CERN-KEK **Collaborative Activities for Linear Colliders**

Steinar Stapnes – with information/slides from many others at KEK and CERN

Today:

- ILC-IDT renewed (Appendix 24)
- ILC - ITN (Appendix 26 – new annex recently signed)
- ATF (collaboration) very active – in the original ICA, also part of the ILC ITN
- EAJADE (EU funded exchange programme with Japan (and Americas) for Higgs factories – supports ATF, SuperKEKb, sustainability studies, SCRF, etc)
- Normal conducting cavities and test-stands, originally linked to X-band studies, recently used for dielectric studies (Appendix 2)
- A few summary lines

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.
CERN's involvement covered by CERN-KEK appendix 24. Just extended by 2 years.

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 the main activity in the area of LC studies. CERN-KEK appendix 26. See next slides.

ITN: The International ILC Technology Network ILC

Globally performing high-priority R&D for the IDT in 13 WPPs; based on MEXT funding

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 16-17.10.2023 jointly organized by KEK and the IDT
- Interest matrix for the ITN work-packages (next slide)

ITN in Europe

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	√			√					√														

APPENDIX 26
KR5783/ATSAPPENDIX26-to-ICA-J

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

Support for the European International Linear Collider (ILC) Technology Network

2023

Contributing to ITN activities in Europe:
- Planning ongoing: significant interests and expertise already represented (see interest & capability matrix)
- Formally being implemented; CERN (supported by KEK) facilitates and organises work at European partners

ITN: European Contributions

… concentrate on five main activity areas:

Main linac (ML) related tasks (ITN WPPs 1-3)

- SRF and ML elements: cavities and cryo-module, crab cavities, ML quads and cold BPMs (INFN, CEA, DESY, CERN, IJCLAB, UK, CIEMAT, IFIC)

Sources (ITN WPPs 4-11)

- Pulsed magnet and wheel/target (UHH, DESY, CERN)

Damping ring including kickers (ITN WPPs 12,14)

- Low Emittance Rings, fast kicker electronics (UK)

ATF activities, final focus and nanobeams (ITN WPPs 15-17)

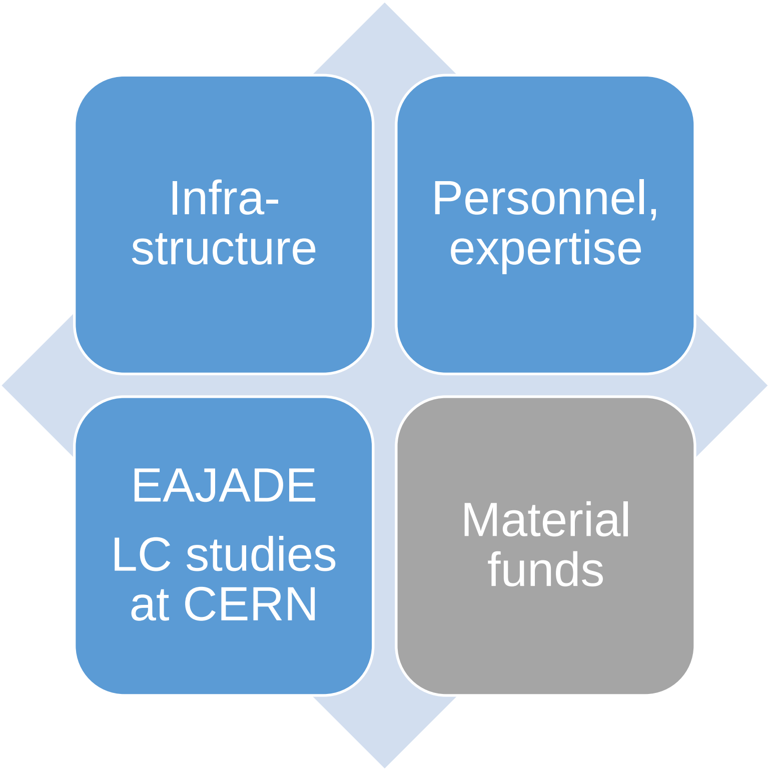
- ATF and MDI (UK, DESY, IJCLAB, CERN, IFIC)

Implementation

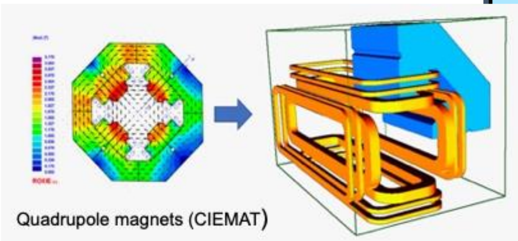
- Dump, CE, Cryo – follow-up efforts at CERN
- Sustainability, life-cycle assessment (CERN, DESY, CEA, UK groups)

Supported by the European Commission

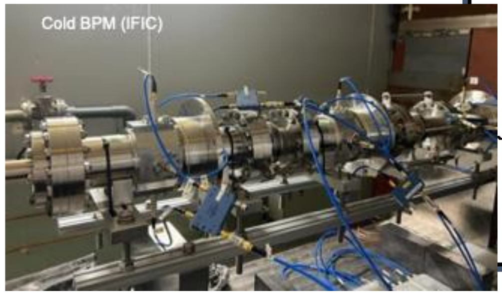
- EAJADE (EU funding for DESY, UK, CEA, CNRS, IFIC, INFN, UHH, CERN)



