PROCEEDINGS OF SCIENCE

B_s^0 and B^+ nuclear modification factors in PbPb collisions at $\sqrt{s_{NN}} = 5.02\,\mathrm{TeV}$ with the CMS detector

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Beauty quark production in heavy-ion collisions is considered to be one of the key measurements to address the flavour-dependence of in-medium energy loss in heavy-ion collisions. On the other hand, the measurement of the production of strange beauty mesons can provide fundamental insights into the relevance of mechanisms of beauty recombination in the quark-gluon plasma. In this talk, CMS results on the nuclear modification factor, R_{AA}, of fully reconstructed B_s^0 and B^+ mesons as a function of transverse momentum at $\sqrt{s_{NN}} = 5.02$ TeV in PbPb collisions will be presented for the first time. The R_{AA} double ratio between B_s^0 and B^+ will also be presented.

International Conference on Hard and Electromagnetic Probes of High-Energy Nuclear Collisions
30 September - 5 October 2018
Aix-Les-Bains, Savoie, France

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PoS(HardProbes2018)143

1. Introduction

Heavy-ion collisions generate an environment of very high energy density and temperature. In such conditions, quarks and gluons move freely in a deconfined state of matter called quark-gluon plasma (QGP). Charm and beauty quarks may probe this state, as they are produced in hard scatterings before the expansion of the medium, and they form hadrons that decay long after its cool-down. They also interact strongly with the medium via elastic collisions and gluon radiation, and thereby lose energy. Thanks to this so-called jet quenching [1], they probe the energy density and diffusion properties of the QGP. At temperatures above the strange quark threshold, the strangeness content of the medium is expected to be enhanced [2]; numerous support for this idea has been brought at RHIC [3]. The competition between strange quark enhancement at low-medium transverse momentum (p_T) and the quenching of beauty quarks at high p_T makes the study of strange beauty particles such as the B_s^0 mesons particularly enlightening for the beauty hadronisation in heavy-ion collisions. At low p_T, such particles thus should be enhanced due to the recombination mechanism, through which the b quark would recombine with a s quark from the medium and not produced in the same hard scattering [4]. The existence of this mechanism would firmly signal the presence of a QGP; an indication of it was recently observed by ALICE, namely an enhancement of the D_s^+ mesons with respect to non-strange charmed mesons for $p_T < 5$ GeV in central PbPb collisions [5].

We measure here the exclusive B_s^0 decays in pp collisions, and provide the first measurement of the B_s^0 meson production in nucleus-nucleus collisions, both at a centre-of-mass energy per nucleon pair $\sqrt{s_{NN}} = 5.02$ TeV, in the channel $B_s^0 \to J/\psi\,\phi \to \mu^+\mu^-K^+K^-$. The pp measurement is performed in three bins of transverse momentum (p_T), and is compared to FONLL calculations [6]. The nuclear modification factor R_{AA} of B_s^0 mesons (charge conjugated modes are implied and not distinguished) is measured for $7 < p_T < 15$ GeV and $15 < p_T < 50$ GeV, in the rapidity range $|y| < 2.4$. It is then compared to that of B^+mesons [7]. These measurements are performed with the CMS detector [8].

2. Analysis method

The used data were collected during Run II of the LHC, with a trigger requiring two muons without explicit kinematic cuts. The respective integrated luminosities of the pp and PbPb samples are $351\,\mu b^{-1}$ and $28.0\,pb^{-1}$. A selection to reject beam-gas collisions and beam-scraping events is applied. Monte Carlo (MC) samples were generated, both for the signal B_s^0 decay and for the inclusive J/ψ samples, via PYTHIA 8 interfaced with GEANT, EVTGEN and PHOTOS. HYDJET was also used for the embedding into PbPb collision events.

The same selection cuts were applied to pp and PbPb events. First, muons must pass basic kinematic cuts corresponding to the acceptance of the detector, from $p_T > 3.5$ GeV at central pseudorapidities to $p_T > 1.8$ GeV at higher $|\eta^\mu|$; then they must pass identification criteria optimized for low p_T. The J/ψ candidates, formed by two muons of invariant mass within 150 MeV of the J/ψ nominal mass, are kept if the fit of the di-muon vertex fit has a χ^2 probability above 1%. The ϕ candidates are formed similarly from a fit of two tracks passing standard selections, with an invariant mass within 15 MeV of the ϕ nominal mass. B_s^0 candidates are built from a J/ψ and a ϕ originating from the same vertex. Multiple B_s^0 variables are exploited for the selection procedure, such as the

