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ATLAS $t\bar{t}$ Resonance Searches

Victoria Sanchez Martinez, on behalf of the ATLAS Collaboration

Instituto de Fisica Corpuscular (IFIC), Valencia, Spain

Abstract

The ATLAS experiment has performed a search for new states decaying to top quark pairs using a data set of 14 fb^{-1} of proton-proton collisions collected during the 2012 run at $\sqrt{s} = 8\ TeV$ of the Large Hadron Collider (LHC). The combination of a classical, resolved analysis with a novel algorithm designed specifically for boosted top quarks yields good acceptance for a broad range of resonance masses. No deviations from the Standard Model expectations are observed and stringent limits are set on the production cross-section times branching ratio of several resonance models.

Keywords: LHC, ATLAS, exotics, resonance, searches, top quark, boosted object

1. Introduction

The top quark mass is close to the electroweak symmetry breaking (EWSB) scale. This could be an indication of a special role in Beyond the Standard Model (BSM) physics. Several new physics scenarios give rise to heavy particles that couple strongly to $t\bar{t}$ pairs. A search for new particles that decay into $t\bar{t}$ pairs [1] is performed with the ATLAS experiment at the LHC using an integrated luminosity of 14 fb^{-1} of pp collision data collected at $\sqrt{s} = 8\ TeV$. The analysis focuses on the $lepton + jets$ final state with isolated electrons or muons. It is designed to deal both with the collimated topologies that arises in the decay of boosted top quarks and the case of more moderate top quark momentum, where all top quark decay products are resolved individually. Backgrounds are estimated using a mixture of Monte Carlo (MC) and data-driven methods. The invariant mass distribution of the $t\bar{t}$ candidate system is reconstructed and searched for a local excess or deficit.

2. Data & MC Samples

The analyzed data set corresponds to the first 14 fb^{-1} of ATLAS data at $\sqrt{s} = 8\ TeV$ collected in 2012. The Standard Model expectation is constructed using a mixture of Monte Carlo and data-driven estimates for the following background sources: SM $t\bar{t}$ production, $W + jets$ and $Z + jets$ production, electro-weak single-top production, di-boson production and QCD multi-jet background.

3. Benchmark Models

Two benchmark models for resonant high-mass $t\bar{t}$ production are considered:

- A Z' boson with a natural width that is small compared to the detector resolution. The cross-section times branching ratio corresponds to that of the topcolor-assisted technicolor (TC2) model [2, 3] also used extensively by the Tevatron experiments.
- A broad, coloured resonance with natural width $\Gamma = 0.15\ M$. For the concrete model parameters the Kaluza-Klein gluon (g_{KK}) in Randall-Sundrum warped extra-dimension of Reference [4] is assumed.

4. Selection and reconstruction

The analysis combines two strategies:

- an algorithm specifically designed for boosted top quarks is attempted first. This requires a small-R jet in the vicinity of the isolated lepton and a trimmed large-R jet with large transverse momentum ($p_T > 350$ GeV) and significant substructure (jet mass $m_j > 100$ GeV, k_t splitting scale $d_{12} > 40$ GeV) in the opposite hemisphere.

- for events that fail to meet the requirements above a more classical selection and reconstruction of the top quark pairs is attempted, that assumes the jets from top quark decay are resolved. Four small-R jets are required with $p_T > 25$ GeV and pseudo-rapidity $|\eta| < 2.5$.

Both strategies share the requirement of an isolated lepton, missing transverse momentum and at least one b-tagged small-R jet. The signal selection efficiency of both algorithms is shown in Figure 1. Clearly, both approaches have complementary ranges. The resolved approach recovers efficiency below the turn-on of the boosted selection at approximately $m_{t\bar{t}} = 800$ GeV.

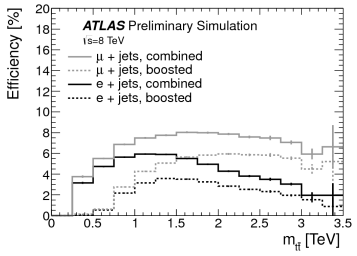

Figure 1: The efficiency of the boosted analysis and the combination with the resolved selection versus the invariant mass of the top quark pair.

The top quark candidates are reconstructed by combining the isolated lepton with the neutrino (reconstructed using the W-mass constraint) and a selected small-R jet. In the boosted selection the hadronic top quark decay is identified with the large-R jet.

5. Results

After the reconstruction of the $t\bar{t}$ mass spectrum, the observed distribution is compared to the SM expectation in Figure 2. The uncertainty in the background template is indicated with a shaded area. It is evaluated by considering multiple sources of instrumental uncertainties, of which the jet energy scale uncertainty is the most important. Modelling uncertainties are also taken into account for the main backgrounds. The total systematic uncertainties on the yield is 14% in the resolved topology and 22% in the boosted analysis. The reconstructed distribution is found to be in good agreement with the SM expectation.

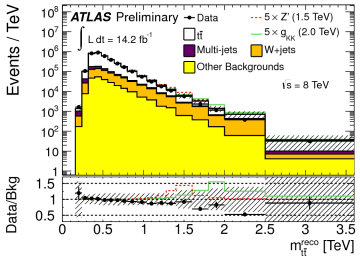

Figure 2: Reconstructed invariant mass distribution of the top quark pair. The boosted and resolved final states are combined to form the spectrum.

Expected and observed upper cross section limits times the $t\bar{t}$ BR are derived on a narrow Z' boson (left panel in Figure 3) and a Kaluza Klein gluon (right panel in Figure 3). The 95% CL upper limits range from 5.3 pb for a narrow resonance at a mass of 500 GeV to 0.08 pb at 3 GeV. The limits are nearly doubled for the broad resonance.

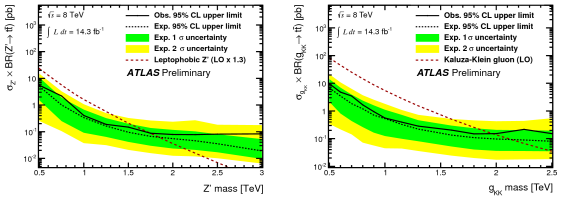

Figure 3: Limits at 95% CL on the production cross-section times the branching ratio to top quark pairs of a narrow (left panel) and broad resonance (right panel).

References

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