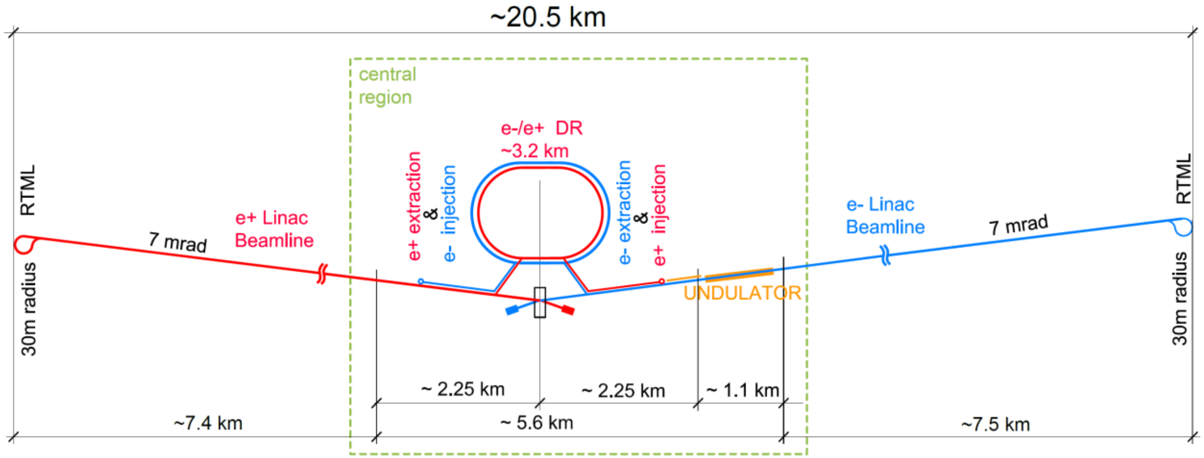
ILC Technology Networkでの開発項目

KEK/IDT-WG2

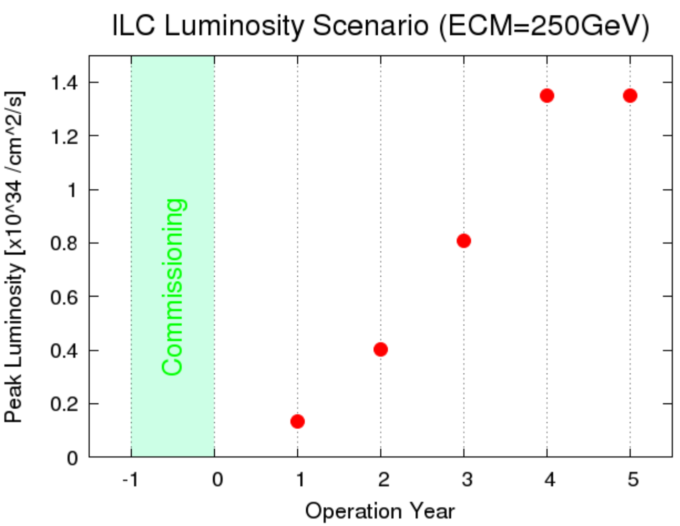
Shinichiro MICHIZONO

ILC accelerator



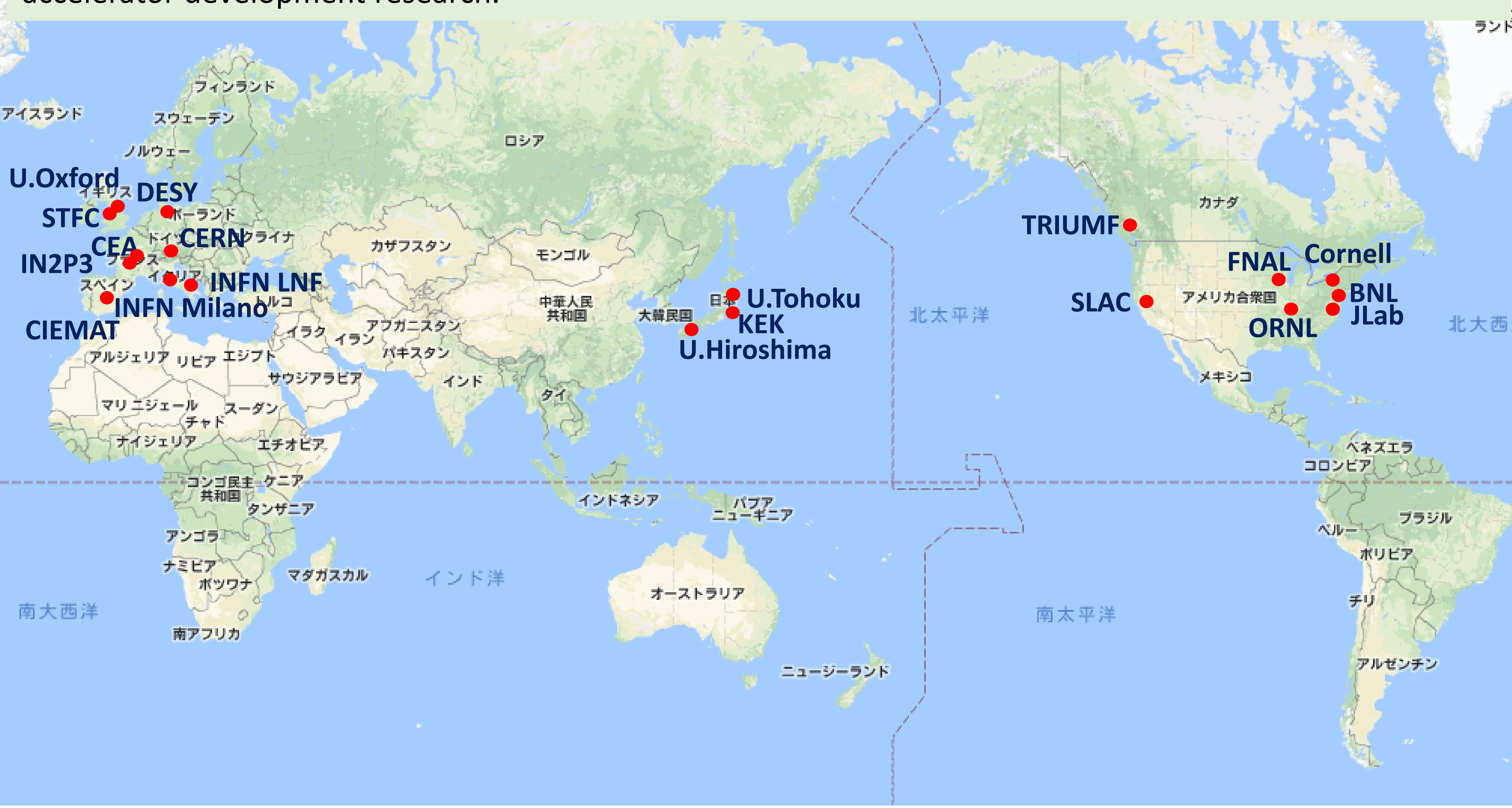
Item	Value
Beam Energy	125 GeV
# of e− e+/bunch	2×10^{10}(3.2nC)
# of bunches	1,312
Repetition	5 Hz
Luminosity	1.35 $\times10^{34}$ $cm^{-2}s^{-1}$
Beam size at IP	7.7 nm
Beam power	2.6 MW

- Electron and positron beams are
  - Converted into parallel beams (low emittance) by a damping ring (DR).
  - Accelerated to 125 GeV in the main accelerator, which is about 7.5 km long.
  - Tuned to be narrowed by the beam delivery system (BDS), which is about 2.3 km long, and narrowed down to nanometer size by an electromagnet just before the collision point.
  - Absorbed by beam dumps.
- To obtain a given luminosity, each area is designed to meet the specifications.
  - Sources: 4.8 nC electron and positron production to obtain 3.2 nC at the collision point
  - Superconducting rf acceleration: 31.5 MV/m on average to 125 GeV reliably
  - Nano beam technology: narrowing down to about 7.7nm at the collision point to a given luminosity
- It is assumed that the accelerator will be adjusted over a period of about 5 years to reach the target luminosity.



