Studies of Jets and MET At CMS

Salvatore Rappoccio for the CMS Collaboration
Johns Hopkins University, Baltimore MD

During the LHC early commissioning phase, CMS recorded about 350000 minimum bias events from proton-proton collisions at $\sqrt{s} = 900$ GeV, and 20000 minimum bias events from proton-proton collisions at $\sqrt{s} = 2360$ GeV. Three types of jets and missing transverse energy are reconstructed: from calorimeter energy depositions, from combined calorimeter and tracker information, and from particle flow candidates. We present the properties of inclusive jets and dijet events, as well as missing transverse energy from inclusive events. The collision data are in good agreement with predictions from PYTHIA minimum bias events simulated with the full CMS detector simulation.

1 Introduction

In 2009 CMS recorded roughly 350k and 20k minimum bias events from LHC proton-proton collisions at $\sqrt{s} = 900$ GeV and $\sqrt{s} = 2360$ GeV respectively. Here we present studies of jets and missing transverse energy, reconstructed from different detector inputs, with the intention to demonstrate that the jet and MET reconstruction in CMS is performing well at these energies.

Three different types of jet and MET reconstruction are employed by CMS [1], characterized by the way that the sub-detector inputs are used.

Calorimeter jets and MET are reconstructed using energy deposits in the electromagnetic and hadronic calorimeter cells.

The **Jet-Plus-Tracks and Track-Corrected MET** (JPT, tcMET) algorithms [2] correct the energy and the direction of calorimeter jets and MET using the excellent CMS tracking detectors [3].

The **Particle Flow** (PF) algorithm [4] aims to reconstruct, identify and calibrate each individual particle in the event by combining the information from all CMS sub-detector systems. PF particles are reconstructed as a combination of charged particle tracks and clusters in the electromagnetic and hadronic calorimeters, as well as signals in either of the two CMS pre-shower detectors and the muon system.

Jets are reconstructed with the anti-k_T algorithm [5], and corrected using Pythia [6] QCD events from proton-proton collisions at $\sqrt{s} = 900$ GeV and $\sqrt{s} = 2360$ GeV which were further processed with the full, GEANT4 [7] based, CMS detector simulation. They consist of two stages: the relative (Rel) 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 (Abs) correction that removes the p_T dependence of the jet response.

First we examine a sample of dijet events for which both jets with the highest transverse momentum p_T in the event are back-to-back in azimuth φ. The resulting high purity dijet sample allows the study of jet properties with loose additional jet quality criteria and serves as a benchmark sample for the jet commissioning.

Secondly, beyond the dijet selection, we also report on the characteristics of jets inclusively. In the absence of topological constraints, the purity of the inclusive jet sample is enhanced by applying tight kinematic selection requirements and jet quality criteria.

Finally, the missing transverse energy in an inclusive sample is examined. There are no physical sources of true missing transverse energy in the collisions at this time since the rate of such processes is much lower than the collected luminosity, so this gives a measurement of the missing transverse energy resolution.

2 Cleaning and Object Identification

In the jet results, jets are purified in two selections, "loose" for the dijet results, and "tight" for the inclusive jet results. The loose selection requires that jets are inconsistent with sources of calorimeter noise (both hadronic and electromagnetic), and the tight selection additionally rejects very "narrow" jets that are consistent with electronics noise.

In the $\not{E}_T$ results, several sources of noise are identified, including anomalous noise from hybrid photo-diodes (HPDs) in the hadronic barrel and hadronic endcap calorimeters (HB/HE), and photomultiplier window hits in the forward hadronic calorimeter (HF). Only the second source is removed for the $\not{E}_T$ results because the probability of HPD noise overlapping with real events is measured to be negligible.

3 Results

For brevity, only the results of 900 GeV data are shown. Please see References [8–10] for full results and the 2360 GeV comparisons. Results of dijet comparisons for the 900 GeV data and MC are shown in Figure 1. Results of inclusive $\not{E}_T$ comparisons for the 900 GeV data and MC are shown in Figure 2.

Good agreement is seen between the data and the MC in the distributions examined.

