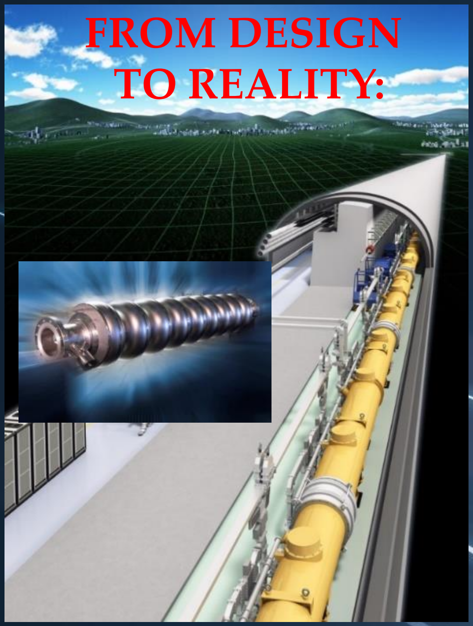
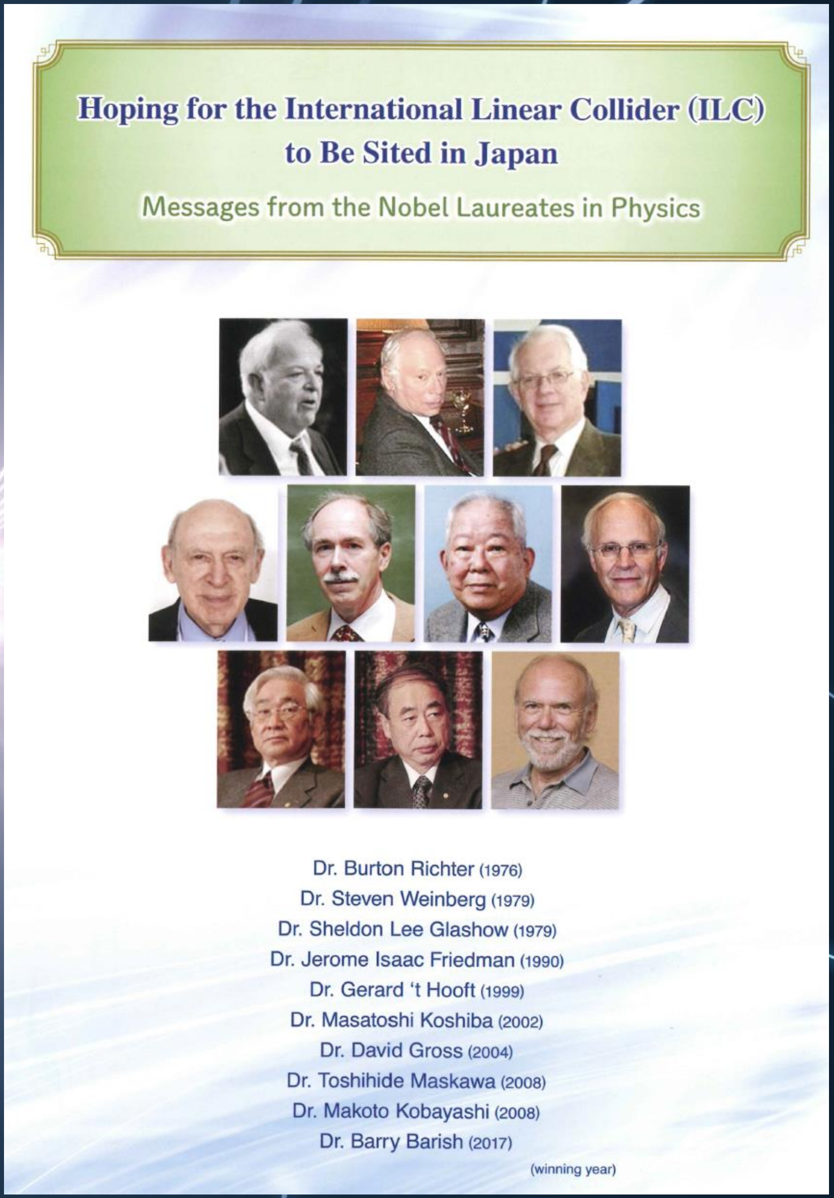
ILC Project Status and Inputs to the European Strategy

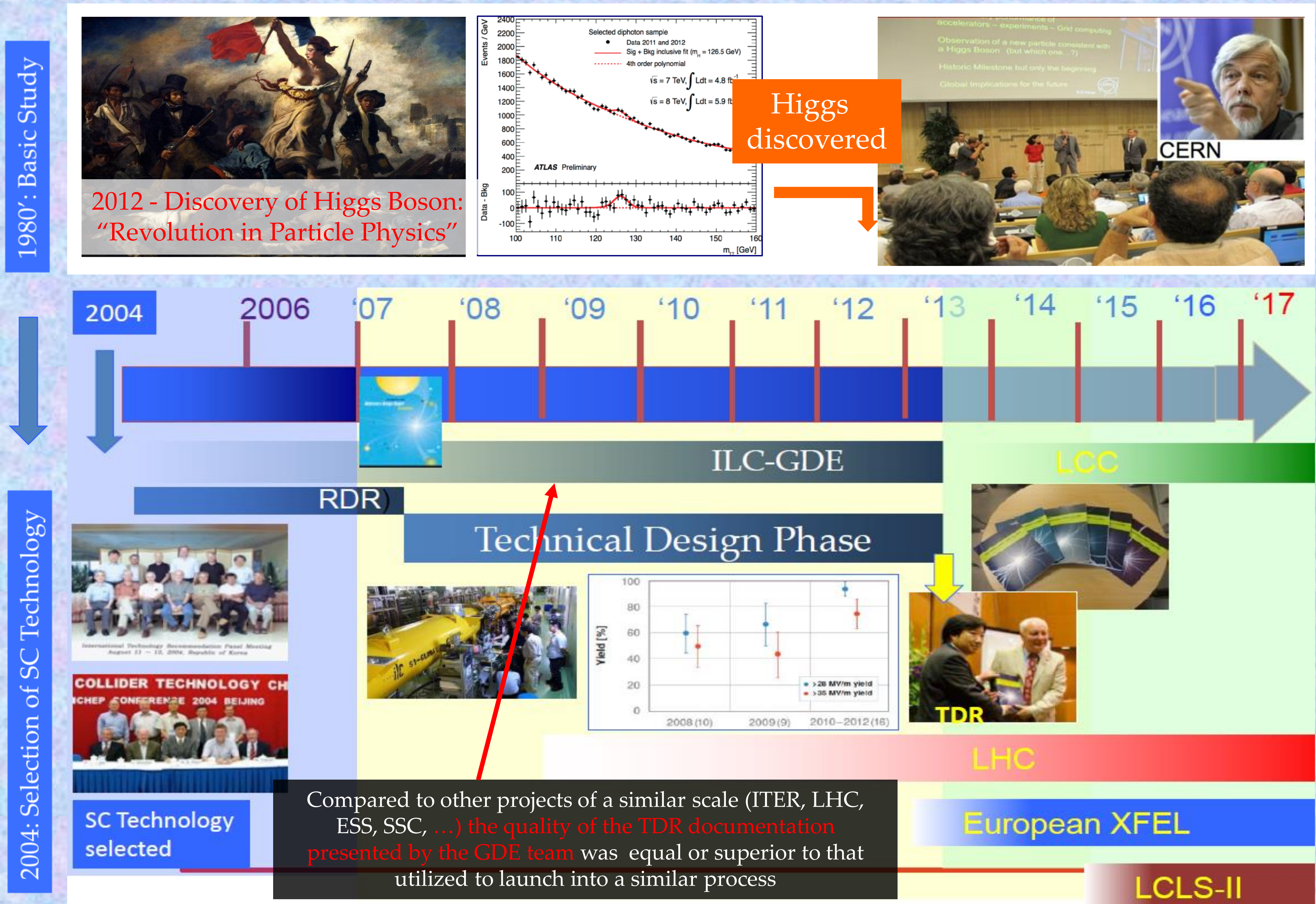




Maxim Titov, Irfu/DPhP Meeting, April 9, 2018

Acknowledgments to 1000's people who advanced the ILC Project to the current stage

The International Linear Collider (ILC): From GDE to LCC

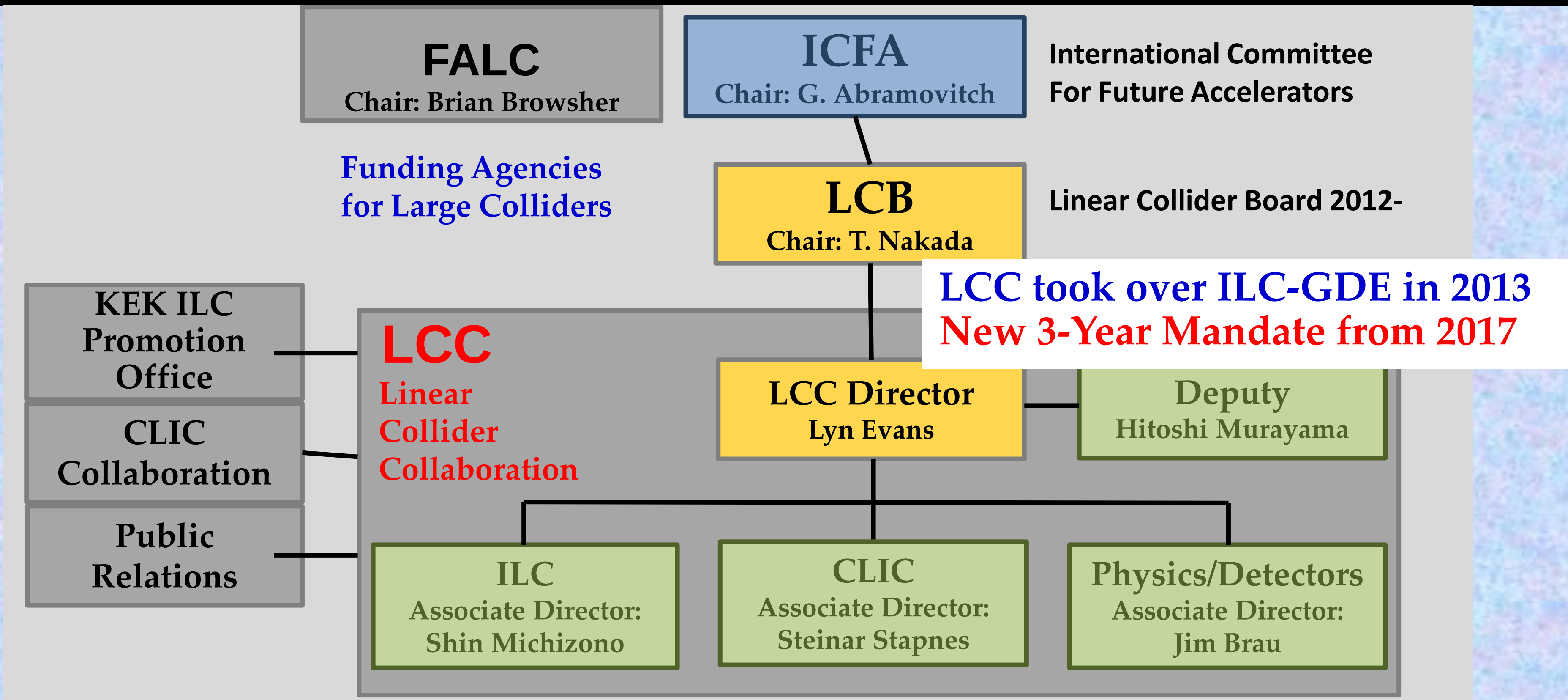


LCC / LCB Organization 2017

New LCC management:

Press Conference at ALCW2016 (Morioka, Dec 2016)

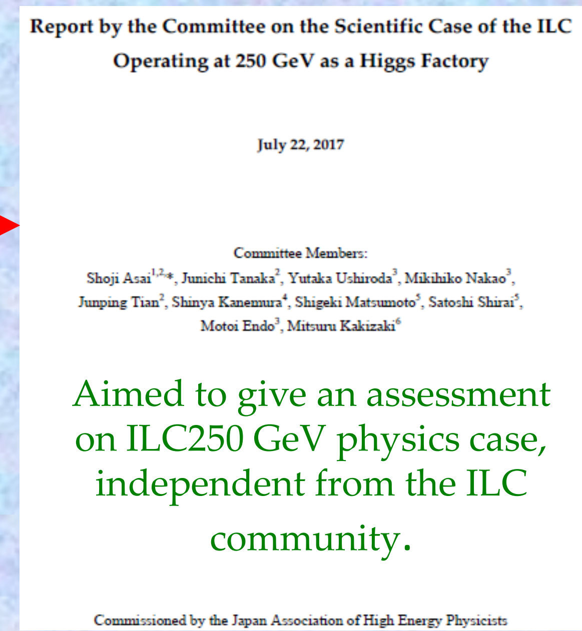
S. Stapnes J. Brau L. Evans H. Murayama S. Michizono



ILC Recent Developments: 2017

Japanese HEP (JAHEP) Community Statement: July 22,2017

"To conclude, in light of the recent outcomes of LHC Run2, JAHEP proposes to promptly construct ILC as a Higgs factory with the center-of-mass energy pf 250 GeV in Japan


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]

Commissioned by the Japan Association of High Energy Physicists

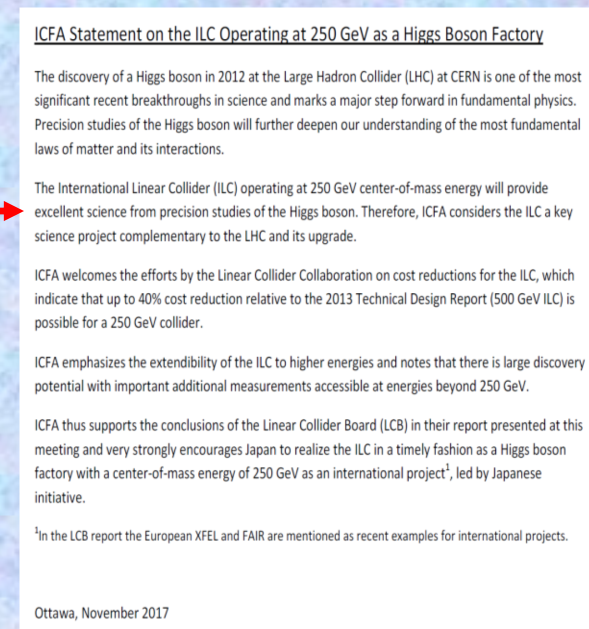
Aimed to give an assessment on ILC250 GeV physics case, independent from the ILC community.

LCB Statement: November 8, 2017:

"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."

ICFA Statement: November 8, 2017:

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."


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 2017

ILC Recent Developments: 2017

- Compelling Physics Case for a "Higgs Factory" @ 250 GeV / Energy Frontier Machine

- Substantial cost reduction by up to ~40%, compared to the original 500 GeV ILC (TDR costs of ~ 8 BILCU for 500 GeV; ILCU = 2012 US$ estimate)

  → Up to 40% reduction for the TDR construction cost (predominantly due to the number of the main linac components needed); up to 25% reduction for the human resources due to less assembly, installation and testing work; up to 25% reduction for the operation due to less electricity consumption.

