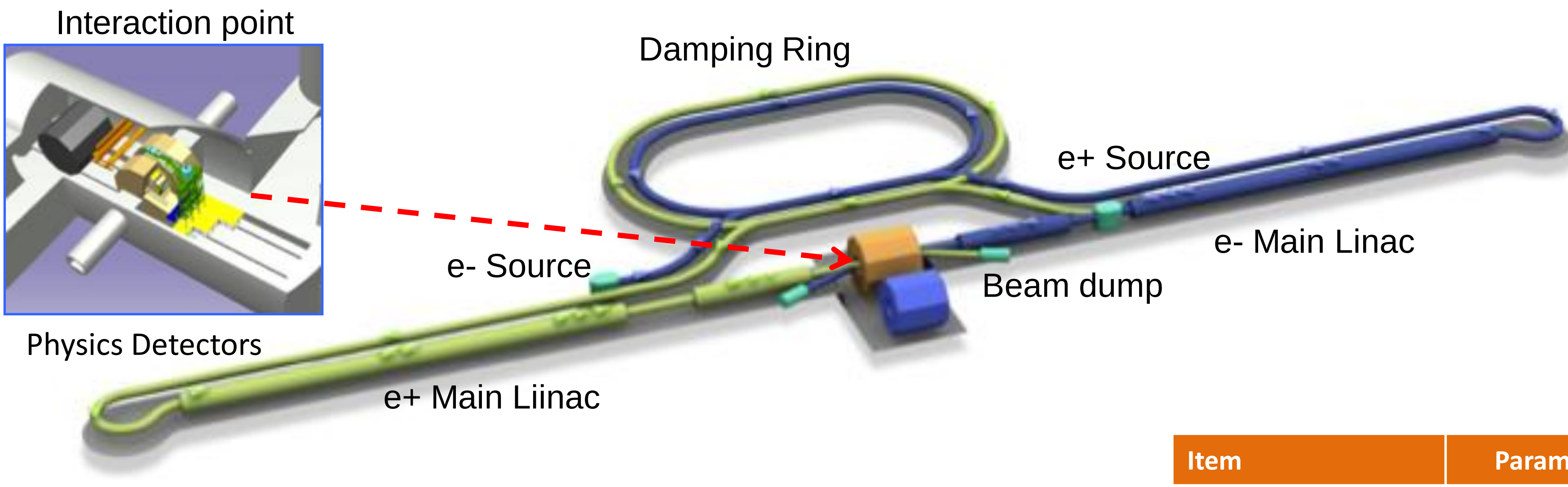
Current Status of the ILC

Shin MICHIZONO
KEK/Linear Collider Collaboration (LCC)

- *250 GeV ILC*
- *Area systems*
- *SCRF R&Ds*
- *ILC preparation*
- *Remaining technical topics*
- *Recent ILC status*

ILC250 Acc. Design Overview



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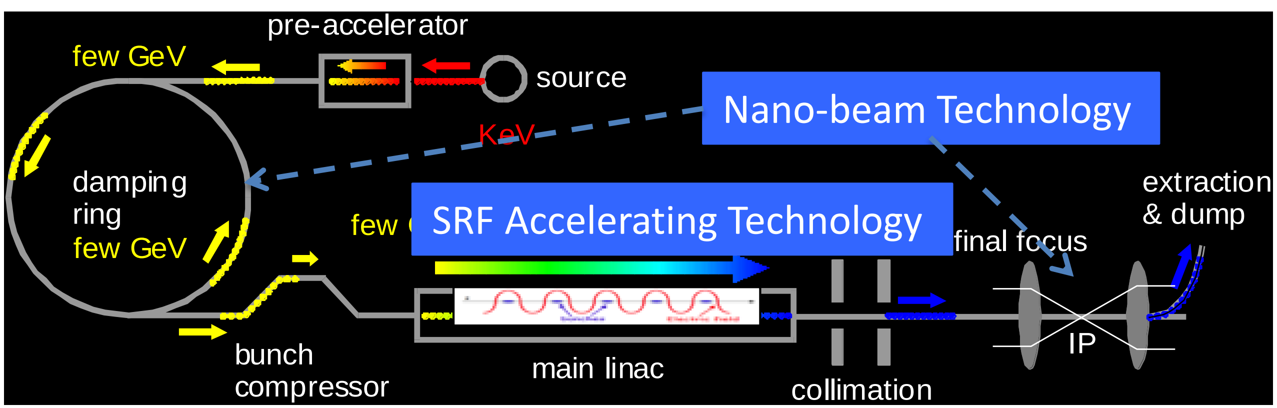
Key Technologies



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

Brief history of the ILC R&D

2004 2006 '07 '08 '09 '10 '11 '12 '13 '14 '15 '16 '17 '18 '19

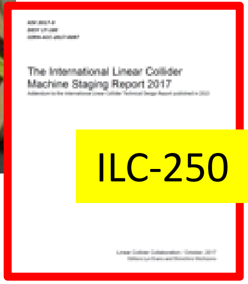
SC Technology selected

ILC-GDE | TDR | LCC

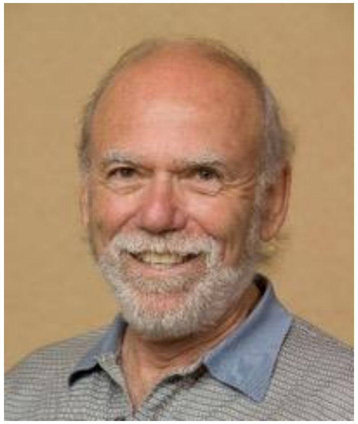
RDR)

Technical Design Phase

TDR:
49 countries
392 institutions
>2400 researchers



ILC-250



Barry Barish
GDE director
(the Nobel Prize winner for physics in 2017)

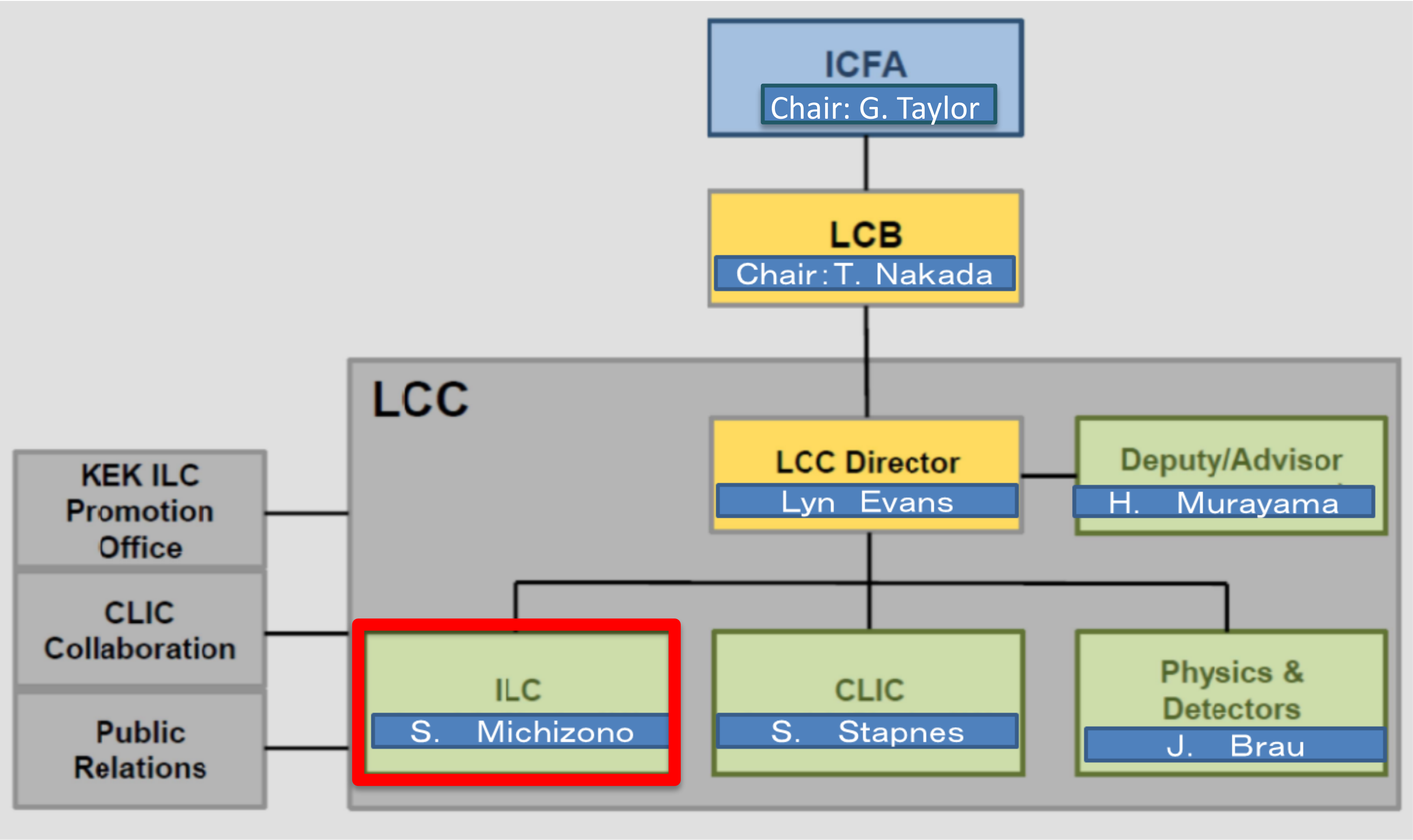
Lyn Evans
LCC director
(former LHC project manager)

