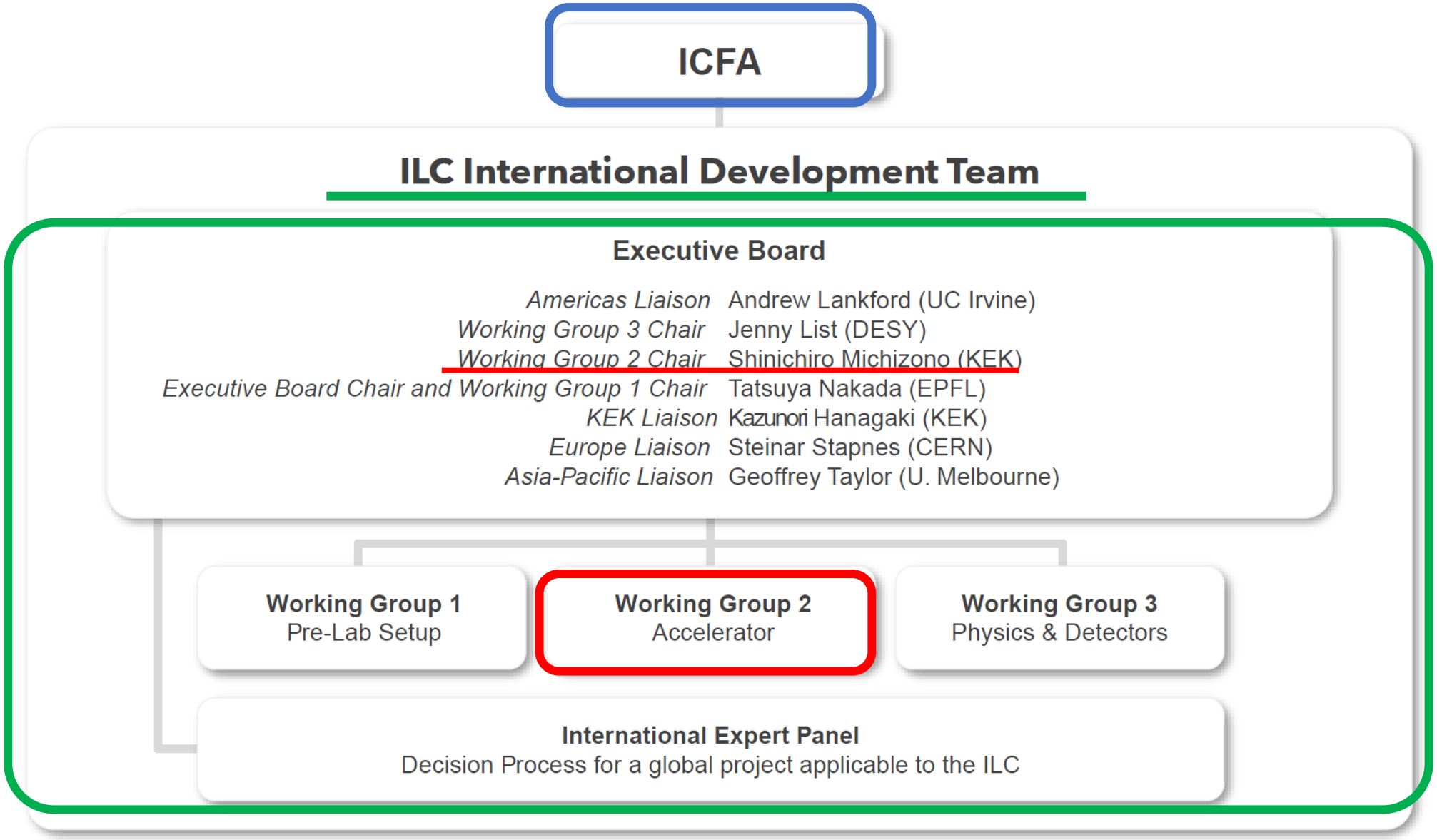
ILC Technology Network (ITN)

KEK / IDT-WG2
Shin MICHIZONO (KEK)

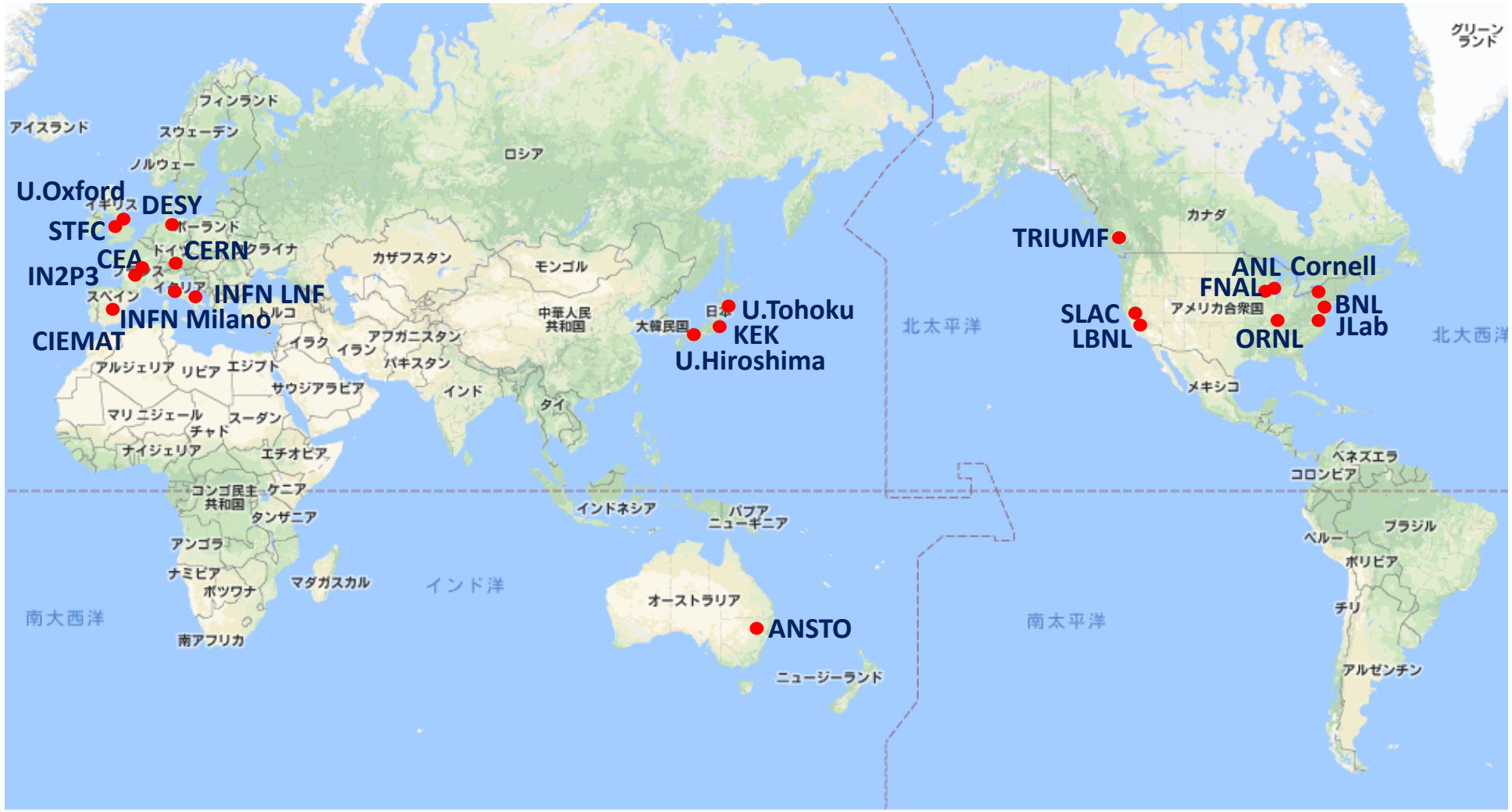
- IDT
- ILC Technology Network (ITN)
  - SRF
  - Sources
  - Nanobeams
  - Application
- ITN activities
  - CERN-KEK agreement
  - ITN information meetings
  - ITN in progress
- Summary

