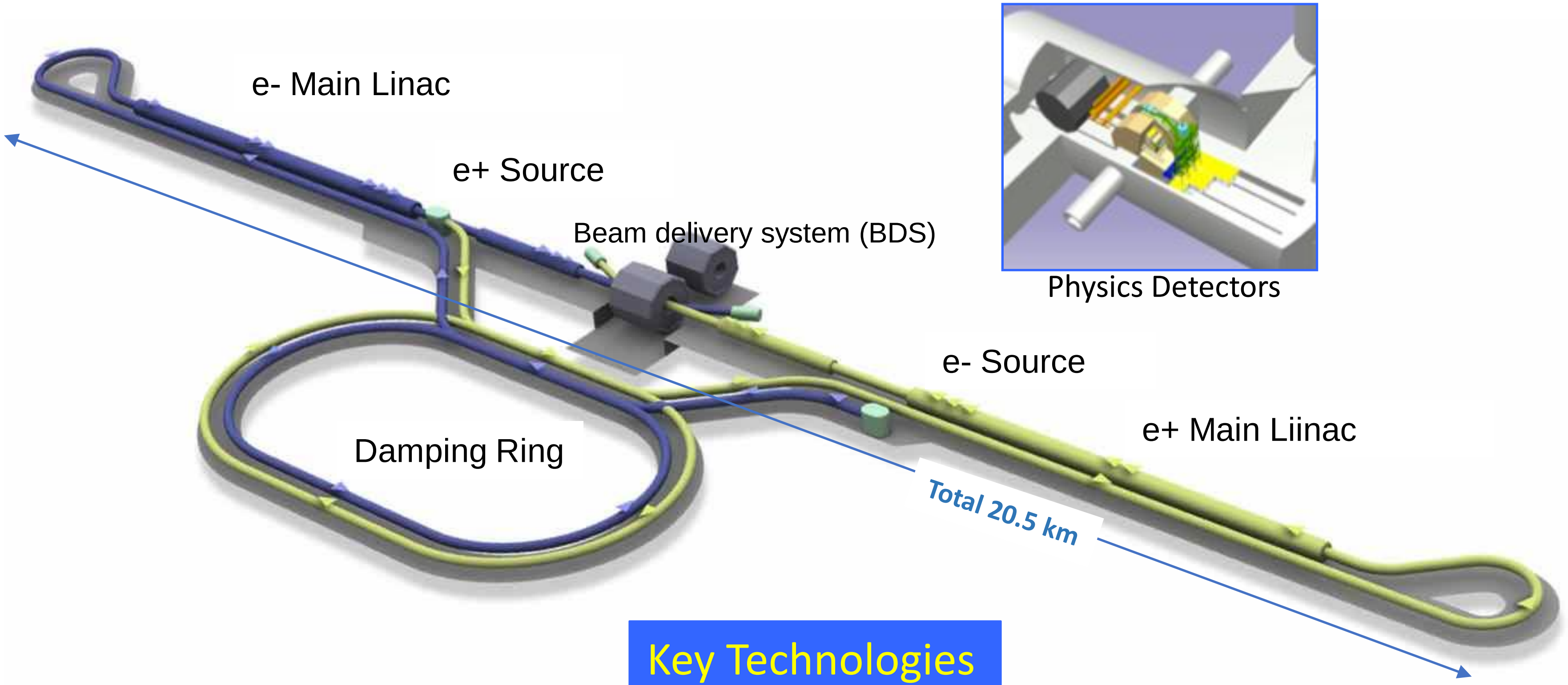
ILC 250 accelerator

Shin MICHIZONO

International Development Team (IDT) WG2/ KEK

- *ILC250 accelerator overview*
- *International Development Team (IDT)*
- *ILC area systems*
    - *Sources*
    - *Nano-beam*
    - *SRF*
- *Civil engineering*
- *Summary*

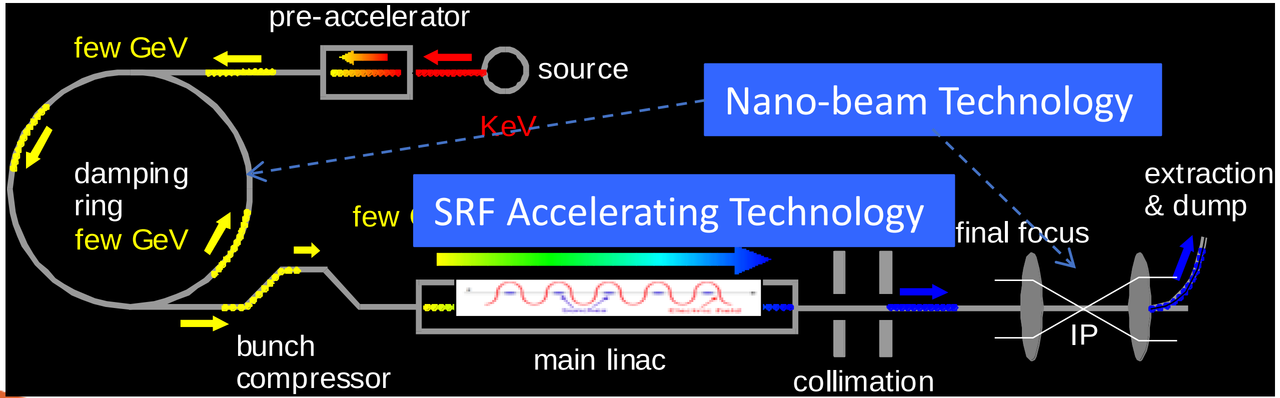
ILC250 accelerator facility



Physics Detectors

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

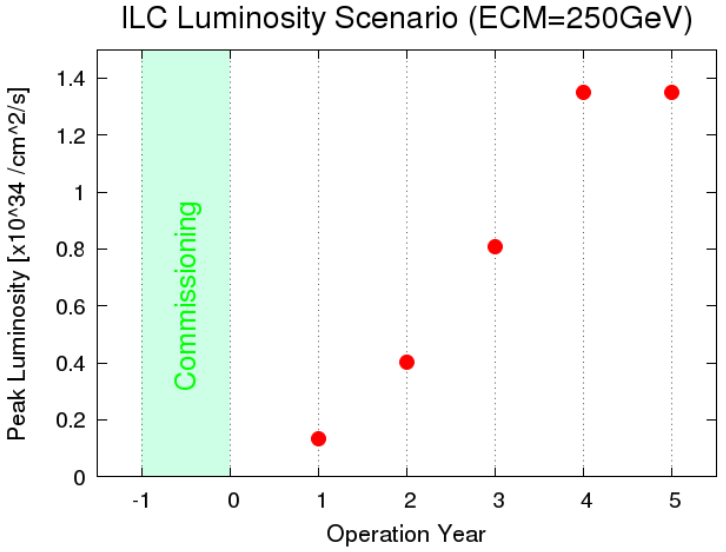
Key Technologies

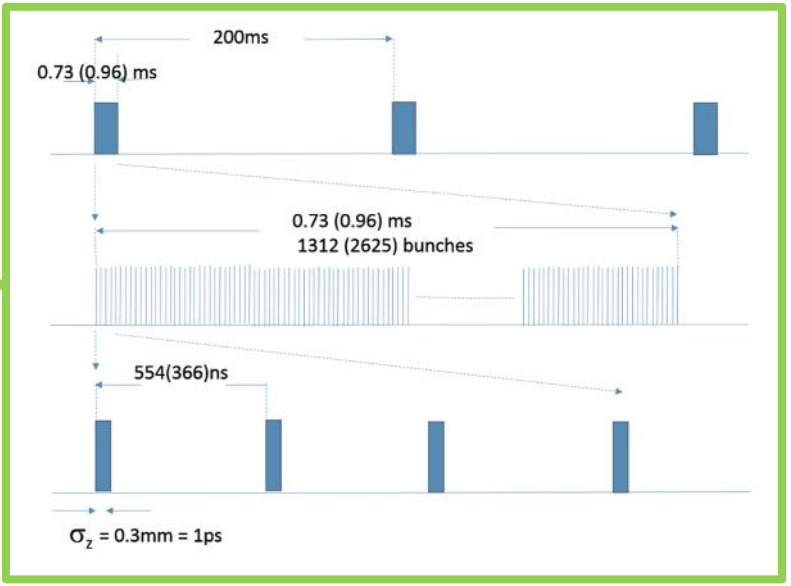


8,000 SRF cavities will be used.