LHC

European XFEL

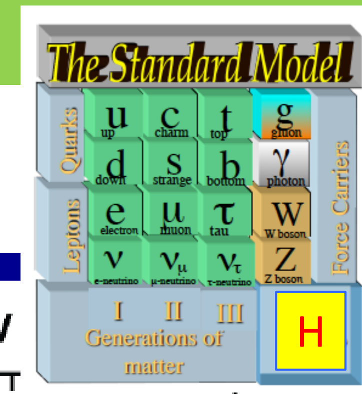
LCLS-II

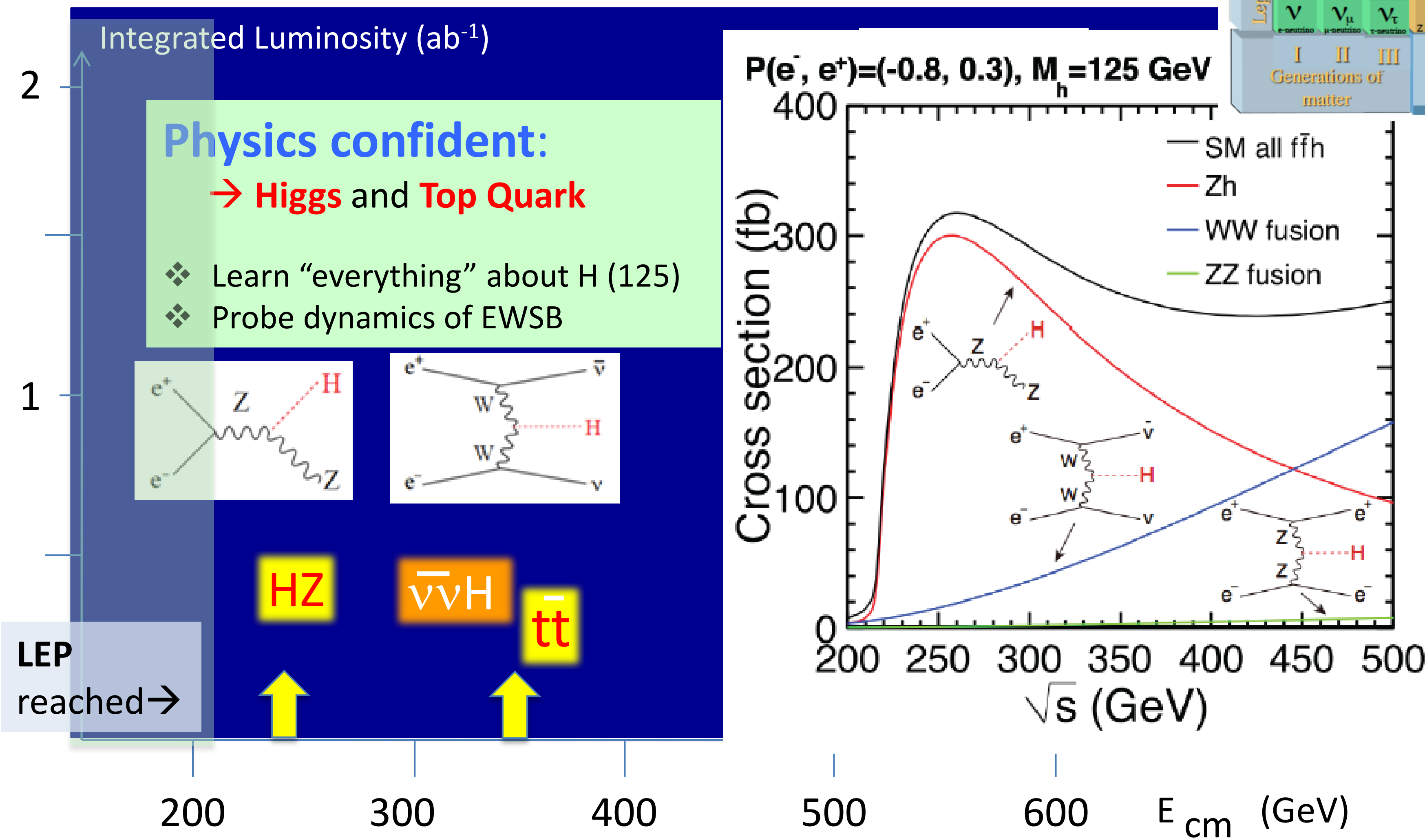
LCC international structure



Important Energies in ILC

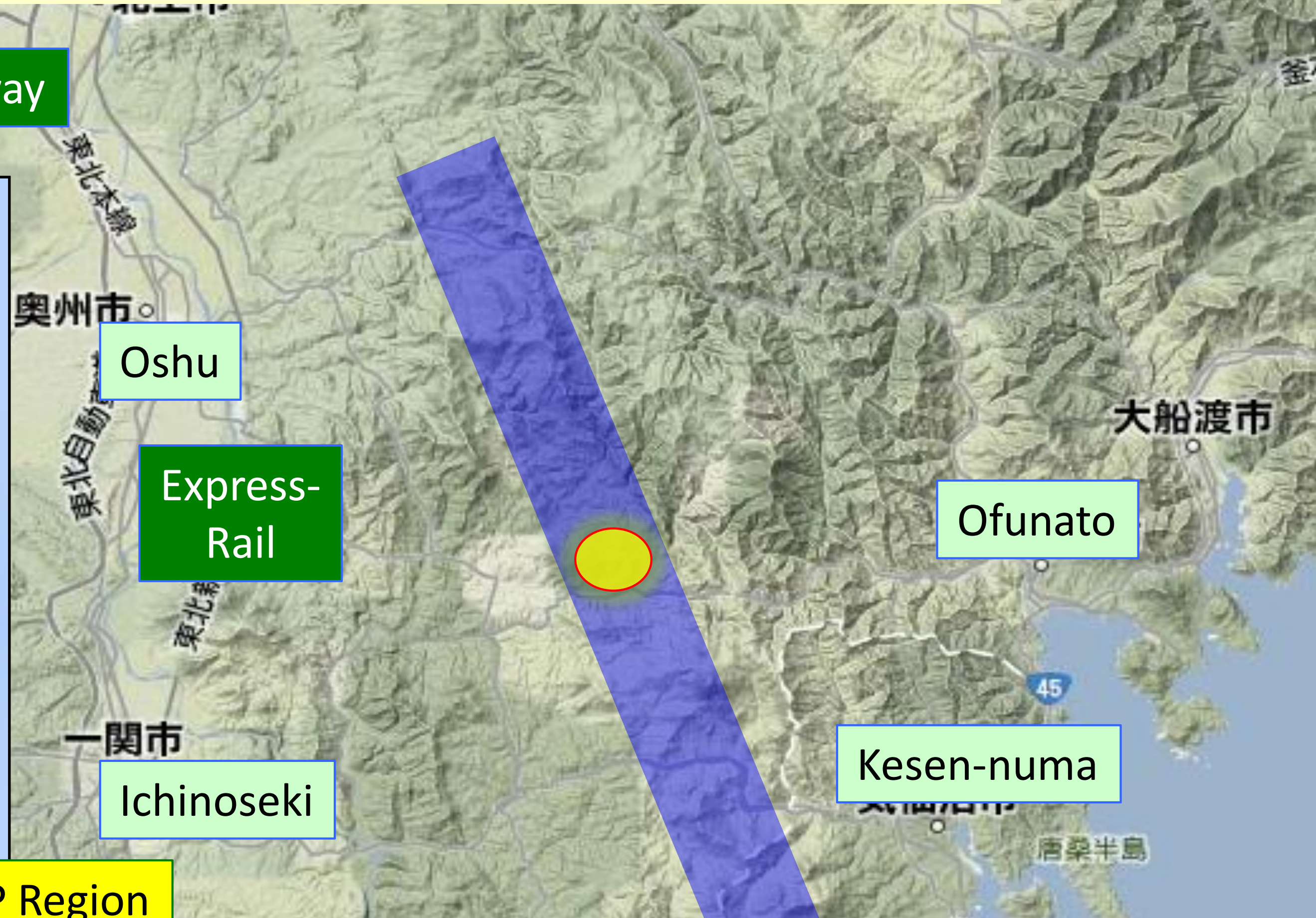
125 GeV Higgs discovery reinforcing the ILC importance

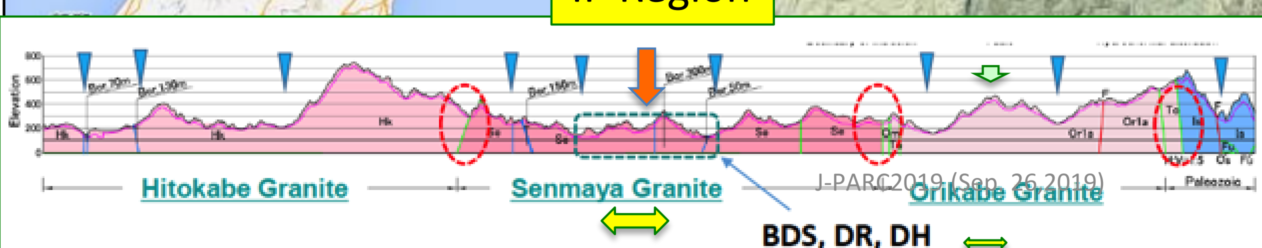




ILC Site Candidate Location in Japan: Kitakami

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





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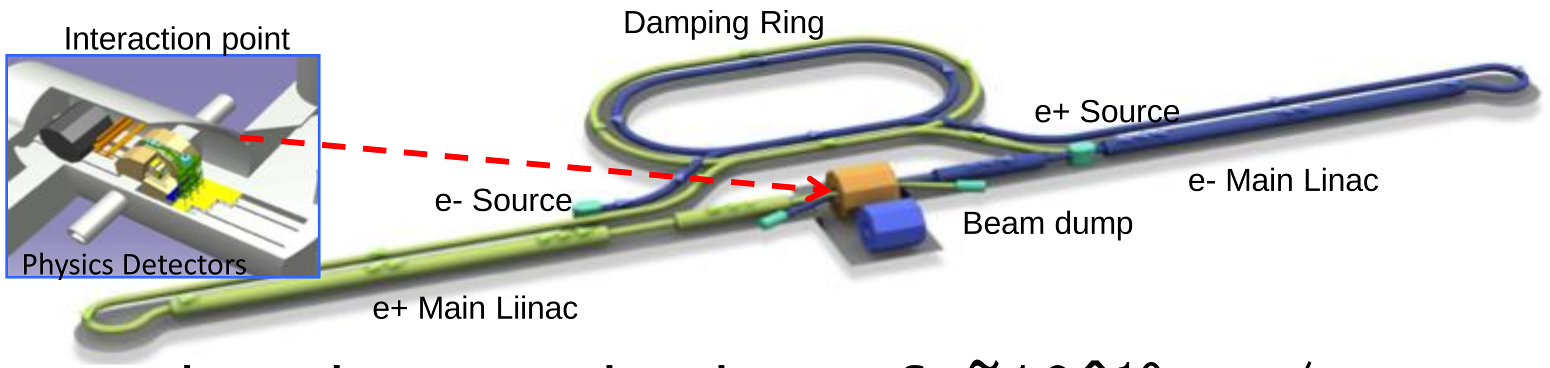
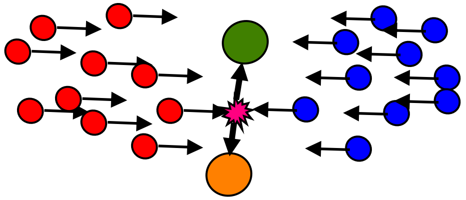
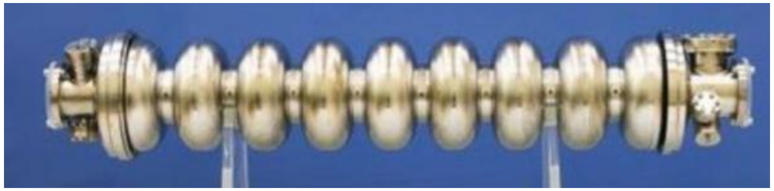
Technology of the ILC



bunch, consisting of ~10^10 e+/e−

- 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 (SCRF)
- Getting them collided ***Final focus***
  - nano-meter beams
- Go to ***Beam dump***





Demonstrated ILC accelerator parameters

Parameters	Unit	Required	Design	Demonstrated	Comment
Electron Source					
Bunch charge	nC	**3.2**	4.8	8.0	SLAC-SLC
Beam current	uA	**21**	42	1,000	Jlab
Polarity	%	**80**	80	90	U.Nagoya, SLAC,KEK
Positron Souce					
Bunch charge	nC	**3.2**	4.8	8.0	SLAC-SLC
Polarity	%	**30**	30	80	SLAC E166
Superconducting RF					
Module gradient	MV/m	**31.5 (+/- 20%)**		～31.5	DESY, FNAL, JLab, Cornell, KEK,
Cavity Q value (Q_0)		**10^{10}**		**～10^{10}**	
Cavity gradient	MV/m	**35 (±20%)**		33.4 MV/m	
Beam current	mA	**5.8**		> 5.8	DESY, KEK
Number of bunches		**1312**		1312	DESY
Bunch charge	nC	3.2		3	
Bunch interval	ns	554		333	
Beam pulse width	μs	**730**		800	DESY, KEK
RF pulse width	ms	**1.65**		1.65	DESY, KEK, FNAL
Repetition	Hz	**5**		10	DESY
Nano-beam					
ATF-FF beam size (y) ILC-FF beam size(y)	nm nm	**37** **7.7**		41 at ATF (@ 1.3 GeV)	ATF hosted at KEK

Most of the parameters are already demonstrated at the various facilities.

