Invisible Z Estimation in the Monojet final state

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Abstract

A study in jet plus missing transverse energy (MET) in the LHC has high potential for discovery of new physics. One of dominant backgrounds remaining after applying monojet event selections is invisible Z. In this work, a contribution of irreducible invisible Z background is estimated by using Z($\mu\mu$)+jets and W($\mu\nu$)+jets events. Since they are statistically uncorrelated, the final estimate is determined by taking the weighted average of the two predictions. Finally, the exclusion limit is calculated from the result.

1. Introduction

Monojet plus missing transverse energy has high potential in discovering new Physics. One of dominant backgrounds remaining after applying the monojet event selections is a Z($\nu\nu$) event which represents an irreducible background as an invisible Z decay leading to real missing transverse energy. To predict a $Z(\nu\nu)$ contribution in the monojet final state, a $Z(\mu\mu)$ event is employed. Since this estimation gives rise to large statistical uncertainty because of limited numbers of the Z(μμ) events at high energy, an alternative method is introduced by employing a W(μν)+jets sample. The uncertainty can be reduced due to larger statistics.

2. Theoretical Background

An estimated number of the $Z(\upsilon\upsilon)$ events is obtained by utilizing the fact that, excluded the lepton, the jet kinematics of the W + jets and the Z + jets events at high boson p_T are very similar. Muons from the decay are interpreted as missing energy. The number of the Z($\nu\nu$) events can be estimated by using

$$N(Z \rightarrow \upsilon\upsilon) = \frac{N_{obs}-N_{bgd}}{A*\varepsilon} \cdot R\left(\frac{Z\rightarrow\nu\nu}{Z\rightarrow\mu\mu}\right) \quad (1)$$

where N_{obs} represents the number of observed dimuon events. N_{bgd} accounts for the number of background events contributing to the dimuon sample obtained by preforming a Monte Carlo simulation. A is an acceptance, a fraction of simulated events passing all selection requirements and all simulated events. ε is a selection efficiency which is determined by a fraction of the number of events passing acceptance cuts and the number of events passing the muon identification and isolation. R is a ratio of the branching fraction of the $Z \rightarrow \nu\nu$ and the $Z \rightarrow \mu\mu$.

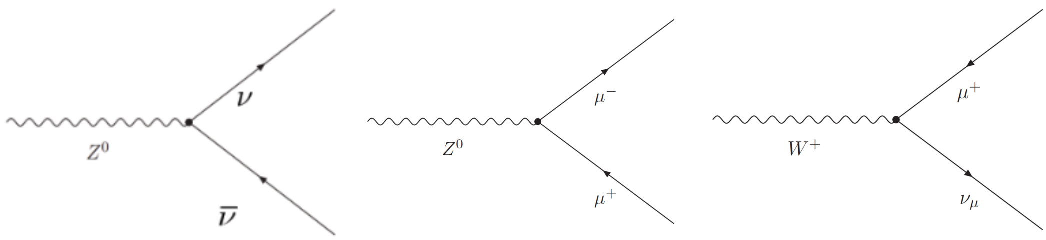

Figure 1 Feynman diagrams showing decays of (a) a Z particle to neutrinos (b) Z particle to muons and (b) W particle to muon and neutrino

3. Method

In this study, the number of the invisible Z background was obtained from $Z(\mu\mu)$+jets and $W(\mu\nu)$+jets events provided by p-p collision at $\sqrt{s} = 8$ TeV in the LHC corresponding to an integrated luminosity of 19.712 fb^{-1}.

3.1 Event selection

The number of the Z($\mu\mu$) and the W($\mu\nu$)+jets control samples are obtained by applying the full monojet selection with the exception of the muon veto. For a Z($\mu\mu$) control sample, events need to pass all signal selection requirements and have two muons with p_T>20 GeV/c, $|\eta|$<2.4 and invariant mass between 60 and 120 GeV. The transverse mass is defined as $M_T = \sqrt{2p_T^{\mu}E_T^{miss}(1-\cos\Delta\phi)}$ where p_T^{μ} is the transverse momentum of the muon and $\Delta\phi$ is the angle between the muon p_T and the E_T^{miss} vectors. The muon veto is replaced by requiring two muons and at least one of these has to be well identified and isolated. To obtain the W($\mu\nu$)+jets sample, all signal selections are also required apart from the muon veto. A well-identified and isolated muon with p_T>20 GeV/c, $|\eta|$<2.4 and a reconstructed W transverse mass between 50 and 100 GeV is selected.

3.2 Estimation of Z($\nu\nu$) background

Since the Z($\upsilon\upsilon$) and the Z($\mu\mu$) events have similar kinematic characteristics, the muons from the Z decay are interpreted as missing energy. The missing transverse energy of the Z($\mu\mu$) event is determined by the vector sum of the transverse momentum of the muons and the E_T^{miss}, and so called MET-like. The number of the Z($\nu\nu$) events can be estimated by using the Z($\mu\mu$) events with equation (1).

