PROCEEDINGS OF SCIENCE

Inclusive W and Z production at LHC startup

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We report on the potential measurement of the inclusive W and Z boson production cross section with the CMS detector at the LHC assuming pp collision data at a center-of-mass energy of 14 TeV. We have designed W and Z triggers, selection algorithms and event reconstruction techniques for both muon and electron decay modes, for low luminosity operation of the LHC integrating up to about 10 pb^{-1} . Initial calibrations and alignment conditions are assumed. While the accuracy of the cross section extracted will be dominated by the integral luminosity measurement, the understanding of the rate and characteristics of these processes will be of vital importance for the LHC physics programme.

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1. Overview of the measurement

The signature of high transverse momentum leptons (electrons/muons) from W and Z decays is very distinctive in the environment of hadron collisions. As such, the decays of W and Z bosons into leptons provide a clean experimental measurement of their production rate. The production cross section is high, approximately 190 nb for W's and 56 nb for Z's to be compared with the 100 mb of the total proton-proton cross section at $\sqrt{s}$ = 14 TeV.

2. Selection of W and Z samples

The $W \rightarrow e\nu$ and $\gamma^*/Z \rightarrow e^+e^-$ samples are selected from events that pass the single isolated electron High Level Trigger [1]. We require one (for W) or two (for Z) high-p_T electrons (P_T >30 GeV for W and P_T >20 GeV for the Z selection) that should fall within the $PbWO_4$ crystal electromagnetic calorimeter (ECAL) fiducial region ($|\eta|$<2.5, excluding the Barrel-Endcap transition region). Since the electron(s) from the W(Z) decay is(are) isolated, we require low particle activity around the(each) electron candidate. Three different isolations were applied : track, ECAL and HCAL. They are defined by summing the P_T of tracks, the transverse energies of additional ECAL clusters and the transverse energies of HCAL cells respectively, within a dedicated (for each isolation) $\eta - \phi$ annular isolation cone centered on the reconstructed electron. Additionally, electrons should satisfy loose(tight) electron identification criteria for the Z (W) selection. Electron identification is based on calorimetric shower shape variables and on track-cluster matching requirements. The exact definition of the $W \rightarrow e\nu$ and $\gamma^*/Z \rightarrow e^+e^-$ selections can be found in [2].

The W $\rightarrow \mu\nu$ and $\gamma^*/\mathrm{Z} \rightarrow \mu^+\mu^-$ samples are selected from events that pass the single muon High Level Trigger. We require one (for W) or two (for Z) high-p_T muons (P_T >25 GeV for W and P_T >20 GeV for Z selection) that should fall within $|\eta|$<2.0 . Muon tracks are reconstructed from hits in both the tracker system and the muon chambers. The isolation criteria set thresholds on the P_T sum of all tracks in an $\eta - \phi$ cone around the muon direction. The $\gamma^*/\mathrm{Z} \rightarrow \mu^+\mu^-$ selection also requires opposite sign charges for the two selected muons. In the W $\rightarrow \mu\nu$ selection, events with more than 3 jets with $E_T^{jet} > 40$ GeV are rejected. The exact definition of the W $\rightarrow \mu\nu$ and $\gamma^*/\mathrm{Z} \rightarrow \mu^+\mu^-$ selections can be found in [3].

In the leptonic W boson decays, the undetectable neutrino carries out a fraction of the energy. This results in events with unbalanced energy in the transverse plane ($\not{E}_T$). The reconstructed $\not{E}_T$ and M_T distributions for the signal and the various backgrounds for events passing the above $W \rightarrow e\nu$ and W $\rightarrow \mu\nu$ selections are shown in Figs. 1,2. As can be seen the most important background for both cases is the di-jet background.

Assuming NLO signal cross sections and 10 pb^{-1} of integrated luminosity we expect 64K (28K) of W $\rightarrow \mu\nu$ ($W \rightarrow e\nu$) events to pass selection requirements. Mis-calibration and misalignment conditions expected for the first 10 pb^{-1} were applied.

The reconstructed invariant mass distributions for the signal and the various backgrounds for events passing the $\gamma^*/Z \rightarrow e^+e^-$ and $\gamma^*/\mathrm{Z} \rightarrow \mu^+\mu^-$ selections are shown in Figs. 3,4. The background after selection is negligible. Assuming NLO signal cross sections and 10 pb^{-1} of integrated luminosity we expect to pass selection requirements 5.5K (4.6K) of $\gamma^*/\mathrm{Z} \rightarrow \mu^+\mu^-$ ($\gamma^*/Z \rightarrow e^+e^-$) events counted in the 70 GeV $< M_{ee,\mu\mu} <$ 110 GeV mass region.

