D mesons suppression in Pb–Pb collisions at $\sqrt{s_{\text{NN}}} = 2.76$ TeV measured by ALICE

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**Abstract**

The measurement of the prompt charm mesons $D^0$, $D^+$, $D^{*+}$, and their antiparticles, in Pb–Pb collisions at the LHC, at a centre-of-mass energy $\sqrt{s_{\text{NN}}} = 2.76$ TeV, with the ALICE detector, using 2010 data, is presented. The $R_{\text{AA}}$ of the three meson species show a suppression of a factor 3–4, for transverse momenta larger than 5 GeV/$c$, in the 20% most central collisions. The suppression is reduced for peripheral collisions. The results are compared with those of charged particles, charged pions, and non-prompt $J/\psi$, and also with theoretical calculations.

**Keywords:** Heavy flavor, Charm, Heavy-Ion, QGP, LHC

1. Introduction

Charm and beauty production in proton-proton collisions at the LHC is an important tool to test pQCD calculations in a new energy domain. Their spectra in heavy-ion interactions are influenced by the formation of hot and dense QCD matter. Due to their relative large mass and the difference between quark and gluon color charge, the medium effects for heavy flavor hadrons differ from those of light hadrons. RHIC results show that they effectively lose energy in the medium through (elastic and/or inelastic) interactions, but a possible quark-mass hierarchy has not yet been elucidated. LHC measurements at higher energies, with larger cross sections and better capabilities to separate charm and beauty production, can help to answer these questions.

Open heavy flavor production can be measured with the ALICE experiment at the LHC in different colliding systems. The $D$ meson reconstruction and analysis strategy using 2010 Pb–Pb data at $\sqrt{s_{\text{NN}}} = 2.76$ TeV [1–3] is summarized here. The results are compared with those of charged particles [8], charged pions, and non-prompt $J/\psi$ [9], and also with theoretical calculations [11–19].

2. Measurements in Pb–Pb collisions at $\sqrt{s_{\text{NN}}} = 2.76$ TeV with 2010 data

In heavy-ion collisions, the influence of the hot and dense QCD matter on the produced particles is commonly evaluated by comparing particle production in proton–proton (pp) and nucleus–nucleus (AA) collisions. It is usually presented in the form of the nuclear modification factor ($R_{\text{AA}}$):

$$R_{\text{AA}}(p_T) = \frac{1}{\left( \frac{dN_{\text{AA}}}{dp_T} \right)} \frac{dN_{\text{PP}}}{d\ln p_T},$$

(1)
the ratio between the invariant yield in AA collisions \(dN_{AA}/dp_T\), and the pp cross section \(d\sigma_{pp}/dp_T\) normalized by the average nuclear overlap function \(T_{AA}(L_{int})\).

The data sample, analyzed at \(5\text{ nb}^{-1}\), consisted of minimum bias \(\text{Pb}+\text{Pb} \) collisions at \(\sqrt{s_{NN}} = 2.76\text{ TeV}\). The selection of D mesons and their antiparticles was reconstructed in the central rapidity region in their hadronic decay channels: \(D^0 \rightarrow K^−π^+, D^+ \rightarrow K^−π^+π^+, D^{*+} \rightarrow D^0π^+\). Only good quality tracks, with \(|η| < 0.8\), at least 70 associated space points in the Time Projection Chamber (TPC), with \(χ^2/ndf<2\), and at least 2 (out of 6) associated hits in the Inner Tracking System (ITS), were selected to build the combinatorics. The selection of D mesons from B decays was validated by comparing the scaled results to the measurements at 2 TeV, and at least 2 out of 6 associated hits in the ITS were used as proton-proton reference. The scaling factor was evaluated as the ratio of the FONLL calculations at 7 TeV to the 2 TeV data sample, the 7 TeV cross sections scaled down to 2 TeV was allowed to vary to evaluate the measurement systematics. More details on the analysis and the systematic uncertainties determination can be found in ref. 1.

D\(^0\), D\(^+\) and D\(^{*-}\) mesons cross sections in pp collisions at \(\sqrt{s} = 7\text{ TeV}\) and 2.76 TeV were reported in ref. 2, 3. Due to the limited statistics of the \(\sqrt{s} = 2.76\text{ TeV}\) data sample, the 7 TeV cross sections scaled down to 2.76 TeV were used as proton-proton reference. The scaling factor was evaluated as the ratio of the FONLL calculations at 2.76 TeV to the 7 TeV data to Tevatron energies and comparing to CDF data 6. The scaling was also verified by using GM-VFNS calculations 7.

