Confidential

ILC Cost-Update 2024: Task-Force Work Progress and Plans

Akira Yamamoto
ILC Cost-Update-2024 Task Force and KEK

Discussed originally at the **4th** ILC-CU24 TF meeting, 2024-6-14, and
To be reported at **ILC-CU24 TF meeting**, 2024-7-17 and
To be reported at IDT-WG2 meeting, 2024-7-23

Updated: 2024-7-23

ILC Cost-Update study requested to the Task Force

https://agenda.linearcollider.org/event/10134/overview

Status of the ILC

-Activities of the International Development Team (IDT)-

LCWS2024 at University of Tokyo

Tokyo, Japan, 8-11 July 2024

Tatsuya Nakada

EPFL, Switzerland

Chair of the IDT Executive Board

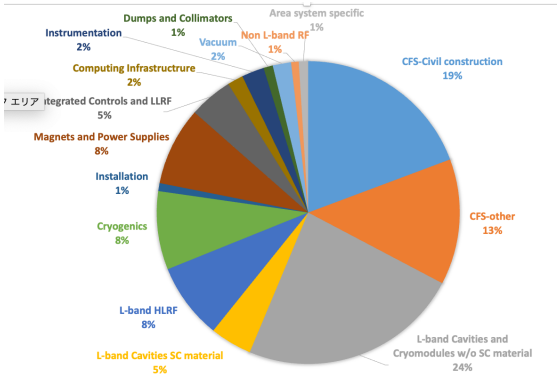
The IDT established by ICFA in August 2020 has been supporting the Japanese HEP community, who had proposed to host the ILC in Japan as a global project.

- Working Group 1: Giving advices for founding the ILC Preparatory Laboratory, Pre-lab: (MEXT considered that it was premature for establishing a Pre-lab.)
- Working Group 2: Forum of the accelerator community interested in the ILC: Through regular meetings, it established the accelerator work packages for the Pre-lab proposal and ILC Technology Network (ITN). It follow the ITN activities as well as the ILC Cost Update work.

Cost update task force members:

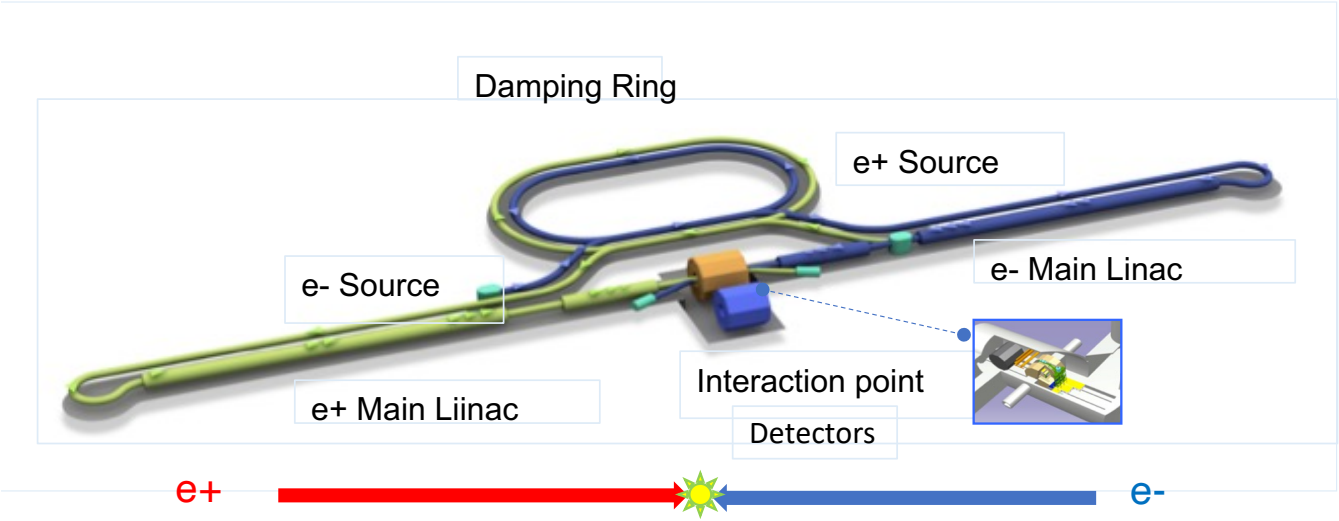
Gerry Dugan	(Cornell)
Benno List	(DESY)
Marc Ross	(SLAC)
Hiroshi Sakai	(KEK)
Nobuhiro Terunuma	(KEK)
Nick Walker	(DESY)
Akira Yamamoto*)	(KEK)
and from IDT EB	
Andy Lankford	(UCI)
Shinichiro Michizono	(KEK)
Steinar Stapnes	(CERN)

