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Using b-tagging to enhance the SUSY reach of the CERN Large Hadron Collider

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Abstract

Assuming that supersymmetry is realized with parameters in the hyperbolic branch/focus point (HB/FP) region of the minimal supergravity (mSUGRA) model, we show that by searching for multijet + $E_T^{\rm miss}$ events with tagged b jets the reach of experiments at the LHC may be extended by as much as 20% from current projections. The reason for this is that gluino decays to third generation quarks are enhanced because the lightest neutralino has substantial higgsino components. Although we were motivated to perform this analysis because the HB/FP region is compatible with the recent determination of the relic density of cold dark matter, our considerations may well have a wider applicability since decays of gluinos to third generation quarks are favoured in a wide variety of models.

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The WMAP collaboration [1] has determined the cosmological density of cold dark matter (CDM) to be,

$$\Omega_{CDM}h^2 = 0.1126^{+0.008}_{-0.009}\,. \tag{1}$$

This measured value is of the same order of magnitude as the density expected from the production in the Big Bang of a stable, weakly interacting particle with a mass $\mathcal{O}(100\text{ GeV})$, assuming only that it was in thermal equilibrium at some point in the past [2]. Hence, the precise WMAP measurement provides a stringent constraint on all models that include heavy, stable weakly interacting particles. However, since the dark matter may well be made of several components, strictly speaking (1) only implies an upper bound on the density of such particles. In particular this bound applies to the stable lightest supersymmetric particle (LSP), frequently the lightest neutralino $\widetilde{Z}_1$, of R-parity conserving supersymmetric models that have been the focus of much attention during the last twenty-five years [3], and leads us to conclude that,

$$\Omega_{\widetilde{Z}_1}h^2 \leq 0.129 \quad (2\sigma)\,. \tag{2}$$

Compatibility with (2) is possible only if the neutralinos can annihilate efficiently which, in turn, is possible only if one of the following holds:

i. The lightest neutralino is hypercharge gaugino-like and annihilates via t-channel exchanges of relatively light ($\sim$ 300 GeV) sfermions [4].

ii. The neutralino mass $m_{\widetilde{Z}_1} \simeq \frac{1}{2}m_{A,H}$ so that it annihilates resonantly via the exchange of the neutral Higgs bosons A or H in the s-channel [5]. Since these heavier Higgs bosons are typically quite broad, and because the neutralinos have thermal motions, resonant Higgs annihilation occurs over a rather large range of parameters. There is also a small range of parameters where resonant annihilation via the lightest scalar Higgs boson h leads to efficient neutralino annihilation [6].

iii. The neutralino mass is close to that of a charged or coloured particle; since this latter particle can annihilate efficiently, the neutralino density is correspondingly reduced as long as its interactions maintain it in thermal equilibrium with the co-annihilating charged particle [7].

iv. The parameter $|\mu|$ is small compared to the gaugino masses so that the lightest neutralino has significant higgsino components and annihilates effectively via couplings to electroweak gauge bosons [8].

v. The neutralino has significant $SU(2)$ gaugino components, and so annihilates to W^+W^- via large isotriplet $SU(2)$ couplings. In this case, the lighter chargino tends to be close in mass to $\widetilde{Z}_1$, so co-annihilations may also be important [9].

Most SUSY analyses of the implications of the WMAP measurement have been performed within the framework of the mSUGRA model [10] which, assuming radiative electroweak symmetry breaking, is specified by the well known parameter set,

$$m_0, m_{1/2}, A_0, \tan\beta, \mathrm{sign}(\mu).$$

Within this framework, which has also been the paradigm for many phenomenological analyses of supersymmetry (SUSY), neutralino annihilation as in item i. occurs in the so-called *bulk region* with small values of m_0 and $m_{1/2}$; as in ii. in the A or H funnels which occur only if $\tan\beta$ is large; as in iii. only close to the boundary of parameter space where $\tilde{\tau}_1$ becomes the LSP [11], or for special values of A_0, where $\tilde{t}_1$ becomes the LSP [12]; and as in iv. in the hyperbolic branch/focus point (HB/FP) region with large values of m_0 and modest to large values of $m_{1/2}$ [13]. The last option v. is not realized within mSUGRA or for that matter in any model with unification of gaugino masses, or in any SUSY Grand Unified Theory (GUT) unless the field that breaks SUSY also breaks the GUT gauge symmetry [14]. In the recently studied non-universal Higgs masses (NUHM) extensions of mSUGRA [15], the Higgs funnel occurs for any value of $\tan\beta$ while the low $|\mu|$ region is accessible even for relatively low values of m_0 [16].

