Z decay into a bottom quark, a light sbottom, and a light gluino

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The discrepancy between the measured and theoretical production cross section of b quarks at the Fermilab Tevatron can probably be explained by the recently proposed scenario of light gluinos of mass 12–16 GeV and light sbottoms of mass 2–5.5 GeV. In this scenario, we study a related process at the Z pole, $Z\to b\tilde{b}_1^*\tilde{g}+\bar{b}\tilde{b}_1\tilde{g}$ followed by $\tilde{g}\to b\tilde{b}_1^*/\bar{b}\tilde{b}_1$. The hadronic branching ratio for this channel is $(1-3)\times 10^{-3}$, which is of the order of the size of the uncertainty in R_b. We find that a typical event consists of an energetic prompt bottom jet back to back with a "fat" bottom jet, which consists of a bottom quark and two bottom squarks. Such events with a 10^{-3} branching ratio may affect the measurement of R_b; they are even more interesting if the fat bottom jet can be identified.

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I. INTRODUCTION

There has been a persistent discrepancy that the measured cross section of hadronic production of b quarks measured by both Collider Detector at Fermilab (CDF) and DØ Collaborations [1] is about a factor of 2 larger than the prediction in perturbative QCD with the most optimal choice of parameters, such as b-quark mass (m_b) and the factorization scale μ, tuned to maximize the calculated rate.[1] Recently, Berger *et al.* [5] interpreted the discrepancy in the scenario of light gluinos and light sbottoms. Light gluinos of mass between 12–16 GeV are pair produced by QCD $q\bar{q}$ and gg fusion processes, followed by subsequent decays of gluinos, $\tilde{g}\to b\tilde{b}_1^*/\bar{b}\tilde{b}_1$, where the sbottom has a mass 2–5.5 GeV. Therefore, in the final state there are $b\bar{b}+\tilde{b}_1\tilde{b}_1^*$, and the sbottoms either remain stable or decay into other light hadrons (e.g., via R-parity violating couplings) and go into the b jets. Gluino-pair production thus gives rise to inclusive b-quark cross section. The mass range of the gluino is $m_{\tilde{g}}=12-16$ GeV and the sbottom is $m_{\tilde{b}_1}=2-5.5$ GeV. Such masses are chosen so that both the total cross section and the transverse momentum spectrum of the b quark are reproduced. Before the work of Berger *et al.*, there have been some studies in the light sbottom and/or light gluino scenario [6]. However, such a scenario cannot be ruled out, unless there exists an sneutrino of at most 1–2 GeV.

Such a scenario easily contradicts other experiments, especially the Z^0-pole data because of the light sbottom. However, it can avoid the Z-pole constraints by tuning the coupling of $Z\tilde{b}_1\tilde{b}_1^*$ to zero by choosing a specific mixing angle θ_b of $\tilde{b}_L$ and $\tilde{b}_R$: $\sin^2\theta_b=\frac{2}{3}\sin^2\theta_W$, where θ_W is the Weinberg mixing angle. In spite of this, subsequent studies [7–9] showed that such a light gluino and sbottom will still contribute significantly to R_b via one-loop gluino-sbottom diagrams. In order to suppress such contributions, the second $\tilde{b}_2$ has to be lighter than about 180 GeV (at 5σ level) with the corresponding mixing angle in order to cancel the contribution of $\tilde{b}_1$ in the gluino-sbottom loop contributions to R_b. Although the scenario of Berger *et al.* is not ruled out, it certainly needs a lot of fine-tuning in the model. In other words, instead of saying this scenario is fine-tuned, we can say that so far the light gluino and light sbottom scenario is not ruled out. It definitely deserves more studies, no matter whether it was used to explain the excess in hadronic bottom-quark production or not.

The light gluino and light sbottom scenario will possibly give rise to other interesting signatures, e.g., decay of χ_b into the light sbottom [10], enhancement of $t\bar{t}b\bar{b}$ production at hadron colliders [11], decay of Υ into a pair of light sbottoms [12], and affecting the Higgs decay [13]. In a previous work [14], we calculated the associated production of a gluino pair with a $q\bar{q}$ pair and compared it to the standard model (SM) prediction of $q\bar{q}b\bar{b}$ at both CERN e^+e^- collider LEPI and LEPII (here q refers to the sum over u,d,c,s,b). We found that at LEPII the $q\bar{q}\tilde{g}\tilde{g}$ production cross section is about 40–20 % of the SM production of $q\bar{q}b\bar{b}$, which may be large enough to produce an observable excess in $q\bar{q}b\bar{b}$ events [14]. This is rather model independent, independent of the mixing angle in the sbottom, and is a QCD process.

