# Little Higgs with T-parity measurements at the ILC

**LCWS11**

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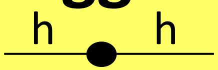
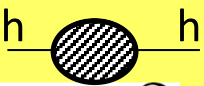
# Little Higgs model

**There are 2 predictions on where the energy scale of new physics should emerge.**

1. **Fine tuning of Higgs mass**




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

**Measured Higgs mass** **Bare mass** **Correction term**

**Λ : Energy scale** $\delta m^2 \approx (0.27\Lambda)^2$

**Λ<1 TeV**

2. **Electroweak precision measurement** **Λ>10TeV**

Conflict between the 2 energy scales.

**Little Higgs model was proposed!**

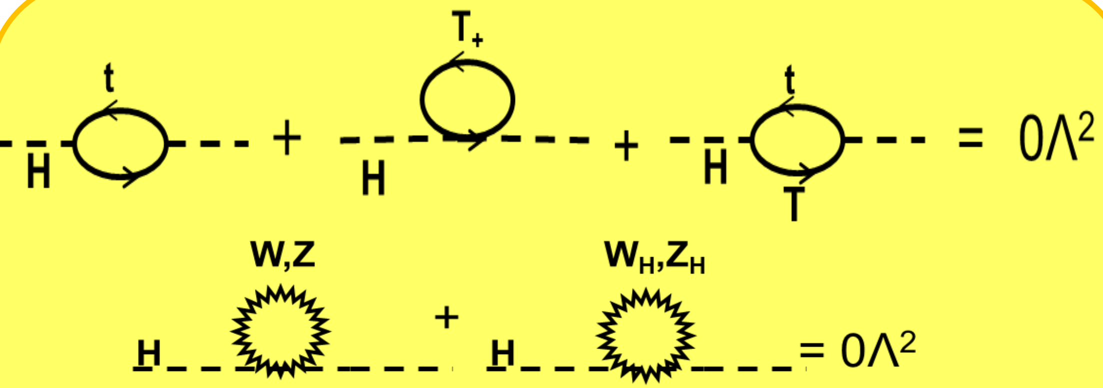
# Little Higgs model

## <Little Higgs mechanism>

Global Symmetry : SU(5) —— **f ~ 1 TeV** ⇨ SO(5) —— **v ~ <h>** ⇨

subgroup : $[\, SU(2)_L \times U(1)_Y ]^2$ ⇨ $SU(2)_L \times U(1)_Y$ ⇨ $U(1)_Y$

## <Higgs mass contribution>



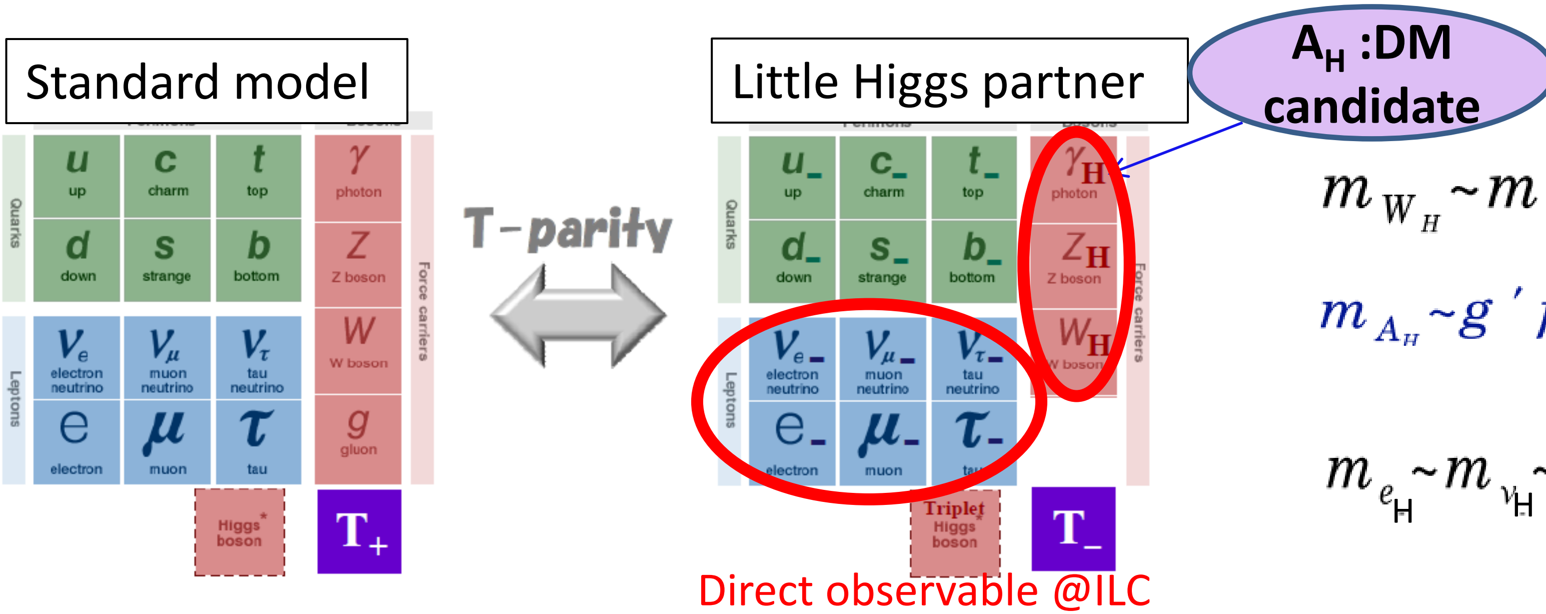

**Quadratic divergent terms cancel at 1-loop order**

## <features of Little Higgs>

- prediction of top partner
- prediction of gauge boson partner
- Definite relation between model parameters (little higgs mechanism)

