Updating the Costing of ILC in Japan

G. Dugan, B List, M. Ross, H. Sakai, N. Terunuma, N. Walker, A. Yamamoto (TF Leader),
A._Lankford, S. Michizono, S. Stapnes

ILC Cost-Update Task Force

LC Vision Community Event, 9 Jan. 2025

ILC Cost-Update Taks Force Study requested

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

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.

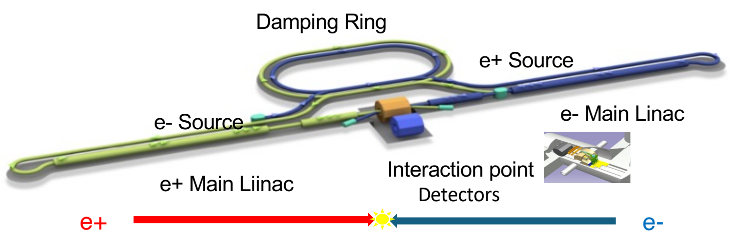
Status of the ILC
-Activities of the International Development Team (IDT)-
LCWS2024 at University of Tokyo
Tokyo, Japan, 8-11 July 2024

Tatsuya Nakada
EPFL, Switzerland
Chair of the IDT Executive Board

Cost update task force members:

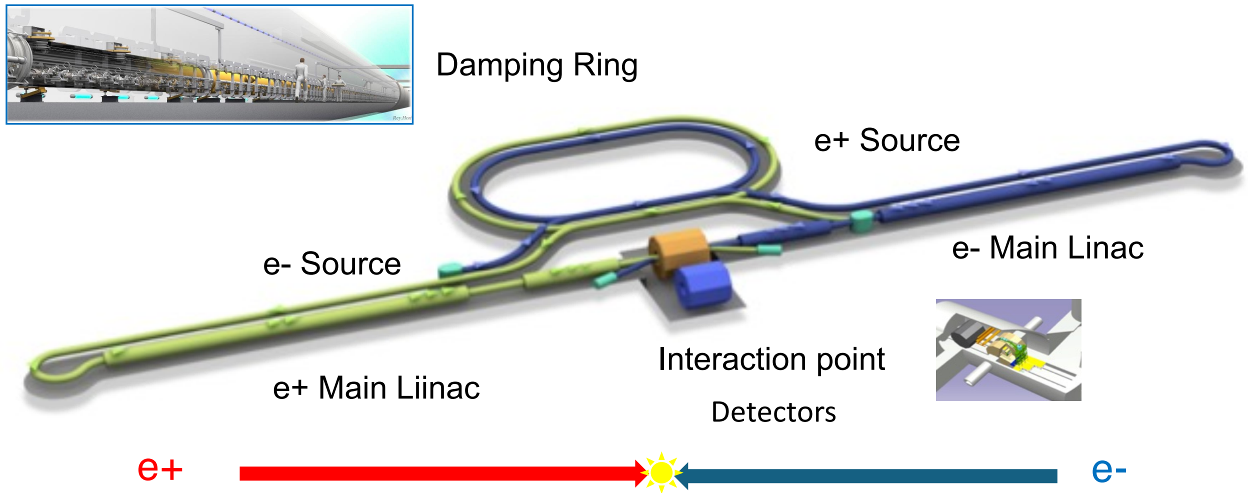
Gerry Dugan	(Cornell)
Benno List	(DESY)
Marc Ross	(SLAC)
Hiroshi Sakai	(KEK)
Nobuhiro Terunuma	(KEK)
Nick Walker	(DESY)
Akira Yamamoto*)	(KEK)
and from IDT EB	
Andy Lankford	(UCI)
Shinichiro Michizono	(KEK)
Steinar Stapnes	(CERN)

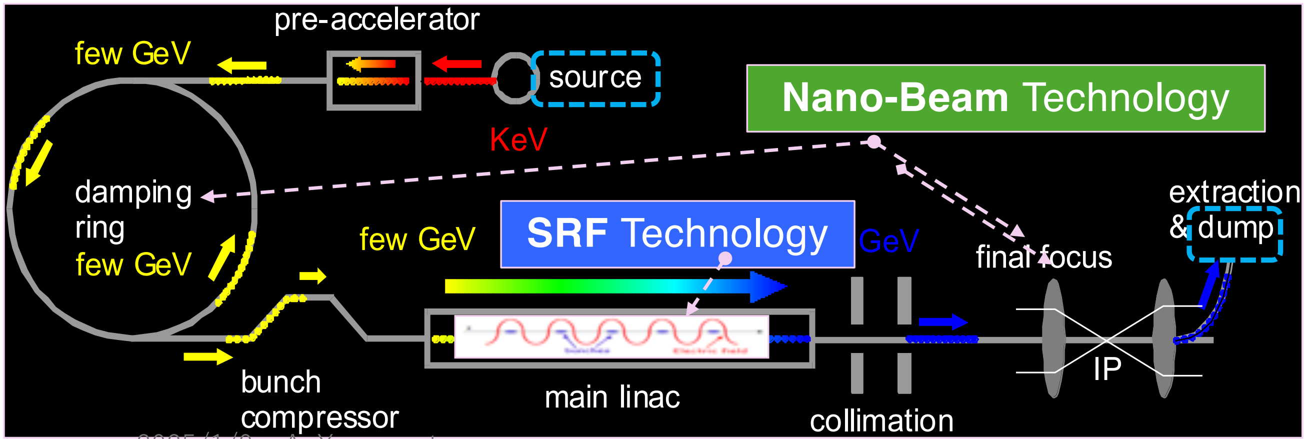
*)Task Force leader



ILC250-A Cost fraction in 2017, to be updated

ILC-250: Accelerator Technology and Parameters





Note: The ILC Cost-update (2024) is done for the the Baseline design.

Parameters	unit	Value	
		Baseline	L.U. (Option)
Beam Energy	GeV	125 + 125	
Accelerator Length	km	20.5	
Luminosity	10^{34} cm^2/s	1.35	2.7
Beam rep. rate	Hz	5	
Pulse duration	ms	0.73	0.961
# bunch / pulse		1312	2625
Beam Current	mA	5.8	8.8
Beam size (y) at FF	nm	7.7	
SRF Field Gradient	MV/m --	< 31.5 > (+/-20%) $Q_0 = 1x10^{10}$	
# SRF 9-cell cavities # CM		~ 9,000 (~ 8,500 x 1.05) ~ 990	
# RF units:		~ 240	TBD
AC-plug Power	MW	111	138

Outline

- Cost-Update by TDR Methodology
- Cost-Update based on new quotes for SRF and CFS
- The ILC250 Cost update reached
- Optional studay

Methodology 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 2024 if necessary
    - Converted to a new ILCU2024 using PPP rates
  - **Define a new ILCU2024:**
    "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

- **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 2012 rates used for TDR
    - Escalate cost from 2012 to 2024 using local escalation rates
    - Convert cost to ILCU2024 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
- Newer cost estimates are escalated to 2024, if necessary, and converted to ILCU2024

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

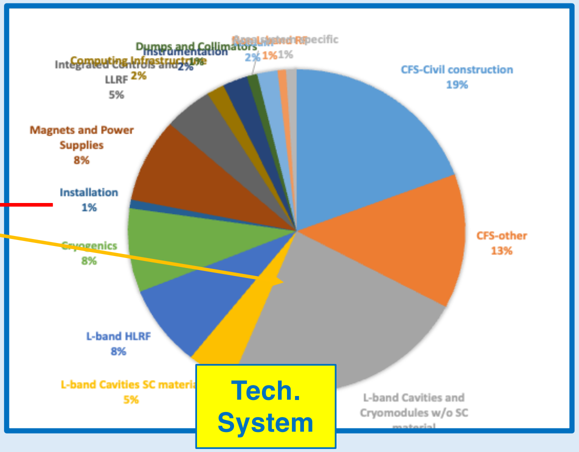
Acc. Area Systems							
e+	e-	Common	IR	BDS	ML	RTML	DR

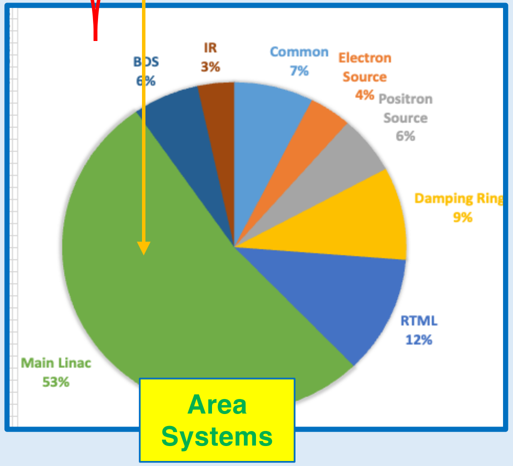
Tech. Systems

CFS
(Civil E. & Conf. F.)