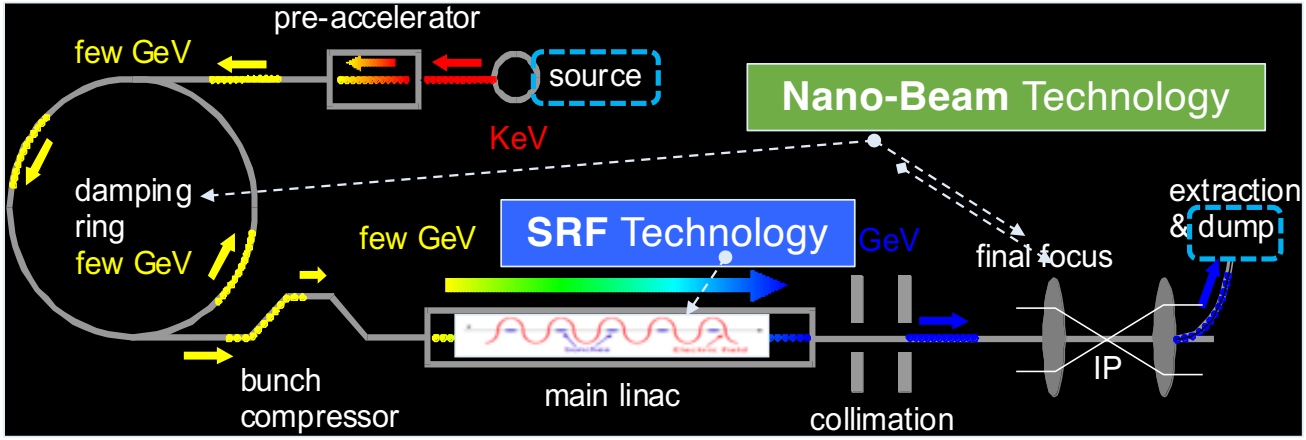
*)Task Force leader

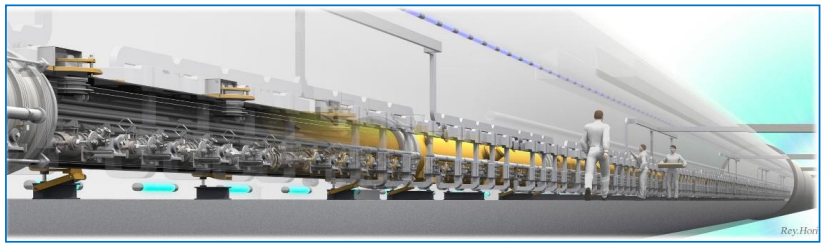


ILC250-A Cost fraction In 2017, to be updated

ILC-250 and the Accelerator Technology







Parameters	Value
Beam Energy, Length	125 + 125 GeV, 20.5 km
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	**~ 9,000** (~ 8,500 x 1.05) **~ 1,000**
# RF units:	**~ 240**
AC-plug Power	111 / 138 MW

ILC-250 SRF Cavity-, Mag-, CM-, and RF-units

arXiv: 1711.00568 v3.

KEK 2017-3
DESY 17-180
CERN-ACC-2017-0097

The International Linear Collider
Machine Staging Report 2017
Addendum to the International Linear Collider Technical Design Report published in 2013