For the estimate from W($\mu\nu$)+jets events, the invisible Z decay of the Z boson is mimicked by removing the muon from the W($\mu\nu$) event and adding to the missing transverse energy. The number of the invisible Z background is determined by the same equation where R becomes the difference between the Z and the W in shape of distributions on which cuts are applied.

4. Results and Discussion

Prediction results from the Z($\mu\mu$) and the W($\mu\nu$) samples are shown in table 1 and 2, respectively. The dominant uncertainty is the statistical uncertainty from the number of the Z($\mu\mu$) events while the method of using the $W(\mu\nu)$+jets events allows a much more precise of the invisible Z estimation.

MET	N_{obs}	N_{bgd}	Acceptance	Efficiency	$Z(\upsilon\upsilon)$
> 250 GeV	3695	288	0.89±0.02	0.74±0.02	30700±1898
> 300 GeV	1538	128	0.91±0.02	0.75±0.02	12199±831
> 350 GeV	685	70	0.93±0.02	0.76±0.02	5174±423
> 400 GeV	348	31	0.94±0.02	0.76±0.02	2630±238
> 450 GeV	183	15	0.94±0.02	0.75±0.03	1420±152
> 500 GeV	96	7.7	0.94±0.02	0.76±0.03	732±98
> 550 GeV	47	5.1	0.95±0.02	0.75±0.04	349±66

Table 1: Invisible Z prediction by using $Z(\mu\mu)$ events

MET	N_{obs}	N_{bgd}	Acceptance	Efficiency	$Z(\upsilon\upsilon)$
> 250 GeV	17191	1816	0.86±0.02	0.39±0.02	21874±1090
> 300 GeV	6955	712	0.89±0.02	0.39±0.02	8719±444
> 350 GeV	3104	319	0.90 ±0.02	0.38±0.02	3860±210
> 400 GeV	1484	148	0.91±0.02	0.38±0.02	1851±109
> 450 GeV	780	76	0.92±0.02	0.37±0.03	990±66
> 500 GeV	402	44	0.93±0.02	0.37±0.03	521±43
> 550 GeV	228	31	0.94±0.02	0.38±0.04	287±31

Table 2: Invisible Z prediction by using $W(\mu\nu)$ events

The final result of the invisible Z background estimation shown in the table 3 is obtained by taking weight average on two predictions where the uncertainty in the predicted number is the quadratic sum. By combining the estimate of the invisible Z from two samples, the uncertainty was reduced. However, it should be noted here that the $W(\mu\nu)$ and the $Z(\mu\mu)$ are not completely uncorrelated due to the lepton identification. Other backgrounds obtained from a Monte Carlo simulation are combined to calculate the exclusion limit.

MET (GeV)	> 250	> 300	> 350	> 400	> 450	> 500	> 550
$Z(\nu\nu)$+jets	26287±1094	10459±471	4517±236	2241±131	1205±83	626±53	318±36
W+jets	17177±1030	5908±365	2333±154	1012±72	495±39	247±24	119±14
$t\bar{t}$	446±223	167±84	69±35	31±16	15±7.7	6.6±2.3	2.8±1.4
Z(ll)+jets	134±67	43±21	17±8.7	8.4±4.2	4.7±2.3	2.3±1.2	1.0±0.5
Single t	155±77	53±26	18±9.1	6.1±3.1	0.9±0.4	0.0±0.0	0.0±0.0
QCD Multijets	462±231	101±51	32±16	5.5±2.7	2.3±1.2	1.2±0.6	0.6±0.3
Diboson	3421±1710	1396±698	641±320	305±153	165±83	88±44	55±28
Total SM	48081±2302	12600±924	7628±429	3609±214	1889±124	971±73	497±48
Data	52157	19783	8324	3825	1828	934	519
Exp limit	4225	1707	787	368	199	122	90
Obs limit	7627	3103	1360	564	170	102	107

Table 2: SM background predictions compared with data after passing the selection requirement for different E_T^{miss} thresholds. The last two rows show expected and observed limits on possible contributions from new physics passing the selection criteria obtained from RooStat.

6. Summary

One of useful methods to estimate the $Z(\nu\nu)$+jets irreducible background is the use of W($\mu\nu$)+jets data. The method takes advantage of the fact that at high boson p_T, the event kinematics is similar for the two processes. The advantage comes from large statistic compared to the method using Z($\mu\mu$)+jets events. Another benefit of the use of the Z+jets and the W+jets samples is that both signals and backgrounds are from the same dataset because they are selected by the same monojet+MET trigger. By the way, γ +jets control sample also can be used in the invisible Z estimation by treating a photon as transverse missing energy. It has large statistic and has cleaner signal than the W+jets control samples but another dataset from a photon trigger is required.

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