

Analysis of 4-jet mode in ZHH

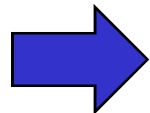
'08 11/17 Y. Takubo (Tohoku U.)

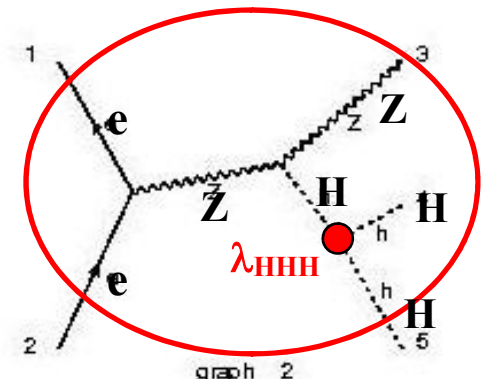
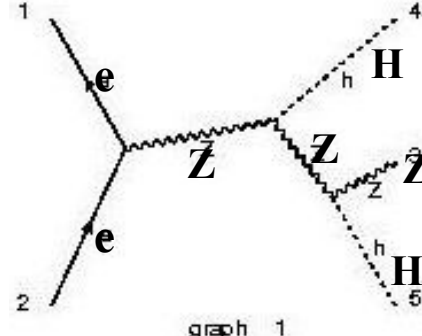
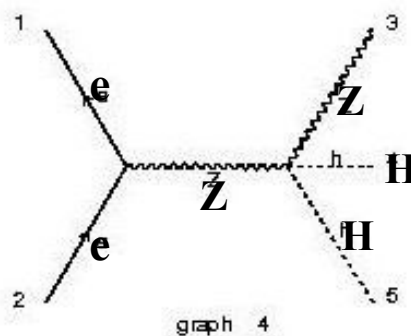
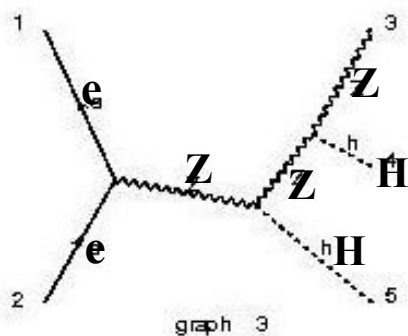
for GLD-ZHH analysis group

Introduction

Motivation of ZHH analysis

- ZHH has the information of Higgs self-coupling.
- The analysis method will be different, depending on Higgs mass.
 - $H \rightarrow b\bar{b}$ for $M_H < 160 \text{ GeV}$
 - $H \rightarrow W\bar{W}$ for $M_H > 160 \text{ GeV}$
- Any case should be considered before results from LHC.

 **ZHH study for some cases of Higgs mass is started.**



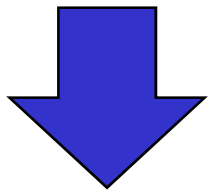
Analysis menu

ZHH analysis was started to cover wide Higgs-mass region.

ZHH study

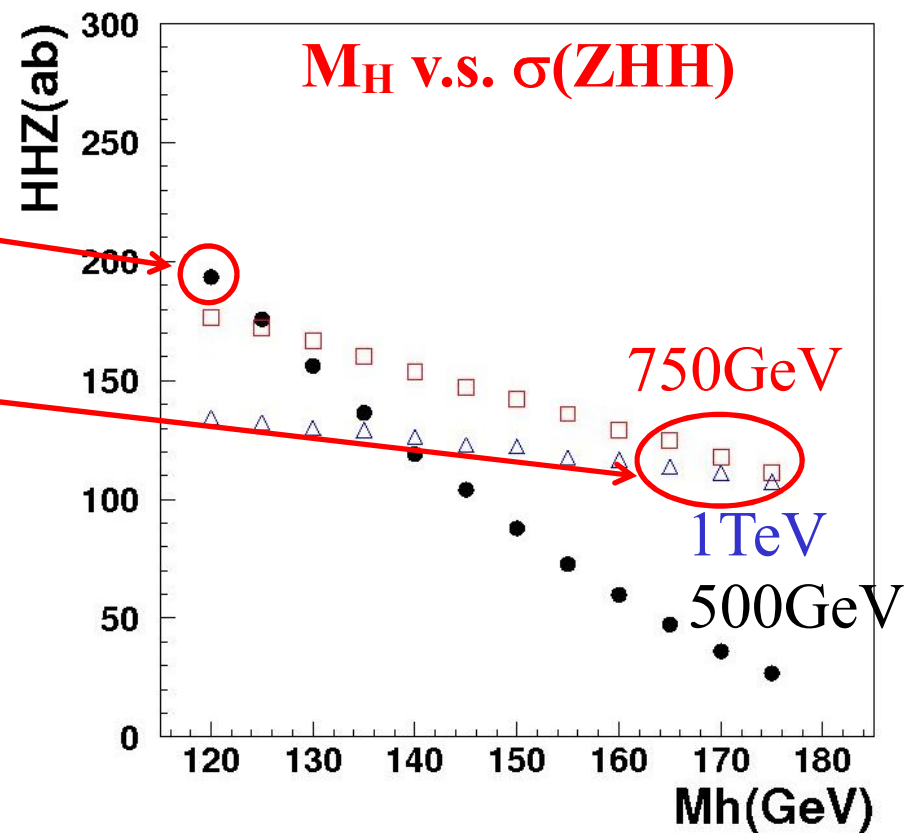
$E_{\text{CM}}=500\text{GeV}$ is the best for $M_{\text{H}}=120\text{GeV}$.

