Future of energy frontier physics

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LEP symposium at ICEPP, Tokyo

November 6, 2001

Fundamental concepts of particle physics in the 20th century

- Relativity
- Quantum mechanics
- Gauge field theory
- The Standard Model
  $SU(3) \times SU(2) \times U(1)$ gauge symmetry
  Electroweak symmetry breaking (Higgs mechanism)

LEP experiments established the gauge structure of the SM, and also gave indications for a light Higgs boson from precision EW measurements, and SUSY GUT from gauge coupling unification.

Energy frontier experiments in 10 - 15 years

Tevatron Run II	2001-	$p\bar{p}$	$\sqrt{s} = 2$ TeV
LHC	2006-	pp	$\sqrt{s} = 14$ TeV

e^+e^- Linear Collider, 2010 (?)-, $\sqrt{s} = 250 - 500$ GeV, with possible option of $\gamma\gamma, e\gamma, e^-e^-$.

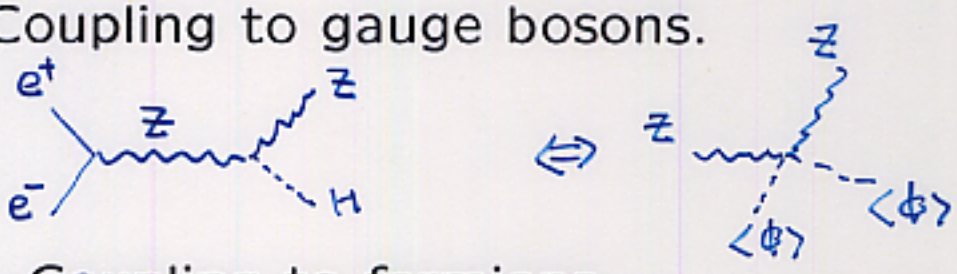
General consensus is emerging among high energy community for early construction of LC.
JLC-I (1992)
TESLA TDR, Snowmass 2001, 2nd ACFA statement on e^+e^- LC (2001)

In a distance future ($\gtrsim$ 15 years):
VLHC($p\bar{p}$, $\sqrt{s} = 40-200$ TeV), TeV LC, muon collider.

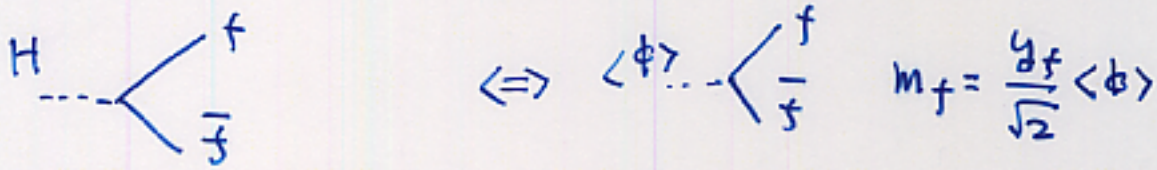
- Establish mechanism of the electroweak symmetry breaking.

- Discover a Higgs particle and study its properties.

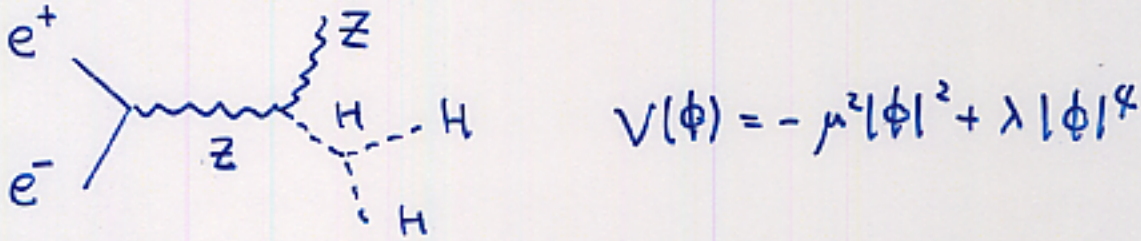
  Coupling to gauge bosons.



  Coupling to fermions.



  Self-coupling constant.



- Find physics scenario beyon the electroweak scale. (SUSY, GUT, TeV scale gravity, or other ideas ?)

Summary

- Higgs boson and SUSY searches at LHC will determine the future direction of high energy physics.

- LC will be essential to explore physics of the electroweak scale and beyond, whatever the outcome of the LHC experiment is.

- If SUSY is the correct theory, both LHC and LC are necessary to obtain a whole picture of SUSY Lagrangian.

Relation with flavor physics

If SUSY is discovered at energy frontier machines, the flavor physics such as B physics and lepton flavor violation is very important.

Energy frontier

→SUSY mass spectrum, chargino/neutralino mixing

Flavor physics

→ Squark and slepton flavor mixings

Flavor mixings of squark and slepton mass matrices are determined by:

- SUSY breaking mechanism
- Interaction at high energy scale

In order to understand SUSY breaking and interactions at GUT scale, we need both energy frontier experiments and flavor physics.

$\tan\beta$ determination from various processes:

- The light Higgs mass formula.

- The heavy Higgs boson production/decay
  J.Feng and T.Moroi 1997, V.Barger, T.Han and J.Jiang 2001
  The branching ratio and production depend on $\tan\beta$
  Branching ratio:
  $A, H \to t\bar{t}, H^- \to t\bar{b}$ (small $\tan\beta$)
  $A, H \to b\bar{b}, \tau\bar{\tau}$ (large $\tan\beta$)
  $H^- \to \tau\bar{\nu}, t\bar{b}$ (large $\tan\beta$)
  Enhancement of the production at a large $\tan\beta$:
  $e^+e^- \to t\bar{b}H^-$
  $e^+e^- \to b\bar{b}H, b\bar{b}A$

- Chargino/neutralino production.

- Stau decay: M.M.Nojiri 1995
  $\tilde{\tau}_R \to \tau_R\tilde{B}$ (gauge coupling)
  $\tilde{\tau}_R \to \tau_L\tilde{H}$ (Yukawa coupling)
  Measurement of the tau polarization in $\tilde{\tau}_R$ decay determine $\tan\beta$.