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J/ψ production cross section and polarization with LHCb

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Summary. — Despite the large experimental and theoretical efforts, the J/ψ production rate and states in hadronic collisions are not yet satisfactorily understood. The comparison between the J/ψ differential cross section measurement and the most recent theoretical models shows a general good agreement but it is still unsatisfactory. The double differential J/ψ cross section has been measured at LHCb with $5\,\text{pb}^{-1}$ out of the $37\,\text{pb}^{-1}$ data sample recorded during the 2010 data taking, disentangling the prompt component and the component coming from the b-hadrons decays. With the full data sample LHCb aims to give a measurement of the prompt J/ψ polarization with a full angular analysis, in both the polar and azimuthal angle.

PACS 14.40.Pq – Heavy quarkonia.
PACS 13.60.Le – Meson production.

1. – Introduction

The mechanism of charmonium production has been the subject of many interesting studies in the recent years. Many different theoretical models (with the non-relativistic QCD being among the most promising ones) have been proposed to describe the production of the prompt component, directly produced in the collisions or fed by the decays of higher states such as $\psi(2S)$, χ_{c1}, χ_{c2}. However none of them is able to successfully predict both the cross section and the polarization. The large rate of J/ψ production at LHC allows to extend the phase space examined so far and, in particular, LHCb [1] has the possibility to explore the forward rapidity region. LHCb has performed the measurement of the double differential production cross section of J/ψ prompt and delayed component, coming from the decays of the b-hadrons, in the fiducial region $p_T \in [0; 14]\,\text{GeV}/c$ and $y \in [2; 4.5]$, where p_T and y are, respectively, the J/ψ transverse momentum and rapidity. Moreover the production cross section of the b component has been used to extrapolate the $b\bar{b}$ cross section in the full solid angle.

2. – Cross section measurement and selection

The cross section is measured selecting J/ψ decaying in two muons: the data sample corresponds to an integrated luminosity $L = (5.2 \pm 0.5)\,\text{pb}^{-1}$ of pp collisions at

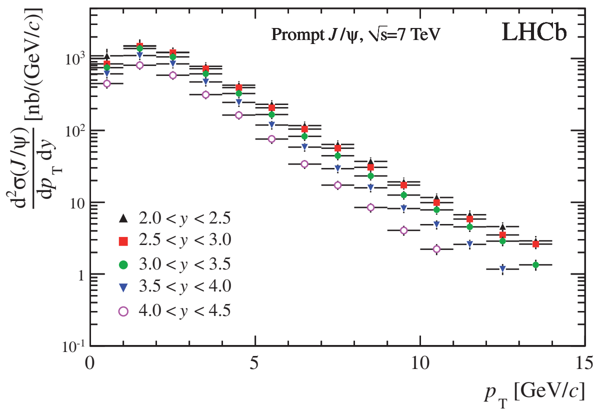

Fig. 1. – Double differential cross section of prompt component.

$\sqrt{s} = 7\,\text{TeV}$ recorded by the experiment during September 2010. The double differential cross section is defined as following:

$$\frac{\mathrm{d}^2\sigma}{\mathrm{d}p_T\mathrm{d}y} = \frac{N(J/\psi \to \mu^+\mu^-)}{L \times \varepsilon_{tot} \times Br(J/\psi \to \mu^+\mu^-)\Delta p_T \Delta y}\,, \tag{1}$$

where $N(J/\psi \to \mu^+\mu^-)$ is the number of selected J/ψ decaying in two muons, L is the integrated luminosity, ε_{tot} is the total efficiency (estimated from Monte Carlo including the detector acceptance, the reconstruction and trigger efficiency), $Br(J/\psi \to \mu^+\mu^-)$ is the branching ratio of the $J/\psi \to \mu^+\mu^-$ decay, Δp_T and Δy are, respectively, the J/ψ transverse momentum and rapidity bin sizes. The analysis selection requires at least one reconstructed primary vertex in each event. The J/ψ candidates are formed from pairs of opposite sign charged tracks reconstructed in the tracking system and identified as muons. The two muons must have a good quality of the track fit and originate from a common vertex. To separate the prompt and the delayed component the J/ψ pseudo proper time is used, defined as $t_z = \frac{(z_{J/\psi} - z_{PV}) m_{J/\psi}}{p_z}$, where $z_{J/\psi}$ and z_{PV} are the J/ψ decay vertex and the primary vertex positions along the beam axis, $m_{J/\psi}$ and p_z are, respectively, the mass and the momentum component of the J/ψ along the beam axis.

