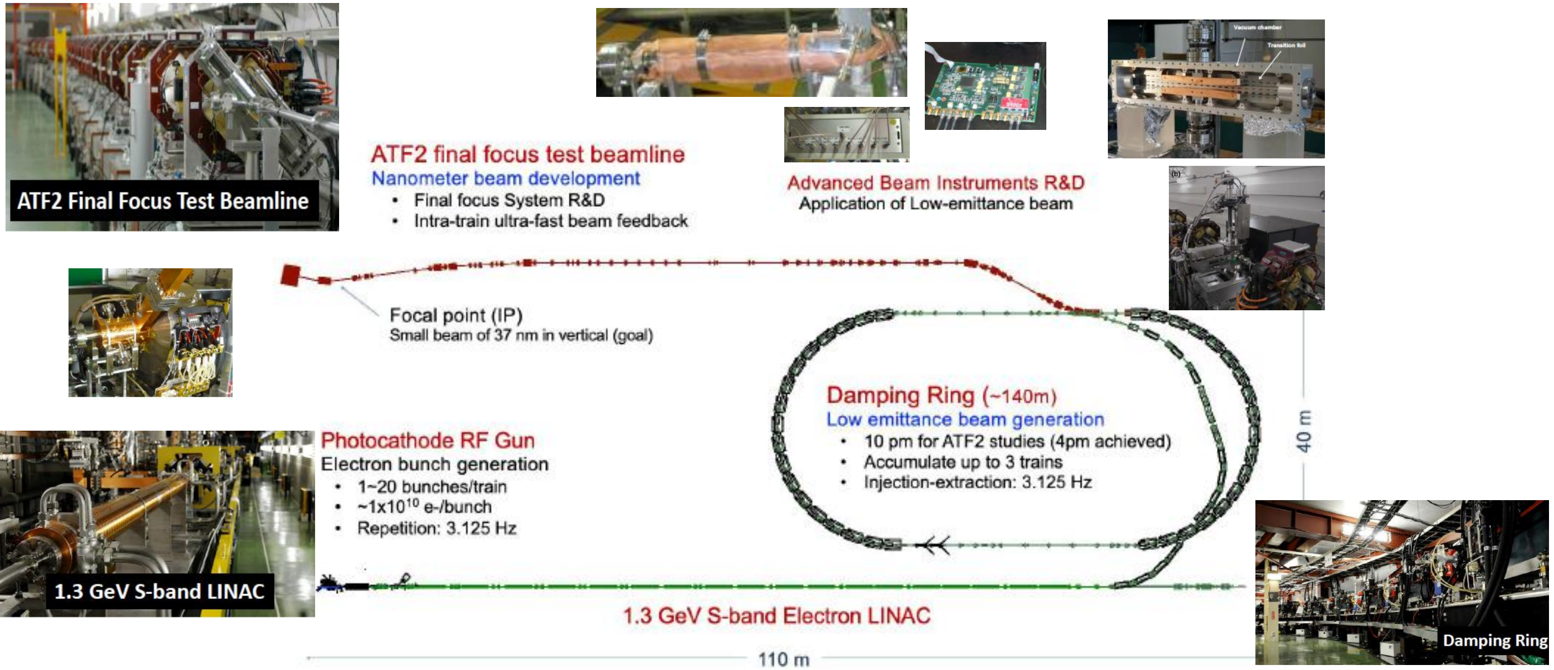
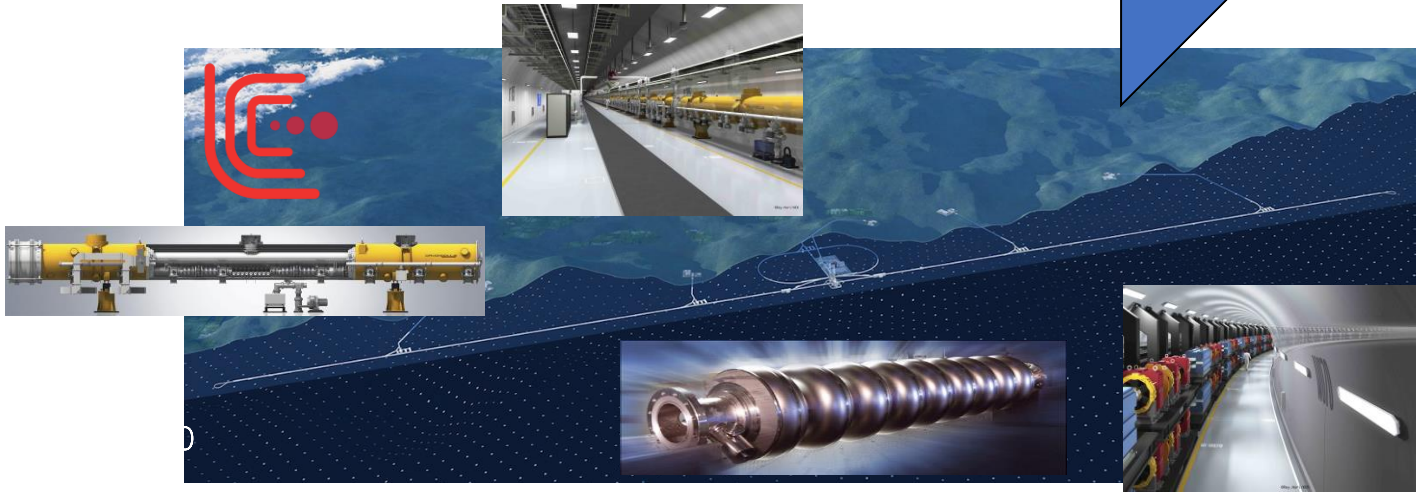


