ILC250 accelerator

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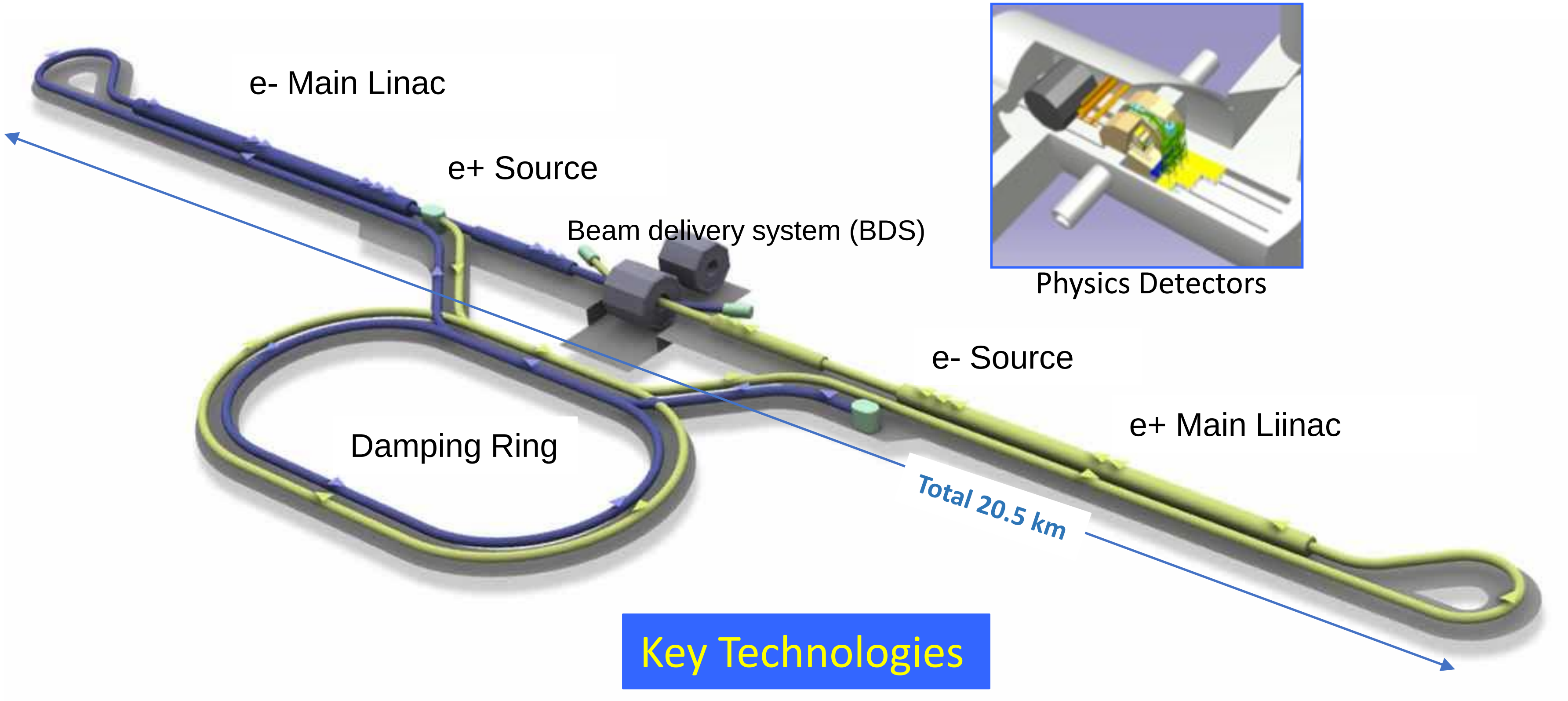
International Development Team (IDT) WG2/KEK

