Detecting an invisible Higgs boson at Fermilab Tevatron and CERN LHC

Shou-hua Zhu
Institute of Theoretical Physics, School of Physics, Peking University, Beijing 100871, China
(Dated: March 26, 2022)

In this paper, we study the observability of an invisible Higgs boson at Fermilab Tevatron and CERN LHC through the production channel $q\bar{q} \rightarrow ZH \rightarrow \ell^+\ell^- + P_T$, where $P_T$ is reconstructed from the $\ell^+\ell^-$ with $\ell = e$ or $\mu$. A new strategy is proposed to eliminate the largest irreducible background, namely $q\bar{q} \rightarrow Z(\rightarrow \ell^+\ell^-)Z(\rightarrow \nu\bar{\nu})$. This strategy utilizes the precise measurements of $q\bar{q} \rightarrow Z(\rightarrow \ell^+\ell^-)Z(\rightarrow \ell^+\ell^-)$. For $m_H = 120$ GeV and with luminosity $30fb^{-1}$ at Tevatron, a $5\sigma$ observation of the invisible Higgs boson is possible. For $m_H = 114 \sim 140$ GeV with only $10fb^{-1}$ luminosity at LHC, a discovery signal over $5\sigma$ can be achieved.

PACS numbers: 14.80.Cp

I. INTRODUCTION

Understanding the mechanism of electroweak symmetry breaking (EWSB) is a primary goal of the Fermilab Tevatron, CERN LHC and the proposed ILC. In the standard model (SM) of high energy physics, EWSB is realized via a weak-doublet fundamental Higgs field. After EWSB spontaneously, namely Higgs field acquiring a vacuum expectation value (VEV), only one neutral Higgs boson is left in particle spectrum. The Higgs boson mass is theoretical unknown within the SM. Therefore searching all mass region is necessary and great efforts have been put on it since the establishment of the SM. The latest direct search at LEP sets the lower bound of SM Higgs boson of 114.4 GeV at 95% confidence level (CL) \cite{1}. The Higgs boson can also affect electro-weak observables through radiative corrections. Therefore precise measurements of these observables can predict the Higgs boson mass. Studies show that data from LEP, SLD and Tevatron are in good agreement with SM predictions \cite{2}. Based on the global fit of those data, the Higgs boson mass is predicted to be $m_H = 98^{+52}_{-36}$ GeV and $m_H < 208$ GeV at 95% CL using latest preliminary top quark mass $m_t = 174.3 \pm 3.4$ GeV \cite{3}.

The Higgs boson decay width in the SM varies dramatically within the experiments preferable mass region $114.4 \sim 208$ GeV. For example, for $m_H = 120$ GeV, $\Gamma(H) \simeq 3.65$ MeV while for $m_H = 200$ GeV, $\Gamma(H) \simeq 1.425$ GeV \cite{3}. The tiny decay width for light Higgs ($2m_W$) is due to the suppressed coupling among Higgs boson and fermion which is proportional to $m_f/m_W$ with $m_f$ the light fermion mass. Therefore the light Higgs boson ($2m_W$) can possibly decay into non-SM particles with large branching ratio. For example the Higgs boson may decay dominantly into scalar dark matter in the simplest cold dark matter model \cite{4}. Study of Ref. \cite{5} shows that the correct cold dark matter relic abundance within $3\sigma$ uncertainty ($0.093 < \Omega_{dm}h^2 < 1.129$) and experimentally allowed Higgs boson mass ($114.4 \leq m_H \leq 208$ GeV) constrain the scalar dark matter mass within $48 \leq m_S \leq 78$ GeV. This result is in excellent agreement with that of W. de Boer et.al. ($50 \sim 100$ GeV) \cite{6}. Such kind of dark matter annihilation can account for the observed gamma rays excess ($10\sigma$) at EGRET for energies above $1$ GeV in comparison with the expectations from conventional Galactic models. The most important phenomenological consequence of this model is that the Higgs boson decays dominantly into scalar cold dark matter if its mass lies within $48 \sim 64$ GeV. In Ref. \cite{7} $O(1 \sim 100)$ MeV scalar dark matter was proposed to account for the observation of a 511 KeV bright $\gamma$-ray line from the galactic bulge \cite{8}. From theoretical point of view, containing a stable singlet scalar which interacts possibly with SM Higgs boson, is a generic feature of models of scalar dark matter \cite{9,10}. In other models beyond the SM, it is not rare that the Higgs boson can decay into dark matter. For example in supersymmetrical models with R-parity, the Higgs boson can decay into pair of neutralino if kinematically allowed.