IDT–WG2

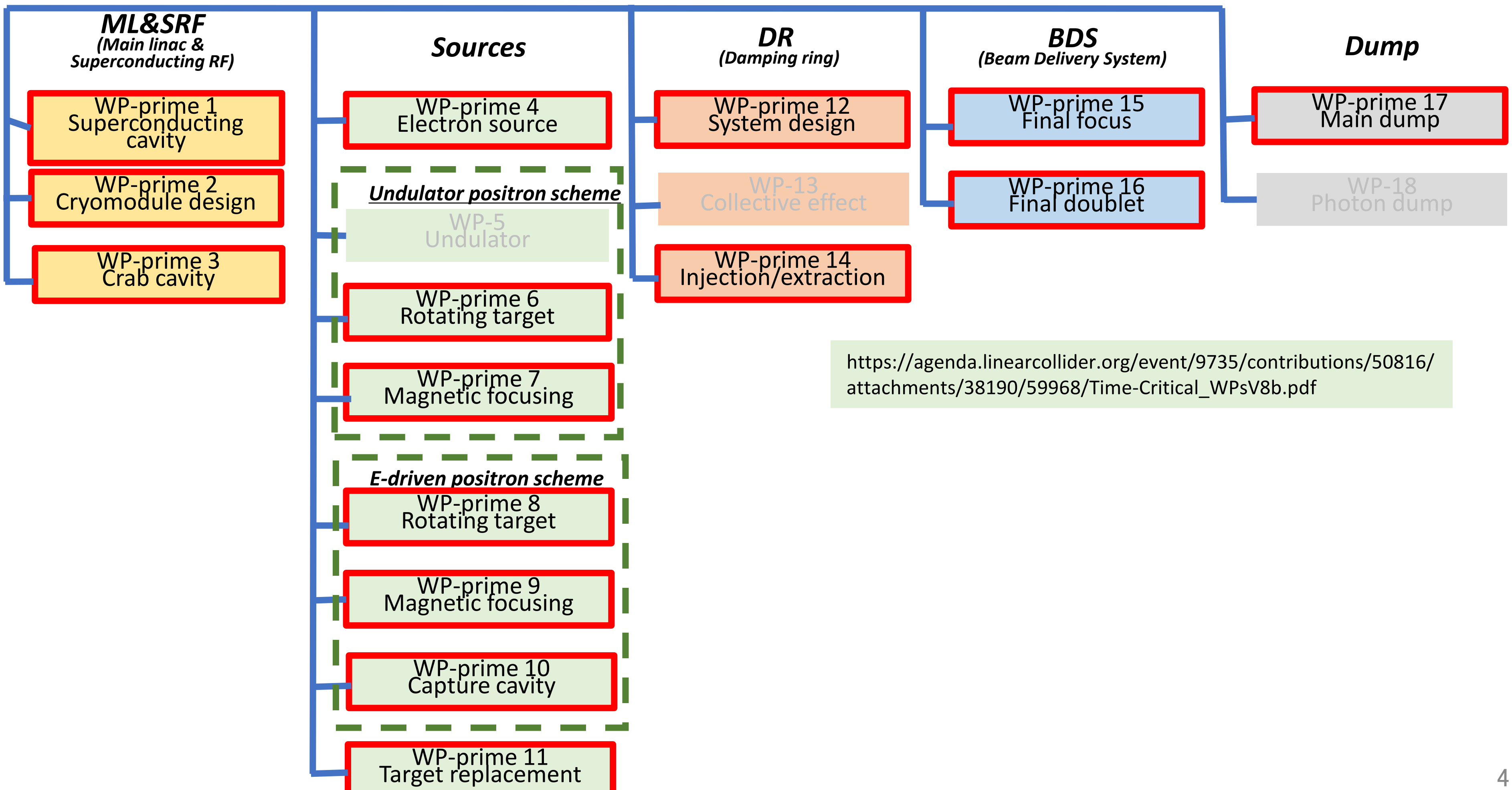
The Accelerator Division (WG2) of the International Development Team (IDT) has about 50 accelerator researchers from 19 research institutes in 9 countries around the world participating in discussions on ILC accelerator development research.



ILC Technology Network

- “Pre-lab Proposal” proposed 18 work packages.
- Important issues were selected from among them. (WPP)
- The cost will be shared internationally as in-kind contribution.
  → **ILC Technology Network**

Time-critical WPs



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

ILC Technology Network

	Topics	Candidates （except KEK）
SRF		CEA, CERN, Cornell, DESY, FNAL, INFN, JLAB, SLAC, STFC,…
WPP-1	Superconducting cavity	
WPP-2	Cryomodule	
WPP-3	Crab cavity	
Sources		CERN, DESY, JLAB, Hamburg Uni., Hiroshima Uni., SLAC,…
WPP-4	Electron source	
WPP-6	Und: target	
WPP-7	Und: magnetic focusing	
WPP-8	E-Dr: target	
WPP-9	E-Dr: magnetic focusing	
WPP-10	E-Dr: capture cavity	
WPP-11	Target replacement	
Nano beam		BNL, Cornell, ESS-Bilbao, IJCLab, INFN, UOXF,…
WPP-12	DR system design	
WPP-14	DR injection/extraction	
WPP-15	Final focus	
WPP-16	Final focusing magnet	
WPP-17	Main dump	

So far, explanations about ITN have been done at SLAC, FNAL, and JLAB. In Europe, it was explained at the Lab Directors' meeting (November).