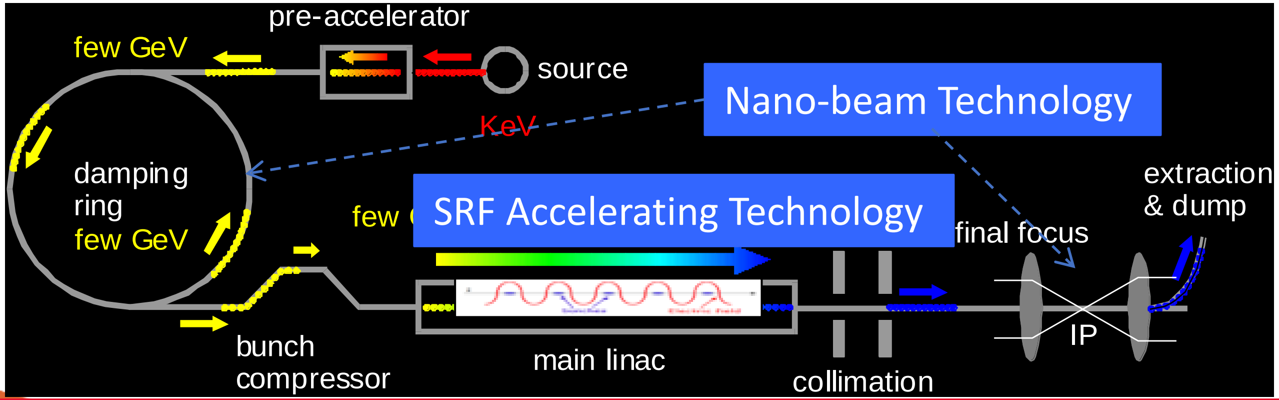
- Design outline
- Readiness
- Similar existing technology
- State of Technical Design Report
- State of Proposal
- Proposals for upgrades or extensions
- Stageability to future experiments

1.7.1 Design outline: ILC250 accelerator facility



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

Key Technologies



1.7.2 Readiness: Technical Maturity

- ILC based on superconducting radiofrequency (SRF) technology started its R&D from 2005 (GDE). Reference Design Report (RDR) was published in 2007 and TDR was published in 2013.
- More than 2,400 researchers contributed to the TDR.

