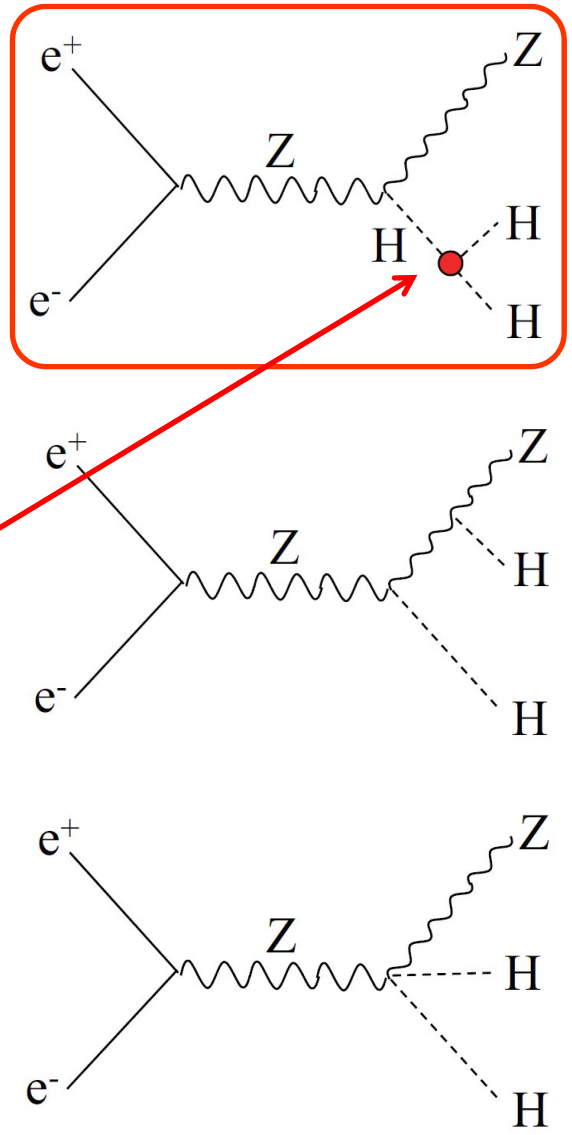
ZHH analysis with ILD

’09 10/1 Y. Takubo (Tohoku U.)

Introduction

Higgs self-coupling

- In Higgs mechanism, Higgs mass and self-coupling have a relation of $\lambda_{HHH} = m_H^2/v$.
  - $m_H^2 = 6\lambda v^2$ (v~236GeV)
  - $\lambda_{HHH} = 6\lambda v$
- Measurement of Higgs self-coupling is necessary to confirm Higgs mechanism.
- ZHH has information of Higgs self-coupling.



Analysis result of ZHH events is reported.

Analysis condition

Analysis condition

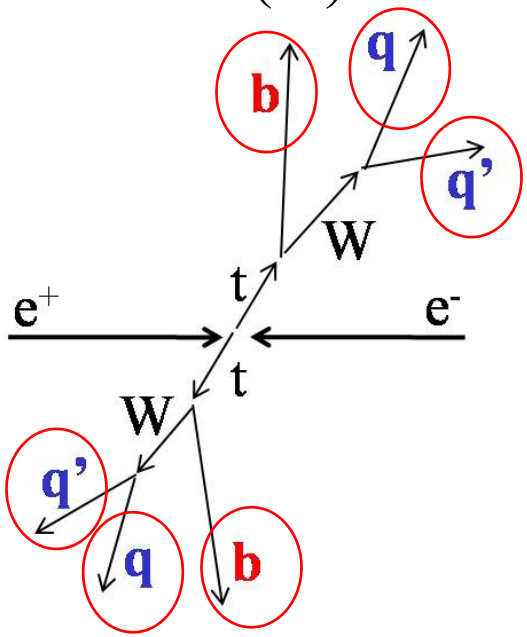
- Signal: ZHH→qqHH
- BG: 6f, qqqqH, ttqq
- E_{CM}: 500 GeV
- Higgs mass:120GeV
- Beam polarization: 80% left-handed (e^-), 30% right-handed (e^+)
- Integrated luminosity: 500fb^{-1}