- $E_{\text{CM}}>750\text{GeV}$ is preferable to study for $M_{\text{H}}>160\text{GeV}$.



Our analysis menu

- Light Higgs : $M_{\text{H}}=120\text{GeV}$, $E_{\text{CM}}=500\text{GeV}$ ← **Today's topic**
- Heavy Higgs : $M_{\text{H}}=170\text{GeV}$, $E_{\text{CM}}=750\text{GeV}\sim 1\text{TeV}$



ZHH at $M_H=120\text{GeV}$

According to Z-decay types, there are 3 analysis modes.

- $\text{HHZ} \rightarrow \text{HHqq}$ (6-jets)
 - 135.2 ab
 - The most attractive mode due to the largest cross-section.
- $\text{HHZ} \rightarrow \text{HH}\nu\nu$ (4-jets) $\leftarrow$ My talk
 - 38.8 ab
 - Easy to analyze and not bad cross-section.
- $\text{HHZ} \rightarrow \text{HHl}^+\text{l}^-$ (4-jets + 2leptons)
 - 19.8 ab
 - The smallest cross-section.

$\text{HH}\nu\nu$ was investigated in my study.

Signal v.s. B.G.

Many B.G. processes contaminate into HHvv analysis.

HHvv : 38.8ab  **# of events at 2 ab⁻¹** 77.6

B.G. processes

• ZZ : 395.78fb	• 790,000
(ZZ→bbbb : 9.05fb)	(18,000)
• tt : 583.6fb	• 1,200,000
• ZH : 62.1fb	• 120,000
• tbtb : 1.2fb	• 2,400
• ZZZ : 1.2fb	• 2,400
• ⋮	

Considered in
this analysis

Simulation study is performed, including B.G..

Simulation study

Simulation procedure

- **Event generation**
 - MadGraph or Physsim
 - Hadronization is done by Pythia

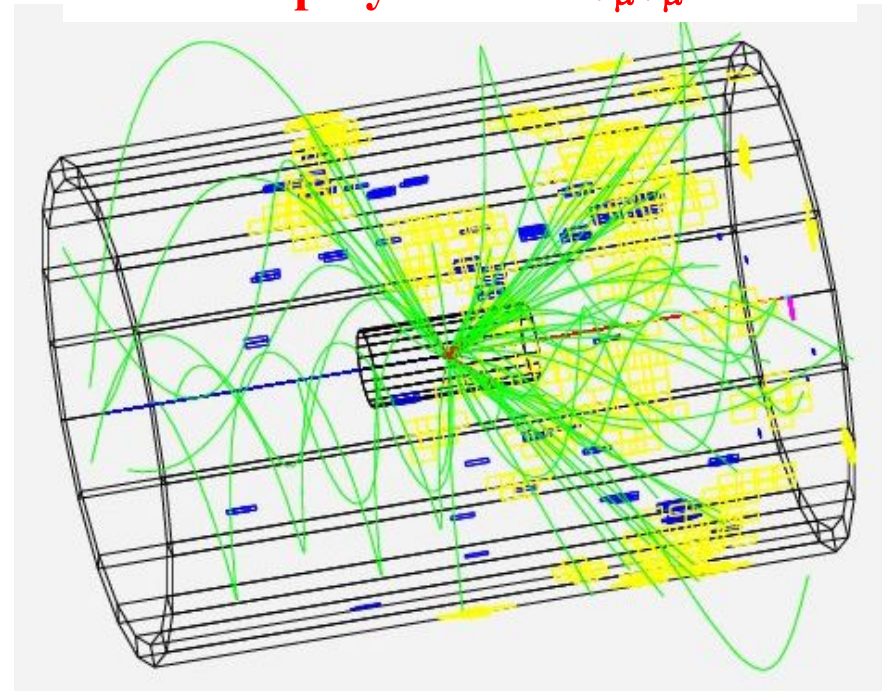


- **Detector simulation**
 - Quick-sim for GLD



- **Analysis**
 - ROOT based analysis

Event display of a $HH\nu_\mu\nu_\mu$ event



Reconstruction of Higgs mass was performed.

