The study of ZH->vvH with ILD

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Tohoku University

Kohei Yoshida

Introduction

- Target value : ΔBr(H->cc), ΔBr(H->bb)
- $E_{C.M.}$: 250 GeV
- Luminosity : 250 fb^{-1}
- Polarization : e^{+}(+30%), e^{-}(-80%)
- Simulation tool
  - Detector simulation : Mokka
  - Reconstruction : Marlin
- Data
  - SLAC SM sample

Data sample for 250fb^{-1}

Signal($e^+e^-\to\nu\nu H$)
(2 jets in final states)

Final states	# of events
$\nu_e\nu_e H$	9,086
$\nu_\mu\nu_\mu H$	5,138
$\nu_\tau\nu_\tau H$	5,135
Total	19,360

Background
(4 fermion in final states)

Final states	# of events
$\nu\nu ll$	1,113,014
νlqq	4,114,190
$qqqq$	4,048,386
$\nu\nu qq$	149,979
$llqq$	393,817
$llll$	762,973
Total	10,582,360

Analysis outline

① Reconstruction as 2 jets

② Background rejection

- Missing mass cut
- Momentum cut (P_T, P_L, mom^{max})
- Number of charged tracks cut
- Y value cut (Yplus, Yminus)

③ Preparation of H->cc/bb sample

- Flavor tagging (b-, c-tagging)

④ Estimation of measurement accuracy of branching ratio

- Fitting of Higgs mass distribution
- Estimation of $N_{\nu\nu H}$ in H->cc/bb sample

Background rejection

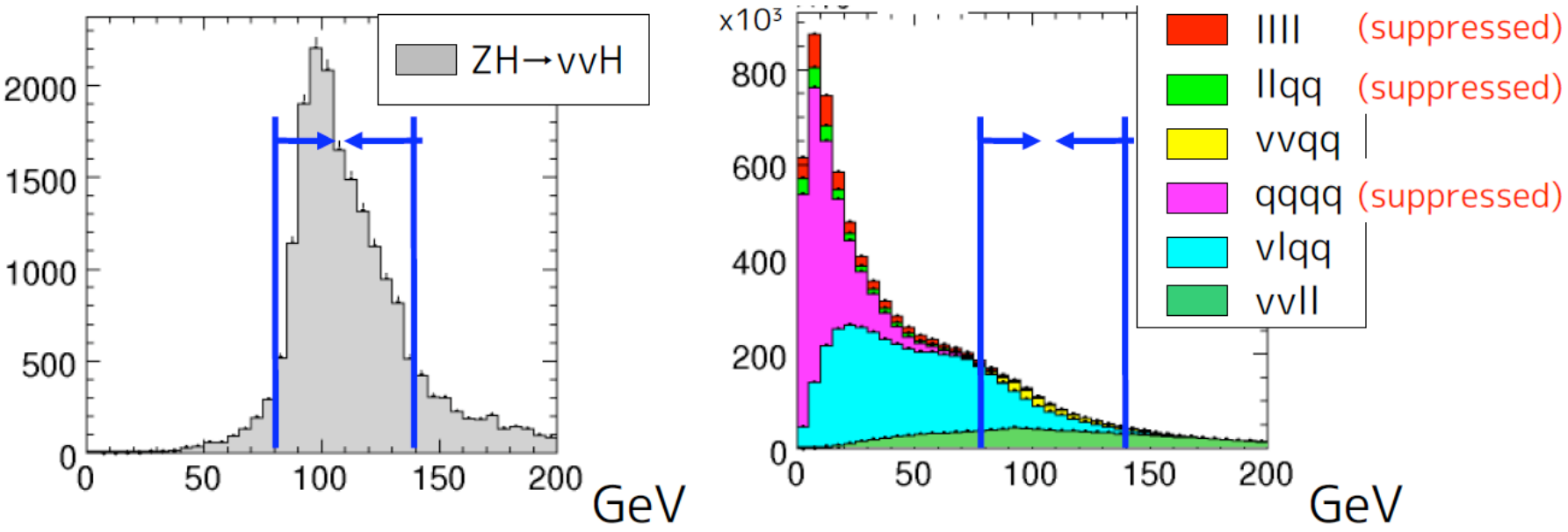
Missing mass cut

Missing mass was evaluated by two reconstructed jets.

To select Z->vv events, missing mass cut was applied.

