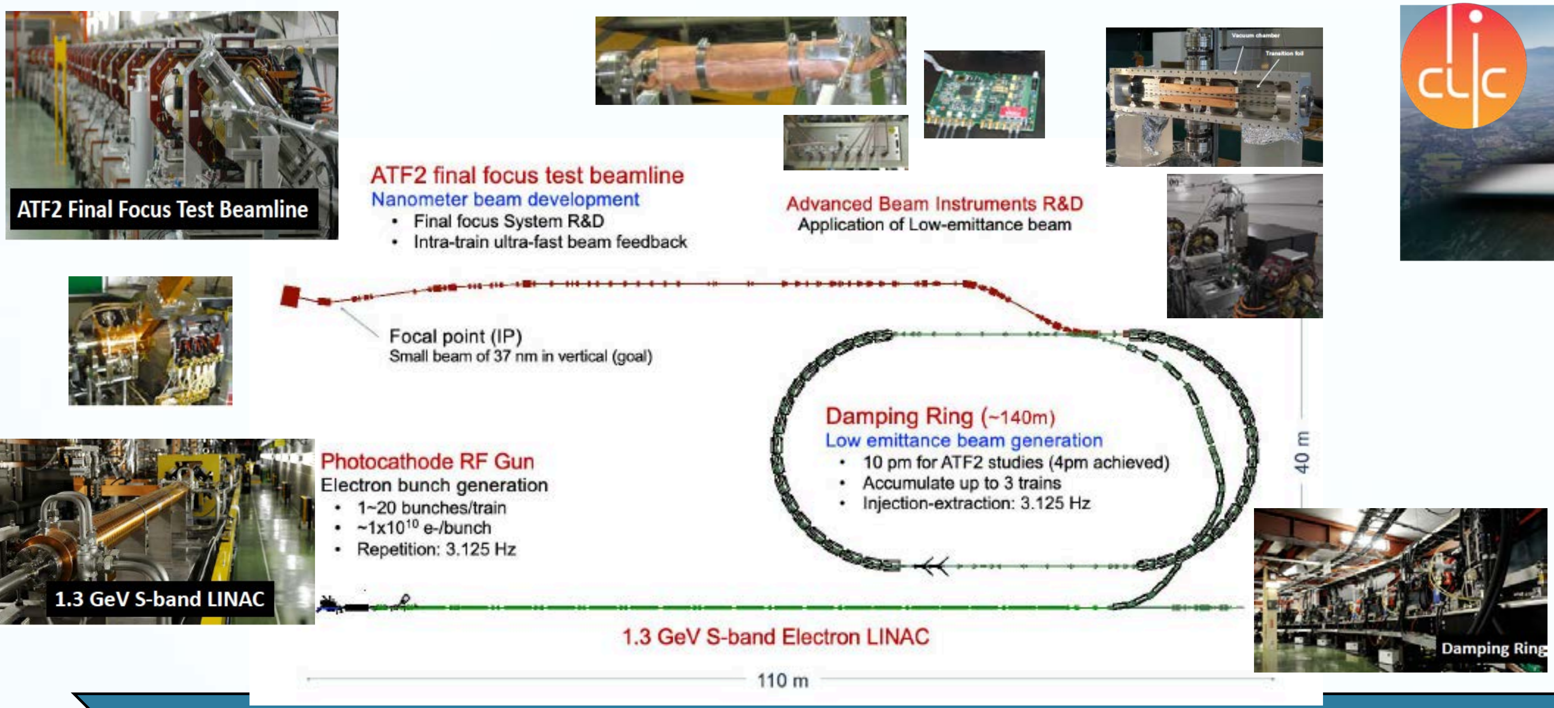
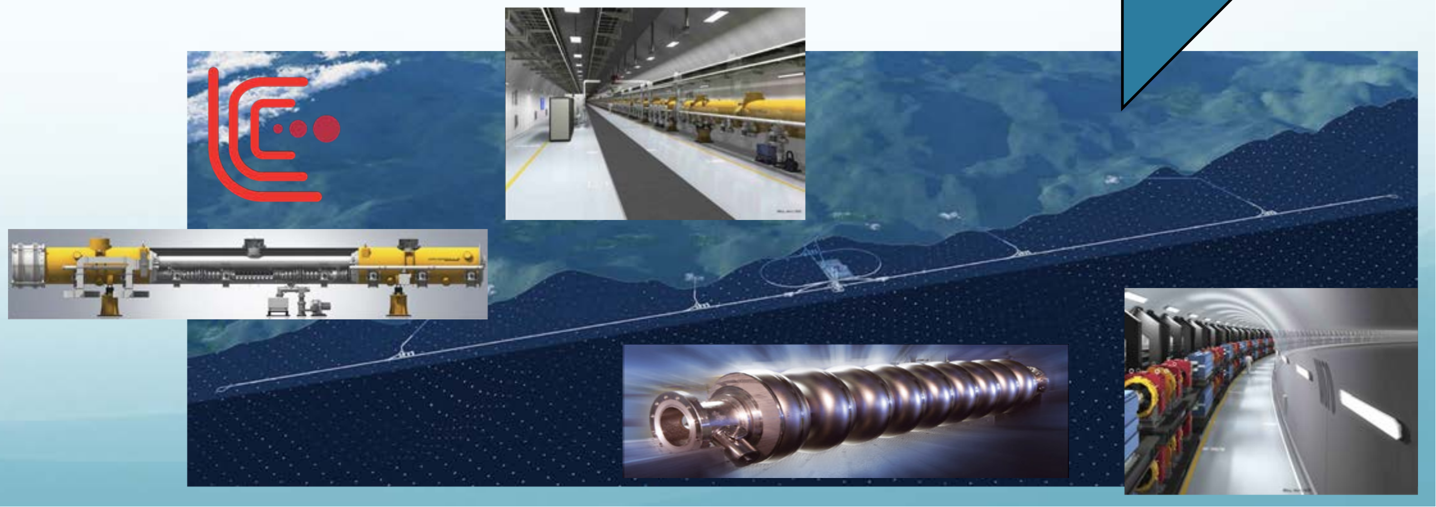


From ATF2 to ATF3

A. Faus-Golfe
on behalf of ATF collab.



CLIC Mini week

30 Sept - 1 Oct 2020

Outline

- ATF2 status
  - Nanobeams and Stability
  - Instrumentation R&D
  - Operational Issues
- ATF2 and ILC Implementation plan
- Perspectives: ATF3 ??

ATF Review 2020

29 sept. 2020 à 19:30 → 30 sept. 2020 à 00:00 Asia/Tokyo
https://zoom.us/j/95322225259 (Zoom)

Description
Charge 1: Evaluate the scientific results at ATF/ATF-2
Charge 2: Evaluate future ATF operation for LC R&Ds
Charge 3: Evaluate future ATF operation (other than LC)

ATF-Papers-Conf-P... ATF-Papers-Refere... ATF-Phi...v2020081... ATF_Review_Repor...

MARDI, 29 SEPTEMBRE

20:00 → 20:05	Welcome 5m Orateur: Masanori Yamauchi (KEK)	
20:05 → 20:15	Timeline 10m Orateur: Nobuhiro Terunuma (KEK)	Intro-timeline-2020...
20:15 → 20:40	ATF Introduction, Instrum. R&Ds 25m Orateur: Shigeru KURODA (KEK)	ATFIntroInstrumRD-...
20:40 → 21:05	ATF2 small beam, Wakefield 25m Orateur: Kiyoshi Kubo (KEK)	SmallbeamWakefiel...
21:05 → 21:30	ATF2 stabilization (FONT) 25m Orateur: Philip Burrows	FONT_ATF2review_...
21:30 → 21:55	ATF2 ultra-low beta optics 25m Orateur: Renjun Yang (CERN)	ATF2 ultra-low beta ...
21:55 → 22:20	ATF2 future R&D 25m Orateur: Toshiyuki Okugi (KEK)	ATFreview2020_oku...
22:20 → 22:45	R&D other than LC 25m Orateur: Alexander Aryshev (KEK)	R&D other than LC.p...
22:45 → 23:10	Operational status and concerns 25m Orateur: Nobuhiro Terunuma (KEK)	Operation-2020091...
23:10 → 00:00	Discussions 50m	

