PROCEEDINGS OF SCIENCE

Search for new physics in multijet final states with CMS

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The latest results on new physics searches in multijet final states are presented using data collected by the CMS experiment at $\sqrt{s} = 8$ TeV. Searches for new physics with dijets, b-tagged dijets, and jet triplets are all considered. Also shown is the search for TeV-scale gravity performed as a search for extinction in the inclusive jet p_T spectrum.

The European Physical Society Conference on High Energy Physics -EPS-HEP2013
18-24 July 2013
Stockholm, Sweden

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PoS(EPS-HEP 2013)310

1. Introduction

Many extensions of the standard model (SM) predict final states involving quarks and gluons. Due to large backgrounds these final states can be difficult to handle. The CMS collaboration [1] has conducted a broad range of searches in various jet multiplicities. We will discuss the latest results on searches for resonances in the dijet and b-tagged dijet invariant mass spectrum, pair produced three-jet resonances, and the effects of terascale gravity on the inclusive jet p_T spectrum. The data sample was collected by the CMS experiment at a center of mass energy of 8 TeV.

2. Search for jet extinction in the inclusive jet p_T spectrum

Theories of terascale gravity predict new resonant states like Randall-Sundrum gravitons or black holes, which would decay with striking signatures. Another way how gravity at the TeV scale could manifest itself is through the suppression of high p_T objects beyond a new extinction scale M. For this search a dataset corresponding to 10.7 fb^{-1} of pp collisions at 8 TeV is used [2]. Events are selected that contain at least one particle flow jet that is reconstructed with the anti-k_t algorithm with a distance parameter $R = 0.7$, $p_T > 592$ GeV, and $|\eta| < 1.5$. The inclusive jet p_T spectrum in data is shown on the left in Figure 1. The observed spectrum is compared to a theoretical expectation, which is modeled using the CT10 parton distribution function (PDF) set. Perturbative corrections are included in the simulated spectrum, which is then convolved with the experimental response of the detector and scaled to the total observed cross section. The green bands represent uncertainties on the jet p_T spectrum due to uncertainties on the jet energy scale, jet energy resolution, and effects of different PDFs. The right plot in Figure 1 shows the ratio of the measured jet p_T spectrum and theoretical prediction. The effect of three different extinction scales M is shown as well. Overall good agreement is found between the data and theoretical prediction and limits are place at the 95% confidence level at $M = 3.3$ TeV.

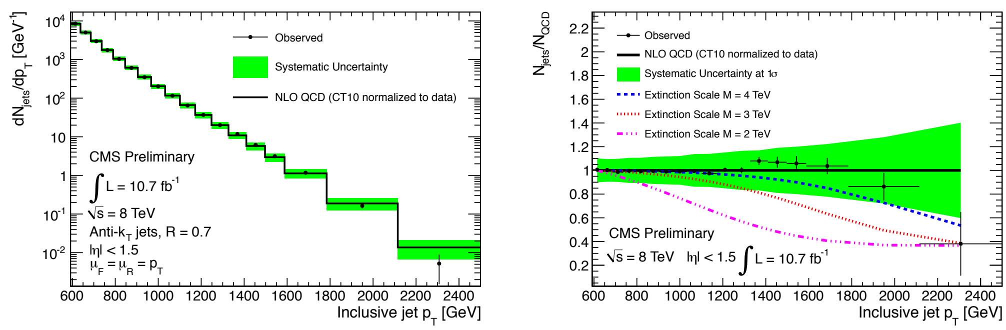

Figure 1: Left: Inclusive jet p_T spectrum, Right: Ratio of measured jet p_T spectrum and theoretical prediction. The effect of extinction is shown for three different values of M.

