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First observation of W associated single top (tW) production in proton-proton collisions at 8 TeV

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The first observation of the associated production of a single top quark and a W boson in proton-proton collisions at $\sqrt{s}$ = 8 TeV with the CMS experiment at the LHC is presented. The data correspond to an integrated luminosity of 12.2 fb^{-1}. The measurement is performed using events with two leptons and a jet originated from a b quark. A multivariate analysis based on kinematic properties is used to separate the signal from the $t\bar{t}$ background. The signal is observed with a 6.0 standard deviation excess above a background only hypothesis. A production cross section of $23.4^{+5.5}_{-5.4}$ pb is measured, in agreement with the standard model expectation of 22.2 ± 1.5 pb.

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1. Observation of W associated single top production

1.1 Introduction

While top quarks are predominantly produced in pairs via the strong interactions in pp collisions, they can also be produced singly via electroweak interactions, involving a Wtb vertex. Because of its interference with top quark pair production, its sensitivity to new physics and its role as a background to several SUSY and Higgs searches, the associated production of a single top and a W boson (tW) production is a particularly interesting mechanism and its production cross section represents a significant contribution to single-top-quark production at the LHC. This analysis presents the first observation of tW production [2] with a significance of at least 5 σ above the background only hypothesis in pp collisions at $\sqrt{s} = 8$ TeV with the Compact Muon Solenoid [1].

1.2 Analysis Strategy

The analysis is performed using the dilepton final states, in which both W bosons (the one produced in association with the top quark, and the one from the decay of the top quark) decay leptonically into a muon or an electron, and a neutrino. This leads to a final state composed of two oppositely charged isolated leptons, a jet resulting from the fragmentation of a b quark, and missing transverse energy (E_T^{miss}) due to the two escaping neutrinos. The primary background to tW production in this final state is $t\bar{t}$ production, with Z/γ^* events being the next most significant.

Events with exactly two oppositely charged, isolated leptons are selected. Low mass dilepton resonances and $Z \to \ell\ell$ in the same-flavor final states events are suppressed using selection criteria based on the invariant mass of the dilepton system ($m_{\ell\ell}$) and E_T^{miss}.

For events passing this selection, a region rich in signal (signal region) and two regions dominated by background (control regions) are defined. The signal region contains events with exactly one jet passing the selection requirements, which is b-tagged (1j1t region). Two control regions enriched in $t\bar{t}$ background are defined as having exactly two jets with either one or both b-tagged (2j1t and 2j2t regions, respectively). After the selection, the simulated samples in the 1j1t signal region contain predominantly tW and $t\bar{t}$ events (comprising 16% and 76% of the events, respectively), with a smaller contribution from Z/γ^* events (6%). The two control regions are dominated by top quark pair production events.

In order to separate the tW signal from the $t\bar{t}$ background a boosted decision trees (BDT) analyzer is trained using several kinematic variables, the most powerful being those involving extra jets in the event that fail the jet selection criteria. The BDT analyzer provides a single discriminant value for each event. The distributions of the BDT discriminant in data and simulation are shown in Fig. 1 for a combination of all three final states in the 1j1t, 2j1t, and 2j2t regions.

1.3 Results

A simultaneous binned likelihood fit to the BDT distributions of the three final states in the three regions is performed, including nuisance parameters for all the systematic uncertainty sources. Templates for the shapes of signal and background distributions are taken from simulation. Using four billion pseudo-experiments we observe an excess of events above the expected background with a significance of $6.0\,\sigma$, compared to an expected significance from simulation

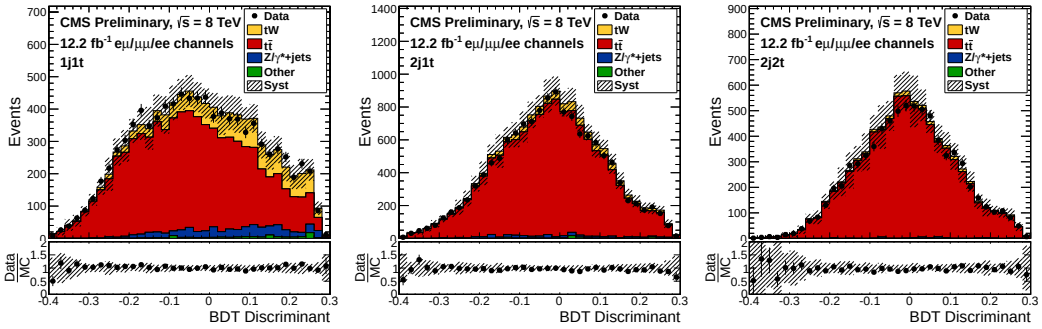

Figure 1: The BDT discriminant, in the signal region (1j1t) and control regions (2j1t and 2j2t) for all final states combined. Shown are data (points) and simulation (histogram). The hatched band represents the combined effect of all sources of systematic uncertainty.

of $5.4^{+1.5}_{-1.4}\,\sigma$. A profile likelihood method is used to determine the signal cross section and 68% confidence level interval. The measured cross section is found to be $23.4^{+5.5}_{-5.4}$ pb, in agreement with the predicted SM value of $22.2 \pm 0.6 \pm 1.4$ pb.

The cross section measurement is used to determine the absolute value of the Cabibbo-Kobayashi-Maskawa matrix element $|V_{\rm tb}|$, assuming $|V_{\rm tb}| \gg |V_{\rm td}|$ and $|V_{\rm ts}|$:

$$|V_{\rm tb}| = \sqrt{\frac{\sigma_{\rm tW}}{\sigma^{\rm th}_{\rm tW}}} = 1.03 \pm 0.12\ ({\rm exp.}) \pm 0.04\ ({\rm th.})$$

where $\sigma^{\rm th}_{\rm tW}$ is the theoretical prediction of the tW cross section assuming $|V_{\rm tb}| = 1$, and the uncertainties are separated into experimental and theoretical values. Using the SM assumption of $0 \leq |V_{\rm tb}|^2 \leq 1$, a lower bound on $|V_{\rm tb}|$ at a 95% CL of $|V_{\rm tb}| > 0.78$ is found using the approach of Feldman and Cousins.

Two additional cross-check analyses, based on the event selection above, are conducted: one performing a fit to the $p_{\rm T}^{\rm sys}$ distribution, the other using a cut and count approach. The results from both cross-check analyses are consistent with the multivariate one within uncertainties.

2. Conclusions

The production of a single top quark in association with a W boson is observed in the dilepton decay channel in pp collisions at $\sqrt{s} = 8$ TeV [2]. An excess of events above a background-only hypothesis is observed with a significance of 6.0σ. The cross section is measured to be $23.4^{+5.5}_{-5.4}$ pb, in agreement with the standard model prediction [3].

References

[1] CMS Collaboration,*The CMS experiment at the CERN LHC*, JINST 03 (2008) S08004, doi:10.1088/1748-0221/3/08/S08004.

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[3] N. Kidonakis, *NNLL threshold resummation for top-pair and single-top production*, arXiv:1210.7813