IDT organization

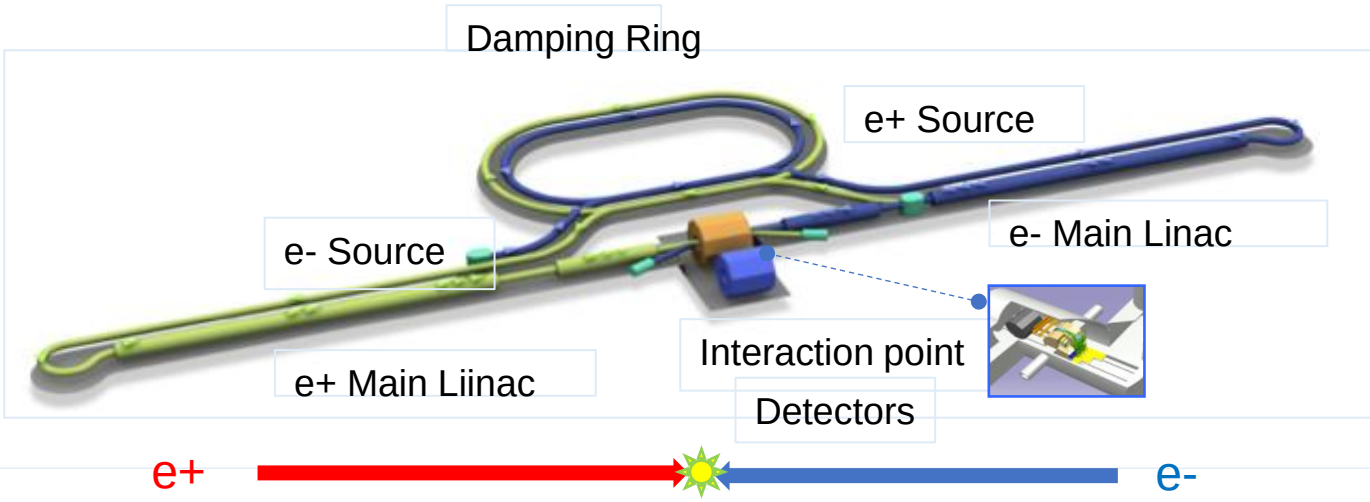


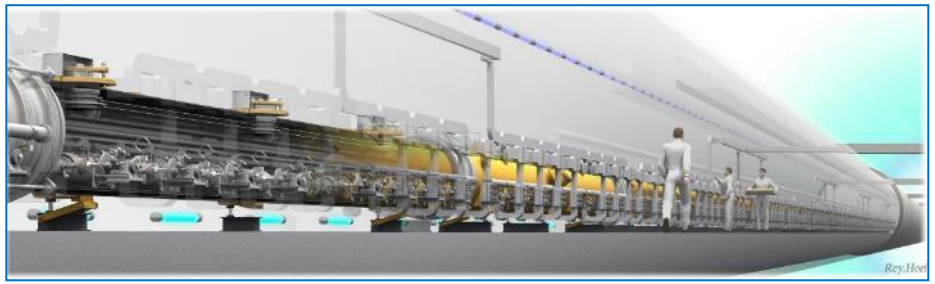
IDT-WG2

IDT-WG2 has about 50 accelerator researchers from around the world participating in discussions on ILC accelerator development research.

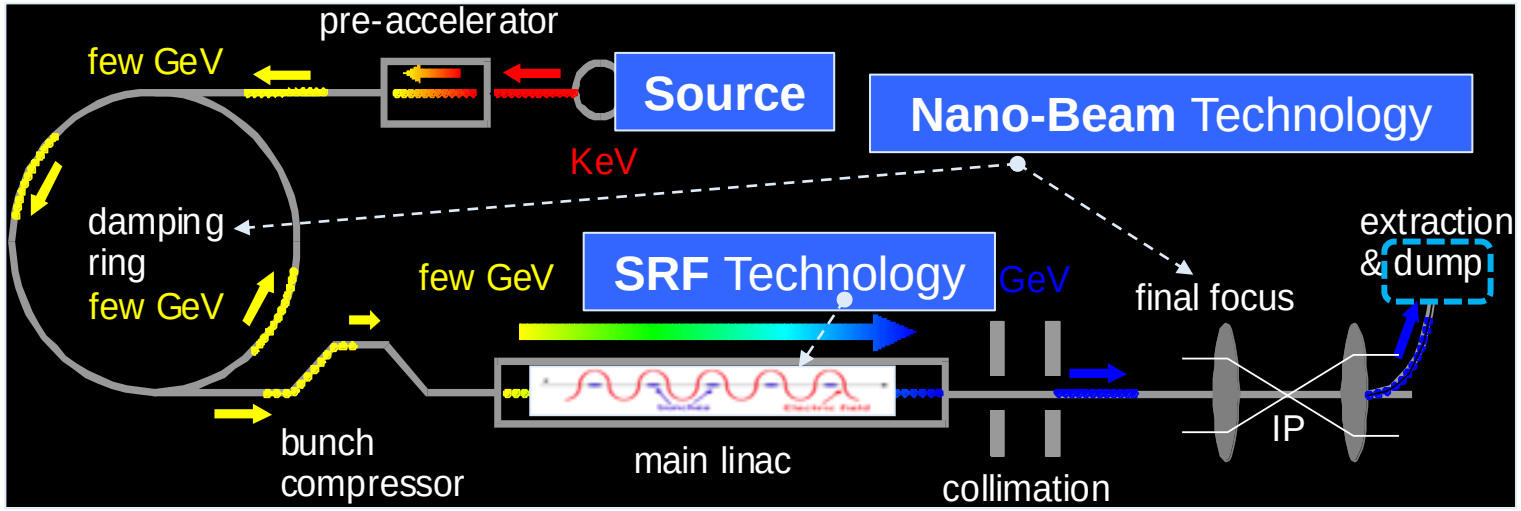


ILC and the Accelerator Technology





TDR was published in 2013 and SRF technology became matured by large-SRF accelerators (European XFEL, LCLS-II etc.).



