Analysis of 4-jet mode in ZHH

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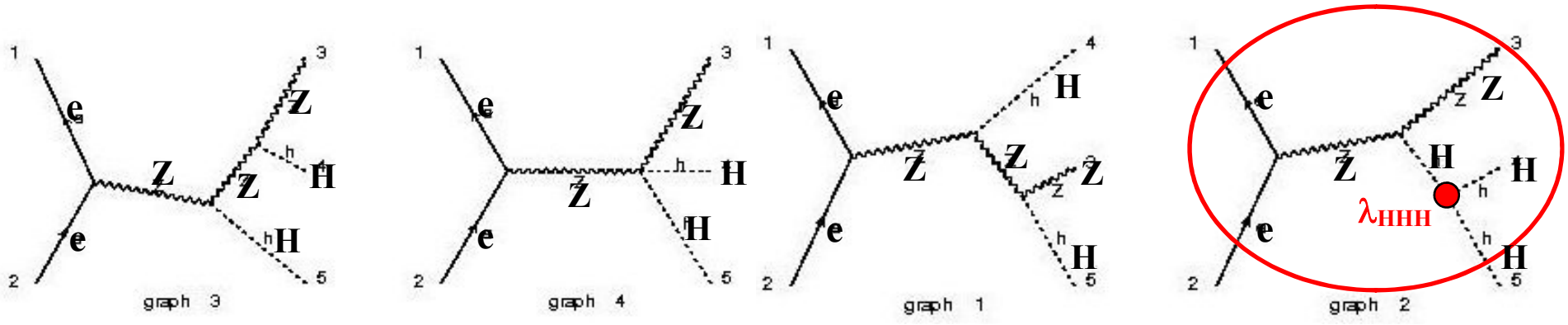
Introduction

Motivation of ZHH analysis

- ZHH has the information of Higgs self-coupling.
- The analysis method will be different, depending on Higgs mass.
  - H→bb for M_H<160GeV
  - H→WW for M_H>160GeV
- Any case should be considered before results from LHC.

ZHH study for some cases of Higgs mass is started.



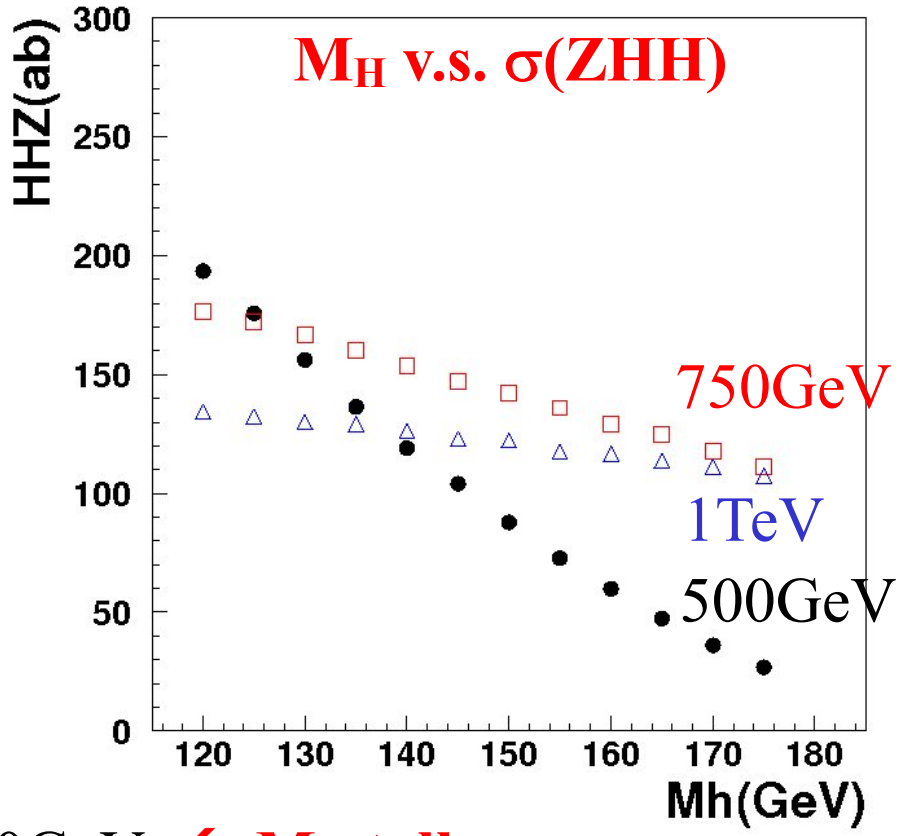
Analysis menu

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

ZHH study

E_{CM}=500GeV is the best for M_H=120GeV.

- E_{CM}>750GeV is preferable to study for M_H>160GeV.