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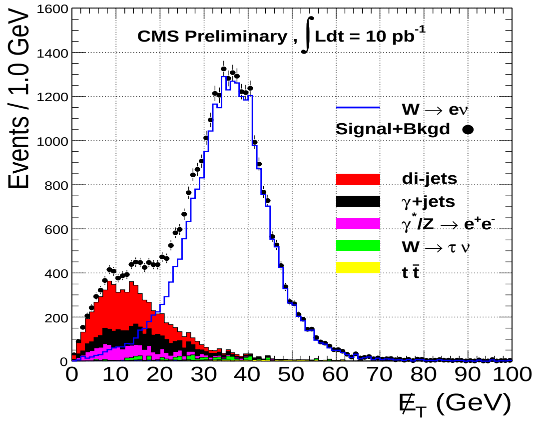

Figure 1: Reconstructed missing transverse energy $\not{E}_T$ distribution for the $W \rightarrow e\nu$ signal together with the considered backgrounds after selection cuts applied for 10 pb^{-1} of integrated luminosity.

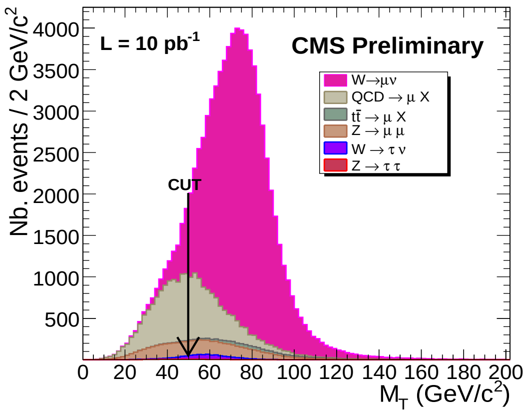

Figure 2: Reconstructed transverse mass M_T distribution for the W $\rightarrow \mu\nu$ signal together with the considered backgrounds after selection cuts applied for 10 pb^{-1} of integrated luminosity.

The reconstruction, selection and trigger efficiencies are measured in data using tag-and-probe methods [4]. The method relies upon Z decays to provide an unbiased, high-purity, electron or muon sample with which to measure the efficiency of a particular cut or trigger. One of the leptons, the "tag", is required to pass stringent lepton identification criteria whilst the other lepton, the "probe", is only required to satisfy a set of criteria depending on the efficiency under study.

3. Background Studies

The electroweak background in the W sample consists mostly of γ^*/Z events with one electron(muon) escaping detection, and W and Z decays to τ's followed by a τ decay to an electron(muon). Since these backgrounds are small, and because they arise from electroweak cross sections that can be computed reliably, they can be estimated with adequate precision from simulation. The γ^*/Z background can be efficiently suppressed by demanding no other electron(muon) in the event with $P_T >$20 GeV.

The hadronic background in the W sample consists mostly of QCD events with two hard E_T-balanced jets (di-jet events), in which one jet is misidentified as an electron/muon while missing transverse energy results from mismeasurements. The size of the di-jet background depends on the probability of a jet faking an electron(muon). This is hard to estimate and control from simulation, and therefore must be measured from the data. A missing transverse energy or transverse mass template for the di-jet background is obtained requiring the full set of selection criteria but inverting the track isolation one. Figure 5, shows the reconstructed missing transverse energy distributions for events in the signal region (events with a track isolated electron) and in the QCD-enriched region (events where the electron is non-isolated). Both distributions are in good agreement in the

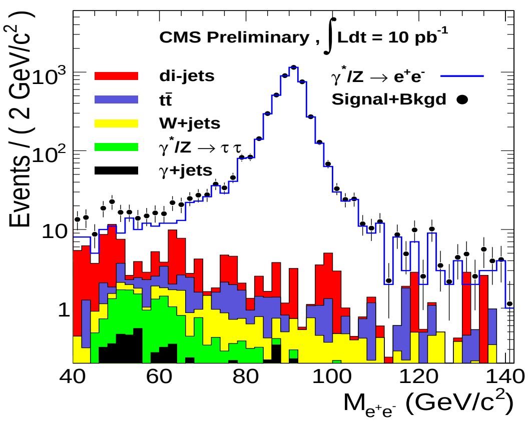

Figure 3: Invariant mass of the selected $\gamma^*/Z \to e^+e^-$ candidates, for an integrated luminosity of 10 pb^{-1} . The contributions of the different background components are also shown.

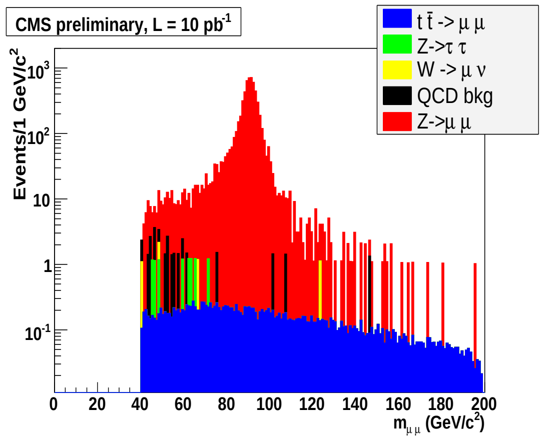

Figure 4: Invariant mass of the selected $\gamma^*/Z \to \mu^+\mu^-$ candidates, for an integrated luminosity of 10 pb^{-1} . The contributions of the different background components are also shown.

whole $\not\!\!E_T$ range, and therefore, the latter one can be applied as an $\not\!\!E_T$ template in the signal region. The same argument is true in the muon case.

