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# Search for s channel single top-quark production in 8 TeV pp collisions

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Results of the search for single top-quark production in the *s* channel in pp collisions at a center-of-mass energy of 8 TeV by the CMS experiment at the LHC is presented. Leptonic decay modes of top quarks with an electron or muon in the final state are considered. In order to separate the expected signal from the background processes, a multivariate discriminant is defined using Boosted Decision Trees (BDT). For signal extraction a maximum-likelihood fit is performed on the distribution of the BDT discriminant. This analysis leads to an upper limit on the cross section of 11.5 pb, corresponding to 2.1 times the standard model cross section, at 95% Confidence Level.

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## 1. Introduction

In the proton proton collisions at CERN LHC, top quarks are produced mainly in pair through the strong interactions. Single top quarks are produced in electroweak interactions, see figure 1, hence the study of single top quark in three different production mechanisms allows probe of this sector of standard model (SM) of particle physics. All the single top quark production channels provide a direct measurement of the Cabibbo-Kobayashi-Maskawa (CKM) matrix element $V_{\mathrm{tb}}$. Beside that, the *s* channel is very sensitive to new physics involving a non-SM mediator, such as a W′ or a charged Higgs boson.

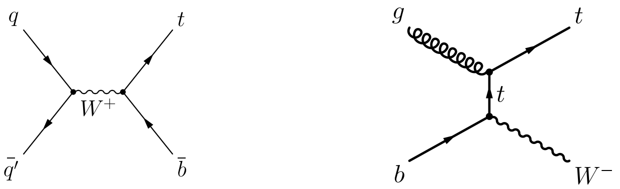


**Figure 1:** Leading order Feynman diagram for single top quark production in *s* channel (left), W-associated or "tW" (middle), and *t* channel (right).

The first observation of single top quark production in the *s*+*t* channel was reported by the CDF and D0 collaborations in 2009, while the *s* channel observation was announced through the combination of CDF and D0 data in 2014. The *s* channel production is suppressed in proton-proton collisions, and the SM prediction at $\sqrt{s} = 8\,\mathrm{TeV}$ is about 5.6 pb [1].

This work is dedicated to the search for single top quark production in the *s* channel at the CMS experiment. Leptonic decay modes of the top quarks are considered, where the W boson produced in the top quark decay, further decays into a muon or electron and a corresponding neutrino. This measurement is performed on LHC pp collision data at the center-of-mass energy of 8 TeV, collected by the CMS detector during 2012 and corresponding to an integrated luminosity of $19.3\,\mathrm{fb}^{-1}$[2].

## 2. Event Selection And Reconstruction

The final-state topology in the *s* channel is characterized by the presence of exactly one isolated muon or electron and two b quarks, one from the top-quark decay and one recoiling against the top quark. Events with exactly one electron or muon with $p_{\mathrm{T}}$ above 30 GeV/*c* and 26 GeV/*c* respectively, are selected for the analysis. Lepton relative isolation, which is defined as the ratio of transverse energy sum deposited in a cone with size of 0.4 (0.3) around muon (electron) and its $p_{\mathrm{T}}$, is required to be $I_{\mathrm{rel}} < 0.12$ $(0.1)$.

The analysis considers jets within $|\eta| < 4.5$ with $p_{\mathrm{T}}$ greater than 40 GeV/*c* for two most energetic jets and 30 GeV/*c* for the rest. In order to identify the jets stemming from b quarks, the track counting algorithm in tight working point is used. The missing transverse energy of the event, $E\!\!\!/_{\mathrm{T}}$, is assumed as transverse momentum of the escaping neutrino, and the z component of the neutrino momentum is calculated with a W-mass constraint. The top quark candidate of the event is reconstructed from the lepton, the missing energy, and the b jet which provides the top candidate with the invariant mass closest to 172.5 GeV/$c^2$. The efficiency of association of the correct b jet to the top quark is 74% in *s* channel.

Henceforth we will use the notation: “N-jets M-tags” to refer to a sample that has N reconstructed jets, M of which pass the b-tag requirement. Notable samples which are used in this analysis are the 2-jets 2-tags (*s* channel enriched) and the 3-jets 2-tags, enriched with $t\bar{t}$ events.

## 3. QCD Extraction

The event yield of multijet QCD events in signal and control samples is estimated performing a fit to the distributions of the transverse W-boson mass in the muon channel and the $\not{E}_{\mathrm{T}}$ in the electron channel (see figure 2). The shape of QCD distribution is obtained from a QCD-enriched region in data defined by inverting the lepton isolation criteria. An extra cut on $\Delta R_{(lepton,jet)} > 0.3$ is applied here to ensure that the lepton does not come from the jet. Shapes for other contributions are taken from simulation. To reduce the QCD contribution in the signal sample and to constrain the uncertainty on its estimation, we divide both the 2-jets 2-tags and the 3-jets 2-tags categories in two, based on the lepton relative isolation, using $I^0_{\mathrm{rel}} = 0.04$ and 0.06, for electrons and muons respectively. The QCD-depleted region finally used in signal extraction is $I_{\mathrm{rel}} < I^0_{\mathrm{rel}}$, and the QCD-enriched region for the QCD extraction fit is $I_{\mathrm{rel}} > I^0_{\mathrm{rel}}$.

