Search for Baryon Number Violating Top Quark Decays in pp collisions at $\sqrt{s}$ = 8 TeV

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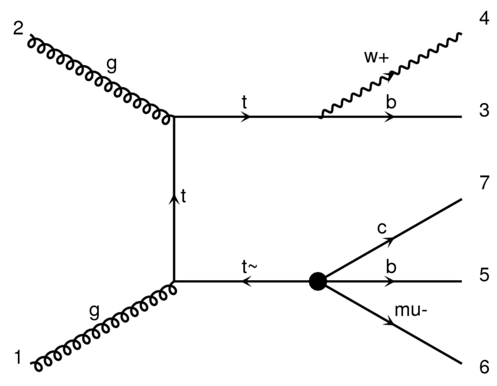
A search for the decay of top quarks that violate baryon number conservation is performed using p-p collisions produced by the LHC at $\sqrt{s}$ = 8 TeV. The top quark decay signature considered in this analysis consists of one light lepton (electron or muon), two jets, but no neutrino in the final state. Data collected by the CMS detector [2] and corresponding to an integrated luminosity of 19.6 fb^{-1} are used for the analysis. No significant excess of events over the expected yields from Standard Model (SM) processes is observed. The upper limits at 95% confidence level on the branching fraction of the baryon number violating top-quark decay are found to be 0.0016 and 0.0017 for muon analysis and for the electron analyses, respectively.

Motivations

- Tiny baryon number violation (BNV) predicted even in SM [3]
- Strong BNV effects predicted in many BSM models
- BNV is a necessary condition for the observed baryon-antibaryon asymmetry in the universe [4]
- No BNV processes observed so far
- BNV in top quark system suggested in [5]

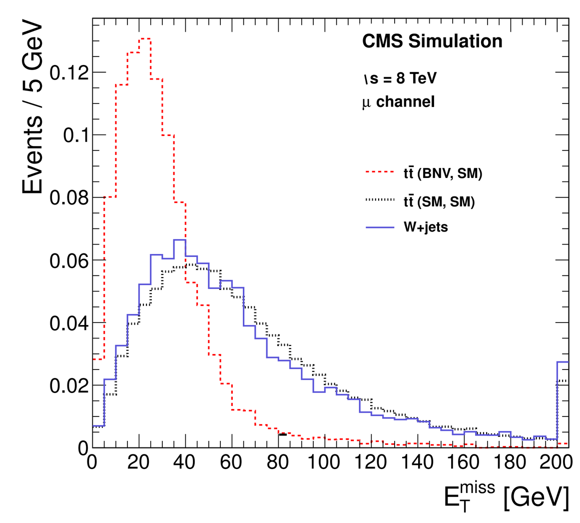
We look at $t\bar{t}$ pairs, where one top undergoes an hadronic decay, and the other a BNV decay in one lepton and two jets



$$gg(q\bar{q}) \to t\bar{t} \to \mu^- cbbjj$$
$$gg(q\bar{q}) \to t\bar{t} \to e^- \bar{u}bbjj$$

Signal Features

- 1 Isolated lepton
- No physical missing energy
- At least 5 jets
- Two same-sign b-quarks



Left: E_T^{miss} distibution for signal, SM $t\bar{t}$, W+Jets

ANALYSIS STRATEGY

Counting Experiment in signal region

Simplified selection to reduce the dependence on the model as much as possible

BASIC SELECTION

GOAL:
- Normalize MC and DATA by scaling top yield
- Reduce impact of systematic uncertainties
- Reduce non top-background

SELECTION:
Exactly 1 isolated muon (electron) with:
p_T > 20 (30) GeV
$|\eta|$ < 2.1 (2.4)

At least 5 jets with p_T > 30 GeV
(3 Jets with p_T > 70, 55, 40 GeV respectively)

At least 1 b-tagged jet

TIGHT SELECTION

GOAL:
- Enhance signal
- Expectation expressed as simple ratios of efficiencies as function of BR and cross section

SELECTION:

Basic Selection + $\begin{cases} E_T^{miss} < 20 \text{ GeV} \\ \chi^2 < 20 \end{cases}$

$$\chi^2 = \sum_i \frac{(x_i - \bar{x}_i)^2}{\sigma_i^2}$$

BNV t-quark mass
Hadronic t-quark mass
W boson mass

1 The sum of expected signal and background events that pass the basic selection is normalized to the number of observed events.

