Current Status and Future Technological Collaboration for the ILC

KEK / IDT-WG2

Shin MICHIZONO (KEK)

1. Why linear collider?
2. Higgs Factory
3. Global Collaboration
4. ILC Accelerator
   - ILC design
   - Recent Progress
   - Candidate site
5. Pre-lab proposal
6. Global Project
7. ILC Technology Network
8. KEK's effort
9. Future Upgrade
10. Beam dump (industrial application)
11. Sustainability
12. Summary

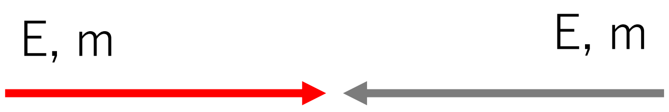
Why collider?

Center of Mass Energy (Ecm) = discovery reach

Fixed Targets

$$E_{CM} = \sqrt{2mE}$$

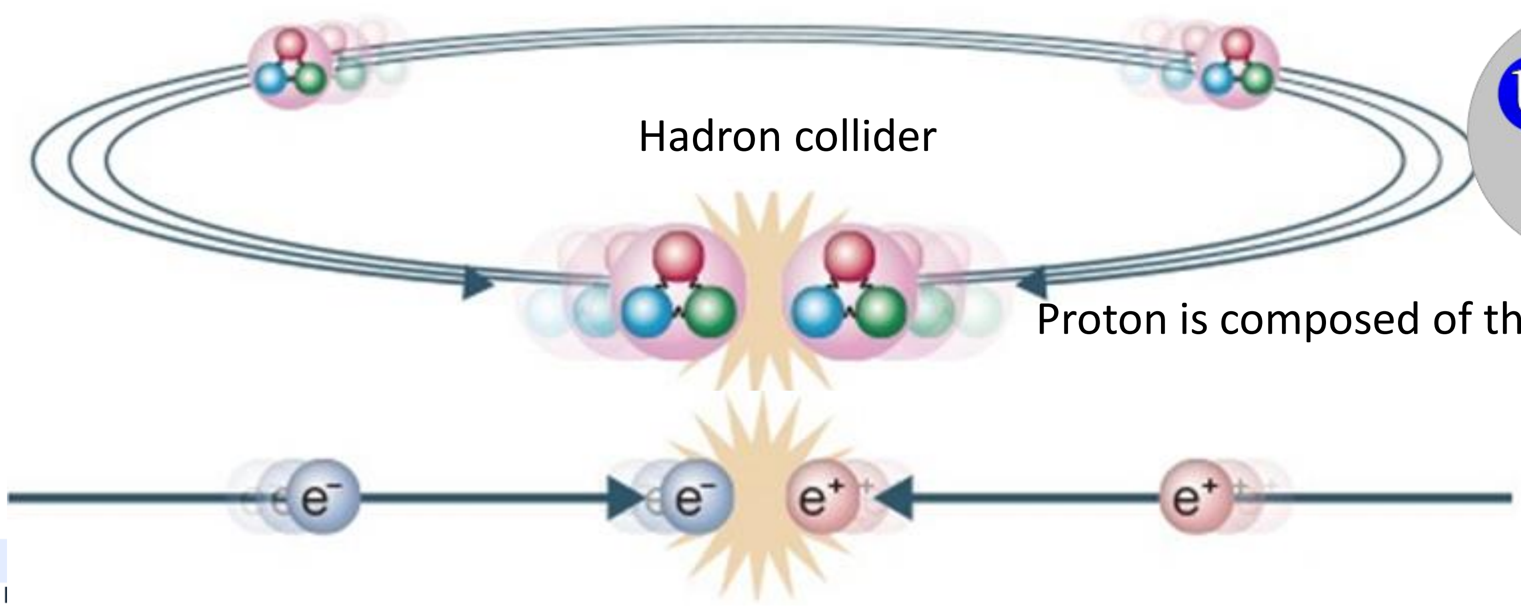
Colliders



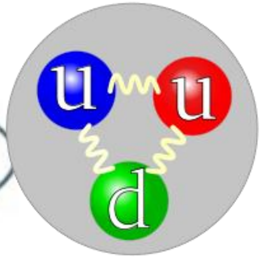
$$E_{CM} = 2E$$

We must collide the beams ,,,,, efficiently,,,,,,

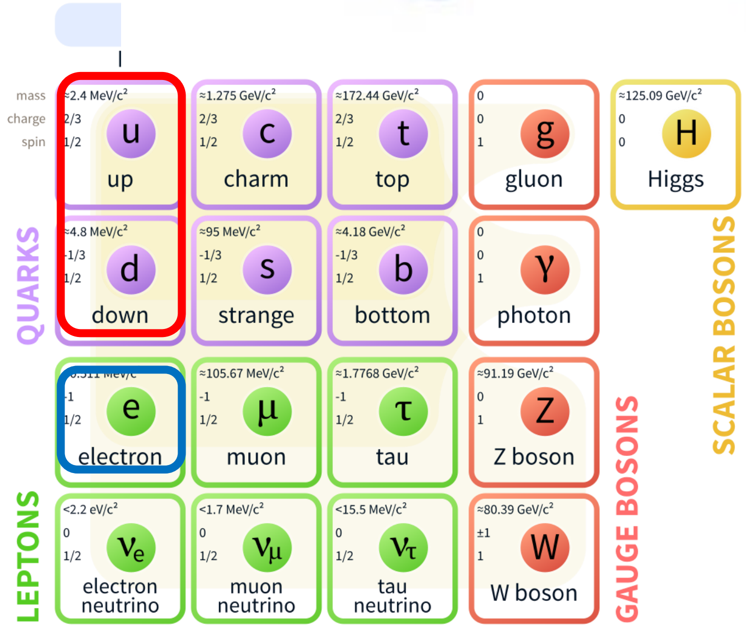
Why electron-positron?



Hadron collider



Proton is composed of three quarks.



Lepton collider

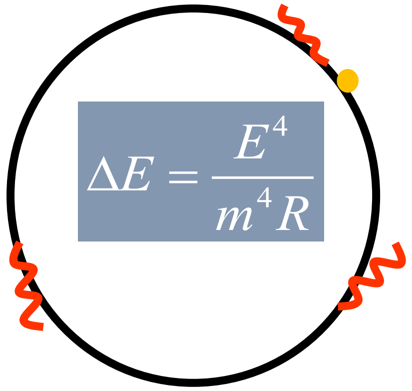
Collision analysis of electron/positron (Lepton) is simple.

Main advantages of the ILC

- A linear accelerator is more advantageous for accelerating electron and/or positron beams to higher energies.

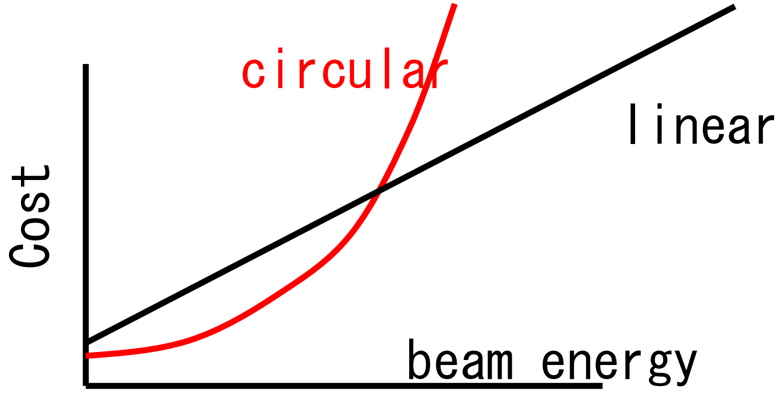
- The spin of the electron and/or positron beam can be maintained during the acceleration and collision. This can help significantly improve measurement precision.

- The small surface resistance of the SRF accelerating structure (cavity) made of Nb enables the efficient power transfer from the AC power source to the beam.



$$\Delta E = \frac{E^4}{m^4 R}$$

Circulating beam loses energy by synchrotron radiation.
Linear collider can extend its collision energy by longer tunnel/ higher gradient.



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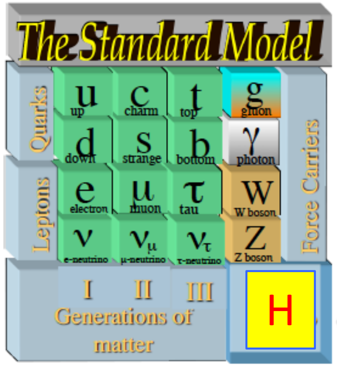
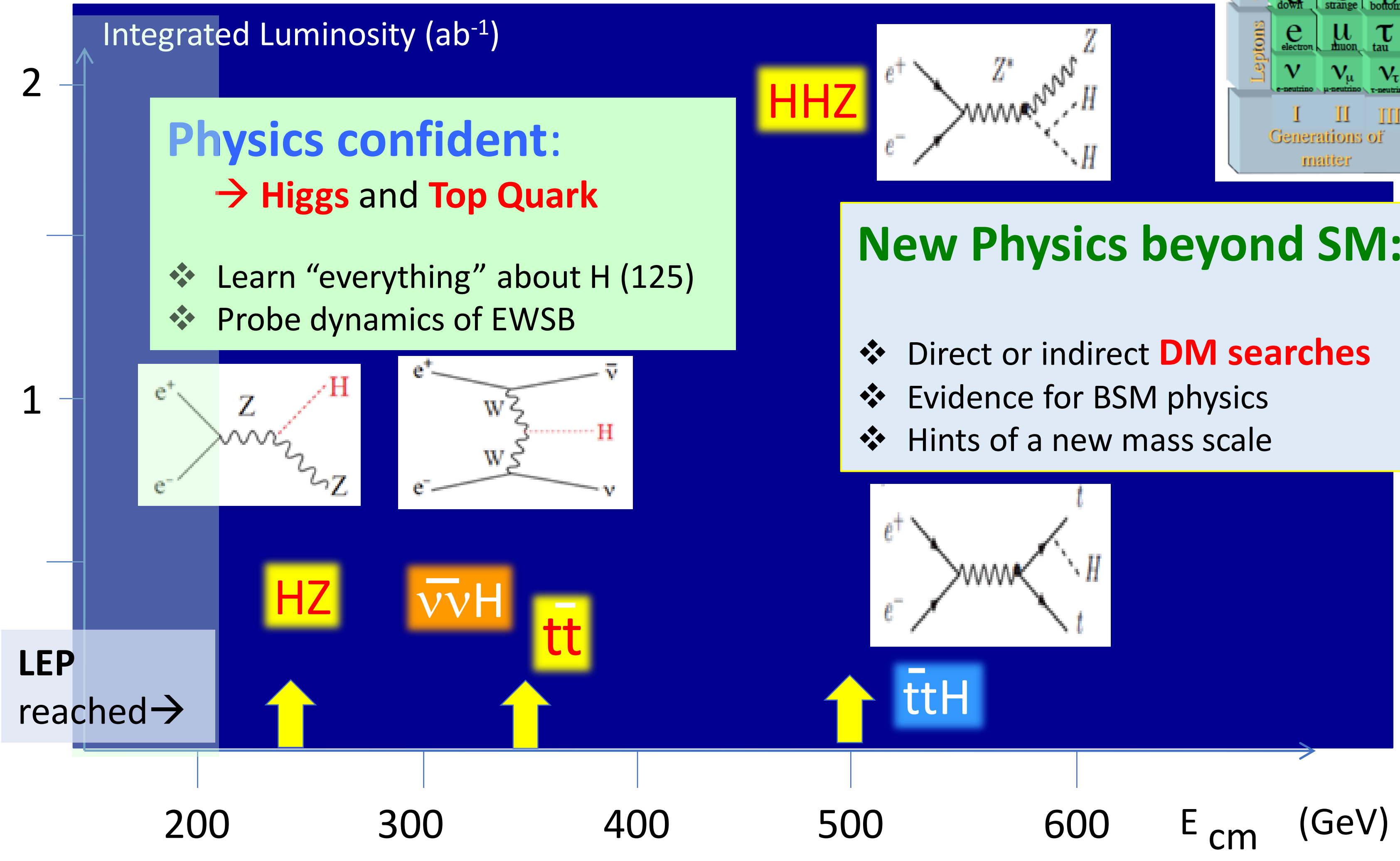
Important Energies in ILC

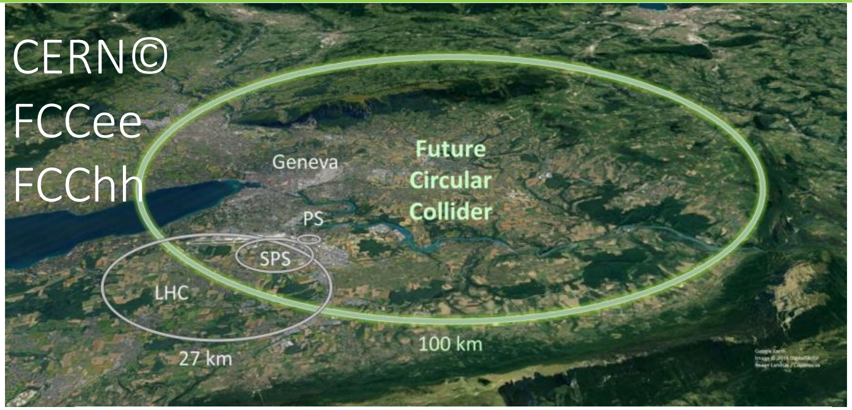
125 GeV Higgs discovery reinforcing the ILC importance

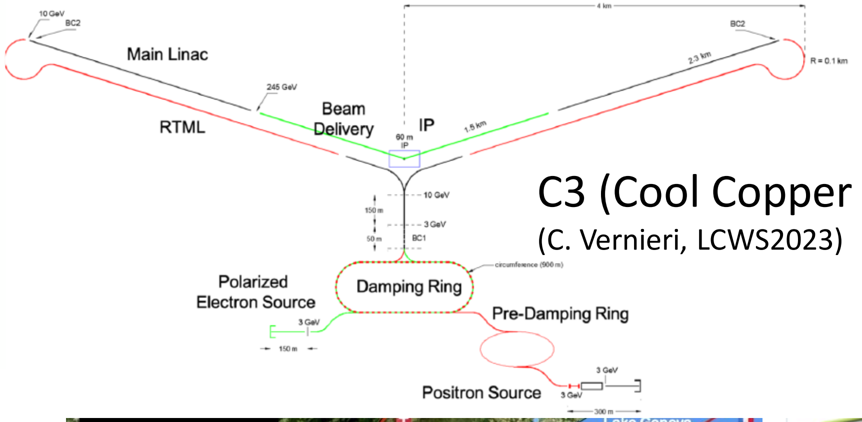




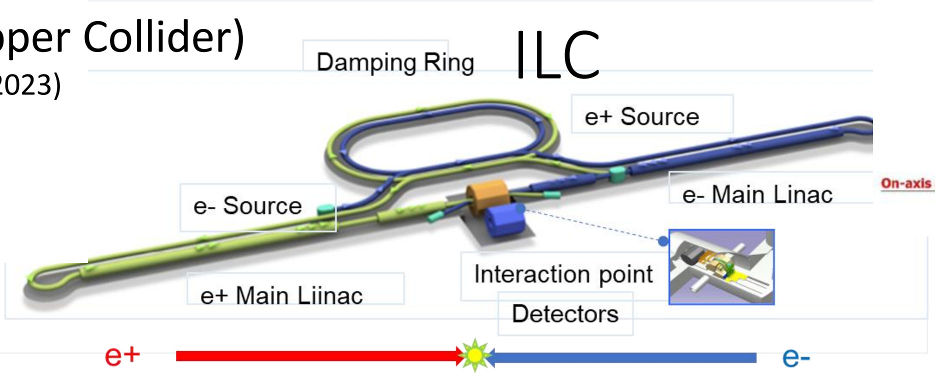
How do we make Higgs particles?

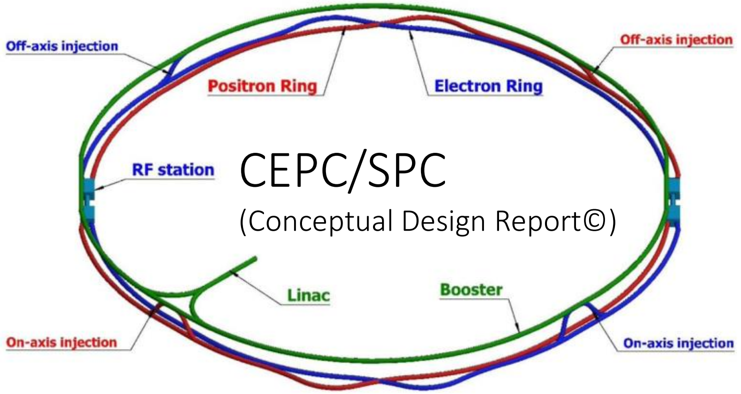
- The only source now is the Large Hadron Collider (LHC) at CERN:
  - -copious sources of Higgs particles 😊
  - -limitation due to difficult (“noisy”) environment ☹
- Some of the projects currently being considered:
  - -Lepton colliders
    - Circular colliders: CEPC (CN), FCCee (CERN) e^+e^- and an idea of Muon collider
    - Linear colliders: CLIC (CERN), C3 (US), ILC (JP) e^+e^-
  - -Hadron (proton) colliders: FCChh (CERN), SPC (CN) pp

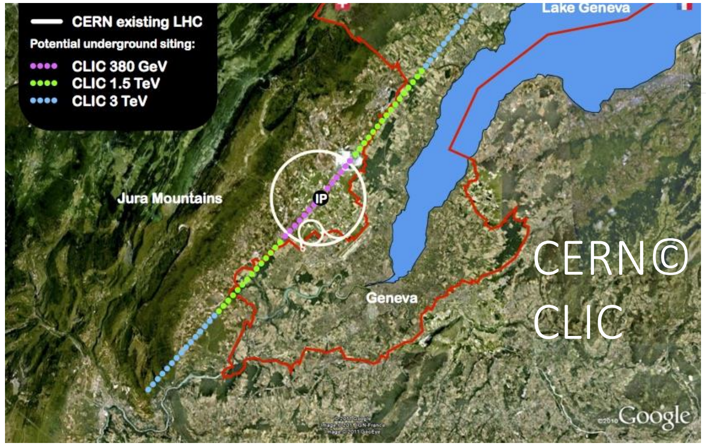


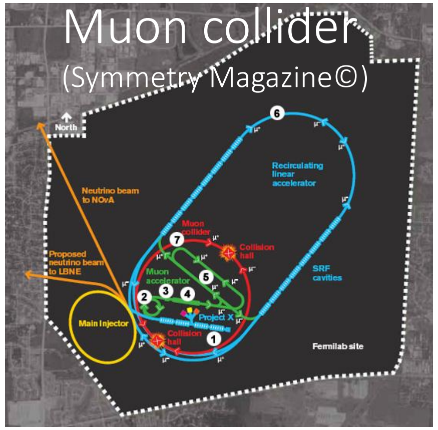


C3 (Cool Copper Collider)
(C. Vernieri, LCWS2023)









Linear collider in international environment

- 2004: Superconducting technology was selected as LC (by ITRP: International Recommendation Panel)

- 2004: Global Design Effort (GDE) was established.

- 2012: Discovery of the Higgs particle and a proposal by the Japanese HEP community for Japan to host the ILC as a global project

- 2013: International Committee for Future Accelerator (ICFA) decided to continue promoting the construction of a linear collider with an international effort by setting up the Linear Collider Board (LCB) and Linear Collider Collaboration (LCC)

- International support for the ILC
  - 2013: European Strategy for Particle Physics 1st update
  - 2014: Particle Physics Project Priority Panel (P5) report
  - 2020: European Strategy for Particle Physics 2nd update2020: LCB/LCC ended its term and IDT established.

European Strategy for Particle Physics

- Initiated by the CERN Council, the first Strategy established in 2006
- "European" strategy in the global context
- Community Open Symposium, Physics Preparatory Group compiling physics input
- Strategy statements drafted by the Strategy Group appointed by the Council (one delegate per member state plus invitees) with a week-long meeting
- After Council discussion, final Strategy released as a Council document

2013 Update

e) There is a strong scientific case for an electron-positron collider, complementary to the LHC, that can study the properties of the Higgs boson and other particles with unprecedented precision and whose energy can be upgraded. The Technical Design Report of the International Linear Collider (ILC) has been completed, with large European participation. The initiative from the Japanese particle physics community to host the ILC in Japan is most welcome, and European groups are eager to participate. *Europe looks forward to a proposal from Japan to discuss a possible participation.*

2020 Update

The timely realisation of the electron-positron International Linear Collider (ILC) in Japan would be compatible with this strategy and, in that case, the European particle physics community would wish to collaborate.

Particle Physics Project Prioritization Panel (P5)

- The Panel is a sub-panel of the US Department of Energy High Energy Advisory Panel (HEPAP): HEPAP advises Federal Government on the national program in experimental and theoretical high energy physics (HEP) research
- A ten-year strategic plan for high energy physics in the U.S., taking the budgetary constraint into account.

P5 report (2014), Executive Summary

> - Play a world-leading role in the ILC experimental program and provide critical expertise and components to the accelerator, should this exciting scientific opportunity be realized in Japan.

Report of the Particle Physics Project Prioritization Panel (P5) May 2014
https://www.usparticlephysics.org/wp-content/uploads/2018/03/FINAL_P5_Report_053014.pdf

- Next P5 report will be published in this year.

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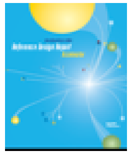
History of ILC Collaboration

2004 ‘06 ’07 ’08 ‘09 ‘10 ‘11 ‘12 ‘13 ‘14 ‘15 ‘16 ‘17 ‘18 ‘19 ‘20 ‘21 ’22 ‘23

RDR | ILC-GDE | TDR | LCC

Technology Selection by ITRP



ILC technical design

TDR:
49 countries
392 institutions
>2400 researchers

International ***D***evelopment ***T***eam

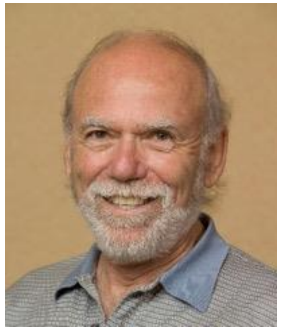
Tatsuya Nakada (EPFL)
IDT chair

LHC

European XFEL

LCLS-II

SRF technology maturered after European XFEL/LCLS-II



Barry Barish
GDE director
(the Nobel Prize winnerin 2017)

Lyn Evans
LCC director
(former LHC project manager)

IDT organization

ICFA

ILC International Development Team

Executive Board

Americas Liaison	Andrew Lankford (UC Irvine)
Working Group 3 Chair	Jenny List (DESY)
Working Group 2 Chair	Shinichiro Michizono (KEK)
Executive Board Chair and Working Group 1 Chair	Tatsuya Nakada (EPFL)
KEK Liaison	Yasuhiro Okada (KEK)
Europe Liaison	Steinar Stapnes (CERN)
Asia-Pacific Liaison	Geoffrey Taylor (U. Melbourne)

Working Group 1
Pre-Lab Setup

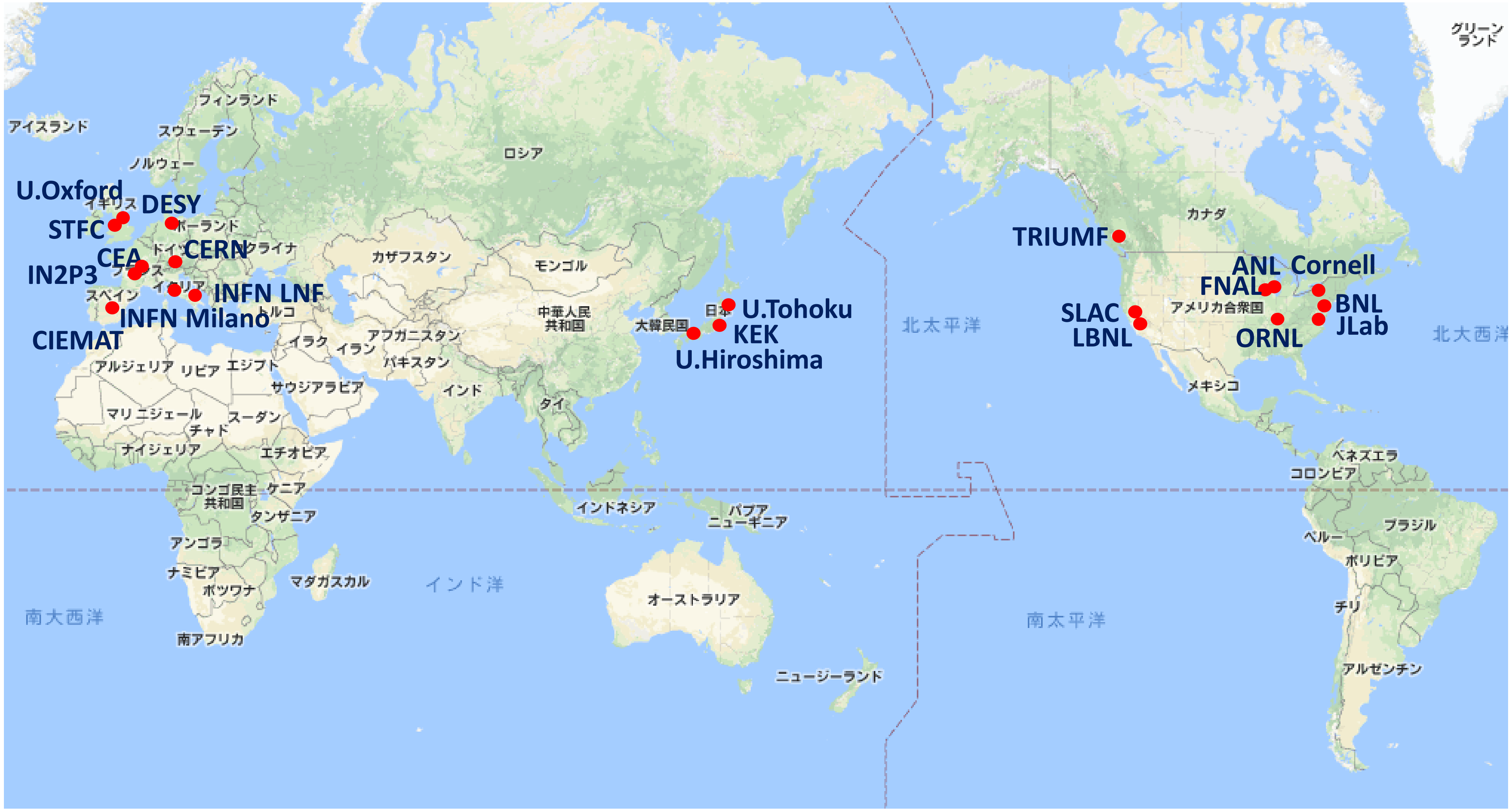
Working Group 2
Accelerator

Working Group 3
Physics & Detectors

International Expert Panel
Decision Process for a global project applicable to the ILC

IDT-WG2

IDT-WG2 has about 50 accelerator researchers from around the world participating in discussions on ILC accelerator development research.



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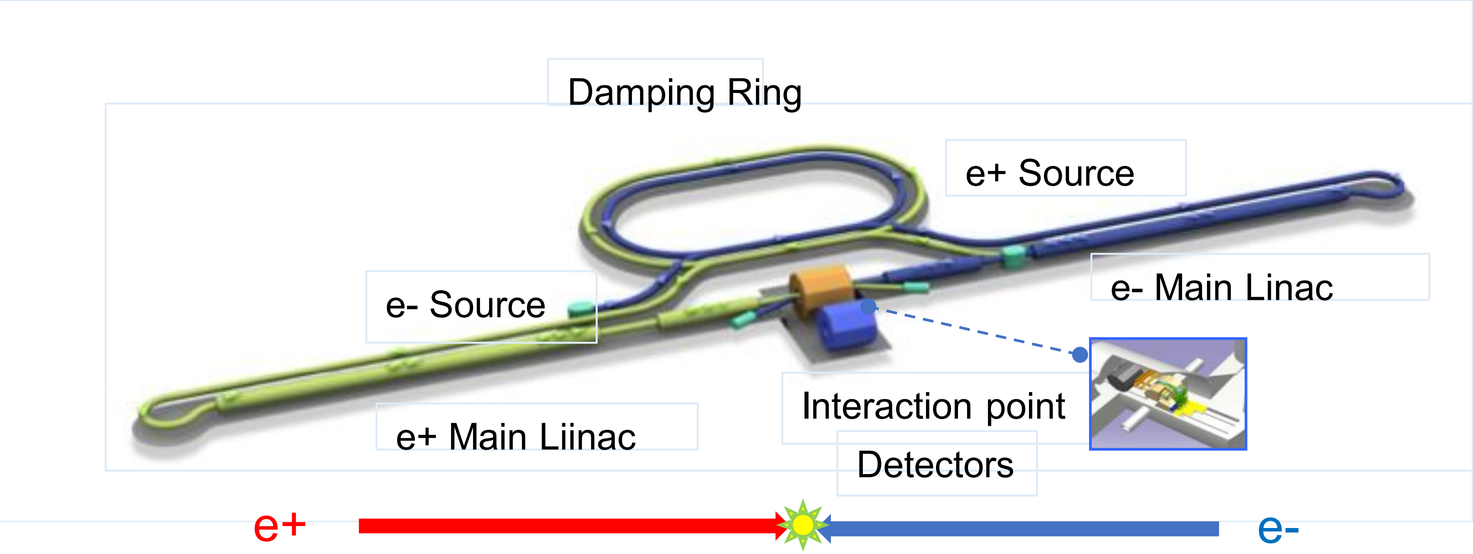
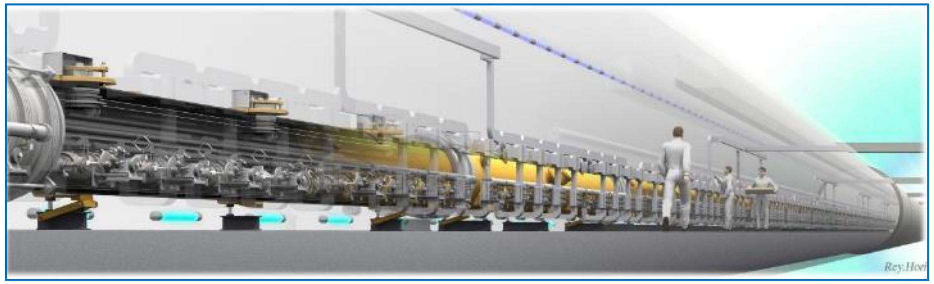
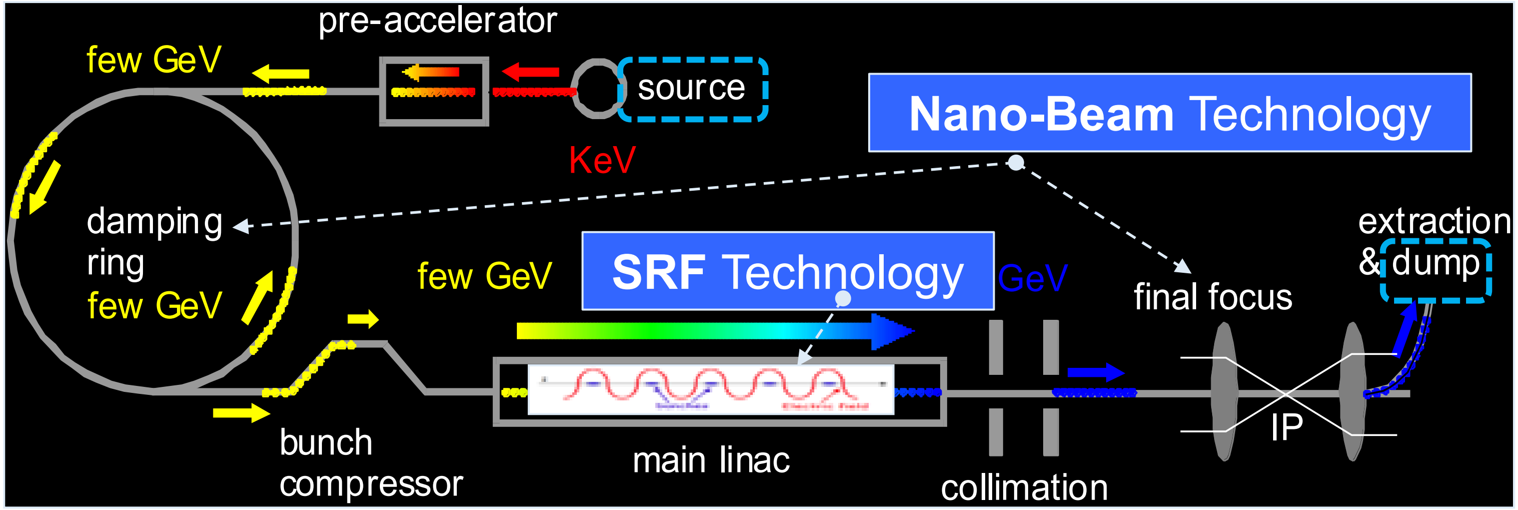
ILC and the Accelerator Technology





