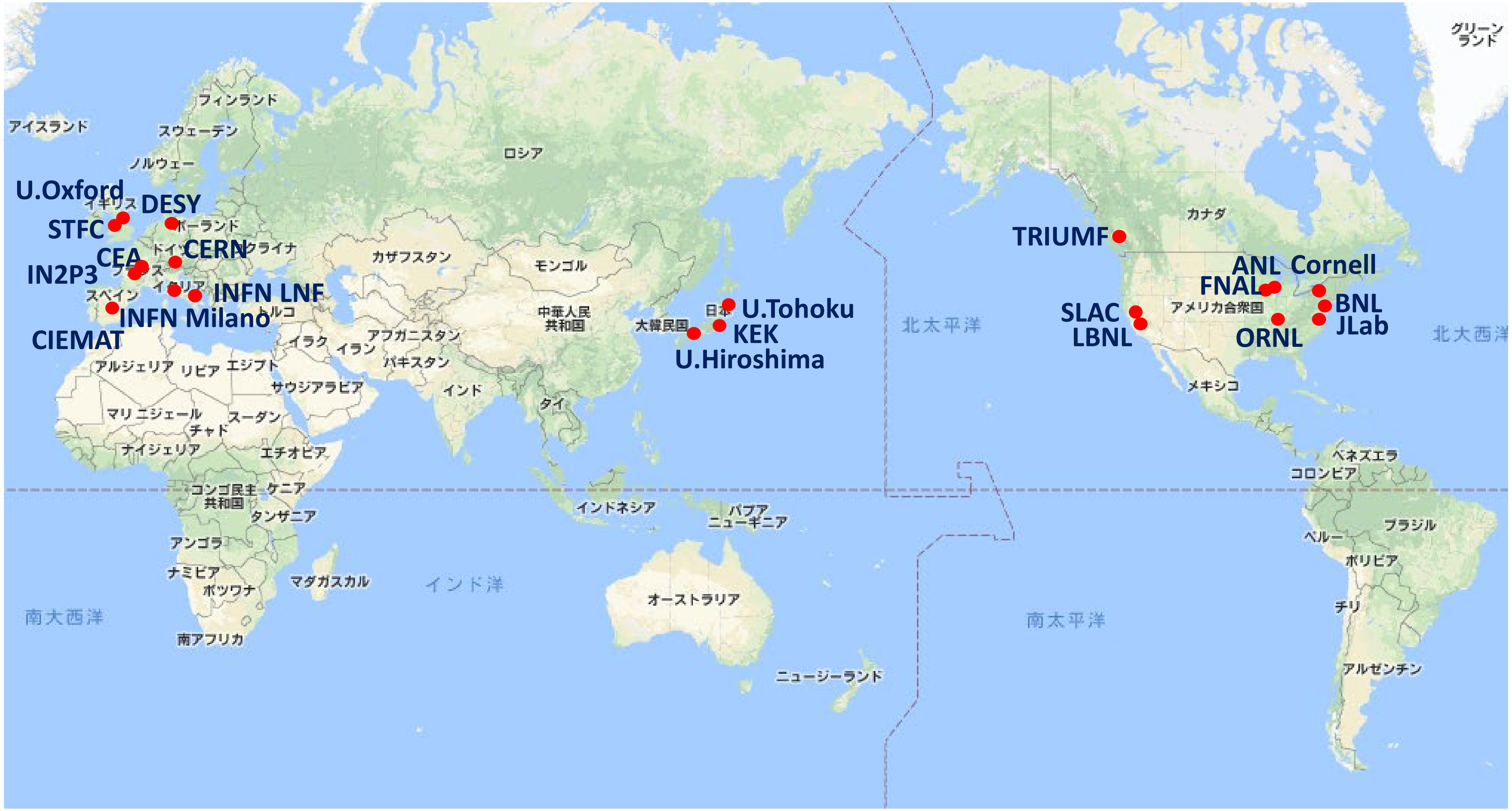
ILC Technology Network (ITN)

KEK / IDT-WG2
Shin MICHIZONO (KEK)

- ILC accelerator
- ILC Technology network
  - SRF
  - Sources
  - Nanobeam

IDT-WG2

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



IDT–WG2

IDT EB

IDT WG2
Shin Michizono (Chair)
Benno List (Deputy)

ML&SRF group

Yasuchika Yamamoto	***KEK***
Sergey Belomestnykh	**FNAL**
Nuria Catalan	CERN
Enrico Cenni	**CEA**
Dimitri Delikaris	CERN
Luis Garcia Tabares	CIEMAT
Rongli Geng	JLAB
Hitoshi Hayano	KEK
Bob Laxdal	Triumf
Matthias Liepe	Cornell
Peter McIntosh	**STFC**
Laura Monaco	**INFN Milano**
Olivier Napoly	CEA
Sam Posen	FNAL
Robert Rimmer	JLAB
Roger Ruber	JLAB
Marc C. Ross	SLAC
Kensei Umemori	KEK
Hans Weise	DESY
Akira Yamamoto	**KEK**

DR/BDS/Dump group

Toshiyuki Okugi	***KEK***
Karsten Buesser	DESY
Philip Burrows	**U. Oxford**
Rohan Dowd	Australian Synchrotron
Angeles Faus-Golfe	**IJCLab**
Andrea Latina	CERN
Kiyoshi Kubo	KEK
Jenny List	DESY
Thomas Markiewicz	SLAC
Brett Parker	BNL
Ivan Podadera	CIEMAT
David L. Rubin	**Cornell**
Nikolay Solyak	FNAL
Nobuhiro Terunuma	**KEK**
Kaoru Yokoya	KEK
Mikhail Zobov	INFN LNF

