Confidential

ILC Cost-Update Task Force: Progress Report

B. List, N. Terunuma, and A. Yamamoto

for

ILC Cost-Update Task Force Team

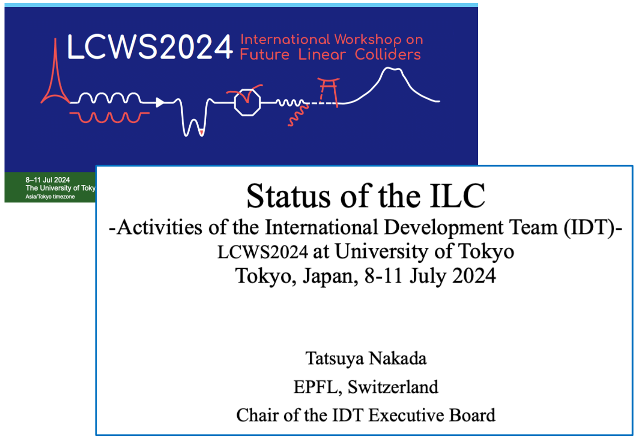
To be reported to IDT WG2 meeting, 2024-10-15-b

Outline

- **Overview**
- **Work in Progress :**
  - Strategy and Methodology → topics, on 17 Sept.
  - Progress in Acc. Tech. System Cost-Update Study → topics on 15 Oct.
  - Prospects for the Cost-Update
- **Optional Estimates:**
  - e-driven Positron Source
  - Future Energy Upgrade
  - Two Interaction Points
- **Review for the Cost Update** :
  - Internal and External Review

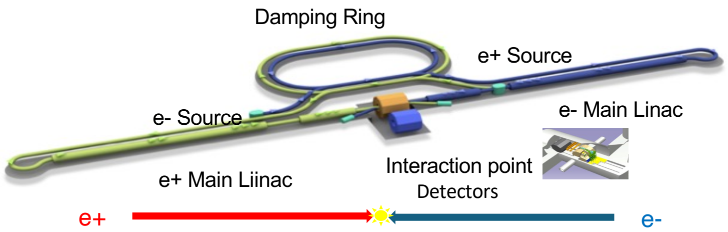
ILC Cost-Update study requested to the Task Force

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



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 Technolog Total: 4.78-5/26 GILC N). It follow the ITN activities as well as the ILC Cost Update work.



ILC250-A Cost fraction in 2017, to be updated

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

Discussion Zoom meeting on the ILC cost update
16:00 CEST7 May 2024, Convened by Tatsuya Nakada (IDT Chair)

Purpose and goal of the ILC Cost-Update in 2024

Charged by IDT EB

Purpose:

- Provide an updated cost of the ILC,
  - for HEP community's consideration on the next energy fronter machine for the European Strategy discussion in 2025-2026.

Goal:

- Provide cost estimates for the TDR baseline,
  - **Higgs factory**, i.e. **250 GeV**, i.e. 350 GeV , and t-t threshold i.e. $\sqrt{s}$ = 500 GeV,,
  - with a written report by the end of 2024 (responding to the ILC community inputs).

Input for European Particle Physics Strategy Update (EPPSU) - 2020

The International Linear Collider – A Global Project

arXiv:1903.01629v3 [hep-ex] 5 Apr 2019

DESY 19-037, FERMILAB-FN-1067-PPD, IFIC/19-10
IRFU-19-10, JLAB-PHY-19-2854, KEK Preprint 2018-92
LAL/RT 19-001, PNNL-SA-142168, SLAC-PUB-17412
March 2019

Based on the TDR cost estimate, an updated cost estimate was produced for the 250 GeV accelerator. This updated cost estimate includes the cumulative effect of the changes to the design since the TDR (see Sect. 2.1), and evaluates the cost for the reduced machine by applying appropriate scaling factors to the individual cost contributions of the TDR cost estimate.

The resulting Value estimate for the ILC accelerator at 250 GeV is 4, 780 – 5, 260 MILCU [2] in 2012 prices, where the lower number assumes a cavity gradient of 35 MV/m, while the higher number is based on the TDR number of 31.5 MV/m. In addition, 17, 165 kh (thousand person-hours) are required of institutional Labour.

In 2018, the ILC Advisory Panel of the Japanese Ministry of Education, Culture, Sports, Science and Technoloy (MEXT) concluded its review of the ILC [105]. For this review, costs were evaluated in Japanese Yen in 2017 prices, taking into account the local inflation for goods and construction costs. For the purpose of this estimate, also the Labour costs were converted to Yen to yield 119.8 G¥, resulting in a total range of the accelerator construction cost of 635.0 – 702.8 G¥, where the range covers uncertainties in the civil construction costs (18 G¥) and of the gradient (49.8 G¥). For the this estimate, conversion rates of 1 US$ = 100 JP¥ and 1 € = 1.15 US$ were assumed.

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arXiv:1901.09829v1 [hep-ex] 28 Jan 2019

The international Linear Collider -- A Global Project

	[2012] TDR: ILC500 [B ILCU] (Estimated by GDE)	[2017] ILC250 [B ILCU] (Estimated by LCC)
Accelerator Construction: sum	**n/a**	**n/a**
Value: sub-sum	7.98	4.78 ~ 5.26
Tunnel & building	1.46	1.01
Accelerator & utility	6.52	3.77 ~ 4.24
Labor: Human Resource	22.9 M person-hours (13.5 K person-years)	17.2 M person-hours (10.1 K person-years)
Detector Construction: sum	**n/a**	**n/a**
Value: Detectors (SiD+ILD)	0.315+0.392	0.315+0.392
Labor: Human Resource (SiD + ILD)	748+1,400 person-years	748+1,400 person-years
Operation/year (Acc.) : sum	**n/a**	**n/a**
Value: Utilities/Maintenance	0.390	0.290 ~ 0.316
Labor: Human Resource	850 FTE	638 FTE
Others (Acc. Preparation)	**n/a**	**n/a**
Uncertainty	**25%**	**25%**
Contingency	**10%**	**10%**

[2024]

to be updated
In price of 2024

moto, 2024/8/19

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ILC Cost Estimate Update 2024: TF Working Approach

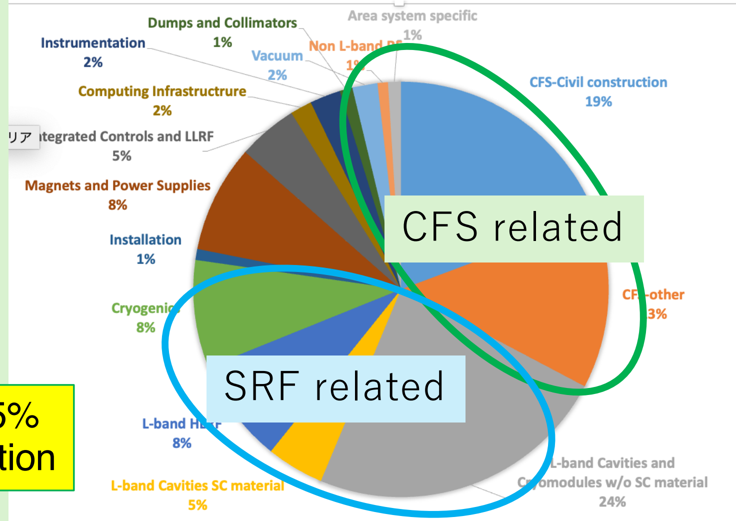
Strategy and Methodology:

- Currency : ILC Unit (M-ILCU), Purchasing Power Parity (**PPP**)
- Time variation / escalation:

Cost Update based on:

- **Acc. Technology** (except for SRF)
  - Scaled from TDR cost-2012 to the cost-2024
- **SRF Technology**
  - New inputs from **LCLS-II-HE experiences, scaled to 2014 price**
  - New inputs **from Industry** in prices of 2024.
- **CFS (CE & CF):** (focusing on a mountain-site model in Japan)**:**
  - New Inputs from consultants in Japan

≥ 75% fraction



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Proposal for Updated Cost

- **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~~ 2024
    - Converted to a new ILCU 2024 using PPP rates
  - Define a new ILCU 2024:
    "1 ILCU(2024) corresponds to the purchasing power of 1 US$ in the U.S. in Jan 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

