ILCX2021 Workshop: Executive Summary

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FCC Workshop / France / 2nd Decembre 2021

ILCX URL: https://agenda.linearcollider.org/event/9211/

Contents

- Evolution of Physics objectives
- Status & Outlook of the Pre-Lab ($\longmapsto$ ILC)
- Progress of accelerator R&D
- Detector R&D links ...
- Conclusions

$>$ **600 REGISTERED PARTICIPANTS**

$>$ **250 TALKS**

The workshop will address all the aspects of the collider program at the Interaction Point (IP), including, in addition to the established concepts, ideas for new detector technologies or concepts, detector performance and physics reach, software and computing, and theoretical developments. In addition, we will discuss possible beam dump experiments, forward detectors near the IP, off-axis far detectors, experiments with extracted beams for particle physics and other areas of science, including e.g. nuclear physics, or condensed matter physics. Some of these ideas will require additional infrastructure and civil engineering, and therefore need to be incorporated into the ILC site planning.

PHYSICS STUDIES

- Incorporating new physics results and phenomenological ideas in the evaluation of ILC's scientific motivation

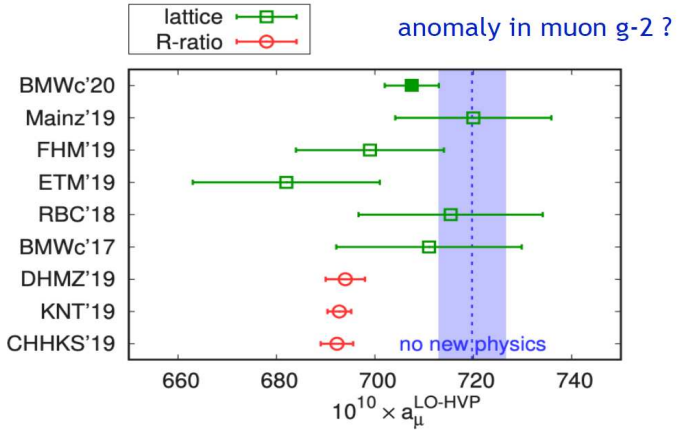
- Evaluating the relevance of ILC's beam dumps for fixed target experiments

- Overviews from M.Peskin (g-2, B decay anomalies) and M. Perelstein (Fixed target experiments at ILC)

Emerging Physics Perspectives: 1) $(g-2)_\mu$, B decays, LHC ?

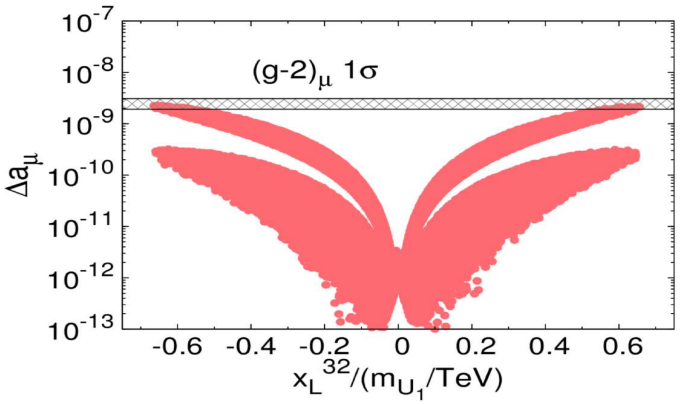
- **New aspects for ILC physics case: low energy results** M.Peskin
  - ”Anomalies” (?) in the B system: $B \to K^{(\star)} l^+ l^-$, $B \to D^{(\star)} \tau \nu$
  - ”Anomaly” (?) in the muon g-2
  - Q: non-trivial flavour dynamics underlying Higgs couplings ?
  - Variety of models considered where ILC relevant: SUSY, LQ, ...

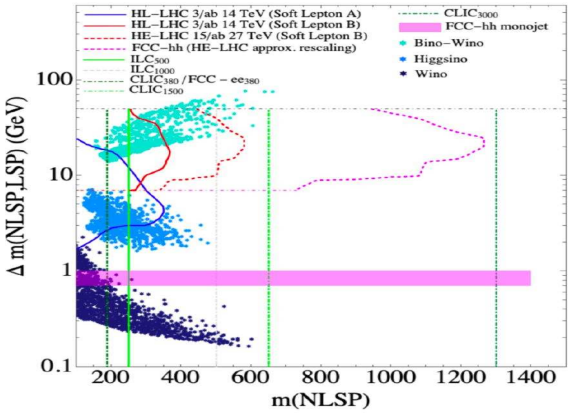
  $\Rightarrow$ New particles, non-SM H couplings (H $\to$ $b\bar{s}$), ...



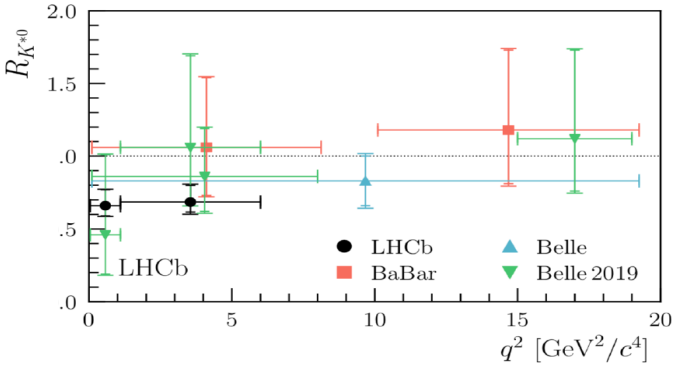
Borsanyi et al. (BMW group), arXiv:2020.14327

- **Corresponding phenomenology to be addressed with ILC:**
  - LQ: K. Ban et al.; arXiv:2104.06656
  - mSUSY: Chakraborti, Heinemeyer, Saha; arXiv:2105.06408





failure of μ/e universality ?



