Studies of open heavy flavour production at LHCb

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INTRODUCTION

Measurements of the production cross-sections of heavy flavour in proton-proton collisions test the predictions of Quantum chromodynamics (QCD). As the LHCb detector [1] is a single forward spectrometer, it has unique regime in pseudorapidity η and transverse momentum p_T for production studies: η covers from 2 to 6 and p_T can go down to almost 0.

In the paper, we will discuss the LHCb measurements of the cross-sections of heavy flavour productions at a centre-of-mass energy of 7 TeV from the LHC.

$b\bar{b}$ CROSS-SECTION USING b SEMILEPTONIC DECAYS

LHCb use the $b \to D^0 X \mu^- \overline{\nu}, D^0 \to K^- \pi^+$ decays [2] to measure the $b\bar{b}$ cross-section [3]. The measurement is performed using two independent data samples with different trigger settings: minimal trigger with integrated luminosity $\mathscr{L} = 2.9$ nb^{-1} and physics trigger with $\mathscr{L} = 12.2$ nb^{-1} . We reconstruct D^0 and μ^- and require them forming a vertex and detaching from the primary vertex (PV). The primary and $D^0\mu^-$ vertexes define the pseudorapidity (η) of B meson. The prompt D^0 and the D^0 from b (Dfb) can be statistically separated by the impact parameter (IP), defined as the smallest distance between the D^0 reconstructed trajectory and the PV. Fig. 1 shows the distributions of $\ln(IP/mm)$ with (left) and without (right) the additional muon requirement.

The signal Dfb yield ($N_{\rm sig}$) is extracted by fitting the two-dimensional distributions of $K^-\pi^+$ invariant mass and $\ln(IP/mm)$. The cross-section is calculated by

$$\sigma(pp \to b\bar{b}X) = \frac{N_{\rm sig}}{2\mathscr{L} \times \text{efficiency} \times \mathscr{B}(b \to D^0 X \mu^- \overline{\nu}) \times \mathscr{B}(D^0 \to K^-\pi^+)}. \quad (1)$$

The value $\mathscr{B}(b \to D^0 X \mu^- \overline{\nu}) = (6.84 \pm 0.35)\%$ measured from LEP is used by assuming the b-hadron fractions are the same between the energies in LHC and LEP. Fig. 2 shows the measured cross-section as a function of η, compared with theoretical calculations [4, 5]. We measure $(pp \to b\bar{b}X) = (75.3 \pm 5.4 \pm 13.0)\mu$b in the interval $2 < \eta < 6$. The first error is statistical, the second systematic. The value changes to $(89.6 \pm 6.4 \pm 15.5)\mu$b if using the b-baryon fraction from Tevatron. By extrapolating to full η region using PYTHIA 6.4, we find a total $b\bar{b}$ cross-section $(284 \pm 20 \pm 49)\mu$b based on the LEP fragmentation fraction.

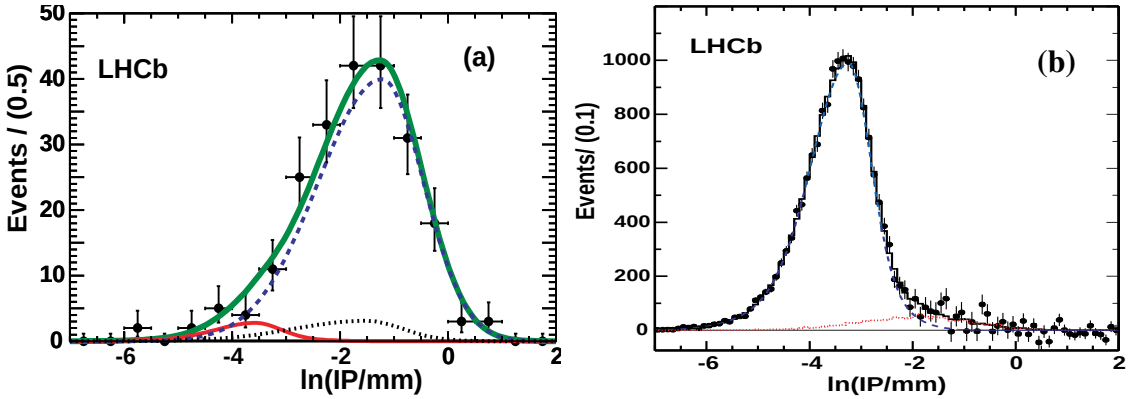

FIGURE 1. The distributions of $\ln(IP/mm)$ with from 12.2 nb^{-1} (left) and without from 2.9 nb^{-1} (right) the additional muon requirement. In (a), the dotted curve shows the D^0 sideband backgrounds, the thin solid curve the Prompt yields, the dashed curve the Dfb signal, and the thick solid curve the total. In (b), the dashed curve shows the result of the fit to the Prompt component, the dotted line the Dfb component, and the histogram the sum of the two; the background is subtracted.