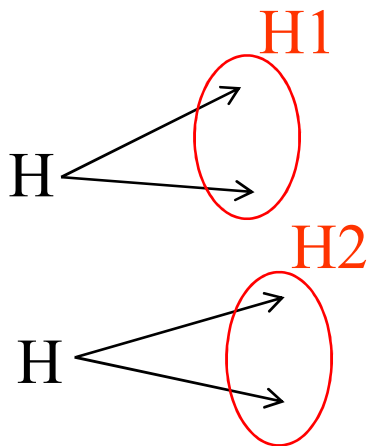
Reconstruction of Higgs mass

Higgs mass reconstruction for HHvv events

- $M_H = 120 \text{ GeV}$, $E_{\text{CM}} = 500 \text{ GeV}$
- All events are reconstructed as 4-jet events.
- Two jet-pairs are selected by minimizing the χ^2 function.

$$\chi^2 = \frac{(\text{rec.}M_{H1} - \text{true}M_H)^2}{\sigma_{H1}^2} + \frac{(\text{rec.}M_{H2} - \text{true}M_H)^2}{\sigma_{H2}^2}$$

- $\text{rec.}M_{H1, H2}$: Reconstructed Higgs mass by a jet-pair
- $\text{true}M_H$: 120 GeV
- $\sigma_{H1, H2}$: estimated by using 31%/sqrt(E_{jet})

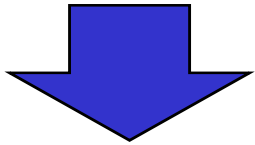


The distribution of the reconstructed Higgs mass was investigated with B.G. events.

Reconstructed M_H distribution

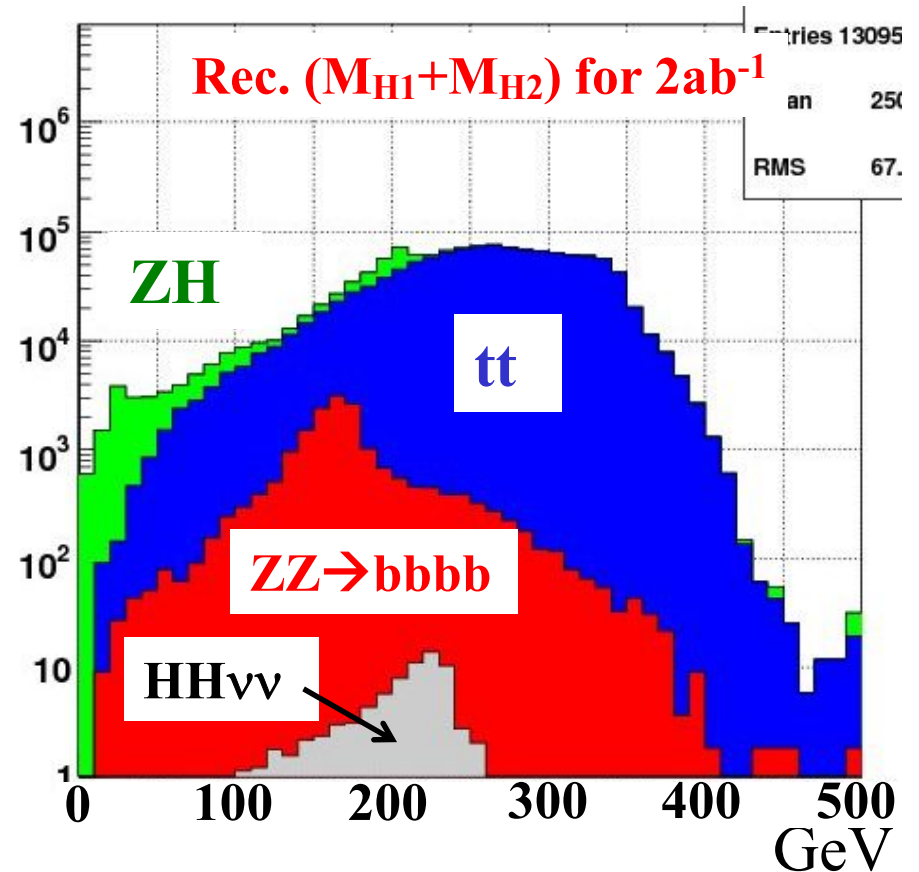
Higgs mass is reconstructed with B.G..

