

Search for New Physics in the Same Sign Dilepton final state with b Jets and Missing Energy at the LHC

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Abstract

A search for New Physics in the same sign dilepton final state with at least two b jets and \cancel{E}_T is performed. This analysis uses a data sample collected with the CMS detector of pp collisions at a centre-of-mass energy of 7 TeV, corresponding to an integrated luminosity of 4.68 fb^{-1} . For these searches, the dominant background is from $t\bar{t}$ events. No excess above the standard model background expectation is observed. Upper limits at 95% confidence level are set on the number of observed events.

1 Introduction

The CMS Collaboration recently published a search for new physics in same-sign top production using events with same-sign isolated dileptons, jets, and \cancel{E}_T [1]. In that study, as well as a closely related one [2] the major background is from $t\bar{t}$ production, as shown in Fig. 1.

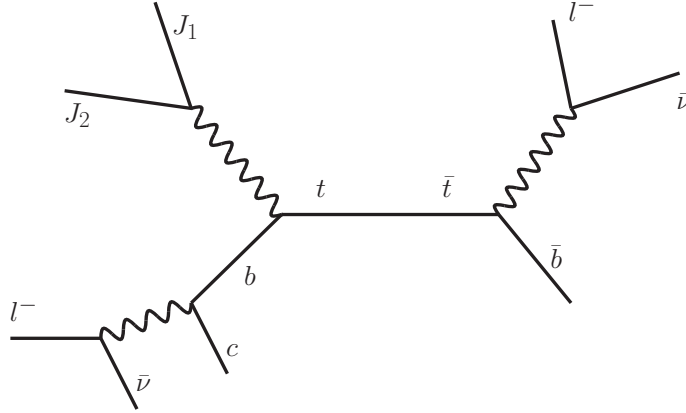


Figure 1: Diagram for $t\bar{t}$ decays giving rise to same-sign dilepton final states

The dominant source of same-sign dileptons in $t\bar{t}$ events are produced via, $t \rightarrow Wb$; where one of the leptons is from $W \rightarrow \ell\nu$ and the other originates from semi-leptonic b decays. We refer to the first as “real lepton” and the second as “fake lepton”. An additional requirement on the number of b jets ≥ 2 , is expected to reduce this background significantly as a b -quark can not produce an isolated lepton and at the same time provide a b -tag.

Same-sign dileptons in association with two or more b -quarks appear naturally in many new physics scenarios. They have been proposed as signatures of supersymmetry (SUSY) [15, 16, 17, 18, 19, 20, 21, 22], models of maximal flavor violation [23, 24, 25], same-sign top quark production from flavor changing neutral currents in the top sector [31], pair production of $T_{5/3}$ [26], top compositeness [27, 28, 29], color-octet scalars in the context of minimal flavor violation [30], among others.

All of these new physics scenarios have in common that the isolated same-sign leptons are typically decay products of on-shell W ’s, thus allowing us to increase the minimum lepton p_T requirements in our search to 20 GeV which reduces backgrounds even further. The combination of requiring at least two b jets and increasing the lepton p_T threshold to 20 GeV reduces the standard model backgrounds by roughly a factor 20 over a more generic search [2].

For the purpose of this note we restrict ourselves to the ee , $e\mu$, and $\mu\mu$ final states, *i.e.*, we do not consider τ ’s, except in the case that the τ decays leptonically.

This note is organized as follows: in Section 2 we briefly outline the event selection used in this study along with event yields and background estimation for the inclusive search. The description of systematics uncertainties on the acceptance is given in Section 3. In Section 4 we summarize the results of the inclusive search. Section 5 then refines this search for the various physics scenarios considered, and we conclude in Section 6.

2 Search for same-sign dileptons with b jets

This analysis is based on the same-sign dilepton search documented in AN-2011/258 [3] and corresponds to an integrated luminosity of 349 pb^{-1} . In that study we searched for events with two isolated same-sign leptons in association with 2 additional jets and \cancel{E}_T . Here we re-use most of the baseline event selection¹⁾ as summarized in Section 2.1 below. In addition, we require at least 2 b -tagged jets using Track Counting High Efficiency Medium (TCHEM) working point tagger [4]. We refer to TCHEM with the requirement that three of the tracks have IP significance > 3.3 . For this tagger the expected b -tagging efficiency is 62% with a roughly 20% systematic uncertainty. The acceptance of light flavor jets is $\sim 2\%$ [4].

¹⁾ The additional Z veto is not applied in this study

2.1 Event Selection

As mentioned previously, this search is a refinement of [3], and we thus discuss here only differences and briefly summarize the basic kinematics and triggers. For more details, we refer to [3].

- We separately look at the dilepton triggered and dilepton plus H_T triggered samples.
- At least two isolated same-sign leptons (ee , $e\mu$, and $\mu\mu$) with $|\eta| < 2.4$.
- For the dilepton triggered samples, we require one lepton with $p_T > 20$ GeV and a second lepton with $p_T > 10$ GeV. We refer to this as the “high- p_T analysis”.
- For the dilepton plus H_T triggered sample, we require electrons with $p_T > 10$ GeV and muons with $p_T > 5$ GeV. We refer to this as the “low- p_T analysis”.
- At least two particle flow jets tagged using TCHEM tagger with $p_T > 40$ GeV and $|\eta| < 2.4$ corrected with L1FastL2L3 corrections.
- The selected jets must be separated from the lepton by $\Delta R > 0.4$.
- $\cancel{E}_T > 30$ GeV.
- We remove dilepton events with invariant mass $M_{ll} < 5$ GeV.

More details are found in Reference [3].

2.2 Event Yields and Background Estimation

The results of this search in the above-mentioned kinematical region are summarized in Table ???. As mentioned in the introduction, and quantified by this table, SM background is expected to be dominated by $t\bar{t}$ production with one real and one fake lepton. We estimate this background from the data itself using the “Tight-To-Loose ratio” (Fake Rate) method [5]. Electron charge mis-reconstruction is estimated by weighting opposite-sign dilepton events that pass all our cuts by a charge flip rate obtained from single electron Monte Carlo as described in detail in [3]. The probability for muons to be reconstructed with the wrong sign in the relevant momentum range is negligible. Both of these techniques are described in more detail in [3]. Systematic errors on these two estimates are 50% and 25% respectively.

In addition, we use MC to estimate contributions from the following additional SM production processes. All of these are quite small.

- $qqW^\pm W^\pm$, WWW , $t\bar{t}W$, and double parton $W^\pm W^\pm$ with two real leptons in the final state.
- WZ and ZZ with two real leptons in the final state.
- $W\gamma$ with one real lepton and a photon conversion. This background is a priori not estimated by the fake rate method because the photon is generally isolated. In practice, this background is completely negligible.

Need to update the tables to include the remaining MC bkg as the MC becomes available !!!

