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D meson production in heavy ion collisions with CMS

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Abstract. The nuclear modification factor, $R_{\rm AA}$, of the D^0 meson production has been measured in pp and PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV and 5.02 TeV with CMS detector. This measurement is important in investigating the properties of the high-density QCD (quantum chromodynamics) matter. The dependence on the centrality and transverse momentum up to 100 GeV were presented in a poster at this conference.

1 Introduction

The production of heavy quarks is an attractive probe of understanding the mechanism of heavy quark interaction with the medium created in heavy ion collisions. Usually the heavy quarks (charm and beauty) are produced mainly in the initial stage of heavy ion collisions, before the formation of the hot and dense QCD matter. When they propagate through the matter, their properties are modified, therefore, the measurement of heavy-flavor mesons (a quark antiquark light-heavy quarks) probes the medium-induced energy loss of partons created in heavy ion collisions. Theoretical models expect a flavor dependent energy loss in heavy ion collisions, which is limited by dead cone effect (suppression of gluon radiation from massive partons at small angles [1]) for heavier beauty and charm quarks, compared to gluons and up, down or strange quarks.

At the LHC (Large Hadron Collider) energies, the charm cross-section, and hence that of charm mesons, like D meson, is high. The CMS (Compact Muon Solenoid) Collaboration measured the production of the prompt D^0 mesons in PbPb collisions at $\sqrt{s_{NN}} = 2.76$ TeV [2] with Run 1 data (using an extrapolated pp reference), and at $\sqrt{s_{NN}} = 5.02$ TeV [3] with both pp and PbPb data recorded in the LHC Run 2. In this presentation, there were presented the analysis procedure and the results of the nuclear modification factor $R_{\rm AA}$ (the ratio of the corrected yield of D meson in PbPb and pp collisions) at the two collision energy.

2 Experimental environment and analysis procedure

The D^0 meson and its charge conjugate are reconstructed in the mid-rapidity region ($|y| < 1$) of the CMS detector via the hadronic decay channel $D^0 \rightarrow K\pi$. A detailed description of the CMS detector can be found in Ref. [4]. Out of whole CMS detector system, the inner silicon tracker is the main detector used for this analysis. The silicon tracker, located in the 3.8 T magnetic field generated by the superconducting solenoid, has an excellent track impact parameter resolution: 200 μm at 1 GeV/c, and 10 μm at 20 GeV/c.

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These studies are performed using 2011 PbPb data collected at $\sqrt{s_{NN}} = 2.76$ TeV, and 2015 pp and PbPb at $\sqrt{s_{NN}} = 5.02$ TeV. The 2011 and 2015 PbPb samples correspond to an integrated luminosity of 166 μb^{-1} and 404 μb^{-1}, respectively, while the 2015 pp sample corresponds to an integrated luminosity of 25.8 pb^{-1}. Both 2011 and 2015 data analyses use large minimum bias sample to measure D^0 candidates in the p_T ranges of $2.5 - 40$ GeV/c (2011) and $2 - 16$ GeV/c (2015). In order to enhance the amount of data at high p_T, dedicated high-level trigger (HLT) were used for both the 2015 pp and PbPb data taking in the higher p_T region ($p_T > 16$ GeV/c).

D^0 candidates are reconstructed by combining pairs of oppositely charged tracks and requiring an invariant mass within 0.2 GeV/c^2 of the nominal D^0 mass provided by the particle data group [5]. Kaon and pion candidates from D^0 are reconstructed from the inner trackers in the mid-rapidity region ($|\eta| < 1$) and p_T larger than 1 GeV/c by assuming one of the particles has the mass of the pion while the other has the mass of kaon, and vice-versa. In order to reduce background and enhance signal, several topological cuts are applied such as two-dimensional decay length normalized by its uncertainty, pointing angle which is the angle between total momentum of D^0 meson and the vector from primary vertex to secondary vertex in transverse plane and chi-square fit probability of D^0 vertex.

For the reference, pp data and FONLL expectation [6] are used. For the 2.76 TeV analysis, the ALICE measurement in pp collisions at 7 TeV is used, rescaled to 2.76 TeV using FONLL calculations in the lower p_T range ($p_T < 16$ GeV/c), while in the high p_T range ($p_T > 16$ GeV/c) FONLL calculation itself is used. In the 5.02 TeV analysis, 25.8 pb^{-1} pp collision events were collected by CMS, and the cross-section of prompt D^0 meson is calculated with the same procedure as for the PbPb analysis. The results from pp data is confirmed by FONLL expectation at the same energy scale.

3 Results

Figure 1 shows two example of invariant mass distributions for prompt D^0 meson candidates in PbPb collisions at 2.76 TeV (left) and 5.02 TeV (right). The signal shape is modeled by two Gaussian functions with same mean but different widths. The combinatorial background from random combination of pairs of tracks not produced from a D^0 meson decay is modeled by an exponential function in the 2.76 TeV analysis, and by a third order polynomial function for the 5.02 TeV data analysis. In addition, the background from mis-identified D^0 by swapped kaon-pion mass is shaped by a single Gaussian function.