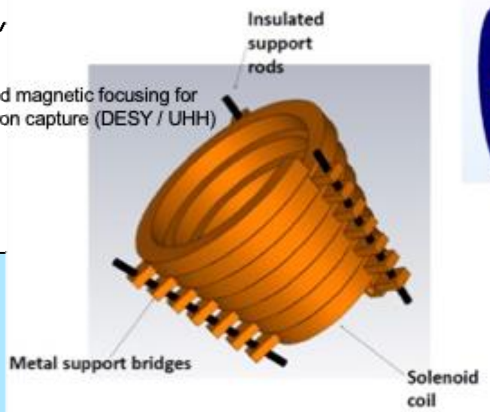
SRF cavities (CERN, CEA, INFN, DESY)



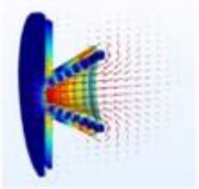
Quadrupole magnets (CIEMAT)



Cold BPM (IFIC)



Pulsed magnetic focusing for positron capture (DESY / UHH)



The EAJADE Work Packages

Addressing the most pressing items for Higgs factories

1) R&D&I at currently operating acilities.

2) State-of-the-art high-gradient high-efficiency reduced-cost radio-frequency structures and power sources

3) Special technologies, devices and systems performance

4) Sustainable technologies for scientific facilities

5) Investigation of potential early applications of novel and advanced technologies for colliders

ATF3 in EAJADE project

Next 6 slides from
Angeles Faus-Golfe

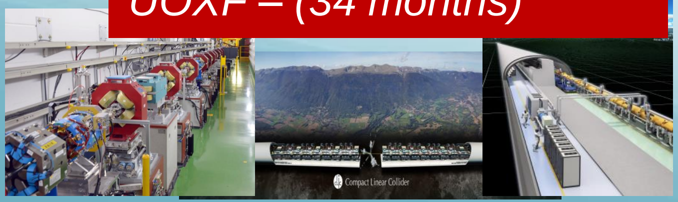
EAJADE
Europe-America-Japan Accelerator Development Exchange Programme

WP1 (112 months): **R&D&I at currently operating state-of-the-art accelerator facilities**

Task 1.1 *(57 months)* Future e^+e^- linear collider studies

ATF3 (KEK) – *46 months*
LCLSII (SLAC) – *5 months*
IOTA (FNAL) – *6 months*

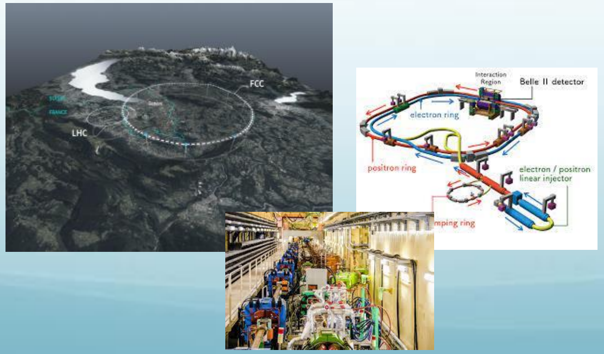
CERN – *18 months*
CEA – *2 months*
CNRS – *16 months*
CSIC-IFIC – *17 months*
DESY - *4 months*
UOXF – (34 months)



Task 1.2 *(30 months)* Future e^+e^- circular collider studies

SuperKEKB – *30 months*

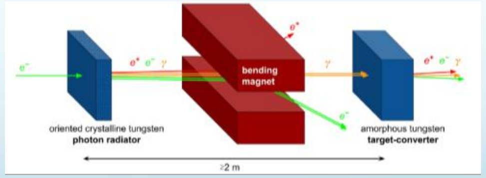
CERN – *7 months*
CEA – *2 months*
CNRS – *16 months*
INFN – *5 months*



Task 1.3 *(19 months)* e^+ production for e^+e^- colliders

SuperKEKB – *17 months*
FACETII (SLAC) – *1 month*
CEBAF (JLAB) – *1 month*

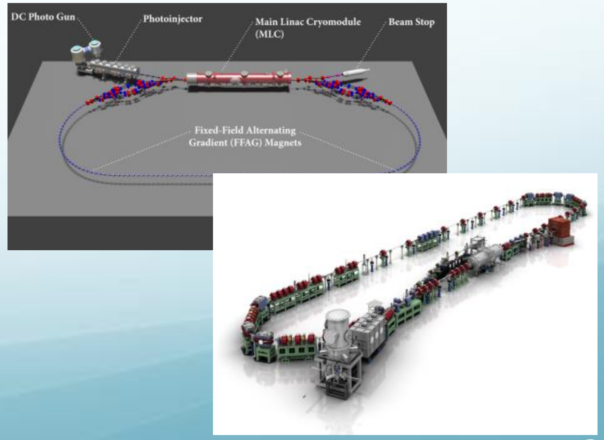
CERN – *4 months*
CNRS – *15 months*



Task 1.4 *(6 months)* R&D on ERLs

CBETA (JLAB) – *3 months*
CERL (KEK) – *3 months*

CNRS – *6 months*



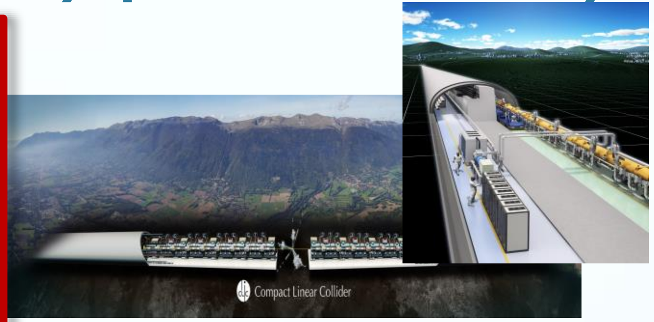
Task 1.1: Future e^+e^- linear collider studies

(CERN, CEA, CNRS, CSIC/IFIC DESY, UOX, 57 (34) person-months)

- R&D objectives of the **ATF3** linear collider test facility at **KEK**, to maximize the luminosity potential of the next generation linear-collider-based Higgs factories, focused on ILC and CLIC **final focus system** (FFS). The main topics are (1) long-term stability and availability in routine operation, (2) vibration monitoring and beam-based feed-back / feed-forward, (3) wakefield mitigation, (4) high-order aberration control and in ultra-low-β_y^* optics, and (5) AI-based machine learning beam tuning techniques.