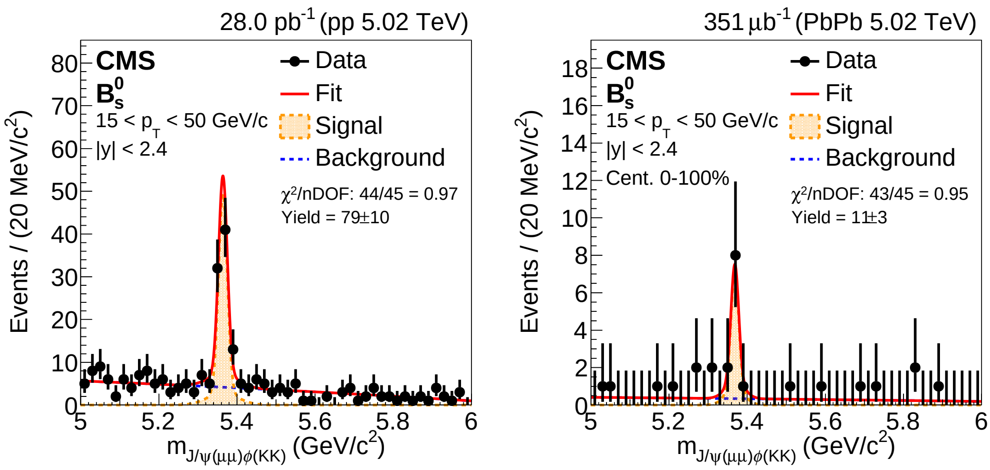

Figure 1: Invariant mass distributions of B_s^0 and $\overline{B_s^0}$ candidates in pp (left) and PbPb (right) collisions measured in $|y| < 2.4$ and in the p_T region 15–50 GeV. Figures from Ref. [9].

probability of the B_s^0 vertex fit or the significance of its displacement from the primary vertex. A boosted decision tree (BDT) algorithm combines these variables into a single one, separately for pp and PbPb and for each p_T bin. For the BDT training, the MC sample is used for signal, and the B_s^0 mass sidebands in data are used for background. The chosen cut on the BDT variable maximizes the statistical significance of the signal within 80 MeV of the B_s^0 nominal mass.

The signal yields are obtained by fitting the B_s^0 invariant mass in the range $5 < M_{\mu\mu KK} < 6$ GeV, as shown for example in Fig. 1 for the second p_T bin. The signal shape is a double Gaussian with common mean and two different widths taken from MC studies. The background arises mostly from combinations of J/ψ candidates with random tracks, and its shape is taken as a first order polynomial after a study of the inclusive J/ψ MC sample. The tight cut around the ϕ meson mass renders negligible all peaking backgrounds from other B meson decays.

The differential B_s^0 production cross sections are calculated in each p_T bin as

$$\left.\frac{d\sigma^{B_s^0}}{dp_T}\right|_{|y|<2.4} = \left.\frac{1}{2}\frac{1}{\mathscr{B}\mathscr{L}}\frac{1}{\Delta p_T}\frac{N_{pp}^{(B_s^0+\overline{B_s^0})}(p_T)}{\alpha_{pp}(p_T)\,\varepsilon_{pp}(p_T)}\right|_{|y|<2.4} \tag{2.1}$$

for pp, and similarly for PbPb, replacing the luminosity $\mathscr{L}$ by $N_{MB}\,T_{AA}$, with N_{MB} the number of minimum bias events, and T_{AA} the nuclear overlap function. $\mathscr{B}$ is the branching fraction for the decay chain, and $(\alpha(p_T)\,\varepsilon(p_T))_{pp,\,PbPb}$ is the acceptance times efficiency for each p_T bin, obtained from simulation.

3. Systematic uncertainties

A detailed review of the considered sources of uncertainty can be found in Ref. [9]. The systematic uncertainties are evaluated separately for pp and PbPb and for each p_T bin. The dominant uncertainties are on the BDT selection efficiency (up to 19% of R_{AA}) and on the kaon tracking efficiency (up to 12% of R_{AA}). Correlated uncertainties partially cancel in the R_{AA}, and in the ratio of R_{AA} of B_s^0 and B^+ mesons.

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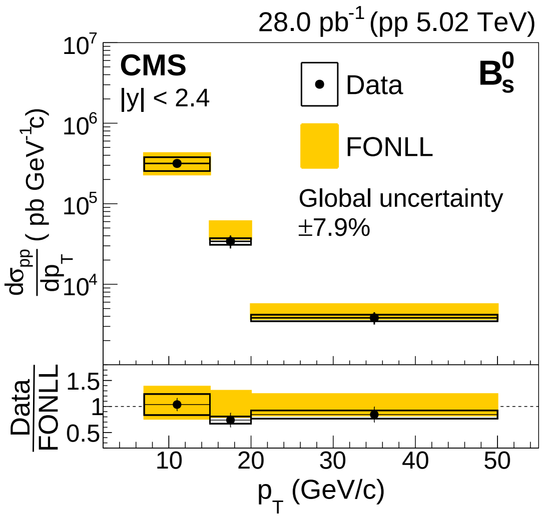

Figure 2: The p_T-differential production cross section of B_s^0 in pp collisions in three p_T bins and in the rapidity range $|y| < 2.4$, compared to FONLL calculations. The vertical bars (boxes) correspond to statistical (systematic) uncertainties. The correlated and uncorrelated systematic uncertainties are added in quadrature, but the global systematic uncertainty is not included. Figure from Ref. [9].

