CERN-KEK Collaborative Activities for Linear Colliders

Steinar Stapnes – with information/slides from Shinichiro Michizono and Akira Yamamoto

2019-20 – a few examples:

- X-band facility and industrial studies, HiEff klystron (superconducting solenoid, for high-efficiency klystrons), Nano-beam technology (using ATF-2)

2020-21:

- New basis for common work established: CERN LC planning after the ESPP and the ILC IDT startup
  - CERN – KEK new addendum for ILC-IDT
  - Active work in IDT, WG1 and 2
- High efficiency klystrons
- X-band facility back in operation

LC studies CERN 2021-26


CLIC and High Gradient technology:

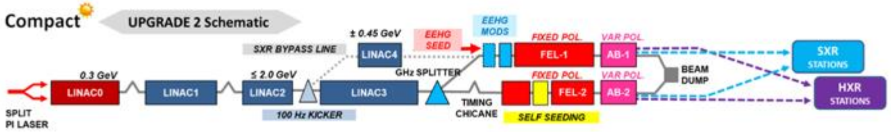
- Design and manufacturing of X-band structures and components, system interfaces
- Study structures breakdown limits and optimization, operation and conditioning
- Beam-dynamics and parameters: Nanobeams (focus on beam-delivery), pushing multi-TeV region (parameters and beam structure vs energy efficiency)
- Tests in CLEAR (wakefields, instrumentation) and other facilities (e.g. ATF2)

See talks by Phil Burrows (CLIC), Nuria Catalan (Nanobeams), Chetan Gohil (Luminosity Performance)

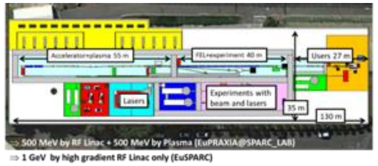
Application of X-band technology (examples):

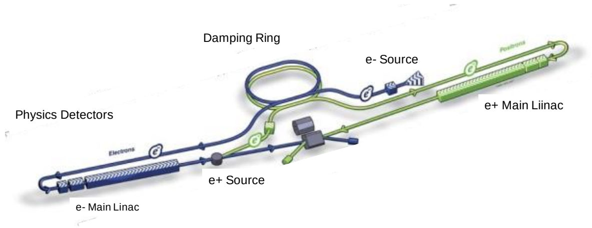
- 1 GeV X-band linac at LNF
- A compact FEL (CompactLight: EU Design Study 2018-21)
- Compact Medical linacs (proton and electrons)
- Inverse Compton Scattering Source (Smart-Light)
- Linearizers and deflectors in FELs (PSI, DESY, more)

See talk by Walter Wuensch (Applications of High Gradient Technologies)









ILC related R&D and Pre-lab Planning

- Positron flux concentrator, ATF2/3, Hi-klystrons, various SRF topics, cryo, dumps, beam-dynamics, DR, etc
- IDT participation and Common Fund contributions.
- Numerous ILC and/or KEK collaborative R&Ds, linking to CLIC, generic R&D or SRF for HL LHC and FCC and other CERN activities.

See talks by Joachim Mnich and Steinar Stapnes (CERN and European reports)

MTP text and goals 2022

The design and implementation studies for the CLIC e^+/e^- multi-TeV linear collider are at an advanced stage. The main feasibility issues, cost and project timelines have been developed, demonstrated and documented in a comprehensive project implementation plan for the accelerator, and a summary report covering the physics, detector and accelerator status, including future plans. An initial stage at 380 GeV was presented in detail for the European Strategy update (ESPP), together with upgrade paths to higher energy stages, 1.5 and 3 TeV. During 2019-20 further potential improvements in luminosity performance and components designs were introduced and will be a focus of further studied. On the design side the parameters for running at multi-TeV energies, with X-band or other RF technologies, will be studied further, in particular with energy efficiency guiding the designs. The work-programme, technical R&D and design studies, are carried out by a collaboration of 53 institutes providing the overall (M&P) resources for the activities. The CLIC accelerator studies are closely connected with associated physics and detector studies with 30 institutes involved.

During the coming years the focus will remain on core technology development and spread making use of existing facilities (High Gradient Test Stand and the CLEAR beam facility), optimising X-band components for performance and manufacturability towards full modules, and efficient use of the abovementioned collaborations with the many laboratories and universities now using the technology in linac systems. This allows CLIC to remain a future accelerator option for CERN, and increases the overall availability and knowledge of the technology, with modest investments. The use of the CLIC technology - primarily X-band RF, associated components and nano-beams - in compact medical, industrial and research accelerators in many of the CERN Member States has become increasingly important development and test grounds for CLIC, and is destined to grow further. An EC supported design study with 24 partners pursue the use of the technology in future FELs facilities (CompactLight).

The International Linear Collider (ILC) studies are progressing rapidly lead by an International Development Team (IDT) where CERN participates. The CERN linear collider studies support this effort through combined activities with CLIC, co-operation with KEK for specific technology developments where CERN has expertise, and studies using ATF2 facility. The future of the ILC focused part of linear collider activities will depend on the progress of the ILC project in Japan, building on the commonalities between CLIC and ILC, common R&D interests between CERN and KEK, and extensive European activities and capabilities related to ILC studies and technologies, inside and outside CERN.

- Development of X-band technology with industry and collaboration partners; structures, RF networks and high efficiency power units, as needed for CLIC R&D, the high gradient test-stands and applications in compact linacs in general
- Continue studies of the luminosity performance at 380 GeV and multi-TeV energies, including nanobeam hardware developments as needed for these, and power efficiency studies.
- Conclude the most central collaboration agreements for the period 2022-2025, including collaborations for applications of the core technologies in research and medical linacs
- Participate in relevant working groups for ILC and organize collaborative R&D efforts with KEK for ILC and CLIC
- Continue to play a coordinating and facilitating role for European planning and contributions to the ILC as the project evolves

IDT structure from Summer 2020

EB: Steinar Stapnes

WG1: Paul Collier

WG2: Nuria Catalan and Dimitri Delikaris (SRF and Cryogenics)
Andrea Latina (DR/BDS/Dump including ATF2/3)
Steffen Doebert (Sources)
John Osborne (Civil Engineering)

WG3: In progress

CERN – KEK agreement for the ILC IDT in 2020

CERN will facilitate the European participation in the work during the transition to the Pre-Lab Phase; including working groups on Pre-Lab preparation, accelerator and facility, and physics and detectors.

CERN will coordinate the European contributions to the Team's common fund, as well as the in-kind contributions to the tasks supported by the common fund during the preparation of the Pre-Lab Phase. The CERN office at KEK (set up under Appendix 10) will, as one of its tasks, provide administrative support to the European efforts related to transition to the Pre-Lab Phase.

The Parties will continue, or, as the case may be, undertake, collaborative work in studies related to:

- the accelerator's beam-delivery system and the Accelerator Test Facility 2 (ATF2) (as set out in the 2009 Agreement on Collaborative Work and Appendix 13);
- high gradient acceleration for linear colliders;
- high efficiency klystrons (as set out in Appendix 23);
- detector, physics and software (as set out in Appendix 8);
- cryogenics systems, beam-dumps, superconducting radiofrequency (SC RF) module components and technologies, civil engineering (all areas where CERN has provided technical advice as part of the LCC collaboration); and
- other areas of common interest (e.g.: positron production and beam-dynamics) and/or information exchange related to common challenges (e.g.: costing methodology and power reduction studies).

Any existing collaborative work referred to above will continue to be executed under its relevant Appendix.

