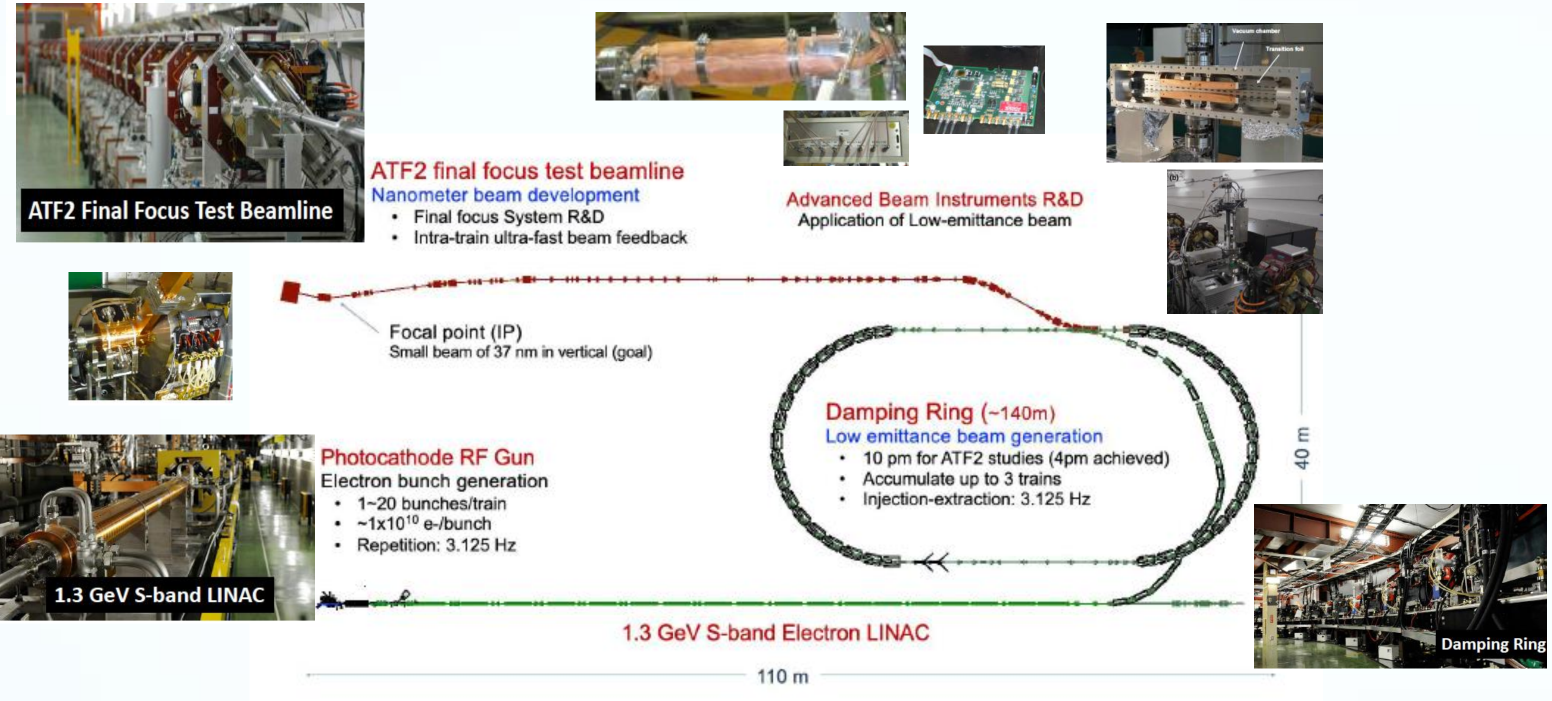
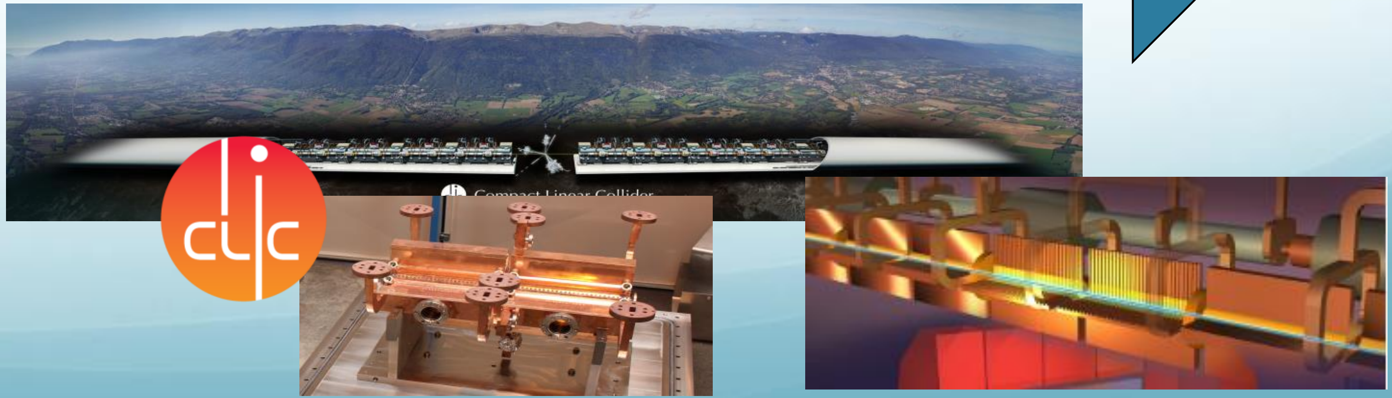


ATF plans and opportunities

A. Faus-Golfe & N. Terunuma



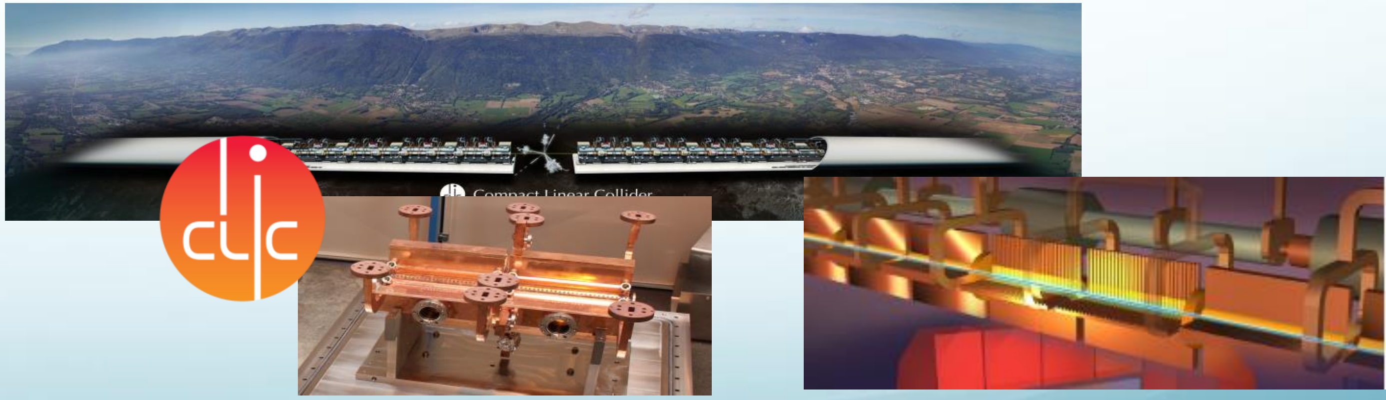
CPM #37

7 December 2022

Outline

- ATF2 context
- ATF2 in ILC FFS Technical Preparation Plan: ATF3
  - Goals and Tasks
- ATF2 current status
- ATF2-3 opportunities

