PROCEEDINGS OF SCIENCE

Top quark mass measurement using template methods, with 35 pb^{-1} recorded by the ATLAS detector, at $\sqrt{s}$ = 7 TeV.

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A measurement of the top quark mass (m_{top}) has been performed by ATLAS with the first 35 pb^{-1} recorded by the experiment. This measurement is based on three template methods, in the $t\bar{t} \rightarrow lepton + jets$ channel. One of these methods, described in detail here, makes use of the observable R_{32}, the event-by-event ratio of the reconstructed top-quark and W boson masses associated to the hadronically decaying top quark candidates; combining the electron and muon channels, the measured top quark mass is:

$$m_{top} = (169.3 \pm 4.0_{stat} \pm 4.9_{syst})\,\mathrm{GeV}$$

Two additional template methods are also presented; they lead to consistent results, with different sensitivities to systematic effects.

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1. Introduction

The top quark mass is a fundamental parameter of the Standard Model (SM) of particle physics. Electroweak precision observables depend on the value of the top mass, through radiative corrections; therefore, a precise top quark mass measurement is needed to perform consistency tests of the SM, constrain the Higgs boson mass within the SM, and search for new physics beyond the Standard Model. The world average value of this mass, measured at Tevatron, is: $m_{top} = 173.2 \pm 0.6(stat.) \pm 0.8(syst.)$GeV [1]. At ATLAS, top quark mass measurements have been performed up to now in the lepton (e,μ) channel ($t\bar{t} \rightarrow b\bar{b}l\nu$qq'), independently, and combined afterwards. The methodology used here [2] consists of defining an estimator sensitive to m_{top}, then producing and fitting templates of it for signal and background. A likelihood fit based on the resulting Probability Distribution Functions (PDFs) is performed on the data, and a top quark mass is thus measured.

2. Event selection

The measurement uses 35 pb^{-1} of data recorded by the ATLAS detector [3] from pp collisions at a centre-of-mass energy $\sqrt{(s)}$ = 7 TeV produced by the Large Hadron Collider (LHC). Events are selected by requiring exactly one isolated lepton in the event, with p_T > 20 GeV, missing transverse energy[1] E_T^{miss} > 35 (20) GeV in the electron (muon) channel, cuts on the W boson transverse mass[2], at least 4 jets with p_T > 25 GeV and $|\eta|$[3] < 2.5. of which at least one b-tagged jet is required. In addition, two requirements specific to the R_{32} analysis are imposed. Events with two b-tagged jets in the jet-triplet assigned to the hadronically decaying top-quark are rejected, and the mass of the reconstructed hadronically decaying W boson is required to be within a window of 60 GeV < m_W^{reco} < 100 GeV. The relevant sources of background in the lepton + jets $t\bar{t}$ channel are listed in Table 1; all background levels are estimated using the corresponding Monte Carlo samples, except QCD multijets, which is directly determined from data. A good agreement between the expected and observed numbers of events is found.

3. R_{32} template method

The R_{32} method uses the ratio of the reconstructed W and top masses, in the hadronic side, and reduces therefore the sensitivity to jet energy scale uncertainties.

For each of the selected events, the top quark mass is reconstructed: among all selected jets, the three whose 4-vector sum yields the highest transverse momentum are interpreted as the products

[1] The E_T^{miss} is based on the vector sum of transverse momenta of all jets with $p_T > 20$ GeV and $|\eta|$ < 4.5. The calibrated transverse energies of electron candidates and contributions from all well-identified muon candidates and calorimeter clusters not belonging to a reconstructed object are also included.

[2] $m_W^T > 25$GeV in the electron channel, $m_T^W + E_T^{miss} > 60$GeV in the muon channel

[3] ATLAS uses a right-handed system with its origin at the nominal interaction point (IP) in the center of the detector and the z-axis along the beam pipe. The x-axis points from the IP to the center of the LHC ring, and the y axis points upward. Cylindrical coordinates (r,ϕ) are used in the trasnverse plane, ϕ being the azimuthal angle around the beam pipe. The pseudorapidity is defined in terms of the polar angle θ as $\eta = -ln tan(\theta/2)$. Distances in $\eta - \phi$ sapce are given as $\Delta R = \sqrt{\Delta\phi^2 + \Delta\eta^2}$.

