PROCEEDINGS OF SCIENCE

Measurement of J/ψ and $\psi(2S)$ production at $\sqrt{s} = 7$ TeV with the CMS experiment

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A measurement of the J/ψ and $\psi(2S)$ production cross sections in pp collisions at $\sqrt{s} = 7$ TeV with the CMS experiment at the LHC is presented. The data sample corresponds to an integrated luminosity of 37 pb^{-1}. Using a fit to the invariant mass and decay length distributions, production cross sections have been measured separately for prompt and non-prompt charmonium states, as a function of the meson transverse momentum in several rapidity ranges.

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1. Introduction

Quarkonium production at hadron colliders provides important tests of calculations in the context of both perturbative and non-perturbative quantum chromodynamics (QCD), via measurements of production cross sections and polarizations.

The present analysis extends the result using early CMS data [1], with a larger amount of statistically independent data and complements it by providing a measurement of the $\psi(2S)$ production cross section.

2. Event selection

The analysis is based on a data sample collected in 2010 with the CMS detector [2], in pp collisions at a centre-of-mass energy of 7 TeV. The sample is selected to have consistent trigger requirements for the data used in the analysis and without overlap with the sample used in Ref. [1]. It corresponds to a total integrated luminosity of nearly 37 pb^{-1}.

The J/ψ and $\psi(2S)$ mesons are reconstructed in the $\mu^+\mu^-$ decay channel. Events are selected by dimuon triggers that exploit advanced processing at the HLT level. Information from all three muon systems, as well as from the tracker, are used to make the trigger decision. Both muons are required to be consistent with a L1 muon signal, requiring at least two independent segments in the muon chambers, and to be matched to a track reconstructed in a region of interest defined by the L1 seed. No explicit requirement on the transverse momentum p_{T} is applied.

To select events with J/ψ or $\psi(2S)$ decays, muons with opposite charge are paired and their invariant mass is computed. The mass is required to be between 2.5 and 4.7 GeV/c^2. The two muon trajectories are refitted with a common vertex constraint, and events are retained if the χ^2 probability of the fit is larger than 1%.

3. Cross section measurement

The inclusive yields are extracted from the $\mu^+\mu^-$ invariant mass distribution. Yields are derived using an extended unbinned maximum-likelihood method.

The sum of a Gaussian and a Crystal Ball function is used for the description of the signal, simultaneously taking into account Final State Radiation and rapidity-dependent resolution variations. The background is modelled using a sum of two exponential functions.

The fitted yields are corrected for acceptance and efficiency. The acceptance reflects the geometrical coverage of the CMS detector and the kinematic reach of the muon trigger and reconstruction. The acceptance is estimated by Monte Carlo simulations, and depends upon the assumed polarization of the quarkonia. Similarly as done in [1], results are given for several polarization scenarios. The muon efficiency is measured from data for muons in the acceptance, in several $(p_{\text{T}}^{\mu}, \eta^{\mu})$ bins, and is based on the *tag-and-probe* (T&P) method, using independent triggers. The efficiency to detect a dimuon event is expressed as the product of the individual single-muon efficiencies, times the efficiency to vertex the two muon tracks, times a correction factor, taken from the simulation and that accounts for the finite size of the $(p_{\text{T}}^{\mu}, \eta^{\mu})$ bins and, more importantly, for

the possible bias introduced by the T&P measurement, due to correlation effects. Except for some bins at high p_T, the values, the correction is smaller than 10%.

To estimate the J/ψ and $\psi(2S)$ fraction from b-hadron decays, a two-dimensional fit is performed, in which the pdfs and fit procedure are the same as those described in Ref. [1]. The variables used for the two-dimensional fits are the dimuon invariant mass and the "pseudo proper decay length" $\ell_{J/\psi}$, defined as the most probable value of the transverse distance between the dimuon vertex and the primary vertex, corrected by the transverse Lorentz boost of the charmonium.

The resolution of the pseudo proper decay length is described by a function depending on an event-by-event uncertainty determined from the covariance matrices of the primary and secondary vertex fits. The uncertainty is used as the r.m.s. of the resolution Gaussian function that describes the core of the resolution, while a second Gaussian function with a small relative normalization (usually $< 1\%$) parametrizes the effect of incorrect primary vertex assignments.

4. Results

The prompt and non-prompt double differential cross sections for the two charmonium states are obtained by multiplying the measured inclusive cross sections with the fraction of prompt and non-prompt events, respectively. In addition the cross-section ratio of the two charmonium states is calculated.

Statistical uncertainties and contributions from the investigated sources to the total systematic uncertainties on these cross sections are summed in quadrature. The largest uncertainties are due to the efficiency correlations.

Figures 1 and 2 show the measured prompt and non-prompt cross sections for the J/ψ and the $\psi(2S)$ as a function of p_T, for the various rapidity bins and corrected for detector acceptance. They are compared with theoretical predictions from NRQCD [3] and from FONLL [4, 5] for the prompt and non-prompt cases, respectively.

Good agreement is found in both the J/ψ and the $\psi(2S)$ cases. For non-prompt production the measurements lie systematically below the FONLL predictions, possibly because of the large uncertainty on the $b \to \psi(2S)X$ branching fraction. In general, for both states, the observed differential cross sections seem to fall more rapidly than the FONLL prediction at high p_T, and this effect is more evident for the J/ψ because of the higher p_T reach.

