Measurement of Z $\rightarrow \mu^+\mu^-$ cross section in pp collisions at $\sqrt{s} = 13$ TeV

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A measurement of Z $\rightarrow \mu^+\mu^-$ cross section in pp collisions at $\sqrt{s} = 13$ TeV is presented. Muon final states are analyzed in a data sample collected with the CMS detector corresponding to an integrated luminosity of 593 pb^{-1}. The measured cross section is $\sigma(Z \rightarrow \mu^+\mu^-) = 1844 \pm 4(stat.) \pm 184(lum.)$ pb for dimuon mass in the range of 60 to 120 GeV. The measured values agree with next-to-next-to-leading order QCD cross section calculations.

I. INTRODUCTION

Z boson is a particle which mediate the weak interaction. The production of Z bosons in pp collisions is mainly via the weak Drell-Yan process [1]. Z boson immediately decays into lepton-antilepton pairs. Cross section of $Z \rightarrow \mu^+\mu^-$can be measured by reconstructing muon data from the CMS detector.

Theoretical prediction are available at next-to-next-leading order (NNLO) [2–6] in perturbative quantum chromodynamics (QCD). Precise measurements of $Z \rightarrow \mu^+\mu^-$ cross section provide tests of perturbative QCD and validate the theoretical prediction s of higher-order corrections. Monte Carlo simulation method is used for theoretical prediction.

II. THE CMS DETECTOR

The Compact Muon Solenoid (CMS) detector is a multi-purpose apparatus due to operate at the Large Hadron Collider (LHC) at CERN. CMS contatins a silicon pixel and strip tracker, an electromagnetic calorimeter (ECAL), a hadron calorimeter (HCAL), superconducting solenoid, and a muon detector. The solenoid provides 3.8T magnetic field and this bends muon trajectory oppositely inside and outside. Muons are detected from silicon pixel and strip tracker, and muon detector.

Muons are detected in the pseudorapidity window $|\eta| < 2.4$. Three technologies are used for detecting muons: drift tubes, cathode strip chambers, and resistive plate chambers. [7]

III. ANALYSIS

Z boson candidates are required to have reconstructed dimuon mass between 60 and 120 GeV. Because of the high rate of collisions and limited bandwidth for data processing, data must be selected by triggers for making rapid decisions. Muons are triggered by $p_T > 20$ GeV and $|\eta| < 2.4$ with isolation requirement. Muons are reconstructed from seed tracks in the muon detector with silicon pixel and strip tracker.

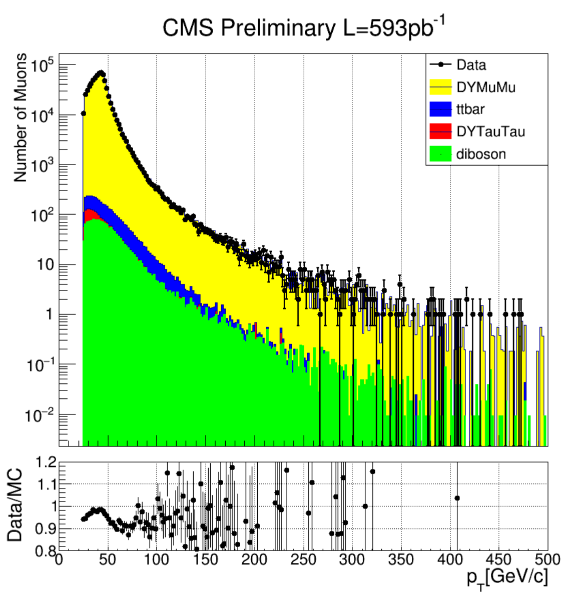

FIG. 1. Transverse momentum distributions for muons in Z boson candidates.

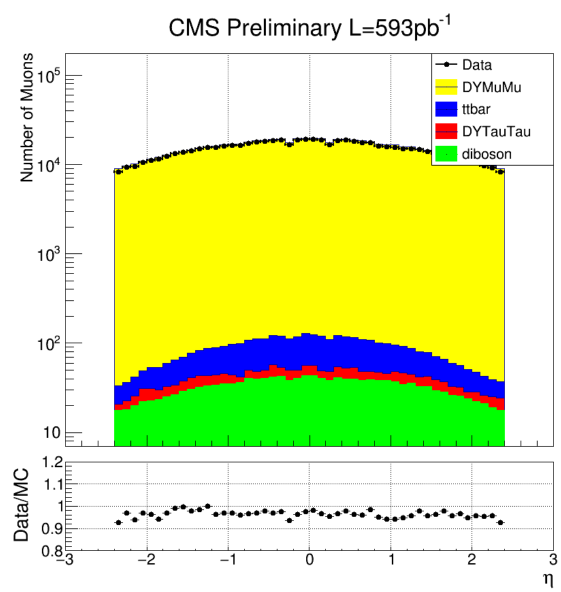

FIG. 2. Pseudorapidity distributions for muons in Z boson candidates.