- There are many B.G. events in the signal region.
- Powerful B.G. rejection is necessary.



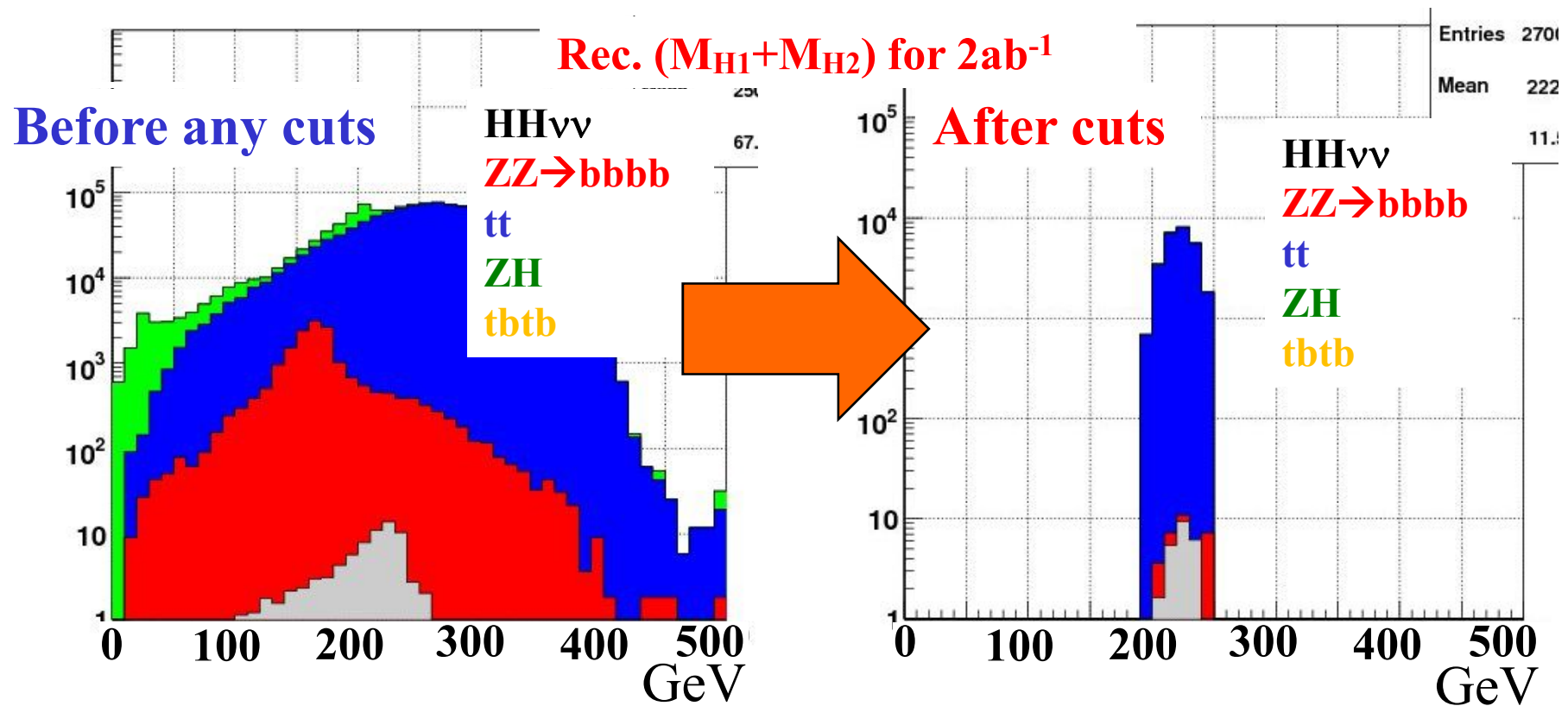
Selection cut

- χ^2 cut
- Higgs mass cut
- Missing mass cut
- Angular cut
- Missing P_T cut
- Lepton track cut
- b-tag cut



