Little Higgs with T parity at ILC

Senior presentation 2010/3/10

Tohoku Univ. Eriko Kato

Out line

- Introduction of International Linear Collider(ILC)
- Introduction of Little Higgs model(LHT)
- Motivation
- Selection criteria
- Mass extraction
- Summary

International Linear Collider(ILC)

High energy $e^+ e^-$ collider

- Clean
- High precision measurements

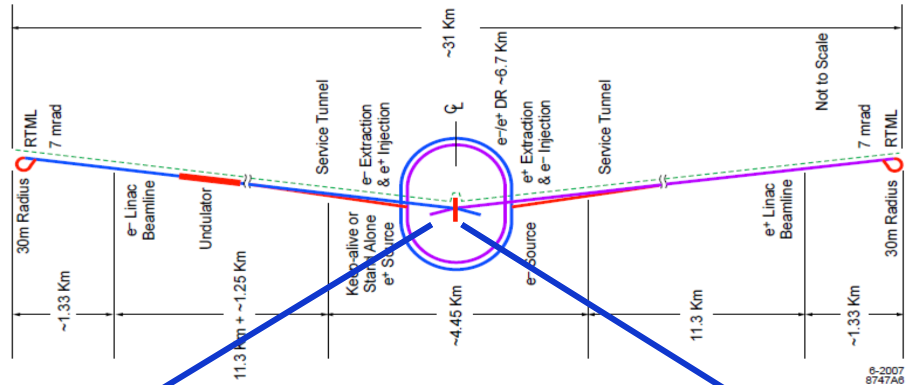
(position ,momentum ,energy etc…)

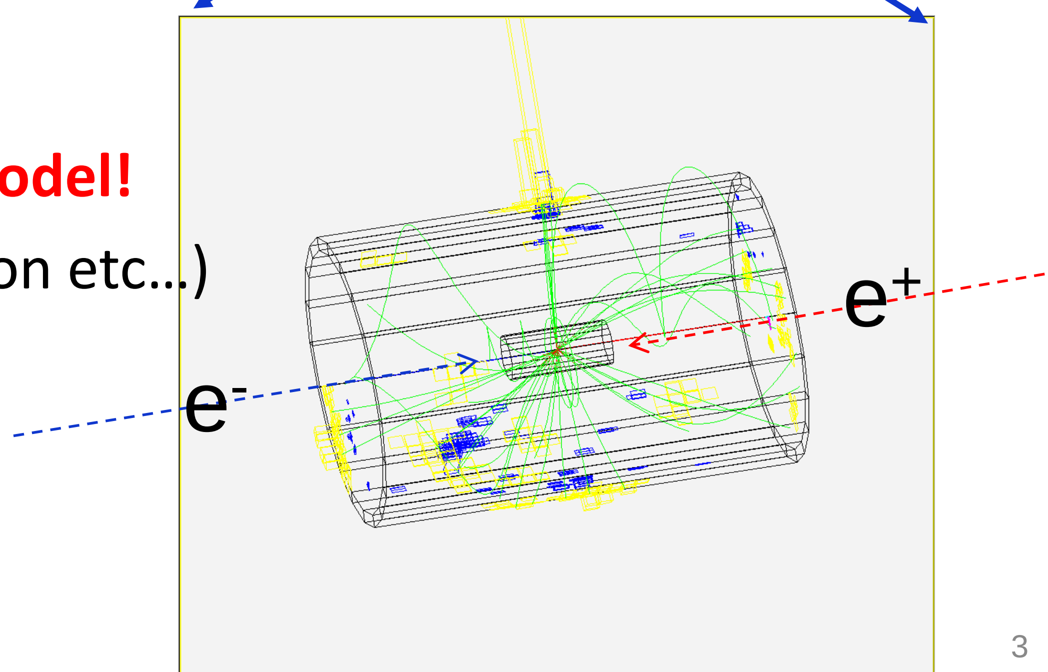
analyze

Search for

new physics beyond standard model!

(SUSY, Little Higgs, extra dimension etc…)





new physics beyond standard model

little hierarchy problem

$$m_{Higgs}^2 = m_0^2 + \delta m^2$$

- m_{Higgs}^2 : Higgs mass
- m_0^2 :Bare Higgs mass
- δm^2 :Higgs mass quadrically divergent corrections
- Λ :Cutoff scale

$$\delta m^2 \approx (0.27\Lambda)^2$$

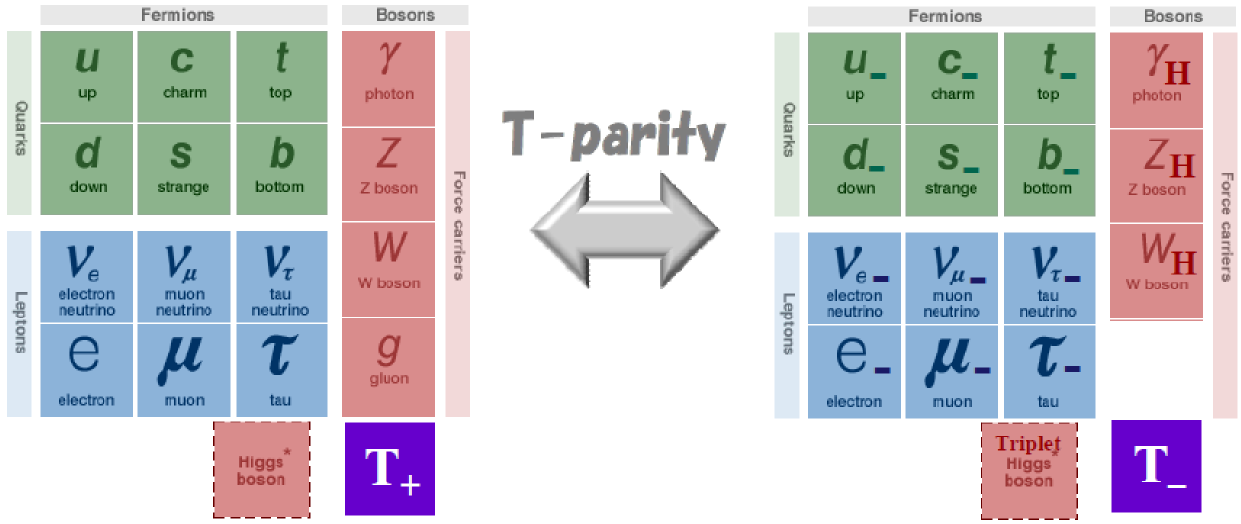
1. Fine tuning Λ<1 TeV
2. Electroweak precision measurements Λ>10TeV

