International Development Team

ILC Status and Plans

Benno List

CLIC Mini WS

11.12.23

The ILC IDT organization – initiated at the ICFA meeting at SLAC February 2020

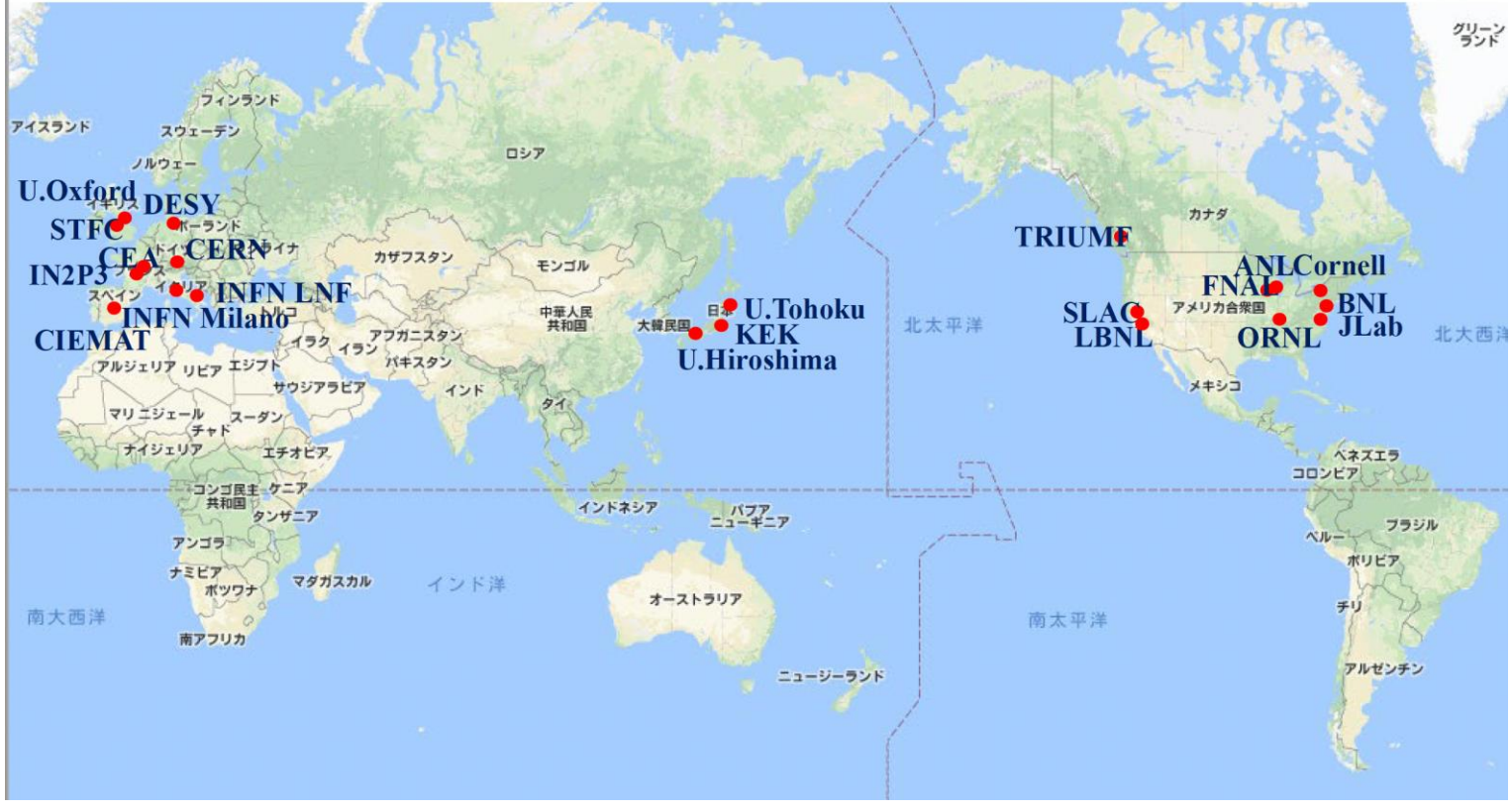
2020-21: The IDT – created by ICFA and hosted by KEK – was set up to move ILC towards construction. The worldwide structure of the WGs: https://linearcollider.org/team/
A set of key activities were identified in a Preparation Phase Programme.

2022-23: A subset of the technical activities of the full ILC preparation phase programme have been identified as critical (next slide). These are being addresses by a ~4 year programme called ITN – the ILC Technology Network. Moving forward with this work is being supported by the MEXT (ministry) providing crucial increased funding.