$ZZ \rightarrow bbbb$ rejection

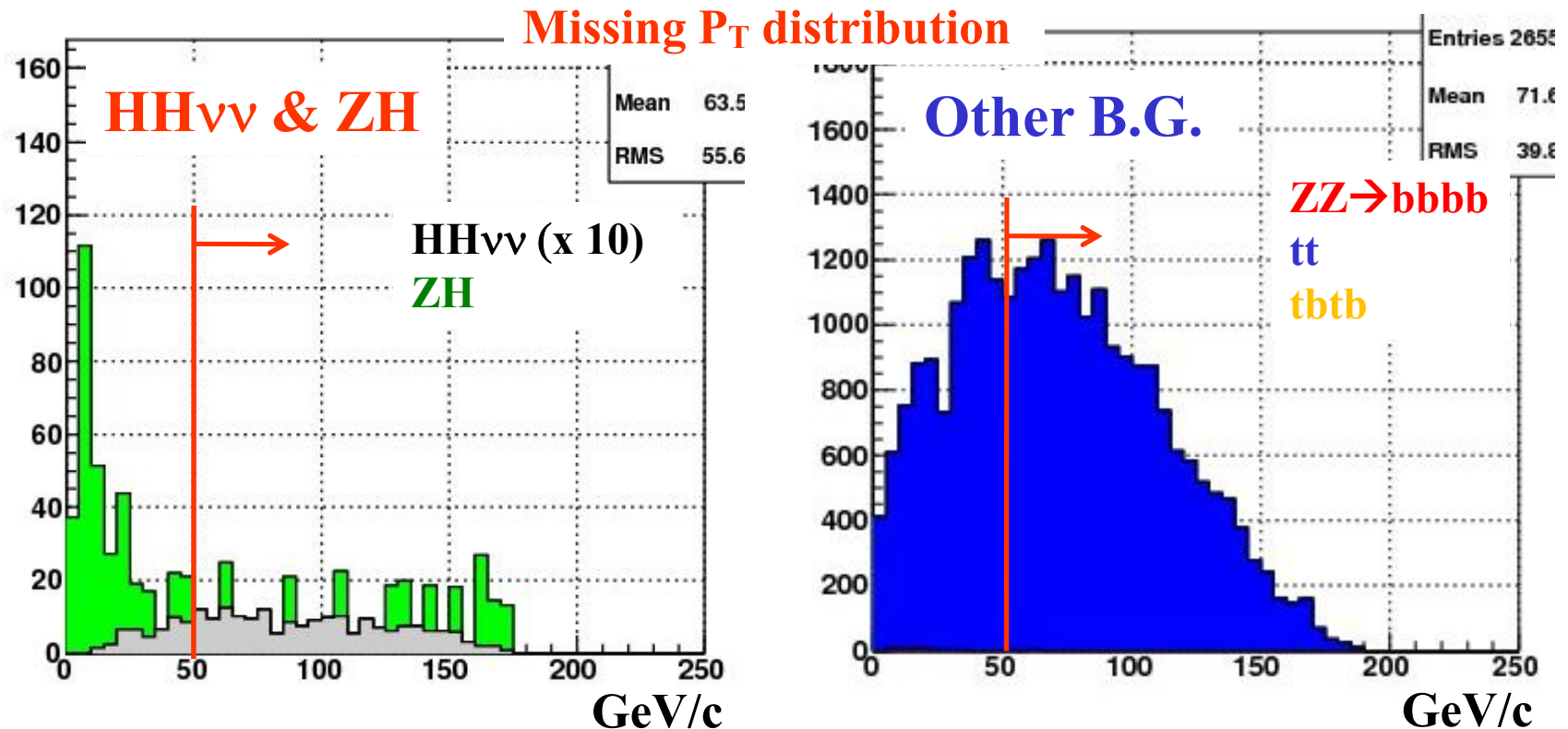
- $ZZ \rightarrow bbbb$ can be rejected by selection of χ^2 , M_H , M_{miss} , and $\cos\theta$.
 - $\chi^2 < 20$, $95 < M_H < 125 \text{ GeV}$, $90 < M_{\text{miss}} < 170 \text{ GeV}$, and $|\cos\theta| < 0.9$
- tt , ZH , and $t\bar{t}b\bar{b}$ still contaminate in the signal region.
 - tt : 26,521, ZH : 447, $t\bar{t}b\bar{b}$: 37



ZH rejection (Missing P_T cut)

Missing P_T was used to reject ZH-B.G..