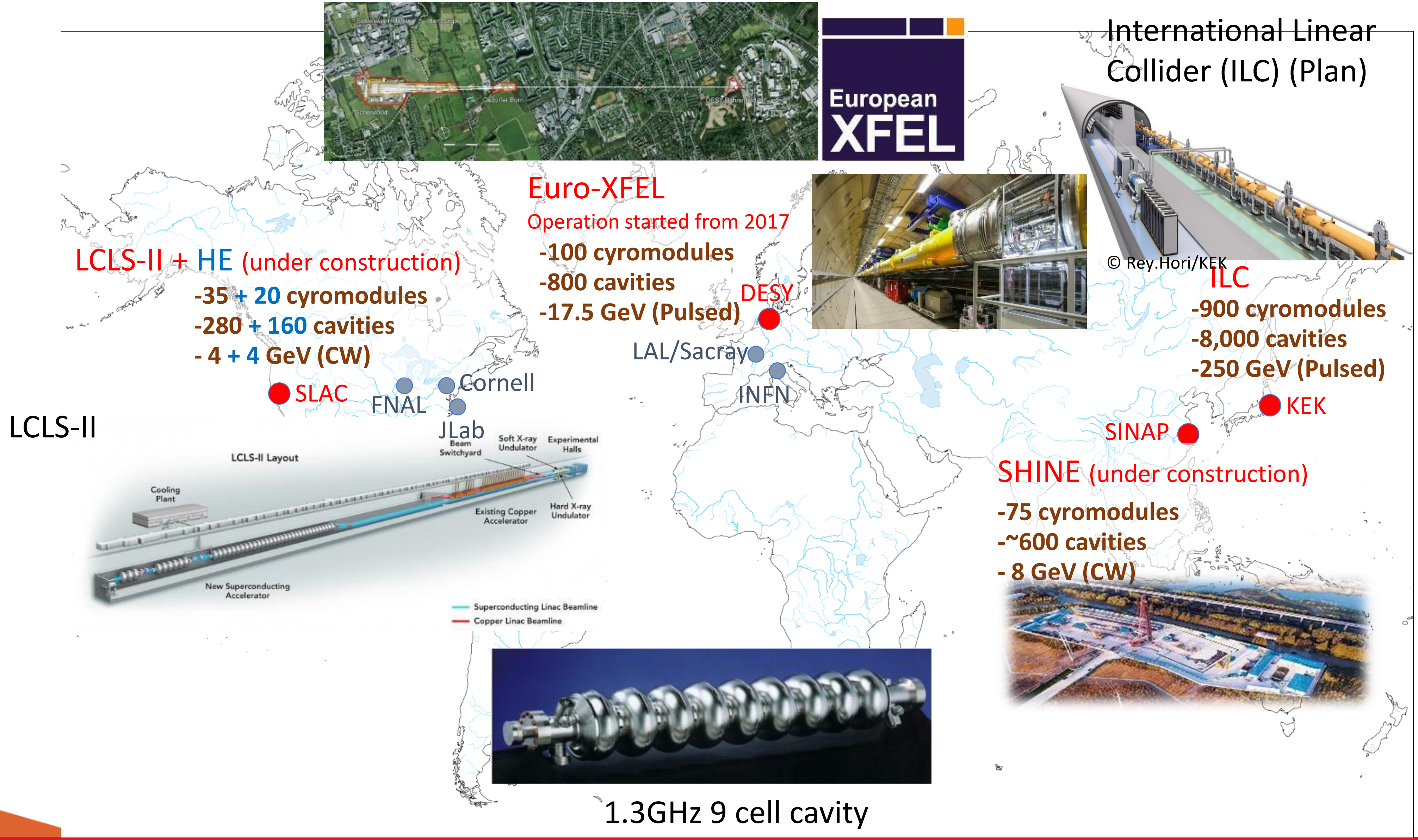
- The SRF technology's maturity has been proven by the operation of the European X-ray Free Electron Laser (X-FEL) in Hamburg, where 800 superconducting cavities (1/10 of ILC SRF cavities) have been realized and successfully operated since 2017.
- In addition to European XFEL, LCLS-II at SLAC, SHINE in Shanghai are under construction.

- Nano-beam technology has been demonstrated at ATF hosted in KEK under international collaboration, almost satisfying the requirements of the ILC.

- Demonstrations at CESR (Cornell) have established confidence in ILC damping ring.