ATF2 final focus test beamline



ATF2 the ILC/CLIC FFS testbench

ATF/ATF2: Accelerator Test Facility

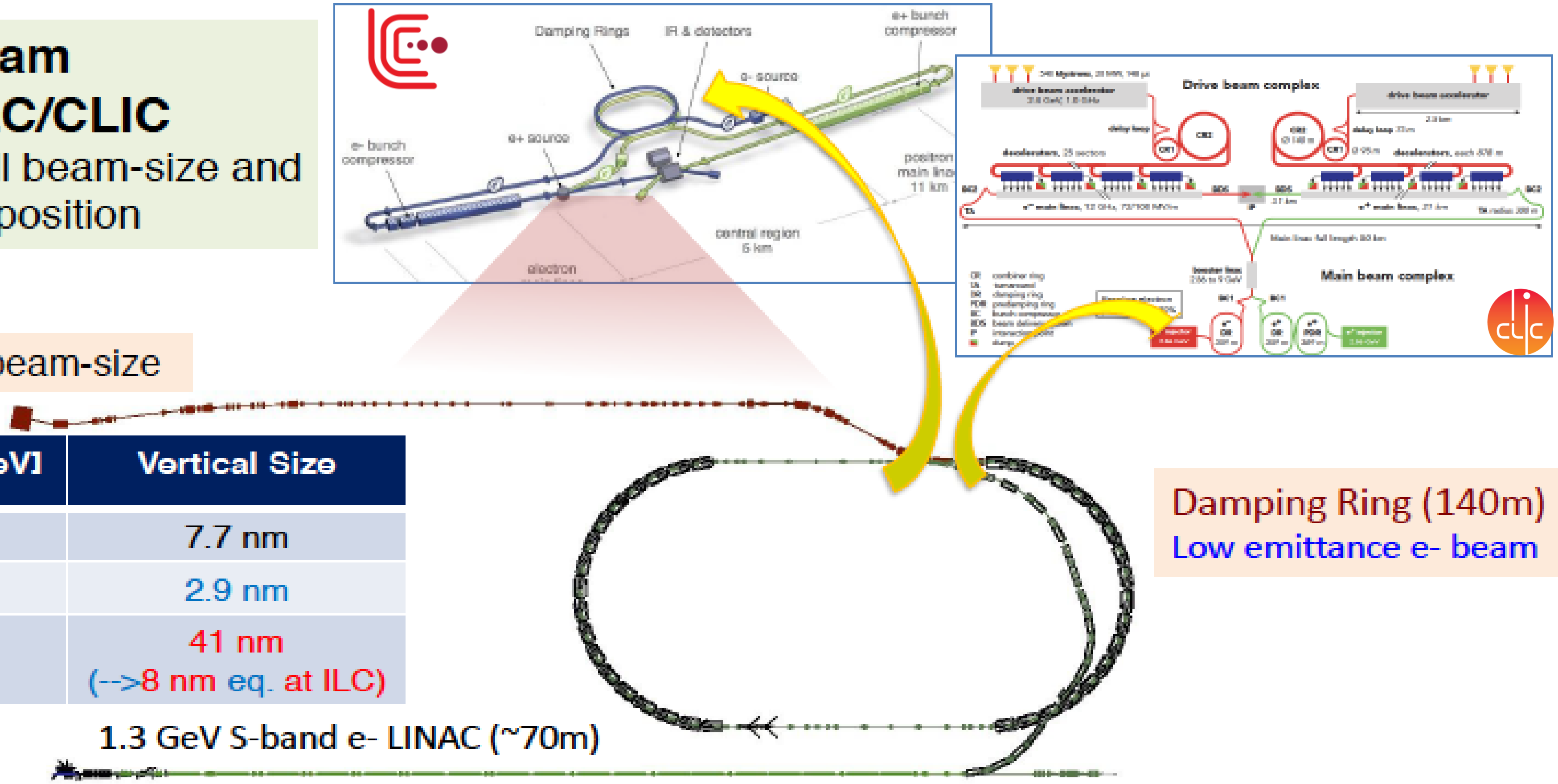
Courtesy: N. Terunuma

Develop nano-beam technology for ILC/CLIC

- Goal: Realize small beam-size and theStabilize beam position

FF: Nano beam-size

	B Energy [GeV]	Vertical Size
ILC-250	125	7.7 nm
CLIC-380	190	2.9 nm
ATF2 (achieved)	1.3	41 nm (-->8 nm eq. at ILC)



Damping Ring (140m)
Low emittance e- beam

1.3 GeV S-band e- LINAC (~70m)

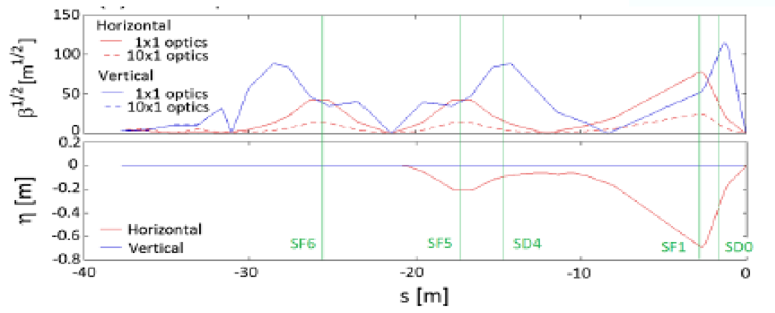
A. Yamamoto, 190513bb

8

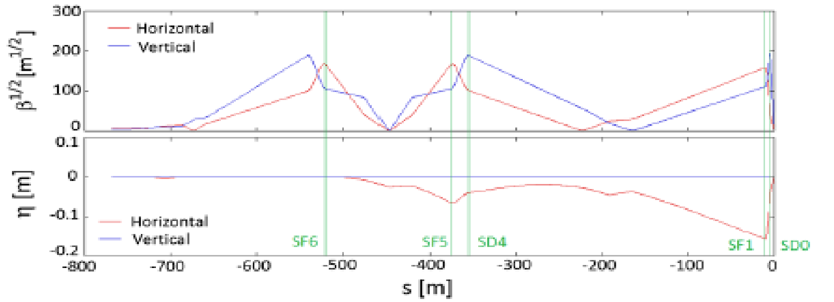
The context

	Units	ATF2	ILC	CLIC
E_{cm}	[GeV]	1.3	250	380
L	[10^{34} cm^{-2} s^{-1}]		1.35	1.5
f_{rep}	[Hz]	3.12	5	50
$n_{bunches}$	1	1 - 20	1312	352
N_e	[10^{10}]	1.0	2.0	0.52
σ_b	[µm]	7000	300	70
Δt_b	[ns]	154	554	0.5
$\gamma\epsilon_x / \gamma\epsilon_y$	[nm]	5000 / 30	5000 / 35	950 / 30
σ_x^* / σ_y^*	[nm]	9000 / 37	516 / 7.7	149 / 2.9
$IP_{Stabilization}$	σ_y^*	< 0.05	< 0.2	< 0.08
L^*	[m]	1	4.5	6

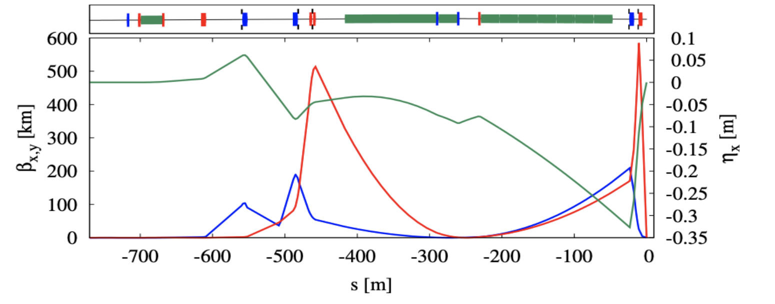
FFS optics



ATF2



ILC



CLIC

The context

FFS is among the most challenging sections of a linear collider

- Very-large β and the presence of nonlinear elements make it **extremely sensitive** to **imperfections as:**
  - **Wakefields** introduce energy spread, bunch head-to-tail distortions, and amplify transverse deflections...
  - **Magnets misalignment** introduce dispersion, beta-beating, orbit deflections, transverse coupling, …
  - **Beam jitter** unavoidably cause betatron oscillations that propagate all the way to the IP, etc.

