Searching the sbottom in the four lepton channel at the LHC

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Abstract.

Direct searches at the Large Hadron Collider (LHC) have pushed the lower limits on the masses of the gluinos ($\tilde{g}$) and the squarks of the first two generations ($\tilde{q}$) to the TeV range. On the other hand, the limits are rather weak for the third generation squarks and masses around a few hundred GeV are still allowed. A comparatively light third generation of squarks is also consistent with the lightest Higgs boson with mass $\sim 125$ GeV. In view of this, we consider the direct production of a pair of sbottom quarks ($\tilde{b}_1$) at the LHC and study their collider signatures. We focus on the scenario where the $\tilde{b}_1$ is not the next-to-lightest supersymmetric particle (NLSP) and hence can also decay to channels other than the commonly considered decay mode to a bottom quark and the lightest neutralino ($\tilde{\chi}^0_1$). For example, we consider the decay modes containing a bottom quark and the second neutralino ($\tilde{b}_1 \rightarrow b\tilde{\chi}^0_2$) and/or a top quark and the lightest chargino ($\tilde{b}_1 \rightarrow t\tilde{\chi}^\pm_1$) following the leptonic decays of the neutralino, chargino and the top quark giving rise to a 4 leptons ($\ell$) + 2 $b$-jets + missing transverse momentum ($p_T$) final state. We show that an sbottom mass $\lesssim 550$ GeV can be probed in this channel at the 14 TeV LHC energy with integrated luminosity $\lesssim 100$ fb$^{-1}$. 
1. Introduction

The Large Hadron Collider (LHC) is currently operational at the center of mass (c.m.) energy of 8 TeV and both the experiments CMS and ATLAS have collected about 10 fb$^{-1}$ of data each. The hint of a Standard Model (SM) like Higgs boson with mass around 125 GeV has been reported [1, 2, 3, 4] and it has spurred a large number of studies specially in the context of constraining and probing physics beyond the standard model (BSM). Supersymmetry (SUSY) has been a leading candidate for BSM for more than three decades and constitutes a major search program at the LHC. As of now a huge amount of data has been analyzed in the context of the Minimal Supersymmetric Standard Model (MSSM) and limits have been placed on the MSSM parameter space particularly in the framework of constrained MSSM (cMSSM). The current limits on squarks and gluinos from direct searches stand around 1.5 TeV for approximately equal squark and gluino masses and about 950 GeV for the case where gluino masses are much smaller than the squark masses [2]. The discovery of a light SM like Higgs boson however has put SUSY and in particular the cMSSM into perspective. A large number of papers have been written in this context [6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37] and the message from them seems to suggest that the SUSY parameter space is now extremely constrained, specially the gluinos and the first two generations of squarks.

The third generation of squarks is however special owing to the large Yukawa couplings and hence can decouple from the first two generations of squarks to become comparatively lighter. Light stop squarks ({$\tilde{t}$}) are also favorable in order to cancel large radiative corrections from the top quark in Higgs mass and hence a necessity to reduce the problem of fine tuning in the SM. The signatures for a light stop quark at the LHC have been studied extensively in the past and have recently seen a flurry of activities [38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49]. As $\tilde{t}_L$ and $\tilde{b}_L$ belong to the same weak doublet, a light stop mass eigenstate may also be associated with a light sbottom mass eigenstate in specific scenarios.

In this paper we consider the possibility of a light third generation of squarks, in particular we focus on a light sbottom and investigate the viability of its signal at the LHC with 14 TeV c.m. energy. We do not confine ourselves to a particular SUSY breaking scenario and perform our study without assuming any relations among the soft SUSY breaking parameters at the electroweak scale.

