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Search for electroweak production of charginos in final states with two tau leptons in pp collisions at $\sqrt{s} = 8$ TeV

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Results are presented from a search for the electroweak production of supersymmetric particles in pp collisions in final states with two τ leptons. The data sample corresponds to an integrated luminosity between 18.1 fb^{-1} and 19.6 fb^{-1} depending on the final state of τ lepton decays, at $\sqrt{s} = 8\ TeV$, collected by the CMS experiment at the LHC. The observed event yields in the signal regions are consistent with the expected standard model backgrounds. The results are interpreted using simplified models describing the pair production and decays of charginos. For models describing the pair production of the lightest chargino, exclusion regions are obtained in the plane of chargino mass vs. neutralino mass under the following assumptions: the chargino decays into third-generation leptons, which are taken to be the lightest leptons, and the slepton masses lie midway between those of the chargino and the neutralino. Chargino masses below 420 GeV are excluded at a 95% confidence level in the limit of a massless neutralino, and for neutralino masses up to 100 GeV, chargino masses up to 325 GeV are excluded at 95% confidence level. .

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1. Introduction

Supersymmetry (SUSY) [1] is one of the most promising extensions of the standard model (SM) of elementary particles. A key prediction of SUSY is the existence of new particles with the same gauge quantum numbers as SM particles but differing by a half-unit in spin (sparticles).

Extensive searches at the LHC have excluded the existence of strongly produced (colored) sparticles in a broad range of scenarios, with lower limits on sparticle masses ranging up to 1.8 TeV for gluino pair production. While the limits do depend on the details of the assumed SUSY particle mass spectrum, constraints on the colorless sparticles are generally much less stringent. This motivates the electroweak SUSY search described in this paper.

In various SUSY models, the lightest of the SUSY partners of the SM leptons are those of the third generation, resulting in enhanced branching fractions for final states with τ leptons [1].

In this paper, a search for the electroweak production of the lightest charginos ($\widetilde{\chi}^{\pm}$) is reported using events with two opposite-sign τ leptons and missing transverse momentum (p_T^{miss}), assuming the masses of the third-generation sleptons are between those of the chargino and the lightest neutralino. Two τ leptons can be generated in the decay chain of $\widetilde{\chi}^{\pm}$, as shown in Fig. 1. The results

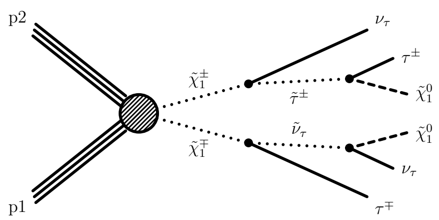

Figure 1: Schematic production of τ lepton pairs from chargino pair production.

of the search are interpreted in the context of SUSY simplified model spectra (SMS) [2] for both production mechanisms.

The results are based on a data set of proton-proton (pp) collisions at $\sqrt{s} = 8$ TeV collected with the CMS detector at the LHC during 2012, corresponding to integrated luminosities of 18.1 and 19.6 fb-1 in different channels. This search makes use of the stransverse mass variable (M_{T2}) [3], which is the extension of transverse mass (M_T) to the case where two massive particles with equal mass are created in pairs and decay to two invisible and two visible particles. In the case of this search, the visible particles are both τ leptons. The distribution of M_{T2} reflects the scale of the produced particles and has a longer tail for heavy sparticles compared to lighter SM particles. Hence, SUSY can manifest itself as an excess of events in the high-side tail of the M_{T2} distribution. Final states are considered where two τ leptons are each reconstructed via hadronic decays ($\tau_h\tau_h$), or where only one τ lepton decays hadronically and the other decays leptonically ($\ell\tau_h$, where ℓ is an electron or muon).

2. Event selection requirements

The event selection requirements including preselection and signal selection are described in Table 1. After applying the preselection, in $\tau_h\tau_h$ and $\ell\tau_h$ channels additional requirements are introduced to define two and one search regions respectively. The first search region ($SR1$) of $\tau_h\tau_h$ targets models with a large mass difference (Δm) between charginos and neutralinos. In this case, the M_{T2} signal distribution can have a long tail beyond the distribution of SM backgrounds. The second search region ($SR2$) of $\tau_h\tau_h$ is dedicated to models with small values of Δm. In this case, the sum of the two transverse mass values, $\Sigma m_{\mathrm{T}}^{\tau_i} = M_T(\tau_h^1, ^{\mathrm{miss}}) + M_T(\tau_h^2, ^{\mathrm{miss}})$, provides additional discrimination between signal and SM background processes.

