The simulation study of the Higgs self-coupling at the ILC

Hirai Shun
Department of Physics, Tohoku University
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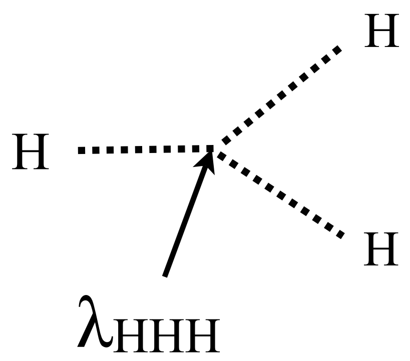
Outline

1. Introduction
2. Analysis
3. Result

1. Introduction

1.1 The aim of my study

→ To check if the measurement of the *Higgs self-coupling* is possible at the International Linear Collider

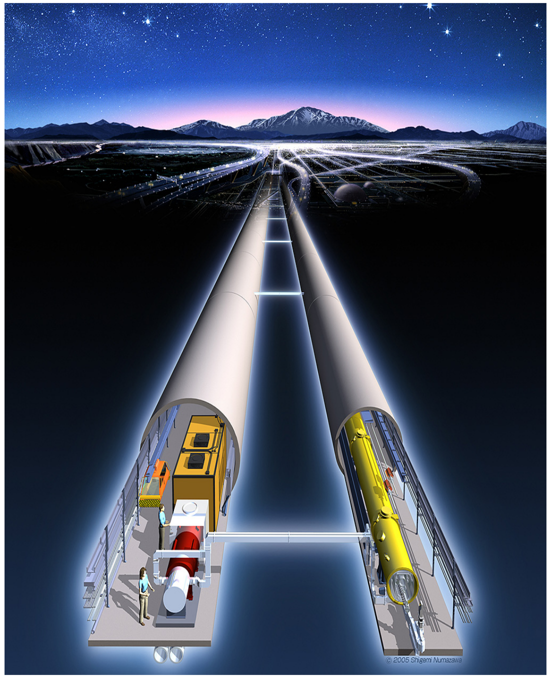


<u>Conclusion : I could not check the possibility</u>

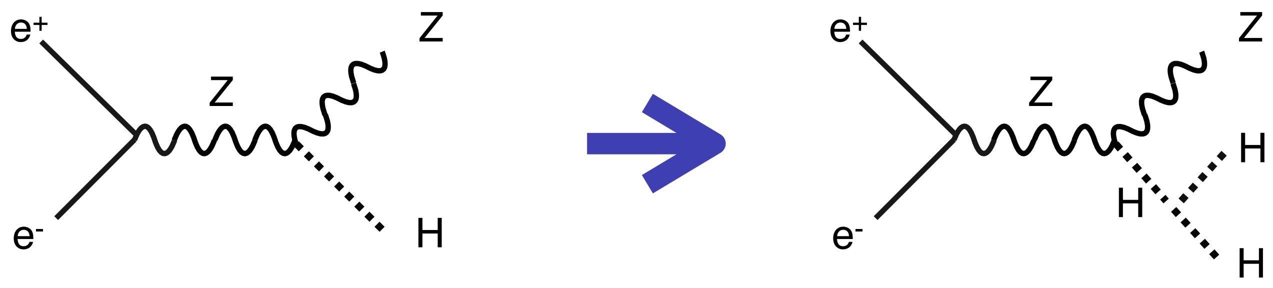
1.2 International Linear Collider

The International Linear Collider (ILC) is future electron-positron linear collider

- Length : 30 km
- Center of mass energy : 200~500 GeV
- Time to start working : ?