Another reason why light Higgs boson is especially interesting is due to the aspect of experiments. It is known for a long time that hadronic asymmetry measurements, namely $A_F$, $A_{FB}$ and $Q_F$ prefer the heavier Higgs mass with central value around 400 GeV, while the leptonic ones, $m_W$, $F_Z$ and $R_\ell$ prefer the very light Higgs which already indicates certain tension with direct search limit 114.4 GeV \cite{3}. While such situation maybe totally due to statistical fluctuations, it is not unreasonable to suspect that some unknown systematic errors lie in hadronic asymmetry measurements. If this is true, the SM Higgs boson tends to lie just above the current direct search limit, otherwise the tension will become stronger.

In this paper we will study invisible Higgs boson in $ZH$ associated production channel in which Higgs boson decays invisibly, i.e. we can’t tag Higgs decay products, and $Z \rightarrow \ell^+\ell^-$ with $\ell = e, \mu$. The signal is $\ell^+\ell^- P_T$, where $P_T$ is reconstructed from the $\ell^+\ell^-$. This channel has been widely discussed in literature \cite{11,12,13,14,15}. As one of the characteristics of this mode, we can’t get Higgs boson invariant mass peak out of continuum background. Therefore it is quite interesting to know how to get Higgs boson mass information from the experimental measurements. As pointed out by Ref. \cite{14}, this process may provide an interesting handle on the Higgs boson mass at LHC. The Higgs mass can be extracted from the production cross section and the uncertainty is 35-50 GeV (15-20 GeV) with integrated luminosity $10(100)fb^{-1}$ at
Therefore, precise understanding of backgrounds is essential. At hadron colliders the precise predictions for backgrounds are commonly thought difficult because of uncertainty in parton distribution function (PDF), large QCD radiative corrections etc. However for this channel, we only care about charged leptons final states, and the backgrounds seem to be less severe than those of hadronic final states. Another interesting question is how to suppress background efficiently. In literature, lots of techniques are proposed [11, 12, 13, 14, 15]. However the largest irreducible ZZ background, with one Z decays into neutrinos and the other charged lepton pair, can’t be eliminated by kinematical cuts. In this paper, we will propose a method, i.e. utilizing the precise measurement of $Z(\rightarrow \ell^+\ell^-)Z(\rightarrow \ell^+\ell^-)$, to reduce the largest irreducible ZZ background.

II. DETAIL SIMULATION

In this paper, we consider the production of Higgs boson in association with a Z boson, and Higgs decays 100% invisibly. Therefore the signal is:

$$p p (\text{or } \bar{p}) \rightarrow Z(\rightarrow \ell^+\ell^-) + h_{\text{inv}}; \quad \ell = e, \mu.$$  

(1)

As the signal is $\ell^+\ell^-$, $p_T$ where $p_T$ is reconstructed from the $\ell^+\ell^-$, the most significant sources of background are

$$Z(\rightarrow \ell^+\ell^-)Z(\rightarrow \nu\bar{\nu}), \quad W^+(\rightarrow \ell^+\nu)W^-(\rightarrow \ell^-\bar{\nu}),$$

$$Z(\rightarrow \ell^+\ell^-)W^+(\rightarrow \ell^-\nu),$$

(2)

with the lepton (e, $\mu$ and $\tau$, and only here we consider $\tau$ lepton) from the W decay in $ZW$ missed, and $Z+$ jets final states with fake $p_T$. We simulate the signal and the three backgrounds in Eq. 2 using Pythia [17] without initial and final QCD and QED radiation corrections. In order to reduce the fake $p_T$ background to an insignificant level, we set $p_T > 85, 100\, \text{GeV}$ for LHC and $p_T > 55, 75, 100\, \text{GeV}$ for Tevatron.

