Measurement of Higgs anomalous coupling with H→WW*

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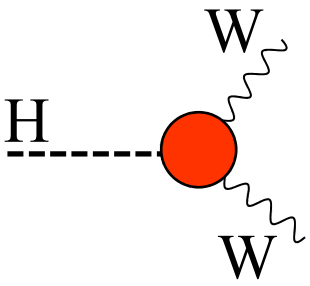
Higgs anomalous coupling with W

• Anomalous coupling between a Higgs and gauge boson can exist as loop effect of new physics.

→ We focus on anomalous coupling with W.



• Three terms contribute to the anomalous coupling.

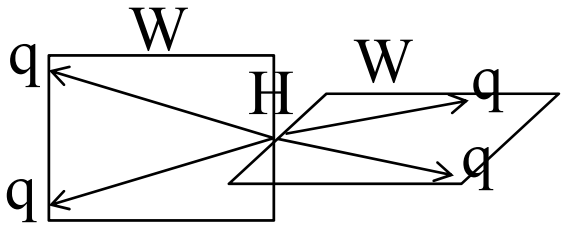
CP-odd CP-even

$$\mathcal{L} = 2m_W^2 \left(\frac{1}{v} + \frac{a}{\Lambda}\right) H W_\mu^+ W^{-\mu} + \frac{b}{\Lambda} \varepsilon^{\alpha\beta\mu\nu} W_{\mu\nu}^+ W_{\alpha\beta}^- + \frac{c}{\Lambda} H W_{\mu\nu}^+ W^{-\mu\nu}$$

Measurement variables

• a/Λ : BR(H→WW)

• b/Λ : Angular distribution for W decay planes.



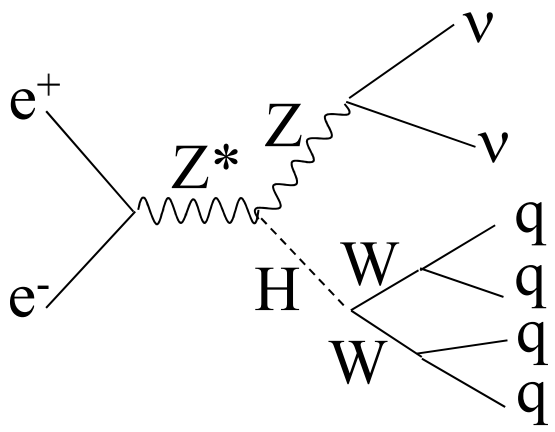
Today's talk

• c/Λ : Ratio of $H \to W_T W_T$ and $H \to W_L W_L$

Simulation condition

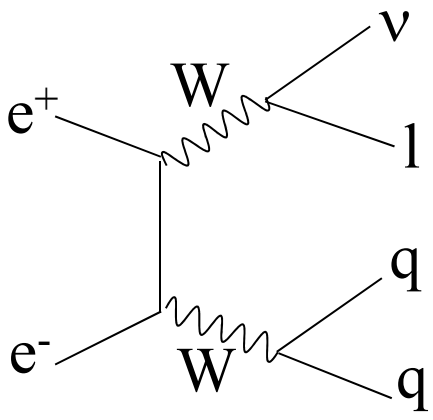
Analysis processes

- Signal: ZH → ννWW* → ννqqqq
- SM-BG: 4 fermion final states
  - ννqq, qqlν, llqq, llll, qqll, qqqq



Simulation condition

- CM energy: 250GeV
- Higgs mass : 120 GeV
  - BR(H→WW*) = 15.0%
- Integrated luminosity: 250fb^{-1}
- Simulation tool: Mokka/Marlin
  - Detector model: ILD

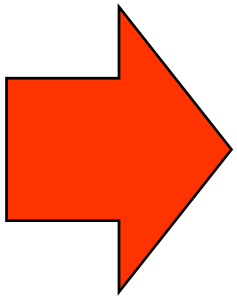


The effect of the beam polarization was checked to reject WW/ZZ backgrounds.

Optimization of beam polarization

80% e_L^- & 30% e_R^+

- vvh: 18,907 (h→WW→4j: 1252)
- vlqq: 4,143,860
- vvll: 615,231
- llll: 761,222
- vvqq: 149,979
- qqll: 398,335
- qqqq: 4,048,390



80% e_R^- & 30% e_L^+

- vvh: 10634 (h→WW→4j: 680)
- vlqq: 299,866
- vvll: 103,704
- llll: 753,964
- vvqq: 63,649
- qqll: 335,762
- qqqq: 378,726

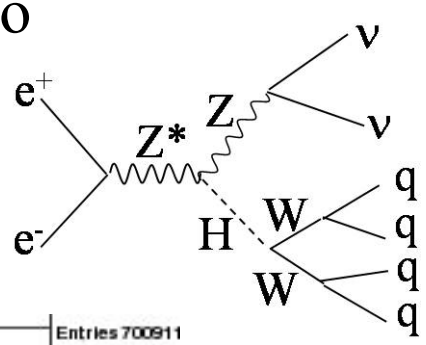
SM-BG can be suppressed by using right-handed polarization.

→ Right-handed polarization is used for this analysis.

Event reconstruction

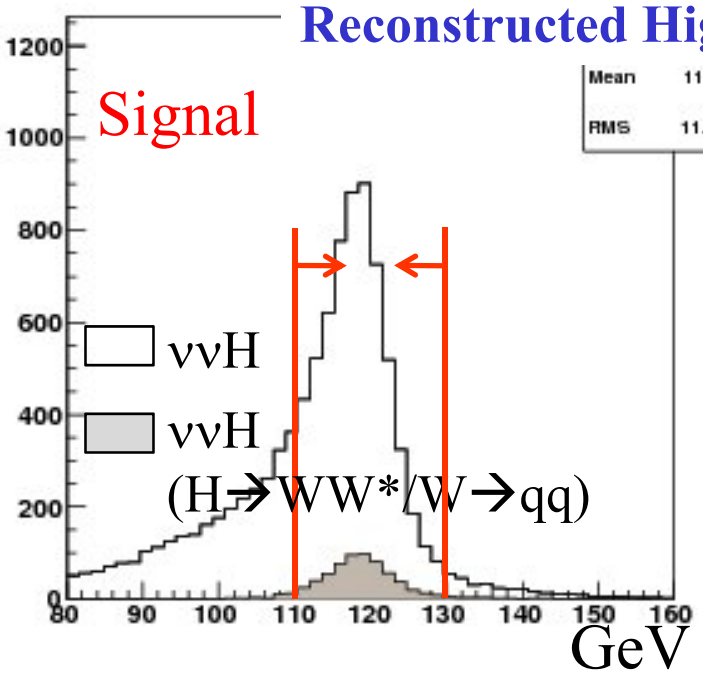
- All the events are reconstructed as 4-jet events.
- The masses of Higgs and on-shell W is reconstructed to minimize χ^2 value:

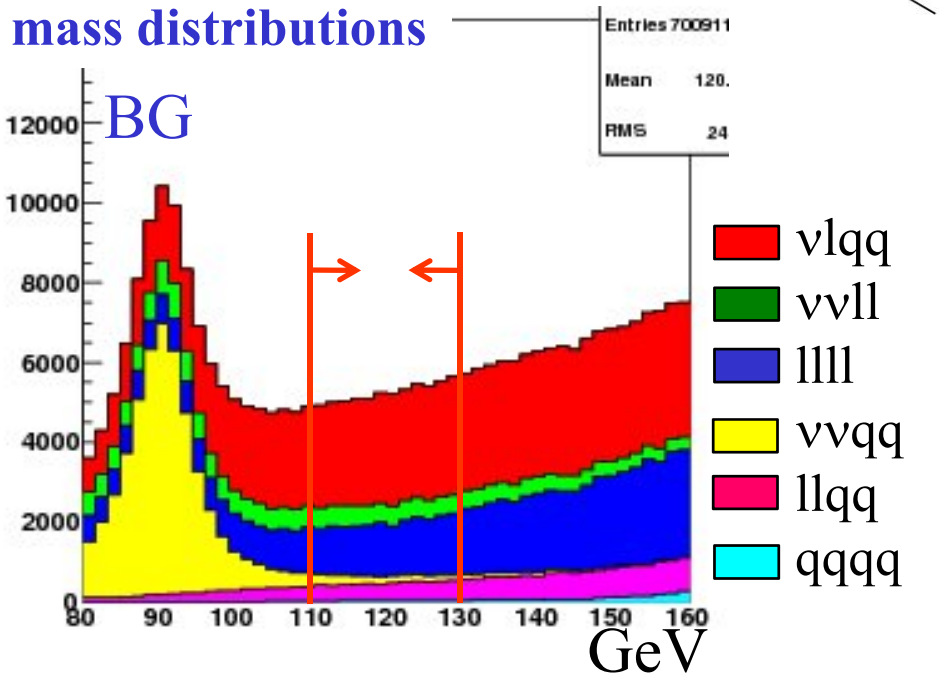
$$\chi^2 = \frac{({}^{rec}M_H - {}^{tr}M_H)^2}{\sigma_H^2} + \frac{({}^{rec}M_W - {}^{tr}M_W)^2}{\sigma_W^2}$$



- Large number of BG contaminate in the signal region.