SRF Tech.
(mainly for ML)
- SC material
- Cavity, Mag, CM
- HLRF
- Cryogenics

Conv. Acc. Tech.
(e+e--, DR, RTML, BDS)
- Mag & PS,
- Vac.,
- Der. & MDI,
- Cntl, LLRF,
- Comp./Infra.,
- Non-L-RF Spec

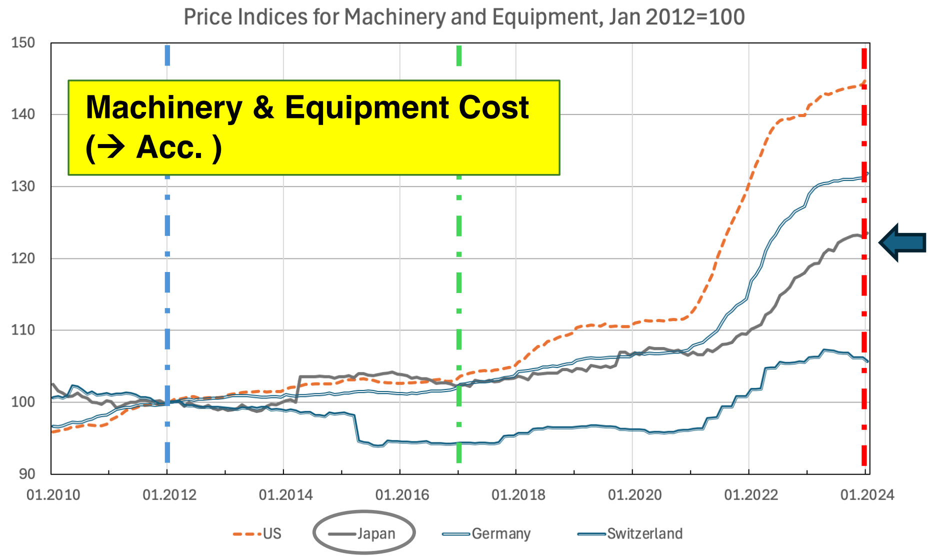


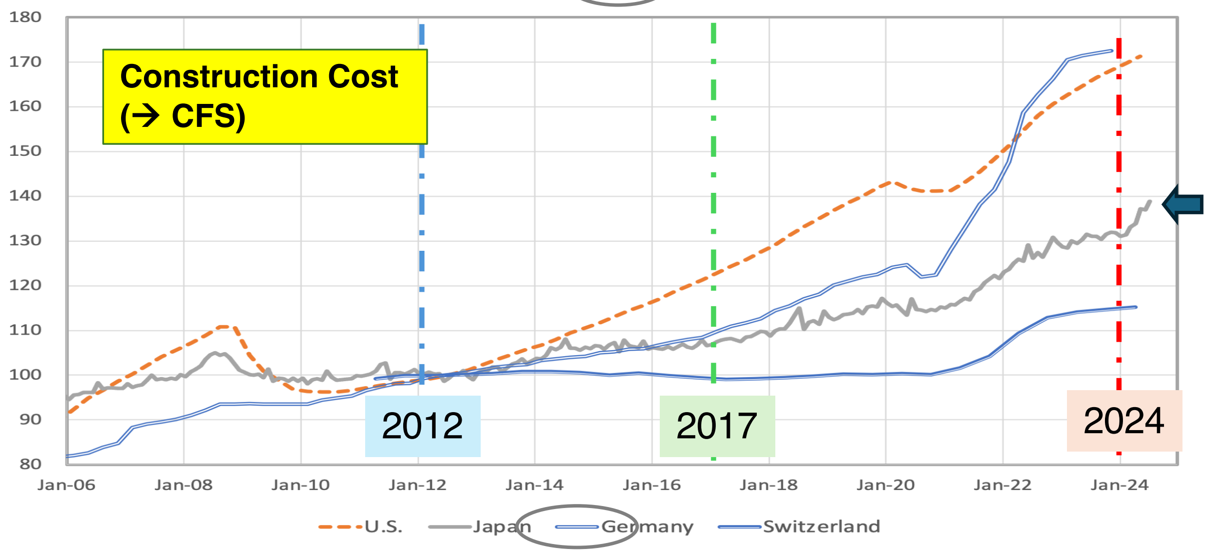


Escalation Factors for Machinery and Construction

Courtesy: B. List

- **Significant inflation** from 2021 on: Covid, Ukraine war
- **Selection of price indices** most appropriate:
  - Average of 3 specific indices (G. Dugan): CPA (European product code) categories 25, 27, 28.1.&28.2
  - **Machinery Escalation** factors 2012 -> 2024:
    - US: +45.3% ± 17.7%
    - Japan: +23.5% ± 18.7%
    - Europe / Germany: +31.9% ± 6.9%
    - Europe / Switzerland: +5.7% ± 7.2%
    - Uncertainties taken from RMS spread of sub-categories
  - **Construction price indices** 2012 -> 2024 :
    - Japan: +30.4%
    - Switzerland: +15.1%
    - U.S: + 71% -> determines the rise in Value of Buildings (even if built in Japan)



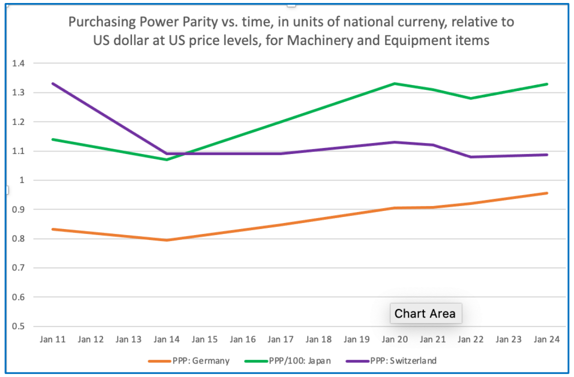


PPP Evaluation for 2024

- PPP is evaluated by OECD regularly
- PPP depends on the type of goods. We use
  - Machinery and Equipment
  - Construction
- Most recent goods-specific numbers from OECD are for 2022
- Evolution is governed by relative inflation
- -> corrections 2022->2024: 0.6 – 4%

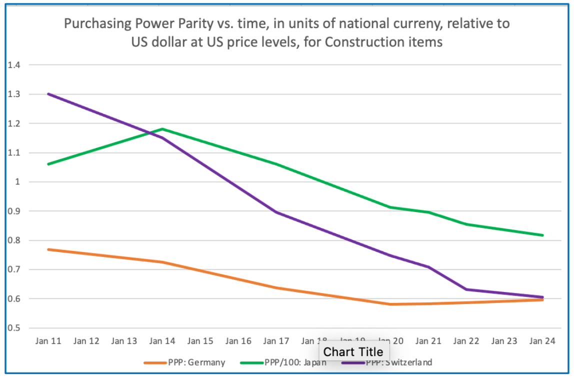
Machinery & Equipment

	DE	JP/100	CH
12/01	0.82	1.11	1.31
17/01	0.85	1.20	1.09
24/01	0.955	1.33	1.09



Construction (CE)

	DE	JP/100	CH
12/01	0.75	1.10	1.24
17/01	0.64	1.06	0.90
24/01	0.60	0.82	0.61



ILC Cost Estimate Update 2024: Task-Force Approach

Methodology:

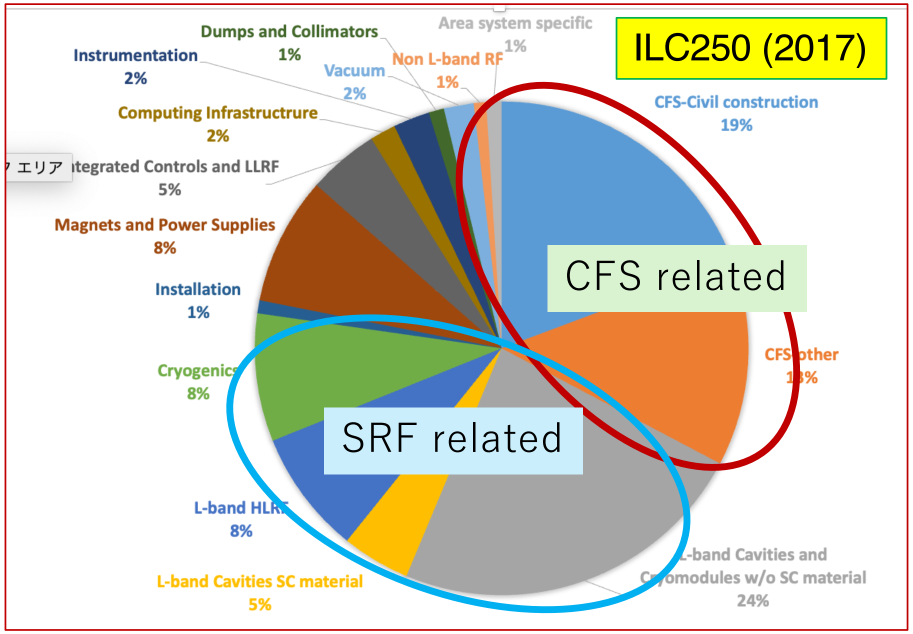
- **Currency :** ILC Unit (ILCU),
- Exchange: Purchasing Power Parity (**PPP**)
- Time variation / escalation,

