Figure 2: The prompt $\eta_c$ production cross-section as a function of centre-of-mass energy. (Left) Relative $\eta_c$ prompt production cross-section. (Right) Absolute $\eta_c$ (black rectangles) and $J/\psi$ (blue circles) prompt production cross-sections. The error bars show uncertainties due to statistical, systematic, and to the knowledge of the branching fractions $B_{b\rightarrow J/\psi X}$.

which combined with $B_{b\rightarrow J/\psi X} = 1.16 \pm 0.10\%$ [?] gives

$$B_{b\rightarrow \eta_c X} = (5.51 \pm 0.32 \pm 0.29 \pm 0.77) \times 10^{-3}.$$ 

The last uncertainty includes the uncertainty on $B_{b\rightarrow J/\psi X}$. This result is the most precise measurement of the inclusive $b\rightarrow \eta_c X$ branching fraction to date and is in good agreement with the previous LHCb measurement from Ref. [?]. The measurement is limited by the knowledge of the branching fractions $B_{\eta_c\rightarrow p\bar{p}}$ and $B_{b\rightarrow J/\psi X}$.

Numerical results of the measurements of $p_T$-differential $\eta_c$ production are given in Appendix B. The relative $\eta_c$ to $J/\psi$ $p_T$-differential cross-sections for prompt and $b$-hadron decay production are compatible to those measured at $\sqrt{s} = 7$ and 8 TeV [?] and are shown in Fig. 3. This is the first $p_T$-differential cross-section measurement of $\eta_c$ prompt production at $\sqrt{s} = 13$ TeV. The $p_T$ dependence of the prompt cross-section ratio is found to be linear with a slope of $0.22 \pm 0.11$ GeV$^{-1}$. While the integrated cross-section is in good agreement with the colour-singlet model prediction [?], a hint of a difference between the $J/\psi$ and $\eta_c$ slopes motivates the extension of the measurement to larger $p_T$ values. A larger measured slope with respect to the prediction from Ref. [?] would indicate a possible colour-octet contribution. The absolute $\eta_c$ and $J/\psi$ differential production cross-sections are shown in Fig. 4. The exponential slopes for the $\eta_c$ and $J/\psi$ prompt differential cross-sections are determined from the fit to data points to be $0.41 \pm 0.07$ GeV$^{-1}$ and $0.57 \pm 0.01$ GeV$^{-1}$, respectively.

7 Measurement of the $J/\psi$–$\eta_c$ mass difference

While the prompt $\eta_c$ production measurement requires stringent selection criteria at the trigger level to compete with the challenging background conditions, charmonia produced in $b$-hadron decays are reconstructed in an environment with a controlled background level and are more suitable for a mass measurement. For this reason, a looser selection is