3. Search for narrow dijet and di-bjet resonances

Several new physics models predict heavy resonances that decay into pairs of jets (quark-

quark, quark-gluon, gluon-gluon). These quark final states can either be comprised of light-flavor or heavy-flavor quarks. Dedicated searches have been performed by CMS for these scenarios using 19.6 fb^{-1} of pp collisions [3, 4]. Events are selected that contain two wide jets with $|\eta| < 2.5$, $|\Delta\eta| < 1.3$, and dijet mass $M_{jj} > 890$ GeV. To form a wide jet one first starts out with an anti-k_t jet with distance parameter $R = 0.5$ with $p_T > 30$ GeV and subsequently adds the four-vectors from adjacent jets within a radius of 1.1 to the seed jet. This technique reduces the sensitivity to gluon radiation. The dijet invariant mass spectrum can be seen in on the left of Figure 2. The background is estimated from a fit to the data, which shows good agreement with a smoothly falling distribution. Limits are placed on several different models (string resonances (S), excited quarks (q), E6 diquarks (D), axigluon (A), coloron (C), W', Z', RS graviton (G), color octet scalar (S8)) and mixtures of quarks and gluons in the final state. The right plot in Figure 2 shows the model independent limits at the 95% confidence level on $\sigma\times$ BR $\times$ acceptance accompanied by the theory lines of the aforementioned models. Limits reach up to 5.1 TeV for string resonances.

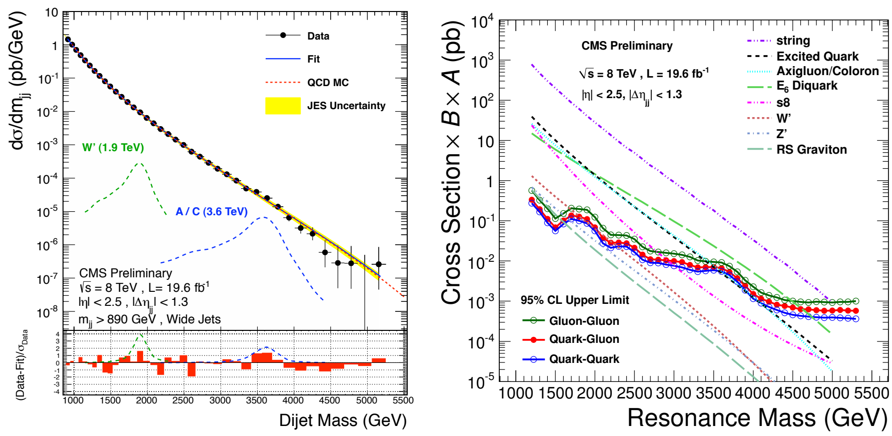

Figure 2: Left: Dijet mass spectrum, Right: Model independent limits at the 95% confidence level on $\sigma\times$ BR $\times$acceptance

A natural extension of this search is the addition of b jet identification. The data is split up into three exclusive categories where either none, one, or both of the wide jets are b-tagged. Limits are placed depending on the quark-gluon content of the final state and $f_{b\bar{b}} = BR(X \to b\bar{b})/BR(X \to jj)$, which describes the contribution to the different b-tagging categories. Figure 3 shows limits at the 95% confidence level on $\sigma\times$ BR $\times$ acceptance on the left for a Z' model with $f_{b\bar{b}} = 0.2$ and on the right for an RS graviton with $f_{b\bar{b}} = 0.1$.

4. Search for light- and heavy-flavor three jet resonances

Another favored extension of the SM is supersymmetry (SUSY), predicting a variety of new particles at the TeV scale. A new quantum number called R-parity is defined to distinguish between SM particles and their supersymmetric partners. With strong limits placed on R-parity conserving scenarios, it becomes more and more important to widen the scope and consider other possibilities as well. In the case of R-parity violation (RPV), SUSY particles can couple strongly to SM particles