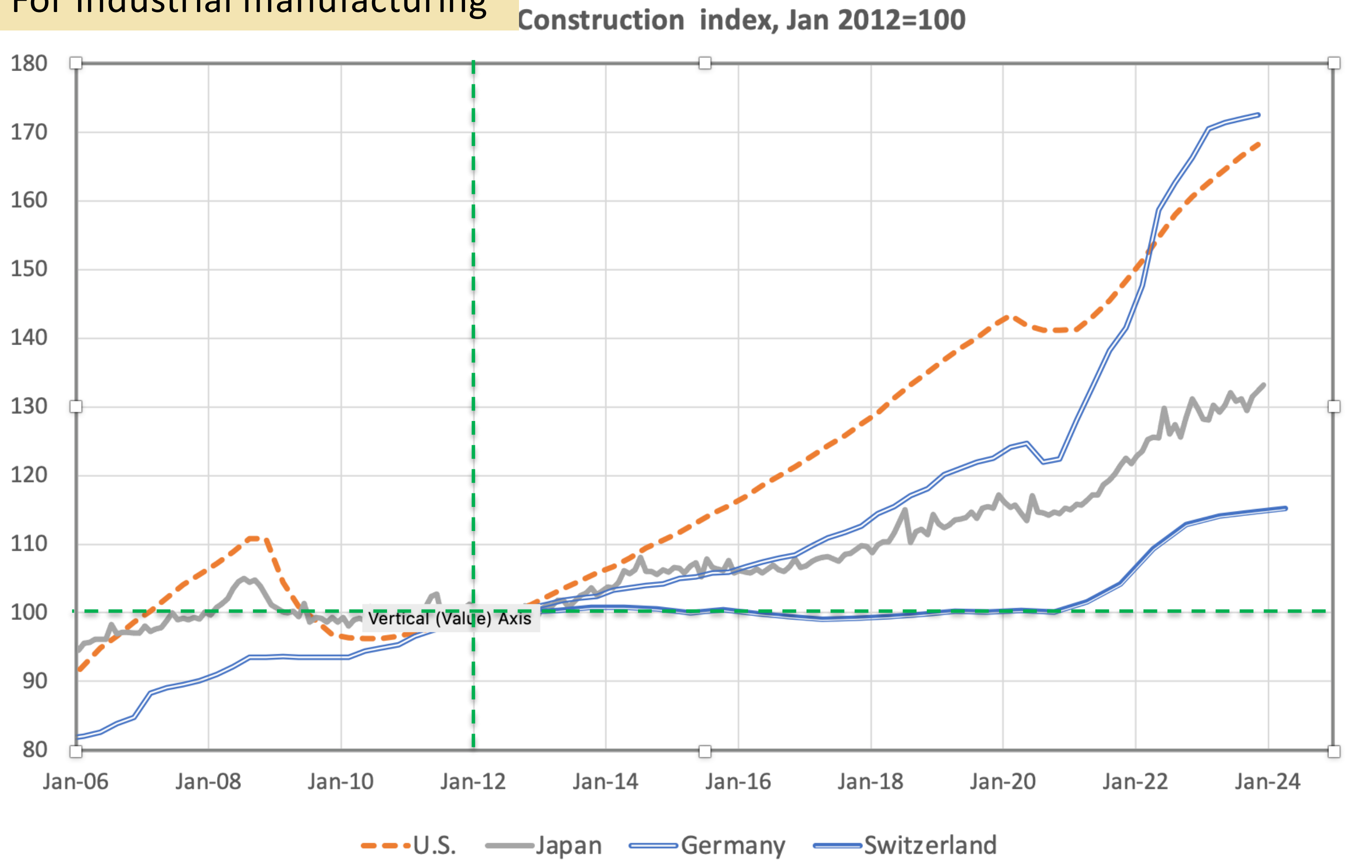
- Technical implementation for escalation:
  - Starting from TDR cost estimate:
    - Evaluate which costs were evaluated in which currency / region originally
    - Convert cost back from ILCU2012 to local currency using PPP(2012) rates from TDR
    - Escalate cost from 2012 to 2024 using local escalation rates
    - Convert cost to ILCU 2024 using PPP(2024) rates
  - Can be considered as evaluating an effective escalation factor from ILCU2012 to ILCU2024, 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.

}1 factor

Escalation Factors for Construction Costs

Courtesy: B. List

For Industrial manufacturing



Escalation Factors (2012 → 2014)

- **Germany**: > 170 %
- US: ~ 170 %
- **Japan**: ~ 130 %
- **Switzerland**: ~114%

Average: ~147 %

(CFS costs to be re-evaluated separately)

[Reference to be added]

Collecting the Input: 2022 PPP rates

To be extended to 2024 PPP

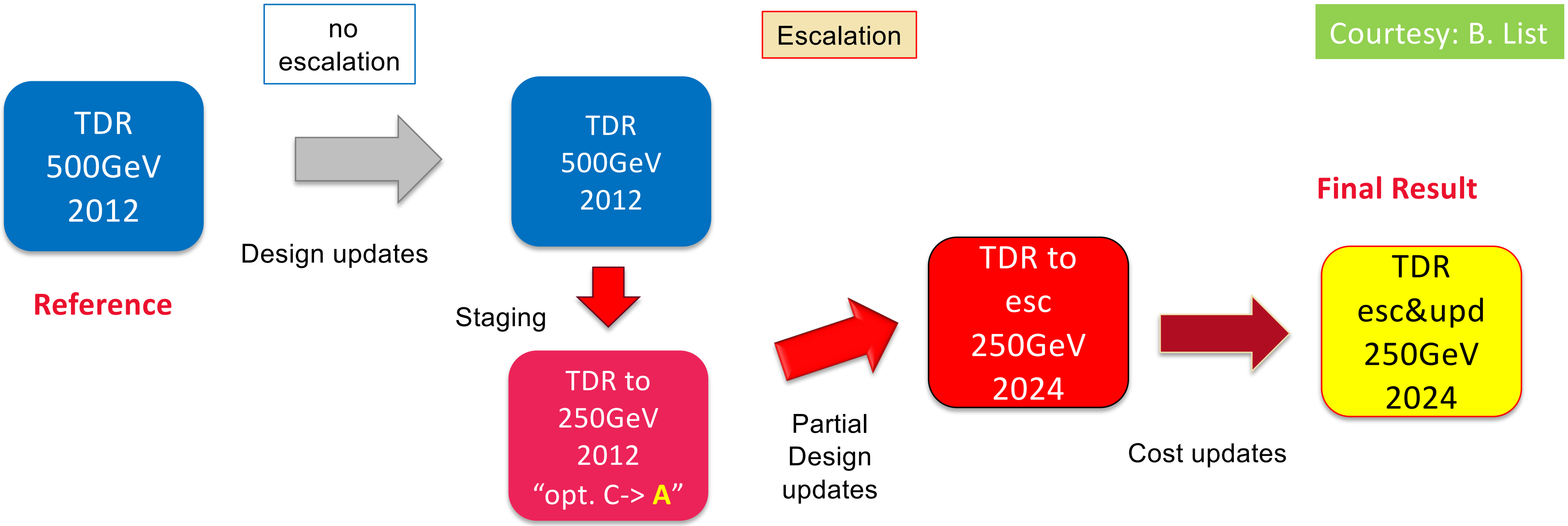
- Updated results from OECD available for 2022
- 2023 PPP rates available only for GDP, differences are small

PPP detailed results, 2020 onwards

Measure: Purchasing power parities ● ***Base reference area:*** United States ● ***Time period:*** 2022
Combined unit of measure: National currency per US dollar

Analytical categories	GDP	Actual individual consumption	Machinery and equipment	Construction	Consumer goods	Non-durable goods	Semi-durable goods	Durable goods
Reference area								
Germany	0.694	0.683	0.92	0.587	0.921	0.937	0.904	0.892
Japan	94.9	94.3	128	85.4	136	148	117	115
Switzerland	0.981	1.15	1.08	0.632	1.2	1.26	1.18	1.04
United Kingdom	0.651	0.701	0.844	0.369	0.846	0.898	0.709	0.827
United States	1	1	1	1	1	1	1	1
Euro area (20 countries)	0.651	0.66	0.941	0.432	0.904	0.904	0.9	0.917
OECD	0.78	0.787	1.02	0.588	0.96	0.955	0.94	0.978

Cost Estimates: Intermediate Steps and Deliverables in 2024



- Reference estimates: TDR (500GeV) and 250GeV estimate with design updates ✅
- effect of **design updates** on cost known, needs to be implemented in spreadsheet -> wip
- Escalation known ✅ -> Intermediate Result ✅
- Staging scaling factors known ✅
- **Cost updates 2024**: New estimates for cost drivers: Work in progress
- -> **Final result: Cost estimates for 2024, for 50, 350 GeV, and 500 GeV**

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 LCC ~ IDT)	ILC250 (2024) Expected: (by IDT)
Year	2012 ~ 2013	2017 ~ 2018	2018 ~ 2024	
Tech. Sys. (Mag., PS, Vac., Cntrol, others. ..)	- Lab study & - Scaling:	**- Staging:**	--------------> **(Optional study: e-driven e+ source)**	- **Price scaled** from 2012 to 2024
SRF	- Referring Eu-XFEL, - Industrial study	**- Staging** - Industrial study update-1	**- referring LCLS-II-HE,** **- Industrial-study, Cost update-2 (New inputs),**	- **Price in 2024,** - **scaled in part**

CFS
(CE & CF)
	- Global efforts:	**- Staging**
		- **New multiple design, &** cost-studies in JP, resulting good consistency.
			- Consultant study, Cost-update (New inputs)
			- (New, optional design inputs)
			  - e-driven e+ source tunnel to be added
			  - Post IP experimental hall
			  - Laser room, etc.
				- **Price in 2024,**
				- **scaled in part**