Cross-section

- qqHH : 0.157fb
- 6f : 412.8fb
- qqqqH : 0.407fb
- ttqq : 1.08fb

of events for 500fb^{-1}

- 79
- 206,400
- 204
- 540



Analysis procedure

Analysis procedure

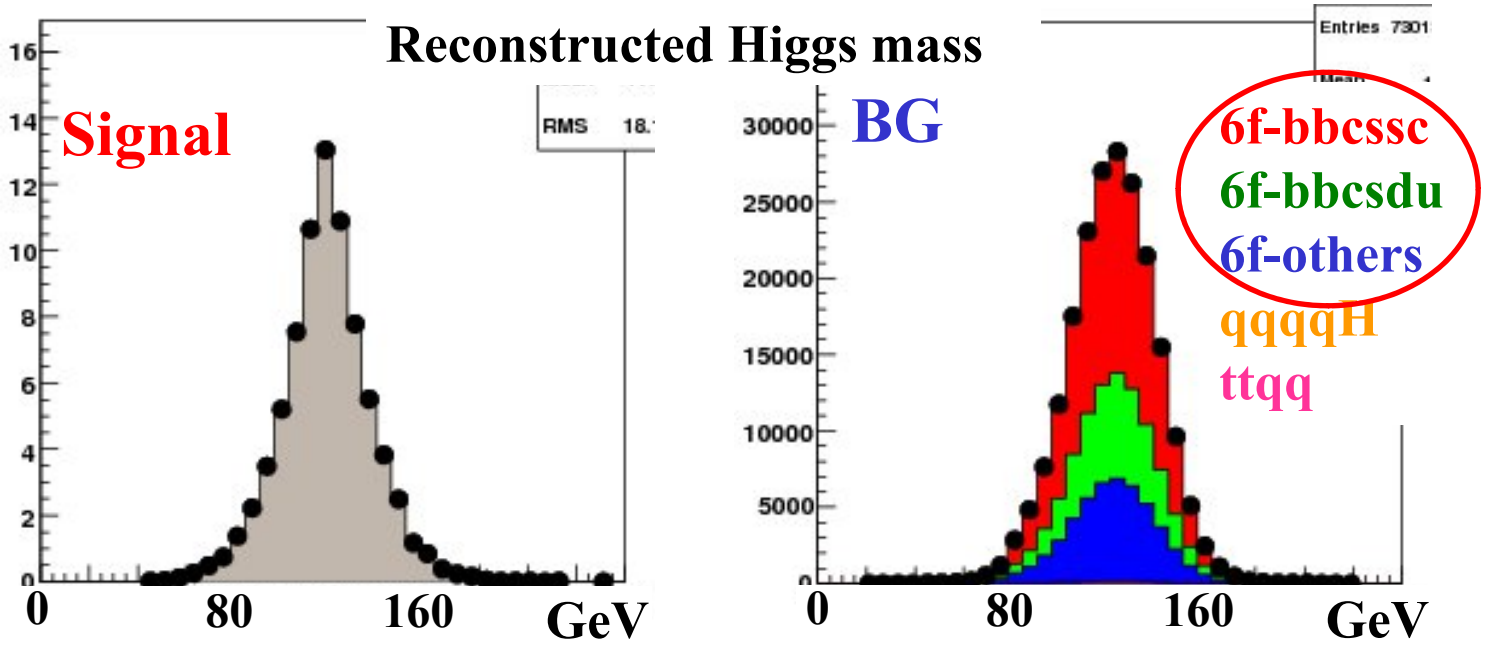
- Event generation : WHIZARD
- Detector simulation: Mokka
  - Hadronization : Phythia
- Reconstruction : MarlinReco
  - All the events are reconstructed as 6-jet events.
  - Flavor tagging: LCFIVertex
- Analysis : MARS & ROOT
  - Reconstruction of ZHH events
  - Optimization of b-tag
  - Selection of analysis samples
  - Likelihood analysis

Analysis results are presented.

Reconstruction of ZHH events

Reconstruction of ZHH events

- Higgs and Z were reconstructed to minimize χ^2 function.
  - $\chi^2 = \frac{({}^{rec.}M_{H1} - {}^{true}M_H)^2}{\sigma_{H1}{}^2} + \frac{({}^{rec.}M_{H2} - {}^{true}M_H)^2}{\sigma_{H2}{}^2} + \frac{({}^{rec.}M_Z - {}^{true}M_Z)^2}{\sigma_{H2}{}^2}$
- Many 6f events contaminate in the signal region.



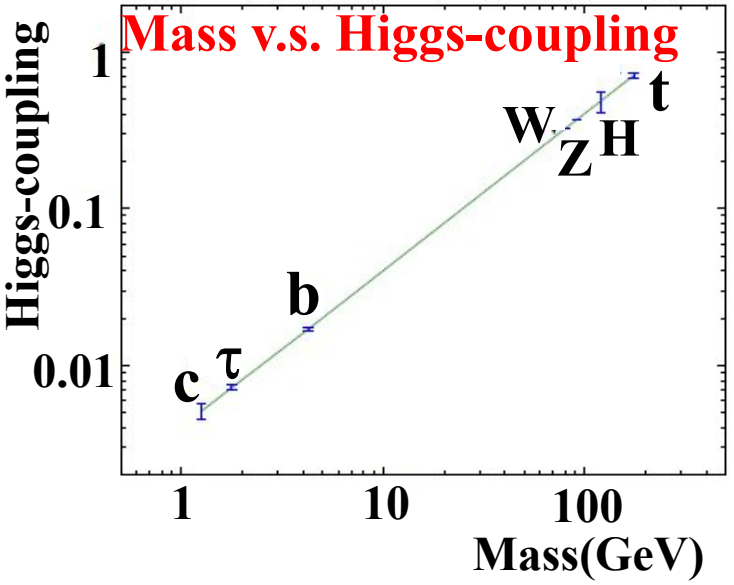
b-tag was applied to reject 6f events.