**Solves Little hierarchy problem**

# Littlest Higgs with T-Parity model




$$m_{W_H} \sim m_{Z_H} \sim g f$$

$$m_{A_H} \sim g' f / \sqrt{5}$$

$$m_{e_H} \sim m_{\nu_H} \sim \sqrt{2} k_l f$$

LHT masses in gauge & lepton sector can be described in 2 parameters

f(VEV): energy scale of global symmetry breaking
K : lepton Yukawa coupling

Important parameters which describe how LHT particles obtain masses & solve little hierarchy problem.

# Aim of study

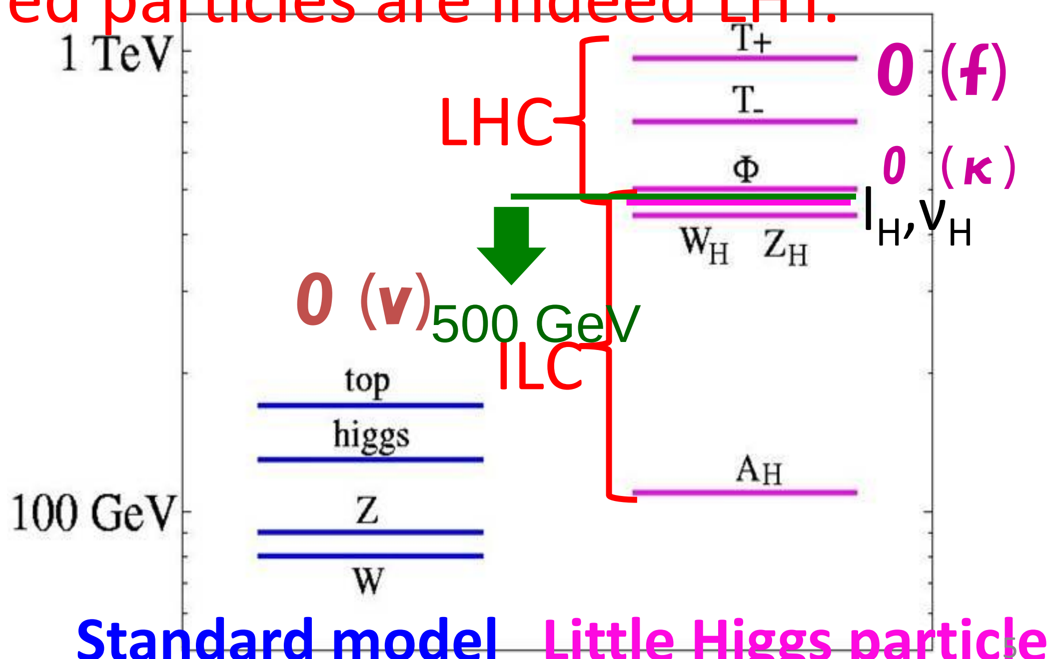
Evaluate ILC's sensitivity on …

- 1st aim : extracting model parameters(f&kappa)
- 2nd aim: completing the mass spectrum and checking consistency with parameters
- 3rd aim: meas. coupling check consistency with parameters

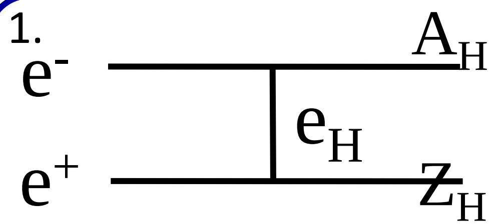
Strong proof that discovered particles are indeed LHT.

| κ | f |
|---|---|
| 0.5 | 580(GeV) |

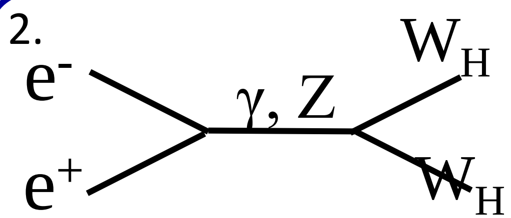
$E_{cm}$=1TeV,
Luminocity = 500fb$^{-1}$



