D^0 Meson Production in Heavy Ion Collisions in CMS experiment

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Abstract. The measurement of heavy flavour production is a powerful tool to study the properties of the high-density QCD medium created in heavy-ion collisions as heavy quarks are sensitive to the transport properties of the medium and may interact with the QCD matter differently from light quarks. In particular, the comparison between the nuclear modification factors of light and heavy flavoured particles provides insights into the expected flavour dependence of in-medium parton energy loss. With the CMS detector, the D^0 meson production is studied in pp and PbPb collisions at 2.76 and 5.02 TeV. In this talk, the nuclear modification factor of D^0 meson are presented and compared to the charged hadron nuclear modification factor and theoretical calculations.

1. Introduction

Heavy quarks are considered to be produced mainly via initial hard scatterings in heavy ion collisions. Therefore, they propagate through the medium and carry information about the system at early stage. That makes heavy flavor hadrons good probes of the properties of QCD matter and important tools to study the mechanism of interaction with the matter. The interactions with the medium, the energy loss of a parton, happens via elastic and inelastic collisions, and via gluon brhemstrahlung. At small angles, the radiative energy loss is thought to be suppressed, the manifestation of the 'dead cone effect' [1]. If only this effect would be dominant, the nuclear modification factor of heavy flavor hadrons should be larger (less suppression) than that of light hadrons. This effect is also expected to have a strong p_T dependence, with the highest contribution at low transverse momentum of the heavy meson.

The measurements of the D^0 meson production were conducted by the Compact Muon Solenoid (CMS) [2] detector in PbPb collisions at 2.76 TeV [3] and 5.02 TeV [4]. The talk presented the analysis technique for extracting the D^0 signal, and the D^0 nuclear modification factor

$$R_{AA} = \frac{1}{T_{AA}} \frac{dN^{AA}/dp_T}{d\sigma^{pp}/dp_T}$$ (1)

results.

2. Analysis technique

Prompt D^0 production in PbPb collisions at 2.76 TeV was studied with CMS detector during LHC Run I in 2011, and that in both pp and PbPb collisions at 5.02 TeV was studied during Run II in 2015. The decay channel $D^0 \rightarrow K\pi$ is analyzed in the rapidity range $|y| < 1$. A

detailed description of the CMS experiment can be found in Ref. [2]. Specifically, the silicon tracker, located in the 3.8 T magnetic field of the superconducting solenoid, is used to measure charged particles within the pseudorapidity range $|\eta| < 2.5$.

For 2.76 TeV, events selected online by a minimum bias trigger are used for the analysis. For 5.02 TeV, minimum bias events (about 2 billion events for pp and 150 million events for PbPb) are used for the results at low p_T (< 20 GeV/c), while events selected by a dedicated D^0 High-Level-Trigger (HLT) are used for the result at $p_T > 20$ GeV/c. The D^0 HLT path starts from events tagged by energy deposited in the calorimeters. A full track reconstruction is performed for these events, and pairs of tracks with $p_T > 2$ GeV/c (pp) or 8 GeV/c (PbPb) are analyzed. An event is selected if the pair passed a loose selection on their common vertex displacement. This D^0 trigger worked well and allows reaching very high p_T D^0.

Offline, D^0 candidates are reconstructed by combining pairs of oppositely charged particles and requiring an invariant mass within 0.2 GeV/c^2 of the nominal D^0 mass, as given by the particle data group (PDG) [5]. Topological selections based on pointing angle, 3D decay length normalized by its error and D^0 vertex probability are applied to reduce combinatorial background. The pointing angle is defined as the angle between D^0 momentum and the vector from primary vertex and secondary vertex in transverse plain.

Figure 1 shows the invariant mass distribution for selected D candidates, for $5 < p_T < 6$ GeV/c, for pp and PbPb collisions at 5.02 TeV. The signal shape is modeled by two Gaussians with same mean but different widths. The combinatorial background, generated by randomly combining pairs of tracks not originating from a D^0 meson decay, is modeled by a third order polynomial. With the choice of not using particle identification, one track is assigned the mass of a K, and the other the mass of a π. An additional Gaussian function is used to describe the invariant mass shape of D^0 candidates with incorrect mass assignment from the exchange of K and π designation.
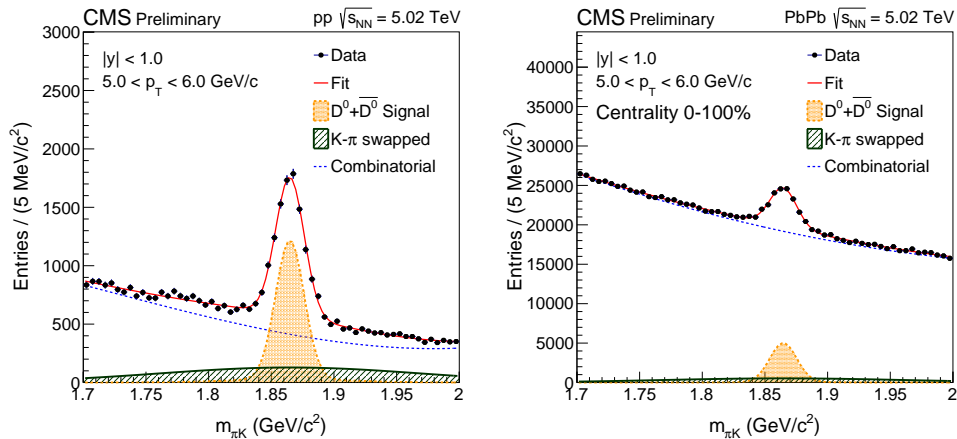

Figure 1. Invariant mass distributions of D^0 candidates and their charge conjugates for selected p_T intervals of pp (left) and PbPb (right) at 5.02 TeV in centrality 0-100%

The raw yields are then corrected for detector acceptance and reconstruction efficiency effects, calculated using PYTHIA, and PYTHIA events embedded in HYDJET PbPb events. In addition, the fraction of D^0 comming from c-quark fragmentation, are determined by fitting data distribution of the distance of closest approach (DCA) of D^0, with a prompt and nonprompt shape from Monte Carlo.