80 GeV < missing mass < 140 GeV

The distributions of reconstructed missing mass



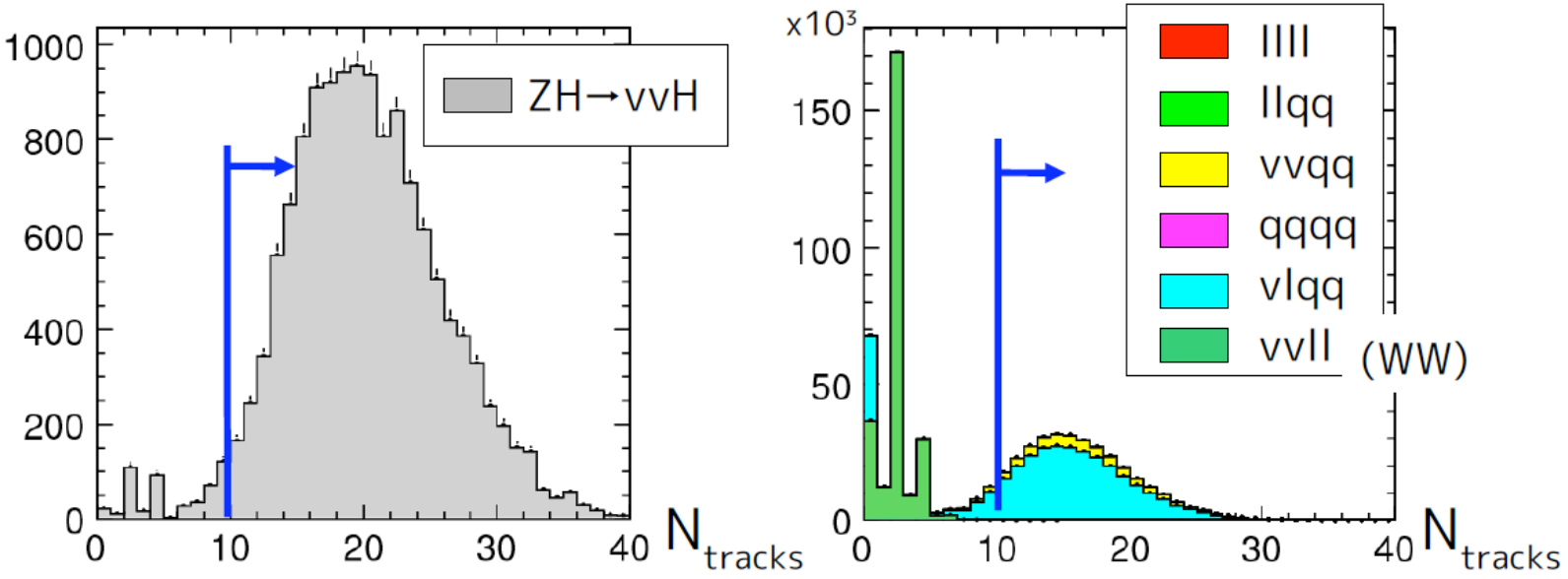
llll, llqq, and qqqq were suppressed.

Number of charged tracks cut

To reject WW(W->νl) events,
the number of charged tracks was checked.

-> We required $N_{tracks} > 10$.

The distribution of the number of charged tracks



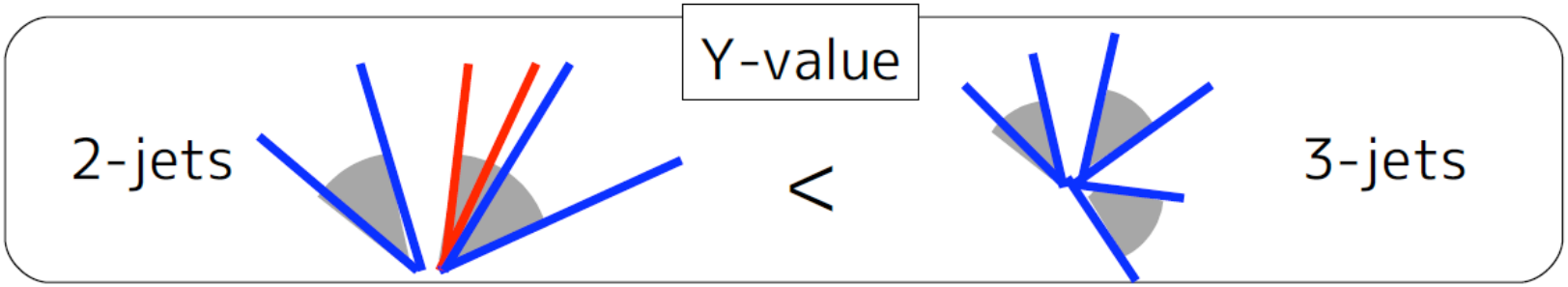
WW(W->νl) events were suppressed.
$\tau\nu_\tau$qq events become the main background.