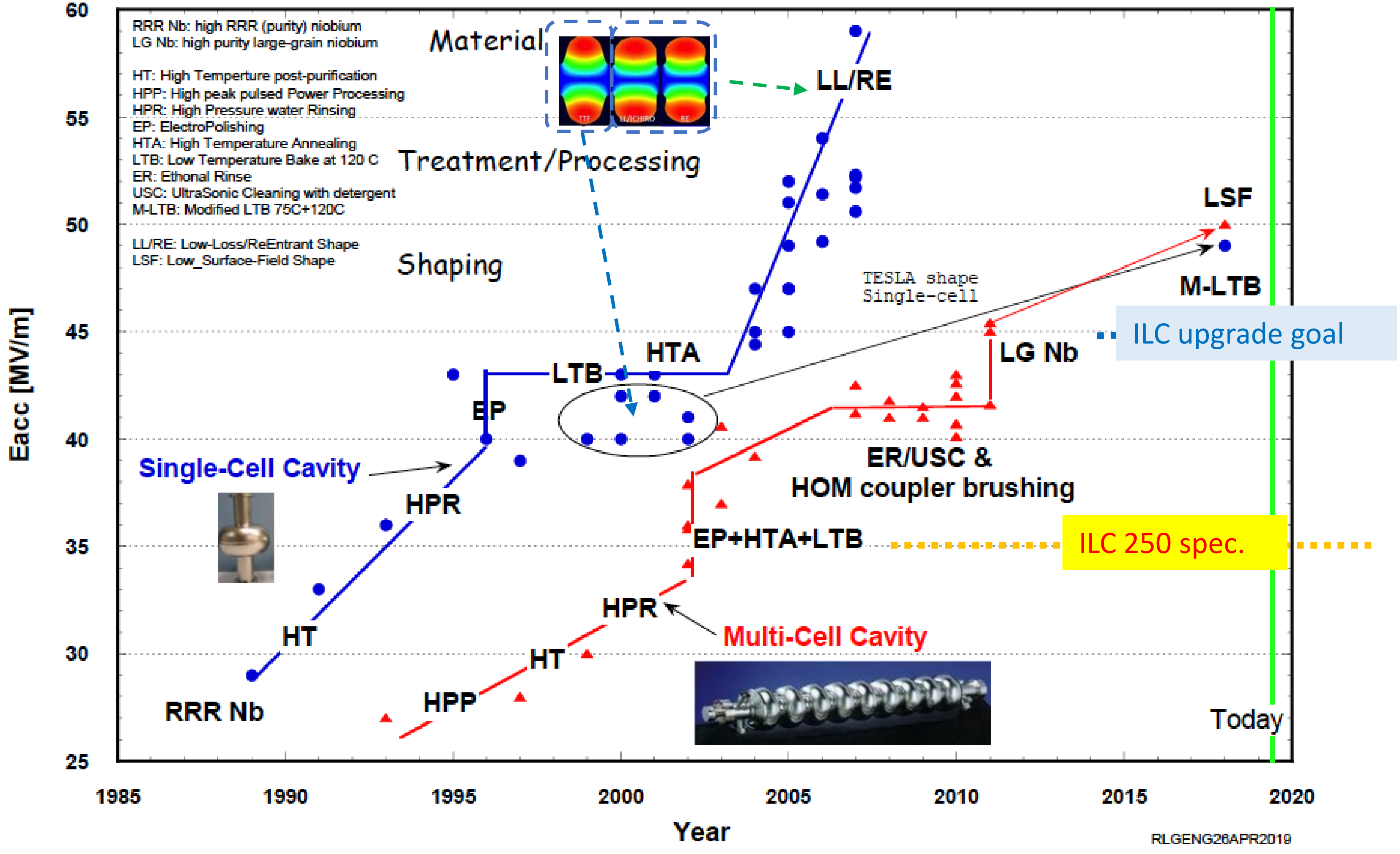
- Remaining technical preparation (such as mass-production of SRF cavities and Global Transfer of SRF cavities and cryomodules, positron source, beam dump) can be carried out during the preparation phase before ILC construction. These are generally listed in "Recommendations on ILC Project Implementation" [7].

1.7.3 Similar existing technology: Worldwide large scale SRF accelerators



1.7.3 Similar existing technology: Matured SRF technologies

Courtesy: R. Geng,

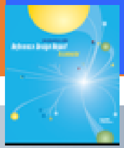


1.7.4 State of Technical Design Report

international development team

2004

2006 '07 '08 '09 '10 '11 '12 '13 '14 '15 '16 '17 '18 '19 '20



SC Technology selected

ILC-GDE

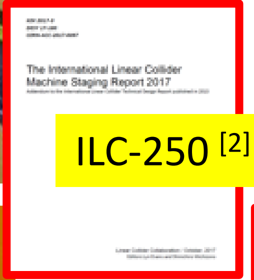
TDR

LCC

RDR)

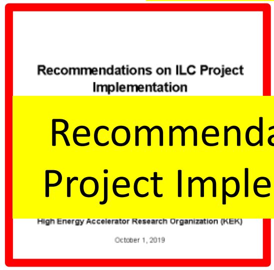
Technical Design Phase

TDR [1] :
49 countries
392 institutions
>2400 researchers

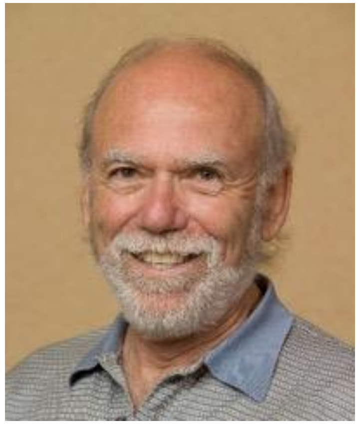


ILC-250 [2]

*I*nternational *D*evelopment *T*eam



Recommendations on ILC Project Implementation [3]



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

1.7.5 State of Proposal

IDT is formed under ICFA. KEK serves as its host.

