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Suppression of open bottom at high p_T via non-prompt J/ψ decays in PbPb collisions at 2.76 TeV with CMS

Mihee Jo for the CMS Collaboration

Abstract

Measurements of the nuclear modification factor of mesons with open heavy flavor content in PbPb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV from the CMS experiment will be presented. These modification factors provide stringent constraints on the theoretical models of heavy quark energy loss. Until recently only indirect measurements of this effect existed, through single electrons from semileptonic open heavy-flavor decays. The importance of an unambiguous measurement of open bottom flavor is driven by the lack of knowledge regarding key features of the dynamics of parton energy loss in the QGP, such as its color-charge and parton-mass dependencies and the relative role of radiative and collisional energy loss. CMS is the first, and so far only, experiment to measure the nuclear modification factor of b hadrons, identified via their decays into J/ψ displaced from the primary collision vertex. First results have shown that b hadrons are strongly suppressed in PbPb collisions at a level comparable to open charm. New results on the centrality dependence of non-prompt J/ψ R_{AA} will be presented, based on the full 2011 PbPb data sample corresponding to an integrated luminosity of $150\mu\mathrm{b}^{-1}$.

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Measurements of the nuclear modification factor of mesons with open heavy flavor content in PbPb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV from the CMS experiment will be presented. These modification factors provide stringent constraints on the theoretical models of heavy quark energy loss. Until recently only indirect measurements of this effect existed, through single electrons from semileptonic open heavy-flavor decays. The importance of an unambiguous measurement of open bottom flavor is driven by the lack of knowledge regarding key features of the dynamics of parton energy loss in the QGP, such as its color-charge and parton-mass dependencies and the relative role of radiative and collisional energy loss. CMS is the first, and so far only, experiment to measure the nuclear modification factor of b hadrons, identified via their decays into J/ψ displaced from the primary collision vertex. First results have shown that b hadrons are strongly suppressed in PbPb collisions at a level comparable to open charm. New results on the centrality dependence of non-prompt J/ψ R_{AA} will be presented, based on the full 2011 PbPb data sample corresponding to an integrated luminosity of 150μb^{-1}.

1. Introduction

At high temperatures and large energy densities provided by in collisions of heavy nuclei at ultra-relativistic energies, a formation of the quark-gluon-plasma (QGP) that consists of deconfined quarks and gluons is expected. Partons, produced in the initial hard scattering process, are subject to energy loss while propagating through the medium.The measurement of energy loss, and in particular its dependence on color charge and parton mass, is expected to shed light on basic thermodynamical and transport properties of the medium.

Due to their large mass, the radiative energy loss of b quarks by gluon emission is expected to be reduced at small angles [1]. Therefore, the suppression of heavy quarks is expected to be smaller than that of light quarks and gluons. Non-prompt J/ψ from b-hadron decays as well as b jets provide clean probes to study the in-medium energy loss of b quarks. Based on these phenomena, b-hadron measurements could provide more information of energy loss in the medium.

In these proceedings, the nuclear modification factors (R_{AA}) of non-prompt J/ψ from b-hadron decays [2] and b jets [3] are presented as measured in PbPb collisions with the CMS detector [4].

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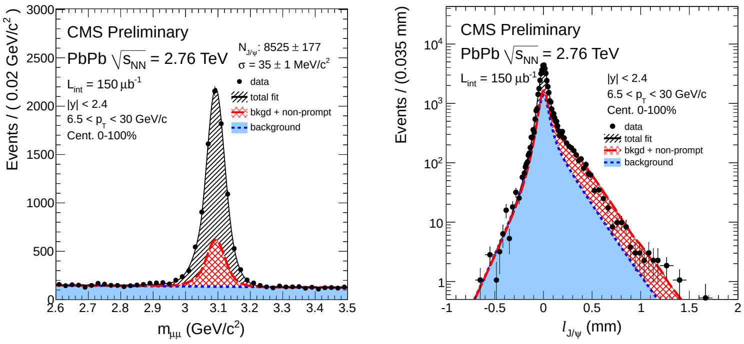

Figure 1: Invariant mass *(left)* and pseudo-proper decay length *(right)* distributions of $\mu^+\mu^-$ pairs integrated over rapidity $|y| < 2.4$, $6.5 < p_T < 30$ GeV/c and centrality 0-100% are presented. Prompt J/ψ *(black solid line)*, non-prompt J/ψ *(red dashed line)* and backgrounds *(dotted blue line)* represent projected components on the 1-dimensional distributions.

2. Non-prompt J/ψ measurement

Non-prompt J/ψ from b-hadron decays can be identified via the measurement of their secondary $\mu^+\mu^-$ vertex, which is displaced from the primary collision vertex [5].

