Measurement of the Drell–Yan differential cross section with the CMS detector at the LHC

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1 Introduction

The production of lepton pairs in hadron-hadron collisions via the Drell–Yan (DY) process is described in the standard model (SM) by the s-channel exchange of γ^*/Z. Theoretical calculations of the differential cross section $d\sigma/dM$ and the double-differential cross section $d^2\sigma/dMdY$, where M is the dilepton invariant mass and Y is the absolute value of the dilepton rapidity, are well established up to the next-to-next-to-leading order (NNLO). Comparisons between calculations and precise experimental measurements provide stringent tests of perturbative quantum chromodynamics (QCD) and constraints on the parton distribution functions (PDFs). Furthermore, the production of DY lepton pairs constitutes a major source of background for various physics analyses, such as $t\bar{t}$ and diboson measurements, as well as for searches for new physics beyond the standard model, such as production of high mass dilepton resonances. We present measurements of the differential DY cross section $d\sigma/dM$ in the dimuon and dielectron channels and the double-differential cross section $d^2\sigma/dMdY$ in the dimuon channel. The measurements are performed with the full 2011 dataset corresponding to an integrated luminosity of 4.5 fb^{-1} of proton-proton collisions collected with the Compact Muon Solenoid (CMS) [1] detector at the Large Hadron Collider (LHC) at a centre-of-mass energy of $\sqrt{s} = 7$ TeV.

2 Analysis

The analysis is based on data samples selected by di-lepton triggers. The events in the dimuon channel are triggered by two muons, where each muon track is matched to a silicon tracker track. Asymmetric muon p_T-thresholds of 8 and 13 GeV are applied. Muons are required to pass the standard CMS muon identification and quality criteria, based on the number of hits found in the tracker, the response of the muon chambers, and a set of matching criteria between the muon track parameters as determined by the inner tracker section of the detector and as measured in the muon chambers.

In order to reduce the fraction of muon pairs from (different) light-meson decays a common vertex for the two muons is fitted and the event is rejected if the dimuon vertex χ^2 probability is smaller than 2. The events in the dielectron channel are triggered by two electrons with minimum E_T requirements of 17 GeV for one of the electrons and 8 GeV for the other. Energy-scale corrections are applied to individual electrons and each electron candidate is required to be consistent with a particle originating from the primary vertex in the event. Electron identification criteria based on shower shape and track-cluster matching are applied to the reconstructed candidates. Electrons originating from photon conversions are rejected by eliminating those electrons for which a partner track consistent with a conversion hypothesis is found, and requiring no missing hits in the pixel detector. Isolation requirements are imposed on muons and electrons.

The differential $d\sigma/dM$ cross section measurements are performed in 40 mass bins. The double-differential cross section measurement is performed in 6 dimuon invariant mass bins. For each mass bin, 24 bins of absolute dimuon rapidity are defined, except for the highest mass bin, where only 12 absolute dimuon rapidity bins are used.

The main backgrounds at high dilepton invariant masses are caused by $t\bar{t}$ and diboson production, while at invariant masses below the Z peak, DY production of $\tau^+\tau^-$ pairs becomes the dominant background. At low dimuon invariant masses, most background events are QCD multijet events. At low dielectron invariant masses, most background events are from $\tau^+\tau^-$ and $t\bar{t}$, whilst the contribution from QCD is small. For the dimuon channel, the electroweak and $t\bar{t}$ backgrounds are evaluated through simulation studies, expected to provide a good description of the real contributions. In contrast, the QCD background is evaluated from data. The background estimation is performed with the same methods [2]. There are two categories of dielectron backgrounds: the first category contributes candidates composed of two genuine electrons and the second contributes candidates in which at least one particle is a misidentified electron. We estimate the contribution from these processes with a sample of $e^\pm\mu^\mp$ events having the same physical origin. The genuine dielectron background from WZ and ZZ production is estimated from simulation. The misidentified electron backgrounds originate from QCD multijet and W+jet events.

The reconstructed dilepton invariant mass spectra are first corrected for acceptance (in case of the $d\sigma/dM$ measurement) and detector efficiencies. Then the corrected spectra are altered by a bin-by-bin final state electromagnetic radiation (FSR) correction factor which relates the yields before and after the FSR takes place. The effects of the detector resolution on the observed dilepton spectra are corrected through an unfolding procedure [2]. The trigger, reconstruction and identification efficiency is estimated using clean samples of muon pairs in the Z peak. To describe the observed efficiency variations between data and simulation, efficiency correction factors are obtained in bins of p_T and η as the ratio of the efficiencies measured with data and with the simulated events.

3 Results

In order to reduce systematic uncertainties, the Drell-Yan differential cross section is normalized to the cross section in the Z peak region ($60 < M < 120$ GeV). The result of this measurement in the full phase space is presented in Fig. 1. The $d\sigma/dM$ measurement is in agreement with the NNLO theoretical predictions, as computed with FEWZ [3] using the MSTW2008 PDFs.