Stage 1 International Development Team (~1.5 years)

ILC Pre-Lab. is established by MOU's among the laboratories.

Stage 2 ILC Pre-Laboratory (4 years)

ILC Lab. is established by governmental agreement.

Stage 3 ILC Laboratory (10 years for construction)

Stage 4 Experiment at ILC!

International Development Team (IDT)

IDT: ***to prepare for smooth transition to the ILC Pre-lab***

- Prepare a proposal for the organization and governance of the ILC Pre-Lab
- Prepare the work and deliverables of the ILC Pre-laboratory and workout a scenario for contributions with national and regional partners

KEK's role at IDT and beyond

- The next focus will be when ILC Pre-Lab can be started following the IDT.

- The function of the ILC Pre-lab is to do the remaining works in four years.
  - Solve remaining technical issues of the accelerator.
  - Design of the organization and functions of the ILC laboratory
  - and launch the ILC laboratory

- Since the start of the ILC Laboratory is the official start of the ILC project, it is necessary to reach an international agreement including cost sharing before its start. The ILC Pre-Lab also plays an important role in supporting such international negotiations

- KEK is making every possible effort to start the ILC Pre-Lab soon after the IDT completes its mandate, and to realize the ILC together with the Japanese physics community and supporting groups in the political sector, industrial sector and Tohoku region.

M. Yamauchi, AWLC2020

1.7.6 Proposals for upgrades or extensions

The ILC can be upgraded to higher energy and luminosity.

			Z-Pole [4]		Higgs [2,5]			500GeV [1*]		TeV [1*]
			Baseline	Lum. Up	Baseline	Lum. Up	L Up.10Hz	Baseline	Lum. Up	case B
Center-of-Mass Energy	E_{CM}	GeV	91.2	91.2	250	250	250	500	500	1000
Beam Energy	E_{beam}	GeV	45.6	45.6	125	125	125	250	250	500
Collision rate	f_{col}	Hz	3.7	3.7	5	5	10	5	5	4
Pluse interval in electron main linac		ms	135	135	200	200	100	200	200	200
Number of bunches	n_b		1312	2625	1312	2625	2625	1312	2625	2450
Bunch population	N	10^{10}	2	2	2	2	2	2	2	1.737
Bunch separation	Δt_b	ns	554	554	554	366	366	554	366	366
Beam current		mA	5.79	5.79	5.79	8.75	8.75	5.79	8.75	7.60
Average beam power at IP (2 beams)	P_B	MW	1.42	2.84	5.26	10.5	21.0	10.5	21.0	27.3
RMS bunch length at ML & IP	σ_z	mm	0.41	0.41	0.30	0.30	0.30	0.30	0.30	0.225
Emittance at IP (x)	$\gamma\epsilon^*_x$	μm	6.2	6.2	5.0	5.0	5.0	10.0	10.0	10.0
Emittance at IP (y)	$\gamma\epsilon^*_y$	nm	48.5	48.5	35.0	35.0	35.0	35.0	35.0	30.0
Beam size at IP (x)	σ^*_x	μm	1.118	1.118	0.515	0.515	0.515	0.474	0.474	0.335
Beam size at IP (y)	σ^*_y	nm	14.56	14.56	7.66	7.66	7.66	5.86	5.86	2.66
Luminosity	L	10^{34}/cm^2/s	0.205	0.410	1.35	2.70	5.40	1.79	3.60	5.11
Luminosity enhancement factor	H_D		2.16	2.16	2.55	2.55	2.55	2.38	2.39	1.93
Luminosity at top 1%	$L_{0.01}/L$	%	99.0	99.0	74	74	74	58	58	45
Number of beamstrahlung photons	n_g		0.841	0.841	1.91	1.91	1.91	1.82	1.82	2.05
Beamstrahlung energy loss	δ_{BS}	%	0.157	0.157	2.62	2.62	2.62	4.5	4.5	10.5
AC power [6]	Psite	MW			111	138	198	173	215	300
Site length	Lsite	km	20.5	20.5	20.5	20.5	20.5	31	31	40

Energy

Lumi.

