ILC as a Global Project
Status and Activities of the International Development Team (IDT)

P5 Town Hall meeting at SLAC
Menlo Park, USA, 2-5 May 2023

Tatsuya Nakada
EPFL, Switzerland
Chair of the IDT Executive Board

Contents

1) ILC development

1. International Committee for Future Accelerators (ICFA) has been for many years supporting a linear collider, in particular the one based on superconducting RF technology (ILC), to be constructed as a global project.
2. ILC started as a global project when JLC, NLC and TESLA joined together, starting with technology selection without predestined site or host (2004). The following work on RDR (2007) and TDR (2013) was made by the Global Design Effort as a collaborative effort by Americas-Asia-Europe, under the ICFA umbrella.
3. The Japanese HEP community proposed to host the ILC in Japan (2012) and sought a way that the Japanese government would declare its interest to host. Some Japanese Diet members actively support this initiative. The Japanese 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.
4. ICFA is supporting the Japanese HEP community by establishing IDT (2020), which also coordinates global ILC activities on accelerator and on physics and detector.

2) What IDT thinks a global project is

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.

⇒ Given the required cost and geopolitical and socioeconomical development of the world, future HEP accelerator projects must become global. A Higgs factory could be a good entry point for this new phase!

3) 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.

The following key issues must be be addressed in order to move forward:

- Resources are needed to move forward with technical work for engineering studies.
- Opportunities are needed to revitalise discussion of government authorities, supported by the community, on how to realise the ILC as a global project.

4) Attractiveness of ILC

ILC is very attractive as a global Higgs factory;

- Thanks to the GDE effort, ILC is technically mature and ready to proceed to construction*).
- As a global project, ILC cost*) is affordable.
- ILC power consumption*) and environmental impact is modest.
- ILC has a clear upgrade path to higher energies: to t·t-bar threshold, to *ZHH*, to ~1 TeV (and possibly beyond with technological advancement, when physics justifies).
- ILC's proponents have already been working together globally.

*) A comprehensive comparison can be found in "Report of the 2021 U.S. Community Study on the Future of Particle Physics (Snowmass 2021)" (arXiv:2301.06581v2, arXiv:2209.14136)

5) Moving forward: IDT initiatives

- 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 address important topics.

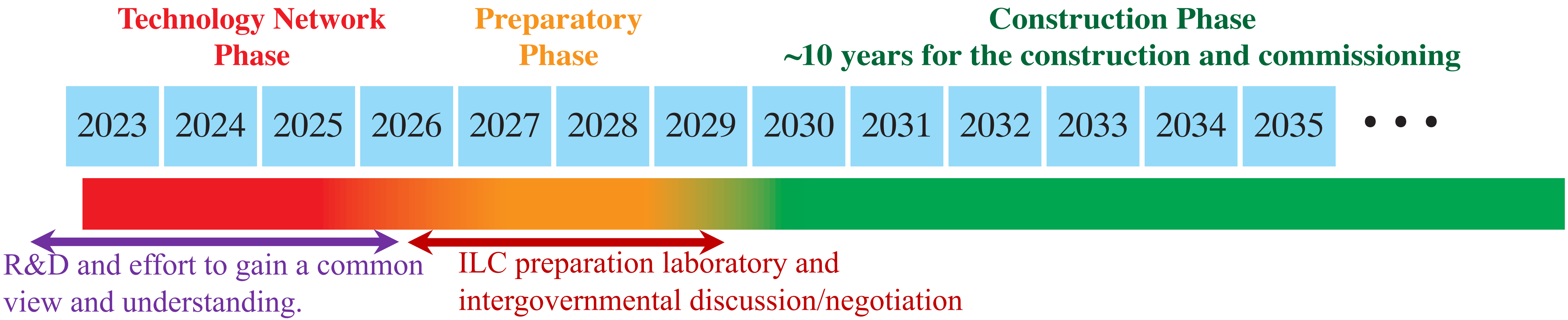
- Move forward with the political process for
  - Establishing regular interactions among partner government authorities.
  - Developing a common view on how to proceed with a global project, applicable to ILC.

  A forum of government authorities/agencies of ITN participating laboratories is being setup, where the IDT International Expert Panel interacts to foster common discussion.

The goal is to arrive at the ILC Preparatory Phase, i.e. final work for the construction readiness and intergovernmental discussion/negotiation for realisation.

6) Overall ILC timeline

-success oriented and asuming no major incident-



- Technology Network Phase responds to the recommendations by the MEXT Expert Panel.
- ITN work packages are two to four years.
- MEXT funding programme for ILC-accelerator R&D is planned for five years.
- For entering the Preparatory Phase, interested government authorities, not only Japanese but also European and US, must become ready to discuss ILC specific matters.
- Given ITN, the Preparatory Phase could be less than the four years in the Pre-lab proposal for the accelerator and site-related work.
- P5 discussion in the U.S. and FCC Feasibility Study at CERN will impact the timeline.

6) Conclusions

- HEP accelerators are reaching a scale required to be global.
- A Higgs factory could be a good entry point to make this transition.
- A linear collider based on SRF acceleration is a Higgs factory that is technically mature and globally affordable with a small environmental impact.
- ILC has been developed as a global project from the conception.
- IDT has put forward a plan to progress in three to four years to start the Preparatory Phase for ILC realisation
- In the meantime, the ILC Technology Network ensures that ILC will remain at the technological forefront among Higgs factory candidates. U.S. participation is crucial for ITN, but will also benefit US accelerator R&D activities.
- As a global project, ILC is everybody's project, not a project of Laboratory A or Country B, i.e. it is a US project no matter where it will be built.

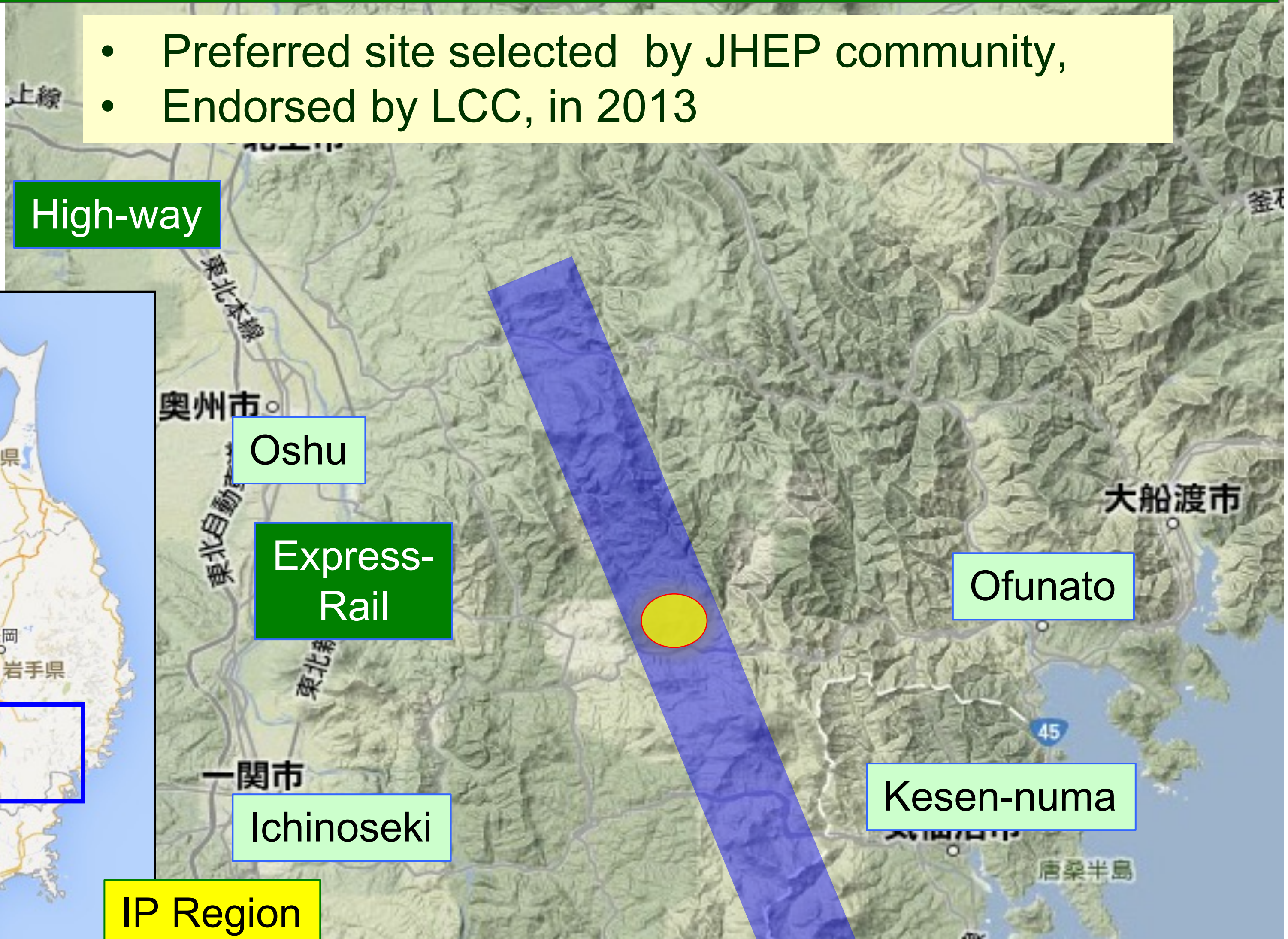
ILC and SRF

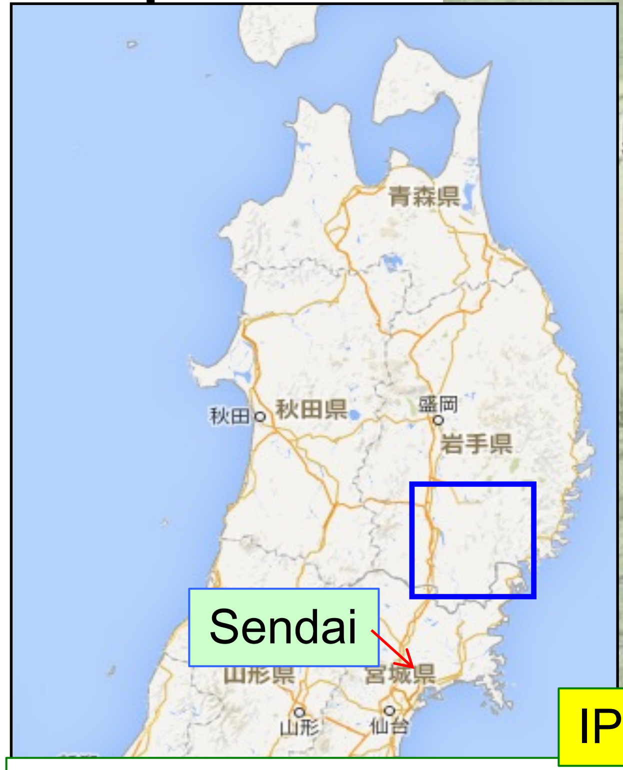
KEK / IDT-WG2
Shin MICHIZONO (KEK)