References

[1] **CMS** Collaboration, "The CMS Experiment at the CERN LHC", *JINST* **3** (2009) S08004.

[2] **CMS** Collaboration, "Jet Plus Tracks Algorithm for Calorimeter Jet Energy Corrections in CMS", *CMS PAS* **JME-09-002** (2009).

[3] **CMS** Collaboration, "Tracking and Vertexing Results from First Collisions", *CMS PAS* **TRK-10-001** (2010).

[4] **CMS** Collaboration, "Particle-Flow Event Reconstruction in CMS and Performance for Jets, E_T^{miss}, and Taus", *CMS PAS* **PFT-09-001** (2009).

[5] M. Cacciari, G. P. Salam, and G. Soyez, "The anti-kt jet clustering algorithm", *JHEP* **0804:063** (2008).

[6] T. Sjostrand, S. Mrenna, and P. Skands, "PYTHIA 6.4 physics and manual", *JHEP* **05:026** (2007).

[7] S. Agostinelli and et al., "Geant 4 – A Simulation Toolkit", *Nucl.Inst.A* **506** (2003) 250–303. `doi:10.1016/S0168-9002(03)01368-8`.

[8] **CMS** Collaboration, "Jets in 0.9 and 2.36 TeV pp Collisions", *CMS Physics Analysis Summary* **JME-10-001** (2010).

