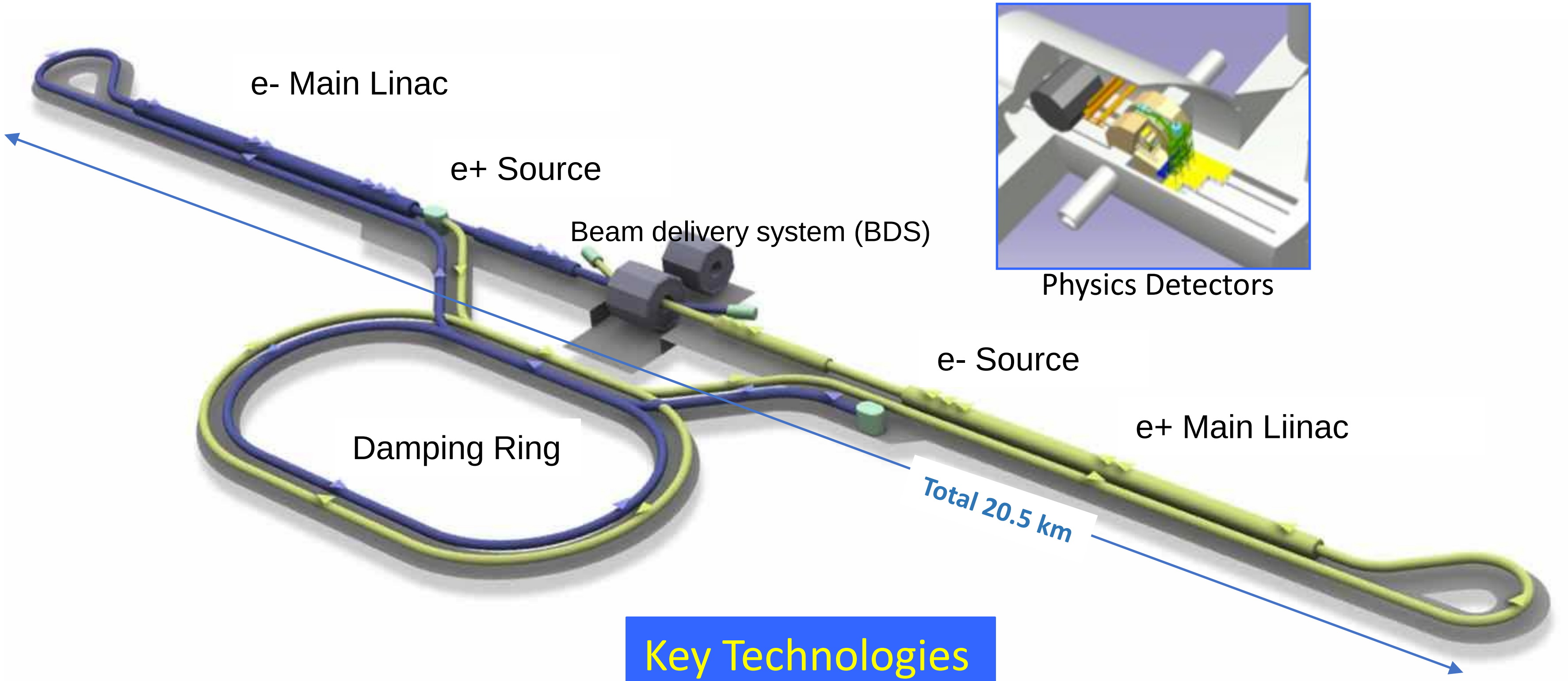
ILC 250 accelerator

Shin MICHIZONO

International Development Team (IDT) WG2/ KEK

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

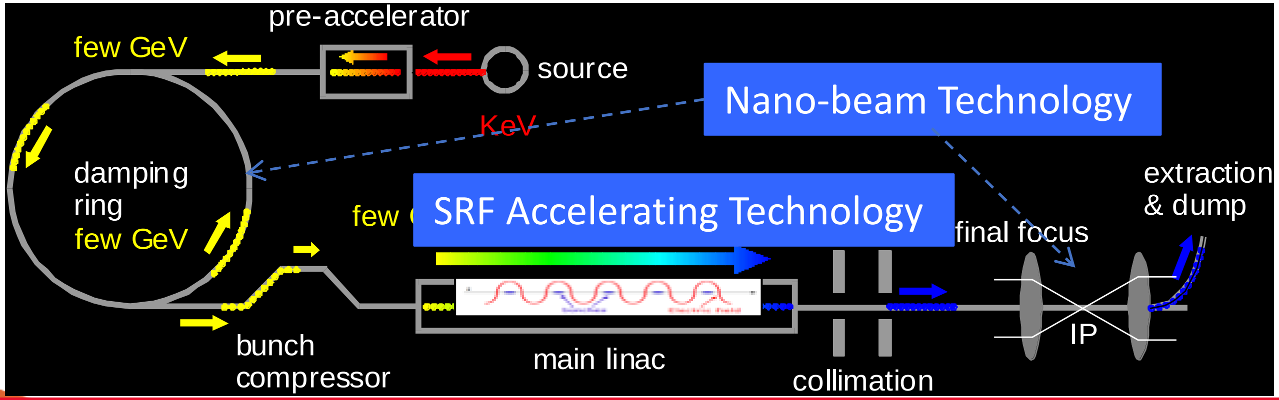
ILC250 accelerator facility



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. Q_0	31.5 MV/m (35 MV/m) Q_0 = 1x10 ^{10}

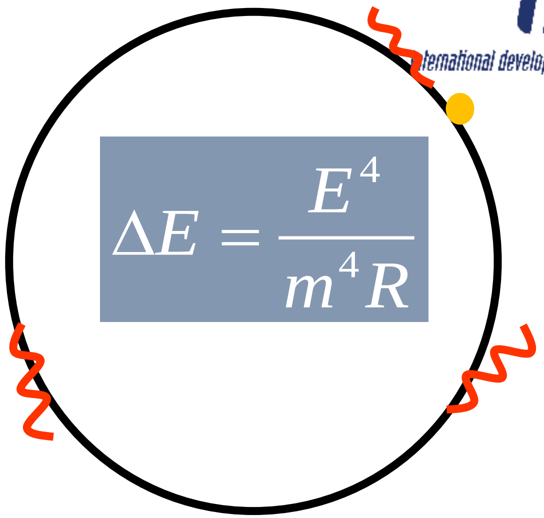
Key Technologies



8,000 SRF cavities will be used.

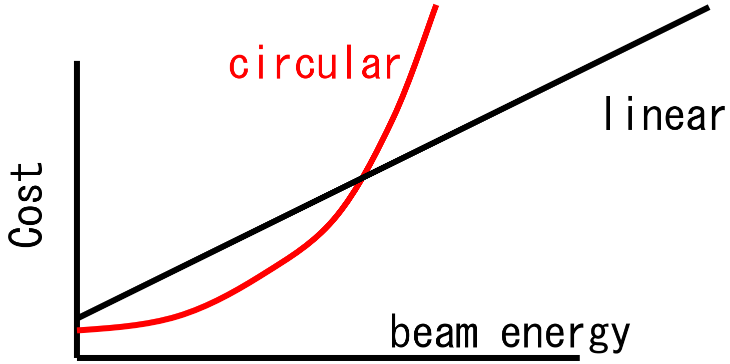
Main advantages

- A linear accelerator is more advantageous for accelerating electron and/or positron beams to higher energies.
- The spin of the electron and/or positron beam can be maintained during the acceleration and collision. This can help significantly improve measurement precision.
- The small surface resistance of the SRF accelerating structure (cavity) made of Nb enables the efficient power transfer from the AC power source to the beam.
- Further energy efficiency improvements are considered as part of the of Green ILC concept, which aims to establish a sustainable laboratory.