International Review Panel

K. Oide (chair)
V. Shiltev
Z. Zao
T. Pieloni
M. Kato

https://agenda.linearcollider.org/event/8626

Close-out 6 October

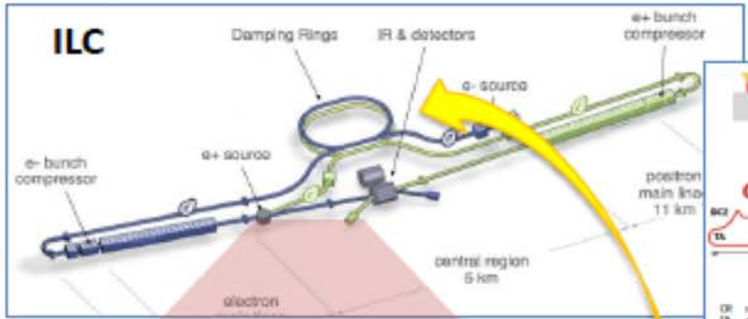
Nanobeam and Stability

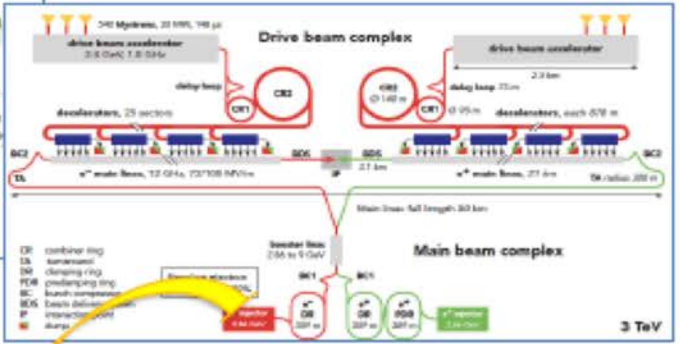
ATF/ATF2: Accelerator Test Facility

Courtesy: N. Terunuma

Develop nano-beam technology for ILC/CLIC

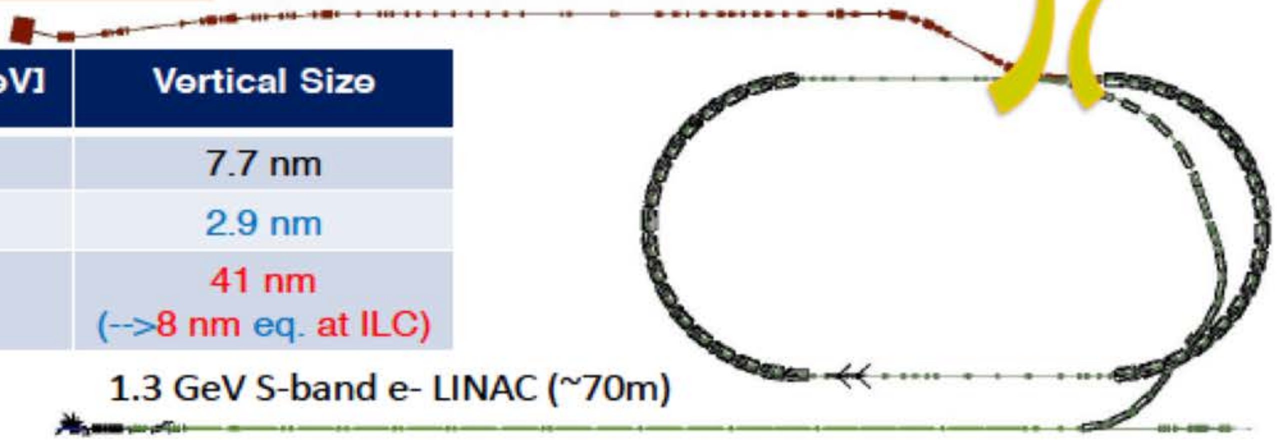
- Goal: Realize small beam-size and theStabilize beam position



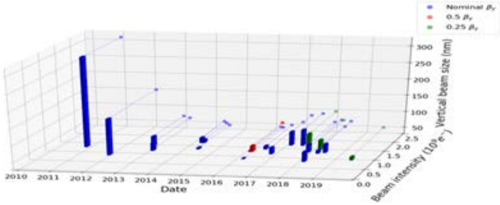


FF: Nano beam-size

	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



Intensity dependence-wakefiels

A. Yamamoto, 190513bb

8

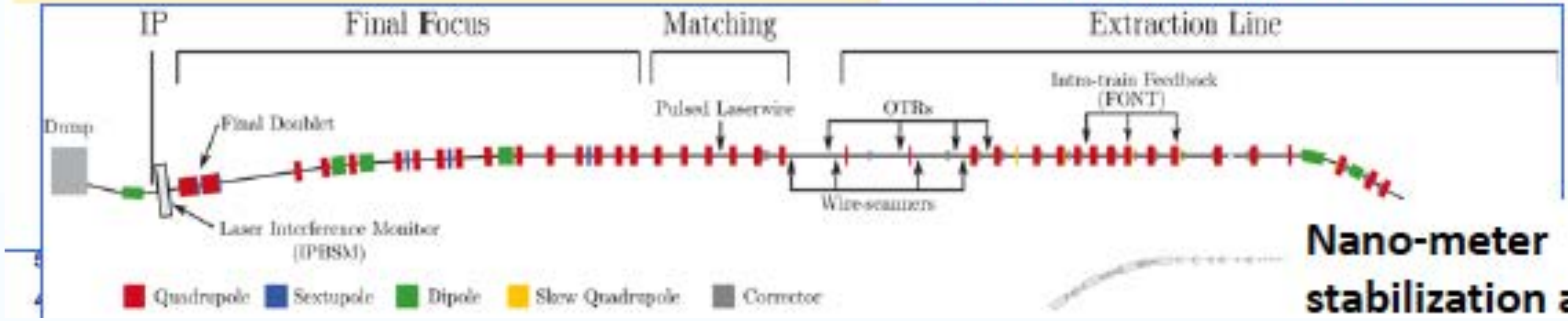
Nanobeam and Stability

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

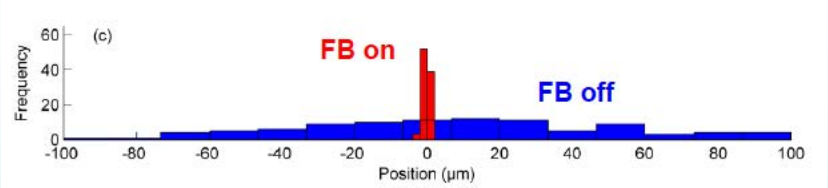
- ATF2 Goal : **37** nm → ILC **7.7** nm (ILC250)
  - Achieved **41 nm** (2016)

Goal 2: Develop a few nm position stabilization for the ILC collision

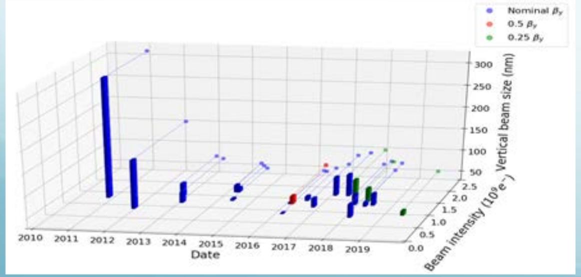
- **FB latency 133 nsec achieved** (target: < 366 nsec)
- **positon jitter at IP: 106 → 41 nm (2018)** (limited by the BPM resolution)



