Available online at www.sciencedirect.com

ScienceDirect

Nuclear Physics A 982 (2019) 186–188

www.elsevier.com/locate/nuclphysa

XXVIIth International Conference on Ultrarelativistic Nucleus-Nucleus Collisions
(Quark Matter 2018)

Fragmentation of J/ψ in jets in pp collisions at $\sqrt{s}$ = 5.02 TeV

Batoul Diab for the CMS collaboration

Laboratoire Leprince-Ringuet, École polytechnique, 91128 Palaiseau Cedex, France

Abstract

The fragmentation of jets containing a J/ψ meson is studied in $\sqrt{s}$ = 5.02 TeV pp data using an integrated luminosity of $\mathcal{L}$ = 27.39 pb^{-1}. The fraction of the jet transverse momentum $p_{\mathrm{T,jet}}$ carried by the J/ψ is measured for prompt J/ψ and J/ψ coming from b hadron decays, named nonprompt. Whereas the fragmentation function of nonprompt J/ψ is well-modeled by simulations using a Monte Carlo generator, the prompt J/ψ are found to be accompanied by a larger level of jet activity. The fraction of J/ψ mesons that are produced inside a jet is also reported, and found to be larger in data than in simulation, for both prompt and nonprompt J/ψ.

Keywords: CMS, J/ψ, Jets, pp collisions

1. Introduction

The production of J/ψ mesons in hadronic collisions remains far from being fully understood [1]. Among the various theoretical approaches, the non-relativistic QCD (NRQCD) effective field theory is able to reproduce the absolute differential production cross sections measured in collider experiments. However, NRQCD predicts that quarkonia are produced transversely polarized, which is not observed in the data from the LHC [2]. Clearly the detailed parton dynamics responsible for the formation of heavy quark bound states remains elusive. J/ψ hadronization dynamics can be studied by measuring the transverse momentum (p_{T}) fraction carried by the J/ψ meson detected inside a jet, $z \equiv p_{\mathrm{T,J/\psi}}/p_{\mathrm{T,jet}}$.

The fragmentation of jets into J/ψ was recently measured in pp collisions at $\sqrt{s}$ = 13 TeV by the LHCb Collaboration [3]. The measurement was performed in the pseudorapidity range $2.5 < \eta < 4.0$, and using jets with $p_{\mathrm{T}} > 20$ GeV. It was found that while the production of nonprompt J/ψ in jets is well-described by PYTHIA 8 [4], prompt J/ψ mesons tend to be produced with lower z than predicted by NRQCD. Here we report a similar study of J/ψ production in jets with the CMS detector [5, 6] in the dimuon decay channel. We measure the fragmentation function z using jets with $25 < p_{\mathrm{T}} < 35$ GeV clustered using the anti-k_t algorithm [7], and selecting J/ψ in two rapidity regions $0 < |y| < 1.6$ and $1.6 < |y| < 2.4$ for $6.5 < p_{\mathrm{T}} < 35$ GeV and $3.0 < p_{\mathrm{T}} < 35$ GeV, respectively. The results are reported separately for prompt and nonprompt J/ψ mesons.

https://doi.org/10.1016/j.nuclphysa.2018.09.049

2. Analysis strategy

Due to the difference in the production mechanisms, prompt and nonprompt J/ψ are separated. J/ψ coming from b hadron decays are identified with the measurement of a secondary $\mu^+\mu^-$ vertex displaced from the primary collision vertex. The displacement can be resolved using the pseudo-proper decay length $\ell_{J/\psi}$ [8]. To measure the fraction of nonprompt J/ψ, the invariant mass spectrum of $\mu^+\mu^-$ pairs and their $\ell_{J/\psi}$ distribution are fitted using a two-dimensional (2D) extended unbinned maximum-likelihood fit [9] in the different z bins after applying corrections for the acceptance and efficiency of the CMS detector.

