PROCEEDINGS OF SCIENCE

Particle Production Studies at LHCb

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This paper summarises four analyses of minimum bias data collected with the LHCb detector from pp collisions at the LHC. The geometry and particle identification system of the LHCb experiment provide unique capabilities for this type of study. Results will be presented on the production cross section of K^0_S at $\sqrt{s} = 0.9\,\text{TeV}$ and the prompt $\bar{\Lambda}/\Lambda$, $\bar{\Lambda}/K^0_S$ and $\bar{p}/p$ production ratios and the inclusive Φ production cross section at $\sqrt{s} = 0.9\,\text{TeV}$ and $\sqrt{s} = 7\,\text{TeV}$. Baryon ratios are also presented in terms of rapidity loss, Δy, and show good agreement with previous measurements. Results suggest a higher baryon transport and an underestimated strangeness production compared with predictions from Monte Carlo generators.

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1. Introduction

The Large Hadron Collider Beauty experiment (LHCb) at CERN is a single-arm forward spectrometer for precision measurements of CP violation and rare B meson decays. The tracking system is composed by a precision Vertex Locator (VELO) surrounding the interaction region, a dipole magnet and three downstream tracking stations [1]. The resolution for primary (secondary) vertices is $\sim 50(100)\mu$m and the momentum resolution for tracks having hits in both the VELO and the tracking stations is around 5%. Two Ring Imaging Cherenkov (RICH) detectors provide excellent charged particle identification capabilities over a wide momentum range of $2-100$ GeV/c.

The results presented here are based on $6.8\,\mu\mathrm{b}^{-1}$ from the LHC 2009 pilot run at $\sqrt{s} = 0.9\,\mathrm{TeV}$, and $14\,\mathrm{nb}^{-1}$ accumulated by summer 2010 at $\sqrt{s} = 0.9\,\mathrm{TeV}$ and $\sqrt{s} = 7\,\mathrm{TeV}$. These data-sets were recorded using minimum bias triggers, which require a minimum energy deposit in the LHCb calorimeters or at least one reconstructed track in the event. Due to the finite beam size and crossing angle, the two halves of the VELO were partially retracted during the $\sqrt{s} = 0.9\,\mathrm{TeV}$ runs. The measurements presented in this paper are the production cross section of K_S^0 at $\sqrt{s} = 0.9\,\mathrm{TeV}$, and the prompt $\bar{\Lambda}/\Lambda$, $\bar{\Lambda}/K_S^0$ and $\bar{p}/p$ production ratios and inclusive Φ production cross section at $\sqrt{s} = 0.9\,\mathrm{TeV}$ and $\sqrt{s} = 7\,\mathrm{TeV}$.

2. K_S^0 production cross section

Strangeness production studies provide a valuable input to phenomenological models and in particular to the hadronisation mechanism. This is an ideal early measurement since K_S^0s are relatively abundant in minimum bias data and $K_S^0 \to \pi^+\pi^-$ candidates from the 2009 pilot run can be selected using only the tracking system. The results in Figure 1 show a harder p_T spectrum than model predictions but are in good general agreement. Systematic uncertainties are dominated by the estimation of the integrated luminosity ($\sim$ 12%) and tracking efficiency ($\sim$ 10%). A detailed description of the analysis procedure and results are reported in [2].

3. V^0 production ratios

Another probe of strangeness production is the measurement of the baryon versus meson suppression through the $\bar{\Lambda}/K_S^0$ production ratio. Moreover, the $\bar{\Lambda}/\Lambda$ ratio gives an estimate of the baryon number transport from the initial state protons to the final state products. High purity samples of $\Lambda(\bar{\Lambda}) \to p\pi^-(\bar{p}\pi^+)$ and $K_S^0 \to \pi^+\pi^-$ are selected via a Fisher discriminant involving impact parameters with respect to the primary vertex. Preliminary results suggest that models underestimate the baryon number transport in $\bar{\Lambda}/\Lambda$ at $\sqrt{s} = 0.9\,\mathrm{TeV}$ and overestimate baryon suppression in $\bar{\Lambda}/K_S^0$ at both energies, as can be seen in Figure 2. Since these measurements do not require the absolute luminosity, the systematic uncertainties are estimated to be relatively low, $\sim 2\%$ for $\bar{\Lambda}/\Lambda$ and $2-12\%$ for $\bar{\Lambda}/K_S^0$. The full analysis procedure and results are detailed in [4].

