Simulation study of $Z_H A_H$ mode in Littlest Higgs model with T-parity

LCWS 08 Chicago

Nov. 18 2008

Tomonori Kusano(Tohoku Univ.)

with

Theorist : S.Matsumoto(Univ. of Toyama), M.Asano(ICRR)

Experimentalist : K.Fujii(KEK), Y.Takubo,R.Sasaki(Tohoku Univ.)

Today's topic

- Introduction
- Simulation Setup
- Event selection
- Mass determination

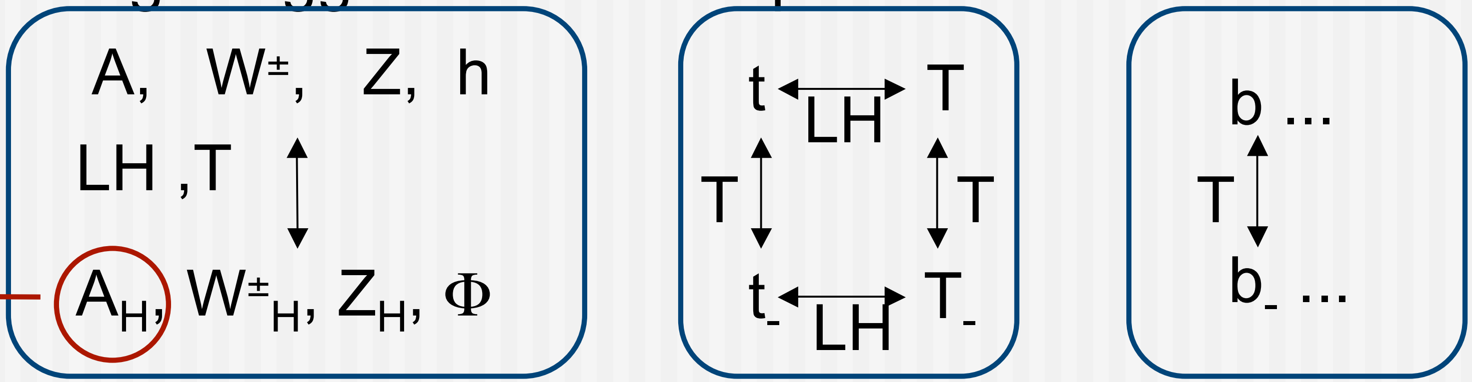
Introduction

- Little Higgs Model with T-Parity could solve the little hierarchy problem and suggest the DM candidate.

LH: Little Higgs partner
T: T-Parity partner

Particle contents

Gauge-Higgs sector | Top sector | fermion sector

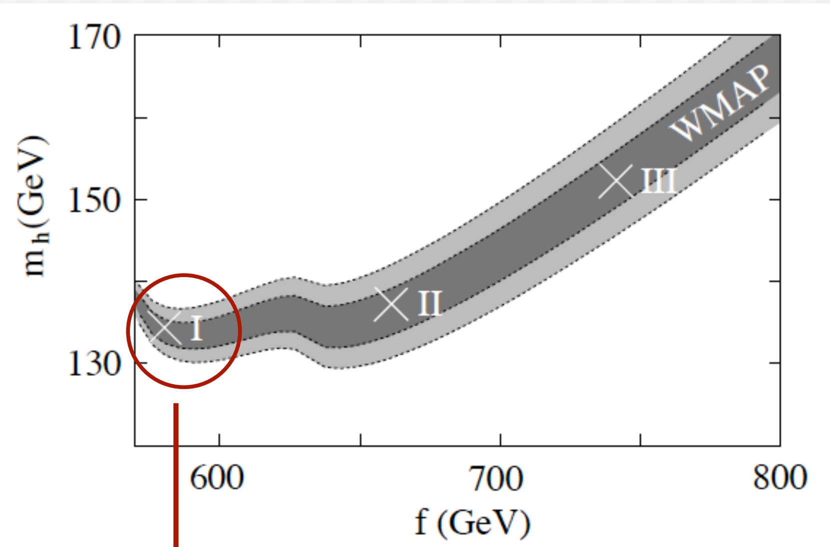


A_H is stable due to T-Parity. → Dark matter Candidate!

Parameters region

Spectrum in the Gauge-Higgs sector is determined by breaking scale (f) and Higgs boson mass (m_h).

f and m_h are constrained by the WMAP experiment.



