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

D. Barge, C. Campagnari, D. Kovalskyi, V. Krutelyov

University of California, Santa Barbara

W. Andrews, G. Cerati, D. Evans, F. Golf, I. MacNeill, S. Padhi, Y. Tu, F. Würthwein, A. Yagil, J. Yoo

University of California, San Diego

L. Bauerdick, K. Burkett, I. Fisk, Y. Gao, O. Gutsche, B. Hooberman, S. Jindariani, J. Linacre

Fermi National Accelerator Laboratory, Batavia, Illinois

Abstract

A search for New Physics in the same sign dilepton final state with at least two b jets and $\not\!\!E_T$ 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 $4.68\ \mathrm{fb}^{-1}$. 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 $\not\!\!E_T$ [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.

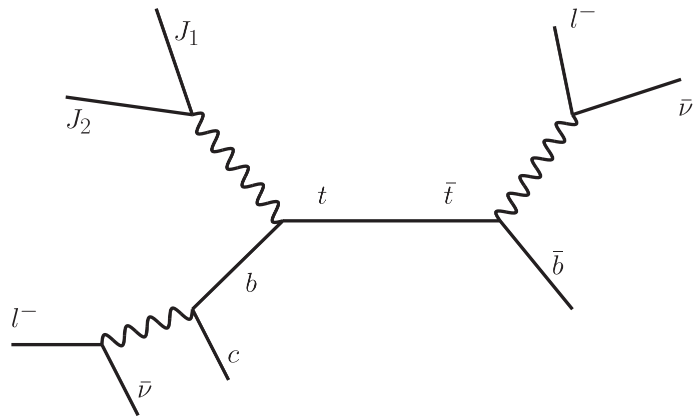

Figure 1: Diagram for $t\bar{t}$decays giving rise to same-sign dilepton final states

The dominant source of same-sign dileptons in $t\bar{t}$events are produced via, $t \to Wb$; where one of the leptons is from $W \to \ell\nu$ 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 20GeV which reduces backgrounds even further. The combination of requiring at least two b jets and increasing the lepton p_T threshold to 20GeV 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 4. In Section 5 we summarize the results of the inclusive search. Section 6 then refines this search for the various physics scenarios considered, and we conclude in Section 7.

2 Search for same-sign dileptons with b jets

This analysis is based on the same-sign dilepton search documented in AN-2011/468 [3] and corresponds to an integrated luminosity of $4.68\ \text{fb}^{-1}$. In that study we searched for events with two isolated same-sign leptons in association with 2 additional jets and $\not\!\!E_T$. Here we re-use most of the baseline event selection as summarized in Section 2.1 below. In addition, we require at least 2 b-tagged jets using Simple Secondary Vertex High Efficiency Medium (SSVHEM) working point tagger [4]. **ADD BRIEF DESCRIPTION OF SSVHEM**

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].

- At least two isolated same-sign leptons (ee, $e\mu$, and $\mu\mu$) with $|\eta| < 2.4$.

- We require both leptons to have p_T >20 GeV.
- We tighten the isolation cut on the leptons to 0.1.
- At least two particle flow jets tagged using SSVHEM tagger with $p_T > 40$ GeV and $|\eta| < 2.4$ corrected with L1FastL2L3 corrections.
- The selected jets must be separated from the leptons by $\Delta R > 0.4$.
- $\not\!\!E_T$> 30 GeV.
- We remove dilepton events with invariant mass $M_{ll} < 8$ GeV.
- We veto events if a third lepton in the event passing loosened identification and isolation requirements makes an opposite-sign same-flavor pair with either of the hypothesis leptons such that the pair has a mass within 15 GeV of the Z mass.

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 summerized 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 form single electron Monte Carlo as described in detail in [3]. The probability for muons to be reconstructed with the wrong sign in the relevant momemtum 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.