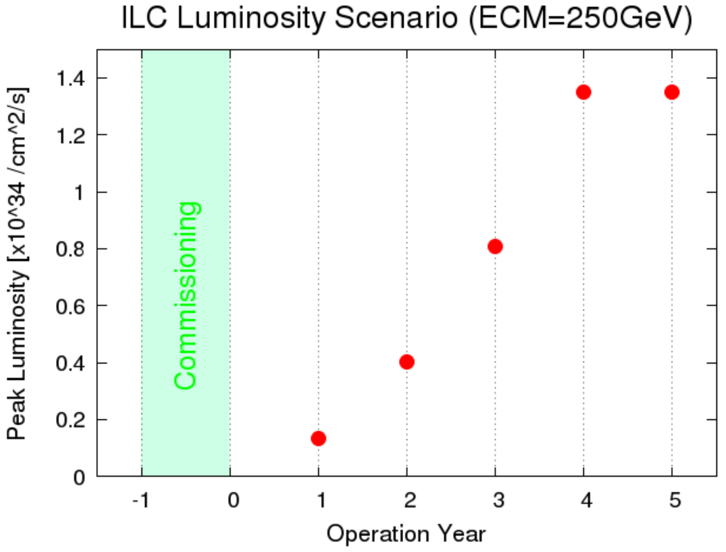
$$\Delta E = \frac{E^4}{m^4 R}$$

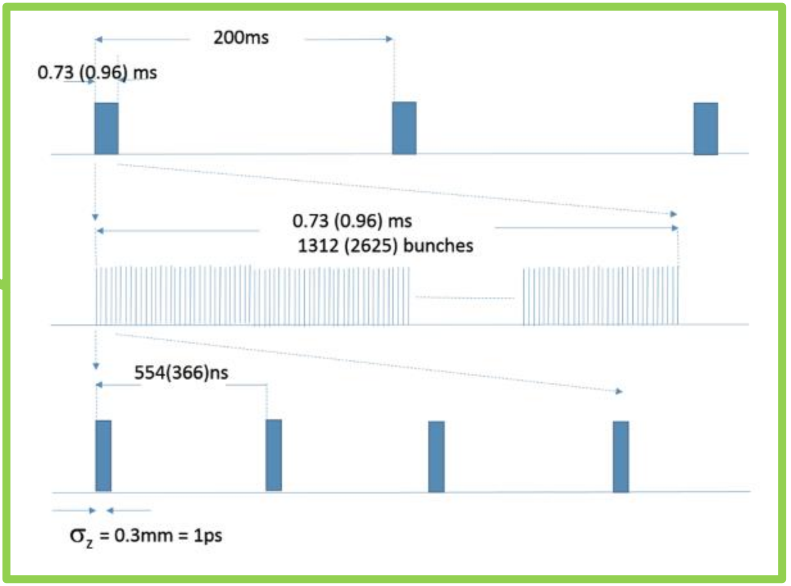
Circulating beam loses energy by synchrotron radiation.
Linear collider can extend its collision energy by longer tunnel/ higher gradient.



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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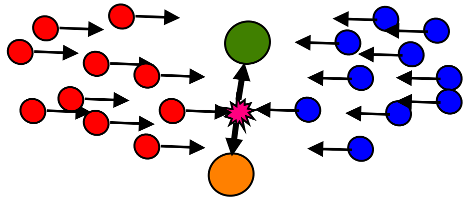
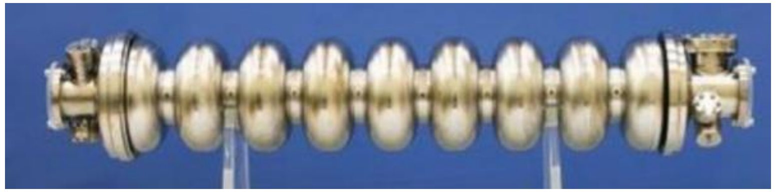
Area systems of the ILC

bunch, consisting of ~10^10 e+/e−

- Creating particles — ***Sources***
  - polarized elections/positrons



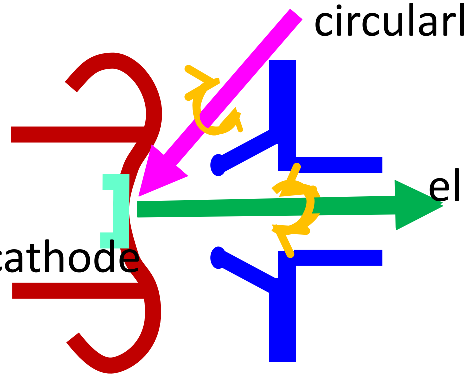
- High quality beams — ***Damping ring***
  - Low emittance beams
    - Small beam size (small beam spread)
    - Parallel beam (small momentum spread)
- Acceleration — ***Main linac***
  - superconducting radio frequency (SRF)



- Getting them collided — ***Final focus***
  - nano-meter beams
- Go to ***Beam dumps***

Beam sources -electron/positron-

Polarized electron beams

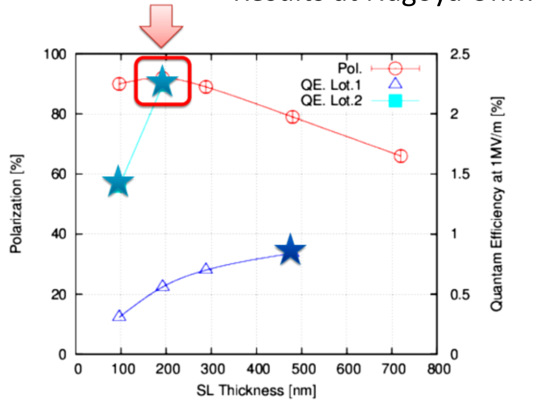


$$P \equiv \frac{N_L - N_R}{N_L + N_R} > 0.8$$

GaAs-GaAsP Strain–Compensated

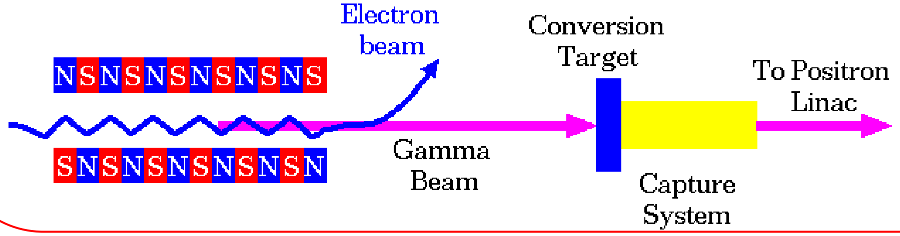
Max. Pol. (~ 92%)
QE(~ 2.2 %) were achieved

Results at Nagoya Univ.



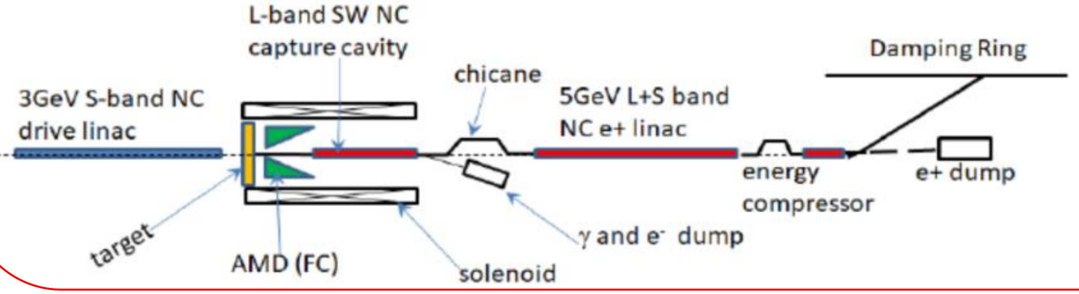
Undulator positron source

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

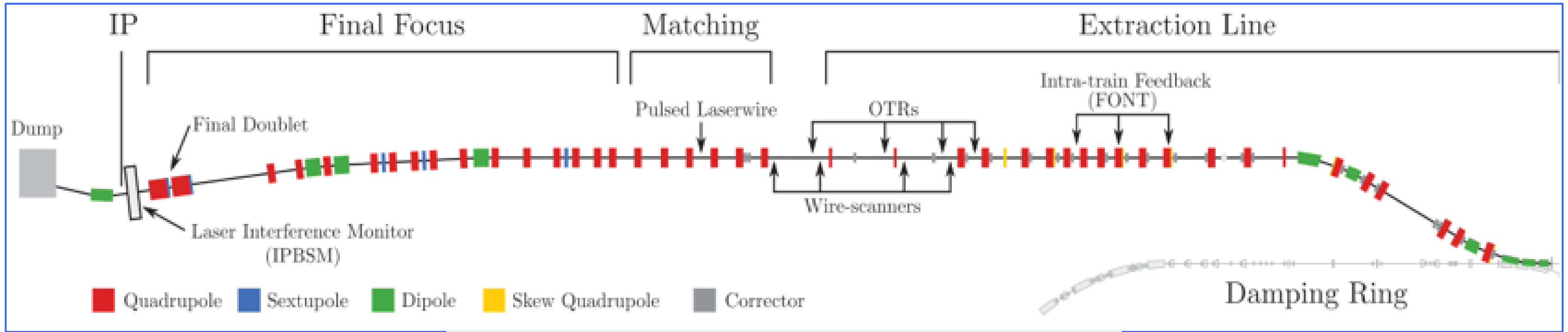
Nano-beam R&D at ATF2

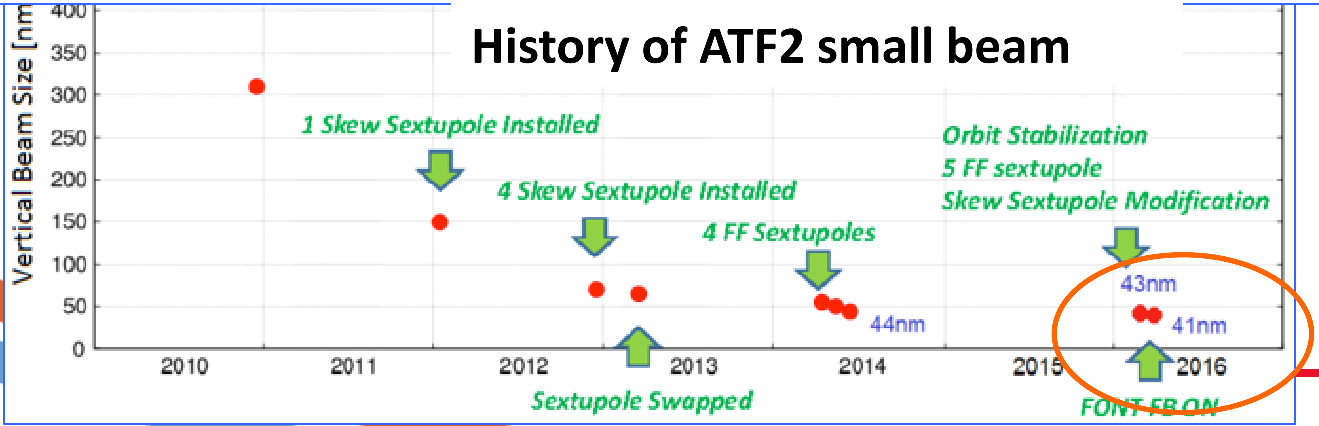
Goal 1: Establish the ILC final focus method with same optics and comparable beamline tolerances