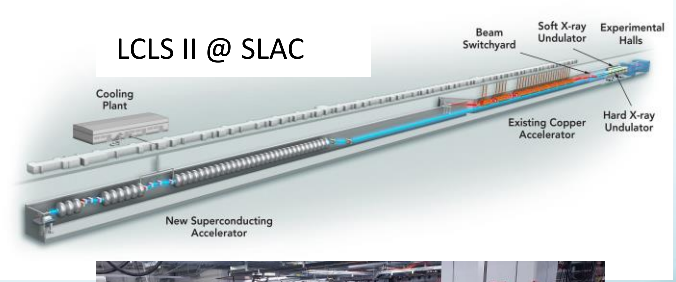
- **Main linac linear collider subsystem**: **LCLS II at SLAC** is ideal to acquire experience with issues specific to operating SC RF linacs, relative to beam dynamics and collective effects as well as to efficiency considerations of the CW RF modules.

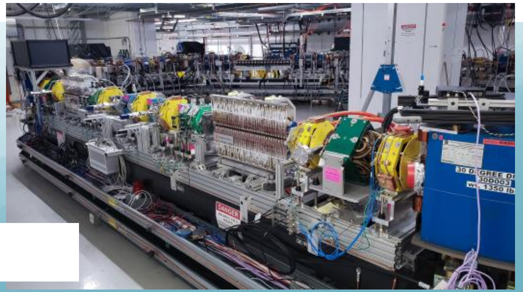
- **High-current and high-gradient superconductive RF linac** operation experience at **FAST-IOTA at FNAL** can be acquired, especially with respect to emittance preservation in the presence of beam loading. Knowledge on non-integrable optics, amplitude detuning techniques, AI based machine-learning tools, including simulation benchmarking, will also be acquired.



ATF2 @ KEK

LCLS II @ SLAC





IOTA @ FNAL

EAJADE
Europe-America-Japan Accelerator Development Exchange Programme

ATF3 operational plan FY2024

ATF Beam Schedule 2024-2025

Beam Weeks

Proposed
Proposal has been submitted to KEK and is awaiting approval for power allocation.

2024

January

Su	Mo	Tu	We	Th	Fr	Sa
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

February

Su	Mo	Tu	We	Th	Fr	Sa
				1	2	3
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11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29		

March

Su	Mo	Tu	We	Th	Fr	Sa
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17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

April

Su	Mo	Tu	We	Th	Fr	Sa
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14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30				

May

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12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

June

Su	Mo	Tu	We	Th	Fr	Sa
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30						

July

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	1	2	3	4	5	6
7	LCWS2024				12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

August

Su	Mo	Tu	We	Th	Fr	Sa
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18	19	20	21	22	23	24
25	26	27	28	29	30	31

September

Su	Mo	Tu	We	Th	Fr	Sa
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15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

October

Su	Mo	Tu	We	Th	Fr	Sa
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13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

November

Su	Mo	Tu	We	Th	Fr	Sa
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24	25	26	27	28	29	30

December

Su	Mo	Tu	We	Th	Fr	Sa
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

2025

January

Su	Mo	Tu	We	Th	Fr	Sa
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

February

Su	Mo	Tu	We	Th	Fr	Sa
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	

March

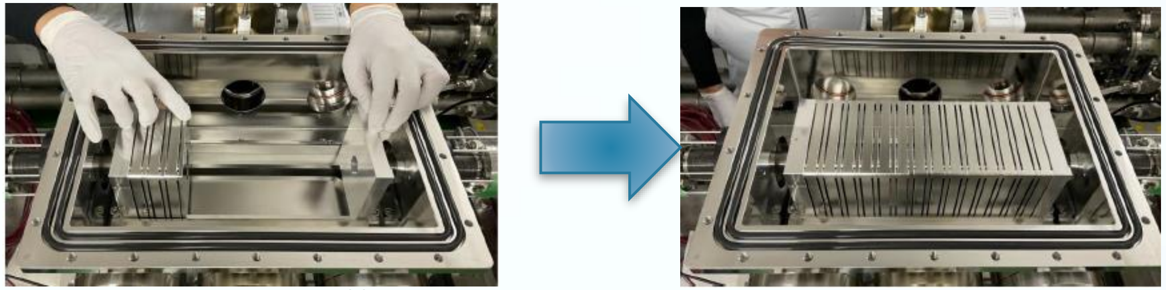
Su	Mo	Tu	We	Th	Fr	Sa
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

April

Su	Mo	Tu	We	Th	Fr	Sa
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

R&D Programs and Experimental Studies

- **Wakefield mitigation** (new wakefield test station)
  - Static: mitigation by relocating the sources in lower β-positions: modelling of ATF2 beam line
  - Dynamic: FONT feedback (minimization of injection fluctuation)

