ECFA linear collider physics and detector study
(status report on activities-2017-ILC)

LINEAR COLLIDER COLLABORATION

Juan A. Fuster Verdú, IFIC-Valencia

Plenary ECFA Meeting, CERN 17th November 2017

Thanks for providing material and discussions:

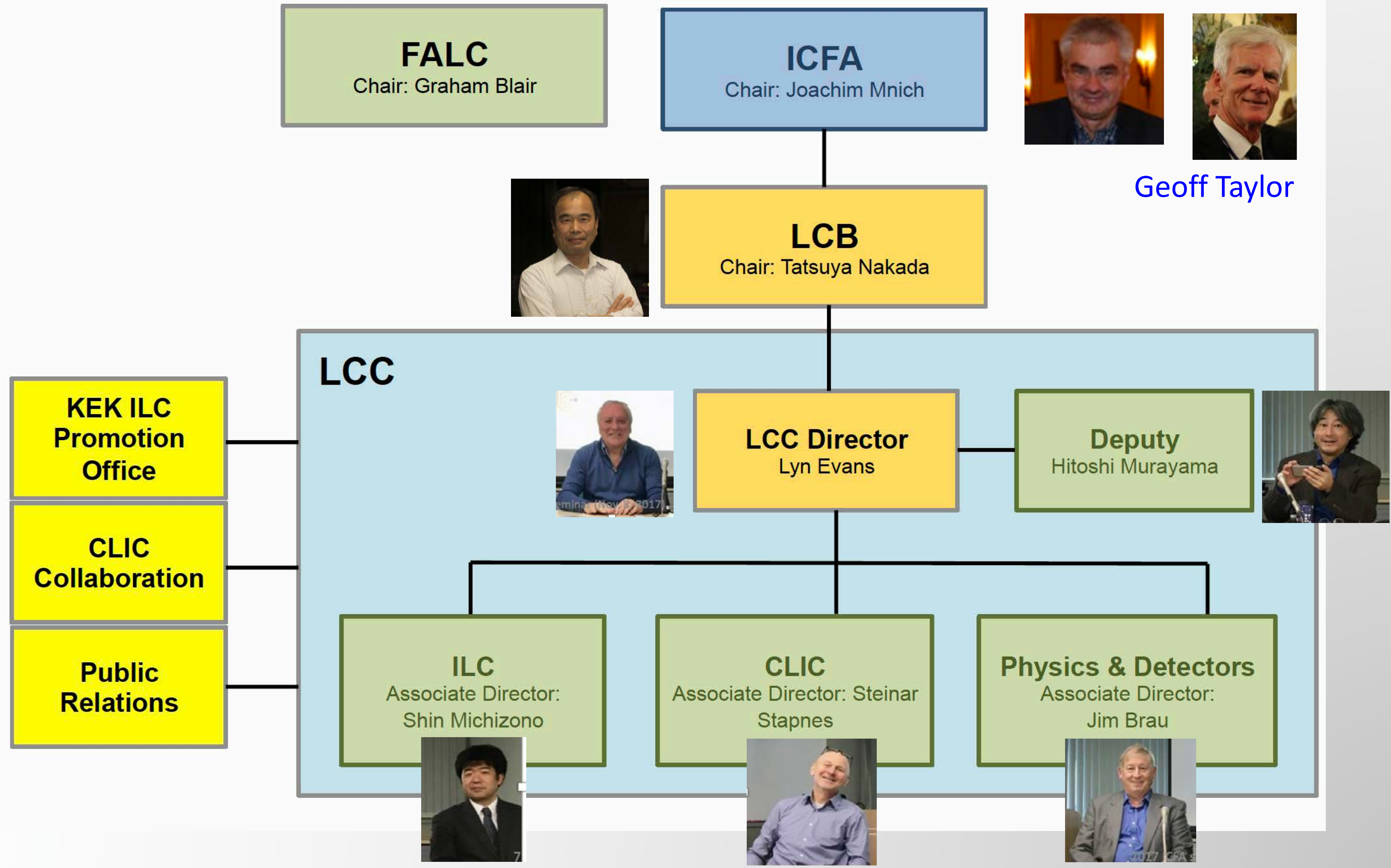
T. Behnke, J. Brau, S. Komamiya, J. List, S. Michizono, M. Peskin, F. Richard, M. Stanitzki, S. Stapnes, A. White, S. Yamashita, H. Yamamoto

Outline

- The LCC structure
- On going situation of ILC in Japan: ILC@250, cost reduction, physics…
- ICFA statement
- Detector ongoing activities
- Funding: European grants, an essential contribution for present LC activities
- Preparation to the next European Strategy update
- Conferences 2017/2018
- Summary

***** CLIC status will be presented by L. Linssen (next talk)***

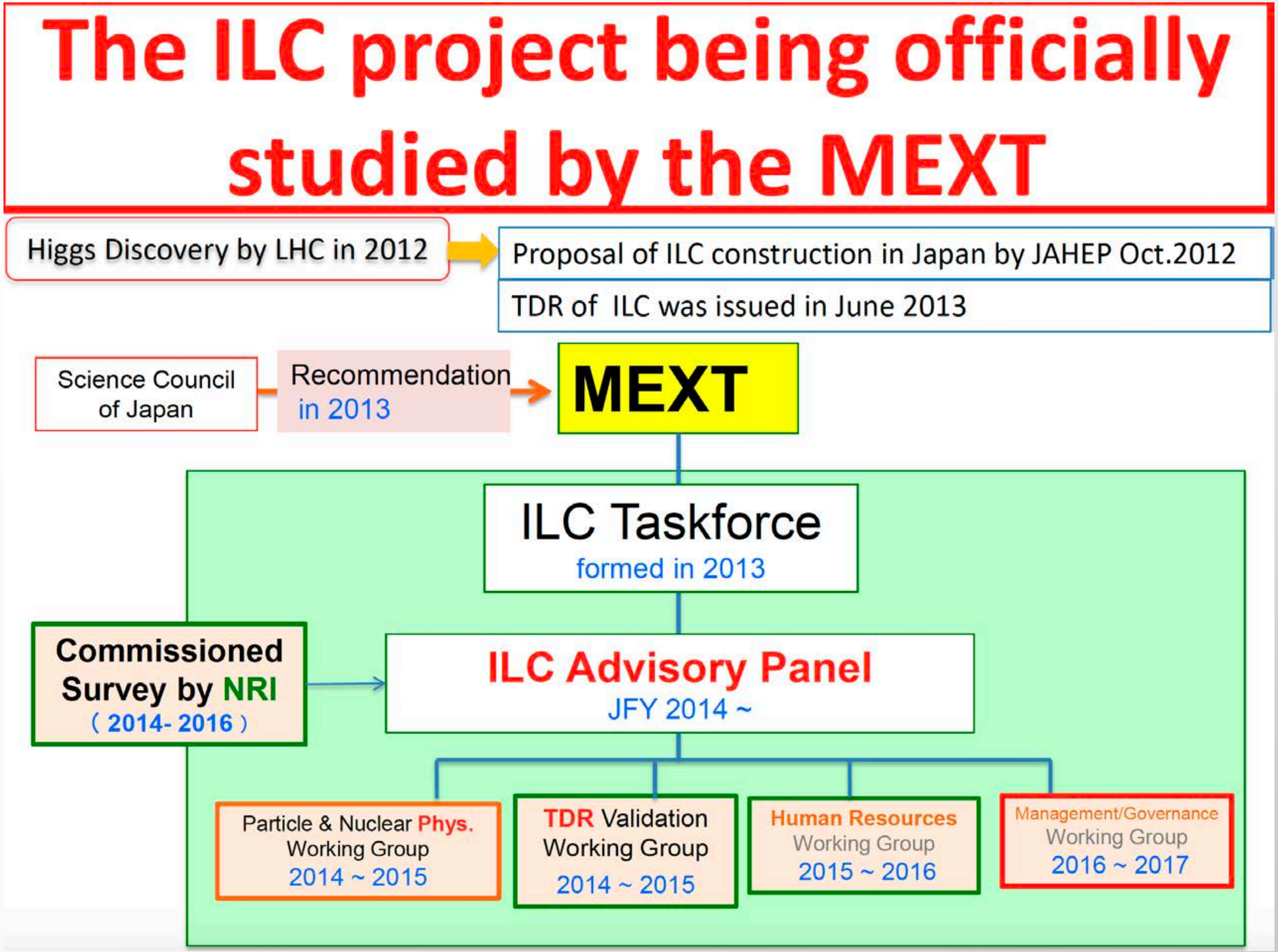
The Linear Collider Collaboration




All ILC
Global Design Effort
Physics and Detectors
航空写真
アジア
大西洋
アフリカ
南アメリカ
太平洋
インド洋
オーストラリア
Google

Japan: MEXT and Japanese Government towards ILC

S. Komamiya (ICFA-Seminar 2017)



Y. Okada (LCWS-2017)

KEK
High Energy Accelerator Research Organization

- KEK works closely with LCC and LCB to realize the ILC hosted in Japan.
- KEK cooperates with various sectors/organizations that promote the ILC project vigorously in Japan; Federation of Diet members, the industrial sector (AAA), local sectors, etc.
- KEK provides the ILC Advisory Panel in MEXT with appropriate information to help their timely conclusion.
- KEK promotes activities to obtain general understanding by the public and scientific communities.
- KEK cooperates with international physics communities to facilitate discussions between governments and funding authorities.
- KEK efforts for the ILC promotion are coordinated at the Planning Office for the ILC headed by KEK-DG.

Japan: JAHEP statement and cost reduction

Tatsuya Nakada (LCWS17- 2017)

- The Japanese Association for High Energy Physicists produced a new statement by July 2017:

  "To conclude, in light of the recent outcomes of LHC Run 2, **JAHEP proposes to promptly construct ILC as a Higgs factory with the center-of-mass energy of 250 GeV in Japan."**

  Documents are publically available at :

  - Japanese community statement
    http://www.jahep.org/files/JAHEP-ILCstatement-170816-EN.pdf
  - Japanese community study on physics of 250 GeV machine
    http://www.jahep.org/files/ILC250GeVReport-EN-FINAL.pdf

  (Full text included at the end of this presentation in backup slides)

- **This statement also implies a cost reduction of up to 40% as compared to the 500 GeV machine in the TDR.**

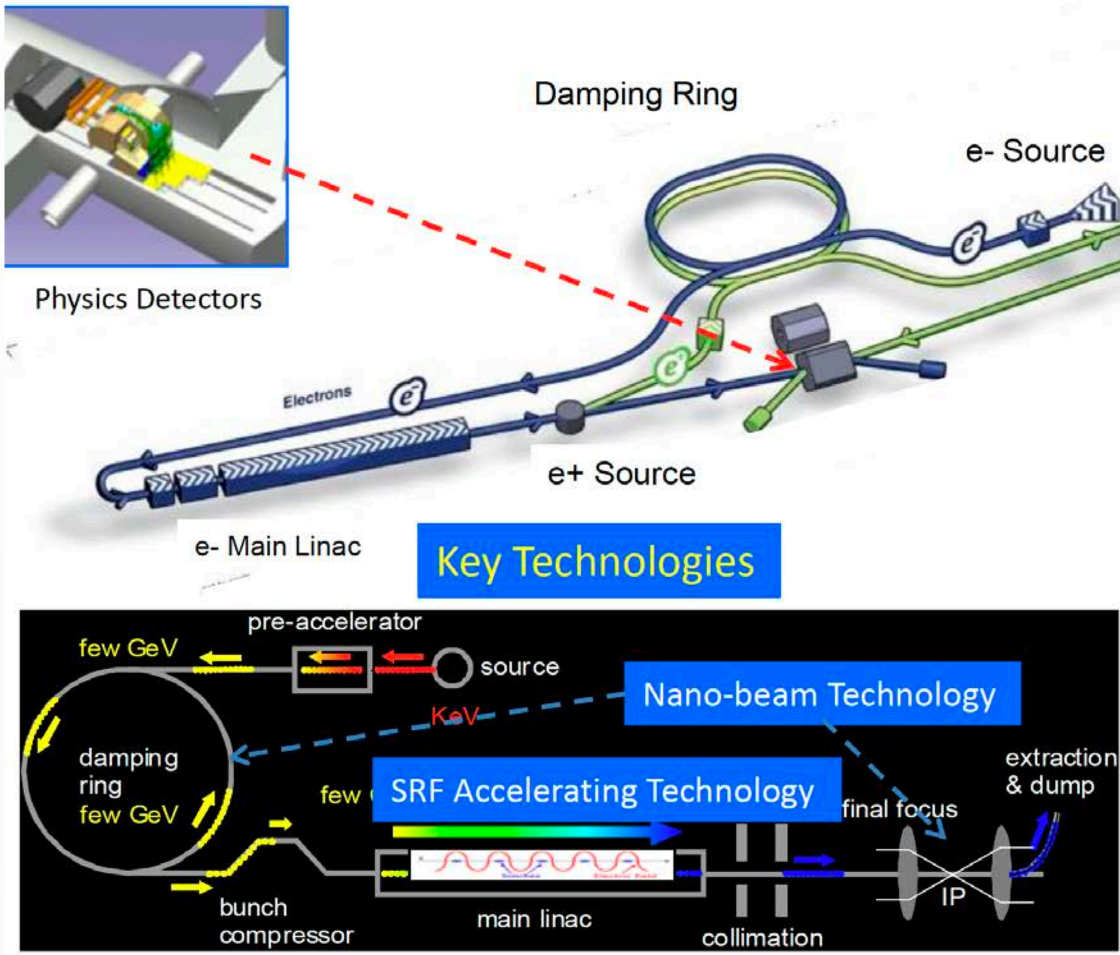
Y. Okada (LCWS-2017)

Conclusion of JAHEP statement July 2017:

- **ILC250 should run concurrently with HL-LHC** to enhance physics outcomes from LHC.
- Given that a new physics scale is yet to be found, ILC250 is expected to deliver physics outcomes that are nearly comparable to those previously estimated for ILC500 in **precise examinations of the Higgs boson** and the Standard Model.
- **The ILC250 Higgs factory, together with HL-LHC and SuperKEKB**, will play an indispensable role in the discovery of new phenomena originating from new physics with the **energy scale up to 2–3 TeV** and the elucidation of the origin of matter-antimatter asymmetry.
- A linear collider has a definite advantage for **energy-upgrade capability**. ILC250 possesses a good potential for its upgrades to reach the higher energy of new physics that the findings of ILC250 might indicate.