Source	ee	$\mu\mu$	$e\mu$	all
$t\bar{t} \rightarrow \ell\ell X$	0.469 ± 0.305	0.000 ± 0.199	1.133 ± 0.580	1.603 ± 0.656
$t\bar{t}$ other	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199
$t\bar{t} \rightarrow \ell(b \rightarrow \ell)X$	0.000 ± 0.199	0.193 ± 0.143	0.000 ± 0.199	0.193 ± 0.143
$t\bar{t} \rightarrow \ell(\cancel{b} \rightarrow \ell)X$	0.563 ± 0.399	0.000 ± 0.199	0.143 ± 0.131	0.706 ± 0.420
t , s-channel	0.000 ± 0.057	0.000 ± 0.057	0.000 ± 0.057	0.000 ± 0.057
t , t-channel	0.077 ± 0.077	0.000 ± 0.055	0.000 ± 0.055	0.077 ± 0.077
tW	0.000 ± 0.045	0.000 ± 0.045	0.016 ± 0.045	0.016 ± 0.045
$Z \rightarrow ee$	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429
$Z \rightarrow \mu\mu$	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429
$Z \rightarrow \tau\tau$	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429
W +jets	0.000 ± 1.808	0.000 ± 1.808	0.000 ± 1.808	0.000 ± 1.808
WW	0.000 ± 0.019	0.000 ± 0.019	0.000 ± 0.019	0.000 ± 0.019
$V\gamma$	0.000 ± 0.248	0.000 ± 0.248	0.000 ± 0.248	0.000 ± 0.248
$W\gamma^* \rightarrow \ell\nu ee$	0.000 ± 0.097	0.000 ± 0.097	0.000 ± 0.097	0.000 ± 0.097
$W\gamma^* \rightarrow \ell\nu\mu\mu$	0.000 ± 0.075	0.000 ± 0.075	0.000 ± 0.075	0.000 ± 0.075
$W\gamma^* \rightarrow \ell\nu\tau\tau$	0.000 ± 0.028	0.000 ± 0.028	0.000 ± 0.028	0.000 ± 0.028
WZ	0.034 ± 0.012	0.017 ± 0.008	0.031 ± 0.012	0.082 ± 0.019
ZZ	0.000 ± 0.000	0.001 ± 0.001	0.002 ± 0.001	0.003 ± 0.001
$dpW^\pm W^\pm$	0.000 ± 0.004	0.000 ± 0.004	0.000 ± 0.004	0.000 ± 0.004
$spW^- W^-$	0.000 ± 0.001	0.000 ± 0.001	0.003 ± 0.002	0.003 ± 0.002
$spW^+ W^+$	0.000 ± 0.006	0.000 ± 0.006	0.000 ± 0.006	0.000 ± 0.006
$t\bar{t}\gamma$	0.000 ± 0.059	0.000 ± 0.059	0.000 ± 0.059	0.000 ± 0.059
$t\bar{t}W$	0.572 ± 0.025	0.733 ± 0.028	1.286 ± 0.038	2.591 ± 0.053
$t\bar{t}Z$	0.118 ± 0.009	0.158 ± 0.010	0.268 ± 0.013	0.544 ± 0.019
$WW\gamma$	0.000 ± 0.015	0.000 ± 0.015	0.000 ± 0.015	0.000 ± 0.015
WWW	0.001 ± 0.000	0.001 ± 0.000	0.001 ± 0.001	0.003 ± 0.001
WWZ	0.000 ± 0.000	0.000 ± 0.000	0.001 ± 0.001	0.001 ± 0.001
WZZ	0.000 ± 0.000	0.001 ± 0.000	0.001 ± 0.000	0.002 ± 0.001
ZZZ	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
Total MC	1.834 ± 0.509	1.103 ± 0.146	2.885 ± 0.597	5.822 ± 0.797
LM6	0.000 ± 0.000	0.186 ± 0.186	0.383 ± 0.275	0.569 ± 0.332
SF	1.13 ± 0.67	0.30 ± 0.20	1.92 ± 0.74	3.36 ± 1.02
DF	0.04 ± 0.12	0.02 ± 0.02	0.02 ± 0.09	0.08 ± 0.16
SF + DF	$1.17 \pm 0.63 \pm 0.58$	$0.32 \pm 0.20 \pm 0.16$	$1.95 \pm 0.72 \pm 0.97$	$3.43 \pm 0.98 \pm 1.72$
Charge Flips	$0.390 \pm 0.032 \pm 0.078$	- \pm -	$0.544 \pm 0.032 \pm 0.109$	$0.934 \pm 0.045 \pm 0.187$
MC Pred	$0.725 \pm 0.029 \pm 0.362$	$0.912 \pm 0.031 \pm 0.456$	$1.595 \pm 0.042 \pm 0.797$	$3.231 \pm 0.059 \pm 1.616$
Total Pred	$2.281 \pm 0.633 \pm 0.691$	$1.232 \pm 0.199 \pm 0.483$	$4.086 \pm 0.725 \pm 1.263$	$7.600 \pm 0.983 \pm 2.365$
data	2	2	3	7

Table 1: Observed event yields in baseline ($\cancel{E}_T > 30$ GeV, and at least 2 jets with $p_T > 40$ GeV) high- p_T ($p_T > 20/10$) dileptons compared to expectations from simulation alone, and from the data-driven methods. The *simulated backgrounds* contribution includes contributions from genuine same-sign lepton pairs (WZ , ZZ , leptons from same-sign W from single-parton, double-parton, and $t\bar{t}W$ production, etc.), as well as electrons from converted photons in $V\gamma$ production. Entries with zero contributing events are reported with an uncertainty corresponding to one event. This uncertainty is not added to the total MC contribution. Systematic uncertainties (the second uncertainty if present) are displayed only for the final combined type of background, no systematic uncertainty is added for estimates with zero entries. Systematic uncertainties are 100% correlated among the channels.

Source	ee	$\mu\mu$	$e\mu$	all
$t\bar{t} \rightarrow \ell\ell X$	0.071 ± 0.199	0.000 ± 0.199	0.000 ± 0.199	0.071 ± 0.199
$t\bar{t}$ other	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199
$t\bar{t} \rightarrow \ell(b \rightarrow \ell)X$	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199
$t\bar{t} \rightarrow \ell(\cancel{b} \rightarrow \ell)X$	0.272 ± 0.272	0.000 ± 0.199	0.130 ± 0.130	0.402 ± 0.301
t , s-channel	0.000 ± 0.057	0.000 ± 0.057	0.000 ± 0.057	0.000 ± 0.057
t , t-channel	0.000 ± 0.055	0.000 ± 0.055	0.000 ± 0.055	0.000 ± 0.055
tW	0.000 ± 0.045	0.000 ± 0.045	0.000 ± 0.045	0.000 ± 0.045
$Z \rightarrow ee$	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429
$Z \rightarrow \mu\mu$	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429
$Z \rightarrow \tau\tau$	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429
W +jets	0.000 ± 1.808	0.000 ± 1.808	0.000 ± 1.808	0.000 ± 1.808
WW	0.000 ± 0.019	0.000 ± 0.019	0.000 ± 0.019	0.000 ± 0.019
$V\gamma$	0.000 ± 0.248	0.000 ± 0.248	0.000 ± 0.248	0.000 ± 0.248
$W\gamma^* \rightarrow \ell\nu ee$	0.000 ± 0.097	0.000 ± 0.097	0.000 ± 0.097	0.000 ± 0.097
$W\gamma^* \rightarrow \ell\nu\mu\mu$	0.000 ± 0.075	0.000 ± 0.075	0.000 ± 0.075	0.000 ± 0.075
$W\gamma^* \rightarrow \ell\nu\tau\tau$	0.000 ± 0.028	0.000 ± 0.028	0.000 ± 0.028	0.000 ± 0.028
WZ	0.009 ± 0.006	0.001 ± 0.003	0.006 ± 0.004	0.016 ± 0.008
ZZ	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
$dpW^\pm W^\pm$	0.000 ± 0.004	0.000 ± 0.004	0.000 ± 0.004	0.000 ± 0.004
$spW^- W^-$	0.000 ± 0.001	0.000 ± 0.001	0.001 ± 0.001	0.001 ± 0.001
$spW^+ W^+$	0.000 ± 0.006	0.000 ± 0.006	0.000 ± 0.006	0.000 ± 0.006
$t\bar{t}\gamma$	0.000 ± 0.059	0.000 ± 0.059	0.000 ± 0.059	0.000 ± 0.059
$t\bar{t}W$	0.200 ± 0.015	0.214 ± 0.015	0.416 ± 0.021	0.831 ± 0.030
$t\bar{t}Z$	0.037 ± 0.005	0.055 ± 0.006	0.094 ± 0.008	0.186 ± 0.011
$WW\gamma$	0.000 ± 0.015	0.000 ± 0.015	0.000 ± 0.015	0.000 ± 0.015
WWW	0.000 ± 0.000	0.000 ± 0.000	0.001 ± 0.001	0.002 ± 0.001
WWZ	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
WZZ	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
ZZZ	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
Total MC	0.589 ± 0.281	0.271 ± 0.016	0.649 ± 0.132	1.509 ± 0.311
LM6	0.000 ± 0.000	0.186 ± 0.186	0.383 ± 0.275	0.569 ± 0.332
SF	0.27 ± 0.54	0.00 ± 0.37	0.54 ± 0.59	0.81 ± 0.74
DF	0.00 ± 0.14	0.00 ± 0.10	0.00 ± 0.16	0.00 ± 0.16
SF + DF	$0.27 \pm 0.45 \pm 0.14$	$0.00 \pm 0.31 \pm 0.00$	$0.54 \pm 0.50 \pm 0.27$	$0.81 \pm 0.67 \pm 0.40$
Charge Flips	$0.036 \pm 0.010 \pm 0.007$	- \pm -	$0.069 \pm 0.012 \pm 0.014$	$0.104 \pm 0.015 \pm 0.021$
MC Pred	$0.247 \pm 0.017 \pm 0.123$	$0.271 \pm 0.016 \pm 0.135$	$0.519 \pm 0.023 \pm 0.260$	$1.037 \pm 0.033 \pm 0.518$
Total Pred	$0.555 \pm 0.453 \pm 0.184$	$0.271 \pm 0.315 \pm 0.135$	$1.123 \pm 0.496 \pm 0.373$	$1.949 \pm 0.672 \pm 0.658$
data	1	1	0	2

Table 2: Observed event yields in high- p_T ($p_T > 20/10$) dileptons passing the $low-m_0$ signal selections ($H_T > 320$ GeV, $\cancel{E}_T > 50$ GeV) compared to expectations from simulation alone, and from the data-driven methods. The *simulated backgrounds* contribution includes contributions from genuine same-sign lepton pairs (WZ, ZZ, leptons from same-sign W from single-, double-parton, and $t\bar{t}W$ production, etc.), as well as electrons from converted photons in $V\gamma$ production. Entries with zero contributing events are reported with an uncertainty corresponding to one event. This uncertainty is not added to the total MC contribution. Systematic uncertainties (the second uncertainty if present) are displayed only for the final combined type of background, no systematic uncertainty is added for estimates with zero entries. Systematic uncertainties are 100% correlated among the channels.