- In **ILC and CLIC**, the **much shorter bunch length** and the **much larger beam energy** make the situation **"simpler"**

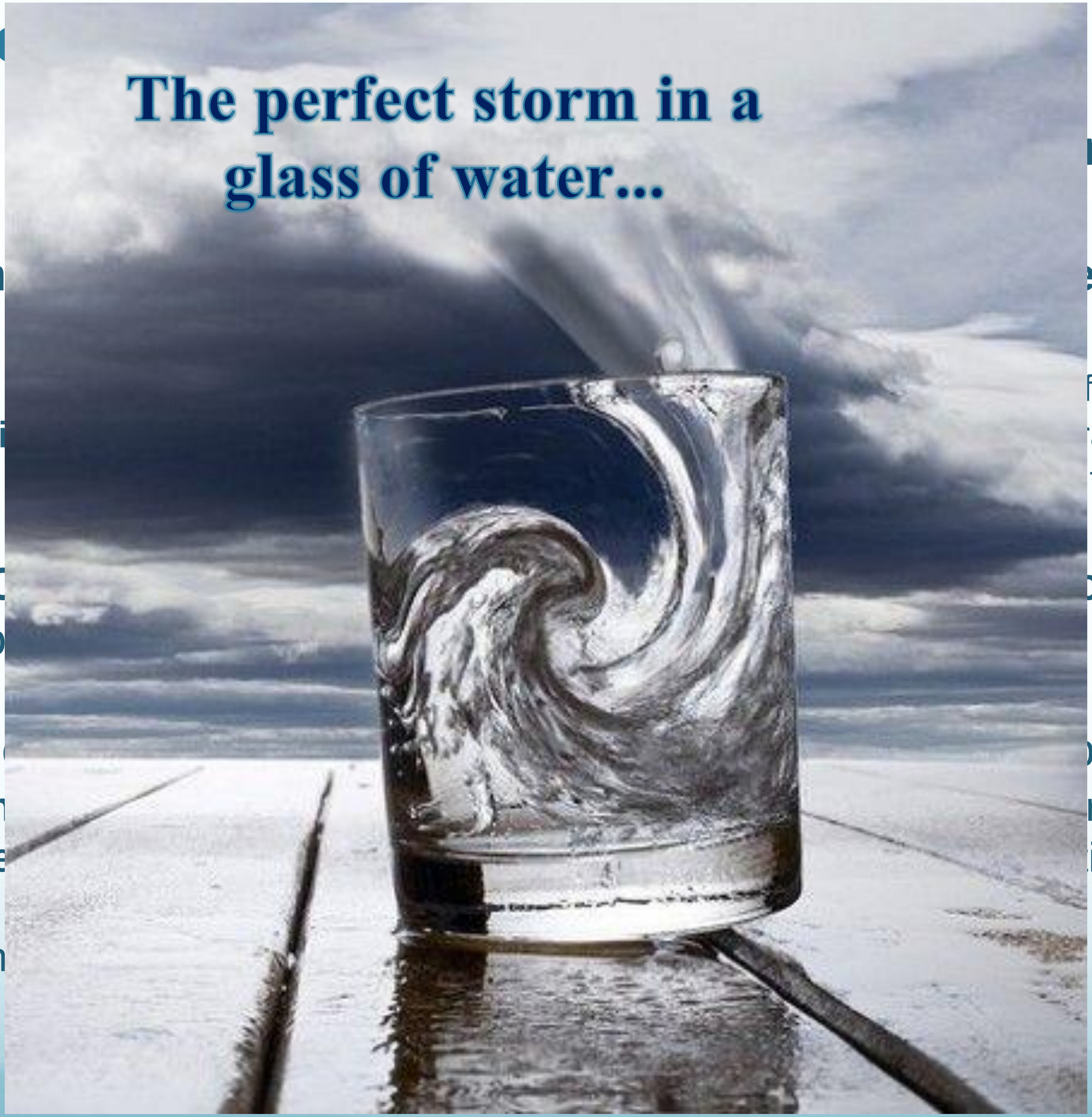
- **ATF2** tackles its critical task with **two major disadvantages** w.r.t. its "bigger brothers":
  - **Bunch length** is much longer: **7 mm** vs **300 μm** (ILC), about 25 times larger
  - **Beam energy** is significantly lower: **1.3 GeV** vs **125 GeV** (ILC), about 100 times smaller

- **Measurement** of the **nanobeam sizes involves a** complex device: Shintake monitor (IPBSM)

The

FFS is … r collider:

- Very-large β an… extremely sensitive to **imperfections**
  - **Wakefields** … fy transverse deflections
  - **Magnets mi…** … ansverse coupling, …
  - **Beam jitter** … to the IP, etc.
- In the **ILC and C…** … **ch larger beam energy** make the situatio…
- **ATF2** tackles its … bigger brothers:
  - **Bunch len…** … r
  - **Beam ene…** … times smaller
- **Measurement** of th…



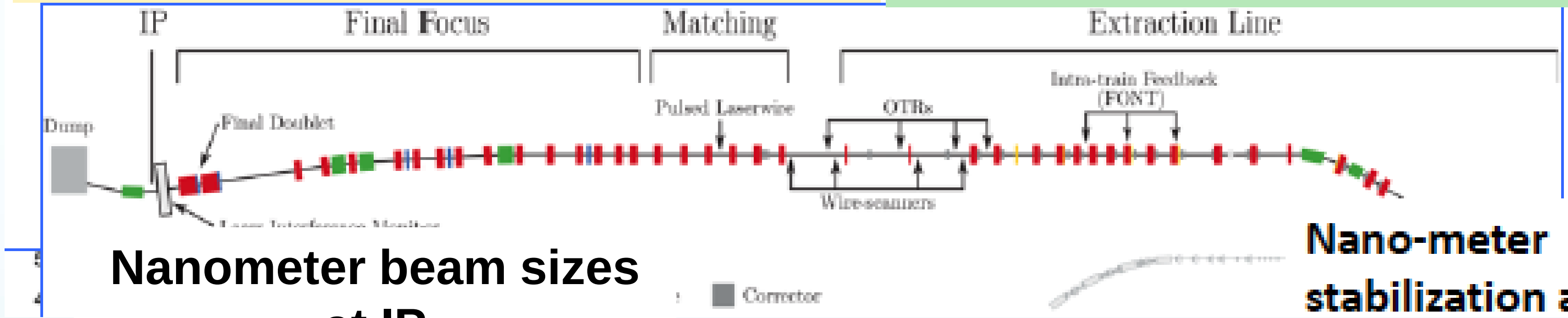
ATF2 goals and achievements

Goal 1: Establish the ILC final focus method with same optics and comparable beamline tolerances

- ATF2 Goal : **37** nm → ILC **7.7** nm (ILC250)
  - Achieved **41 nm** (2016)

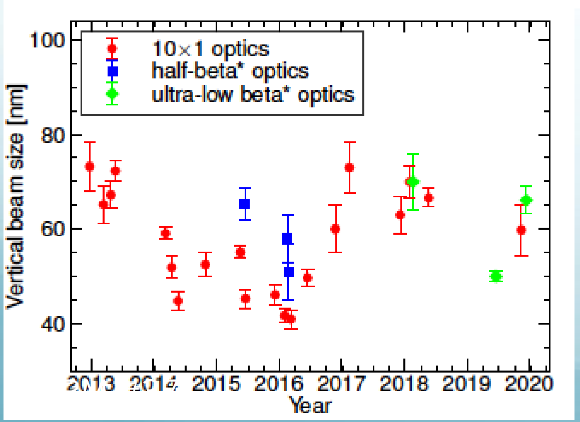
Goal 2: 2 nm beam stabilization at ATF2 IP, (much harder than nm stabilization in collision at ILC).