Studies on the prospect of an sbottom search at the LHC, although not neglected in literature, are rather sparse. Some of the earliest studies of sbottom phenomenology at colliders were performed in [50, 51, 52, 53]. A study on the possibility of determining the sbottom spin at the LHC using angular correlations was performed in [54]. It should be noted that the sbottom pair production cross section is at par with that of stop and hence sbottom search should be conducted with the same priority as stop searches. In fact, differing topologies in various scenarios (leptons, b-jets etc.) can be used to distinguish between stop and sbottom and can provide useful information about the
nature of SUSY parameter space in question. Hence sbottom search at the LHC can be complementary to stop quark searches. Study of the prospect of a SUSY signal in a scenario where the sbottom is the NLSP has been performed in the literature in the channel $\tilde{b}_1 \to b\tilde{\chi}^0_1$ in the context of both LHC and ILC [55, 56, 57, 58, 59].

Recently the CMS collaboration ruled out sbottom mass up to 500 GeV with 4.98 fb$^{-1}$ of 7 TeV data assuming the branching ratio $\text{BR}(\tilde{b}_1 \to b\tilde{\chi}^0_1)$ to be 100% and the LSP mass of about 175 GeV [60]. This exclusion was also crucially dependent on the LSP mass and there was no exclusion limit for the LSP mass of about 200 GeV or higher.

However, in a large part of the MSSM parameter space the sbottom is not the NLSP. As a consequence, the branching ratios (BR) to channels other than $\tilde{b}_1 \to b\tilde{\chi}^0_1$ may be significant. Recently both the ATLAS and CMS collaborations have also searched for sbottoms in the leptonic channel in the decay mode $\tilde{b}_1 \to t\tilde{\chi}^\pm_1$ and in the hadronic mode with b-tagged jets in the $\tilde{b}_1 \to b\tilde{\chi}^0_1$ channel and have constrained a narrow region of parameter space assuming specific mass relations among $\tilde{b}_1$, $\tilde{\chi}^0_1$ and $\tilde{\chi}^\pm_1$ [61, 62]. For the leptonic channel the $\tilde{b}_1$ exclusion limits are $\sim 360-370$ GeV for a $\tilde{\chi}^\pm_1$ mass $\sim 180-190$ GeV, and a $\tilde{\chi}^0_1$ mass of 50 GeV. For the hadronic mode the exclusion limits are given in a model with gluino decaying into sbottom pairs with further decay into b-jets and lightest neutralino. The search excludes gluino masses around 1.1 TeV for sbottom masses in the range $\sim 400 - 800$ GeV and a $\tilde{\chi}^0_1$ mass of 60 GeV.

In this paper we consider the decay of sbottom to the channels $\tilde{b}_1 \to b\tilde{\chi}^0_2$ and $\tilde{b}_1 \to t\tilde{\chi}^\pm_1$. The subsequent decays of $\tilde{\chi}^0_2 \to \tilde{\chi}^0_1 Z$ and $\tilde{\chi}^\pm_1 \to \tilde{\chi}^0_1 W$ can now produce a number of hard leptons in the final state. A sample Feynman diagram is shown in Fig. 1.

![Feynman diagram](image)

Figure 1. A sample Feynman diagram for the process $pp \to b\bar{b} \ell^+\ell^+\ell^-\ell^- + p_T$ in MSSM.

The merits of considering the leptonic final state in particular, the 4 lepton channel
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is that it is rather clean and has minimal background. As we shall demonstrate below, it is possible to discover a SUSY signal for a substantial range of sbottom mass at 14 TeV LHC.

In the following section we compute the BR of sbottom to the above mentioned channels and choose some benchmark points for the collider study. We discuss the signal and backgrounds in section 3. Finally, we summarize our findings and conclude in section 4.

2. SUSY Framework and Sbottom Branching Ratios

If no specific mechanism for the SUSY breaking is assumed then the total number of unknown parameters (the so called soft SUSY breaking terms) reaches a huge number (105) and it is almost impossible to carry out any phenomenological analysis with such a large number of free parameters. Many of these parameters in particular the intergenerational mixing terms and the complex phases are rather constrained from various measurements of both Charge-Parity (CP) conserving and CP-violating observables in $K$, $B$ and $D$ decays as well as lepton flavor violating decays. It is then phenomenologically useful to make a few assumptions (which are indeed supported by experiments) like no new source of CP violation, diagonal sfermion mass matrices and tri-linear couplings etc. to reduce the number of free parameters. This rather simplified version of MSSM is called a phenomenological MSSM (pMSSM) which has 22 free parameters. These parameters include

