Discovery Potential of New Boson $W_1^\pm$ in the Minimal Higgsless Model at LHC

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(Dated: May 18, 2009)

Abstract

In this paper, we demonstrate the LHC discovery potential of new charged vector boson $W_1^\pm$ predicted by the Minimal Higgsless model in the process $pp \to W_1^\pm qq' \to W^\pm Z^0 qq' \to \ell^\pm \ell^+ \ell^- \nu qq'$ ($\ell = e, \mu$) by analyzing the generator level events of the signal and backgrounds. The generator for the signal $pp \to W_1^\pm qq' \to W^\pm Z^0 qq'$ at tree level is developed with the Minimal Higgsless model and then interfaced with PYTHIA for the parton showers and hadronization. The backgrounds are produced with PYTHIA and ACERMC. We give integrated luminosities required to discover $5\sigma$ signal as a function of $W_1^\pm$ mass.

PACS numbers: 12.60.Cn, 14.70Pw, 14.70Fm, 14.70Hp
I. INTRODUCTION

The Higgs boson of the electroweak standard model has been sought in vain by all known experiments so far. The absence of such a Higgs boson will violate perturbative unitarity of the high energy longitudinal weak boson scattering $V_L V_L \rightarrow V_L V_L$ ($V = W^\pm, Z^0$). To postpone this unitarity violation, the Higgsless models are proposed, in which the new spin-1 gauge bosons (rather than spin-0 Higgs scalars) play the key role in both 5d and 4d realizations\cite{1}.

Ref.\cite{2} presented the first LHC-study on the distinct signatures of the Minimal Higgsless Model which is exactly gauge-invariant and predicts just a pair of new gauge bosons $(W^\pm_1, Z^0_1)$ as light as about 400 GeV. In ref.\cite{2}, the signature of new boson $W^\pm_1$ in the process $pp \rightarrow W^\pm Z^0 qq' \rightarrow \nu 3\ell qq'$ and the process $pp \rightarrow W^\pm Z^0 Z^0 \rightarrow qq'4\ell$ ($\ell = e, \mu$) were investigated at the parton level, without the initial and final state parton showers and hadronization for the signal and backgrounds, while only the background $pp \rightarrow W^\pm Z^0 qq'$ was considered, which included non fusion and fusion processes. Assuming $W^\pm_1$ mass within the region of (550, 750) GeV, the integrated luminosity required for $5\sigma$ $W^\pm_1$ signal detection is from about 12/fb to 25/fb for the first channel, while from about 40/fb to 300/fb for the second channel\cite{2}.

This work presents the results on the study of $W^\pm_1$ production in the process $pp \rightarrow W^\pm_1 qq' \rightarrow W^\pm Z^0 qq'$ by analyzing the fully hadronized events of the signal and backgrounds at the generator level. The final state is chosen to be $\ell^\pm \nu \ell^+ \ell^- qq'$ ($\ell = e, \mu$), because electrons and muons are well identified by the LHC detectors. The generator for the signal $pp \rightarrow W^\pm_1 qq' \rightarrow W^\pm Z^0 qq' \rightarrow \ell^\pm \nu \ell^+ \ell^- qq'$ is developed based on the Minimal Higgsless model and incorporated with PYTHIA\cite{3} for the parton showers and parton hadronization.

Fig. 1 is the Feynman diagram for the process $pp \rightarrow W^\pm_1 qq' \rightarrow W^\pm Z^0 qq' \rightarrow \ell^\pm \ell^+ \ell^- \nu qq'$. The intermediate state $W^\pm_1$ proceeds through $W^\pm Z^0$ fusion. The typical cross sections (assuming $m_{W^\pm_1}$ to be 700 GeV) are 2.828 fb and 1.538 fb for $pp \rightarrow W^+_1 qq' \rightarrow W^+ Z^0 qq' \rightarrow \ell^+ \nu \ell^+ \ell^- qq'$ and $pp \rightarrow W^-_1 qq' \rightarrow W^- Z^0 qq' \rightarrow \ell^- \nu \ell^+ \ell^- qq'$ respectively.