As of today: With funding from 1.4.2023 ITN is now starting. An agreement KEK and CERN and several European lab activities have been/are being set up. In the US the P5 process is ongoing, the hope is that ITN planning and interests can turn into important ITN involvements in due time.

IDT WG2 around the World

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



ILC Timeline

-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

2022 June

Time-critical WPs for the ILC construction

WP-Primes for Time Critical

http://doi.org/10.5281/zenodo.4742018

https://agenda.linearcollider.org/event/9735/contributions/50816/attachments/38190/59968/Time-Critical_WPsV8b.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.

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The ITN

Promoting the technological development of the International Linear Collider:
Twenty-eight research institutes participated in the ITN Information Meeting

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

Building the ITN activities:

- Planning in the IDT WG2 – significant interests and expertise already represented
- Information meeting at CERN 16-17.10 jointly organized by KEK and the IDT
- Interest matrix for the ITN work-packages, being consolidated
- The next step: Further technical discussion to define deliverables, followed by agreement who among the laboratories will deliver what

SRF	WPP	1	Cavity production	✓		✓	✓	✓			✓	✓	✓					✓	✓	✓		✓	✓		✓	✓	
	WPP	2	CM design	✓				✓				✓			✓	✓	✓	✓	✓	✓			✓		✓	✓	
	WPP	3	Crab cavity			✓	✓							✓				✓	✓	✓			✓	✓		✓	✓
Sources	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	✓																							
Nano-beams	WPP	12	DR System design	✓	✓				✓	✓		✓							✓					✓	✓		
	WPP	14	DR Injection/extraction	✓					✓										✓					✓	✓		
	WPP	15	Final focus	✓			✓		✓		✓							✓				✓			✓		
	WPP	16	Final doublet	✓	✓													✓									
	WPP	17	Main dump	✓			✓					✓															

ITN Agreement between KEK and 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.

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

Topics

2023/07/08

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

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

ITN Kickoff at CERN

*The "ILC Technology Network (ITN) Information Meeting" was held at the European Organization for Nuclear Research (CERN) in Geneva on **October 16 and 17**, hosted jointly by KEK and the ILC International Development Team (IDT). Sixty-eight participants from 28 research institutes over ten countries participated in the meeting either in person or remotely.*

The ITN is a framework for international collaboration to promote high-priority tasks of accelerator development (called "work packages") for the International Linear Collider (ILC), jointly established by KEK and the IDT. ITN membership is defined through bilateral arrangements between KEK and laboratories. In July of this year, CERN became a member by exchanging an agreement with KEK, which states that CERN will serve as a hub for European research institutions participating in the ITN.

This meeting was held to present the opportunities provided by the ITN and to collect interests of the potential members to achieve its goal. CERN was chosen as the venue to facilitate participation by the European research institutes, which are major players in ITN activities at this moment.

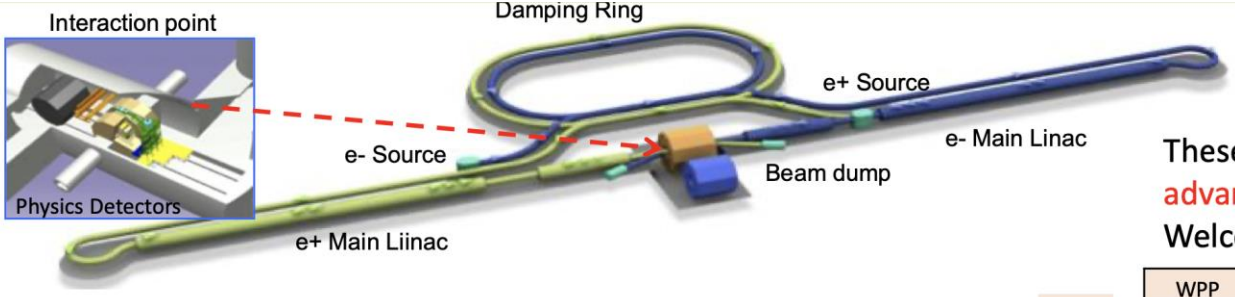
Promoting the technological development of the International Linear Collider: Twenty-eight research institutes participated in the ITN Information Meeting

Topics

2023/11/16

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

The updated Priority Work Packages (WP')