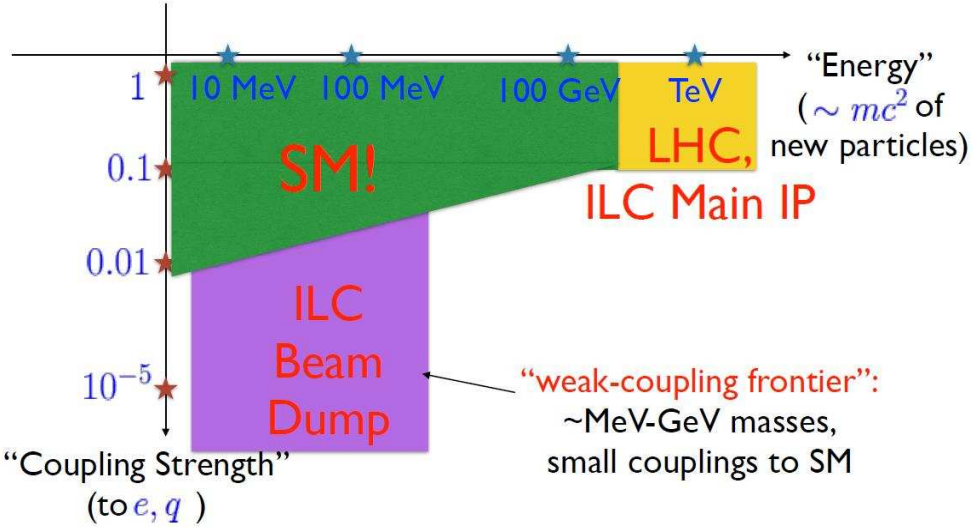
LHCb arXiv:1705.05802

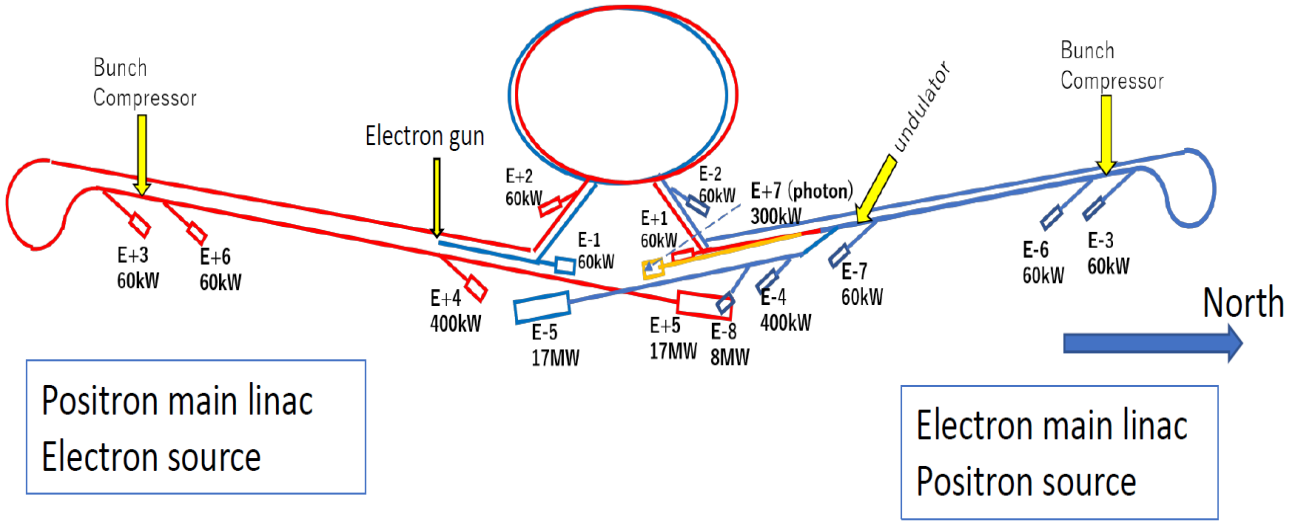
- **BSM phys. signs from LHC ? :** A.Crivellin et al., *Accumulating Evidence for the Associate Production of a Neutral Scalar with Mass around 151 GeV*; CERN-TH-2021-129

F.Richard, *Global Interpretation of LHC indications within the Georgi Machacek model*

Emerging Physics Perspectives: 2) fixed target experiments

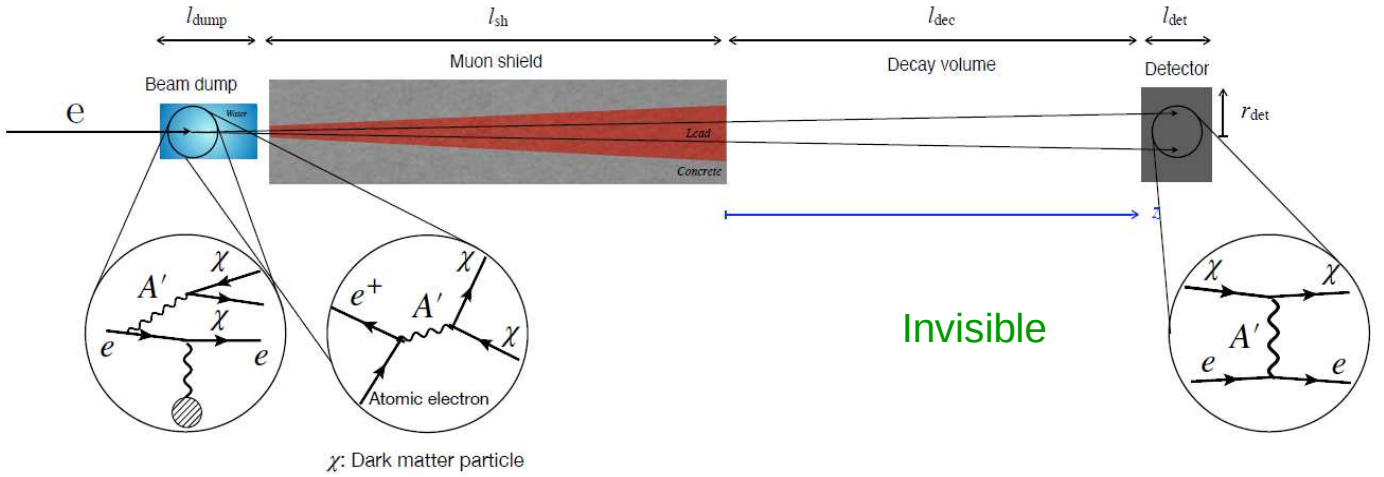
- **General remarks:**
  - Fixed-target experiments at ILC beam dumps offer access to a regime complementary to ILC collider experiments: $<$ 10 GeV mass scale, $<<$ 1 coupling strength
  - Huge effective luminosity: $4{\cdot}10^{11}$ $e^{\pm}$ on target/yr
  - Motivation: DM, ALPs, Strong QED, LLPs, ...
  - Far detectors (on or under ground) may extend search for long-lived particles (LLPs) produced at main IP



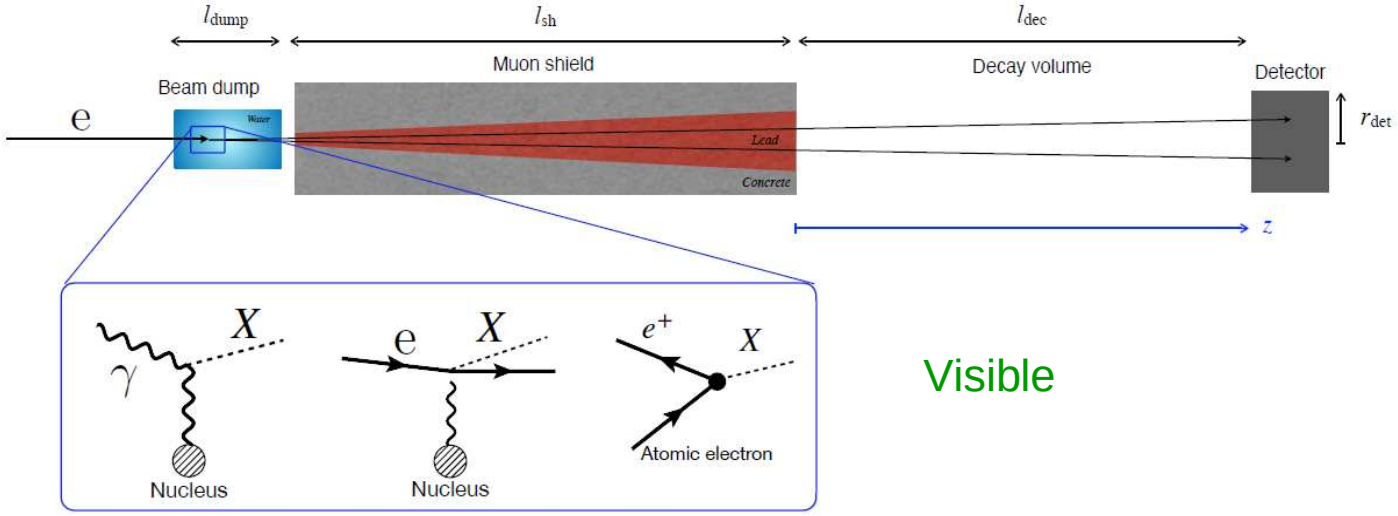


Example of Set-Up for Visible/Invisible New Particle Decay

- **Set-up includes :**
  - Beam dump: $l_{dump} \simeq 10$ m
  - Muon shield: $l_{sh} \simeq 70$ m
  - Decay volume: $l_{dec} \simeq 50$ m
  - Detector: $l_{det} \simeq r_{det} \simeq 1$ m