ATF-2 nano-beam collaboration

Examples of European contribution

	CERN	France		Germany	Spain	UK	
		LAL	LAPP	DESY	IFIC	Oxford	RHUL
Goal 1 Small beam							
Very-low β	✔						
Ultra-low β	✔						
Halo control		✔			✔		
Wakefield/Intensity	✔				✔	✔	✔
Instrumentation	✔	✔			✔	✔	✔
Ground motion	✔		✔			✔	
Background				✔			✔
Goal 2 Beam stabilization							
Stabilisation/Feedback		✔				✔	

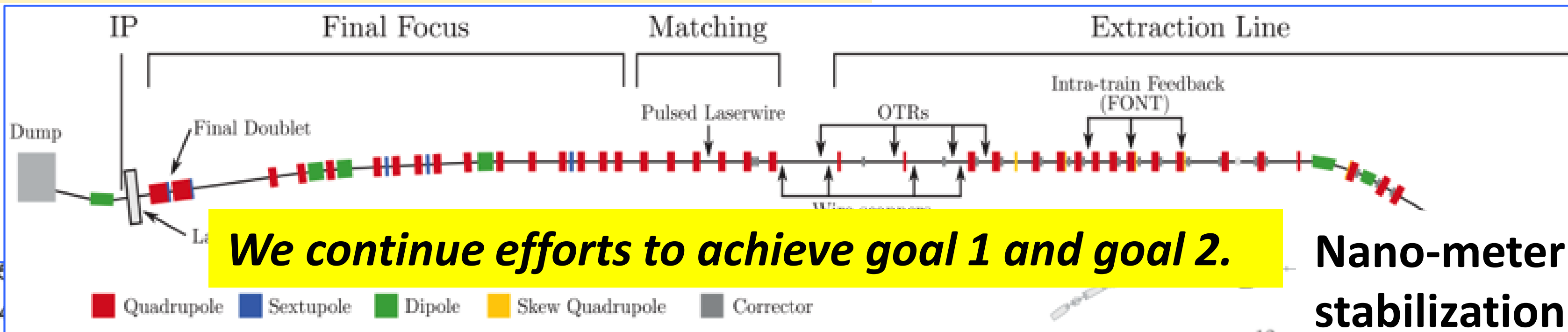
Progress in FF Beam Size and Stability at ATF2

Goal 1: Establish the ILC final focus method with same optics and comparable beamline tolerances

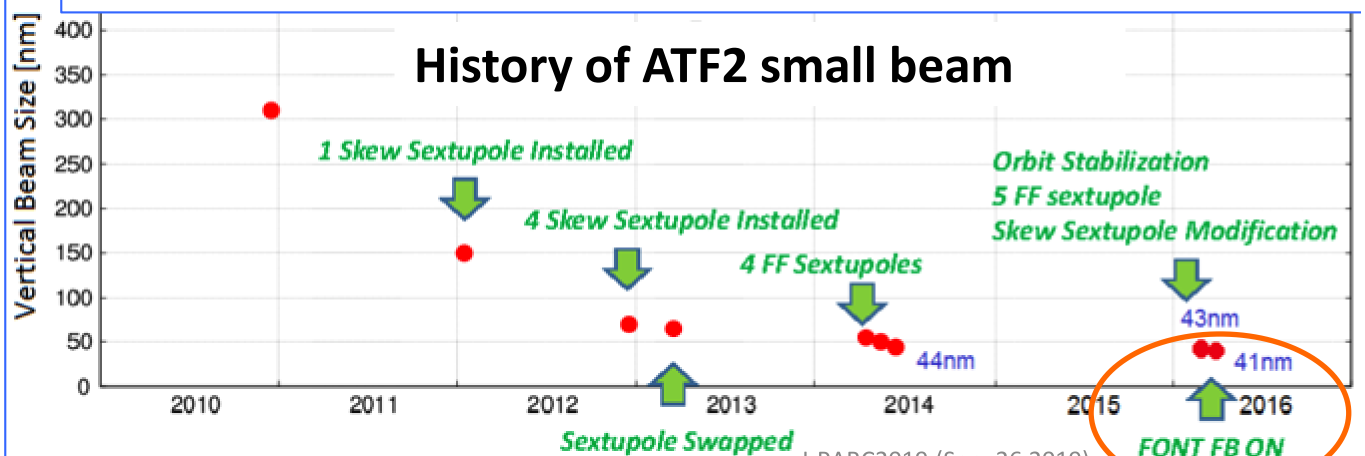
- ATF2 Goal : **37** nm → ILC **7.7** nm (ILC250)
  - Achieved **41 nm** (2016)

Goal 2: Develop a few nm position stabilization for the ILC collision

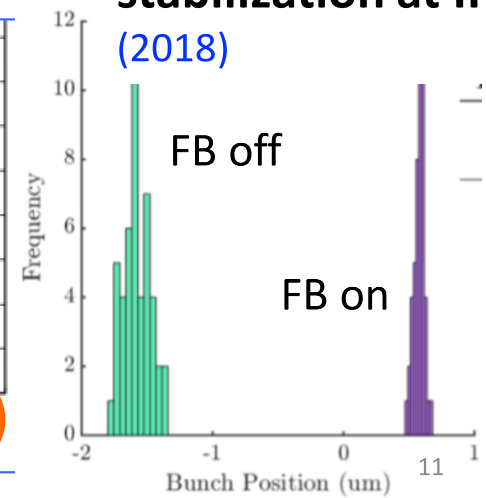
- **FB latency 133 nsec achieved** (target: < 300 nsec)
- **positon jitter at IP: 106 → 41 nm (2018)** (limited by the BPM resolution)



We continue efforts to achieve goal 1 and goal 2.

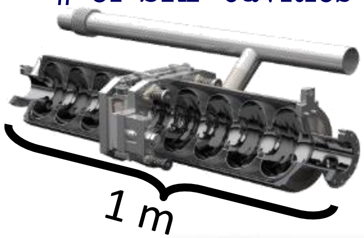


Nano-meter stabilization at IP (2018)