Point I

m_{AH} : 81.9GeV

m_{ZH} : 369GeV

m_h : 134GeV

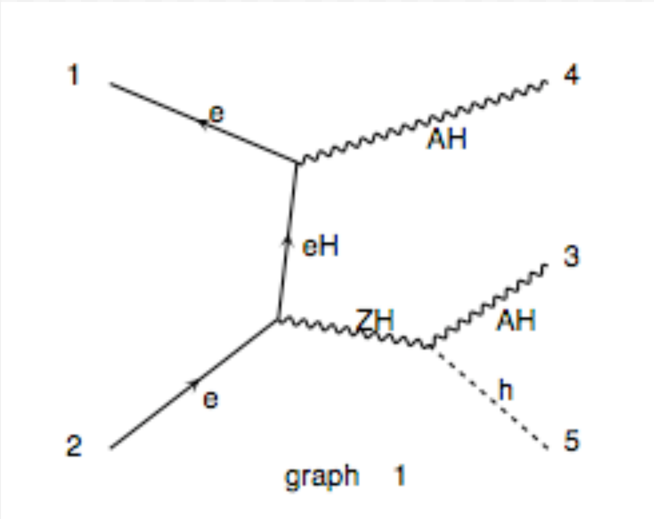
f : 580GeV

Heavy Gauge bosons are less than 500GeV.

ILC can search them!

Our target Process

- One of the attractive processes in LHT is $e^+e^- \to Z_H A_H$.
($Z_H \to A_H + h$ with 100% branching ratio)

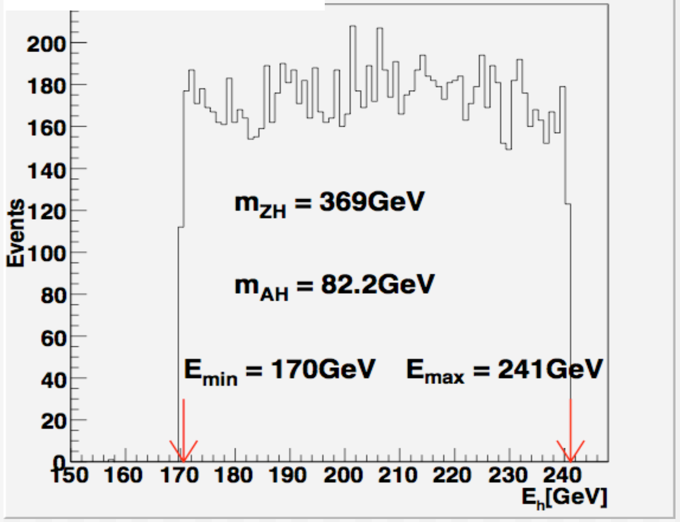


DM candidate (A_H) will be produced.
This process can occur at ILC for $s^{1/2} = 500\text{GeV}$.

Motivation of our analysis

- Our goal is the determination of the masses of heavy gauge bosons, Z_H and A_H.
  This is higgs energy dist. before the detector simulation.

Higgs energy



- These masses can be determined from the edges of higgs energy distribution.

Analysis flow chart

- Analysis flow chart is as follows.

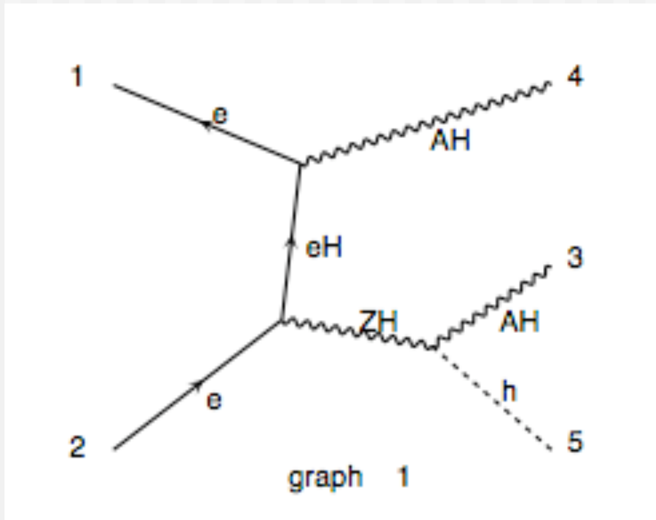
  Event generation : Madgraph (for signal)
  and physsim (for BG)
  ↓
  Hadronization : Pythia
  ↓
  Detector simulation : JSF quick-simulator
  ↓
  Analysis : ROOT