χ: Dark matter particle



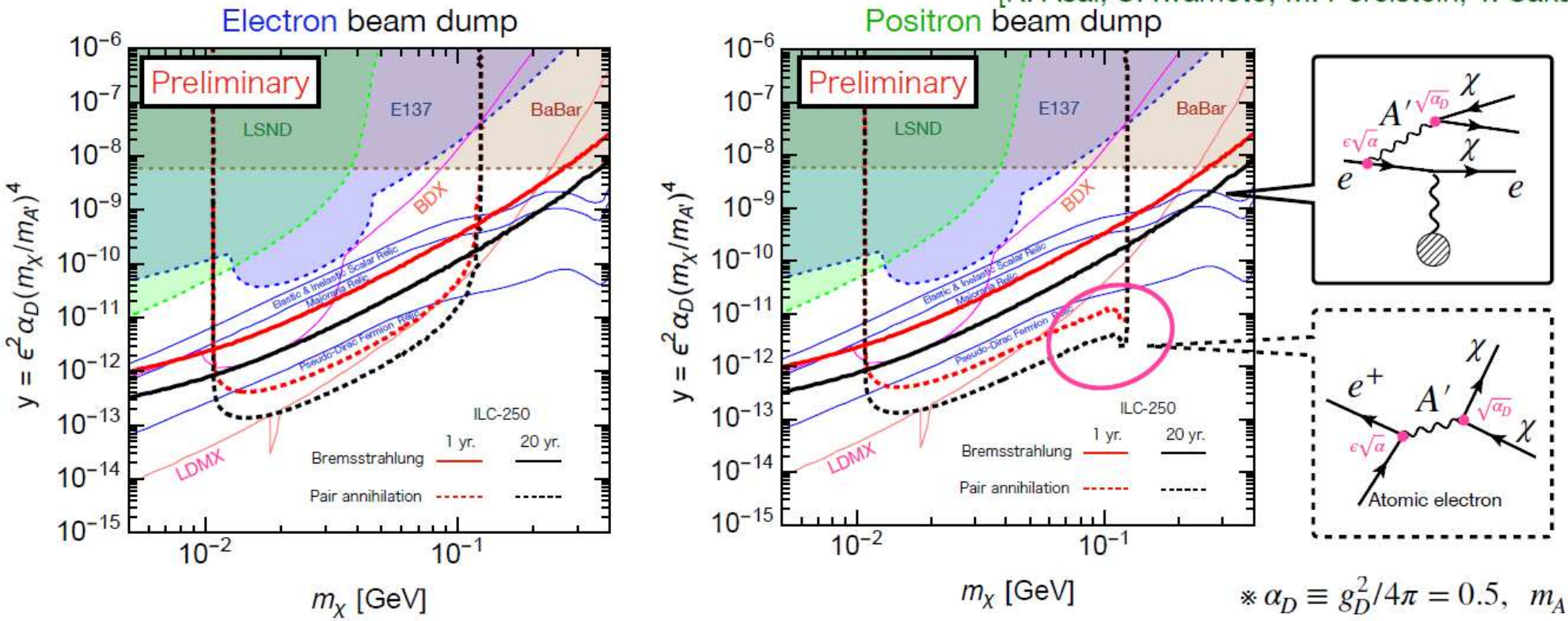
X: New particle

Example of Sensitivity to Invisible New Particle Decay

Results of invisible decay search

Sensitivity comparison of positron and electron beam dump experiment

[K. Asai, S. Iwamoto, M. Perelstein, Y. Sakaki, DU.]



※ $\alpha_D \equiv g_D^2/4\pi = 0.5, \quad m_{A'} = 3m_\chi$

A benchmark Model: $-\frac{1}{4}F^{A'}_{\mu\nu}F^{A'}_{\mu\nu} - \frac{\epsilon}{2}F_{\mu\nu}F^{A'}_{\mu\nu} + \frac{m^2_{A'}}{2}A'_\mu A'_\mu + \bar{\chi}(iD_\mu\gamma^\mu - m_\chi)\chi, \quad D_\mu = \partial_\mu + ig_D A'_\mu$

STATUS OF PRE-LAB AND ILC PROJECT

- International Development Team (IDT) Pre-Lab
- Position of MEXT w.r.t. Pre-Lab & ILC perspectives
- Summaries from M.Yamauchi (KEK), T.Nakada (IDT) and S.Henderson (ICFA, see back-up slides)

ICFA Report (1/3)

ILC International Development Team

Activities

- Three Working Groups formed to carry out work of IDT
- Technical Preparation and Work Packages for ILC Pre-Lab
- Pre-Lab proposal developed and submitted to MEXT June 2, 2021 (https://arxiv.org/abs/2106.00602)

Proposal for the ILC Preparatory Laboratory (Pre-lab)

International Linear Collider
International Development Team

1 June 2021

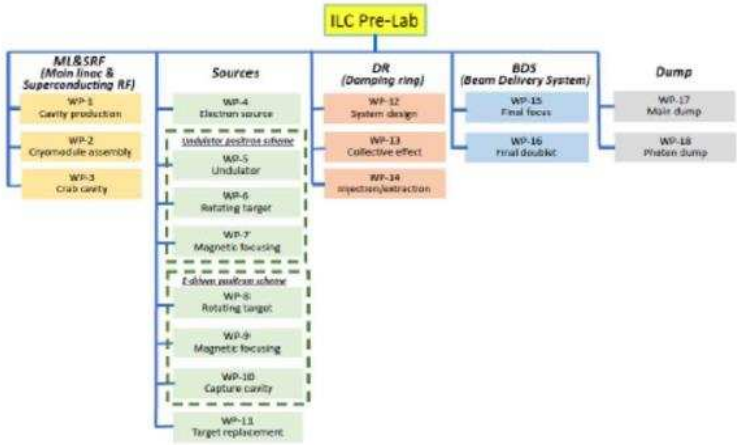
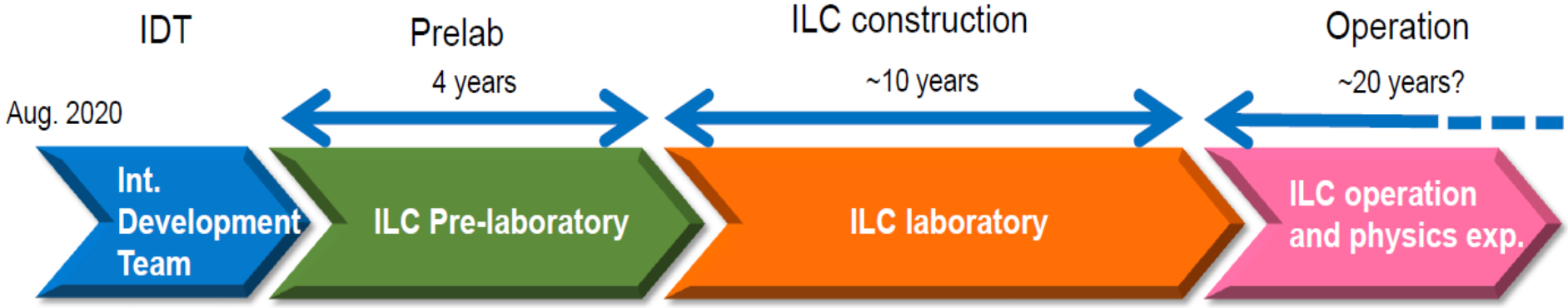


Figure 2: Summary of work packages.

KEK Report (1/5)

Step-wise realization of ILC

The ICFA created the International Development team (IDT) at its meeting in February 2020 to advance the ILC realization step-wise.



ILC Prelab is started with agreement among the laboratories

- In-kind contribution from the participating labs.
- Head-quarter in Japan

ILC Lab. Is started by the governmental agreement.

KEK Report (2/5)

Message from MEXT (March 2021)

Message given by the MEXT Minister

- The ILC project needs to resolve its various challenges including its international cost sharing and technical feasibility, as well as to obtain broad internal and external cooperation not for its pre-laboratory but for the ILC project itself.

- Under the current situation that the perspective of broad internal and external cooperation for the ILC project itself as well as its pre-laboratory is not promised, it is difficult to obtain the people's understanding in Japan for investing the pre-laboratory. It is necessary to obtain the clear perspectives on financial contributions to the ILC project itself from the US and European countries in prior considering the pre-laboratory."

Three keys to move ILC forward given by MEXT:

1. Technical feasibility (← Prelab)
2. International cost sharing (← Governments, IDT, Phys. community)
3. Broad consensus in Japan (← Japanese phys. community)

IDT work plan for the near future (1)

- EB continues to work closely with the Japanese colleagues to support their interactions with the MEXT Expert Panel.
- EB has started the preparation for the Pre-lab start-up process, i.e. identifying the candidates for the founder laboratories and facilitating discussion among them on the process and necessary conditions to start the process.
- A realistic start-up scenario needs to be developed reflecting upon discussion among the founding laboratories, consultation with international partners interested in the Pre-lab, discussion between MEXT and Japanese community, MEXT Panel discussion, etc.
- WG1 and WG2 discussion should start on the scenario once it starts developing.

IDT work plan for the near future (2)

- IDT needs to report on status and plan for the Pre-lab start-up process to ICFA in spring 2022.
- One of the current thinking's of the EB is that the start of "Pre-lab" (even "Pre-lab light"), which is sufficient to open the funding opportunities for some of the Pre-lab work packages, must be emerging within a year or so. (NB: MEXT Expert Panel report is expected for the end of this calendar or Japanese fiscal year, if latter March 2022). Pre-lab (even the light one) will build up confidence on the project, which is essential for meaningful governmental discussion.
- This then should evolve toward the Pre-lab as envisaged.
- Needs by WG3 in the detector R&D to be defined within a realistic boundary and seek a mechanism to satisfy them.