We adopt the following “LHC cuts” from [14]:

$$p_T(\ell^+) > 10\, \text{GeV}, \quad |\eta(\ell^\pm)| < 2.5, \quad \Delta R(\ell^+\ell^-) > 0.4,$$

(3)

where $\eta$ denotes pseudo-rapidity and $\Delta R$ is the separation between the two particles in the detector, $\Delta R = \sqrt{(\Delta \eta)^2 + (\Delta \phi)^2}$; $\phi$ is the azimuthal angle. The $WW$ background can be largely eliminated by

$$|m_{\ell^+\ell^-} - m_Z| < 10\, \text{GeV}, \quad \Delta \phi_{\ell^+\ell^-} < 2.5.$$  

(4)

In order to reduce the third background in Eq. 2, we veto events with

$$p_T(\ell) > 10\, \text{GeV}, \quad |\eta(\ell)| < 3.0.$$  

(5)

At Tevatron we adopt the following “Tevatron cuts” from [13]:

$$p_T(\ell^\pm) > 12\, \text{GeV}, \quad |\eta(\ell^\pm)| < 2.0, \quad \Delta R(\ell^+\ell^-) > 0.4,$$

$$|m_{\ell^+\ell^-} - m_Z| < 7\, \text{GeV}, \quad \Delta \phi_{\ell^+\ell^-} < 2.7,$$

(6)

and veto events with

$$p_T(\ell) > 10\, \text{GeV}, \quad |\eta(\ell)| < 2.5.$$  

(7)

The signal and background are shown in Fig. 1 and 2 as a function of $p_T$ for $e^+e^-$ final states at Tevatron and LHC. Our results are consistent with those of Ref. 12 and 14.

![Fig. 1: Missing $p_T$ distribution for $Z(\rightarrow e^+e^-) + h_{\text{inv}}$, signal and backgrounds at Tevatron with $\sqrt{s} = 2\, \text{TeV}$ after applying the “Tevatron cuts” in Eqs. 6, 7, and 8. Here “C” represents signal with $m_h = 120, 130\, \text{and } 140\, \text{GeV}$ from top to bottom, and “SUB” stands for $R \times \sigma_{4\ell}/2$ (see text).](image1)

![Fig. 2: Same conventions with figure 1 but at the LHC with $\sqrt{s} = 14\, \text{TeV}$ after applying the “LHC cuts” in Eqs. 3, 4, and 5.](image2)
natural because of two reasons. The first one is that $ZZ \rightarrow 4\ell$ is almost background free due to the excellent leptonic reconstruction efficiency and mass resolution of $Z$ boson (decays to a pair of charged leptons). For example with integrated luminosity $30 \text{ fb}^{-1}$ cross section of this channel can be measured to an accuracy of $5\%$ at LHC [18]. The second reason is that $ZZ$ background and $ZZ \rightarrow 4\ell$ share almost the same kinematics, the same higher order QCD radiative correction and PDF uncertainties, as well as the uncertainty of luminosity etc. We can then get improved $ZZ$ background by subtracting contributions from $ZZ \rightarrow 4\ell$

$$
\sigma_{4\ell,\text{improved}}^{ZZ} = \sigma_{bkg}^{ZZ} - R \times \sigma_{4\ell}
$$

where $\sigma_{4\ell}$ is the cross section for $ZZ \rightarrow 4\ell$ with each pair of leptons satisfying "LHC cuts" or "Tevatron cuts" in Eqs. (3-8). Actually $ZZ \rightarrow 4\ell$ event does not have missing $P_T$ if we run through all the final state particles. However in our case $P_T$ is reconstructed via the momentum of charged lepton pair, invariance mass of which is effectively around $m_Z$. Thus $ZZ \rightarrow 4\ell$ is the extra data set which is not included in that of $\ell^+\ell^- P_T$. Note that the purity of $ZZ \rightarrow 4\ell$ is the most crucial factor for the subtraction purpose. Thus besides "LHC cuts" or "Tevatron cuts" (e.g. invariance mass of each pair is effectively around $m_Z$), we can further require that missing $P_T$ of four leptons should be small, in order to guarantee that they do come from $ZZ$. The detail study of $ZZ \rightarrow 4\ell$ can be found in Ref. [18]. In Eq. (9) $R$ is the ratio defined as

$$
R = \frac{2 \sum_{i=1}^{3} Br(Z \rightarrow \ell_i \bar{\nu}_i)}{3 Br(Z \rightarrow e^+ e^-)}.
$$

