PROCEEDINGS OF SCIENCE

Top quark mass measurements with CMS

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The top quark mass is a fundamental parameter of the Standard Model (SM). Precise measurements constrains important SM observables like the Higgs boson mass. The CMS experiment has performed several mesurements of the top quark mass with different techniques in order to have a better understanding and precision in that parameter. The results presented in this document, correspond to the latest measurements performing by CMS detector using data taken in 2010, 2011 and 2012 in pp collisions at the LHC.

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1. Introduction

The top quark mass (m_t) is experimentally defined by the position of the peak in the invariant mass distribution of its decay products (W boson and a b-quark jet). This closely corresponds to the pole mass of the top quark. m_t was measured for the first time at Tevatron[1] by analysing different decays modes. The average result obtained was $m_t = 173 \pm 18(\text{stat.}) \pm 0.75(\text{syst.})$. CMS experiment has performed several measurements of Standard Model processes and observables since the first pp collisions, being one of them the top quark mass. In this document we present the most relevant CMS results in the measurement of the top quark mass with different methods in the three decay modes: fully hadronic, semileptonic and fully leptonic.

2. CMS Experiment

The central feature of the CMS detector is a superconducting solenoid, 13 m in length and 6 m in diameter, which provides a magnetic field of 3.8 T. Inside of the bore of the solenoid are various particle detection systems. Charged particle trajectories are measured by the silicon pixel and strip subdetectors with an acceptance $0 < \phi < 2\pi$ in azimuth and $|\eta| < 2.5$, where the pseudorapidity η is defined as $\eta = -\ln\tan[\theta/2]$, with θ being the polar angle of the trajectory of the particle with respect to the anticlockwise beam direction. A lead tungstate crystal electromagnetic calorimeter (ECAL) and a brass/scintillator sampling hadronic calorimeter (HCAL) surround the tracking volume. Muons are measured using drift tubes, cathode strip chambers, and resistive plate chambers embedded in the flux-return yoke of the solenoid. The detector is nearly hermetic, allowing for p_T imbalance measurements in the plane transverse of the detector. A two-level trigger system selects the most interesting pp collision events for use in the different physics analysis. A detailed description of the CMS detector can be found in Ref.[2].