Final remarks

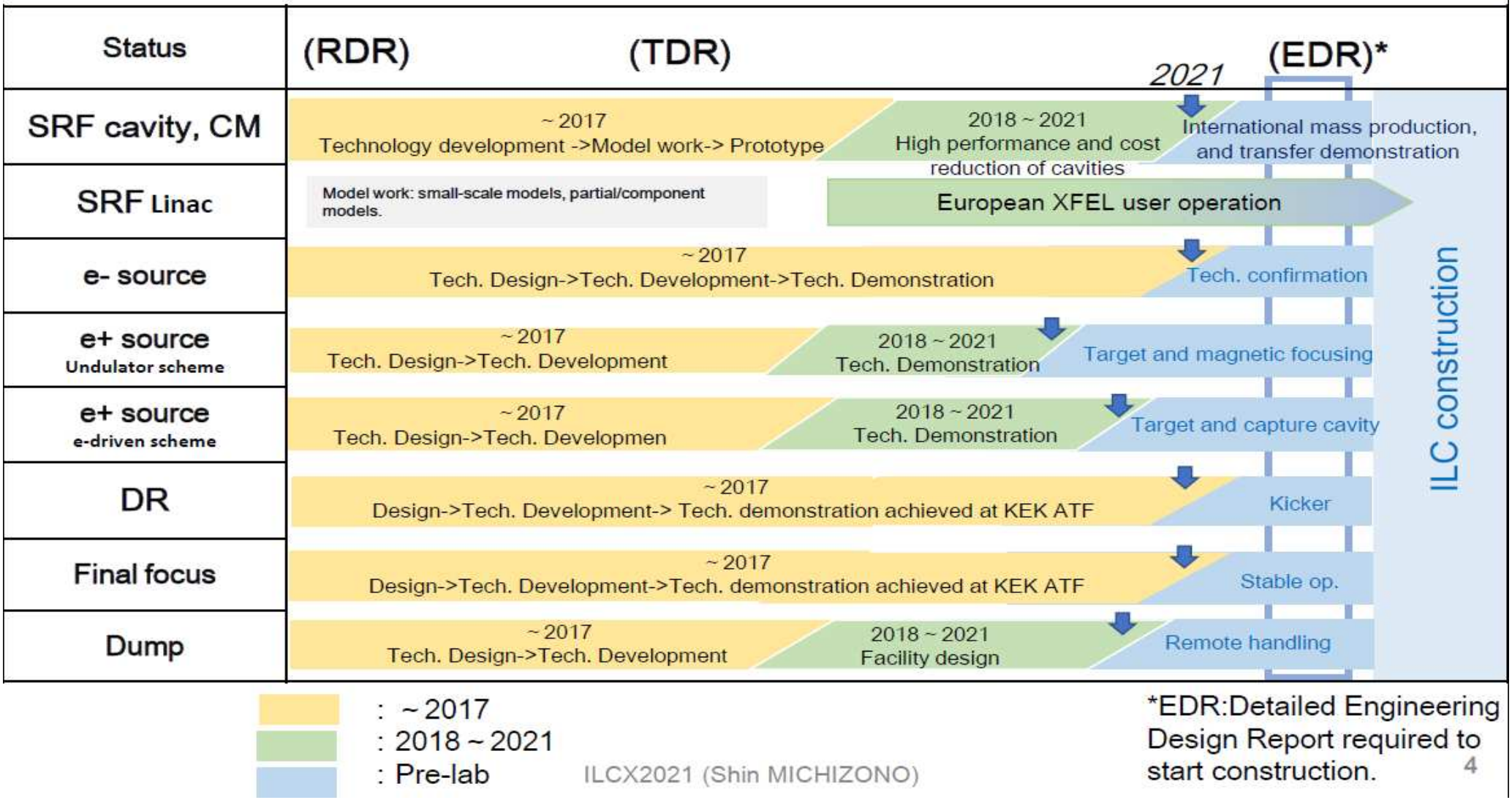
- Political process in Japan appears to have been stalled for sometime…
- Meetings between MEXT and foreign authorities are not quite regular and systematic, and seem to be stagnating.
- We know that without positive signs from Japan indicating their interest in hosting the ILC, situation in the other countries will not change.
- What can we still still do to help unlocking the situation?

COLLIDER R&D

- Progress achieved in recent years and on-going activities
- Work Plan within Pre-Lab
- Summary by S. Michizono (IDT-WG2)
- N.B.: sustained interest of industry (European !) for Pre-Lab (see Industry Forum)

ILC Technology Level

Since the publication of the conceptual design report (RDR) in 2007 and the Technical Design Report (TDR) in 2013, the technical development has been progressing steadily toward the start of construction.



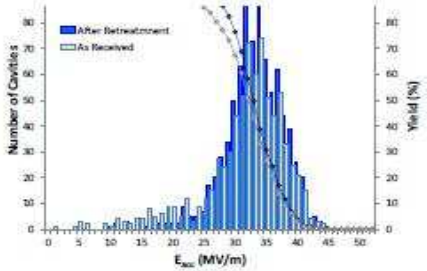
Progress in SRF

~ 2017	2018 ~ 2021	Pre-lab

Cavity

Yield evaluation of cavities based on TDR

The mass production of European XFEL has reached ≥ 83% of the ILC specification yield (90%).

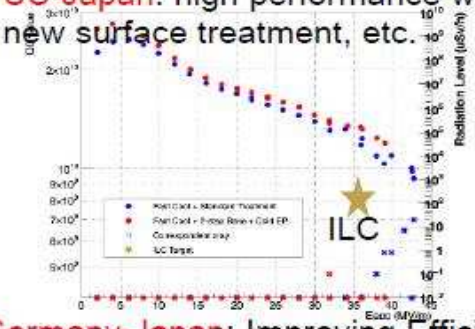


Euro-XFEL Operation (Europe)
~800 cavities/
~100 Modules

LCLS-II Construction (USA)
~280 cavities/
~35 Modules

High performance and cost reduction

US-Japan: high performance with new surface treatment, etc.



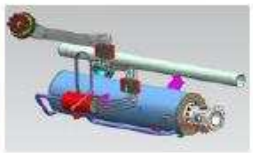
Germany-Japan: Improving Efficiency in Cavity Manufacturing
Final design is underway to comply with "High Pressure Gas Safety".

~41 M$,285 FTE-yr

Cavity manufacturing, performance demonstration (Yield demonstration in three areas)

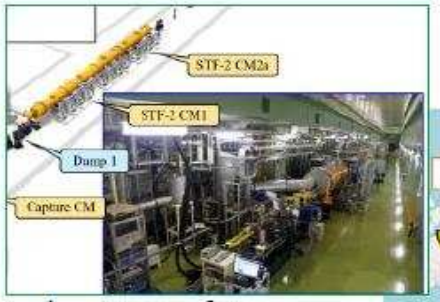
Cryomodule

Eng. design



Realized through international cooperation and procurement

Module assembly



Accelerator performance verification at KEK-STF2

Demonstration of cryomodule assembly, transfer, and performance

France-Japan: Automation of cavity cleaning

Progress in Positron Source

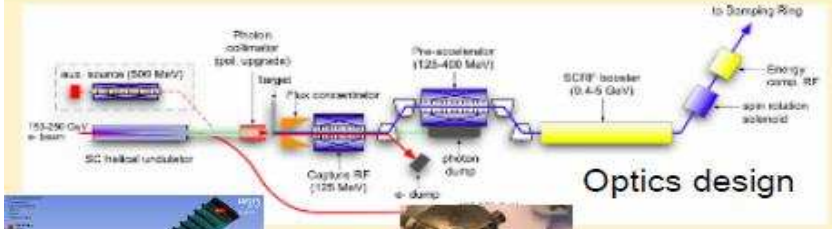
~ 2017 tech. design

2018 ~ 2021 tech. verification

Pre-lab

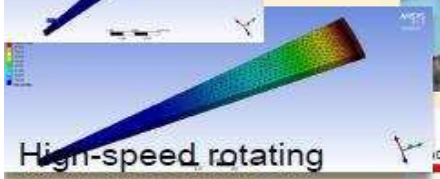
Undulator scheme to obtain polarization

1.5 M$ 10FTE-yr



Optics design

Undulator prototype



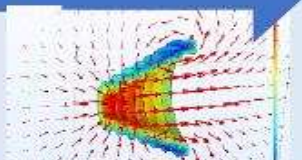
Photon dump design

High-speed rotating positron target, Technology Design

Ti target beam test

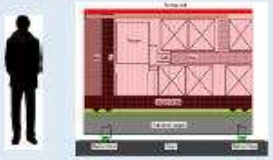
Practical Operation of Superconducting Helical Undulator (APS)

