Simulation Study of $e^+ e^- \rightarrow Z_H A_H$ in Littlest Higgs Model

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Little Hierarchy Problem

- Standard model is the successful model describing physics below 100GeV.
- The model will be extended at new physics scale Λ.
- LEP result requires Λ>10TeV.
- Fine tuning problem :
  $m_h^2 = m_0^2 + \delta m^2$,$\delta m^2 \sim \Lambda^2$
  (quadratic divergent corrections to the Higgs mass term m_h)
  →Low energy cut off scenario: Λ <1TeV.

Little Hierarchy Problem!

Little Higgs Mechanism

- Little Higgs model
  Higgs boson is regarded as Pseudo NG boson of the global symmetry at some higher scale.

  Explicit breaking of the global symmetry is specially arranged to cancel quadratic divergent correction to m_h at 1-loop level (Collective symmetry breaking).

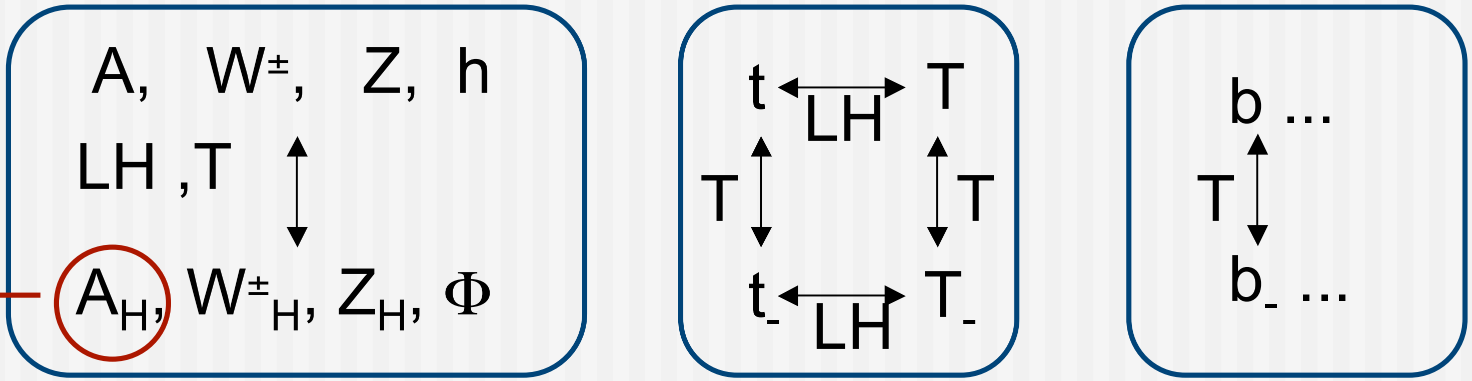
  ↓

  Λ can be 10 TeV without the fine turning.

Littlest Higgs model with T-parity

Particle contents

LH: Little Higgs partner
T: T-Parity partner



Gauge-Higgs sector   Top sector   fermion sector

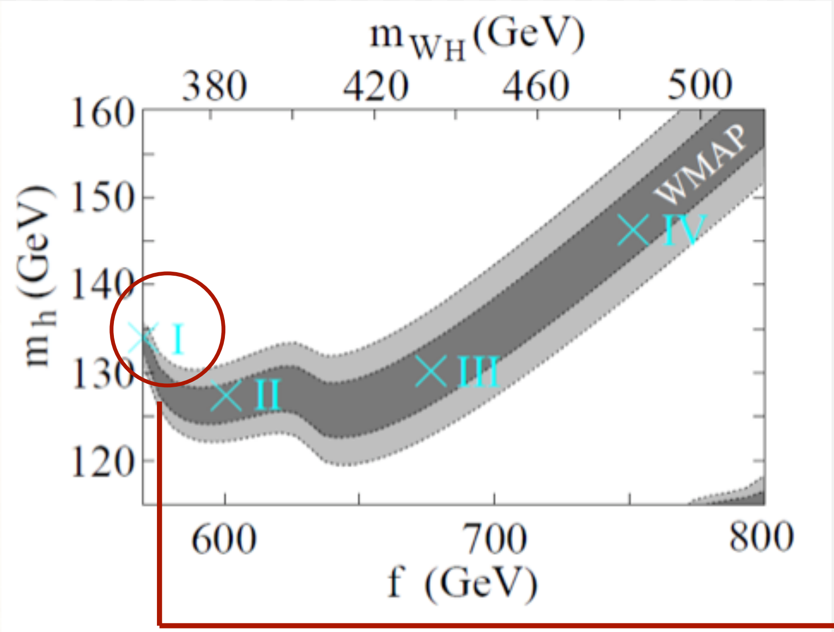
A_H is stable due to T-Parity.