Dump sub-group

Nobuhiro Terunuma	***KEK***
Toshiyuki Okugi	KEK

Crab sub-group

Peter McIntosh	***STFC***
Yasuchika Yamamoto	KEK

Sources group

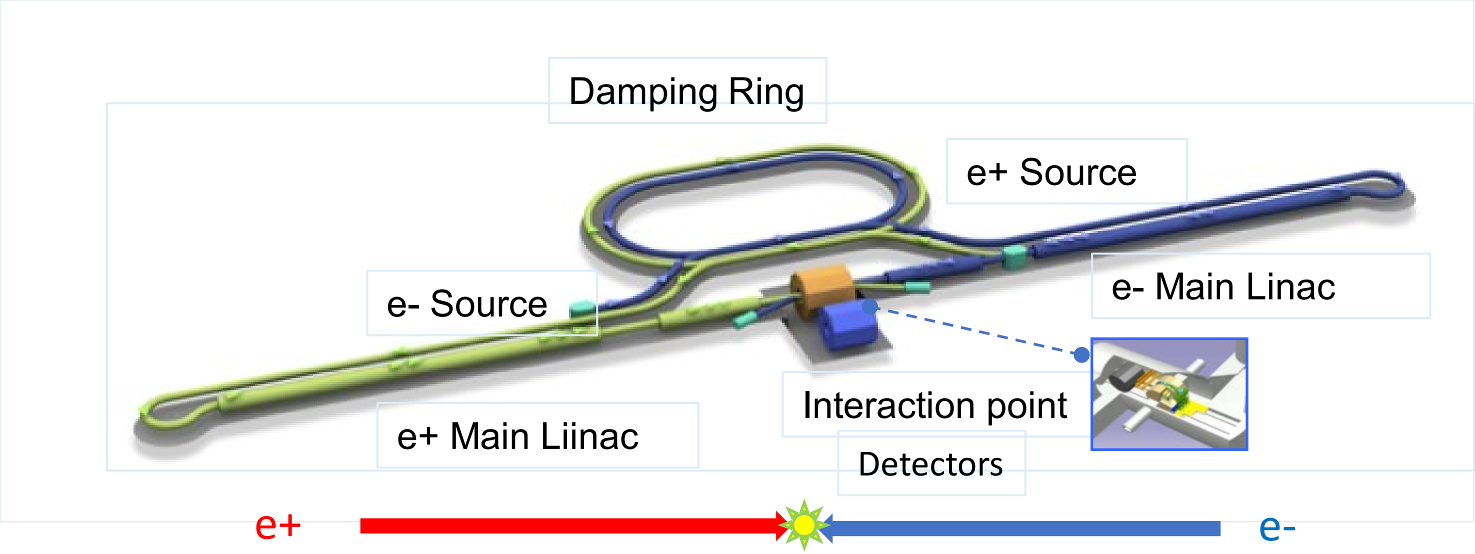
Kaoru Yokoya	***KEK***
Jim Clarke	STFC
Steffen Doebert	CERN
Yoshinori Enomoto	KEK
Joe Grames	**JLAB**
Hitoshi Hayano	KEK
Masao Kuriki	**U. Hiroshima**
Benno List	DESY
Jenny List	DESY
Gudrid Moortgat-Pick	**U. Hamburg**
Sabine Riemann	DESY
Peter Sievers	CERN - retired
Tohru Takahashi	U. Hiroshima

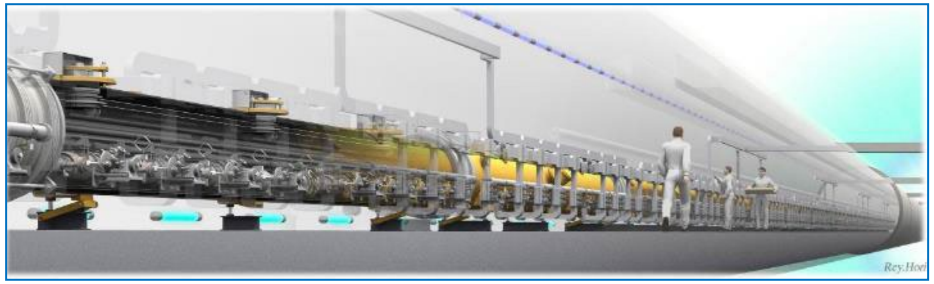
Civil engineering group

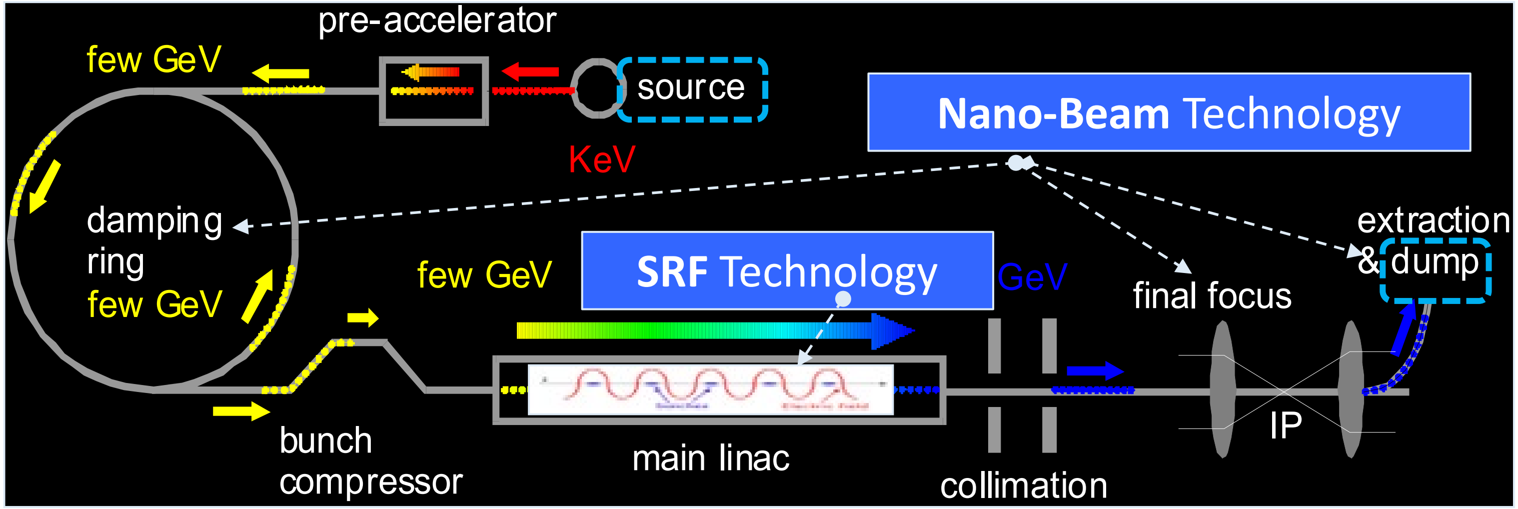
Nobuhiro Terunuma	***KEK***
John Andrew Osborne	CERN
Tomoyuki Sanuki	U. Tohoku

Those in red are Steering members.

