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W and Z boson production at CMS in pp collisions at sqrt(s)=7 TeV

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The first measurements of inclusive W and Z production cross sections in muon and electron decay channels at $\sqrt{s} = 7$ TeV are reported, obtained using 198 nb^{-1} of pp collisions in the Compact Muon Solenoid (CMS) detector at the Large Hadron Collider (LHC). The measured inclusive cross sections are $\sigma(\mathrm{pp} \to \mathrm{W}+X \to \ell\nu+X) = 9.22 \pm 0.24(\mathrm{stat.}) \pm 0.47(\mathrm{syst.}) \pm 1.01(\mathrm{lumi.})$ nb, and $\sigma(\mathrm{pp} \to \mathrm{Z}(\gamma^*)+X \to \ell^+\ell^- +X) = 0.882^{+0.077}_{-0.073}(\mathrm{stat.})^{+0.042}_{-0.036}(\mathrm{syst.}) \pm 0.097(\mathrm{lumi.})$ nb, limited to the di-lepton invariant mass range: $[60, 120]$ GeV$/c^2$. The luminosity-independent cross section ratios are $\sigma(\mathrm{pp} \to \mathrm{W}+X \to \ell\nu+X)/\sigma(\mathrm{pp} \to \mathrm{Z}(\gamma^*)+X \to \ell^+\ell^- +X) = 10.46^{+0.99}_{-0.88}(\mathrm{stat.})^{+0.65}_{-0.56}(\mathrm{syst.})$ and $\sigma(\mathrm{pp} \to \mathrm{W}^+ +X \to \ell^+\nu+X)/\sigma(\mathrm{pp} \to \mathrm{W}^- +X \to \ell^-\overline{\nu}+X) = 1.51^{+0.08}_{-0.07}(\mathrm{stat.}) \pm 0.04(\mathrm{syst.})$. The measured values agree with NNLO QCD cross section calculations and current parton distribution functions. Measurements of the W lepton charge asymmetry in three bins of pseudorapidity are also reported.

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1. Introduction

This note describes the first measurement by the CMS experiment of the inclusive production of W and Z bosons, observed via their decay to electrons and muons. The production of W and Z bosons is an important measurement at the LHC as the leptonic decays are simultaneously a benchmark for lepton identification and reconstruction, a precision test of perturbative QCD and the parton distribution functions of the proton (PDFs), and an important background for many searches for new physics planned at the LHC. Precise QCD calculations for the production of W and Z bosons at the LHC are available to next-to-next-to leading order (NNLO) in the strong coupling α_{S}, which provide predictions with a few percent uncertainty [1][2] when combined with recent NNLO PDFs.

The study uses 198 nb^{-1} of proton collisions collected at $\sqrt{s} = 7$ TeV in the 2010 LHC run using the CMS detector. A detailed description of CMS and its performance can be found in Ref. [3]. The systematic uncertainty on the luminosity is currently 11% [4]. Several large samples of simulated events are used to evaluate signal and background efficiencies and to validate the analysis techniques. Further details, including the event generation and simulation processes used for this analysis, are available in Ref. [5].

2. Lepton Identification

The muon identification strategy followed in this note is based on both the muon detectors and the inner tracker. Events are recorded online using the Level-1 and HLT muon triggers, with an HLT threshold of $p_{\mathrm{T}} > 9$ GeV$/c$ in the region $|\eta| < 2.1$. Muon identification requirements ensure good consistency between the measurements of the muon detector and the inner tracker and suppress muons from decay-in-flight of hadrons as well as shower punch-through. These backgrounds can be further suppressed by summing the transverse energy or momentum from objects nearby the muon (within $\Delta R < 0.3$). More stringent requirements are applied to muons in W events than in Z events, where the presence of two leptons very effectively suppresses background.

Electrons are identified as clusters of ECAL energy deposits matched to tracks from the silicon tracker. Events are recorded using the Level 1 and HLT electromagnetic trigger, with an HLT threshold of $E_T > 15$ GeV. ECAL clusters are required to have $E_T > 20$ GeV and to match tracks using an algorithm which accounts for possible energy loss due to bremsstrahlung in the tracker layers. Particles misidentified as prompt electrons are suppressed by requiring a narrow ECAL cluster width in η and by imposing limits on the sums of calorimeter E_T and track p_T in a cone of $\Delta R < 0.3$ around the electron candidate direction.