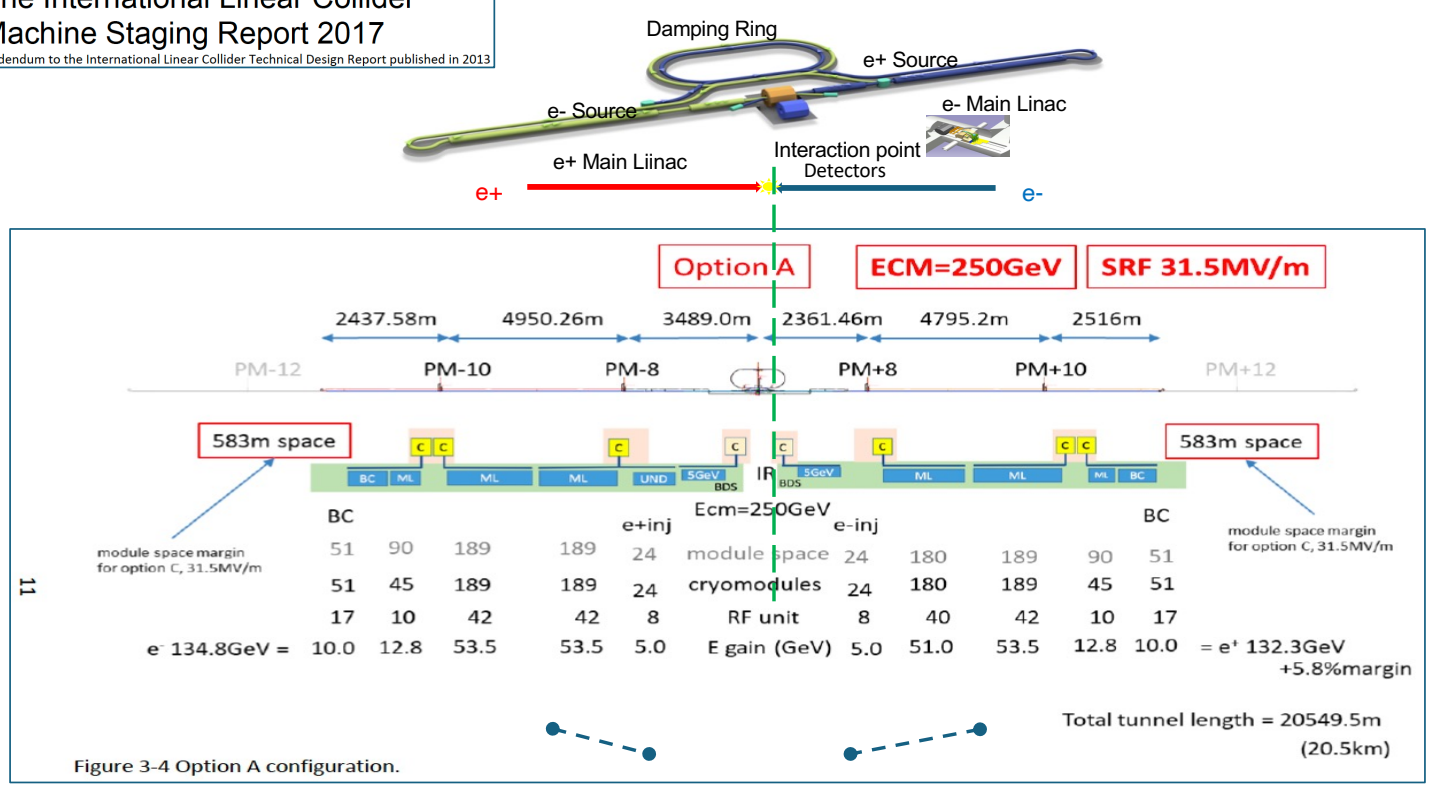
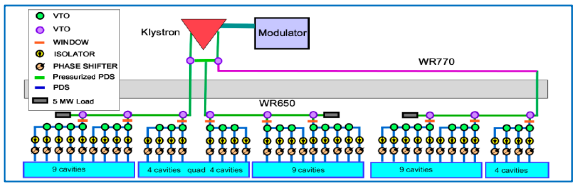
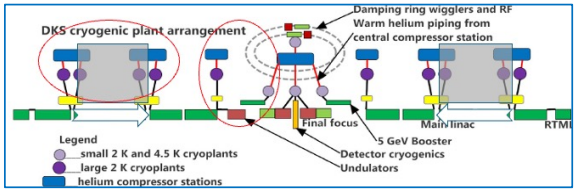


Figure 3-4 Option A configuration.