Parameters	Value
Beam Energy	125 + 125 GeV
Luminosity	1.35 / 2.7 x 10^{34} 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)	~ 8,000 (~ 900)
AC-plug Power	111 / 138 MW

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IDT Scope for ILC Realization

-success oriented and asuming no major incident-

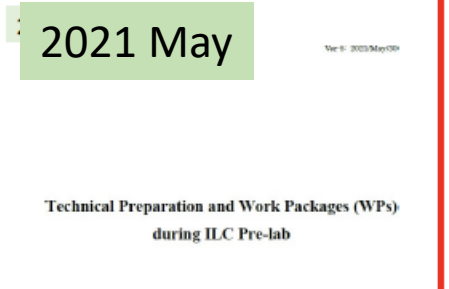
Technology Network Phase | **Preparatory Phase** | **Construction Phase** ~10 years for the construction and commissioning

2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 • • •

R&D and effort to gain a common view and understanding.

ILC preparation laboratory and intergovernmental discussion

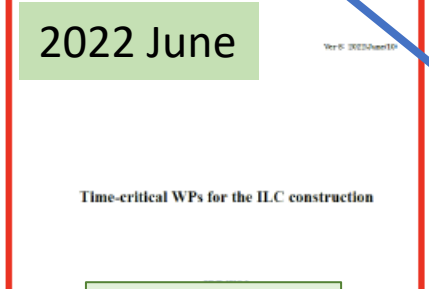
2021 May


Technical Preparation and Work Packages (WPs) during ILC Pre-lab

Work Packages (**WPs**) for ILC Pre-Lab

https://linearcollider.org/wp-content/uploads/2023/09/IDT-EB-2021-001.pdf

2022 June


Time-critical WPs for the ILC construction

WP-Primes for Time Critical

https://linearcollider.org/wp-content/uploads/2023/09/IDT-EB-2023-002.pdf

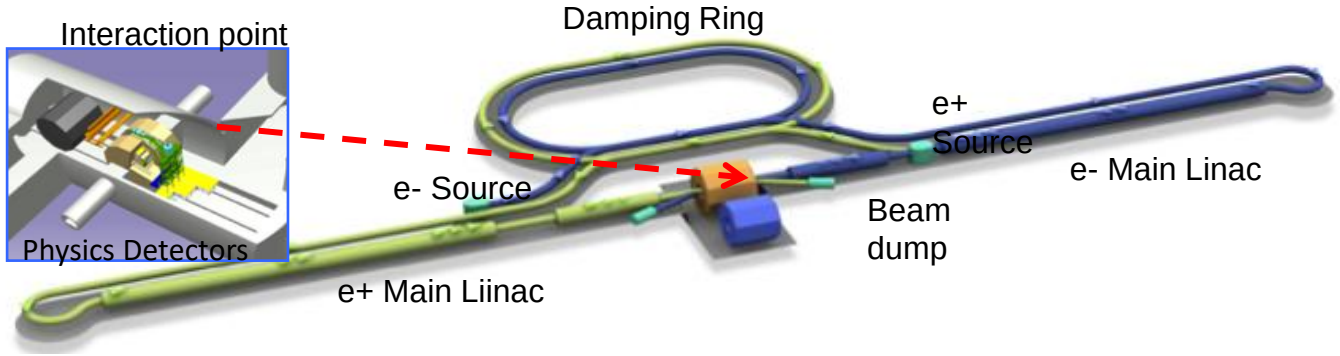
ILC Technology Network (ITN)

-- global collaboration program---

- **Acc. R&Ds** focusing on
  - SRF
  - e- & e+ Sources
  - Nano-beam

KEK obtained a budget for these R&Ds and started the activity from 2023.

ILC Technology Network



Not only for the **ILC** but also for **various application**

- 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***

SRF

e-, e+ Sources

Nano-Beam

WPP	1	Cavity production
WPP	2	CM design
WPP	3	Crab cavity
WPP	4	E- source
WPP	6	Undulator target
WPP	7	Undulator focusing
WPP	8	E-driven target
WPP	9	E-driven focusing
WPP	10	E-driven capture
WPP	11	Target replacement
WPP	12	DR System design
WPP	14	DR Injection/extraction
WPP	15	Final focus
WPP	16	Final doublet
WPP	17	Main dump

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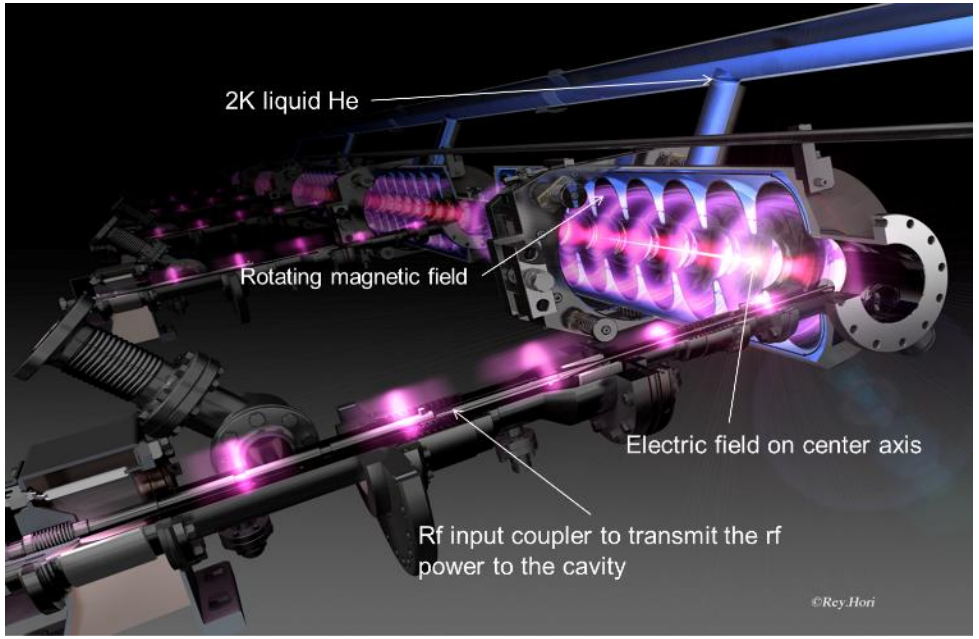
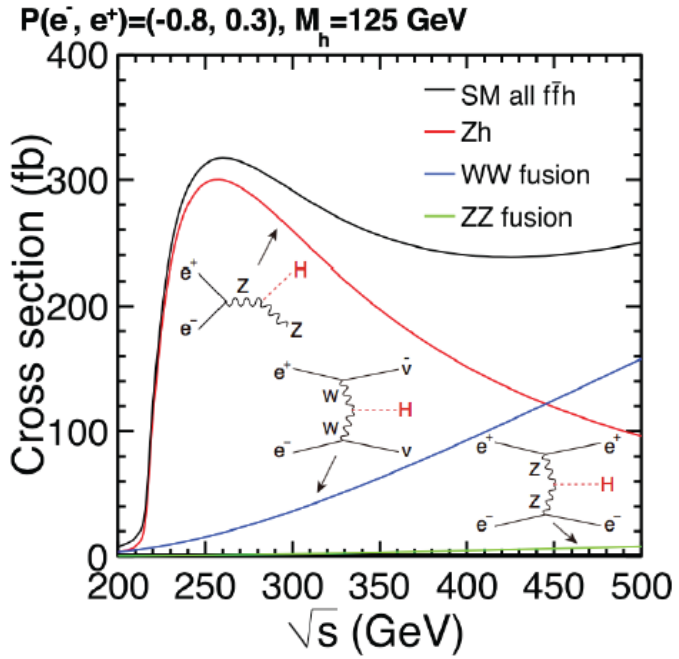
SRF for energy-reach

- To generate Higgs particles, electrons and positrons must be accelerated to **125 GeV** each and collide.
- The **most important** topics of the Higgs Factory.

