Inclusive W and Z production with CMS at LHC startup

R. Paramatti
INFN Rome, P.le Aldo Moro 2, 00185 Rome, Italy

We report on potential for measurement of inclusive W and Z boson production cross section using initial data from the LHC. 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 accuracies are assumed. While the accuracy of the cross section extracted will be dominated by the integral luminosity measurement, ratios of W and Z production, and asymmetry distributions will be important early measurements from LHC.

I. INTRODUCTION

An early measurement of the inclusive W and Z production cross section in leptonic decay channels is presented, assuming 10 pb$^{-1}$ data at LHC. Signature of high transverse momentum leptons 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 $W \rightarrow l \nu$ cross section can be calculated using the following formula (a similar formula can be used for the Z cross section):

$$\sigma_W \cdot BR(W \rightarrow l \nu) = \frac{N_{W}^{\text{pass}} - N_{W}^{\text{bkgd}}}{A_W \cdot \epsilon_W \cdot \int L dt}$$

where $N_{W}^{\text{pass}}$ is the number of candidates selected from the data, $N_{W}^{\text{bkgd}}$ represents the expected background events and $A_W$ is the acceptance defined as the fraction of these decays satisfying the geometric constraints of the detector and the kinematic constraints of the imposed selection criteria. The $\epsilon_W$ is the selection efficiency for W decays falling within the acceptance and $\int L dt$ is the integrated luminosity.

II. EVENT SELECTION

The $W \rightarrow e\nu$ and $\gamma^*/Z \rightarrow e^+e^-(Z \rightarrow ee$ in the following) samples are selected from events that pass the single isolated electron High Level Trigger $[1]$. We require one (for $W \rightarrow e\nu$) or two (for $Z \rightarrow ee$) high-$p_T$ electrons formed from the association of a high $E_T$ supercluster in the $PbWO_4$ crystal electromagnetic calorimeter (ECAL) and a high-$p_T$ GSF track in the Tracker. An ECAL supercluster gathers the energy deposited in a region around the main energy cluster in an attempt to recover most of the energy of Bremsstrahlung photons emitted along the electron trajectory. The momentum of a GSF track is fitted along its trajectory using a Gaussian-Sum Filter algorithm (GSF) dealing with the possible emission of hard Bremsstrahlung photons in the scattering layers of the Tracker. The electron(s) should fall within the ECAL fiducial region ($|\eta| < 2.5$, excluding the Barrel-Endcap transition region). The ECAL supercluster(s) should have a transverse energy $E_T > 20.0$ (30.0) GeV for $Z \rightarrow ee$ ($W \rightarrow e\nu$). Since the electrons from the Z and W decays are isolated, we demand low charged particle activity in a cone around each electron candidates. The reconstructed $M_{\mu\mu}$ distribution for the signal and the various backgrounds for events passing the $Z \rightarrow ee$ selection is shown in Fig. 1. An invariant mass cut of 70-110 GeV is applied. The background after selection is negligible.

In order to select the $Z \rightarrow \mu^+\mu^-$ sample, we require two isolated muons with tracks reconstructed from hits in both the tracker system and the muon chambers. The muons must satisfy a cut on the transverse momentum:

* on behalf of the CMS Collaboration
$p_T > 20$ GeV. The isolation criteria requires the $p_T$ sum of all tracks in a cone around the muon direction to be less than 3 GeV. The invariant mass of the $\mu^+\mu^-$ pair must be greater than 40 GeV.

Fig. 2 shows the reconstructed transverse mass, $M_T$, of the W system after $W \rightarrow \mu\nu$ selection cuts. The W system is built in the plane transverse to the beam by combining the measured muon and the missing transverse energy in the event. The latter is interpreted as a measurement of the transverse momentum of the undetected neutrino. Muons must satisfy the cuts: $p_T > 25$ GeV and $|\eta| < 2$ and be isolated. The isolation criteria for $W \rightarrow \mu\nu$ requires the $p_T$ sum of all tracks cone around the muon direction, normalized to the muon $p_T$, to be less than 0.09. The figure shows that the QCD background is largely suppressed with the cut $M_T > 50$ GeV.

A full description of the selection is described in [2] for electron channels and in [3] for muon channels.

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**FIG. 1**: The $M_{ee}$ for the $Z \rightarrow ee$ signal together with the considered backgrounds after all selection cuts but the invariant mass one.

**FIG. 2**: Reconstructed transverse mass $M_T$ of W candidates. All $W \rightarrow \mu\nu$ selection cuts but the one shown in the plot have been applied.
III. TAG AND PROBE METHOD

The efficiency of trigger, lepton reconstruction and selection can be measured directly from data using the Tag and Probe method [4]. The method relies upon $Z \rightarrow ll$ decays to provide an unbiased, high-purity, lepton 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.

Fig. 3 shows the single muon trigger efficiencies measured. It is computed on a $Z \rightarrow \mu^+\mu^-$ sample corresponding to an integrated luminosity of 10 pb$^{-1}$. The results are shown as a function of the muon pseudorapidity. The good agreement observed between the measured reconstruction efficiencies using Tag and Probe method and the efficiencies evaluated using the Monte Carlo generator level information is interpreted as a validation of the method.

![Graph showing trigger efficiency as a function of eta for high-$p_T$ muons with $p_T > 20$ GeV](image)

**FIG. 3**: The trigger efficiency for high-$p_T$ muons ($p_T > 20$ GeV) as a function of $\eta$.

IV. BACKGROUND STUDIES

Electroweak background in $W \rightarrow l\nu$ is small and can be estimated with adequate precision from simulation. On the other hand the QCD background is hard to estimate and control from simulation and therefore must be measured from the data. A missing transverse energy (transverse mass) template for the background is obtained requiring the full set of selection criteria but reverting the $\sigma_{\eta\eta}$ (muon isolation) one in the electron (muon) channel. To obtain the signal missing transverse energy (transverse mass) template, we use $Z \rightarrow ll$ candidate removing one lepton to emulate the neutrino [2] [3].

[1] CMS Collaboration, “Data Acquisition and High-Level-Trigger TDR”, CERN/LHCC 2002-26.
[2] CMS Collaboration, “Towards a Measurement of the Inclusive $W \rightarrow e\nu$ and $\gamma^*/Z \rightarrow e^+e^-$ Cross Sections in pp Collisions at $\sqrt{s} = 14$ TeV.”, CMS PAS EWK-07-001.
[3] CMS Collaboration, “Towards a Measurement of the Inclusive $W \rightarrow \mu\nu$ and $Z \rightarrow \mu^+\mu^-$ Cross Sections in pp Collisions at $\sqrt{s} = 14$ TeV.”, CMS PAS EWK-07-002.
[4] CMS Collaboration, “Measuring Electron Efficiencies at CMS with Early Data”, CMS PAS EGM-07-001.