PRAMANA — journal of physics
© Indian Academy of Sciences
Vol. 79, No. 4
October 2012
pp. 839–843

Dijet physics with CMS detector at the Large Hadron Collider

SUVADEEP BOSE, on behalf of the CMS Collaboration
University of Nebraska Lincoln, Department of Physics and Astronomy, 855 N 16th Street, Lincoln, NE 68588, USA
E-mail: sbose@fnal.gov

Abstract. The results from various dijet distributions in proton–proton collisions at a centre-of-mass energy of 7 TeV, with 2010 and 2011 data from the CMS experiment, are presented. The measurements of the dijet mass spectra, centrality ratio, azimuthal decorrelation and angular distribution are shown. Sensitivity of the phenomenological parameters used to model different event generators is also investigated. Prospects for observing evidence for new physics in these distributions are presented.

Keywords. CMS; dijets; quark compositeness; resonance models.

PACS Nos 12.60.Rc; 14.65.Jk

1. Introduction

Jets are experimental signatures of quarks and gluons. At large momentum transfer events with at least two jets (dijets) may be used to confront predictions of perturbative QCD and to search for signatures of new physics. In this paper, we report on dijet analyses based on data collected by the Compact Muon Solenoid (CMS) detector [1] at the CERN Large Hadron Collider, at a proton–proton collision energy of $\sqrt{s} = 7$ TeV.

2. Event selection

The analyses discussed here are done with particle flow jets or calorimeter jets [2] using the anti-k_T clustering algorithm [3] with a distance parameter $R = 0.5$ (0.7). Spurious jets from noise and noncollision backgrounds are eliminated by loose quality criteria on the jet properties. The jet four-momenta are corrected for the nonlinear response of the calorimeters [4]. Events are required to have a primary vertex reconstructed within 24 cm of the detector centre along the beam line. Events having at least two jets with two highest transverse momenta (p_T) are selected and the two highest-p_T jets are used for the analyses discussed here.

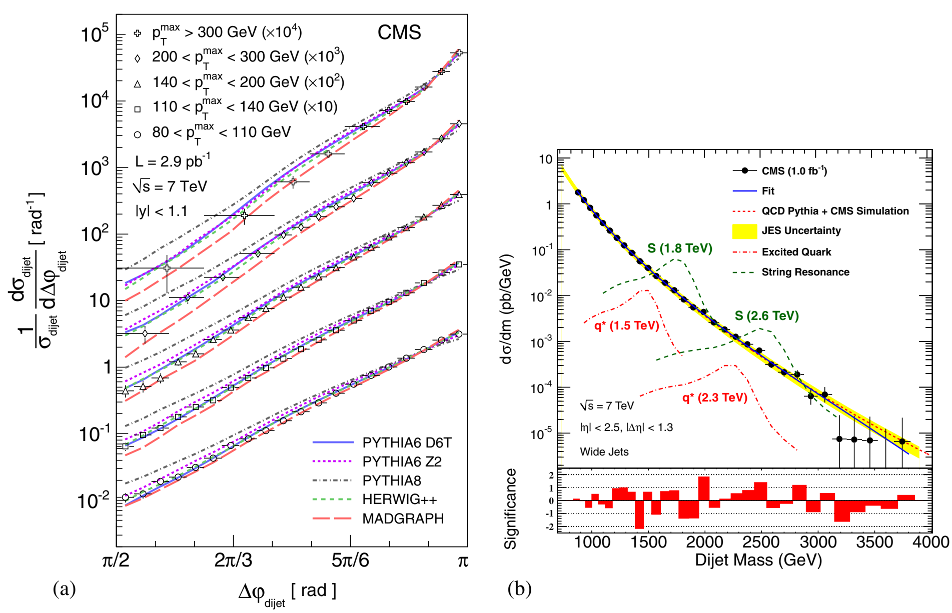
3. Results

3.1 *Dijet azimuthal decorrelation*

The difference in the azimuthal angles of the dijets ($\Delta\phi_{\text{dijet}}$) is used to study higher order QCD radiation effects without the need to reconstruct additional jets. Soft-gluon emissions in the initial and final states decorrelate the two leading jets and cause deviations from π. The measured normalized dijet distributions (figure 1a) are better described by PYTHIA [5] and HERWIG++ [6] event generators. The MADGRAPH [7] event generator predicts less azimuthal decorrelation than observed in data [8].