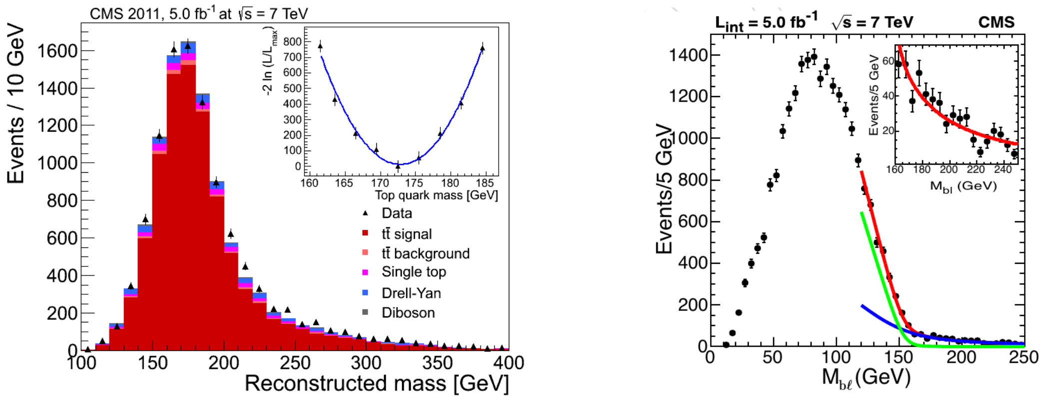
3. Decay Modes

3.1 Dilepton Channel

The reconstruction of the top decay in the dilepton channel is limited by the presence of two neutrinos which can not be detected, producing an underconstrained system. For each $\mathrm{t\bar{t}}$ event, the kinematic properties are fully specified by 24 parameters leaving one free parameter that must be constrained by using some hypotheses. The method used is an improvement of the *Matrix Weighting Technique (MWT)* wich fully constrain the $\mathrm{t\bar{t}}$ system. A weight was assigned to each mass hypothesis, selecting the one with the maximum weight (m_{AMWT}). A likelihood is computed for values of m_t between 161.5 and 184.5 GeV, from data in the range $100 < m_{AMWT} < 300\,\text{GeV}$. Figure 1 (a) shows the predicted distribution of the reconstructed m_{AMWT} for a simulated top quark with $m_t = 172.5\,\text{GeV}$ and the observed data. The obtained value in the dilepton channel is $m_t = 172.5 \pm 0.4(\text{stat.}) \pm 1.5(\text{syst.})\,\text{GeV}$.

3.2 Dilepton Channel: Kinematic Endpoints

The endpoint method of mass extraction is based on several variables that are designed for use in the kinematically complex environment of events with two cascade decays, each ending in



(a) (b)

Figure 1: (a) Distribution of the reconstructed mass in data and simulation for a top-quark mass hypothesis of 172.5 GeVwith the AMWT method. All events used in the analysis are included in the distribution. The inset shows $-2\ln(\mathscr{L}/\mathscr{L}_{max})$ versus m_t with the quadratic fit superimposed. (b) Results of the fit to m_t with the endpoints method, where the red line is the full fit, the green and the blue curves are for background and signal, respectively. Both plots are in the dilepton channel

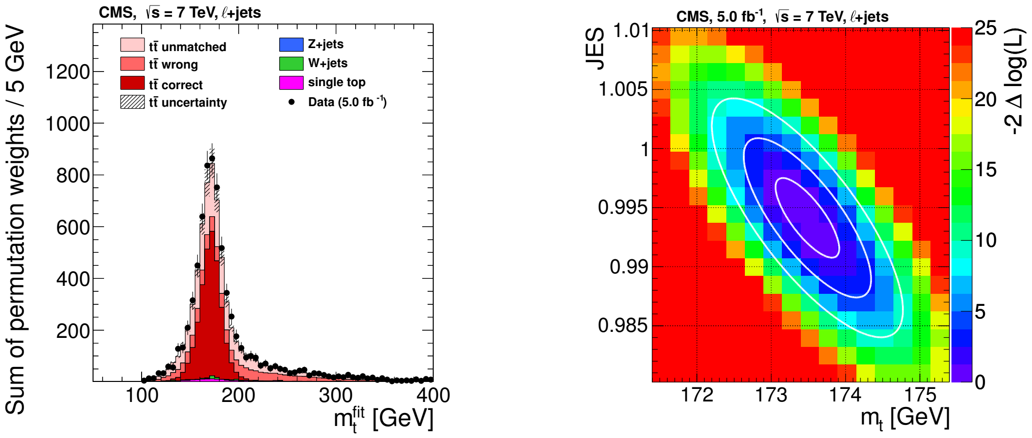
an invisible particle (two neutrinos in the dilepton case). The observables used is the M_{T2}, which is based on the transverse mass of a decay with two identical decay chains and missing particles. Figure 1 (b) shows the distribution of m_t and the corresponding fit to the end points. The value obtained is $m_t = 173.9 \pm 0.9(\text{stat.})^{+1.6}_{2.0}(\text{syst.})\,\text{GeV}$, comparable to other dilepton measurements. One of the most relevant constribution of the M_{T2} method is its possible use in future application to new-physics scenarios.

3.3 Single Lepton Channel

The final state in the single lepton channel consists of a lepton, four jets, and an undetected neutrino producing a constrained system. The analysis employs a kinematic fit of the decay products to a tt̄ hypothesis and two-dimensional likelihood functions for each event to estimate simultaneously both the top-quark mass and the jet energy scale (JES). Due to the precise knowledge of the W-boson mass from previous measurements [3] is possible to use the invariant mass of the two jets associated with the $W \to qq$ decay as an additional observable in the likelihood functions. Figure 2 shows the top quark mass distribution and the 2D likelihood over JES and m_t. The top quark mass measured with a 2D likelihood is $m_t = 173.32 \pm 0.43(\text{stat.} + \text{JES}) \pm 0.98(\text{syst.})\,\text{GeV}$, which is the most precise measurement provided by CMS at the moment.