3. W Signal Extraction

For the W signal, the measurement of the missing transverse energy in the event is a crucial element of the analysis. For the results presented in this note, the missing transverse energy is reconstructed using the particle-flow technique, which uses both calorimeter measurements of energy and input from the tracking detector. The technique attempts to perform particle identification and therefore corrects and improves the resolution depending on specific particle assumptions.

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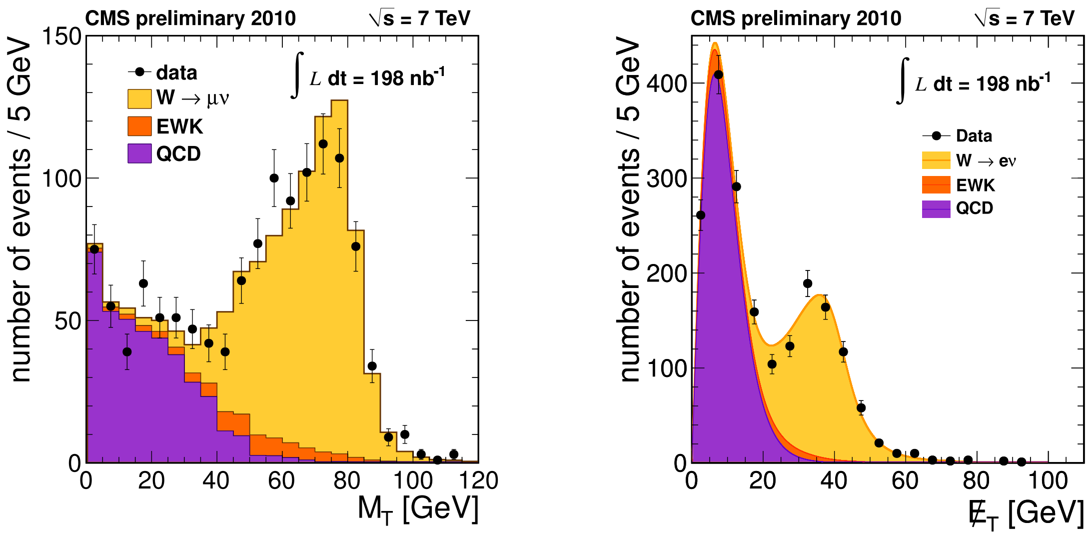

Figure 1: Distribution of M_T for the selected $\mathrm{W} \to \mu\nu$ (left) and distribution of $E_{\mathrm{T}}^{\mathrm{miss}}$ for $\mathrm{W} \to e\nu$ (right) candidates in data. Superimposed are simulated estimates of the background and signal components from the fitting procedure, normalized to 198 nb^{-1}.

The W signal is extracted using fits of signal and background templates to the observed data. For the muon channel, the fits are performed using a binned likelihood technique on the transverse mass variable. The QCD background shape is taken from events in data which fail the isolation criteria. For the electron channel, the signal is extracted using an unbinned-likelihood fit on the missing transverse energy. The parameters of the QCD background shape are constrained by the data. For both channels, the signal and electroweak background shapes are taken from Monte Carlo. The results of the fits and the observed data are shown in Fig 1. To suppress background from Z events, events with a second identified electron or muon are removed from the analysis.

Extensive studies were performed to understand possible systematic effects in the measurement. For the muon channel, uncertainties in lepton reconstruction, trigger efficiency, and background subtraction are the primary contributions to an uncertainty of 6.3%. For the electron channel, the dominant contribution to the 7.7% uncertainty is due to the lepton identification which is estimated using limited numbers of Z events.

For an integrated luminosity of 198 nb^{-1}, the fit process yields the following total cross sections for W production:

$$\begin{aligned}
\sigma(\mathrm{pp} \to \mathrm{W} + X \to \mu\nu + X) &= 9.14 \pm 0.33(\mathrm{stat.}) \pm 0.58(\mathrm{syst.}) \pm 1.00(\mathrm{lumi.})\ \mathrm{nb}, \\
\sigma(\mathrm{pp} \to \mathrm{W} + X \to \mathrm{e}\nu + X) &= 9.34 \pm 0.36(\mathrm{stat.}) \pm 0.70(\mathrm{syst.}) \pm 1.03(\mathrm{lumi.})\ \mathrm{nb}, \\
\sigma(\mathrm{pp} \to \mathrm{W} + X \to \ell\nu + X) &= 9.22 \pm 0.24(\mathrm{stat.}) \pm 0.47(\mathrm{syst.}) \pm 1.01(\mathrm{lumi.})\ \mathrm{nb}.
\end{aligned}$$

The NNLO prediction is 10.44 ± 0.52 nb, which agrees well with this result.

