Anomalous Higgs coupling study in H→WW*

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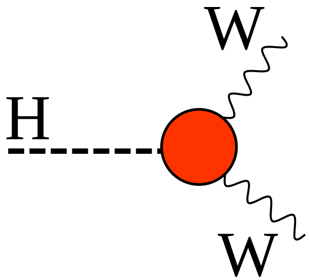
Higgs anomalous coupling with W

In SM, Higgs bosons couple to particle masses.

- The branching ratio depends on the particle masses.



• The new physics might contribute to the anomaly of Higgs coupling with gauge bosons as the loop effect.

→ **We focus on the coupling with W.**

• Anomalous couplings: Scale factor to the SM coupling, CP even/odd term

- Λ: Energy scale for the new physics (1TeV for this study)

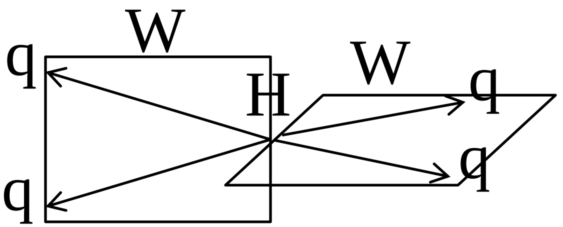
CP even CP odd

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

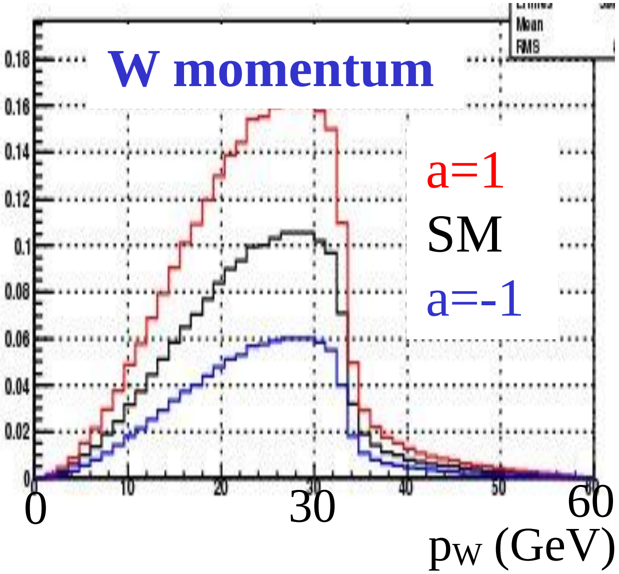
Physics variables sensitive to anomaly

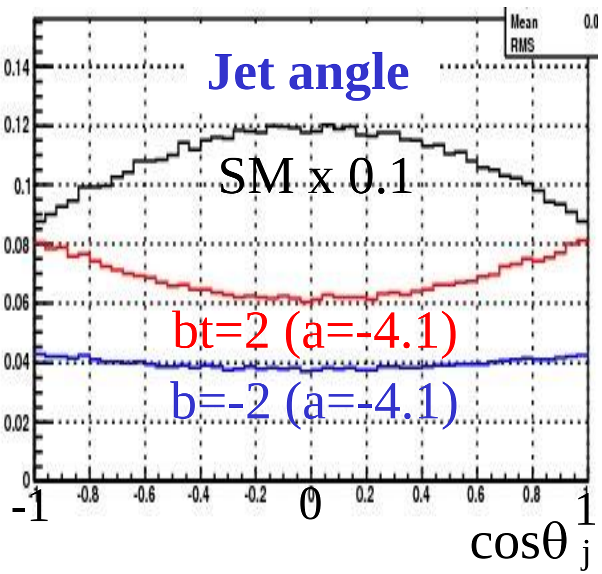
$$\mathcal{L} = 2m_W^2 \left(\frac{1}{v} + \frac{a}{\Lambda}\right) H W_\mu^+ W^{-\mu} + \frac{b}{\Lambda} H W_{\mu\nu}^+ W^{-\mu\nu} + \frac{\tilde{b}}{\Lambda} H \varepsilon^{\alpha\beta\mu\nu} W_{\mu\nu}^+ W_{\alpha\beta}^-$$

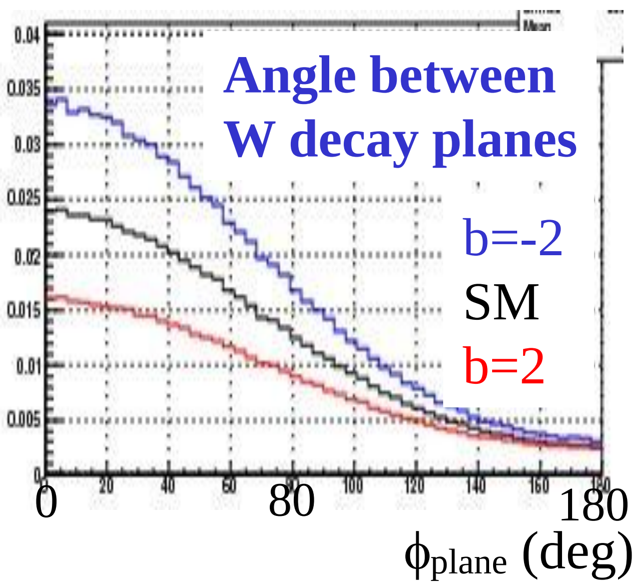
- W momentum at Higgs rest-frame: a, b
- Jet angle at W rest-frame: b, btilde
- Angle of W decay planes: b, btilde



The sensitivity to the anomalous coupling was studied by using these physics variables.



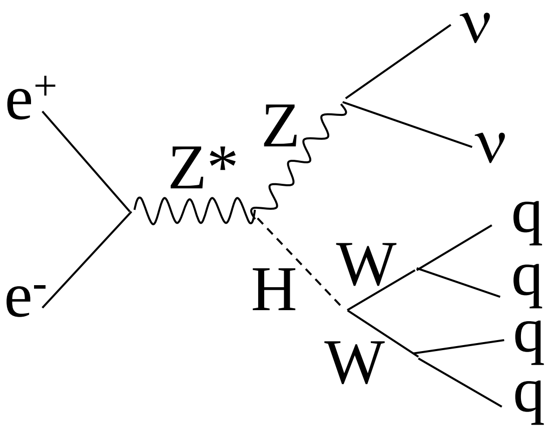




Analysis of H→WW*

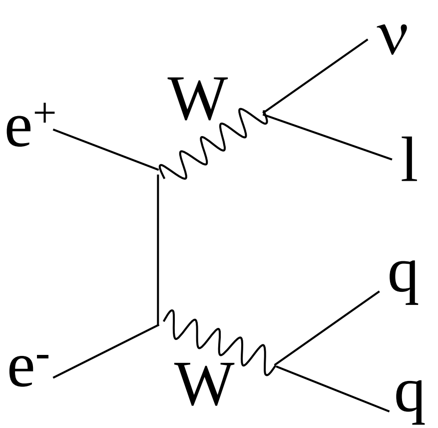
Analysis mode

- Signal: ZH → ννWW →ννqqqq (2.7fb)
- BG: 4 fermion final states
  - qqνl (1,199fb), ννqq (255fb), …



Analysis conditions

- CM energy: 250GeV
- Higgs mass: 120 GeV (BR(H→WW*) = 15.0%)
- Int. luminosity: $250fb^{-1}$
- Beam polarization: 80% right-handed(e^-), 30% left-handed(e^+)
- Analysis data:
  - Physsim for the signal
  - LOI data for BG.

