Improvement of signal significance in WH $\rightarrow \ell + \nu + b + \bar{b}$ search at TeV33

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ABSTRACT

We could increase the statistics of Higgs search in WH $\rightarrow \ell + \nu + b + \bar{b}$ channel using the CDF soft lepton b-tagging and loose secondary vertex b-tagging in addition to the CDF secondary vertex b-tagging by a factor of 1.8. We studied several kinematic variables to enhance the signal significance of the Higgs search. We found a Higgs scattering angle in WH CM system, cos(θ_H), is effective for this purpose. With $|\cos(\theta_H)| < 0.8$ cut, we obtained the signal significance better than before by 7% for a Higgs mass of 100 GeV/c^2. Discovery Higgs mass limit at an integrated luminosity of 30 fb^{-1} is 120 GeV/c^2.

I. HIGGS SEARCH IN WH $\rightarrow \ell + \nu + B + \bar{B}$ CHANNEL

We use the same event selection as in the report of TEV2000 study group [1].

- P_T(e) $>$ 20 GeV/c.
- $\not{E}_T >$ 25 GeV.
- The number of jets ($E_T >$ 15 GeV, $|\eta| < 2.5$) $\geq$ 2.
- The number of jets ($E_T >$ 30 GeV, $|\eta| < 2.5$) $\leq$ 2.
- 84 GeV/c^2 $<$ M$_{jj}$ $<$ 117 GeV/c^2 for M$_H$ = 100 GeV/c^2.
- The two jets are tagged with the CDF secondary vertex (SVX) b-tagging algorithm.

M$_H$ (GeV/c^2)	60	80	100	120
signal: WH	166	98	52	27
(a) W$b\bar{b}$	564	270	134	77
(b) WZ	7	69	77	16
(c) $t\bar{t}$	13	10	13	16
(d) W^*	9	29	21	17
(e) tqb	15	12	12	11
total bkgd	608	390	257	137
S/B	0.27	0.25	0.20	0.20
S/$\sqrt{B}$	6.7	5.0	3.2	2.3

Table I: The number of events at 10 fb^{-1} at TeV 33 for various M$_H$'s. Dijet mass cuts were applied such as 48 GeV/c^2 $<$ M$_{jj}$ $<$ 72 GeV/c^2 for M$_H$ = 60 GeV/c^2, 66 GeV/c^2 $<$ M$_{jj}$ $<$ 96 GeV/c^2 for M$_H$ = 80 GeV/c^2, 84 GeV/c^2 $<$ M$_{jj}$ $<$ 117 GeV/c^2 for M$_H$ = 100 GeV/$c^2$and 102 GeV/c^2 $<$ M$_{jj}$ $<$ 141 GeV/c^2 for M$_H$ = 120 GeV/c^2.

After applying the above selection cuts, we have the following dominant backgrounds:

- W$b\bar{b}$ (VECBOS)
- WZ, Z $\rightarrow b\bar{b}$ (PYTHIA)
- $t\bar{t}$ (HERWIG)
- $W^* \rightarrow t\bar{b}$ (PYTHIA)
- W-gluon fusion $\rightarrow$ tqb (HERWIG)

The numbers of WH signal (PYTHIA) and backgrounds at TeV33 were estimated using the event generaters shown in parenthesis and the CDF detector simulator as listed in Table I which was reported by TEV2000 study group [1]. Here we corrected the number of $t\bar{t}$ by taking into account the dilepton decay mode which was neglected in the TEV2000 report. The mass window for dijet mass cut was the same as the preceeding study by Stange et al. which is not optimized for the best significance [2].

The Higgs search in ZH $\rightarrow \nu + \bar{\nu} + b + \bar{b}$ or $\ell + \bar{\ell} + b + \bar{b}$ channel has been studied and is reported elsewhere in these proceedings [3]. This channel increases the WH statistics significantly due to the a large branching ratio of Z decay. When the Higgs is discovered, the production ratio of ZH to WH gives us the information on the coupling strength ratio of ZZH to WWH.