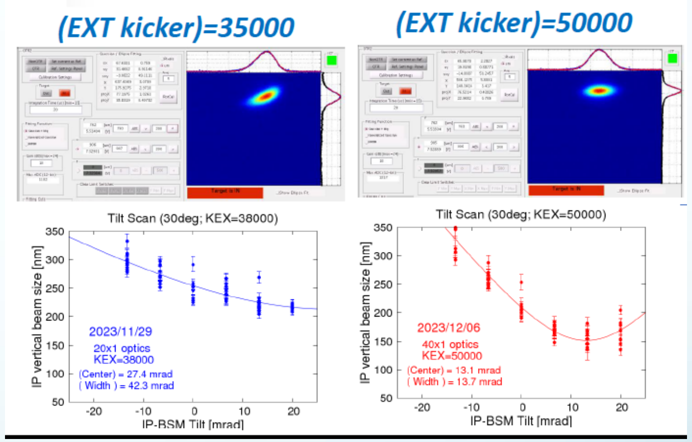


Installation of flange like structure in Abe Chamber

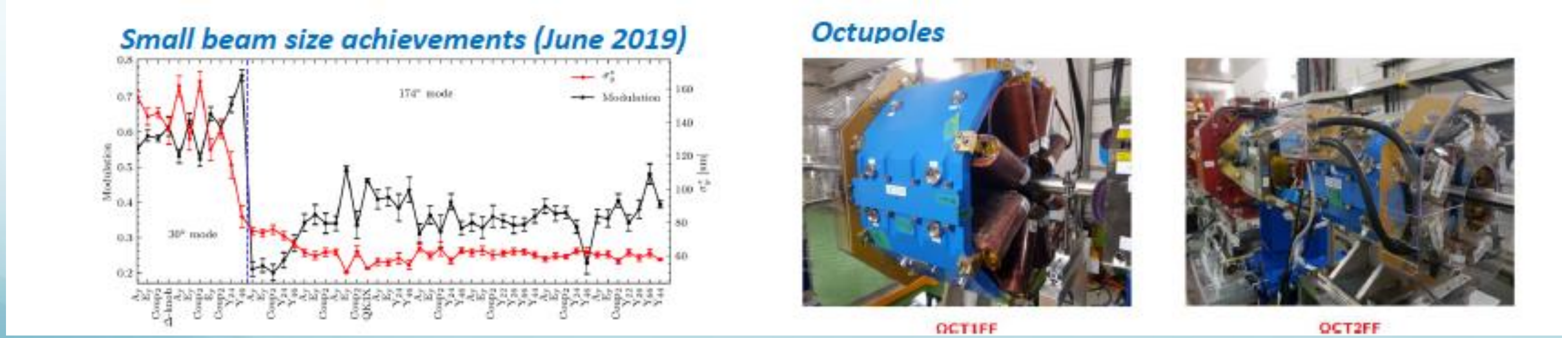
- **High-order aberration correction and mitigation**
  - Measurement of FF quads mutipoles
  - Impact of tilt scan (mitigation by beam orbit control)
  - Ultra low-β studies

CERN contribution

Beam studies of non-linear field at the septum extraction magnet



Ultra low-β studies with octupoles

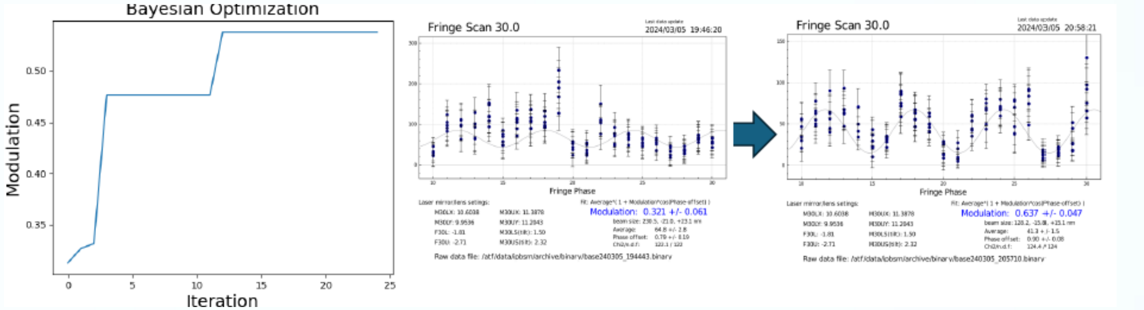


ATF2-3 recent experimental studies

EAJADE
Europe-America-Japan Accelerator Development Exchange Programme

- **ILC beam tuning (ML)**
  - Automatic beam tuning
    - Minimize the tuning parameters
    - Simultaneous optimization
  - Beam optimization (ATF Linac, ATF DR and ATF2)
    - “Black-box”
    - Bayesian optimization