先端加速器の研究開発

- 高エネルギー物理学実験の歴史は、大型加速器発展の歴史と言っても過言ではありません。過去、超伝導電磁石などは物理実験を実現するために研究開発が進められ、その成果は社会にも広く還元されてきました。
- ILCにおいても、粒子源、超伝導加速、ナノビームなど**ILCでの実験を実現するために不可欠な加速器の研究開発**があります。これらも**将来的には産業・医療応用などを含め社会にも貢献できる**内容であると確信しています。
- 大学の様々な分野からの参加が可能で、本研究開発を通して若手研究者の育成に大きく貢献して行きたいと思っています。
- KEKでは、**大型の装置を用いた実験**が行なえ、世界中の研究者や研究者の卵と肩を並べて研究を進められる機会が得られます。特に、**ハードウェア開発に興味のある学生の皆さん**にはうってつけの場所です。高エネルギー実験などでハードウェアに触れる機会が少ないフェーズに当たっている実験に所属している修士課程の学生さんが、実際の加速器に触れることで、ハードの適用範囲など端末の上の作業だけではない経験を積む機会に活用してもらうことも可能です。

Example of topics (1)

SRF		
超伝導高周波加速技術は、高エネルギー物理学の発展に大いに貢献してきました。国内では、80～90年代のTRISTAN計画、90～2000年代のKEKB-Factory計画、そして現在はSuperKEKB計画へと用いられ、海外では、LEP、LEP-II、LHC、HERA、CESR、BEPC-II、などに用いられてきました。ILCでは<u>ニオブ材を用いた高性能の超伝導空洞</u>を大量に用いる計画で、その性能を極限まで高める努力が世界中で行われてきました。具体的には、高品質の**空洞製造**、**電解研磨法**による表面処理、**真空炉**による高温熱処理、性能試験前に実施する低温熱処理、の改良です。ここでは、最適な方法による空洞性能達成およびその成功率の評価を行うことになっており、これを実現するには空洞表面でどのような物理現象が発生しているのかを詳しく理解することが肝要です。表面処理の最適化に加え、**ニオブ材**の評価、**性能試験**の最適化や空洞を調べる測定器開発なども含まれます。		
WPP-1	Optimization of mass production cavity manufacturing	KEK
WPP-1	Automation of cavity inner surface inspection + local polishing	KEK
WPP-1	Automation of pre-tuning	KEK
WPP-1	Optimization of cavity performance measurement	KEK
WPP-1	Nb material fundamentals, FG/MG/LG, optimization	KEK
WPP-1	Nb3Sn, MgB2 for higher Q and thermal efficiency at higher temperatures	KEK
WPP-1	Thin film (including multilayer film) for high electric field	KEK
WPP-1	Cavity shape (optimization of Ep, Bp, etc. by low surface field cavities)	Remote (if the university has someone available to teach)
WPP-1	Development of magnetic shielding materials, reduction of environmental magnetic field, improvement of efficiency of demagnetization method of modules	KEK
WPP-2	Tuner design, manufacturing and testing (for larger LFD)	KEK
WPP-2	(for higher power) Coupler design, manufacturing, and testing	KEK
WPP-2	Design, manufacturing, and testing of SC electromagnets + cold BPM (for higher radiation tolerance)	KEK
WPP-2	Establishment of multi-point simultaneous alignment method	KEK
WPP-2	Module design (optimization of thermal balance), manufacturing, and testing	KEK
WPP-2	Establishment of module transportation and storage methods (including vacuum system and moisture control)	KEK
WPP-2	Development of beam loss monitor in STF-2 accelerator module	Remote (if the university has someone available to teach)
WPP-2	Development of high-power RF equipment by resonant ring	KEK

WPP-1: Superconducting cavity

SRF technology has matured during the operation of the European XFEL, which uses the same type of cavity. Japan-U.S., Japan-Europe cooperation have been working on cavity performance improvement and cost reduction.

- ◆ Demonstration of mass production technology: 36 cavities (0.4% of 9,000 cavities) manufactured worldwide (20 cavities/Japan)

(Goal)

- ◆ Cavity performance (35MV/m), success yield 90%

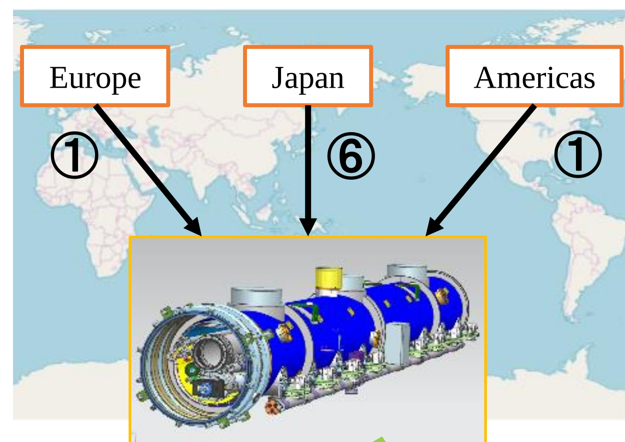
(Final confirmation items)

- ◆ Consistency with Japan's High Pressure Gas Safety Law
- ◆ Performance/cost-effective manufacturing method demonstration (results after TDR)
  - ◆ Superconducting material (Nb) production: no impurities (direct slicing) + cost reduction
  - ◆ New surface treatment method: performance improvement due to high electric field and low loss in cavities
- ◆ Confirmation of optimal surface treatment recipe

WPP-1

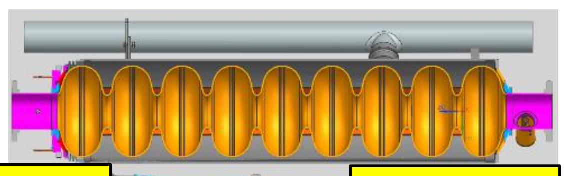
Cavity fabrication
↓
Surface treatment
↓
Performance test
↓
(WPP-2:cryomodule)

6 cavities are used for module integration and 10 are used for cost reduction evaluation.

