Measurements of Particle Production in pp Collisions in the Forward Region at the LHC

Raluca MUREŞAN*)
on behalf of the LHCb Collaboration

Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland

The phase space coverage of the LHCb detector allows a unique insight into the particle production in the forward region at the LHC. Due to its unique pseudorapidity range and to the possibility of extending the measurements to low transverse momenta, the LHCb data provide important input to the understanding of particle production in a kinematical range where QCD models have large uncertainties. Measurements of the production of charged particles and of the strange ϕ mesons are presented. In addition the ratio of $\bar{\Lambda}/\Lambda$ is studied as a function of rapidity and transverse momentum for centre-of-mass energies $\sqrt{s} = 0.9$ TeV and $\sqrt{s} = 7.0$ TeV, probing baryon number transport from the beam. Baryon strangeness suppression is evaluated through the measurement of $\bar{\Lambda}/K^0_S$. The LHCb results are compared with lower energy measurements, phenomenological models and Monte Carlo event generators.

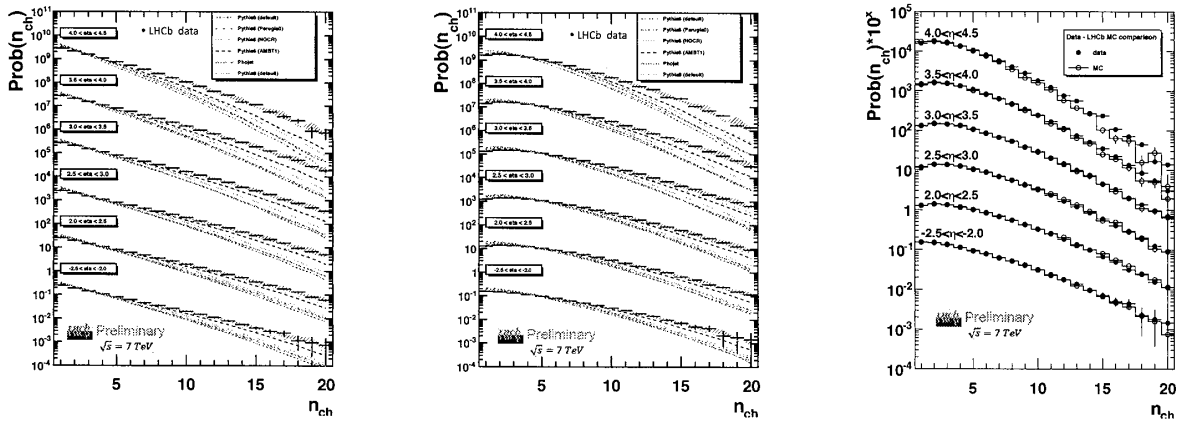
§1. Introduction

The LHCb detector, described in detail elsewhere,[1)] is designed to look for New Physics through precise measurements of CP violation and rare decays in the beauty and charm sector. To benefit from the large and correlated $b\bar{b}$ quark production in the forward region the LHCb detector is built as a forward single arm spectrometer with a coverage of 15-300(250) mrad in the bending respective non-bending plane. The unique pseudorapidity coverage of LHCb, fully instrumented in the region $1.9 < \eta < 4.9$, is complementary to the other LHC experiments. This setup offers the unique opportunity to perform not only b-physics studies, but also production measurements in a region of phase space where the hadronization models diverge as they are extrapolated not only in energy but also in (pseudo)rapidity. The excellent tracking and vertexing system and the outstanding hadron particle identification abilities are instrumental not only for the heavy quark studies but also for light hadron production measurements. Such kind of studies were already presented at the XL ISMD meeting: the K_S production cross-section[2)] and the baryon transport from the beam using the $\bar{p}/p$ measurement.[3)] In what follows preliminary results on the multiplicity studies,[4)] the updated result on the V^0 ratios[5)] and a measurement of the ϕ cross-section in bins of y and p_T are presented.[6)]

§2. Multiplicity studies

A measurement of the number of prompt charged particles, leptons, mesons and hadrons e, μ, π, K, p with the average proper lifetimes of the ancestors $\Sigma\tau < 10$ ps,

*) Also at "Horia Hulubei" National Institute of Physics and Nuclear Engineering - IFIN HH, Bucharest, Romania.



