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Recent results on heavy flavour in small and large systems from LHCb

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In these proceedings, we report on the latest results on heavy flavour production obtained by the LHCb collaboration in small and large systems. After a short introduction, we present results on open-beauty mesons measurements and their ratios in pp collisions at $\sqrt{s}$ =7,8 and 13 TeV. Then, we focus on the first measurement of prompt double charm production in pPb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 8.16 TeV and the studies of double parton scattering.

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1. Introduction

Initially designed to study the matter-antimatter asymmetry with b-hadrons and rare decays, LHCb [1] is a one-arm spectrometer fully instrumented at forward rapidity. Over the years, the detector has shown great performances [2] for particle identification capabilities, vertex reconstruction, mass and momentum resolution down to zero p_{T}. Since 2013 and the recording of the first pPb data sample, LHCb has turned into a multipurpose detector with an ever expanding heavy-ion physics program, thanks to its unique capability among the LHC experiments to run both in collider and fixed-target mode via the injection of noble gases at the interaction point.

The versatility of the detector allows the collaboration to study heavy-flavour (HF) hadrons over a large range of colliding energy and colliding species. While many recent results in pp collisions at $\sqrt{s}$ = 13 TeV have been obtained in the sector of hadron spectroscopy [3, 4], we first turn our attention to b-hadron production fractions and the associated measurement of fragmentation fraction ratios. Then, we focus on pPb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 8.16 TeV. Here also, many results have been obtained in the beauty sector [5], but only the recent double charm production results are discussed in these proceedings.

2. Recent results on pp collisions: b-hadron ratios

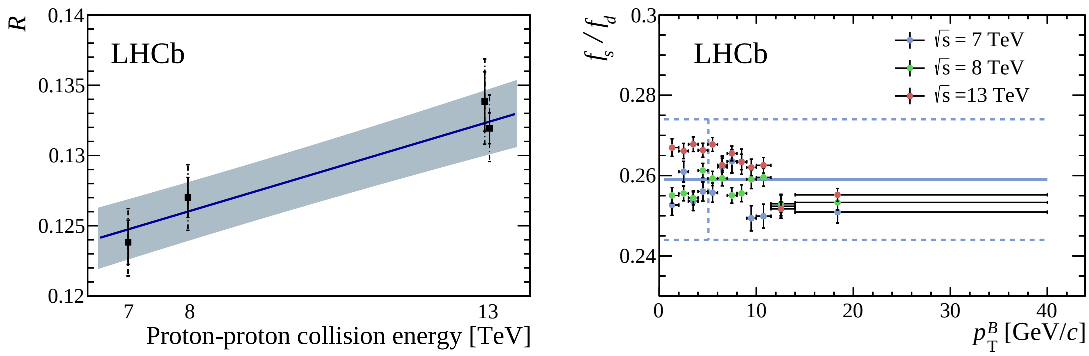

Figure 1: Left: efficiency-corrected $B_s^0 \to J/\psi\phi$ to $B^+ \to J/\psi K^+$ yield ratios (R) at different pp collision energies with the total (uncorrelated, including statistical) uncertainties denoted by dashed (solid) error bars. A linear fit is shown with the blue solid line, the blue band denotes the 68% confidence region. Right: R in bins of mesons p_{T}^{B} in the three collision energies. The ratios are scaled to match the measured f_s/f_d value (horizontal blue lines, the $\pm 1\sigma$ interval is indicated by the dashed blue lines) at the positions indicated by the vertical gray lines.

Heavy quarks (i.e charm and beauty) are natural probes to test pQCD factorization thanks to their relatively high mass compared to Λ_{QCD}. By measuring heavy quarks (HQs) production in high-energy pp collisions, one can test the universality of the non perturbative parts of pQCD models such as parton distribution functions and fragmentation functions. The laters describe the hadronization mechanisms of HQs into mesons and baryons. Therefore, mesons production fractions or baryon-to-meson rations make for excellent observables to study in order to understand these hadronization mechanisms.

By measuring B_s^0/B^+ or B_s^0/B^0 ratios [6] in pp collisions at $\sqrt{s}$ = 7, 8 and 13 TeV, LHCb has studied the dependence of fragmentation functions f_s/f_u and f_s/f_d on p_{T} and rapidity for multiple colliding energies. While no rapidity dependence has been observed for the three datasets, a p_{T} dependent behaviour has been measured with 6 sigma significance, driven especially by the 13 TeV sample (Fig. 1, right). Moreover, a 4.8σ significance is seen for f_s/f_u dependence on collision energy (Fig. 1, left), while no energy dependence is observed in the charm sector [9]. Likewise, the baryon-to-meson ratio $\Lambda_b^0/(\bar{B}_0 + B^-)$ has been measured to access the $f_{\Lambda_b^0}/(f_u + f_d)$ fragmentation fraction ratios in pp at $\sqrt{s}$ = 13 TeV [7]. This new measurement is in a good agreement with previous results obtained at $\sqrt{s}$ = 7 TeV [8] for the p_{T} dependence of the $f_{\Lambda_b^0}/(f_u + f_d)$ ratio, with no rapidity dependence.