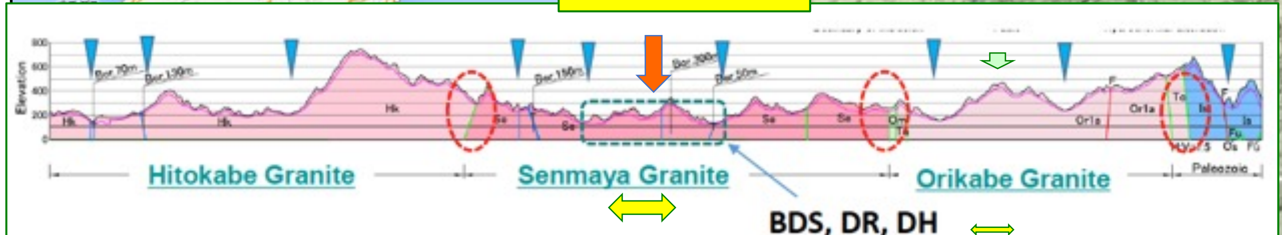
1. Current status of the ILC technology
2. ILC Technology Network (ITN) and future upgrade

ILC Site Candidate Location in Japan: Kitakami

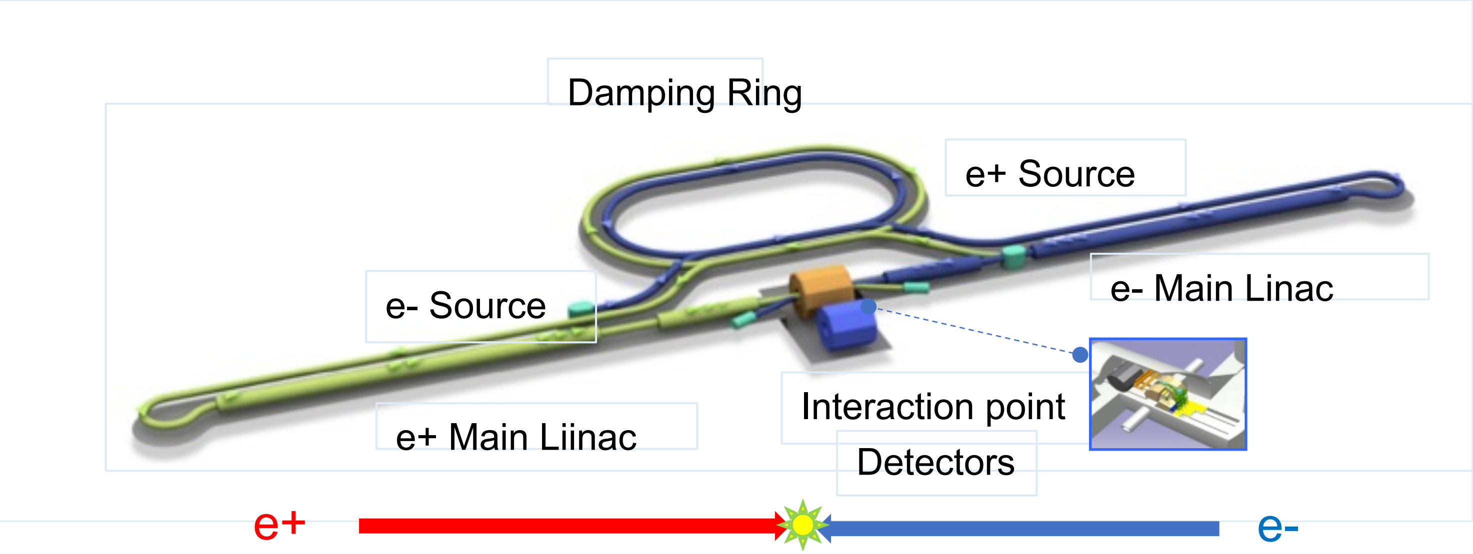
- Preferred site selected by JHEP community,
- Endorsed by LCC, in 2013

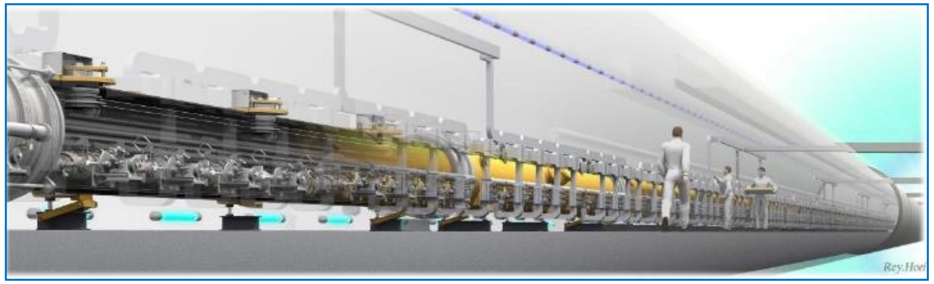


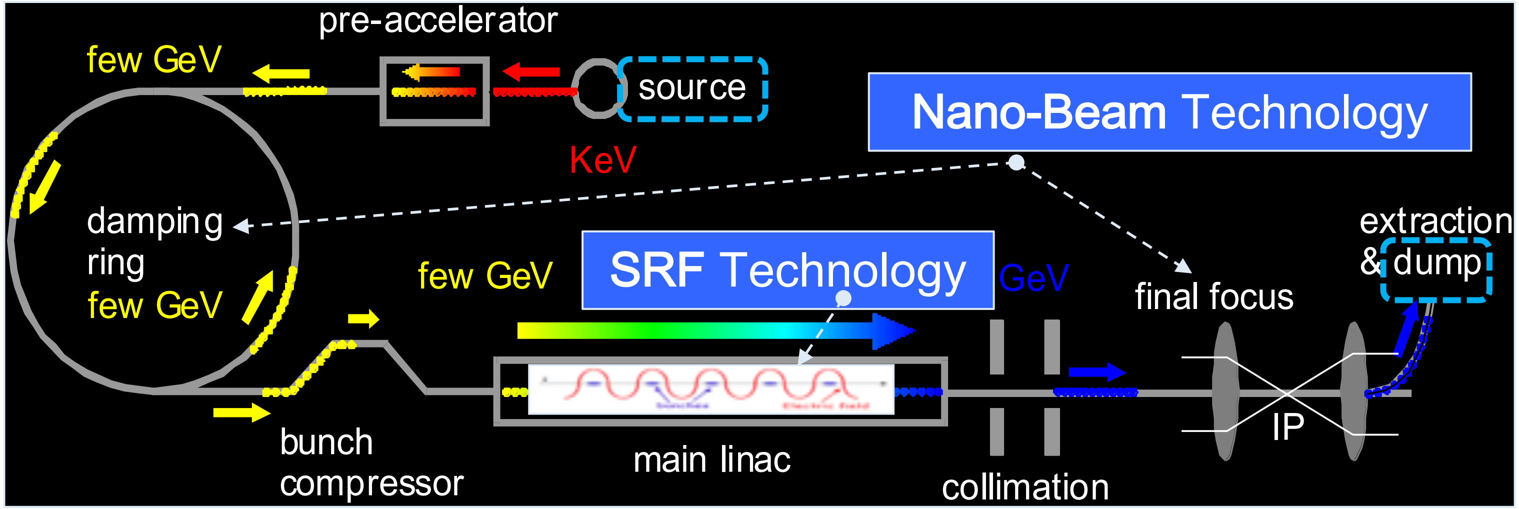




ILC and the Accelerator Technology







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.

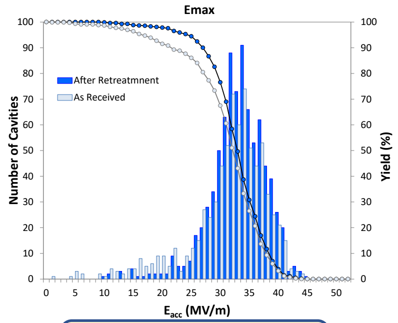
Progress in SRF

~ 2017	2018 ~

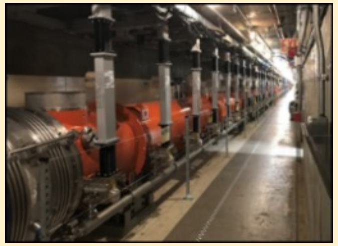
Cavity

Yield evaluation of cavities based on TDR

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



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

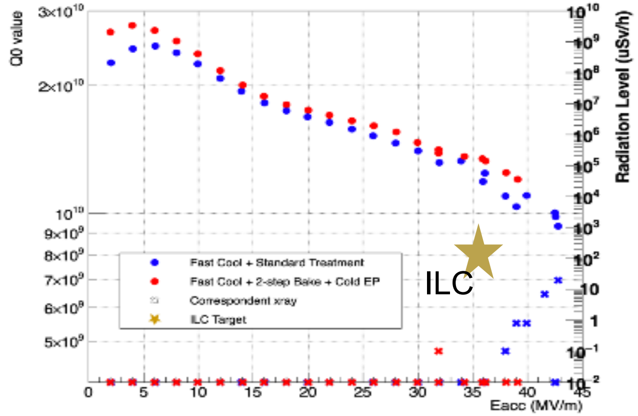


LCLS-II Construction (USA)
~280 cavities/
~35 Modules

Realized through international cooperation and procurement

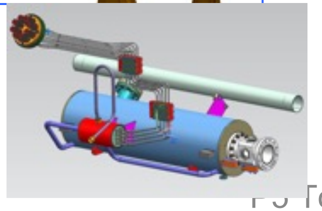
High performance and cost reduction

high performance with new surface treatment, etc.