- The gaugino (bino, wino and gluino) mass parameters $M_1$, $M_2$ and $M_3$.
- The Higgs mass parameters $m_{H_u}$, $m_{H_d}$ (which can be traded as $\mu$ and $M_A$) and the ratio of the Vacuum Expectation Values (VEV) of the two Higgs doublet namely tan $\beta$.
- Common first and second generation sfermion mass parameters $m_{\tilde{Q}}$, $m_{\tilde{U}}$, $m_{\tilde{D}}$, $m_{\tilde{L}}$, $m_{\tilde{E}}$ and the third generation sfermion mass parameters $m_{\tilde{Q}_3}$, $m_{\tilde{t}_R}$, $m_{\tilde{b}_R}$, $m_{\tilde{L}_3}$, $m_{\tilde{\tau}_R}$.
- The common first and second generation tri-linear couplings $A_u$, $A_d$ and $A_e$. The third generation tri-linear couplings $A_t$, $A_b$ and $A_\tau$.

In this work we take the pMSSM as our model framework and consider the constraints on the parameters coming only from the LEP exclusion limits, theoretical considerations like correct electroweak symmetry breaking, electric and color neutral LSP etc. and the lightest Higgs mass in the range 123 -128 GeV. The tree level Higgs mass in MSSM is always less than the $Z$ boson mass and is given by the formula $m_h \leq m_Z \cos(2\beta)$. Hence, large corrections from the virtual particles in the loop are required for the Higgs mass to be consistent with the range given above. The one loop contribution is dominated by the contribution from the stop and top quark sector and is given by

$$\Delta m_h^2 \simeq \frac{3}{4\pi^2} \frac{m_t}{v^2} \left[ \frac{\tilde{X}_t^4}{2} + \frac{1}{16\pi^2} \left( \frac{3 m_t^2}{2 v^2} - 32\pi \alpha_3 \right) \left( \tilde{X}_t t + t^2 \right) \right]$$

(1)
where \( t = \log \frac{M_s^2}{m_t^2} \), \( \tilde{X}_t = \frac{2 A_t^2}{M_S^2} \left( 1 - \frac{A_t^2}{12 M_S^2} \right) \), \( v = 246 \text{ GeV} \), \( M_S = \sqrt{m_{t_1} m_{t_2}} \), the geometric average of the two stop masses and \( \tilde{A}_t = A_t - \mu \cot \beta \), the mixing parameter in the stop sector. If both the stop quark mass eigenstates are light, it will be difficult to raise the Higgs mass to 125 GeV. However, with a large splitting in the stop sector facilitated by a large \( A_t \) term, it is possible to achieve one light eigenstate while the other heavy and thus achieving the required Higgs mass. In this case the overall stop mass scale \( M_S = \sqrt{m_{t_1} m_{t_2}} \) can be of order TeV and hence the fine-tuning in the cancellation of the quadratic divergence will be small. On the other hand, this would require a large negative value of \( A_t \) introducing an adjustment of parameter in the model.

There can be important loop corrections from the bottom squark sector also and is given by [66]

\[
\Delta m_h^2 \simeq - \frac{h_b^4 v^2}{16 \pi^2 M_S^4} \left( 1 + \frac{t}{16 \pi^2} (9h_b^2 - 5m_t^2/v^2 - 64\pi \alpha_3) \right).
\]

Here \( h_b \) is the bottom Yukawa coupling which is given by \( h_b \simeq \frac{m_b v}{\sqrt{\cos \beta (1 + \tan \beta \Delta h_b)}} \), where \( \Delta h_b \) denotes the one loop correction[66].

Hence, when \( \mu \tan \beta \) is large the contribution from the sbottom sector can be non-negligible. Thus, probing the sbottom sector is also crucial to understand the Higgs sector and in turn the Electroweak Symmetry Breaking in the MSSM.