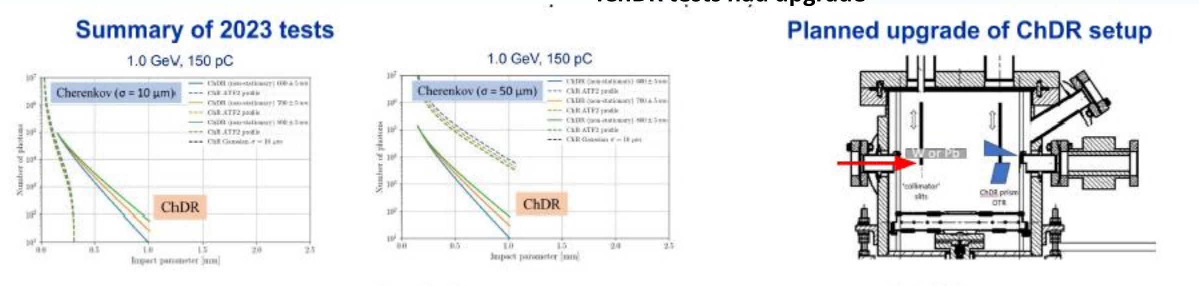
CERN contribution



Bayesian optimization of IP-BSM modulation

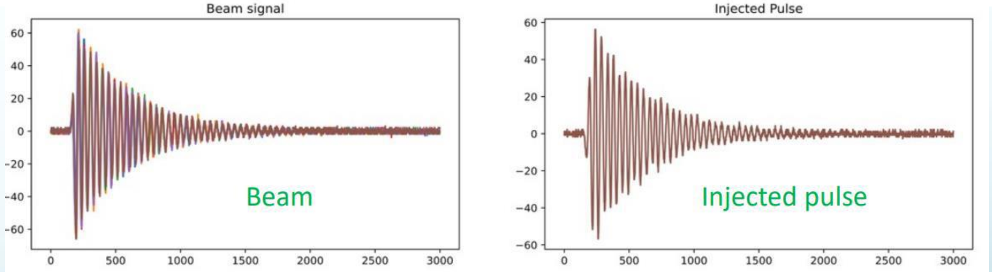
- **Incoherent Cherenkov Diffraction Radiation**
  - Proof of concept validation in progress

IChDR tests nad upgrade

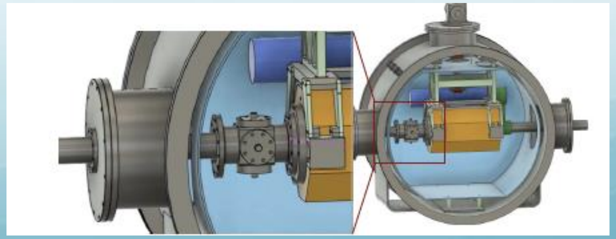


- **Cavity BPM Calibration pulse injection**
  - Proof of concept validated
  - Hardware specifications in progress

Calibration pulse injection



- **ILC Cavity BPM for ILC ML**
  - Prototype under designs
  - First test with re-entrant CBPM FLASH-CEA type



ML Quadrupole end CBPM

Secondment Task 1.1

- **Names**: Andrii Pastushenko (Postdoc), Enrico Manosperti (PhD)
- **Institution:** CERN
- **Dates:** 03/12/2023 – 16/12/2023
- **Visiting Lab:** ATF2-3 KEK

Objectives

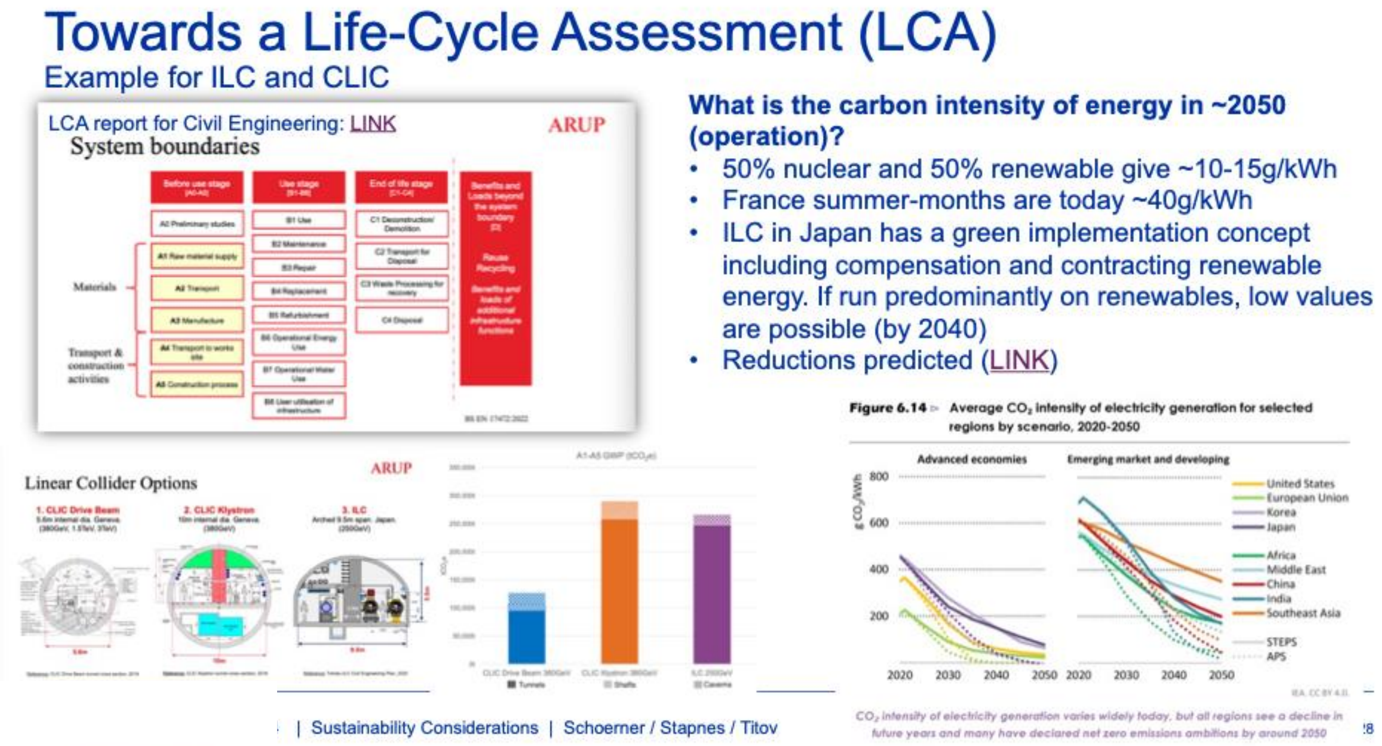
- Train in the small beam size tuning at ATF2-3.
- Upload, set up, and verify the ultra-low β^*_y optics at ATF2-3.

