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The search for charged sleptons and flavour lepton number violation at LHC (CMS)

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Abstract

We study a possibility to detect charged sleptons and flavour lepton number violation at LHC (CMS). We investigate the production and decays of right- and left-handed sleptons separately. We have found that for $L = 10^5 pb^{-1}$ it would be possible to detect right-handed sleptons with a mass up to 325 GeV and left-handed ones with a mass up to 350 GeV. We also investigate a possibility to look for flavour lepton number violation in slepton decays due to the mixing of different sleptons generations. We find that for maximal $(\tilde{\mu}_R - \tilde{e}_R)$ mixing sleptons detection is possible up to masses of about 250 GeV.

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1 Introduction

One of the LHC goals is the discovery of the supersymmetry. In particular, it is very important to investigate a possibility to discover nonstrongly interacting superparticles (sleptons, higgsino, gaugino). In ref.[1, 2, 3] the LHC slepton discovery potential has been investigated within the minimal SUGRA-MSSM framework where all sparticle masses are determined mainly by two parameters: m_0 (common squark and slepton mass at GUT scale) and $m_{\frac{1}{2}}$ (common gaugino mass at GUT scale). The signature used for the search for sleptons at LHC is $two\ same-flavour\ opposite-sign\ leptons + E_T^{miss} + no\ jets$ [1, 2, 3]. The conclusion of these studies is that LHC is able to detect sleptons with the masses up to (300-400) GeV.

In this paper we investigate the discovery potential for sleptons and for flavour lepton number violation in slepton decays at CMS. This study complements the previous ones [1, 2, 3] as we do not use the minimal SUGRA-MSSM framework. Instead, we investigate separately the production and decays of right-handed and left-handed sleptons. Despite the simplicity of the SUGRA-MSSM framework it is a very particular model. The mass formulae for sparticles in SUGRA-MSSM model are derived under the assumption that at GUT scale ($M_{GUT} \approx 2 \cdot 10^{16}$ GeV) soft supersymmetry breaking parameters are universal. However, in general, we can expect that real sparticle masses can differ in a drastic way from sparticle masses pattern of SUGRA-MSSM model due to many reasons:

1. in superstring inspired models soft scalar supersymmetry breaking terms are not universal at Planck scale in general [4],
2. in supersymmetric SU(5) model an account of the evolution of soft supersymmetry breaking terms between Planck and GUT scale [5, 6] is very essential,
3. in models with additional relatively light vector like supermultiplets the mass formulae for superparticles can drastically differ [7] from the standard ones [8].

Therefore, it is more appropriate to investigate the LHC SUSY sensitivity in a model-independent way. The cross section for the production of the right(left)-handed sleptons depends mainly on the mass of right(left)-handed sleptons and the decay properties of the sleptons are determined mainly by the mass of the lightest superparticle (LSP).

Thus, the discovery potential of the right(left)-handed sleptons depends mainly on 2 parameters – the slepton mass and the LSP mass. Here we investigate the possibility to look for right(left)-handed sleptons for the case of arbitrary masses of right(left)-handed sleptons and LSP. We also investigate the possibility to look for flavour lepton number violation in slepton decays at LHC.

For the LHC slepton search we use the signature:

$two\ same\ flavour\ with\ the\ opposite\ charged\ leptons + E_T^{miss} + no\ jets$. There are two types of backgrounds for this signature: standard model background and SUSY strong ($\tilde{g}\tilde{g},\ \tilde{g}\tilde{q},\ \tilde{q}\tilde{q}$) and weak ($\tilde{\chi}_1^{\pm}\tilde{\chi}_2^0,\ \tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\mp}$) backgrounds. As a rule the SUSY strong and weak backgrounds are not very large [3] and they only increase the LHC discovery potential of new SUSY physics (however, in general, it could be nontrivial to separate a slepton signal from SUSY backgrounds).

Our simulations are made at the particle level with parametrized detector responses based on a detailed detector simulation. The CMS detector simulation program CMSJET 3.2 [11] is used. All SUSY processes with full particle spectrum, couplings, production cross section and decays are generated with ISAJET 7.13, ISASUSY [9]. The Standard Model backgrounds are generated with PYTHIA 5.7 [10]. We have used the same cuts and estimates for the Standard Model backgrounds obtained in ref. [3].

In Section 2 we give short review of sleptons in MSSM. In Section 3 we describe slepton production and decay mechanisms. Section 4 is devoted to the discussion of the Standard Model backgrounds. In Sections 5, 6 and 7 we discuss the case of right-handed, left-handed and left- plus right-handed sleptons, correspondingly. Section 8 is devoted to the discussion of the search for flavour lepton violation in slepton decays. Section 9 contains concluding remarks.

2 Sleptons in MSSM framework

In MSSM framework all gaugino masses coincide at GUT scale $M_{GUT} \approx 2 \cdot 10^{16} GeV$. As a result of the evolution of the effective masses between GUT and electroweak scales the relation between the chargino and neutralino masses is [8]

$$m(\tilde{\chi}_2^0) \approx m(\tilde{\chi}_1^{\pm}) \approx 2\, m(\tilde{\chi}_1^0) \approx m_{\frac{1}{2}},$$

where $m_{\frac{1}{2}}$ is common gaugino mass at GUT scale.

In MSSM slepton masses are determined by formulae [8]:

$$m^2_{\tilde{l}_R} = m_0^2 + 0.15\, m^2_{\frac{1}{2}} - sin^2\theta_W M_Z^2 cos2\beta \qquad (1)$$

$$m^2_{\tilde{l}_L} = m_0^2 + 0.52\, m^2_{\frac{1}{2}} - \frac{1}{2}(1 - 2\, sin^2\theta_W) M_Z^2 cos2\beta \qquad (2)$$

$$m^2_{\tilde{\nu}} = m_0^2 + 0.52\, m^2_{\frac{1}{2}} - \frac{1}{2} M_Z^2 cos2\beta, \qquad (3)$$

where m_0 is the common scalar soft breaking mass at GUT scale. As it follows from formulae (1-3) right-handed sleptons are lighter than left-handed ones, i.e. $m_{\tilde{l}_R} < m_{\tilde{l}_L}$.

In general the decays of sleptons can be rather complicated. For the case when right-handed sleptons are the lightest among non LSP sparticles they decay dominantly to LSP

$$\tilde{l}_R^- \longrightarrow l^- + \tilde{\chi}_1^0.$$

The left-handed sleptons decay (if kinematically accessible) to charginos and neutralinos

$$\tilde{l}_L^\pm \longrightarrow l^\pm + \tilde{\chi}_{1,2}^0$$

$$\tilde{l}_L^\pm \longrightarrow \nu_L + \tilde{\chi}_1^\pm$$

$$\tilde{\nu}_L \longrightarrow \nu_L + \tilde{\chi}_{1,2}^0$$

$$\tilde{\nu}_L \longrightarrow l^\pm + \tilde{\chi}_1^\mp.$$

Slepton pairs ($\tilde{l}_L\ \tilde{l}_L,\ \tilde{l}_R\ \tilde{l}_R,\ \tilde{\nu}_L\ \tilde{\nu}_L,\ \tilde{\nu}_L\ \tilde{l}_L$) can be produced either through a Drell - Yan mechanism or, if kinematically allowed through the decays of other supersymmetric particles ($\tilde{\chi}_2^0,\ \tilde{\chi}_1^\pm,\ ...$). For the case when $\tilde{\chi}_2^0,\ \tilde{\chi}_1^\pm$ are heavier than sleptons, an indirect slepton production is open:

$$\tilde{\chi}_2^0 \longrightarrow \tilde{l}_{L,R}^\pm l^\mp$$

$$\tilde{\chi}_2^0 \longrightarrow \tilde{\nu}_L \bar{\nu}_L$$

$$\tilde{\chi}_1^\pm \longrightarrow \tilde{\nu}_L l^\pm$$

$$\tilde{\chi}_1^\pm \longrightarrow \tilde{l}_L^\pm \nu_L.$$

Right-handed and left-handed charged sleptons decay to LSP and leptons

$$\tilde{l}_R^- \longrightarrow l^- + \tilde{\chi}_1^0,$$

$$\tilde{l}_L^- \longrightarrow l^- + \tilde{\chi}_1^0,$$

leading to the signature: $two\ same - flavour\ opposite - sign\ leptons + E_T^{miss} + no\ jets$. This signature can be realized also as a result of the gaugino decays:

$$\tilde{\chi}_2^0 \longrightarrow \tilde{\chi}_1^0 + l^+ l^-$$

$$\tilde{\chi}_2^0 \longrightarrow \tilde{\chi}_1^0 + \nu\bar{\nu}$$

$$\tilde{\chi}_2^0 \longrightarrow \tilde{\chi}_1^0 + Z^0$$

$$\tilde{\chi}_1^\pm \longrightarrow \tilde{\chi}_1^0 + l^\pm + \nu$$

$$\tilde{\chi}_1^\pm \longrightarrow \tilde{\chi}_1^0 + W^\pm.$$

3 Sleptons production and decays

In this paper we study only direct production of charged sleptons via the Drell - Yan mechanism with their subsequent decays into leptons and LSP. We study the case when right-handed and left-handed charged sleptons decay to LSP and leptons

$$\tilde{l}_R^- \longrightarrow l^- + \tilde{\chi}_1^0,$$
$$\tilde{l}_L^- \longrightarrow l^- + \tilde{\chi}_1^0.$$