ILC machine parameters

ILC	electron/positron	ILC250
Beam Energy	GeV	125 (e-) and 125 (e+)
Peak Luminosity (10^34)	cm-2 s-1	1.35
Int. Luminosity	ab-1/yr	0.24* ** 5,000-hour operation at peak luminosity*
Beam dE/E at IP		0.188% (e-), 0.150% (e+)
Transv. Beam sizes at IP x/y	nm	515/7.66
Rms bunch length /	cm	0.03 (σ_z)
beta*	mm	bx*=13mm, by*=0.41mm
Crossing angle	mrad	14
Rep./Rev. frequency	Hz	5
Bunch spacing	ns	554
# of bunches		1,312
Length/Circumference	km	20.5
Facility site power	MW	111
Cost (value) range	$B US	~5 (tunnel and accelerator)
Timescale till operations	years	(~1) + 4(prep.) + 9(construction)





Potential for upgrades

The ILC can be upgraded to higher energy and luminosity.

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

Energy

Lumi.

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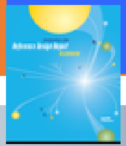
1.7.4 State of Technical Design Report

ilc international development team

2004

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



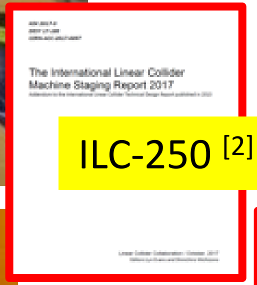
SC Technology selected

ILC-GDE | TDR | LCC

RDR)

Technical Design Phase

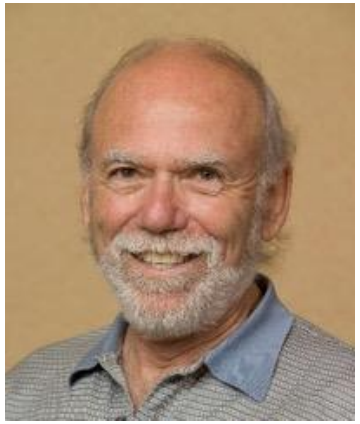
TDR [1]：
49 countries
392 institutions
>2400 researchers



ILC-250 [2]

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

Recommendations on ILC Project Implementation [3]



Barry Barish
GDE director
(the Nobel Prize winner for physics in 2017)

Lyn Evans
LCC director
(former LHC project manager)

LHC

European XFEL

LCLS-II

1.7.5 State of Proposal

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

Stage 1 International Development Team (~1.5 years)

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

Stage 2 ILC Pre-Laboratory (4 years)

ILC Lab. is established by governmental agreement.

Stage 3 ILC Laboratory (10 years for construction)

Stage 4 Experiment at ILC!

International Development Team (IDT)

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

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

Accelerator activities at ILC Pre-lab phase

Technical preparations & SRF R&D for cost reduction [shared across regions]

- SRF performance R&D, quality testing of a large number of cavities (~100), fabrication and shipping of cryomodules from North America and Europe (for validating shipping)
- Positron source final design and verification
- Nanobeams (ATF3 and related): Interaction region: beam focus, control; and Damping ring: fast kicker, feedback
- Beam dump: system design, beam window, cooling water circulation
- Other technical developments considered performance critical

Technical preparation

Final technical design and documentation [central office in Japan with a support from other labs]

- Engineering design and documentation, WBS
- Cost confirmation/estimates, tender and purchase preparation, transport planning, mass-production planning and QA plans, schedule follow up and construction schedule preparation
- Site planning including environmental studies, CE, safety and infrastructure (see below for details)
- Review office
- Resource follow up and planning (including human resources)

Engineering Design Report (EDR)

Preparation and planning of deliverables [distributed across regions coordinated by the central office]

- Prototyping and qualification in local industries and laboratories, from SRF production lines to individual WBS items
- Local infrastructure development including preparation for the construction phase (including Hub.Lab)
- Financial follow up, planning and strategies for these activities

Planning and preparation of Hub lab.

Civil engineering, local infrastructure and site [mainly by the Japanese institutions]

- Engineering design including cost confirmation/estimate
- Environmental impact assessment and land access
- Specification update of the underground areas including the experimental hall
- Specification update for the surface building for technical scientific and administrative needs

Civil engineering

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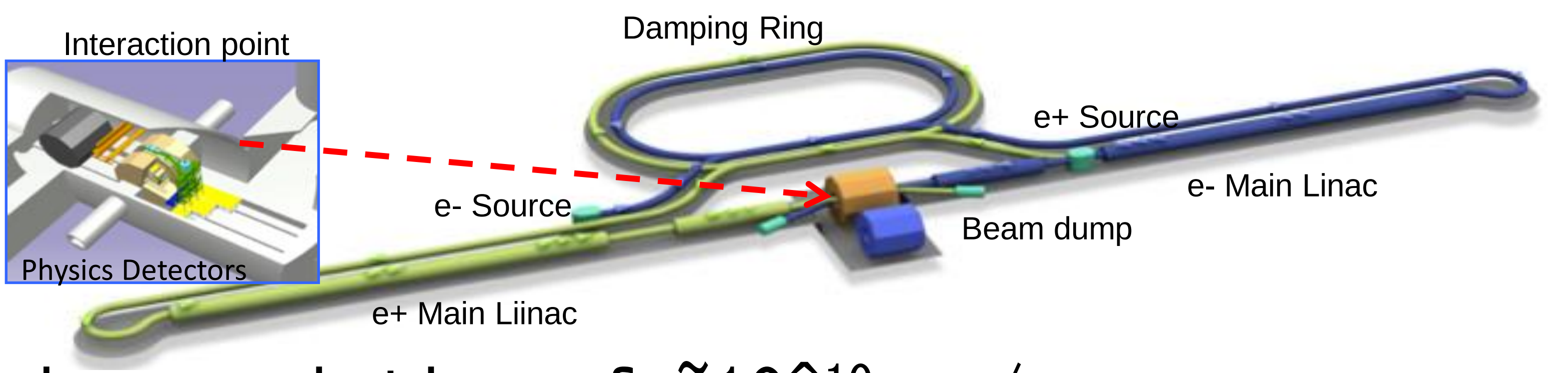
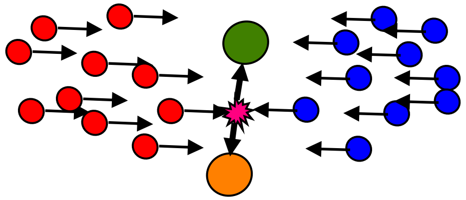
Area systems of the ILC

