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Measurement of the Top Quark Mass With 2012 CMS Data

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ABSTRACT

The mass of the top quark was an active topic of research at CMS using 2011 data, and remains so as the 2012 data analysis campaign proceeds. Here we discuss some of the earliest results on the top mass using 2012 $\sqrt{s} = 8$ TeV CMS data, including measurements of the top mass from semileptonic $t\bar{t}$ decays and the lifetime of the B -hadron, as well as a measurement of the top-antitop mass difference.

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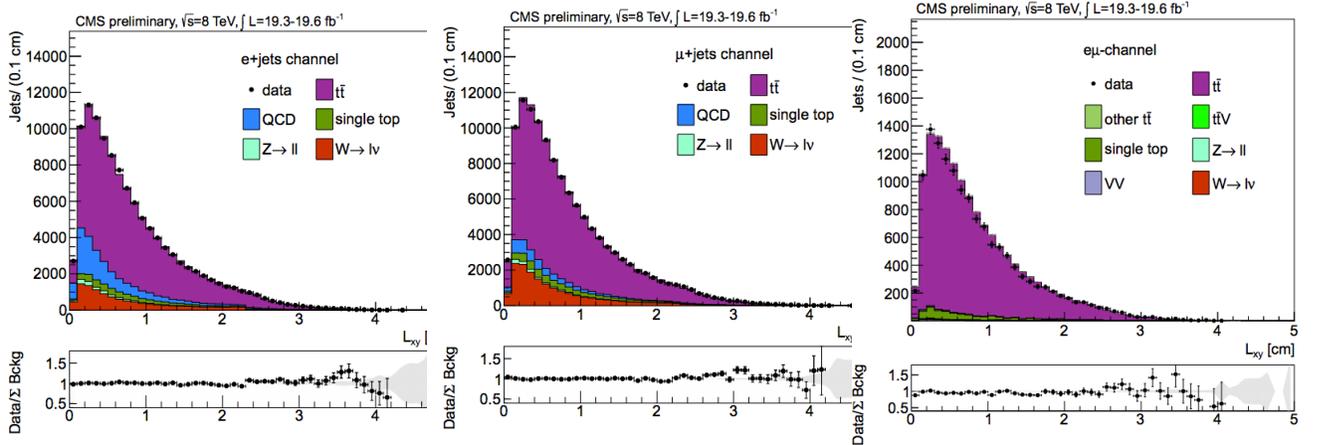
1 Introduction

The mass of the top quark is one of the nineteen empirical parameters of the Standard Model (SM), and is an active topic of research at CMS. The top mass is an input to global electroweak fits, and is linked by radiative corrections to the mass of the Higgs and W bosons, making its measurement crucial for understanding both SM and beyond SM physics. Combined 2011 CMS measurements of the top quark mass found $m_t = 173.36 \pm 0.38$ (stat.) ± 0.91 (syst.) GeV [1]. Here, we discuss several early measurements of or relating to the top mass using data collected in 2012 by the CMS detector, described in [2].

2 Measuring the Top Mass from B -Hadron Decays

In CKM-favored $t \rightarrow Wb$ decays, B hadrons are formed by the b -quark. In such events, it can be shown through an analysis of event kinematics that the decay length L_{xy} of this B hadron is directly proportional to m_t . In particular, $L_{xy} = \gamma_B \beta_B \tau_B \propto 0.4 \frac{m_t}{m_b} \beta_B \tau_B$ [3]. It was hence proposed to measure the top mass from distributions of L_{xy} in B -hadron decays as a supplement to more traditional measurement methods. Importantly, such an analysis uses information from CMS's tracker, instead of its calorimeter, and hence avoids systematics from the jet energy scale (JES), which dominate other measurements.

Two categories of events are examined: events with one charged lepton and at least four jets, and events with exactly one electron and one muon, with at least two jets; this gives a total of three channels (single electron, single muon, electron and muon). In each event that passes cuts, the largest L_{xy} associated with a secondary vertex is chosen. Distributions of L_{xy} are generated separately for each of the three channels. These distributions are shown in Figure 1.