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

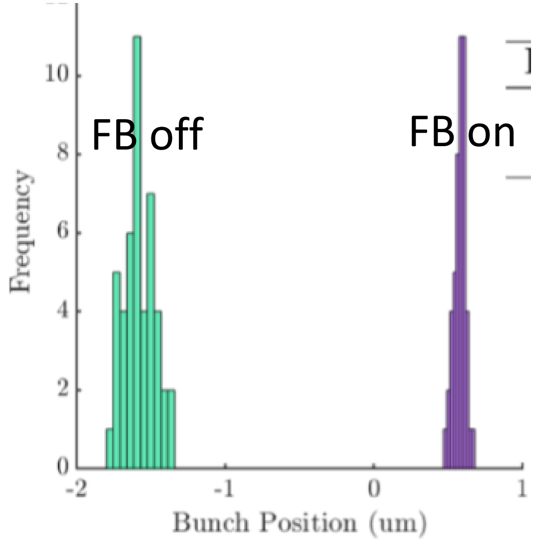
Goal 2: Develop the position stabilization for the ILC collision

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





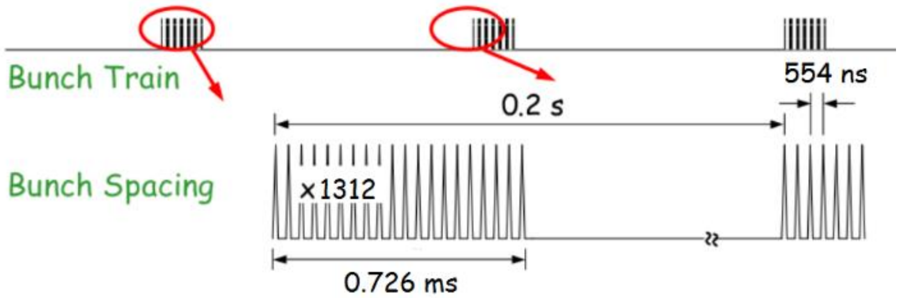
Nano-meter stabilization at IP (2018)



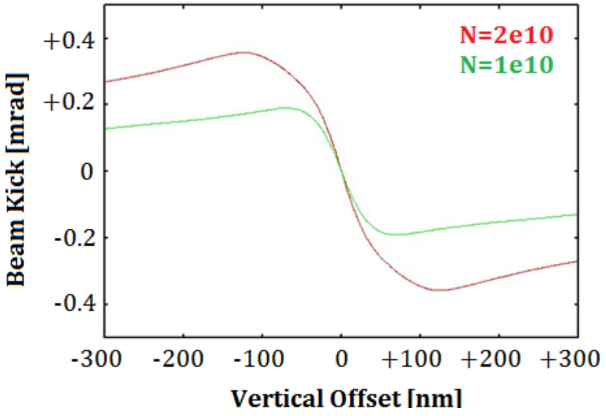
FONT* Bunch train feedback at final focus

*Feedback On Nanosecond Timescales by Oxford University
https://journals.aps.org/prab/abstract/10.1103/PhysRevAccelBeams.21.122802

ILC bunch structure

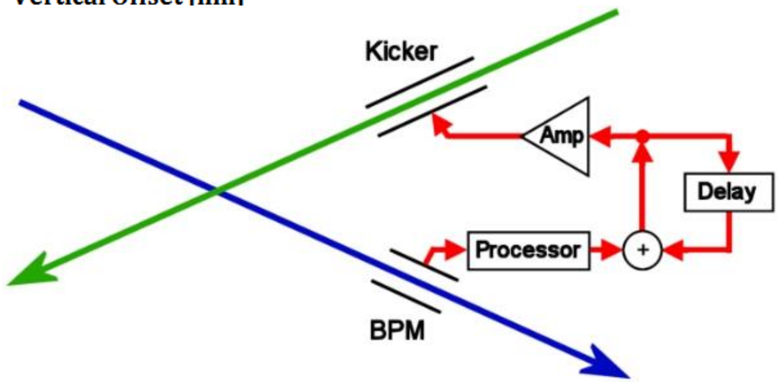


CAIN simulation

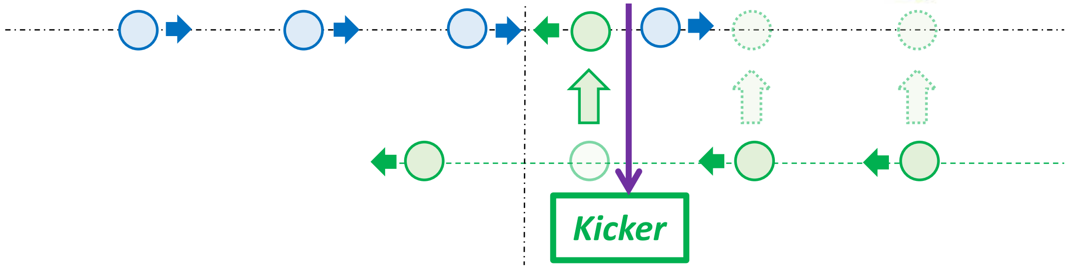


Depending on the relative position of the beam, beams are greatly scattered by the beam-beam effect.

The position of the beam between pulses shifts due to ground vibrations and equipment noise.
On the other hand, the position of the beam does not change significantly inside the bunch train.



Efficient beam collision can be achieved with high-speed feedback that measures the initial beam position of the bunch train and corrects the position of subsequent bunches in the train.
Feedback latency should be less than bunch space.



The first bunch does not collide, but the second and subsequent bunches will collide.

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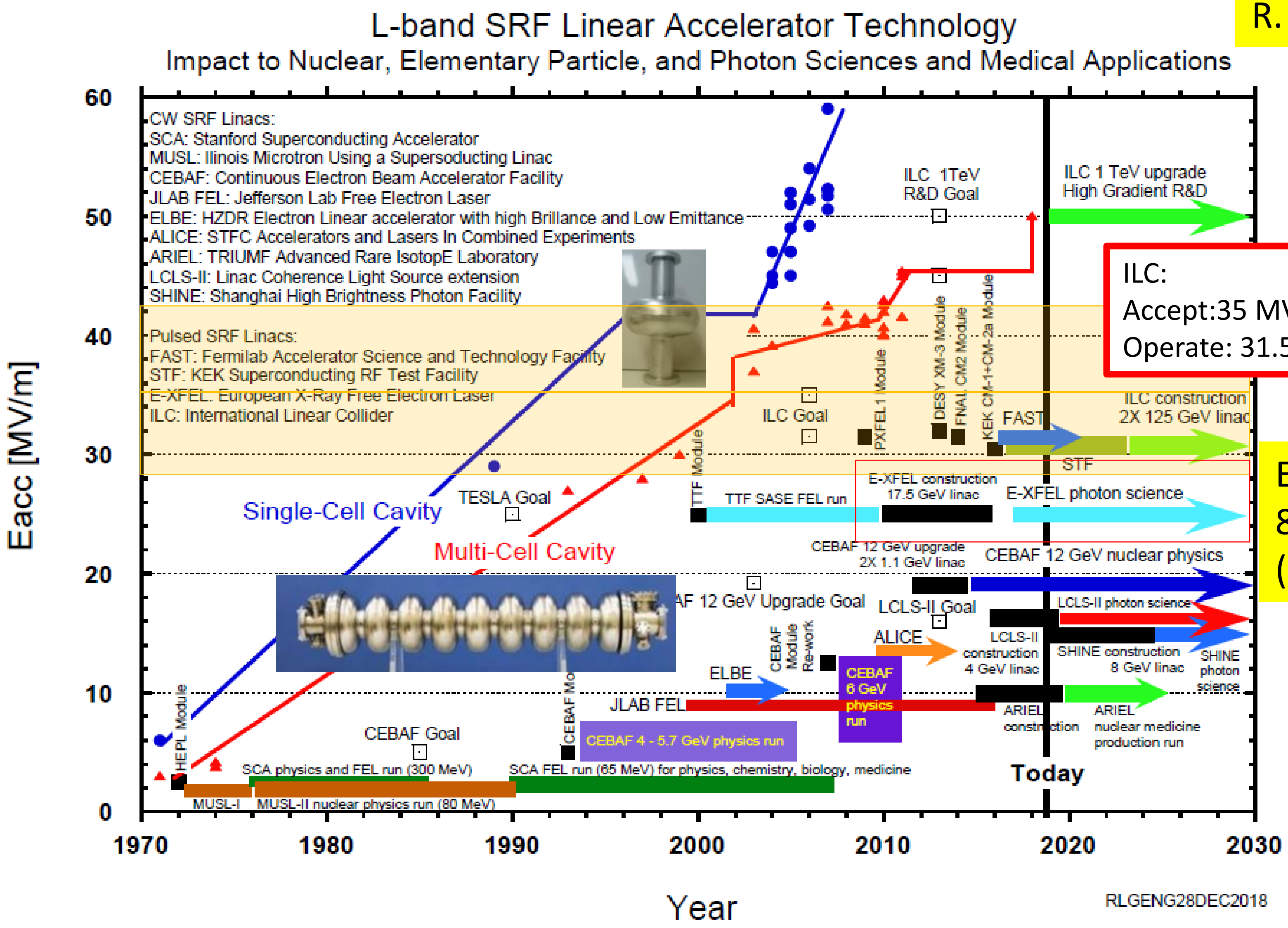
Matured SRF technologies

