Charged Higgs search in Triplet Higgs model with $e^+e^- \rightarrow WH$

October 8th, 2014

Yuko Shinzaki

Jan strube, Akimasa Ishikawa, Keisuke Fujii[a]

Shinya Kanemura[b], Kei Yagyu[c], Hitoshi Yamamoto

Tohoku univ., KEK[a], Toyama univ.[b], National Central univ.[c]

Introduction

Motivation

- In July, 2012, LHC experiments announced the discovery of a neutral Higgs boson. In the Standard Model this is a manifestation of a Higgs doublet field.

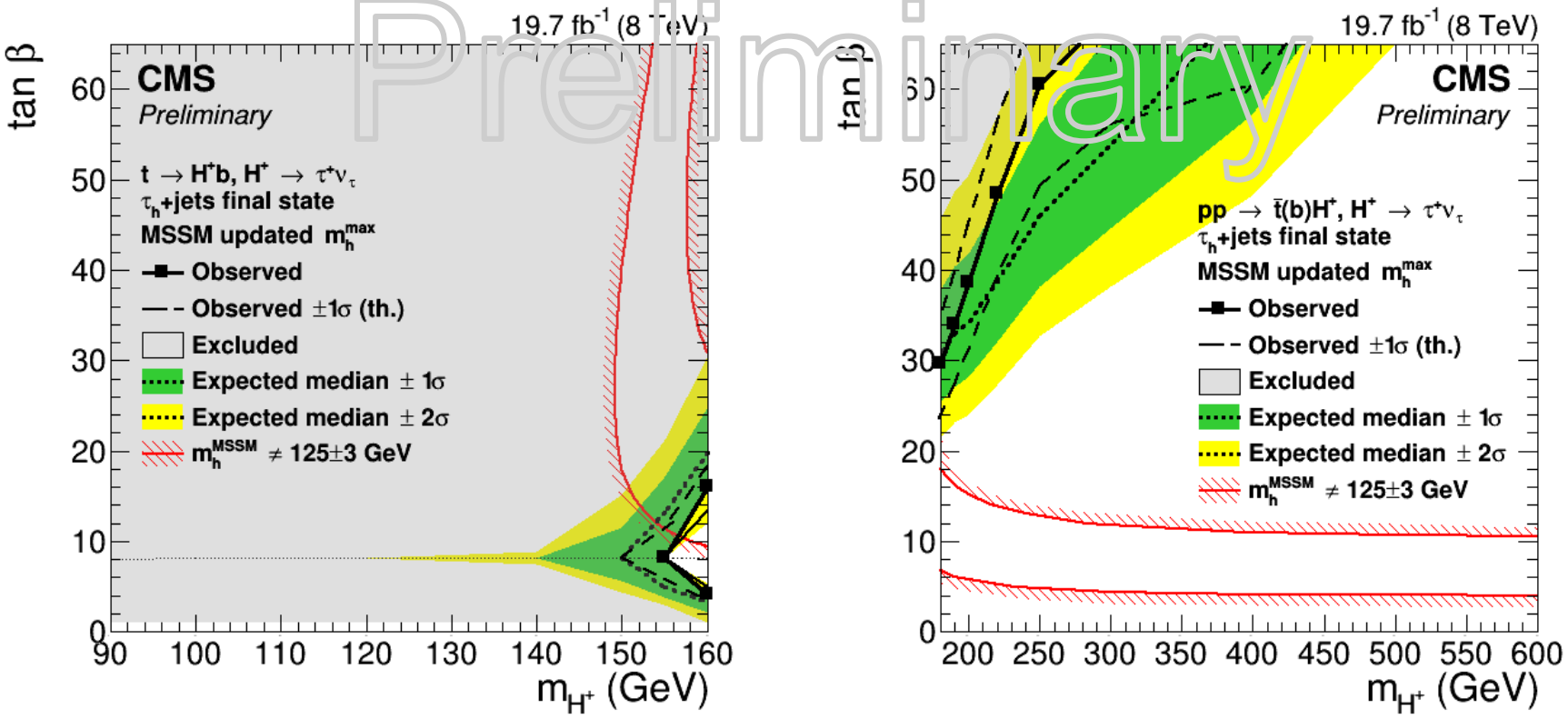
- Extensions of the Standard Model could have charged Higgs bosons in addition to the one that was discovered at the LHC.

- If charged higgs is light enough, one can search for charged Higgs with e+e-→WH at 250GeV. A tree level coupling of ZWH appears in triplet Higgs models which explain neutrino masses.

(Shinya Kanemura, Kei Yagyu, physical review D 83, 075018(2011))