→ Dark matter Candidate!

Parameter region

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

f and m_h are constraint by the WMAP experiment.



Selected parameters

m_{AH} : 82.1GeV

m_{ZH} : 377GeV

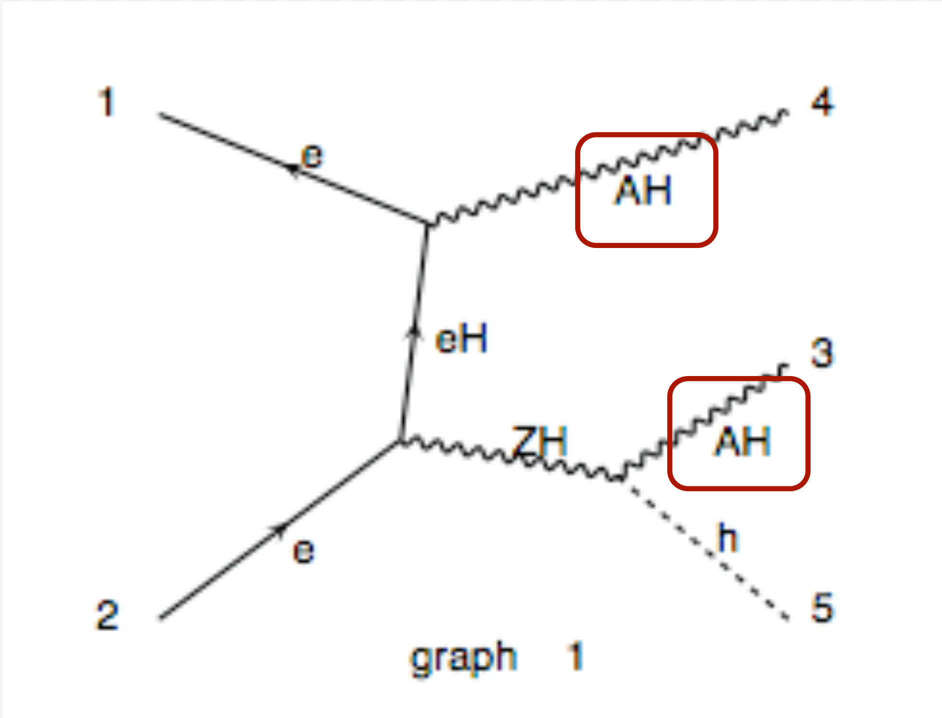
m_h : 134GeV

f : 570GeV

Heavy Gauge bosons are less than 500GeV.

ILC can search them!