Cost Update based on:

- **Acc. Technology**
  - **Staging/Scaling** based on the methodology: in 2012 → 2024
- **SRF Technology**
  - **New inputs: LCLS-II-HE experiences, & Industry and labs** in **2024.**
- **CFS:** (mountain-site model in Japan)**:**
  - **New Inputs: industry & consultants** in 2024

≥ 75% fraction

2024: Cost element type	ILCU→$	ILCU→€	ILCU→¥	ILCU→CHF
Machinery & Equipment (PPP)	1	0.955	132.8	1.087
Superc. Material (EX)	1	0.924	149.1	0.887
Civil construction (PPP)	1	0.596	81.8	0.606



ILC Project & the Cost Update:
- Approach Updated -

- Energy scaled

- Large inflation

2013:
ILC-TDR
250 – 1,000 GeV
in 2012 price

→

ILC-250 GeV
Acc.
&
CFS
in **2012** price

CFS new design,
dedicated to JP
in **2017** price

→

ILC 250 GeV
in 2024 price

- **Energy scaled down from 500 GeV (TDR) to 250 GeV, in 2012 prices,**
- Accelerator and CFS designs kept based on the TDR.

- **ILC-250** cost affected by major inflation,
- **CFS design re-evaluated and renewed for a mountain-site model in Japan, since 2017,**

ILC Project & the Cost Update:
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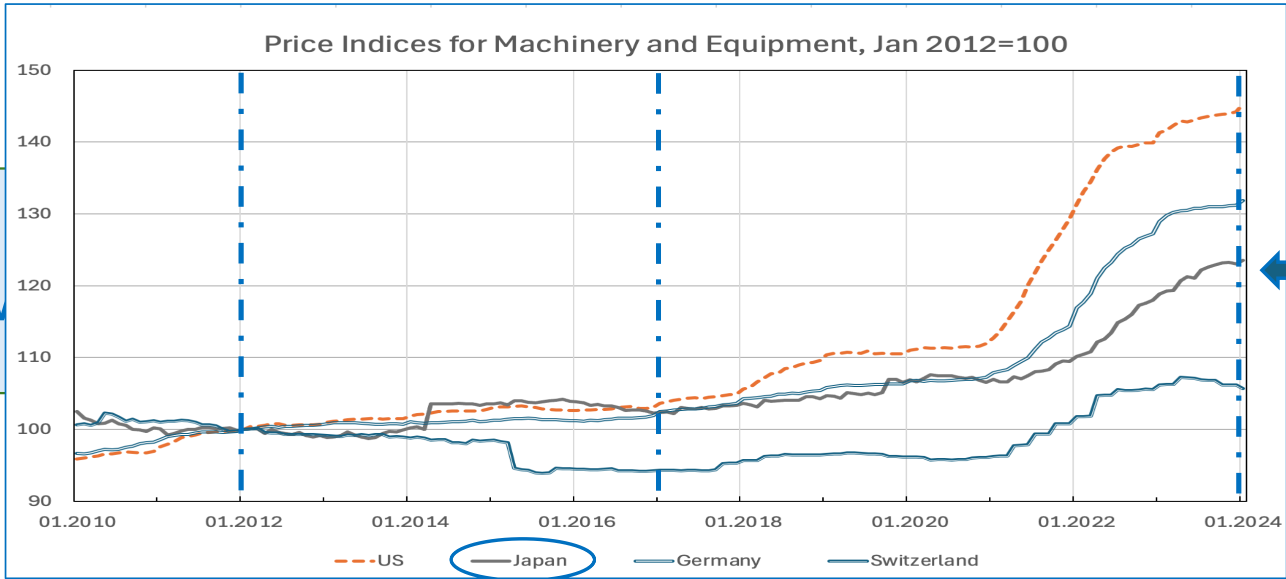

ILC 250 GeV
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- **Energy scaled down from 500 GeV (TDR) to 250 GeV, in 2012 prices,**
- Accelerator and CFS designs kept based on the TDR.

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- **CFS design re-evaluated and renewed for a mountain-site model in Japan, since 2017,**

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) requested (by IDT)
Year	2012 ~ 2013		2017 ~ 2018		2018 ~ 2024	
Conv. Tech. Sys. - mainly for Sources, DR, BDS	- Lab study & - Scaling:		- Scaling:		--------------> - Additional design update - Evaluating the escalation & currency variation	**Price scaled,** 2012 to 2024
SRF - mainly for ML	- Referring Eu-XFEL, - Industrial study		- Scaling, - Industrial study update-1		- Design update for ILC250, - referring LCLS-II-HE, - Industrial-study as (New inputs),	**Price in 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,**

- TDR Ext. Cost Review, 2013

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

ILC Cost Update 2024

Steps for the ILC-250 Cost-update 2024

1. **Scaling with Methodology** using known variants, 2012~2024, for **Conventional Accelerator Technology (magnet, PS, vac., etc)**
2. **New-Inputs : Cost-quotation as of 2024** for **SRF** and **CFS**
3. **Evaluate** them to be assembled
4. **Conclude** the **ILC Cost-update, 2024**

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

4. Other Technologies:
(*) Cryogenics → moved to SRF tech.

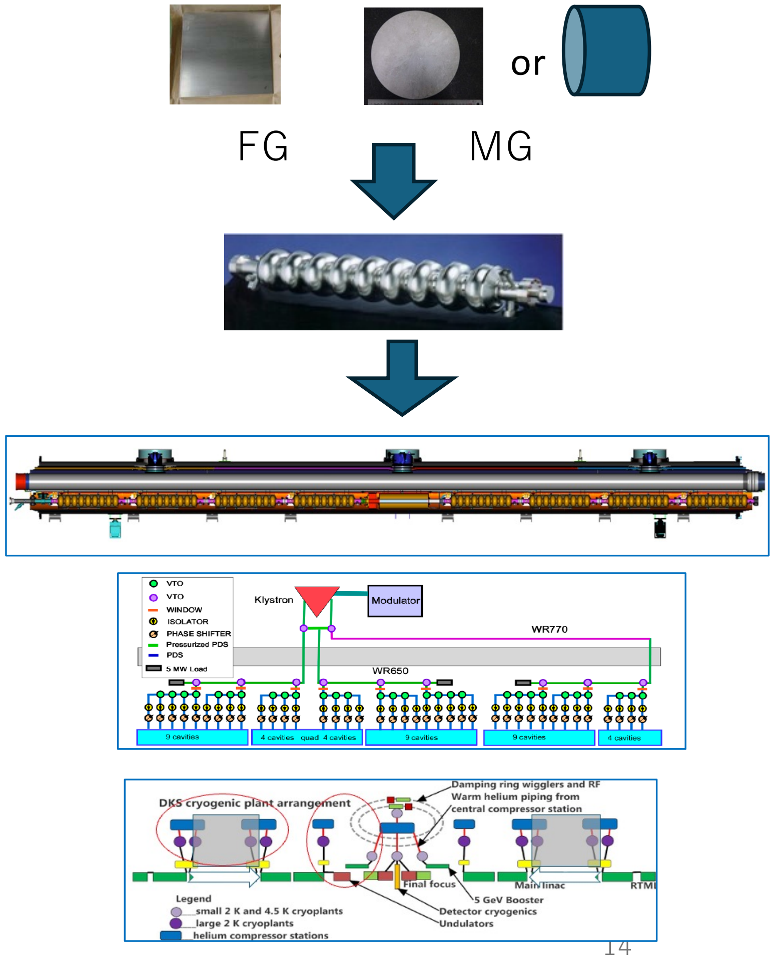
Cavity related:
- SC Material:
- Cavity:
- Coupler :
- Tuner:
- Mag. Shield

Magnet:

Cryo-Module(CM):
- CM-Components
- CM-Assembly

HLRF:
- Klystron
- Modulator
- PDS

Cryogenics:



ILC250 SRF Industrial Cost Update Plan

1. Cavity and CM
(1) Cavity related
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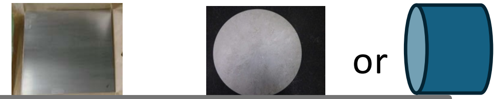
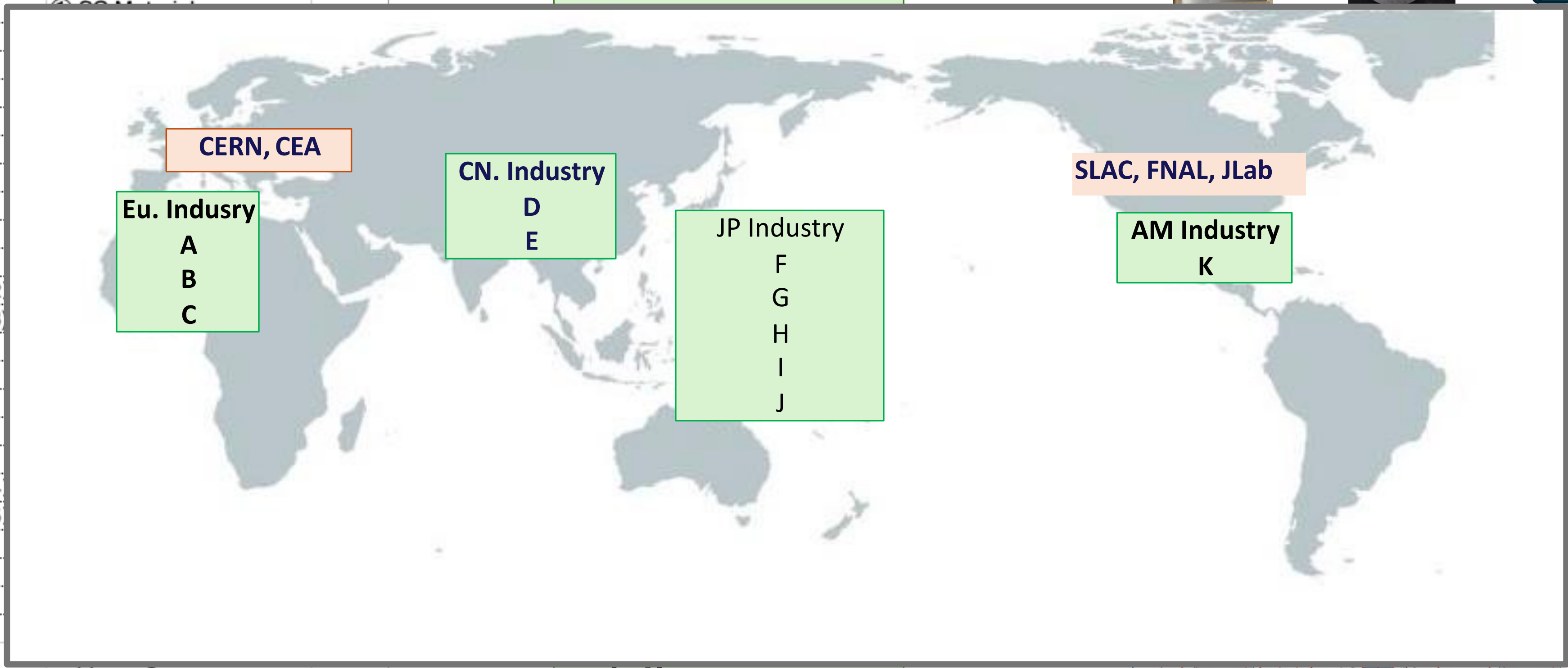
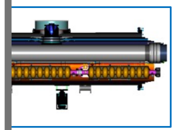
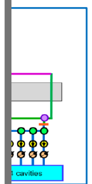
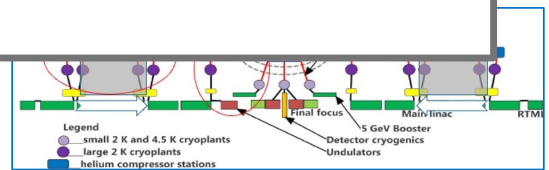








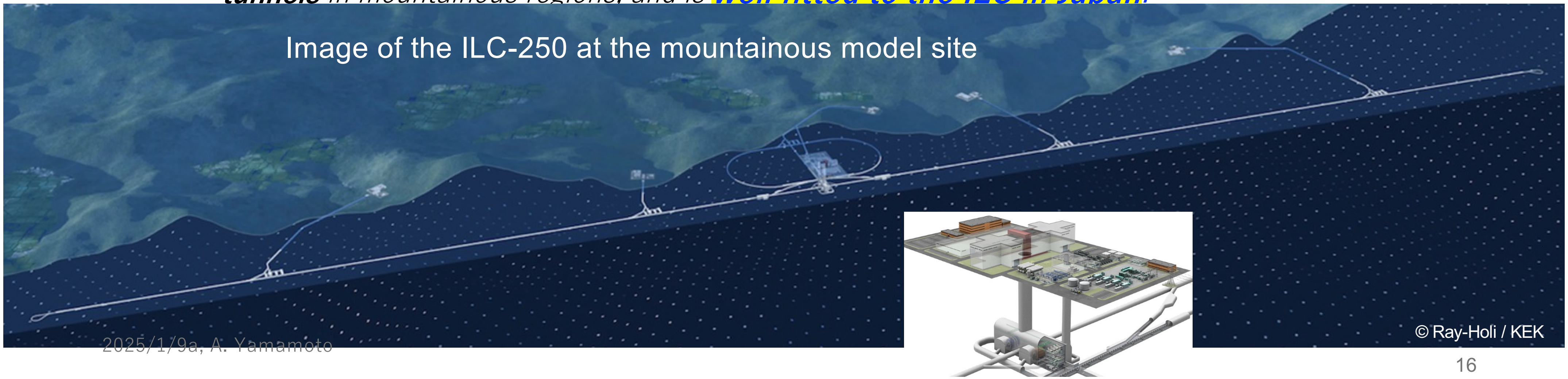


4. Other Technologies:
(*) Cryogenics → moved to SRF tech.

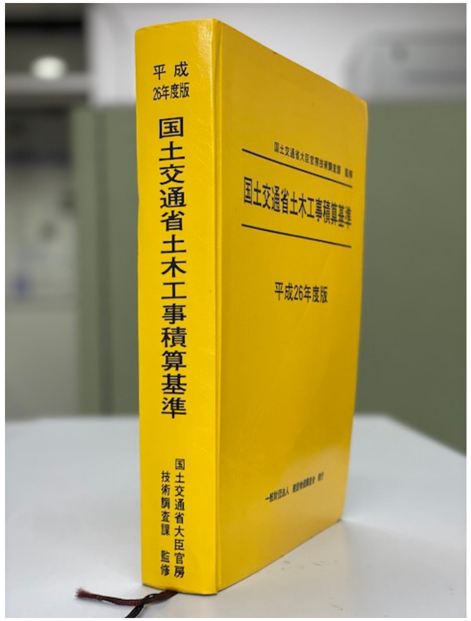
CFS cost update policy

■ Re-evaluate the CFS cost based on the "ILC in Japan".

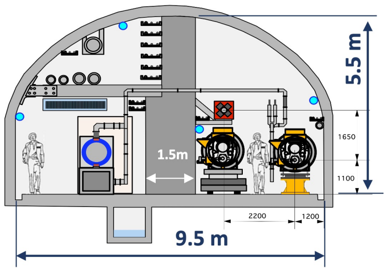
- Geological and topographical constraints differ from those in Europe and America.
- **Mountainous site in Japan** while others are flatter sites.
  - Access to the underground accelerator and facilities are done through **sloped access tunnels** and two **vertical shafts at IP;** one for lifting down the detector blocks and the other for utilities.
  - Civil works are based on the **NATM tunneling method** (blasting, excavation and concrete reinforcement). ***NATM is a standard and well-established method in Japan for road and rail tunnels*** *in mountainous regions, and is* ***well fitted to the ILC in Japan.***



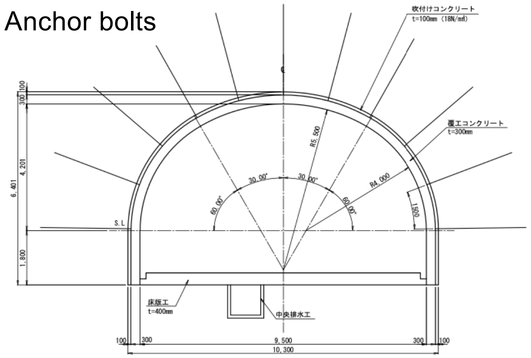
■ Civil engineering costing method



- The civil engineering cost is assessed according to ***the national tunnel costing standards***, which is updated annually by the Ministry of Land, Infrastructure and Transport.
  - **This costing method is a standard for tunnel construction in Japan. It is well established and is the most reliable approach. Once a design was fixed, mostly the cost is automatically derived.**
  - Same procedure was applied for costing in TDR (2012) and ILC-250 (2017).
- We update the cost according to **the national costing standard updated in 2024.**

