PROCEEDINGS OF SCIENCE

Study of Dibosons at the LHC using the CMS detector

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The study of dibosons like $W\gamma$, $Z\gamma$, WW, WZ and ZZ at the LHC will be an interesting test of the Electroweak gauge structure of the Standard Model at the highest possible energies , and may indicate the presence of new physics as deviations of the gauge boson couplings from their Standard Model values. We present here the analysis strategy for measuring the cross-sections for the WW and WZ processes and Monte Carlo generator-based studies of the physics of $W\gamma$ and $Z\gamma$ production at the LHC. We show that the WW cross-section can be measured with 100 pb^{-}1 of data at $\sqrt{s}$ = 10 TeV and WZ, with 300 pb^{-}1 of data at $\sqrt{s}$ = 14 TeV.

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1. Dibosons at the LHC

The study of dibosons is one of the most important physics topics which will be studied at the LHC. Previous studies at the Tevatron experiments have studied many of the aspects of diboson production like $W\gamma$, $Z\gamma$, WW, WZ and ZZ and these measurements need to be extrapolated to higher energy regimes as well. At the LHC we expect significant enhancement of the rates of production of the dibosons, starting from the early running conditions of the machine. We present here the CMS efforts towards study of diboson production at the LHC. Studies have been carried out for the WW production process at 10 TeV and the WZ process at 14 TeV. The study of other diboson processes are underway and we provide some glimpses of the Monte Carlo generator level studies for these.

2. Cross-sections and gauge-boson couplings

The measurement of triple gauge boson couplings is one of the primary goals of diboson studies. Differential cross-sections, with respect to certain kinematic variables are most sensitive to the value of the gauge couplings by showing enhancement in the higher side of the spectrum from any anomalous couplings that may exist. By measuring the couplings one can test the electroweak gauge structure of the Standard Model or look for new physics. Besides, dibosons are important backgrounds to the search for the Higgs bosons and other supersymmetric searches and understanding their production at the LHC is important in the context of new discoveries.

3. Methods

Single or double lepton (electron or muon) triggers are used to select diboson events in CMS as the leptonic decay mode of the W and Z provide a cleaner experimental signature. Offline selection criteria are then applied to reject potential background events. Then the number of background events remaining in those that pass the trigger and selection criteria are estimated either from Monte Carlo simulation studies or from data-driven methods. This number subtracted from the number of events passing the trigger and selection criteria – N^{events} – give the actual number of signal events. To obtain the cross-section of the process, we have to estimate the detector acceptance and efficiencies of the triggering, reconstruction and the selection criteria applied as well as the total integrated luminosity of the dataset used. The cross-section measurement is given by the formula:

$$cross-section = \frac{N^{events} - N^{bkg}}{\mathscr{A}\,\varepsilon \int \mathscr{L} dt}$$

where N^{events} is the number of "good" events selected by a certain trigger criteria, N^{bkg} is the number of backgrounds estimated either from Monte Carlo simulations of data-driven methods, $\mathscr{A}$ is the detector acceptance as defined by the fiducial volume, ε is the total efficiency of triggering, reconstruction, and the other selection criteria and $\int \mathscr{L} dt$ is the integrated luminosity of the processed dataset.

Now we shall elucidate the Monte Carlo based studies undertaken by the CMS collaboration for some of the diboson production processes.

4. WW Process

The study of WW production [1] was undertaken for 10 TeV running of the LHC with 100 pb^{-1} of integrated luminosity. The main observables for the WW production process are the dilepton transverse mass from the leptonic decay of each of the W-bosons and the missing transverse energy. The main backgrounds are: W+jets, where the jet may fake a lepton; Drell-Yan process leading to ee or $\mu\mu$ or $\tau\tau$; $t\bar{t}$ where the two W-bosons are created from top-quark decay; other dibosons like WZ, ZZ or $W\gamma$ processes. Fig. 1 shows the dilepton invariant mass from the two charged lepton from W-decays on the left and the missing transverse energy of the WW decay on the right.

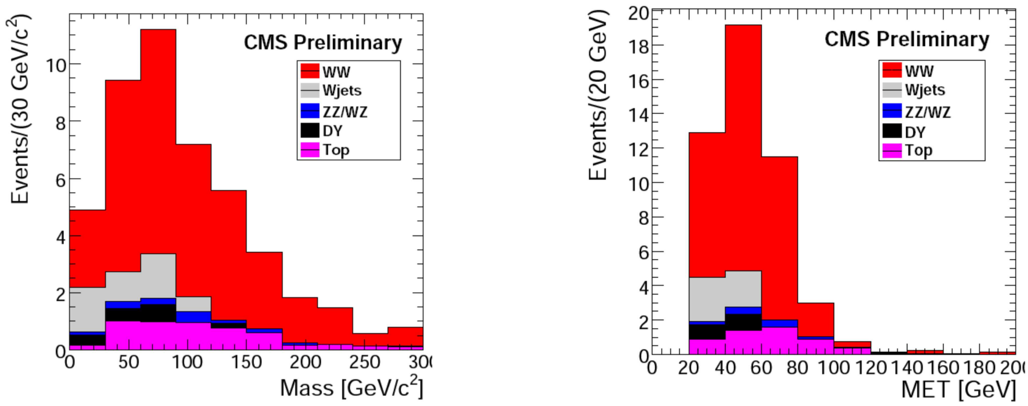

Figure 1: Dilepton invariant mass (left) and missing transverse energy (right).

