ATLAS NOTE

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Exotics Sensivity at 33 TeV

The ATLAS collaboration

1   Introduction

The energy upgrade of the LHC to 33 TeV will greatly increase the potential of the ATLAS detector for discovery and study of exotic new phenomena. While the range of models and their respective parameters is quite large, their salient feature is the production of high-p_T leptons, photons, jets and missing E_T. Our goal is to ensure that the detector design maintains the sensitivity to any signature containing these characteristics. In this section we discuss benchmark models of new physics and the expected sensitivity for ATLAS datasets of 300 fb^{-1} and 3 ab^{-1} at a center-of-mass energy of 33 TeV.

In order to characterize the high-mass reach we consider resonances with different production and decay mechanisms. As an example of strongly-produced, wide resonances we consider the Kaluza-Klein (KK) gluons g_{KK} in extra-dimensional models [1]. Many signatures of new physics contain cascade decays. To capture these scenarios we consider the g_{KK} decay to a pair of top-antitop quarks. Cascade decays can also occur from weakly-produced particles with narrow width. As an example of this scenario we consider Z' bosons decaying to top-antitop pairs in the topcolor model [1]. Finally, one of the simplest and most robust signatures of a new particle is its two-body decay to two leptons, exemplified by $Z' \to ee$ and $Z' \to \mu\mu$ decays [2].

2 $t\bar{t}$ resonances

Strongly- and weakly-produced $t\bar{t}$ resonances provide benchmarks not only for cascade decays containing leptons, jets (including b-quark jets) and missing E_T, but also the opportunity to study highly boosted topologies. We study the sensitivity to the KK gluon via the process $pp \to g_{KK} \to t\bar{t}$ in both the dileptonic and the lepton+jets decay modes of the $t\bar{t}$ pair. These decay modes are complementary in a number of ways. The lepton+jets mode allows a more complete reconstruction of the final-state invariant mass which increases the sensitivity of the search. This is particularly true for narrow resonances such as the $Z' \to t\bar{t}$ decay. On the other hand, this mode is susceptible to a large W+jets background and to loss of top quark discrimination when the top-jets merge at high boost. This mode also requires b-tagging to suppress a huge light-flavor background. The dominant background for the dilepton channel is Standard Model (SM) $t\bar{t}$ production and b-tagging is not essential for suppressing this background (b-tagging can help suppress diboson and Z+jets backgrounds but these are already insignificant after the Z-mass veto). Finally, the dilepton channel is less susceptible to the merging of top decay products because leptons (especially muons) are easier to identify in close proximity to the b-jet. By studying both channels we obtain conservative (dilepton) and best-case (lepton+jets) estimates of the upgraded detector's sensitivity.

We have investigated the search sensitivity for different integrated luminosity scenarios. For the dilepton mode, the dominant background is from $t\bar{t}$ production, followed by Z+jets and diboson production. The analysis of current ATLAS data have shown that mis-identification backgrounds from W+jets and QCD multi-jets are not significant. The statistical analysis is performed by constructing templates of the H_T distribution for background plus varying amounts of signal at different resonance masses and cross sections. H_T is defined as the scalar sum of the transverse momenta of the two leading leptons, the two leading jets, and the missing E_T. The likelihood function is defined as the Poisson probability product over all bins for the pseudo-data given the expectation in each bin. The Z+jets and diboson background normalizations are given by the theory cross section, while the $t\bar{t}$ background is floated and is effectively constrained by the low-H_T region. The resulting expected limits in the absence of signal, which we quote as a measure of sensitivity using statistical errors only, are shown in Table 1.

We perform a similar study for the lepton+jets channel where we use the reconstructed $t\bar{t}$ mass spectrum to search for the signal. In this channel we consider the dominant $t\bar{t}$ and W+jets backgrounds; the diboson background is not significant. The sensitivity obtained from the statistical analysis is also shown in Table 1. The distribution of reconstructed resonance mass and the resulting limits as a function

Table 1: Summary of expected limits for $g_{KK} \rightarrow t\bar{t}$ and $Z'_{\text{Topcolor}} \rightarrow t\bar{t}$ searches in the lepton+jets (dilepton) channel at pp collision center-of-mass energy of 33 TeV. All boson mass limits are quoted in TeV.