4. $\bar{p}/p$ production ratio

A further test of baryon number transport and hadronisation mechanisms is provided by the $\bar{p}/p$ production ratio. This analysis requires PID information from the RICH system in order to

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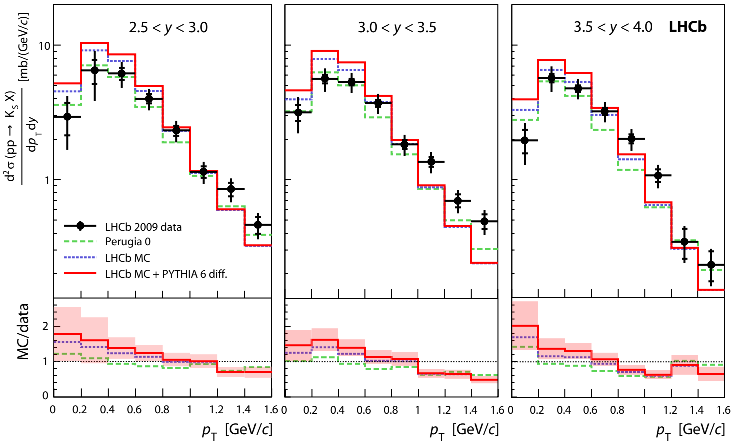
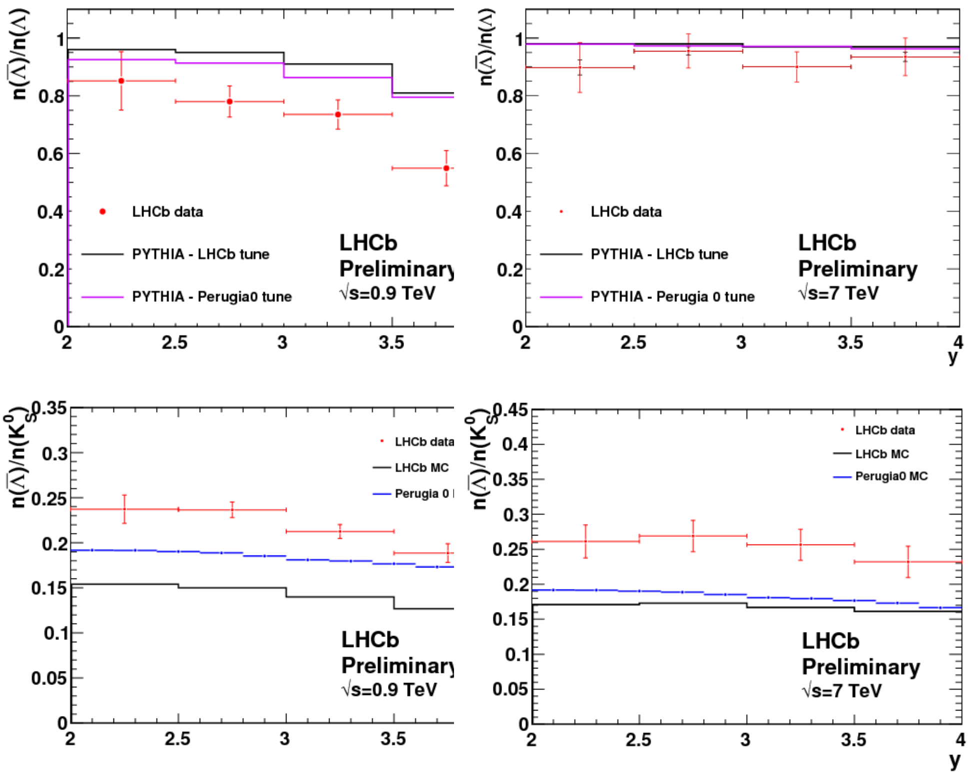