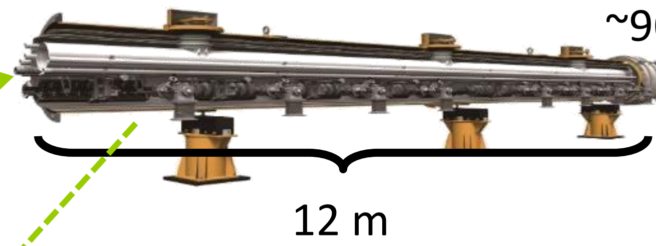


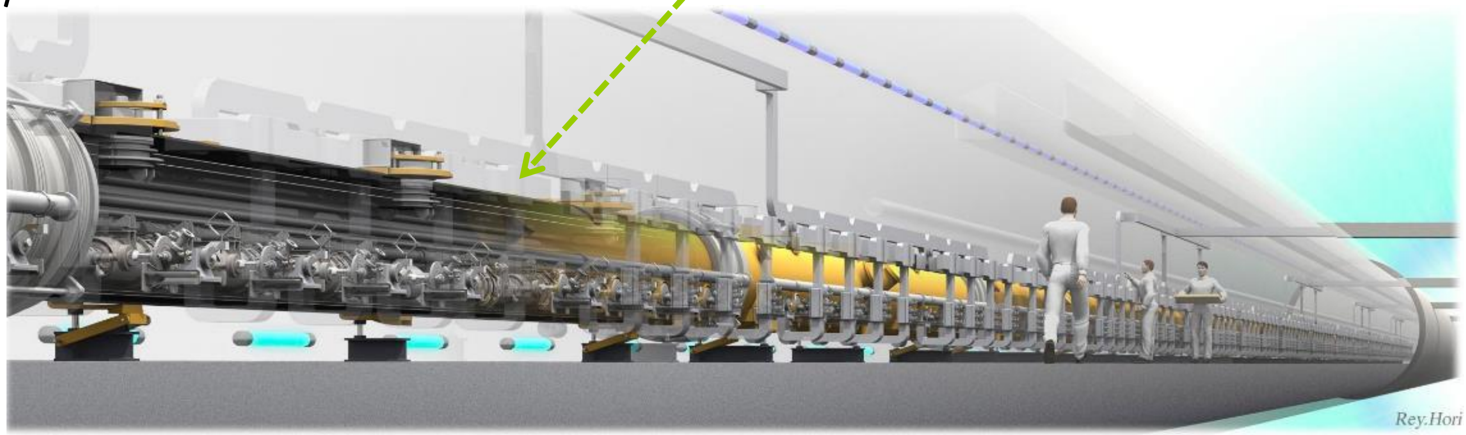
Main Linac at the ILC

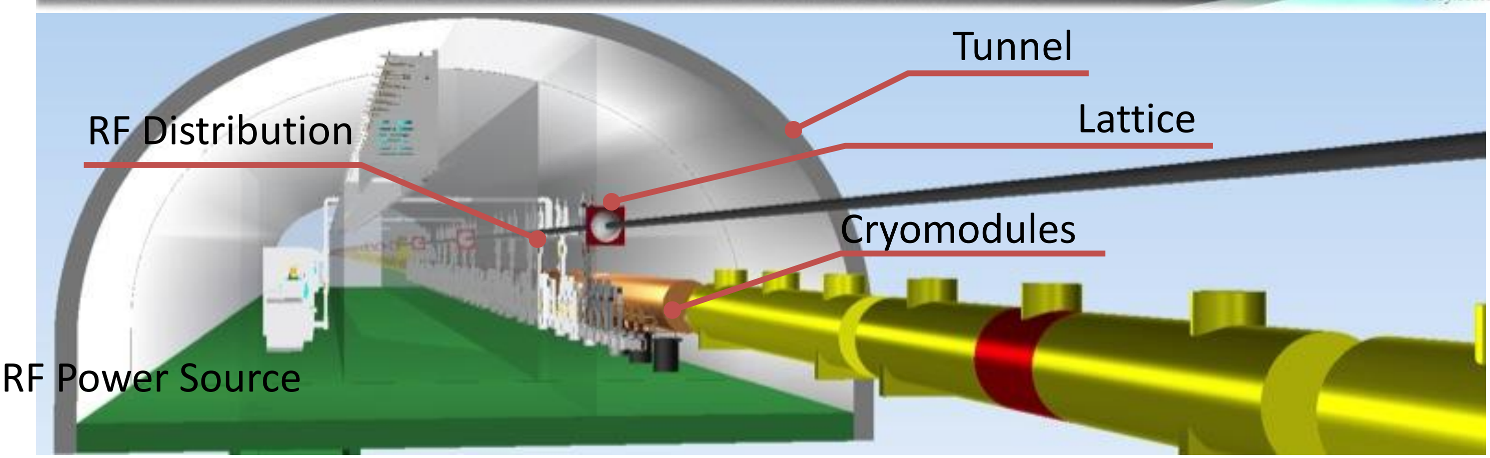
of SRF cavities ~8,000



~900 cyomodules

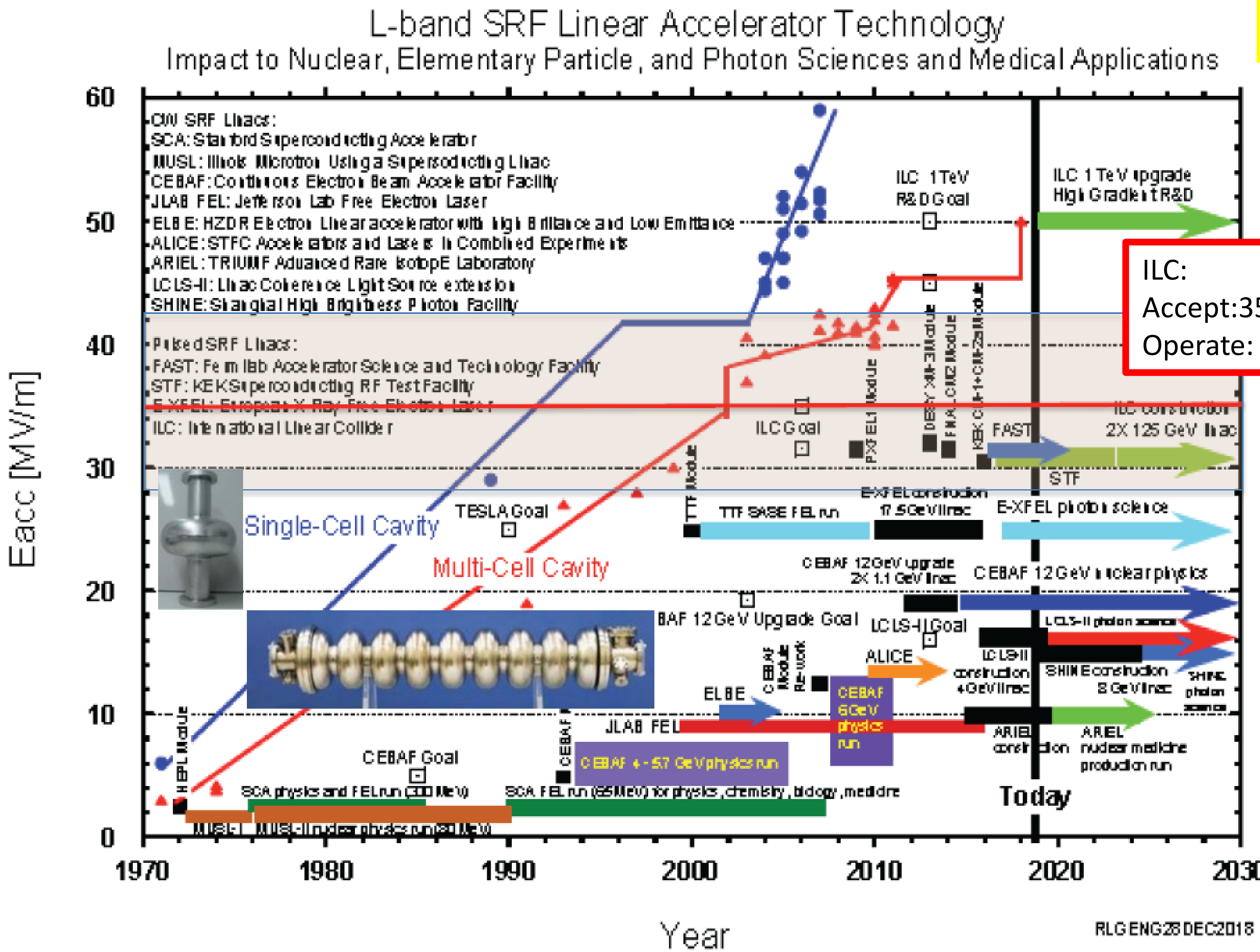






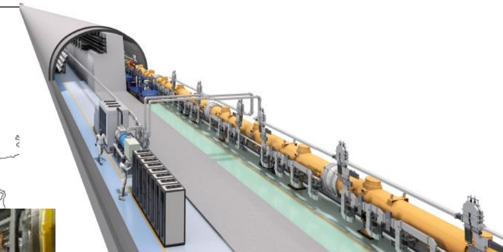
Matured SRF technologies

R. Geng (JLAB)



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

SRF accelerators in the world



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Euro-XFEL

Operation started from 2017

- -100 cyromodules
- -800 cavities
- -17.5 GeV (Pulsed)

LCLS-II (under construction)

- -35 cyromodules
- -280 cavities
- - 4 GeV (CW)

ILC

- -900 cyromodules
- -8,000 cavities
- -250 GeV (Pulsed)

DESY

LAL/Sacray

INFN

SLAC

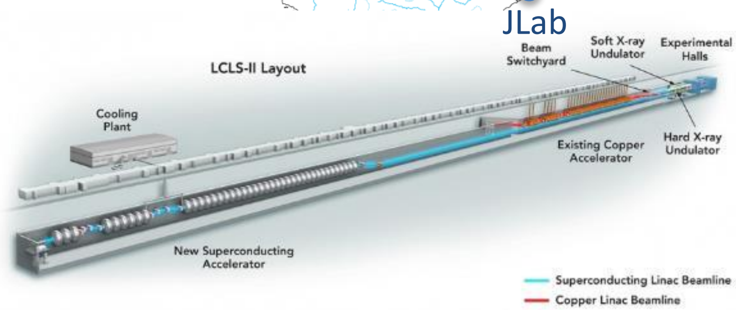
FNAL

Cornell

JLab

KEK

SINAP



SHINE (under construction)

- -75 cyromodules
- -~600 cavities
- - 8 GeV (CW)

1.3GHz 9 cell cavity

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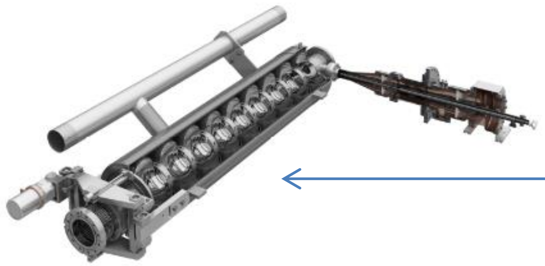
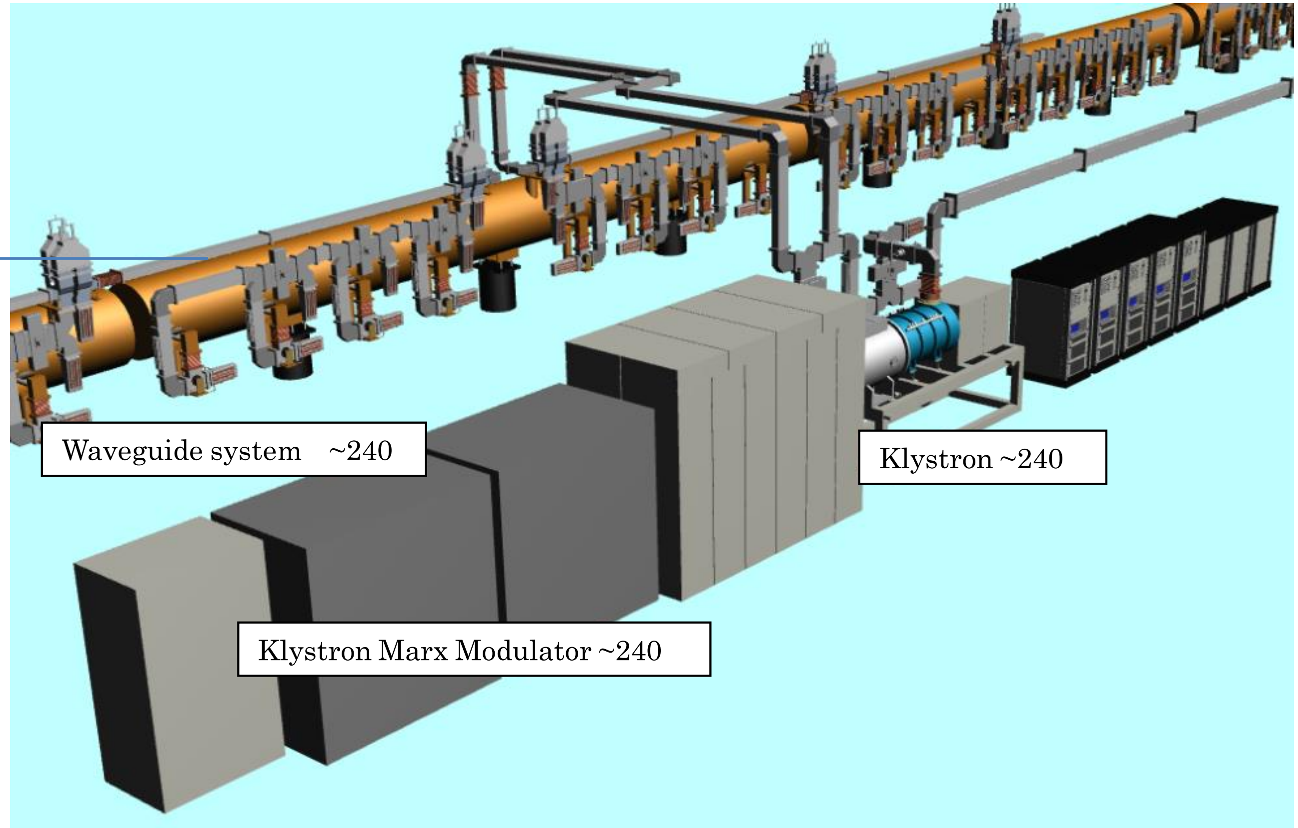
ILC cost reduction R&D

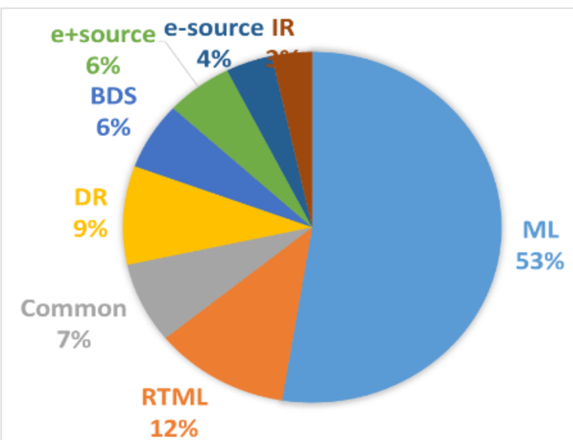
Input coupler ~8,000



Cavity ~9,000

(including ~10% margin)