$$\mathcal{L}_{\text{eff}} = g m_W f_{HWV} H^{\pm} W_{\mu}^{\mp} V^{\mu}$$

Charged Higgs search at the LHC



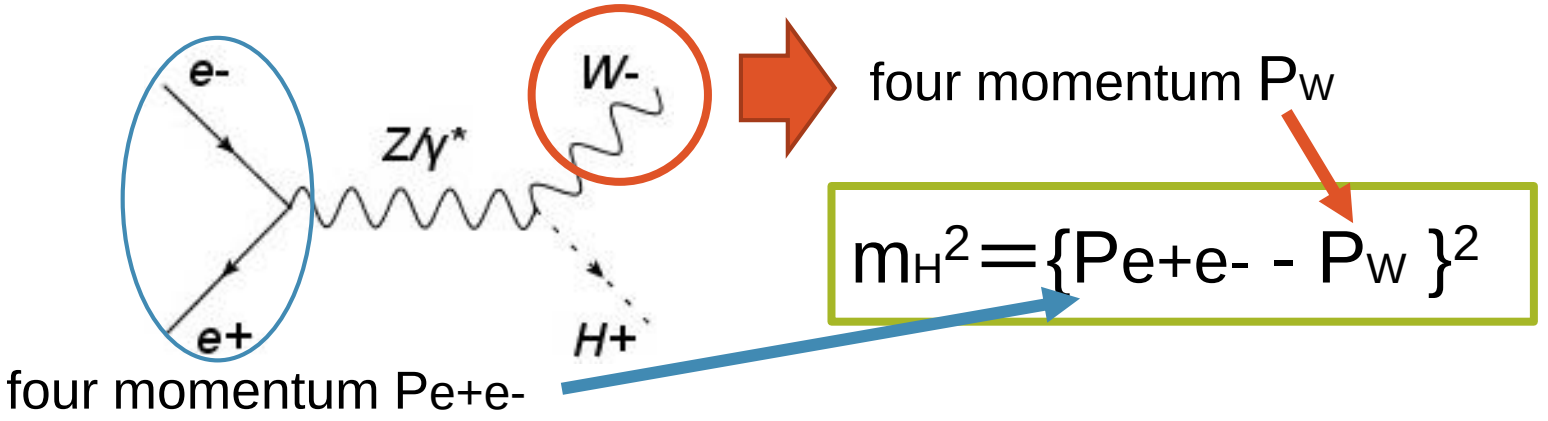
- The CMS experiment searches MSSM charged Higgs at m_h^{max} scenario.
- Charged Higgs mass limit > 150 GeV

Charged Higgs analysis

- In my study, charged Higgs mass is reconstructed from recoil mass against W boson, and measurement accuracy of the mass and cross section are evaluated.
- We want to find Higgs signal inclusively from recoil mass but it is very hard so we first try forced n-jet analysis.

recoil method

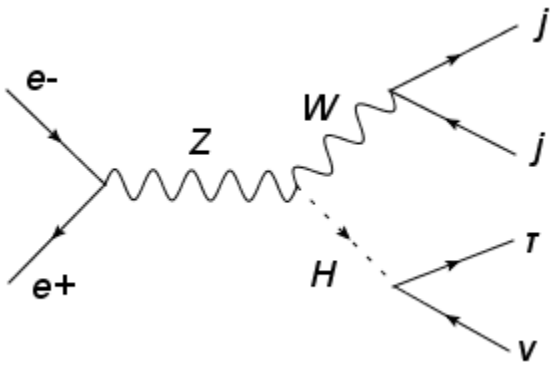
get W four momentum Pw, and calculate invariant mass from Pe+e- and Pw.
→ At ILC e+e- collider, initial state energy is known.



Charged Higgs analysis

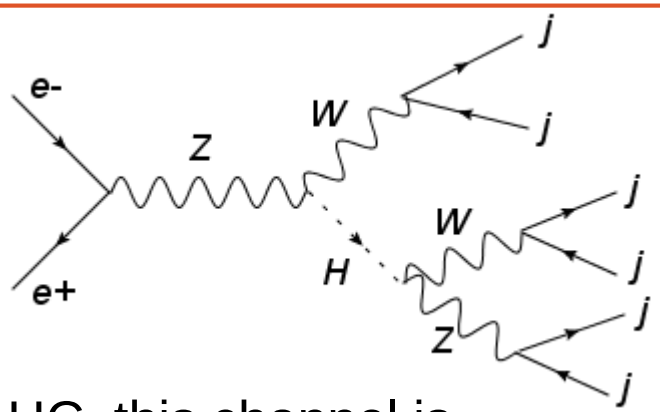
- In my study, charged Higgs mass is reconstructed from recoil mass against W boson, and measurement accuracy of the mass and cross section are evaluated.
- We want to find Higgs signal inclusively from recoil mass but it is very hard so we first try forced n-jet analysis.

3j : H → taunu channel



This channel is easily analyzed.

6j : H → WZ channel



At the LHC, this channel is buried in other hadronic events.

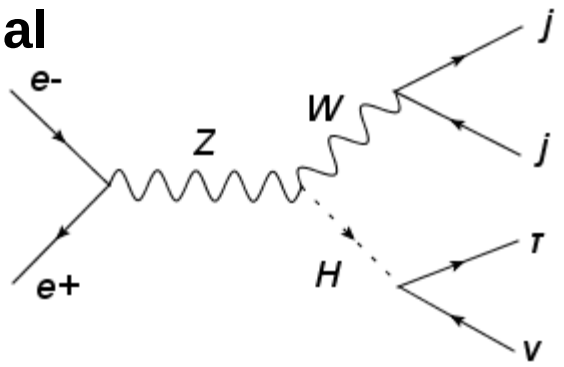
H→taunu channel

Signal and Background

Signal status

- Ecm = 250 GeV
- Integrated luminosity = 250 fb^{-1}
- Polarization
  P(e+, e-) = (-30%, +80%)
- Charged higgs mass
  $m_{H^{\pm}}$ = 150 GeV
- Detector
  ILD_01_v05 (DBD ver.)
- Form factor
  F_{HWZ}=1, $F_{HW\gamma}$= 0

Signal



		cross section (fb)	# of event
Sig.	WH → jjτν	107	26k
SM BG	Di-jet	46.2k	12M
	evW →evjj	445	110k
	Zee →jjee	300	74k
	WW →jjlν	758	190k
	WW → jjjj	600	150k
	ZZ →jjll	467	120k
	ZZ → jjjj	402	100k
	ZZorWW → jjjj	565	140k
	Zh → ffh	205	51k