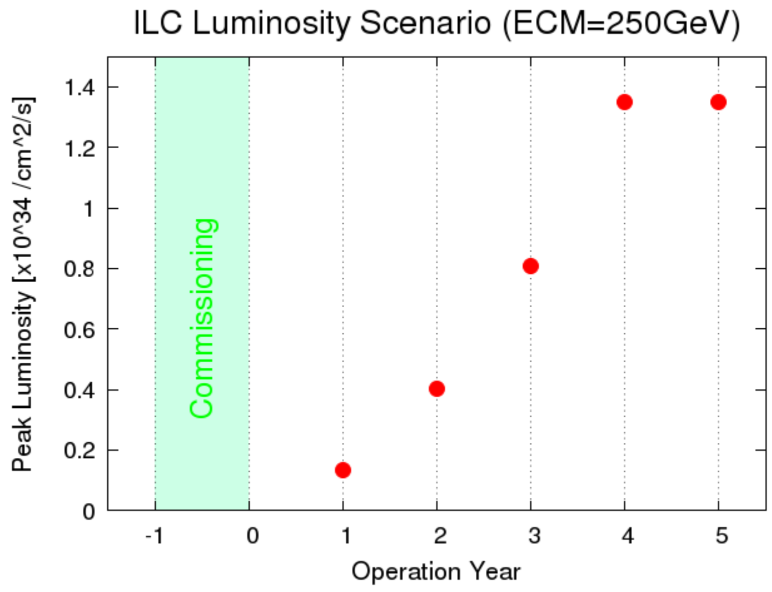
Parameters	Value
Beam Energy	125 + 125 GeV
Luminosity	1.35 / 2.7 x 10^{10} cm^2/s
Beam rep. rate	5 Hz
Pulse duration	0.73 / 0.961 ms
# bunch / pulse	1312 / 2625
Beam Current	5.8 / 8.8 mA
Beam size (y) at FF	**7.7** nm
SRF Field gradient	< 31.5 > MV/m (+/-20%) Q_0 = 1x10^{10}
#SRF 9-cell cavities (CM)	~ 8,000 (~ 900)
AC-plug Power	111 / 138 MW

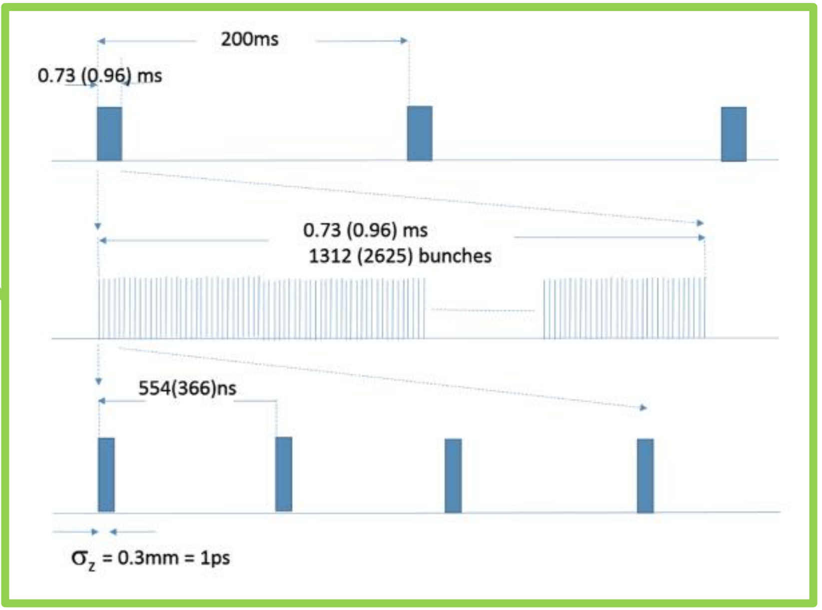


TDR was published in 2013.

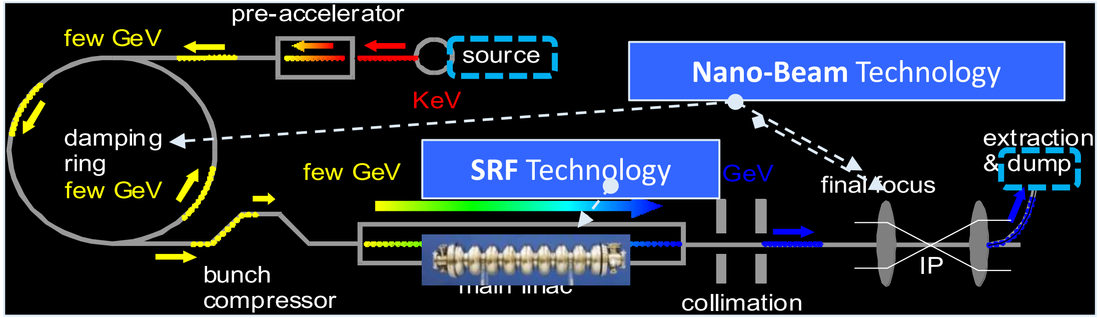
ILC accelerator parameters

ILC	unit	ILC250
Beam Energy	GeV	125 (e-) and 125 (e+)
Peak Luminosity (10^34)	cm-2 s-1	1.35
Int. Luminosity	ab-1/yr	0.24* ** 5,000-hour operation at peak luminosity*
Beam dE/E at IP		0.188% (e-), 0.150% (e+)
Transv. Beam sizes at IP x/y	nm	515/7.66
Rms bunch length /	cm	0.03 (σ_z)
beta*	mm	bx*=13mm, by*=0.41mm
Crossing angle	mrad	14
Rep./Rev. frequency	Hz	5
Bunch spacing	ns	554
Bunch population		2×10^{10}
# of bunches		1,312
Length/Circumference	km	20.5
Facility site power	MW	111
Cost (value) range	$B US	~5 (tunnel and accelerator)
Timescale till operations	years	4(prep.) + 9(construction)



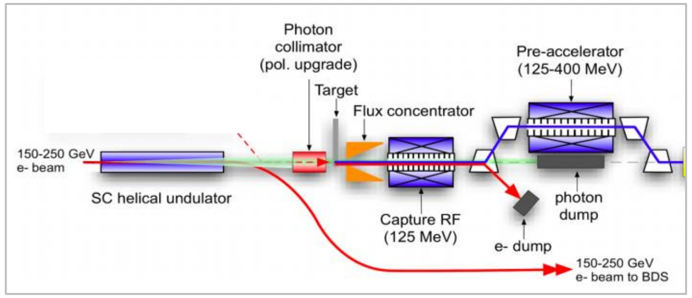


ILC Area systems

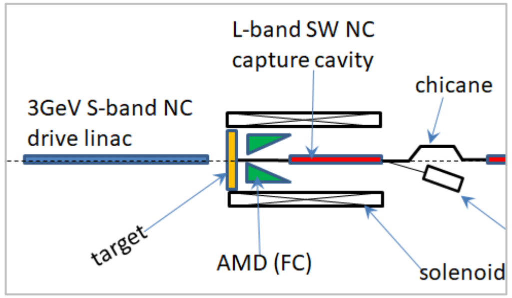


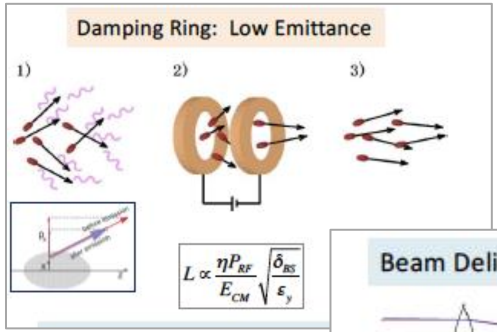
- •Creating particles → ***Sources***
  - •polarized elections / positrons
- •High quality beams → ***Damping ring***
  - •Low emittance beams
    - •Small beam size (small beam spread)
    - •Parallel beam (small momentum spread)
- •Acceleration → ***Main linac***
  - •superconducting radio frequency (SRF)
- •Getting them collided → BDS / ***Final focus***
  - •nano-meter beams
- •Go to → ***Beam dumps***

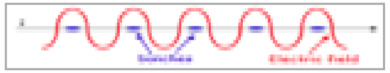
Undulator driven **e+** source

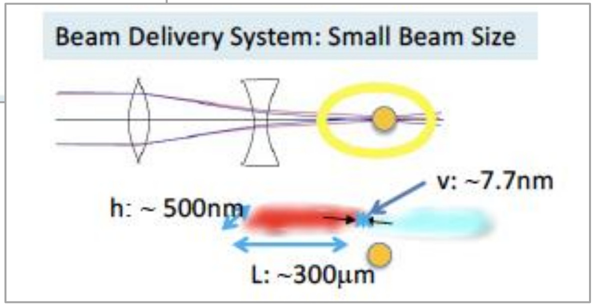


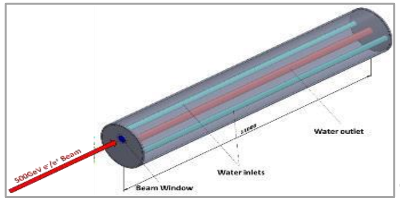
e-driven **e+** source





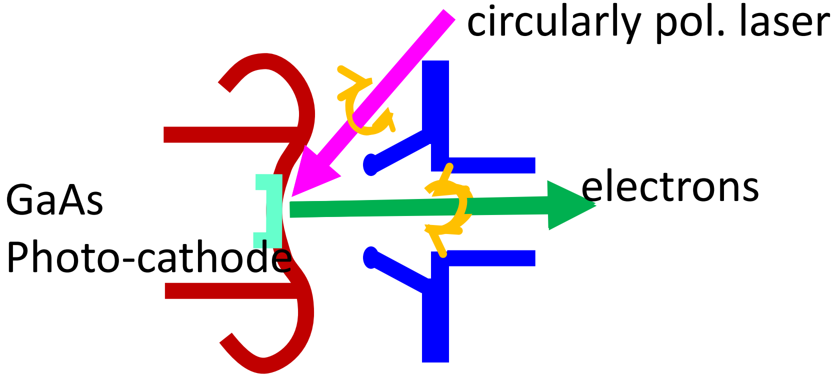






Beam sources -electron/positron-

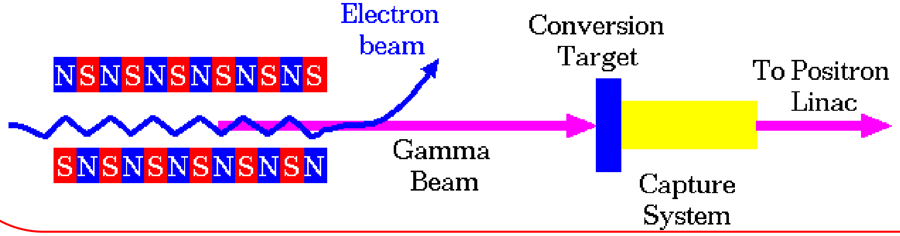
Polarized electron beams



$$P \equiv \frac{N_L - N_R}{N_L + N_R} > 0.8$$

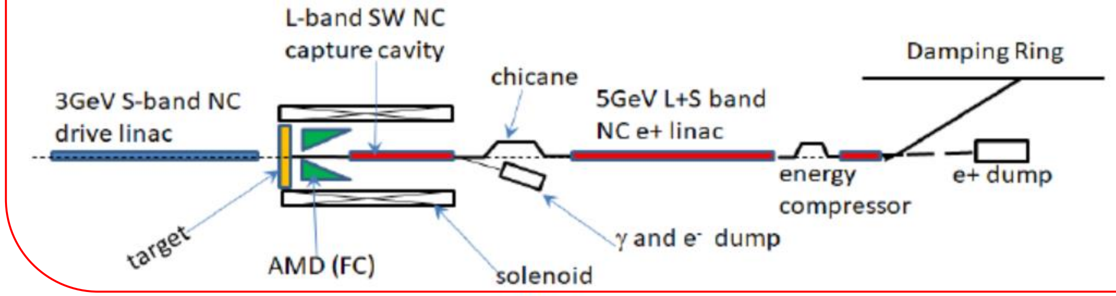
Undulator positron source

125 GeV electrons are injected to the helical undulator. The photons produced at the undulator is used for the electron/positron pair creation at the rotating target. Polarized positrons can be generated.

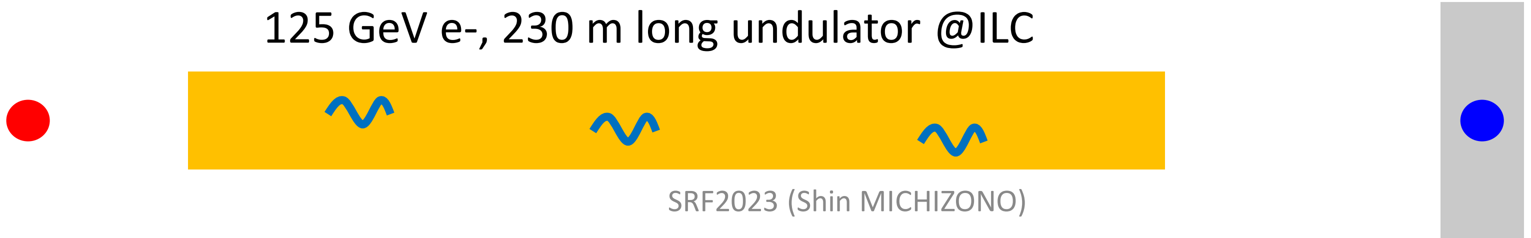


Electron driven positron source

Extra 3GeV linac is used for the positron generation. High energy electrons are not necessary. (Electron independent commissioning is possible. However, polarization is not available.)

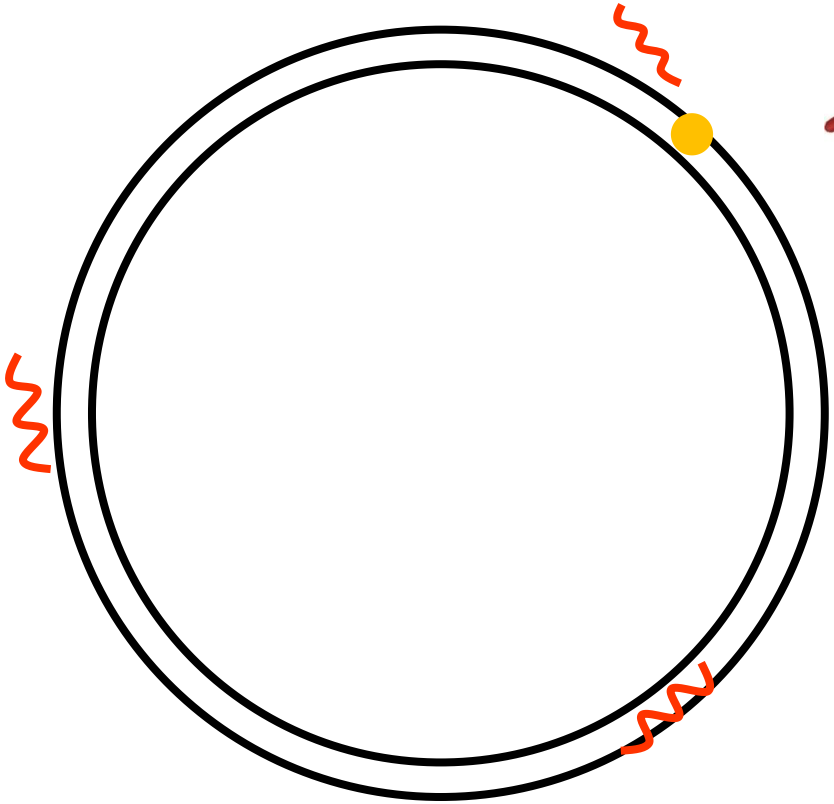


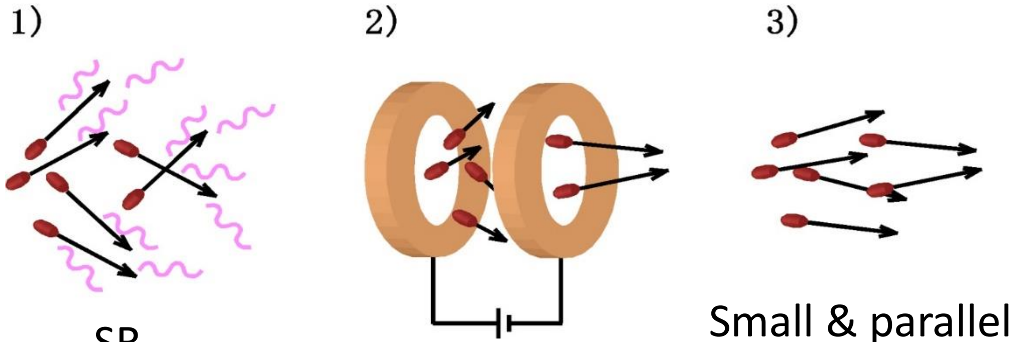
125 GeV e-, 230 m long undulator @ILC



Damping ring

e-/e+ beam will be focused down to ~8 nm at the IP.
Preparation of the high quality beams to make it possible

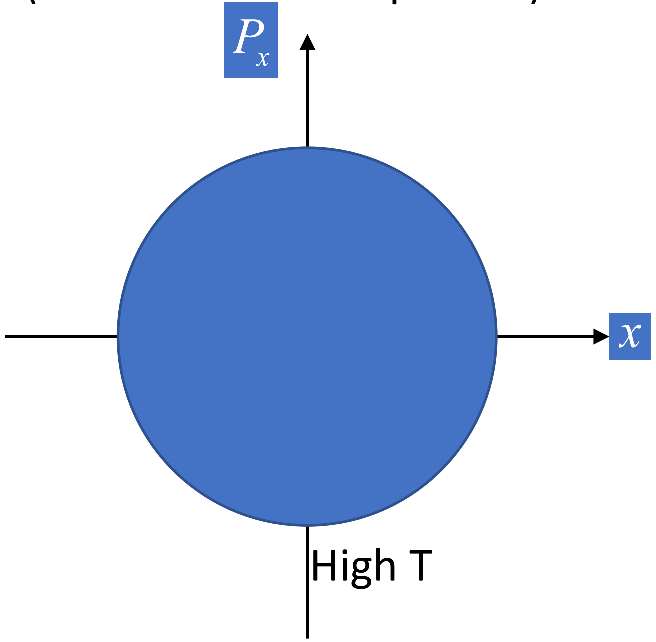




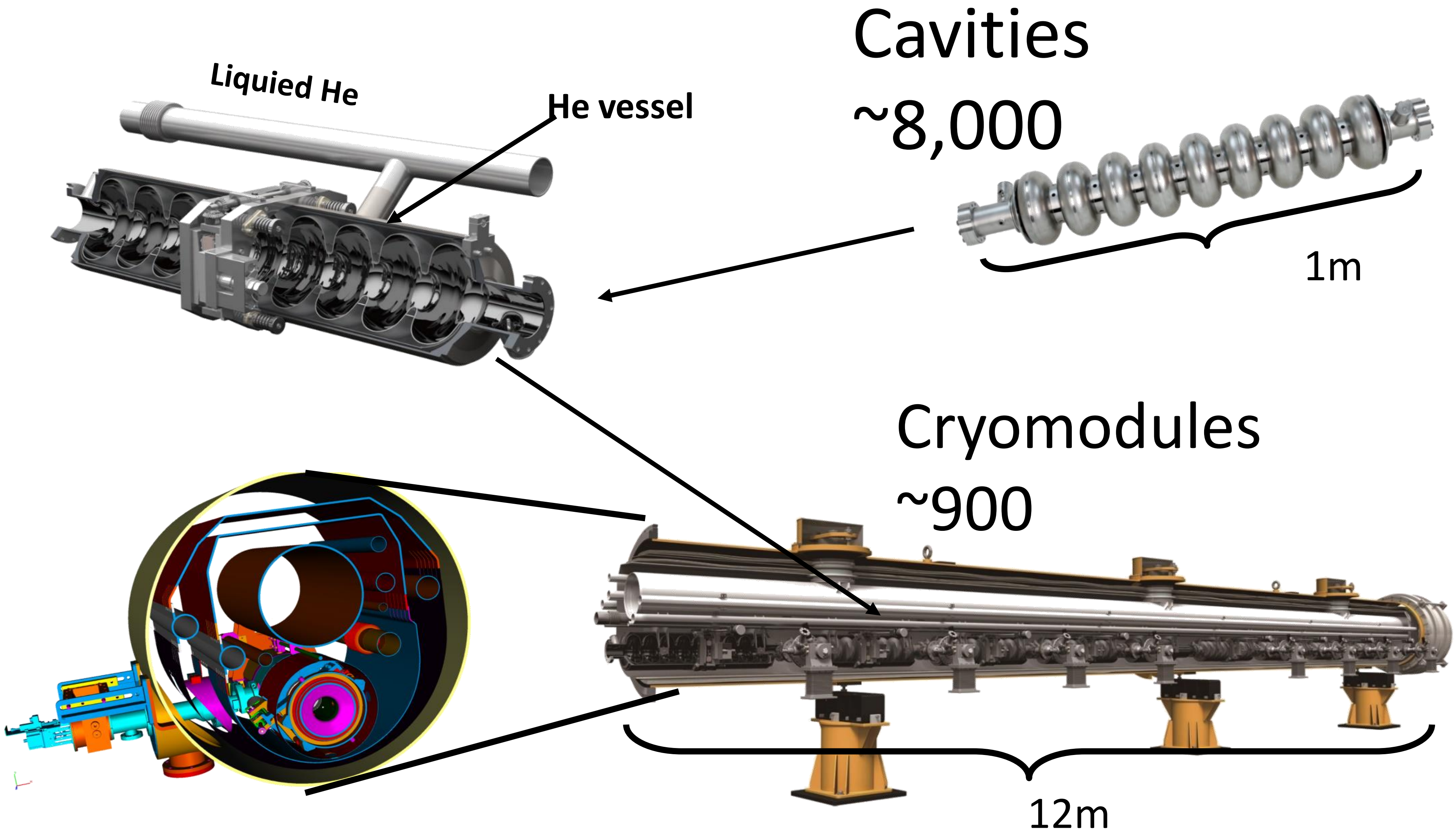
SR

ΔE is compensated
(on beam axis component)

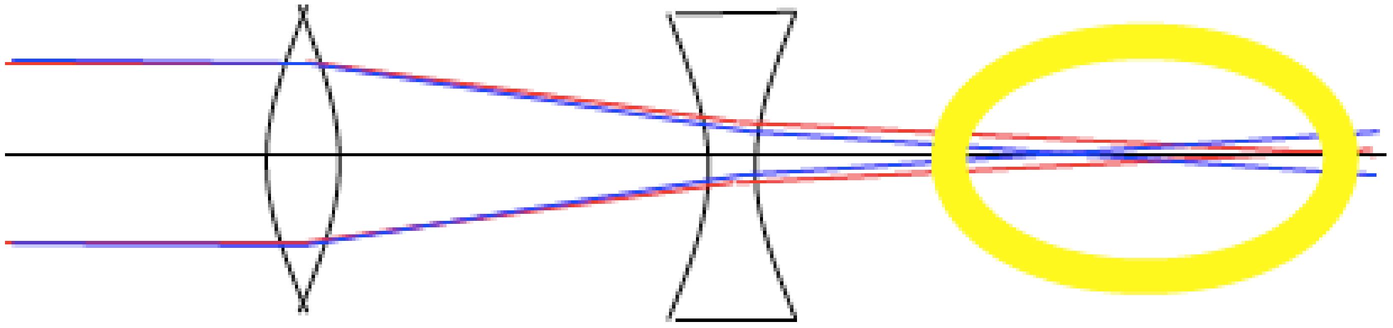
Small & parallel



Main linac (SRF accelerator)

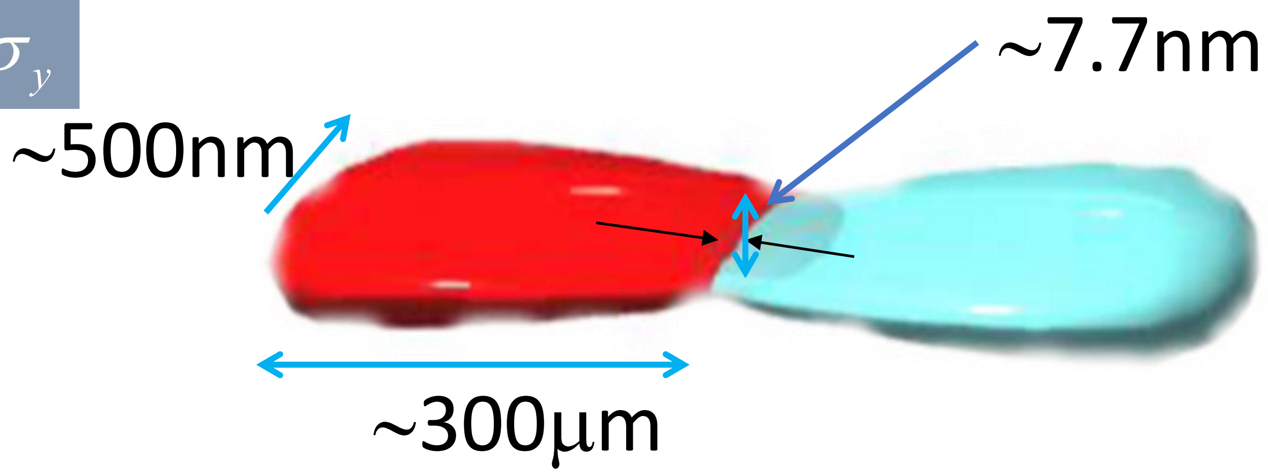


nano beams at interaction point (IP)



$$L \propto \frac{f\,N^2}{\pi\sigma_x\sigma_y}$$

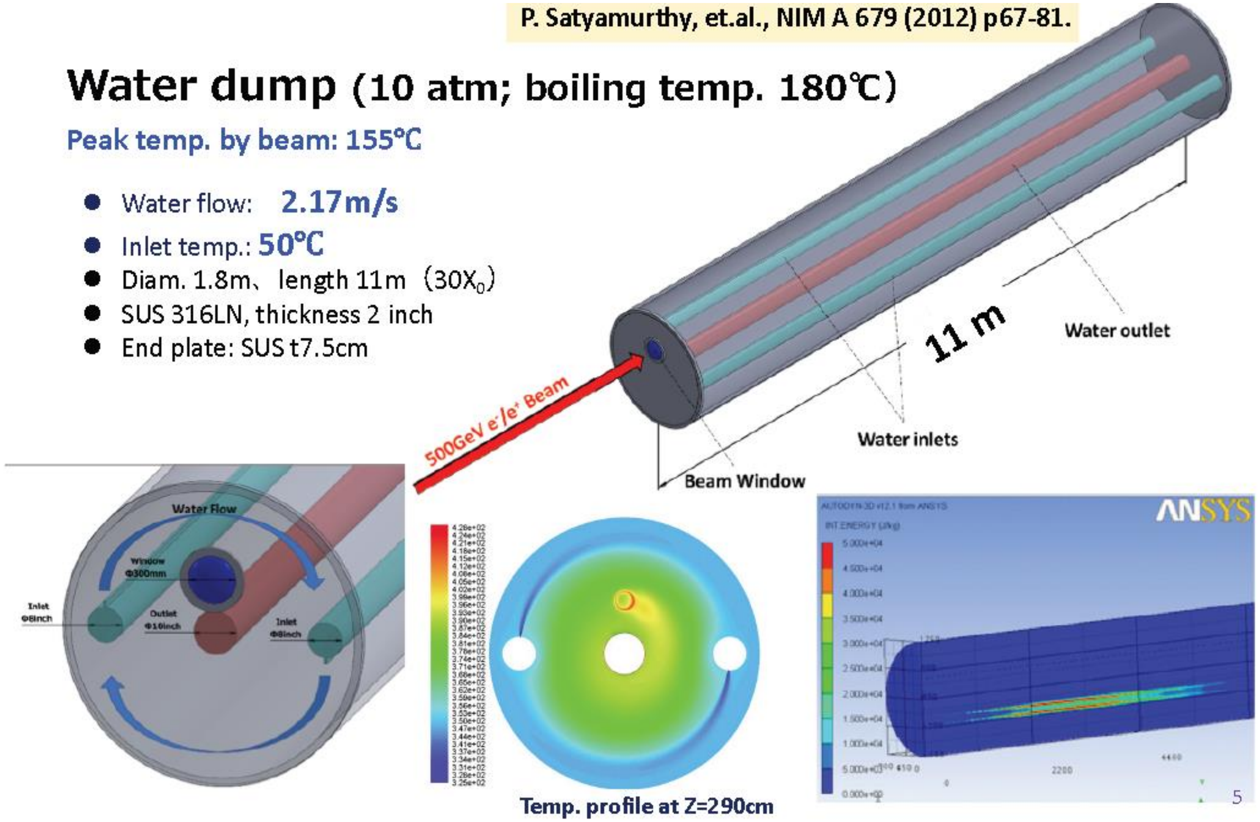
Beam power ~ cost



Final Focus system: developed at ATF/ATF2 in KEK

Beam dump

- ILC beam dump is designed for 1TeV collision energy, and ILC250 has enough margin.



Water beam dump	Req.	Des.	Achieved	unit	Comment
ILC 250GeV	**2.6**	**17**	**-**	**MW**	**Designed for 500GeV beam**
SLAC 2mile LINAC	**-**	**2.2**	**0.75**	**MW**	**ILC beam dump prototype**
CEBAF	0.9	1.0	0.73	MW	In operation at Jefferson Lab from the 90s to the present. 2 units (2 beam lines). Composite type with aluminum plates arranged in water.

ILC construction/operation cost

ILC accelerator (including tunnel) construction cost is ~5 BILCU.