1.3-GHz SRF-**Cavities** (total): 8,554
(Indust. Prod. Study)→ **~ 9,000**)
BC: 68x9 + 34x8 = 884
ML: 558x9 + 279X8 = 7,254
e+e- S.: 32x9+ 16x8 = 416

SC-mag +BPM (total): 329
(→ ~ 330)
BC: 34
ML: 279
e+e- S.: 16

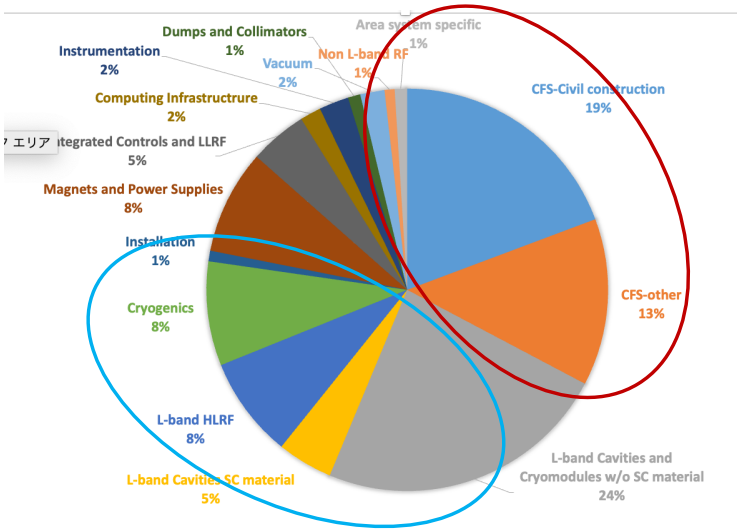
1.3-GHz **CMs** (total): 987
(→ ~ 990)
BC: 102
ML: 837
e+e- S.: 48

1.3-GHz **RF-units** (total: 236
(→ ~ 240)
BC: 34
ML: 186
e+e- S.: 16

Cryogenics 6 (Large) + 2 (Small)
(→ 6+2))
BC + ML : 6 (large)
e+e- S (Lnac).: 2 (small)

ILC Cost Estimate Update 2024: Working Approach

- **Strategy Update:**
  - Various boundary conditions on currency (ILCU or real exchange rates?), ppp?, inflation, and further social status to be well defined.
- **Accelerator Cost Update:**
  - **SRF:**
    - Understand Eu-XFEL, LCLS-II-HE experiences as facts,
    - Update of **Industrial study for Cavity,** Tuner, Coupler, **CM**, HLRF, and Cryogenics.
    - Re-validate the cost update.
  - **Other Technical Systems.**
    - re-validate the cost based on systematic scaling.
  - **CFS (CE & CF)**:
    - No site-specific: re-validate the cost based on recent multiple studies, as to be '**fresh**'.
    - (Site-specific: to be separately handled with care.)



LINEAR COLLIDER COLLABORATION

Designing the world's next great particle accelerator

Methodology for 2024 Cost Update

Benno List

ILC-CU24 Task Force Meeting

19.7.2024

Proposal for Updated Cost

Courtesy: B. List
"IDT methodology for 2024 Cost Update"
ILC-CU24 Task Force Meeting, 19.7.2024

- Keep the TDR methodology:
  - Stay consistent with existing cost estimates
  - IDT mandate is for ILC in Japan as a global, in-kind contribution project
- This means:
  - Equipment prices (**Value**)
    - Taken from quotes/estimates in a specific region (either 2012 estimate or **new estimate/quote**)
    - escalated using regional escalation factor to 2023 if necessary
    - Converted to a new ILCU2023 using PPP rates
  - Define a new ILCU2023:
    "1 ILCU(2023) corresponds to the purchasing power of 1 US$ in the U.S. in Jan 2023, as representative for 2022-2024"
- Depending on item
  - escalate values from TDR
  - Update value from new quote, convert with PPP
- **Start from accelerator area / technical system matrix, do not go back to full item list**

- Technical implementation for escalation:
  - Starting from TDR cost estimate:
    - Evaluate which costs were evaluated in which currency / region originally
    - Convert cost back from ILCU2012 to local currency using PPP(2012) rates from TDR
    - Escalate cost from 2012 to 2023 using local escalation rates
    - Convert cost to ILCU2023 using PPP(2023) rates

  } 1 factor

  - Can be considered as evaluating an effective escalation factor from ILCU2012 to ILCU2023, based on a "basket" of goods and regions
    -> do separately for each accelerator area/technical system
- The resulting escalation factors can be applied also to scaled cost estimate, i.e. the 2017 cost estimate for a staged machine

Reminder from last meeting

Use of Purchasing Power Parity Indices for the Value Estimate

Purchasing Power Parity indices reflect how the value of goods change from place to place. In contrast to currency exchange rates, they are goods dependent as well as dependent on the country (PPP rates for Euro to Dollar conversion differ for the various member states of the Euro zone).