Within the mSUGRA framework that we adopt for this study, it has been shown that, with an integrated luminosity of 100 fb^{-1}, experiments at the Large Hadron Collider (LHC) will probe all of the bulk region, most of the Higgs funnel and, except for the largest values of $\tan\beta$, all of the stau co-annihilation region allowed by the WMAP data [17]. The reach in the low $|\mu|$ HB/FP region, however, cuts off around $m_{\tilde{g}} \sim 1.6 - 1.8$ TeV, where the signal from gluino pair production becomes rate limited. Although $\widetilde{W}_1$ and $\widetilde{Z}_2$ are relatively light and will be abundantly produced at the LHC, if $|\mu|$ is indeed small the efficiency for the well studied trilepton signal from $\widetilde{W}_1\widetilde{Z}_2$ production [18] is reduced, especially if we are deep in the HB/FP region where the mass gap between $\widetilde{W}_1$ (or $\widetilde{Z}_2$) and $\widetilde{Z}_1$ becomes rather small and the daughter leptons as well as $E_T^{\rm miss}$ from charginos and neutralinos are soft. In this case, it has been shown [19] that by implementing specially designed cuts to separate the chargino pair production soft decay products from Standard Model (SM) background, experiments at an e^+e^- linear collider operating at $\sqrt{s} = 500 - 1000$ GeV will be able to probe portions of the HB/FP region not accessible at the LHC. Since the LHC is scheduled to commence operations in 2007, while a linear collider is even very optimistically at least a decade away, it is clearly worthwhile to explore all strategies that can potentially expand the LHC reach, especially in this low $|\mu|$ region favoured by the WMAP measurements.

An obvious option would be to re-examine the trilepton signal to see whether it is possible to separate it from SM background processes.[1] In this paper, however, we follow a completely different strategy and focus on the signal from gluino pair production (since squarks are very heavy). Our starting point is the observation that since the lighter higgsino-like neutralinos and charginos couple much more strongly to the third generation than to the first two generations, decays of gluino into third generation fermions will be strongly enhanced so that the signal may be expected to be rich in high E_T b-jets [21]. In contrast, the dominant SM backgrounds to multijet + $E_T^{\rm miss}$ channels which give the largest SUSY reach at the LHC come from $t\bar{t}$ production, from $V+$jet production ($V = W, Z$) and from QCD processes. Since the latter two backgrounds are not expected to be especially rich in hard bottom quark jets, and because experiments at the LHC are expected to have good b tagging capability, we explore whether requiring the presence of tagged b-jets in the signal allows us to probe portions of the hyperbolic branch that are inaccessible using the by now standard analyses [22–24] of the various multijet + $E_T^{\rm miss}$ channels at the LHC. While b-tagging has been suggested before to explore the nature of the underlying model [25], to our knowledge it has never been proposed as a tool for SUSY discovery. We remark that although the b-tagged signal will be rate limited, unlike the trilepton signal from $\widetilde{W}_1\widetilde{Z}_2$ production, this signal will be relatively insensitive to how deep we are in the HB/FP region.

We use the program ISAJET 7.69 [26] with a toy calorimeter described in Ref. [22] for our analysis. Jets are found using a cone algorithm with a cone size $\Delta R = \sqrt{\Delta\eta^2 + \Delta\phi^2} = 0.7$. Clusters with $E_T > 40$ GeV and $|\eta(\text{jet})| < 3$ are defined to be jets. Muons (electrons) are classified as isolated if they have $E_T > 10$ GeV (20 GeV) and visible activity in a cone with

[1] While we were preparing this manuscript, we learnt that the reach via the trilepton channel has recently been re-examined in Ref. [20], and found to be smaller or comparable to the reach in other leptonic and the $E_T^{\rm miss}$ channels even when $|\mu| < M_{1,2}$.

