Towards the measurement of the J/ψ cross section at $\sqrt{\mathrm{s}} = 7\,\mathrm{TeV}$ in LHCb

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The J/ψ production in inelastic collisions at a centre-of-mass energy of $\sqrt{s} = 7\,\mathrm{TeV}$ is studied with the LHCb detector. Using the data collected between April and June 2010 at the Large Hadron Collider, LHCb will measure the p_T differential cross section in the region $p_\mathrm{T} \in [0; 10]\,\mathrm{GeV}/c$ integrating over the rapidity range $y \in [2.5; 4]$. The ongoing analysis should lead to a first measurement with an accuracy better than 15% ignoring the effect of the unknown J/ψ polarization.

1 Introduction

The measurement of heavy quark production in hadron colliders allows probing the spectrum and dynamics of the partons of the colliding hadrons. In particular, the study of heavy quark-antiquark resonances (quarkonia), such as the $c\bar{c}$ bound state J/ψ, is interesting because these states have large production cross sections and can be produced in different spin configurations. Although J/ψ production was studied by several experiments in the past, the underlying production mechanism is still not yet completely understood.

In the comparison between experimental J/ψ observables and theoretical computations one should take into account the fact that there are three major sources of J/ψ production in pp collisions:

- direct J/ψ production,
- feed-down J/ψ from other heavier prompt charmonium states like χ_{c1} or χ_{c2},
- J/ψ from b-hadron decay chains, possibly through heavier charmonium intermediate decays.

The first two sources will be called prompt J/ψ in the following. The third source will be abbreviated as J/ψ from b.

As a first measurement with early LHC data, LHCb aims at measuring the production cross sections of J/ψ and of J/ψ from b, as a function of the J/ψ transverse momentum p_T integrating over the rapidity range $y \in [2.5; 4]$ in the pp centre-of-mass frame. The J/ψ are reconstructed in the decay mode J/$\psi \to \mu^+\mu^-$ and J/ψ from b-hadron decays are separated from prompt J/ψ using the J/ψ pseudo-propertime. The status of this analysis is reported here.

2 The LHCb detector and dataset

The study reported here uses data collected at the LHC at a centre-of-mass energy of 7 TeV between April and June 2010 with low pile-up conditions. This data sample corresponds to about 14 nb^{-1} of pp collisions. The LHCb detector is a forward detector described in detail in [1]. The analysis makes use of all LHCb detector components, except the RICH detectors. For all data included in the analysis the VELO detector was at its closed nominal position.

3 Monte-Carlo simulation

Monte Carlo samples were generated at a centre-of-mass energy of 7 TeV using a software based on the PYTHIA generator [2]. Prompt J/ψ production processes activated in PYTHIA are the Leading Order Color Singlet and Color Octet processes. Their implementation and the parameters used are described in detail in [3].

4 Selected J/ψ

4.1 J/ψ selection

In this preliminary analysis, the J/ψ candidates are formed from a pair of long tracks[1] of opposite charge with p_{T} larger than 700 MeV/c, which are required to be well reconstructed both in the tracking detectors and in the the muon stations. Both tracks must be identified as muons and of good track fit quality ($\chi^2/ndof < 4$). The two muons are required to originate from a common vertex, and only candidates giving a good quality vertex ($\chi^2/ndof < 15$) are kept. The invariant mass distribution of the muon pairs passing this selection is shown in Fig. 1.

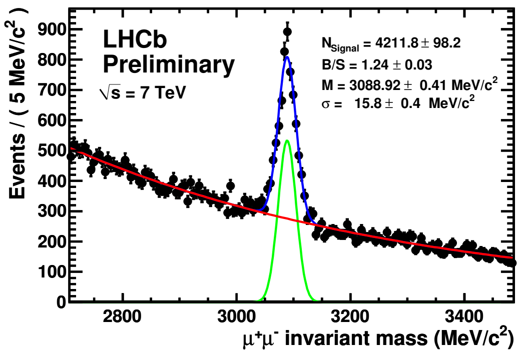

Figure 1: $\mu^+\mu^-$ invariant mass distribution

[1] A track is defined as long if it has hits reconstructed in the vertex detector and in the main tracking stations after the dipole magnet

4.2 Raw spectra

The transverse momentum and rapidity distributions of the selected J/ψ is plotted in Fig. 2, showing a softer p_{T} spectrum in the data than the one used in our simulation.