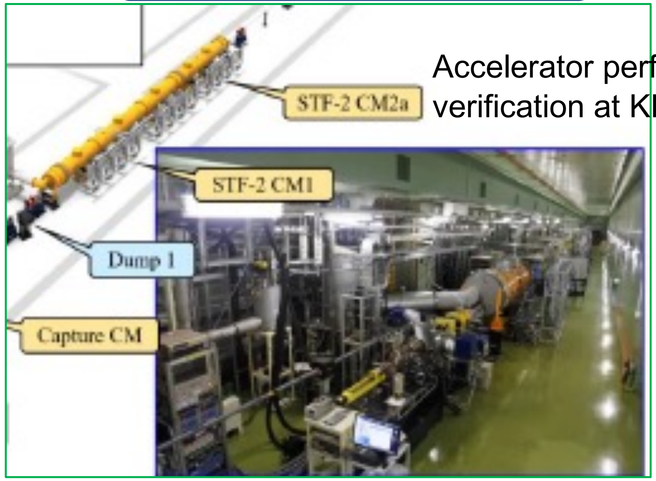


Cryomodule

Design



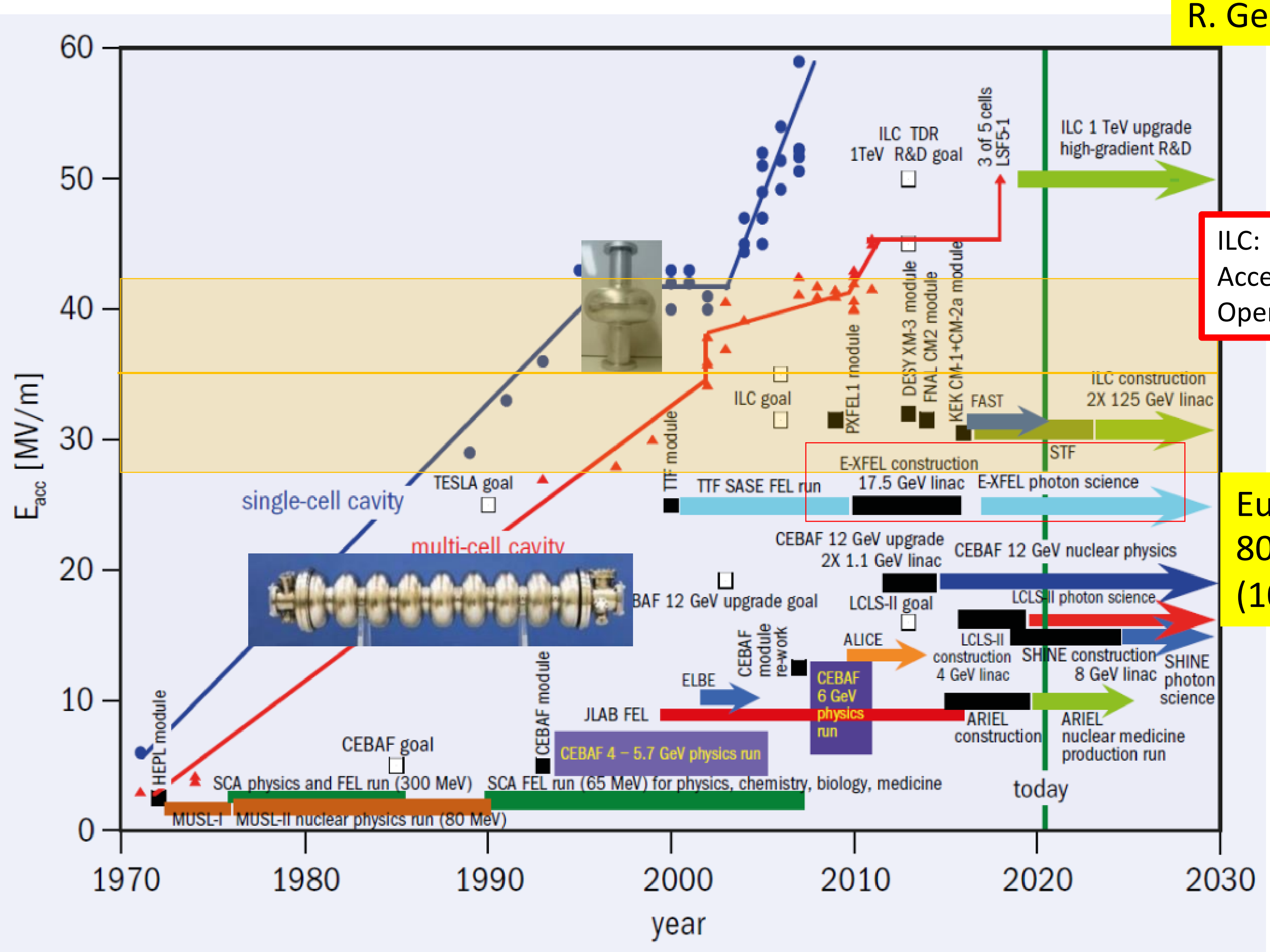
Module assembly



Accelerator performance verification at KEK-STF2

Matured SRF technologies

R. Geng (JLAB)

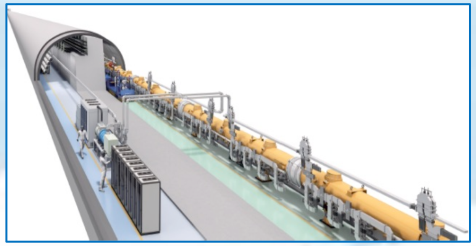


ILC:
Accept: 35 MV/m +/-20%
Operate: 31.5MV/m +/-20%

European XFEL
800 cavities
(10% of ILC ML)

~ 1.3 GHz SRF Accelerators, worldwide

ESS (0.8 GHz)
(under construction)



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)

European XFEL
(in operation, 2017~)

800 cavities
100 CMs
17.5 GeV (Pulsed)

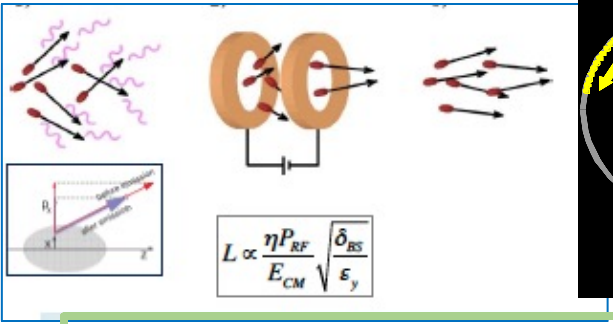
SHINE
(under construction)

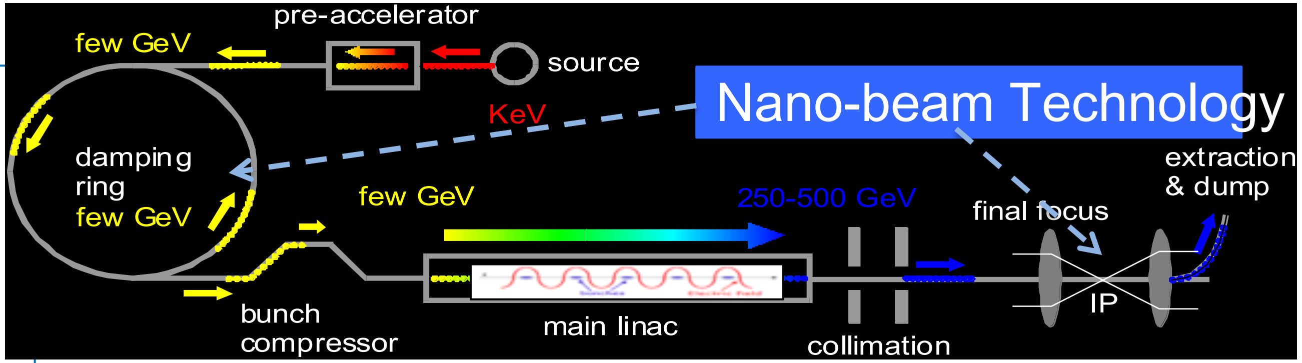
~600 cavities
75 CMs
8 GeV (CW)

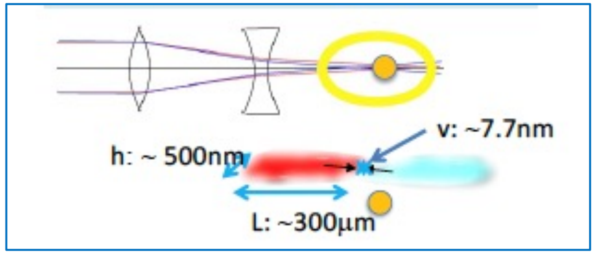
JLab-CEBAF(1.5 GHz)
(in operation)
40 CMs
6~12 GeV(CW)

> 2,000 ~1.3 GHz SRF cavities being realized!

Progress in Nano-beam Technology







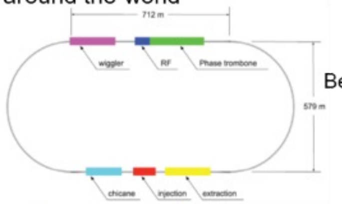
Progress in DR

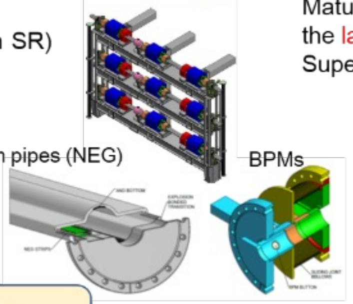
~2017	2018~

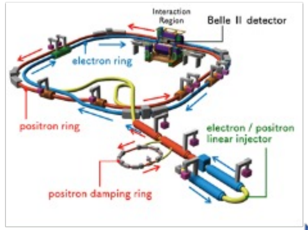
DR — Eng. design

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

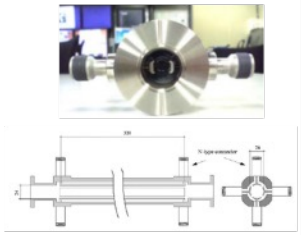


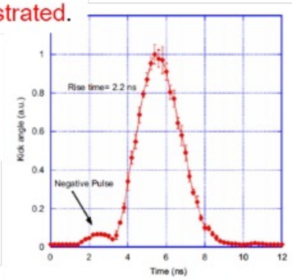




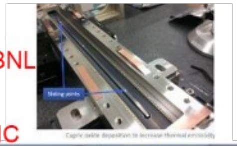
Inj./Ext. — Eng. Design, Equipment verification

Beam extraction demonstrated.