W^+ and W^- bosons are produced at different rates in pp collisions, due to the prevalence of u quarks over d quarks. By performing separate fits for W^+ and W^-, the inclusive ratio is measured to be $\sigma(\mathrm{pp} \to \mathrm{W}^+ + X \to \ell^+\nu + X)/\sigma(\mathrm{pp} \to \mathrm{W}^- + X \to \ell^-\overline{\nu} + X) = 1.51^{+0.08}_{-0.07}(\mathrm{stat.}) \pm 0.04(\mathrm{syst.})$

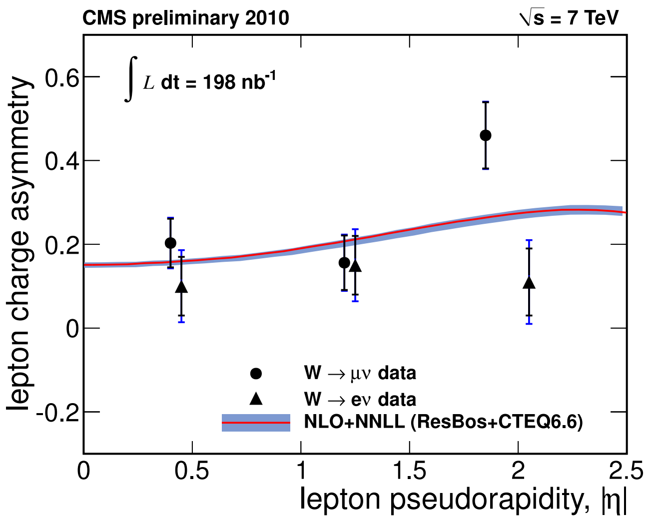

Figure 2: Raw lepton charge asymmetry in three bins of $|\eta|$. Electron and muon results are plotted together, and compared to the theoretical prediction. These results have not been corrected for relative differences in ℓ^+ and ℓ^- acceptance.

which is in agreement with expectations. By recasting this measurement as an asymmetry, useful constraints on parton distribution functions can be derived. The first measurements of the lepton charge asymmetry as a function of pseudorapidity at $\sqrt{s} = 7$ TeV are shown in Fig 2, which are in agreement with the expectation from the Standard Model.

4. Z Signal Extraction

Z events are identified by requiring a pair of opposite-charge high transverse-momentum leptons. The remaining background after selection is extremely small, as can be seen in Fig. 3. A cut-and-count technique is used to measure the following cross sections for Z production, using 198 nb^{-1} of data:

$$\begin{aligned}
\sigma(\text{pp} \to \text{Z}(\gamma^*) + X \to \mu^+\mu^- + X) &= 0.881^{+0.104}_{-0.097}(\text{stat.})^{+0.042}_{-0.034}(\text{syst.}) \pm 0.097(\text{lumi.})\ \text{nb},\\
\sigma(\text{pp} \to \text{Z}(\gamma^*) + X \to \text{e}^+\text{e}^- + X) &= 0.884^{+0.118}_{-0.108}(\text{stat.})^{+0.076}_{-0.059}(\text{syst.}) \pm 0.097(\text{lumi.})\ \text{nb},\\
\sigma(\text{pp} \to \text{Z}(\gamma^*) + X \to \ell^+\ell^- + X) &= 0.882^{+0.077}_{-0.073}(\text{stat.})^{+0.042}_{-0.036}(\text{syst.}) \pm 0.097(\text{lumi.})\ \text{nb}.
\end{aligned}$$

The reported $Z(\gamma^*)$ cross sections are limited to the di-lepton invariant mass range $[60, 120]$ GeV$/c^2$, and corrected for the kinematic acceptance. The NNLO prediction for Z production is 0.97 ± 0.04 nb, in good agreement with these measurements.