The simulation when the slepton decay dominantly to LSP and leptons correspond to the case when chargino and second neutralino are heavier than sleptons. In our study we neglect indirect slepton production. Inclusion of indirect slepton production or other SUSY backgrounds only increases the excess of the supersymmetric signal over SM background and enhances the value of significance.

4 Standard Model backgrounds

The expected main Standard Model background process should be $t\bar{t}$ production, with both W's decaying to leptons, or one of the leptons from W decay and the other from the $b-$decay of the same $t-$quark; the other SM backgrounds come from WW, WZ, $b\bar{b}$ and $\tau\tau$-pair production, with decays to electrons and muons. Standard model backgrounds for different kinematical cuts have been calculated [3] with the PYTHIA 5.7 code. In this paper we use the results from ref. [3]. We also considered possible backgrounds from

$$pp \to Z\ Z \to \nu\nu\ \ \bar{\tau}\tau,$$
$$pp \to Z\ jet \to \bar{\tau}\tau\ \ jet$$

processes and have found that they are small. These backgrounds give less than two events for $L\ =\ 10^5 pb^{-1}$.

The set of kinematical variables which are useful to extract the slepton signals and typical selection cuts are [3]:

i) for leptons ($l = e, \mu$) :

- p_T-cut on leptons and lepton isolation (Isol), which is here defined as the calorimetric energy flow around the lepton in a cone $\Delta R\ <\ 0.5$ divided by the lepton energy;
- mass of the same-flavour opposite-sign leptons $M_{l^+l^-}\ \neq\ M_Z$ to suppress WZ and potential ZZ backgrounds by rejecting events in a $M_Z \pm \delta M_Z$ band;
- $\Delta\Phi(l^+l^-)-$relative azimuthal angle between two same-flavour opposite-sign leptons in plane transverse to the beam;

ii) for E_T^{miss} :

– $E_T^{miss}-$cut,

– $\Delta\Phi(E_T^{miss}, ll)-$relative azimuthal angle between E_T^{miss} and the resulting dilepton momentum in the transverse plane;

iii) for jets :

– ”jet veto”-cut : $N_{jet} = 0$ for some E_T^{jet} threshold, in some rapidity interval, typically $|\eta_{jet}| < 4.5$ (we use standard $UA1$ jet definition with $R_{cone} = 0.5$.

Namely, we adopt from the ref. [3] the sets of cuts which in our notation looks as it is presented in Table 1.

Table 1: The cut values of kinematical variables for sets (1-7) of cuts and the distribution of SM backgrounds events for each set of cuts[3].

Cut \ Set #	1	2	3	4	5	6	7
$p_T^l >$	20 GeV	20 GeV	50 GeV	50 GeV	60 GeV	60 GeV	60 GeV
$Isol <$	0.1	0.1	0.1	0.1	0.1	0.1	0.03
$\lvert\eta_l\rvert <$	2.5	2.5	2.5	2.5	2.5	2.5	2.5
$E_T^{miss} >$	50 GeV	50 GeV	100 GeV	120 GeV	150 GeV	150 GeV	150 GeV
$\Delta\Phi(E_T^{miss}, ll) >$	160^o	160^o	150^o	150^o	150^o	150^o	150^o
$N_{jet} =$	0	0	0	0	0	0	0
$E_T^{jet} >$	30 GeV	30 GeV	30 GeV	30 GeV	45 GeV	45 GeV	45 GeV
$\lvert\eta_{jet}\rvert <$	4.5	4.5	4.5	4.5	4.5	4.5	4.5
$M_Z - cut$	yes	yes	yes	yes	yes	yes	yes
$\Delta\Phi(l^+l^-)$	$> 130^o$	no	$< 130^o$	$< 130^o$	$< 130^o$	$< 140^o$	$< 130^o$
WW [3]; $\sigma_{WW} = 70pb$	454	1212	97	69	38	46	32
$Wt\bar{b}$ [3]; $\sigma_{Wt\bar{b}} = 160pb$	163	577	33	13	1	1	1
$t\bar{t}$ [3]; $\sigma_{t\bar{t}} = 660pb$	345	574	21	6	0	0	0
WZ [3]; $\sigma_{WZ} = 26pb$	15	43	21	17	6	6	5
$\tau\tau$ [3]; $\sigma_{\tau\tau} = 7.5pb$	15	15	0	0	0	0	0
N_B^{SM} [3]	992	2421	172	105	45	53	38

Here N_B^{SM} is the number of the Standard Model background events for $L = 10^4 pb^{-1}$ (cuts 1-2) and for $L = 10^5 pb^{-1}$ (cuts 3-7). $M_Z - cut$ is condition that $M_{l^+l^-} < 86\, GeV$ or $96\, GeV < M_{l^+l^-}$. $CTEQ2L$ parton distributions have been used. Note that the sets of cuts (1-2) are effective for the search for relatively light sleptons $(m_{\tilde{l}} \leq 150\, GeV)$ whereas the sets (3-7) are appropriate for the heavy sleptons with $(m_{\tilde{l}} > 150\, GeV)$.

As has been mentioned above, we neglect indirect slepton production and also we neglect SUSY backgrounds which are mainly due to $\tilde{q}\tilde{q},\ \tilde{g}\tilde{q},\ \tilde{g}\tilde{g}$ production and with subsequent cascade decays with jets outside the acceptance or below the threshold. As has been demonstrated in ref. [3] SUSY background is, as a rule, much less than the SM background and we shall neglect it.

5 Right-handed sleptons

In this section we study the possibility to search for right-handed sleptons at CMS. Namely, we consider the signature *dilepton* + E_T^{miss} + *no jets*. We do not consider the left-handed slepton contribution to this signature, i.e. we consider the situation when left-handed sleptons are much heavier than the right-handed ones and it is possible to neglect them. In this case right-handed sleptons decay dominantly to an LSP

$$\tilde{l}_R^- \to l^- + \tilde{\chi}_1^0.$$

The cross section of the right-handed slepton production is determined mainly by the mass of the right-handed slepton. The dependence of the right-handed slepton cross section production for the case of 3-flavour degenerate right-handed charged sleptons as a function of the slepton mass is presented in Table 2 and in Fig.1. Comparison of shapes of E_T^{miss} distribution and p_T^l of leptons distribution in case of charged right-handed sleptons ($m_{\tilde{l}_R}$ = 200 GeV, $m_{\tilde{\chi}_1^0} = 53\, GeV$) with background is shown in Fig.2.

Table 2: The cross section $\sigma(pp \to \tilde{l}_R^+ \tilde{l}_R^- + ...)$ in pb for different values of charged right-handed slepton masses for 3 slepton generations at LHC. Right-handed sleptons are assumed to be degenerate in mass.