Compared with the analysis in ref.\cite{2}, which was at the parton level, this work considers the parton showers and hadronization and studies more backgrounds. The hadronization and more backgrounds are supposed to bring much more difficulty for data analysis and decrease the sensitivity to find the signal. More realistic selections should be designed to
Fig. 1 Feynman diagram for the process $pp \rightarrow W^\pm Z^0 qq' \rightarrow \nu 3 \ell qq'$.

suppress these backgrounds.

II. SIGNAL AND BACKGROUND PRODUCTION

A. Signal cross section and sample

The generator for the signal is developed by the authors of ref.[2] based on the matrix element calculation of the LHC process $pp \rightarrow W^+_1 qq' \rightarrow W^\pm Z^0 qq' \rightarrow \ell^\pm \ell^+ \ell^- \nu qq'$ at a full tree level in the Minimal Higgsless model. The Parton Distribution Function (PDF) CTEQ6L[4] is used. In this work the loose preselections at parton level are used to replace the original ones[2] to increase the cross section. Quarks satisfy transverse momentum $p_{tq} > 25 \text{ GeV}$ and pseudorapidity $|\eta_q| < 7.0$. Leptons satisfy $p_{t\ell} > 5 \text{ GeV}, \ |\eta_\ell| < 2.5$. The weighted parton level events from the generator are fed into PYTHIA for sampling. The initial and final state showers and hadronization are done by PYTHIA. It should be emphasized that quarks with $|\eta_q| > 4.5$ may result in some jets with $|\eta_j| < 4.5$ after hadronization, but these events were ignored in Ref.[2]. The pseudorapidity of 4.5 is the coverage of the LHC detectors.

The cross section after the preselection, the number of events and the normalization factors are listed in Table. 1. The integrated luminosity is set to be 20/fb. The $W^+_1$ signal and $W^-_1$ signal are produced separately with 1000 events each. The normalization factor is $(\text{cross section}) \times 20(\text{fb}^{-1})/\text{events}$. The uncertainties of the cross section are discussed in the section IV.

For comparison, the cross section for the $W^+_1$ Drell-Yan production $pp \rightarrow W^\pm \rightarrow W^+_1 Z^0 \rightarrow W^\pm Z^0 Z^0 \rightarrow qq'4\ell$ ($\ell = e, \mu$) is listed here, which is $0.2585 \pm 0.0013 \pm 0.0034$, $0.1891 \pm 0.0008 \pm 0.0023$, $0.1432 \pm 0.0006 \pm 0.0029$, $0.1136 \pm 0.0004 \pm 0.0037$ and $0.0939 \pm 0.0003 \pm 0.0038 \text{ fb}$ for $m_{W^+_1} = 550, 600, 650, 700$ and $750 \text{ GeV}$ respectively. The first error
is statistical and the second is systematic. The integrated luminosity to find 5 $\sigma$ $W^{\pm}$ signal through this process is discussed in a separate paper[5].

Table 1 Production of signal sample. The first error is statistical and the second is systematic.

| $W^{\pm}$ mass (GeV) | $W^{\pm}_{1}qq' \rightarrow W^{\pm}Z^{0}qq' \rightarrow \ell^{\pm}\nu\ell^{\pm}\ell^{-}qq'$ cross section (fb) | events | norm | $W^{-}_{1}qq' \rightarrow W^{-}Z^{0}qq' \rightarrow \ell^{-}\nu\ell^{+}\ell^{-}qq'$ cross section (fb) | events | norm |
|----------------------|-------------------------------------------------|-------|------|-------------------------------------------------|-------|------|
| 550                  | 6.303 ± 0.364 ± 0.076                          | 1000  | 0.126| 3.674 ± 0.248 ± 0.896                          | 1000  | 0.073|
| 600                  | 4.844 ± 0.260 ± 0.440                          | 1000  | 0.097| 2.728 ± 0.156 ± 0.056                          | 1000  | 0.054|
| 650                  | 3.685 ± 0.192 ± 0.264                          | 1000  | 0.074| 2.101 ± 0.124 ± 0.080                          | 1000  | 0.042|
| 700                  | 2.828 ± 0.152 ± 0.164                          | 1000  | 0.056| 1.538 ± 0.072 ± 0.012                          | 1000  | 0.031|
| 750                  | 2.215 ± 0.124 ± 0.056                          | 1000  | 0.044| 1.176 ± 0.060 ± 0.048                          | 1000  | 0.023|

