Opening Comments

2015/04/11 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 energy upgrade of LHC 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 started its review. In parallel, site-specific design started and a new ILC parameter WG was formed to provide information necessary to optimize the staging scenario. Make inputs to the MEXT's physics WG. The next target for us to show our activities to the LC community is ALCWS15 on Apr. 20-24 in Tsukuba.

MEXT's ILC Review (Schedule)

- 2014/06/24 1st Physics WG Mtg.
  - particle physics in general
  - Overview of ILC project and physics
- 2014/07/29 2nd Physics WG Mtg.
  - European strategy and P5 report
  - ILC's physics case discussions
- 2014/08/27 3rd Physics WG Mtg.
  - Cosmic rays, astronomy
  - ILC's physics case discussions
- 2014/09/22 4th Physics WG Mtg.
  - Flavor physics, neutrinos
  - ILC's physics case discussions (Comparison with LHC)
- 2014/10/21 5th Physics WG Mtg.
  - Interim summary
- 2014/11/14 2nd Expert Panel Mtg.
- 2015/01/08 6th Physics WG Mtg.
  - SSC case study
  - Discussions on the requests from the Expert Panel
- 2015/02/17 7th Physics WG Mtg.
- 2015/03/30 8th Physics WG Mtg.

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)

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 (tau+tau-)
  Recoil mass: Watanuki, Jacqueline, Ogawa (ll), Tomita/Suehara (qq), CP mixing in h->tau+tau-: Yokoyama, Ogawa (HVV couplings), CPV in Zh production (Watanuki)
- 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 (high level reconstruction)
- 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?
- New analysis (enW) : Koya Tsuchimoto
- 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. Jun. 13?, 2015 (KEK MCU2 conf. ID:XXX)
- ALCW 2015, Tsukubba, Ap.r 20-24, 2015
- LCWS 2015, Vancouver, Nov. 2-6, 2015

MEXT's ILC Review

2015/04/07

Report on 8th Meeting of MEXT Particle and Nuclear Physics WG

Keisuke Fujii

Item 2: (Draft) report from the particle and nuclear physics WG

- **Chair man Kajita explained the changes (indicated in red)**

(Draft) Report to the Academic Experts Committee Regarding
The International Linear Collider (ILC)
The Particle and Nuclear Physics Working Group: Outline

1. Scientific Case (Future Perspectives of Particle Physics (HEP field) and the ILC's Role)

○ History and current status of elementary particle physics

- Elementary particle physics has been making a great progress along with advances of particle accelerators, in recent years, with that of colliding accelerators in particular.
- By the end of the 20th century the correctness of the standard model of particle physics had turned out to be quite solid.
- In 2012, the Higgs boson that gives masses to elementary particles was discovered.
- It has also been widely recognized that the standard model would not be the ultimate theory.
- The mainstream of particle physics is now shifting to the quest for physics beyond the standard model.

○ The International Linear Collider (ILC) is a facility to do experiments and searches concerning the following items:

① Full elucidation of the Higgs boson properties and precision studies of the top quark
② Searches for new particles (such as supersymmetric particles)
③ Others (such as dark matter and extra dimensions)

○ There are significant scientific meanings as targets of future elementary particle physics to study the items listed above.

2. Cost (Excerpt from the TDR validation WG report)

- The accelerator and the tunnels to house it: about 8,300 x 10^8 JYen.
  (In addition, costs for the detectors to observe collision events and labor for construction, etc. will be needed.)
- Total construction cost of the accelerator facility and detectors: about 1.1 x 10^{12} JYen (including labor).
- Running cost: about 400 x 10^8 JYen/year.
- The cost is to be internationally shared.

3. Past examples of construction costs in accelerator facility implementations

① Examples in Japan

- Even the largest accelerator facility so far built in Japan was about 1,500 x 10^8 JYen.

② Examples overseas

- The world largest accelerator: the LHC at CERN (accelerator implementation: about 5,000 x 10^8 JYen + existing facilities and tunnels + cost for labor)
- The LHC has been built by CERN, which is an international organization consisting of 20 European countries (at that time) (with additional contributions from Japan, the US, Russia, etc.)
- There was a prospect for the Higgs discovery at the time of the construction start based on the experimental data available by that time and the standard model assumption. However, the discovery could have been made by some other experiment before the LHC.

4. Experiments that ILC will be able to carry out as described in the TDR

○ The ILC will enable the following:

- Searches for physics beyond the standard model through precision measurements of the Higgs boson and the top quark.
- Searches for supersymmetric (SUSY) particles (Note that the LHC after its energy-upgrade will also search for strongly interacting SUSY particles (mainly in 2015~2017)).
- Searches for dark matter particles and extra dimensions.

