Study of Hadronic Event Shapes with the CMS detector at LHC

S. Banerjee, G. Dissertori, M. Guchait, G. Majumder, F. Moortgat, F. Ronga, M. Weber, J. Weng
on behalf of the CMS collaboration

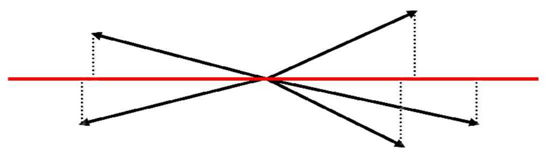
ETH Institute for Particle Physics

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.

Definition of Event-Shape Variables:

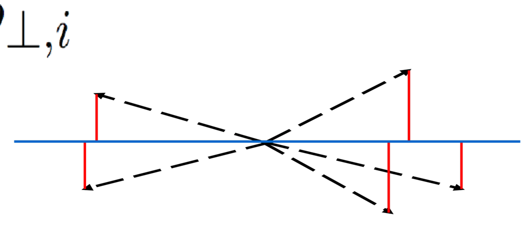
The definitions of [1] are used:

- **central transverse thrust:**



$$T_{\perp,\mathcal{C}} \equiv \max_{\vec{n}_T} \frac{\sum_{i\in\mathcal{C}} |\vec{p}_{\perp,i} \cdot \vec{n}_T|}{\sum_{i\in\mathcal{C}} p_{\perp,i}}$$

- **central thrust minor:**



$$T_{m,\mathcal{C}} \equiv \frac{\sum_{i\in\mathcal{C}} |\vec{p}_{\perp,i} \times \vec{n}_{\mathrm{T},\mathcal{C}}|}{\sum_{i\in\mathcal{C}} p_{\perp,i}}$$

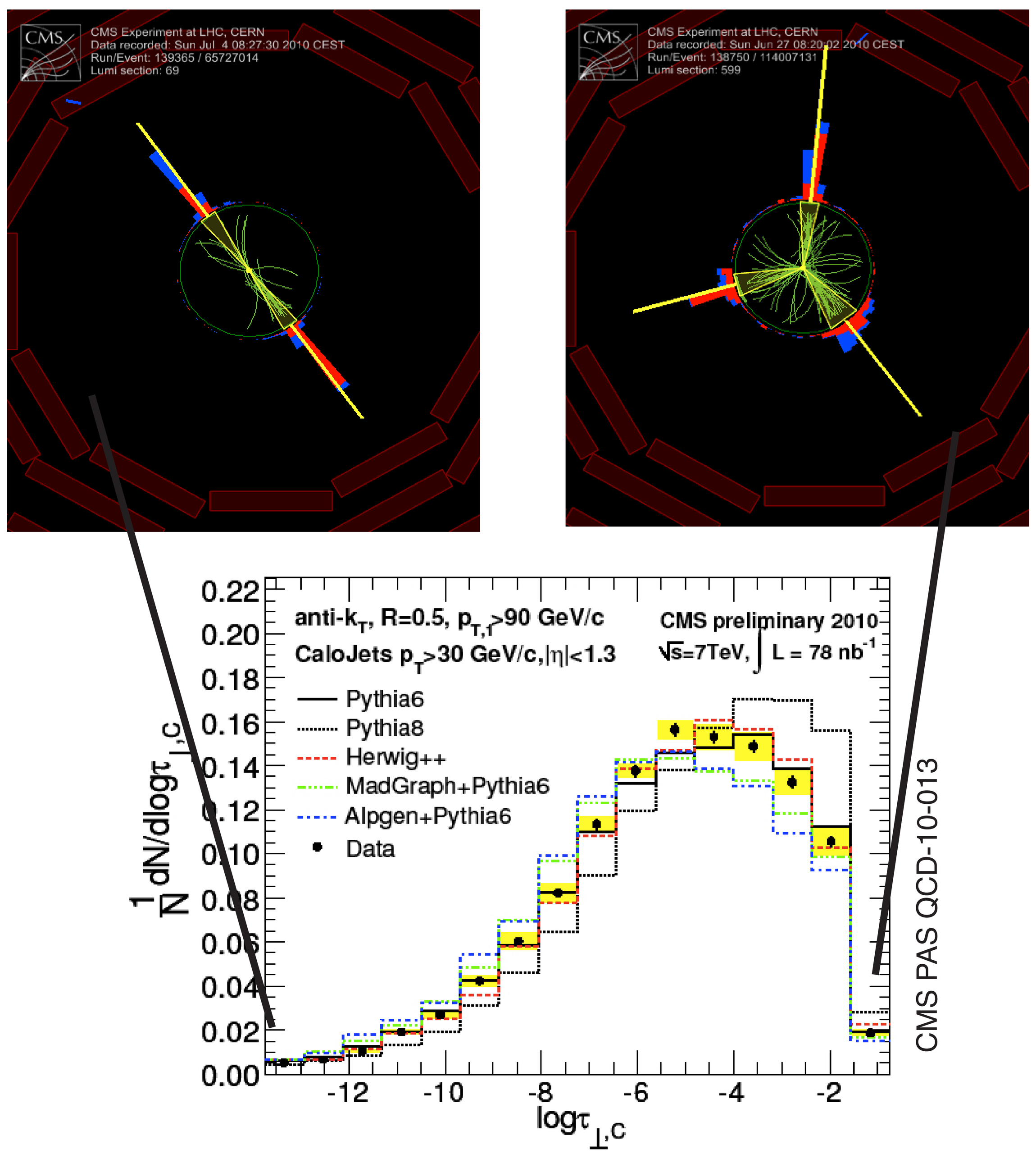
- Jet four-momenta are used as input (jet-algo: anti-k$_T$, R=0.5).