The fraction of non-prompt J/ψ is obtained from the 2-dimensional extended unbinned maximum likelihood fit, which follows the b-fraction extraction method on pp $\sqrt{s} = 7$ TeV [6]. Compared to the previous analysis of the 2010 data sample [5], the twenty times larger PbPb data sample, collected in 2011, allows for a more detailed description both on the invariant mass and pseudo-proper decay length spectra. The invariant mass spectrum is fitted with sum of a Crystal Ball and a Gaussian function, with a common mean but different widths, for the signal and an exponential for the background. The pseudo-proper decay length has a resolution function that is described by Gaussian functions considering an event-by-event uncertainty. Pseudo-proper decay length shapes of prompt and non-prompt J/ψ are based on MC templates and the background shape is obtained from the events in the sidebands of the invariant mass spectrum. The method of the b-fraction extraction is illustrated in Fig. 1.

Reconstruction and trigger efficiencies of $\mu^+\mu^-$ pairs are derived from MC simulations and validated using a data-driven method, tag-and-probe [5]. Differences between data and MC simulations are either corrected for, in case of the trigger efficiency, or enter as systematic uncertainty, in case of the reconstruction efficiency. Systematic uncertainties on the prompt and non-prompt J/ψ R_{AA} in efficiencies are $1-10\%$. For the signal extraction, various signal and background shapes on invariant mass and pseudo-proper decay length spectra have been tested to take any variations into account for the systematic uncertainties. The uncertainties from the signal extraction are $0.2-1.7\%$ and $0.6-8.4\%$ for prompt and non-prompt J/ψ, respectively.

The amount of suppression in PbPb collisions compared to pp collisions is expressed as:

$$R_{AA} = \frac{\mathcal{L}_{pp}}{T_{AA} N_{\mathrm{MB}}} \frac{N_{\mathrm{PbPb}}}{N_{pp}} \cdot \frac{\varepsilon_{pp}}{\varepsilon_{\mathrm{PbPb}}} \tag{1}$$

In Eq. (1), N_{PbPb}, N_{pp} are the raw number of non-prompt J/ψ decayed in the $\mu^+\mu^-$ channel measured in PbPb and pp, respectively. N_{MB} is the number of minimum-bias events in PbPb

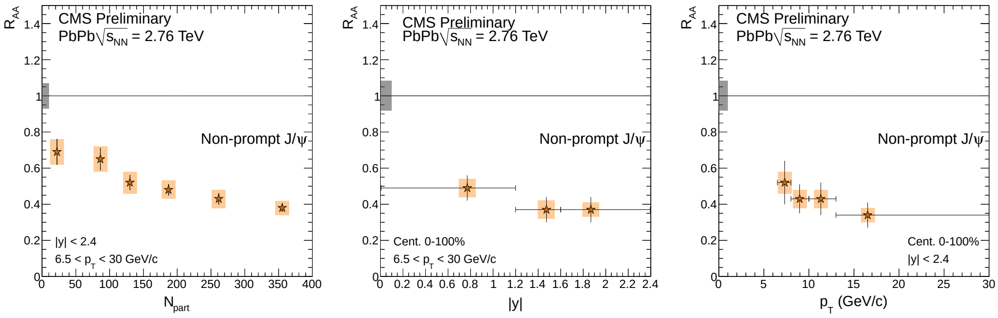

Figure 2: Non-prompt J/ψ R_{AA} as a function of centrality *(left)*, rapidity *(center)* and p_T *(right)* is shown. A global pp integrated luminosity uncertainty is presented with a gray box. Statistical (systematic) errors are drawn with lines (boxes).

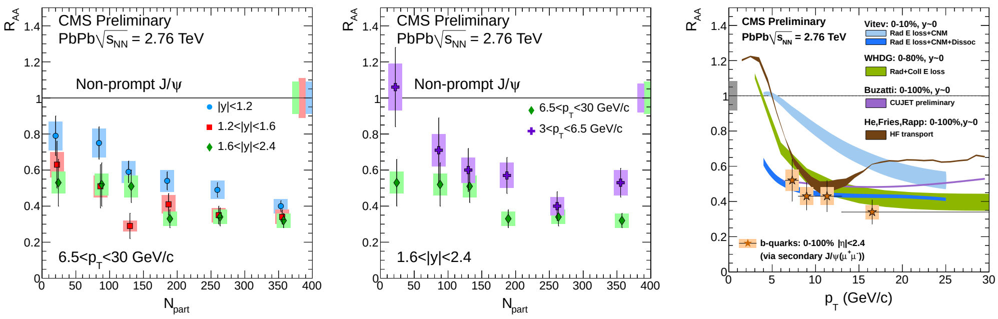

Figure 3: Non-prompt J/ψ R_{AA} in bins of rapidity and centrality *(left)* and p_T and centrality in the forward region *(center)*. Theory curves are compared to the measurement with respect to the b-hadron and J/ψ p_T *(right)*.

sampled by the event selection, ε is the combined efficiency, T_{AA} is the nuclear overlap function. $\mathcal{L}_{pp}$ is the integrated luminosity of the pp collisions and is $(231 \pm 14)\text{nb}^{-1}$.