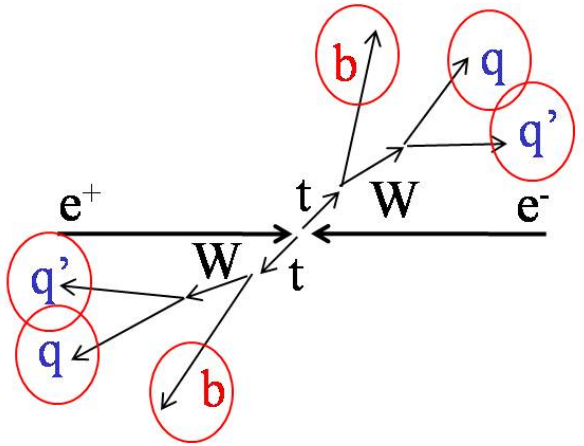
Importance of b-tag in ZHH analysis

Characteristics of ZHH analysis

- 43% of qqHH events decays into qqbbbb.
  - BR(H→bb) is 65.7%.
- BG is mainly bbqqqq in 6f events.
  - tt→bbcssc, bbuddu, etc.

→ **bbqqqq can be rejected, requiring the number of b-jets above 3.**





Performance of b-tag determines the sensitivity to ZHH events!

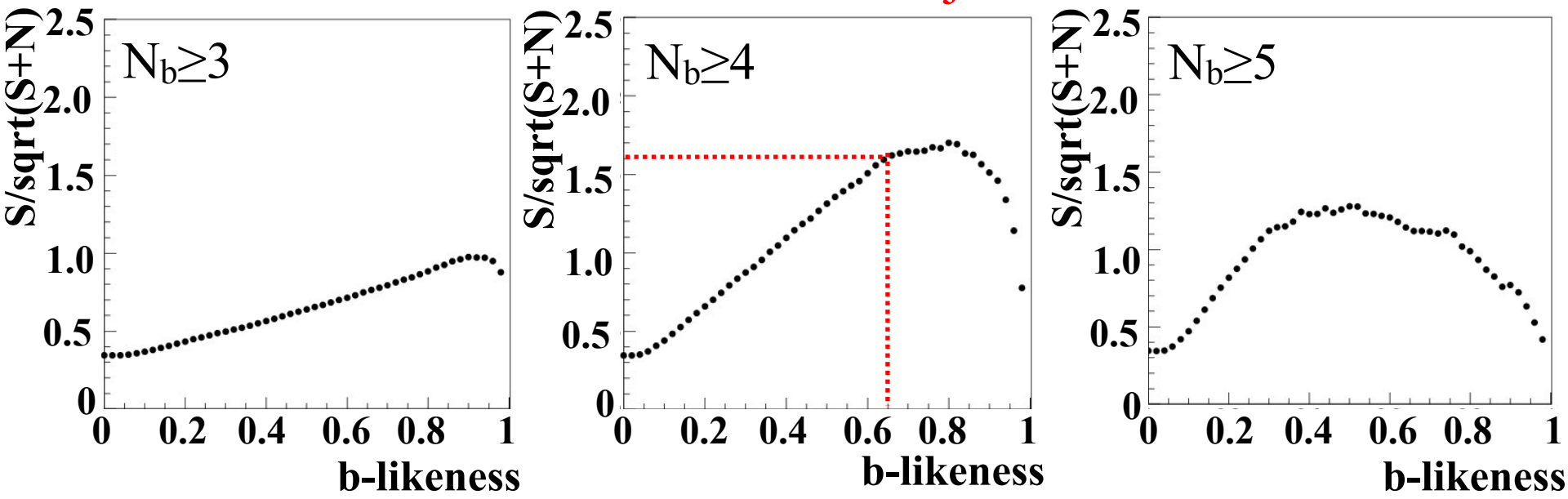
b-tag requirement was optimized for this analysis.

Optimization of b-tag requirement

Signal significance v.s. b-likeness

- The signal significance was checked as a function of b-likeness required to identify a b-jet.
  - N_b: # of jets identified as b-jet
- A event sample with $N_b \geq 4$ has the largest significance, requiring b-likeness above 0.65.

→ b-likeness above 0.65 is identified as a b-jet.