S. Michizono (LCWS-2017, ICFA-Seminar-2017)

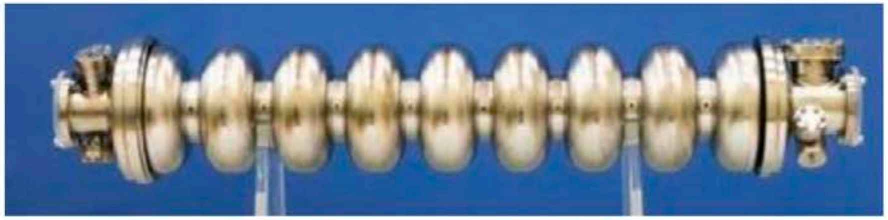
ILC Acc. Design Overview (in TDR)



Item	Parameters
C.M. Energy	500 GeV
Length	31 km
Luminosity	1.8 x10^{34} $cm^{-2}s^{-1}$
Repetition	5 Hz
Beam Pulse Period	0.73 ms
Beam Current	5.8 mA (in pulse)
Beam size (y) at FF	5.9 nm
SRF Cavity G. Q_0	31.5 MV/m Q_0 = 1x10^{10}

LCWS2017 (Oct. 23,2017)

S. Michizono (LCWS-2017, ICFA-Seminar-2017)



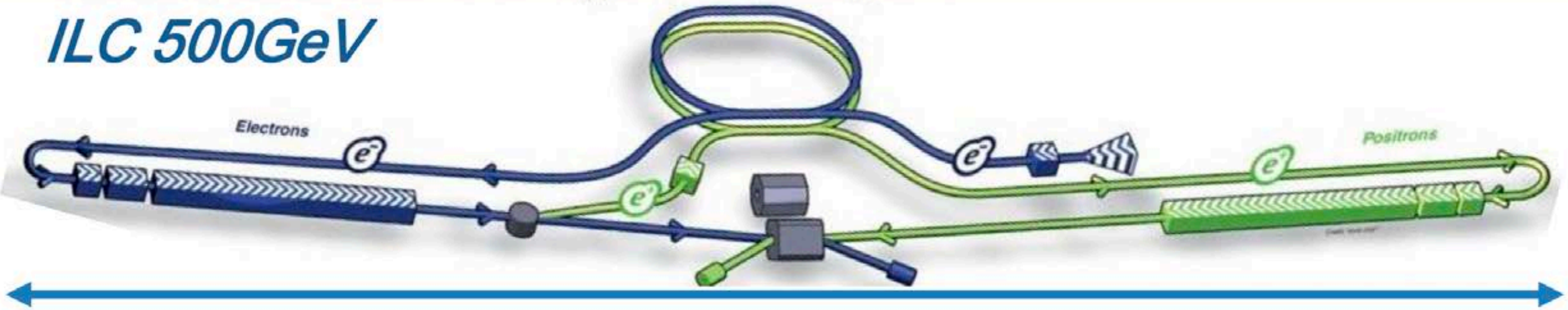
Cost reduction by technological innovation

Innovation of Nb (superconducting) material process: decrease in material cost

Innovative surface processing for high efficiency cavity by FNAL: decrease in number of cavities

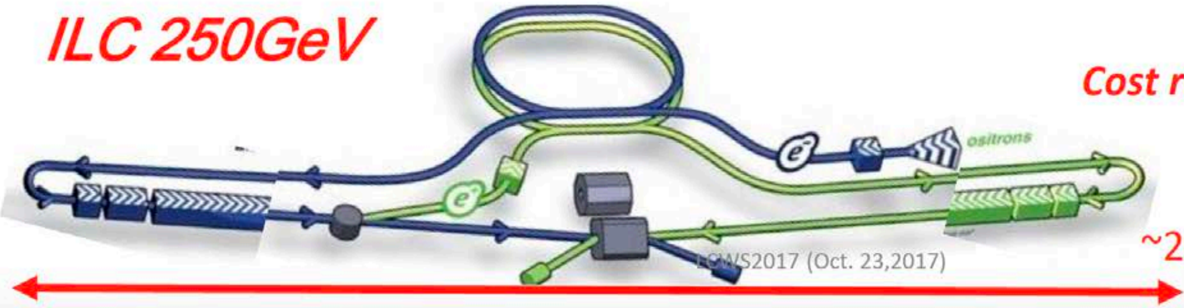
Staging

ILC 500GeV



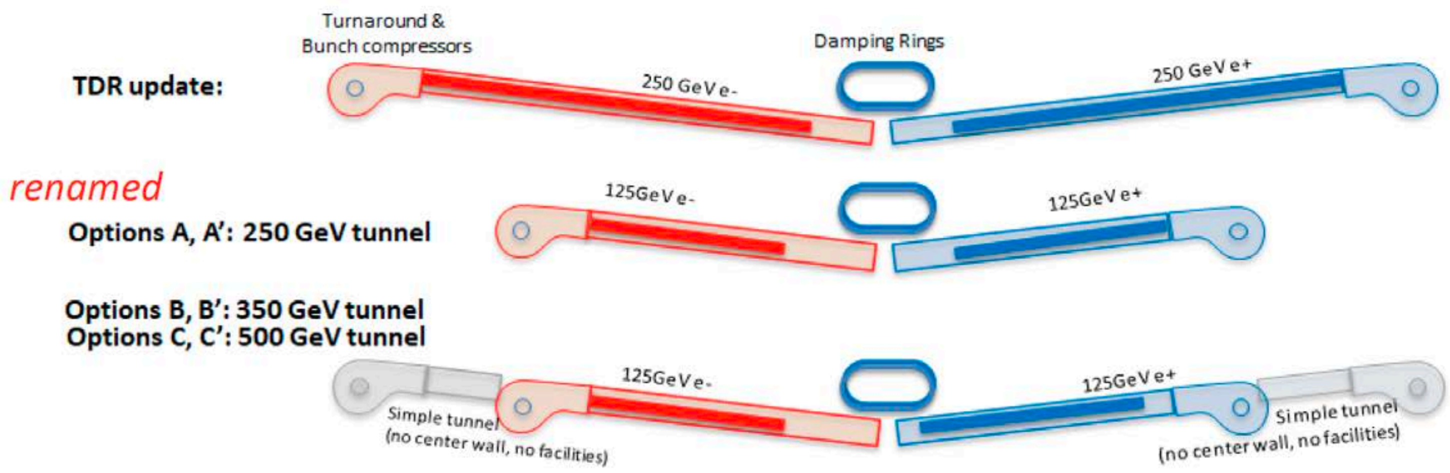
ILC 250GeV

Cost reduction by compact ILC



S. Michizono (LCWS-2017, ICFA-Seminar-2017)

Options for ILC250GeV



Options	Gradient [MV/m]	E_{CM} [GeV]	Total E_{CM} Margin	n	Space margin	Reserved tunnel	Total tunnel
TDR update	31.5	500	2%	10	1,473 m	0 m	33.5 km
Option A		250	6%	6	583 m	0 m	20.5 km
Option B				6&8		3,238 m	27 km
Option C				6&10		6,477 m	33.5 km
Option A'	35			6	1,049 m	0 m	20.5 km
Option B'				6&8		3,238 m	27 km
Option C'				6&10		6,477 m	33.5 km

LCWS2017 (Oct. 23,2017) 19

S. Michizono (LCWS-2017, ICFA-Seminar-2017)

Results of cost estimate

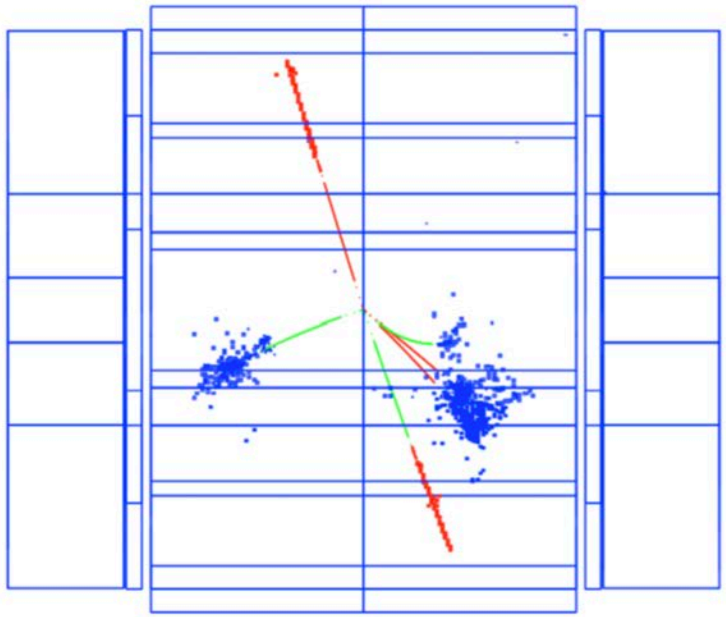
The cost estimate is carried out with the ILCU (USD as of January, 2012).
RF unit cost and other unit cost is calculated from TDR.
The staging cost is obtained by subtracting the decreased number of units.
Reduced volume production effect and price fluctuation from 2012 are ignored because these depend on the different components.
Options A'/B'/C' include the effect the cost reduction R&D.

	e+/e- collision [GeV]	Tunnel Space for [GeV]	Value Total (MILCU)	Reduction [%]
TDR	250/250	500	7,980	0
TDR update	250/250	500	7,950	-0.4
Option A	125/125	250	5,260	-34
Option B	125/125	350	5,350	-33
Option C	125/125	500	5,470	-31.5
Option A'	125/125	250	4,780	-40
Option B'	125/125	350	4,870	-39
Option C'	125/125	500	4,990	-37.5

M. Peskin (ICFA-Seminar-2017), Standard Model Effective Theory (EFT)

The absolute cross section for $e^+e^- \to Zh$ can be measured.

At 250 GeV, to first approximation, any Z boson with $E_{lab} = 110$ GeV is recoiling against a Higgs boson.



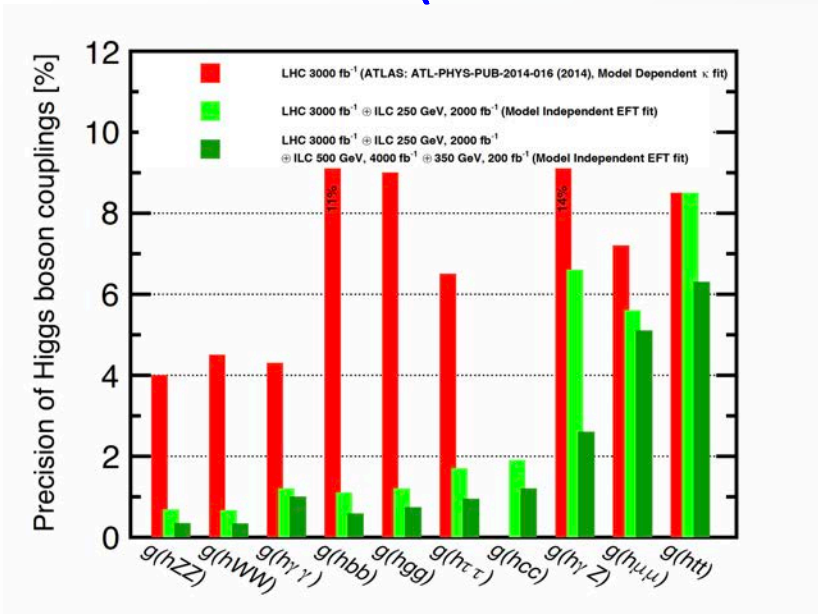
(thanks to Manqi Ruan)

Here are some final results for various proposed colliders:

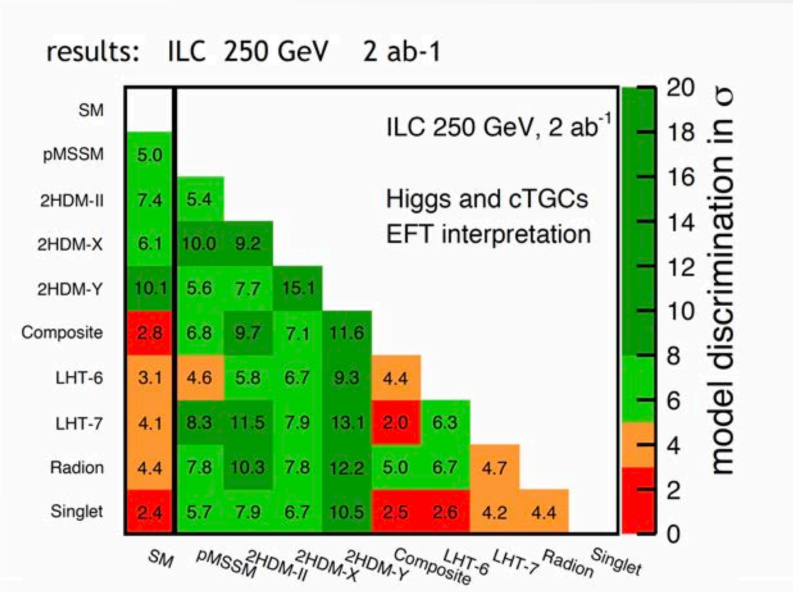
	2 ab^{-1} w. pol.	2 ab^{-1} 350 GeV	5 ab^{-1} no pol.	+ 1.5 ab^{-1} at 350 GeV	full ILC 250+500 GeV
$g(hb\bar{b})$	1.04	1.08	0.98	0.66	0.55
$g(hc\bar{c})$	1.79	2.27	1.42	1.15	1.09
$g(hgg)$	1.60	1.65	1.31	0.99	0.89
$g(hWW)$	0.65	0.56	0.80	0.42	0.34
$g(h\tau\tau)$	1.16	1.35	1.06	0.75	0.71
$g(hZZ)$	0.66	0.57	0.80	0.42	0.34
$g(h\gamma\gamma)$	1.20	1.15	1.26	1.04	1.01
$g(h\mu\mu)$	5.53	5.71	5.10	4.87	4.95
$g(hbb)/g(hWW)$	0.82	0.90	0.58	0.51	0.43
$g(hWW)/g(hZZ)$	0.07	0.06	0.07	0.06	0.05
Γ_h	2.38	2.50	2.11	1.49	1.50
$\sigma(e^+e^- \to Zh)$	0.70	0.77	0.50	0.22	0.61
$BR(h \to inv)$	0.30	0.56	0.30	0.27	0.28
$BR(h \to other)$	1.50	1.63	1.09	0.94	1.15

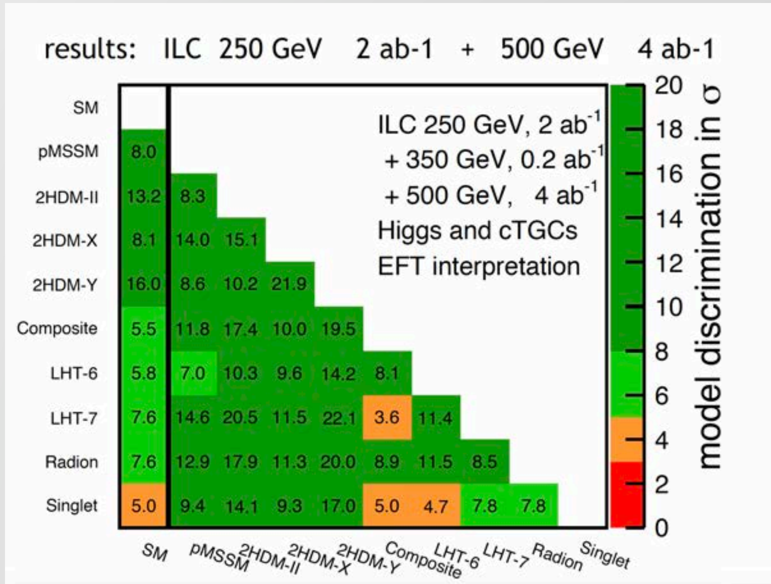
errors in % (+ slightly different polarization scheme)

