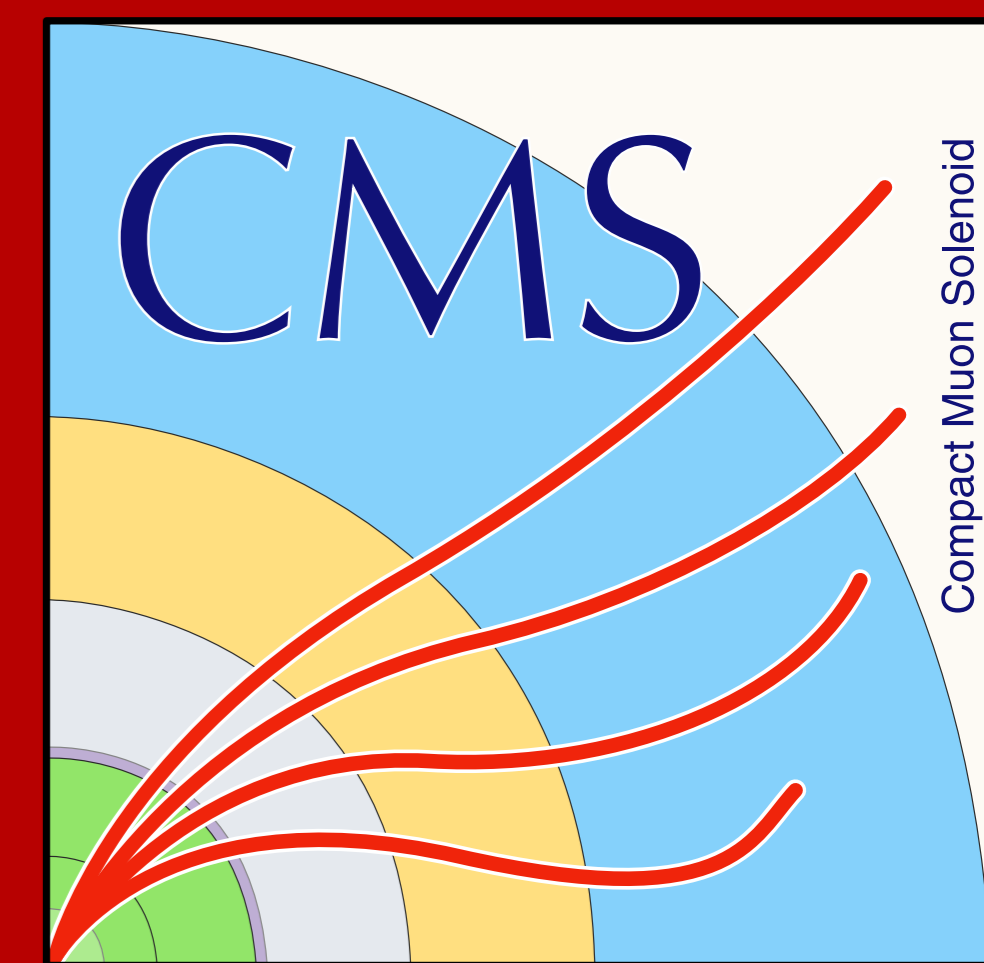


# Measurement of the WZ production cross section in pp collisions at $\sqrt{s} = 13$ TeV with the CMS detector

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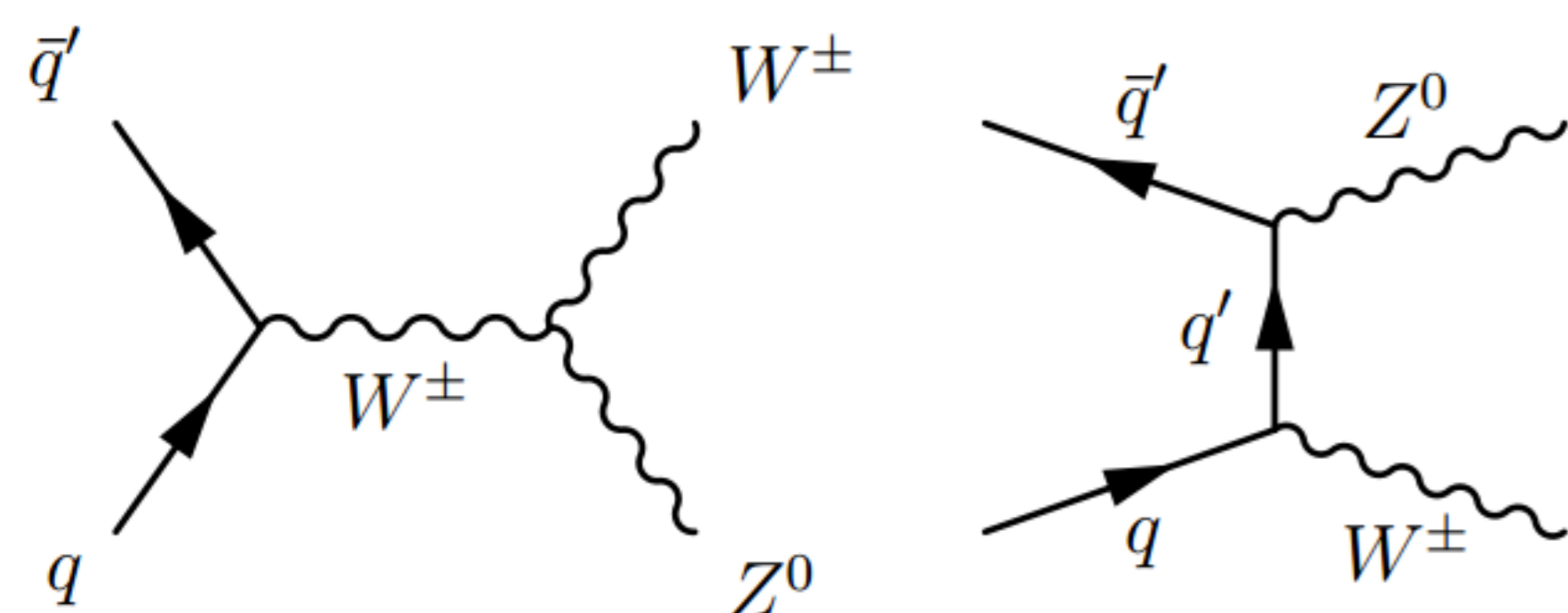
## Abstract

A measurement is presented of the WZ production cross section in proton-proton collisions at  $\sqrt{s} = 13$  TeV with the CMS experiment at the LHC using a data sample corresponding to an integrated luminosity of  $1.34 \text{ fb}^{-1}$ . The measurement is performed in the leptonic decay modes  $WZ \rightarrow \nu\ell\ell'\ell'$ , where  $\ell, \ell' = e, \mu$ . The measured cross section  $\sigma(\text{pp} \rightarrow WZ) = 36.8 \pm 4.6$  (stat)  $_{-6.2}^{+8.1}$  (syst)  $\pm 0.6$  (theo)  $\pm 1.7$  (lumi) pb, for Z bosons produced in the mass region  $60 < m_Z < 120$  GeV, is consistent with standard model predictions.

## Introduction

Massive multiboson production of WZ

- ▶ Electroweak interaction
- ▶ Precision test of non-abelian  $SU(2)_L \times U(1)_Y$  gauge group
- ▶ Self-interactions via TGC and QGC
- ▶ Probe for new physics
  - ▶ aTGC and aQGC
  - ▶ Resonant production of new physics particles



## Data and Monte Carlo Samples

This measurement uses a sample of proton-proton collisions collected in 2015 with the CMS experiment at the LHC at  $\sqrt{s} = 13$  TeV. The integrated luminosity of the sample is  $1.34 \text{ fb}^{-1}$ .

WZ production compared to NLO Monte Carlo sample and cross section calculation.

## Event Selection

Event passes double lepton trigger with  $p_T$  threshold 17 GeV, 12 (8) GeV for electrons (muons).

Exactly three  $p_T > 10$  GeV leptons passing identification and isolation requirements in the event.

Z selection

- ▶ Opposite sign same flavor pair with leading lepton  $p_T > 20$  GeV
- ▶ Within Zmass window of  $60 < m_Z < 120$  GeV

Wselection

- ▶ Lepton  $p_T > 20$  GeV
- ▶ Missing transverse energy  $E_T^{\text{miss}} > 30$  GeV

Trilepton invariant mass passes  $m_{3\ell} > 100$  GeV selection.

All lepton pairs  $m_{\ell\ell} > 4$  GeV to match generator level cuts on WZ.