Source	ee	$\mu\mu$	$e\mu$	all
$t\bar{t} \rightarrow \ell\ell X$	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199
$t\bar{t}$ other	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199
$t\bar{t} \rightarrow \ell(b \rightarrow \ell)X$	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199
$t\bar{t} \rightarrow \ell(\cancel{b} \rightarrow \ell)X$	0.272 ± 0.272	0.000 ± 0.199	0.000 ± 0.199	0.272 ± 0.272
t , s-channel	0.000 ± 0.057	0.000 ± 0.057	0.000 ± 0.057	0.000 ± 0.057
t , t-channel	0.000 ± 0.055	0.000 ± 0.055	0.000 ± 0.055	0.000 ± 0.055
tW	0.000 ± 0.045	0.000 ± 0.045	0.000 ± 0.045	0.000 ± 0.045
$Z \rightarrow ee$	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429
$Z \rightarrow \mu\mu$	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429
$Z \rightarrow \tau\tau$	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429
W +jets	0.000 ± 1.808	0.000 ± 1.808	0.000 ± 1.808	0.000 ± 1.808
WW	0.000 ± 0.019	0.000 ± 0.019	0.000 ± 0.019	0.000 ± 0.019
$V\gamma$	0.000 ± 0.248	0.000 ± 0.248	0.000 ± 0.248	0.000 ± 0.248
$W\gamma^* \rightarrow \ell\nu ee$	0.000 ± 0.097	0.000 ± 0.097	0.000 ± 0.097	0.000 ± 0.097
$W\gamma^* \rightarrow \ell\nu\mu\mu$	0.000 ± 0.075	0.000 ± 0.075	0.000 ± 0.075	0.000 ± 0.075
$W\gamma^* \rightarrow \ell\nu\tau\tau$	0.000 ± 0.028	0.000 ± 0.028	0.000 ± 0.028	0.000 ± 0.028
WZ	0.000 ± 0.003	0.001 ± 0.003	0.004 ± 0.004	0.005 ± 0.004
ZZ	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
$dpW^\pm W^\pm$	0.000 ± 0.004	0.000 ± 0.004	0.000 ± 0.004	0.000 ± 0.004
$spW^- W^-$	0.000 ± 0.001	0.000 ± 0.001	0.001 ± 0.001	0.001 ± 0.001
$spW^+ W^+$	0.000 ± 0.006	0.000 ± 0.006	0.000 ± 0.006	0.000 ± 0.006
$t\bar{t}\gamma$	0.000 ± 0.059	0.000 ± 0.059	0.000 ± 0.059	0.000 ± 0.059
$t\bar{t}W$	0.099 ± 0.011	0.097 ± 0.010	0.184 ± 0.014	0.379 ± 0.020
$t\bar{t}Z$	0.020 ± 0.004	0.028 ± 0.004	0.049 ± 0.005	0.098 ± 0.008
$WW\gamma$	0.000 ± 0.015	0.000 ± 0.015	0.000 ± 0.015	0.000 ± 0.015
WWW	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.001 ± 0.001
WWZ	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
WZZ	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
ZZZ	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
Total MC	0.391 ± 0.272	0.126 ± 0.011	0.239 ± 0.015	0.756 ± 0.273
LM6	0.000 ± 0.000	0.186 ± 0.186	0.383 ± 0.275	0.569 ± 0.332
SF	0.00 ± 0.58	0.00 ± 0.37	0.15 ± 0.54	0.15 ± 0.54
DF	0.00 ± 0.14	0.00 ± 0.10	0.00 ± 0.16	0.00 ± 0.16
SF + DF	$0.00 \pm 0.50 \pm 0.00$	$0.00 \pm 0.31 \pm 0.00$	$0.15 \pm 0.44 \pm 0.07$	$0.15 \pm 0.44 \pm 0.07$
Charge Flips	$0.011 \pm 0.004 \pm 0.002$	- \pm -	$0.016 \pm 0.005 \pm 0.003$	$0.027 \pm 0.006 \pm 0.005$
MC Pred	$0.119 \pm 0.011 \pm 0.060$	$0.126 \pm 0.011 \pm 0.063$	$0.239 \pm 0.015 \pm 0.119$	$0.485 \pm 0.022 \pm 0.242$
Total Pred	$0.130 \pm 0.501 \pm 0.060$	$0.126 \pm 0.315 \pm 0.063$	$0.404 \pm 0.438 \pm 0.141$	$0.661 \pm 0.438 \pm 0.254$
data	1	0	0	1

Table 3: Observed event yields in high- p_T ($p_T > 20/10$) dileptons passing the $high-m_0$ signal selections ($H_T > 440$ GeV, $\cancel{E}_T > 50$ GeV) compared to expectations from simulation alone, and from the data-driven methods. The *simulated backgrounds* contribution includes contributions from genuine same-sign lepton pairs (WZ, ZZ, leptons from same-sign W from single-, double-parton, and $t\bar{t}W$ production, etc.), as well as electrons from converted photons in $V\gamma$ production. Entries with zero contributing events are reported with an uncertainty corresponding to one event. This uncertainty is not added to the total MC contribution. Systematic uncertainties (the second uncertainty if present) are displayed only for the final combined type of background, no systematic uncertainty is added for estimates with zero entries. Systematic uncertainties are 100% correlated among the channels.

Source	ee	$\mu\mu$	$e\mu$	all
$t\bar{t} \rightarrow \ell\bar{\ell}X$	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199
$t\bar{t}$ other	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199
$t\bar{t} \rightarrow \ell(b \rightarrow \ell)X$	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199
$t\bar{t} \rightarrow \ell(\cancel{b} \rightarrow \ell)X$	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199
t , s-channel	0.000 ± 0.057	0.000 ± 0.057	0.000 ± 0.057	0.000 ± 0.057
t , t-channel	0.000 ± 0.055	0.000 ± 0.055	0.000 ± 0.055	0.000 ± 0.055
tW	0.000 ± 0.045	0.000 ± 0.045	0.000 ± 0.045	0.000 ± 0.045
$Z \rightarrow ee$	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429
$Z \rightarrow \mu\mu$	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429
$Z \rightarrow \tau\tau$	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429
W +jets	0.000 ± 1.808	0.000 ± 1.808	0.000 ± 1.808	0.000 ± 1.808
WW	0.000 ± 0.019	0.000 ± 0.019	0.000 ± 0.019	0.000 ± 0.019
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$W\gamma^* \rightarrow \ell\nu ee$	0.000 ± 0.097	0.000 ± 0.097	0.000 ± 0.097	0.000 ± 0.097
$W\gamma^* \rightarrow \ell\nu\mu\mu$	0.000 ± 0.075	0.000 ± 0.075	0.000 ± 0.075	0.000 ± 0.075
$W\gamma^* \rightarrow \ell\nu\tau\tau$	0.000 ± 0.028	0.000 ± 0.028	0.000 ± 0.028	0.000 ± 0.028
WZ	0.010 ± 0.007	0.001 ± 0.003	0.000 ± 0.003	0.011 ± 0.007
ZZ	0.000 ± 0.000	0.000 ± 0.000	0.001 ± 0.001	0.001 ± 0.001
$dpW^\pm W^\pm$	0.000 ± 0.004	0.000 ± 0.004	0.000 ± 0.004	0.000 ± 0.004
$spW^- W^-$	0.000 ± 0.001	0.000 ± 0.001	0.001 ± 0.001	0.001 ± 0.001
$spW^+ W^+$	0.000 ± 0.006	0.000 ± 0.006	0.000 ± 0.006	0.000 ± 0.006
$t\bar{t}\gamma$	0.000 ± 0.059	0.000 ± 0.059	0.000 ± 0.059	0.000 ± 0.059
$t\bar{t}W$	0.097 ± 0.010	0.121 ± 0.011	0.244 ± 0.016	0.462 ± 0.022
$t\bar{t}Z$	0.016 ± 0.003	0.023 ± 0.004	0.041 ± 0.005	0.079 ± 0.007
$WW\gamma$	0.000 ± 0.015	0.000 ± 0.015	0.000 ± 0.015	0.000 ± 0.015
WWW	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.001 ± 0.000
WWZ	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
WZZ	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
ZZZ	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
Total MC	0.123 ± 0.013	0.145 ± 0.012	0.288 ± 0.017	0.555 ± 0.024
LM6	0.000 ± 0.000	0.186 ± 0.186	0.383 ± 0.275	0.569 ± 0.332
SF	0.00 ± 0.58	0.00 ± 0.37	0.32 ± 0.57	0.32 ± 0.57
DF	0.00 ± 0.14	0.00 ± 0.10	0.00 ± 0.16	0.00 ± 0.16
SF + DF	$0.00 \pm 0.50 \pm 0.00$	$0.00 \pm 0.31 \pm 0.00$	$0.32 \pm 0.47 \pm 0.16$	$0.32 \pm 0.47 \pm 0.16$
Charge Flips	$0.021 \pm 0.007 \pm 0.004$	- \pm -	$0.022 \pm 0.006 \pm 0.004$	$0.043 \pm 0.009 \pm 0.009$
MC Pred	$0.123 \pm 0.013 \pm 0.061$	$0.145 \pm 0.012 \pm 0.072$	$0.288 \pm 0.017 \pm 0.144$	$0.555 \pm 0.024 \pm 0.278$
Total Pred	$0.144 \pm 0.501 \pm 0.061$	$0.145 \pm 0.315 \pm 0.072$	$0.634 \pm 0.474 \pm 0.217$	$0.923 \pm 0.474 \pm 0.322$
data	1	0	1	2