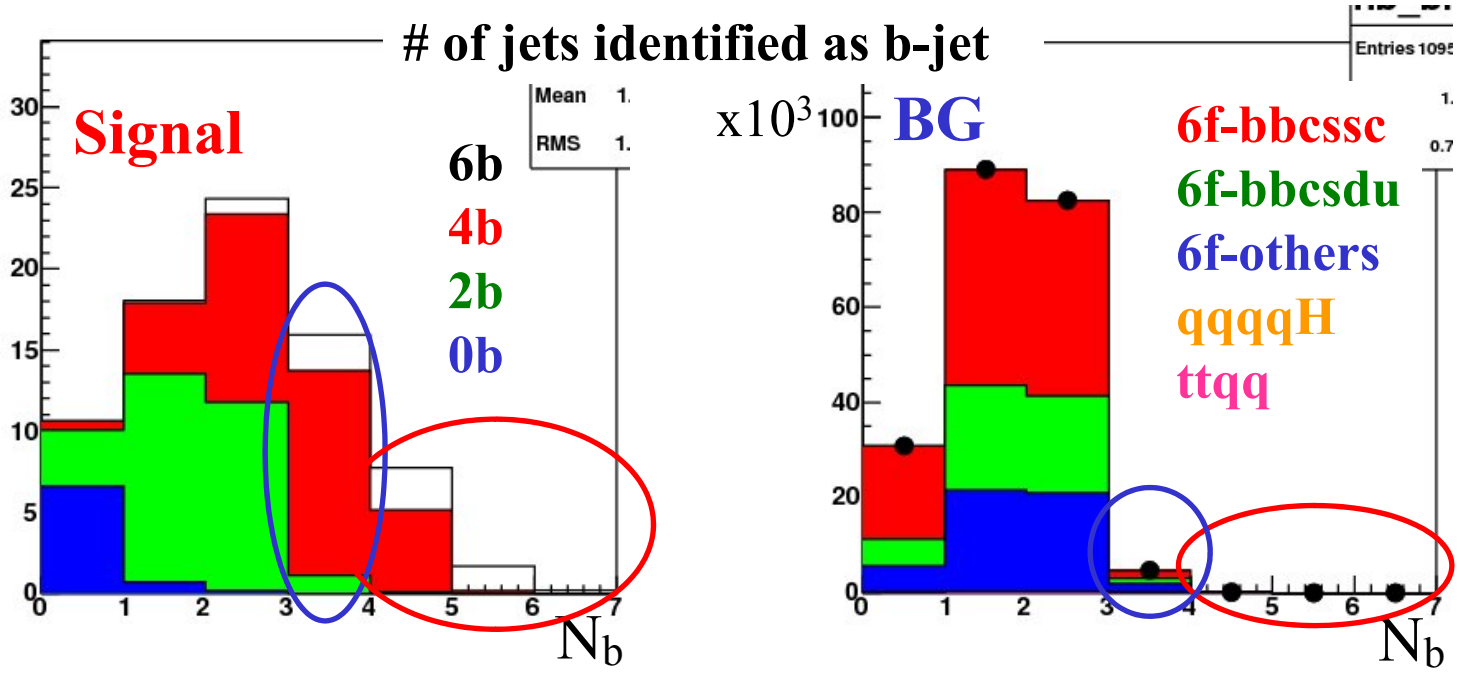


Selection of event samples

BG can be rejected effectively by using events with $N_b \geq 3$.

	No cut	$N_b = 3$	$N_b \geq 4$
Signal	79	15.9(0.20)	9.5(0.12)
BG	207,144	4663(0.02)	147(7×10^{-4})

Events with $N_b = 3$ and $N_b \geq 4$ were selected as analysis samples.



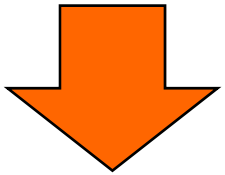
Likelihood analysis

Likelihood function was made by using MC data for about $1ab^{-1}$.

Variables for likelihood function

- χ^2(ZHH), χ^2(tt)
- Rec. masses of Higgs and Z
- Rec. mass of W
- top energy
- Missing energy
- Thrust angle
- c-likeness of two jets for a Z candidate
- Total b-likeness and c-likeness
- # of b(c) jets

17 variables are used.