2 The normalization is performed by scaling only the tt and tW production rates.

3 The comparison between the expected and observed numbers of events in tight selection is used to infer an upper limit on BR

The expected yield in the tight selection (N^T_{exp}) can be expressed as a function of: **(a)** the total observed yield in the basic selection (N^B_{obs}) **(b)** the expected non-top yield in the basic selection (N^B_{bck}) **(c)** the expected non-top yield in the tight selection (N^T_{bck}) **(d)** $t\bar{t}$ and tW cross sections ($\sigma_{t\bar{t}}$ and σ_{tW}) **(e)** the integrated luminosity **(f)** efficiencies ϵ^B (ϵ^T) to pass the basic (tight) selections for $t\bar{t}$ and tW (functions of BR):

$$N^T_{exp} = \left(N^B_{obs} - N^B_{bck}\right)\left[\frac{1}{1+\frac{\sigma_{tW}\epsilon^B_{tW}(BR)}{\sigma_{t\bar{t}}\epsilon^B_{t\bar{t}}(BR)}} \times \frac{\epsilon^T_{t\bar{t}}(BR)}{\epsilon^B_{t\bar{t}}(BR)} + \frac{1}{1+\frac{\sigma_{t\bar{t}}\epsilon^B_{t\bar{t}}(BR)}{\sigma_{tW}\epsilon^B_{tW}(BR)}} \times \frac{\epsilon^T_{tW}(BR)}{\epsilon^B_{tW}(BR)}\right] + N^T_{bck}$$

PROS

- Correlated uncertainties highly reduced in the efficiency ratios
- Impact of integrated luminosity confined to non top-background
- V+ 5 jets yield uncertainties have limited impact because of cancellations
- $t\bar{t}$ and tW cross section uncertainties confined to subdominant terms
- Dominant uncertainty remains in $t\bar{t}$ tight-to-basic efficiency ratio

QCD ESTIMATE

QCD is calculated using a data-driven approach:

$$N_{QCD} = R(N^{anti-iso}_{data} - N^{anti-iso}_{non-QCD})$$

1. A control region where isolation criteria are inverted is defined: such a selection is called "anti-isolated"

2. Electroweak, single top and $t\bar{t}$ yields (estimated from MC) are subtracted from data

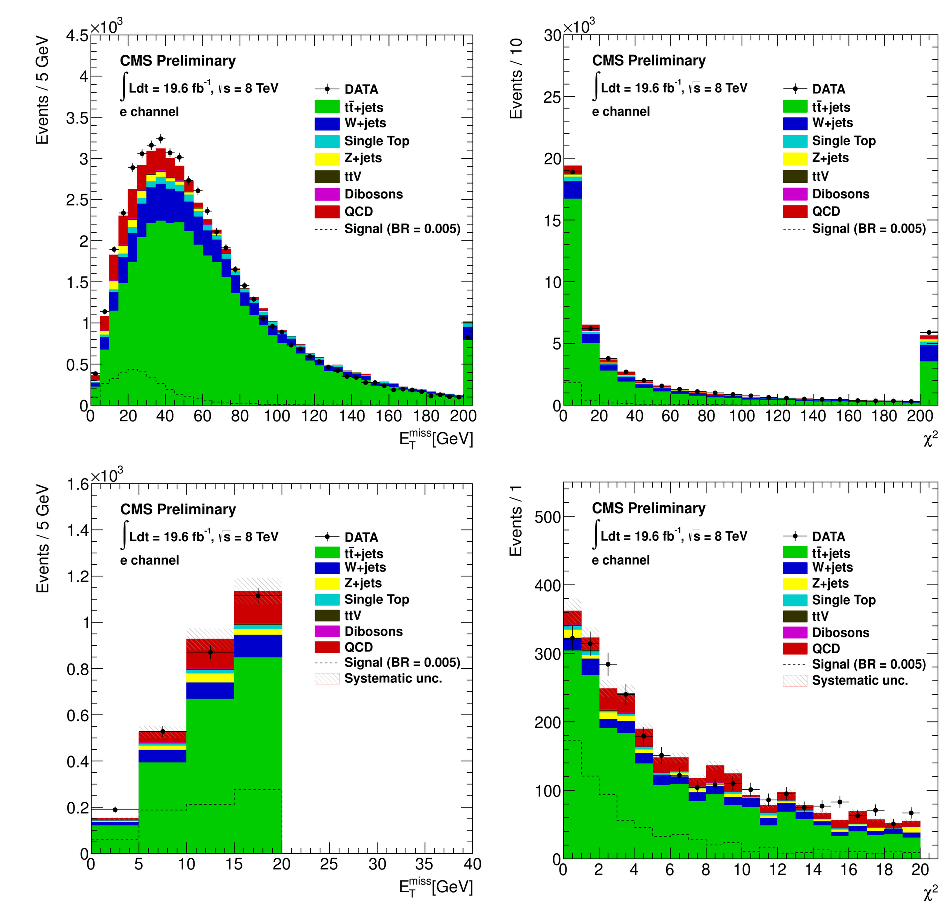
3. R is calculated as *f/(1-f)*, being *f* the probability to reconstruct a genuine jet as an isolated lepton, which is estimated from data

