Top properties at ATLAS

Carolina Gabaldon, on behalf of the ATLAS Collaboration

CERN, CH-1211 Geneve 23, Switzerland

Abstract. The measurements of the top-quark mass in the lepton + jets and all-hadronic channels are summarised in this proceedings. The precise measurement of the top-quark properties at the LHC is of great interest since it offers both stringent tests of the Standard Model (SM) and possible pathways to dicovering new physics. The ATLAS experiment has measured many of the top-quark properties with unprecedented precision in 2011. This article presents most recent measurements of top-quark properties from the ATLAS detector. In particular, W boson polarization in top-quark decays, the charge asymmetry and the $t\bar{t}$ spin correlation.

Keywords: top properties, top-quark mass, top-quark physics, ATLAS, CERN
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INTRODUCTION

The top-quark can be produced in two ways: in pairs via strong interactions or as a single quark via electroweak interactions. Top-quark pairs at the LHC are produced either through $q\bar{q}$ annihilation (15%) or through gluon fusion (85%). Top-quarks are predicted to decay in the SM almost exclusively via the electroweak interaction into a W boson and a bottom quark. Events are classified according to the decay of the W bosons as all-hadronic, lepton + jets, τ + jets and dilepton. The lepton + jets topology provides a good combination of large statistics and distinct event signatures and is therefore used in most of the analysis presented in this article. In spite of a lower branching ratios and a more difficult reconstruction procedure, the dilepton topology is used for example in the spin correlation analyses due to its lower backgrounds and higher sensitivity to spin correlations. For all the analysis presented in this paper the dominating systematic uncertainties are the light jet energy scale (JES), the b-jet energy scale, the additional initial or final state radiation and the uncertainty on background estimations.

TOP-QUARK MASS

In 2011, the first ATLAS [1] measurement of the top mass was performed by using the lepton + jets final states [2]. This analysis used different templated-based methods to reduce the impact of the main sources of systematic uncertainties. In particular, the 1-D templates are made of the reconstructed mass ratio distribution ($R_{32} = m_{top}/m_W$) to minimize jet energy scale (JES) dependences. The 2-D strategy consist of a simultaneous fit of m_{top} and a global JES factor (JSF). JSF is sensitive to all possible differences in data and predictions reducing the final systematic uncertainties. A summary of the results is shown in Figure 1 and compared with results obtained at the Tevatron. The ATLAS results are compatible with the Tevatron, although still have a larger uncertainties.

The top-quark mass was also measured in ATLAS in the all-hadronic channel with 1.04 fb^{-1} data [3]. In this analysis, the main challenge is the reduction and the estimate of the remaining QCD multijet background. This background is obtained by event mixing data-driven method. For each event, a χ^2-fit was performed to assign the jets to the top-pair events. Only events with a $\chi^2 < 8$ are considered to minimize the dominant systematics. The jet triplet mass distribution, extracted by a template method, was used to measure the top-quark mass. Figure 1 (right) shows the obtained invariant mass of the top candidates. A top-quark mass of $174.9 \pm 2.1\,(\text{stat.}) \pm 3.8\,(\text{syst.})$ GeV was determined by fitting this distribution using a binned likelihood.

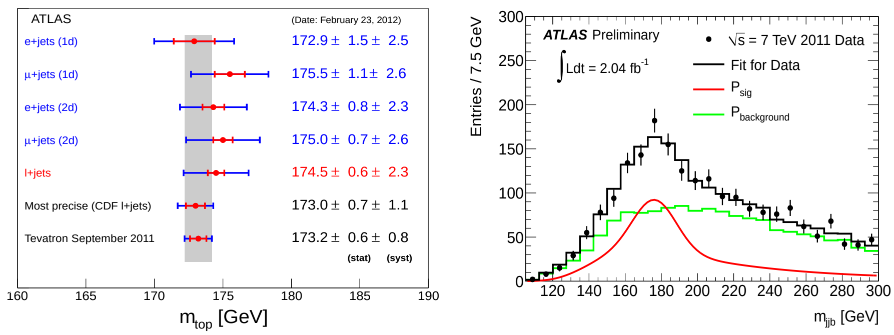

FIGURE 1. Summary of measurements of the top-quark mass for the single lepton topology compared to results obtained at the Tevatron [2] (right). Fit of the top-quark mass for the all-hadronic topology [3] (left).