- It is necessary to demonstrate that the SRF cavities can provide the **required acceleration gradient** in a cavity package (cavity + tuner + jacket + input coupler, etc.).



Parameters	Value
Beam Energy	125 + 125 GeV
# e-/e+/bunch	2×10^{10} (3.2 nC)
Bunch space	554 ns
# bunch / pulse	1312
Beam rep. rate	5 Hz
Luminosity	1.35×10^{34} cm^2/s
Beam size (y) at FF	**7.7** nm

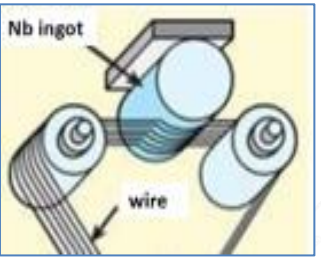


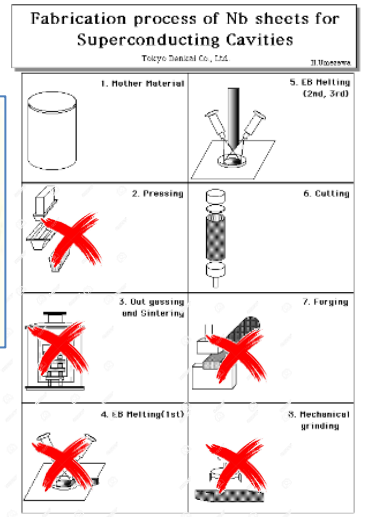
WP-prime 1: SRF Cavity
(Scoping the Industrial-Production Readiness)

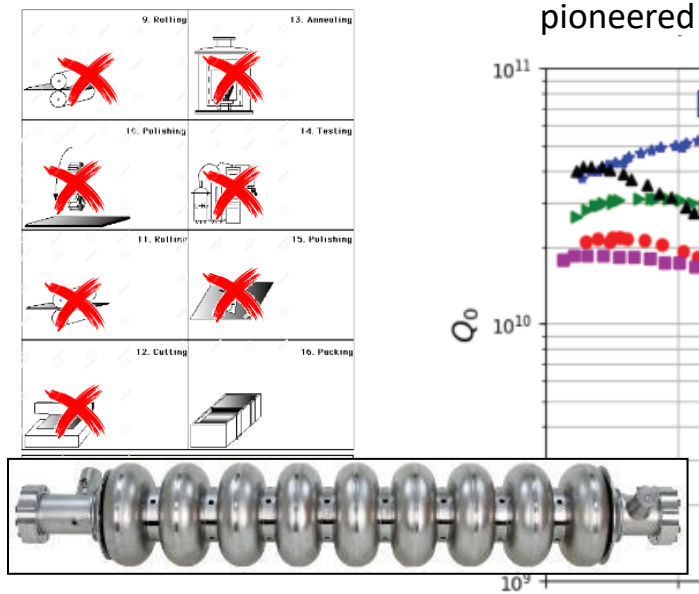
- Research with single-cell cavities to establish the best production process including:
  - Advanced Nb sheet production method
  - Advanced surface treatment recipe(mainly developed by **FNAL**)
- Globally common design with compatible High Pressure Gas Safety (HPGS) regulation
- 24 nine-cell cavities are to be developed for industrial-production readiness
  - 8 cavities in each region
  - Production process encouraged to be optimized in each region
  - Cavity performance expected: E_{acc} = <35 MV/m> (+/− 20%), Q_0 = 1.0 x 10^{10}, Yield = ≥90%
- RF performance/success yield to be examined (including 2nd pass and further)
  - 3rd pass to be examined if effective

	# of cavities to be produced		
	Americas	Europe	JP/Asia
single-cell	2	2	2
nine-cell	8	8	8

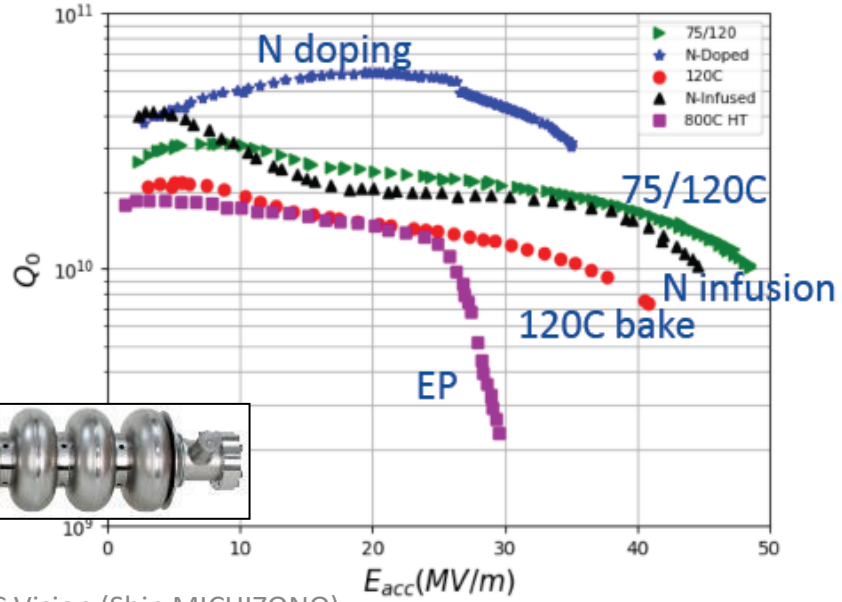
Advanced Nb sheet production by direct slicing

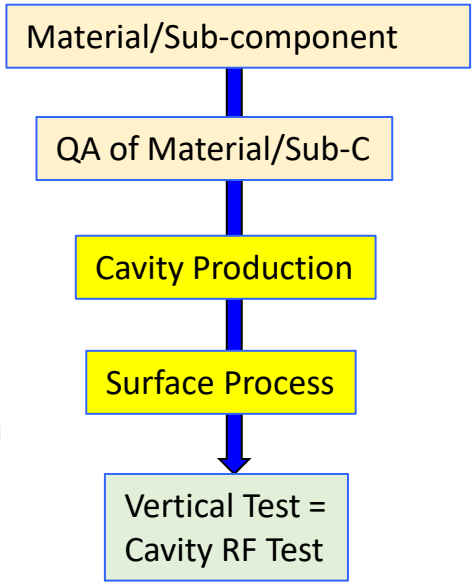






Advanced surface treatment technologies pioneered by **FNAL**





Production process

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Sources for ensuring e-/e+ collision

- The **polarized electron** (>80%) source is effective in improving the **real luminosity** in Higgs factory (contributing to a relative luminosity **improvement of about 2x**).
- The top priority for the source is to **ensure that $2x10^{10}$ particles** are available for collision experiments.
- **Undulator scheme** (which uses light emitted from high-energy electrons) and **electron-driven scheme** (which uses a separate 3GeV electron source) are proposed.
- The key to both are a **target** to generate electron-positron pairs, a **magnetic focusing** system to collect positrons generated in a wide range of directions, and subsequent **positron acceleration**.