M. Peskin (ICFA-Seminar-2017), Standard Model Effective Theory (EFT)

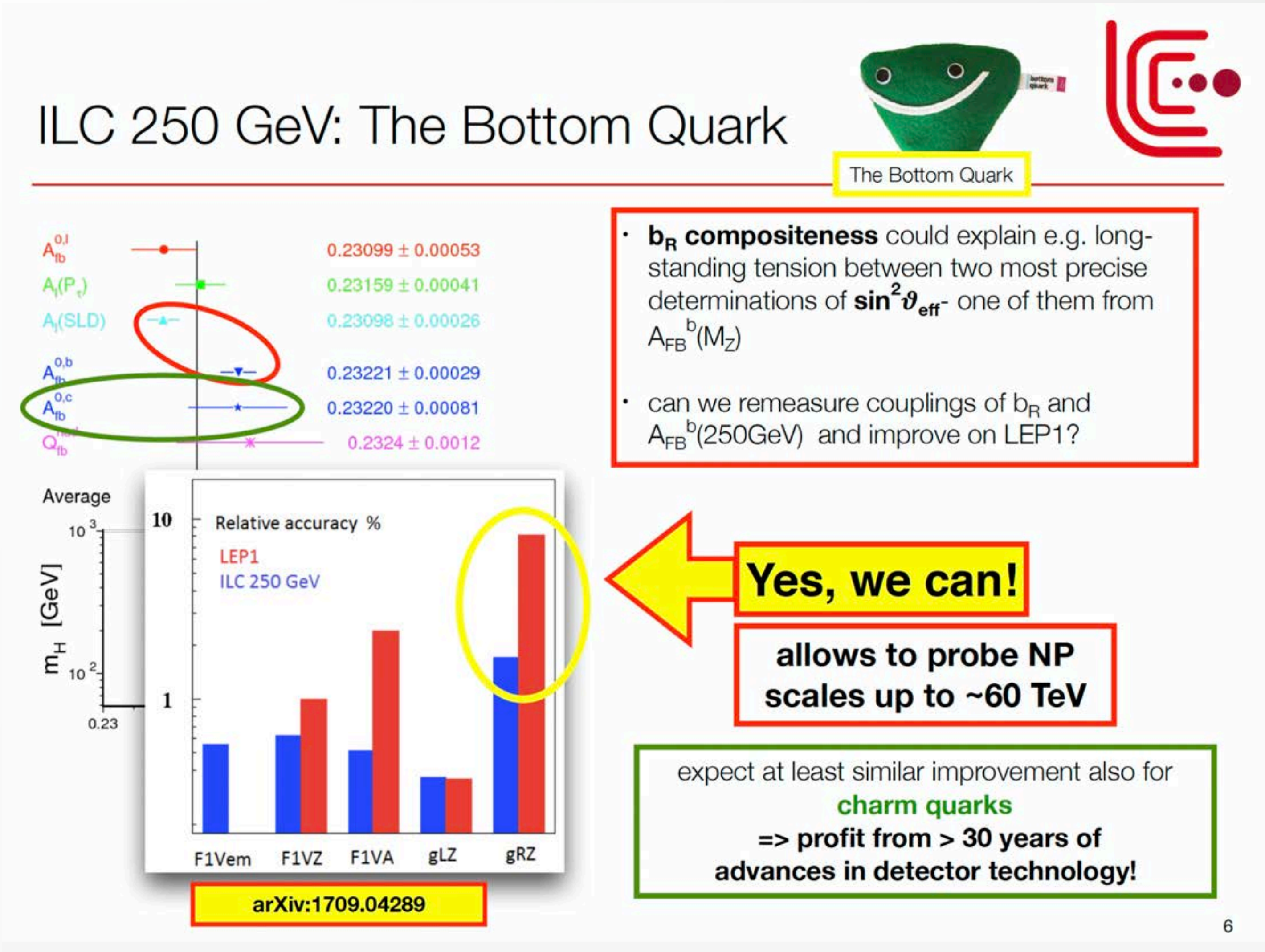


- **High precision** in Higgs couplings – **Model Independent**
- High capability to **distinguish** among SM and BSM (themselves)
- **Polarization** is an added value to increase precision





J. List & F. Richard (LCWS-2017)



Polarization provides model independent access to vector and tensor couplings

LCB Statement

Conclusions on the 250 GeV ILC as a Higgs Factory proposed by the Japanese HEP community - Short Summary -

Linear Collider Board

8 November 2017, Rev 1

Physics studies by the Linear Collider Collaboration Physics and Detector Group [1], and the Japanese Association of High Energy Physicists (JAHEP) [2] show a compelling physics case for constructing an ILC at 250 GeV centre of mass energy as a Higgs factory. The cost of such a machine is estimated to be lower by up to 40% compared to the originally proposed ILC at 500 GeV [3]. The acceleration technology of the ILC is now well established thanks to the experience gained from the successful construction of the European XFEL in Hamburg. One of the unique features of a linear collider is the capability to increase the operating energy by improving the acceleration technology and/or extending the tunnel length. For these reasons, the Linear Collider Board strongly supports the JAHEP proposal [4] to construct the ILC at 250 GeV in Japan and encourages the Japanese government to give the proposal serious consideration for a timely decision.

In recent examples of similar international projects[1], the host country made the majority contribution. A natural expectation would be that the cost for the civil construction and other infrastructure is the responsibility of the host country, while the accelerator construction should be shared appropriately. A clear expression of interest to host the machine under these principles would enable Japan to start negotiations with international partners. It would also allow members of the international community to initiate meaningful discussions with their own governments on possible contributions.

References

[1] K. Fujii et. al. (Linear Collider Collaboration), "Physics Case for the 250 GeV Stage of the International Linear Collider", DESY-17-155 / KEK Preprint 2017-31 / LAL 17-059 / SLAC-PUB-17161, arXiv:1710.07621 [hep-ex].

[1] Recent examples in the field close to the ILC are European XFEL and FAIR in Germany.

1

- LCB meeting on 7 November in Ottawa, reached a definite agreement and made a proposal to ICFA.

- Conclusion based on:
  - Japanese community statement http://www.jahep.org/files/JAHEP-ILCstatement-170816-EN.pdf
  - Japanese community study on physics of 250 GeV machine http://www.jahep.org/files/ILC250GeVReport-EN-FINAL.pdf
  - LCC study on physics of 250 GeV machine
  - Cost evaluation of the 250 GeV machine by gives a reduction of up to ~40% compared to the TDR cost for the 500 GeV machine.

[2] S. Asai et al, "Report by the Committee on the Scientific Case of the ILC Operating at 250 GeV as a Higgs Factory", arXiv:1710.08639 [hep-ex].

[3] L. Evans and S. Michizono (Edit.) (Linear Collider Collaboration), "The International Linear Collider Machine Staging Report 2017, Addendum to the International Linear Collider Technical Desgn Report published in 2013", DESY 17-180, CERN, KEK Report 2017-3, arXiv:1711.00568 [hep-ex].

[4] JAHEP, "Scientific Significance of ILC and Proposal of its Early Realization in light of the Outcomes of LHC Run 2", http://www.jahep.org/files/JAHEP-ILCstatement-170816-EN.pdf.

Tatsuya Nakada (ICFA-Seminar 2017)

ICFA Statement

ICFA Statement on the ILC Operating at 250 GeV as a Higgs Boson Factory

The discovery of a Higgs boson in 2012 at the Large Hadron Collider (LHC) at CERN is one of the most significant recent breakthroughs in science and marks a major step forward in fundamental physics. Precision studies of the Higgs boson will further deepen our understanding of the most fundamental laws of matter and its interactions.

The International Linear Collider (ILC) operating at 250 GeV center-of-mass energy will **provide excellent science from precision studies of the Higgs boson**. Therefore, ICFA considers the ILC a key science project complementary to the LHC and its upgrade.

ICFA **welcomes the efforts** by the Linear Collider Collaboration on cost reductions for the ILC, which indicate that up to **40% cost reduction** relative to the 2013 Technical Design Report (500 GeV ILC) is possible for a 250 GeV collider.

ICFA emphasizes the **extendibility of the ILC to higher energies** and notes that there is large discovery potential with important additional measurements accessible at energies beyond 250 GeV.

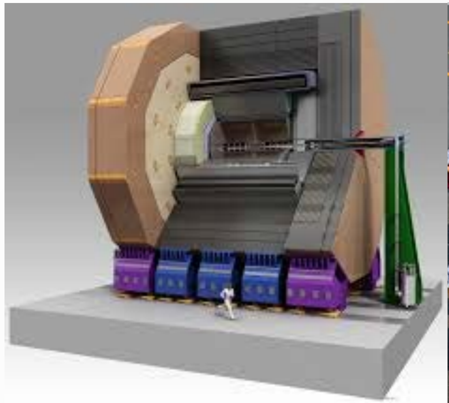
ICFA thus supports the conclusions of the Linear Collider Board (LCB) in their report presented at this meeting and very strongly **encourages Japan to realize the ILC in a timely fashion** as a Higgs boson factory with a center-of-mass energy of 250 GeV **as an international project[1], led by Japanese initiative**.

[1]In the LCB report the European XFEL and FAIR are mentioned as recent examples for international projects.

Ottawa, November 2018

The ILD Experiment group

T. Behnke (LCWS-2017)



http://www.ilcild.org
http://confluence.desy.de/ILD

71 groups have signed up,
1 group pending approval
Currently around 420 members
on the central mailing list.

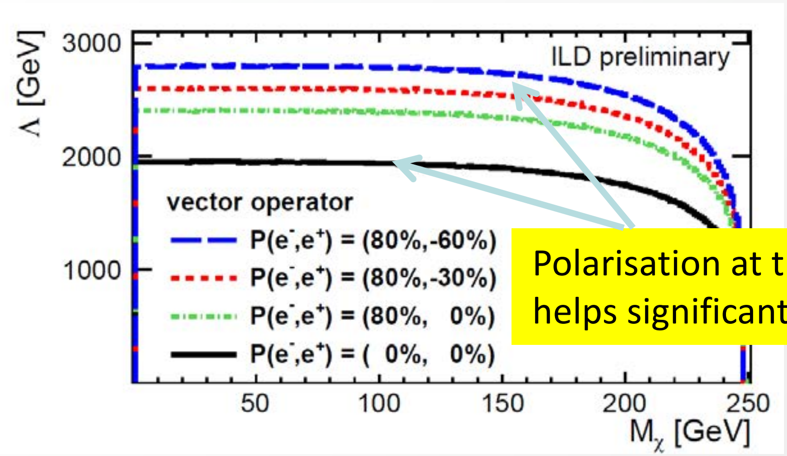
Organisation of the group in place and working.

New: established central publication and speakers bureau, to organise talks and papers within ILD
(Chair K. Kawagoe)

Since 4-2017: 14 ILD talks at intl. conferences, 3 posters

Recent Physics Highlights in ILD

Example 1: WIMP searches



Polarisation at the ILC helps significantly!

Search for WIMPs at colliders

- ILC measures couplings to leptons
- LHC measures couplings to hadrons
- ILC and LHC are complementary and probe different area of phase space.

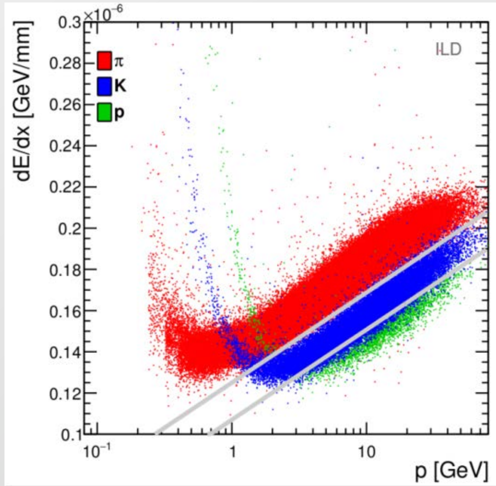
Example 2: HF EW

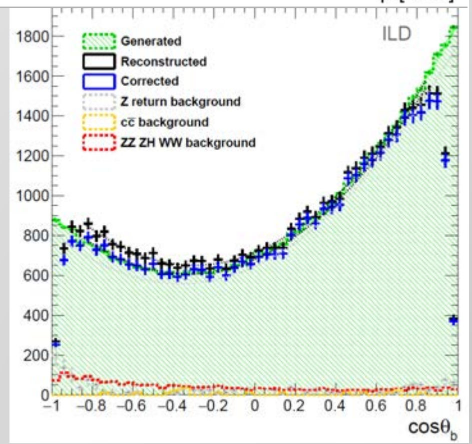
Goal: measure the b-electroweak coupling to the Z at 250 GeV

Analysis relies on

- Vertex tagging
- dEdx capabilities

Vertex charge determination: Kaon ID with 97% purity with 87% purity for p>3GeV





Continued significant activities on ILD despite of the uncertain project status

T. Behnke (LCWS-2017)

arXiv:1709.04289

ILD technical status and plans

T. Behnke (LCWS-2017)

Two baseline detector models (large/small) defined for global performance comparison

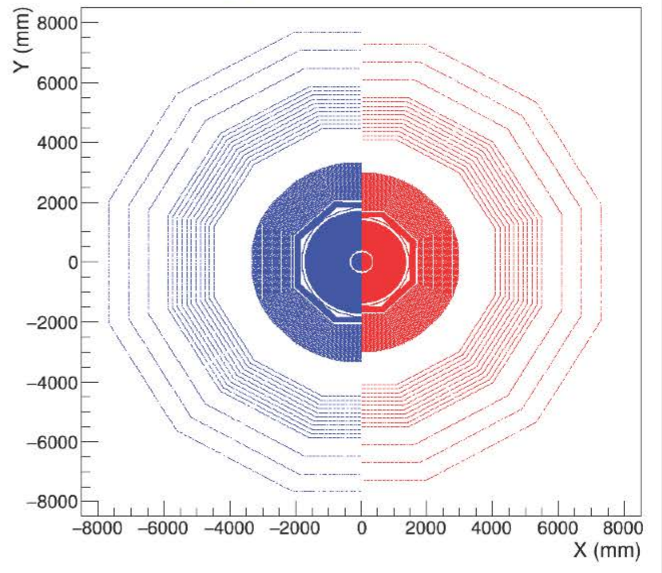
Technical progress

Forward detector layout adapted to new beams optics

Technological prototypes built and beam tested within the R&D collaborations (LCTPC, CALICE, FCAL...)

R&D spinoffs (LHC upgrades, Belle II, etc...) will help consolidating the technologies.

Global components and integration issues (coil, yoke, mechanical stability ...) under study



Optimisation process

Detector simulation tools migrated towards a new framework common to SiD and CLICdp

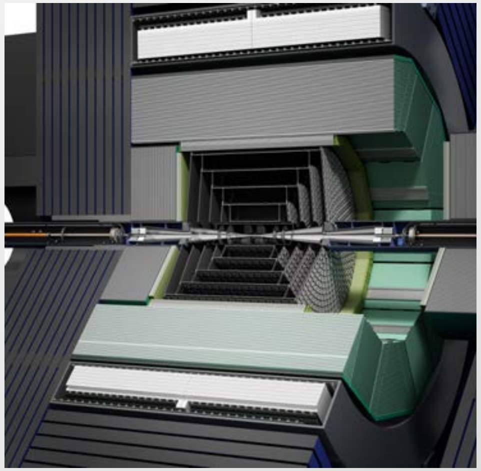
Hybrid simulation of all considered calorimetry sensors (Silicon, Scintillator, RPCs) implemented to allow comparison of response with the same events

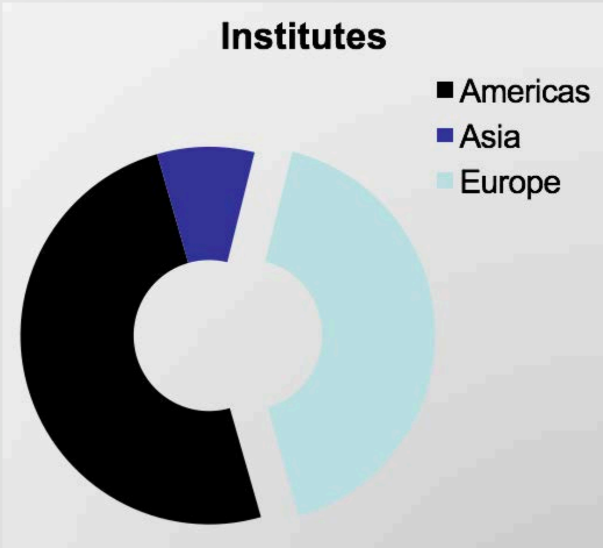
Large simulation of physics benchmark samples is about to start.