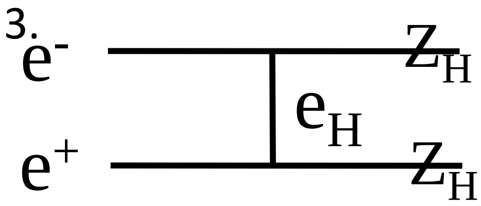
# Analysis



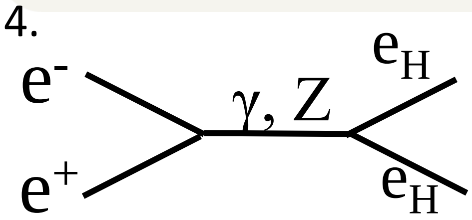

- **First signal of LHT!**



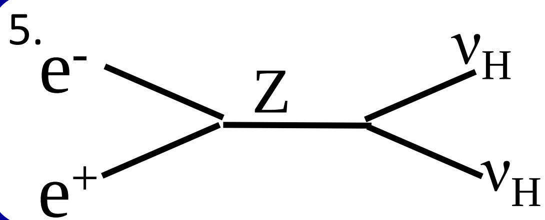

- **Precision measurement on f.**



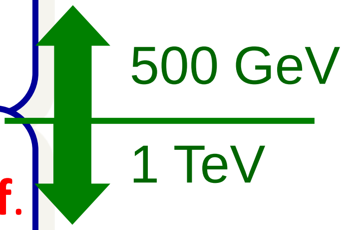

- **complete mass spectrum in gauge sector**

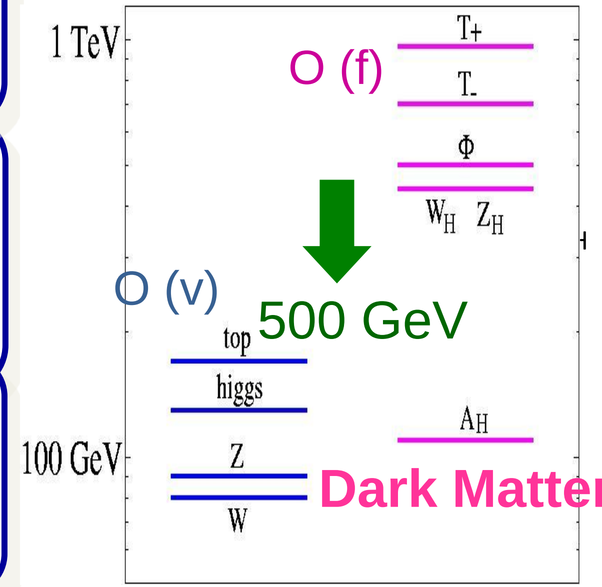



- **Precision measurement on κ**



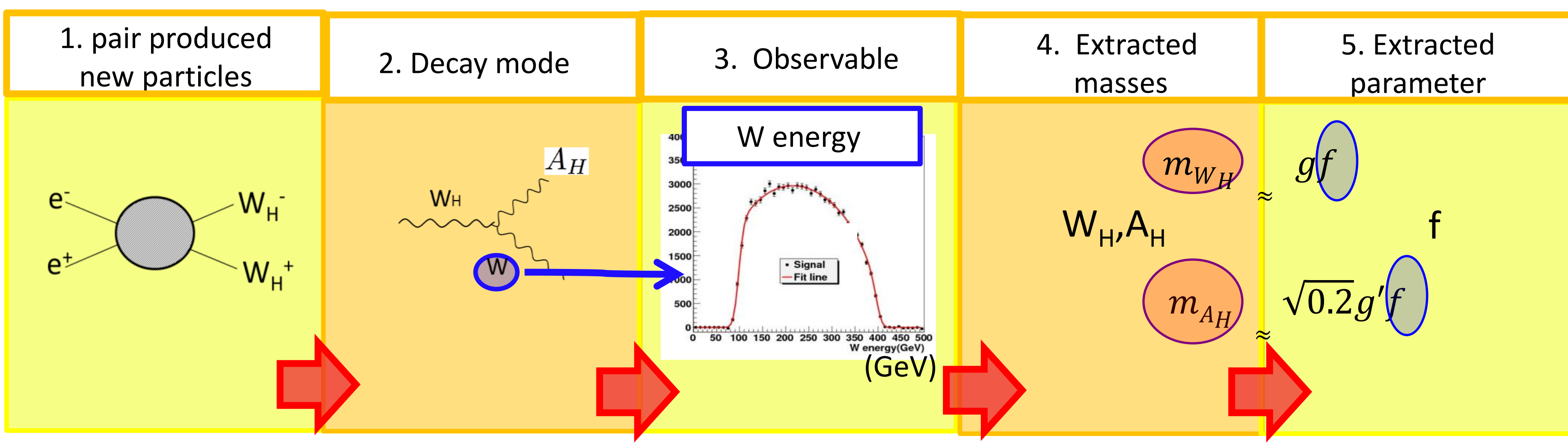

- **Complete mass spectrum in lepton sector**



# Analysis procedure

1. T-Parity ➔ new particles are produced in pairs
2. ➔ produced new particles decay into SM and LHT particles.
3. Extract LHT mass information by recognizing end point of SM energy.
4. Extract model parameters, using the fact that LHT masses are expressed with them.