B. Background cross sections and samples

There are three leptons ($\ell = e^{\pm}, \mu^{\pm}$) and two forward quarks in the signal process. Therefore the contamination to the signal process comes from processes including multiple leptons in the final state. In this work, all the backgrounds but $pp \rightarrow Z^{0}t\bar{t}$ are generated using PYTHIA. $pp \rightarrow Z^{0}t\bar{t}$ is generated using ACERMC[6].

In view of the final state of the signal process, the irreducible backgrounds are $pp \rightarrow W^{\pm}Z^{0} \rightarrow \ell^{\pm}\nu\ell^{\pm}\ell^{-}$ and $pp \rightarrow W^{\pm}Z^{0}qq' \rightarrow \ell^{\pm}\nu\ell^{+}\ell^{-}qq'$, hereafter $Z^{0}$ denotes $\gamma^{*}/Z^{0}$ for all the background channels, while $Z^{0}$ does not include $\gamma^{*}$ for the signal channels though it is interfaced with PYTHIA. The lepton components in the two backgrounds are identical to that of the signal process. The first process is a leading order non-fusion process. The second is a leading order fusion process, in which there are two forward quarks $qq'$. Here fusion means $W^{\pm}Z^{0} \rightarrow W^{\pm*} \rightarrow W^{\pm}Z^{0}$. The cross section of the second process is about 0.06% of that of the first process. The initial and final gluon radiations will add jets to both of them, i.e. $pp \rightarrow W^{\pm}Z^{0} + njets$ (n=0,1,2,...; jet=q, gluon) for the non-fusion process and $pp \rightarrow W^{\pm}Z^{0}qq' + njets$ (n=0,...; jet=q, gluon) for the fusion process. In Ref.[2], the non-fusion and fusion processes $pp \rightarrow W^{\pm}Z^{0}2jets$ (jet=q, gluon) were discussed.

Because additional leptons may come from decays of quarks, there is a possibility that the two lepton process $pp \rightarrow W^{+}W^{-} \rightarrow 2\ell 2\nu$ and the corresponding fusion process $pp \rightarrow$
\( W^+W^-qq' \to 2\ell2\nuqq' \) may construct 3 lepton states. The second process includes \( Z^0Z^0 \to W^+W^- (0.003\%) \) and \( W^+W^- \to W^+W^- (99.997\%) \).

If a lepton goes beyond the detection region where \(|\eta| > 2.5^{[7]}\), the four lepton process \( pp \to Z^0Z^0 \to 4\ell \) and the corresponding fusion process \( pp \to Z^0Z^0qq' \to 4\ellqq' \) possibly become backgrounds. If an additional lepton comes from a quark decay, the two lepton process \( pp \to Z^0Z^0 \to 2\ell q_i q_i \) and the corresponding fusion process \( pp \to Z^0Z^0qq' \to 4\ell q_i q_i qq' \) also become backgrounds. The second process includes \( Z^0Z^0 \to Z^0Z^0 (0.1\%) \) and \( W^+W^- \to Z^0Z^0 (99.9\%) \). As above mentioned, in PYTHIA \( Z^0 \) denotes \( Z^0/\gamma^* \), the processes include \( Z^0Z^0, Z^0\gamma^*, \gamma^*\gamma^* \) and their interference. Therefore, one of the two \( Z^0 \) is chosen to decay into a pair of electrons or muons and another is allowed to decay free in this work.