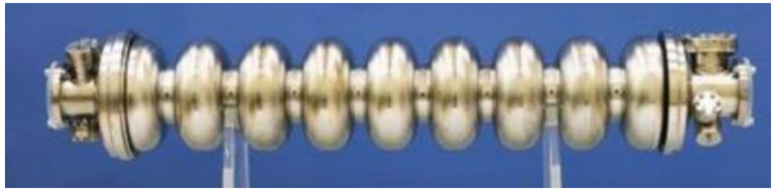


bunch, consisting of ~10^10 e+/e−

- Creating particles **_Sources_**
  - polarized elections/positrons
- High quality beams **_Damping ring_**
  - Low emittance beams
    - Small beam size (small beam spread)
    - Parallel beam (small momentum spread)



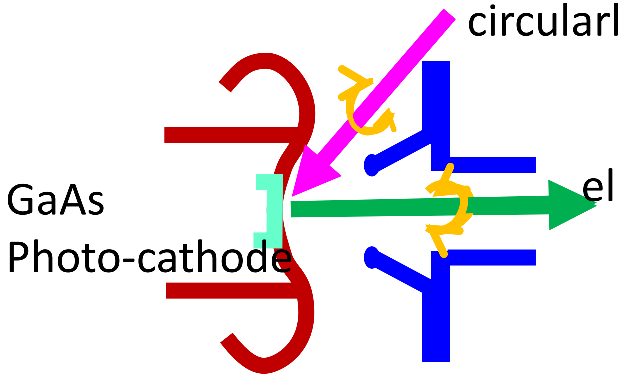
- Acceleration **_Main linac_**
  - superconducting radio frequency (SRF)



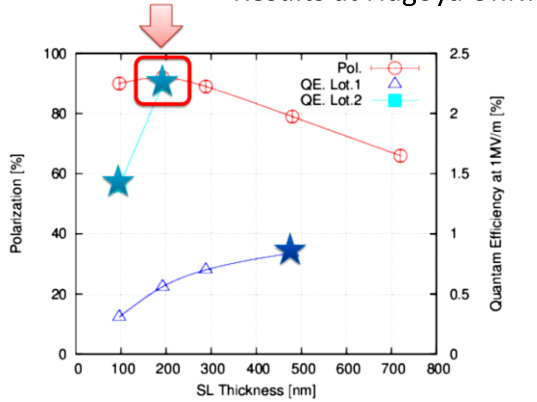
- Getting them collided **_Final focus_**
  - nano-meter beams
- Go to **_Beam dumps_**

Beam sources -electron/positron-

Polarized electron beams

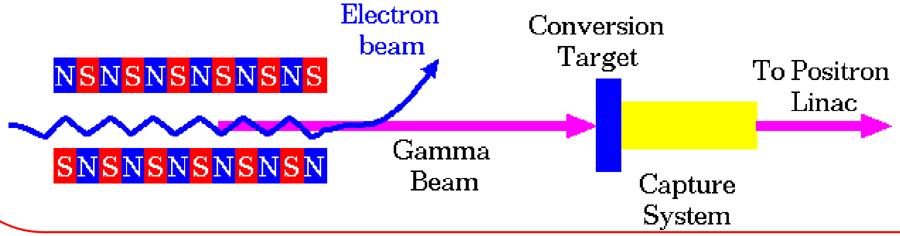


$$P \equiv \frac{N_L - N_R}{N_L + N_R} > 0.8$$



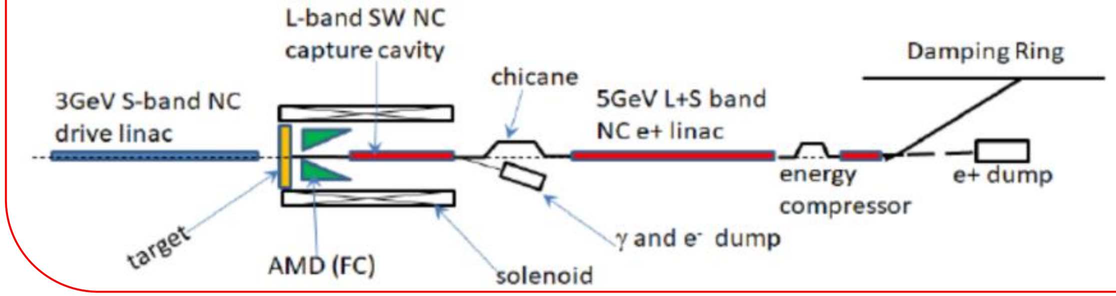
Undulator positron source

125 GeV electrons are injected to the helical undulator. The photons produced at the undulator is used for the electron/positron pair creation at the rotating target. Polarized positrons can be generated.

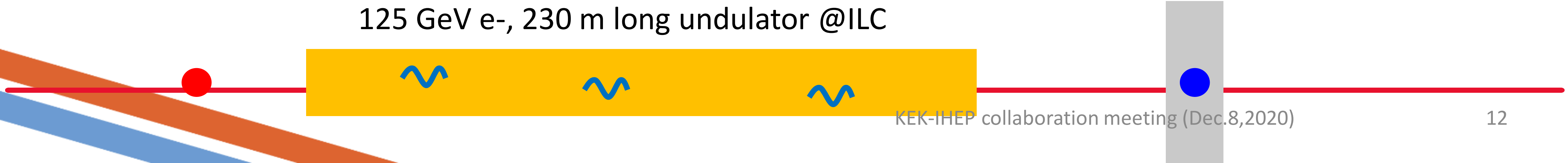


Electron driven positron source

Extra 3GeV linac is used for the positron generation. High energy electrons are not necessary. (Electron independent commissioning is possible. However, polarization is not available.)



125 GeV e-, 230 m long undulator @ILC



Nano-beam R&D at ATF2

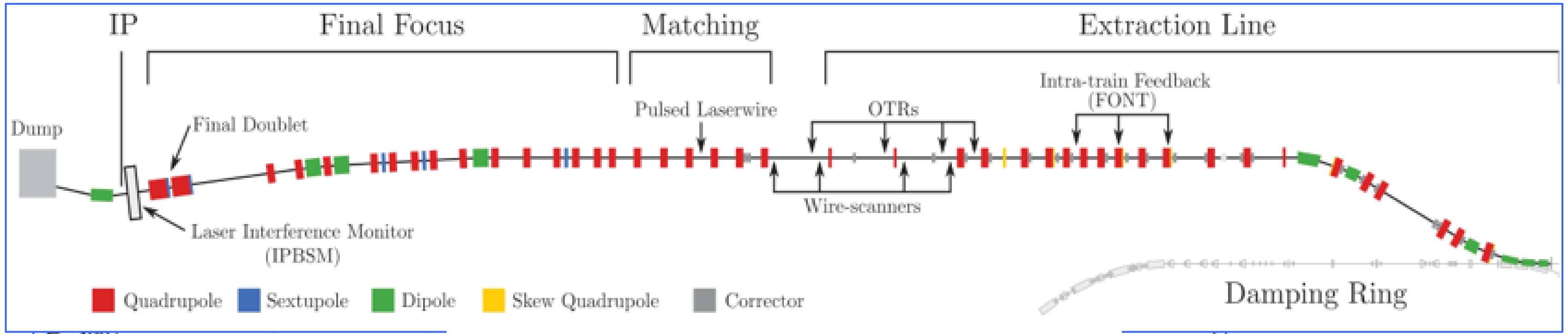
Institute of High Energy Physics, Chinese Academy of Sciences · Fermilab · KOREA UNIVERSITY · THE UNIVERSITY OF TOKYO 東京大学 · SLAC NATIONAL ACCELERATOR LABORATORY · IFIC INSTITUT DE FÍSICA CORPUSCULAR · ROYAL HOLLOWAY UNIVERSITY OF LONDON · UNIVERSITY OF OXFORD · lapp Laboratoire d'Annecy-le-Vieux de Physique des Particules · LAL LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE · CERN