- $qqW^{\pm}W^{\pm}, WWW, WWZ, WZZ, ZZZ, WW\gamma, t\bar{t}W, t\bar{t}Z, t\bar{t}\gamma$ 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	$\mu\mu$	eμ	all
$t\bar{t} \to \ell\ell X$	0.469 $\pm$ 0.305	0.000 $\pm$ 0.199	1.133 $\pm$ 0.580	1.603 $\pm$ 0.656
$t\bar{t}$ other	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199
$t\bar{t} \to \ell(b \to \ell)X$	0.000 $\pm$ 0.199	0.193 $\pm$ 0.143	0.000 $\pm$ 0.199	0.193 $\pm$ 0.143
$t\bar{t} \to \ell(\not{b} \to \ell)X$	0.563 $\pm$ 0.399	0.000 $\pm$ 0.199	0.143 $\pm$ 0.131	0.706 $\pm$ 0.420
t, s-channel	0.000 $\pm$ 0.057	0.000 $\pm$ 0.057	0.000 $\pm$ 0.057	0.000 $\pm$ 0.057
t, t-channel	0.077 $\pm$ 0.077	0.000 $\pm$ 0.055	0.000 $\pm$ 0.055	0.077 $\pm$ 0.077
tW	0.000 $\pm$ 0.045	0.000 $\pm$ 0.045	0.016 $\pm$ 0.045	0.016 $\pm$ 0.045
$Z \to ee$	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429
$Z \to \mu\mu$	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429
$Z \to \tau\tau$	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429
W+jets	0.000 $\pm$ 1.808	0.000 $\pm$ 1.808	0.000 $\pm$ 1.808	0.000 $\pm$ 1.808
WW	0.000 $\pm$ 0.019	0.000 $\pm$ 0.019	0.000 $\pm$ 0.019	0.000 $\pm$ 0.019
Vγ	0.000 $\pm$ 0.248	0.000 $\pm$ 0.248	0.000 $\pm$ 0.248	0.000 $\pm$ 0.248
$W\gamma^* \to \ell\nu ee$	0.000 $\pm$ 0.097	0.000 $\pm$ 0.097	0.000 $\pm$ 0.097	0.000 $\pm$ 0.097
$W\gamma^* \to \ell\nu\mu\mu$	0.000 $\pm$ 0.075	0.000 $\pm$ 0.075	0.000 $\pm$ 0.075	0.000 $\pm$ 0.075
$W\gamma^* \to \ell\nu\tau\tau$	0.000 $\pm$ 0.028	0.000 $\pm$ 0.028	0.000 $\pm$ 0.028	0.000 $\pm$ 0.028
WZ	0.034 $\pm$ 0.012	0.017 $\pm$ 0.008	0.031 $\pm$ 0.012	0.082 $\pm$ 0.019
ZZ	0.000 $\pm$ 0.000	0.001 $\pm$ 0.001	0.002 $\pm$ 0.001	0.003 $\pm$ 0.001
dp$W^{\pm}W^{\pm}$	0.000 $\pm$ 0.004	0.000 $\pm$ 0.004	0.000 $\pm$ 0.004	0.000 $\pm$ 0.004
sp$W^{-}W^{-}$	0.000 $\pm$ 0.001	0.000 $\pm$ 0.001	0.003 $\pm$ 0.002	0.003 $\pm$ 0.002
sp$W^{+}W^{+}$	0.000 $\pm$ 0.006	0.000 $\pm$ 0.006	0.000 $\pm$ 0.006	0.000 $\pm$ 0.006
$t\bar{t}\gamma$	0.000 $\pm$ 0.059	0.000 $\pm$ 0.059	0.000 $\pm$ 0.059	0.000 $\pm$ 0.059
$t\bar{t}W$	0.572 $\pm$ 0.025	0.733 $\pm$ 0.028	1.286 $\pm$ 0.038	2.591 $\pm$ 0.053
$t\bar{t}Z$	0.118 $\pm$ 0.009	0.158 $\pm$ 0.010	0.268 $\pm$ 0.013	0.544 $\pm$ 0.019
$WW\gamma$	0.000 $\pm$ 0.015	0.000 $\pm$ 0.015	0.000 $\pm$ 0.015	0.000 $\pm$ 0.015
WWW	0.001 $\pm$ 0.000	0.001 $\pm$ 0.000	0.001 $\pm$ 0.001	0.003 $\pm$ 0.001
WWZ	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.001 $\pm$ 0.001	0.001 $\pm$ 0.001
WZZ	0.000 $\pm$ 0.000	0.001 $\pm$ 0.000	0.001 $\pm$ 0.000	0.002 $\pm$ 0.001
ZZZ	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000
Total MC	1.834 $\pm$ 0.509	1.103 $\pm$ 0.146	2.885 $\pm$ 0.597	5.822 $\pm$ 0.797
LM6	0.000 $\pm$ 0.000	0.186 $\pm$ 0.186	0.383 $\pm$ 0.275	0.569 $\pm$ 0.332
SF	1.13 $\pm$ 0.67	0.30 $\pm$ 0.20	1.92 $\pm$ 0.74	3.36 $\pm$ 1.02
DF	0.04 $\pm$ 0.12	0.02 $\pm$ 0.02	0.02 $\pm$ 0.09	0.08 $\pm$ 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 ($\not{E}_T$> 30 GeV, at least 2 jets with pT > 40 GeV, and at least two of these jets b-tagged using SSVHEM) high-p_T (pT > 20/20) 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	$\mu\mu$	eμ	all
$t\bar{t} \to \ell\ell X$	0.071 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.071 $\pm$ 0.199
$t\bar{t}$ other	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199
$t\bar{t} \to \ell(b \to \ell)X$	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199
$t\bar{t} \to \ell(\not{b} \to \ell)X$	0.272 $\pm$ 0.272	0.000 $\pm$ 0.199	0.130 $\pm$ 0.130	0.402 $\pm$ 0.301
t, s-channel	0.000 $\pm$ 0.057	0.000 $\pm$ 0.057	0.000 $\pm$ 0.057	0.000 $\pm$ 0.057
t, t-channel	0.000 $\pm$ 0.055	0.000 $\pm$ 0.055	0.000 $\pm$ 0.055	0.000 $\pm$ 0.055
tW	0.000 $\pm$ 0.045	0.000 $\pm$ 0.045	0.000 $\pm$ 0.045	0.000 $\pm$ 0.045
$Z \to ee$	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429
$Z \to \mu\mu$	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429
$Z \to \tau\tau$	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429
W+jets	0.000 $\pm$ 1.808	0.000 $\pm$ 1.808	0.000 $\pm$ 1.808	0.000 $\pm$ 1.808
WW	0.000 $\pm$ 0.019	0.000 $\pm$ 0.019	0.000 $\pm$ 0.019	0.000 $\pm$ 0.019
Vγ	0.000 $\pm$ 0.248	0.000 $\pm$ 0.248	0.000 $\pm$ 0.248	0.000 $\pm$ 0.248
$W\gamma^* \to \ell\nu ee$	0.000 $\pm$ 0.097	0.000 $\pm$ 0.097	0.000 $\pm$ 0.097	0.000 $\pm$ 0.097
$W\gamma^* \to \ell\nu\mu\mu$	0.000 $\pm$ 0.075	0.000 $\pm$ 0.075	0.000 $\pm$ 0.075	0.000 $\pm$ 0.075
$W\gamma^* \to \ell\nu\tau\tau$	0.000 $\pm$ 0.028	0.000 $\pm$ 0.028	0.000 $\pm$ 0.028	0.000 $\pm$ 0.028
WZ	0.009 $\pm$ 0.006	0.001 $\pm$ 0.003	0.006 $\pm$ 0.004	0.016 $\pm$ 0.008
ZZ	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000
dp$W^{\pm}W^{\pm}$	0.000 $\pm$ 0.004	0.000 $\pm$ 0.004	0.000 $\pm$ 0.004	0.000 $\pm$ 0.004
sp$W^{-}W^{-}$	0.000 $\pm$ 0.001	0.000 $\pm$ 0.001	0.001 $\pm$ 0.001	0.001 $\pm$ 0.001
sp$W^{+}W^{+}$	0.000 $\pm$ 0.006	0.000 $\pm$ 0.006	0.000 $\pm$ 0.006	0.000 $\pm$ 0.006
$t\bar{t}\gamma$	0.000 $\pm$ 0.059	0.000 $\pm$ 0.059	0.000 $\pm$ 0.059	0.000 $\pm$ 0.059
$t\bar{t}W$	0.200 $\pm$ 0.015	0.214 $\pm$ 0.015	0.416 $\pm$ 0.021	0.831 $\pm$ 0.030
$t\bar{t}Z$	0.037 $\pm$ 0.005	0.055 $\pm$ 0.006	0.094 $\pm$ 0.008	0.186 $\pm$ 0.011
$WW\gamma$	0.000 $\pm$ 0.015	0.000 $\pm$ 0.015	0.000 $\pm$ 0.015	0.000 $\pm$ 0.015
WWW	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.001 $\pm$ 0.001	0.002 $\pm$ 0.001
WWZ	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000
WZZ	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000
ZZZ	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000
Total MC	0.589 $\pm$ 0.281	0.271 $\pm$ 0.016	0.649 $\pm$ 0.132	1.509 $\pm$ 0.311
LM6	0.000 $\pm$ 0.000	0.186 $\pm$ 0.186	0.383 $\pm$ 0.275	0.569 $\pm$ 0.332
SF	0.27 $\pm$ 0.54	0.00 $\pm$ 0.37	0.54 $\pm$ 0.59	0.81 $\pm$ 0.74
DF	0.00 $\pm$ 0.14	0.00 $\pm$ 0.10	0.00 $\pm$ 0.16	0.00 $\pm$ 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 (pT > 20/20) dileptons passing the *low-m_0* signal selections ($H_T >$ 320 GeV, $\not{E}_T >$ 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	$\mu\mu$	eμ	all
$t\bar{t} \to \ell\ell X$	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199
$t\bar{t}$ other	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199
$t\bar{t} \to \ell(b \to \ell)X$	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199
$t\bar{t} \to \ell(\not b \to \ell)X$	0.272 $\pm$ 0.272	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.272 $\pm$ 0.272
t, s-channel	0.000 $\pm$ 0.057	0.000 $\pm$ 0.057	0.000 $\pm$ 0.057	0.000 $\pm$ 0.057
t, t-channel	0.000 $\pm$ 0.055	0.000 $\pm$ 0.055	0.000 $\pm$ 0.055	0.000 $\pm$ 0.055
tW	0.000 $\pm$ 0.045	0.000 $\pm$ 0.045	0.000 $\pm$ 0.045	0.000 $\pm$ 0.045
$Z \to ee$	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429
$Z \to \mu\mu$	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429
$Z \to \tau\tau$	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429
W+jets	0.000 $\pm$ 1.808	0.000 $\pm$ 1.808	0.000 $\pm$ 1.808	0.000 $\pm$ 1.808
WW	0.000 $\pm$ 0.019	0.000 $\pm$ 0.019	0.000 $\pm$ 0.019	0.000 $\pm$ 0.019
Vγ	0.000 $\pm$ 0.248	0.000 $\pm$ 0.248	0.000 $\pm$ 0.248	0.000 $\pm$ 0.248
$W\gamma^* \to \ell\nu ee$	0.000 $\pm$ 0.097	0.000 $\pm$ 0.097	0.000 $\pm$ 0.097	0.000 $\pm$ 0.097
$W\gamma^* \to \ell\nu\mu\mu$	0.000 $\pm$ 0.075	0.000 $\pm$ 0.075	0.000 $\pm$ 0.075	0.000 $\pm$ 0.075
$W\gamma^* \to \ell\nu\tau\tau$	0.000 $\pm$ 0.028	0.000 $\pm$ 0.028	0.000 $\pm$ 0.028	0.000 $\pm$ 0.028
WZ	0.000 $\pm$ 0.003	0.001 $\pm$ 0.003	0.004 $\pm$ 0.004	0.005 $\pm$ 0.004
ZZ	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000
dp$W^\pm W^\pm$	0.000 $\pm$ 0.004	0.000 $\pm$ 0.004	0.000 $\pm$ 0.004	0.000 $\pm$ 0.004
spW^-W^-	0.000 $\pm$ 0.001	0.000 $\pm$ 0.001	0.001 $\pm$ 0.001	0.001 $\pm$ 0.001
spW^+W^+	0.000 $\pm$ 0.006	0.000 $\pm$ 0.006	0.000 $\pm$ 0.006	0.000 $\pm$ 0.006
$t\bar{t}\gamma$	0.000 $\pm$ 0.059	0.000 $\pm$ 0.059	0.000 $\pm$ 0.059	0.000 $\pm$ 0.059
$t\bar{t}W$	0.099 $\pm$ 0.011	0.097 $\pm$ 0.010	0.184 $\pm$ 0.014	0.379 $\pm$ 0.020
$t\bar{t}Z$	0.020 $\pm$ 0.004	0.028 $\pm$ 0.004	0.049 $\pm$ 0.005	0.098 $\pm$ 0.008
$WW\gamma$	0.000 $\pm$ 0.015	0.000 $\pm$ 0.015	0.000 $\pm$ 0.015	0.000 $\pm$ 0.015
WWW	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.001 $\pm$ 0.001
WWZ	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000
WZZ	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000
ZZZ	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000
Total MC	0.391 $\pm$ 0.272	0.126 $\pm$ 0.011	0.239 $\pm$ 0.015	0.756 $\pm$ 0.273
LM6	0.000 $\pm$ 0.000	0.186 $\pm$ 0.186	0.383 $\pm$ 0.275	0.569 $\pm$ 0.332
SF	0.00 $\pm$ 0.58	0.00 $\pm$ 0.37	0.15 $\pm$ 0.54	0.15 $\pm$ 0.54
DF	0.00 $\pm$ 0.14	0.00 $\pm$ 0.10	0.00 $\pm$ 0.16	0.00 $\pm$ 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 (pT > 20/20) dileptons passing the *high-m_0* signal selections ($H_T >$ 440 GeV, $\not E_T >$ 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	$\mu\mu$	eμ	all
$t\bar{t} \to \ell\ell X$	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
$t\bar{t} \to \ell(b \to \ell)X$	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199	0.000 ± 0.199
$t\bar{t} \to \ell(\not{b} \to \ell)X$	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
$Z \to ee$	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429
$Z \to \mu\mu$	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429	0.000 ± 0.429
$Z \to \tau\tau$	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
Vγ	0.000 ± 0.248	0.000 ± 0.248	0.000 ± 0.248	0.000 ± 0.248
$W\gamma^* \to \ell\nu ee$	0.000 ± 0.097	0.000 ± 0.097	0.000 ± 0.097	0.000 ± 0.097
$W\gamma^* \to \ell\nu\mu\mu$	0.000 ± 0.075	0.000 ± 0.075	0.000 ± 0.075	0.000 ± 0.075
$W\gamma^* \to \ell\nu\tau\tau$	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
dp$W^{\pm}W^{\pm}$	0.000 ± 0.004	0.000 ± 0.004	0.000 ± 0.004	0.000 ± 0.004
sp$W^{-}W^{-}$	0.000 ± 0.001	0.000 ± 0.001	0.001 ± 0.001	0.001 ± 0.001
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
$t\bar{t}W$	0.097 ± 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 ± 0.50 ± 0.00	0.00 ± 0.31 ± 0.00	0.32 ± 0.47 ± 0.16	0.32 ± 0.47 ± 0.16
Charge Flips	0.021 ± 0.007 ± 0.004	- ± -	0.022 ± 0.006 ± 0.004	0.043 ± 0.009 ± 0.009
MC Pred	0.123 ± 0.013 ± 0.061	0.145 ± 0.012 ± 0.072	0.288 ± 0.017 ± 0.144	0.555 ± 0.024 ± 0.278
Total Pred	0.144 ± 0.501 ± 0.061	0.145 ± 0.315 ± 0.072	0.634 ± 0.474 ± 0.217	0.923 ± 0.474 ± 0.322
data	1	0	1	2