1.3 How can ILC measure the self-coupling?



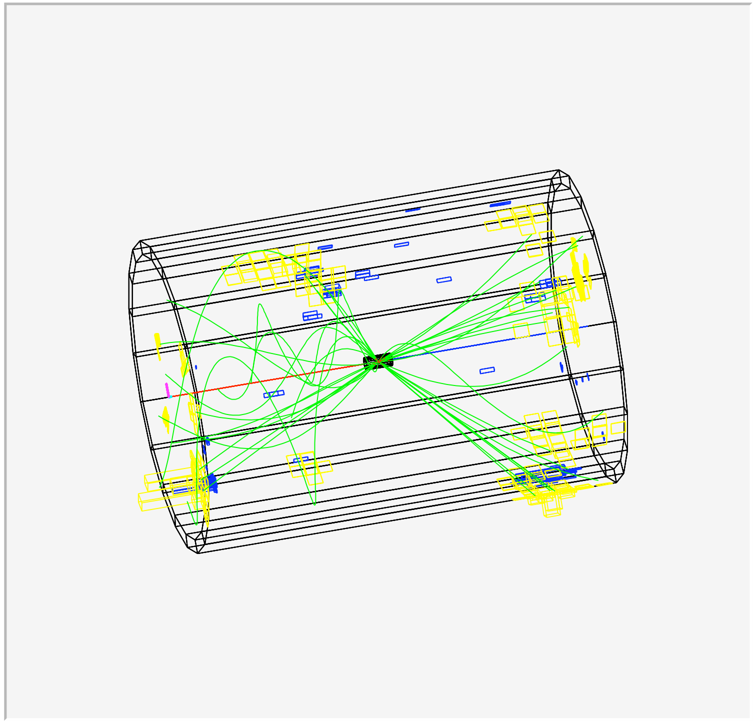
The cross section of ZHH depends on the strength of the coupling

What we have to do is to
count the number of ZHH signal.
= measure the ZHH cross section σ_{ZHH}

→ *ILC is supposed to have a potential to do this.*

1.3 How can ILC measure the self-coupling?

However, it is not so easy.

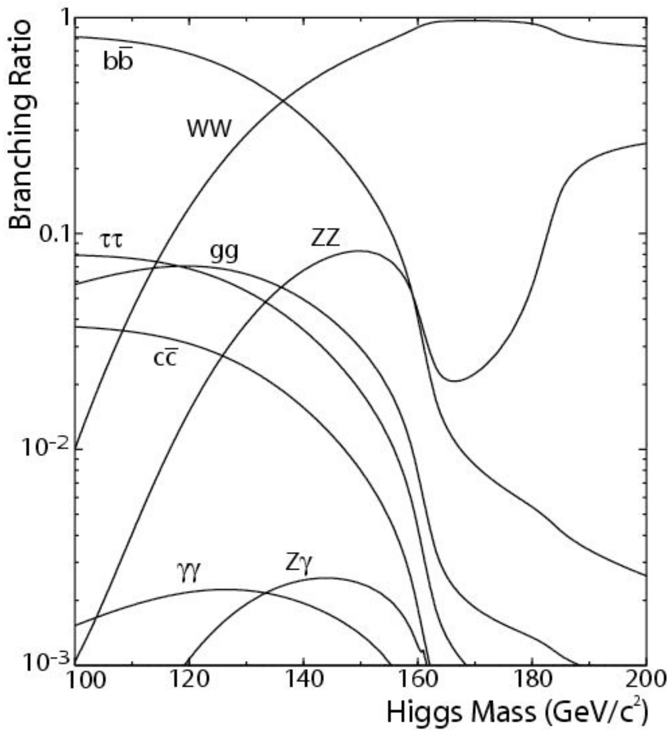


Distinguishing the signal from background is the most important point in this experiment

2. Analysis

2.1 Signal

2.1.1 Z & H decay mode



- H → bb (77%)

ZHH decay mode is categorized into three types.

- Z → *qq* (71%)
  ll (10%)
  vv (19%)

	qq HH	(145 ab)	large cross section, but complicated
e^+e^-→ZHH→	*ll* HH	(19.8 ab)	easy signature, but small cross section
	vv HH	(38.8 ab)	easy signature, not so small cross section

2.1 Signal

2.1.2 Signal & Background

Signal

$e^+e^- \rightarrow ZHH \rightarrow \nu\nu HH$ (38.8 ab)

Background

e^+e^-	$\rightarrow$	ZZ	$\rightarrow$ bbbb	(9,050 ab)
e^+e^-	$\rightarrow$	tt		(583,000 ab)
e^+e^-	$\rightarrow$	ZH		(62,100 ab)
e^+e^-	$\rightarrow$	tbtb		(1,200 ab)