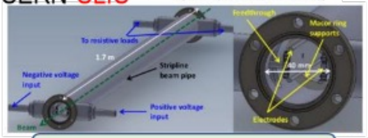




LBNL



CERN-CLIC



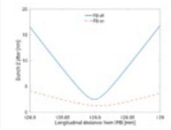
Fast kicker technology

Progress in Final Focus

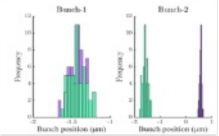
~2017	2018~

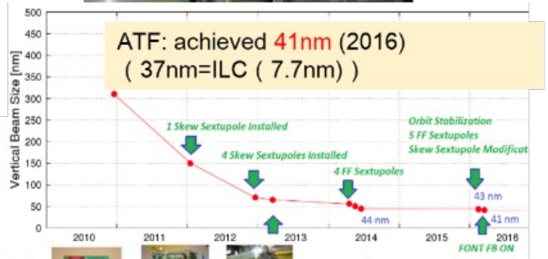
Tech. design completed
Spec. almost achieved

Wakefield effects

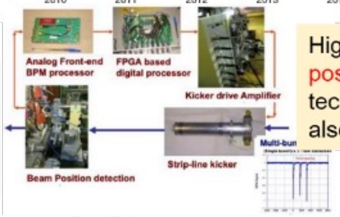


Distribution of bunch positions measured at IPB, with two-BPM FB off (green) and on (purple)



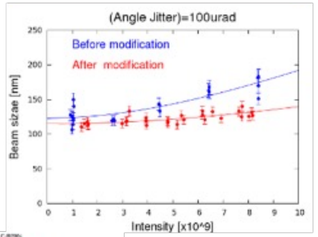


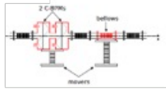
ATF: achieved 41nm (2016)
(37nm=ILC (7.7nm))



High-speed beam position control technology was also demonstrated.

FONT feedback system





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/

ILC and SRF

KEK / IDT-WG2
Shin MICHIZONO (KEK)

1. Current status of the ILC technology
2. ILC Technology Network (ITN) and future upgrade

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

2022 June

Time-critical WPs for the ILC construction

WP-Primes for Time Critical

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

https://agenda.linearcollider.org/event/9735/contributions/50816/attachments/38190/59968/Time-Critical_WPsV8b.pdf

ILC Technology Network (ITN)

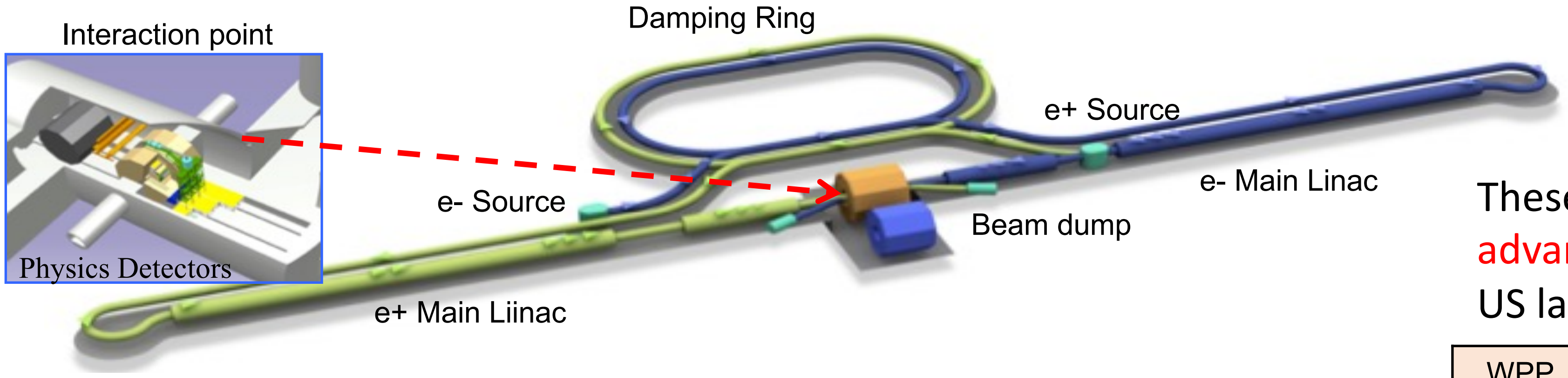
-- global collaboration program---

- 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.
US labs 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

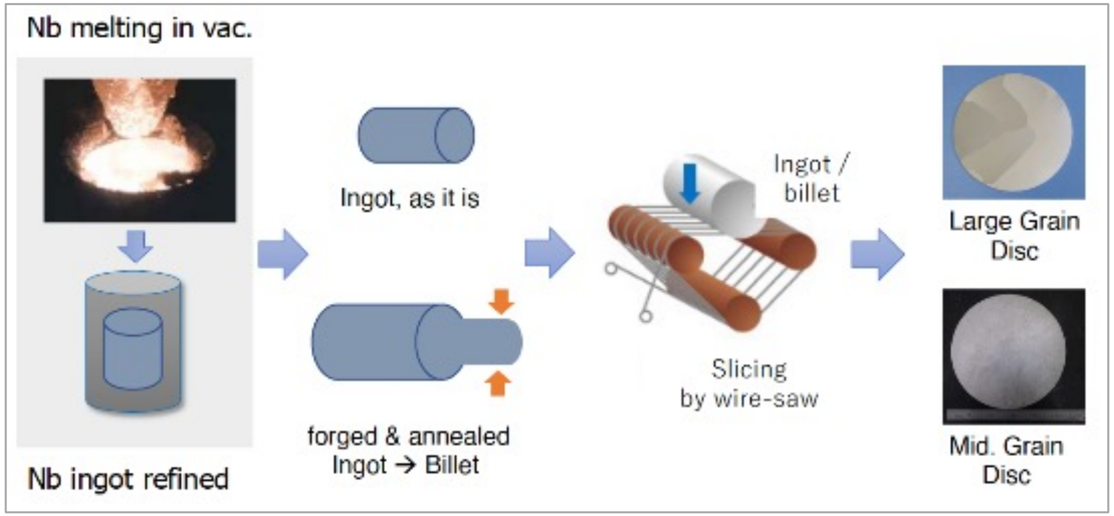
WPP	1	Cavity production
WPP	2	CM design
WPP	3	Crab cavity
WPP	4	E- source
WPP	6	Undulator target
WPP	7	Undulator focusing
WPP	8	E-driven target
WPP	9	E-driven focusing
WPP	10	E-driven capture
WPP	11	Target replacement
WPP	12	DR System design
WPP	14	DR Injection/extraction
WPP	15	Final focus
WPP	16	Final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

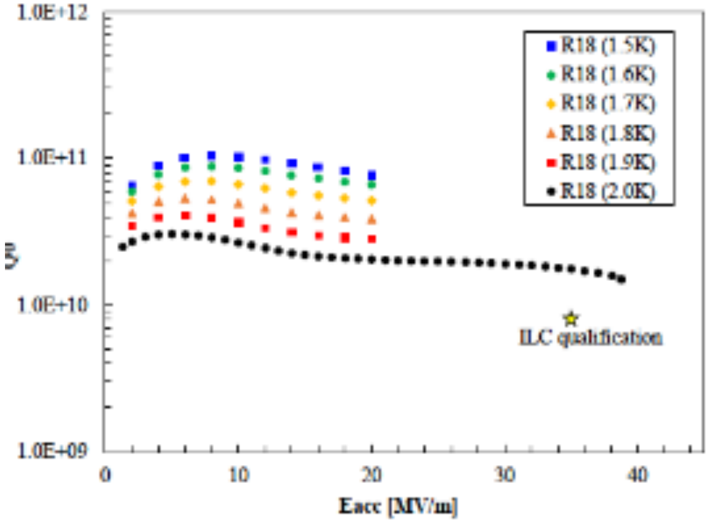
WP-prime 1: SRF Cavity
(Scoping the Industrial-Production Readiness)

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 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)





Material/Sub-component

QA of Material/Sub-C

Cavity Production

Surface Process

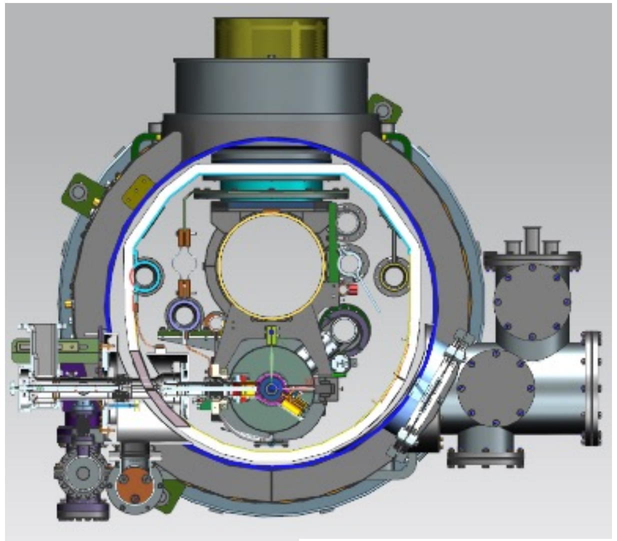
Vertical Test = Cavity RF Test

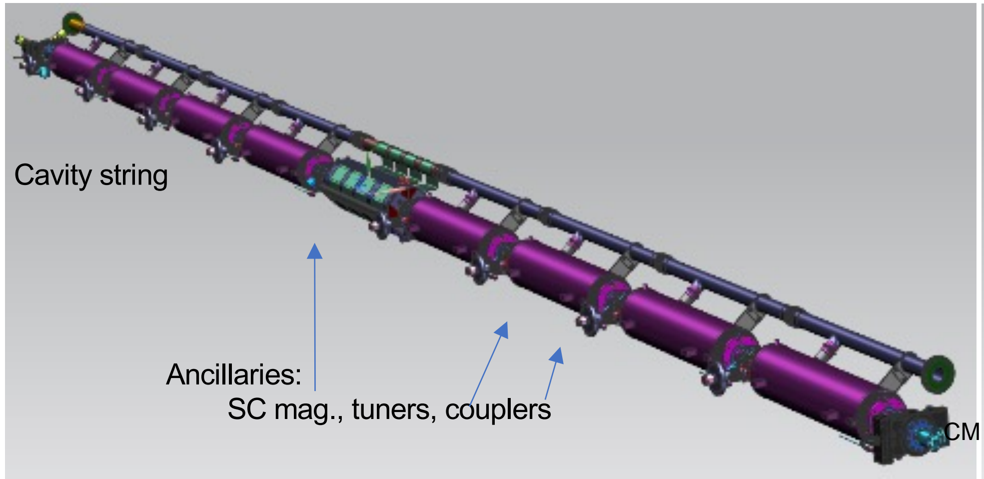
Production process

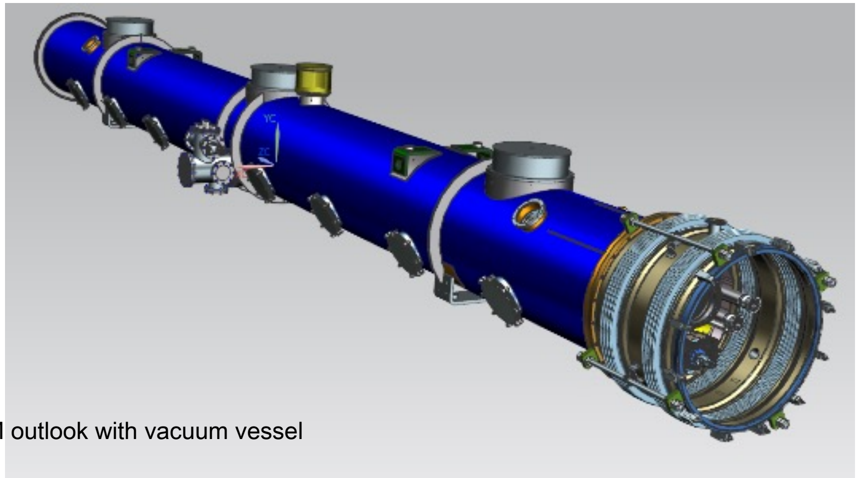
WP-prime 2: Cryomodule (CM) Design
(Scoping the CM Global Transfer and Performance Assurance)

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.		