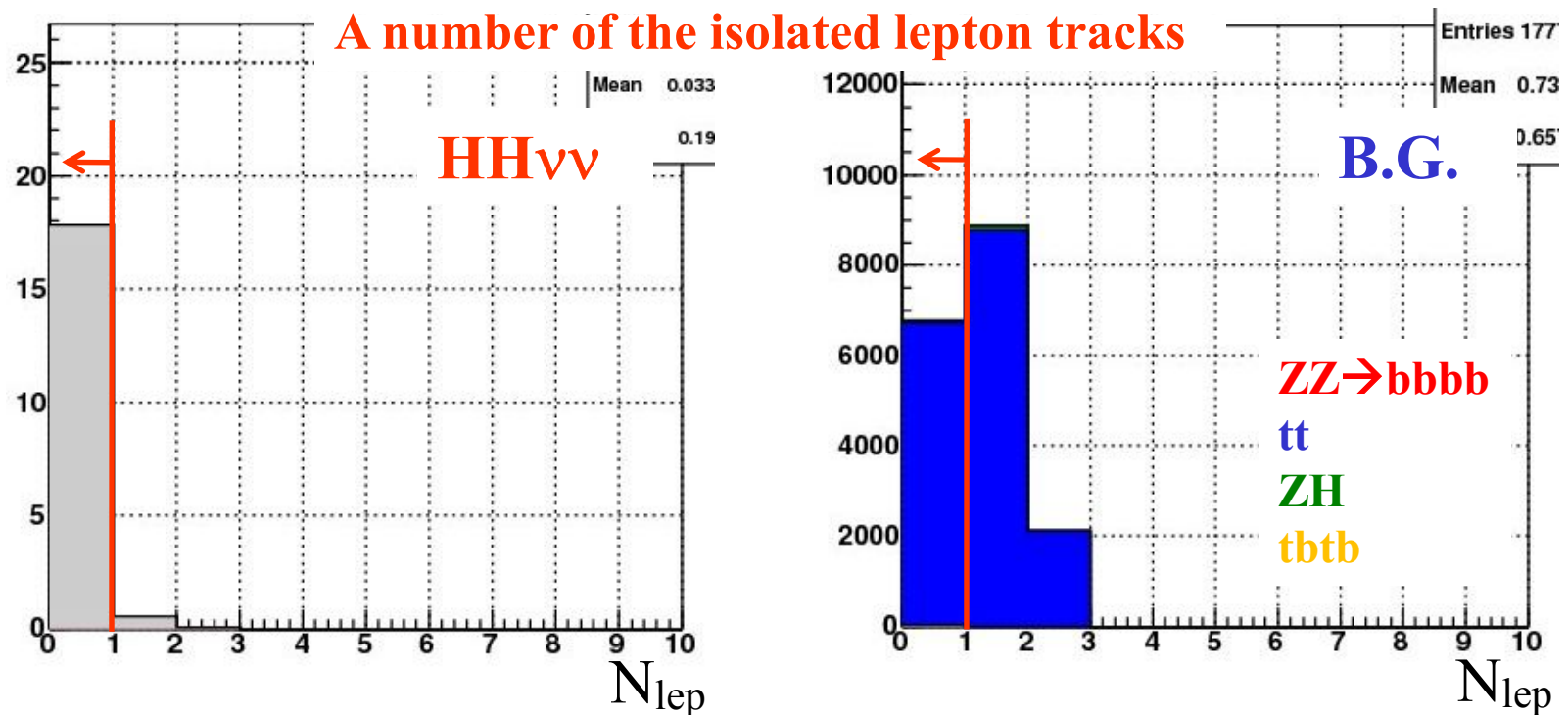
- ZH-B.G. has a peak at low $^{\text{miss}}P_T$ region.
- $^{\text{miss}}P_T > 50\text{GeV}$ was selected.
 - tt: 17,591, ZH: 137, tbtb: 25



tt-rejection (Lepton track cut)

of isolated lepton tracks are investigated to reject tt-B.G..