APPENDIX 24

to

The Agreement on Collaborative Work (ICA-JP-0103)

between

THE HIGH-ENERGY ACCELERATOR RESEARCH ORGANIZATION (KEK)

and

THE EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN)

concerning

The work of the ILC International Development Team to facilitate the transition into the "Pre-Lab Phase"

2020

- Add annexes for specific common studies, positrons, possibly klystrons, dumps, etc
- In some areas we have other appendixes ..

ILC overall timeline

IDT (~1.5 years)
- Prepare the work and deliverables of the ILC Pre-Laboratory and work out, with national and regional laboratories, a scenario for their contributions
- Prepare a proposal for the organisation and governance of the ILC Pre-Laboratory

CERN will facilitate the European participation in the work during the transition to the Pre-Lab Phase; including working groups on Pre-Lab preparation, accelerator and facility, and physics and detectors.

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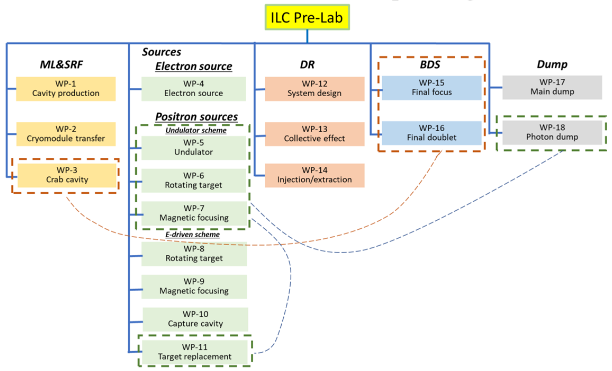
Any existing collaborative work referred to above will continue to be executed under its relevant Appendix.

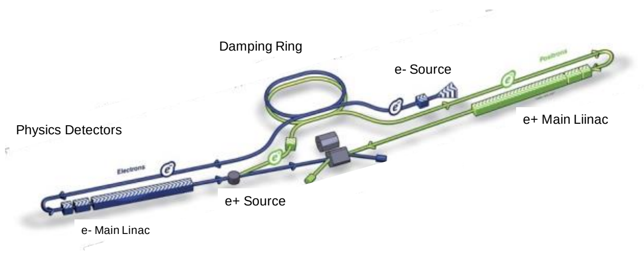
R&D and common work with ILC/KEK – already accounted for. Expect to run 2021-23

ILC Pre-Laboratory (~4 years)
- Complete all the technical preparation necessary to start the ILC project (infrastructure, environmental impact and accelerator facility)
- Prepare scenarios for the regional contributions to and organisation for the ILC.



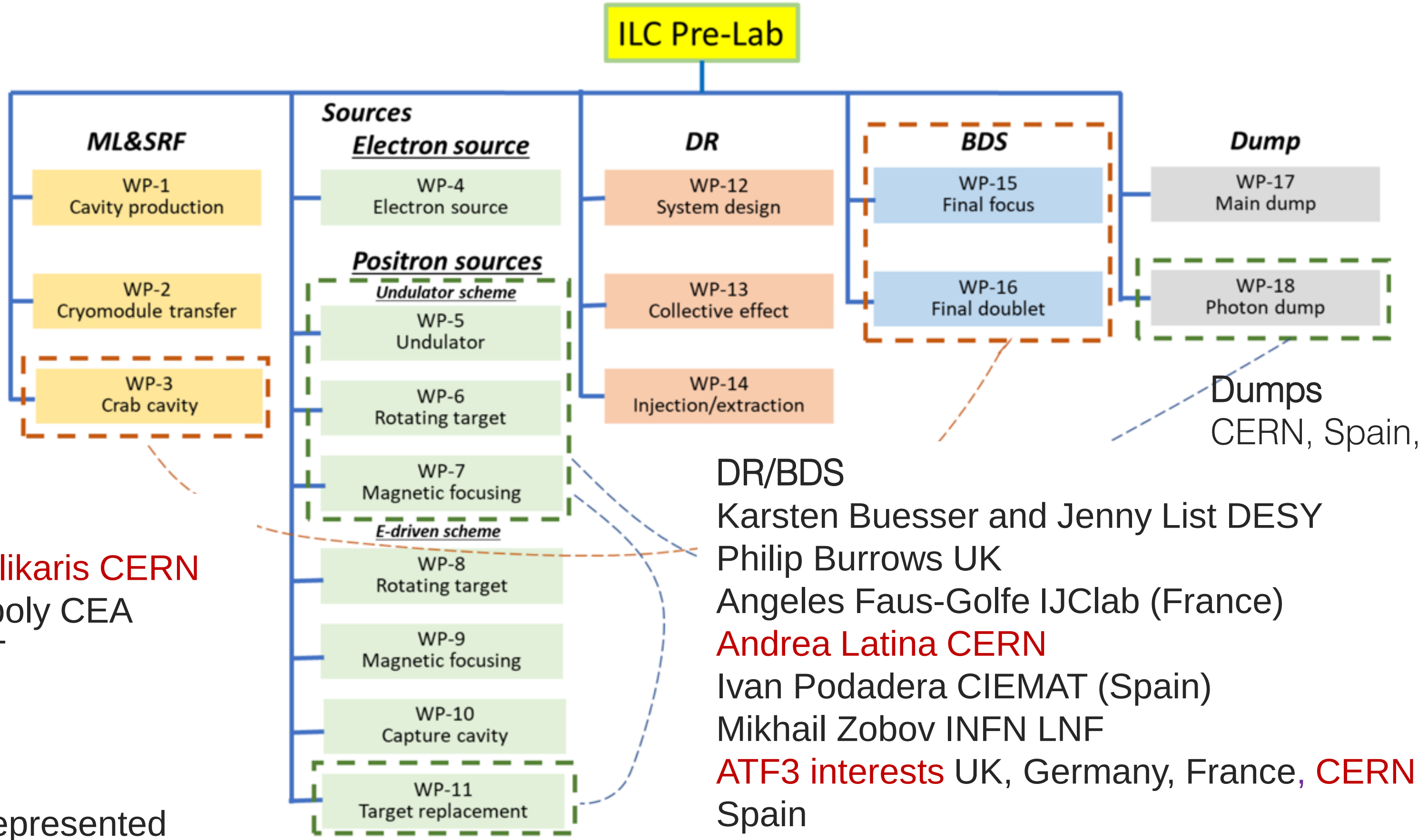
Planning, except to start in 2022 at the earliest

ILC laboratory
- Construction and commissioning of the ILC (~9-10 years)
- Followed by the operation of the ILC
- Managing the scientific programme of the ILC



Later

Pre-lab work-packages



Dumps
CERN, Spain, CERN

DR/BDS
Karsten Buesser and Jenny List DESY
Philip Burrows UK
Angeles Faus-Golfe IJClab (France)
Andrea Latina CERN
Ivan Podadera CIEMAT (Spain)
Mikhail Zobov INFN LNF
ATF3 interests UK, Germany, France, CERN, Spain
Other light-sources labs possible (DR)

ML & SRF
Nuria Catalan and Dimitri Delikaris CERN
Enrico Cenni and Olivier Napoly CEA
Luis Garcia-Tabares CIEMAT
Peter McIntosh UK
Laura Monaco INFN Milano
Hans Weise DESY
Not all European SRF labs represented
Additionally:

- Long term cryo collaboration with CERN. HiEff RF another relevant activity
- SRF "basic" R&D for fabrication improvements or long term performance improvements (i.e. for upgrades)

Sources
Jim Clarke UK
Steffen Doebert, CERN and Peter Sievers, CERN retired
Benno List, Jenny List, Sabine Riemann, Gudrid Moortgat-Pick DESY
IJCLab also, other groups also possible (FCC-ee, Dafne)

Engineering Design
working group being set up

Also in WG2, but related to Civil Engineering
John Osborne CERN

Accelerator WP reviewers:
Erk Jensen CERN
Deepa Angal Kalinin STFC
Nick Walker DESY