RESULTS

Electron Analysis

Dataset	Cross Section (pb)	Basic	Corrected basic	Tight
$t\bar{t}$	234	36500 ± 7100	38200 ± 3800	2030 ± 200
$W + jets$	37500	6500 ± 3300	6500 ± 3300	240 ± 120
$Z + jets$	3500	760 ± 380	760 ± 380	85 ± 45
tW	22.2	1120 ± 190	1170 ± 180	37.3 ± 7.5
$t-channel$	87.1	230 ± 120	230 ± 120	6.6 ± 3.6
$s-channel$	5.55	27 ± 14	27 ± 14	0.70 ± 0.50
WW	54.8	78 ± 39	78 ± 39	3.7 ± 2.0
WZ	33.2	45 ± 23	45 ± 23	2.1 ± 1.1
ZZ	17.7	11.1 ± 5.6	11.1 ± 5.6	1.40 ± 0.70
$t\bar{t}W$	0.23	132 ± 66	132 ± 66	6.3 ± 3.2
$t\bar{t}Z$	0.17	86 ± 43	86 ± 43	4.4 ± 2.2
QCD	-	2900 ± 1400	2900 ± 1400	330 ± 160
Total exp.	-	48300 ± 9500	50108 ± 220	2740 ± 140
Data	-	50108 ± 220	50108 ± 220	2703 ± 52

Electron analysis (Table): cross-sections, expected and observed yields in the basic and tight selection for BR = 0. The reported uncertainties are statistical plus systematic.