➢ Conflict between these two scales

Little Higgs with T parity model

Solution to little hierarchy problem

- Higgs boson is regarded as pseudo Nambu-Goldstone boson of a symmetry at some higher scale.
- T-parity predicts A_H as a dark matter candidate

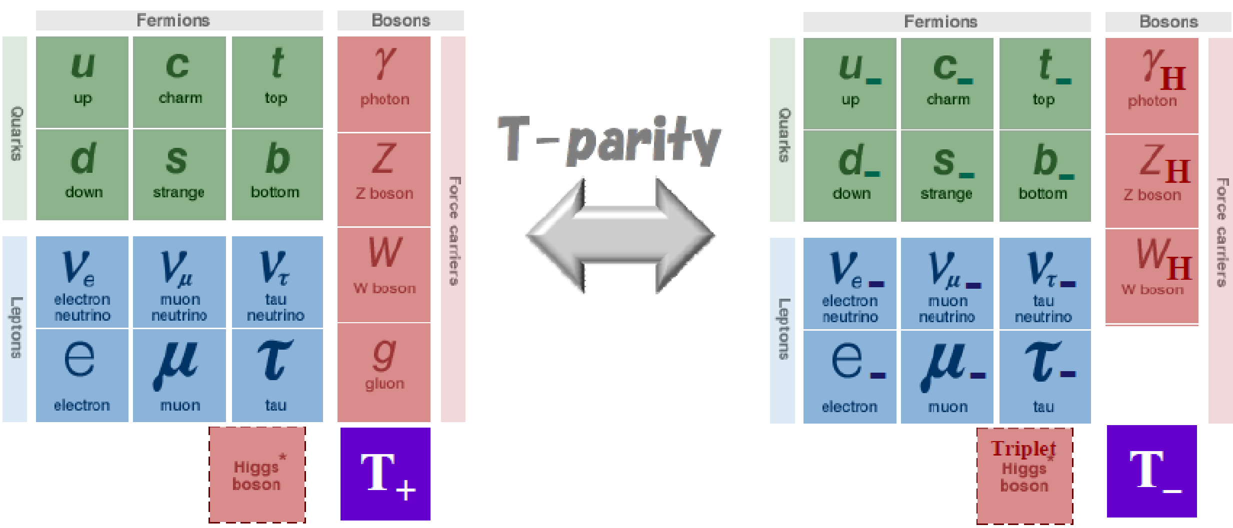


Motivation

Little Higgs with T-parity(LHT) predicts new heavy gauge bosons :A_H,Z_H,W_H

- By measurements of heavy gauge bosons we can find f:vacuum expectation value

➢ Analyze $e^+e^- \rightarrow Z_H Z_H$ and see how precise ILC can measure f at 1TeV



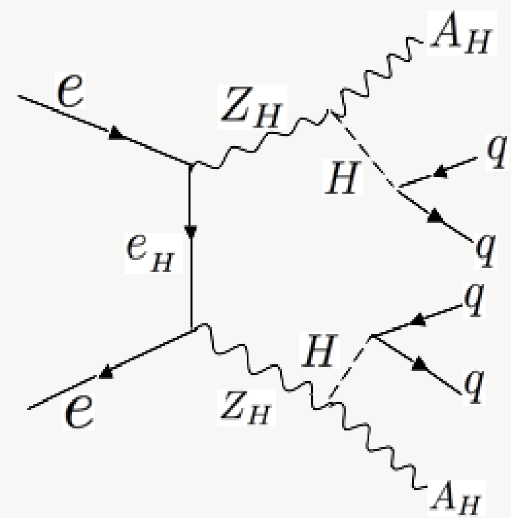
$$m_{Z_H} \approx gf$$

$$m_{A_H} \approx \sqrt{0.2}gf$$

Simulation environment

Signal

- $e^+e^- \to Z_H Z_H$ (99.52fb)



Background

- $e^+e^- \to WW$ (3069fb)
- $e^+e^- \to tt$ (192.9fb)
- $e^+e^- \to WWZ$ (5.922fb)
- $e^+e^- \to \nu\nu WW$ (6.682fb)

Set up

$\sqrt{s}$ = 1 TeV
Luminosity=500 fb^{-1}
No beam polarization
Higgs mass=134GeV

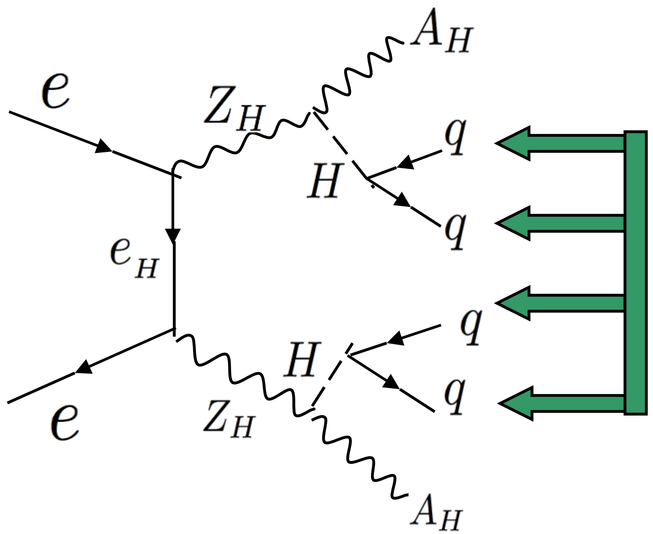
Higgs event reconstruction

- Used χ^2 to assign each jet to reconstruct a higgs with a mass close to 134GeV

➢ select jet pair with minimum χ^2 as the true solution

$$\chi^2_H = \left(\frac{M_{H1} - M_H}{\sigma_{M_H}}\right)^2 + \left(\frac{M_{H2} - M_H}{\sigma_{M_H}}\right)^2$$