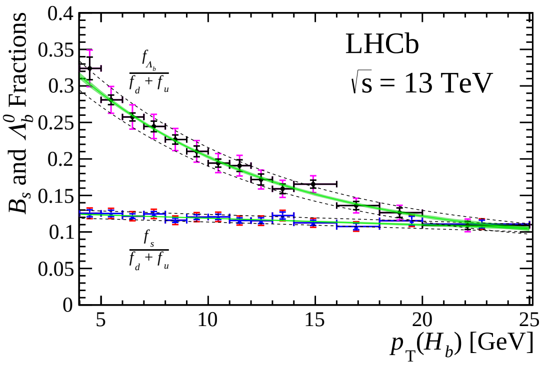

Figure 2: The $f_s/(f_u + f_d)$ $(\bar{B}_s^0/(\bar{B}_0 + B^-))$ and $f_{\Lambda_b^0}/(f_u + f_d)$ $(\Lambda_b^0/(\bar{B}_0 + B^-))$ yields ratios in bins of $p_{\mathrm{T}}(Hb)$. The smaller (black, blue) error bars show the combined bin-by-bin statistical and systematic uncertainties, and the larger (ref, magenta) ones show the global systematics added in quadrature. The fits to the data are shown to guide the eye, with a $\pm 1\sigma$ uncertainty band (green) on the fit shapes, and the dashed lines give the total uncertainty on the fit results.

3. Recent results on pPb collisions: prompt double charm production

The LHCb collaboration has recently measured the double prompt charm production at $\sqrt{s_{\mathrm{NN}}}$ = 8.16 TeV [11]. The measurement is sensitive to the underlying event associated to a charm quark production, but could also give access to correlated parton distributions such as double transverse momentum dependent PDFs [10]. Experimentally, one can measure the associated production cross-section of two particle (A and B) in the same event ($\sigma^{A,B}$) as a proxy for double parton scattering (DPS), and build an effective cross-section $\sigma_{eff} \propto \frac{\sigma^A \sigma^B}{\sigma^{AB}}$, where $\sigma^{A,B}$ is the production cross-section of particle A, B, a proxy for single parton scattering (SPS). This σ_{eff} cross-section can be measured both in pp ($\sigma_{eff,pp}$) but also in pA collisions ($\sigma_{eff,pA}$). Simple scaling rules relates the two quantities [13], and any deviation of the measured $\sigma_{eff,pA}$ compared to the predicted value from scaled $\sigma_{eff,pp}$ would indicate additional correlation effects.

Fig. 3 shows the measured $\sigma_{eff,p\mathrm{Pb}}$ as a function of rapidity, for associated like-sign $D^0 - D^0$ and

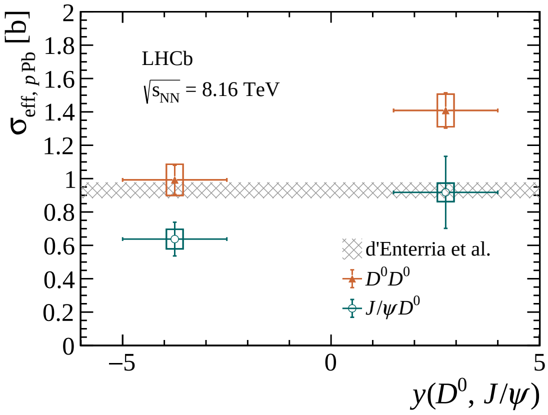

Figure 3: $\sigma_{eff,p\mathrm{Pb}}$ (in barn) as function of rapidity in the centre-of-mass system in pPb ($y > 0$) and Pbp ($y < 0$) collisions at $\sqrt{s_{\mathrm{NN}}}$ = 8.16 TeV for like-sign $D^0 - D^0$ (green) and $D^0 - J/\psi$ (red) pairs. The error bars represent the statistical uncertainties, while boxes around the points represent the systematic uncertainties. The grey band is the theory prediction based on scaled $\sigma_{eff,pp}$ results [13].

$D^0 - J/\psi$ which are dominated by DPS production. The mean value from the theory $\sigma_{eff,p\mathrm{Pb}} \sim 0.9$b is consistent with the measured data, which indicates DPS/SPS enhancement by a factor three compared to pp collisions. In addition, we observe that $\sigma_{eff,p\mathrm{Pb}}(D^0 - D^0) > \sigma_{eff,p\mathrm{Pb}}(D^0 - J/\psi)$, but also $\sigma_{eff,p\mathrm{Pb}}(D^0 - D^0, D^0 - J/\psi) > \sigma_{eff,Pbp}(D^0 - D^0, D^0 - J/\psi)$. The two observations indicate DPS/SPS enhancement in $(D^0 - D^0)$ compared to $D^0 - J/\psi$ production, but also an enhancement in pPb with respect to Pbp collisions. However, one must be cautious about potential remaining SPS contamination in like-sign $D^0 - D^0$ and $D^0 - J/\psi$.

4. Conclusions

The large catalogue of datasets together with great performances make LHCb an ideal detector to study heavy-flavour productions. The forward acceptance of the detector and the reconstruction of tracks down to zero p_{T} give access to a phase space coverage unique at the LHC. Recent results in pp collisions allow to study HF hadronization mechanisms with great precision while new analyses are performed for the first time in high-energy pPb collisions such as the double charm production. With future upgrades and new data samples, the LHCb collaboration will continue to be a major actor in heavy-flavour measurements in small and large systems.

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