Opening Comments

2015/10/24 Keisuke Fujii

WG Objectives

- On July 4, 2012, ATLAS and CMS announced the discovery of a Higgs-like boson with a mass of about 125GeV and the data that followed strongly indicates that it is a Higgs boson indeed. The world has changed since then. The discovery has vaulted the question of its properties on the top of the list of questions in HEP. The 125GeV boson is a window to BSM physics and ILC is the best machine to use it.
The LHC has just started its Run2 at 13TeV. This will probably bring us more. It is important to stress that ILC, too, is an energy frontier machine. It will access the energy region never explored with any lepton collider. There can be a zoo of new uncolored particles or new phenomena that are difficult to find at LHC but can be discovered and studied in detail at ILC.

  We need to demonstrate that ILC will advance our understanding of particle physics qualitatively beyond the information that will be available from the results expected from the future stages of the LHC. Be prepared for LHC Run2 results!

- The ILC project preparation office has been formed in KEK and the MEXT's ILC Task Force is reviewing the project. In parallel, site-specific design started and the ILC parameter WG published a run scenario document (arXiv:1506.07830) and the ILC Physics WG published a physics case document (arXiv:1506.05992) as a byproduct of its effort to make inputs to the MEXT's physics WG. Given the interim summary from the MEXT expert panel, we now need to prepare a 3-to-4 page long summary of BSM scenario (new particle discovery potential in particular) by the end of CY2015.
On the HEP community side, the next target for us to show our activities to the LC community is LCWS15 on Nov.2-6 in Whistler, Canada.

What we want

- We have the 125 GeV boson that is a powerful tool to explore the symmetry breaking sector (SBS).
  We need to invent a way to make maximal use of it.
  - Is it possible to map various BSM models in ideally a single and hopefully a small number of generic parameter spaces so as to compare the physics reach of ILC with that of the future upgraded LHC.
  - If yes, explore the possibility of fingerprinting BSM models in the generic parameter space. --> partially done in the Snowmass process
- The most important Mission of ILC = bottom-up reconstruction of the SBS and clarification of its relation to other open questions of elementary particle physics.
  - Make a strategy to reconstruct the SBS
    - Shape of SBS: Multiplet Structure (a SM-like 2-let main but what about small admixtures of 1-let?, 3-let? If there, how many?, ….)
    - Dynamics behind SBS: weakly/strongly interacting = elementary/composite
  - Clarify relation to other open questions: DM, Baryogenesis, Neutrino mass, Hierarchy, …
- ILC is an energy frontier machine. We need to re-examine the possibilities given the existence of the 125GeV boson and their relations to the open questions.

More Exercises Needed

- For theorists:
  - ILC can measure various quantities such as mh, gamma_h, ghxx, mt, etc. far better than LHC. But how accurately do we really need to measure them?
  - What will be the ultimate theoretical uncertainties in various predictions for LHC and ILC, respectively?
  - Update various ILC physics plots to accommodate LHC constraints, etc.
- For Experimentalists:
  - Update all the old analyses with mh=120 GeV to mh=125GeV: urgent!
  - Complete the analyses such as rare Higgs decays: urgent!
  - Improve the analyses such as self-coupling, H->gamma gamma, recoil mass (jets?), where the results are not yet satisfactory.
  - Studies at Ecm = 350 GeV : requests from the ILC parameter WG.
  - With the projected running scenarios described in DBD, the most measurements are still statistically limited and should improve by a luminosity upgrade or by running longer. Nevertheless, ILC, too, will hit systematics limits, eventually. It is probably the right time to start more serious studies of expected systematic errors.
    - Identify possible sources of systematic errors
    - Estimate to what degree we can control them (partially done in the Snowmass process)

Oct. 16, 2015

Draft Reply to MEXT ILC Advisory Panel

Concerning

New Particle Searches

Keisuke Fujii, KEK

Guideline

1. Start from the basic points made in the interim summary.
2. Reemphasize the importance of precision studies of the Higgs boson and the top quark.
3. Accept the questions asked by the MEXT panel as they were formulated:
   What if the LHC finds no new particles?
   What if the LHC finds relatively light new particles?
   What if the LHC finds heavy new particles?
4. Try to answer these questions as straightforwardly as possible.

