Open-charm production as a function of charged particle multiplicity in pp collisions at $\sqrt{s}$=7 TeV with ALICE

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Abstract. Heavy quarks (charm and beauty) are an effective tool to investigate the properties of the Quark-Gluon Plasma created in heavy-ion collisions as they are produced in initial hard scattering processes and as they experience all the stages of the medium evolution. The measurement of heavy-flavour production cross sections in pp collisions at the LHC, besides providing a reference for heavy-ion studies, allows one to test perturbative QCD calculations. A brief review of ALICE results on the production of heavy-flavoured hadrons measured from fully reconstructed hadronic decay topologies in pp collisions at $\sqrt{s}$ = 7 TeV is presented. Furthermore, heavy-flavour production was also studied as a function of the particle multiplicity in pp collisions. This could provide insight into multi-parton scatterings. A measurement of the inclusive J/ψ yield as a function of the charged-particle pseudorapidity density was performed by the ALICE Collaboration at the LHC in pp collisions at $\sqrt{s}$ = 7 TeV. An increase of the J/ψ yield with increasing multiplicity was observed. In this context, the study of the yield of D mesons as a function of the charged-particle multiplicity could provide a deeper insight into charm-quark production in pp collisions. We will present the first results obtained for prompt D^0, D^+, and D^{*+} mesons using hadronic decay channels at midrapidity in pp collisions at $\sqrt{s}$=7 TeV as a function of the charged-particle multiplicity. The prompt D-meson yields as a function of multiplicity are measured in different p_T intervals. These yields will be compared to the results obtained for inclusive and non-prompt J/ψ.

1. Introduction

Heavy quarks are unique probes to study the Quark-Gluon Plasma produced in heavy ion collisions at the LHC. Due to their large masses, they are produced predominantly in hard parton scattering processes, during the initial stages of the collision. Therefore, they experience the entire evolution of the medium created in the collision and can act as probes of its properties. The measurement of heavy-quark production in pp collisions besides providing a necessary reference for the study of medium effects in Pb-Pb collisions, serves as a precision test for perturbative Quantum Chromodynamics (pQCD). In addition, the study of heavy-quark production as a function of charged particle multiplicity could provide insight into multiple hard parton scattering. This allows one to investigate the interplay between hard and soft QCD processes and to study the role of multi-parton interactions. It is interesting to remark that the highest multiplicities reached in pp collisions at 7 TeV are similar to those observed in Cu-Cu collisions at RHIC energies.

2. Open charm measurement with ALICE

ALICE (A Large Ion Collider Experiment) is the LHC experiment dedicated to heavy ion studies. ALICE [1] consists of two parts: a barrel at central rapidity and a muon spectrometer at forward rapidity. For the present analysis, we have used the information from a subset of the central barrel detectors, namely the Inner Tracking System (ITS), the Time Projection Chamber (TPC) and the Time Of Flight detector (TOF) for charged particle tracking and identification, the T0 for time zero measurement and the VZERO scintillator for triggering. The two tracking detectors, the ITS and the TPC, allow the reconstruction of charged-particle tracks in the pseudorapidity range -0.9 < η < 0.9 with a momentum resolution better than 2% for p_T < 20 GeV/c and they provide particle identification via a dE/dx measurement. The ITS, in particular, is a key detector for open heavy flavour studies because it allows us to measure the track impact parameter (i.e. the distance of closest approach of the track to the primary vertex) with a resolution better than 75 μm for p_T > 1 GeV/c thus providing the capability to detect secondary vertices originating from heavy-flavour hadron decays. The TOF detector provides particle identification by time of flight measurement.

The results presented here are obtained from pp data recorded in 2010 at $\sqrt{s}$= 7 TeV. The analyzed sample was collected with a minimum bias trigger condition requiring at least one hit in the Silicon Pixel Detector (SPD) (equipping the two innermost layers of the ITS), or a signal in at least one of the two VZERO detectors, which cover the pseudorapidity ranges $-3.7 < \eta < -1.7$ and $2.8 < \eta < 5.1$.

D^0, D^+, D^{*+} and D_s^+ mesons are reconstructed in the central rapidity region from their hadronic decay channels $D^0 \rightarrow K^-\pi^+, D^+ \rightarrow K^-\pi^+\pi^+, D^{*+} \rightarrow D^0\pi^+ \rightarrow K^-\pi^+\pi^+$ and $D_s^+ \rightarrow \phi\pi^+ \rightarrow K^+K^-\pi^+$ (and charge conjugates). The D-meson yield is measured with an invariant mass analysis of fully reconstructed decay topologies displaced from the interaction vertex selected by requiring a large decay length and a good alignment between the reconstructed D-meson momentum vector and flight line. The identification of charged kaons in the TPC and TOF detectors helps to further reduce the background at low p_T.