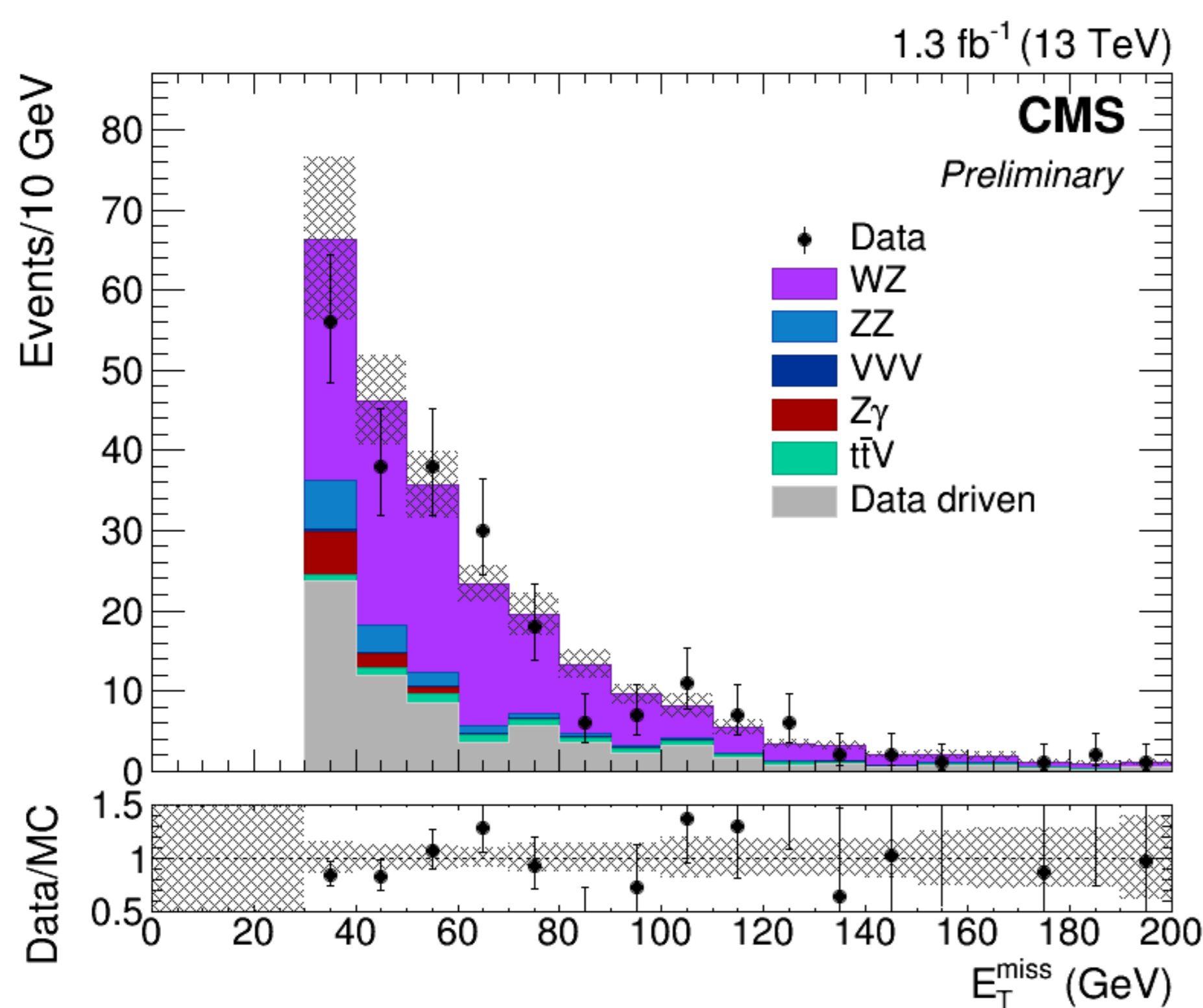


Figure: Distribution of the reconstructed missing transverse energy summed for all decay channels.

## Background Estimation

Background estimated in two categories

- ▶ Prompt isolated leptons estimated from simulation
  - ▶ ZZ, Zγ, ttV, and VVV
- ▶ Non-prompt estimated from data
  - ▶ Z+jets, tt, W+jets, and QCD multijets

The non-prompt background uses a "tight-to-loose" method. Each lepton is categorized as:

- ▶ **P**: pass "tight" requirement
- ▶ **F**: pass "loose" but fail "tight"

Background source	Control region
Z+jets	PPF
tt	PPF, FFP
W+jets	PPF, FPF, FFP
QCD multijets	FFF

Table: The primary background associated with each control region.

