Opening Comments

2015/01/24 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 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! (longer-term goal)

- 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 (monthly). The next mid-term target for us to show our activities to the LC community is ALCWS14 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.

Higgs
Top
BSM

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)
- 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 -> publicaton?
- 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
- W-H+/W+H-: Shinzaki (exp) + Kanemura, yagyu (th)
- New projects?
  - AMSB: Tanabe
  - Single photon (DM search): Tanabe?
  - Heavier Higgs bosons?: Yokoya, Abhinav
  - 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. Apr. 11?, 2015 (KEK MCU2 conf. ID:XXX)
- HPNP 2014, Toyama, Feb. 11-15, 2015
- ALCW 2015, Tsukubba, Apr 20-24, 2015

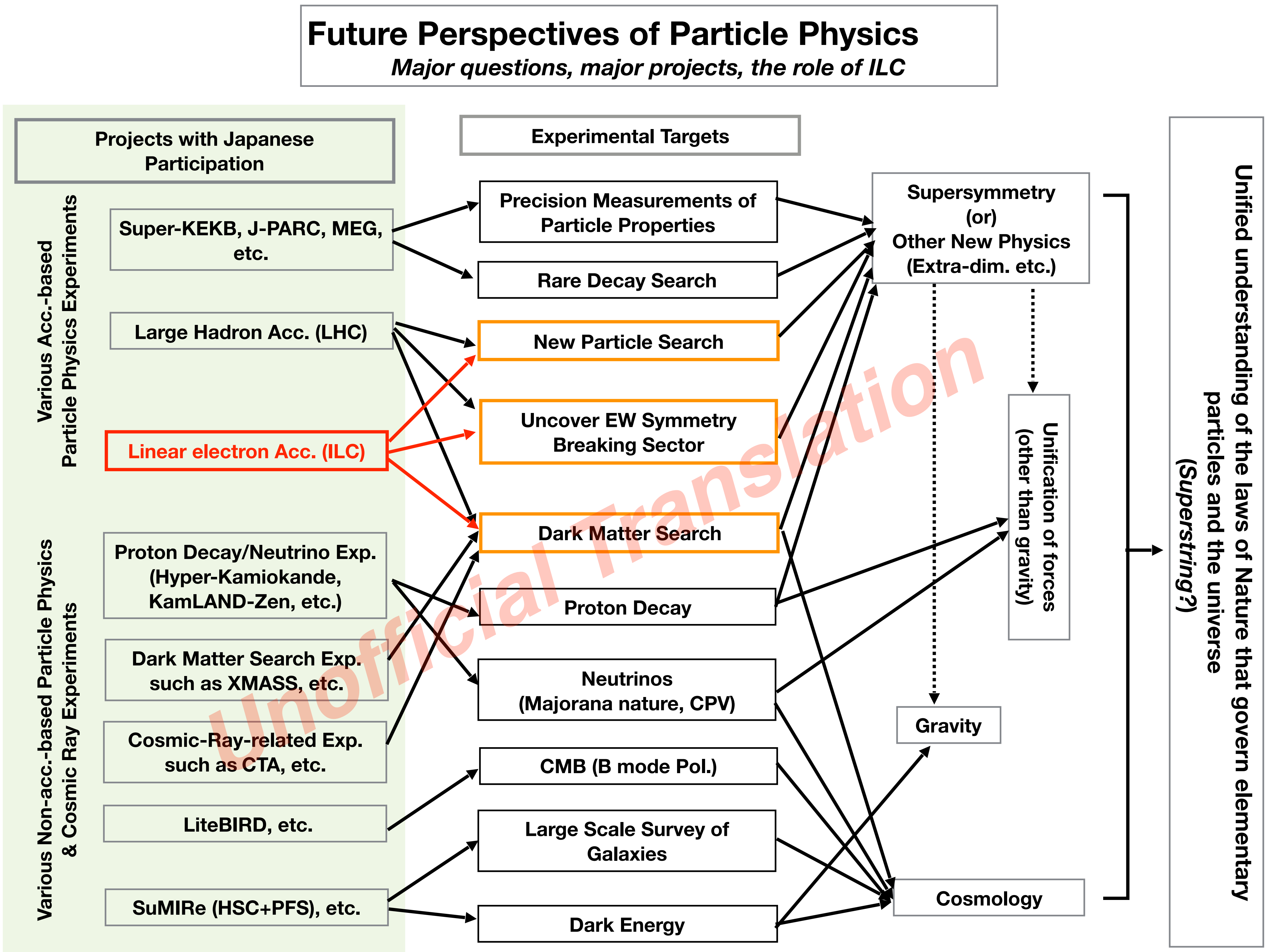
MEXT's ILC Review

Progress Report from MEXT Particle & Nuclear Physics WG

Presented by WG Chair, Prof. T.Kajita
at the 2nd Academic Experts Committee Mtg.

***Unofficial Translation*: official version available only in Japanese from**
http://www.mext.go.jp/b_menu/shingi/chousa/shinkou/038/shiryo/1353569.htm

Responsibility for the contents belongs to KF.



Unofficial Translation

Physics case for the ILC based on the LHC achievements

(1) Achievements anticipated at LHC	(2) Next priority in physics	(3) Research tasks about (2) that ILC will be able to contribute	(4) Scientific impact of ILC discovery in (3)		(5) Notes
1. Discovery of new particles					
Discovery of events that appear to be supersymmetry (SUSY)	*Elucidation of SUSY*	*From (1) the discovery of non-colored SUSY particles and (2) precise measurements of the Higgs boson: clarify the relation with the LHC discovery and establish SUSY and aim to elucidate the breaking mechanism. In (1), expect the identification of dark matter.*	*Prove the existence of SUSY*	Origin of electroweak symmetry breaking	*(1) Needed ILC capabilities depend on the mass of the lightest SUSY particle (LSP)* *(2) Possible to detect at ILC 250-500 GeV*
