The International Linear Collider (ILC)

-current status-

Presentation at
IAS Program on High Energy Physics: Conference
Zoom meeting hosted by HKUST Jockey Club Institute for Advanced Study
17-19 January 2022

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ILC International Development Team, Executive Board Chair

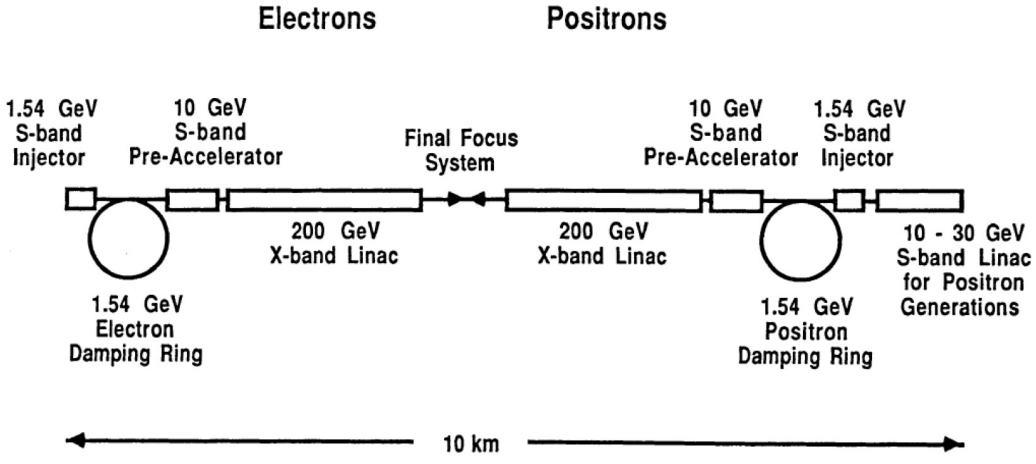
Linear Collider

- Advantages
  - No beam energy loss due to the synchrotron radiation
    ⇒ collision energies can be increased through
    extending the linac + deploying more advanced acceleration technology
  - Collisions with longitudinally polarised beams
    ⇒ Analysing power for physics can be increased.
    Globally speaking, Higgs physics performances are basically comparable for all the e^+e^- Higgs factories under consideration.
- Disadvantages
  - Beams collide only once
    ⇒ More difficult to achieve high luminosities; technical challenges for the interaction point, positron sources, small emittance beam, …
  - Only one collision point
    ⇒ No natural way to accommodate more than one experiment.