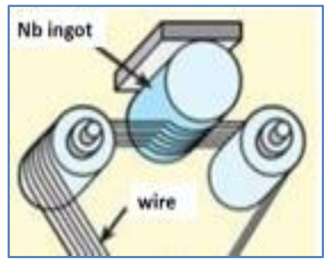
The half of the construction cost is coming from main linac (ML).
Thus we focused our cost reduction R&D into ML (superconducting RF technology)

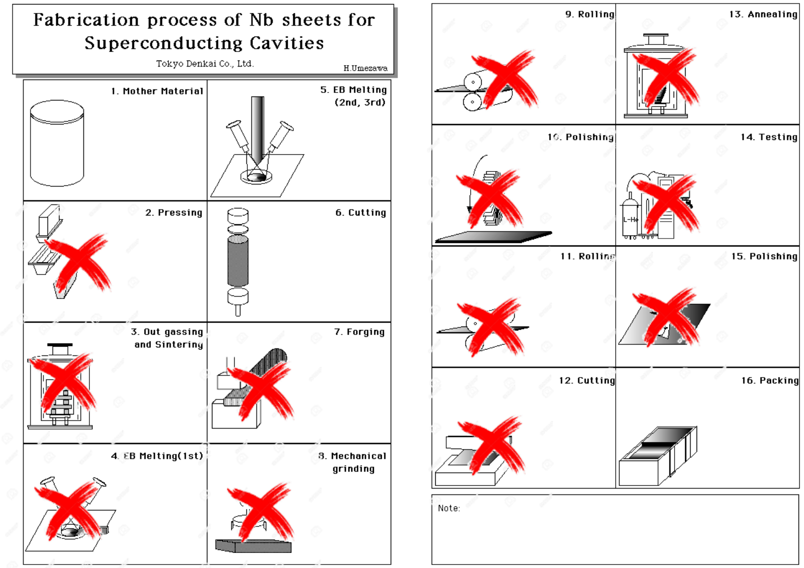
ILC Cost-Reduction R&D in US-Japan Cooperation on SRF Technology

Based on recent advances in technologies;

– Nb material/sheet preparation

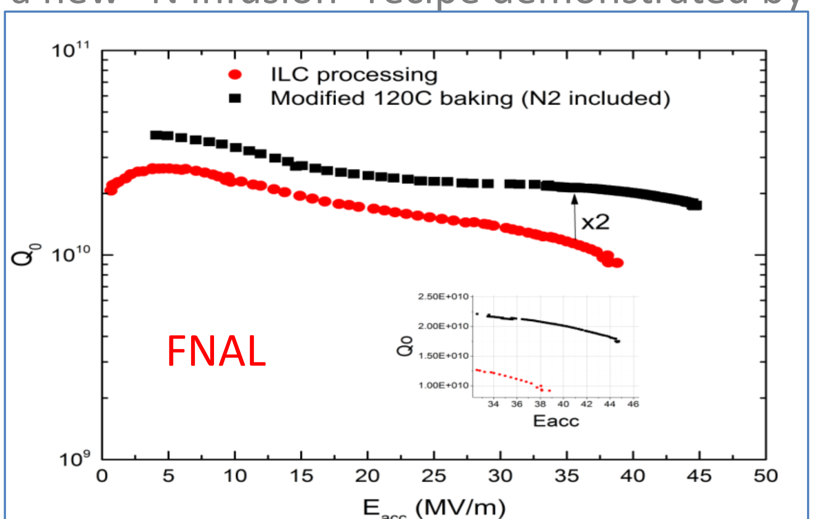
- w/ optimum Nb purity and clean surface

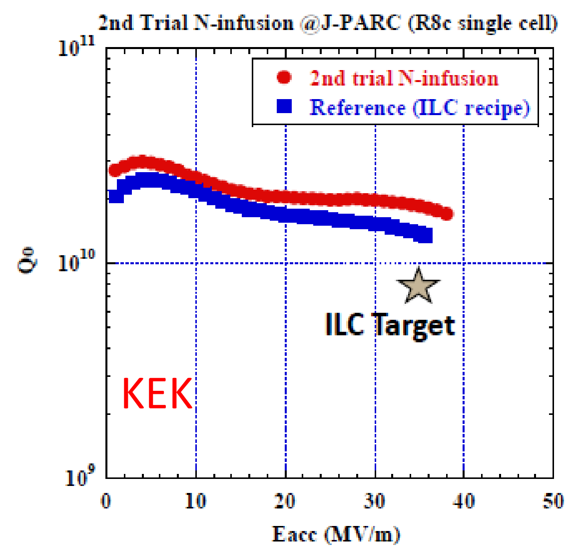




– SRF cavity fabrication for high-Q and high-G

-w/ a new "N Infusion" recipe demonstrated by **Fermilab**





J-PARC2019

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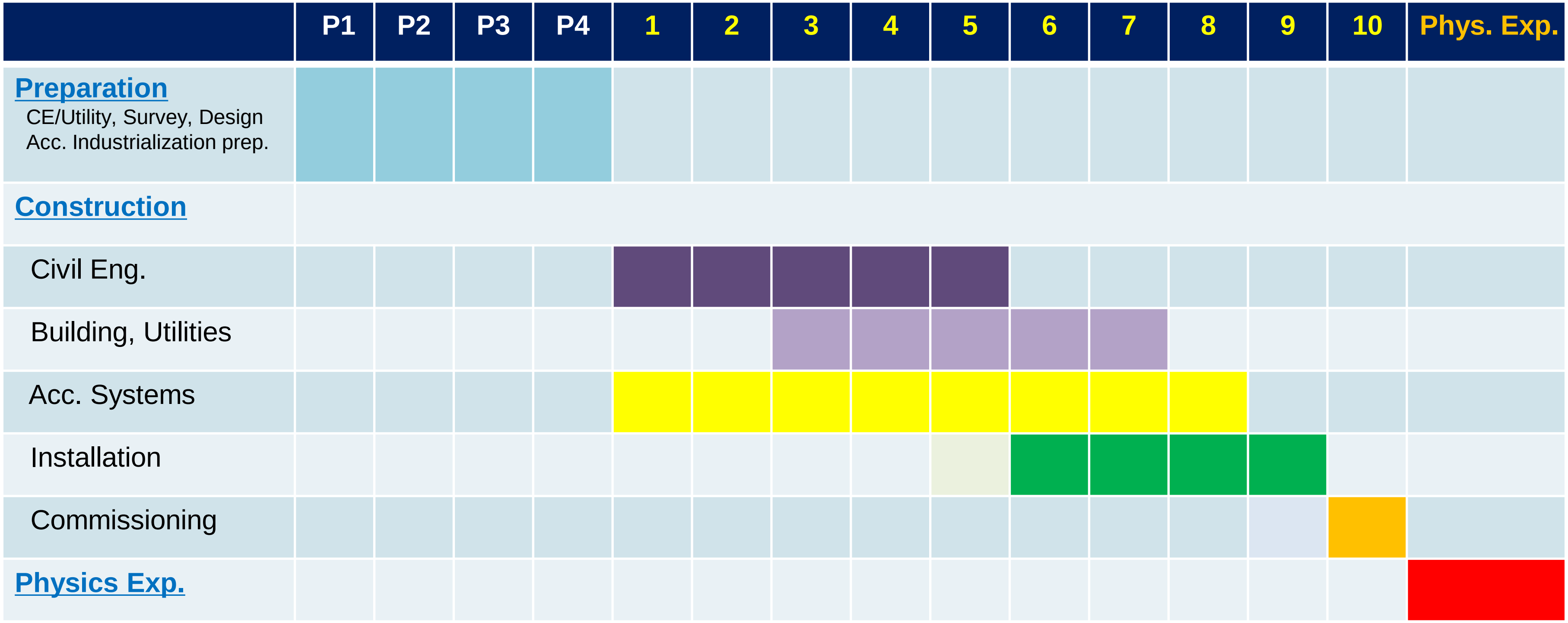
ILC-250 TimeLine

Now we are at pre-preparation phase (waiting for the preparation phase).
Four years preparation and 9 years construction.



ILC preparation plan/activity

European ILC preparation plan as “E-JADE” report

https://www.e-jade.eu/sites/sites_custom/site_e-jade/content/e49893/e65922/e73204/ILC-EIPP.E-JADE.v2.12.20180703.pdf

E-JADE — THE EUROPEAN ILC PREPARATION PLAN (EIPP)

Grant Agreement No: 645479

E-JADE

Europe-Japan Accelerator Development Exchange Programme

Horizon 2020 / Marie Skłodowska-Curie Research and Innovation Staff Exchange (RISE)

REPORT

THE EUROPEAN INTERNATIONAL LINEAR COLLIDER PREPARATION PLAN (EIPP)

The International Linear Collider
A European Perspective

Prepared by: Philip Bambade[1], Ties Behnke[2], Mikael Berggren[2], Ivanka Bozovic-Jelisavcic[3], Philip Burrows[4], Massimo Caccia[5], Paul Colas[6], Gerald Eigen[7], Lyn Evans[8], Angeles Faus-Golfe[1], Brian Foster[2,4], Juan Fuster[9], Frank Gaede[2], Christophe Grojean[2], Marek Idzik[10], Andrea Jeremie[11], Tadeusz Lesiak[12], Aharon Levy[13], Benno List[2], Jenny List[2], Joachim Mnich[2], Olivier Napoly[6], Carlo Pagani[14], Roman Poeschl[1], Francois Richard[1], Aidan Robson[15], Thomas Schoerner-Sadenius[2], Marcel Stanitzki[2], Steinar Stapnes[8], Maksym Titov[6], Marcel Vos[9], Nicholas Walker[2], Hans Weise[2], Marc Winter[16].

[1]LAL-Orsay/CNRS, [2]DESY, [3]INN VINCA, Belgrade, [4]Oxford U., [5]U. Insubria, [6]CEA/Irfu, U. Paris-Saclay, [7]U. Bergen, [8]CERN, [9]IFIC, U. Valencia-CSIC, [10]AGH, Kraków, [11]LAPP/CNRS, [12]IFJ PAN, Kraków, [13]Tel Aviv U., [14]INFN, [15]U. Glasgow, [16]IPHC/CNRS.

European Strategy input
The International Linear Collider
A European Prospective

USA

US-Japan Joint Research on ILC Cost Reduction from FY 2017.

- -High field / high efficiency cavity treatment (FNAL)
- -Reducing price of niobium materials

KEK ILC action plan

https://www.kek.jp/en/newsroom/KEK-ILC_ActionPlan_Addendum-EN%20%281%29.pdf

Issued on 2016-1-6
Addendum issued on 2018-1-14

KEK-ILC Action Plan

KEK-ILC Action Plan Working Group

issued on Jan. 2016.
Addendum issued on Jan.2018

1. Introduction

The International Linear Collider (ILC) is a next-generation energy frontier electron–positron collider. It will reach a center-of-mass energy of 500 GeV in the first stage, and can be upgraded to an energy to 1 TeV in the future. It aims to precisely measure the properties of the Higgs particle and Top quark, discover new particles and phenomena, and search for new physics beyond the Standard Model of elementary particle physics.

The worldwide high-energy physics community has recognized importance of the ILC, and established the Global Design Effort (GDE) in 2005 under the supervision of the International Committee for Future Accelerators (ICFA). The GDE has advanced the design and technical development of the ILC within the international framework. In June 2013, GDE published its progress in the ILC Technical Design Report (ILC-TDR); this report included accelerator design, technology, construction costs, and the human-resource requirements necessary to realize the ILC. The ICFA established the Linear Collider Collaboration (LCC) under the supervision of the Linear Collider Board in February 2013 to oversee the detailed ILC accelerator design and engineering.