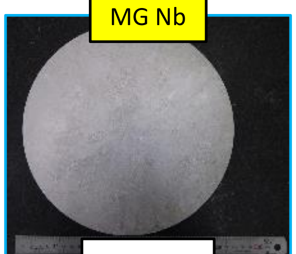


Cavities from Janan, U.S. and European regions are tested in a one module.

Cavity design based on TESLA/LCLS-II

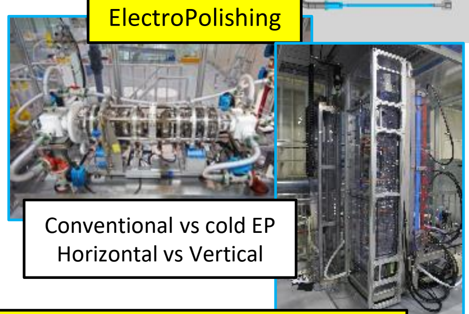


MG Nb



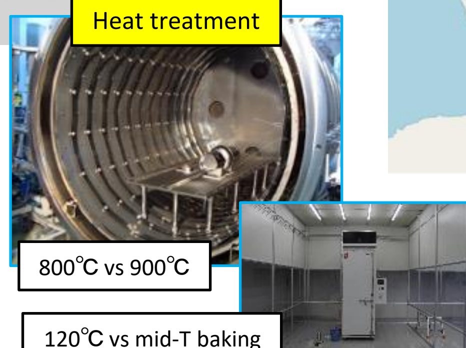
FG vs MG

ElectroPolishing



Conventional vs cold EP
Horizontal vs Vertical

Heat treatment



800℃ vs 900℃

120℃ vs mid-T baking

Optimal mass production method confirmed for ILC

WPP−2: Cryomodule

Assembly and testing of the cryomodule that house the cavities will be performed. Some of the cavities from overseas will also be installed.

WPP-2

Cavity string
↓
Module production
↓
Module test
↓
Finalize module design

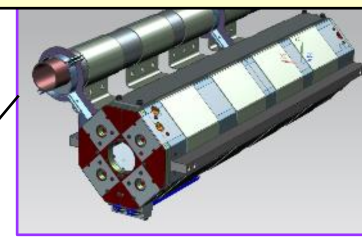
- 1 cryomodule (CM) manufactured in Japan
- 8 cavities manufactured at WPP−1 are installed (including cavities brought in from overseas)
- Consistent with Japan's High Pressure Gas Safety Law

(Final confirmation items)

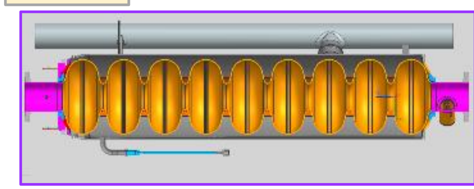
- ***Mounting of accessory parts (input coupler, tuner, superconducting electromagnet, magnetic shielding material)***
- ***Consideration of design changes (change requests)***

