LATEST RESULTS ON JET PRODUCTION AND PROPERTIES FROM THE LHC

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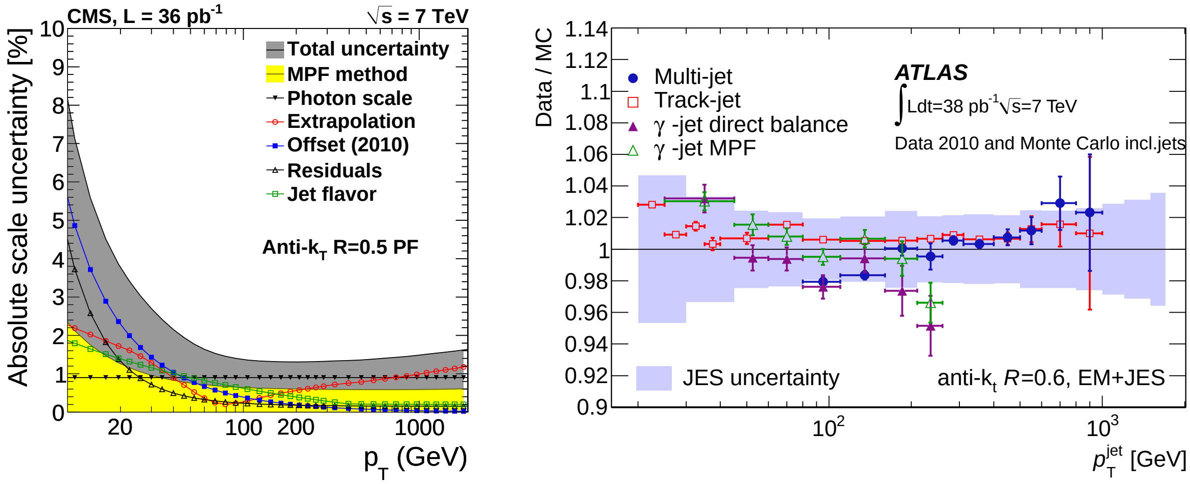
Investigations of jets performed by the ATLAS and CMS collaborations using collisions at $\sqrt{s} = 7$ TeV are described. Topics of interest are jet performance, production and the precision measurement of their properties. Comparison of the results to theoretical predictions are discussed and areas with poor agreement identified.

1 Introduction

The LHC has made amazing progress in the past few years to provide the experiments with a tremendous increase in the amount of data available for analysis, where 2011 brought approximately 4.7 fb^{-1} of data. The study of jets at the LHC is an important topic for many analysis, not simply due to the nature of the hadron collider environment, but also because the signature of many processes involves the production of jets. The kinematic properties of a jet are believed to reflect those of the progenitor particle, and thus provides a window into the hard process of the original scatter. Therefore measurements of jets provide important tests of the Standard Model of particle physics.

2 Performance

Both collaborations have performed extensive performance studies for the measurement of jets. [1] [2] ATLAS reconstructs jets using the anti-kT jet algorithm [3] using recombination parameters equal to 0.4 and 0.6, which can be crudely thought of as the jet radius. The jet energy scale uncertainty was determined to be less than 5% in the central region for 2010 data. Additional interactions have so far been seen to contribute little to the overall jet uncertainty, with the dominant contribution being from the single particle calorimeter response. In situ techniques have been used to cross check the calibration of jets, where results have shown the simulation and MC based techniques are consistent within the derived uncertainties, as illustrated in figure 1b. The CMS collaboration has chosen to use the same jet algorithm but different recombination parameters, 0.5 and 0.7. In addition to the clustering of energy collected by the calorimeters CMS use information from other parts of the detector, such as the tracker, creating objects known as particle flow jets. This improves the resolution and response for jet measurements. The performance of these particle flow jets can be seen in figure 1a, where there is a low uncertainty in the jet energy calibration down to low jet transverse momentum, p_T.



