Jet commissioning and dijet physics in CMS

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The hadronic jets are comissionned in *pp* collisions by the CMS collaboration using the data produced at $\sqrt{s} = 0.9$, 2.36 and 7 TeV. Then the dijet final state is used to test the behavior of QCD at new energy scales and to search for new physics beyond the standard model.

1 Introduction

Jets are experimental signatures of the hadronisation of quarks and gluons, which are produced in high energy processes such as the hard scattering of partons in the *pp* collisions. Due to their large production cross section, jets are an ideal tool to probe the physics processes within and beyond the standard model. At leading order the jets are produced by pairs in a hard scattering of two partons. From one hand this process is expected to be well described by perturbative QCD with a t-channel matrix element. From the other hand the selection of dijet final states may be used to search for new resonances in parton-parton channels ($q\bar{q}$, qq, qg and gg) such as excited quarks or the presence of contact interactions.

2 Jet reconstruction at CMS collaboration

Three different types of jet reconstruction are employed by CMS [1], characterized by the way that the sub-detector inputs are used during the jet finding procedure: calorimeter jets (Calo jets), jet-plus-tracks jets (JPT jets) and particle flow jets (PF jets). Very briefly:

The calorimeter jets (Calo) are reconstructed using energy deposits in the electromagnetic and hadronic calorimeter cells, combined into calorimeter towers as inputs. A calorimeter tower consists of one or more hadron calorimeter (HCAL) cells and the geometrically corresponding electromagnetic calorimeter (ECAL) crystals.

The Jet-Plus-Tracks (JPT) algorithm corrects the energy and the direction of a calorimeter jet. It exploits the excellent performance of the CMS tracking detectors [1] to replace the calorimeter towers by tracks when they are well matched in $\eta - \phi$ space. This procedure improves significantly the resolution of calorimeter jets up to $\eta \approx 2.4$.

The Particle Flow (PF) algorithm aims to reconstruct, identify and calibrate individually each particle by combining the information from all CMS sub-detector systems. As a result of the PF reconstruction, the inputs to the jet clustering are almost fully calibrated and the resulting higher level objects (jets) require small a posteriori energy corrections.

Jet energy corrections need to be applied to account for the non-linear and non-uniform response of the CMS calorimeters. These corrections are estimated in QCD events simulated by the PYTHIA MC generator as described in [2]. The principle consists in comparing the p_T of the reconstructed jet to the p_T of the matched generated jet taken just after the hadronisation process. The correction procedure consists of two stages: the relative correction that makes the jet response uniform in η, by calibrating, on average, to the response in the central region of the calorimeters $|\eta| < 1.3$; the absolute correction that removes the p_T dependence of the jet response. The combined correction factor $C(p_T, \eta)$ is derived as the product of the two steps. Its size is typically 2 for Calo jets at 20 GeV while it's only 1.1 for the PF jets. Additional corrections exist for pile-up and noise effects (*offset corrections*). Their importance is small with present luminosity but would increase together with the LHC performance.

The MC driven calibration procedure was checked using the data sample collected at $\sqrt{s} =$ 7 TeV using the p_T balance between two jets in the dijet data sample or the between the jet and the photon in *jet+photon* events. A conservative value of jet energy scale uncertainty of 10% (5%) was confirmed for Calo (JTP and PF) jets by comparing the difference between the jet response for data and MC.

3 Study of jet properties at $\sqrt{s} = 0.9$, 2.36 and 7.0 TeV

The CMS collaboration took advantage of the first data samples collected at $\sqrt{s} = 0.9$ (350k events) and $\sqrt{s} = 2.36$ TeV (20k events) to test our understanding of the jet kinematics and structure [3, 4]. While many jet algorithms are considered for jet reconstruction [1], it was agreed to restrict the first jet validation analyses to the anti-k_T [5] clustering algorithm with $R = 0.5$.