5. View points for judging if the scientific case is matching the investment or not

- ~~In order to optimize the strategic prospects for research outcomes, it is necessary to reassess the ILC performance based on the results of searches for strongly interacting SUSY particles, etc. at the LHC.~~ The optimal strategic prospects for research should be clarified based on the results of searches for strongly interacting SUSY particles, etc. at the 13TeV LHC.
- ~~Judgment to approve the project or not should wait until the above reassessment will have been made.~~
- ~~In case the ILC's search region would have been restricted to a certain degree by experiments using existing accelerators, it would be necessary to reassess the appropriateness of the performance described in the ILC TDR.~~ In order to carry out the research program according to the optimal strategic prospects, it is necessary to reassess the appropriateness of the performance described in the ILC TDR.
- ~~Considering the enormous cost needed for the ILC project and the budgetary situation in Japan, significant (more or less 50 to 50?) international cost sharing is indispensable.~~
  Since the ILC is an international project that requires the enormous cost, significant (more or less 50 to 50?) international cost sharing should be prerequisite, considering the budgetary situation in Japan.
- ~~Considering the scale of the necessary investment for the ILC project, it is necessary to get understanding and cooperation from communities of other fields about putting higher priority to the ILC project.~~ Considering the scale of the necessary investment for the ILC project, it is important to get understanding and cooperation from communities of other fields.
- In case timely decision should not be made concerning the ILC project implementation, the project might lose its international appeal. It is hence important to formulate a system so as not to delay the decision.

6. Scenarios at the ILC based on anticipated achievements at the 13TeV LHC

(1) In the case of discovery of a new particle (which appears to be consistent with SUSY):

Strategy: Using the ILC, elucidate new physics phenomena behind the new particle through precision measurements of the Higgs boson, etc. If the ILC energy is sufficient, discovery of some other new particles linked to the LHC discovery is anticipated.

(2) In the case of observation (or discovery) of events hinting at a new phenomenon (dark matter, etc.) other than the above:

Strategy: Scrutinize the new phenomenon discovered at the LHC.

(3) In the case of no discovery of any new particle or phenomenon at the 13TeV LHC:

Strategy: Search for physics beyond the standard model through precision measurements of the Higgs boson, etc. Search also for new particles that are difficult to find at the LHC. Investigate in detail possible reason for the non-discovery at the 13TeV LHC and examine whether energy upgrade would be necessary in the future or not.

~~※ In any case, for the decision to go ahead with the ILC project implementation or not, it is necessary to evaluate if the anticipated achievements would be widely accepted as matching the investment, considering performances such as required machine energy, etc. The scenarios described above assume that the project should have been approved after such evaluation.~~

- **Summary of major changes:**
  - (1) Added brief history and current status of particle physics at the beginning.
  - (2) ILC Physics: **Full elucidation** of the Higgs boson. Added **detailed measurements of the top quark**.
  - (3) Cost: Clarify that **the cost is to be internationally shared**.
  - (4) Past examples of accelerator implementations: improved the description about the LHC.
  - (5) Research capabilities of ILC as shown in TDR: improved the wordings.
  - (6) View points for judging if the scientific case matching the investment.
    - (1) Made explicit **the timing** to clarify the optimal strategic prospects: **(13TeV LHC)**
    - (2) Made clear that ILC is an international project, and **significant international cost sharing is a prerequisite**.
    - (3) Improved the wordings about understanding/cooperation from other fields.
    - (4) Added a bullet point on negative impact expected if timely decision should not be made.→ **Clarify the importance to formulate a system not to delay the decision**.
  - (7) **Avoid repeating reservations concerning the decision making.**

There was essentially no discussion on the draft.

Item 3: Table (Attachment to the Report)

ILC's Vision based on results from the 13TeV LHC run

Research at ILC based on 13TeV LHC results	Expected change according to the 13TeV LHC results		Notes
	Scientific case of 500GeV ILC	ILC's international appeal	
1. New physics study through direct searches for new particles that go beyond the standard model such as SUSY particles			
In the case where a new particle is found at the LHC, but the chance to directly access corresponding new particles at ILC is low:	△	○/△	*In this case energy upgrade of ILC will be needed eventually. ILC's international appeal may or may not go down depending on how people evaluate prospects for*
In the case where a new particle is found at the LHC, and the chance to directly access corresponding new particles at ILC is high:	◎	◎	*In this case ILC is expected to make a very significant scientific impact in elucidating the properties of these new particles and hence its attractiveness will be greatly*
In case no new particle is found at the LHC	△	○/◎	*In this case the mass range of new particles accessible by the 500GeV ILC will be reduced. Since ILC is sensitive to different kinds of new particles, ILC's attractiveness will not change or may even increase*
2. Search for new physics beyond the standard model through precision measurements of the Higgs boson and the top quark			
In the case where a new particle is found	○/◎	○	*In this case we will need the precision measurements to identify new physics models and that deviations from the standard model become more likely to be seen. Some say this will enhance ILC's scientific case, while others say*
In case no new particle is found at the LHC	◎/○	◎	*In this case there will be no means other than ILC. Some say this will enhance ILC's scientific case while others say it will not change. If the centripetal force of LHC is diminished, precision measurements at ILC will become relatively more attractive as a approach to physics*

(1) **Change in ILC's scientific significance and appeal as of now: ◎ greatly enhanced, ○ unchanged, △ slightly lowered.**

(2) **In the case where a new particle found at LHC turns out to be a strongly interacting SUSY particle, the mass of the lightest new particle directly accessible at ILC is about 1/7 of its mass (the mass could be even lighter due to mixing).**

(3) **The upper limit of the mass reach for a new particle searchable by the 13TeV LHC is 2TeV (2000GeV). The upper limit of the mass reach of direct search for new particles at the 500GeV ILC is 250GeV. (LHC's new particle searches at 8TeV resulted in no new strongly interacting particle discovered below 1TeV.**