- **FB latency 133 nsec achieved** (target < 366 nsec)
- **Position jitter at ATF2 IP: 41 nm (2018)** (direct stabilization limited by IPBPMs resolution 20 nm). Upstream FB shows capability for 2nm stabilization. **Demonstrated ILC IPFB system.**

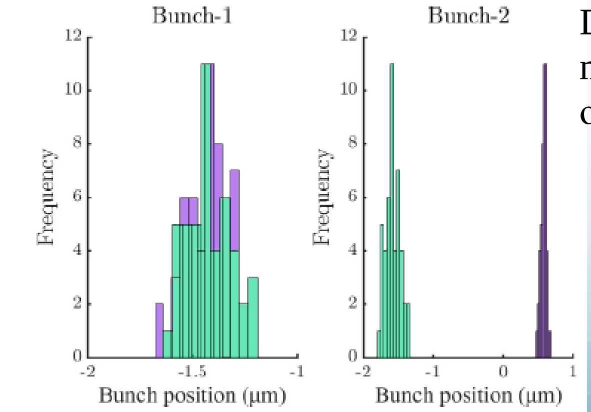


Nanometer beam sizes at IP

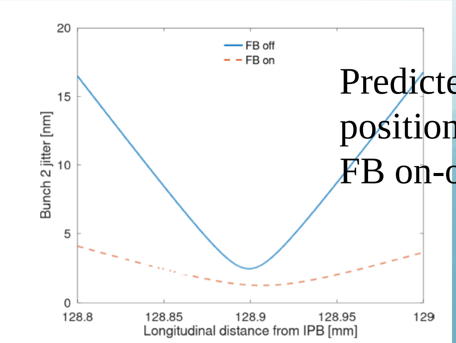
Nano-meter stabilization at IP



Small beam sizes were obtained with beam intensities of 0.5-1.5 10^9 e^- /bunch (10^{10} design value) and reduced aberration optics ($10\beta_x^* \times \beta_y^*$)



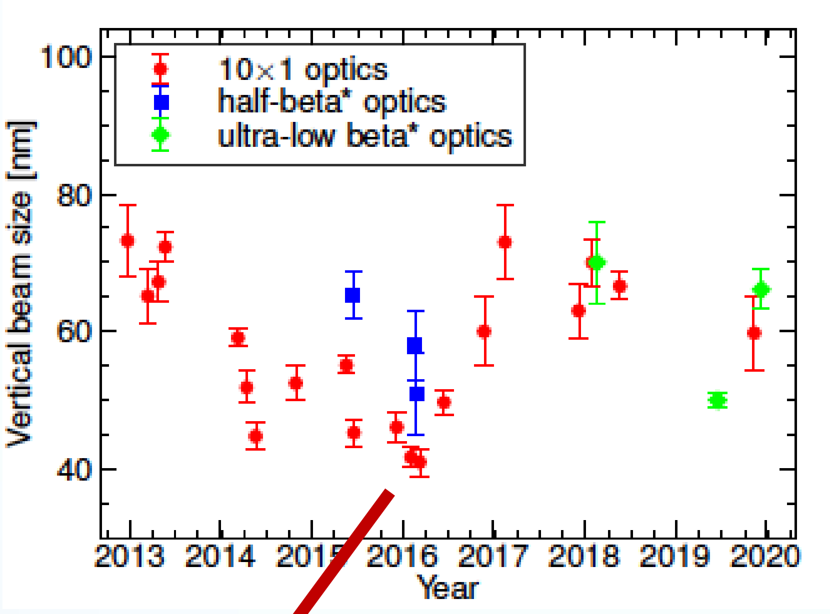
Distribution of bunch positions measured at IPB, with two-BPM FB off (green) and on (purple)



Predicted vertical position jitter with FB on-off

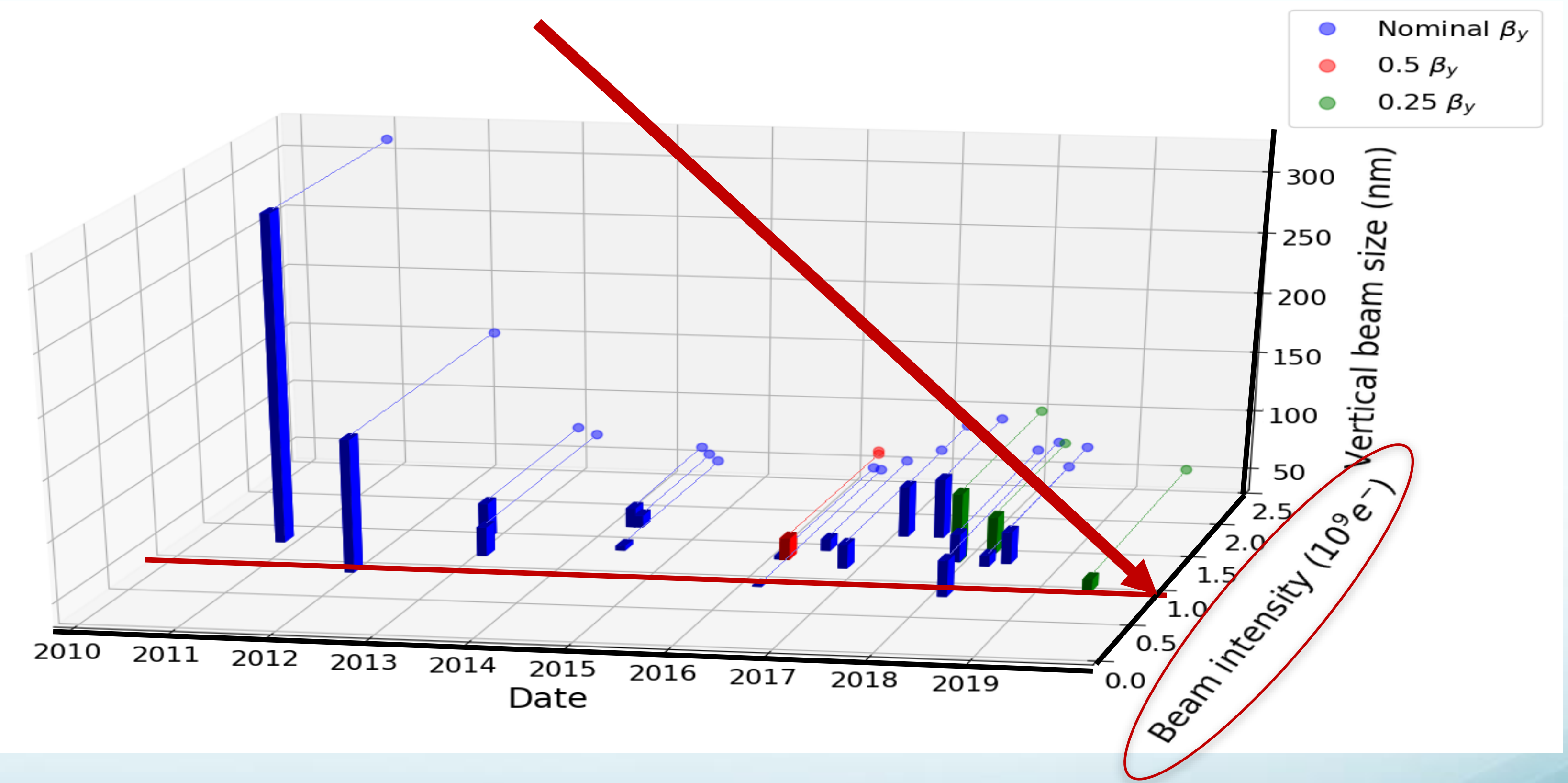
Intensity dependence studies (wakefields)

Beam size History



smallest beam size ~41 nm (2016)

But small beam sizes were obtained with beam intensities of 0.5-1.5 10^9 e^-/bunch (10^{10} design value)



Beam size shows a degradation with increase of the intensity compatible with wakefields

Nominal ($10\beta_x^*$ x β_y^*)
Half ($25\beta_x^*$ x 0.5 β_y^*)
Ultra-Low ($25\beta_x^*$ x 0.25 β_y^*)

Reduced optics aberration conditions

Design optics (β_x^* x β_y^*) not tested !!!

