Measurement of the forward energy flow in pp collisions at $\sqrt{s} = 7$ TeV with the LHCb detector

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We present the results on the energy flow measured with minimum-bias data collected by the LHCb experiment in pp collisions at $\sqrt{s} = 7$ TeV for inclusive minimum-bias interactions, hard scattering processes and events with enhanced or suppressed diffractive contribution. The measurements are performed in the pseudorapidity range $1.9 < \eta < 4.9$, which corresponds to the main detector acceptance of the LHCb spectrometer. The data are compared to predictions given by the PYTHIA-based and cosmic-ray Monte Carlo event generators, which model the underlying event activity in different ways.

1 Introduction

The energy flow created in inelastic hadron-hadron interactions at large values of the pseudorapidity $\eta = -\ln\tan\theta/2$ with θ being the polar angle of particles w.r.t. the beam axis, is expected to be directly sensitive to the amount of parton radiation and multi-parton interactions (MPI) [1]. The latter mainly arise in the region of a very low $x = p_{\text{parton}}/p_{\text{hadron}} \to 0$, where parton densities are large so that the probability of more than a single parton-parton interaction per hadron-hadron collision is high. MPI represent a predominant contribution to the soft component of a hadron-hadron collision, called the underlying event (UE). Its precise theoretical description still remains a challenge as MPI phenomenon is currently weakly known.

In this study, experimental results on the energy flow are compared to predictions given by the PYTHIA-based [2, 3, 4] and cosmic-ray Monte Carlo (MC) event generators [5], which model the UE activity in different ways. The analysis was performed using a sample of minimum-bias data collected by the LHCb experiment [6] in pp collisions at $\sqrt{s} = 7$ TeV during the low luminosity running period in 2010. The events were recorded using a trigger that has required the presence of at least one reconstructed track segment in the spectrometer. For a particular pseudorapidity bin with the width $\Delta\eta$, the total energy and total number of stable particles E_{tot} and $N_{part,\eta}$, the energy flow is defined as

$$\frac{1}{N_{\text{int}}}\frac{dE_{tot}}{d\eta} = \frac{1}{\Delta\eta}\left(\frac{1}{N_{\text{int}}}\sum_{i=1}^{N_{part,\eta}} E_{i,\eta}\right) , \tag{1}$$

where N_{int} is the number of inelastic pp interactions and $E_{i,\eta}$ is the energy of an individual particle.

