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Differential cross section measurement of the Drell-Yan process at 13 TeV proton-proton collisions with the CMS detector

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Abstract

Measurement of the differential Drell-Yan cross sections in the dilepton decay channel is presented. It is based on proton-proton collision data at 13 TeV recorded with the CMS detector at the LHC. The differential cross section in the dilepton mass range 15 to 3000 GeV is measured and corrected to the full phase space.

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Keywords: CMS, Standard Model, Drell-Yan

1 Introduction

Drell-Yan (DY) process [1] in hadron-hadron collisions is described in the standard model (SM) by s-channel γ^*/Z exchange. Theoretical calculations of the DY differential cross section are well established up to the next-to-next-to-leading order (NNLO). Comparison between various theoretical predictions and experimental measurements provide tests of perturbative quantum chromodynamics (QCD) and effective input for constraints on parton distribution functions (PDFs). In addition, the study of DY lepton-pair production is important for various physics analysis at the Large Hadron Collider (LHC) as a background source for $t\bar{t}$ and diboson measurements, as well as for searches of new physics beyond the SM.

A measurement of DY differential cross section $d\sigma/dm$ where m is the invariant mass of the dilepton pair is presented [2] in dimuon channel in the mass range $15 < m < 3000$ GeV using an integrated luminosity of 2.8 fb^{-1} of proton-proton collision data collected using the Compact Muon Solenoid (CMS) detector [3] at the LHC at $\sqrt{s} = 13$ TeV. The measured differential cross section is obtained using the following formula:

$$\sigma = \frac{N_u}{A \cdot \epsilon \cdot \rho \cdot L_{int}} \quad (1)$$

where N_u denotes the signal yield obtained after subtracting the backgrounds and applying an unfolding technique [4] to the background subtracted data in order to correct for bin-to-bin migration effect due to detector resolution and

final-state Quantum electrodynamics radiation (FSR) effect. A and ϵ denote the acceptance and efficiency for signal events and are obtained from MC simulation. In addition, ρ is the scale factor which accounts for the difference in the efficiency between data and MC. L_{int} is the integrated luminosity corresponding to 2015 dataset.

The events are collected using an isolated single muon trigger with $p_T > 20$ GeV. The muons are required to pass the standard CMS muon identification and quality control criteria. The leading muon p_T in the event is required to have $p_T > 22$ GeV and subleading muon $p_T > 10$ GeV. The muons should be within the acceptance of the muon system ($|\eta| < 2.4$). The two muons are required to have opposite charge and in case of more than one muon pair in an event, the one with smallest χ^2 for the dimuon vertex is selected. At least one of the two muons selected in each event should match the HLT trigger object. The $d\sigma/dm$ measurement is performed in 43 dilepton invariant mass bins. The edge of mass bins is identical to the previous measurement [5] performed at $\sqrt{s} = 8$ TeV. The highest mass bin is extended to 3000 GeV considering the highest mass event observed in the dataset to be 2.3 TeV. The systematic uncertainties from different sources [2] are obtained in each mass bin. The dominant uncertainty vary depending on the mass range from 15 to 3000 GeV.

2 Results and Discussion

The DY differential cross section in the full phase space is measured after applying all the corrections discussed in the previous section. The cross section is presented as a function of dimuon invariant mass in the range of 15 to 3000 GeV. The results are compared to the NNLO theoretical prediction in Figure 1 (left) which are calculated using FEWZ 3.1 [6] with NNPDF3.0 [7] and NLO EW correction as well as MADGRAPH5_AMC@NLO [8] predictions with NNPDF3.0 (NLO). The ratio between data and theoretical prediction is shown in the middle and bottom plots, where red colour denotes total uncertainty which is the combination of statistical, systematical, theoretical and luminosity uncertainties. The band with purple colour denotes statistical uncertainty only.

In addition to the fully corrected DY differential cross section measurement, the fiducial cross section within the detector acceptance and without FSR correction is produced. Figure 1 (right) shows the results compared to the NLO prediction by MADGRAPH5_AMC@NLO. The ratio between data and theoretical prediction is shown in the bottom plot, where red colour denotes the total uncertainty and the band with purple colour denotes statistical uncertainty only.

3 Summary

A measurement of the DY differential cross section $d\sigma/dm$ is presented in the dimuon channel in the mass range $15 < m < 3000$. The measurement is performed with 2.8 fb^{-1} of proton-proton collision data collected using the CMS detector at the LHC at a center-of-mass energy of $\sqrt{s} = 13$ TeV. The results

Fig. 1: The DY differential cross section measurement as a function of dimuon invariant mass is shown for the full phase space (left) and the fiducial phase space (right) [2]. Overlaid on the left panel are the NNLO theoretical prediction of FEWZ (red) and the NLO prediction of MADGRAPH5_AMC@NLO (green) with FSR correction, while on the right the NLO theoretical prediction using MADGRAPH5_AMC@NLO is shown at particle level.

are corrected for detector resolution effect resulting in event migration between mass bins, efficiency which considers the difference between data and MC simulation, acceptance to take into account the coverage of CMS detector and FSR effects dominant below the Z peak region. The results are in good agreement with the SM theoretical predictions at NNLO predictions calculated with FEWZ and NLO predictions calculated with MADGRAPH5_AMC@NLO.

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