Table 1: Event selection requirements.

channel	$\ell\tau_h$	$\tau_h\tau_h$ $SR1$	$\tau_h\tau_h$ $SR2$
preselection	OS $\ell\tau_h$	OS $\tau_h\tau_h$	
	Extra lepton veto		
	Invariant mass of $\ell\tau_h$ or $\tau_h\tau_h > 15$ GeV		
	Z boson mass veto		
	$p_T^{miss} > 30$ GeV		
	$M_{T2} > 40$ *GeV*		
	$\Delta\phi > 1.0$ *radians*		
signal selection	b-tagged jet veto	—	b-tagged jet veto
	$M_{T2} > 90$ *GeV*		$M_{T2} < 90$ *GeV*
	$M_T^{\tau_h} > 200$ *GeV*	—	$\Sigma m_{\mathrm{T}}^{\tau_i} > 250$ *GeV*

3. Background estimation

In $\ell\tau_h$ channels, the QCD multijet contribution is very low and is counted among "W". For both cases, the QCD multijet and $W + jets$ and fake contribution from other channels are considered. The 2 top plots of Figure 2 compare data and MC simulation expectation in these channels.

Backgrounds are taken into account in different categories, including DY which is MC-driven, Low rate backgrounds ($t\bar{t}$, di-boson "VV", Higgs boson), "W" in $\tau_h\tau_h$ $SR1$ and QCD which are data-driven. $W + jets$ in $\tau_h\tau_h$ $SR2$ is MC-driven. As a summary of results, the data and background yields are listed in Table 2.

Figure 2 compares the data and the SM expectation in the four search regions. All the uncertainties include both the statistical and systematic uncertainties.

4. Systematic uncertainties

Systematic uncertainties can affect the shape or normalization of the backgrounds estimated

Table 2: Data yields and background predictions with uncertainties in the four signal regions of the search.

	$e\tau_h$	$\mu\tau_h$	$\tau_h\tau_h$ $SR1$	$\tau_h\tau_h$ $SR2$
DY	$0.19 \pm 0.04 \pm 0.03$	$0.25 \pm 0.06 \pm 0.04$	$0.56 \pm 0.07 \pm 0.12$	$0.81 \pm 0.56 \pm 0.18$
tX, VV, hX	$0.03 \pm 0.03 \pm 0.02$	$0.19 \pm 0.09 \pm 0.09$	$0.19 \pm 0.03 \pm 0.09$	$0.75 \pm 0.35 \pm 0.38$
$W+jets$	$3.30^{+3.35}_{-3.30} \pm 0.56$	$8.15 \pm 4.59 \pm 1.53$	$0.70 \pm 0.21 \pm 0.55$	$4.36 \pm 1.05 \pm 1.63$
QCD multijet	—	—	$0.13 \pm 0.06 \pm 0.21$	$1.15 \pm 0.39 \pm 0.74$
SM total	$3.52 \pm 3.35 \pm 0.56$	$8.59 \pm 4.59 \pm 1.53$	$1.58 \pm 0.23 \pm 0.61$	$7.07 \pm 1.30 \pm 1.84$
Observed	3	5	1	2
SUSY(380, 1)	$2.14 \pm 0.08 \pm 0.38$	$2.16 \pm 0.08 \pm 0.39$	$4.10 \pm 0.10 \pm 0.90$	$1.10 \pm 0.05 \pm 0.27$
SUSY(240, 40)	$1.43 \pm 0.19 \pm 0.21$	$0.96 \pm 0.14 \pm 0.14$	$4.35 \pm 0.27 \pm 0.91$	$3.60 \pm 0.25 \pm 0.83$
SUSY(180, 60)	$0.12 \pm 0.04 \pm 0.02$	$0.04 \pm 0.02 \pm 0.01$	$0.73 \pm 0.11 \pm 0.17$	$2.36 \pm 0.17 \pm 0.54$