For an international in-kind contribution project such as the ILC, use of PPP indices is appropriate because it gives the cost for domestic production or procurement of the respective items. It is assumed that in-kind contributions will mostly be produced and purchased in the contributing regions.

For example, if, a cryo module would cost 1.0 M€ to produce in Europe, then it would be expected to cost 1.185M$ to produce in the U.S. (as a PPP index of 0.844 for $/€), and 1.283 Oku¥ to produce in Japan (at a PPP index of $/¥=108.3). In contrast, the currency exchange rate would indicate how much it cost to acquire the item in Europe, e.g. it would cost 1.35 Oku¥ to pay for a European made cryomodule in Yen, at an exchange rate of €/¥=135.

If due to currency fluctuations a region has an overvalued currency (which means that the currency costs more on the money market than would be appropriate from its Purchasing Power, a situation currently faced by the Euro zone and even more by Switzerland, compared to the U.S.), it can make use of that advantage and acquire goods from abroad at lower prices, or decide to support the own economy and buy local. Insofar, the PPP cost estimate can be considered “conservative” for overvalued currencies. On the other hand, if a currency is undervalued (such as the Yen compared to the Euro in the preceding example), the PPP rates reflect the true buying power of the currency for locally produced goods instead of inflating the cost estimate due to (possibly temporarily) unfavourable exchange rates.

ILC Cost-Update2024 Approaches

Category	ILC-TDR-500 (2012) Updated from RDR &.. (by GDE)		ILC250 (2017) Updated from TDR & .. (bu LCC)		New Efforts for ILC250 further update, in progress (by IDT)	ILC250 (2024) Expected: (by IDT)
Year	**2012 ~ 2013**		**2017 ~ 2018**		**2018 ~ 2024**	
SRF	- Eu-XFEL, - Industrial study		- Scaling, - Industrial study update-1		- Design update for ILC250, - Comparison w/ LCLS-II-HE, ← Cavity - Comparison w/ Eu-XFEL (update) **←Cavity and CM** - Industrial-study update-2, ← Cavity	**- 2024-based cost update**
Other Tech. Sys. (Mag., PS, Vac., Cntrol, others. ..)	- Lab study & - Scaling:		- Scaling:		----------> e-driven e+ source studied to be an alternate	**- Scaling-update** - e-driven e+ source as alternate ?
CFS (CE & CF)	- Global efforts:		- Scaling, - New multiple design- and cost-studies in JP, resulting good consistency.		- Further design- and cost-update	**- 2024-based, design- and cost-update**

- TDR Ext. Cost Review, 2013

- ILC250 JP/MEXT Adv. Panel, 2018
- ESPPU input-2020, US-Snowmass-input, 2022

The international Linear Collider -- A Global Project

Appendix: ILC250 Project Costs

[2013] [2018]

	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**

to be updated [2024]

http://www.mext.go.jp/component/b_menu/shingi/toushin/__icsFiles/afieldfile/2018/09/20/1409220_2_1.pdf

FIG. 7. Costs of the ILC250 project in ILCU as evaluated by the Linear Collider Collaboration (LCC), converted to JPY and re-evaluated by KEK, and summarised in the MEXT ILC Advisory Panel report, in July, 2018.

ILC250 SRF Industrial Cost Update Plan

1. Cavity and CM		
(1) Cavity related		
	① SC Material	
	② Resonater (main body)	
	③ Cavity Inspection	
	④ Input power coupler	
	⑤ Coupler Processing	
	⑥ Tuner	
	⑦ Helium Vessel	
	⑧ Magnetic Shield	
	⑨ Transportation	
(2) Quadrupole SCM package		
(3) Cryomodule		
	① TDR Engineering study	
	② Cryostat and Cold-mass	
	③ CM assembly	
	④ CM transportation	
	⑤ CM Acceptance	
(4) Coupler Process Infra-St.		
(5) Kly	RF Power and Distribution	
	① Klystron	
	Associated equipment	
	② Assoc. : Modulator	
	(3) RF Power distr.	
	Supporting structure	

