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Nuclear Physics B (Proc. Suppl.) 207–208 (2010) 355–358
NUCLEAR PHYSICS B PROCEEDINGS SUPPLEMENTS
www.elsevier.com/locate/npbps

Studies of open charm and charmonium production at LHCb

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Abstract

The first heavy flavour measurements at LHCb will concern open charm and J/ψ production. Here we report on the first experience from the 2010 LHC run and review the status of the measurements.

Keywords: LHC, LHCb, charm

1. Introduction

The LHCb detector at LHC is designed for the searches of New Physics in CP violation and rare decays. The detector is optimized for B physics studies: this is a single arm spectrometer with a polar angle coverage of approximately 15–300 and 15–250 mrad in the horizontal and vertical plane, respectively. The detailed description of the LHCb detector can be found elsewhere [1].

The production cross-sections of open charm and charmonium states at LHC are rather large, and will be measured at the very first stage of the LHC operation. These measurements test the predictions of quantum chromodynamics at the yet unexplored centre-of-mass energies. LHCb, due to its forward angular coverage, can measure these differential cross-sections in an area not accessible by other LHC experiments.

Abundant production of D mesons will allow LHCb to address important topics of charm physics.

Here we report on the first experience from the 2010 LHC run, and review the status of the open charm and charmonium production study at LHCb. The prospects for charm physics studies on 2010 data are also discussed.

2. The LHCb detector and 2010 run conditions

In 2010 the LHC accelerator is running at E_{CM}=7 TeV, gradually increasing its luminosity. By the moment of the talk, a total of 32 nb^{-1} had been delivered to LHCb, with a top instantaneous luminosity of $7{\cdot}10^{29}$cm^{-2}s^{-1}. During 2010 the LHC is expected to deliver several tens pb^{-1}, with a peak luminosity of up to few 10^{31}cm^{-2}s^{-1}.

At the LHCb design luminosity, $2{\cdot}10^{32}$cm^{-2}s^{-1}, the parameters of the trigger system will be optimized for the B-physics studies, with 10% efficiency for the prompt D-meson decays. However during the 2010 run, with lower luminosity, the bandwidth of the LHCb data acquisition system will allow to work at lower thresholds, such that the efficiency for prompt D's will be 40–50%. A significant sample of prompt D-meson decays will be collected.

3. J/ψ production studies

There are three major sources of J/ψ production in pp collisions: direct J/ψ production, feed-down J/ψ from decays of heavier prompt charmonium states like χ_{c1} or χ_{c2}, and J/ψ from b-hadron decay chains. The first two sources will be called prompt J/ψ; the third one will be referred to as secondary, or J/ψ from b.

Although prompt J/ψ production was studied by several experiments in the past, the underlying production mechanism is not completely understood. In the Color Singlet Model (CSM) [4], prompt J/ψ production occurs through the Leading Order process $gg \rightarrow J/\psi g$. However, experiments at the Tevatron have shown that the CSM under-predicts J/ψ production by two orders of magnitude [3]. In the Color Octet Mechanism (COM) [5], the $c\bar{c}$ pair is produced in a colored state, and hadronizes at long distance into a J/ψ. With proper tuning of the model's parameters, it can explain the magnitude and p_T-dependence of the measured J/ψ production cross-section, but not its polarization. In

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doi:10.1016/j.nuclphysbps.2010.10.090

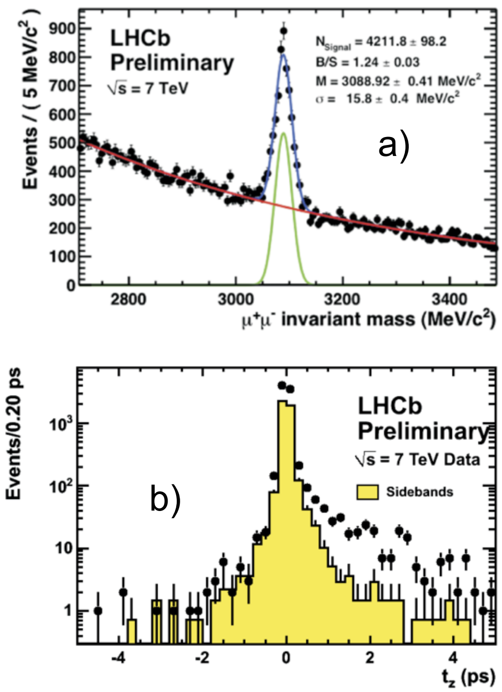

Figure 1: (a) the $\mu^+\mu^-$ effective mass spectrum; (b) the pseudo propertime distribution for the J/ψ candidates;