Combining the results for the two electroweak bosons, the ratio of cross sections for W and Z(γ^*) production is measured to be:

$$\begin{aligned}
\sigma(\text{pp} \to \text{W} + X \to \mu\nu + X)/\sigma(\text{pp} \to \text{Z}(\gamma^*) + X \to \mu^+\mu^- + X) &= 10.38^{+1.34}_{-1.15}(\text{stat.})^{+0.78}_{-0.64}(\text{syst.}),\\
\sigma(\text{pp} \to \text{W} + X \to \text{e}\nu + X)/\sigma(\text{pp} \to \text{Z}(\gamma^*) + X \to \text{e}^+\text{e}^- + X) &= 10.57^{+1.54}_{-1.30}(\text{stat.})^{+1.20}_{-0.97}(\text{syst.}),\\
\sigma(\text{pp} \to \text{W} + X \to \ell\nu + X)/\sigma(\text{pp} \to \text{Z}(\gamma^*) + X \to \ell^+\ell^- + X) &= 10.46^{+0.99}_{-0.88}(\text{stat.})^{+0.65}_{-0.56}(\text{syst.}).
\end{aligned}$$

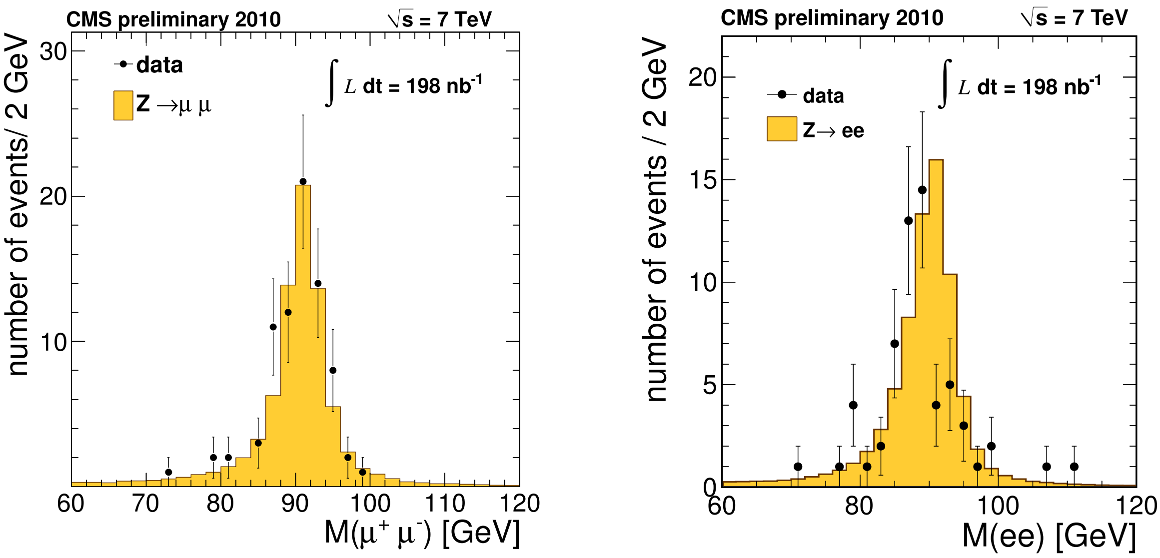

Figure 3: Distribution of $M_{\ell\ell}$ for the selected $Z \rightarrow \mu^+\mu^-$ (left) and $Z \rightarrow e^+e^-$ (right) candidates in data (points). Superimposed are simulated estimates of the signal component, normalized to 198 nb^{-1}. Backgrounds are too small to be visible on this scale.

In the combination, the relative acceptance between W and Z is assumed to be fully correlated and other uncertainties are assumed to be uncorrelated. The NNLO prediction for this ratio is 10.74 ± 0.04, in agreement with these measurements.

5. Conclusion

First measurements of W and $Z(\gamma^*)$ cross sections have been made using approximately 198 nb^{-1} of data taken with the CMS detector at the LHC. In addition, the W charge asymmetry as a function of lepton pseudorapidity has been measured. Within large statistical uncertainties, no disagreements with the predictions of the Standard Model have been observed.

References

[1] A. D. Martin, W. J. Stirling, R. S. Thorne, and G. Watt. *Parton distributions for the LHC*, Eur. Phys. J. **C63** (2009) 189-295.

[2] K. Melnikov and F. Petriello. *Electroweak gauge boson production at hadron colliders through O(alpha(s)**2)*, Phys. Rev. **D74** (2006) 114017.

[3] CMS Collaboration. *The CMS experiment at the CERN LHC, JINST* 0803:S08004, 2008.

[4] CMS Collaboration. CMS-PAS-EWK-10-004, (2010) [CDS/1279145].

[5] CMS Collaboration. *Measurements of Inclusive W and Z Cross Sections in pp Collisions at* $\sqrt{s} = 7$ TeV, CMS-PAS-EWK-10-002, (2010) [CDS/1279615].