Search for 4th Generation Quarks with the ATLAS Detector at the LHC

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Abstract. We present the results from the searches for fourth generation quarks using data samples collected in 2011 by the ATLAS detector at the Large Hadron Collider (LHC) at CERN.

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INTRODUCTION

A 4th generation of quarks is predicted in a number of theories and stands in agreement with electroweak precision data [1]. Furthermore, CP violation can be significantly enhanced to a level that it might account for the baryon asymmetry in the Universe [1]. At the LHC proton-proton collider, 4th generation quarks can be either produced strongly in pairs or singly via electroweak production. In the following we present searches for pair production of these new heavy quarks performed by the ATLAS detector at the LHC.

SEARCH AND RESULTS

The ATLAS detector is described in reference [2]. The dataset used in these analyses was recorded in 2011. The corresponding integrated luminosity is 1 fb^{-1} for the analyses except for the $b' \rightarrow Zb$ search, which uses 2 fb^{-1} . The Monte Carlo samples, background modeling, event selection criteria, optimization of discriminant, and treatment of systematic uncertainties are described in detail in the reference for each analysis. Here we briefly describe the searches and present the results.

Search for t' quark pair with subsequent decays $t' \rightarrow Wb$

We performed a search for a pair of t' quark, a heavy up-type quark, in the lepton+jets final state [3], characterized by a high transverse momentum (p_T), isolated e or μ , high missing transverse momentum (E_T^{miss}), and ≥ 3 jets. The reconstructed heavy quark mass (m_{reco}) is the primary discriminating variable. For events with exactly 3 jets, m_{reco} is taken to be the invariant mass of the 3-jet system. For events with ≥ 4 jets, m_{reco} is estimated by performing a kinematic likelihood fit. Good agreement between data and background prediction is observed in the m_{reco} distribution. In the absence of any

significant data excess, upper limits on t' quark pair production cross section are derived using the CL_S method (as shown in Fig. 1). At the 95% confidence level a t' quark with mass < 404 GeV that decays entirely via $t' \rightarrow Wb$ is excluded.

FIGURE 1. (Left): m_{reco} distribution in the combined $e/\mu+4$ jets channel. (Right): Observed and expected 95% C.L. upper limits on t' quark pair cross section as a function of t' quark mass [3].

Search for heavy quark Q pair with subsequent decays $Q \rightarrow Wq$

We performed a search for a pair of heavy quarks $Q\bar{Q}$ with the decay $Q \rightarrow Wq$, where $q = u, d, c, s, b$, in the dilepton final state by requiring 2 charged leptons, large E_T^{miss} and ≥ 2 jets [4]. Q can be any new heavy quark, though the up-type 4th generation quarks decaying through weak charged currents are used as a benchmark. The reconstructed mass of the heavy quark ($m_{\text{Collinear}}$), is the final discriminant. Good agreement between data and background prediction is observed in the $m_{\text{Collinear}}$ distribution. In the absence of any significant data excess, upper limits on the Q pair production cross section are derived using the CL_S method (as shown in Fig. 2). At the 95% confidence level a heavy quark, Q , with mass < 350 GeV that decays entirely via $Q \rightarrow Wq$ is excluded.

FIGURE 2. (Left): $m_{\text{Collinear}}$ distribution for the sum of ee , $\mu\mu$, and e/μ channels after applying the final selection for $m_Q = 350$ GeV. (Right): Observed and expected 95% C.L. upper limits on Q pair cross section as a function of Q mass [4].

Search for b' quark pair with subsequent decays $b' \rightarrow Wt$

We performed a search for a fourth generation down-type quark, b' , with subsequent decay $b' \rightarrow Wt \rightarrow WWb$ [5]. Pair production of b' quarks leads to 4 W bosons and 2 b quarks. In the decay mode studied here, one of the W bosons decays leptonically

and others decay hadronically. The final signature consists of exactly 1 charged lepton, large E_T^{miss} and ≥ 6 jets. The distribution of the number of events as a function of jet multiplicity ($N_{\text{jets}} = 6, 7, \geq 8$) with 0, 1, ≥ 2 reconstructed W boson is the final discriminant. The number of reconstructed W bosons (N_W) is defined as the number jet pairs within $\Delta R < 1.0$ and with an invariant mass in the range 70-100 GeV. In the absence of any significant data excess, upper limits on the b' pair production cross section are derived using the CL_S method (as shown in Fig. 3). At the 95% confidence level a b' quark with mass < 480 GeV that decays entirely via $b' \rightarrow Wt$ is excluded.

FIGURE 3. (Left): Distribution of the number of events observed for $N_{\text{jets}} = 6, 7, \geq 8$ with $N_W = 0, 1, \geq 2$. (Right): Observed and expected 95% C.L. upper limits on the b' pair cross section as a function of b' mass [5].

Search for b' pair with subsequent decays $b' \rightarrow Zb$

Using a dataset collected in 2011 with integrated luminosity of 2 fb^{-1} , we performed a search for a pair of vector-like b' quarks with the subsequent decay $b' \rightarrow Zb$ with the Z boson decaying to an electron-positron pair [6]. The mass distribution of large transverse momentum b' , $m(Zb)$, is tested for an excess. In the absence of any significant data excess, upper limits on the b' pair production cross section are derived using the CL_S method (as shown in Fig. 4). At the 95% confidence level, a b' quark with mass < 400 GeV that decays entirely via $b' \rightarrow Zb$ is excluded. In the case of a vector-like singlet b' quark mixing only with the third generation, masses $m_{b'} < 358$ GeV are excluded.

FIGURE 4. (Left): Mass distribution of the b' quark candidates. (Right): Observed and expected 95% C.L. upper limits on b' quark pair cross section as a function of the b' quark mass [6].

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