PROCEEDINGS OF SCIENCE

Search for di-jet resonances along with an isolated charged lepton at $\sqrt{s} = 13$ TeV pp collision with the ATLAS detector

Wasikul Islam*
On behalf of the ATLAS Collaboration
Department of Physics, University of Wisconsin, Madison, USA
E-mail: wasikul.islam@cern.ch

A search for dijet resonances in events with identified leptons was performed using the full Run 2 data collected in pp collisions at $\sqrt{s}$ = 13 TeV with the ATLAS detector, corresponding to an integrated luminosity of 139 fb^{-1}. The dijet invariant-mass (m_{jj}) distribution from events with at least one isolated electron or muon was probed in the range of $0.22 < m_{jj} < 6.3$ TeV. The analysis probes much lower m_{jj} than traditional inclusive dijet searches and is sensitive to a large range of new physics models in association with a final-state lepton. As no statistically significant deviation from the Standard Model background hypothesis was found, limits were set on contributions from generic gaussian signals and on various beyond-the-Standard Model (BSM) scenarios including the Sequential Standard Model, a charged Higgs boson model, a simplified Dark Matter model etc.

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*Speaker

1. Introduction

The Searches for Dijet resonance is very common at the Large Hadron Collider [1] experiments such as the ATLAS and CMS as resonance searches in the dijet invariant mass spectrum provide scopes to explore wide ranges of beyond the standard model (BSM) Physics. To overcome the trigger limitations of the inclusive dijet searches, a spectator object such as lepton can be used for triggering. A lepton in the final state helps to get access to a wide search range, reduces QCD multijet backgrounds and is sensitive to various physics processes. In this study at the ATLAS experiment [2], along with model independent searches various BSM models such as the Sequential Standard Model, a technicolor model, a charged Higgs boson model and a simplified Dark Matter model are probed.[3]

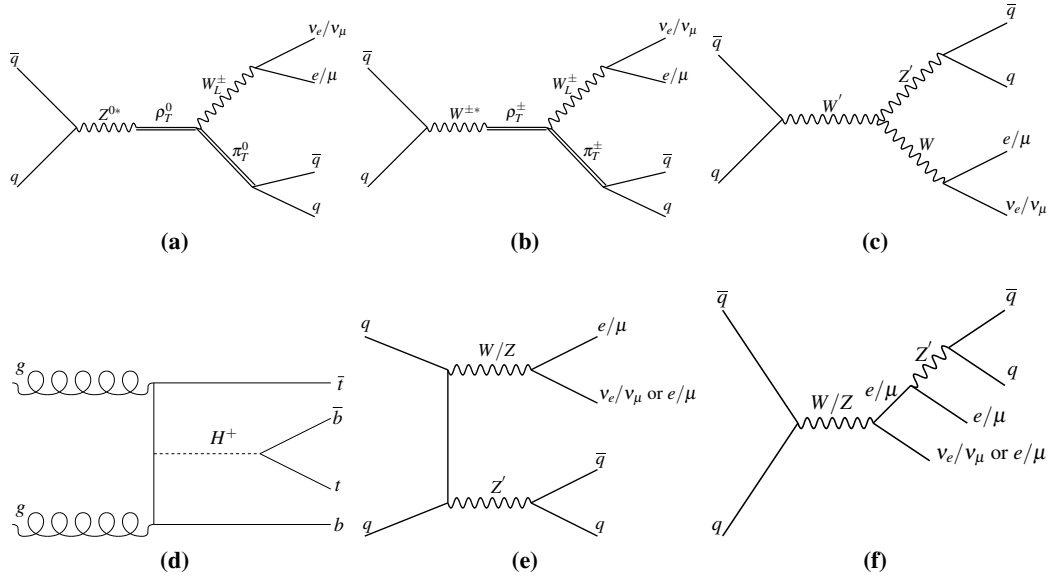


Figure 1: Representative Feynman diagrams for the processes considered in this analysis: (a)-(b) the techicolor model with production of ρ_T decaying into $\pi_T W^{\pm}$, (c) $W' \rightarrow Z'W^{\pm}$ production in the Sequential Standard Model, (d) the charged Higgs boson production in association with a top quark, tbH^{+}, (e)-(f) the simplified dark-matter model.