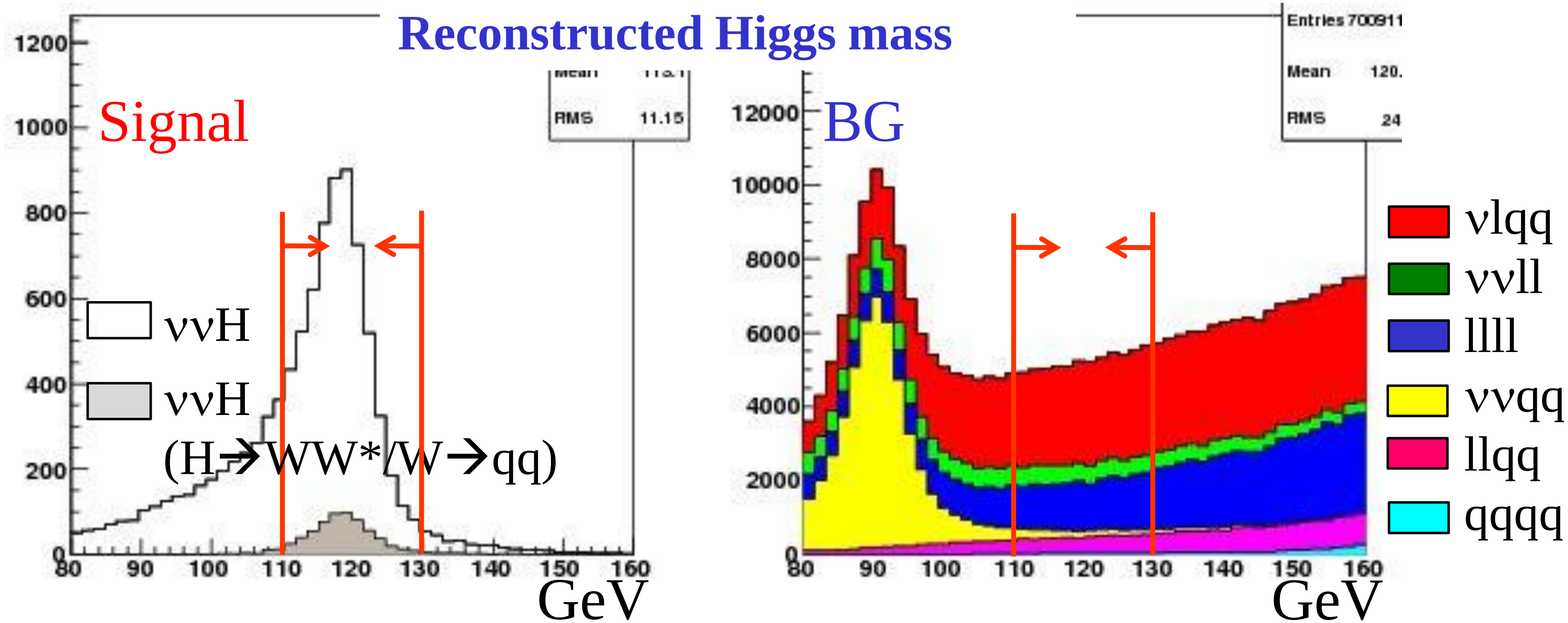


Event reconstruction

- All events are reconstructed as 4-jet events.
- The jets are paired to have masses of Higgs and on-shell W.

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

Reconstructed Higgs mass

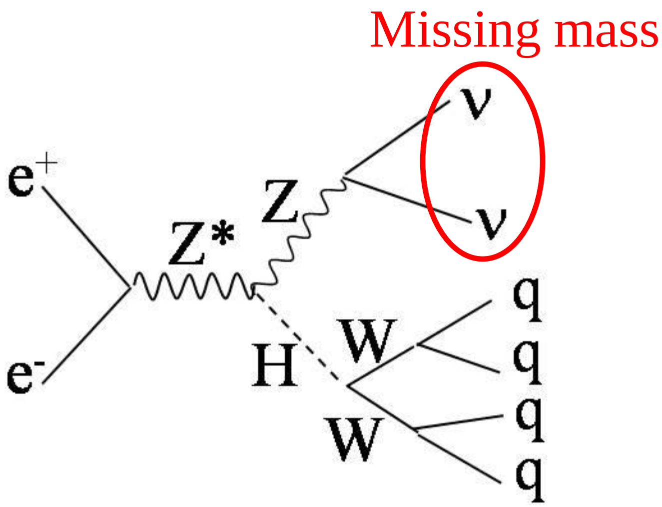


Many BGs contaminate in the signal region.

→ The selection cuts were applied.

Rejection of SM-BG

- Higgs mass: $110 < M_H < 130$GeV
- Missing mass: $70 < {}^{miss}M < 140$GeV
- Higgs angle: $|\cos\theta_H| < 0.95$
- Y-value: Y- > 0.0005
- Track energy: $E_{trk} < 30$GeV



- SM-BG was rejected effectively.
- ZH-BGs are problem since they contaminate in the signal region.

→ Rejection of ZH-BG was studied.

	Bf. cut	Aft. cut
ZH→ννWW(4j)	680	540
ZH→others	9,953	4,286
SM-BG	1,935,671	11,596

Rejection of ZH-BG

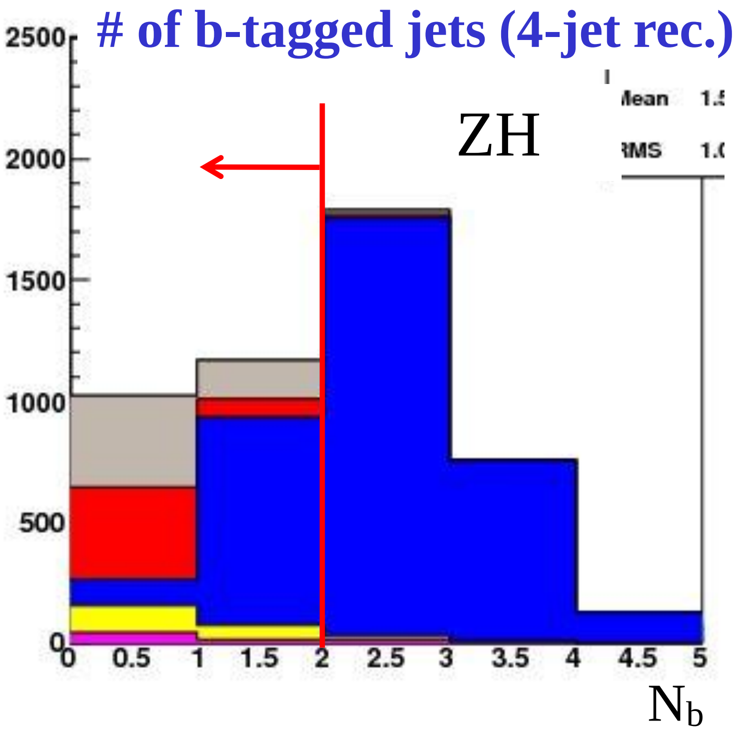
b-tag was applied to reject H→bb events.

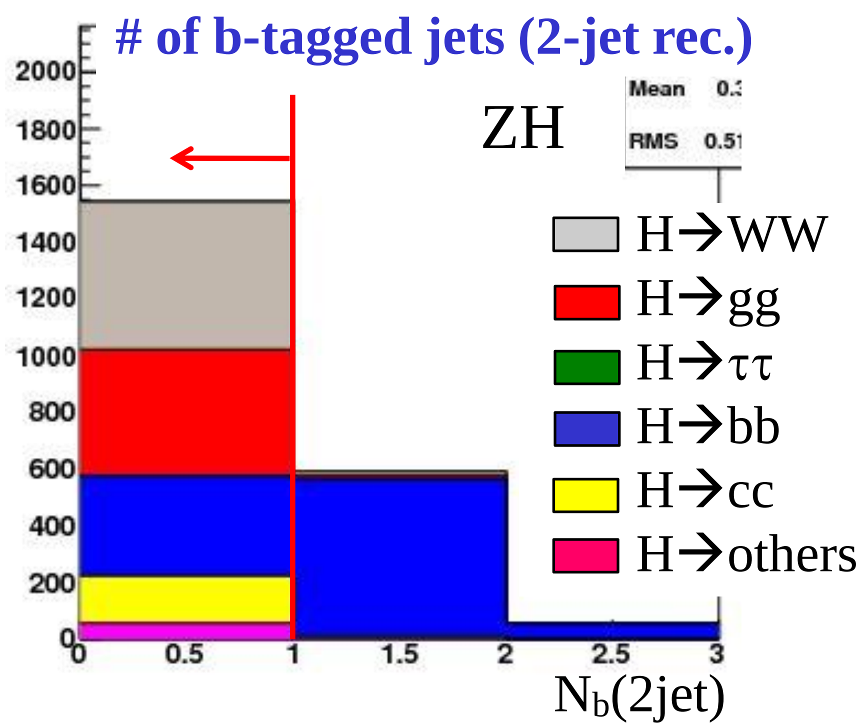
- # of b-tagged jets: N_b <= 1
- # of b-tagged jets after 2-jet reconstruction: N_b(2jet) = 0

→

- ZH→ννWW(4j): 512
- ZH-others: 1,006
- SM-BG: 10,127

ZH-BG was suppressed to ¼.



