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The Compact Muon Solenoid Experiment

Conference Report

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Abstract

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Towards a simultaneous measurement of the top quark mass and decay width with single top quark events at CMS

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Abstract

We report a precise measurement of the mass of the top quark in the t-channel, which is the most dominant production process for single top quarks at the LHC. The final state comprises a top quark along with a light quark, giving rise to at least two jets, of which one arises from the hadronization of a b-quark, an isolated high-momentum lepton (electron or muon), and a large missing transverse momentum due to an escaping neutrino from the W boson decay. The study uses proton-proton collision data recorded by the CMS experiment during 2016 at $\sqrt{s}$ = 13 TeV. Dominant standard model backgrounds are studied in complementary regions defined based on the number of b- and light-quark jets in the final state. A multivariate technique that relies on boosted decision tree and deep neural networks is deployed to separate signal from backgrounds. The top-quark mass is reconstructed using kinematic information from the W boson and the b jet. We obtain the top quark mass from a fit and investigating further to study a simultaneous measurement of mass and width.

1 Introduction

A precise measurement of the top quark mass and decay width is of profound importance, being important parameters of the standard model (SM) and for the self-consistency check for the SM. The top quark mass is also directly related to the stability of the electroweak vacuum because it is the largest contributor among all elementary particles in terms of radiative corrections to the mass of the Higgs boson. Due to its large mass, it has a unique property of decaying preferentially to b-quark and W boson before it can hadronise. If the measured top quark decay width deviates from its expected value, it would provide the signature of the beyond-SM particles. The four-momentum of the top quark (and hence its mass) is reconstructed from that of its decay products: the charged lepton, the neutrino, and the b-tagged jet. This document summarise the precision management of the top quark mass with partial Run-2 data collected during 2016 and an updated measurement for the top quark mass and its decay with which is underway.

2 Event categories and QCD estimation

Events are selected by requiring at least one isolated lepton, a large missing momentum due to the escaping neutrino, and exactly two jets, of which one must be a b-tagged jet. The event categories are defined according to the number of total jets J and b-tagged jets T (nJmT) in the final state. The 2J1T category is the largest contributor to t-channel signal events. QCD templates are derived from sideband data for each event category separately. For the top quark mass measurement in the t-channel process [1], the QCD contribution in the signal region is estimated by means of a two-component, namely the QCD and nonQCD, maximum-likelihood fit to the binned distribution of transverse mass (m_{T}) of the charged lepton and neutrino system, as shown in Fig. 1. To reject the QCD contribution, $m_{\mathrm{T}} > 50$ GeV is required for further analysis.

3 Machine learning techniques

A number of kinematic variables are combined into a multivariate technique, called boosted decision tree (BDT), to optimally separate single top quark events from back-

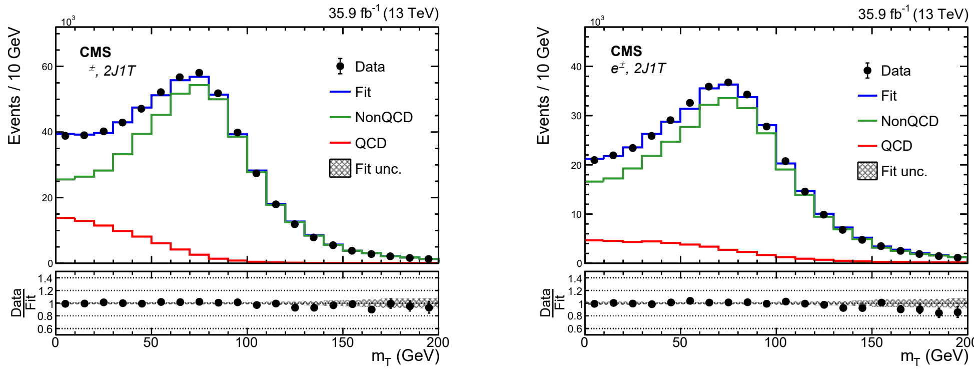

Figure 1: Postfit distributions of m_{T} for the muon and electron final states.

grounds for the top quark mass measurement. The receiver-operator-characteristic (ROC) curve, as shown in Fig. 2 (top left) has an area of 0.16 between the ROC curve and the horizontal axis. A criterion on the BDT response has been applied, which results in 64% (58%) signal purity for the muon (electron) final state. The updated measurement of top quark mass and width uses a deep neural network (DNN) to separate correctly reconstructed signal from backgrounds as well as mis-reconstructed signal events. The area between the ROC curves and the horizontal axis for DNN, shown in Fig. 2 (bottom right), is smaller or equal to the BDT ROC curve.