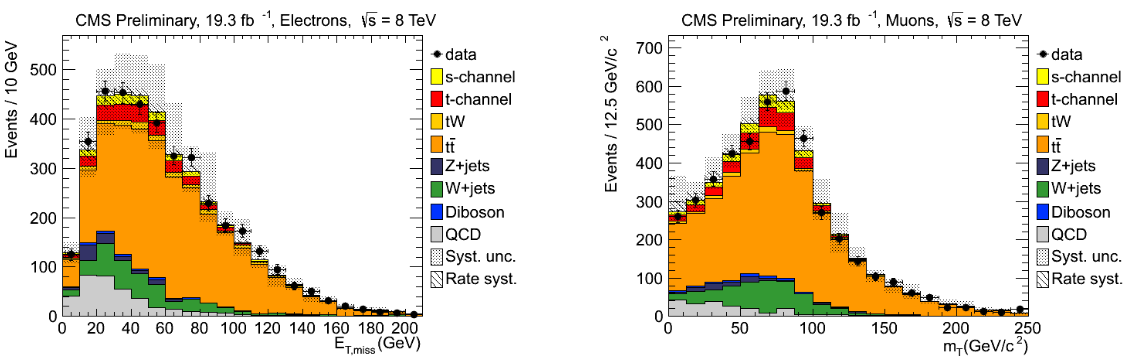


**Figure 2:** QCD extraction by fitting distributions of $\not{E}_{\mathrm{T}}$ for electrons (left) and transverse mass of W-boson for muons (right)

QCD yields are extracted from the maximum-likelihood fits in the QCD-enriched regions, extrapolated to the signal regions. The difference in QCD estimation that corresponds to a variation by 20% of the other backgrounds is considered as an additional systematic uncertainty, which is added quadratically to the statistical uncertainty of the fit.

## 4. Discrimination Of Signal And Backgrounds Using Multivariate Analysis

To profit from the most discriminating power between signal and backgrounds, it has been chosen to use multivariate classification approach, in particular Boosted Decision Trees (BDT). Two independent BDT are trained in the 2-jets 2-tags and 3-jets 2-tags categories to separate signal from backgrounds and $t\bar{t}$ from the other contributions respectively.
Transverse W-boson mass, $\Delta\Phi_{(top,recoiled-b)}$ and missing transverse energy are the highest ranked variables for electrons. For muons they are $p_{\mathrm{T}}$ of two b jets, invariant mass of reconstructed top and transverse W-boson mass.

## 5. Results

Signal extraction is performed using a binned maximum-likelihood fit to the BDT distributions in the 2-jets 2-tags and 3-jets 2-tags categories simultaneously (figure 3). Combining electron and muon channels, the 68% CL interval on the *s* channel inclusive production cross section has been determined using the Feldman-Cousins unified approach [3], to avoid negative cross section values:

$$\sigma_{sch.}\ (combined) = 6.2^{+8.0}_{-5.1}\ pb$$

The observed/expected significance of the measurement is 0.7/ 0.9 standard deviations.

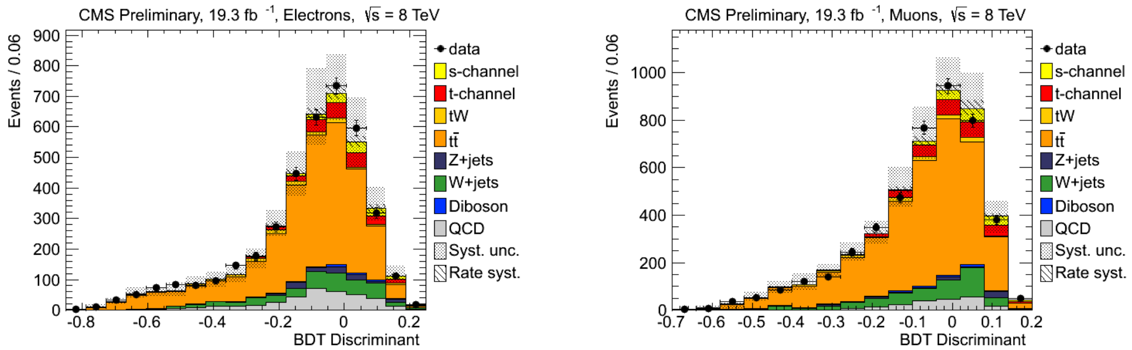


**Figure 3:** Data-simulation comparison for the distributions of the BDT discriminator in the 2-jets 2-tags sample: electron channel(left) muon channel (right). The simulation is normalized to the fit results.

The 68% CL interval for the expected significance is [0.0,1.9]. Using a Bayesian approach, the observed and expected upper limits on the *s* channel cross section, the latter quoted as "(SM signal, background-only)", are evaluated. The upper limit at 95% CL is 2.1 (3.1, 1.6) times the SM cross section, which corresponds to 11.5 (17.0, 9.0) pb.

Effects from different sources of instrumental and theoretical uncertainties are taken into account as systematic uncertainty for this result. The dominant systematic uncertainty in this analysis is the jet energy scale and factorization and renormalization scale with 83% and 53% relative shift in signal strength, respectively. The uncertainties coming from the different systematic sources are combined together according to [4].

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## References

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