Figure 1: The prompt K^0_S production cross section in pp collisions at $\sqrt{s} = 0.9\,\mathrm{TeV}$ as a function of p_T and rapidity. Measurements are compared with the PYTHIA tuning Perugia0 [3] and the LHCb Monte Carlo (MC) with



(c) $\bar{\Lambda}/K^0_S$ at $\sqrt{s} = 0.9\,\mathrm{TeV}$ (d) $\bar{\Lambda}/K^0_S$ at $\sqrt{s} = 7\,\mathrm{TeV}$

Figure 2: The prompt V^0 production ratio from pp collisions at $\sqrt{s} = 0.9\,\mathrm{TeV}$and $\sqrt{s} = 7\,\mathrm{TeV}$ as a function of rapidity. The measurements are compared with the Perugia0 tuning and the LHCb MC. The error bars account for the total statistical and systematic uncertainty.

select pure samples of p, K and π. The RICH performance is calibrated using Λ, Φ and K_S^0 decays reconstructed directly from data and this represents the main systematic uncertainty, particularly at high pseudorapidity. Preliminary results are consistent with MC predictions at $\sqrt{s} = 7\,\text{TeV}$ but differ significantly at $\sqrt{s} = 0.9\,\text{TeV}$ and low transverse momenta (see Figure 3). Details of the analysis and results can be found in [5].

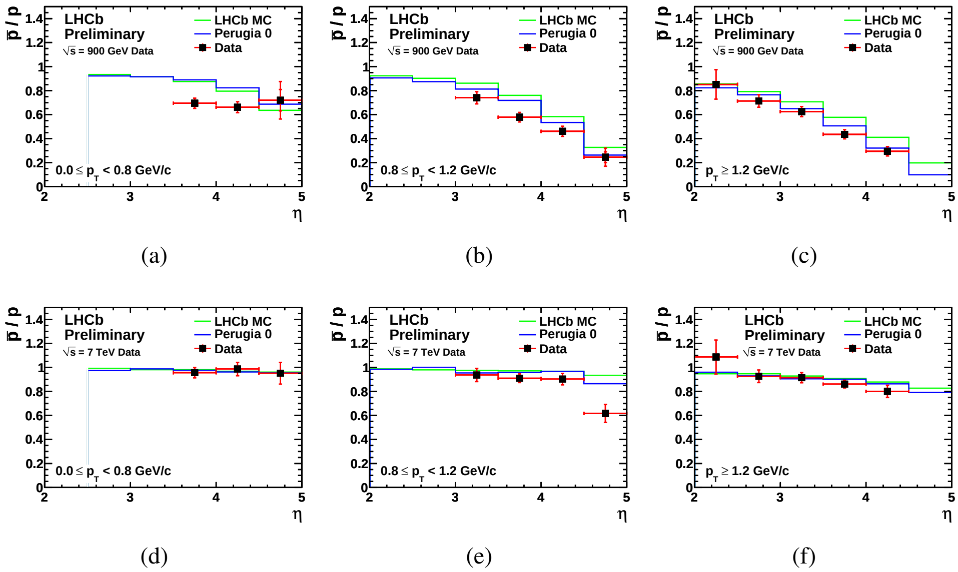


Figure 3: The prompt $\bar{p}/p$ production ratio from pp collisions at $\sqrt{s} = 0.9\,\text{TeV}$and $\sqrt{s} = 7\,\text{TeV}$ as a function of pseudorapidity, η, in three bins of transverse momentum. The measurements are compared with the Perugia0 tuning and the LHCb MC. The error bars account for the total statistical and systematic uncertainty.