$\Delta R = 0.3$ about the lepton direction smaller than $E_T < 5$ GeV. We identify a hadronic cluster with $E_T \geq 40$ GeV and $|\eta(j)| < 1.5$ as a b jet if it also has a B hadron, with $p_T(B) > 15$ GeV and $|\eta(B)| < 3$, within a cone with $\Delta R = 0.5$ of the jet axis. We take the tagging efficiency $\epsilon_b = 0.5$, and assume that gluon and other quark jets can be rejected as b jets by a factor $R_b = 150$ (50) if $E_T < 100$ GeV ($E_T > 250$ GeV) and a linear interpolation in between [27]. While we make no representation about the tagging efficiency and rejection against light quark and gluon jets that will be finally achieved, especially at high LHC luminosity and in the jetty environment of SUSY events, we felt that an exploratory study of just how much b-jet tagging helps with the LHC reach would be worthwhile.

Rather than perform time consuming scans over the WMAP favoured HP/FB regions of the $m_0 - m_{1/2}$ planes of the mSUGRA model for several values of $\tan\beta$, we have chosen three diverse model lines for our analysis. For each of these model lines, we take $\mu > 0$ (the sign favoured by the result of experiment E821 at Brookhaven [28]) and fix $A_0 = 0$ — our results are largely insensitive to this choice — and

- $m_{1/2} = 0.295 m_0 - 477.5$ GeV with $\tan\beta = 30$ for Model Line 1,
- $m_{1/2} = 0.295 m_0 - 401.25$ GeV with $\tan\beta = 30$ for Model Line 2, and
- $m_{1/2} = \frac{17}{60} m_0 - 390$ GeV with $\tan\beta = 52$ for Model Line 3.

For values of $m_0 \gtrsim 1500$ GeV, these model lines all lie in the WMAP allowed HB/FP region of the mSUGRA parameter space delineated in Ref. [17]. The first two model lines have an intermediate value of $\tan\beta$ with Model Line 1 being deep in the HB/FP region while Model Line 2 closer to the periphery of the corresponding WMAP region. We choose Model Line 3 again deep in the HB/FP region, but with a very large value of $\tan\beta$ to examine any effects from a very large bottom quark Yukawa coupling. We take $m_t = 175$ GeV throughout this analysis.

The branching fractions for the decays of the gluino with a mass ~ 1650 GeV (close to the limit that can be probed at the LHC via the usual multijet + multilepton $+E_T^{\rm miss}$ analyses) into third generation fermions are shown in Table I for the three model lines introduced above. The following features of Table I are worth noting.

1. In all three cases, almost 90% of the gluino decays are to the third generation, so that we expect very hard top and bottom quark jets in SUSY events.

TABLE I: The branching fractions for the decays of the gluino with $m_{\tilde{g}} \simeq 1650$ GeV to third generation quarks in the three WMAP allowed model lines introduced in the text, together with the corresponding values of the hypercharge gaugino mass parameter M_1, and the superpotential Higgs mass parameter μ.

	Model Line 1	Model Line 2	Model Line 3
$m_{\tilde{g}}$ (GeV)	1637	1665	1665
μ (GeV)	181	335	164
M_1 (GeV)	269	278	275
$\tilde{g} \to \widetilde{W}_1^- t\bar{b} + \widetilde{W}_1^+ \bar{t}b$	37%	34%	39%
$\tilde{g} \to \widetilde{W}_2^- t\bar{b} + \widetilde{W}_2^+ \bar{t}b$	8%	11%	8%
$\tilde{g} \to \widetilde{Z}_1 t\bar{t} + \widetilde{Z}_1 b\bar{b}$	15%	5%	17%
$\tilde{g} \to \widetilde{Z}_2 t\bar{t} + \widetilde{Z}_2 b\bar{b}$	19%	16%	20%
$\tilde{g} \to \widetilde{Z}_3 t\bar{t} + \widetilde{Z}_3 b\bar{b}$	6%	17%	4%
$\tilde{g} \to \widetilde{Z}_4 t\bar{t} + \widetilde{Z}_4 b\bar{b}$	4%	5%	4%

2. In Model Lines 1 and 3 that are deep in the HB/FP region, the gluino mainly decays to the higgsino-like lighter chargino and the two lightest neutralinos; in Model Line 2, $\widetilde{Z}_1$ is dominantly the hypercharge gaugino, so that gluino decays to $\widetilde{Z}_2$ and to $\widetilde{Z}_3$ are favoured.