Discovery of heavy resonances that hint composite Higgs	*Elucidation of the new force*	*Through detailed measurements of the Higgs boson and the top quark, and relating to the LHC discovery, verify the compositeness of the Higgs boson.*	*Verification of composite Higgs* *(Discovery of a new strong force)*	Origin of electroweak symmetry breaking; New forces	*Measurements possible at ILC 500 GeV*
Discovery of new particles that decay to a pair of leptons	*Elucidation of the new gauge interaction*	*Establish the new gauge interaction by examining the interference effects of the particle discovered at the LHC with the Standard Model particles.*	*Establish new gauge interaction* *(Discovery of a new weak force)*	New forces	*Possible to determine details of new interaction and identify models at ILC 500 GeV*
2. Determination of the details of the Higgs mechanism					
Measurement of the Higgs three-point coupling (self-coupling)	*Precise measurement of deviation from the SM*	*Verify the Higgs mechanism by determining the Higgs potential from the measurement of the Higgs three-point coupling* *(1) Observe no deviation* *(2) Observe a deviation*	*(1) Verify the SM.* *(2) Observe new physics.** **Can test models that explain the matter-antimatter asymmetry in the universe.*	Physics of the "vacuum"	*(1) ~30% measurement possible at ILC 500 GeV* *(2) Precise measurement possible at ILC 1 TeV*
Measurement of the top mass and Higgs mass	*More precise measurements of the two masses*	*Determine the energy scale of new physics from the precise measurements of the top mass and Higgs mass.*	*Test of the SM at high energies* *(Settle the question on the vacuum stability)*	Physics of the "vacuum"	*Possible to observe at ILC 500 GeV*