ATF2 studies and ILC preparation – ARD10

2023 Joint Workshop TYL/FJPPL and FKPPL



K. Kubo, A. Faus-Golfe

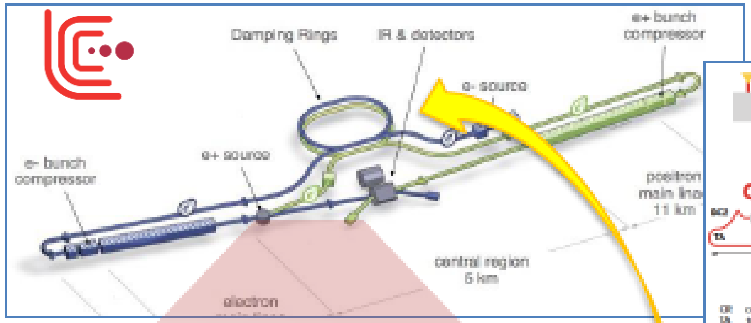
ATF2 the ILC FFS testbench

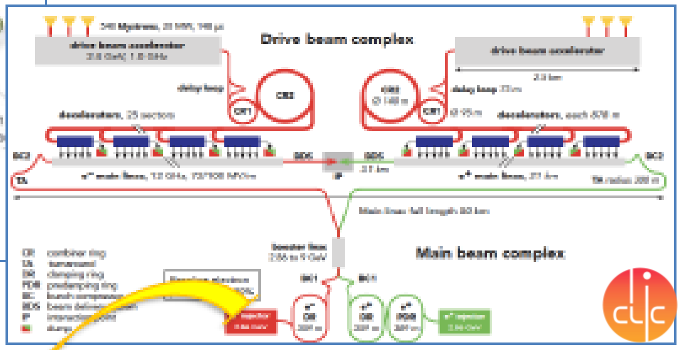
ATF/ATF2: Accelerator Test Facility

Courtesy: N. Terunuma

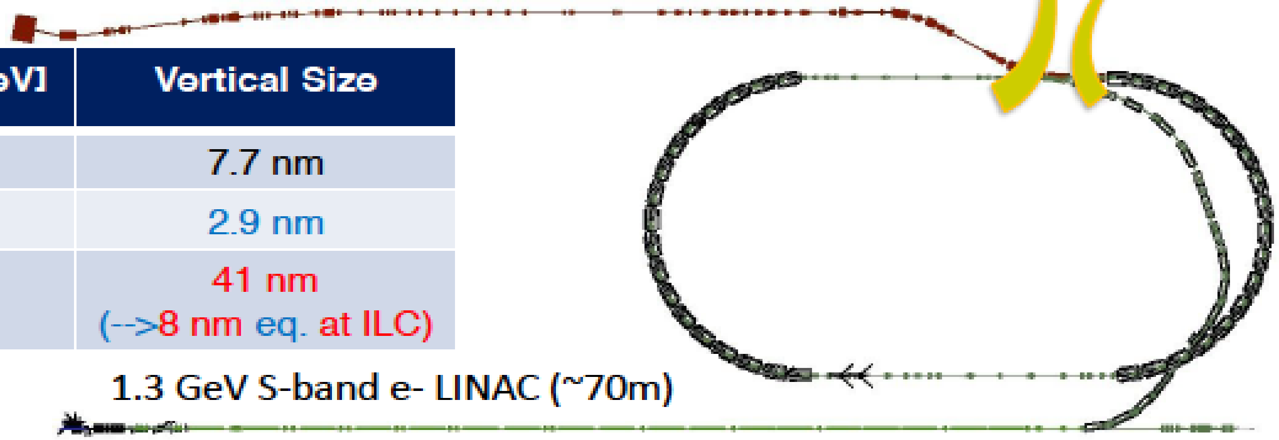
Develop nano-beam technology for ILC/CLIC

- 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)