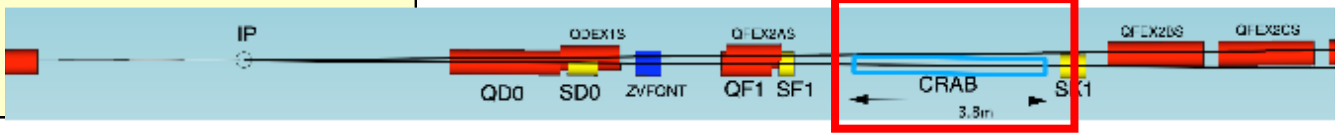
WP-prime 3: Crab Cavity Development

- Pre-down-selection review hosted by KEK chose two primary candidates on Apr/2023
  - RFD (1st), QMiR (2nd), Elliptical (3rd)
- Development and evaluation of two prototype cavities
  - KEK will provide for necessary Nb material to produce them
- RF property simulation to optimize cavity design
- Demonstration of synchronized operation with two prototypes
- Down-selection to choose final cavity design
- Cryomodule design based on final cavity design

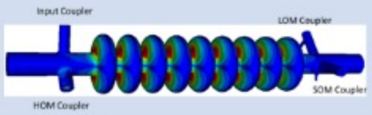
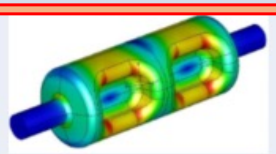
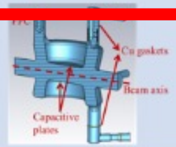
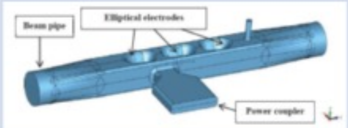
Both two candidates are from US!

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)

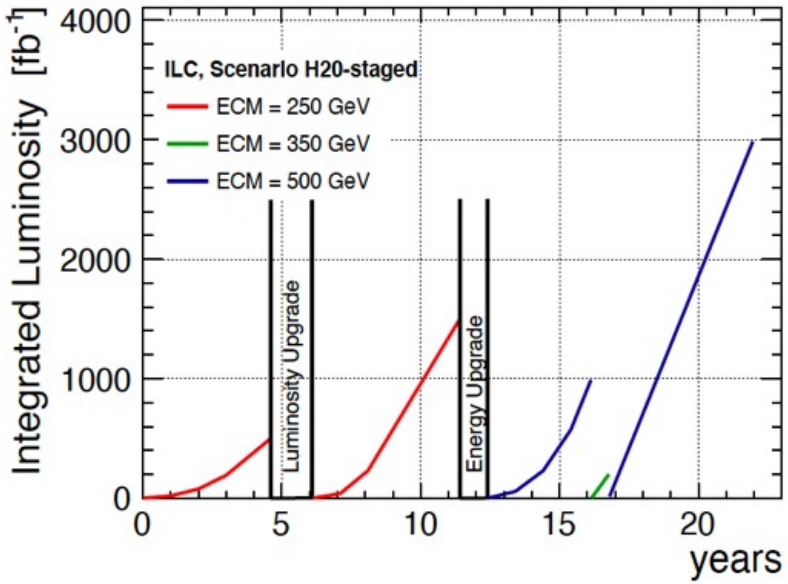
Elliptical/Racetrack (3.9 GHz)	Lanc. Univ.	
RF Dipole (RFD)	ODU	
Double Quarter Wave (DQW)	CERN	
Wide Open Waveguide (WOW)	BNL	
Quasi-waveguide MultIcell Resonator (QMIR)	FNAL	

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** $\mathbf{Q_0}$**=1** x 10^{10})
  - 1TeV (**45 MV/m** $\mathbf{Q_0}$**=2** x 10^{10}, 300 MW)
  - more SCRF, tunnel extension



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

U.S. contributions to ILC

Sergey Belomestnykh (Fermilab)

P5 Town Hall Meeting at SLAC, May 3-5, 2023

Introduction

U.S. coordination group prepared this input to P5 on potential U.S. contributions to ILC.

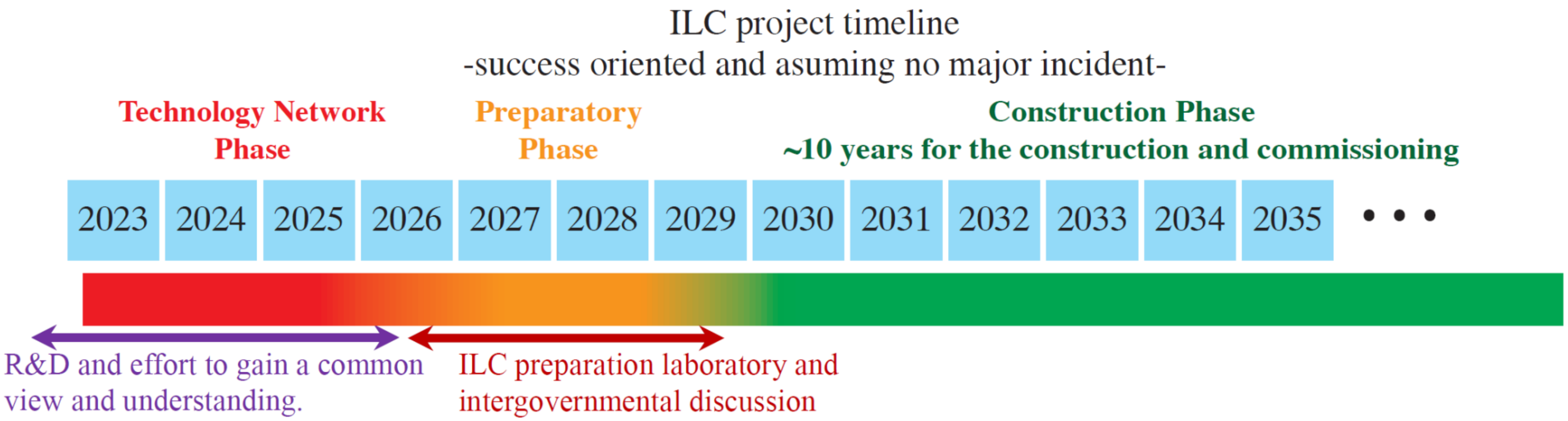
Members of the group are S. Belomestnykh (Fermilab), S. Gessner (SLAC), D. Rubin (Cornell), G. White (SLAC), with contributions from many others

- The U.S. accelerator community has a long history of involvement in ILC:
  - Made major contributions in developing many ILC accelerator technologies, including Superconducting RF (SRF), and to the ILC Global Design Effort (GDE) and Technical Design Report (TDR)
  - Continued to actively participate in accelerator studies at Accelerator Test Facility (ATF) at KEK and in the IDT accelerator working group (WG2)
- U.S. accelerator expertise is required for the realization of the ILC, and substantial deliverables to ILC accelerator construction (~1/3) are needed for this global project.
- With a recommendation from P5 and DOE approval, we hope that support will be extended to the ITN phase and beyond
  - This presentation focuses on the pre-construction activities
  - ITN activities lead to preparatory phase activities and construction responsibilities

Potential U.S. contributions to ILC

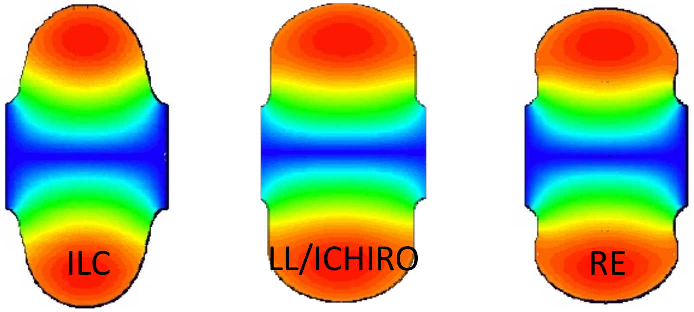
The U.S. community is interested in partnering on the following areas:

1. Main Linac (ML) and SRF, including crab cavities
2. Polarized electron source
3. Polarized and electron-driven positron source options
4. Damping rings
5. Beam delivery system
6. Simulations, software management and global systems



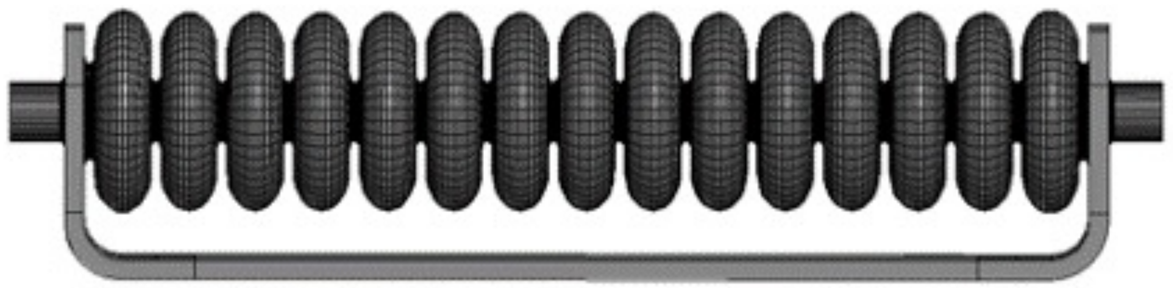
SRF technology for ILC-250 and beyond present limits

- The baseline Main Linac SRF technology was developed in 1990s-2000s and described in the TDR.
- It is a mature technology, already used in such machines as European XFEL and LCLS-II / LCLS-II-HE. The U.S. community is one of the leaders that brought the technology to where it is today.
- However, ongoing generic SRF R&D efforts (not part of the ILC ITN and Preparatory Phase, but funded by GARD, US-Japan and other programs) promise to bring SRF to a new level with potential applications to the ILC energy upgrades as well as other future accelerators.
  1. Advanced shape standing wave SRF cavities – Low Loss (LL), ICHIRO, Reentrant (RE) – increase peak quench magnetic field by 10-20%, potentially bringing accelerating gradient limit to $\lesssim 60$ MV/m