In this work, we present another interesting channel in Z

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[1]References [2,3] argued that if the most up-to-date B fragmentation function is used the observed excess can be reduced to an acceptable level. Field [4] interestingly pointed out that correlations between the b and $\bar{b}$ can be used to isolate various sources of production; especially, in his study he included the fragmentation of gluon and light quarks.

decay in the light gluino and light sbottom scenario:

$$Z\to b\tilde{b}_1^*\tilde{g}+\bar{b}\tilde{b}_1\tilde{g}, \quad \text{followed by } \tilde{g}\to b\tilde{b}_1^*/\bar{b}\tilde{b}_1. \qquad (1)$$

Since the gluino is a Majorana particle, it can decay either into $b\tilde{b}_1^*$ or $\bar{b}\tilde{b}_1$. The final state can be $bb\tilde{b}_1^*\tilde{b}_1^*$, $\bar{b}\bar{b}\tilde{b}_1\tilde{b}_1$, or $b\bar{b}\tilde{b}_1\tilde{b}_1^*$. This channel, unlike that mentioned above, depends on the mixing angle of $\tilde{b}_L$ and $\tilde{b}_R$ in the $b\tilde{b}_1^*\tilde{g}$ coupling.

The hadronic branching ratio of this channel will be shown to be $(3.4–2.5)\times 10^{-3}$ for $\sin 2\theta_b>0$ and $(1.4–1.1)\times 10^{-3}$ for $\sin 2\theta_b<0$, and for $m_{\tilde{g}}=12–16$ GeV and $m_{\tilde{b}_1}=3$ GeV, which is of the order of the size of the uncertainty in R_b. The process is the supersymmetric analogue of $Z\to b\bar{b}g$, but kinematically they are very different because of the finite mass of the gluino and sbottom. A typical event consists of an energetic prompt bottom jet back to back with a "fat" bottom jet, which consists of a bottom quark and two bottom squarks. If such events cannot be distinguished from the prompt $b\bar{b}$ events, they may increase the R_b measurement ($R_b^{\rm exp}=0.21646\pm 0.00065$ [15]) with a hadronic branching ratio of $(1–3)\times 10^{-3}$. If the fat bottom jet can be distinguished from the ordinary bottom jet, then this kind of events would be very interesting on their own. It is a verification of the light gluino and light sbottom scenario. Furthermore, if the flavor of the bottom quarks can be identified, the ratio of bb:$\bar{b}\bar{b}$:$b\bar{b}$ events can be tested (theoretically it is 1 : 1 : 2) [5].

The paper is organized as follows. In the following section, we present the calculation, including the decay of the gluino into $b\tilde{b}_1^*$ or $\bar{b}\tilde{b}_1$. In Sec. III, we show the results and various distributions that verify the fat bottom jet. We conclude in Sec. IV. There is an analogue in hadronic collisions, $p\bar{p}\to b\tilde{b}_1^*\tilde{g}$ followed by $\tilde{g}\to b\tilde{b}_1^*/\bar{b}\tilde{b}_1$. Thus, it also gives rise to two hadronic bottom jets. However, in the hadronic environment it is very difficult to identify the fat bottom jet. We believe it only gives a small correction to the inclusive bottom cross section.

II. FORMALISM

The interaction Lagrangian among the bottom quark, sbottom, and gluino is given by

$$\mathcal{L}\supset\sqrt{2}g_s[\tilde{b}_{1,i}^\dagger\overline{\tilde{g}^a}(\sin\theta_b P_L+\cos\theta_b P_R)T^a_{ij}b_j+\text{H.c.}], \qquad (2)$$

where the lighter sbottom $\tilde{b}_1$ is a superposition $\tilde{b}_1=\sin\theta_b\tilde{b}_L+\cos\theta_b\tilde{b}_R$ of the left- and right-handed states via the mixing angle θ_b. As mentioned above, the vanishing of the $Z\tilde{b}_1\tilde{b}_1^*$ coupling requires $g_L\sin^2\theta_b+g_R\cos^2\theta_b=0$, where $g_L=-\frac{1}{2}+\frac{1}{3}\sin^2\theta_W$ and $g_R=\frac{1}{3}\sin^2\theta_W$. It implies $\sin^2\theta_b=\frac{2}{3}\sin^2\theta_W$.