YPlus Cut

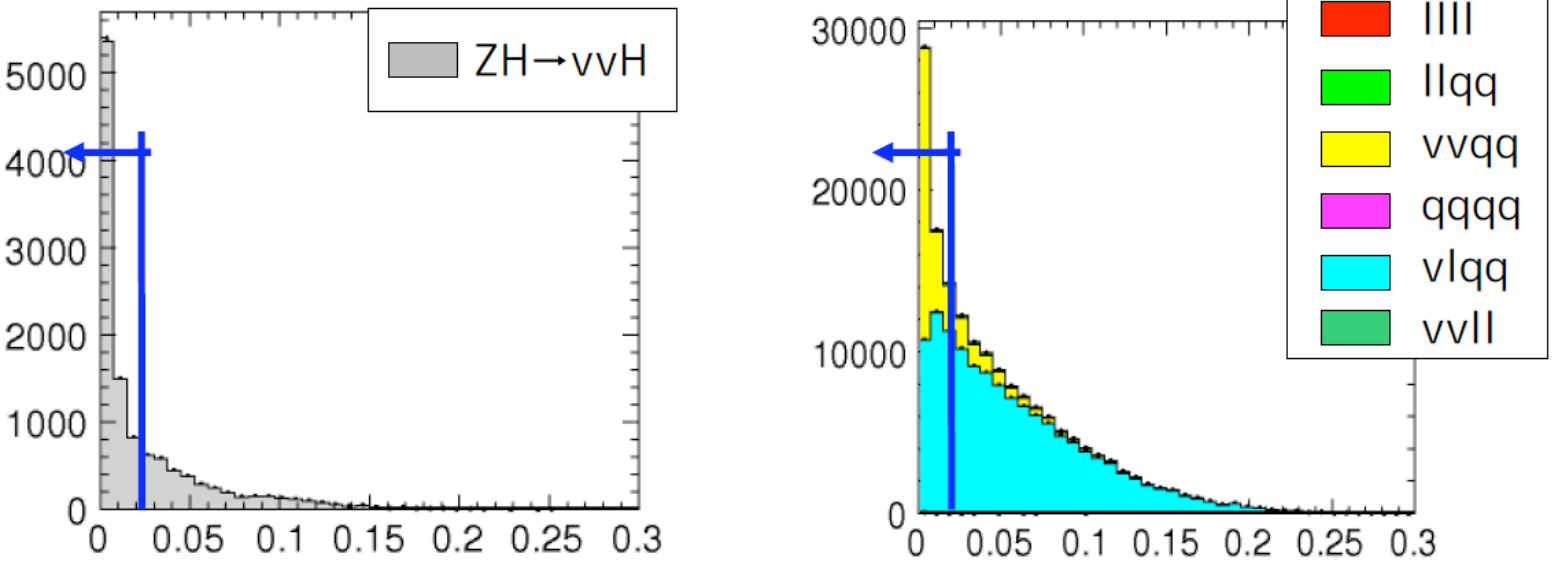
YPlus < 0.02 was selected to reject $\tau\nu_\tau qq$ events.

YPlus: y-value to reconstruct as 3(2+1)-jets

To reconstruct 2-jets as 3-jets, y-value should be small.