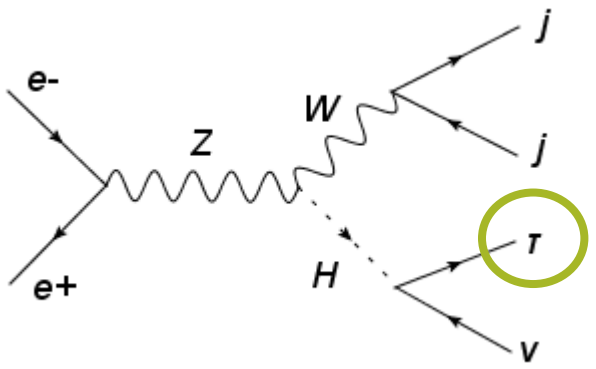
3-jet reconstruction

- forced 3-jet analysis using Durham algorithm
- W boson is reconstructed by pairing di-jet which gives the smallest χ^2

$$\chi^2 = \left(\frac{M_j - m_W}{\sigma_W}\right)^2$$

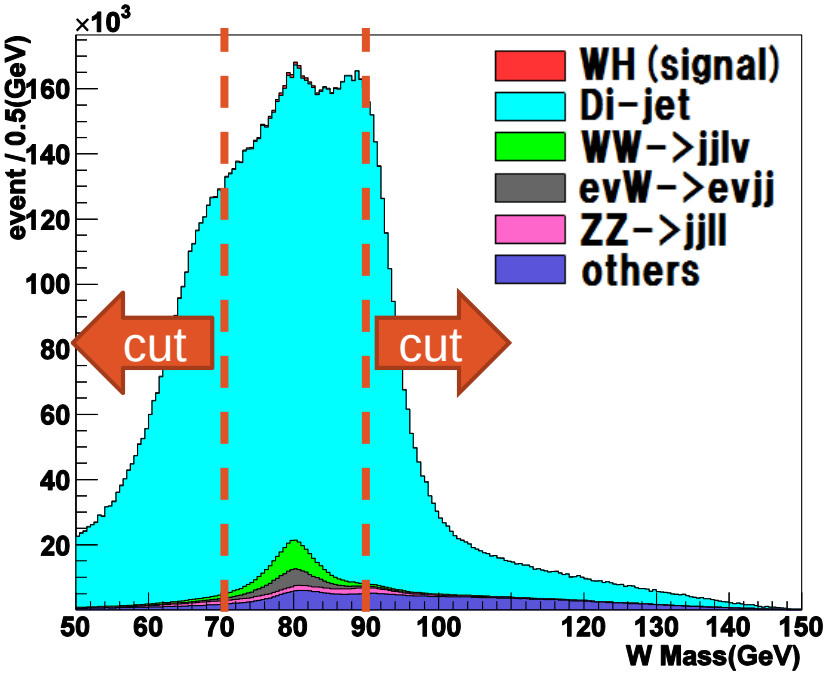
M_j : mass of jet pair
m_W : mass of W($= 80.0\text{GeV}$)
σ_W : mass resolution($= 4.8\text{GeV}$)

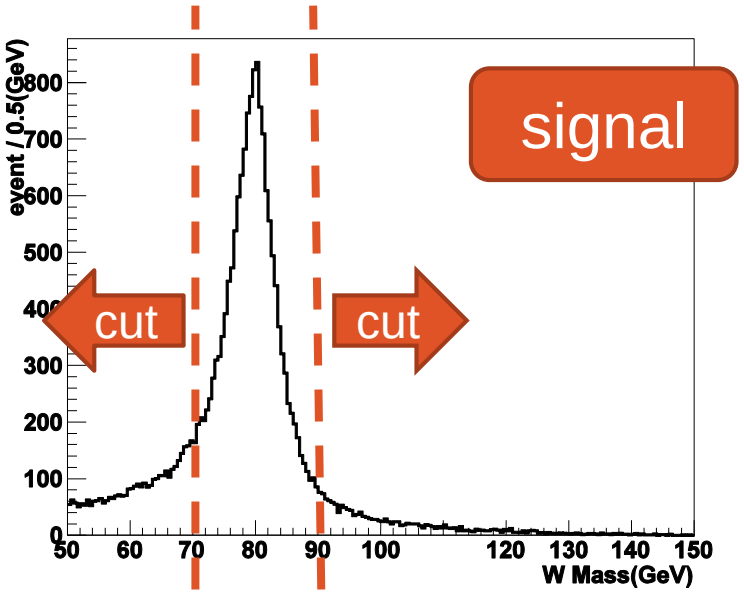
- H mass is calculated by recoil mass method



1st cut (W mass & recoil mass)

70 < Mw < 90 (GeV)