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
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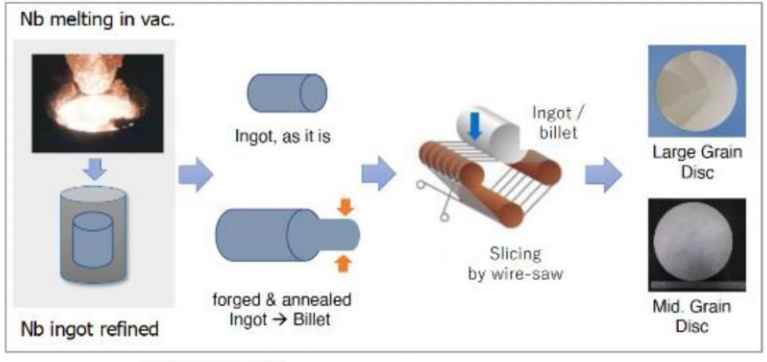
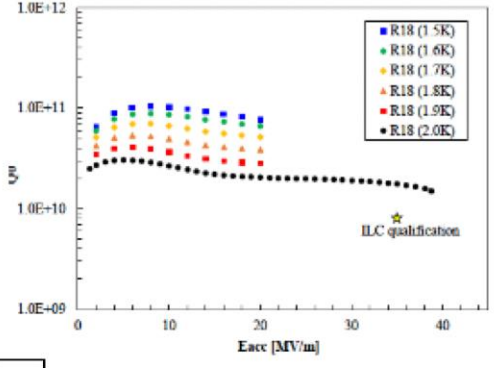
WP'1: Cavity Production

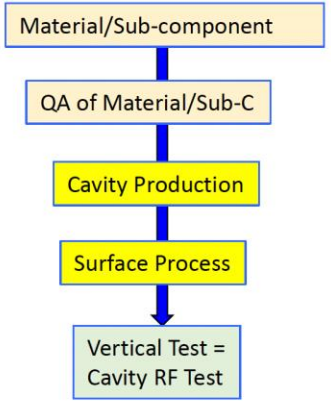
Referring European XFEL and LCLS-II experiences

- 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 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 (+4)
nine-cell	8	8	8 (+ 4)







Production process

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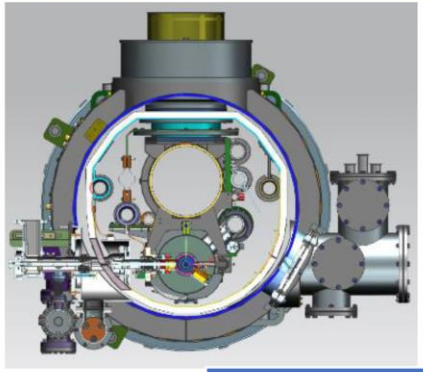
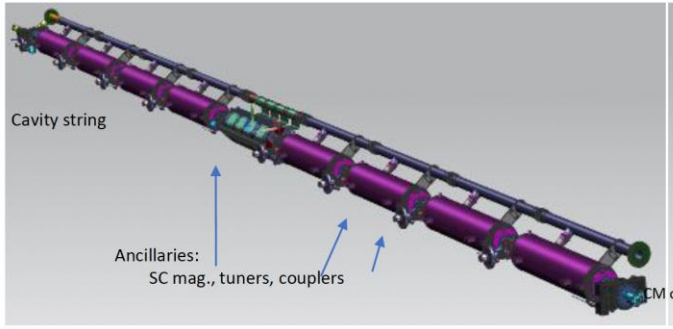
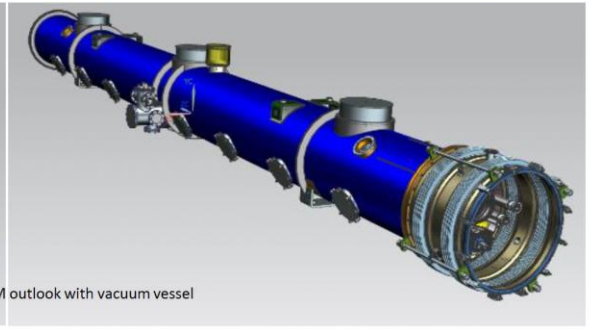
WP'2: Cryomodule Design

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.		