The distributions of YPlus

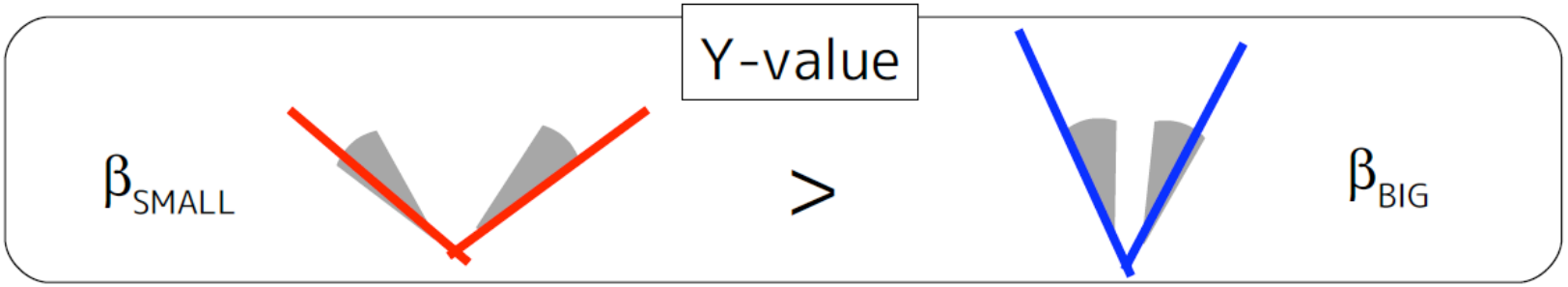


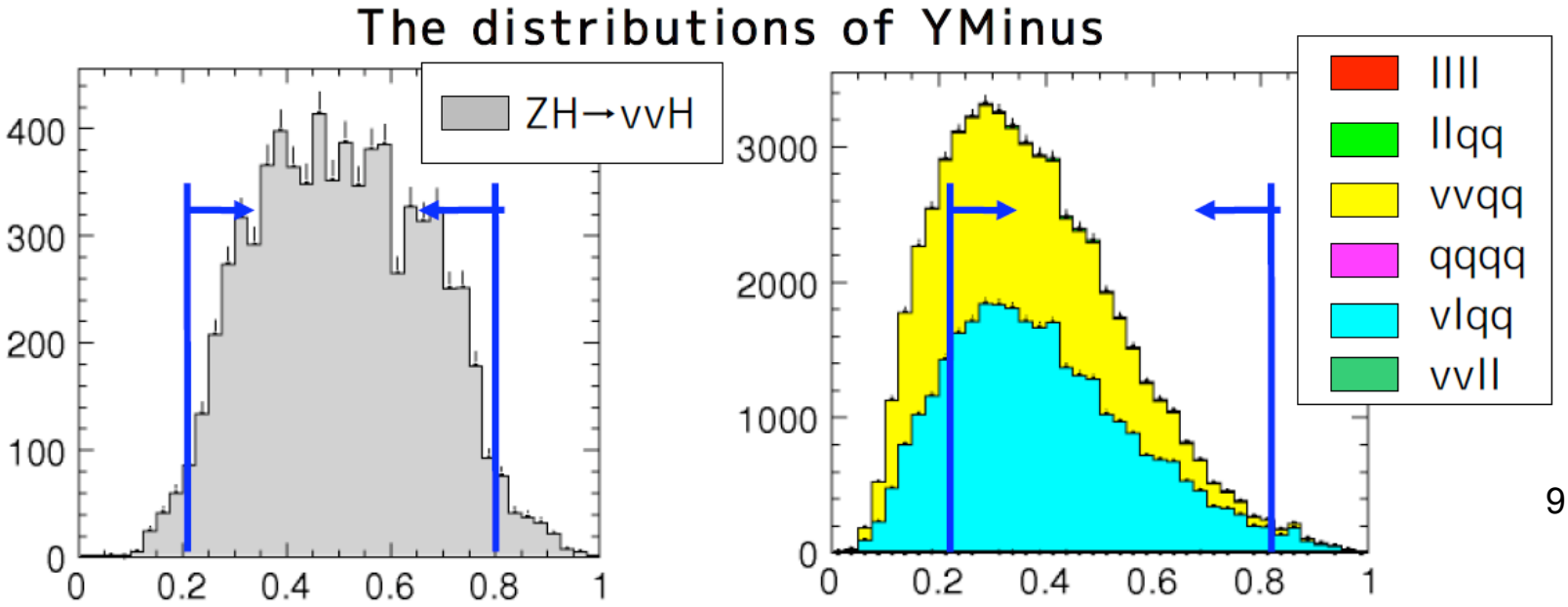
YMinus Cut

$\tau\nu_\tau qq$ events were rejected by requirement 0.2 < Yminus < 0.8.

Yminus: y-value to reconstruct as 1(2-1) jet

Y-value of Signal is bigger than that of WW, ZZ because of β.





Summary of Background rejection

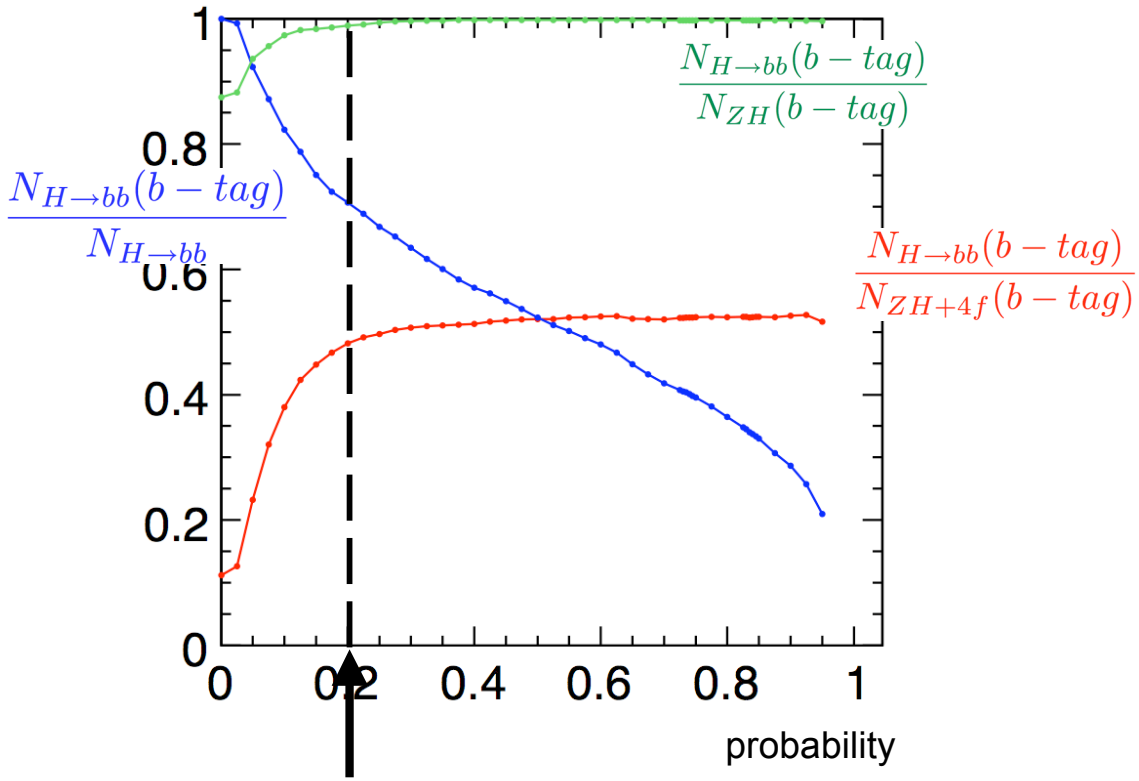
	nocut	missing mass	P_T	P_L	N_{tracks}	mom^{max}	Yplus	Yminus	Efficiency
ZH	19,360	15,684	13,918	13,534	12,859	11,849	7,689	7,335	37.89%
H->bb	13,179	11,843	10,498	10,226	9,931	9,158	6,744	6,417	48.69%
H->cc	675	608	557	547	531	469	354	348	51.52%
$\nu_e$eqq	1,460,797	80,931	67,135	61,437	25,966	5,088	961	851	0.06%
$\nu_\mu$$\mu$qq	1,327,332	92,360	75,143	61,715	52,355	10,540	2,747	2,288	0.17%
$\nu_\tau$$\tau$qq	1,326,061	386,690	268,190	200,443	176,370	123,045	29,135	24,979	1.88%
$\nu\nu$qq	149,979	124,843	85,774	49,745	43,229	35,942	26,713	21,653	14.44%
other	6,318,190	491,631	337,800	266,307	2,676	2,001	370	335	0.01%

Background events were rejected efficiently.