*1 ILCU= 1 US$ in 2012 prices

	TDR: ILC500 [B ILCU] (Estimated by GDE)	ILC250 [B ILCU]* (Estimated by LCC)	Conversion to: [B JPY] (Reported to MEXT/SCJ)
Accelerator Construction: sum	**n/a**	**n/a**	**635.0 ~ 702.8**
Value: sub-sum	7.98	4.78 ~ 5.26	515.2 ~ 583.0
Tunnel & building	1.46	1.01	111.0 ~ 129.0
Accelerator & utility	6.52	3.77 ~ 4.24	404.2 ~ 454.0
Labor: Human Resource	22.9 M person-hours (13.5 K person-years)	17.2 M person-hours (10.1 K person-years)	119.8
Detector Construction: sum	**n/a**	**n/a**	**100.5**
Value: Detectors (SiD+ILD)	0.315+0.392	0.315+0.392	76.6
Labor: Human Resource (SiD + ILD)	748+1,400 person-years	748+1,400 person-years	23.9
Operation/year (Acc.) : sum	**n/a**	**n/a**	**36.6 ~ 39.2**
Value: Utilities/Maintenance	0.390	0.290 ~ 0.316	29.0 ~ 31.6
Labor: Human Resource	850 FTE	638 FTE	7.6
Others (Acc. Preparation)	**n/a**	**n/a**	**23.3**
Uncertainty	**25%**	**25%**	**25%**
Contingency	**10%**	**10%**	**10%**
Decommission	**n/a**	**n/a**	**Equiv. to 2-year op. cost**

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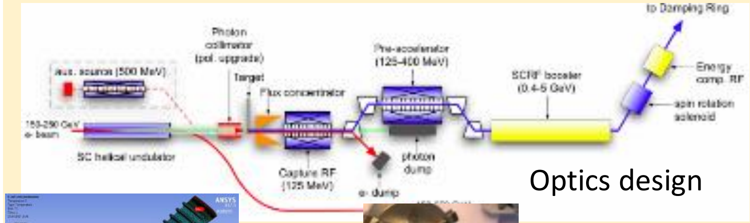
Progress in positron source

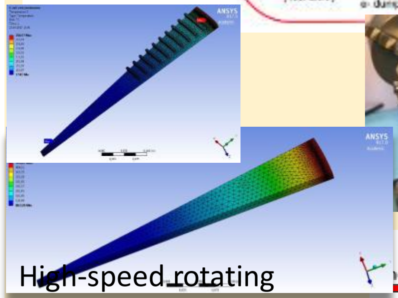
～2017 **tech. design**

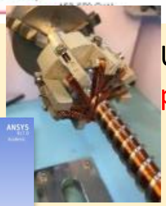
2018～ **tech. verification**

Undulator scheme to obtain polarization



Optics design



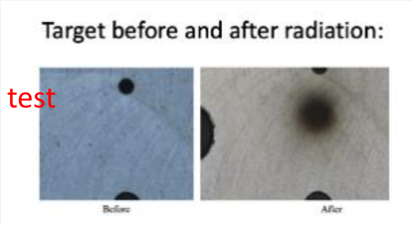


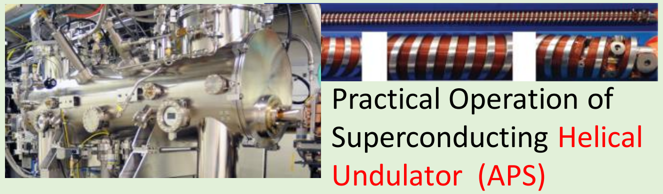
Undulator prototype

Photon dump design

High-speed rotating positron target, Technology Design

Ti target beam test



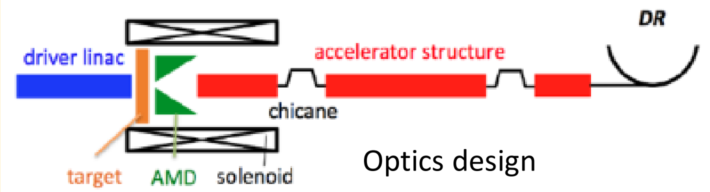


Practical Operation of Superconducting Helical Undulator (APS)

Long undulator operation at European XFEL

Next Steps:
evaluate both schemes by international cooperation

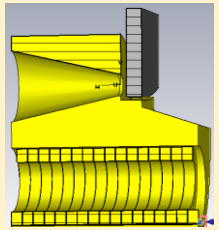
Conventional e-Driven



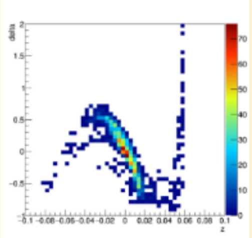
Optics design

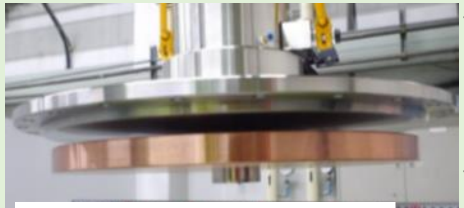
Target thermal simulation

Mag. focusing

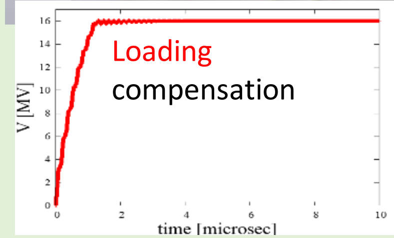


Paricle simulation

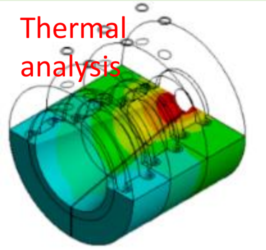




Target Prototyping Vacuum characteristics Testing



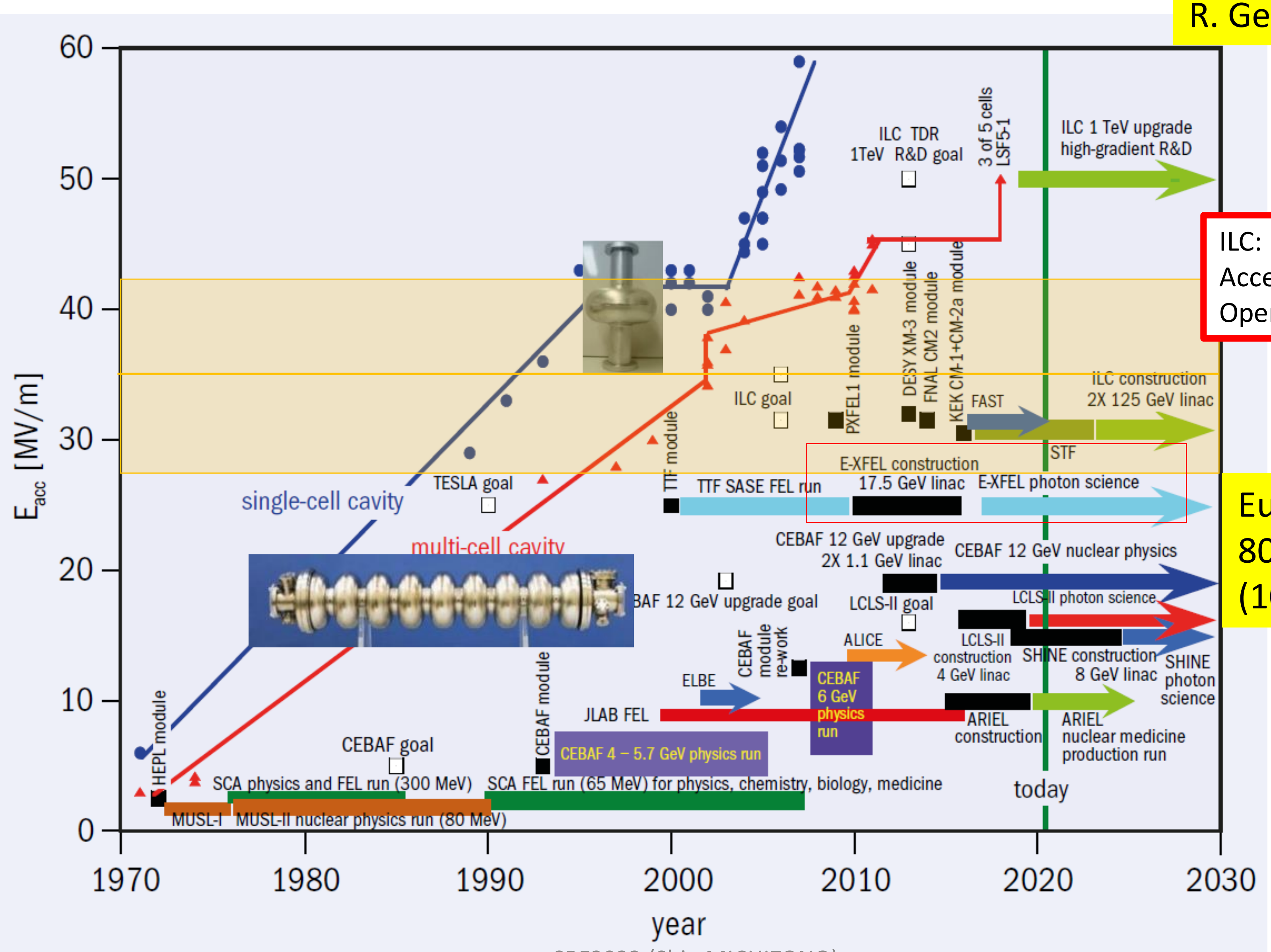
Loading compensation



Thermal analysis

Matured SRF technologies

R. Geng (JLAB)



ILC:
Accept:35 MV/m +/-20%
Operate: 31.5MV/m +/-20%

European XFEL
800 cavities
(10% of ILC ML)

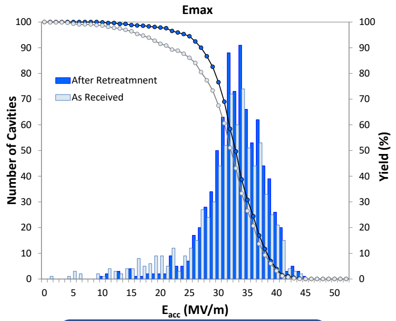
Progress in SRF

～2017	2018～

Cavity

Yield evaluation of cavities based on TDR

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



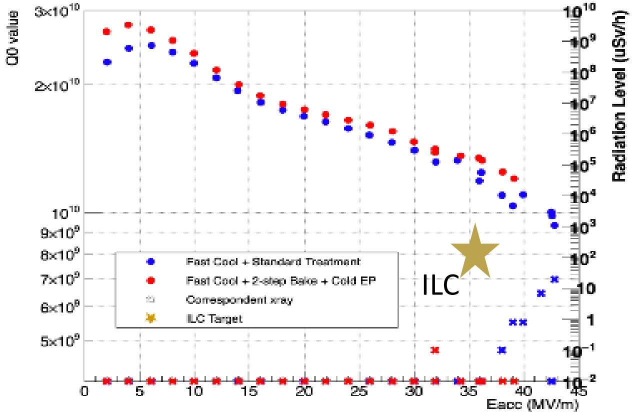
European-XFEL Operation (Europe)
~800 cavities/
~100 Modules

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

Realized through international cooperation and procurement

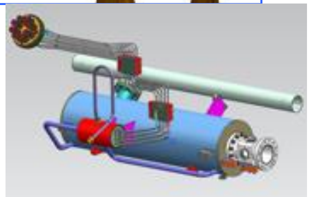
High performance and cost reduction

high performance with new surface treatment, etc.

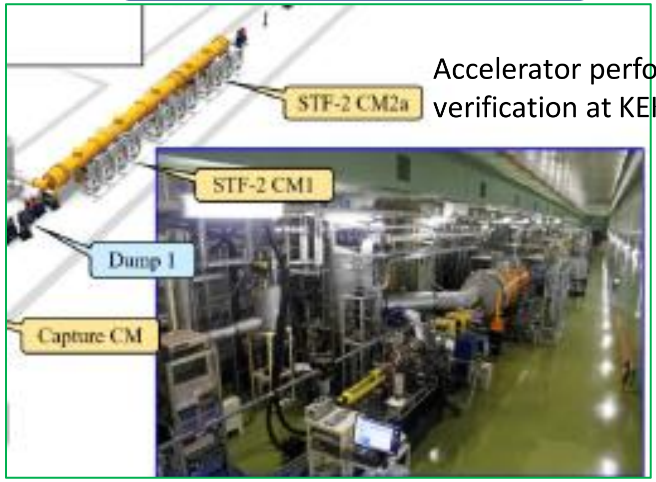


Cryomodule

Design



Module assembly



Accelerator performance verification at KEK-STF2

~ 1.3 GHz SRF Accelerators, worldwide

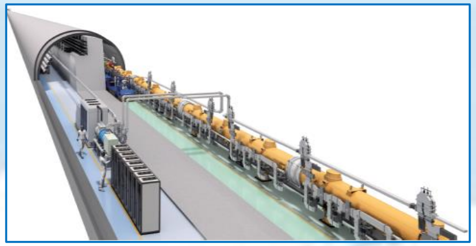
European XFEL
(in operation, 2017~)

800 cavities
100 CMs
17.5 GeV (Pulsed)

ESS (0.8 GHz)
(under construction)

SHINE
(under construction)

~600 cavities
75 CMs
8 GeV (CW)



ILC (planned)

8,000 9-cell cavities
900 CMs
2 x 125 GeV (Pulsed)

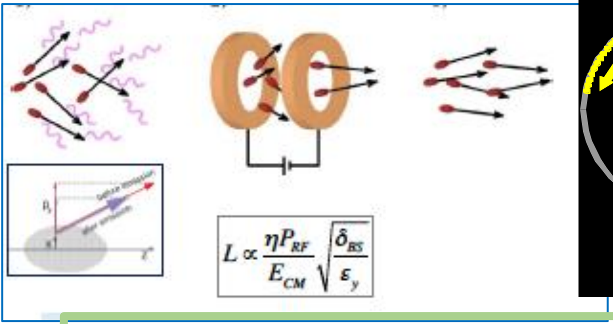
LCLS-II -HE
(in commissioning)

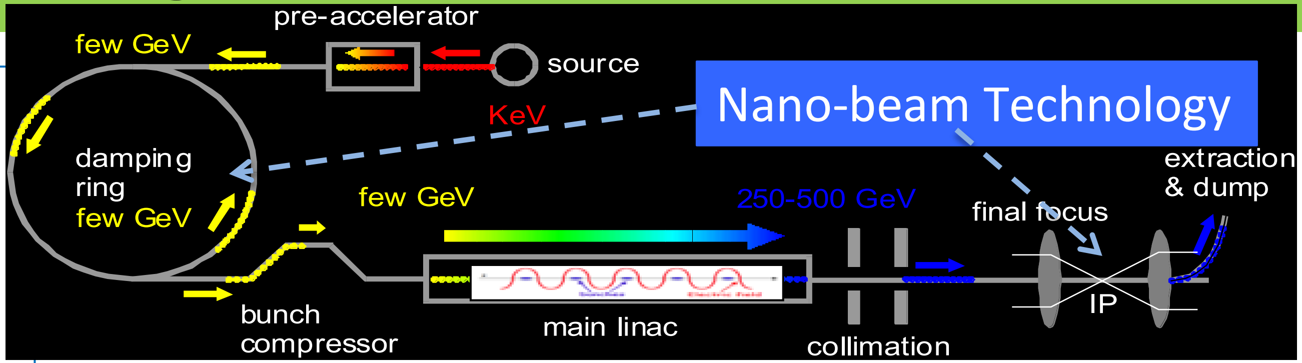
-280+200 cavities
-35+25 CMs
- 4 +4 GeV (CW)

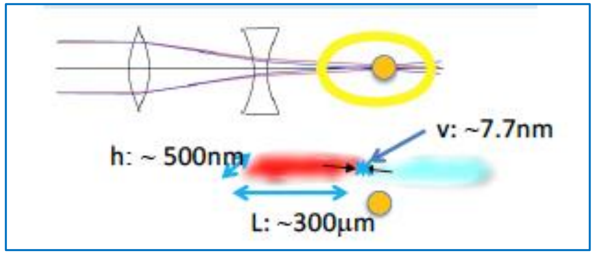
JLab-CEBAF(1.5 GHz)
(in operation)
40 CMs
6~12 GeV(CW)

> 2,000 SRF cavities being realized!

Progress in Nano-beam Technology







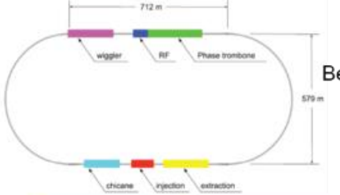
Progress in DR

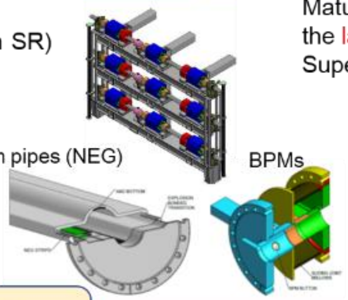
~ 2017	2018 ~

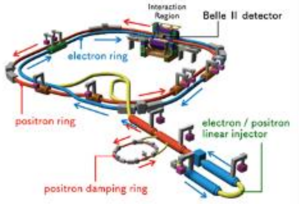
DR — Eng. design

Design based on experience with circular accelerators (4th generation SR) around the world

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

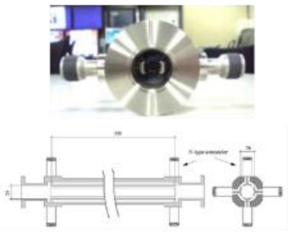


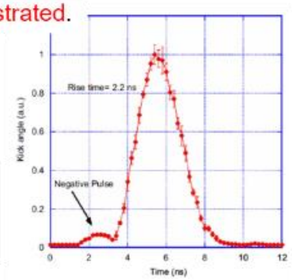


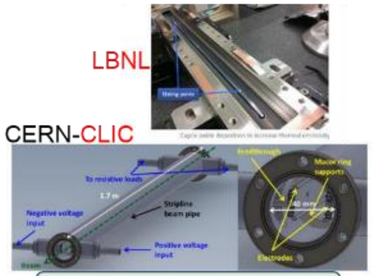


Inj./Ext. — Eng. Design, Equipment verification

Beam extraction demonstrated.







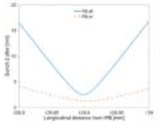
Fast kicker technology

Progress in Final Focus

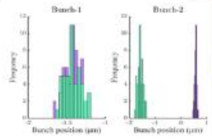
~ 2017	2018 ~

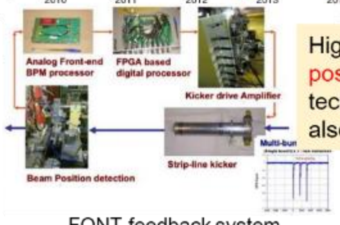
Tech. design completed
Spec. almost achieved

Wakefield effects



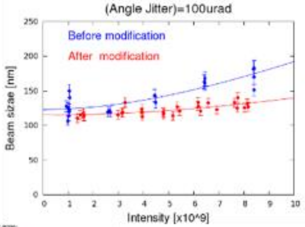
Distribution of bunch positions measured at IPB, with two-BPM FB off (green) and on (purple)

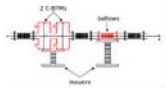




FONT feedback system

High-speed beam position control technology was also demonstrated.





ATF2 wakefield knobs system be-tween BPM QD10BFF and QD10AFF

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

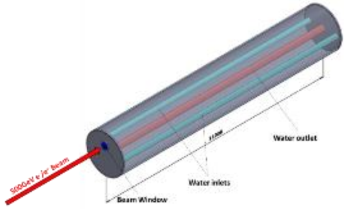
ATF International Review (Committee)*
-The committee highly evaluated the achievements of ATF so far.
-The committee pointed out the importance of continuing research to contribute to the detailed design of the ILC final convergence.

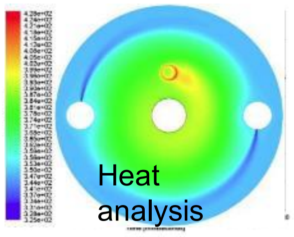
*https://agenda.linearcollider.org/event/8626/

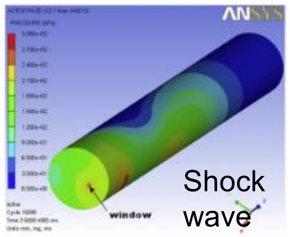
Progress in beam dump

～2017	2018～
Basic design (by SLAC researchers)	Design revalidation and specific facility design

Designed with 500GeV beam (17 MW) based on the SLAC water dump.
ILC250 (2.6 MW) has enough margin.
Absorber: Water(10 atm)





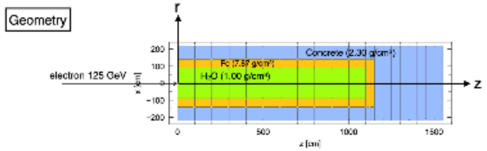


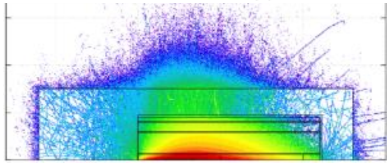
Consultations with beam target/dump experts from around the world beyond ILC

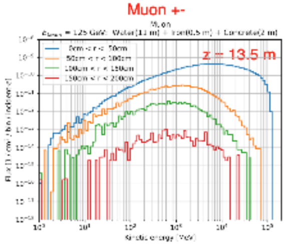
LHC beam dump

RADIATE collaboration

Specific design of radiation shield

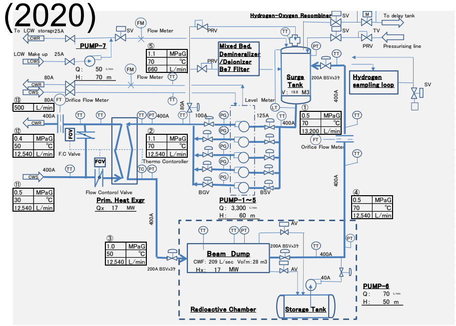






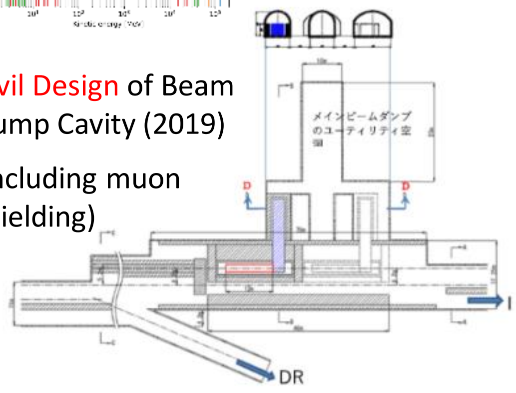
Design for shielding of muon particles generated by beam dump

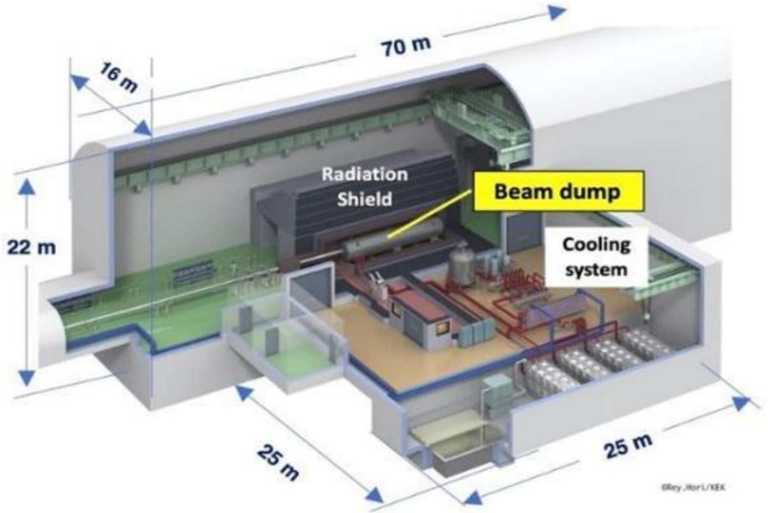
Beam Dump Water Circulation System Design (2020)



Civil Design of Beam Dump Cavity (2019)

(including muon shielding)





Current Status and Future Technological Collaboration for the ILC

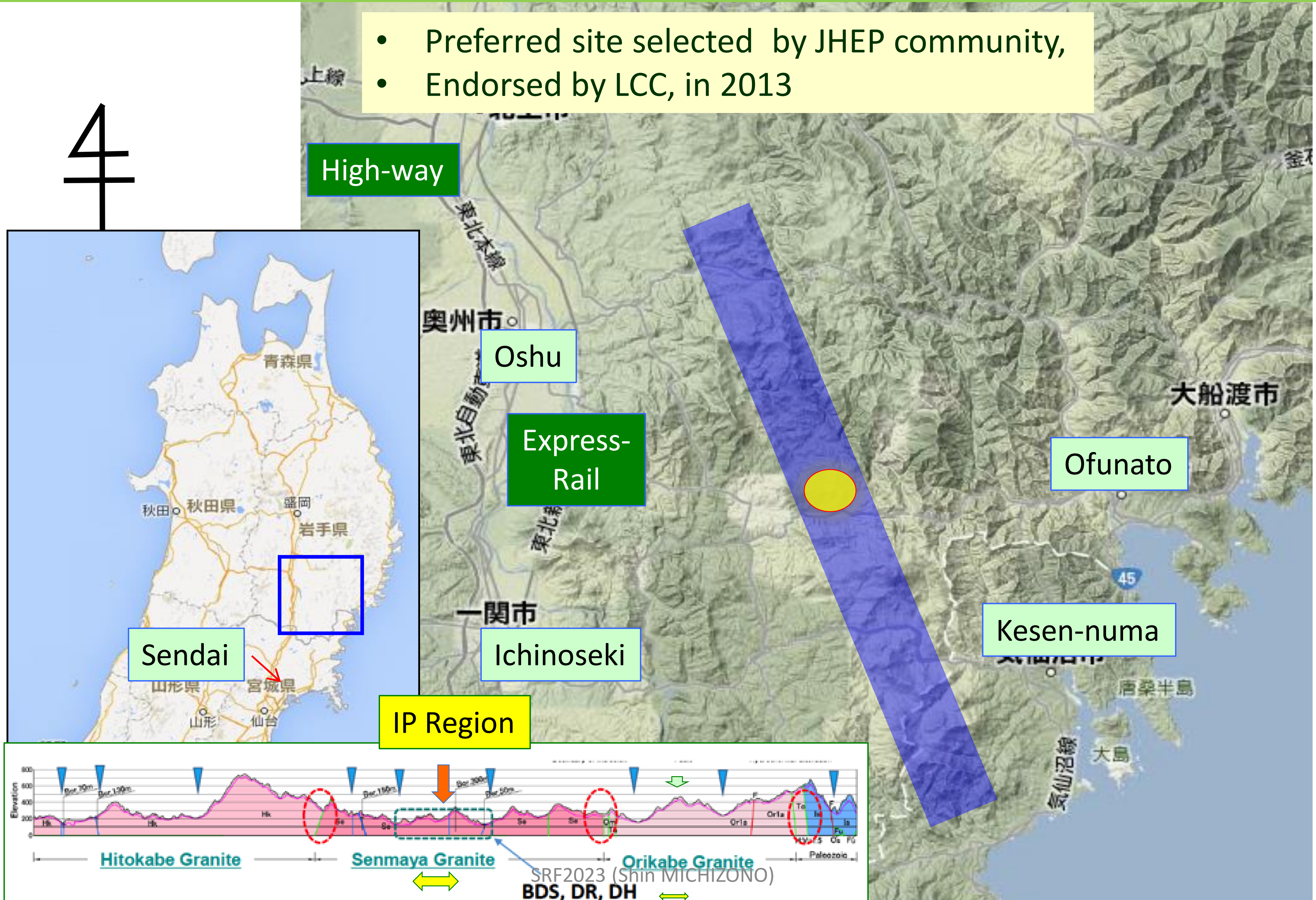
KEK / IDT-WG2

Shin MICHIZONO (KEK)

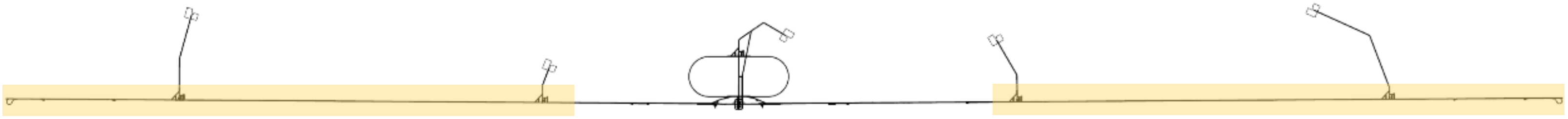
1. Why linear collider?
2. Higgs Factory
3. Global Collaboration
4. ILC Accelerator
   - ILC design
   - Recent Progress
   - ⇨ Candidate site
5. Pre-lab proposal
6. Global Project
7. ILC Technology Network
8. KEK's effort
9. Future Upgrade
10. Beam dump (industrial application)
11. Sustainability
12. Summary

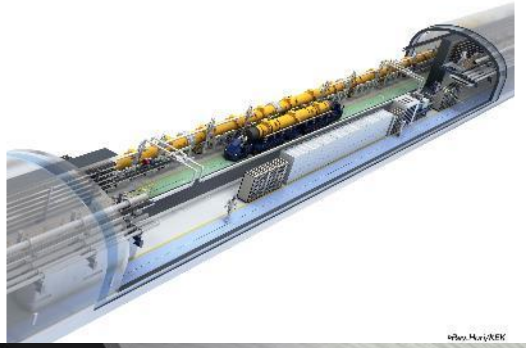
ILC Site Candidate Location in Japan: Kitakami

- Preferred site selected by JHEP community,
- Endorsed by LCC, in 2013

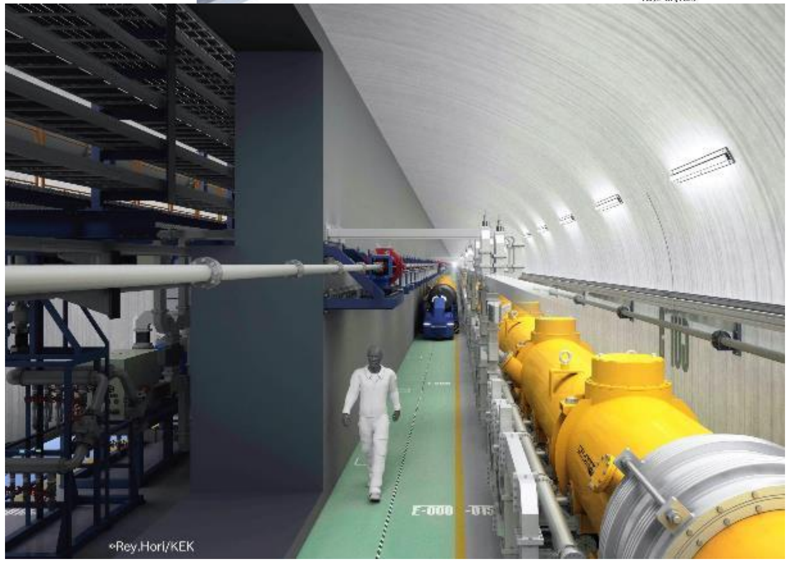


Main Linac (ML) tunnel



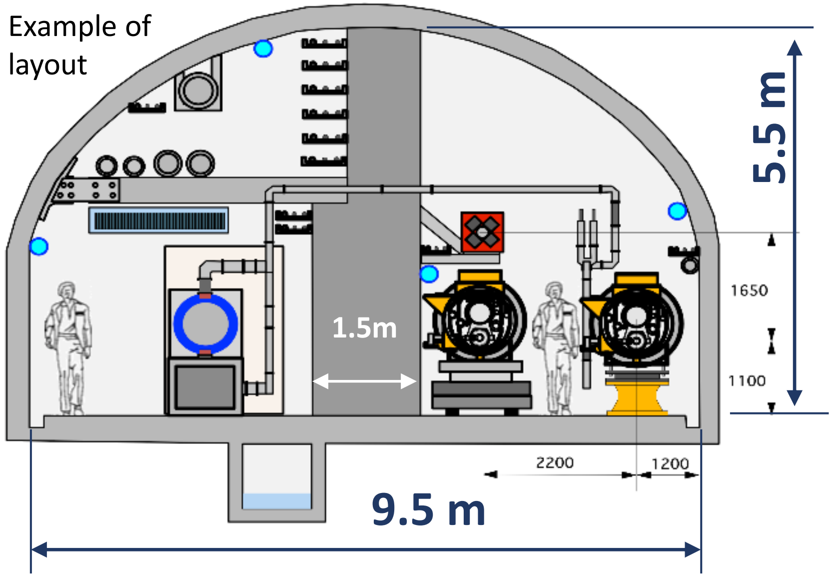


- 15 km in (e+e-) total
- follow the geoid in vertical
- **Kamaboko 9.5m X 5.5m**
- **1.5m central radiation shield**
- Further optimization will be done.