Input coupler

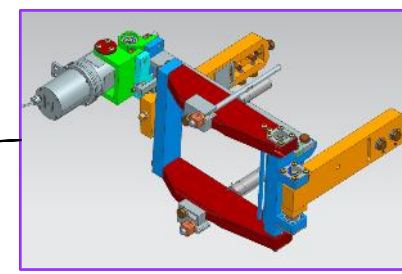
Magnet

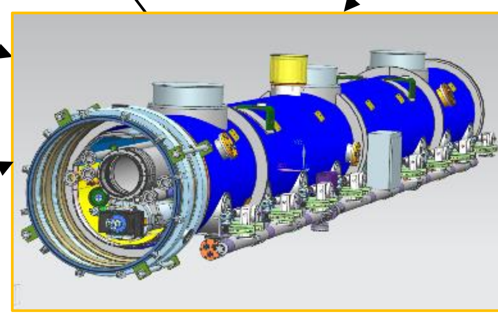


Cavity

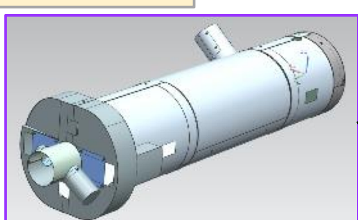


Tuner





Magnetic shield

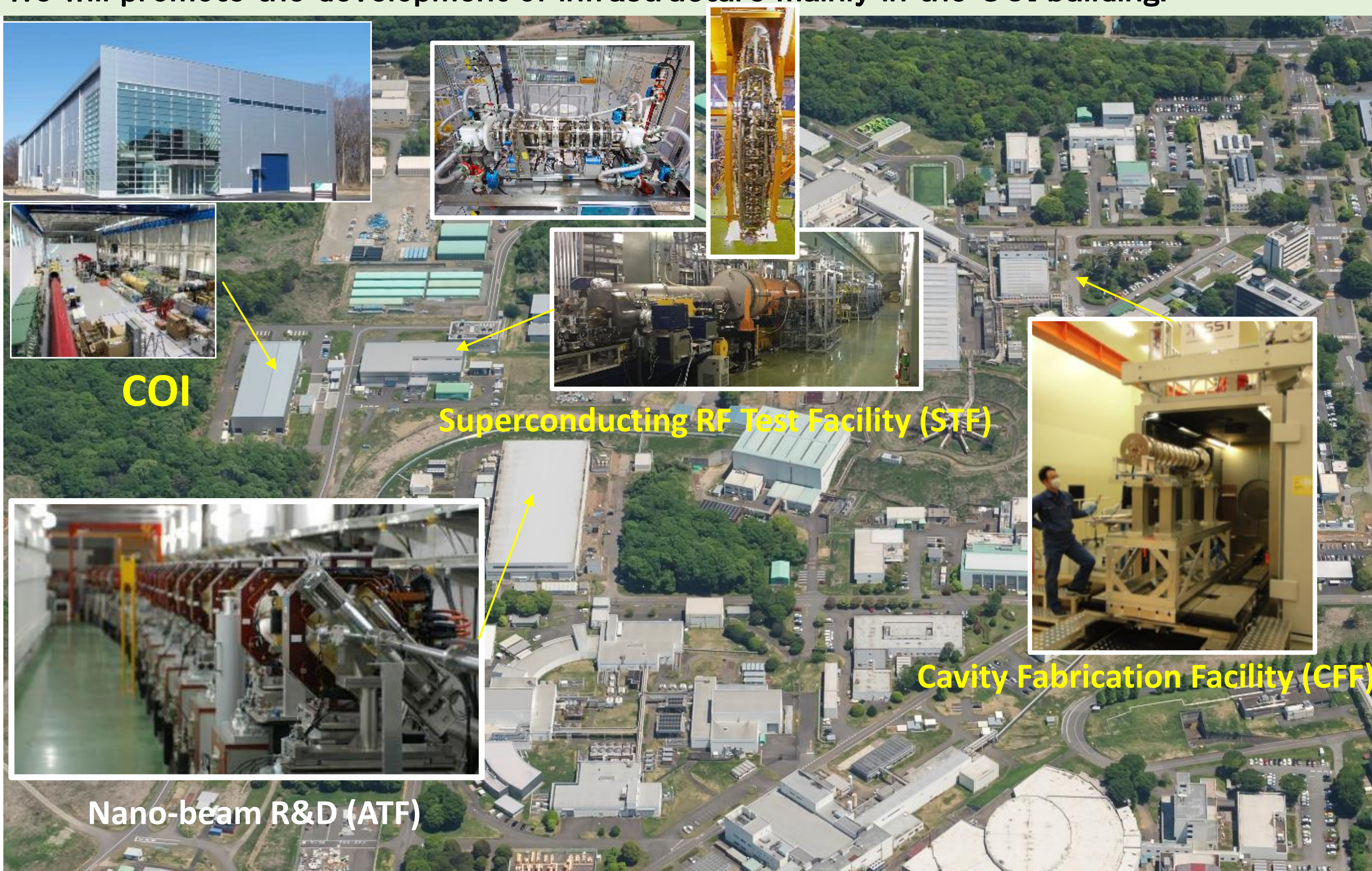


Complete the first ILC CM with a common design

Design changes after TDR will be determined after seeing the results of this module test.
(1) Tuner
(2) Current read port

ILC related facilities at KEK

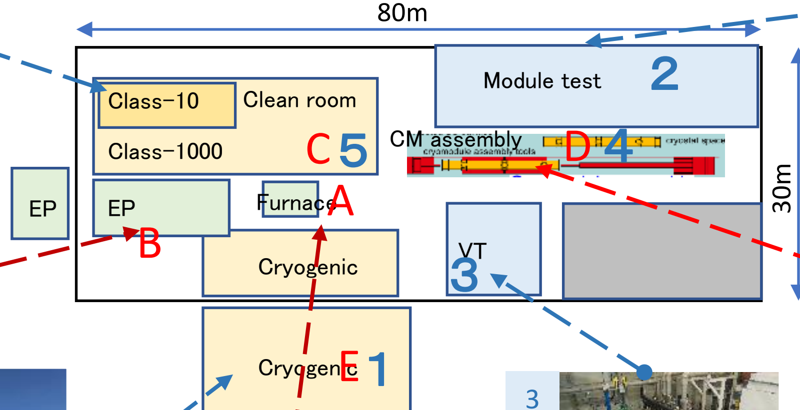
In Europe and the U.S., infrastructure for evaluating SRF accelerators at European XFEL and LCLS-II is already in place, but additional infrastructure is needed in Japan.
We will promote the development of infrastructure mainly in the COI building.



