PROCEEDINGS OF SCIENCE

ATLAS results on charmonium production and B_c production and decays

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Recent results from the ATLAS experiment at the LHC on the charmonium production and on the B_c production and decays are presented. These include studies of the associated production of the J/ψ meson and W boson, the measurement of J/ψ and $\psi(2S)$ mesons differential production cross-sections, the measurement of the differential ratios of the B_c^+ and B^+ production cross-sections, and the new results on the B_c^+ decays to $J/\psi D_s^{(*)}$ final states. The results are obtained with pp collision data collected at centre-of-mass energies $\sqrt{s}$ = 8 and 13 TeV.

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1. Introduction

ATLAS detector [1] at the LHC is a multi-purpose facility, designed to study a variety of physics phenomena. In heavy flavour physics it is mainly focused on studying final states with two muons, due to the availability of corresponding triggers with relatively low muon thresholds. This proceedings contribution overviews the recent measurements of charmonium production and B_c^+ meson properties performed with pp collision data collected at 8 and 13 TeV centre-of-mass energies.

2. Charmonium production measurement

Differential production cross-section of J/ψ and $\psi(2S)$ mesons was measured with full ATLAS $\sqrt{s} = 13$ TeV dataset corresponding to an integrated luminosity of 139 fb^{-1} [2]. The measurement aimed at high-p_T charmonium production, to benefit from using high-p_T single-muon triggers.

Prompt and non-prompt J/ψ and $\psi(2S)$ mesons production cross-sections are measured in bins of the meson p_T and rapidity, as well as non-prompt fraction for both mesons and ratio between $\psi(2S)$ and J/ψ productions. The studied p_T range extends to 360 (140) GeV for J/ψ ($\psi(2S)$) meson. This is higher than in all other similar measurements to date.

Figure 1 shows a comparison of the measured non-prompt production cross-sections to the fixed-order next-to-leading-logarithm (FONLL) model [3, 4] expectation. The theory overestimates the data for J/ψ meson p_T above 100–150 GeV while the agreement for $\psi(2S)$ meson is reasonable within the available precision.

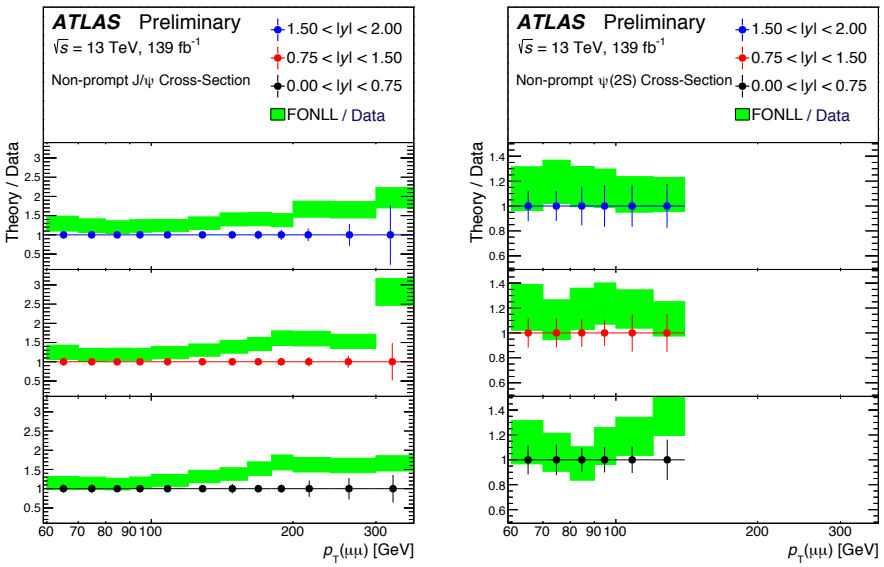

Figure 1: The ratios of the FONLL prediction to the measured differential cross-sections for non-prompt (left) J/ψ and (right) $\psi(2S)$ mesons. The green shaded bands represent the range of theoretical uncertainty associated to the variations of the scales. Figure is taken from Ref. [2].