$M(GeV)$	90	100	125	150	175	200	225
σ	0.41	0.27	0.13	0.068	0.039	0.024	0.016
$M(GeV)$	250	275	300	325	350	375	400
σ	0.011	0.0079	0.0055	0.0041	0.0032	0.0025	0.0020

The sum of distributions of the SM backgrounds and signal events after set 7 for E_T^{miss} (a) and p_T^l of leptons (b) in case of $m_{\tilde{l}_R}$ = 200 GeV, $m_{\tilde{\chi}_1^0} = 53\, GeV$ is shown in Fig.3. The number of signal events passing through the cuts 1-7 essentially depends on the LSP mass $m_{\tilde{\chi}_1^0}$. The results of our calculations for different values of the slepton and the LSP masses are presented in Tables $4 - 15$. In Tables the significance S is defined as [3]

$$S = \frac{N_S}{\sqrt{N_S \; + \; N_B^{SM}}}, \tag{4}$$

where N_B^{SM} have been calculated in ref. [3]. The meaning of the definition (4) is the following. Suppose the background and signal cross sections are σ_B^{SM} and σ_S correspondingly. For a given luminosity L the average number of events expected in the experiment is $N_{ev} \; = \; N_S + N_B^{SM} \; = \; (\sigma_S + \sigma_B^{SM})L$. The fluctuation of this number is $\sqrt{N_S + N_B^{SM}}$. So the definition (4) takes into account statistical uncertainty in the determination of the total number of events. Standard definition of the significance $S = \frac{N_S}{\sqrt{N_B}}$ corresponds to the situation with real experiment when the total number of events $N_{ev} \; = \; N_B^{SM} + N_S$ is given number and we have to compare N_{ev} with the expected number of background events N_B^{SM}.

Besides statistical error we have systematical error related with nonexact knowledge of the background cross section. We assume that the accuracy in the determination of background cross section is between 10 and 50 percents. Therefore the ratio $\frac{N_S}{N_B^{SM}}$ at least has to be bigger than 0.1 for the optimistic case when the accuracy in the determination of the background cross section is 10 percent.

As it follows from Tables 4-15 for $L = 10^5 pb^{-1}$, it is possible to detect the right-handed sleptons at 5 σ significance level with a mass up to 325 GeV (Table 14, $m_{\tilde{\chi}_1^0} = 85\ GeV$, cut 6). For the right-handed sleptons with a mass $90\ GeV \leq m_{\tilde{l}_R} \leq 300\ GeV$ it is possible to discover sleptons for not very large values of the LSP mass. Typically, $m_{\tilde{\chi}_1^0} \leq (0.4 - 0.6) m_{\tilde{l}_R}$ should be chosen.

It should be noted that the SM background coming from $W\ W,\ W\ t\ \bar{b},\ W\ Z,\ \bar{t}\ t,\ \bar{\tau}\ \tau$ production with subsequent leptonic decays predicts the equal number of $\mu^+\ \mu^-,\ e^+\ e^-,\ \mu^+\ e^-$ and $e^+\ \mu^-$ events up to statistical fluctuation whereas the signal contains an equal number of $\mu^+\ \mu^-$ and $e^+\ e^-$ pairs coming from

$$p\,p \to \tilde{\mu}_R^+\,\tilde{\mu}_R^- \ + \ \ldots \ \to \mu^+\,\mu^- \ + \ 2\,LSP \ + \ \ldots$$

and

$$p\,p \to \tilde{e}_R^+\,\tilde{e}_R^- \ + \ \ldots \ \to e^+\,e^- \ + \ 2\,LSP \ + \ \ldots .$$

It should be noted that the criterion based on the measurement of $\Delta N = N_{ev}(e^+e^- + \mu^+\mu^-) - N_{ev}(e^+\mu^- + e^-\mu^+) = N_S$ is free from the systematical uncertainty related with the nonexact knowledge of the background cross section. The 1σ statistical fluctuation of ΔN is $\sqrt{1N_B^{SM}}$.

We have found also that the reaction

$$p\,p \to \tilde{\tau}_R^+\,\tilde{\tau}_R^- \ + \ \ldots \ \to \mu^+\,\mu^-,\ e^+\,e^-,\ e^+\,\mu^-,\ \mu^+\,e^- \ + \ \ldots$$

virtually does not contribute to the number of signal events and can be neglected for the considered signature. Then we study the production and decays of the first two generations of sleptons. Therefore, we have qualitatuve consequence of the existence of slepton signal – the excess of $\mu^+\mu^-$ and e^+e^- events over μ^+e^- and $e^+\mu^-$ events. It allows to apply sequential analysis in observation of difference between two processes (one of them gives $\mu^+\mu^-$ and e^+e^- events, the other gives μ^+e^- and $e^+\mu^-$ events). This is an additional criterion for new physics discovery for the case of standard slepton production, which also allows to eliminate systematics related with the nonexact knowledge about background.

6 Left-handed sleptons

In this section we study the case when the right-handed sleptons are much heavier than the left-handed ones (of course, this case looks pathological since in MSUGRA approach the left-handed sleptons are heavier than the

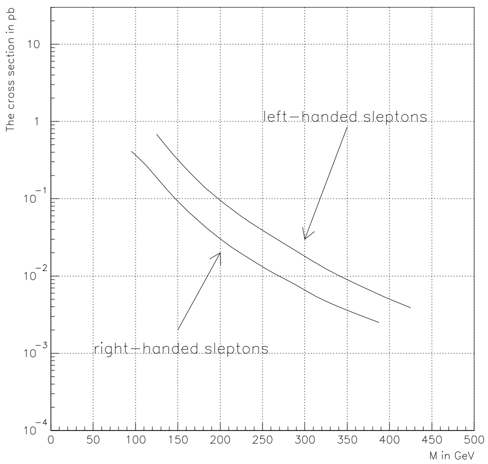

Figure 1: The cross section $\sigma(pp \to \tilde{l}_R^+ \tilde{l}_R^- + ...)$ in pb for different values of charged right-handed slepton masses at LHC (right-handed sleptons are assumed to be degenerate in mass) and the cross section $\sigma(pp \to \tilde{l}_L^+ \tilde{l}_L^- + ...)$ in pb for different values of charged left-handed slepton masses for at LHC (left-handed sleptons masses are assumed to be degenerate in flavour).

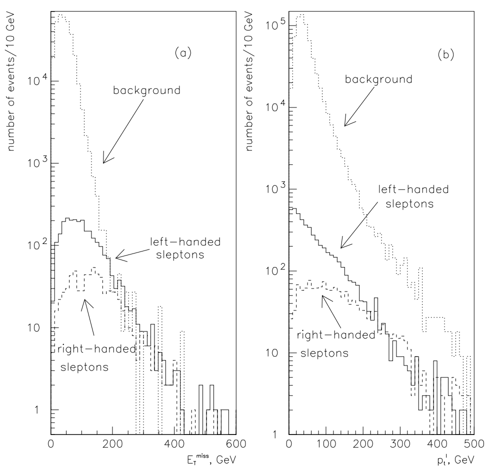

Figure 2: E_T^{miss} distributions (a) and p_T^l of leptons (b) distributions for sleptons and backgrounds before applying of sets (1-7) of cuts. Here $m_{\tilde{l}_R} = 200\,GeV$, $m_{\tilde{\chi}_1^0} = 53\,GeV$ in case of right-handed sleptons and $m_{\tilde{l}_L} = 200\,GeV$, $m_{\tilde{\chi}_1^0} = 53\,GeV$ for left-handed sleptons.

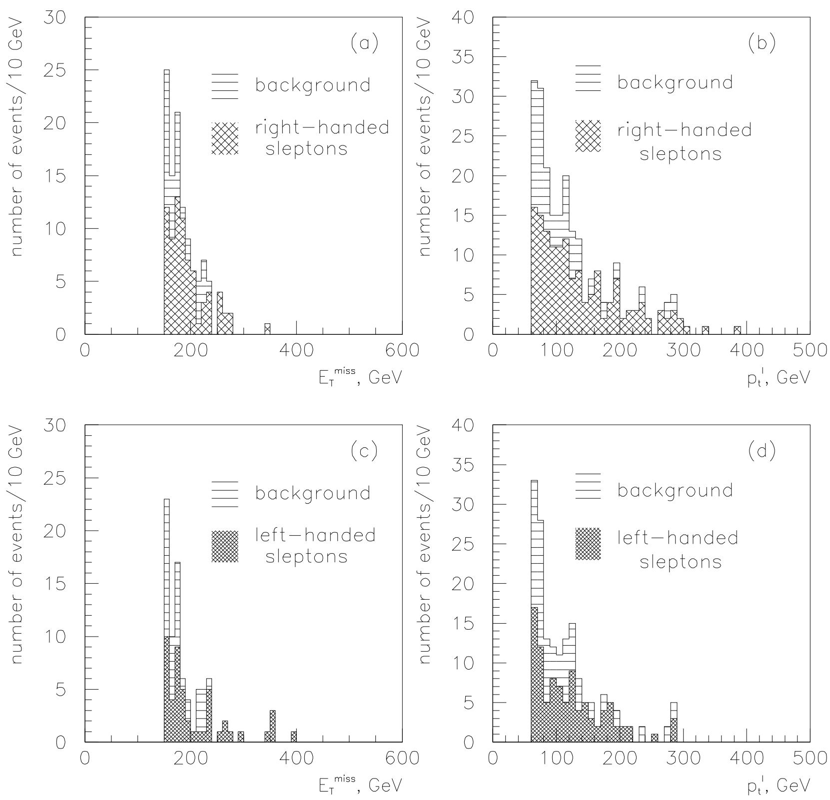

Figure 3: The sum of distributions SM backgrounds and signal events after cut 7 for E_T^{miss} (a,c) and p_T^l of leptons (b,d). Here $m_{\tilde{l}_R} = 200\ GeV$, $m_{\tilde{\chi}_1^0} = 53\ GeV$ in case of right-handed sleptons and $m_{\tilde{l}_L} = 200\, GeV$, $m_{\tilde{\chi}_1^0} = 53\, GeV$ for left-handed sleptons.

