J/ψ differential cross sections in pp collisions at $7\mathrm{TeV}$ measurement with the CMS experiment

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Abstract. The J/ψ differential cross sections in pp collisions at 7TeV is shown, as a function of transverse momentum and in several rapidity ranges, on the basis of a fraction of the data collected by CMS in 2010 [1]. The B to J/ψ fractions will also be presented, and compared to other measurements as well as to theory calculations.

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INTRODUCTION

Heavy-flavour and quarkonium production at hadron colliders [2] provides an important test of the theory of Quantum Chromodynamics (QCD). J/ψ mesons are classified as prompt when produced directly in the proton-proton collision or indirectly via decay of heavier charmonium states, and non-prompt when produced in the decay of b hadrons.

Different J/ψ polarizations cause different muon momentum spectra in the laboratory frame, and consequently different cross-section results. Due to this effect, for prompt J/ψ mesons the final results of this measurement are quoted for different polarization scenarios.

DATA SELECTION

The analysis is based on a data sample recorded by the CMS detector [3] in pp collisions at a centre-of-mass energy of 7TeV . The sample corresponds to a total integrated luminosity of $\mathscr{L} = 314 \pm 34\mathrm{nb}^{-1}$. J/ψ mesons are reconstructed in the $\mu^+\mu^-$ decay channel.

Simulated events were used to compute the acceptance and to derive corrections to the efficiencies. Prompt J/ψ mesons have been simulated using Pythia 6.421 [4], events with b-hadron pairs were also generated with Pythia and the b-hadrons decayed inclusively into J/ψ using the EvtGen [5] package. Final-state bremsstrahlung was implemented using PHOTOS [6, 7].

J/ψ RECONSTRUCTION

Muons were reconstructed by matching tracker and muon chambers signals; opposite charge muon pairs were then selected and a vertex fit was performed. The J/ψ yield

was obtained from a maximum likelihood fit to the invariant mass distribution with a Crystal-ball function [8] for the signal plus an exponential for the background.

Acceptance has been estimated from the simulation by taking the ratio of reconstructed over generated J/ψs, as a function of dimuon transverse momentum p_T , rapidity y and polarization λ_θ :

$$A(p_T, y; \lambda_\theta) = \frac{N_{det}(p_T, y; \lambda_\theta)}{N_{gen}(p_T, y; \lambda_\theta)} \tag{1}$$

Several polarization scenarios were considered, where the J/ψ is unpolarized or fully polarized, both longitudinal and transverse in Collins-Soper and Helicity frames [9].

Several systematic uncertainties have been investigated: the acceptance was computed using the dimuon momentum or the generated J/ψ momentum to estimate the effect of FSR, J/ψ spectra were generated using Pythia and CASCADE [10], the fraction of J/ψ from b-hadron decay has been taken from this measurement and it was varied inside its uncertainty, muon momentum was varied inside the calibration error. Total systematic error ranges from 1.0% to 4.5% in the different transverse momentum and rapidity regions.

Reconstruction efficiency is given by the product of single muon efficiencies, a correlation factor and the vertex recontruction efficiency. Single muon efficiency was estimated by a "Tag and Probe" method, by selecting dimuons in the J/ψ mass region: one muon passing a tight selection is the tag, while the other one is the probe. The correlation between efficiencies has been computed with the simulation. The vertex reconstruction efficiency was estimated in a very pure sample of dimuons selected in the data.

$$\varepsilon(J/\psi) = \varepsilon(\mu^+) \cdot \varepsilon(\mu^-) \cdot (1+\rho) \cdot \varepsilon_{vertex} \tag{2}$$

Systematic uncertainties over the J/ψ efficiency include the uncertainty over the correlation factor ρ , estimated by varying the J/ψ spectrum according to various models, and the single muon efficiency statistical error. Total systematic error ranges from 2.0% to 14.6% .

The product of acceptance and efficiency ranges from 0.016 ± 0.002 to 0.445 ± 0.013 .

INCLUSIVE CROSS SECTION

The differential cross section has been determined as a function of tranverse momentum and rapidity from the number of J/ψs, taken from the dimuon invariant mass fit and corrected with acceptance and efficiency, and the integrated luminosity and bin sizes:

$$\frac{d^2\sigma(J/\psi)}{dp_T dy} \cdot Br(J/\psi \to \mu^+\mu^-) = \frac{N_{corr}(J/\psi)}{\mathscr{L} \cdot \Delta p_T \cdot \Delta y} \tag{3}$$

Systematic uncertainty was estimated by varying the functions used in the mass fit; figure 1 shows the differential cross-section in 3 rapidity bins, for the different polarization scenarios; the 11% luminosity error is not included.