ILC IDT EB – news

The Proposal for the ILC Preparatory Laboratory is now published: https://arxiv.org/abs/2106.00602
"This proposal is intended to provide information to the laboratories and governmental authorities interested in the ILC project to allow them to consider participation"

Several announcements, e.g http://newsline.linearcollider.org/2021/06/01/ilc-preparatory-laboratory-proposal-released/
Endorsed by IFCA, (being) sent to IDT WGs, ICFA, ECFA and Lab directors

The Technical Preparation Document describing the 18 WPs is at: (https://zenodo.org/record/4742019#.YLfkLi0RrqY)

And a document (in Japanese) addressing, "key issues related to the ILC project", as identified in various reviews, is also sent

Further information about Japanese funding needs also provided

Ongoing:
MEXT review panel meetings 14 and 18.10, presentations and background slides include information about CERNs recent work related to ILC and its key technologies, and indicate capabilities for the ILC Prelab (next slides)

Table 2: List of estimated material costs and human resource requirements for deliverables of the technical preparation activities, where ILCU is defined in the text. (Resources for the infrastructure needed for deliverables are not included.)

Domains	Material cost [MILCU]	Human resources [FTE-yr]
Main Linacs (ML) and SRF	41.25	285
Electron Source	2.60	6
Positron Source	5.85	15
Damping Ring (DR)	2.50	30
Beam Delivery System	2.20	16
Dump	3.20	12
Total	57.60	364

Table 4: Estimated civil engineering cost and human resources requirement.

Item	Cost [MILCU]	Human resources [FTE-yr]
Site surveys	22	70
Detailed designs	43	

With the IDT proposal numbers (integrated over 4 years):

Personnel from Europe ~200-250 FTEy
Material around 35-40 MEURO (including – very uncertain – 15-20 M for infrastructure)
Possible qualification of companies not included

Table 3: Estimated human resource requirements for engineering design and documentation.

Item	Human resources [FTE-yr]
Accelerator/Engineering design and integration	75
Sources	35
Damping Ring (DR)	30
Beam transfer system from DR to ML	25
Main Linacs (ML)	60
Beam Delivery System	25
Total	250

Table 5: Pre-lab Central Bureau human resource requirement

Item	FTE/Year
Directorate Office	12
Director and associate directors	4
Secretarial support, legal service, communication, safety	8
Administration Office	9
Head	1
International Relation, Finance & Procurement, Human Resources & Travel, Local IT service	8
Central Technical Office	9
Project management and technical coordination	5
Coordination for the common physics and detector needs	2
IT service for Engineering Data Management System	2
Total	30

Worldwide efforts for the ILC

	～2017	2018～2021
CERN	Cooperation on nano-beam at ATF, study on industrialization of cavity and cryomodule for SRF, cooperation on design of cryogenics, beam dump, and civil engineering	Nanobeam collaboration at ATF, SRF cavity fabrication technology, cryogenics, beam dump and civil design collaboration. Overall coordination of ILC R&D in Europe.
Americas (USA+Canada)	Start of construction of LCLS-II; development of a new SRF cavity treatment method for LCLS-II; development of a crab cavity for HL-LHC.	US-Japan collaboration on SRF cavity performance improvement and cost reduction, assembly and installation of cryomodules for LCLS-II.Production began for in-kind contributions of the RFD crab cavities and cryomodules to the HL-LHC by the US & Canada
France	Experience in assembly of SRF input couplers and cryomodule assembly at XFEL in Europe, cooperation with Nanobeam at ATF	In-kind contributions to the European Neutron Source (ESS), the US PIP-II project, cavity performance improvement at SRF, nanobeam collaboration at ATF.
Germany	TESLA (preliminary stage of ILC) planning study, XFEL construction started in 2007, SRF cost estimate for TDR.	Demonstration of large SRF accelerator with stable operation of XFEL, and improvement of SRF cavity performance
Italy	Contribution to ILC-TDR for cryomodules, cavities and reference Blade tuners, in-kind contribution to half of the cavities and cryomodules at XFEL in Europe.	In-kind contributions to the European Neutron Source (ESS), the US PIP-II project, cavity tuner design at the VSR Upgrade of BESSY storage ring HZB
Spain	Nanobeam collaboration at ATF, in-kind contributions such as superconducting magnets at European XFEL, in-kind contributions to IFMIF in Japan	In-Kind contribution to the European Neutron Source (ESS), CIEMAT was awarded a budget for the R&D of the ILC superconducting magnet.
UK	Nanobeam collaboration at ATF. Contributions to TDR for damping rings, positron sources, beam delivery system, RF sources, and beam dump.	In-kind contributions to the European Neutron Source (ESS) and the US PIP-II projects, design of the LHC crab cavity.

CERN's Activities for ILC Acc. Technology

~ 2017

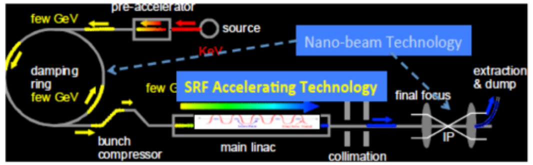
- **Nano-beam: Achieved** the Final Focus beam size of 41 nm at ATF-II, equivalent to 7 nm at ILC-FF.
- **SRF:** Progressed industrialization study of **c**avity and cryomodule fabrication,
- **RF:** Developed fundamental input-coupler w/ new-ceramic,
- **Cryogenics:** Progressed the **s**ystem design reliable & sustainable in emergency, total power failure,
- **Beam Dump:** Investigated > 10 MW water-dump design feasibility,
- **Civil Engineering:** Developed Tunnel Optimization Tool (TOT), referring the FCC CE study at CERN,

2018 ~ 2021

- **Nano-beam:** demonstrated the stability, focusing on beam dynamics, wake field, and ground vibration,
- **SRF:** developed new fabrication technology (such as inner-EB welding and hydroforming),
- **RF:** Developed high-efficiency RF source (klystron) with applying superconducting magnet technology,
- **Cryogenics:** Established the sustainable system-design to conserve helium resource in any emergencies,
- **Beam dump**, Developed remote-handling technology in particular for beam-window maintenance,
- **Civil engineering** design, reflecting CERN's HL-LHC civil work for vertical shafts at beam interaction points.

Plan (2022 ~ : Pre-Lab)

- **Lead European Cooperation** for ILC-Pre-Lab
- Nano-beam: Contribution to the ATF2/ATF3 program,
- SRF, RF, Cryog., Beam Dump, Beam Dynamics,