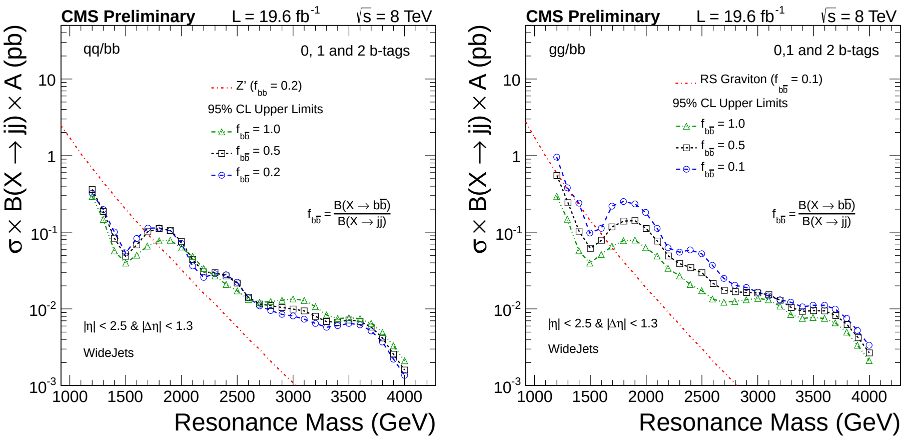

Figure 3: Model independent limits at the 95% confidence level on $\sigma\times$ BR $\times$ acceptance on the left for a Z' model with $f_{b\bar{b}}$ =0.2 and on the right for an RS graviton with $f_{b\bar{b}}$ =0.1.

(i.e., quarks) without leaving a large amount of missing energy in the final state. A search for one of these scenarios, described by pair production of new heavy resonances (gluinos) decaying through R-parity violation exclusively into three quarks is presented. Two different coupling scenarios are considered where the three final state quarks are all light-flavor quarks, or where there are two light-flavor and one heavy-flavor quark. The data used comprises 19.5 fb^{-1} of pp collisions at 8 TeV [5]. Events are selected that contain at least six particle flow jets clustered with the anti-k_t algorithm and a distance parameter of $R = 0.5$. The jet-ensemble technique is used to associate the six leading jets in each event into 20 unique triplet combinations. When plotting the triplet invariant mass M_{jjj} vs. the scalar sum of the transverse momenta $\sum_{jjj}|p_T^{jet}|$ of each triplet one can see that correct combinations pile up along a horizontal line, as shown by the colored area on the right hand side of Figure 6. For incorrect combinations M_{jjj} scales with the $\sum_{jjj}|p_T^{jet}|$ which is shown in gray with colored contour lines in Figure 6. By selecting triplets that satisfy: $M_{jjj} < \sum_{jjj}|p_T^{jet}| - \Delta$, where Δ is an adjustable offset, one can pick out the correct combinations as shown on the left hand side of Figure 6. Three different search regions are defined each satisfying optimized kinematic selection criteria. The inclusive search is optimized for heavy gluinos with a mass above 400 GeV. Event shape variables help to improve the sensitivity in this high mass region by selecting more isotropic events with Sphericity ≥ 0.4, consistent with the expectation of heavy particle decays. Each jet has to have a p_T of at least 110 GeV. The background estimate comes from a binned maximum likelihood fit directly to the data as shown on the left in Figure 5. For the heavy-flavor search b jet identification is used to enhance sensitivity. Triplets are only selected if at least on jet is tagged as a b jet, otherwise the kinematic selection criteria are identical to the inclusive search. To validate the analysis technique with all-hadronic $t\bar{t}$ events, a low mass region from 200–600 GeV is defined with lower p_T thresholds (fourth-jet $p_T \geq 80$ GeV, sixth-jet $p_T \geq 60$ GeV) and no requirement on sphericity. Here the background is modeled by a b jet control region in data and simulated $t\bar{t}$ events, showing overall good agreement with the data. Examples of the M_{jjj} distributions in data accompanied by the background estimates are shown in Figure 5. Overall the data agrees well with the background prediction and the search is performed by examining the smoothly falling

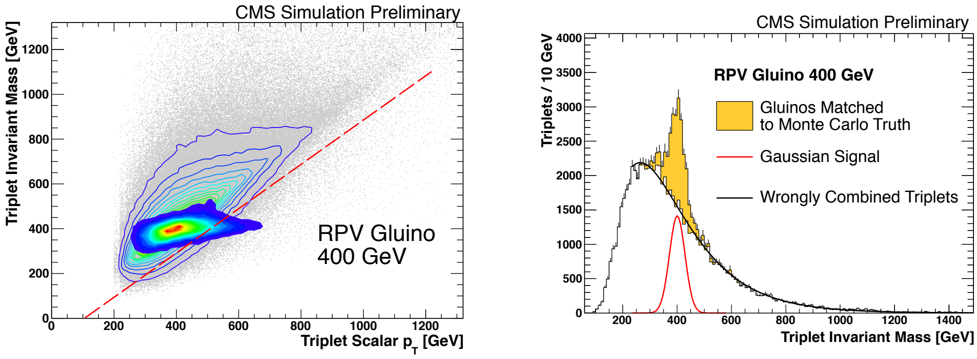

Figure 4: Left: M_{jjj} vs. $\sum_{jjj}|p_T^{jet}|$ for a gluino with mass of 400 GeV. Right: M_{jjj} distribution of triplets passing the $\Delta = 110$ GeV selection.