2.2 Simulation flowchart

1. Generating events

   MadGraph & Physsim

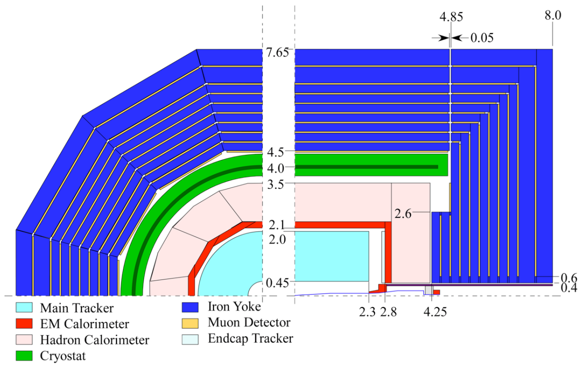
   ↓

2. Detector Simulation

   fast simulation

   ↓

3. Analysis



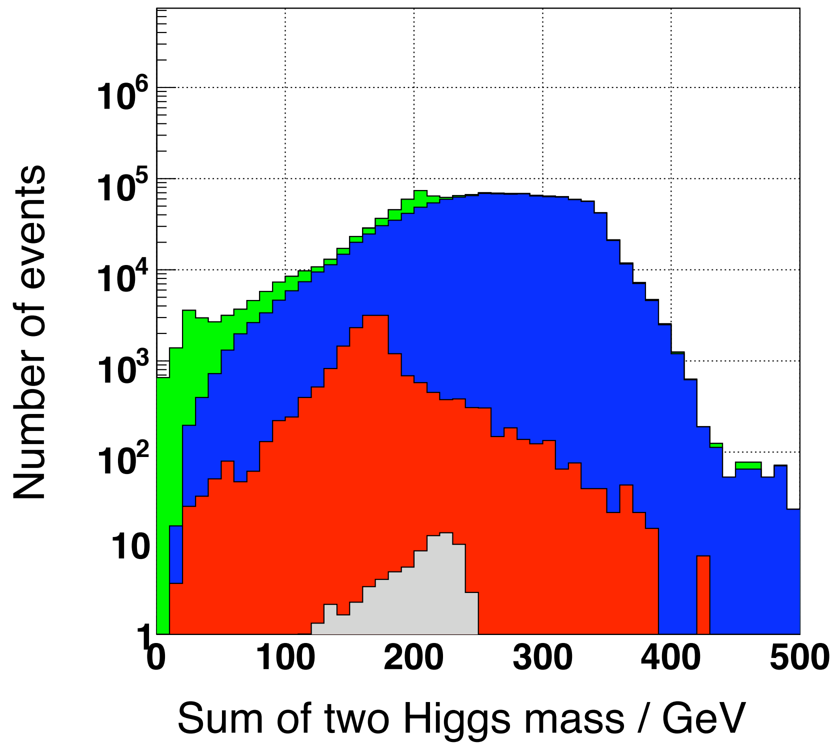
GLD detector

Parameter

- Higgs mass : 120 GeV
- Integrated Luminosity : 2000 fb^{-1}
- Model : Standard Model

2.3 Background rejection

The number of the events after jet pairing are described as below

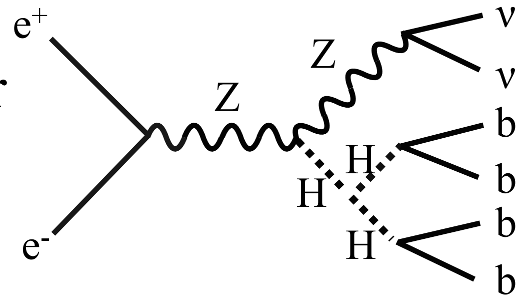


Signal	Number of events
ννHH	77.6
ZZ → bbbb	18,100
tt	1,167,200
ZH	124,200
tbtb	2,154