An updated reference document of the ILD detector description and performance is planned for end 2018 (will also serve as basis for input for European Strategy)

Status of the consortium

- Letter of Intent (2009) had ~ 275 Signatories from 72 institutions
- Consortium currently has 22 member institutions
  - 50 % from the US
  - 42 % from Europe
  - 8% from Asia
- SiD is committed to grow globally, especially in Asia
- Structures are in place to realize SiD once there is a green light from Japan



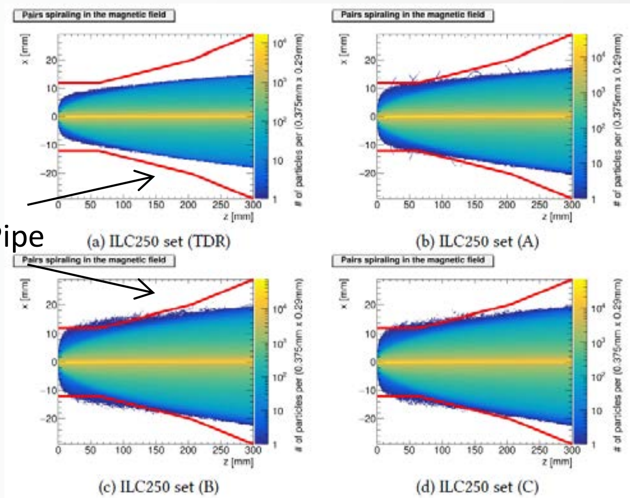


M. Stanitzki & A. White (LCWS-2017)

ILC detectors: SiD

Impact of new beam parameters

- Recent change request to modify final-focus optics at 250 GeV
  - Increase luminosity by reducing ε_x and/or β_x
  - Up to a 4 times TDR luminosity
  - larger beam-beam interactions -> increased pair background
- SiD has studied the new parameter sets in detail
  - Particularly location of the beam pipe and impact on the Vertex Detector (VTX)
- Occupancy in layer 0 for the new sets is significantly increased with respect to the TDR scheme…but can be accommodated in SiD VTX design.

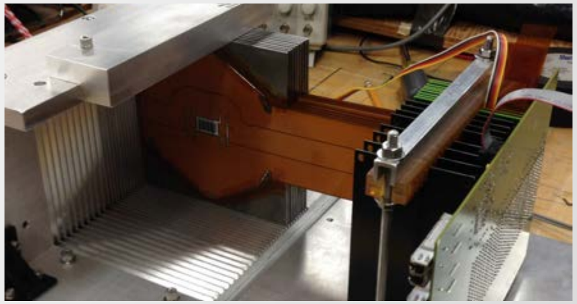


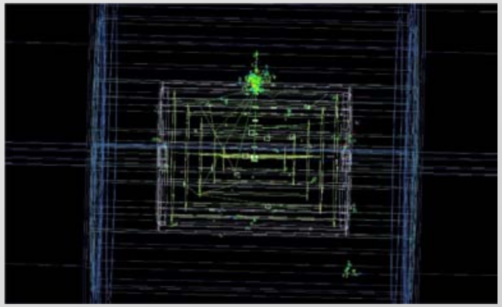
Beam Pipe

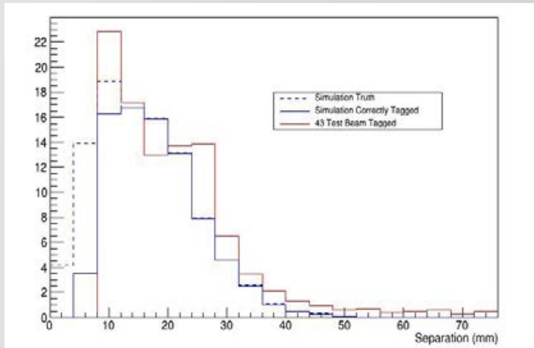
M. Stanitzki & A. White (LCWS-2017)

Calorimetry R&D

- SiD ECAL
  - Silicon-Tungsten design using hexagonal sensors
  - Recent test beam campaign at SLAC
    - 9 layer Si/W Calorimeter
    - ~ 6 X_0
    - 13 mm^2 pixels
  - Next generation sensor currently being bump-bonded
- SiD HCAL
  - CALICE Scintillator AHCAL design implemented in the Simulation
  - Validation: Comparing simulated single particle energy resolution with actual CALICE test beam results
  - Studying Particle Flow performance of new design as a next step
  - Engineering Work has started





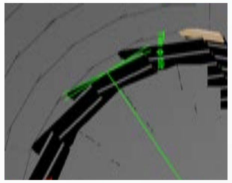


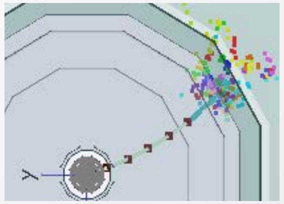
J. Fuster

ILC detectors: SiD

Software & Optimization

SiD is now implemented in the common DD4hep framework; had several iterations to incorporate geometry changes and for compatibility with latest DD4hep





SiD_o2_v02	production	• based on 2015 engineering drawings • includes a Scintillator AHCal • many custom drivers • includes Pandora extensions & det_type flags required for particle flow reconstruction • **being used for ECal/HCal optimisation studies and tracking studies**
SiD_o3_v02	test	• same as SiD_o2_v02 but AHCal has Cu/brass instead of steel absorbers
SiD_o2_v03	under developme nt	• will include new detector envelopes and XML structure • Some new custom drivers • incorporates important changes in DDSim and DDRec

SiD Status

- SiD has been very active in the evaluation of the new ILC layout at 250 GeV
- Software is now built around the common DD4HEP development
- Calorimeter R&D has been quite active including test beam campaigns

A positive statement of support for ILC from Japan crucial for the project to move ahead

- The danger of irrevocably losing key expertise has become very real
- That is particularly true for the US groups

Upon the "green light" we are ready and organized to make SiD a reality

- Studying also new technologies and potential for further cost reductions
- Plan to take a very active in role in the Europeans Strategy process

M. Stanitzki & A. White (LCWS-2017)

EU-H2020 support for LC detector/accelerator R&D

Many ILC/CLIC activities in Europe are possible thanks to EU-H2020 funding which allows for some coherent work on accelerator and detector R&D to be performed.

E-JADE

- Scientific Exchange
- Accelerator development

AIDA2020

- Integrated Infrastructure Initiative
- Detector development

ILC detector/accelerator R&D: accelerators

S. Stapnes (LCWS-2017)

Accelerator current ongoing ILC activities in Europe

Item/topic	Brief description	CERN	France CEA	Germany DESY	Time line
SCRF	Cavity fabrication including forming and EBW technology,	✓			2017-18
	Cavity surface process: High-Q &–G with N-infusion to be demonstrated with statics, using High-G cavities available (# > 10) and fundamental surface research		✓	✓	2017-18
	Power input-coupler: plug compatible coupler with new ceramic window requiring no-coating	✓			2017-19
	Tuner: Cost-effective tuner w/ lever-arm tuner design	✓	✓		2017-19
	Cavity-string assembly: clean robotic-work for QA/QC.		✓		2017-19
Cryogenics	Design study: optimum layout, emergency/failure mode analysis, He inventory, and cryogenics safety management.	✓			2017-18
HLRF	Klystron: high-efficiency in both RF power and solenoid using HTS	✓			2017- (longer)
CFS	Civil engineering and layout optimization, including Tunnel Optimization Tool (TOT) development, and general safety management.	✓			2017-18
Beam dump	18 MW main beam dump: design study and R&D to seek for an optimum and reliable system including robotic work	✓			2017- (longer)
Positron source	Targetry simulation through undulator driven approach			✓	2017-19
Rad. safety	Radiation safety and control reflected to the tunnel/wall design	✓			2017 – (longer)

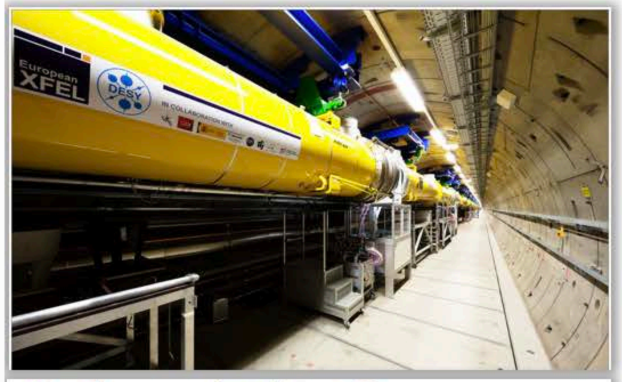
Focused R&D on some key areas (cost, power, technically critical)

ILC detector/accelerator R&D: Applications to other projects

S. Stapnes (LCWS-2017)

SCRF applications

SCRF – European XFEL and ESS



	Germany	France		Italy		Poland		Russia	Spain
	DESY	CEA Saclay	LAL	INFN Milan	IFJ PAN	WUT	NCBJ	BINP	CIEMAT
Linac									
Cryomodules	✓	✓		✓					
SCRF Cavities	✓			✓					
Power Couplers	✓		✓						
HOM Couplers							✓		
Frequency Tuners	✓								
Cold Vacuum	✓							✓	
Cavity String Assembly	✓	✓							
SC Magnets	✓				✓				✓
Infrastructure									
AMTF	✓				✓	✓		✓	
Cryogenics	✓								
Sites & Buildings									
AMTF hall	✓								

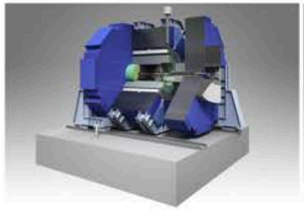
- Expertise across all essential parts of ILC
- Facilities set up in Europe
- Industrial capacity in Europe
- E-XFEL: ~7% of a 250 GeV ILC (~100 modules)

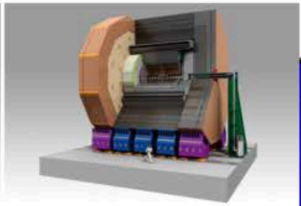
- ESS cryo-module production next
- Expertise/facilities being maintained and developed

	Germany	France		Italy		Poland	Spain	Sweden		UK
	DESY	CEA	IPNO	Elettra	INFN-LASA	IFJ-PAN	ESS Bilbao	ESS	Uppsala	STFC
RF systems				✓			✓	✓		
LLRF									✓	
Cryomodules		✓	✓							
SCRF Cavities		✓	✓		✓					✓
Power Couplers		✓	✓							
HOM couplers										
Frequency Tuners		✓	✓							
Cold Vacuum		✓	✓					✓		
Cavity String Assembly		✓	✓							
RF Tests (Cavities)	✓									✓
RF Tests (Cryomodules)		✓	✓			✓		✓	✓	

S. Stapnes (LCWS-2017)

ILC – detector studies and final overview



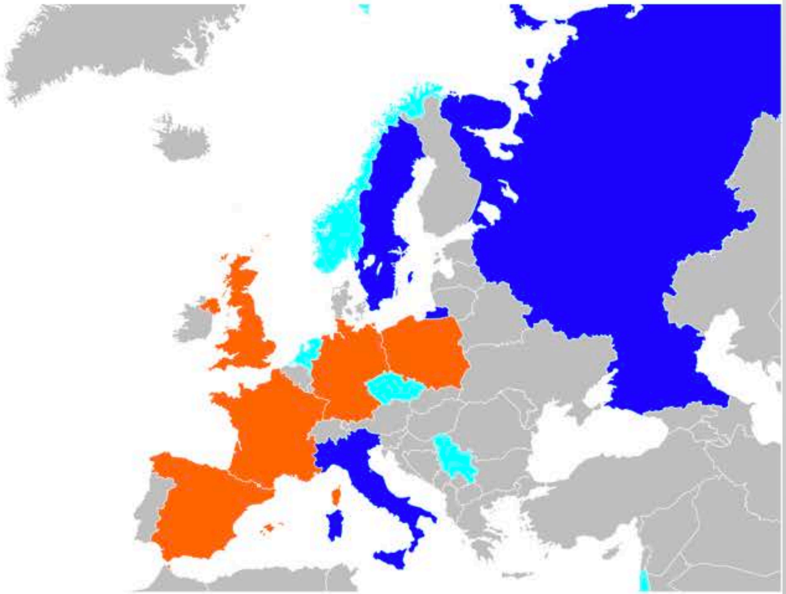


	CERN	DESY	Czech Republic	France	Germany	Israel	Netherlands	Norway	Poland	Serbia	Spain	UK
Vertexing	✓	✓	✓	✓	✓				✓		✓	✓
Tracking	✓	✓		✓	✓		✓				✓	✓
Calorimetry	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓
MDI	✓	✓						✓				✓
System Integration	✓	✓		✓							✓	

ILC summary:

Europe has played – and continues to play – a central role in development of the ILC project

Large European projects are being implemented where the ILC/SCRF technology is being put to use and is being validated



Produce two documents (still under discussion, yet to be agreed)

- General ILC project description and impact in Europe
- Description of European participation and capabilities (accelerator, detector, physics)

ILC Project Phases

S. Stapnes (LCWS-2017)

2017–2018: Pre-preparation phase
The on-going activities with relevance to the ILC in Europe are reviewed.

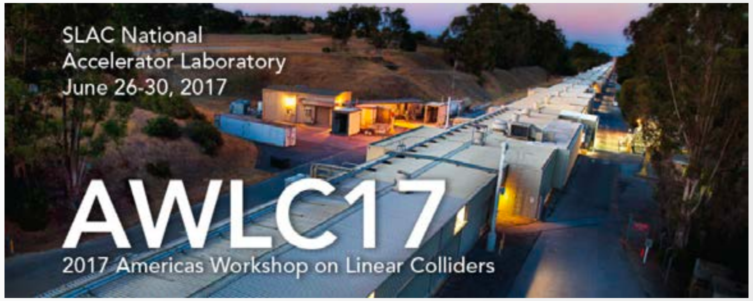
2019–2022: Preparation phase
This period needs to be initiated by a positive statement from the Japanese government about hosting the ILC, followed by a European strategy update that ranks European participation in the ILC as a high-priority item. The preparation phase focuses on preparation for construction and agreement on the definition of deliverables and their allocation to regions.

2023 and beyond: Construction phase
The construction phase will start after the ILC laboratory has been established and inter-governmental agreements are in place. At the current stage, only the existing capabilities of the European groups relevant for this phase can be described.

LC workshops 2017

- **CLIC workshop 2017, CERN, Mar. 6-10 (220 participants)**
  https://indico.cern.ch/event/577810/
  Local chairs; Steinar Stapnes, Lucie Linssen

- **AWLC17 – Americas Workshop on Linear Colliders, SLAC, June 26-30 (151 participants)**
  http://www.ifca.unican.es/congreso/ECFALC2016
  Local chairs: Norman Graf, Michael Peskin. Bruce Schumm
  "Omnibus" type workshop: Accelerator, ILD, CLICdp, SiD, R&D Collaborations, Plenaries, etc..