Reconstructed Higgs mass distributions





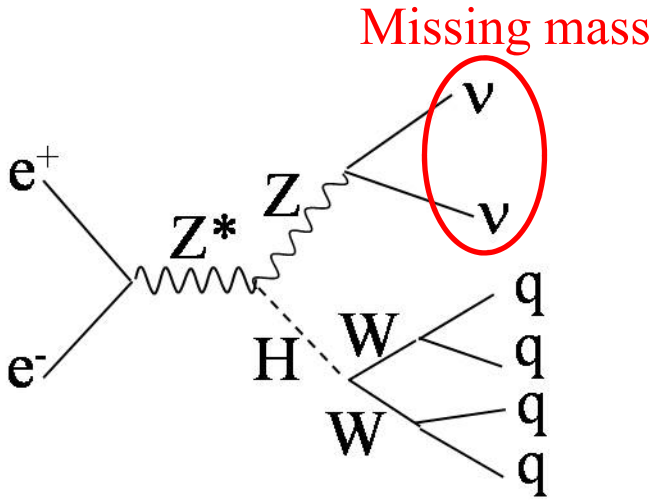
The selection cut was applied.

Event selection

Selection criteria

- Higgs mass: $110 < M_H < 130\text{GeV}$
- Missing mass: $70 < {}^{miss}M < 140\text{GeV}$
- Higgs angle: $|\cos\theta_H| < 0.95$
- Y-value: $Y > 0.0005$

$$Y = \frac{2E_i^2(1-\cos\theta_{ij})}{E_{vis}^2}$$ i, j : Index of jet-cluster



- Maximum track energy: $E_{trk} < 30\text{GeV}$
- # of b-tagged jets: $N_b <= 1$
- # of b-tagged jets: N_b for 2-jet reconstruction: 0

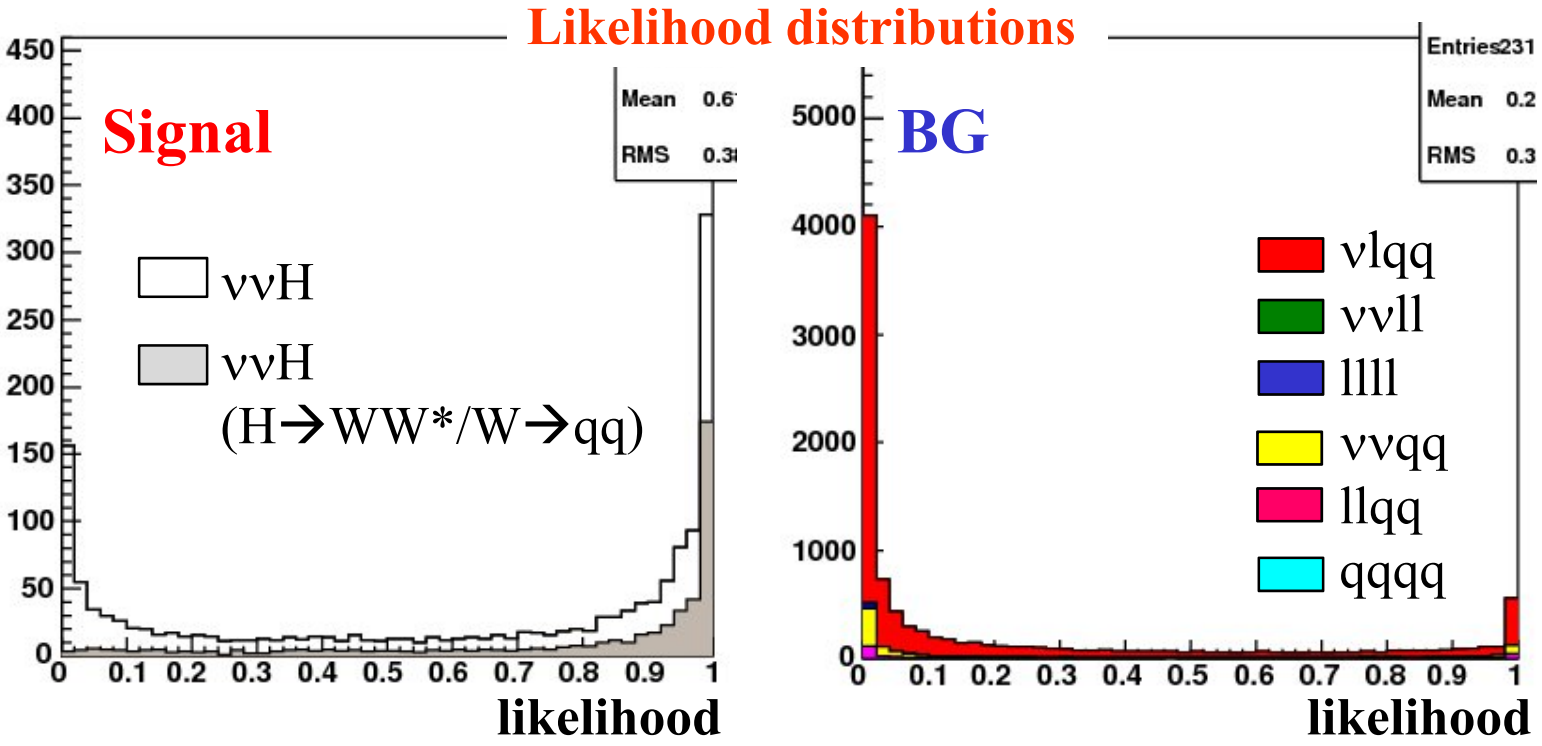
	Before cut	After cut
ZH→ννWW(4j)	680	512
ZH→others	9,953	1,006
SM-BG	1,935,671	10,127

The likelihood analysis was performed.

Likelihood analysis

- Likelihood function: L = L(S)/(L(S) + L(BG))
- Input variables: ^{miss}M, $\cos\theta_H$, Y, N_b, # of charged tracks
- The signal and BG could be separated clearly.

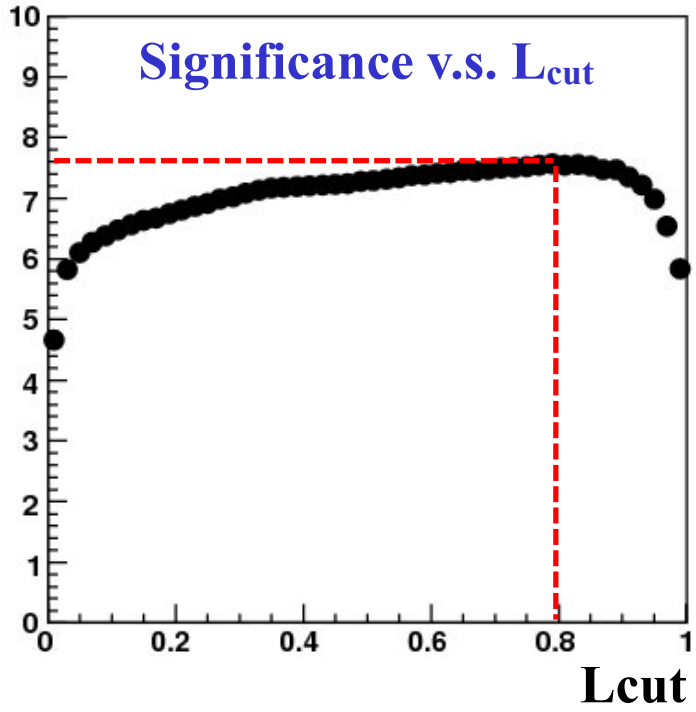
→ Likelihood cut position was optimized.

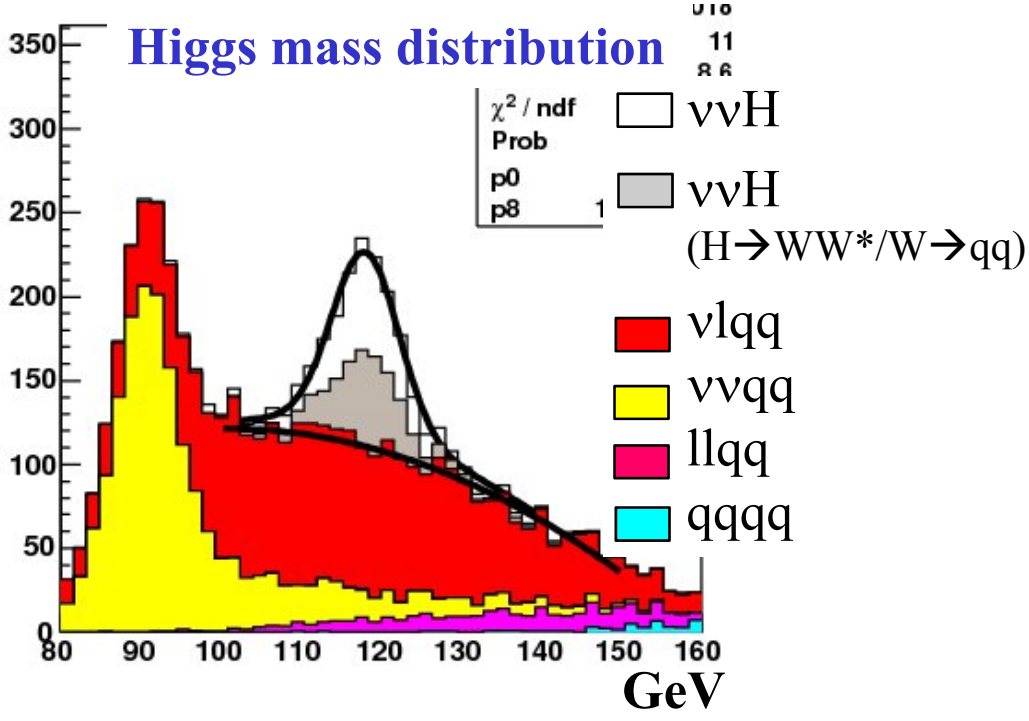


Accuracy of BR(H→WW)