SRF infrastructure

Current status	Future
A) Heat treatment B) Electro polishing (EP) C) Clean room D) Cryomodule (CM) Assembly (partly done) E) Cryogenic system (partly done)	1. Cryogenic system upgrade 2. High power rf system for module test 3. Vertical test (VT) stand 4. CM assembly 5. Clean room working environment 6. (cavity fabrication equipment at CFF)

Infrastructure at COI



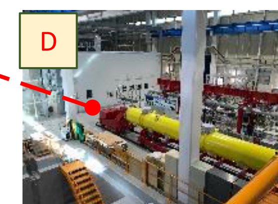
Future : cavity string at European XFEL

Future : CM test at European XFEL

EP

Cryogenic sytem

Future : VT @FNAL

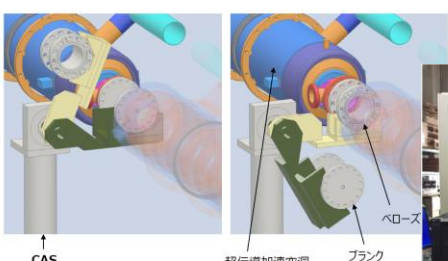


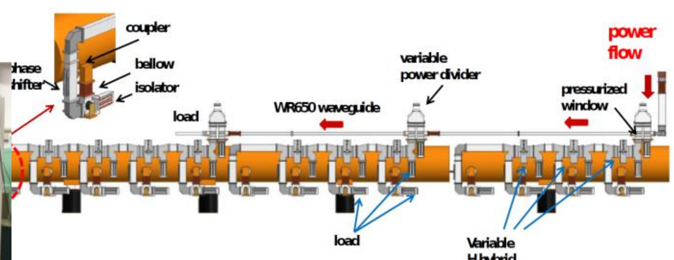
CM assembly at KEK

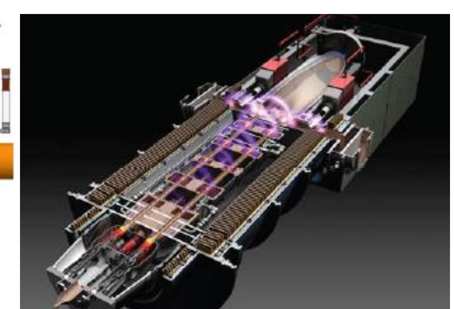
Future : CM assembly at XFEL

Example of topics (2)

SRF		
Infra	Construction of high-frequency system + monitor system for VT	KEK
Infra	Development of X-ray/neutron mapping for VT and module testing	KEK
Infra	Optimization of cooling and test evaluation methods for VT and module testing	KEK
Infra	Infrastructure design for VT (cryostat, radiation shield) + refrigerator control	KEK
Infra	Infrastructure design (radiation shielding, installation) for module testing	KEK
Infra	Dark current measurement (including energy) in module testing	KEK
Infra	Cryogenic system control (thermal efficiency optimization) for module testing	KEK
Infra	RF system in module testing (LLRF)	KEK
Infra	RF system in module testing (modulators)	KEK
Infra	RF system in module testing (high-efficiency high-frequency sources)	KEK
Infra	RF system for module testing (distribution system)	KEK
Infra	Establishment of clean room work methods using robots (including tool development)	KEK
Infra	Optimization of surface treatment (electropolishing, heat treatment)	KEK
Infra	Simulation (RF calculations, thermal calculations) related to RF devices and modules	Remote (if the university has someone available to teach)
Infra	Database construction	Remote (if the university has someone available to teach)