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

Damping Ring (140m)
Low emittance e- beam

Normalized emittance

ATF: 1×10^{-8} m

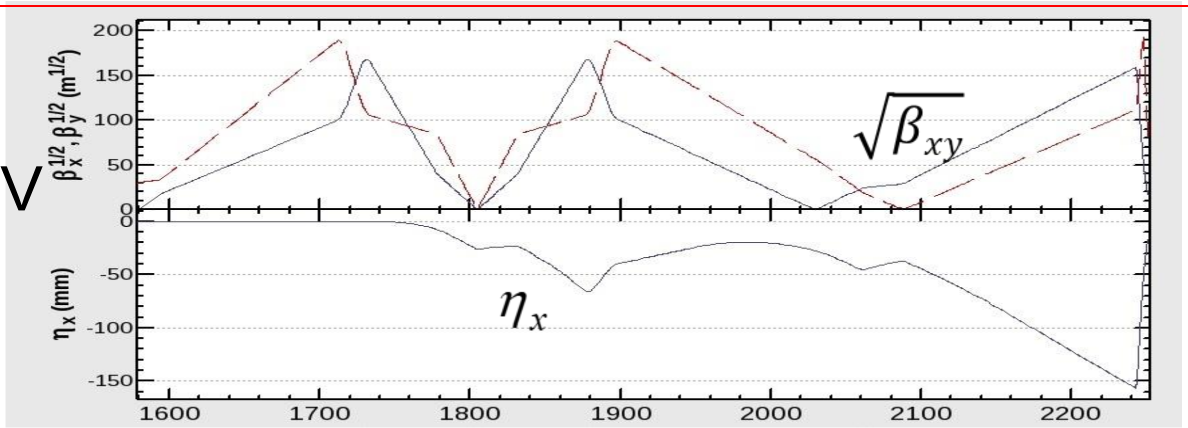
ILC: 2×10^{-8} m

Final Focus Optics, ILC and ATF2

Almost identical optics
Same magnet configuration (same magnet names),
Similar tolerances of magnetic field errors

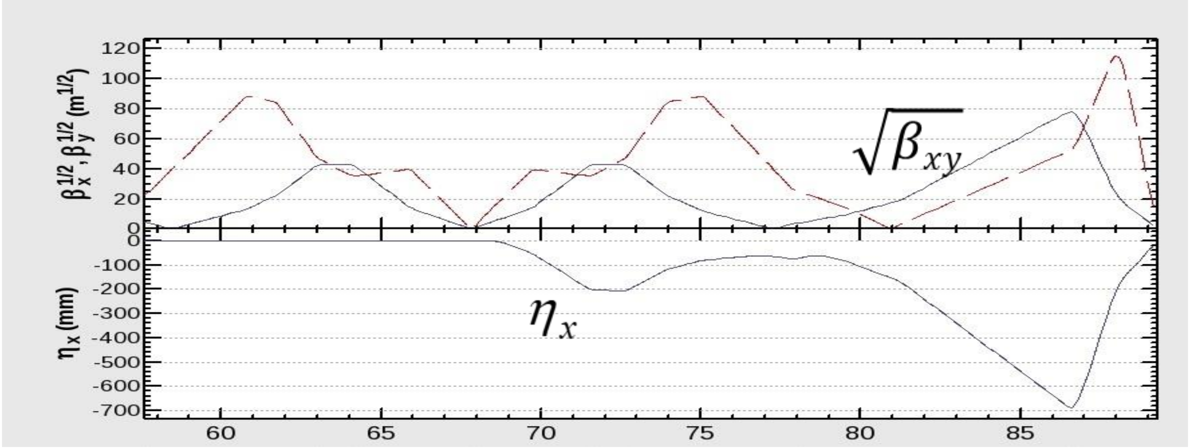
ILC

Up to 500 GeV
~700 m



ATF2

1.3 GeV
~30 m



Nano Beam Stabilization

Goal2: Beam position control in 2 nm by intra-pulse feedback

ILC intra-pulse Feedback

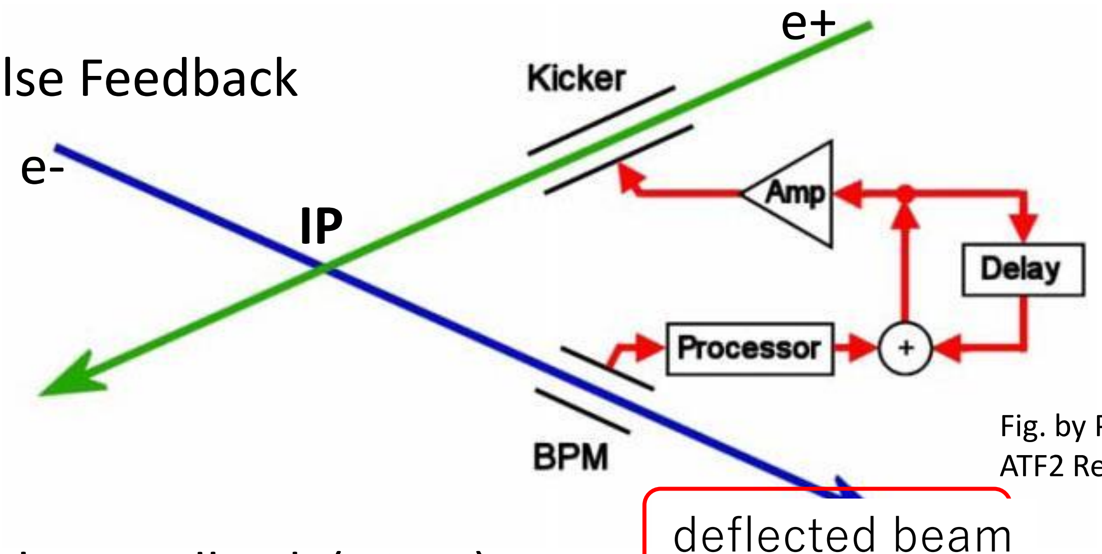
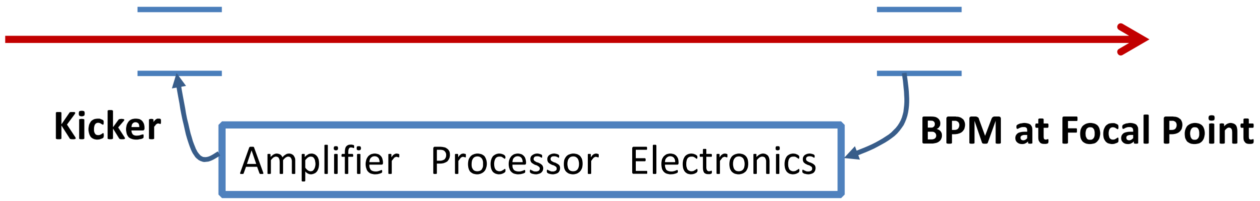