Table 4: Observed event yields in high-p_T (pT > 20/20) dileptons passing the *simplified model* signal selections ($H_T > 200$ GeV, $\not{E}_T >$ 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	$\mu\mu$	eμ	all
$t\bar{t} \to \ell\ell X$	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199
$t\bar{t}$ other	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199
$t\bar{t} \to \ell(b \to \ell)X$	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199
$t\bar{t} \to \ell(\not{b} \to \ell)X$	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199
t, s-channel	0.000 $\pm$ 0.057	0.000 $\pm$ 0.057	0.000 $\pm$ 0.057	0.000 $\pm$ 0.057
t, t-channel	0.000 $\pm$ 0.055	0.000 $\pm$ 0.055	0.000 $\pm$ 0.055	0.000 $\pm$ 0.055
tW	0.000 $\pm$ 0.045	0.000 $\pm$ 0.045	0.000 $\pm$ 0.045	0.000 $\pm$ 0.045
$Z \to ee$	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429
$Z \to \mu\mu$	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429
$Z \to \tau\tau$	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429
W+jets	0.000 $\pm$ 1.808	0.000 $\pm$ 1.808	0.000 $\pm$ 1.808	0.000 $\pm$ 1.808
WW	0.000 $\pm$ 0.019	0.000 $\pm$ 0.019	0.000 $\pm$ 0.019	0.000 $\pm$ 0.019
Vγ	0.000 $\pm$ 0.248	0.000 $\pm$ 0.248	0.000 $\pm$ 0.248	0.000 $\pm$ 0.248
$W\gamma^* \to \ell\nu ee$	0.000 $\pm$ 0.097	0.000 $\pm$ 0.097	0.000 $\pm$ 0.097	0.000 $\pm$ 0.097
$W\gamma^* \to \ell\nu\mu\mu$	0.000 $\pm$ 0.075	0.000 $\pm$ 0.075	0.000 $\pm$ 0.075	0.000 $\pm$ 0.075
$W\gamma^* \to \ell\nu\tau\tau$	0.000 $\pm$ 0.028	0.000 $\pm$ 0.028	0.000 $\pm$ 0.028	0.000 $\pm$ 0.028
WZ	0.004 $\pm$ 0.004	0.001 $\pm$ 0.003	0.000 $\pm$ 0.003	0.006 $\pm$ 0.005
ZZ	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000
dp$W^{\pm}W^{\pm}$	0.000 $\pm$ 0.004	0.000 $\pm$ 0.004	0.000 $\pm$ 0.004	0.000 $\pm$ 0.004
spW^-W^-	0.000 $\pm$ 0.001	0.000 $\pm$ 0.001	0.001 $\pm$ 0.001	0.001 $\pm$ 0.001
spW^+W^+	0.000 $\pm$ 0.006	0.000 $\pm$ 0.006	0.000 $\pm$ 0.006	0.000 $\pm$ 0.006
$t\bar{t}\gamma$	0.000 $\pm$ 0.059	0.000 $\pm$ 0.059	0.000 $\pm$ 0.059	0.000 $\pm$ 0.059
$t\bar{t}W$	0.069 $\pm$ 0.009	0.080 $\pm$ 0.009	0.168 $\pm$ 0.013	0.317 $\pm$ 0.018
$t\bar{t}Z$	0.013 $\pm$ 0.003	0.014 $\pm$ 0.003	0.033 $\pm$ 0.005	0.060 $\pm$ 0.006
$WW\gamma$	0.000 $\pm$ 0.015	0.000 $\pm$ 0.015	0.000 $\pm$ 0.015	0.000 $\pm$ 0.015
WWW	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.001 $\pm$ 0.000
WWZ	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000
WZZ	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000
ZZZ	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000
Total MC	0.086 $\pm$ 0.010	0.096 $\pm$ 0.010	0.203 $\pm$ 0.014	0.385 $\pm$ 0.020
LM6	0.000 $\pm$ 0.000	0.186 $\pm$ 0.186	0.383 $\pm$ 0.275	0.569 $\pm$ 0.332
SF	0.00 $\pm$ 0.58	0.00 $\pm$ 0.37	0.15 $\pm$ 0.54	0.15 $\pm$ 0.54
DF	0.00 $\pm$ 0.14	0.00 $\pm$ 0.10	0.00 $\pm$ 0.16	0.00 $\pm$ 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 (pT > 20/20) dileptons passing the *pMSSW/sneutrino* signal selections ($H_T > 320$ GeV, $\not{E}_T >$ 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 5.