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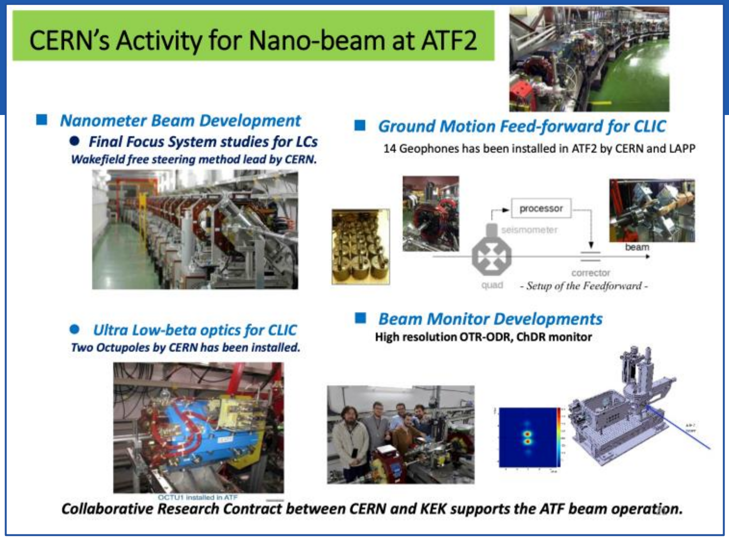
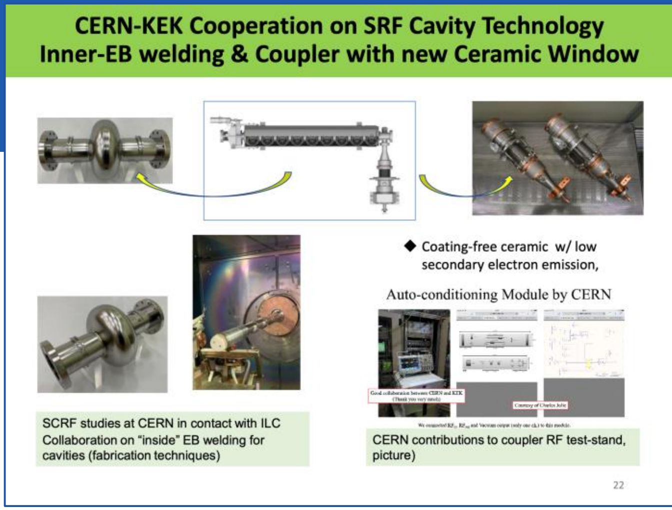
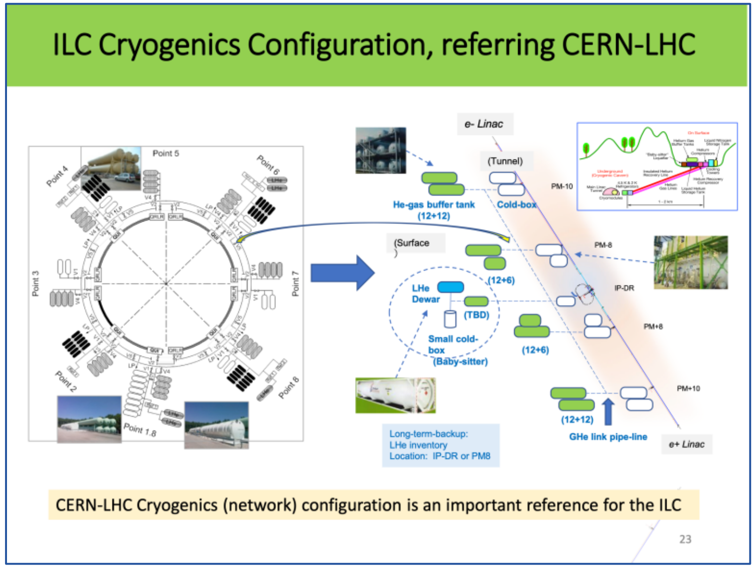
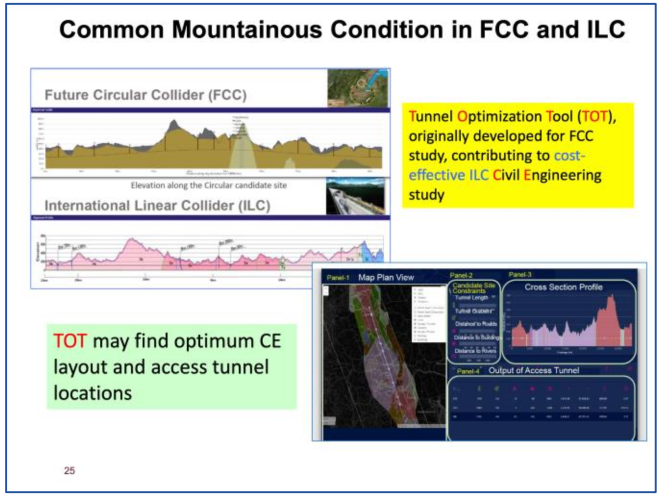
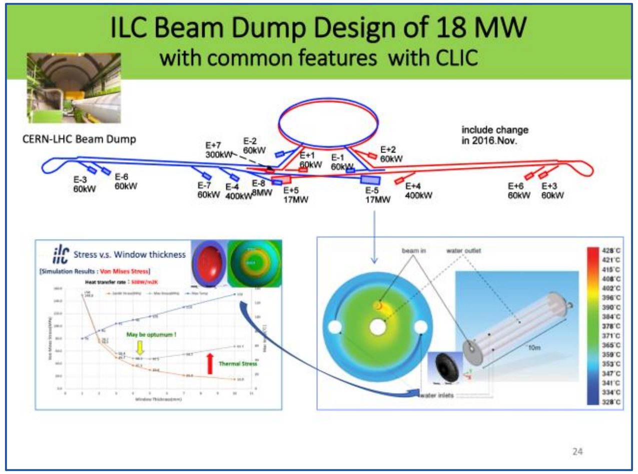








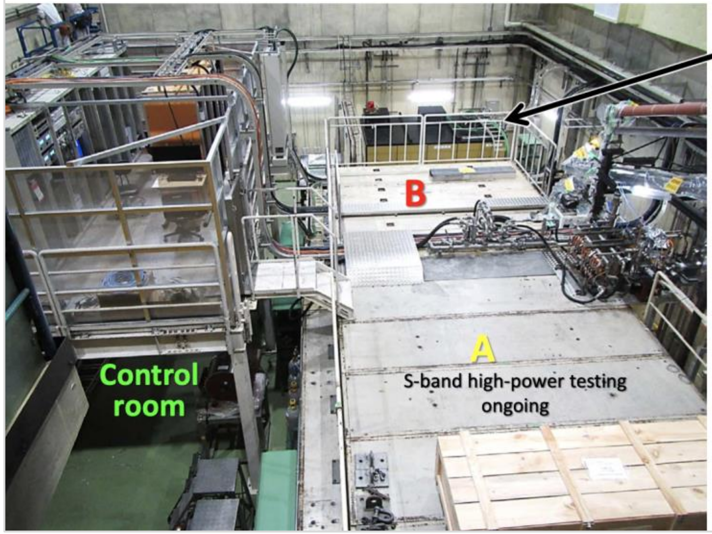


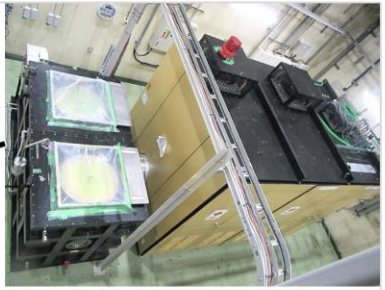
R&D areas with common interests

Topics	CLIC – ILC communality	Other	Status wrt ILC and KEK
CE and Cryo	CE common	LHC, all future project	WG2 reps from CERN
ATF2(3), BDS, beamdynamics, instrumentation and related beam-elements	Common	Other nanobeam projects	Participate in ATF3 study – BDS optimization, WG2 rep. from CERN
Positrons	Common for e-driven	All e+e- colliders	WG2 rep. from CERN, target, AMD, pulsed magnet for undulator version
Damping Rings	Common	All low emittance rings	Possible effort (performance studies, design and also kicker for CLIC relevant) – only partly in current LC studies, WG2 rep. from CERN
Hi-Eff klystron	Common (L-band)	FCC, CEPC etc	Designed (also ongoing SC solenoid work with KEK), now in Hi-Eff klystron project
SCRF cavities	For ILC	SCRF generally	Common manufacture studies, e.g. internal EB welding studies/hydro-forming, long term Nb3Sn studies, surface treatment, crab-cavities, WG2 rep. from CERN, recent APT first attempt to include limited personnel in this area
Couplers	For ILC	SCRF generally	Possible design effort, also common work in the past
Beam dumps	Common	(HL)LHC/FCC/muons ..	Advisory, visits and common studies to be considered
Physics and Detectors	Common	Higgs factories	Some common tools, not defined longer term
CERN – KEK office, agreements, WEB pages, LCWS	Partly common	NA	LC project office at CERN working with KEK communication and international office