Based on discussions for its future plan, the Japan Association of High Energy Physicists proposed to host and to realize the ILC as a global project in October 2012. In May 2013, the Ministry of Education, Culture, Sports, Science and Technology of Japan (MEXT) asked the Science Council of Japan (SCJ) to study the ILC project from a scientific viewpoint. In September 2013, the SCJ produced a “Report on the International Linear Collider Project”. In May 2014, MEXT established the ILC Advisory Panel (ILC-AP), and has been studying issues pointed out by the SCJ. In June 2015, MEXT ILC-AP produced a report, “Summary of the International Linear Collider (ILC) Advisory Panel’s Discussions to Date”. Based on this report, further action has been taken to establish a new working group to verify the human resource and training plan necessary to realize the ILC.

Accelerator preparation phase R&Ds

KEK ILC action plan

Area	Tasks
Accelerator Design	Design parameter optimization
SCRF	Mass-production and quality control Superconducting material, cavity properties (electric field, resonance characteristics) Hub-lab functioning System performance stabilization (Stabilization of the performance and maintenance, including international transport of CM)
Nanobeam	Minimizing the beam size and demonstrating stability Beam handling (DR, RTML, BDS, BD)*
Accelerator elements - Positron source (e+) - Beam dump	e+: Undulator-driven (polarization) or an electron-driven system (backup), heat balance of the dump, cooling, safety
CFS	Basic Plan by assuming a model site, engineering design, drawings, survey, assessment
common technical support	Safety (radiation, high-pressure gas, etc.) Communication and network
Administration	General affairs, finace, int. relations, public relations Administrative support for ILC pre-lab

European ILC preparation plan

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

European ILC preparation plan

European Strategy input document

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	SCRF	HLRF	Sources	Damping Rings	Instru-mentation	Beam Dynamics	Beam Delivery System	Cryogenics
CERN		C,O	O	G,C,O	C,G	C,G	C,G	O
France	X,E,G		G		A,G	G	C,G	
Germany	X,G	X	G	G	X	G		X,O
Italy	X,E,G			G				
Poland	X,E		O		E,O			X,E,O
Russia	X		G					
Spain	X,E				A		C,G	
Sweden	E						G	
Switzerland					X,C			
UK	E		G	G	A,C,G	C,G,A	C,G,A	

TABLE III. European expertise relevant for ILC accelerator construction, based on experience in the recent past. This is based on two major construction projects, the E-XFEL (X) and the ESS (E), several more R&D oriented efforts namely the GDE/LCC (G), ATF-2 (A), CLIC (C) and experience in other accelerator projects (O)

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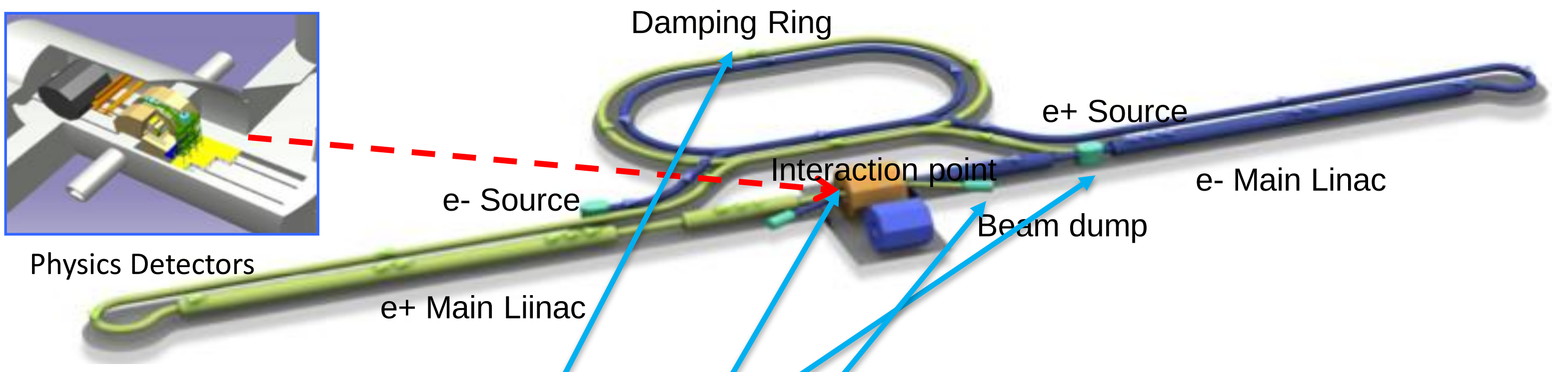
Remaining technical topics



SCRF in main linac:
    improving the yield and performance, quality assurance

Positron source:
    rotating target, magnetic focusing system, replacement of the target

Damping ring:
    injection/extraction, beam control

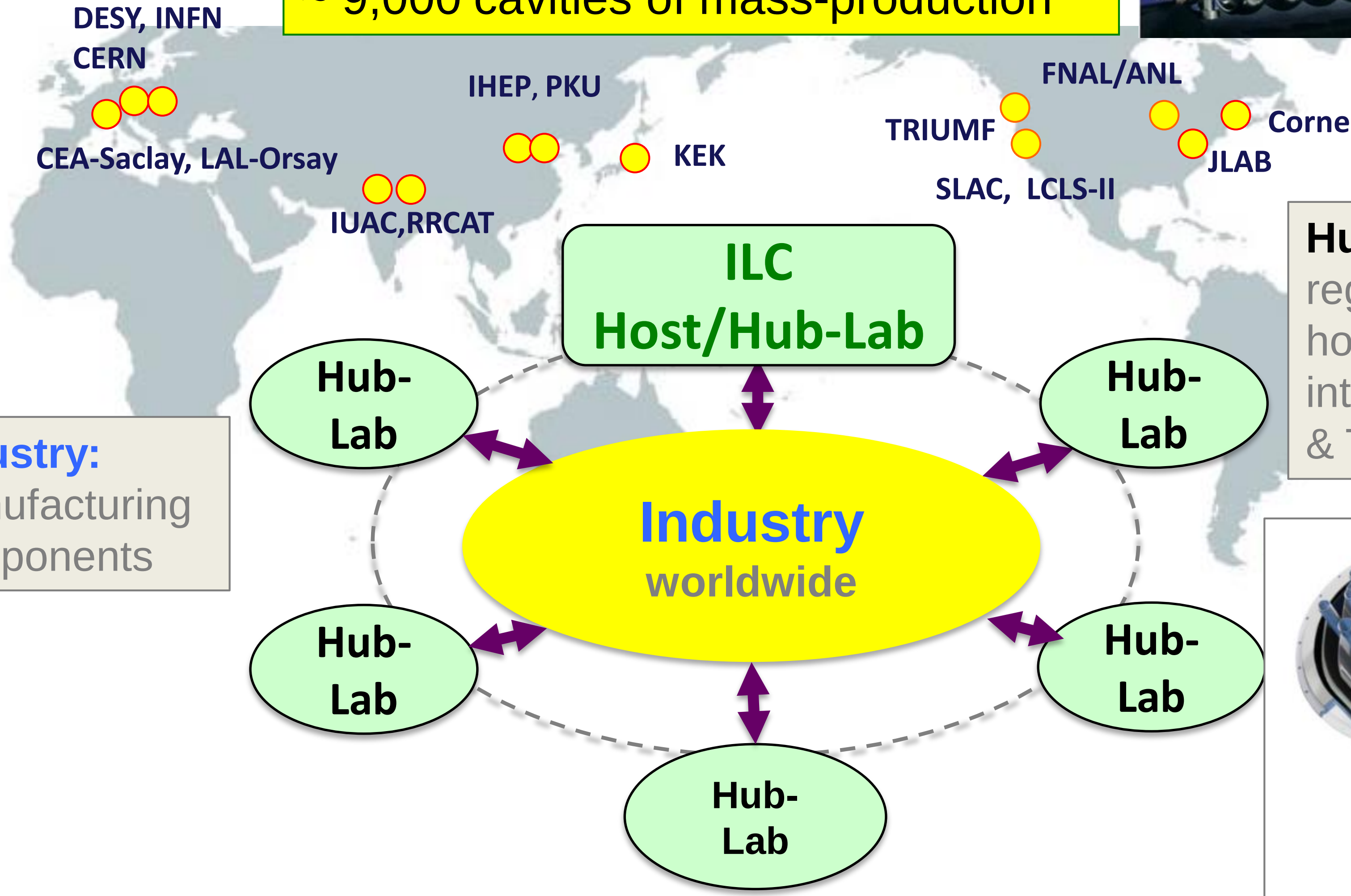
Interaction region:
    beam focus, position control

Beam dump:
    cooling of the dump, beam dump window, replacement of the window

These technical preparation will be carried out with the international collaboration during preparation phase.

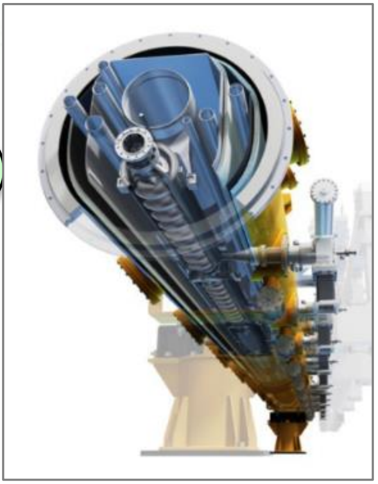
ILC SCRF Global Integration Model

~8,000 x 1.1(Yield = 90%)
~ 9,000 cavities of mass-production



Industry: manufacturing components

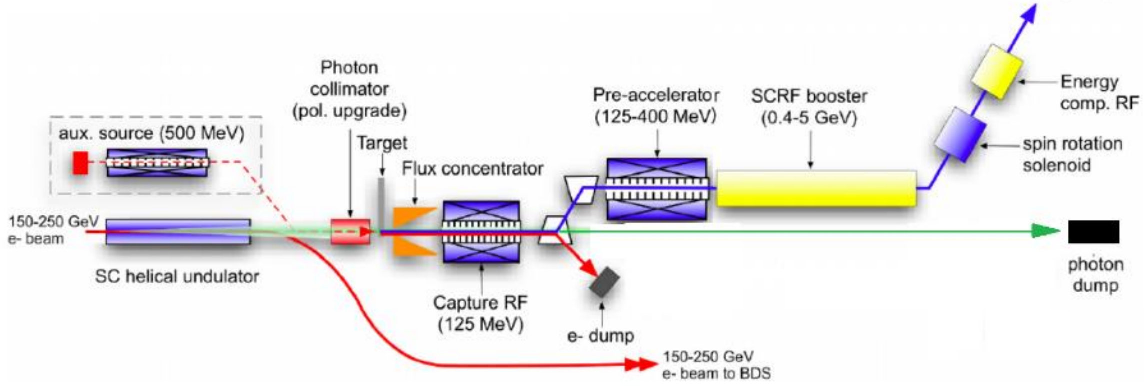
Hub-lab: regionally hosting integration & Test