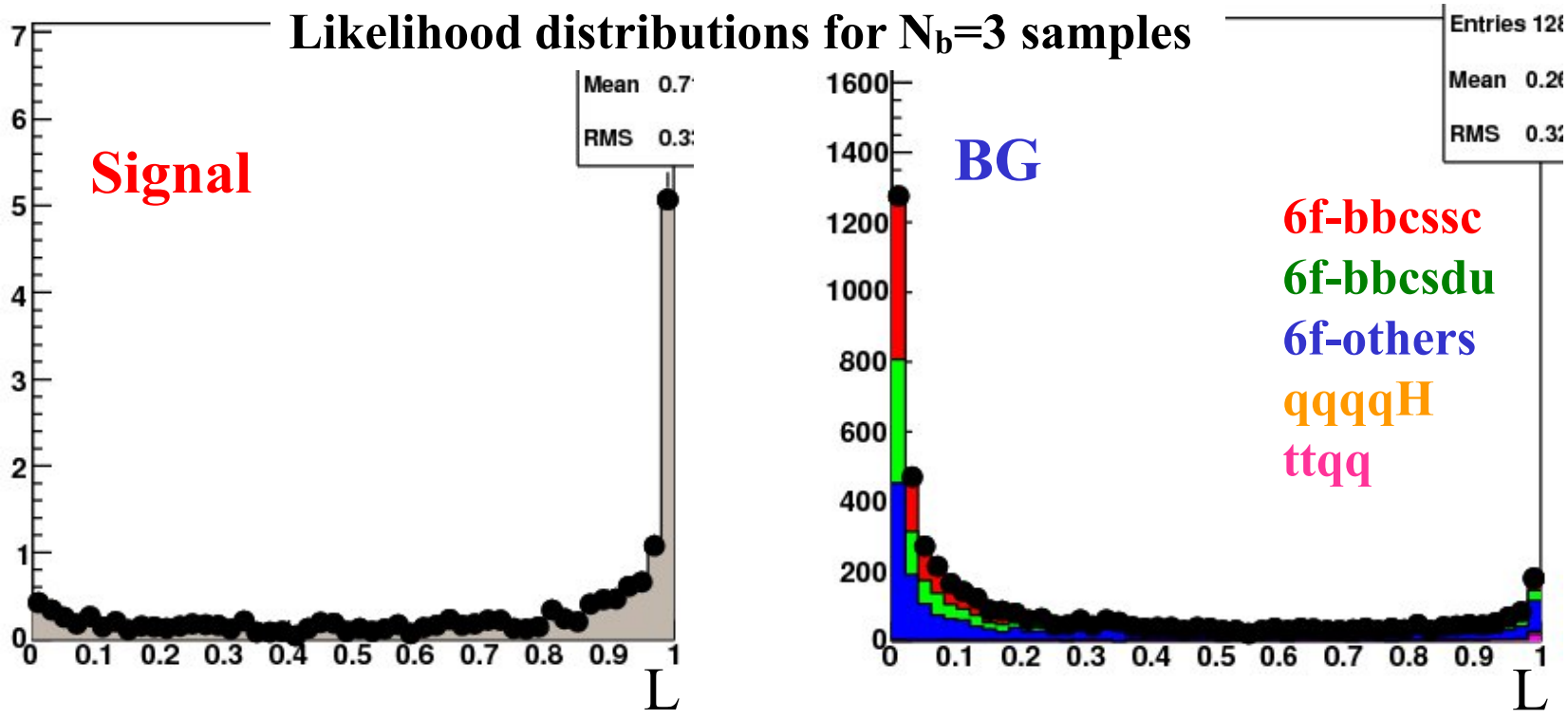
$$L = \frac{L(S)}{L(S) + L(BG)}$$

Likelihood analysis was applied to N_b=3 and $N_b \geq 4$ samples.

Likelihood for N_b=3 sample

Likelihood for N_b=3 sample

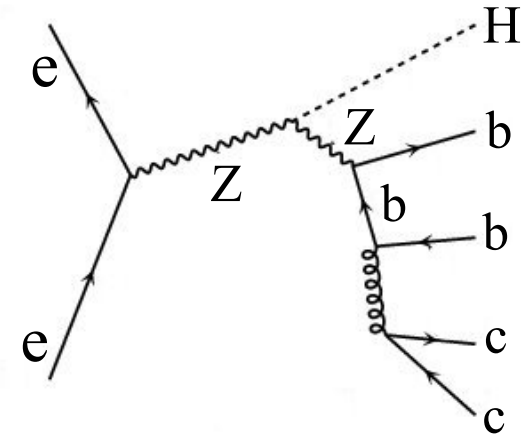
- Signal and BG can be separated clearly.
- Many BGs contaminate in the signal region
  - The main BG is 6f events