Target process

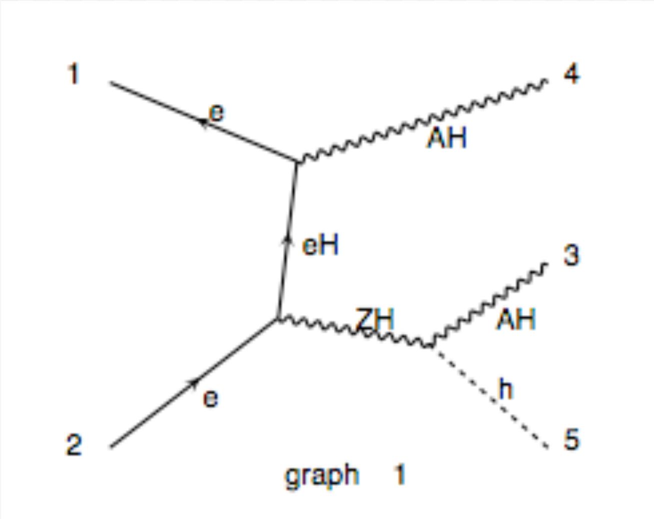


$Z_H \rightarrow A_H + h$ with 100% branching ratio

This process can occur for $s^{1/2}$ = 500GeV

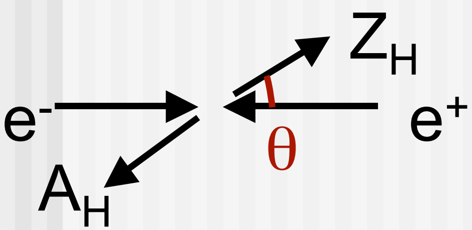
Signal event generation

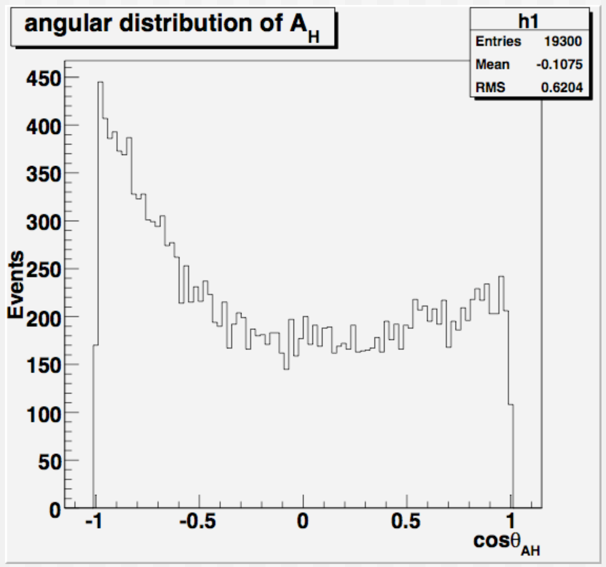
- The cross section and kinematical distribution were calculated by MadGraph.
- Parameters set
  mass:
  A_H : 82.1GeV
  Z_H : 377GeV
  h : 134GeV
  e_H : 410GeV
  $s^{1/2}$ = 500GeV
  cross section : 1.8fb

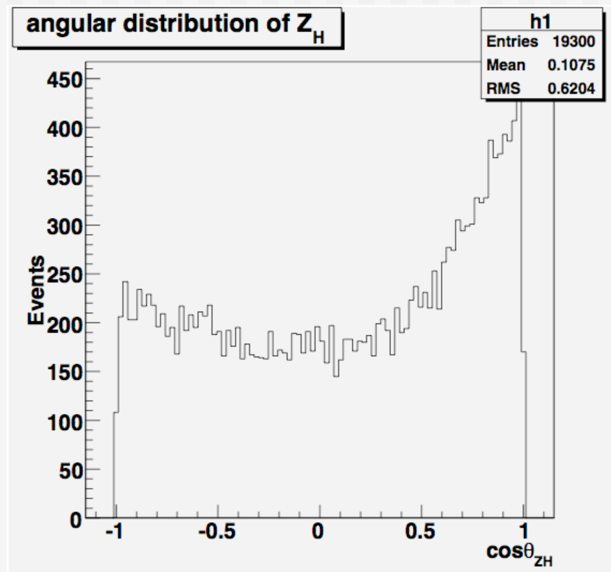


Production angles of Z_H and A_H

- The production angles were studied for Z_H and A_H in the lab frame(C.M frame).



