J/ψ prompt and non-prompt cross sections in pp collisions at $\sqrt{s} = 7$ TeV

Zongchang Yang on behalf of the CMS collaboration
University of Tennessee, Knoxville, USA

Abstract

Measurements of the J/ψ prompt and non-prompt cross sections in proton-proton collisions at 7 TeV by the CMS experiment are presented. The differential cross sections are measured as a function of the J/ψ transverse momentum, up to 30 GeV/c, and in several rapidity ranges. The fraction of J/ψ cross section due to b-hadron decays is determined from a fit to the decay length distribution, using the distance between the di-muon vertex and the interaction point. We will also show comparisons between the measurements and several model calculations, for both the prompt and the non-prompt J/ψ cross sections.

Key words: LHC, CMS, J/ψ, cross section
PACS:

1. Introduction

Heavy-flavor and quarkonium production at hadron colliders provides an important test of the theory of Quantum Chromodynamics (QCD). The production of J/ψ meson occurs in three ways: prompt J/ψ produced directly in the proton-proton collision, prompt J/ψ produced indirectly (via decay of heavier charmonium states such as χ_c), and non-prompt J/ψ from the decay of a b hadron. This paper presents the first measurement of the differential inclusive, prompt and non-prompt (b hadron) J/ψ production cross sections in pp collisions at a center-of-mass energy of 7 TeV, in the rapidity range $|y| < 2.4$, by the Compact Muon Solenoid (CMS) experiment.

2. Muon reconstruction and di-muon resonances

A detailed description of the CMS detector is provided elsewhere [1]. Muons are identified as tracks that are reconstructed in the inner silicon tracker which are associated

Preprint submitted to Elsevier *29 January 2011*

to compatible signals in the outer muon spectrometer. A relative momentum resolution better than 2% is achieved for transverse momenta p_T smaller than 100 GeV/c [2]. Fig. 1 (left) shows the opposite-sign di-muon mass distribution reconstructed from the full 2010 data sample of pp collisions, of 40 pb^{-1} integrated luminosity.

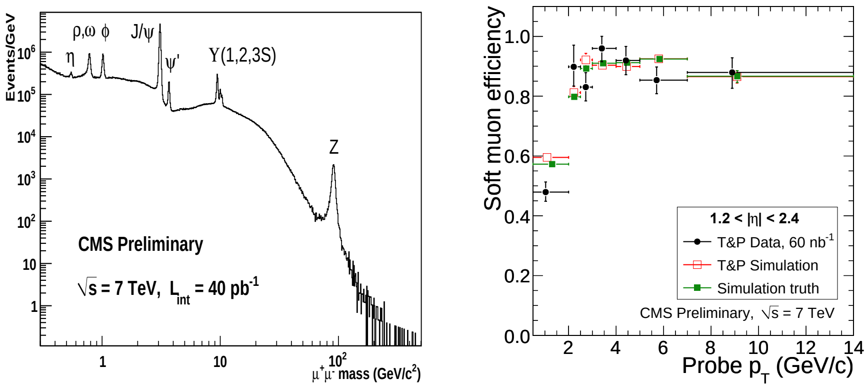

Fig. 1. Opposite-sign di-muon mass distribution measured by CMS in pp collisions at $\sqrt{s} = 7$ TeV (left). An example of the tag-and-probe reconstruction efficiency as a function of the probe muon p_T [3] (right).

The analysis is based on events triggered by a double-muon trigger with relatively loose requirements, allowing to collect events down to very low momenta. Muon trigger and reconstruction efficiencies are determined from the data, using a tag-and-probe method applied to the J/ψ resonance [3]. With a well-identified muon, called "tag", the method tests if the second muon (probe) can be found. The efficiency of the soft muon reconstruction is shown in Fig. 1 (right) for a single-leg (probe) muon.