It is obvious that $\sigma_{bkg,\text{improved}}^{ZZ} \approx 0$ if we can measure all 4 charged lepton final states in any kinematical region. Though this ratio at tree level can be expressed as, omitting the final state lepton mass,

$$
R = 2 \times \frac{(g_{V}^{(f)})^2 + (g_{A}^{(f)})^2}{(g_{V}^{(f)})^2 + (g_{A}^{(f)})^2}
$$

with $g_{V}^{(f)} = T_{w3}^{(f)} - 2 \sin^2 \theta_W Q^{(f)}$ and $g_{A}^{(f)} = T_{w3}^{(f)}$. The higher order radiative corrections can be included by replacing the couplings $g_{V}$ and $g_{A}$ by the effective ones. In this paper we alternatively adopt the experimental central values as input: $\Gamma(Z \rightarrow \text{inv}) = 499 \text{ MeV}$ and $\Gamma(Z \rightarrow \ell^+\ell^-) = 83.984 \text{ MeV}$ [19], and get

$$
R = \frac{2 \Gamma(Z \rightarrow \text{inv})}{3 \Gamma(Z \rightarrow \ell^+\ell^-)} = 3.961.
$$

In Fig. 1 and 2, we also show the $P_T$ distribution for $4\ell$ process (in fact, one can reconstruct two equal $P_T$ based on two pair of leptons, and invariant mass of each lepton pair is around $Z$ mass peak). The shape of $ZZ$ background and $ZZ \rightarrow 4\ell$ process is very similar and the difference represents the incomplete cancelation due to the kinematical cuts on charged leptons.

Our results for the background and signal cross sections are tabulated in Table II for Tevatron and IV for LHC. The corresponding signal to background ratio, $S/B$, and significance, $S/\sqrt{B}$, are tabulated in Table III for Tevatron and IV for LHC.

| $p_T$ cut | B(ZZ) | improved B(ZZ) | B(WW) | B(ZW) |
|---|---|---|---|---|
| 55 GeV | 6.73 | 1.78 fb | 2.96 fb | 0.70 fb |
| 75 GeV | 3.96 | 0.97 fb | 0.71 fb | 0.35 fb |
| 100 GeV | 1.96 | 0.45 fb | 0.10 fb | 0.15 fb |

| $m_h$ | S(Z + h_{inv}) |
|---|---|---|---|
| 55 GeV | 2.07 fb | 1.62 fb | 1.27 fb |
| 75 GeV | 1.46 fb | 1.18 fb | 0.95 fb |
| 100 GeV | 0.88 fb | 0.73 fb | 0.61 fb |

TABLE I: Background and signal cross sections for associated $Z(\rightarrow \ell^+\ell^-) + h_{inv}$ production at the Tevatron, combining the $e\ell$ and $\mu\mu$ channels.

| $p_T$ cut | B(ZZ) | improved B(ZZ) | B(WW) | B(ZW) |
|---|---|---|---|---|
| 85 GeV | 30.4 | 9.1 fb | 2.6 fb | 6.2 fb |
| 100 GeV | 22.0 | 6.4 fb | 1.1 fb | 4.1 fb |

| $m_h$ | S(Z + h_{inv}) |
|---|---|---|---|
| 85 GeV | 10.5 fb | 8.8 fb | 7.4 fb |
| 100 GeV | 8.3 fb | 7.1 fb | 6.0 fb |

TABLE II: Same with Table I but at the LHC.

From Table IV we can see that $ZZ$ background is greatly eliminated after including the measurement of $ZZ \rightarrow 4\ell$. Accordingly $S/B$ and $S/\sqrt{B}$ are improved significantly. At Tevatron, for $m_H = 120$ GeV and with luminosity $30 fb^{-1}$, over $5\sigma$ observation of Higgs boson is possible through this channel, while one can only achieve the significance less than $4\sigma$ without input from measurement of $ZZ \rightarrow 4\ell$. For the heavier Higgs mass even for $m_H = 140$ GeV, this channel can yield a signal of $3\sigma$ significance with $30 fb^{-1}$ luminosity. At LHC, our results show that for $114-140$ GeV Higgs boson and with only $10 fb^{-1}$ luminosity, this channel can provide over $5\sigma$ significance observation of invisible Higgs boson.