Parameters	Value
Beam Energy	125 + 125 GeV
# e-/e+/bunch	$2x10^{10}$ (3.2 nC)
Bunch space	554 ns
# bunch / pulse	1312
Beam rep. rate	5 Hz
Luminosity	1.35 $x10^{34}$ cm^2/s
Beam size (y) at FF	**7.7** nm

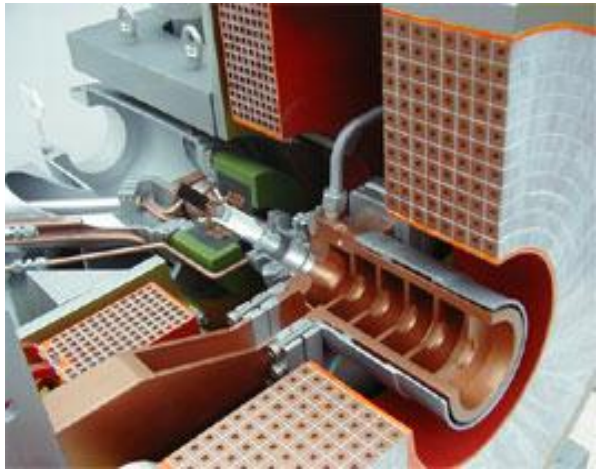
- The positron source produces 1.5 times more positrons than required at the collision point. (4.8nC)
- The amount of positrons is determined by

γ rays from the undulator (230m) or **electron dose** (3 GeV)
x
Positron generation from **target**
x
Amount of positrons captured by **magnetic focusing**

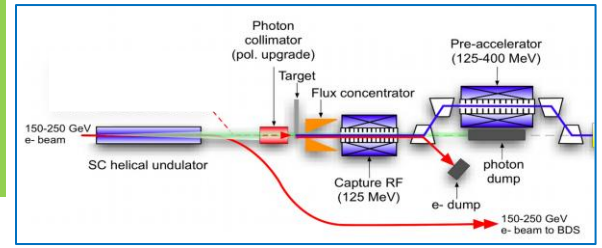
- The specifications for positron production should be satisfied.(e.g., **target heat load** and cooling, **peak magnetic field** at magnetic focusing, etc.)

LC Vision (Shin MICHIZONO)

KEKB positron source (cut-model)

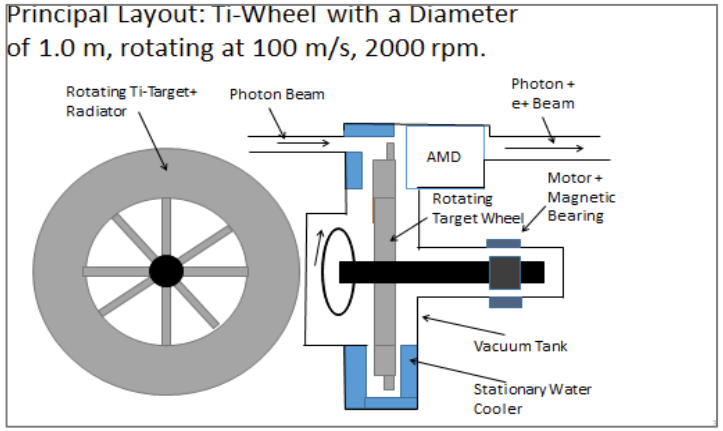


WP-prime 6/7:
Undulator-driven e+ Source



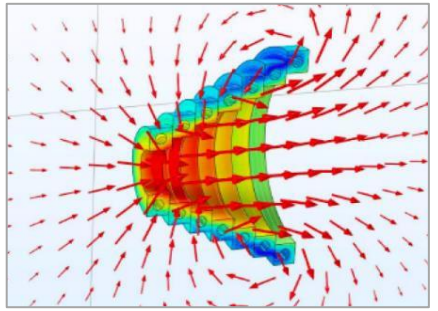
WP-prime 6: Rotating Target for Undulator Scheme

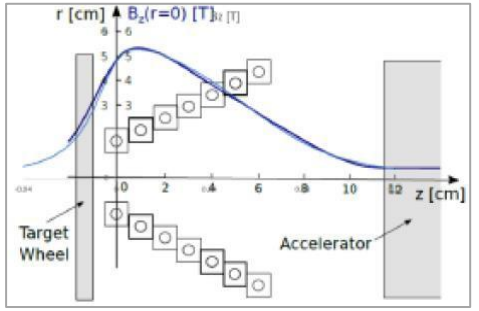
- Target specification
  - Titanium alloy, 7mm thick (0.2 X_0), diameter 1m
  - Rotating at 2,000 rpm (100 m/s) in vacuum
  - Photon power ~60 kW, deposited power ~2 kW
  - Radiation cooling
  - Magnetic bearings
- R&D to be done as WP-prime
  - Design finalization, partial laboratory test, mock-up design (in the first 2 years)
  - Magnetic bearings: performance, specification, test (in the remaining years)



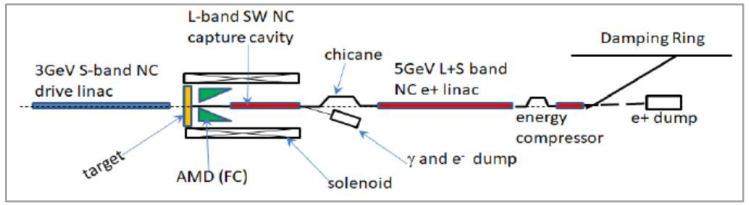
WP-prime 7: Focusing System for Undulator Scheme

- The critical item for the undulator scheme is the magnetic focusing system right after the target
- Possible candidates are: (a) Pulsed solenoid, (b) Plasma lens
- The strongest candidate is (a) pulsed solenoid.
- R&D items to be done as WP-prime
  - Detailed simulations for (a) (already on-going)
  - Principal design for a prototype pulsed solenoid
  - Field measurements with 1kA (pulsed and DC) and with 50kA both in a single pulse mode and finally in a 5ms pulsed mode
  - Prototype of (b) plasma lens (funded study on-going)





WP-prime 8~11:
Electron(e-) driven positron source



WPP-8: Rotating Target

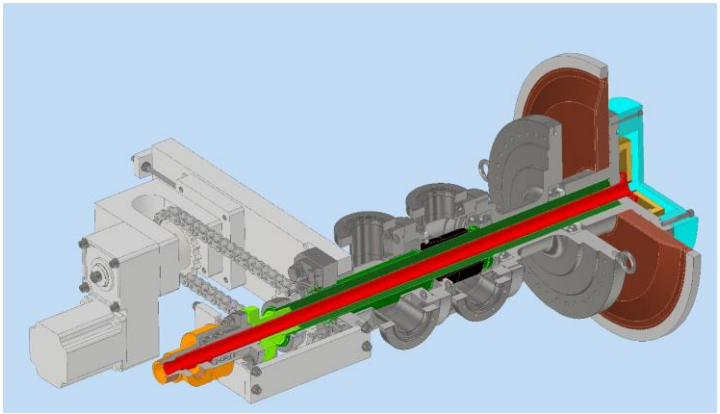
- 74 kW (3 x SLC) beam power
- Rotating mechanism
  - Water-cooled
  - UHV compatible
  - 225 rpm
  - Radiation hard
- Target disk
  - W-Cu connection
  - Target material selection and evaluation
  - Cooling water flow