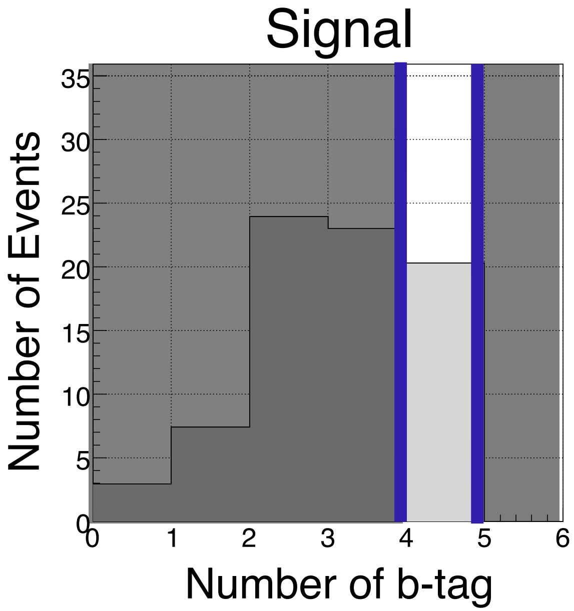
2.3 Background rejection

2.3.1. Flavor tagging method

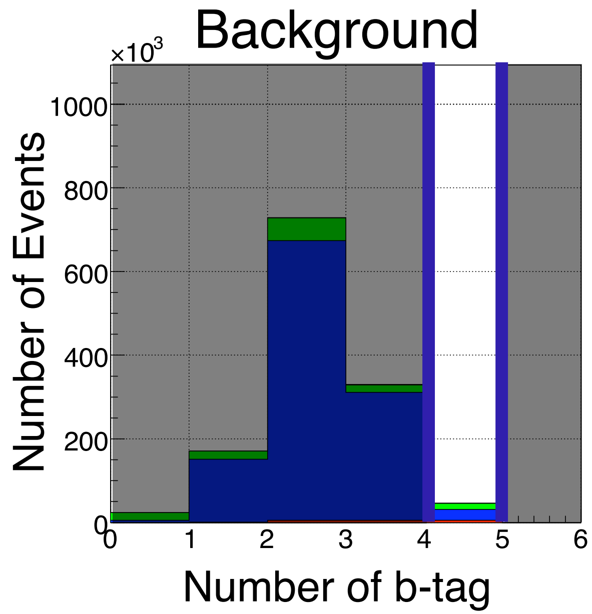
b quark has relatively long lifetime than other flavor of quarks(u,d,c,s). So it can be distinguished from others with 80% efficiency.



Cut : Number of b-tag = 4



77.6 → 20.1

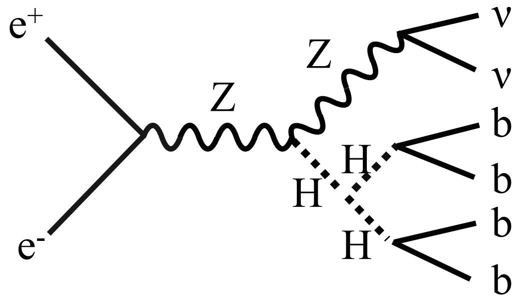


1,300,133 → 37,213

2.3 Background rejection

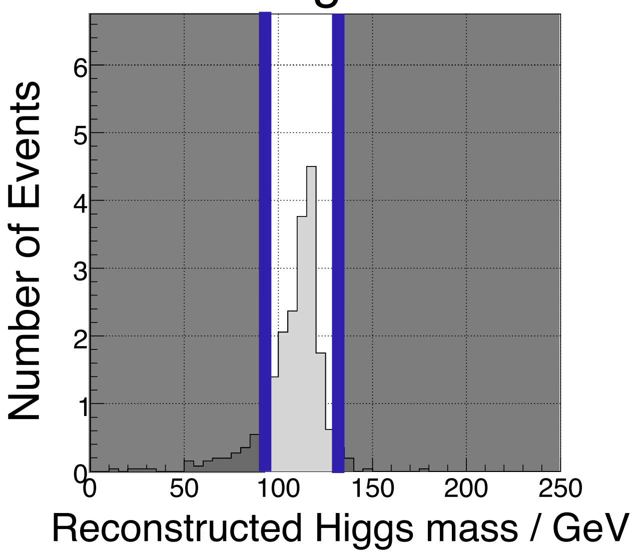
2.3.2. Higgs mass

If a event is a ννHH event, reconstructed two di-jet masses (${}^{rec}M_{H1,2}$) are around Higgs mass (120 GeV).