Systematic uncertainties from various sources are taken into account. Systematic uncertainty from signal extraction is estimated by varying signal and background fitting function. Systematic uncertainty from D^0 meson selection is obtained by comparing data and MC driven efficiencies varying cut values. Tracking efficiency systematic uncertainty is estimated by 2- and 4- prongs decays of D^0. Systematic uncertainty from prompt fractions is obtained by comparing the results of default method and an alternative method based on FONLL predictions.

3. Results

Figure 2 shows the prompt D^0 R_{AA} in PbPb collisions at 2.76 TeV as a function of p_T for centrality 0-20% and the comparison with the result of ALICE [6]. The pp reference used for this result was built using both FONLL [7] and data extrapolation: in the range $p_T < 16$ GeV/c range, the ALICE collaboration measurement of prompt D^0 cross-section at 7 TeV [8] was rescaled to 2.76 TeV using FONLL input, following the same procedure used in Ref. [9].
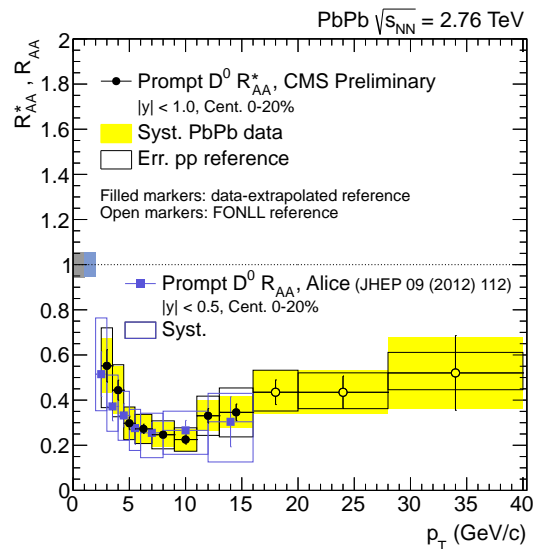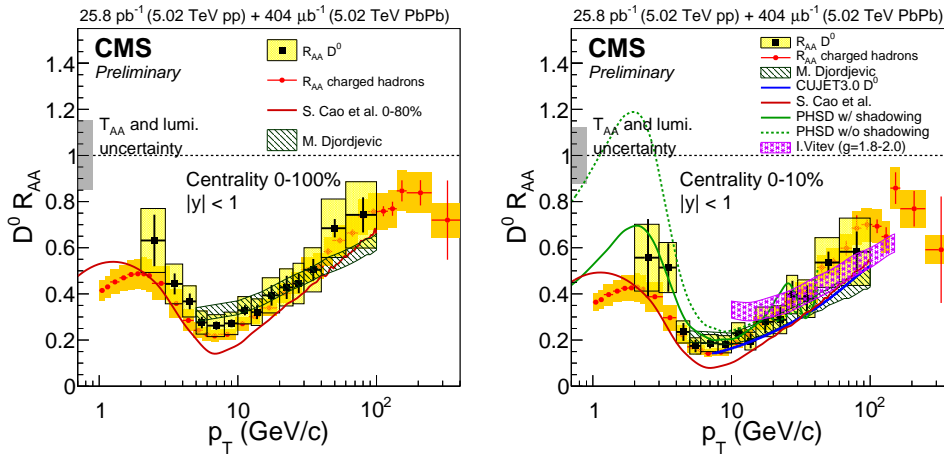

Figure 2. Prompt D^0 R_{AA} as a function of p_T for centrality 0-20% in PbPb collisions at 2.76 TeV by CMS collaboration. The results from ALICE collaboration are also shown for comparison [6]

Prompt D^0 R_{AA} as a function of p_T in PbPb collisions at 5.02 TeV for centrality classes 0-100% (left) and 0-10% (right) are shown in Figure 3. The measurements are compared with predictions from some theoretical calculations [10, 11, 12, 13, 14, 15, 16, 17, 18], and most of them describe data well. Comparison with charge particles R_{AA} in PbPb collisions at 5.02 TeV in the same centrality classes [19] is also shown in Figure 3.

4. Summary

The measurements of prompt D^0 nuclear modification factors in 5.02 TeV PbPb collisions from CMS collaboration are presented. D^0 production presents strong suppression. No significant difference of R_{AA} is observed between D^0 and charged hadrons, in the kinematic region studied. These results put strong constraints on theoretical calculations in a wide kinematic range. With LHC Run II data, there are various exciting studies concerning heavy flavors. For c quark related studies, there is an effort to reach prompt D^0 R_{AA} at very low p_T, and D^0 v_n measurements are

Figure 3. Prompt D^0 R_{AA} as function of p_T in PbPb collisions at 5.02 TeV for centrality classes 0-100% (left) and 0-10% (right)

also conducted. Also, the results of measurements of B mesons nuclear modification factor are expected to come soon.

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