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Associated production of heavy flavors and W, Z bosons at CMS

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Summary. — The mechanism of production of heavy-flavoured jets, originated by the hadronization of b or c quarks, in association with vector bosons, W or Z, in the Standard Model is of primary importance. It allows to refine the theoretical calculations in perturbative QCD, as well as validate associated predictions from simulation. The understanding of these processes is furthermore required by Higgs and Beyond the Standard Model searches with similar final states. Using the LHC proton-proton collision data collected at a center-of-mass energy of 7 TeV by the CMS detector, measurements of the W+b, W+c, Z+b and Z+B hadrons cross sections are presented, comparing experimental data with several theoretical predictions in quantum chromodynamics.

PACS 12.38.Aw – General properties of QCD.
PACS 12.39.Hg – Heavy quark effective theory.
PACS 14.65.Dw – Charmed quarks.
PACS 14.65.Fy – Bottom quarks.

1. – W+b and W+c differential cross section at 7 TeV

The W+c production in proton-proton collisions allows to study the strange quark content of the proton. The cross section for this final state is measured using an integrated luminosity of $5\,\text{fb}^{-1}$ with the LHC center-of-mass energy of 7 TeV [1]. Events are selected requiring an isolated lepton (electron, muon) with high momentum (p_T) within the pseudorapidity (η) of $\eta < 2.1$ coming from a W boson decay. Jets originated by the hadronization of a c quark are reconstructed exploiting the decays of charmed mesons the displaced secondary vertex of the charm quark. The p_T of the c-jet is then required to be greater than 25 GeV in the pseudorapidity range of 2.5. Selected events are then combined with the integrated luminosity and the efficiency for the leptons and jets identification in order to give the cross section, after the background subtraction. Results are compared to the theoretical predictions of the next-to-leading order event generator MCFM [2]. Several PDF sets have been used including MSTW08 [3], CT10 [4], NNPDF23 [5]. Results for the combination of electron and muon final states are presented in fig. 1 (top left), showing good agreement between measured data ad the

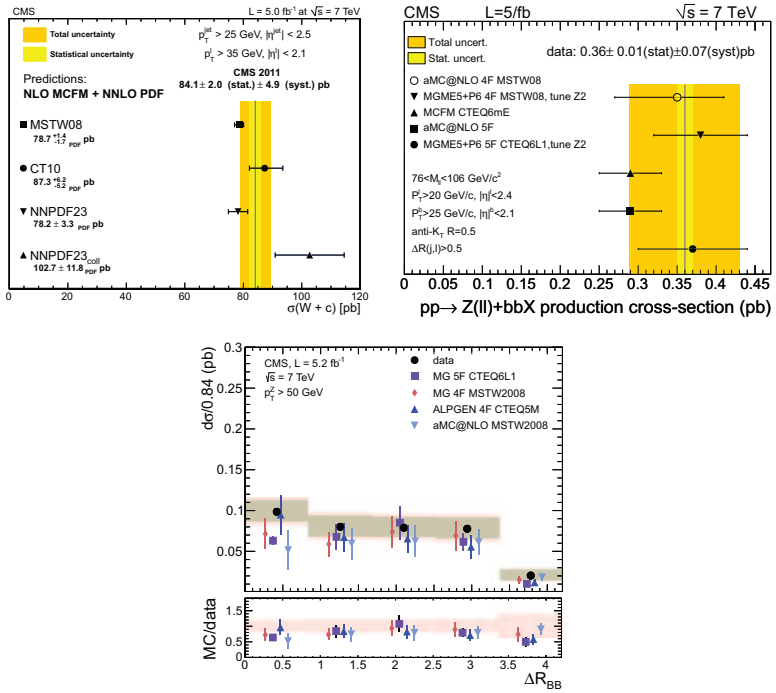

Fig. 1. – Top-left: comparison of the theoretical predictions for the W+c cross section computed with MCFM and several sets of PDFs with the average of the experimental measurements, combining the electron and muon final states. Top right: the inclusive Z+bb cross section measurement compared with the theoretical expectations of the 4 and 5 FS tree level MADGRAPH calculations, the 5FS aMC@NLO, MCFM. Measurements are presented together with the relative statistical and statistical plus systematic uncertainty. Bottom: differential Z+B hadrons cross section as a function of the Z boson momentum, compared with the 4FS and 5FS MADGRAPH event generator at tree level, aMC@NLO, ALPGEN 4FS.