Process	Electron	Muon
$t\bar{t}$ signal	52.6 ± 0.5	77.3 ± 0.6
Single top	2.23 ± 0.07	3.12 ± 0.08
W+jets	3.9 ± 0.3	6.6 ± 0.4
Z+jets	0.71 ± 0.05	0.63 ± 0.04
ZZ, WW, WZ	0.07 ± 0.01	0.11 ± 0.01
QCD multijet (data)	2.1 ± 2.1	4.5 ± 4.5
m_{top} independent background	6.9 ± 2.1	11.8 ± 4.5
Total background	9.1 ± 2.2	14.9 ± 4.5
Signal + background	61.7 ± 2.2	92.2 ± 4.5
Data	56	99
S/B	5.8	5.2

source	**e channel**	**μ channel**
Method calibration	0.7	0.5
Signal MC generator (POWHEG vs MC@NLO)	0.7	0.6
Hadronization POWHEG (PYTHIA vs HERWIG)	1.0	0.5
Pile-up	0.6	0.8
ISR/FSR (signal only)	2.2	2.6
Proton PDF	0.6	0.5
W/Z+jets background normalization ($\pm$ 100%)	1.3	1.7
W/Z+jets background shape	0.6	1.0
QCD background normalization ($\pm$ 100%)	0.8	0.7
QCD background shape	0.6	0.5
Jet energy scale	2.3	1.9
b-jet energy scale ($\pm$ 2.5%)	2.5	2.5
Jet energy resolution	0.6	1.1
b-tagging scale factor	0.6	0.5
Jet reconstruction efficiency	0.6	0.5
Total (GeV)	**4.8**	**5.0**

Table 1: The observed numbers of events per channel in the data compared to the expected numbers of signal and background events for the data luminosity, for the R_{32} analysis (left). Contributions of various sources to the uncertainty for m_{top} (right); all numbers are in GeV, and correspond to systematic uncertainties only.

of the hadronic top. The corresponding invariant mass spectrum is shown in Fig.1(a). Once the final state is reconstructed, the template parameterization of the R_{32} distribution can be carried out, for signal and background [4]. Signal and background probability distribution functions (PDFs) are used in an extended unbinned likelihood fit to the data. The robustness of the method has been checked using pseudo-experiments, randomly constructed from the signal and background histograms: a good linearity is observed. In addition, the mean values and widths of the pull distributions are consistent with 0 and 1, as expected.

Several sources of systematic uncertainties have been taken in consideration; their estimate is given in Table 1. The main contributions come from initial and final state QCD radiation (ISR/FSR), jet energy scale, and relative b-jet to light jet energy scale.

Figure 1 shows the results of the likelihood fit performed on 35 pb^{-1} of data. Using the results of the fits, and the estimate of the systematic uncertainties detailed above, the measured values of the top quark mass are: $m_{top} = (173.8 \pm 6.7_{stat.} \pm 4.8_{syst.})$ GeV (electron channel), $m_{top} = (166.7 \pm 5.0_{stat.} \pm 5.0_{syst.})$ GeV (muon channel) and $m_{top} = (169.3 \pm 4.0_{stat.} \pm 4.9_{syst.})$ GeV (combined). The combination of both channels is obtained from a χ^2 minimization of the individual measurements using their full uncertainties (the statistical uncertainties are treated as uncorrelated and the systematic uncertainties as fully correlated).