ILC and the Accelerator Technology

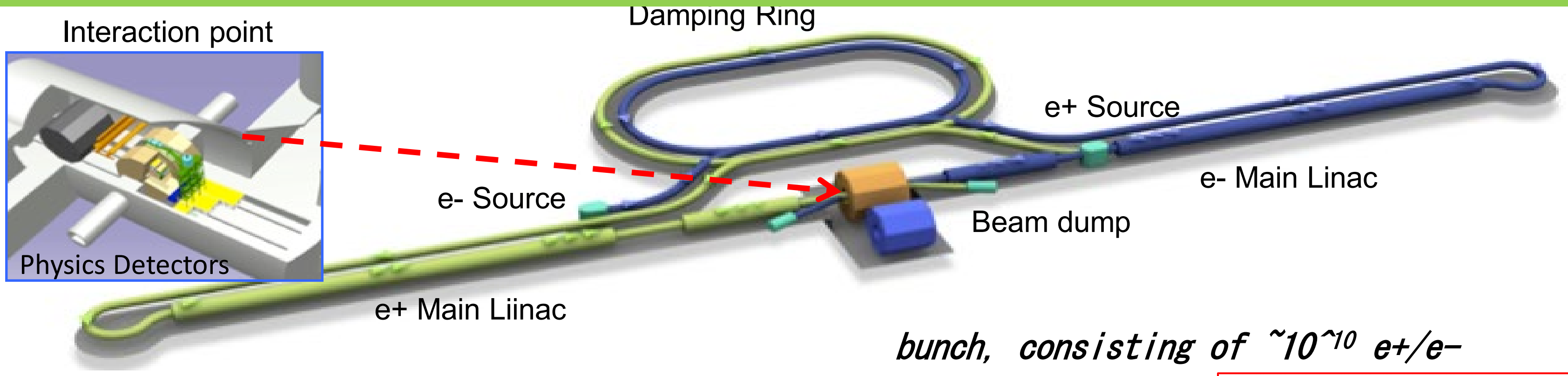






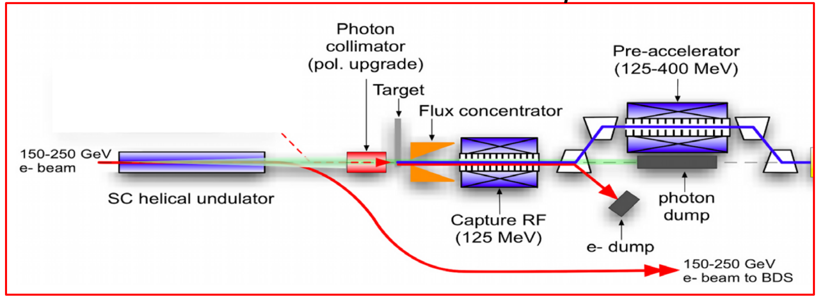
Parameters	Value
Beam Energy	125 + 125 GeV
Luminosity	1.35 / 2.7 x 10^{10} cm^2/s
Beam rep. rate	5 Hz
Pulse duration	0.73 / 0.961 ms
# bunch / pulse	1312 / 2625
Beam Current	5.8 / 8.8 mA
Beam size (y) at FF	**7.7** nm
SRF Field gradient	< 31.5 > MV/m (+/-20%) Q_0 = $1x10^{10}$
#SRF 9-cell cavities (CM)	~ 8,000 (~ 900)
AC-plug Power	111 / 138 MW

Area systems of the ILC

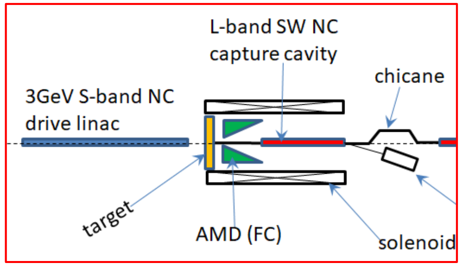


bunch, consisting of ~10^10 e+/e−

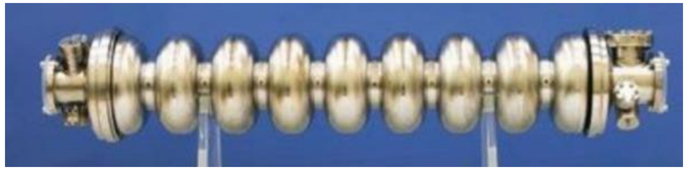
Undulator positron source



Electron driven positron source



- 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**



IDT Scope for ILC Realization

ilc international development team

-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

Ver 0: 2021May30

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

Ver 0: 2022June10

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)

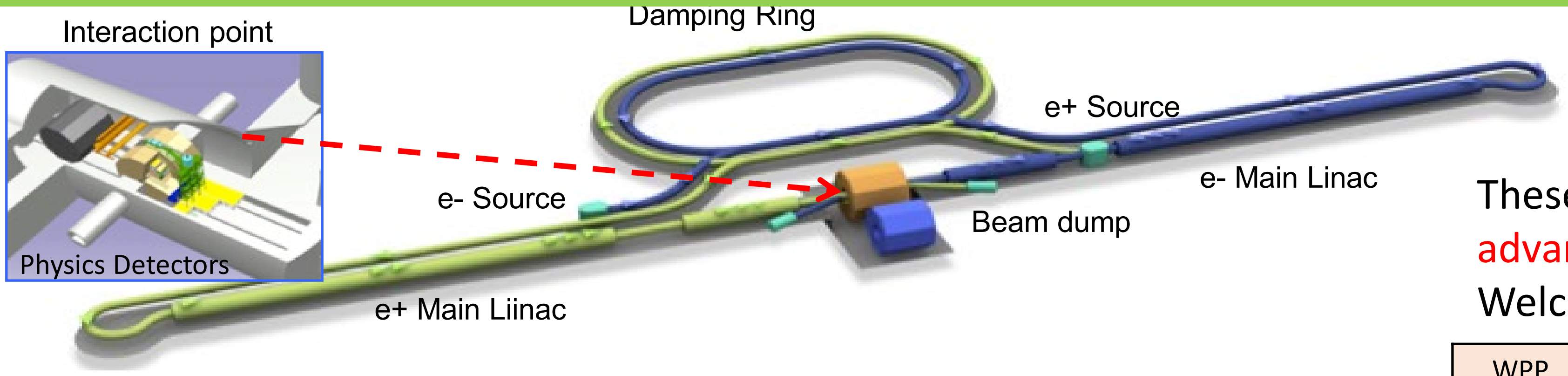
-- global collaboration program---

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

Synergy with other colliders

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

WP-Primes at ILC Technology Network



These WPs can be applied to various advanced accelerators.
Welcome to join!

- 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

KEK / IDT-WG2

Shin MICHIZONO (KEK)

- ILC accelerator
- ILC Technology network
  - SRF
  - Sources
  - Nanobeam

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

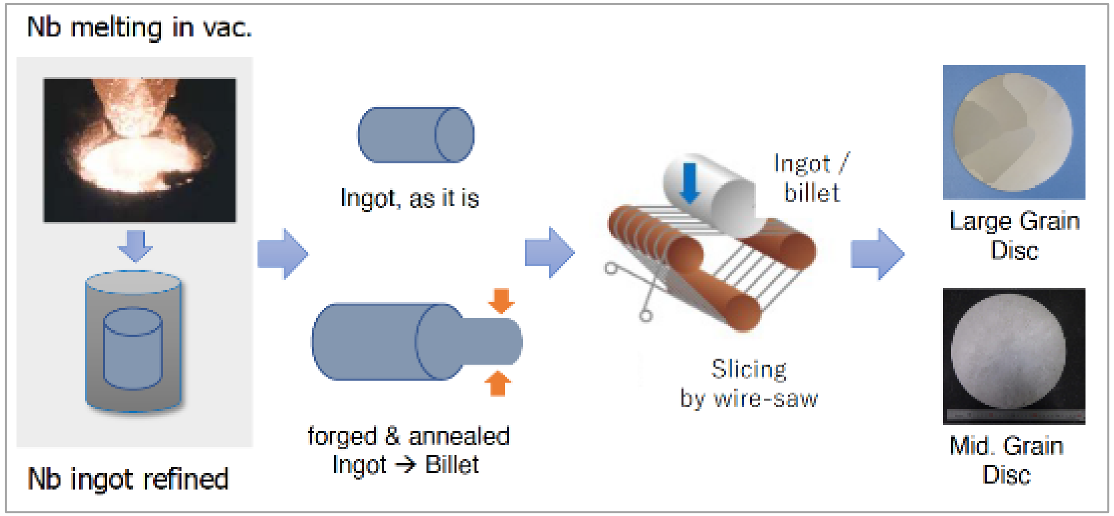
Referring European XFEL and LCLS-II experiences