- TDR Ext. Cost Review, 2013

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

ILC Cost Update 2024

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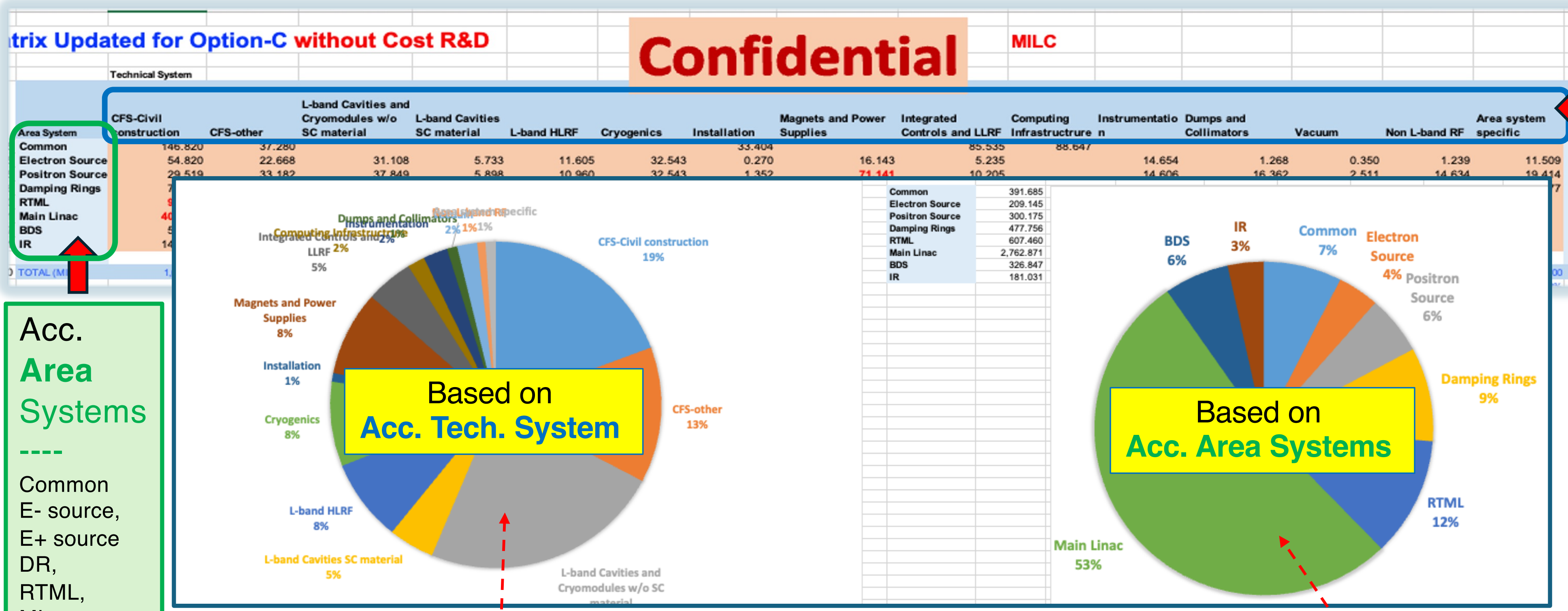
ILC250 Cost Matrix (Acc. Area v.s. Acc. Tech. Systems)

Excel file: Option-C –CostRandD-20170914-ay240603, Matrix OptionC

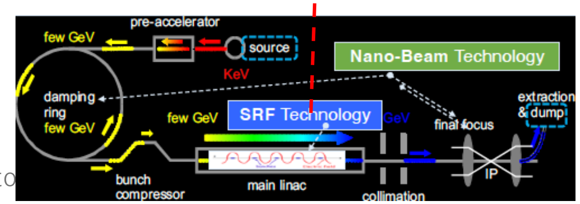


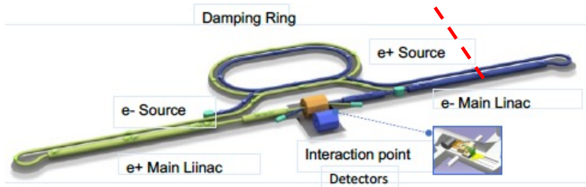
Acc. Area Systems

Common
E- source,
E+ source
DR,
RTML,
ML
BDs
IR

Acc. Technical Systems

CFS,
Conc. Acc. Tech
Mag & PS,
Vac.,
Der. & MDI,
Cntl, LLRF,
Comp./Infra.,
Non-L-RF
Specific
SRF Tech.
SC material
Cavity, Mag, CM
HLRF
Cryogenics





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

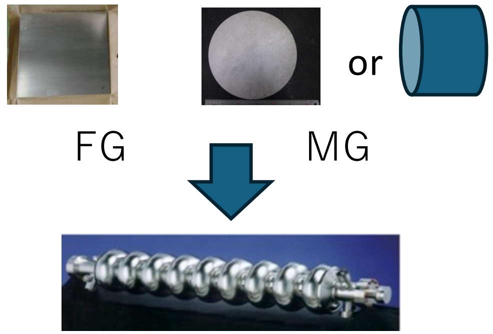
Cavity related:
- SC Material:
- Cavity (resonater):
- Coupler :
- Tuner:
- Mag. Shield ?

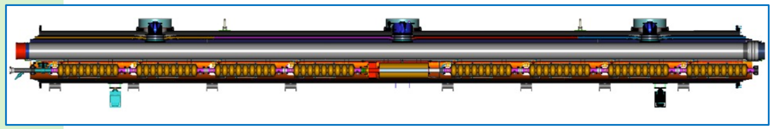
Magnet:

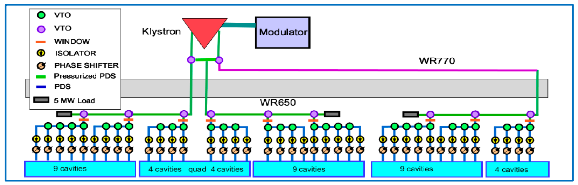
CM:
- Components
- Assembly

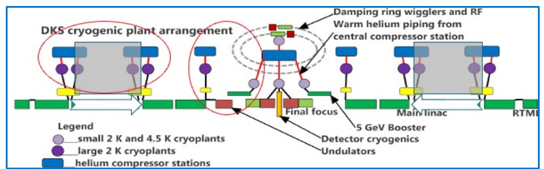
HLRF:
- Klystron ?
- Modulator ?
- PDS ?

Cryogenics:









Cost-updates Study for SRF-related Systems

Strategy to reach the cost-update in 2024:

1. **Efforts to receive new inputs** from:
   - LCLS-II-HE construction experiences as facts in ~ 2019, and to be scaled to the price 2024.
   - Industry experiences and direct cost-estimate, directly with the price 2024.

2. **Evaluate** these inputs in comparisons with the TDR and ILC250 (2017) cost-estimate

3. **Reach** the ILC250 **cost-update in 2024**.

Inputs from LCLS-II-HE-SRF Experiences

Courtesy: M. Ross

Update on LCLS-II-HE SRF Cost Actuals
20240827

1. Background (until now)
2. Status and General Remarks
3. Updated costs (table and bar-chart)
    a. SC Material
    b. Cavity
    c. Quadrupole
    d. Cryostat
    e. FPC
    f. Tuner
4. Escalation table

HE procurement history:

- HE received authorization for an additional three (bringing the total to 23) cryomodules and components for these were separately contracted (or options were exercised). These costs are listed in the pivot table separately but were not used in the sum. (Referred to as F11-13)
- In addition, the first two HE cryomodules were considered demonstration units and were not included in the base project construction cost. The total (23) thus has 3 parts: 1) 2 for demonstration, 2) 18 for initial construction scope, 3) 3 for additional construction scope. In most cases, 18 CM is used for learning curve count
- Generally the additional cost scope units (3 each CM) were more expensive.
- Updated bar chart is shown on each blue tab worksheet
- No labor information is included.

- Escalation due to inflation follows the DOE rules and is used
    1) to translate 2021 (contract-date) cost backwards to 2013 for comparison with TDR (and entry into TDR bar charts)
    2) to estimate 2024 cost as required for CU24 report
    3) to account for components (few) that have not been awarded yet (few)
- Escalation tables are from DOE guidance and are listed on the Escalation tab. From 2021 back to 2013 is 1.305. (Depends on US location)
- Learning curve function used with 0.95, just as with TDR and is included (separately) in bar chart

Methodology: LCLS-II-HE price in 2020-2021 → (converted back to the price in 2021 to be compared with ILC-TDR in 2012

Communication with Industry and Laboratories for new inputs for the ILC Cost-Updates

Updated: 2024-08-30a

Attention: ____________

ILC Cost-Update Task Force
c/o Akira Yamamoto (KEK)
e-mail : akira.yamamoto@kek.jp
Phone : +81-29-864-5272

Inquiry for ILC SRF Acc. Technical System Cost-Estimates/Updates

1. Introduction

International Linear Collider (ILC) program has been optimized as a Higgs Factory (ILC250) since 2017, in the first phase with the beam-collision energy of 250 GeV and with the cost reduced to be approximately 2/3 to the ILC500 (TDR), reflecting the Main Linac (ML) cost reduced to be approximately 1/2 while other accelerator sub-systems (Sources and Damping Ring (DR)) remaining unchanged.

The ILC Cost Update Task Force (TF) assigned has been in charge to update the ILC cost-estimate, reflecting progress in the accelerator technology advances, variations of industrial production costs, and others. The TF is requested to report the cost update work to the ILC global collaboration management (International Development Team: IDT), to be implemented in the ILC status and prospect report to be submitted to the next European Particle Physics Strategy Update 2026 (EPPSU-2026) . The TF is to complete the cost-estimate update report due the end Nov. 2024.

Tble 1. ILC SRF-related production and # units for the cost-estimates/updates (in 2024 prices).

Category	Productions	Features	Technical Notes	# units for the production cost inquired	(# units for the full production for ILC250)
SC material	Nb300-sheet or Nb300-disc NbTi flange	FG-sheet or MG-billet For beam-pipe flange	0.265 (sq) x 0.0028 m^3 (303 tons) 0.26(ϕ) x 0.2 m^3] (246 tons) 0.142(ϕ) x 0.19 m^3	60,000 sheets 900 billets 2 x 60.000	(180,000) (2,700) (2x180,000)
Cavity	1.3 GHz Resonator	9-cell cavity w/ ancillaries	E:35 MV/m, Q: 1e10	3,000	(9,000)
	Fundamental Power-coupler	Power-input coupler, TTF-III type,	1.3 GHz, 1.65 ms, 5~10 Hz 600 kW for 1.6 ms pule width	3,000	(9,000)
	Tuner	Motor for slow tuner Piezo for fast tuner	Slow tuner range: > 600 kHz Fast Tuner range > 1k kHz	3,000	(9,000)
	Magnetic shield	Inner or outer shield	Inner or outer shield wtill to be optimized	3,000	(9,000)
SC mag.	SC-mag + BPM	SC-mag, conduction cooled	40T/m, 0.9 (ap), L = 0.25/1m	110	(330)
CM	Cryomodule (CM) Components	Cold-mass, V. Vessel, and ancillaries	1 m (ϕ) x 12.5 m (L) (E=31.5 MV/m and Q= 1e10 in CM)	330	(990)
	[CM Assembly]	Cavity-string assembly and the installation into vacuum vessel	Ass. site hosted by hub-lab., and work contracted with industry	330	(990)
HLRF	Modulator	Marx-type modulator for flat HV pulse	10 MW, 120kV, 140A, 1.65ms, 5Hz,	80	(240)
	Klystron	10 MW MBK to drive up 30 cavities.	1.3 GHz, 10 MW, 5.8 mA, 32.7 MV, 1.65 ms, 5 Hz	80	(240)
	Power Distr. System (PDS)	Waveguide, circulator, and…	< 8% for average lose in PDS	80	(240)
Cryogenics	[Cooling System]	Compressor, cold-box, valve-box, TRT, etc.	~ 20 kW @ 4.5 K, and ~ 2 kW @ 4.5 K	2~3 large systems, 1~2 small systems	(6 large) (2 small)

from Industry

from Lab. CM assembly

from Industry

from Lab. Cryogenics

Guide-line for the Industrial Production Study, 2014
- 1/3 scale, production, in ≤ 4 (+2) Years -