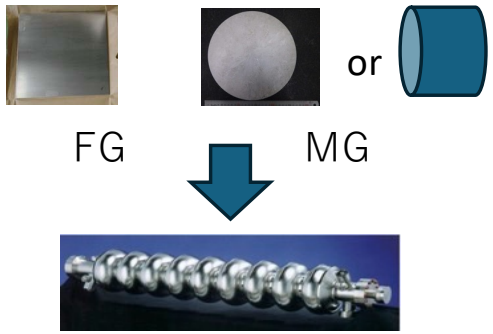
Cavity related:
- SC Material:
- Cavity (resonater):
- Coupler :
- Tuner:
- Mag. Shield ?

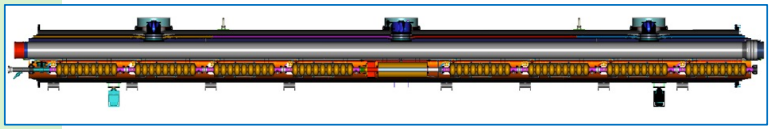
Magnet:

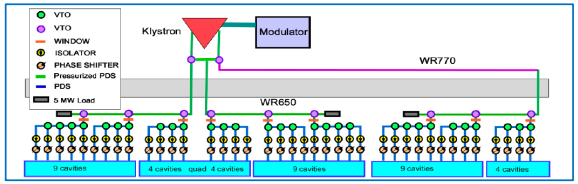
CM:
- Components
- Assembly

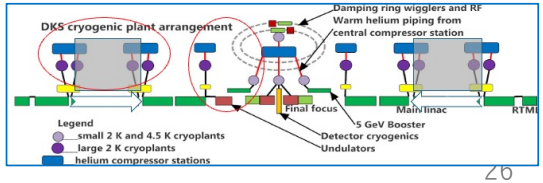
HLRF:
- Klystron ?
- Modulator ?
- PDS ?

Cryogenics:







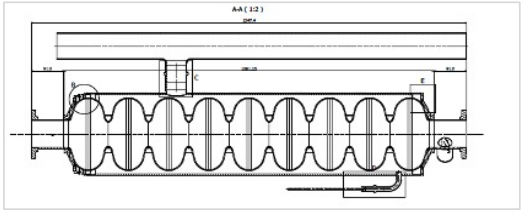


Clarifying ILC250 SRF Industrial Cost Update Plan

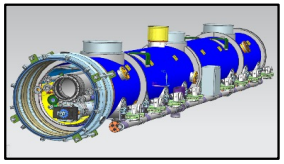
A.Yamamoto
2024-7-7

SRF Cavity:

- Update of the 1.3 GHz **SRF cavity** industrial production study on ILC250 as of 2024
- Delivery expected to be ready for the cold RF test and for assembly into CM
- **3,000 cavities** as a baseline industrial production model, to be shared with 3 region/industry,



To be Ready for



- ~ 6 years production period, including **4 yrs steady production period** (or alternate proposal)
- Additionally, results of the study will be **scaled to the 9,000 full production.**

Study plan expected:

- The study contract to be made by the end of July, 2024, (→ to be discussed)
- The study result to be reported to IDT/CERN by the end of October, 2024.