2.3 Discussion of Background Expectation From MC

THIS SECTION NEEDS TO BE UPDATED

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 $t\bar{t}$ sample [1)] 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 Selection Efficiency

3.1 Data - Monte Carlo Scale Factor

The efficiencies of the lepton isolation and identification requirements (including all quality requirements) are measured with the tag&probe method in dilepton Z events using the full 2011 dataset. The efficiency of the identification requirements is a property of the lepton itself and is directly applicable to the leptons in signal events. The efficiency of the isolation requirement, however, is a strong function of all other (mainly hadronic) activity in the event. The following results are based on measurements using the full dataset and compared to simulation that is re-weighed to have a pile-up distribution comparable to that observed in data.

The electron selection efficiencies are measured in events passing the `Ele17..._SC8_Mass30` and

[1)] The POWHEG sample TTToLNu2Q2B_7TeV-powheg-pythia6_Spring11-PU_S1_START311_V1G1-v1

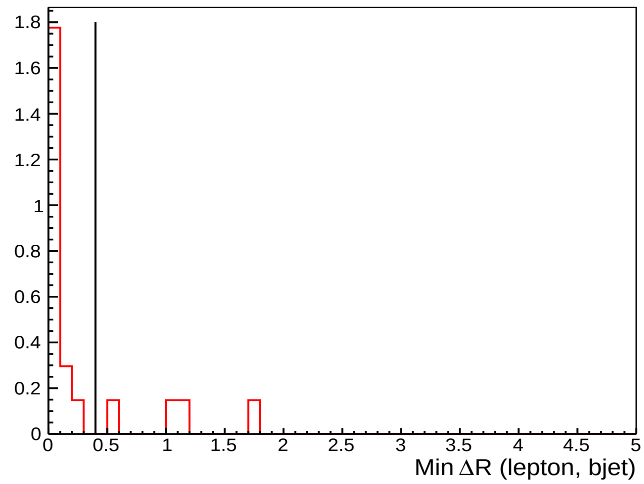

Figure 2: Minimum ΔR between the lepton and the b-tag jet in $t\bar{t}$decays.

`Ele17.._Ele8_Mass30` triggers, which require one well-identified electron and one super-cluster or GSF electron with $p_T > 8$ GeV forming a pair with a mass above 30 GeV$/c^2$. For higher p_T electrons, the `Ele32...SC_17` triggers are also used, which require one well identified electron and one super-cluster with $p_T > 17$ GeV. In the tag&probe analysis the electron tag is required to match to the well-identified electron from the trigger and also to pass all the electron requirements described in [3]. The probe electron is required to have

- $p_T > 20$ GeV, $|\eta| < 2.4$, excluding the superclusters with $1.4442 < |\eta| < 1.566$.

The isolation efficiency is measured with the probes passing all electron selections , except for the trigger requirement and the isolation itself. The identification efficiency is measured with probes passing the isolation requirement. Results of the measurement are summarized in Table 8. The contribution from the Z events is based on simple counting in the mass range of 86–96 GeV$/c$, the MC contribution includes Wjet events to match the expected residual backgrounds in this mass window. The following sources of systematic uncertainty are attributed to this measurement: background contribution, selection of dielectron events, factorization of the isolation and ID parts. The size of the background contribution can be estimated using MC alone and also tested in data with the same-sign dielectron events, which should represent the number of backgrounds reasonably well. The effect of backgrounds on the measured efficiency is established to be approximately 2% for the combined identification and isolation selection efficiency. The narrow mass window used to count electron pairs introduces a bias of about 3% to the measured efficiency by rejecting failing probes that happen to have a worse resolution or a shift in the measured momentum. This bias is expected to approximately cancel in data and simulation. We include a half of the 3% as a source of systematics. Based on simulation alone, the combined selection efficiency, measured with respect to the probe electron, differs from the product of the components by approximately 1% or less depending on the momentum range. All of these effects combined give a systematic uncertainty on the total data-to-MC scale factor in the lepton selection efficiencies of 2.5% for $p_T > 20$ GeV.

