# Measurements of particle production and energy flow in pp collisions at $\sqrt{s} = 7$ TeV with the LHCb experiment

*Marianna Fontana on behalf of the LHCb collaboration*
*Max-Planck-Institut für Kernphysik, 69029 Heidelberg, GERMANY*

We present the results on the charged particle multiplicity and energy flow measured with minimum-bias data collected by the LHCb experiment in pp collisions at $\sqrt{s} = 7$ TeV. The measurements are performed in the pseudorapidity range $2 < \eta < 5$ and compared to predictions given by several Monte Carlo (MC) generators.

# 1 Introduction

The measurements of particle production and forward energy flow (EF) are important inputs to tune Monte Carlo generators and to model the soft component of a hadron-hadron collision, called the underlying event (UE).

Designed for precise measurements of B meson decays, the LHCb experiment [1] at CERN is a one arm forward spectrometer, providing particle reconstruction in a unique kinematic range of $2 < \eta < 5$ and low transverse momenta. The forward region is of special interest as it is much less covered by other experiments and QCD models have large uncertainties. The vertex locator (VELO) provides an excellent vertex resolution and two RICH detectors allow high quality particle identification. The calorimeter system consists of a scintillating pad- and preshower detector (SPD/PS), the electromagnetic and the hadronic calorimeter. A loose minimum bias trigger requiring at least one track segment in the detector is used for the analysis presented here.

These proceedings present the measurements of charged particle multiplicities and densities in Section 2 followed by the energy flow measurements in Section 3. Measurements of strange particle production [2, 3] and hadron ratios [4] are not included in these proceedings.

# 2 Charged particle multiplicity

Charged particle multiplicity is a basic observable that characterizes the hadronic final state. In this analysis [5] the charged particles produced in pp collisions or from short lived particles are reconstructed in the VELO. This subdetector was designed to provide high efficiency in the forward $(2 < \eta < 4.5)$ and in the backward

($-2.5 < \eta < -2$) regions. In the absence of almost any magnetic field no momentum information is available, hence the measurement can only be performed as a function of pseudorapidity. In this analysis a sample of 3 million events from the low luminosity running phase in early 2010 is used. A set of quality criteria to minimise the contribution of secondary particles and fake tracks is imposed. The reconstructed multiplicity distributions are corrected for the tracking and selection efficiencies and the background contribution. The charged particle multiplicity is then measured using an unfolding procedure.

Figure 2 shows the multiplicity distribution in the forward region compared to different MC predictions. Only events with at least one track in the forward $\eta$ range are selected. All generators underestimate the mean multiplicity distributions, with

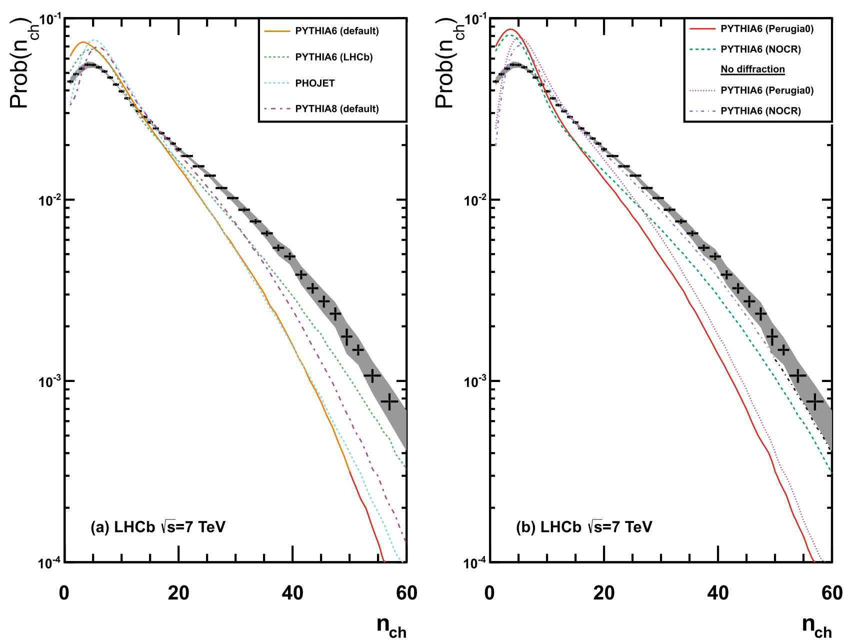


Figure 1: The multiplicity distribution in the forward $\eta$ range with predictions of different event generators and UE tunes.

the LHCb tune giving the best description of the data. The agreement is improved excluding the diffractive processes in Pythia. Figure 2 shows the charged particle pseudorapidity density $\rho$ as a function of pseudorapidity, normalised to events with at least one charged particle in the forward acceptance, in comparison with different generator predictions. As a consequence of the requirement of at least one track in the forward range the data show an asymmetry between the forward and the backward region. The predictions fail to describe the data but a better agreement is obtained