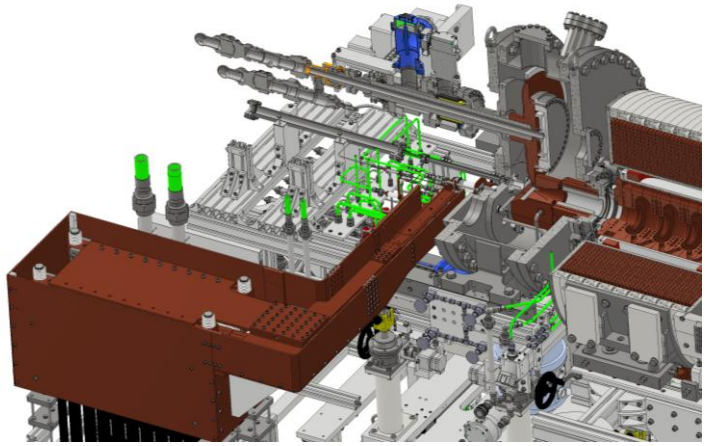
WPP-9: Focusing System

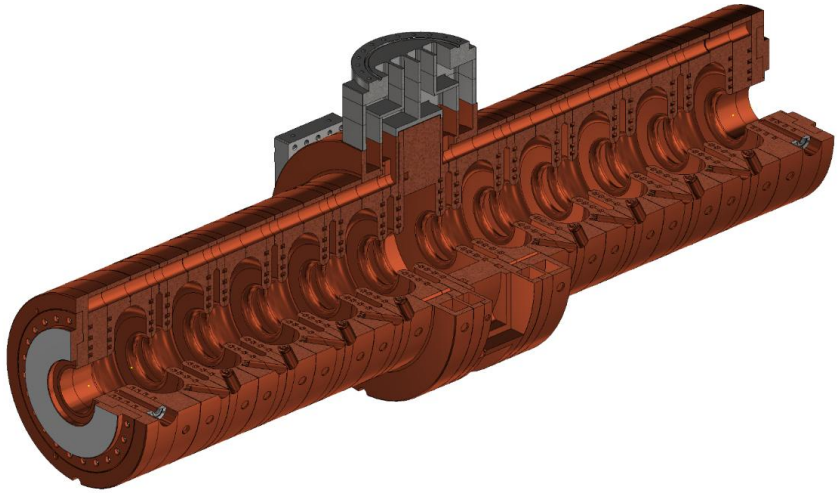
- Flux concentrator
  - One order higher ohmic loss than that of SKEKB
  - Additional loss from target
  - Fully 3D simulation
  - Prototype and high-power test
- Pulsed power supply
  - 300 Hz compatible
  - One order higher power than that of SKEKB
  - Energy recovery mechanism

WPP-10: Capture cavity

- Design challenges:Large aperture L-band cav.
  - Beam loading compensation
    - Full model RF & multi bunch simulation using CST
  - Very high heat load of shower from target
    - novel cooling design
  - Remote beam flange connection
    - Connection point is surrounded by solenoid
- Prototype to establish manufacturing process







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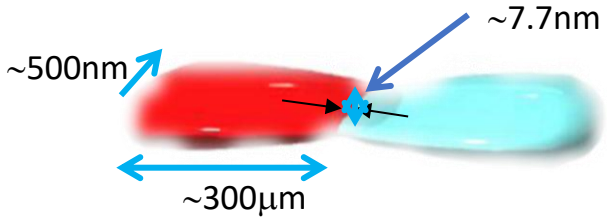
Nanobeam for high luminosity

- In the final focusing, the beam is prepared to obtain a specified luminosity and is narrowed down to **nanometer size at the collision point** by an electromagnet just before the collision point. (**7.7 nm in vertical**)



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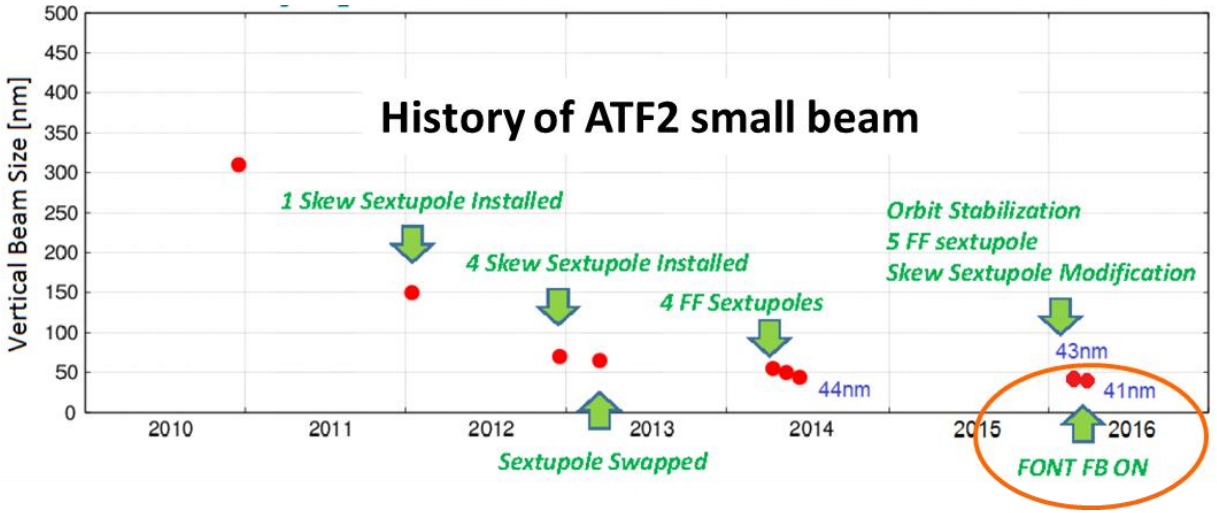
Luminosity	$1.35\ x10^{34}\ cm^2/s$
Beam size (y) at FF	**7.7** nm

- **KEK-ATF** has developed and demonstrated nanometer-size generation and position stabilization techniques by electron beam.(ATF goal: 37 nm (equivalent to ILC 7.7 nm)

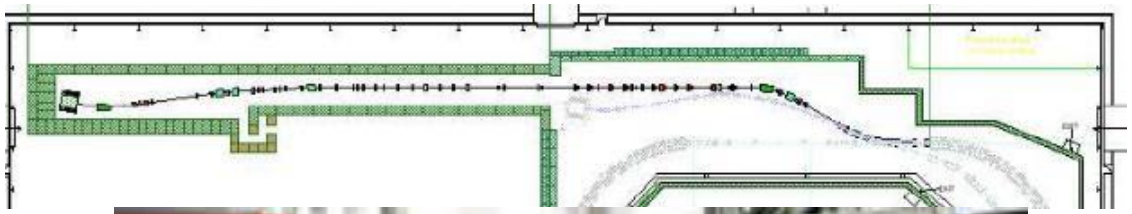
- Establishment of **nanometer-size beam tuning** technology is essential for **improving luminosity**, and ATF has been developing this technology since the 2000s.