Results

- Became familiar with the correction routines and aberrations control techniques at ATF2.
- Uploaded and used the ultra-low β^*_y lattice for the first time since March 2020.
- Successfully used the optics matching routines written in MAD-X to match the ultra-low β^*_y optics.

EAJADE WP5

WEB page: https://wsfa2023.huhep.org



“Young” CERN researches in CERN office at KEK last week, LCA studies and common paper on sustainability issues

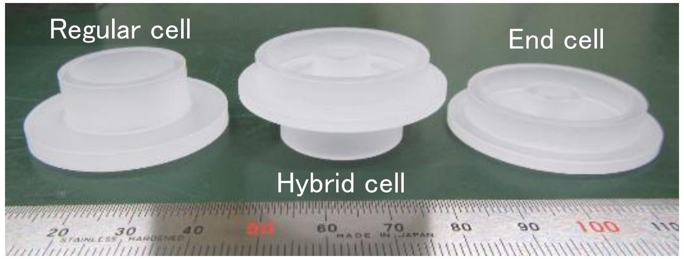
High-power test of the 2nd DAA (Dielectric-Assist Accelerating) test cavity at Nextef2

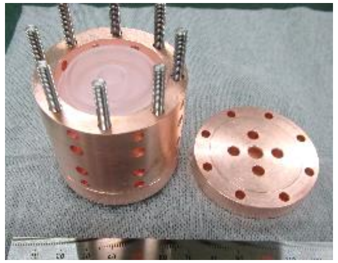
conducted by Daisuke Satoh (AIST)

supported by "*MEXT Development of Key Element Technologies to Improve the Performance of Future Accelerators Program*" (Japan Grant Number JPMXP1423812204)

- ✓ DAA has one order of magnitude higher Q_0 than those of conventional metallic cavities due to loaded ultra-low loss dielectrics.
- ✓ But the accelerating gradient is limited by multipacting ($E_{acc} \lesssim$ ~10 MV/m).
- ✓ This program aims to achieve higher gradients with DAA.

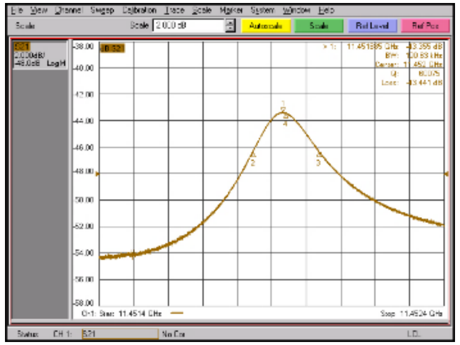
Dielectrics made of single-crystal sapphire for DAA#X1



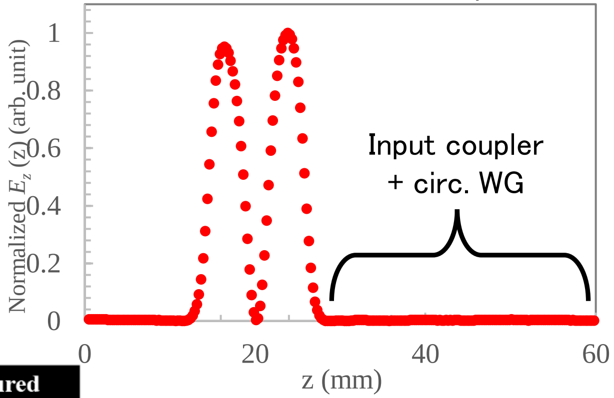


This time, no DLC (Diamond-Like Carbon) coating in order to highlight the nature of the problems toward higher gradients

Low−power RF meas.



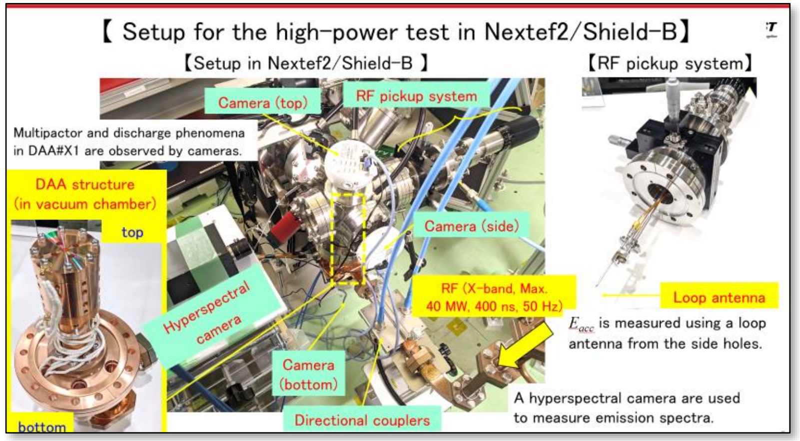
On−axis E−field from bead−pull meas.