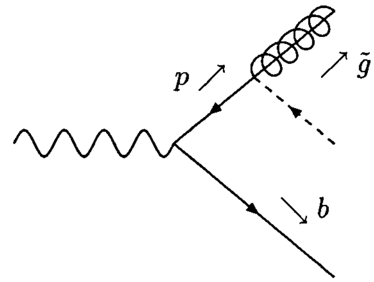

FIG. 1. The Feynman diagram for the process $Z\to b\tilde{b}_1^*\tilde{g}$.

A. Primary production

Even after a perfect cancellation in the amplitude $Z\to\tilde{b}_1\tilde{b}_1^*$, the Z boson can still decay at tree level into $b\tilde{b}_1^*\tilde{g}$ (or its conjugated channel) as shown in Fig. 1. The Feynman amplitude is

$$\mathcal{M}=\sqrt{2}g_s g_Z\overline{u}(b)\not{\epsilon}_Z(g_L P_L+g_R P_R)\frac{-\not{p}+m_b}{p^2-m_b^2}(\sin\theta_b P_R+\cos\theta_b P_L)T^a_{ij}v(\tilde{g}), \qquad (3)$$

where $P_{L,R}=(1\mp\gamma^5)/2$, $g_Z=g_2/\cos\theta_W$, and i,j,a correspond to the color indices of the final-state particles b, $\tilde{b}_1^*$ and $\tilde{g}$, respectively. We can tabulate the complete formula of the transitional probability, summing over the initial- and final-state spin polarizations or helicities, and colors, as

$$\sum|\mathcal{M}|^2=\frac{16g_s^2g_Z^2}{(p^2-m_b^2)^2}(N_0+m_b m_{\tilde{g}}N_1\sin 2\theta_b+m_b^2N_2), \qquad (4)$$

$$N_0=(g_L^2\sin^2\theta_b+g_R^2\cos^2\theta_b)[4\tilde{g}\cdot p\, b\cdot p+p^2\tilde{g}\cdot b(p^2-m_b^2-2s)/s+2\tilde{g}\cdot p\, p\cdot Z m_b^2/s], \qquad (5)$$

$$N_1=3(p^2+m_b^2)g_Lg_R+(g_L^2+g_R^2)(p\cdot b+2p\cdot Z\, b\cdot Z/s),$$

$$N_2=6g_Lg_R\tilde{g}\cdot p+(g_R^2\sin^2\theta_b+g_L^2\cos^2\theta_b)\times(\tilde{g}\cdot b+2\tilde{g}\cdot Z\, b\cdot Z/s),$$

where $s=M_Z^2$. Here the momenta of the particles are denoted by their corresponding symbols. We use p to denote the momentum of the virtual $\bar{b}$, which turns into $\tilde{g}$ and $\tilde{b}_1^*$ (i.e., $p=\tilde{g}+\tilde{b}_1^*$).

One can integrate the exact three-body phase space to find the decay rate,

$$d\Gamma(Z\to b\tilde{b}_1^*\tilde{g})=\frac{1}{3}\sum|M|^2\frac{\sqrt{s}}{\pi^3}\frac{dx_b dx_{\tilde{b}}}{256}. \qquad (6)$$

The scaling variables of the three-body phase space are defined by

$$x_b=2E_b/M_Z, \quad x_{\tilde{b}}=2E_{\tilde{b}_1^*}/M_Z, \quad x_{\tilde{g}}=2E_{\tilde{g}}/M_Z, \qquad (7)$$

with the energies E_i measured in the Z rest frame, and $x_b + x_{\tilde{b}} + x_{\tilde{g}} = 2$. The ratios of the mass-squared are

$$\mu_b = m_b^2/M_Z^2, \quad \mu_{\tilde{b}} = m_{\tilde{b}_1}^2/M_Z^2, \quad \mu_{\tilde{g}} = m_{\tilde{g}}^2/M_Z^2. \tag{8}$$