Aug. 2020

Current Snapshot (1/2)



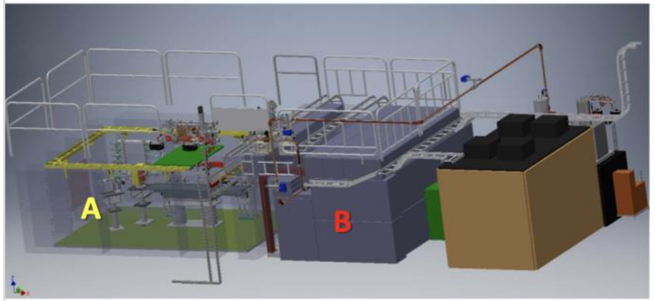


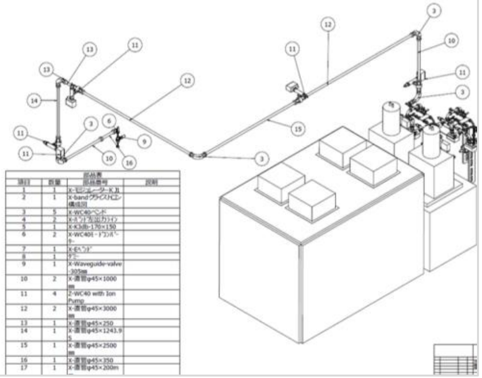
↑ Oil tank with any klystron not yet installed

↑ X-band Modulator

Work to be performed within this JFY (by Mar. 2021)

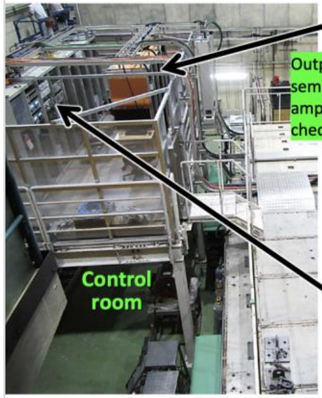
1. Fabricate power line of waveguides from the klystron to Shield-B
2. Reboot the vacuum system
3. Install the klystron
4. Re-construct LLRF and DAQ systems





Aug. 2020

Current Snapshot (2/2)



Output from the semiconductor amp. already checked

For the X-band high-power source

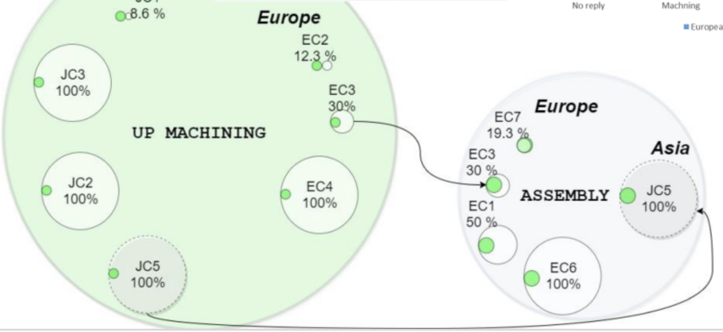
Rad. Safety System in operation

Control for Shield-A

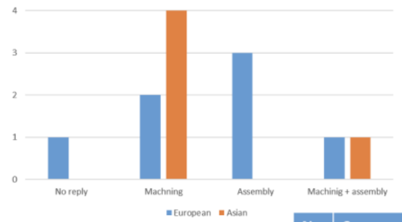
Control for Shield-B

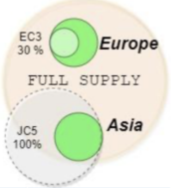
Companies distribution (survey results)

Nr	Company	Volume (%)
1	JC1	8.6
2	JC2	100
3	JC3	100
4	JC5	100
5	EC2	12.3
6	EC3	30
7	EC4	100