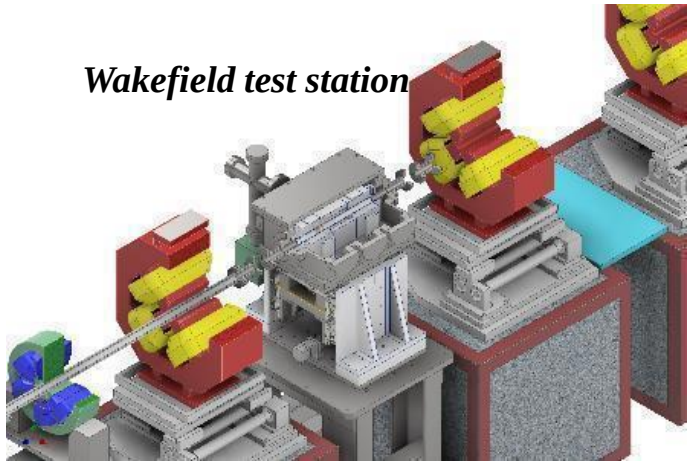
WP-prime 15: System design of ILC FFS

ATF collaboration

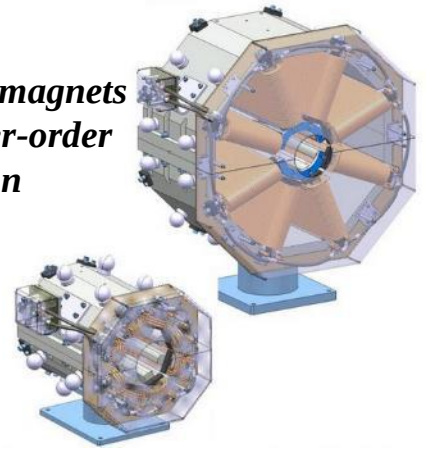
- ATF2 beamline is the only existing test accelerator in the world to test the final focus system (FFS) of linear colliders.
- The following 3 research topics are important to be pursued at the ATF for stable nano-beam.
  - wakefield mitigation
  - correction of higher-order aberration
  - training for ILC beam tuning (machine learning)
- The technical research at ATF2 beamline has proceeded by ATF international collaboration (welcome to new collaborators).



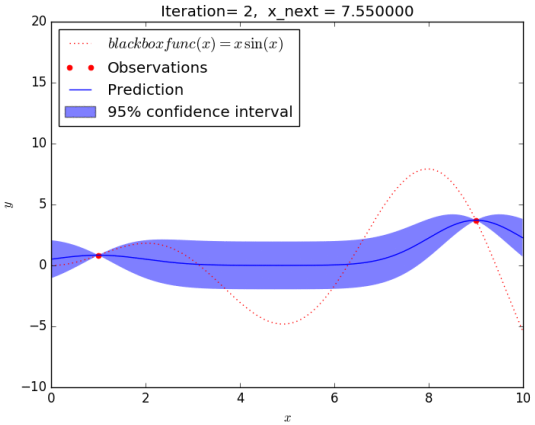
Maximum search algorithms to be applied to beam tuning (Machine Learning)



Wakefield test station



Octupole magnets for higher-order aberration



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Advanced Accelerator Development through ITN

ITN WPs can be applied not only to ILC but also to a wide range of advanced accelerators

① SRF

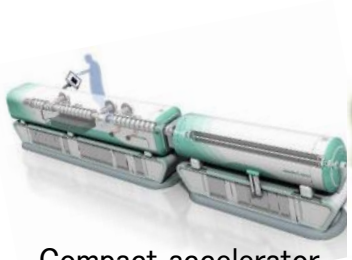
- Superior energy efficiency has been demonstrated and is expected to be deployed in a wide range of applications (such as semiconductor lithography, compact accelerator for medical/industrial applications)

② Source (especially positron source)

- High-intensity positron sources will be required for future collider accelerators (circular colliders such as FCCee and CEPC, linear colliders such as ILC and CLIC, muon colliders (LEMMA), etc.).
- Positrons are also useful for exploring physical properties, and high-intensity, slow-positrons are expected for surface structure analysis.
- Positron source targets and beam dumps are also closely related to targets for neutron generation and beam irradiation targets used in industrial/medical applications.

③ Nanobeam

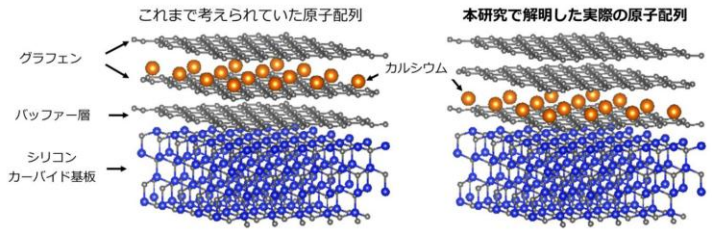
- Nano-beam technology can be applied to new-generation synchrotron radiation facilities, etc..
- Advanced beam tuning techniques such as machine learning can be applied to a wide range of accelerators.



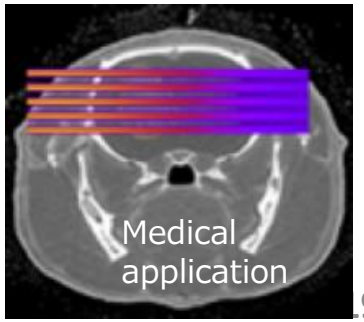
Compact accelerator

Extreme ultraviolet (EUV) lithography based on ERL technology

Mobile accelerator



Determination of atomic arrangement using slow positrons
https://www.kek.jp/ja/newsroom/attic/PR20191114.pdf



ILC Technology Network (ITN)

KEK / IDT-WG2

Shin MICHIZONO (KEK)

- IDT
- ILC Technology Network (ITN)
  - SRF
  - Sources
  - Nanobeams
  - Application
- ITN activities
  - CERN-KEK agreement
  - ITN information meetings
  - ITN in progress
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July 2023

KEK and CERN Conclude Agreement on R&D for International Linear Collider

Topics

2023/07/08

https://www.kek.jp/en/topics-en/202307081205/

Dr. Masanori Yamauchi and CERN Director General Dr. Fabiola Gianotti (left to right) (courtesy of CERN)

On July 7th, 2023, KEK and European Organization for Nuclear Research (CERN) concluded an agreement on "Support for the European International Linear Collider (ILC) Technology Network," concerning a new framework of research and development for the ILC: the ILC Technology Network (ITN).

This Agreement was signed by KEK Director General Dr. Masanori Yamauchi and CERN Director General Dr. Fabiola Gianotti while DG Yamauchi was visiting CERN. It is stated in this agreement that CERN will cooperate for ITN specific studies and at the same time will act as a coordinating and facilitating hub for ITN-specific technology developments and studies in Europe.

ITN is a framework to promote high priority tasks of the ILC accelerator development. It is based on bilateral arrangements, for instance a memorandum of understanding (MoU), an addendum to an existing agreement, or new agreement, between KEK and laboratories. This conclusion became the first agreement under this framework. KEK would like to conclude similar arrangements with other research institutes and expand this ITN framework.

