Confidential

ILC Cost-Update Task Force: Progress Report

Benno List and Akira Yamamoto

for

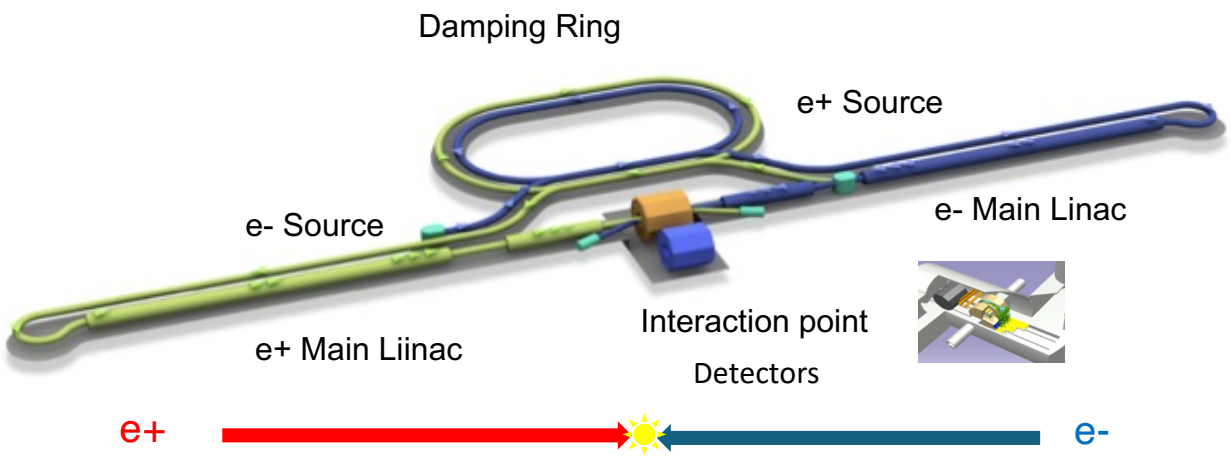
ILC Cost-Update Task Force Team

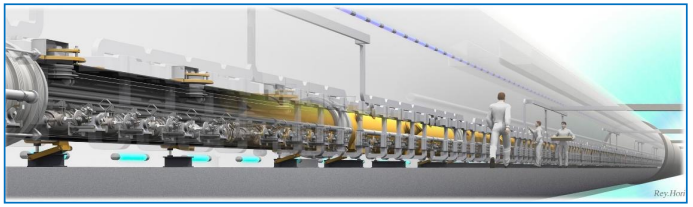
To be reported to IDT WG2 meeting, 2024-9-17

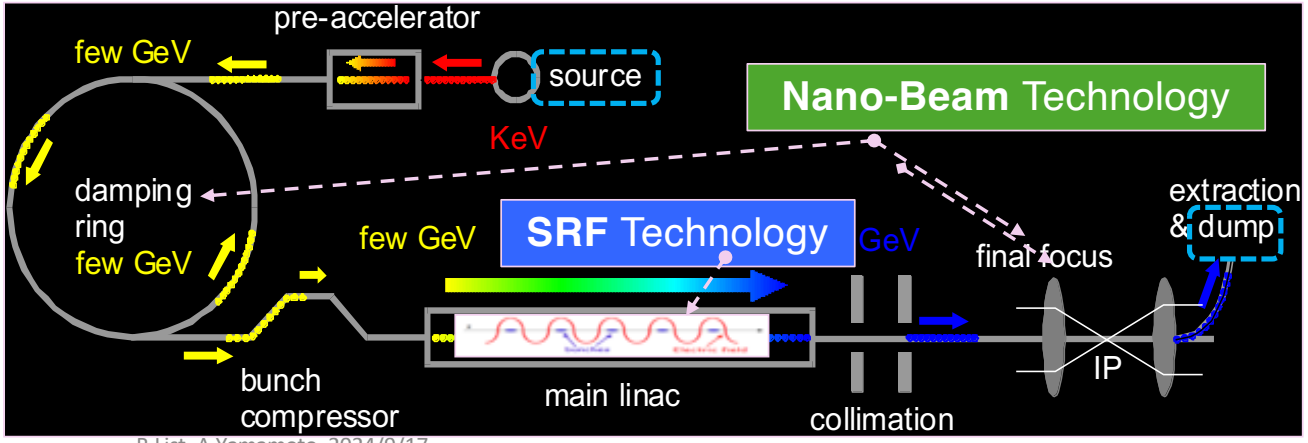
Outline

- **Overview**
- **Work in Progress :**
  - Strategy and Methodology → main topics, TODAY !
  - SRF and Others → topics in the next WG2-meeting (expected 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-250: Accelerator Technology and Devices







B.List, A.Yamamoto, 2024/9/17

Parameters	Value
Beam Energy	**125 + 125** GeV
Accelerator Length	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) **~ 990**
# RF units:	**~ 240**
AC-plug Power	111 / 138 MW

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 Technology Network (ITN). It follow the ITN activities as well as the ILC Cost Update work.

