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Study of Hadronic Event Shapes with the CMS detector at LHC

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Hadronic event shapes are studied using the first 78 nb^{-1} of 7 TeV proton-proton collision data collected with the CMS detector at the Large Hadron Collider. Hadronic event shapes are used to study the geometric structure of the hadronic final state. Normalized event-shape distributions, using jet four-momenta as input, are shown to be robust against various sources of systematic uncertainty. It is demonstrated, that this early measurement of event-shape variables allows to study differences in the modelling of QCD multi-jet production.

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1. Event-Shape Variables

Event shapes belong to the most widely used variables to study QCD dynamics, especially at e^+e^- and ep colliders. They provide geometrical information about the energy flow in hadronic events. More recently, a large set of event-shape variables suitable for pp colliders has been proposed in [1]. Below the results of a first measurement of two event-shape variables[2] in 7 TeV proton-proton collision data is summarized. The data is collected with the Compact Muon Solenoid (CMS) detector [3] at the LHC, corresponding to an integrated luminosity of 78 nb^{-1}. The four-momenta of jets in the hadronic final state are used as input for the event-shape calculation, using the anti-k_T clustering algorithm with R=0.5 [4].
Here we focus on the *central transverse thrust* $T_{\perp,C}$. The term central indicates that the input for the variables are jets in the central region of the detector ($|\eta|<1.3$). The central transverse thrust is defined as:

$$T_{\perp,C} = \max_{\vec{n}_T} \frac{\sum_{i\in C} |\vec{p}_{T,i} \cdot \vec{n}_T|}{\sum_{i\in C} p_{\perp,i}}, \tag{1.1}$$

where $p_{\perp,i}$ are the transverse momenta with respect to the beam axis $\vec{n}_B$. The variable which is typically used in perturbative calculations is $\tau_{\perp,C} = 1 - T_{\perp,C}$, referred to as central transverse thrust in the following.

2. Event Selections

Non-collision background is removed and quality cuts are applied to ensure the presence of a well-defined primary vertex. The jets are reconstructed out of energy deposits in the calorimeter and corrected for their η dependent and absolute jet energy response. Only jets with $p_\mathrm{T} > 30\,\mathrm{GeV}/c$ are considered. If one of the two leading jets does not pass jet quality citeria, the event is rejected. The two leading jets of the event are required to be in the central region of the detecor ($|\eta|<1.3$). The leading jet is required to have $p_\mathrm{T} > 60\,\mathrm{GeV}/c$ for the low p_T data sample and $p_\mathrm{T} > 90\,\mathrm{GeV}/c$ for the high p_T data sample. All central jets with $p_\mathrm{T} > 30\,\mathrm{GeV}/c$, passing jet quality criteria, are used for the event-shape calculation.

3. Results

The comparison of the normalized event shape distributions from data with Monte Carlo predictions from PYTHIA6.4.22[5], PYTHIA8.135 [6], HERWIG++2.4.2 [7], MADGRAPH4.4.24+PYTHIA6 [8] and ALPGEN2.13+PYTHIA6 [9] can be seen in Fig. 3. The generated events have been processed with a GEANT 4 based simulation of the CMS detector response. The bars show the statistical uncertainty on the data, and the band shows the sum of statistical and systematic errors. The uncertainty on the jet energy scale is the dominant systematic error on the distributions. In order to estimate the resulting uncertainty, an absolute $\pm10\%$ shift and and an η-dependent $\pm2\% \times |\eta|$ shift is applied to all jets entering the calculation. This sensitivity test is based on preliminary studies with the early CMS data [10]. The effect of the shifts is less than 10% on the distributions.
The PYTHIA6 and HERWIG++ agree with the measurement within experimental uncertainties.

PYTHIA8 underestimates the fraction of back-to-back dijet events, while ALPGEN and MADGRAPH overestimate it.