(a) (b)

Figure 1: The absolute uncertainty of the jet energy calibration as a function of jet p_T for particle flow jets in 2010 data is shown in figure (a). [2] The ratio of jet p_T to the reference jet using data and MC for a number of data driven techniques with the jet energy scale uncertainty shown as a reference in figure (b). [1]

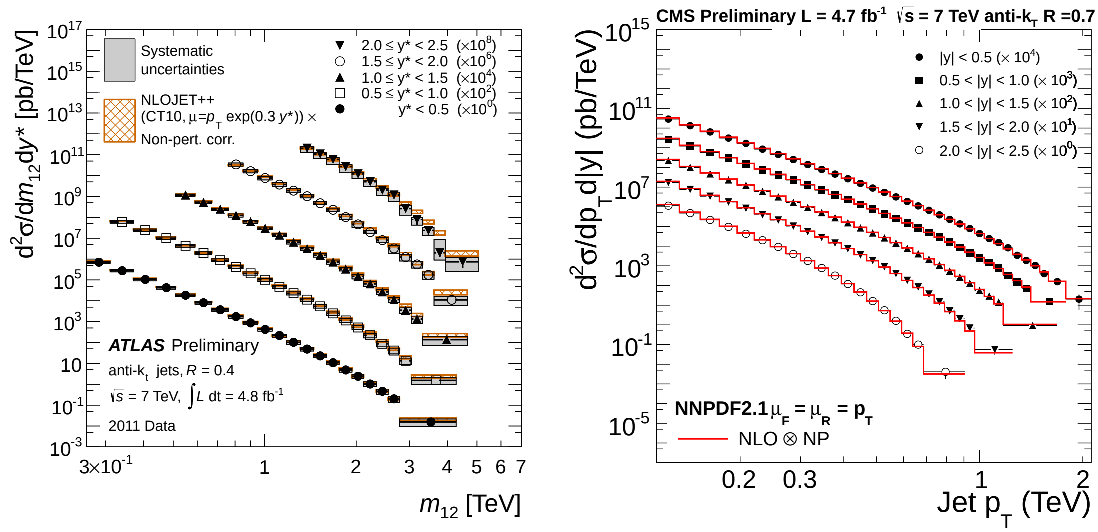
3 Cross Section

The ATLAS and CMS collaborations have both published analysis [4 5] of the inclusive single jet and dijet cross sections using data samples corresponding to approximately 35 pb^{-1}, collected during 2010 running. The inclusive jet cross section was measured for jet p_T, between 20 GeV and 1.5 TeV, and split into absolute rapidity regions up to $|y| = 4.4$. The dijet mass cross section measurement has also been extended with masses observed between 70 GeV and 5 TeV. Good agreement was seen with the latest theoretical NLO jet predictions over many orders of magnitude, with no sign of physics beyond the Standard Model evident. Using the detailed information released about the correlations amongst the different systematic uncertainties it should be possible to use the data to provide new constraints on parton distribution functions. The larger integrated luminosity collected during 2011 is still undergoing analysis, however initial results are looking promising. Using the full dataset from 2011 ATLAS has measured the dijet mass cross section, in figure 2a, which has improved experimental uncertainties. Whilst figure 2b shows CMS has extended the single jet cross section to $p_T = 2$ TeV.

Analysis of the cross section for events containing both a forward and central jet allowed the study of collisions where one of the colliding partons could carry a small fraction of the total proton momentum, and so gave an opportunity to test different models of parton evolution. Results showed a large disagreement in the predicted and measured cross section for these events for many Monte Carlo generators. [6]

4 Jet Flavour

ATLAS has measured the $D^{*\pm}$ meson production rate in jets. Figure 3b shows the significant disagreement at low values of z, the fraction of jet momentum which the meson comprises. This indicated that current modelling of fragmentation by Monte Carlo generators is incorrect. An improved understanding of flavour composition would aid many analysis, given the large dependence of many of the jets properties on flavour.