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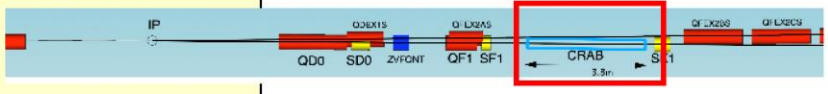
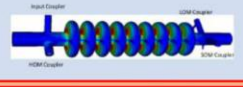
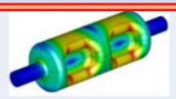
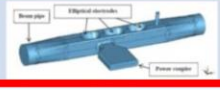
WP'3: Crab Cavities

- 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	

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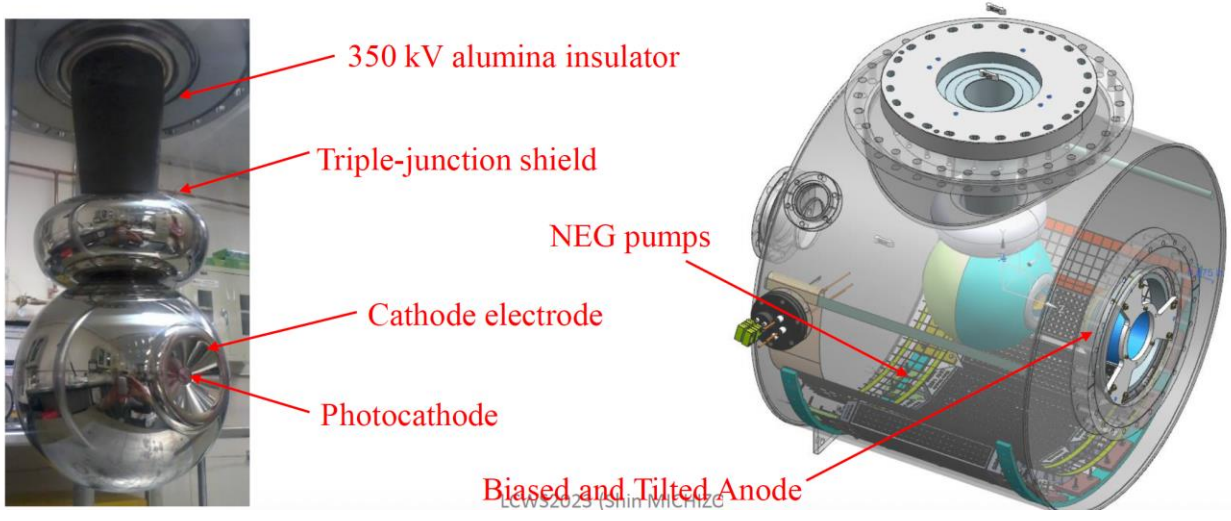
WP'4: Electron Gun

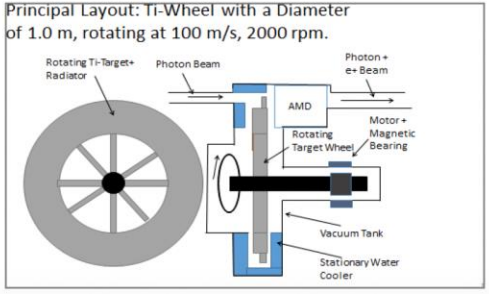
- The electron gun consists of
  - High-voltage photo gun
  - Drive laser system
  - GaAs/GaAsP Photocathode
- High-voltage gun is the most urgent item
  - The gun voltage in TDR is 200 kV. A higher voltage desirable.
  - Meaningful technical progresses since TDR would be reflected in a new design
 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



WP' 6-7: Undulator Driven Positron Source

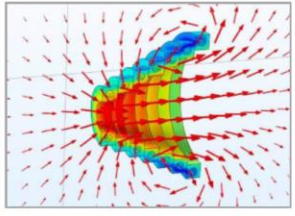
WP-prime 6: Rotating Target for Undulator Scheme

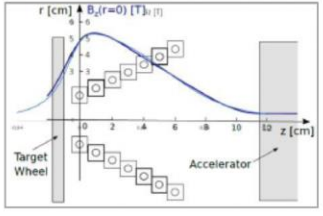
- Target specification
  - Titanium alloy, 7mm thick (0.2 X_0), diameter 1m
  - Rotating at 2,000 rpm (100 m/s) in vacuum
  - Photon power ~60 kW, deposited power ~2 kW
  - Radiation cooling
  - Magnetic bearings
- R&D to be done as WP-prime
  - Design finalization, partial laboratory test, mock-up design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





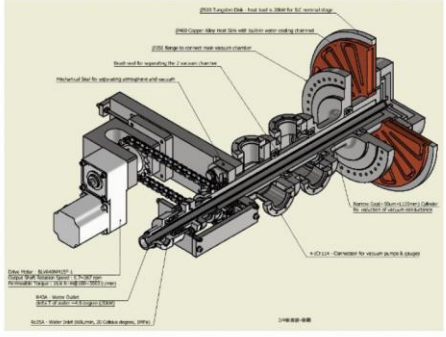
WP' 8-11: Electron Driven Positron Source