Preparation of H->bb/cc sample

Preparation of H->bb sample with b-tag

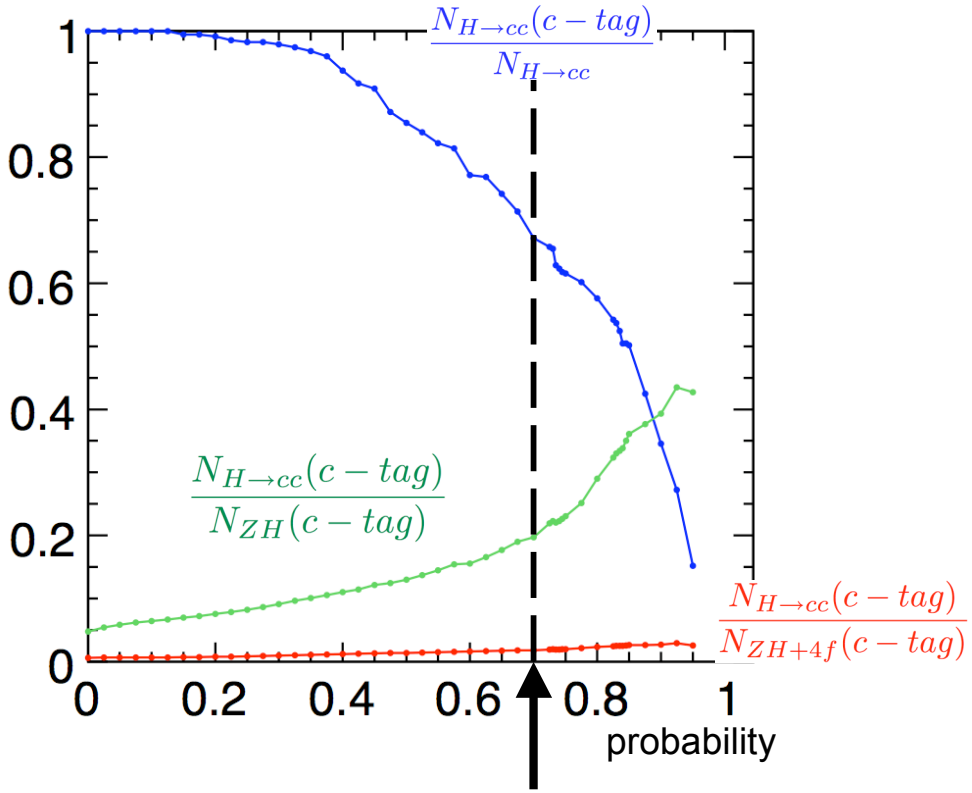
Efficiency and Purity of b-tagging were checked after background rejection



We applied b-tagging after background rejection with b-prob1 > 0.2 AND b-prob2 > 0.2

Preparation of H->cc sample with c-tag

Efficiency and Purity of c-tagging were checked after background rejection



We applied c-tagging after background rejection with c-prob1 > 0.7 OR c-prob2 > 0.7

Summary of the number of events

Preparation of H->bb/cc sample

	nocut	B.G. rejection	b-tag	c-tag
ZH	19,360	7,335	4,583	1,184
H->bb	13,179	6,417	4,534	
H->cc	675	348		234
$\nu_e$eqq	1,460,797	851	12	147
ν_μμqq	1,327,332	2,288	21	464
ν_ττqq	1,326,061	24,979	454	7,365
ννqq	149,979	21,653	4,274	3,730
other	6,318,190	335	89	98

$$P_{bb} : \frac{N_{H\to bb}(b-tag)}{N_{ZH}(b-tag)} = 98.9\% \qquad \epsilon_{bb} : \frac{N_{H\to bb}(b-tag)}{N_{H\to bb}(no\ cut)} = 34.4\%$$

$$P_{cc} : \frac{N_{H\to cc}(c-tag)}{N_{ZH}(c-tag)} = 19.7\% \qquad \epsilon_{cc} : \frac{N_{H\to cc}(c-tag)}{N_{H\to cc}(no\ cut)} = 34.7\%$$

These values are used to estimate the branching ratio.

Estimation of measurement accuracy of branching ratio

Calculation of branching ratio

The definition of the branching ratio of H->ff(f=c,b)