theoretical predictions. The cross section is unfolded to particle level. The production of W bosons in association with b quarks is studied using proton proton collisions at 7 TeV with the CMS experiment at the LHC [6] in a data sample corresponding to an integrated luminosity of $5.0\,\mathrm{fb}^{-1}$. The W+b events are selected in the muonic decay mode requiring a muon and exactly two b-tagged jets. The measured particle-level cross section times the $\mathrm{W} \to \mu\nu$ branching ratio is $0.53 \pm 0.05(\mathrm{stat}) \pm 0.10\ (\mathrm{sys}) \pm 0.01\ (\mathrm{lumi})$ pb, in agreement with the Standard Model prediction. The unfolded cross section is compared to the NLO cross section calculated with the MCFM event generator.

2. – Z+b and Z+B hadrons differential cross section at 7 eV

The production cross section of events with Z boson decaying into two leptons (electrons and muons) in association with one or more b jets is measured at a centre-of-mass energy of 7 TeV [7] using an integrated luminosity of $5\,\mathrm{fb}^{-1}$ recorded by the CMS experiment. The Z boson is selected from isolated, high momentum dilepton pairs in the invariant mass range of 76–106 GeV within the pseudorapidity range of 2.4. The b-jets are identified by means of secondary vertex measurements. The Z+b-jets cross sections

are measured for a Z boson produced with exactly one or at least two b jets. Measured data are compared to several theoretical calculation in pQCD, and the data show agreement with the five-flavour scheme, where b quarks are assumed massless. The measured cross sections are compared with the predictions from the tree-level calculation by MADGRAPH [8] event generator rescaled to the next- to-next to leading order precision, with MSTW08 parton density function set using the PYTHIA parton shower simulation, aMC@NLO [9] and MCFM event generators. Results are presented in fig. 1 (top right). The inclusive and differential cross sections as function of the angular separation in the η-ϕ plane (ΔR) between B hadrons produced in association with a Z boson at a center-of-mass energy of 7 TeV using an integrated luminosity of $5\,\mathrm{fb}^{-1}$ is performed [10]. The B hadrons are identified through their displaced secondary vertex only, not involving jets. This allows to study B-hadron pair production without any angular restrictions. The differential cross sections as function of ΔR and as a function of the Z boson p_T are compared to several calculations made at tree-level and NLO precisions. MADGRAPH in the 4- and 5-flavour schemes, ALPGEN and aMC@NLO in the 4 flavour scheme have been used to test the pQCD calculations. The Z bosons are selected requiring two isolated charged leptons with high transverse momentum, making an invariant mass in the Z boson mass range, 81 to 111 GeV, and of two B hadrons with a transverse momentum greater than 15 GeV inside the pseudorapidity range of 2.0. The measurements of the differential cross section is presented in fig. 1 (bottom), showing the comparison between measured data and the different theoretical predictions. The cross section result shows a discrepancy in the collinear region ($\Delta R < 1$), which is dominated by the contribution of the gluon splitting process. In this region only ALPGEN describes the data, while the other predictions underestimate the cross section.

3. – Conclusions

Standard Model W, Z boson measurements in association with c jets and b jets in LHC proton-proton collision at a center of mass energy of 7 TeV with the CMS experiment have been presented. Results on the W+c process cross section, W+b jets differential cross sections, Z+b jets and Z+B hadrons have been measured and compared with different theoretical expectation from several Monte Carlo generators and PDF tunings, up to the NNLO precision in perturbative QCD when available.

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