$D^+_s$ production at central rapidity in pp collisions at \(\sqrt{s} = 7\) TeV and in Pb–Pb collisions at \(\sqrt{s_{NN}} = 2.76\) TeV with the ALICE detector

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Abstract. We present the measurements of the $D^+_s$ production in pp collisions at $\sqrt{s} = 7$ TeV and in Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV performed in the central rapidity region with the ALICE detector through the reconstruction of the hadronic decay channel $D^+_s \rightarrow \phi\pi^+ \rightarrow K^+K^-\pi^+$. The ratios of the yields of $D^+_s$ and non-strange D mesons as a function of the transverse momentum are also shown for both pp and Pb-Pb collisions.

1. Introduction

The study of charm production in proton-proton and in heavy-ion collisions allows one to investigate properties of the high-density QCD medium created in heavy-ion collisions and to study the mechanism of in-medium energy loss of heavy quarks [1]. In addition, since strange quarks are abundant in the medium [2], the relative yield of $D^+_s$ mesons with respect to non-strange charm mesons ($D^0$, $D^+$ and $D^{*+}$) is predicted to be largely enhanced if in-medium hadronization is the dominant mechanism for charm hadron formation in the low momentum region [3, 4]. An effective observable to study these processes is the nuclear modification factor which is defined for a given particle species $h$ as $R_{AA}^{h}(p_T)=\frac{dN_{AA}^{h}/dp_T}{\langle T_{AA} \rangle \times d\sigma_{pp}^{h}/dp_T}$, where $N_{AA}^{h}$ is the yield measured in heavy-ion collisions, $\langle T_{AA} \rangle$ is the average nuclear overlap function calculated using the Glauber model and $\sigma_{pp}^{h}$ is the production cross section in pp collisions at the same energy. We present the measurement of the nuclear modification factor of the $D^+_s$ meson in Pb–Pb collisions performed at central rapidity ($|y| < 0.5$) with the ALICE detector [5] at 2.76 TeV. The proton-proton measurement at $\sqrt{s} = 7$ TeV used as a reference for this analysis is described in details in [6].

2. Detector layout and data sample

Charmed mesons are reconstructed in ALICE using the tracking detectors and particle identification systems of the central barrel, which cover the pseudo-rapidity region $-0.9 < \eta < 0.9$ and is embedded in a magnetic field of $B = 0.5$ T. A brief description of the detectors utilized in these analyses will be given in this section (more details in [5]). The Time Projection Chamber (TPC) is the main tracking detector, which provides track reconstruction and particle identification via the measurement of the specific energy deposit $dE/dx$. The Inner Tracking System (ITS) is the central barrel detector closest to the beam axis and it is composed of six
entries / 8 MeV/c

Figure 1. Invariant mass distributions for $D_s^+$ candidates and charge conjugates in the three considered $p_T$ intervals in the range $4 < p_T < 12$ GeV/c obtained from the analysis of 16 million Pb–Pb events in the centrality range 0–7.5%.