Action Progress in Communication with Industry/Labs for the ILC-CU24 TF Work

A. Yamamoto, 240715

Category	Production Items	Consisting of	Key Parameters	# required for ILC250	Indust. Prod. Model (w/ 3 regions/venders)	Option for full production	Reference in 2024 price
ML/SRF	SC material	FG sheets, or MG discs	265^2. x 2.8 [mm] 260 (dia) x 2.8 [mm]	9,000 x (18+2)	3,000	(tbd)	Ind. Cost Quotation
	Cavity/Resonator	9-cell, end-g, 2p-He pipe, HOM	1.3 GHz, pulse, E:35 MV/m, Q: 1e10	9,000	3,000	9,000	Ind. Cost Quotation LCLS-II-HE (2021)
	Input-Coupler	Warm-, cold-sections	1.3 GHz, pulse,	9,000	3,000	(tbd)	Ind. Cost Quotation LCLS-II-HE (2021)
	Tuner	Lever-Mech., Motors, Piezo	ΔF: ?? Hz T-response: < 0.1 ms ?	9,000	3,000	9,000	Ind. Cost Quotation LCLS-II-HE (2021)
	Magnetic Shield	Single-layer (outside)	Residual B field : < ? mT	9,000	3,000	9,000	Ind. Cost Quotation LCLS-II-HE (2021)
ML/SCM package	SC-mag + BPM	SC-mag, BPM	G: 40 T/m, L: 0.9 m Conduction cooling	330	110	330	Ind. Cost Quotation LCLS-II-HE (2021)
ML/CM	Components	Cold-mass, V. Veseel,	Size: 1 m x 12.5 m T-op: 2 K,	900 + α	300 + α'	900 + α	Ind. Cost Quotation LCLS-II-HE (2021)
	Assembly	Cavity-string assembly, Installation into V.V.		900 + α	300 + α'	?	Lab's expert estimate, scaling from Eu-XFEL
ML/HLRF	Modulators			240 + β	80 + β'	240 + B	Ind. Cost Quotation
	Klystron		1.3 GHz	240 + β	80 + β'	240 + β	Ind. Cost Quotation
	Power Distr. System			240 + β	80 + β'	240 + β	Ind. Cost Quotation
ML/Cryogenics	Refrigerator System		~ 20 KW @ 4 .5 K	6 large system	3 large large system	6 large+	Lab's expert estimate based on HL-LHC
Others: - Sources				Similar to TDR			Scaling for inflation from 2012 (TDR)
Others: - DR/RTML/BDS				Similar to TDR			Scaling for inflatiation from 2012 (TDR)
CFS	CE, CF,	Tunnel, Build., Utilities					New estimate in 2024

ILC250 SRF Industr. Cost Update Work in Progress

2	TDR Cost Estimate (Break Down) for MEXT
3	
4	Item
5	
6	
7	1. Cavity and CM
8	(1) Cavity related
9	① SC Material
10	② Resonater (main body)
11	③ Cavity Inspection
12	④ Input power coupler
13	⑤ Coupler Processing
14	⑥ Tuner
15	⑦ Helium Vessel
16	⑧ Magnetic Shield
17	⑨ Transportation
18	
19	(2) Quadrupole SCM package
20	(3) Cryomodule
21	① TDR Engineering study
22	② Cryostat and Cold-mass
23	③ CM assembly
24	④ CM transportation
25	⑤ CM Acceptance
26	(4) Coupler Process Infra-St.
27	(5) Kly RF Power and Distribution
28	① Klystron
29	Associated equipment
30	② Assoc. : Modulator
31	(3) RF Power distr.
32	Supporting structure
33	

Cavity related:
- SC Material: → **OTIC (cn), ATI (us),** Tokyo-Denkai (jp)
- Cavity: → **RI (de), Mirapro (jp), MHI (jp)**
- Coupler : → **RI-Thales (de-fr),** CPI (us)
- Tuner: → Suzuki-Kikai (jp)
- Mag. Shield → tbd/scaling

CM:
- Components (VV and cold-mass): → WUXI (cn), Zanon (it)
- Assembly → CEA-Saclay(eu-XFEL), Fnal (us-LCLS-II)

HLRF:
- Klystron: → Canon (jp) and ?
- Modulator: → tbd
- PDS → tbd/scaling?

Cryogenics: CERN (HL-LHC), SLAC (LCLS-II)