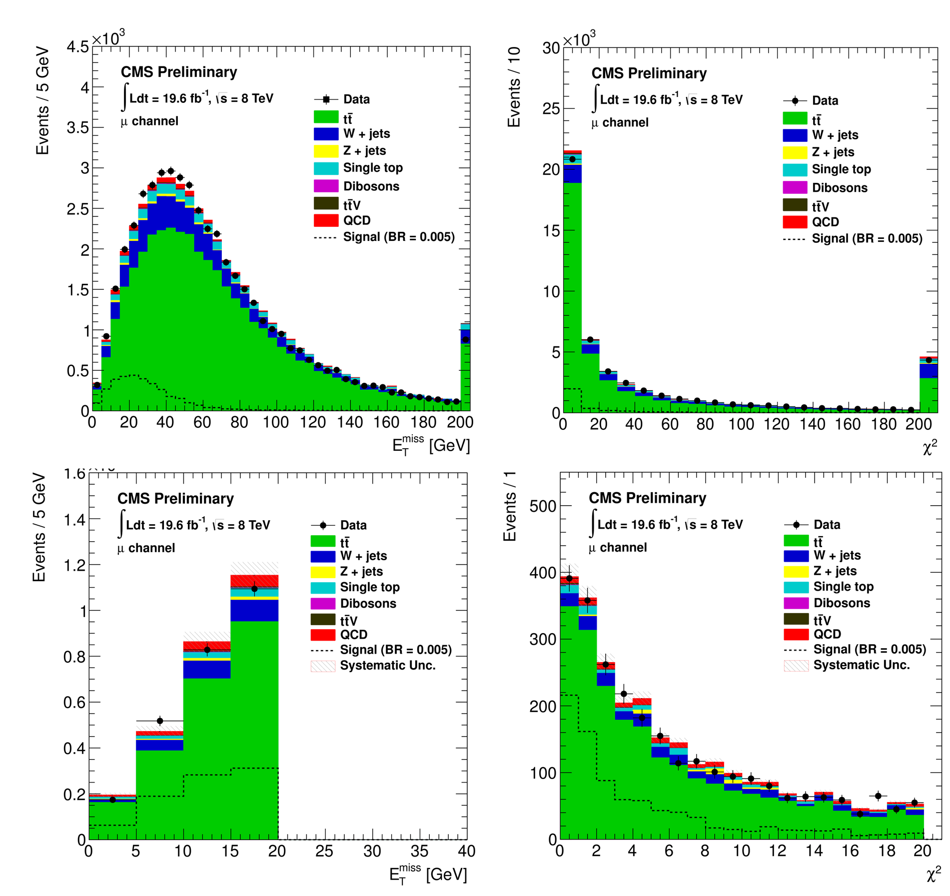


Electron analysis (Figure): distribution of E_T^{miss} (left) and χ^2 (right). Observations and SM expectations for the corrected basic (top) and tight (bottom) selection.

Muon Analysis

Dataset	Cross Section (pb)	Basic	Corrected basic	Tight
$t\bar{t}$	234	37100 ± 7800	38600 ± 3900	2200 ± 270
$W + jets$	37500	6300 ± 3200	6300 ± 3200	230 ± 120
$Z + jets$	3500	380 ± 190	380 ± 190	32 ± 18
tW	22.2	1160 ± 250	1210 ± 240	51 ± 11
$t-channel$	87.1	250 ± 130	250 ± 130	5.7 ± 3.0
$s-channel$	5.55	32 ± 16	32 ± 16	0.85 ± 0.52
WW	54.8	87 ± 43	87 ± 43	3.1 ± 1.7
WZ	33.2	41 ± 21	41 ± 21	1.43 ± 0.78
ZZ	17.7	5.6 ± 2.8	5.6 ± 2.8	0.50 ± 0.28
$t\bar{t}W$	0.23	129 ± 64	129 ± 64	6.0 ± 3.0
$t\bar{t}Z$	0.17	79 ± 40	79 ± 40	4.2 ± 2.1
QCD	-	790 ± 550	790 ± 550	118 ± 59
Total exp.	-	46000 ± 10000	47951 ± 220	2660 ± 140
Data	-	47951 ± 220	47951 ± 220	2614 ± 51

Muon analysis (Table): cross-sections, expected and observed yields in the basic and tight selection for BR = 0. The reported uncertainties are statistical plus systematic.



Muon analysis (Figure): distribution of E_T^{miss} (left) and χ^2 (right). Observations and SM expectations for the corrected basic (top) and tight (bottom) selection.

In both muon and electron analyses the observed yield in the tight selection agrees with the SM expectations.

LIMITS

The Upper limit on BR at 95% CL is obtained with the Feldman-Cousins approach [6].

	95% CL Upp. lim.	Exp. lim.	68% exp. lim. range
Muon ch.	0.0016	0.0029	[0.0017, 0.0042]
Electron ch.	0.0017	0.0031	[0.0018, 0.0045]
Combined	0.0015	0.0029	[0.0016, 0.0042]

The combined results of the muon and electron channels are obtained by maximising the product of the two likelihood functions, assuming a common value of BR for the two channels.

References:

[1] CMS Collaboration, "Search for baryon number violating top quark decays at s = √8 TeV", CMS Physics Analysis Summary CMS-PAS-B2G-12-023, (2013)

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[4] A. D. Sakharov, "Violation of CP in variance, C asymmetry, and baryon asymmetry of the universe", Soviet Physics Uspekhi 34 (1991) 392.

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