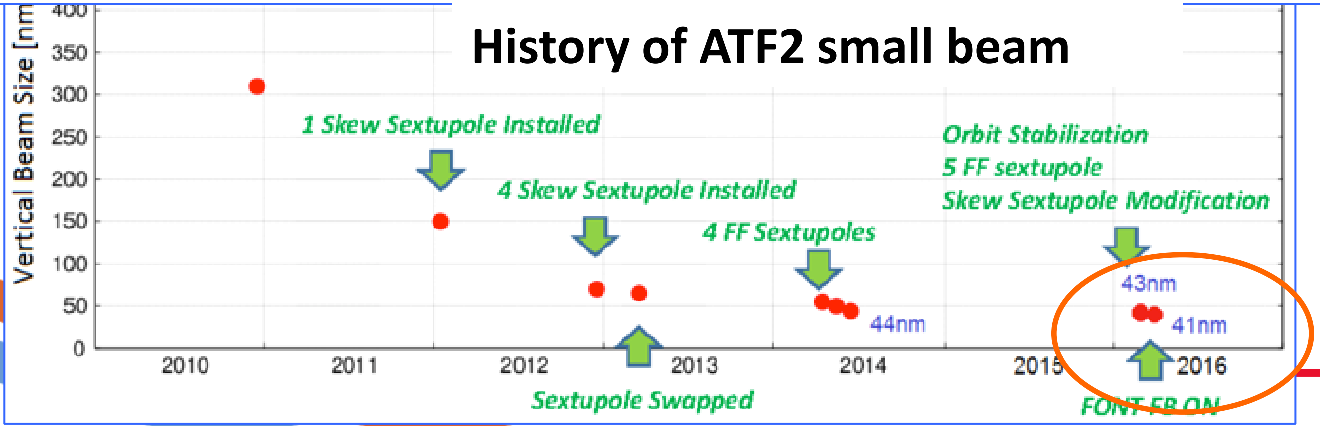
Goal 1: Establish the ILC final focus method with same optics and comparable beamline tolerances

ATF2 Goal : **37** nm → ILC **7.7** nm (ILC250); achieved **41 nm** (2016)

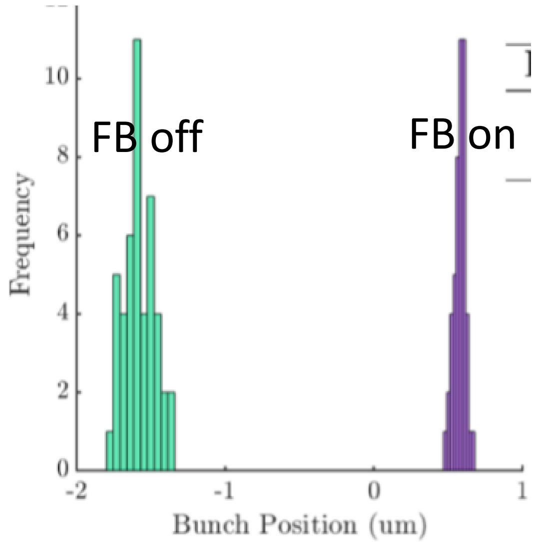
Goal 2: Develop the position stabilization for the ILC collision

- **FB latency 133 nsec achieved** (target: < 366 nsec)
- **positon jitter at IP: 106 → 41 nm (2018)** (limited by the BPM resolution)

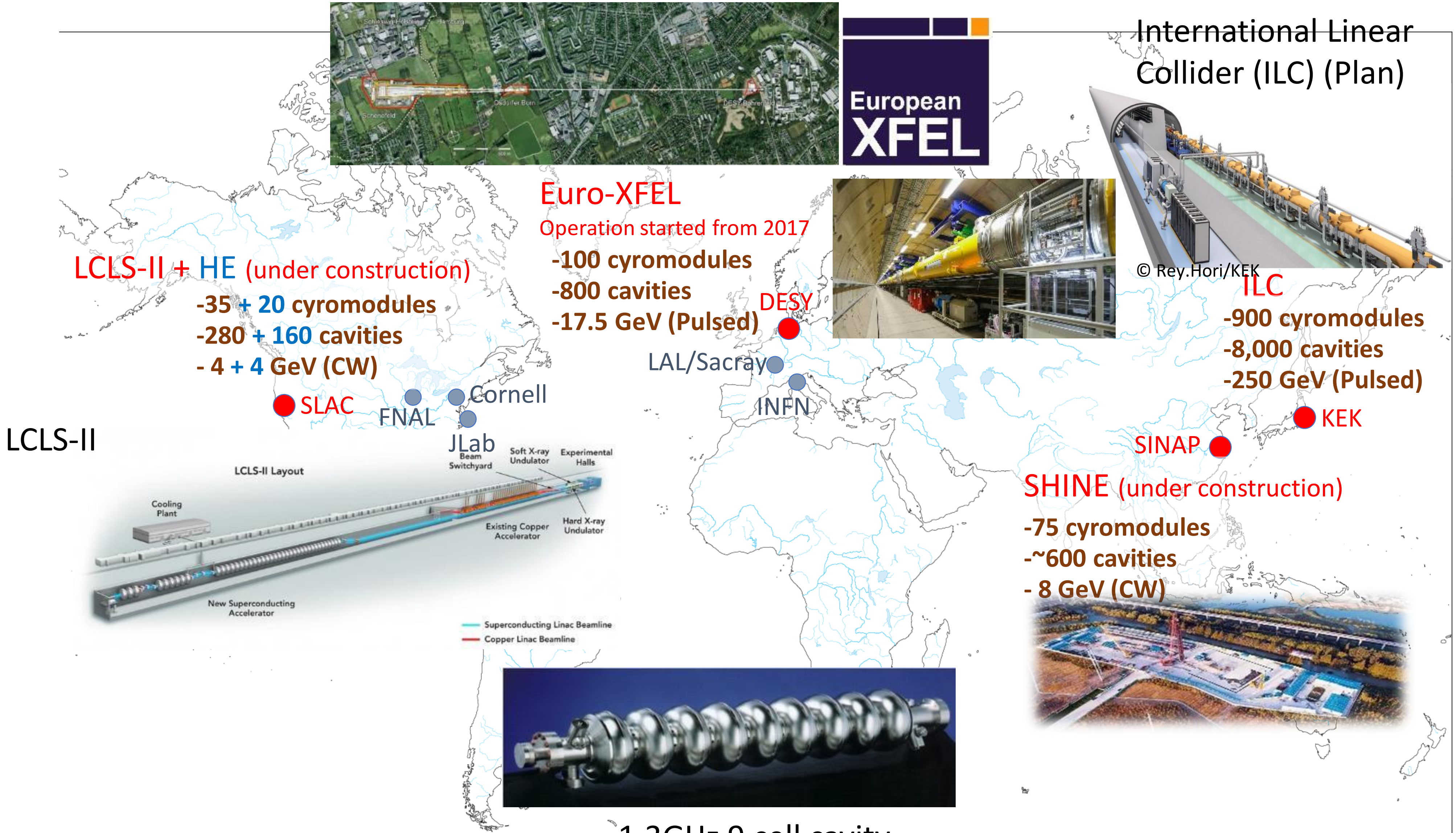




Nano-meter stabilization at IP (2018)



