

Measurement of Charm and Beauty Production in Proton–Proton Collisions with CMS

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The production of charm and beauty quarks in proton–proton collisions provides an important test of quantum chromodynamics. Because their masses are large compared with the characteristic scale of QCD, their production can be calculated perturbatively. Heavy-flavour measurements can therefore test these calculations and provide input for determinations of the quark masses and the parton distribution functions of the proton, particularly at small parton momentum fractions [1, 2, 3].

In this analysis, charm and beauty production is studied through charged D^* mesons, using 40.17 nb^{-1} of proton–proton collision data recorded with the CMS detector in 2015 at $\sqrt{s} = 5.02 \text{ TeV}$ [4]. The candidates are reconstructed through the decay chain $D^{*\pm} \rightarrow D^0 \pi_s^\pm \rightarrow K^\mp \pi^\pm \pi_s^\pm$, where π_s denotes the slow pion. The small energy release in the D^* decay produces this low-momentum pion. Its charge fixes the kaon and pion assignments. The narrow mass-difference peak provides a relatively clean signal region. The characteristic decay topology allows the combinatorial background to be estimated directly from data using charge combinations that are incompatible with the signal decay, following the strategy of an earlier CMS measurement [5].

The measurement distinguishes between prompt and nonprompt D^* production. Prompt D^* mesons originate from charm-quark hadronisation, directly or through excited charm-hadron decays. Nonprompt D^* mesons originate from beauty-hadron decays. Because beauty hadrons travel a measurable distance before decaying, the displacement of the reconstructed D^0 vertex is used to separate prompt and nonprompt contributions with simulation templates. After correcting the extracted signal yields for detector acceptance, reconstruction, and selection efficiencies, double-differential production cross sections are determined as functions of transverse momentum and absolute rapidity. Prompt results cover $p_T \geq 1.5 \text{ GeV}$ and $|y| < 2.5$. The interval $1.5 \leq p_T < 2 \text{ GeV}$ is omitted for $2 < |y| < 2.5$. Nonprompt results cover $p_T \geq 2 \text{ GeV}$ and $|y| < 2$. The prompt and nonprompt results are compared with FONLL predictions [1]. The nonprompt measurement is additionally compared with an NNLO+NNLL calculation of open-beauty production [6].

The prompt CMS measurement is combined with a complementary measurement by the LHCb experiment in the forward region [7]. Together, the measurements cover a large fraction of the charm-production phase space. The remaining unmeasured regions are estimated using the data-constrained ddFONLL framework [8]. This approach combines perturbative heavy-quark kinematics with parameters constrained by data and a transverse-momentum-dependent D^* production fraction that accounts for nonuniversal charm fragmentation. The combination determines the total charm-pair production cross section, which is compared with fixed-order NNLO calculations [2, 3].

References

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