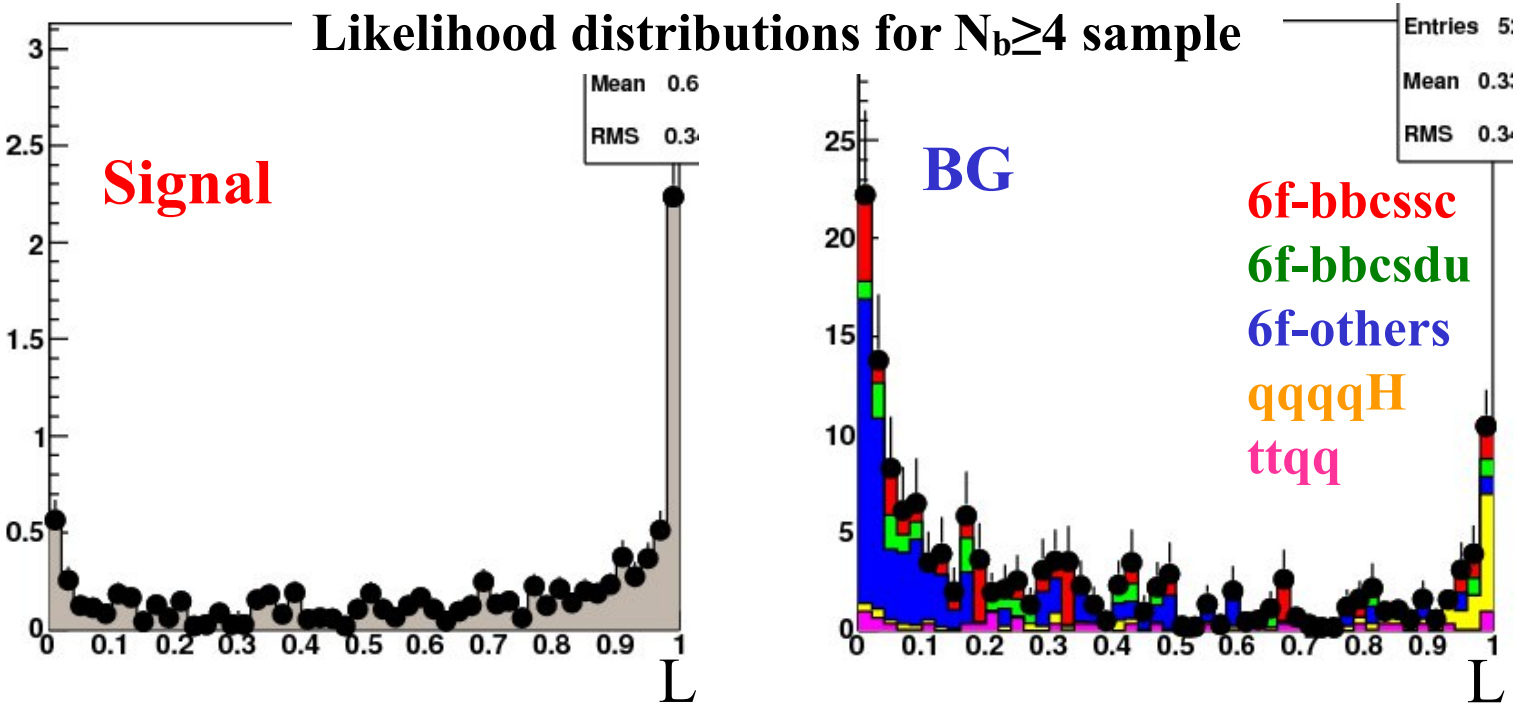
Likelihood for $N_b \geq 4$ samples

Likelihood for $N_b \geq 4$ samples

- Signal and BG can be separated.
- qqqqH events contaminate in the signal region.
  - Main BG: qqbbH(H→bb)



Likelihood distributions for $N_b \geq 4$ sample



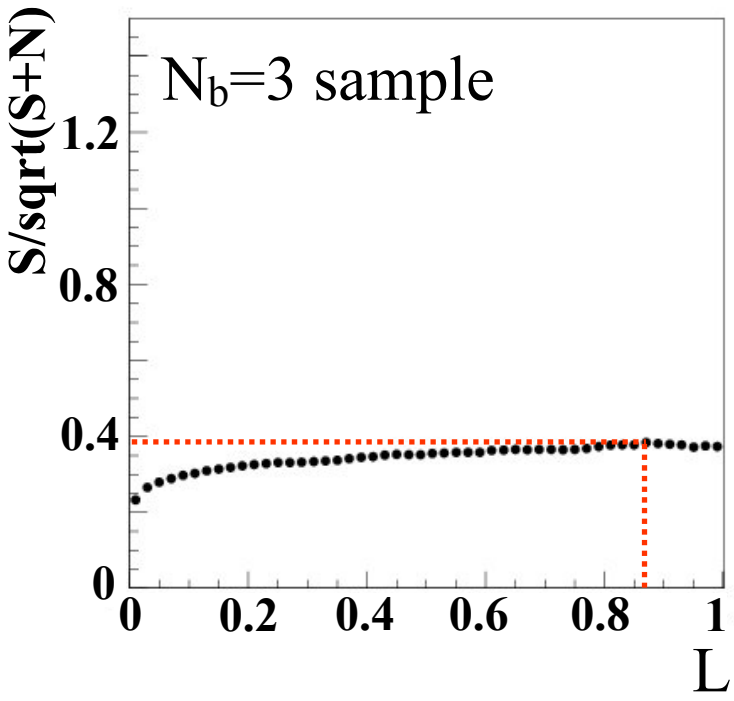
Signal significance

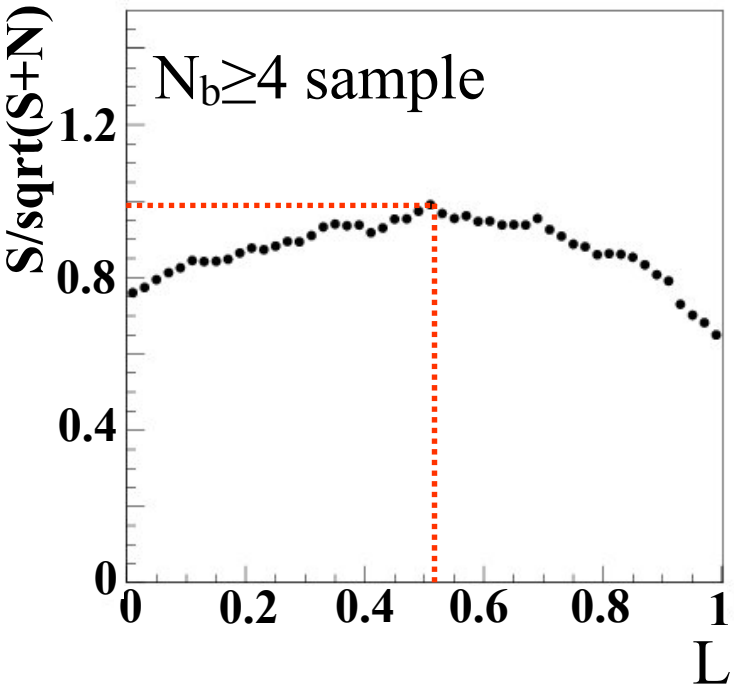
Signal significance

- N_b=3 sample: 0.38 @ L=0.87
  - Signal: 8.8
  - BG: 512.6
- $N_b \geq 4$ sample: 0.99 @ L= 0.51
  - Signal: 6.6
  - BG: 38.3