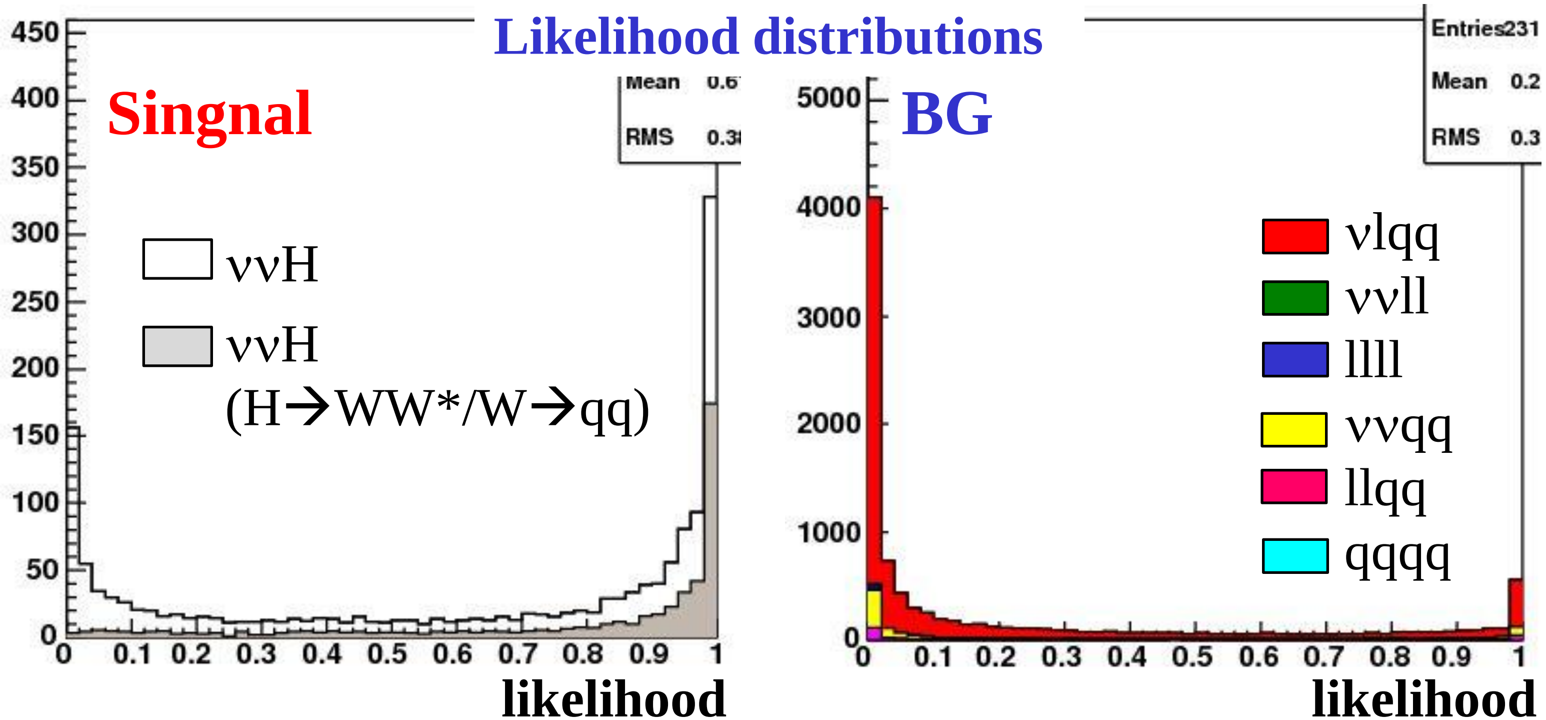


Likelihood analysis

The likelihood analysis was used.

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

→ Likelihood cut position (L_{cut}) was optimized.



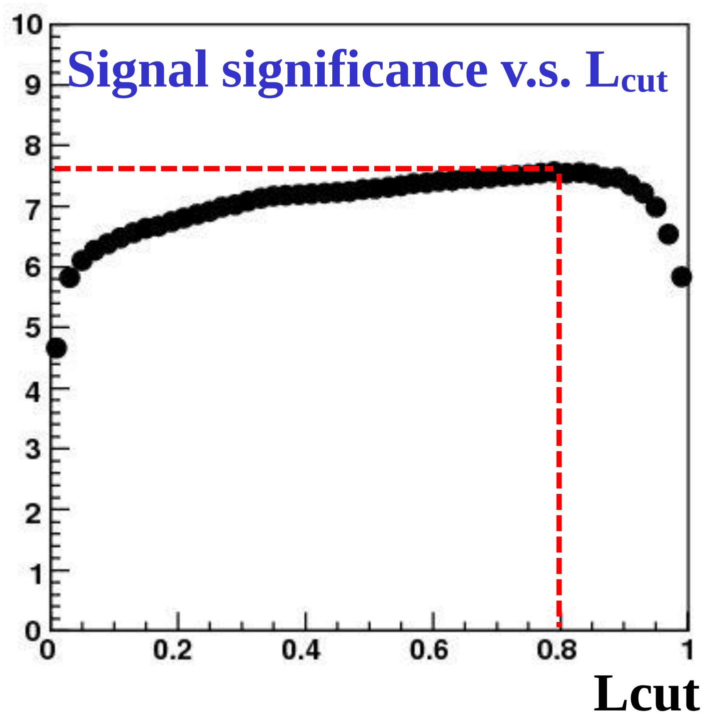
Optimization of likelihood cut

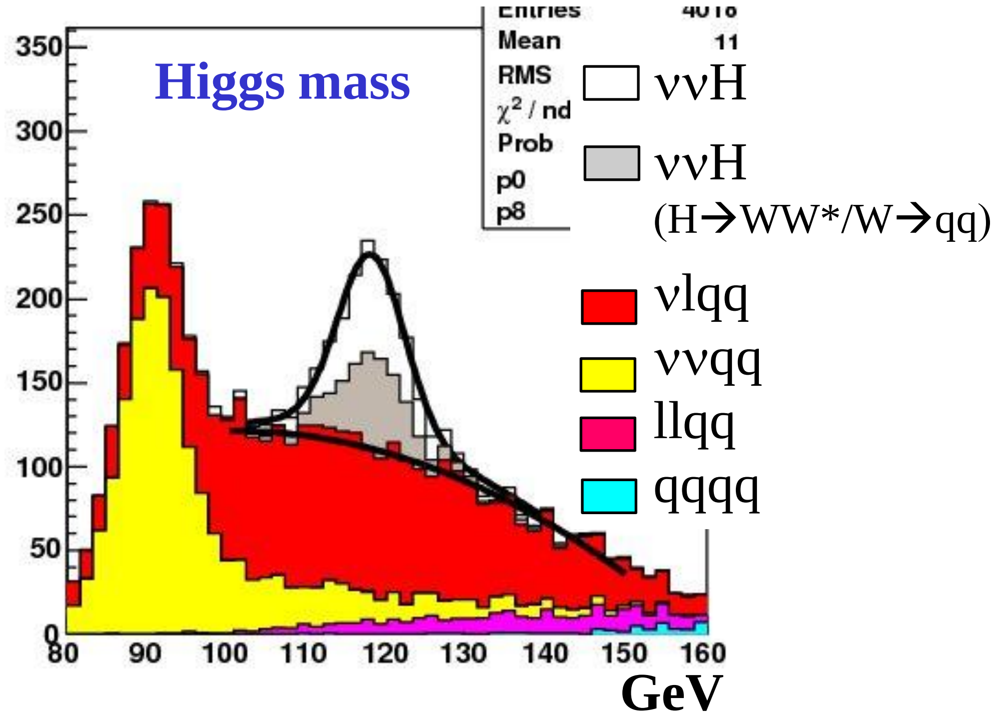
L_{cut} was set to maximize the signal significance.

- Signal significance: 7.6 (@ $L_{cut} > 0.79$)

→ The physics variables sensitive to the anomaly were reconstructed.