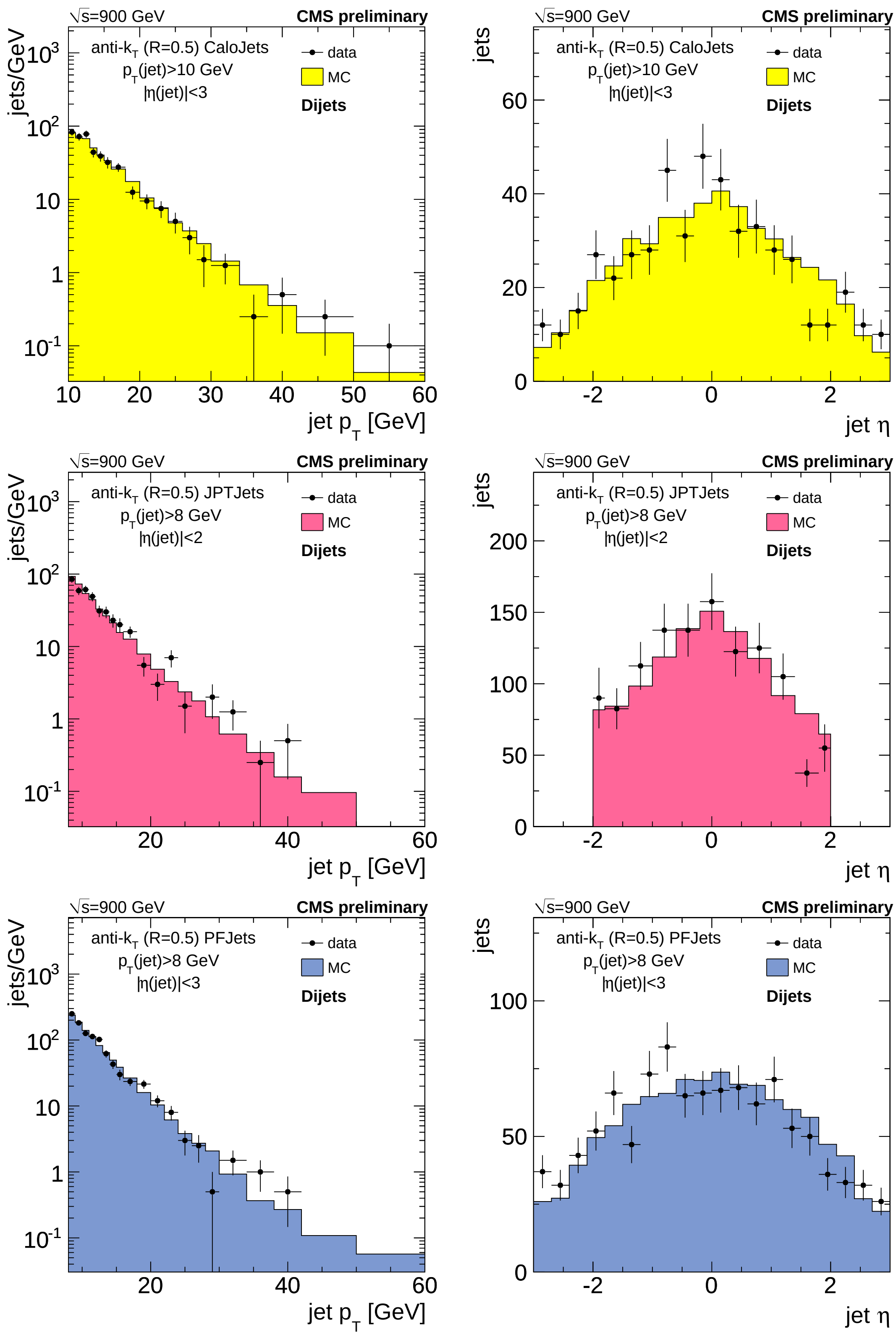
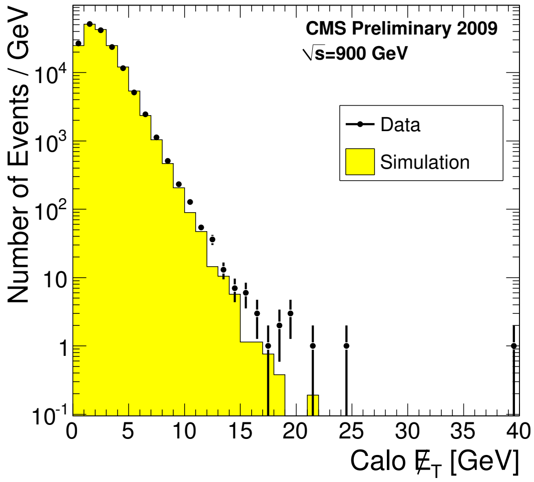
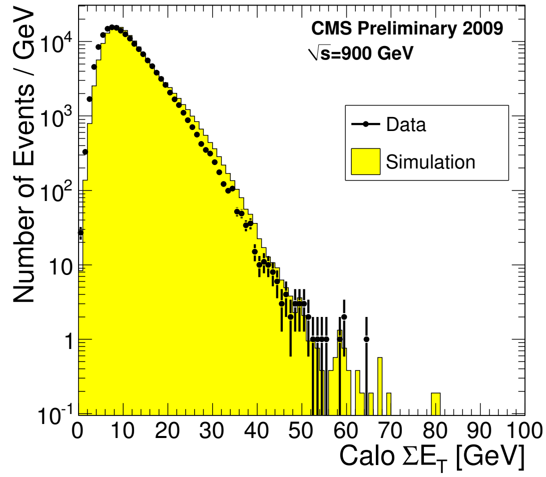


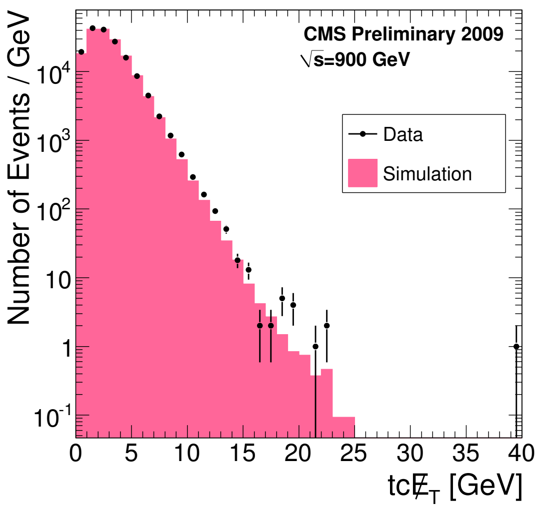
Figure 1: Comparisons of data and MC distributions for the two leading jets for selected $\sqrt{s} = 900$ GeV dijet events. Jet p_T is plotted on the left, jet η on the right. The calorimeter-only jets are plotted in the first row, track-corrected calorimeter jets ("jet-plus-tracks" jets) in the second, and the PF jets are plotted in the third row. Jets are reconstructed with the anti-k_T $R = 0.5$ algorithm.