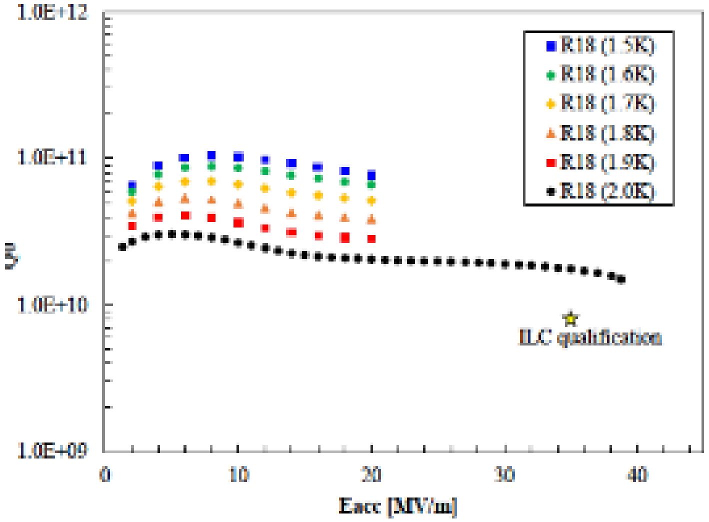
- Research with single-cell cavities to establish the best production process including:
  - Advanced Nb sheet production method
  - Advanced surface treatment recipe
- Globally common design with compatible High Pressure Gas Safety (HPGS) regulation
- 24 nine-cell cavities are to be developed for industrial-production readiness
  - 8 cavities (4 / batch) in each region
  - Production process encouraged to be optimized in each region
  - Cavity performance expected: E_{acc} = <35 MV/m> (+/− 20%), $Q_0 = 1.0 \times 10^{10}$, Yield = ≥90%
- RF performance/success yield to be examined (including 2nd pass and further)
  - 3rd pass to be examined if effective

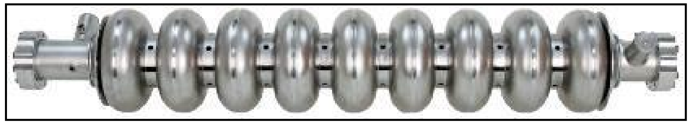
	# of cavities to be produced		
	Americas	Europe	JP/Asia
single-cell	2	2	2 (+4)
nine-cell	8	8	8 (+ 4)

Material/Sub-component
↓
QA of Material/Sub-C
↓
Cavity Production
↓
Surface Process
↓
Vertical Test = Cavity RF Test

Production process



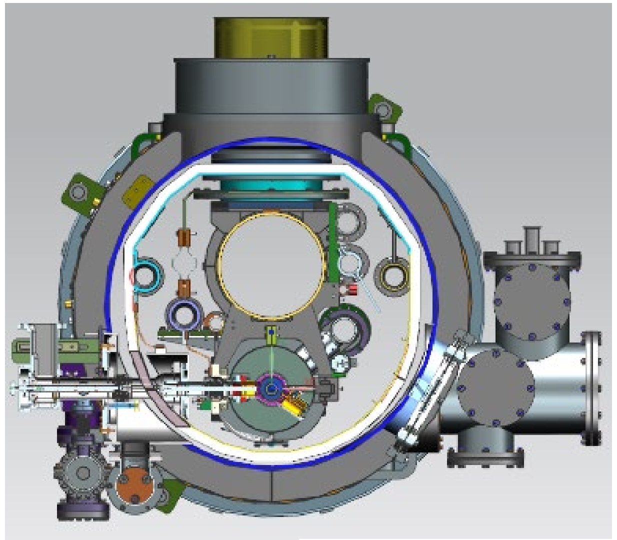


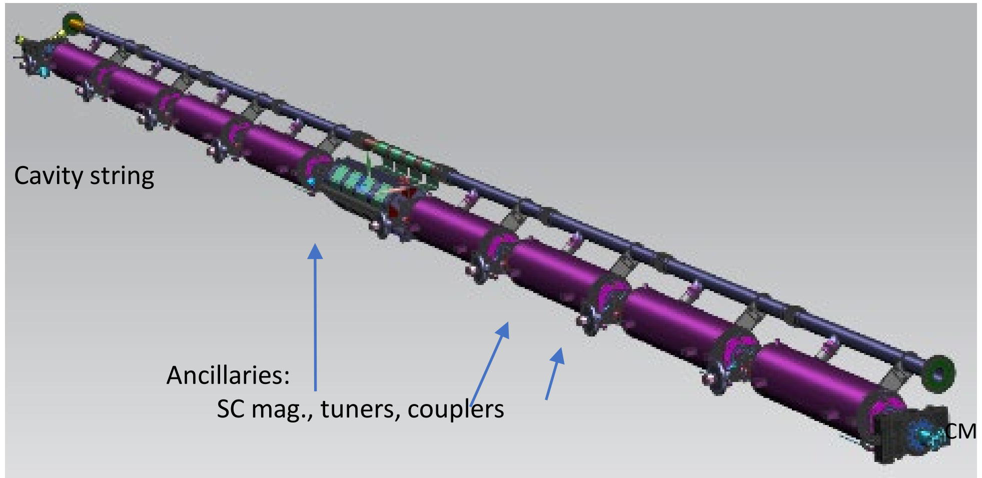


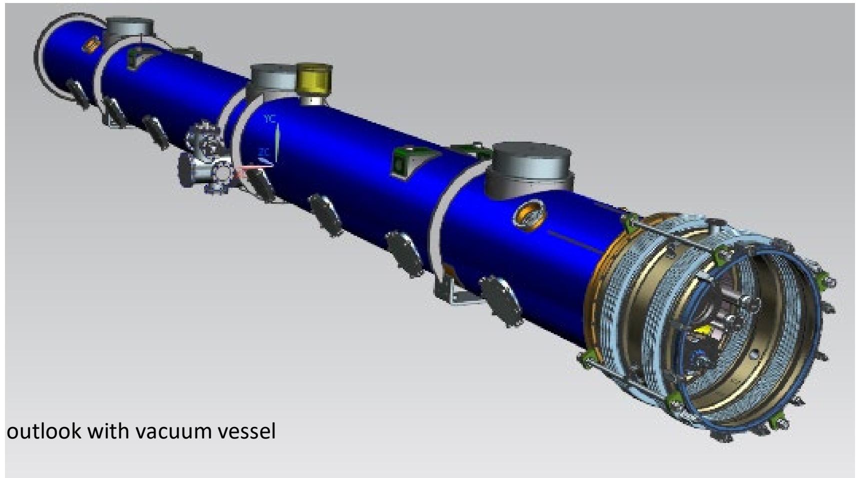
WP-prime 2: Cryomodule (CM) Design
(Scoping the CM Global Transfer and Performance Assurance)

Referring European XFEL and LCLS-II experiences

- ◆ Unify cryomodule (CM) design with ancillaries, based on globally common engineering design, drawings & data-base
- ◆ Establish globally compatible safety design base to be approved/authorized by HPGS regulations individually in each region, most likely referring ASME guidelines to be compatible with Japanese regulations.







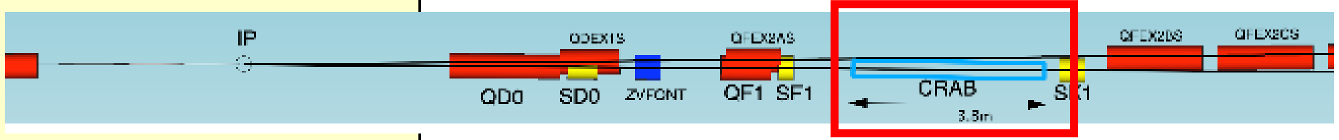
Region Regulation	Americas ASME	Europe Eu-EN, TUV	Japan/Asia JP-HPGS Act
CM tech. design base	LCLS-II	Euro-XFEL	KEK-STF, AST-IFMIF
ILC CM design	Common CM design globally compatible to HPGS regulation in all regions, and most likely ASME guidelines to be compatible with Japanese regulations.		