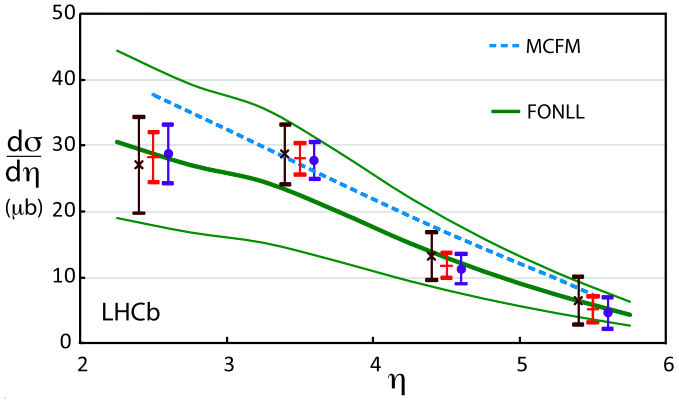

FIGURE 2. The $b\bar{b}$ cross-section as a function of η for the minimal trigger ($\times$) and triggered ($\bullet$) samples, and the average ($+$). Superimposed also theoretical predictions[4, 5].

$b\bar{b}$ CROSS-SECTION USING J/ψ

LHCb measure the $b\bar{b}$ cross-section using $J/\psi \to \mu^+\mu^-$ decays based on 5.1 pb^{-1} data [6]. The J/ψ comes from the sources: the prompt and the $J\psi$ from b. To separate them, the pseudo-proper time $t_z = \frac{(z_{J/\psi} - z_{\rm PV}) \times M_{J/\psi}}{p_z}$ is used, where $z_{J/\psi}$ and $z_{\rm PV}$ are the positions along the z-axis of the J/ψ decay vertex and of the PV; p_z is the measured J/ψ momentum in the z direction and $M_{J/\psi}$ the nominal J/ψ mass. Fig. 3 shows an example of the fits to J/ψ invariant mass and t_z distributions in the specified bin of rapidity (y) and p_T.

Fig. 4 shows the differential production cross-section of J/ψ from b as a function of y (left) and p_T (right) integrated over the other variable. Fig. 4 (right) also shows the prediction of a calculation based on the FONLL formalism [5]. This model predicts

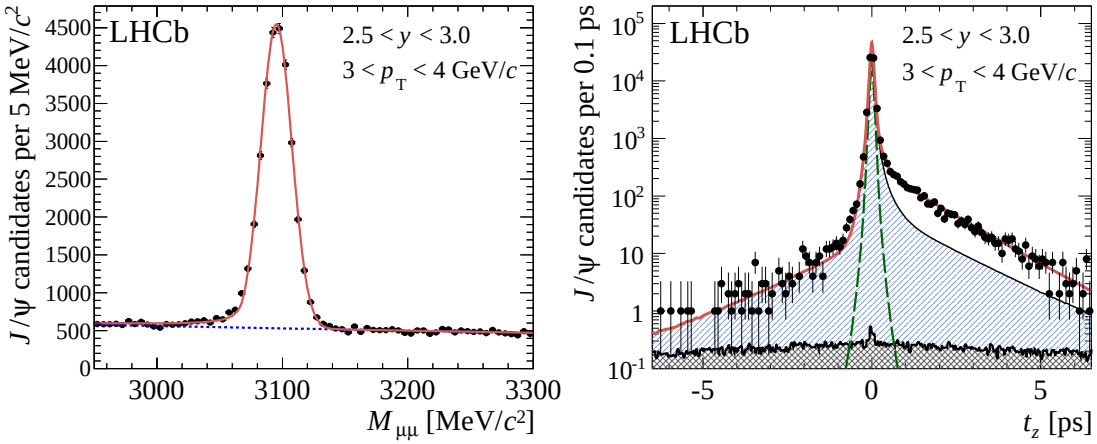

FIGURE 3. Dimuon mass (left) and t_z (right) distributions with fit results superimposed, for one bin ($3 < p_T < 4$ GeV and $2.5 < y < 3.0$). The red curves correspond to the overall fits. In the left figure, the dashed blue line represents the background. In the right figure, the green dashed line is the prompt J/ψ contribution described by a delta function at $t_z = 0$, the single-hatched area is the background component and the cross-hatched area corresponds to J/ψ associated with wrong primary vertex; the J/ψ from b component modeled by an exponential decay is not shown.

the b-quark production cross-section, and includes the fragmentation of the b-quark into b-hadrons and their decay into J/ψ mesons. The measurements show a very good agreement with the calculation.