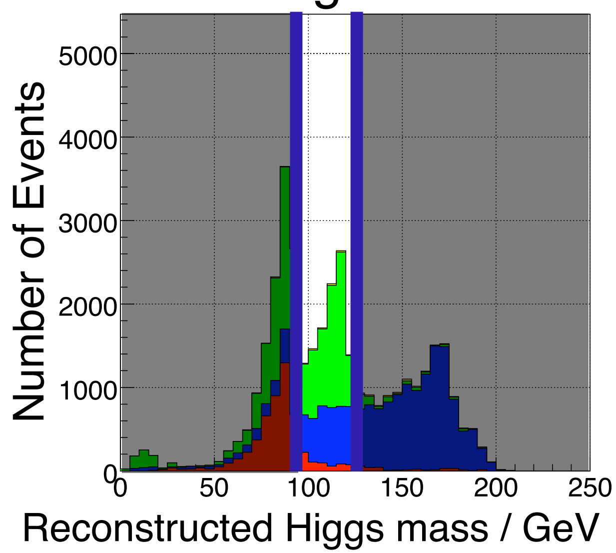
Cut : 90GeV < ${}^{rec}M_{H1,2}$ < 126GeV

Signal



20.1 → 15.3

Background

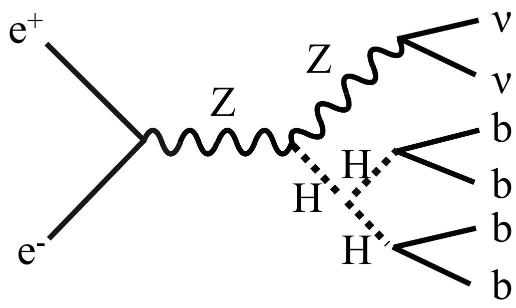


37,213 → 5,263

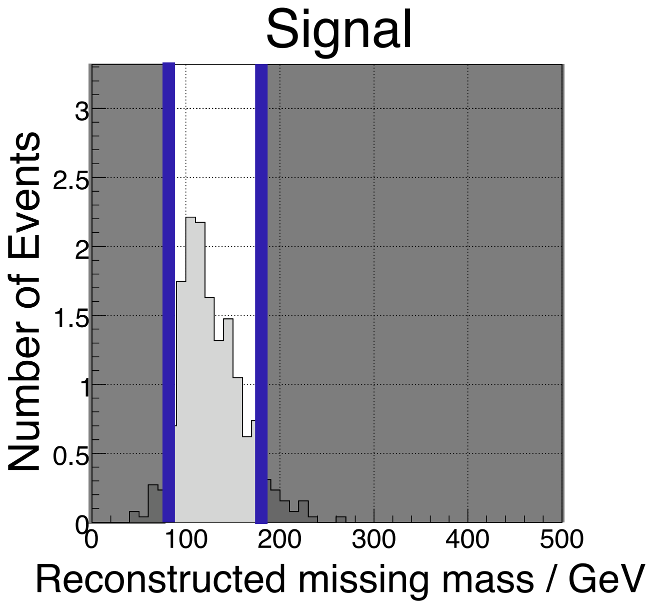
2.3 Background rejection

2.3.3. Missing mass

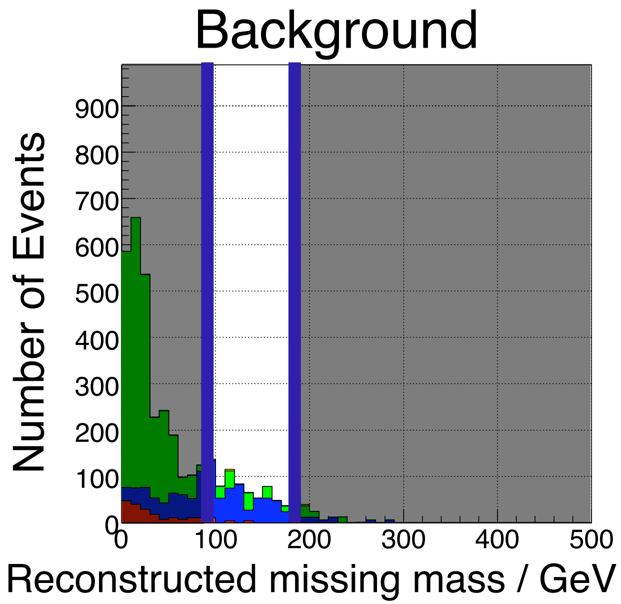
Two neutrinos can not be detected, so the missing mass ($^{rec}M_{miss}$) is around Z mass (91.2 GeV).