The measured R_{AA}, defined in Eq. 1, and theoretical calculations for two centrality categories, 0 - 10% and 0 - 100%, are compared in Fig. 2. R_{AA} is decreasing up to p_T of 10 GeV/c, and increasing up to 100 GeV/c. The results are compared to various theoretical models in Fig. 2 [9–17].

$$R_{AA}(p_T) = \frac{1}{T_{AA}} \frac{dN^{D^0}_{PbPb}}{dp_T} / \frac{d\sigma^{D^0}_{pp}}{dp_T}. \quad (1)$$

where T_{AA} is the nuclear overlap function ($T_{AA} = 5.58$ mb^{-1} for inclusive PbPb collisions and $T_{AA} = 23.2$ mb^{-1} for events in the centrality interval 0 - 10%) [7]. Results have similar p_T dependence for both 2.76 and 5.02 TeV. Also no significant centrality difference in the shape is observed. Lastly, Fig. 3 shows a comparison of R_{AA} for prompt D^0 meson, charged hadrons and non-prompt J/ψ at $\sqrt{s_{NN}} = 2.76$ TeV. The open charm is more suppressed than the open beauty in the most central events.

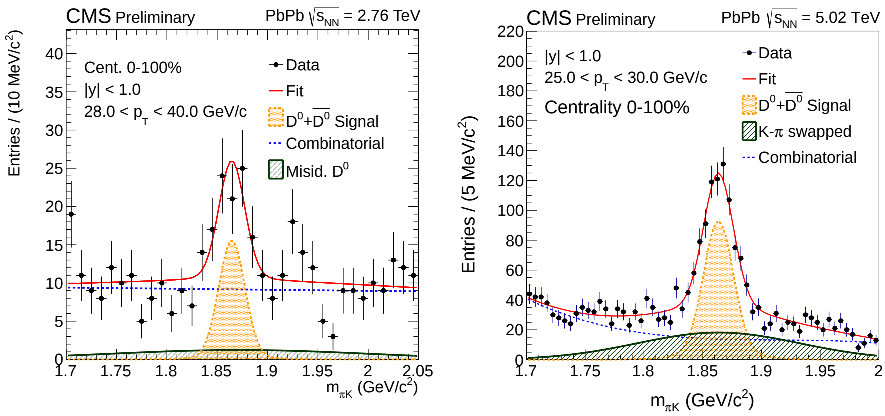

Figure 1. Invariant mass distributions of prompt D^0 meson candidates in an arbitrary p_T region in PbPb collisions at 2.76 TeV (left) [2] and 5.02 TeV (right) [3]. The orange areas represent the fitted prompt D^0 meson signal distributions, and the green-hatched areas show the background from kaon-pion mass swapping. The blue-dotted lines represent the combinatorial backgrounds.

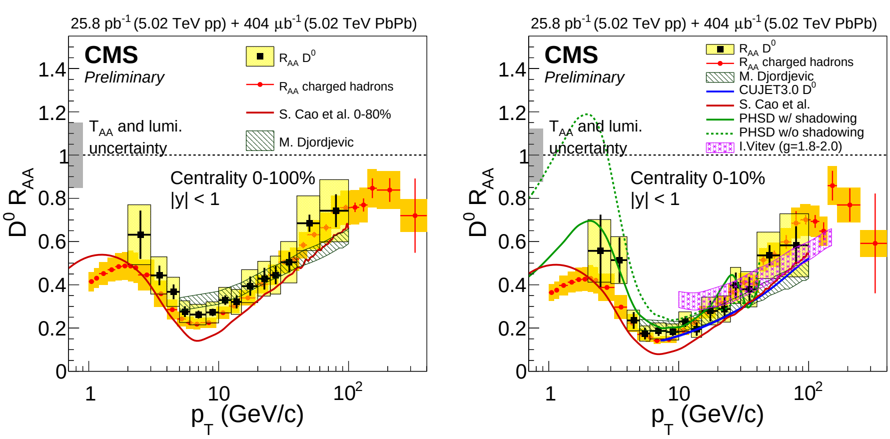

Figure 2. The R_{AA} of prompt D^0 meson as function of transverse momentum, for centrality inclusive range $(0 - 100\%)$ (left) and most central range $(0 - 10\%)$ (right), at 5.02 TeV [3]. The R_{AA} of inclusive charged particles are superimposed for equivalent event selections [8]. Experimental results are compared to various theoretical calculations [9–17].

4 Summary

The measurements of prompt D^0 meson production in 2.76 TeV and 5.02 TeV PbPb collisions from the CMS Collaboration were presented. Similar suppression trends between prompt D^0 meson and charged hadrons are observed in the kinematic regions analyzed.

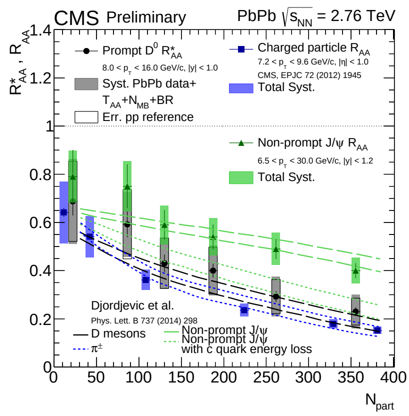

Figure 3. The $R_{\rm AA}$ of prompt D^0 meson (black circles) [2] compared to those of charged particle (blue squares) [18], and non-prompt J/ψ (green triangles) [19] from b quark, at 2.76 TeV, as function of number of participants. The systematic errors of prompt D^0 meson, charged particle and non-prompt J/ψ R_{AA} are drawn as gray, blue and green boxes respectively.

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