3.2 *Dijet mass and search for resonances*

The dijet mass spectrum predicted by quantum chromodynamics (QCD) falls smoothly and steeply with increasing dijet mass. Many extensions of the Standard Model predict the existence of new massive objects that couple to quarks (q) and gluons (g), and result in resonant structures in the dijet mass spectrum. A smooth parametrization of the dijet mass data distribution is used to model the background prediction for the narrow resonance search. If a dijet resonance exists, it should appear in the dijet mass spectrum as a resonance peak on top of a smooth background. The measured dijet mass spectrum is shown in figure 1b and the data look to be in good agreement with Standard Model (SM) prediction. In the absence of a new physics signal, mass limits on a few models of dijet



(a) (b)

Figure 1. (**a**) $\Delta\phi_{\text{dijet}}$ distributions in different leading jet p_{T} regions. Data points include statistical and systematic uncertainties. (**b**) Dijet mass distribution compared to simulations of excited quarks and string resonance signals in the CMS detector.

resonance are set. At 95% CL string resonances with mass less than 4 TeV, excited quarks with mass less than 2.49 TeV and axigluons and colourons of mass less than 2.47 TeV, are excluded [9] with 1 fb^{-1} of CMS data.

3.3 *Dijet centrality ratio and angular distributions*

The QCD processes produce more dijet events at forward rapidities, while the production of new heavy particles, beyond the Standard Model, populates more central rapidities. The dijet centrality ratio, defined as the number of events with both jets having $|\eta| < 0.7$ divided by the number of events with both jets having $0.7 < |\eta| < 1.3$, is sensitive to these effects. The measured dijet centrality ratio is flat as predicted by QCD. In the presence of contact interaction, the dijet centrality ratio rises rapidly with the departure from the SM prediction occurring at a dijet mass that depends on the scale Λ of the interaction. The measured ratio is used [10] to search for contact interaction among left-handed quarks at an energy scale Λ in the process $qq \rightarrow qq$. This is modelled with the effective Lagrangian $L_{qq} = (\pm 2\pi/\Lambda^2)(\bar{q}_L \gamma^\mu q_L)(\bar{q}_L \gamma_\mu q_L)$. Figure 2a shows a comparison of the measured dijet centrality ratio with the predictions of NLO QCD and various new physics models. In figure 2b we show the log-likelihood-ratio for the data, the 95% CL_s points, and the SM expectation (with 1 and 2σ bands) vs. contact interaction scale Λ. We exclude a contact interaction with scale $\Lambda < 4$ TeV at 95% CL

A complimentary approach to look for new physics with quark compositeness is carried out with the dijet angular distributions which probe the properties of parton–parton scattering without strong dependence on the details of the parton distribution functions. The dijet angular distribution is expressed in terms of $\chi_{\text{dijet}} = \exp(|y_1 - y_2|)$, where y_1 and y_2 are the rapidities of the two leading jets. In this variable QCD exhibits a flat distribution, while signatures of new physics (e.g., contact interactions) are expected to produce an excess at low values of χ_{dijet}. The measured χ_{dijet} distributions (figure 3a) are in agreement with next-to-leading order (NLO) QCD calculations [11]. We exclude

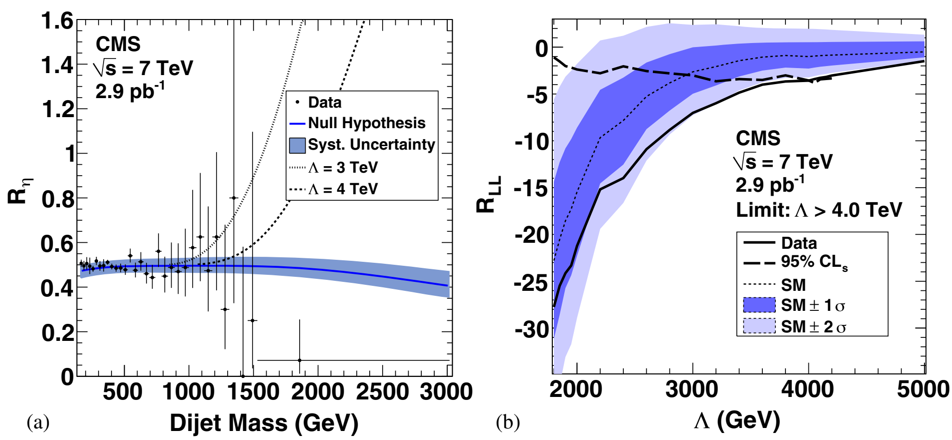


Figure 2. (**a**) Dijet centrality ratio compared to QCD prediction, contact interactions with $\Lambda = 3, 4$ TeV. (**b**) Summary of the limit for the contact interaction scale Λ.