Event Preselection:

- Two hardest jets are required to be central: $|\eta| < 1.3$
- Only central jets with p_T>30 GeV/c are used for the event shape calculation.
- Correct jets for their η-dependent and absolute jet energy response.
- Two bins according to the leading jet $p_{T,1}$> 60 GeV/c and $p_{T,1}$>90 GeV/c.

For Illustration: central transverse thrust

central transverse thrust plotted in natural logarithm: $\log \tau_{\perp,\mathcal{C}} = \log(1 - T_{\perp,\mathcal{C}})$.

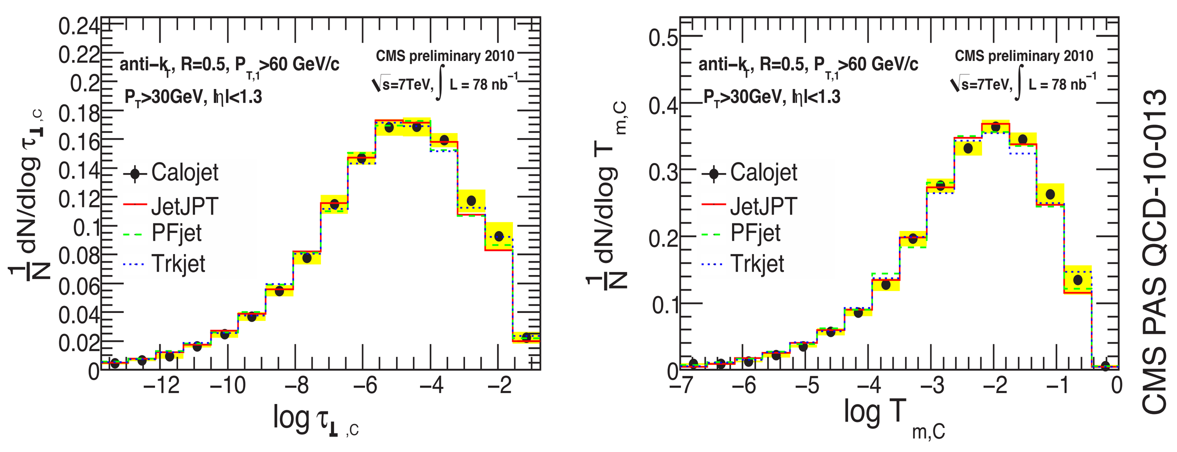


The region of low values is mainly populated with back-to-back dijet events. Multi-jet events dominate in the region of higher values.

Sensitivity to different Jet Types

Four different jet reconstruction types are used at CMS:

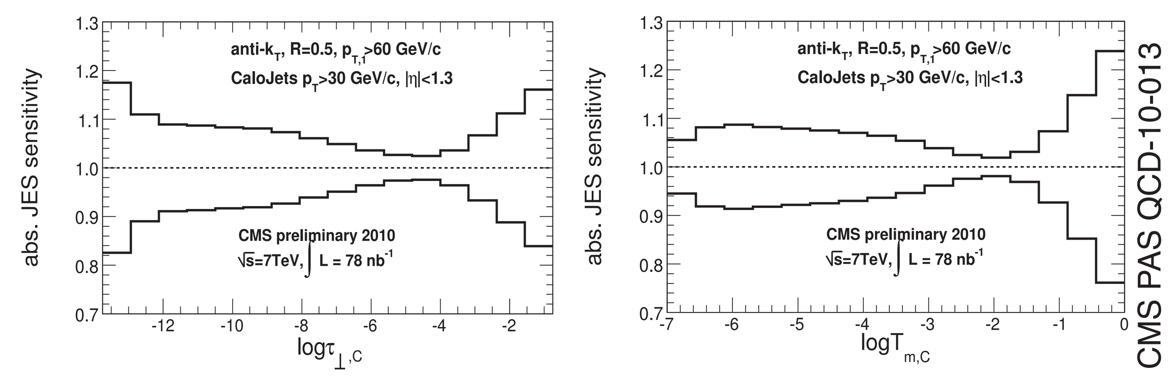
- Calorimeter Jets (CaloJets) use energy deposits of calorimeter cells as input.
- Jet-Plus-Track-Jets (JetJPT): Calojets are modified in energy and position using associated tracks.
- TrackJets: charged tracks are combined into jets.
- Particle Flow Jets (PFJets): particles are reconstructed as a combination of tracks and calorimeter deposits using particle flow techniques. Then jets are clustered out of these [3].