QCD enriched control region to estimate misidentification rate in bins of  $p_T$  and  $\eta$

- ▶ Single "loose" lepton
- ▶ Jet with  $p_T > 30$  GeV
- ▶  $E_T^{\text{miss}} < 20$  GeV
- ▶  $M(\ell, E_T^{\text{miss}}) < 25$  GeV

The estimated background in the signal region is calculated using the control regions and the misidentification rate. Contributions from prompt leptons estimated from simulation are subtracted from the observed data in each control region before the application of the misidentification rate.

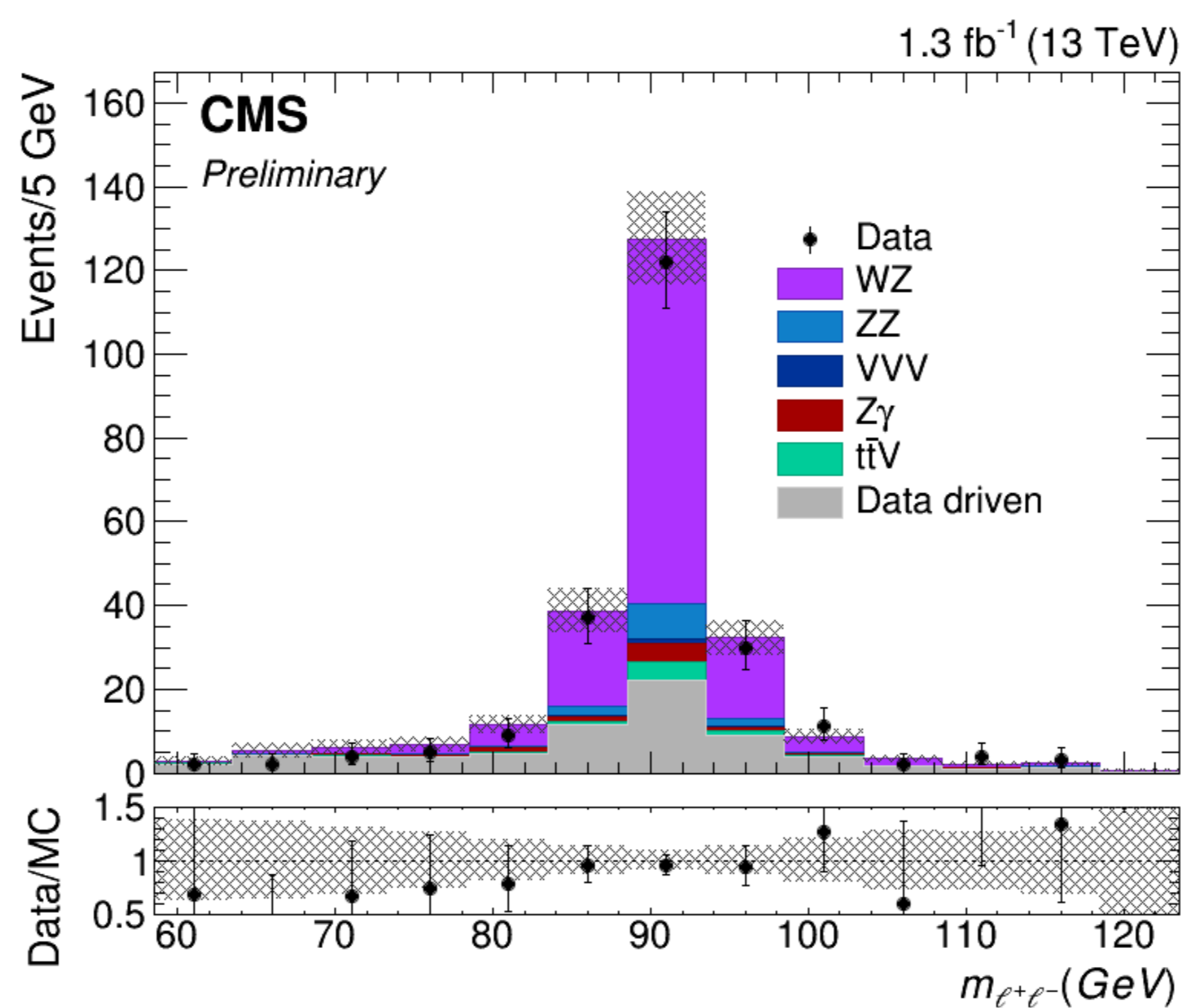


Figure: Distribution of the Z reconstructed mass summed for all decay channels with the full selection.