*There were several typos in the values of the luminosities in the TDR. They have been fixed by CR-0005. https://edmsdirect.desy.de/item/D00000001100895

1.7.7 Stageability to future experiments: Further Studies Underway

- Further luminosity upgrades (8.1×10^{34}) are under study using higher Q values for longer RF pulse lengths and higher Rep rate[*1]
  - R&D over last 5 years leads to higher (x2) Q values with Nitrogen doping
  - Now used for LCLS-2
- Further energy upgrade studies are underway to reach 3 TeV[*2]
- Promising R&D exploration underway for Gradient and Q advances, and for lowering cost [*1,*2]

[*1] Snowmass LoI, "Perspectives on International Superconducting Linear Colliers (ILC) to the Next Century Part A: High Luminosity Higgs Factory and Top Factory"

Contact person: Hasan PADAMSEE https://www.snowmass21.org/docs/files/summaries/AF/SNOWMASS21-AF3_AF0_Hasan_Padamsee-074.pdf

[*2] Snowmass LoI, " Perspectives on International Superconducting Linear Colliers (ILC) to the Next Century Part B: ILC Energy Upgrades to 3 TeV and Beyond",

Contact person: Hasan PADAMSEE https://www.snowmass21.org/docs/files/summaries/AF/SNOWMASS21-AF4_AF0_Hasan_Padamsee-075.pdf

Summary

1. Design outline: e-/e+ collision using two key technologies (SRF acceleration and nano-beam)
2. Readiness: TDR was published in 2013 and more than 2,400 researchers contributed to the TDR.
3. Similar existing technology: European XFEL, LCLS-II, SHINE adopted the same SRF technology.
4. State of Technical Design Report: Global collaboration established in 2005 and TDR was published in 2013.
5. State of Proposal: After TDR, LCC (linear collider collaboration) and IDT (international development team) have taken over the global collaboration. IDT is now preparing for the ILC Pre-lab.
6. Proposals for upgrades or extensions: The staging scenario to reach 1 TeV including both luminosity- and energy- upgrade(s) has been studied and proposed in TDR.
7. Stageability to future experiments: SRF technology is lively improving. Future technology breakthroughs allow higher energy upgrade (beyond 1 TeV).

Thank you for your attention

References

[1] TDR
https://ilchome.web.cern.ch/publications/ilc-technical-design-report
https://arxiv.org/ftp/arxiv/papers/1306/1306.6328.pdf
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[4] “Operation of ILC250 at the Z-pole“, Jan. 2020: https://arxiv.org/abs/1908.08212
https://agenda.linearcollider.org/event/8389/contributions/45113/attachments/35257/54621/ILC-CR-0019.pdf
[5] “Luminosity Upgrades for ILC“, Aug.2013: https://arxiv.org/abs/1308.3726
[6] “Updated power estimate for ILC-250”, Dec.2019
https://edmsdirect.desy.de/item/D00000001169675
[7] “Summary of the ILC Advisory Panel's Discussions to Date after Revision” (MEXT, Japan):
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https://indico.cern.ch/event/765096/contributions/3295702/
https://arxiv.org/pdf/1903.01629.pdf
[9] “Green ILC project," http://green-ilc.in2p3.fr/home/ (2018).