Our analysis menu

- Light Higgs : M_H=120GeV, E_{CM}=500GeV ← My talk
- Heavy Higgs : M_H=170GeV, E_{CM}=750GeV~1TeV

ZHH at M_H=120GeV

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

- HHZ → HHqq (6-jets)
  - 135.2 ab
  - The most attractive mode due to the largest cross-section.
  - Analysis of 6-jet events is a little bit complicated.
- HHZ→ HHνν (4-jets)
  - 38.8 ab
  - Easy to analyze and not bad cross-section.
- HHZ→ HHl^+l^- (4-jets + 2leptons)
  - 19.8 ab
  - The smallest cross-section.

HHνν was investigated as the first step.

Signal v.s. B.G.

Many B.G. processes contaminate into HHνν analysis.

	# of events at 2 ab^{-1}
HHνν : 38.8ab	77.6

B.G. processes

Overestimated at TILC08(21.3fb)

• 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 : 7,700fb	• 150,000,000
⋮	

Considered in this analysis

Simulation study is performed, including B.G..

Simulation study

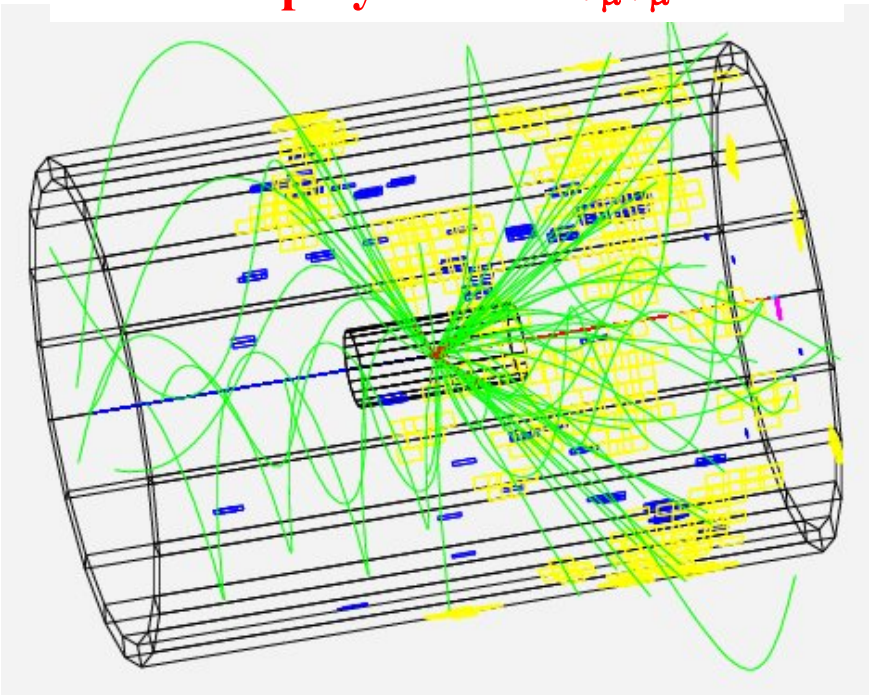
Simulation procedure

- **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.

