Early searches with jets with the ATLAS detector at the LHC

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First data collected with the ATLAS detector in 2010 allow us to search for new physics in various jet signatures. One of these analyses, a search for threshold effects in multi-body signatures, is presented. The results are not covered by previous collider searches.

1 Introduction

First data collected with the ATLAS detector in 2010 in pp collisions at a center-of-mass energy of $\sqrt{s} = 7\,\text{TeV}$ revealed an impressive detector performance in measurements of basic final state objects, in particular of jets [1]. The good quality of data allowed us to perform first searches for new physics beyond the Standard Model (SM) in jet signatures with the first $300\,\text{nb}^{-1}$ of data. The searches are performed for exotic dijet resonances [2], for deviations in dijet angular distributions [3], for threshold effects in multi-body signatures [4], as well as for SUSY signatures [5]. In the following, the multi-body search is discussed which is a search of a completely new type.

2 Search for new physics in multi-body signatures

High multi-jet cross-sections can be expected in particular, in models of new physics with a low scale of gravity, such as models with extra dimensions [6]. In these models, the fundamental scale of gravity, M_D, can be in the TeV range, while the Planck scale is an effective scale seen in a three-dimensional world. The lower limit from collider experiments on M_D is $940\,\text{GeV}$ for six extra dimensions [7], while for greater than six extra dimensions it is about $800\,\text{GeV}$ [8].

A striking prediction of such models is a continuum production of non-perturbative gravitational states, such as black holes [9], string balls [10], or p-branes [11] above the new mass threshold. Due to the lack of a UV-complete theory of quantum gravity there are few robust theoretical predictions. As gravity couples only to the energy-momentum content of matter, the decays of strong-gravitational objects should be approximately democratic to all degrees of freedom in the Standard Model. One expects high multiplicity final states dominated by jets, since quarks and gluons together include more degrees of freedom that the other SM particles.

A first search for final states of this kind is performed by ATLAS in the first $295\,\text{nb}^{-1}$ of data. One searches for a deviation from the SM prediction in the spectrum of the reconstructed invariant mass of the final state above a threshold of $800\,\text{GeV}$. The studied signatures include

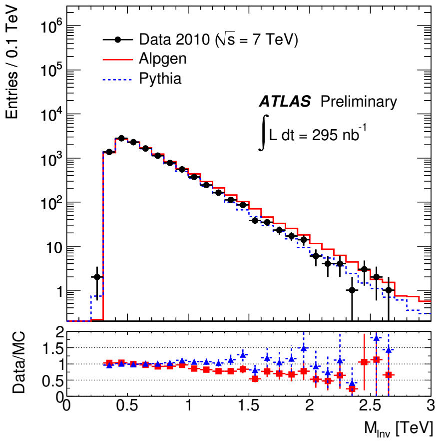

Figure 1: Invariant mass distribution for events with at least three objects and with $\sum p_T > 300\,\mathrm{GeV}$ after normalising the background to data. The solid dots are the data, while the solid and dashed histograms are the background predictions using scaled Alpgen and Pythia, respectively.

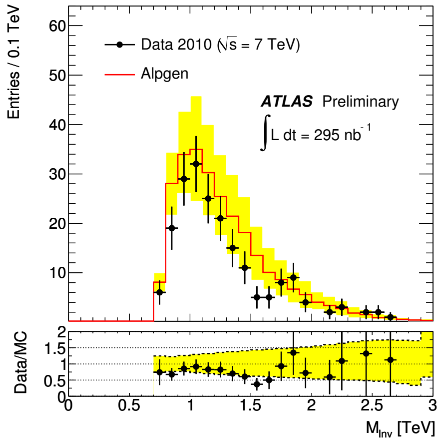

Figure 2: Invariant mass distribution for events with $\sum p_T > 700\,\mathrm{GeV}$. The solid dots are the data and the histogram is the rescaled background prediction using Alpgen simulation. The error band on the background is the total uncertainty: statistical (negligible) and systematic uncertainties added in quadrature.

jets as well as electrons, photons and muons, and make no requirement on the particle types or their number other than there be at least three. The search is thus kept as general as possible. The invariant mass, M_{inv}, is calculated from all objects and including missing transverse energy.

An additional requirement is imposed on the scalar sum of transverse momenta of all reconstructed objects in an event: $\sum p_T > 700\,\mathrm{GeV}$. This cut is useful for reducing the QCD $2 \to 2$ scattering processes characterised by a strong forward peak in the differential cross section, as it selects more centrally produced objects.

Since most of the objects passing the selections are jets, the dominant Standard Model background is QCD jet production. It is estimated using the MC generator Alpgen combined with Jimmy and Herwig. Since simulations can only approximate the true multi-jet cross section, the MC samples are normalised to the number of observed events in a nearby control region, where no new physics effects are expected. The predictions are then extrapolated to the signal region, hence relying only on the simulation of the shape of the differential cross section in mass. A control region in the range $300 < M_{\mathrm{inv}} < 800\,\mathrm{GeV}$ and $\sum p_T > 300\,\mathrm{GeV}$ is chosen.

The QCD model uncertainties are estimated by taking the difference between the Alpgen and Pythia predictions, where the Pythia samples are renormalised in the control region in the same way. The M_{inv} distributions for data, as well as for the Alpgen and Pythia predictions are shown in Fig. 1. Further major systematic uncertainties are obtained from the variation of the control region, from the choice of the parton density functions (PDF) in the simulations, and from the jet energy scale uncertainty. The M_{inv} distribution for events with $\sum p_T > 700\,\mathrm{GeV}$ for the data and for the simulation with its total uncertainty is shown in Fig. 2.

After all the event selections, 189 events are observed in the signal region, while the number of background events is estimated to be 251 ± 17(stat.) $\pm$ 84(syst). Using a Bayesian approach and assuming a flat prior p.d.f. over the cross section, an upper limit of 0.34 nb at the 95% confidence level is obtained for the cross section times signal acceptance.

For an estimate of a possible signal, black hole MC event samples are generated using the Blackmax and Charybdis programs. The samples are produced with an energy threshold equal to the fundamental scale of $M_D = 800\,\mathrm{GeV}$ and six extra dimensions. Using the simulated acceptance value as an illustration, the upper limit on the production cross section for high invariant mass events above 800 GeV is 0.6 nb. This limit does not include systematic uncertainties in the signal acceptance which is expected to be large due to the lack of a well established physics model in the mass region near the gravity scale. At the mass threshold of 800 GeV, the most optimistic calculation for the black hole cross-section can give $\sim$60 nb [12]. The upper limit is well below this value, which illustrates the potential rejection power of this result on low scale gravity models.

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