Worldwide large scale SRF accelerators



1.3GHz 9 cell cavity

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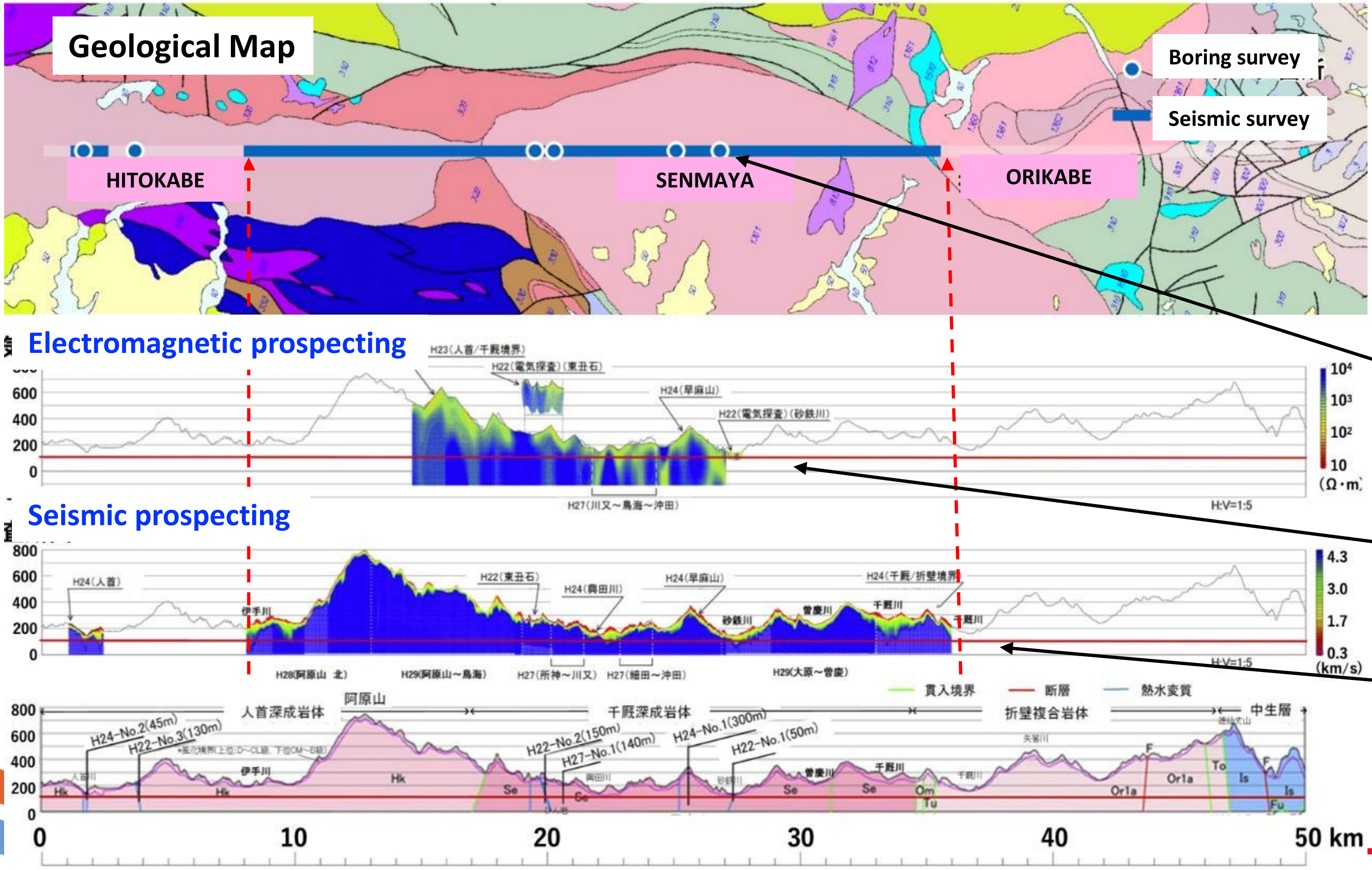
Geological Surveys for ILC: Kitakami Mountains

ILC-250 (20.5 km)



- Continuous **granite region**

  HITOKABE, **SENMAYA** and **ORIKABE** bedrock

- **Have capability to extend the ILC up to 50 km in future**

- **Boring geological survey**

  → Direct sampling down to the accelerator depth

- **Electromagnetic prospecting**

  → Cracks in the rock

- **Seismic prospecting**

  → Rock hardness

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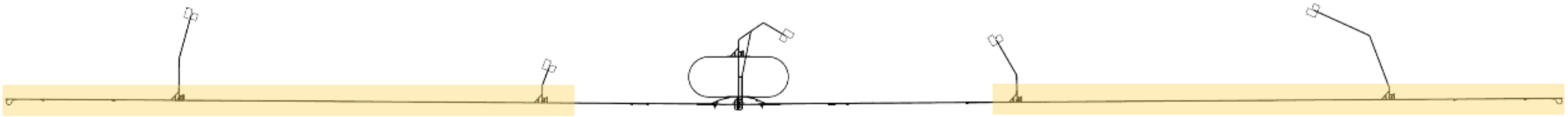
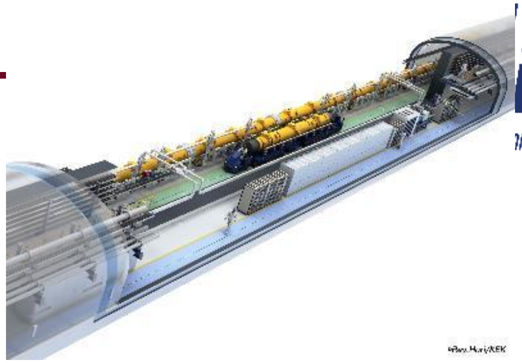
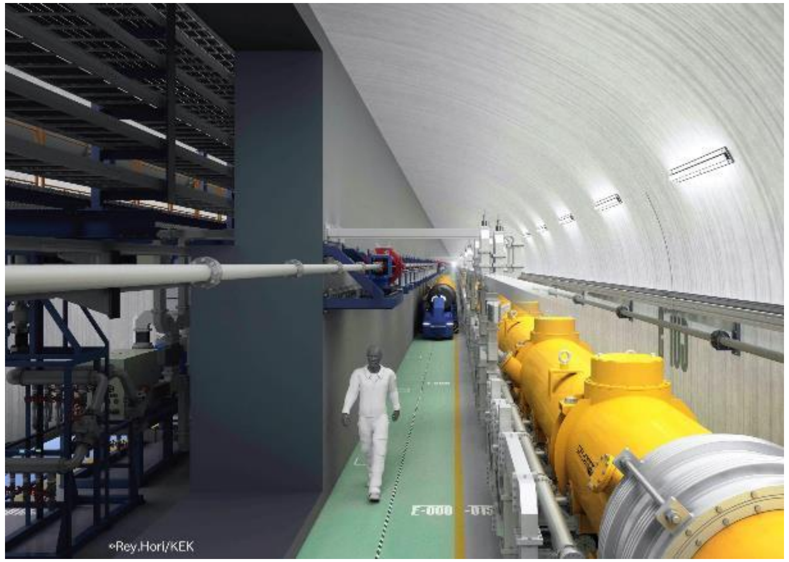
Main Linac (ML) tunnel