- Technology is mature, thanks to the European XFEL at DESY → successfully constructed and put into operation - a key technology demonstration

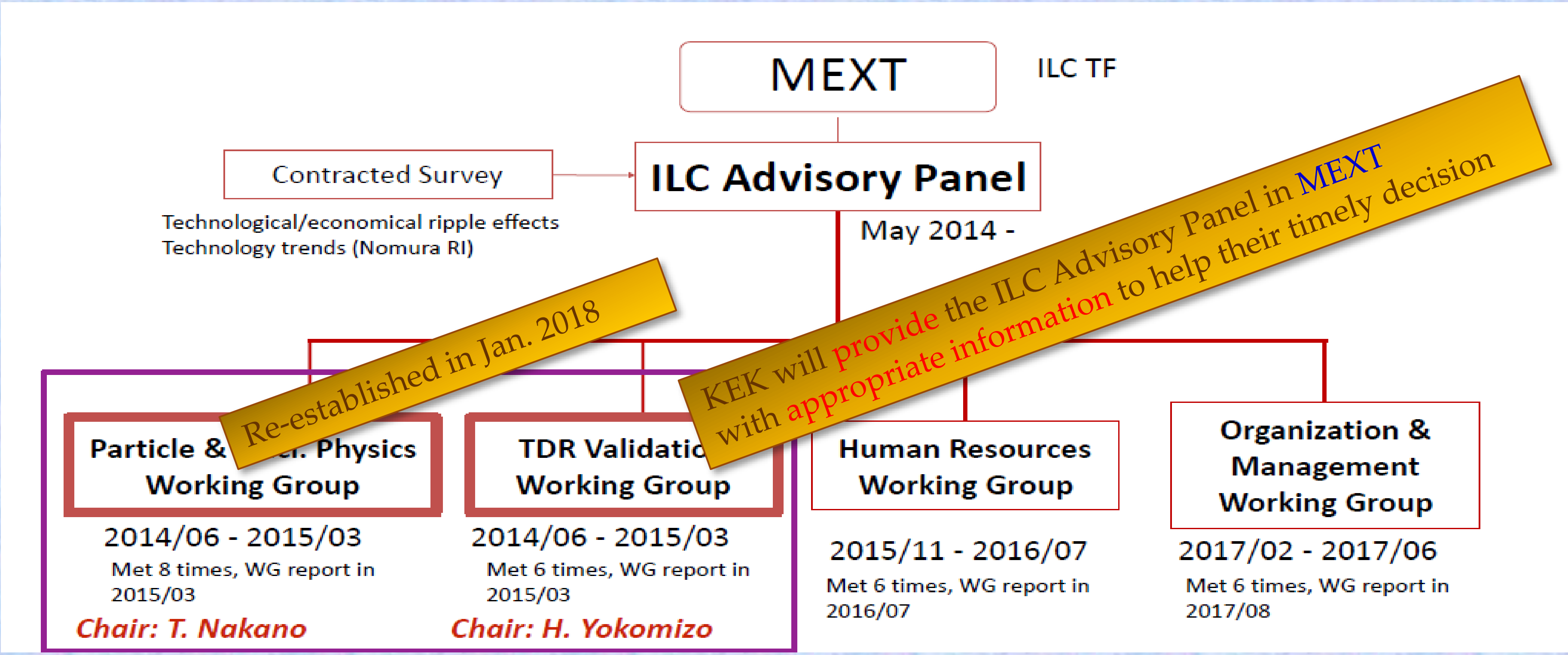
- Operation energy of a linear collider is intrinsically upgradable:
  – by extending the tunnel and acceleration structure (technically straightforward), or/and

  – Adopting improved acceleration technology with higher acceleration gradient (for a longer term).

T. Nakada

ILC Advisory Panel in MEXT

Set up in 2014 under MEXT ILC Task Force to investigate various issues concerning the possibility of hosting the ILC in Japan



- TDR validation WG meetings were held on Jan. 30, Mar. 2 and Mar. 22 (2018) → next meeting on Apr. 19, 2018 → main topics are CFS (which was not discussed on 2015 TDR Validation WG) and ILC250 cost
- Particle & Nuclear Physics WG group are re-established to evaluate ILC 250 GeV; meetings were held on Jan. 18, Feb. 5, Mar. 1 → next meeting on Apr. 13 (2018)
- Final reports are expected in May / June 2018

MEXT Particle and Nuclear Physics WG

❖ Charge: taking into account recommendations made in the interim report by MEXT ILC Panel, review the 250 GeV ILC physics case and clarify potential issues if any;

❖ Most probably, there will be no further inputs (in the coming years) to judge the new particle discovery potential of ILC;

❖ Next WG Meeting on April 13, 2018:
→ Hearings on XFEL/FAIR;
→ Discussion on the draft WG report

1st meeting on Jan. 18

- **General remark from the secretariat (WG charge, history)**
- **Development of the LHC experiment: K. Hanagaki**
- **On the revision of the ILC project (Physics Case of the 250 GeV ILC): K. Fujii**
  LCC Physics WG Report（arXiv: 1710.07621）

2nd meeting on Feb. 5

- **Discussions in JAHEP: S. Asai**
  Asai committee's report (arXiv: 1710.08639)
- **Physics potential of the ILC at 250 GeV: G. Weiglein**

3rd meeting on March 1: discussions on skeleton draft

- **Main points in the discussions so far**
- **Comparison of scientific case of 500 GeV ILC and 250 GeV ILC (Comparison Table)**

Main points made in KF's talk

- ***Given the situation that LHC Run II saw no BSM signal so far, the importance of the precision Higgs measurements became further enhanced.***
- ***Recent development (EFT) made it possible it possible to measure absolute values of the Higgs couplings model-independently with 250 GeV data only.***
- ***Through the precision Higgs coupling measurements, the 250 GeV ILC will find the pattern of coupling deviations from the SM and decide the future direction of particle physics.***
- ***Based on the results at 250 GeV and adding data at higher energies, we will be able to precisely measure top quark properties and the triple Higgs coupling, thereby further narrowing down the new physics possibilities.***
- ***In this way, we will be able to pave the way to unified understanding of Nature. The 250 GeV ILC will be the first step.***

K. Fijii

Main points made in Asai's talk

- *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.*

These are the same 4 points made in the Asai Committee's report (arXiv: 1710.08639)

KEK-ILC Action Plan

- KEK-DG Yamauchi set up a WG to develop a KEK-ILC action plan in May, 2015.

The KEK-ILC Action Plan was released in January 2016. It contains technical preparation tasks and a human resource development plan for the pre-preparation phase (current efforts) and the main-preparation phase (after "green sign" from MEXT). It focuses mainly on a development plan for KEK.

- "Producing a EAP (European Action Plan) for the ILC in timely manner is very important."

"After having established a discussion group with DOE, discussions with Europe are likely to become the next important topic for MEXT."

Extracted from slides of Y.Okada, KEK – EJADE meeting 6.9.16

On the European side it was suggested to use the EJADE H2020 MC project to prepare the EAP – the effort was started October 2016

E-JADE

Europe-Japan Accelerator Development Exchange Programme

Programme 2015-2018:

- Three main technical WPs
- Supports extended stays of European Researchers in Japan
- Recently adapted to include detector and physics studies for ILC (new partners)

Technical WPs: WP1: LHC with upgrades/FFC/ SuperKEKb, WP2: ATF2, WP3: ILC/CLIC

Partners: CERN (coord), DESY, CEA, CNRS, CSIC, RHUL, OXF with Uni. Tokyo and KEK -> WG for EAP

New partners: VINCA, AGH-Cracow, Tel Aviv University, Liverpool University, Université de Strasbourg, Université Paris-Sud, Tohoku University and Kyushu University.

Authors of EAP:
For EJADE institutes:
CERN: S.Stapnes, CEA: O.Napoli, DESY: N.Walker/H.Weise/B.List, CNRS: P.Bambade/A.Jeremi, UK: P.Burrows, CSIC: A.Faust-Golfe

EJADE WP3 and centrally: T.Schoerner-Sadenius, M. Stanitzki
TDR: B.Foster

S. Stapnes

European Action Plan for the ILC

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

Draft Document:

Preparation Phase 2019-22: Organization and resources

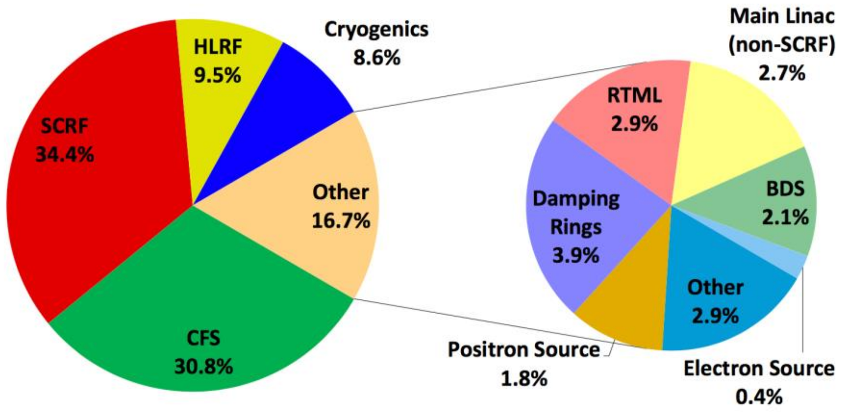
A European ILC project in the preparation phase 2019-22:

- Resources needed estimated to ~25 MCHF/year (material) and 60 FTE/year (personnel), ramping up from 2019
- Move towards more engineering personnel
- The organisational model above is used for
- existing studies at CERN, e.g. CLIC/HE-LHC/FCC

S. Stapnes

Construction phase 2023 and beyond

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.



As mentioned above, the detailed contributions will have to be defined during the preparation phase and formalized by inter-governmental agreements. Some contributions from Europe are imperative for the project - most prominently superconducting RF modules.

So premature to plan in detail, however some comments can be made:

- Focus on technical items for ILC (not CE and infrastructure)
- E-XFEL ~7% of a 250 GeV ILC – and more than 10% of the cryo-modules needed
- Detector construction expected to follow LHC detector model
- Spending significantly above the levels mentioned on previous page only by ~2025-26

Any guidance from Japan on contributions would allow us to make firmer European planning for this period

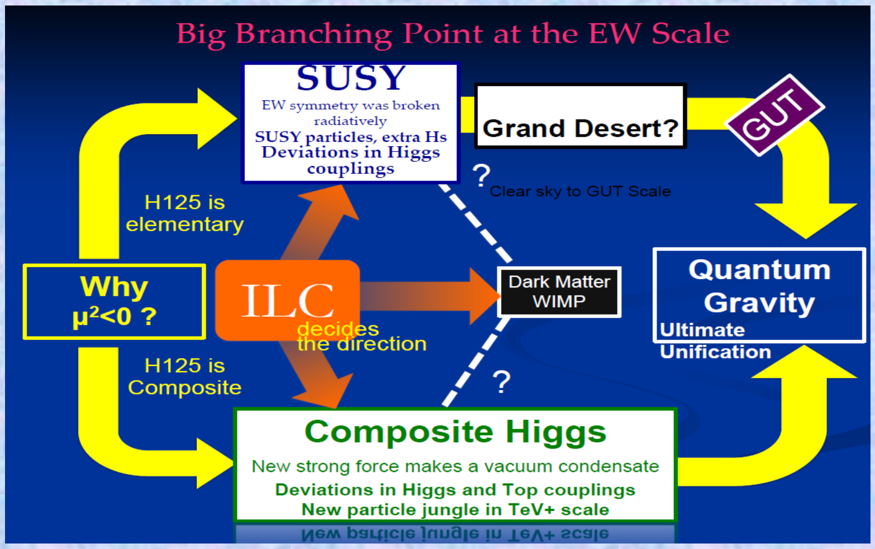
S. Stapnes

ILC (250 GeV) Physics: Precision "Higgs Factory" / Energy Frontier Machine

Recent proposal to start with ILC@ 250 GeV:

- Higgs precision depends significantly on HL performance and theory assumptions
- Below ttbar threshold
- Reduced search capabilities

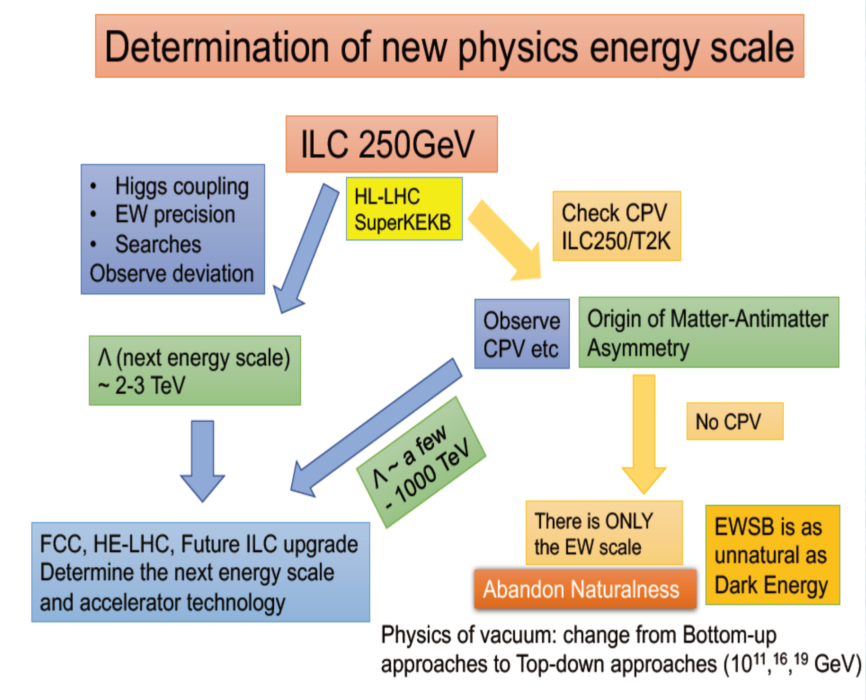
→ Nevertheless, provides impressive precision, and remains upgradable



- Strong and compelling physics case for ILC as a "Higgs Factory" (added value w.r.t. HL-LHC and all kinds of other experiments; taking into account ILC technical readiness)

- Emerging LHC Physics Results (no new particle found at 13 TeV or it is in the LHC's blind spot) → the most important goal of ILC250 GeV is to look for BSM effects through precision Higgs measurements.

- The deviation pattern is expected to show the direction of the future particle physics



Studies by LCC Physics WG since the Interim Report from the MEXT ILC Advisory Panel

Physics Case for the ILC
arXiv: 1506.05992, Jun.19, 2015

Update on overall ILC physics pro... ...R and the Snowmass summer st...

The Potential of the ILC for Discovering New Particles
arXiv: 1702.05333, Feb. 17, 2017

Update foc... ...R and ...

LCWS 2016, Nov. 2016, M...

The LCC Physics Working Group put out three papers in the past year:

- "The Potential of the ILC for Discovering New Particles", arXiv:1702.05333
- "Physics Case for the 250 GeV Stage of the International Linear Collider", arXiv:1710.07621
- "The Role of Positron Polarization for the Initial 250 GeV stage of the ILC", arXiv:1801.02840

In addition, major physics research papers on precision Higgs physics:

- "Improved Formalism for Precision Higgs Coupling Fits", arXiv:1708.08912
- "Model-Independent Determination of the Triple Higgs Coupling at e+e− Colliders", arXiv: 1708.09079
- "Report by the Committee on the Scientific Case of the ILC Operating at 250 GeV as a Higgs Factory", arXiv:1710.08639

...taged ILC.

...-page report to ICFA.

A...

LC...

... analysis framework developed for ...pendent Higgs self-coupling measurements, ...eformulated precision Higgs coupling measurements at 250 GeV and produced an updated report (=this report) on physics case for the 250 GeV ILC as input to November meetings of LCB/ICFA in Otawa.