To obtain the W $\not\!\!E_T$ template, we use γ^*/Z candidates with one lepton (electron or muon) removed from the $\not\!\!E_T$ calculation. The remaining lepton should satisfy the conditions imposed on the lepton in the W selection. The 'ersatz' $\not\!\!E_T$ is corrected for the difference in kinematics between W and γ^*/Z events and the neutrino acceptance. As shown in Fig. 6, $\gamma^*/\mathrm{Z} \to \mu^+\mu^-$ candidates with one muon removed, provide a reasonable representation of the transverse mass distribution in W $\to \mu\nu$ events.

Assuming that the distributions of the $\not\!\!E_T$ (or M_T) obtained from the isolation-inverted selection of di-jet events on the one side, and from the one-lepton-removed γ^*/Z events on the other, are good representations of the actual distributions for the QCD di-jet background and the W signal $\not\!\!E_T$ (or M_T) distributions, respectively, one can extract a background-subtracted W yield. The estimated systematic uncertainty on the W yield from the modelling of the QCD di-jet background and the W signal $\not\!\!E_T$ (or M_T) distributions is around 3% while the systematic uncertainty related to the accuracy of the prediction of the electroweak backgrounds remains to be estimated.

Misalignment and miscalibration biases and uncertainties have also an impact on the measured cross sections. Studies showed the distortions in the reconstructed Z boson mass due to the muon momentum scale corrections, misalignment and the uncertainties on the magnetic field. The dominant systematic uncertainty, $\sim 2.7\%$, is due to momentum scale corrections.

Studies based on the event generator MC@NLO [5] interfaced to PHOTOS [6] demonstrate that an overall theoretical uncertainty on the experimentally measured $\gamma^*/Z \to e^+e^-$ and $\gamma^*/Z \to \mu^+\mu^-$ acceptance due to higher order calculations, PDFs, renormalization scale and electroweak corrections can be controlled at the percent level.

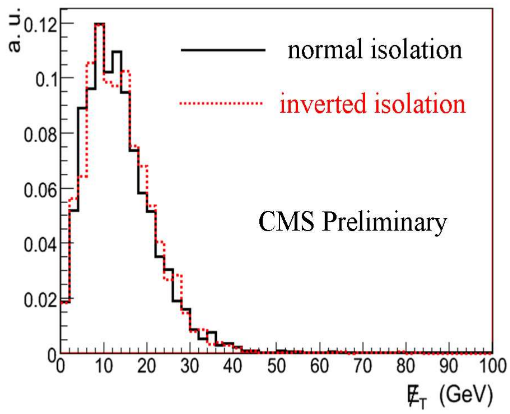

Figure 5: $\not{E}_T$ distribution for electron candidates in di-jets events which pass (black) and fail (red) the isolation requirement.

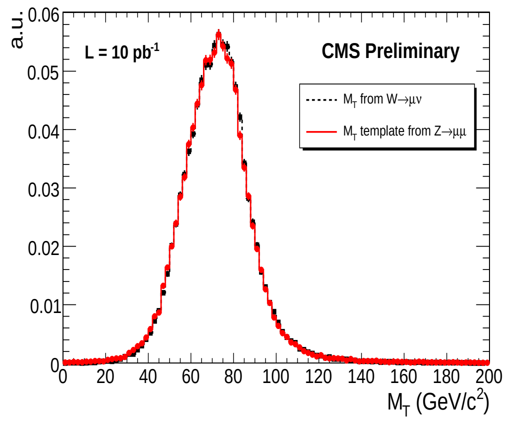

Figure 6: Reconstructed transverse mass, M_T , distributions obtained in Monte Carlo W $\rightarrow \mu\nu$ events (black dashed histogram) and $\gamma^*/Z \rightarrow \mu^+\mu^-$ events (solid red histogram).

4. Conclusions

We have presented a strategy for the early measurement of the inclusive W and γ^*/Z production cross sections in the electron and muon decay channel, assuming 10 pb^{-1} of pp collision data. A simple and robust lepton selection was applied in order to cope with the imperfections in calibration and alignment of the CMS detector during the initial data taking. The "Tag and Probe" technique was used to determine the selection efficiency from the data and a method to estimate the QCD background in the W sample was developed. The dominant systematic in the cross section measurement will come from the measurement of the integrated luminosity (10%).

References

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