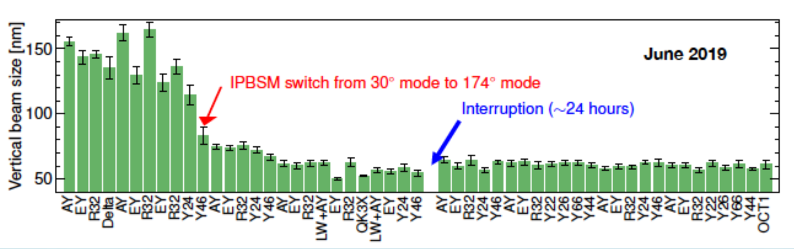
Nano-meter stabilization at IP

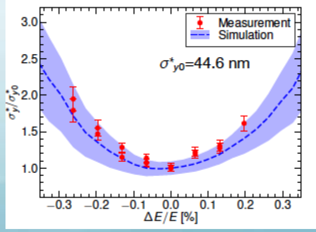


Intensity dependence studies

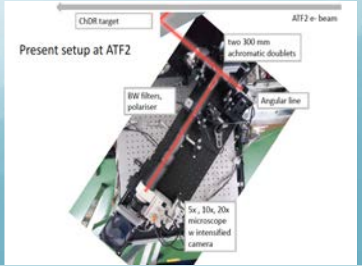


Ultra low β^* studies



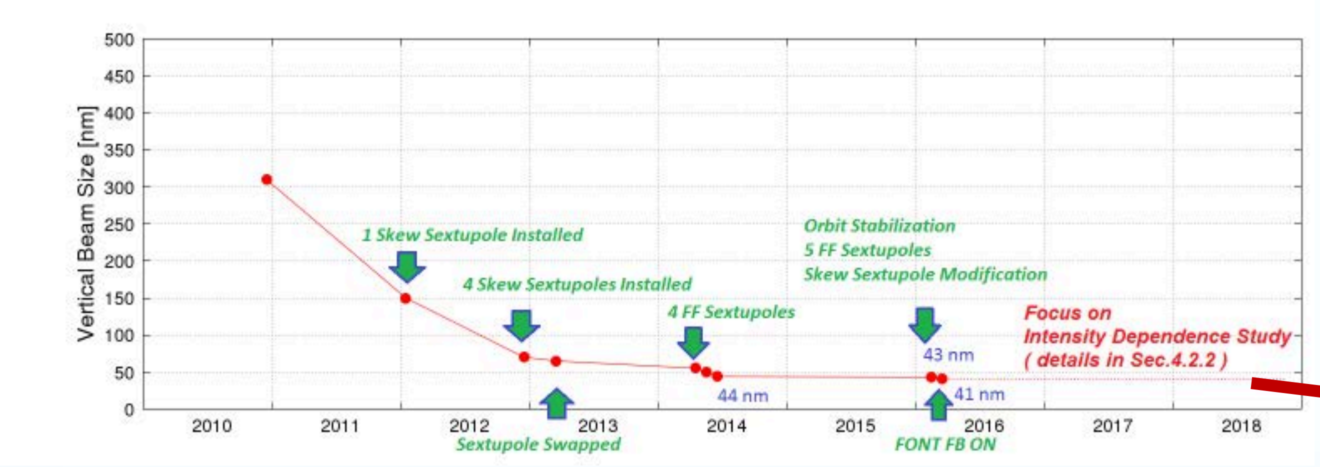


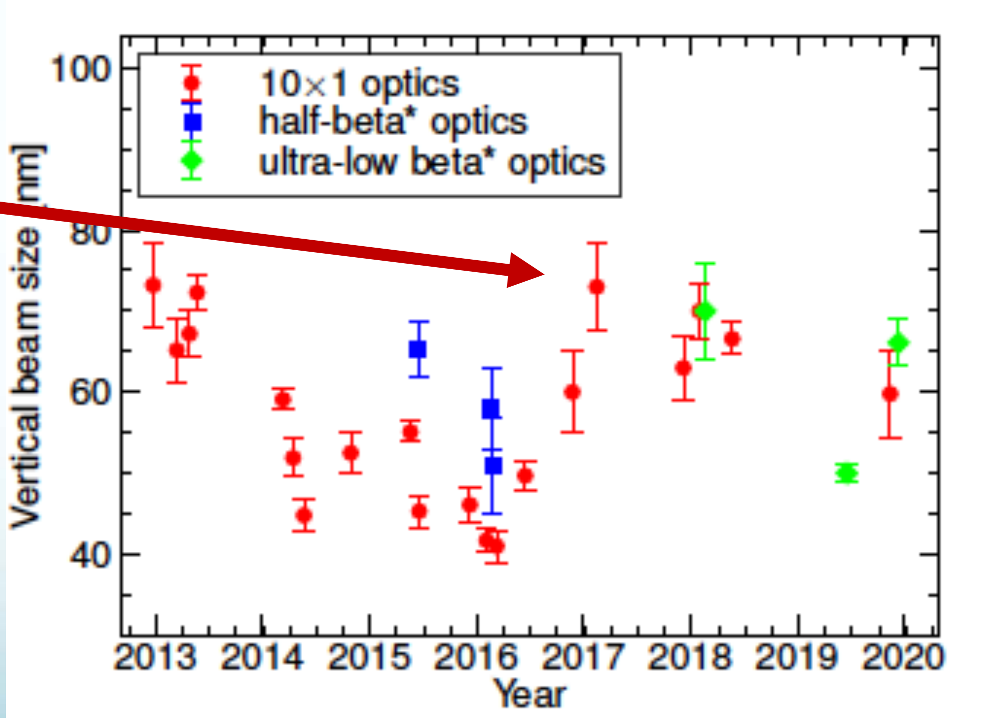
Instrumentation R&D



Intensity dependence studies

Beam size History **smallest beam size ~41 nm (2016)**

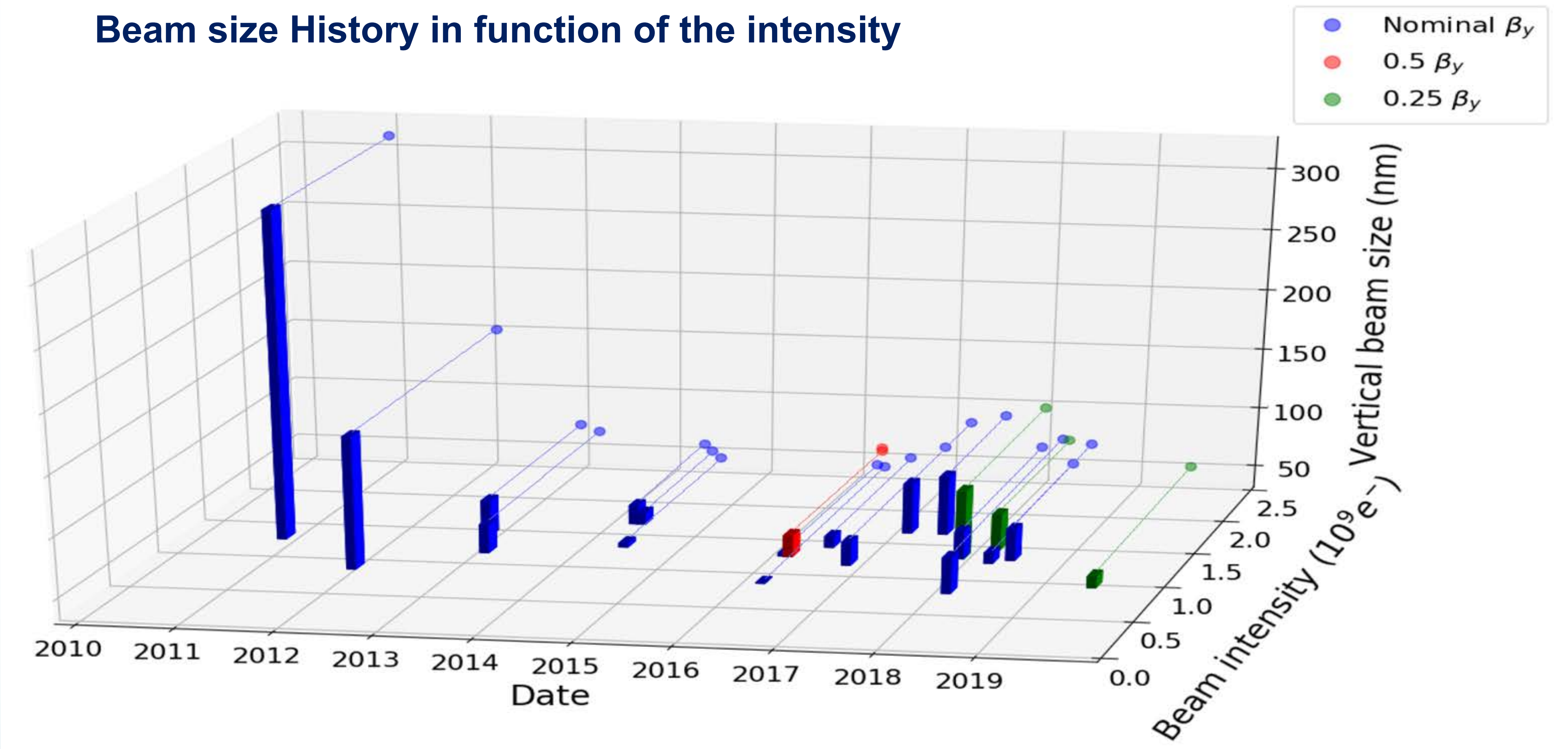




But small beam sizes were obtained with a beam intensity of 0.5-1.5 10^9 e^-/bunch

Intensity dependence studies

Beam size History in function of the intensity



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

Intensity dependence studies

Since November 2016 a considerable effort in modelling, simulating, measuring wakefields and dedicated hardware changes, has been carried out in order to understand and mitigate the wakefields in ATF2.