Unofficial Translation

(1) Achievements anticipated at LHC	(2) Next priority in physics	(3) Research tasks about (2) that ILC will be able to contribute	(4) Scientific impact of ILC discovery in (3)		(5) Notes
3. Discoveries of other new phenomena					
Discovery of events that appear to be dark matter	*Elucidate dark matter*	*Identify the new phenomenon discovered at the LHC as dark matter particle by studying mono-photon events.*	*First discovery of dark matter particle* *Structure formation in the universe*	Dark matter	*If detectable at LHC, also possible to observe at ILC 500 GeV*
Discovery of phenomena that hint extra dimensions, e.g. multiple heavy resonances	*Elucidate new phenomena through similar discoveries in other experiments*	*Take a first step in elucidating extra dimensions by searching for similar non-colored particles and precision measurements of the Higgs boson, top quark, and other SM particles, clarifying the relation with the LHC discovery.*	*Observe further evidence of extra dimensions* *Discovery of an extended spacetime*	Extra dim.	*Phenomena detectable at the LHC also possible to observe at ILC 500 GeV*

4. No discoveries beyond the Standard Model (SM)

In case of no discoveries of new particles or phenomena beyond the SM, the ILC's strategy to pursue BSM physics would be as follows:

(1) Precisely measure the Higgs boson couplings to other SM particles and look for deviations from the SM, so as to decide the future direction of particle physics by uncovering the physics behind the electroweak symmetry breaking through fingerprinting the deviation patterns.

(2) Probe the limit (energy scale) of the applicability of the SM by precise measurements of the top quark and the Higgs boson masses.

(3) Carry out precision measurements of the top quarks's spin-dependent couplings to the Z and the W bosons and investigate BSM physics such as composite Higgs models or models with extra-dimensions.

(4) Investigate the non-discovery of SUSY at the LHC and search for SUSY particles that are not accessible at the LHC. In particular dark matter searches would be important.

(5) Search for a new neutral gauge boson (new force carrier) through measurements of interference effects with the photon and the Z boson over the mass region exceeding 5TeV.

(6) In order to discover new particles or phenomena inconceivable from the current theoretical ideas, search systematically for deviations from the SM through categorized event topologies. At the ILC there will be chances to find new particles undiscoverable at the LHC.

(7) Measure the Higgs self-coupling and decide the shape of the Higgs potential. Look for a possible deviation from the SM.

Feasibilities of these studies are guaranteed in the 250-500 GeV energy range. Taking advantages of e+e- collisions, i.e. a clean environment due to low background and precise theoretical predictions, probe new physics, making full use of energy scan (measurements with varying energy little by little), electron (positron) beam polarization, energy momentum conservation, as needed. The searches in (4) are limited to new particles with a mass less than the beam energy. As for (7), the error at 500GeV is 30%, which can be improved to 10% with the energy upgrade to 1TeV.

Guidelines
(1)Anticipated achievements at the LHC: describe possible cases.
(2)Next priority in physics: describe the highest priority issue based on the LHC result in each case.
(3)Research tasks that ILC will be able to contribute: identify specific tasks.
(4)Scientific impact of ILC discovery: identify specific items that address the issues in (2)
(5)Notes: identify relation between the energy scale found at the LHC and the requirements for the ILC

Unofficial Translation

Progress Report to the Academic Experts Committee Regarding The International Linear Collider (ILC)

(The Particle and Nuclear Physics Working Group)

Unofficial Translation

- Summary of investigations and discussions so far made in the WG

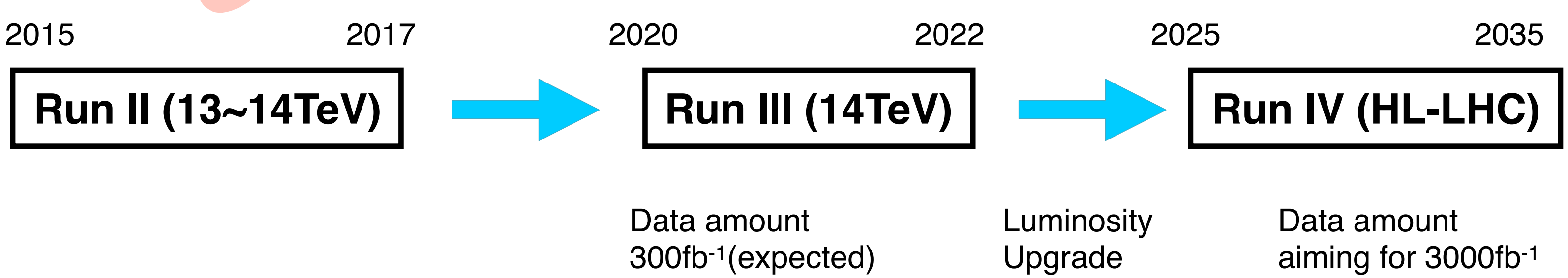
1. Overview (items to be investigated)