The total cross section integrated for $6.5\text{GeV}/c < p_T < 30\text{GeV}/c$ and $|y| < 2.4$ in the unpolarized scenario gives:

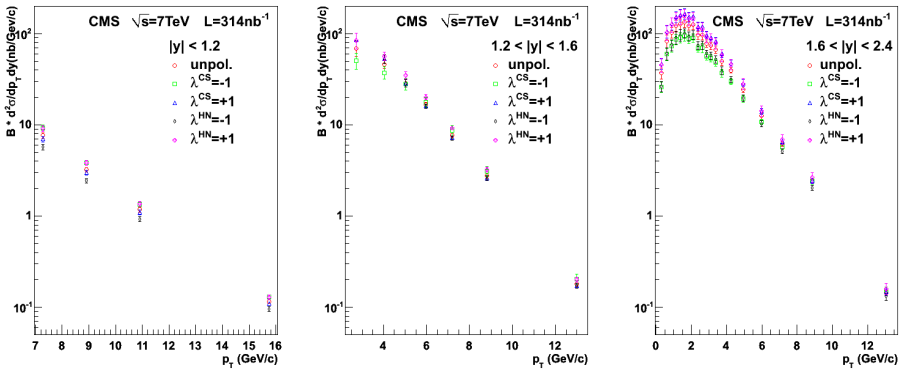

FIGURE 1. J/ψ differential cross-section. Luminosity uncertainty 11% is not shown.

$$\sigma(pp \to J/\psi + X) \cdot Br(J/\psi \to \mu^+\mu^-) = 97.5 \pm 1.5(stat) \pm 3.4(syst) \pm 10.7(lumi)nb \tag{4}$$

PROMPT AND NON-PROMPT CROSS SECTION

J/ψ produced in b-hadron decays were discriminated by computing the "proper distance" in the transverse plane between the primary vertex and the dimuon vertex:

$$\ell_{J/\psi} = L_{xy} \cdot m_{J/\psi}/p_T \tag{5}$$

The $\ell_{J/\psi}$ distribution has been fitted with a sum of 3 functions describing the prompt and non-prompt component plus the background; the fit was performed simultaneously together with the dimuon mass in each transverse momentum and rapidity bin. As fitting function for the decay distance a resolution function, built with gaussians, convoluted with the true $\ell_{J/\psi}$ distribution given by the simulation was used.

Fig. 2 shows the fraction of J/ψ coming from b decay, compared with CDF results [11] obtaind with $p\bar{p}$ collision at 1.96TeV .

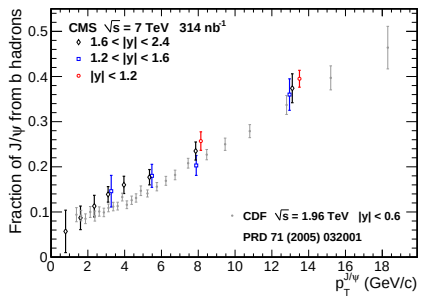

FIGURE 2. Non-prompt J/ψ fraction, compared with CDF results

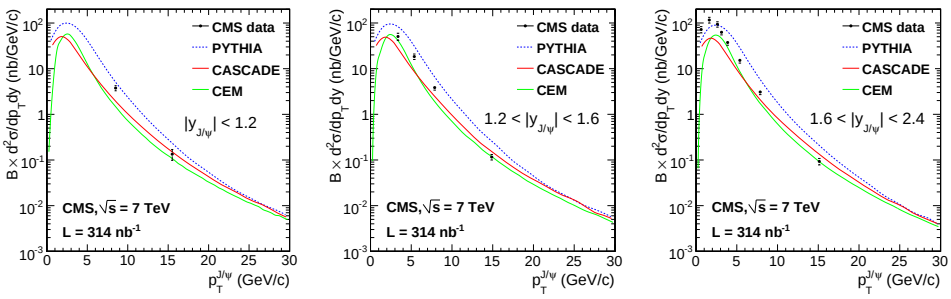

FIGURE 3. Differential prompt J/ψ cross-section, compared with different models

Fig. 3 and 4 show the prompt and non-prompt differential cross sections. The prompt yield was compared with Pythia [4] event generator, CASCADE [10], as well as with the Colour Evaporation Model (CEM) [12, 13]. At forward rapidity and low p_T the calculations shown in Fig. 3 underestimate the measured yield.

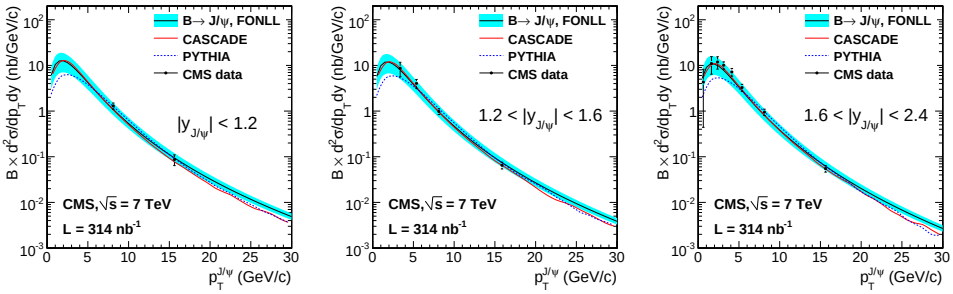

FIGURE 4. Differential non-prompt J/ψ cross-section, compared with different models

The non-prompt J/ψ differential production cross sections have been compared with calculations made with the Pythia [4] and CASCADE [10] Monte Carlo generators, and in the FONLL [14] framework. The agreement with FONLL and CASCADE is excellent, while Pythia tends to underestimate the yield below 5GeV$/c$ in p_T .

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