The Compact Muon Solenoid Experiment

Conference Report

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Single and Double differential Drell-Yan cross section measurements using the CMS detector

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Abstract

The neutral current Drell-Yan (DY) process, $q\bar{q} \rightarrow Z/\gamma^* \rightarrow \mu^+ \mu^-$, is one of the best-studied benchmark physics processes at the LHC. The large production cross section and the experimentally clean final state allows excellent tests for perturbative Quantum Chromodynamics (QCD). A thorough understanding of the transverse momentum(q_T) spectra of the vector bosons at hadron colliders is essential for a future high precision measurement of the mass of the W boson. However the measurements at LHC are limited due to the resolution in the measurement of momenta of the daughter leptons, electron and muon, in particular. The phistar (ϕ^*) variable, which uses the angular correlation of the lepton pairs from Z decay to probe the transverse momenta the vector boson, has intrinsically better resolution and less sensitivity to experimental systematic uncertainties compared to q_T . Results from differential cross-measurements as function of the ϕ^* variable will be presented in this talk.

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1 Introduction

The Drell-Yan (DY) [1] events is the best studied physics process at the Large Hadron Collider (LHC) due to very clean final state of a pair of isolated and opposite sign leptons. The total and differential cross sections, for the DY process have been calculated up to the next-to-next-to-leading-order (NNLO) in the perturbation theory. At the LHC, the measured cross section as a function of the accessible dilepton invariant mass varies over about 9 orders of magnitude and it matches the prediction within few percent. A thorough understanding of the origin of the transverse momentum (p_T) of the vector bosons is essential for future high precision measurement of W-mass. In recent years, a new variable ϕ^* [2] has been proposed which utilizes the angular correlation among the leptons as a measure to probe p_T . The first measurement of the differential cross section $d\sigma/d\phi^*$ in the CMS experiment at $\sqrt{s} = 8$ TeV is presented [3]. The rapidity dependence of this distribution is measured in terms of a double-differential cross section $d^2\sigma/d\phi^*d|y|$ and is reported here.

2 Analysis Strategy

The work presented in this paper is based on single muon data collected by the CMS[4] experiment during the 2012 run corresponding to the total integrated luminosity of 19.7 fb^{-1} . The simulation samples are used to model the signal (DY) and various background processes. The hard-scatter part of signal and some of the dominant background processes have been generated using matrix element (ME) calculations: either MADGRAPH [5] at leading order(LO) or POWHEG [6] at next-to-leading-order (NLO).

The online di-muon event selection is done using inclusive single-muon trigger requiring $p_T > 24 \text{ GeV}$ and muon rapidity ($|\eta| < 2.1$). For muon reconstruction, Particle Flow Algorithm is used, which relies on an optimised combination of information from the various elements of the CMS detector. Reconstructed muon candidates are then required to satisfy CMS recommended identification and isolation selection criteria. The oppositely charged dimuon events with invariant mass in the range $60 < M_{\mu\mu} < 120 \text{ GeV}$ are retained, in which one muon, consistent with the trigger, satisfies $p_T > 30 \text{ GeV}$ and $|\eta| < 2.1$, while the other has $p_T > 20 \text{ GeV}$ and $|\eta| < 2.4$. For data simulation comparison, various correction factors are applied on both the data and simulated samples.

The event selections described above leads to a very pure Z-boson events, with less than 0.1% background contamination, as shown in Fig 1 [3]. The inclusive production of $t\bar{t}$ and dibosons production are the major background processes and are estimated from the simulation. After the removal of estimated background by bin-by-bin subtraction, the data is unfolded from the reconstructed distribution to the true produced ϕ^* distribution. The variation of reconstructed ϕ^* as function of generated ϕ^* is of the order of 1% for 1-dimensional case. For the two dimensional unfolding, 216 bins has been defined corresponding to 36 ϕ^* bins and 6 $|y|$ bins and the bin-migration is of the order of 6%.

Fig. 1. Distributions of ϕ^* in dimuon channel[3]. The data are represented by points and the shaded histograms show the simulation normalised according to the theoretical cross sections and the luminosity.

3 Results and Discussion

The measured cross sections are compared with three different theoretical predictions : (i) ResBos [7], (ii) POWHEG interfaced with PYTHIA6 and (iii) MADGRAPH. The total cross sections for the theoretical predictions, except for ResBos, are scaled to the value from FEWZ. The uncertainty of the data distribution is dominated by the fully correlated uncertainty on the integrated luminosity (2.6%) of the data sample. The uncertainty on the MADGRAPH distribution is dominated by the PDF uncertainty of the FEWZ calculated on the cross-section. For POWHEG the uncertainty is dominated by the PDF uncertainty calculated by varying the CT10 PDF.

The absolute and normalised cross sections measured in the dielectron and dimuon channels are combined using the best linear unbiased estimator (BLUE) [8]. None of the predictions matches the measurements perfectly for the entire range of ϕ^* covered in this analysis. Figure 2 [3] shows MADGRAPH provides best description with a disagreement of at most 4% over the entire range. ResBos successfully describes the data at low ϕ^* and has a disagreement up to 9% for $\phi^* > 0.1$. POWHEG interfaced with PYTHIA6 provides the least accurate prediction, with a disagreement up to 8% for $\phi^* < 0.1$ and up to 18% for $\phi^* > 0.1$.

Fig. 2. The measured single (left) and double (right) differential cross sections after BLUE combination[3].

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