	Aft. cut
ZH→ννWW(4j)	348
ZH→others	408
SM-BG	874





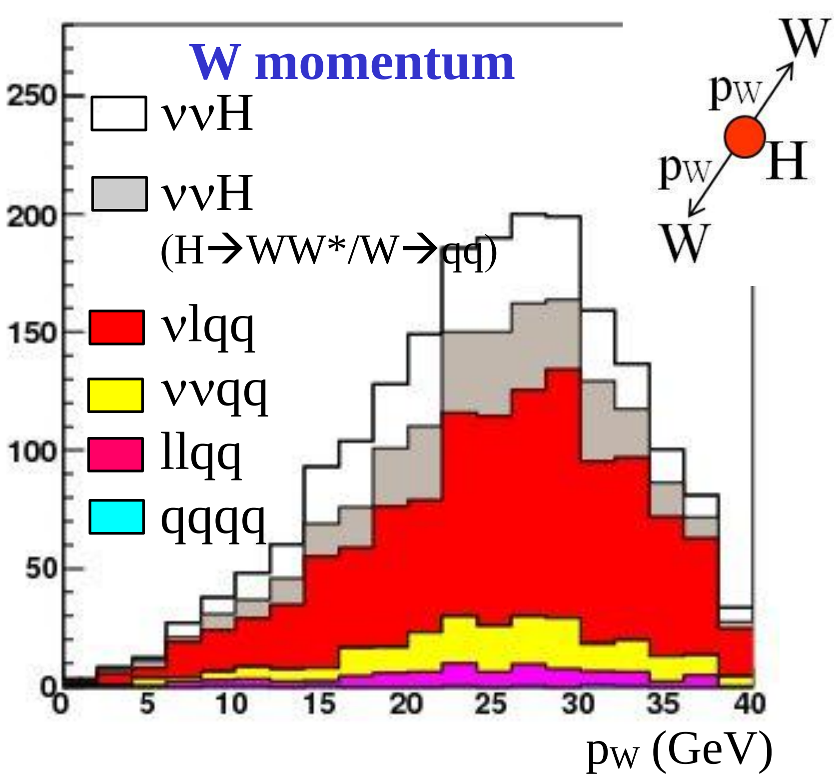
W momentum and jet angle

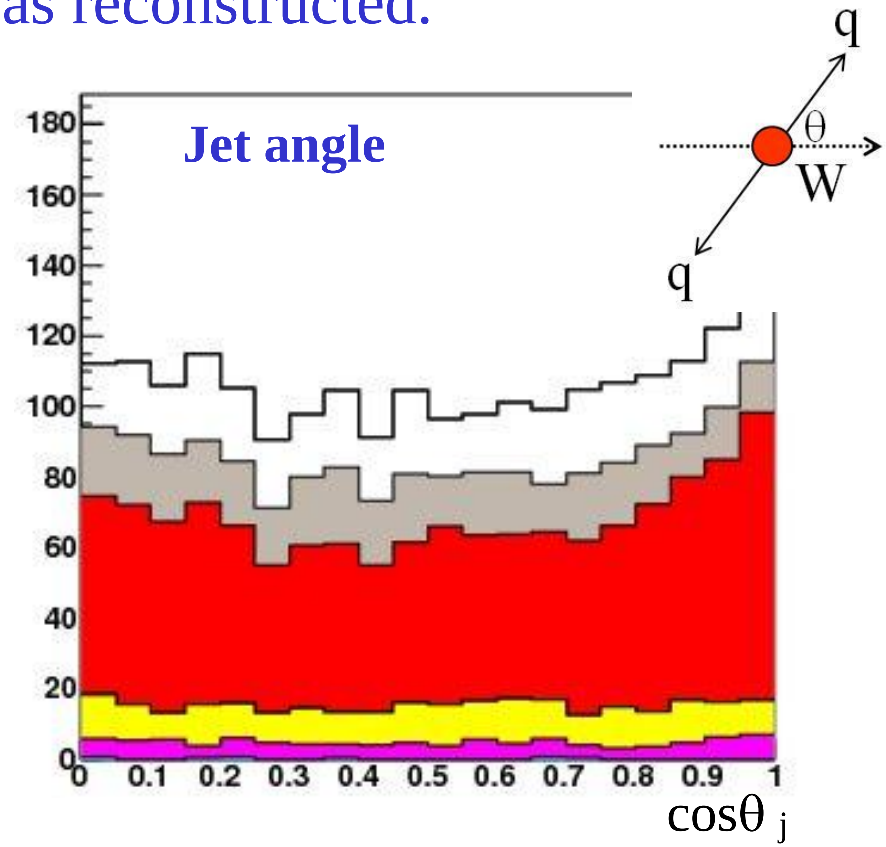
At first, the following variables were reconstructed.

- W momentum at Higgs rest-frame
- Jet angle at W rest-frame

} The distributions were obtained.

→ Angle between W decay planes was reconstructed.

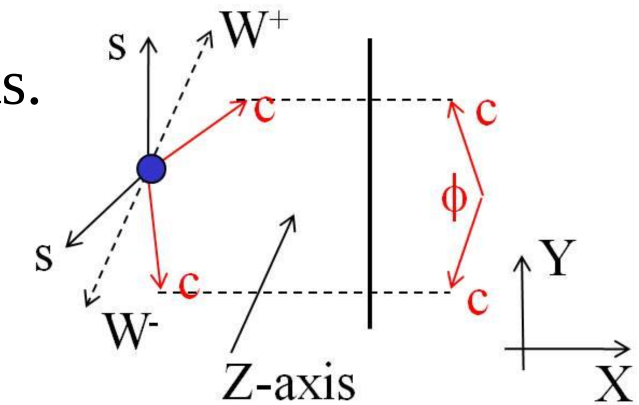


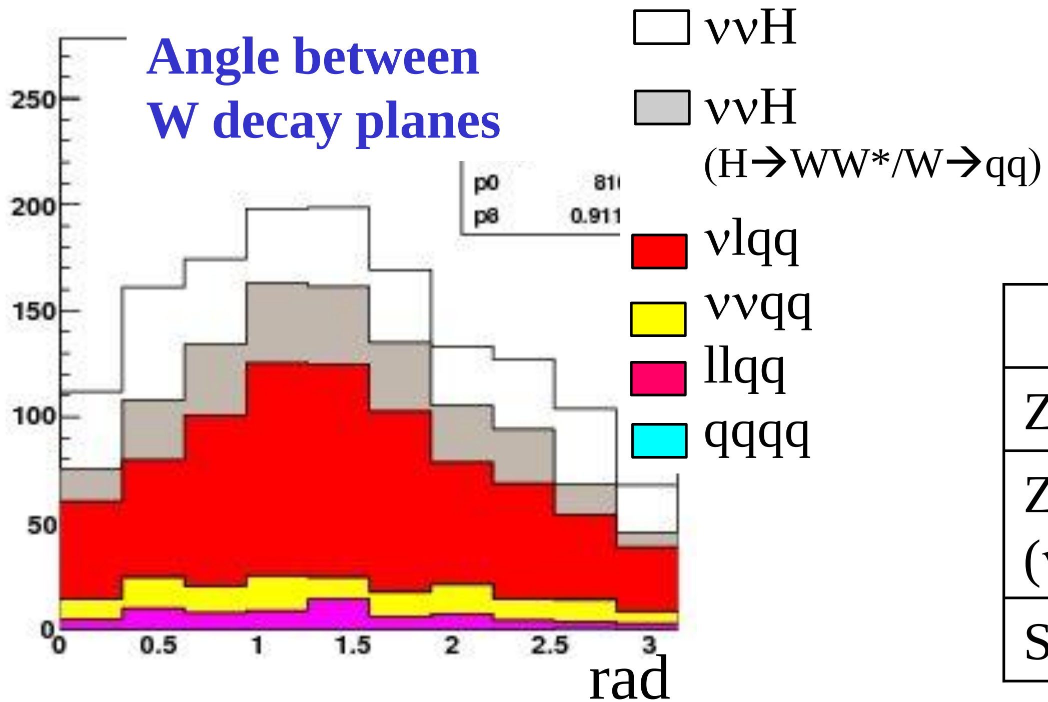


Angle between W decay planes

Angle between W decay planes at Higgs rest-frame was reconstructed.

- The angle corresponds to angle between up-type quarks.
- Two c-jets were selected by using c-tag.
  - Efficiency of ZH→ννWW→ννcscs: 88%
- The angle was calculated by using c-tagged jets.





	Bf. c-tag	Aft. C-tag
ZH→ννcscs	81	71
ZH→others (ννudud)	675 (267)	475 (187)
SM-BG	1,367	874

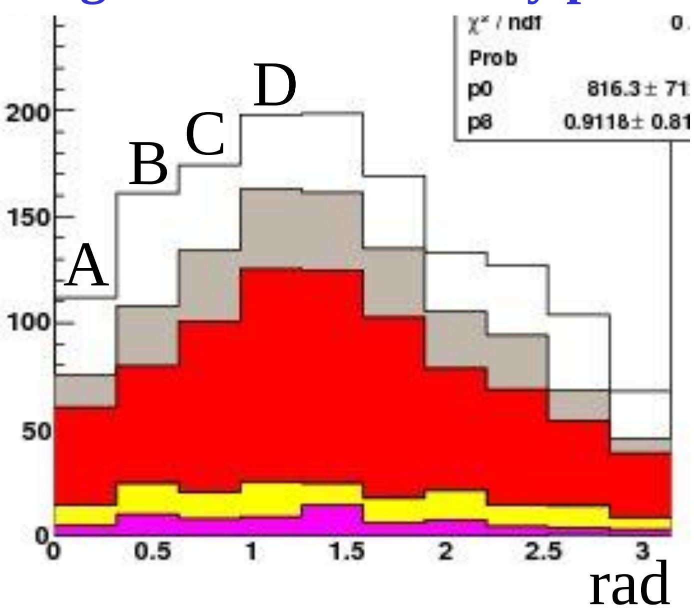
BG estimation

• SM-BG was estimated by fitting the Higgs mass distributions for each bins of the distributions.

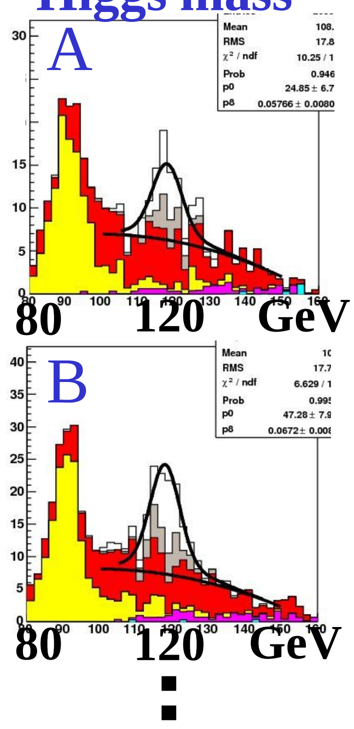
→ Distributions for ZH events were obtained.

• It is assumed that the contamination of ZH-BG can be evaluated by measurement of Higgs branching ratio for each decay mode.