The region of the phase space is limited by

$$2\sqrt{\mu_b} \leqslant x_b \leqslant 1 + \mu_b - \mu_{\tilde{b}} - \mu_{\tilde{g}} - 2\sqrt{\mu_{\tilde{b}}\mu_{\tilde{g}}}, \tag{9}$$

$$x_{\tilde{b}} \lessgtr \tfrac{1}{2}(1 - x_b + \mu_b)^{-1}[(2 - x_b)(1 + \mu_b + \mu_{\tilde{b}} - \mu_{\tilde{g}} - x_b) \pm (x_b^2 - 4\mu_b)^{1/2}\lambda^{1/2}(1 + \mu_b - x_b, \mu_{\tilde{b}}, \mu_{\tilde{g}})]$$

with the function $\lambda(a,b,c) = a^2 + b^2 + c^2 - 2ab - 2bc - 2ca$. The scalar dot products can be expressed in terms of the scaling variables as

$$p^2 = s(1 + \mu_b - x_b), \quad \tilde{g} \cdot b = \tfrac{1}{2}s(1 - x_{\tilde{b}} + \mu_{\tilde{b}} - \mu_{\tilde{g}} - \mu_b),$$

$$b \cdot p = \tfrac{1}{2}s(x_b - 2\mu_b), \quad \tilde{g} \cdot p = \tfrac{1}{2}s(1 - x_b - \mu_{\tilde{b}} + \mu_{\tilde{g}} + \mu_b).$$

The calculation for the charge-conjugated process $Z \to \bar{b}\tilde{b}_1\tilde{g}$ can be repeated in a straightforward manner. Equations (4) and (5) remain valid if we make the substitutions $b \leftrightarrow \bar{b}$, $\tilde{b}_1^* \leftrightarrow \tilde{b}_1$.

B. Decay of gluino

Since the gluino so produced will decay promptly into $b\tilde{b}_1^*$ or $\bar{b}\tilde{b}_1$, the event ends up with the final states $bb\tilde{b}_1^*\tilde{b}_1^*$, $b\bar{b}\tilde{b}_1\tilde{b}_1^*$, or $\bar{b}\bar{b}\tilde{b}_1\tilde{b}_1$. In the minimal hypothesis that the sbottom hadronizes completely in the detector, it behaves like a hadronic jet. The final configuration includes $bb + 2j$, $b\bar{b} + 2j$, and $\bar{b}\bar{b} + 2j$ at the parton level. We will show below that the $2j$ most of the time goes together with the softer b, and therefore makes the b look "fat." Although the gluino decays into conjugated channels $\bar{b}\tilde{b}_1$ and $b\tilde{b}_1^*$ with equal rates, corresponding distributions can be different as they are correlated to the specified primary process $Z \to b\tilde{b}_1^*\tilde{g}$. For this reason, we perform the full helicity calculation following the decay chains $Z \to b\tilde{b}_1^*\tilde{g}$ and $\tilde{g} \to b\tilde{b}_1^*$ or $\bar{b}\tilde{b}_1$. Based on Feynman rules for the Majorana fermions, we replace $v(\tilde{g})$ in the above Eq. (3) by

$$\text{Channel 1,} \quad v(\tilde{g}) \to -\sqrt{2}g_s T^a \frac{-\tilde{\not{g}} + m_{\tilde{g}}}{\tilde{g}^2 - m_{\tilde{g}}^2 + i\Gamma_{\tilde{g}}m_{\tilde{g}}} \times (\sin\theta_b P_L + \cos\theta_b P_R)v(\bar{b}), \tag{10}$$

for the process $\tilde{g} \to \bar{b}\tilde{b}_1$. Similarly, we replace $v(\tilde{g})$ in Eq. (3) by

$$\text{Channel 2,} \quad v(\tilde{g}) \to \sqrt{2}g_s T^a \frac{-\tilde{\not{g}} + m_{\tilde{g}}}{\tilde{g}^2 - m_{\tilde{g}}^2 + i\Gamma_{\tilde{g}}m_{\tilde{g}}} \times (\sin\theta_b P_R + \cos\theta_b P_L)v(b), \tag{11}$$

for the process $\tilde{g} \to b\tilde{b}_1^*$. We use the narrow-width approximation to calculate the on-shell gluino propagator

$$\frac{1}{(\tilde{g}^2 - m_{\tilde{g}}^2)^2 + \Gamma_{\tilde{g}}^2 m_{\tilde{g}}^2} \to \frac{\pi}{m_{\tilde{g}}\Gamma_{\tilde{g}}}\delta(\tilde{g}^2 - m_{\tilde{g}}^2), \tag{12}$$

where $\tilde{g} = b + \tilde{b}_1^*$ or $\bar{b} + \tilde{b}_1$. Assuming the gluino only decays into $b\tilde{b}_1^*$ and $\bar{b}\tilde{b}_1$, we find that the decay width of the gluino is

$$\Gamma_{\tilde{g}} = \tfrac{1}{4}(\alpha_s/m_{\tilde{g}})\lambda^{1/2}(1, m_b^2/m_{\tilde{g}}^2, m_{\tilde{b}_1}^2/m_{\tilde{g}}^2)(m_{\tilde{g}}^2 + m_b^2 - m_{\tilde{b}_1}^2 + 2m_{\tilde{g}}m_b\sin 2\theta_b). \tag{13}$$