- Likelihood cut is set to maximize the signal significance.
  - Signal significance: 7.6 (@ $L_{cut} > 0.79$)
- Accuracy of BR(H→WW) is evaluated by fitting Higgs mass dist..
  - ➢ Δσ(ZH→ννWW) = 15.5%

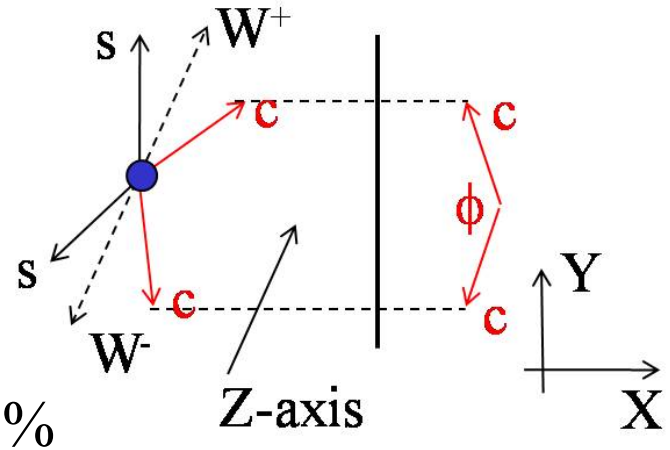
  → **ΔBR(H→WW) = 15.7%** (with Δσ(ZH)=2.5%)

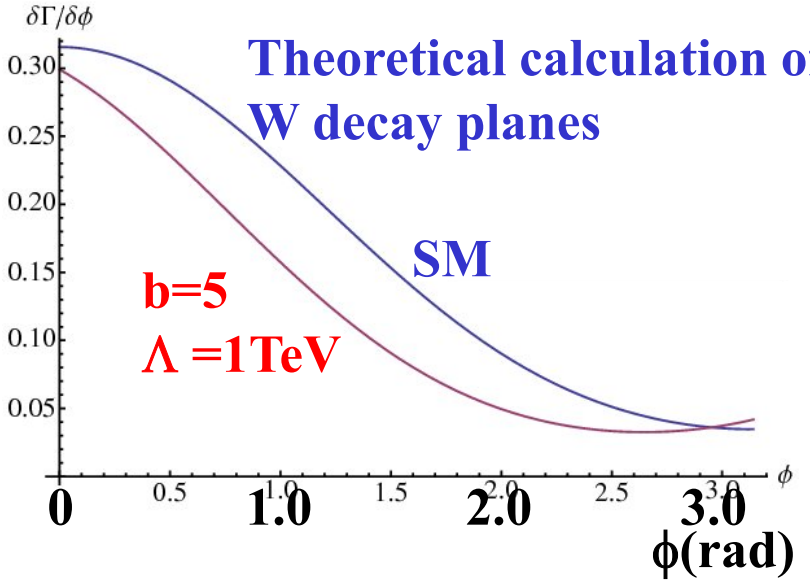




Calculation of plane angle

- Angle of W decay planes was evaluated by the angle of the two up-type quarks.
  - There is a peak at 0 rad..
  - The distribution shape changes with the anomalous coupling.
- Two c-jet is selected with c-tagging.
  - Selection efficiency of ZH→ννcxcx is 88%



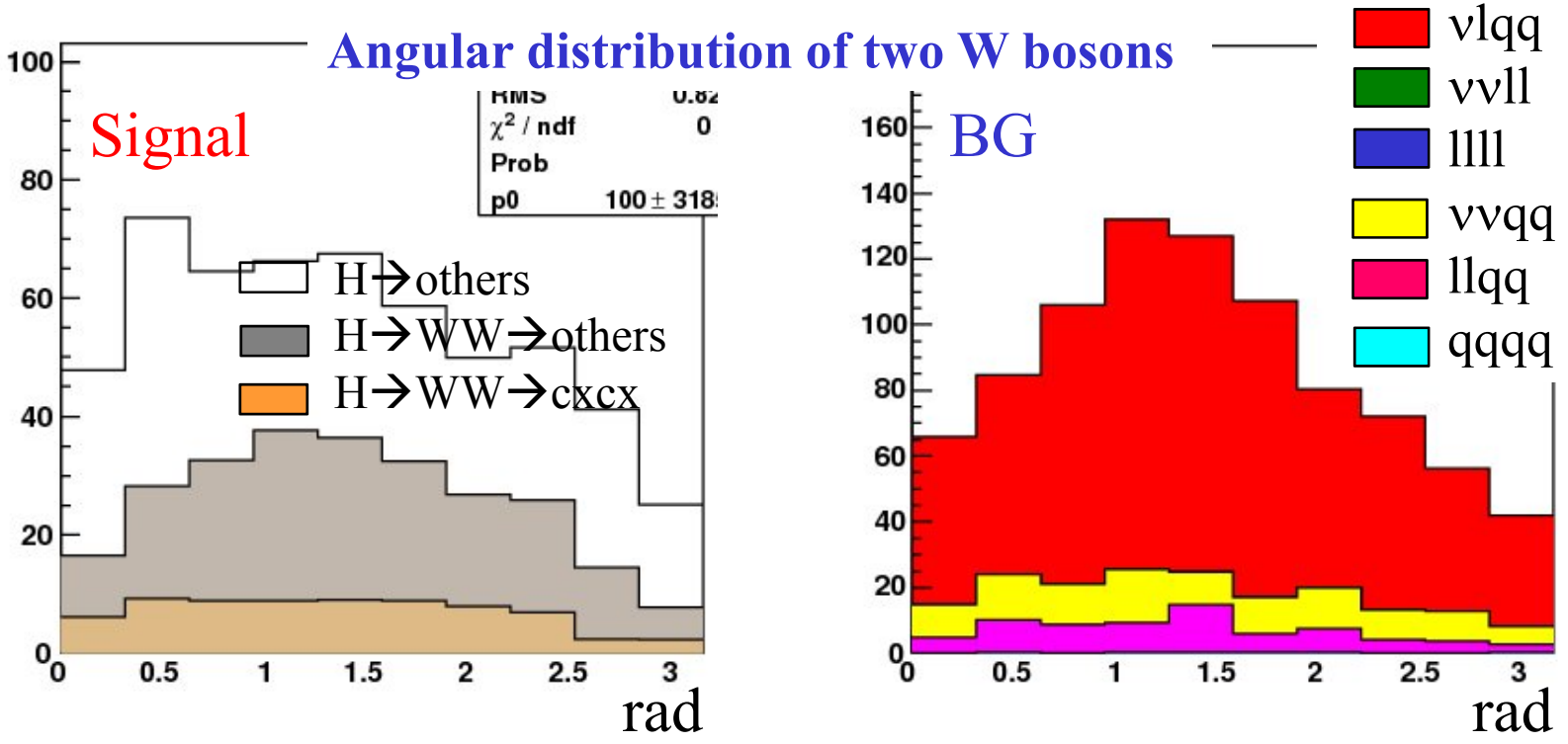


	Before c-tag	After c-tag
ZH→ννcxcx	81	71
ZH→others	675	475
SM-BG	1,367	874

Plane angle after selection cut

- The angular information seems to remain for the signal events.
  - The events decrease at 0 degree because jet-clustering is difficult with small angle separation.
- BG evaluation is necessary to obtain the signal distribution.

→ BG estimation was considered.