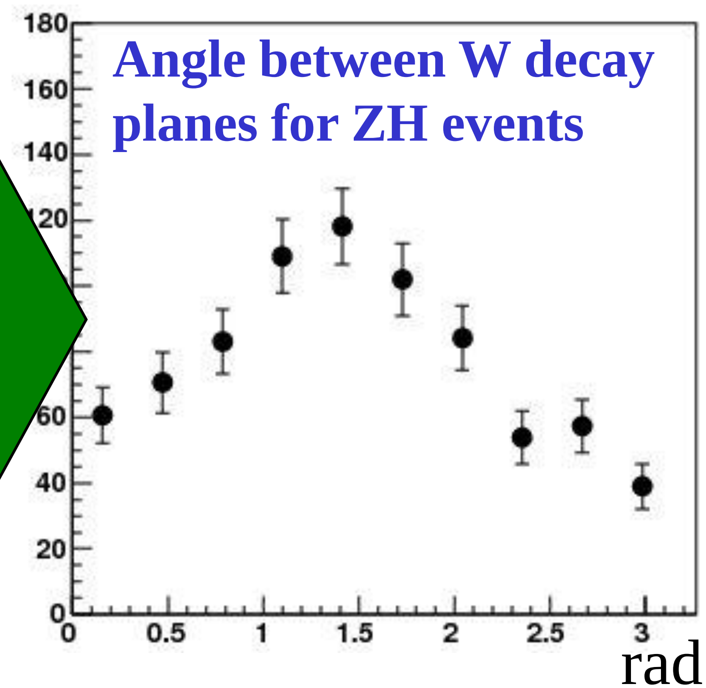
Angle between W decay planes



Higgs mass



Angle between W decay planes for ZH events



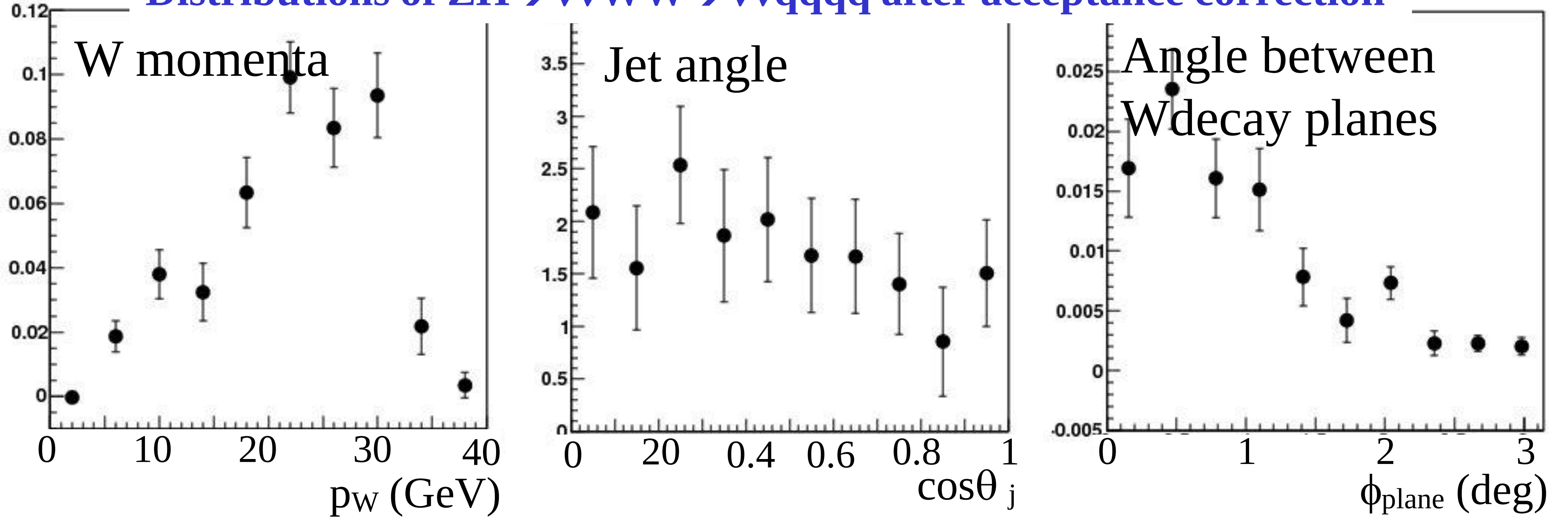
Acceptance correction

The acceptance correction was applied to compare the theoretical distributions with the anomaly.

- Acceptance : Detector + Selection cut

→The sensitivity to the anomaly was evaluated by comparing the number of events and distribution shape.

Distributions of ZH→ννWW→ννqqqq after acceptance correction



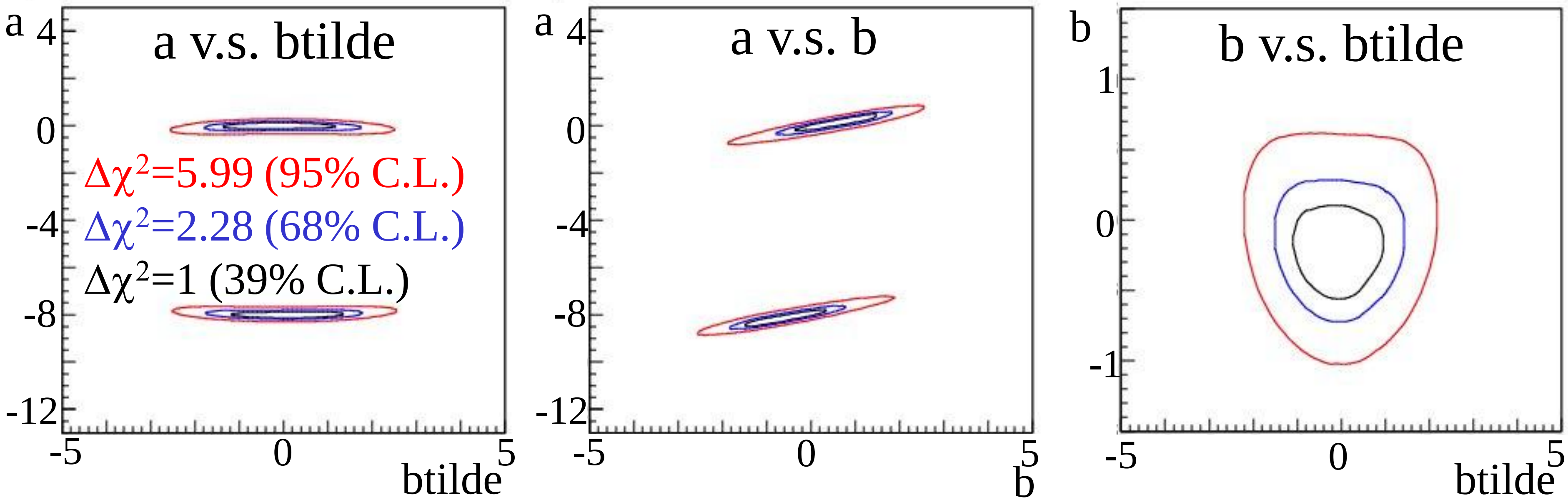
Sensitivity to the anomalous coupling

Sensitivity to the anomalous coupling was evaluated by using SM events.

- The probability contour was made for the 2 parameters.
  - The remaining 1 parameter was set to 0.
- Two allowed region exits since the SM coupling cancels with a=-4.1.

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

Comparison of this result with physics model is the next step.



Summary

- The new physics might contribute to the anomaly of Higgs coupling with W bosons.
- Sensitivity to the anomaly was studied by using $ZH \rightarrow \nu\nu WW \rightarrow \nu\nu qqqq$ events
- After the selection cuts, sensitivity to the anomaly was evaluated with the physics variables sensitive to the anomaly.
  - W momenta at the Higgs rest-frame
  - Jet angle at W the rest-frame
  - Angle between W decay planes
- Comparison of the result with physics models is the next step.