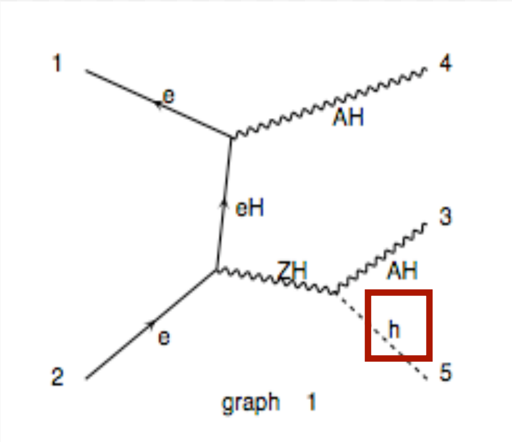


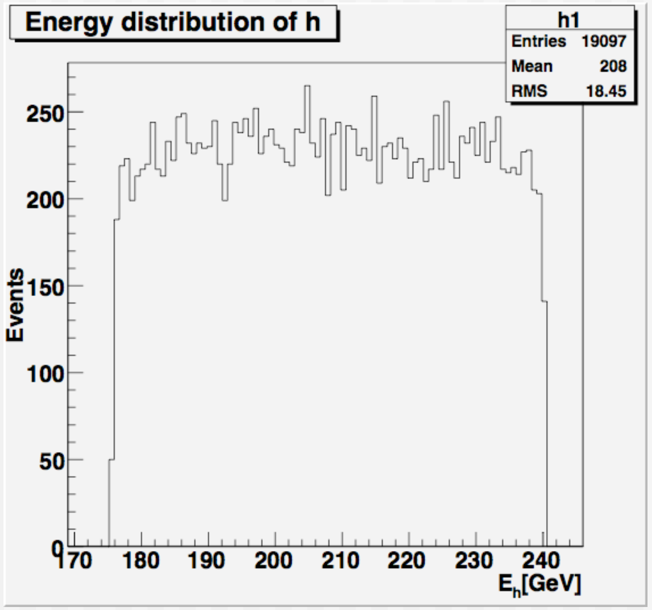


Clear forward-backward asymmetry can be seen, due to t-channel exchange of heavy left-handed electron.

Energy distribution of Higgs

- The energy distribution was studied for Higgs from Z_H in the lab frame.

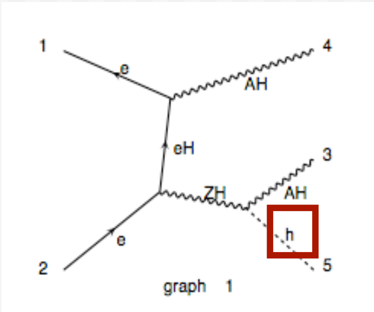


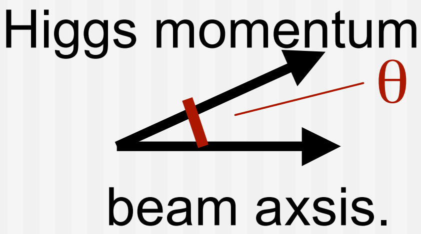


The clear edge can be seen.
Mass of Z_H and A_H will be determined with the distribution.

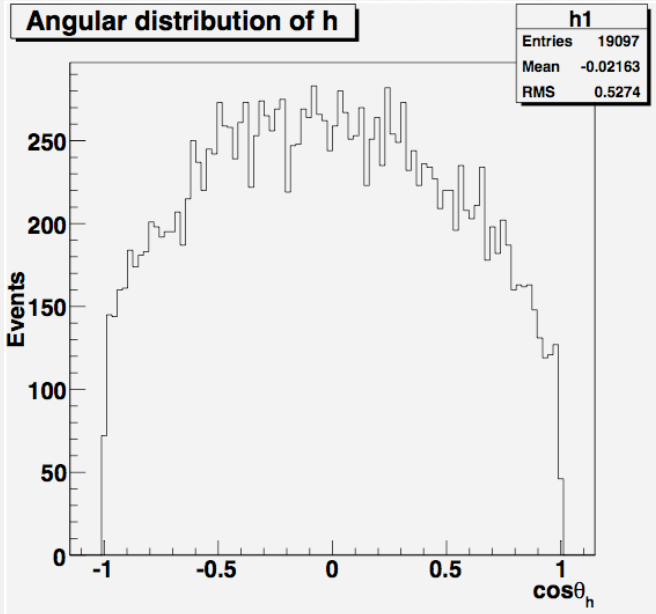
Angular distribution of Higgs

- Angular distribution was checked for Higgs from Z_H in the lab frame.