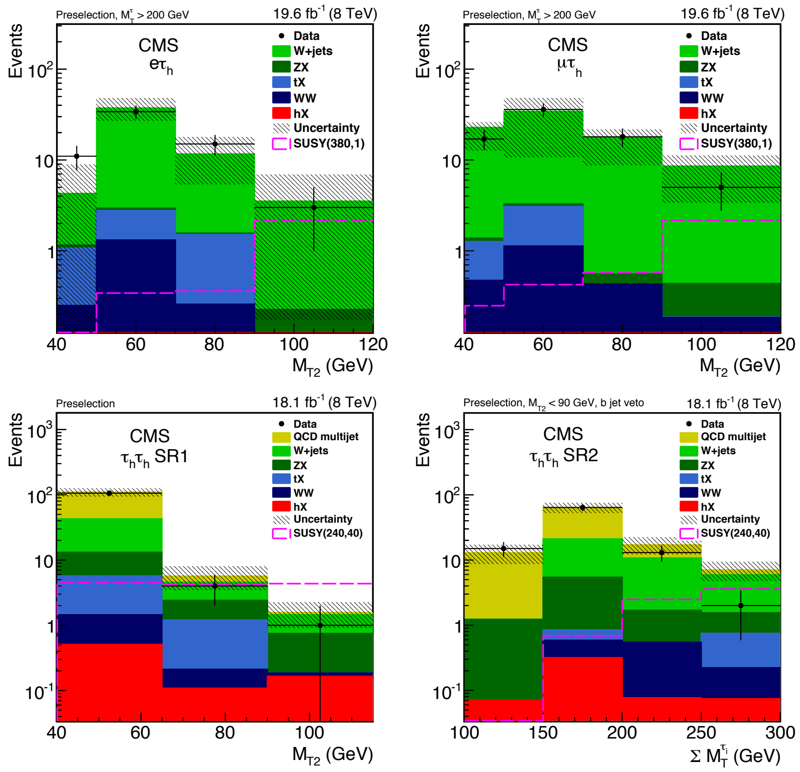

Figure 2: The data yield is compared with the SM expectation in different channels.

from simulation ($t\bar{t}$, Z+jets, diboson, and Higgs boson events), as well as the signal acceptance. These uncertainties and summarized in Table 3.

The systematic uncertainties that can alter the shapes are added in quadrature and treated as correlated when two signal regions of the $\tau_h\tau_h$ channel are combined. Other systematic uncertainties of these two channels and all of the systematic uncertainties of the $\ell\tau_h$ channels are treated as uncorrelated.

5. Results and interpretation

There is no excess of events over the SM expectation. These results are interpreted in the context of a simplified model of chargino pair production and decay, corresponding to the Fig. 1.

A modified frequentist approach, known as the LHC-style CL_s criterion [4], is used to set limits on cross sections at a 95% confidence level (CL). The results on the excluded regions are shown in Fig. 3.

References

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Table 3: Summary of the systematic uncertainties that affect the signal event selection efficiency, DY and rare backgrounds normalization and their shapes. The sources that affect the shape are indicated by (*) next to their names. .

Systematic uncertainty source	Background (%)			Signal (%)		
	$\ell\tau_h$	$\tau_h\tau_h$ $SR1$	$\tau_h\tau_h$ $SR2$	$\ell\tau_h$	$\tau_h\tau_h$ $SR1$	$\tau_h\tau_h$ $SR2$
τ_h energy scale (*)	10	15		2–12	3–15	
τ_h identification efficiency	6	12		6	12	
τ_h trigger efficiency	3	9		3	9	
Lepton trigger and ident. eff.	2	—		2	—	
b-tagged jets veto	4	—	4	8	—	8
Pileup		4			4	
PDF (*)		—			2	
Integrated luminosity		—			2.6	
ISR (*)		—			3	
$\Delta\phi_{min}$		—			6	
p_T^{miss} (*)		5			5	
Fast/full τ_h ident. eff.		—		5	10	
Total shape-affecting sys.	11	16	16	6–13	7–16	
Total non-shape-affecting sys.	9	16	16	14	20	21
Total systematic	14	22	22	15–19	21–25	22–26
MC statistics	22	13	70		3–15	
Total	26	26	73	15–24	21–29	22–30
Low-rate backgrounds		50			—	

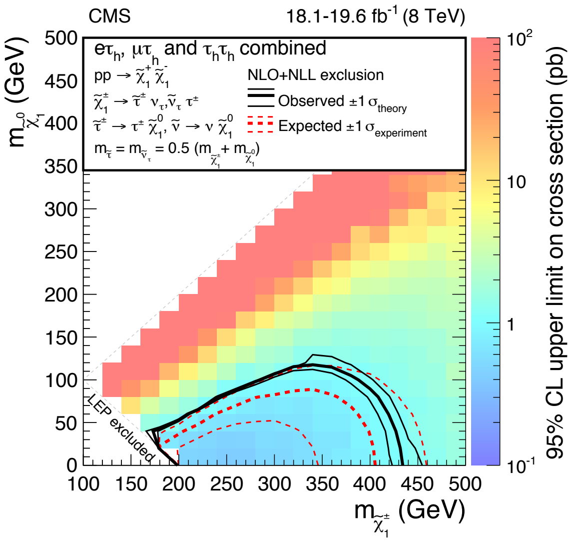

Figure 3: Expected and observed exclusion regions in terms of simplified models of chargino pair production with the total data set of 2012.

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