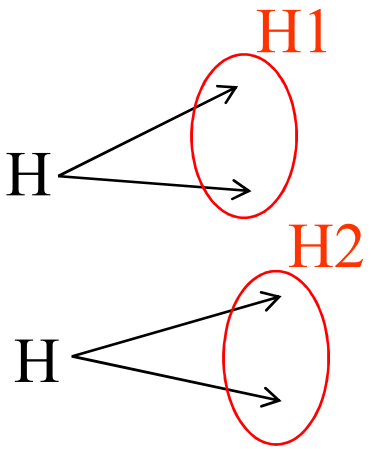
Reconstruction of Higgs mass

Higgs mass reconstruction for HHνν events

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

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

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



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

Reconstructed M_H distribution

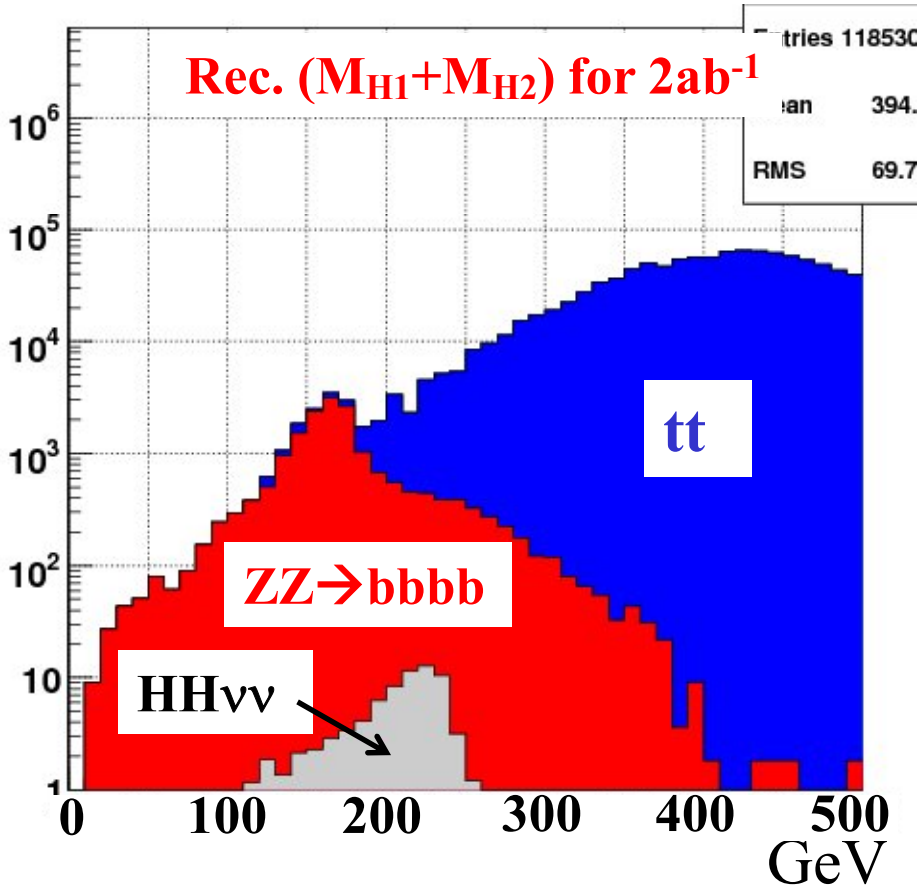
Higgs mass is reconstructed with B.G..

- 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
- b-tag cut

B.G. rejection is shown at each step.