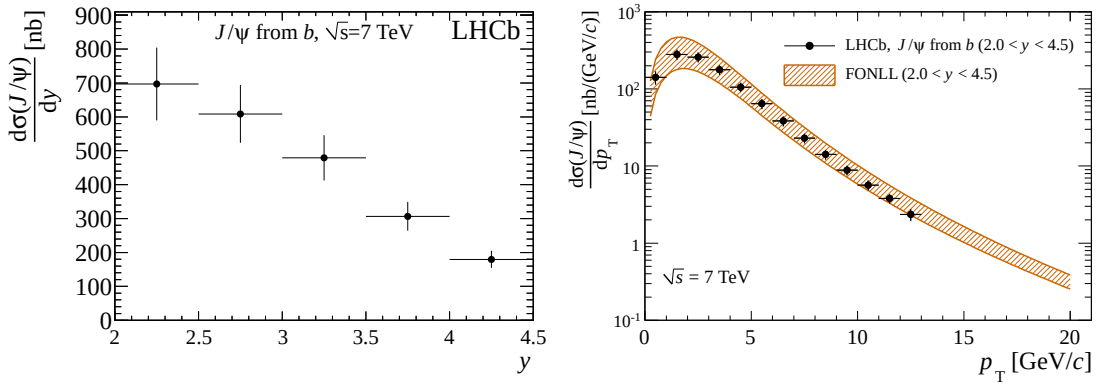

FIGURE 4. The differential production cross-section of J/ψ from b as a function of y (left) and p_T (right), superimposed theoretical prediction based on the FONLL formalism [5].

By using the branching fraction $\mathscr{B}(b \to J/\psi X) = (1.16 \pm 0.10)\%$ [7] measured from LEP and extrapolate to the full polar angle range, the total $pp \to b\bar{b}X$ cross-section is measured to be $288 \pm 4 \pm 48$ μb[6], which is consistent with the measurement using b semileptonic decays [3].

OPEN CHARM PRODUCTION

Using 1.8nb^{-1} data, LHCb give the preliminary results of the cross-sections of D^0, $D^*(2010)^+$, D^+ and D_S^+ in bins of p_T and y from $0 < p_T < 8$ GeV and $2 < y < 4.5$. As an example, Fig 5 shows the cross-sections of D^0 compared to the theoretical predictions from MC et al. [8], BAK et al. [9] and the LHCb tune of PYTHIA. The similar results for other charm mesons can be found in Ref [10]. The measurements show a very good agreement with the predictions. By summing over all charm mesons, we measure the cross-sections $\sigma(pp \to c\bar{c}X) = 1.23 \pm 0.19$ mb in $p_T < 8$ GeV and $2 < y < 4.5$ and $\sigma(pp \to c\bar{c}X) = 6.10 \pm 0.93$ mb in full p_T and y with PYTHIA extrapolation [10].

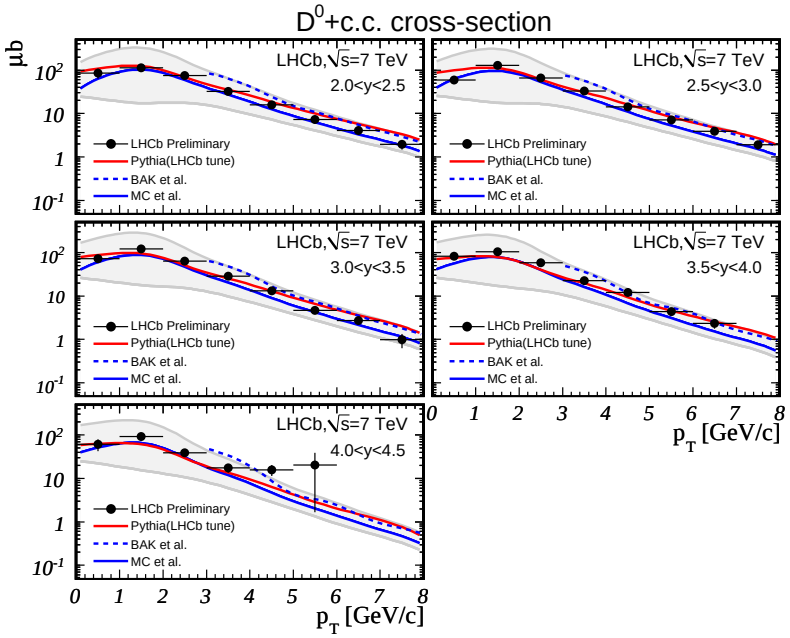

FIGURE 5. Measured D^0 cross-sections compared to theoretical prediction. Data are shown as a function of p_T for different ranges in y. The error bars show statistical and uncorrelated systematics added in quadrature. In addition, there is a global correlated error of 12% (left). The shaded areas are theoretical uncertainties of the predictions by MC et al. [8].

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