The multiple lepton processes that have very large cross sections are \( pp \to Z^0b\bar{b} \to 2\ell b\bar{b} \) and \( pp \to t\bar{t} \to W^+bW^-\bar{b} \to 2\ell 2\nu b\bar{b} \) including \( q\bar{q} \to t\bar{t} (13.9\%) \) and \( gg \to t\bar{t} (86.1\%) \). There are two leptons in the final state. The third \( \ell \) production may come from the direct or cascade decay of \( b \) quark.

The process \( pp \to Z^0t\bar{t} \to 2\ell t\bar{t} \) with \( t \) and \( W^\pm \) free decay is generated using ACERMC\(^{[6]} \). \( t\bar{t} \) will produce a pair of \( W^+W^- \). Due to the leptonic and hadronic decays of \( W^\pm \), this process includes two leptons, three leptons and four leptons in the final state.

The cross sections, the numbers of the events and the normalization factors for the background samples are given in the Table 2. It is worth noting that all normalization factors are less than 1.

Table 2 production of backgrounds. \( f \) represents a fundamental fermion of flavour

| Process | cross section (fb) | events | norm. factor |
|---------|-------------------|--------|--------------|
| \( f\bar{f}, W^\pm Z^0 \to W^\pm Z^0 \to 3\ell \nu \) | 389.70, 0.24 | 6E4 | 0.130 |
| \( f\bar{f}, W^+W^-, Z^0Z^0 \to W^+W^- \to 2\ell 2\nu \) | 3295, 5673, 0.14 | 54E4 | 0.332 |
| \( f\bar{f}, W^+W^-, Z^0Z^0 \to Z^0Z^0 \to 2\ell X \) | 1676, 0.54, 7.4E-4 | 14E4 | 0.240 |
| \( t\bar{t} \to W^+W^- b\bar{b} \to 2\ell 2\nu b\bar{b} \) | 22980 | 2.16E6 | 0.213 |
| \( Z^0b\bar{b} \to 2\ell b\bar{b} \) | 3.244E5 | 2.7E7 | 0.240 |
| \( Z^0t\bar{t} \to 2\ell t\bar{t} \) | 33.43 | 7000 | 0.095 |
III. EVENT SELECTION

Event selection is based on the feature of the signal process. There are three leptons with high momentum and two hard forward quarks at the parton level. Two of three leptons come from the $Z^0$ decay and one from the $W^\pm$ decay. The two forward quarks are supposed to evolve into hard forward jets. Events are accepted if there are three leptons in the final states and the total charge of three leptons is equal to 1 or -1. Each lepton satisfies $|\eta_\ell| < 2.5$, $p_{t\ell} > 10 \text{ GeV}$. Then the number of jets is required to be equal to or larger than 2. Each jet is reconstructed with cone of $\Delta R = \sqrt{\Delta \eta^2 + \Delta \phi^2} = 0.7$ and satisfies $|\eta_j| < 4.5$ and $p_{tj} > 25 \text{ GeV}$ and $\Delta R(j, \mu) > 0.3$ to suppress fake jets.

The jet reconstruction algorithm is one provided with PYTHIA$^{[3]}$, in which a detector grid is assumed, with the pseudorapidity range $|\eta_j| < \eta_{\text{max}}(4.5)$ and the full azimuthal range each divides into 50 equally large bins, giving a rectangular grid; the cell with largest $E_t$ is taken as a jet initiator; a candidate jet is defined to consist of all cells which are within $(\eta - \eta_{\text{initiator}})^2 + (\phi - \phi_{\text{initiator}})^2 < \Delta R^2$; the candidate jet is accepted if the summed transverse energy $E_t$ is above 7 GeV and its all cells are removed from future consideration; the sequence is now repeated within the remaining cell of highest $E_t$ and so on. The cut is powerful to suppress the backgrounds $W^\pm Z^0 \rightarrow 3\ell \nu$, $WW \rightarrow 2\ell 2\nu$ and $Z^0 Z^0 \rightarrow 4\ell$, because there are no quarks at the parton level.

![Fig. 2](image.png)

Fig. 2 The distribution of highest momentum of the three leptons. The solid line is for the signal. The dashed line is for the backgrounds.