right-handed ones, however, in a general case we can not exclude such a possibility) and we can neglect them. The dependence of the left-handed slepton cross section production on slepton mass is presented in Table 3 and in Fig.1. Our results are presented in Tables 16-21. The notation is similar to the case of the right-handed sleptons. Correspondingly, comparison of shapes of E_T^{miss} and p_T^l distributions ($m_{\tilde{l}_L}$ = 200 GeV, $m_{\tilde{\chi}_1^0} = 53\ GeV$) with background is shown in Fig.2 and the sum of distributions SM backgrounds and signal events after cut 7 for E_T^{miss} (c) and p_T^l of leptons (d) in case of $m_{\tilde{l}_L}$ = 200 GeV, $m_{\tilde{\chi}_1^0} = 53\ GeV$ is shown in Fig.3. As follows from Tables 16-21, it is possible to detect left-handed sleptons with a mass up to 350 GeV (Table 21, $m_{\tilde{\chi}_1^0} = 196\ GeV$, cut 6). The discovery potential of the left-handed sleptons depends, as in the case of the right-handed sleptons, on the mass of LSP. The LSP masses $m_{\tilde{\chi}_1^0} = (0.4 - 0.6) m_{\tilde{l}_L}$ give the maximal number of events which passed cuts unlike the case of the right-handed sleptons when small LSP masses are the most preferable as far as detection of LHC sleptons is concerned.

As it follows from the Tables 4-20 the number of the signal events for the same values of right-handed and left-handed slepton masses and the same value of the LSP mass is not proportional to the production cross sections of the right- and left-handed sleptons. The explanation of this fact is that rapidity distributions of right- and left-handed sleptons do not coincide.

Table 3: The cross section $\sigma(pp \to \tilde{l}_L^+ \tilde{l}_L^- + ...)$ in pb for different values of charged left-handed slepton masses at LHC. Left-handed sleptons masses are assumed to be degenerate in flavour.

$M(GeV)$	100	150	200	250	300	350	400	450
σ	0.6830	0.1651	0.05921	0.02644	0.01238	0.00665	0.00389	0.00229

7 Right-handed plus left-handed sleptons

As has been mentioned in the Introduction, in general, we can expect that MSUGRA model, in the best case, gives qualitative description of the sparticle spectrum. So, in general, masses of the LSP, the right-handed and the left-handed sleptons are arbitrary. In many models the left-handed sleptons are heavier than the right-handed ones. With a good accuracy the right-handed and the left-handed sleptons give an additive contribution to the signal event, i.e.

$$N(signal) = N_{Left}(signal) + N_{Right}(signal).$$

To obtain some flavour we have studied as an example the direct charged slepton production for the case when $m_{\tilde{l}_L} = m_{\tilde{l}_R} + 50$ GeV. The results of our investigation are presented in Tables 22-25. As follows from Tables 22-25, it is possible to discover sleptons with a mass of the right-handed slepton up to 350 GeV (see Table 25). The inclusion of the left-handed sleptons increases the slepton discovery potential; moreover, it is possible to discover sleptons in a wide range of LSP masses. Again the criterion based on the difference between $(e^+e^- + \mu^+\mu^-)$ and

$(e^+\mu^- + \mu^+e^-)$ events gives some additional information about the existence of new physics related to slepton production.

8 The search for flavour lepton number violation in slepton decays

As has been mentioned above, in MSUGRA the scalar soft supersymmetry breaking terms are postulated to be universal at GUT scale. For such ”standard” supersymmetry breaking terms the lepton flavour number is conserved in supersymmetric extension of the Weinberg - Salam model. However, in general, squark and slepton supersymmetry breaking mass terms are not diagonal due to many reasons [12] (for instance, in SU(5) SUSY GUT model an account of the evolution between Planck and GUT scales leads to the appearance of nondiagonal soft supersymmetry breaking terms) and flavour lepton number is explicitly broken due to nondiagonal structure of slepton soft supersymmetry breaking mass terms. As a consequence such models predict flavour lepton number violation in $\mu-$ and $\tau-$ decays [12]. In ref. [13, 14, 15] it has been proposed to look for flavour lepton number violation in slepton decays at LEP2 and NLC. In ref. [16] the possibility to look for flavour lepton number violation in slepton decays at LHC has been studied with 2 points of ref. [3]. It has been shown that CMS/ATLAS detectors at LHC will be able to discover flavour lepton number violation in slepton decays for the case of maximal mixing up to $m_{\tilde{l}} \approx 200\, GeV$.

In this paper we investigate this signature in a more careful way. We consider the case of mixing between the right-handed selectron and the right-handed smuon. The mass term for the right-handed $\tilde{e}'_R$ and $\tilde{\mu}'_R$ sleptons has the form

$$-\Delta\mathcal{L} = m_1^2 \tilde{e}_R^{+\prime}\tilde{e}'_R + m_2^2 \tilde{\mu}_R^{+\prime}\tilde{\mu}'_R + m_{12}^2(\tilde{e}_R^{+\prime}\tilde{\mu}'_R + \tilde{\mu}_R^{+\prime}\tilde{e}'_R). \tag{5}$$

In formula (5) the last term explicitly violates lepton flavour number. After the diagonalization of the mass term (5), we find that the eigenstates of the mass term (5) are

$$\tilde{e}_R = \tilde{e}'_R cos(\phi) + \tilde{\mu}'_R sin(\phi), \tag{6}$$

$$\tilde{\mu}_R = \tilde{\mu}'_R cos(\phi) - \tilde{e}'_R sin(\phi), \tag{7}$$

with the masses

$$M_{12}^2 = \frac{1}{2}[(m_1^2 + m_2^2) \pm (\ (m_1^2 - m_2^2)^2 + 4(m_{12}^2)^2\ )^{\frac{1}{2}}], \tag{8}$$

which coincide virtually for small values of $m_1^2 - m_2^2$ and m_{12}^2. Here the mixing angle is determined by the formulae

$$tan(2\phi) \ = \ \frac{2m_{12}^2}{m_1^2 - m_2^2}. \tag{9}$$

The crucial point is that even for a small mixing parameter m_{12}^2 due to the smallness of $(m_1^2 - m_2^2)$ the mixing angle ϕ is, in general, not small (at the present state of art, it is impossible to calculate the mixing angle ϕ reliably). For the most probable case when the lightest superparticle is the superpartner of the $U(1)$ gauge boson plus some small mixing with other gaugino and higgsino, the sleptons $\tilde{\mu}_R$, $\tilde{e}_R$ decay mainly into leptons μ and e plus $U(1)$ gaugino λ. The corresponding terms in the Lagrangian responsible for slepton decays are

$$L_1 \ = \ \frac{2g_1}{\sqrt{2}}(\bar{e}_R\lambda_L\tilde{e}'_R \ + \ \bar{\mu}_R\lambda_L\tilde{\mu}'_R \ + \ h.c.), \tag{10}$$

where $g_1^2 \approx 0.13$. For the case when mixing is absent the decay width of the right-handed slepton into lepton plus LSP is given by the formulae

$$\Gamma = \frac{g_1^2}{8\pi}M_{sl}\Delta_f \approx 5 \cdot 10^{-3}M_{sl}, \tag{11}$$

$$\Delta_f = (1 - \frac{M_{LSP}^2}{M_{sl}^2})^2, \tag{12}$$

where M_{sl} and M_{LSP} are the masses of the slepton and the lightest superparticle ($U(1)-$gaugino), respectively. For the case of nonzero mixing the Lagrangian (10) in terms of the slepton eigenstates reads

$$L_1 \ = \ \frac{2g_1}{\sqrt{2}}[\bar{e}_R\lambda_L(\tilde{e}_R cos(\phi) \ - \ \tilde{\mu}_R sin(\phi)) + \bar{\mu}_R\lambda_L(\tilde{\mu}_R cos(\phi) \ - \ \tilde{e}_R sin(\phi)) \ + \ h.c.). \tag{13}$$