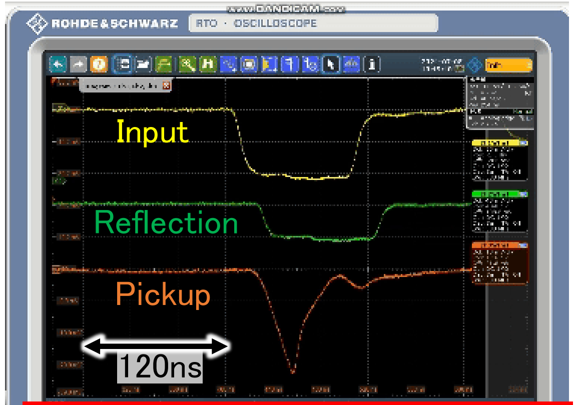
Parameters	Simulation Results	Measured Results
f_0	11.4526 GHz	11.4519 GHz
Q_0	59,000	60,000

← One order of magnitude higher Q_0 than metallic cavities

High-power test performed from June to July, 2024

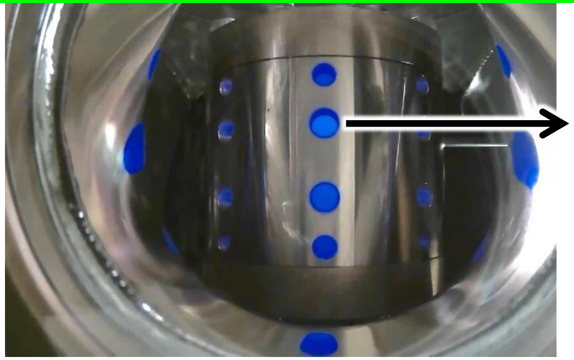


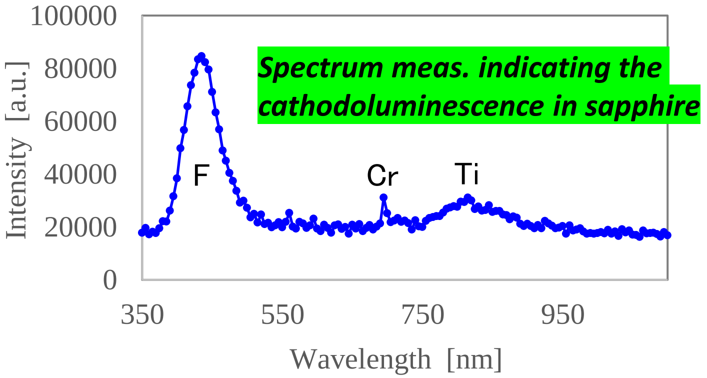
(Shown in LCWS2024)



Significant fluctuation observed in pickup indicating multipacting

Beautifull blue light during the high-power test!





We collected enough data to move to the next step toward higher gradients with DAA.

D. Satoh and collaborator at Nextef2

High-power test of the new standing-wave DDA (Dielectric-Disk Accelerating) test cavity at Nextef2 conducted by Sarah Weatherly (Illinois Institute of Technology)

supported by US-Japan Ozaki Exchange Program

- ✓ DDA has a higher group velocity with maintaining a high shunt impedance compared with conventional metallic cavities due to loaded dielectric disks.
- ✓ DDA is different from DAA.
- ✓ The high-power test of the traveling-wave DDA test structure with short RF pulses (~9 ns) at Argonne Wakefield Accelerator (AWA) Complex showed withstanding capability against more than 320 MW RF power that corresponds to an accelerating gradient over 100 MV/m.
- ✓ This program aims to investigate the performance and characteristics of DDA for longer RF pulses (>> 10 ns) using a newly designed standing-wave DDA test cavity.
- ✓ The work is also supported by ANL/AWA and Euclid Beamlabs.

(Extracted from the AAC paper written by S. Weatherly)

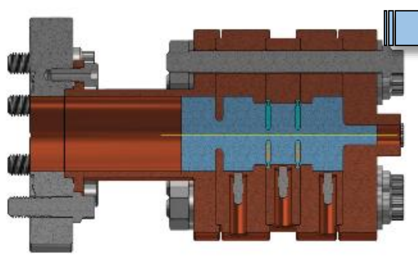


Figure 7: Standing wave DDA structure engineering design.

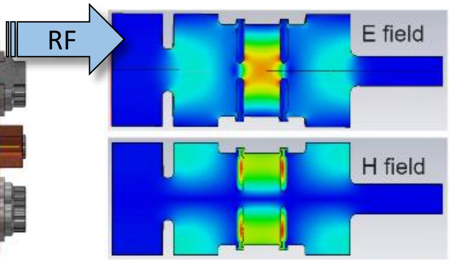
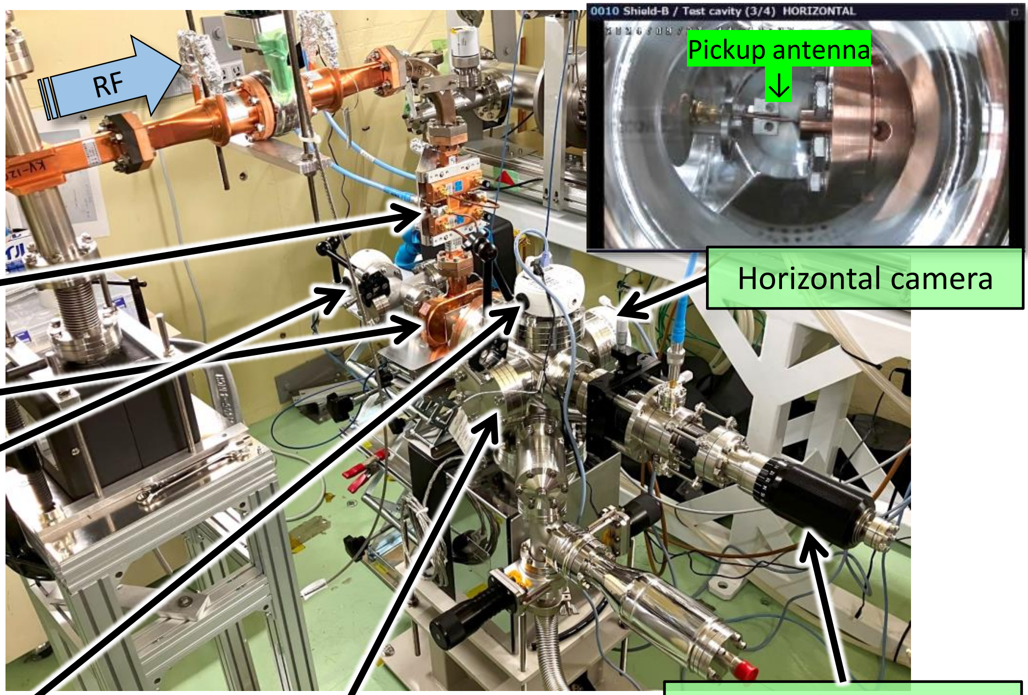