2. Analysis strategy

The analysis used full ATLAS Run 2 data corresponding to 139 fb^{-1}. High quality objects were selected based on performances. Various single-electron/muon triggers with different p_T(muon), E_T(electron), quality, and isolation thresholds were used. For muon triggers, lowest thresholds of $p_T > 24$ GeV and for electron triggers lowest thresholds of $E_T > 26$ GeV have been used. Electrons and muons with $p_T > 60$ GeV and jets with $p_T > 60$ GeV are selected. EMTopojets Jets are reconstructed using the Anti-kt algorithm with radius 0.4 and jet cleansing techniques have also been used. Overlap removal techniques have been applied between leptons jets. Dominant sources of background modeled by Monte carlo have been multi-jets (≥ 2 jets), $t\bar{t}$ and W+jets processes.

Two control regions have been used for the analysis are: 1. MC based control region and 2. Loose electron control regions(LE-CR). The MC based control region forms a "2+1 jets" or 3 jet control region while 3rd jet fulfils the same p_T requirement of $p_T > 60$ GeV. To ensure that no spurious bumps are contributed by jet reconstruction effects, or m_{jj} distributions don't have any biases due to object and event selections, another control region has been constructed by requiring the 2 jets + an isolated charged lepton but with loose lepton identification criteria.The following fit

function is used to model the shape of the estimated background,

$$f(x) = p_1(1-x)^{p_2}x^{p_3+p_4\ln x+p_5\ln^2 x}, \tag{1}$$

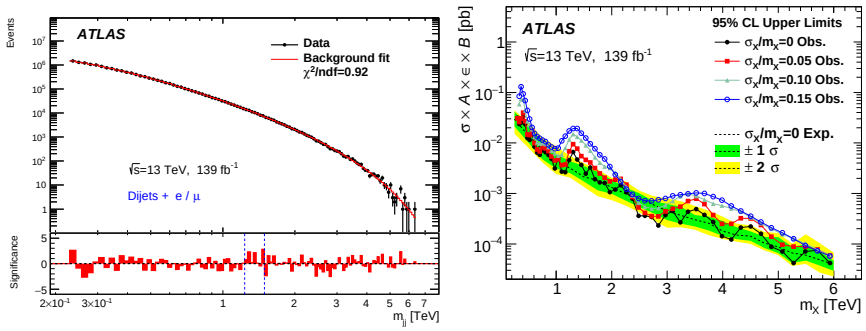
where $x \equiv m_{jj}/\sqrt{s}$ and the p_i are free parameters.

Detailed studies on various systematic uncertainties associated with the background fit, fit parameters, JES, JER, lepton systematics, PDF, scale, luminosity etc. have been performed. The fit uncertainty extracted by fitting pseudo-experiments with an alternative 5p fit. It has been found, uncertainties on limits are not dominated by systematic uncertainties and the combined effect from all systematic uncertainties leads to a 6% worsening of the limits. Systematic uncertainties are also included as nuisance parameters.

BumpHunter(BH) test has been used extensively for this analysis to find the deviation from the hypothesis that describes only the background. While scanning over the dijet invariant mass m_{jj} distributions, for a fixed number of possible intervals, BumpHunter calculates local p values using unique hypothesis test statistic while it uses the look elsewhere effect. BumpHunter gradually combines each of those different hypothesis tests and forms a new hypothesis test and calculates the minimum p value from different sets. While repeating the same procedure as a Pseudo experiment, the corresponding global significance is also calculated.