Table 4: Observed event yields in high- p_T ($p_T > 20/10$) dileptons passing the *simplified model* signal selections ($H_T > 200$ GeV, $\cancel{E}_T > 120$ GeV) compared to expectations from simulation alone, and from the data-driven methods. The *simulated backgrounds* contribution includes contributions from genuine same-sign lepton pairs (WZ , ZZ , leptons from same-sign W from single-, double-parton, and $t\bar{t}W$ production, etc.), as well as electrons from converted photons in $V\gamma$ production. Entries with zero contributing events are reported with an uncertainty corresponding to one event. This uncertainty is not added to the total MC contribution. Systematic uncertainties (the second uncertainty if present) are displayed only for the final combined type of background, no systematic uncertainty is added for estimates with zero entries. Systematic uncertainties are 100% correlated among the channels.

Source	ee	$\mu\mu$	$e\mu$	all
$t\bar{t} \rightarrow \ell\bar{\ell}X$	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199
$t\bar{t}$ other	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199
$t\bar{t} \rightarrow \ell(b \rightarrow \ell)X$	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199
$t\bar{t} \rightarrow \ell(\cancel{b} \rightarrow \ell)X$	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199
t , s-channel	0.000 ± 0.057	0.000 ± 0.057	0.000 ± 0.057	0.000 ± 0.057
t , t-channel	0.000 ± 0.055	0.000 ± 0.055	0.000 ± 0.055	0.000 ± 0.055
tW	0.000 ± 0.045	0.000 ± 0.045	0.000 ± 0.045	0.000 ± 0.045
$Z \rightarrow ee$	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429
$Z \rightarrow \mu\mu$	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429
$Z \rightarrow \tau\tau$	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429
W +jets	0.000 ± 1.808	0.000 ± 1.808	0.000 ± 1.808	0.000 ± 1.808
WW	0.000 ± 0.019	0.000 ± 0.019	0.000 ± 0.019	0.000 ± 0.019
$V\gamma$	0.000 ± 0.248	0.000 ± 0.248	0.000 ± 0.248	0.000 ± 0.248
$W\gamma^* \rightarrow \ell\nu ee$	0.000 ± 0.097	0.000 ± 0.097	0.000 ± 0.097	0.000 ± 0.097
$W\gamma^* \rightarrow \ell\nu\mu\mu$	0.000 ± 0.075	0.000 ± 0.075	0.000 ± 0.075	0.000 ± 0.075
$W\gamma^* \rightarrow \ell\nu\tau\tau$	0.000 ± 0.028	0.000 ± 0.028	0.000 ± 0.028	0.000 ± 0.028
WZ	0.004 ± 0.004	0.001 ± 0.003	0.000 ± 0.003	0.006 ± 0.005
ZZ	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
$dpW^\pm W^\pm$	0.000 ± 0.004	0.000 ± 0.004	0.000 ± 0.004	0.000 ± 0.004
$spW^- W^-$	0.000 ± 0.001	0.000 ± 0.001	0.001 ± 0.001	0.001 ± 0.001
$spW^+ W^+$	0.000 ± 0.006	0.000 ± 0.006	0.000 ± 0.006	0.000 ± 0.006
$t\bar{t}\gamma$	0.000 ± 0.059	0.000 ± 0.059	0.000 ± 0.059	0.000 ± 0.059
$t\bar{t}W$	0.069 ± 0.009	0.080 ± 0.009	0.168 ± 0.013	0.317 ± 0.018
$t\bar{t}Z$	0.013 ± 0.003	0.014 ± 0.003	0.033 ± 0.005	0.060 ± 0.006
$WW\gamma$	0.000 ± 0.015	0.000 ± 0.015	0.000 ± 0.015	0.000 ± 0.015
WWW	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.001 ± 0.000
WWZ	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
WZZ	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
ZZZ	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
Total MC	0.086 ± 0.010	0.096 ± 0.010	0.203 ± 0.014	0.385 ± 0.020
LM6	0.000 ± 0.000	0.186 ± 0.186	0.383 ± 0.275	0.569 ± 0.332
SF	0.00 ± 0.58	0.00 ± 0.37	0.15 ± 0.54	0.15 ± 0.54
DF	0.00 ± 0.14	0.00 ± 0.10	0.00 ± 0.16	0.00 ± 0.16
SF + DF	$0.00 \pm 0.50 \pm 0.00$	$0.00 \pm 0.31 \pm 0.00$	$0.15 \pm 0.44 \pm 0.07$	$0.15 \pm 0.44 \pm 0.07$
Charge Flips	$0.014 \pm 0.006 \pm 0.003$	- \pm -	$0.011 \pm 0.005 \pm 0.002$	$0.025 \pm 0.008 \pm 0.005$
MC Pred	$0.087 \pm 0.010 \pm 0.043$	$0.096 \pm 0.010 \pm 0.048$	$0.203 \pm 0.014 \pm 0.101$	$0.385 \pm 0.020 \pm 0.192$
Total Pred	$0.101 \pm 0.501 \pm 0.043$	$0.096 \pm 0.315 \pm 0.048$	$0.364 \pm 0.438 \pm 0.126$	$0.560 \pm 0.438 \pm 0.206$
data	0	0	0	0

Table 5: Observed event yields in high- p_T ($p_T > 20/10$) dileptons passing the $pMSSW/sneutrino$ signal selections ($H_T > 320$ GeV, $\cancel{E}_T > 120$ GeV) compared to expectations from simulation alone, and from the data-driven methods. The *simulated backgrounds* contribution includes contributions from genuine same-sign lepton pairs (WZ , ZZ , leptons from same-sign W from single-, double-parton, and $t\bar{t}W$ production, etc.), as well as electrons from converted photons in $V\gamma$ production. Entries with zero contributing events are reported with an uncertainty corresponding to one event. This uncertainty is not added to the total MC contribution. Systematic uncertainties (the second uncertainty if present) are displayed only for the final combined type of background, no systematic uncertainty is added for estimates with zero entries. Systematic uncertainties are 100% correlated among the channels.

The estimation is in a good agreement with the observation. We also note that the backgrounds with respect to the inclusive same-sign dilepton search is suppressed by an order of magnitude due to the b-tag requirements.

We have visually scanned all the events in data and provide details in Section 4.

2.3 Discussion of Background Expectation From MC

Three MC studies are presented. First, we show the origin of fake leptons in MC. Second, we show explicitly the degree to which the fake rate method accurately predicts the fake lepton background in $t\bar{t}$ MC, and third, we present evidence for our assertion that a b-quark can not simultaneously provide a b-tag and produce a fake lepton.

We use a large $t\bar{t}$ sample²⁾ normalized to 1 fb^{-1} for these studies. The fake rates were obtained from QCD MC as described in detail in [3].

We classify $t\bar{t}$ background events based on truth matching to their “parent parton” as either “Heavy Flavor” or “Light Flavor”. Charm quarks from W decay are classified as heavy flavor. It is thus possible to have three heavy quarks in the same event, one of which provides the isolated lepton, the two others the b-tags.

As is shown in Table 6 about 60% (40%) of the fake leptons are from heavy (light) flavor.