Industrialization scenarios

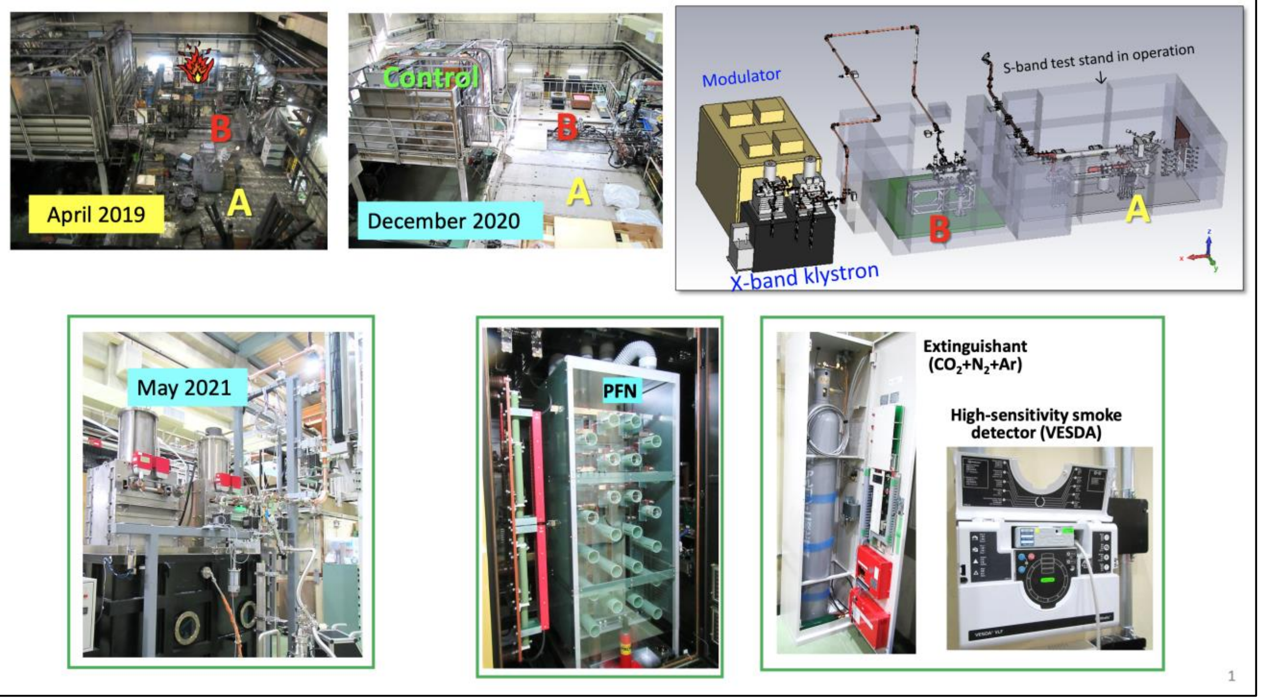




Nr	Company	Volume (%)
1	JC5	100
2	EC3	30

Nr	Company	Volume (%)
1	EC1	50
2	EC3	30
3	EC6	100
4	EC7	19.3
5	JC5	100

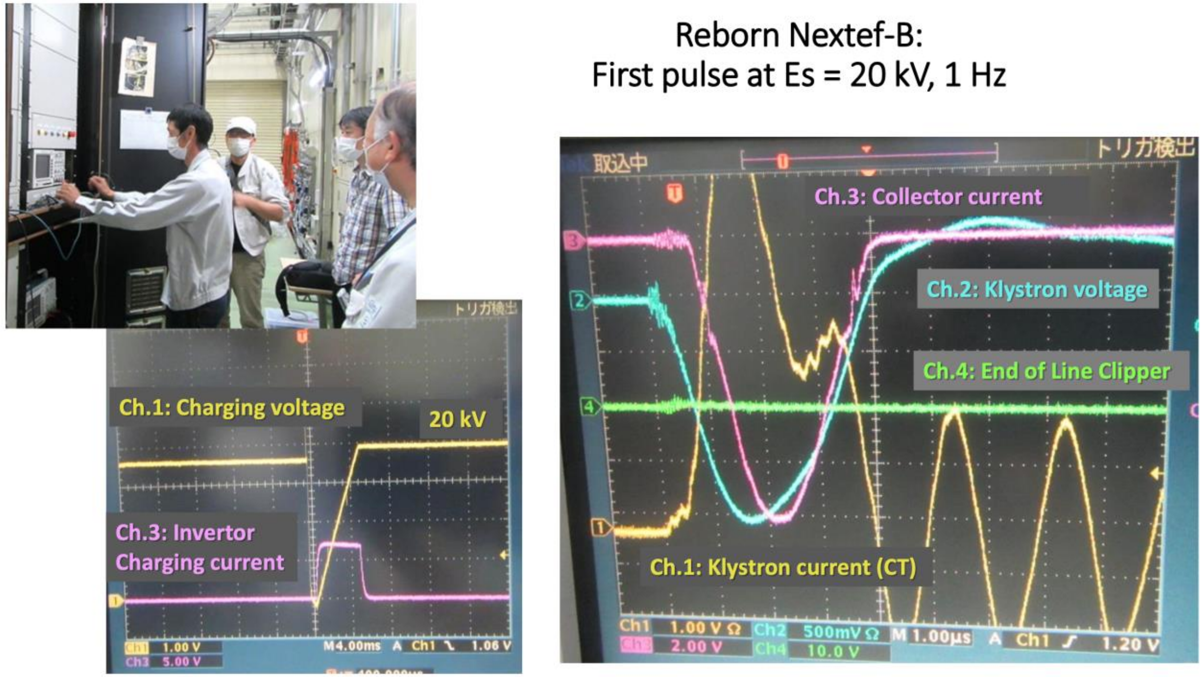
11



Pictures from T.Higo

Today

Reborn Nextef-B:
First pulse at Es = 20 kV, 1 Hz



SC solenoid for HiEff klystrons

CERN – EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CLIC – Note – 1160

PERFORMANCE OF MGB2 SUPERCONDUCTOR DEVELOPED FOR HIGH-EFFICIENCY KLYSTRON APPLICATIONS

H. Tanaka[3], T.Suzuki[3], M. Kodama[3], T. Koga[3], H. Watanabe[3], A. Yamamoto[1,2] and S. Michizono[2]

[1]CERN, Geneva, Switzerland
[2]KEK, Tsukuba, Japan
[3]Hitachi, Tokyo, Japan

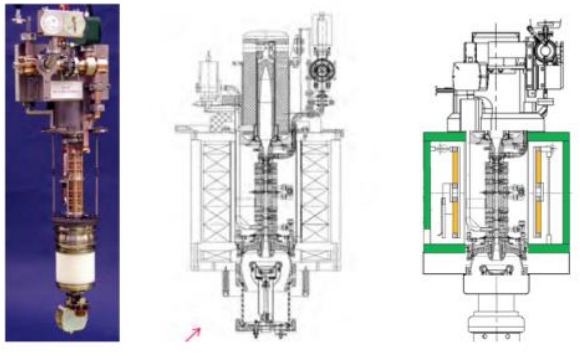


Fig. 3. (a) 12 GHz Klystron (main RF part), (b) Klystron assembled with conventional Cu solenoid, and (c) Klystrons assembled with a superconducting solenoid magnet.

TABLE III
SPECIFICATIONS OF PRELIMINARY EXPERIMENTAL TEST COIL

PARAMETER	VALUE
Current (A)	57.1
Coil Inner diameter (mm)	165.7
Outer diameter (mm)	175.7
Length (mm)	53.6
Turn number (turns)	236
Inductance (H)	0.05
Stored energy (kJ)	0.08
Load factor (%)	21

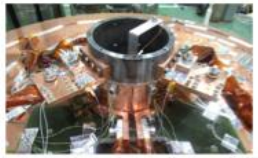


Fig. 10. Preliminary experimental test coil on test facility

Fig. 11. Prototype coils on test facility

Fig. 12. Finished magnet

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CLIC – Note – 1159

APPLYING SUPERCONDUCTING MAGNET TECHNOLOGY FOR HIGH-EFFICIENCY KLYSTRONS IN PARTICLE ACCELERATOR RF SYSTEMS

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CERN – EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

CLIC – Note – 1161

DEVELOPMENT OF PROTOTYPE MGB2 SUPERCONDUCTING SOLENOID MAGNET FOR HIGH-EFFICIENCY KLYSTRON APPLICATIONS

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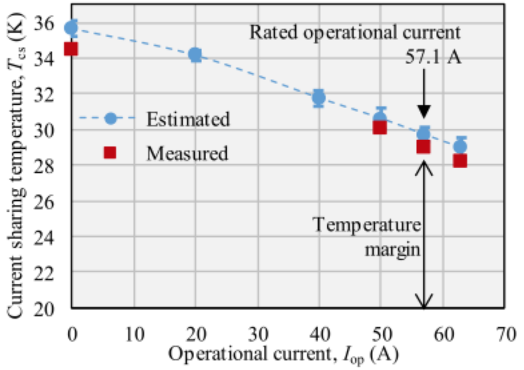
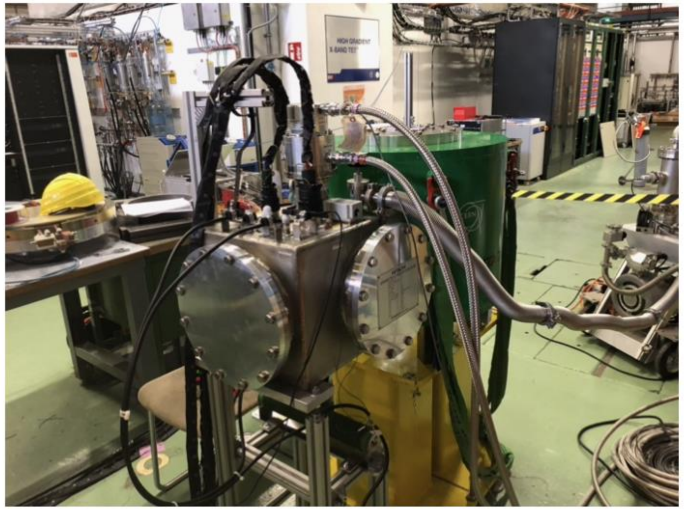
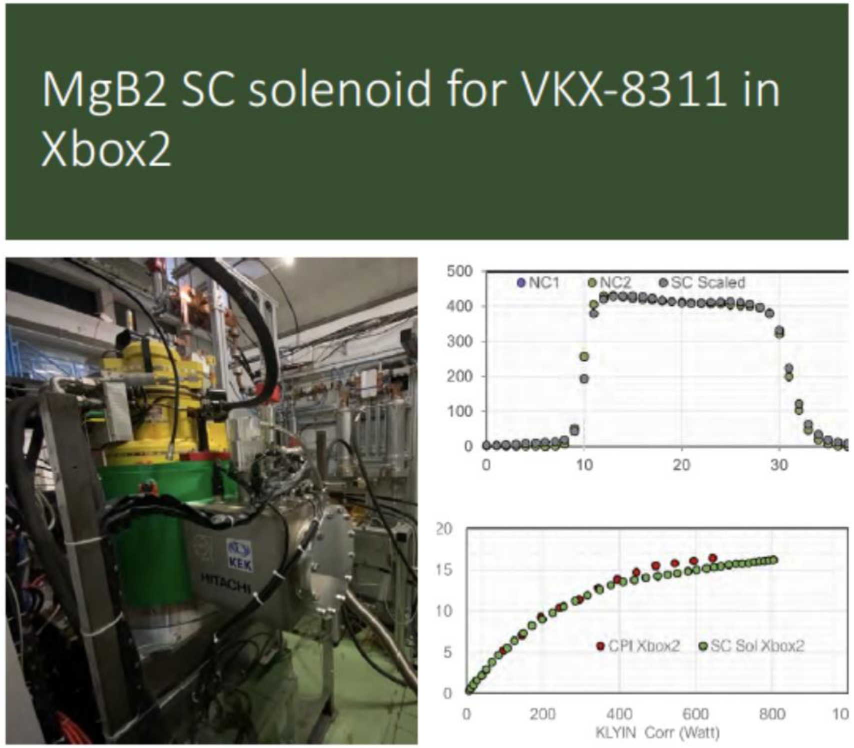


Fig. 7. Comparison of measured and estimated values of T_{cs}.