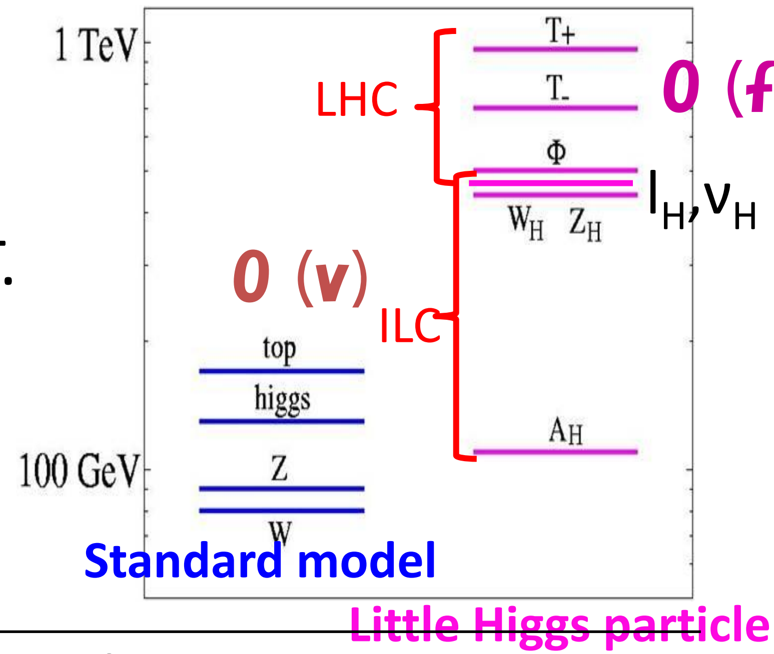
# Mass/parameter measurement accuracy

For details, ILD work shop talk

- ■ results show that ILC is capable of highly accurate precision measurements on LHT masses and parameters.

➢ This is extremely important in study -ing LHT's mass generation mechanism.

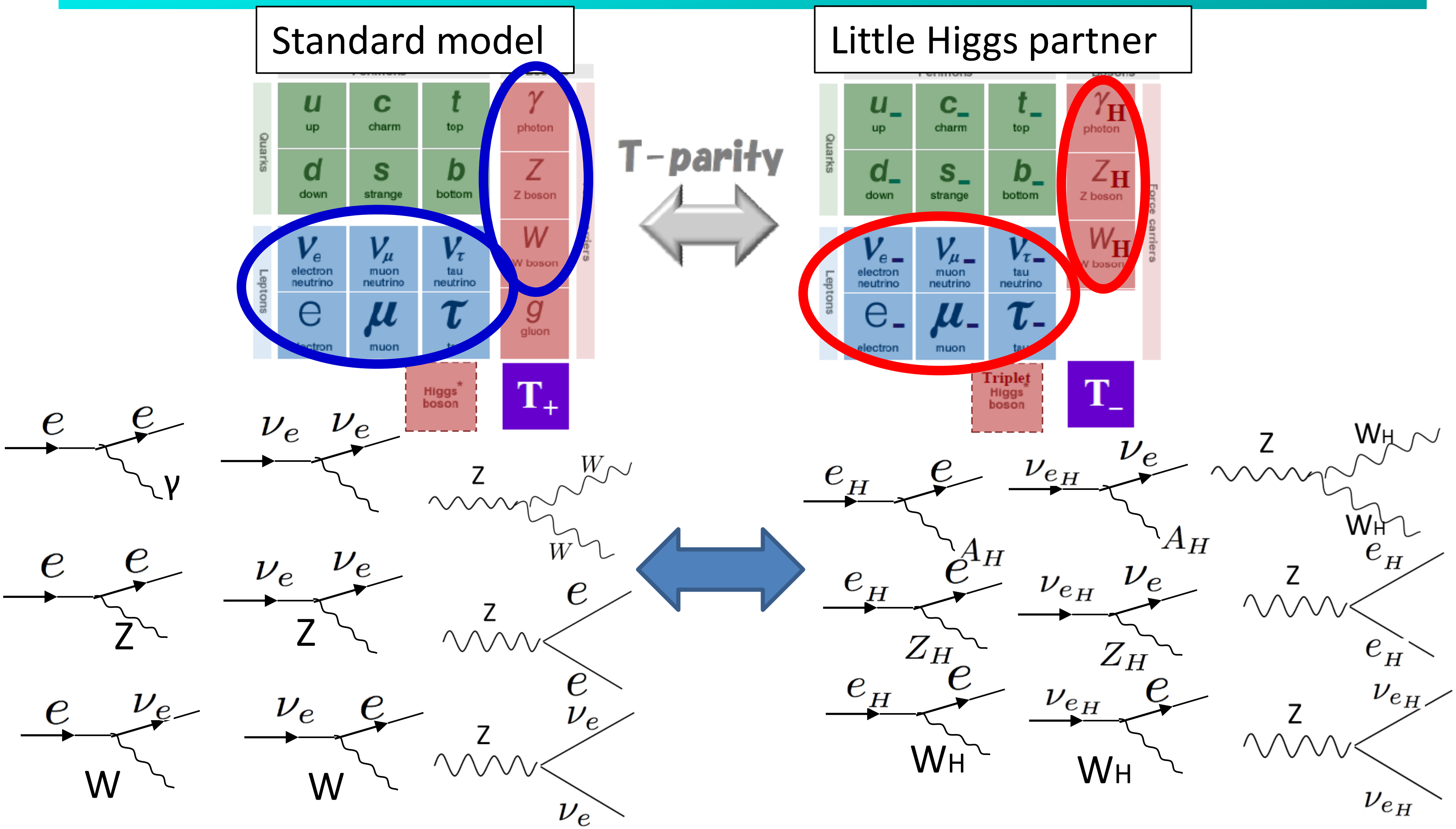
➢ Shows how likely it is actually it is LHT.