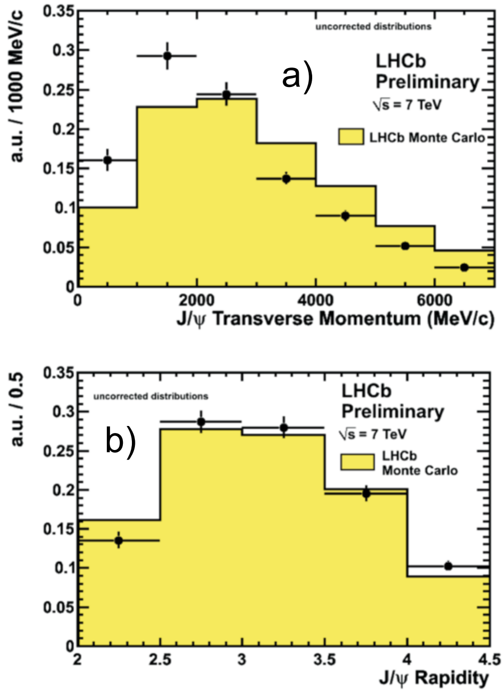

Figure 2: The p_T (a) and y (b) spectra, simulation and data superimposed.

COM the J/ψ is predominantly produced with transverse polarization at high p_T, which is in disagreement with the CDF polarization measurement [6].

In recent theoretical studies (see [7] and references therein) it was shown that the addition of higher order corrections to the CSM significantly reduces the discrepancy with the experimental data, but the agreement is still not perfect.

The LHCb analysis is based on J/ψ mesons reconstructed in the $\mu^+\mu^-$ final state. Usage of the LHCb muon identification system allows selection of J/ψ in this decay mode with low background.

The goal is to measure the cross-section of prompt and secondary J/ψ production as a function of J/ψ polarization. The measurements will be performed in the transverse momentum range $0 < p_T < 12$ GeV/c and rapidity range $2 < y < 4.5$, subdivided into 12 and 5 bins, respectively. We aim for $O(10\%)$ precision in each (p_T,y) bin.

For these preliminary studies, the data corresponding to 14 nb^{-1} was used. The Monte Carlo simulation for the analysis [8] was based on PYTHIA version 6.4 [9] with the CTEQ6 Parton Density Function set [10]. The GEANT4 package [11] (version 9.2) was used for the full detector simulation.

With loose cuts suitable for the cross-section measurement, there are $\sim 4 \cdot 10^3$ reconstructed events with $J/\psi \to \mu^+\mu^-$ decays. Their effective mass spectrum is shown in Fig.1a.

The separation between prompt J/ψ and those from b is based on the fact that the former decays immediately at the primary vertex (PV), while the latter originates from a secondary vertex displaced from PV. The discriminating variable is the pseudo propertime of the J/ψ candidates, $t_z = M_{J/\psi}\Delta z/p_z$; here Δz is the displacement of the J/ψ decay vertex from PV along the beam axis. Its distribution is shown in Fig.1b. One can see a clear evidence of secondary J/ψ production from decays of B hadrons.

The p_T and y distributions for J/ψ are shown in Fig.2a and b, respectively. Superimposed are corresponding distributions from simulation. One can see that, while there is good data-MC agreement in y, the p_T spectrum in data is somewhat softer than that in the simulation.

Full analysis will be performed with several million J/ψ decays, at (10–20) pb^{-1}. For the cross-section measurements one needs precise knowledge of the detector efficiency in the region of interest, which includes efficiency of trigger, track reconstruction and muon iden-