3. – Results

Figures 1 and 2 show, respectively, the double differential cross section and the differential cross section integrated over rapidity of the prompt component of the J/ψ as a function of p_T. Results are also compared with the prediction of three different theoretical models (Colour Singlet Model, Colour Octet Model and Colour Evaporation Model) for the production of the "direct" component (directly produced in the pp collisions, top raw) and adding the contribution from the decays of higher charmonium states (bottom row). In fig. 3 the double differential cross section of the b component is shown and in fig. 4 it is integrated over rapidity and compared with the FONLL computation. The

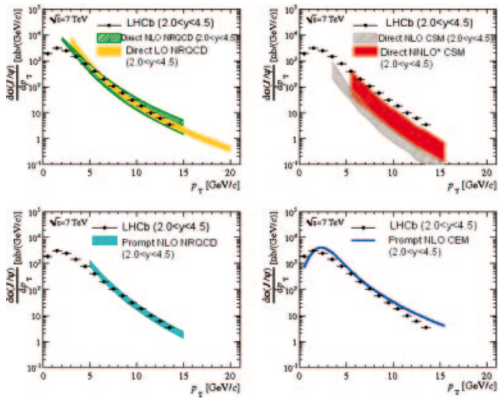

Fig. 2. – Prompt differential cross section compared with different theoretical models.

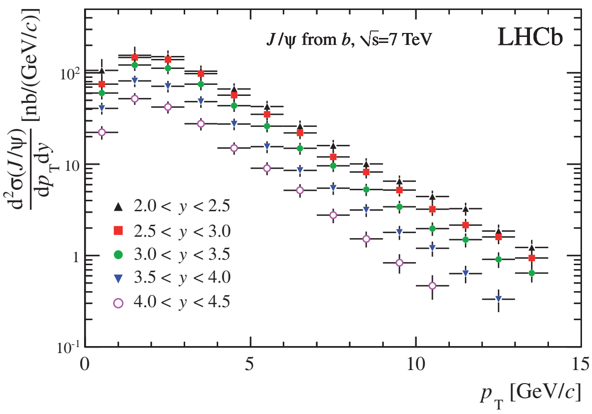

Fig. 3. – Double differential cross section of component coming from b decays.

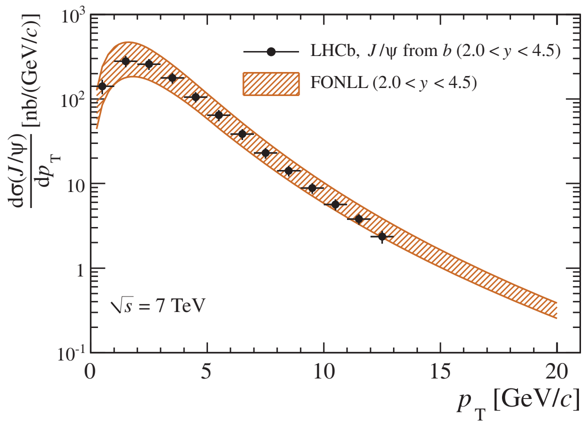

Fig. 4. – Differential cross section of b component compared with FONLL computation.

total cross sections, summing over each analysis bin, are

$$\sigma_{prompt} = (10.52 \pm 0.04(\text{stat}) \pm 1.40(\text{sys})^{+1.64}_{-2.20}(\text{pol}))\,\mu\text{b}, \tag{2}$$

$$\sigma_{from\,b} = [1.14 \pm 0.01(\text{stat}) \pm 0.16(\text{sys})]\,\mu\text{b}. \tag{3}$$

The first and the second uncertainties are, respectively, the statistical and the systematic. The main sources of systematic uncertainty come from the luminosity measurement, the tracking and trigger efficiency. The third uncertainty on the prompt cross section is due to the unknown polarization of J/ψ and it is estimated calculating the total efficiency in two possible extreme scenarios of fully transverse and fully longitudinal polarization. The deviation from the case of zero polarization is assigned as systematic error to the measurement. From eq. (3) the $b\bar{b}$ cross section is extrapolated to the full solid angle

$$\sigma(pp \to b\bar{b}X) = \alpha_{4\pi} \frac{\sigma_{from\,b}}{2\mathcal{B}(b \to J/\psi X)} = [288 \pm 4(\text{stat}) \pm 48(\text{sys})]\,\mu\text{b}. \tag{4}$$

All these results have been published in ref. [2].

4. – Outlook for polarization measurement

With the full 2010 data sample the prompt J/ψ polarization will be measured studying the full angular distribution of the two muons:

$$\frac{\mathrm{d}N}{\mathrm{d}(\cos\theta)\mathrm{d}\phi} \propto 1 + \lambda_\theta \cos^2\theta + \lambda_\phi \sin^2\theta \cos 2\phi + \lambda_{\theta\phi} \sin 2\theta \cos\phi, \tag{5}$$

where θ and ϕ are the polar and azimuthal angles in the helicity frame (using the J/ψ momentum as polarization axis). The measurement will be performed in bins of J/ψ transverse momentum and rapidity. The statistical sensitivity should be under 0.2 for λ_θ and under 0.01 for λ_ϕ and $\lambda_{\theta\phi}$, the systematic uncertainty is expected to be of the same order of magnitude.

REFERENCES

[1] LHCb Collaboration, *CERN-LHCC*-030-2003.
[2] LHCb Collaboration, *Eur. Phys. J. C*, **71** (2011) 1645.