(a) Distribution of L_{xy} in the e +jets channel. (b) Distribution of L_{xy} in the μ +jets channel. (c) Distribution of L_{xy} in the $e\mu$ +jets channel.

Figure 1: Distributions of L_{xy} in the three channels used in the analysis.

From event kinematics, we see that the mean \widehat{L}_{xy} of each of these distributions has a linear dependency on m_t ; the exact linear coefficient, however, is not given explicitly. Instead, the coefficients are found by calibrating the measurement independently in each channel. Monte Carlo (MC) distributions of L_{xy} are generated at several fixed values of the top mass; at each of these mass points, \widehat{L}_{xy} is found for each of the three channels. Lines are then fit to these three distributions of \widehat{L}_{xy} , providing the needed linear coefficients. With the linear dependencies calibrated, the top mass itself is extracted from the means of the distributions. The final measured value of the top mass is the best linear unbiased estimator of the combination of the results of the three channels, and is found to be $m_t = 173.5 \pm 1.5$ (stat.) ± 1.3 (syst.) ± 2.6 (p_T^t) GeV. The last uncertainty is derived from considering the distributions of top quark p_T in simulation, and dominates the result.

3 Measuring the Top Mass from Semileptonic $t\bar{t}$ Decays

A standard top mass measurement technique, known as the ideogram method, analyzes semileptonic $t\bar{t}$ decays, i.e. events with $t\bar{t} \rightarrow bWbW \rightarrow bl\nu b\bar{q}\bar{q}$. Events with exactly one charged lepton and at least four jets, with exactly two b -tagged jets among the four leading jets [4]. The mass m_W^{reco} of the W boson from the leptonic decay can be reconstructed directly from the measured energy and momenta of the two leading non- b -tagged jets. Meanwhile, a top mass estimator m_t^{fit} can be obtained from a kinematic fit to the leptonic decay products. Distributions of m_W^{reco} and m_t^{fit} are shown in Figure 2.

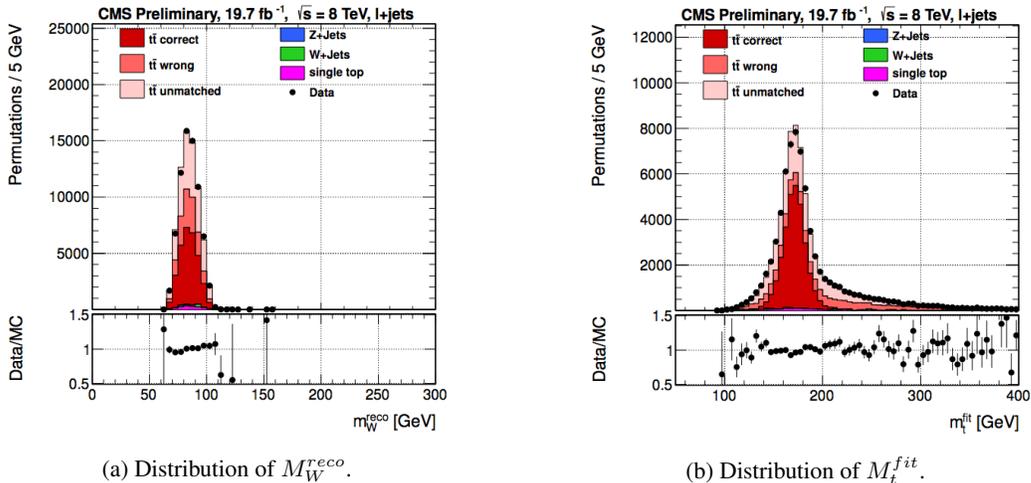


Figure 2: Distributions of m_W^{reco} and m_t^{fit} in data and simulation used in the ideogram measurement.