3. D-meson production cross section measurement
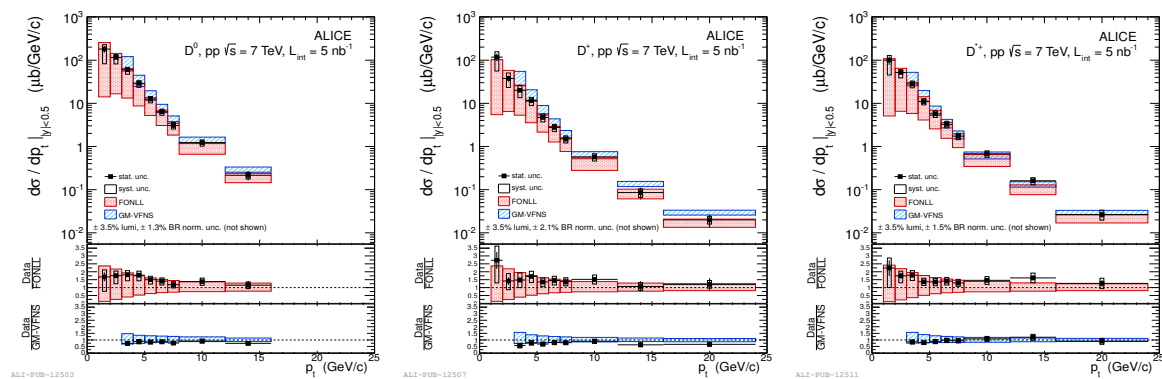
Figure 1. p_T differential cross section for D^0 (left panel), D^+ (middle panel) and D^{*+} (right panel) in pp collisions at $\sqrt{s}$=7 TeV, compared to FONLL [2] and GM-VFNS [3] theoretical predictions.

The differential cross section has been measured for prompt D^0, D^+, D^{*+} and D_s^+ mesons in pp collisions at $\sqrt{s} = 7$ TeV [4, 5]. To obtain the cross section for prompt D-mesons, the contribution due to beauty hadron decays, which is of about 10-15%, was evaluated based on Fixed Order with Next-to-Leading-Log resummation (FONLL) pQCD calculations [2] and subtracted from

the inclusive D-meson yield. The resulting cross sections are compared to FONLL and General Mass Variable Flavour Number Scheme (GM-VFNS) [3] pQCD calculations. Figure 1 shows the p_T-differential cross section for prompt D^0, D^+ and D^{*+} mesons at $\sqrt{s} = 7$ TeV. The data are well described by pQCD calculation: at the upper limit of the uncertainty band when compared to FONLL and at the lower limit when compared to GM-VFNS predictions. Recently, it was reported that data are also well described by the k_T factorization approach [6].

4. D-meson yields as a function of charged-particle multiplicity
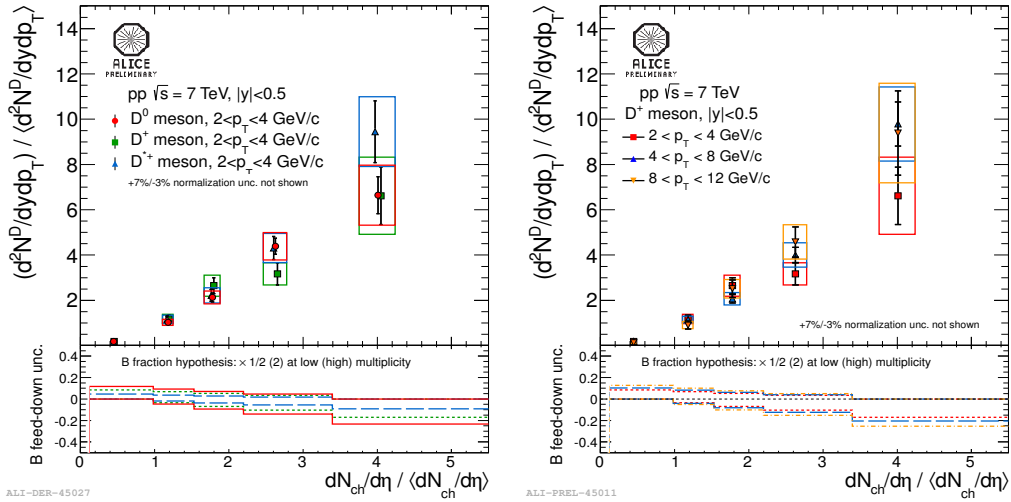
Figure 2. Left: Relative D^0, D^+ and D^{*+} yields in $2 < p_T < 4$ GeV/c as a function of the relative multiplicity of charged particles produced in pp collision at $\sqrt{s} = 7$ TeV. Right: Relative D^+ yields in three p_T intervals as a function of the relative multiplicity of charged particles produced in pp collision at $\sqrt{s} = 7$ TeV