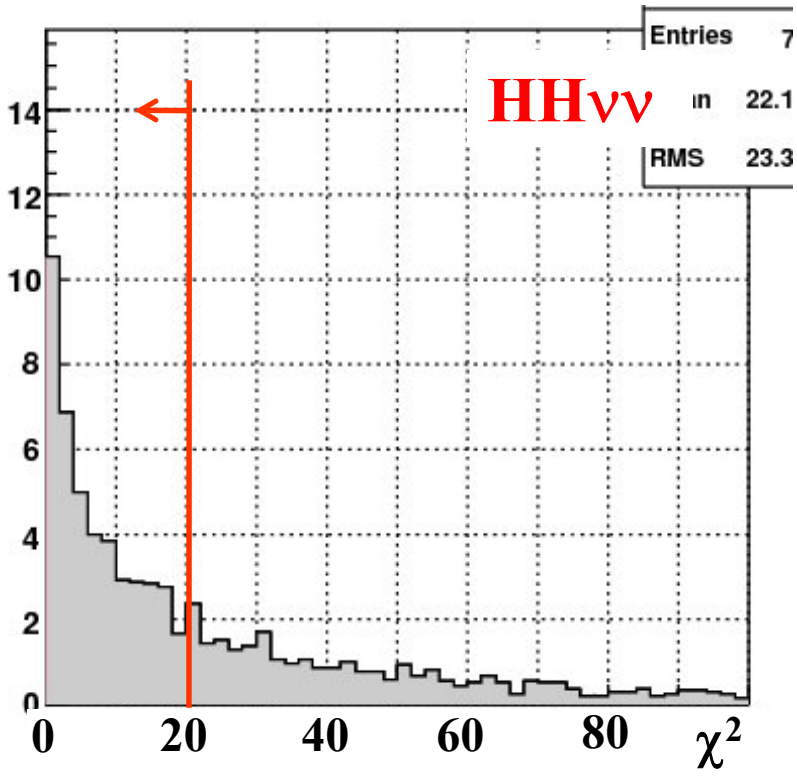


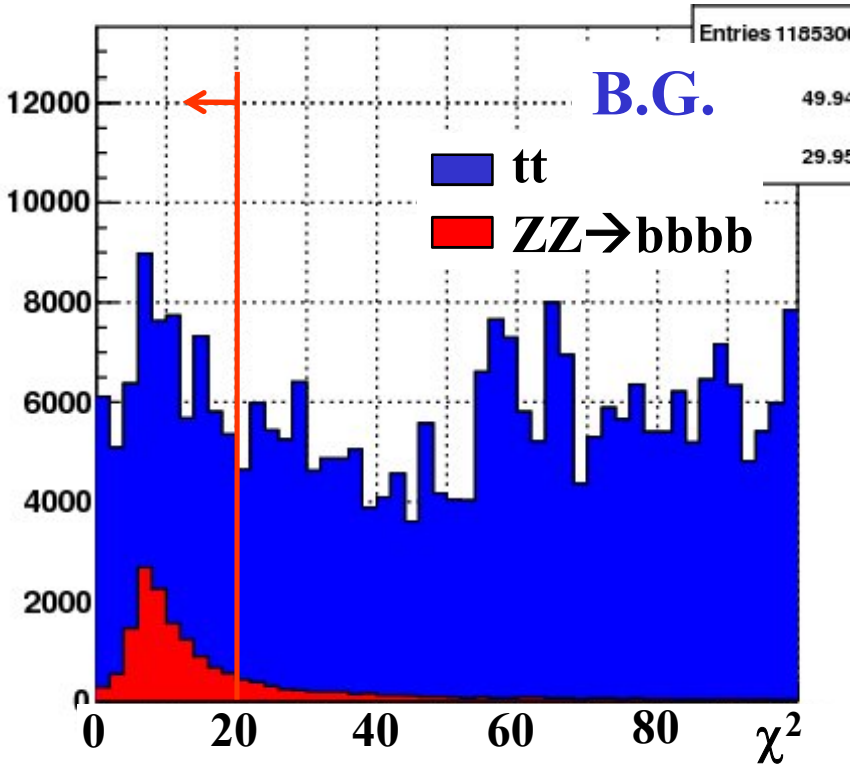
χ^2 cut

χ^2 distribution was checked after momentum and β selection.

- The signal has the peak at χ^2 =0.
- B.G. has the broader shape than the signal.

  → χ^2<20 was selected.