2. General Inquiry for the SRF Accelerator Components Cost-Estimate/Updates
Cost Estimate/Update Guidelines:

- The cost-estimates/updates of the SRF related production, in 2024 prices, are inquired with industrial production shared with 3-venders/regions, based on the ILC global program
- The cost estimate for the full production by 1-vender, as an option, may be discussed, depending on the components (see Table 1).
- The production period is to be to be ≤4 years (steady production) and <6 years (including preparation)
- Th cost-estimate/update is to be answered by the end of October, with notes/comments on advances of the technology and variations on production (material and person) costs in recent years, depending on the components and regions.

Inquiry of Nb-RRR FG sheets and MG discs

Industrial Production Cost-Estimate

<u>**Inquiry** of the Cost-estimate/updated</u>

Case A: Fine Grain (FG) Sheets:

- Grain Size: < 0.05 mm
- Sheet size: 265mm x 265mm x 2.8 mm (t)
- Numbers of sheets: 2 x 9 x 9,000 x 1.1 = 178,200 --> **180,000** sheets (total)
- Total Weight: $(0.265^2 \times 0.0028)\ m^3 \times 180{,}000 \times 8.57\ ton/m^3 = \sim 303$ tons
-

- **Question: Cost estimate/update for,**
- <u>**60,000 sheets,**</u> as a baseline ?

  180,000 sheets, as an option for the full production ?

Case B: Medium Grain (MG) Disc/Billet:

- Grain Size: < 0.3 mm (occasionally < 3 mm within a few %)
- Billet size: 260mm (dia.) x 200 mm (length)
- Number of billets : 180,000 x 3 / 200 = **2,700 billets**
- Total Weight: $(0.13^2 \times 3.14 \times (0{,}003))\ m^3 \times 180{,}000 \times 8.57\ ton/m^3 = \sim 246$ tons
- Numbers of discs: 2 x 9 x 9,000 x 1.1 = 178,200 --> **180,000** discs (total)

- **Question1: Cost estimate/update for**
- <u>**900 billets**</u> (as a baseline to be shared w/ 3 regions) >>>

  2,700 billets (as an option for the full production

- **Question2: Cost estimate/update for**
- <u>**60,000 discs**, after direct slicing (if available)</u> ? >>>

  180,000 discs, after direct slicing, as an option for the full production (if available) ?

Common issues:

- **Cost-estimate breakdown** including (i) investment required dedicated for this work if needed, (ii) production and QC/QA, and (iii) shipping cost (before exporting) as additional information.

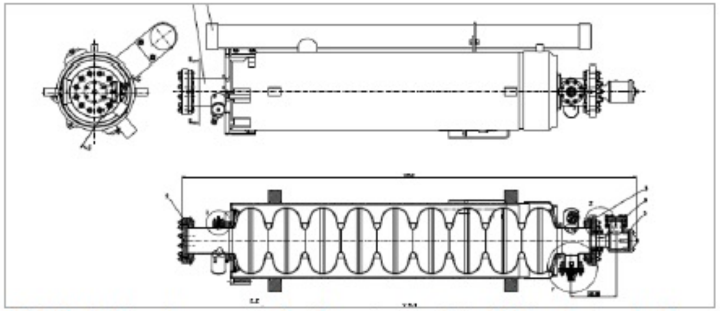
1.3 GHz SRF cavity production Cost Updates

3.2 SRF cavity and ancillaries:
3.2.1 SRF cavity
Specifications:

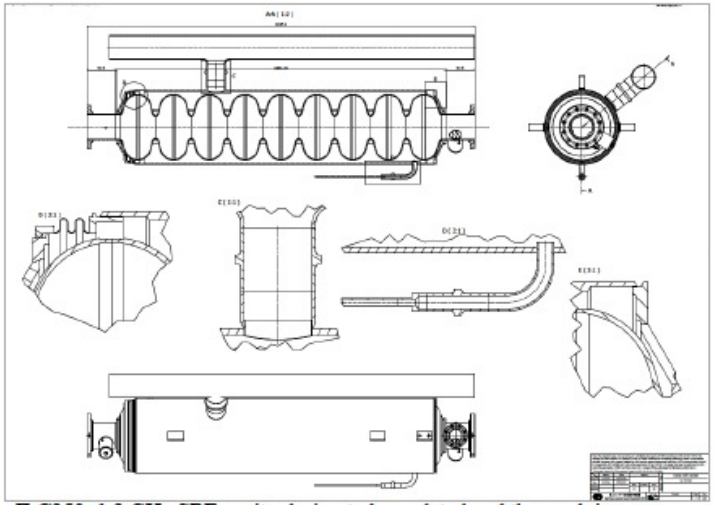
Main Parameters:		
Type of elliptical cavity-cell:		Tesla type
Fundamental frequency:	1.3 GHz,	
Type of accelerating structure:		Standing wave
Pulse-mode operation:		1 ms, 5 Hz,
RF performance:		
Average gradient:		35 MV/m
Quality factor:		> 1e10
Physical Dimensions:		
Active length:		1038. 5 mm
Total length (b/w beam-flange):		1247.4 mm
Input-coupler pitch distance:		1326.7 mm
Beam pipe distance incl. bellows:		292 mm (compared with 353 mm for XFEL)
Iris aperture:		70 mm
Equator inner diameter:		210 mm
Materials:		
Elliptical cavity:		Nb (RRR 300)
End-flange:		NbTi
He vessel:		Ti
2-Phase He-pipe:		Stainless steel
Design pressure		
High-pressure safety code:		0.2 MPa
Hydraulic-test pressure:		0.3 MPa

Note: Designs to be updated from ILC-TDR-500 to ILC-250:

- **2Phase-He-pipe** material: Ti to SUS associated with Ti-SUS transition joint,
- **Bellows** at He-vessel end: external pressure type to internal pressure type,
- **Surface treatment** updated to: Bulk-EP (100 --> 150 mm) baking Heat treat. (800 --> 900C, 3h) --> Final-EP (Cold, 20 mm) --> HPR --> Baking, 1-step to 2-step baking (75C, 4h + 120C, 48h).



ILC-TDR, 1.3 GHz SRF cavity overview for the cost estimate in 2012, referring the European-XFEL SRF cavity specification (Courtesy, H. Weise and W. Singer).



ILC250, 1.3 GHz SRF cavity design to be updated and the work in progress (Courtesy, K. Umemori and T. Dohmae).

1.3 GHz SRF Cavity Cost Updates

Inquiry for the cost estimate/update:

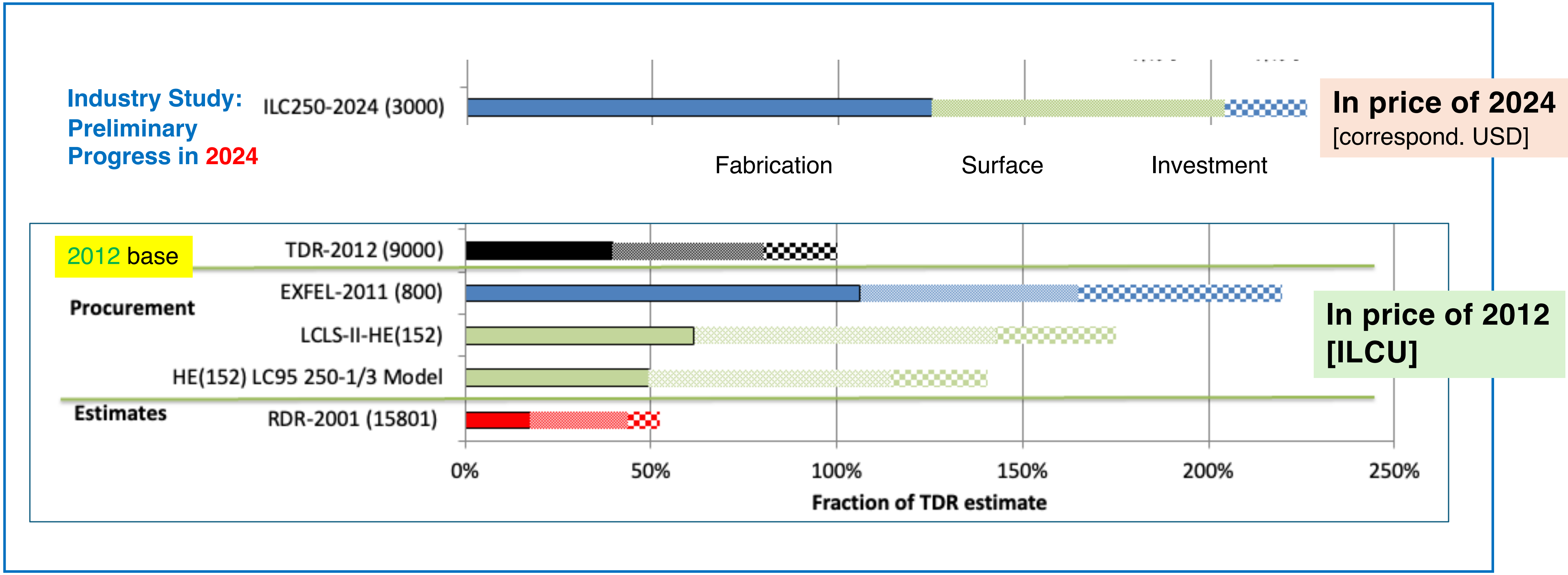
1) **Question-1: Cost** for the TDR-based design in prices 2024:
- **3000 cavities** in ≤ 4 years steady production and < 6 years (overall) ?
- **9,000 cavities** in < ? yeas, and the feasibility?