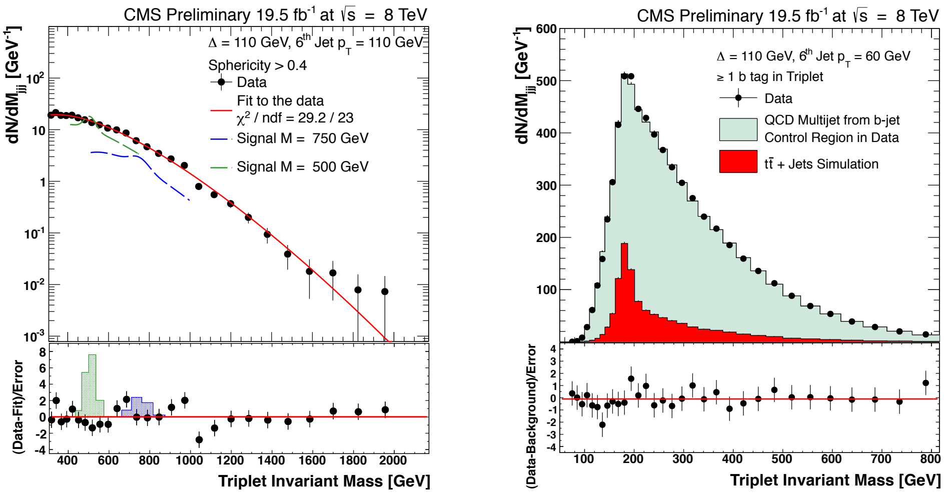

Figure 5: Left: M_{jjj} distribution for the inclusive search, Right: M_{jjj} low mass heavy-flavor search with the $t\bar{t}$ contribution shown in red.

spectrum in data for a localized Gaussian deviation. Light-flavor gluinos are excluded up to a mass of 650 GeV, extending the previous CMS exclusion by almost 200 GeV. Likewise heavy-flavor gluinos are excluded between 200 – 835 GeV for the first time.

5. Conclusion

Several searches for new physics in multijet final states have been presented. All analyses used data collected by the CMS experiment at a center of mass energy of 8 TeV. No evidence of new physics processes were found and strong limits were placed on a variety of models.

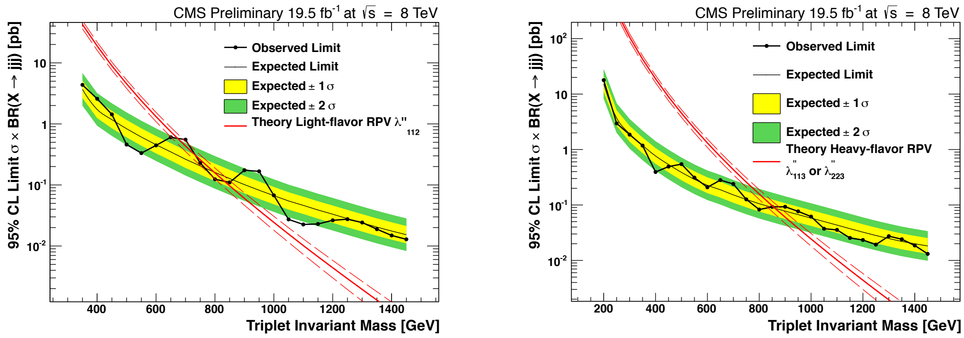

Figure 6: Observed and expected frequentist CLs cross section limits at the 95% confidence level as a function of mass, for light-flavor (left) and heavy-flavor gluinos (right).

References

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