$$\mathrm{Br}(\mathrm{H}\to f\,f) = \frac{N_{H\to f\,f}}{N_{ZH}}$$

estimated by fitting Higgs mass distribution

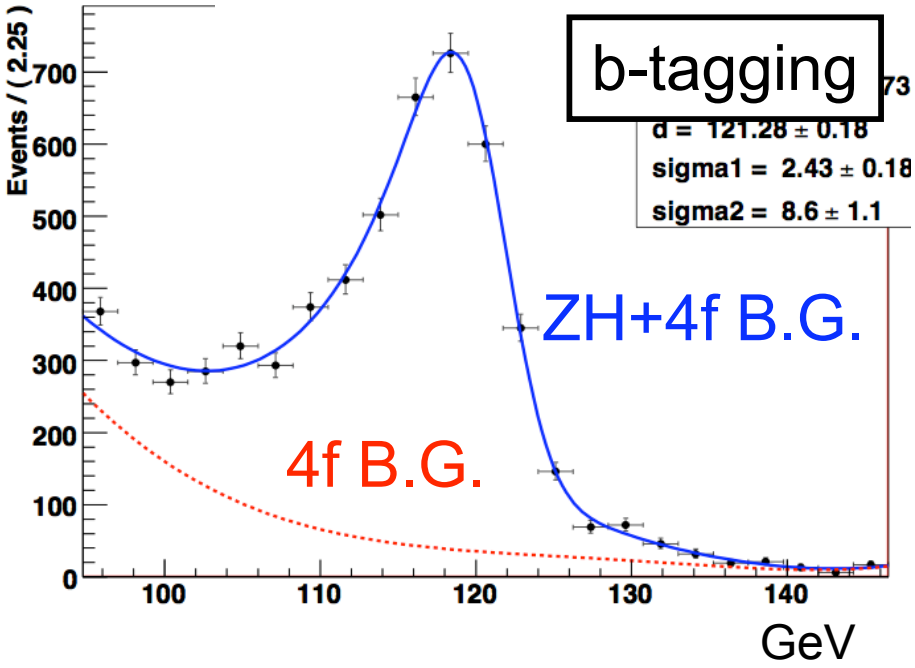
$$N_{H\to f\,f} = \frac{P_{f\,f}\cdot N_{ZH}^{fit}}{\epsilon_{f\,f}}$$

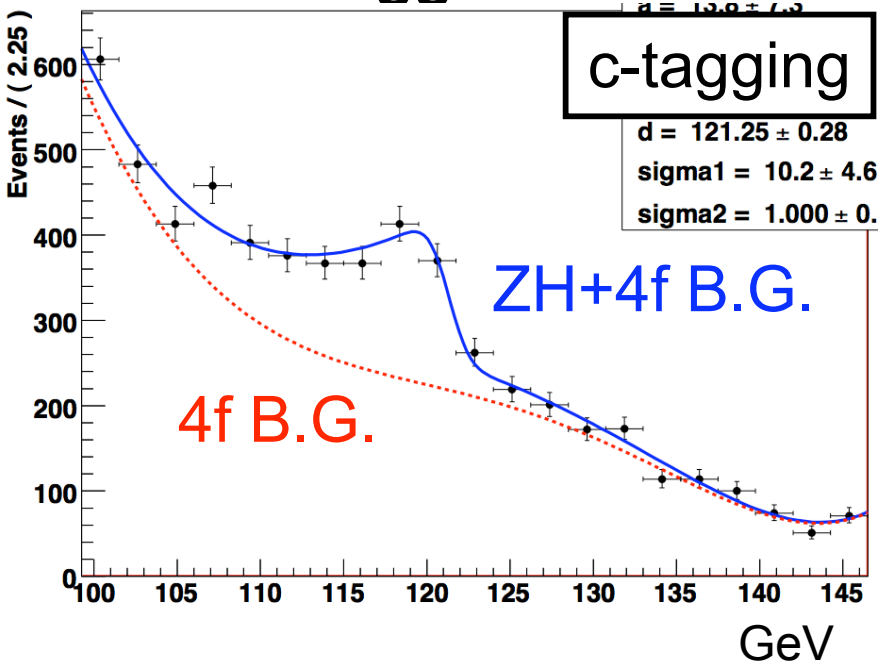
Evaluated by MC true information

Fitting result

- The number of ZH events in H->cc and H->bb sample are estimated by fitting Sig+B.G.
  - N_{ZH}^{fit}=4510.5 +/- 220.0 (N_{ZH}^{true} : 4583) (b-tagging)
  - N_{ZH}^{fit}=1118.6 +/- 351.1 (N_{ZH}^{true} : 1184) (c-tagging)

The distribution of reconstructed higgs mass





Estimation of branching ratio

The branching ratio of H->ff(f=c,b) is estimated by,

$$\mathrm{Br}(\mathrm{H}\to ff) = \frac{N_{H\to ff}}{N_{ZH}} \quad \left(N_{H\to ff} = \frac{P_{ff}\cdot N_{ZH}^{fit}}{\epsilon_{ff}} \right)$$

$$P_{ff} : \frac{N_{H\to ff}(f-tag)}{N_{ZH}(f-tag)}$$

$$\epsilon_{ff} : \frac{N_{H\to ff}(f-tag)}{N_{H\to ff}(no\ cut)}$$

$N_{H\to bb}$: 12967.7 +/- 632.5

- P_{bb} : 98.9%
- ϵ_{bb} : 34.4%
- N_{ZH}^{fit}: 4510.5 +/- 220.0

N_{ZH} : 19360

$N_{H\to cc}$: 635.1 +/- 199.3

- P_{cc} : 19.7%
- ϵ_{cc} : 34.7%
- N_{ZH}^{fit}: 1118.6 +/- 351.1

N_{ZH}: 19360

$Br(H\to bb)$: 67.0 +/- 3.3% (68.1%)

$Br(H\to cc)$: 3.28 +/- 1.03% (3.49%)