Status of the ILC

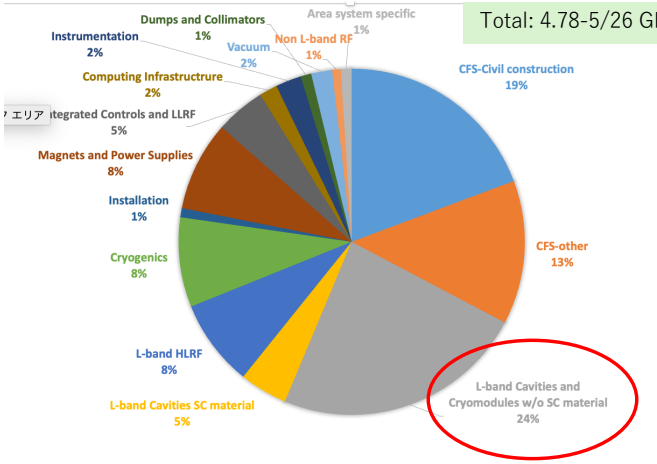
-Activities of the International Development Team (IDT)-
LCWS2024 at University of Tokyo
Tokyo, Japan, 8-11 July 2024

Tatsuya Nakada
EPFL, Switzerland
Chair of the IDT Executive Board

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



Total: 4.78-5/26 GILC

ILC250-A Cost fraction in 2017, to be updated

B.List, A.Yamamoto, 2024/9/17

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

By T. Nakada (IDT EB Chair)

Purpose:

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

Goal:

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

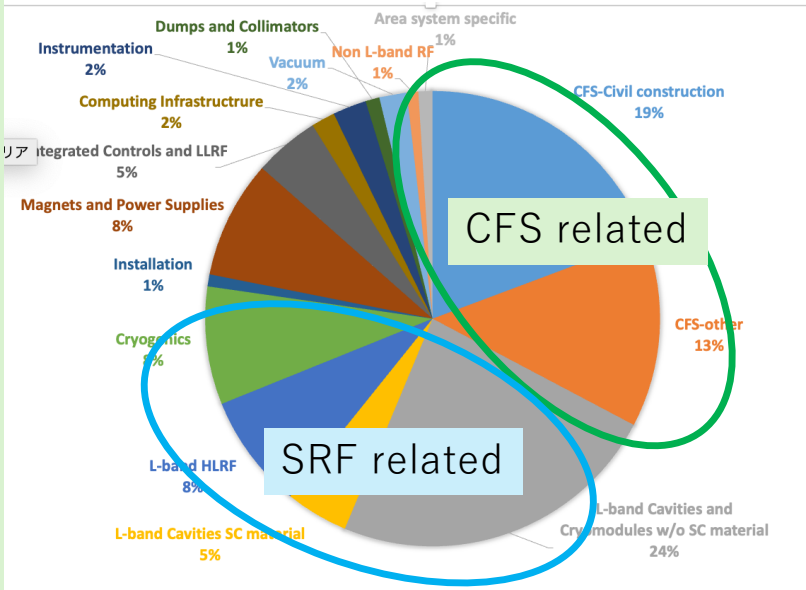
ILC Cost Estimate Update 2024: TF Working Approach

Strategy and Methodology:

- Currency and the variation: rely on **ILCU and ppp**

Accelerator Cost Update:

- **SRF (mainly for ML):**
  - Referring Eu-XFEL and **LCLS-II-HE experiences** as facts,
  - **Industrial study inputs** in prices of 2024.
- **Other Technical Systems (mainly for Sources, DR, RTML, BDS, ML:.**
  - re-validate based on scaling.
- **CFS (CE & CF):**
  - Non site-specific issues: the cost update based on recent inputs in Japan
  - (Site-specific: not covered.)



ILC-Cost Update Taskforce Work Assignment:

Category	TF Work approach:	Work assigned to*:	In cooperation w/
Strategy & Methodology (Focused, today !)	PPP/Currency, Inflation, contingency, uncertainty etc.	**BL,** GD, AY, HS	KEK
SRF related, mainly for ML {**Cav**, CM, RF, CR, mainly for M}	Scaling, Referring Eu-XFEL, LCLS-II experience, New estimate in coop. w/ industry/labs	**AY,** MR, NW, HS	KEK, CERN, INFN, DESY, CEA, SLAC-Fermilab-JLab,
Other tech. systems, {Mag. PS, LLRF, Vac, mainly for Source, DR, BDS	Scaling	**BL,** NW, AY, HS	KEK
CFS (CE and CF): - limited to no site-specific	Scaling, New estimate in coop. w/ consultants	**NT,** AY, HS	CERN, Tohoku U.

Work together

***Taskforce members:** Akira Yamamoto (**AY**, Chair), Benno List (**BL**), Gerry Dugan (**GD**), Marc Ross (**MR**), Nick Walker (**NW**), Hiroshi Sakai (**HS**), and Nobuhiro Terunuma (**NT**), Andy Lankford, Steinar Stapnes, Shinichiro Michizono

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**	
SRF	- Referring Eu-XFEL, - Industrial study		- Scaling, - Industrial study update-1		- Design update for ILC250, - referring LCLS-II-HE, - Industrial-study and Cost update-2 (New inputs),	- **Price in 2024,** - scaled in part
Other Tech. Sys. (Mag., PS, Vac., Cntrol, others. ..)	- Lab study & - Scaling:		- Scaling:		----------> e-driven e+ source studied to be an alternate	- **Price scaled** from 2012 to 2024
CFS (CE & CF)	- Global efforts:		- Scaling, - New multiple design- and cost-studies in JP, resulting good consistency.		- Consultant study & Cost-update (New inputs)	- **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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Proposal for Updated Cost

Methodology for 2024 Cost Update
Benno List
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
  - 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

} 1 factor

Use of Purchasing Power Parity Indices for the Value Estimate

- Purchasing Power Parity (**PPP**) 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).