After the yield extractions, the migration across z bins, due to the finite jet p_T resolution, is corrected for with an unfolding procedure with D'Agostini's iterative method [10], as encoded in the RooUnfold software package [11]. The unfolding is carried out in two dimensions, z and jet p_T, using the detector response derived from Monte Carlo simulations. To handle the migration into the nominal jet p_T range from lower and higher p_T, the unfolding is performed using two additional jet p_T bins: 15 – 25 and 35 – 45 GeV. The unfolding is initiated starting from a prior that is flat in z. Three iterations are then carried out until a convergence of unfolding is reached. The prior is then reinitialized, but this time reweighting its z distribution to match the output of the first 3 iterations. This procedure is repeated three times.

3. Results

The self-normalized z distributions are presented for mid-rapidity and forward rapidity in Fig. 1. Prompt and nonprompt J/ψ data show a qualitatively similar behaviour in each rapidity region. A similar trend is observed in PYTHIA 8 for nonprompt J/ψ. The distribution for prompt J/ψ in PYTHIA 8, on the other hand, is very different than that observed in data. It is harder in PYTHIA than data, indicating that the jet activity accompanying J/ψ mesons is underestimated. For the nonprompt case, the z distribution of the parent b hadron from PYTHIA 8 is also shown, which is peaked at much larger values of z compared to the daughter J/ψ due to the decay kinematics.

The fraction of prompt and nonprompt J/ψ mesons that belong to jets within the p_T selection, as well as the data-to-MC ratio of these fractions, is shown in Fig. 2. We find that less than 7% of J/ψ mesons are produced in jets in the p_T range. This fraction is underpredicted by PYTHIA 8 for both prompt and nonprompt J/ψ, for both rapidity ranges. These J/ψ-in-jet fractions have not been computed before and provide complementary information to the z distributions that should prove useful for developments of models of charmonium production.

Recently, calculations have become available that treat quarkonium production not only directly from the hard scattering, but also over the course of the subsequent parton showers [12]. These calculations are able to describe the z distributions measured by the LHCb Collaboration. Formation of quarkonia at later time may have an important implications for the interpretation of quarkonium nuclear suppression factors, such as those recently measured in PbPb collisions by the CMS Collaboration [9].

References

[1] A. Andronic, et al., Heavy-flavour and quarkonium production in the LHC era: from proton-proton to heavy-ion collisions, Eur. Phys. J. C 76 (2016) 107.
[2] B. Abelev, et al., J/ψ polarization in pp collisions at $\sqrt{s}$ = 7 TeV, Phys. Rev. Lett. 108 (2012) 082001.
[3] R. Aaij, et al., Study of J/ψ production in jets, Phys. Rev. Lett. 118 (19) (2017) 192001.
[4] T. Sjöstrand, et al., An Introduction to PYTHIA 8.2, Comput. Phys. Commun. 191 (2015) 159.
[5] S. Chatrchyan, et al., Production of prompt and nonprompt J/ψ mesons in jets in pp collisions at $\sqrt{s}$ = 5.02 TeV, Tech. Rep. CMS-PAS-HIN-18-012, https://cds.cern.ch/record/2318344 (2018).
[6] S. Chatrchyan, et al., The CMS experiment at the CERN LHC, Journal of Instrumentation 3 (08) (2008) S08004.
[7] M. Cacciari, G. P. Salam, G. Soyez, The anti-k_t jet clustering algorithm, JHEP 04 (2008) 063.
[8] D. Buskulic, et al., Measurement of the anti-B^0 and B^- meson lifetimes, Phys. Lett. B 307 (1993) 194.
[9] A. M. Sirunyan, et al., Measurement of prompt and nonprompt charmonium suppression in PbPb collisions at 5.02 TeV, Eur. Phys. J. C 78 (6) (2018) 509.
[10] G. D'Agostini, A multidimensional unfolding method based on Bayes' theorem, Nucl. Instrum. Meth. A 362 (1995) 487.
[11] T. Adye, Unfolding algorithms and tests using RooUnfold.
[12] R. Bain, Y. Makris, T. Mehen, L. Dai, A. K. Leibovich, NRQCD Confronts LHCb Data on Quarkonium Production within Jets, Phys. Rev. Lett. 119 (3) (2017) 032002.