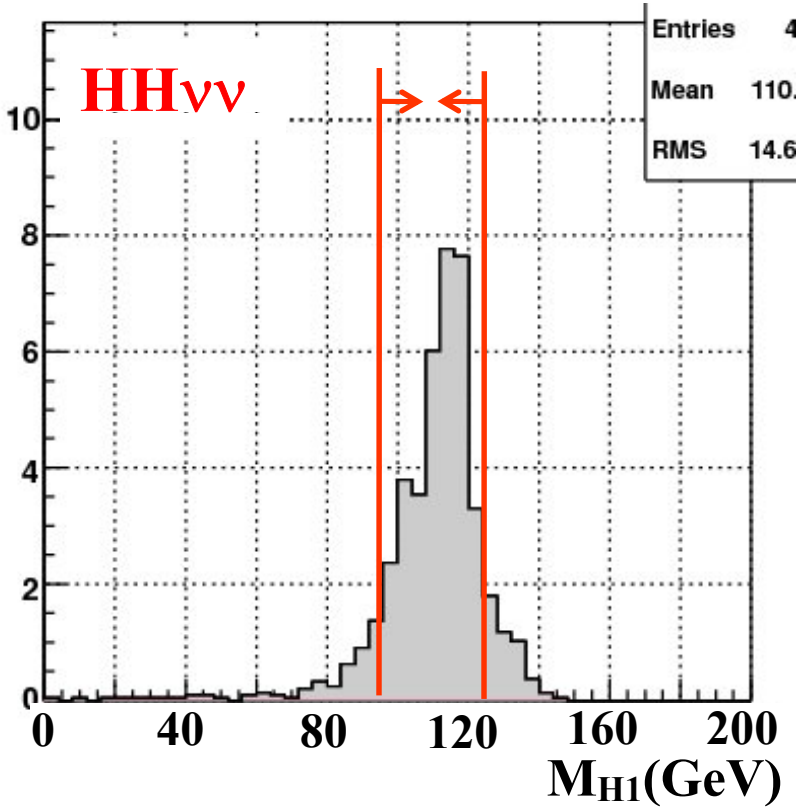


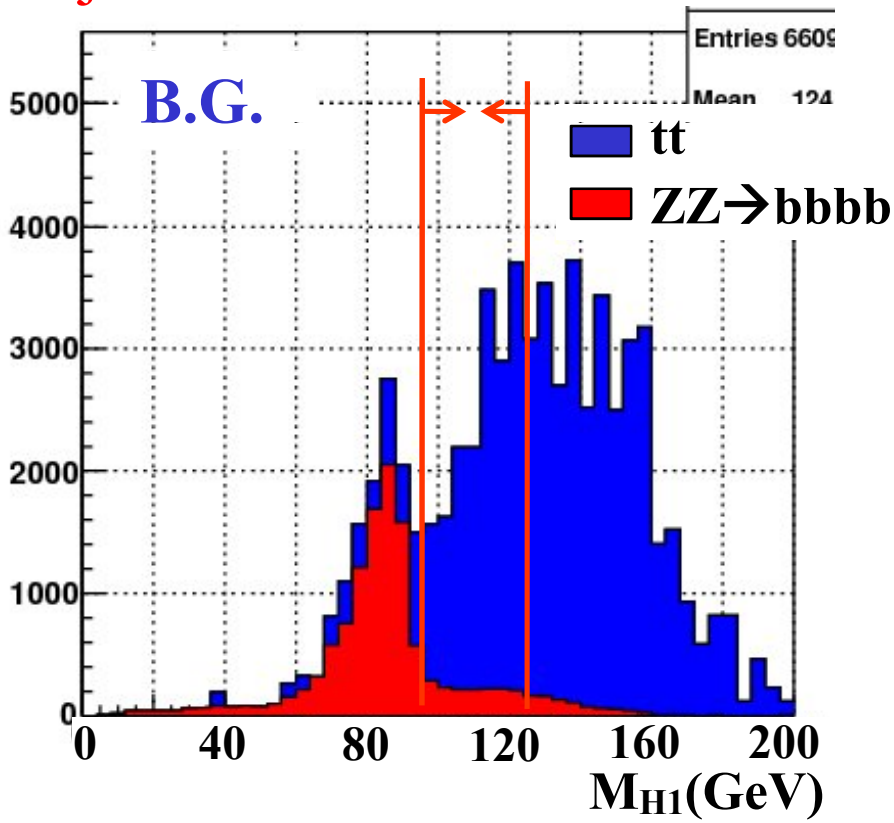
Higgs mass cut

The Higgs mass cut is applied to select well-reconstructed events.

- Selection: 95GeV < M_H < 125GeV
- This cut is applied to two reconstructed mass, separately.

→ The main part of ZZ→bbbb was rejected.