Blue: Communication in progress

Action Progress in Communication with Industry/Labs for the ILC-CU24 TF Work

A. Yamamoto, 240715

		Contacted	To be contacted	TF members in charge	Advisors @ KEK (requested)	Advisors / Contacts IDT / ITN labs. (expected) , or comments
SRF	SC material	OTIC, ATI-jp	Tokyo-Denkai	**WG-2 : SRF** A. Yamamoto (AY) M. Ross (MR) N. Walker (NW) H. Sakai (HS)	T. Saeki K. Umemori,	J. Gao (IHEP)
	Cavity/Resonator	RI*, MHI, **Mirapro***			KU, TS	S. Steinar / K. Schirm (CERN)
	Input-Coupler	**RI/Thales***	CPI ?		Y. Yamamoto (YY)	SS/KS,
	Tuner	**Suzuki-Kikai**	Sanyo?		M. Omet, T. Dohmae	Y, Picharnikov (Fnal)
	Magnetic Shield		??		R. Ueki	
SC-mag			Mitsubishi,		Y. Arimoto, T. Yamada	T. Fermando (CIEMAT)
CM	Components (Cold-mass, V.Vessel)		WUXI, Zanon		YY, TD	J. Gao (IHEP), L. Monaco (INFN)
	Assembly	CERN, FNAL/CEA, (XFEL) Hitachi	Fnal / CEA		YY & others (robotics)	V. Parma (CERN), O. Napoli (Fnal), (C, Madec, S. Berry (CEA), T. Semba (Hitachi) (T. Peterson, T. Arkan, (SLAC/Fnal, JLab)
HLRF	Modulators		?		T. Matsumoto	tbd
	Klystron	**Canon**			TM	T. Harada (Canon)
	Power Distr. System		?		TM	
Cryogenics	Refrigerator System	**CERN (HL-LHC)** SLAC (LCLS-II)			K. Nakanishi	D. Delicaris (CERN), E, Fauve, T. Peterson (SLAC)
Others: **Sources**				WG-1 and -3; Strategy and Other Tech. B.List (BL), G.Dugan (GD) NW, AY, HS	Y. Enomoto,	(based on 'scaling')
Others: **DR/RTML/BDS**					T. Okugi	(based on 'scaling')
CFS		P. Consulting		WG4: N.Terunuma (NT)		T. Sanuki (U. Tokyo)

ILC-CU-2024 TF Actions Progress

- Strategy:
  - Currency : to keep ILC unit, and to redefine the new reference point at January 2023 (to be in balace with ppp availability).
  - Inflation/escalation: to rely on ppp (latest available in 2023)
- SRF:
  - Mass production sale down to ILC250,
    - learning curve co-efficiency: < 95 % model> → a half production resulting 5 % up/unit
  - Cost renewal actions in progress in global communication,
    - to figure out the price in 2024
- Other technologies:
  - Scaling from ILC-500 (TDR) to ILC-250,
    - from 2012 to 2023 (or 2024)
- CFS (CE and CF):
  - Cost renewal action in progress in Japan
    - to figure out the price in 2024.

Cost Evaluation: ILC-500 (AS) to -ILC250-A (A') – Confidential --

– update-ay180112, for MEXT-TDR-WG-180120 → ILC-Cost-Update-2024

180103: S. Michizono, B. List, A. Yamamoto
240609: A. Yamamoto, S. Michizono (for ILC250-2024)

Progress Year-base Unit [MILC]	ILC500 2012-base	Energy 500→250 # Reduction R.	ILC250-A 2012-base	ILC250-A' 2012-base	Unit cost-up Due to prod. Scale-down	Design/Production update effect (tbd)	Escalation effect*, 2012-2024 (tbd)	ILC250-A 2024-base (tbd)
Year of work ~ report	*2012 ~ 2013*	*2017 and reported in EXPPU2020, SnowMass2022*			*→ ILC cost update 2024*			
Acc. SRF								
SC material	440	x 0.53	235	108	x 1.02	x ~ 1	x ~ 1.3	311
Cavity-CM	2,317	0.53	1,239	1,053	<1.07> (1.05~1.08)	~ 1.1	~ 1.3	1,895
HLRF	789	0.53	427	407	<1.07> (1.05-1.09)	~ 1.1	~ 1.3	653
Cryogenics	674		440		<1.02>	~ 1	~ 1.3	583
Other Tech. System	(2,065 -674) =1,391	0.79	(1,636 -440) = 1,195	1,494	<1.02>	~ 1.1	~ 1.3	1,741
e-dr. e+Source						x		x
CE & CF								
CE & Build.	1,466	0.69	1.014	1,014	1	~ 1	~ 1.3	1,318
Tun. for e-dr. e+ S.								
Electrial	333	0.77	258	258		~		
Mechanical: C./Vent., Safety & Alignment	576	0.76	448	448	1	~ 1	~ 1.3	582
Sum	7,985	0.66	5,256	4,780				7,418
Note;	(1.0)	ML-RF unit (500/250): 378 /186 = 0.49 All-RF units (500/250): 438/242 = 0.55	(0.66)	(0.60)	LC model assumed; 95% → 1.05 93% → 1.07		* Assuming same ppp	(0.93)

Learning curve coefficient Unified to be 95 %

To be justified using ppp and currency ILC Unit

Excel Reference: CostBasis20190315_20211110_20240610, (Sheet: Option A_for_MEXT-20240610)