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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 pp collisions produced by the LHC at $\sqrt{s} = 8$ TeV [1]. 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. The event selection is optimised for top quarks produced in pairs, with one having the baryon-number violating decay and the other the standard model hadronic decay to three jets. No significant excess of events over the expected yields from standard model 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 the muon and the electron analyses, respectively.

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1. Motivations

In the Standard Model (SM) Baryon Number is a conserved quantity. Nevertheless Baryon Number Violation (BNV) is a necessary condition for the observed asymmetry between matter and antimatter in the universe [3] adn slight violations can even arise from both non-perturbative SM effects [4] and from scenarios of Physics beyond the SM. However, no BNV processes have been observed so far. In this analysis [1] we search for evidence of BNV top decays in $t\bar{t}$ final states, where one top decays into three jets and the other undergoes a BNV decay of the type $t \to bc\mu^-$ or $t \to bce^-$ (as proposed by [5]). This search has been performed using 19.6 fb^{-1} of pp collisions data at $\sqrt{s} = 8$ TeV collected in 2012 by CMS Experiment [2].

2. Analysis Strategy

A counting experiment has been setup to reduce the complexity of the analysis and keep it as model independent as possible. The observed yield, calculated in a region where the presence of the signal is enhanced, is compared to the expected one.
First, non-top background is reduced, requiring one isolated muon (electron) with $p_T > 20$ (30) GeV/c in $|\eta| < 2.4$ (2.5), plus five jets with $p_T > 30$ GeV (the three leading jets having $p_T > 70, 55, 40$ GeV/c), of which at least one of these is b-tagged. A veto on the presence of further leptons is also applied.
For each assumed value of BR the number of expected $t\bar{t}$ and tW events in this region (which is called "basic") is scaled such that the total expected yield is normalized to the number of observed events. A further selection (called "tight") is applied on top of the basic selection, to enhance the presence of the signal: all the events with $E_T^{miss} < 20$ and $\chi^2 < 20$ are retained, being χ^2 variable defined as

$$\chi^2 = \sum \frac{(x_i - \bar{x}_i)^2}{\sigma_i^2} \tag{2.1}$$

The x_i variables respectively stands for the reconstructed mass of hadronic top, BNV top and W boson, being $\bar{x}_i$ and σ_i the mean and the standard deviation of the gaussian fit of x_i distributions. The expected yield in the tight selection (N^T_{exp}) can be expressed as a function of the total observed yield in basic (N^B_{obs}), the expected non-top yield in the basic selection (N^B_{bck}), the expected non-top yield in the tight selection (N^T_{bck}), $t\bar{t}$ and tW cross section ($\sigma_{t\bar{t}}$ and $\sigma_{t\bar{W}}$) and the efficiencies ε^B (ε^T) for $t\bar{t}$ and tW to pass the basic (tight) selection, which are both function of branching ratio (BR):

$$N^T_{exp} = \left(N^B_{obs} - N^B_{bck}\right) \times \left[\frac{1}{1 + \frac{\sigma_{tW}\varepsilon^B_{tW}(BR)}{\sigma_{t\bar{t}}\varepsilon^B_{t\bar{t}}(BR)}} \times \frac{\varepsilon^T_{t\bar{t}}(BR)}{\varepsilon^B_{t\bar{t}}(BR)} + \frac{1}{1 + \frac{\sigma_{t\bar{t}}\varepsilon^B_{t\bar{t}}(BR)}{\sigma_{tW}\varepsilon^B_{tW}(BR)}} \times \frac{\varepsilon^T_{tW}(BR)}{\varepsilon^B_{tW}(BR)} \right] + N^T_{bck} \tag{2.2}$$

The presence of the efficiency ratios in Equation 2.2 strongly reduces contributions of correlated uncertainties; the impact of luminosity, as well as V+5 jets cross section uncertainties, is confined to non-top background; remarkably $\sigma_{t\bar{t}}$ and $\sigma_{t\bar{W}}$ are confined to subdominant terms, while dominant uncertainty remains in $t\bar{t}$ to tW efficiency ratio.
In this approach all the SM contributions are computed from simulation, whereas $t\bar{t}$, tW, and the QCD multi-jet background are calculated using data-driven methods.

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3. Results

In both muon and electron analyses no significant excess has been observed over the SM expectation for events with one isolated lepton and five jets. In Figure 1 the distribution of E_T^{miss} in tight selection is shown for both channels. An observed upper limit on BR at 95% CL has been computed using a Feldman-Cousins approach [6] for muon and electron channels and for their combination, assuming in this case a common value of BR. The observed upper limit for muon (electron) channel has been found to be 0.0016 (0.0017) while the combined limit, which has been obtained maximizing the product of muon and electron likelihood, has been calculated to be 0.0015.

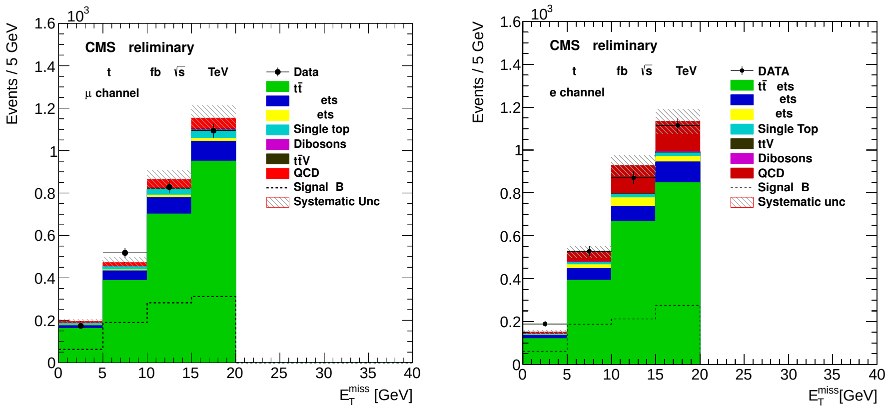

Figure 1: Distribution of E_T^{miss} for muon (left) and electron channel (right) in tight selection. The gray band in the distribution corresponds to the relative systematic uncertainty in the total expected yield. The signal contribution expected for $BR = 0.005$ has been overlayed.

References

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