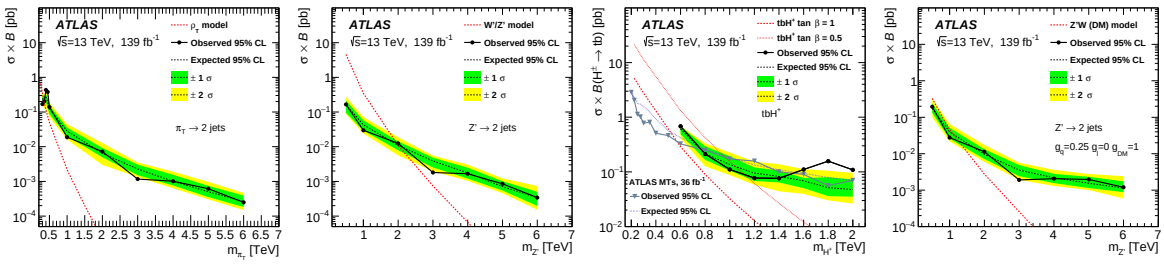
3. Results

In the BumpHunter search no significant deviation from background hypothesis was found. Using Bayesian method [4] at 95% C.L. upper limits have been calculated on cross sections. The 95% CL observed limits for a hypothetical particle X resulting in a contribution to the observed distribution with a Gaussian shape and various widths , corresponding to 0%, 5%, 10% and 15% of the signal mass have been calculated. The Bayesian limits are calculated for 4 different BSM models using the m_{jj} distribution with the background description discussed earlier.



(a) **(b)**

Figure 2: (a) Dijet invariant-mass distribution from the 2015–2018 data, from events with a high- lepton (e+μ combined).The largest deviation reported by BumpHunter is indicated by the vertical dashed lines. The global p-value of this deviation is 0.31. (b) The 95% CL observed limits for a hypothetical particle X resulting in a contribution to the observed distribution with a Gaussian shape and various widths.



(a) **(b)** **(c)** **(d)**

Figure 3: Observed (filled circles) and expected (dotted line with uncertainty bands) 95% credibility-level upper limits on the cross-section (σ) times branching ratio (B) for (a) the techicolor model with production of ρ_T decaying into $\pi_T W^{\pm}$, (b) $W' \to Z'W^{\pm}$ production in the Sequential Standard Model, (c) the tbH^+ model for $\tan\beta = 1$ (thick red dashed line) and $\tan\beta = 0.5$ (thin red dashed line), (d) the simplified dark-matter model. Figure (c) also shows the expected and observed limits (without indicating the 1 and 2σ bands) from the early Run 2 paper based on the multivariate techniques (MTs) in the signal regions to enhance the separation of signal from background. The presented limits are obtained using two leading jets in events with at least one isolated lepton with $p_{\mathrm{T}}^{\ell} > 60$ GeV.

4. Conclusion

Resonances through dijet invariant masses with the presence of an isolated charged lepton (electron or muon) with $p_T > 60$ GeV have been probed in the mass spectrum in between 216 GeV and 6.3 TeV. While using full Run 2 data of pp collision corresponding to 139 fb^{-1} from the ATLAS detector have been used for the studies. High quality object selection and not having any bias towards any BSM model have been part of the strategies for the analysis. In the entire search range, the maximum deviation from the background hypothesis while including all the systematic uncertainties found was at the dijet invariant mass of 1.3 TeV, which corresponds to p value of 0.3. At the absence of any significant deviation, limits have been set on Gaussian signals and 4 BSM models. In a simplified Dark Matter model, Z' mediator with masses below 1.2 TeV with leptophobic couplings ($g_q = 0.25$, $g_\ell = 0$ and $g_{\mathrm{DM}} = 1$) has been excluded. Though the analysis was not optimized for dedicated Charged Higgs searches and used conservative approaches on generic dijet resonance searches, the limits found from the analysis exclude Charged Higgs boson below 1.15 TeV assuming $\tan(\beta) = 0.5$ in the m_h^{mod-} scenario of the Minimal Supersymmetric Standard Model (MSSM) Higgs sector. The obtained limit was 150 GeV higher than the dedicated Charged Higgs search analysis by ATLAS collaboration earlier.

References

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