Fig. by P.Burrows
ATF2 Review 2013

deflected beam

ATF2 intra-pulse Feedback (FONT)

3 bunches/pulse 150 ns spacing or 2 bunches/pulse 230 ns spacing



BPM resolution must be 2 nm, much better than required in ILC (~ micron).

Final Focus Scheme of ILC Validated

Confirmed smallest beam size ~41 nm (2016)

ILC Final Focus method,

Local Chromaticity Correction Demonstrated

Without chromaticity correction,

expected beam size ~ 300 nm

Beam size without chromaticity correction

$$\sigma = \sigma_0 \sqrt{1 + (\sigma_\delta \xi)^2}$$

Chromaticity: $\xi \approx L^* / \beta^* \approx 10^4$

Energy spread: $\sigma_\delta \approx 10^{-3}$

Intra-beam Feedback of ILC Validated

Feedback latency 133 nsec achieved

(target < 366 nsec)

Position jitter at ATF2 IP: 41 nm (2018)

Limited by BPM resolution (~20 nm). (not relevant for ILC)

Upstream Feedback shows capability for 2nm stabilization.

Demonstrated ILC Feedback system.

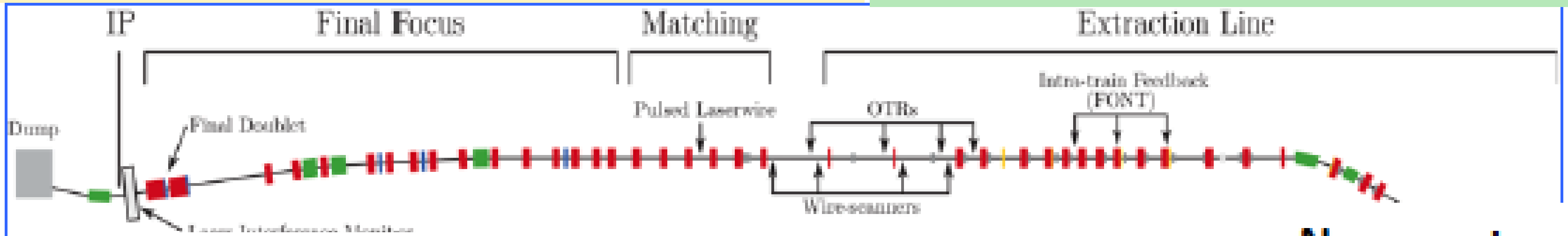
ATF2 goals and achievements

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

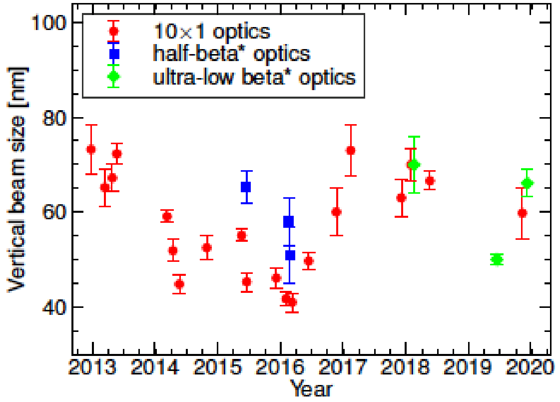
- ATF2 Goal : **37** nm → ILC **7.7** nm (ILC250)
  - Achieved **41 nm** (2016)