(lab frame)



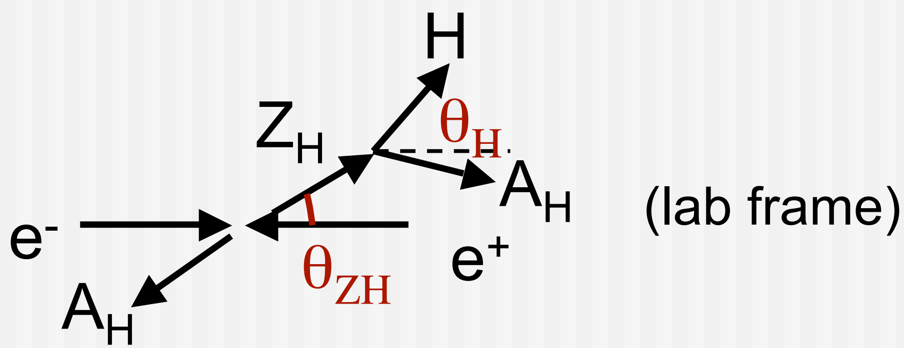
The angular dependence on the polarization can be seen.
→Does Higgs have the information of Z_H-spin?

Determination of the production angle of Z_H

- Measurement of Z_H-spin is important to identify Little Higgs Model.
  →The production angle of Z_H must be measured.

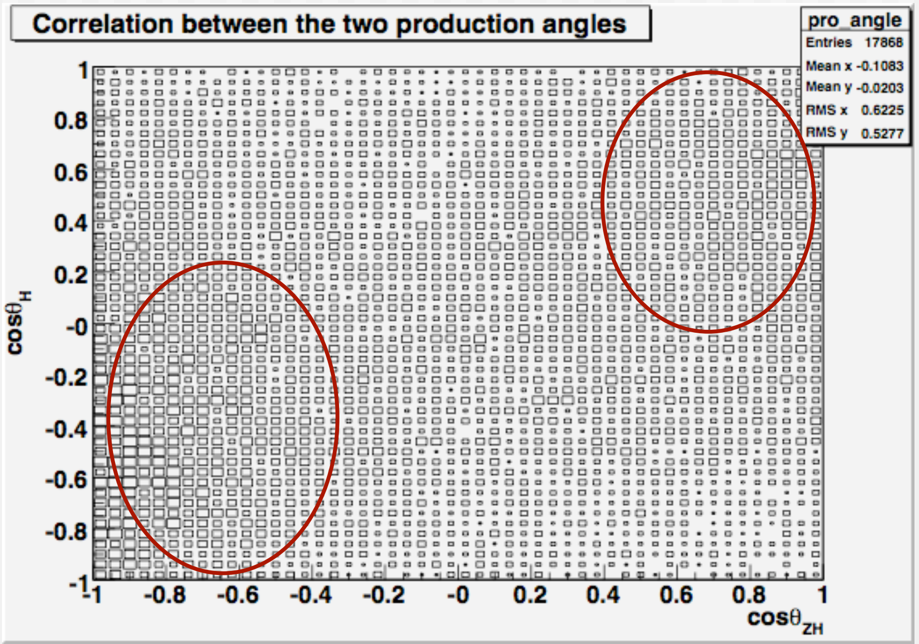
  Does angular distribution of Higgs have information of that of Z_H ?

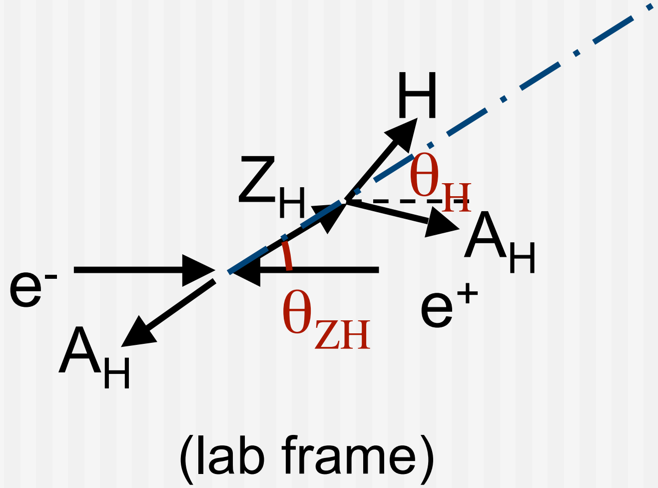
  The relation between θ_{ZH} and θ_H was studied.



θ_{ZH} V.S. θ_H

- θ_H is studied as a functions of θ_{ZH} .