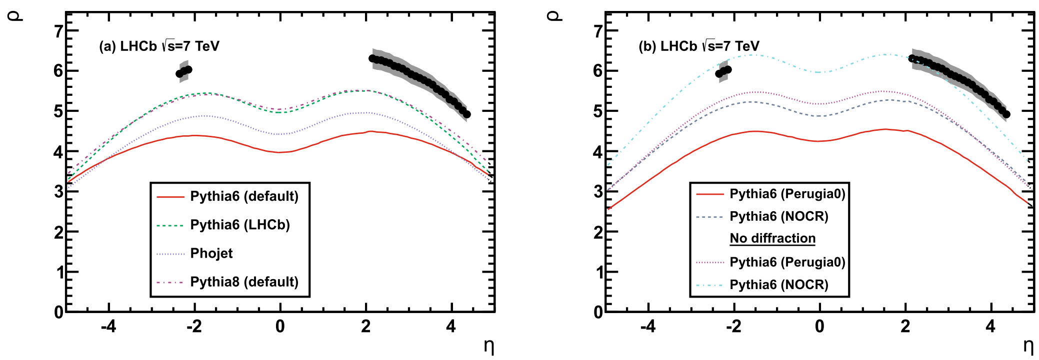


Figure 2: The charged particle densities as a function of $\eta$ with predictions of different event generators and UE tunes.

when diffractive processes have been excluded.

# 3 Forward energy flow

The energy flow (EF) is defined as the average energy created in a particular $\eta$ interval ($E_{TOTAL}$) per inelastic pp interaction ($N_{inter}$) and normalised to the $\eta$ bin size:

$$EF = \frac{1}{N_{inter}} \frac{dE_{TOTAL}}{d\eta} \tag{1}$$

At large values of pseudorapidity it is expected to be directly sensitive to the amount of parton radiation and multiparton intecations (MPI), which represent an important contribution to the soft component of a hadron-hadron collision.

In this analysis [6] reconstructed tracks of good quality traversing the full LHCb tracking system were used. The charged EF was estimated from the reconstructed momentum and it was corrected for detector effects. Finally the total EF was estimated from the corrected charged EF using a data-constrained MC estimate of the neutral component.The experimental results on the total EF presented here refer to events with at least one track in $1.9 < \eta < 4.9$ with $p > 2\,\mathrm{GeV}/c$ (inclusive minimum bias events).

In Figure 3 the results are compared to the predictions given by PYTHIA based [7, 8, 9] and cosmic-ray [10] MC event generators. Energy flow development as a function of $\eta$ is reasonably well reproduced by MC models. Nevertheless, the PYTHIA-based generators underestimate the corrected data at large $\eta$, while all the cosmic-ray interaction models overestimate it except the SYBILL generator.

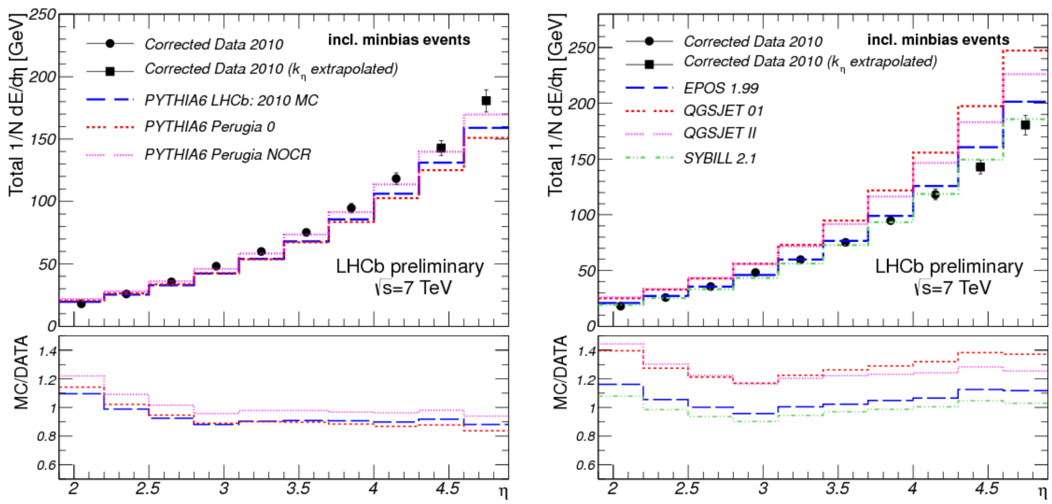


Figure 3: Total corrected energy flow for the inclusive minimum bias events compared to the PYTHIA models (a) and the cosmic-ray interaction models (b).

# 4 Conclusions

LHCb is an excellent detector for particle production measurements in the forward region. The charged particle multiplicities and the energy flow are underestimated by PYTHIA based MC generators. Most of the cosmic-ray interaction models overestimate the energy flow.

# References


[1] A. A. Alves et al. JINST 3 (2008) S08005.

[2] R. Aaij et al. Phys. Lett. B693 (2010) 6980, arXiv:1008.3105 [hep-ex].

[3] R. Aaij et al. J. High Energy Phys. 08(2011)034

[4] arXiv:1206.5160 [hep-ex]

[5] R. Aaij et al. Eur. Phys. J. C 72 (2012) 1947.

[6] R. Aaij et al. CERN-LHCb-CONF-2012-012.

[7] P. Skands, Phys. Rev. D82 (2010) 074018.

[8] M. Clemencic et al., Journal of Physics: Conference Series 331 (2011), no. 3 032023.

[9] T. Sjostrand et al., Comput. Phys. Commun. 178 (2008) 852.

[10] D. d'Enterria et al., Astropart.Phys. 35 (2011) 98-113 and references therein.