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

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Abstract

We present 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 with the ALICE detector at central rapidity through the reconstruction of the hadronic decay channel D$_s^+ \to \phi\pi^+ \to$ K$^+$K$^-\pi^+$. Preliminary results of the D$_s^+$ nuclear modification factor will be presented.

1. Introduction

The measurement of heavy-flavour production provides insights on the properties of the high-density QCD medium created in ultra-relativistic heavy-ion collisions. The comparison of charm production in pp and in Pb–Pb collisions allows one to study the mechanism of in-medium partonic energy loss of heavy quarks which are expected to lose less energy with respect to light partons due to the presence of the so called "dead cone" effect [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]. A sensitive observable in order to address these open questions is the nuclear modification factor, which is defined for a given particle species h as $R^h_{AA}(p_T)= \frac{dN^h_{AA}/dp_T}{\langle T_{AA}\rangle \times d\sigma^h_{pp}/dp_T}$, where N^h_{AA} is the yield measured in heavy-ion collisions, $\langle T_{AA}\rangle$ is the average nuclear overlap function calculated using the Glauber model and σ^h_{pp} is the production cross section in pp collisions at the same energy. In these proceedings we present the first measurement of the nuclear modification factor of the D$_s^+$-meson in Pb–Pb collisions at 2.76 TeV performed in the central rapidity region of the ALICE experiment. A detailed description of the pp results used as a reference for this analysis can be found in [5].

2. Detector layout and data sample

Open charm measurements are performed in ALICE using the tracking detectors and particle identification systems of the central barrel, which covers the pseudo-rapidity region -0.9 < η < 0.9 and is embedded in a magnetic field of B = 0.5 T. The central barrel detectors allow to track

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[1]A list of members of the ALICE Collaboration and acknowledgements can be found at the end of this issue.

charged meson down to low transverse momenta ($\approx$ 100 MeV/c) and provides charged hadron and electron identification as well as an accurate measurement of the positions of the primary and secondary (decay) vertices [6]. A short description of the detectors utilized in these analyses will be given in this section. 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 cylindrical layers of silicon detectors. The two innermost layers (at radii of 3.9 and 7.6 cm) are made of pixel detectors (SPD), the two intermediate layers (radii $\approx$ 15 and 24 cm) are equipped with drift detectors, while strip detectors are used for the two outermost layers (radii $\approx$ 39 and 44 cm). The ITS is crucial to reconstruct secondary vertices originating from open charm decays because it allows for the measurement of the track impact parameter in the transverse plane with a resolution better than 50 μm for tracks with p_T > 1.3 GeV/c [7]. The Time-of-Flight (TOF) detector is used for pion, kaon and proton identification on the basis of their time of flight. The TOF measurement provides kaon/pion separation up to a momentum of about 1.5 GeV/c. All the three detectors have full azimuthal coverage. The data sample used for this analysis has been collected during the 2011 LHC run (November-December 2011) with Pb–Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 2.76 TeV and it consists of 16 million events selected in the centrality range 0 – 7.5% according to centrality-based trigger requirements on the signal from the SPD and from the VZERO detectors. The latter is made of two scintillator hodoscopes positioned in the forward and backward regions of the experiment [6]. Only events with a vertex found within $\pm$ 10 cm from the centre of the detector along the beam line were used for the analysis.

3. D_s^+ meson reconstruction in ALICE

D_s^+ mesons and their antiparticles were reconstructed in the decay chain $D_s^+ \rightarrow \phi\pi^+$ (and its charge conjugate) followed by $\phi \rightarrow K^-K^+$. The branching ratio (BR) of this chain is 2.28 $\pm$ 0.12% [8]. D_s^+ mesons have a mean proper decay length $c\tau$ = 150 $\pm$ 2 μm [8] which allows to resolve their decay vertex from the interaction (primary) vertex. Thus, the analysis strategy for the extraction of the signal out of the large combinatorial background can be based on the reconstruction and selection of secondary vertex topologies with significant separation from the primary vertex. The D_s^+ meson candidates are built starting from track combinations with proper charges and selected according to topological cuts. Single tracks are previously selected with respect to to their pseudorapidity ($|\eta|$ < 0.8), momentum and to quality cuts. Candidates are then filtered by applying kinematical and topological cuts together with particle identification criteria in order to improve the statistical significance while keeping the selection efficiency as high as possible. The candidate triplets were selected according to the sum of the distances of the decay tracks to the reconstructed decay vertex, the decay length and the cosine of the pointing angle, that is the angle between the reconstructed D_s^+ meson momentum and the line connecting the primary and the secondary vertex. In addition, D_s^+ candidates were selected by requiring that one of the two pairs of opposite-charge tracks has an invariant mass compatible with the PDG value for the ϕ meson mass [8]. The same topological and PID strategy has been adopted in the pp and Pb–Pb analyses with tighter topological selection cuts used in nucleus-nucleus collisions to cope with the higher combinatorial background. In Fig. 1 the invariant mass distributions of D_s^+ candidates in the centrality interval 0 – 7.5% in three p_T bins from 4 to 12 GeV/c are presented. 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.
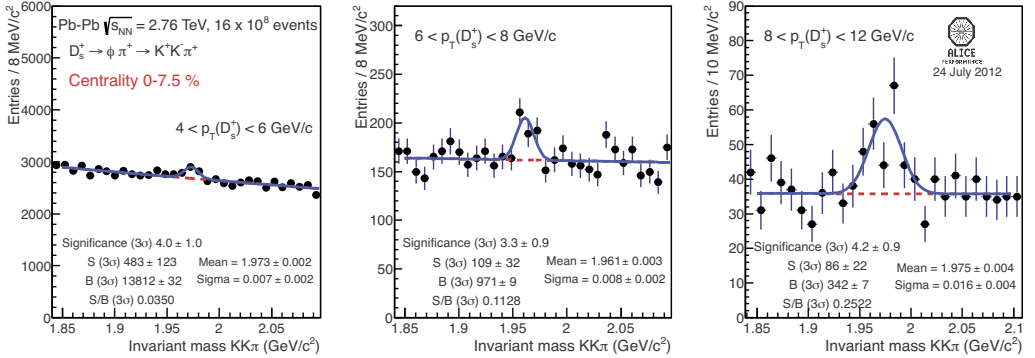
Figure 1: Invariant mass distributions for D_s^+ candidates and charge conjugates in the three considered p_T intervals in the range $4 < p_T < 12$ GeV/c obtained from the analysis of 16 million Pb–Pb events in the centrality range $0 - 7.5\%$.