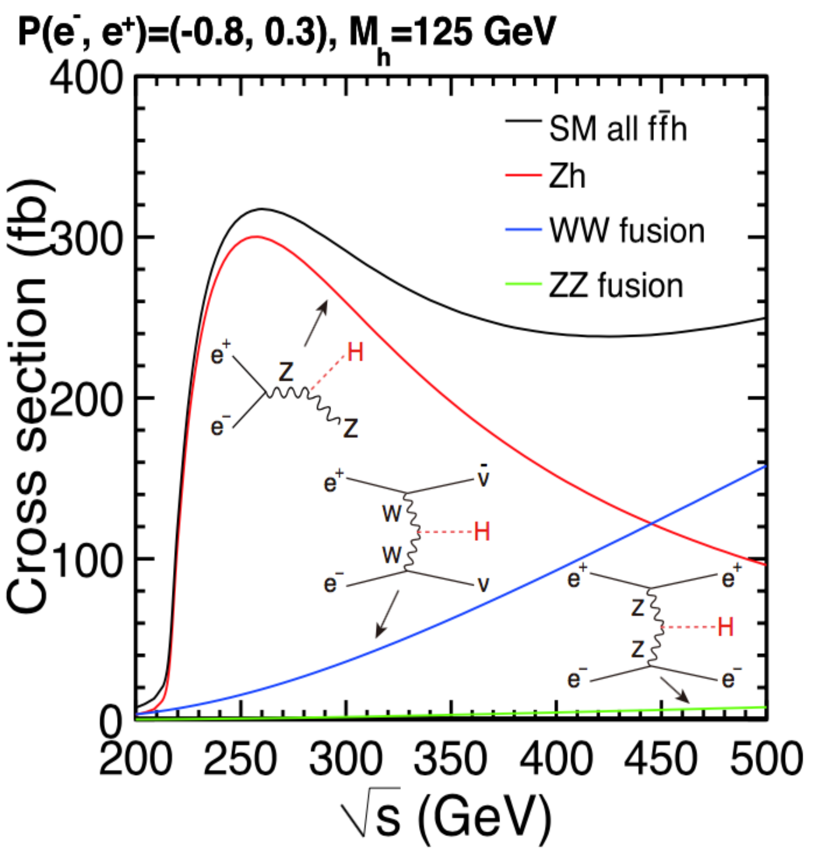
LCB/ICFA, Nov. 2017, Otawa

arXiv: 1710.07621, Oct., 2017 (physics)
arXiv: 171100568, Oct., 2017 (machine)

LCB/ICFA Statements

K. Fujii

What is the Added Value of the ILC (250 GeV) Collider



Importance of precision Higgs measurements enhanced: to test BSM physics, one has to know the absolutely normalized Higgs couplings (not just their ratios)

A problem for 250 GeV is no real access to h→W+W- ⇒ introduce a relation to h→Z*Z (SU(2)×U(1) symmetry) → EFT approach

- **Higgs production (Zh) cross section is at maximum: 2 ab^{-1} → ~ 600 000 Zh events**

→ (recoil) mass
→ total Zh cross section (***the*** key to model independent determination of absolute couplings)
→ all kinds of branching ratios
→ CP properties of h-fermion, Zh couplings

- **Opportunities for direct discoveries:**

Thanks to 1000x integrated luminosity compared to LEP2 and polarized beams ILC can cover blind spots of LHC (compressed spectra, trigger requirements …)

→ searches for additional light (Higgs) bosons with reduced couplings to the Z
→ MSSM: most general limit (any mixing, any mass difference to LSP); ILC serves as Higgsino Factory
→ sterile neutrinos with m > 45 GeV from WW cross section: expect 1-2 orders of magnitude improvement on mixing parameter
→ h-> invisible (Dark Matter!): expected limited < 0.3% @ 95% … and WIMPs

J. List

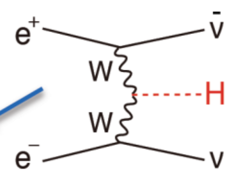
Recent Developments: EFT Analysis

Potential drawback:

It has been said that Γ_h (Higgs total width) necessary for absolute coupling normalization requires >350GeV.

$$\Gamma_h = \frac{\Gamma(h \to WW^*)}{BR(h \to WW^*)}$$

$$\Gamma(h \to WW^*) \propto \sigma(\nu\bar{\nu}h)$$



cross section: small@250GeV

arXiv: 1708.08912

$$\mathcal{L} = \mathcal{L}_{SM} + \Delta\mathcal{L}$$

↑ **SU(2)xU(1) inv. dim.6 operators**

Solution: *EFT* (*E*ffective *F*ield *T*heory)

to relate **hZZ** and **hWW** couplings

EFT: Effect of BSM physics can be expressed as a power series of (q^2/M^2) after integrating out heavy degrees of freedom.→ If energy scale is sufficiently smaller than M, most general BSM effects can be represented by adding SU(2)xU(1)-invariant dim.6 operators to the SM Lagrangian.

LHC Run II results suggest **a large M.**
250 GeV is likely **in the validity range of the EFT**

EFT coefficients to decide:

~50 @ LHC, 17 @ ILC

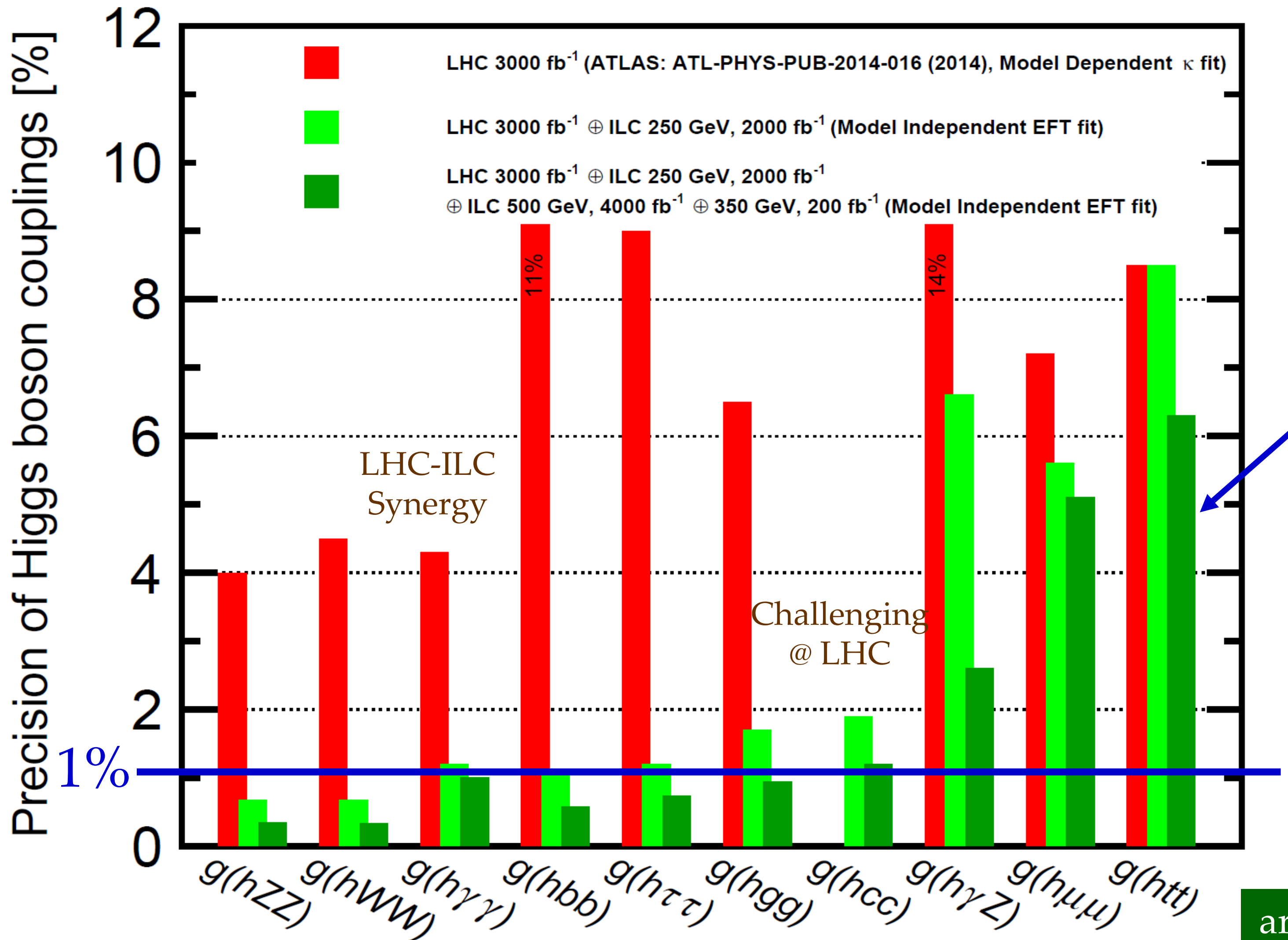
ILC the number is much smaller.

Remember ***W_L and Z_L are NGBs from the Higgs sector***. We can use all the SM processes involving W and Z to constrain them. →***possible to precisely measure all the EFT coefficients model-independently at ILC250.*** (The importance of the σ_{Zh} measurement by recoil mass technique remains the same!)

Beam polarization essentially doubles the number of usable observables.
→ ***can test the validity of the EFT***

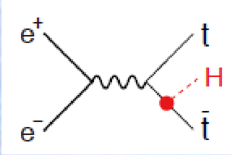
Absolute Higgs coupling measurements possible with the 250 GeV data alone!

Higgs Coupling Precision with full EFT fit



2ab^{-1} @ 250 GeV: ~10 years of data taking

Top Yukawa coupling:



→ not accessible @ 250 GeV

→ can reach 3% @ 550 GeV

arXiv: 1710.07621

- ❖ ILC(250 GeV) offers huge quantitative *and* qualitative improvement over HL-LHC precision
  → much better sensitivity to BSM !
- ❖ ~ 1 % or better reached for many couplings → adding 500 GeV improves up to a factor of ~2

New Physics Sensitivity of EFT Analysis

Selection of 9 models with all new particles outside of projected reach of direct searches at HL-LHC

	Model	$b\bar{b}$	$c\bar{c}$	gg	WW	$\tau\tau$	ZZ	$\gamma\gamma$	$\mu\mu$
1	MSSM [36]	+4.8	-0.8	- 0.8	-0.2	+0.4	-0.5	+0.1	+0.3
2	Type II 2HD [35]	+10.1	-0.2	-0.2	0.0	+9.8	0.0	+0.1	+9.8
3	Type X 2HD [35]	-0.2	-0.2	-0.2	0.0	+7.8	0.0	0.0	+7.8
4	Type Y 2HD [35]	+10.1	-0.2	-0.2	0.0	-0.2	0.0	0.1	-0.2
5	Composite Higgs [37]	-6.4	-6.4	-6.4	-2.1	-6.4	-2.1	-2.1	-6.4
6	Little Higgs w. T-parity [38]	0.0	0.0	-6.1	-2.5	0.0	-2.5	-1.5	0.0
7	Little Higgs w. T-parity [39]	-7.8	-4.6	-3.5	-1.5	-7.8	-1.5	-1.0	-7.8
8	Higgs-Radion [40]	-1.5	- 1.5	+10.	-1.5	-1.5	-1.5	-1.0	-1.5
9	Higgs Singlet [41]	-3.5	-3.5	-3.5	-3.5	-3.5	-3.5	-3.5	-3.5

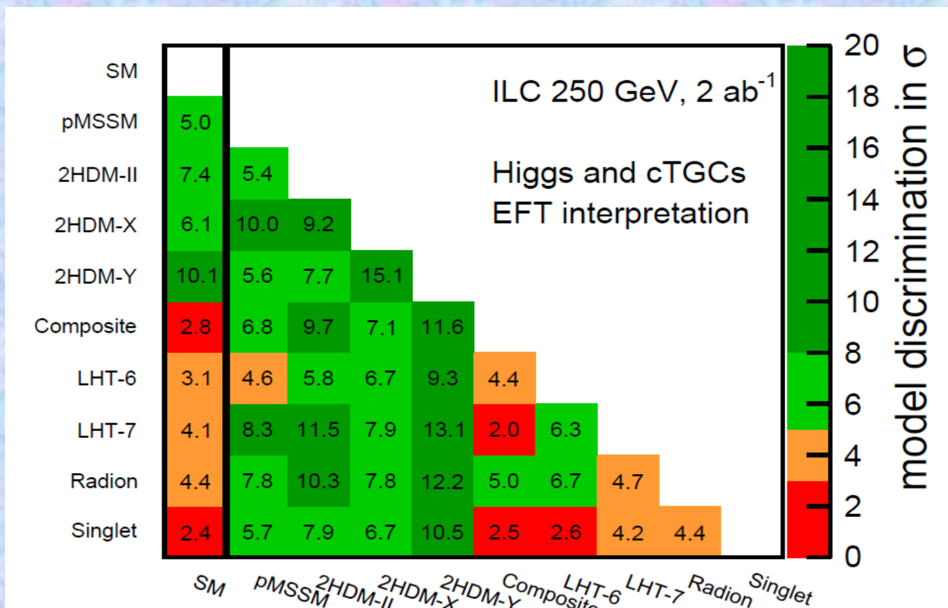
Table 3: Percent deviations from SM for Higgs boson couplings to SM states in various new physics models. These model points are unlikely to be discoverable at 14 TeV LHC through new particle searches even after the high luminosity era ($3\,\text{ab}^{-1}$ of integrated luminosity). From [15].

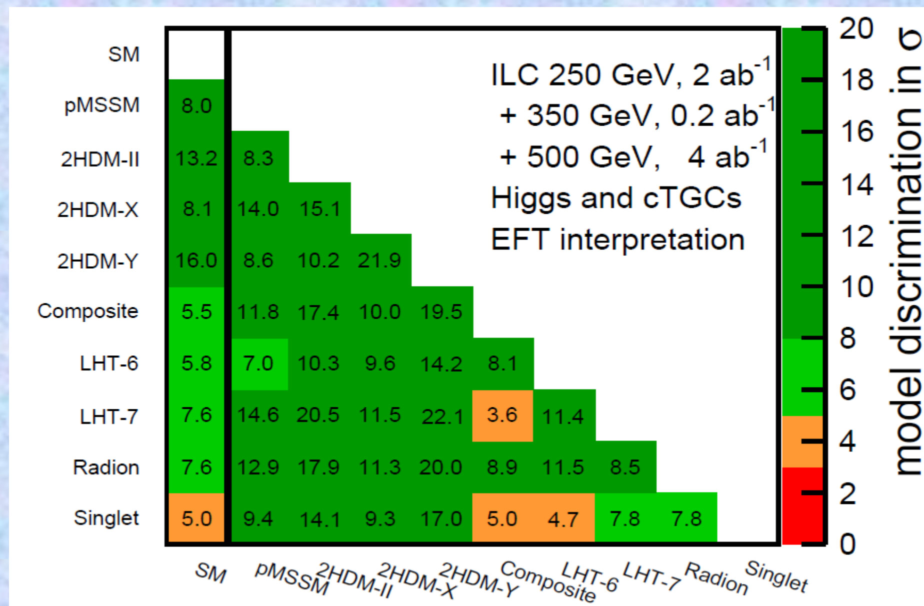
arXiv: 1710.07621

To sample new physics scenarios outside the projected reach of HL-LHC
→ The only probe would be precision measurements of the Higgs couplings

Expected deviations are at most 10% or so needs high precision to see deviations
→ Different new physics models predict different deviation patterns
→ We can discriminate the models!