Cut : 70GeV < $^{rec}M_{miss}$ < 180GeV



15.3 → 14.3

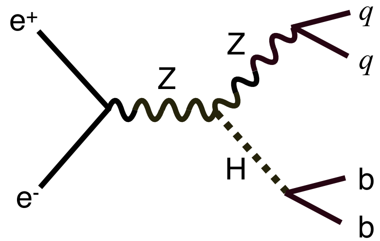


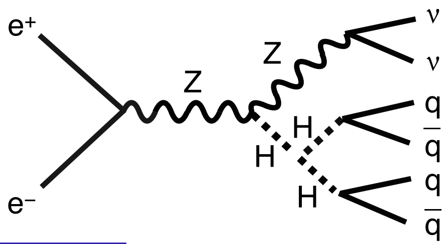
5,263 → 1,067

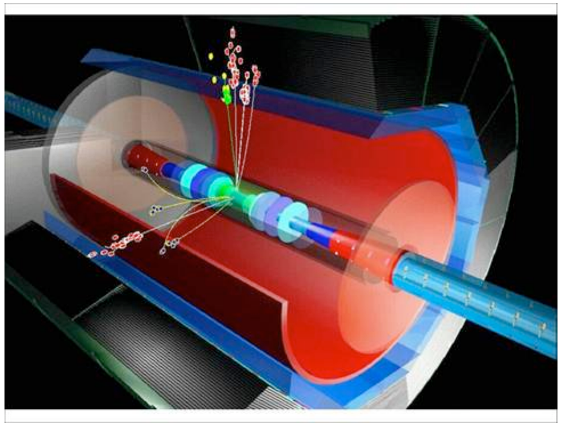
2.3 Background rejection

2.3.4. Missing transverse momentum

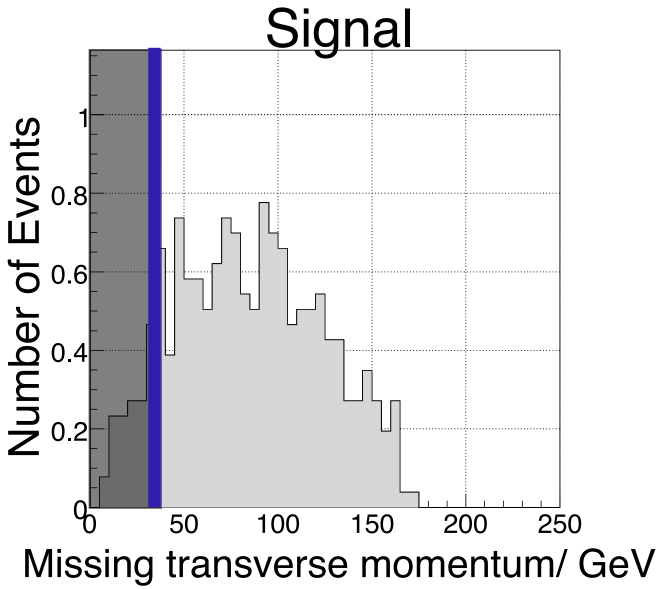
ZH has small missing transverse momentum ($^{miss}P_t$).