Figure 8: Electric and magnetic fields in the standing wave DDA structure.

Figure 9: Fabricated and assembled standing wave DDA structure.

Low-power RF meas. performed at Nextef2 just before starting the high-power test

High-power test performed in October, 2024



Directional coupler

TM_{01} mode launcher ($rect.TE_{10}$→$circ.TM_{01}$)

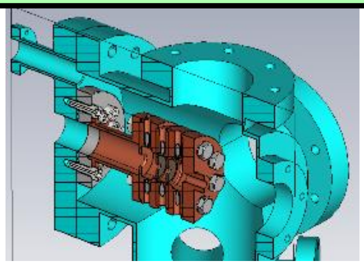
On-axis camera

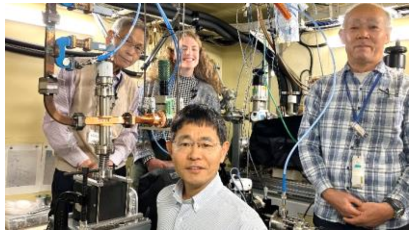
Vertical camera

Horizontal camera

DDA test cavity inside this vacuum chamber

Linear manipulator for the pickup antenna





S. Weatherly and collaborators at Nextef2

Detailed data analysis on-going at ANL (US)

Concluding words

- Interesting ongoing collaborative R&D with Japan and KEK with relevance for Linear Colliders (and Higgs factories in general), within a wide range of technologies, including ATF3 and benefitting from EAJADE related exchanges of people.
- KEK and CERN works closely with European partners in many cases
- Common work on sustainability issues very beneficial to align methodologies in this area
- ILC ITN moving ahead well in Europe, financial and material support from KEK very important
- In 2025-2026(7) nine cell cavities for ITN will be the largest single ”investments”

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

Agreement on SCRF

APPENDIX 25

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

Research and Development for the SRF Cavity Fabrication

2022

Article 2
Scope of Collaboration

As part of the SRF Elliptical Cavities R&D Project (here below 'SRF R&D'), the Parties will collaborate on the following subjects:

Subject 1: R&D on 1.3 GHz cavities:

Deliverable will be a set of seamless **1.3 GHz single-cell cavities** (three minimum); the tools and subcomponents needed to successfully manufacture the cavities, to perform surface conditioning and to execute radio-frequency ("RF") performance tests.

Tasks contribution will be divided as following:

- **KEK and CERN** co-contribute to the following: engineering of process and tooling, and to execute RF performance tests.
- **KEK** contributes to the following: design and manufacturing of the needed tooling; to procure material; to fabricate single cell elliptical structures by using an advanced hydroforming process proposed by KEK and CERN.
- **CERN** contributes to the following: study fabrication process with numerical simulations; to assemble the single cell structure into elliptical cavities; to perform related surface treatments and Niobium (Nb) coating; to perform process characterisation via destructive tests (DT) and non-destructive tests (NDT).

For performance evaluation, the assembled cavities will be shared by both parties as such: one at CERN premises for NDT and DT characterisations, one at CERN premises for the RF performance test, and one at KEK premises for the RF performance test.

Subject 2: R&D on 400 MHz cavities

Deliverable will be a set of seamless **400 MHz single-cell cavities** (two minimum); the tools and subcomponents needed to successfully manufacture the cavities, to perform surface conditioning and to execute RF performance tests.

Tasks contribution will be divided as following:

- **KEK and CERN** co-contribute to the following: engineering of process and tooling, and to procure material (depending on the availability).
- **KEK** contributes to the following: design and manufacturing of the needed tooling; to fabricate single cell elliptical structures by using an advanced hydroforming process proposed by KEK and CERN.
- **CERN** contributes to the following: study fabrication process with numerical simulations; to assemble the single cell structure into elliptical cavities; to process related surface treatments and Niobium (Nb) coating; to perform process characterisation via destructive tests (DT) and non-destructive tests (NDT and to execute RF performance tests.

Subject 3: R&D on Alternative Fabrication Processes

Deliverables will be ad-hoc cooperative R&D activities for processes of interest for SRF cavity fabrication. Namely for: development of internal electron beam welding, additive manufacturing of Niobium for cavity components such as HOM couplers, other ad-hoc activities such as R&D for other cavity frequencies, shapes, surface coating and/or treatment.

Tasks will be discussed and determined, according to further discussions.