3. The main difference due to the large $\tan\beta$ value for Model Line 3 is the increased branching ratio for the decays $\tilde{g} \to b\bar{b}\widetilde{Z}_i$ relative to $\tilde{g} \to t\bar{t}\widetilde{Z}_i$. Although we have not separated these out in the Table, we have checked that while the direct decays to bottom comprise just about 10% of all gluino decays to neutralinos for Model Lines 1 and 2, these decays constitute about a third of all gluino to neutralino decays for Model Line 3. This is, of course, due to the increased Yukawa coupling of the bottom quark [29].

4. In each of these cases, we see that decays of the gluino to the wino-like charginos and neutralinos have relatively small branching fractions despite their large $SU(2)$

gauge couplings. This is because decays mediated by lighter third generation squarks that have large Yukawa couplings dominate because these are dynamically as well as kinematically favoured.

The main message of this Table is that in the WMAP favoured HB/FP regions of the mSUGRA model, decays to third generation quarks dominate gluino decays. Moreover, although detailed decay patterns depend on both $\tan\beta$ and the value of μ/M_1 (*i.e.* on how deep we are in the HB/FP region), the total branching fraction for decays to third generation quarks is relatively insensitive to these details. Motivated by these observations we begin our examination of the inclusive b-jet signal for each of the model lines introduced above.

The major SM backgrounds to the multijet plus $E_T^{\rm miss}$ signal, with or without b-jets, come from W or $Z+$ jet production, from $t\bar{t}$ production and from QCD production of light quarks and gluons. In the last case, the $E_T^{\rm miss}$ arises from neutrinos from c and b quarks, from showering of W, Z bosons and their subsequent decays to neutrinos, and from energy mismeasurement. The backgrounds from these sources are shown in Table II for two representative choices of cuts discussed below. Here S_T is the transverse sphericity, $m_{\rm eff}$ is the scalar sum of the E_T of the four hardest jets and $E_T^{\rm miss}$, $\Delta\phi$ is the azimuthal angle between $E_T^{\rm miss}$ and the hardest jet, and $\Delta\phi_b$ is the azimuthal opening angle between the two hardest b jets in events with $N_b \geq 2$. Since we do not require multileptons in our analysis, backgrounds from WW, WZ and ZZ as well as three vector bosons processes are expected to be much smaller [22].

We see that for both sets of cuts the SM background is dominated by QCD. This differs from earlier results where it is argued that the QCD background can be reduced to negligible levels by requiring the signal to be sufficiently hard. Indeed, to track the reason for this difference, we have done a very high statistics analysis of the QCD background that was not possible in Ref. [22]. Specifically, we took particular care to divide the event generation into a large number (50 bins for QCD, fewer for other backgrounds) of finely spaced hard scattering p_T bins, especially for lower values of the hard scattering p_T where the event weights are very large, even if the efficiency for passing the cuts is low.[2] We have checked that our

[2] If, for any set of cuts, we find no events in our simulation of a particular background, we set this background cross section to a value corresponding to the single event level in the smallest weight bin in our simulation.

TABLE II: Cross sections for the dominant SM backgrounds to SUSY processes at the CERN LHC for two representative choices of cuts, together with signal cross sections for three cases along the model lines introduced in the text.