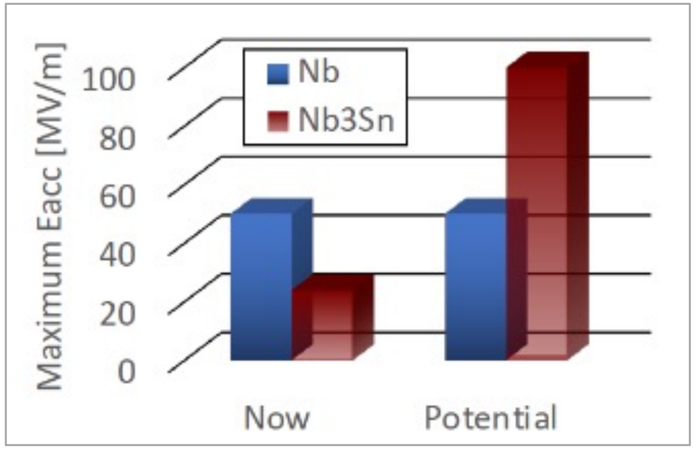


SRF technology R&D

2. Traveling wave (TW) SRF offers better cryogenic efficiency and higher accelerating gradient up to ~ 70 MV/m – possible application: ILC energy upgrade, HELEN collider, Accelerator Complex Evolution at Fermilab



3. Advanced SRF materials – Nb_3Sn cavities can potentially reach ~ 90 MV/m



U.S. participation in ITN: WP-prime 1

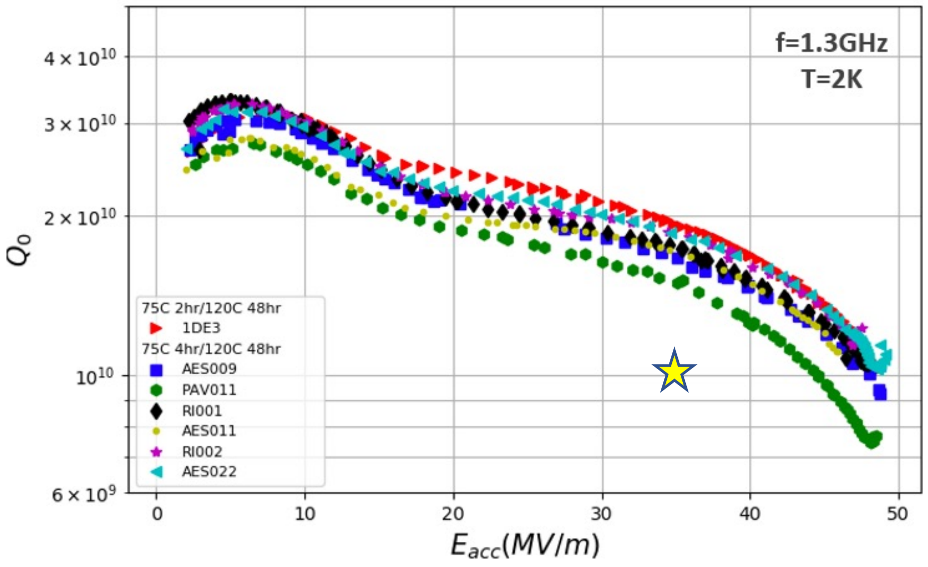
SRF cavity production readiness

a) Optimize the production process based on recent advances in cavity surface treatment (first on single-cell cavities, then on 9-cell cavities) – confirm via cavity exchange between regions

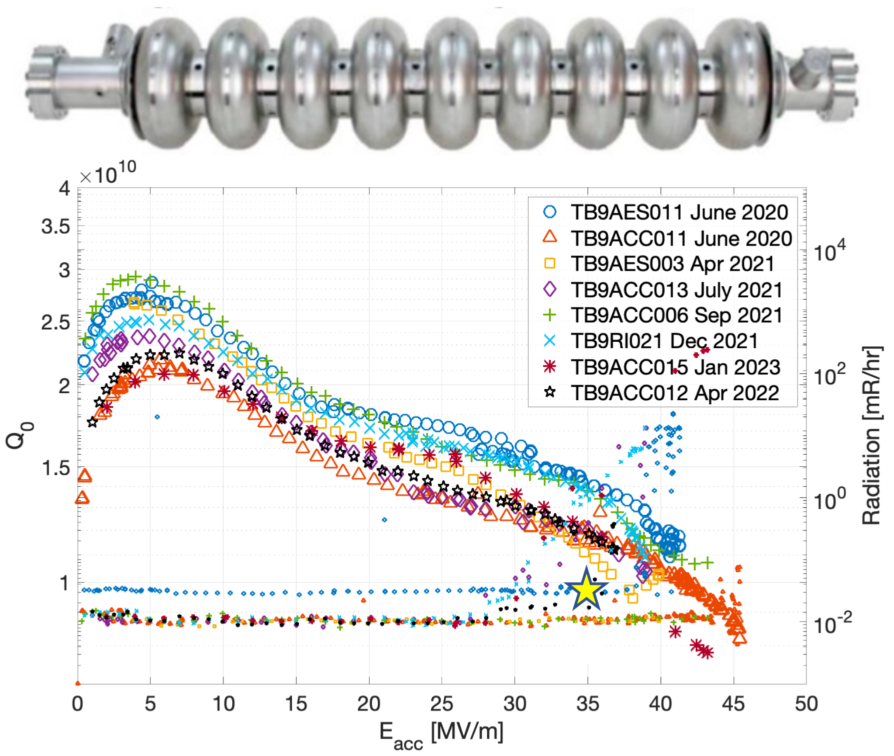
b) Establish the cavity design compliant with the Japanese High Pressure Gas Safety (HPGS) regulation in close collaboration with KEK

c) Transfer the cavity treatment to industry, order a set of cavities (2 batches for Americas during ITN, 4 cavities per batch), confirm performance yield. Continue with larger statistics through the **Preparatory Phase**

2-step low-temperature baking (single-cell cavities)



Grassellino et al. https://arxiv.org/abs/1806.09824



U.S. participation in ITN: WP-prime 2

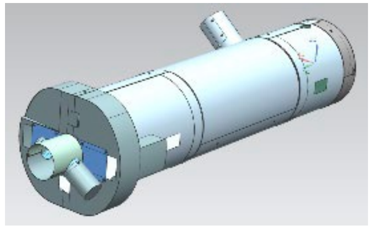
Cryomodule (CM) design

a) Finalize the common CM design incorporating lessons learned from recent SRF projects (European XFEL, LCLS-II) and test facilities' operation (STF at KEK, FAST ay Fermilab). Goals: improve performance, lower cost. Some potential changes: compact LCLS-II style frequency tuner, split conduction-cooled SC magnet, better magnetic shielding of cavities for high Q-factor preservation)

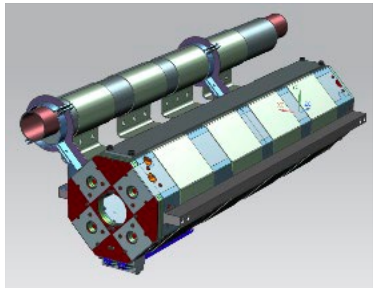
b) Confirm that the CM design is compliant with the Japanese HPGS – close collaboration with KEK, learn from AST-IFMIF experience

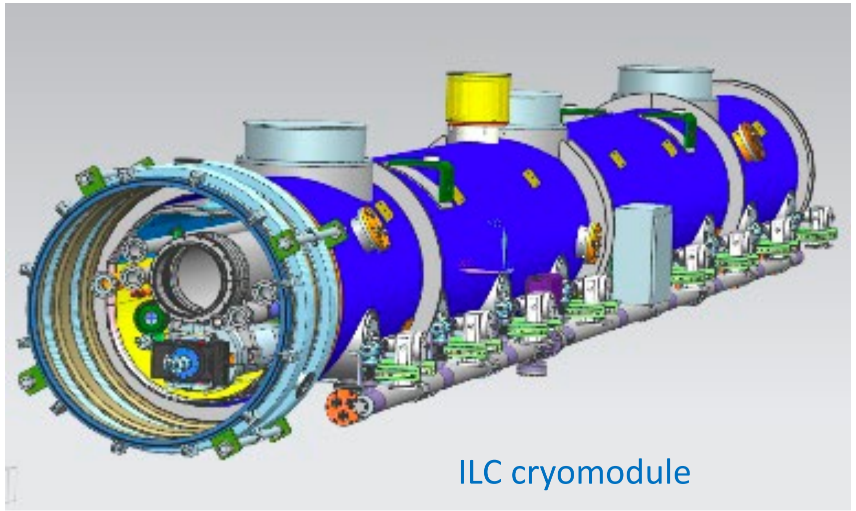
c) Engineering design and transport study during the **Preparatory Phase**

Cavity magnetic shield



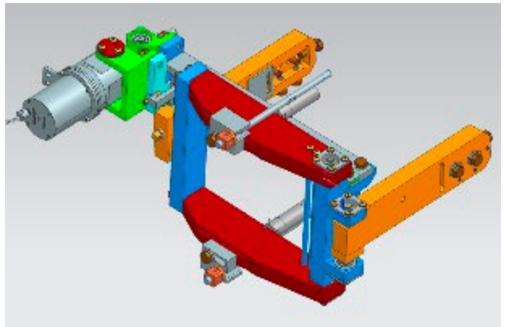
SC magnet package





ILC cryomodule

Compact frequency tuner



U.S. participation in ITN: WP-prime 3

SRF Crab Cavity (CC) development

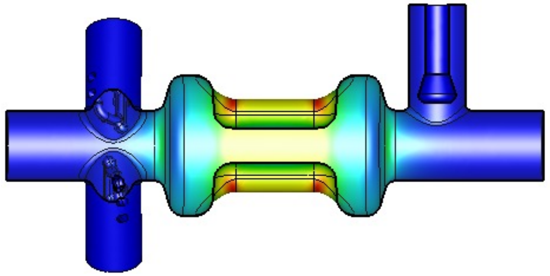
a) HL-LHC R&D and prototyping demonstrated viability of compact crab cavity designs. ILC team has initiated efforts on re-optimization of the CC design. 5 designs were under initial consideration.