Intensity dependence parameter:

$$w[nm/10^9] = \frac{\sqrt{\sigma_y^2 - \sigma_{y,N=0}^2}}{N}$$

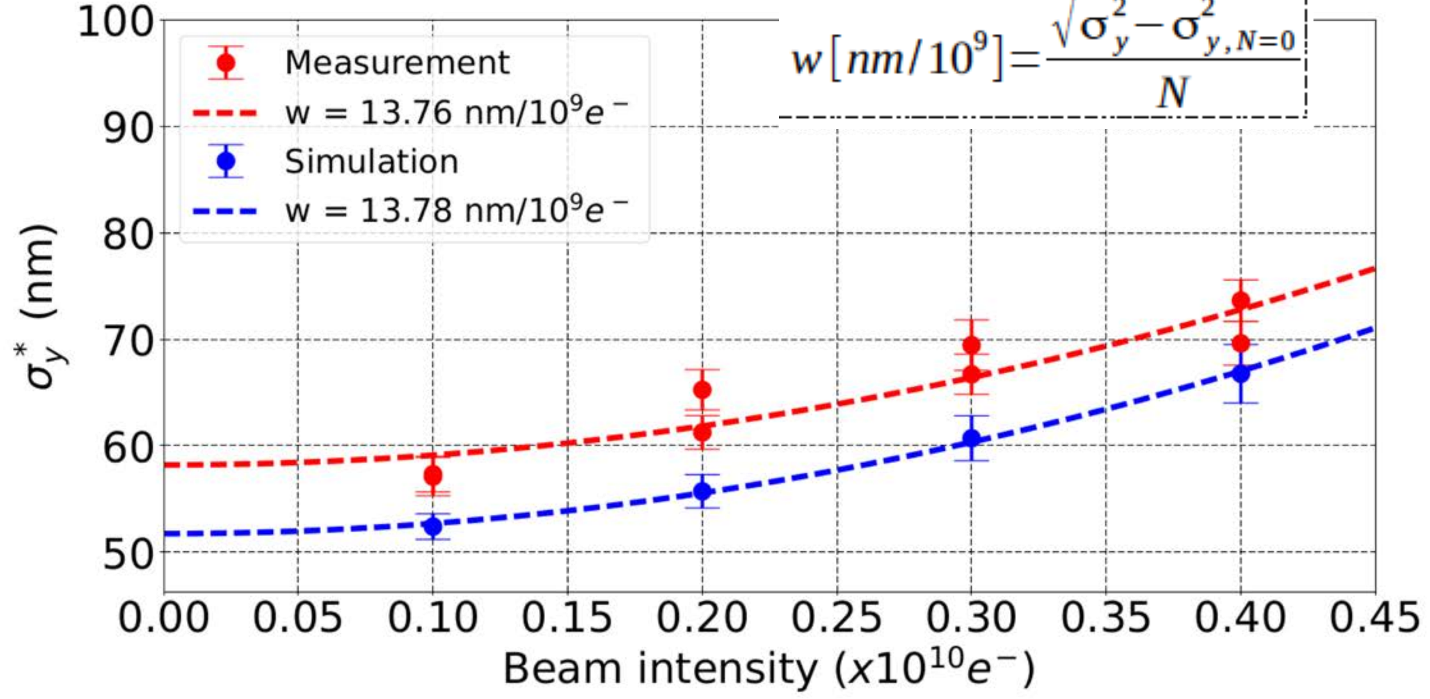


Figure: Comparison between measurements and simulations of the vertical beam size at the IP (σ_y^*) vs. the beam intensity and the intensity-dependent parameter w.

PLACET Simulation vs. Measurements

Case	w [nm/10^9 e^-]	Beam intensity [e^-]	Average σ_y^* [nm]
Measurement	13.76	0.1×10^{10}	57 ± 1.7
		0.2×10^{10}	63 ± 1.7
		0.3×10^{10}	68 ± 2.1
		0.4×10^{10}	72 ± 2.0
Simulation	13.78	0.1×10^{10}	52 ± 1.2
		0.2×10^{10}	56 ± 1.6
		0.3×10^{10}	61 ± 2.1
		0.4×10^{10}	67 ± 2.8

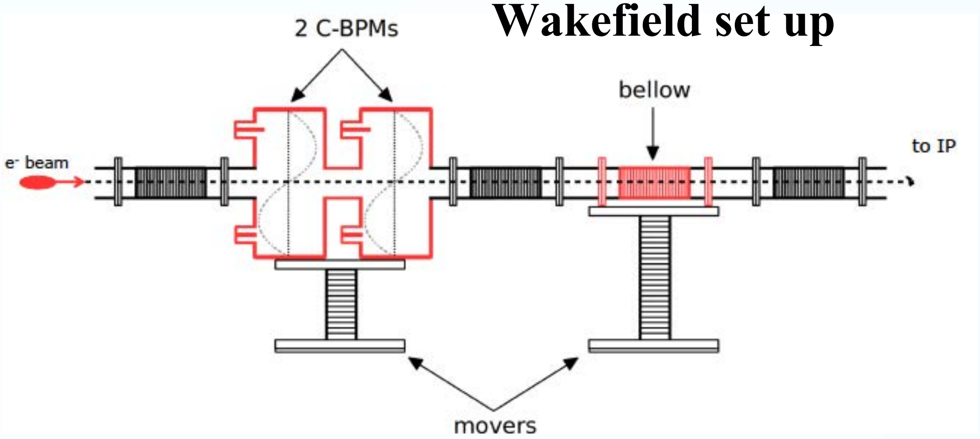
A. Latina and P. Korysko

Intensity dependence studies

Mitigation techniques: Wakefields knobs

Goal: Use two well-known wakefield sources on movers to compensate intensity-dependent effects.
Setup: Made of two movers, the first one carries two C-BPMs and the second one carries a bellows.

Wakefield set up



PLACET simulations

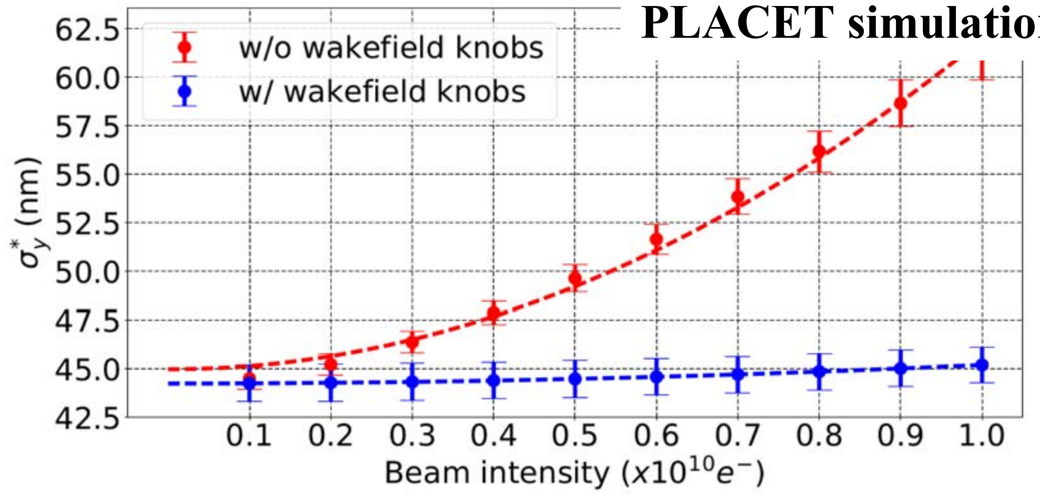


Figure: Simulations of the impact of the ATF2 wakefield knobs on the vertical IP beam size (σ_y^*).