Signal Event generation

- Signal Events are generated by MadGraph.
  Parameters : sample point 1

  mass:
  A_H :81.9GeV
  Z_H : 369GeV
  h : 134GeV
  e_H : 410GeV

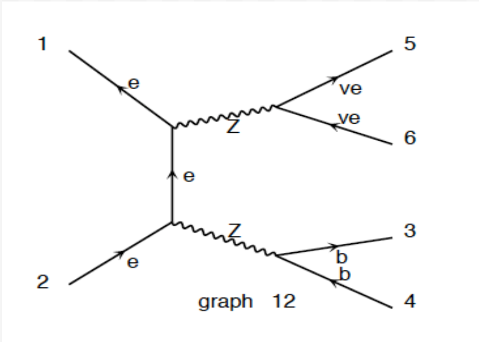
  BR($h \to bb$)= 55%
  BR($h \to WW$)=26%
  BR($h \to cc$)=6.4%
  $s^{1/2}$ = 500GeV
  cross section : 1.9fb

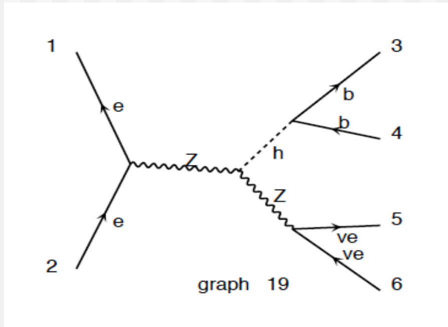


Event generation for BG

- The main BG processes are those of the final states with bbνν and ccνν. These are diagrams of BG processes.

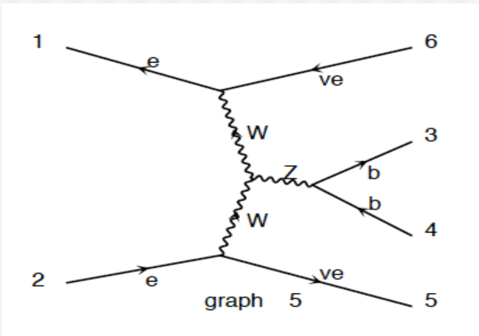
ZZ

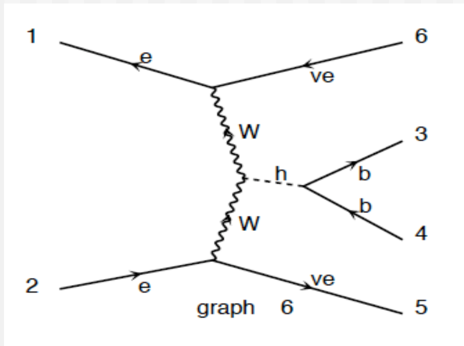




Zh

ννZ





ννh

ZZ ,Zh, ννZ,ννh are BG.

Cross section summary

- This is a table of cross section for each process.

process	cross section[fb]	$\times Signal$
$Z_H A_H$	1.9	1
$ZZ \to bb\nu\nu$	25.5	13.4
$ZZ \to c\bar{c}\nu\nu$	20.1	10.6
$\nu\nu Z \to b\bar{b}\nu\nu$	44.3	23.3
$\nu\nu Z \to c\bar{c}\nu\nu$	34.8	18.3
$Zh \to b\bar{b}\nu\nu$	5.57	2.93
$Zh \to c\bar{c}\nu\nu$	0.64	0.337
$\nu\nu h \to b\bar{b}\nu\nu$	34.0	17.9
$\nu\nu h \to c\bar{c}\nu\nu$	3.91	2.06

The cross sections for W fusions ($\nu\nu$Z,$\nu\nu$h) are large.