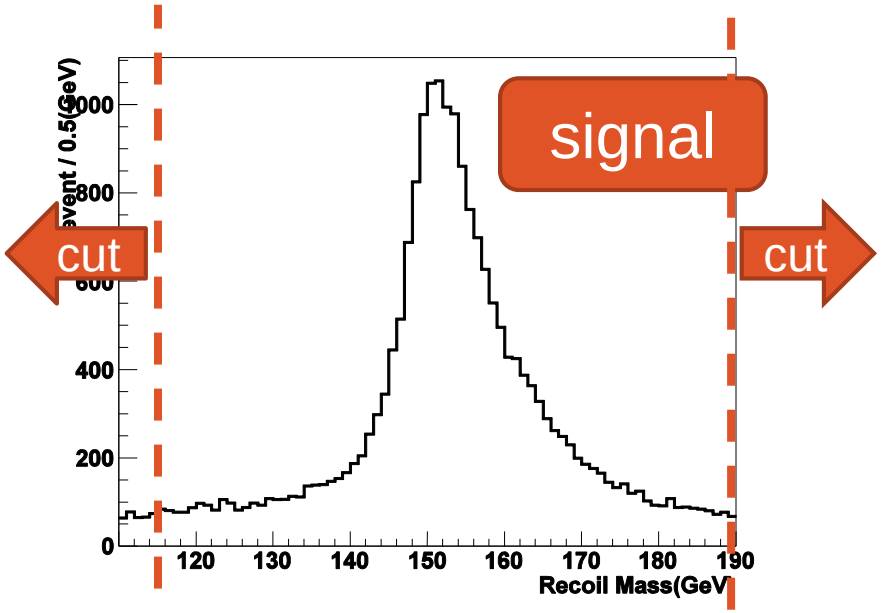


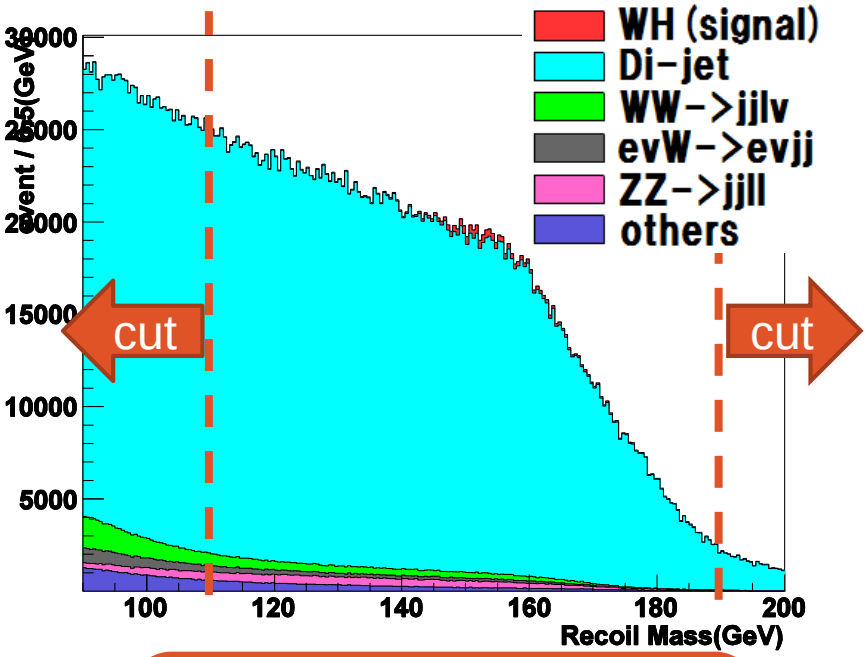
- different event from signal clearly
ZZ→jjjj, Di-jet, WW→jjjj, WW→jjlv

others :
Zee →jjee, WW → jjjj
ZZ → jjjj, ZZorWW → jjjj
Zh → ffh

1st cut (W mass & recoil mass)

110 < Mrec < 190 (GeV)



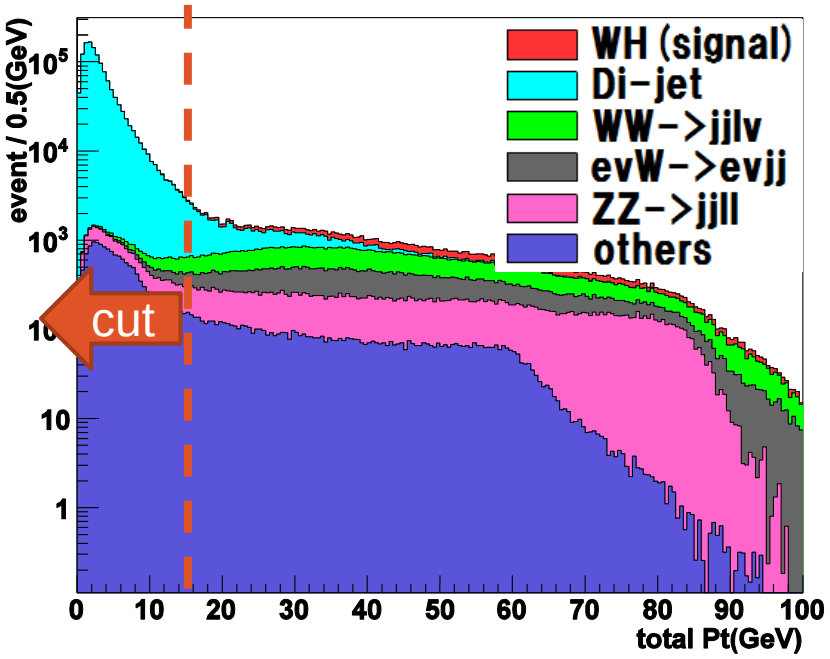


- different event from signal clearly ZZ→jjjj, Di-jet, WW→jjjj, WW→jjlv

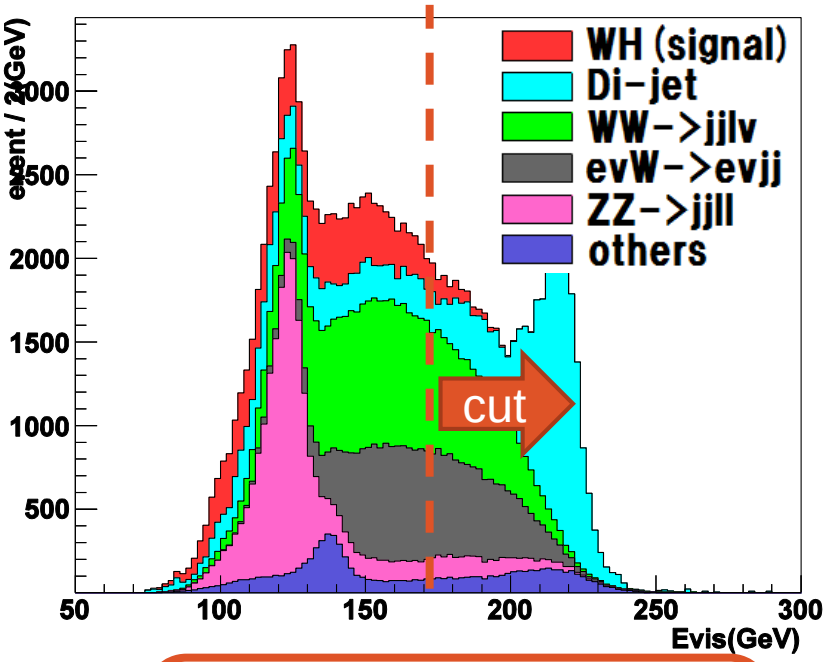
others :
Zee →jjee, WW → jjjj
ZZ → jjjj, ZZorWW → jjjj
Zh → ffh