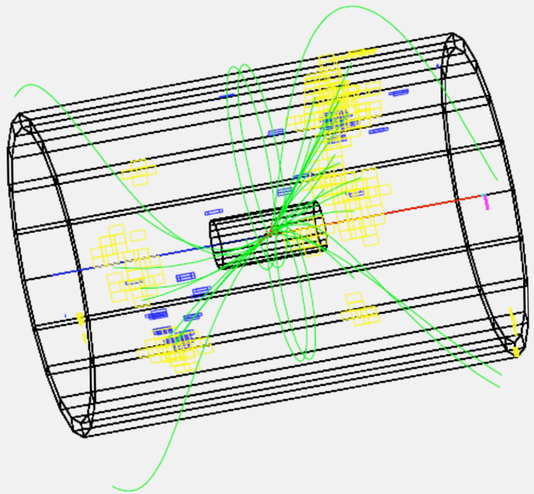




Weak correlation can be seen.→It's hard to determine θ_{ZH}.
Higgs with high momentum will have same direction of $Z_{H.}$
The relation between θ_{ZH} and θ_H will be checked
for each momentum region .

Simulation with quick-simulation

- The data generated by MadGraph was read by quick simulation.



Simulation seems to work for Little Higgs model.

Summary

- Simulation study of Littlest Higgs model with T-parity was started.
- The distribution of the kinematical variables for Z_H ,A_H and Higgs were checked.
- The data made by MadGraph can be read by quick-simulator.

Plan

- Mass determination of Z_H and A_H from the energy distribution of Higgs.
- Check of the angular correlation between Z_H and Higgs, as a function of Higgs momentum.
- Background study such as ZZ,ZH and ZZH.

Back up

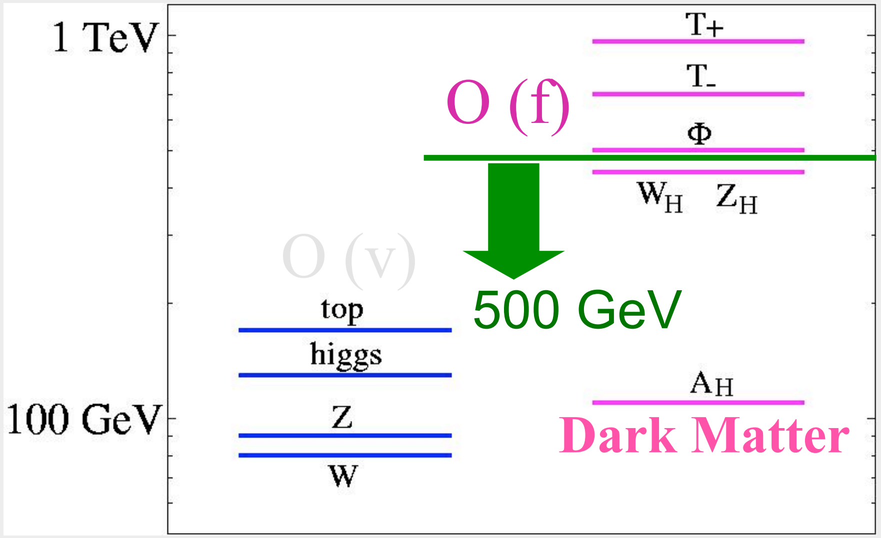
II. LHT at the ILC

Sample Points

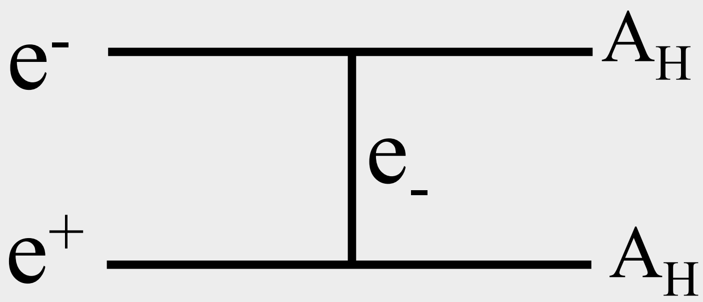
	Point I	Point II	Point III	Point IV
f	570 (GeV)	600 (GeV)	675 (GeV)	750 (GeV)
m_h	134 (GeV)	127 (GeV)	130 (GeV)	146 (GeV)
$\Omega_{\rm DM}h^2$	0.108	0.103	0.105	0.107
m_{A_H}	81.2 (GeV)	86.5 (GeV)	99.4 (GeV)	112 (GeV)
m_{W_H}	363 (GeV)	383 (GeV)	433 (GeV)	482 (GeV)
$m_{Z_H} - m_{W_H}$	774 (MeV)	666 (MeV)	471 (MeV)	346 (MeV)
m_Φ	439 (GeV)	438 (GeV)	504 (GeV)	629 (GeV)
m_{f_-}	806 (GeV)	849 (GeV)	955 (GeV)	1060 (GeV)