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.**

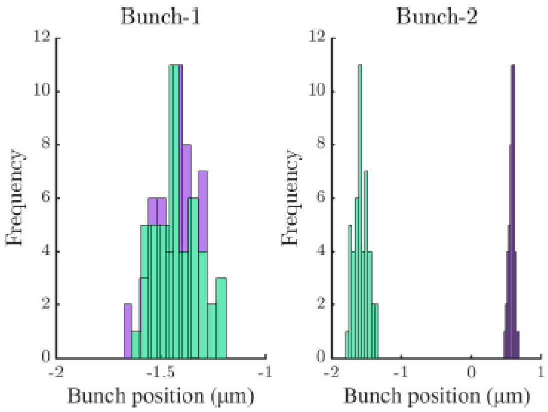


Nanometer beam sizes at IP

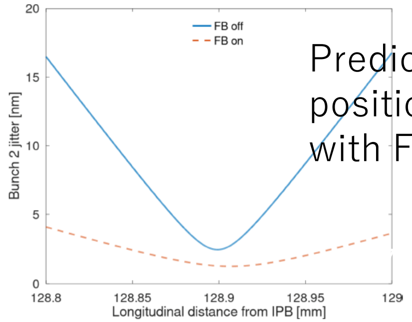


Small beam sizes were obtained with beam intensities of 0.5-1.5 10^9 e^-/bunch (10^{10} design value) and reduced aberration optics ($10\beta_x^*$ x β_y^*)

Nano-meter stabilization at IP



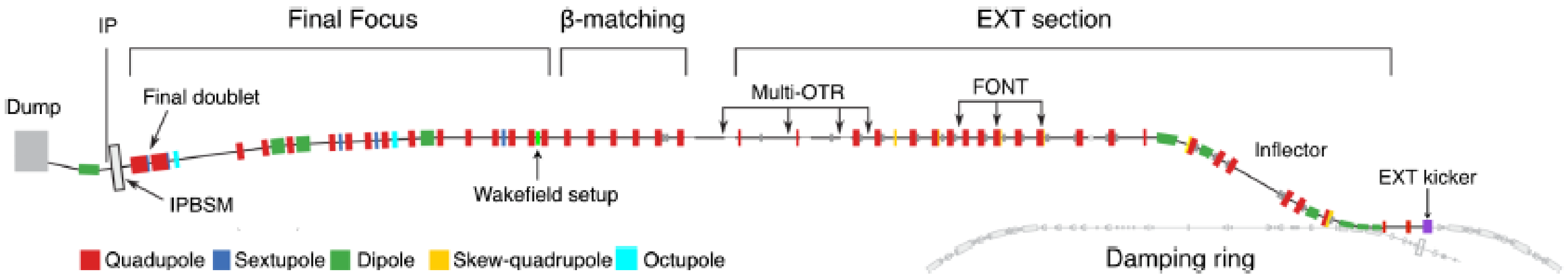
Distribution of bunch positions measured at IPB, with two-BPM FB off (green) and on (purple)



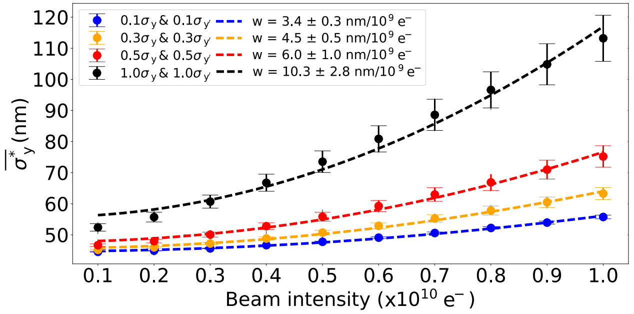
Predicted vertica position jitter with FB on-off

ILC FFS - ATF3 objective and collaboration:

Based on the achievements of the ATF2 no showstopper for ILC has been found.
ATF3: Pursue the necessary R&D to **maximize** the **luminosity potential of ILC**.
Assessment of the **ILC FF system design**
from point of view of Beam dynamics and Technological/hardware choices
long-term stability operation issues.