Discrimination power in σs:

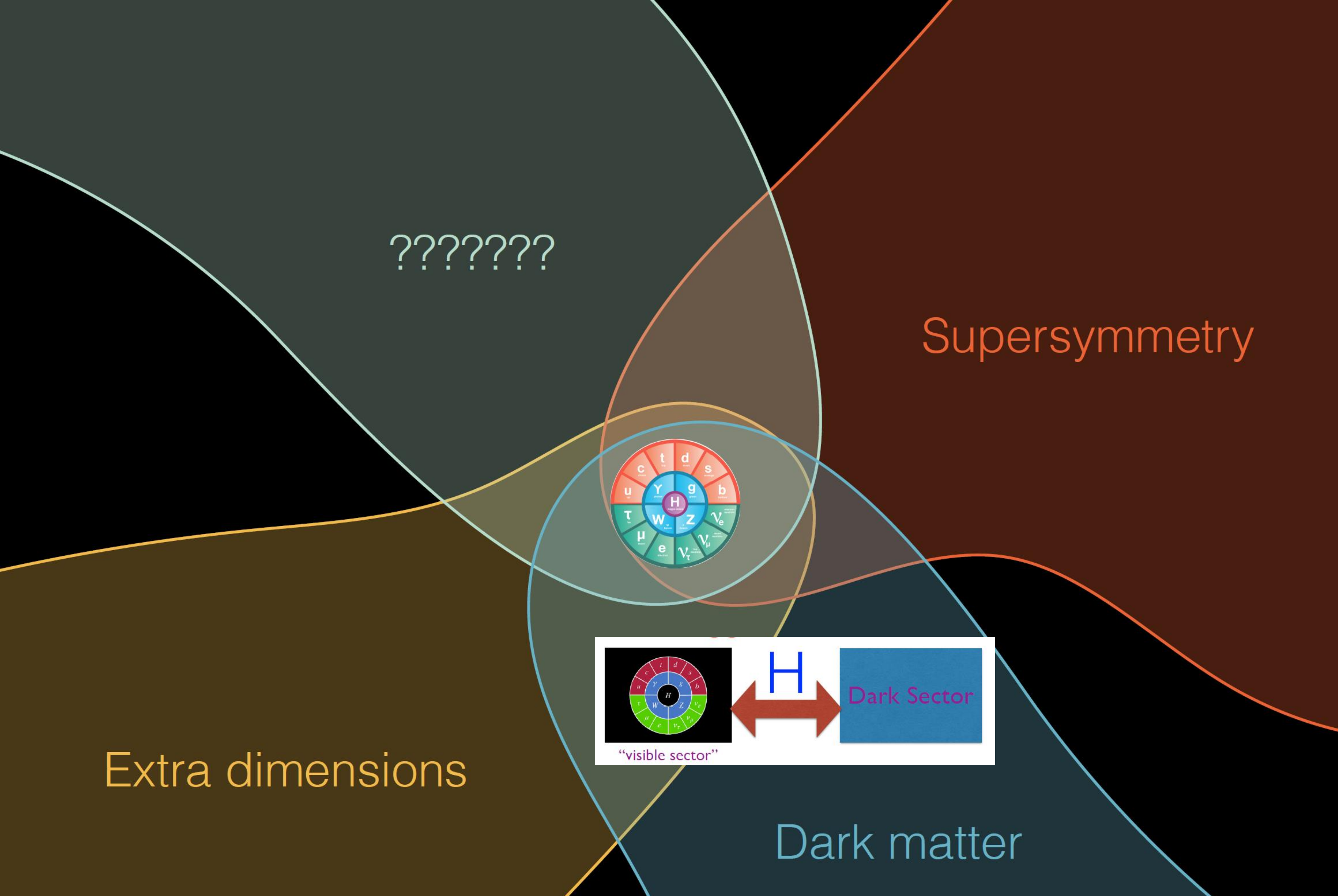




> 3σ sensitivities to most models @ 250 GeV

K. Fujii

> 4σ sensitivities to almost all models @ 500 GeV



Dark Matter need not be a single, simple particle
Could we well an entire « dark sector » as diverse as the Standard Model

Dark Matter & the Higgs at the ILC

- Light (even <GeV) DS particles are allowed thanks to weak interactions with quarks, leptons
- Higgs decays to dark sector particles (e.g.) maybe a unique opportunity to produce them!
- Simplest scenario: H → invisible;
- But it is also possible that DS particles decay back to the SM → exotic Higgs decays

- How can dark-sector fields interact with the SM? Not so easy: most gauge-invariant interactions must be suppressed ("non-renormalizable")
- In fact, only three unsuppressed interaction terms possible:

Dark Photon searches

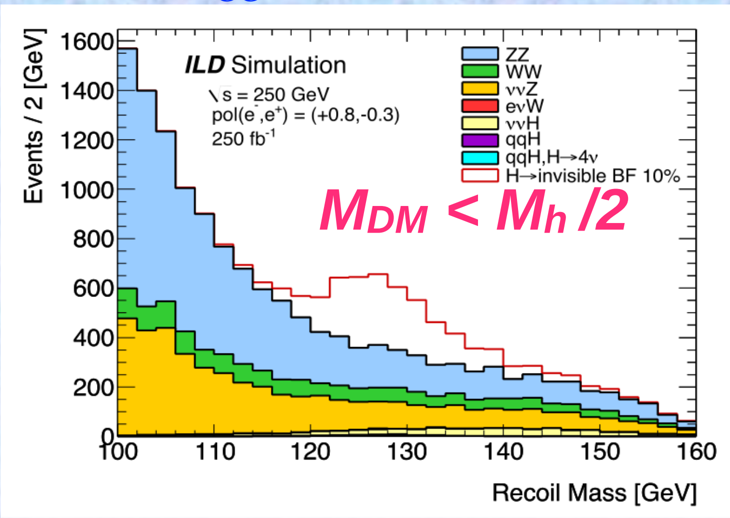
$$-\frac{\epsilon}{2\cos\theta_W} B_{\mu\nu} F'^{\mu\nu}\,, \quad \text{vector portal}$$

$$(\mu\phi + \lambda\phi^2) H^\dagger H\,, \quad \text{Higgs portal} \leftarrow \text{Precision Higgs}$$

$$y_n L H N\,, \quad \text{neutrino portal}$$

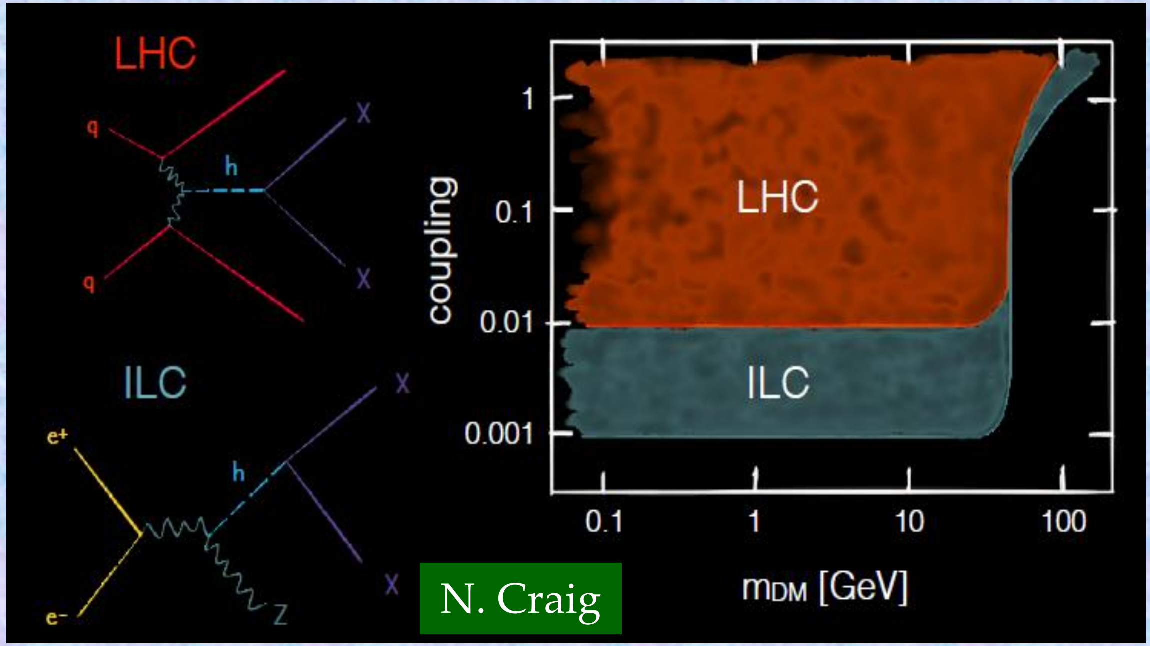
Neutrino program

Invisible / Exotic Higgs Decays → ideal hunting ground for Higgs / Neutrino Portal:

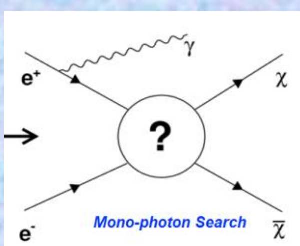


BR(H→invis.) < 0.3% at 250 GeV

An example: dark matter interacting via the Higgs force



Dark Matter: Effective Operator Approach

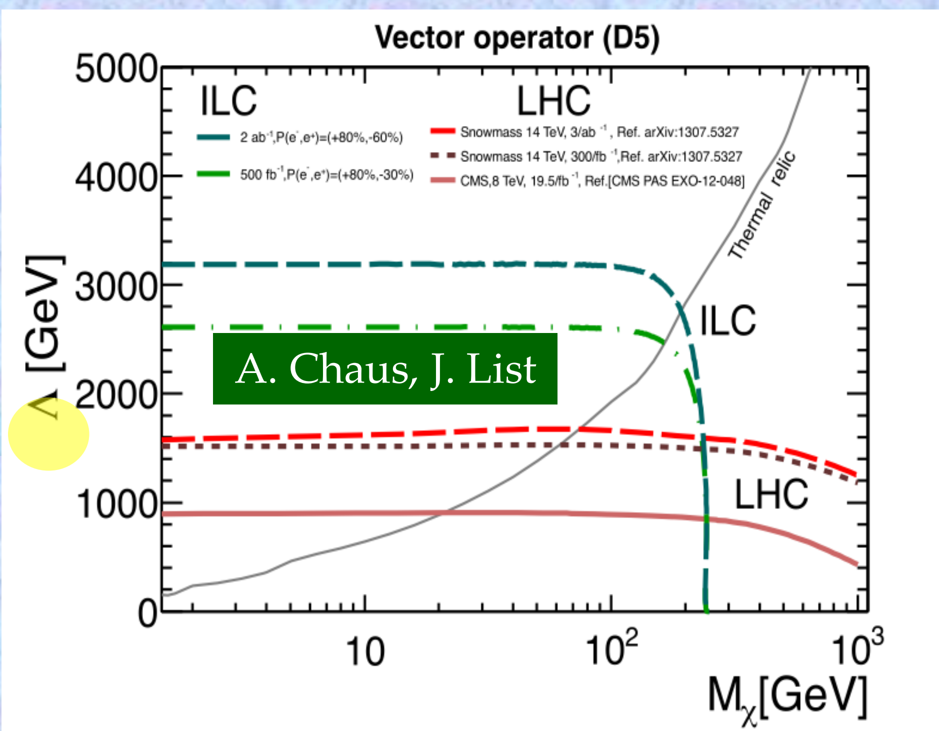


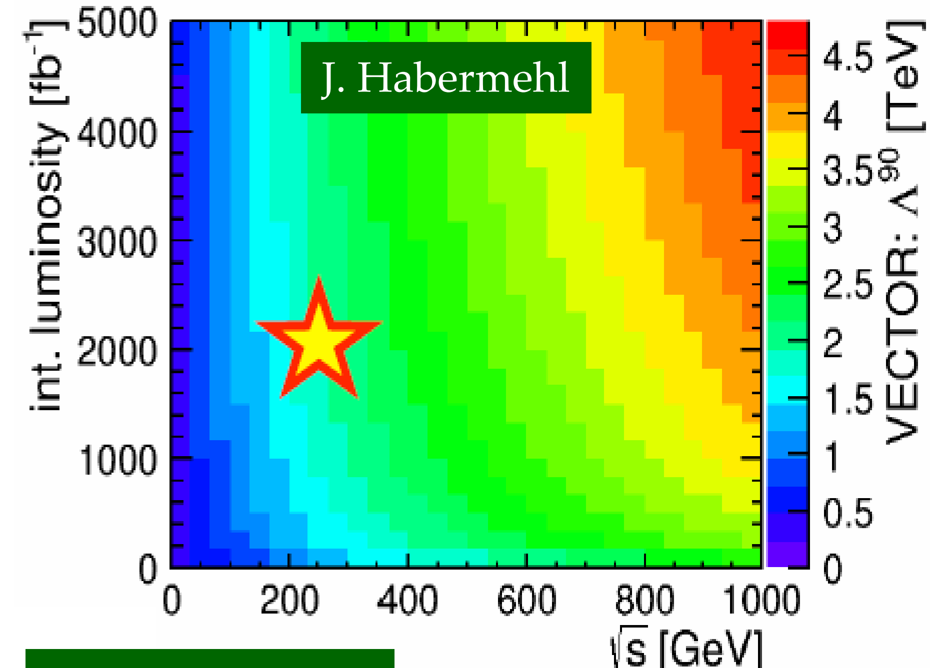
$$\mathcal{L}_{\rm int} = \frac{1}{\Lambda^2}\mathcal{O}_i$$

$$\mathcal{O}_V = (\bar{\chi}\gamma_\mu\chi)(\bar{\ell}\gamma^\mu\ell)$$

e+e- ->$\chi\chi\gamma$ "mono-photons"
Effective operator interpretation
[nota bene: valid in e+e- collider sensitivity range]

- for Mχ < 100 GeV ILC probes Λ:
  - → up to ~1.9 TeV @ 250 GeV
  - → up to ~3 TeV @ 500 GeV





arXiv: 1702.05377

- **LHC sensitivity:** Mediator mass up to Λ~1.5 TeV for large DM mass
- **ILC sensitivity:** Mediator mass up to Λ~3 TeV for DM mass up to ~√s/2

Major Physics Targets at Each Energy (250, 350, 500 GeV)

	ILC Physics Targets	250 GeV	350 GeV	500 GeV
Precision Higgs	Precision Higgs couplings	✔	✔	✔
	Precision Higgs mass	✔		
	Absolute normalization of Higgs couplings	✔ (red)	✔	✔
	Invisible / Exotic Higgs decays※1	✔	✔	✔
	Cubic Higgs self-coupling※2			✓
Top quark physics	Top Yukawa coupling※3			✓
	Precision top mass		✔	
	Precision EW couplings of top※4			✔
Other precision studies	Precision EW couplings of bottom	✔	✔	✔
	Precision W boson (incl. m_W, TGC)	✔	✔	✔
	Heavy resonance search with 2f processes	○ (small)	○ (medium)	○ (large)
Direct searches for new particles	Search for DM and other invisible particles	○ (small)	○ (medium)	○ (large)
	Each for SUSY particles	○ (small)	○ (medium)	○ (large)
	Search for extra Higgs bosons	○ (small)	○ (medium)	○ (large)

A 500 GeV machine can run at 350 and 500 GeV. In order to clarify measurements that require particular energies, this table shows physics targets at each energy.

✔ : precision measurements possible

✓ : certain level of measurements possible

✔ (red) : Recent development

※1: exotic decays = non-SM decays

※2: cubic Higgs self-coupling = self-interaction of three Higgs bosons

※3: Top Yukawa coupling = coupling between Higgs boson and top

※4: top quark is the heaviest in the SM and deeply connected to the new physics responsible for the Higgs condensation: ttZ coupling is expected to show the new physics effect.

New Particle (NP) Searches

The size of ○ is proportional to the mass reach.

For direct searches:

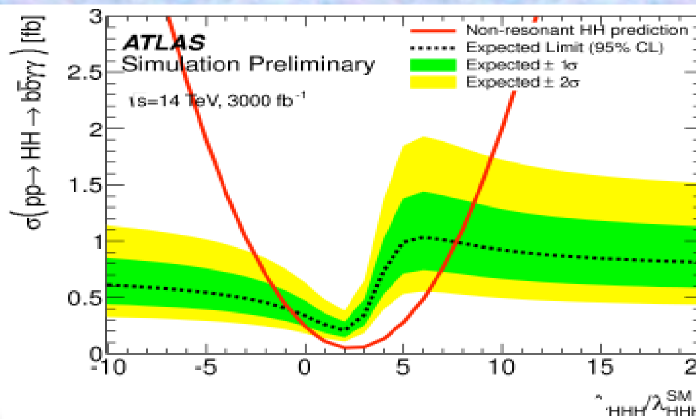
$M_{NP} \sim E_{cm}/2$

K. Fujii

Higgs Self-Coupling: Measurements Prospects

recent update: ATL-PHYS-PUB-2017-001

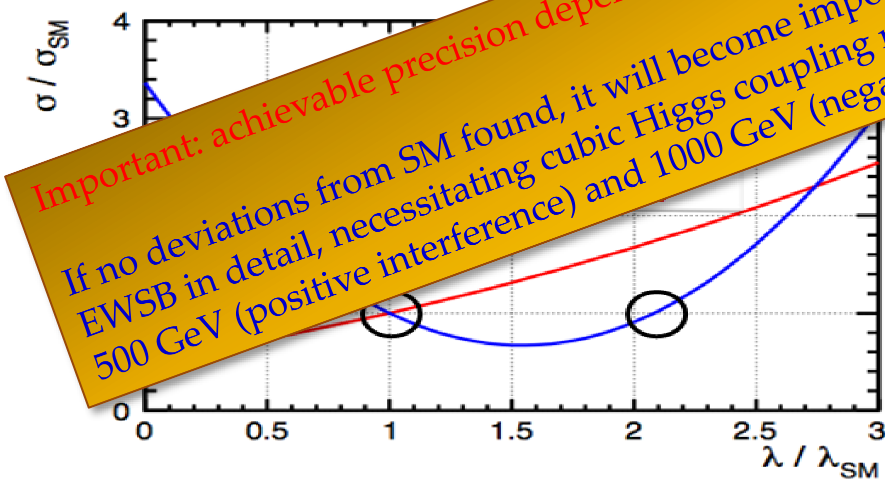
- **HL-LHC, generator-level + smearing:**
  1. Observation of HH < 3σ :(
  2. exclude extreme values of λ/λ_{SM} ≲0 and ≳ 8 assuming that all other couplings = SM

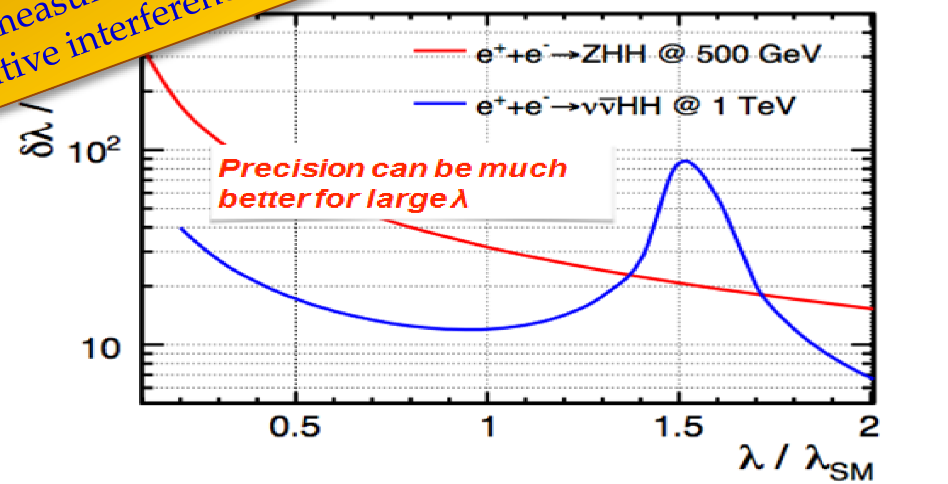


ILC Sensitivit... ...79, Eur. Phys. J. C77(2017) N7, 475

Important: achievable precision depends strongly on actual value of λ!