In Fig. 2 we show the production c.s. of a sbottom pair at the 14 TeV LHC. The cross sections are calculated using PROSPINO [67] in the limit where 1st two generation squarks are \( \sim 5 \text{ TeV} \), the gluino mass is around \( \sim 1.2 \text{ TeV} \) and the stop mass is around 400 GeV. The Renormalization and Factorizations scales are set to the their default values in PROSPINO and the CTEQ6L parton distribution function has been used for the c.s. calculation. It can be seen that the cross section falls sharply from \( \sim 10 \text{pb} \) at 300 GeV to \( \sim 10 \text{fb} \) at 1TeV. It must be noted that the NLO cross section depends on the squark and gluino masses to some extent. In our scenario the first two generation of squarks and the gluino is decoupled from the 3rd generation squarks.

The direct decay of sbottom to the LSP is always kinematically favored, and for right-handed squarks it can dominate if \( \tilde{\chi}_1^0 \) is bino like. This is generally the case with models like CMSSM which has a large right handed component in the third generation mixing matrix. The bino co-annihilation case where the bino can co-annihilate with the NLSP sbottom is also an important scenario and has been considered in [56]. The interplay of sbottom and stop in the context of natural SUSY has been discussed in [57], where the authors argue that direct searches on sbottom can set limits on the stop sector from below causing a tension between naturalness which sets the stop scale from above and direct searches which constrain it from below. They also suggest that the limits on direct searches should depend on the admixture of left and right handed components of sbottom. The left handed nature of sbottom has been searched by CMS in [61], for 7 TeV LHC where they investigate the channel \( \tilde{b}_1 \rightarrow t \tilde{\chi}_1^\pm \) in the dilepton + b-jets channel. This motivates us to investigate the scope of MSSM to admit a large left handed sbottom and ways to detect such a scenario. If the sbottom is left handed then it may prefer to
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Figure 2. The central value of the Next to Leading Order (NLO) c.s. for the sbottom pair production at the 14 TeV LHC.

decay strongly into heavier charginos or neutralinos instead, for example $\tilde{b}_1 \rightarrow b\tilde{\chi}_2^0$ and $\tilde{b}_1 \rightarrow t\tilde{\chi}_1^\pm$. This is because the relevant squark-quark-wino couplings are much bigger than the squark-quark-bino couplings. Squark decays to higgsino-like charginos and neutralinos are less important for sbottom (than stop) because of its relatively smaller Yukawa coupling. A light left-handed sbottom can be achieved by a large splitting between the left-handed and the right-handed components ($m_{\tilde{Q}_3}$ and $m_{\tilde{b}_R}$), in particular a light left-handed component ($m_{\tilde{Q}_3}$) and a heavy right-handed component ($m_{\tilde{b}_R}$). This ensures that once diagonalized the lighter sbottom remains predominantly left handed while the heavier sbottom remains mostly right handed. The sbottom mixing matrix in such a scenario is diagonal with the mixing angle $\theta_b \sim 0$. For our purpose therefore, the relevant parameters are the third generation squark mass parameters ($m_{\tilde{Q}_3}$, $m_{\tilde{t}_R}$, $m_{\tilde{b}_R}$), the tri-linear couplings $A_t$ and $A_b$, the SU(2) and U(1) gaugino mass parameters ($M_1$ and $M_2$) and the Higgs sector parameters $\mu$ and $\tan\beta$.

To show that the situation we are considering is not a very fine tuned parameter space we vary the four parameters $m_{\tilde{Q}_3}$, $m_{\tilde{t}_R}$, $m_{\tilde{b}_R}$ in the range [100, 3000] GeV and $A_t$ in the range [-3000, 3000] GeV and calculate the branching ratios of sbottom to different channels. We keep $\tan\beta = 10$, $M_1 = 150$ GeV and $M_2 = 250$ GeV in the scan.