$$M_H = 134.0(GeV) \qquad \sigma_{M_H} = 8.0(GeV)$$

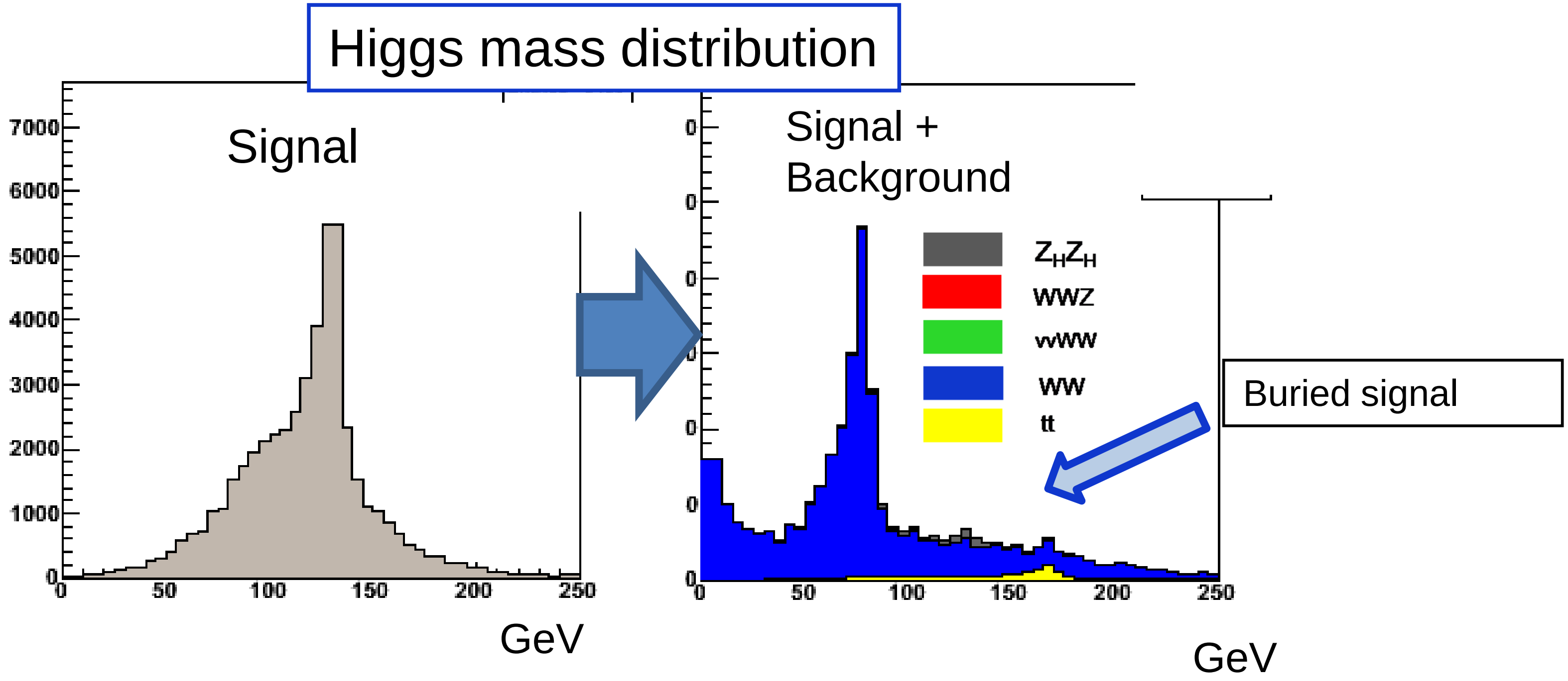


There are ${}_4C_2 /2 = 3$ ways to reconstruct the jets into higgs

Higgs mass distribution

- Success in Higgs reconstruction
  - – Signal is buried in background

➤ Selection cut was studied



χ^2 distribution

Calculated χ^2

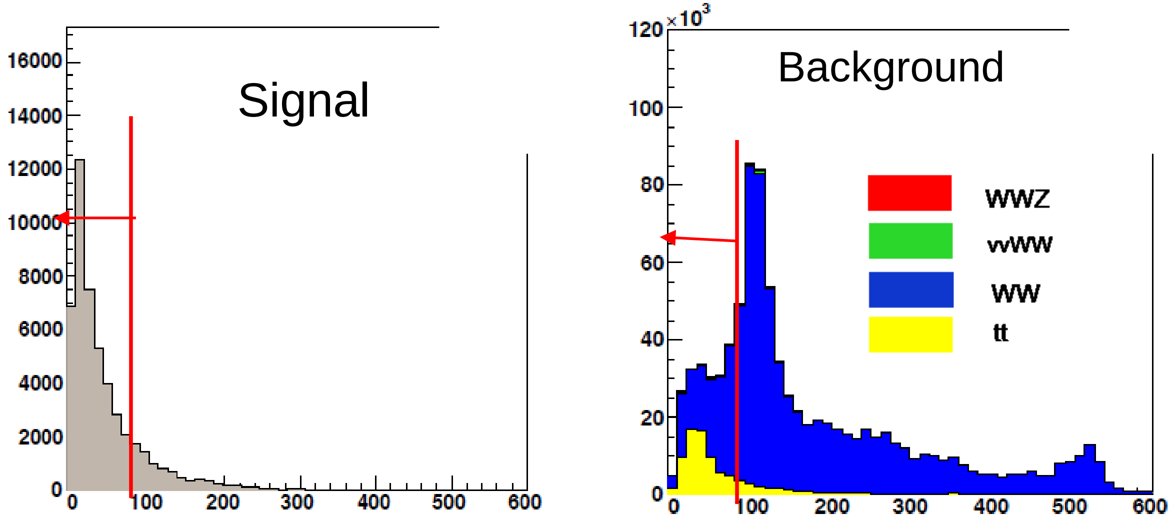
- χ^2 shows mass difference from higgs.