Variables		Cut 1 (cut 2)	
$N_j \geq$		4 (5)	
$E_T^{\rm miss}$ (GeV) $>$		400 (500)	
E_T^{j1} (GeV) $>$		400 (400)	
E_T^{j2} (GeV) $>$		250 (250)	
E_T^{j3} (GeV) $>$		150 (175)	
E_T^{j4} (GeV) $>$		100 (125)	
$m_{\rm eff}$ (GeV) $>$		1500 (2250)	
$S_T >$		0.0 (0.0)	
$\Delta\phi <$		180° (140°)	
$\Delta\phi_b <$		180° (180°)	
$N_b \geq$	0	1	2
Source		σ (fb)	
QCD	27.71 (0.636)	8.95 (0.112)	1.72 (0.009)
$t\bar{t}$	5.17 (0.043)	3.42 (0.034)	1.10 (0.005)
$W+$jets	13.60 (0.462)	1.42 (0.045)	0.13 (0.002)
$Z+$jets	5.68 (0.180)	0.65 (0.018)	0.05 (0.001)
Total	52.16 (1.32)	14.44 (0.209)	3.00 (0.017)
Case 1: $m_{\tilde{g}} = 1054$ GeV	12.1 (0.667)	9.25 (0.537)	4.58 (0.290)
Case 2: $m_{\tilde{g}} = 1436$ GeV	3.81 (0.541)	3.10 (0.47)	1.68 (0.24)
Case 3: $m_{\tilde{g}} = 1705$ GeV	1.11 (0.230)	0.90 (0.185)	0.50 (0.106)

backgrounds levels from $W+$jets, $Z+$jets and $t\bar{t}$ processes are in agreement with those in Ref. [22] and attribute the difference in the QCD background to statistics of the background simulation.[3] Since QCD typically contributes about half the background in Table II, we

[3] In passing, we mention that we also found a significant QCD contribution to the background in the

may expect a small degradation of the LHC reach from these earlier projections.[4]

Also shown in Table II is the SUSY signal for three points along model lines. In our analysis, we consider a signal to be observable with a given integrated luminosity if, (a) its statistical significance $N_S/\sqrt{N_B} \geq 5$, (b) $N_S/N_B \geq 0.25$, and (c) $N_S \geq 10$. We see that Case 1 with $m_{\tilde{g}} \simeq 1$ TeV which by early analyses should be easily observable at the LHC is also observable using cuts 1 with an integrated luminosity of just 10 fb^{-1}, and moreover, the significance of the signal improves with increasing b multiplicity. For Case 2, the SM background with the softer cuts 1 is too large except in the $2b$ channel, where the signal is observable for an integrated luminosity ≥ 26 fb^{-1}. However with the harder cuts of set 2 the signal, though unobservable without b-tagging, should be observable in the $1b$ ($2b$) channel for an integrated luminosity exceeding 26 fb^{-1} (41 fb^{-1}). For Case 3, both b-tagging capability and an integrated luminosity of at least 72 fb^{-1} are essential for the observability of the signal. It is clear that b-tagging improves the reach of the LHC for points in the HB/FP region.

To quantify the improvement b-tagging makes to the capabilities of the LHC for the detection of SUSY, we have re-computed the reach of the LHC for each of the three model lines introduced above. Towards this end, for every mSUGRA parameter point that we examined, we generated a set of SUSY events using ISAJET. We also generated large samples of SM background events. We passed these events through the toy calorimeter simulation mentioned previously, and then analysed both the signal and the background for the entire set of cuts ($5 \times 5 \times 6 \times 5 \times 3^4 = 60750$ choices in all) listed in Table III. We regard the signal as observable if it satisfies the observability criteria (a)–(c) listed above for at least

multijets + 1ℓ + $E_T^{\rm miss}$ channel. This is in contrast to the result in Ref. [30] which was obtained using PYTHIA. We attribute this difference to the fact that PYTHIA does not include showering of W and Z bosons in QCD events. While this may result in some double counting of "Drell-Yan" W and Z production, we note that showering of vector bosons from the final state quarks will, in general tend to populate a different region of phase space.

