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Measurement of the J/ψ cross section and polarization in CMS

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Summary. — This paper describes the measuremet of J/ψ inclusive, prompt and non-prompt cross section using the dimuon channel in the CMS experiment with the first 314 nb^{-1} of LHC data. An important contribution to the systematic uncertainty is given by the unknown polarization of the prompt J/ψ, in particular for what concerns the measurement of the detector acceptance. A complex framework for a measure of the prompt J/ψ polarization has been developed by the CMS collaboration and a measure of the angular parameters is foreseen in the close future. A brief description of the main issues of the polarization measurement is also given.

PACS 14.20.Lq – Charmed baryons ($|C| > 0$, $B = 0$).
PACS 13.20.Gd – Decays of J/ψ, Υ and other quarkonia.

1. – Introduction

The J/ψ at hadron colliders can be produced via three different processes:

1. *direct*, produced at the vertex of interaction directly by the two colliding partons;
2. *undirect*, from the decay of heavier chrmonium states (*i.e.* $\psi(2S)$);
3. form decays of b-hadrons.

The first two components are produced at the decay vertex and are generally referred as prompt component, while the long lifetime of the b quark makes the third category to decay at a considerable distance from the primary vertex and is called the non-prompt component. The higher mass of the b quark with respect to the c quark, makes the pQCD predictions for the non prompt J/ψ much more reliable than for the prompt component for which a fully perturbative approach is not adeguate. At present we do not have a theoretical framework capable to describes the CDF results on prompt J/ψ cross section and polarization at the same time, on the other hand the previsions on the non prompt component production is more robust and can be used as a test of pQCD. This paper describe the mesuremet of the total and double differential production cross section of the J/ψ in the inclusive case and discriminating the prompt and non-prompt components obtained with the CMS experiment. Here only the main results of the analysis are reported, for a detailed description see ref. [1].

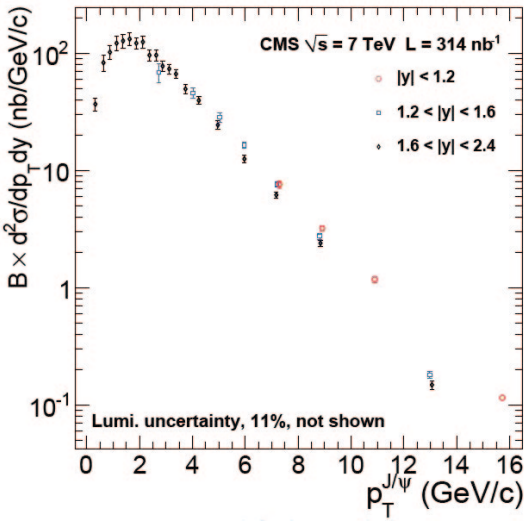

Fig. 1. – J/ψ inclusive double differential cross section.

2. – The J/ψ cross section measurement

The mesurement is based on $314\,\mathrm{nb}^{-1}$ of LHC data, corresponding to the first three months of machine operation. At that time the reduced instaneus luminosity of about $10^{30}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$ allowed for the use of very loose trigger selection criteria, in this analysis a trigger requiring two muons at Level-1 without any further p_T cut is used. The total statistics of J/ψ used for the measuremet consists in about 90000 events, splitted over about 30 bins of p_T and rapidity. The acceptance is computed by the Monte Carlo while the trigger and reconstruction efficiencies are taken from data using the Tag and Probe method. The signal yields are extracted by unbinned maximum likelihood fits of the invariant mass distribution of opposite charge muons. Results are presented in fig. 1; the cross section is strongly dependent on the p_T of the J/ψ while there is no evident dependence on the rapidity as expected. The total production cross section times the branching ratio for $6.5\,\mathrm{GeV}/c \leq p_T \leq 30\,\mathrm{GeV}/c$ is

$$\sigma(pp \to J/\psi + X) \times \mathrm{Br}(J/\psi \to \mu^+\mu^-) = 97.5 \pm 1.5(\mathrm{stat}) \pm 3.4(\mathrm{sys}) \pm 10.7(\mathrm{Lumi})\,\mathrm{nb}$$