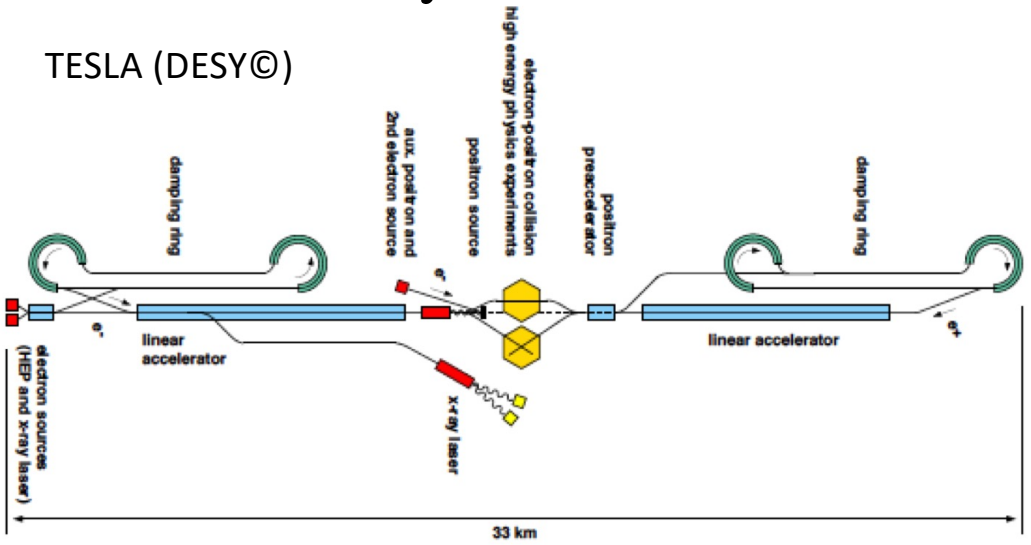
Linear Collider Efforts

- Long history of linear collider efforts, some started already before 1990

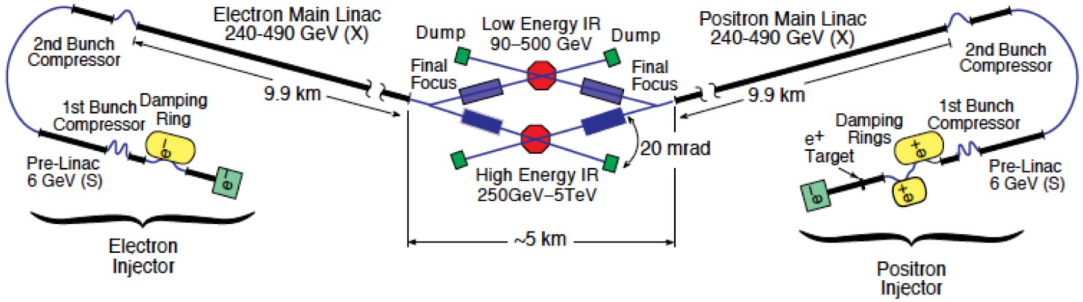
Japan Linear Collider©



TESLA (DESY©)



Next Linear Collider (SLAC©)



Under the ICFA support, merging of the three ideas to the International Linear Collider project, based on the TESLA technology (superconducting radio frequency cavity) in 2004 and Global Design Effort started in 2005.

CLIC remained as a separate project, development continued at CERN

ILC = superconducting RF

- Advantages
  - Large mechanical tolerance
  - Stable operation
  - Economical operation
  - Increasing number of users, now
- Disadvantages
  - Require cryogenic installation
  - Lower acceleration gradient compared to some other technologies, e.g. normal conducting X-band cavities a la CLIC, JLC and NLC

The International Linear Collider (ILC)

- A linear collider based on the superconducting cavity structure.
- Started as a joint effort of the Europe (TESLA@DESY), Japan (JLC) and the USA (NLC@SLAC), under the ICFA guidance, without pre-defined site.
- Collision energies at around 500 GeV
  NB: most of the work for the Technical Design Reports (TDRs) was done before the Higgs discovery.

ILC TDRs

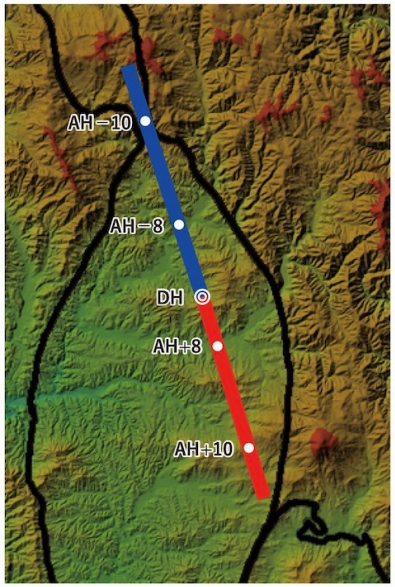
- Technical designs for the accelerator and infrastructure produced by the Global Design Effort led by B. Barish, completed in 2013.
- Truly worldwide effort without a laboratory designated to host the accelerator
- Infrastructure work without specific site definition.
- Provide the technical description of the project. Still now remain as the reference documents.
- Design energy at 200-500 GeV, with a possibility to cover from Z to 1 TeV:

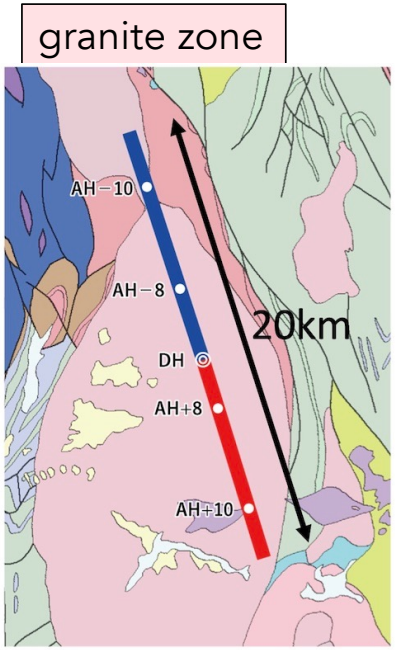
ILC after the TDRs

- Japanese HEP community expressed its interest to host the ILC in Japan as an international project before the Higgs discovery and after the discovery proposed a phased approach; i.e. starting at 250 GeV for the Higgs study.
- The community selected a site in the Tohoku region following the recommendation by an expert committee (Another candidate was in the northern Kyushu region). One of the main advantages was more space for the future prolongation of the tunnel for higher energies.
- Regional support for the site studies (topographical, geological, environmental, etc. etc…)