Since we have already assumed CP invariance in Eq. (2), event distributions of CP-conjugated variables in the, respectively, CP-conjugated processes of Z decays are the same. For example, the angle between the two b quarks from $Z \to b\tilde{b}_1^*\tilde{g}$ followed by $\tilde{g} \to b\tilde{b}_1^*$ has the same distribution as the angle between the two $\bar{b}$ quarks from $Z \to \bar{b}\tilde{b}_1\tilde{g}$ followed by $\tilde{g} \to \bar{b}\tilde{b}_1$.

III. RESULTS

We first list the input parameters in our study

$$m_b = 4.5\ \text{GeV}, \quad m_{\tilde{b}_1} = 3\ \text{GeV}, \quad \sin\theta_b = \sqrt{\tfrac{2}{3}\sin^2\theta_W}, \quad \cos\theta_b = \pm\sqrt{1 - \tfrac{2}{3}\sin^2\theta_W}.$$

The scale Q that we used in the running strong coupling constant is evaluated at $\alpha_s(Q = M_Z/2)$.[2]

We show in Fig. 2 the partial width of the channel $Z \to b\tilde{b}_1^*\tilde{g} + \bar{b}\tilde{b}_1\tilde{g}$ versus the gluino mass $m_{\tilde{g}}$ for two different sign choices $\sin 2\theta_b \gtrless 0$. Numerically, the effect of m_b is not negligible at $\sqrt{s} = M_Z$. Given that the total hadronic width of the Z boson is 1.745 GeV [15], the hadronic branching fraction of the process $Z \to b\tilde{b}_1^*\tilde{g} + \bar{b}\tilde{b}_1\tilde{g}$ is $(3.4–2.5) \times 10^{-3}$ for $\sin 2\theta_b > 0$ and $(1.4–1.1) \times 10^{-3}$ for $\sin 2\theta_b < 0$, and $m_{\tilde{g}} = 12–16$ GeV. Thus, this hadronic branching ratio is at the

[2]The difference in α_s between including and not including the light gluino and sbottom in the running of α_s from $Q = M_Z$ to $M_Z/2$ is only 3%. Thus, we neglect the effect of the light gluino and sbottom in the running of α_s. References [5,12] also estimated the effect of including the light gluino in the running of α_s in their studies. A recent work [16] studied the running of α_s from low-energy scales such as m_τ to M_Z including a light gluino and a light sbottom. However, it cannot rule out the existence of such light particles from current data.

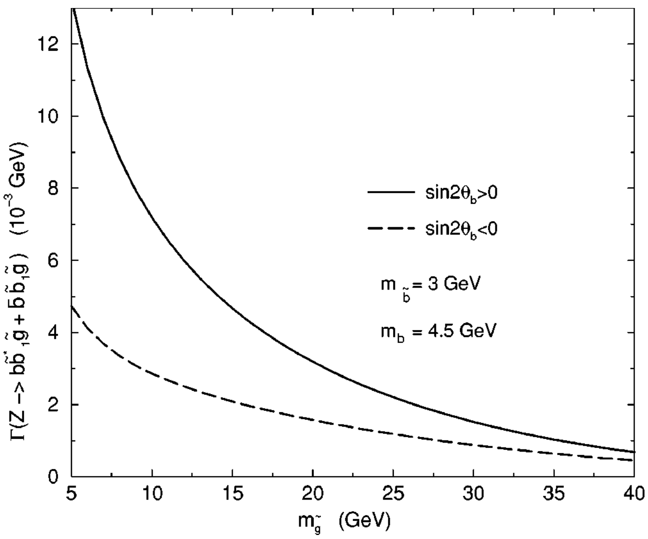

FIG. 2. Partial width of $Z \to b\tilde{b}_1^*\tilde{g} + \bar{b}\tilde{b}_1\tilde{g}$ vs $m_{\tilde{g}}$ for $m_{\tilde{b}_1} = 3$ GeV and $m_b = 4.5$ GeV.

level of, or even larger than, the uncertainty in the R_b measurement ($R_b^{\rm exp} = 0.21646 \pm 0.00065$). If it cannot be distinguished from the prompt $b\bar{b}$ events, it will affect the precision measurement on the $b\bar{b}$ yield at LEP I.