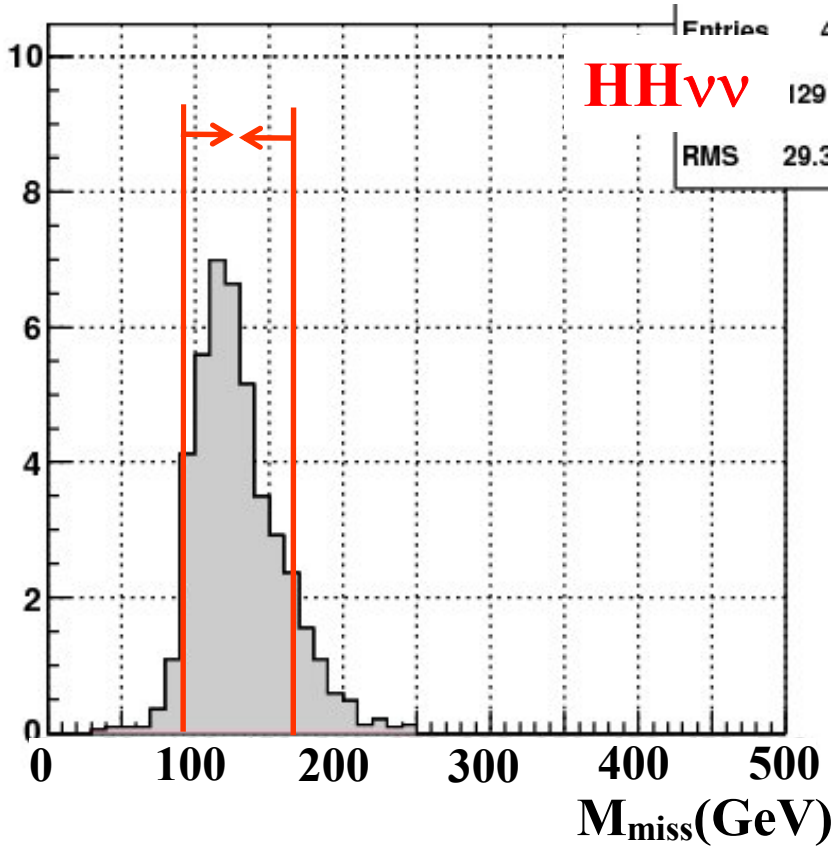


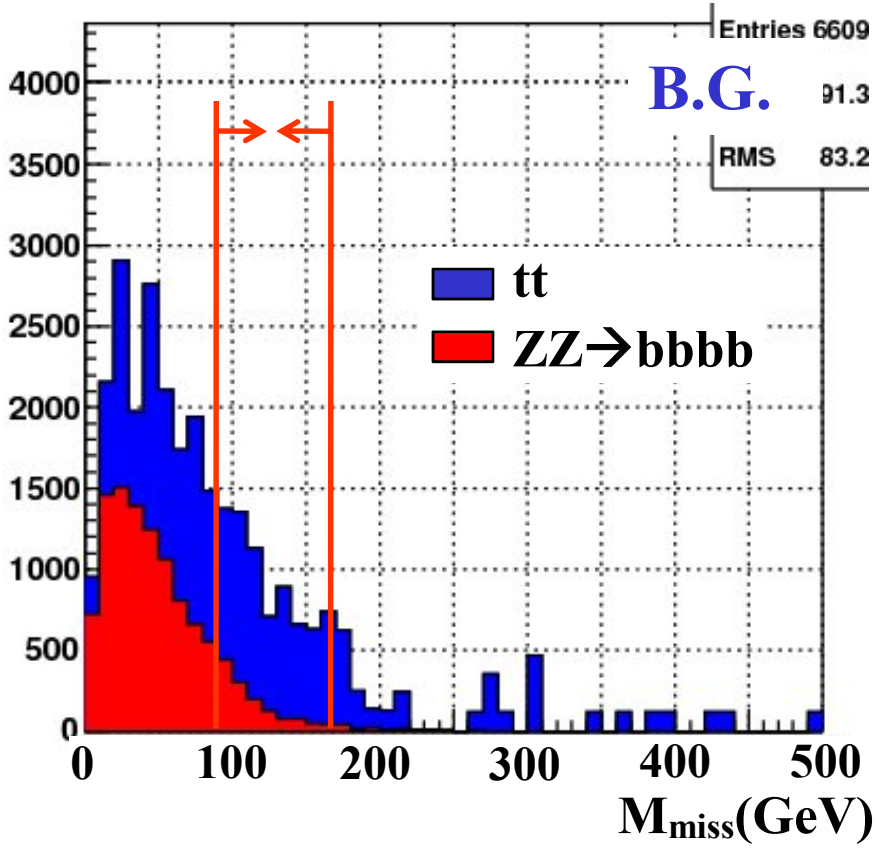


Missing mass cut

The missing mass was reconstructed.

- The peak is observed at M_Z in HHνν events.
- Selection: 90GeV < M_{miss} < 170GeV