$$\chi_H^2 = \left(\frac{M_{H1} - M_H}{\sigma_{M_H}}\right)^2 + \left(\frac{M_{H2} - M_H}{\sigma_{M_H}}\right)^2$$

$$M_H = 134.0(GeV) \qquad \sigma_{M_H} = 8.0(GeV)$$

➢ **We can cut WW background by selecting events χ^2 <80**

χ^2 distribution

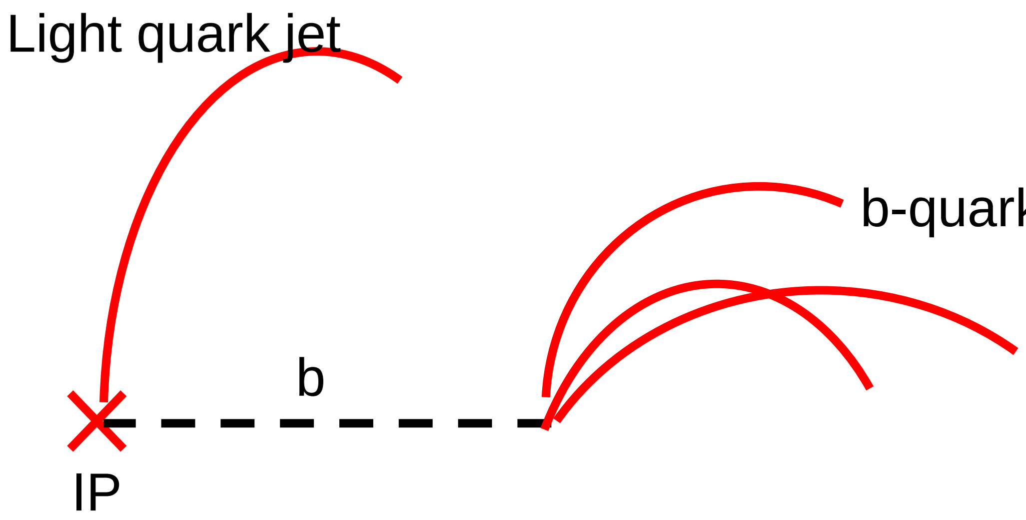


b-tagging principle

b-tagging algorithm in simulator tags jets as b quark

Using the following b quark features

- Light quark jets have short life times
- b-jets have relatively long life times and tend to decay into multiple tracks.

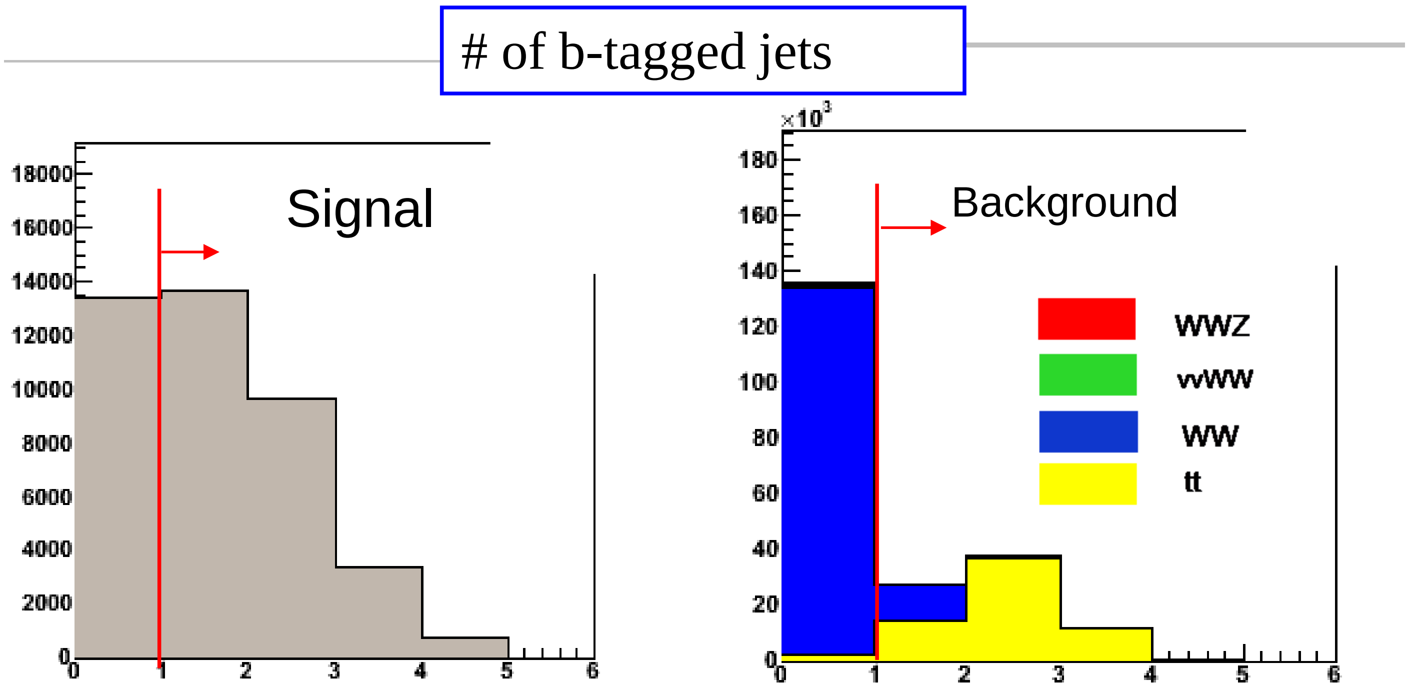


of b-tagged jet distribution

of b-tagged jets

- Br(H→bb) =42.35% Br(H→WW)=39.57%

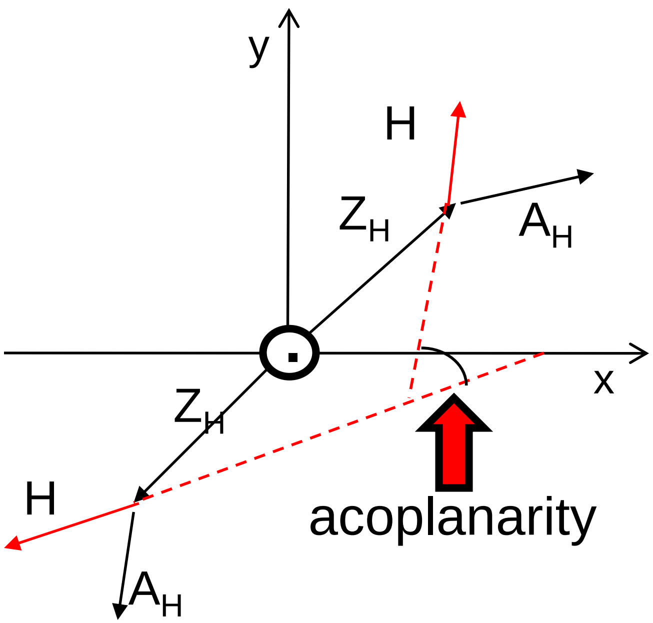
We can cut WW background by selecting #b-tagged jets>0