| particle | mass | sensitivity |
|---|---|---|
| $A_H$ | 81.9(GeV) | 1.3% |
| $W_H$ | 369(GeV) | 0.20% |
| $Z_H$ | 368(GeV) | 0.56% |
| $e_H$ | 410(GeV) | 0.46% |
| $\nu_H$ | 400(GeV) | 0.10% |

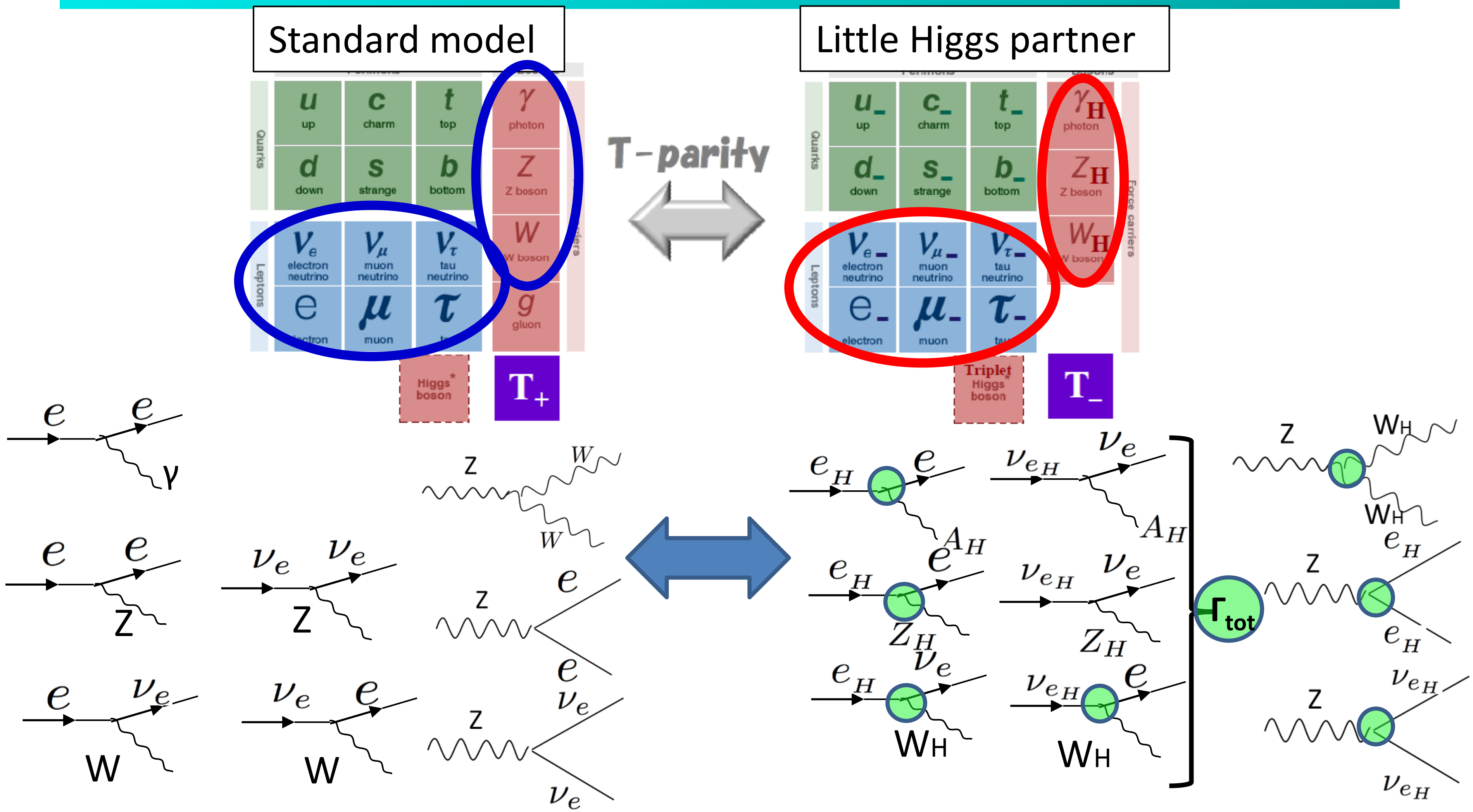
| parameter | True value | Measurement accuracy |
|---|---|---|
| f | 580(GeV) | 0.16% |
| K | 0.5 | 0.01% |

# Coupling relationship




- It will be extremely important to measure couplings between LHT particles and SM particles in order to know how particles interact with each other.

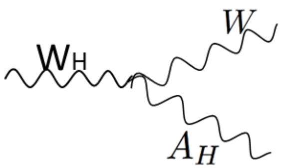
# Coupling relationship

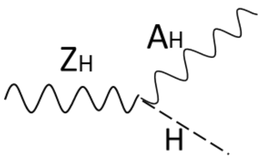



- With the method I am going to introduce we can derive the couplings In the vertices shown above.