WP-prime 3: Crab Cavity Development

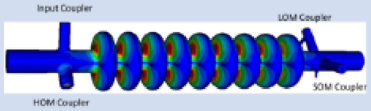
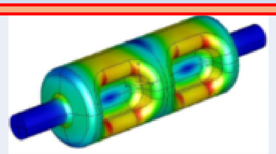
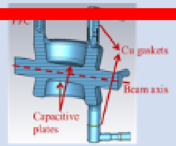
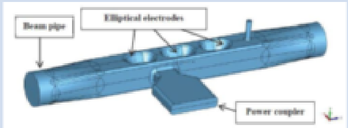
- Pre-down-selection review hosted by KEK chose two primary candidates on Apr/2023
  - RFD (1st), QMiR (2nd), Elliptical (3rd)
- Development and evaluation of two prototype cavities
  - KEK will provide for necessary Nb material to produce them
- RF property simulation to optimize cavity design
- Demonstration of synchronized operation with two prototypes
- Down-selection to choose final cavity design
- Cryomodule design based on final cavity design

two beamline distance

14.049m x 0.014rad = **197mm**



Item	Recent specification (after TDR)
Beam energy	125 GeV (e^-)
Crossing angle	**14 mrad**
Installation site	14 m from IP
RF repetition rate	5 Hz
Bunch train length	727 µsec
Bunch spacing	554 nsec
Operational temperature	2.0 K (?)
Cavity frequency	1.3/3.9 GHz
Total kick voltage	1.845/0.615 MV
Relative RF phase jitter	0.023/0.069 deg rms (49 fs rms)

Elliptical/Racetrack (3.9 GHz)	Lanc. Univ.	
RF Dipole (RFD)	ODU	
Double Quarter Wave (DQW)	CERN	
Wide Open Waveguide (WOW)	BNL	
Quasi-waveguide MultIcell Resonator (QMIR)	FNAL	

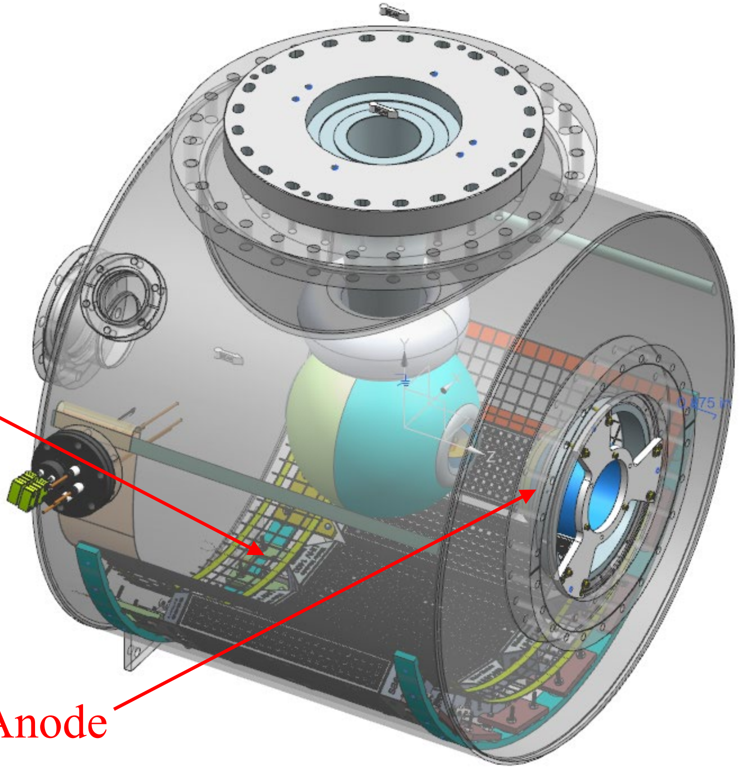
ILC Technology Network (ITN)

KEK / IDT-WG2
Shin MICHIZONO (KEK)

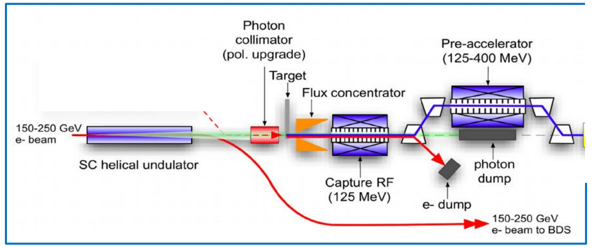
- ILC accelerator
- ILC Technology network
  - SRF
  - Sources
  - Nanobeam

WP-prime 4: Electron Gun

- The electron gun consists of
  - High-voltage photo gun
  - Drive laser system
  - GaAs/GaAsP Photocathode
- High-voltage gun is the most urgent item
  - The gun voltage in TDR is 200 kV. A higher voltage desirable.
  - Meaningful technical progresses since TDR would be reflected in a new design
  - New GaAs gun based on lessons learned from 350 kV CsKSb magnetized dc photogun



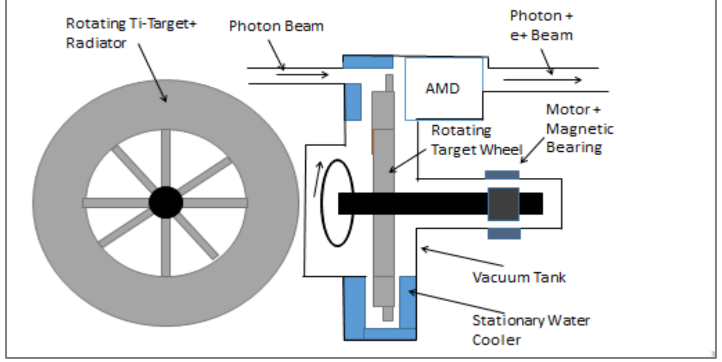
WP-Prime 6/7:
Undulator-driven e+ Source



WP-prime 6: Rotating Target for Undulator Scheme

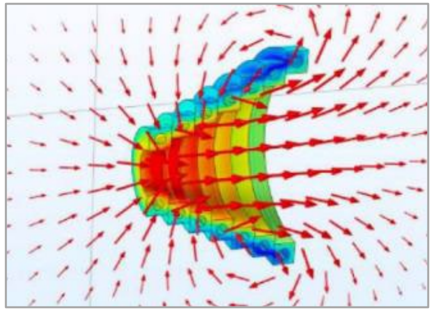
- Target specification
  - Titanium alloy, 7mm thick (0.2 X_0), diameter 1m
  - Rotating at 2,000 rpm (100 m/s) in vacuum
  - Photon power ~60 kW, deposited power ~2 kW
  - Radiation cooling
  - Magnetic bearings
- R&D to be done as WP-prime
  - Design finalization, partial laboratory test, mock-up design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

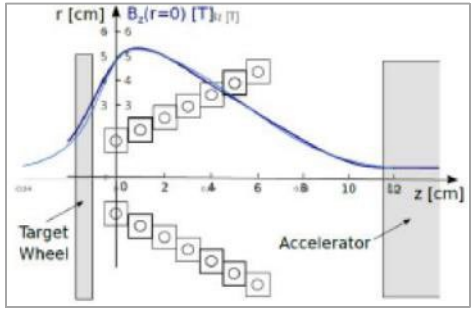
Principal Layout: Ti-Wheel with a Diameter of 1.0 m, rotating at 100 m/s, 2000 rpm.