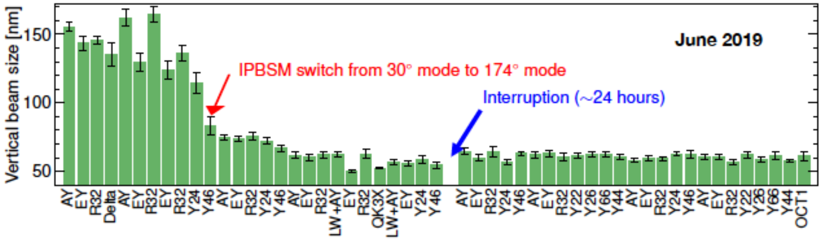


Long Term stability



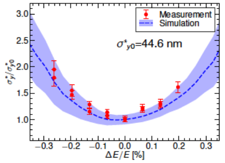
Intensity dependence studies

High-order aberrations

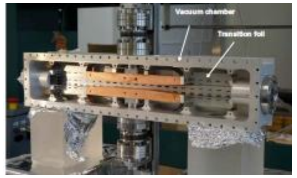


Ultra-low β* studies

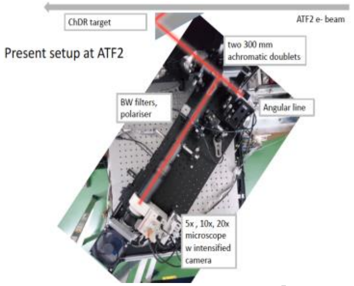
Energy bandwidth



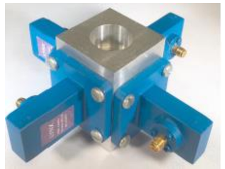
Instrumentation R&D



Collimator



Incoherent Diffraction Cherenkov Radiation Monitor

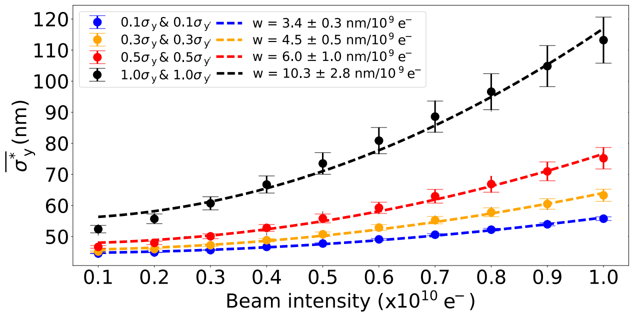


Waveguide BPM

ILC FFS Technical Preparation Plan: Tasks

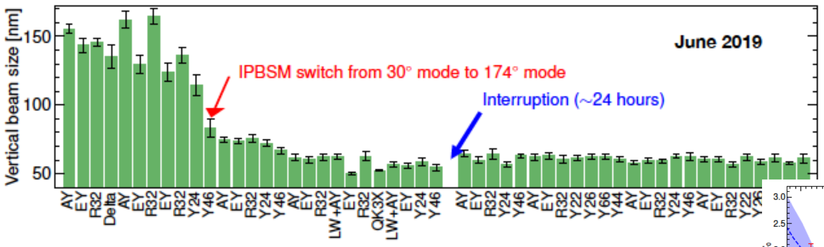
ILC-FFS Tasks : Maximize Luminosity potential of ILC	
T1: **ILC-FFS system design**	**T1.1**: Hardware optimization
	T1.2: Realistic beam line driven / IP design
T2: ILC-FFS beam tests	**T2.1**: Long-Term stability
	T2.2: High-order aberrations
	T2.3: R&D complementary studies

Long Term stability

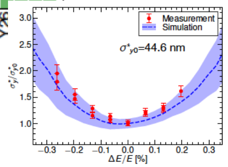


Intensity dependence studies

High-order aberrations

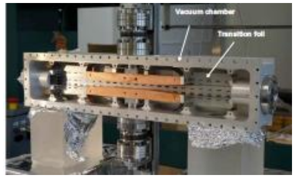


Ultra-low β* studies

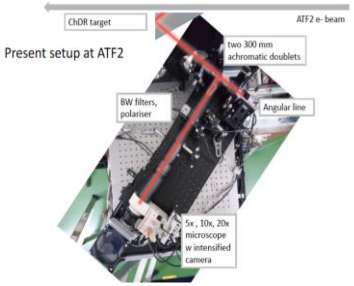


Energy bandwidth

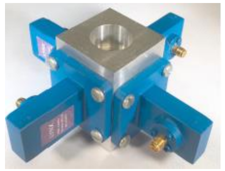
Instrumentation R&D



Collimator



Incoherent Diffraction Cherenkov Radiation Monitor



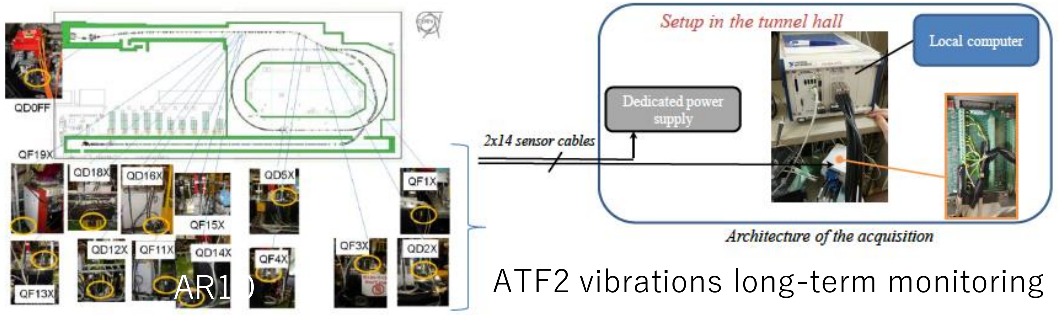
Waveguide BPM

T2.1 ILC FFS beam tests: Long-Term stability

- **Nominal ($10\beta_x^* \times \beta_y^*$) optics operation routine assessment**
  - Automated steering procedures and basic tuning algorithms (like envisaged for ILC)
  - 2nd order correction knobs assessment (sextupoles and skew, octupoles)
  - Energy bandwidth measurements

- **Wakefield evaluation and mitigation**
  - Upstream beam line (relatively low- β_y)
  - Movable set-up mitigation techniques