ILC superconducting linear collider

1. Design outline
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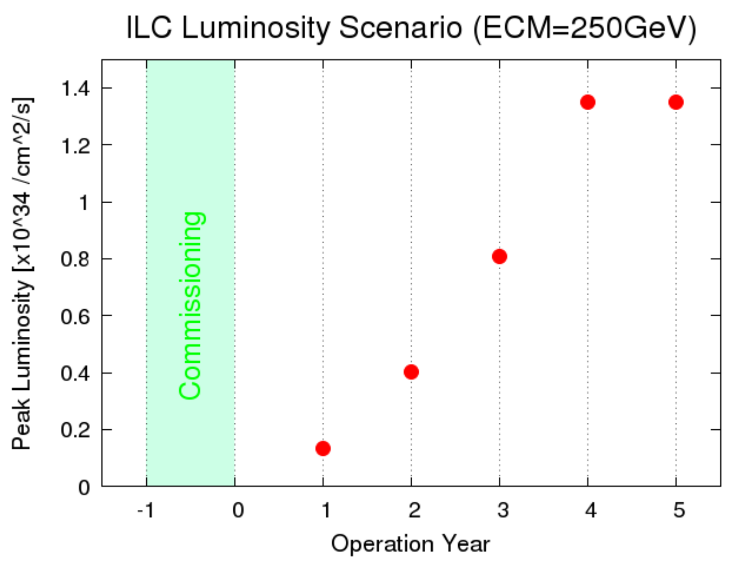
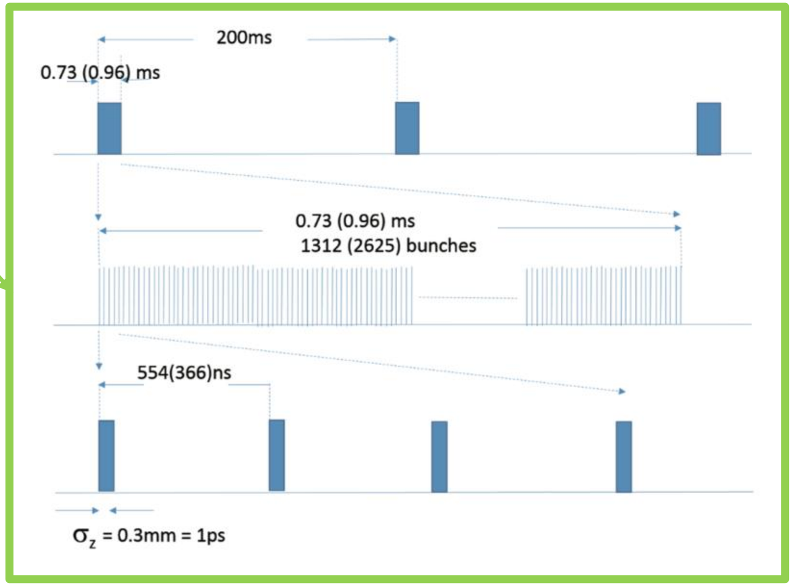
4. State of Technical Design Report
5. State of Proposal
6. Proposals for upgrades or extensions
7. Stageability to future experiments

ILC machine parameters

ILC	electron/positron	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*
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
# 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	(~1) + 4(prep.) + 9(construction)

** 5,000-hour operation at peak luminosity*





IP parameters and conditions

The BDS is designed such that it can be upgraded to a maximum beam energy of 500 GeV; components necessary for 125 GeV beam operation are installed and space for a later upgrade is reserved.

To bring the beams to collision with the necessary nano-meter accuracy requires a continuous compensation of drift and vibration effects. Along the ILC, the pulse length and bunch separation (727 μs and 554 ns, respectively) are large enough to allow corrections between pulses as well as within a bunch train (intratrain feedback).

Finally, the 3.9 GHz crab cavities close to the interaction point are incorporated that rotate the bunches to compensate for the 14 mrad beam crossing angle.

Parameter			Z-pole [4]	Higgs [2]	500 GeV [1]	TeV [1]
Beam size at IP (x)	σ^*_x	μm	1.118	0.515	0.474	0.335
Beam size at IP (y)	σ^*_y	nm	14.56	7.66	5.86	2.66
Luminosity (baseline)	L	$10^{34}/cm^2/s$	0.205	1.35	1.79	5.11
Luminosity at top 1%	$L_{0.01}/L$	%	99	74	58	45
Number of beamstrahlung photons	n_γ		0.841	1.91	1.82	2.05
Beamstrahlung energy loss	δ_{BS}	%	0.157	2.62	4.5	10.5

Nano-beam is well studied at ATF2 in KEK.