[4] A more significant background issue may be that the showering algorithms appear to obtain a significantly softer distribution of the variable $m_{\rm eff}$ (introduced below) relative to evaluations using exact multijet plus W, Z production matrix elements [31]. We have nothing to say about this, except that requiring additional b's (and in the case of W, also requiring a transverse mass cut) will reduce this background considerably. At the very least, our analysis will indicate the extent to which the presence of tagged b's increases the LHC reach. We may add that the $E_T^{\rm c}$ analysis of Ref.[22] that requires $E_T^{\rm miss}$ together with just two (rather than four) additional hard jets, with just one of these jets from showering, may be more robust to these matrix element corrections.

TABLE III: The set of cuts used to optimize the SUSY signal at the LHC along the hyperbolic branch of the mSUGRA model.

Variable	Values
$N_j \geq$	4, 5, 6, 7, 8
$E_T^{\rm miss}$ (GeV) $>$	400, 500, 600, 700, 800
$(E_T^{j1}, E_T^{j2}, E_T^{j3}, E_T^{j4})$ (GeV) $>$	(400, 250, 150, 100), (400, 250, 175, 125), (400, 250, 200, 150), (500, 350, 150, 100), (500, 350, 175, 125), (500, 350, 200, 150)
$m_{\rm eff}$ (GeV) $>$	$[E_T^{\rm miss} + \sum_{i=1}^4 E_T^{ji}]_{\rm min} + 200 \times n, n = 0, 1, 2, 3, 4$
$S_T >$	0.0, 0.1, 0.2
$\Delta\phi <$	180°, 160°, 140°
$\Delta\phi_b <$	180°, 160°, 140°
$N_b \geq$	0, 1, 2

one choice of cuts.

Notice that the cuts in this Table are much harder than those used in a recent analysis of the LHC SUSY signal [17]. This is because, unlike in Ref. [17] where the cuts were designed to extract the signal for a wide range of squark and gluino masses, here we focus on the optimization of the signal in the portion of the HB/FP region with heavy gluinos where the previous strategy fails. Note also that cut 1 in Table II corresponds to the softest of these cuts. Since, as we saw earlier, the signal for Case 1 (with $m_{\tilde{g}} \simeq 1$ TeV) is comfortably observable with the present set of cuts as well as those in Ref. [17], there is no danger that there will be a gap in the HB/FP region of parameter space where the signal is unobservable with either strategy.

Our results for the LHC reach are shown in Fig. 1, where we plot the largest statistical significance of the signal as we run over the cuts in Table III for a) Model Line 1, b) Model Line 2, and c) Model Line 3. The solid curves, from lowest to highest, denote this maximum