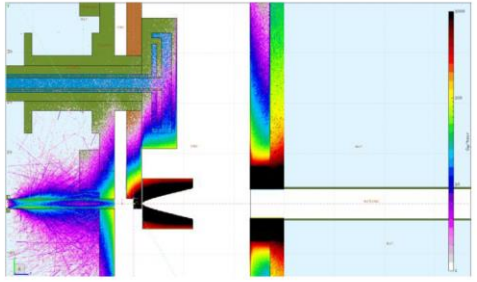
WP-prime 8: Rotating Target for e-Driven Scheme

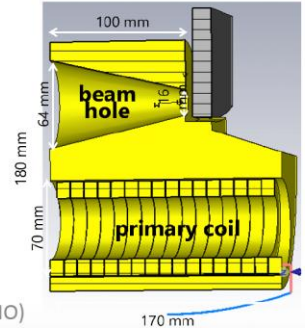
- Target specification
  - W or W-alloy, ~16 mm (5 X_0) thick, diameter 50 cm
  - Rotating at 5 m/s in vacuum
  - Water cooled.
  - Vacuum seal
- R&D items to be done in 2 years
  - Target stress calculation with FEM
  - Vacuum seal
  - Target module design and prototyping
  - W-Cu connection test and 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' 8-11: Electron Driven Positron Source (cont'd)

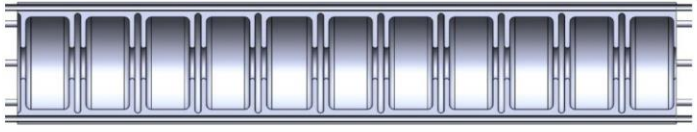
Common for both sources

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)

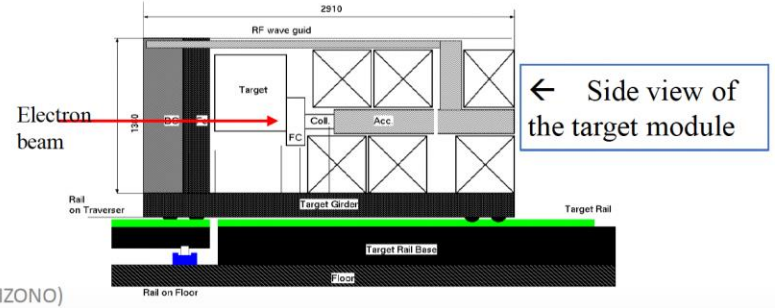
- R&D items as WPP-10 for the first 2 years
  - ➢ APS (Alternating Periodic Structure) cavity design and cold model
  - ➢ Beam-loading compensation and tuning method
  - ➢ Power unit prototype design
  - ➢ solenoid design
- Prototyping of these components in later years

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

WP' 12/14: Damping Ring

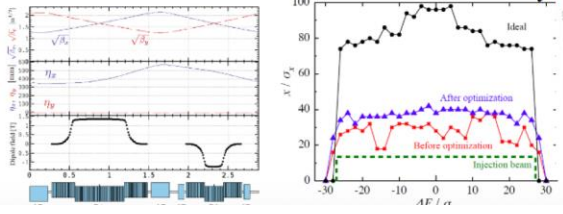
WP-prime 12: System design of ILC DR

- 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.

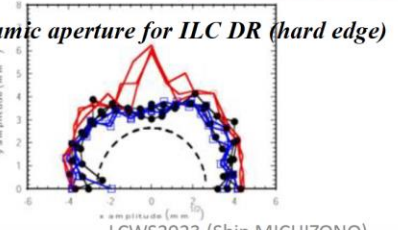
WP-prime 14: System design of ILC DR injection/extraction kickers

- 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.

