

Opening Comments

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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.

So far no additional new particles or new phenomena have been found in the LHC Run 2, suggesting that there seem to be no easily discoverable new particles, which enhanced the importance of the precision measurements of H125 and loophole-less searches at ILC more than ever. 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. The MEXT ILC Advisory Panel says "it is necessary to closely monitor, analyze and examine the development of LHC experiments". We did and proposed ILC250 as a JAHEP agreement on July 22, 2017.

- The MEXT showed its position on March 7, 2018 with three bullet points, one of which suggested necessity to discuss ILC in the SCJ Master plan process. The MP process finished with ILC listed in its long list though not in its short. The next point was ESU, which was published on June 18, 2020 with ILC mentioned favorably. Meanwhile, LCB/ICFA met on Feb. 20, 2020 at SLAC with participation of a MEXT representative and a key diet member from Japan, made a statement outlining the timeline towards ILC realization including International Development Team hosted at KEK, which was established on Aug.2 and marked a new step towards the ILC realization. In parallel, the U.S. Snowmass process is on-going.

- **The political environment about ILC is now very good, thanks, in particular, to strong US support. A new deputy-MEXT minister, Ms. Takahashi, responsible for S&T policy from Iwate, very supportive. Multiple discussion sessions held.**
→ **Remaining hurdle: how to secure financial resource outside the ordinary S&T budget.**
- **The climate change: The first stage of the ILC is 250 GeV but, now studies on energy upgrade even above 1 TeV is encouraged. Discussions on non-colliding beam experiments using the ILC facility starting.**
- **In spite of the recent resurgence of the COVID19, KEK is operating in the new normal mode, and various ILC promotion activities are on-going. Various strategy discussions on going in KEK and JAHEP (Future HEP Project Committee). Note: Interim version of KEK RM is out for comments from JAHEP, the final version expected after international review, maybe in April.**
- **JAHEP ILC Steering Panel** was established on Oct.28 to lead the HEP community in Japan to advance the ILC project towards its timely realization.
- **The International Development Team (IDT) took over LCC/LCB:**
→ **IDT Membership is open to public since Sep.11, substructure formed.**
→ **Actively working on Snowmass process to expand the ILC community.**
→ **Preparation on-going for JFY2022 budget request to establish Pre-Lab.**
- **Tohoku upgraded its ILC promotion organization, Tohoku ILC Project Development Center, on Aug.6.**
→ **Now actively promoting ILC.**

A New Long Writeup for Snowmass

Purposes:

- 1. To assemble the full ILC story for the benefit of the Snowmass conveners and P5.**
- 2. To provide a vehicle for many members of the US community to sign and hopefully contribute.**

New Schedule (See next page)

Snowmass has been delayed by one year so does the schedule for the document!

Michael Peskin

New Schedule for the document

- Feb. 15, 2021** Due date for the editors to write some basic material in each section, so that one can have an idea of the scope of the document and of additional studies needed for Snowmass.
MP will edit these materials, to have a first basic -- though very incomplete -- version ***to present at LCWS 2021 (March 15-19, virtual)***.
- Oct. 25, 2021** Target date for a complete first draft of the report, ***to be presented at the Tsukuba ILC EOI Workshop (Oct. 26-30)***.
- Jan. 2022** arXiv posting of v1, submission ***to the Snowmass Energy Frontier conveners*** ; beginning of a drive for signatures
- Jun 2022** arXiv posting of v2
- Aug 2022** ***final version***, which will also be a reference document for the upcoming US P5 and National Academy panels

- 1 Introduction
- 2 Outline of the ILC Physics Case
- 3 Route to the ILC
 - 3.1 International Design Team
 - 3.2 ILC Pre-Lab
 - 3.3 ILC Laboratory
 - 3.4 Timeline for ILC Detectors
- 4 ILC Accelerator
 - 4.1 ILC Accelerator Design
 - 4.1.1 Design evolution since the TDR
 - 4.1.2 SuperconductingRFTechnology
 - 4.1.3 Accelerator design
 - 4.1.4 Upgrade options
 - 4.1.5 Civil engineering and site
 - 4.1.6 Cost and schedule
 - 4.2 ILC Staging up to 1 TeV
 - 4.3 ILC Scope Beyond 1TeV
 - 4.3.1 Gradient status for the ILC baseline 250 GeV
 - 4.3.2 High Gradient (45MV/m) SRF for Upgrade Paths to 1 TeV
 - 4.3.3 Toward 60 MV/m-Advanced Shape Cavities
 - 4.3.4 Nb₃Sn
 - 4.4 Issues for ILC Accelerator R&D
 - 4.5 Opportunities for US contributions
 - 4.5.1 SuperconductingLinac
 - 4.5.2 Electron and Positron Sources
 - 4.5.3 Damping Ring, Beam Delivery System, and Beam Dump
 - 4.5.4 Summary
- 5 General Aspects of the ILC Physics Environment
 - 5.1 Key Standard Model Processes
 - 5.2 Energy and Luminosity
 - 5.3 Beam Polarization