		20 - 40 GeV	40 GeV -
ISO	MC	0.9268 ± 0.0004	0.9768 ± 0.0002
	DATA	0.9247 ± 0.0003	0.9737 ± 0.0002
	DATA/MC	0.9977 ± 0.0005	0.9968 ± 0.0003
ID	MC	0.8069 ± 0.0005	0.8500 ± 0.0004
	DATA	0.8005 ± 0.0005	0.8343 ± 0.0004
	DATA/MC	0.9921 ± 0.0008	0.9815 ± 0.0006
ID X ISO	MC	0.7478 ± 0.0005	0.8303 ± 0.0004
	DATA	0.7403 ± 0.0005	0.8124 ± 0.0004
	DATA/MC	0.9899 ± 0.0010	0.9784 ± 0.0007

Table 8: Electron isolation and identification efficiencies measured with the tag&probe method. The uncertainties are statistical only.

The muon selection efficiencies are measured using events passing the double-muon trigger. The tag muon is required to pass all of the muon selection requirements described in [3]. The probe muon is required to pass

- $p_T > 20~\mathrm{GeV}/c$;
- $|\eta| < 2.4$;
- have both the global and the tracker muon types.

Both the isolation and the identification efficiency are measured using probes failing only the requirement in question, assuming the efficiencies factorize. Results of the muon identification and isolation efficiency measurements are presented in Table 9. As expected, the identification efficiency for muons measured in data and in MC agree well, while there is some discrepancy for the isolation efficiency. Similar sources of systematic uncertainty are considered here as those considered for electrons. Most of the reconstructed (probe) muons are real muons and the measurement of the identification efficiency is not affected significantly by backgrounds. With the tighter mass window used here to select events, the backgrounds are estimated to be small. This narrow mass window, however, introduces a bias of about 1.5% to the measured efficiency by rejecting failing probes that happen to have a worse resolution or a shift in the measured momentum. This bias is expected to approximately cancel in data and simulation. We include a half of the 1.5% as a source of systematics. We assign a systematic uncertainty of 1% on the identification and isolation efficiency measurement from a comparison between the simple counting of Z events and fitting the mass shape to a gaussian signal and an exponential background component. Based on studies in MC events, we find that the isolation and the identification efficiencies factorize near-perfectly and do not assign any additional systematic uncertainty. The total systematic uncertainty on the muon efficiency measurement in data, simply covering the full momentum range, is 2%.

		20 - 40 GeV	40 GeV -
ISO	MC	0.9111 $\pm$ 0.0003	0.9747 $\pm$ 0.0002
	DATA	0.8969 $\pm$ 0.0003	0.9668 $\pm$ 0.0002
	DATA/MC	0.9844 $\pm$ 0.0004	0.9919 $\pm$ 0.0002
ID	MC	0.9710 $\pm$ 0.0002	0.9612 $\pm$ 0.0002
	DATA	0.9666 $\pm$ 0.0002	0.9561 $\pm$ 0.0002
	DATA/MC	0.9955 $\pm$ 0.0003	0.9947 $\pm$ 0.0003
ID X ISO	MC	0.8847 $\pm$ 0.0003	0.9369 $\pm$ 0.0002
	DATA	0.8669 $\pm$ 0.0003	0.9244 $\pm$ 0.0002
	DATA/MC	0.9799 $\pm$ 0.0005	0.9866 $\pm$ 0.0003

Table 9: Muon isolation and identification efficiencies measured with the tag&probe method. The uncertainties are statistical only.

The tag&probe results in Tables 8 and 9 show for both electrons and muons the ID part of the selection is reproduced well by simulation. The isolation efficiency in data is measured lower than in simulation with a scale factor still fairly close to 1. As discussed in Section **??** assign a systematic uncertainty of 5% due to modeling of the isolation efficiency for signal events. This uncertainty is expected to cover the remaining discrepancy in the isolation efficiency measured using the tag&probe method. Using these arguments we choose to not apply the data-to-simulation scale factors.

4 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 uncertanities 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 (m0) $= 1.45$ TeV, the common gaugino mass (m1/2) = 175 GeV, the ratio of the Higgs expectation values (tanβ) $= 10$, tri-linear coupling (A0) = 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.

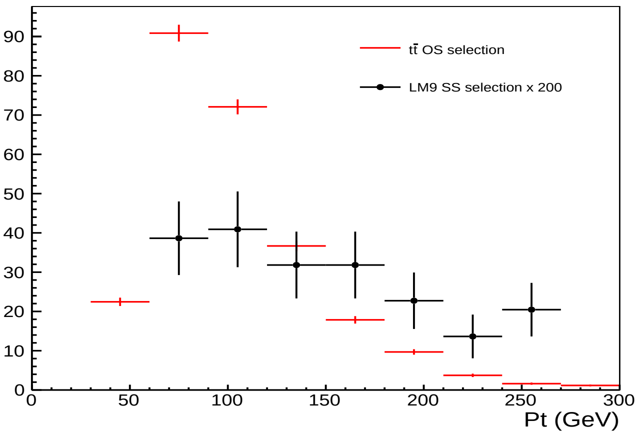

Figure 3: Differential distributions of leading b-tag jet p_T for the LM9 benchmark point and $t\bar{t}$simulations using 349 pb^{-1} of luminosity normalization.

For the b-tagging efficiency as well as the systematic uncertanities we refer to the work by the BTV POG group for 2011 data [4]. In that study they provide the uncertanities 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 explicitely use opposite-sign dileptons in order to gain statistics. Given that the bulk of the p_T range accessable 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 6, 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 10.

Table 10: 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)%

open

5 Results on Inlcusive Signature Search

This section is missing two things. First, we will add a $\not\!\!E_T$ 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 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 $\int_{r'}^{\inf} p(r)dr = 0.05$.

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.

6 Searches for Specific Models

Our signature, two isolated same-sign leptons plus, at least two b-tagged jets, and $\not\!\!E_T$, 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 $\not\!\!E_T$ typical for two leptonic W decays.
- A simplified model for same-sing top pair production as suggested in [12]. The production mechanisms here range from t-channel uu-scattering to tt, as in the previous example, to $tt\bar{u}\bar{u}$. The main difference to the previous model is different kinematics of the top quarks due to an intermeditate resonance $\eta^0 \to t\bar{u}$ 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 $\not\!\!E_T$, 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 $t\bar{t}t\bar{t}$ plus $\not\!\!E_T$, or $tt\bar{Q}\bar{Q}$ plus $\not\!\!E_T$ with Q being charm or beauty, and charge conjugates, as sources for the same sign dilepton plus two btags plus $\not\!\!E_T$. Independent of stop mass, final states with same sign dileptons plus four heavy flavor quarks plus $\not\!\!E_T$ 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, $\not\!\!E_T$, 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 $\not\!\!E_T$, $t\bar{b}$ plus $\not\!\!E_T$, or $b\bar{b}$ plus $\not\!\!E_T$, and is thus not relevant for us. It's being looked at in the context of the $\not\!\!E_T$ 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

$\not\!\!E_T$ 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 $\not\!\!E_T$ for the $\not\!\!E_T$ 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 $\not\!\!E_T$. Not sure to what extend 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 $\not\!\!E_T$ beyond the neutrinos from leptonic W decay. This might thus be possibly missed by the usual $\not\!\!E_T$ plus jets analyses because it doesn't have enough $\not\!\!E_T$. It might be a target for us more than them.