Same Sign Leptons	Total	Heavy Flavor	Light Flavor
ee	0.31 ± 0.07	0.11 ± 0.04	0.21 ± 0.05
$\mu\mu$	0.26 ± 0.06	0.22 ± 0.05	0.04 ± 0.04
$e\mu$	0.57 ± 0.09	0.37 ± 0.07	0.21 ± 0.05
total	1.15 ± 0.13	0.70 ± 0.10	0.45 ± 0.08

Table 6: Expected number of $t\bar{t}$ events in 1 fb^{-1} of integrated luminosity. Uncertainties are from MC statistics.

Table 7 shows the same breakdown for the fake rate prediction. Here we use an MC sample where one of the W’s is forced to decay leptonically while the other is not allowed to decay leptonically. We use this sample as it has x10 the luminosity equivalent than the standard $t\bar{t}$ sample, thus providing higher statistics for this test. We observe an overprediction of 30% which appears to be primarily due to overpredicting the fakes from heavy flavor.

Same Sign Leptons	Total	Heavy Flavor	Light Flavor
ee	0.39 ± 0.03	0.20 ± 0.02	0.19 ± 0.03
$\mu\mu$	0.36 ± 0.03	0.30 ± 0.03	0.06 ± 0.01
$e\mu$	0.76 ± 0.05	0.54 ± 0.04	0.22 ± 0.03
total	1.51 ± 0.06	1.04 ± 0.05	0.47 ± 0.04

Table 7: Predicted number of $t\bar{t}$ events in 1 fb^{-1} of integrated luminosity. Uncertainties are from MC statistics.

Finally, Figure 2 shows the minimum ΔR between one of the two b-tagged jets and the fake lepton in the MC after relaxing the jet veto cone around the lepton. The black line indicates the jet veto cone size. Clearly, a b-quark can not simultaneously provide a b-tag and an isolated lepton.

3 Acceptance Systematics

Systematic uncertainties arise from uncertainties on event selections expected in simulation compared to the actual performance of the detector. As this search is in many ways similar to the inclusive same-sign dilepton search [3], our treatment of efficiency systematics parallels the one in that analysis. In this section, we briefly summarize those results, and describe the uncertainties due to the b-tagging requirement.

For the inclusive search without a well-defined signal, we evaluate the systematics with reference to the SUSY benchmark point LM9, as well as opposite sign $t\bar{t}$ simulation, both of which have b-enriched event topologies. The CMS benchmark point LM9 defines the common scalar mass (m_0) = 1.45 TeV, the common gaugino mass ($m_{1/2}$) = 175 GeV, the ratio of the Higgs expectation values ($\tan\beta$) = 10, tri-linear coupling (A_0) = 0 and the sign of the Higgsino mass parameter (μ) > 0. This produces heavy squarks with light gluinos leading to several heavy flavor final states.

²⁾ The POWHEG sample TTToLNu2Q2B_7TeV-powheg-pythia6_Spring11-PU_S1_START311_V1G1-v1

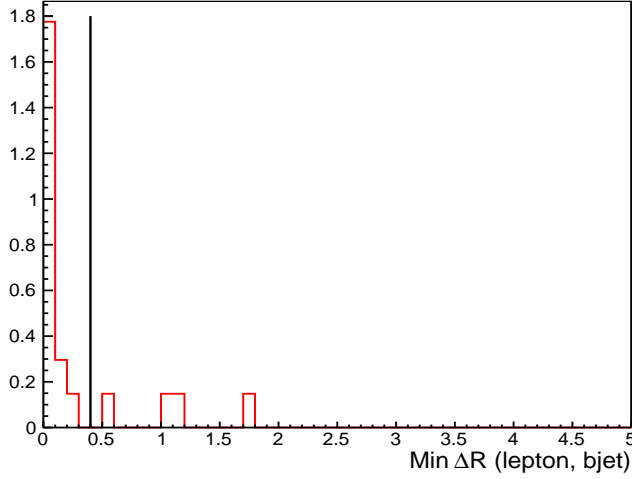


Figure 2: Minimum ΔR between the lepton and the b-tag jet in $t\bar{t}$ decays.

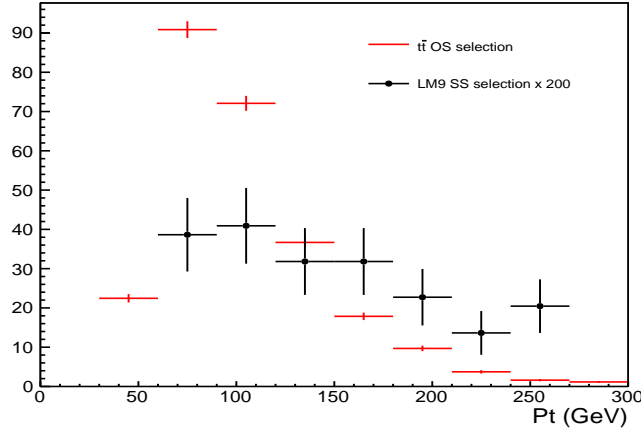


Figure 3: Differential distributions of leading b-tag jet p_T for the LM9 benchmark point and $t\bar{t}$ simulations using 349 pb^{-1} of luminosity normalization.

For the b-tagging efficiency as well as the systematic uncertainties we refer to the work by the BTV POG group for 2011 data [4]. In that study they provide the uncertainties on b-tagging efficiency, as well as scale factors (SF) for $t\bar{t}$ events. In Fig. 3 we compare the leading jet p_T normalized distribution for LM9 using the same-sign dilepton selection. For the $t\bar{t}$ events, we explicitly use opposite-sign dileptons in order to gain statistics. Given that the bulk of the p_T range accessible by LM9 is also covered by the $t\bar{t}$ decays, we consider 8.0% as the systematic uncertainty on the efficiency (per b-jet) from PtRel measurements [4]. We thus use the measurement of scale factors (SFs) for $t\bar{t}$ for the inclusive search.

Once we have all the various signal MCs we mention in Section 5, we will replace Figure 3 with one that compares all of these models, and revisit the statement about b-tagging systematics. It is likely that we will adopt different systematics for different models, given the differences in jet p_T for the different models.

A complete summary of systematic uncertainties is given in Table 8.

open

4 Results on Inclusive Signature Search

This section is missing two things. First, we will add a E_T vs H_T plot that shows the data and one of the models overlayed. Second, we will add a summary of the events we see. We expect to add this information once we update the results for the full data sample up to the technical stop on June 29th 2011.

We see 2 (1) events in the high- p_T (low- p_T) analysis with a predicted background of 1.0 ± 0.8 (0.5 ± 0.7). In

Table 8: Summary of systematic uncertainties on the signal selection and expectation. Reported values are fractional, relative to the total cross section. The values in parentheses are for electrons with p_T below 20 GeV and muons with p_T below 15 GeV for muons.

Source	ee	$\mu\mu$	$e\mu$	all
Lepton selection	11(15)%	11(15)%	11(15)%	11(15)%
Energy scale	5%	5%	5%	5%
ISR/FSR and PDF	2%	2%	2%	2%
b-tag selection	16%	16%	16%	16%
Total without luminosity	20(23)%	20(23)%	20(23)%	20(23)%
Integrated luminosity	6%	6%	6%	6%
Total	21(24)%	21(24)%	21(24)%	21(24)%

absence of any significant deviation from the predicted background, we set 95% CL. on the number of observed events. Two statistical methods have been used for the upper limit. Both methods assume the uncertainties on signal and background are un-correlated and use a log-normal distribution for error pdfs.

The first method used to compute the upper limit is based on the Bayesian method [7]. A posterior probability $p(r)$ is used as a function of the signal strength $r = \sigma/\sigma_{SM}$ assuming a uniform prior for the signal strength r integrating the nuisance parameters associated with the uncertainties. The upper limit at 95% confidence level is then determined by integrating $p(r)$ to determine r' , which satisfies $\int_{r'}^{\infty} p(r)dr = 0.05$.

We use the hybrid frequentist-bayesian CLs approach [6] as the second method. Although the two statistical approaches are not equivalent, in this case we get similar results.

- Upper limit using high- p_T analysis at 95% CL. with 24% signal systematic error using Bayesian approach = 6.1
- Upper limit using high- p_T analysis at 95% CL. with 24% signal systematic error using CLs = 5.8
- Upper limit using low- p_T analysis at 95% CL. with 24% signal systematic error using Bayesian approach = 4.8
- Upper limit using low- p_T analysis at 95% CL. with 24% signal systematic error using CLs = 4.6

We use 6.1 and 4.8 events as the upper limit for the rest of this document for high- and low- p_T analyses.

5 Searches for Specific Models

Our signature, two isolated same-sign leptons plus, at least two b-tagged jets, and \cancel{E}_T , is common to many different new physics scenarios, as well as standard model $t\bar{t}W$ production.