4 Results and outlook

The distributions of $\zeta = \ln(m_{\mathrm{t}}/1\ \mathrm{GeV})$ obtained from the muon and electron final states are considered in a simultaneous maximum-likelihood fit. The distribution is described by a combination of parametric shapes, namely an asymmetric Gaussian core with a Landau tail, a Crystal Ball function [2], a Novosibirsk function [3] to model signal, top background, and electroweak background, respectively. The normalization for signal, $\mathrm{t\bar{t}}$ and electroweak background are constrained using log-normal priors with 15%, 6%, and 10% based on their respective cross-section results [4, 5, 6, 7]. The top quark mass is obtained from the postfit ζ distribution, as shown in Fig. 2, by taking the exponential of the postfit value of parameter of interest ζ_0 and is given by $m_{\mathrm{t}} = 172.13\,^{+0.76}_{-0.77}$ GeV [1], reaching a sub-GeV precision for the first time in such a phase space. The mass ratio and difference of the top antiquark to quark is determined to be $0.9952\,^{+0.0079}_{-0.0104}$ and $0.83\,^{+1.79}_{-1.35}$ GeV. This measurement dominated by

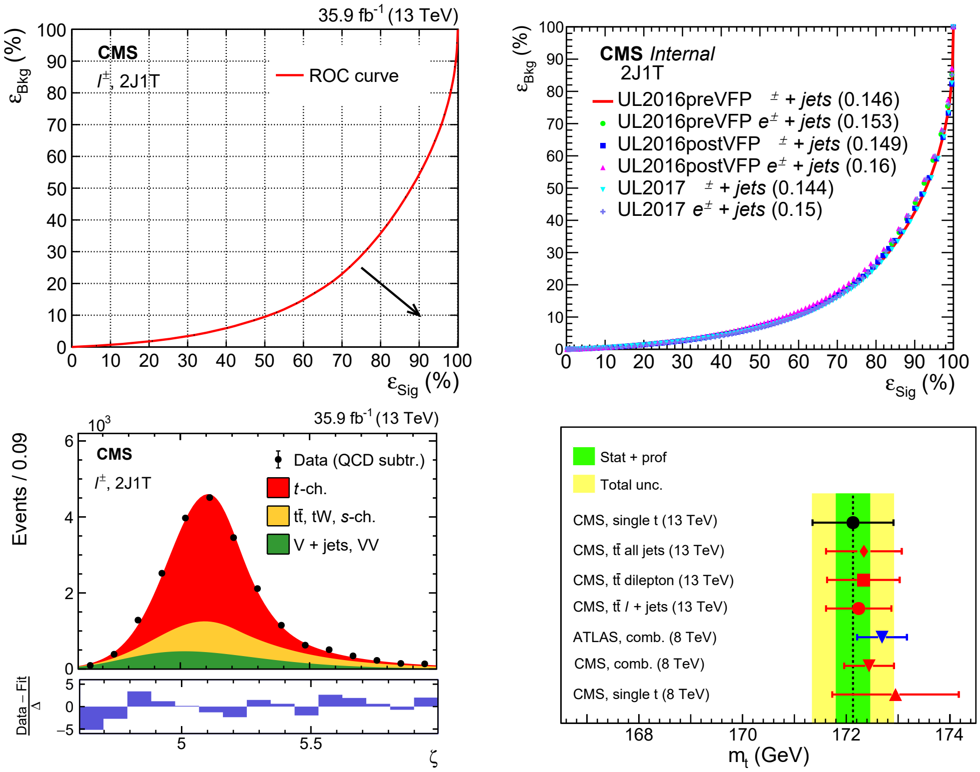

Figure 2: Combined BDT performance in terms of the ROC curve (top left), and overlay of the DNN ROC curves (top right) for different eras and lepton flavors. The ROC integral is shown in brackets in each era. Projections of fit (bottom left) result onto the $\zeta = \ln(m_t/1\ \text{GeV})$ distributions for signal and background processes compared to data. A comparison of measured m_t values (bottom right) from this analysis (black circle), with previous CMS [8, 9, 10, 11, 12] and ATLAS [13] results.

the jet energy scale and parton shower scale systematic uncertainties.

The new measurement of the top quark mass and decay width with CMS data collected during year 2016, 2017 and 2018, is underway where a better methods is applied to extract QCD contribution in the both lepton final state. In this measurement the parametric fit will performed using the Higgs combine tool to float systematic uncertainties as nuisance parameters to constraint the these uncertainties in batter way.

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