acoplanarity

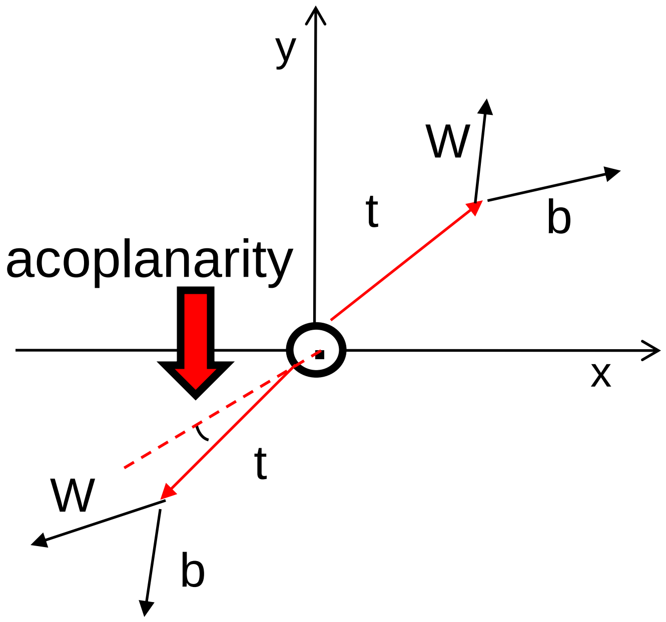
acoplanarity= angle difference from back-to-back

signal



not back-to-back

tt

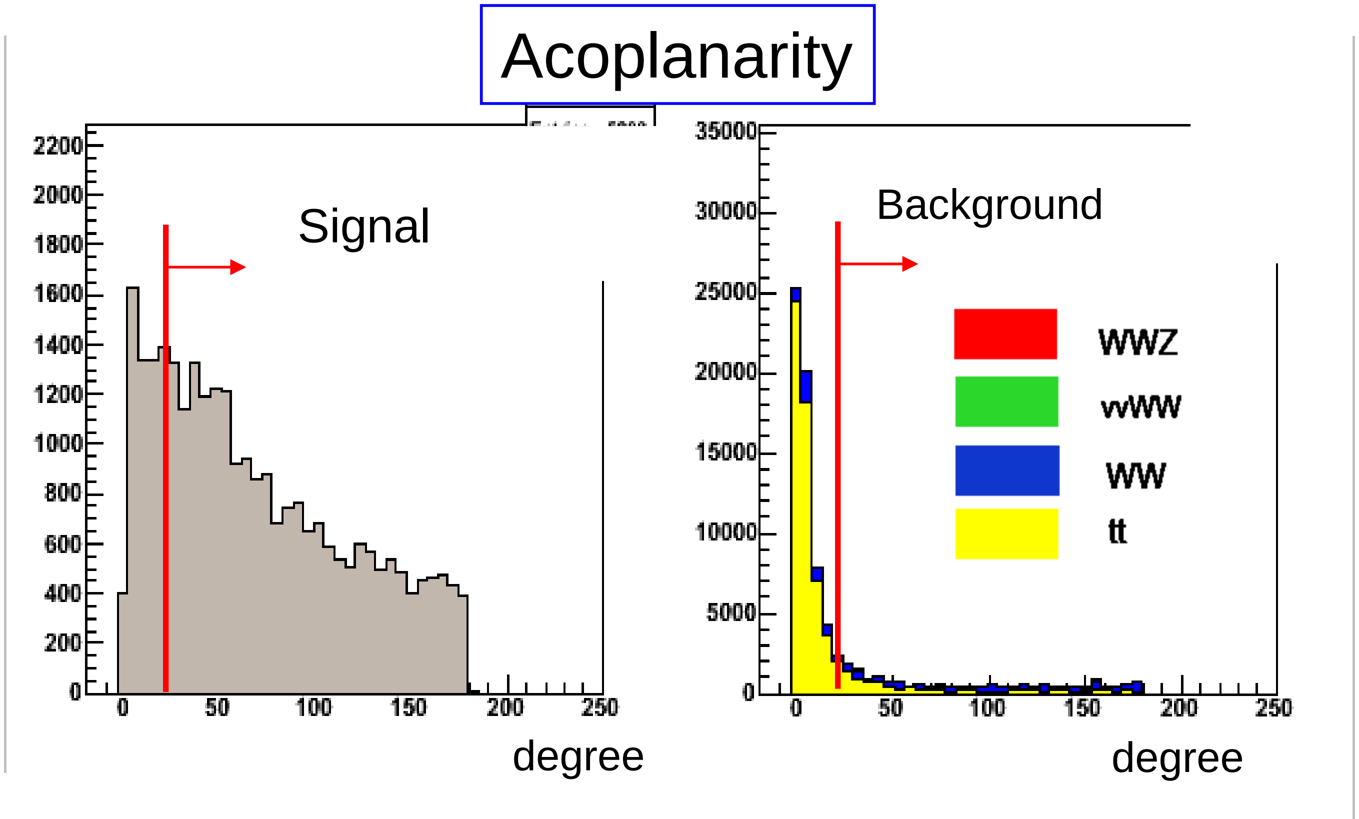


Back-to-back

Acoplanarity distribution

Acoplanarity cut

- We can cut tt background by selecting acop>25°



results

#Event (efficiency %)	$Z_H Z_H$	WWZ	ννWW	WW	tt	significance
Cross section (fb)	97.97	5.922	6.682	3932	192.9	
No cut	$4.973*10^4$	2961	3340	$8.945*10^5$	$9.647*10^4$	**48.60**
χ^2<80	$4.155*10^4$ (83.55%)	871 (29.41%)	1607 (48.11%)	$1.449*10^5$ (16.20%)	$6.668*10^4$ (69.12%)	**82.18**
#b-tag>0	$2.798*10^4$ (56.26%)	114.5 (3.867%)	536.5 (16.06%)	$1.321*10^4$ (0.1477%)	$6.412*10^4$ (66.47%)	**85.96**
acop>25	$2.136*10^4$ (42.95%)	95.74 (3.093%)	442.8 (13.26%)	$8.463*10^3$ (0.09461%)	$8.354*10^3$ (8.670%)	**108.6**

