Japanese HEP community discussion on the 250 GeV ILC

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Reassessment of the ILC project

- Physics landscape
  - Discovery of 125 GeV Higgs (2012)
  - Results from LHC Run II (2016)
- International HEP landscape
  - HL-LHC in EU
  - Circular Higgs Factory proposed in China
  - DUNE in US
- Japanese HEP landscape
  - Super KEKB/ JPARC
  - Hyper Kamiokande proposed

- Feedbacks (domestic only)
  - Academia in general: reserved/hostile
  - Funding authorities: reserved/critical
  - Political allies (Local/Central): enthusiastic/cautious

- Japan's economy: The International Monetary Fund warned in 2015 that the ratio of Japan's government debts to its gross domestic product is expected to rise to 250 percent by 2020 if the country maintains its current fiscal policy.

- Japanese HEP community proposes, to Government of Japan, construction of the International Linear Higgs Factory (previously known as ILC250) in Japan.

- This facility will have the accelerator complex in Tohoku and a data-processing center in Kyushu. (Recommend GOJ to invest in superconducting technology and information infrastructure in Japan.)

- It is an advanced accelerator based on the ILC technology and, therefore, possesses the intrinsic upgradability of energy/luminosity.

- It does require broad participation and strong support from the HEP community abroad.

- It must be managed in a cost-conscious way by an organization formed by industries, local/central governments, international partners and academics.

Scientific justification (must be reaffirmed)

- JAHEP asked a commission consisting of non-ILC physicists to evaluate the physics case for Linear Higgs Factory.
  - Chaired by Prof. Shoji Asai (of ATLAS Japan).

- JAHEP prepares the statement; Affirmation of Scientific Significance of ILC 250 as Higgs Factory.

- Town hall meeting at KEK on July 22.

Committee on the Scientific Case of ILC250 Higgs Factory

July 22, 2017 Report to the HEP community (V1)

Shoji Asai* (U. Tokyo), Junichi Tanaka (ICEPP, U. Tokyo), Yutaka Ushiroda (KEK), Mikihiko Nakao (KEK), Junping Tian (ICEPP, U.Tokyo), Shinya Kanemura (Osaka U.), Shigeki Matsumoto (Kavli IPMU, U.Tokyo), Satoshi Shirai (Kavli IPMU, U. Tokyo), Motoi Endo (KEK), Mitsuru Kakizaki (Toyama U.)
***chair**

Commissioned by the Japan Association of High Energy Physicists
An independent review of the scientific case of the ILC by ATLAS, Belle II, Theory members

Assumptions

1) L=120-240 fb^{-1} /year (TDR & 2 bunches) and Maximum 360fb^{-1} / year →**2ab^{-1}** in 10 years

2) **Concurrent operation with HL-LHC:** Start in 2028-2030, Physics results around 2040

3) Beam polarizations (TDR): **Positrons 30%, Electrons 80%**

4) Input from other experiments: **Synergy**

Take full advantage of expected physics results in 2030-2040

HL-LHC (top mass, Higgs coupling, direct search)
SuperKEKB (rare decay, charged Higgs, CP phase)
T2K (If CP phase → leptogenesis)
Double beta decay (→ leptogenesis)
Electric dipole moment (→ electroweak baryogenesis)
Lepton flavor violation (→ leptogenesis)
Gravitational waves (→ electroweak baryogenesis)
Lattice QCD (α_s , m_c , m_b), higher-order corrections

Contents

1. **Determination of the new physics energy scale**

2. **Uncovering EWSB and the origin of matter-antimatter asymmetry**

3. **New particle searches based on naturalness and dark matter**

4. **Summary**
   Synergies with LHC, SuperKEKB, Neutrino, and other experiments
   Ideas for studies which were the scope of ILC above 250 GeV
   Upgrade scenarios
   Conclusions

ILC250 can cover regions where HL-LHC and Belle II by themselves cannot cover, and probe the energy scale of new physics. Specifically, ILC250 has sensitivity to heavy Higgs in 2HD models. ILC250 is important in new physics scenarios based on naturalness and/or dark matter.