The first two generation squarks, and the three slepton generations are fixed at 5 TeV along with $M_3 = 1$ TeV, and $A_u = A_d = A_\tau = 100$ GeV as they are irrelevant for our study. The $\mu$ parameter is set to 1000 GeV which implies that the lighter neutralino is gaugino like. We generate the physical mass spectrum using the spectrum generator SuSpect$^{[68]}$. A different set of choices for $M_1$ and $M_2$ do not significantly alter the collider results significantly as long as $\chi_2^0 \rightarrow \tilde{\chi}_1^0 Z$ is kinematicaly allowed as can be observed in the next section.

We choose $A_b = 0$ GeV in our scan but other values do not change the result in a significant manner. Fig$^{[6]}$ shows the maximum values of the branching ratios for the channels $\tilde{b}_1 \rightarrow b\tilde{\chi}_2^0$ and $\tilde{b}_1 \rightarrow t\tilde{\chi}_1^\pm$ as a function of the sbottom mass when we vary the
parameters in the ranges mentioned above. It can be seen that significant branching ratios to these channels are allowed.

\[
\begin{align*}
\text{BR}(\tilde{b}_1 \rightarrow b\tilde{\chi}_0^2) & \quad \text{BR}(\tilde{b}_1 \rightarrow t\tilde{\chi}_1^\pm) \\
\end{align*}
\]

Figure 3. Maximum branching ratios of $\tilde{b}_1 \rightarrow b\tilde{\chi}_0^2$ (red/continuous) and $\tilde{b}_1 \rightarrow t\tilde{\chi}_1^\pm$ (blue/dotted) as a function of $\tilde{b}_1$ mass.

3. Signal and Background

In this section we choose a few benchmark points to carry out the collider analysis. The parameters for these benchmark points along with the relevant BRs are shown in Table 1.

|   | $A_t$ | $m_{\tilde{Q}_3}$ | $m_{\tilde{t}_R}$ | $m_{\tilde{b}_R}$ | $m_{\tilde{t}_1}$ | $m_{\tilde{b}_1}$ | $m_{\tilde{\chi}_1^0}$ | $m_{\tilde{\chi}_1^0}$ | $m_{\tilde{\chi}_1^\pm}$ | $\text{BR}(\tilde{b}_1 \rightarrow b\tilde{\chi}_0^2)$ | $\text{BR}(\tilde{b}_1 \rightarrow t\tilde{\chi}_1^\pm)$ |
|---|-------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| P1 | -2060 | 308              | 1922             | 1041             | 392              | 350              | 153              | 272              | 272              | 86 %            | —                |
| P2 | -2335 | 401              | 1907             | 2626             | 470              | 450              | 153              | 272              | 272              | 71 %            | 24 %             |
| P3 | -2680 | 492              | 2232             | 1904             | 573.1            | 550              | 152              | 271              | 271              | 44.5 %          | 54.5 %           |
| P4 | -2680 | 492              | 2232             | 1904             | 573.1            | 550              | 254              | 377              | 377              | 95 %            | —                |

Table 1. Masses of some of the sparticles for three benchmark points. In all the cases the other pMSSM parameters are fixed to values as described in the text.

In these parameter points the decay of sbottom proceeds mostly through the channels $\tilde{b}_1 \rightarrow b\tilde{\chi}_2^0$ and/or $\tilde{b}_1 \rightarrow t\tilde{\chi}_1^\pm$ following the decays $\tilde{\chi}_2^0 \rightarrow \tilde{\chi}_1^0 Z \rightarrow l^+l^-\tilde{\chi}_1^0$ and $\tilde{\chi}_1^\pm \rightarrow \tilde{\chi}_1^0 W^\pm \rightarrow l^\pm\nu_l\tilde{\chi}_1^0$ from both sides which finally yield a 4-leptons + 2 b-jets + $p_T$ signal in the final state.

