Searches for Exotics physics states in jets and boosted objects final states

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Searches for Exotics physics states in jets and boosted objects final states at ATLAS

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1 Introduction

Due to the outstanding performance of the Large Hadron Collider [1] (LHC) that in 2011 delivered more than 5 fb^{-1} of proton-proton collision data at center-of-mass energy of 7 TeV, the ATLAS experiment [2] has been able to explore a wide range of exotic models in order to address the questions unanswered by the Standard Model (SM) of particle physics. ATLAS searches for new particles decaying to jets, photons and jets, monojet, $t\bar{t}$ resonances and 4th generation particles decaying hadronically are presented in this paper. No evidence for physics beyond the SM is found and model-independent limits and limits on the parameters of particular models are set.

2 New Physics searches with jets in the final state

Searches in Dijet Mass and Angular Distribution

The production of events with two energetic jets of particles (dijet events) is well understood within the Standard Model. An enhanced production of dijet final states is expected in several scenarios of new physics. A variety of models of new physics, including models with excited quarks and axigluons, predict the resonant production of states decaying predominantly to two jets. Other models, such as quark contact interactions, predict an excess of events with two jet of central rapidity and forming a high invariant mass. By studying the dijet invariant mass (m_{jj}) and the dijet angular distributions, sensitive searches for both resonant and non-resonant deviations from the Standard Model are performed. In the dijet resonance search, the m_{jj} of the two leading jets is studied using 4.8 fb^{-1} of data collected in 2011. In the analysis the BumpHunter [4] algorithm is used to evaluate the presence of an excess of events in the m_{jj} spectrum on top of a smooth background estimate by fitting the data with the formula $f(x) = p_1(1-x)^{p2}x^{p3+p4\ln x}$ (where the p_i are the fit parameters and $x \equiv m_{jj}/\sqrt{s}$). No resonant structure is founded and masses of excited quark less then 3.35 TeV are excluded at 95% confidence level (C.L.). In the angular analysis convenient variables that emphasizes the dijet central scattering region are employed. The χ variable is defined as the exponential of the rapidity difference of the two jets with the highest transverse momenta (p_T). In Figure 1 (left) the χ distribution for different m_{jj} interval is shown in data along with background predictions from NLO QCD. The $F_\chi(m_{jj})$

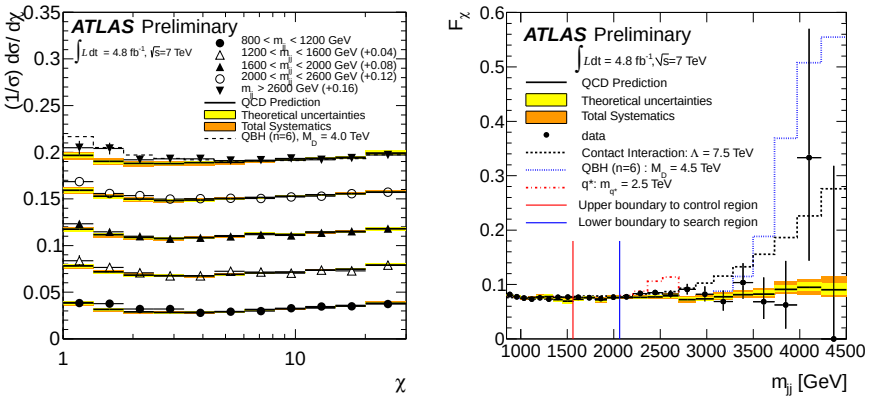

Figure 1: Left: The χ distributions for different dijet mass bins. Right: $F_\chi(m_{jj})$ distribution versus m_{jj}. The QCD predictions are shown with theoretical and total systematic uncertainties (bands) as well as the data points with statistical uncertainties [3].

variable is defined as the ratio $F_\chi(m_{jj}) = N_{central}/N_{total}$ where $N_{central}$ is the number of dijet events in a defined central region, and N_{total} is the number of dijet events in the full distribution extending to $\chi < 30$. This variable has excellent sensitivity to resonant as well as non-resonant excesses of central jets. The resulting distribution for different m_{jj} values is shown in Figure 1 (right) for the data and the NLO QCD background. Data and QCD prediction agrees in each m_{jj} bin. Limits at 95% C.L. are set on models of contact interactions and quantum black holes. The full analysis details, including limits on additional models, are given in Reference [3].

Searches in Photon-Jet Mass Distribution

The photon-jet invariant mass distribution ($m_{\gamma j}$) is shown to be a useful tool for searching for resonances indicative of new physics. The most recent ATLAS results [5] are obtained from the analysis of 2.11 fb^{-1} of 2011 proton-proton collision data. Data events with $m_{\gamma j}$ masses up to 2 TeV are compared with a smooth background estimate, and no evidence of resonant production is found. Limits are set on generic Gaussian-shape signals (excluded below 2 TeV) and on a benchmark excited-quark model excluding masses below 2.46 TeV.