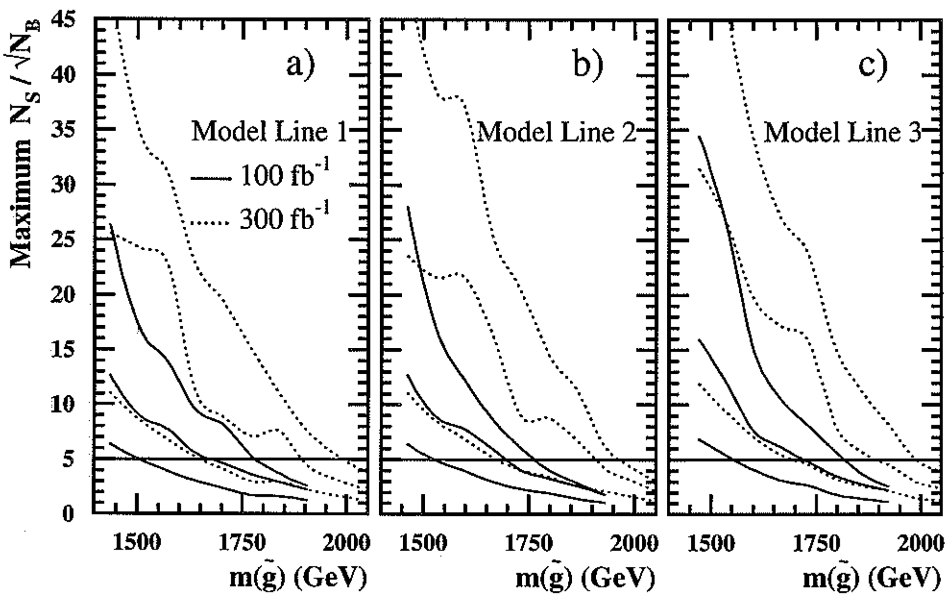

FIG. 1: The maximum value of the statistical significance for the multijet + $E_T^{\rm miss}$ SUSY signal at the LHC as we run over the cuts listed in Table III for the three model lines introduced in the text, requiring in addition that $N_S \geq 10$ events and that $N_S \geq 0.25 N_B$. The solid lines from bottom to top denote this statistical significance without any b tagging requirement, with at least one tagged b-jet, and with at least two tagged b-jets respectively, assuming an integrated luminosity of 100 fb^{-1} and a tagging efficiency of 50%. The dotted lines show the corresponding result for an integrated luminosity of 300 fb^{-1}.

statistical significance without any b tagging requirement, requiring ≥ 1 tagged b-jet, and ≥ 2 tagged b-jets respectively, for an integrated luminosity of 100 fb^{-1}, while the dotted curves show the corresponding results for 300 fb^{-1} of integrated luminosity that may be expected from three years of LHC operation with the high design luminosity. While, without b-tagging, our reach for gluinos is $\sim$ 200 GeV smaller than earlier projections [17, 23, 24], presumably because of differences in the background levels discussed above, we see that b-tagging will improve the mass reach of gluinos by 15-20%, provided that LHC experiments can accumulate an integrated luminosity of 100-300 fb^{-1} and that b-tagging with an efficiency of $\sim$ 50% remains possible even in the high luminosity environment.

A few remarks appear to be in order at this point:

- The statistical significance in Fig. 1 is not significantly improved if the b-tagging efficiency improves to 60%. The reason is that before tagging the signal typically contains (on average) 3-4 b quark jets while the background typically contains (at most) just two b quark jets. As a result, the increased efficiency enhances the b-tagged background more than the signal, and the statistical significance is essentially unchanged.

- We have also checked that with a b-tagging efficiency of 50% and an integrated luminosity of 100 fb^{-1}, the signal with ≥ 3 tagged b-jets is *rate limited* and no increase in the reach is obtained from that shown in the Figure.[5]

- The search strategy proposed here does not use lepton information at all. We have checked that a transverse mass cut $M_T(\ell, E_T^{\mathrm{miss}}) \gtrsim 100$ GeV on events with at least one isolated lepton does not increase the significance of the signal because the fraction of signal events (after our cuts) with an isolated lepton is not especially large.

- Although we have not shown this explicitly, we have checked that requiring the presence of additional isolated leptons does not lead to an increase in the reach relative to the $\geq 2b$ channel.

In summary, we have shown that in the HB/FP region of the mSUGRA model the reach of the LHC as measured in terms of gluino masses may be increased by 15-20% by requiring the presence of hard, tagged b-jets in SUSY events. While we were mainly motivated in our investigation by the fact that this part of parameter space is one of the regions compatible with the WMAP data, our considerations may have wider applicability since decays of heavy gluinos to third generation fermions are favoured in all models with common masses for sfermions with the same gauge quantum numbers. This is in part because the large top Yukawa coupling and, if $\tan\beta$ is large, also the bottom quark Yukawa coupling, cause the third generation squarks to be lighter than their siblings in the first two generations, and

[5] It is possible that a slightly increased reach may be obtained if the tagging efficiency is significantly larger than 50% or if the integrated luminosity is considerably higher than 100 fb^{-1}. It would, however, be necessary to evaluate backgrounds from $4b$, $4t$ and $t\bar{t}b\bar{b}$ production processes before a definitive conclusion can be made.

in part because of new contributions to gluino decay amplitudes from these large Yukawa couplings [29]. Specifically, we may expect that signals with tagged b-jets may also be useful in models with an inverted squark mass hierarchy [32], in models with unification of Yukawa couplings (because they require large $\tan\beta$), and possibly also in models with non-universal Higgs mass parameters that have recently been re-examined in light of the WMAP data [16]. Since the CMS and ATLAS experiments are expected to ultimately have good b-tagging capability, we urge that it be utilised to maximize the SUSY reach of the LHC.

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