3. Inclusive J/ψ cross section

The measurement of the inclusive p_T differential cross section is based on the following equation:

$$\frac{d\sigma}{dp_T}(J/\psi) \cdot \text{BR}(J/\psi \to \mu^+\mu^-) = \frac{N_{\text{corr}}(J/\psi)}{\int Ldt \cdot \Delta p_T} \tag{1}$$

where $N_{\text{corr}}(J/\psi)$ is the J/ψ yield, corrected for the J/ψ selection efficiency, in a given p_T bin, $\int Ldt$ is the integrated luminosity, Δp_T is the size of the p_T bin, and BR$(J/\psi \to \mu^+\mu^-)$ is the branching ratio of the J/ψ decay into two muons, which is $(5.88\pm0.10)\%$ [4].

The corrected yield, $N_{\text{corr}}(J/\psi)$, is determined from an unbinned maximum likelihood fit to the $\mu^+\mu^-$ invariant mass distribution in each J/ψ rapidity and p_T bin. The resulting yield is then corrected by a factor that takes into account the average acceptance and detection efficiency in the bin under consideration.

On the basis of a di-muon event sample of 314 nb^{-1} integrated luminosity, we measured the J/ψ production cross section as a function of transverse momentum in three rapidity ranges: $|y| < 1.2$, $1.2 < |y| < 1.6$ and $1.6 < |y| < 2.4$ [5]. Fig. 2 (left) shows the inclusive cross section results.

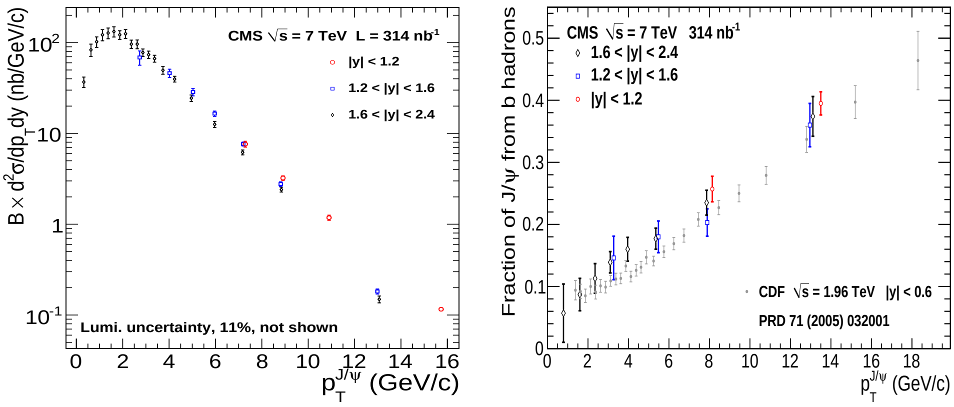

Fig. 2. Differential inclusive J/ψ cross section as a function of p_T for the three different rapidity intervals and in the unpolarized production scenario [5] (left). Fraction of the J/ψ production cross section originating from b-hadron decays, as a function of the J/ψ p_T, as measured by CMS in three rapidity bins and by CDF (right).

4. Fraction of J/ψ from b-hadron decays

The measurement of the fraction of J/ψ yield coming from b-hadron decays relies on the discrimination of the J/ψ meson produced away from the pp collision vertex, determined by the distance between the di-muon vertex and the primary vertex in the plane orthogonal to the beam line. Fig. 2 (right) shows the measured b fraction. It increases strongly with p_T. The CMS results are compared to the higher-precision data of CDF [6], obtained in proton-antiproton collisions at $\sqrt{s} = 1.96$ TeV. It is interesting to note that the increase with p_T of the b fraction is very similar between the two experiments, the CMS points being only slightly higher, despite the different collision energies.

The prompt component of the J/ψ differential cross section is shown in Fig. 3, as a function of p_T, for the three rapidity ranges mentioned above. The measurements are compared to calculations made with the Pythia [7] and CASCADE [8] event generators, as well as with the Color Evaporation Model (CEM) [9]. The non-prompt J/ψ differential production cross sections, as shown in Fig. 4, have been compared with calculations made with the Pythia and CASCADE Monte Carlo generators, and in the FONLL framework [10].