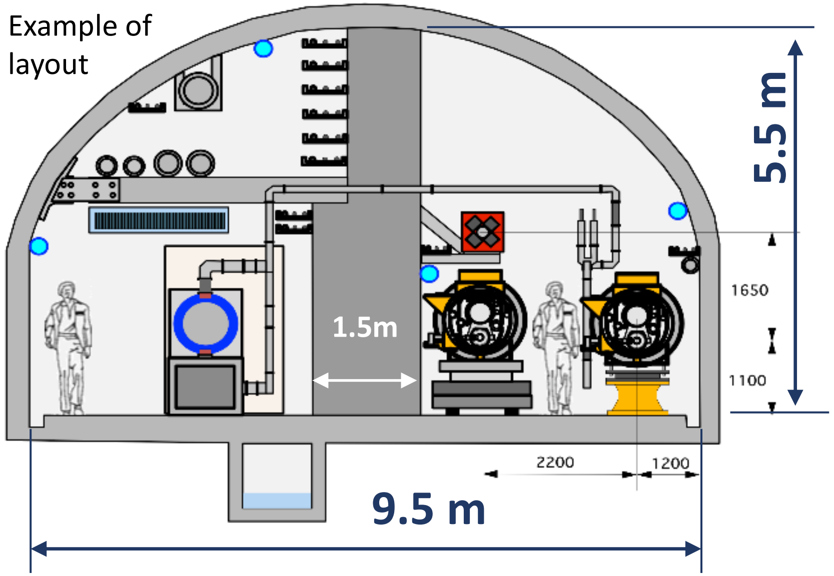




- 15 km in (e+e-) total
- follow the geoid in vertical
- **Kamaboko 9.5m X 5.5m**
- **1.5m central radiation shield**
- Further optimization will be done.



Example of layout



- **66 kV distribution cables**
- **Colling water pipes**
- Fan Coil Units
- Low power and signal cables
- **RF klystrons and modulators**
- **Electric Power Stations**

- **ML Cryomodules**
- **RTML**
- Low power and signal cables

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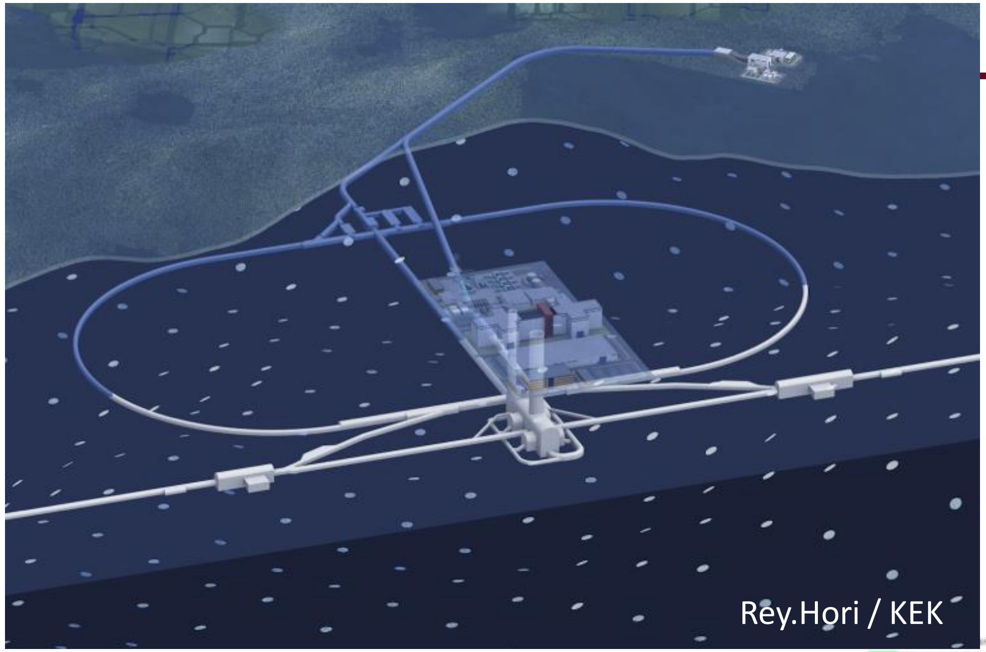
Damping Ring



- Circumference: 3.2km
- Start with two rings
- Arc section: **single tunnel, no central shield.**
- Straight section: **Kamaboko with a central shield** (3.5m in TDR).

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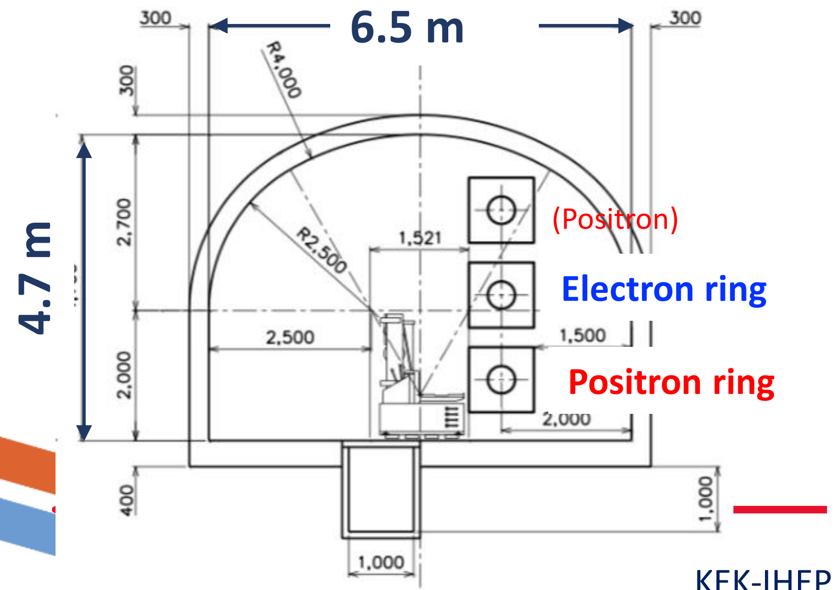
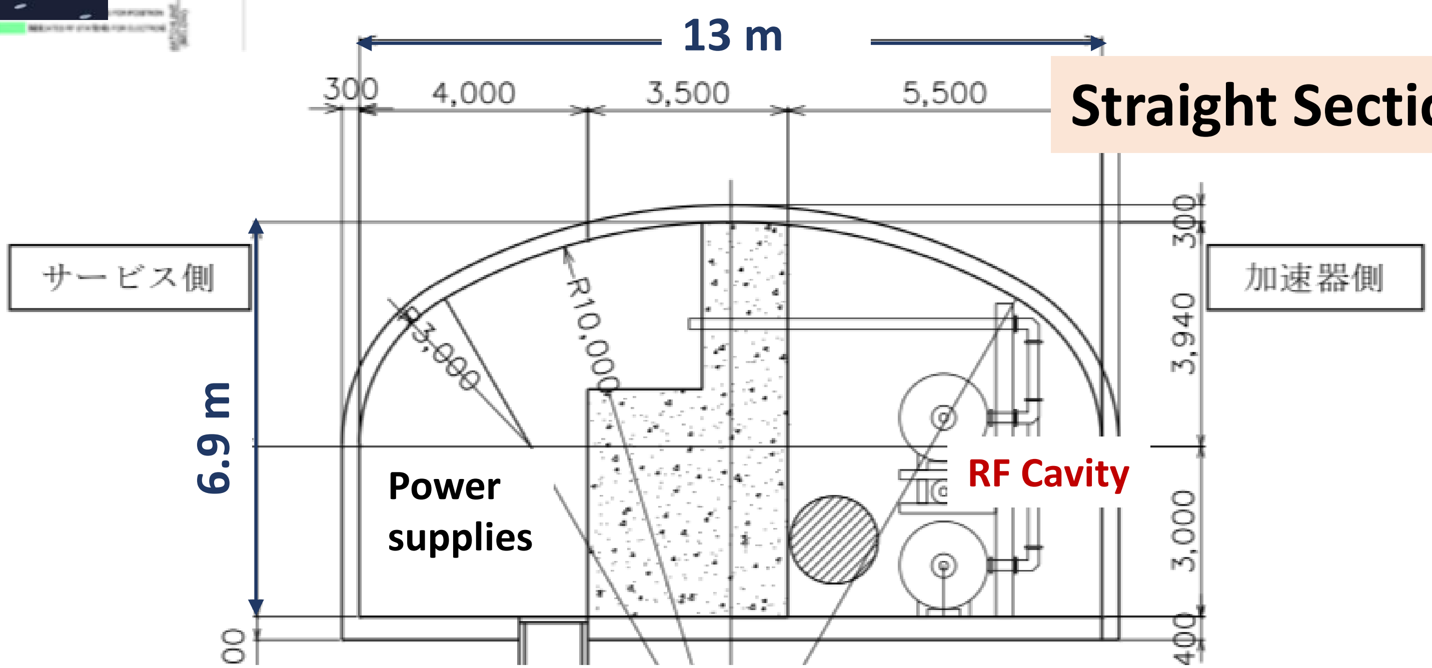
Arc Section