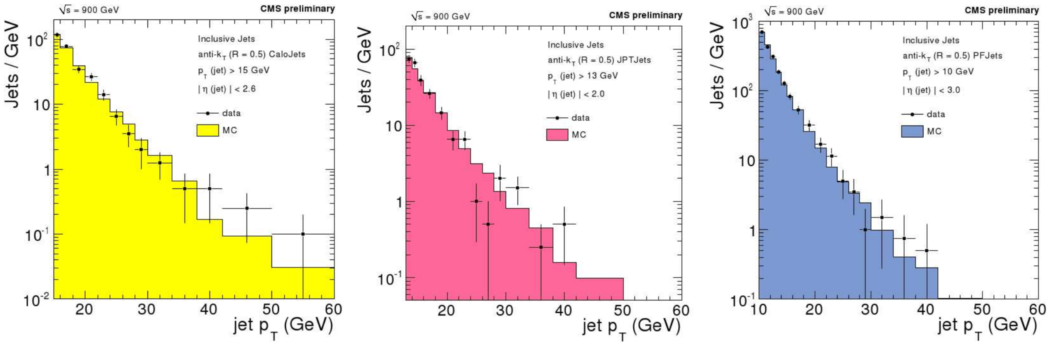

Figure 1: Comparisons of data and MC for inclusive jets p_T spectrum at $\sqrt{s} = 0.9$ TeV. From left to right: Calo, JPT and PF jets.

The inlusive jets sample was selected with relatively loose cuts: $p_T > 10 - 15$ GeV and $|\eta| < 2 - 3$ dependant on the kind of the jet [3]. A jet quality selection allowed to remove the most of the noise jets passing the kinematics cuts. Very briefly it consists in rejecting Calo or JPT jets made purely of HCAL clusters or of a single tower jet, while the PF jets are rejected if they do not contain charged hadrons. In Fig. 1 is shown the distribution of the inclusive jets spectrum for 3 kind of jets well described by MC. The jet resolution is worse in case of Calo jets and leads to a larger extension of the high p_T tail due to migrations. The good purity of the PF jets allows to reduce the p_T down to 5 GeV in order to show that the calorimeter noise is well under control [4].

The internal composition of jets separated into electromagnetic and hadronic fraction for Calo jets is well described by MC [3]. The quality of understanding is even more striking in case of PF jets since the particle flow algorithm allow to separate between different energy fractions. The figure 2 produced in a similar analysis at $\sqrt{s} = 7.0$ TeV shows the reconstructed jets in data and MC with a striking agreement between them [6].

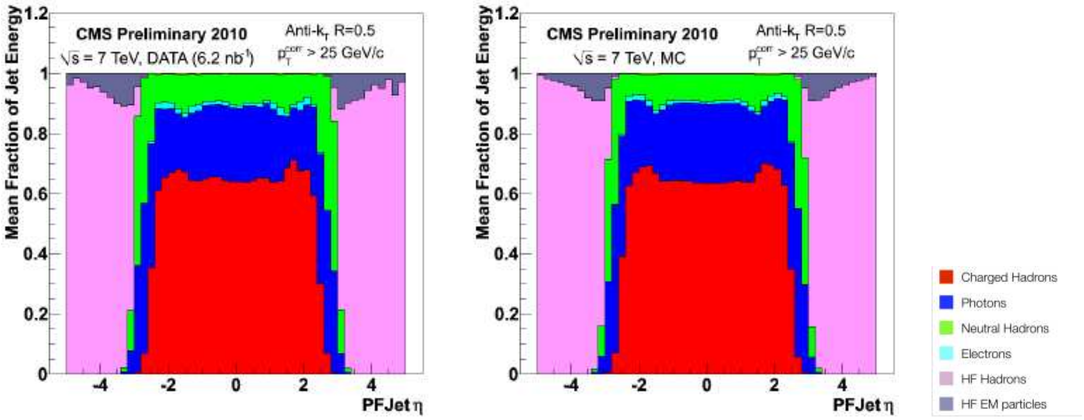

Figure 2: Reconstructed jet energy fractions as a function of pseudorapidity in the data (left) and in the simulation (right) at $\sqrt{s} = 7.0$ TeV. From bottom to top in the central region: charged hadrons, photons, electrons, and neutral hadrons. In the forward regions: hadronic deposits, electromagnetic deposits.