ATF2 Beam parameters

	ATF2 nominal	ATF2 half-β^*	ATF2 ultralow β^*
L^* [m]	1	1	1
β_x^* [mm]	4 (40)[b]	4 (100)[c]	4 (100)[c]
β_y^* [mm]	0.1	0.05	0.025
$\xi_y \sim L^*/\beta_y^*$	10000	20000	40000
ϵ_y [pm.rad]	12	12	12
σ_E [%]	0.8	0.8	0.8
$\sigma^*_{y,\mathrm{design}}$ [nm]	37	25	23
$\sigma^*_{y,\mathrm{measured}}$ [nm]	42.3 ± 2.7[b]/41.1 ± 0.7[b,e]	51 ± 6[c]	50.1 ± 0.6[c]

Relaxed optics ($10\beta_x^*$ x β_y^*) is the standard one

b: Optics with ($10\beta_x^*$ x β_y^*)

c: Optics with ($25\beta_x^*$ x half/ultralow β_y^*)

e: Results achieved with beam stabilization in two-bunch mode

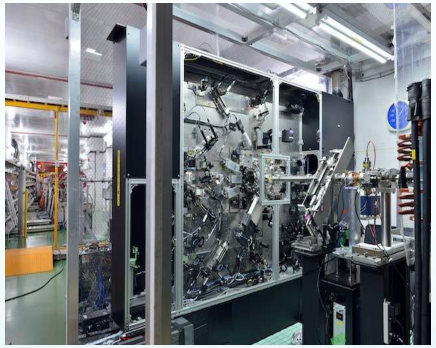
Hardware issues

➢ **Vacuum Chambers** (ID beam 24 mm)**:**

- Bellows shielding
- Clamp Flanges (ATF-DR type)
- Cavity BPM tapering (ID 20 mm)
- Stripline BPMs
- Dipole chamber (box type replaced by simple pipe)
- Septum chambers (A, B, C)
- FONT stripline kicker
- Pumping port chamber (ID 24 mm)

➢ **IP-BSM Laser:**

- Nd:YAG laser replacement choice, new laser parameters
- Start LTL, FF-IP simulation study
- Start laser stability study (energy, pointing, mode, and fringe pattern)
- e-beam arrival and timing jitter



IPBSM (nanometer beam size monitor)

➢ **FD vibration girder**

- Girder for all the final elements coupled with a global positioning system

➢ **CBPMs:**

- Re-installation of all CBPMs (current #24, all #32)
- Add separate fast small movers for centering and position calibration, including mechanical study, specs (~10kg load and um resolution, prioritize high-β regions)
- Electronics: analogue electronics reliable but spares needed
- Digitizers: 20-year old model, higher resolution ADCs would increase the dynamic range.

➢ **New Magnets**

- FD: QD0, QF1, SD0, SD1
- Skew sextupoles including movers
- Septum C (standard dipole)
- ZVOX vertical corrector (between septum B and C)

➢ **IP-BPMs**

- Re-design towards sub-10 nm, wide dynamic range and linearity (new electronics/digitizers)

➢ **Multi-OTR system**

- Focusing motor, Filter actuator, CDD cameras
- XPS with oriented motor

➢ **FONT IP feedback**

- Font kicker to improve wakefields

The context

FFS is amo[...]**llider:**

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  - **Beam energy** is [...]s smaller

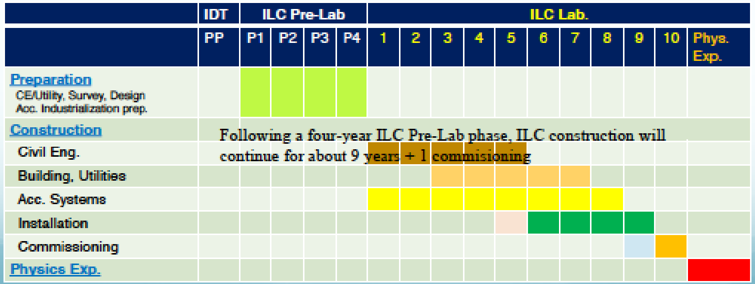
- **Measurement** of the **nanobeam sizes**, complex device: Shintake monitor

ILC-IDT

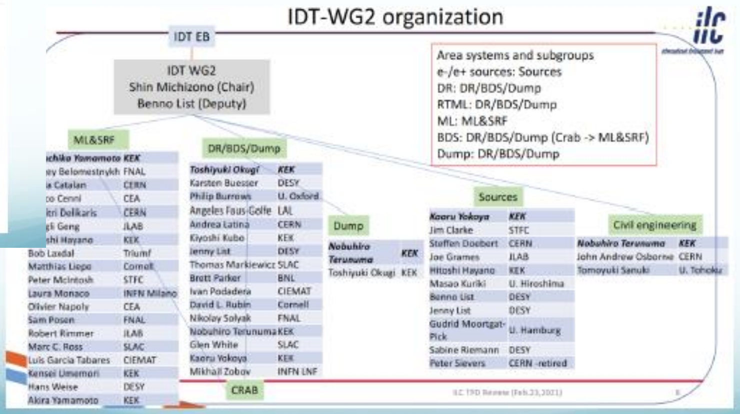
ILC Timeline

2020: ICFA set up International Development Team (IDT) ‘towards … timely realisation of ILC’

- **International Development Team** (IDT) prepares **Pre-Lab**
- 4 year Pre-Lab (hosted by KEK, Japan) phase for **R&D**, **Engineering Design Report**, Construction preparation
- **ILC Laboratory** (international): 10 year construction phase

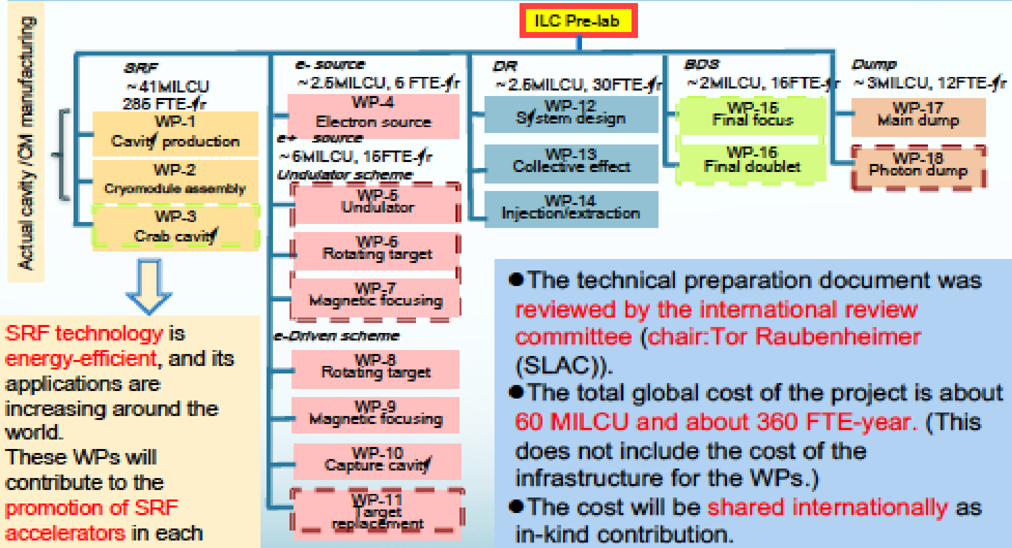


IDT Working Group 2 - Accelerator



ILC proposal state and R&D (4 years)

IDT-WG2 summarized the technical preparation as work packages (**WPs**) in the **Technical Preparation Document** http://doi.org/10.5281/zenodo.4742018



SRF technology is energy-efficient, and its applications are increasing around the world.
These WPs will contribute to the promotion of SRF accelerators in each region.