Final integrated tests at CERN
to be done (this was status in November last year)





The Science and Technology Impact Prize awarded to:

HITACHI-KEK-CERN Collaboration (International Cooperation Team),

Hiroyuki Watanabe*, Tomoyuki Koga, Hideki Tanaka, Takeshi Wakuda (Hitachi, Ltd.), Akira Yamamoto, Shinichiro Michizono (KEK, CERN), in cooperation with Nuria Catalan Lasheras, Gerald Mcmonagle, and Steinar Stapnes (CERN).

* Leading Principal Engineer.

The "**Science and Technology Impact Prize**" has been newly established by "Cryogenics and Superconductivity Society of Japan **(CSSJ)**" in FY2021. It is awarded to those who have made outstanding impact in cryogenic engineering and superconducting technology, or in research and development contributed to fundamental research and/or advanced applications in recent two to three years. The HITACHI-KEK-CERN Collaboration has been selected as the first recipient, and the award ceremony was organized in the Annual Assembly of CSSJ, remotely held, May 2021.

The collaboration has developed a conduction cooled MgB_2 superconducting solenoid magnet for klystrons and has successfully demonstrated the stable operation at 25 K (much higher than 2 ~ 4 K for NbTi) with realizing significant power saving, motivated with a "green accelerator" concept. The klystron is a device that generates RF power to accelerate charged particles and the power consumption of klystrons is a critical issue in accelerator operation. Aa a future accelerator candidate, Compact Linear Collider (CLIC) of CERN will require 5,000 klystrons in the case of Klystron-based high-level RF design. A total wall-plug power consumption of 100 MW has to be consumed only for magnetic field provided for beam focusing in the Klystron, if conventional water-cooled copper coil normal-conducting solenoid magnets were used. The HITACHI-KEKK-CERN Collaboration has developed the MgB_2 superconducting solenoid magnet applicable for the 12 GHz Klystrons for CLIC, which is safely and easily operational as a normal-conducting magnet based on its very stable self-protection without any additional external protection system. The fact that the total power consumption including cryogenics power consumption was reduced down to one order of magnitude (less than 1/7 of that of a normal-conductive magnet) is a very significant achievement enabling approximately 90 MW power saving in the CLIC project.

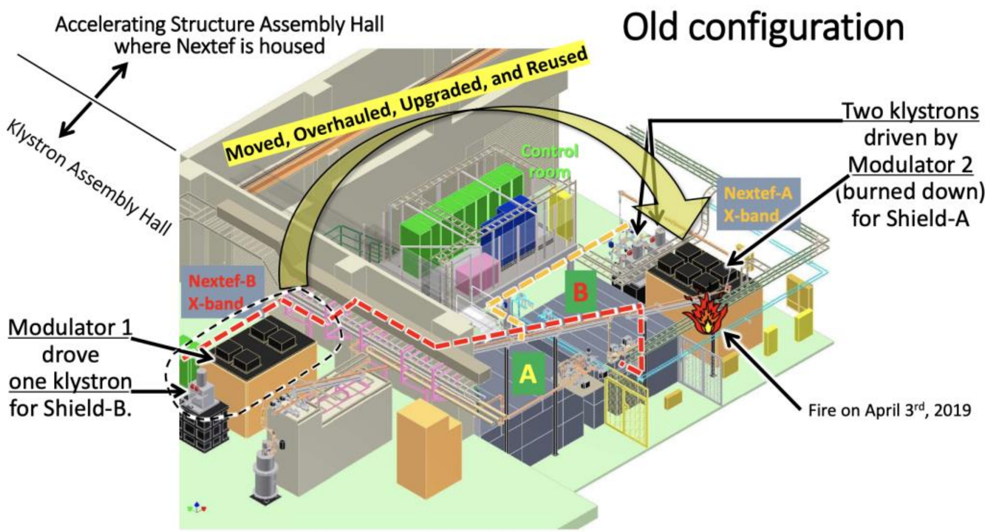
This development is a great achievement with the MgB_2 application in the much higher temperature operation at 25 K. Extending the application from the accelerator field, it is also expected to be widely applicable in other fields such as medicine: MRI superconducting magnets so on. For these reasons, the HITACHI-KEK-CERN Collaboration has been selected to be worthy of the FY2021 Science and Technology Impact Project.

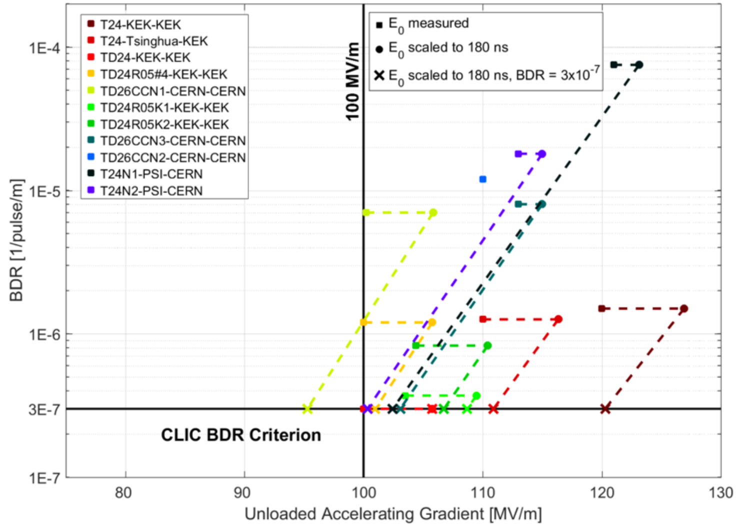
Conclusion

- Collaborative work has continued as much as allowed by the Covid situation
- A lot of progress in the area of ILC prelab planning – including work between KEK-CERN, still unclear if/when one can get into implementation
- Hi-efficiency klystron testing done successfully – and a price awarded
- X-band facility becoming operational again at KEK, potentially important also for other groups as Tsinghua, Shanghai and Melbourne
- The hope is that in 2022 more personnel exchange, as needed for ATF, positrons, beamdumps etc., can actually take place (this we have funding for)
- A possible implementation of the ILC prelab would imply a change of gear, expect this to become clearer during 2022