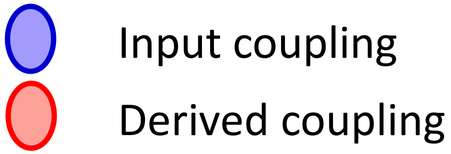
# Observables for coupling extraction

- Cross section
  - Assume $W_H$ ,$Z_H$ decays 100% to $A_H$
    - ➤ Derive coupling

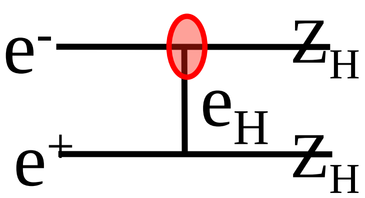


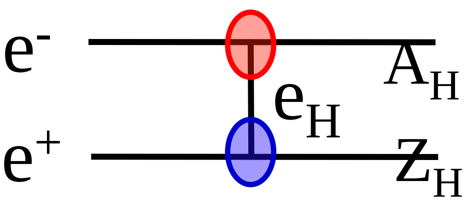




- However….
  - We don't know Br of particles which have several decay modes.
    - ➤ We need an additional observable.




Ex)

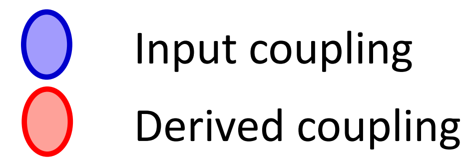



※Vertex structure(spin, ratio between Left right coupling) will be assumed

# Observables for coupling extraction

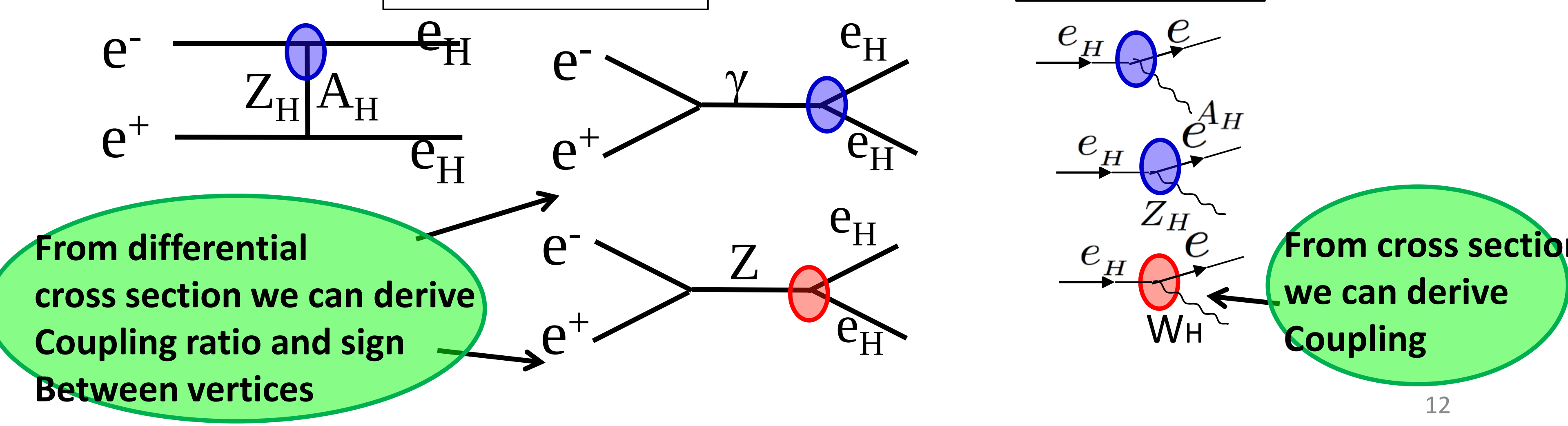
- **Differential cross section**
  - We know masses of LHT particles.
  - Angular distribution of pair produced LHT particle can be derived by solving kinematics.
  - ➢ Derive coupling from angular distribution
  - ➢ Coupling sign can also be derived (s-channel contribution destructive/ constructive )




※Vertex structure(spin, ratio between Left right coupling) will be assumed

Total cross section

Decay branch



# Deriving coupling

Input coupling

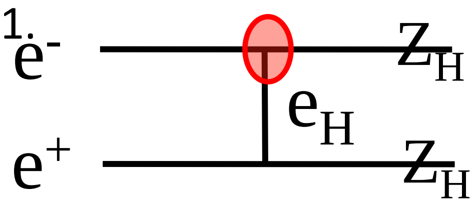
Derived coupling

**Observable:**

cross section(**CS**)

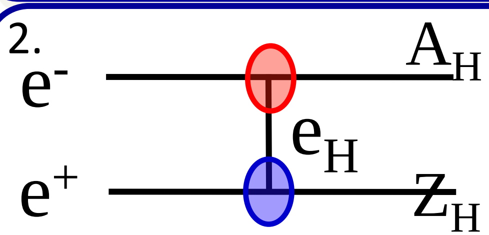
differential cross section(**DCS**)

1.



