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ABSTRACT

We have performed a search for the scalar bottom quark (\tilde{b}_1) from gluino (\tilde{g}) decays in an R-parity conserving SUSY scenario with $m_{\tilde{g}} > m_{\tilde{b}_1}$, by investigating a final state of large missing transverse energy, with three or more jets, and some of them from the hadronization of b-quarks. A data sample of 156 pb^{-1} collected by the Collider Detector at Fermilab at a center-of-mass energy of $\sqrt{s} = 1.96 \text{ TeV}$ was used. For the final selection, jets containing secondary displaced vertices were required. This analysis has been performed 'blind', in that the inspection of the signal region was only made after the standard model prediction was finalized. Comparing data with SUSY predictions, we can exclude masses of the gluino and sbottom of up to 280 and 240 GeV/c^2 respectively.

1. Introduction

Despite of its extraordinary success, the Standard Model (SM) is incomplete and can be seen as one part of a bigger theory. One attractive extension of the Standard Model is Supersymmetry (SUSY) [1], a spacetime symmetry that relates bosons to fermions and introduces for each SM particle a SUSY partner. The states \tilde{q}_L and \tilde{q}_R are the partners of the left-handed and right-handed quarks, which mix to form mass eigenstates $\tilde{q}_{1,2}$. For scenarios with large $\tan \beta$ (the ratio of the vacuum expectation values of the two Higgs fields), the mixing can be quite substantial in the sbottom sector [2], so that the lighter sbottom mass eigenstate (denoted by \tilde{b}_1), can be significantly lighter than other squarks.

2. Gluino and Sbottom production at Tevatron

The gluino pair production cross-section is expected to be large compared to other SUSY particles. Next to leading order (NLO) program PROSPINO [3] predicts for a gluino of mass $240 \text{ GeV}/c^2$ a cross-section of 2.04 pb at $\sqrt{s} = 1.96 \text{ TeV}$, which is large compared to the direct production cross-section of 0.072 pb for sbottoms of the same mass. The two body-decays $\tilde{g} \rightarrow q\tilde{q}$, are expected to be the dominant gluino decays, if they are allowed, because of the gluino-quark-squark coupling.

3. Search for Sbottom quarks from Gluino decays at CDF II

We assume a scenario where the sbottom is lighter than the gluino. Further we assume R-parity conservation and the Lightest Supersymmetric Particle (LSP), which is stable, to be the lightest neutralino $\tilde{\chi}_1^0$ with a mass of $60 \text{ GeV}/c^2$. Gluinos are pair-produced and then decay 100% into sbottom bottom ($\tilde{g} \rightarrow \tilde{b}_1 b$), followed by the sequential decay of the sbottom in bottom and lightest neutralino ($\tilde{b}_1 \rightarrow b\tilde{\chi}_1^0$). Since the neutralinos escape detection, this leaves a signature of four b-jets and missing transverse energy (\cancel{E}_T).

We investigate whether the described scenario [4] is observable in inclusive three jets events with large \cancel{E}_T collected with the Collider Detector at Fermilab (CDF), which is described elsewhere [5]. \cancel{E}_T was required to be larger than 35 GeV and specific clean up cuts were applied. At the selection stage the data is dominated by QCD multijet, with the large \cancel{E}_T resulting from jet mis-measurements or from semileptonic b-decays in which the neutrino escapes detection. In both cases the \cancel{E}_T is aligned with the mis-measured or b-jet respectively. The \cancel{E}_T in signal originates from the neutralinos from the sequential decay of the gluinos and is therefore not driven by the jets. We select events in which the \cancel{E}_T is not aligned with any of the first three leading jets (ordered in E_T), which is achieved by computing the opening azimuthal angle $\Delta\phi$ between the \cancel{E}_T and each of the jets. By requiring $\Delta\phi(\cancel{E}_T, 1\text{-}3\text{jet}) > 40^\circ$, the standard model background can be effectively reduced while keeping a large signal acceptance. A secondary vertex tagging algorithm is applied to identify b-jets and to reduce the background further. Four regions are defined based on the $\cancel{E}_T \in \{(35, 50), \geq 50\}$ GeV and the absence or presence of high P_t isolated leptons. We expect our signal to have large \cancel{E}_T and no leptons. Hence, we define this region as our signal regions and the other three regions serve as control regions. The two regions with low \cancel{E}_T ($35 \text{ GeV} < \cancel{E}_T < 50 \text{ GeV}$) serve as control regions for the QCD multijet background, while the control regions containing high P_t isolated leptons, are used to check the top and W/Z+jets/Diboson background.