5. Comparison with previous experiments

A more convenient form of presenting the $\bar{p}/p$ and $\bar{\Lambda}/\Lambda$ ratios is in terms of rapidity loss, $\Delta y = y_{beam} - y_{p,\Lambda}$. In this way results from different centre of mass energies, both at LHCb and past experiments, can be directly compared. The overall agreement is good, as shown in Figure 4.

6. Inclusive Φ production cross section

A further way to study strangeness production and to understand the hadronisation mechanism is the measurement of the Φ cross section. Like the $\bar{p}/p$ analysis, PID information from the RICH is required to efficiently select $\Phi \to K^+K^-$ candidates [6]. Preliminary results indicate a discrepancy from theoretical models, as shown in Figure 5. As for the K_S^0 cross section, the estimate of luminosity and tracking efficiency are the major systematic errors, the overall uncertainty is $\sim 14\%$.

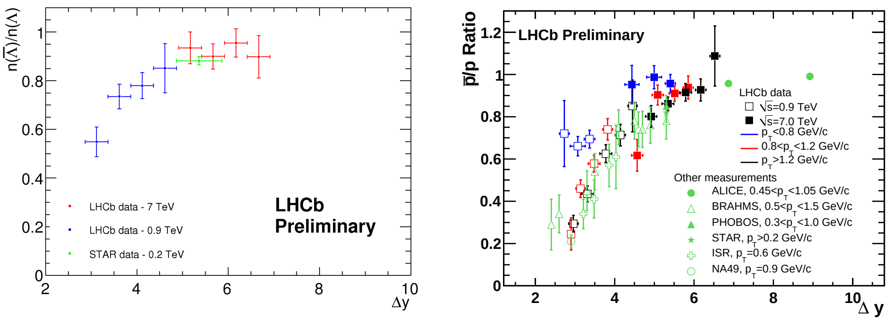


Figure 4: The prompt $\bar{\Lambda}/\Lambda$ and $\bar{p}/p$ production ratios as a function of the rapidity loss, Δy, comparing different experiments at different beam energies and p_T intervals.

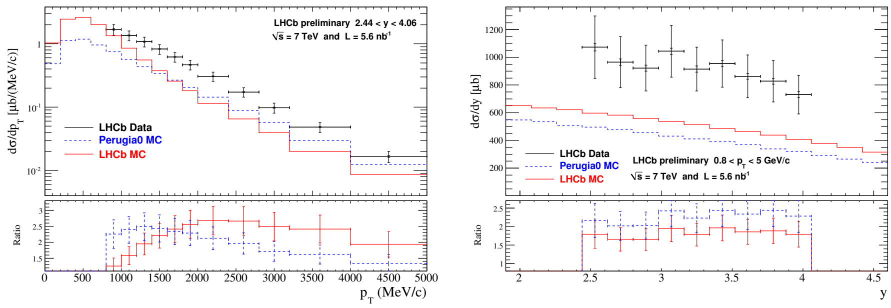


Figure 5: The prompt Φ production cross section from pp collisions at $\sqrt{s} = 7\,\text{TeV}$ as a function of rapidity and transverse momentum. The measurements are compared with the Perugia0 tuning and the LHCb MC.

7. Conclusions

The K_S^0 cross section results are in good agreement with theoretical models. Preliminary results for the $\bar{\Lambda}/K_S^0$ ratio suggest an overestimated baryon suppression in strange quark hadronisation. The combination of the two measurements and the Φ cross sections indicate an overall underestimate of strangeness production in pp collisions.

The $\bar{\Lambda}/\Lambda$ and $\bar{p}/p$ ratio measurements indicate a higher baryon number transport at $\sqrt{s} = 0.9\,\text{TeV}$ and are consistent with model predictions at $\sqrt{s} = 7\,\text{TeV}$. Both ratios show good agreement with previous experiments when presented as a function of rapidity loss.

References

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