- (1) Goals of particle and nuclear physics and the role of the ILC
- (2) Among (1), achievements anticipated from existing accelerators (such as the LHC)
- (3) Among (1), achievements the ILC is aiming at and its required performance

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

- Ultimate goal of particle physics is unified understanding of the laws of Nature that govern elementary particles and the universe. In order to achieve this goal, it is important to experimentally study unification of the forces other than gravity, supersymmetry, and other new physics.
- For these studies, direct searches for new particles such as supersymmetric particles are being performed using the energy frontier accelerator, the LHC※. In parallel, various research programs are on-going including indirect searches with accelerators such as KEKB or J-PARC aiming at high intensities.

※ LHC schedule



※ fb^{-1} (inverse femto barn): unit for # collisions. $1fb^{-1}$ at the current LHC corresponds to about 70 trillion collisions.

Unofficial Translation

- Independently of whether the LHC will discover new phenomena currently being searched for or not, the ILC being proposed as the next generation project of a linear electron positron collider is, thanks to its clean environment with low background, an experimental facility having research capability that goes beyond the limit of the LHC experiments and will be important because of its potential to contribute to full elucidation of new physics through various precision measurements and searches for new particles and new phenomena.
- Basically the research program at the ILC is to uncover and understand new physics beyond the Standard Model (SM), which includes the following:

1) To look for evidence of physics beyond the SM through precision studies of the Higgs boson and the top quark.
2) To search for new physics such as supersymmetric particles, and their detailed studies when discovered※.
3) Others

※ When a new physics signal will be discovered at the LHC, it should be evaluated if it is within the energy or the precision reach of the ILC.

Unofficial Translation

3. Scenarios at the ILC, etc. based on anticipated achievements at the LHC

1) In the case of an observation (or discovery) of a new particle at the LHC, which appears to be consistent with supersymmetry or composite Higgs models:

Next Step: Using the ILC, elucidate new physics phenomena behind the new particle through the connection with the LHC discovery. If the energy is sufficient, measurements in electron positron collisions will be very effective to understand the new physics at large.

Impact: It would prove the existence of supersymmetry or confirm compositeness of the Higgs boson, thereby leading to a great discovery and advancing the research field significantly.

2) In the case of a significant deviation from the SM observed at the LHC in Higgs-related measurements:

Next Step: Through precision measurements of the Higgs self-coupling and its mass and the top quark couplings and its mass, which are difficult at the LHC, identify the deviation from the SM and clarify the new physics scale.

Impact: Confirmation of the new phenomenon beyond the SM is in itself a great discovery and would boost the efforts to construct a new theory.

3) In the case of an observation (or discovery) at the LHC of a possible signal that hints at some other new phenomenon (such as dark matter or extra dimensions):

Next Step: Using the ILC, study in detail the new phenomenon discovered at the LHC.

Impact: First observation of a dark matter particle or a foothold to investigate extra dimensions, which would lead to a great discovery and significantly advance the research field.

Unofficial Translation

4) In the case of no discovery beyond the SM at the LHC:

Next Step: There are multiple strategies exploiting the ILC in this case. ILC will be able to scrutinize the Higgs boson properties through precision measurements, which are difficult at the LHC, and uncover physics beyond the SM (such as supersymmetry or composite Higgs models) behind the Higgs mechanism.