- **Workshop on top physics at the LC 2017, CERN, Jun. 7-9 (60 participants)**
  https://indico.cern.ch/event/595651/
  Local chair: Philipp Roloff

LC workshops 2017

- **LCWS17, Linear Collider Workshop 2017, Strasbourg, October 23-27 (participants 248+industries)**
  https://agenda.linearcollider.org/event/7645/overview
  Local chairs: Marc Winter, Maxim Titov
  Very well attended industrial session (France, Germany, Spain, Japan, etc..)
  Reception by local authorities, EU representatives from Germany (Stefan Kaufmann) and France (Olivier Becht), Japanese ambassador
  Supportive speeches by Japanese Diet members: Takeo Kawamura, Ryu Shionoya, Tatsuo Hirano

LC workshops 2017

LCWS2017 Strasbourg October 2017

Diet members speeches at LCWS2017 in Strasbourg

Hon. Takeo KAWAMURA

Member, House of Representatives
Liberal Democratic Party

Constituency: Yamaguchi 3
Number of times elected: 10

Born: November 10, 1942
Education: Keio University

Current Position:
Director, Province Creation Headquarters of Liberal Democratic Party
Chair, Special Committee on Space and Marine Development of Liberal Democratic Party

Career:

2001–2004	Vice Minister of Education, Culture, Sports, Science and Technology
2003–2004	Minister of Education, Culture, Sports, Science and Technology
2008–2009	Chief Cabinet Secretary
2010–2014	Director, Election Headquarters of Liberal Democratic Party
2016	Chair, Committee on National Budget of House of Representatives

Hon. Ryu SHIONOYA

Member, House of Representatives
Liberal Democratic Party

Constituency: Shizuoka 8
Number of times elected: 9

Born: February 18, 1950
Education: Keio University

Current Position:
Chairman, Election Strategy Committee, Liberal Democratic Party

Career:

2008–2009	Minister of Education, Culture, Sports, Science and Technology
2011–2012	Chairman, Executive Council, Liberal Democratic Party
2012–2014	Chairman, Committee on Science-Technology-Innovation Strategy, Liberal Democratic Party

Hon. Tatsuo HIRANO

Member, House of Councilors
Liberal Democratic Party

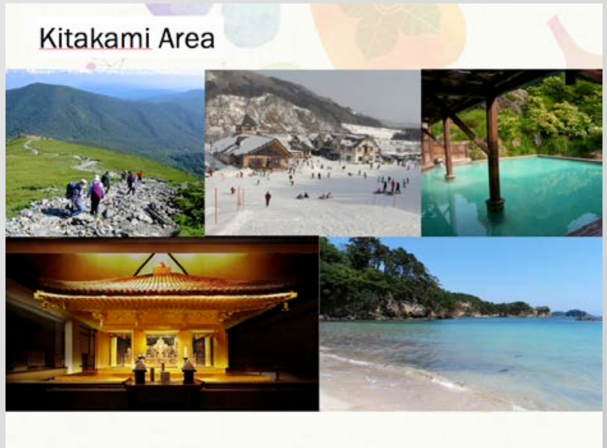
Constituency: Iwate
Number of times elected: 3

Born: May 2, 1954
Education: Tokyo University, Iowa State University
Ministry of Agriculture, Forestry and Fisheries (1977-2001)

Current Position:
Member, Agriculture, Forestry and Fisheries Committee
Member, Budget Committee
Executive Member, Special Committee on Reconstruction After Great East Japan Earthquake

Career:

2010	Chairman, Committee on Budget, House of Councilors
2010-2011	Senior Vice Minister of Cabinet Office for National Policy
2011-2012	Minister of Reconstruction Minister of State for Disaster Management
2012	Minister for Comprehensive Review of Measures in Response to the Great East Japan Earthquake



Highlights (personal) from Diet members speeches

- Cost reduction has had a very positive impact in Japanese politicians.
- The project is being discussed at very high political level in Japan.
- Japan understands the ILC as an International Research Infrastructure which needs the cooperation of countries outside Japan as ITER, International Space Station, CERN, etc...
- ILC is seen as “investing in future” and “regional revitalization” for internal Japanese politics.
- It is well understood by Japanese politicians that next year is crucial to the project and in particular to provide an input to the European Strategy update process.
- Visits and discussions with European politicians and governments are planed by next year seeking for future cooperation. Already happening in January 2018.
- The regional government in Kitakami is highly engaged and supportive to the project.

**** Full text of their speeches can be found in the backup slides of this talk.**

LC workshops 2018

- **CLIC workshop 2018, CERN, Jan. 22-26**
- **ILD workshop 2018, Ichenoseki, Feb. 20-22**
- **ALCW2018, Asian Linear Collider Workshop, Fukuoka, May 28 – Jun. 1**
- **Linear Collider top workshop 2018, Sendai, June-July**
- **LCWS18-Linear Collider Workshop, fall-2018, USA**

Summary

- The Linear Collider Collaboration (LCC/LCB) new structure is on work.
- New scenario has been brought into consideration as proposed by JAHEP, this is ILC@250 GeV while keeping possible the extension in energy. Big impact in cost. A 40% reduction with respect to ILC@500 GeV.
- Very well received in many instances such as physics community as well as the politicians, in both Japan and outside Japan.
- ILC@250 will provide precise model independent measurements of Higgs couplings but not only. Polarization is important is to achieve these physics goals.
- Detector work at SiD and ILD continues despite shortage of resources. EU-funding important to keep some activity and make it coherent.
- ICFA has reacted positively to ILC@250 and has supported the initiative as a Higgs factory while keeping its extendibility in energy and as an international project lead by Japan.
- 2018 is a crucial year for the project. This seems to be understood by all communities and not only by physicists but also by politicians.
- In Europe we are in the way to prepare the ILC contributions to next European Strategy update. For that, having new input from Japan on the new proposal is mandatory.

Personal summary

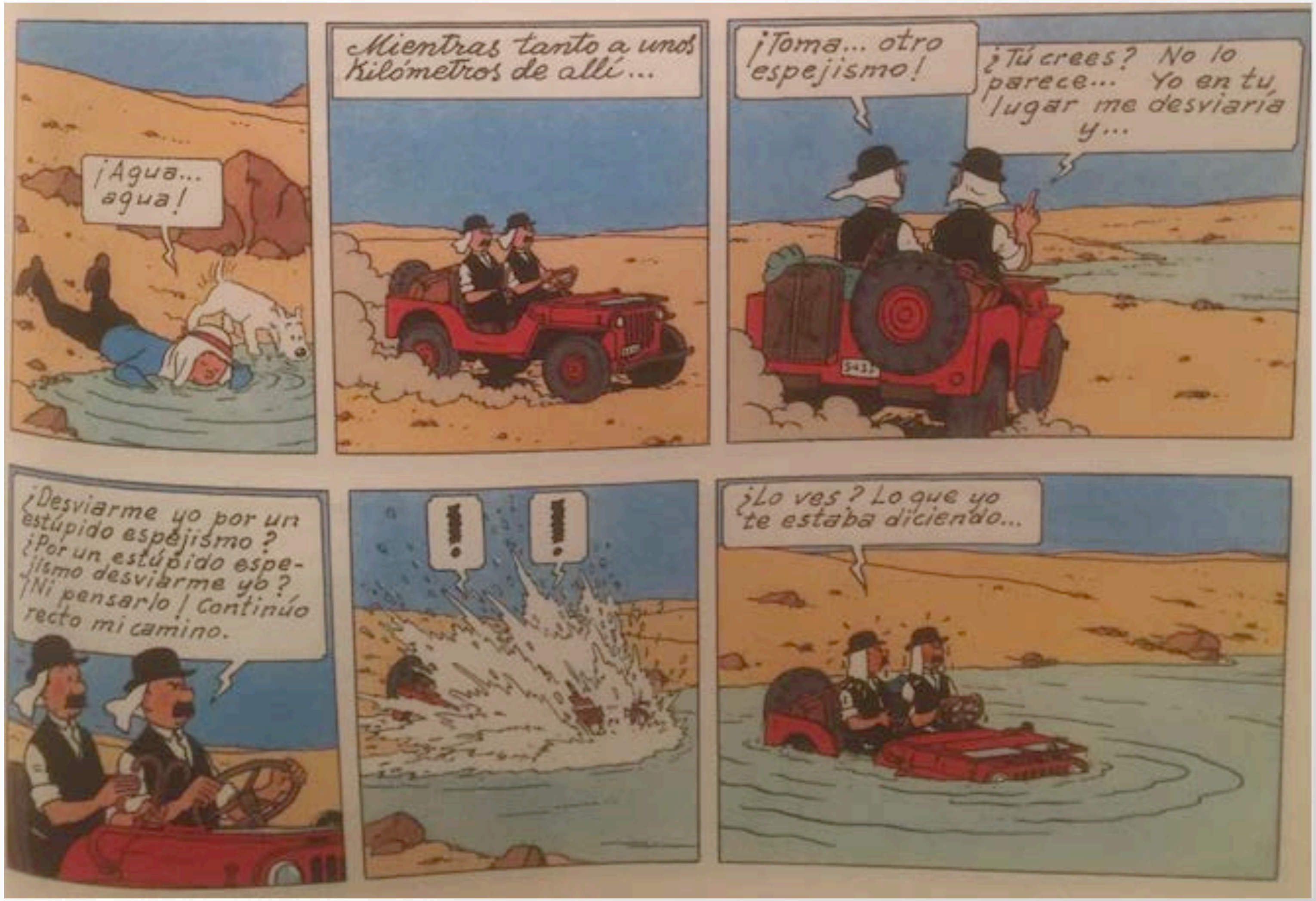
Oasis = ILC project

Our physics community:

Thomson & Thompson;
Dupont & Dupond;
Hernández & Fernández;
Jansen & Jansens;
Schulze & Schultze;
デュボン & デュポン;
Tajniak & Jawniak;
Tkadlec & Kadlec;
湯姆森 & 湯普森;
etc..

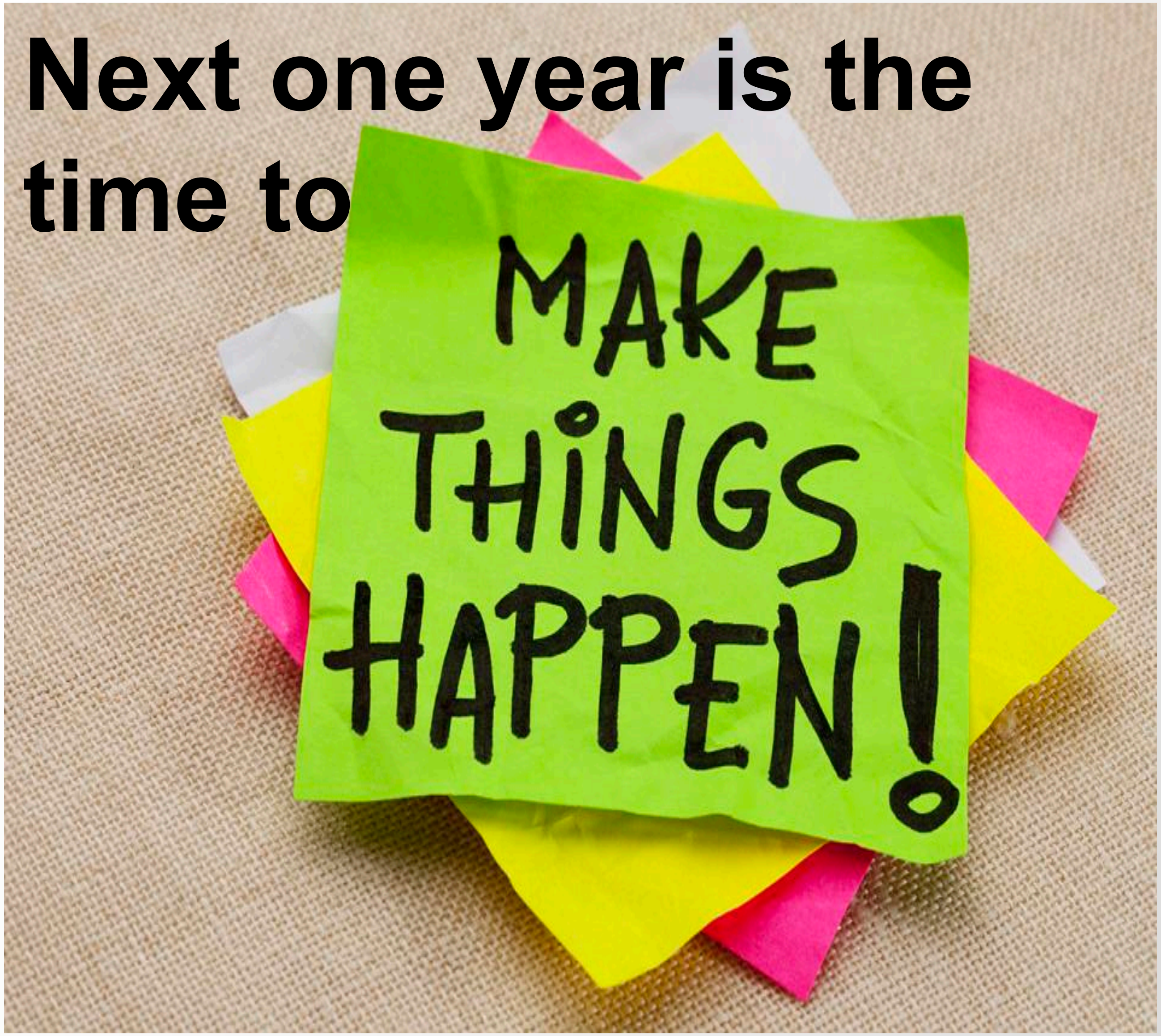
ILC a mirage, an illusion during past years

Personal summary



What about this time, real or illusion ?