7 Conclusion

In conclusion, the first search using same-sign dileptons with b-jets and $\not\!\!E_T$has been presented. In the proton-proton collision data sample corresponding to an integrated luminosity of 349 pb^{-1} at $\sqrt{s}$ = 7 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.

References

[1] “ ” ,this is our same sign top paper from 2010

[2] CMS Collaboration, “Search for new physics with same-sign di-leptons at the LHC”, arXiv:1104.3168, Submitted to JHEP.

[3] “Search for New Physics with Same-Sign Dileptons using the 2011 dataset of CMS”, CMS AN-2011/258

[4] “Measurement from data of efficiency and mistag rate of b-tagging algorithms using 2010 data”, PAS BTV-11-001 (Submitted)

[5] “Fake Rates for Dilepton Analyses”, AN2010/257

[6] A.L. Read, CERN Report 2000-005 p. 81 (2000).

[7] whatever, some bayesian reference.

[8] http://arxiv.org/abs/hep-ph/0512284,SUSY Gluinos to light stop

[9] http://arxiv.org/abs/1004.2256,more SUSY Gluinos to light stop

[10] The same sign top, E. Berger et al.

[11] http://arxiv.org/abs/0801.1679, $T_{5/3}$ fermion pair production leading to $t\bar{t}W^+W^-$ final state.

[12] http://lhcnewphysics.org/l.006.00.r000, Simplified model by Felix Yu, UCI

[13] http://lhcnewphysics.org/b.011.00.r000 , Stop anti-stop production proposal by Toro et al.

[14] http://lhcnewphysics.org/b.007.00.r000 , $t\bar{t}t\bar{t}$ production via pair production of a neutral color octet resonance by Toro et al.

[15] http://arxiv.org/abs/0901.3367 , http://arxiv.org/abs/1101.1963, gluino with virtual stop

[16] http://arxiv.org/abs/hep-ph/0512284 ,gluino with stop real

[17] http://arxiv.org/abs/0810.3919,“Seeking Sgluons”

[18] http://arxiv.org/abs/1110.6443,Wacker et al. sms paper

[19] http://arxiv.org/abs/hep-ph/9607394,A.G.Cohen, D.B.Kaplan, A.E.Nelson

[20] http://arxiv.org/abs/hep-ph/9507282 ,S.Dimopoulos, G.F. Giudice

[21] http://arxiv.org/abs/hep-ph/9512388,R.Barbieri, G.Dvali, L.Hall

[22] http://arxiv.org/abs/1110.6926,“Natural SUSY Endures”

[23] http://arxiv.org/abs/0711.3193,“Models and Phenomenology of Maximal Flavor Violation”

[24] http://arxiv.org/abs/0803.3795,“Collider Signals of Maximal Flavor Violation: Same-Sign Leptons from Same-Sign Tops at the Tevatron”

[25] http://arxiv.org/abs/0809.4903,CDF search for MxFlv

[26] doi:10.1088/1126-6708/2008/06/026.,R. Contino and G. Servant, Discovering the top partners at the LHC using same-sign dilepton final states, JHEP 06 (2008) 026.

[27] http://arxiv.org/abs/0712.3057,“Top Compositeness at the Tevatron and LHC”

[28] http://arxiv.org/abs/0806.3247,“Top Quark Compositeness: Feasibility and Implications”

[29] http://arxiv.org/abs/0901.3808,“Manifestations of Top Compositeness at Colliders”

[30] http://arxiv.org/abs/0710.3133,“Color-octet scalara at the LHC”