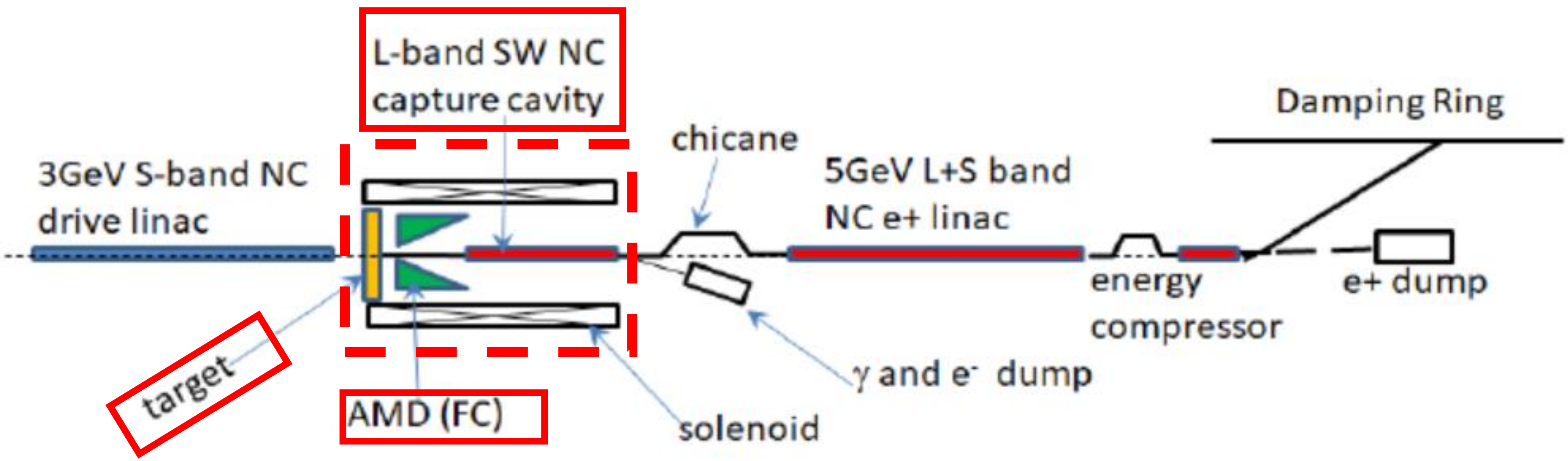






Example of topics (3)

電子駆動陽電子源		
陽電子は、高いエネルギーの電子ビーム(あるいは光子)を標的に入射して生成します。強いビーム負荷のもとでの耐久度の高い標的を製作すること、発生した陽電子を急速に収束させて高い捕獲率を得ること、などが焦点です。 陽電子源は、高エネルギーコライダーを中心に、ますます大強度化が要求されるようになっています。過去においては、SLC, SuperKEKB, DAFNE, CESRなどで使われており、将来にわたっても、ILC, CLIC, CCCなどの直線型コライダーは単位時間あたりの必要陽電子数がもっとも高いです。FCCee, CEPCなどの円形コライダーでも以前よりは要求値が上がっています。さらにはミュー粒子コライダー(LEMMA) などにおいても必要になる可能性があります。CEBAFのように、コライダー以外でも大電流の陽電子源がつかわれています。 これらの陽電子源の技術には共通点が多く、ILC用の陽電子源の開発はそのまま世界の陽電子源につながっています。		
WPP-8	Target	KEK
WPP-9	Flux Concentrator	KEK
WPP-9	Flux Concentrator Power Supply	KEK
WPP-10	APS Cavity	KEK
WPP-10	RF Source	KEK
WPP-10	Beam loading compensation	Remote (if the university has someone available to teach)
WPP-11	Target Replacement	KEK



Example of topics (4)

Damping Ring

円形加速器の設計の高度化は、次世代の放射光源など世界中で研究が進められています。本研究の成果は、ILCへの貢献に限らず最先端の高性能加速器の設計に多くの知見を提供することになります。

WPP-12	Damping ring design	Remote (if the university has someone available to teach)
WPP-12	Investigation of fringe field and dynamic aperture	KEK(beam test at ATF-DR)
WPP-14	Injection/extraction system	KEK(test at ATF extraction line)

BDS

近年、**機械学習**などを活用した加速器の自動化へのニーズが高まっています。最終衝突点へのビームラインのシステム設計はビーム動力学の最先端の研究を進めることで、ILCへの貢献に限らず将来のナノビームの設計や運用に多くの知見を得ることができます。

WPP-15	Development of online beam diagnostic system	KEK(test at ATF2)
WPP-15	Fast feedback tests	KEK(test at ATF2)
WPP-15	System design of BDS beamlines	Remote (if the university has someone available to teach)

Dump

将来の大強度加速器では既存設備のビーム強度を超える**数MWのビーム**を取り扱うなど、最先端のビームダンプ技術が求められています。ビームダンプ関連としては、その**放射線遮蔽**、冷却システムや**遠隔操作機構**の設計に加え、ビームダンプを利用した新粒子探索実験やソフトエラー問題評価のための2次粒子照射利用など、先端実験設備としての利用を含めた総合的なシステム設計と鍵となる装置のプロトタイプ試験を行ないます。

WPP-17	Main Dump design	KEK
WPP-17	Radiation calculation	Remote (if the university has someone available to teach)
WPP-17	Window remote hndling	KEK