpartners and $\chi^+\chi^-$, $\chi^\pm\chi^0_2$ pair production cross-sections at the Tevatron in some scenarios for case 1.

Table 2: Mass spectrum for the superpartners and $\chi^+\chi^-$, $\chi^\pm\chi^0_2$ pair production cross-sections in some scenarios for case 2 and case 3.

Table 3: Branching ratios for different final states for $\chi^+\chi^-$, $\chi^\pm\chi^0_2$ pair productions in case 1. The values of $\sigma.B$ represent the cross-sections times the branching ratios at $\sqrt{s} = 1.8$ TeV for the final states where each of the two $\tau$’s or each of the 3 $\tau$’s have high $p_T$, accompanied by any number of soft charged leptons.

FIGURE CAPTIONS

Fig. 1: The cross-sections in fb for the $\chi^+\chi^-$, $\chi^\pm\chi^0_2$ pair productions at the Tevatron. The solid lines are for $\sqrt{s} = 2.0$ TeV while the dotted line are for $\sqrt{s} = 1.8$ TeV. The bottom two lines correspond to the $\chi^+\chi^-$ productions, the middle two lines correspond to the $\chi^\pm\chi^0_2$ productions and the upper two line corresponds to the sum of these two cross-sections.
| Scenario 1 | Scenario 2 | Scenario3 | Scenario 4 |
|------------|------------|-----------|------------|
| $\Lambda = 18$ TeV, $n=3, M = 40\Lambda$ | $\Lambda = 20$ TeV, $n=3, M = 60\Lambda$ | $\Lambda = 60$ TeV, $n=3, M = 20\Lambda$ | $\Lambda = 59.7$ TeV, $n=3, M = 40\Lambda$ |
| $\tan\beta = 18$ | $\tan\beta = 18$ | $\tan\beta = 19$ | $\tan\beta = 12$ |
| $m_h\,(GeV)$ | 111 | 113 | 113 | 109 |
| $m_{H^\pm}$ | 224 | 242 | 268 | 216 |
| $m_A$ | 210 | 229 | 256 | 201 |
| $m_{\chi^0}$ | 67 | 75 | 81 | 61 |
| $m_{\chi^0_2}$ | 114 | 129 | 142 | 106 |
| $m_{\chi^0_3}$ | -202 | -216 | -243 | -191 |
| $m_{\chi^0_4}$ | 238 | 254 | 275 | 230 |
| $m_{\chi^\pm}$ | 112,240 | 127,255 | 140,276 | 101,231 |
| $m_{\tilde{\tau}_{1,2}}$ | 51,141 | 57,151 | 57,162 | 60,130 |
| $m_{\tilde{e}_{1,2}}$ | 72,132 | 77,143 | 81,153 | 70,125 |
| $m_{\tilde{\nu}}$ | 105 | 119 | 130 | 97 |
| $m_{\tilde{t}_{1,2}}$ | 384,465 | 427,506 | 439,528 | 365,446 |
| $m_{\tilde{b}_{1,2}}$ | 403,427 | 449,472 | 469,496 | 384,401 |
| $m_{\tilde{u}_{1,2}}$ | 417,430 | 463,478 | 488,504 | 394,405 |
| $m_{\tilde{d}_{1,2}}$ | 419,438 | 465,485 | 488,510 | 395,413 |
| $m_{\tilde{g}}$ | 480 | 533 | 560 | 453 |
| $\mu$ | -191 | -206 | -233 | -179 |
| $\sigma_{p\bar{p} \rightarrow \chi^+\chi^-}$ (fb) | 427.43 | 250.55 | 172.42 | 635.20 |
| | (508.26) | (304.45) | (213.85) | (744.34) |
| $\sigma_{p\bar{p} \rightarrow \chi^\pm \chi^0_2}$ (fb) | 547.48 | 314.82 | 222.04 | 776.49 |
| | (669.05) | (394.76) | (284.78) | (933.60) |
| Table 2 |
|---|---|---|---|---|
| | Scenario 5 | Scenario 6 | Scenario 7 | Scenario 8 |
| $\Lambda = 18 \text{ TeV},$ $\tan \beta = 18$ | $\Lambda = 15 \text{ TeV},$ $\tan \beta = 12$ | $\Lambda = 28 \text{ TeV},$ $\tan \beta = 20$ | $\Lambda = 30 \text{ TeV},$ $\tan \beta = 25$ |
| $n=4, M = 40\Lambda$ | $n=4, M = 40\Lambda$ | $n=2, M = 15\Lambda$ | $n=2, M = 4\Lambda$ |
| $m_h (\text{GeV})$ | 115 | 111 | 114 | 116 |
| $m_{H^\pm}$ | 272 | 230 | 263 | 256 |
| $m_A$ | 260 | 215 | 251 | 243 |
| $m_{\chi^0}$ | 92 | 73 | 72 | 78 |
| $m_{\chi^0_{\lambda_2}}$ | 159 | 125 | 126 | 135 |
| $m_{\chi^0_{\lambda_3}}$ | -245 | -202 | -237 | -232 |
| $m_{\chi^0_{\lambda_4}}$ | 284 | 246 | 265 | 264 |
| $m_{\chi^\pm}$ | 157,284 | 120,247 | 125,266 | 133,265 |
| $m_{\tilde{t}_{1,2}}$ | 59,162 | 61,135 | 60,166 | 55,176 |
| $m_{\tilde{e}_{1,2}}$ | 81,154 | 71,131 | 83,157 | 86,165 |
| $m_{\tilde{\nu}}$ | 132 | 104 | 135 | 144 |
| $m_{\tilde{t}_{1,2}}$ | 466,557 | 393,479 | 453,529 | 501,567 |
| $m_{\tilde{b}_{1,2}}$ | 499,523 | 419,436 | 475,501 | 515,544 |
| $m_{\tilde{d}_{1,2}}$ | 516,531 | 429,441 | 493,510 | 535,553 |
| $m_{d_{1,2}}$ | 517,537 | 430,448 | 494,516 | 535,558 |
| $m_{\tilde{\mu}}$ | 640 | 533 | 498 | 538 |
| $\mu$ | -236 | -192 | -226 | -222 |
| $\sigma_{p\bar{p}\to\chi^+\chi^-}$ | 94.73 | 295.92 | 296.22 | 214.04 |
| (fb) | (120.75) | (356.12) | (358.92) | (262.56) |
| $\sigma_{p\bar{p}\to\chi^\pm\chi^0_{\lambda_2}}$ | 113.42 | 352.46 | 394.38 | 277.78 |
| (fb) | (150.30) | (437.53) | (492.35) | (351.80) |
Table 3

| Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 |
|------------|------------|------------|------------|
| 2\tau      | 0.406      | 0.388      | 0.350      | 0.349      |
| 4\tau      | 0.166      | 0.168      | 0.171      | 0.166      |
| 6\tau      | 0.017      | 0.018      | 0.021      | 0.019      |
| e(\mu)3\tau| 0.148      | 0.151      | 0.156      | 0.158      |
| e(\mu)5\tau| 0.030      | 0.033      | 0.038      | 0.038      |
| 2e(2\mu)4\tau| 0.013    | 0.015      | 0.017      | 0.018      |
| e\mu4\tau  | 0.027      | 0.029      | 0.035      | 0.036      |
| \sigma(\chi^+\chi^-)B(\tau^-\tau^-)(fb) | 300.56 | 173.89 | 116.35 | 428.90 |
| \sigma(\chi^+\chi^-)B(\tau^-\tau^-\tau^-\tau^-) | 126.86 | 76.65 | 56.06 | 206.29 |

| Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 |
|------------|------------|------------|------------|
| 3\tau      | 0.549      | 0.534      | 0.494      | 0.327      |
| 5\tau      | 0.112      | 0.116      | 0.121      | 0.078      |
| 2e(2\mu)3\tau| 0.044    | 0.045      | 0.049      | 0.132      |
| 2e(2\mu)5\tau| 0.009    | 0.009      | 0.012      | 0.031      |
| e(\mu)4\tau| 0.099      | 0.104      | 0.110      | 0.074      |
| 3e(3\mu)4\tau| 0.008    | 0.009      | 0.011      | 0.029      |
| e2\mu4\tau | 0.008      | 0.009      | 0.011      | 0.029      |
| \sigma(\chi^+\chi_2^0)B(\tau^-\tau^-)(fb) | 456.83 | 216.96 | 167.76 | 276.82 |
| \sigma(\chi^+\chi_2^0)B(\tau^-\tau^-\tau^-\tau^-) | 45.32  | 43.74  | 23.04  | 233.75 |
| \sigma(\chi^+\chi_2^0)B(\tau^-\tau^-\tau^-\tau^-) | 45.32  | 43.74  | 23.04  | 233.75 |
Fig. 1