Case	$\overline{\sigma_y^*}$ [nm]
No source on movers	61.2 ± 1.4
Using the bellow on mover	48.4 ± 1.0
Using the 2 C-BPMS on mover	45.5 ± 0.9
Using both the bellow and the 2 C-BPMs on movers	45.2 ± 0.9

Experimental results

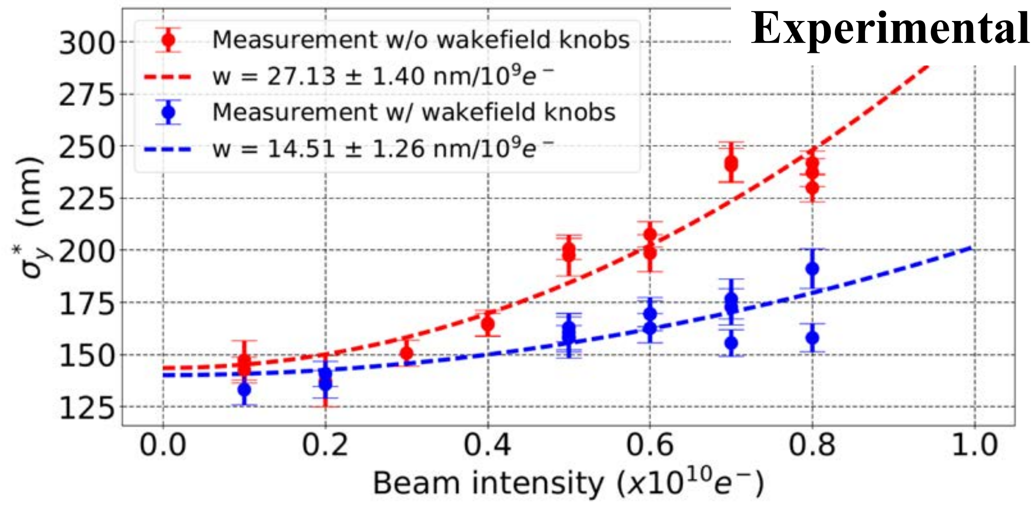


Figure : Measured vertical IP beam size (σ_y^*) vs. the beam intensity before and after applying wakefield knobs.

The wakefield knobs reduced the intensity dependence parameter from 27.13 nm/10^9 to 14.51 nm/10^9.

Intensity dependence studies

Scaling the results for ILC and CLIC

Intensity-dependent effects at ILC 250 GeV

BDS imperfections:
- Misalignments : 50 µm RMS; 200 µrad RMS; strength: 0.1% RMS
- Wakefields from the 104 C-band cavity BPMs
- Resistive-wall wakes from beam pipe

Simulation:
- 100 random machines
- Full tuning procedure (same as in the CLIC case)
- Studied beam size dependence on bunch charge
- Studies impact of long-range resistive-wall in case of multi-bunch

Tuning procedure:
- Global orbit correction (1:1)
- Dispersion-Free Steering (DFS)
- Wakefield-Free Steering (WFS)
- Knobs (Y, YP D XP XP.*XP XP.*YP XP.*D)
  - First order: Y, YP D XP
  - Second order: XP.*XP XP.*YP XP.*D

Single-bunch effects:
--> negligible dependence

$$w[nm/10^9 e] = \frac{\left(\sqrt{\sigma_{y,q}^2 - \sigma_{y,0}^2}\right)}{q}$$

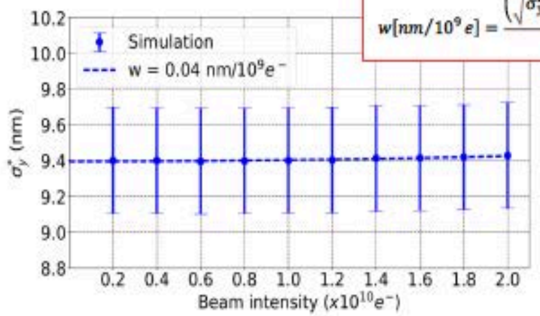


Figure : Vertical IP beam size σ_y^* vs. beam intensity in the 250 GeV BDS, calculated with PLACET with wakefields.

Multi-bunch effects:
--> intra-train correction required

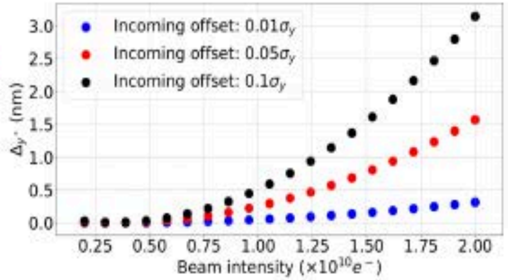


Figure : Vertical orbit deflection at the IP between the first and last bunch of a train Δy^* vs. beam intensity for three incoming constant position offsets of the train of bunches in the 500 GeV ILC BDS: $0.01\sigma_y$, $0.05\sigma_y$ and $0.1\sigma_y$, calculated with PLACET with resistive wall effects included.

Intensity-dependent effects at CLIC 380 GeV

BDS imperfections:
- Misalignments : 50 µm RMS; 200 µrad RMS; strength: 0.1% RMS
- Wakefields from the 134 X-band cavity BPMs
- Resistive-wall wakes from beam pipe

Simulation:
- 100 random machines
- Full tuning procedure (same as in the CLIC case)
- Studied beam size dependence on bunch charge
- Studies impact of long-range resistive-wall in case of multi-bunch

Tuning procedure:
- Global orbit correction (1:1)
- Dispersion-Free Steering (DFS)
- Wakefield-Free Steering (WFS)
- Knobs (Y, YP D XP XP.*XP XP.*YP XP.*D)
  - First order: Y, YP D XP
  - Second order: XP.*XP XP.*YP XP.*D

Single-bunch effects:
--> small dependence

$$w[nm/10^9 e] = \frac{\left(\sqrt{\sigma_{y,q}^2 - \sigma_{y,0}^2}\right)}{q}$$

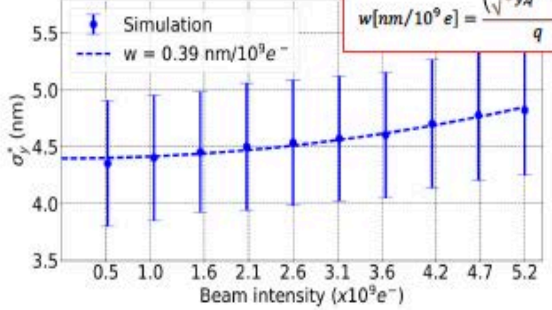


Figure : Vertical IP beam size σ_y^* vs. beam intensity in the 380 GeV BDS, calculated with PLACET with wakefields.