Simulation Setup

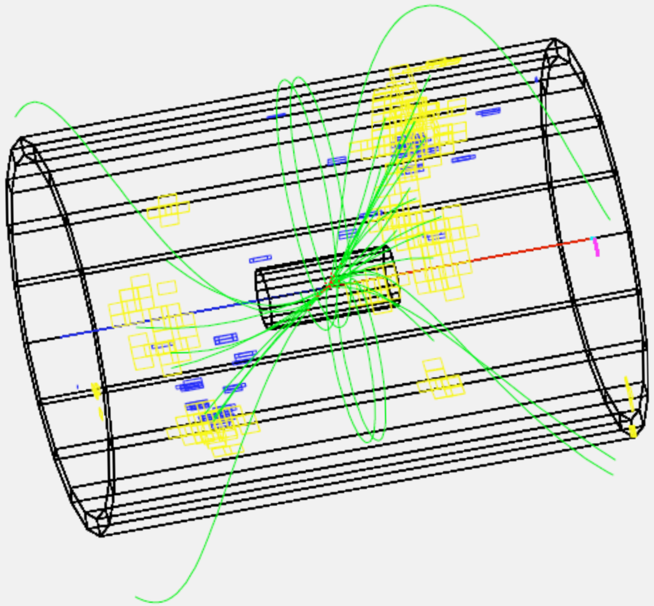
- After the event generation, detector simulation is done with JSF quick-simulator.
  We study for 1000events of signals.
  (corresponding to about $500fb^{-1}$)

  BR(h→bb)=55%, BR(h→WW)=26%,
  BR(h→cc)=6.3%.

- Signal events are reconstructed from only two jets mode. (Force 2-jets)

Event Display

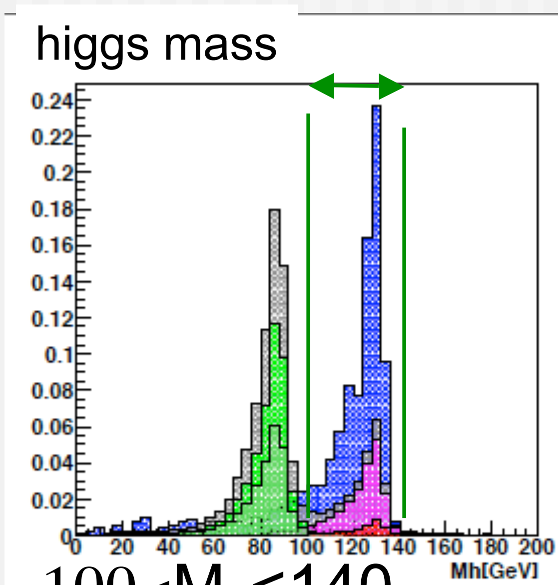
- This is an event display for $Z_H[A_H h]\ A_H$ after the detector simulation.



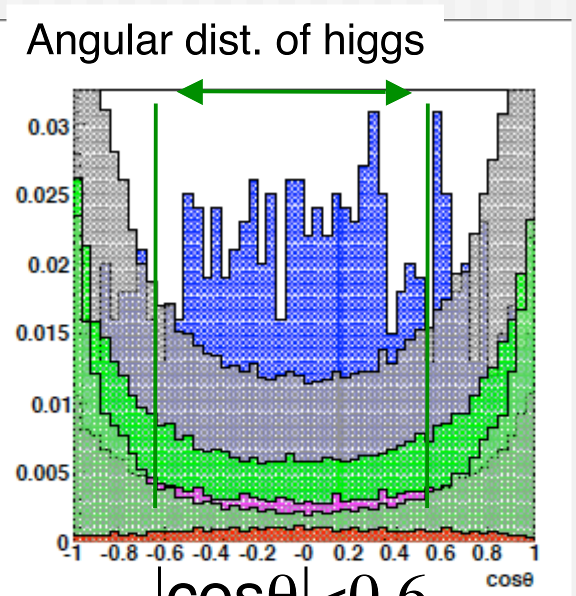
Jets from higgs can be seen.

Event selection

- Only Energy - independent selection can be applied since energy is fitted for mass determination. Reconstructed higgs mass and angular distribution of higgs are used. # of Signal and total B.G are normalized to 1 in the figures bellow.