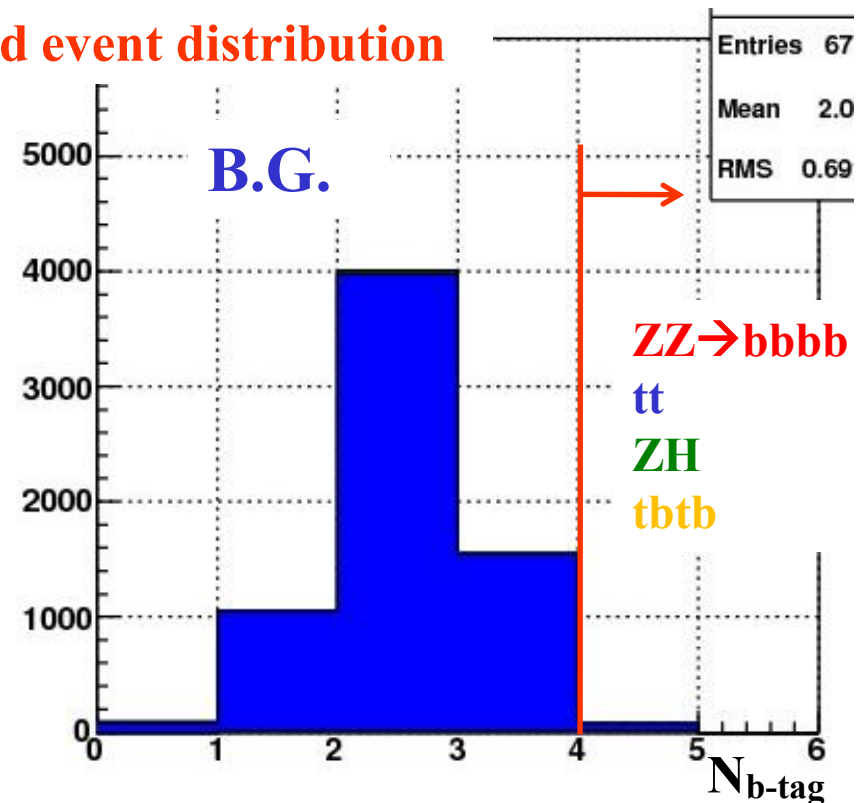
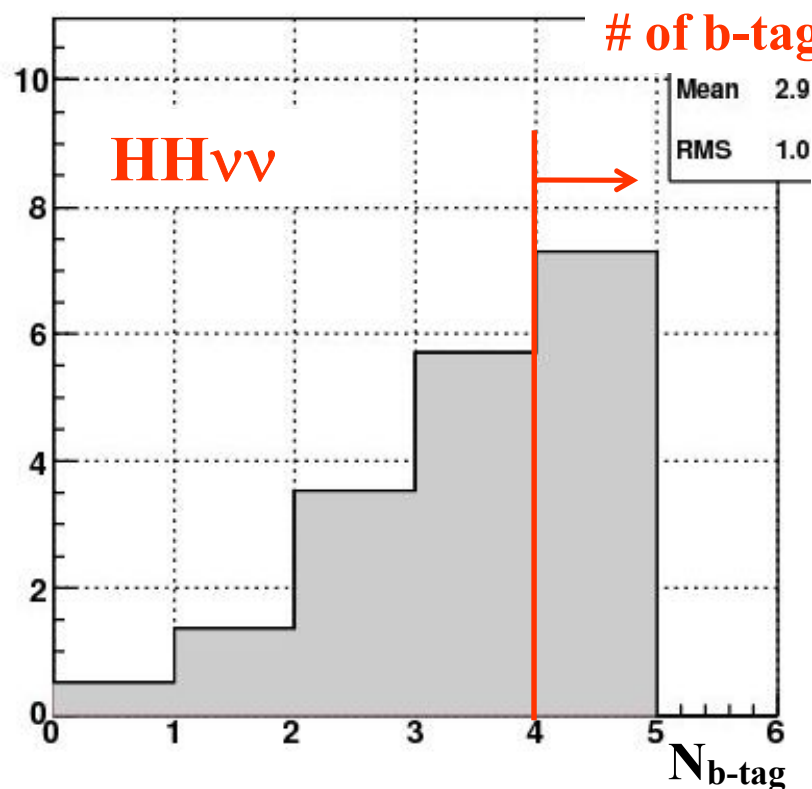
- The lepton track from W will be rejected.
- The total energy within 20 deg. around the lepton tracks were used to select the isolated lepton tracks.
- $N_{\text{lep}}=0$ was selected.



tt rejection (b-tag selection)

of b-tagged jets are investigated to reject tt-B.G..

- b-tag requirement: 2 tracks with 3σ from IP
- HHvv and tt-B.G. have their peak at $N_{b\text{-tag}} = 4$ and 2, respectively.
- tt-B.G. can be suppressed by choosing $N_{b\text{-tag}} = 4$.



Reduction summary

The reduction rate at each cut was summarized for 2 ab^{-1} .