Searches in Monojet plus Missing Transverse Momentum Final States

The search for new physics in events with a jet of high transverse energy and large missing transverse energy constitute one the simplest and most striking signatures that can be observed at a hadron collider. Different theoretical models for physics Beyond the Standard Model predict the presence of *monojet* signatures in the final state like, for example, Large Extra Dimension scenarios. In the analysis presented in Reference [6] 1 fb^{-1} of data are used to select events with one high p_T jet and a large amount of missing transverse energy. A lepton veto is applied to reduce the electroweak background. The shape of the dominant

electroweak background is taken from Monte Carlo normalized using data in control regions, while the multi-jet contribution and the non-collision background are estimated with a data-driven technique. Good agreement is observed between the data and the Standard Model predictions. Model-independent upper limits at 95% C.L. are set on the fiducial cross section for the non-Standard Model production of different signal p_T-region varying between 2.02 pb and 0.045 pb. Additionally, an interpretation is made in terms of the Large Extra Dimensions model. Values of the fundamental Planck scale between 3.2 and 2.0 TeV are excluded for a number of extra dimensions corresponding to 2 and 6, respectively.

3 Searches of High-Scale physics scenarios with Boosted Objects in the Final State

Hadronic decays of heavy particles such as W bosons, top quarks and potential hitherto unobserved particles may be collimated into a single heavy jet characterized by a distinct substructure and large mass. In this section exotic analyses using boosted or mostly resolved reconstruction topology are presented.

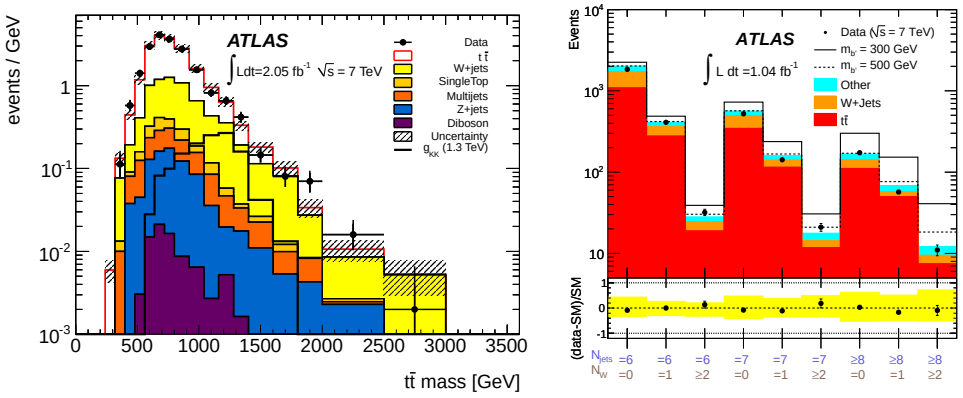

Figure 2: Left: Reconstructed invariant mass distribution of the $t\bar{t}$ candidates after the lepton plus jets signal selection. The shaded band indicates the uncertainty in the normalization of the Standard Model prediction [7]. Right: Distribution of the numbers of events observed in the data and expected from SM processes for $N_{jets} = 6, 7, \geq 8$ with $N_W = 0, 1, \geq 2$. The expected b' signals for two masses are also shown, stacked on top of the backgrounds [9].

Search for $t\bar{t}$ resonances in lepton plus jets events with highly boosted top quarks

A search for resonant production of high-mass top-quark pairs is performed on 2.05 fb^{-1} of ATLAS 7 TeV data [7]. The signal is assumed to originate from the resonance of a leptophobic Z' or a Kaluza-Klein gluon. The analysis focuses on the lepton plus jets final state obtained when one W boson decays to a charged lepton and a neutrino, and the other

decays to a quark and an anti-quark pair. The selection and reconstruction are specifically designed for the collimated topology that arises from the decay of boosted top quarks. The hadronically decaying top quark candidate is identified as a single *fat* jet with radius parameter R = 1. In Figure 2 (left) the reconstructed $t\bar{t}$ mass spectrum is compared with a template for the Standard Model prediction constructed using a combination of Monte Carlo simulations and data-driven measurements using control samples. The data are found to be compatible with the SM within uncertainties. Upper limits at 95% CL on the production cross section times the branching ratio of narrow Z' resonances and broad colored resonances are derived. Leptophobic Z' with masses between 600 GeV and 1.2 TeV is excluded and Kaluza-Klein gluon with a mass smaller than 1.5 TeV is also excluded. The sensitivity of this search obtained with highly boosted top quarks is significantly enhanced in the 1-2 TeV region with respect to a previously published search using the same data set [8].

Search for exotic heavy quarks

A search for pair production of a fourth generation down-type quark b' in events with one lepton is performed with 1.04 fb^{-1} of 7 TeV data [9]. In the model where b' is a chiral quark with mass larger than $m_t + M_W$, the predominant decay mode is $b' \to Wt \to WWb$, which leads to four W bosons and two b quarks in the $b'\overline{b'}$ production events. Due to the high expected b' mass, the W bosons coming from the $b' \to Wt$ decay are expected to have a high momentum and the decay products of such W bosons should be closer together than jets for background processes, but still resolvable as separate jets (mostly resolved topology). Considering this, the quantity suitable for distinguishing b' signal from background is the number of jet pairs with small opening angle and an invariant mass close to the W boson mass. The final discriminant consists of nine exclusive bins as a function of the multiplicity of hadronic W decays ($N_W = 0, 1, \geq 2$) and jet multiplicity ($N_{jet} = 6, 7, \geq 8$), as shown in Figure 2 (right). A binned maximum likelihood fit is performed to derive the most likely cross-section of $b'\overline{b'}$ pairs. No evidence of b' production is observed with 1.04 fb^{-1} data. The b' masses below 480 GeV are excluded at 95% confidence level.

References

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