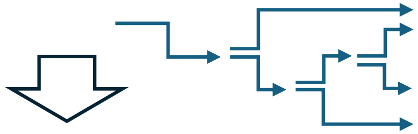


Base design



Civil engineering design

Plan the construction work flow



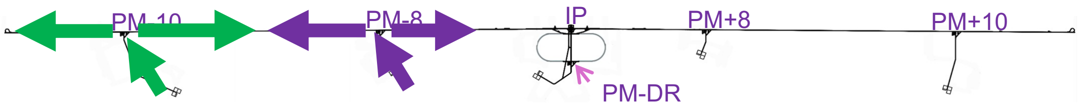
Costing by national standards

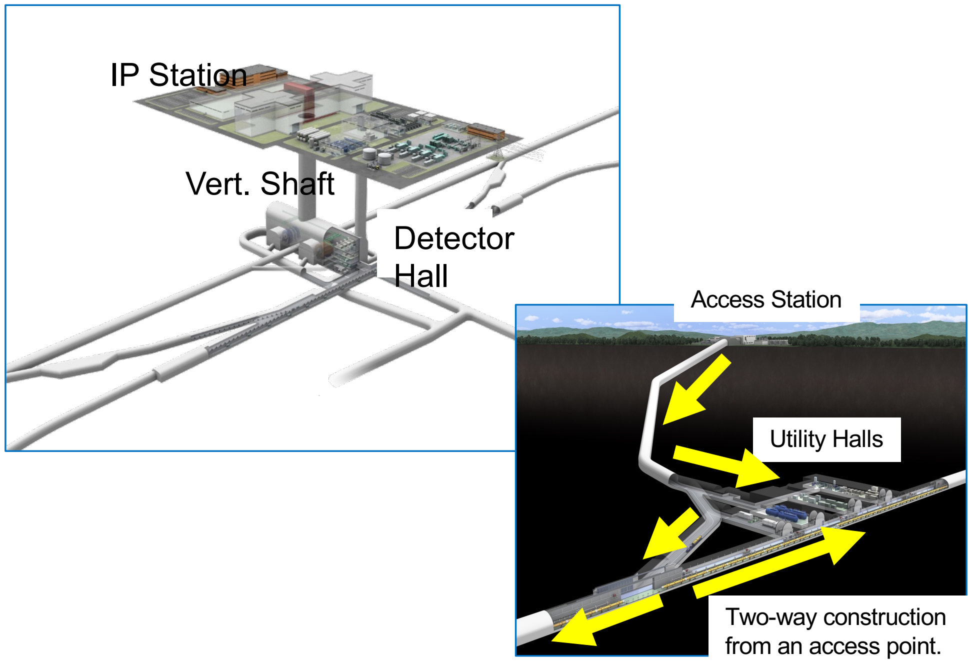
Results

ILC CE Design and Cost-Update Work proceeded in cooperation of Academia, Industry, Region, and the Task Force

Academia / Insutry / Region	Effort for ILC Cost-update
Academia cooperation: - KEK and Tohoku Univ. - JSCE (Japan Soc. CE) - The Japanese Geotechnical Society,	basic design design feasibility evaluation
Industrial cooperation: ● AAA ● General Constractors joining AAA - **A. Corp.** - **B. Corp.** - **C. Corp.** - **D. Corp.** - E Corp. - F Corp. - G Corp. - HCorp. - I Corp ● Consultants - J - K Co. Ltd. - **L. Co. Ltd.**	Industrial consortium coordination Industrial design and cost quotation ↓ - Assembly of Cost-update 2018 - design study acc. Tunnel; - Assembly of Cost-update 2024
Regional cooperation: - Tohoku ILC Project Dev. Center - Tohoku ILC Promotion Council	Regional coop. coordination Regional coop. coordination

- Note: **Companies colored by blue are core members having contributed to the update of the ILC CE cost estimation in 2024.**





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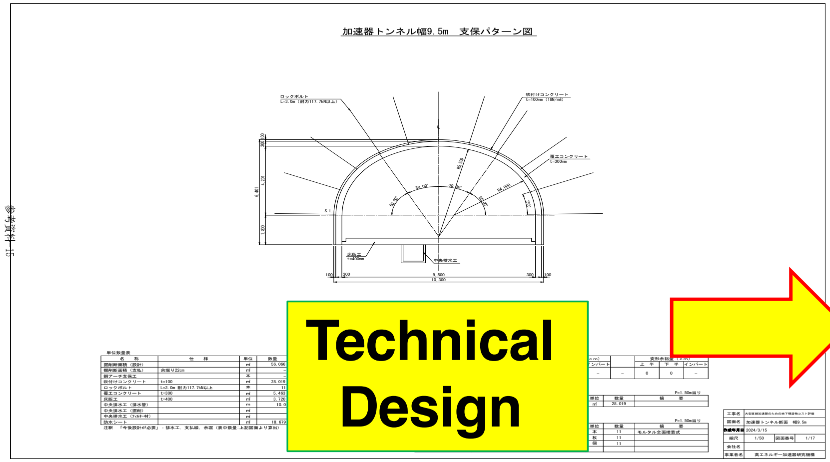
Bottom-up Work-flow for the Design to Cost-Estimate following JP/MLIT standard (from Pacifico Report, March 2024)

CE design of the ML tunnel with a list of CE parts;
reinforce steels, rockbolts, lining and floor concretes, drainage, and labors.



Technical Design

File: Ref3-2024-PC-details.pdf

Unit cost from MLIT standard and that from the market price;
parts, labour, and the operation of construction equipment.

Part & Unit Cost:

- **Material Cost**
- **Labor Cost**
- **Rental fee, …**

Cost estimation based on unit cost of parts and labour costs

- **Sum-up cost:** **of all parts & labor.**

Construction Zone Cost
(see page21)

Methodology from Design to Cost-estimate

To be shown

ILC250nCost-Update Evaluation

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

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Progress Year-base Unit [MILC]-	ILC500 (TDR) 2012-base [MILC]	ILC250 2012-base [MILC]	ILC250-2017-base JP-CFS ([Oku-JPY]	Escalation & design-update [factor]	ILC250-2024-base JP-CFS [OkuJPY]
Year of work ~ report	*2012 ~ 2013*	2017 TDR-base	2017 New JP-CFS Design	[2012-2024]	[2024]
Acc. Tech. (except for SRF)	**1,390**	**1,196**		To be reported	
SRF Tech. (CM, HLRF, Cryog,)	**4,221**	**2,340**		To be reported	
CFS:CF		706	To be reported	To be reported	
CFS:CE		1,014	To be reported		To be reported
CFS-Total		**1,720**	To be reporte		
Sum	**7,985**	**5,256**			

Acc. Tech., SRF Tech., CFS:CF → [MILC]

CFS:CE → [Oku-JPY]

Comments on the ILC250 Cost-Update 2024

- The ILC250 cost increase of **~60%+** (in overall), in 2017 – 2024.
- It may be caused by the following origins:
  - **General (for all Conv. Acc., SRF, and CFS)**:
    - Increase of **30 – 50 %** because of **inflation** from 2017 to 2024,
  - **SRF (specific):**
    - Increase of **8 ~ 10 %** because of the **1/3 mass production, resulting unit cost-up**
    - Increase of **10 ~ 20 %** because of integration of **averaged cost** in 2024, instead of cheapest cost in TDR, and **design updates and/or production cost changes**.
  - **CFS (specific):**
    - Increase of 20 – 40 % because of design update in JP specific site,
    - dynamic change of exchange rates (in particular between USD/.EU and JPY)
    - Significant, material (Cu, SUS etc.) cost increase,

Optional Study: Energy Upgrades

Charge given: Cost-estimates for:

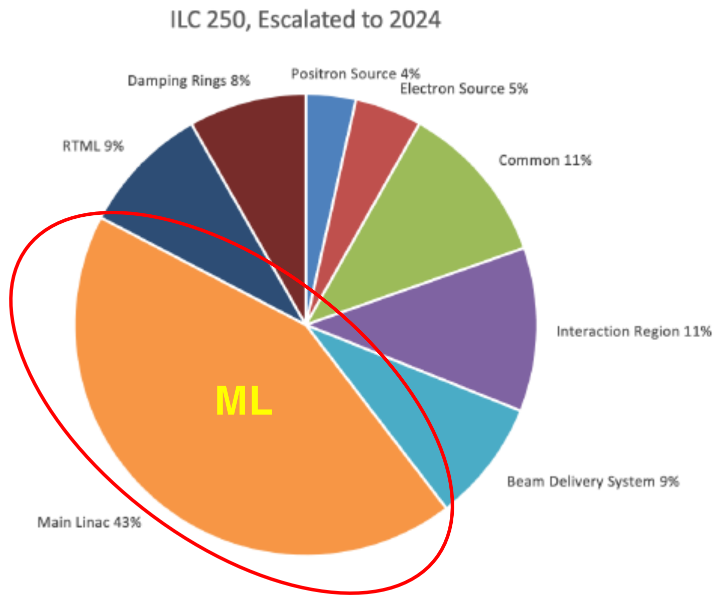
- √*s* = 500 GeV, t-t threshold,
- i.e. 350 GeV and
- **Higgs factory, i.e. 250 GeV**