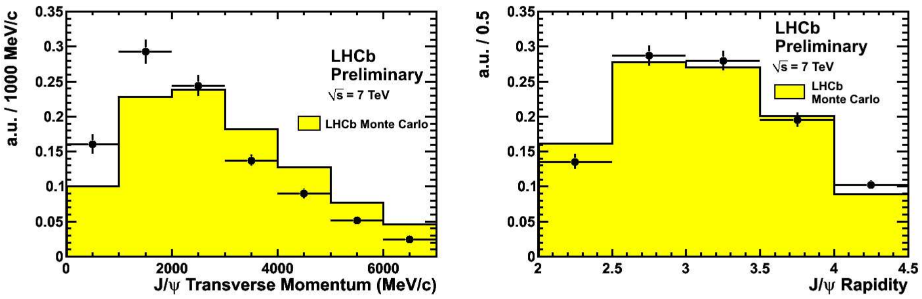

Figure 2: Transverse momentum (left) and rapidity (right) spectra for selected J/ψ (dots) and simulation (filled histogram)

4.3 Distinction between prompt J/ψ and J/ψ from b

J/ψ from b tend to be far from the primary vertex. They are separated from prompt J/ψ which are produced immediately at the primary vertex by exploiting the J/ψ proper time in the z direction. The z axis is defined along the beam axis in the LHCb frame, and is oriented from the VELO to the Muon detector. The discriminating variable (J/ψ pseudo propertime) is defined as:

$$t_z(\mathrm{J}/\psi) = \frac{d_z \times M_{\mathrm{J}/\psi}}{p_z} \tag{1}$$

where d_z is the distance along the z-axis between the J/ψ decay vertex and the primary vertex from which it originates ; p_z is the J/ψ momentum in the z direction and $M_{\mathrm{J}/\psi}$ is the nominal J/ψ mass.

The obtained distribution for J/ψ candidates is shown in Fig. 3. The plot on the right, obtained after subtracting the background using the sidebands, shows a clear signal from B hadron decays.

5 Towards the cross section determination

The cross section σ is defined as:

$$\sigma = \frac{N\left(\mathrm{J}/\psi \to \mu^+\mu^-\right)}{\mathcal{L} \times \epsilon \times \mathcal{B}\left(\mathrm{J}/\psi \to \mu^+\mu^-\right)}, \tag{2}$$

where $N\left(\mathrm{J}/\psi \to \mu^+\mu^-\right)$ is the number of observed J/$\psi \to \mu^+\mu^-$, ϵ is the J/ψ detection efficiency, $\mathcal{L}$ the integrated luminosity, and $\mathcal{B}\left(\mathrm{J}/\psi \to \mu^+\mu^-\right)$ the branching fraction of the J/$\psi \to \mu^+\mu^-$ decay.

The determination of the quantities entering Eq. 2 is ongoing. The luminosity will be determined with a 10% uncertainty using measurements of the beam profiles that exploit the high

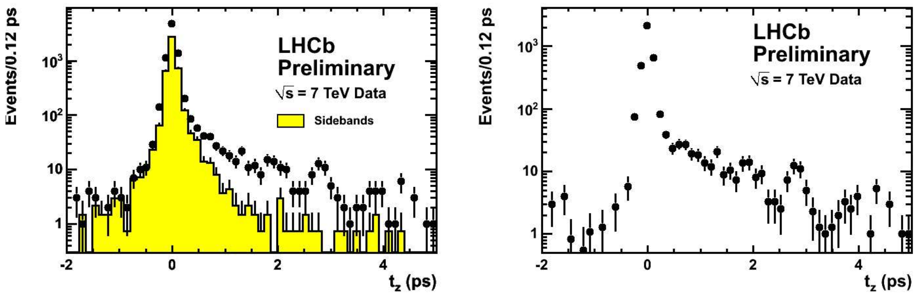

Figure 3: Left : Pseudo propertime distribution for candidates in signal (dots) and sidebands regions (filled histogram); right : pseudo proper time for signal events after sideband subtraction.

precision of the LHCb VELO. The detection efficiency factorizes the geometrical acceptance, the reconstruction and selection efficiency, and the trigger efficiency. For this first measurement, it will be estimated from simulation. The unknown J/ψ polarization yields to large uncertainties (up to 20%) on the geometrical acceptance that will be studied using simulation. The remaining systematic uncertainties will be assigned using data driven methods and are expected to be kept below 15% in total.

6 Conclusion

With a sample of $\sim 14\,\mathrm{nb}^{-1}$ of pp collisions, LHCb will measure the production cross sections of prompt J/ψ and of J/ψ from b, as a function of the J/ψ transverse momentum p_{T} integrating over the rapidity range $y \in [2.5; 4]$ in the pp centre-of-mass frame. The analysis is ongoing and shows excellent prospects. It should allow to measure the total cross section in the region $p_{\mathrm{T}} \in [0; 10]\,\mathrm{GeV}/c$ and $y \in [2.5; 4]$ with an accuracy better than 15% ignoring the effect of the unknown J/ψ polarization.

References

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