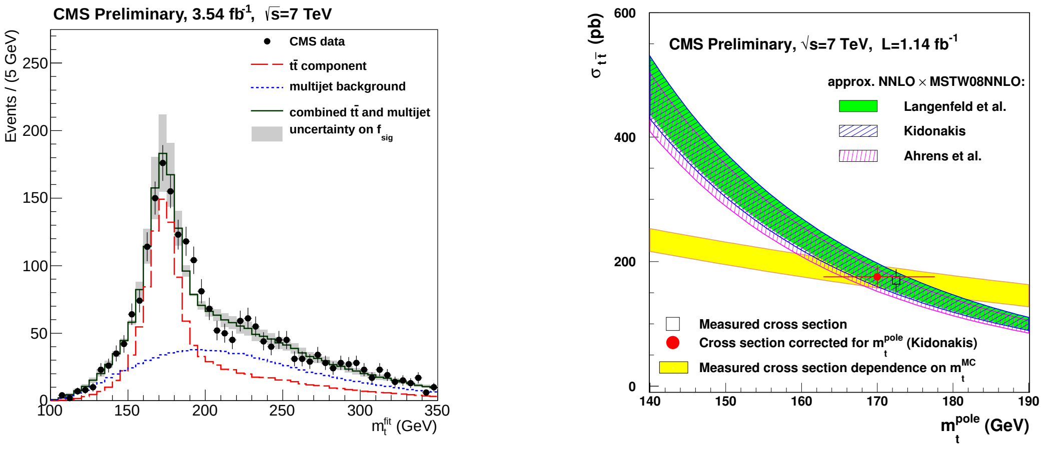
3.4 Hadronic Channel

It is possible to measure the mass of the top quark using a sample of tt̄ candidate events with at least six jets in the final state. Events are selected with at least four jets with $p_T > 60$ GeV, a fifth jet with $p_T > 50$ GeV, and a sixth jet with $p_T > 40$ GeV. In a similar way to the single lepton analysis, the m_t has been estimated with a fixed JES or simultaneously with the JES (2D method). The top quark mass value measured with a fixed JES is $173.49 \pm 0.69(\text{stat.}) \pm 1.25(\text{syst.})\,\text{GeV}$. This value has better precision than the 2D analysis. Figure 3 (a) shows the reconstructed top quark mass from the kinematic fit.



(a) (b)

Figure 2: (a) Fitted top quark mass from the kinematic fit after the goodness-of-fit cut in the single lepton channel. (b) the 2D likelihood measured on m_t and JES.



(a) (b)

Figure 3: (a) Reconstructed top quark mass from the kinematic fit in all jets channel. (b) tt̄ cross section obtained in the dilepton channel. Different approximate NNLO predictions are shown as a differently hatched bands.

4. Top Quark Mass from the Cross Section of tt̄ Production

The top quark mass can be extracted by comparing the measured inclusive tt̄ production cross section, $\sigma_{t\bar{t}}$, to fully inclusive calculations at high-order QCD that involve an unambiguous definition of m_t. This method to extract the m_t could be used as a test of the mass scheme applied in MC simulations and gives complementary information, with different sensitivity to theoretical and experimental uncertainties. In figure 3 (b) the measured $\sigma_{t\bar{t}}$ together with its dependence on the m_t^{MC} assumption and NNLO prediction are presented.

5. Summary

In summary, this document presents a brief description of the last analysis performed by CMS detector in the measurement of the top quark mass. The analysis have been performed with several techniques which provide a better understanding of the models, Monte Carlo simulations and systematic uncertainties involved in the m_t measurement.

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