II. SOFT LEPTON B-TAGGING AND LOOSE SVX B-TAGGING

In addition to the SVX b-tagging, we adopted the CDF standard soft lepton tagging (SLT) to the second b jet to increase the statistics. By this addition, we increase the double b-tagging rate for true two b jets by a factor of 1.3, while the fake rate changes from 10^{-4} to 5×10^{-4} for two non-b jets where the W + jj (non-b) background remains negligible comapred with the W + $b\bar{b}$ background. Furthermore we adopted the CDF loose SVX b-tagging (JP b-tagging) with a jet probability less than 2% to the second b jet [3]. As a result, we increase the double b-tagging rate for true two b jets by an additional factor of 1.4, while the fake rate becomes 9×10^{-4} for two non-b jets where the W + jj (non-b) background still remains negligible comapred with the W + $b\bar{b}$ background.

The numbers of WH signal(PYTHIA) and backgrounds at TeV33 after including SLT tagging and loose JP b-tagging for the second b-tagging are listed in Table II.

The dijet mass resolution is not degraded by including the soft lepton b-tagging as shown in Fig. 1.

M_H (GeV/c^2)	60	80	100	120
signal: WH	302	178	95	49
(a) Wbb	1026	491	244	140
(b) WZ	13	126	140	29
(c) $t\bar{t}$	22	20	22	28
(d) W^*	17	53	38	31
(e) tqb	28	22	22	20
total background	1106	712	466	248
S/B	0.27	0.25	0.20	0.20
S/$\sqrt{B}$	9.1	6.7	4.4	3.1

Table II: The number of events at 10 fb^{-1} at TeV 33 for various M_H's including SLT b-tagging and loose SVX b-tagging.

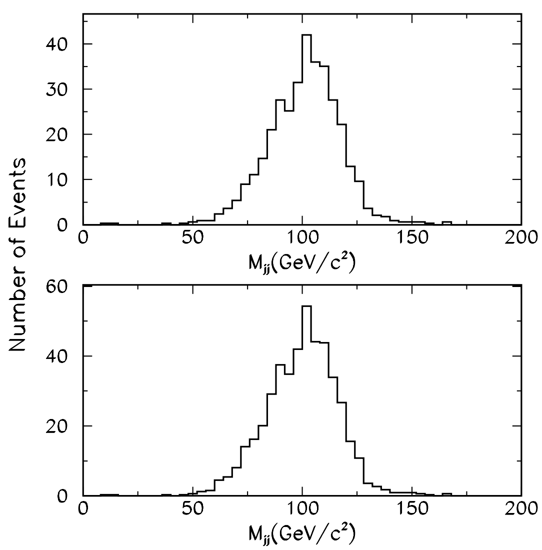

Figure 1: Dijet mass distributions for WH(M_H = 100 GeV/c^2) events without (top plot) and with (bottom plot) soft lepton tagging.

III. FURTHER SELECTION FOR HIGGS SIGNAL ENHANCEMENT

To reduce the backgrounds against WH signals in $\ell + \nu + b + \bar{b}$ channel at TeV33, we use the following kinematic variables [4]:

- $\cos(\theta_H)$: Higgs scattering angle in WH CM system
- $\cos(\theta_{b\bar{b}})$: angle between b and $\bar{b}$ in WH CM system
- $\cos(\theta_b)$: b decay angle in Higgs rest system

In order to calculate these angles, we need determine the z-component of a neutrino momentum $P_z(\nu)$. We chose the larger $P_z(\nu)$ for W^+ and the smaller $P_z(\nu)$ for W^- because the eta distribution of a neutrino has a clear asymmetry as shown in Fig. 2. By this selection criteria, we chose the right $P_z(\nu)$ at a probability of 85%. The right $P_z(\nu)$ means the $P_z(\nu)$ closer to the true one at a generator level.

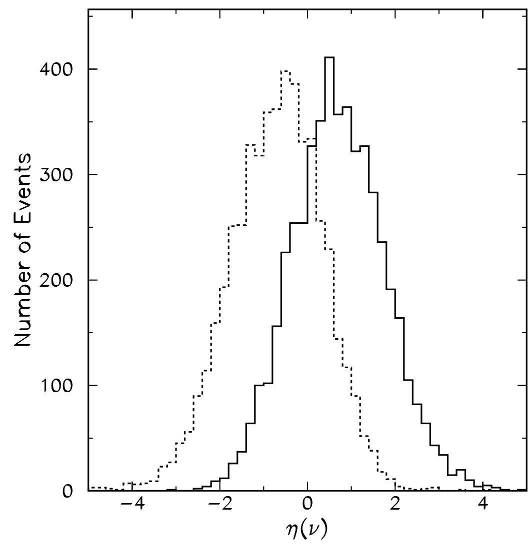

Figure 2: η (ν) distributions for W^+ (solid) and W^- (dashed) for WH(M_H = 100 GeV/c^2) events.