Due to nonzero slepton mixing $(sin(\phi) \neq 0)$ we have lepton flavour number violation in slepton decays, namely:

$$\Gamma(\tilde{\mu}_R \to \mu + LSP) \ = \ \Gamma cos^2(\phi), \tag{14}$$

$$\Gamma(\tilde{\mu}_R \to e + LSP) \ = \ \Gamma sin^2(\phi), \tag{15}$$

$$\Gamma(\tilde{e}_R \to e + LSP) \ = \ \Gamma cos^2(\phi), \tag{16}$$

$$\Gamma(\tilde{e}_R \to \mu + LSP) \ = \ \Gamma sin^2(\phi). \tag{17}$$

At LHC the right-handed sleptons are produced mainly through the Drell - Yan mechanism which is flavour blind in such a way that even for nonzero slepton mixing, the cross section $\sigma(p\,p \;\rightarrow\; \tilde{\mu}^{\pm}_R \tilde{e}^{\mp}_R + ...)$ vanishes and the single manifestation of the flavour lepton number violation are sleptons decays with violation of lepton flavour number.

We consider here the most optimistic case of maximal slepton mixing ($\phi \;=\; \frac{\pi}{2}$) and neglect the effects related to destructive interference [14, 15, 16]. For the case of maximal selectron - smuon mixing, the number of signal events coming from slepton decay is (up to statistical fluctuations)[1)]

$$N_{sig}(e^+e^-) \;=\; N_{sig}(\mu^+e^-) \;=\; N_{sig}(\mu^-e^+) \;=\; \frac{1}{4} N_{sig}^{no\;mix}(e^+e^- \;+\; \mu^+\mu^-). \tag{18}$$

Therefore, for the case of maximal $(\tilde{\mu}-\tilde{e})$ slepton mixing we expect equal number of signal $e^+e^-,\ \mu^+\mu^-,\ e^+\mu^-,\ \mu^+e^-$ events with E_T^{miss} and with small jet activity. Note that for the mixing absence case signal events are only e^+e^- and $\mu^+\mu^-$ and, as a consequence, we have an excess of $(e^+e^- + \mu^+\mu^-)$ events over $(e^+\mu^- + \mu^+e^-)$ events due to nonzero signal events. The number of signal $(e^+e^- + \mu^+\mu^- + e^+\mu^- + \mu^+e^-)$ events for the case of maximal mixing coincides (up to statistical fluctuations) with the number of $(e^+e^- + \mu^+\mu^-)$ signal events without mixing. Therefore, in our estimates we can use the results of our calculations performed for the case of zero mixing. We compare the number of background events

$$N_B^{SM}(e^+e^- + \mu^+\mu^- + e^+\mu^- + \mu^+e^-) \;=\; 2N_B^{SM}(e^+e^- + \mu^+\mu^-)$$

with the number of signal events

$$N_{signal}(e^+e^- + \mu^+\mu^- + e^+\mu^- + \mu^+e^-) \;=\; N_{signal}^{no\;mix}(e^+e^- + \mu^+\mu^-).$$

The significance is determined by the formulae

$$S = \frac{N_{signal}^{mix}}{\sqrt{N_{signal}^{mix} + N_B^{mix}}} = \frac{N_S}{\sqrt{N_S + 2\,N_B^{SM}}}, \tag{19}$$

where N_S and N_B^{SM} are the numbers of the signal and the background events for the case of zero mixing. We adopt the standard criterion according to which the sleptons will be discovered provided the significance is bigger than $S \;\geq\; 5$. As it follows from formulae (19), the maximal $(\tilde{\mu} - \tilde{e})$ mixing will be discovered provided the significance of the detection of $(e^+e^- + \mu^+\mu^-)$ events for the case of the mixing absence is larger than 7. We have found that for the case of the right-handed sleptons the $(\tilde{\mu} - \tilde{e})$ mixing and, hence, flavour lepton number violation can be detected for the slepton masses up to 250 GeV. For the case of the left-handed sleptons we can also search for the mixing effects. In this case, the $(\tilde{\mu} - \tilde{e})$ mixing can also be detected for the slepton mass up to 250 GeV.

[1)] As has been mentioned above, the contribution of $\tilde{\tau}_R-$sleptons into the $l^+l^- \;+\; E_T^{miss}$ + no jets signature is practically zero and we neglect it.

With the maximal stau - smuon mixing the corresponding formulae are similar to those given above for the selectron - smuon mixing. In this case we expect the number of e^+e^- signal events to be twice greater than the number of $\mu^+\mu^-$ signal events and twice smaller than the number of the $e^+e^- + \mu^+\mu^-$ signal events with no mixing. Then the significance is

$$S = \frac{N_S(e^+e^-) + N_S(\mu^+\mu^-)}{\sqrt{N_S(e^+e^- + \mu^+\mu^-) + N_S(e^+e^-) + N_S(\mu^+\mu^-)}} = \frac{\frac{3}{4}N_S}{\sqrt{\frac{3}{4}N_S + N_B}}, \quad (20)$$

where N_S and N_B are the numbers of signal and background events for the case of no mixing. Again, if the significance for the case of zero mixing is larger than 6.6, then the significance (20) will be larger than 5.

For the case of $(\tilde{e} - \tilde{\tau})$ mixing we do not expect $\mu^\pm e^\mp$ signal events as in the case of the mixing absence. However, for the case of $(\tilde{e} - \tilde{\tau})$ mixing we expect the excess of $\mu^+\mu^-$ events over e^+e^- events.

In the Standard Model the difference $N^{back}(e^+e^-) - N^{back}(\mu^+\mu^-)$ is zero up to statistical fluctuations. At 1 σ level the statistical fluctuation is $\sqrt{N_B^{SM}}$, where N_B^{SM} is the number of $e^+e^- + \mu^+\mu^-$ background events, whereas $N^{sig}(e^+e^-) - N^{sig}(\mu^+\mu^-) = 0.25\, N^{sig}$ (zero mixing). Therefore, it is very difficult to distinguish at the 5 σ level between the mixing absence case and the $(\tilde{\mu} - \tilde{\tau})$ mixing case.

The case of selectron - stau mixing is similar to that of smuon - stau mixing, the only difference being the interchange $e \to \mu, \;\; \mu \to e$.

For the maximal selectron - smuon - stau mixing, we expect the equal numbers $e^+e^-, \; \mu^+\mu^-, \; e^+\mu^-$ and μ^+e^- signal events. Therefore, this case is too similar to that of the maximal $(\tilde{\mu} - \tilde{e})$ mixing. The sole difference is the number of signal events

$$N_S(e^+e^- + \mu^+\mu^- + e^+\mu^- + e^-\mu^+) \; = \; \tfrac{2}{3}N_S^{zero\ mixing}(e^+e^- + \mu^+\mu^-).$$

So, the significance is $S \; = \; \frac{\frac{2}{3}N_S}{\sqrt{2N_B + N_S}}$, where N_S and N_B is the number of signal events for the case of zero mixing. The significance S for the maximal $(\tilde{\mu} - \tilde{e} - \tilde{\tau})$ mixing exceeds 5 provided the corresponding significance for the case of zero mixing is larger than 10. So, at CMS it would be extremely difficult to detect the $(\tilde{\mu} - \tilde{e} - \tilde{\tau})$ mixing.

9 Conclusion

We have studied separetely the possibility to detect the right-handed sleptons, the left-handed sleptons and right-plus left-handed sleptons at CMS in a model independent way.

For the right-handed sleptons the number of signal events passing through cuts depends on the mass of the slepton and the mass of the LSP. We have found that for luminosity $L \; = \; 10^5 pb^{-1}$ it would be possible to discover the right-handed sleptons for a mass up to 325 GeV using the standard significance criterion $S \; = \; \frac{N_S}{\sqrt{N_S + N_B}} \; \geq \; 5$. However, the SM background has an equal number of $(e^+e^- + \mu^+\mu^-)$ and $(e^+\mu^- + \mu^+e^-)$ events and the signal contributes only to $(e^+e^- + \mu^+\mu^-)$ events, so we can estimate the difference $\Delta N = N(e^+e^- + \mu^+\mu^-) - N(e^+\mu^- + \mu^+e^-)$. Only signal events contribute to ΔN. In the Standard Model ΔN is equal to zero up to statistical fluctuations. Nonzero ΔN is an independent and very important check for the slepton discovery at LHC. For the case when only the left-handed sleptons contribute to signal events, we have found that it is possible to discover the left-handed sleptons with a mass up to 350 GeV.