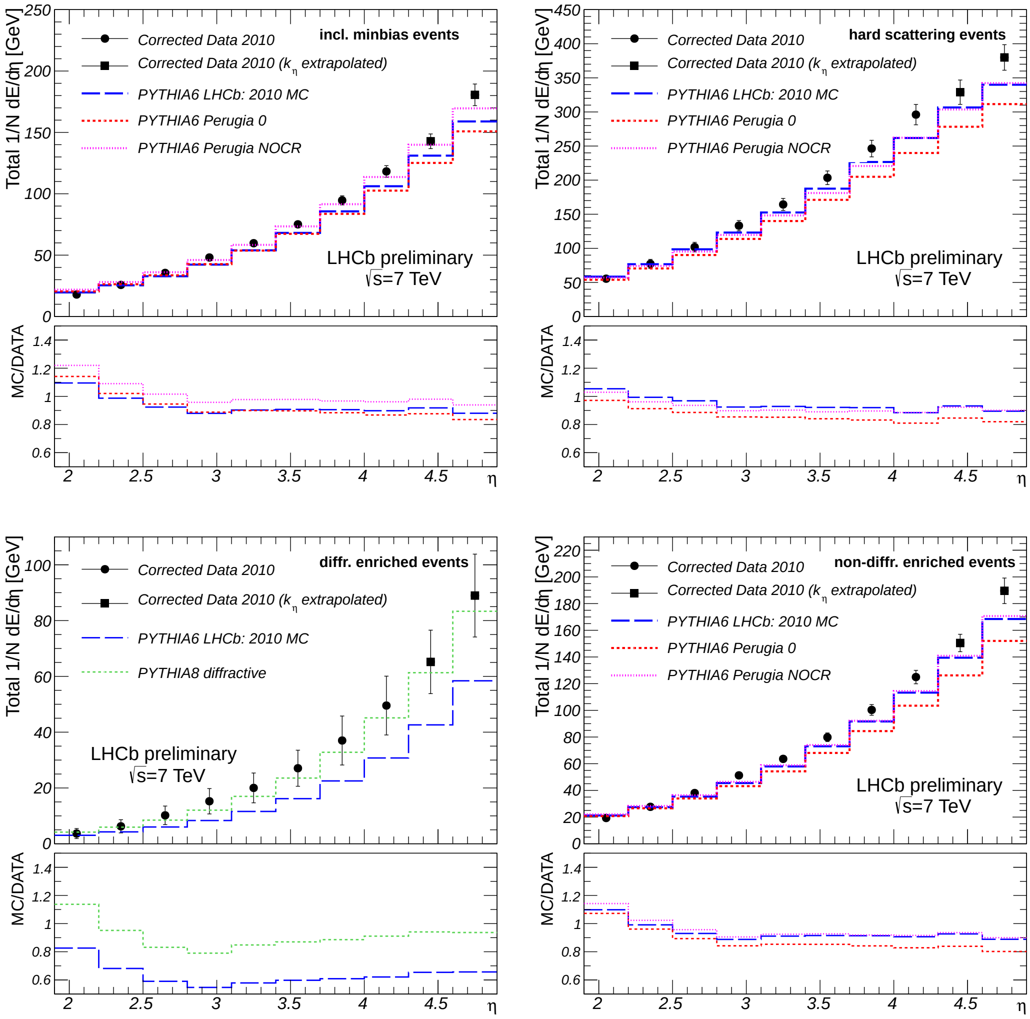

Figure 1: *Total corrected energy flow obtained for all event classes under consideration. The measurements are indicated by points with error bars representing the systematic uncertainties, while the generator level predictions given by the PYTHIA-based models are shown as histograms. The ratios between the model predictions and corrected data are demonstrated in addition.*

2 Analysis Strategy

In this analysis, the energy flow carried by the charged stable particles was measured using good quality reconstructed tracks traversing the full LHCb tracking setup with a momentum in the range $2 < p < 1000$ GeV/c and $1.9 < \eta < 4.9$. Particle identification was not used in this study. Instead, the energy was simply estimated from the reconstructed momentum. The reconstructed charged energy flow was corrected for detector effects using the average of correction factors