(a) (b)

Figure 2: The mass of the dijet system measured in different regions of $y^* = |y_1 - y_2|/2$ in figure (a).[7] The inclusive single jet cross section measured in regions of absolute rapidity in figure (b).[8]

5 The Third Jet

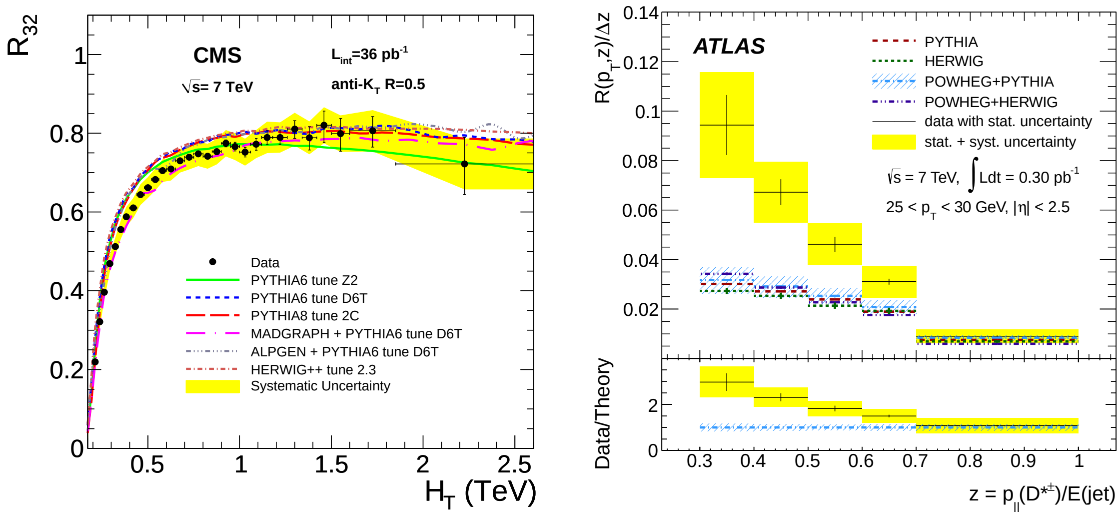
Increasingly more complex final states have been analysed. Both the detection and prediction of these states is challenging. Even relatively simple $N_{\text{jet}} > 2$ events, which probe higher orders of QCD, are fraught with difficulties. The inclusive three to two jet cross section ratio has been measured by CMS up to a total transverse momentum sum of 2.5 TeV[10], see figure 3a. There is a general trend for the Monte Carlo simulations to predict too many three jet events at low total transverse momenta.

Studies have also been carried out with the restriction that any third jet must to be in a rapidity region bounded by the two highest p_T jets in an event[11]. A measurement was made of the probability of an event not containing a third jet with $p_T > 20$ GeV, resulting in a quantity known as the gap fraction. When the rapidity region or the average p_T of the leading jets was large, huge variations in theoretical predictions for the gap fraction were observed compared to the small experimental uncertainties. This precision measurement should prove useful for future theoretical development related to wide angle radiation.

6 Conclusions

A significant number of results have been published by each experiment at the LHC using data collected in both 2010 and 2011 involving jets. A wide range of precision jet measurements have been made, which required many detailed performance studies. Properties of jets are still understood even in the highest pile-up conditions seen so far. The jet measurements performed have shown good agreement with Standard Model predictions in many areas, however weaknesses such as in the large rapidity limit and the modelling of fragmentation are evident.

At the time of writing the LHC has started producing data at a new collision energy of $\sqrt{s} = 8$ TeV for the 2012 programme. The new running conditions will prompt yet another rediscovery of the Standard Model for many measurements involving jets and allow extensions to searches for exotic physics. Given the quantity and quality of results already available, the



(a) (b)

Figure 3: The inclusive three to two jet cross section ratio, R_{32}, shown as a function of the total transverse energy of the event, H_T in figure (a). [10] The production rate of $D^{*\pm}$ mesons, R, as a function of the fractional momentum of the jet it resided in, z in figure (b) . [9]

future is certainly bright for extending our knowledge of QCD and the Standard Model into previously unreachable territories.

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