To reduce the backgrounds, the maximum momentum of the three leptons is required to be larger than 150 GeV, see Fig. 2. For the signal process, the threshold of the momentum
distribution is 150 GeV, thanks to the three leptons coming from \( W_1^\pm \) with large mass. Out of the same reason, the scalar sum of pt of 3 \( \ell \)s and missing \( Et \) is required to be larger than 700 GeV, see Fig. 3.

The reconstruction of \( Z^0 \) and \( W^\pm \) using 3 \( \ell \)s and one missing neutrino is a prerequisite for the signal event selection. The remaining events are required to satisfy \( | m_{\mu^+\mu^-} - 91.18 | < 15 \text{ GeV} \) and \( W^\pm \) transverse mass \( mt_{W^\pm} < 200 \text{ GeV} \).

To suppress the background \( pp \rightarrow W^\pm Z^0 \) and \( Z^0 b\bar{b} \) further, the ratio of the scalar sum of jets’ transverse momenta over the scalar sum of jets’ momenta is larger than 0.1 and the maximum momentum of jets is larger than 200 GeV. Finally, the transverse mass of \( W^\pm Z^0 \) denoted as \( mh \) for the remaining events is shown in Fig. 4. Its root mean square is 226.0 GeV. The definition of \( mh \) is

\[
mh = \sqrt{Eh^2 - ph^2},
\]

where

\[
Eh = \sum_{i=1}^{3} E_{\ell_i} + \sqrt{px_{\text{miss}}^2 + py_{\text{miss}}^2},
\]

\[
ph = \sqrt{\left( \sum_{i=1}^{3} px_{\ell_i} + px_{\text{miss}} \right)^2 + \left( \sum_{i=1}^{3} py_{\ell_i} + py_{\text{miss}} \right)^2 + \left( \sum_{i=1}^{3} pz_{\ell_i} \right)^2},
\]

where \( p_{i\text{miss}}(i = x, y, z) \) is minus value of sum of momenta in \( i \) direction for the three leptons and the all jets. The new definition is different from the conventional transverse mass

\[
mt = \sqrt{\left( \sum_{i=1}^{3} Et_{\ell_i} + \sqrt{px_{\text{miss}}^2 + py_{\text{miss}}^2} \right)^2 - \left( \sum_{i=1}^{3} px_{\ell_i} + px_{\text{miss}} \right)^2 - \left( \sum_{i=1}^{3} py_{\ell_i} + py_{\text{miss}} \right)^2}.
\]

We call it half transverse mass temporarily, because it takes all available components of momenta into account so that the number of components of momenta involved is larger than that of the transverse mass and less than that of the mass. For comparison, the transverse mass of \( W^\pm Z^0 \) defined as \( mt \) is shown in Fig. 5. Its root mean square is 268.5 GeV, which is worse than that of \( mh \).

The number of remaining events and efficiency after each cut are shown in Table 3 where \( W_1^\pm \) mass is 700 GeV. The significance is 7.0 \( \sigma \) using \( \text{significance}=\sqrt{2ln(Q)}, \ Q = (1 + N_s/N_b)^{N_{\text{obs}}exp(-N_s)} \), which corresponds to 5.0 \( \sigma \) for the integrated luminosity of 10.2 \( fb^{-1} \).
For $m_{W_1}$ to be 550, 600, 650, 750 GeV, the signal process can be processed with the same criteria. The remaining events, the significances and the integrated luminosity for 5$\sigma$ signal detection are shown in Table 4.

IV. SYSTEMATIC UNCERTAINTIES

For the analysis based on the generator level events, the main uncertainties of $W_1^{\pm}$ discovery potential are the errors of both the signal and background cross sections. In order to be more realistic than the generator level events, the fake electrons and muons from jet misidentification are also estimated.

The cross section uncertainty for the signal process includes the statistical error and the difference between two PDFs CTEQ6L\cite{4} and CTEQ6M\cite{9} listed in Table 2 as the first and second errors respectively. The uncertainty of the background cross sections are assumed to be 100%. The uncertainties on the number of the signal events, the number of the background events for luminosity of 20/fb are listed on Table 4.