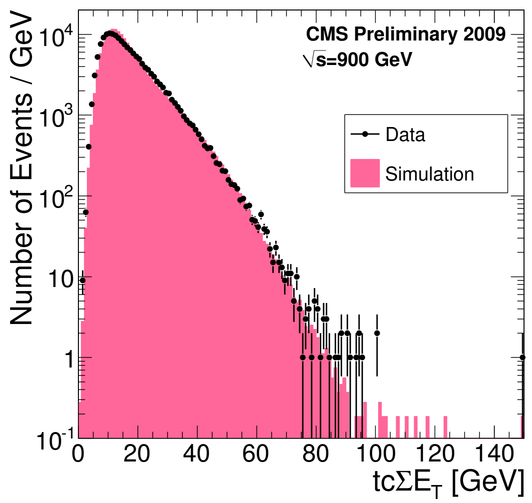
(a) Calo$\not{E}_T$ distribution



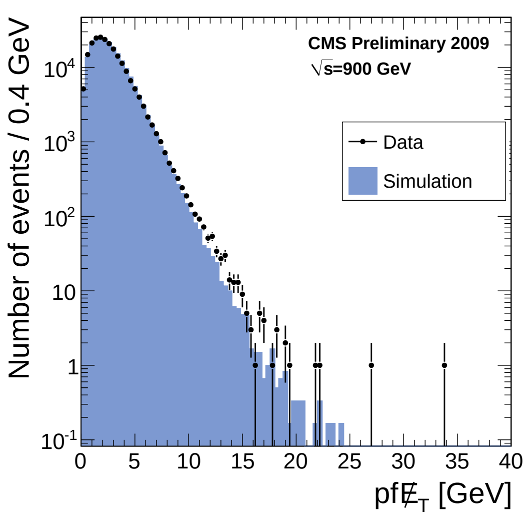
(b) CaloΣE_{T} distribution



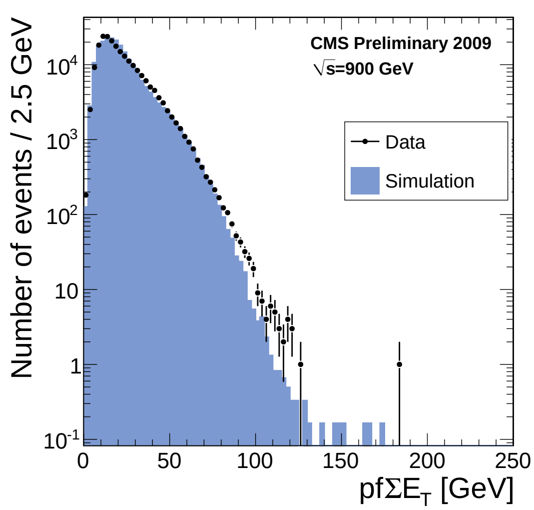
(c) tc$\not{E}_T$ distribution



(d) tcΣE_{T} distribution



(e) pf$\not{E}_T$ distribution



(f) pfΣE_{T} distribution

Figure 2: Comparisons of data and MC for the $\not{E}_T$ distributions (after cleanup procedure) in the 900 GeV data. $\not{E}_T$ is plotted on the left, ΣE_{T} is plotted on the right. The calorimeter-only $\not{E}_T$ is plotted in the first row, track-corrected $\not{E}_T$ in the second, and the PF $\not{E}_T$are plotted in the third row.

[9] **CMS** Collaboration, "Missing ET in 0.9 and 2.36 TeV pp Collisions", *CMS Physics Analysis Summary* **JME-10-002** (2010).

[10] **CMS** Collaboration, "Commissioning of the Particle-Flow Event Reconstruction with the first LHC collisions recorded in the CMS detector", *CMS Physics Analysis Summary* **PFT-10-001** (2010).