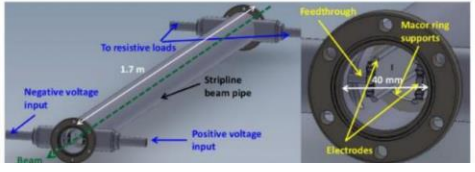
Dynamic aperture evaluation with fringe effect (SuperKEKB DR)

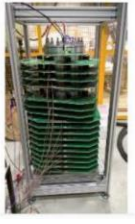


Dynamic aperture for ILC DR (hard edge)



Beam injection/extraction system for CLIC damping ring





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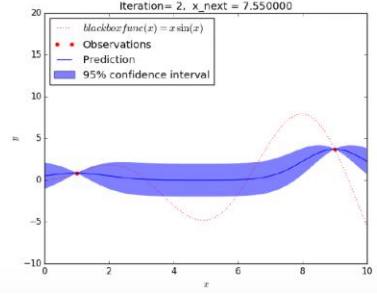
WP' 15: Final Focus System

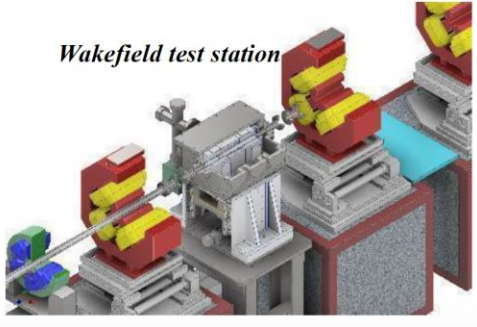
- ATF2 beamline is the only existing test accelerator in the world to test the final focus system (FFS) of linear colliders.
- The following 3 research topics are important to be pursued at the ATF.
  - wakefield mitigation
  - correction of higher-order aberration
  - training for ILC beam tuning
- 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).

ATF Collaboration

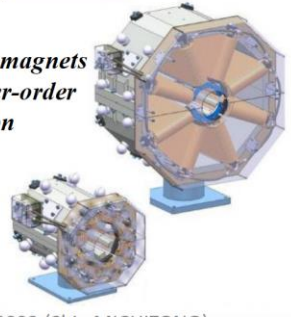
Maximum search algorithms to be applied to beam tuning (Machine Learning)



Wakefield test station



Octupole magnets for higher-order aberration



WP' 16-17: Final Doublet, Main Dumps

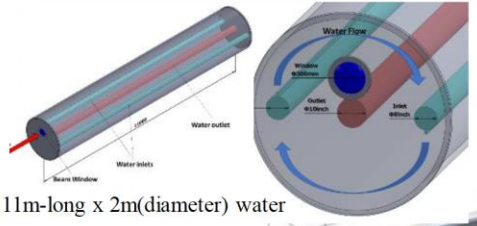
WP-prime 16: Final doublet design optimization

- 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

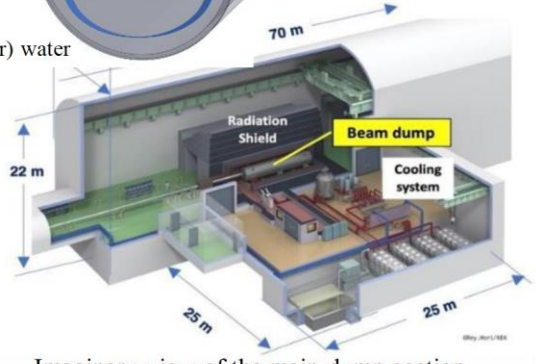
- Finalize the engineering design of the main beam dump system
  - Vortex water flow in the dump vessel
  - Cooling water circulation and heat exchange
  - Remote exchange of the beam window
  - Countermeasure for failures / safety system



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

S. Michizono, LCWS 20223

Linking IDT and ITN

Lab's interest

Preliminary list of the interests (to be confirmed by Labs).

				comments																					
SRF	WPP	1	Cavity production	Asia/Eu./Am.	✓		✓	✓	✓			✓	✓	✓				✓	✓	✓		✓	✓		✓	✓	
	WPP	2	CM design	Asia/Eu./Am.	✓				✓				✓			✓	✓	✓	✓	✓			✓		✓	✓	
	WPP	3	Crab cavity	RFD, QMIR, (Elliptical)			✓	✓							✓					✓			✓	✓		✓	✓
Sources	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		✓																						
Nano beam	WPP	12	DR System design		✓	✓				✓	✓		✓							✓					✓	✓		
	WPP	14	DR Injection/extraction		✓					✓										✓					✓	✓		
	WPP	15	Final focus	KEK-ATF	✓			✓		✓		✓							✓			✓				✓		
	WPP	16	Final doublet			✓																					
	WPP	17	Main dump		✓			✓																			

IDT-WG2

IDT Subgroups (SRF, Sources, BDS/DR/Dumps) contact & invite representatives from interested/participating labs

-> IDT subgroups initiate formation of ITN work packages

The European ITN activities – 2023

European ITN studies are distributed on five main activity areas:

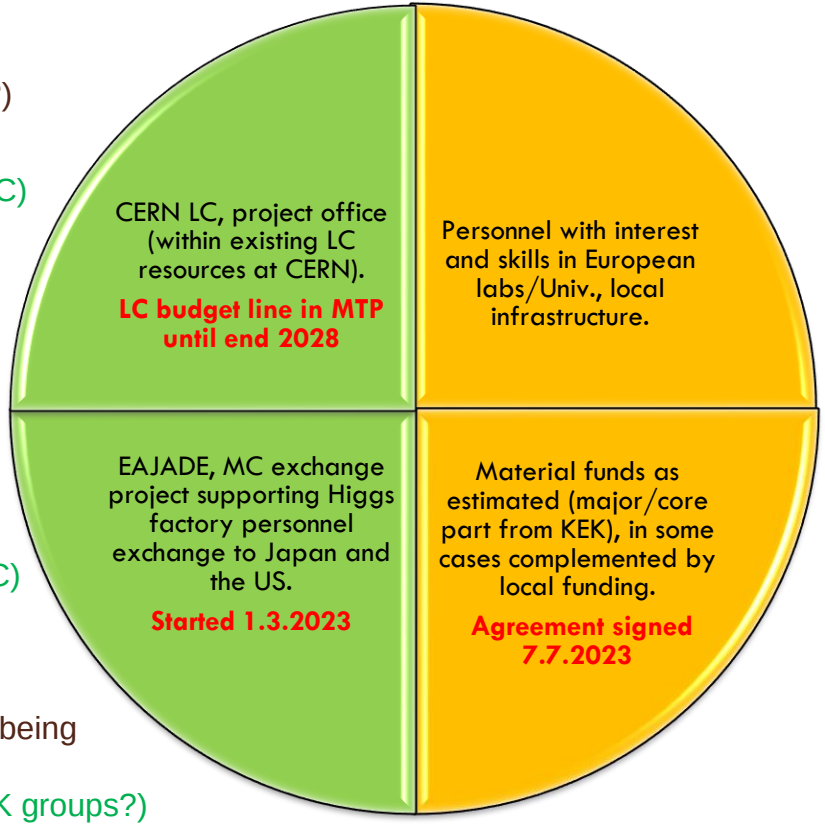
A1 with three SC RF related tasks
- SRF: Cavities and Cryo Module (INFN, CEA, DESY, IJCLAB?)
- Crab-cavities (STFC, CERN?)
- Main Linac elements: ML quads and cold BPMs (CIEMAT, IFIC)

A2 Sources
- Pulsed magnet (Uni.H, DESY, CERN)
- Wheel/target (the same and UK groups)

A3 Damping Ring including kickers
- Low Emittance Ring lab(s) (UK?)

A4 ATF activities for final focus and nanobeams
- On-going/restarted (Oxford, DESY, IJCLAB, CEA, CERN, IFIC)
- MDI here ?

A5 Implementation including Project Office
- Dump, CE, Cryo – earlier efforts at CERN, possible follow up being considered
- Sustainability, Life Cycle Assessment (CERN, DESY, CEA, UK groups?)
- EAJADE started (EU funding) SHOW groups?



EAJADE: Information at LINK

Next step

IDT-EB sent an e-mail to each lab to **check the list** and nominate **contact person** in each WPP.

now

Happening now

Response from each lab

iteration

Explanation of the detailed WPP (prepared by IDT-WG2 steering members)

November?

Contribution plan from each lab. (Or questions from each contact person)

Report them from IDT-WB2 to IDT-EB

IDT-EB will consider the ITN framework

Summary

- ILC accelerator R&D effort is now conducted by the **International Technology Network ITN**
- ITN is based on bi-lateral agreements between laboratories
- KEK provides funding for ITN activities
- CERN serves as Hub laboratory for Europe
- ITN is now in the process of being constituted, with a specific work plan and commitments by contributing laboratories