Total significance: 1.1 @500fb^{-1}

(3.1 @4ab^{-1})





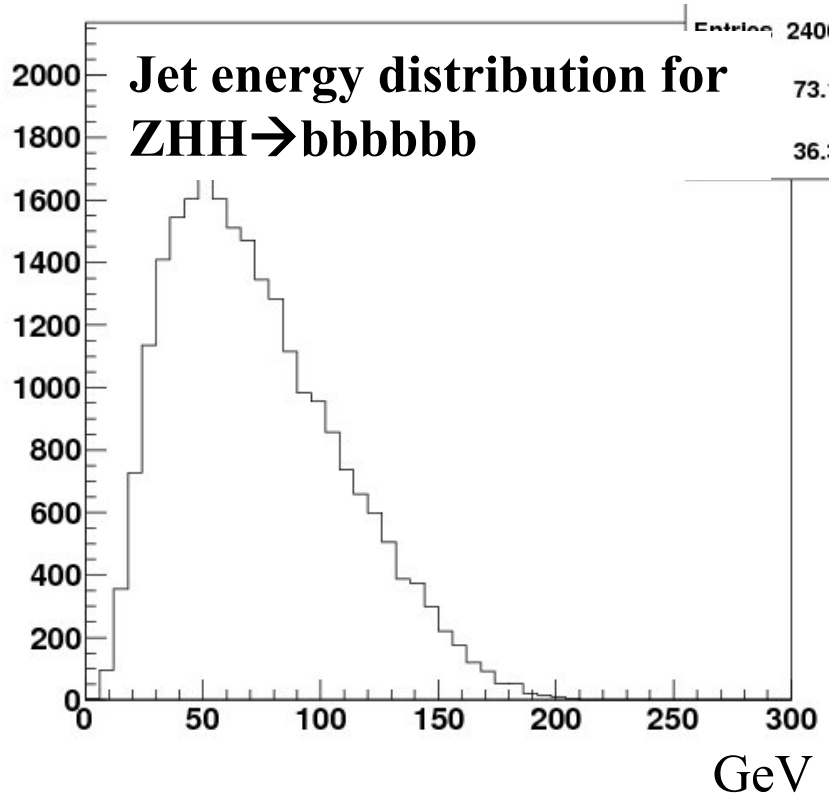
Improvement of b-tag

Improvement of b-tag is essential to obtain more signal significance.

- NN training for LCFIVertex is done at Z-pole (90 GeV).
- The average jet energy is about 70 GeV for ZHH events.

→ Performance of the flavor tagging might be improved by NN training at 140GeV.

NN training was done at 140GeV.