- **Vibrations long-term monitoring system**

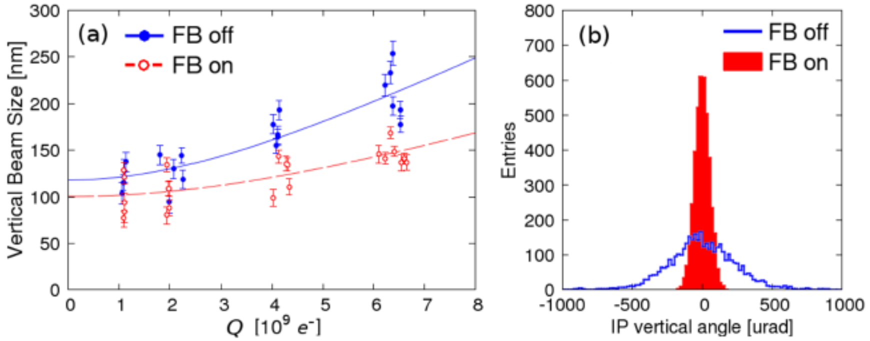


ATF2 vibrations long-term monitoring

- **Jitter sources assessment**
  - Measurements (entrance/IP)

- **CBPMs calibration process upgrade**
  - Duration of calibration optimization
  - Lifetime - degradation of calibration over time
  - New time and phase invariant digital processing software to be developed, algorithm could first be tested on simulated data.

- **FONT FB system performance optimization**
  - Long-term beam trajectory control
  - Routine use of y-y' FB to reduce jitter