R. Geng (JLAB)



ILC:
Accept:35 MV/m +/-20%
Operate: 31.5MV/m +/-20%

European XFEL
800 cavities
(10% of ILC ML)

Worldwide large scale SRF accelerators

European XFEL

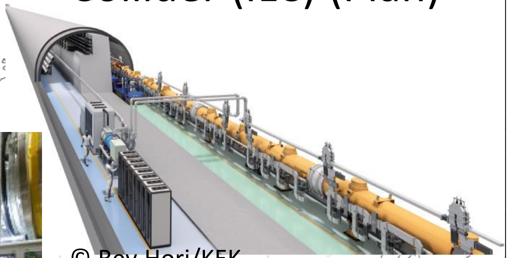
Euro-XFEL

Operation started from 2017

- -100 cyromodules
- -800 cavities
- -17.5 GeV (Pulsed)

DESY

International Linear Collider (ILC) (Plan)



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ILC

- -900 cyromodules
- -8,000 cavities
- -250 GeV (Pulsed)

KEK

LCLS-II + HE (under construction)

- -35 + 20 cyromodules
- -280 + 160 cavities
- - 4 + 4 GeV (CW)

SLAC

FNAL

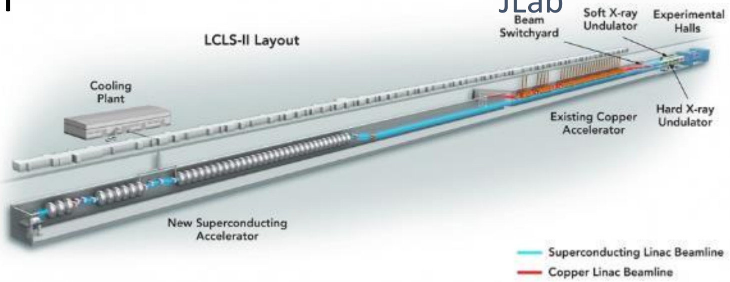
Cornell

JLab

LAL/Sacray

INFN

LCLS-II



SINAP

SHINE (under construction)

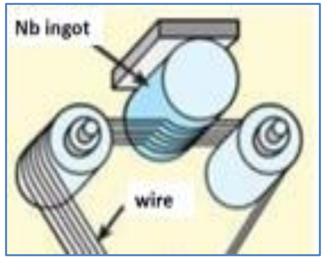
- -75 cyromodules
- -~600 cavities
- - 8 GeV (CW)

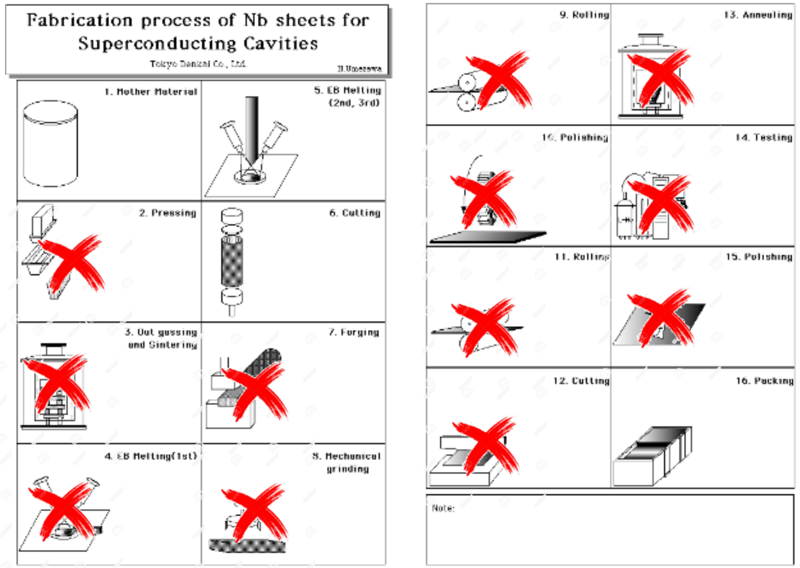
1.3GHz 9 cell cavity

ILC Cost-Reduction R&D in US-Japan Cooperation

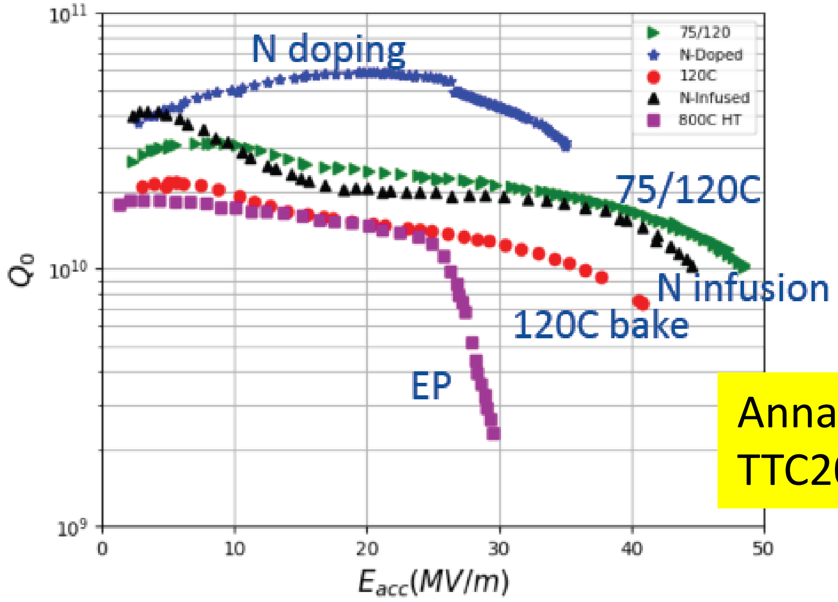
Based on recent advances in technologies;

- Nb material/sheet preparation
  - w/ optimum Nb purity and clean surface

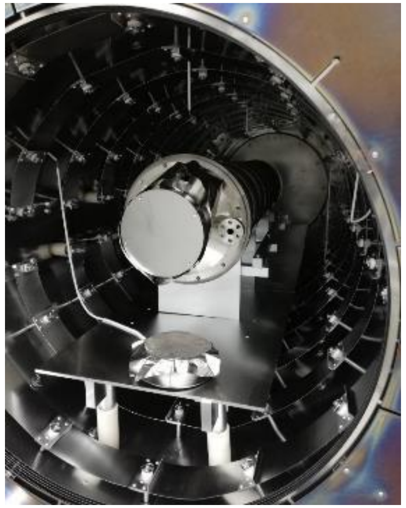




- Surface treatments for high-Q and high-G



Anna Grassellino
TTC2019 Vancouver



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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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Civil Engineering related Schedule for ILC-250GeV