3. $D_s^+$ meson reconstruction in ALICE

$D_s^+$ mesons and their antiparticles ($cτ = 150$ μm) were reconstructed in the decay channel $D_s^+ → φπ^+ → K^+K^−π^+$ (and its charge conjugate) which has a branching ratio (BR) of $2.28 ± 0.12%$ [7]. The analysis strategy is based on the reconstruction and selection of secondary vertex topologies with significant separation from the primary vertex. The $D_s^+$-meson candidates were defined starting from combinations of tracks selected with respect to their pseudorapidity ($|η| < 0.8$), transverse momentum and number of associated space points. In order to improve the statistical significance of the signal, the $D_s^+$ candidates were filtered by applying kinematical and topological cuts together with particle identification criteria. The selection was based on the decay length, the cosine of the pointing angle and on the sum of the distances of the decay tracks to the reconstructed decay vertex. Moreover, the $D_s^+$ candidates were required to have one of the two pairs of opposite-charge tracks with an invariant mass compatible with the PDG value for the $φ$ meson mass [7]. The selection strategy adopted in this analysis (similar to the one performed in the pp measurement) aims at reducing the combinatorial background while keeping the selection efficiency as large as possible. In Fig. 1 the invariant mass distributions of $D_s^+$ candidates in the centrality interval 0–7.5% in three $p_T$ intervals from 4 to 12 GeV/c are shown. In order to evaluate the signal yield, a fit to the distributions with a Gaussian function for the signal and an exponential shape for the background was used. The raw yields were then corrected for acceptance and selection efficiency of prompt $D_s^+$ mesons using Monte Carlo simulations based on PYTHIA (Perugia-0 tuning) [8] and HIJING [9]. The correction factor that accounts for the feed-down contribution from B meson decays was evaluated using FONLL.
predictions for the $p_T$-differential cross section of B mesons, the $B \to D^\ast_0$ decay kinematics and the Monte Carlo efficiency for feed-down $D^+_s$ mesons. Indeed, FONLL calculation describe well bottom production at Tevatron [10] and at the LHC [11, 12]. The contribution estimated with FONLL was multiplied in the Pb–Pb analysis by the average nuclear overlap factor estimated via the Glauber Model $\langle T_{AA} \rangle$ and by a hypothesis on the suppression of $D^+_s$ from B decays ($R_{AA}^{\text{feed-down}}$) (more details in [13]). The estimated contribution of $D^+_s$ from B meson decays is $\approx 20\%$ in the three $p_T$ intervals considered. To estimate the systematic uncertainties on the B feed-down subtraction the full spread of the results obtained by varying the FONLL parameters and the values of $R_{AA}^{\text{feed-down}}$ was considered. The latter was varied in the range $1/3 < R_{AA}^{\text{feed-down}}/R_{AA}^{D^0} < 3$. The reference for the nuclear modification factor was obtained by scaling the pp cross section at 7 TeV to $\sqrt{s} = 2.76$ TeV using the ratio of FONLL cross sections for meson production at the two energies. To compute the systematic uncertainties on the scaling (about 15% in the three $p_T$ intervals), the parameters of the FONLL calculation (factorization and renormalization scales, charm quark mass) were varied. The validity of the energy scaling was tested for $D^0$, $D^+$ and $D^{*+}$ mesons through the comparison with the measured $p_T$-differential cross section in pp collisions at 2.76 TeV [14].

4. Results

The $D^+_s$ yield measured in Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV in the centrality range 0–7.5% is shown in the left panel of Fig. 2 together with the pp reference which is obtained by scaling with FONLL the cross-section measured at $\sqrt{s} = 7$ TeV at the Pb–Pb center of mass energy and by multiplying it by the corresponding $\langle T_{AA} \rangle$ value. In the right panel of Fig. 2 the $D^+_s$ $R_{AA}$ in the same centrality class is shown and compared to the average of $D^0$, $D^+$ and $D^{*+}$ [15]. The statistical uncertainties are shown as vertical bars while the boxes around the data points represent the systematic uncertainties, which include the contribution of signal extraction, track reconstruction efficiency, topological and PID selection and of the B feed-down subtraction. The $D^+_s$ nuclear modification factor in the highest $p_T$ interval is $\approx 0.25$ and it is compatible within uncertainties with the value measured for non-strange D mesons. At lower transverse momenta, the $D^+_s$ $R_{AA}$ presents an increase which is however not significant within present uncertainties if compared to the average value of $D^0$, $D^+$ and $D^{*+}$. In Fig. 3, the ratios between the $D^+_s$ yield and
Figure 3. Ratios of the yield $D^+ / D^0$ (left) and $D^+_s / D^+$ (right) measured in Pb–Pb collisions in the centrality range 0–7.5% as a function of $p_T$ compared with the ratios of the production cross sections measured in pp collisions at 7 TeV.

the $D^0$ and $D^+$ ones measured in Pb–Pb collisions in the centrality range 0–7.5% are presented as a function of $p_T$ together with the ratios of the production cross sections measured in pp collisions at 7 TeV. In the evaluation of the systematic uncertainties, the sources of correlated and uncorrelated systematic effects were treated separately. In particular, the contributions of the yield extraction, cut efficiency and PID selection were considered as uncorrelated and summed in quadrature, while the uncertainty on the tracking efficiency, being completely correlated, cancels in the ratio. The FONLL contribution to the B feed-down systematic uncertainty was considered as completely correlated both in pp and in Pb–Pb and estimated as the spread of the ratios obtained by varying the factorization and renormalization scales and the heavy quark mass in FONLL coherently for all mesons. In the Pb–Pb analysis, the contribution from the hypothesis on the $R^{feed-down}_{AA}$ was considered completely uncorrelated between the considered D meson species and summed in quadrature due to the possible different nuclear modification factor of B mesons which decay in $D^+$ (mainly $B^+$ mesons) and $D^0$, $D^+$ and $D^{**}$ (mainly $B^0$ and $B^+$ mesons). Larger values of the ratios are observed in Pb–Pb collisions in the lowest $p_T$ interval but they are still compatible with the pp results within uncertainties. Therefore, larger statistics samples from the future LHC runs are needed to draw firm conclusions on a possible enhancement of $D^+_s$ production in Pb–Pb collisions at low-intermediate $p_T$.

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