Straight Section



Interaction Point (IP)

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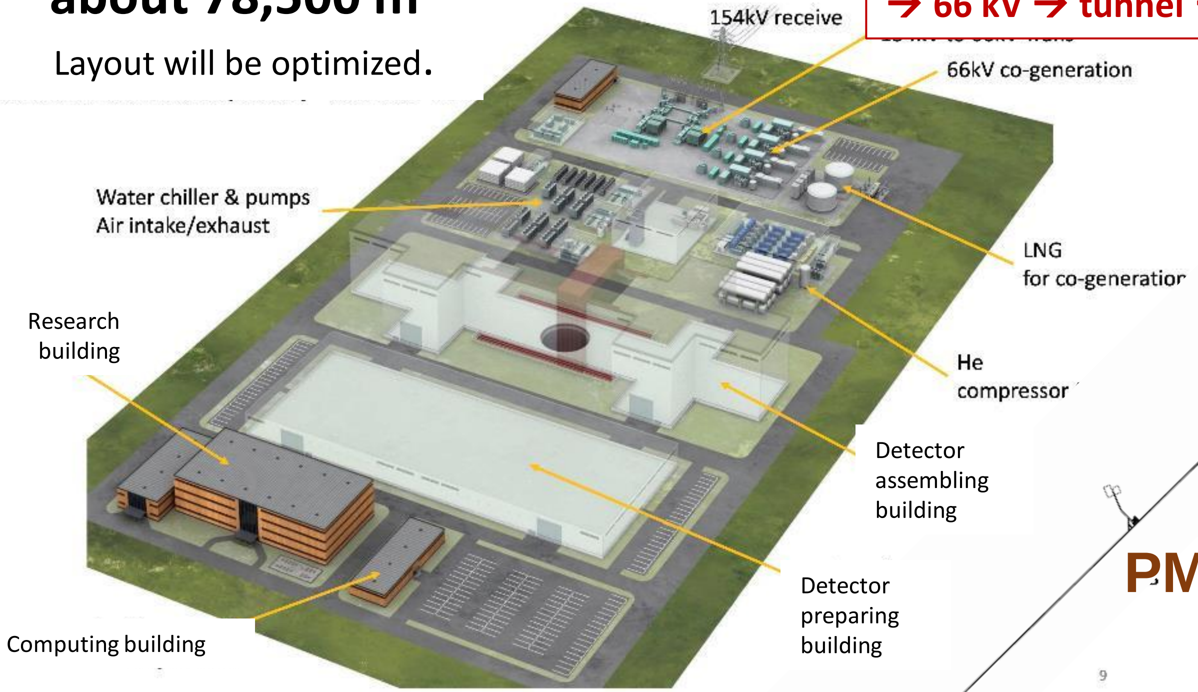
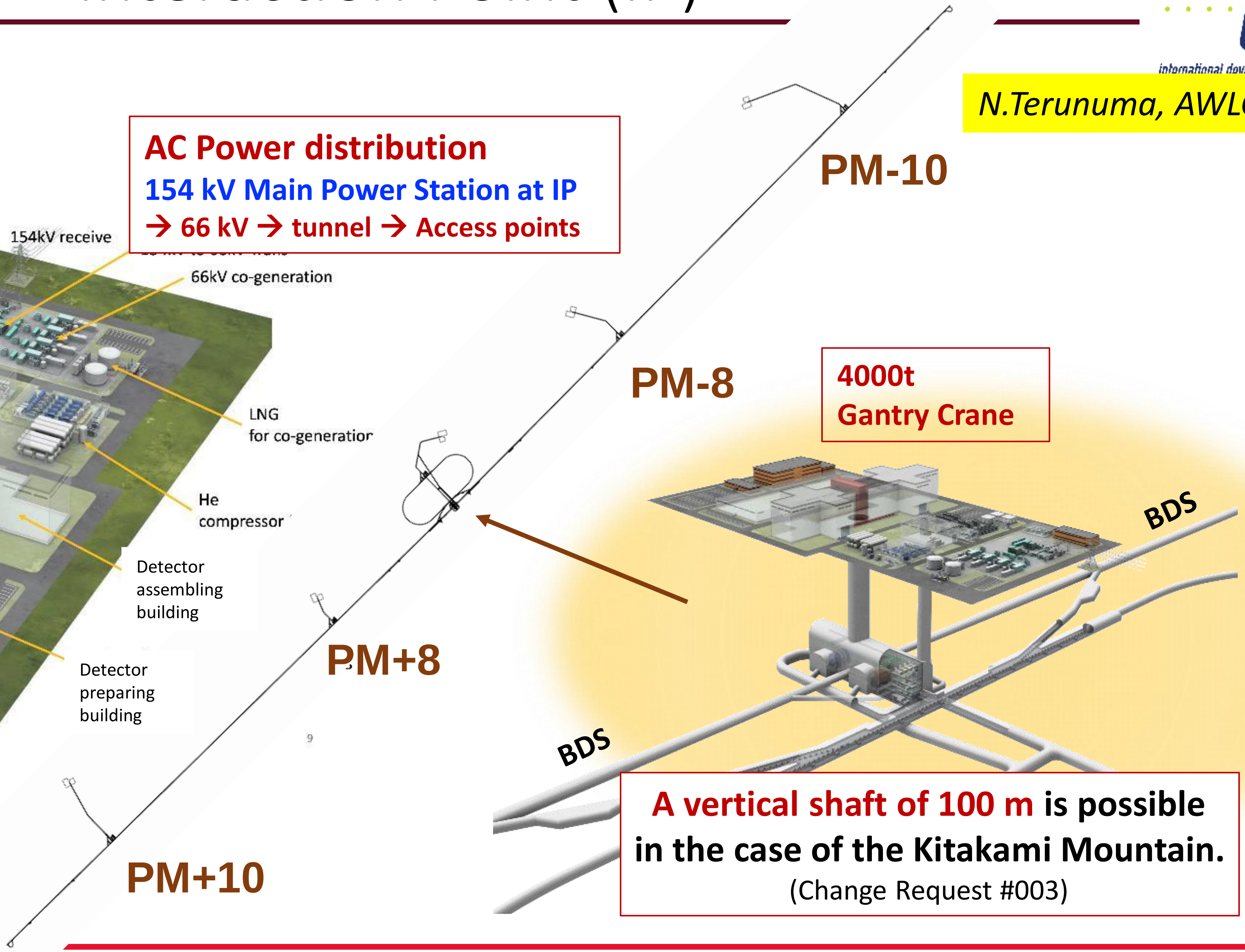
IP surface area
about 78,500 m^2

Layout will be optimized.