If no deviations from SM found, it will become important to study EWSB in detail, necessitating cubic Higgs coupling measurements at 500 GeV (positive interference) and 1000 GeV (negative interference)





- ZHH: interference is constructive, enhanced λ will increase σ, and improve sensitivity factor as well, e.g. if $\lambda = 2\lambda_{SM}$, σ increases by 60%, $\delta\lambda/\lambda$ ~15%
  for ννHH, interference is destructive, enhanced λ will decrease σ, minimum when $\lambda \sim 1.5\lambda_{SM}$, $\delta\lambda/\lambda$ degrades significantly if $\lambda/\lambda_{SM} \in (1.3, 1.7)$
- two channels are complementary in terms of λ measurement in BSM

J. List

ILC TDR: Accelerator Layout

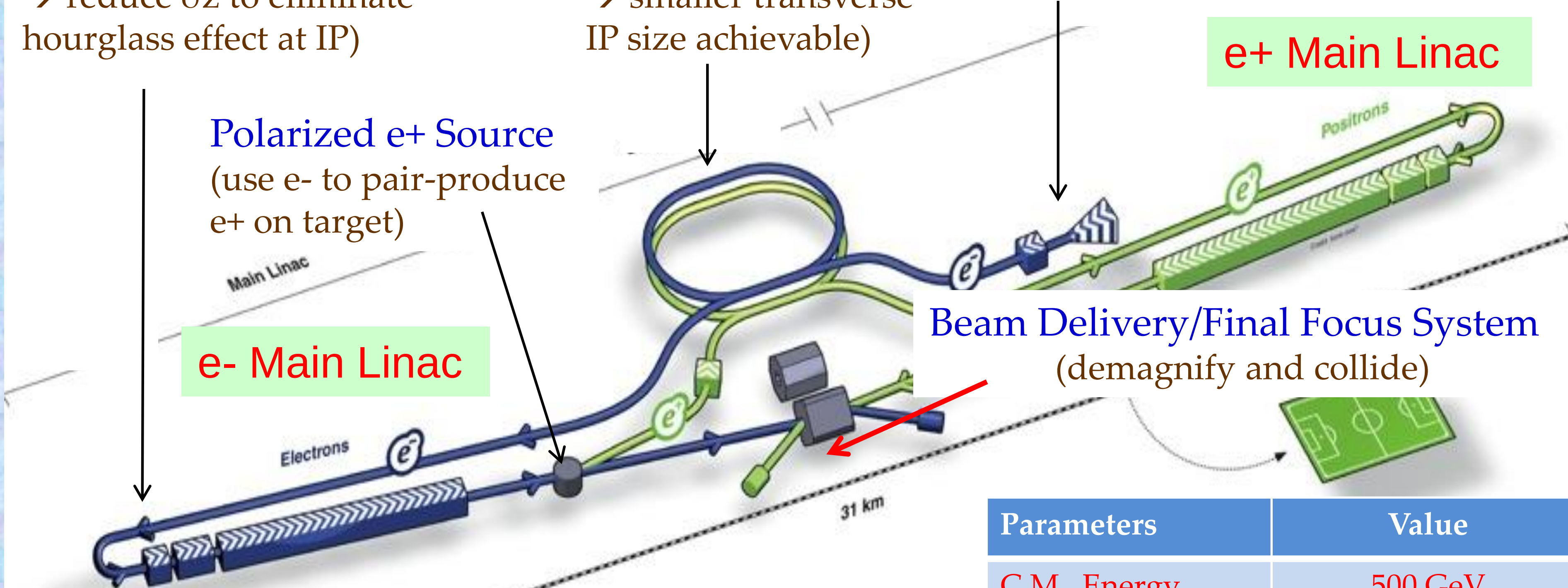
Ring to Main Linac
(including bunch compressors → reduce σz to eliminate hourglass effect at IP)

Damping Rings
(reduce emittance → smaller transverse IP size achievable)

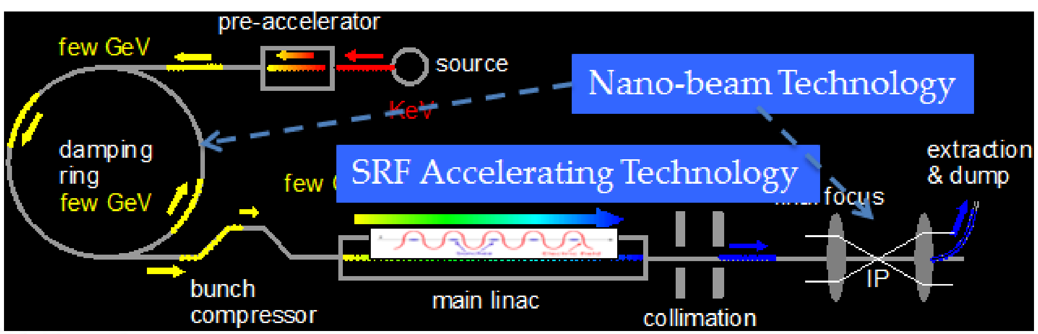
Polarised Electron Source
(deliver stable beam current)

Polarized e+ Source
(use e- to pair-produce e+ on target)

Beam Delivery/Final Focus System
(demagnify and collide)



Key Technologies



Parameters	Value
C.M. Energy	500 GeV
Peak luminosity	1.8 x10^{34} $cm^{-2}s^{-1}$
Beam Rep. rate	5 Hz
Pulse duration	0.73 ms
Average current	5.8 mA (in pulse)
E gradient in SCRF acc. cavity	31.5 MV/m +/-20% Q_0 = 1E10

TDR-based 250 GeV Main Linac Configuration

Substantial cost reduction (by up to 40%) compared to the original 500 GeV ILC

L. Evans and S. Michizono (Edit.) (Linear Collider Collaboration), "The International Linear Collider Machine Staging Report 2017, Addendum to the International Linear Collider Technical Design Report published in 2013", arXiv:1710.08639

22.6 Million person-hours

	e+/e- collision [[illegible]	Tunn[illegible]	[illegible]ILCU*)	Reduction [%]
TDR	[illegible]	[illegible]500	7,980	0
TDR upd[illegible]	[illegible]	500	7,950	-0.4
Option [illegible]	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

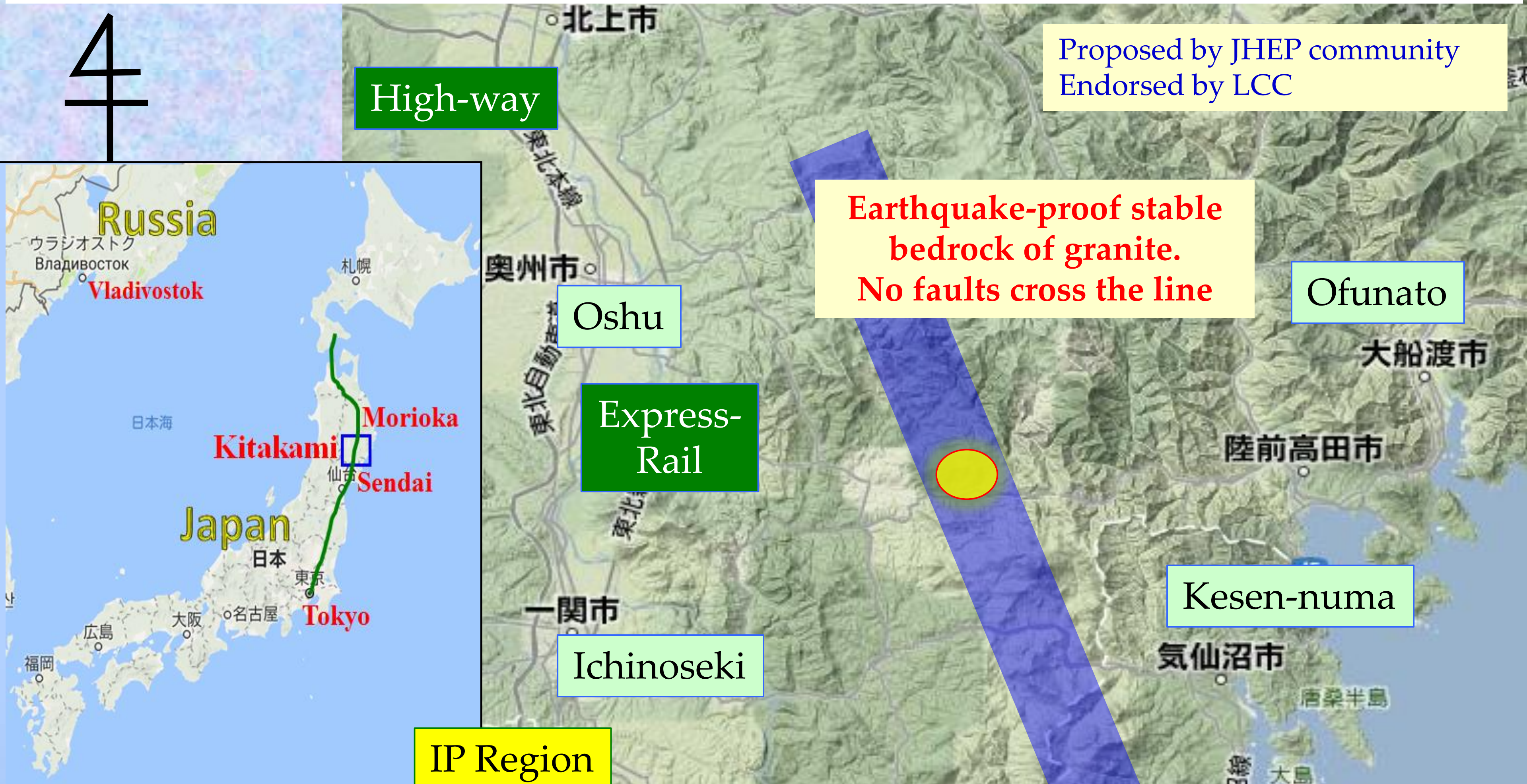
Item	Parameters
C.M. Energy	250 GeV
Length	20km
Luminosity	1.35 x10^{34} $cm^{-2}s^{-1}$
Power	125 MW
Repetition	5 Hz
Beam Pulse Period	0.73 ms
Beam Current	5.8 mA (in pulse)
Beam size (y) at FF	7.7 nm@250GeV
SRF Cavity G. Q_0	31.5 MV/m (35 MV/m) Q_0 = 1x10^{10}

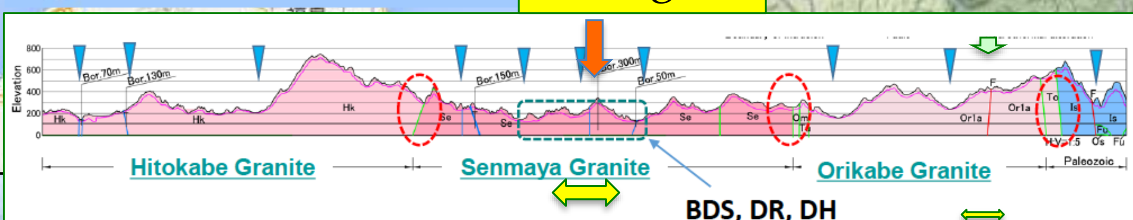
* ILCU:US$ as of 2012 Jan.

S. Michizono

ILC Site Candidate Location in Japan: Kitakami Area

Establish a site-specific Civil Engineering Design - map the (site independent) TDR baseline onto the preferred site - assuming "Kitakami" as a primary candidate





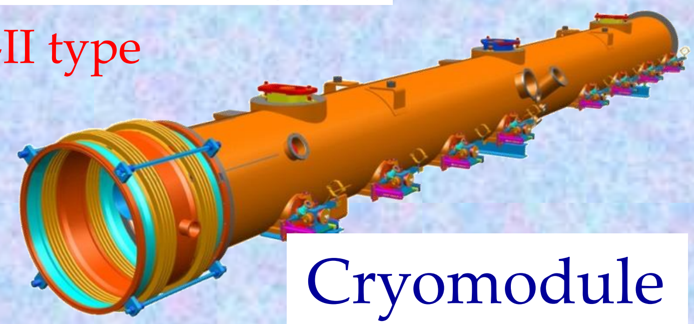
Need to finalize:

- IP / Linac orientation and length
- Access points and IR infrastructure
- Conventional Facilities and Siting (CFS)

Global Superconducting RF Linac Technology

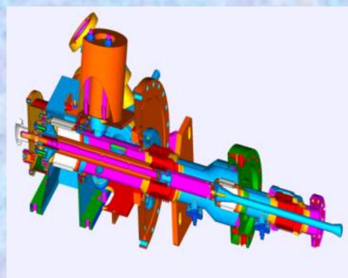
Cryomodule based on EXFEL and LCLS-II type

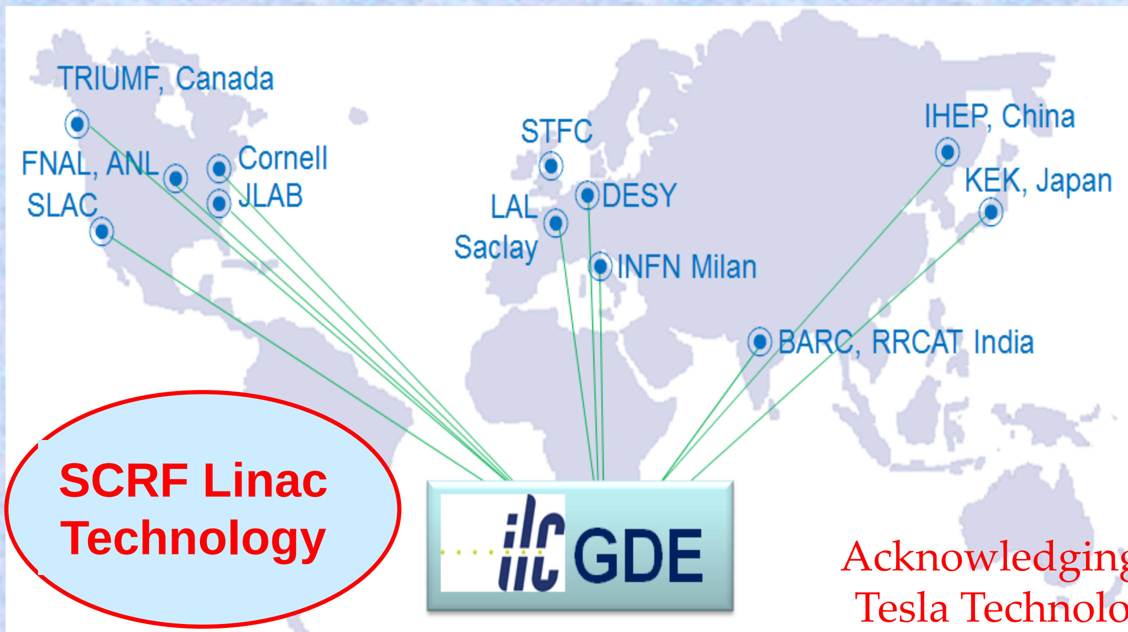
RF Cavity



Cryomodule

Power Coupler

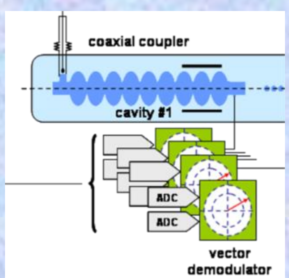




Frequency Tuner

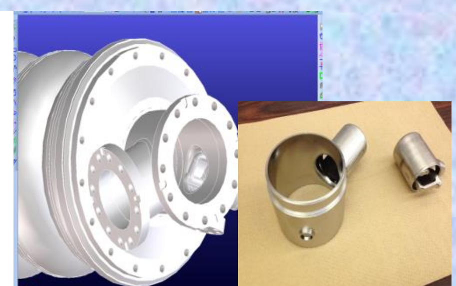
Acknowledging the efforts of the Tesla Technology Collaboration