- **66 kV distribution cables**
- **Cooling water pipes**
- Fan Coil Units
- Low power and signal cables
- **RF klystrons and modulators**
- **Electric Power Stations**

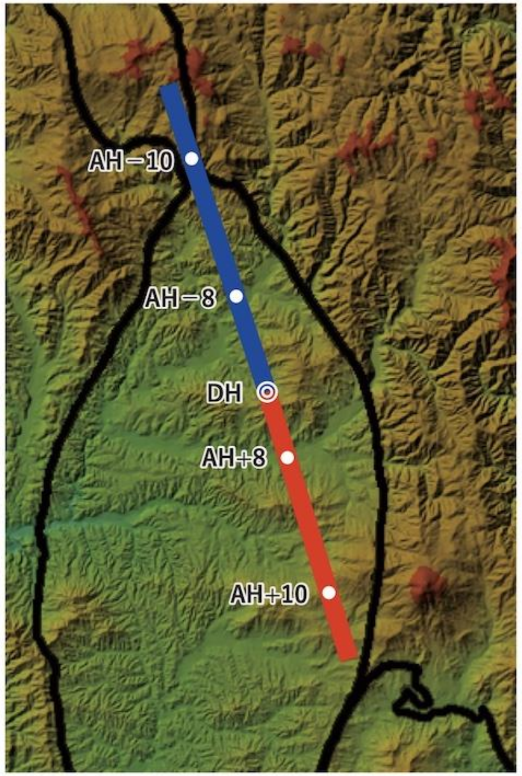
Example of layout



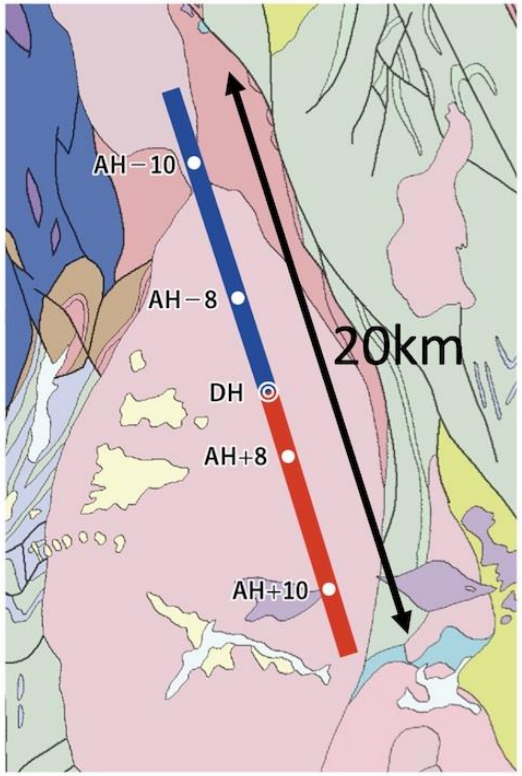
- **ML Cryomodules**
- **RTML**
- Low power and signal cables

Topography and geology assumed in civil engineering design of ILC

- Rock mass is generally uniform over a long distance of 50 km
- Solid rock zone is less susceptible to ground vibration
- No "known faults" crosses the site, which is expected to be active faults



granite zone



Tohoku ILC Civil Engineering Plan
https://tipdc.org/assets/uploads/2021/03/Tohoku_ILC_CEP.pdf

- Seismic survey (total 30 km), electromagnetic survey (13 km), and borehole survey (7 boreholes) were carried out.
- In the area of the accelerator tunnel, hard and uncracked granite is considered to be widely distributed.

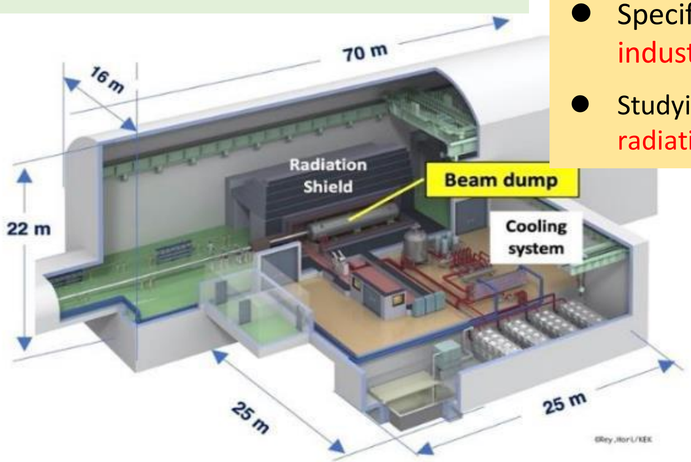
Radiation safety and community understanding

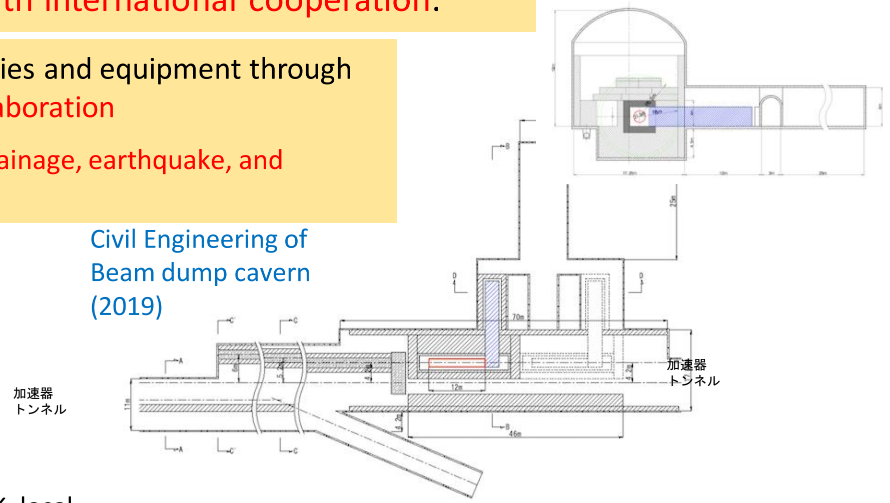
Facility design for radiation safety (radiation protection and long-term maintenance of radioactive materials)

- KEK and other large accelerators around the world have enough experiences
  Such as proton accelerators with more severe activation (Selection of materials for beam dump windows and positron targets)

- The final design for safety, including the structure of radiation shielding, maintenance methods for activated components, measures against leakage of beam dump water, and long-term maintenance of activated materials, is being carried out with international cooperation.

- Specific design of facilities and equipment through industry-academia collaboration
- Studying measures for drainage, earthquake, and radiation (AAA WG)





Civil Engineering of Beam dump cavern (2019)

Briefing sessions to promote understanding among local residents

- Explanation of safety management and environmental impact measures
- Briefing sessions were held at 16 venues, including the Community Exchange Center, in order to broaden the participation of local residents.
- Questions asked at the briefing sessions and answers to questions and concerns raised by local residents were compiled and made available on the website.

https://tipdc.org/inquiries#qa (in Japanese)

KEK, local Universities and local government

Environmental Initiatives

- Environmental impact assessment policy

"ILC Environmental Assessment Advisory Board" was established 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

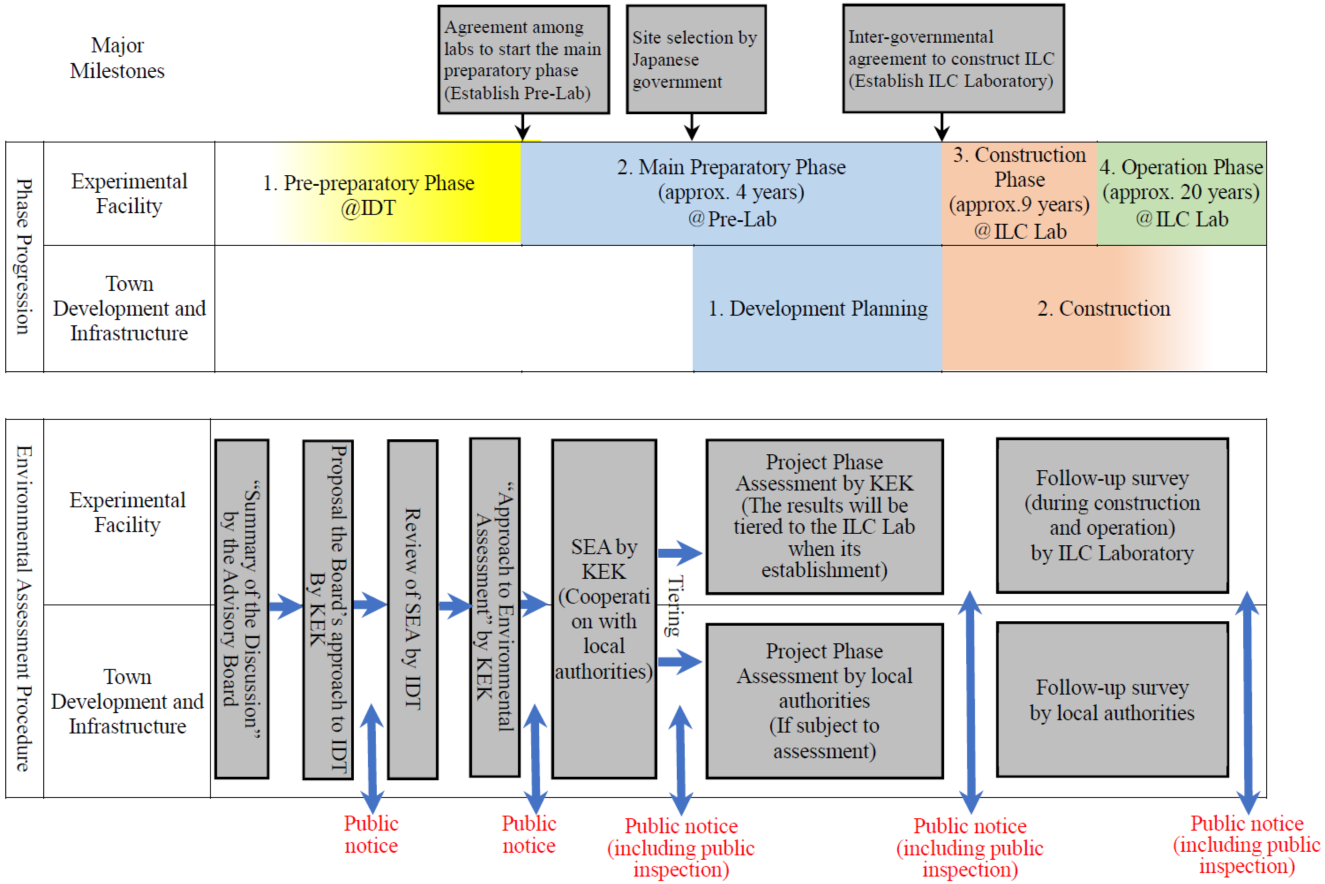


Figure 2: Procedure of Environmental Assessment for the ILC project.

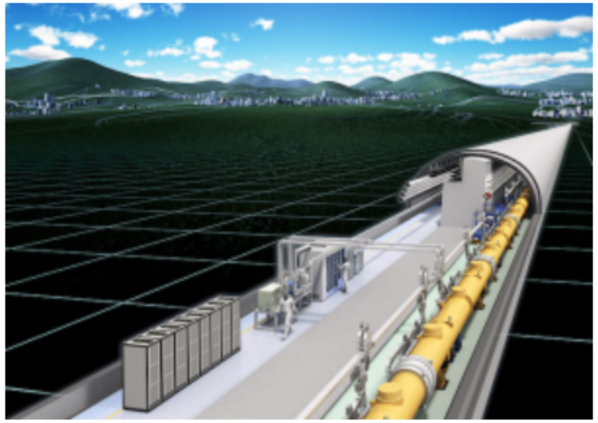
KEK / IDT-WG2

Shin MICHIZONO (KEK)

Pre-lab proposal (2021)

ILC newsline June 1,2021
https://newsline.linearcollider.org/2021/06/01/ilc-preparatory-laboratory-proposal-released/

The ILC International Development Team (IDT) was established by the International Committee for Future Accelerator (ICFA) in August 2020, to prepare the ILC Preparatory Laboratory (Pre-lab) that would complete the technical development and engineering preparation for the International Linear Collider project to be ready for construction. During the same period, governmental authorities of interested nations are expected to forge an agreement on the sharing of the cost and responsibilities for the construction and operation of the ILC facility and on the organisational structure and governance of the ILC Laboratory.



Artist's impression of the ILC. Image: Rey. Hori

After ten months of work, the IDT has achieved the first major milestone of completing the ILC Pre-lab proposal, which outlines the organisational framework, an implementation model and work plan of the Pre-lab. Three working groups were the key players and an impressive number of people have been contributing to this effort. Working Group 1 worked on the mandate, governance model, organisational structure and Pre-lab start-up procedure. Working Group 2 identified necessary technical development and engineering preparation work for the ILC accelerator and site construction. Working Group 3 discussed a strategy for developing the compelling ILC physics programme. Then the Executive Board took the responsibility of compiling the document. It was very encouraging to see the growing number of participants in those activities.

The IDT activity now enters the next phase of implementing the steps for establishing the Pre-lab along the lines described in the proposal. The plan for the accelerator technical development and engineering preparation work needs to be further elaborated and people and laboratories with interest and expertise in the work must be identified. The physics community needs encouragement and support for further exploring the physics potential of the ILC and converging towards concrete designs of experiments. Discussion on the Pre-lab start-up process must be initiated among the world key laboratories.

An equally crucial factor now is to understand what kind of process is needed to achieve the establishment of the Pre-lab. Unlike the ILC itself, the Pre-lab activities will be driven at the level of laboratories rather than having a direct involvement of governmental authorities. For the managements of interested laboratories to engage seriously in the discussion of responsibility sharing for the Pre-lab activities, however, a signal from the Japanese government indicating its interest in hosting the ILC and supporting the Pre-lab would be required. In parallel, we will make further effort to gain more support for the ILC worldwide.

We will continue to do our best for the swift realisation of the Pre-lab. Exciting times are head of us all.

Proposal for the ILC Preparatory Laboratory (Pre-lab)

International Linear Collider International Development Team

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.

Preview

ページ: 1 / 48 自動ズーム

Proposal for the ILC Preparatory Laboratory (Pre-lab)

International Linear Collider
International Development Team

1 June 2021

Full text of Pre-lab proposal:
https://zenodo.org/record/4884744

Technical preparation @Pre-lab (proposed on 2021)

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

ILC Pre-lab

Actual cavity /CM manufacturing

SRF ～41MILCU 285 FTE-yr
- WP-1 Cavity production
- WP-2 Cryomodule assembly
- WP-3 Crab cavity

e- source ～2.5MILCU, 6 FTE-yr
- WP-4 Electron source

e+ source ～6MILCU, 15FTE-yr

Undulator scheme
- WP-5 Undulator
- WP-6 Rotating target
- WP-7 Magnetic focusing

e-Driven scheme
- WP-8 Rotating target
- WP-9 Magnetic focusing
- WP-10 Capture cavity
- WP-11 Target replacement

DR ～2.5MILCU, 30FTE-yr
- WP-12 System design
- WP-13 Collective effect
- WP-14 Injection/extraction

BDS ～2MILCU, 16FTE-yr
- WP-15 Final focus
- WP-16 Final doublet

Dump ～3MILCU, 12FTE-yr
- WP-17 Main dump
- WP-18 Photon dump

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

- 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.

1MILCU=1M$(2012)

MEXT expert panel (2021/2022)

MEXT expert panel had been held in 2021/22 and summary was published on Feb. 2022.
(MEXT: Ministry of Education, Culture, Sports, Science and Technology)

Next step toward the ILC realization: MEXT expert panel publishes recommendations

Topics

https://www.kek.jp/en/topics-en/202202251335/

2022/02/25

KEK has been working on the realization of the International Linear Collider (ILC) in Japan, together with ILC-Japan, a community organization under the Japan Association of High Energy Physicists (JAHEP), the ILC International Development Team (IDT) established by the International Committee for Future Accelerator (ICFA), and other supporting organizations around the world. In June 2021, IDT published the "Proposal for the ILC Preparatory Laboratory (Pre-lab)," which proposes an outline of the organizational framework, an implementation model, work plan and required resources for the preparatory phase of the ILC. At the same time, KEK and JAHEP submitted a report to the Ministry of Education, Culture, Sports, Science and Technology (MEXT) that summarizes progress on ILC activities over the past three years. In response to these developments, MEXT organized an expert panel in July 2021 for discussions to evaluate the progress of the ILC activities. On 14 February, the panel issued their recommendations, pointing out following five main points:

1. The panel recognizes the academic significance of particle physics and the importance of the research activities, including that of a Higgs factory, and understands the value of international collaborative research. However, the panel found that it is still premature to proceed into the ILC Pre-lab phase, which is coupled with an expression of interest to host the ILC by Japan as desired by the research community proposing the project.

2. Given the increasing strain in the financial situation of the related countries, the panel recommends the ILC proponents to reflect upon this fact and to reevaluate the plan. They should reexamine the approach towards a Higgs factory in a global manner taking into account the progress in the various studies such as the Future Circular Collider (FCC) and ILC.

-> International expert panel

3. The panel recommends that the development work in the key technological issues for the next-generation accelerator should be carried out by further strengthening the international collaboration among institutes and laboratories, shelving the question of hosting the ILC.

-> ILC Technology Network

4. For realizing a very large project such as the ILC, cultivating a framework where the related countries can exchange information on their situations and discuss required steps would be important.

-> International expert panel

5. The panel recommends that the research community should continue efforts to expand the broad support from various stakeholders in Japan and abroad by building up trust and mutual understanding through bi-directional communication with the people concerned.

-> ILC-Japan

In light of the panel's findings, KEK will make an effort to reexamine the path for realizing the ILC as a Higgs factory, taking into account the progress in various fronts including the FCC feasibility study. In this process, the interaction with the domestic and international research community as well as the opportunities in the exchange of information through ICFA will be crucial. Also, in collaboration with the IDT, KEK will propose a framework to ICFA to address some of the pressing accelerator R&D issues for the Pre-lab, where joint developments will be done by the participating laboratories on the selected subjects. KEK and the Japanese ILC community is committed to further advance important technological and engineering development in the accelerator area and to continue the effort for the realization of the ILC.

Furthermore, KEK, in collaboration with ILC-Japan, will establish a new organization that will centrally manage ILC communications activities. The new organization will strengthen activities to communicate the significance of the ILC to all parties involved, such as the general public, academia, or industry, focusing on communicating the importance to build an international laboratory for basic science, which will contribute greatly to the development of a new generation of scientists and advancement of knowledge, science and technology.

KEK endeavors to promote these activities for the realization of the ILC in the future, maintaining a relationship of trust with related organizations.

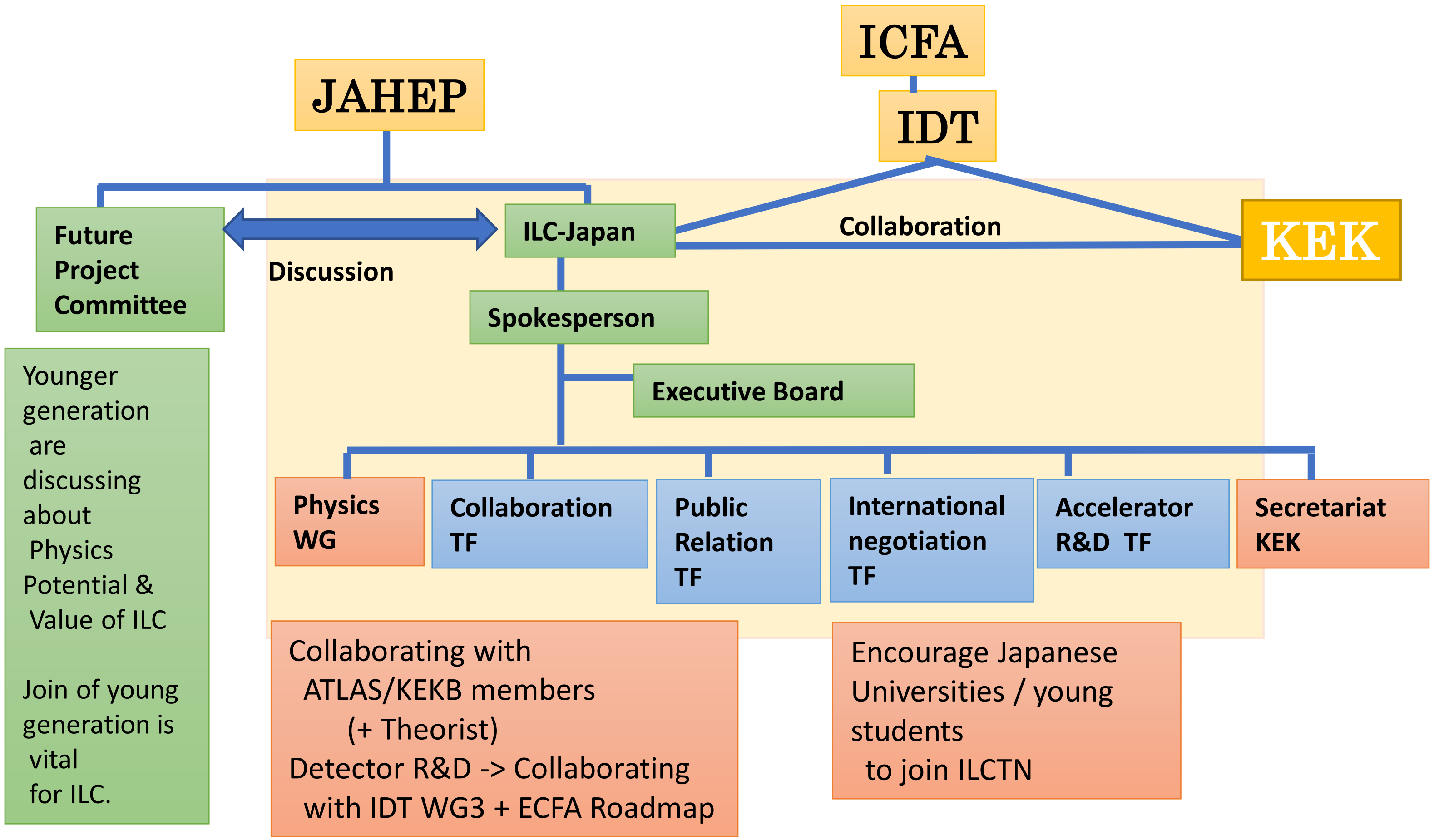
Related Sites

Summary of Discussions on Issues Related to the International Linear Collider (ILC) Project (written in Japanese)

https://www.mext.go.jp/content/20220401-mxt_kiso-000020463_9.pdf

New scheme for ILC ILC-Japan (May 2021)

Shoji ASAI
@LCWS2023



- ILC-Japan represents the community for ILC Promotion.
- Spokesperson is Prof. Shoji ASAI (U. Tokyo).
- Tight collaboration with KEK and IDT.

ILC Technology Network (in progress)

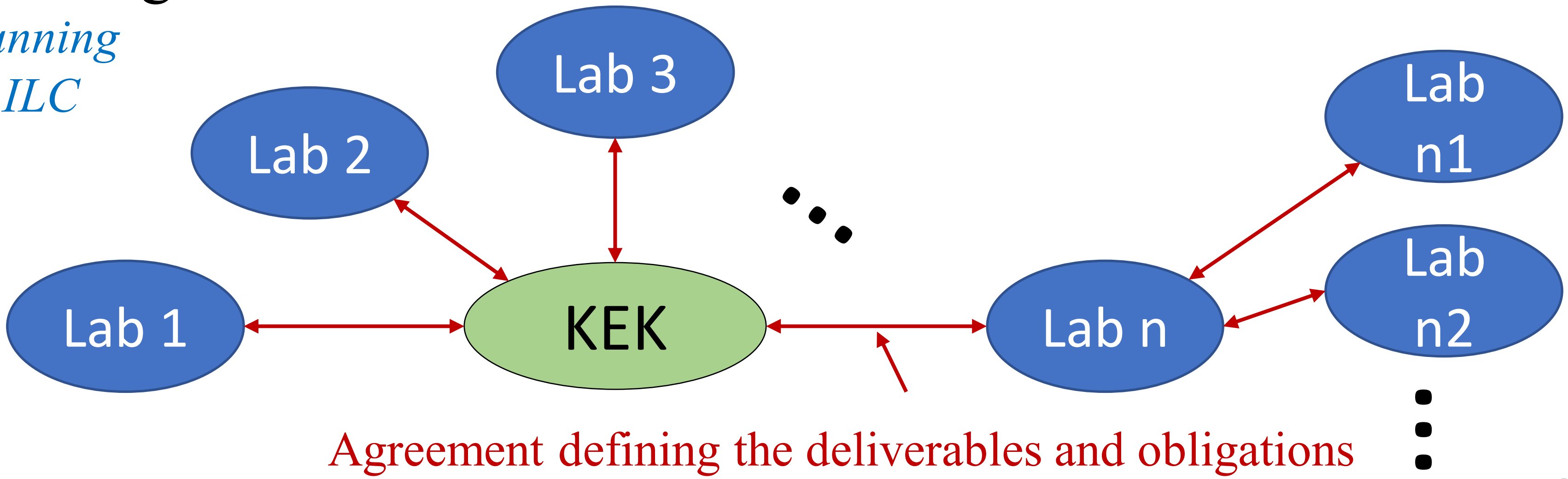
Tatsuya NAKADA
@LCWS2023

Move forward with engineering study, benefiting from the fact that:

- Pre-lab proposal identified the necessary technical preparations for ILC construction
- Many of the identified topics are in line with broader interests in accelerator R&D
- Increased Japanese budget for the ILC related technology R&D provides a seed for required resources

ILC Technology Network (ITN), based on bilateral agreements between KEK and partner laboratories worldwide, has been launched to execute important work packages, based on its own organisation.

NB: IDT-WG2 will continue planning and overall coordination of the ILC accelerator development,



International Expert Panel (in progress)

Setting up the IDT International Expert Panel, for

Step 1 **Developing a path for a global project adoptable for the ILC:**

- Establish the full lifecycle of an accelerator global project, adoptable to the ILC
- Identify decision points and decision makers in the lifecycle
- Identify associated responsibilities for the decision makers
- Identify consequence of those decisions.
- Share this idea with the government authorities (CA, CERN, DE, ES, FR, GB, IT, JP, US and possibly others)
- Produce a discussion document summarising the emerging consensus

Step 2 **Developing the ILC decision roadmap by adopting this path**

- Adapting the ILC realisation to the process described in the discussion document
- Achieving the consensus among the government authorities for the adaptation.
- Producing a second discussion document

After this exercise, the governments might be in a better position to discuss the ILC, which could lead us to the Pre-lab and beyond.

Tatsuya NAKADA
@Snowmass 2022
https://indico.fnal.gov/event/22303/timetable/?view=standard

IDT International Expert Panel members

Panel members

Ursula Bassler	(FR)
Philip Burrows	(GB)
Beate Heinemann	(DE)
Stuart Henderson	(US, ICFA Chair)
Karl Jacobs	(DE, EFCA Chair)
Andrew Lankford	(US, IDT-EB Americas)
Nadia Pastrone	(IT)
Antonio Pich	(ES)
Steinar Stapnes	(CERN, IDT-EB Europe)
Nigel Smith	(CA)
Geoffrey Taylor	(AU, IDT-EB Asia-Pacific)
Katsuo Tokushuku	(JP)

Core Group
- Andrew Lankford
- Steinar Stapnes
- Geoffrey Taylor

Chair
- Tatsuya Nakada (IDT-EB Chair)

Scientific Secretary
- Wataru Ootani (IDT EB Scientific Secretary)

Current Status and Future Technological Collaboration for the ILC

KEK / IDT-WG2
Shin MICHIZONO (KEK)

1. Why linear collider?
2. Higgs Factory
3. Global Collaboration
4. ILC Accelerator
   - ILC design
   - Recent Progress
   - Candidate site
5. Pre-lab proposal
6. ➡ **Global Project**
7. ILC Technology Network
8. KEK's effort
9. Future Upgrade
10. Beam dump (industrial application)
11. Sustainability
12. Summary

Global project

Global project: Starts and evolves as a collaborative project of partner countries who make collective decisions on all aspects of the project, such as the scheme for cost and responsibility sharing, project organisation, and host and site location. The ownership is shared among the partners. ITER (an example of top down approach) and SKA (an example of bottom up approach) are examples of large global projects, while HEP projects to date have been international projects.

International project: Initiated as a project of a laboratory with a limited international participation, a total of *O*(10~20%) of the accelerator, like HERA (started as a DESY project) and LHC (started as a CERN project). This fraction may become larger but the ultimate ownership remains with the initiator.

NB: Implementation of ITER is not necessarily judged as a success, but they succeeded to start as a global project.

ILC as a global project

Technical work of ILC has already advanced to a post-TDR stage by the global effort under the GDE guidance. Meanwhile, there has been no regular discussion among the partner government authorities to drive the project forward politically, apart from exchanging "information" at FALC meetings. For this reason, there has been little advance in realisation of ILC as a global project.

For both ITER and SKA, the government authorities of partner countries had regular interactions and drove the political side of the progress, including site and host decision, in parallel with the technical development made by the community.

Japanese HEP community sought the government to declare its interest to host, supported by some Diet members. The government expressed its interest in ILC (2019), however considers that the decision of the host/site should be made through discussion among the partner countries as the evolution process of a global project.

Federation of Diet members meeting

Federation of Diet Members had the extended plenary meeting

27th April 2023

Shoji ASAI
@LCWS2023

(about 150 joined:
close 30 Diet members)

(By Sugawara-san Kesennuma mayor)

visited two Minsters with Diet members
to explain the resolution (next page).

Minister of State for Science and Technology Policy

(By Takaichi-san Minster)

Minister of Education, Culture, Sports, Science and Technology

(By Fujiwara-san
Diet member)

Resolution on the Promotion of ILC Project

Shoji ASAI
@LCWS2023

- The ILC International Development Team（**IDT**）, in **strong collaboration** with **ILC Japan**, an organization of related researchers in Japan, and the High Energy Accelerator Research Organization (**KEK**), is steadily building the **ILC Technology Network (ITN),** an organization dedicated to perfecting ILC-related technologies through collaboration among accelerator research institutes around the world.
- The IDT has established an "**International Expert Panel**", whose progress is well underway, to organize a roadmap for the realization of **a large-scale accelerator as a global project** and the concept of responsibility sharing, and based on these discussions, to provide a forum for explanations and discussions to the governments of individual countries.
- Since the ILC project cannot be realized by one country alone and international cooperation is essential, **the Japanese government should work closely with researchers** who promote the above activities and exchange views with the governments of the countries concerned.
- Steadily **promote the development of next-generation accelerator technology** that will lead to the promotion of the ILC project under appropriate international cooperation, and **ensure that the necessary budget is secured** for this purpose.

Some parts are picked up. you can find all in appendix.

Current Status and Future Technological Collaboration for the ILC

KEK / IDT-WG2
Shin MICHIZONO (KEK)

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3. Global Collaboration
4. ILC Accelerator
   - ILC design
   - Recent Progress
   - Candidate site
5. Pre-lab proposal
6. Global Project
7. ➡ **ILC Technology Network**
8. KEK's effort
9. Future Upgrade
10. Beam dump (industrial application)
11. Sustainability
12. Summary

IDT Scope for ILC Realization

-success oriented and asuming no major incident-

Technology Network Phase	Preparatory Phase	Construction Phase ~10 years for the construction and commissioning

2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 • • •

R&D and effort to gain a common view and understanding.