All sample points
satisfy all experimental
and cosmological constraints!

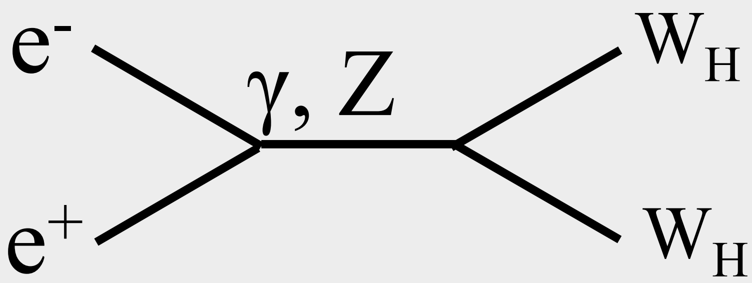
Heavy gauge bosons turns out to be less than 500 GeV.
→ It is possible to produce them in pair at the ILC!



II. LHT at the ILC



1. **No signal**
2. **Vertex is suppressed**

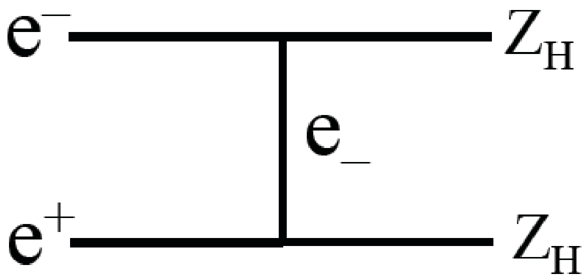


1. **Depend only on f**
2. **Large Cross section**

($W_H^{\pm} \to A_H + W^{\pm}$ with 100% branching ratio!)

	Point I	Point II	Point III	Point IV
σ at 1 TeV	390 (fb)	300 (fb)	130 (fb)	25 (fb)
Γ_{W_H}	110 (MeV)	110 (MeV)	90 (MeV)	79 (MeV)

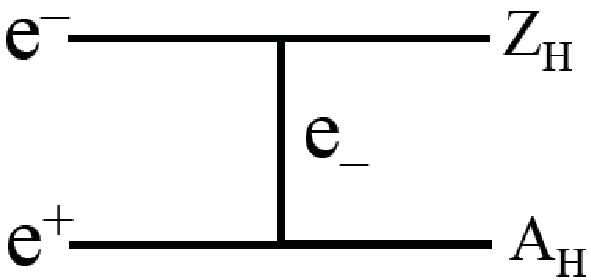
IV. Processes of interests at the ILC



1. **Depends on f and κ_e**

($Z_H^{\pm} \to A_H + h$ with 100% branching ratio! (κ_{l_1} is set to be 1))

	Point I	Point II	Point III	Point IV
σ at 1 TeV	39 (fb)	31 (fb)	16 (fb)	6.0 (fb)
Γ_{Z_H}	45 (MeV)	48 (MeV)	49 (MeV)	46 (MeV)



1. **OK even for $s^{1/2}$ = 500 GeV**
2. **Small Cross section**

($Z_H^{\pm} \to A_H + h$ with 100% branching ratio! (κ_{l_1} is set to be 1))

	Point I	Point II	Point III	Point IV
σ at 500 GeV	0.23 (fb)	0.13 (fb)	—	—
σ at 1 TeV	5.1 (fb)	4.2 (fb)	2.6 (fb)	1.5 (fb)
Γ_{Z_H}	45 (MeV)	48 (MeV)	49 (MeV)	46 (MeV)