Long undulator operation at European XFEL



Pulse solenoid design

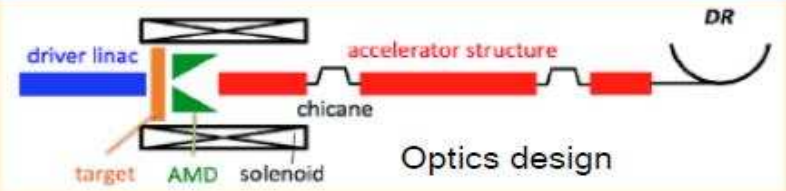
Next Steps:
evaluate both schemes by international cooperation



Target maintenance

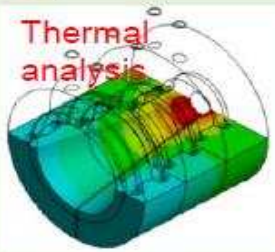
Conventional e-Driven

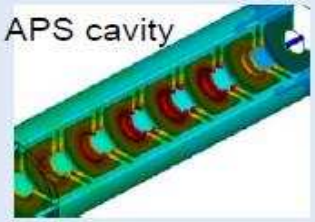
4.4 M$, 5FTE-yr



Optics design

Target Prototyping Vacuum characteristics Testing

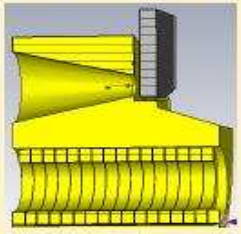




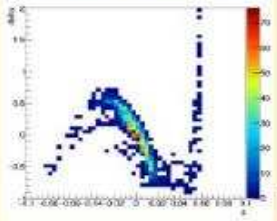
RF stability test

Target thermal simulation

Mag. focusing



Paricle simulation



Technology selection

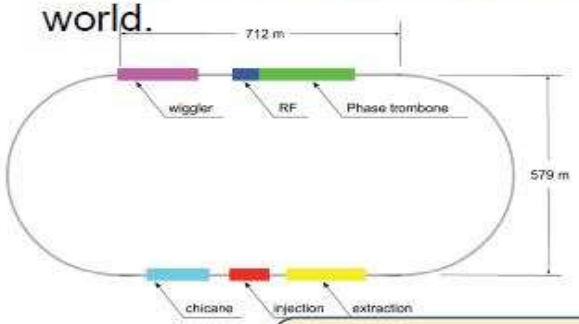
Progress in Damping Rings

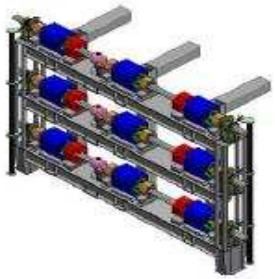
~ 2017	2018 ~ 2021	Pre-lab

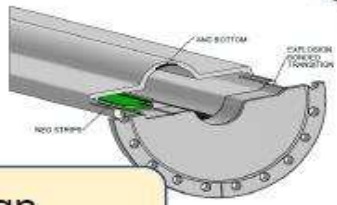
DR

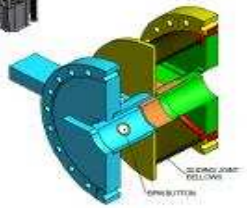
Eng. design

Design based on experience with circular accelerators around the world.

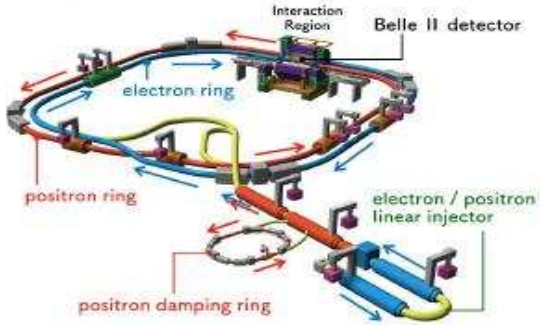




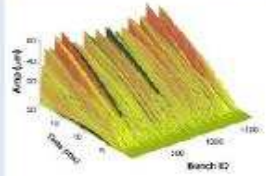




Maturing technology for beams in the latest ring accelerators such as SuperKEKB



~2.5 M$,30 FTE-yr

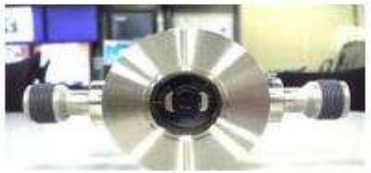


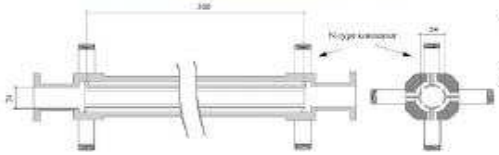
Inj./Ext.

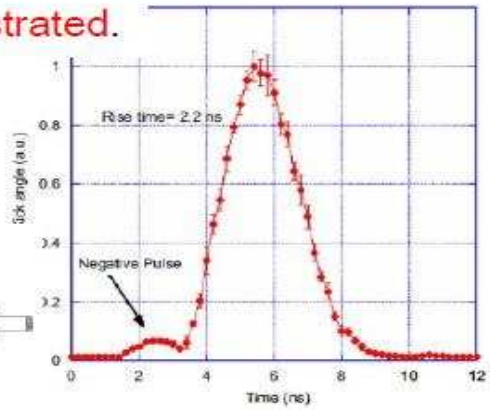
Eng. Design
Equipment verification

Final design

Beam extraction demonstrated.

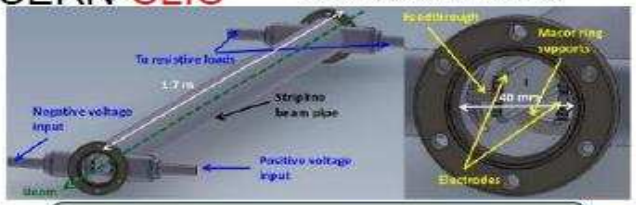




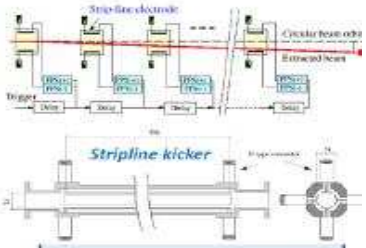


LBNL

CERN-CLIC



Fast kicker technology



Stable op.

8

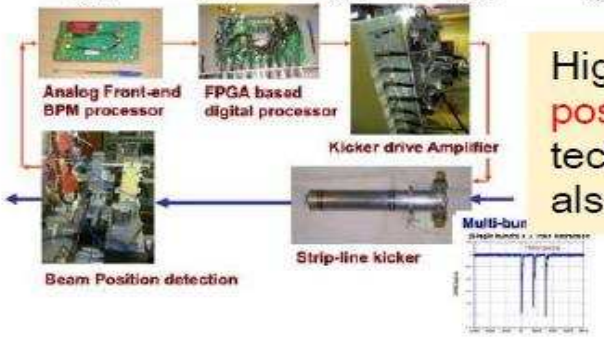
ILCX2021 (Shin MICHIZONO)

Progress in Final Focus

~ 2017	2018 ~ 2021	Pre-lab

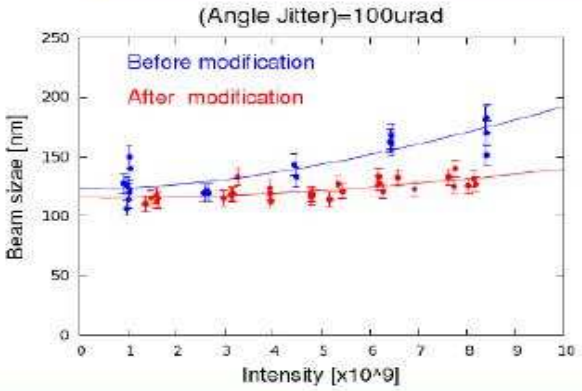
Tech. design completed
Spec. almost achieved

ATF: achieved 41nm (2016)
(37nm=ILC (7.7nm))



High-speed beam position control technology was also demonstrated.