ILC preparation laboratory and intergovernmental discussion

2021 May

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

Work Packages (**WPs**) for ILC Pre-Lab

http://doi.org/10.5281/zenodo.4742018

2022 June

Time-critical WPs for the ILC construction

WP-Primes for Time Critical

https://agenda.linearcollider.org/event/9649/attachments/38003/60567/Time-Critical_WPsV8b.pdf

ILC Technology Network (ITN)

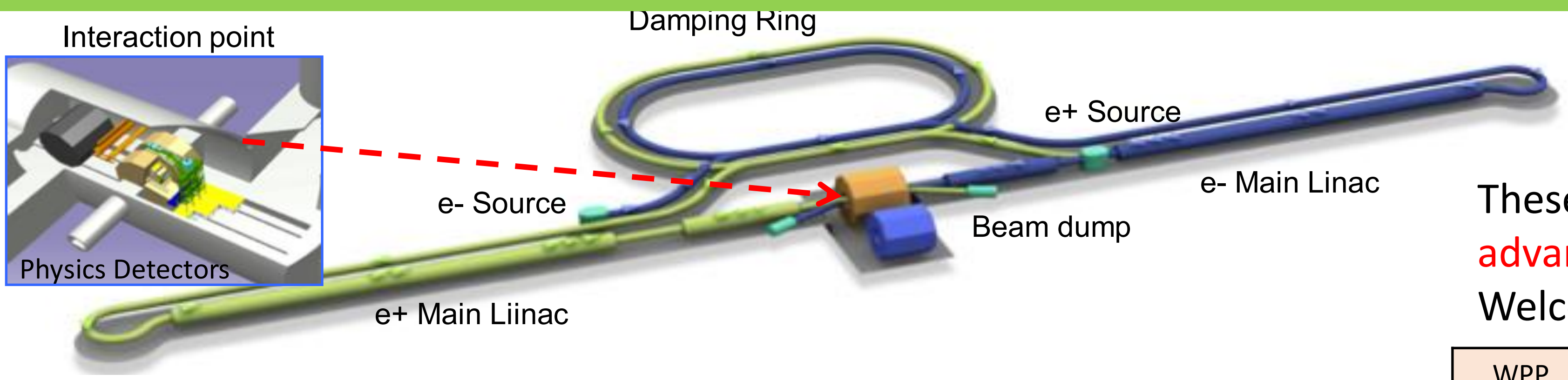
-- global collaboration program---

- **Acc. R&Ds** focusing on
  - SRF
  - e- & e+ Sources
  - Nano-beam

Synergy with other colliders

KEK obtained a budget for these R&Ds and started the activity from this April.

WP-Primes at ILC Technology Network



These WPs can be applied to various advanced accelerators.
Welcome to join!

- Creating particles — ***Sources***
  - polarized elections / positrons
- High quality beams — ***Damping ring***
  - Low emittance beams
    - Small beam size (small beam spread)
    - Parallel beam (small momentum spread)
- Acceleration — ***Main linac***
  - superconducting radio frequency (SRF)
- Getting them collided — ***Final focus***
  - nano-meter beams
- Go to ***Beam dumps***

SRF

e-, e+ Sources

Nano-Beam

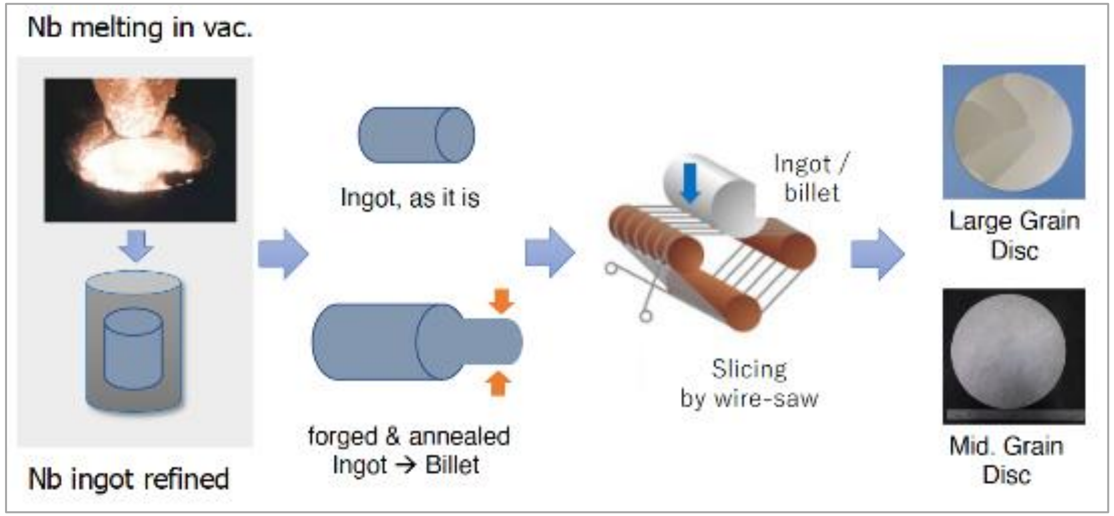
WPP	1	Cavity production
WPP	2	CM design
WPP	3	Crab cavity
WPP	4	E- source
WPP	6	Undulator target
WPP	7	Undulator focusing
WPP	8	E-driven target
WPP	9	E-driven focusing
WPP	10	E-driven capture
WPP	11	Target replacement
WPP	12	DR System design
WPP	14	DR Injection/extraction
WPP	15	Final focus
WPP	16	Final doublet
WPP	17	Main dump

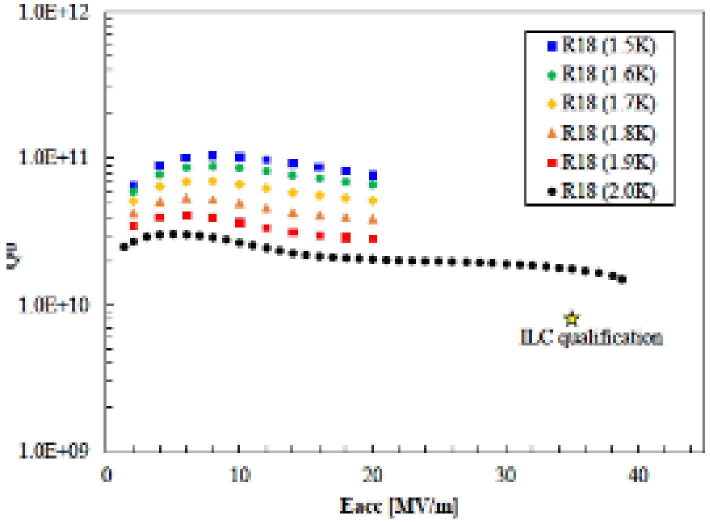
WP-prime 1: SRF Cavity
(Scoping the Industrial-Production Readiness)

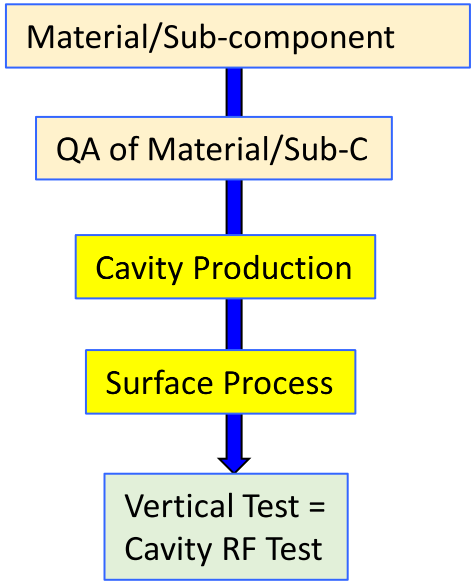
Referring European XFEL and LCLS-II experiences

- Research with single-cell cavities to establish the best production process including:
  - Advanced Nb sheet production method
  - Advanced surface treatment recipe
- Globally common design with compatible High Pressure Gas Safety (HPGS) regulation
- 24 nine-cell cavities are to be developed for industrial-production readiness
  - 8 cavities (4 / batch) in each region
  - Production process encouraged to be optimized in each region
  - Cavity performance expected: E_{acc} = <35 MV/m> (+/– 20%), $Q_0 = 1.0 \times 10^{10}$, Yield = ≥90%
- RF performance/success yield to be examined (including 2nd pass and further)
  - 3rd pass to be examined if effective

	# of cavities to be produced		
	Americas	Europe	JP/Asia
single-cell	2	2	2 (+4)
nine-cell	8	8	8 (+ 4)





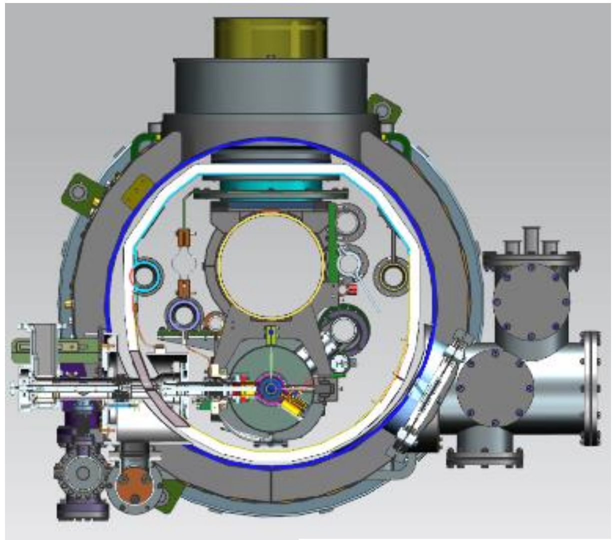


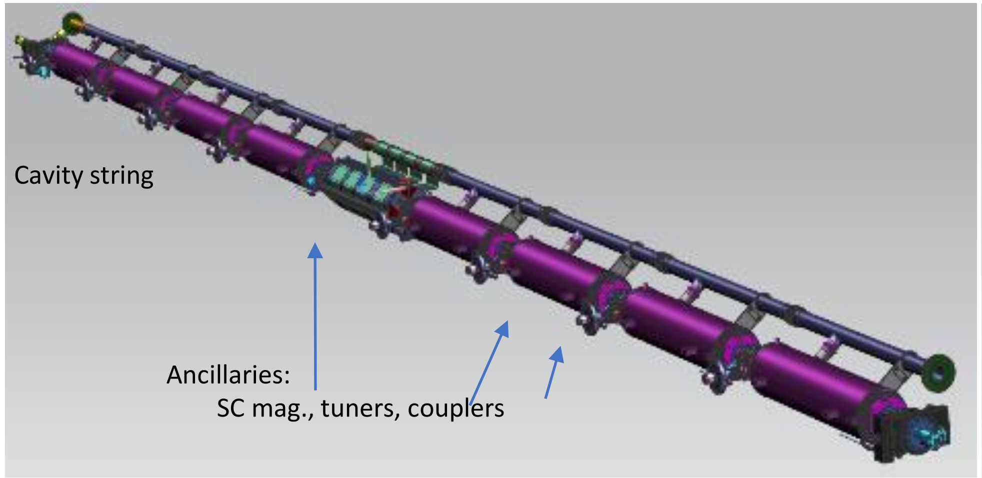
Production process

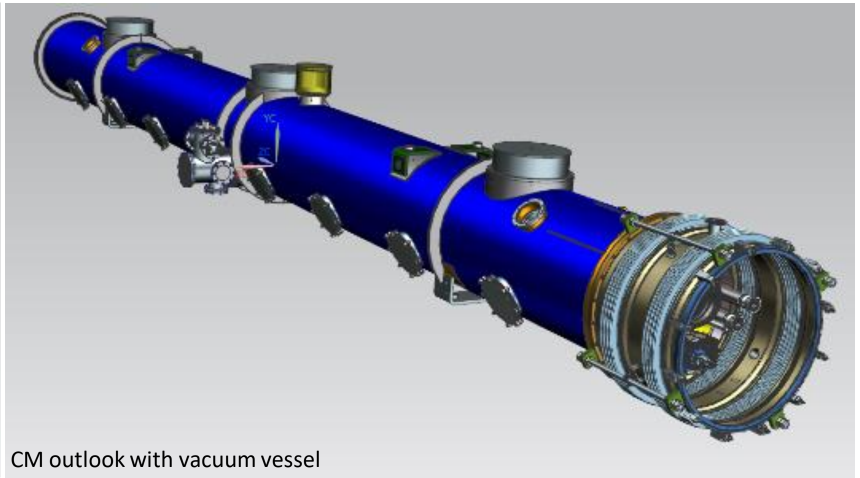
WP-prime 2: Cryomodule (CM) Design
(Scoping the CM Global Transfer and Performance Assurance)

Referring European XFEL and LCLS-II experiences

- ◆Unify cryomodule (CM) design with ancillaries, based on globally common engineering design, drawings & data-base
- ◆Establish globally compatible safety design base to be approved/authorized by HPGS regulations individually in each region, most likely referring ASME guidelines to be compatible with Japanese regulations.







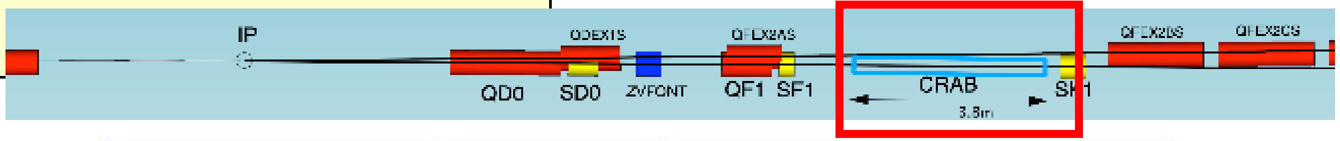
Region Regulation	Americas ASME	Europe Eu-EN, TUV	Japan/Asia JP-HPGS Act
CM tech. design base	LCLS-II	Euro-XFEL	KEK-STF, AST-IFMIF
ILC CM design	Common CM design globally compatible to HPGS regulation in all regions, and most likely ASME guidelines to be compatible with Japanese regulations.		

WP-prime 3: Crab Cavity Development

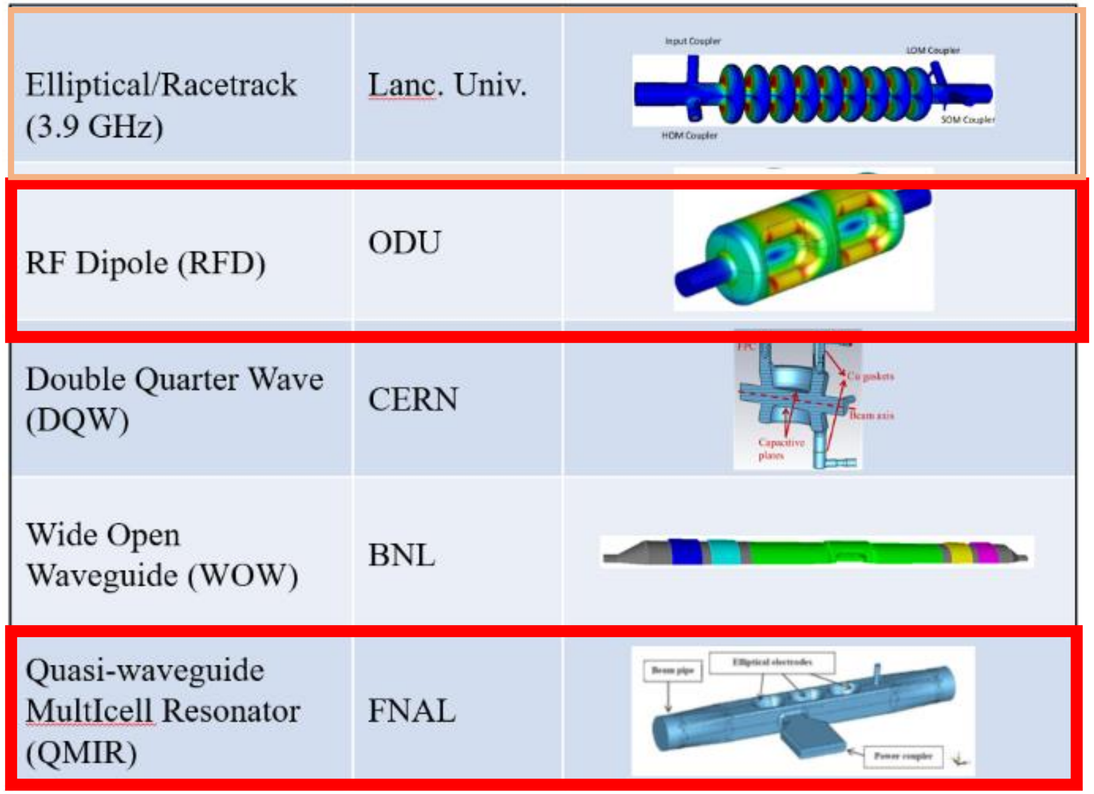
- Pre-down-selection review held at KEK on Apr/2023 chose two primary candidates
  - RFD (1st), QMiR (2nd), Elliptical (3rd)
- Development and evaluation of two prototype cavities
- Demonstration of synchronized operation with two prototypes
- Down-selection to choose final cavity design
- Cryomodule design based on final cavity design

two beamline distance

14.049m x 0.014rad = **197mm**



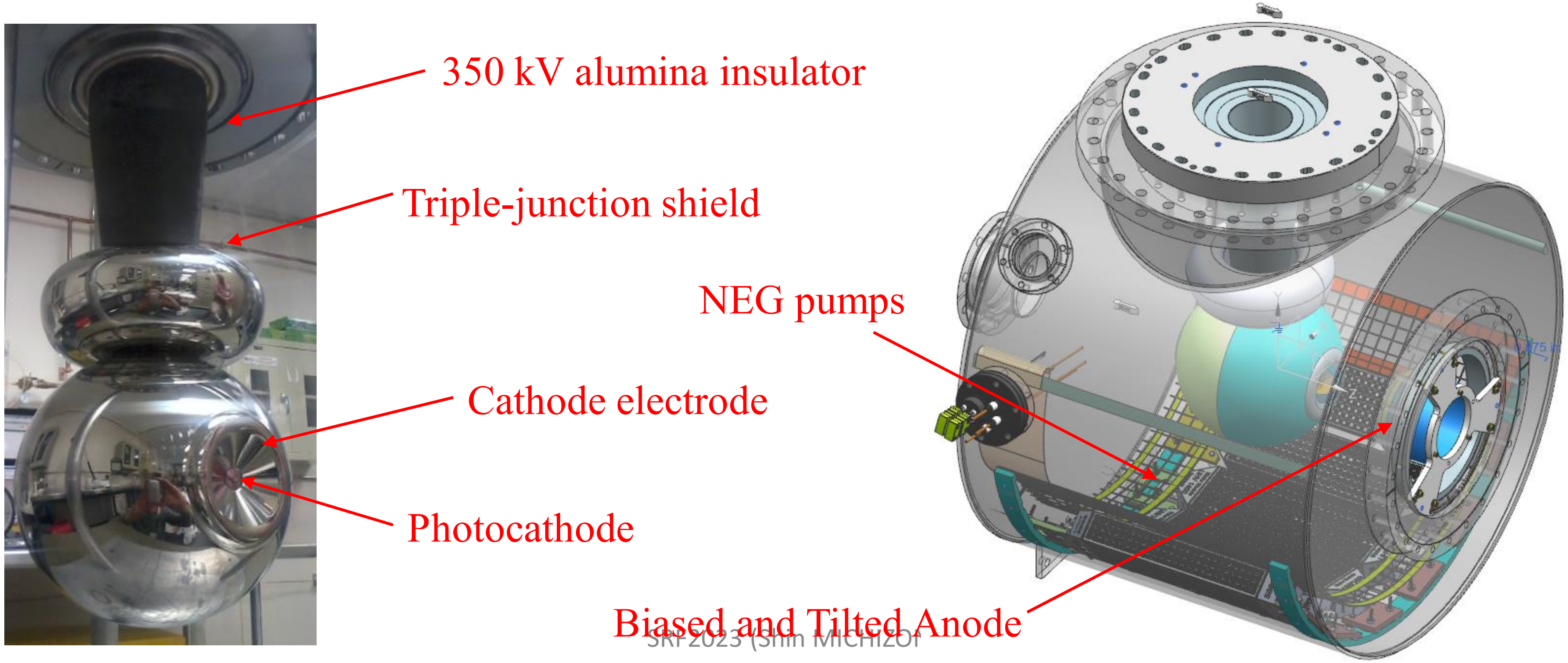
Item	Recent specification (after TDR)
Beam energy	125 GeV (e^-)
Crossing angle	**14 mrad**
Installation site	14 m from IP
RF repetition rate	5 Hz
Bunch train length	727 μsec
Bunch spacing	554 nsec
Operational temperature	2.0 K (?)
Cavity frequency	1.3/3.9 GHz
Total kick voltage	1.845/0.615 MV
Relative RF phase jitter	0.023/0.069 deg rms (49 fs rms)



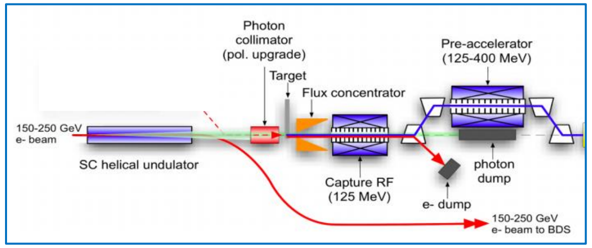
Elliptical/Racetrack (3.9 GHz)	Lanc. Univ.	
RF Dipole (RFD)	ODU	
Double Quarter Wave (DQW)	CERN	
Wide Open Waveguide (WOW)	BNL	
Quasi-waveguide MultIcell Resonator (QMIR)	FNAL	

WP-prime 4: Electron Gun

- The electron gun consists of
  - High-voltage photo gun
  - Drive laser system
  - GaAs/GaAsP Photocathode
- High-voltage gun is the most urgent item
  - The gun voltage in TDR is 200 kV. A higher voltage desirable.
  - Meaningful technical progresses since TDR would be reflected in a new design
  - New GaAs gun based on lessons learned from 350 kV CsKSb magnetized dc photogun



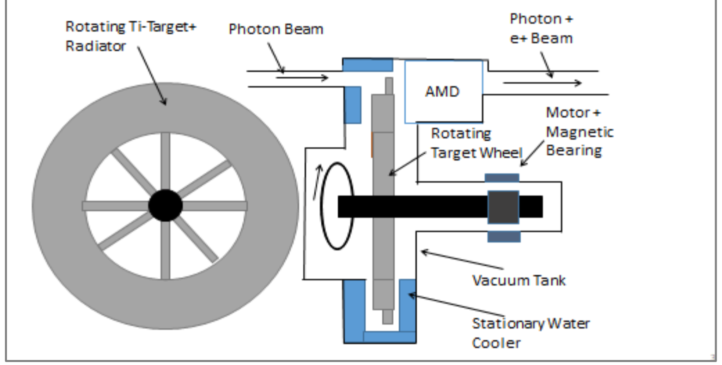
WP-Prime 6/7:
Undulator-driven e+ Source



WP-prime 6: Rotating Target for Undulator Scheme

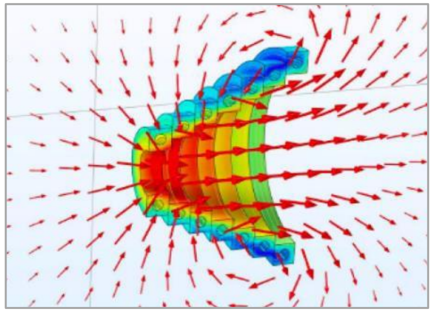
- Target specification
  - Titanium alloy, 7mm thick (0.2 X_0), diameter 1m
  - Rotating at 2,000 rpm (100 m/s) in vacuum
  - Photon power ~60 kW, deposited power ~2 kW
  - Radiation cooling
  - Magnetic bearings
- R&D to be done as WP-prime
  - Design finalization, partial laboratory test, mock-up design (in the first 2 years)
  - Magnetic bearings: performance, specification, test (in the remaining years)

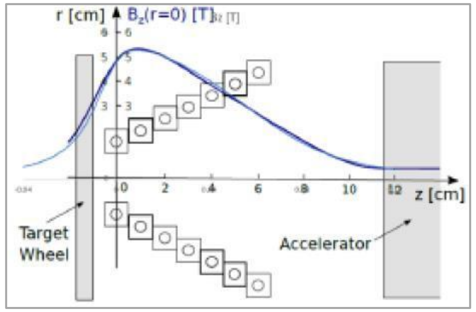
Principal Layout: Ti-Wheel with a Diameter of 1.0 m, rotating at 100 m/s, 2000 rpm.



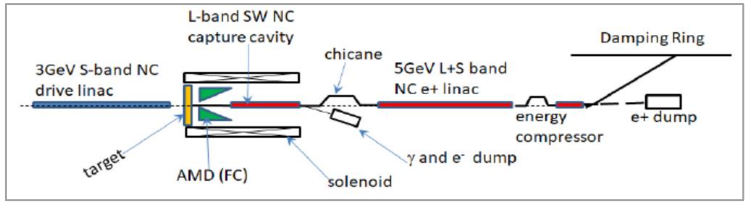
WP-prime 7: Focusing System for Undulator Scheme

- The critical item for the undulator scheme is the magnetic focusing system right after the target
- Possible candidates are: (a) Pulsed solenoid, (b) Plasma lens
- The strongest candidate is (a) pulsed solenoid.
- R&D items to be done as WP-prime
  - Detailed simulations for (a) (already on-going)
  - Principal design for a prototype pulsed solenoid
  - Field measurements with 1kA (pulsed and DC) and with 50kA both in a single pulse mode and finally in a 5ms pulsed mode
  - Prototype of (b) plasma lens (funded study on-going)





WP-Prime 8~11:
Electron(e-) driven positron source (1/3)

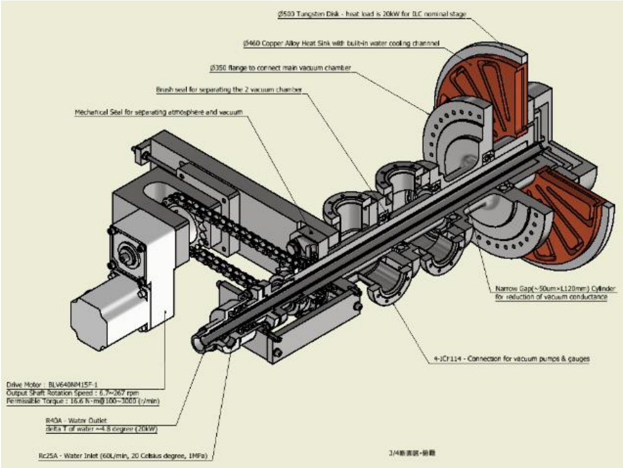


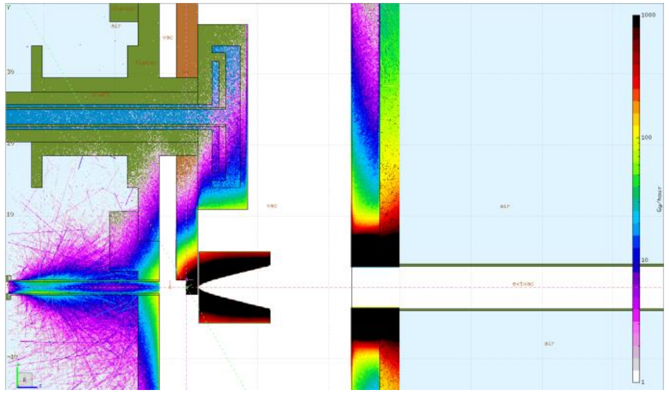
WP-prime 8: Rotating Target for e-Driven Scheme

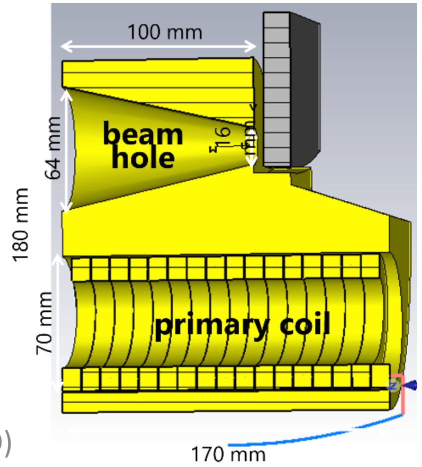
- Target specification
  - W or W-alloy, ~16 mm (5 X_0) thick, diameter 50 cm
  - Rotating at 5 m/s in vacuum
  - Water cooled.
  - Vacuum seal
- R&D items to be done in 2 years
  - Target stress calculation with FEM
  - Vacuum seal
  - Target module design and prototyping
  - W-Cu connection test and evaluation

WP-prime 9: Focusing System

- Flux Concentrator (FC) is chosen as the focusing device after the target
- The specification parameters such as max field, electric current and the dynamic force are satisfied in existing target, but the pulse energy and the heat load are higher.
- A prototype necessary after detailed design study
- R&D items as WP-prime
  - Flux concentrator conductor design (in first 2 years)
  - Conductor prototyping (in the remaining years)

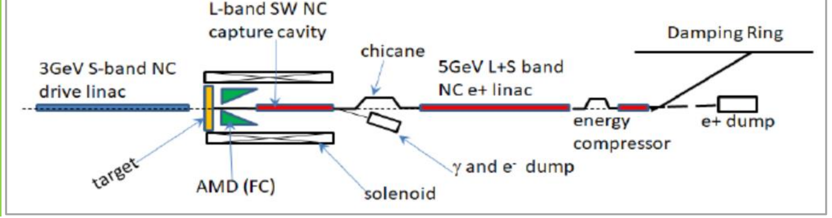






Parameter	ILC FC	Unit
Max. B field	5	T
Max. surf. current	25	KA
Dynamic force	125	kA.T
Pulse energy	140	J
Average Power	13.7	kW

WP-Prime 8~11:
e- driven positron source (2/3)

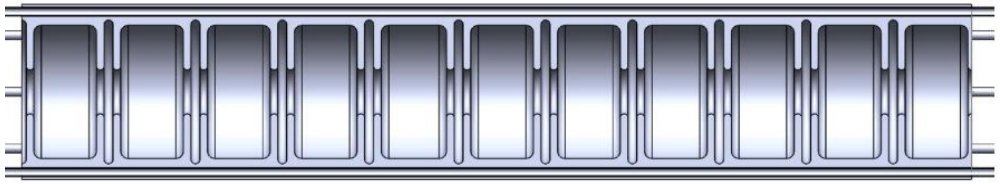


WP-prime 10: Capture Cavity and Linac for e-Driven Scheme

- Technically the most critical element is the L-band, standing-wave structure right after the target and FC.
  - High beamloading (up to ~1A)
  - Special bunch pattern
  - Changing beam current (mixed electron-positron, capture process in RF buckets)

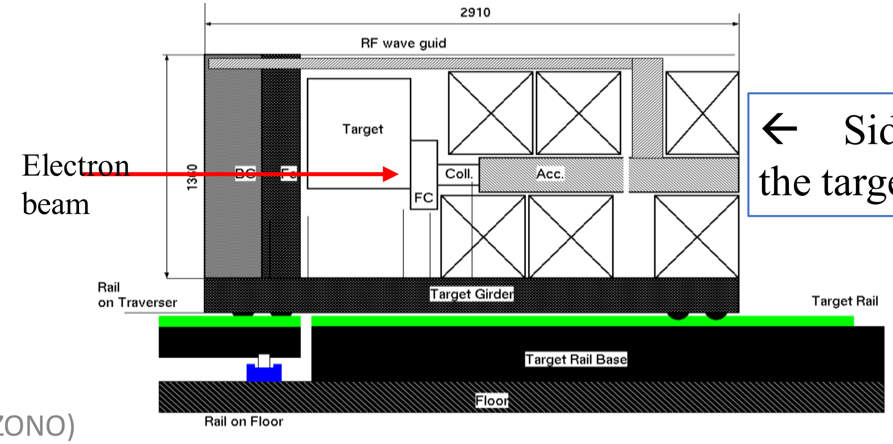
- R&D items as WPP-10 for the first 2 years
  - APS (Alternating Periodic Structure) cavity design and cold model
  - Beam-loading compensation and tuning method
  - Power unit prototype design
  - solenoid design
- Prototyping of these components in later years

APS cavity



WP-prime 11:Target replacement

- Special attention is needed due to the high radiation of the target area. This is a common issue for E-Driven and Undulator positron source.
- Careful design of shielding is required.
- The components near the target (target, flux concentrator, first cavity with solenoid) require replacement in every few years. The work must be done remotely.
- The works to be done as WP-prime
  - Conceptual design
  - Mockup fabrication
  - Prototyping of critical components



← Side view of the target module

WP-prime 12/14: Damping ring

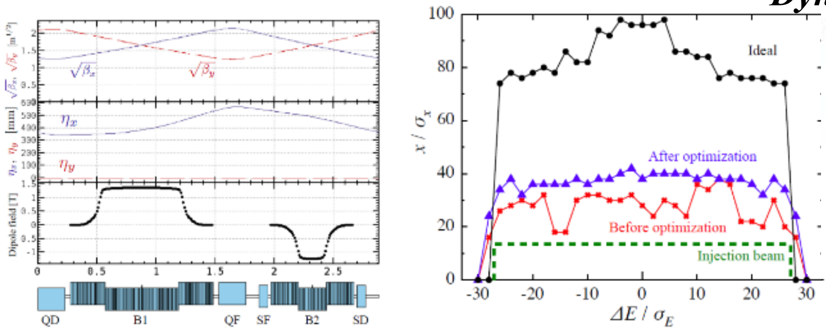
WP-prime 12: System design of ILC DR

- ◆The ILC damping ring (DR) is required to satisfy the low emittance and the large dynamic aperture simultaneously.
- ◆The ILC DR will be further improved by incorporating the findings of the latest light source design. Increasing the dynamic aperture is also important in the design of DR.
- ◆By quantitatively evaluating the effect of fringe field to the dynamic aperture of magnets in ILC DR, the method for evaluating fringe field to the dynamic aperture in accelerator design will be established and the design of ILC DR will be optimized.