$100 < M_h < 140$



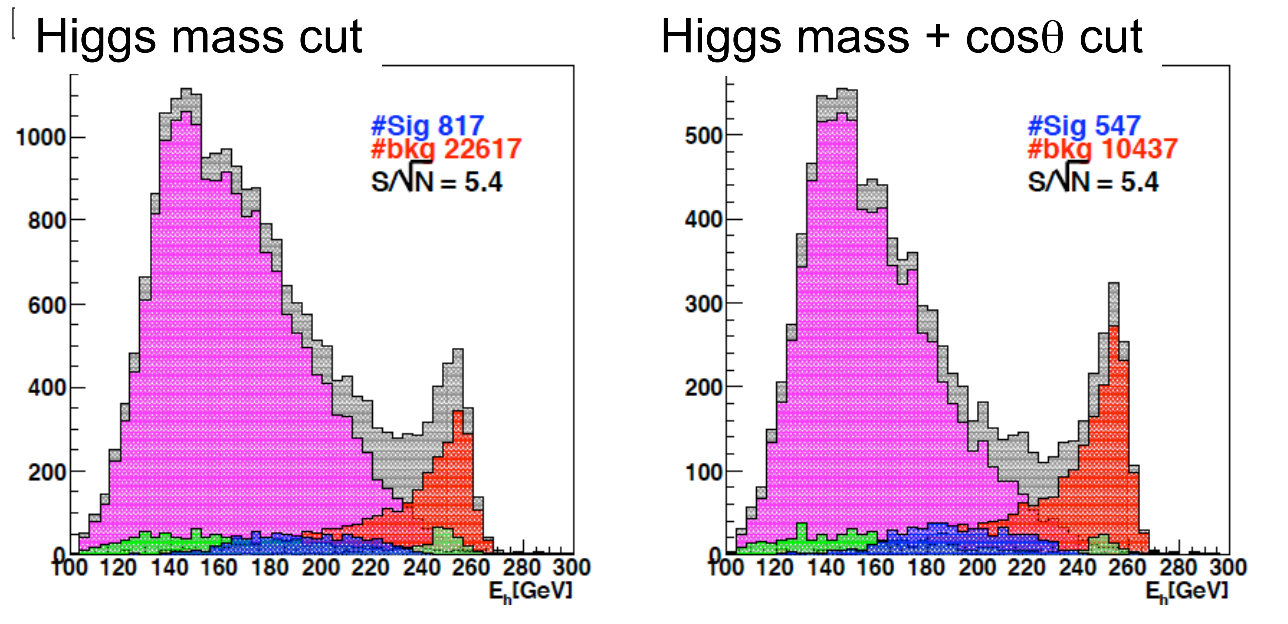
$|\cos\theta| < 0.6$

Signal
Total B.G
$\nu\nu Z$
$\nu\nu h$
ZZ
Zh

$\nu\nu h$ and Zh are remaining.

Reduction Summary

- These are higgs energy distributions after the selection.



cut	Sig/Sig_{Nocut}	1 - (bkg/bkg_{Nocut})	$S/\sqrt{N}$
higgs mass	0.817	0.745	5.4
$\cos\theta$	0.547	0.883	5.4

Signal
Total B.G
ννZ
ννh
ZZ
Zh

Large contribution from ννh and Zh can be seen.

Procedure of mass fit

- The energy distribution is fitted to determine the masses of new particles from the edges.
  Fit func is (Error func) × (6th order polynomial).

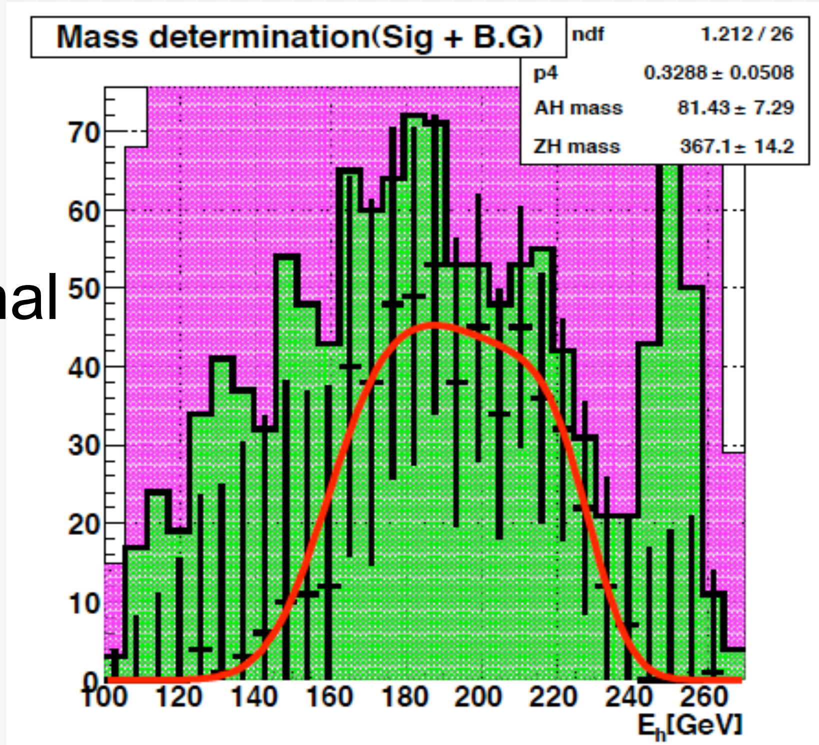
$$(1+Erf(\frac{E_h - E_{min} - \Delta E_{min}}{a\sigma_{Emin}\sqrt{E_h}}))\times(1-Erf(\frac{E_h - E_{max} - \Delta E_{max}}{a\sigma_{Emax}\sqrt{E_h}}))$$
$$\times p_4(1+E_h(p_5+E_h(p_6+E_h(p_7+E_h(p_8+E_h(p_9+E_h(p_{10}+E_h)))))))$$