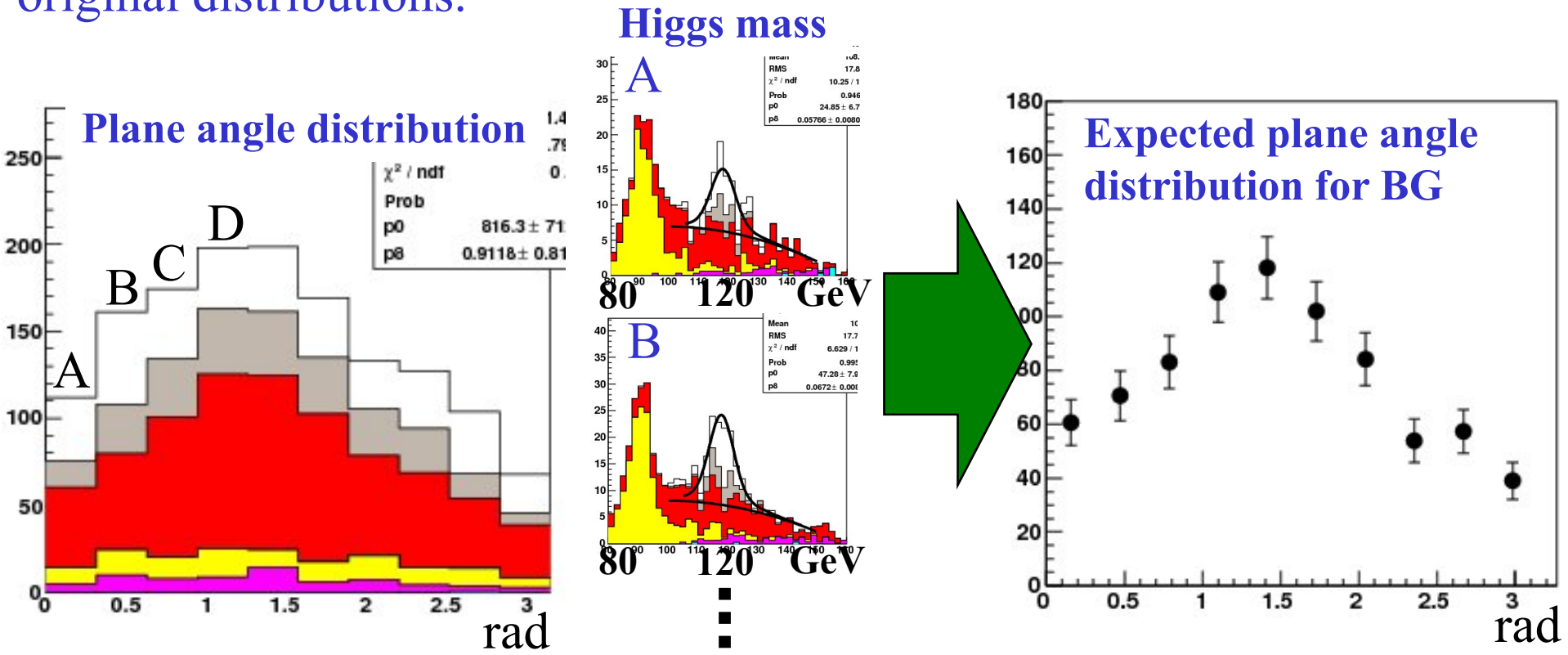


BG estimation

• # of BG is estimated, fitting M_H distributions prepared for each bin of the plane angle distribution.

• Fitting function: double gaussian + 2nd order polynomials.

→ The expected background distribution was compared with the original distributions.

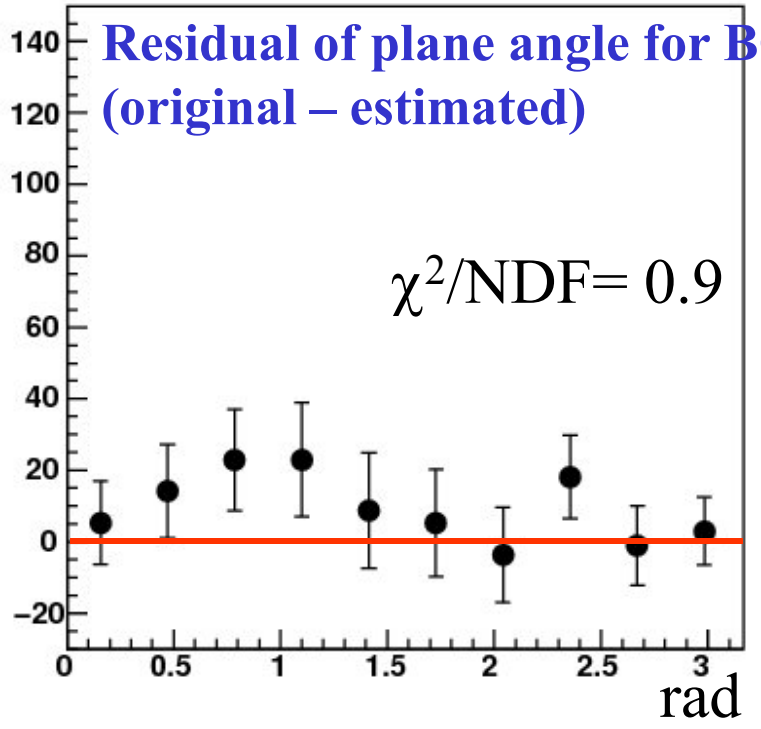


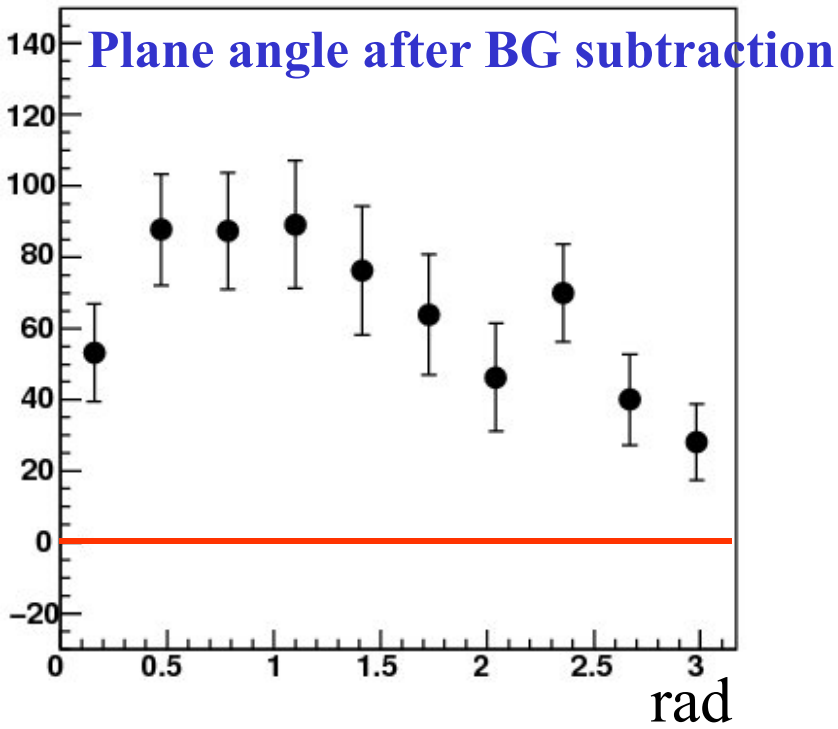
Angular dist. After BG subtraction

- The estimated BG distribution is consistent with the original dist..

  → The plane angle for ZH events was obtained, subtracting estimated BG.

- Next step: Comparison of the angular distribution, including the anomalous coupling.





Summary

• The Higgs anomalous coupling to gauge bosons are good probe of the new physics.

  ➢ The sensitivity of ILC to Higgs anomalous coupling to W was studied.

• The measurement accuracy of BR(H→WW) was 15.7% with $\Delta\sigma$(ZH) of 2.5%.

• The decay angle of decay plains was reconstructed by using two c-tagged jets.

  ➢ The next step is comparison of the angular distribution, including the anomalous coupling.

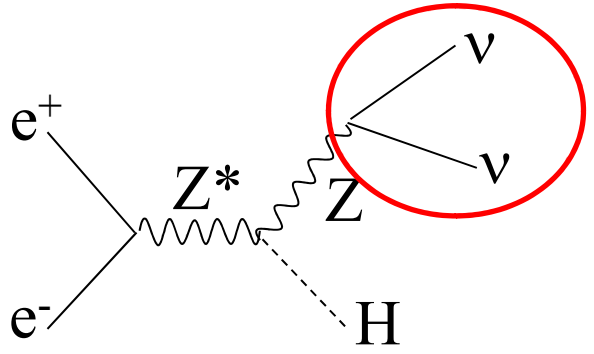
Cut summary

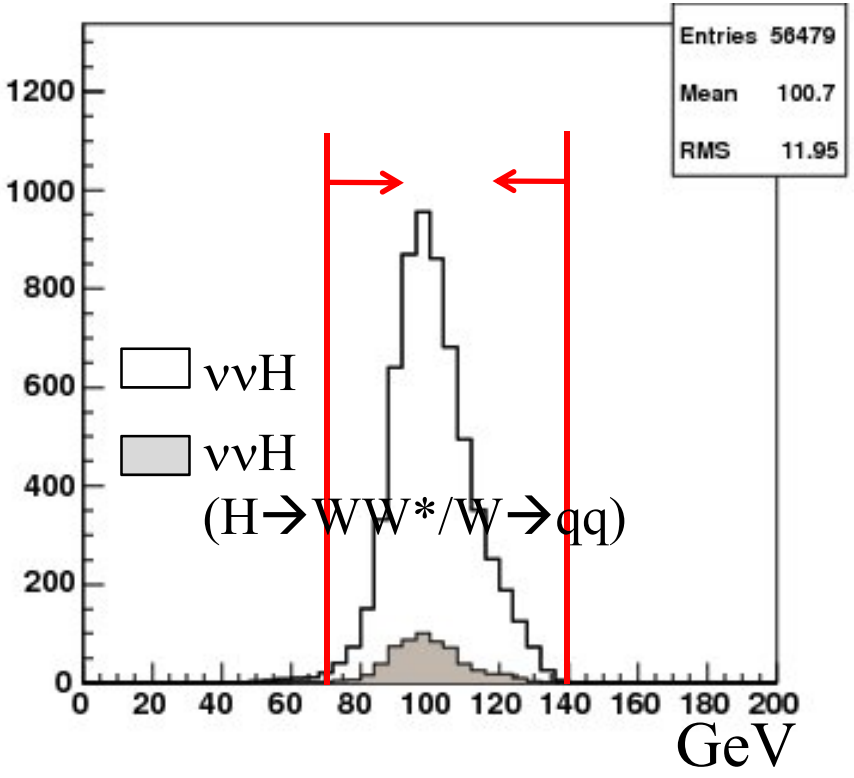
of events at each selection cut is summarized.