Two candidate sites

- Both are with strong and stable granite bedrocks
- Kitakami site selected





The next step by the ICFA

- Also in 2013, ICFA setup the Linear Collider Board (to oversee) and Linear Collider Collaboration (to work) for the realisation of a liner collider as an international effort. The first Chair of the LCB, S. Komamiya and the Director of LCC, L. Evans.
- LCC had three components:
  - ILC accelerator
  - CLIC accelerator
  - Physics and detector for a linear collider

  NB: CLIC was effort by an international collaboration with a very strong CERN component, ILC continued to be worldwide effort with a strong involvement of the ICFA through LCB.

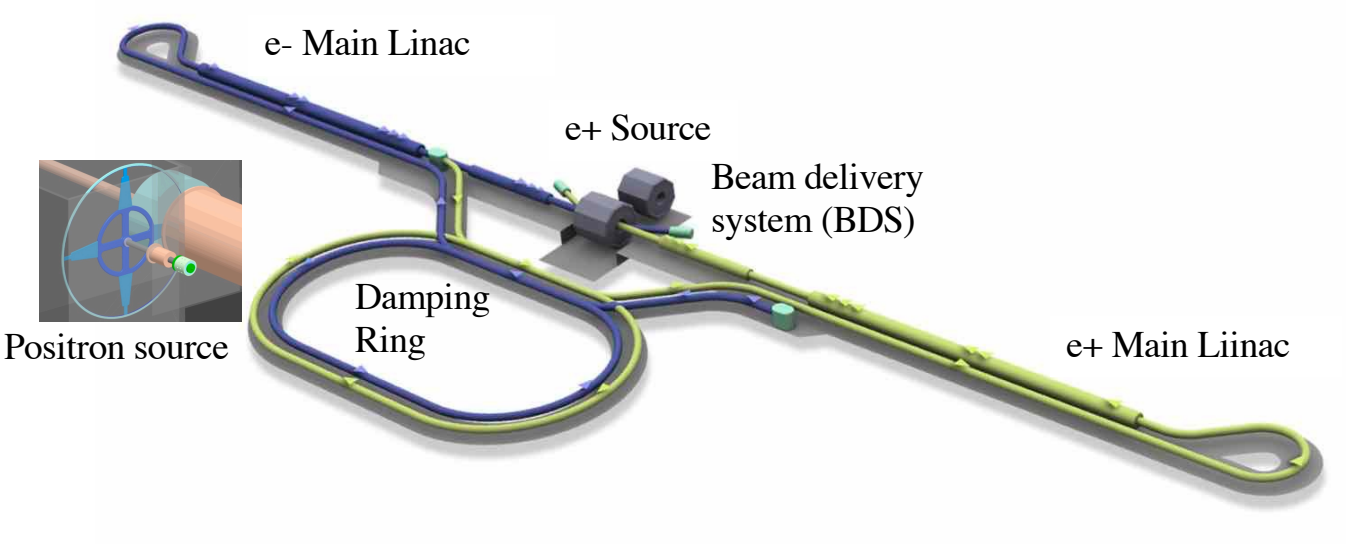
ILC 250 GeV

- In 2017, LCB/LCC decided to focus on the Higgs physics and proposed ILC 250 for optimised at 250 GeV ($e^+e^- \rightarrow HZ$).
  - CM energy = 500 GeV → 250 GeV
  - Total tunnel length = 33.5 km → 20.5 km
  - Cost reduction = up to ~40%

    (→ estimated cost of ~5B ILCU, USD, EUR, CHF…)
- Sign of progress in the political side in Japan during 2018 to 19
  - In March 2019 ICFA/LCB meeting in Tokyo, a high level MEXT officer acknowledged the interest of the ILC in a general term.
  - Encouraging presentations by the Japanese Diet members in the linear collider workshops.