The measured raw yields were corrected for acceptance and selection efficiency of prompt D_s^+ mesons using Monte Carlo simulations based on PYTHIA (Perugia-0 tuning) [9] and HI-JING [10]. The correction factor that accounts for the feed-down from B meson decays was evaluated using the Monte Carlo efficiency for feed-down D_s^+ mesons and the FONLL calculations, which describe well bottom production at Tevatron [11] and at the LHC [12, 13]. In the Pb–Pb analysis, the contribution estimated with FONLL was multiplied by the average number of binary collisions estimated via the Glauber Model $\langle N_{coll} \rangle$ and by the hypothesis on the energy loss of D_s^+ from B (R_{AA}^B) (more details in [14]). The systematic uncertainties on the B feed-down subtraction was estimated as the full spread of the results obtained by varying the FONLL parameters and the values of R_{AA}^B (the latter only in the Pb–Pb case). In particular, the hypothesis on the R_{AA}^B has been varied in the range $1/3 < R_{AA}^B/R_{AA}^D < 3$. The estimated fraction of D_s^+ from B meson decays is ≈ 0.8 in the three p_T intervals considered. In order to obtain a reference for the nuclear modification factor, the pp cross section at 7 TeV has been scaled to $\sqrt{s} = 2.76$ TeV using the ratio of the FONLL cross sections for the D_s^+ meson production at the two energies. To compute the systematic uncertainties on the scaling, the parameters of the FONLL calculation (factorization and renormalization scales, charm quark mass) were varied. The resulting contribution to the systematic uncertainty is about 15%.

The validity of the energy scaling was tested for the non-strange D_s^+ meson through the comparison with the measured p_T-differential cross section in pp collisions at 2.76 TeV [15].

4. Results

In Fig. 2 (Left) the D_s^+ yield measured in Pb–Pb collisions at $\sqrt{s_{NN}} = 2.76$ TeV in the centrality range $0 - 7.5\%$ and the rescaled pp reference at the same energy are presented. In the right panel of Fig. 2 the D_s^+ R_{AA} in the same centrality class is shown and compared to the average non-strange D-meson one (D^0, D^+ and D^{*+}) [16]. The vertical bars represent the statistical uncertainties while the total systematic uncertainties are shown as boxes. The total systematics include the uncertainties on signal extraction, track reconstruction efficiency, cut and PID selection and on the B feed-down subtraction. The last contribution is e.g. $^{+11\%}_{-45\%}$ in the transverse momentum range $4 < p_T < 6$ GeV/c and the total systematic uncertainty is $^{+50\%}_{-68\%}$. The D_s^+ nuclear
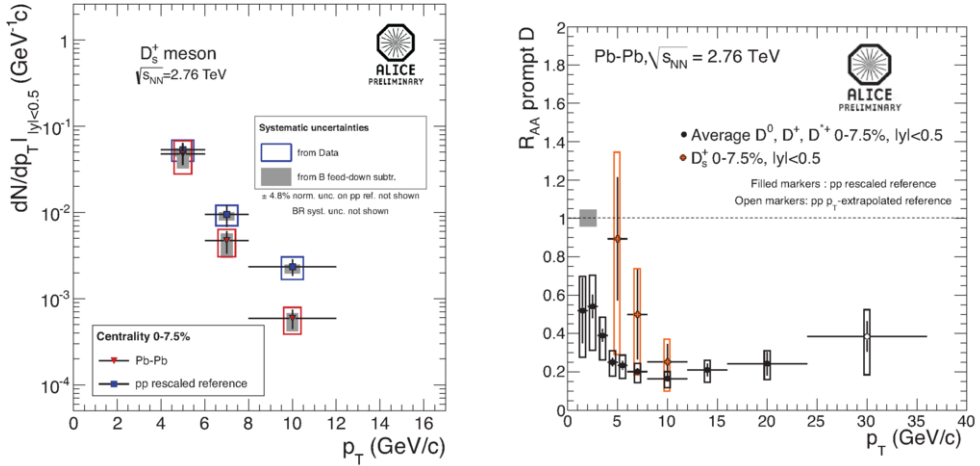
Figure 2: (Left) D_s^+ yield for central Pb–Pb collisions $(0 – 7.5\%)$ at $\sqrt{s_{NN}}$=2.76 TeV compared to the reference spectra rescaled at the same energy. (Right) D_s^+ nuclear modification factor measured in central $(0 – 7.5\%)$ Pb–Pb collisions compared to the average non-strange D-meson R_{AA} also measured in ALICE [16].

modification factor in the highest p_T bin is ≈ 0.25 and it is compatible within the 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 if compared to the average value of D^0, D^+ and D^{*+}. Therefore, larger statistics samples from the future LHC runs should allow us to draw firm conclusions on a possible enhancement of D_s^+ production in Pb–Pb collisions

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