ALPGEN [6] in combination with the HERWIG [7] event generator was used to estimate the acceptance of the W and Z boson background. The cross-sections at NLO were obtained using the MCFM [8] program; The top contributions and the QCD heavy flavor background were predicted using the PYTHIA [9] event generator. The fake b-tag contribution, which originates from light flavor jets being mis-identified as heavy flavor jets, was estimated using a parameterization of the fake tag rate obtained from data.

Various distributions in the control regions have been studied and found to be in agreement with observations, as an example, Fig. 1 shows the azimuthal opening angle between the \cancel{E}_T and the leading jet $\Delta\phi(\cancel{E}_T, 1^{\text{st}} \text{ jet})$.

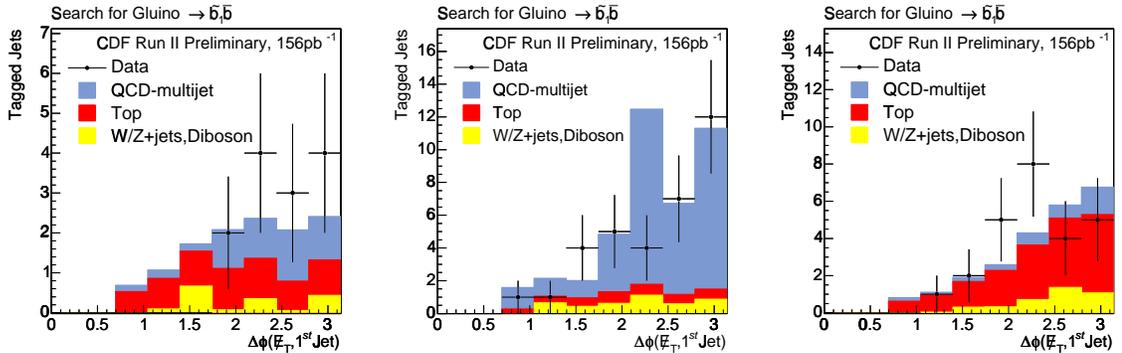


Figure 1: Comparing observations with prediction in three control regions for $\Delta\phi(\cancel{E}_T, 1^{\text{st}} \text{ jet})$, where $1^{\text{st}} \text{ jet}$ is the leading jet in the event, if it is tagged. Left: $35 \text{ GeV} < \cancel{E}_T < 50 \text{ GeV}$ and high P_t isolated lepton, Middle: $35 \text{ GeV} < \cancel{E}_T < 50 \text{ GeV}$ and no high P_t isolated leptons (QCD multijet dominated control region), Right: $\cancel{E}_T > 50 \text{ GeV}$ and high P_t isolated lepton (Top dominated control region).

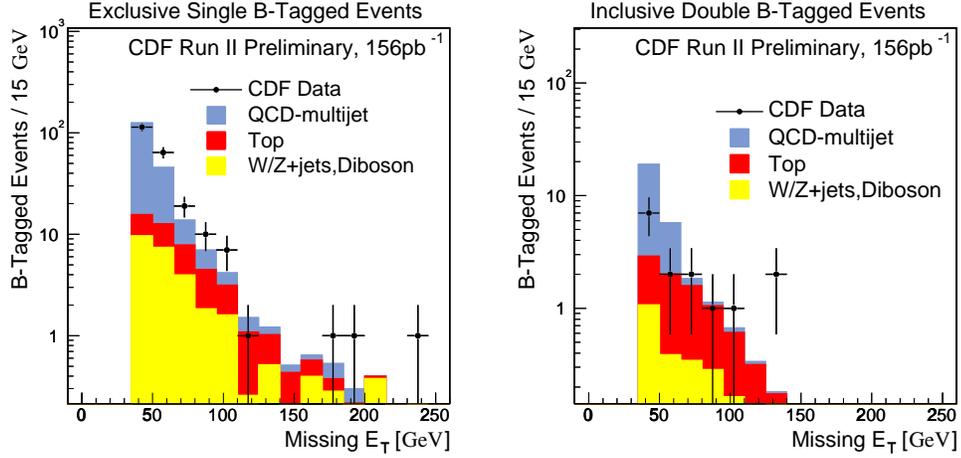


Figure 2: \cancel{E}_T spectrum after vetoing events with high P_t isolated leptons, for exclusive single tagged events (left) and inclusive double tagged events (right).

The signal predictions were computed using the ISAJET [10] event generator with the CTEQ5L parton distribution functions.