2nd cut (total Pt) 3rd cut (visible energy)

15 < total Pt (GeV)



Evis < 170 (GeV)

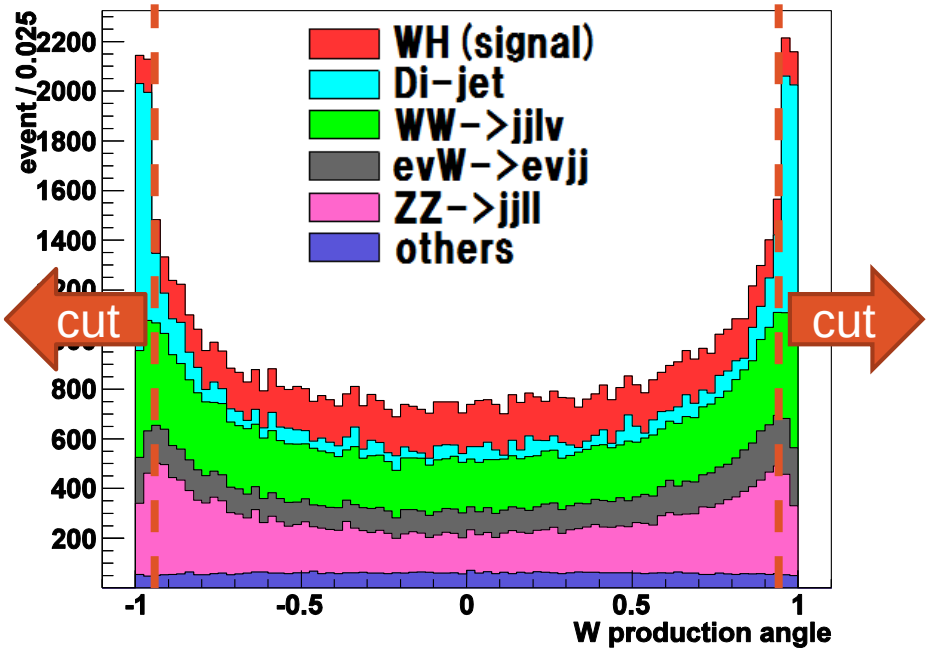


- the event not include neutrinos
Di-jet, ZH→ffh, ZZorWW→jjjj

others :
Zee →jjee, WW → jjjj
ZZ → jjjj, ZZorWW → jjjj
Zh → ffh

4th cut (W production angle) & 5th cut

0.95 < | cos(W production angle)|



▸ have peak forward, Di-jet, etc

others :
Zee →jjee, WW → jjjj
ZZ → jjjj, ZZorWW → jjjj
Zh → ffh

140 < Mrec < 160 (GeV)

▸ final selection, Z event,

Cut table

	WH	Di-jet	evW→evjj	WW→jjlv	ZZ→jjll	others
no cut	26803	11553700	111356	189596	116797	518315
mw&mrec	15809	1304890	23786	35738	28599	22220
pt	14627	30613	21994	32379	20977	8127
Evis	13417	9447	11427	21227	18535	4710
Wangle	12876	5368	10427	19448	17136	4506
mrec	9590	2048	3599	6352	4557	1983

S/N=0.00215→0.517

efficiency = 35.8%

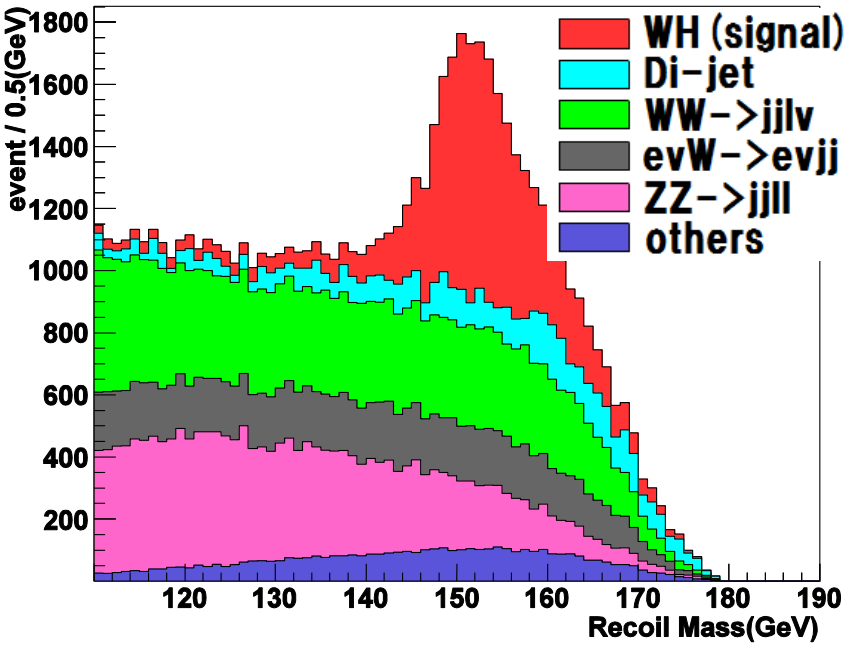
significance = 57.18 → statistic error **1.75%**