Note-1: SC material (Nb and NbTi) to be supplied (i.e. not included in the cost-estimate).
Note-2: Cost-estimate to include total cost, cost per unit, and the breakdown including (i) investment required for this work, (ii) fabrication (mechanical work and surface treatment) and QC/QA including HPGS issues (assuming the regulation technically similar in Europe, US, and in Japan).

2) **Question-2: Cost difference** from TDR-based design to the ILC250-based design (updated):
- Relative cost difference for the possible updates for (i) 2-phase He-pipe material, (ii) bellows design to internal pressure type, and (iii) surface treatment recipe updated ?

Note: Designs to be updated from ILC-TDR-500 to ILC-250:
- **2Phase-He-pipe** material: Ti to SUS associated with Ti-SUS transition joint,
- **Bellows** at He-vessel end: external pressure type to internal pressure type,
- **Surface treatment** updated to: Bulk-EP (100 --> 150 mm) baking Heat treat. (800 --> 900C, 3h) --> Final-EP (Cold, 20 mm) --> HPR --> Baking, 1-step to 2-step baking (75C, 4h + 120C, 48h).

1.3 GHz SRF Cavity Production Cost-Updates
including industrial production study in progress

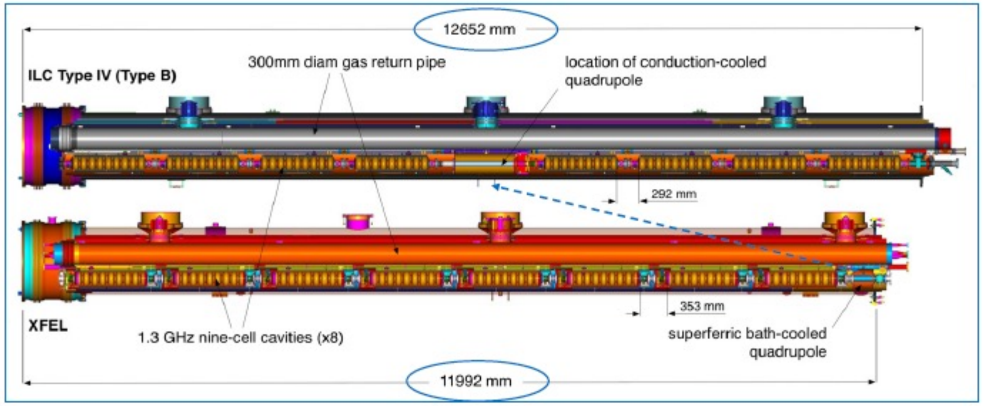


A.Yamamoto et al., 2024/10/15

Courtesy: O. Napoly, C. Madec, S. Berry

CM Assembly Study in cooperation based on

European XFEL Experiences, hosted by Lab, and contracted with Industry



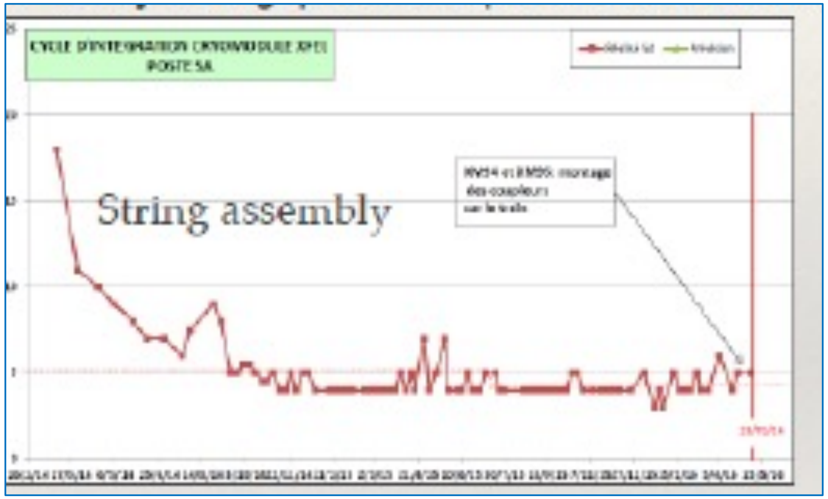
European-XFEL CM Assembly Cost Model

- Manpower cost can be estimated as follows (1 m.d = 8 m.h):
  - 4-day throughput per cryomodule with 7 workstations (2 inside clean room, 5 outside)
  - 30 persons from industrial operator ➔ 120 m.d / CM = 960 m.h / CM
  - 10 FTE from CEA ➔ 40 m.d / CM = 320 m.h/ CM

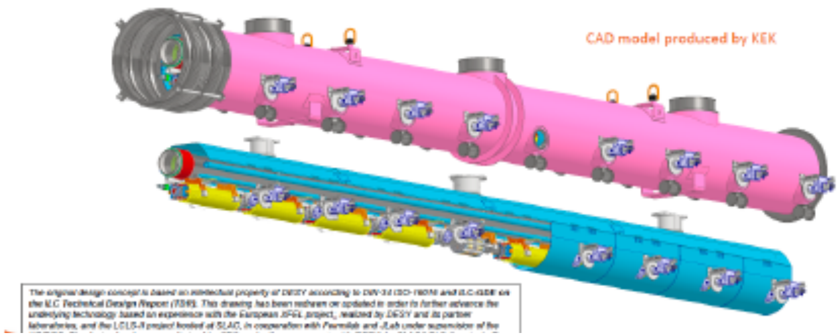
The key was to organize an extended workday of 12 hours with two consecutive and slightly overlapping day shifts at most workstations.

All workstations were doubled, except cantilever and shipment.

- This included clean room assembly labour, as follows:
  - Coupler assembly: 2 shifts of 1 person ➔ 8 m.d / CM
  - String assembly: 2 shifts of 2 persons ➔ 16 m.d / CM
  - Total is 24 m.d = 192 m.h in the clean room



ILC CM Assembly Cost Model



ILC cost model

Without robotics:

- 3-day throughput (demonstrated at Eu-XFEL, but not simultaneously, on all workstations)
- 30 persons from industrial operator → 90 m.d / CM = 720 m.h /CM
- 10 FTE from host lab → 30 m.d / CM = 240 m.h / CM

This model assumes that all workstations are doubled, including the cantilever and shipment workstations.

This model includes 18 m.d of clean room assembly labour, as follows:

- Coupler assembly: 2 shifts of 1 person → 6 m.d / CM
- String assembly: 2 shifts of 2 persons → 12 m.d / CM

Note:

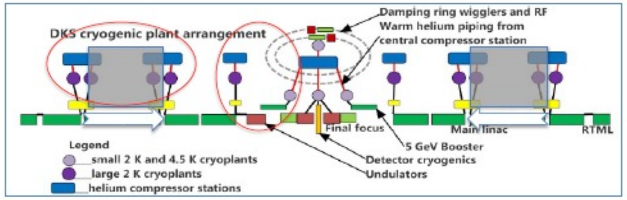
Robotics allows to reduce clean room assembly from 18 m.d/CM to 9 m.d/CM.
Main advantage is quality of assembly.

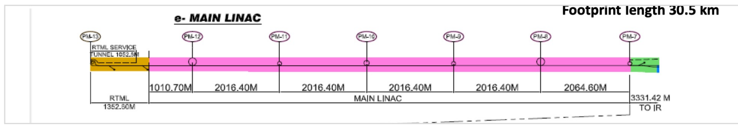
CFS cost update policy

N. Terunuma

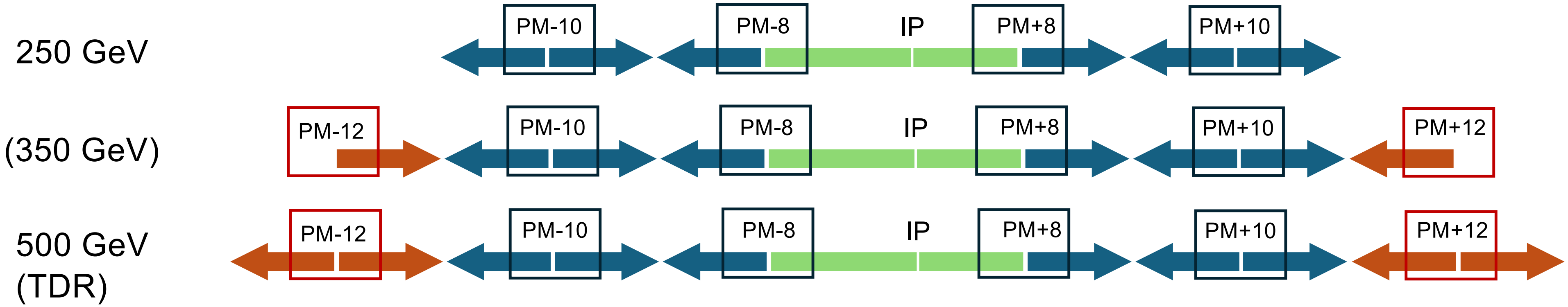
- Evaluate the CFS cost based on the "ILC in Japan".
  - Geological and topographical constraints differ from those in Europe and America. Mountainous site in Japan while others are flatter sites.
    - Access to the underground is mainly through sloped tunnels; only IP has vertical shafts.
    - Civil engineering work based on the NATM tunneling method (blast and sprayed concrete).
- Include some design updates from TDR/ILC-250
  - Some tunnels and caverns are extended to meet latest accerelator/utility designs.
    - BDS tunnels, beam dump halls, utility halls, etc.,…
  - Evaluate the CFS cost of the e-driven positron source as an addon option to the baseline.
- The majority of civil engineering works have been re-evaluated according to the 2024 National Cost Estimating Standards.