ILC 250 GeV

- Schematic view and baseline machine parameters



AC power ~100 MW
Lumi increase potential up to a factor >3
with a modest increase of AC power

Item	Parameters
C.M. Energy	250 GeV
Length	20km
Luminosity	1.35 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	**7.7** nm@250GeV
SRF Cavity G. Q_0	**31.5** MV/m (**35** MV/m) Q_0 = 1x10^{10}

A further step by the ICFA: setting up the IDT

- In February 2020 at SLAC after the presentations by a high level MEXT officer and a Japanese Diet member in the ICFA/LCB meeting, ICFA decided to proceed towards the preparatory phase for the ILC to be hosted in Japan.
- In July 2020, LCB proposed to establish the International Design Team (IDT) hosted by KEK, as its last action: The IDT should make the ILC project to be ready for construction in Japan, i.e. engineering designs for the machine and civil construction, when it is approved. The Pre-lab should be established by the end of 2021, and if not, ICFA should review the situation.
- In August 2020, ICFA established the IDT and its key members. (LCB/LCC terminated in June 2020.)

IDT organisation

ICFA

ILC-IDT

Executive Board

Andrew Lankford (UC Irvine): Americas Liaison
Shinichiro Michizono (KEK): Working group 2 Chair
Hitoshi Murayama (UC Berkeley/U. Tokyo): Working group 3 Chair
Tatsuya Nakada (EPFL): Executive Board Chair and Working group 1 Chair
Yasuhiro Okada (KEK): KEK Liaison
Steinar Stapnes (CERN): Europe Liaison
Geoffrey Taylor (U. Melbourne): Asia-Pacific Liaison

Working group 1 Pre-lab set-up	Working group 2 Accelerator	Working group 3 Physics & Detectors

Scientific secretary: ' Wataru Ootani (Uni Tokyo)
Communication team led by Rika Takahashi (KEK)

IDT activities

- Biweekly working group meetings for the accelerator (WG2) and physics and detector (WG3) with many subgroup meetings.
- Weekly Executive Board meetings and occasional WG1 meeting when necessary.
- Pre-lab proposal completed in June 2021 together with a Technical Preparation document.
  - Proposal describes
    - Goal (move from technical to engineering description and support intergovernmental discussion)
    - Organisation and start-up (international collaboration of laboratories with small headquarters in Japan for coordination)
    - Work packages for the accelerator and civil construction (in-kind contribution MoU with laboratories)
    - Material budget and required personnel (57.6M ILCU and 364 FTE-yr for the accelerator, civil engineering related work taken by Japan)
    - Time plan (4 years),
    - Timeframe for establishing the physics programme
  - Technical Preparation document gives further technical details on the accelerator work packages.
- Organising a physics workshop to attract more peoples to the ILC, beyond the traditional collider community : ILCX2021 in November 2021, with an industry forum and discussion on the “green” aspects.

Proposal and Technical Preparation document

Proposal for the ILC Preparatory Laboratory (Pre-lab)

International Linear Collider
International Development Team

1 June 2021

Abstract

During the preparatory phase of the International Linear Collider (ILC) project, all technical development and engineering design needed for the start of ILC construction must be completed, in parallel with intergovernmental discussion of governance and sharing of responsibilities and cost. The ILC Preparatory Laboratory (Pre-lab) is conceived to execute the technical and engineering work and to assist the intergovernmental discussion by providing relevant information upon request. It will be based on a worldwide partnership among laboratories with a headquarters hosted in Japan. This proposal, prepared by the ILC International Development Team and endorsed by the International Committee for Future Accelerators, describes an organisational framework and work plan for the Pre-lab. Elaboration, modification and adjustment should be introduced for its implementation, in order to incorporate requirements arising from the physics community, laboratories, and governmental authorities interested in the ILC.