Significance 48.60 → 108.60

$$significance \equiv \frac{N_{sig}}{\sqrt{N_{sig} + N_{bg}}}$$

Performing mass extraction

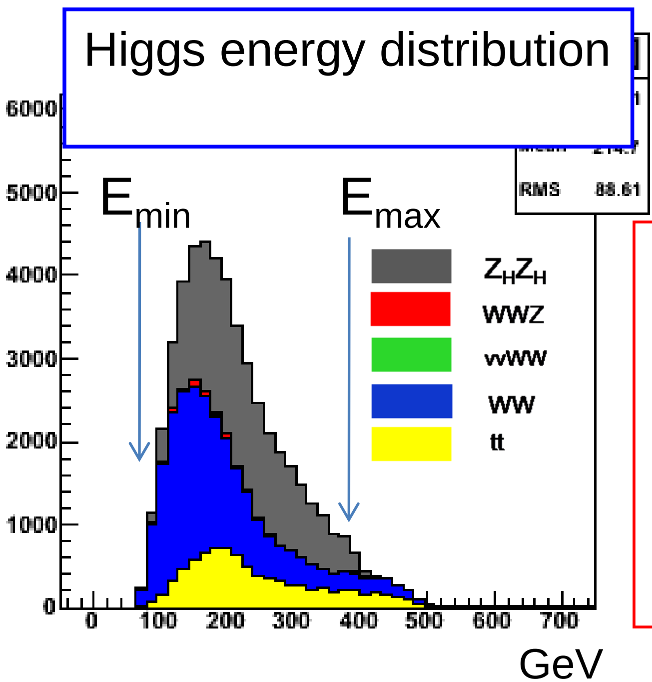
~ Determining Z_H A_H mass ~

Higgs energy distribution

The edge of Higgs energy possesses information of Z_H A_H mass

E_{min} E_{max} → m_{ZH} m_{AH}

(E_+ E_-)



$$E_- \equiv \frac{E_{max} - E_{min}}{2}$$

$$E_+ \equiv \frac{E_{max} + E_{min}}{2}$$

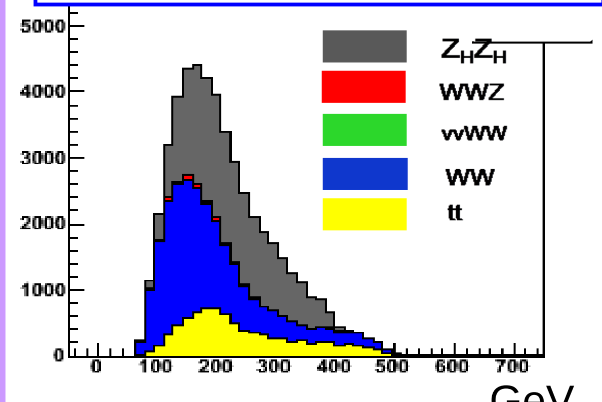
$$m_{Z_H} = \sqrt{s}\left(\frac{(E_+^2 - E_-^2 + m_H^2) \pm \sqrt{(E_+^2 - E_-^2 + m_H^2)^2 - 4E_+^2 m_H^2}}{8E_+^2}\right)^{\frac{1}{2}}$$

$$m_{A_H} = \left(m_H^2 + \left(1 - \frac{4E_+}{\sqrt{s}}\right) m_{Z_H}^2\right)^{\frac{1}{2}}$$

Determining Z_H A_H masses

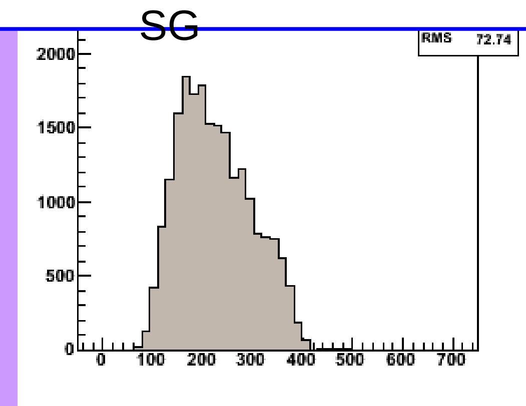
Subtract background and fit signal

Higgs energy distribution



assuming SM information

Higgs energy distribution



Fit function

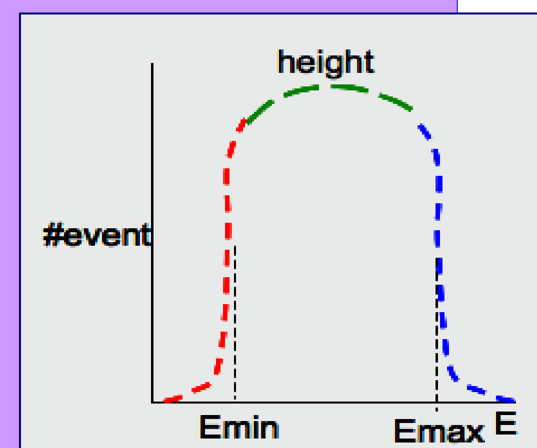
Height Rising edge Falling edge

$$F(E; c_{0\ 6}, E_{min,max}) = \frac{1}{4} c_0 \{1 + f_{Err}\left(\frac{E - E_{min}}{c_1}\right)\}\{1 - f_{Err}\left(\frac{E - E_{max}}{c_2}\right)\}$$

$$\times \left(1 + c_3 E + c_4 E^2 + c_5 E^3 + c_6 E^4 + c_7 E^5 + c_8 E^6\right)$$

