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Production of open charm and beauty states in p-Pb collisions with LHCb

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A rich set of open heavy flavour states is observed by LHCb in p-Pb and Pb-p collisions data collected at $\sqrt{s_{NN}} = 5.02$ and 8.16 TeV. In these proceedings, latest results obtained by the LHCb collaboration are reported, with a special focus on the data recorded in 2013 at $\sqrt{s_{NN}} = 5.02$ TeV (L_{int}= 1.6 nb^{-1}). Results include the new measurements of production of beauty hadrons through cleanly reconstructed exclusive decays, as well as the Λ_c^+ baryon on the open charm states sector, observed in p-Pb collisions for the first time by LHCb.

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1. Physics motivation : From A-A to p-A collisions

Heavy-quarks (i.e charm and beauty) are well known probes to study the deconfined state of hadronic matter, namely the Quark-Gluon Plasma (QGP), presumably formed in high-energy nucleus-nucleus collisions. With their relatively high-mass compared to Λ_{QCD}, heavy-quarks (HQs) are mostly produced at the early stage of the collision and experience the full evolution of the fire-ball.

However, one must take good care to disentangle QGP-related processes affecting heavy-quarks from the ones due to a confined nuclear medium. Those effects, often referred in the literature as cold nuclear matter (CNM) effects, are extensively studied in proton-nucleus collisions. A non exhaustive list includes parton energy loss mechanism [1, 2], interaction with the co-moving hadrons [3], saturation effect [4], and the influence of the nuclear parton distribution functions (nPDFs) in the target [5]. One observable to quantify them is the ratio of the HQs cross-section in p-A collisions divided by the one in pp collisions scaled by the number of nucleons in the target, the so-called nuclear modification factor $R_{pA} = \frac{\sigma_{pA}}{A \cdot \sigma_{pp}}$. Any deviation from unity of this ratio would indicate an enhancement (higher than one) or a suppression (lower than one) compare to the pp scenario.

Originally designed to study particles containing *b* or *c* quarks, the LHCb detector [6] is a fully equipped single-arm spectrometer covering a range in pseudorapidity $2 < \eta < 5$. This acceptance, coupled to the high collision energy in the center-of-mass, grants access to the low Bjorken-x regime of the CNM effects depending on the probe studied. On top of it, the high precision on the vertex resolution [7] allows to disentangle prompt (direct) and non-prompt (from b-hadrons decay) hadron productions, both in p-Pb (forward rapidity $y > 0$) and Pb-p (backward rapidity $y < 0$)

2. Results : Charm and beauty production

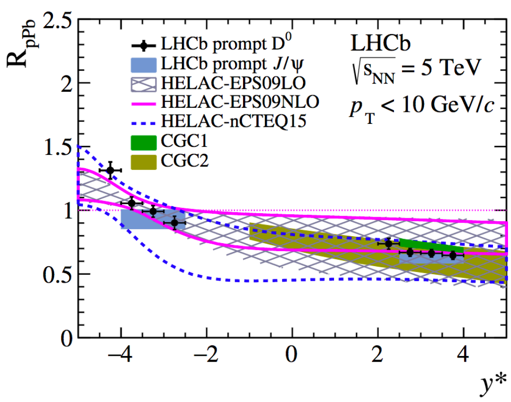

Figure 1: Nuclear Modification factor of the prompt D^0 versus rapidity (in the center-of-mass system) compared to various model predictions (see [8] for details). The uncertainty is the quadratic sum of the statistical and systematic components.

Starting on the charm sector, LHCb has measured the prompt D^0 production through its decay channel $D^0 \to K^- + \pi^+$ [8]. The rapidity dependence of the $\mathrm{R_{pA}}$ is shown in Fig. 1 and compared to several models. One can see a good descriptions of the data pattern by model predictions, showing an increasing suppression moving from backward to forward rapidity.

From the same recorded data, the Λ_c^+ production has been measured [9]. Among other quantities, charm baryon-to-meson ratios ($R_{\Lambda_c^+/D^0}$) have been computed. Such ratios are sensitive to the c quark fragmentation as nPDFs effects largely cancel. Data are compared to HELAC-Onia predictions [10][11], previously tuned to pp data and including different nPDF sets. While a good agreement is generally found between data and predictions for $R_{\Lambda_c^+/D^0}$, tensions appear at forward rapidity for $\mathrm{p_T} > 7$ GeV/c as shown in Fig. 2.