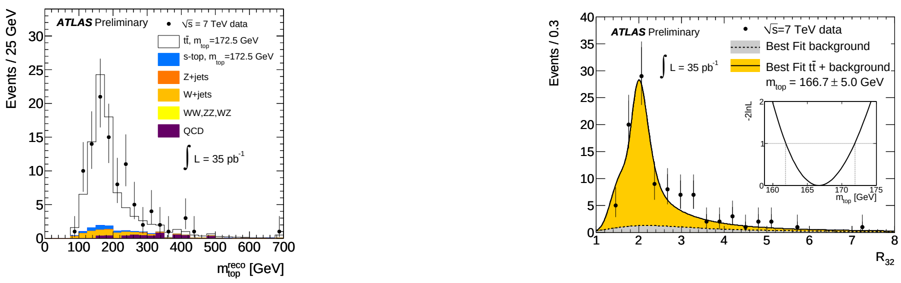

Figure 1: Muon channel: Hadronic top quark mass reconstructed (a). Measured R_{32} distribution (b). [2]

[4]Single top background is included in the signal for the template parameterization

4. Alternative methods

2D method: in the so-called 2D analysis, both m_{top} and a global Jet energy Scale Factor (JSF) are determined simultaneously using m_{top}^{reco} and m_{W}^{reco}. The final state reconstruction, based on the W boson mass constraint, is slightly different [4]. Templates of both m_{W}^{reco} and m_{top}^{reco} are built, for signal and background. The resulting PDFs depend on JSF and m_{top} (JSF only for the template of m_{W}^{reco}). A likelihood fit is then applied to the data, and leads to a simultaneous measurement of JSF and m_{top}: $m_{top} = (168.3 \pm 6.2_{stat.} \pm 4.3_{syst.})$ GeV (electron channel), $m_{top} = (163.5 \pm 6.7_{stat.} \pm 4.6_{syst.})$ GeV (muon channel) and $m_{top} = (169.3 \pm 4.6_{stat.} \pm 4.4_{syst.})$ GeV (combined). The measured JSF is $1.08^{+0.04}_{-0.06}$ ($1.01^{+0.05}_{-0.05}$) in the electron (muon) channel, where the quoted uncertainties are statistical only. The systematic uncertainty on the top mass is dominated by ISR/FSR, and b-JES: the systematic uncertainty on m_{top} due to the JES is strongly reduced (by a factor 3 in average), compared to the R_{32} method, and partly transformed into an additional statistical uncertainty.

Kinematic fit: this third template method relies on a more complex final state reconstruction, where information from the entire event is used to reconstruct both sides of the $t\bar{t}$ decay, with a kinematic likelihood fitter (KLFitter) relating the observed objects to parton level predictions [2]. The resulting top quark mass distribution is narrower, resulting in a significantly reduced statistical uncertainty on the top mass measurement. However, the analysis is subject to a stronger JES sensitivity than the other two analyses described above. This method leads to the following results: $m_{top} = (179.0 \pm 4.3_{stat.} \pm 7.5_{syst.})$ GeV (electron channel), $m_{top} = (172.0 \pm 3.5_{stat.} \pm 7.5_{syst.})$ GeV (muon channel) and $m_{top} = (174.8 \pm 2.7_{stat.} \pm 7.5_{syst.})$ GeV (combined).

5. Conclusion

The top quark mass has been measured directly via three complementary template methods in the $t\bar{t} \rightarrow$ lepton+jets channel, with the first 35 pb^{-1} recorded by the ATLAS detector. All analyses lead to consistent results within their uncertainties; these approaches are complementary in their sensitivity to systematic and statistical uncertainties. The top quark mass measured by ATLAS is also consistent with the measurement provided by Tevatron [1]. With the larger dataset collected until the end of 2011, the precision of the top quark mass measurement will be limited by systematic uncertainties. A reduction of the b-JES, together with a measurement of the level of ISR/FSR, will become crucial.

References

[1] Tevatron Electroweak Working Group, *Combination of CDF and DO results on the mass of the top quark using up to 5.8 fb^{-1} of data*, arXiv:1107.5255v3 (2011).

[2] ATLAS Collaboration,*Measurement of the top quark mass using the template method in pp collisions at $\sqrt{s}$ = 7 TeV with the ATLAS detector*, ATLAS-CONF-2011-033, http://cdsweb.cern.ch/record/1337783 (2011).

[3] ATLAS Collaboration, *The ATLAS Experiment at the CERN Large Hadron Collider*, JINST 3 (2008).

[4] ATLAS Collaboration, *Prospects for the measurement of the top quark mass using the template method with early ATLAS data*, ATL-PHYS-PUB-2010-004, http://cdsweb.cern.ch/record/1263583 (2010).

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