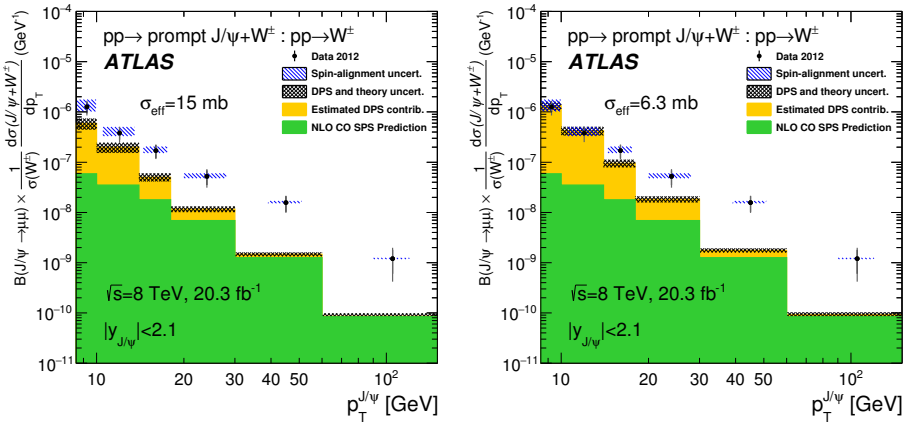

Figure 2: The measured inclusive (SPS+DPS) differential rate of associated $J/\psi + W^{\pm}$ production. NLO colour-octet SPS predictions are shown with long-distance matrix elements extracted from the differential cross-section and spin alignment of prompt J/ψ mesons at the Tevatron. The DPS contribution is estimated using (left) $\sigma_{\text{eff}} = 15^{+5.8}_{-4.2}$ mb and (right) $\sigma_{\text{eff}} = 6.3 \pm 1.9$ mb. Figure is taken from Ref. [5].

3. Associated $J/\psi + W^{\pm}$ production measurement

Associated production of J/ψ and $W^{\pm}$ boson was measured using the dataset collected at $\sqrt{s} = 8$ TeV in 2012 [5]. This process can occur via single (SPS) or double parton scattering (DPS) mechanism.

In the analysis a ratio of the associated production cross-section to that of the inclusive $W^{\pm}$ boson production is measured and the SPS contribution to the associated production is evaluated. To that end a DPS fraction is estimated based on two different measurements of effective DPS cross-section, σ_{eff}, in $W^{\pm}$+jets and double J/ψ production processes.

The remaining SPS production rate is in tension with the theory predictions made at NLO precision for colour-octet production mechanism. Figure 2 shows the comparison of the measurement with the expectation as a function of $p_{\text{T}}(J/\psi)$. Even though at low p_{T} the DPS contribution is sufficient to cover the data–theory difference if the lower σ_{eff} is assumed, for high p_{T} the discrepancy reaches an order of magnitude irrespectively to the σ_{eff} value. This may indicate a significant contribution of colour-singlet production mechanism not accounted for in the theory prediction.

4. B_c^+ meson measurements

With the same $\sqrt{s} = 8$ TeV dataset ATLAS has measured [6] a relative B_c^+/B^+ mesons production rate defined as:

$$\frac{\sigma(B_c^+)}{\sigma(B^+)} \times \frac{\mathcal{B}(B_c^+ \to J/\psi\pi^+)}{\mathcal{B}(B^+ \to J/\psi K^+)}.$$

The measurement is done inclusively as well as in two bins of the meson p_{T} or rapidity. The results are shown in Figure 3. The B_c^+ production cross-section is found to decrease with p_{T} faster than that of the B^+ production while no significant dependence of the relative rate on the rapidity is seen. The ATLAS result is consistent with one obtained by CMS in a similar kinematic range at $\sqrt{s} = 7$ TeV

and smaller than in the measurement of LHCb at lower p_{T} and higher rapidity (see corresponding references in Ref. [6]).

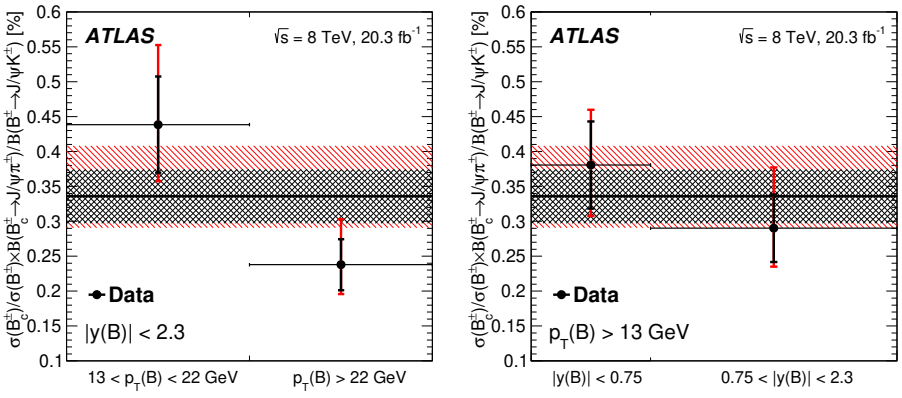

Figure 3: Production cross-section for the B_c^+ relative to the B^+ (times the corresponding branching fractions) in two bins of (left) p_{T} and (right) rapidity bins. Inner black (outer red) error bars show the statistical (total) uncertainty. For the inclusive bin, the horizontal black (red) bands show the statistical (total) uncertainty. Figure is taken from Ref. [6].