Staging report (arXiv:1711.00568):

- **defines possible options.** Tunnel length defines maximum energy:
  - 500-550 GeV: 33.5km (TDR: 31.5km)
  - 350-380 GeV: 27km
  - 250GeV: 20.5km

TDR design:

- **changed from 31.5 to 33.5km** in CR-0004 (timing constraint) -> would permit installation of more cryomodules to reach **550 GeV**

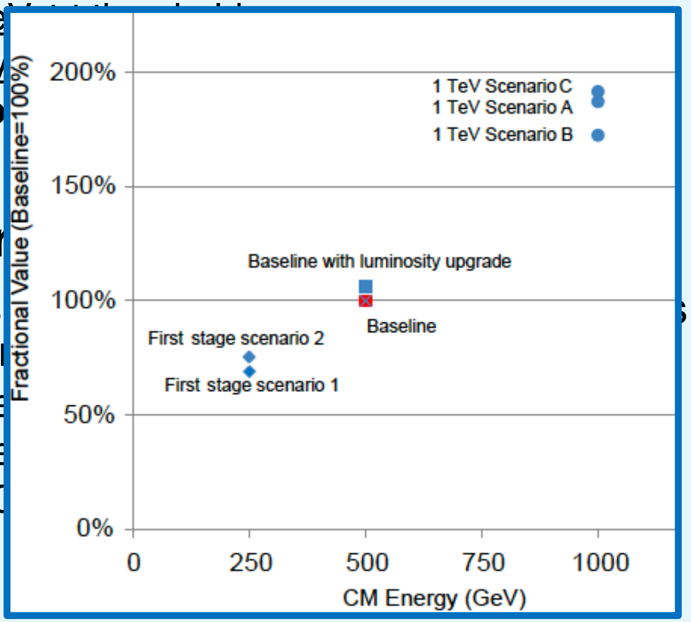


- **Energy upgrades:**
  - **250 GeV:** = 100 % (normalized)
  - **350 GeV:** = 100 + 35 → **+ 35 %**
  - **500 GeV:** = 100 + 35 + 35 → **+ 70 %**

Optional Study: Energy Upgrades

Charge given: Cost-estimates for:

- √s = 500 Ge
- i.e. 350 GeV
- **Higgs facto**



Staging repor

- **defines poss** maximum ener
  - 500-550 Ge
  - 350-380 Ge
  - 250GeV: 20

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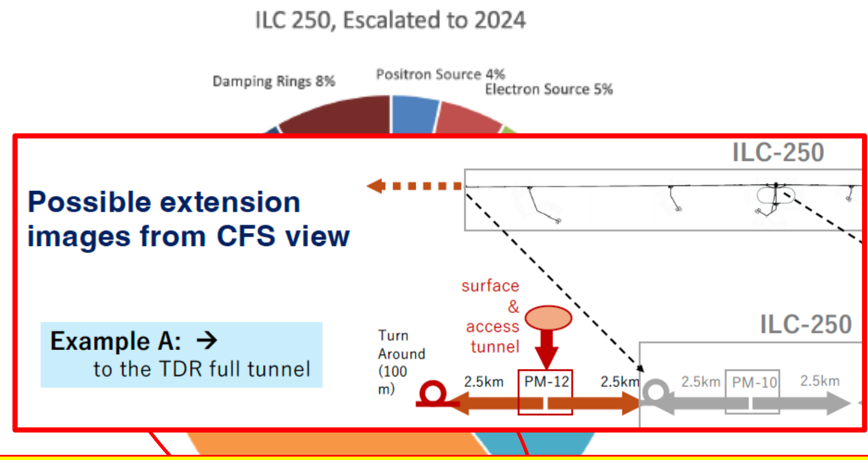
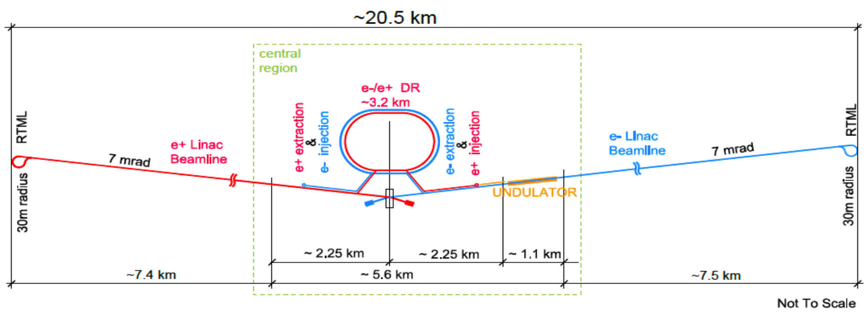


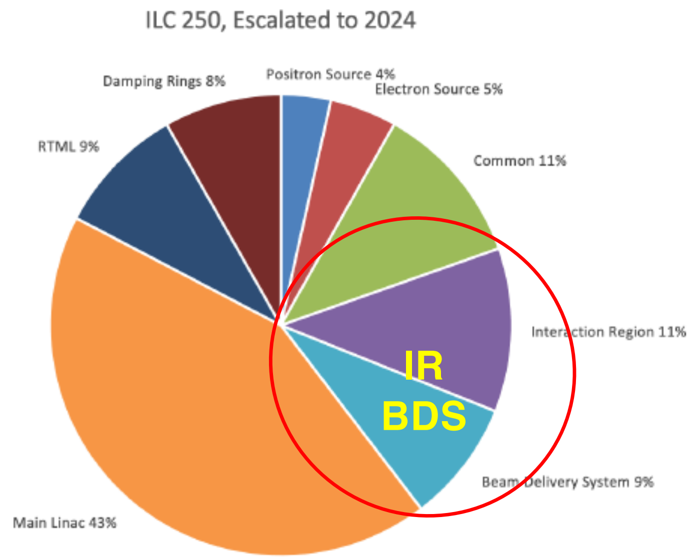
Addit.Access Tunnel needed, and
It may be efficient to be done in **350 GrV upgrade**

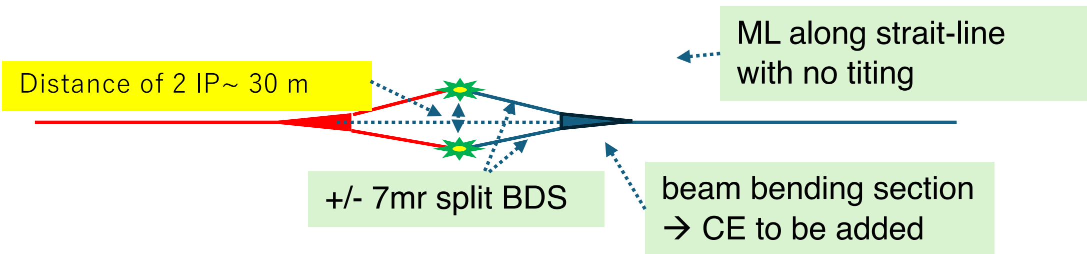
- **Energy upgrades:**
  - **250 GeV:** = 100 % (normalized)
  - **350 GeV:** = 100 + 35 → **+ 35 %**
  - **500 GeV:** = 100 + 35 + 35 → **+ 70 %**

Optional Study: 2 IPs

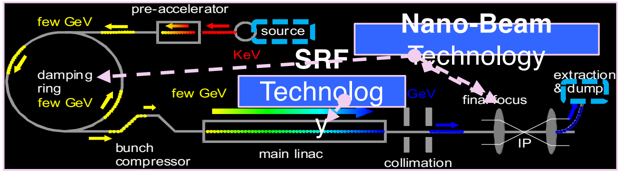
- Beam needs to be split at the upstream ends of BDS
- Doubling the **BDS , IR, Dump (+ some others)** value