May 30, 2021

Technical note | Open Access

Technical Preparation and Work Packages during ILC Pre-Lab

ILC International Development Team - Working Group 2

The International Linear Collider (ILC) is an electron–positron collider with a total length of approximately 20 km. The International Development Team (IDT) was established by the International Committee for the Future Accelerators in August 2020 to prepare for establishing the ILC Pre-lab as the first step toward the construction of the ILC in Japan. IDT-WG2 is now identifying the accelerator-related activities for the ILC Pre-lab necessary before starting the construction of the ILC. The ILC Pre-lab activities is expected to continue about 4 years and the following accelerator-related activities will be carried out: (1) Technical preparations; (2) Final technical design and documentation; (3) Preparation and planning of deliverables; (4) Civil engineering, local infrastructure, and site.

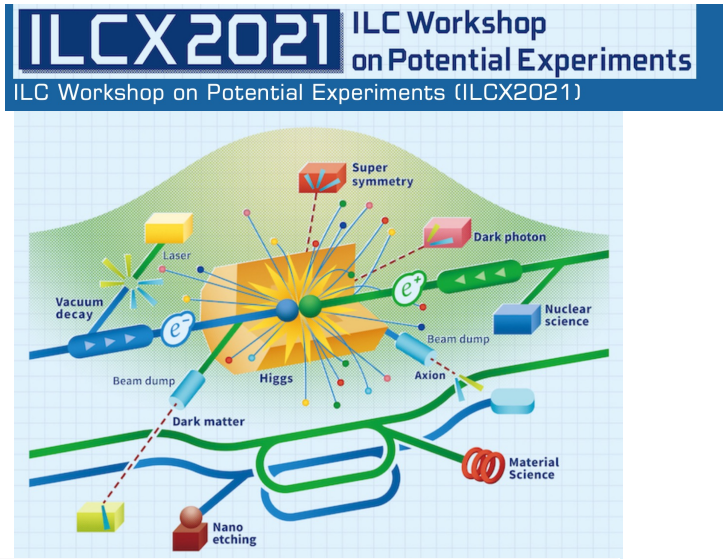
This document summarizes the "Technical preparations", i.e., accelerator work necessary for producing the final engineering design document. It is anticipated that this document will be a starting point to discuss the international cooperation and technical efforts to be shared as in-kind contribution among the participating laboratories worldwide. It is also expected that the budget requests by the participating laboratories to their funding authorities will be made with reference to this document.

Preview

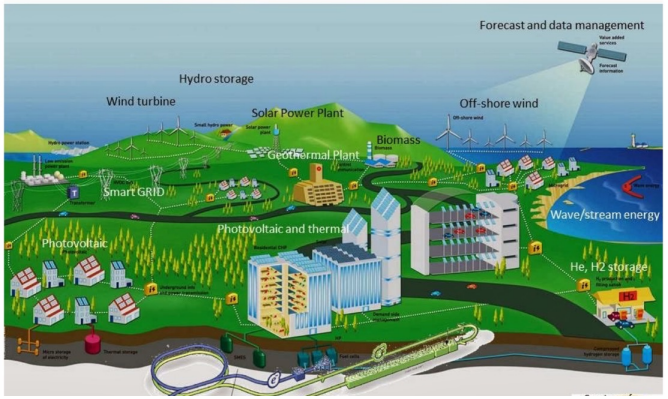
Page: 1 of 97 70%

Technical Preparation and Work Packages (WPs) during ILC Pre-lab

ILCX2021



ILC center futuristic view



Industry Forum at the ILCX2021: Oct. 26, 2021

17:00-21:00 JST Japan (10:00 – 14:00 CET Europe, 4:00-8:00 EDT US)

Indico link: https://agenda.linearcollider.org/event/9211/sessions/5325/#20211026

Zoom: https://us02web.zoom.us/j/87822164767 (passcode: "ilcx2021")

The goal of the event is to strengthen international cooperation between academia and industrial partners involved in the development of advanced accelerator technologies and instrumentation techniques

17.00-17.10 - Introduction
17.10-17.30 - Overview of the AAA Activities (Tohru Takahashi, Hiroshima University/AAA)
17.30-17.55 - Development of positron source components using HIP technologies through industry-government-academia collaboration (Yutaka Nagasawa, Metal Technology Co. Ltd.)
17.55-18.15 - The possible collaborations on ILC Pre-lab in accelerator technologies from China from Academic and industries (Jie Gao, IHEP, China)
18.15-18.35 - Acceleration technology: A Sustainable Approach to Cleaner Indian Rivers (Raghava Varma, Indian Institute of Technology Bombay)
18.35-18.50 Coffee Break
18.50-19.10 - ILC industry capabilities in Europe, some examples from recent SRF projects (Steinar Stapnes/CERN - Benno List/DESY)
19.10-19.30 - Document on industrial interests on ILC in Spain (Erik Fernández, INEUSTAR)
19.30-20.00 - CERN Industrial Experience (Christina Lara Arnaud, CERN)
20.00-20.30 - Review of Accelerator Technologies in the US (Eric Colby, US DOE-SC-ARDAP)

A possible international collaboration on the construction and operation of "a sustainable large scientific infrastructure with the ILC as a model" with the Tohoku region?