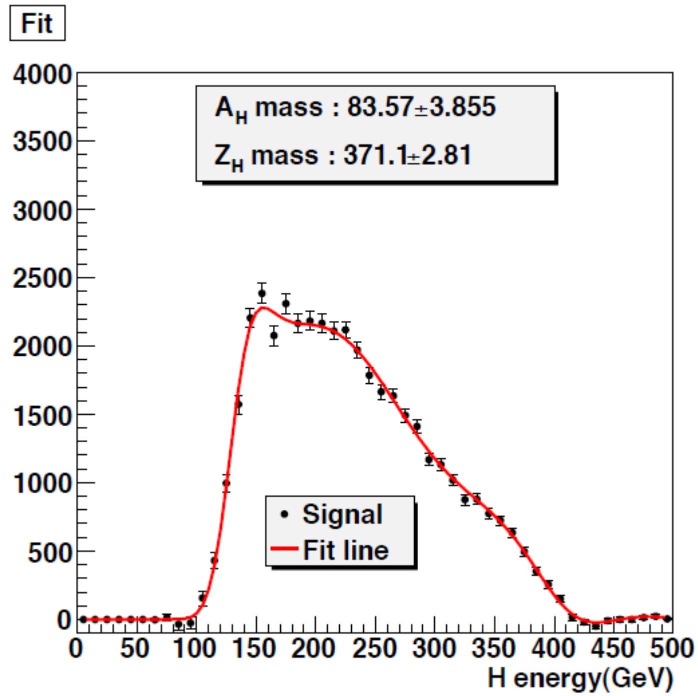
correction

$$f_{Err}(x) \equiv \int_0^x \frac{2}{\sqrt{\pi}} exp(-t^2) dt$$



result

We determined Z_H A_H mass by fitting



$A_H$mass = 83.57± 3.86GeV true value:81.9GeV

$Z_H$mass = 371.1 ±2.81GeV true value:369GeV

When analyzing $A_H Z_H$ at 500GeV 500fb^{-1}

$A_H$mass = 83.2 ± 13.3 GeV

$Z_H$mass = 366.0 ±16.0 GeV

Succeed in high-precision measurement

summary

- LHT is as a beyond standard model that solves little hierarchy problem .
- Our motive is to investigate how precise ILC can measure LHT parameters .
- When performed cutting ,significance was 108.6.
- Introduced and performed mass extraction.
- An reasonable value of A_H Z_H mass was found.

$A_H$mass = 83.57± 3.86GeV   (true value:81.9GeV)
$Z_H$mass = 371.1 ±2.81GeV   (true value:369GeV)

plan

- Continue studying on evaluating background contamination.
- Determine vacuum expectation value f.

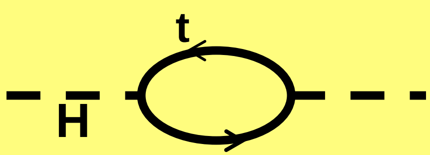
Backup slides

Diagram cancellations

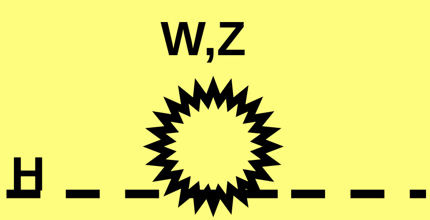
Contribution to δm^2

- **Standard model**

top contribution



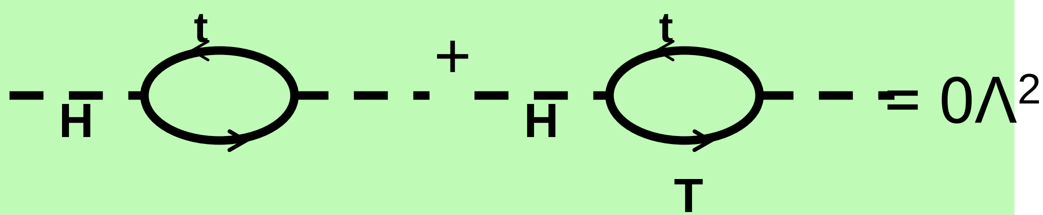
gauge contribution



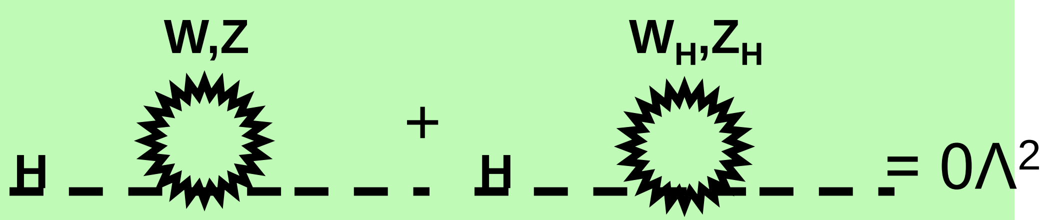
fine tuning

- **Little Higgs with T parity**

top contribution



gauge contribution



No need for fine tuning at 1-loop level

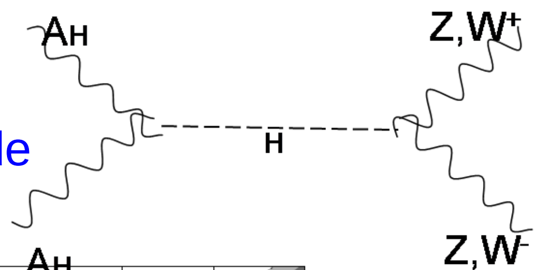
Higgs mass @LHT

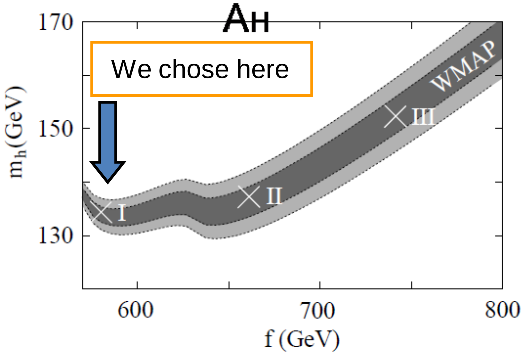
Higgs mass constraints by WMAP observation

- $A_H A_H H$ vertex is given by the SM coupling.
- Annihilation cross section depends on m_{AH} and m_H

➢ WMAP constraints on Relic abundance A_H:$\Omega h^2(m_{AH}(f), m_H)$

Main annihilation mode





$$\Omega h^2 = 0.106 + -0.008$$

(wmap observation)