CFS layout and the energy upgrade





- Access point is a key of CFS layout
  - He distribution from a utility hall is limited up to 2.5 km.
  - ILC-250 (20.5 km) layout already uses full capability of this distribution, then we need additional utility halls(access points) for energy upgrade.
  - A best location of the next utility hall will be 2.5 km from the edge of ILC-250, if we prepare further energy upgrades. This is the access point PM12 designed in TDR and will cover the update of 350 GeV.



CFS cost update status and plan 2024/10/2 N.Terunuma

- **CFS subgroup meetings** (N.Terunuma , T.Sanuki, A.Yamamoto, H.Sakai)
  - **6/28, 7/24, 9/6, 10/9,…**
- **Evaluation with consultants is in progress**
  - **Civil Engineering: Evaluation with updated CE design**; IP-BDS(Dump), e-driven tunnel with utility hall -> **mostly done, have a meeting on Oct. 8th**.
  - **Utilities:**
    - Update of staging 250: **intermidiate results said about ~x1.5 of previous**.
    - new evaluation for e-driven: piping cost for 2km linac was done. waiting for others; pump etc.
- **Prospect of work** (not changed from last meeting on 9/4)
  - Mid of Oct: sum of major parts by new evaluation and scaling from previous
  - End of Oct: correction/update of works
  - Mid of Nov: summarize the work

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Tble 1. ILC SRF-related production and # units for the cost-estimates/updates (in 2024 prices).

Category	Productions	Features	Technical Notes	# units for the production cost inquired	(# units for the full production for ILC250)
SC material	Nb300-sheet or Nb300-disc NbTi flange	FG-sheet or MG-billet For beam-pipe flange	0.265 (sq) x 0.0028 m³ (303 tons) 0.26(ϕ) x 0.2 m³] (246 tons) 0.142(ϕ) x 0.19 m³	60,000 sheets 900 billets 2 x 60.000	(180,000) (2,700) (2x180,000)
Cavity	1.3 GHz Resonator	9-cell cavity w/ ancillaries	E:35 MV/m, Q: 1e10	3,000	(9,000)
	Fundamental Power-coupler	Power-input coupler, TTF-III type,	1.3 GHz, 1.65 ms, 5~10 Hz 600 kW for 1.6 ms pule width	3,000	(9,000)
	Tuner	Motor for slow tuner Piezo for fast tuner	Slow tuner range: > 600 kHz Fast Tuner range > 1k kHz	3,000	(9,000)
	Magnetic shield	Inner or outer shield	Inner or outer shield wtill to be optimized	3,000	(9,000)
SC mag.	SC-mag + BPM	SC-mag, conduction cooled	40T/m, 0.9 (ap), L = 0.25/1m	110	(330)
CM	Cryomodule (CM) Components	Cold-mass, V. Vessel, and ancillaries	1 m (ϕ) x 12.5 m (L) (E=31.5 MV/m and Q= 1e10 in CM)	330	(990)
	[CM Assembly]	Cavity-string assembly and the installation into vacuum vessel	Ass. site hosted by hub-lab., and work contracted with industry	330	(990)
HLRF	Modulator	Marx-type modulator for flat HV pulse	10 MW, 120kV, 140A, 1.65ms, 5Hz,	80	(240)
	Klystron	10 MW MBK to drive up 30 cavities.	1.3 GHz, 10 MW, 5.8 mA, 32.7 MV, 1.65 ms, 5 Hz	80	(240)
	Power Distr. System (PDS)	Waveguide, circulator, and…	< 8% for average lose in PDS	80	(240)
Cryogenics	[Cooling System]	Compressor, cold-box, valve-box, TRT, etc.	~ 20 kW @ 4.5 K, and ~ 2 kW @ 4.5 K	2~3 large systems, 1~2 small systems	(6 large) (2 small)

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	Tuner	Motor for slow tuner Piezo for fast tuner	Slow tuner range: > 600 kHz Fast Tuner range > 1k kHz	3,000	(9,000)
	Magnetic shield	Inner or outer shield	Inner or outer shield wtill to be optimized	3,000	(9,000)
SC mag.	SC-mag + BPM	SC-mag, conduction cooled	40T/m, 0.9 (ap), L = 0.25/1m	110	(330)
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	Power Distr. System (PDS)	Waveguide, circulator, and…	< 8% for average lose in PDS	80	(240)
Cryogenics	[Cooling System]	Compressor, cold-box, valve-box, TRT, etc.	~ 20 kW @ 4.5 K, and ~ 2 kW @ 4.5 K	2~3 large systems, 1~2 small systems	(6 large) (2 small)

New Inputs Coming in

from Industry

from Lab. CM assembly

from Industry

from Lab. Cryogenics

Cost Evaluation: ILC-500-AS to -ILC250-A, in Progress

— 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)
240819, --1015: A. Yamamoto (for ILC250 including e-driven e+ source

Progress Year-base Unit [MILC]	ILC500 (TDR) 2012-base	Energy 500→250 # Reduction R.	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. Tech. (w/o SRF)	1,390	0.86	1,196	~ 1	~ 1	x 1.3 ~ 1.5	x 1.3~1.5
Installation equipment ~~He Cryogenics~~ Conventional Mag. and PSs Vacuum Detector and MDI related Dump and Collimators General Control and LLRF Computor Infrastructure Non-L-band-RF Area System Specific	57 ~~675~~ 457 113 126 67 357 118 43 53		45 ~~440~~ 441 103 126 52 244 89 43 53				
SRF Tech.	4,221	0.554	2,340	x ~ 1.05		x TBD	x TBD
SC material Cavity-Mag-CM w/Ancillaries HLRF Cryogenics	440 2,317 789 675	x 0.53 0.53 0.53	234 1,239 427 440				
CFS	2,375		1,720	~ 1	TBD (x1.0~ 1.1)	TBD (x1 .4~ 1.5)	x TBD
CE & Build. Electrical systems Mechanical, C.Ventilation. systems Hnling, Safety, Survey, & Alignment equip.	1,466 333 576	0.69 0.77 0.76	1.014 258 448	.			
Sum	**7,985**	0.66	5,256	x TbD	x TBD	x TBD	x TBD
Note;	(1.0)	ML-RF unit (500/250): 378 /186 = 0.49 All-RF units (500/250): 438/242 = 0.55	(0.66)	To be justified to use 95% learning curve coefficient		To be justified using ppp and currency ILC Unit	

.

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

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  - Future Energy Upgrade
  - Two Interaction Points
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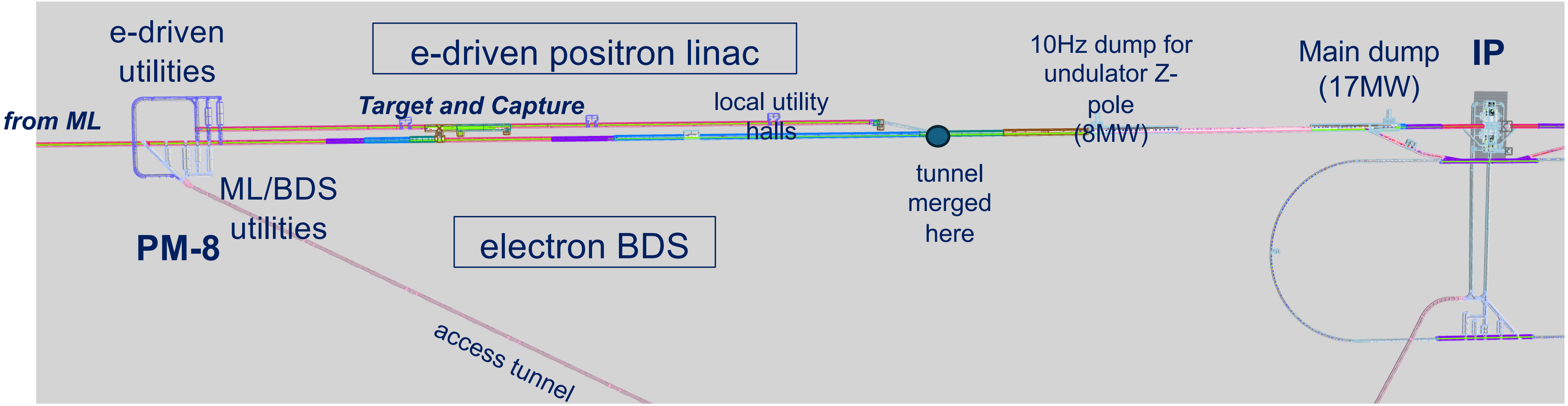
Courtesy; N. Terunuma
Reported at LCWS2024

CFS design for the e-driven positron source

- dedicated accelerator tunnels and utility halls are required (Keep undulator/linac section)
- 2 km tunnel with 17m-wide section; i.e., target and capture linac (with RF devices on both sides)
- Requires 20 MW of utilities comparable to other access halls: distributed in local utility halls along the linac



AS-08

Cost Evaluation: ILC-500-AS to -ILC250-A, in Progress

— 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)
240819, --1015: A. Yamamoto (for ILC250 including e-driven e+ source