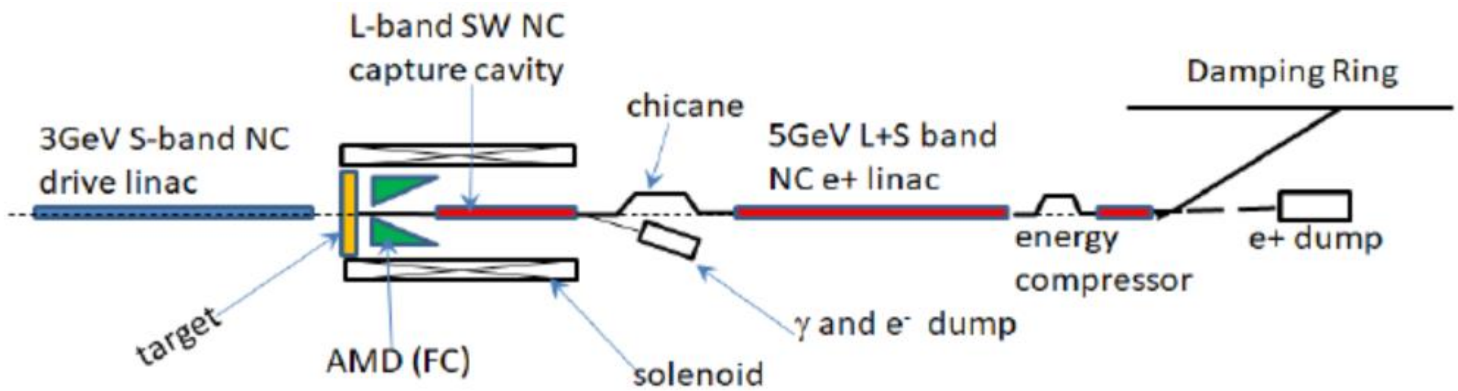
Cavity production with high quality (keeping the high performance)
Cryomodule transportation from hub-lab to the host (keeping the high performance)

Positron Source

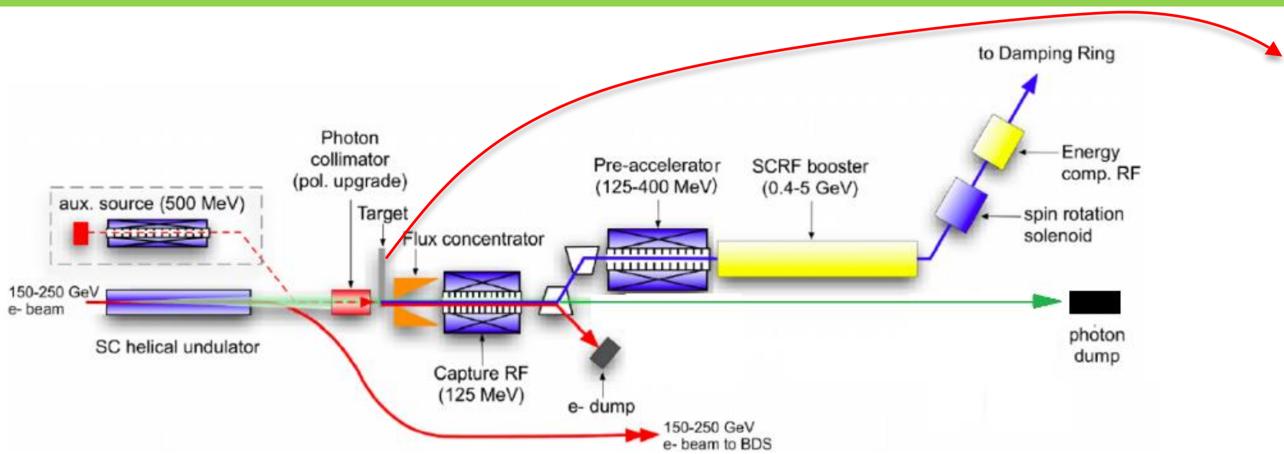
Undulator: baseline of the ILC. 125 GeV electrons are injected to the helical undulator. The photons produced at the undulator is used for the electron/positron pair creation at the rotating target. Polarized positrons can be generated.

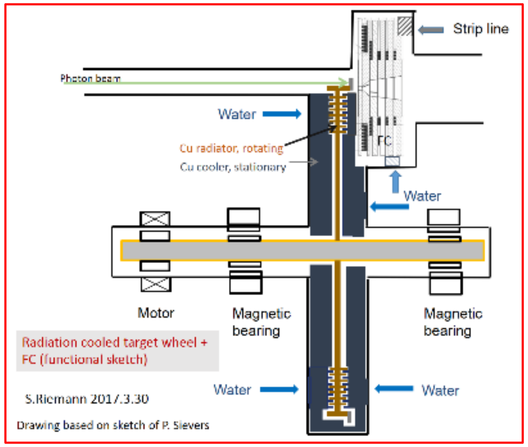


Electron-driven: alternative of the ILC. Extra 3GeV linac is used for the positron generation. High energy electrons are not necessary. (Electron independent commissioning is possible. However, polarization is not available.)



Positron rotating target





	E-Driven	undulator	Existing X-ray generator
Cooling/Seal	water/magnetic fluid	Radiation/ magnetic levitation	water/magnetic fluid
radius（mm）	250	500	160
weight（kg）	65*	50*	17
Tangential velocity（m/s）	5	100	160
rotation (rpm)	200	2,000	10,000
Beam heat load(kW)	20	2	90
Vacuum pressure（Pa）	10^{-6}	10^{-6}	10^{-4}

*The weight depends on the design of the disk part and the material

- Reliable rotating target
- Replacement of rotating target

ILC beam dump

	TDR		250 GeV ILC
Center of mass energy (GeV)	500	**1,000 (for future upgrade)**	**250**
Beam energy(GeV)	250	500	125
Repetition (Hz)	5	4	5
Number of bunches	1312	2450	1312
Bunch interval (nsec)	554	366	554
Pulse width (msec)	0.727	0.897	0.727
Number of charges	$2x10^{10}$ (3.2nC)	$1.74x10^{10}$ (2.79nC)	$2x10^{10}$ (3.2nC)
Charges per pulse (μ C)	4.20	6.83	4.20
Pulse current (mA)	5.78	7.61	5.78
Pulse energy (MJ)	1.05	3.41	0.53
Average power(MW)	5.25	**13.7**	**2.63**

Design：20% margin → **17 MW**

20%

Main beam dump

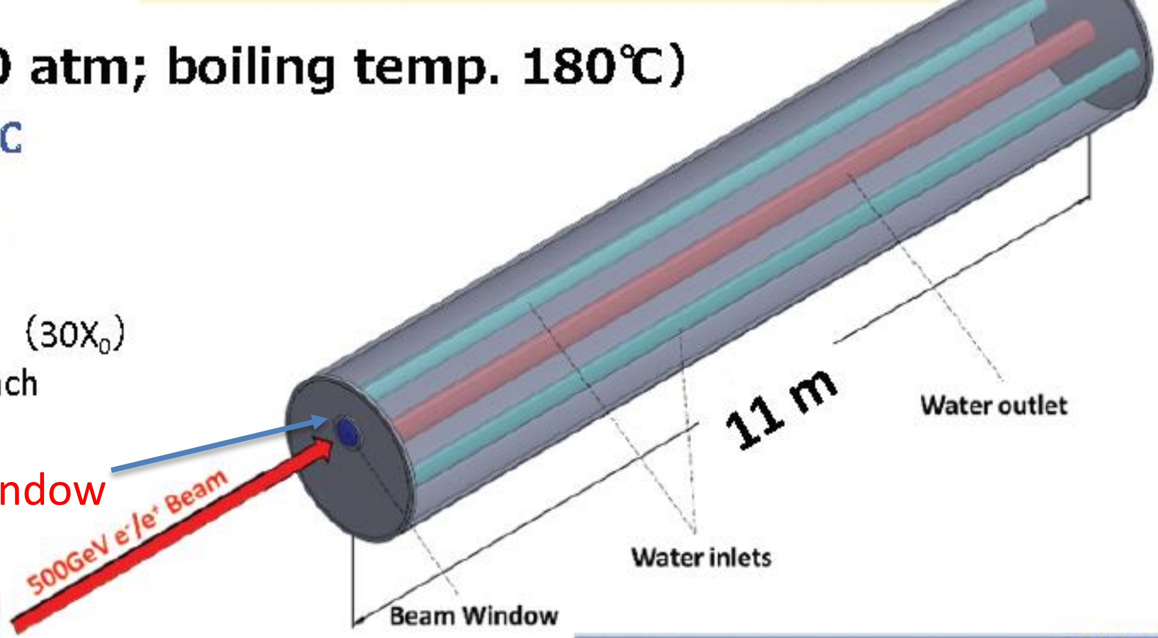
P. Satyamurthy, et.al., NIM A 679 (2012) p67-81.

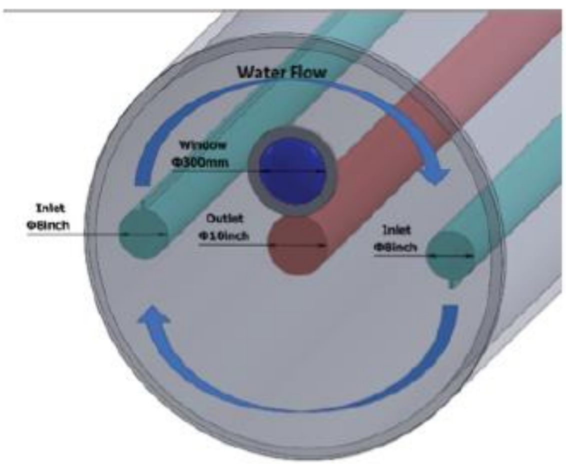
Water dump (10 atm; boiling temp. 180℃)

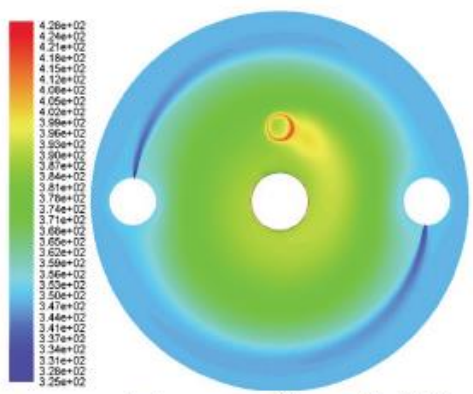
Peak temp. by beam: 155°C

- Water flow: **2.17m/s**
- Inlet temp.: **50°C**
- Diam. 1.8m、length 11m（$30X_0$）
- SUS 316LN, thickness 2 inch
- End plate: SUS t7.5cm