E_h : higgs Energy
E_{min},E_{max} : Fit parameters with mass info.

Result of mass fit

- This is a result of mass fit.

Signal
$\nu\nu Z$
$\nu\nu h$



- Assuming contributions from all B.G are measured, only signal (points with error bar) is fitted. Errors of signal are set to $\sqrt{(\#Sig + \#All\ B.G)}$

Input :
m_{AH} = 81.9 GeV,
m_{ZH} = 369 GeV
fit results :
m_{AH} = 81.4 ±7.3 GeV,
m_{ZH} = 367±14GeV

Summary and Plan

- Summary
  In $e^+e^- \rightarrow Z_H A_H$ process, Dark matter candidate could be produced at $s^{1/2}$=500 GeV.
  $S/\sqrt{N}$ = 5.2 for BG reduction of ZZ, Zh, $\nu\nu$Z and $\nu\nu$h.
  The result of mass fit is
  m_{AH} = 81.4 ±7.3 GeV, m_{ZH} = 367±14GeV.

- Plan
  Other BG study (tt and $Z\gamma(Z \rightarrow bb)$).

Backup

Procedure of mass fit

- The energy distribution is fitted to determine the masses of new particles from the edges.
  Fit func is (Error func) × (6th order polynomial).

$$(1 + Erf(\frac{E_h - E_{min} - \Delta E_{min}}{a\sigma_{Emin}\sqrt{E_h}})) \times (1 - Erf(\frac{E_h - E_{max} - \Delta E_{max}}{a\sigma_{Emax}\sqrt{E_h}}))$$
$$\times p_4(1 + E_h(p_5 + E_h(p_6 + E_h(p_7 + E_h(p_8 + E_h(p_9 + E_h(p_{10} + E_h)))))))$$