For the right-handed sleptons we have found that the number of signal events decreases with the increase of the LSP mass and, typically, it is possible to detect the right-handed sleptons, provided the LSP mass $m_{LSP} \leq 0.4\, m_{\tilde{l}_R}$.

For the left-handed sleptons we have found that the number of the signal events is maximal for $m_{LSP} = (0.4 - 0.6)\, m_{\tilde{l}_L}$. For the LSP masses in this interval, the CMS left-handed slepton discovery potential is the maximal one. Note that these results are in agreement with the similar observations of ref. [3].

We have also studied the case of flavour lepton number violation in slepton decays. For the case of maximal $(\tilde{\mu}_R - \tilde{e}_R)$ mixing we have found that the signature qualitatively differs from the case of zero mixing, namely, in this case we do not have an excess of $\Delta N = N(e^+e^- + \mu^+\mu^-) - N(e^+\mu^- + \mu^+e^-)$ events unlike the case of zero mixing where $\Delta N > 0$. So, it is possible to distinguish zero mixing and maximal mixing. We have found that it is possible to detect the maximal $(\tilde{\mu}_R - \tilde{e}_R)$ mixing for the right-handed sleptons with a mass up to 250 GeV. We also considered the cases of $(\tilde{\mu} - \tilde{\tau})$ and $(\tilde{\mu} - \tilde{e} - \tilde{\tau})$ mixings. However, for such mixing at $L = 10^5 pb^{-1}$ it is not so easy to distinguish the mixings from the case of the mixing absence. Our conclusion about the possibility to detect sleptons with a mass up to 300 GeV is in qualitative agreement with the similar results of ref. [3]. However, in our paper we have studied a more general situation (we have not assumed MSUGRA model, which as it has been explained in the Introduction is, at best, only a rough description of the sparticle spectrum). In fact, the number of signal events passing the cuts depends mainly on the masses of the right- and the left-handed sleptons and on the LSP mass. So, those 3 parameters determine the possibility to detect sleptons at CMS. As a rule, we neglecte cascade neutralino or chargino decays resulting in the dilepton signature. However, we have checked that (especially for cuts 3-7) their contribution is generally not very large and, moreover, an account of such contribution increases the significance. The reason why we have neglected gaugino decays is that, in general, the masses of $\tilde{\chi}_2^0,\ \tilde{\chi}_1^\pm$ are model dependent (they are determined from standard but an ”ad hoc” assumption that at GUT scale all gaugino masses coincide).

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Table 4: The number of events N_{ev} and significance S for the case of right-handed sleptons, $m_{\tilde{l}_R}$ = 96 GeV, L = 10^4 pb^{-1} and for different LSP masses $m_{\tilde{\chi}_1^0}$. Columns for sets 3-7 contain insignificant information.

$m_{\tilde{\chi}_1^0}$		cut 1	cut 2
24 GeV	N_{ev}	243	463
	S	6.9	8.6
38 GeV	N_{ev}	89	180
	S	2.7	3.5
53 GeV	N_{ev}	34	34
	S	2.7	3.5
	N_B^{SM} [3]	992	2421

Table 5: The number of events N_{ev} and significance S for the case of right-handed sleptons, $m_{\tilde{l}_R}$ = 100 GeV, L = 10^4 pb^{-1} and for different LSP masses $m_{\tilde{\chi}_1^0}$.

$m_{\tilde{\chi}_1^0}$		cut 1	cut 2
24 GeV	N_{ev}	195.	366.
	S	5.7	6.9
38 GeV	N_{ev}	171.	316.
	S	5.0	6.0
53 GeV	N_{ev}	120.	219.
	S	3.6	4.3
69 GeV	N_{ev}	48.	79.
	S	1.5	1.6

Table 6: The number of events N_{ev} and significance S and for the case of right-handed sleptons, $m_{\tilde{l}_R} = 125$ GeV, $L = 10^5$ pb^{-1} and for different LSP masses $m_{\tilde{\chi}_1^0}$.

$m_{\tilde{\chi}_1^0}$		cut 1	cut 2	cut 3	cut 4	cut 5	cut 6	cut 7
26 GeV	N_{ev}	1086.	2091.	189.	79.	12.	27.	12.
	S	10.4	12.9	9.9	5.8	1.6	3.0	1.7
54 GeV	N_{ev}	806.	1632.	50.	19.	0.	6.	1.
	S	7.8	10.2	3.4	1.7	0.0	0.8	0.2
85 GeV	N_{ev}	446.	845.	0.	0.	0.	0.	0.
	S	4.4	5.3	0.0	0.0	0.0	0.0	0.0
	N_B^{SM} [3]	9920	24210	172	105	45	53	38

Table 7: The number of events N_{ev} and significance S for the case of right-handed sleptons, $m_{\tilde{l}_R}$ = 150 GeV, $L = 10^5$ pb^{-1} and for different LSP masses $m_{\tilde{\chi}_1^0}$.

$m_{\tilde{\chi}_1^0}$		cut 1	cut 2	cut 3	cut 4	cut 5	cut 6	cut 7
24 GeV	N_{ev}	626.	1209.	185.	127.	38.	60.	38.
	S	6.1	7.6	9.8	8.3	4.2	5.6	4.4
53 GeV	N_{ev}	595.	1183.	149.	83.	15.	23.	15.
	S	5.8	7.4	8.3	6.1	1.9	2.6	2.1
69 GeV	N_{ev}	472.	922.	23.	5.	0.	1.	0.
	S	4.6	5.8	1.6	0.5	0.0	0.1	0.0

Table 8: The number of events N_{ev} and significance S for the case of right-handed sleptons, $m_{\tilde{l}_R}$ = 175 GeV, $L = 10^5$ pb^{-1} and for different LSP masses $m_{\tilde{\chi}_1^0}$.

$m_{\tilde{\chi}_1^0}$		cut 1	cut 2	cut 3	cut 4	cut 5	cut 6	cut 7
26 GeV	N_{ev}	345.	679.	155.	130.	73.	92.	72.
	S	3.4	4.3	8.6	8.5	6.7	7.6	6.9
54 GeV	N_{ev}	289.	648.	137.	108.	49.	61.	49.
	S	2.9	4.1	7.8	7.4	5.1	5.7	5.3
85 GeV	N_{ev}	317.	647.	83.	47.	7.	17.	7.
	S	3.1	4.1	5.2	3.8	1.0	2.0	1.0

Table 9: The number of events N_{ev} and significance S for the case of right-handed sleptons, $m_{\tilde{l}_R}$ = 200 GeV, $L = 10^5$ pb^{-1} and for different LSP masses $m_{\tilde{\chi}_1^0}$.

$m_{\tilde{\chi}_1^0}$		cut 1	cut 2	cut 3	cut 4	cut 5	cut 6	cut 7
24 GeV	N_{ev}	229.	506.	170.	152.	110.	128.	110.
	S	2.3	3.2	9.2	9.5	8.8	9.5	9.0
53 GeV	N_{ev}	248.	476.	117.	106.	75.	96.	75.
	S	2.5	3.0	6.9	7.3	6.8	7.9	7.1
85 GeV	N_{ev}	231.	447.	90.	73.	40.	55.	40.
	S	2.3	2.8	5.6	5.5	4.3	5.3	4.5
119 GeV	N_{ev}	81.	175.	1.	0.	0.	0.	0.
	S	0.8	1.1	0.1	0.0	0.0	0.0	0.0

Table 10: The number of events N_{ev} and significance S for the case of right-handed sleptons, $m_{\tilde{l}_R} = 225\,GeV$, $L = 10^5 pb^{-1}$ and for different LSP masses $m_{\tilde{\chi}_1^0}$.