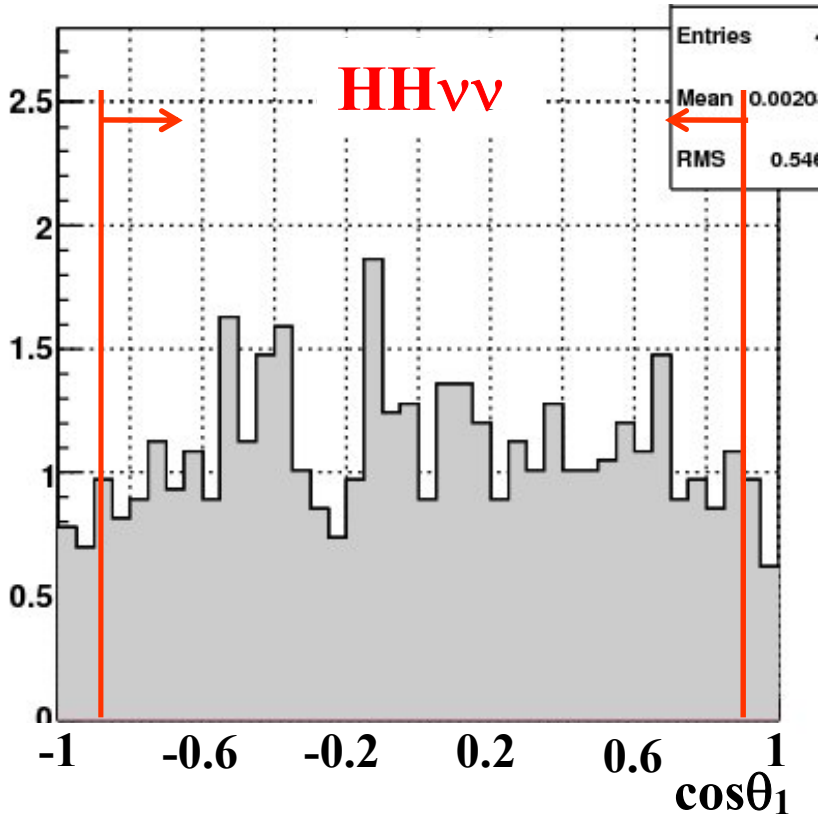


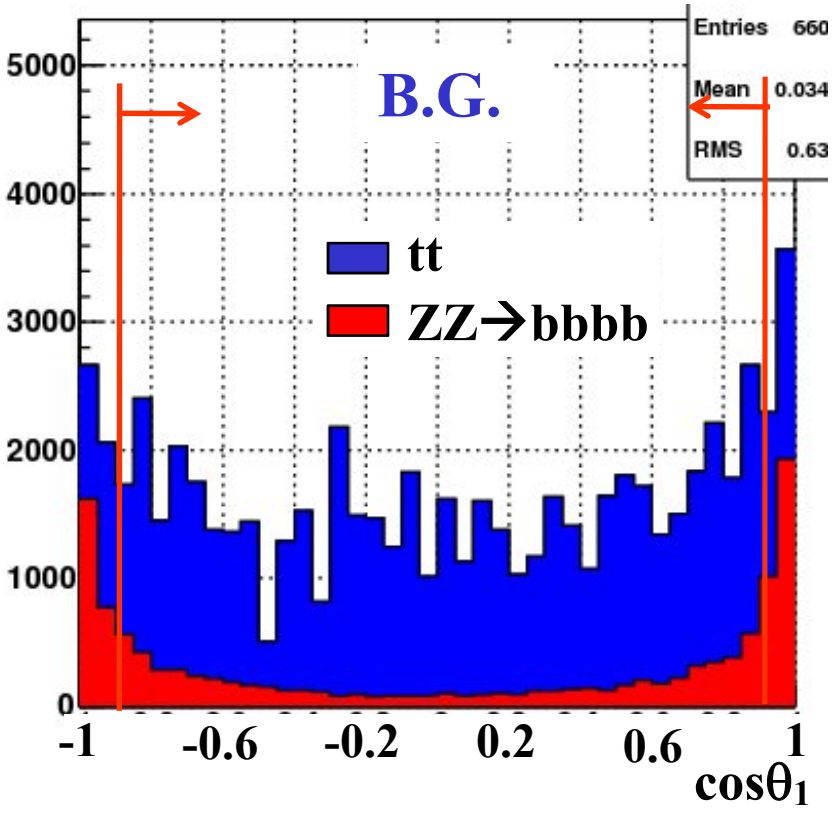


Angular cut

The angular distributions of the reconstructed jet-pair are checked.

- The angular cut is effective to reject ZZ→bbbb.
- Selection: $|\cos\theta|<0.9$

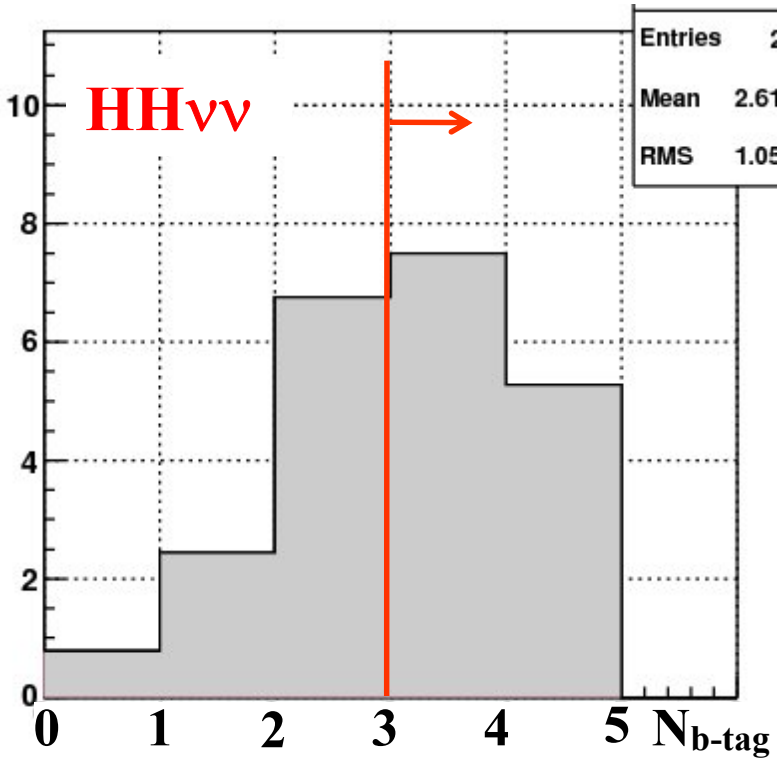


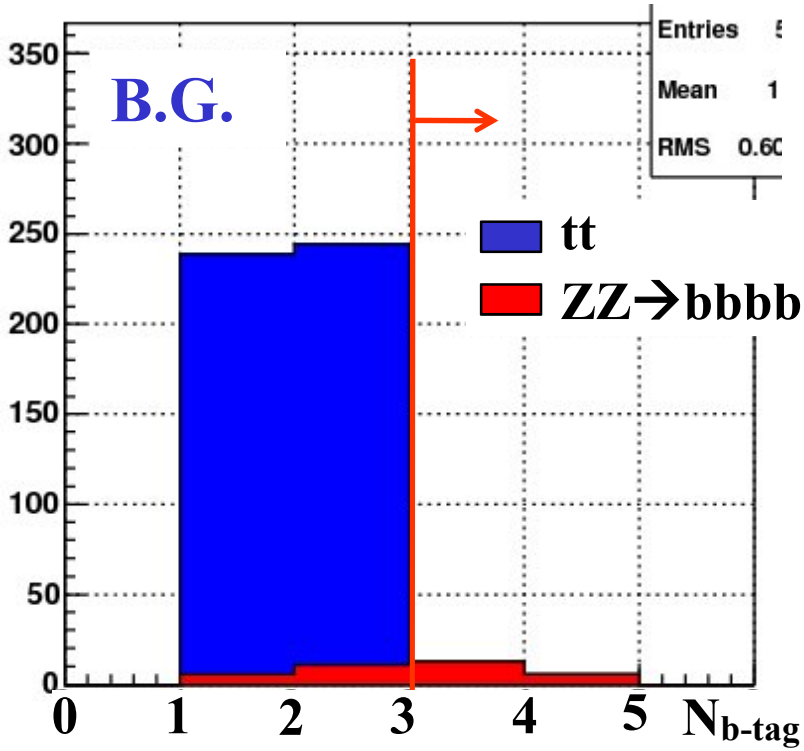


B-tag cut

After the selection cuts, b-tagging was applied.