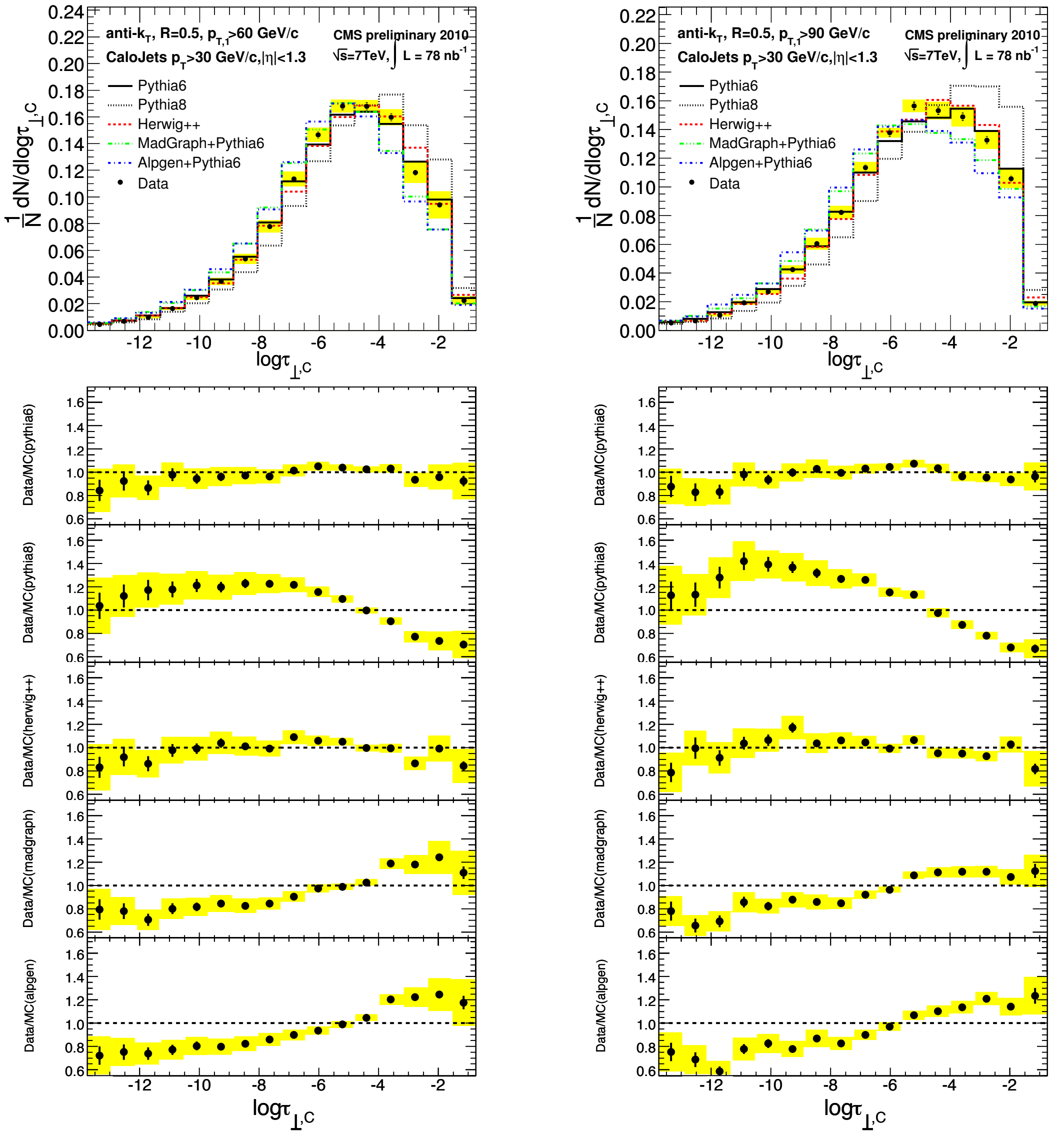

Figure 1: The central transverse thrust distribution for calorimeter jets in events with leading jet $p_{\mathrm{T},1} > 60\,\mathrm{GeV}/c$ (right) and $p_{\mathrm{T},1} > 90\,\mathrm{GeV}/c$ (left). The bars represent the statistical uncertainty on the data, and the band represents the sum of statistical and systematic errors. Bottom plots show the ratio between data and the different simulation samples, including the jet resolution uncertainty on Monte Carlo simulations.

4. Conclusions

A first study of hadronic event shapes in proton-proton collisions data at $\sqrt{s}$=7 TeV is presented. The data sample, accumulated by the CMS detector during the first months of 2010, corresponds to an integrated luminosity of 78 nb^{-1}. The data is compared with predictions from the PYTHIA6, PYTHIA8, HERWIG++, ALPGEN and MADGRAPH Monte Carlo generators after full simulation. A good agreement between the data and PYTHIA6 and HERWIG++ predictions can be observed. The event shape distributions from ALPGEN, MADGRAPH and PYTHIA8 show deviations from the data distributions.

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