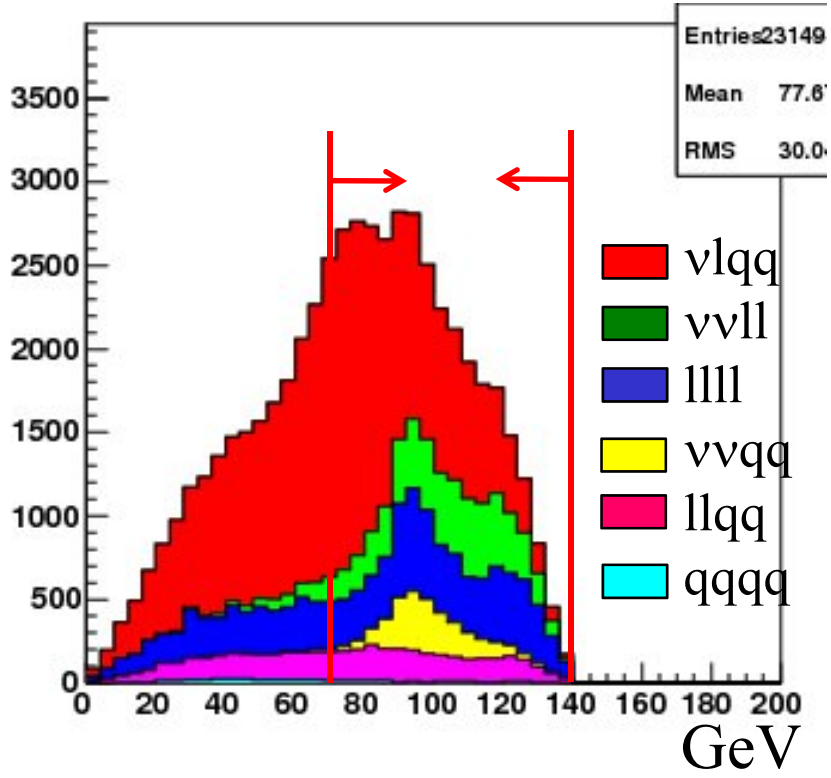
	ννH(H→WW*→4j)	vlqq	vvll	llll	vvqq	llqq	qqqq
No cut	10,634(680)	299,866	103,704	753,964	63,649	335,762	378,726
$110<M_H<130$GeV	6,191(614)	34,540	6,057	16,561	2,361	5,488	518
$70<{}^{miss}M<140$GeV	6,134(607)	17,211	5,405	6,605	2,308	2,596	168
$\lvert\cos\theta_H\rvert < 0.95$	5,863(581)	15,043	4,910	1,144	2,088	934	17
Yminus>0.0005	5,176(580)	12,593	81	514	1,695	890	16
Etrk <30GeV	4826(540)	9,386	4	62	1,389	740	15
Nb<=1	2,175(520)	8,692	4	46	1,157	433	10
Nb(2jet)=0	1,518(512)	8,571	3	46	1,090	409	8
L>0.79	756(348)	1,063	0	0	207	94	3
Nc =2	546(258) (cxcx: 71)	692	0	0	110	70	2

Missing mass

- Selection: 70GeV < ^{miss}M < 140 GeV

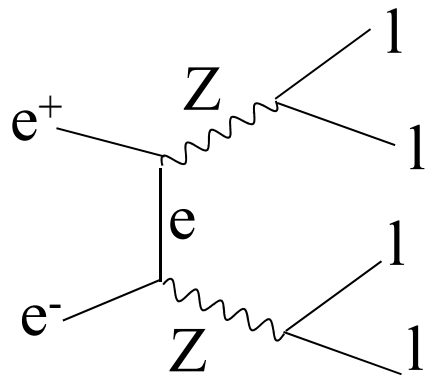


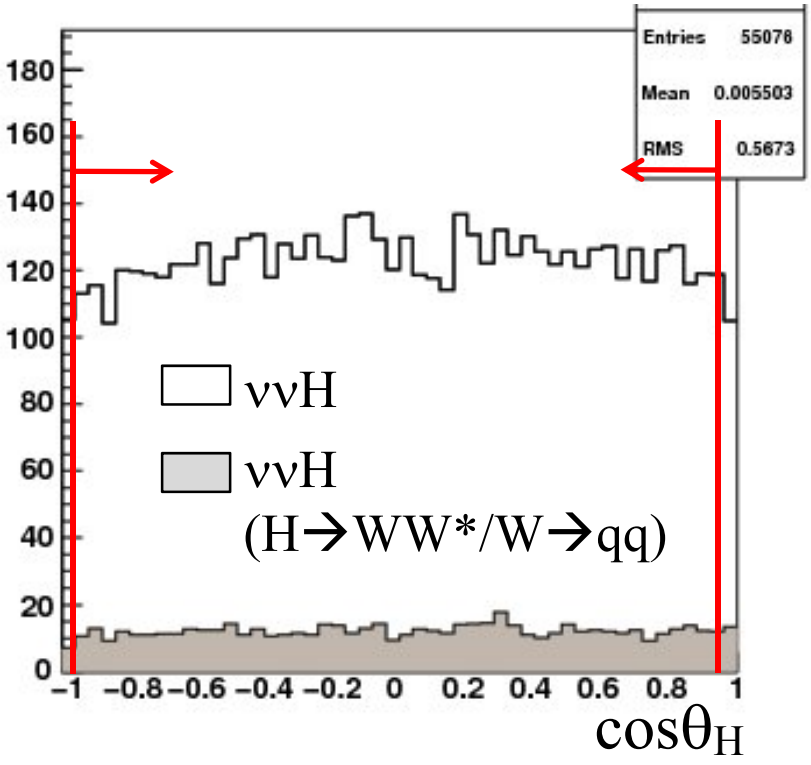


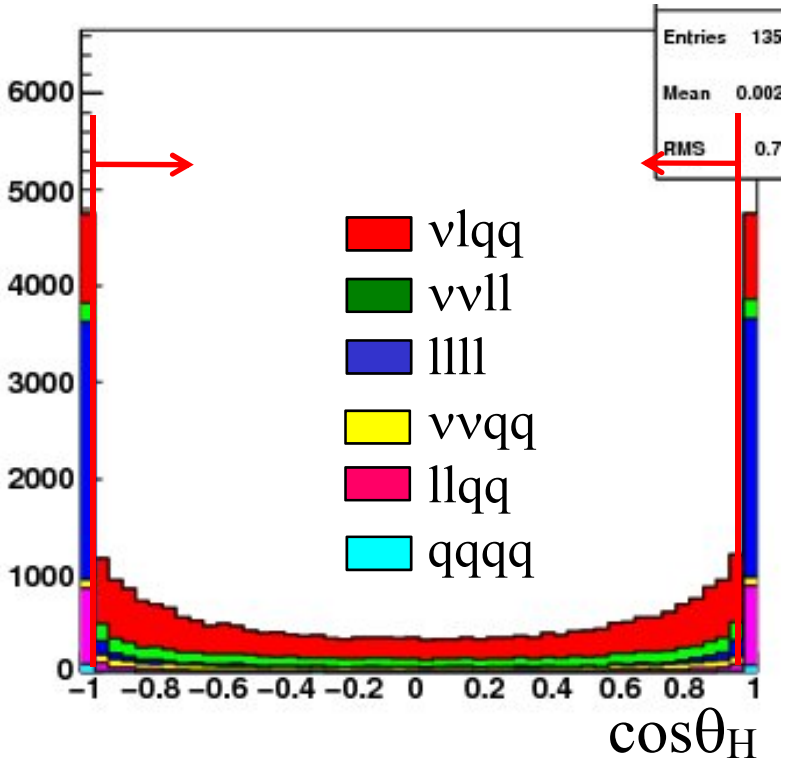


Higgs angular distribution

- Selection: $|\cos\theta_H| < 0.95$







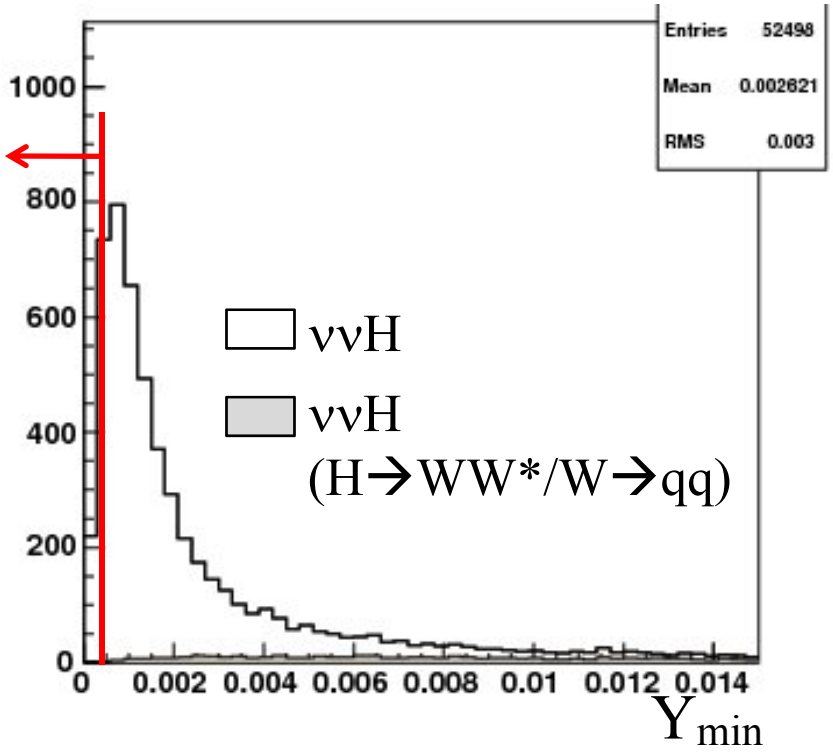
Ymin

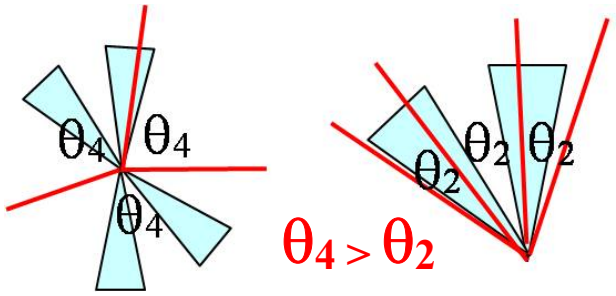
- Yminus: threshold y-value to reconstruct 3 jets from 4 jets.