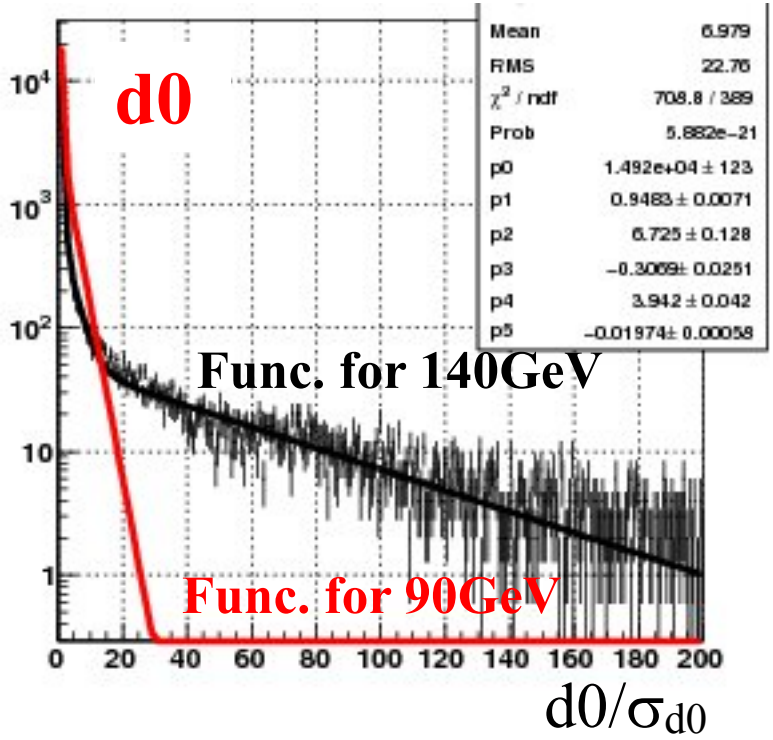


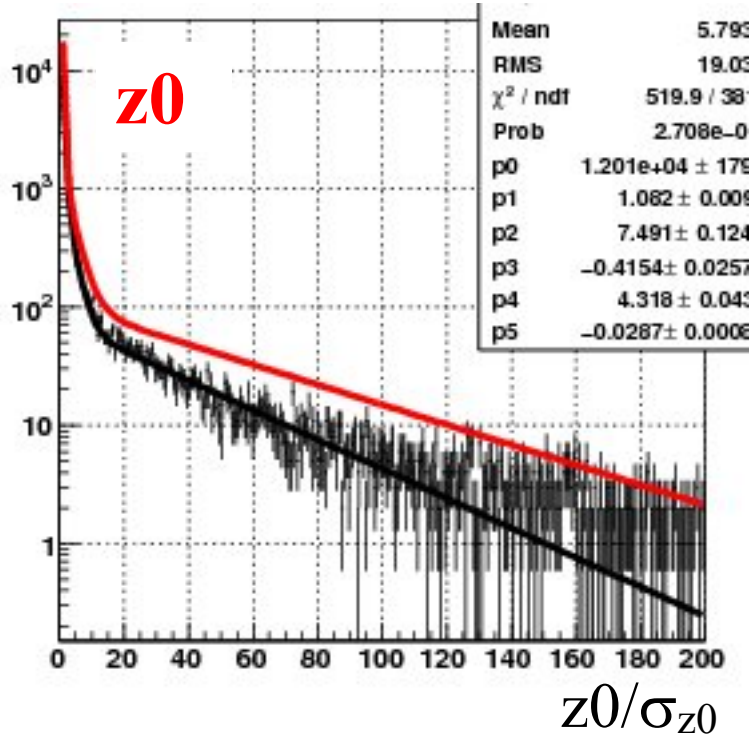
d0 and z0 at 140GeV

The impact parameter distributions were checked for 140 GeV.

- The distributions were fitted by an empirical function (Significance fit).
  - The fitting parameters are used in LCFIVertex.
- The fitting results of 140 GeV are much different from 90GeV.

Performance of b-tag was studied.

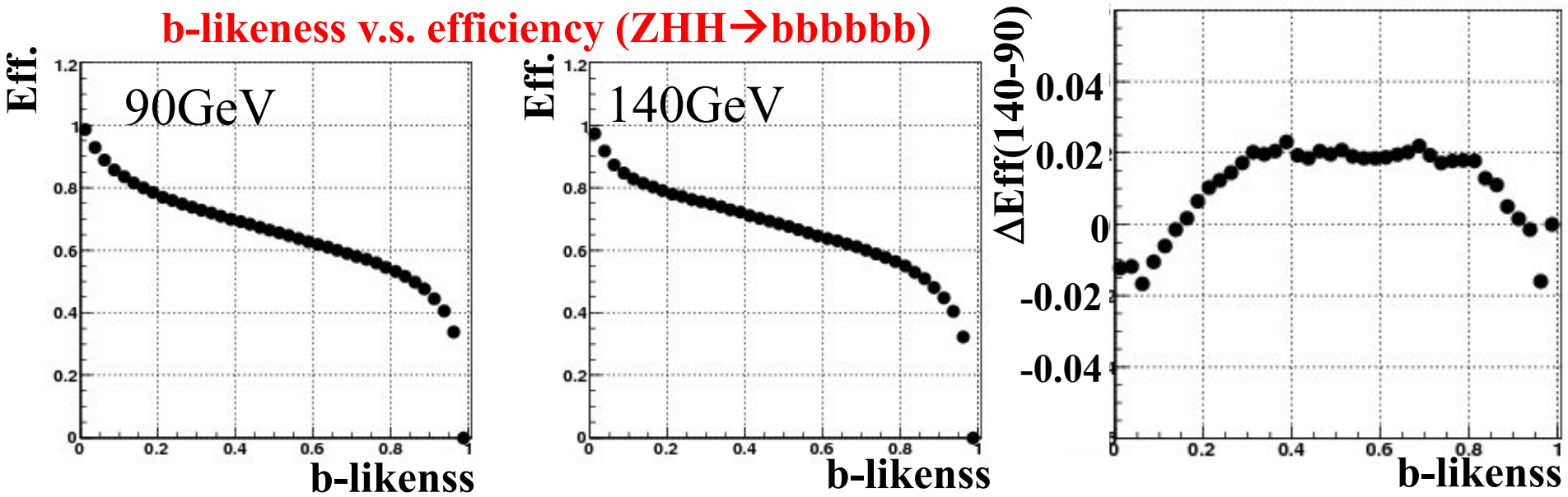




b-tag performance

The efficiency was compared as a function of b-likeness between training at 90 GeV and 140 GeV.

- The performance is 2% better for training at 140 GeV.
  - The difference is within performance fluctuation of LCFIVertex.
- The impact of this improvement on the analysis must be investigated.



Summary

- ZHH events were studied with ILD MC data.
- b-tag was optimized for ZHH analysis.
- We obtained the signal significance of 1.1 for 500fb^{-1} with likelihood analysis.
  - 3.3 sigma for 4ab^{-1}.
- Improvement of b-tag. is essential to obtain more signal significance.
- NN training was done at the average jet energy of ZHH (140 GeV)
  - The impact on the analysis result must be checked.