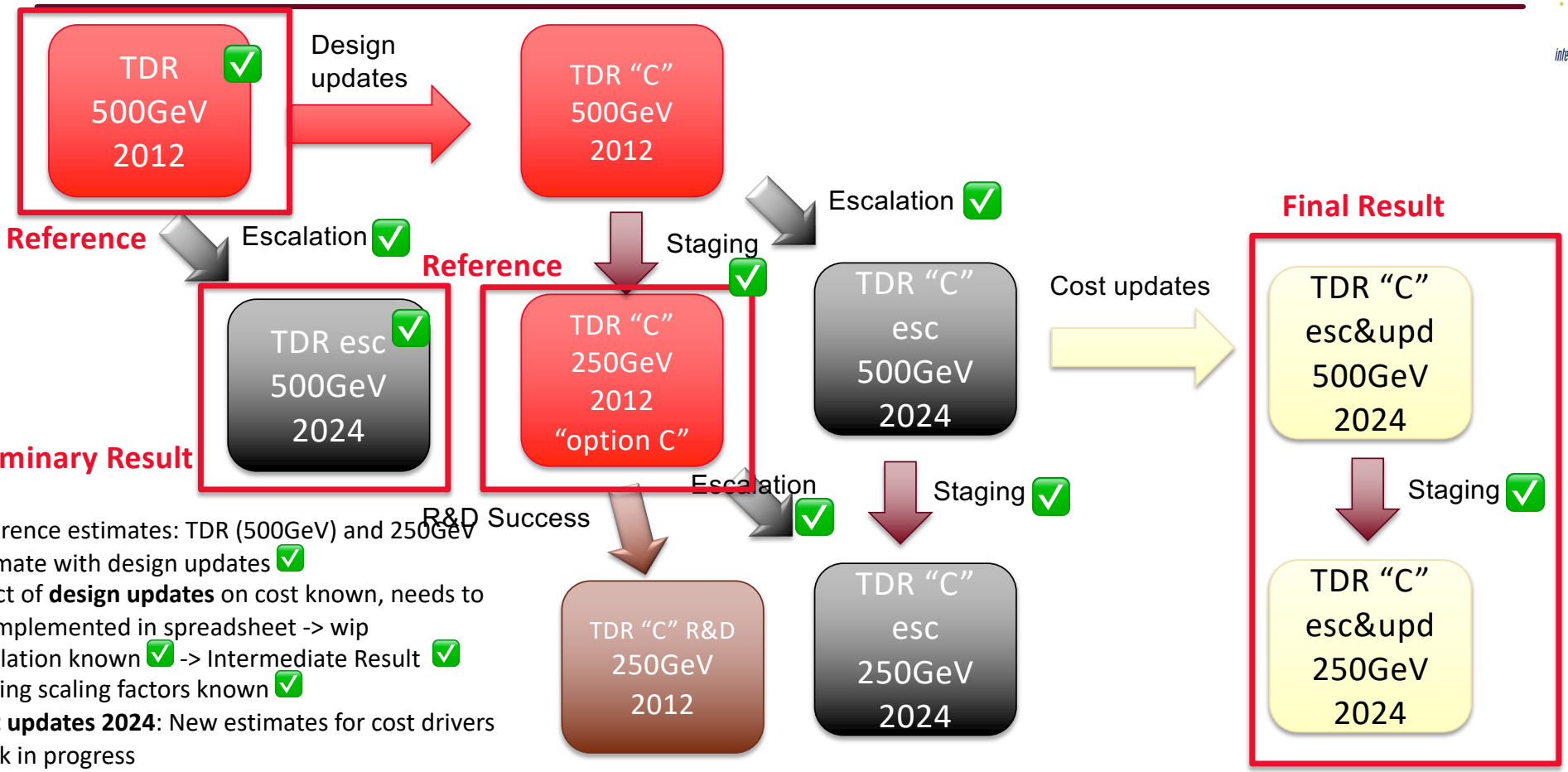
- For an international in-kind contribution project such as the ILC, use of PPP indices is appropriate because it gives the cost for domestic production or procurement of the respective items. It is assumed that in-kind contributions will mostly be produced and purchased in the contributing regions.

- 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.