5. Conclusions

A measurement of the prompt and non-prompt J/ψ and $\psi(2S)$ production cross sections in pp collisions at with the CMS experiment at the LHC has been presented. The data sample corresponds to an integrated luminosity of about 37 pb^{-1}. The two cross sections and their ratio have been measured as a function of the p_T up to 70 GeV/c for the $J/\psi$and 30 GeV/c for the $\psi(2S)$. The measurements have been compared with NRQCD (for prompt) and FONLL (for non-prompt) predictions. A good agreement with is found in the prompt case. In the non-prompt case, general agreement in shape is found for $\psi(2S)$in the entire $p_T$range considered, but an overall scale discrepancy is observed, possibly because of the assumption on the inclusive branching fraction $B(B \to \psi(2S)X)$.

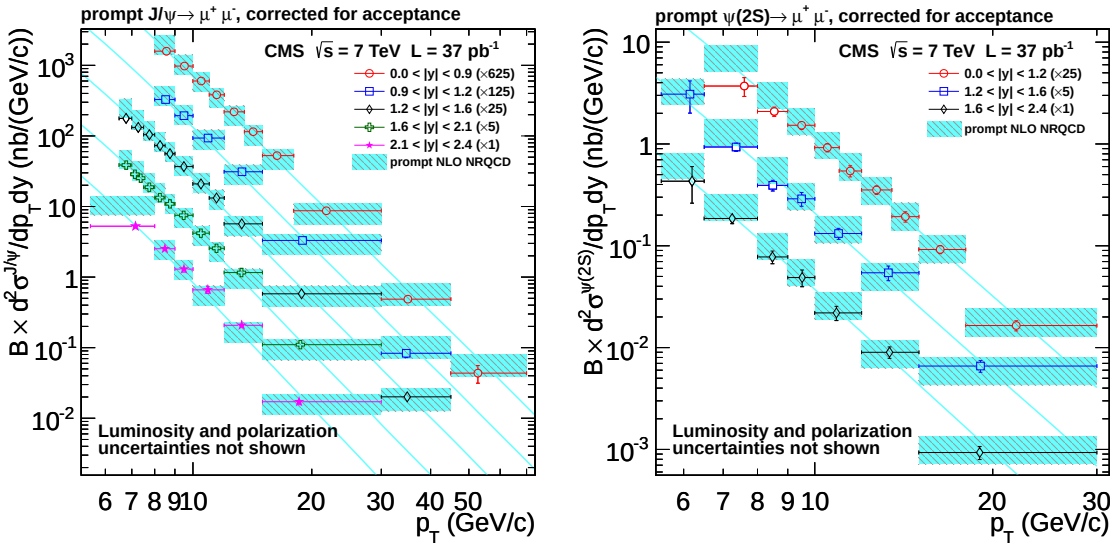

Figure 1: Measured differential cross section for prompt J/ψ and $\psi(2S)$ production (left and right, respectively) as a function of p_{T} for different rapidity bins. The error bars on the data points include all the statistical and systematic contributions except luminosity and polarization. The coloured (dark) bands indicate the theoretical predictions from NRQCD calculations.

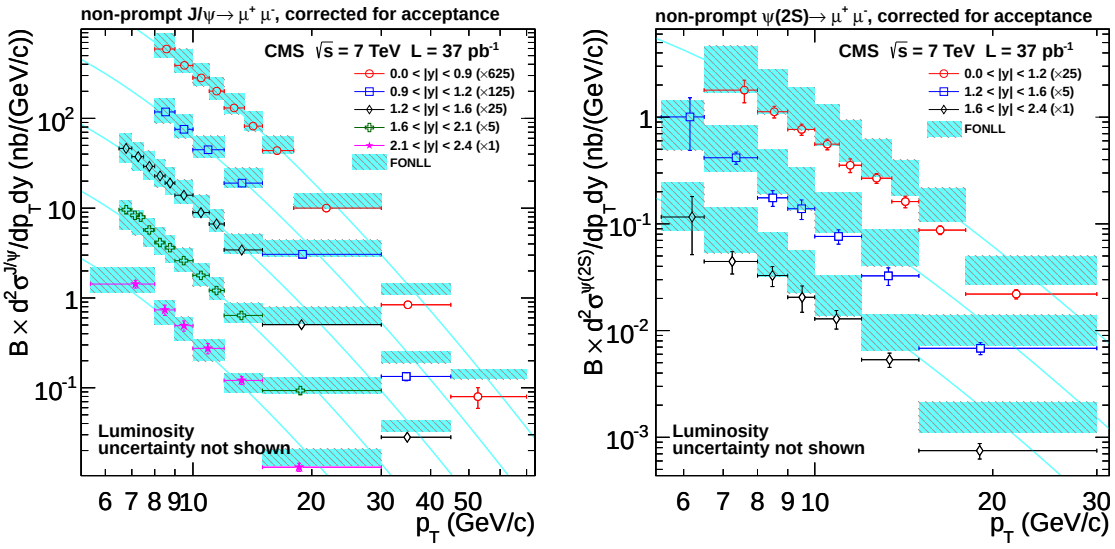

Figure 2: Measured differential cross section for non-prompt J/ψ and $\psi(2S)$ production (left and right, respectively) as a function of p_{T} for different rapidity bins. The error bars on the data points include all the statistical and systematic contributions except luminosity. The coloured (dark) bands indicate the theoretical predictions from FONLL calculations. The lines are added only for illustrative purposes.

References

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