The synergy of ILC250 and HL-LHC establishes a search network to probe the energy scale of new phenomena & new principles up to Λ=2-3 TeV. Thus ILC250 plays an important role.

Furthermore, ILC250 can probe the origin of matter. A crucial test of electroweak baryogenesis is possible. This study provides a second pathway to access the energy scale of new phenomena and new principles.

ILC	Higgs precision measurement, SM precision measurement, electroweak baryogenesis Search scenarios: Higgsino, DM ligher than 62 GeV, small tan beta
HL-LHC	Higgs coupling measurement, new physics direct search, top quark mass Search scenarios: Bino, Wino, large tan beta
Belle II	Additional CPV search, bottom quark mass, tau LFV (GUT) Search scenarios: large tan beta
T2K, HK	Leptogenesis, GUT
LFV	Leptogenesis, right-handed neutrino, GUT
EDM	Flavor-conserving additional CPV, EW baryogenesis
LISA DECIGO	EW baryogenesis 1st order transition: alternative to HHH coupling measurement
Underground Experiment	DM direct search search scenarios: heavy region

Synergy is Key

Challenging tasks for ILC250	Solutions with Synergy
Higgs Full Width	HL-LHC: custodial symmetry ($K_W/K_Z = 1$) Replace Γ_{HZZ} with Γ_{HWW} $\Gamma_{total}=\Gamma_{HWW}/Br(H\rightarrow WW)$ → comparable with ILC500 precision
Self-coupling HHH (challenging with ILC500)	Baryon number violation → EWBG or LG (T2K, double beta decay) EW baryogenesis HL-LHC, ILC250, SuperKEKB, Gravitational waves ILC250 possible
Higgs coupling	HL-LHC (Yt) Lattice (mb,mc,αs uncertainty) → comparable with ILC500 SuperKEKB (Lattice examination)
Search	Electroweak gaugino search based on naturalness Higgsino mass < ~200GeV Dark matter search (<62GeV)
Top mass	HL-LHC(0.2~0.3GeV) SM precision sufficient Precision sufficient for vacuum stability discussion (if a detailed probe of high scale physics needed, upgrade to ILC350)

Conclusions

- Concurrent running of the ILC250 helps to enhance HL-LHC physics case.
- Given the fact that the energy scale of new physics is currently unknown, the physics reach of precision Higgs and other SM probes of ILC250 are comparable to that of ILC500.
- Combining with HL-LHC, SuperKEKB, and other experiments, ILC250 "Higgs Factory" will play an indispensable role to fully cover new phenomena up to Λ~2-3 TeV and to uncover the origin of matter-antimatter asymmetry.
- The inherent advantage of a linear collider is its energy upgradability. ILC250 can not only uncover the energy scale of new physics, but has the potential to reach its energy scale itself in due course.

What's next ? All-out campaign !

- Push this through, following the advices from our political and industry allies.
- Get a buy-in from
  - **PM's office and Cabinet Bureau**
  - Ministry of Finance
  - MEXT
  - Ministry of Economy, Trade and Industry
  - Ministry of Land, Infrastructure, Transport and Tourism, and
  - Ministry of Foreign Affairs.

JAHEP definitely needs your enthusiastic support.

Future Energy Upgrade Scenarios

1. Results from ILC250 and HL-LHC show the energy scale of new phenomena and new principles.
2. Top quark mass precision: for SM precision probes and vacuum stability, 0.2-0.3 GeV precision from LHC is sufficient. If future results from HL-LHC and ILC250 show that very high energy scale (e.g. GUT) becomes the target of new study, and a detailed investigation of the vacuum stability becomes needed, then ILC350 becomes important.
3. If everything is consistent with SM, detailed investigation of the electroweak symmetry breaking and the Higgs potential becomes important. In this case, it will be needed to probe not only gravitational waves but also the Higgs self coupling HHH, and precision measurements at the CM energy of 500 GeV (positive interference) and 1 TeV (negative interference) become important.