$m_{\tilde{\chi}_1^0}$		cut 1	cut 2	cut 3	cut 4	cut 5	cut 6	cut 7
26 GeV	N_{ev}	150.	268.	81.	76.	69.	87.	69.
	S	1.5	1.7	5.1	5.6	6.5	7.4	6.7
54 GeV	N_{ev}	140.	264.	84.	82.	63.	75.	62.
	S	1.4	1.7	5.3	6.0	6.1	6.6	6.2
85 GeV	N_{ev}	156.	306.	85.	78.	54.	66.	53.
	S	1.6	2.0	5.3	5.8	5.4	6.1	5.6
119 GeV	N_{ev}	135.	277.	68.	55.	28.	33.	28.
	S	1.3	1.8	4.4	4.3	3.3	3.6	3.4

Table 11: The number of events N_{ev} and significance S for the case of right-handed sleptons, $m_{\tilde{l}_R}$ = 250 GeV, $L = 10^5$ pb^{-1} and for different LSP masses $m_{\tilde{\chi}_1^0}$.

$m_{\tilde{\chi}_1^0}$		cut 1	cut 2	cut 3	cut 4	cut 5	cut 6	cut 7
24 GeV	N_{ev}	128.	237.	84.	78.	81.	92.	81.
	S	1.3	1.5	5.3	5.8	7.2	7.6	7.4
53 GeV	N_{ev}	125.	232.	82.	76.	78.	91.	78.
	S	1.2	1.5	5.1	5.6	7.0	7.6	7.2
85 GeV	N_{ev}	117.	220.	78.	73.	68.	80.	68.
	S	1.2	1.4	4.9	5.5	6.4	6.9	6.6
119 GeV	N_{ev}	116.	217.	66.	61.	49.	56.	49.
	S	1.2	1.4	4.3	4.7	5.1	5.4	5.3
157 GeV	N_{ev}	94.	187.	43.	31.	15.	18.	15.
	S	0.9	1.2	2.9	2.7	1.9	2.1	2.1

Table 12: The number of events N_{ev} and significance S for the case of right-handed sleptons, $m_{\tilde{l}_R}$ = 275 GeV, $L = 10^5$ pb^{-1} and for different LSP masses $m_{\tilde{\chi}_1^0}$.

$m_{\tilde{\chi}_1^0}$		cut 1	cut 2	cut 3	cut 4	cut 5	cut 6	cut 7
25 GeV	N_{ev}	73.	130.	45.	44.	40.	49.	40.
	S	0.7	0.8	3.1	3.6	4.3	4.9	4.5
54 GeV	N_{ev}	68.	139.	53.	52.	49.	59.	49.
	S	0.7	0.9	3.5	4.2	5.1	5.6	5.3
85 GeV	N_{ev}	60.	115.	35.	32.	31.	34.	31.
	S	0.6	0.7	2.4	2.7	3.6	3.6	3.7
119 GeV	N_{ev}	91.	169.	56.	54.	47.	57.	46.
	S	0.9	1.1	3.7	4.3	4.9	5.4	5.0

Table 13: The number of events N_{ev} and significance S for the case of right-handed sleptons, $m_{\tilde{l}_R}$ = 300 GeV, $L = 10^5$ pb^{-1} and for different LSP masses $m_{\tilde{\chi}_1^0}$.

$m_{\tilde{\chi}_1^0}$		cut 1	cut 2	cut 3	cut 4	cut 5	cut 6	cut 7
24 GeV	N_{ev}	64.	134.	59.	59.	56.	65.	56.
	S	0.6	0.9	3.9	4.6	5.6	6.0	5.8
52 GeV	N_{ev}	59.	117.	50.	46.	45.	53.	45.
	S	0.6	0.8	3.4	3.7	4.7	5.1	4.9
85 GeV	N_{ev}	55.	118.	49.	46.	45.	54.	45.
	S	0.6	0.8	3.3	3.7	4.7	5.2	4.9
119 GeV	N_{ev}	56.	114.	46.	44.	41.	48.	41.
	S	0.6	0.7	3.1	3.6	4.4	4.8	4.6
157 GeV	N_{ev}	54.	112.	38.	36.	33.	40.	33.
	S	0.5	0.7	2.6	3.0	3.7	4.1	3.9
196 GeV	N_{ev}	52.	105.	29.	25.	13.	16.	13.
	S	0.5	0.7	2.0	2.2	1.7	1.9	1.8

Table 14: The number of events N_{ev} and significance S for the case of right-handed sleptons, $m_{\tilde{l}_R}$ = 325 GeV, $L = 10^5$ pb^{-1} and for different LSP masses $m_{\tilde{\chi}_1^0}$.

$m_{\tilde{\chi}_1^0}$		cut 1	cut 2	cut 3	cut 4	cut 5	cut 6	cut 7
53 GeV	N_{ev}	24.	72.	35.	35.	36.	45.	35.
	S	0.2	0.5	2.4	3.0	4.0	4.5	4.1
85 GeV	N_{ev}	44.	89.	39.	38.	40.	51.	40.
	S	0.4	0.6	2.7	3.2	4.3	5.0	4.5
119 GeV	N_{ev}	32.	74.	37.	36.	33.	43.	33.
	S	0.3	0.5	2.6	3.0	3.7	4.4	3.9
157 GeV	N_{ev}	34.	76.	31.	29.	28.	37.	28.
	S	0.3	0.5	2.2	2.5	3.3	3.9	3.4
196 GeV	N_{ev}	32.	73.	28.	26.	19.	26.	19.
	S	0.3	0.5	2.0	2.3	2.4	2.9	2.5
233 GeV	N_{ev}	30.	62.	17.	13.	4.	6.	4.
	S	0.3	0.4	1.2	1.2	0.6	0.8	0.6

Table 15: The number of events N_{ev} and significance S for the case of right-handed sleptons, $m_{\tilde{l}_R}$ = 350 GeV, $L = 10^5$ pb^{-1} and for different LSP masses $m_{\tilde{\chi}_1^0}$.

$m_{\tilde{\chi}_1^0}$		cut 1	cut 2	cut 3	cut 4	cut 5	cut 6	cut 7
53 GeV	N_{ev}	33.	68.	33.	33.	33.	40.	33.
	S	0.3	0.4	2.3	2.8	3.7	4.1	3.9
119 GeV	N_{ev}	32.	69.	35.	34.	35.	36.	35.
	S	0.3	0.4	2.4	2.9	3.9	3.8	4.1
196 GeV	N_{ev}	30.	65.	31.	31.	27.	27.	27.
	S	0.3	0.4	2.2	2.7	3.2	3.0	3.3
233 GeV	N_{ev}	27.	61.	25.	23.	18.	18.	18.
	S	0.3	0.4	1.8	2.0	2.3	2.1	2.4
270 GeV	N_{ev}	23.	56.	12.	7.	3.	3.	3.
	S	0.2	0.4	0.9	0.7	0.4	0.4	0.5

Table 16: The number of events N_{ev} and significance S for the case of left-handed sleptons, $m_{\tilde{l}_L}$ = 100 GeV, L = 10^4 pb^{-1} and for different LSP masses $m_{\tilde{\chi}_1^0}$. Columns for sets 3-7 contain insignificant information.

$m_{\tilde{\chi}_1^0}$		cut 1	cut 2
24 GeV	N_{ev}	132.	546.
	S	3.9	10.0
38 GeV	N_{ev}	122.	372.
	S	3.7	7.0
53 GeV	N_{ev}	421.	602.
	S	11.2	10.9
69 GeV	N_{ev}	209.	291.
	S	6.0	5.6
	N_B^{SM} [3]	992	2421

Table 17: The number of events N_{ev} and significance S for the case of left-handed sleptons, $m_{\tilde{l}_L}$ = 150 GeV, L = 10^5 pb^{-1} and for different LSP masses $m_{\tilde{\chi}_1^0}$.

$m_{\tilde{\chi}_1^0}$		cut 1	cut 2	cut 3	cut 4	cut 5	cut 6	cut 7
24 GeV	N_{ev}	682.	1815.	302.	131.	32.	41.	32.
	S	6.6	11.3	13.9	8.5	3.6	4.2	3.8
53 GeV	N_{ev}	663.	1762.	143.	111.	113.	120.	113.
	S	6.4	10.9	8.1	7.6	9.0	9.1	9.2
85 GeV	N_{ev}	951.	2029.	72.	11.	2.	23.	2.
	S	9.1	12.5	4.6	1.0	0.3	2.6	0.3
119 GeV	N_{ev}	273.	485.	2.	1.	1.	2.	1.
	S	2.7	3.1	0.2	0.1	0.1	0.3	0.2
	N_B^{SM} [3]	9920	24210	172	105	45	53	38

Table 18: The number of events N_{ev} and significance S for the case of left-handed sleptons, $m_{\tilde{l}_L}$ = 200 GeV, L = 10^5 pb^{-1} and for different LSP masses $m_{\tilde{\chi}_1^0}$.