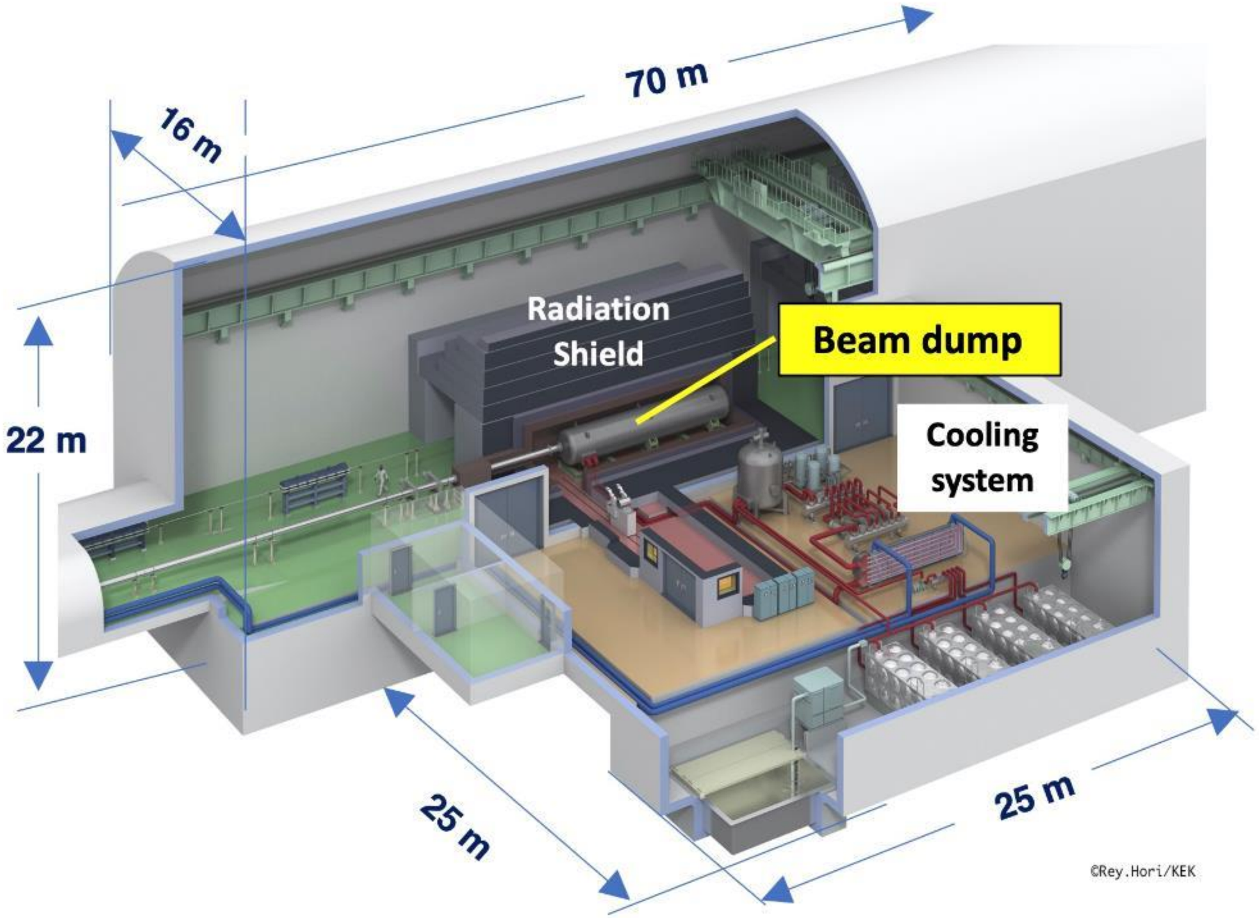
AC Power distribution
154 kV Main Power Station at IP
→ 66 kV → tunnel → Access points



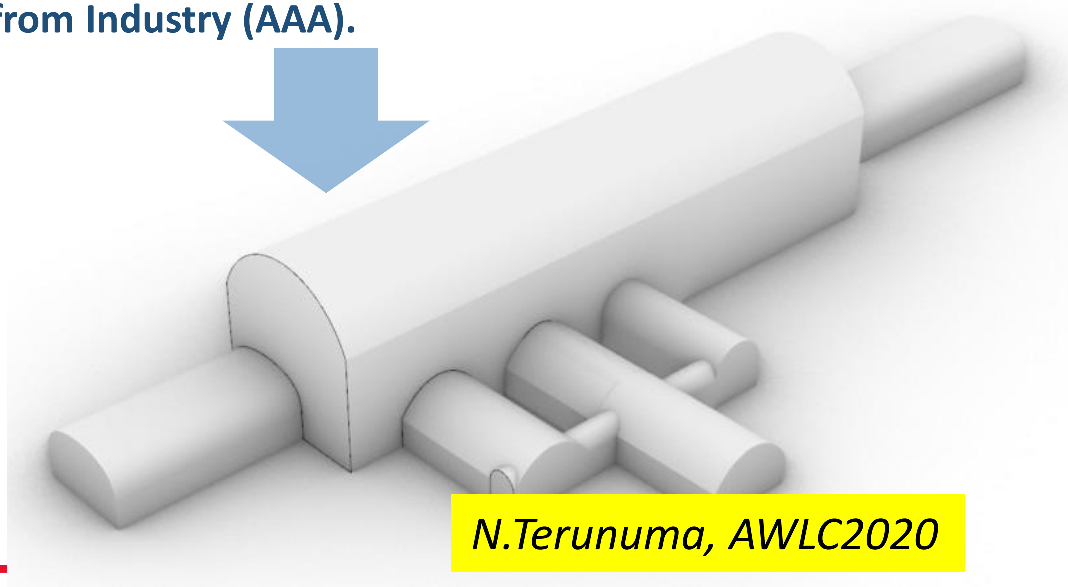
4000t
Gantry Crane

A vertical shaft of 100 m is possible in the case of the Kitakami Mountain.
(Change Request #003)

Cavern for Main Beam Dump



- **Three big caverns**
  - Two main beam dumps
  - e- dump for undulator, low energy collision (5 x 5 Hz)
- The main beam dump has been designed for **1 TeV collisions.**
  - **5 m thick concrete shield in all directions**
  - **17 MW power cooling (wider utility hall)**
  - **¼ volume of detector hall**
- **The civil engineering design is updating with experts from Industry (AAA).**



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Summary

- *ILC250 accelerator is 20 km long e-/e+ collider for the Higgs factory.*

- *We assume 4-year preparation and 9-year construction.(now we are at pre-preparation phase (IDT))*

- *The ILC is upgradable in energy and luminosity.*

- *Preparation phase activities are*
    - *Technical preparation*
    - *Final engineering design*
    - *Planning and preparation of Hub lab.*
    - *Civil engineering survey*
    - *Human resources for ILC construction …*

- *Key technologies at the ILC are superconducting rf (SRF) and nano-beam.*
    - *SRF technology has been widely adopted at XFELs such as European XFEL.*
    - *Nano-beam technology has been demonstrated at ATF hosted by KEK*

- *Civil Engineering study is on-going.*

Thank you for your attention