Here we refine our analysis to define dedicated signal regions for a few of these scenarios, and provide 95% C.L. upper limits on their respective model parameter space.

We expect to explore the following models for the final paper:

- Top pair production via t-channel Z' exchange as proposed by [10] and searched for by CMS with 2010 data [1]. This is in some ways a minimal model for our purposes, as it produces nothing other than same sign dileptons, two b-jets, and moderate \cancel{E}_T typical for two leptonic W decays.
- A simplified model for same-sign top pair production as suggested in [12]. The production mechanisms here range from t-channel uu -scattering to $t\bar{t}$, as in the previous example, to $t\bar{t}u\bar{u}$. The main difference to the previous model is different kinematics of the top quarks due to an intermediate resonance $\eta^0 \rightarrow t\bar{u}$ decay. The mass of the η^0 is the main parameter in the simplified model.
- Standard model $t\bar{t}W$ production. Here the final state is same sign dileptons, two neutrinos, i.e. moderate \cancel{E}_T , plus one top quark that decays generically.
- $T_{5/3}$ fermion from Little Higgs models as suggested in [11] lead to a $t\bar{t}W^+W^-$ final state, thus providing one additional W over the previous example.

- SUSY gluino pair production with the gluino decaying to top and stop as suggested in [8][9]. Depending on stop mass, this leads to a final state of either $t\bar{t}\bar{t}\bar{t}$ plus \cancel{E}_T , or $t\bar{t}\bar{Q}\bar{Q}$ plus \cancel{E}_T with Q being charm or beauty, and charge conjugates, as sources for the same sign dilepton plus two btags plus \cancel{E}_T . Independent of stop mass, final states with same sign dileptons plus four heavy flavor quarks plus \cancel{E}_T are produced.

We will fill this in as we generate the samples, and figure out what minor changes to our baseline cuts each model requires to be sort of moderately optimized. In general, we expect changes in lepton p_T , \cancel{E}_T , H_T , and possibly jet p_T requirements, but no object selection changes.

Below are some other ideas being tossed around for other analyses, that we might be competitive with in some parts of the parameter space.

- Pair production of heavy flavored squarks and their anti-squarks [13]. In its simplest form, this just gives $t\bar{t}$ plus \cancel{E}_T , $t\bar{b}$ plus \cancel{E}_T , or $b\bar{b}$ plus \cancel{E}_T , and is thus not relevant for us. It's being looked at in the context of the \cancel{E}_T plus jets analyses. However, there is a variant for which the stop decay proceeds through an intermediate neutralino that decays to W plus chargino, with the chargino being close to degenerate in mass with the neutralino LSP. In this case, the stop anti-stop production mechanism results in a $t\bar{t}W^+W^-$ plus \cancel{E}_T final state. This is thus the same final state as the $T_{5/3}$ pair production mentioned above, except with two additional LSPs. There may be parts of the parameter space for which the LSP is very light, thus not providing enough \cancel{E}_T for the \cancel{E}_T plus jets analyses to see it, or the opposite extreme, where the LSP is so massive, that the Q value of the decays leads to LSPs at rest in the labframe, and thus little \cancel{E}_T . Not sure to what extent these corners of phase space are big enough to pursue.
- Pair production of color octet neutral scalars that each decay to $t\bar{t}$ [14], thus leading to a final state similar as the the SUSY gluino pair production, except with no additional \cancel{E}_T beyond the neutrinos from leptonic W decay. This might thus be possibly missed by the usual \cancel{E}_T plus jets analyses because it doesn't have enough \cancel{E}_T . It might be a target for us more than them.

6 Conclusion

In conclusion, the first search using same-sign dileptons with b -jets and \cancel{E}_T has been presented. In the proton-proton collision data sample corresponding to an integrated luminosity of 349 pb^{-1} at $\sqrt{s} = 7 \text{ TeV}$, no significant deviations from the Standard Model expectations are observed. We use this data to set 95% CL. on the number of observed events.

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A Results - Exclusive Yields

In the following we report yields of events observed in data and compare them to the predictions from the data-driven methods as well as from simulation. These results are reported for *high- p_T* and *low- p_T* dilepton selections with H_T and \cancel{E}_T selected as defined in the baseline selection described in Section ??, as well as for the signal regions defined in Section ?. As anticipated, the MC predicts that $t\bar{t}$ is the largest background in all cases. The data yield is in good agreement with the prediction from both MC as well as the data driven prediction. The procedure for arriving at these data driven predictions is detailed in Section ?. These data-driven predictions supersede all the MC estimates of the contributions from events with fake leptons or with leptons with misreconstructed charge. The remaining MC contribution in the final estimates of background events are those with real leptons: $WZ \rightarrow lll\nu$, $ZZ \rightarrow llll$; same-sign W from single-parton (sp WW), double-parton (dp WW), and $t\bar{t}W$ production. Note that we have also included a contribution from W/Z+ γ background events where the asymmetric conversion of the photon can give rise to an electron of the same sign as a lepton from W or Z. This background is not predicted by the fake lepton prediction method. Results of background estimates in simulation and data are compared with the number of observed events in data in the tables below. The SUSY LM2 point yield based on the LO cross section is provided as a reference. The NLO/LO k-factor for LM2 is 1.33 [?].

Source	ee	$\mu\mu$	$e\mu$	all
$t\bar{t} \rightarrow \ell\bar{\ell}X$	0.071 ± 0.199	0.000 ± 0.199	0.000 ± 0.199	0.071 ± 0.199
$t\bar{t}$ other	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199
$t\bar{t} \rightarrow \ell(b \rightarrow \ell)X$	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199
$t\bar{t} \rightarrow \ell(\cancel{b} \rightarrow \ell)X$	0.000 ± 0.199	0.000 ± 0.199	0.130 ± 0.130	0.130 ± 0.130
t , s-channel	0.000 ± 0.057	0.000 ± 0.057	0.000 ± 0.057	0.000 ± 0.057
t , t-channel	0.000 ± 0.055	0.000 ± 0.055	0.000 ± 0.055	0.000 ± 0.055
tW	0.000 ± 0.045	0.000 ± 0.045	0.000 ± 0.045	0.000 ± 0.045
$Z \rightarrow ee$	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429
$Z \rightarrow \mu\mu$	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429
$Z \rightarrow \tau\tau$	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429
W +jets	0.000 ± 1.808	0.000 ± 1.808	0.000 ± 1.808	0.000 ± 1.808
WW	0.000 ± 0.019	0.000 ± 0.019	0.000 ± 0.019	0.000 ± 0.019
$V\gamma$	0.000 ± 0.248	0.000 ± 0.248	0.000 ± 0.248	0.000 ± 0.248
$W\gamma^* \rightarrow \ell\nu ee$	0.000 ± 0.097	0.000 ± 0.097	0.000 ± 0.097	0.000 ± 0.097
$W\gamma^* \rightarrow \ell\nu\mu\mu$	0.000 ± 0.075	0.000 ± 0.075	0.000 ± 0.075	0.000 ± 0.075
$W\gamma^* \rightarrow \ell\nu\tau\tau$	0.000 ± 0.028	0.000 ± 0.028	0.000 ± 0.028	0.000 ± 0.028
WZ	0.005 ± 0.005	0.000 ± 0.003	0.002 ± 0.002	0.007 ± 0.005
ZZ	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
$\text{dp}W^\pm W^\pm$	0.000 ± 0.004	0.000 ± 0.004	0.000 ± 0.004	0.000 ± 0.004
$\text{sp}W^- W^-$	0.000 ± 0.001	0.000 ± 0.001	0.000 ± 0.001	0.000 ± 0.001
$\text{sp}W^+ W^+$	0.000 ± 0.006	0.000 ± 0.006	0.000 ± 0.006	0.000 ± 0.006
$t\bar{t}\gamma$	0.000 ± 0.059	0.000 ± 0.059	0.000 ± 0.059	0.000 ± 0.059
$t\bar{t}W$	0.073 ± 0.009	0.077 ± 0.009	0.145 ± 0.013	0.295 ± 0.018
$t\bar{t}Z$	0.012 ± 0.003	0.021 ± 0.004	0.032 ± 0.005	0.065 ± 0.007
$WW\gamma$	0.000 ± 0.015	0.000 ± 0.015	0.000 ± 0.015	0.000 ± 0.015
WWW	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
WWZ	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
WZZ	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
ZZZ	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
Total MC	0.160 ± 0.072	0.099 ± 0.010	0.309 ± 0.131	0.568 ± 0.150
LM6	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
SF	0.27 ± 0.54	0.00 ± 0.37	0.39 ± 0.57	0.66 ± 0.72
DF	0.00 ± 0.14	0.00 ± 0.10	0.00 ± 0.16	0.00 ± 0.16
SF + DF	$0.27 \pm 0.45 \pm 0.14$	$0.00 \pm 0.31 \pm 0.00$	$0.39 \pm 0.47 \pm 0.19$	$0.66 \pm 0.65 \pm 0.33$
Charge Flips	$0.016 \pm 0.007 \pm 0.003$	- \pm -	$0.047 \pm 0.010 \pm 0.009$	$0.063 \pm 0.012 \pm 0.013$
MC Pred	$0.089 \pm 0.011 \pm 0.045$	$0.099 \pm 0.010 \pm 0.049$	$0.179 \pm 0.014 \pm 0.090$	$0.367 \pm 0.020 \pm 0.183$
Total Pred	$0.378 \pm 0.453 \pm 0.144$	$0.099 \pm 0.315 \pm 0.049$	$0.612 \pm 0.470 \pm 0.213$	$1.089 \pm 0.653 \pm 0.377$
data	0	1	0	1