Wakefield effect



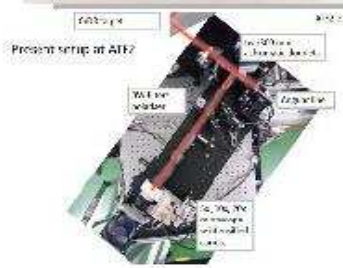
Wakefield effect was evaluated at ATF.
-confirm no serious problem at ILC
-demonstrate a technique to reduce the wakefield effect

ATF International Review (Committee)*
-The committee highly evaluated the achievements of ATF so far.
-The committee pointed out the importance of continuing research to contribute to the detailed design of the ILC final convergence.

* https://agenda.linearcollider.org/event/8626/

~2M$, 16FTE-yr

Detailed design
Stable operation demonstration

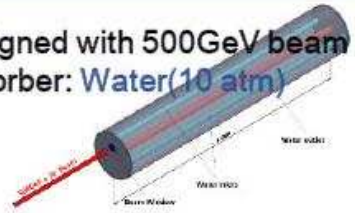


Modify the beam monitor system, etc. at ATF to demonstrate stable operation.

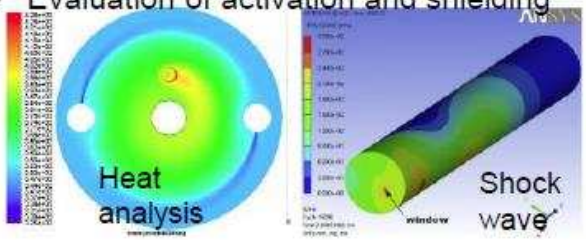
Progress in Beam Dump

Basic design (by researchers abroad) → Design revalidation and specific facility design → ~3M$, 12FTE-yr Remote Maintenance

Designed with 500GeV beam
Absorber: Water(10 atm)



Confirmation of safety by simulation
- Heat and stress in beam window, heat and shock waves in water
- Evaluation of activation and shielding

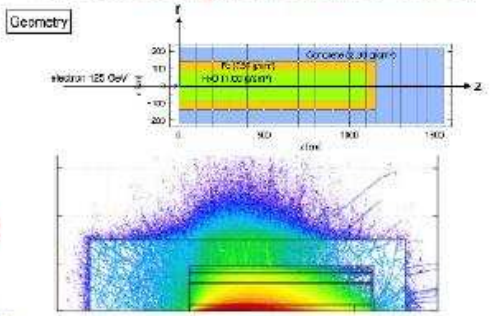


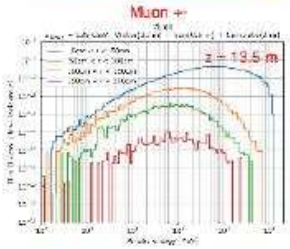
Consultations with beam target/dump experts from around the world beyond

LHC beam dump

RADIATE collaboration

Specific design of radiation shield

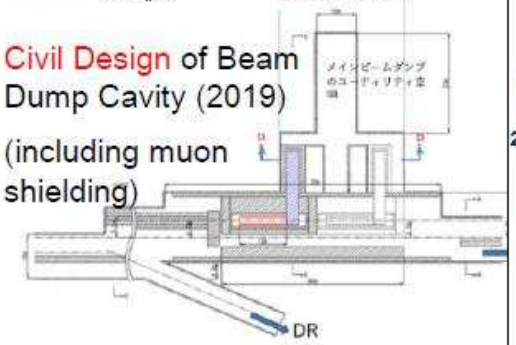




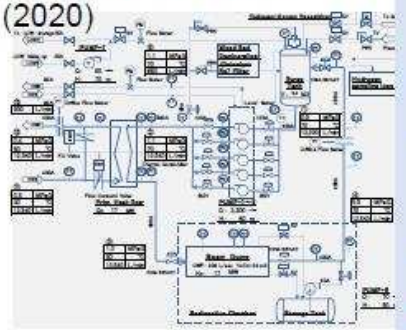
Design for shielding of muon particles generated by beam dump

Civil Design of Beam Dump Cavity (2019)

(including muon shielding)

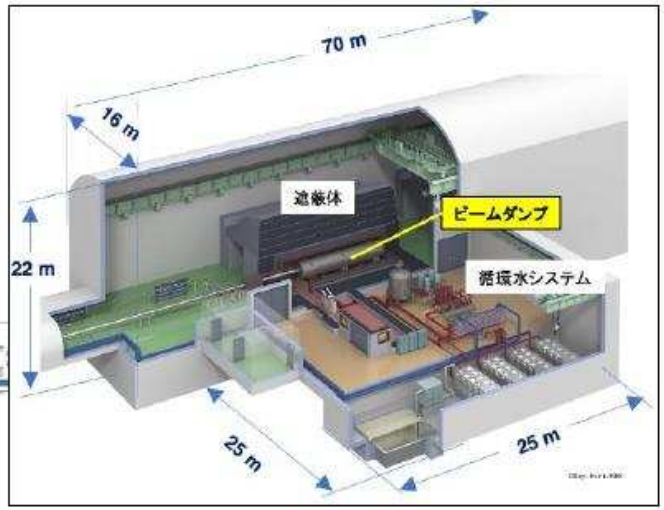


Beam Dump Water Circulation System Design (2020)



- Testing of main components of circulating water system
- Beam window replacement device
- Leakage countermeasures for radiating dump water
- Earthquake resistant design

Detailed system design (pursuit of safety design)



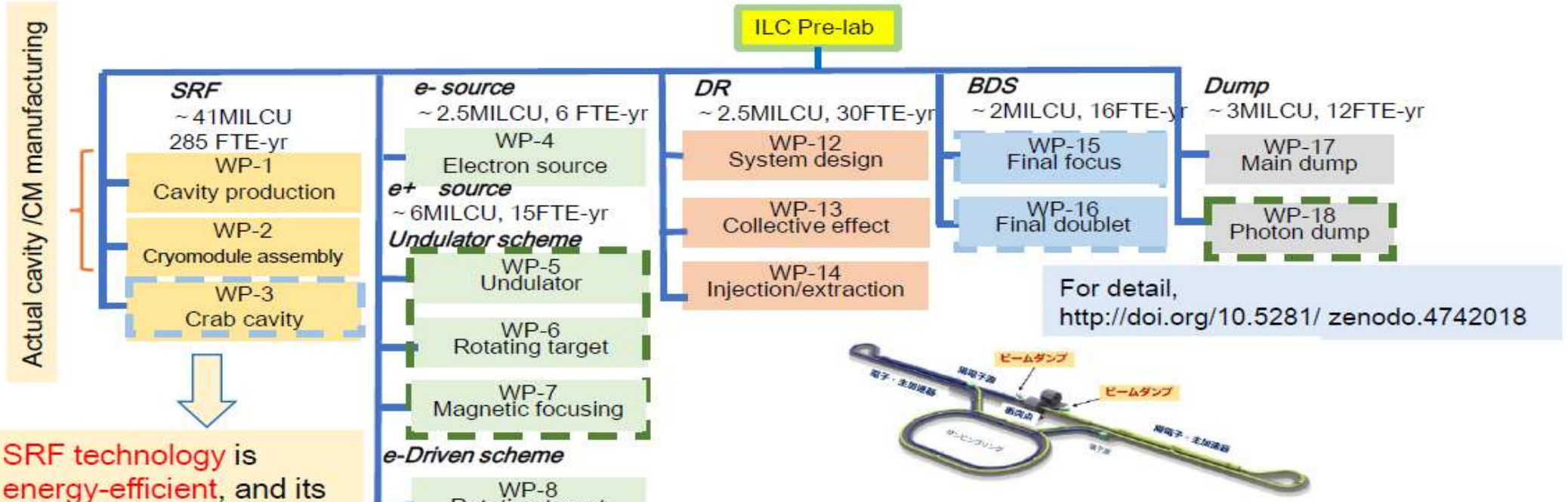
Example of World Wide Effort

	~ 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.

https://doi.org/10.5281/zenodo.5535621

Technical Preparation

IDT-WG2 summarized the technical preparation as work packages (WPs) in the technical preparation document.