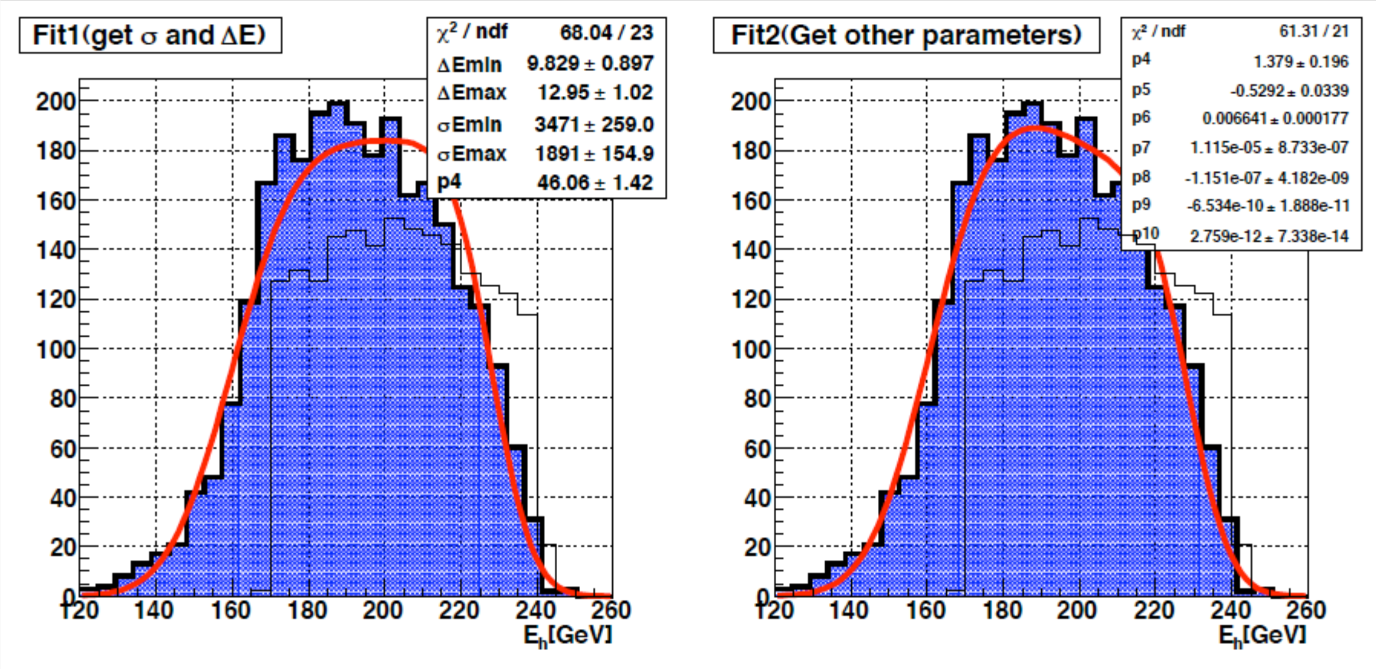
Mass fit is done as following 4 steps.

step	motivation	luminosity[fb^{-1}]	E_{min}, E_{max}	$\sigma_E, \Delta E$	p_4	$p_5 - p_{10}$
1	Get σ *and* ΔE	Sig 5 $\times$500	cheated	free	free	fixed to 0
2	Get other shape par	Sig 5 $\times$500	cheated	fixed	free	free
3	Fit edge	Sig 500	free	fixed	free	fixed
4	Fit edge with B.G	Sig + B.G 500	free	fixed	free	fixed

"Cheated" means edges are calculated from Z_H and A_H masses.

Results of mass fit(1)

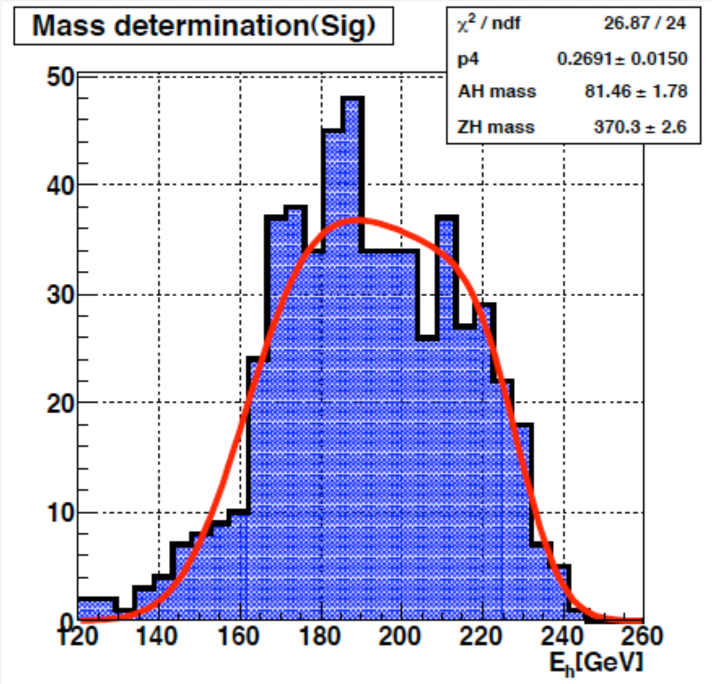
- These are fit results of 1st and 2nd step of the fit. (Edges are cheated,and 5× signal events are used.)



The shape parameters are obtained.

Results of mass fit(2)

- Fixing the shape parameters,mass are obtained from the fit.



input :

m_{AH} = 81.9 GeV,

m_{ZH} = 369 GeV

fit results :

m_{AH} = 81.5 ±1.8 GeV,

m_{ZH} = 370±2.6GeV

-0.2σ and 0.4σ respectively.

Fit procedure seems to be O.K.