(E_{cm}250 GeV, 250fb^{-1})

$$Significance = \frac{N_{signal}}{\sqrt{N_{signal}+N_{bg}}}$$

others :
Zee →jjee
WW → jjjj
ZZ → jjjj
ZZorWW → jjjj
Zh → ffh

Recoil mass plot



signal definition

70 < Mw < 90 (GeV)
140 < Mrec < 160 (GeV)
15 < Pt (GeV)
170 < Evis (GeV)
0.95 < |cos(w production angle)|

	WH	Di-jet	evW→evjj	WW→jjlv	ZZ→jjll	others
no cut	26803	11553700	111356	189596	116797	518315
after cut	9590	2048	3599	6352	4557	1983

significance = 57.18 → statistic error **1.75%**(E_{cm}250 GeV, 250fb^{-1})

Less model dependent analysis

- Previous analysis is model dependent.
  - It was considered Higgs goes to taunu; including Evis and Pt cut .

→ We should do less model dependent analysis.

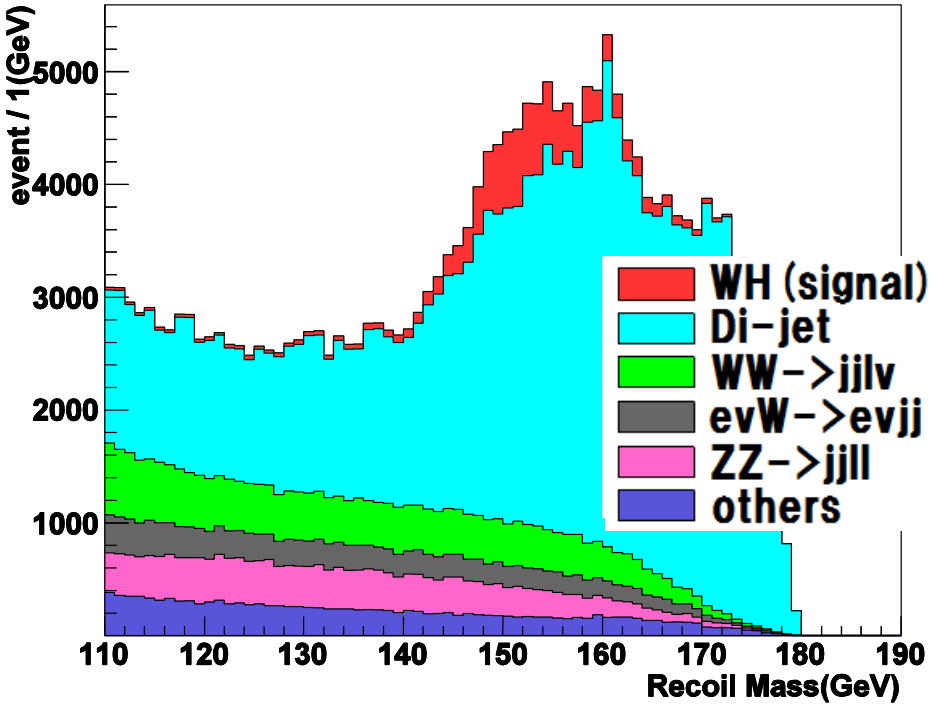
cut parameter

W mass
recoil mass
W production angle

visible energy
total Pt

- use only these three parameters for cut and optimize each cut values again.

Less model dependent analysis



signal definition

70 < Mw < 90 (GeV)

140 < Mrec < 160 (GeV)

0.85 < |cos(w production angle)|

- There is a peak from di-jet around 160GeV.
- It is the reason that candidate W which almost satisfies E_{CM}-M_W ~ 170GeV.
  If E_{CM} is larger, we can separate signal and this peak.

efficiency = 38.2%

significance = 19.44 → statistical error **5.14%**

(E_{cm}=250GeV, 250fb^{-1})

H→WZ channel

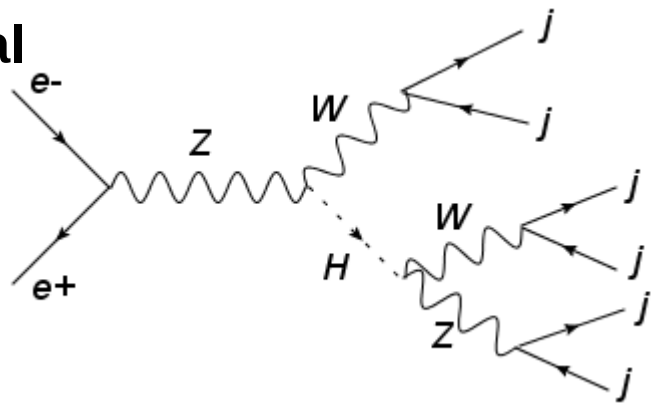
Signal and Background

Signal status

- Ecm = 250 GeV
- Integrated luminosity = 250 fb^{-1}
- Polarization
  P(e+, e-) = (+30%, -80%)
- Charged higgs mass
  $m_{H^{\pm}}$ = 150 GeV
- Detector simulator
  ILD_01_v05 (DBD ver.)
- Form factor
  F_{HWZ}=1, F_{HWA}= 0

		cross section (fb)	# of event
Sig.	WH → WWZ → 6j	105	26k
SM BG	Di-jet	78k	19M
	evW →evjj	5.9k	1.5M
	Zee →jjee	378	95k
	WW →jjlv	11k	2.7M
	WW → jjjj	8.7k	2.2M
	ZZ →jjll	857	214k
	ZZ → jjjj	841	210k
	ZZorWW → jjjj	7.3k	1.8M
	Zh → ffh	314	79k
	WWZ	41.6	10k