model	300 fb^{-1}	3 ab^{-1}
g_{KK}	7.1 (6.7)	11.4 (10.1)
Z'_{Topcolor}	4.1 (2.2)	7.6 (4.3)

Table 2: Summary of expected limits for $Z'_{SSM} \rightarrow ee$ and $Z'_{SSM} \rightarrow \mu\mu$ searches in the Sequential Standard Model at pp center-of-mass collision energy of 33 TeV. All boson mass limits are quoted in TeV.

model	300 fb^{-1}	3 ab^{-1}
$Z'_{SSM} \rightarrow ee$	12.7	15.8
$Z'_{SSM} \rightarrow \mu\mu$	11.6	15.1

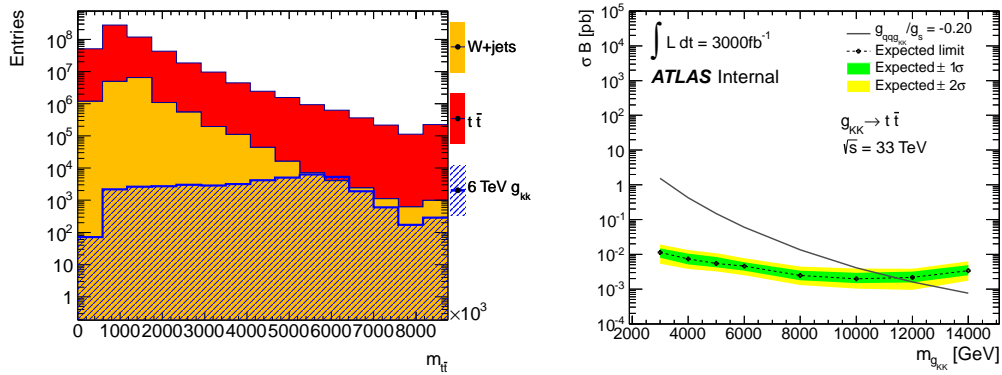of g_{KK} pole mass for the lepton+jets channel are shown in Fig. 1.

Figure 1: The reconstructed resonance mass spectrum (left) and limits (right) for the $g_{KK} \rightarrow t\bar{t}$ search in the lepton+jets channel with 3 ab^{-1} at pp center-of-mass collision energy of 33 TeV.

3 Dilepton resonances

The main issues in the detection and reconstruction of very high-p_T electrons and muons from heavy dilepton resonances such as Z' bosons and Randall-Sundrum gravitons are (i) the prevention of EM calorimeter response saturation for electrons due to the readout electronics, (ii) maintaining muon momentum resolution at high p_T, and (iii) maintaining sufficient angular coverage to measure the spin of the resonance. In our sensitivity studies of the Z' boson, we have separated the dielectron and dimuon channels since their momentum resolutions scale differently with p_T and the detector acceptances are different. The sensitivity analysis uses the same methodology that is used for the $t\bar{t}$ study and the Z' search with the current ATLAS data, which is the template-based likelihood fit of the dilepton mass spectrum. The background is dominated by the SM Drell-Yan production, while $t\bar{t}$ and diboson backgrounds are substantially smaller. In the electron channel, there is an additional background from jet-misidentification which needs to be suppressed with good rejection of photon conversions. We assume that the required jet rejection will be achieved with the upgraded detector. The sensitivity study is based on the the Drell-Yan background and lepton momentum resolutions of the current detector. The resulting sensitivity is shown in Table 2.

4 Conclusions

We have shown results of sensitivity studies for representative exotics signatures, comparing ATLAS datasets of 300 fb^{-1} and 3 ab^{-1} of integrated luminosity at a pp collision center-of-mass energy of 33 TeV. Strongly- and weakly-produced $t\bar{t}$ resonances and narrow dilepton resonances serve as benchmark processes with complex and simple final states respectively. The sensitivity to high-mass resonances approaches 12 TeV for $t\bar{t}$ resonances and 16 TeV for dilepton Z'_{SSM} resonances.

References

[1] ATLAS Collaboration, (2012) , and references therein.

[2] ATLAS Collaboration, Phys. Rev. Lett. **107** (2011) 272002, and references therein.