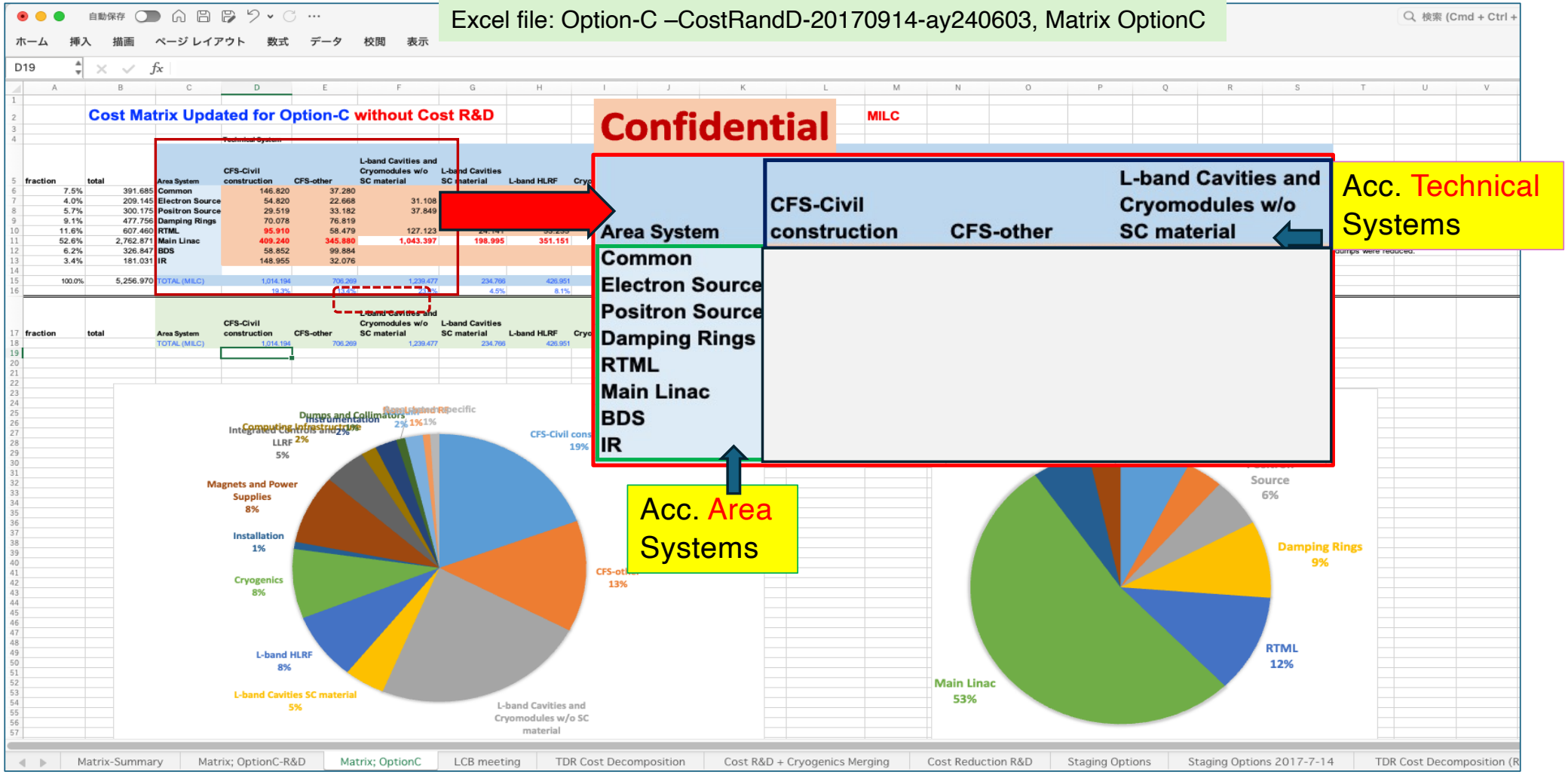
- Insofar, the PPP cost estimate can be considered “conservative” for overvalued currencies. On the other hand, if a currency is undervalued (such as the Yen compared to the Euro in the preceding example), the PPP rates reflect the true buying power of the currency for locally produced goods instead of inflating the cost estimate due to (possibly temporarily) unfavourable exchange rates.

Cost Estimates: Intermediate Steps and Final Deliverables



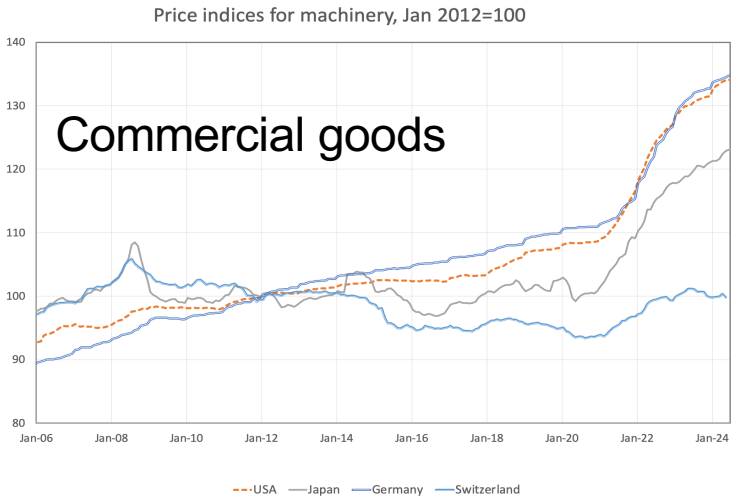
- Reference estimates: TDR (500GeV) and 250GeV estimate with design updates ✅
- effect of **design updates** on cost known, needs to be implemented in spreadsheet -> wip
- Escalation known ✅ -> Intermediate Result ✅
- Staging scaling factors known ✅
- **Cost updates 2024**: New estimates for cost drivers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

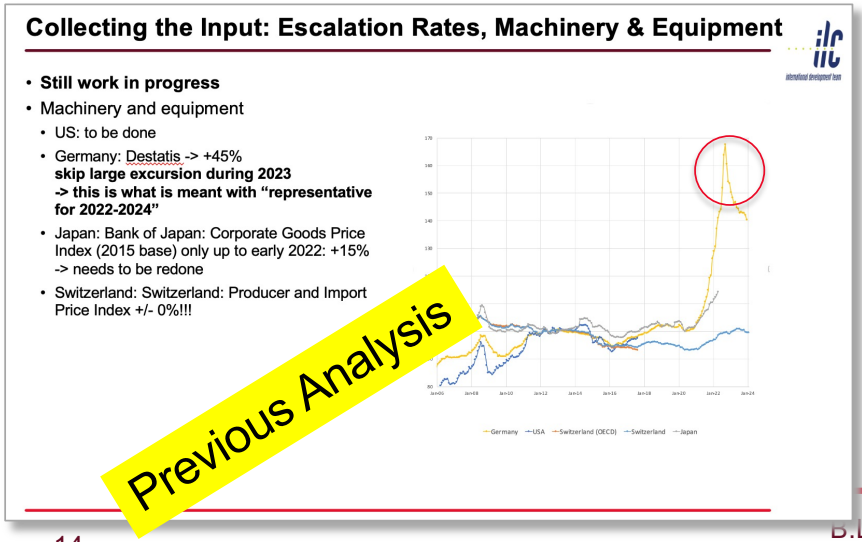
ILC250 Option(C→)A Cost Matrix (Acc. Area v.s. Tech. Systems)