Signal



6j reconstruction

- forced6-jet analysis using Durham algorithm
- selecting the jet pairs so that χ_1^2 is minimized

$$\chi_1^2 = (p_{j1}^{pair1} + p_{j2}^{pair1})^2 + (p_{j1}^{pair2} + p_{j2}^{pair2})^2 + (p_{j1}^{pair3} + p_{j2}^{pair3})^2$$

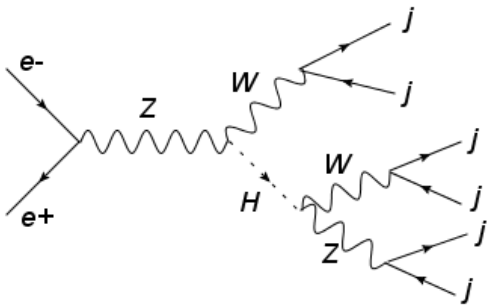
p_j : 3 vector momentum

- find prompt W by minimizing χ_2^2

$$\chi_2^2 = \left(\frac{M_{pair3} - m_W}{\sigma_W}\right)^2$$

m_W : mass of W($= 80.0$GeV)
m_H : mass of H($= 150$GeV)
σ_W : mass resolution($= 5.5$GeV)
σ_H : mass resolution($= 15$GeV)

- get W mass and calculate recoil mass



W mass and recoil mass

- Complex hadronic final states
  lower kinematic energy → large jet size
  →higher confusion between jets

- current selection needs improvement.

- Analysis at 350 GeV has easier jet reconstruction, celarsepalation between W and H thanks to larger boost.

Summary and plan

Summary

Charged higgs search at ILC 250 GeV

- 3j analysis …H→taunu channel
  - integrated luminosity = 250 fb-1, mh = 150GeV, form factor FHWZ = 1
  - we can measure this signal with statistical error **1.75%**
  - less model dependent analysis : statistical error **5.14%**
- 6j analysis …H→WZ channel
  - we still optimizing this selection.

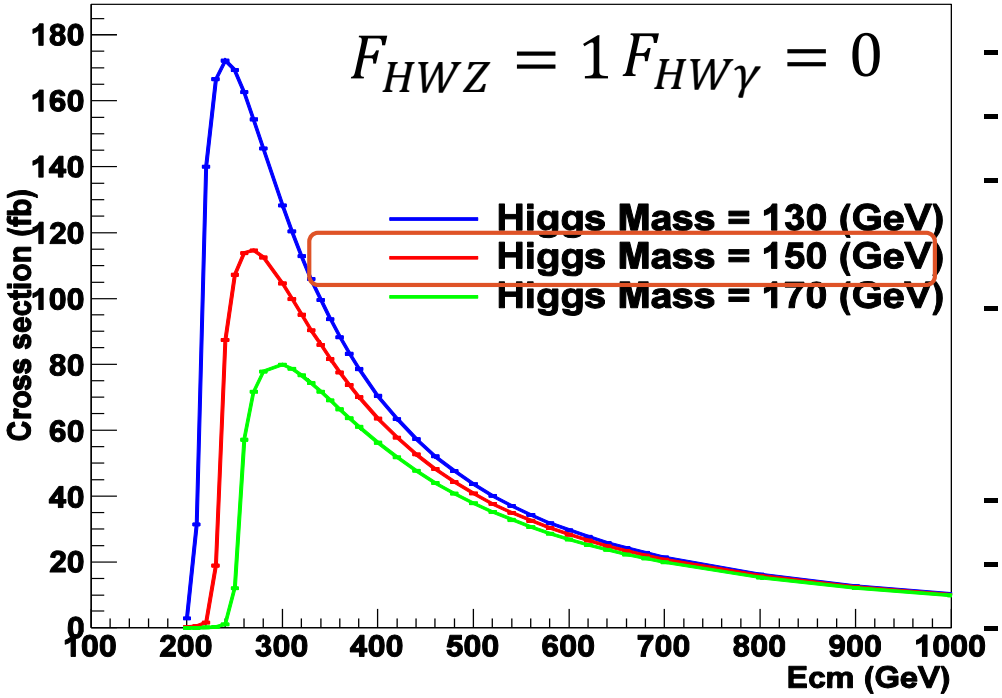
If E_{CM} is larger, we can separate signal and this peak.

Plan

- 3j analysis…H→taunu
  - mh vs Fhwz limit
- 6j analysis …H→WZ channel
  - optimization of jet pairing and boson selection
  - WWZ analysis at Ecm 350 GeV

Backup slides

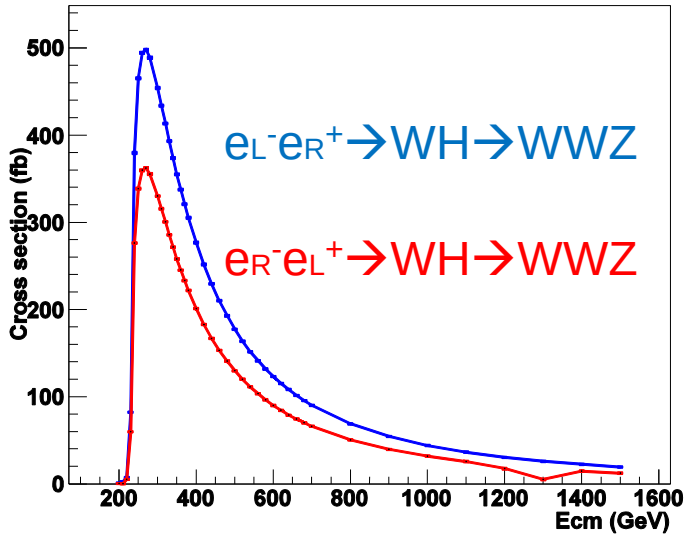
Total cross section of e+e-→WH→jjtaunu channel