[31] theory motivating our same sign top paper in 2010,need to fill this in

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 $\not\!\!E_T$ 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: $WZ \to lll\nu$, $ZZ \to llll$; same-sign W from single-parton (spWW), double-parton (dpWW), 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	$\mu\mu$	eμ	all
$t\bar{t} \to \ell\ell X$	0.071 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.071 $\pm$ 0.199
$t\bar{t}$ other	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199
$t\bar{t} \to \ell(b \to \ell)X$	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199
$t\bar{t} \to \ell(\not b \to \ell)X$	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.130 $\pm$ 0.130	0.130 $\pm$ 0.130
t, s-channel	0.000 $\pm$ 0.057	0.000 $\pm$ 0.057	0.000 $\pm$ 0.057	0.000 $\pm$ 0.057
t, t-channel	0.000 $\pm$ 0.055	0.000 $\pm$ 0.055	0.000 $\pm$ 0.055	0.000 $\pm$ 0.055
tW	0.000 $\pm$ 0.045	0.000 $\pm$ 0.045	0.000 $\pm$ 0.045	0.000 $\pm$ 0.045
$Z \to ee$	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429
$Z \to \mu\mu$	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429
$Z \to \tau\tau$	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429
W+jets	0.000 $\pm$ 1.808	0.000 $\pm$ 1.808	0.000 $\pm$ 1.808	0.000 $\pm$ 1.808
WW	0.000 $\pm$ 0.019	0.000 $\pm$ 0.019	0.000 $\pm$ 0.019	0.000 $\pm$ 0.019
Vγ	0.000 $\pm$ 0.248	0.000 $\pm$ 0.248	0.000 $\pm$ 0.248	0.000 $\pm$ 0.248
$W\gamma^* \to \ell\nu ee$	0.000 $\pm$ 0.097	0.000 $\pm$ 0.097	0.000 $\pm$ 0.097	0.000 $\pm$ 0.097
$W\gamma^* \to \ell\nu\mu\mu$	0.000 $\pm$ 0.075	0.000 $\pm$ 0.075	0.000 $\pm$ 0.075	0.000 $\pm$ 0.075
$W\gamma^* \to \ell\nu\tau\tau$	0.000 $\pm$ 0.028	0.000 $\pm$ 0.028	0.000 $\pm$ 0.028	0.000 $\pm$ 0.028
WZ	0.005 $\pm$ 0.005	0.000 $\pm$ 0.003	0.002 $\pm$ 0.002	0.007 $\pm$ 0.005
ZZ	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000
dp$W^{\pm}W^{\pm}$	0.000 $\pm$ 0.004	0.000 $\pm$ 0.004	0.000 $\pm$ 0.004	0.000 $\pm$ 0.004
sp$W^{-}W^{-}$	0.000 $\pm$ 0.001	0.000 $\pm$ 0.001	0.000 $\pm$ 0.001	0.000 $\pm$ 0.001
sp$W^{+}W^{+}$	0.000 $\pm$ 0.006	0.000 $\pm$ 0.006	0.000 $\pm$ 0.006	0.000 $\pm$ 0.006
$t\bar{t}\gamma$	0.000 $\pm$ 0.059	0.000 $\pm$ 0.059	0.000 $\pm$ 0.059	0.000 $\pm$ 0.059
$t\bar{t}W$	0.073 $\pm$ 0.009	0.077 $\pm$ 0.009	0.145 $\pm$ 0.013	0.295 $\pm$ 0.018
$t\bar{t}Z$	0.012 $\pm$ 0.003	0.021 $\pm$ 0.004	0.032 $\pm$ 0.005	0.065 $\pm$ 0.007
$WW\gamma$	0.000 $\pm$ 0.015	0.000 $\pm$ 0.015	0.000 $\pm$ 0.015	0.000 $\pm$ 0.015
WWW	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000
WWZ	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000
WZZ	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000
ZZZ	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000
Total MC	0.160 $\pm$ 0.072	0.099 $\pm$ 0.010	0.309 $\pm$ 0.131	0.568 $\pm$ 0.150
LM6	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000
SF	0.27 $\pm$ 0.54	0.00 $\pm$ 0.37	0.39 $\pm$ 0.57	0.66 $\pm$ 0.72
DF	0.00 $\pm$ 0.14	0.00 $\pm$ 0.10	0.00 $\pm$ 0.16	0.00 $\pm$ 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 11: Observed event yields in high-p_T (pT $>$ 20/10) dileptons passing the *low-m_0* signal selections (320 $< H_T <$ 440 GeV, 50 $< \not{E}_T <$ 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	$\mu\mu$	eμ	all
$t\bar{t} \to \ell\ell X$	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199
$t\bar{t}$ other	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199
$t\bar{t} \to \ell(b \to \ell)X$	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199
$t\bar{t} \to \ell(\not{b} \to \ell)X$	0.272 $\pm$ 0.272	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.272 $\pm$ 0.272
t, s-channel	0.000 $\pm$ 0.057	0.000 $\pm$ 0.057	0.000 $\pm$ 0.057	0.000 $\pm$ 0.057
t, t-channel	0.000 $\pm$ 0.055	0.000 $\pm$ 0.055	0.000 $\pm$ 0.055	0.000 $\pm$ 0.055
tW	0.000 $\pm$ 0.045	0.000 $\pm$ 0.045	0.000 $\pm$ 0.045	0.000 $\pm$ 0.045
$Z \to ee$	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429
$Z \to \mu\mu$	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429
$Z \to \tau\tau$	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429
W+jets	0.000 $\pm$ 1.808	0.000 $\pm$ 1.808	0.000 $\pm$ 1.808	0.000 $\pm$ 1.808
WW	0.000 $\pm$ 0.019	0.000 $\pm$ 0.019	0.000 $\pm$ 0.019	0.000 $\pm$ 0.019
Vγ	0.000 $\pm$ 0.248	0.000 $\pm$ 0.248	0.000 $\pm$ 0.248	0.000 $\pm$ 0.248
$W\gamma^* \to \ell\nu ee$	0.000 $\pm$ 0.097	0.000 $\pm$ 0.097	0.000 $\pm$ 0.097	0.000 $\pm$ 0.097
$W\gamma^* \to \ell\nu\mu\mu$	0.000 $\pm$ 0.075	0.000 $\pm$ 0.075	0.000 $\pm$ 0.075	0.000 $\pm$ 0.075
$W\gamma^* \to \ell\nu\tau\tau$	0.000 $\pm$ 0.028	0.000 $\pm$ 0.028	0.000 $\pm$ 0.028	0.000 $\pm$ 0.028
WZ	0.000 $\pm$ 0.003	0.001 $\pm$ 0.003	0.004 $\pm$ 0.004	0.005 $\pm$ 0.004
ZZ	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000
dp$W^{\pm}W^{\pm}$	0.000 $\pm$ 0.004	0.000 $\pm$ 0.004	0.000 $\pm$ 0.004	0.000 $\pm$ 0.004
sp$W^{-}W^{-}$	0.000 $\pm$ 0.001	0.000 $\pm$ 0.001	0.001 $\pm$ 0.001	0.001 $\pm$ 0.001
sp$W^{+}W^{+}$	0.000 $\pm$ 0.006	0.000 $\pm$ 0.006	0.000 $\pm$ 0.006	0.000 $\pm$ 0.006
$t\bar{t}\gamma$	0.000 $\pm$ 0.059	0.000 $\pm$ 0.059	0.000 $\pm$ 0.059	0.000 $\pm$ 0.059
$t\bar{t}W$	0.099 $\pm$ 0.011	0.097 $\pm$ 0.010	0.184 $\pm$ 0.014	0.379 $\pm$ 0.020
$t\bar{t}Z$	0.020 $\pm$ 0.004	0.028 $\pm$ 0.004	0.049 $\pm$ 0.005	0.098 $\pm$ 0.008
$WW\gamma$	0.000 $\pm$ 0.015	0.000 $\pm$ 0.015	0.000 $\pm$ 0.015	0.000 $\pm$ 0.015
WWW	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.001 $\pm$ 0.001
WWZ	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000
WZZ	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000
ZZZ	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000
Total MC	0.391 $\pm$ 0.272	0.126 $\pm$ 0.011	0.239 $\pm$ 0.015	0.756 $\pm$ 0.273
LM6	0.000 $\pm$ 0.000	0.186 $\pm$ 0.186	0.383 $\pm$ 0.275	0.569 $\pm$ 0.332
SF	0.00 $\pm$ 0.58	0.00 $\pm$ 0.37	0.15 $\pm$ 0.54	0.15 $\pm$ 0.54