	HH $\nu\nu$	ZZ$\rightarrow$bbbb	tt	ZH	tbtb
• No cut	: 77.6	18100	1167200	124200	2154
• $\chi^2 < 20$	: 43.7	12169	364921	83065	468
• $95\text{GeV} < M_{H1,2} < 125\text{GeV}$	: 29.5	387	70557	8570	82
• $90\text{GeV} < M_{\text{miss}} < 170\text{GeV}$	: 26.2	127	32570	696	45
• $ \cos\theta_{1,2} < 0.9$	: 23.0	34.4	26521	447	37
• missing $P_T > 50\text{GeV}$	: 18.4	3.6	17591	137	25
• $N_{\text{lepton}}=0$	: 17.8	3.6	6708	37.3	9.7
• $N_{\text{b-tag}}=4$	: 7.3	1.8	65	0	2.4

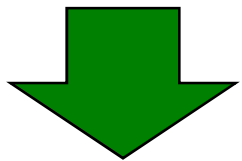
- All the B.G. processes are rejected effectively by the selection cut.
- Remaining tt-events are still large (65 events).
- Additional selection cut should be studied.

Remaining tt-events

The Higgs mass distribution and signal significance was checked after all the selection cuts.

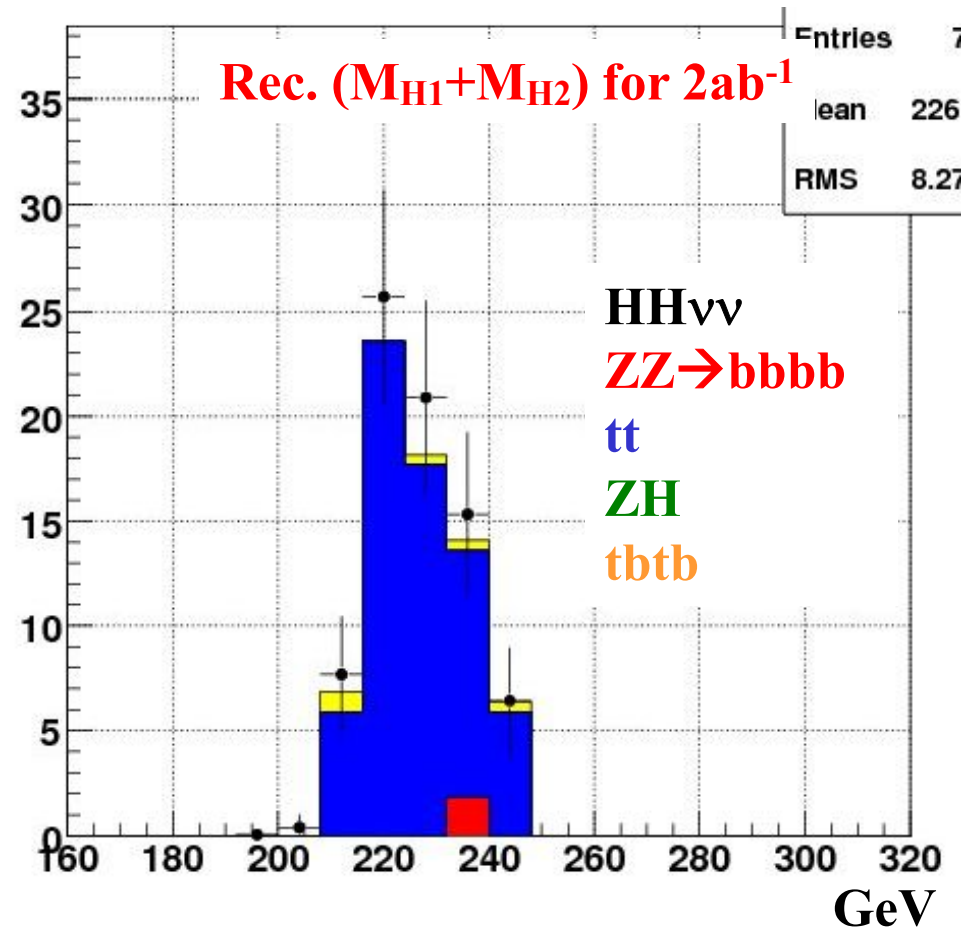
Remaining events

- $HH\nu\nu$: 7.3
- $ZZ \rightarrow bbbb$: 1.8
- tt : 65.0
- ZH : 0
- $t\bar{t}b\bar{b}$: 2.4



Significance : 0.9

→ Far from confident observation



Summary

- ZHH is studied to investigate ILC performance for some Higgs mass case.
- HH $\nu\nu$ is analyzed for light Higgs case in this study.
- The signal significance of 0.9 was obtained.
 - ZZ, tt, ZH, and tbtb can be rejected effectively by the selection cuts.
 - Remaining tt-events are still large (65 events).
- Additional selection cut should be investigated.