Progress Year-base Unit [MILC]	ILC500 (TDR) 2012-base	Energy 500→250 # Reduction R.	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)	Option: e-driven e+ Source
Year of work ~ report	*2012 ~ 2013*	*2017 and reported in EXPPU2020, SnowMass2022*		*→ ILC cost update 2024*				(Oku-yen)
Acc. Tech. (w/o SRF)	1,390	0.86	1,196 ·	n/a (or ~1.00)	~ 1	x 1.3 ~ 1.5	x 1.3~1.5	1,741 - 244 +365
Installation equipment ~~He Cryogenics~~ Conventional Mag. and PSs Vacuum Detector and MDI related Dump and Collimators General Control and LLRF Computor Infrastructure Non-L-band-RF Area System Specific	57 ~~675~~ 457 113 126 67 357 118 43 53		45 440 441 103 126 52 244 89 43 53					
SRF Tech.	4,221	0.554	2,340	x ~ 1.05	x TBD	x TBD	XxTBD	
SC material Cavity-Mag-CM w/Ancillaries HLRF Cryogenics	440 2,317 789 675	x 0.53 0.53 0.53	234 1,239 427 440					
CFS	2,375		1,720	n/a (~1.00)	x 1.00 ~ 1.10	x 1.4~1.5	x 1.4~1.6	+165
CE & Build. Electrical systems Mechanical, C.Ventilation. systems Hnling, Safety, Survey, & Alignment equip.	1,466 333 576	0.69 0.77 0.76	1.014 258 448	.				
Sum	**7,985**	0.66	5,256	x ~1	x TBD	x TBD	x TBD	+ ~ 300 OkuY →~ +250 MILC
Note;	(1.0)	ML-RF unit (500/250): 378 /186 = 0.49 All-RF units (500/250): 438/242 = 0.55	(0.66)	To be justified to use 95% learning curve coefficient .		To be justified using ppp and currency ILC Unit		

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

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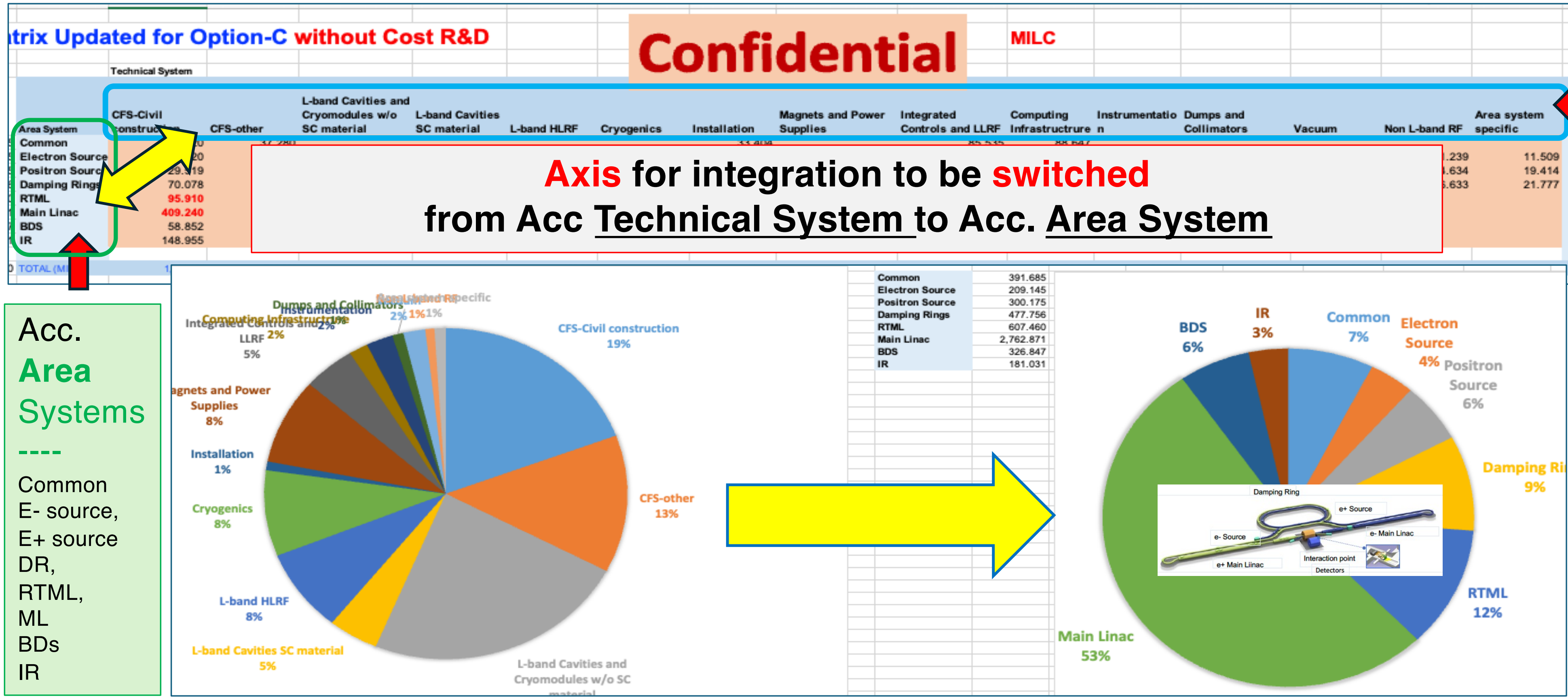
ILC250 Cost Matrix (Acc. Area v.s. Acc. Tech. Systems)

Excel file: Option-C –CostRandD-20170914-ay240603, Matrix OptionC



Acc. Area Systems

- Common
- E- source,
- E+ source
- DR,
- RTML,
- ML
- BDs
- IR

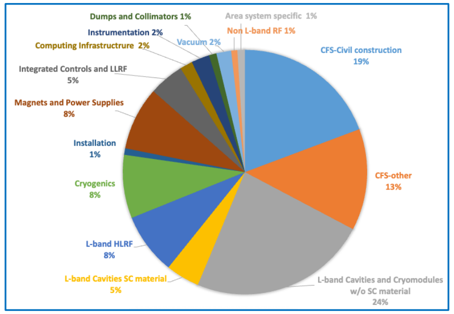
Acc. Technical Systems

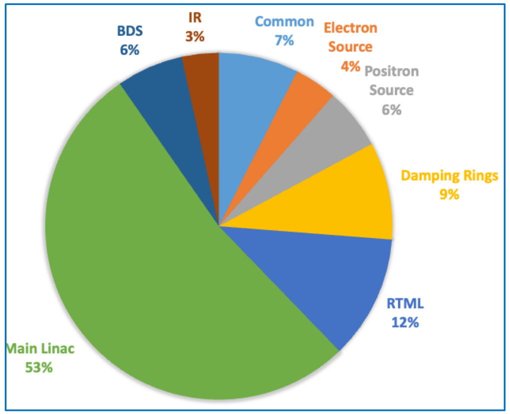
- CFS,
- Conc. Acc. Tech
  - Mag & PS,
  - Vac.,
  - Der. & MDI,
  - Cntl, LLRF,
  - Comp./Infra.,
  - Non-L-RF
  - Specific
- SRF Tech.
  - SC material
  - Cavity, Mag, CM
  - HLRF
  - Cryogenics

Based on Acc. Tech. System

Based on Acc. Area System

ILC Cost: Acc. Syst. Oriented --> Convenient to see energy upgrade effect for future.





Reference, excel-file: Option-C-CostRandD-20170914-ay240603

Cost-Update: Unit [MILC]	ILC500(TDR)-2013 (2012-prices)	ILC250-A-2017 (2012-prices)	Extension to ILC500 (2012-prices)	Extension to ILC500 (2024-prices)
Common	532	392	tbd	tbd
e- Source	209	[illegible]		
e+ Source	290	[illegible]	Similar ~ x 1.0	
Damping RIngs	478	[illegible]		
RTML	[illegible]	607		
Main Linac	[illegible]	2,763		X ~ 2.1
BDS	341	327	Similar tbd	
IR	181	181		
Sum	**7,985**	**5,257**		
	1.0	**0.66**		

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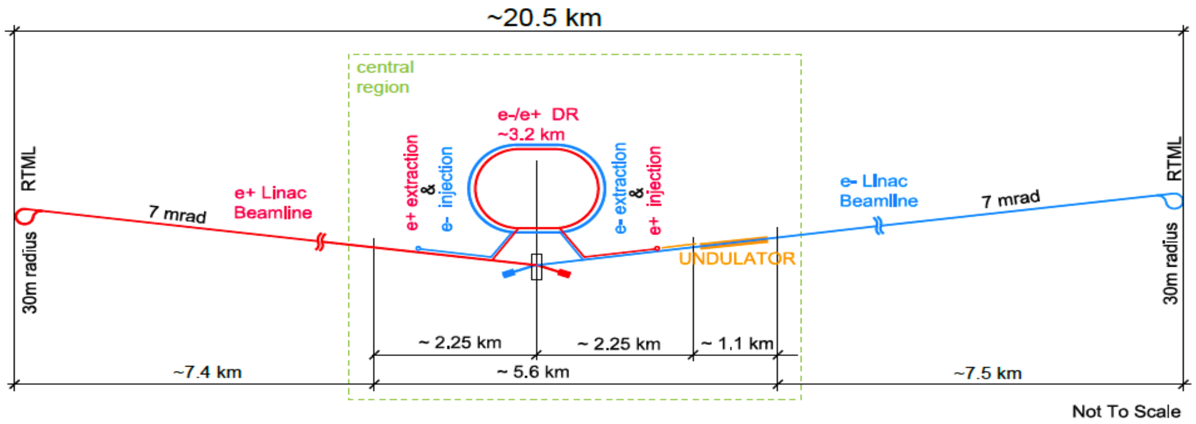
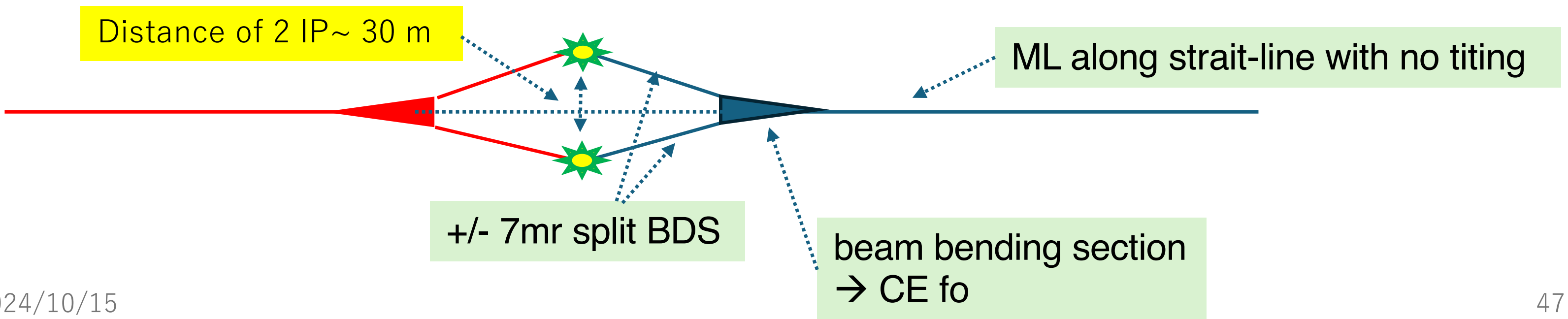
ILC250: 2-IP Options?