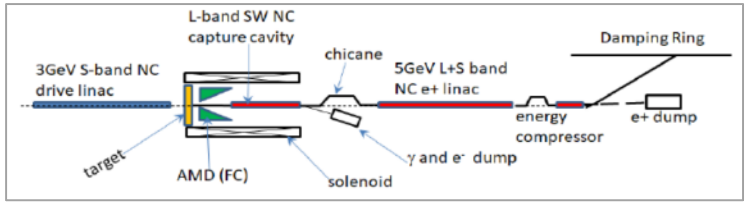
WP-prime 7: Focusing System for Undulator Scheme

- 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

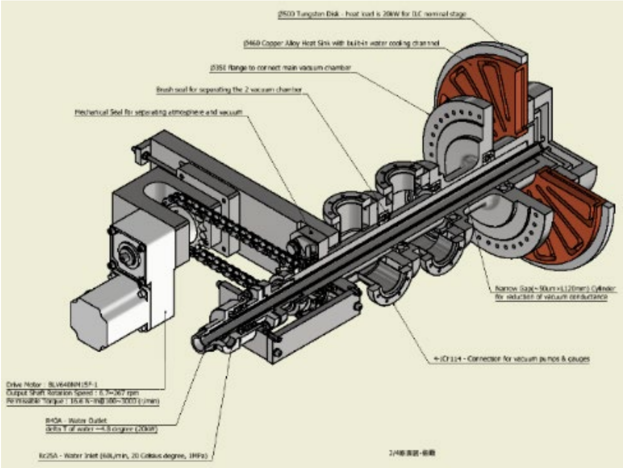


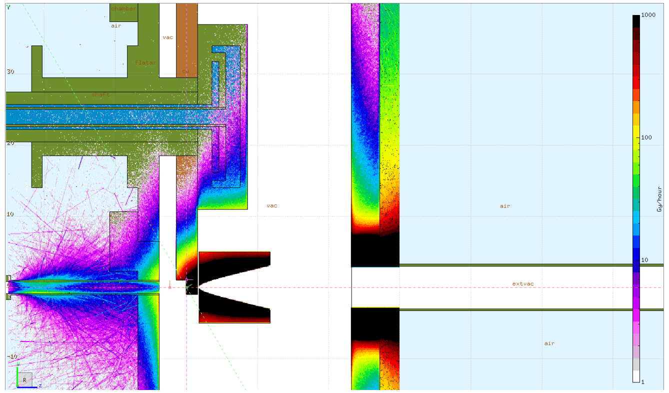
WP-prime 8: Rotating Target for e-Driven Scheme

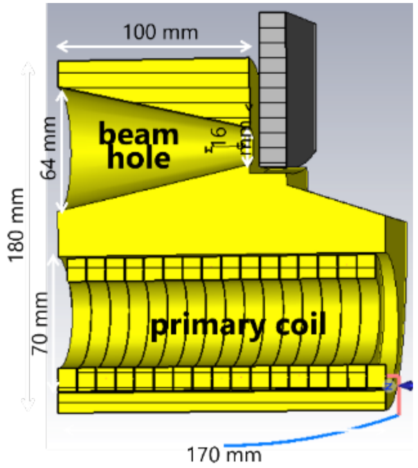
- Target specification
  - W or W-alloy, ~16 mm (5 X_0) thick, diameter 50 cm
  - Rotating at 5 m/s in vacuum
  - Water cooled.
  - Vacuum seal
- R&D items to be done in 2 years
  - Target stress calculation with FEM
  - Vacuum seal
  - Target module design and prototyping
  - W-Cu connection test and evaluation

WP-prime 9: Focusing System

- Flux Concentrator (FC) is chosen as the focusing device after the target
- The specification parameters such as max field, electric current and the dynamic force are satisfied in existing target, but the pulse energy and the heat load are higher.
- A prototype necessary after detailed design study
- R&D items as WP-prime
  - Flux concentrator conductor design (in first 2 years)
  - Conductor prototyping (in the remaining years)

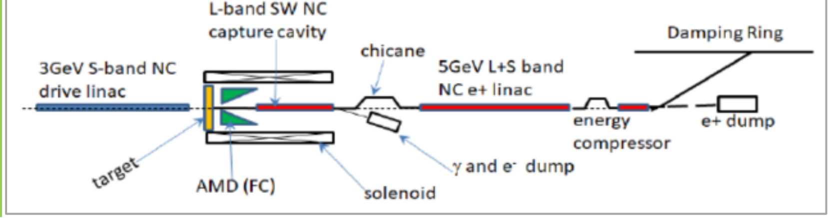






Parameter	ILC FC	Unit
Max. B field	5	T
Max. surf. current	25	KA
Dynamic force	125	kA.T
Pulse energy	140	J
Average Power	13.7	kW

WP-Prime 8~11:
e- driven positron source

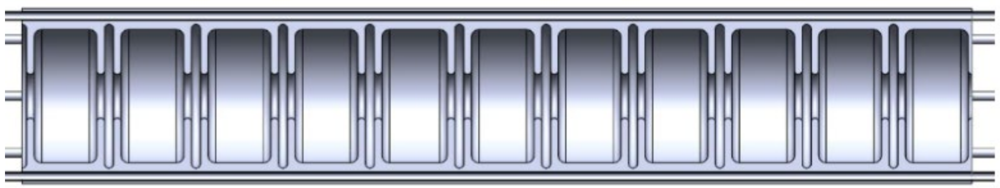


WP-prime 10: Capture Cavity and Linac for e-Driven Scheme

- ◆ Technically the most critical element is the L-band, standing-wave structure right after the target and FC.
  - ➢ High beamloading (up to ~1A)
  - ➢ Special bunch pattern
  - ➢ Changing beam current (mixed electron-positron, capture process in RF buckets)

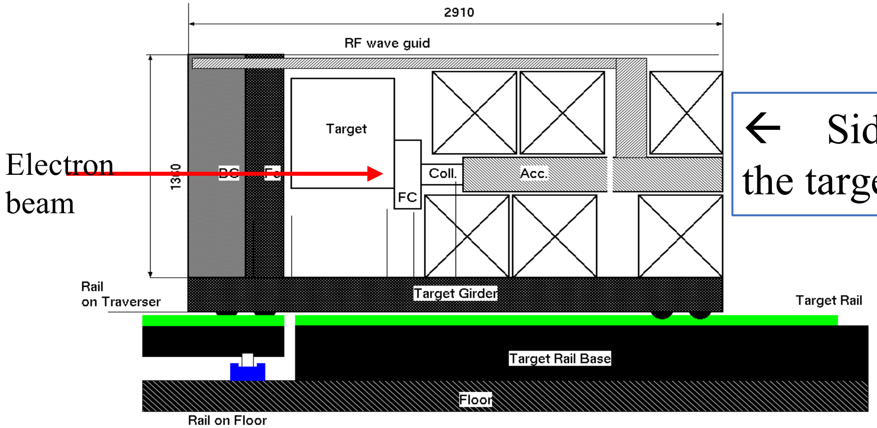
- ◆ R&D items as WPP-10 for the first 2 years
  - ➢ APS (Alternating Periodic Structure) cavity design and cold model
  - ➢ Beam-loading compensation and tuning method
  - ➢ Power unit prototype design
  - ➢ solenoid design
- ◆ Prototyping of these components in later years