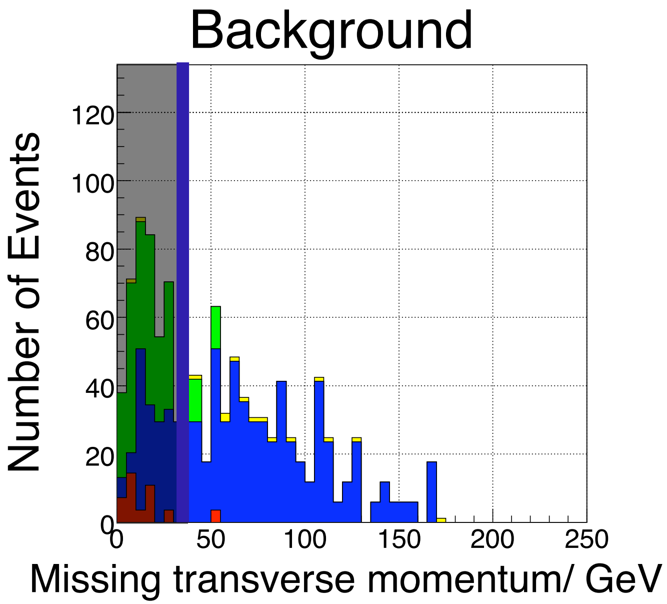




Cut : 30GeV < $^{miss}P_t$



14.3 → 13.7

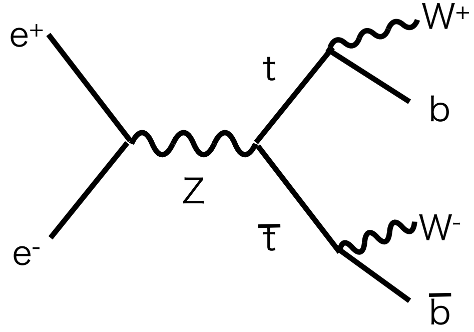


1,067 → 659

2.3 Background rejection

2.3.5. Lepton

tt events produce lepton tracks

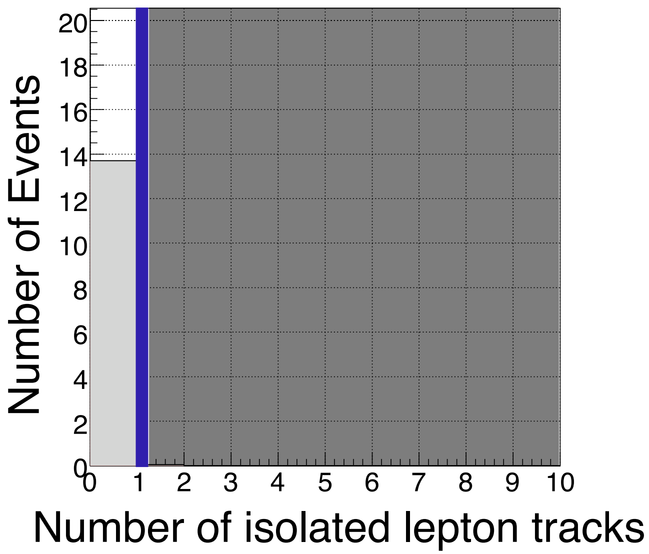


$W \rightarrow e + \nu_e$

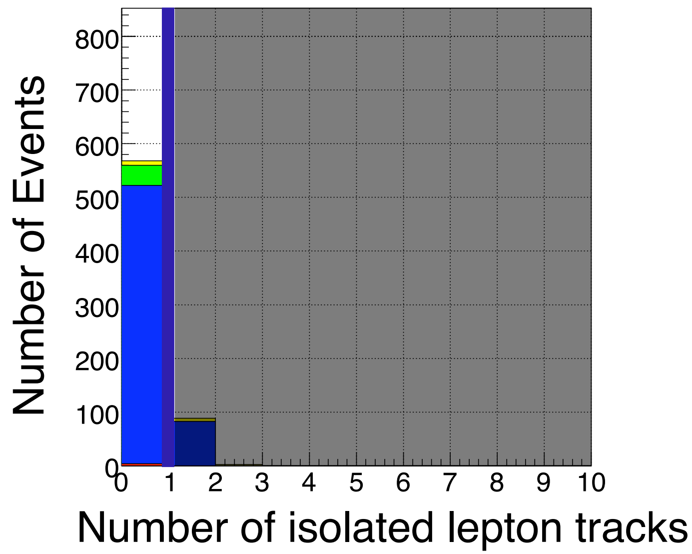
$\quad\quad\; \mu + \nu_\mu$

with 30% branching ratio

Cut : Number of isolated lepton tracks = 4



13.7 → 13.7



659 → 567

3. Result

RESULT

After selection cuts so far, we got a result

Selection cut	Signal	Background
No cut	77.6	1,300,133
Number of b-tagging = 4	20.1	37,213
90GeV < ${}^{rec}M_{H1,2}$ < 126GeV	15.3	5,263
70GeV < ${}^{rec}M_{miss}$ < 180GeV	14.3	1,067
30GeV < Missing P_t	13.7	659
Number of leptons = 0	13.7	567

RESULT

Signal significance is 0.57 ($=13.7 \div \sqrt{13.7+567}$)

Stronger background rejection is necessary.