While doing so, we will investigate the reason for the non-discovery at the LHC and clarify the properties of new particles that will have been missed at the LHC. Using the ILC we will then search intensively for these new particles that are difficult to find at the LHC.

If any supersymmetric particle is found, it will be a great discovery. There is a chance for the ILC to discover a new particle that is impossible to find at the LHC.

Impact:

※ In any case, 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.

(To be discussed in the future)

Unofficial Translation

4. Various Approaches to New Physics for Specific Issues

5. International Collaboration and How to Foster Necessary Human Resources

Some Comments from the Academic Experts Committee

Relevant to Our Action Plan

Based on unofficial notes

Responsibility for the contents belongs to KF.

- ***Since the project cost is so big, I wonder if it is really acceptable for people in general unless the scientific case of the project is explained in a plain language in such a way that it would stimulate their intellectual curiosities. It is necessary to explain it accurately and at the same time in a language understandable by the general public. The local people near the candidate site seem excited about the project, but other than that it seems not yet widely disseminated.***
- ***Show the timeline and priorities, too.***
- ***Show prospects for international collaboration including human resources and cost-sharing. (How to obtain necessary human resources including preparation for necessary training system)***

Based on Unofficial Notes

A List of Discussion Items

Presented by Chief of MEXT Particle and Nuclear Research Promotion Office , Mr. Shimazaki at the 2nd Academic Experts Committee Mtg.

***Unofficial Translation*: official version available only in Japanese from http://www.mext.go.jp/b_menu/shingi/chousa/shinkou/038/shiryo/1353569.htm**

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Unofficial Translation

Items to be discussed regarding the ILC project (Material No.4)

❖ Based on the recommendation by SCJ, etc., it is necessary to investigate and obtain a clear vision on the following items in 2~3 years.

(1) The project cost and its international sharing over the periods of construction, operation, upgrade and decommissioning.

- Validate construction and operation costs described in the TDR
- Estimate additional cost for quake-proof design, tunnel expansion, etc.
- Estimate additional cost for infrastructures around the lab.
- Investigate possibility of cost reduction.
- Validate the total cost based on the considerations above.
- Investigate various future projects in related countries, etc. and assess prospects for the ILC.

(2) Clear strategy for the particle physics research program at the ILC, taking into account the LHC upgrade. Estimation of additional cost to carry out the program.

- Reevaluate the ILC project considering the LHC project and estimate additional cost.
- Estimate the cost for future upgrade (expansion of the facility to 50km (1TeV)).

(3) Manpower, human resources (leader class persons in particular) necessary for construction and operation

- How to obtain researchers and engineers, taking into account other domestic and international projects.
- Assessment of the number of people to be assembled around the site including accompanied family members.

(4) Domestic organization centered around researchers at KEK, universities, etc. and their management

- Domestic project implementation planning
- Governance issues related to the international lab. (regal entity, etc., governance structure, decision making mechanism, etc.)
- Cooperation / negotiation with local governments, etc.

→ **Particle & Nuclear Physics WG**

TDR Validation WG

(5) Social impact of the ILC project

- Technological and economical ripple effects (※ make use of outsourcing here)
- Outreach effort to acquire understanding from the genial public
- Potential obstacles (restriction on land utilization, ecological assessment, etc.)

(6) Budgetary framework not to cause stagnation of efforts to solve various other national issues or progress of various other fields of science

※ items to be investigated are subject to change if needed

Unofficial Translation

Summary

- **We need to convey the ILC physics case (big picture) in a language intelligible to the general public.**
- **We need to show that there are enough number of interested and capable people to realize the ILC. → *video message!***
- **We need to convince them that the project is well designed and feasible.**
- **We need to convince them the reliability of the cost estimate.**
  (We are asked to provide the total cost including preparation, construction, operation, upgrade, and even decommissioning periods. Notice that this also applies to detectors)
- **Inputs to MEXT needed well before the next Experts Committee meeting (in March/April?)**