The central transverse thrust (left) and central thrust minor (right) distributions show a nice agreement for all four jet reconstruction types.

Sensitivity to systematic uncertainties:

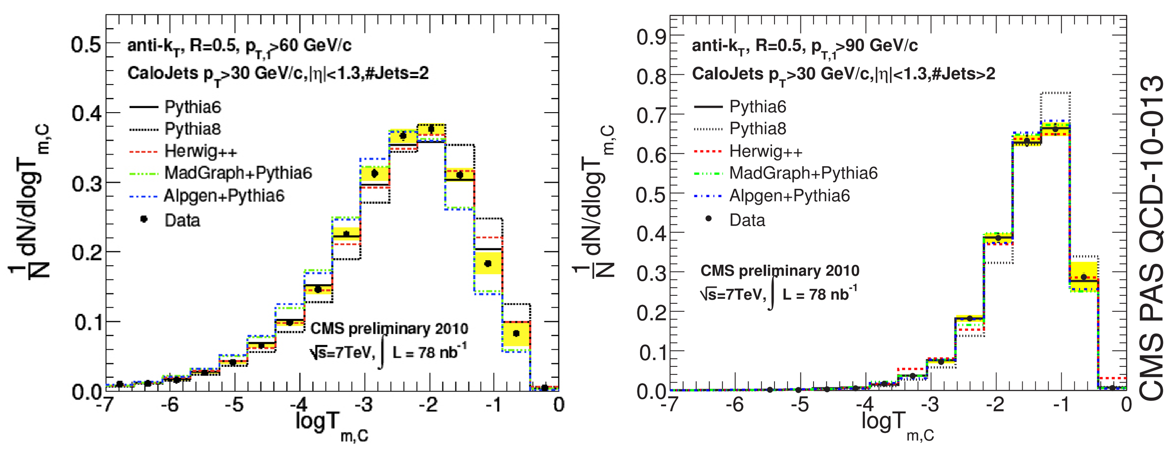
- Sensitivity to the jet energy scale uncertainty estimated by absolute ±10% and η-dependent ±2%*|η|-variations, based on preliminary studies with CMS data [4].
- The uncertainty on the jet energy scale modifies the number of jets passing the p_T-threshold and thus effects the distributions.
- The maximum bin-by-bin difference between the original and the two shifted distributions is assigned as systematic error. At present this constitutes the dominant systematic error.



Effect of a 10% variation in the jet energy scale on the central transverse thrust (left) and the central thrust minor (right) distribution for event with $p_{T,1}$>60 GeV/c.

- Systematic error on the Monte Carlo distributions due to the imperfect simulation of the jet energy and position resolutions: 2-4% deviations on distributions.

Event Shapes in multiplicity bins:



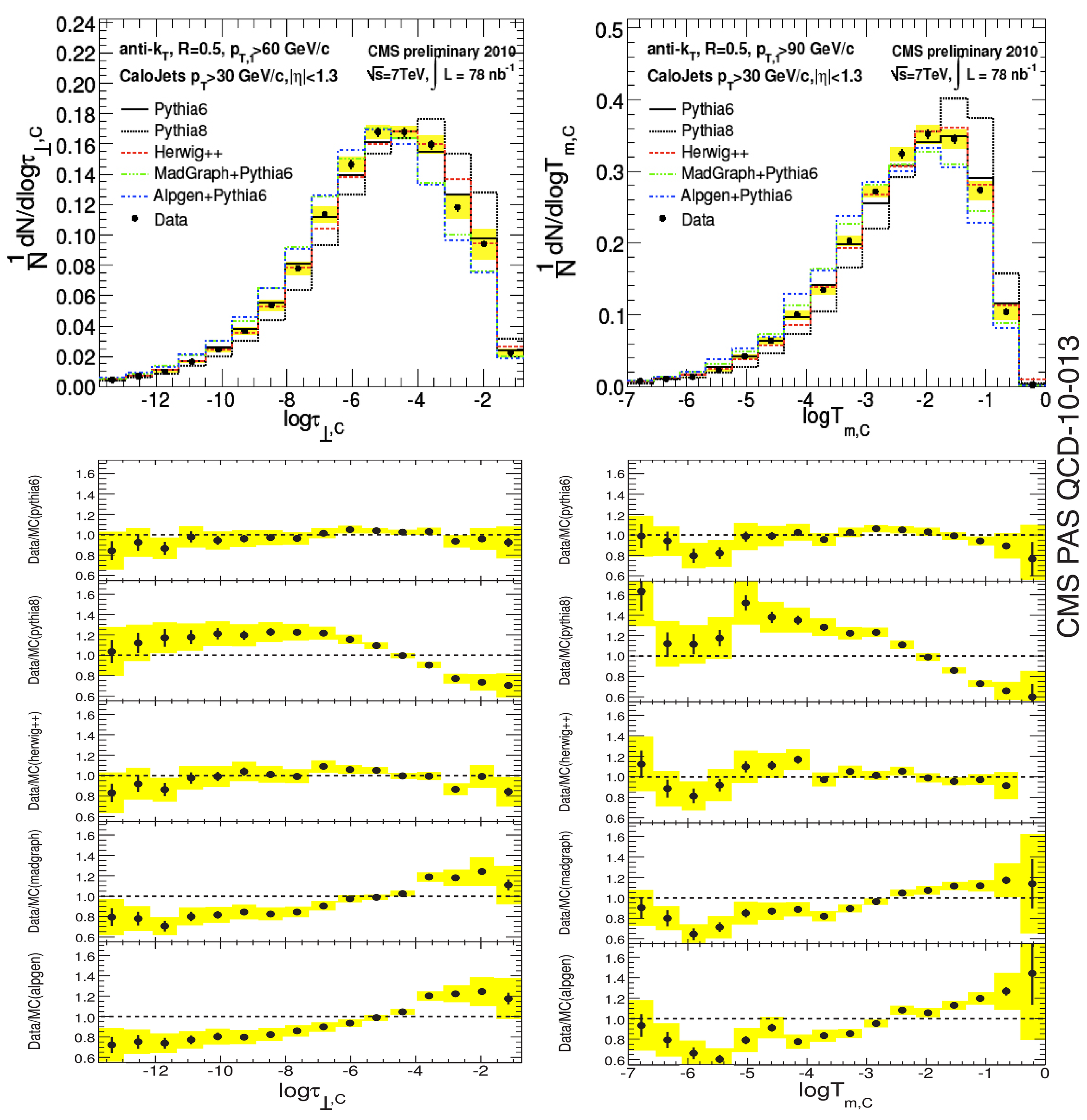
The distribution of thrust minor for events with exactly two central jets (left) and events with three or more central jets (right).

- Event shapes are shown seperately for exactly two and ≥3 central jets.
- In the phasespace region of three or more well-separated hard central jets, MadGraph, Alpgen, Pythia6 and Herwig++ show a reasonable agreement with the data.
- Deviations of Madgraph and Alpgen are more pronounced in the phasespace region of exactly two hard central jets.

Results:

Normalized event shape distributions are compared with predictions of Pythia6, Pythia8, Herwig++, Alpgen and MadGraph.

- Integrated recorded luminosity of 78 nb^{-1}.
- The bars represent the statistical error on the data, the yellow band the sum of systematic and statistical errors.
- The bottom plots show the ratio between data and the predictions. The band additionally includes the jet resolution uncertainty on Monte Carlo.



The central transverse thrust distribution for events with $p_{T,1}$>60 GeV/c (left) and the central thrust minor distribution for events with $p_{T,1}$>90 GeV/c (right) using a dataset of 78 nb^{-1}. The bottom plots show the ratio between data and the different simulation samples.

- Pythia6 and Herwig++ predicitions agree with the measurement within experimental uncertainties.
- Pythia8 underestimates the fraction of back-to-back dijet events, Alpgen and MadGraph overestimate it.

Summary

- Hadronic event-shape distributions have been measured in a dataset of 78 nb^{-1} of 7 TeV proton-proton collisions collected with the CMS detector.
- Event Shapes are shown to be robust against uncertainties in the jet energy scale and experimental resolution.
- The data is compared with predictions after full detector simulation:
  - The distributions from Pythia6 and Herwig++ show a satisfactory agreement with the data.
  - Discrepancies between the data and predictions from Alpgen, MadGraph and Pythia8.

References:
[1] A. Banfi, G.P. Salam, G. Zanderighi, JHEP **06** (2010) 038
[2] **CMS** Collaboration, CMS-PAS **QCD-10-013** (2010)
[3] **CMS** Collaboration, CMS-PAS **PFT-10-002** (2010)
[4] **CMS** Collaboration, CMS-PAS **JME-10-003** (2010)