$m_{\tilde{\chi}_1^0}$		cut 1	cut 2	cut 3	cut 4	cut 5	cut 6	cut 7
53 GeV	N_{ev}	202.	618.	117.	88.	49.	51.	49.
	S	2.0	3.9	6.9	6.3	5.1	5.0	5.3
85 GeV	N_{ev}	252.	641.	108.	86.	43.	54.	43.
	S	2.5	4.1	6.5	6.2	4.6	5.2	4.8
119 GeV	N_{ev}	468.	920.	91.	42.	11.	14.	11.
	S	4.6	5.8	5.6	3.5	1.5	1.7	1.6

Table 19: The number of events N_{ev} and significance S for the case of left-handed sleptons, $m_{\tilde{l}_L} = 250$ GeV, L = 10^5 pb^{-1} and for different LSP masses $m_{\tilde{\chi}_1^0}$.

$m_{\tilde{\chi}_1^0}$		cut 1	cut 2	cut 3	cut 4	cut 5	cut 6	cut 7
53 GeV	N_{ev}	77.	211.	63.	49.	49.	52.	49.
	S	0.8	1.4	4.1	3.9	5.1	5.1	5.3
85 GeV	N_{ev}	47.	175.	45.	41.	36.	37.	36.
	S	0.5	1.1	3.1	3.4	4.0	3.9	4.2
119 GeV	N_{ev}	148.	382.	130.	118.	81.	101.	81.
	S	1.5	2.4	7.5	7.9	7.2	8.1	7.4
157 GeV	N_{ev}	183.	424.	78.	59.	23.	38.	23.
	S	1.8	2.7	4.9	4.6	2.8	4.0	2.9

Table 20: The number of events N_{ev} and significance S for the case of left-handed sleptons, $m_{\tilde{l}_L}$ = 300 GeV, L = 10^5 pb^{-1} and for different LSP masses $m_{\tilde{\chi}_1^0}$.

$m_{\tilde{\chi}_1^0}$		cut 1	cut 2	cut 3	cut 4	cut 5	cut 6	cut 7
53 GeV	N_{ev}	40.	107.	31.	31.	30.	35.	30.
	S	0.4	0.7	2.2	2.7	3.5	3.7	3.6
85 GeV	N_{ev}	29.	90.	27.	24.	22.	25.	22.
	S	0.3	0.6	1.9	2.1	2.7	2.8	2.8
119 GeV	N_{ev}	26.	65.	19.	18.	22.	25.	22.
	S	0.3	0.4	1.4	1.6	2.7	2.8	2.8
	$S_{1.5}$	0.2	0.3	1.1	1.4	2.3	2.4	2.5
138 GeV	N_{ev}	72.	155.	55.	51.	46.	57.	46.
	S	0.7	1.0	3.7	4.1	4.8	5.4	5.0
157 GeV	N_{ev}	127.	252.	78.	71.	59.	80.	59.
	S	1.3	1.6	4.9	5.4	5.8	6.9	6.0
177 GeV	N_{ev}	118.	238.	64.	60.	46.	61.	46.
	S	1.2	1.5	4.2	4.7	4.8	5.7	5.0

Table 21: The number of events N_{ev} and significance S for the case of left-handed sleptons, $m_{\tilde{l}_L} = 350$ GeV, L = 10^5 pb^{-1} and for different LSP masses $m_{\tilde{\chi}_1^0}$.

$m_{\tilde{\chi}_1^0}$		cut 1	cut 2	cut 3	cut 4	cut 5	cut 6	cut 7
53 GeV	N_{ev}	18.	38.	6.	6.	4.	15.	4.
	S	0.2	0.2	0.4	0.6	0.6	1.8	0.6
119 GeV	N_{ev}	12.	28.	11.	10.	10.	12.	10.
	S	0.1	0.2	0.8	0.9	1.3	1.5	1.4
157 GeV	N_{ev}	40.	82.	28.	28.	24.	30.	24.
	S	0.4	0.5	2.0	2.4	2.9	3.3	3.0
196 GeV	N_{ev}	65.	144.	51.	51.	41.	49.	41.
	S	0.7	0.9	3.4	4.1	4.4	4.9	4.6
233 GeV	N_{ev}	59.	130.	39.	39.	23.	29.	23.
	S	0.6	0.8	2.7	3.3	2.8	3.2	2.9
270 GeV	N_{ev}	51.	114.	16.	16.	4.	5.	4.
	S	0.5	0.7	1.2	1.5	0.6	0.7	0.6

Table 22: The number of events N_{ev} and significance S for the case of right- and left-handed sleptons, $m_{\tilde{l}_R}$ = 100 GeV, $m_{\tilde{l}_L}$ = 150 GeV, L = 10^4pb^{-1} and for different LSP masses $m_{\tilde{\chi}_1^0}$. Columns for sets 3-7 contain insignificant information.

$m_{\tilde{\chi}_1^0}$		cut 1	cut 2
24 GeV	N_{ev}	263.	547.
	S	7.4	10.0
38 GeV	N_{ev}	238.	494.
	S	6.8	9.1
53 GeV	N_{ev}	166.	403.
	S	4.9	7.6
69 GeV	N_{ev}	110.	262.
	S	3.3	5.1
	N_B^{SM}	992	2421

Table 23: The number of events N_{ev} and significance S for the case of right- and left-handed sleptons, $m_{\tilde{l}_R} = 200\, GeV$, $m_{\tilde{l}_L} = 250\, GeV$, $L = 10^5 pb^{-1}$ and for different LSP masses $m_{\tilde{\chi}_1^0}$.

$m_{\tilde{\chi}_1^0}$		cut 1	cut 2	cut 3	cut 4	cut 5	cut 6	cut 7
53 GeV	N_{ev}	325.	687.	180.	155.	124.	148.	124.
	S	3.2	4.4	9.6	9.6	9.5	10.4	9.7
85 GeV	N_{ev}	278.	622.	135.	114.	76.	92.	76.
	S	2.8	3.9	7.7	7.7	6.9	7.6	7.1
119 GeV	N_{ev}	264.	599.	79.	59.	23.	38.	23.
	S	2.6	3.8	5.0	4.6	2.8	4.0	2.9
	N_B^{SM}	9920	24210	172	105	45	53	38

Table 24: The number of events N_{ev} and significance S for the case of right- and left-handed sleptons, $m_{\tilde{l}_R} = 300\, GeV$, $m_{\tilde{l}_L} = 350\, GeV$, $L = 10^5 pb^{-1}$ and for different LSP masses $m_{\tilde{\chi}_1^0}$.

$m_{\tilde{\chi}_1^0}$		cut 1	cut 2	cut 3	cut 4	cut 5	cut 6	cut 7
53 GeV	N_{ev}	77.	155.	56.	52.	49.	68.	49.
	S	0.8	1.0	3.7	4.2	5.1	6.2	5.3
119 GeV	N_{ev}	68.	142.	57.	54.	55.	66.	55.
	S	0.7	0.9	3.8	4.3	5.5	6.1	5.7
157 GeV	N_{ev}	94.	194.	66.	64.	65.	78.	65.
	S	0.9	1.2	4.3	4.9	6.2	6.8	6.4
196 GeV	N_{ev}	117.	249.	80.	71.	54.	63.	54.
	S	1.2	1.6	5.0	5.4	5.4	5.8	5.6

Table 25: The number of events N_{ev} and significance S for the case of right- and left-handed sleptons, $m_{\tilde{l}_R} = 350\, GeV$, $m_{\tilde{l}_L} = 400\, GeV$, $L = 10^5 pb^{-1}$ and for different LSP masses $m_{\tilde{\chi}_1^0}$.

$m_{\tilde{\chi}_1^0}$		cut 1	cut 2	cut 3	cut 4	cut 5	cut 6	cut 7
53 GeV	N_{ev}	44.	91.	40.	40.	47.	51.	47.
	S	0.4	0.6	2.7	3.3	4.9	5.0	5.1
119 GeV	N_{ev}	64.	133.	63.	60.	50.	54.	50.
	S	0.6	0.9	4.1	4.7	5.1	5.2	5.3
196 GeV	N_{ev}	70.	138.	62.	61.	60.	61.	60.
	S	0.7	0.9	4.1	4.7	5.9	5.7	6.1
270 GeV	N_{ev}	55.	122.	40.	33.	18.	20.	18.
	S	0.6	0.8	2.7	2.8	2.3	2.3	2.4