III. DISCUSSIONS AND OPEN QUESTIONS

In this paper we studied the invisible Higgs boson at Fermilab Tevatron and CERN LHC, i.e. $qq \rightarrow ZH \rightarrow \ell^+\ell^- + P_T$, where $P_T$ is reconstructed from the $\ell^+\ell^-$ with $\ell = e$ or $\mu$. Moreover, in order to reduce the largest $Z(\rightarrow \ell^+\ell^-)Z(\rightarrow \nu\bar{\nu})$ background, we propose to utilize precise measurement of $Z(\rightarrow \ell^+\ell^-)Z(\rightarrow \ell^+\ell^-)$ as input.
TABLE III: Signal significance for associated $Z(\rightarrow \ell^+\ell^-)+h_{inv}$ production at the Tevatron, combining the ee and $\mu\mu$ channels. The numbers in the parentheses correspond to $ZZ$ background without improvement (see text).

| $y_T$ cut | $S/B$ | $S/\sqrt{B}$ (10 fb$^{-1}$) | $S/\sqrt{B}$ (30 fb$^{-1}$) |
|-----------|------|-------------------------------|-------------------------------|
| 55 GeV    | 0.38(0.25) | 2.81(2.26) | 4.86(3.91) |
| 75 GeV    | 0.72(0.29) | 3.20(2.06) | 5.61(3.57) |
| 100 GeV   | 1.26(0.40) | 3.32(1.87) | 5.76(2.70) |

| $y_T$ cut | $S/B$ | $S/\sqrt{B}$ (10 fb$^{-1}$) | $S/\sqrt{B}$ (30 fb$^{-1}$) |
|-----------|------|-------------------------------|-------------------------------|
| 55 GeV    | 0.23(0.15) | 1.72(1.39) | 2.98(2.40) |
| 75 GeV    | 0.47(0.19) | 2.11(1.34) | 3.65(2.32) |
| 100 GeV   | 0.87(0.28) | 2.31(1.30) | 3.99(2.25) |

TABLE IV: Same with Table III but at the LHC.

| $y_T$ cut | $S/B$ | $S/\sqrt{B}$ (10 fb$^{-1}$) | $S/\sqrt{B}$ (30 fb$^{-1}$) |
|-----------|------|-------------------------------|-------------------------------|
| 85 GeV    | 0.59(0.27) | 7.8(5.3) | 13.6(9.2) |
| 100 GeV   | 0.72(0.31) | 7.7(5.0) | 13.3(8.7) |

| $y_T$ cut | $S/B$ | $S/\sqrt{B}$ (10 fb$^{-1}$) | $S/\sqrt{B}$ (30 fb$^{-1}$) |
|-----------|------|-------------------------------|-------------------------------|
| 85 GeV    | 0.49(0.22) | 6.6(4.4) | 11.4(7.7) |
| 100 GeV   | 0.61(0.26) | 6.6(4.3) | 11.4(7.5) |

| $y_T$ cut | $S/B$ | $S/\sqrt{B}$ (10 fb$^{-1}$) | $S/\sqrt{B}$ (30 fb$^{-1}$) |
|-----------|------|-------------------------------|-------------------------------|
| 85 GeV    | 0.41(0.19) | 5.5(3.7) | 9.6(6.5) |
| 100 GeV   | 0.52(0.22) | 5.6(3.6) | 9.6(6.3) |

Our study shows that at Tevatron, for $m_H = 120$ GeV and with luminosity $30 fb^{-1}$, over 5$\sigma$ observation of Higgs boson is possible via this channel. At LHC, for 114-140 GeV Higgs boson and with only 10 fb$^{-1}$ luminosity, this channel can achieve over 5$\sigma$ discovery. We should note that the feasibility of this discovery mode depends crucially on the understanding of the backgrounds. Therefore the simulation incorporated with at least NLO QCD radiative correction for signal $^{20}$ and background $^{21}$ is very important and will put the analysis on a firmer ground. Moreover we are aware that the simulation presented here is very rough and the full detector simulation, which is beyond the scope of this paper, is the natural further investigation.

It is worth to mention that invisible Higgs boson can also be investigated through weak boson fusion (WBF) provided that events with two energetic forward-backward jets of high dijet invariant mass and with substantial missing transverse momentum can be triggered efficiently $^{22}$. The study shows that it is possible to discover invisible Higgs boson with masses up to 480 GeV at the 5 sigma level if the invisible branching ratio is close to 100% $^{22}$. While WBF can detect invisible Higgs boson with higher mass, the $ZH$ channel may provide a better handle on the mass determination $^{14}$. Moreover the combined analysis of WBF and $ZH$ modes allows a relatively model-independent determination of invisible Higgs boson mass.