- The technical preparation document was reviewed by the international review committee (chair:Tor Raubenheimer (SLAC)).
- The total global cost of the project is about 60 MILCU and about 360 FTE-year. (This does not include the cost of the infrastructure for the WPs.)
- The cost will be shared internationally as in-kind contribution.

ILC-IDT

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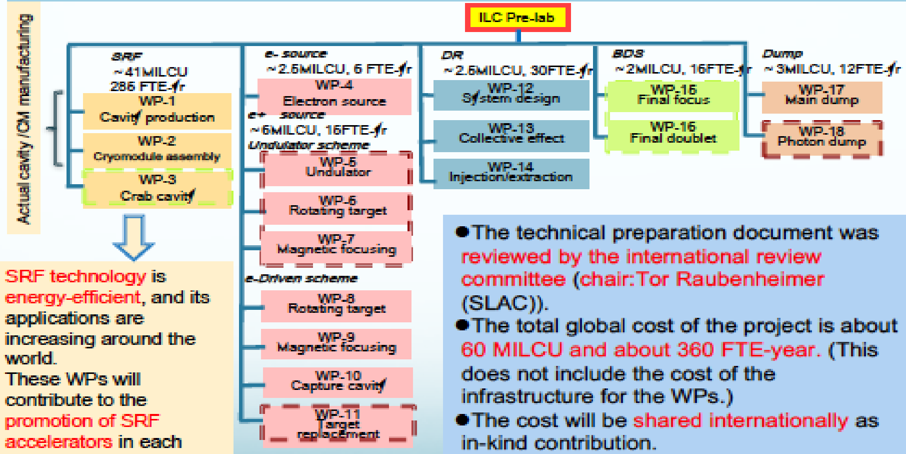

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MEXT review: ILC Advisory Panel (July 21 – Feb 22)

https://www.mext.go.jp/content/20220401-mxt_kiso-000020463_9.pdf

Synthesis of findings:

Recognise importance of precision Higgs physics

Premature to transition to ILC Pre-lab on the premise that Japanese Govt. will express an interest to host ILC

Interested countries should continue to work on technical issues

Decouple technical progress from 'hosting issue'

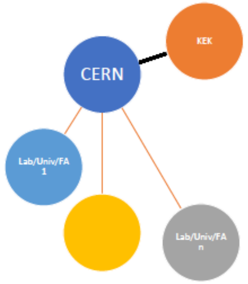
Build relationships between ILC community and stakeholders (government funding agencies) through reinforced collaboration and step-by-step R&D

'ILC Japan' set up to coordinate among scientific community, local and regional authorities, Diet members, and industry to promote ILC

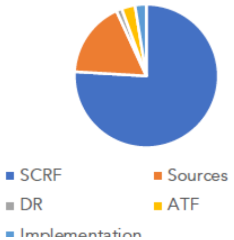
European Organisation of an ILC programme

- Focus on priority and time-critical WPs for ILC (2-4 years) – ITN (ILC Technology Network)
- CERN plays coordinating role
- KEK contribution to the material cost is essential
- Main contract for flow of funds between CERN and KEK*
  - CERN-KEK ILC IDT agreement already extended by 2 years
  - Amendments/modifications would be needed for ITN
- Subsequent contracts* – similar to what is done for other studies for future colliders – between CERN and European Labs in the cases where money flow is needed (limited number)
- Establish a distributed Project Office, administratively anchored to CERN, to follow up the work.
- Aim to involve CERN personnel, fellows, PJAS within the current LC resource planning at CERN (in many cases using long term collaborative links and common studies between CLIC and ILC)

*Additional collaboration agreements between KEK and FA/countries might be very beneficially, where these activities are recognised directly



Materials ~4 MCHF



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The European activities, and resources

European presentation of ILC studies, distributed on five main activity areas:

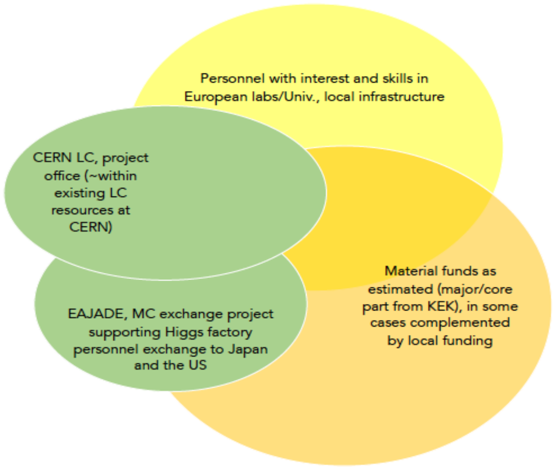
A1 with three SC RF related tasks
- SRF: Cavities, Module, Crab-cavities
- Might want to split into 3 separate WPs

A2 Sources
- Concentrate on undulator positron scheme, consult on conventual one (used by CLIC and FCC-ee)

A3 Damping Ring including kickers
- Low Emittance Ring community

A4 ATF activities for final focus and nanobeams
- Groups active in ATF (including new ones)

A5 Implementation including Project Office
- Dump, CE, Cryo, Sustainability, MDI, others (many of these are continuations of on-going collaborative activities)



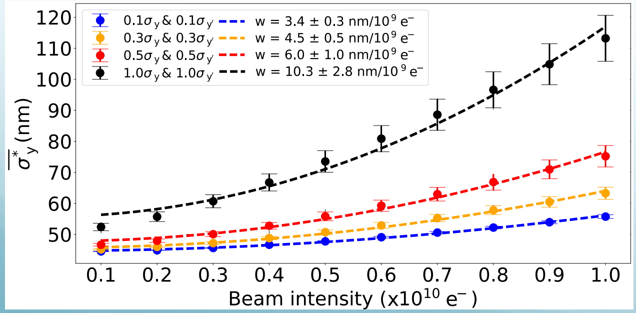
EAJADE: Information at LINK

15

WP15: ILC FFS Technical Preparation Plan: Tasks

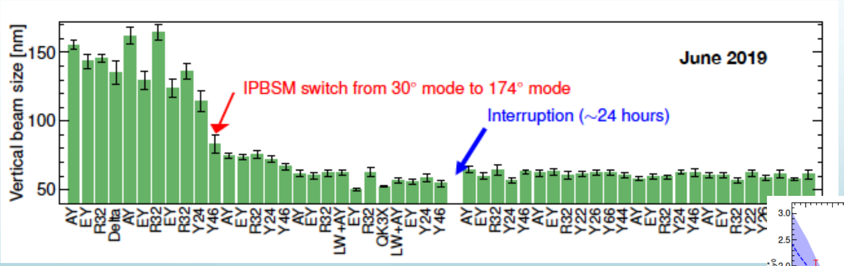
ILC-FFS Tasks : Maximize Luminosity potential of ILC	
T1: **ILC-FFS system design**	**T1.1**: Hardware optimization
	T1.2: Realistic beam line driven / IP design
T2: ILC-FFS beam tests	**T2.1**: Long-Term stability
	T2.2: High-order aberrations
	T2.3: R&D complementary studies