N.Terunuma, AWLC2020

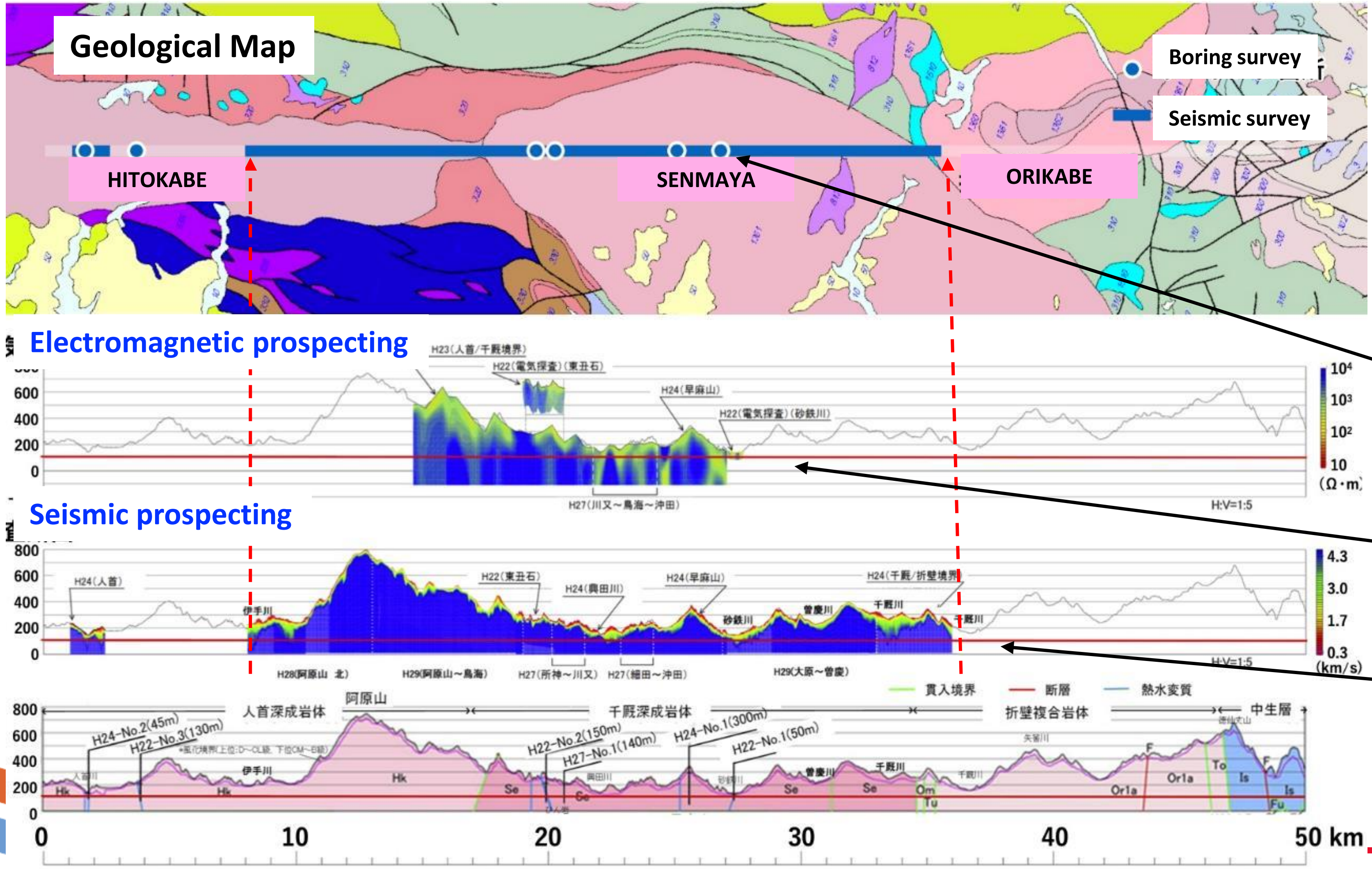
	Pre-preparatory Phase		**Main Preparatory Phase**				**Construction / Operation Phase**									
	International Development Team		**ILC Pre-lab**				**ILC Laboratory**									
Years	**Now**	-1	P1	P2	P3	P4	1	2	3	4	5	6	7	8	9	10 -
	Civil Engineering and Infrastructure Basic Design			**Detailed Design** (construction ready documents)			**Civil Engineering Work**									
										Utility Installation						
	Accelerator Design Update		**EDR**				**Accelerator Preparation**									
												Accelerator Installation				**Commissioning/ Operation**
	Strategic Environment Assessment Project planning stage assessment (Natural, Social, Economic,...)				**Environmental Impact Assessment**		Follow-up Assessment									

Approval of ILC construction

References; (1) TDR, (2) Recommendations on ILC Project Implementation, 2019.

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

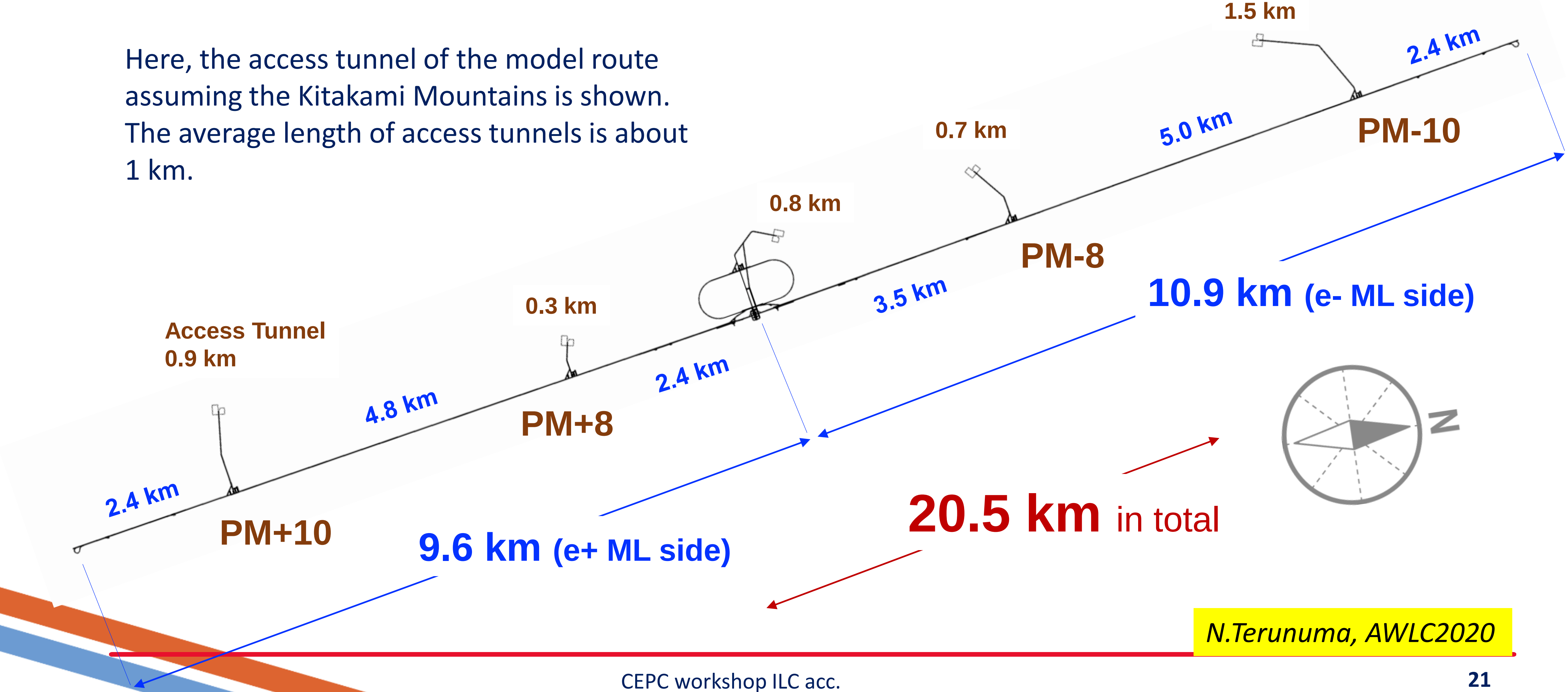
- **Seismic prospecting**

  → Rock hardness

N.Terunuma, AWLC2020

Scale of the ILC-250GeV

Here, the access tunnel of the model route assuming the Kitakami Mountains is shown. The average length of access tunnels is about 1 km.