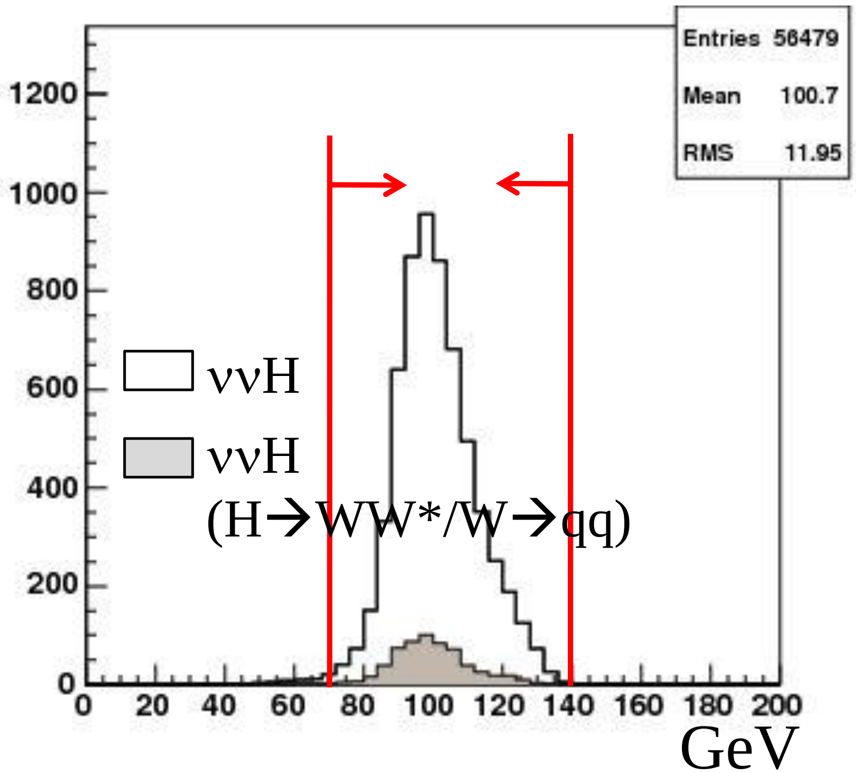
Cut summary

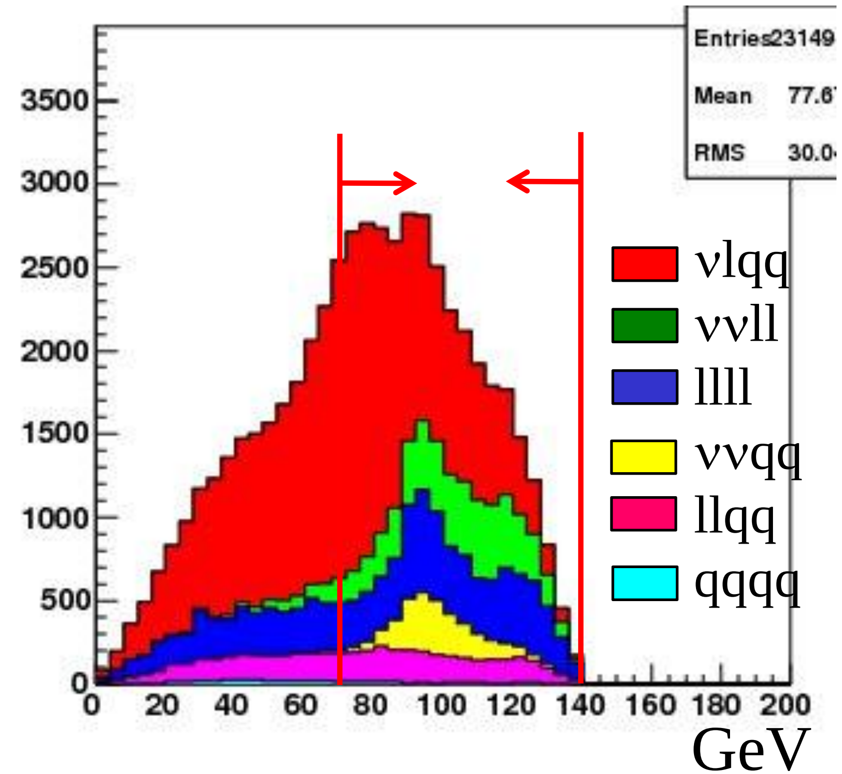
of events at each selection cut is summarized.

	$\nu\nu H(H\rightarrow WW^*\rightarrow 4j)$	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

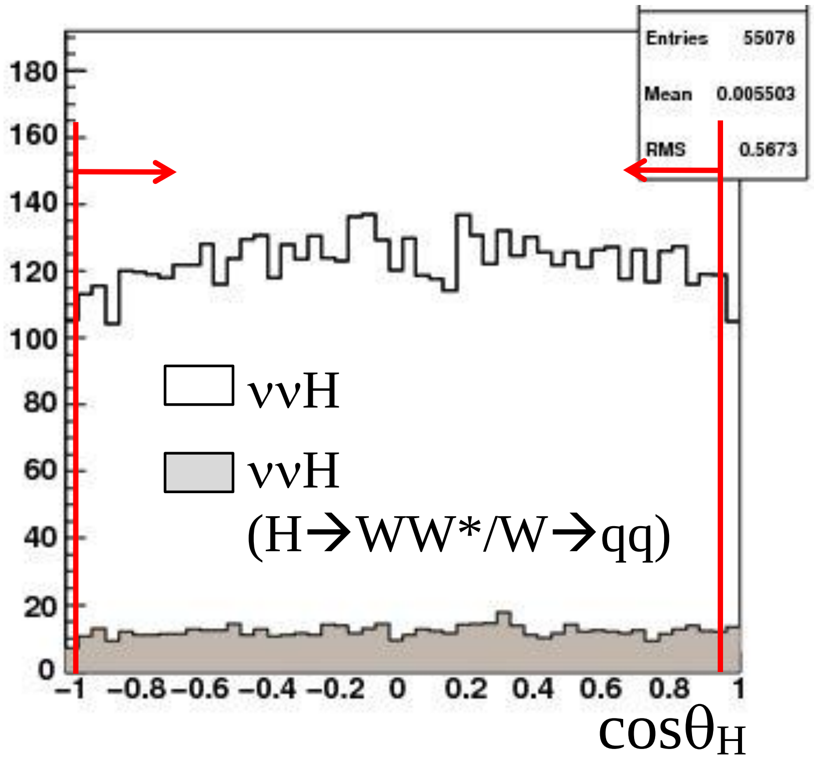
- 70GeV < ^{miss}M < 140 GeV was selected.

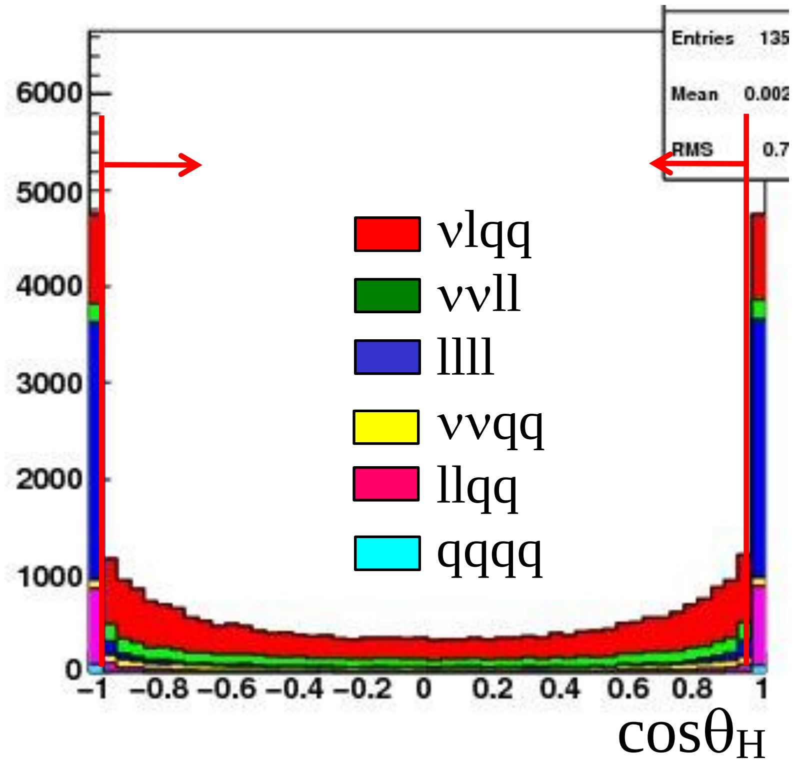




Higgs angle

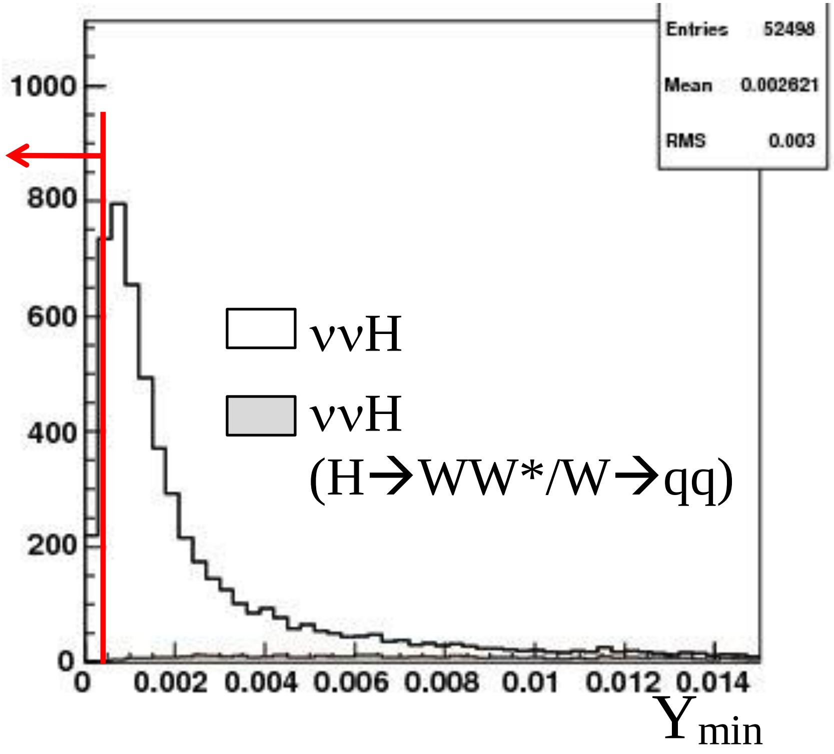
- $|\cos\theta_H| < 0.95$ is selected.

