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# Measurement of top properties in ATLAS

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**Summary.** — The top quark may play a special role in the Standard Model of particle physics. It is, for instance, the heaviest fundamental particle known, with a mass close to the electroweak symmetry breaking scale. Millions of top quark pairs will be produced per year at the LHC at nominal luminosity. ATLAS will measure many of the top quark properties with unprecedented precision. The ATLAS sensitivity studies done with Monte Carlo for the measurements of the top quark mass, the top quark charge, rare top quark decays and flavour changing neutral currents, the $t\bar{t}$ spin correlations and $W$ boson polarization, the anomalous couplings at the $Wtb$ vertex and $t\bar{t}$ resonances are reviewed.

PACS 14.65.Ha – Top quarks.
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## 1. – Introduction

The ATLAS [1] sensitivity to the measurement of several top quark properties was studied using Monte Carlo simulation. The analyses developed to measure the top quark mass, the top quark charge, rare top quark decays associated to flavour changing neutral currents (FCNC) ($t \to qX, X = \gamma, Z, g$), the $t\bar{t}$ spin correlations and $W$ boson polarization, the anomalous couplings at the $Wtb$ vertex and the search of $t\bar{t}$ resonances are presented in the following sections. A centre-of-mass energy of 10 TeV was considered in the top quark mass analysis, while for the others, a centre-of-mass energy of 14 TeV was assumed. The results presented were obtained assuming an expected luminosity of $1\,\text{fb}^{-1}$.

## 2. – Top quark mass

The ATLAS potential at $\sqrt{s} = 10\,\text{TeV}$ for the reconstruction of the top quark mass was studied using two variants of a template method, optimized for $100\,\text{pb}^{-1}$ and $1\,\text{fb}^{-1}$ [2]. More details can also be found in these proceedings [3]. The statistical uncertainty for the $100\,\text{pb}^{-1}$ ($1\,\text{fb}^{-1}$) analysis is 3 (0.6) GeV. The total systematic uncertainties (3.8 and 2.0 GeV for the $100\,\text{pb}^{-1}$ and $1\,\text{fb}^{-1}$ analysis, respectively) are dominated by quantities related to jet energy scales.

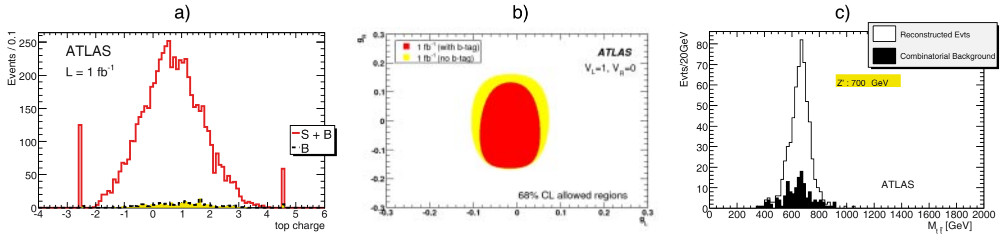


Fig. 1. – Expectation Monte Carlo plots: a) reconstructed top quark charge (full line) and its background (dashed line). b) The ATLAS expected 68.3% CL confidence regions on the anomalous couplings $(g_{\mathrm{L}}, g_{\mathrm{R}})$-plane with and without using a $b$-tag in the analysis. c) The reconstructed mass of a 700 GeV $Z'$ boson.

## 3. – Top quark charge

The Standard Model top quark, with a charge of $+2/3|e|$, decays into a $b$-quark $(-1/3|e|)$, a positively charged lepton $(+1|e|)$ and a neutrino. An exotic scenario where the top quark has a charge of $-4/3|e|$ and decays to a $b$-quark $(-1/3|e|)$, a negatively charged lepton $(-1|e|)$ and a neutrino was explored. This exotic charge hypothesis was excluded at 95% confidence level (CL) by CDF [4] and at 92% CL by DØ [5]. Two major issues need to be addressed to reconstruct the top quark charge using semileptonic $t\bar{t}$ events: 1) pairing correctly the $b$-quark and charged lepton coming from the same top quark decay and 2) reconstructing the $b$-jet charge itself. A cut on the $b$-jet and charged lepton invariant mass will be used to address the first issue [6]. The $b$-jet charge will be measured using two methods. The first one is the charge weighting technique, where the charge of the $b$-quark is extracted from the weighted sum of the $b$-jet track charges. The obtained reconstructed $b$-jet charge is $Q_{\mathrm{comb}} = -0.094 \pm 0.0042(\mathrm{stat})$ with a total systematic uncertainty of 12.5%. The corresponding top quark charge is $Q_t = 0.67 \pm 0.06 \pm 0.08$. The distribution of reconstructed top quark charges is shown on fig. 1 a). The other method measures the charge of a non-isolated lepton produced in the semileptonic $b$-quark decay. The combined $b$-jet charge is $\bar{Q}^{(\mathrm{comb})}_{\mathrm{nonIs}} = -0.31 \pm 0.04$, with a total systematic uncertainty of 19.3%. ATLAS will be able to distinguish both charge hypotheses with a significance above $5\sigma$ for $1\,\mathrm{fb}^{-1}$ of data.