(a) (b) (c)

Fig. 1. (color online) Charged particles distribution (a) all events; (b) and (c) hard events, at least one charged particle with p_T larger than 1 GeV/c and $\eta \in (2.5, 4.5)$. The different η-distributions are scaled by factors of hundred or ten.

produced in LHCb pseudorapidity, η, range was performed. Tracks were only reconstructed in the Vertex Locator, a retractable silicon vertex detector located around the pp interaction point. No information from the other components of the tracking system was used. This approach insures high efficiency, minimal material interaction, partial backward coverage, but does not allow momentum measurements. Two event samples of 1.5 M events recorded at $\sqrt{s}$ =7 TeV in the low interaction run in 2010, with the LHCb magnet set in both polarities were analysed. There is no explicit momentum cut applied in the analysis but it was observed that the efficiency drops at low momentum. This effect was considered when the efficiency correction was applied. A correction for the remnant non-prompt contamination is calculated from the simulation resulting in a systematic error of $\sim 1\%$. The presence of a small number of events with more than one interaction $(3.7 \pm 0.4)\%$ in the sample was also taken in to account. The charged particle distributions are presented in the Fig. 1 in several η ranges compared to various PYTHIA tunes predictions.[7] One can notice that the predictions of default PYTHIA 6 and the Perugia 0 tune are far from the data Fig. 1(a). For hard events, defined as the events with at least one charged particle with transverse momentum, p_T, larger than 1 GeV/c and η between 2.5 and 4.5 one can notice a good agreement to the Perugia NOCR, AMBT1 see Fig. 1(b) and LHCb PYTHIA 6 tune[8] see Fig. 1(c). PYTHIA 6 tunes used for comparison include diffraction.

§3. V^0 ratios

Data sets of 0.3 nb^{-1} recorded at $\sqrt{s} = 0.9$ TeV and 1.8 nb^{-1} at $\sqrt{s} = 7$ TeV with both polarities of the dipole magnet were analysed. Only tracking and vertexing information were used to identify the V^0s: K^0_S, Λ and $\bar{\Lambda}$. The selection used favoured the prompt V^0, defined in MC as $\Sigma_{i=1}^{n} c\tau_i < 10^{-9}$m, i index for ancestors. The remnant non-prompt contaminations, 2–6% for $\Lambda(\bar{\Lambda})$ and 1% for K^0_S, were taken into account by corrections to the ratios of order 1%. Due to the primary

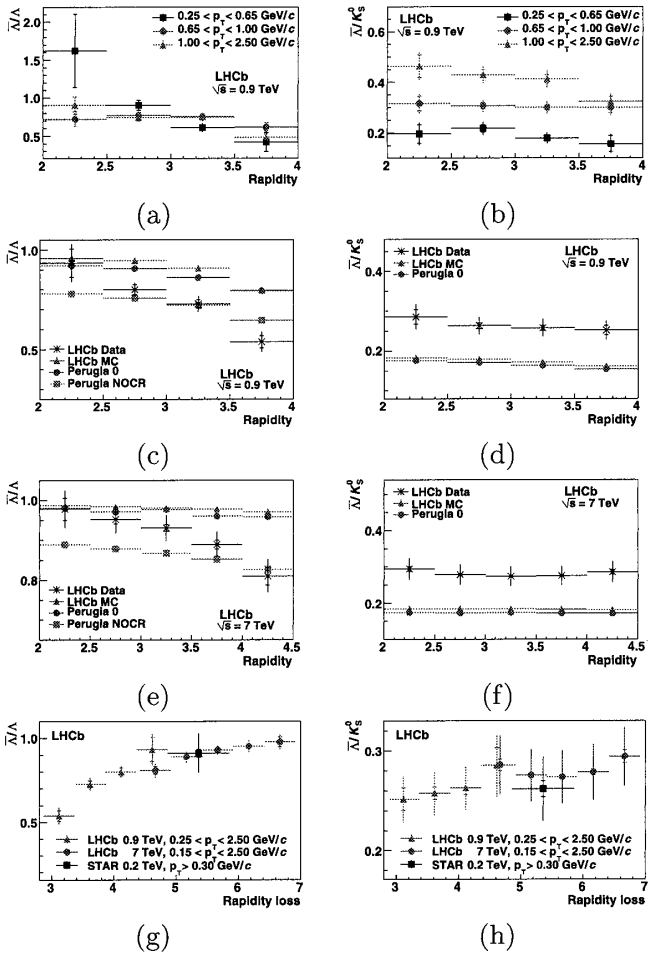


Fig. 2. (color online) Ratios $\bar{\Lambda}/\Lambda$ and $\bar{\Lambda}/K^0_S$: (a) and (b) in different ranges of p_T and y; (c), (d), (e), (f) compared with Monte Carlo generator predictions; (g) and (h) comparison between the results at the two energies and STAR result where $\Delta y = y_{beam} - y$.