- $N_{b\text{-}tag} \geqq 3$ was selected.
- All generated tt-events were rejected.
- ~18 events of ZZ→bbbb still contaminates for 2 ab^{-1}.





Signal significance

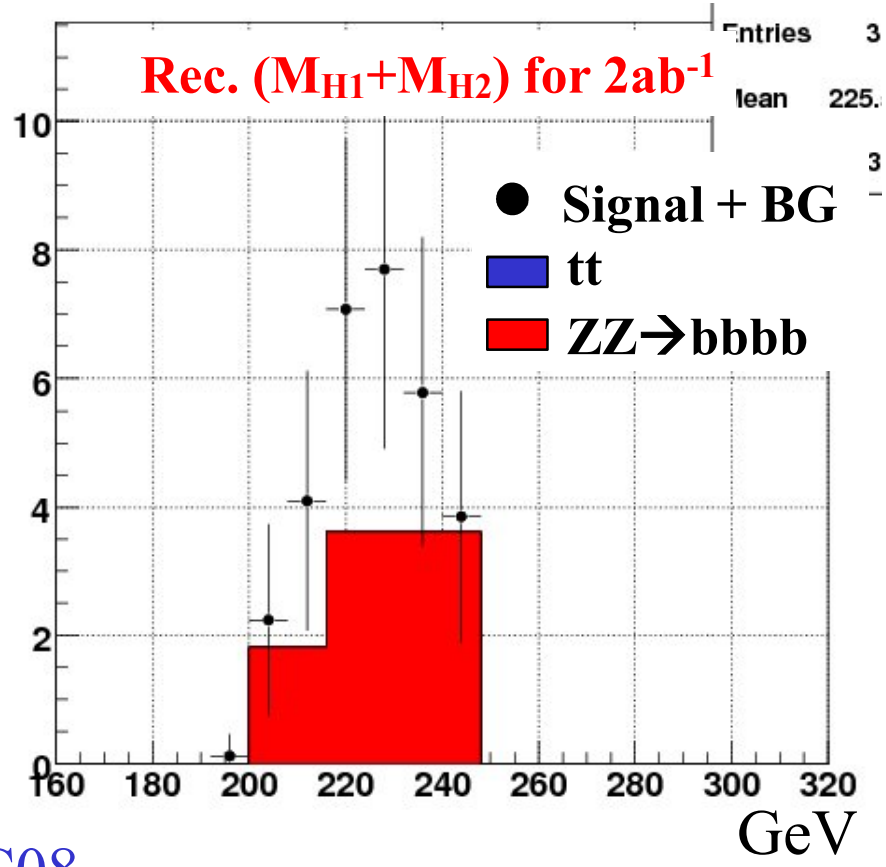
The signal significance was estimated for $2ab^{-1}$

- Signal : 12.8 events
- B.G. : 18.1 events

TILC08
- Signal : 12
- ZZ→bbbb : 64

→ 1.4 σ

Significance : 2.3 σ



Reason of the improvement from TILC08

- Overestimation of σ(ZZ→bbbb) at TILC08
- Re-optimization of Higgs-mass cut and missing-mass cut

Reduction summary

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

	HH νν	ZZ→bbbb	tt
• No cut	: 77.6	18,100	1,167,200
• $\chi^2 < 20$	: 43.3 (x 0.56)	12,169 (x 0.67)	53,925 (x 0.046)
• $95GeV < M_{H1,2} < 125GeV$	: 29.5 (x 0.68)	387 (x 0.032)	3,735 (x 0.069)
• $90GeV < M_{miss} < 170GeV$	: 26.2 (x 0.89)	127 (x 0.33)	817 (x 0.22)
• $\lvert\cos\theta_{1,2}\rvert < 0.9$	: 22.7 (x 0.87)	34.4 (x 0.27)	467 (x 0.57)
• $N_{b\text{-}tag} \geqq 3$	: 12.8 (x 0.56)	18.1 (x 0.53)	0 (x 0.0)

- The signal efficiency is 16%.
- The signal is lost mainly at the selection of Higgs mass and b-tag..
  - Improvement seems to be not easy.

Next step is to consider the other B.G.-mode like tbtb.

Summary

- ZHH is studied to investigate ILC performance for some Higgs mass case.
- HHνν is analyzed as the first step to study light Higgs case.
- The overestimation of σ(ZZ→bbbb) at TILC08 was modified.
- The signal significance of 2.3 σ was obtained against the ZZ→bbbb and tt.
- The other B.G. modes like tbtb should be taken into account.