LLRF

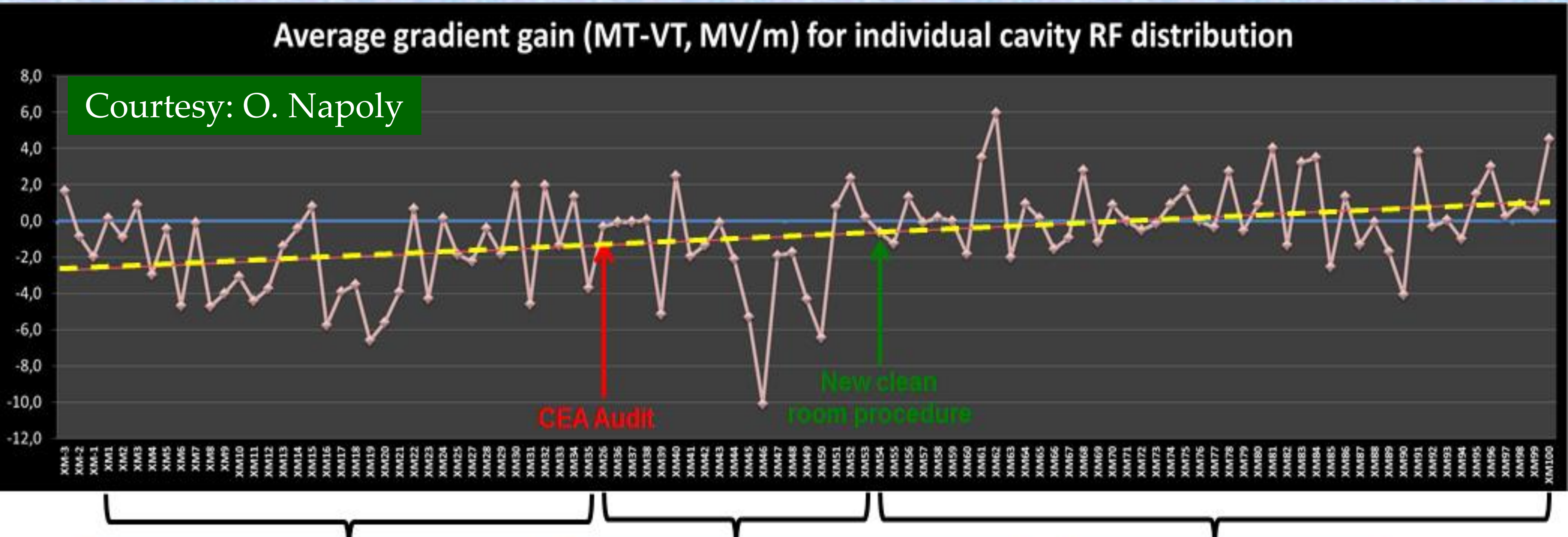


RF power

HOMs (higher order modes) coupler



Gradient Performance: Cryomodule vs Cavity



1st sample of 34 series CM
ΔE_{op} = -2.1 MV/m

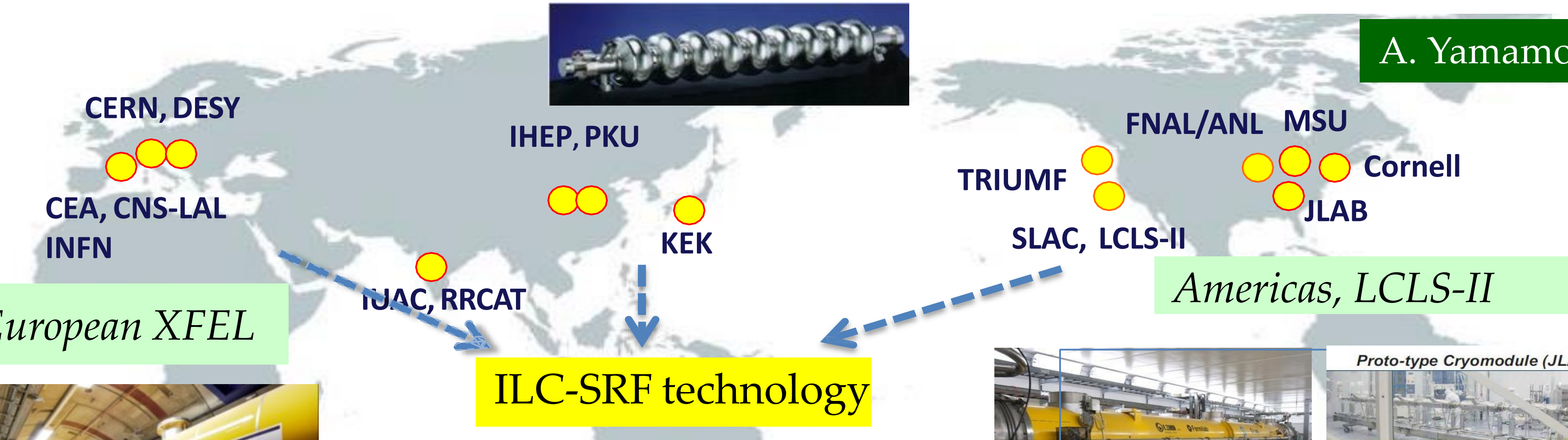
2nd sample of 19 series CM
ΔE_{op} = -1.7 (-0.9) MV/m

last 47 series CM
ΔE_{op} =+0.5 MV/m

Degradation mitigated through critical efforts during the 100 European XFEL cryomodule assembly. No-degradation achieved.

WorldWide SRF Collaboration

A. Yamamoto



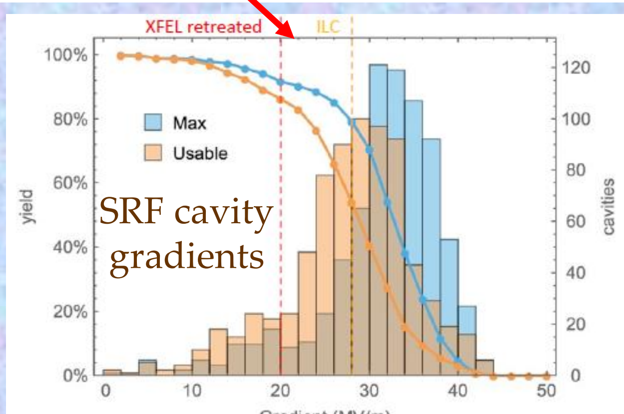
European XFEL

ILC-SRF technology

Asia,
PAPS@IHEP CFF/STF@KEK

Americas, LCLS-II

EXFEL →
10% prototype
for the ILC 250 GeV:



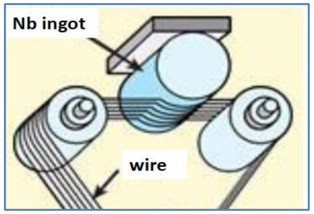
D. Wang

	EuropeanXFEL	LCLS-II (HE)	Shanghai XFEL
RF mode	Pulsed	CW	CW
Power source	Klystron	SSA	SSA
Install	Single ac Tunnel	Tunnel + Gallery	Single ac Tunnel
2K heat load/CM	~20w/CM	~80w/CM	~80w/CM
Tunnel slope	~	0.5%	~
N of modules	~100	~35 (+19)	~75
2K capability	~3kW	~ 2 x 4kw	~ 3x4 or 4x3 kw

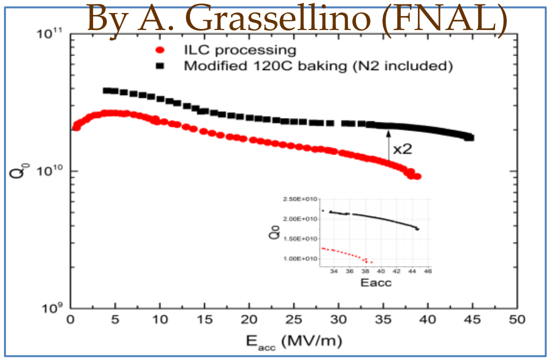
ILC Cost Reduction R&D on SRF Technology (2-3 years)

Cost reduction by technological innovation in the framework of US –Japan cooperation

- Innovative Niobium material process → decrease in material cost
  - with new processing for sheeting/piping and clean surface

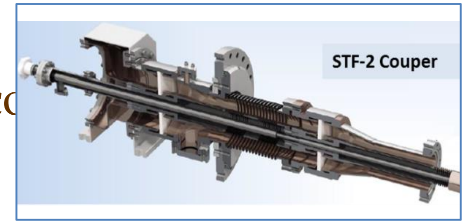


By A. Grassellino (FNAL)

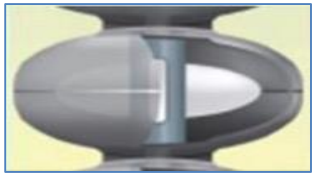


- Innovative surface process for SRF cavity fabrication for high-Q and high-G → decrease in number of cavities
  -with a new "N Infusion" recipe provided by **Fermilab**

- Power input coupler fabrication
  - with new (low Second. e- emission) ceramic without TiN cc



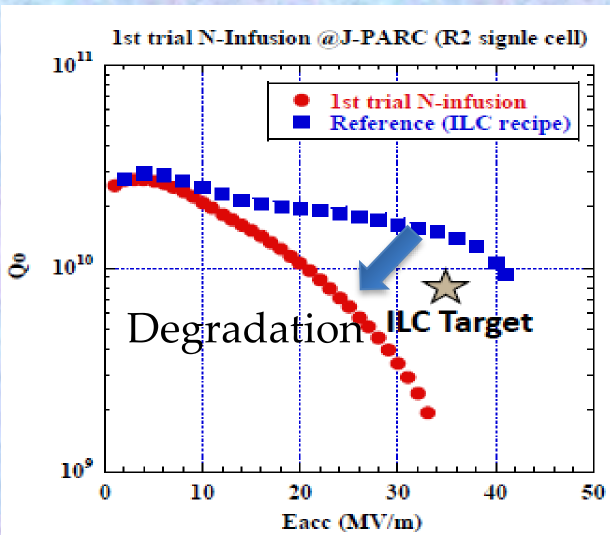
- Cavity chemical treatment
  - with vertical EP and new chemical (non HF) solution



- Others

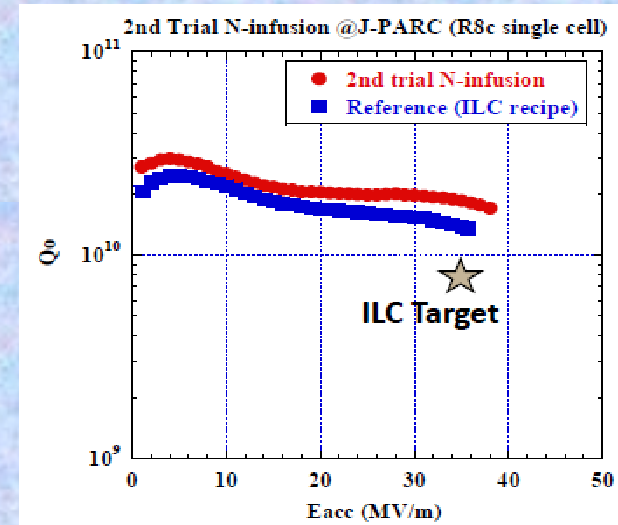
A. Yamamoto

SRF Cavity Fabrication for High Gradient and High-Q (Nitrogen Infusion)



Recent N-infusion (120 C) result @ KEK:

After the vacuum pumping (bkg vacuum improved from 1.7e-2Pa to 1e-5Pa) & system improvement



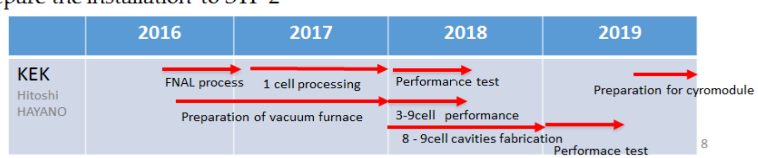
R&D plans for High-Q : High Gradient:

JFY2016:
- Process single-cell KEK-cavity at FNAL (done)
- Measure Q-value at FNAL (done)

JFY2017:
- Measure Q-value at KEK (to confirm the measurement system configuration)
- Produce new single-cell cavities
- Process single-cell cavities at small vacuum furnace
  (iteration with electro-polishing & vertical test)
- Procure new vacuum furnace for 9-cell cavity

JFY2018:
- Process High-Q High-G to 3 nine-cell cavities
- Produce 8 nine-cell cavities

JFY2019:
- Check performance
- Prepare the installation to STF-2



→ More in talk by C. Antoine

	On-going	R&D: ML Cavity	Assoc. System	Cryomodule	RF
Fermilab	LCLS-II	N_2-infusion (HQ-HG)	Coupler		
JLab	LCLS-II	Nb-LG/FG (Ingot-sliced/rolled) , LSF cavity, N_2-infusion			
DESY	EXFEL	N_2-infusion Nano-Lab study		High-performance CM	
INFN-LASA	ESS	Nb-LG/FG systematic study for ESS			
CEA/ CNRS-LAL	IFMIF ESS, SARAF	Vertical EP (VEP), N_2-Infusion	Magnetic shield Coupler	Assembly robotizing	
KEK	STF	Nb-LG/FG N_2-infusion	Coupler, Tuner Crab. C.		Marx M.
IHEP	ADS	N_2-infusion, Industrialization		Industrialization	Marx M. h.e. Klystron
CERN	HL-LHC Hi-Isolde	Thin-film (Nb on Cu)	Coupler		h.e. Klystron
TRIUMF	ISAS-II, ARIEL	VEP, muSR			
(Cornell)		N_2-infusion, VEP			

The European XFEL @ DESY

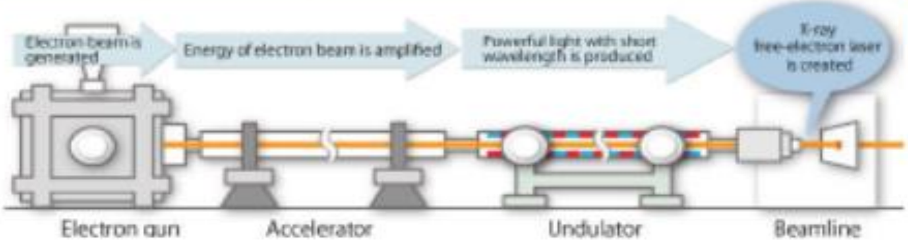
E-XFEL successfully constructed and put into operation - a key technology demonstration