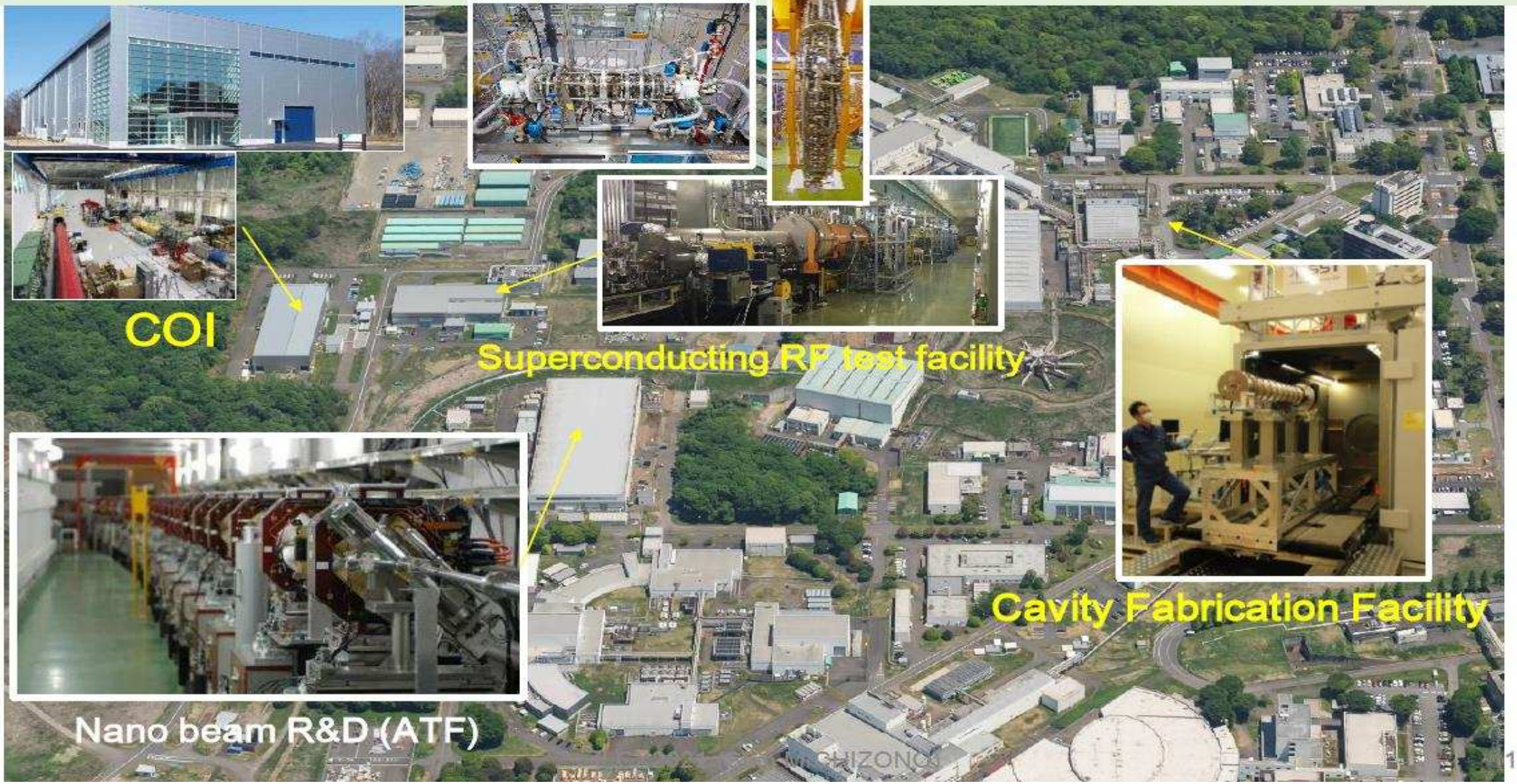
For detail,
http://doi.org/10.5281/ zenodo.4742018

SRF technology is energy-efficient, and its applications are increasing around the world.
These WPs will contribute to the promotion of SRF accelerators in each region.

- The technical preparation document was reviewed by the international review committee (chair:Tor Raubenheimer (SLAC)).
- The total global cost of the project is about 60 MILCU and about 360 FTE-year. (This does not include the cost of the infrastructure for the WPs.)
- The cost will be shared internationally as in-kind contribution.

ILC R&D Facilities in KEK

In Europe and the U.S., basic facilities for the evaluation of the superconducting accelerator at the European XFEL and LCLS-II are in place, but in Japan, additional basic facilities are needed.

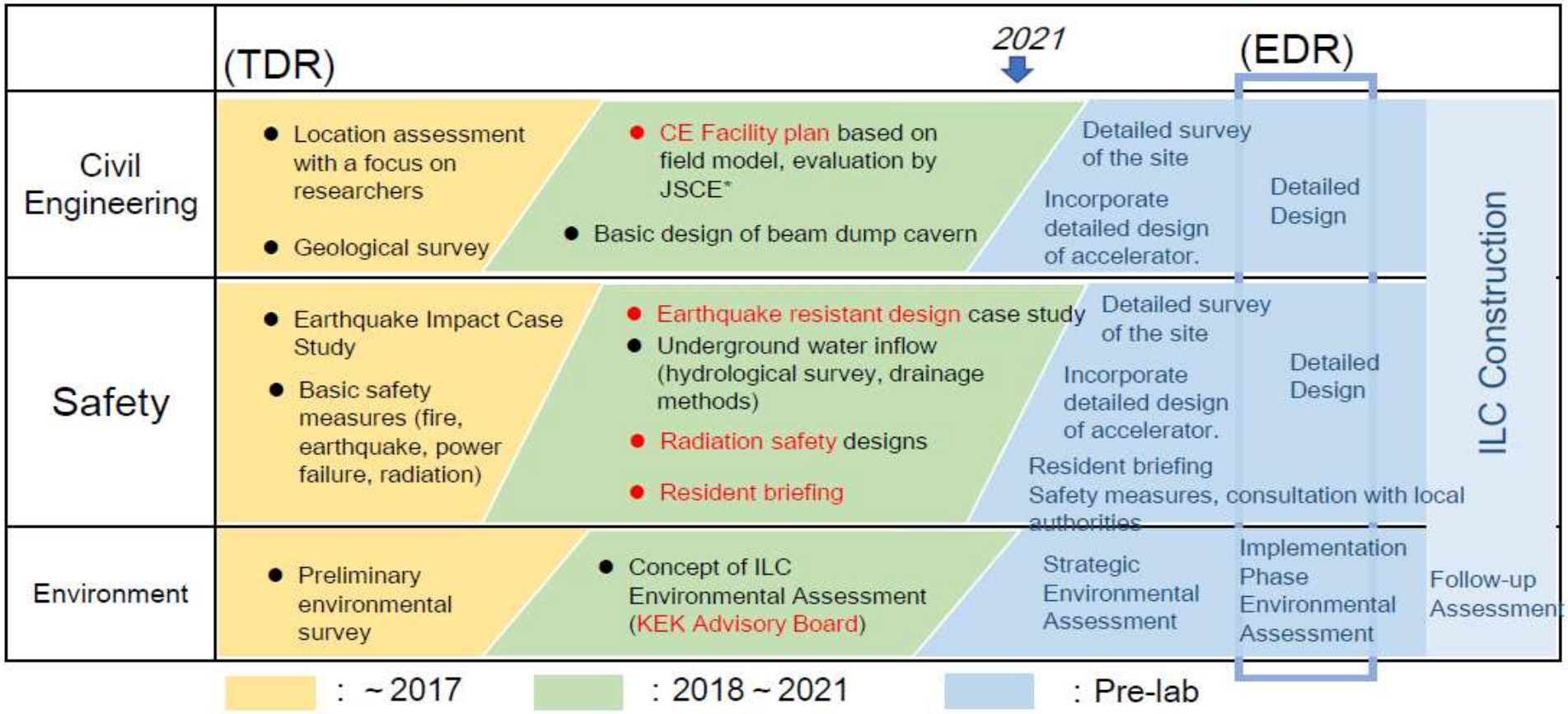


Civil Engineering and Environmental and Safety Measures

The next stage is the detailed design of the civil engineering facilities and the design of related concrete safety measures, for which a detailed topographical and geological survey of the site is essential.

The environmental assessment must also be initiated.

These detailed investigations and designs will require a new budget.