- 6 ILC Detectors
 - 6.1 Detector Requirements for the Physics Program
 - 6.2 The ILD Detector
 - 6.2.1 Detector description and capabilities
 - 6.2.2 R&D issues for the ILD design
 - 6.3 The SiD Detector
 - 6.3.1 Detector description and capabilities
 - 6.3.2 R&D issues for the SiD design
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 - 6.4.6 Timing Elements
- 7 ILC Detector Simulation
 - 7.1 ILC Fast Simulation Frameworks
 - 7.2 ILCSoft Framework
 - 7.3 ILC SM Background Samples
- 8 ILC Physics Measurements at 250 GeV
 - 8.1 Higgs – Conventional Decays
 - 8.1.1 Hadronic decays
 - 8.1.2 Leptonic decays
 - 8.1.3 EW-bosonic decays
 - 8.2 Higgs – Exotic Decays
 - 8.3 W Boson
 - 8.4 4-Fermion Processes
 - 8.5 Precision QCD
 - 8.6 Dark Sector

9 ILC Precision Electroweak Measurements

9.1 Radiative Return to the Z

9.2 Z Pole Program

9.3 W and Z Boson Masses

10 ILC Physics Measurements at 350, 500, and 1000 GeV

10.1 Top Quark

10.1.1 Top Quark Mass

10.1.2 Current state of the art and (HL-)LHC prospects

10.1.3 Top Quark Electroweak Couplings

10.2 Higgs

10.2.1 WW fusion

10.2.2 Higgs Self-Coupling

10.2.3 Top Quark Yukawa Coupling

10.3 W Boson

10.4 4-Fermion Processes

10.5 New Particle Searches – DarkSector

11 ILC Fixed-Target Program

11.1 Nuclear Physics with Electron and Positron Beams

11.2 Beam-Dump Experiments

11.3 Dedicated Secondary-Beam Experiments

11.4 ILC as an Accelerator Test-Bed

12 Precision Tests of the Standard Model

12.1 Precision Standard Model Theory for ILC

12.2 Frameworks for Effective Field Theory

12.3 Expectations from a Unified SMEFT Analysis

12.4 Expectations for CP-Violating Operators

12.5 Expectations for Heavy-Quark Operators

13 Big Physics Questions Addressed by ILC

13.1 Can the Standard Model be exact to very high energies?

13.2 What is the energy scale of new physics?

13.3 Why is electroweak symmetry broken? (weak-coupling models)

13.4 Why is electroweak symmetry broken (strong-coupling models)?

13.5 Why is there more matter than antimatter?

13.6 What is the dark matter of the universe?

14 ILC Probes of the Big Questions

14.1 Higgs boson: tests for violation of the Standard Model

14.2 Higgs boson: the Higgs Inverse Problem

14.3 Electroweak sector

14.4 Top Quark

15 Long-Term Future of the ILC Laboratory

15.1 Future Accelerators in the ILC Tunnel

15.1.1 Very High Gradient Superconducting RF

15.1.2 Very High Gradient Copper Accelerators

15.1.3 Plasma-Wake field and Dielectric Accelerators

15.2 Physics Opportunities at Multi-TeV

15.3 Physics Opportunities at Multi-10 TeV

16 Conclusions

***New areas that need
your inputs!***

LC Workshops

1. LCWS 2021 organized by Europe, with session on experiments, new ideas, ... *March 15-19, 2021, fully virtual*

<https://indico.cern.ch/event/995633/>

2. EOI WS, intended to be a community engagement workshop on Experiments, *October 25-29, 2021, hopefully in person in Japan*