## Systematic Uncertainties

Theoretical uncertainties on the  $WZ \rightarrow \nu\ell\ell'\ell'$  acceptance are evaluated using MCFM and POWHEG by varying the QCD scales up and down by a factor of two with respect to the default values  $\mu_R = \mu_F = m_{WZ}$ .

Uncertainty on the data-driven background estimation arises from limited statistics in the control regions and an assumed 40% uncertainty on the misidentification rate which provides coverage of differences observed in QCD and Drell-Yan control regions.

Uncertainty Source	Uncertainty
LHC integrated Luminosity	4.6%
Trigger efficiency	2%
Lepton identification	1–2%
Pileup simulation	1%
Missing energy reconstruction	1–3%
WZ acceptance, pdf, and scale	1%
Data driven estimation	17–32%

Table: Effect of systematic uncertainty sources on cross section

## WZ Cross Section Measurement

Observed and expected yields for each channel are reported below. The final cross section is calculated from a simultaneous fit of the observed yields in each channel.

Decay channel	$N_{WZ}^{\text{exp}}$	Background Datadriven	Background Monte Carlo	Total expected	Observed
eee	$28.4 \pm 0.5$	$14.1 \pm 2.3$	$7.9 \pm 0.9$	$50.4 \pm 2.5$	39
eeμ	$32.5 \pm 0.5$	$13.7 \pm 1.9$	$6.3 \pm 0.3$	$52.5 \pm 2.0$	49
μμe	$39.1 \pm 0.5$	$22.3 \pm 2.5$	$10.3 \pm 0.9$	$71.7 \pm 2.7$	74
μμμ	$46.7 \pm 0.9$	$18.8 \pm 1.9$	$8.1 \pm 0.3$	$73.6 \pm 2.0$	69
<b>Total</b>	<b><math>146.6 \pm 1.0</math></b>	<b><math>69.0 \pm 4.4</math></b>	<b><math>32.6 \pm 1.3</math></b>	<b><math>248.2 \pm 4.7</math></b>	<b>231</b>

Table: The observed and expected yields of WZ events, and estimated yield of background events obtained from data driven method as explained in the text for each decay channel together with the prompt leptons background, estimated from simulation.

Two cross sections are reported:

- ▶ Fiducial
  - ▶ Leading lepton from Z with  $p_T > 20$  GeV
  - ▶ Subleading lepton from Z with  $p_T > 10$  GeV
  - ▶ Lepton from W with  $p_T > 20$  GeV
  - ▶ All leptons with  $|\eta| < 2.5$
  - ▶  $60 < m_Z < 120$  GeV
- ▶ Total cross section

Measured fiducial cross section

$$\sigma_{\text{fid}} = 239 \pm 29 \text{ (stat)}_{-40}^{+52} \text{ (syst)} \pm 11 \text{ (lum)fb.} \quad (1)$$

Total cross section

$$\sigma_{\text{tot}} = 36.8 \pm 4.6 \text{ (stat)}_{-6.2}^{+8.1} \text{ (syst)} \pm 0.6 \text{ (theo)} \pm 1.7 \text{ (lum)pb.} \quad (2)$$

Theoretical values

- ▶ Fiducial cross section:  $274_{-8}^{+13}$  fb
- ▶ Total cross section:  $42.7_{-0.8}^{+1.6}$  pb

These theoretical values are calculated with

- ▶ MCFM 7.0 at NLO with NNPDF3.0 PDF
- ▶ dynamic renormalization and factorization scales set to  $\mu_R = \mu_F = m_{WZ}$ .

The uncertainty is obtained by varying the factorization and renormalization scales from  $\frac{1}{2}\mu_R$  to  $2\mu_R$ .