*Japan Society of Civil Engineering

Environmental Initiatives

Environmental impact assessment policy

Establishment of the "ILC Environmental Assessment Advisory Board" with external experts (2019)

Chair: Kenichiro Yanagi (Professor Emeritus, Meiji University), Chairman of Tokyo Olympic and Paralympic Environmental Assessment Committee

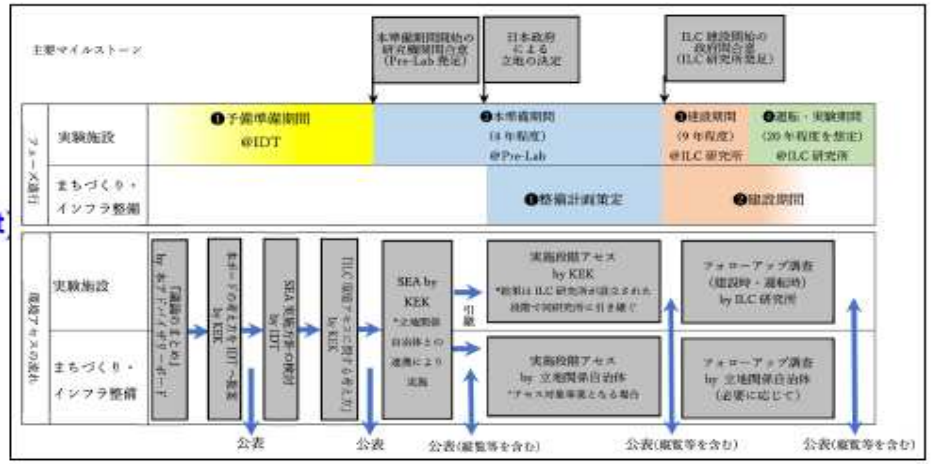
Based on the project characteristics of ILC,

- Basic guidelines for assessment, and
- Implementation structure, process, and
- Methodology and assessment targets

(environmental impact, social and economic impact)

Summary of the Discussion

https://www2.kek.jp/ilc/ja/contents/docs/Strategic_Environmental_Assessment_of_the_ILC_Project_Summary_of_the_Discussion_r.pdf



Flow of environmental assessment for the ILC project (assumed)

"Green ILC" for the environment

(Green ILC WG, AAA)

https://tipdc.org/assets/uploads/2020/12/guideline03.pdf (in Japanese)
https://tipdc.org/assets/uploads/2020/12/guideline04.pdf (in Japanese)

- Energy measures: Biomass, Power-GRID, waste heat utilization
- Utilization of resources: Use of local wood for ILC-related facilities, use of high-quality granite produced during tunnel excavation

IDT-WG3: DETECTOR R&D, SOFTWARE & PHYSICS STUDIES

- **What was neglected, or poorly addressed, in this summary ($>$ 130 talks):**
  - Calorimetry (21 talks) summarised by Taıkan Suehara
  - Tracking (21 talks) summarised by Yasuo Araï
  - Software (13-15 talks) summarised by Thomas Madlener
  - Higgs physics (34 talks) summarised by Shinya Kanemura
  - BSM physics studies (33 talks) summarised by Shigeki Matsumoto
  - Top / Heavy flavor / QCD / EW physics studies summarised by Adrian Irles and Graham Wilson
- **MDI Activities:** Towards working plan for Pre-lab Intermediate report summarised by R.Pöschl

$\longmapsto$ **addresses a wide spectrum of expertise/experience & studies also relevant for other e^+e^- collider options**

SUMMARY & CONCLUSION

- IDT, mandated by ICFA, has produced a Pre-Lab proposal, which prefigurates the final step allowing to take a decision w.r.t. the construction of ILC
- The proposal contains in particular a detailed long work plan anticipated to finalise the R&D of all essential accelerator components and deliver a complete Engineering Design Report of the machine
- The proposal was submitted to MEXT by KEK-DG in May,
  where it encountered very restrained interest $\Rrightarrow$ Pre-Lab start is adjourned
- IDT is investigating on how to start some Pre-Lab related activities, especially on accelerator R&D, without targetting ILC restrictively
- Panel discussion on global view of future realistic landscape of colliders:
  Speakers : T. Nakada, S. Asai, U. Bassler, S. Henderson, K. Jakobs, M. Peskin, Y. Wang
- The first step of Pre-Lab fits per se into European Strategy generic priorities:
  Higgs factory, accelerator R&D, detector R&D within ECFA's recommendations
  $\Rrightarrow$ opportunity for a wide community to address topics common to all H/t/EWB factory options
- France: detector R&D activities are already pursued in this spirit and several accelerator on-going or planned R&D tasks fit into Pre-Lab objectives

BACKUP SLIDES

ICFA Report (2/3)

ICFA Letters to and from MEXT

- ICFA Letter to MEXT Minister Hagiuda, March 17, 2021
  - *"ICFA looks forward to the MEXT minister inviting foreign government officials to discuss potential commitments toward realizing the ILC Project. We also note the keen willingness of potential foreign partners to begin engaging in such discussions…"*
- Letter from MEXT Minister Hagiuda to ICFA Chair: May 31, 2021
  - *"Therefore I recognize that it is appropriate to continue discussions regarding the ILC Project between administrative officials of the relevant countries at the right time, as well as to pay attention to the researchers' efforts to deal with the remaining challenges."*
  - *"Under the current situation that the perspective of broad internal and external cooperation for the ILC project itself as well as its pre-laboratory is not promised, it is difficult to obtain the Japanese citizens' understanding for investing in the pre-laboratory*
  - *It is necessary to obtain the clear perspectives on financial contributions to the ILC project itself by the United States and European countries prior to considering the pre-laboratory budget."*

ICFA Report (3/3)

Perspective

- ICFA Statement February 2020:
  - *ICFA reconfirms the international consensus for a Higgs factory and wishes to see the timely construction of the ILC in Japan.*
  - *ICFA acknowledges and welcomes the inter-governmental discussion between Japan, the United States and European nations, to advance international collaborative activities for the ILC.*
  - *ICFA notes the need for a preparatory phase ahead of the establishment of the ILC laboratory and the construction of the ILC in Japan.*
  - *ICFA advocates establishment of an international development team to facilitate transition into the preparatory phase.*
- ICFA has taken action to organize ILC activities across the globe and has been actively supportive and advocating for taking the next step with the ILC in Japan
- ICFA applauds the European particle physics community and CERN on the Strategy Update, and supports its calls for strong international collaboration that continues to be a unique strength in the field.
  - *"For the future initiatives, an electron-positron Higgs factory is considered as the highest priority next collider, consistent with ICFA Statement(2), and a proton-proton collider at the highest achievable energy is recognized as the ambition for the longer term."*
- ICFA looks forward to the MEXT Expert Panel Report, and then the IDT report on status and plan for the Pre-lab start-up process to ICFA in spring 2022
- Personal view: Start of Pre-Lab is key. Encourage all to continue to make the case for its importance.

KEK Report (3/5)

Japanese ILC community submitted a report to MEXT describing the progress on the key issues of the ILC (June 2021).

1. Outlook on International Research Cooperation and Cost Sharing
2. Scientific Value and Dissemination to General Public and Science Community
3. Clarification on Technical Feasibility
   [1] ILC Accelerators
   [2] Civil Engineering and Environmental/Safety Issues
4. Cost Estimation Feasibility
5. Development and Securement of Human Resources
6. Others
   [1] Organization and other issues of the prelab
   [2] Technical and economic spillover from the ILC technology

This is a response to the inquiries given by the previous ILC Expert Panel (2018) and ILC Committee of SCJ (2018).

KEK Report (4/5)

ILC Expert Panel reopened by MEXT

Preamble of the note to request to reopen the ILC Expert Panel (July 2021)

IDT, a working group of physicists formed by the international research community, has recently published a proposal for the ILC Prelab, and the domestic research community has submitted the status report describing the progress of major issues related to the ILC program. At this occasion, the ILC Expert Panel will be resumed in order to do follow-up discussions from a professional viewpoint regarding the progress in the entire ILC plan and to organize the latest information.

Panel members

14 scientists from various research fields, astronomy, civil engineering, particle accelerator, high energy physics, nuclear physics, journalist, public relations,…

Schedule

July 29 First meeting

Oct. 14 and 18 Presentations by the Japanese ILC community and IDT

Report will be published by the end of 2021 or March 2022 at the latest.

KEK Report (5/5)

New Organization of ILC Promotion in Japan