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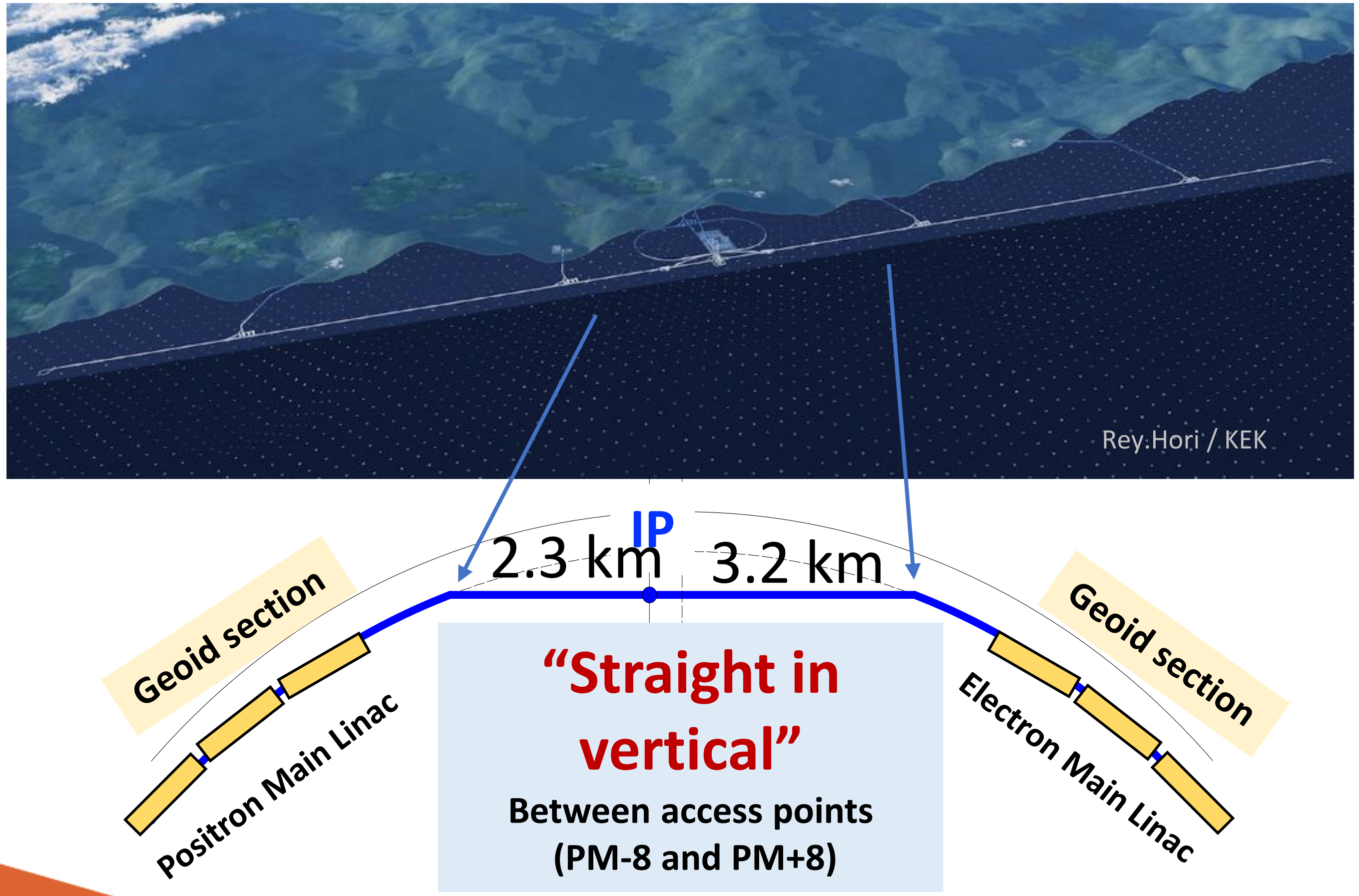
Laser Straight Section

- BDS: “laser straight” in vertical
- ML: Cryomodule will be aligned to the geoid.



- ILC optics DECK has been updated to incorporate corrections for **geoid** and **straight sections** around the IP.
- Asymmetric straight sections
  - The e- side is longer to include undulator and dog-leg.
  - If e+ and e- MLs are at the same altitude, the IP is tilted by 0.1 mrad.
  - If e- ML is placed 0.6 m higher than e+, the IP has no tilt and BDSs are symmetrically sloped to the IP.

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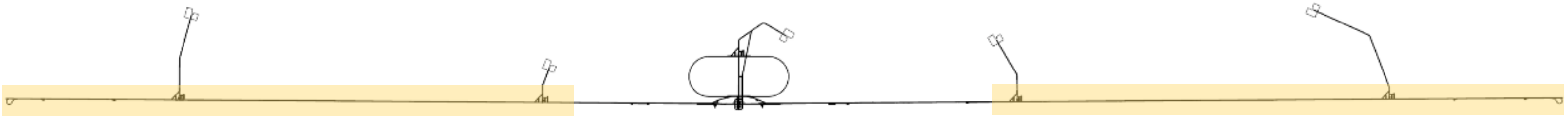
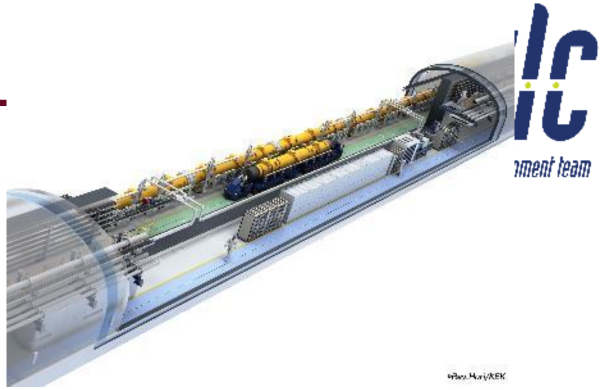
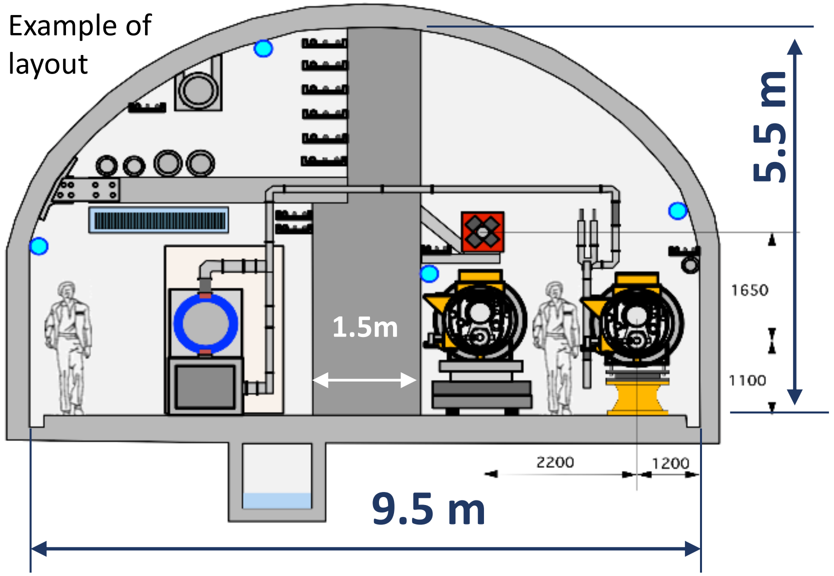
Main Linac (ML) tunnel

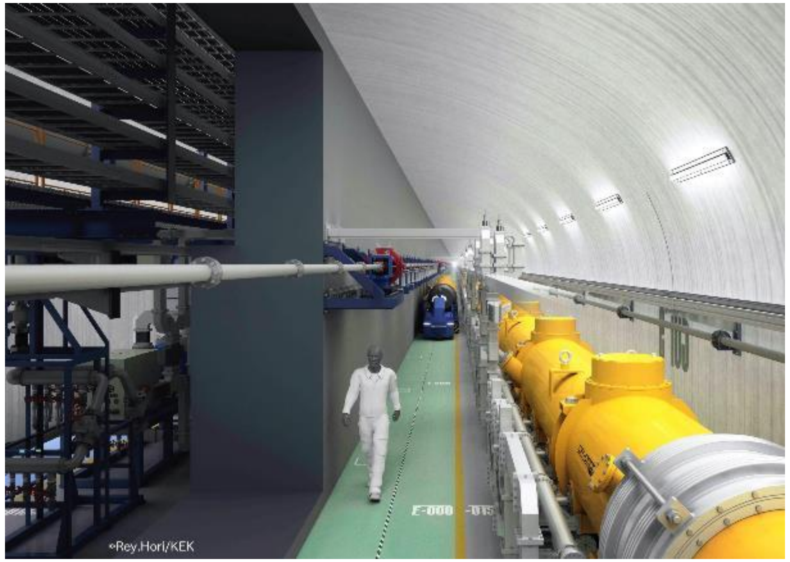




- 15 km in (e+e-) total
- follow the geoid in vertical
- **Kamaboko 9.5m X 5.5m**
- **1.5m central radiation shield**
- Further optimization will be done.