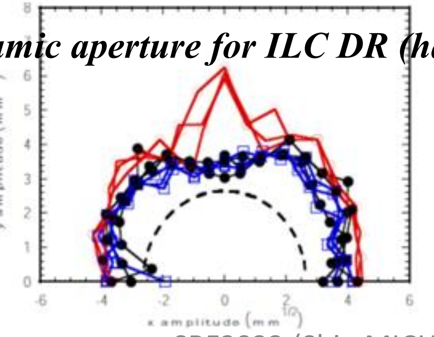
WP-prime 14: System design of ILC DR injection/extraction kickers

- ◆A fast kicker system using a semiconductor pulse power supply with nanosecond response was confirmed as proof of principle at KEK's ATF about 10 years ago.
- ◆Semiconductor technology has been evolving, and it is now possible to advance nanosecond response beam injection/excitation systems using the recent semiconductor technology.
- ◆The technical evaluation of the fast kicker power supply using the recent semiconductor technologies.
- ◆The evaluation of fast pulsed power supply technology will contribute not only to the fast kicker system but also to the performance and reliability of nanosecond-scale beam control technology and its application to a wide range of accelerator systems.

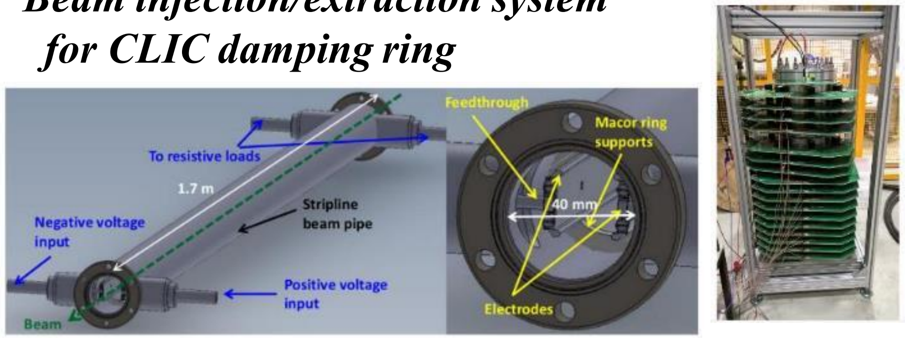
Dynamic aperture evaluation with fringe effect (SuperKEKB DR)



Dynamic aperture for ILC DR (hard edge)



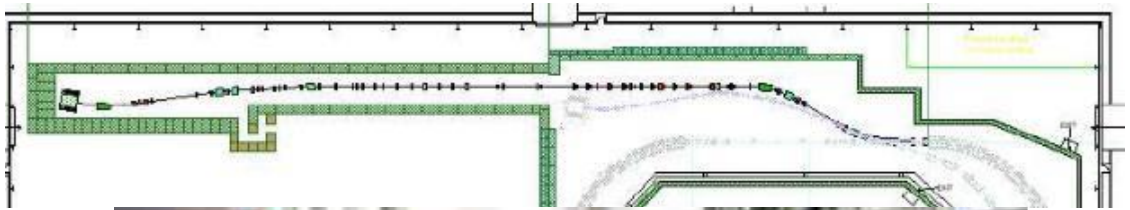
Beam injection/extraction system for CLIC damping ring



WP-prime 15: System design of ILC FFS

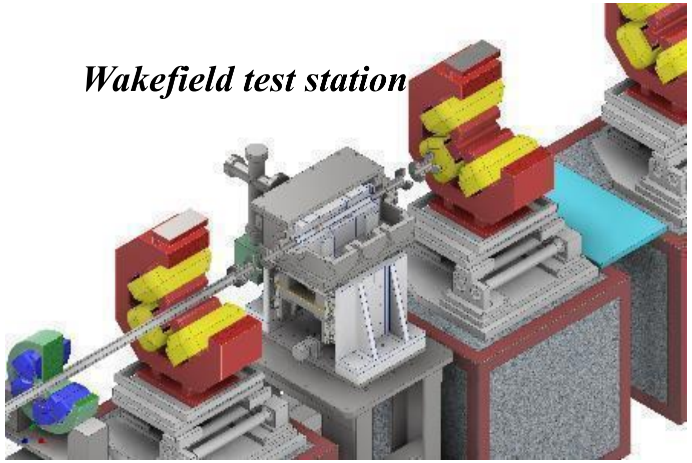
ATF collaboration

- ATF2 beamline is the only existing test accelerator in the world to test the final focus system (FFS) of linear colliders.
- The following 3 research topics are important to be pursued at the ATF.
  - wakefield mitigation
  - correction of higher-order aberration
  - training for ILC beam tuning
- The technical research at ATF2 beamline has proceeded and should continue to be based on the ATF international collaboration, or its extension (welcome to new collaborators).

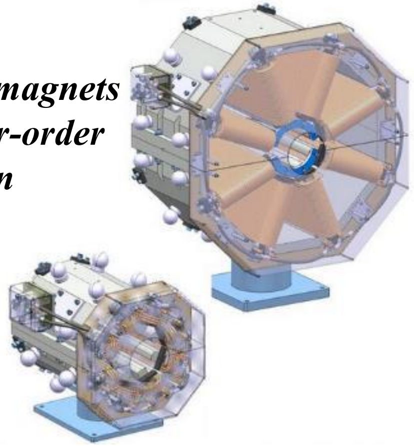


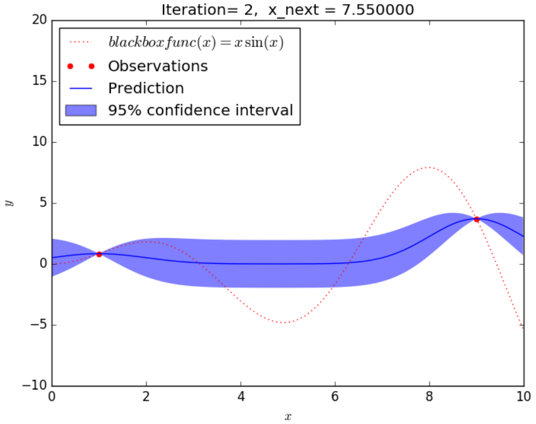
Maximum search algorithms to be applied to beam tuning (Machine Learning)

Wakefield test station



Octupole magnets for higher-order aberration





WP-prime 16/17:Final doublet/Beam dump

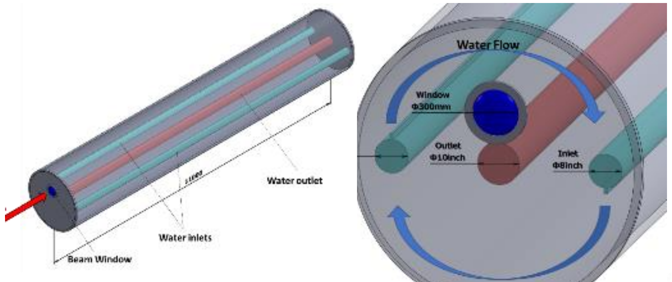
WP-prime 16: Final doublet design optimization

- ◆Cooling of the superconducting ILC final focus magnets will be performed using 2K superfluid helium to realize superconducting magnets with high oscillation stability.
- ◆Quantitative evaluation of the vibration generated by the 2K cooling system located on the side of the final focus magnets has not been completed.
- ◆We will measure and evaluate the vibration generated by the 2K cooling system by using the prototype.

Prototype of ILC service cryostat
(2K cooling system ; BNL)

WP-prime 17: Beam Dump

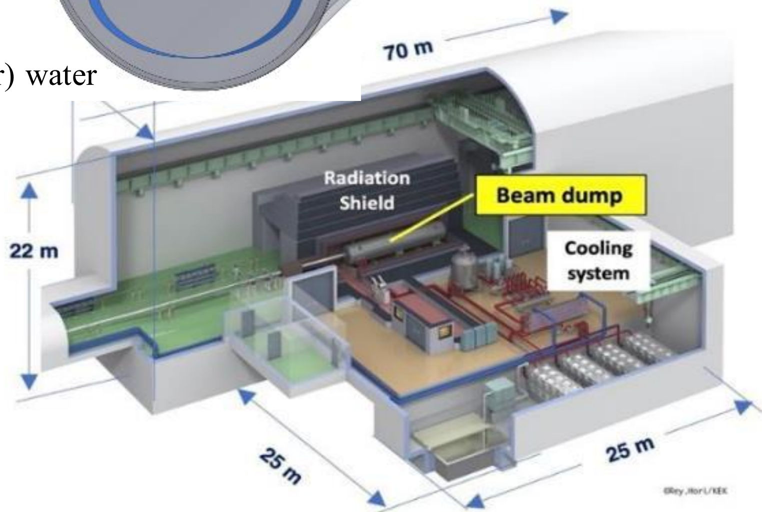
- ◆ Finalize the engineering design of the main beam dump system
  - ● Vortex water flow in the dump vessel
  - ● Cooling water circulation and heat exchange
  - ● Remote exchange of the beam window
  - ● Countermeasure for failures / safety system



11m-long x 2m(diameter) water

Vortex water flow

- ● **17 MW** at 500 GeV beam
- ● 1 MPa to prevent boiling



Imaginary view of the main dump section

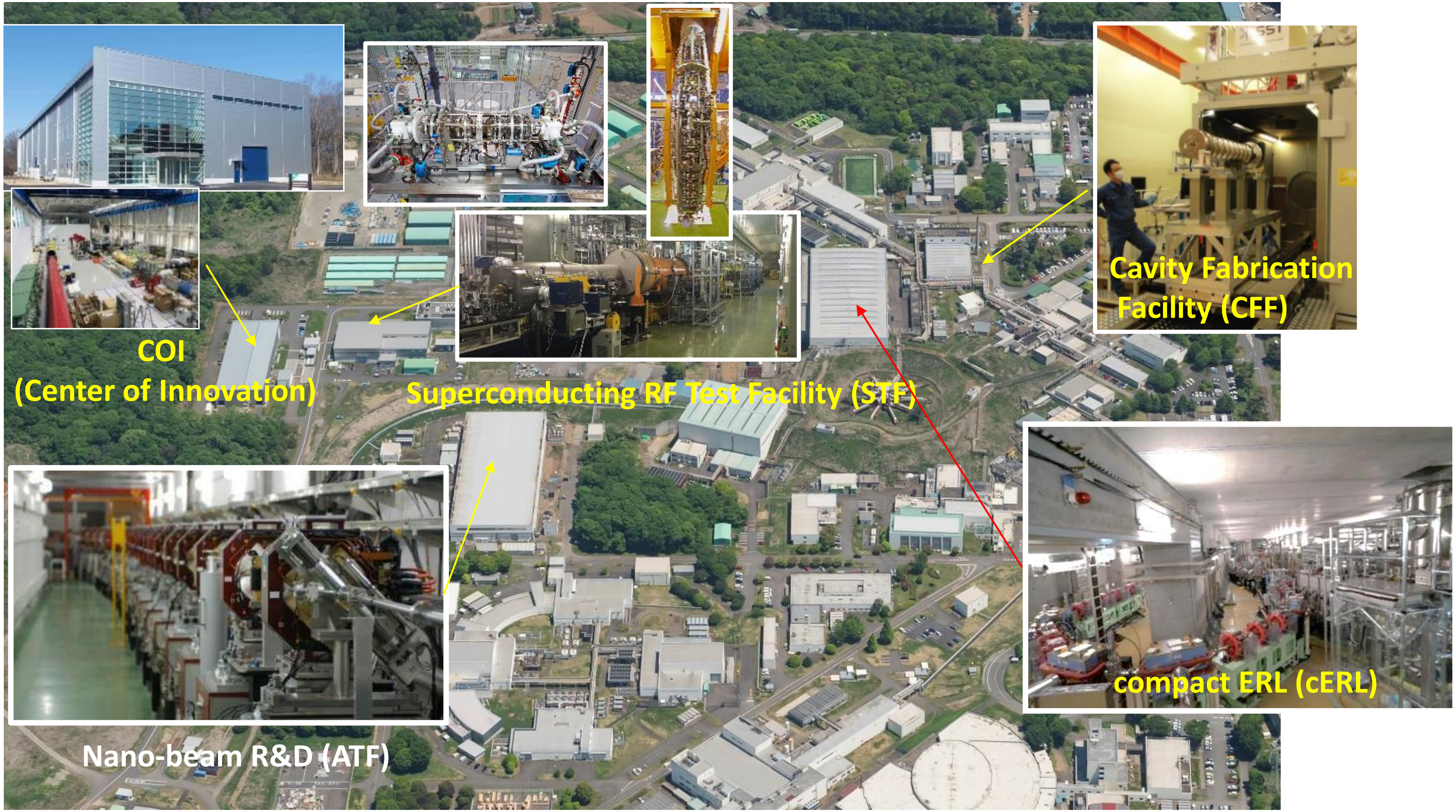
Current Status and Future Technological Collaboration for the ILC

KEK / IDT-WG2

Shin MICHIZONO (KEK)

1. Why linear collider?
2. Higgs Factory
3. Global Collaboration
4. ILC Accelerator
   - ILC design
   - Recent Progress
   - Candidate site
5. Pre-lab proposal
6. Global Project
7. ILC Technology Network
8. ➡ KEK's effort
9. Future Upgrade
10. Beam dump (industrial application)
11. Sustainability
12. Summary

Advanced accelerator facilities at KEK



Superconducting RF (SRF) related facilities –STF & CFF-

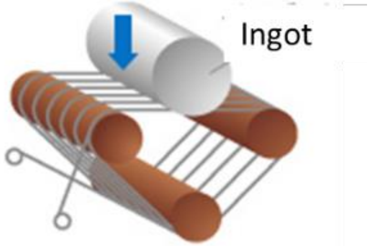

508MHzTRISTAN (1989)

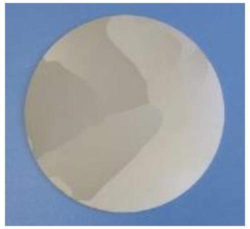

508MHzKEKB (1998)

SRF cavity R&D since 1980s
Experiences at TRISTAN/KEKB/SuperKEKB

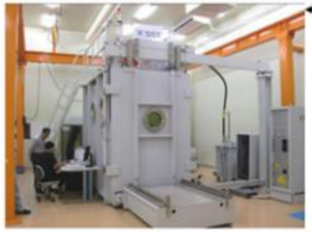

STF (2005-) for Superconducting Cavity Evaluation

CFF(2011-) cavity fabrication facility

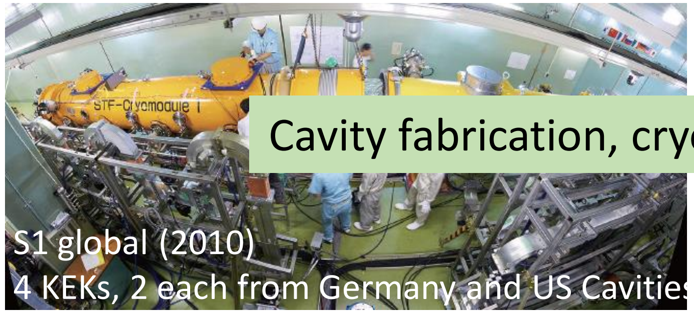




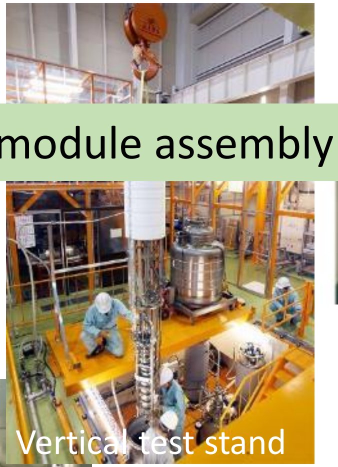
Cavity material R&D at CFF


EBW

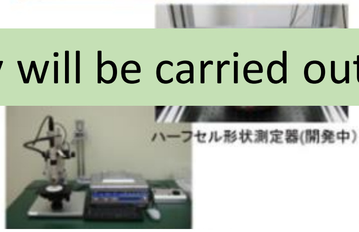
Chemical polishing



S1 global (2010)
4 KEKs, 2 each from Germany and US Cavities


Vertical test stand

Cavity fabrication, cryomodule assembly will be carried out.

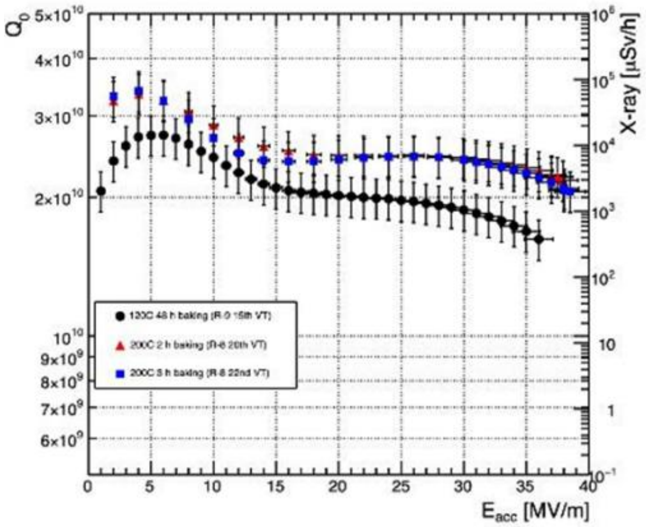


Surface Inspection

Press machine


Vertical lathe

High-Q/G R&D at STF




STF-2(2016～)
14 srf cavities

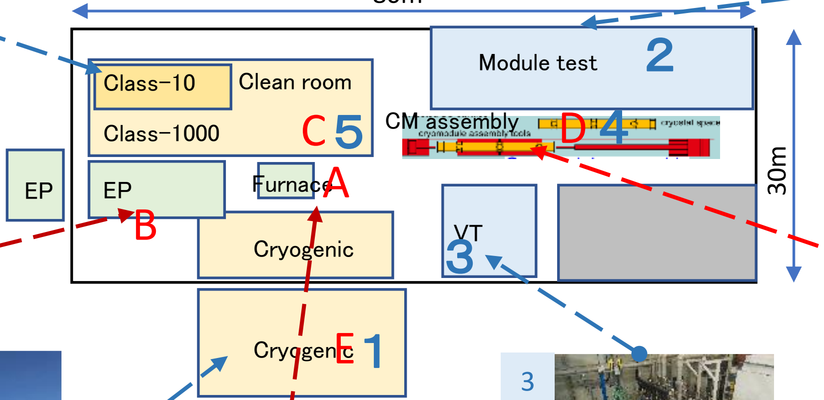
COI (SRF infrastructure)

Current status	Future
A) Heat treatment B) Electro polishing (EP) C) Clean room D) Cryomodule (CM) Assembly (partly done) E) Cryogenic system (partly done)	1. Cryogenic system upgrade 2. High power rf system for module test 3. Vertical test (VT) stand 4. CM assembly 5. Clean room working environment 6. (cavity fabrication equipment at CFF)

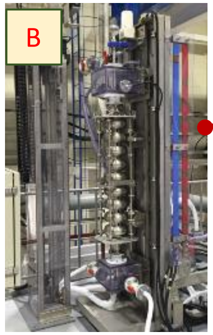
SRF infrastructure (including CM test stand) will be completed.

Future : cavity string at European XFEL

Infrastructure at COI



Future : CM test at European XFEL



EP

CM assembly at KEK

Cryogenic sytem

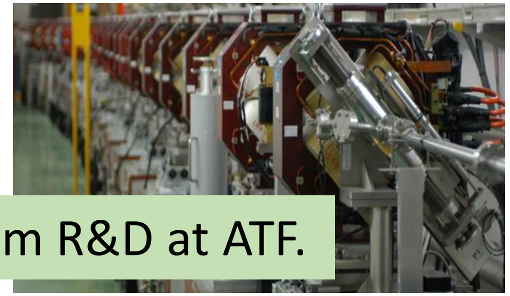
Future : VT @FNAL

Future : CM assembly at XFEL

ATF/ATF2: Accelerator Test Facility@KEK

Develop the nanometer beam technologies for ILC

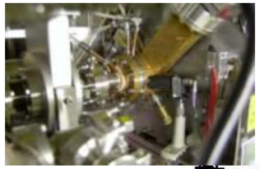
- Key of the luminosity maintenance
- 7.7 nm beam at IP (ILC)

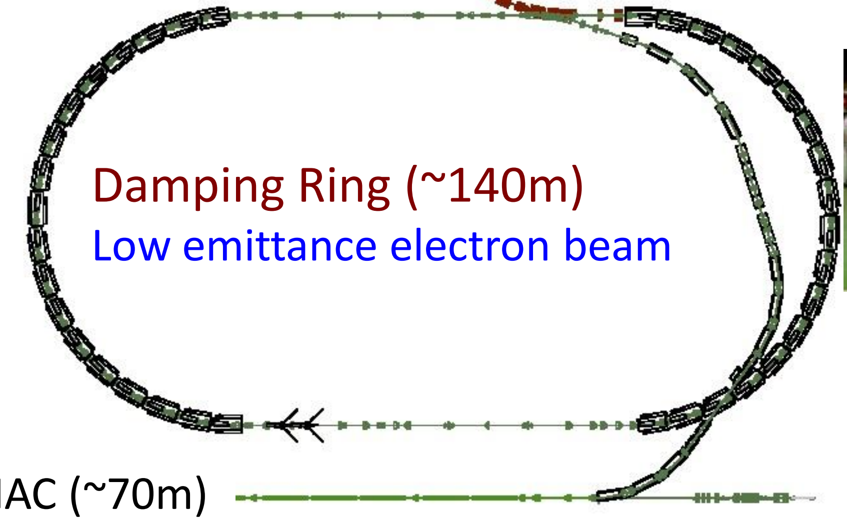


KEK hosts the nanobeam R&D at ATF.

ATF2: Final Focus Test Beamline

Establish the ILC final focus method with same optics and comparable beamline tolerances





Damping Ring (~140m)

Low emittance electron beam

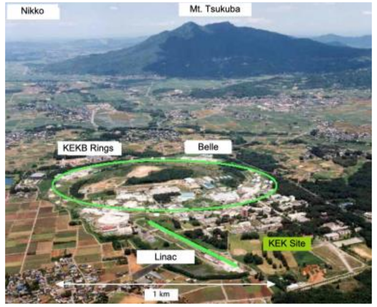
1.3 GeV S-band Electron LINAC (~70m)

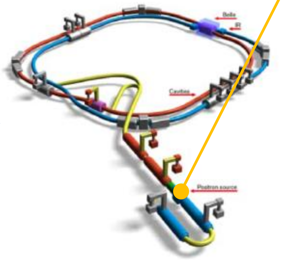
e-driven e+ source R&D

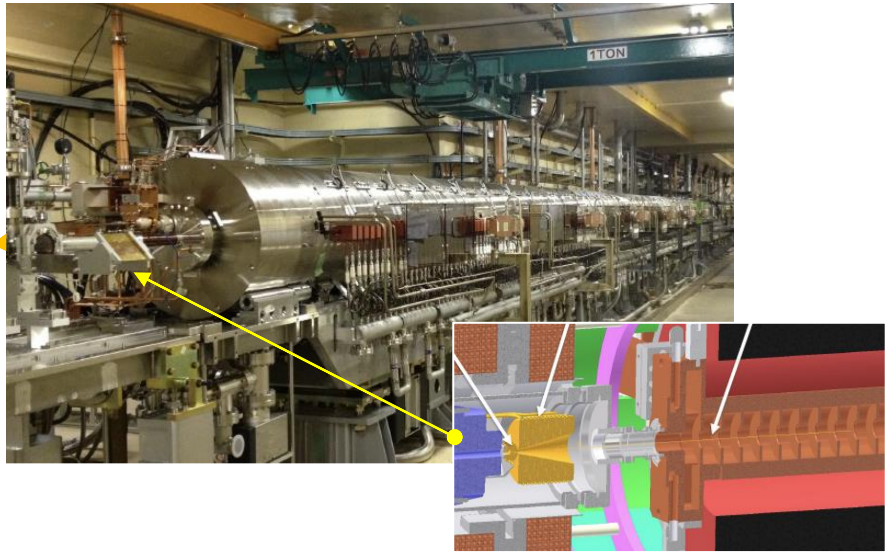
SuperKEKB positron source:
current biggest positron source in the world!

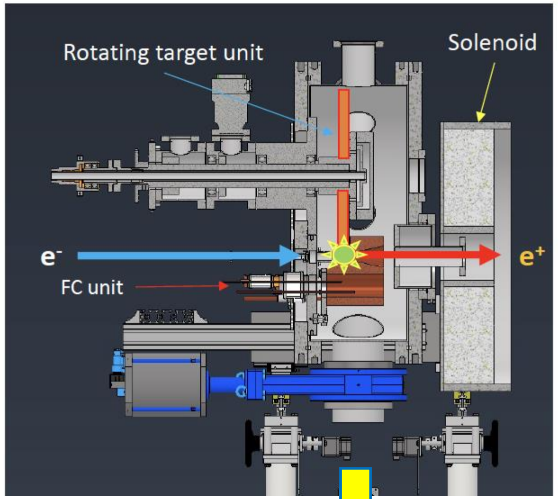
- A prototype development, based on experiences at SuperKEKB e+ source

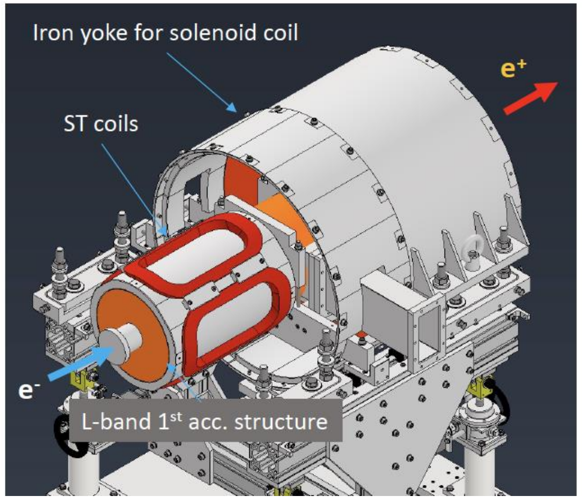
- Engineering design toward ILC:
  - 3D-CAD model and engineering drawings for manufacturing, based on simulation and experiments

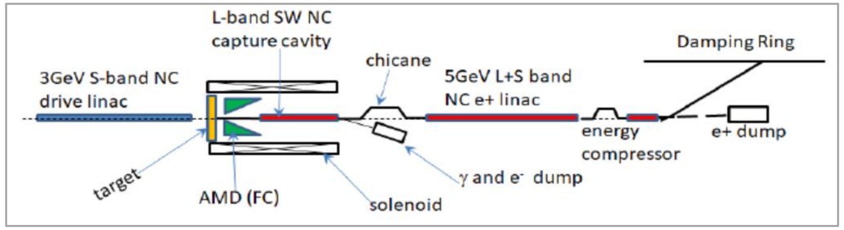






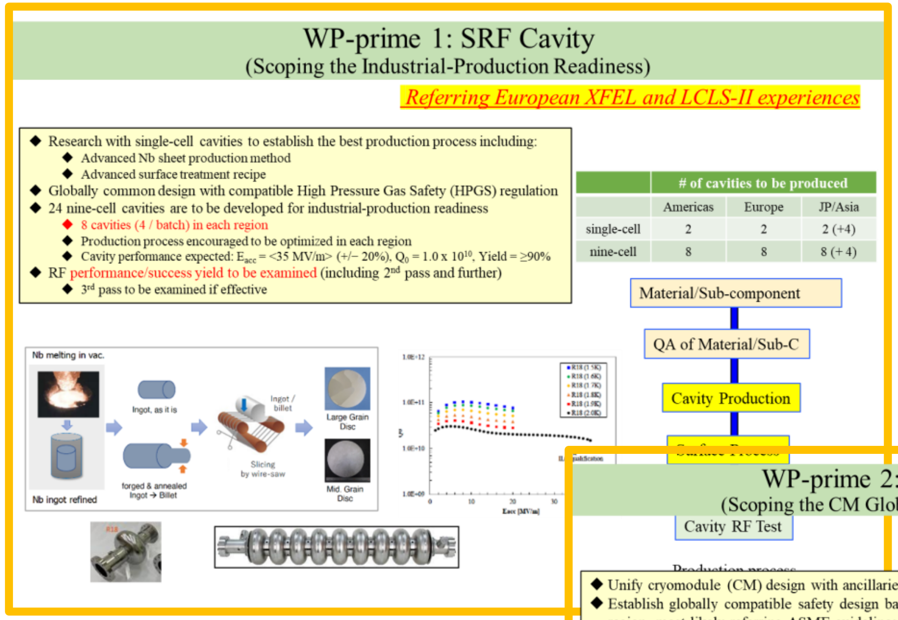






ITN in progress

For WPP-1&2 (SRF cavity, CM), we have already started technical discussions with researchers in Europe and the USA.
For WPP-15 (Final Focus System), European researchers joined to the ATF experiments in this June operation.