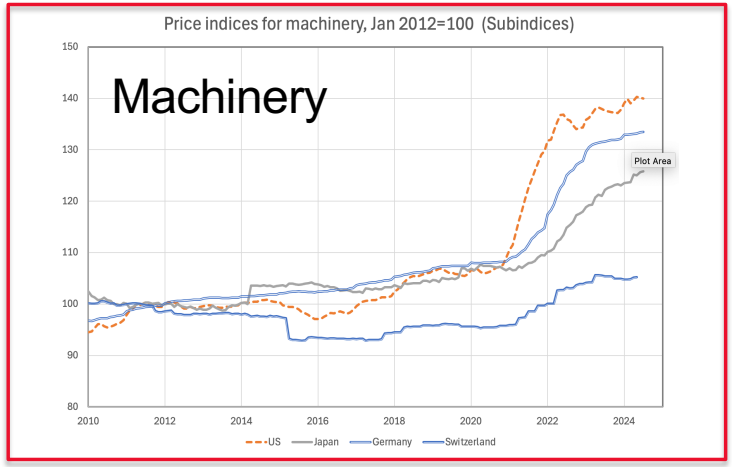


Escalation Rates for Industrial Goods (Machinery)

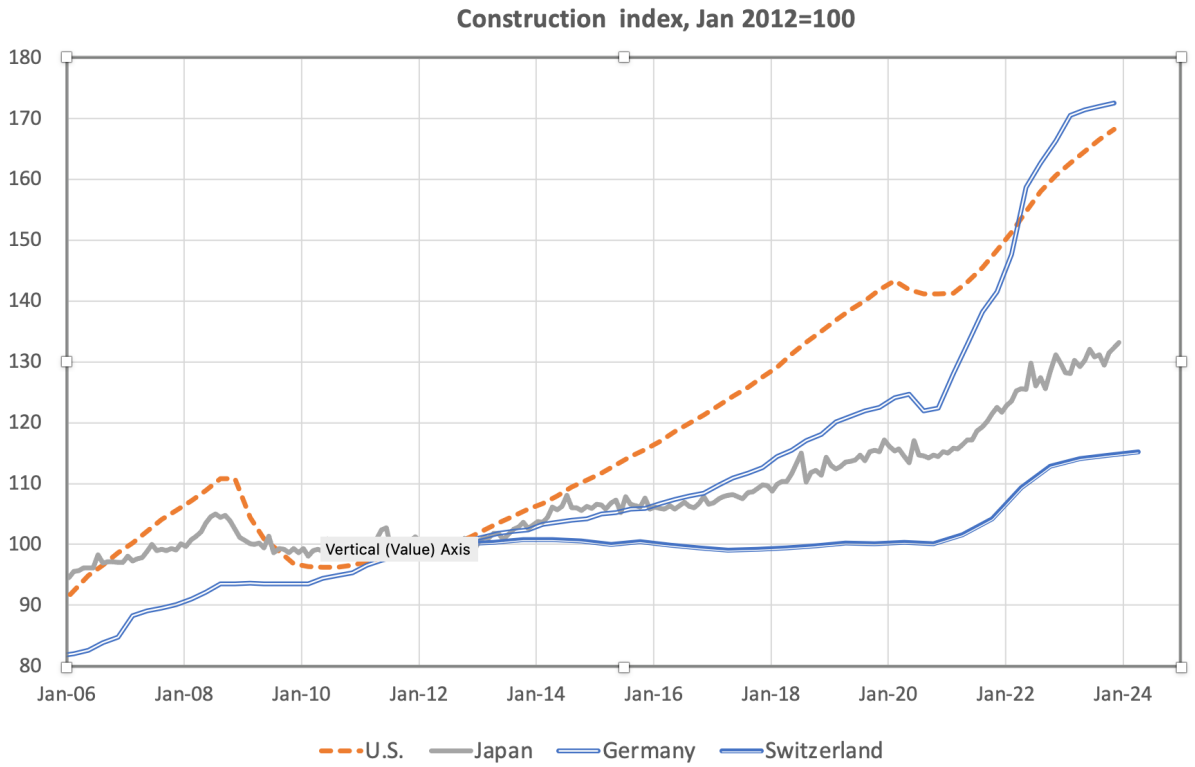
- Significant inflation starting 2021: Covid, Ukraine war
- Price spikes due to energy costs
- Selection of price indices matters:
  - Average of commercial goods w/o energy: no energy spike
  - **Average of 3 specific indices (G. Dugan):** CPA (European product code) categories 25, 27, 28.1.&28.2
  - Escalation factors 2012 -> 2023 (updated, still preliminary):
    - US: +36%
    - Japan: +18%
    - Europe / Germany: +29%
    - Europe / Switzerland: +6%