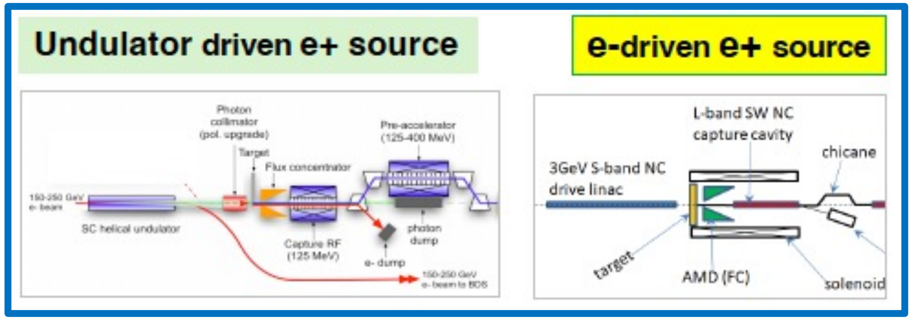


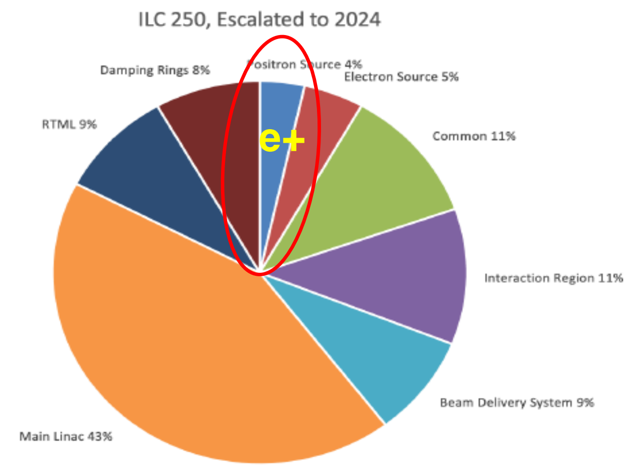


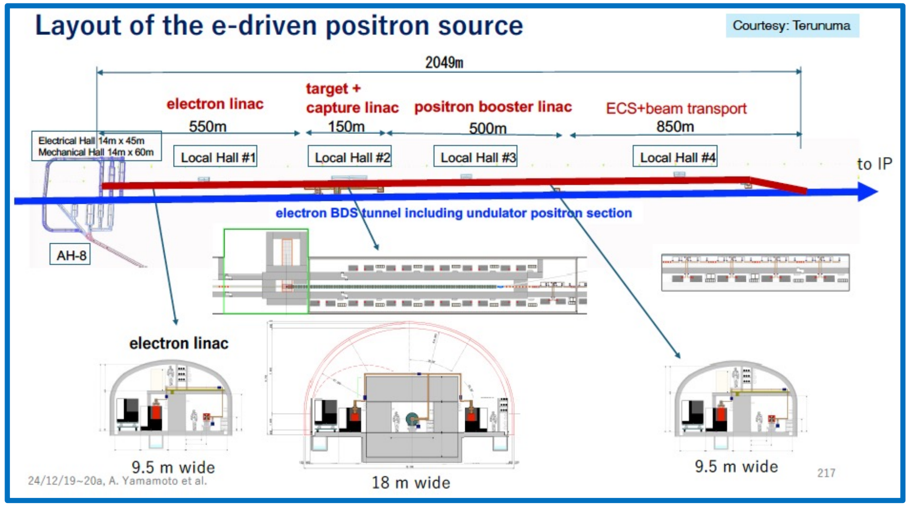
- **2-IPs: Necessary Addition:**
  BDS + IR + (Split sys+ Others)
  = 9 %+ 11 %+ tbd → **20 % + tbd**



Option: e- driven e+ Source







- **e^- driven positron Source:**
  - **Acc: -** (Undulator-driven) + (e-driven) → small
  - **CFS: 4~5 % of total ILC250 cost**
  - **Balance: → add. CFS (for doubling tunnel) needed**

Summary

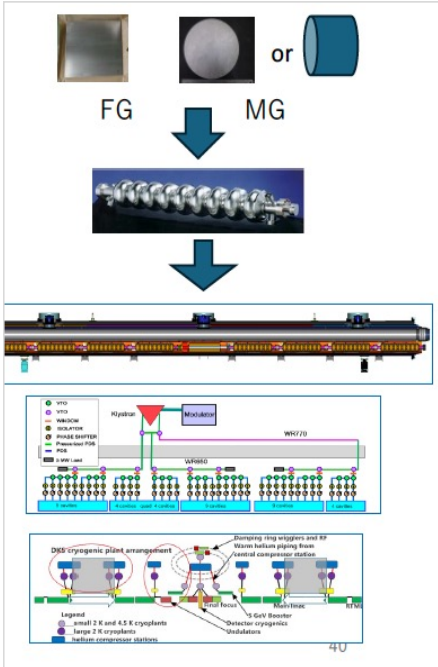
- **ILC cost-update work progressed**, **with steps of**
  - **Methodology based the cost update** according to the ordinal methodoloty,
    - reflecting **currency** and escalation changes, and design updates, **from 2012-2024.**
  - **Direct cost estimate with new quotations** from labs and industries**, in price of 2024.**
  - **Those two results verified to be reasonably consistent**
  - **The cost update well explained with inflation factors and mass production scale factors, and some design update considered.**
  - **Optional studies** made, on energy upgrade, , 2-Ips, and on e-driven e+ source.

  - **Then the ILC cost update results will become available after an appropriate process.**

Reserved:

Table 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)



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

The International Linear Collider – A Global Project

	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**

ILC Cost-Update In 2024

Requested

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.

Energy Upgrade: Staging configurations

Charge given: Cost-estimates for:

- $\sqrt{s}$ = 500 GeV, t-t threshold,
- i.e. 350 GeV and
- **Higgs factory, i.e. 250 GeV**

Staging report (arXiv:1711.00568):

- **defines possible options.** Tunnel length defines maximum energy:
  - 500-550 GeV: 33.5km (TDR: 31.5km)
  - 350-380 GeV: 27km
  - 250GeV: 20.5km

TDR design:

- **changed from 31.5 to 33.5km** in CR-0004 (timing constraint) -> would permit installation of more cryomodules to reach **550 GeV**

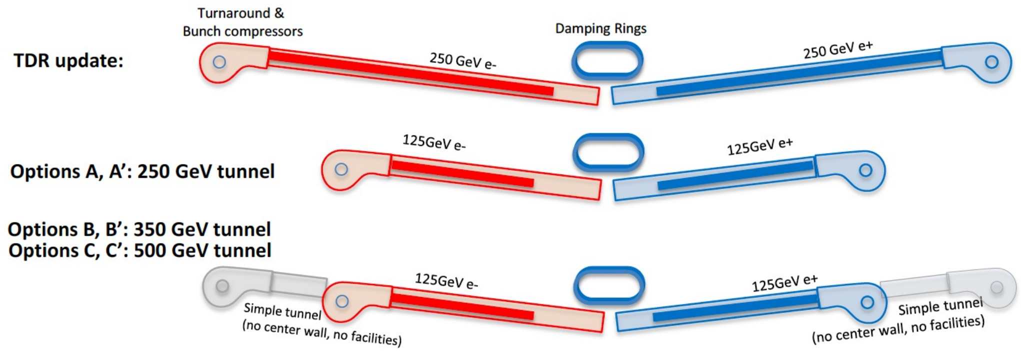


Figure 3-1 Staging options.

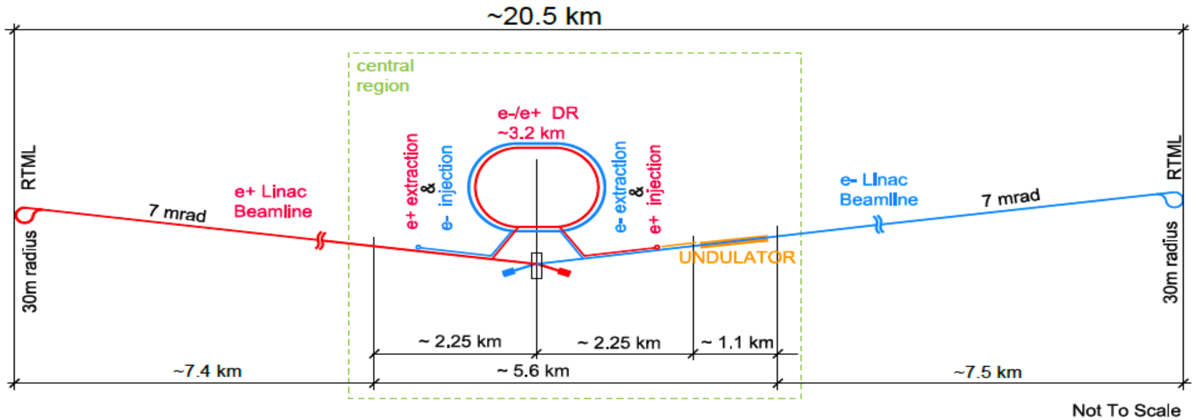
Table 3-1: Summary of baseline configurations.