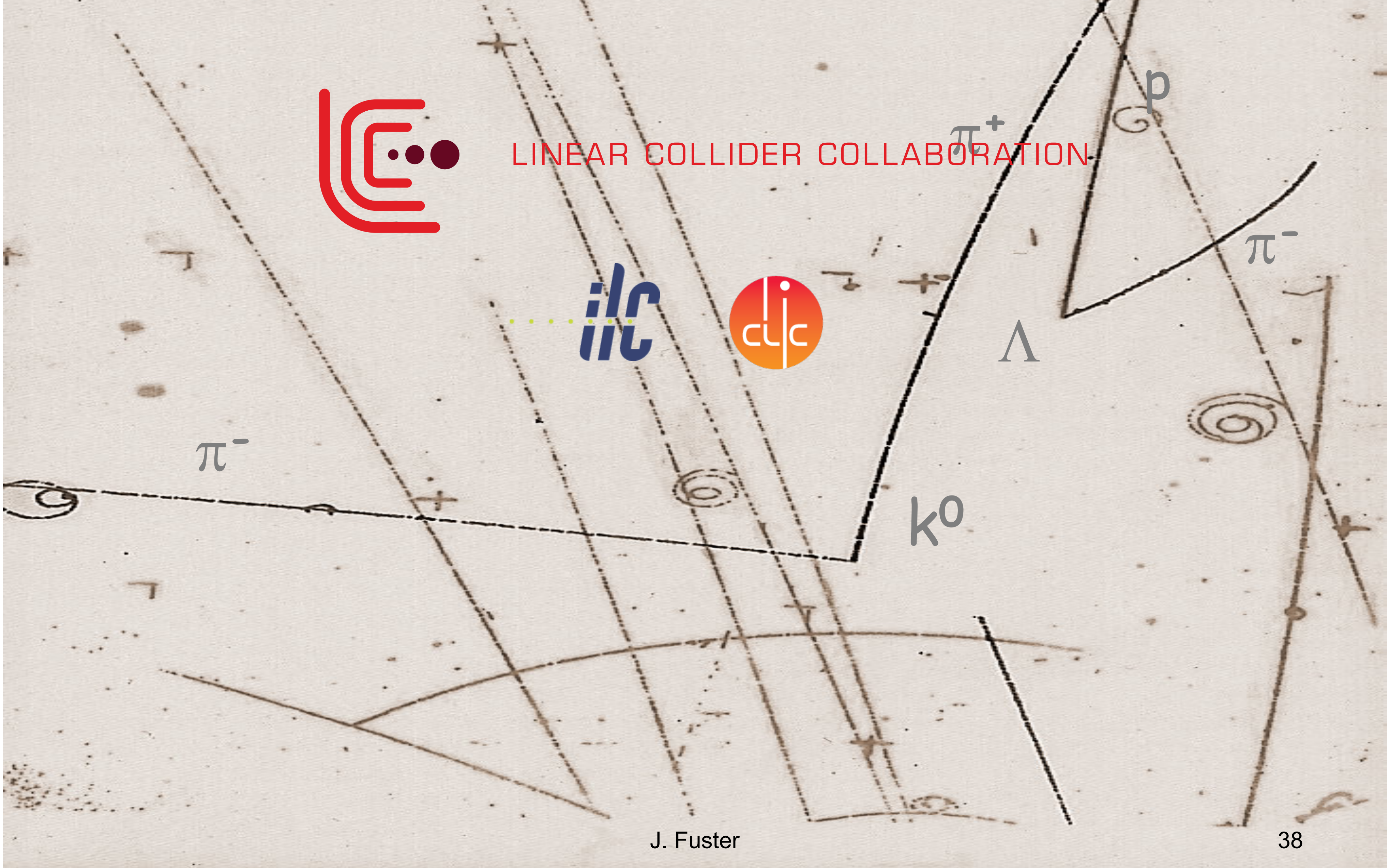
Next one year is the time to



Hon. Takeo Kawamura
LCWS2017-Strasbourg

Backup slides

LINEAR COLLIDER COLLABORATION



JAHEP statement, July 22nd 2017

2017/07/22

revised 2017/08/16

Japan Association of High Energy Physicists

Scientific Significance of ILC and Proposal of its Early Realization in light of the Outcomes of LHC Run 2

The International Linear Collider (ILC) is a linear electron-positron collider, a key experimental facility that enables forefront research at the energy frontier in high energy physics. The ILC has been developed through an international collaboration overseen by the International Committee for Future Accelerators (ICFA). The international team of physicists, Global Design Effort, published in 2013 the Technical Design Report of a 200-500 GeV (extendable to 1TeV) center-of-mass collider. In October 2012, the Japan Association of High Energy Physicists (JAHEP) proposed to construct ILC in Japan under a global collaboration with consensus of the international community and active participation from each country. This proposal received many positive responses from the international community. In particular, it garnered support from European countries and the United States, who were also developing their future particle physics projects, as well as from the ICFA. Upon the launch of JAHEP's proposal, the Science Council of Japan and a panel of experts under the Ministry of Education, Culture, Sports, Science and Technology discussed the proposal. They noted that the large expense and cost sharing are issues that must be solved. Subsequently, a research and development project was initiated to reduce the costs associated with ILC based on the discussions between the governments of Japan and United States. Meanwhile, the Large Hadron Collider (LHC) Run 2 experiments at CERN have continued to progress, and new results have been published. In this context, JAHEP has deliberated the scientific significance of ILC and has come to a conclusion; JAHEP proposes to construct a 250 GeV center-of-mass ILC promptly as a Higgs factory.

JAHEP statement, July 22nd 2017

The driving force for JAHEP's proposal released in October 2012 is that particle physics entered a new phase following the discovery of a Higgs boson. Research in the 20th century particle physics focused on elucidating fundamental forces, save gravity, of nature: strong, weak and electromagnetic forces. The existence of a Higgs boson was predicted by the Standard Model, which successfully describes these three forces in a unified way. A Higgs boson was discovered as predicted, indicating that our understanding of these three forces has greatly advanced. On the other hand, the real nature of the Higgs boson remains unknown. Candidate theories to explain the origin of Higgs bosons include new forces, new hierarchies of matter, and extension of the space-time structure. In this light, studying the Higgs boson is definitively important to determine the future of elementary particle physics. The ILC, with additional advantage of energy-extendable and beam-polarization capabilities due to being a linear accelerator, would be the best suited facility for this purpose.

The LHC experiments have an excellent ability to explore new physics by observing new strongly-interacting particles and their decays. The LHC Run 2 experiment, where the center-of-mass energy was increased from 8 TeV to 13 TeV, began in 2015 and the accelerator operated smoothly throughout 2016. The exploratory area (or mass scale) of the Run 2 has, indeed, significantly expanded compared to that under 8-TeV-energy operations. The results reported in 2016 showed that new particles anticipated by physics beyond the Standard Model are unlikely to exist below the mass scale of 1 TeV. This important finding at LHC underscores that the most imminent and important goal of ILC is to explore new physics by precision measurements of the Higgs boson and search for a class of new particles that ILC could directly produce but LHC has difficulty to observe.

JAHEP has established the "Committee on the Physics Significance of ILC 250 GeV Higgs Factory." The charge to this committee is to verify the significance of a 250 GeV center-of-mass energy ILC ("ILC250"), in particular, by comparing with the case for a 500 GeV center-of-mass ILC ("ILC500") and the case for no ILC at all. The roles that ILC250 should play were examined from the following perspectives: determination of the energy scale of new physics by precision measurement of the Higgs boson and thorough examination of the Standard Model, elucidation of electroweak symmetry breaking and the origin of matter and antimatter asymmetry, and searching for particles that are candidates of the dark matter. In the Committee's deliberation, possible synergies with the High-Luminosity LHC (HL-LHC) and SuperKEKB /Belle II were taken into account.

JAHEP statement, July 22nd 2017

The Committee's conclusions are summarized as follows:

- ILC250 should run concurrently with HL-LHC to enhance physics outcomes from LHC.
- Given that a new physics scale is yet to be found, ILC250 is expected to deliver physics outcomes that are nearly comparable to those previously estimated for ILC500 in precise examinations of the Higgs boson and the Standard Model.
- The ILC250 Higgs factory, together with HL-LHC and SuperKEKB, will play an indispensable role in the discovery of new phenomena originating from new physics with the energy scale up to 2–3 TeV and the elucidation of the origin of matter-antimatter asymmetry.
- A linear collider has a definite advantage for energy-upgrade capability. ILC250 possesses a good potential for its upgrades to reach the higher energy of new physics that the findings of ILC250 might indicate.

As discussed above, the scientific significance and importance of ILC has been further clarified considering the current LHC outcomes. ILC250 should play an essential role in precision measurement of the Higgs boson and, with HL-LHC and SuperKEKB, in determining the future path of new physics. Based on ILC250's outcomes, a future plan of energy upgrade will be determined so that the facility can provide the optimum experimental environment by considering requirements in particle physics and by taking advantage of the advancement of accelerator technologies. It is expected that ILC will lead particle physics well into the 21st century.

To conclude, in light of the recent outcomes of LHC Run 2, JAHEP proposes to promptly construct ILC as a Higgs factory with the center-of-mass energy of 250 GeV in Japan.

ILC @ 250 GeV physics case, Asai et al. report

Report by the Committee on the Scientific Case of the ILC Operating at 250 GeV as a Higgs Factory

July 22, 2017

Committee Members:
Shoji Asai[1,2,*], Junichi Tanaka[2], Yutaka Ushiroda[3], Mikihiko Nakao[3], Junping Tian[2], Shinya Kanemura[4], Shigeki Matsumoto[5], Satoshi Shirai[5], Motoi Endo[3], Mitsuru Kakizaki[6]

* Chair
[1] The University of Tokyo
[2] ICEPP, The University of Tokyo
[3] High Energy Accelerator Research Organization (KEK)
[4] Osaka University
[5] Kavli IPMU, The University of Tokyo
[6] University of Toyama

Commissioned by the Japan Association of High Energy Physicists

Preface

In July 2012, a Higgs boson with 125 GeV mass was discovered at the LHC. The discovery of new phenomena and new principles that can (naturally) explain the electroweak symmetry breaking (EWSB) including the existence of this Higgs boson is now the most important and urgent target of research. In order to attain this goal, the LHC is performing direct searches for new phenomena and new principles with a center-of-mass (CM) energy increased to 13 TeV. So far, there is no evidence of new physics beyond the Standard Model (SM). The purpose of this committee is to investigate and compare, under the current circumstances, the capability to determine the energy scale of new phenomena and new principles and the capability to uncover the origin of matter-antimatter asymmetry for the following three cases: (i) an ILC operating at 250 GeV as a "Higgs Factory" (ILC250); (ii) an ILC operating up to 500 GeV (ILC500); and (iii) the case of no ILC construction. The committee members consist primarily of members of the ATLAS collaboration, the Belle II collaboration, and theorists. The committee aimed to give an assessment on the physics case of the ILC250 in a way that is independent from the ILC community.

This report consists of the following five chapters:

1. Introduction
2. Precise measurements of Higgs and other SM processes: Determination of the energy scale of new phenomena via precise measurements.
3. EWSB and the origin of matter-antimatter asymmetry.
4. Direct search for dark matter and new particles based on "Naturalness".
5. Summary: Comparison of the ILC operating at 250 GeV and 500 GeV

Different approaches are summarized in Chapters 2 and 3 to probe the next energy scale beyond EWSB through precise measurements. Chapter 4 discusses searches to elucidate dark matter (DM) and probes to test the idea of "naturalness".

1. Introduction

For the purpose of this discussion, the following points are assumed for the timeline and the conditions of the ILC operation.

1. The operation will start around 2028-2030. It will run concurrently with the High-Luminosity LHC (HL-LHC) experiment and produce complementary results.
2. The CM energy is fixed at 250 GeV. No energy scan is performed. The integrated luminosity is 200 fb^{-1} per year, accumulating 2 ab^{-1} by 2040.

2

ILC @ 250 GeV physics case, Asai et al. report

3. Beam polarization is used (30% for positrons, 80% for electrons).

The key is the synergy with other experiments, including the HL-LHC, SuperKEKB, Hyper-Kamiokande, electric dipole moment (EDM) searches, lepton flavor violation (LFV) searches, and satellite probes to detect gravitational waves (LISA, DECIGO, etc.), as well as theory development in Lattice QCD and higher-order corrections. Various implications are considered combining rich outputs from these experiments with the ILC results, and we elucidate the role of the ILC with respect to the other experiments.

2. Higgs and Other Standard Model Processes: Determination of the New Energy Scale via Precision Measurements

2.1. Precise measurements of Higgs couplings

The precise measurements of the couplings between Higgs boson and other elementary particles can be performed at the 0.6-1.8% level at the ILC250. The measurement precisions are summarized in Tables 1 and 2. It is the important task of ILC to measure the total decay width model-independently. The previous strategy is as follows, the HWW coupling is measured using the vector boson fusion process, and decay branching fraction Br(H→WW) can be measured precisely. Then total decay can be determined model-independently. The vector boson fusion process enables the precise measurement of the HWW coupling at higher energies. At the ILC250, however, this cross section is small. It was one of motivations for higher center of mass at ILC.

As an alternative approach, we can measure Higgs decay branching fraction at the HL-LHC to examine the symmetry between the HWW and HZZ couplings (custodial symmetry) at the 2% level. By taking this symmetry as an assumption, the ee→ZH cross section (HZZ coupling) and the H→WW decay branching ratio measurements can be combined for the model-independent determination of the total decay width. This idea can be further extended in the framework of effective field theories to determine the coupling (denoted as g), in a model-independent way (Ref. airXiv 1708.09079).

The estimated precisions of various Higgs boson couplings are shown in Table 1, combining ILC250 and HL-LHC results. The precisions are at the 10% level with the HL-LHC alone, less than 1% accuracies can be obtained as shown in Table 1. The comparison between ILC250 and ILC500 shown in Fig.1 shows that the differences in the achievable precisions are small for the same total integrated luminosity of 2 ab^{-1}. This illustrates the importance of the combination of the HL-LHC and the ILC250 results. These combined results are comparable to those at ILC500 (combined with HL-LHC). Table 2 summarizes the precision of the coupling ratios from the direct

determination at ILC250. Many experimental systematic uncertainties cancel by taking the ratios. These ratios are useful for the precise comparison between the SM predictions and the experimentally observed values.

Table 1: Precision of Higgs boson couplings in the effective field theory framework. Combination of the ILC250 and the HL-LHC measurements

	g(HZZ)	g(HWW)	g(Hbb)	g(Hττ)	g(Htt)	g(Hμμ)	g(Hcc)
Δg/g	0.63%	0.63%	0.89%	1.0%	7% (LHC)	6.2%	1.8%

Table 2: Precision of Higgs coupling ratios from the direct measurements at the ILC250.

	g(HWW)/g(HZZ)	g(Hbb)/g(HWW)	g(Hττ) /g(HWW)	g(Hcc) /g(HWW)
Δ	1.9%	0.64%	0.84%	1.7%

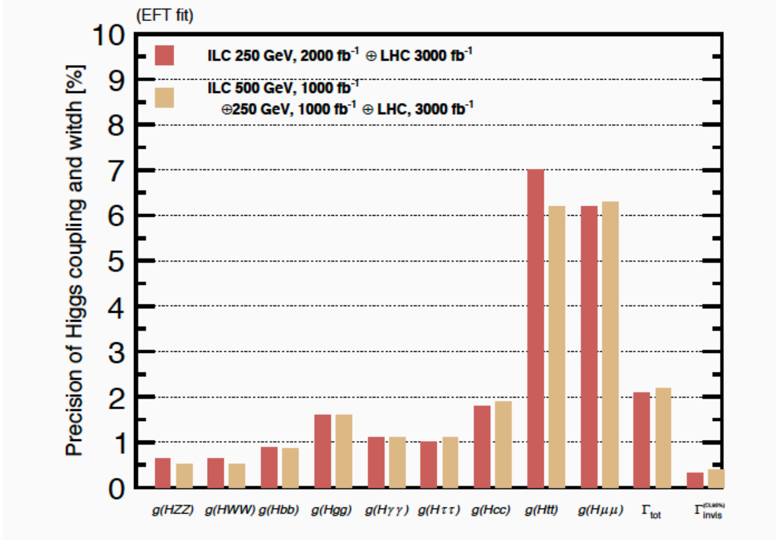


Figure 1: Precision of coupling measurements.

It will be possible to measure the Yukawa couplings of the second-generation leptons and quarks with about 2-6% precision. This will show that the differences in the Higgs boson couplings give rise to the generations, providing insight into our understanding of generations. Furthermore, the measurement of the Higgs boson coupling with the Z boson and the differential cross section can be

ILC @ 250 GeV physics case, Asai et al. report

done model-independently and provides sensitivity to new phenomena with a mass scale of up to 2.5 TeV for CP-even states and 3.9 TeV for CP-odd states using the effective Lagrangian approach.

Among the various new phenomena and new principles, the supersymmetry is the most promising theory. There are three approaches to discover supersymmetric particles, as described below. The capability of these three approaches depends on the model and the parameter space. Thus it is crucial to be able to cover all three approaches.

(a) Direct search for supersymmetric partners with SU(3) color charge, such as the squarks and the gluino. The HL-LHC has good sensitivities to search for the squarks and gluino up to about 3 TeV.

(b) Search for supersymmetric partners with SU(2) and U(1) charge, such as the electroweak gauginos and higgsinos. In contrast to (a), the mass spectrum can be naturally highly compressed. The ILC will play an important role as described in Chapter 4.