Slides/plots and pictures from many colleagues in CLIC and ILC – many thanks

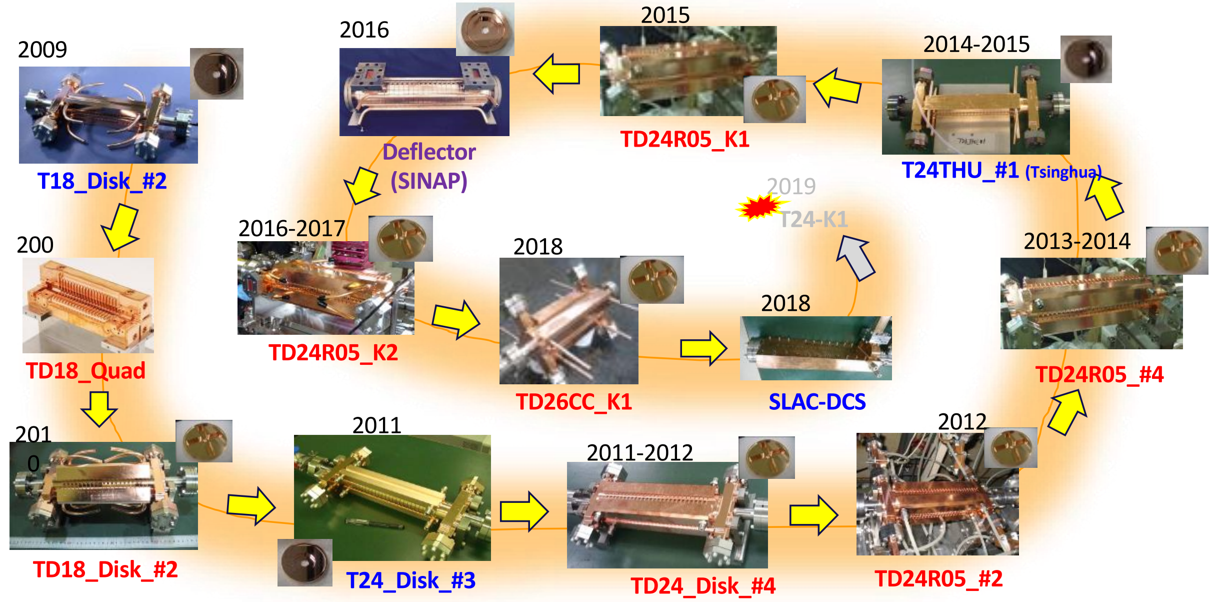
NEXTEF: New X-band Test Facility (11.4 GHz)





X-band Prototype Structures Tested at Nextef

T18 →Quad → TD18→T24→TD24→TD24R05→TD24R05 →T24THU→TD24R05 →Deflector →TD24R05 → TD26CC → DCS → T24-K1 (terminated by the fire)



ATF2-3 for nanobeams

- ATF2 work has continued (affected by Covid)
- AFT2 analysis – PhD students, some at CERN – also
- AFT2 review in September (extract from draft report on the left)
- ATF3 planning started
- In all cases with CERN involvement

Scientific results at ATF/ATF2

The committee has been impressed on outstanding and unique results achieved in ATF/ATF2:

- The smallest spot size, 40 nm, in any accelerators.
- Intra-train bunch orbit feedback (FONT).
- Vertical emittance in the ring, 4 pm, smallest at the beginning of the century.

The committee also applauds pioneering developments on various accelerator components:

- Fast extraction kickers with rise/fall time less than 3 ns
- Laser wires measuring 1 μm beam size
- Cavity BPMs with 20 nm resolution
- Single- and multi- OTR/ODR beam profile monitors

Some of these devices have been spread to other accelerators including CERN PS and light sources.

Educating graduate students and young scientists under international collaboration was another achievement of ATF, which is the best project at KEK in this aspect.

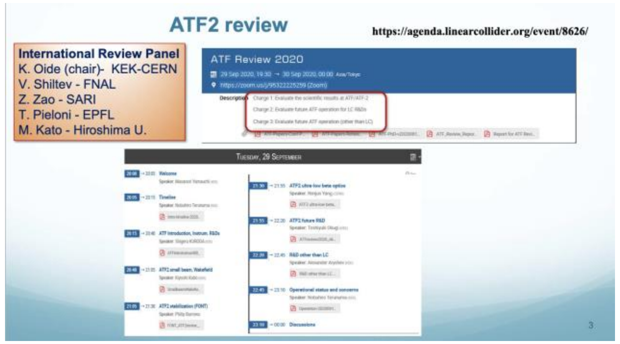
Future ATF operation for LC R&Ds

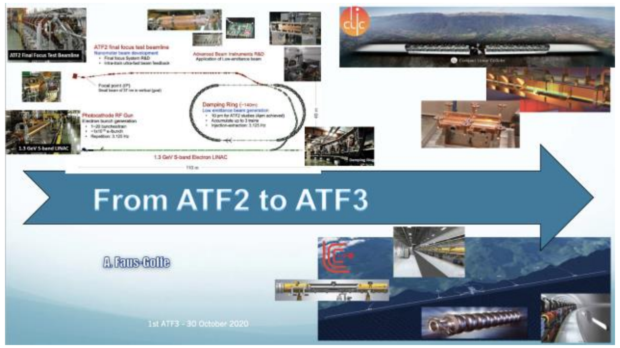
The committee recognizes that the achievements at ATF/ATF2 have already verified the minimum technical feasibility on the beam focusing and control for the ILC. However there will be a number of possibilities for further extensions to investigate:

- intensity dependent effects on the spot size
- optical aberrations, esp. with smaller horizontal β^*
- beam halo and collimation
- even smaller spot sizes with higher chromaticities

Besides the studies on the beam spot, the committee notices some possibilities of ATF to explore other components which will benefit the ILC preparation:

- polarized electron source, transport, and storage in the damping ring.
- beam collimation study using fancy devices such as using a laser or another beam.
- beam feedback within one turn of the ring circulation to simulate a fast feedback at the extraction of the ILC DR

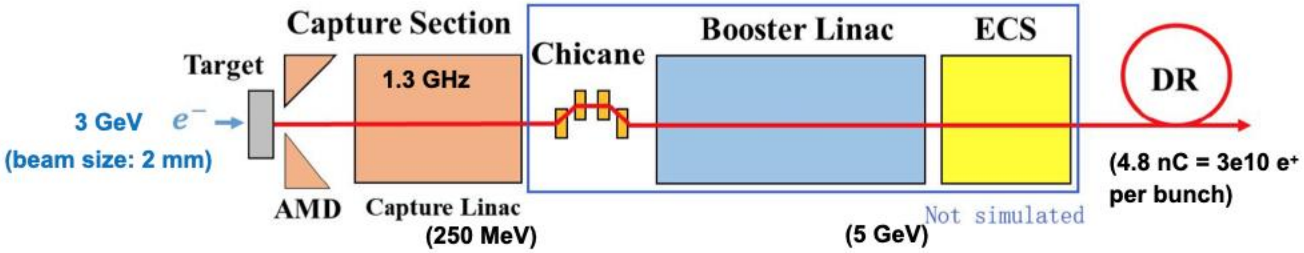




Positrons

Code validation: ILC reproduction

- ILC positron source (e-driven) quite similar as CLIC, which can be used to cross-check and validate our code



e^+ yield	Software	After target	After AMD	After Capt. Sect.	DR accepted
ILC	Geant4	7.13	5.09	1.94	1.03
Reprod.	Geant4+RF_Track	7.07	4.48	1.97	1.11
Diff.		1%	12% *	2%	8%

* Difference after AMD due to particle interactions in Geant4. Otherwise, it is reduced to 2%

2.4 nC e^- bunch	ILC	Reprod.	Diff.
PEDD (in target) [J/g]	22.0	23.7	8%

Good agreement!

Positron production modelling and target, AMD optimization

Common Project with Shandung University

Evaluating next stages with KEK (SuperKEKb and ILC) and Orsay and PSI (FCC-ee)

Target studies and simulation studies for CLIC are very relevant – and visa versa, example on the left where ILC studies are used as code validation for CLIC