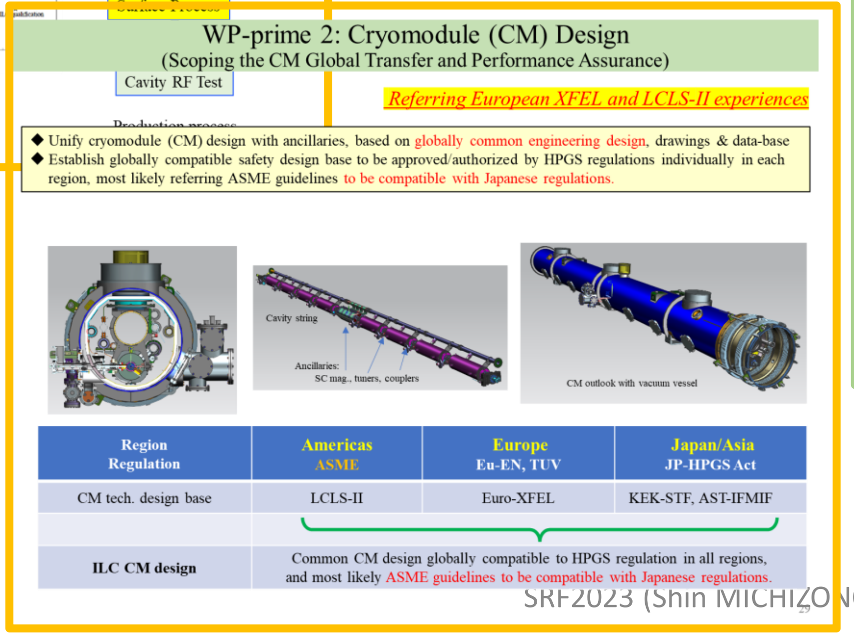


WP-prime 1: SRF Cavity
(Scoping the Industrial-Production Readiness)

Referring European XFEL and LCLS-II experiences

- Research with single-cell cavities to establish the best production process including:
  - Advanced Nb sheet production method
  - Advanced surface treatment recipe
- Globally common design with compatible High Pressure Gas Safety (HPGS) regulation
- 24 nine-cell cavities are to be developed for industrial-production readiness
  - 8 cavities (4 / batch) in each region
  - Production process encouraged to be optimized in each region
  - Cavity performance expected: E_{acc} = <35 MV/m> (+/− 20%), Q_0 = 1.0 x 10^{10}, Yield = ≥90%
- RF performance/success yield to be examined (including 2nd pass and further)
  - 3rd pass to be examined if effective

# of cavities to be produced	Americas	Europe	JP/Asia
single-cell	2	2	2 (+4)
nine-cell	8	8	8 (+4)

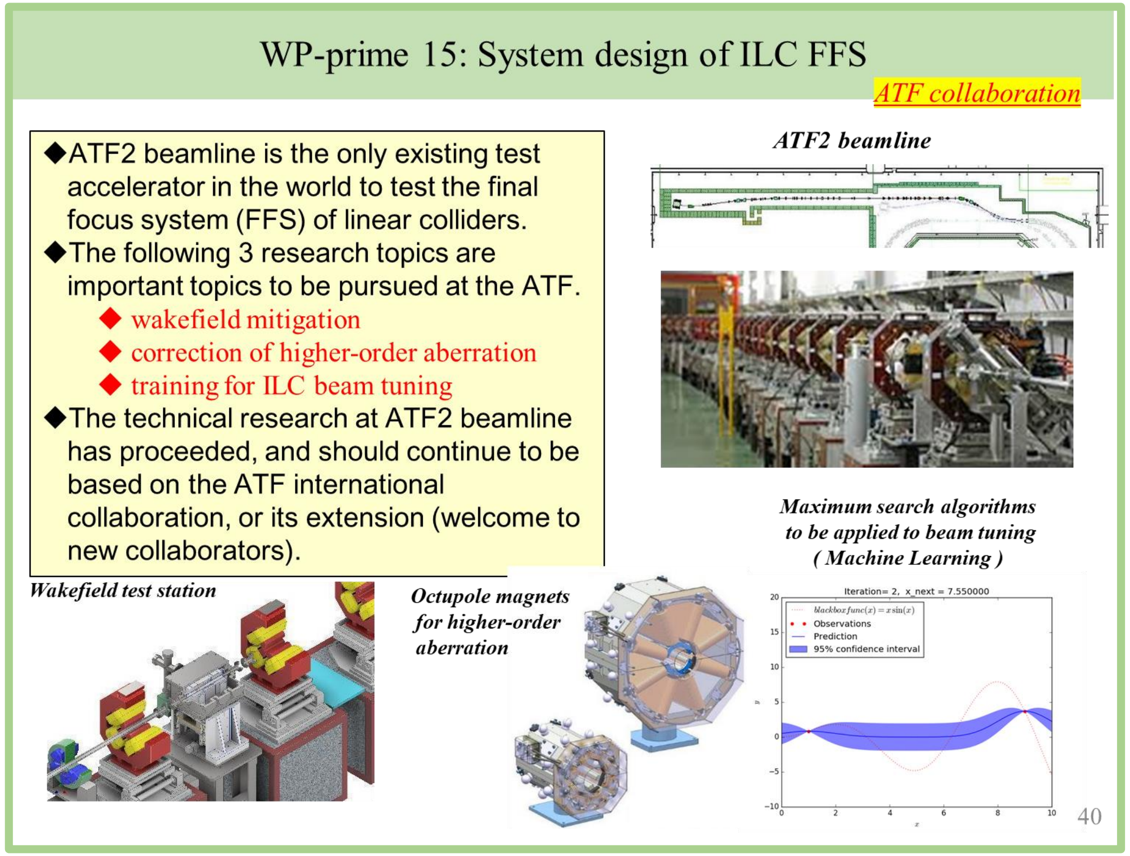


WP-prime 2: Cryomodule (CM) Design
(Scoping the CM Global Transfer and Performance Assurance)

Referring European XFEL and LCLS-II experiences

- Unify cryomodule (CM) design with ancillaries, based on globally common engineering design, drawings & data-base
- Establish globally compatible safety design base to be approved/authorized by HPGS regulations individually in each region, most likely referring ASME guidelines to be compatible with Japanese regulations.

Region Regulation	Americas ASME	Europe Eu-EN, TUV	Japan/Asia JP-HPGS Act
CM tech. design base	LCLS-II	Euro-XFEL	KEK-STF, AST-IFMIF
ILC CM design	Common CM design globally compatible to HPGS regulation in all regions, and most likely ASME guidelines to be compatible with Japanese regulations.		

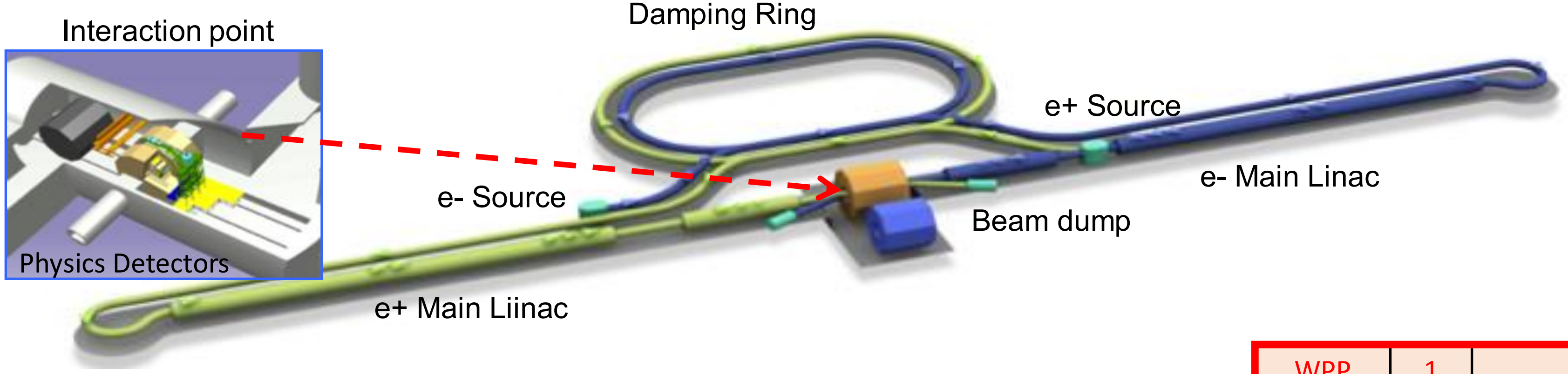


WP-prime 15: System design of ILC FFS

ATF collaboration

- ATF2 beamline is the only existing test accelerator in the world to test the final focus system (FFS) of linear colliders.
- The following 3 research topics are important topics to be pursued at the ATF.
  - wakefield mitigation
  - correction of higher-order aberration
  - training for ILC beam tuning
- The technical research at ATF2 beamline has proceeded, and should continue to be based on the ATF international collaboration, or its extension (welcome to new collaborators).

KEK's efforts



- Creating particles — ***Sources***
  - polarized elections / positrons
- High quality beams — ***Damping ring***
  - Low emittance beams
    - Small beam size (small beam spread)
    - Parallel beam (small momentum spread)
- Acceleration — ***Main linac***
  - superconducting radio frequency (SRF)
- Getting them collided — ***Final focus***
  - nano-meter beams
- Go to ***Beam dumps***

Area				Note
SRF	WPP	1	Cavity production	Collaboration with Europe, Americas
	WPP	2	CM design	
	WPP	3	Crab cavity	
e-, e+ Sources	WPP	4	E- source	
	WPP	6	Undulator target	
	WPP	7	Undulator focusing	
	WPP	8	E-driven target	Experiences at SuperKEKB
	WPP	9	E-driven focusing	
	WPP	10	E-driven capture	
	WPP	11	Target replacement	
Nano-Beam	WPP	12	DR System design	
	WPP	14	DR Injection/extraction	ATF collaboration
	WPP	15	Final focus	
	WPP	16	Final doublet	
	WPP	17	Main dump	

Current Status and Future Technological Collaboration for the ILC

KEK / IDT-WG2
Shin MICHIZONO (KEK)

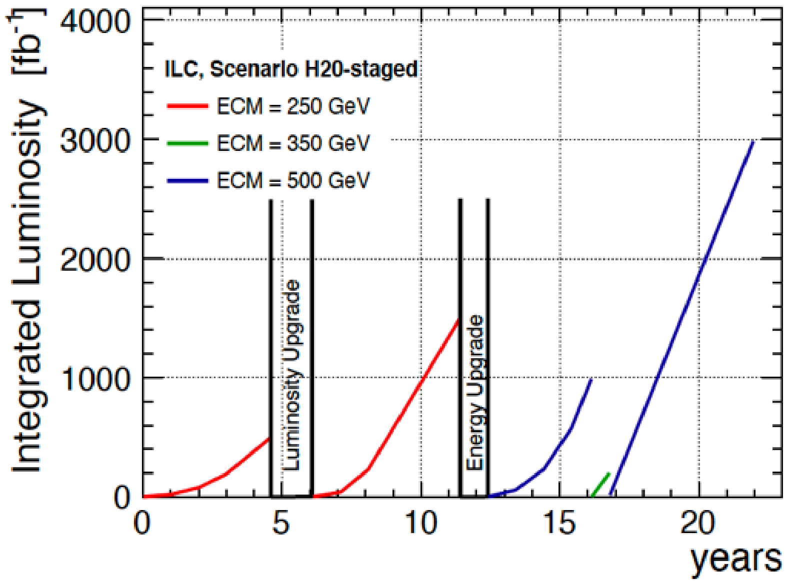
1. Why linear collider?
2. Higgs Factory
3. Global Collaboration
4. ILC Accelerator
   - ILC design
   - Recent Progress
   - Candidate site
5. Pre-lab proposal
6. Global Project
7. ILC Technology Network
8. KEK's effort
9. Future Upgrade
10. Beam dump (industrial application)
11. Sustainability
12. Summary

ILC Baseline and the Upgrades

Quantity	Symbol	Unit	Initial	$\mathcal{L}$ Upgrade	Z pole	E / $\mathcal{L}$ Upgrades		
Centre of mass energy	$\sqrt{s}$	GeV	250	250	91.2	500	250	1000
Luminosity	$\mathcal{L}$	$10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$	1.35	2.7	0.21/0.41	1.8/3.6	5.4	5.1
Polarization for e^-/e^+	$P_-(P_+)$	%	80(30)	80(30)	80(30)	80(30)	80(30)	80(20)
Repetition frequency	f_{rep}	Hz	5	5	3.7	5	10	4
Bunches per pulse	n_{bunch}	1	1312	2625	1312/2625	1312/2625	2625	2450
Bunch population	N_e	10^{10}	2	2	2	2	2	1.74
Linac bunch interval	Δt_b	ns	554	366	554/366	554/366	366	366
Beam current in pulse	I_{pulse}	mA	5.8	8.8	5.8/8.8	5.8/8.8	8.8	7.6
Beam pulse duration	t_{pulse}	μs	727	961	727/961	727/961	961	897
Accelerating gradient	G	MV/m	31.5	31.5	31.5	31.5	31.5	45
Average beam power	P_{ave}	MW	5.3	10.5	1.42/2.84*)	10.5/21	21	27.2
RMS bunch length	σ^*_z	mm	0.3	0.3	0.41	0.3	0.3	0.225
Norm. hor. emitt. at IP	$\gamma\epsilon_x$	μm	5	5	5	5	5	5
Norm. vert. emitt. at IP	$\gamma\epsilon_y$	nm	35	35	35	35	35	30
RMS hor. beam size at IP	σ^*_x	nm	516	516	1120	474	516	335
RMS vert. beam size at IP	σ^*_y	nm	7.7	7.7	14.6	5.9	7.7	2.7
Luminosity in top 1 %	$\mathcal{L}_{0.01}/\mathcal{L}$		73 %	73 %	99 %	58.3 %	73 %	44.5 %
Beamstrahlung energy loss	δ_{BS}		2.6 %	2.6 %	0.16 %	4.5 %	2.6 %	10.5 %
Site AC power *	P_{site}	MW	111	138	94/115	173/215	198	300
Site length	L_{site}	km	20.5	20.5	20.5	31	31	40

- **AC** plug-**power** may be further **reduced** (10 ~ 20 %), if the RF **(Klystron)** and SRF/Cryogenics (Q-value) **Efficiency** may be **improved**.

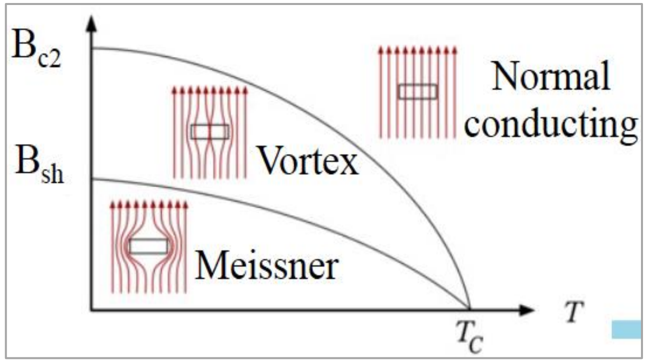
Energy upgrades:
- 500GeV (**31.5 MV/m Q_0=1** x 10^{10})
  - 1TeV (**45 MV/m Q_0=2** x 10^{10}, 300 MW)
  - more SCRF, tunnel extension



Further energy upgrades can be realized by
- Nb_3Sn cavity (>80MV/m)
- Nb Traveling Wave (TW) structures (>70MV/m)

Nb_3Sn cavity for the future upgrade

Courtesy, S. Posen

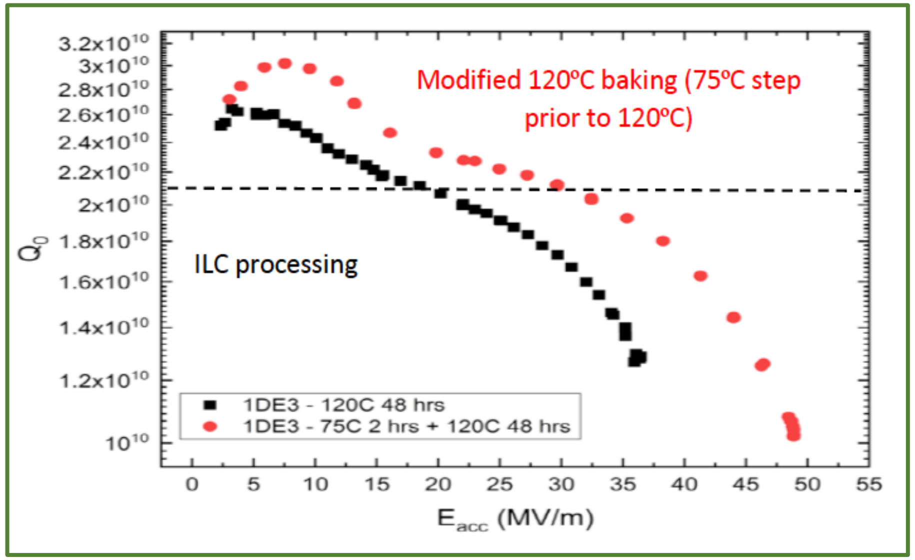


SRF cavity

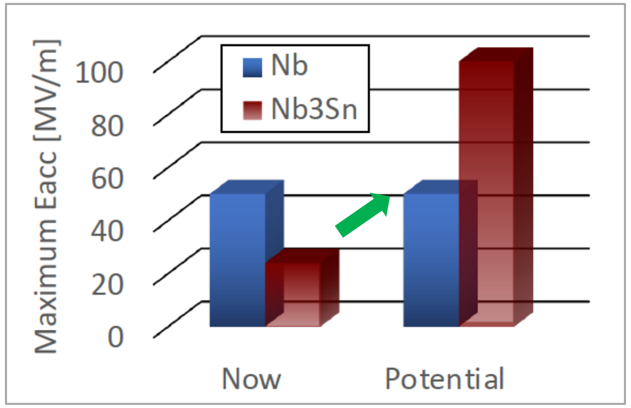
- B_{sh} = practical limit for SRF
  - Bs_{sh-Nb} : 210 mT
  - $Bs_{sh-Nb3Sn}$: 430mT

x2

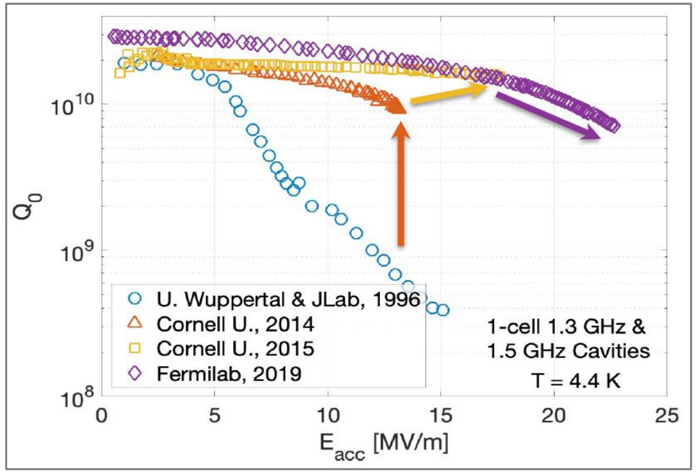
>80 MV/m in future



Progress at Fermilab: Nb, 75/120 bake
A. Grassellino et al., arXiv: 1806/09824



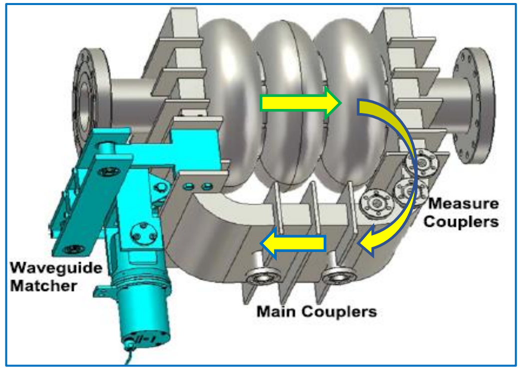
Nb_3Sn progress at Fermilab.
S. Posen et al., SUST, 34, 02507 (2021)



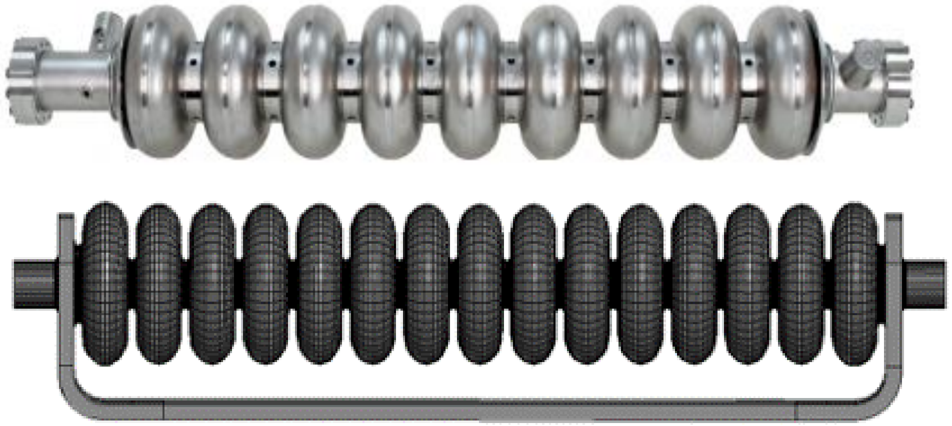
Nb_3Sn Potential in high-G future

A new concept for SRF proposed for ILC-3TeV and Helen: Traveling Wave (TW) SRF cavity, compared with Standing Wave

Courtesy: H. Padamsee et al., for ILC-3TeV
S. Belomestnykh et al., for HELEN



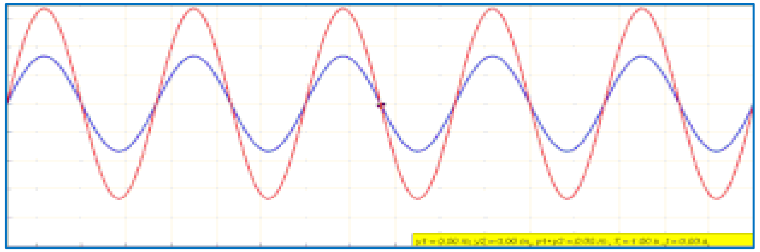
Prototype TW structure under test



SW: TESLA cavity (ILC baseline)

TW: proposed for ILC-3TeV, Helen

>70 MV/m operation



← Red standing wave – High Peak Fields,

← Green (acc.) and Blue (Return) Waves are Travelling Waves Lower peak fields,

← **Guide blue** wave in a return wave-guide to avoid SW peak fields

– attached to both ends

HELEN: A LINEAR COLLIDER BASED ON ADVANCED SRF TECHNOLOGY*

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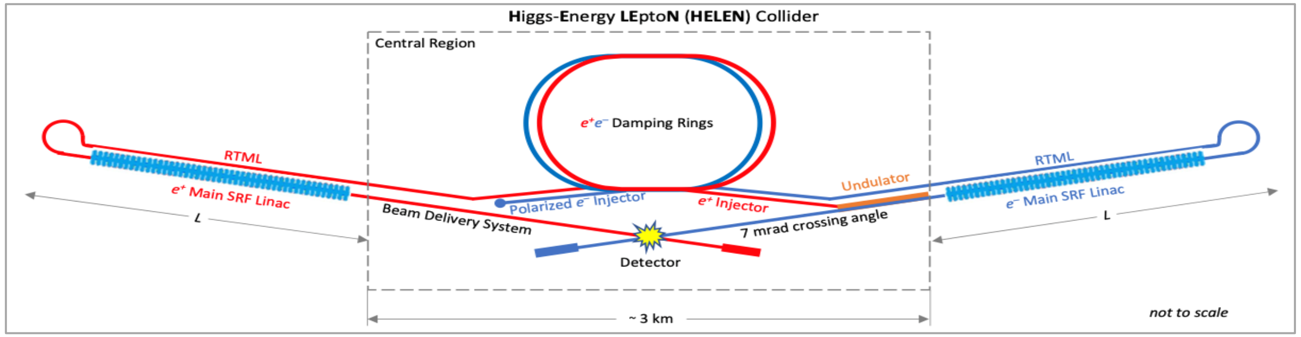
https://doi.org/10.48550/arXiv.2209.01074



Current Status and Future Technological Collaboration for the ILC

KEK / IDT-WG2

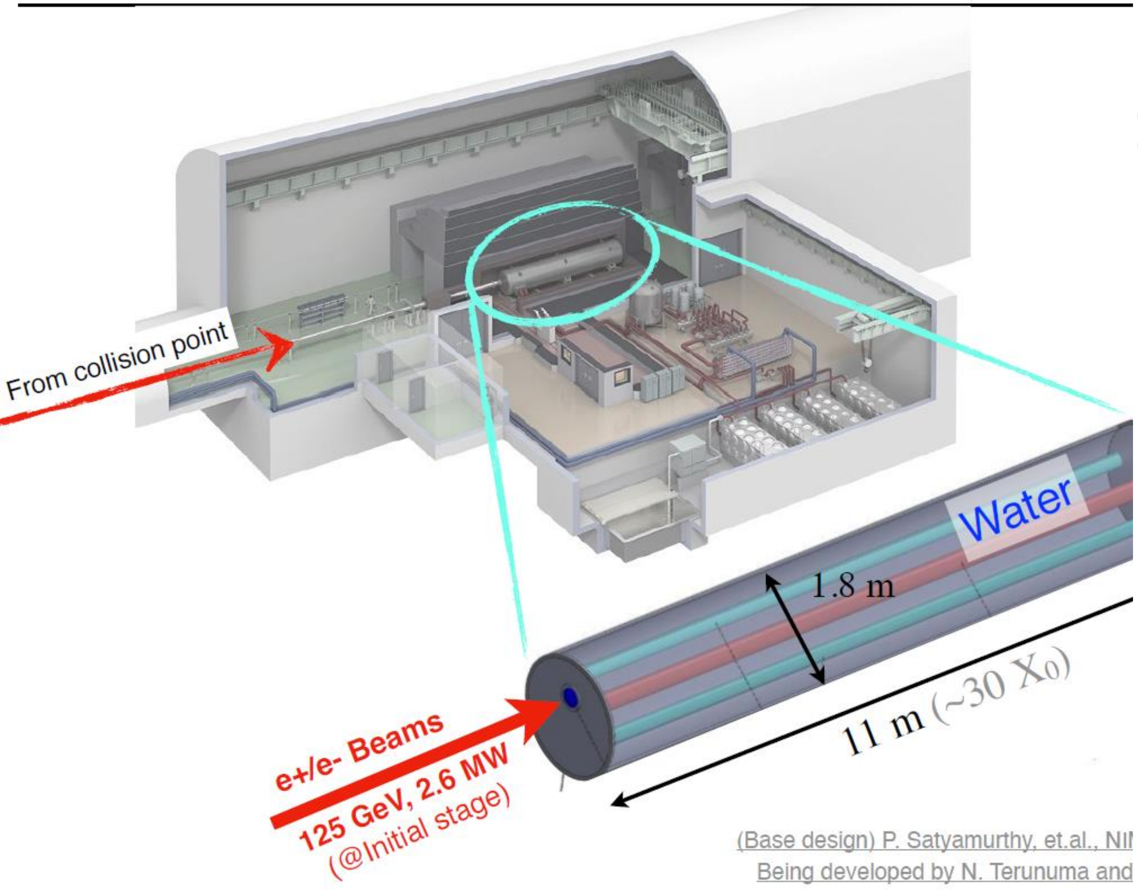
Shin MICHIZONO (KEK)

1. Why linear collider?
2. Higgs Factory
3. Global Collaboration
4. ILC Accelerator
   - ILC design
   - Recent Progress
   - Candidate site
5. Pre-lab proposal
6. Global Project
7. ILC Technology Network
8. KEK's effort
9. Future Upgrade
10. ⇨ Beam dump (industrial application)
11. Sustainability
12. Summary

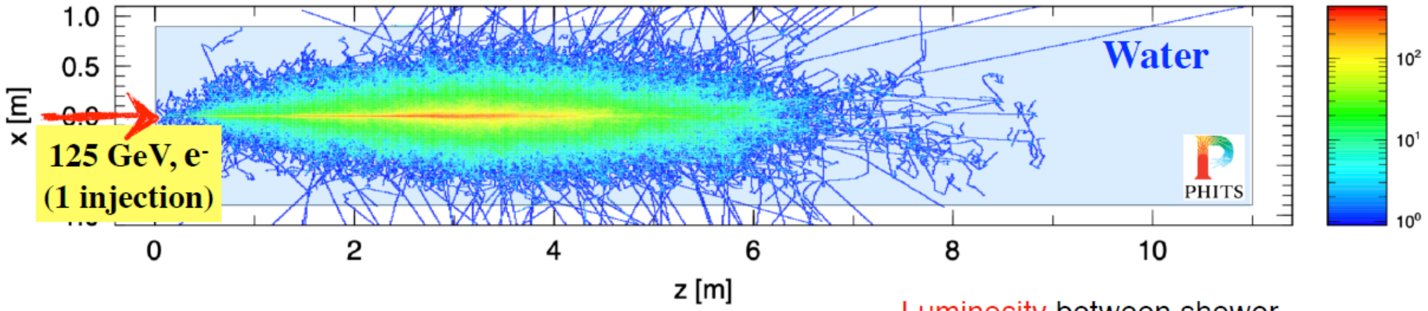
ILC main water beam dump for industrial application (soft error)

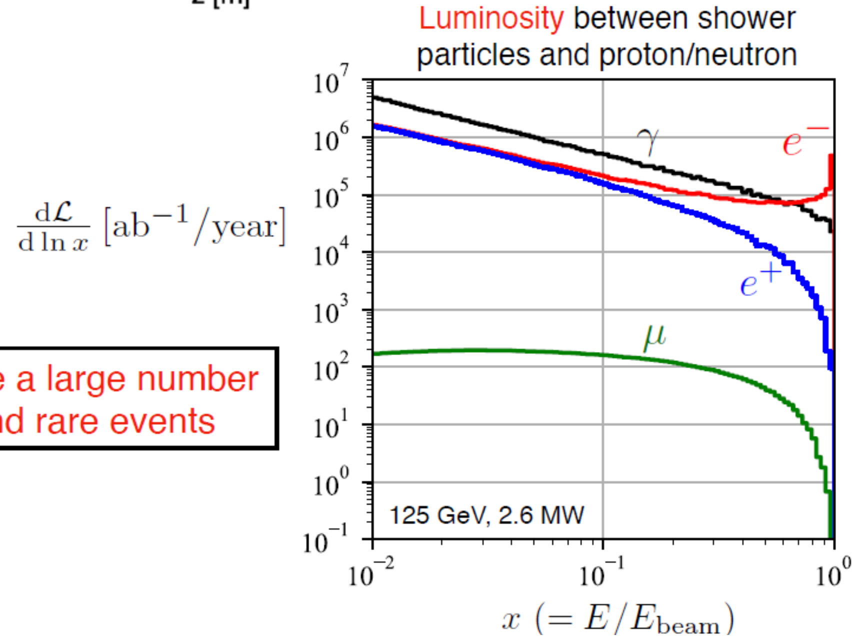
Yasuhito SAKAKI
@LCWS2023

Main beam dumps



Secondary particles





Shower particles can create a large number of secondary particles and rare events

Atmospheric-like radiation fields for soft error studies

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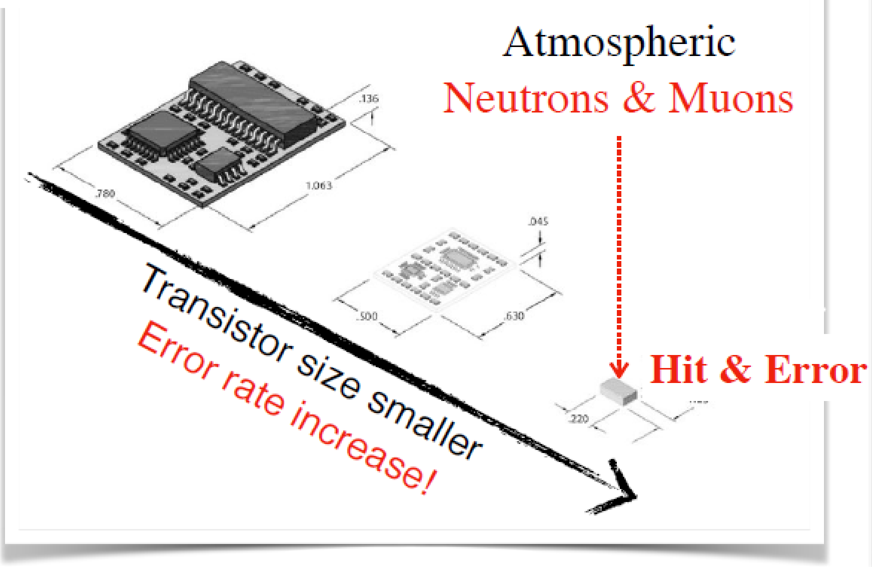
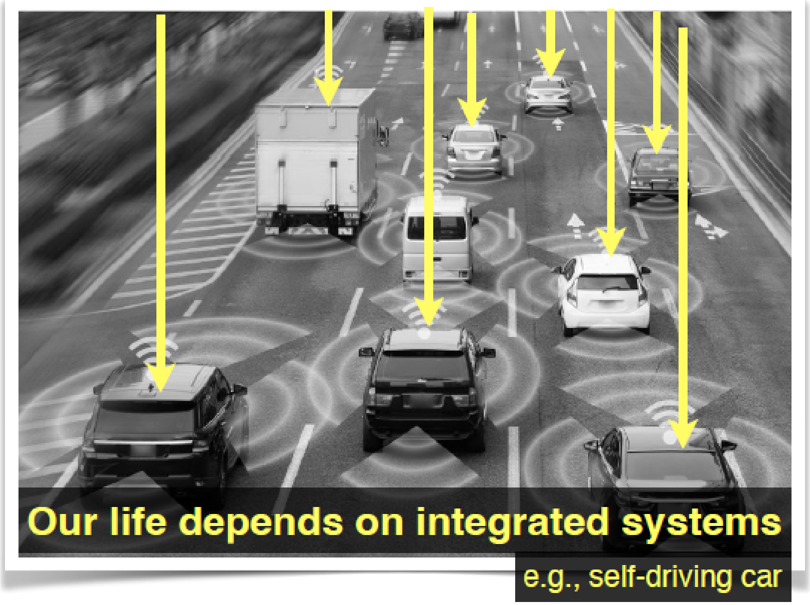
- Soft error is a temporary malfunction of transistor, mainly caused by atmospheric neutrons and muons.