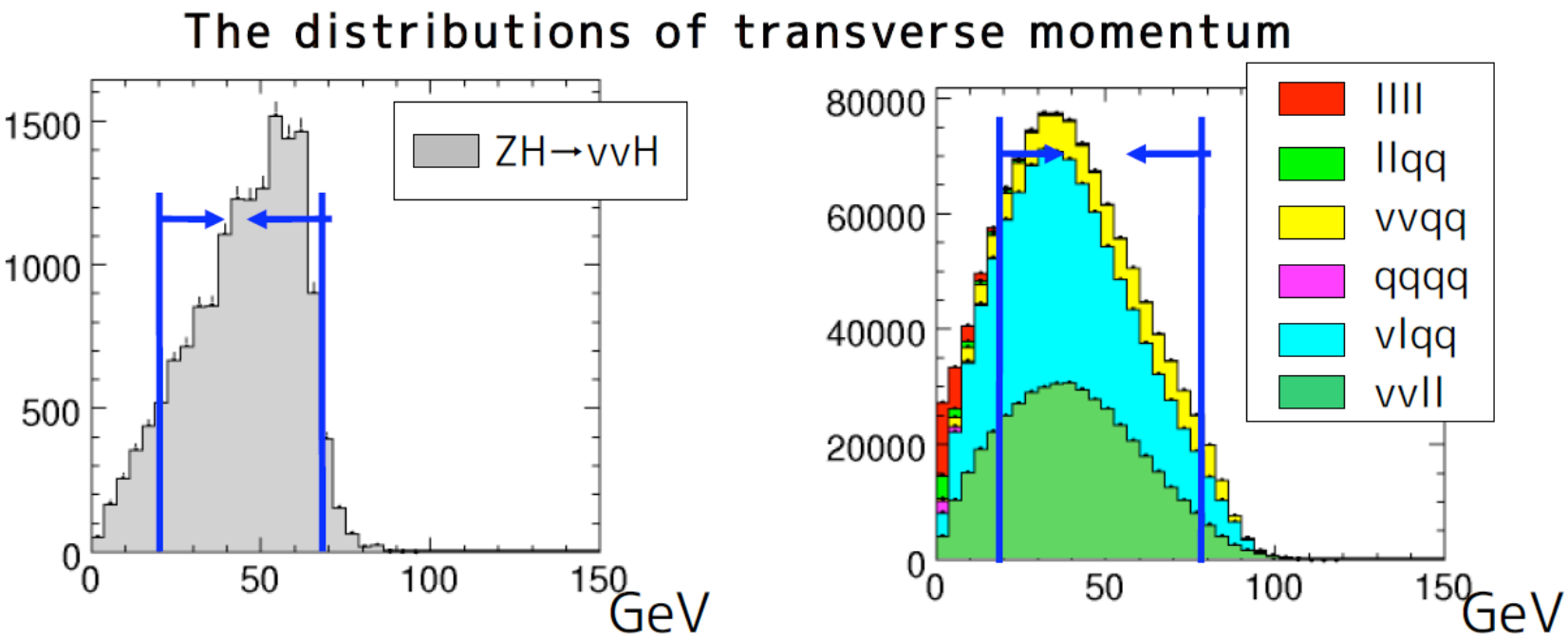
True branching ratio

Summary

- Branching ratio of H->cc and H->bb were estimated by using ZH->$\nu\nu$H
  - Br(H->bb) = 67.0 +/- 3.3% (1 +/- 4.93%)
  - Br(H->cc) = 3.28 +/- 1.03% (1 +/- 31.4%)