And now

- The original timescale to start the Pre-lab was too optimistic:
  - Perception by the Japanese government (MEXT): The Pre-lab is directly couple to the site, one in the Tohoku area. Starting the Pre-lab is almost approving the ILC in Japan, i.e. caution needed.
  - Perception by the others: The Pre-lab is a necessary step for the intergovernmental negotiation, which may or may not result in the approval of the ILC.
  - Other government authorities will not start considering the ILC till the Japanese government takes an initiative.

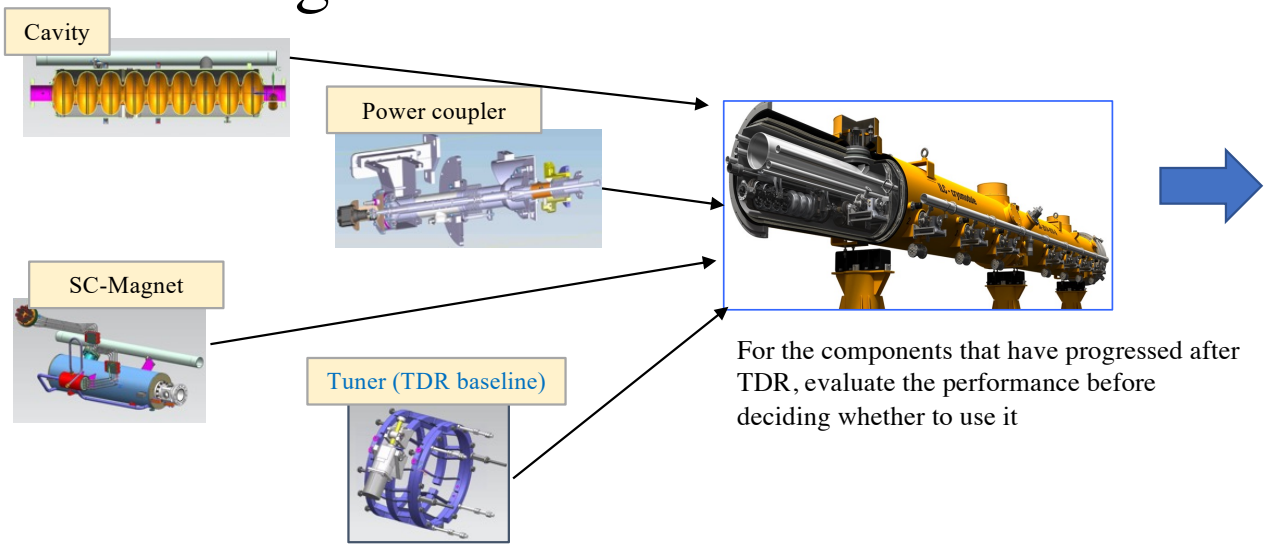
  ⇒ Although the Pre-lab is proposed to start through the agreements among the laboratories, rather than among the governments as for the ILC, it cannot be started without the MEXT acceptance.
- It seems to require somewhat more time for the Japanese colleagues to persuade MEXT to move toward the Pre-lab.