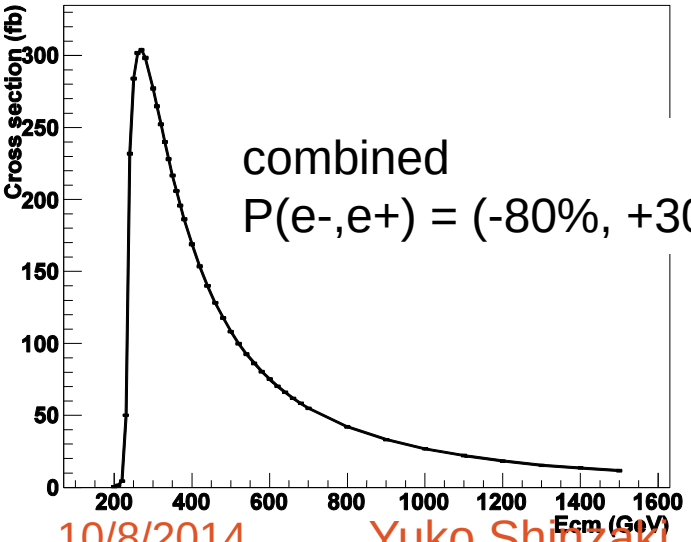


- Ecm = 250 GeV
- Integrated luminosity = 250 fb^{-1}
- Polarize : P(e+, e-)
  = (-30%, +80%)
- Charged higgs mass
  $m_{H^{\pm}}$ = 150 GeV

- Form factor : F_{HWZ}=1, F_{HWA}= 0
- beamstrahlung = 0
- bremsstrahlung = 0

Total cross section of e+e-→WH→WWZ channel





- Charged higgs mass = 150 GeV
- Ecm = 200 - 1500 GeV
- beamstrahlung = 0
- bremsstrahlung = 0
- Form factor ： F_{HWZ}=1, F_{HWA}= 0

- cross section = 284.1 (fb)
  at Ecm = 250 GeV
  P(e-,e+) = (-80%, +30%)

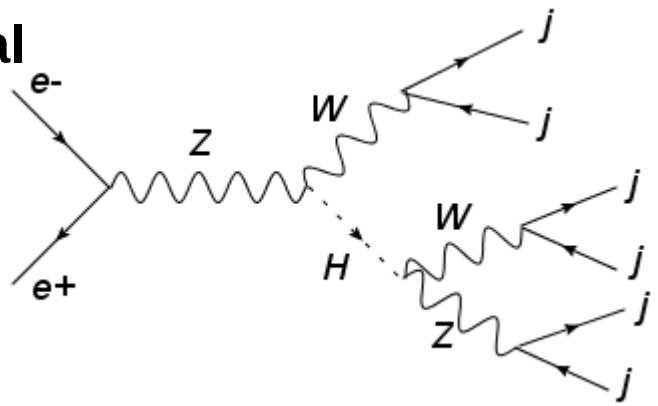
only hadronic Xs ~ Xs * 0.37
= 105 (fb)

Signal and Background

Signal status

- Ecm = 250 GeV
- Integrated luminosity = 250 fb^{-1}
- Polarization
  P(e+, e-) = (-30%, +80%)
- Charged higgs mass
  $m_{H^{\pm}}$ = 150 GeV
- Detector simulator
  ILD_01_v05 (DBD ver.)
- Form factor
  F_{HWZ}=1, F_{HWA}= 0

Signal

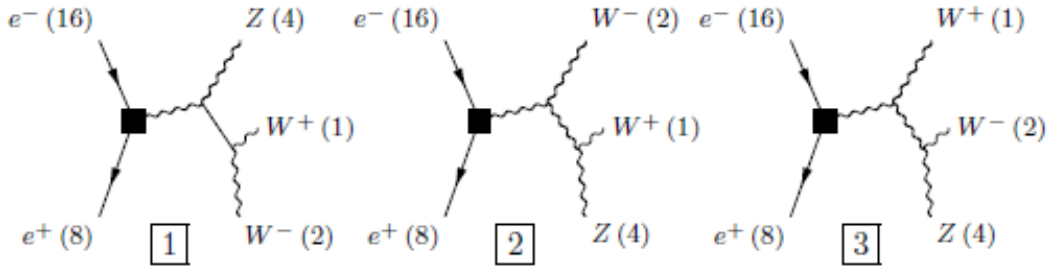


		cross section (fb)	# of event
Sig.	WH → WWZ → 6j	82.0	21k
SM BG	Di-jet	46.2k	12M
	evW →evjj	445	110k
	Zee →jjee	300	74k
	WW →jjlv	758	190k
	WW → jjjj	600	150k
	ZZ →jjll	467	120k
	ZZ → jjjj	402	100k
	ZZorWW → jjjj	565	140k
	Zh → ffh	205	51k
	WWZ	31.6	7.9k

WWZ standard model BG

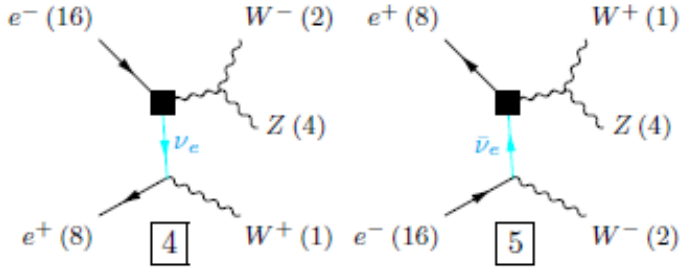
Grove 1

Multiplicity: 3
Resonances: 0
Log-enhanced: 0
Off-shell: 2
t-channel: 0



Grove 2

Multiplicity: 3
Resonances: 0
Log-enhanced: 1
Off-shell: 1
t-channel: 1



Grove 3

Multiplicity: 3
Resonances: 0
Log-enhanced: 1
Off-shell: 1
t-channel: 1