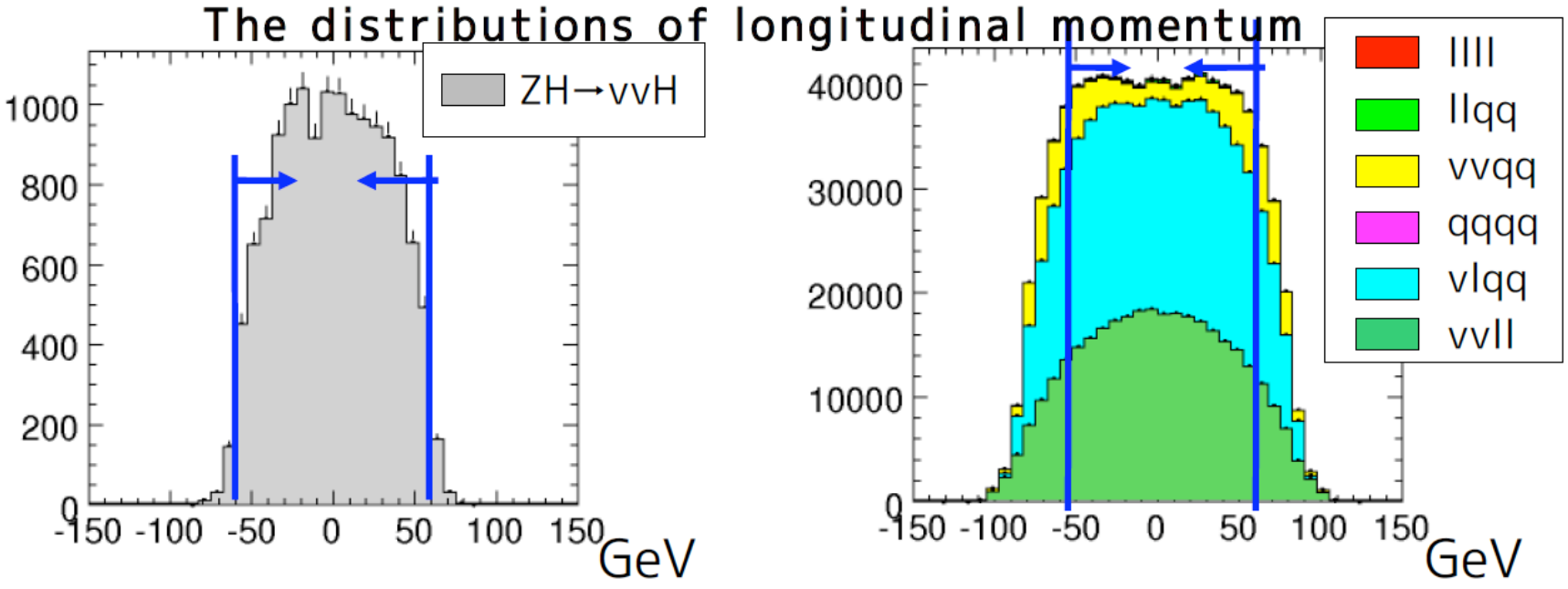
P_T cut

20 GeV < P_T < 70 GeV



P_L cut

$-60\ \text{GeV} < P_L < 60\ \text{GeV}$

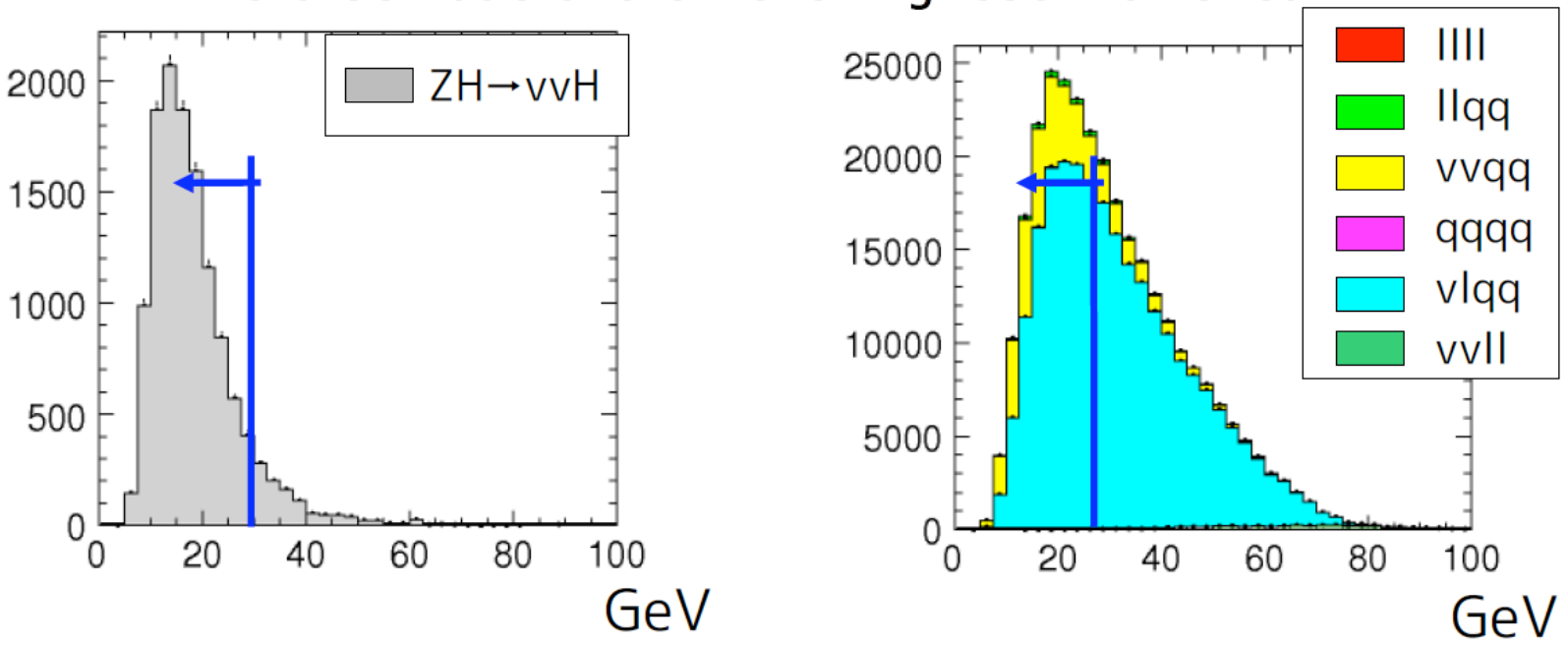


Momentum^{max} cut

Momentum^{max} is the highest momentum.

Momentum^{max} < 30GeV

The distributions of the highest momentum



Fit function

Signal

$$F(m) = N \int_{-m}^{-m} dt(e^{B(m+t)} + C)(e^{-\frac{t^2}{2\sigma^2}} + Ae^{-\frac{t^2}{2\sigma'^2}})$$

Background

Chebychev polynomial

Hand calculation of ΔBR

$$\frac{\sqrt{N_{ZH}+N_{4f}}}{N_{ZH}}$$