## 4. – Rare top quark decays and FCNC

According to the Standard Model, the FCNC top quark decays ($t \to qX$, $X = \gamma$, $Z$ or $g$) have a branching ratio (BR) of about $10^{-12}$ [7]. There are, however, Standard Model extensions which predict higher values (up to $10^{-4}$) for these BR [7]. ATLAS performed a sensitivity study to these FCNC processes in $t\bar{t}$ events using a model-independent approach [6]. Events were reconstructed with a Standard Model leptonic top quark decay and an anomalous decay of the other top quark. Discriminant variables were built using momenta, masses and angles between final state particles as probability density functions. In the absence of a FCNC top quark decay signal, the following expected limits at 95% CL were obtained for $L = 1\,\mathrm{fb}^{-1}$: $\mathrm{BR}(t \to q\gamma) < 6.8 \times 10^{-4}$, $\mathrm{BR}(t \to qZ) < 2.8 \times 10^{-3}$ and $\mathrm{BR}(t \to qg) < 1.2 \times 10^{-2}$.

## 5. – $t\bar{t}$ spin correlations and $W$ boson polarization

The top quark decays before hadronisation and spin information is preserved. In events with $t\bar{t}$ production, the spin asymmetry $A$ can be measured from the angles between the $t$ ($\bar{t}$) in the $t\bar{t}$ rest frame and the $t$ ($\bar{t}$) decay product in the $t$ ($\bar{t}$) rest frame [8]. The production asymmetry $A_{\mathrm{D}}$ can be measured from the angle between the two spin analysers (in the corresponding top quark rest frames) [8]. A semileptonic sample of $t\bar{t}$ events was used to reconstruct the angular distributions. Due to detector and event selection effects, a correction function was applied. The expected measured values for $A$ and $A_{\mathrm{D}}$ are $A = 0.67 \pm 0.34$ (stat + sys) and $A_{\mathrm{D}} = -0.40 \pm 0.14$ (stat + sys) [6]. The distribution of the angle between the lepton in the $W$ boson rest frame and the $W$ boson in the top quark rest frame [9] can be used to extract the fractions of the $W$ boson helicity states: longitudinal ($F_0$), left-handed ($F_{\mathrm{L}}$) and right-handed ($F_{\mathrm{R}}$). The ATLAS expectations for $L = 1\,\mathrm{fb}^{-1}$ are $F_{\mathrm{L}} = 0.29 \pm 0.02 \pm 0.03$, $F_0 = 0.70 \pm 0.04 \pm 0.02$ and $F_{\mathrm{R}} = 0.01 \pm 0.02 \pm 0.02$, where the first error is statistical and the second is systematic [6].

## 6. – Anomalous couplings at the $Wtb$ vertex

The $Wtb$ anomalous couplings ($V_{\mathrm{R}}$, $g_{\mathrm{L}}$ and $g_{\mathrm{R}}$) can be studied by measuring the $W$ boson helicity ratios, $\rho_{\mathrm{R,L}} = F_{\mathrm{R,L}}/F_0$ or through the $A_{\mathrm{FB}}$ and $A_{\pm}$ angular asymmetries involving the angle of the charged lepton in the $W$ boson rest frame and the $W$ boson direction in the top quark rest frame. The different observables evaluated from the angular distribution, which was reconstructed after a probabilistic analysis, were used with the TopFit [10] program, to derive constraints on the anomalous couplings. The expected ATLAS sensitivity to the $V_{\mathrm{R}}$, $g_{\mathrm{L}}$ and $g_{\mathrm{R}}$ anomalous couplings is 0.15, 0.07 and 0.15, respectively [6]. The obtained 68.3% CL confidence region for the $(g_{\mathrm{L}}, g_{\mathrm{R}})$-plane is show in fig. 1 b).

## 7. – $t\bar{t}$ resonances

Two analyses aimed at different $t\bar{t}$ mass regions were developed by ATLAS. The standard $t\bar{t}$ analysis, optimized to the low mass region, is based on the reconstruction of the semileptonic $t\bar{t}$ topology [6]. The ATLAS $5\sigma$ discovery limit on $\sigma \times \mathrm{BR}$ for $m_{Z'} = 700\,\mathrm{GeV}$ is 11 pb. Figure 1 c) shows the reconstructed mass of a 700 GeV $Z'$ boson. The other analysis was optimized for the higher $Z'$ masses [11]. These events have boosted top quarks and a topology characterised by a monojet and a non-isolated lepton. The 95% CL expected limits on $\sigma \times \mathrm{BR}$ for $m_{Z'} = 2\,\mathrm{TeV}$ ($3\,\mathrm{TeV}$) is 550 fb (160 fb).

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