The European X-ray Free Electron Laser

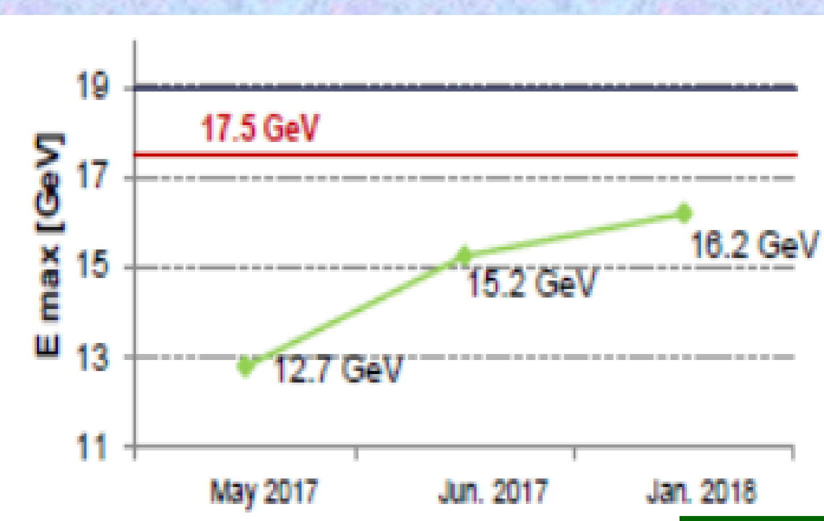
- 17.5 GeV light source user facility
- TESLA superconducting 1.3 GHz RF cavities
- 1.4 msec RF pulses at 10 Hz
- e- beam 1.35 mA nom., up to 500kW beam power

The XFEL accelerator

- 800 SRF cavities, couplers, tuners
- (720 in operation for now) + 64 next months
- 101 cryomodules, 26 RF stations
- 2 years of cavity / cryomodules tests / tunnel installation



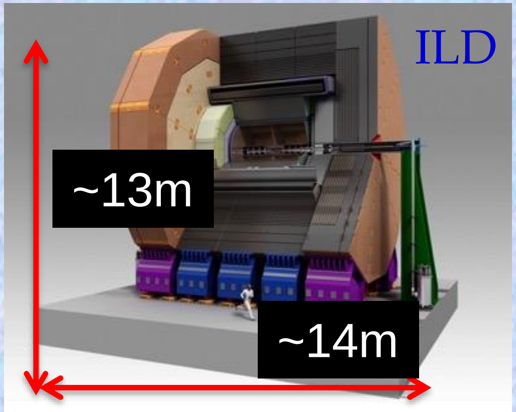
YouTube watch online:
https://www.youtube.com/watch?v=p3G90p4gIQA

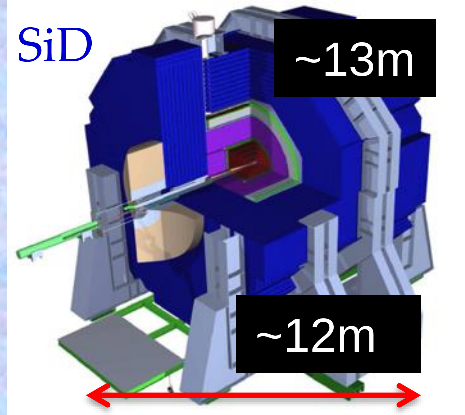


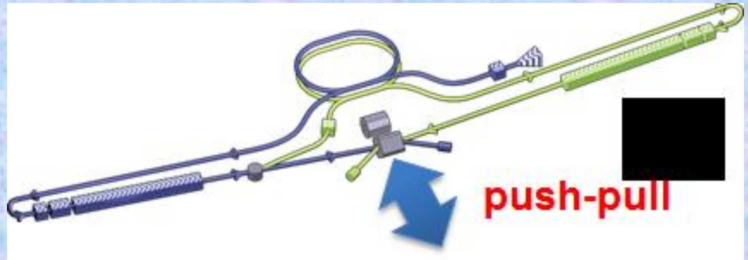
- ➢ Very fast commissioning → no fundamental issues (cryo, vacuum, RF)
- ➢ 2 successful runs Sep. And Dec. 2017 (3 weeks each) → beam delivery above expectations (beam power/time)
- ➢ 2018: Further commissioning + 2000 hours users
- ➢ 2019: Nominal operation with 6 experiments + 4000 hours users

J. Branlard

Two Validated Detector Concepts: ILD and SiD







❖ **VERTEX**: flavour tag, IP resolution (H → bb, cc ττ)
~1/5 $r_{beampipe}$, 1/30 pixel size, ~1/10 resolution (ILC vs LHC)

$$\sigma_{IP} = 5 \oplus \frac{10}{p \sin^{3/2}\theta} (\mu m)$$

❖ **TRACKING**: recoil mass to Higgs (e+e- → ZH → llX)
~1/6 material, ~1/10 resolution (ILC vs LHC); B = 3.5 – 5T

$$\sigma(1/p) = 2 \times 10^{-5} (\mathrm{GeV}^{-1})$$

❖ **CALORIMETRY:** particle flow, di-jet mass resolution
1000x granularity, ~1/2 resolution (ILC vs LHC);
detector coverage down to very low angle

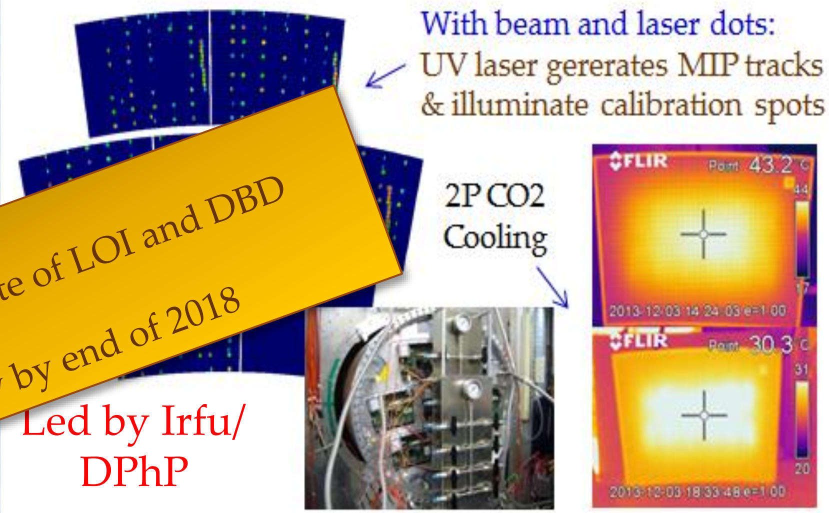
$$\sigma_E / E = 0.3 / \sqrt{E(\mathrm{GeV})}$$

ILD	**SiD**
Both optimized for PFA PFA Performance **~B·$R_{ECAL,inner}^2$** (two-track separation @ ECAL)	
B = 3.5 T	**B = 5 T**
$R_{ECAL,inner}$ = 1.8 m	**$R_{ECAL,inner}$ = 1.27 m**
Si + TPC tracking	**Tracking: Si only**
Share interaction point via push-pull	

The ILD Meeting in Ichinoseki: Feb. 2018

Hosted by Tohoku University in Ichinoseki, Japan

➤ 7 Micromegas modules with 2-phase C02 cooling



- ILD Document: ready end 2018/ early 2019
  → comprehensive description of the ILD update of LOI and DBD
- Short ILD document for European Strategy by end of 2018

- ➤ Define a ... cost optimized ILD detector
- ➤ Demonstrate the performance of the ILD concept
- ➤ Develop a realistic implementation of the ILD detector
- ➤ Document the
  1. Design
  2. Engineering
  3. Performance

  of the ILD detector model

→ More in talk by P. Colas

ILD collaboration maintains good level of activity in spite of challenging conditions

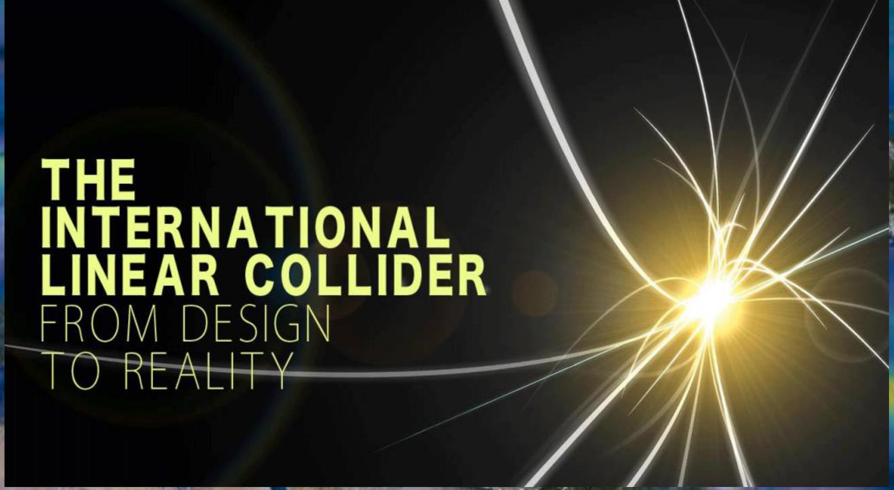
- Have given ourselves a clear goal towards the end of 2018
- Important to
  → document the work of the past few years
  → provide a well defined stating point in case ILC moves forward
- ILD is ready to take up the challenge if ILC moves forward

The "Comité Collisionneur Linéaire" of IN2P3

M. Winter

- **Mandate of CCL :**
  - inform the IN2P3 community about the evolution of the ILC project
  - organise regular meetings where progresses on accelerator, detectors, physics studies are presented
  - prepare the contribution of IN2P3 to an ILC experiment
- **Activities :**
  - detector R&D on calorimetry (ECAL, HCAL) and inner tracking-vertexing, develop PFA
  - prospective physics studies, used to guide the R&D
  - several tens of PhDs defended, hundreds of publications and presentations at conferences
  - strong impact on ILC detector concepts (numerous spin-offs, e.g. upgrades of LHC expt
- **Composition :**
  - 1 representative per group/lab (LAL, LLR, IPHC, IPNL, LA ... C, LPCC, CCPM)
  - about 30 - 50 physicists and engineers in ... ., post-docs, students)
- **Since 2016/17, important progres ... ieved, including at European level :**
  - Japanese government prepares for declaring its position w.r.t. ILC for the European HEP strategy update
  - The CCL intends to write a document feeding the European Strategy Update WGs

→ Aim for a common document with IN2P3 (feeding the European Strategy Update WG) from the French community ?

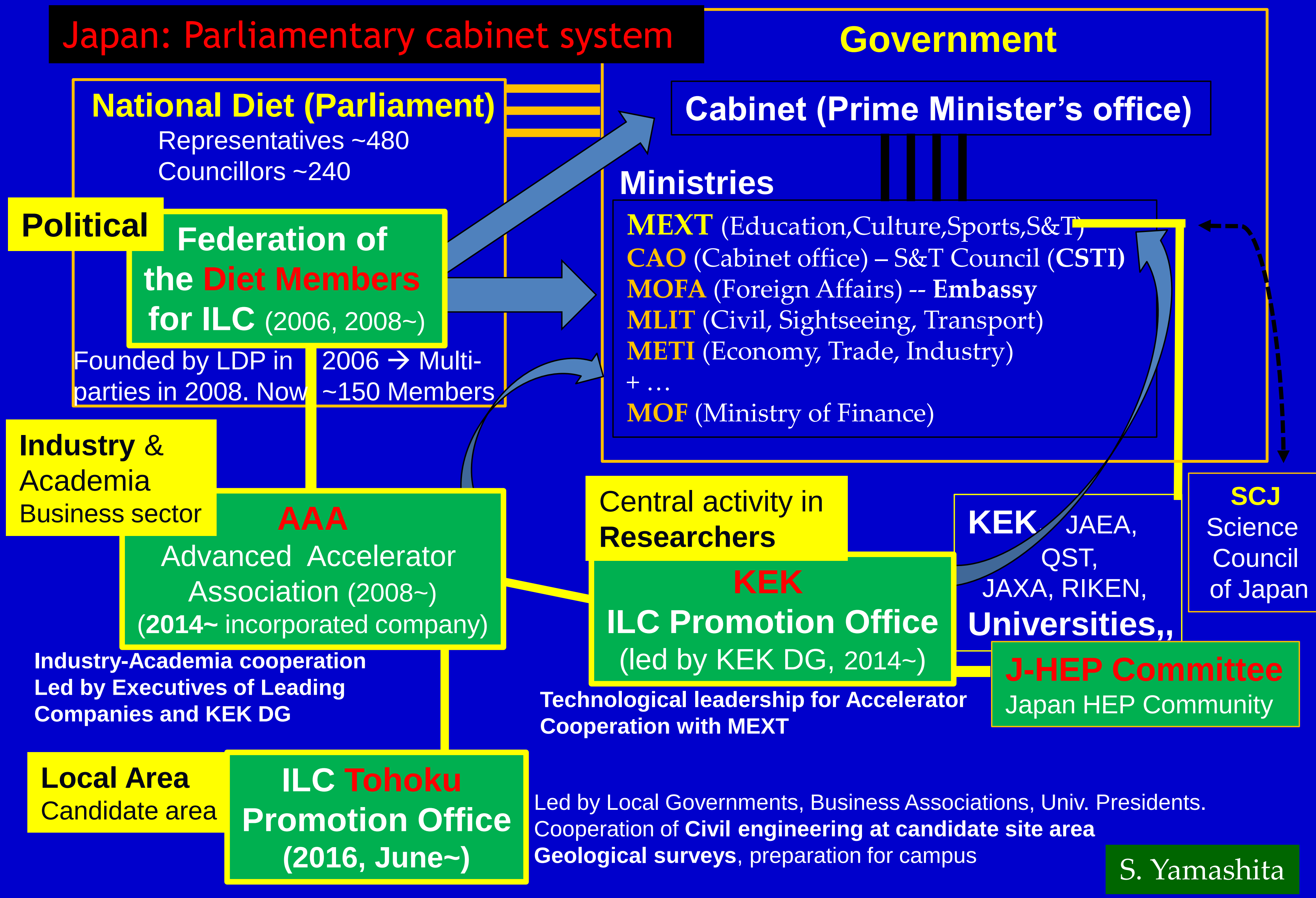


Status of the International Linear Collider Project

The First Global HEP Project in Asia

IWATE and the ILC:
http://www.iwate-ilc.jp/eng

Essential Bodies for ILC Promotion in Japan



US-Japan High Level International Discussions

- ❖ Ongoing discussions starting from April 30,2013
  - → Government (DOE Office of Science);
  - → Congress (S&T and Appropriation Committee members

Boost S&T cooperation, In general

- ❖ DOE-MEXT "discussion group" → R&D on cost-reduction towards ILC realization
- ❖ Industry should be involved to play a leading role

The European Strategy for Particle Physics 2012-2013: High-Priority Large-Scale Scientific Activities*

After careful analysis of many possible large-scale scientific activities requiring significant resources, sizeable collaborations and sustained commitment, the following four activities* have been identified as carrying the highest priority*:

- *Point 1: Europe's top priority should be the exploitation of the full potential of the LHC, including the high-luminosity upgrade of the machine and detectors with a view to collecting ten times more data than in the initial design, by around 2030* → Well underway (HL-LHC is approved by the CERN Council);

- *Point 2: CERN should undertake design studies for accelerator projects in a global context, with emphasis on proton-proton and electron-positron high-energy frontier machines. These design studies should be coupled to a vigorous accelerator R&D programme, including high-field magnets and high-gradient accelerating structures, in collaboration with national institutes, laboratories and universities worldwide* → R&D studies for the future high energy machine (CLIC, HE-LHC/FCC) are being summarized for the European Strategy Update in 2019-2020

- *Point 4: CERN should develop a neutrino programme to pave the way for a substantial European role in future long-baseline experiments. Europe should explore the possibility of major participation in leading long-baseline neutrino projects in the US and Japan* → CERN Neu[illegible]tform for detector R&D being constructed

- *Point 3:* There is a strong sc[illegible] positron collider, complementary to the LHC, that can study the prop[illegible] particles with unprecedented precision and whose energy can [illegible] Report of *the International Linear Collider (ILC)* has been com[illegible]ipation. The initiative from the Japanese particle physics community [illegible] welcome, and *European groups are eager to participate. Europe looks forward to a* [illegible]*scuss a possible participation*

*A priori these 4 activities are not prioritized → all 4 should be pursued

By the end of the 2016 …
Many research / technical studies are being carried for the ILC, but limited progress in Japan - Europe discussions in the political front & governmental level

Europe-Japan
Progress in 2015 – 2018:

1. 2015 EU-Japan Parliament Council → 1st input to EU Parliament members from Japan (Hon. Kosaka -2016)
2. **Spain-Japan (May-Jun. 2016)**: Symposium at Spanish Embassy in Tokyo, on mutually interesting area, "Fusion and Accelerator" related field. → MoU between INEUSTAR and AAA @ Spanish Embassy in Tokyo, Japan in May 2016. Industry-Academia Spain-Japan Workshop at ECFA LC workshop at Santander in Spain in June 2016.
3. **Germany-Japan (Oct. 2016): parliamentary member interactions**@Tokyo
   Direct discussion for ILC between German Parliament Member and JP Diet members
4. **2016 IEEE @ Strasbourg** Two Diet members (Hon. Ito, Hon. Shina), AAA Nishioka
5. **2017/Oct/27 LCWS2017@Strasboug** (Hon. Becht (France)・Hon. Kaufmann（Germany）・3 Diet members (Japan, remote) Kawamura, Shionoya, Hirano
6. **2017/Nov/07 ICFA/LCB statements**, hoping "an international project led by Japanese initiative"
7. **2017/Nov/29 Hon. Becht visited Japan**, had a pre-meeting in Tokyo.
8. 2017/December **Preparation** for the meetings in France and Germany

- Hon. Becht (FRA), Hon. Kaufmann (GER), ILC Federation of Diet Members, Alsace Japan Agency, French Embassy in Japan

S. Yamashita

7. **2018/Jan/9-11 Japanese Delegation visit to Paris and Berlin**

Window to EU and France

IEEE NSS/MIC Conference: Strasbourg, Oct. 2016

@IEEE NSS/MIC Plenary
Hon. T. Shina

Catherine Trautmann,
Former French Minister of Culture
Former EU Parliament member
Former Mayor of Strasbourg

AAA Chairman
T. Nishioka

Two Diet members participated and discussed on ILC

S. Yamashita

@EU-Japan
VIP meeting
Hon. Ito

First Step: High-Level Japan – Europe Contacts

LCWS2017: Strasbourg, Oct. 2017

https://agenda.linearcollider.org/event/7645/

From Europe:

Hon. Olivier BECHT (National Assembly, France)
Hon. Stefan KAUFMANN (Bundestag, Germany)

From Japan (ILC Federation of Diet Members, remote)

Hon. Takeo Kawamura
Hon. Ryu Shionoya
Hon. Tatsuo Hirano

Europe - Japan Industrial Contacts: IEEE2016, LCWS2017

LCWS2017 : 1-Day EU-Japan Industry Forum on Accelerator Technologies and Advanced Instrumentation:

2017 INTERNATIONAL WORKSHOP **ON FUTURE LINEAR COLLIDERS**

23-27 OCTOBER 2017, STRASBOURG, FRANCE

The 2017 International Workshop on Future Linear Colliders (LCWS2017) will be held from 23 to 27 October 2017, at the Strasbourg Convention Center (http://www.strasbourg-events.com/en).

Its programme reviews the progress in the detector and accelerator technologies for both the International Linear Collider (ILC), exploiting the European XFEL technology, and the Compact Linear Collider (CLIC) projects. LCWS2017 occurs at the particular time when Europe prepares for an update of its particle physics strategy while Japan finalises its appraisal of hosting the ILC electron-positron collider.

As a part of the LCWS107 symposium, the organisers are pleased to announce the following special event:
Japanese-European Industrial Forum on Accelerator Technologies and Advanced Instrumentation for the Future Large-Scale Facilities
Date: 25 October 2017
Venue: Strasbourg Convention Center
Purpose of the meeting: strengthen world-wide industrial cooperation towards future electron-positron linear colliders.

Focus on activities related with the development of accelerator technologies and advanced instrumentation techniques. As an example, Advanced Accelerator Association (AAA) in Japan serves as a forum for issues on R&D, intellectual property rights and other related areas concerning the ILC as a model project, bringing together 146 companies, universities, and research laboratories.
Ultimate goal of the meeting: consolidate links and enlarge international cooperation between academia and industrial players involved in accelerator science for the future large scale infrastructures and big science projects of mutual interest in nuclear physics, material science, medical physics, and high energy physics domains.

Expected attendance: delegates from Industrial companies and research scientists from Asia, Europe and North America. Industries interested to participate, please contact: Marc Winter, IPHC Strasbourg (marc.winter@iphc.cnrs.fr), Steinar Stapnes, CERN (steinar.stapnes@cern.ch), Maxim Titov, CEA Saclay (maxim.titov@cea.fr)

http://lcws2017.iphc.cnrs.fr

- Representatives of AAA, French, German, Italy industries and researchers
- Contacts with EU-Japan Center for Industrial cooperation in Brussels initiated: http://www.eu-japan.eu

IEEE2016 - AAA Delegation

https://agenda.linearcollider.org/event/7645/sessions/4537/#20171025

LCWS2017 – Industry forum

The 1st Japanese ILC delegation to Europe (France and Germany)

A big jump

Date: January 9-11, 2018
Meetings@Paris: National Parliament, MESRI, CEA, CNRS, Industry
Meetings@Berlin: Bundestag, BMBF

Federation of Diet Members: Hon. Shionoya, Hon. Ito, Hon. Otsuka
Policy secretary of Hon. Kawamura

Ministry: Mr. Itakura (MEXT) Deputy Director-General of Research Bureau,
Officers of Japanese Embassy in Paris/Berlin (Ministry of Foreign Affairs)

AAA：T. Nishioka (former MHI President),
J. Nishiyama, T. Sakamoto, M. Matsuoka

Tohoku Economy Federation:
H. Takahashi (former President of Tohoku Electric Power),
O. Oe, G. Sato, E. Nishiyama

Researchers：A. Suzuki (Iwate-pref), H. Aihara (Tokyo), S. Yamashita (Tokyo)
N. Niita (KEK, International Affairs Division)

S. Yamashita

French – Japan Meetings in Paris（Jan 9-10）

- Meeting with French National Parliament Members
  - Hon. Alain TOURRET, Hon. Olivier BECHT, Hon. Julien AUBERT, Hon. Pierre HENRIET,,,

- Meeting at Ministry of Higher Education, Research and Innovation (MESRI)
  - Jean-Philippe Bourgoin (Research Advisor of MESRI)
  - Alain BERETZ (Director General of DGRI)
  - Christian CHARDONNET (Director, department of large infrastructure for research)

- Meeting at CNRS → Headquarter (Directorate of CNRS, IN2P3, TGIR)

- Meeting at CEA/Saclay → (Directorate and international division and site visit), Industry sessions (THALES, ALSYOM)

- Visits to LAL/Orsay and THALES

Diet members mention model for cost sharing

Hon. Becht will visit Japan/Tohoku area on May 16/17

LCWS2017

Christian CHARDONNET

Counterparts between France and Japan are established at four levels:

1. Parliament and Diet
2. Ministries
3. F. A. /Laboratories
4. Researchers

S. Yamashita

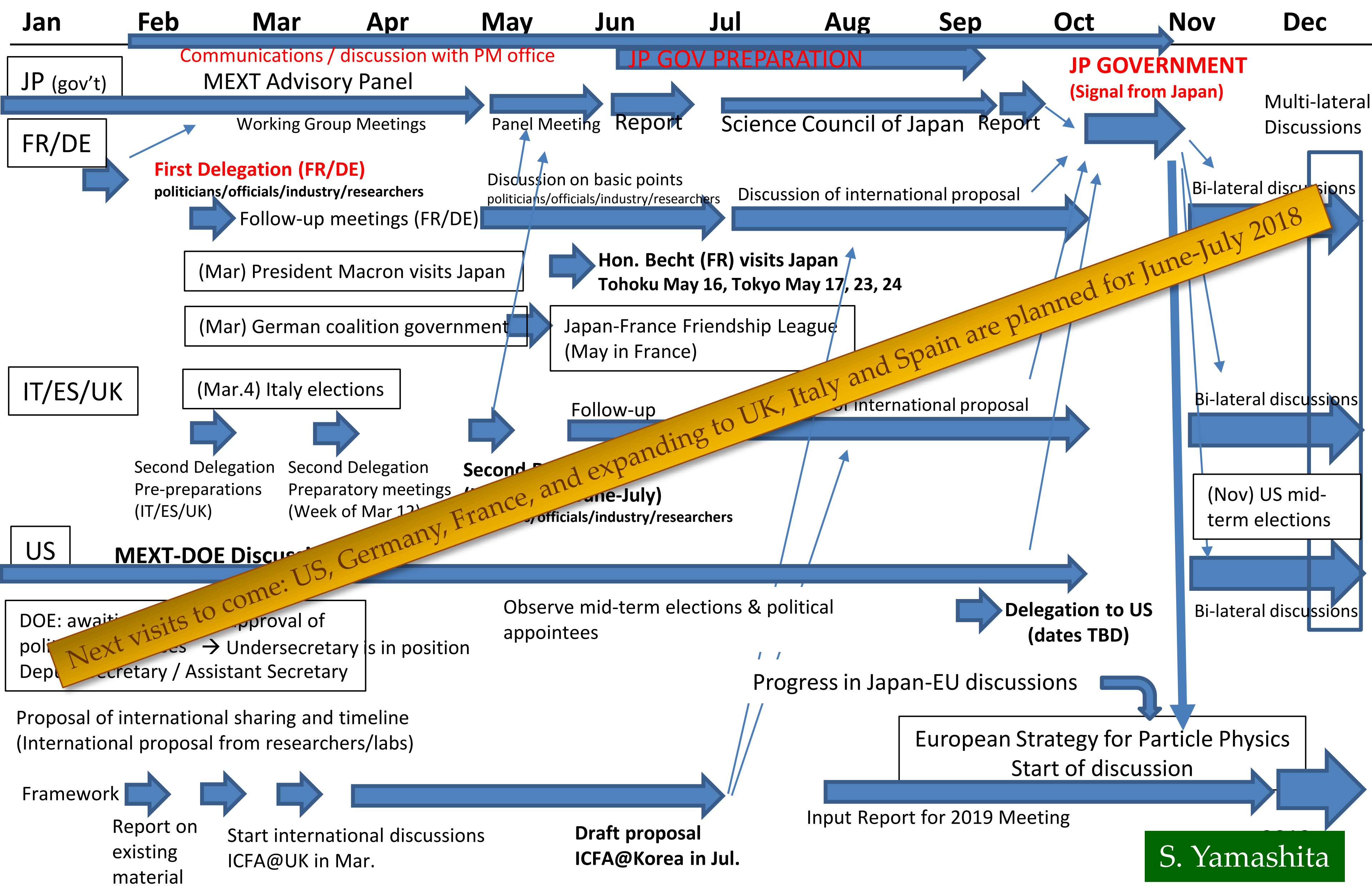
German – Japan Meetings in Berlin（Jan 11）

- Meeting with Hon. Stefan Kaufmann, a member of Bundestag and Dr. Georg Schuette, state secretary at Education and Research (BMBF), and other BMBF officers

Counterparts between Germany and Japan are established at four levels:

1. Bundestag and Diet
2. Ministries
3. F. A. /Laboratories
4. Researchers

2018 Global ILC Schedule



Critical Issues in Year 2018

- **Complete** MEXT Assessment @ ILC Advisory Panel in Spring, receive opinion of Science Council of Japan in summer/autumn.
- **Inform ILC scope** (**model of sharing, timeline, scheme**) **from Japan** to partner nations.
- Establish **Multilayer** (political, ministerial, laboratory-agency, industry and liaison -researchers) **bi-lateral** body first with **European Countries**, and then with **US** (waiting for political appointment in DOE), and with **Asian countries**.
- Boost cooperation with **Prime Minister's Office**

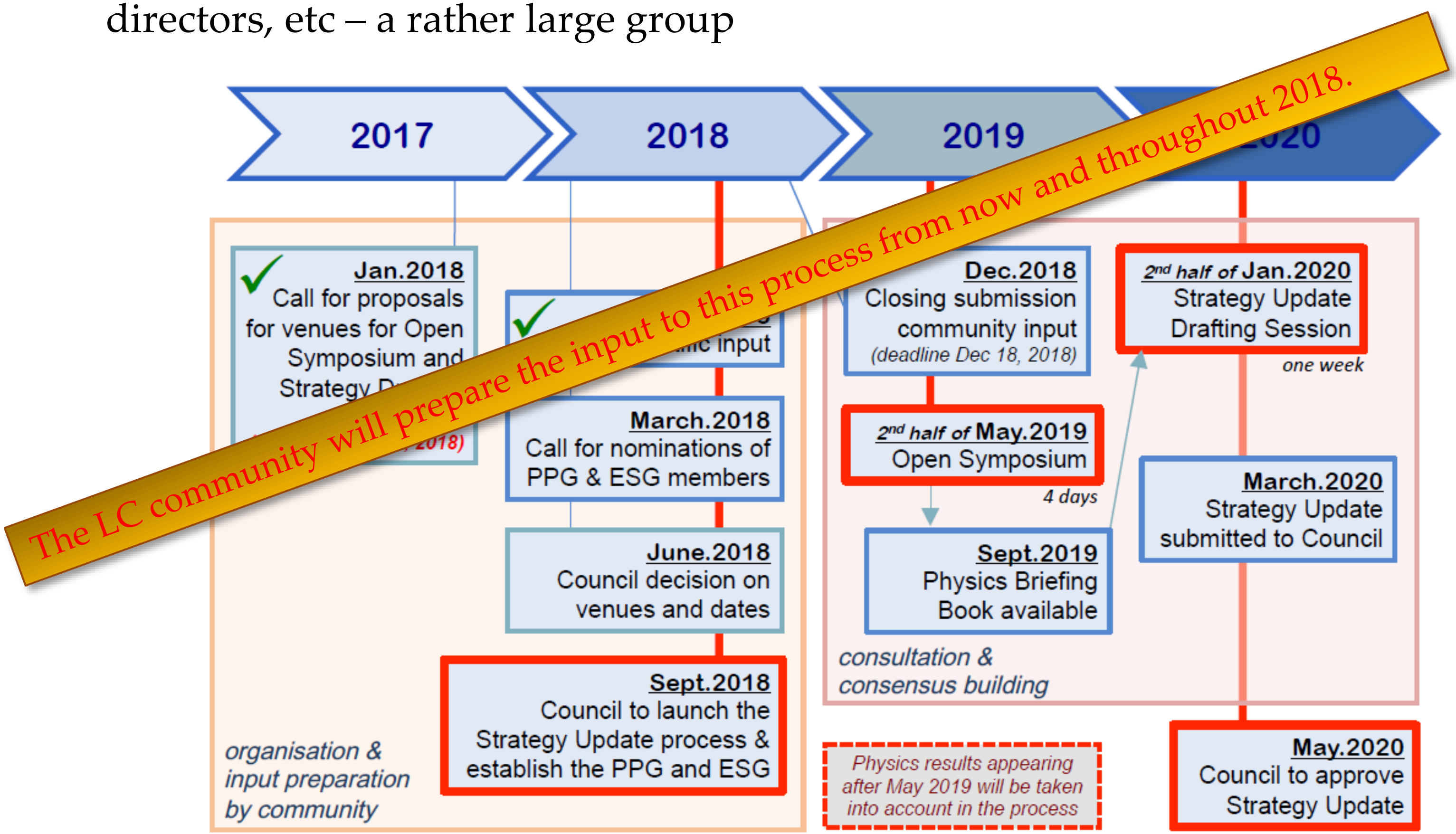
And Clear **Signal from Japan** (Governmental Intention to Host, model for investment share,)

- **All must be done before European Strategy input (end 2018)**

European Strategy Update 2019-20 (ESU)

Structure:

- The Strategy Secretariat: the Scientific Secretary (Prof. Halina Abramowizc), the SPC Chair, the ECFA Chair, the representative of the European Laboratory Directors meeting
- Physics Prep. Group (in 2012): the four above plus four from ECFA and four from the SPS, plus two from other regions and one person from CERN
- European Strategy Group (in 2012): members nominated by Council from each Member State (MS), Associate MS and Observers, European Comm., Lab directors, etc – a rather large group



Making Global ILC Project in Japan a Reality

HEP Community (Worldwide cooperation)

Industry

Governments

- ❖ Strong physics case
  - → Precision Higgs physics measurements
  - → DM searches, BSM physics …

- ❖ Today, is the only mature technology for the future accelerator at the energy frontier

Concluding Wish:

May all "ILC coming challenges"
face ZERO RESISTANCE !!!
(ILC uses "Superconducting Technology")