Abstract

In this thesis, searches for new phenomena involving top quarks and Higgs bosons in proton-proton collisions at CERN's Large Hadron Collider are presented. The first search targets a variety of signals, including the pair production of a vector-like top quark (T) with a significant branching ratio to a top quark and either a Standard Model Higgs boson or a Z boson; four-top-quark production, both within the Standard Model and in several new physics scenarios; and heavy Higgs bosons (neutral and charged) produced in association with, and decaying into, third generation quarks. The second search targets the production of the Standard Model Higgs boson in association with top-quark pairs, $t\bar{t}H$, with $H \to b\bar{b}$, aiming at a direct measurement of the top-Higgs Yukawa coupling.

The searches are based on 13.2 fb^{-1} of proton-proton collision data at a centre-of-mass energy $\sqrt{s} = 13$ TeV collected with the ATLAS detector. Data are analysed for both searches in the lepton-plus-jets final state, characterised by an isolated electron or muon with high transverse momentum, large missing transverse momentum and multiple jets. For the first search data are analysed as well as in the jets+$E_{\mathrm{T}}^{\mathrm{miss}}$ final state, not exploited in Run 1, characterised by multiple jets and large missing transverse momentum. Both searches exploit the high multiplicity of jet and b-jets characteristic of signal events. In the first search the high scalar sum of transverse momenta of all final-state objects, and the presence of boosted, hadronically-decaying resonances reconstructed as large-radius jets are used to discriminate between signal and background events, while in the second search multivariate techniques are employed. Background events for both searches are dominated by $t\bar{t}$+jets production, in particular by the $t\bar{t}+ \geq 1b$ process, for which detailed studies have been performed.

For the first search, in the absence of a significant excess above the Standard Model expectation, 95% CL upper limits are derived for the signal models in a number of benchmark scenarios, in most cases significantly extending the reach of previous searches. For the second search the data are consistent with either the background-only hypothesis or with the Standard Model $t\bar{t}H$ prediction. The ratio of the measured $t\bar{t}H$ signal cross section to the Standard Model expectation is found to be $\mu = 2.1^{+1.0}_{-0.9}$, assuming a Higgs boson mass of 125 GeV.