The next step

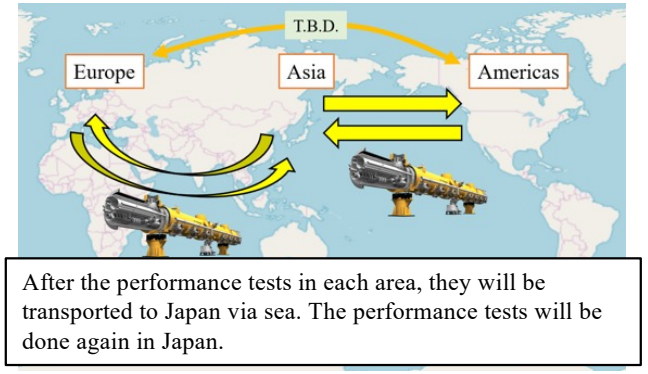
- ICFA needs to review the situation during it meeting in March:
  i.e. the Pre-lab cannot start with the timescale given by ICFA.
  - Should ICFA continue its support for the ILC constructed in Japan as an international project?
  - If so, under which condition and time scale?
- IDT is developing ideas needed for the continuation case: e.g.
  1. Start, in 2022, some of the crucial accelerator work packages defined in the Pre-lab proposal.
  2. Start regular working group meetings among suitable level of people from the governmental authorities, possibly assisted by the scientists, to prepare for high level discussion.

An example of challenging work packages

- SRF is assumed to be produced in the three regions and transported to Japan. Feasibility has to be established for
  - Industrial production and test in the three regions
  - Oversea transportation to Japan
  - Local testing of the all modules



For the components that have progressed after TDR, evaluate the performance before deciding whether to use it



After the performance tests in each area, they will be transported to Japan via sea. The performance tests will be done again in Japan.

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- Many issues to be addressed:
  - For 1. in particular, prospect for the appreciable amount of budget to KEK by MEXT for the accelerator R&D, whose purpose includes the ILC, in 2022 would be necessary.
  - Conclusions of the review by the MEXT Advisory Panel for the ILC progress for the last three years and Pre-lab proposal is expected by early March. Will they include a supporting statement for 1. to happen?
  - Will the Japanese colleagues persuade MEXT to achieve this?
  - Will the laboratories worldwide go along with this scenario to participate in the work packages?

Examples for the ILC related worldwide effort

	~ 2017	2018～2021
CERN	Cooperation on nano-beam at ATF, study on industrialization of cavity and cryomodule for SRF, cooperation on design of cryogenics, beam dump, and civil engineering	Nanobeam collaboration at ATF, SRF cavity fabrication technology, cryogenics, beam dump and civil design collaboration. Overall coordination of ILC R&D in Europe.
Americas (USA+Canada)	Start of construction of LCLS-II; development of a new SRF cavity treatment method for LCLS-II; development of a crab cavity for HL-LHC.	US-Japan collaboration on SRF cavity performance improvement and cost reduction, assembly and installation of cryomodules for LCLS-II.Production began for in-kind contributions of the RFD crab cavities and cryomodules to the HL-LHC by the US & Canada
France	Experience in assembly of SRF input couplers and cryomodule assembly at XFEL in Europe, cooperation with Nanobeam at ATF	In-kind contributions to the European Neutron Source (ESS), the US PIP-II project, cavity performance improvement at SRF, nanobeam collaboration at ATF.
Germany	TESLA (preliminary stage of ILC) planning study, XFEL construction started in 2007, SRF cost estimate for TDR.	Demonstration of large SRF accelerator with stable operation of XFEL, and improvement of SRF cavity performance
Italy	Contribution to ILC-TDR for cryomodules, cavities and reference Blade tuners, in-kind contribution to half of the cavities and cryomodules at XFEL in Europe.	In-kind contributions to the European Neutron Source (ESS), the US PIP-II project, cavity tuner design at the VSR Upgrade of BESSY storage ring HZB
Spain	Nanobeam collaboration at ATF, in-kind contributions such as superconducting magnets at European XFEL, in-kind contributions to IFMIF in Japan	In-Kind contribution to the European Neutron Source (ESS), CIEMAT was awarded a budget for the R&D of the ILC superconducting magnet.
UK	Nanobeam collaboration at ATF. Contributions to TDR for damping rings, positron sources, beam delivery system, RF sources, and beam dump.	In-kind contributions to the European Neutron Source (ESS) and the US PIP-II projects, design of the LHC crab cavity.

The next step and summary

- ICFA needs to review the situation during it meeting in March:
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  - Will the Japanese colleagues persuade MEXT to achieve this?
  - Will the laboratories worldwide go along with this scenario to participate in the work packages?
- **Our Japanese colleagues need a support from the international community. A linear collider is a viable and technically the most mature, particularly the ILC, option for a Higgs factory.**