DF	0.00 $\pm$ 0.14	0.00 $\pm$ 0.10	0.00 $\pm$ 0.16	0.00 $\pm$ 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 12: Observed event yields in high-p_T (pT $>$ 20/10) dileptons passing the *high-*m_0 signal selections ($H_T >$ 440 GeV, $\not{E}_T > 50$ 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	$\mu\mu$	eμ	all
$t\bar{t} \to \ell\ell X$	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199
$t\bar{t}$ other	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199
$t\bar{t} \to \ell(b \to \ell)X$	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199
$t\bar{t} \to \ell(\not b \to \ell)X$	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199
t, s-channel	0.000 $\pm$ 0.057	0.000 $\pm$ 0.057	0.000 $\pm$ 0.057	0.000 $\pm$ 0.057
t, t-channel	0.000 $\pm$ 0.055	0.000 $\pm$ 0.055	0.000 $\pm$ 0.055	0.000 $\pm$ 0.055
tW	0.000 $\pm$ 0.045	0.000 $\pm$ 0.045	0.000 $\pm$ 0.045	0.000 $\pm$ 0.045
$Z \to ee$	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429
$Z \to \mu\mu$	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429
$Z \to \tau\tau$	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429
W+jets	0.000 $\pm$ 1.808	0.000 $\pm$ 1.808	0.000 $\pm$ 1.808	0.000 $\pm$ 1.808
WW	0.000 $\pm$ 0.019	0.000 $\pm$ 0.019	0.000 $\pm$ 0.019	0.000 $\pm$ 0.019
Vγ	0.000 $\pm$ 0.248	0.000 $\pm$ 0.248	0.000 $\pm$ 0.248	0.000 $\pm$ 0.248
$W\gamma^* \to \ell\nu ee$	0.000 $\pm$ 0.097	0.000 $\pm$ 0.097	0.000 $\pm$ 0.097	0.000 $\pm$ 0.097
$W\gamma^* \to \ell\nu\mu\mu$	0.000 $\pm$ 0.075	0.000 $\pm$ 0.075	0.000 $\pm$ 0.075	0.000 $\pm$ 0.075
$W\gamma^* \to \ell\nu\tau\tau$	0.000 $\pm$ 0.028	0.000 $\pm$ 0.028	0.000 $\pm$ 0.028	0.000 $\pm$ 0.028
WZ	0.005 $\pm$ 0.005	0.000 $\pm$ 0.003	0.000 $\pm$ 0.003	0.005 $\pm$ 0.005
ZZ	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000
dp$W^{\pm}W^{\pm}$	0.000 $\pm$ 0.004	0.000 $\pm$ 0.004	0.000 $\pm$ 0.004	0.000 $\pm$ 0.004
sp$W^{-}W^{-}$	0.000 $\pm$ 0.001	0.000 $\pm$ 0.001	0.000 $\pm$ 0.001	0.000 $\pm$ 0.001
sp$W^{+}W^{+}$	0.000 $\pm$ 0.006	0.000 $\pm$ 0.006	0.000 $\pm$ 0.006	0.000 $\pm$ 0.006
$t\bar{t}\gamma$	0.000 $\pm$ 0.059	0.000 $\pm$ 0.059	0.000 $\pm$ 0.059	0.000 $\pm$ 0.059
$t\bar{t}W$	0.028 $\pm$ 0.006	0.041 $\pm$ 0.006	0.076 $\pm$ 0.009	0.145 $\pm$ 0.012
$t\bar{t}Z$	0.003 $\pm$ 0.001	0.009 $\pm$ 0.003	0.008 $\pm$ 0.002	0.020 $\pm$ 0.004
$WW\gamma$	0.000 $\pm$ 0.015	0.000 $\pm$ 0.015	0.000 $\pm$ 0.015	0.000 $\pm$ 0.015
WWW	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000
WWZ	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000
WZZ	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000
ZZZ	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000
Total MC	0.036 $\pm$ 0.008	0.049 $\pm$ 0.007	0.085 $\pm$ 0.009	0.170 $\pm$ 0.014
LM6	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000
SF	0.00 $\pm$ 0.58	0.00 $\pm$ 0.37	0.18 $\pm$ 0.55	0.18 $\pm$ 0.55
DF	0.00 $\pm$ 0.14	0.00 $\pm$ 0.10	0.00 $\pm$ 0.16	0.00 $\pm$ 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 13: Observed event yields in high-p_T (pT > 20/10) dileptons passing the *simplified model* signal selections ($200 < H_T < 320$ GeV, $\not\!\!E_T >$ 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	$\mu\mu$	eμ	all
$t\bar{t} \to \ell\ell X$	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199
$t\bar{t}$ other	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199
$t\bar{t} \to \ell(b \to \ell)X$	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199
$t\bar{t} \to \ell(\not{b} \to \ell)X$	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199	0.000 $\pm$ 0.199
t, s-channel	0.000 $\pm$ 0.057	0.000 $\pm$ 0.057	0.000 $\pm$ 0.057	0.000 $\pm$ 0.057
t, t-channel	0.000 $\pm$ 0.055	0.000 $\pm$ 0.055	0.000 $\pm$ 0.055	0.000 $\pm$ 0.055
tW	0.000 $\pm$ 0.045	0.000 $\pm$ 0.045	0.000 $\pm$ 0.045	0.000 $\pm$ 0.045
$Z \to ee$	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429
$Z \to \mu\mu$	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429
$Z \to \tau\tau$	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429	0.000 $\pm$ 0.429
W+jets	0.000 $\pm$ 1.808	0.000 $\pm$ 1.808	0.000 $\pm$ 1.808	0.000 $\pm$ 1.808
WW	0.000 $\pm$ 0.019	0.000 $\pm$ 0.019	0.000 $\pm$ 0.019	0.000 $\pm$ 0.019
Vγ	0.000 $\pm$ 0.248	0.000 $\pm$ 0.248	0.000 $\pm$ 0.248	0.000 $\pm$ 0.248
$W\gamma^* \to \ell\nu ee$	0.000 $\pm$ 0.097	0.000 $\pm$ 0.097	0.000 $\pm$ 0.097	0.000 $\pm$ 0.097
$W\gamma^* \to \ell\nu\mu\mu$	0.000 $\pm$ 0.075	0.000 $\pm$ 0.075	0.000 $\pm$ 0.075	0.000 $\pm$ 0.075
$W\gamma^* \to \ell\nu\tau\tau$	0.000 $\pm$ 0.028	0.000 $\pm$ 0.028	0.000 $\pm$ 0.028	0.000 $\pm$ 0.028
WZ	0.004 $\pm$ 0.004	0.001 $\pm$ 0.003	0.000 $\pm$ 0.003	0.006 $\pm$ 0.005
ZZ	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000
dp$W^{\pm}W^{\pm}$	0.000 $\pm$ 0.004	0.000 $\pm$ 0.004	0.000 $\pm$ 0.004	0.000 $\pm$ 0.004
spW^-W^-	0.000 $\pm$ 0.001	0.000 $\pm$ 0.001	0.001 $\pm$ 0.001	0.001 $\pm$ 0.001
spW^+W^+	0.000 $\pm$ 0.006	0.000 $\pm$ 0.006	0.000 $\pm$ 0.006	0.000 $\pm$ 0.006
$t\bar{t}\gamma$	0.000 $\pm$ 0.059	0.000 $\pm$ 0.059	0.000 $\pm$ 0.059	0.000 $\pm$ 0.059
$t\bar{t}W$	0.069 $\pm$ 0.009	0.080 $\pm$ 0.009	0.168 $\pm$ 0.013	0.317 $\pm$ 0.018
$t\bar{t}Z$	0.013 $\pm$ 0.003	0.014 $\pm$ 0.003	0.033 $\pm$ 0.005	0.060 $\pm$ 0.006
$WW\gamma$	0.000 $\pm$ 0.015	0.000 $\pm$ 0.015	0.000 $\pm$ 0.015	0.000 $\pm$ 0.015
WWW	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.001 $\pm$ 0.000
WWZ	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000
WZZ	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000
ZZZ	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000	0.000 $\pm$ 0.000
Total MC	0.086 $\pm$ 0.010	0.096 $\pm$ 0.010	0.203 $\pm$ 0.014	0.385 $\pm$ 0.020
LM6	0.000 $\pm$ 0.000	0.186 $\pm$ 0.186	0.383 $\pm$ 0.275	0.569 $\pm$ 0.332
SF	0.00 $\pm$ 0.58	0.00 $\pm$ 0.37	0.15 $\pm$ 0.54	0.15 $\pm$ 0.54
DF	0.00 $\pm$ 0.14	0.00 $\pm$ 0.10	0.00 $\pm$ 0.16	0.00 $\pm$ 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 14: Observed event yields in high-p_T (pT $>$ 20/10) dileptons passing the *pMSSW/sneutrino* signal selections ($H_T > 320$ GeV, $\not{E}_T > 120$ 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.