In the following, we study the event topology to examine the difference from the prompt $b\bar{b}$ production, which essentially consists of two back-to-back clean bottom jets with energy equal to $M_Z/2$. In Fig. 3, we show the energy distributions, in terms of dimensionless variables x_b, $x_{\tilde{b}}$, and $x_{\tilde{g}}$, of the prompt b, sbottom, and gluino, respectively. The prompt b has a fast and sharp energy distribution as expected, but the gluino and the sbottom have slower and flatter energy spectra. We also note that the spectra are different between $\sin 2\theta_b > 0$ and <0. These features are very different from the prompt $b\bar{b}$ production including QCD correction, in which both b and $\bar{b}$ are very energetic and the gluon is quite soft.

In Fig. 4, we show the energy spectra for the decay products, $b_{\rm dec}$ and $\tilde{b}_{\rm dec}$, of the gluino. Since gluino is a Majorana particle, it decays into either $b\tilde{b}_1^*$ or $\bar{b}\tilde{b}_1$. Although there are some differences between these two decay modes because of the difference in the coupling, in both modes the $b_{\rm dec}$ and $\tilde{b}_{\rm dec}$ are rather soft. We also note that the spectra are different between $\sin 2\theta_b > 0$ and <0. Therefore, just by looking at the prompt b and the secondary $b_{\rm dec}$, it is found that the energy spectra are very different from the prompt $b\bar{b}$ production. However, if the first and the second sbottoms go very close with the secondary $b_{\rm dec}$ and cannot be separated experimentally, and the sbottoms deposit all their energies in the detector, then the event will mimic the prompt $b\bar{b}$ event. Thus, it is important to look at the angular separation among the final-state particles.

We show the cosine of the angles between the primary b and the $\bar{b}_{\rm dec}$, between $\bar{b}_{\rm dec}$ and $\tilde{b}_{\rm dec}$, and between $\bar{b}_{\rm dec}$ and $\tilde{b}_1^*$ in Fig. 5. Here we only show the spectra for the case $\sin 2\theta_b > 0$ and gluino decay Channel 1, because for $\sin 2\theta_b > 0$ or <0, Channel 1 or Channel 2, the spectra are very similar. We can immediately see that the primary b is back to back with the secondary $\bar{b}_{\rm dec}$ from gluino decay. The $\bar{b}_{\rm dec}$ and $\tilde{b}_{\rm dec}$ are very much close to each other, so that the cosine of the angle between them is peaked at 0.8–0.9. The cosine of the angle between $\bar{b}_{\rm dec}$ and $\tilde{b}_1^*$ has a broader distribution, but still peaks in the $\cos\theta = 1$ region. Thus, we have the following picture. The decay products, $\bar{b}_{\rm dec}$ and $\tilde{b}_{\rm dec}$, and the primary $\tilde{b}_1^*$ combine to form a wide or fat bottomlike jet. This fat bottom jet is back to back with the primary bottom jet, which has an energy close to $M_Z/2$.