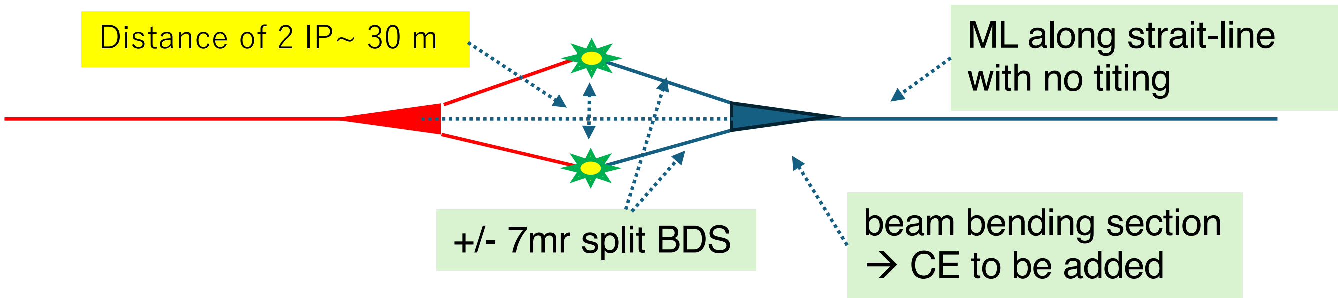
Options	Gradient [MV/m]	E_{CM} [GeV]	Total E_{CM} Margin	n	Space margin	Reserved tunnel (each end)	Total tunnel
TDR update	31.5	500	2%	10	1,473 m	0 m	33.5 km
Option A		250	6%	6	583 m	0 m	20.5 km
Option B				6&8		3,238 m	27 km
Option C				6&10		6,477 m	33.5 km
Option A'	35			6	1,049 m	0 m	20.5 km
Option B'				6&8		3,238 m	27 km
Option C'				6&10		6,477 m	33.5 km

ILC250: 2-IP Options?

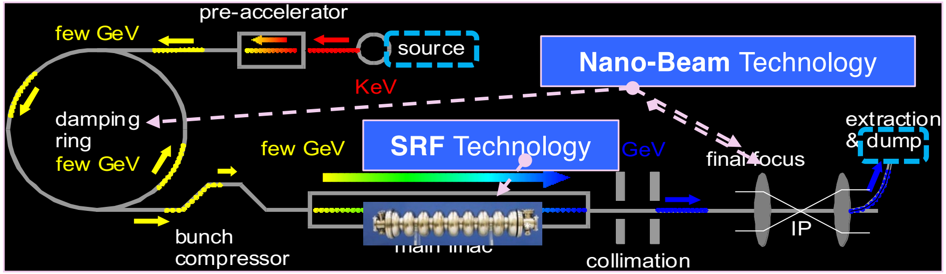
- Beam needs to be split at the upstream ends of BDS sections?
- Can we simple estimate the order of cost-increase with doubling the BDS , IR, Dump (+ some Common) value in the cost matrix?

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

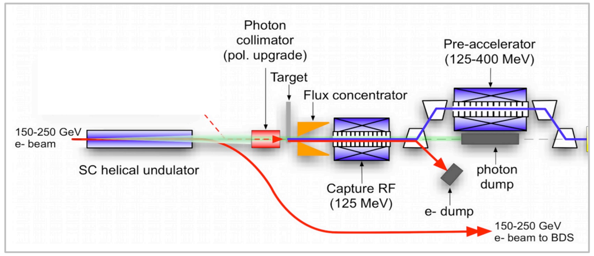




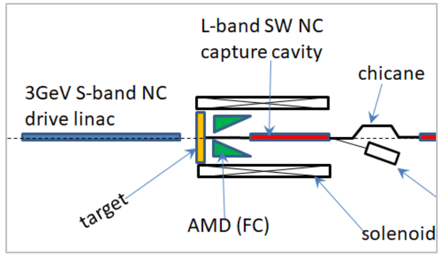
ILC Accelerator Sub-Systems and Functions



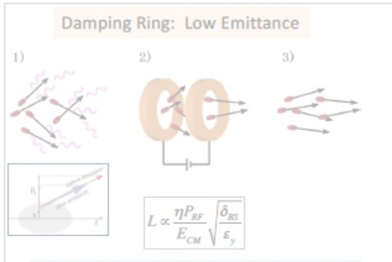
Undulator driven e+ source

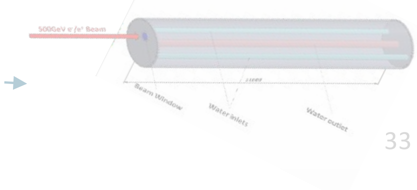


e-driven e+ source



- Creating particles → *Sources*
  - Polarized elections/positrons
- High quality beams → *Damping ring*
  - Low emittance beams
- Acceleration → *Main linac*
  - SRF
- Getting them collided → BDS / *Final focus*
  - Nano beams
- Go to → *Beam dumps*

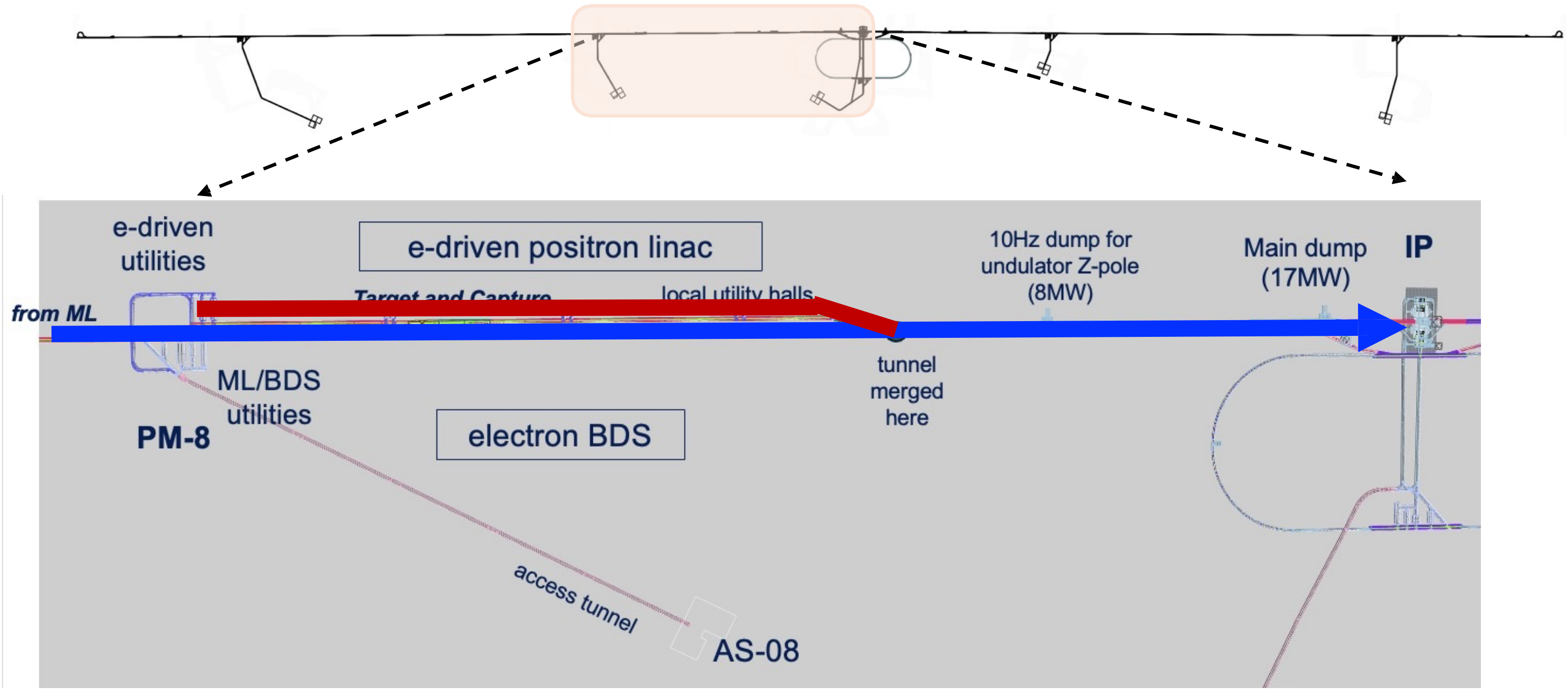




Courtesy: Terunuma

■Optional study: CFS cost for e-driven positron source

- The e-driven positron source is proposed as **an alternative option** since the TDR.
- We will **keep a place for the undulator positron source** even if we start with e-driven. It will enable the collision with polarized positron in the future.
- The e-driven accelerator will then require **its own tunnel with its service halls**. Its length will be 2 km.



Layout of the e-driven positron source

Courtesy: Terunuma