vertex requirement*) only $\sim 3\%$ of the selected V^0 are produced in diffractive events (PYTHIA 6 and PYTHIA 8), complete removal of diffractive events producing only a change of 0.01–0.02 in the ratios across the measurement range. Ratios of the $\bar{\Lambda}/\Lambda$ and $\bar{\Lambda}/K^0_S$ are represented as a function of rapidity and in Figs. 2(a) and (b) for different ranges of p_T and rapidity, y. One can notice the strong p_T dependence of the ratio $\bar{\Lambda}/K^0_s$. In Figs. 2(c)–(f) the two ratios integrated over the p_T range are represented as function of y in comparison to PYTHIA 6 tune predictions. For the $\bar{\Lambda}/\Lambda$ one can notice that the ratio approaches Perugia 0 prediction at low y and Perugia NOCR at high y for both energies. The ratio $\bar{\Lambda}/K^0_S$ is far from the event generator predictions. Excellent agreement between the two energies and STAR[9] result can be noticed in Figs. 2(g) and (h).

*) Minimal requirements for PV reconstruction can be approximated by requiring at least 3 charged particles from the collision with lifetime $c\tau > 10^{-6}$ mm, momentum p > 0.3 GeV/c, polar angle $15 < \theta$ [mrad] < 460.

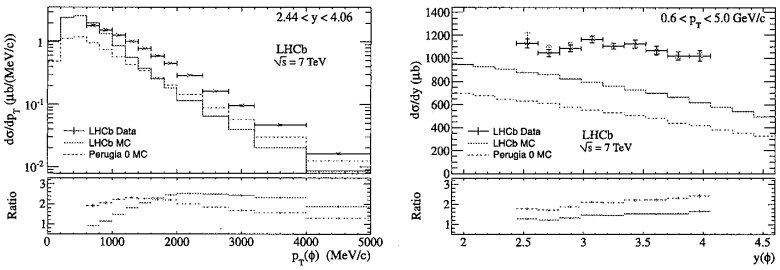


Fig. 3. (color online) ϕ cross-section as a function of y (left) and p_T (right).

§4. ϕ cross-section

The ϕ cross section was measured using the decay $\phi \to K^+K^-$. Kinematic cuts and $K^\pm$ particle identification information provided by the RICH detectors were used for the selection. 14 nb^{-1} of data recorded at $\sqrt{s}$ =7 TeV with the LHCb magnet in both polarities were used. In Fig. 3 the ϕ production cross-section is represented as a function of p_T and y. One can notice that the shape of the p_T and the slope of the y spectrum differ between the data and the simulation. Both Perugia 0 and LHCb MC underestimate the production.

§5. Summary

The capability of LHCb for the study of b-physics at the LHC creates an excellent environment for particle production studies at high rapidities. The charged particle production measurement was shown to be underestimated in most of the generator tunes, the agreement becoming better for hard interactions. The transport of baryon number using $\bar{\Lambda}/\Lambda$ shows good agreement with Perugia 0 at low y, while at high y, the results favour Perugia NOCR. $\bar{\Lambda}/K^0_S$ is significantly larger at LHCb than predicted by PYTHIA 6, particularly at high p_T. Excellent agreement was observed between V^0 ratios LHCb's results at both energies and with STAR's results. The broad coverage of LHCb's results in Δy provides a unique data set. It is complementary to previous measurements and allows to extend the earlier measurements and to test energy scaling. The p_T and y spectra of ϕ look different in data as compared with PYTHIA 6. ϕ production cross-section is considerably underestimated by the event generators.

References

1) LHCb Collaboration (A. Augusto Alves et al.), JINST **3** (2008), S08005.
2) LHCb Collaboration (R. Aaij et al.), Phys. Lett. B **693** (2010), 69.
3) LHCb Collaboration, LHCb-CONF-2010-009, CERN-LHCb-CONF-2010-009.
4) LHCb Collaboration (R. Aaij et al.), CERN-PH-EP-2011-209, arXiv:1112.4592.
5) LHCb Collaboration (R. Aaij et al.), J. High Energy Phys. **08** (2011), 034.
6) LHCb Collaboration (R. Aaij et al.), Phys. Lett. B **703** (2011), 267.
7) T. Sjöstrand, S. Mrenna and P. Skands, J. High Energy Phys. **05** (2006), 026.
P. Skands, Phys. Rev. D **82** (2010), 074018.
8) I. Belyaev et al., Handling of the generation of primary events in Gauss, the LHCb simulation framework, IEEE Nucl. Sci. Symp. Conf. Rec. (2010), 1155.
9) STAR Collaboration (B. I. Abelev et al.), Phys. Rev. C **75** (2007), 064901.