Our Group's Activities

Status & Next Step

Symmetry Breaking & Mass Generation Physics

- ZH : $H \rightarrow bb, cc, gg \rightarrow$ EPJ C (2013) 73:2343, Ono+Miyamoto: IDR: Kurata
 $H \rightarrow WW^*$ anomalous coupling: publication: Takubo \rightarrow P.R.D88,013010(2013)
 $\rightarrow H \rightarrow WW^*$ to be reexamined: Liao Libo, Mila, Uli
 $H \rightarrow$ other modes (AA, $\mu^+\mu^-$) + Kawada/Tanabe/Suehara/Daniel, ($\tau^+\tau^-$) \rightarrow publication \rightarrow EPJC (2015) 75:617., $H \rightarrow Z\gamma$: Kazuki Fujii
- Recoil mass: Jacqueline \rightarrow P.R.D94,113002(2016), Suehara (qq), CP mixing in $h \rightarrow \tau^+\tau^-$: Daniel
 \rightarrow accepted for publication in PRD, HVV couplings: $H\gamma$: Yumi Aoki
- direct mH reconstruction: Junping
- EFT: EFT vs BSM, EFT fit on top EW couplings (NLO SMEFT): Junping
- Zgamma: Takahiro Mizuno
- ZHH : full simulation of the $H \rightarrow bb \& Z \rightarrow$ all modes, fast simulation of $nnuHH$: finished: Junping + Takubo (Ph.D thesis: done) \rightarrow New analysis with improved analysis tools: Junping + Claude + Suehara + Tanabe, Jet-clustering: Masakazu, Shaofeng Ge, LCFIPlus: Suehara, Yonamine; Vertex Finder: Kiichi Goto
New analysis: $ZHH \rightarrow ZbbWW^*$: dE/dx: Kurata, Systematic Error: Tim, EFT: Junping, ZHH paper draft: Junping, Masakazu, Claude
- nnHH : full simulation @ 1TeV, done for DBD: Junping \rightarrow publication
- nnH, eeH : precision measurements of HVV couplings, $m_h=125\text{GeV}$: Junping
BR measurements: Ono, Christian
- TTH : quick simulation studies with NRQCD corrections
 \rightarrow P.R.D84,014033(2011) \rightarrow full sim. @ 0.5 & 1 TeV: (Yonamine left) Tanabe + Sudo
- TT Threshold : Top Yukawa measurement: Horiguchi + Ishikawa + Tanabe, Theory: Kiyo + Sumino \rightarrow publication? (cf. a recent significant theoretical development!): Ozawa \rightarrow Yuto Eda
- W mass (enW) : Koya Tsuchimoto \rightarrow Kotora (controlling systematic uncertainties) \rightarrow Kotera
- AA \rightarrow HH : quick simulation studies, so far $H \rightarrow bb$ and WW BG
 \rightarrow P.R.D85,113009(2012) : Kawada, Theory: Harada

Status & Next Step

Beyond the Standard Model

- SUSY : full simulation studies for LOI → publication
 - **EWkino** (Compressed Spectrum Case): Jacqueline→Tomohiko : P.R.D101, 095026 (2020)
- Extra U(1) (Z' tail), Compositeness, Extra Dimensions, etc.
 - **TT** : full simulation studies for LOI → **New study with MELA**: Yo Sato, **vertex charge**: Okugawa
 - **tau tau** : full simulation studies (benchmark process) → **Keita Yumino**
 - **2f: full simulation study**: Hiroaki Yamashiro → Yuto Deguchi, Uesugi
- 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) , **New analysis**: Yonamine, **Jurina**, Daniel
- 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 --> Takuaki Mori (Tokyo) → ?
- Quasi stable stau: Yamaura (Master's thesis) + Kotera + Kasama → reactivated?
- **Higgs portal/h→Invisible**: Honda → Yamamoto → Ishikawa, Ogawa, Junping → Yu Kato
- **W-H+/W+H-**: (Shinzaki), Ishikawa (exp) + Kanemura, yagyū (th)
- **Generic DM search (mono-photon)**: Tanabe → Yonamine
(exotic higgs decay): Kurata, **Special theory guest**: Shigeki Matsumoto
- Other projects
 - Heavier Higgs bosons?: Yokoya, (Abhinav) → Christian Drews
 - X(750) : Junping → published in PRD (Phys.Rev. D94 (2016) no.9, 095015)
 - **h→cc, bb, bs QFV decays**: Hidaka
 - **Kinematical Fitter** : kajiwara
 - **pair monitor** : Ahmed
 - **LGAD simulation** : Mami Kuhara

Short Term Schedule

- Weekly Meeting
 - Every Fri. at 14:00 (conf. ID: to be announced)
- General Meeting
 - 10:30 on **Tue. March 9, 2021?**
- **LCWS 2021, March 15-19, 2021**
- **EOI WS, October 25-29, 2021 (Tsukuba/Tokyo?)**
- **Snowmass Summer Study: July, 2022 (Seattle)**