Long Term stability

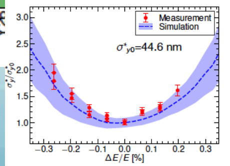


Intensity dependence studies

High-order aberrations

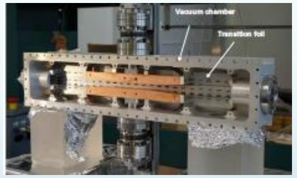


Ultra-low β* studies



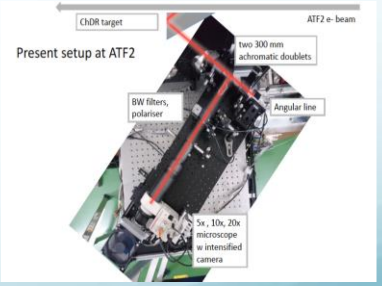
Energy bandwidth

Instrumentation R&D



Collimator

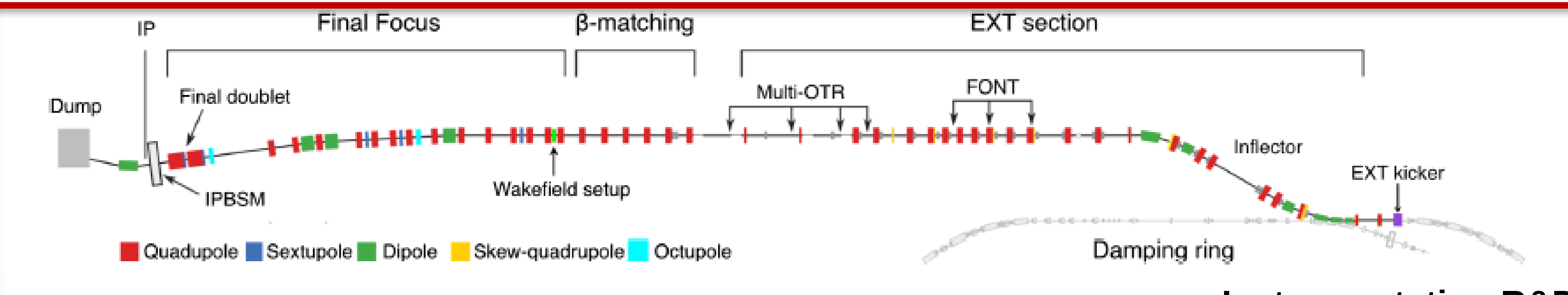
Waveguide BPM



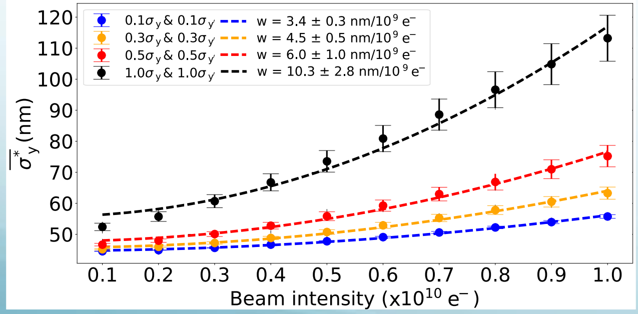
Incoherent Diffraction Cherenkov Radiation Monitor

ILC FFS - ATF3 objective and collaboration:

Based on the achievements of the ATF2 no showstopper for ILC has been found, **ATF3** plan is to pursue the necessary R&D to **maximize** the **luminosity potential of ILC**. In particular the assessment of the **ILC FFS system design** from the point of view of the beam dynamics aspects and the technological/hardware choices and the **long-term stability operation issues.**

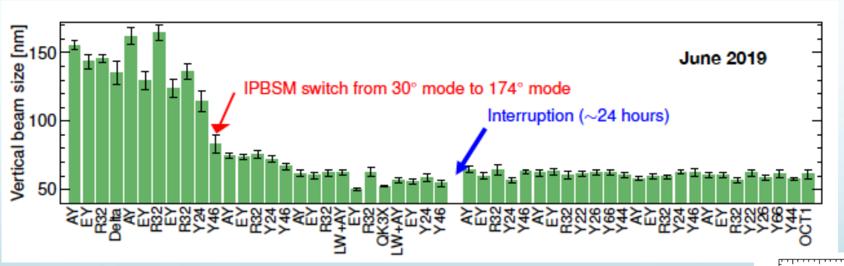


Long Term stability



Intensity dependence studies

High-order aberrations



Ultra-low β* studies

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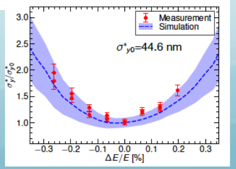
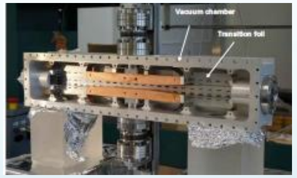
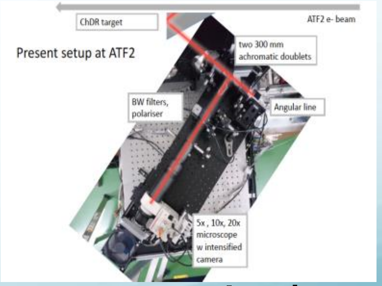
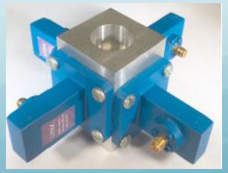


Instrumentation R&D



Collimator





Waveguide BPM

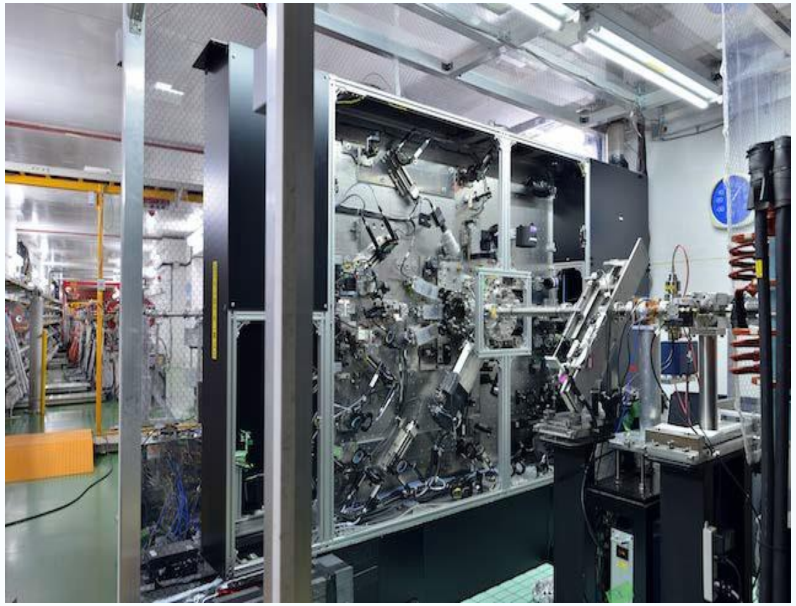
Incoherent Diffraction Cherenkov Radiation Monitor

ATF2 status 2021-2022

- **Beam operation: 10 weeks** (remains 2 in Dec. and 2 in Feb.2023)
  - Limited manpower: member staying at KEK
  - Limited operation weeks; Rising electricity ~ x3 of 2021 but an annual budget is flat
- **Not effective for nanobeam experiments**
  - Need sufficient continuous operation to establish a stable study environment; especially for DR operation.
- Therefore, we are **focused** on:
  - Improvement of beamline equipment, i.e., IPBSM, …
  - Training/education of the graduate students

Improvement of IPBSM

- **Stabilization of the laser transport**
  - Laser hut environment: heat and vibration
  - Renew laser table and its support on floor
  - Transport; rigid frame and mirror holders
- **Handling a Laser at IP**
  - install several laser position sensors
  - Install a linear stage at 174°-mirror for the tilt correction of laser fringe
- **Maintain the high power laser**
  - Cooling water system: pumps, tubes, connectors,…
  - YAG amplifiers