The dominant systematic uncertainties are the twp lepton selection criteria (4%), jet veto (7%), missing transverse energy resolution function (5%) and the parton distribution function (2%).

5. WZ Process

The WZ process was investigated in the muon and electron decay channels of the W and the Z-bosons [2]. The study was conducted for 14 TeV running of the LHC. The main background for this process are Z+jets, bbll, $t\bar{t}$+jets, $W + jets$, ZZ and $Z\gamma$. Fig. 2 shows the reconstructed Z-boson mass using the charged leptons from Z-decay and on the right and the signal significance for various integrated luminosity on the right. It can be concluded that at 14 TeV with the CMS detector, WZsignal can be established with a confidence level of at least 95% with an amount of data less than 350 pb^{-1}.

For this study, the main systematic uncertainties are from the luminosity measurement (10%), W transverse mass requirement (10%), parton distribution function (4%).

6. $W\gamma$ Process

The most useful variable to detect anomalous coupling is the photon transverse momentum spectrum (p_T^γ) as anomalous coupling enhances the higher side of the p_T^γ spectrum. However, at the LHC, higher order QCD corrections to the $W\gamma$ process also produce exactly the same result

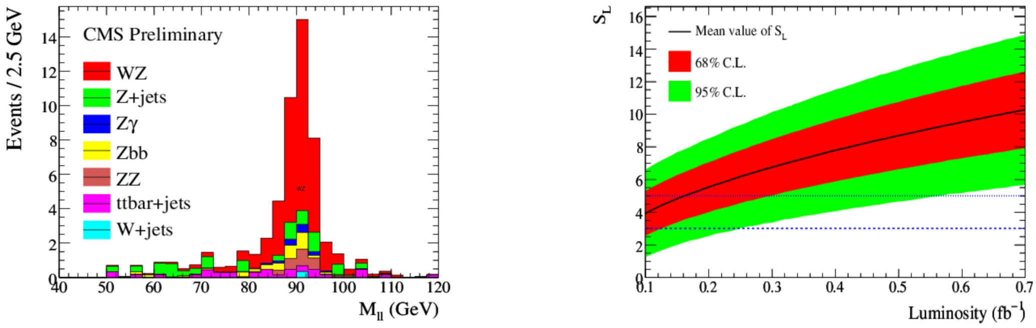

Figure 2: Mass of the Z-boson (left) and the signal significance as a function of integrated luminosity (right).

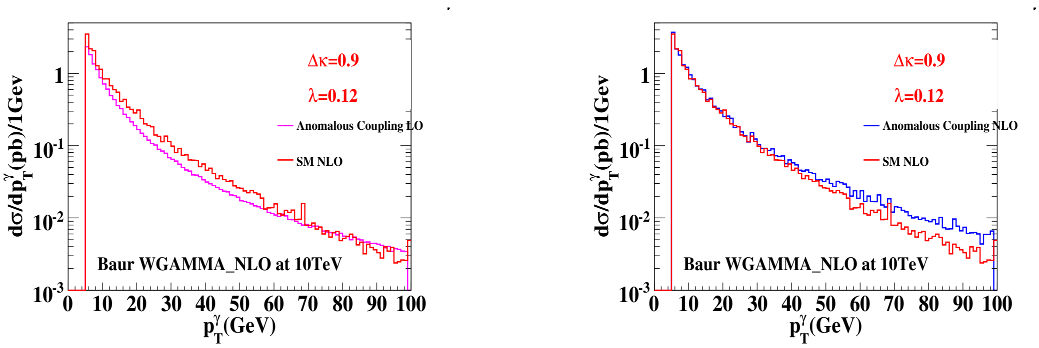

Figure 3: Photon transverse momentum spectrum for anomalous coupling at LO and Standard Model coupling at NLO (left) and both anomalous coupling and the Standard Model coupling at NLO (right).

on the p_T^γ spectrum. Thus it is necessary to ascertain the extent of these QCD corrections at LHC energies to correctly simulate the signal process. Fig. 3 (left) shows p_T^γ with Standard Model coupling at next-to-leading order (NLO) and with anomalous couplings at leading order (LO). The two spectra have the same kinematic shapes thereby proving that one needs to have at least a NLO generator to distinguish between the Standard Model and anomalous couplings. This is shown in Fig. 3 (right).

7. Summary

Dibosons can be observed in CMS starting from the early running of the LHC. Preparedness for measurement has been demonstrated for 10 TeV and 14 TeV for WW and WZ respectively. The measurement of anomalous couplings requires a next-to-leading event generator for event simulation due to large contributions at the LHC from NLO QCD corrections.

References

[1] CMS PAS EWK-09-002

[2] CMS PAS EWK-08-003