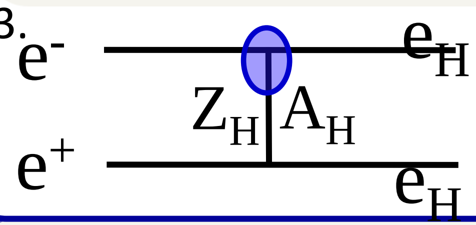

**CS**

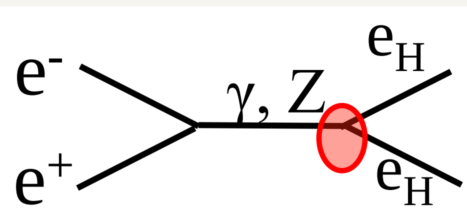
2.



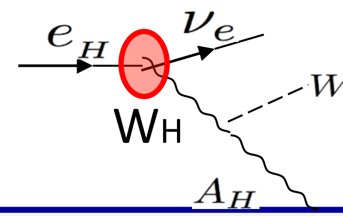

**CS**

3.

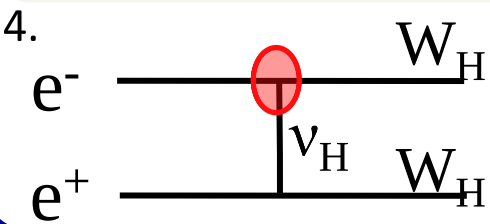


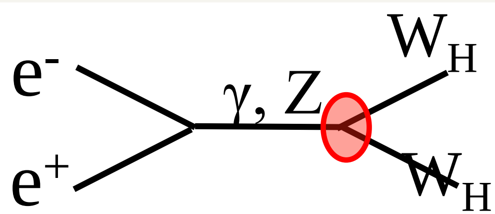




**CS&DCS**




4.

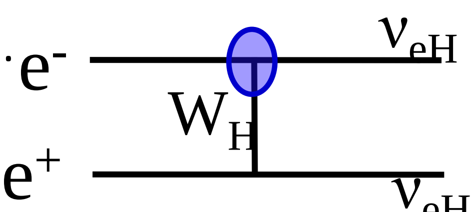


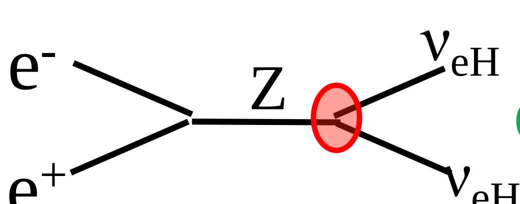




**CS&DCS**

**Total of**
**8 coupling measurements!!**

5.