Acknowledgements: The author thanks T. Han for correspondences on Ref. $^{14}$ and C. Liu for reading the manuscript carefully. This work was supported in part by the Natural Sciences Foundation of China under grant No. 90403004, the trans-century fund and the key grant project (under No. 305001) of Chinese Ministry of Education.

[1] R. Barate et al. [LEP Working Group for Higgs boson searches], Phys. Lett. B 565, 61 (2003).

[2] A. Juste, arXiv:hep-ex/0511025.

[3] For example to see, M. Gruenewald at IOP HEPP 2005, March 2005. http://lepewwg.web.cern.ch/LEPEWWG/misc/mwng_jop05.pdf.

[4] M. S. Chanowitz, Phys. Rev. Lett. 87, 231802 (2001).

[5] A. Djouadi, arXiv:hep-ph/0503172 and references therein.

[6] S.H. Zhu, arXiv:hep-ph/0601224.

[7] W. de Boer, C. Sander, A. V. Gladyshev and D. I. Kazakov, arXiv:astro-ph/0508617.

[8] C. Boehm, D. Hooper, J. Silk, M. Casse and J. Paul, Phys. Rev. Lett. 92, 101301 (2004) arXiv:astro-ph/0309680.

[9] P. Jean et al., Astron. Astrophys. 407, L55 (2003) arXiv:astro-ph/0309484; J. Knodlseder et al., Astron. Astrophys. 411, L457 (2003) arXiv:astro-ph/0309442.

[10] J. McDonald, Phys. Rev. D 50, 3637 (1994); C. P. Burgess, M. Pospelov and T. ter Veldhuis, Nucl. Phys. B 619, 709 (2001); H. Davoudiasl, R. Kitano, T. Li and H. Murayama, Phys. Lett. B 609, 117 (2005); R. Schabinger and J. D. Wells, Phys. Rev. D 72, 093007 (2005).

[11] D. Choudhury and D. P. Roy, Phys. Lett. B 322, 368 (1994) arXiv:hep-ph/9312347.

[12] S. G. Frederiksen, N. Johnson, G. L. Kane and J. Reid, Phys. Rev. D 50 (1994) 4244.

[13] S. P. Martin and J. D. Wells, Phys. Rev. D 60, 035006 (1999) arXiv:hep-ph/9903259.

[14] H. Davoudiasl, T. Han and H. E. Logan, Phys. Rev. D 71, 115007 (2005) arXiv:hep-ph/0412269.

[15] R. M. Godbole, M. Guchait, R. Mazumdar, S. Moretti...
and D. P. Roy, Phys. Lett. B 571, 184 (2003).
[16] P. Gagnon, ATL-PHYS-PUB-2005-011.
[17] T. Sjostrand, L. Lonnblad, S. Mrenna and P. Skands, arXiv:hep-ph/0308153.
[18] See talk by H. Ma at Atlas Physics Workshop (Rome 2005), "Di-boson studies with multi-lepton final states".
[19] S. Eidelman et al. [Particle Data Group], Phys. Lett. B 592 (2004) 1.
[20] For review to see O. Brein et.al., arXiv:hep-ph/0402003.
[21] J. Ohnemus and J. F. Owens, Phys. Rev. D 43, 3626 (1991); J. M. Campbell and R. K. Ellis, Phys. Rev. D 60, 113006 (1999) arXiv:hep-ph/9905386.
[22] O. J. P. Eboli and D. Zeppenfeld, Phys. Lett. B 495, 147 (2000) arXiv:hep-ph/0009158.

[23] The notorious three 3-σ anomalies may indicate new dynamics beyond the SM, moreover even without these anomalies the global fit shows certain tension with direct search limit at LEP.
[24] The precise measurement of $ZZ \to 4\ell$ can reduce the largest ZZ background, and it may also improve the Higgs mass determination.
[25] Due to the large $gg$ luminosity at LHC, $gg \to H \to ZZ^{(*)} \to 4\ell$ can act as the background to $ZZ \to 4\ell$ especially for heavier Higgs, say 140 GeV. However we can apply invariant mass cut to eliminate such kind of background.