In the same fashion, the prompt-charmonium to open-charm ratios have been extensively studied for the same recorded data [12]. Results show no relative J/ψ-to-$D0$ suppression, but a $\psi(2S)$-to-$D0$ relative suppression is measured. This last results is to be linked to the measurements of the prompt $\psi(2S)$-to-J/ψ relative suppression measured by LHCb at $\sqrt{s_{NN}}$ = 5.02 TeV [13], which is at the present time not fully understood.

On the b-hadron productions, LHCb has measured the Υ ($b\bar{b}$ bound state) production [14] at $\sqrt{s_{NN}}$ = 5.02 TeV, the non-prompt J/ψ production at $\sqrt{s_{NN}}$ = 5.02 and 8.16 TeV [15] [16], and finally the $\psi(2S)$ production at $\sqrt{s_{NN}}$ = 5.02 TeV [13]. The rapidity dependence of the $\Upsilon(1S)$ $\mathrm{R_{pA}}$ is well described by model predictions within large statistical uncertainties related to the small size of the recorded data. The conclusions hold for the J/ψ-from-b, and thanks to a larger data sample recorded at 8.16 TeV ($L_{int} = 30\ nb^{-1}$), this measurement has contributed to put strong constraints on the nPDF parametrization [17]. In addition, Fig. 3 shows the non-prompt J/ψ and $\psi(2S)$ nuclear modification factor versus rapidity at $\sqrt{s_{NN}}$ = 5.02 TeV. Due to large statistical uncertainties on the $\psi(2S)$ measurements (as for the $\Upsilon(1S)$), results for the two charmonium states are in agreement with each other. For both $\psi(2S)$ and Υ studies, statistical uncertainties are expected to be reduced in the p-Pb and Pb-p data at $\sqrt{s_{NN}}$ = 8.16 TeV. The still-to-come results may help to understand the relative prompt $\psi(2S)$-to-J/ψ suppression.

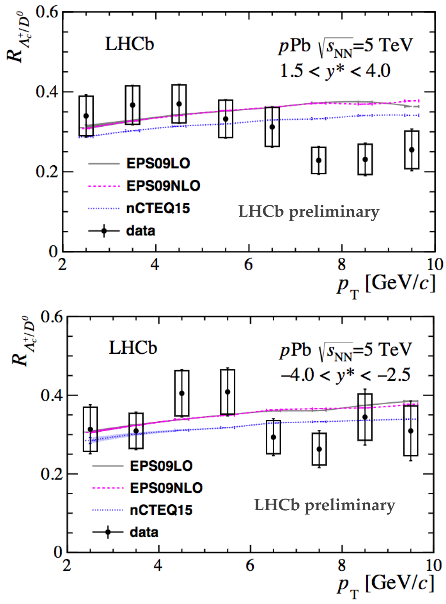

Figure 2: p_T dependence of the baryon-to-meson ratio $R_{\Lambda_c^+/D^0}$ in the forward (top) and backward (bottom) rapidity region compared to model predictions. Bars (boxes) represent the statistical (correlated systematic) uncertainties.

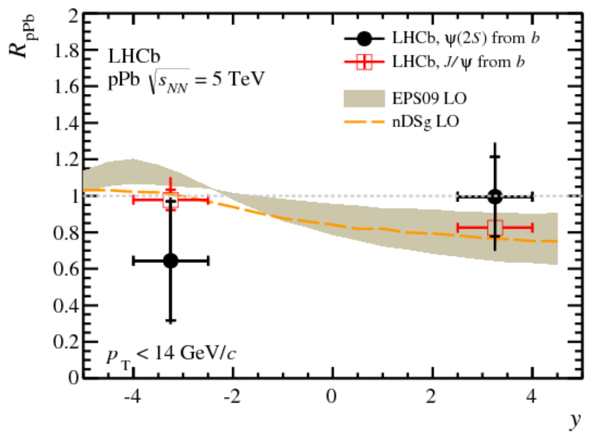

Figure 3: Rapidity dependence of the non-prompt J/ψ and $\psi(2S)$ nuclear modification factor. The first mark on the bar represents the contribution of the statistical uncertainty to the total uncertainty.

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