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

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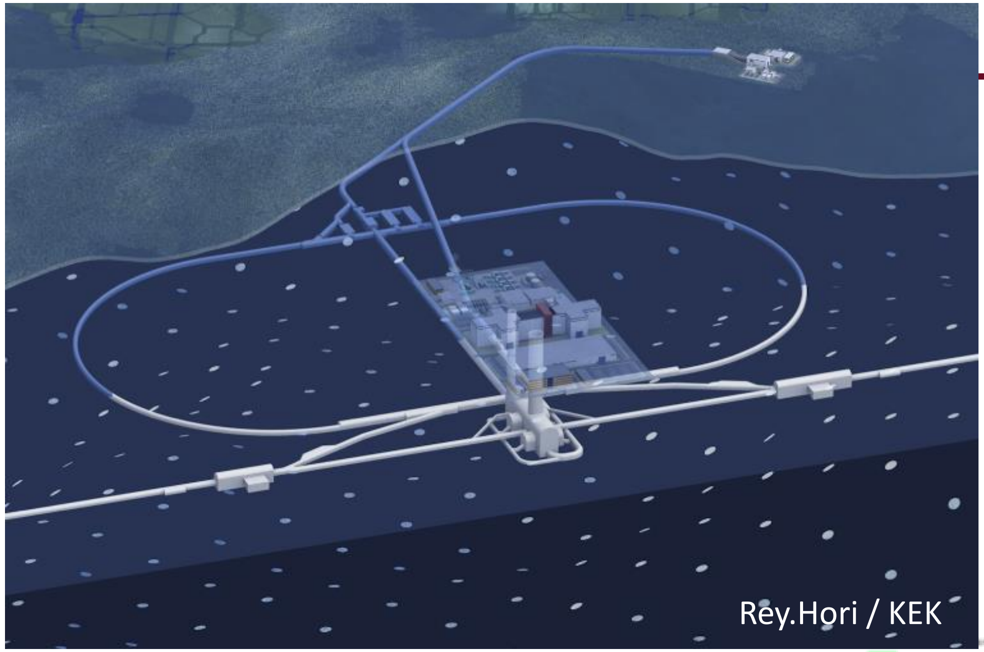
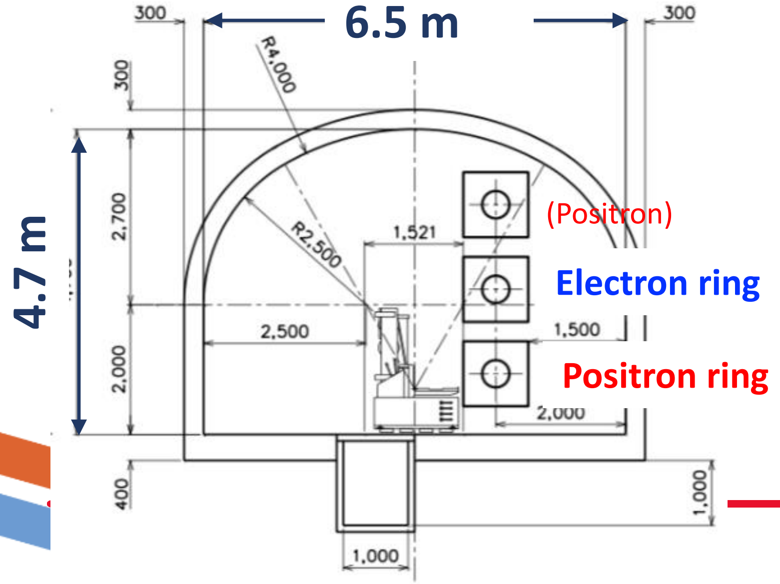
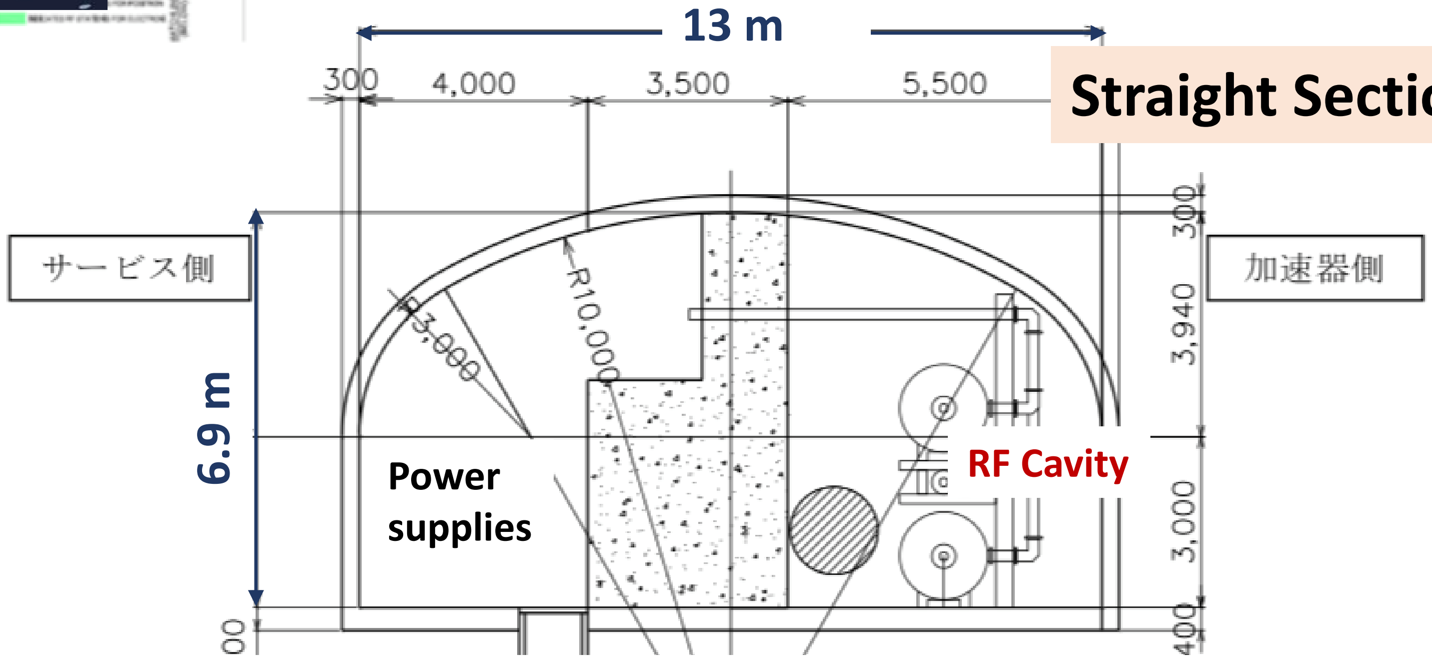


- Circumference: 3.2km
- Start with two rings
- Arc section: **single tunnel, no central shield.**
- Straight section: **Kamaboko with a central shield** (3.5m in TDR).





Interaction Point (IP)

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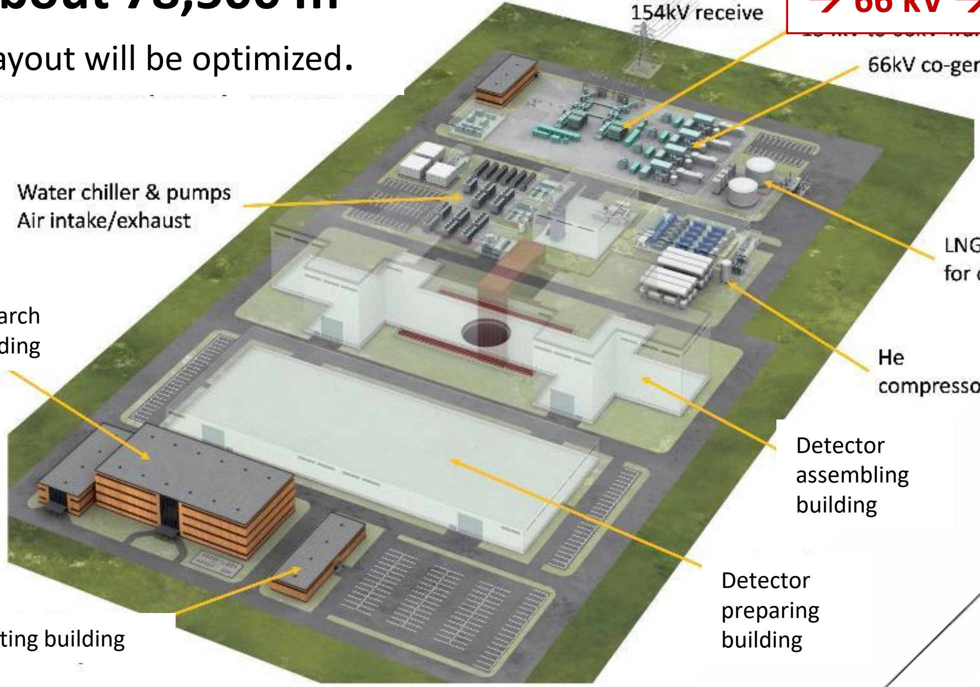
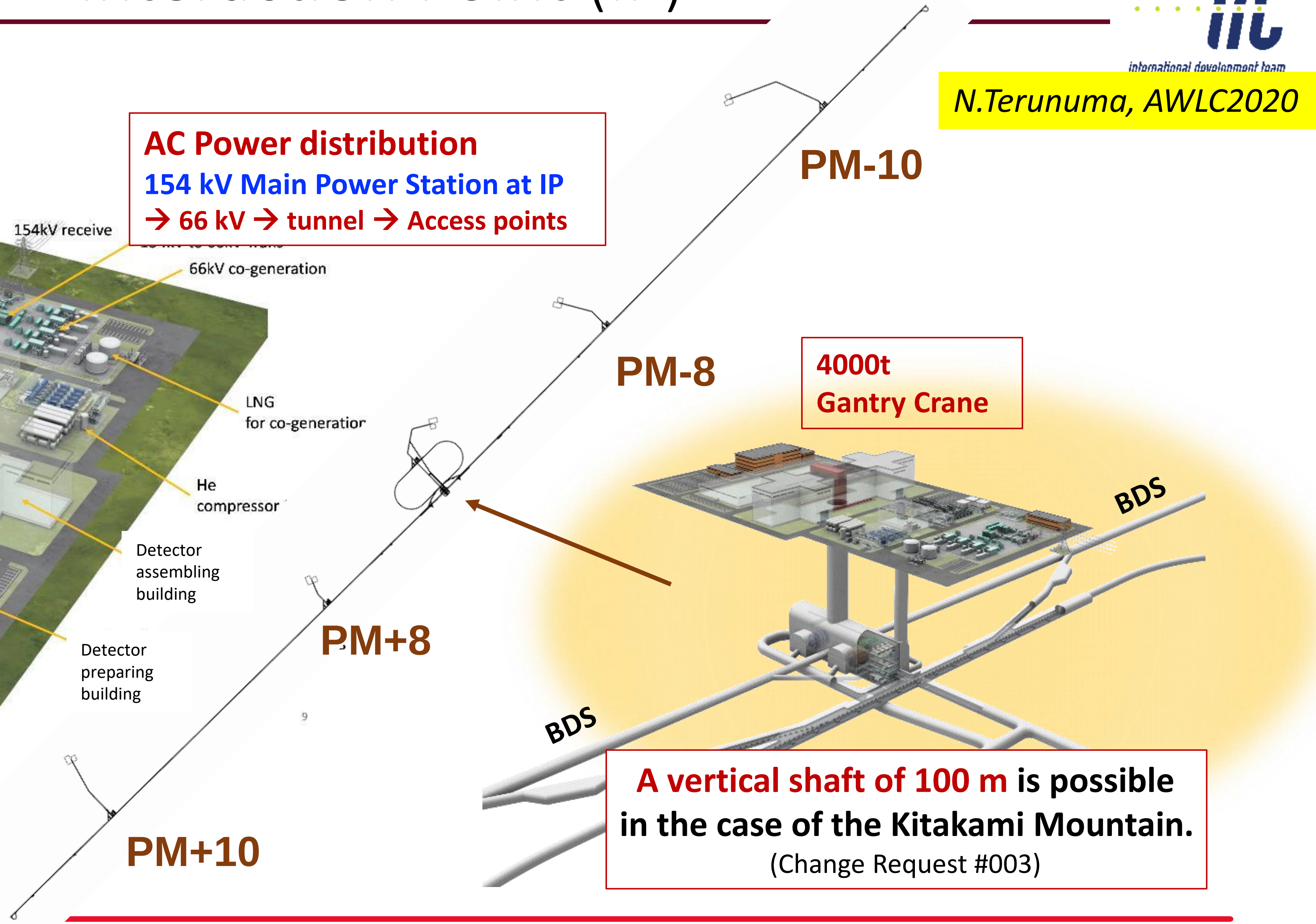
IP surface area
about 78,500 m²
Layout will be optimized.