A look at the spectrum and the decay branching ratios point out that in absence of a sufficient mass gap for the top decay to open up, the principal decay mode is $\tilde{b}_1 \rightarrow b\tilde{\chi}_2^0$. When the mass difference is sufficient for the top channel the branching ratio is fairly equally divided between the two channels. This feature is also demonstrated in Fig. 6.
As mentioned earlier, in order to show that a different choice of $M_1$ and $M_2$ do not change our results significantly as long as the decay $\tilde{\chi}_0^2 \rightarrow \tilde{\chi}_0^1 Z$ opens up we choose the benchmark point P4 in Table [1] in which $M_1$ and $M_2$ are changed to 250 GeV (from 150 GeV in P1 - P3) and 350 GeV (from 250 GeV in P1 - P3) respectively.

We mentioned earlier that the signal cross sections falls sharply with increasing $\tilde{b}_1$ mass. In particular, for an sbottom of 550 GeV (P-3) the NLO cross section reduces to 385 fb which, because of the very low branching ratio for the leptonic decay modes of $Z$, yields a miniscule final cross section. However since the background is miniscule and we are optimistic about high luminosity options for a 14 TeV LHC, this channel still offers some hope even for such high sbottom mass.

In our simulation of events, we have used PYTHIA6 [69] for both the signal as well as the backgrounds. We construct jets using the FastJet [70] package employing the anti-k$_T$ [71] algorithm with a cone size $\Delta R = 0.5$. We use the CTEQ6L [72] parton density function from the LHAPDF [73] package. The scale is set at $Q^2 = \hat{s}$. We then use the following selection criteria for the final events:

(i) We demand four isolated leptons (electron and muon) with the transverse momentum $p_\ell^T \geq 25$ GeV and the pseudo-rapidity $|\eta| \leq 2.5$. Isolation of leptons are ensured by demanding the total transverse energy $p_{AC}^T \leq 10\%$ of $p_\ell^T$. Here $p_{AC}^T$ is the scalar sum of transverse momenta of jets close to leptons satisfying $\Delta R(\ell, j) \leq 0.2$ with a jet $p_T$ threshold of 30 GeV and $|\eta| \leq 3$. We ensure that the sum total charge of the 4 lepton system is 0 to avoid contamination from background.

(ii) Jets are selected with $p_j^T \geq 30$ GeV and $|\eta| \leq 3$. We demand at least 2 jets with $b$ tags. The b-tagging is implemented by performing a matching of the jets with $b$ quarks assuming a matching cone $\Delta R(b, j) = 0.3$.

(iii) In addition we demand $p_T > 50$ GeV.

The effects of the above selection cuts are summarized in Table. 2. The potential SM backgrounds in our case are $t \bar{t}$, $Z Z$, $W Z$, and QCD. In Table. 2 we show only the non-vanishing background which in our case is the $t \bar{t}$.

| Process | Production c.s. (pb) | Simulated Events | 4 isolated $\ell$ | 2 b-tagged jets | $p_T > 50$ GeV | $S / \sqrt{B}$ (50 fb$^{-1}$) |
|---------|----------------------|-----------------|----------------|----------------|----------------|------------------|
| P1      | 4.75                 | 0.5M            | 5.1            | 1.4            | 1.1            | 26               |
| P2      | 1.22                 | 0.1M            | 1.5            | 0.5            | 0.4            | 10               |
| P3      | 0.39                 | 0.1M            | 0.5            | 0.2            | 0.2            | 4                |
| P4      | 0.39                 | 0.1M            | 0.6            | 0.2            | 0.2            | 4                |
| t $\bar{t}$ | 918              | 40M             | 2.8            | 0.09           | 0.09           |                  |