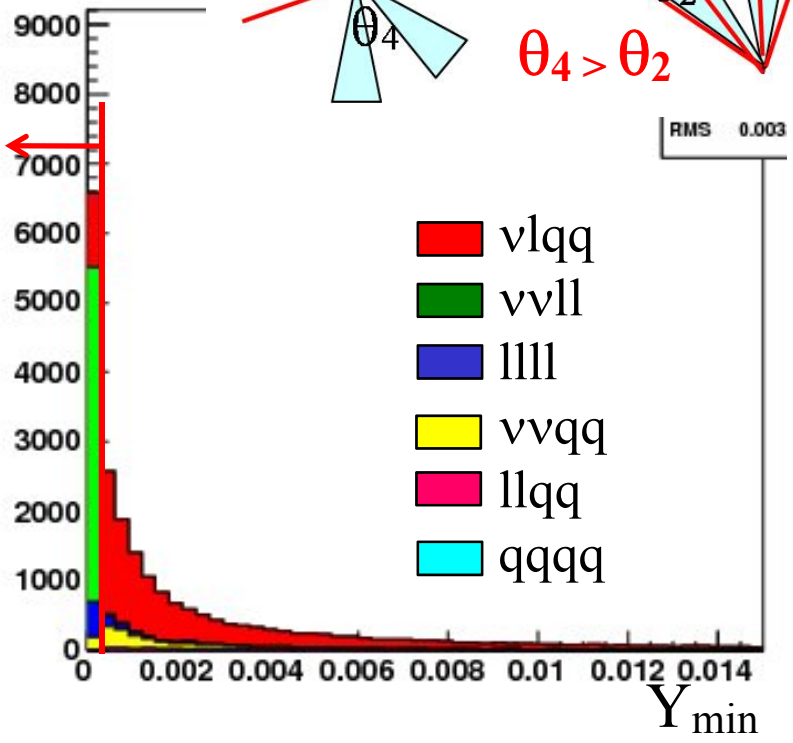
$$\text{y-value} = \frac{2E_i^2(1-\cos\theta_{ij})}{E_{vis}^2}$$