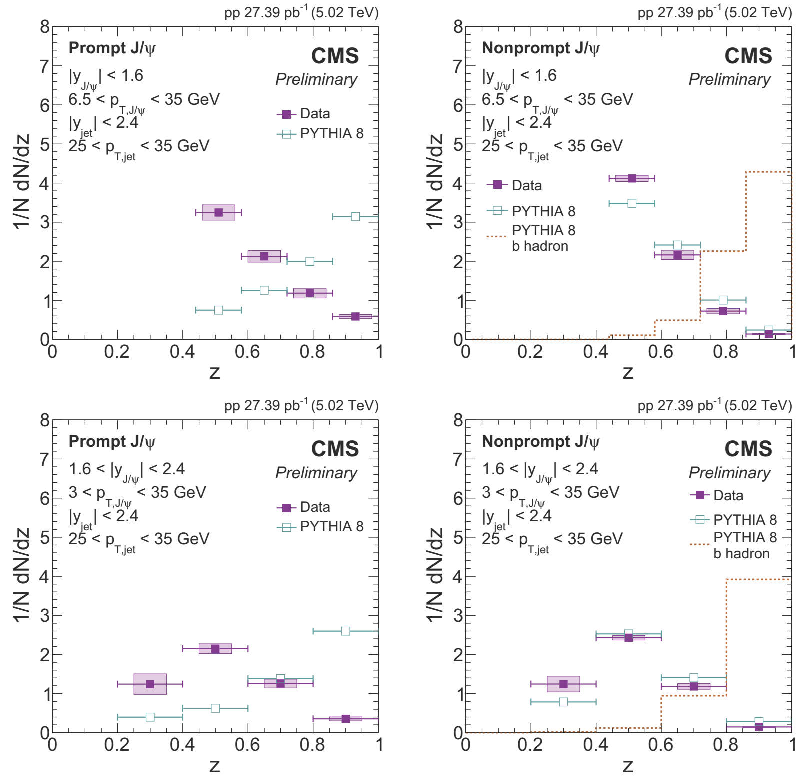

Fig. 1. Self-normalized prompt (left) and nonprompt (right) z distributions in the rapidity ranges $|y| < 1.6$ (top) and $1.6 < |y| < 2.4$ (bottom), for pp data and PYTHIA 8. For the nonprompt case, the z distribution of the parent b hadron is also shown [5].

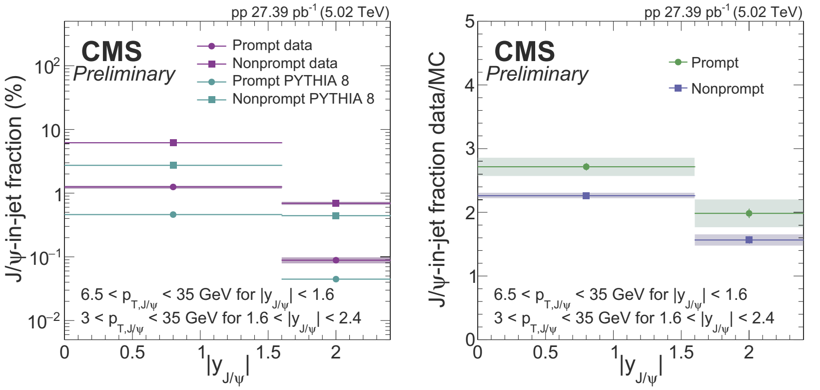

Fig. 2. Left: The fraction of prompt and nonprompt J/ψ in jets of $25 < p_T < 35$ GeV in pp data and in PYTHIA 8, compared to the total number of J/ψ in the relevant the p_T interval, as indicated on the Figure. Right: The ratio of these J/ψ-in-jet fractions in data compared to simulation for prompt and nonprompt J/ψ [5].