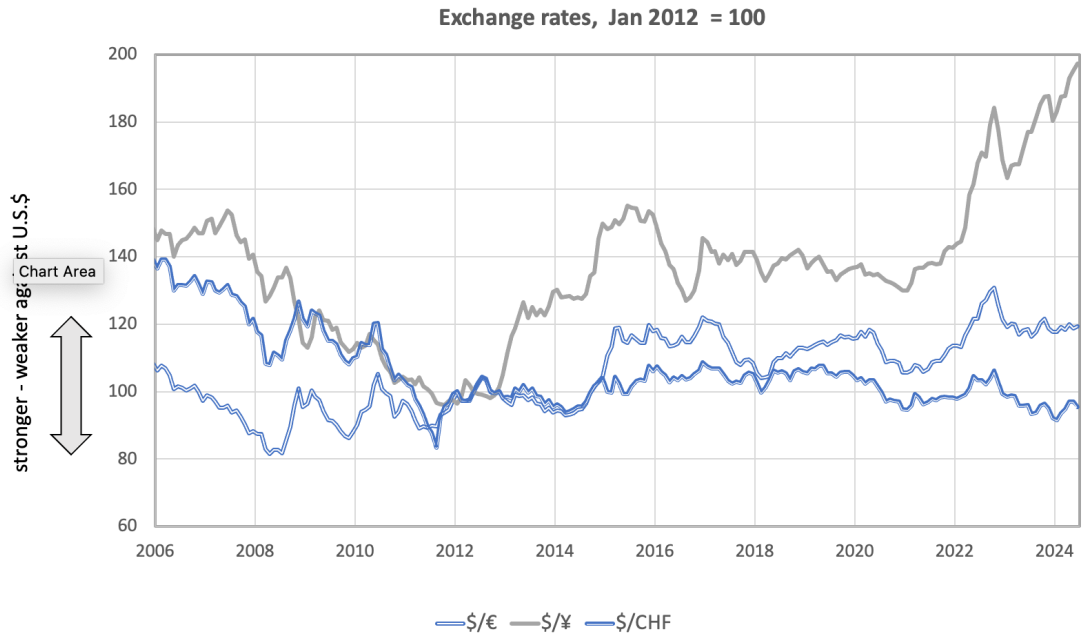


Escalation Factors for Construction Costs



- Japan: +30.5% from 2012 -> 2023
- Switzerland: +13.5%
- CFS costs will be re-evaluated separately

Development of Exchange Rates (not PPP) since 2006



- Yen has lost ~45% against US$ since 2012
  -> external in-kind contributions more expensive in Yen
- Euro has lost ~17% against US$
- Swiss Franc very stable compared to US$

These rates are not used in the cost update

Collecting the Input: 2022 PPP rates

- 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

TDR Cost Estimate, Escalated to 2024

- Current state of escalated cost estimate for 500GeV machine in ILCU 2023: 10.85 $BILCU_{2023}$, contingency 3.21 BILCU
- Does not include design updates
- Does not include updated costs

Costs in 2012 prices in respective currencies

Costs in 2012 prices in $ILCU_{2012}$

Appropriate escalation factors (inflation)

Costs in 2024 prices in respective currencies

Costs in 2023 prices in $ILCU_{2023}$

N (nation)	AG (aggregate level)	% Total Value	MILCU (1/2012)	PPP^(AG) (2012) (N/ILCU)	Exchange rate (2012) (N/ILCU)	N Currency (2012)	N Currency (unit)	Escalation factor (AG)(2011->2023)	Source of escalation factor	N Currency (2024)	PPP^(AG) (2023) (N/ILCU)	Exchange rate (2023) (N/ILCU)	MILCU (1/2024)	Fractional increase in MILCU from TDR	% Total Value
Japan	Construction	18.36	1465.9	109.281		160	GYen	1.305	US PPI-construction and PPP	209	85.220		2453	67.3	22.62%
Japan	Machinery and Equipment	12.81	1022.8	127.291		130	GYen	1.183	US PPI-M&E and PPP	154	127.730		1206	17.9	11.12%
Germany	Machinery and Equipment	26.76	2136.5	0.927		1981	MEuro	1.286	US PPI-M&E and PPP	2547	0.943		2702	26.5	24.92%
US	Machinery and Equipment	35.38	2824.7	1		2825	$M	1.359	US-PPI-M&E	3839	1.000		3839	35.9	35.40%
Switzerland	Machinery and Equipment	1.21	96.6	1.48		143	MCHF	1.060	US PPI-M&E and PPP	152	1.052		144	49.1	1.33%
Germany	Metal	5.48	437.5		0.78	341	MEuro	1.359	Germany-PPI-metals			0.925	501	14.6	4.62%
		7984	**7984**	**TOTAL**									**10845**	**35.8**	

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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)
240819: 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. SRF							
SC material	440	x 0.53	**235**	x 1~1.1	x 1~1.1	X 1.3 ~ 1.4	tbd
Cavity-CM	2,317	0.53	**1,239**				
HLRF	789	0.53	**427**				
Cryogenics	674		**440**				
Other Tech. System	1,391 (= 2,065 -674)	0.79					
e-dr. e+source(Acc)							
CE & CF							
CE & Build.	1,466	0.69	**1.014**				
e-dr. e+ Source (CE..)							
Electrial	333	0.77	**258**				
Mechanical: C./Vent., Safety & Alignment	576	0.76	**448**				
Sum	7,985	0.66	**5,256**				
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	