The muon data samples are from Run2015C to Run2015D (from Aug. 2015 to Oct. 2015) and integrate luminosity $L = 593\ pb^{-1}$. Muons are selected online by a single-muon trigger. Monte Carlo (MC) simulated samples are used to calculate acceptance efficiencies.

For muon identification, following selection cut are applied. Muon candidates can be reconstructed by two different ways. One is tracker muons, which starts from inner-tracker information, and another is global muons, which starts from segments in the muon chambers. Muon candidates must be reconstructed as a global muon and particle flow muon. Signals require $\chi^2/N_{dof} < 10$, where N_{dof} is number of degree of freedom of global muon track fit. Also at least one muon chamber hit is included in global muon track fit. Muon segments should be at least two muon stations. Tracker track has transverse impact parameter $d_{xy} < 2mm$ with respect to the beam axis, and has longitudinal distance with respect to the primary vertex is $d_z < 5mm$. At least one pixel hits and 6 tracker layers hits are required. Track isolation value $(\Sigma_{tracks} p_T)/p_T$is less than 0.10. Total selected events of data are shown on Table I.

The acceptance is defined as the fraction of simulated Z signal events with $p_T^{gen} > 25\ GeV$ and $|\eta^{gen}| < 2.4$, and $60 < m_{inv} < 120\ GeV$ divided by the total number of signal events in the same mass range. The efficiency of the selection is ratio of the number of selected muon pairs from the total accepted events. The acceptance and efficiency calculated fromthe MC simulated events is $A = 0.3590 \pm 0.0002$, $\epsilon = 0.8580 \pm 0.0007$. Background processes include $Z \to \tau^+\tau^-$, $t\bar{t}$, and diboson production. They are able to produce two muons which satisfies the selection cut. NLO MC samples are used to estimate background contributions and normalized to compare in same integrated luminosity with the data samples.

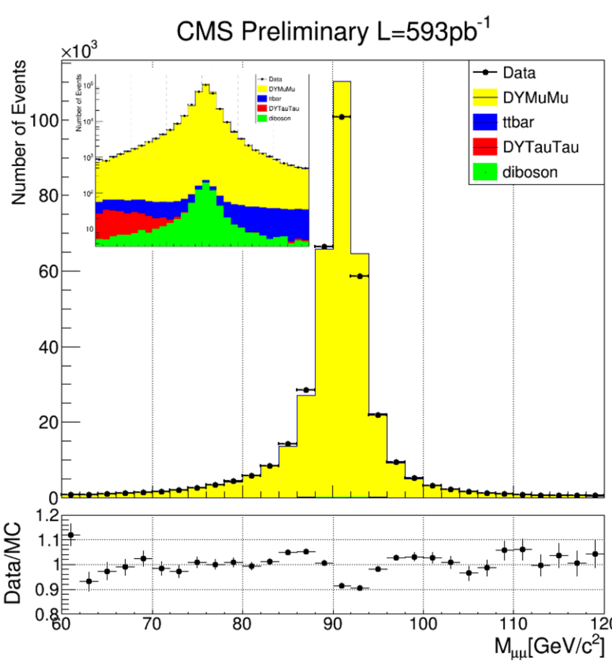

FIG. 3. Dimuon mass distribution for Z boson candidate events in the muon final state.

TABLE I. Theoretical and measured $Z \to \mu^+\mu^-$ cross sections.

Channel	N_{sig}	$\sigma[pb]$	NNLO [pb]
$Z \to \mu^+\mu^-$	336569	$1844 \pm 4(stat.) \pm 184(lum.)$	1868

IV. RESULTS

The cross section for $Z \to \mu^+\mu^-$decays can be expressed as:

$$\sigma(Z \to \mu^+\mu^-) = \frac{N_{sig}}{A \cdot \epsilon \cdot L} \tag{1}$$

N is number of total process events producing two muons in data (Table I). Background contributions are subtracted from N to measure $Z/\gamma^* \to \mu^+\mu^-$. While $\gamma^* \to \mu^+\mu^-$ is 3 % of total Drell-Yan process, N_{sig} is 97% of measured events. A is acceptance , ϵ is efficiency and L is integrate luminosity. Calculated with this equation, measured cross section and uncertainties of $Z \to \mu^+\mu^-$ are shown in Table I. It is in agreement with theoretical calculation.

V. CONCLUSIONS

Measurements of $Z \to \mu^+\mu^-$ production cross sections is carried out using a data sample of pp collision events at$\sqrt{s} = 13\ TeV$ collected with the CMS detector at the LHC in 2015 and corresponding to an integrated luminosity of 593 pb^{-1}. MC simulation samples are used to estimate acceptance, efficiency and background estimations. The cross section results are consistent with the NNLO theoretical calculation.

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