Table 9: Observed event yields in high- p_T ($p_T > 20/10$) dileptons passing the $low\text{-}m_0$ signal selections ($320 < H_T < 440$ GeV, $50 < \cancel{E}_T < 120$ GeV) compared to expectations from simulation alone, and from the data-driven methods. The *simulated backgrounds* contribution includes contributions from genuine same-sign lepton pairs (WZ , ZZ , leptons from same-sign W from single-, double-parton, and $t\bar{t}W$ production), as well as electrons from converted photons in $V\gamma$ production. Entries with zero contributing events are reported with an uncertainty corresponding to one event. This uncertainty is not added to the total MC contribution. Systematic uncertainties (the second uncertainty if present) are displayed only for the final combined type of background, no systematic uncertainty is added for estimates with zero entries. Systematic uncertainties are 100% correlated among the channels.

Source	ee	$\mu\mu$	$e\mu$	all
$t\bar{t} \rightarrow \ell\ell X$	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199
$t\bar{t}$ other	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199
$t\bar{t} \rightarrow \ell(b \rightarrow \ell)X$	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199
$t\bar{t} \rightarrow \ell(\cancel{b} \rightarrow \ell)X$	0.272 ± 0.272	0.000 ± 0.199	0.000 ± 0.199	0.272 ± 0.272
t , s-channel	0.000 ± 0.057	0.000 ± 0.057	0.000 ± 0.057	0.000 ± 0.057
t , t-channel	0.000 ± 0.055	0.000 ± 0.055	0.000 ± 0.055	0.000 ± 0.055
tW	0.000 ± 0.045	0.000 ± 0.045	0.000 ± 0.045	0.000 ± 0.045
$Z \rightarrow ee$	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429
$Z \rightarrow \mu\mu$	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429
$Z \rightarrow \tau\tau$	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429
W +jets	0.000 ± 1.808	0.000 ± 1.808	0.000 ± 1.808	0.000 ± 1.808
WW	0.000 ± 0.019	0.000 ± 0.019	0.000 ± 0.019	0.000 ± 0.019
$V\gamma$	0.000 ± 0.248	0.000 ± 0.248	0.000 ± 0.248	0.000 ± 0.248
$W\gamma^* \rightarrow \ell\nu ee$	0.000 ± 0.097	0.000 ± 0.097	0.000 ± 0.097	0.000 ± 0.097
$W\gamma^* \rightarrow \ell\nu\mu\mu$	0.000 ± 0.075	0.000 ± 0.075	0.000 ± 0.075	0.000 ± 0.075
$W\gamma^* \rightarrow \ell\nu\tau\tau$	0.000 ± 0.028	0.000 ± 0.028	0.000 ± 0.028	0.000 ± 0.028
WZ	0.000 ± 0.003	0.001 ± 0.003	0.004 ± 0.004	0.005 ± 0.004
ZZ	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
$\text{dp}W^\pm W^\pm$	0.000 ± 0.004	0.000 ± 0.004	0.000 ± 0.004	0.000 ± 0.004
$\text{sp}W^- W^-$	0.000 ± 0.001	0.000 ± 0.001	0.001 ± 0.001	0.001 ± 0.001
$\text{sp}W^+ W^+$	0.000 ± 0.006	0.000 ± 0.006	0.000 ± 0.006	0.000 ± 0.006
$t\bar{t}\gamma$	0.000 ± 0.059	0.000 ± 0.059	0.000 ± 0.059	0.000 ± 0.059
$t\bar{t}W$	0.099 ± 0.011	0.097 ± 0.010	0.184 ± 0.014	0.379 ± 0.020
$t\bar{t}Z$	0.020 ± 0.004	0.028 ± 0.004	0.049 ± 0.005	0.098 ± 0.008
$WW\gamma$	0.000 ± 0.015	0.000 ± 0.015	0.000 ± 0.015	0.000 ± 0.015
WWW	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.001 ± 0.001
WWZ	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
WZZ	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
ZZZ	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
Total MC	0.391 ± 0.272	0.126 ± 0.011	0.239 ± 0.015	0.756 ± 0.273
LM6	0.000 ± 0.000	0.186 ± 0.186	0.383 ± 0.275	0.569 ± 0.332
SF	0.00 ± 0.58	0.00 ± 0.37	0.15 ± 0.54	0.15 ± 0.54
DF	0.00 ± 0.14	0.00 ± 0.10	0.00 ± 0.16	0.00 ± 0.16
SF + DF	$0.00 \pm 0.50 \pm 0.00$	$0.00 \pm 0.31 \pm 0.00$	$0.15 \pm 0.44 \pm 0.07$	$0.15 \pm 0.44 \pm 0.07$
Charge Flips	$0.011 \pm 0.004 \pm 0.002$	- \pm -	$0.016 \pm 0.005 \pm 0.003$	$0.027 \pm 0.006 \pm 0.005$
MC Pred	$0.119 \pm 0.011 \pm 0.060$	$0.126 \pm 0.011 \pm 0.063$	$0.239 \pm 0.015 \pm 0.119$	$0.485 \pm 0.022 \pm 0.242$
Total Pred	$0.130 \pm 0.501 \pm 0.060$	$0.126 \pm 0.315 \pm 0.063$	$0.404 \pm 0.438 \pm 0.141$	$0.661 \pm 0.438 \pm 0.254$
data	1	0	0	1

Table 10: Observed event yields in high- p_T ($p_T > 20/10$) dileptons passing the *high- m_0* signal selections ($H_T > 440$ GeV, $\cancel{E}_T > 50$ GeV) compared to expectations from simulation alone, and from the data-driven methods. The *simulated backgrounds* contribution includes contributions from genuine same-sign lepton pairs (WZ, ZZ, leptons from same-sign W from single-, double-parton, and $t\bar{t}W$ production), as well as electrons from converted photons in $V\gamma$ production. Entries with zero contributing events are reported with an uncertainty corresponding to one event. This uncertainty is not added to the total MC contribution. Systematic uncertainties (the second uncertainty if present) are displayed only for the final combined type of background, no systematic uncertainty is added for estimates with zero entries. Systematic uncertainties are 100% correlated among the channels.