- Beam needs to be split at the upstream ends of BDS sections?
- Can we simple estimate the order of cost-increase with doubling the BDS , IR, Dump (+ some Common) value in the cost matrix?

  → Additional Cost : ~ +10~15% of total value (corresponding to another {BDS+IR+tbd} cost)



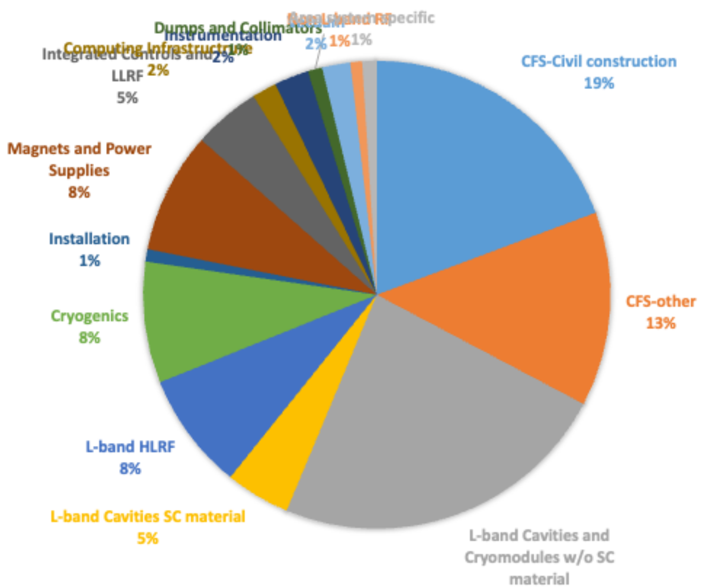


Cost: ILC250 Option C (→ A)

Excel file: Option-C –CostRandD-20170914-ay240603, Matrix OptionC

Area System	CFS-Civil construction	CFS-other	L-band Cavities and Cryomodules w/o SC material	L-band Cavities SC material	L-band HLRF	Cryogenics	Installation	Magnets and Power Supplies	Integrated Controls and LLRF	Computing Infrastructrure	Instrumentation	Dumps and Collimators	Vacuum	Non L-band RF	Area system specific	TOTAL
Common																391.685
Electron Source																209.145
Positron Source																300.175
Damping Rings	70.078	76.819				26.015	1.554	144.158	23.660		21.306		65.756	26.633	21.777	477.756
RTML	95.910	58.479	127.123	24.141	53.235	38.138	3.041	114.664	19.588		36.290	12.296	24.554			607.460
Main Linac	409.240	345.880	1,043.397	198.995	351.151	292.734	3.907	17.066	80.091		19.220		1.190			2,762.871
BDS	58.852	99.884				18.443	1.419	77.334	20.113		19.802	22.481	8.519			326.847
IR	148.955	32.076														181.031

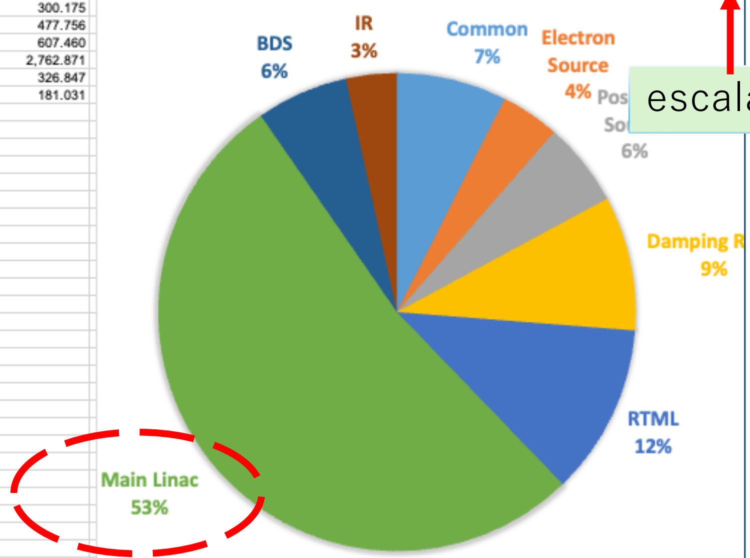
BDS + IR



Common	391.685
Electron Source	209.145
Positron Source	300.175
Damping Rings	477.756
RTML	607.460
Main Linac	2,762.871
BDS	326.847
IR	181.031

BDS++ IP = (326+182)
=> (> 500 x ~1.5 (?))

escalation



ary | Matrix; OptionC-R&D | Matrix; OptionC | LCB meeting | TDR Cost Decomposition | Cost R&D + Cryogenics Merging | Cost Reduction R&D | Staging Options | Staging Options 2017-7-14

Technical Issues need to be studied

- Where is a realistic location to split the beam at the upstream end of BDS?
- How the beam interaction angle may be oprimiws with keeping 14 mrad. ?
- How the IP cavern to be better optimized with the IP distance of ~ 30 m?
- How the beam dump may be placed? In particular, the photon dump location at the center (b/w two tilted beam) becomes a critical issue in case of undulator driven e+ source.
- e-driven option may be managed without facing timing issues.
- Luminosity upgrade to be an issue ?
- Muon shield an issue?
- *etc …*

Any advices will be appreciated.

Outline

- **Overview**
- **Work in Progress :**
  - Strategy and Methodology → topics, on 17 Sept.
  - Progress in Acc. Tech. System Cost-Update Study → topics on 15 Oct.
  - Prospects for the Cost-Update
- **Optional Estimates:**
  - e-driven Positron Source
  - **Future Energy Upgrade**
  - Two Interaction Points
- **Review for the Cost Update :**
  - **Internal and External Review**

External Cost Review requested

- We have been **requested by IDT-EB Chair**, to prepare for the external review to be organized by the end of 2024, **in hybrid mode** (2 days, 4 hours per day).

- **The review committee members anounced:**
  - L. Rivkin (Chair, PSI), R. Brinkmann (DESY), J. Gao (IHEP), P. Lebrun (CERN), T. Raubenheimer (SLAC), and N. Holtkamp (Observer, SLAC)

- **Preparation** planned
  - Nov. 8 (Fri): Introductory meeting with the ext. review committee,
  - **Nov. 21-22 (21-22?) :** Internal review meeting in WG2 (online only),
  - **Dec. 19-20:** External Review meeting (hybrid),

Preparation for the ILC Cost-Update Review

Key Dates and Time (normally, 15:00 – CET, 22:00 or 23:00 JST):

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October:

15: Task Force (TF) activity report for IDT-WG2,
16: TF, small group (acc. tech.) meeting

23: TF, small group (acc. tech.) meeting

November:

(6: TF general meeting)
8: Introductory meeting with the External Review Members (online)
21-22: Internal Review (online)
(backu; 21-22)

December:

(4 or 11: TF general meeting)
19-20: External Review (hybrid)

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ILC Cost-Update TF work
Agenda proposed for the Internal Review

Dates and Time Periods:
Nov. 21 (Thu) ~ 22 (Fri), (backup 20 ~ 21）:
5:30 - 8:30 ma (PST), **14:30 - 17:30 (CET),** 22:30 - 25:30 (JST)
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1st day — 24-11-21 (Thu):

14:30 (CET) Closed Session (committee):

14:45 Opening (Chair)

15:00 Report Session-1: (Presenter)
15:00 - **Overview** (A. Yamamoto)
15:15 - **Strategy-Methodology & Acc. Tech.** (except for SRF) (B. List, N. Walker)
16:15 - **Optional Studies** (A. Yamamoto)

17:00 General Q/A & discussions / close-session
~ 17:30 End

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2nd day, 24-11-22 (Fri):

14:30 Report Session-2:
14:30 - **SRF** (M. Ross, A.Yamamoto)
15:40 - **CFS** (N. Terunuma)

16:40 - **Summary** (A. Yama oto)

16:50 General Q/A & discussions / close-session

17:20 Close-out/
~ 17:30 End

Summary

- ILC Cost-update **TF work in progress**.
- The Cost-update **Strategy and Methodology** has been established to be based on the global currency unit of ILCU and the exchange rate of 1 ILCU based on the 2024 Jan. PPP (extrapolated).
- **SRF** cost update work in progress, with referring LCLS-II experiences as facts, and with new inputs from industry. The new inputs are being received by the end of October.
- **CFS** cost update work in progress, with new inputs coming from professional consultants in Japan. (Tax-handling is to be settled)
- The **Internal** and **External Review on the Cost Update** will be held on 20-21(or 21-22), and **19 -20 De**c. respectively, and will be prepared.