Work in progress

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

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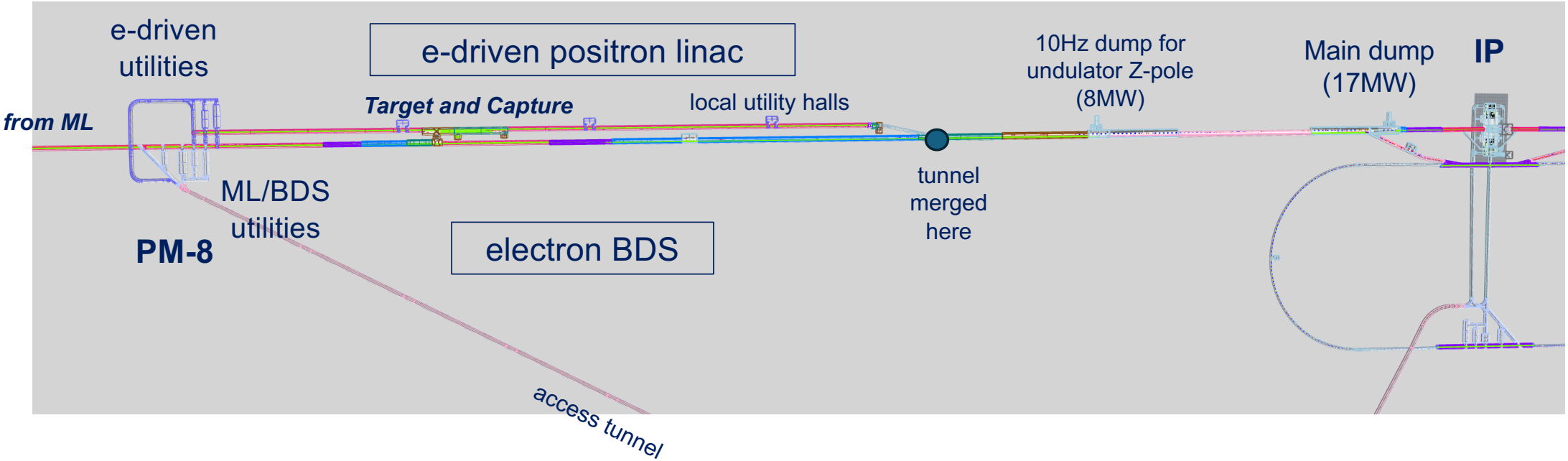
Optional Cost-Estimate to be discussed

- **Electron-driven positron source**
  - Two **independent tunnels** for undulator-driven and e-driven e+ sources must be constructed in the initial tunnel construction included in the initial construction cost.
  - **Accelerator construction** may be **in series**, such as e-driven system at first, and undulator driven system to be realized in the next step, for the cost update study purpose.
  - More details to be discussed.

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

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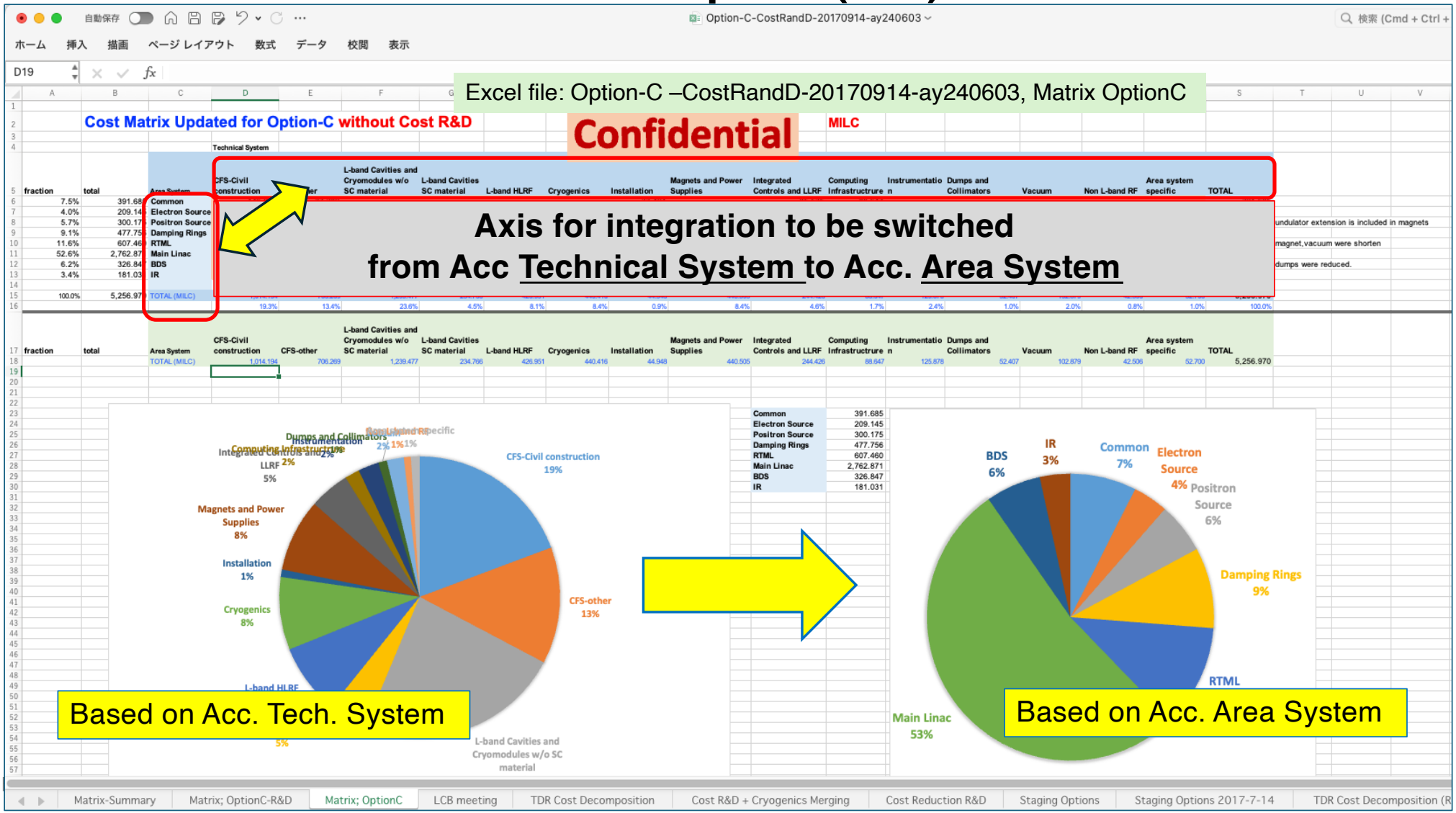
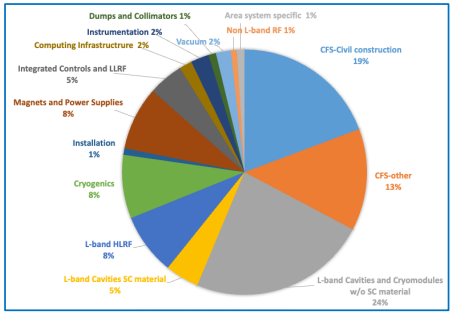
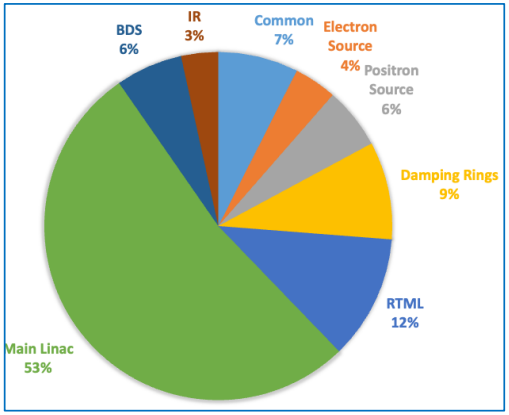
Cost: ILC250 Option (C→) A