Source	ee	$\mu\mu$	$e\mu$	all
$t\bar{t} \rightarrow \ell\bar{\ell}X$	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199
$t\bar{t}$ other	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199
$t\bar{t} \rightarrow \ell(b \rightarrow \ell)X$	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199
$t\bar{t} \rightarrow \ell(\cancel{b} \rightarrow \ell)X$	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199
t , s-channel	0.000 ± 0.057	0.000 ± 0.057	0.000 ± 0.057	0.000 ± 0.057
t , t-channel	0.000 ± 0.055	0.000 ± 0.055	0.000 ± 0.055	0.000 ± 0.055
tW	0.000 ± 0.045	0.000 ± 0.045	0.000 ± 0.045	0.000 ± 0.045
$Z \rightarrow ee$	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429
$Z \rightarrow \mu\mu$	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429
$Z \rightarrow \tau\tau$	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429
W +jets	0.000 ± 1.808	0.000 ± 1.808	0.000 ± 1.808	0.000 ± 1.808
WW	0.000 ± 0.019	0.000 ± 0.019	0.000 ± 0.019	0.000 ± 0.019
$V\gamma$	0.000 ± 0.248	0.000 ± 0.248	0.000 ± 0.248	0.000 ± 0.248
$W\gamma^* \rightarrow \ell\nu ee$	0.000 ± 0.097	0.000 ± 0.097	0.000 ± 0.097	0.000 ± 0.097
$W\gamma^* \rightarrow \ell\nu\mu\mu$	0.000 ± 0.075	0.000 ± 0.075	0.000 ± 0.075	0.000 ± 0.075
$W\gamma^* \rightarrow \ell\nu\tau\tau$	0.000 ± 0.028	0.000 ± 0.028	0.000 ± 0.028	0.000 ± 0.028
WZ	0.005 ± 0.005	0.000 ± 0.003	0.000 ± 0.003	0.005 ± 0.005
ZZ	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
$dpW^\pm W^\pm$	0.000 ± 0.004	0.000 ± 0.004	0.000 ± 0.004	0.000 ± 0.004
$spW^- W^-$	0.000 ± 0.001	0.000 ± 0.001	0.000 ± 0.001	0.000 ± 0.001
$spW^+ W^+$	0.000 ± 0.006	0.000 ± 0.006	0.000 ± 0.006	0.000 ± 0.006
$t\bar{t}\gamma$	0.000 ± 0.059	0.000 ± 0.059	0.000 ± 0.059	0.000 ± 0.059
$t\bar{t}W$	0.028 ± 0.006	0.041 ± 0.006	0.076 ± 0.009	0.145 ± 0.012
$t\bar{t}Z$	0.003 ± 0.001	0.009 ± 0.003	0.008 ± 0.002	0.020 ± 0.004
$WW\gamma$	0.000 ± 0.015	0.000 ± 0.015	0.000 ± 0.015	0.000 ± 0.015
WWW	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
WWZ	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
WZZ	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
ZZZ	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
Total MC	0.036 ± 0.008	0.049 ± 0.007	0.085 ± 0.009	0.170 ± 0.014
LM6	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
SF	0.00 ± 0.58	0.00 ± 0.37	0.18 ± 0.55	0.18 ± 0.55
DF	0.00 ± 0.14	0.00 ± 0.10	0.00 ± 0.16	0.00 ± 0.16
SF + DF	$0.00 \pm 0.50 \pm 0.00$	$0.00 \pm 0.31 \pm 0.00$	$0.18 \pm 0.45 \pm 0.09$	$0.18 \pm 0.45 \pm 0.09$
Charge Flips	$0.007 \pm 0.003 \pm 0.001$	- \pm -	$0.010 \pm 0.004 \pm 0.002$	$0.017 \pm 0.005 \pm 0.003$
MC Pred	$0.036 \pm 0.008 \pm 0.018$	$0.049 \pm 0.007 \pm 0.025$	$0.085 \pm 0.009 \pm 0.042$	$0.170 \pm 0.014 \pm 0.085$
Total Pred	$0.043 \pm 0.501 \pm 0.018$	$0.049 \pm 0.315 \pm 0.025$	$0.270 \pm 0.447 \pm 0.097$	$0.363 \pm 0.447 \pm 0.122$
data	1	0	1	2

Table 11: Observed event yields in high- p_T ($p_T > 20/10$) dileptons passing the *simplified model* signal selections ($200 < H_T < 320$ GeV, $\cancel{E}_T > 120$ GeV) compared to expectations from simulation alone, and from the data-driven methods. The *simulated backgrounds* contribution includes contributions from genuine same-sign lepton pairs (WZ , ZZ , leptons from same-sign W from single-, double-parton, and $t\bar{t}W$ production), as well as electrons from converted photons in $V\gamma$ production. Entries with zero contributing events are reported with an uncertainty corresponding to one event. This uncertainty is not added to the total MC contribution. Systematic uncertainties (the second uncertainty if present) are displayed only for the final combined type of background, no systematic uncertainty is added for estimates with zero entries. Systematic uncertainties are 100% correlated among the channels.

Source	ee	$\mu\mu$	$e\mu$	all
$t\bar{t} \rightarrow \ell\ell X$	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199
$t\bar{t}$ other	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199
$t\bar{t} \rightarrow \ell(b \rightarrow \ell)X$	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199
$t\bar{t} \rightarrow \ell(\cancel{b} \rightarrow \ell)X$	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199
t , s-channel	0.000 ± 0.057	0.000 ± 0.057	0.000 ± 0.057	0.000 ± 0.057
t , t-channel	0.000 ± 0.055	0.000 ± 0.055	0.000 ± 0.055	0.000 ± 0.055
tW	0.000 ± 0.045	0.000 ± 0.045	0.000 ± 0.045	0.000 ± 0.045
$Z \rightarrow ee$	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429
$Z \rightarrow \mu\mu$	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429
$Z \rightarrow \tau\tau$	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429
W +jets	0.000 ± 1.808	0.000 ± 1.808	0.000 ± 1.808	0.000 ± 1.808
WW	0.000 ± 0.019	0.000 ± 0.019	0.000 ± 0.019	0.000 ± 0.019
$V\gamma$	0.000 ± 0.248	0.000 ± 0.248	0.000 ± 0.248	0.000 ± 0.248
$W\gamma^* \rightarrow \ell\nu ee$	0.000 ± 0.097	0.000 ± 0.097	0.000 ± 0.097	0.000 ± 0.097
$W\gamma^* \rightarrow \ell\nu\mu\mu$	0.000 ± 0.075	0.000 ± 0.075	0.000 ± 0.075	0.000 ± 0.075
$W\gamma^* \rightarrow \ell\nu\tau\tau$	0.000 ± 0.028	0.000 ± 0.028	0.000 ± 0.028	0.000 ± 0.028
WZ	0.004 ± 0.004	0.001 ± 0.003	0.000 ± 0.003	0.006 ± 0.005
ZZ	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
$\text{dp}W^\pm W^\pm$	0.000 ± 0.004	0.000 ± 0.004	0.000 ± 0.004	0.000 ± 0.004
$\text{sp}W^- W^-$	0.000 ± 0.001	0.000 ± 0.001	0.001 ± 0.001	0.001 ± 0.001
$\text{sp}W^+ W^+$	0.000 ± 0.006	0.000 ± 0.006	0.000 ± 0.006	0.000 ± 0.006
$t\bar{t}\gamma$	0.000 ± 0.059	0.000 ± 0.059	0.000 ± 0.059	0.000 ± 0.059
$t\bar{t}W$	0.069 ± 0.009	0.080 ± 0.009	0.168 ± 0.013	0.317 ± 0.018
$t\bar{t}Z$	0.013 ± 0.003	0.014 ± 0.003	0.033 ± 0.005	0.060 ± 0.006
$WW\gamma$	0.000 ± 0.015	0.000 ± 0.015	0.000 ± 0.015	0.000 ± 0.015
WWW	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.001 ± 0.000
WWZ	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
WZZ	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
ZZZ	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000	0.000 ± 0.000
Total MC	0.086 ± 0.010	0.096 ± 0.010	0.203 ± 0.014	0.385 ± 0.020
LM6	0.000 ± 0.000	0.186 ± 0.186	0.383 ± 0.275	0.569 ± 0.332
SF	0.00 ± 0.58	0.00 ± 0.37	0.15 ± 0.54	0.15 ± 0.54
DF	0.00 ± 0.14	0.00 ± 0.10	0.00 ± 0.16	0.00 ± 0.16
SF + DF	$0.00 \pm 0.50 \pm 0.00$	$0.00 \pm 0.31 \pm 0.00$	$0.15 \pm 0.44 \pm 0.07$	$0.15 \pm 0.44 \pm 0.07$
Charge Flips	$0.014 \pm 0.006 \pm 0.003$	- \pm -	$0.011 \pm 0.005 \pm 0.002$	$0.025 \pm 0.008 \pm 0.005$
MC Pred	$0.087 \pm 0.010 \pm 0.043$	$0.096 \pm 0.010 \pm 0.048$	$0.203 \pm 0.014 \pm 0.101$	$0.385 \pm 0.020 \pm 0.192$
Total Pred	$0.101 \pm 0.501 \pm 0.043$	$0.096 \pm 0.315 \pm 0.048$	$0.364 \pm 0.438 \pm 0.126$	$0.560 \pm 0.438 \pm 0.206$
data	0	0	0	0

Table 12: Observed event yields in high- p_T ($p_T > 20/10$) dileptons passing the $pMSSW/sneutrino$ signal selections ($H_T > 320$ GeV, $\cancel{E}_T > 120$ GeV) compared to expectations from simulation alone, and from the data-driven methods. The *simulated backgrounds* contribution includes contributions from genuine same-sign lepton pairs (WZ, ZZ, leptons from same-sign W from single-, double-parton, and $t\bar{t}W$ production), as well as electrons from converted photons in $V\gamma$ production. Entries with zero contributing events are reported with an uncertainty corresponding to one event. This uncertainty is not added to the total MC contribution. Systematic uncertainties (the second uncertainty if present) are displayed only for the final combined type of background, no systematic uncertainty is added for estimates with zero entries. Systematic uncertainties are 100% correlated among the channels.