The distributions of $\cos(\theta_H)$, $\cos(\theta_{b\bar{b}})$ and $\cos(\theta_b)$ for the WH signals at M_H of 100 GeV/c^2 and the backgrounds are shown in Figs. 3, 4 and 5, respectively. As seen in the figures, only the $\cos(\theta_H)$ distribution has a large separation power between the WH signal and the backgrounds. We obtained the numbers of WH signal events and background events at TeV33 after the $\cos(\theta_H)$ cut with various thresholds as listed in Table III. By $|\cos(\theta_H)| < 0.8$ cut, we obtained the best significance S/$\sqrt{B}$ of 3.9 which is better than that before the cut by 7% with the S/B improvement by 50%. We performed this threshold optimization for M_H of 60, 80 and 120 GeV/c^2, and obtained the optimized threshold of 0.8 as well as above. The numbers of WH signal events and background events at TeV33 after the $|\cos(\theta_H)| < 0.8$ cut for various Higgs masses are listed in Table IV. About the cuts on $\cos(\theta_{b\bar{b}})$ and $\cos(\theta_b)$, we found that the cuts could not improve the WH signal significance S/$\sqrt{B}$.

IV. SUMMARY

- We could increase the statistics of Higgs search in WH $\rightarrow \ell + \nu + b + \bar{b}$ channel using the CDF soft lepton b-tagging and loose secondary vertex b-tagging in addition to the CDF secondary vertex b-tagging by a factor of 1.8.
- We studied several kinematic variables to enhance the signal significance of Higgs search in WH $\rightarrow \ell + \nu + b + \bar{b}$

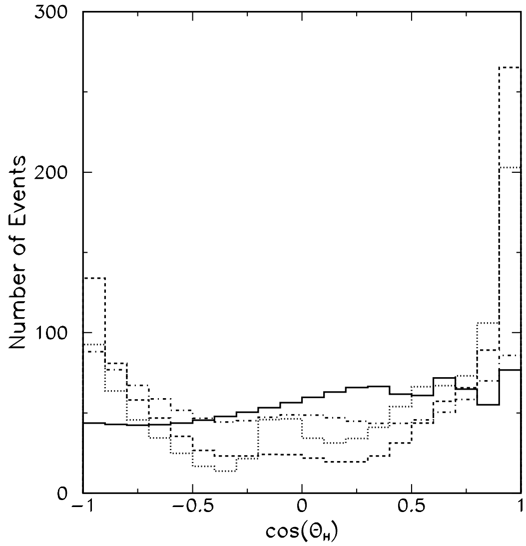

Figure 3: cos(θ_H) distribution for WH(M_H = 100 GeV/c^2) events(solid line), WZ events(dashed line), W$b\bar{b}$(dotted line) and top events(dotted-dashed line)

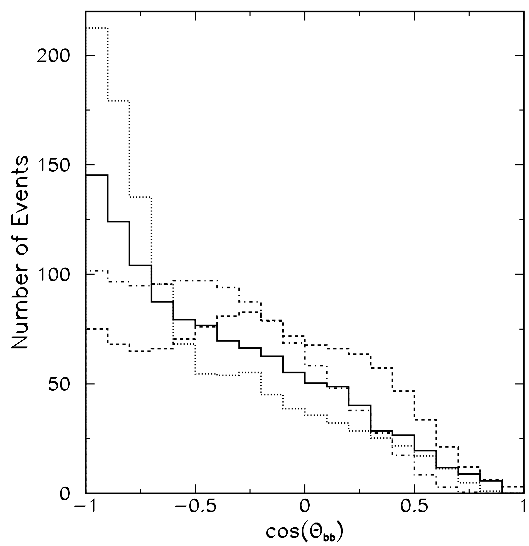

Figure 4: cos($\theta_{b\bar{b}}$) distribution for WH(M_H = 100 GeV/c^2) events(solid line), WZ events(dashed line), W$b\bar{b}$(dotted line) and top events(dotted-dashed line)

channel. We found a Higgs scattering angle in WH CM system, cos(θ_H), is effective for this purpose. With $|\cos(\theta_H)| < 0.8$ cut, we obtained the signal significance better than before by 7% for a Higgs mass of 100 GeV/c^2.