Table 2. Efficiency of the selection cuts for the signal in the three benchmark points and the top background for 14 TeV LHC. The cross-sections after each of the cuts (column 4 - 6) are given in femtobarns. Efficiency for 2 $b$-tagging has been multiplied in the 5th column. The significance has been quoted at a projected luminosity of 50 fb$^{-1}$ in the last column.
The second column represents raw production c.s. for $\tilde{b}_1\tilde{b}_1$ calculated at NLO using PROSPINO [67]. We have used the top pair production cross section at 14 TeV as quoted in Ref [74]. The third column represents the number of events simulated for each of the processes. From the fourth column the cumulative effects of the selection cuts are shown. In demanding b-jets we assume an optimistic b-tagging efficiency of 70% for each b-jet [75]. We find that even for the signal the requirement of four isolated hard leptons with vanishing total lepton charge of the system leaves a small signal cross-section. On the other hand, this takes care of all the other backgrounds with the exception of $t\bar{t}$. The transverse momentum distribution of the 3rd hardest isolated (and $|\eta| < 2.5$) lepton is shown in the left panel of Fig.4 where a clear distinction can be made between the signal and the background. The lepton multiplicities for both the signal (benchmark-2) and $t\bar{t}$ background are also shown in the right panel of Fig. 4. Note that, though in the parton level a 3rd hard lepton is not expected from $t\bar{t}$ events, in real situation such leptons can come from the hadron decays for example, semileptonic decays of $B$ hadrons.

![Figure 4](image)

**Figure 4.** The $P_T$ distribution of the 3rd hardest isolated (and $|\eta| < 2.5$) lepton (left panel) and the lepton multiplicities (right panel) for both the signal (benchmark-2) and the top background.

The demand of two $b$-like jets in addition to the four isolated hard leptons also removes a significant fraction of the top background. Since the $p_T$ is rather soft in the signal due to a low mass difference between $\tilde{\chi}_2^0$ and $\tilde{\chi}_1^0$, only a low $p_T$ cut could be used in selecting events. Our results are summarized in the last column of Table. 2. The signal significance is obtained in terms of Gaussian statistics, given by the ratio $S/\sqrt{B}$ of signal and background events for a particular integrated luminosity. We project our significance ($S/\sqrt{B}$) at 50 fb$^{-1}$ at 14 TeV LHC. We find that for low sbottom masses (up to 450 GeV) a reasonable significance ($S/\sqrt{B} \geq 5$) can be achieved at relatively
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low luminosities (\(\sim 20 \text{ fb}^{-1}\)). For masses of \(\sim 500 \text{ GeV}\) a higher luminosity of \(50 \text{ fb}^{-1}\) will be required. For even higher masses the sbottom production c.s. is miniscule and it will require at least \(100 \text{ fb}^{-1}\) luminosity to get any hint of a signal at LHC. As noted earlier we find that the change in LSP mass does not significantly change our signal significance. This can be seen in the event summary given in Table 2.

4. Summary and Conclusion

We have probed the prospect of a light sbottom search in the 4 lepton + jets (with two b-tagged jets) + \(p_T\) channel in the context of pMSSM at 14 Tev LHC. We have considered the scenario where the lighter sbottom is predominantly left handed and can decay into the second lightest neutralino or lighter chargino which eventually yields 4 leptons and b jets. We find that in pMSSM there is a large part of parameter space where such a scenario is feasible and can be useful to look for sbottom signatures. We also find that such a parameter space is compatible with a Higgs mass of 125 GeV and is in tune with the ongoing motivation for a light 3rd generation scenario.

We have analyzed the signal and background for such regions of parameter space and found that it is possible to discover a substantial range of sbottom masses. In particular we find that for sbottom masses \(\sim 450 \text{ GeV}\) it is possible to find a viable signal at the level of \(S/\sqrt{B} \geq 5\) even at \(20 \text{ fb}^{-1}\) luminosity. For masses \(\sim 550 \text{ GeV}\) and higher it will require higher luminosity LHC options which is achievable in the near future. It has to be noted that the channel has minimal background and the discovery reach is only cross section limited. We have demonstrated that as long as the studied decay channel is kinematically allowed our signal significance primarily depends on the signal cross section. Hence in our study the LSP mass plays a less significant role as compared to the NLSP sbottom searches at the LHC which rely on a significant mass splitting between the sbottom and the LSP. In order to show this we calculated the signal using two different values of LSP mass viz. 152 GeV and 254 GeV.

The 4-lepton channel in the context of 3rd generation squark searches can provide important information about the nature of SUSY parameter space and we hope that our work can be a starting guide to the experimental community to perform further analysis in this channel on the real data.

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