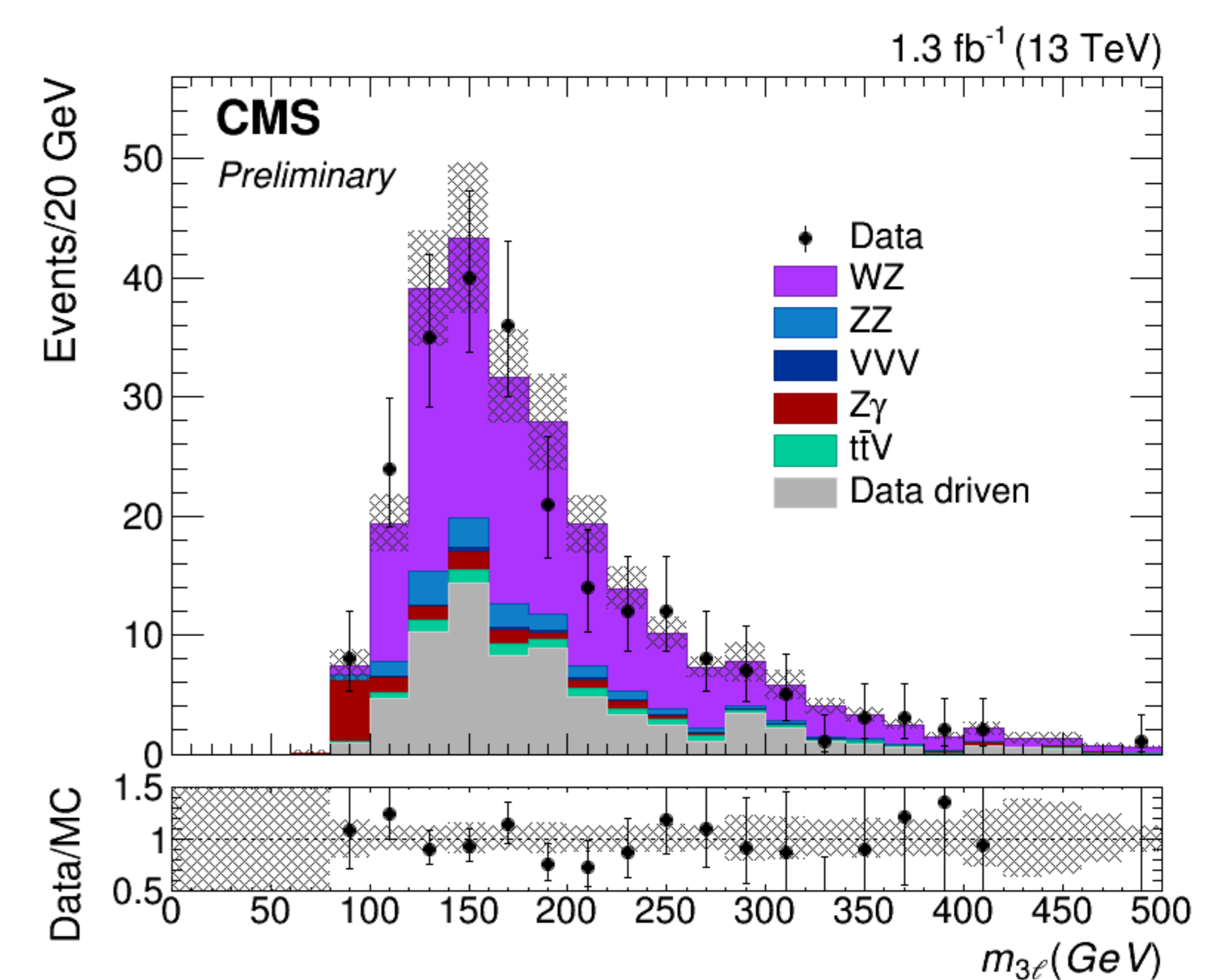


Figure: Distribution of the  $ll'\ell\ell'$  reconstructed mass summed for all decay channels with the  $m_{3\ell} > 100$  GeV selection requirement removed.

## Summary

The WZ production cross section is measured in proton-proton collisions at  $\sqrt{s} = 13$  TeV with the CMS experiment at the LHC using a data sample corresponding to an integrated luminosity of  $1.34 \text{ fb}^{-1}$ . The measurement is performed in the leptonic decay modes  $WZ \rightarrow \nu\ell\ell'\ell'$ , where  $\ell, \ell' = e, \mu$ . The measured cross section  $\sigma(\text{pp} \rightarrow WZ) = 36.8 \pm 4.6$  (stat)  $_{-6.2}^{+8.1}$  (syst)  $\pm 0.6$  (theo)  $\pm 1.7$  (lumi)pb, for Z bosons produced in the mass region  $60 < m_Z < 120$  GeV, is consistent with with the NLO expectation of  $42.7_{-0.8}^{+1.6}$  pb.

## Bibliography

Measurement of the WZ production cross section in pp collisions at  $\sqrt{s} = 13$  TeV, CMS Collaboration, CMS-PAS-SMP-15-006, <http://cds.cern.ch/record/2114821>