ITN Information Meetings

Two ILC Technology Network Information Meetings have been held.

1st meeting on Oct. 2023 @CERN/hybrid
Around 70 joined.
Lab's interests were shown from >20 institutes.

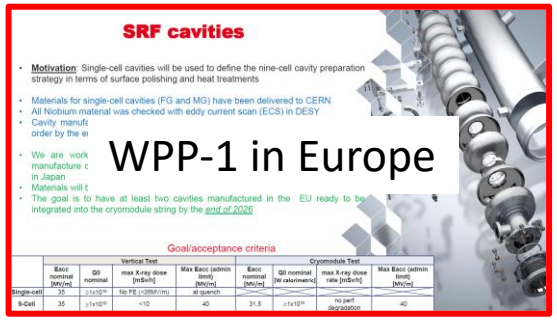
2nd meeting on July 2024 @Tokyo/hybrid
Around 40 joined.
ITN Progress was reported.

https://www.kek.jp/en/topics/202311161700

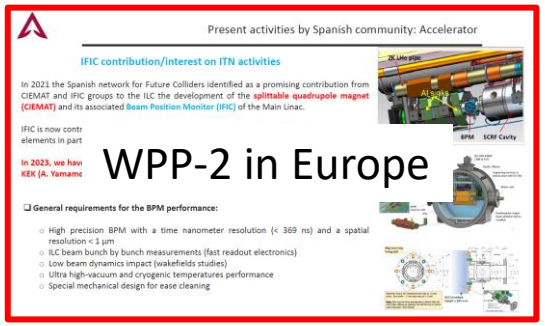
ITN in progress

For **WPP-1&2 (SRF cavity, CM)**, single cell cavity production in Korea/Europe started.
JAI (UK) started WPP-13 (DR Injection/extraction, **synergy with Diamond Light Source upgrade**)
For **WPP-15 (Final Focus System)**, European and Korean researchers have joined to the ATF experiments since 2023.

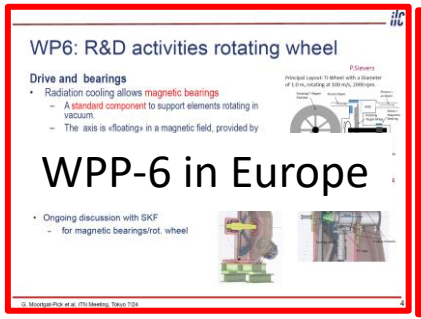
WPP-1/2 in Asia



WPP-1 in Europe

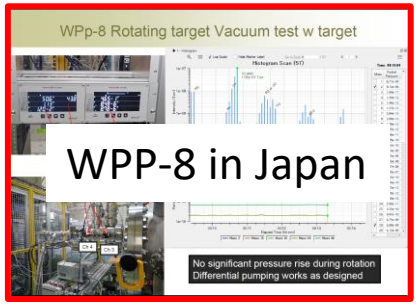


WPP-2 in Europe

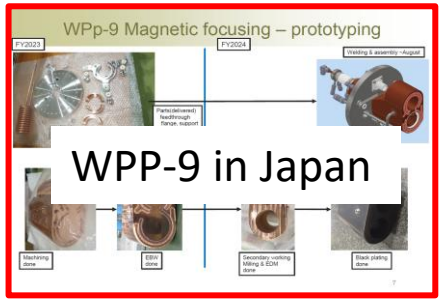


WPP-6 in Europe

WPP-7 in Europe

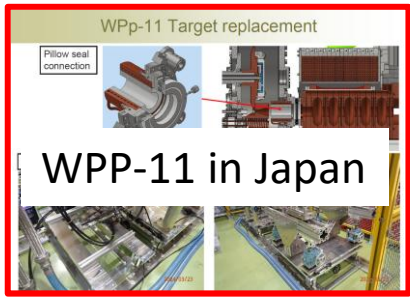


WPP-8 in Japan

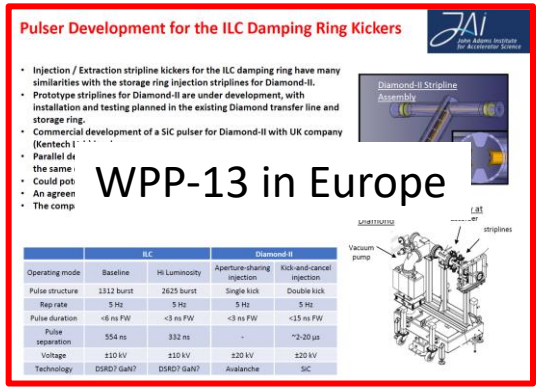


WPP-9 in Japan

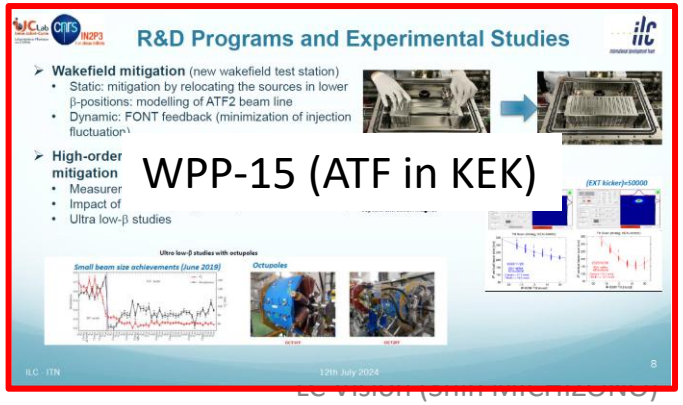
WPP-10 in Japan



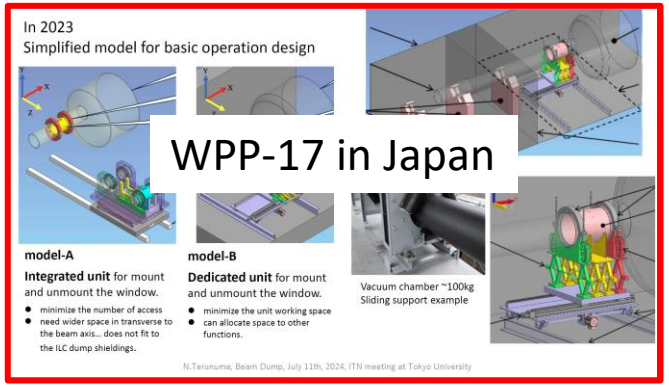
WPP-11 in Japan



WPP-13 in Europe



WPP-15 (ATF in KEK)



WPP-17 in Japan

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Summary

- The ILC key technologies of "**SRF**", "**Sources**" and "**Nano-beam**" .
  - **TDR** was published in 2013.
  - **Matured** to be ready for an e+/e- Higgs Factory based on the **Linear Collider** technology.
- IDT-WG2 identified **important and time-consuming WPs**, which are carried out through "**ILC Technology Network**" (ITN).
- ITN WPs (**SRF, Sources and Nano-beam**) can **be applied to various advanced accelerators (and industry/medical).**
- **KEK obtained a budget** for these R&Ds and started the activity from April,2023.
- **European and Korean activities** at SRF/nano-beam have already started.

Thank you for your attention