We perform two analyses using exclusive single b-tagged events and inclusive double b-tagged events. They serve as an independent cross-check and in addition the single b-tag analysis is expected to have a better reach for nearly mass degenerated gluino-sbottom scenarios. In this case b-jets from the gluino decays are very soft and less likely to be tagged. The double tag suppresses the background more effectively by similar signal acceptance and is expected to perform better in the other kinematic regions. Fig. 2 shows the \cancel{E}_T spectrum for both cases. The best signal sensitivity was achieved by requiring $\cancel{E}_T > 80$ GeV, which was optimized using signal MC. Signal acceptance systematic uncertainty for the exclusive single tag analysis (16.5% in total) was dominated by jet energy scale (10%), modelling of initial and final state radiation (7.5%), b-tagging efficiency (7%), luminosity (6%), Monte Carlo statistics (3%), trigger efficiency (2.5%), parton distribution functions (2%), and lepton veto (2%). The uncertainties for the inclusive double tag analysis were very similar, except the b-tagging efficiency systematics was increased.

The signal region was only analyzed after all the background predictions and selection cuts were finalized. 21 exclusive single b-tagged events were observed, which is in agreement with SM background expectations of 16.4 ± 3.7 events. Requiring inclusive double b-tag we observed 4 events, where 2.6 ± 0.7 were expected, as summarized in Table:1.

Table 1: Number of expected and observed events in the signal region.

Process	Exclusive Single B-Tag	Inclusive Double B-Tag
W/Z+jets/Diboson	$5.66 \pm 0.76(\text{stat}) \pm 1.72(\text{sys})$	$0.61 \pm 0.21(\text{stat}) \pm 0.19(\text{sys})$
TOP	$6.18 \pm 0.12(\text{stat}) \pm 1.42(\text{sys})$	$1.84 \pm 0.06(\text{stat}) \pm 0.46(\text{sys})$
QCD multijet	$4.57 \pm 1.64(\text{stat}) \pm 0.57(\text{sys})$	$0.18 \pm 0.08(\text{stat}) \pm 0.05(\text{sys})$
Total predicted	$16.41 \pm 1.81(\text{stat}) \pm 3.15(\text{sys})$	$2.63 \pm 0.23(\text{stat}) \pm 0.66(\text{sys})$
Observed	21	4

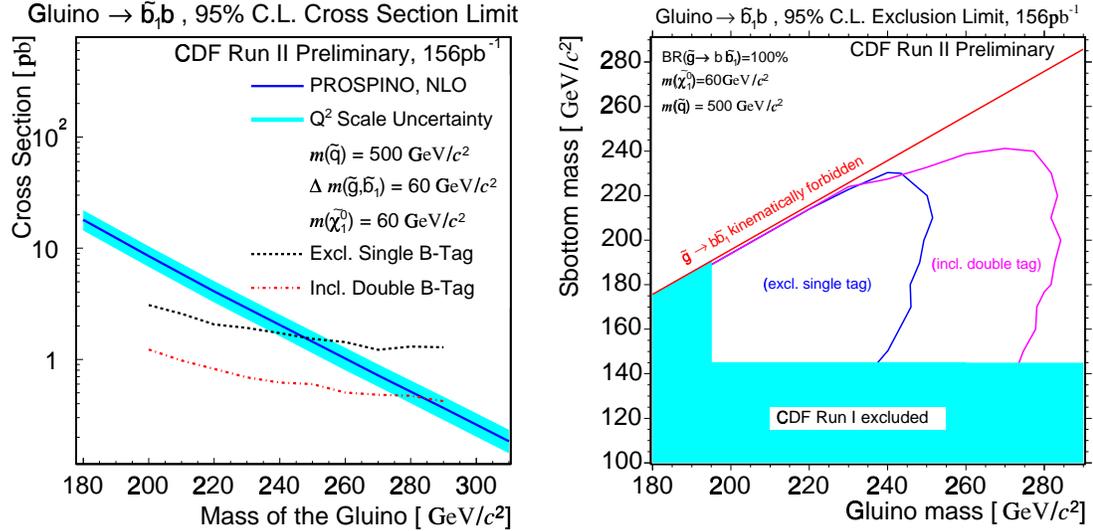


Figure 3: Left: 95% C.L. upper cross-section limit as a function of the gluino mass and for a constant mass difference $\Delta m(\tilde{g}, \tilde{b}_1) = 60 \text{ GeV}/c^2$ between the gluino and sbottom. Right: 95% C.L. exclusion contours in the $m(\tilde{g})$ and $m(\tilde{b}_1)$ plane obtained requiring exclusive single b-tagged events and inclusive double b-tagged events.

Since no evidence for gluino pair production with sequential decay into sbottom-bottom was found, an upper limit cross-sections at 95% C.L. was computed and an exclusion limit set (see Fig. 3) using the Bayesian likelihood method.

4. Conclusion

We have performed a search for gluinos decaying into sbottom bottom at the Tevatron. No evidence for this process was found and a 95% C.L. exclusion limit was set on the masses of the gluino and sbottom of up to 280 and 240 GeV/c^2 respectively.

5. References

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