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)	ILC250 (2024-prices)	Extension to ILC500 (2024-prices)
Common	532	392	tbd	tbd
e- Source	209	209		
e+ Source	290	300		
Damping RIngs	478			
RTML	649			
Main Linac		2,763		
BDS		327		
IR	181	181		
Sum	**7,985**	**5,257**		
	1.0	**0.66**		

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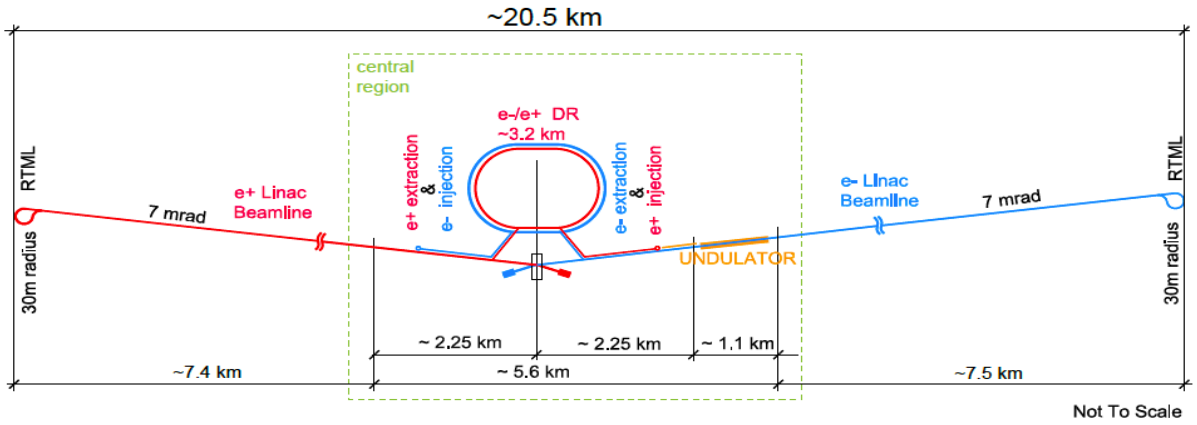
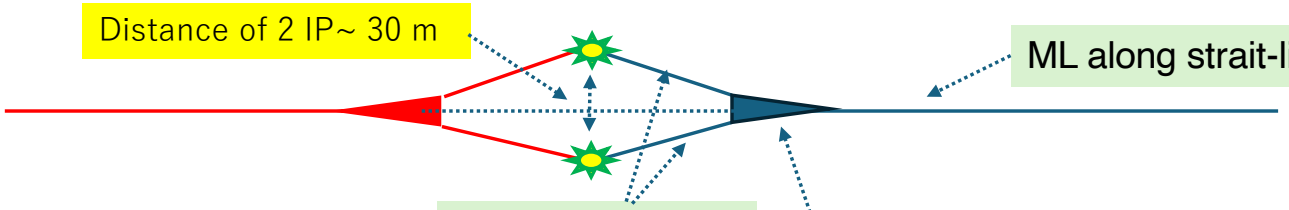
ILC250: 2-IP Options?

- 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)





Technical Issues need to be discussed

- Is it realistic to split the beam at the upstream end of BDS?
- How the beam interaction angle may be managed with keeping 14 mr or any other ?
- How the IP point and IP cavern to be better optimized with the IP distance of ~ 30 m?
- How the beam dump may be managed?
- E-driven option may be managed without timing issues.
- Luminosity upgrade to be an issue ?
- Muon shield an issue?
- *Etc and etc. …*

Any advice will be appreciated.

Outline

- **Overview**
- **Work in Progress :**
  - Strategy and Methodology
  - SRF and Others
  - Prospects for the Cost-Update
- **Optional Study expected:**
  - e-driven Positron Source
  - Two Interaction Points
  - Future Energy Upgrade
- **Review for the Cost Update**:
  - **Internal Review 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. (Tatsuya may report the motivation and goal, with his report).
- **The review meeting** to be held **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 (to be discussed):
  - Nov. 5 (Tue) - 8 (Fri): Introductory meeting with the ext. review committee,
  - **Nov. 20-21 or 21-22? :** IDT internal review meeting (to be discussed),
  - **Dec. 19-20:** External Review meeting,

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 2023 Jan. PPP.
- **SRF** cost update work in progress, with referring LCLS-II experiences as facts, and with new inputs from industry. Further report will be realized in the next WG2 meeting.
- **CFS** cost update work in progress, with new inputs from professional consultants in Japan.
- The **External Review** on the TF work will be held on **19 -20 Dec**. and preparation actions will be required.