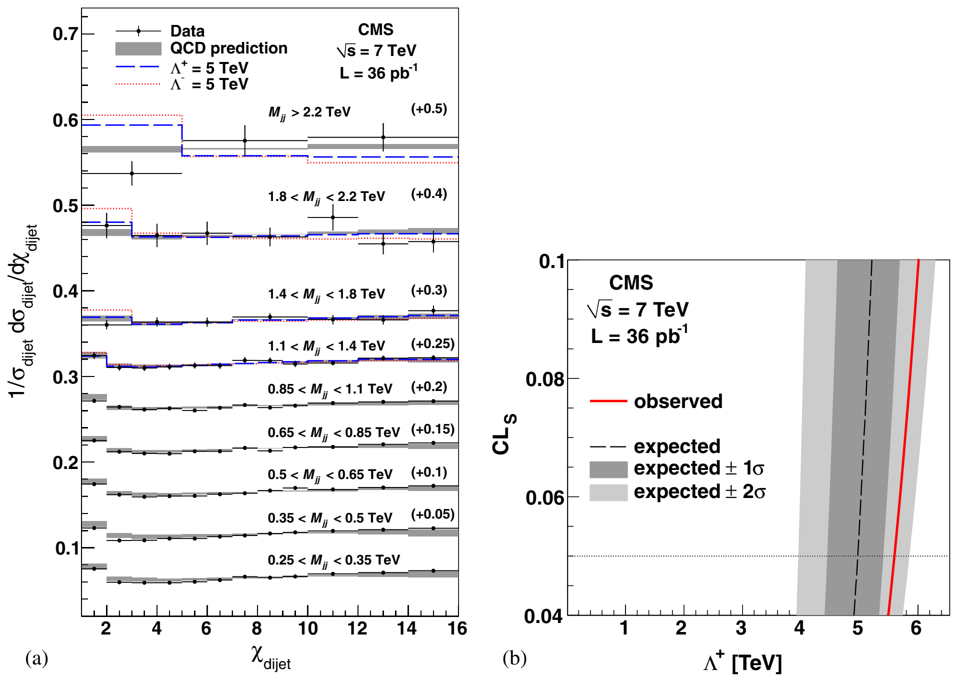


Figure 3. (**a**) Normalized dijet angular distributions in several dijet mass (M_{jj}) ranges compared to QCD prediction (shaded band) and with predictions including a contact interaction term of $\Lambda^+ = 5$ TeV (dashed histogram) and $\Lambda^- = 5$ TeV (dotted histogram). (**b**) Observed $\mathrm{CL_s}$ (solid line) and expected $\mathrm{CL_s}$ (dashed line) with one (two) standard deviation(s) indicated by the dark (light) band as a function of the contact interaction scale Λ^+.

a range of a colour- and isospin-singlet contact interaction scale for a left-handed quark compositeness model at $\Lambda^+ < 5.6$ TeV ($\Lambda^- < 6.7$ TeV) for destructive (constructive) interference at 95% CL (figure 3b).

4. Conclusions

Some results from analyses involving dijets in the CMS experiment are presented. The dijet azimuthal decorrelation is shown to be a handle for testing the sensitivity of the phenomenological parameters responsible for modelling different event generators. A search for narrow resonances with the inclusive dijet final states using 1 fb^{-1} of data shows no evidence of new physics and excludes string resonances with mass less than 4 TeV, excited quarks with mass less than 2.49 TeV and axigluons and colourons of mass less than 2.47 TeV. The dijet angular distribution sets exclusion limits to a contact interaction scale of $\Lambda^+ < 5.6$ TeV ($\Lambda^- < 6.7$ TeV) for destructive (constructive) interference at 95% CL.

References

[1] CMS Collaboration, *J. Instrum.* **3**, S08004 (2008)
[2] CMS Collaboration: CMS jet performance in *pp* collisions at $\sqrt{s} = 7$ TeV, CMS-PAS-JME-10-003 (2010)
[3] M Cacciari, G P Salam and G Soyez, *J. High Energy Phys.* **04**, 63 (2008)
[4] CMS Collaboration, *J. Instrum.* **6**, P11002 (2011)
[5] T Sjöstrand, S Mrenna and P Skands, *Comput. Phys. Comm.* **178**, 852 (2008)
[6] M Bahr *et al*, *Eur. Phys. J.* **C58**, 639 (2008)
[7] J Alwall *et al*, *J. High Energy Phys.* **09**, 028 (2007)
[8] CMS Collaboration, *Phys. Rev. Lett.* **106**, 122003 (2011)
[9] CMS Collaboration, *Phys. Lett.* **B704**, 123 (2011)
[10] CMS Collaboration, *Phys. Rev. Lett.* **105**, 262001 (2010)
[11] CMS Collaboration, *Phys. Rev. Lett.* **106**, 201804 (2011)