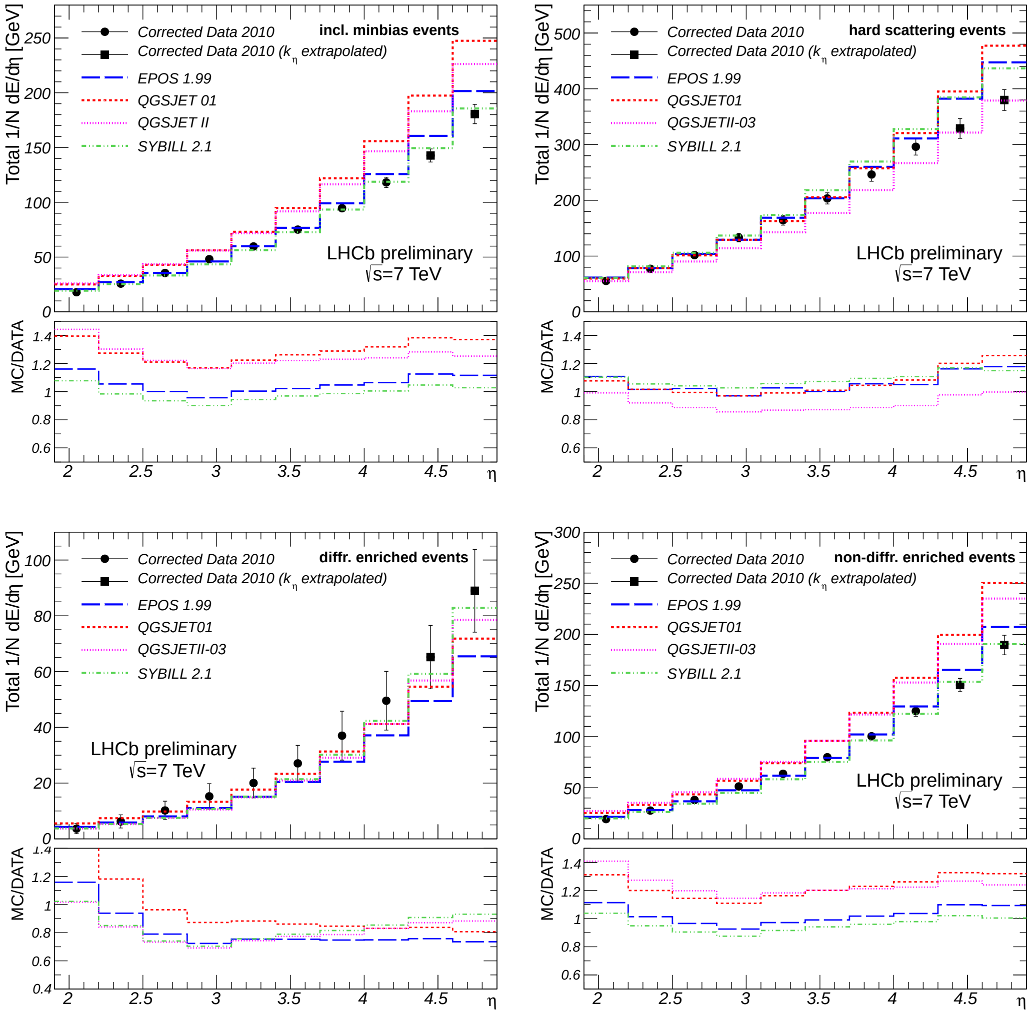

Figure 2: *Total corrected energy flow obtained for all event classes under consideration. The measurements are indicated by points with error bars representing the systematic uncertainties, while the predictions given by the cosmic-ray interaction models are shown as histograms. The ratios between the model predictions and corrected data are demonstrated in addition.*

obtained from various MC models as the ratio of the predictions at generator and detector levels for each η bin. The total energy flow was estimated from the corrected charged one by using a data-constrained MC estimate of the neutral component. For the two highest η bins the data-constrained measurements of the neutral energy flow were extrapolated from the more central region as the LHCb Electromagnetic Calorimeter has no detection coverage for that region of phase space.

In order to probe various aspects of multi-particle production in high-energy hadron-hadron collisions, the measurements were performed for the following four event classes: inclusive minimum-bias (containing at least one track with $p > 2$ GeV/c in $1.9 < \eta < 4.9$), hard scattering (having at least one track with $p_{\mathrm{T}} > 3$ GeV/c in $1.9 < \eta < 4.9$), diffractive and non-diffractive enriched interactions. The last two event types were selected among the inclusive minimum-bias ones requiring the absence and presence of at least one backward track reconstructed by the LHCb Vertex Locator in $-3.5 < \eta < -1.5$, respectively. A detailed description of the whole analysis procedure can be found in [7].

3 Results

The computed total corrected energy flow is illustrated for every event class in Fig. 1 and Fig. 2 along with the PYTHIA-based and cosmic-ray model predictions, respectively. As can be seen, the energy flow increases with the momentum transfer in an underlying pp inelastic interaction. The development of the energy flow as a function of η is reasonably well reproduced by the MC models. Nevertheless, the PYTHIA-based generators underestimate the corrected data at large η, while most of the cosmic-ray interaction models overestimate it, except for the diffractive enriched events. The predictions given by the SIBYLL 2.1 cosmic-ray generator [8] for the inclusive minimum-bias and non-diffractive enriched events provide the best description of the corresponding energy flows across the entire η range of the measurements. In the forward region the total uncertainties for most of the event classes are around 5%. For the diffractive enriched events, the uncertainties are about 3 times larger mainly because of the strong model dependency of the correction factors. None of the MC models used in this analysis are able to describe the energy flow measurements for all event classes that have been studied. It follows that the results obtained in this analysis can be used to improve the existing MC models by further constraining the parameters describing the partonic stage of high-energy hadronic interactions, diffractive particle production and hard QCD processes.

4 Acknowledgements

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