APS cavity



WP-prime 11:Target replacement

- ◆ Special attention is needed due to the high radiation of the target area. This is a common issue for E-Driven and Undulator positron source.
- ◆ Careful design of shielding is required.
- ◆ The components near the target (target, flux concentrator, first cavity with solenoid) require replacement in every few years. The work must be done by remotely.
- ◆ The works to be done as WP-prime
  - ➢ Conceptual design
  - ➢ Fabricate Mockup
  - ➢ Prototyping of critical components



← Side view of the target module

KEK / IDT-WG2
Shin MICHIZONO (KEK)

- ILC accelerator
- ILC Technology network
  - SRF
  - Sources
  - Nanobeam

WP-prime 12/14: Damping ring

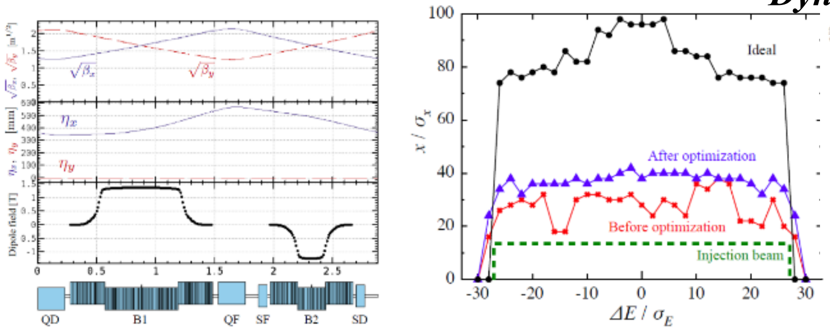
WP-prime 12: System design of ILC DR

- The ILC damping ring (DR) is required to satisfy the low emittance and the large dynamic aperture simultaneously.
- The ILC DR will be further improved by incorporating the findings of the latest light source design. Increasing the dynamic aperture is also important in the design of DR.
- By quantitatively evaluating the effect of fringe field to the dynamic aperture of magnets in ILC DR, the method for evaluating fringe field to the dynamic aperture in accelerator design will be established and the design of ILC DR will be optimized.

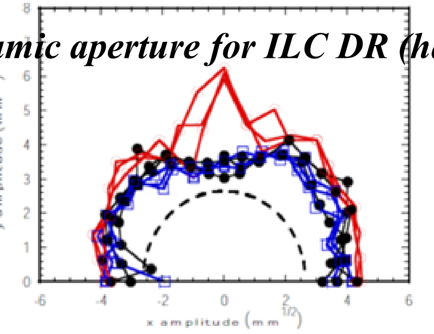
WP-prime 14: System design of ILC DR injection/extraction kickers

- A fast kicker system using a semiconductor pulse power supply with nanosecond response was confirmed as proof of principle at KEK's ATF about 10 years ago.
- Semiconductor technology has been evolving, and it is now possible to advance nanosecond response beam injection/excitation systems using the recent semiconductor technology.
- The technical evaluation of the fast kicker power supply using the recent semiconductor technologies.
- The evaluation of fast pulsed power supply technology will contribute not only to the fast kicker system but also to the performance and reliability of nanosecond-scale beam control technology and its application to a wide range of accelerator systems.

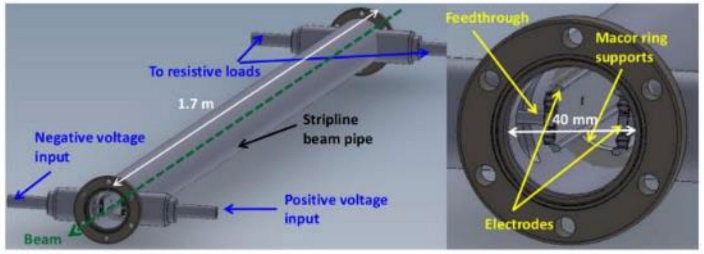
Dynamic aperture evaluation with fringe effect (SuperKEKB DR)



Dynamic aperture for ILC DR (hard edge)



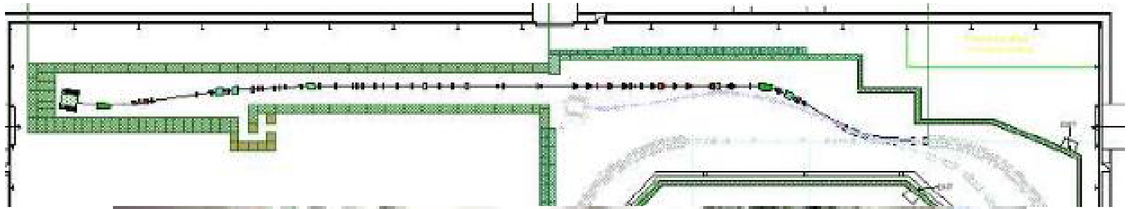
Beam injection/extraction system for CLIC damping ring



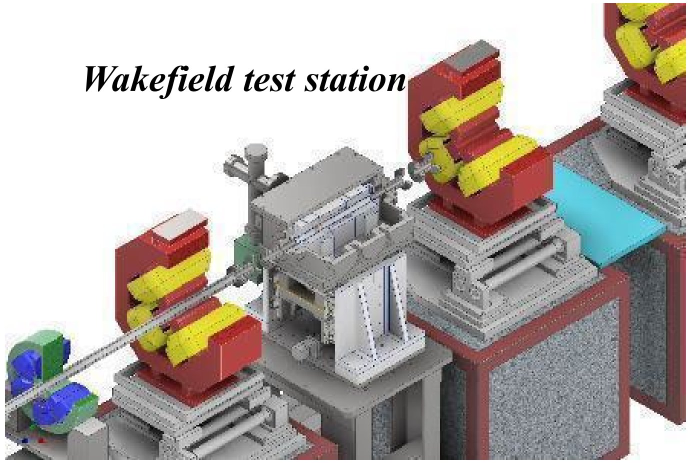
WP-prime 15: System design of ILC FFS

ATF collaboration

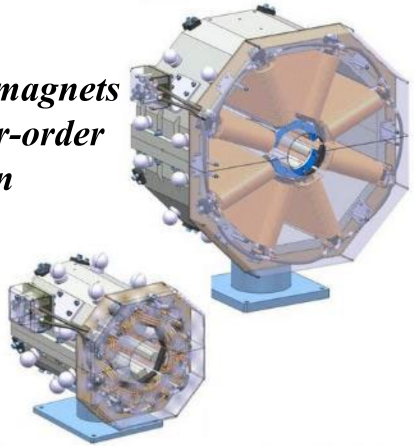
- ATF2 beamline is the only existing test accelerator in the world to test the final focus system (FFS) of linear colliders.
- The following 3 research topics are important to be pursued at the ATF.
  - wakefield mitigation
  - correction of higher-order aberration
  - training for ILC beam tuning
- The technical research at ATF2 beamline has proceeded and should continue to be based on the ATF international collaboration, or its extension (welcome to new collaborators).