(c) There are at least two Higgs doublets (2HD) in all supersymmetric models, in which multiple Higgs bosons exist. These signatures can be accessed even if the supersymmetric partners as described in (a) and (b) are beyond the reach of the experiments.

The precise measurement of the Higgs couplings at the ILC250 provides an important input to the approach (c) above. The Minimal Supersymmetric Standard Model (MSSM) is considered first among the 2HD models. The HL-LHC has a high discovery potential for parameter regions with large $\tan\beta$. In contrast, the deviation of the Higgs boson coupling with the gauge bosons, g(HZZ) or g(HWW), becomes larger for smaller $\tan\beta$, which is favorable for the ILC. The sensitivity of direct searches at the LHC and the ILC250 sensitivity are thus complementary. Heavy Higgs bosons (or SUSY breaking scale Λ) can be discovered almost up to 1.5–2 TeV by combining the ILC250 and the HL-LHC results, even if the supersymmetric partners are heavy. In the extended models such as the Next-to-Minimal Supersymmetric Standard Model (NMSSM), in which the relation between the neutral and charged Higgs bosons become model-dependent, the large $\tan\beta$ region is covered by neutral Higgs boson searches at the HL-LHC and the charged Higgs boson searches at Belle II; the small $\tan\beta$ region is covered by the ILC250.

The energy scale of new phenomena can be probed up to Λ~2 TeV in more general 2HD models not restricted to supersymmetry, through coupling deviations. The Kaluza-Klein (KK) gluon can be probed up to a mass of 10–20 TeV (corresponding to a KK scale of 3–7 TeV).

5

Furthermore, a physics model behind the discovered new phenomena at Λ can be identified through the deviation pattern. These sensitivities are determined by the precision of the Higgs couplings, and do not depend highly on the CM energy (250 GeV or 500 GeV). It will be crucial to reduce the systematic uncertainties (coming from experimental uncertainties, and determining the quark mass and α_s) through the collaboration between the experimental and theory communities.

2.2. Precision measurement of the Higgs boson properties

The total decay width Γ_H can be determined with an accuracy of 2.1% by fitting the both results at ILC250 and HL-LHC in the effective field theory framework as mentioned in Section 2.1. This will allow for the search for decays to unknown particles with decay branching ratios down to 0.3%. Detail is discussed in Chapter 4. The CP phase in the coupling between the Higgs boson and fermions can be measured to 3.8 degree precision, which provides an important clue to the origin of the matter-antimatter asymmetry, whether it is baryogenesis or leptogenesis (See Chapter 3). The discovery of CP violation in the Higgs sector will be an important achievement, as it implies that the SM Higgs field (1HD) is not the correct description of nature, and that the Higgs sector must be more complicated (such as general 2HD models or addition of singlet fields).

From the angular distribution of the decay particles, the compositeness of the Higgs boson can be probed up to a scale of 2.2 TeV.

2.3. Precision observables in the Standard Model: M_W / M_t / $\sin\theta_{eff}$

At ILC250, the W boson mass (M_W) and weak mixing angle ($\sin\theta_{eff}$) can be measured with accuracies of 3 MeV and 3×10^{-5} (relative precision), respectively. Although the top quark mass (M_t) cannot be measured directly at the ILC250, the HL-LHC is expected to determine the top quark mass with an accuracy of 0.2–0.3 GeV. The contribution of various systematic uncertainties such as ΔM_Z and $\Delta\alpha_s$ and a top quark mass precision of 0.3 GeV are roughly equal to check the Standard Model precisely. Thus, from the point of view of precise observables in the SM, the HL-LHC precision of 0.3 GeV is sufficient. Supposing that the current central values for M_W, M_t, and $\sin\theta_{eff}$ remain fixed, the improved precision from the ILC250 and the HL-LHC will yield a 3–4σ deviation from the SM. This will indicate that new physics such as supersymmetry exists around the TeV scale. If an excess is seen at the HL-LHC or if deviations of Higgs couplings are seen at the ILC, it will be crucial to identify the principles behind these anomalies. This will be one of the important achievements expected from the ILC250.

6

ILC @ 250 GeV physics case, Asai et al. report

The stability of our vacuum can be computed from the Higgs boson mass (M_h) and M_t. An upper limit on the energy scale of new physics can be also determined with the assumption that our vacuum is stable. Combining the ILC precision of ΔM_h=14 MeV and the HL-LHC precision of ΔM_t=0.3 GeV will determine that our universe is metastable or that new physics should exist at a scale below 10^{12} GeV to make our universe stable, if the central values are the same as the current values. These results are crucial to understand the early universe, including implications about the possibility of leptogenesis, as described in Chapter 3.

2.4. New phenomena can be discovered up to Λ=2–3 TeV with synergy among the ILC250, HL-LHC and the SuperKEKB. The ILC250 has high sensitivity in the region that cannot be covered with the HL-LHC (heavy higgs boson in the 2HD models with small $\tan\beta$ and the electroweak gaugino). The ILC is therefore complementary to the HL-LHC. If an excess is found at the HL-LHC, ILC can play an important role to reveal the physics behind it.

Figure 2 shows a flowchart of overview. If a deviation from the Standard Model prediction is observed in the Higgs coupling, the EW precise measurements or searches, the new energy scale Λ for the new phenomena and new principles is determined. It also fixes the technology and the CM energy of the next-generation accelerators, such as Future Circular Colliders (FCC, HE-LHC) and the energy upgrade of the ILC.

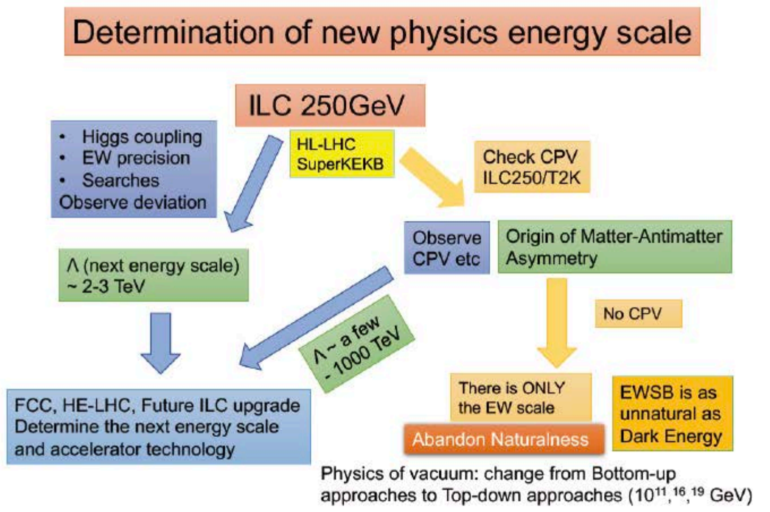


Figure 2: Precision measurements and the energy scale Λ.

The right side of Figure 2 illustrates the different approach, in which the probing for the origin of the matter-antimatter asymmetry will lead to the next new phenomena (where Λ is the new energy scale). As discussed in Chapter 3, it can be determined that the origin of matter is either electroweak baryogenesis (Λ=10–1000 TeV) or leptogenesis (Λ<10 TeV) with the observation of CP violation (in Higgs or neutrino sectors), the precise measurement of the Higgs boson, and measurements of gravitational waves in space.

If the results from the ILC250 and other experiments are found to be consistent with the SM, and no new sources of CP violation are found, it will be determined that the energy scale for the physics behind the EWSB mechanism is O(10) times higher than the EWSB scale itself. It will be found to be at least O(10) times "unnatural" , and the electroweak phase transition (EWPT) will be an as unnatural phenomenon as dark energy. The EWPT is related to the vacuum physics, as the same as the inflation and dark energy, whose scales are also not naturally explained. This will lead to a paradigm shift in our research direction, from the traditional bottom-up approach to the top-down approach.

3. Electroweak Symmetry Breaking and the Origin of Matter-Antimatter Asymmetry

There are two promising scenarios for the origin of matter-antimatter asymmetry; leptogenesis and electroweak baryogenesis (EWBG). Figure 3 shows a flowchart for approaching these scenarios. EWBG can be probed at the ILC250 in two phases as discussed below.

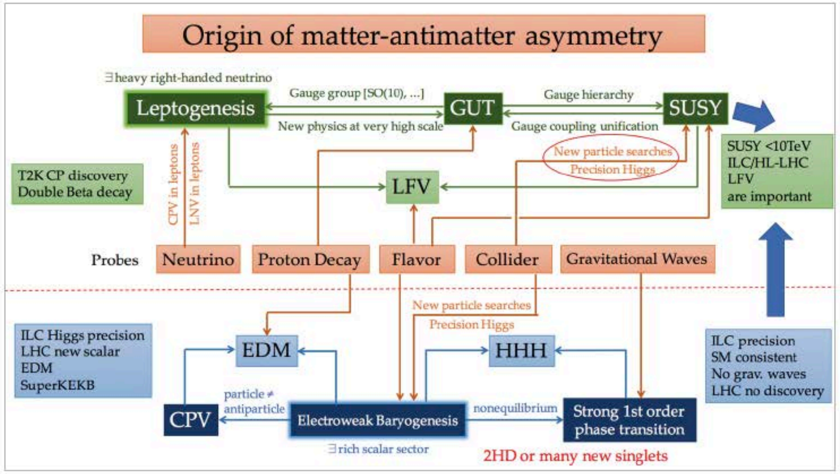


Figure 3: Origin of matter-antimatter asymmetry.

ILC @ 250 GeV physics case, Asai et al. report

As described in Section 2.2, the phase of the couplings between the Higgs boson and fermions can be measured to 3.8-degree precision. Together with the precise measurements of the HZZ coupling and Yukawa couplings, it can be determined whether or not the Higgs boson is responsible for the origin of matter-antimatter asymmetry. These results can be cross-checked with experiments searching for the electric dipole moment of the neutron and the electron. This is the first step to examine EWBG (left-lower side of Figure 3) .

Furthermore, the electroweak symmetry breaking should be a strong first-order phase transition and in non-equilibrium in order to retain the asymmetry produced by the Higgs sector. For this to occur, it is necessary to introduce additional Higgs fields as in 2HD models or an additional singlet. These new scalar fields result in large deviations (>20%) in the trilinear Higgs coupling and most probably a few-percent deviation in Higgs couplings with gauge bosons as well (right-lower side of Figure.3). The ILC250 can investigate these couplings at sufficient precision. Gravitational waves are also emitted during the EWPT in Strong 1^{st} order transition. They can be detected at satellite probes (such as LISA and DECIGO) which are expected to begin operation around 2040. This is the second step to examine EWBG. The Higgs potential demands that new phenomena must be present in the range up to Λ=a few–1000 TeV in the case of EWBG. The energy of the next energy frontier experiment and its accelerator technology can be also determined in this case (as shown in Fig.2)

The ILC250 can examine EWBG scenarios from many sides. The key to probe EWBG scenarios is the precise measurement of CP violation, the Higgs couplings with the gauge bosons, and the Yukawa couplings. The precisions of these measurements are largely similar between the ILC250 and the ILC500 results. Although the Higgs trilinear coupling (HHH coupling) cannot be measured at the ILC250, the precise measurement of the Higgs boson couplings with the gauge bosons and the gravitational wave probes can be used to elucidate the origin of matter. The crucial test of EWBG can be performed at the ILC250.

If the EWBG scenarios are disfavored at the ILC250, or if CP violation is observed in neutrino sector at the T2K experiment and neutrino-less double-beta decay is discovered, the leptogenesis scenario becomes favorable. This implys the existence of a right-handed neutrino at a very high energy scale as well as grand unification (GUT). The most attractive scenario for GUT is supersymmetry with gauginos and higgsinos under 10 TeV. This scenario can be examined with the search for lepton number violation, the search for proton decays at the HyperKamiokande experiment, and the search for gauginos and higgsinos under 10 TeV at the next hadron collider (FCC, HE-LHC, etc.) or at a higher energy lepton collider. The favorability of the leptogenesis scenario is important input for the discussion of the accelerator technology and the CM energy of the next-generation facility. This is the path labeled "Λ~ a few–1000 TeV" in Figure 2. Since this is

9

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9

an important scenario, it is in the interest of Japan's long-term strategy to construct a linear collider which can easily accommodate the next-generation technology.

4. Direct Search for Dark Matter and New Particles Based on Naturalness

Naturalness has played an important role in the history of particle physics. The discovery of the 125 GeV Higgs boson has started to cast some doubt to this idea in the current situation that no new physics is found. The claim is that using supersymmetry to explain a 125 GeV Higgs boson nominally requires fine-tuning on the order of around O(100)–O(1000). However, there are possibilities where squarks become naturally heavy like focus point models. The Higgs boson becomes also naturally heavy in extensions of the MSSM, with additional singlets for example. Before giving up on the idea of naturalness, these possibilities (Higgsino/Wino/Singlet-like) must be probed. They are also scenarios that provide natural candidates of dark matter (DM). Figure 4 summarizes the candidates of WIMP DM and their searches.

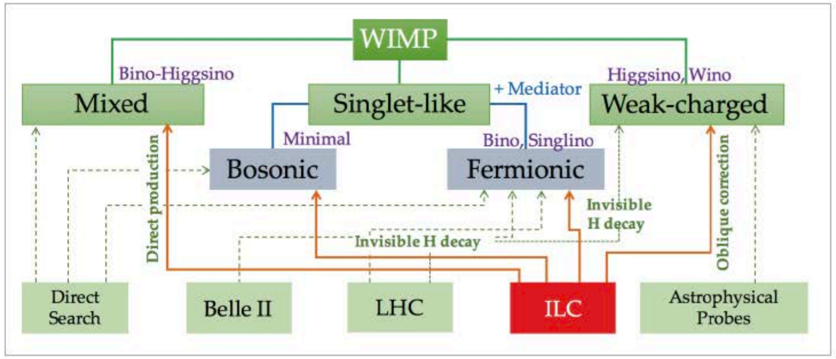

Figure 4: WIMP dark matter candidates and searches.

For the electroweak gauginos and higgsinos, the mass differences from the lightest particle among them (wino, higgsino) are generally small as described in Section 2.1(b). Such compressed spectra are challenging to search for at the LHC. It is also possible that the existence of a singlet particle could suppress the couplings with the gauge bosons. The investigation of these two possibilities are important. Taking together the HL-LHC searches (having a sensitivity for the bino) and the approach of 2.1(b) will make the search strategy complete.

It should be noted that the higgsino mass should be naturally around the Higgs mass; thus the search for the higgsino is particularly important. The ILC250 can probe higgsinos indirectly up to about 200 GeV, corresponding to the test of naturalness of about 10%. This is the higgsino path

shown in Figure 4. Since it is challenging to search for higgsinos at the HL-LHC, the ILC searches are indispensable.

In the case of a singlet-like DM as in the middle of Figure 4, there are bosonic and fermionic DM (bino-like or singlino-like). A bino-like DM can be covered by gaugino searches at the HL-LHC. For singlino-like DM or for bosonic DM, the Higgs invisible decays to unknown particles is important. The ILC250 is sensitive to Higgs invisible decays with a branching ratio of 0.3%. This will be a tight constraint for DM candidates lighter than 62 GeV. Such light DM is challenging for underground direct detection experiments because the recoiling energy is small. The ILC will provide coverage for such particles, which makes the search strategy for DM complete.

In the case of a mixed bino and higgsino (Figure 4, left), the strategy depends on its mass. For a heavy mixed bino-higgsino, it can be covered through the gaugino search at the HL-LHC as well as at direct DM detection experiments. If it is light, it will become challenging for the HL-LHC (due to the compressed spectrum) and direct detection experiments (small recoil energy). The ILC250 is able to cover most of the remaining parameter space for these particles by the direct search.