From CMS Technical Design Report\cite{10}, the rates of a jet faking an electron and a muon due to jet misidentification are about $6 \times 10^{-4}$ and $5^{-4}$ respectively. To estimate the fake lepton effect on the numbers of the signal events and the background events, the jets are misidentified by intention randomly as electrons (50%$e^+$, 50%$e^-$) and muons (50%$\mu^+$, 50%$\mu^-$) using the rates to re-analyze the signal process and the back-
Table 3  Remaining Events and Efficiency(%) for Each Cut. The mass of $W^+_i$ is set to be 700 GeV in the table.

|                  | $W^+_i$ | $W^-_i$ | WZ     | WW     | ZZ     | $tt\bar{t}$ | $Z^0b\bar{b}$ | $Z^0tt\bar{t}$ |
|------------------|---------|---------|--------|--------|--------|------------|---------------|----------------|
| $CR \times 20fb$|    56.6 |    30.8 |  7794.0| 179380.0| 33540.0|  459600.0 |    6.48E6     |     668.6     |
|                  | 100.00%| 100.00%| 100.00%| 100.00%| 100.00%| 100.00%   | 100.00%       | 100.00%       |
| number of        |    54.0 |    29.5 |  3260.2|   682.3| 1097.2 |   58412.6 |   55663.2     |     232.0     |
| leptons = 3      |  95.40%|  96.00%|   41.83%|   0.32%|  3.22% |   12.71%  |    0.86%      |    34.70%     |
| number of        |    46.3 |    23.7 |   90.5 |   521.5|  135.9 |   25147.1 |   21114.5     |     225.3     |
| jets ≥ 2         |  81.80%|  77.20%|   1.16% |   0.29%|  0.41% |    5.47%  |    0.33%      |    33.70%     |
| maximum mon of   |    45.8 |    23.4 |   50.4 |   207.6|   67.8 |   7994.7  |   5251.0      |    125.3      |
| 3 leps. > 150 GeV|  81.0%  |  76.10%|   0.65% |   0.2% |  0.20% |   1.74%  |    0.08%      |    18.74%     |
| sum pt of 3 leps.|    24.3 |    11.1 |    2.3 |    7.3 |    1.3 |    73.6   |     19.4      |     7.4       |
| & $p_{t\text{missing}} > 700$ GeV| 43.00%  | 36.20%  | 0.03%  | 4.1E-3%| 3.8E-3%| 0.016%   | 3.0E-4%       | 1.10%         |
| $|M_{\mu^+\mu^-} - M_{Z^0}| < 15$ GeV| 23.4  |  10.6  |  2.2   |  0.3   |  1.3   |     7.0   |    16.1       |     6.20      |
|                   | 41.30% | 34.3%  |  2.8E-2%|  1.9E-4%| 3.8E-3%| 1.5E-3%  | 2.5E-4%       | 0.93%         |
| $30 < M_{wt}$    |     17.0|    7.7  |  1.7   |  0.3   |  1.3   |     2.1   |     2.4       |     2.4       |
| $< 200$ GeV      |  30.10%| 25.00% |  2.2E-2%| 1.9E-4%| 3.8E-3%| 4.6E-4%  | 3.7E-5%       | 0.36%         |
| Jets’ pt/p       |    15.2 |    7.3  |  1.7   |   0    |  1.2   |     2.1   |     0         |     2.4       |
| $> 0.1$          |  26.90%| 23.60% |  2.2E-2%|   0%   |  3.5E-3%| 4.6E-4%  |    0%         |    0.36%      |
| maximum mon of   |    15.0 |    7.1  |  1.0   |   0    |  0     |     1.7   |     0         |     2.0       |
| jets > 200 GeV   |  26.60%| 23.00% |  1.3E-2%|   0%   |  0%    |  3.7E-4%  |    0%         |  0.30%        |

ground processes. The number of the signal events decreases 0.4, 0.1, 0.4, 0.1 and 0.1 for $m_{W^+_i} = 550$, 600, 650, 700, 750 GeV respectively. The number of the background events increases 0.2 for only the process $pp \rightarrow tt\bar{t}$ and keeps intact for the other processes. The uncertainties on the numbers of the signal events and the background events are listed on Table 4. The uncertainties on the cross sections and the fake leptons are added in quadrature to the total uncertainties in Table 4. The uncertainties on the significances for the luminosity of $20fb^{-1}$ and the luminosity to find 5σ signal caused by the total uncertainties
V. SUMMARY