The production of D mesons is also studied in several p_T intervals as a function of the multiplicity of charged particle generated in the collision. The multiplicity estimator used in this analysis is the number of SPD tracklets (combination of two hits in the two layers of SPD, N_{trk}) in $|\eta| < 1.0$. Since the pseudorapidity coverage of the SPD changes with the z position of the interaction vertex, a correction to the measured N_{trk} is applied event-by-event. Using simulated events, it is verified that N_{trk} is proportional to $dN_{ch}/d\eta$ (pseudorapidity density of primary charged particles produced in the collision). The D-meson yields are extracted in five intervals of multiplicity. The left panel of figure 2 shows the yield of D^0, D^+ and D^{*+} in a given multiplicity interval divided by the value integrated over multiplicity for $2 < p_T < 4$ GeV/c as a function of charged-particle multiplicity, expressed as the ratio between the $dN_{ch}/d\eta$ in the considered multiplicity interval and the $< dN_{ch}/d\eta >$ for pp collisions at 7 TeV. The horizontal size of the error boxes represents the systematic uncertainty in the $dN_{ch}/d\eta/ < dN_{ch}/d\eta >$. The vertical size of the error boxes reflects all uncertainties on the relative yield except for the feed down contribution. The latter uncertainty is shown in the lower panel of each figure. To account for a possible difference in the multiplicity distribution of events with $c\bar{c}$ and $b\bar{b}$ production, the systematic uncertainty was estimated by allowing the B/D ratio predicted by FONLL to vary by a factor 2 up(down) at high(low) multiplicity. The results for D^0, D^+ and D^{*+} are compatible within the statistical and systematic uncertainties and show an increase of the D-meson yields with the charged-particle multiplicity of the event. The same trends are observed in all the

measured p_T intervals as shown in the right panel of figure 2. Within the current uncertainties, no p_T dependence is observed.
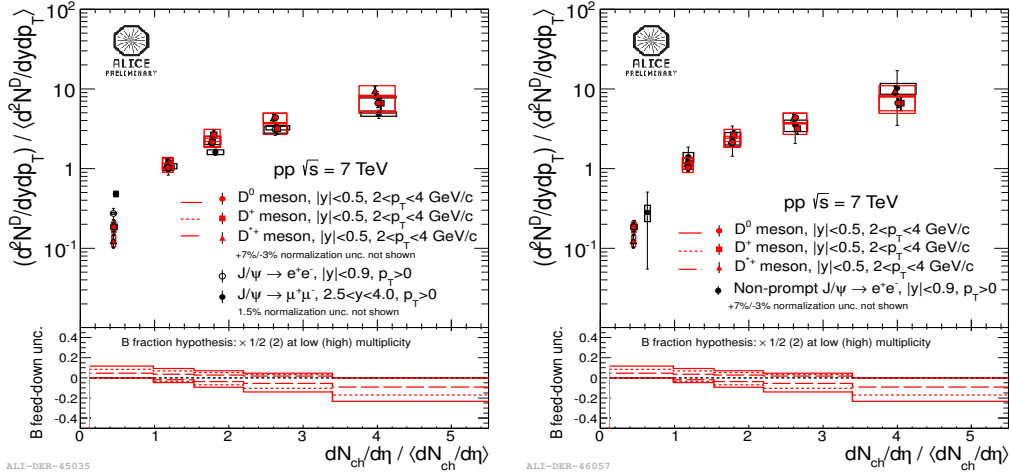
Figure 3. Left: Relative yield of D^0, D^+, D^{*+} for $2 < p_\mathrm{T} < 4$ GeV/c and J/ψ for $p_\mathrm{T} > 0$ as function of the event charged particle multiplicity. Right: Relative yield of D^0, D^+, D^{*+} for $2 < p_\mathrm{T} < 4$ GeV/c and non prompt J/ψ as function of the event charged particle multiplicity.

The left panel of figure 3 shows the comparison of D meson and inclusive J/ψ yields as a function of multiplicity [7]. The J/ψ mesons were measured in two rapidity intervals, namely $|y| < 0.9$ and $2.5 < y < 4.0$, whereas the D-meson rapidity and p_T intervals are $|y| < 0.5$ and $2 < p_\mathrm{T} < 4$ GeV/c respectively. Both open and hidden charm show similar behavior as a function of charged-particle multiplicity. Also the comparison with J/ψ from B-hadron decays in $|y| < 0.9$ (figure 3 right) shows a similar increase of yield.

5. Conclusions

ALICE detector provides excellent tracking, vertexing and particle identification to allow the measurement of charmed mesons via their hadronic decays, over a wide range of transverse momentum. The prompt D-meson production cross section is well described by NLO pQCD calculations. Furthermore, the D-meson yields was studied as a function of the charged particle multiplicity in pp collisions at $\sqrt{s}$=7 TeV. An increase of the D-meson yield as a function of multiplicity is observed. The comparison with the results for prompt and non-prompt J/ψ shows a similar increase as a function of charged-particle multiplicity. These results may indicate that either D-meson production in pp collisions is connected with a strong hadronic activity, or multi-parton interactions also affect the hard momentum scales relevant for charm quark production.

References
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