Thank You

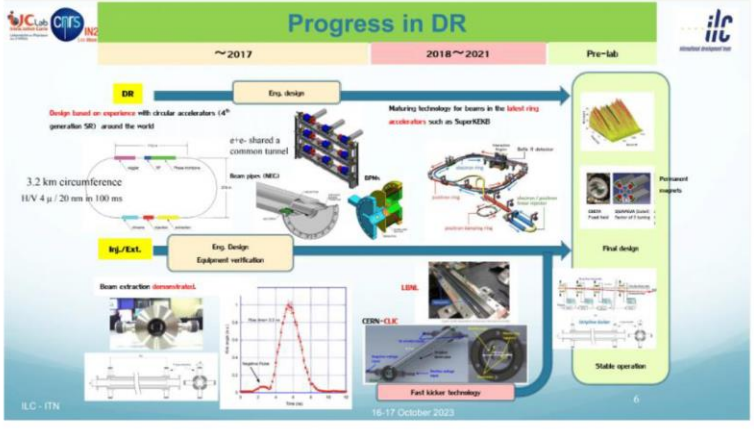
ITN Information Meeting @CERN

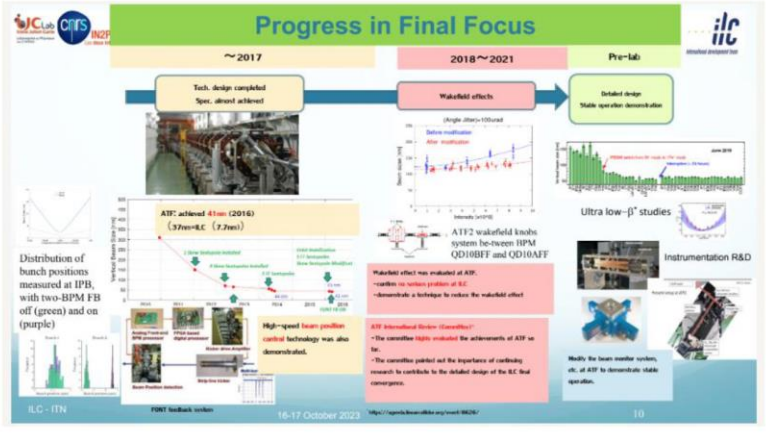
ILC Technology Network Information Meeting was organized by KEK and IDT.
The meeting was in a hybrid mode. Face to face at CERN with remote connection.
October 16th and 17th (3PM-6PM in European time)

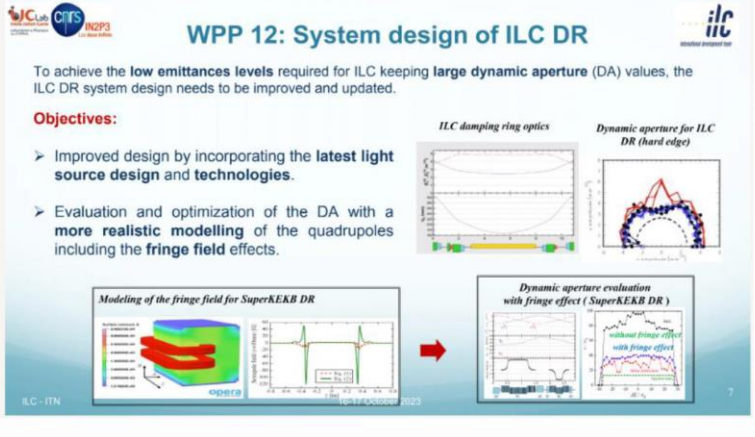
Around 70 joined to this meeting.
Lab's interests were shown from >20 institutes.

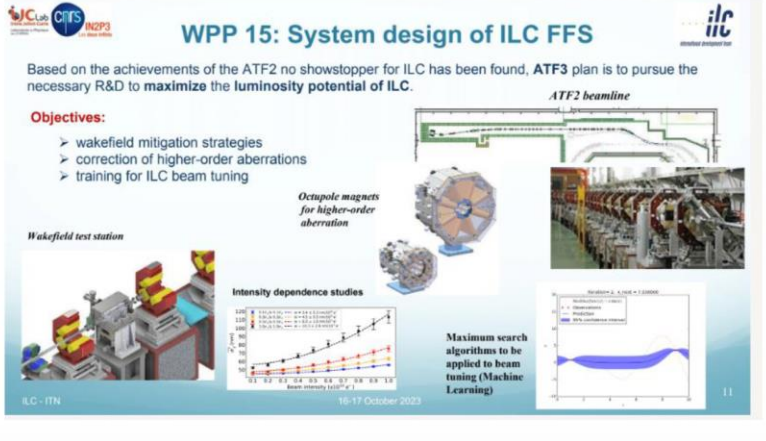
S. Michizono
IDT WG2 Meeting 31.10.23
https://agenda.linearcollider.org/event/10200/contributions/53479/

Prepared by Angeles Faus-Golfe (IJClab)









T. Okugi
IDT WG2 Meeting 31.10.23
https://agenda.linearcollider.org/event/10200/contributions/53483/

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