Multi-bunch effects:
--> intra-train correction required

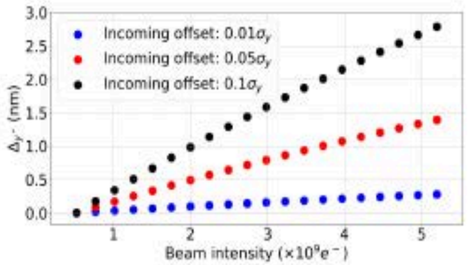


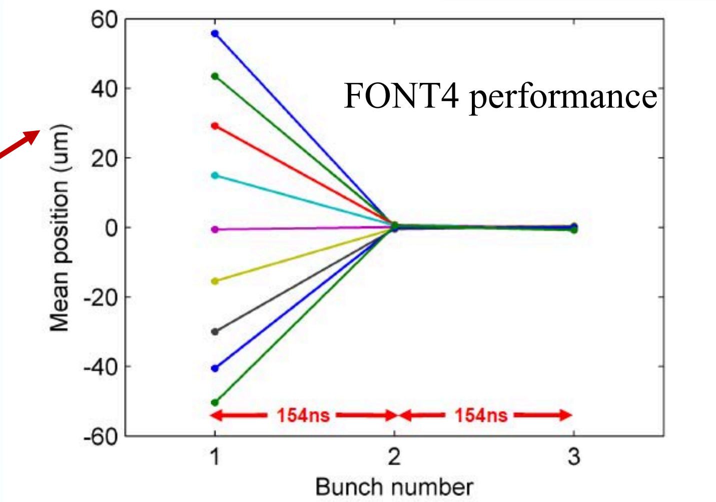
Figure : Vertical orbit deflection at the IP between the first and last bunch of a train Δy^* vs. beam intensity for three incoming constant position offsets of the train of bunches in the 380 GeV CLIC BDS: $0.01\sigma_y$, $0.05\sigma_y$ and $0.1\sigma_y$, calculated with PLACET with resistive walls.

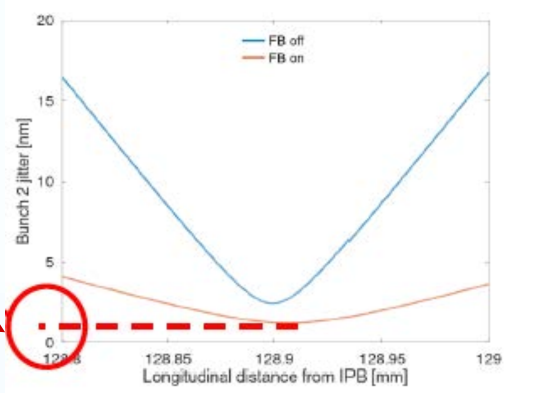
Further studies are needed but, "stable" beam and "stable" IPBSM are essential

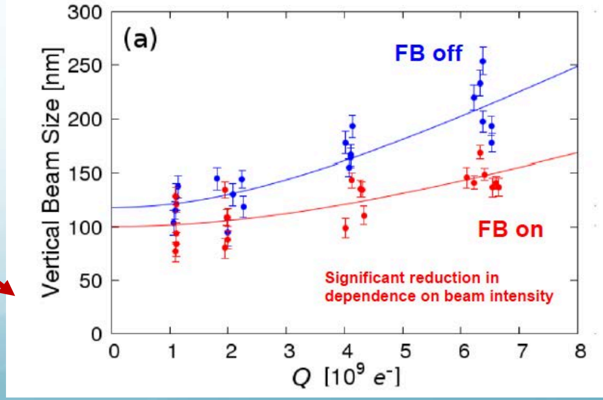
FONT feedbacks

P. Burrows

- ILC IP FB system prototyped + tested:
  meets ILC performance specifications
- Upstream dual-phase FB provides capability for
  1 nm-level beam stabilisation at ATF2 IP
- ATF2 'IP FB' has stabilised beam directly locally
  to c. 40 nm; 25 nm is possible in principle
- Upstream FB reduced observed intensity-dependence of beam size by factor ~ 1.6
- Additional beam time would allow:
  - optimisation of FB system performance
  - study of long-term beam trajectory control





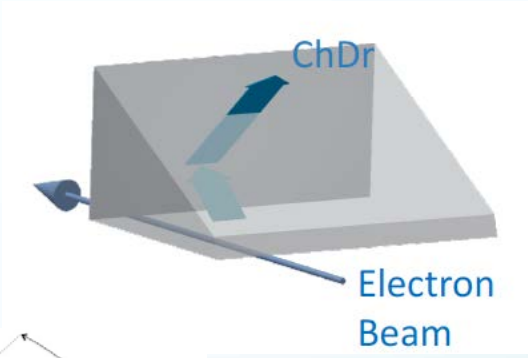


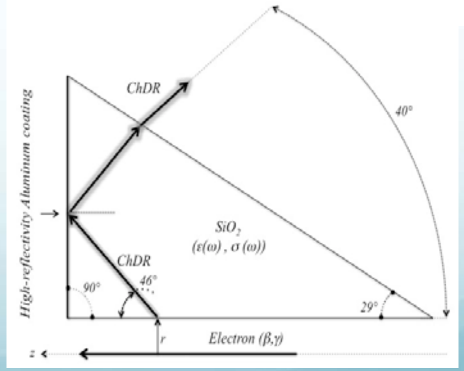
Instrumentation R&D

M. Bergamaschi, T. Lefevre, S. Mazzoni

- **Optical Transition Radiation (OTR) (**2013-2017)
  Sub micron resolution achieved
- **Optical Diffraction Radiation (ODR)** (2017-2018)
  Sensitivity to 3 um with non-invasive technique demonstrated (Bergamaschi et al, Phys. Rev. Applied **13**, 014041 (2020))
- **Incoherent Diffraction Cherenkov Radiation (ChDR)** (Since Nov. 2018) beam size measurement. The motivation for these studies are:
  Suppress Synchrotron Radiation → cleaner signal
  DR and SR are emitted at similar angles
  Looking for a physical process emitted at larger angle

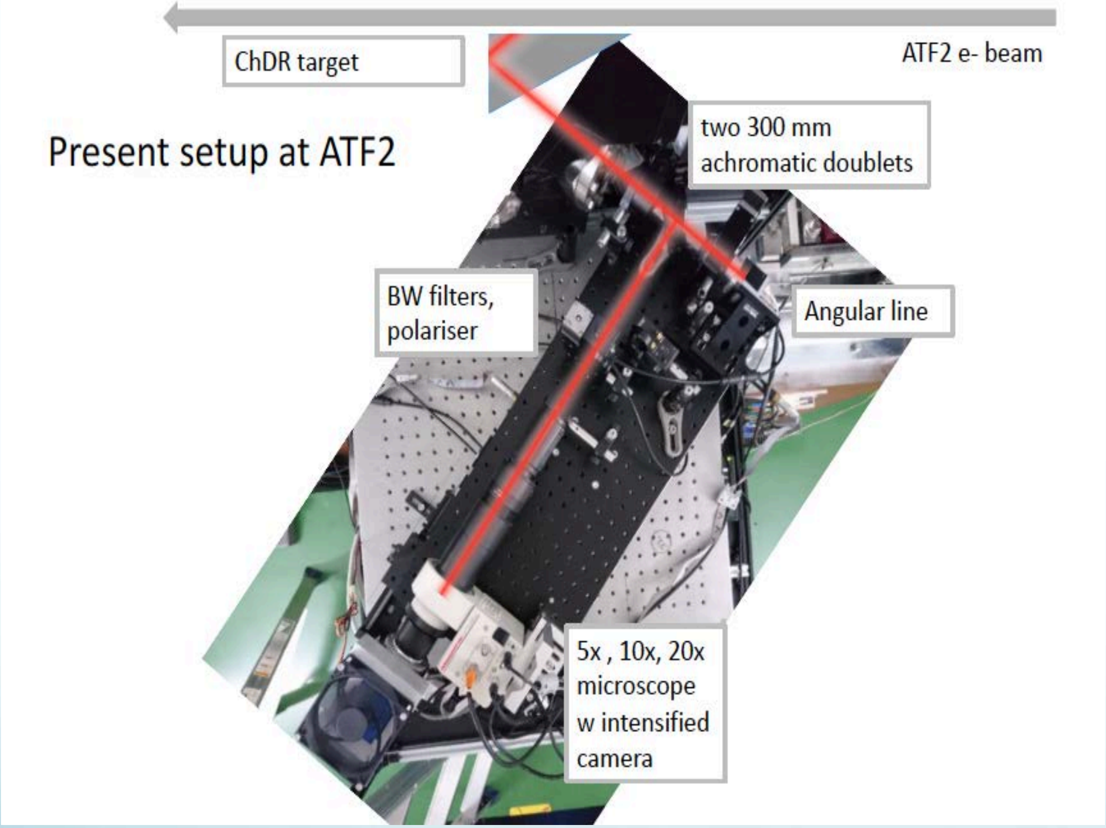
  Larger aperture compare to DR slits (> 500 µm)
  Difficult as DR will provide less photons
  Looking for a physical process providing more photons





Instrumentation R&D

M. Bergamaschi, T. Lefevre, S. Mazzoni



PLANS for 2019-2020

- Results from ChDR shifts in 2019 are probably affected by Cherenokv Radiation produced by halo particles hitting the target
- Plan for 2020 shifts (cancelled due to COVID-19): observe at longer wavelength to increase beam-target distance (reduction of Cherenkov halo background)
- Measure accurately the angular distribution to confirm current ChDR theory from Tomsk group.