We have studied discovery potential of new charged boson $W^\pm_1$ in the process $pp \rightarrow W^\pm_1 qq' \rightarrow W^\pm Z^0 qq' \rightarrow \ell^\pm \nu \ell^+ \ell^- qq' (\ell = e, \mu)$ based on the hadronized events with the initial and final state parton showers at the generator level. The signal generator is developed with the Minimal Higgsless model. In addition to $pp \rightarrow W^\pm Z^0$, the five more background processes with multiple leptons are studied. The uncertainty on the luminosity for 5\sigma signal detection propagated from the uncertainties of cross sections is estimated. It is found that the major backgrounds are $pp \rightarrow t\bar{t}$ and $pp \rightarrow Z^0 t\bar{t}$. The integrated luminosity for 5\sigma signal detection is between 4.2 and 12.2/fb assuming $W^\pm_1$ mass from 550 and 750 GeV. This integrated luminosity can be reached early in LHC.

If we only consider the backgrounds $pp \rightarrow W^\pm Z^0$ and $pp \rightarrow W^\pm Z^0 qq'$, only 1.0 background event remains (see table 4), which means that one can find 5\sigma signal of 700 GeV using the integrated luminosity of 5.0/fb. So, it can see that the other backgrounds will bring more difficulty to the detection of $W^\pm_1$.

The signal cross section decreases with the increase of $W_1$ mass. Because we do not know how large $W_1$ mass is before analyzing data, the identical selection criteria is used to select

| $m_{W_1}$ (GeV) | number of signal | number of bg | significance($\sigma$) with lumi of 20fb$^{-1}$ | lumi(fb$^{-1}$) for 5\sigma signal detection |
|-----------------|-----------------|--------------|-----------------------------------------------|-----------------------------------------------|
| 550             | 39.2 +3.9 +0.0  | 4.7 +4.7 +0.2 | 10.9 +0.98 _-2_6 | 4.2 +3.0 _-0_6 |
| 600             | 31.4 +2.3 +0.0  | 4.7 +4.7 +0.2 | 9.2 +0.5 _-2_1 | 5.9 +4.0 _-0_6 |
| 650             | 24.6 +1.5 +0.0  | 4.7 +4.7 +0.2 | 7.6 +0.4 _-1_8 | 8.6 +6.0 _-0_8 |
| 700             | 22.1 +1.2 +0.0  | 4.7 +4.7 +0.2 | 7.0 +0.3 _-1_6 | 10.2 +7.0 _-0_8 |
| 750             | 19.7 +0.9 +0.0  | 4.7 +4.7 +0.2 | 6.6 +0.2 _-1_5 | 12.2 +8.3 _-0_8 |

are also listed on Table 4.
the signal and background events for the various assumed mass of $W_1$ from 550 to 750 GeV. In future, when we contact with data and the LHC detector simulated events, the selection criteria can be optimized according to practical mass of $W_1$.

This work is supported by NSFC No. 10435070, No. 10721140381, and No. 10099630, MoST No. 2007CB16101, and CAS No. KJCX2-YW-N17 and No. 1730911111.

FIG. 4 The $W^\pm Z^0$ half transverse mass distribution. The solid line is for the signal with $m_{W_1} = 700$ GeV and the integrated luminosity of 20/fb. Its root mean square is 226.0 GeV. The shaded area is the backgrounds.

FIG. 5 The $W^\pm Z^0$ transverse mass distribution. The solid line is for the signal with $m_{W_1} = 700$ GeV and the integrated luminosity of 20/fb. Its root mean square is 268.5 GeV. The shaded area is the backgrounds.
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