3. Results

The transverse momentum distributions \(dN/dp_T\) and \(R_{AA}(p_T)\) of prompt D\(^0\), D\(^+\) and D\(^{*-}\) mesons in the 0–20% and 40–80% centrality classes were first presented in ref. 1. Figure 1 shows \(R_{AA}(p_T)\) of prompt D mesons. The results of the three D meson species are in agreement within statistical uncertainties and show a suppression by a factor of 3–4 for \(p_T > 5\text{ GeV}/c\) in the 0–20% centrality class. The centrality dependence studied in more detail in wider \(p_T\) bins and thinner centrality bins and reported in ref. 1. A tendency to have a larger suppression in the most central collisions is observed, see also Fig. 2(right).

The average D meson \(R_{AA}(p_T)\) was computed from the weighted average \(1\) of D\(^0\), D\(^+\) and D\(^{*-}\) mesons in the 0–20% and 40–80% centrality classes. The centrality dependence studied in more detail in wider \(p_T\) bins and thinner centrality bins and reported in ref. 1. A tendency to have a larger suppression in the most central collisions is observed, see also Fig. 2(right).

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1 The nuclear overlap function, \(T_{AA}\), is defined as the convolution of the colliding ions nuclear density profiles, and it is evaluated in the Glauber model. The estimates of \(T_{AA}\) in the Glauber model are in agreement with those computed in a Glauber Monte Carlo of the VZERO scintillators response, located at \(2.8 < \eta < 5.1\) and \(-3.7 < \eta < -1.7\).
2 In the D\(^{*-}\) case, for the 0–20% centrality class, a \(±2\sigma\) cut was applied to the D\(^0\) decay products.
3 Statistical uncertainties were used as weights to evaluate the average D meson \(R_{AA}(p_T)\).
Figure 1. $R_{AA}$ for prompt $D^0$, $D^+$ and $D^{*+}$ in the 0–20% (left) and 40–80% (right) centrality classes [1]. Statistical (bars), systematic (empty boxes), and normalization (full box) uncertainties are shown. Horizontal error bars reflect bin widths, symbols were placed at the centre of the bin.

Figure 2. Left: Average D meson ($D^0$, $D^+$ and $D^{*+}$) $R_{AA}$ in the 0–20% centrality class vs. $p_T$ compared with charged particles and non-prompt $J/\psi$ [1]. Right: Average D meson $R_{AA}$ vs. centrality, represented by the average number of participant nucleons, $\langle N_{\text{part}} \rangle$, compared with charged particles and CMS non-prompt $J/\psi$. 
$R_{AA}$ vs. centrality, represented by the average number of participant nucleons $\langle N_{\text{part}} \rangle$, for $p_T > 6$ GeV/c. However the comparison of non-prompt $J/\psi$ and the average D meson $R_{AA}$ is not yet conclusive and requires more precise and differential measurements.

The results in the 0–20% centrality class are compared in Fig. 3 (left) to the NLO (MNR) calculations \cite{10} with EPS09 \cite{11} shadowing. The magnitude of D meson suppression at $p_T > 5$ GeV/c in the most central class can therefore not be explained by initial-state effects. Figure 3 (right) presents the ratio of the average D mesons and charged pions $R_{AA}(p_T)$ in 0–20% centrality class. This ratio shows no clear $p_T$ dependence and is of about 1.5. Several theoretical models based on parton energy loss compute the charm nuclear modification factor \cite{12–19}. Those having results for both D mesons and charged pions are shown in Fig. 3 (right) \cite{12–15, 19}. All of them describe reasonably well this ratio and the D mesons and charged pions $R_{AA}(p_T)$. However, it can be noted that a model based on the AdS/CFT correspondence seems to underestimate charm $R_{AA}$ and has limited predictive power for light hadron $R_{AA}$.

Figure 3. Left: Average D meson ($D^0$, $D^+$ and $D^{++}$) $R_{AA}$ in the 0–20% centrality class vs. $p_T$ compared with NLO (MNR) calculations \cite{10} with EPS09 \cite{11} shadowing \cite{1}. Right: Ratio of the average D meson and charged pion $R_{AA}$ vs $p_T$ compared with theoretical calculations \cite{12–15, 19}.

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