	Point I	Point II	Point III
f	580 (GeV)	660 (GeV)	740 (GeV)
m_h	134 (GeV)	137 (GeV)	152 (GeV)
$\Omega_{\rm DM} h^2$	0.106	0.104	0.106
m_{A_H}	81.9 (GeV)	95.9 (GeV)	110 (GeV)
m_{W_H}	368 (GeV)	421 (GeV)	474 (GeV)
m_{Z_H}	369 (GeV)	422 (MeV)	474 (MeV)
m_Φ	440 (GeV)	513 (GeV)	640 (GeV)
$m_{e_H}(\kappa_{l_1} = 0.5)$	410 (GeV)	467 (GeV)	523 (GeV)
$m_{e_H}(\kappa_{l_1} = 1.0)$	820 (GeV)	933 (GeV)	1050 (GeV)

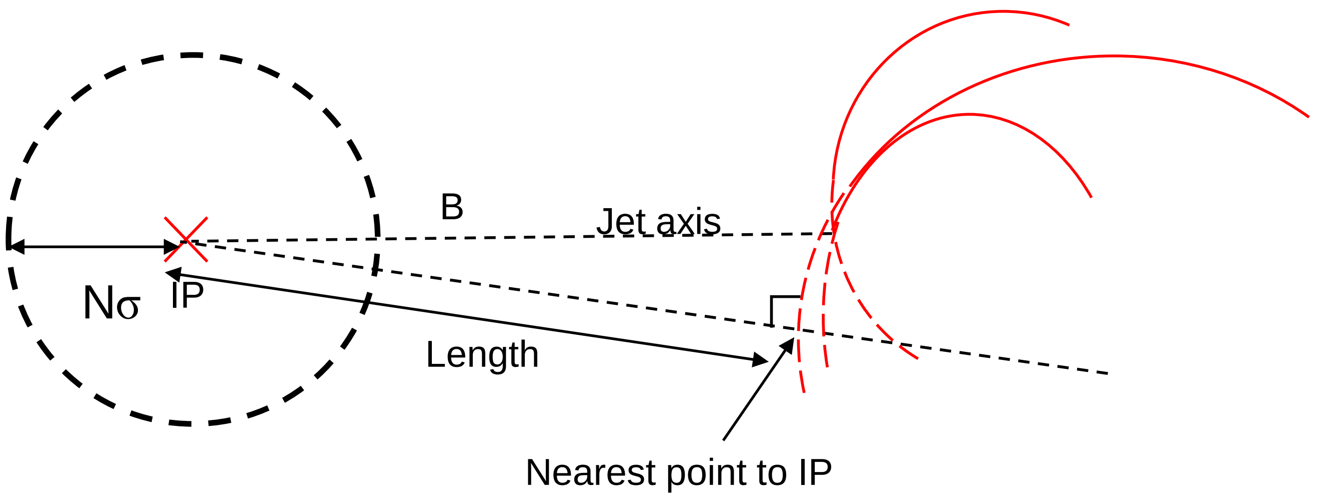
Reference :S.Matumoto M.Asano
"Littlest Higgs with T parity"

b-tagging principle

b-tagging algorithm used in quicksimulator tags jets as b when the events satisfy the following conditions;

- **To maximizes significance (Nσ,#tracks)=(3,2)**
- Distance of closest approach ≧ Nσ
- # of tracks satisfying the above criteria ≧#tracks
- b-tag efficiency is approx.50%

σ=impact parameter resolution



Higgs branching ratio

Standard model information

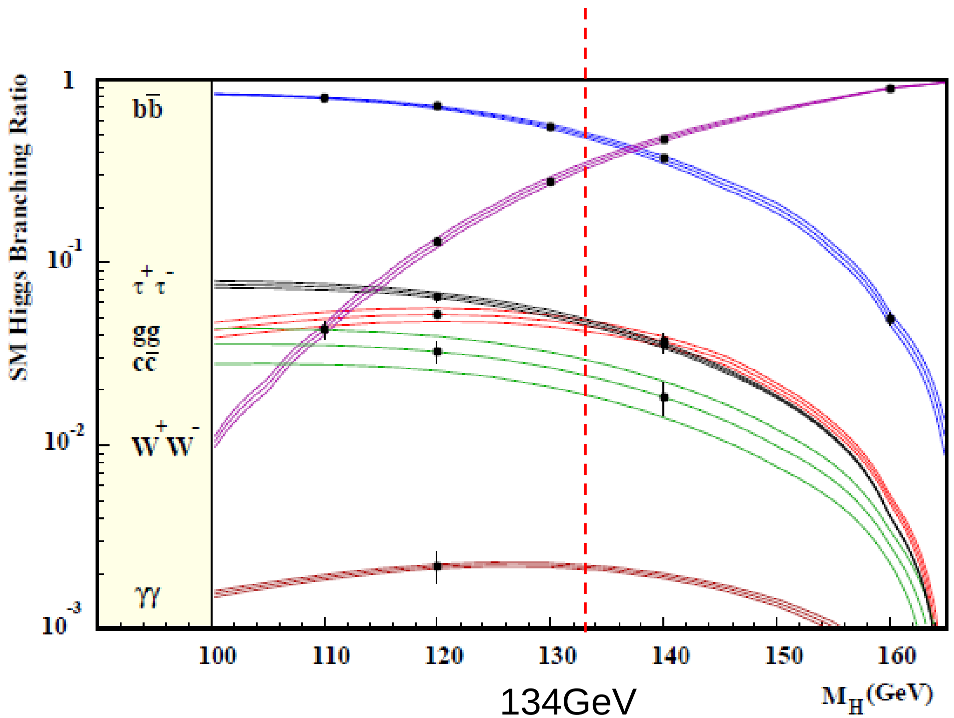


FIGURE 2.12. The branching ratio for the SM Higgs boson with the expected sensitivity at ILC. A luminosity of 500 fb^{-1} at a c.m. energy of 350 GeV are assumed; from Ref. [93].

Pythia information

When higgs mass =134GeV

Br(h→bb) =42.35%
Br(h→WW)=39.57%
Br(h→ZZ) =5.50%
Br(h→ττ)= 5.21%
Br(h→gg) =4.49%□
Br(h→cc)= 2.31%

Problem with analyzing H->WW

H->WW H->bb