i, j : index of the jet cluster

- Selection: $Y_{min} < 0.0005$

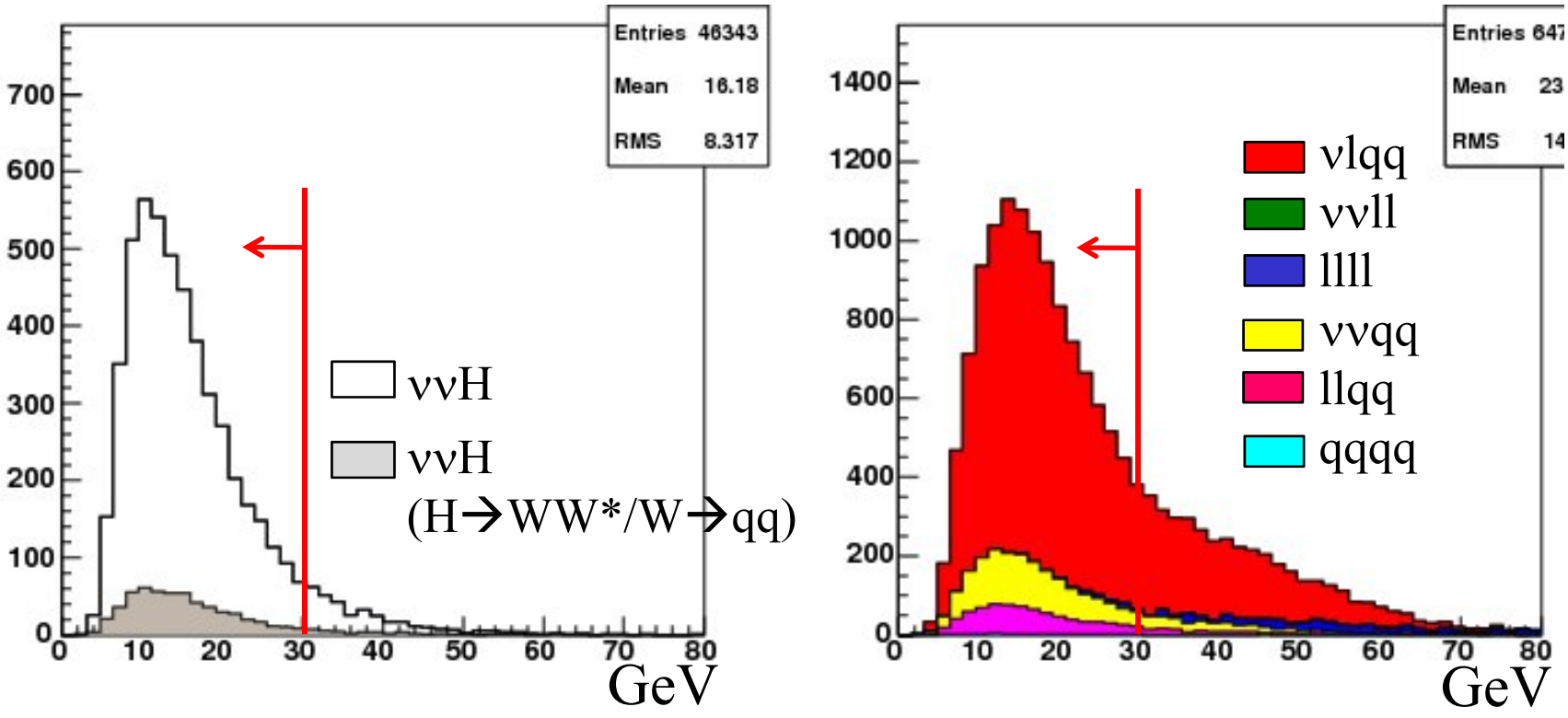






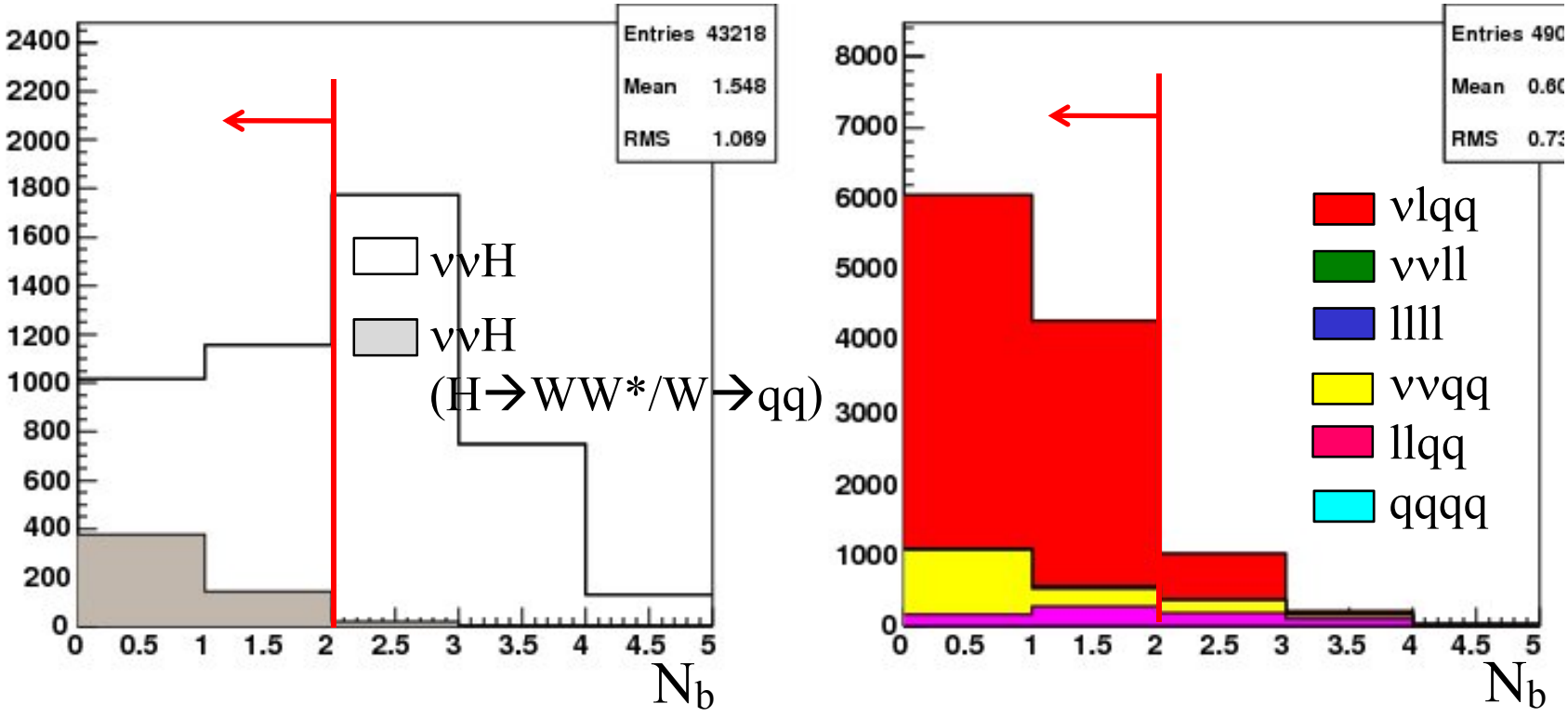
Maximum track energy

- Selection: $E_{trk} < 30GeV$



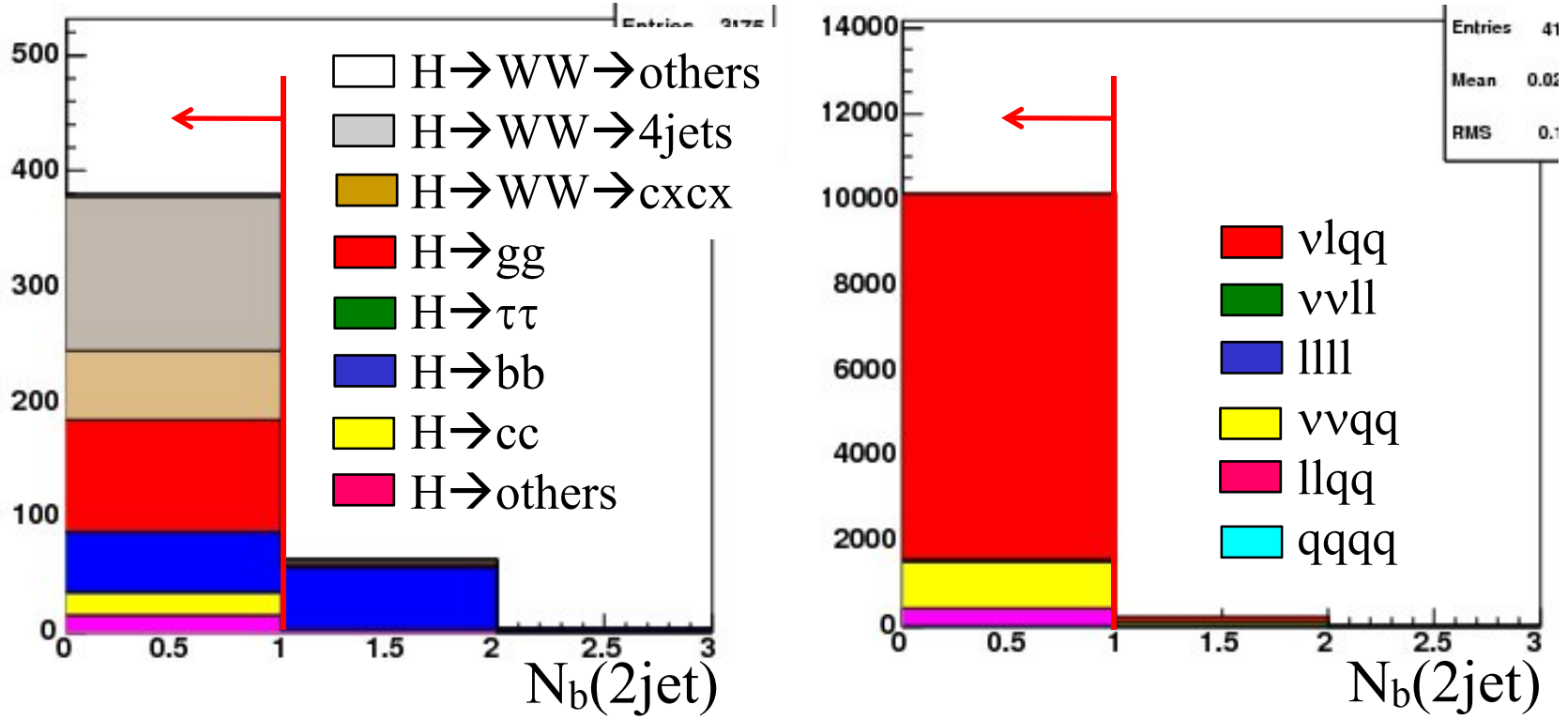
of b-tagged jets

- Selection: $N_b <= 1$



of b-tagged jets(2 jet reconstruction)

- Selection: $N_b(2jet) = 0$
- It is difficult to select more H→WW→4jet/cxcx because only jet-events remain.