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

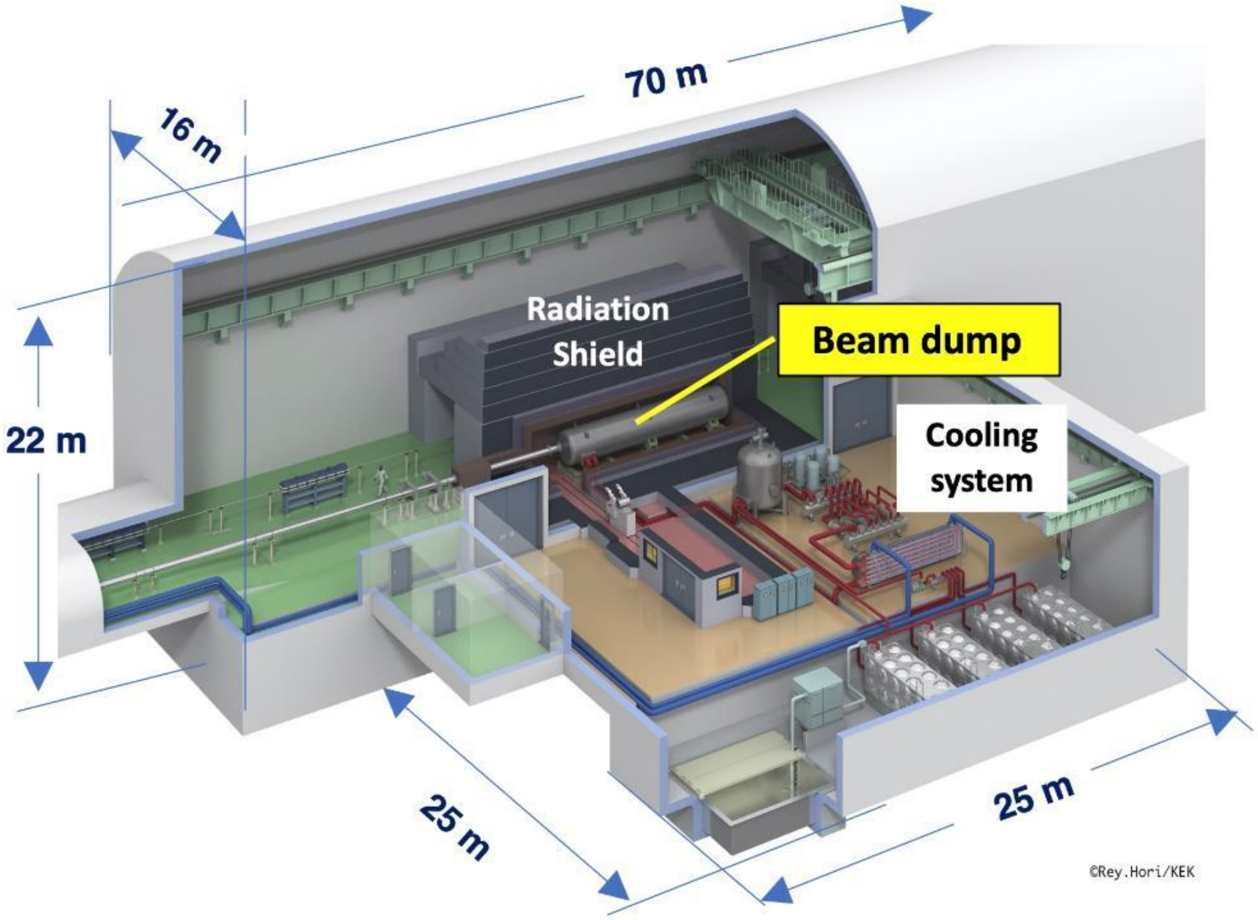




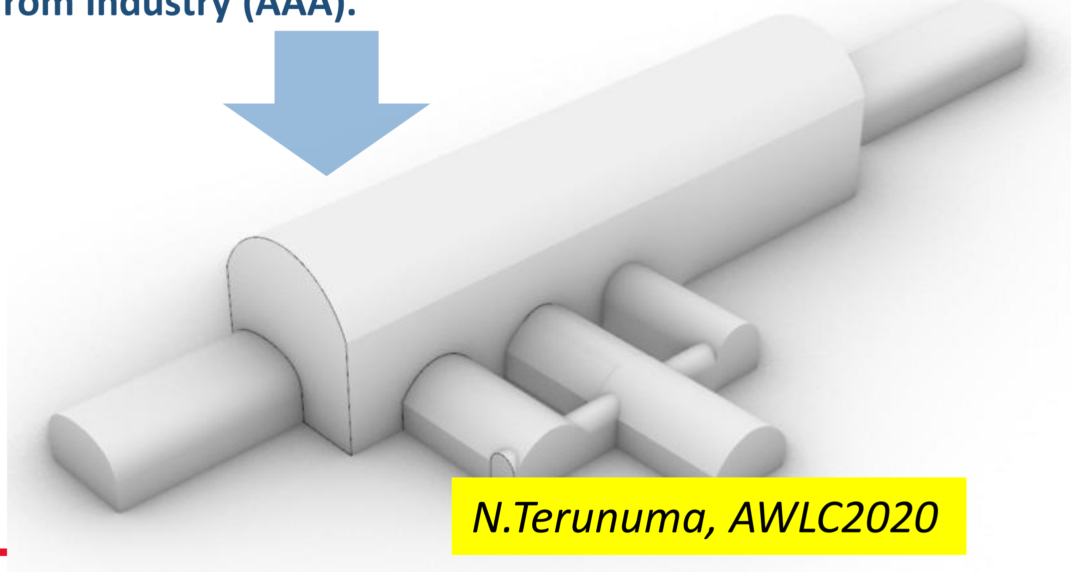
4000t
Gantry Crane

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).**



N.Terunuma, AWLC2020

ILC 250 accelerator

Shin MICHIZONO

International Development Team (IDT) WG2/ KEK

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

Summary

- *ILC250 accelerator is 20 km long e-/e+ collider for the Higgs factory.*
- *The ILC is upgradable in energy and luminosity.*
- *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*
- *We assume 4-year preparation and 9-year construction.(now we are at pre-preparation phase (IDT))*
- *Preparation phase activities are*
  - *Technical preparation*
  - *Final engineering design*
  - *Planning and preparation of Hub lab.*
  - *Human resources for ILC construction …*

Thank you for your attention