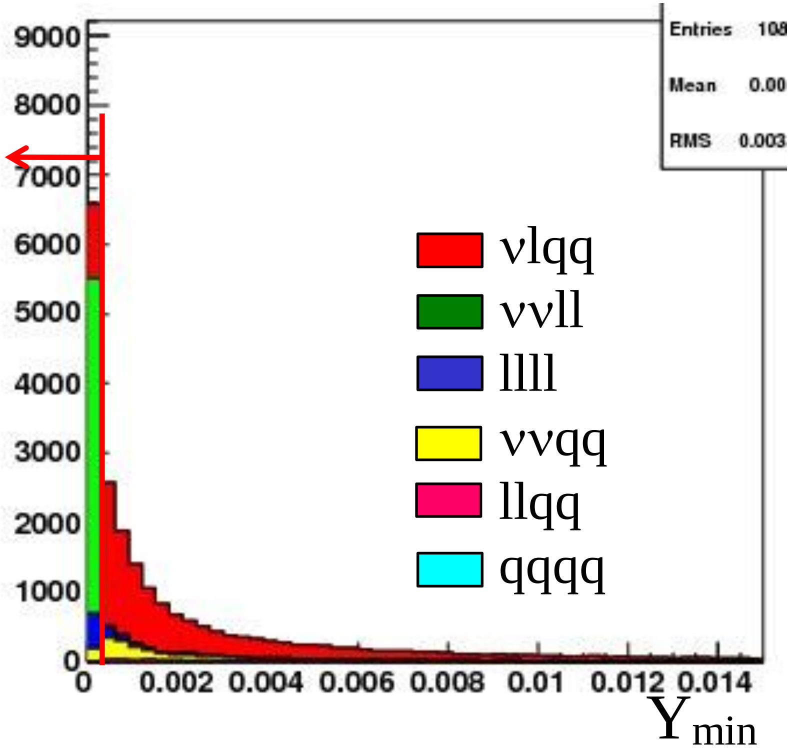




Ymin

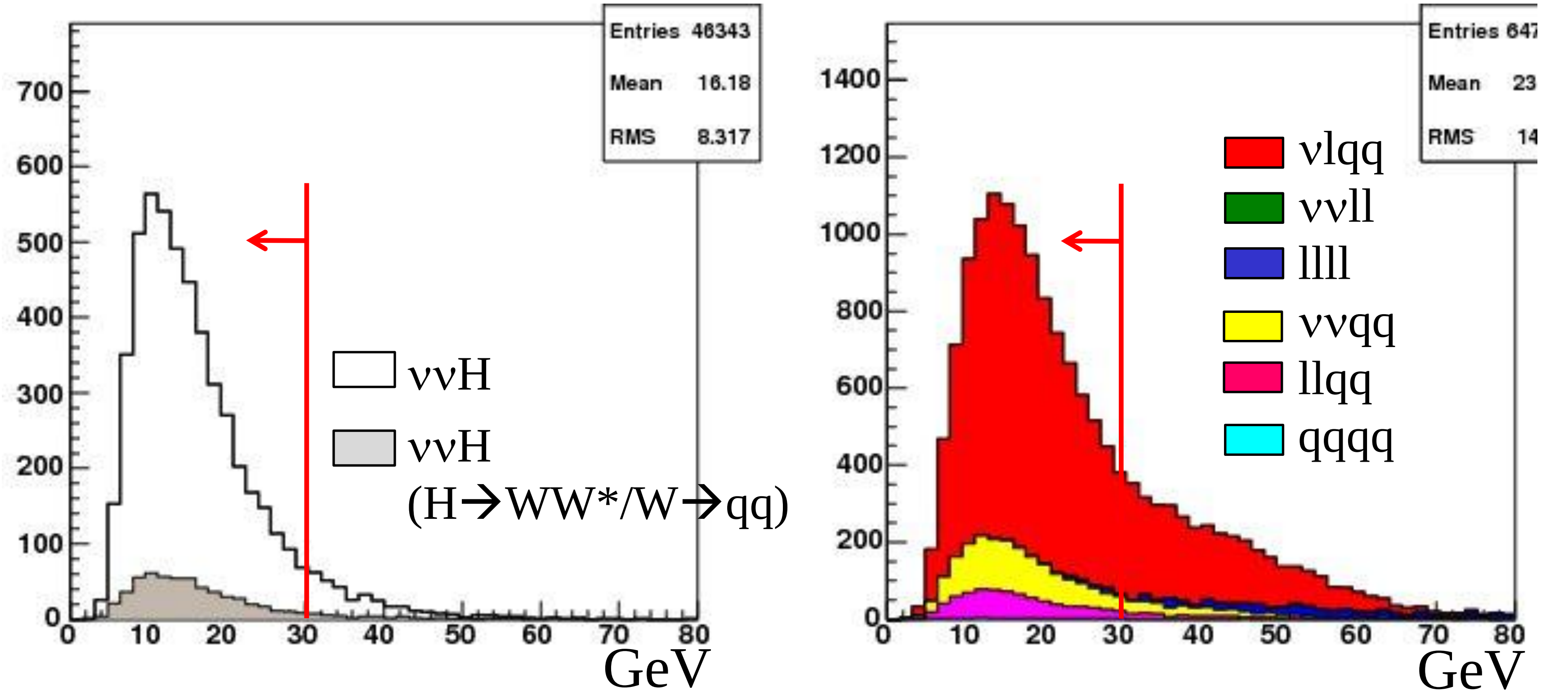
- $Y_{min} < 0.0005$ is selected.





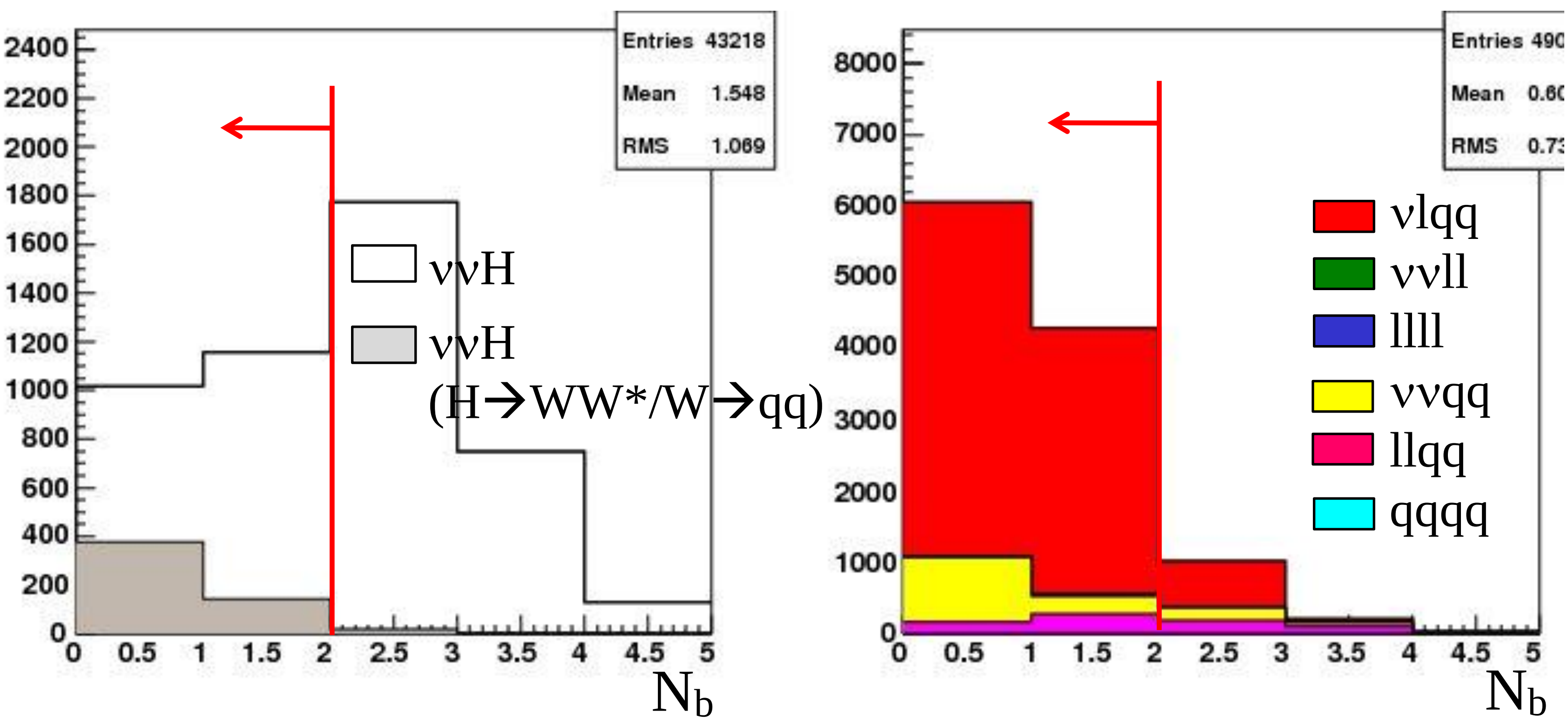
Maximum track energy

- $E_{trk} < 30GeV$ is selected.