The ideogram method is a two-dimensional likelihood fit that simultaneously measures the top mass m_t and the jet scale factor (JSF), a scale factor applied to all simulation jet energies to account for the JES. In an ideogram measurement, a kinematic fit to each event yields a likelihood curve as a function of m_t and the JES; the measured m_t and JES are the global maxima of the product of all single-event likelihood functions. The measured likelihood contours are shown in Figure 3.

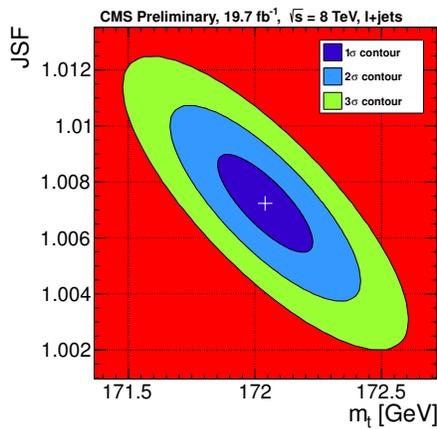
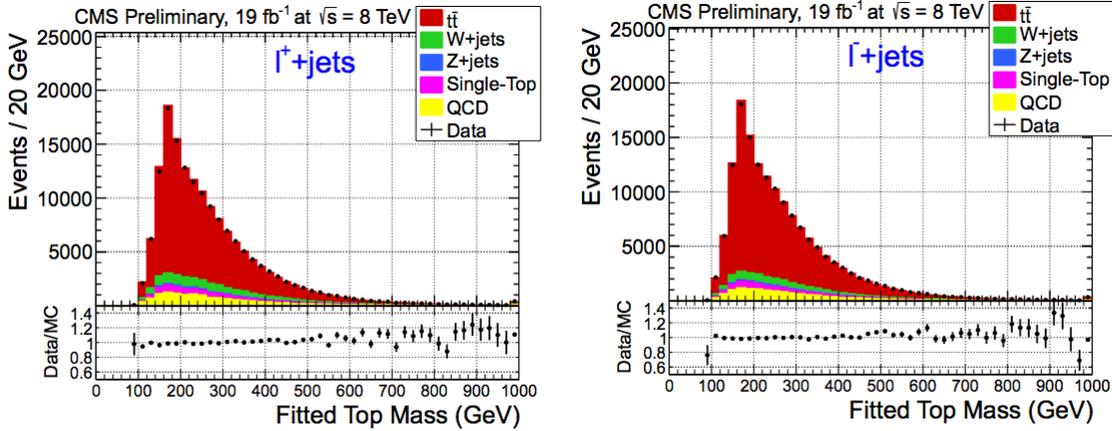


Figure 3: Two-dimensional likelihood contours in m_t -JES space.

The measurement finds $m_t = 172.04 \pm 0.19$ (stat + JSF) ± 0.75 (syst.) GeV, and $JSF = 1.007 \pm 0.002$ (stat.) ± 0.012 (syst.). This is the first single top mass measurement with sub-GeV uncertainty, and hence marks an important achievement.

4 Measuring the Top-Antitop Mass Difference

The ideogram method described above was also used to study the mass difference Δm_t between the top and antitop quarks. In the ideogram method's event selections, it is easy to distinguish between events where the top and antitop quarks decay leptonically; for instance, if a top quark decays leptonically, we will have a positively charged lepton. Events passing cuts in an ideogram analysis were separated by lepton charge, yielding the reconstructed mass distributions shown in Figure 4. An ideogram measurement was performed with the events in each of these two categories, and the results were subtracted to find the mass difference. The measurement found $\Delta m_t = -272 \pm 196$ (stat.) ± 122 (syst.) MeV, consistent with the Standard Model prediction.



(a) Reconstructed top masses in events with a positive lepton.

(b) Reconstructed top masses in events with a negative lepton.

Figure 4: Distributions of reconstructed top masses in semileptonic $t\bar{t}$ events segregated by lepton sign.

5 Conclusions

We have presented three top mass results using 2012 CMS data. From these results alone, we already see single measurements of the top mass that are competitive with world combinations, as well as innovative tests of both the top mass and tests of crucial SM predictions.

References

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