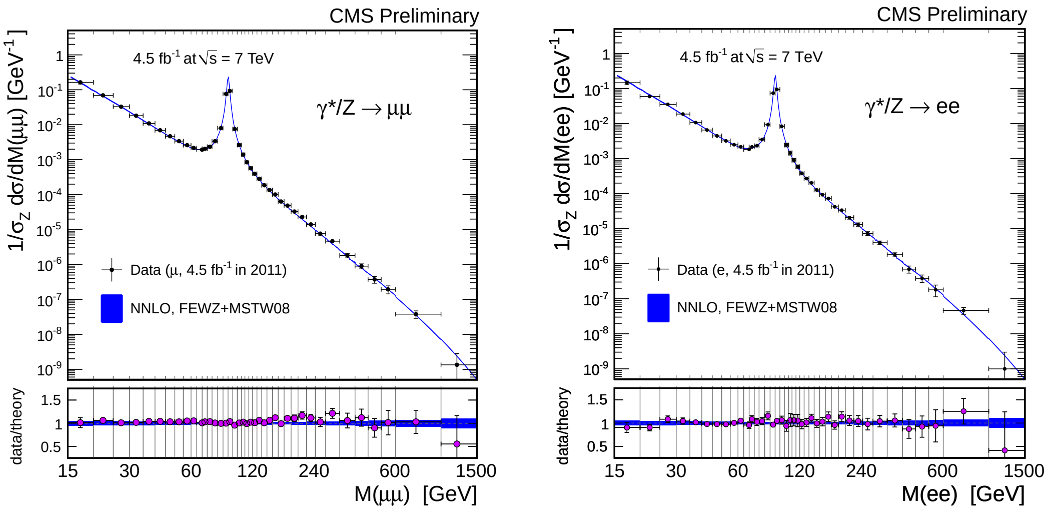

Figure 1: The Drell-Yan invariant mass spectrum, normalized to the Z resonance region, as measured and as predicted by NNLO calculations, for the full phase space in the dimuon channel (left) and the dielectron channel (right).

The result of the double-differential cross section measurement within the detector acceptance is presented in Fig. 2. The measurement is compared to the POWHEG NLO [4] prediction calculated with CT10 PDFs and the NNLO theoretical predictions as computed with FEWZ [3] using the MSTW2008 PDFs.

References

[1] S. Chatrchyan *et al.* (CMS collaboration), JINST **3**, S08004 (2008).

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[4] S. Alioli, P. Nason, C. Oleari *et al.*, JHEP **07** (2008) 060.

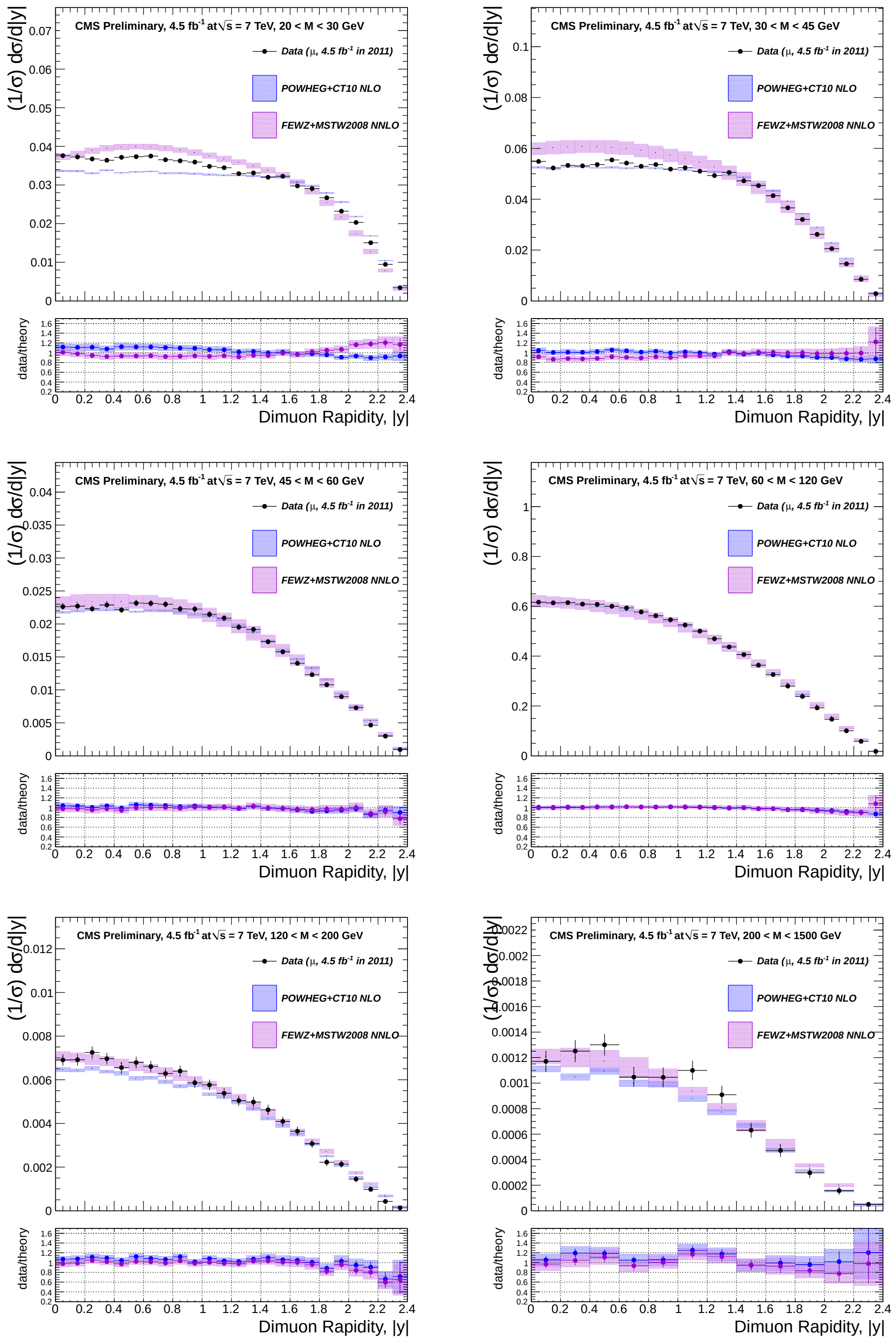

Figure 2: The Drell-Yan rapidity-invariant mass spectrum within the detector acceptance in the dimuon channel, normalized to the Z resonance region.