Theoretical calculation of W decay planes

ϕ Distribution- $M_H = 120$ GeV

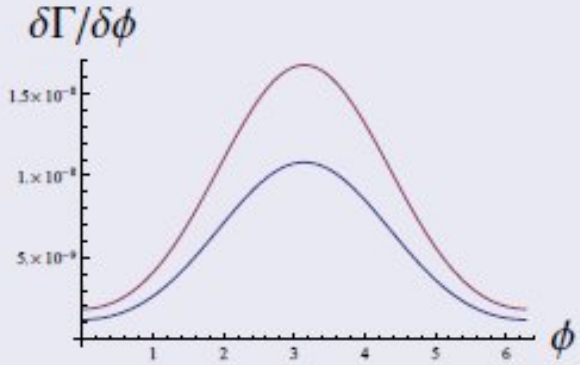


Figure: $a = 1,\ \Lambda = 1$ TeV

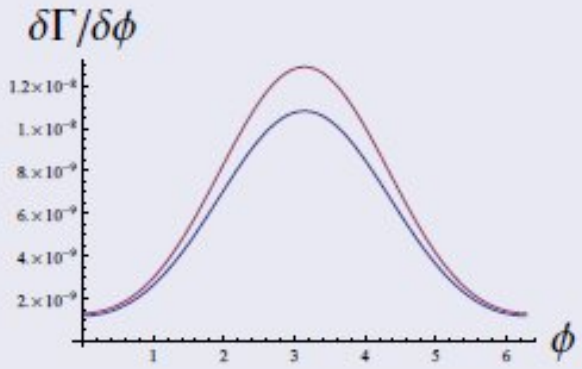


Figure: $b = 1,\ \Lambda = 1$ TeV

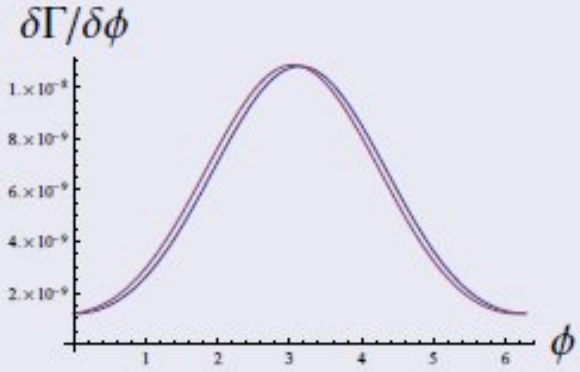


Figure: $\tilde{b} = 1,\ \Lambda = 1$ TeV

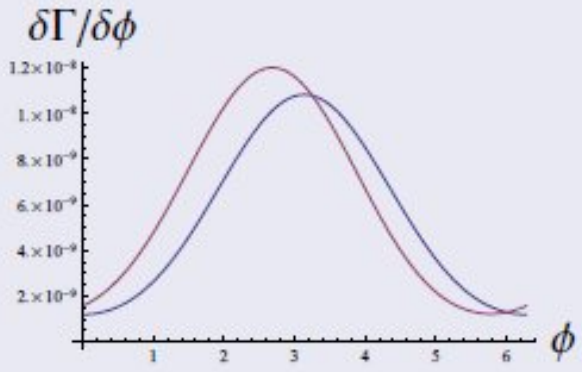
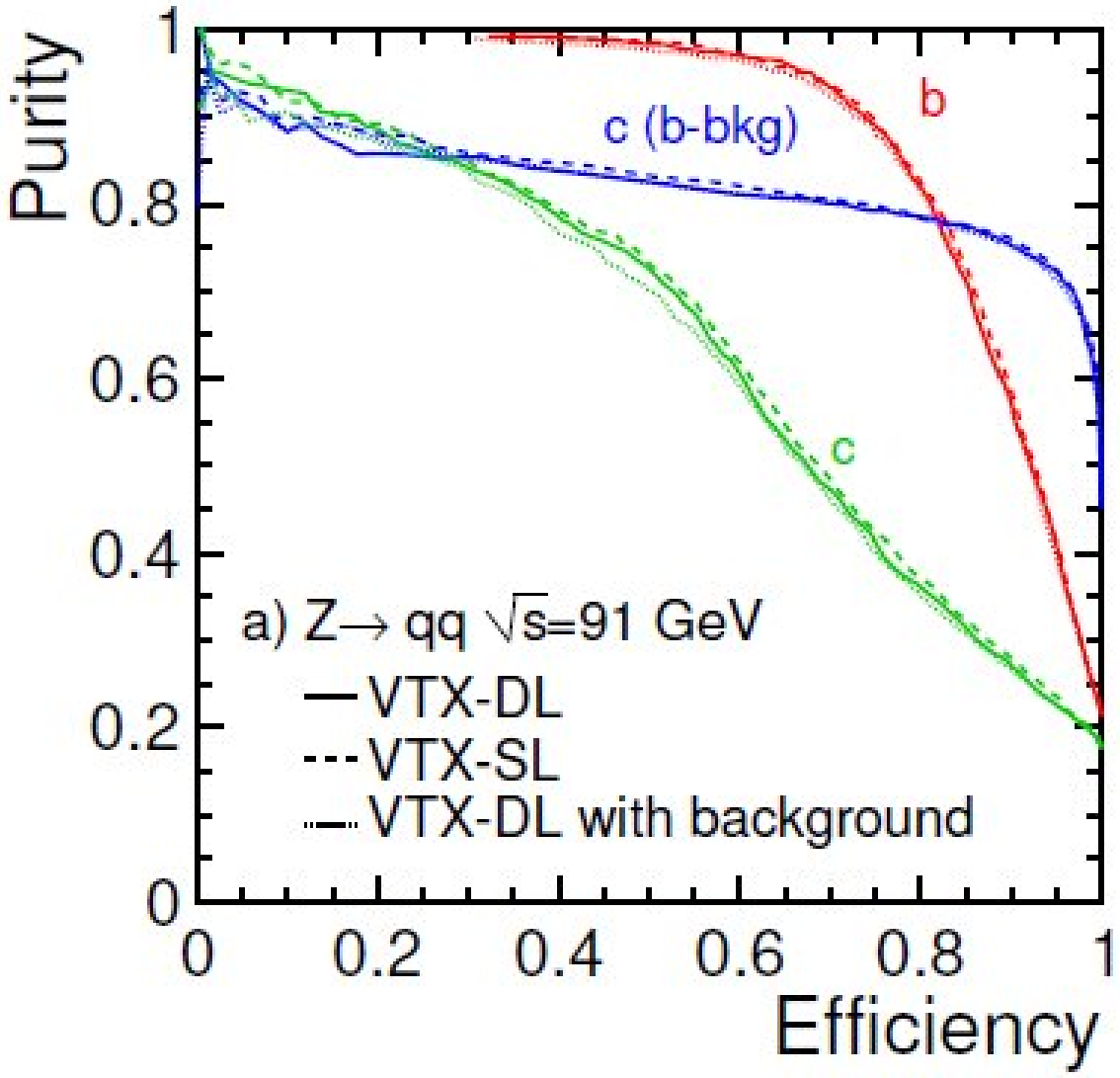


Figure: $\tilde{b} = 5,\ \Lambda = 1$ TeV

Performance of flavor tagging



Systematic error by fitting

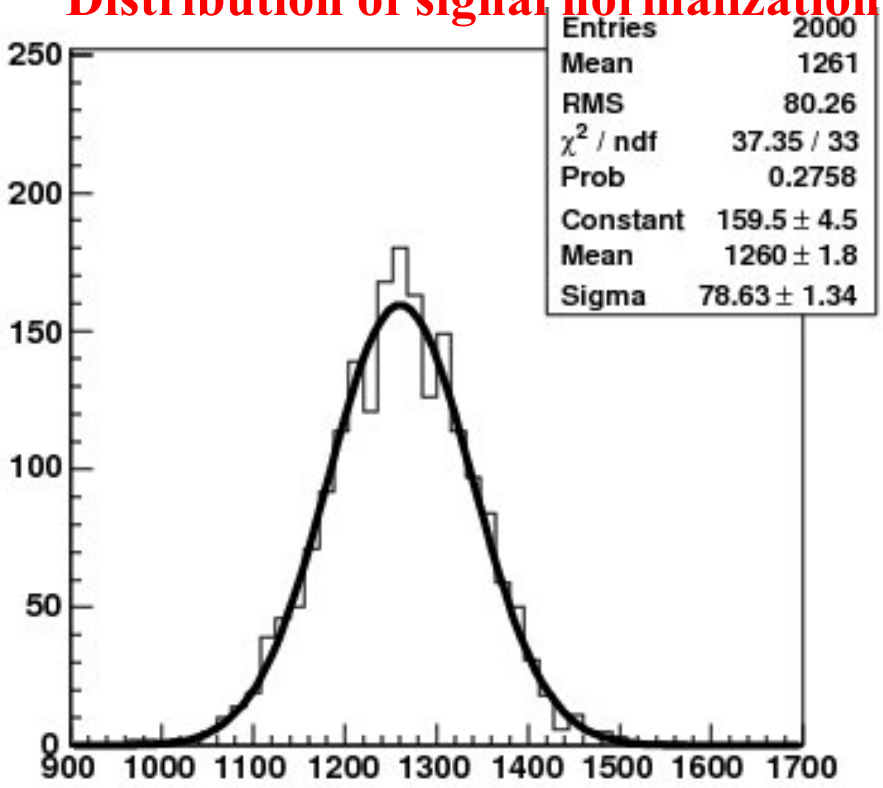
The stability of the fitting for Higgs mass distribution was checked.

• The fitting was done, re-making Higgs mass distributions with statistical error.

• ΔBR(H→WW*): 6.2±0.1%

→ The systematic error by fitting is negligible.

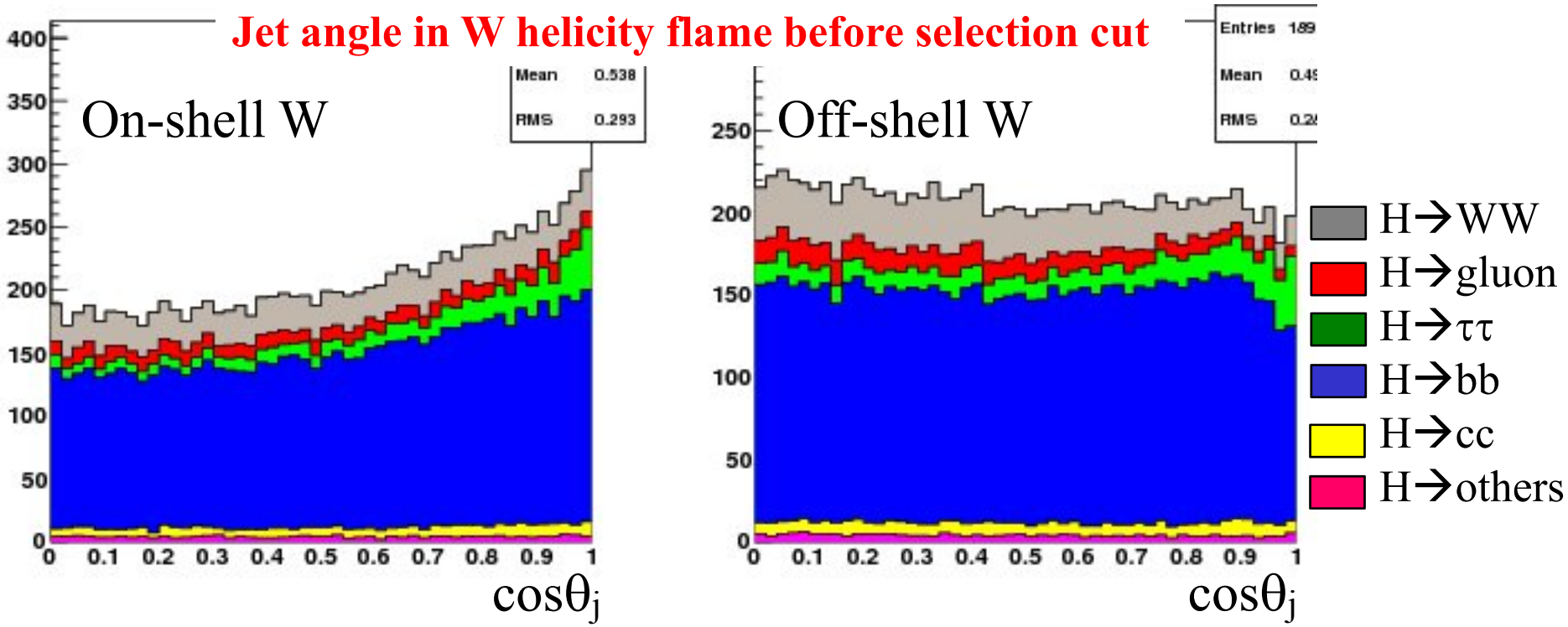
Distribution of signal normalization



Signal normalization

Jet angle in W helicity flame

- The jet angle in W helicity flame was checked to derive information of transverse/longitudinal coupling.
- The signal has flat distribution.
- Are W bosons not helicity eigen-state?



Jet angle in W helicity flame

- The jet angle in W helicity flame was checked to derive information of transverse/longitudinal coupling.
- The signal has flat distribution.
- W is not a helicity eigen-state.
- It is difficult to obtain the coupling information.