The dijet analysis was first carried out at lower center-of-mass energies showing a good understanding of this topology at low transverse momentum [3]. It was repeated at $\sqrt{s} = 7$ TeV with an integrated luminosity of approximatively 0.2 nb^{-1} at larger momentum by requesting a harder p_T cut above 25 GeV and a back-to-back topology [7]. The azimuthal difference $\Delta\phi = |\phi_{\text{jet}1} - \phi_{\text{jet}2}|$ is well described and peaking toward π as expected from LO QCD. To enhance the LO contribution a cut $\Delta\phi > 2.1$ is applied. The preliminary distribution of the invariant mass of two leading jets is well described by MC. Those results allow to push the investigations further to look for new physics beyond the standard model.

4 Searches for new physics

The first results presenting the search for new physics beyond the standard model in the dijet production was recently presented using 120 nb^{-1}. The first analysis [8] looks for an excess in the dijet invariant mass spectrum. Jets are selected in the central region $|\eta| < 1.3$ where the QCD background is expected to be suppressed with respect to the forward region $|\eta| > 1.3$. The search was performed for masses above 0.354 TeV where the trigger starts to be fully efficient. Statistical uncertainties are dominant at large masses while the jet energy scale is the dominant systematic uncertainty all over the mass range. The maximum observed mass range is 2.53

TeV, but no significant excess was observed as shown on the Fig. 3. On this plot the histogram bin widths are approximately equal to the expected dijet mass resolution for narrow resonances measured with calorimeter jets and gradually increase with dijet mass. The exclusion limit at 95% C.L. is drawn for string resonances with mass less than 1.67 TeV, excited quarks with mass less than 0.59 TeV and axigluons and colorons of mass less than 0.52 TeV.

The second analysis [9] was looking for the dijet centrality ratio, which is defined as the number of events with both jets in the region $|\eta| < 0.7$ divided by the number of events with both jets in the region $0.7 < |\eta| < 1.3$. Since many sources of systematic uncertainty cancel in this ratio, the dijet ratio provides a precise test of QCD and is sensitive to new physics. It is expected to be less sensitive to the mass resonances but more to an hypothetical presence of contact interactions. The first data allowed to exclude contact interactions with scale $\Lambda < 1.9$ TeV at 95% C.L.

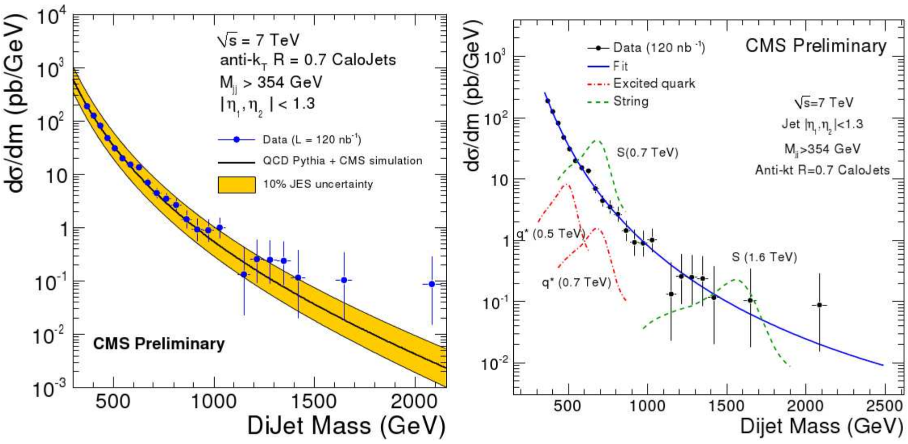

Figure 3: Left: the measured differential cross section data (points) in dijet mass are compared to a QCD MC prediction (black line). The yellow band shows the sensitivity to a 10% systematic uncertainty on the jet energy scale. Right: the dijet mass distribution (points) compared to simulations of excited quarks (dot- dashed red curves) and string resonance (green dashed curve) signals in the CMS detector.

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