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 $J/\psi$ 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 $J/\psi$ 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 $J/\psi$.

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 \(-0.9 < \eta < 0.9\) 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 \(\mu\)m 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. 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

3. D-meson production cross section measurement

![Graphs showing differential cross section for D^0, D^+, and D^{*+} mesons in pp collisions at \(\sqrt{s}=7\) TeV, compared to FONLL and GM-VFNS theoretical predictions.]

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 \(D^{*+}\) 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](https://example.com/fig2.png)

**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, $N_{\text{trk}}$) 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 $N_{\text{trk}}$ is applied event-by-event. Using simulated events, it is verified that $N_{\text{trk}}$ is proportional to $dN_{\text{ch}}/d\eta$ (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 $dN_{\text{ch}}/d\eta$ in the considered multiplicity interval and the $<dN_{\text{ch}}/d\eta>$ for pp collisions at 7 TeV. The horizontal size of the error boxes represents the systematic uncertainty in the $dN_{\text{ch}}/d\eta$/$<dN_{\text{ch}}/d\eta>$. 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](image-url)

**Figure 3.** Left: Relative yield of $D^0$, $D^+$, $D^{+*}$ for $2 < p_T < 4$ GeV/c and $J/\psi$ for $p_T > 0$ as a function of the event charged particle multiplicity. Right: Relative yield of $D^0$, $D^+$, $D^{+*}$ for $2 < p_T < 4$ GeV/c and non prompt $J/\psi$ as function of the event charged particle multiplicity.

The left panel of figure 3 shows the comparison of D meson and inclusive $J/\psi$ yields as a function of multiplicity [7]. The $J/\psi$ 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 $2 < p_T < 4$ GeV/c respectively. Both open and hidden charm show similar behavior as a function of charged-particle multiplicity. Also the comparison with $J/\psi$ 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 $J/\psi$ 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 multiparton interactions also affect the hard momentum scales relevant for charm quark production.

References

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