The International Linear Collider:

Scientific Significance and Potential for Discovering New Particles

Abstract

1. The ultimate goal of particle physics is the unification of the laws of nature that govern the elementary particles and the universe. With the discovery of the Higgs boson, the theoretical framework of the so-called "Standard Model" (SM) has been verified, although there are many phenomena that cannot be explained by the SM. The next goal of particle physics is to look for new physics beyond the SM.

2. At the ILC, new physics could be discovered through the detailed investigation of the Higgs boson and the top quark, which will guide the path for particle physics. This investigation will be important regardless of the results of the LHC experiments.

3. At the ILC, discoveries of new particles are also anticipated. Even if the LHC operating at 13 TeV could not find new particles, the ILC has a lot of potential for discovering new particles that are extremely challenging for the LHC. If the LHC operating at 13 TeV discovers a new particle, in general cases, it is expected that the ILC will also discover a new, different particle that corresponds to the LHC discovery.

Main Body

1. Particle Physics: Current Status, Issues, and Goals

2. The Higgs Boson and the Top Quark

3. Potential for Discovering New Particle

Difference between LHC and ILC

3-1) No discoveries of new particles at LHC Experiments

Dark matter
SUSY
Mechanism for EWSB (self-coupling)

3-2) LHC experiments discover light new particles

SUSY
Dark matter / Mechanism for EWSB (self-coupling)

3-2) LHC experiments discover heavy new particles

SUSY
Composite Particles
Particles that mediate a new force
Dark matter / Mechanism for EWSB (self-coupling)

Summary and Prospects

The energy range that will be probed by the ILC has many keys that could solve the puzzles that particle physics faces today. The ILC can perform clean experiments through collisions of an elementary particle and its antiparticle, which are free of unwanted reactions. Taking advantage of these features, the ILC is anticipated to open the door toward physics that go beyond the SM. Detailed studies of the Higgs boson and the top quark are particularly important, regardless of the results of the LHC experiments. The ILC will be a big step that advances our understanding of matter, forces, space-time, and the universe in a unified way.

The potential for discovering new particles at the ILC in the context of theories that are considered can be summarized into the following three scenarios.

(i) No discoveries of new particles at the LHC experiments

- Dark Matter: Discovery at the ILC is anticipated for the kind of dark that interacts primarily with electrons and positrons or with particles that mediate the weak force in the SM.
- Supersymmetric Particles: Discovery at the ILC is anticipated for *light* supersymmetric particles that are difficult to observe at the LHC.
- Mechanism of Higgs Condensation in the Vacuum: Discovery of the mechanism that condensed the Higgs bosons in the vacuum is possible at the ILC, while it is thought to be difficult at the LHC.

(ii) LHC experiments discover light new particles

- Supersymmetric Particles: There is very high probability that the ILC will discover *light* supersymmetric particles, which have connection to the *heavy* particles discovered at the LHC.
- Dark Matter: Same as in (i).
- Mechanism of Higgs Condensation in the Vacuum: Same as in (i).

(iii) LHC experiments discover heavy new particles

- Supersymmetric Particles: It is probable that the ILC will discover new *light* supersymmetric particles that are different from those discovered at the LHC.
- Composite Particles: Discovery at the ILC is anticipated in the properties of the Higgs boson and the top quark as deviations from the SM prediction. Combining the mass information from the LHC enables us to close in on a full picture of the theory of composite particles.
- Particles that Mediate New Forces: Through ILC's precise measurements of the anomalies in the production rate and angular distributions of known particles, a full picture of the new force can be obtained.
- Dark Matter: Same as in (i).
- Mechanism of Higgs Condensation in the Vacuum: Same as in (i).