Hope to resume activity at ATF2 in 2021 ??

Operational Issues

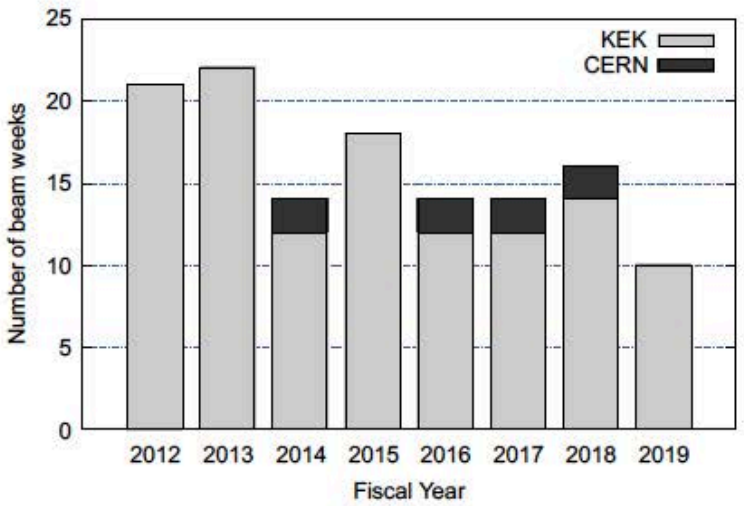
N. Terunuma

ATF is a very unique facility internationally, providing **low-emittance beam** for R&D and developing **nanometer beam technology**.

However, since the **operating budget** is allocated from the **common budget within KEK**, it is determined by DG by the results of coordination with other R&D, and this common budget itself is **becoming tighter year by year.**

Operation History

The ATF operating budget comes from sharing common R&D resources at KEK.



Beam operation

- 1996 ~ 2013: **21 weeks** per year
- 2014 ~ : reduced about **14 weeks** per year
- Rise of electricity prices (twice!) ← 2011 Great East Japan Earthquake

CERN's budgetary contribution to the ATF operation

- in four fiscal years
- two weeks extension each

Further budget difficulty on 2019 → 10 weeks

In this year, 2020, five weeks are approved so far, with additional beam weeks possible by the end of March 2021 will be determined, taking into account the recommendation of this ATF review.

Beam operation is postponed by COVID-19 difficulty especially for collaborators.

In addition, the measure of electric breakdown accident in July also postpones the beam **after January 2021**.

Operational Issues

Main difficulties identified are:

- **Shortage of budget**.

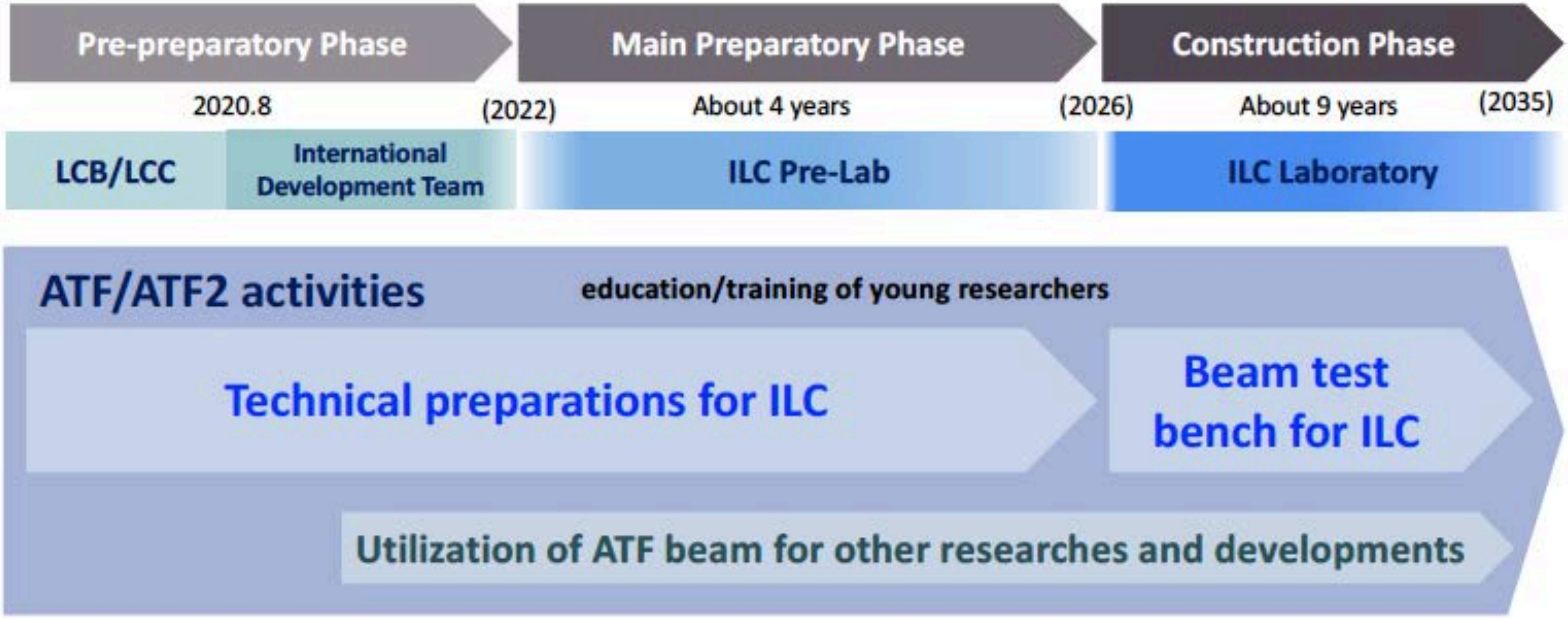
- **Manpower** for ATF operation: KEK (60 %) staff is limited. Well-trained outsourcing staff is essential to keep the ATF running

- **Lack of spares** especially for particularly expensive (Klystrons) and long-lead-time key components is a major concern. In addition, some of the devices are discontinued by suppliers and desired to be updated with a renewal of the system.

- **Various operational concerns:** Temperature control (DR circumference drifts), LINAC RF source (80 MW Klystron), DR RF source (714MHz, 50kW obsolete), Injection/extraction kickers (SLAC 1995), Final Focus magnets (old), human errors and security....

ATF2 and ILC Implementation plan

In August 2020, ICFA established the International Development Team (IDT) for ILC as a successor of the Linear Collider Board (LCB) and Linear Collider Collaboration (LCC). IDT will define the structure of the ILC Pre-Lab.