- We obtained the necessary luminosity for 5σ discovery of Higgs as a function of Higgs mass as shown in Fig. 6. Discovery Higgs mass limit at an integrated luminosity of 30 fb^{-1} is 120 GeV/c^2 for 5σ discovery.

V. REFERENCES

[1] Editted by D. Amidei and R. Brock, Report of the TeV2000 Study Group. FERMILAB-PUB-96/082.

[2] A. Stange, W. Marciano, S. Willenbrock, Phys. Rev. D49, 1354 (1994); D50, 4491 (1994).

[3] W.-M. Yao, these proceedings.

[4] P. Agarawal et al., Signature of the intermediate mass higgs boson at LHC with flavor tagging. MSU-HEP/40901. CPP-94-32.

	No cut	0.9	0.8	0.7	0.6	0.5
signal: WH	95	83	76	67	57	49
(a) Wbb	244	179	137	118	104	78
(b) WZ	140	88	67	52	42	31
(c) $t\bar{t}$	22	21	17	14	11	8
(d) W^*	38	31	27	21	18	15
(e) tqb	22	18	15	13	10	8
total bkgd	466	337	263	218	185	140
S/B	0.20	0.24	0.29	0.31	0.31	0.35
S/$\sqrt{B}$	4.4	4.5	4.7	4.5	4.2	4.1

Table III: The number of events at 10 fb^{-1} at TeV 33 for M_H = 100 GeV/c^2 before and after $|\cos(\theta_H)|$ cut with various thresholds.

M_H (GeV/c^2)	60	80	100	120
signal: WH	227	140	76	39
(a) Wbb	640	288	137	83
(b) WZ	6	64	67	14
(c) $t\bar{t}$	15	14	17	21
(d) W^*	13	39	27	21
(e) tqb	21	15	15	13
total bkgd	695	420	263	152
S/B	0.33	0.33	0.29	0.26
S/$\sqrt{B}$	8.6	6.8	4.7	3.2

Table IV: The number of events at 10 fb^{-1} at TeV 33 for various M_H after $|\cos(\theta_H)| < 0.8$ cut.

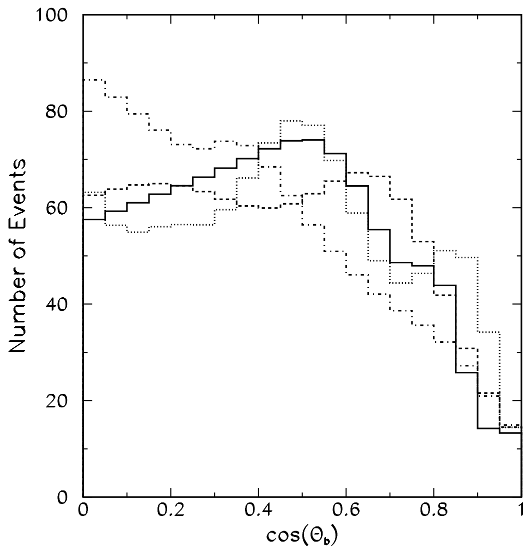

Figure 5: $\cos(\theta_b)$ distribution for WH(M_H = 100 GeV/c^2) events(solid line), WZ events(dashed line), W$b\bar{b}$(dotted line) and top events(dotted-dashed line)

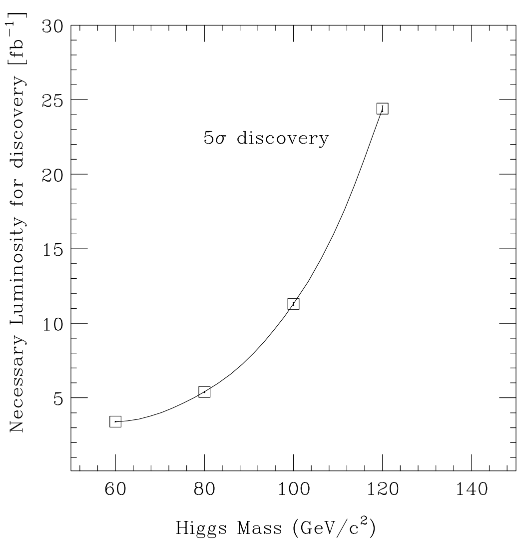

Figure 6: Necessary luminosity for 5σ discovery as a function of Higgs mass.