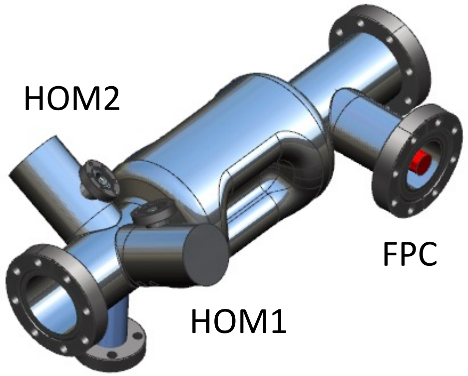
b) After the recent first down-selection review, 2 designs were selected to proceed to the next stage. Both designs are from U.S. teams: RF Dipole cavity (ODU/JLAB) and QMiR cavity (FNAL)

c) Next stage: development and testing of a prototype cavity of each design (KEK will provide Nb material); demonstration of synchronized operation with the two prototypes (possibly in UK); selection of the final cavity design

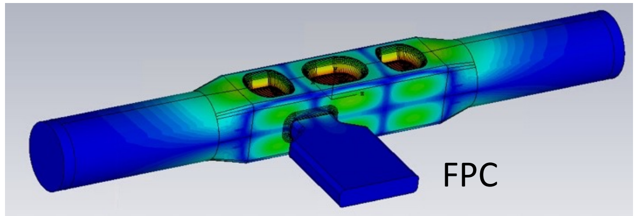
d) Engineering design of the cryomodule for the selected CC design during **Preparatory Phase**

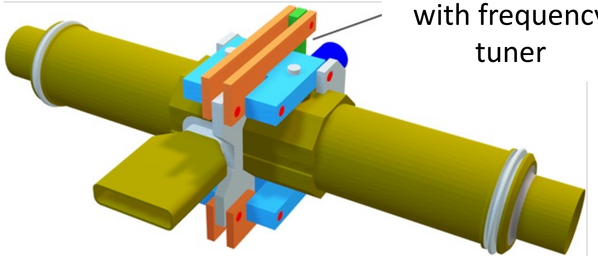
RF Dipole 1.3 GHz crab cavity (ODU/JLAB)





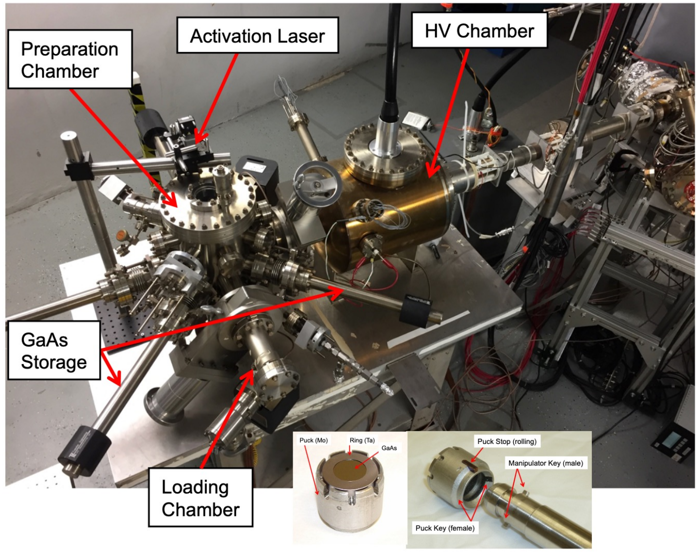
QMiR 2.6 GHz crab cavity (FNAL)



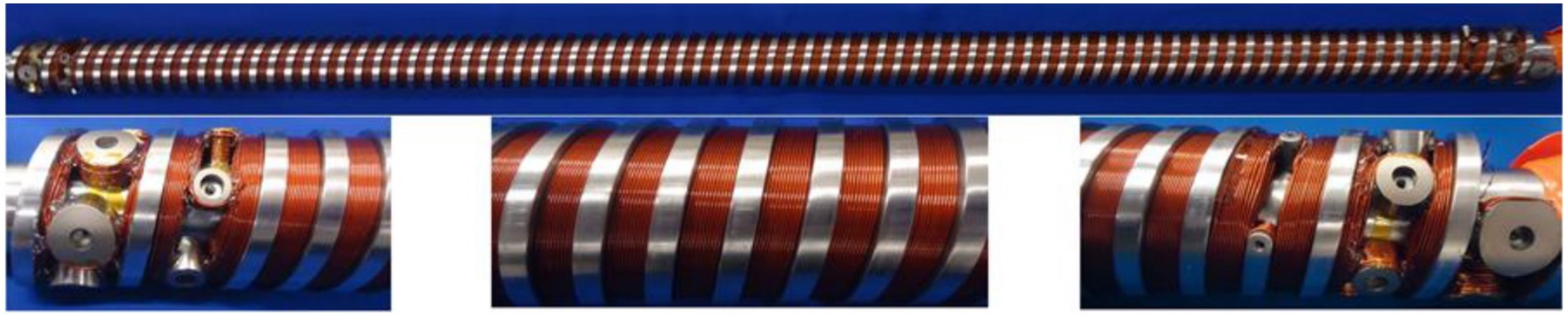


Other WPs: polarized e^- and e^+ sources, WP-prime 4-10

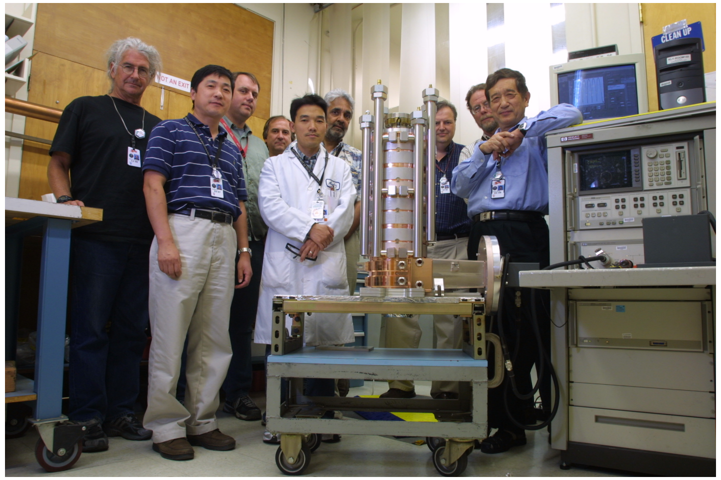
1. Polarized electron source design
   - JLab played leading role in planning remaining development, there is a new US-Japan collaboration
2. Polarized positron source (baseline)
   - Capture and acceleration for positron source (was prototyped during GDE phase by U.S. labs)
   - Developing undulator technology for positron source – synergy with light sources, where helical undulators are now used
3. e^- driven positron source (backup)
   - Investigation of shortening electron linac using C³ technology



Polarized electron source at JLab,
P. Adderley et al., Phys. Rev. Acc. Beams (2010)



Superconducting helical undulator at Argonne, M. Kasa et al. Phys. Rev. Acc. Beams (2020)



L-Band capture section at SLAC
F. Wang et al., PAC09 (2009)

Other WPs: Damping rings (DRs), WP-prime 12&14

The damping ring described in the TDR satisfies the basic requirements. However, developments in magnet technology, high current positron storage rings (SuperKEKB), low emittance light sources, fast kickers, and optimization of the collider parameters, in the decade since, suggest some refinement and reevaluation of the ring design and instrumentation. The U.S. community has significant expertise in design and operation of storage rings.

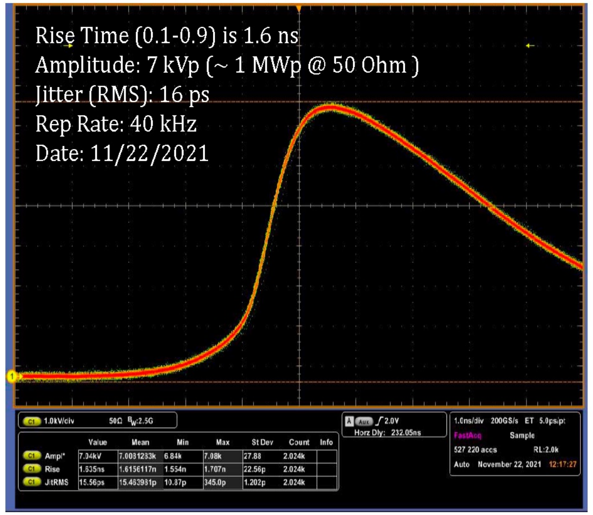
The U.S. community is interested in partnering on the following DR areas:

1. DR system design
   a) Revisit lattice design. Consider combined function/hybrid magnets. Modify injection and extraction straights for consistency with anticipated kicker properties. – **ITN Phase**
   b) Magnet design: normal magnets and SC damping wigglers. Because of the very high synchrotron radiation in the wiggler straight, and the required electron cloud mitigation, design of the vacuum chambers in that region should be integrated with the engineering design of the magnets. – **Preparatory Phase**
   c) Magnet design: permanent magnets. Design of permanent magnets (a possible alternative to electromagnetics) can begin when the lattice design is finalized – **Preparatory Phase**

Other WPs: Damping rings

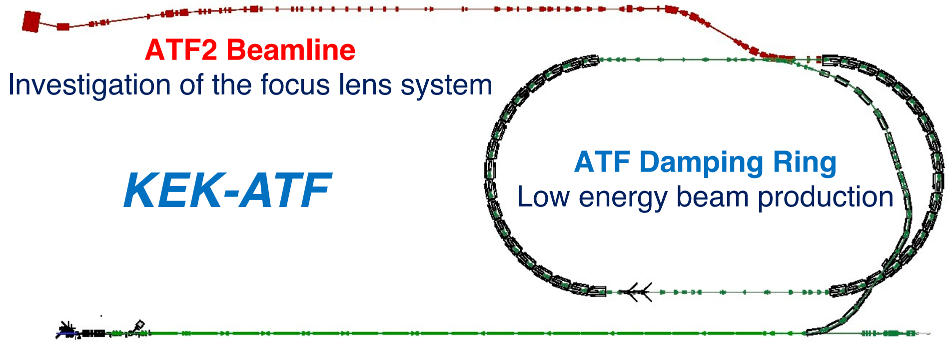
2. Collective effects (electron cloud, ion trapping and fast ion instabilities) – **ITN Phase**
   a) Once the design of the lattice is finalized, the thresholds should be reevaluated.
   b) Fast ion instability feedback should be developed (simulations and scaling from SuperKEKB HER) and possibly tested with beam (if not done already at SuperKEKB)
3. DR injection/extraction kickers: System design, prototyping, and stability test – **ITN / Preparatory Phase**
4. Other opportunities for **Preparatory Phase / Construction**: vacuum chamber, SRF system, instrumentation, SC wigglers, magnets