See talk of M. Hashimoto @ ILCX2021





- Irradiation fields that provide *high-intensity*, *large-area*, and *atmospheric-like spectra* are favored.

Neutrons and muons at ILC beam dump have atmospheric-like spectra?

Beside and downstream of beam dump

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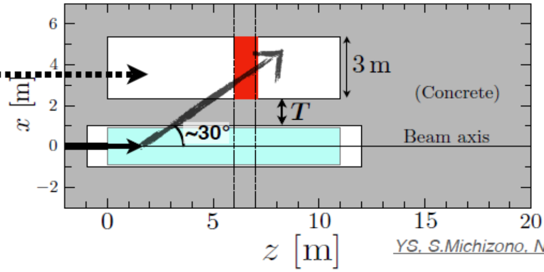
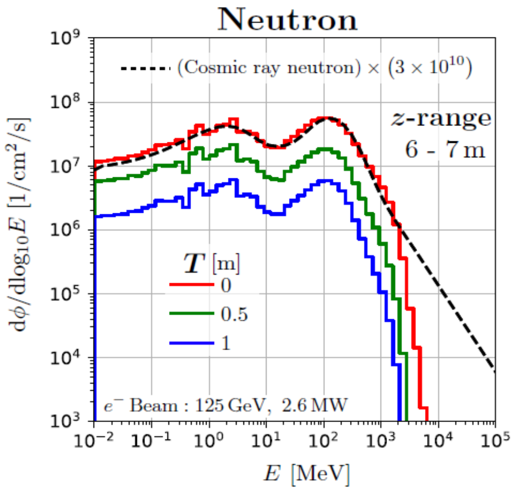
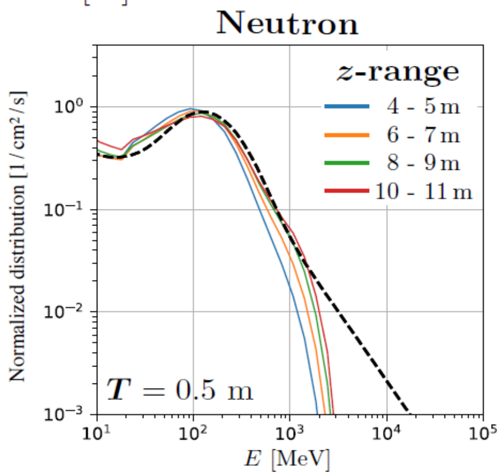
Space beside beam dump



YS, S.Michizono, N.Terunuma, T.Sanami, 2210.08690

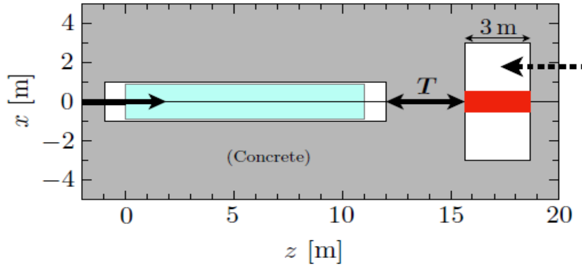


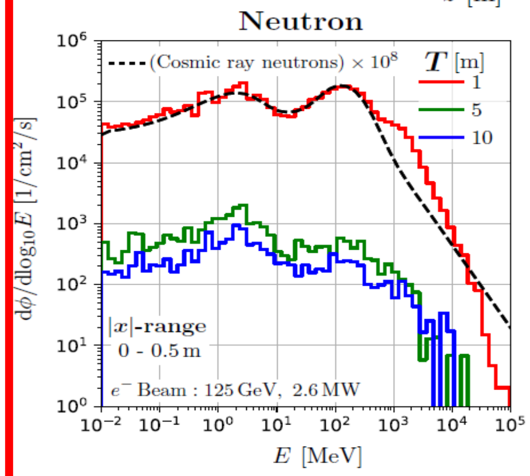


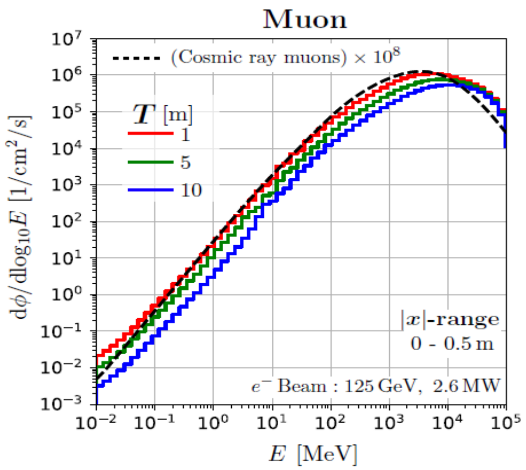
- Atmospheric-like neutrons are obtained. (consistent up to a few GeV!)
  - ➡ High-energy tail behavior slightly depends on z-range
  - ➡ Especially consistent at z=6-7m (~30 degrees)

YS, S.Michizono, N.Terunuma, T.Sanami, 2210.08690

Downstream of beam dump







- Both neutrons and muons have atmospheric-like spectra.
- Muon dominant beam is available with thick shielding.

ILC can also be used for industrial studies.

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Quantitative Approach: Lifecycle Assessment LCA

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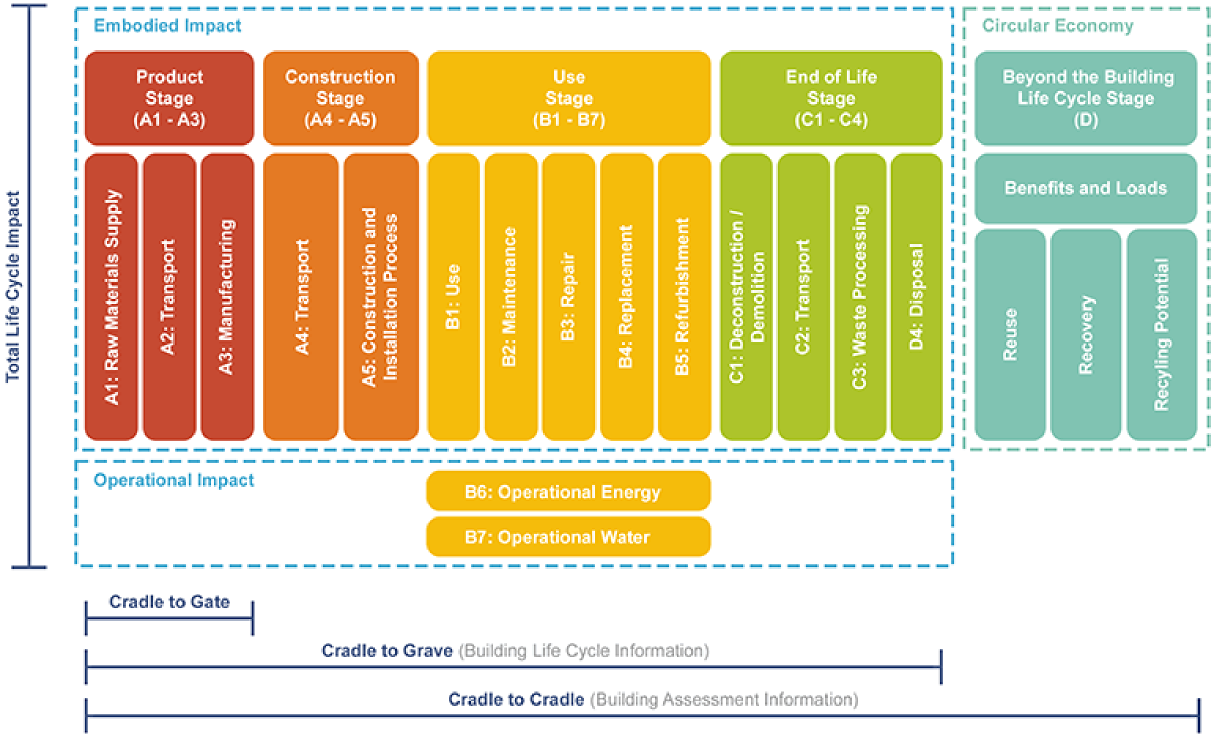
@LCWS2023

Whole Lifecycle

- Raw materials, fabrication & construction
- Usage: operation, maintenance, refurbishment
- End of life: demolition, disposal

Defined in International Standards

https://browningday.com/news/lca-stages-matter-when-tracking-embodied-carbon/

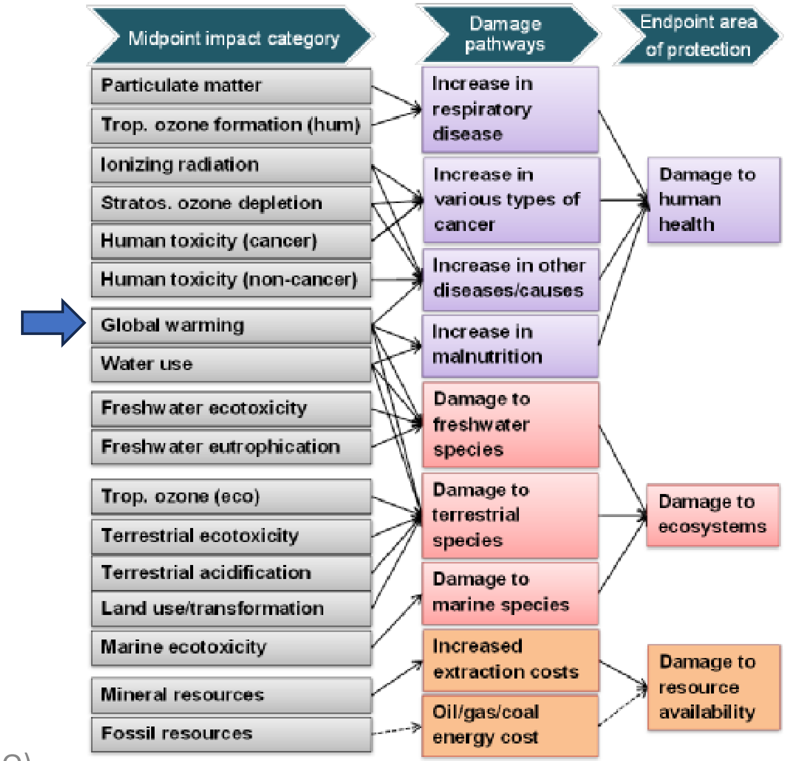


Lifecycle stages according to EN 15978

Whole Environmental Impact

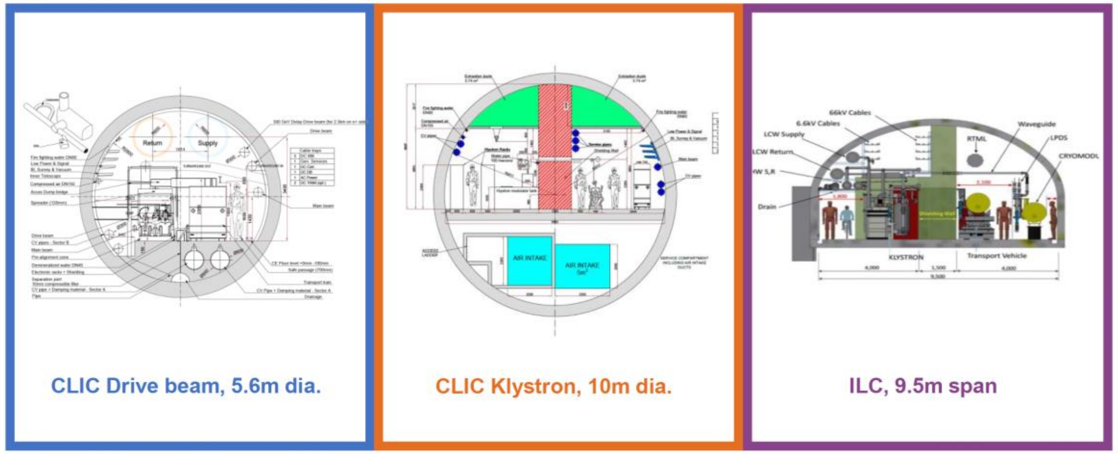
- Quantifying total damage by **endpoint** indicators (e.g. damage to human health) possible but difficult
- ”**Midpoint** indicators” asses impact on environment in a quantitative way:
  - Greenhouse Warming Potential (GWP) – kg CO2 eqiv
  - Ozone Depletion Potential (ODP) – kg CFC-11 equiv

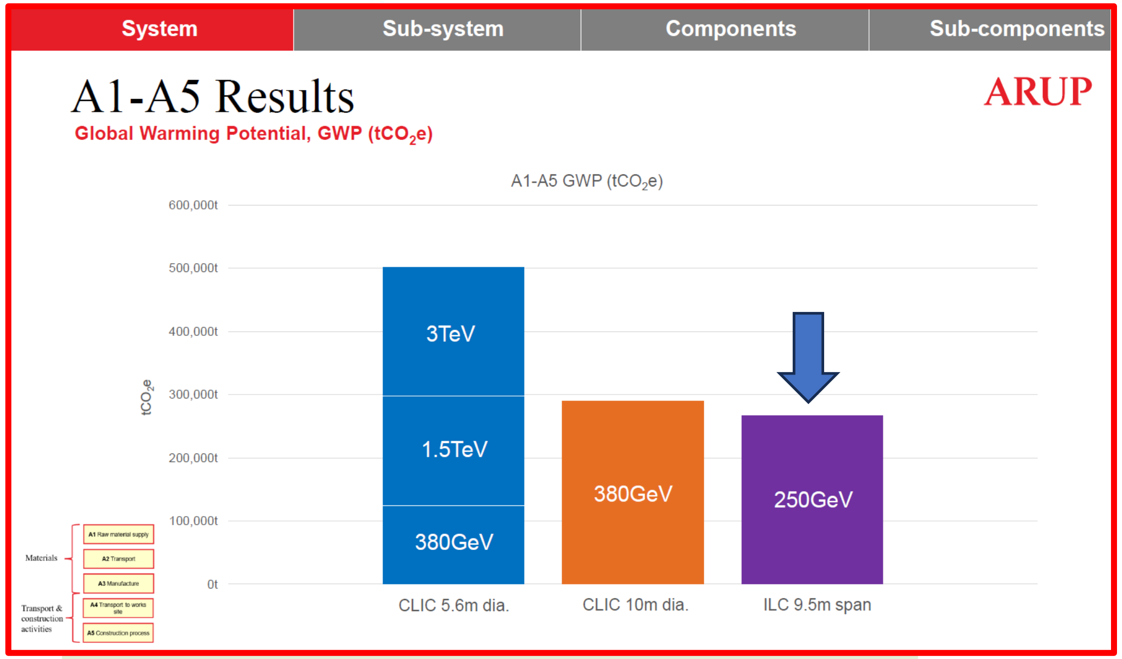
  Ecotoxicity – kg 1,4-DCB equiv



M.A.J. Huijbregts et al., Int. J. Life Cycle Ass. **22** (2017) 138, DOI:10.1007/s11367-016-1246-y

Impact of civil construction / accelerator components (in progress)





Suzanne Evans@LCWS2023
https://indico.slac.stanford.edu/event/7467/timetable/#all.detailed

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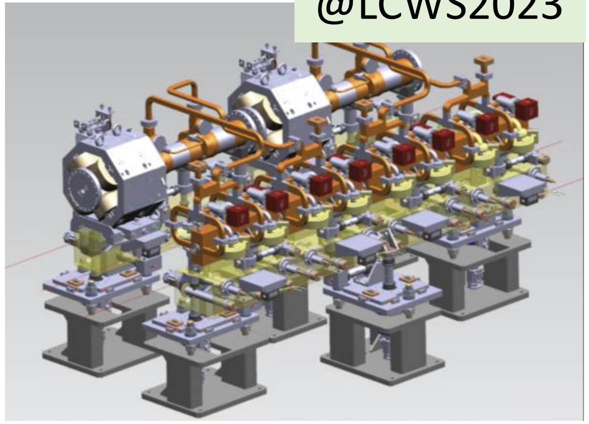
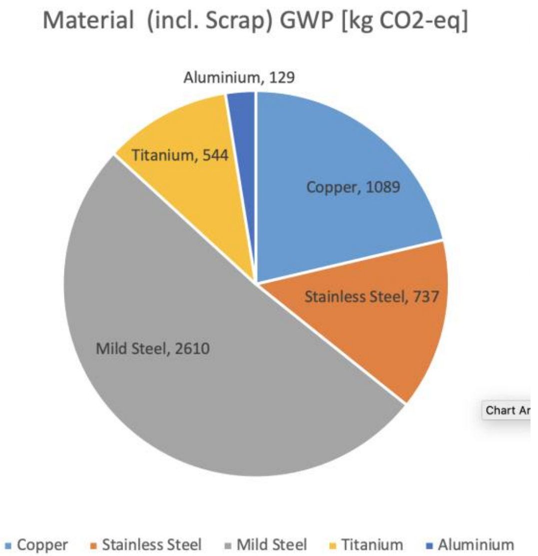
- Study to estimate the Green House Gas emissions from raw materials in CLIC 2-beam module, including waveguides and supports
- ~2.5t CO2-eq / m:
  -> about half of CO2 for tunnel
- Half of CO2 impact is steel for supports
  -> optimization potential
- Services (power, cabling, cooling, ventilation) not included
- Situation in magnet-heavy sections (e.g. damping rings) may be different



CO2 impact of accelerator components is comparable to CO2 of tunnel

Tunnel+Acc. Total ~500,000tCO2



CO2 Intensity of Electricity in the Future (in progress)

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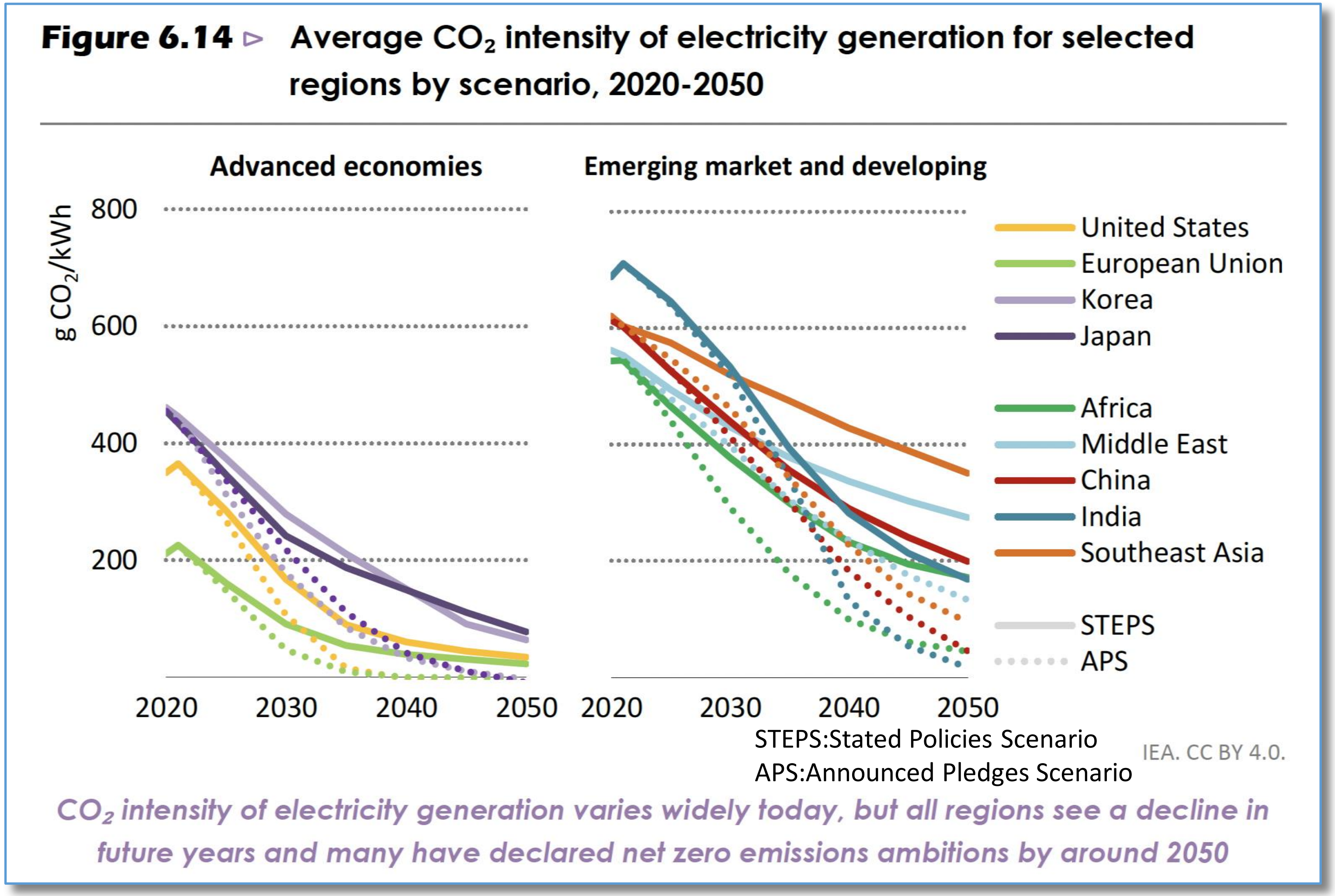
@LCWS2023

What will the CO2 impact of electricity be for the next generation of colliders?

- CO2 intensity of electricity will go down
- Regenerative energies will rise

But

- Not enough – big gap between stated policies to announced pledges, even bigger to net zero
  -> we are not on a path to net zero!
- The energy transition will be a huge effort:
  - Energy storage
  - Energy transport (grid)
- Carbon intensity heavily site dependent
- Electricity will remain expensive



IEA (2022), World Energy Outlook 2022, IEA, Paris
https://www.iea.org/reports/world-energy-outlook-2022,
CC BY NC SA 4.0

200gCO2/kWh * 100,000 kW * 5,000 hours/year =100,000tCO2/year

Green ILC Studies in Tohoku Area (in progress)

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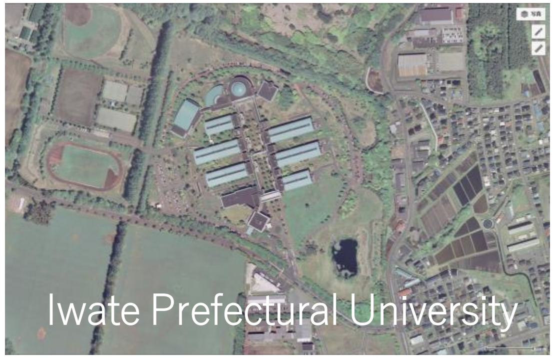
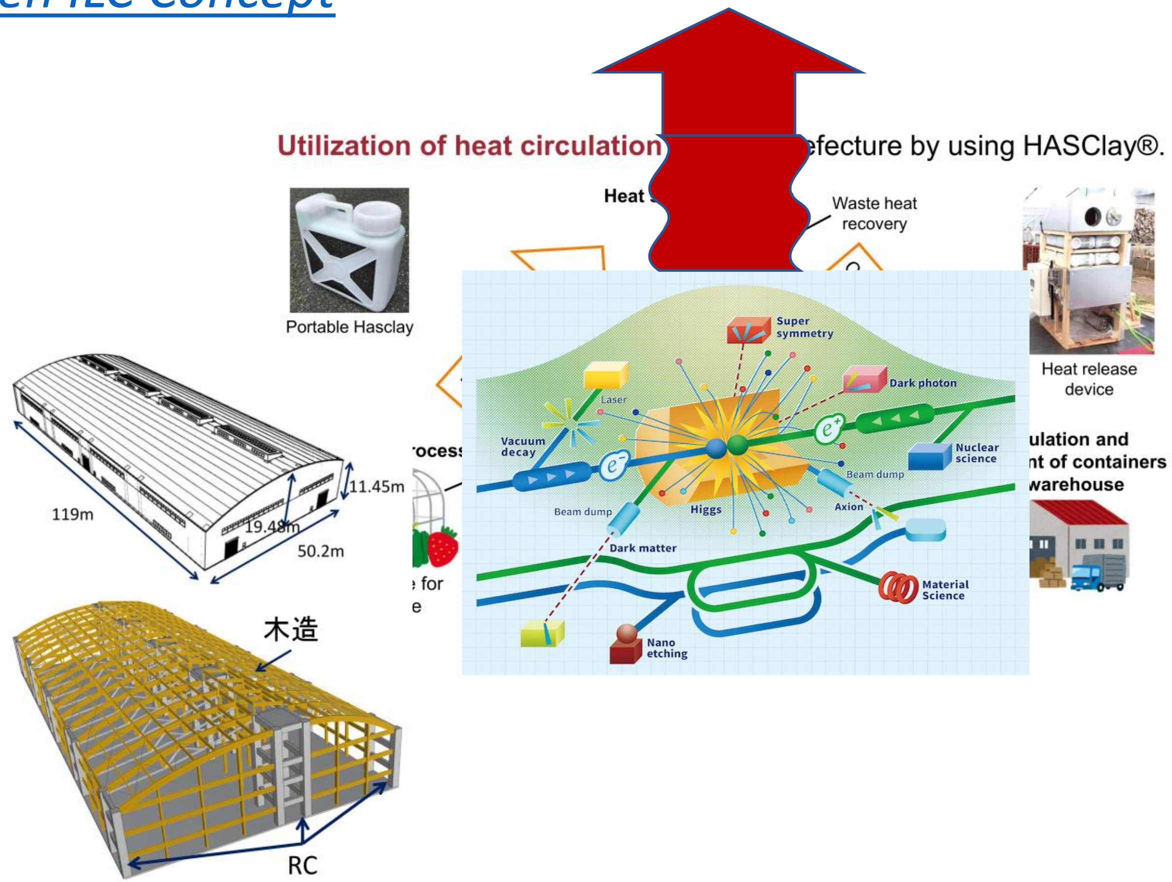
- Studies conducted on
  - Exhaust heat recovery from the ILC and the creation of business derived from it
  - Connecting the ILC with the local forestry industry
  - Utilization of solar heat
  - The ”Green ILC” concept and community development and planning - building an energy recycling society based on the Global Village Vision



Masakazu Yoshioka:
Green ILC Concept

320ktonCO2/year



https://green-ilc.in2p3.fr/home/
M. Yoshioka: https://agenda.linearcollider.org/event/9211/contributions/49408/
M. Yoshioka et al.: https://www.pasj.jp/web_publish/pasj2020/proceedings/PDF/WEPP/WEPP57.pdf

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Summary

- ILC is the e-/e+ linear collider for **the Higgs factory**.
- Current global organization is **ILC International Development Teams (IDT)**
- The ILC key technologies of “**SRF**”, and “**Nano-beam**”
  - **Matured** to be ready for an e+e- Higgs Factory based on the **Linear Collider** technology.
- ILC is the **global project** like ITER and SKA.
- IDT-WG2 identified important and time-consuming WPs.
- These WPs will be carried out by international collaboration as “**ILC Technology Network**”.
- **KEK obtained a budget** for these R&Ds and started the activity from this April.
- New SRF technology (such as **Nb3Sn, TW**) can be applied to ILC future upgrade.
- Beam dumps of the ILC are also useful for the industrial application like “**Soft error**” analysis.
- **Sustainability** is the also important topics for the large accelerators.

Thank you for your attention

Resolution on the Promotion of ILC Project

27th April 2023

Shoji Asai @LCWS2023

Federation of Diet Members to Promote a Construction of International Laboratory for LC

Particle physics and its underlining accelerator science are an important science and technology, which are disciplines that study the ultimate structure of matter and the fundamental forces of nature, and supports a wide range of R&D from academic research to industrial applications.

In addition, Japan has been a world leader in these fields, having produced many Nobel laureates. While Japan's research capabilities have been declining in recent years, the International Linear Collider (ILC) project in Japan, which will create Asia's first large-scale international science and technology center, has great potential to contribute to the improvement of Japan's research capabilities and growth strategy as a country that advocates science and technology.

Based on this recognition, in October 2022, this Federation of Diet Members resolved to steadily promote the development of next-generation accelerator technology, which will lead to the promotion of the ILC project and to ensure that the JFY2023 budget would be secured for this purpose. Since then, progress has been made as follows:

Shoji Asai
@LCWS2023

- In the JFY2023 budget, the budget for the development of advanced accelerator technology was appropriated, far exceeding the previous budget.
- The ILC International Development Team (IDT), in strong collaboration with ILC Japan, an organization of related researchers in Japan, and the High Energy Accelerator Research Organization (KEK), is steadily building the ILC Technology Network (ITN), an organization dedicated to perfecting ILC-related technologies through collaboration among accelerator research institutes around the world.
- The IDT has established an "International Expert Panel", whose progress is well underway, to organize a roadmap for the realization of a large-scale accelerator as a global project and the concept of responsibility sharing, and based on these discussions, to provide a forum for explanations and discussions to the governments of individual countries.

For Japan, which has made science and technology policy the first pillar of its growth strategy toward the realization of "New Form of Capitalism," it is extremely important that particle physics research continue to maintain and improve its international competitiveness. In addition, with international affairs such as COVID-19 and the situation in Ukraine having a major impact on international scientific and technological projects, it is recognized that the activities of the international community of researchers mentioned above, which is entering a new phase of realization, will continue to be important.

This Federation of Diet Members, will strengthen its structure, and under stronger collaboration between the research community with ILC Japan and KEK, the AAA, the Tohoku ILC Council, the Ministry of Education, Culture, Sports, Science and Technology, and related ministries and agencies, will continue to support the activity policies of the international research community and strive to ensure that these activities will lead to the realization of the ILC project in Japan.

Therefore, this Federation of Diet Members resolved as follows:

1. Promote activities in cooperation with related parties to attract the International Linear Collider (ILC Project) to Japan, which will form Asia's first large-scale international science and technology center.
2. Since the ILC project cannot be realized by one country alone and international cooperation is essential, the Japanese government should work closely with researchers who promote the above activities and exchange views with the governments of the countries concerned.
3. Steadily promote the development of next-generation accelerator technology that will lead to the promotion of the ILC project under appropriate international cooperation, and ensure that the necessary budget is secured for this purpose.

(Tentative Translated by KEK)