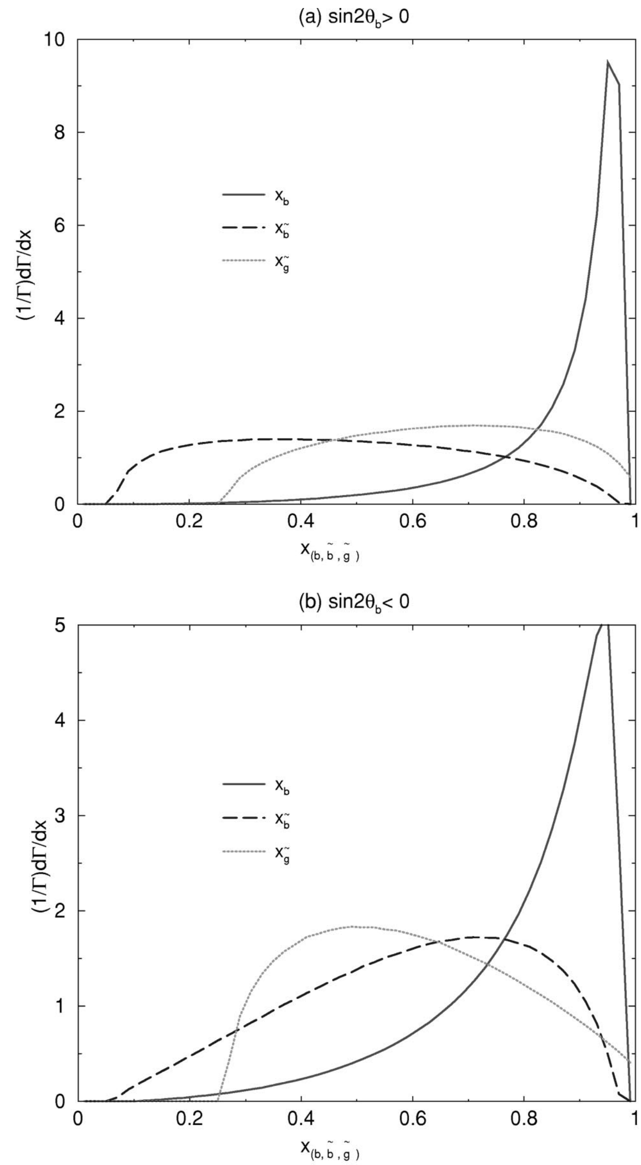

FIG. 3. Normalized energy spectra of the b (x_b), sbottom ($x_{\tilde{b}}$), and gluino ($x_{\tilde{g}}$) in the decay $Z \to b\tilde{b}_1^*\tilde{g}$. (a) $\sin 2\theta_b > 0$ and (b) $\sin 2\theta_b < 0$.

Here we comment on the possibility that the channel that

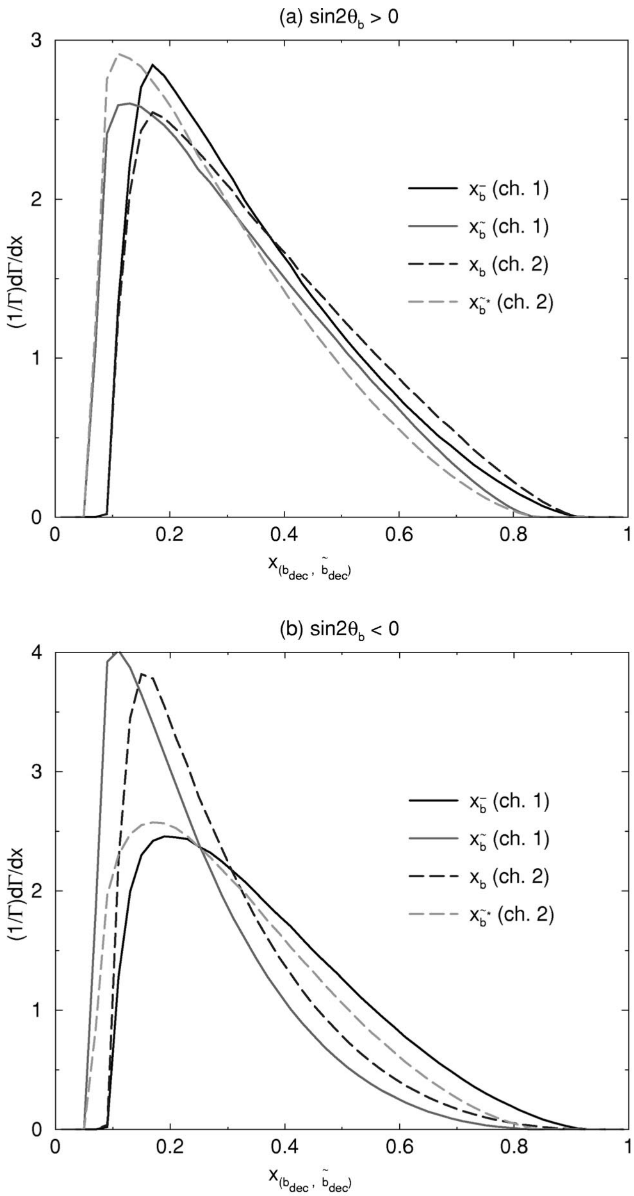

FIG. 4. Normalized energy spectra $x_{b_{\mathrm{dec}}}$ and $x_{\tilde{b}_{\mathrm{dec}}}$, in which the bottom and sbottom are the subsequent decay products of the gluino. (a) $\sin 2\theta_b > 0$ and (b) $\sin 2\theta_b < 0$. Here "ch. 1" and "ch. 2" refer to the decay channels of the gluino in Eqs. (10) and (11), respectively.