where the last error is the systematic uncertanty due to luminosity measurement. To discriminate the prompt and non-prompt components the so-called *pseudo proper decay lenght* has been used, this variable is distributed as a resolution function for the prompt J/ψ while exhibits large exponential tails in the case of the non-prompt component. The relative fractions are determined using a simultaneous unbinned maximum-likelihood fit at the invariant mass and decay lenght distributions. From the mass fit the fraction of signal and background events is extracted, the lifetime fit discriminates the prompt, non-prompt and background components on the basis of the different PDFs shapes. Figure 2 presents an example of a lifetime fit and the results of the b-fraction measurement. The dependence is only on the p_T of the J/ψ, for a $p_T > 12\,\mathrm{GeV}/c$ about one third of the J/ψ's is produced in b-hadrons decays. Despite the considerably higher energy available

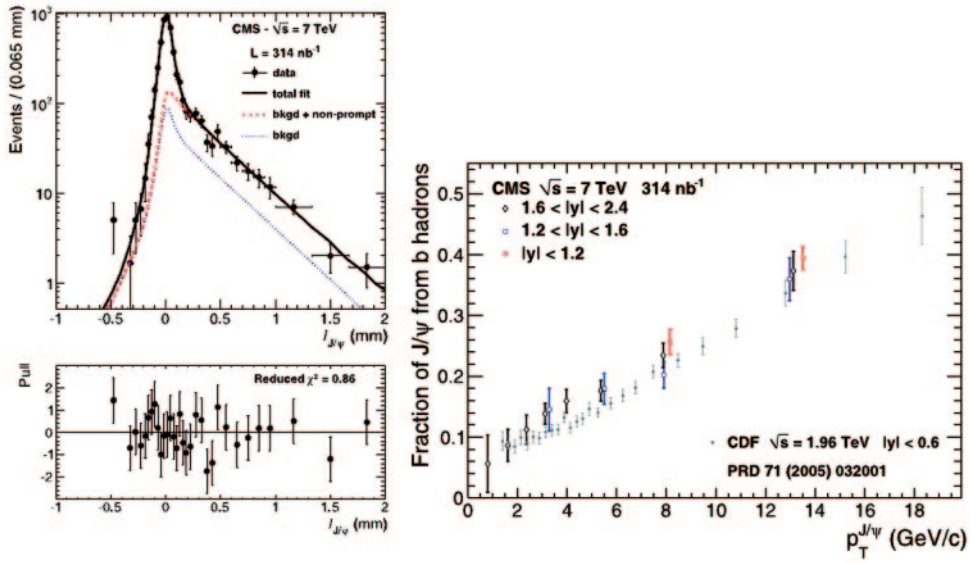

Fig. 2. – Left: example of a fit of the lifetime distribution. Right: fraction of J/ψ from b-hadrons decays as a function of p_T and rapidity, in light grey the points relative to CDF measurement.

in LHC cllisions with respect to Tevatron, the CMS and CDF results are quite compatible, CMS showing a light excess with respect to CDF. Using the non-prompt component it is possible to have a measure of the inclusive production cross section of b quark:

$$\sigma(pp \to bX \to J/\psi + X) \times \mathrm{Br}(J/\psi \to \mu^+\mu^-) = 26.0 \pm 1.4(\mathrm{stat}) \pm 1.6(\mathrm{sys}) \pm 2.9(\mathrm{Lumi})\,\mathrm{nb}$$

2˙1. *The polarization issue.* – The J/ψ's at LHC have in general a large boost in the beam direction and are produced mainly at very high rapidity, where the detector coverage is problematic, as a result the acceptance computation is critical for this analysis. In fact a big source of systematic uncertainty is the unknown polarization of the prompt J/ψ, affecting the muon angular distribution. The overall effect is sizeable and can be as high as 40% in few problematic bins. This problem has been overcome in the past presenting the results for several different polarization scenarios [1]. Now there is a detailed plan for a direct measurement of the J/ψ polarization in CMS, and all the needed tools are in place [2]. In the coming months, hopefully, CMS will reach the necessary amount of collected data for a reliable measurement that would greatly improve the physics content of the J/ψ cross section measurement.

REFERENCES

[1] The CMS Collaboration, *Eur. Phys. J. C*, **71** (2011) 1575.
[2] Faccioli P. *et al.*, *Eur. Phys. J. C*, **69** (2010) 657.