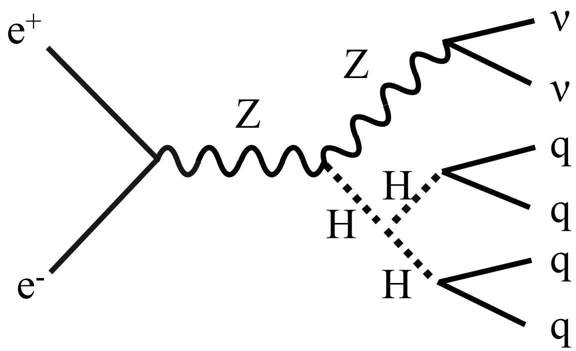
Analysis with ZHH $\rightarrow$ qqHH (6-jet mode) will be studied

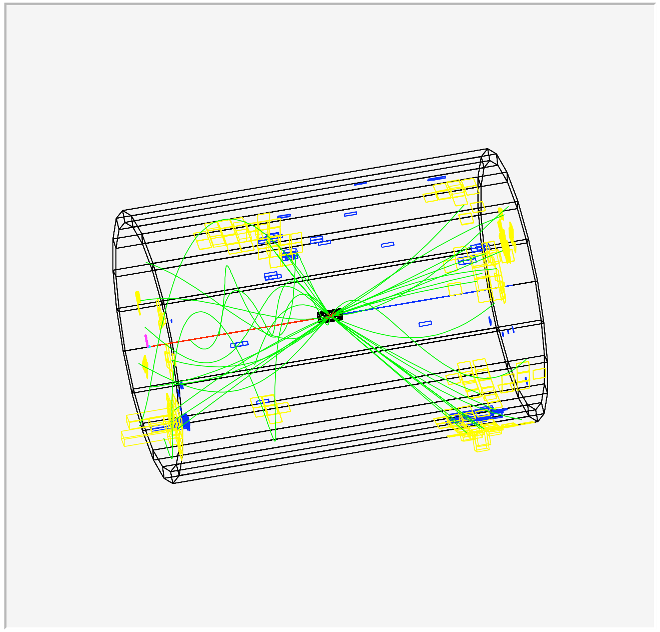
Thank you for listening

Back up

2.4 Jet pairing

We want to know which of the jet pair is coming from Higgs





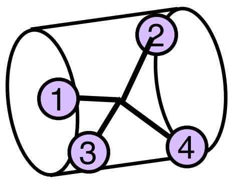
4 jets are forced into 2 jet pairs by energy and momentum.

$$\chi^2 = \frac{({}^{rec}M_{H_1} - M_H)^2}{\sigma_{H_1}^2} + \frac{({}^{rec}M_{H_2} - M_H)^2}{\sigma_{H_2}^2}$$

2.4 Jet pairing

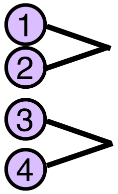
Example

When each jet has the four momentum listed below,



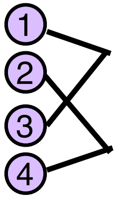
$$p^1 = (E_1 , \mathbf{P}_1) = (114 , 35.9 , 105 , -24.1)$$
$$p^2 = (E_2 , \mathbf{P}_2) = (59.6 , 33.6 , -18.4 , -42.4)$$
$$p^3 = (E_3 , \mathbf{P}_3) = (49.2 , 32.0 , -28.9 , 1.80)$$
$$p^4 = (E_4 , \mathbf{P}_4) = (153 , -81.2 , -125 , 25.9)$$

Three candidates of Higgs are calculated as follows



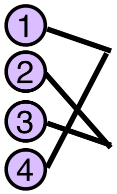
a

$$^{rec}M_{H_1 a} = \sqrt{(E_1 + E_2)^2 - (\boldsymbol{P}_1 + \boldsymbol{P}_2)^2} = 116 \text{ GeV}$$
$$^{rec}M_{H_2 a} = \sqrt{(E_3 + E_4)^2 - (\boldsymbol{P}_3 + \boldsymbol{P}_4)^2} = 118 \text{ GeV}$$



b

$$^{rec}M_{H_1 b} = \sqrt{(E_1 + E_3)^2 - (\boldsymbol{P}_1 + \boldsymbol{P}_3)^2} = 126 \text{ GeV}$$
$$^{rec}M_{H_2 b} = \sqrt{(E_2 + E_4)^2 - (\boldsymbol{P}_2 + \boldsymbol{P}_4)^2} = 101 \text{ GeV}$$



c

$$^{rec}M_{H_1 c} = \sqrt{(E_1 + E_4)^2 - (\boldsymbol{P}_1 + \boldsymbol{P}_4)^2} = 263 \text{ GeV}$$
$$^{rec}M_{H_2 c} = \sqrt{(E_2 + E_3)^2 - (\boldsymbol{P}_2 + \boldsymbol{P}_3)^2} = 81.7 \text{ GeV}$$