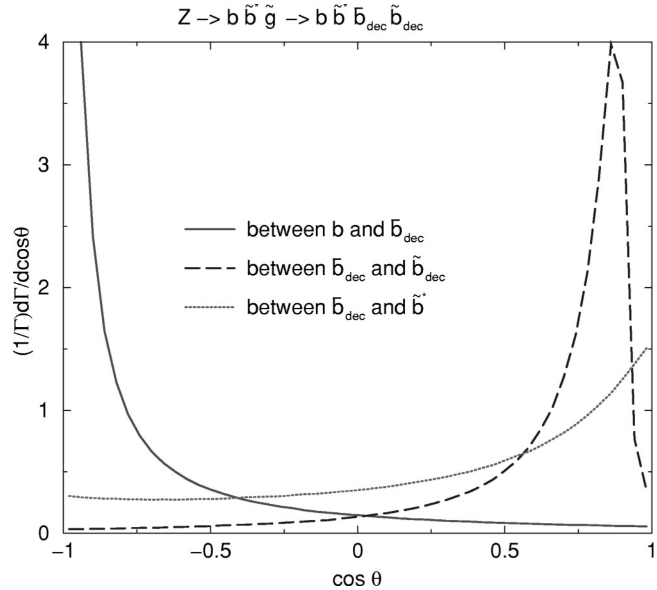

FIG. 5. Normalized spectra of the cosine of the angles between various pairs of final-state partons in the decay process $Z \to b\bar{b}\tilde{b}_1^* \tilde{g}$, followed by $\tilde{g} \to \bar{b}\tilde{b}_1$. Here $\bar{b}_{\mathrm{dec}}$ and $\tilde{b}_{\mathrm{dec}}$ denote the decay products of the gluino.

we consider here may affect the R_b measurement, based on two criteria. First, one of the bottom jets in the channel under consideration is fat. If the two sbottoms cannot be separated from the bottom, the resulting bottom jet will just look like a fat bottom jet and may affect R_b. Second, whether the energy in this fat bottom jet equals to half of the Z mass or not. As mentioned by Berger *et al.* [5], the sbottom can either decay into light hadrons or escape unnoticed from the detector. If the sbottoms escape detection (which means that they do not deposit enough kinetic energy in the detector material for detection), the fat bottom jet would have an energy much less than $M_Z/2$. The final state would be two bottom jets (one energetic and one much less energetic) plus missing energy, and thus would not affect R_b. Nevertheless, this is a very interesting signal on its own. On the other hand, if the sbottoms deposit all their kinetic energy in the detector, the measured energy of the fat bottom jet would be close to $M_Z/2$. In this case, it may affect the measurement of R_b. In fact, it would increase R_b. But if the fat bottom jet could be distinguished from the normal bottom jet, the present channel is also interesting on its own. According to a study on the light gluino [17], an sbottom of mass 2–5.5 GeV, if similar to the gluino, will likely deposit most of its kinetic energy in the detector. If this is the case the signal would be two back-to-back bottom jets, one of which is fat or wide, with no or little missing energy.

IV. CONCLUSIONS

We show that the light-sbottom-gluino scenario predicts the productionof $bb\tilde{b}_1^*\tilde{b}_1^*$, $b\bar{b}\tilde{b}_1\tilde{b}_1^*$, and $\bar{b}\bar{b}\tilde{b}_1\tilde{b}_1$ at the Z pole, with a branching fraction of order of 10^{-3}, depending on the gluino mass and the sign of the mixing angle. The event topology is very different from the prompt $b\bar{b}$ production. Depending on whether the sbottoms deposit little or almost all of their energies in the detector, the signal would be very different. If the sbottoms escape the detector unnoticed, the final state would be two bottom jets (one energetic and one much less energetic) plus missing energy. On the other hand, if the sbottoms deposit all their kinetic energy in the detector, the final state will be two bottom jets, one of which is fat. In this case, it may increase the measurement of R_b. But if the fat bottom jet could be separated from the normal bottom jet, it is a distinct signal. These two kinds of signals may well be hidden in the LEP I data, waiting for a deliberate search.

One special feature of the Majorana nature of the gluino predicts a ratio of 1:1:2 for the rates of bb:$\overline{b}\overline{b}$:$b\overline{b}$ [5]. However, one needs to look for the charged modes B^+B^+ or B^-B^- to avoid effects due to B^0-$\overline{B}^0$ oscillation.

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