One cannot predict today what will come after the ILC operating at 500 GeV. However, it is natural to think that the knowledge obtained there will encourage us to delve deeper into the quest to understand nature. One possibility for such an endeavor, and a likely choice if history repeats itself, is an electron-positron collider with an even higher energy. A linear collider, thanks to its shape, will be able to increase its energy using the best possible technology at the time. Thus the ILC will likely remain an international hub in particle physics and play an important role for many years to come.

Our Group’s Activities

Status & Next Step

Symmetry Breaking & Mass Generation Physics

- ZH : H->bb,cc,gg -> EPJ C (2013) 73:2343, now working on mh=125 GeV case: Ono+Miyamoto
  H -> WW* anomalous coupling: analysis done -> publication: Takubo (revision done, resubmitted to P.R.D.) -> P.R.D88,013010(2013)
  H->other modes: Tino (AA,mu+mu-) + Kawada/Tanabe/Suehara/Daniel (tau+tau-)->publication
  Recoil mass: Jacqueline -> draft-1, Suehara (qq), CP mixing in h->tau+tau-: Yokoyama, Ogawa (HVV couplings)
- ZHH : full simulation of the H->bb&Z->all modes, fast simulation of nunuHH: finished: Junping + Takubo (Ph.D thesis: done) -> New analysis with improved analysis tools: Junping + Claude + Suehara + Tanabe, Jet-clustering: Shaofeng Ge, LCFIPlus: Suehara
  New analysis: ZHH->ZbbWW*: Kurata
- nnHH : full simulation @ 1TeV, done for DBD: Junping -> publication
- nnH, eeH : precision measurements of HVV couplingsm, mh=125GeV: Junping
  BR measurements: Ono, Christian
- TTH : quick simulation studies with NRQCD corrections
  -> P.R.D84,014033(2011) -> full sim. @ 0.5 & 1 TeV: (Yonamine left) Tanabe + Sudo
- TT Threshold : Top Yukawa measurement: Horiguchi + Ishikawa + Tanabe, Theory: Kiyo + Sumino -> publication? (cf. a recent significant theoretical development!): Ozawa
- New analysis (enW) : Koya Tsuchimoto (controlling systematic uncertainties)
- AA->HH : quick simulation studies, so far H->bb and WW BG
  -> P.R.D85,113009(2012) : Kawada, Theory: Harada

Status & Next Step

Beyond the Standard Model

- SUSY : full simulation studies for LOI -> publication
  - EWkino scan: Tanabe
- Extra U(1), etc. -> Z' tail
  - TT : full simulation studies for LOI -> publication in conjunction with tau tau
  - tau tau : full simulation studies for LOI -> ditto
- Hidden Sector / XD : P.R.D78, 015008 (2008)
- LHT : P.R.D79, 075013 (2009)
- Model discrimination: Saito + Suehara .. : P.R.D84, 115003 (2011)
- R-handed neutrinos: Saito : P.R.D82, 093004 (2010)
- LHT: Kato (exp) + Harigaya (th): ZHZH finished, working on eHeH, nHnH, ..: Draft (n-1)?
- Very light gravitino: Katayama (Master's thesis), Tanabe (exp) + Matsumoto (th) --> 1st Draft --> New student: Takuaki Mori (Tokyo)
- Quasi stable stau: Yamaura (Master's thesis) + Kotera + Kasama —> reactivated
- Higgs portal/h->Invisible: Honda -> Yamamoto -> Ishikawa, Ogawa, Junping
- W-H+/W+H-: (Shinzaki), Ishikawa (exp) + Kanemura, yagyu (th)
- New projects?
  - AMSB: Tanabe
  - Single photon (DM search): Tanabe
  - Heavier Higgs bosons?: Yokoya, (Abhinav) -> Ishikawa?
  - Radiative correction to Higgs couplings in 2HDM: Kikuchi
  - H125->ccbar: Hidaka
  - m_nu, DM, baryogenesis: Machida

Short Term Schedule

- Weekly Meeting
  - Every Fri. at 13:30 (conf. ID: to be announced)
- General Meeting
  - 10:30 on Sat. Jan.16?, 2016 (KEK MCU2 conf. ID:XXX)
- LCWS 2015, Whistler (Vancouver), Nov. 2-6, 2015