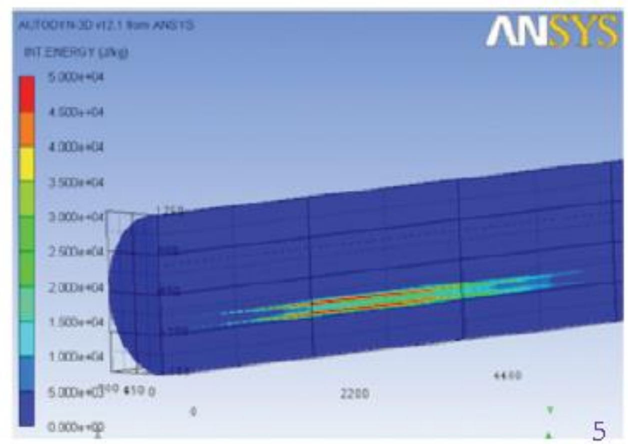
Beam dump window







Temp. profile at Z=290cm



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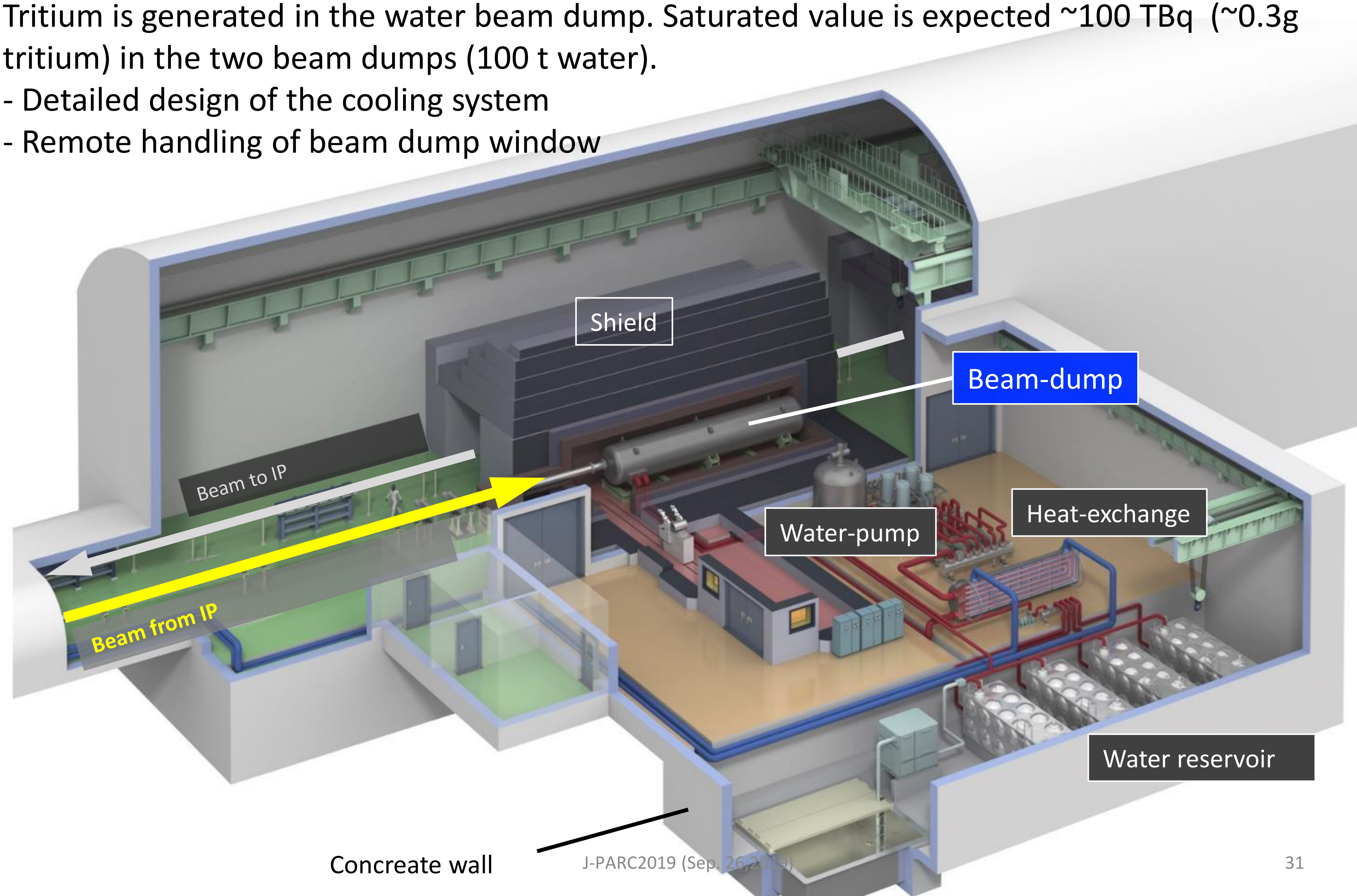
Beam dump system

Tritium is generated in the water beam dump. Saturated value is expected ~100 TBq (~0.3g tritium) in the two beam dumps (100 t water).

- Detailed design of the cooling system
- Remote handling of beam dump window



Current Status of the ILC

Shin MICHIZONO
KEK/Linear Collider Collaboration (LCC)

- *250 GeV ILC*
- *Area systems*
- *SCRF R&Ds*
- *ILC preparation*
- *Remaining technical topics*
- ➡ *Recent ILC status*

ICFA/LCB@Tokyo

Mar.6 evening: Reception speech by Hon. Kawamura
Mar.7 morning: MEXT talk
Mar.7 evening: ICFA media briefing

ICFA media briefing in You Tube. (from 0:11:00 in the timeline)
https://www.youtube.com/watch?v=SbpS8TjdDkI&feature=youtu.be

KEK High Energy Accelerator Research Organization

Statement by MEXT at LCB Meeting in March 2019

- Following the opinion of the SCJ, **MEXT has not yet reached declaration for hosting the ILC in Japan at this moment.** The ILC project requires further discussion in formal academic decision-making processes such as the SCJ Master Plan, where it has to be clarified whether the ILC project can gain **understanding and support from the domestic academic community**.

- MEXT will pay close attention to the progress of the discussions at the European Strategy for Particle Physics Update.

- The ILC project has certain scientific significance in particle physics particularly in the precision measurements of the Higgs boson, and also has possibility in the technological advancement and in its effect on the local community, although the SCJ pointed out some concerns with the ILC project. Therefore, considering the above points, **MEXT will continue to discuss the ILC project with other governments having an interest in the ILC project.**

KEK High Energy Accelerator Research Organization

Message from the Federation of the Diet Members for ILC

- I believe the ILC should be realized through politically-led efforts, cutting across different ministries and agencies. As such, **we're proceeding to realize a budgeting as a national project with a separate budget outside of the regular science and technology budget.**

- **On the international cost sharing, we have to separate the infrastructure part of civil engineering and conventional equipment that is natural to be taken up by the host country and the apparatus part that is natural to be internationally cost-shared among technically competent countries.**

- As the environment has ripened socially, politically, and administratively, **the next mission for politics is to secure the budget for the construction.** In parallel, with the government's administrative process, we will begin in earnest from our role as political and legislative body to obtain the necessary budget for construction.

KEK
High Energy Accelerator Research Organization

Actions to be done by MEXT

Answers given by MEXT at the Diet session on March 13, 2019.

- In the future, while paying close attention to the progress of discussions on the European Elementary Particle Physics Strategy, we would like to **deepen discussions with France and Germany at the governmental level**, by proposing, for instance, to establish a standing discussion group similar to the one with the US. (Mr.Isogai)

- So, also for the ILC project, we expect there will be **a working group set up in the High Energy Accelerator Research Organization, so-called KEK, and at its initiative,** discussions within the community of domestic and foreign researchers will proceed regarding international cost sharing, etc. (Mr.Isogai)

- As I mentioned earlier, I am also aware that this is a project of great significance both from the academic research point of view and from the perspective of regional revitalization. Therefore, I would like to **continue our investigations, closely collaborating with related communities while keeping an eye on the international situation.** (Minister Shibayama)

Lausanne report (from KEK news)

Linear Collider Community Meeting on April 2019 at Lausanne

Masanori Yamauchi, Director General of KEK, made a presentation regarding KEK's plan for the ILC, at the international conference held on 8-9 April 2019 in Lausanne, Switzerland.

About 100 scientists from around the world who aim for the realization of electron-positron linear colliders gathered at the Linear Collider Community Meeting, to discuss the future linear collider activities.

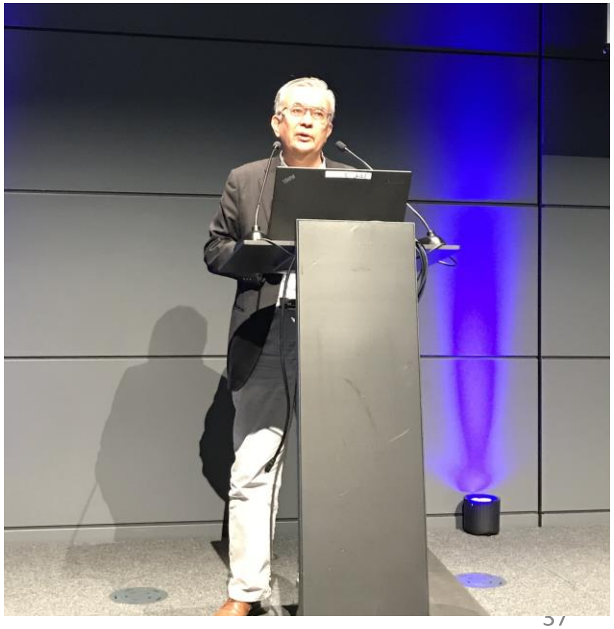
In the conference, Yamauchi presented KEK's plan for the ILC for the upcoming year, summarized as follows:

◇Organise the international working group with close consultation with the Ministry of Education, Culture, Sports, Science and Technology (MEXT).

◇Promote activities to gain a better understanding of the broader academic community in Japan (Propose the ILC project to the Science Council of Japan's Master Plan; Organise a symposium)

◇Cooperate with MEXT to establish the governmental level discussion groups with France and Germany. Also, strengthen the discussion group with the US DOE.

◇Conduct R&D program at ATF, STF and CFF facilities collaborating with the international teams



https://www.kek.jp/en/newsroom/2019/04/12/1700/

KEK International WG

Tasks of the WG:

- Model of international cost-sharing for construction and operation
- Organization and governance of the ILC Laboratory

The "Revised ILC Project Implementation Planning (July 2015, Revision C)" would be used as a starting point of discussions:
http://ilcdoc.linearcollider.org/record/62116/files/PIP_complete_IssueC.pdf

- International share of the remaining technical preparation

Members:

Klaus Desch (Bonn)
Andy Lankford (UC Irvine)
Kajari Mazumdar (TIFR)
Patricia McBride (FNAL)
Shinichiro Michizono (KEK)
Yasuhiro Okada (KEK) **Chair*
Claude Vallée (Marseille)
Scientific Secretary: Keisuke Fujii (KEK)

https://www.kek.jp/en/newsroom/2019/05/21/1900/

Final report will be submitted by early October.

Summary

- *Most of the ILC accelerator parameters have been demonstrated at the various facilities.*
- *SRF accelerators: Technology matured especially after the successful operation of European XFEL (10% scale of ILC Main linac). Large-scale SRF accelerators (such as LCLS-II, SHINE) are under construction.*
- *ILC preparation:*
  - *ILC cost reduction R&Ds are ongoing under US-Japan cooperation.*
  - *KEK issued ILC action plan.*
  - *European ILC preparation plan as "E-JADE" report was summarized.*
- *Technical preparation will be carried out during the preparation period.*
- *KEK international WG has been organized and the final report will be submitted soon.*

Thank you for your attention