5. Conclusions

We have presented the first measurement of the J/ψ production cross section in the di-muon channel in pp collisions at $\sqrt{s} = 7$ TeV, based on 314 nb^{-1} of data collected by the CMS experiment during the first months of LHC operation. The results demonstrate an excellent performance of the CMS detector.

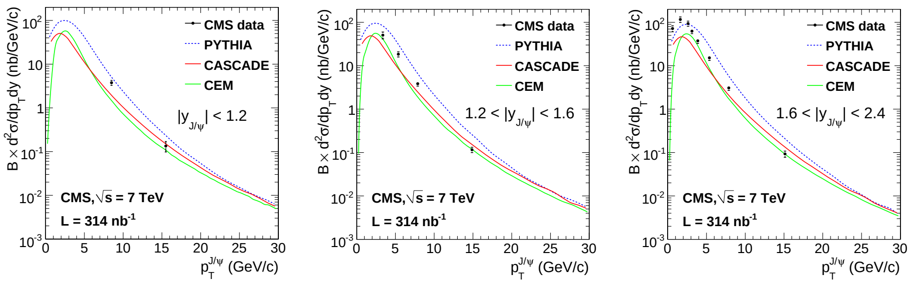

Fig. 3. Differential prompt J/ψ production cross section, as a function of p_T for the three different rapidity intervals. The data points are compared with three different models.

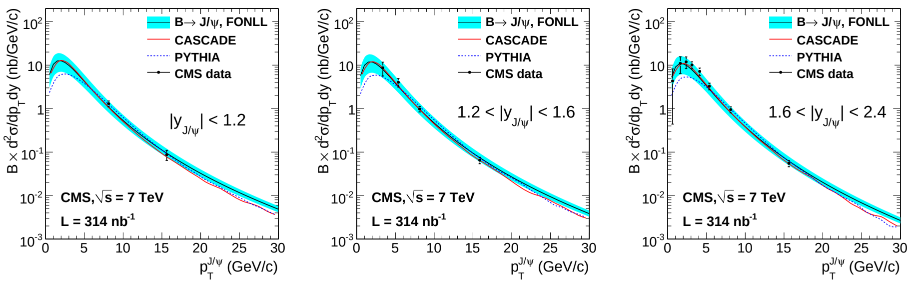

Fig. 4. Differential non-prompt J/ψ production cross section, as a function of p_T for the three different rapidity intervals. The data points are compared with three different models.

References

[1] CMS Collaboration, "The CMS experiment at the CERN LHC", *JINST* **0803** (2008) S08004.

[2] CMS Collaboration, "Measurement of Momentum Scale and Resolution of the CMS Detector using Low-mass Resonances and Cosmic Ray Muons", **CMS-PAS-TRK-10-004** (2010).

[3] CMS Collaboration, "Performance of muon identification in pp collisions at $\sqrt{s} = 7$ TeV", **CMS-PAS-MUO-10-002** (2010).

[4] C. Amsler et al. (Particle Data Group), "2009 Review of Particle Physics and 2009 partial update for the 2010 edition", *Phys. Rev.* **B667** (2008) 1.

[5] CMS Collaboration, "Prompt and non-prompt J/ψ production in pp collisions at $\sqrt{s} = 7$ TeV", submitted to Eur. Phys. J. C; arXiv:1011.4193.

[6] CDF Collaboration, "Measurement of the J/ψ meson and b-hadron production cross section in $p\overline{p}$ collisions at $\sqrt{s} = 1960$ GeV", *Phys. Rev.* **D71** (2005) 032001.

[7] T. Sjöstrand, S. Mrenna, and P. Z. Skands, "PYTHIA 6.4 physics and manual", *JHEP* **0605** (2006) 026.

[8] H. Jung, "The CCFM Monte Carlo generator CASCADE", *Comput. Phys. Commun.* **143** (2002) 100.

[9] A. D. Frawley, T. Ullrich, and R. Vogt, "Heavy flavor in heavy-ion collisions at RHIC and RHIC II", *Phys. Rept.* **462** (2008) 125.

[10] M. Cacciari, M. Greco, and P. Nason, "The p_{T} spectrum in heavy flavor hadroproduction", *JHEP* **9805** (1998) 007.