For DM searches based on the "naturalness", the ILC250 will be able to cover regions that cannot be covered by the HL-LHC and direct detection experiments (up to 200 GeV higgsinos and up to 62 GeV singlet-like DM). The ILC250 together with these experiments make the approach of 2.1(b) and the search strategy for WIMP DM complete.

The ILC will play a crucial role in the search for electroweak gauginos and higgsinos and singlet particles motivated by naturalness and dark matter. It plays a complementary role to the HL-LHC and the DM direct detection experiments. Combining these three approaches makes the search strategy complete. The necessary CM energy of the ILC depends on how much fine-tuning one can test for the naturalness.

5. Summary

The contributions of each project are summarized in Table 3. As discussed in Chapter 2, the ILC250 will be able to explore the phase space of new physics that cannot be covered by the HL-LHC or the Belle II experiments. It will be able to probe the new phenomena in a robust way. In particular, the ILC250 has an excellent sensitive to the heavy Higgs bosons in 2HD models, which is the 3rd approach as mentioned in Section 2.1(c). The ILC250 has also a good sensitivity to search for dark matter based on naturalness described in Section 2.1(b). Combining three approaches ((a)-(c)) by the ILC250 and the HL-LHC will establish a comprehensive search network, capable of probing the energy scale of new phenomena and new principles (up to Λ~2–3 TeV). Thus the ILC250 will play an important role.

ILC @ 250 GeV physics case, Asai et al. report

Table 3: The role of each project.

ILC	Higgs & other SM precision measurements; electroweak baryogenesis; 2.1(b): higgsinos, and DM ligher than 62 GeV; 2.1(c): small tanβ.
HL-LHC	Higgs couplings; direct search of new phenomena; top quark mass; 2.1(a),(b): bino, wino; 2.1(c): large tanβ.
SuperKEKB	Additional CP violation in quark-sector; bottom quark mass; tau LFV (GUT); 2.1(c): large tanβ.
T2K, HK	CPV in neutrino-sector; leptogenesis; GUT.
LFV	Leptogenesis; right-handed neutrinos; GUT.
EDM	Flavor-conserving additional CP violation; electroweak baryogenesis.
LISA, DECIGO	First-order phase transition for electroweak baryogenesis: an alternative to the HHH coupling measurement.
Underground experiments	DM direct search; 2.1(b): heavy regions.

The ILC250 will also be able to elucidate the origin of matter. It can perform a crucial test of the :lectroweak baryogenesis models, and probe the energy scale of new phenomena and new ›rinciples (up to Λ~ a few–1000 TeV).

Table 4 summarizes the list of measurements that become challenging by lowering the ILC ;tarting energy to 250 GeV. As far as the precision measurements of the Higgs and other SM ›bservables are considered, the ILC250 operating together with the HL-LHC and the SuperKEKB :xperiments will be able to play a sufficient role, with precisions not too far from the ILC500.

Table 4: List of measurements that become challenging by making the ILC starting energy 250 GeV.

Observable	Solutions with synergy
Higgs Full Width	From HL-LHC, use custodial symmetry ($K_W/K_Z = 1$) to replace Γ_{HZZ} with Γ_{HWW} in $\Gamma_{total}=\Gamma_{HWW}/Br(H\to WW)$ → becomes **comparable to ILC500 precision**
Self-coupling HHH (also challenging for ILC500)	Baryon number violation → EWBG or leptogenesis **(T2K, neutrino-less double beta decay).** EWBG covered by **HL-LHC, ILC250, SuperKEKB, LISA.** Although direct measurement of self-coupling is not possible, ILC250 can contribute to examine EWBG through CPV in Higgs sector and the precise measurements of Higgs couplings.
Higgs couplings	**HL-LHC** (Top Yukawa coupling) **Lattice** (m_b, m_c, α_s uncertainty) → **comparable to ILC500** **SuperKEKB** (Lattice examination)
Searches	Electroweak gauginos/higgsinos based on naturalness: higgsino (< ~200 GeV); dark matter (<62 GeV).
Top mass	HL-LHC (0.2–0.3 GeV) sufficient precision for test of SM; roughly sufficient for vacuum stability; **(if a detailed study of high scale physics becomes necessary, upgrade to 350 GeV)**

Some of the main merits of the ILC operating at 350 GeV, 500 GeV, or above are

(a) When the energy scale of the new phenomena and new principles is discovered by the combined results of the ILC250 and HL-LHC, this energy scale becomes the next target for an energy upgrade of ILC.

(b) Top quark mass precise measurement: The HL-LHC precision of 0.2–0.3 GeV is sufficient for the test of the SM and the vacuum stability. If the results from the HL-LHC and ILC250 point to physics at very high energy scales such as GUT and the necessity to study the vacuum stability in further detail, then the ILC350 becomes important.

(c) When only the electroweak scale seems to exist (the scenario in Figure 2 (right)), it becomes important to directly study the breaking of the electroweak symmetry and the Higgs potential in detail. In this case, the measurement of the Higgs self-coupling (HHH) becomes important, irrespective to the indirect measurement by gravitational waves. The precise measurement at CM energy of 500 GeV (positive interference) and 1 TeV (negative interference) will be both important.

Future energy upgrade scenarios should be discussed based on the findings of the energy scale of new phenomena and new principles as in point (a) above, or the CM energy will be upgraded, as before, upto 350, 500 GeV or 1TeV based on points (b) and (c).

Conclusions

The conclusions of this committee are the following four points:

- In order to maximally exploit the potential of the HL-LHC measurements, concurrent running of the ILC250 is crucial.
- LHC has not yet discovered new phenomena beyond the Standard Model. The ILC250 operating as a Higgs Factory will play an indispensable role to fully cover new phenomena up to Λ~2–3 TeV and uncover the origin of matter-antimatter asymmetry, combing all the results of ILC250, HL-LHC, the SuperKEKB, and other experiments. Synergy is a key.
- Given that a new physics scale is yet to be found, ILC250 is expected to deliver physics outcomes, combined with those at HL-LHC, SuperKEKB and other experiments, that are nearly comparable to those previously estimated for ILC500 in precise examinations of the Higgs boson and the Standard Model.
- The inherent advantage of a linear collider is its energy upgradability. The ILC250 has the potential, through an energy upgrade, to reach the energy scale of the new physics discovered by its own physics program.

Many thanks to T.Tanabe (ICEPP, U.Tokyo), T.Nakada (EPFL) , H.Aihara (U.Tokyo) and S.Komamiya (U.Tokyo) for useful discussions and suggestions to translate the original document into English.

Translation of the Message from the ILC Federation of Diet members

Takeo Kawamura (connected from Diet office building in Tokyo)

I'm Takeo Kawamura, a member of the House of Representatives of Japan. It is my honor to address you today, in particular the Honorable Olivier Becht from France and the Honorable Stefan Kaufmann from Germany. Thank you very much for joining us today. I would also like to thank the Honorable Catherine Trautmann who joined us last year in Strasbourg and joining us again today, and for her most valuable help. I sincerely regret that I could not be there in person today due to the recent election in Japan.

I am Chairman of the Federation of Diet Members for the ILC. Our Federation started in 2006 within the Liberal Democratic Party. Since 2008, we became a multi-party Federation. Today we are a very active group, with over 150 Diet members.

I had the chance to see many of you in Morioka last December. I said that there was a tendency of various countries around the world to prioritize their own nation, but it was important to put "Science First" and the world should work together. The International Linear Collider (ILC) would be a symbol of such collaboration and we should aim for its early realization.

I also said that the most pressing agenda was to push for cost reduction, and this discussion had already begun between the US and Japanese governments as the number one priority. This was the giant step to take toward the early realization of the ILC.

Many thanks to your efforts, the new design for the ILC is now complete. The staged approach with the initial length of 20 km offers the greatest cost benefit for the scientific achievements while retaining the potential for future upgrades.

Recently I met with Prime Minister Abe, together with the Honorable Shionoya who is here with me. We briefed the Prime Minister about the current situation of the ILC. It is now understood up to the highest level of the Japanese government that the forthcoming year is crucial for the ILC.

Japan will take the initiative for the ILC. We hope you will give us your support even more in the coming years.

Translation of the Message from the ILC Federation of Diet members

Hon. Ryu Shionoya (connected from Diet office building in Tokyo)

I'm Ryu Shionoya, a member of the House of Representatives of Japan. I serve as the Director-General of the Federation of the Diet Members for the ILC.

It is my pleasure to address the scientists and engineers from all over the world gathered in Strasbourg today, and in particular the distinguished guests, the Honorable Olivier Becht and the Honorable Stefan Kaufmann. I sincerely regret that I could not be there in person today.

As you know, the election of the lower house of the Diet took place just last week in October 22, and the Diet members are still not able to leave Japan. We are thus joining by video conference today.

In every country, political stability is very important for science and technology, and education. As Chairman of the Election Strategy Committee of the Liberal Democratic Party, I worked full force for the elections nation-wide. Thanks to the support we received, our political status remains strong and we will push forward to realize the ILC.

Japan is a country that works together with the world. The US-Japan cooperation in national security has been increased. Between Europe and Japan, various forms of cooperation have been strengthened. In July, Prime Minister Abe visited Europe and reached an agreement to strengthen the economic cooperation between Europe and Japan. In the Asia-Pacific, economic and technology cooperation is put forward with countries such as India, Australia, and ASEAN countries.

Japan is contributing to the area of science and technology, such as the International Space Station led by the United States, the ITER nuclear fusion reactor in Europe, and the LHC at CERN for particle physics research.

Today, the policies discussed within the ruling parties are based on "investing in the future" and "regional revitalization". We would like to apply them also to science and technology, and we believe the ILC project is a perfect match.

Translation of the Message from the ILC Federation of Diet members

The ILC project has been discussed in the Diet sessions many times. This took place not only in the Committees for Education, Science and Technology, and Innovation, but also in the Committee for Economy and Industry. Within the government, the discussion process is taking place in MEXT and the ILC Advisory Panel is scheduled to conclude at the end of this fiscal year.

The five-year strategy planning for particle physics in Europe will soon begin. We are very much aware that Japan should take a big step before the European discussions begin.

The most important agenda has always been the cost, both for Japan and for the world. I hear that progress has been made in the past six months to start the ILC with 20 km in length, with an upgrade path in stages. The international committee which will meet in Canada in about 10 days will officially announce this plan.

With this proposal from the committee in November, I believe the discussions about the International Linear Collider within our government will move to the new phase of working out concrete policy towards its realization. In addition, the budget request from MEXT is already being discussed for an increase, and we will advance the proposal to increase the R&D budget for the superconducting accelerating technology within the coalition of ruling parties.

The large cost reduction of the ILC has been communicated to various circles in politics, economic federations, and local areas here in Japan. I believe that they have been received very well. Together with Chairman Kawamura, I have met with Prime Minister Abe and briefed him of this plan. The MEXT Minister is also informed well.

It is very important to start negotiations with other countries concerning the ILC. I have been boosting international activities the last three years with Federation of Diet members led by the Honorable Kawamura. In February last year, we visited the US together with the Deputy Director-General from MEXT, and we had fruitful discussions with the Director of the Office of Science, Department of Energy. As a result of this discussion, we reached an agreement to open discussions on the ILC between Japanese and American governments in May the last year. The joint work is being performed to reduce the cost of the project, which is the prime challenge towards the realization of the ILC.

Translation of the Message from the ILC Federation of Diet members

Between Europe and Japan, we had discussions at the IEEE meeting in Strasbourg last year, joined by the Honorable Shintaro Ito and the Honorable Takeshi Shina from our Federation. Also last year, the Honorable Heinz Riesenhuber and the Honorable Mark Hauptmann from Germany had a meeting about the ILC with the Honorable Shun'ichi Suzuki and other Federation members. Now that the cost reduction is on the table, the time is ripe to start joint action of Europe and Japan at the political and governmental levels.

On the scientific and technical sides, I very much hope that the scientists and industry people will work closely together. We are counting on you.

We could not come in person this time because of the election, but we're putting together a schedule to visit Europe as the Japanese delegation before the start of regular Diet session early January. We hope to bring officers from MEXT and Ministry of Foreign Affairs along with us.

We will push for concrete actions at the political and governmental levels. I'm truly grateful to Honorable Olivier Becht from France and Honorable Stefan Kaufmann from Germany attending the international conference today. I very much hope that you two will be able to help facilitate the dialogues between Europe and Japan at the parliament and government levels.

We will plan to meet members of the parliaments and governments in Europe in person, and start Japan-Europe cooperation at the political and governmental levels. I'm very much looking forward to such cooperation. I also hope that you will start preparation with us. Thank you very much!

Translation of the Message from the ILC Federation of Diet members

Hon. Tatsuo Hirano (connected from Tohoku University)

I'm Tatsuo Hirano, a member of the House of Councilors of Japan. I am connecting from Tohoku.

I was born in Kitakami City, Iwate Prefecture, and am proud of history, culture, and nature of this area. I long for days when topnotch scientists and engineers come to my home ground from around the world, create an international city, contribute to the progress of science for the humankind, and globalize the culture and economy of this area.

I was the first Minister for Reconstruction after the 2011 Tohoku Earthquake. Let me first thank for all the support we received from people around the world.

The Kitakami mountains, the candidate site for the ILC, are based on very old geology that moved from south in ancient times. It has been confirmed by geology experts that it has sufficient stable bed rock suitable for the construction of the ILC. In fact, the National Astronomical Observatory of Japan has precision metrology instruments placed in the tunnel in the Kitakami mountains and they were not at all affected by the great earthquake.

The diverse landscape of Japan offers beautiful mountains. You can reach many hot springs and ski resorts within an hour of drive from the campus for the ILC. In addition, this area hosted the Hiraizumi Culture, which flourished about a millennium ago and was called the Second Kyoto. Its historic monuments form a UNESCO World Heritage site.

If you venture beyond the Kitakami mountains, you will soon see the ocean and the coastal region, where the powerful tsunami caused so much devastation. The sharply curved coastline makes a beautiful landscape, yet it magnified the height of tsunami. Now, you can see very active reconstruction effort in this area, including big land development projects and construction of commercial facilities. The effort is going on strongly supported by people throughout Japan and many in the world.

Translation of the Message from the ILC Federation of Diet members

The main industry in this area is fishing, which recovered to the level of about 80% of what it used to be before the earthquake. The ocean that created tsunami is also the ocean of blessing, and I believe it is the key element for the reconstruction of the area.

I understand that the ILC is a manufacturer of mini-bigbang and a research facility that will address the mystery of the birth of the Universe. Even though it is quite difficult to understand, I've recently been reading many books on this subject, and also listened to many lectures by scientists. The ILC is also called a Higgs factory. I find it absolutely fascinating that the study of the Higgs boson leads to the discovery of new laws of physics that go beyond the standard theory, and answers the profound question whether our Universe is special one among many universes or not.

The questions like "*where do we come from*" and "*where are we going*" are fundamental questions humankind has been pursuing all along. The collaborative research by many scientists towards the grand goal to answer these questions scientifically would surely contribute to the world peace by promoting mutual understanding of different cultures.

The next year will be the critical year for the realization of the ILC. I will keep pushing towards this goal together with Honorable Kawamura, the chair of the Federation, and Honorable Shionoya, the secretary of the Federation, and all of you from the political, government, industry, and academic circles from all over the world.

The Federation is planning to put together a schedule to visit Europe in early January. I hope that this will be a great opportunity to advance the discussions between Europe and Japan at the parliament and government levels, and your help to facilitate this will be greatly appreciated.