W BOSON HELICITY IN TOP-QUARK DECAYS

The polarization of the W bosons in top-quark decays is sensitive to the Wtb vertex structure from which limits on new physics can be extracted. The fractions of the W boson helicity states are predicted at NNLO to be $F_0 = 0.687 \pm 0.005$, $F_L = 0.311 \pm 0.005$, $F_R = 0.0017 \pm 0.0001$ [5].

In ATLAS the helicity fractions and angular asymmetries have been measured in $t\bar{t}$ with single and dilepton final states exploiting the angular distribution of the decay products of the top quark [6]. Two analysis strategies were used in this analysis. The first is based on a comparison of the observed $\cos\theta^*$ [1] distribution with templates for different W boson helicity states. For the second method, the angular aysmmetries are extracted from an unfolded $\cos\theta^*$ with background subtraction. A combination of the measurements yields helicity fractions of $F_0 = 0.67 \pm 0.07$, $F_L = 0.32 \pm 0.04$, $F_R = 0.01 \pm 0.05$. This result is in agreement with the NNLO QCD prediction. The measurements were used to set limits on anomalous contributions to the Wtb-vertex. There are four couplings in the Wtb Lagrangian, V_L V_R, g_L and g_R, being the last three absent in the SM at the tree level. Figure 2 (left) shows the allowed region of the anomalous couplings g_L and g_R with V_R set to zero.

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[1] θ^* is the angle between the direction of the lepton and the reversed momentum of the b-quark from the top-quark decay, both boosted into the W-boson rest frame.

CHARGE ASYMMETRY

The SM predicts a small charge asymmetry A_C in the differential distributions of the t and $\bar{t}$ due to interference among q-$\bar{q}$ vertices at NLO. This asymmetry is measured at the LHC as a function of the difference between the absolute values of the t and $\bar{t}$ rapidities: $A_C = \frac{N(\Delta|Y|>0)-N(\Delta|Y|<0)}{N(\Delta|Y|>0)+N(\Delta|Y|<0)}$.

The measurement of the charge asymmetry in $t\bar{t}$ production [4] has been performed in ATLAS considering lepton + jets final states. The result combining both the electron and the muon channel is $A_C = -0.019 \pm 0.028$ (stat.) ± 0.024 (syst.) in agreement with the Standard Model prediction of $A_C = 0.006 \pm 0.002$.

SPIN CORRELATION IN $t\bar{t}$ EVENTS

A measurement of the spin correlation in dilepton final states has been performed in ATLAS [7]. The top-quark decays before hadronisation, allowing to study the spin correlation in the $t\bar{t}$ system via the angular distributions of its decay products. In this analysis the $\Delta\phi$ distribution between the two leptons in the laboratory frame was used as observable sensitive to the spin correlation. Figure 2 (right) shows the reconstructed $\Delta\phi$ distribution. The amount of spin correlation is extracted by fitting a linear combination of two templates, SM with spin correlation and no spin correlation scenario, to the $\Delta\phi$ distribution. The fit results in a SM fraction of $f^{SM} = 1.30 \pm 0.14$ (stat.) $^{+0.27}_{-0.22} \pm$ (syst.). This is used to extract the spin correlation in the helicity basis of $A_{helicity} = 0.40 \pm 0.04$ (stat.) $^{+0.08}_{-0.07} \pm$ (syst.), in agreement with the NLO SM predictions, $A_{helicity} = 0.31$ [8]. This is the hypothesis of zero spin correlation is excluded at 5.1σ.

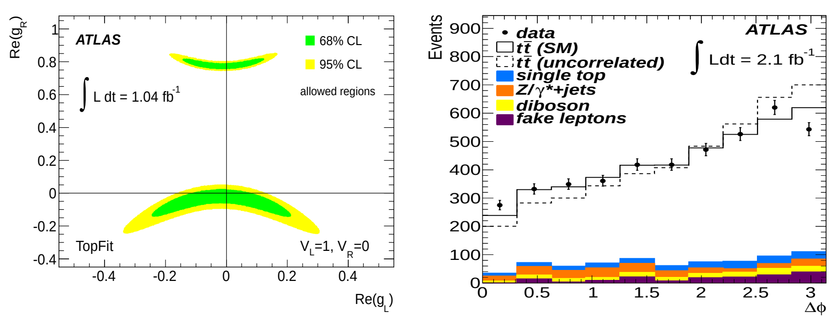

FIGURE 2. Allowed regions at 68 % and at 95 % CL for the Wtb anomalous couplings g_R and g_L [6] (right). Reconstructed charged lepton $\Delta\phi$ distribution for dilepton final states [7] (left).

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