IP-BSM is not just a laser

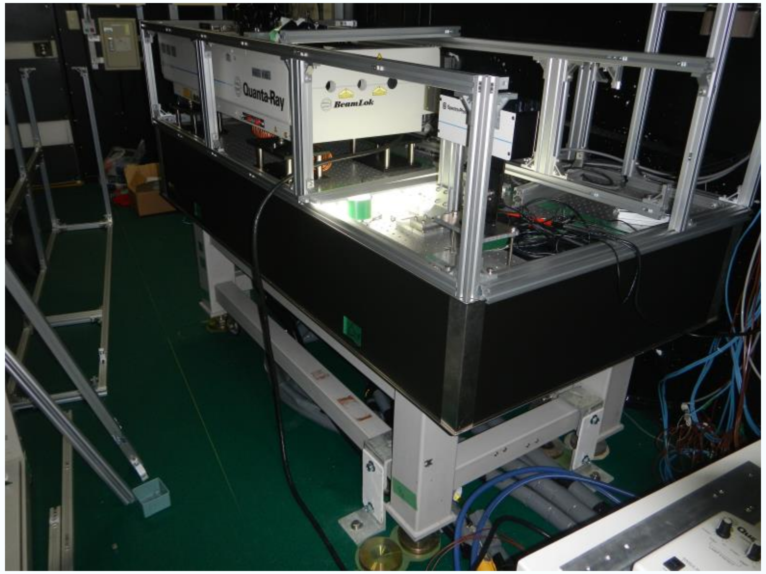
Measurement of IPBSM was improved (confirmed in Jun. and Dec. operation)

- Modulation 0.2, which was previously difficult to recognize, is now well recognized
- Measurement in 174° mode (below 90 nm) is expected to be more stable, better than before.

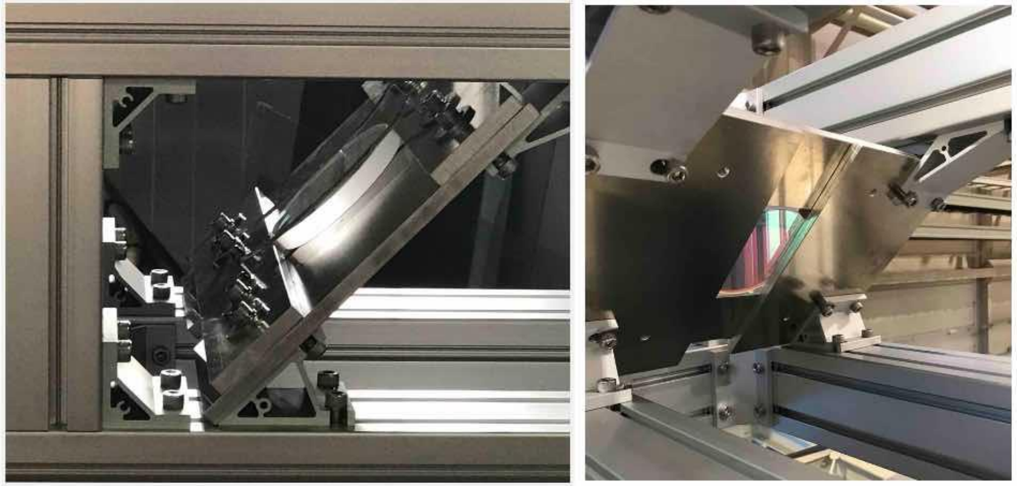
Stabilization of the laser transport in 2022

Laser transport: Pipe -> Box
Reinforced support frames (vertical mirrors) at both ends.

Renewal of the laser table



Vertical mirrors support (hut -> on shields -> IP)



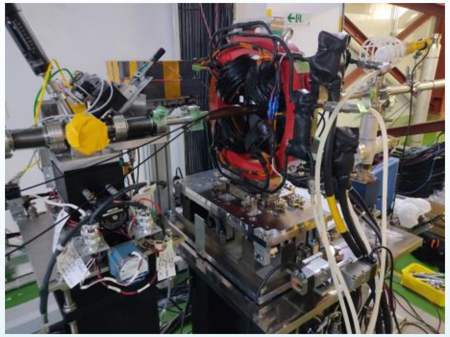
Improvements in the ATF2 beamline in 2022

➢ Skew sextupole movers

- Installed movers for all skew sextupoles (4).
- Repositioning of poles and field measurements were conducted.
- We will renew these magnets for ATF3.

➢ Chicane at the joint of DR/EXT and ATF2

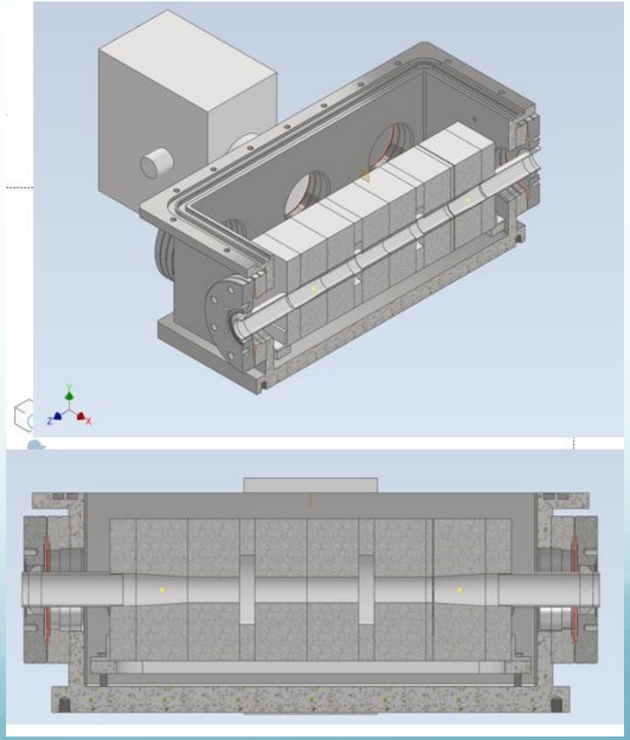
- Seasonal misalignment between DR/EXT and ATF2 because of different floors.
- Installed chicane to cure it and put QD20X (at middle of chicane) on the mover.
- It will relax the commissioning of ATF2.



QD20X on new mover

➢ Movable wakefield source

- Vacuum box on mover has been installed at ATF2.
- Structure of wakefield source in a box is changeable for study.
- Ready for studies from Dec. 2022



ATF2 Prospects for FY2023 operation

- Currently, we are assuming the severe electricity rates in our calculation of operating expenses for the next fiscal year.
- As an ATF group, **we plan to apply for 15 weeks of operations** for the next fiscal year.
  - **Roughly 5 weeks before Apr-Jun, 5 for Oct-Dec and 5 for Jan-Mar**.
- This month, the Ministry of Finance will announce the budget allocation for the next fiscal year to each ministry and agency. Based on this, **operating expenses will be allocated by KEK to each project by the end of January**, and the total operating period of ATF will be determined.
- Part of the cost for the upgrade and operation of the ATF2 has been proposed as a new (ILC) R&D budget proposed to MEXT. We expect them for **ATF3.**

ATF2-3 Opportunities

- An **ATF3 kick-off meeting** is being organized for beginning next 2023 in Europe to catalyze all the possible contributions.

- We have some tools on hand as the recently approved **EAJADE** (Europe–America–Japan Accelerator Development and Exchange programme) focused in Higgs Factories, with participation of major EU (CERN, INFN, CEA, DESY, CNRS, CSIC, UOXF), Japan (KEK, Tokyo Univ., Tohoku Univ.) USA (BNL, FNAL, SLAC, JLAB, LBNL, Cornell Univ.) and Canada (VISPA) labs.

ATF2 final focus test beamline

Thanks for your attention