A novel detailed R_{AA} measurement of non-prompt J/ψ with respect to centrality, p_T and rapidity is presented in Fig. 2 and 3. An increase of the suppression is observed as a function of centrality. At higher p_T and more forward rapidity, a slight hint of increasing suppression is observed. A double differential R_{AA} in rapidity and centrality presents a slightly smaller suppression in the mid-rapidity and peripheral bins. At forward rapidities, a measurement at lower p_T down to 3 GeV/c is possible. In comparison to the higher p_T bin ($6.5 < p_T < 30$ GeV/c), the lower p_T non-prompt J/ψ appear to be slightly less suppressed. In the right panel of Fig. 3, several theoretical calculations of b-quark energy loss as a function of the b-hadron p_T are compared to the measured R_{AA} as a function of the non-prompt J/ψ p_T. Note that the typical b-hadron p_T is on average 3 GeV/c higher than the J/ψ p_T in the measured range, which complicates a quantitative comparison. However, the model involving only radiative energy loss and cold nuclear matter effects clearly fails to describe the data.

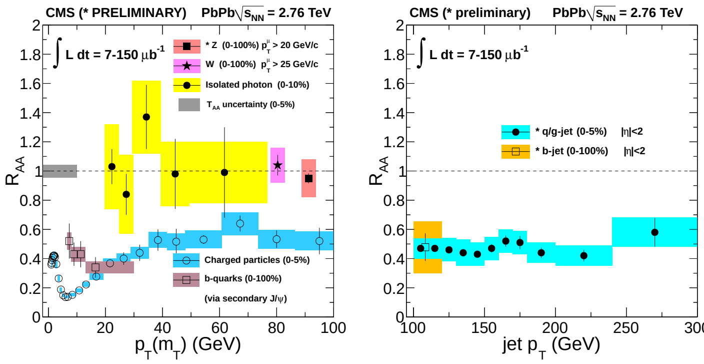

Figure 4: R_{AA} measurement from various observables are spread out from low p_T to high p_T up to 300 GeV/c.

3. *b*-jet measurement

Jets containing b hadrons can be tagged by the displaced vertices. The flight distance between the reconstructed displaced vertex and the primary vertex of the interaction, denoted Simple Secondary Vertex High Efficiency (SSVHE) is used as a discriminator. The c and b quarks have different shape of the invariant mass of the charged tracks used in displaced vertex reconstruction. Unbinned maximum likelihood fit is performed with b jet and non-b-jet shape from MC to get the b-jet fraction. The b jet to inclusive jet ratio is obtained with $(N^{tagged}_{jets}/N_{jets})(P/\varepsilon)$. N^{tagged}_{jets} is the number of b jets and N_{jets} is the number of inclusive jets. P is purity and ε is efficiency. R_{AA} of inclusive jets has been measured and it is 0.50 ± 0.01(stat.) ± 0.06(syst.) for $100 < p_T < 120$ GeV/c [7]. One can calculate the b jet R_{AA} by multiplying the b-jet fraction to the inclusive jet R_{AA} and leading to the value of 0.48 ± 0.09(stat.) ± 0.18(syst.) for $100 < p_T < 120$ GeV/c as shown in the right panel of Fig. 4. More details will be discussed in dedicated proceedings [8].

4. Summary

CMS has presented the first open beauty measurements both at low p_T and high p_T. In the region $6.5 < p_T < 30$ GeV/c, the suppression of non-prompt J/ψ from b-hadron decays is smaller than the one of light charged hadrons. The difference decreases towards higher p_T. Furthermore, b-jets with a jet p_T of 100 GeV/c exhibit comparable suppression as light jets.

References

[1] Dokshitzer, Yuri L. and Kharzeev, D.E., Phys. Lett. B519 (2001) 199-206
[2] CMS Collaboration, CMS PAS HIN-12-014, http://cdsweb.cern.ch/record/1472735
[3] CMS Collaboration, CMS PAS HIN-12-003, http://cdsweb.cern.ch/record/1472721
[4] CMS Collaboration, JINST 3 (2008) S08004
[5] CMS Collaboration, JHEP 05 (2012) 063
[6] CMS Collaboration, JHEP 02 (2012) 011
[7] CMS Collaboration, CMS PAS HIN-12-004, http://cdsweb.cern.ch/record/1472722
[8] Matthew, N. In these proceedings