Physics Letters B 778 (2018) 263–291

Contents lists available at ScienceDirect

Physics Letters B

www.elsevier.com/locate/physletb

Search for the pair production of third-generation squarks with two-body decays to a bottom or charm quark and a neutralino in proton–proton collisions at $\sqrt{s} = 13\,\text{TeV}$

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A R T I C L E I N F O

Article history:
Received 23 July 2017
Received in revised form 22 November 2017
Accepted 8 January 2018
Available online 13 January 2018
Editor: M. Doser

Keywords:
CMS
Physics
Supersymmetry

A B S T R A C T

Results are presented from a search for the pair production of third-generation squarks in proton–proton collision events with two-body decays to bottom or charm quarks and a neutralino, which produces a significant imbalance in the transverse momentum. The search is performed using a sample of proton–proton collision data at $\sqrt{s} = 13\,\text{TeV}$ recorded by the CMS experiment at the LHC, corresponding to an integrated luminosity of $35.9\,\text{fb}^{-1}$. No statistically significant excess of events is observed beyond the expected contribution from standard model processes. Exclusion limits are set in the context of simplified models of bottom or top squark pair production. Models with bottom squark masses up to 1220 GeV are excluded at 95% confidence level for light neutralinos, and models with top squark masses of 510 GeV are excluded assuming that the mass splitting between the top squark and the neutralino is small.

1. Introduction

The standard model (SM) has been extremely successful in describing particle physics phenomena. Nevertheless, it suffers from shortcomings such as the hierarchy problem [1], the need for a fine-tuned cancellation of large quantum corrections to the Higgs mass to maintain a physical value at the observed electroweak scale. Supersymmetry (SUSY) [2–9] postulates a symmetry between bosons and fermions and provides a "natural" solution to the hierarchy problem through the cancellation of quadratic divergences in particle and SUSY particle loop corrections to the Higgs boson mass. In natural SUSY models, light top and bottom squarks are preferred with masses close to the electroweak scale [1,10]. In R-parity conserving SUSY models [11], SUSY particles are created in pairs, and the lightest SUSY particle (LSP) is stable. The LSP is assumed here to be the lightest neutralino ($\widetilde{\chi}^0_1$), which is both weakly interacting and stable and therefore has the properties of a dark matter candidate [12].

This letter presents searches for the direct production of pairs of bottom ($\widetilde{\mathrm{b}}_1\overline{\widetilde{\mathrm{b}}}_1$) and top ($\widetilde{\mathrm{t}}_1\overline{\widetilde{\mathrm{t}}}_1$) squarks, decaying to multijet final states with a large transverse momentum imbalance. The search is performed using $35.9\,\text{fb}^{-1}$ of data collected in proton–proton (pp) collisions by the CMS detector, at a centre-of-mass energy of 13 TeV, at the CERN LHC [13].

The search for bottom squark pair production is based on the decay mode $\widetilde{\mathrm{b}}_1 \to \mathrm{b}\widetilde{\chi}^0_1$. This study considers a scenario for top-squark decay that can arise when the mass splitting, $\Delta m \equiv m_{\widetilde{\mathrm{t}}_1} - m_{\widetilde{\chi}^0_1}$ is below the mass of the W boson. The decay process $\widetilde{\mathrm{t}}_1 \to \mathrm{t}\widetilde{\chi}^0_1, \mathrm{t} \to \mathrm{bW}$ is then suppressed not only because the top quark must be virtual, but also because the W boson must be virtual as well. If flavor-changing neutral current decays $\widetilde{\mathrm{t}}_1 \to \mathrm{c}\widetilde{\chi}^0_1$ are allowed, then the branching fraction for the two-body decay $\widetilde{\mathrm{t}}_1 \to \mathrm{c}\widetilde{\chi}^0_1$ can in principle become substantial. Bottom and top squark pair productions are studied in the context of simplified models [14–16]. Fig. 1 illustrates the bottom and top squark decay modes explored in this letter.

The search techniques are based on the work presented in Ref. [17] but use improved discrimination tools to exploit specific kinematic characteristics of the signal models. A charm quark tagging algorithm is used in the top squark search to identify c quarks originating from top squark decays. In addition, specific object reconstruction tools are employed to improve sensitivity to compressed spectrum scenarios, where visible decay products carry low momenta. The new methods and discriminators, as well as the increase in integrated luminosity, lead to considerably improved sensitivity relative to previous searches. While the analysis improvement for compressed spectra is due to the charm and

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https://doi.org/10.1016/j.physletb.2018.01.012

Table A.1
The bin number and definition for the compressed search region as shown in Fig. A.1 above.

Compressed region			
$N_{\text{b-tags}}$, $N_{\text{c-tags}}$, N_{SV}	p_T^{miss} [GeV]	H_T (b- or c-tagged jets) [GeV]	Bin
$N_{\text{b-tags}} = 1$	250–300	<100	1
	300–500	<100	2
	500–750	<100	3
	750–1000	<100	4
	>1000	<100	5
$N_{\text{b-tags}} = 2$	250–300	<100	6
		100–200	7
	300–500	<100	8
		100–200	9
	>500	<100	10
		100–200	11
$N_{\text{c-tags}} = 1$	250–300	<100	12
	300–500	<100	13
	500–750	<100	14
	750–1000	<100	15
	>1000	<100	16
$N_{\text{c-tags}} = 2$	250–300	<100	17
		100–200	18
	300–500	<100	19
		100–200	20
	500–750	<100	21
		100–200	22
	>750	<100	23
		100–200	24
$N_{\text{b-tags}} + N_{\text{c-tags}} = 0$, $N_{\text{SV}} > 0$	250–300	–	25
	300–500	–	26
	500–750	–	27
	750–1000	–	28
	>1000	–	29
$N_{\text{b-tags}} + N_{\text{c-tags}} + N_{\text{SV}} = 0$	300–500	–	30
	500–750	–	31
	750–1000	–	32
	1000–1250	–	33
	>1250	–	34

public; the Council of Scientific and Industrial Research, India; the HOMING PLUS programme of the Foundation for Polish Science, cofinanced from European Union, Regional Development Fund, the Mobility Plus programme of the Ministry of Science and Higher Education, the National Science Centre (Poland), contracts Harmonia 2014/14/M/ST2/00428, Opus 2014/13/B/ST2/02543, 2014/15/B/ST2/03998, and 2015/19/B/ST2/02861, Sonata-bis 2012/07/E/ST2/01406; the National Priorities Research Program by Qatar National Research Fund; the Programa Clarín-COFUND del Principado de Asturias; the Thalis and Aristeia programmes cofinanced by EU-ESF and the Greek NSRF; the Rachadapisek Sompot Fund for Postdoctoral Fellowship, Chulalongkorn University and the Chulalongkorn Academic into Its 2nd Century Project Advancement Project (Thailand); and the Welch Foundation, contract C-1845.

Appendix A. Correlation matrices for background estimates

To facilitate reinterpretation of the results in a broader range of beyond the standard model scenarios [77], the correlation matrices for the background estimates in the noncompressed and compressed search regions are provided in Figs. A.1 and A.2, respectively. The bin number in the compressed region is the same as in Table 5 of our paper and in the noncompressed region shown below in Table A.1.

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