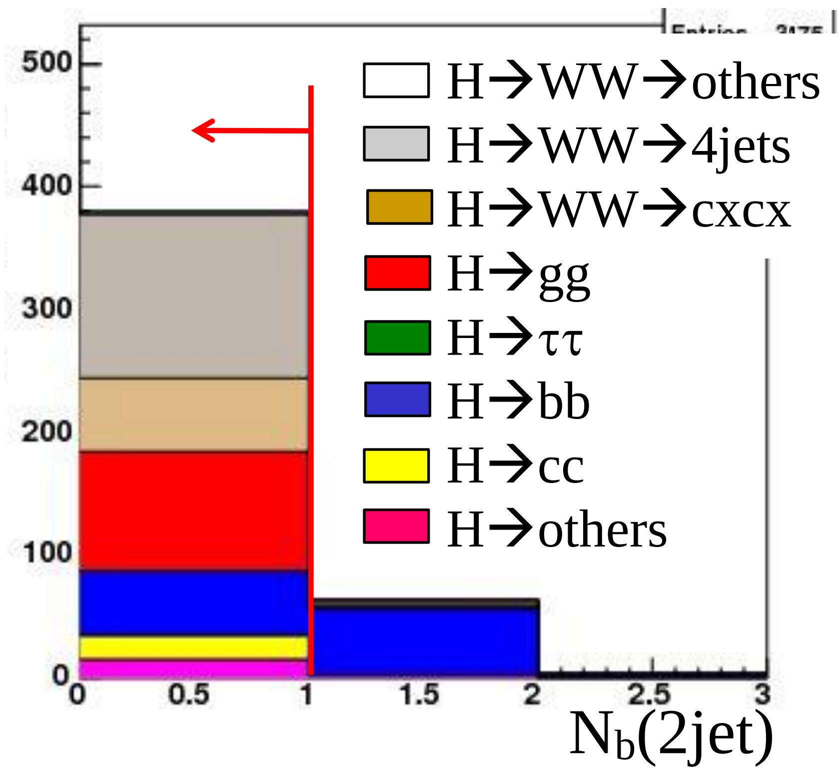
of b-tagged jets

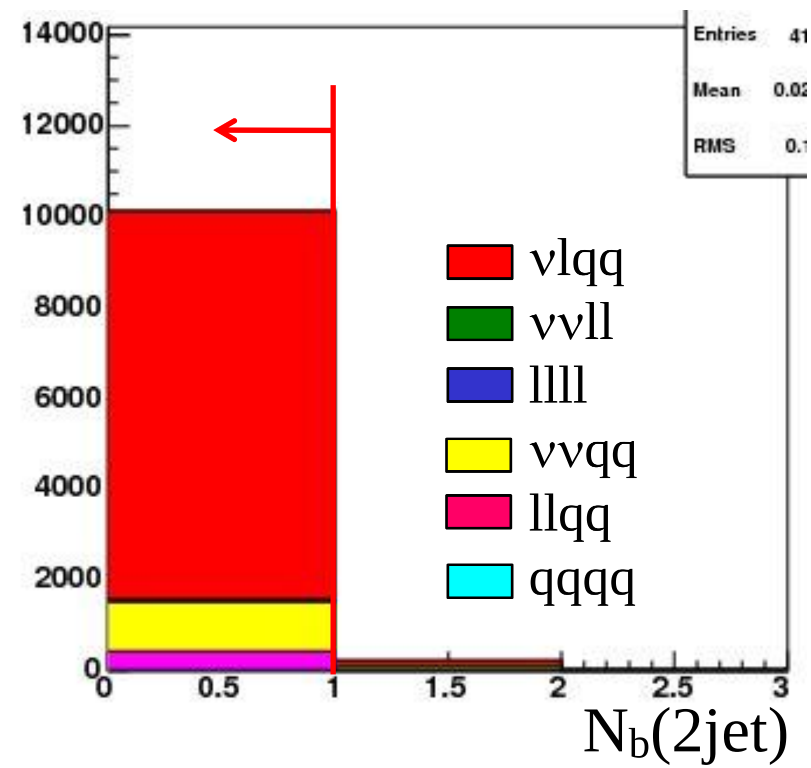
- N_b <= 1 is selected.



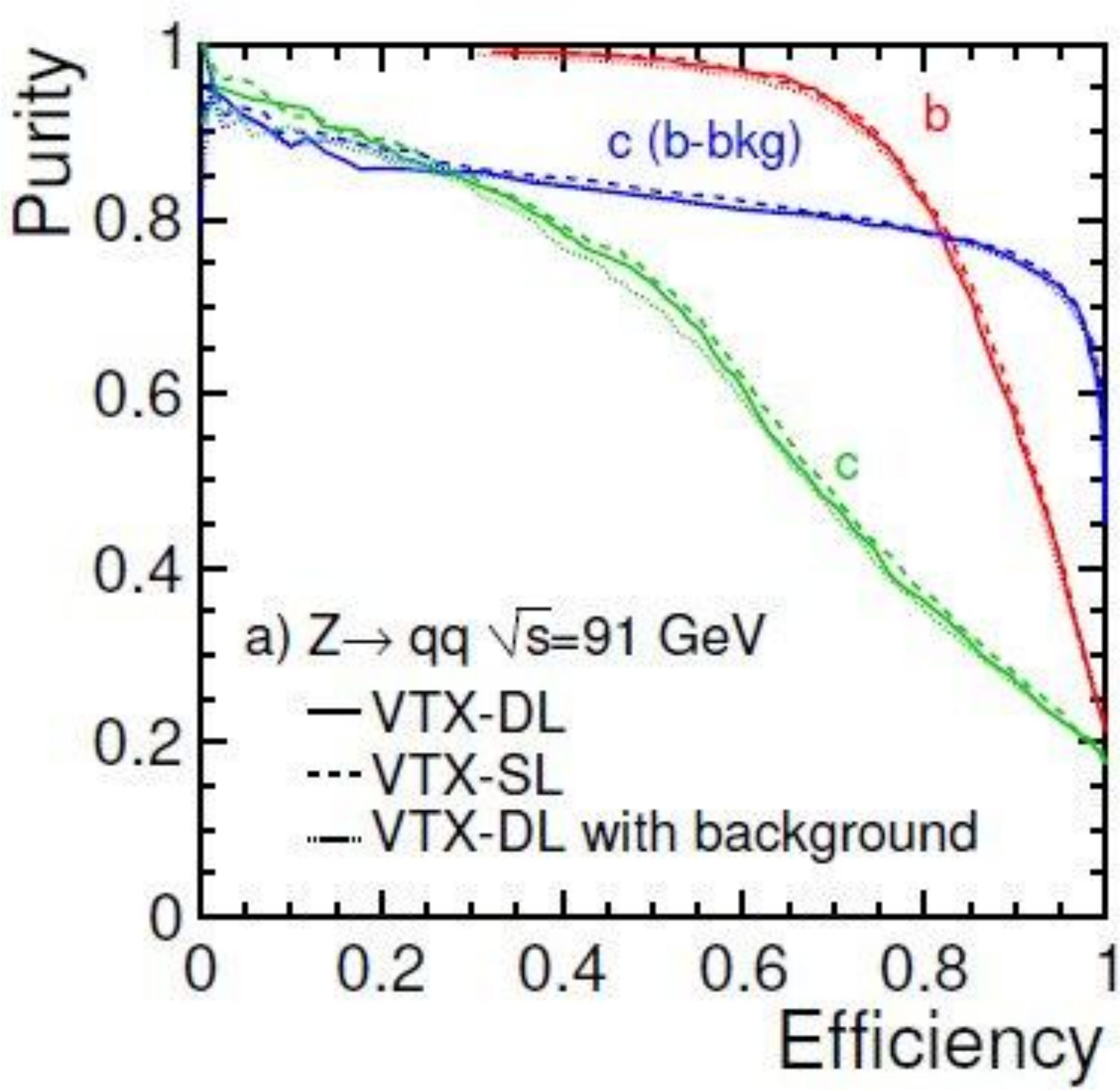
of b-tagged jets (2-jet reconstruction)

- N_b(2jet) = 0 is selected.
- Since only the jet events remain for ZH events, it is difficult to select further H→WW→4jet/cscs.





Performance of flavor tagging

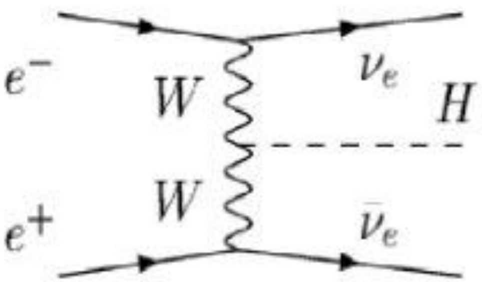


Contribution from WW-fusion process

	100% right-handed	100% left-handed
• $\nu_e\nu_e H$	: 21.7 fb	60.8 fb
• $\nu_\mu\nu_\mu H$	: 21.6 fb	33.8 fb
• $\nu_\tau\nu_\tau H$	: 21.7 fb	33.8 fb

Contribution from WW fusion is 21% (27fb).

BR(H→WW*) : 15%



The measurement accuracy of BR(H→WW) might be able to improve by using WW-fusion.

- However, BG is 10 times larger for left-handed polarization than right-handed.
- Separation of missing mass distribution is key point.

Higgs anomalous coupling with W

- WW-fusion makes events with larger missing mass.
- The separation from ZH events is not clear.

→ Improvement of the background rejection can not be expected.

→ WW-fusion is not useful for study at E_{CM} = 250 GeV.

Missing mass distributions