ATF2 and ILC Implementation plan

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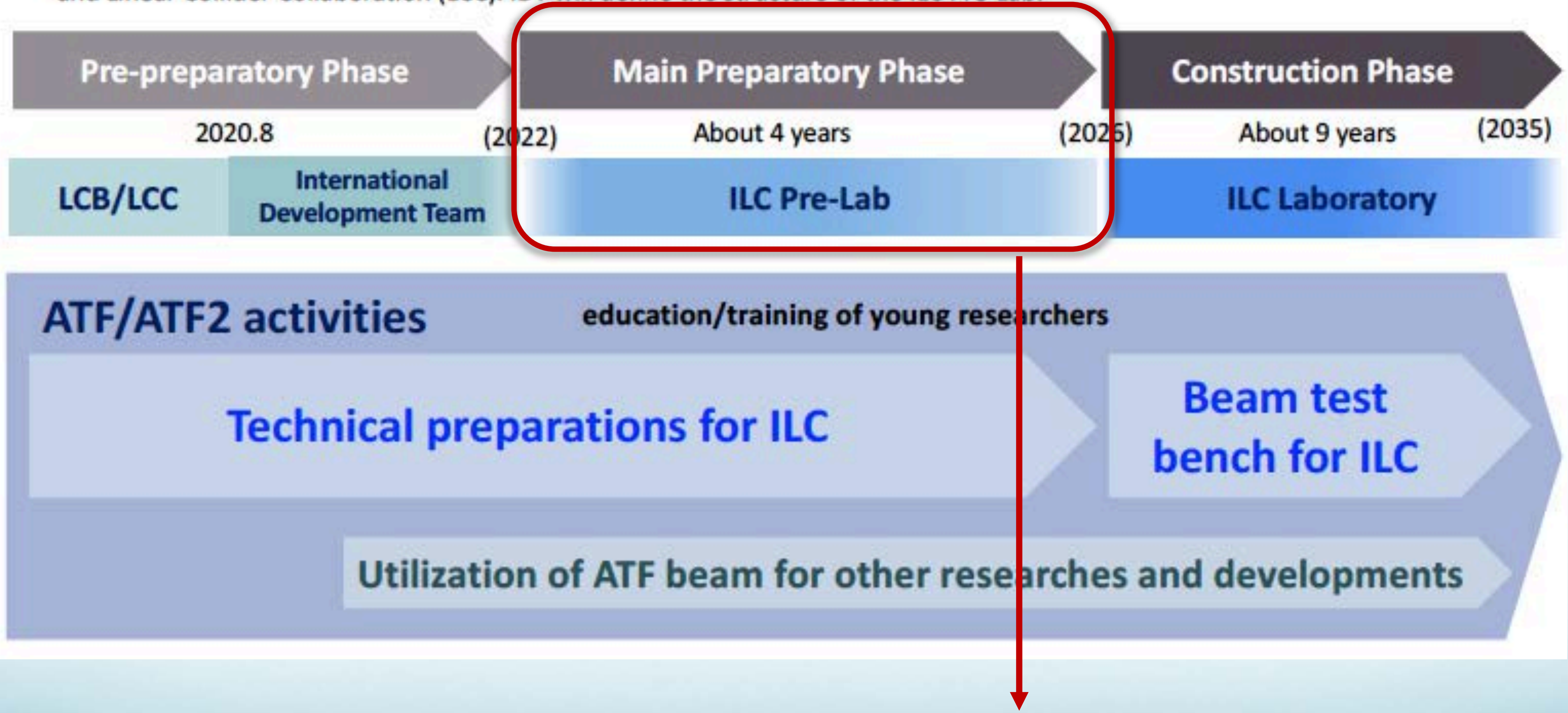


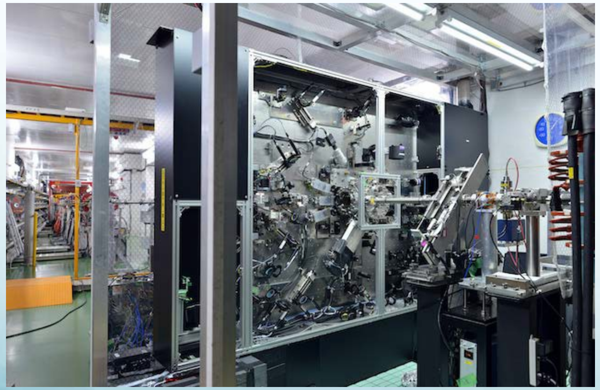
ATF/ATF2 is expected to play an important role in technical preparations of ILC

Upgrade of ATF2 for technical preparations of ILC

Building on the achievements of the ATF2 project a follow-on, **upgraded facility "ATF3"** for pursuing R&D aimed at maximizing the luminosity potential of ILC is necessary.

N. Terunuma

ATF2 final focus test beamline



IPBSM (nanometer beam size monitor)

- An overhaul and upgrade of the existing ATF2 beamline so as to model more accurately the energy-scaled ILC final-focus system.
- Examples of **what to improve**:
  - **Wakefield sources** mitigation
  - **Laser for IPBSM**
    to provide stable and long-term operations
  - **And other "minor' improvements** …
    magnets with poor magnetic field
    ILC-style diagnostics: cavity BPMs...
    SC FF magnets....

T. Okugi

ATF2 studies during technical preparations of ILC

Pre-preparatory Phase		Main Preparatory Phase	Construction Phase
2020.8	(2022)	About 4 years (2026)	About 9 years (2035)
LCB/LCC	International Development Team	ILC Pre-Lab	ILC Laboratory

Remaining studies planned for the next few years

Study of 2nd order aberrations and corrections

- Systematic measurement of the main higher order aberrations
- Evaluation of the energy bandwidth
- IP beam size tuning for the beam optics with stronger aberrations.

Study of intensity dependence (wakefield)

- Quantitative understanding of the wakefield source for ATF2 beamline
- Investigation of the intensity dependence source other than that for wakefield

Systematic studies for the beam size tuning and the intensity dependence reduction with FONT FB

No major upgrades

Technical preparations at ATF/ATF2 in the ILC preparatory phase

Long term stability of beam size and orbit at the ATF2 IP

Long term stability of fast injection/extraction systems

Major upgrades

T. Okugi

Perspectives: ATF3

- Building on the achievements of the ATF2 project a follow-on, upgraded facility "ATF3" for pursuing R&D aimed at maximizing the luminosity potential of ILC is necessary.

- "ATF3" would hence provide the opportunity to attract additional resources from overseas collaborating institutes to deliver the program described above in a modular and sensibly time-ordered fashion.

- **What is from the point of view of the overseas collaborators "ATF3"?**

Perspectives: ATF3

A. Arishev

➢ R&D beyond colliders:

Mini-workshop to discuss potential projects was organized on 28 Aug. 2020 for Japanese community

Project title	Person in charge	Funding	Term	Required ATF modifications	Location
Development of SuperKEKB Fast Kicker .	M. Tawada (KEK)	KEKB	Fall 2021 ~	minor	EXT-mid
Development of SuperKEKB OTR Monitor.	T. Mori (KEK)	KEKB	Fall 2021 ~	minor	EXT-end
New betatron feedback scheme, AC multipole magnets, and ultra-fast quadrupole kicker tests.	T. Nakamura (KEK/JPARC)	?	2021 ~	minor	DR
Accelerator Control System test.	Y. Kaji (KEK)	KEKB	2021 ~	minor	Timing system
Detector radiation resistance tests.	Y. Sugimoto (KEK)	KEKB	2021 ~	80MeV linac optics	Linac-end
Gamma-ray source for user application .	ATF group (KEK)	-	-	minor	DR north
Performance evaluation of ultra-short period undulator.	S. Yamamoto (KEK)	KEK-PF	2021 ~	minor	DR north
Polarized gamma-ray beam generation assuming ILC.	N. Muramatsu (Tohoku Uni.)	?	2023 ~	minor	EXT/FF
Electron beam focusing by active plasma lens.	M. Kando (Osaka U.)	?	2021 ~	New laser, LTL, vacuum bump chamber	EXT-end
Test of the Lorentz invariance.	T. Shima (Osaka Uni.)	JSPS ↑	-	BSM modification	FF
Demonstration of seed FEL (CHG).	Y. Honda (KEK)	JSPS ↑↑	-	EXT beamline modification	EXT-mid
Strong-field QED experiments.	Under discussion	JSPS ↑↑↑	-	ATF2 FF region upgrade and extension	FF

Implementation level: Relatively simple / Intermediate / Difficult

Personal Notes from Review discussion

- How unique is ATF/ATF2/ATF3??
- Feasibility of the plan taking into account the ILC uncertainty
- What to do between now and the “green light” for ILC???
- 2021 run??? (re-start difficulties after shutdown)
- What is the budget/personnel/operation time needed? (summary table will be welcome, priority list...)
- Aging of the operating personnel, no transfer of knowledge, no new Japanese PhDs
- ATF3 R&D open facility as FACET, ATF-BNL, CLEAR...
- Collaboration with other ILC facilities in KEK: SRF and SCF ?

Personal Notes from “others” discussions

- Operational support during runs for overseas collaborators
- Communication problems
- Lack of Coordination and Support between different activities
- Problems with work visibility for PhDs
- .....

.......But when theorists are more confused, it's the time for more, not less experiments.

(Nima Arkani-Hamed Cern Courier March 2019)

Thanks for your attention