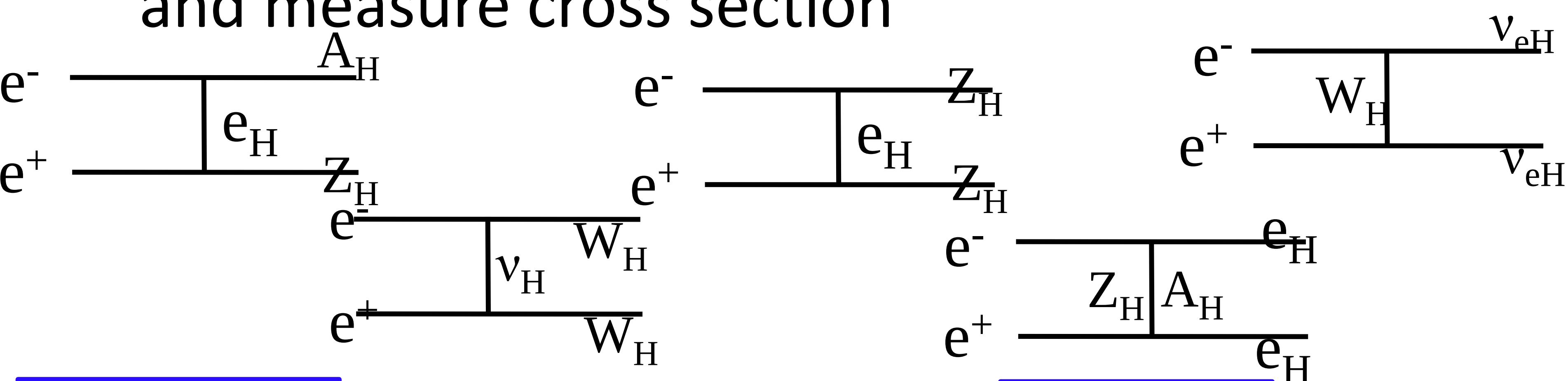



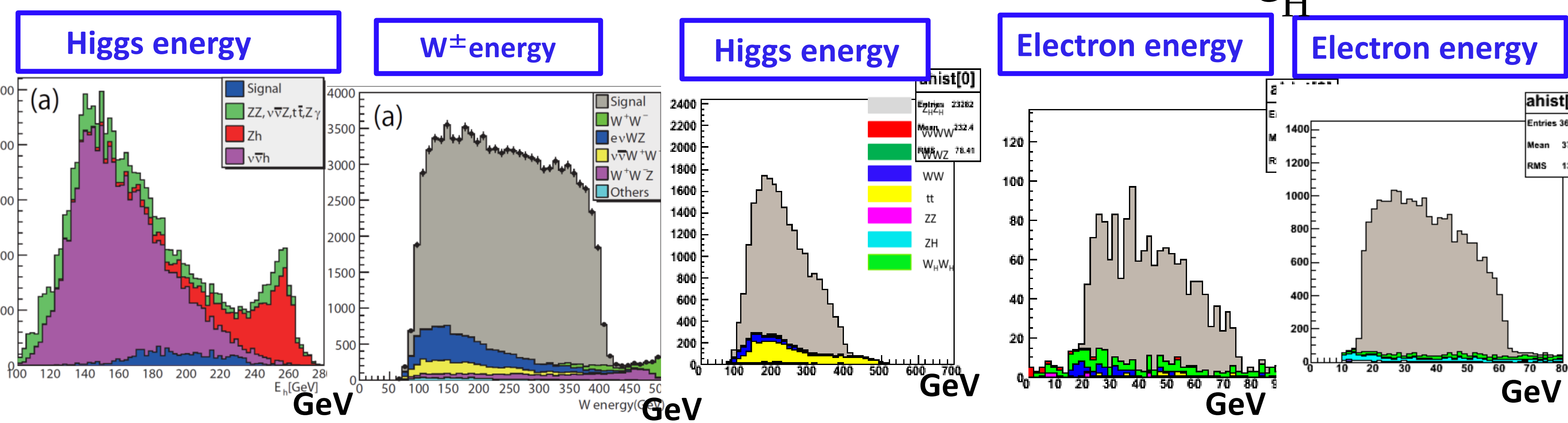

**CS&DCS**

Γtot

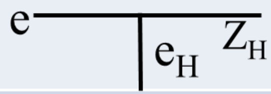
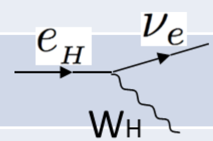
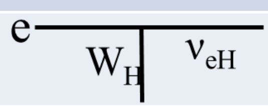
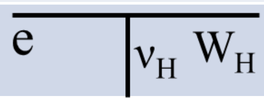
# Cross section meas.

- Fit standard energy distribution used before and measure cross section

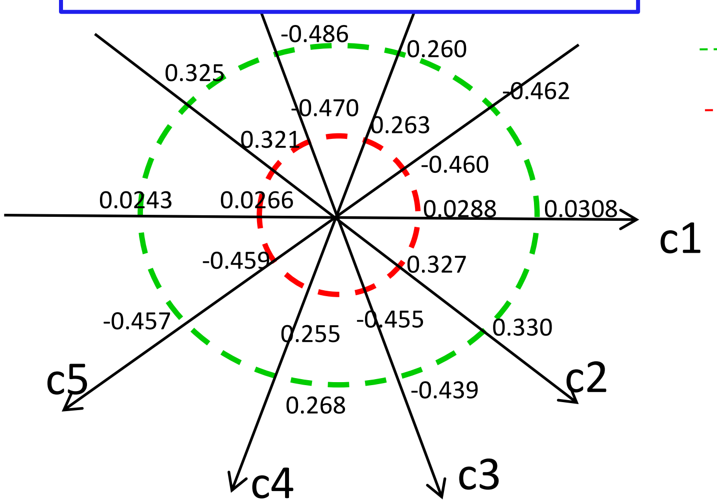




# Cross section measurement

| Mode | | vertex | Xsec Meas. accuracy | Coupling meas. Accuracy |
|---|---|---|---|---|
| $A_H Z_H$ | C1 |   | 7.70% | 3.90% |
| $Z_H Z_H$ | C2 |   | 0.859% | 0.219% |
| $e_H e_H$ | C3 |   | 2.72% | 1.49% |
| $\nu_H \nu_H$ | C4 |   | 0.949% | 0.648% |
| $W_H W_H$ | c5 |   | 0.401% | 0.174% |

Contour of Meas. Coupling




3σ

1σ

Center value of the coupling can be estimated using the previously derived parameter f & kappa.

# Summary/plan

- High precision in parameter extraction , mass measurement & coupling extraction through cross section meas. is possible. Which is extremely important in verifying the LHT.

- All of the other couplings will be derived using template fitting of decay angle distribution.

| particle | mass | sensitivity |
|---|---|---|
| $A_H$ | 81.9(GeV) | 1.3% |
| $W_H$ | 369(GeV) | 0.20% |
| $Z_H$ | 368(GeV) | 0.56% |
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| parameter | True value | Measurement accuracy |
|---|---|---|
| f | 580(GeV) | 0.16% |
| K | 0.5 | 0.01% |

Coupling extracted from xsec

| Mode | Coupling meas. Accuracy |
|---|---|
| $A_H Z_H$ | 3.90% |
| $Z_H Z_H$ | 0.219% |
| $e_H e_H$ | 1.49% |
| $\nu_H \nu_H$ | 0.648% |
| $W_H W_H$ | 0.174% |