4. Results and conclusion

In Fig. 2 is shown the pp cross section, compared to FONLL total b quark production spectrum [6] multiplied by 10.3%, the world-average production fraction of B_s^0. The measured cross section is consistent with the FONLL prediction, and could help constrain it thanks to its smaller uncertainty.

The nuclear modification factor R_{AA} of B_s^0 mesons is measured to be $1.5 \pm 0.6(\mathrm{stat}) \pm 0.5(\mathrm{syst})$ for $7 < p_T < 15$ GeV, and $0.87 \pm 0.30(\mathrm{stat}) \pm 0.17(\mathrm{syst})$ for $15 < p_T < 50$ GeV. It is shown in Fig. 3 (left), alongside the R_{AA} of B^+mesons from Ref. [7], and compared to the predictions of a perturbative QCD based model (CUJET3.0 [10]) and a transport model based on a Langevin equation and including recombination processes (TAMU [11]). This measurement could discriminate between these two models, hence determining if recombination plays a role in beauty hadronisation, albeit with a future higher precision measurement.

The ratio between the R_{AA} of B_s^0 and B^+mesons is also given in Fig. 3 (right). Uncertainties common to both quantities cancel in this double ratio. Assuming that the uncertainties on R_{AA} are Gaussian, a χ^2 test is performed for the hypothesis that the ratio is consistent with unity. The resulting p-values are 18% for $7 < p_T < 15$ GeV, and 28% for $15 < p_T < 50$ GeV, showing that the possibility of no enhancement is not rejected.

To conclude, the first measurement of the B_s^0 differential production cross section in pp and PbPb collisions has been performed. It is compared to that of B^+mesons to assess the importance of recombination mechanisms and strangeness enhancement in the production of strange beauty mesons. A hint of B_s^0 enhancement is found, but the result is not significant with the current precision, leaving the possibility of a scenario without enhancement. However, the feasibility of this measurement is demonstrated.

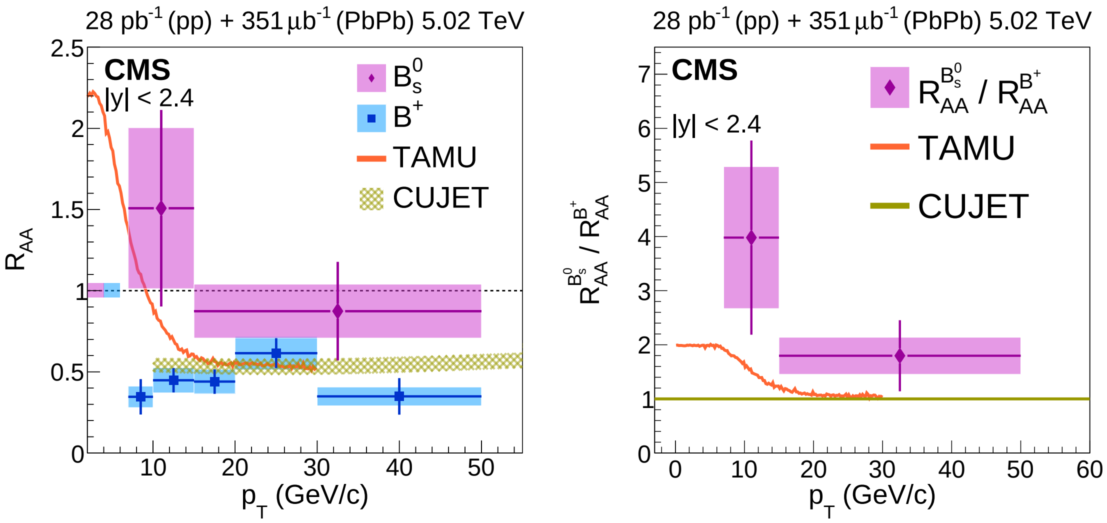

Figure 3: (Left) The nuclear modification factor of B_s^0 and B^+mesons. (Right) Ratio of the nuclear modification factor of B_s^0 and B^+mesons, measured in PbPb collisions at $\sqrt{s_{NN}} = 5.02$ TeV. The vertical bars (boxes) correspond to statistical (systematic) uncertainties. Figures from Ref. [9].

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