Demonstration of ns rise time,
MW power pulse at SLAC

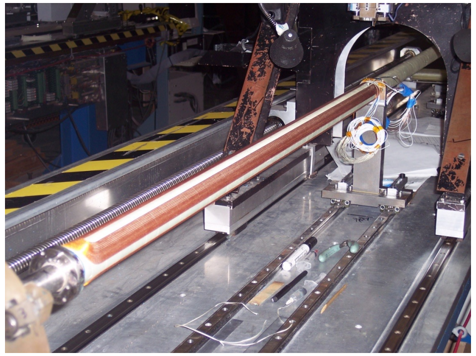


Other WPs: Beam delivery system (BDS), WP-prime 15&16

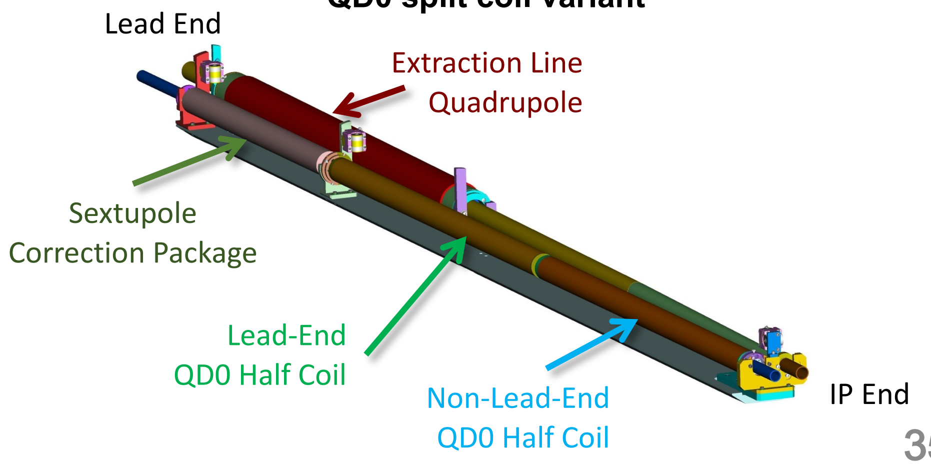
1. BDS design
   a) Participation in the ATF3 studies, e.g., wakefield and magnetic multi-pole characterization and mitigation
   b) Machine Learning applications to Final Focus System (e.g., Bayesian optimized luminosity tuning) – possible to also demo @ ATF3? (Strong accelerator-focused ML group at SLAC)
   c) Fast-kicker hardware for emergency abort dumps (synergy with DR)
   d) MDI work
2. Final doublet (FD) design optimization
   a) Direct-wind technology for SC FD magnet complex assembly (BNL-specific)
   b) Strong need for full-scale prototype and vibration tests at 2 K, need to complete efforts started many years ago – this is arguably priority #1 for outstanding BDS R&D – large consequences if fail to meet vibration tolerances in terms of re-design work for BDS/MDI



QD0 split coil winding



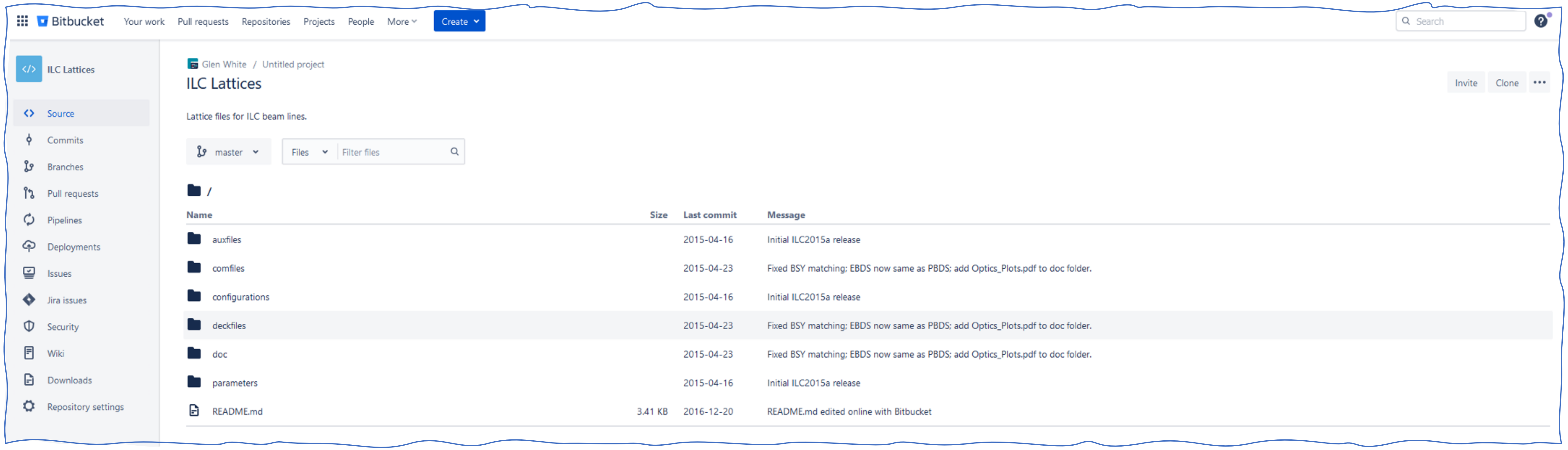
QD0 split coil variant



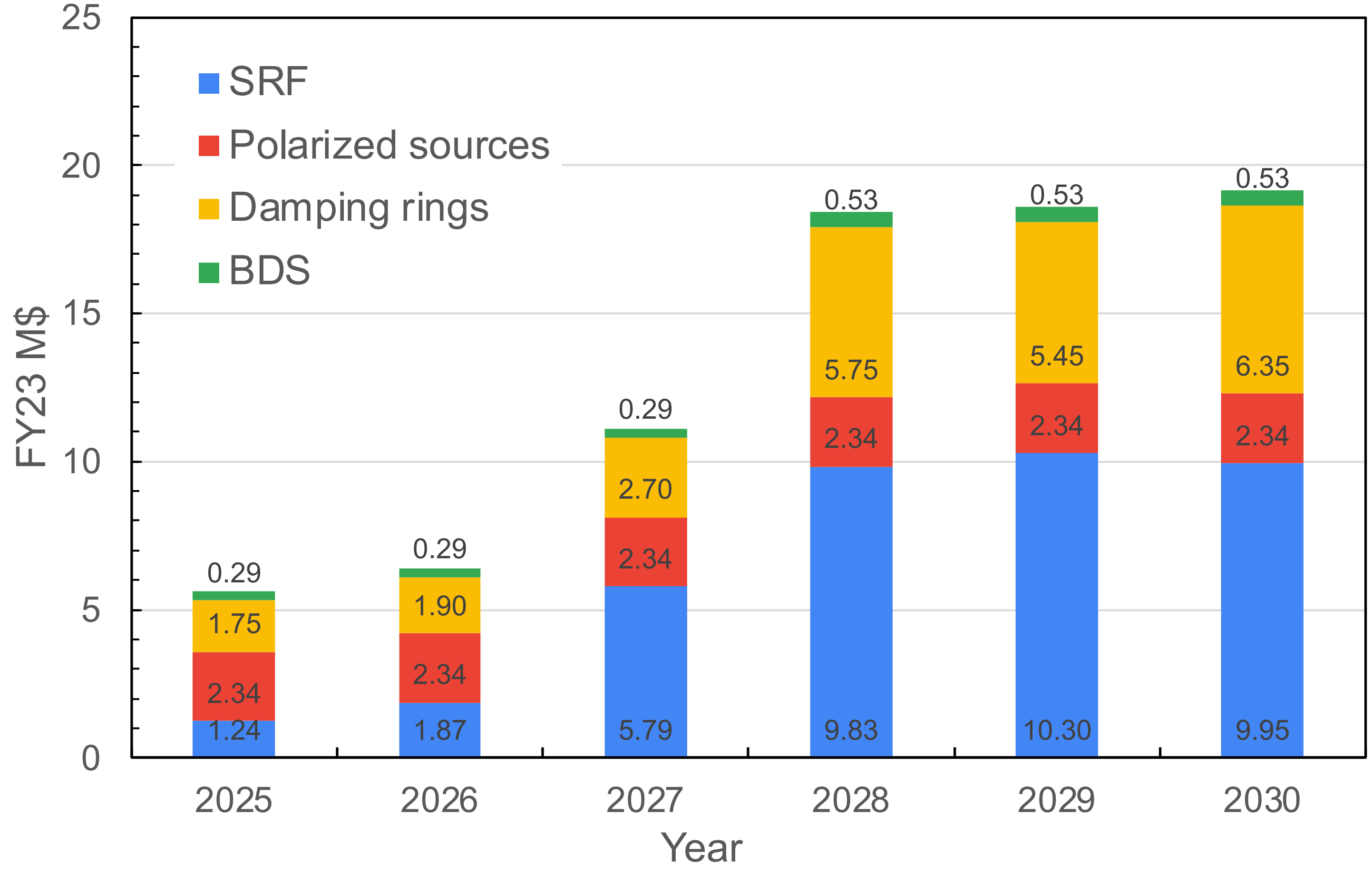
Simulations, software management and global systems

The U.S. ILC community is also interested in

1. Integration & management of all optics decks, enforcement of change control, software repository management, etc.
2. Start-to-end tracking simulation framework



Possible U.S. budget through ITN and Preparatory Phases



- Total ~ 80M$ for ITN and Preparatory phases
- Including FTEs increasing from 13.7 in 2025 to 50.6 in 2030

U.S. accelerator expertise relevant to ILC

	ANL	BNL	Cornell	FNAL	JLAB	LBNL	ODU	SLAC	
Main Linac SRF			✗	✗	✗			✗	
Crab cavities				✗	✗		✗		
Polarized *e-* source		✗	✗		✗			✗	
Undulators for polarized *e+* source	✗					✗		✗	
DR system design & subsystems (SRF, vacuum chamber, magnets, instrumentation …)	✗	✗	✗	✗	✗	✗		✗	
Beam optics, collective effects …	✗	✗	✗	✗	✗	✗		✗	
Fast kickers				✗				✗	
BDS design				✗	✗			✗	
Final doublet		✗		✗		✗			

Summary

- ILC's Technical Design Report (TDR) was published in 2013 by the ILC Global Design Effort (led by Barry Barish)
- SRF technology has matured. Large SRF accelerators (such as at European XFEL and LCLS-II / LCLS-II-HE) are under operation or construction
  - In addition, SRF technology is being improved for higher performance through R&D programs, such as U.S.-Japan cooperation, DOE/HEP GARD, etc. New technological advances may be applied in the future to ILC energy upgrades
- The important and time-consuming remaining ILC R&D items will be conducted through the ILC Technology Network, a global collaboration program
  - KEK obtained funding for this R&D and initiated this activity in April
- It is envisioned that engineering design and prototyping will be during the Preparatory Phase preceding ILC construction
- U.S. accelerator expertise is required for the realization of the ILC