Measurement of the ZZ Production Cross Section in pp Collisions at $\sqrt{s} = 13$ TeV with the CMS Detector

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Abstract

The ZZ production cross section is measured in proton-proton collisions at $\sqrt{s} = 13$ TeV with the CMS detector at the LHC. A data sample corresponding to an integrated luminosity of 1.34 fb$^{-1}$ is used. The cross section $\sigma(pp \rightarrow ZZ)$ is integrated over the yield measured in the lepton decay modes $ZZ \rightarrow l^+l^-\ell^+\ell^-$, where $l^\pm = e, \mu$. The measured cross section $\sigma(pp \rightarrow ZZ) = 16.7^{+0.7}_{-0.7} (\text{stat}) \pm 0.8 (\text{syst}) \pm 0.8 (\text{lum})$ pb, for both $Z$ bosons produced in the mass region 60 $< m_Z < 120$ GeV, is consistent with standard model predictions.

Introduction

Multiboson production of massive vector bosons: ZZ
- Precision test of the electroweak gauge structure of Standard Model
- Small cross section, but clean ZZ $l^+l^-\ell^+\ell^-$ signal visible in small data set
- Resonant $Z$ and Higgs boson production
- Nonresonant ZZ production
- Primary irreducible background to Higgs measurements
- Potential early sign of new physics
- Anomalous triple and quartic gauge couplings
- Resonant production of new particles decaying to ZZ

Data and Monte Carlo Samples

Data Sample
- Sample of $\sqrt{s} = 13$ TeV proton-proton collisions collected by CMS during 2015 LHC run
- Integrated luminosity of the sample is 1.34 $\pm$ 0.06 fb$^{-1}$

Simulated Samples
- $q\bar{q} \rightarrow ZZ$ signal samples generated with POWHEG 2.0
  - Generated at next-to-leading order (NLO)
  - Scattered to next-to-next-to-leading order (NNLO) cross section
- gg $\rightarrow ZZ$ signal samples generated with MCFM
  - Generated at leading order (LO)
  - Scattered to next-to-leading order (NLO) cross section
- PYTHIA package used for parton showering, hadronization, and underlying event simulation.
- Detector response simulated with GEANT4.

Event Selection

- Events must pass an isolated di-lepton trigger, a triple-lepton trigger, or a single-electron trigger
- Z boson candidates $Z_1$ and $Z_2$ from pairs of opposite-sign, same-flavor electrons or muons
  - All leptons $p_T > 10$ GeV
  - Leptons must pass identification and isolation criteria
  - $60 < m_{Z_1Z_2} < 120$ GeV
  - All opposite-sign lepton pairs $m_{m_{\ell\ell}} > 4$ GeV

Systematic Uncertainties

- Uncertainty on signal yield
  - Uncertainty on scale
  - Uncertainty on NNLO
  - Uncertainty on NNLO
  - Uncertainty on parton showering, hadronization

- Uncertainty on background yield taken to be 40%, due to uncertainties on fake rate and background composition

ZZ Cross Section Measurement

- $pp \rightarrow ZZ \rightarrow 2\ell^+2\ell^-$ cross section calculated from simultaneous fit of observed yields in each channel
- The observed and expected yield of ZZ events, and estimated yield of background events evaluated from data are shown for each decay channel and are summed in the total expected yield ($\text{Total}$).

Fiducial definition
- One lepton with $p_T > 20$ GeV
- Other leptons with $p_T > 10$ GeV
- All leptons with $|\eta| < 2.5$
- Both $Z$ bosons with $60 < m_{Z_1Z_2} < 120$ GeV
- All opposite-sign lepton pairs with $m_{m_{\ell\ell}} > 4$ GeV regardless of flavor

Distribution of the reconstructed mass of $Z_1$, i.e. the dilepton pair in each event with mass closest to the nominal $m_Z$. Uncertainty on background yield taken to be 40%, due to uncertainties on fake rate and background composition.

Bibliography


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