A new measurement of the branching fraction of the $B_c^+ \to J/\psi D_s^{(*)+}$ decays relative to that of the reference $B_c^+ \to J/\psi\pi^+$ decay channel was done in ATLAS with the full $\sqrt{s} = 13\,\mathrm{TeV}$ dataset [7]. To extract the signal yields and helicity composition of the $B_c^+ \to J/\psi D_s^{*+}$ decay, distributions of $J/\psi D_s^+$ system invariant mass and the J/ψ helicity angle are exploited. Projections of the corresponding 2D fit are shown in Figure 4.

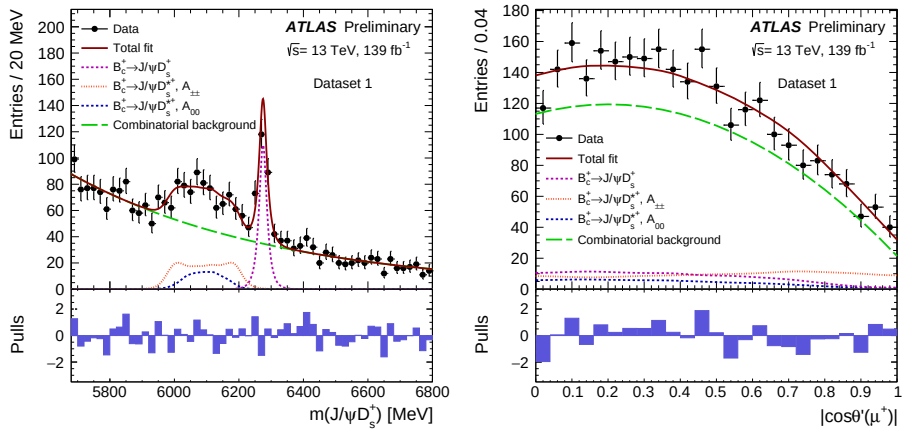

Figure 4: Distributions of (left) the $J/\psi D_s^+$ system invariant mass and (right) absolute cosine of the J/ψ helicity angle for the selected $J/\psi D_s^+$ candidates. The overall fit result is shown, as well as contributions of the $B_c^+ \to J/\psi D_s^+$ decay and different helicity components of $B_c^+ \to J/\psi D_s^{*+}$ decay signal. Figure is taken from Ref. [7].

Three ratios of branching fractions and the fraction of transverse polarization in the $B_c^+ \to J/\psi D_s^{*+}$ decay are measured and summarized in Figure 5, in comparison with results of earlier

ATLAS and LHCb measurements done with $\sqrt{s} = 7, 8$ TeV data and with relevant theory predictions. Precision of all measured quantities exceeds that in the earlier studies. Consistency of the predictions for the branching fraction ratios with data varies between the used approaches. It is worth pointing out though that the measured value of $\Gamma_{\pm\pm}/\Gamma$ agrees with the value of 2/3 expected from naive spin-counting considerations, while the dedicated calculations yield values noticeably below data.

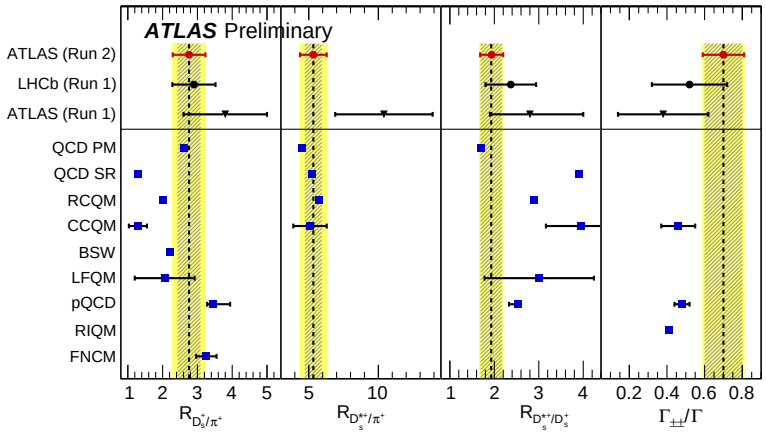

Figure 5: Comparison of the $B_c^+ \to J/\psi D_s^{(*)+}$ decays measurement results with those of ATLAS and LHCb Run 1 measurements and with various theoretical predictions (corresponding references can be found in Ref. [7]). Figure is taken from Ref. [7].

5. Summary

Recent results of ATLAS experiment on charmonium and B_c physics are highlighted in this note. These topics remain relevant and still leaves questions to be answered by further studies with the available data of the LHC experiments as well as with the data to be collected in the forthcoming run that will start in 2022.

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