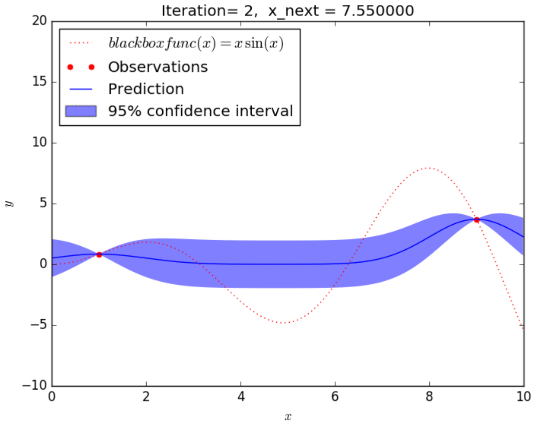
Wakefield test station



Octupole magnets for higher-order aberration



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



WP-prime 16/17:Final doublet/Beam dump

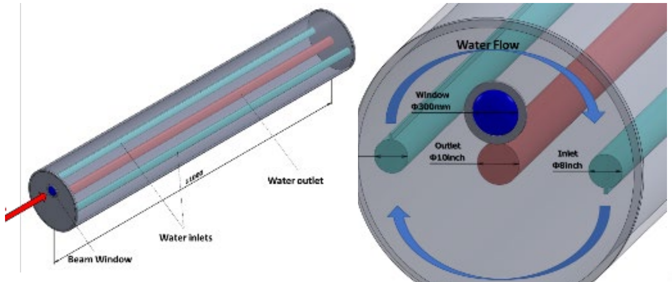
WP-prime 16: Final doublet design optimization

- ◆Cooling of the superconducting ILC final focus magnets will be performed using 2K superfluid helium to realize superconducting magnets with high oscillation stability.
- ◆Quantitative evaluation of the vibration generated by the 2K cooling system located on the side of the final focus magnets has not been completed.
- ◆We will measure and evaluate the vibration generated by the 2K cooling system by using the prototype.

Prototype of ILC service cryostat
(2K cooling system ; BNL)

WP-prime 17: Beam Dump

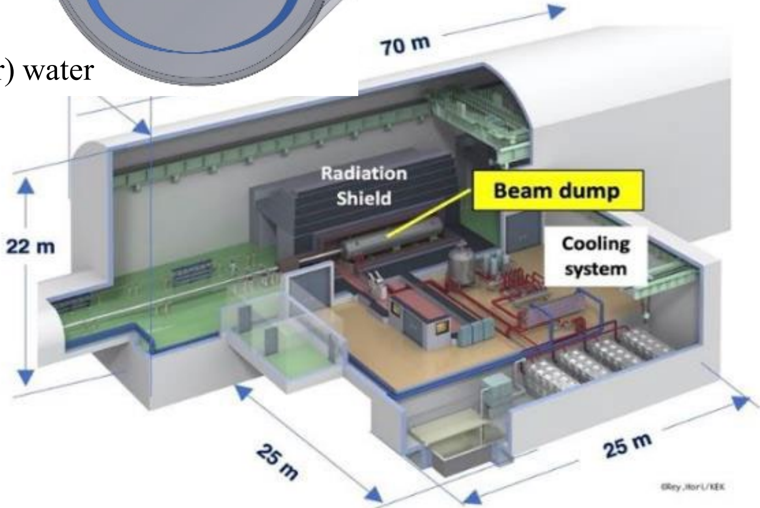
- ◆ Finalize the engineering design of the main beam dump system
  - Vortex water flow in the dump vessel
  - Cooling water circulation and heat exchange
  - Remote exchange of the beam window
  - Countermeasure for failures / safety system



11m-long x 2m(diameter) water

Vortex water flow

- **17 MW** at 500 GeV beam
- 1 MPa to prevent boiling



Imaginary view of the main dump section

ITN in progress

For WPP-1&2 (SRF cavity, CM), we have already started technical discussions with researchers in Europe and the USA.
For WPP-15 (Final Focus System), European researchers joined to the ATF experiments in this June operation.

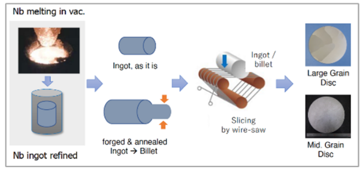
WP-prime 1: SRF Cavity
(Scoping the Industrial-Production Readiness)

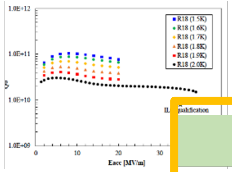
Referring European XFEL and LCLS-II experiences

- Research with single-cell cavities to establish the best production process including:
  - Advanced Nb sheet production method
  - Advanced surface treatment recipe
- 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 (4 / batch) in each region
  - Production process encouraged to be optimized in each region
  - Cavity performance expected: E_{acc} = <35 MV/m> (+/− 20%), $Q_0 = 1.0 \times 10^{10}$, 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 (+4)
nine-cell	8	8	8 (+ 4)

Material/Sub-component → QA of Material/Sub-C → Cavity Production → Surface Process → Cavity RF Test → Production process

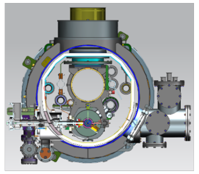


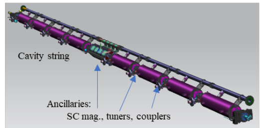


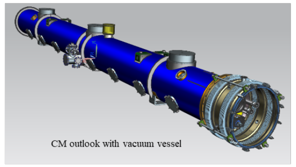
WP-prime 2: Cryomodule (CM) Design
(Scoping the CM Global Transfer and Performance Assurance)

Referring European XFEL and LCLS-II experiences

- Unify cryomodule (CM) design with ancillaries, based on globally common engineering design, drawings & data-base
- Establish globally compatible safety design base to be approved/authorized by HPGS regulations individually in each region, most likely referring ASME guidelines to be compatible with Japanese regulations.







Region Regulation	Americas ASME	Europe Eu-EN, TUV	Japan/Asia JP-HPGS Act
CM tech. design base	LCLS-II	Euro-XFEL	KEK-STF, AST-IFMIF
ILC CM design	Common CM design globally compatible to HPGS regulation in all regions, and most likely ASME guidelines to be compatible with Japanese regulations.		

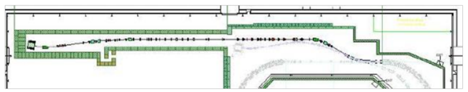
29

WP-prime 15: System design of ILC FFS

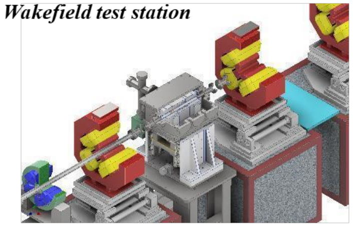
ATF collaboration

- 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 topics to be pursued at the ATF.
  - wakefield mitigation
  - correction of higher-order aberration
  - training for ILC beam tuning
- The technical research at ATF2 beamline has proceeded, and should continue to be based on the ATF international collaboration, or its extension (welcome to new collaborators).

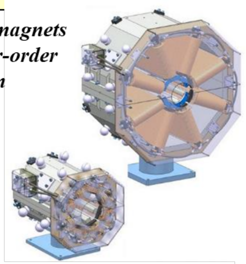
ATF2 beamline



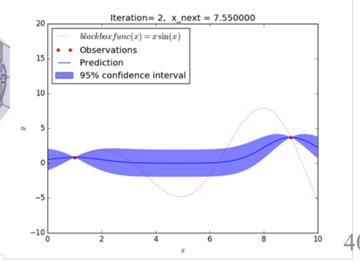
Wakefield test station



Octupole magnets for higher-order aberration



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



40

international development team

Thank you for your attention