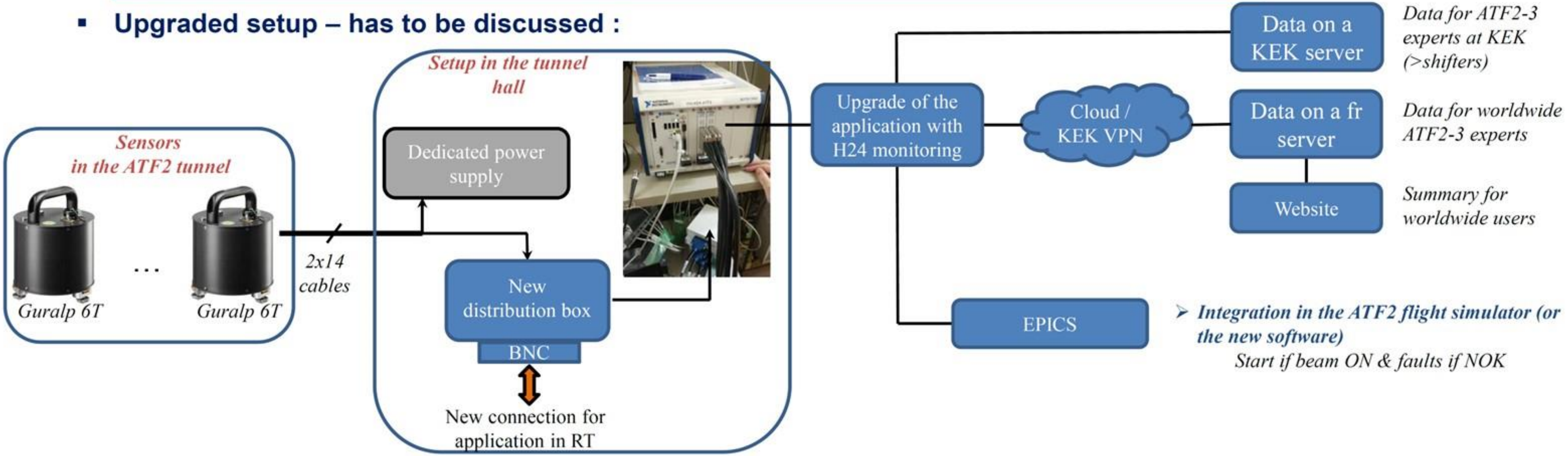


Two bunch operation

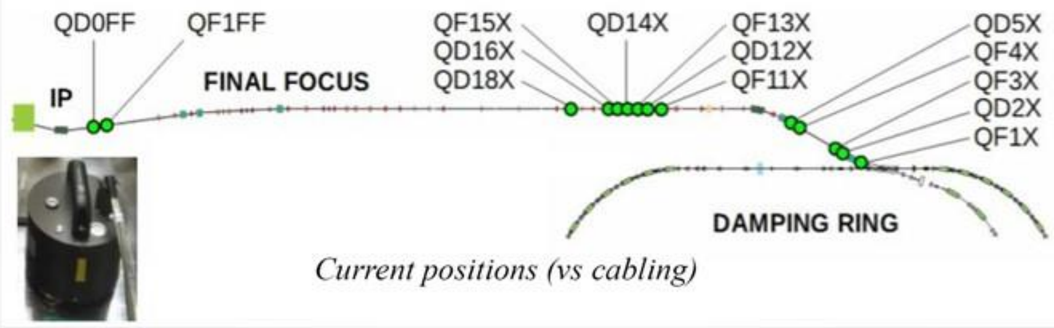
L. Brunetti , 2023.03.09,

Upgrade 1 : ATF2 vibrations long-term monitoring

- **Upgraded setup – has to be discussed :**



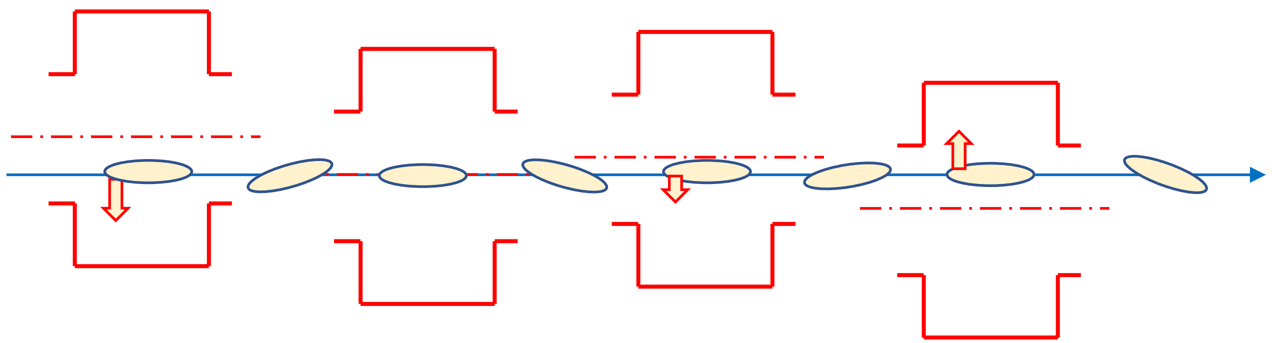
- Upgrade of the application has to be discussed with **CERN team** (availabilities, Labview compatibility (v2012)…) and the synchronization operation.
- The new connection has to be confirmed in function of the impedance and the current setup properties
- Sensors are located at strategic locations in function of the research program (if an upgrade of the positions is needed, extended cables or adaptations of the cabling could be done)

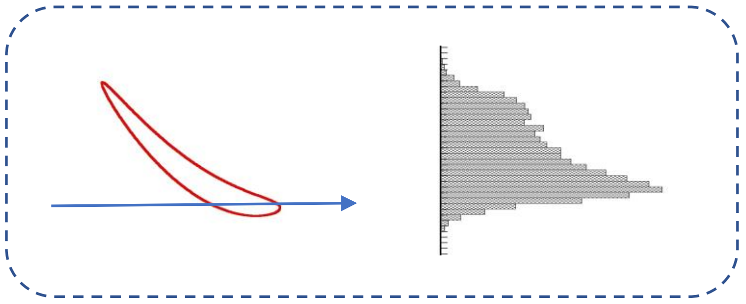


Current positions (vs cabling)

Static Effect of wakefield to beam size

Misalignment of beam line components (with respect to the beam orbit)





Beam shape distorted

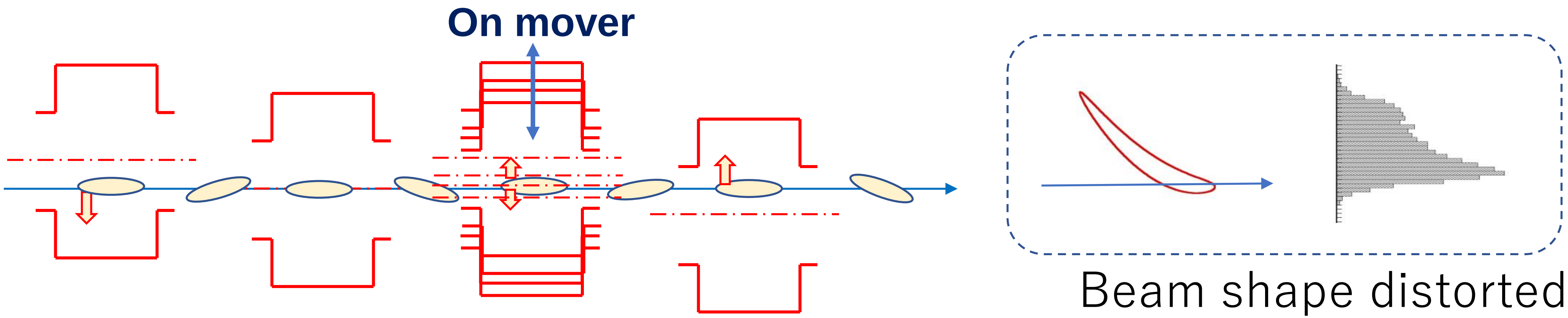
Effect of each wakefield source depends on misalignment, can be positive or negative.

We demonstrated reduction of this effect
by introducing movable wakefield source and searching optimum position.

But cannot completely cancel the effects if shape of wakefield of the movable structure is different from the others.

Static Effect of wakefield to beam size

Misalignment of beam line components (with respect to the beam orbit)



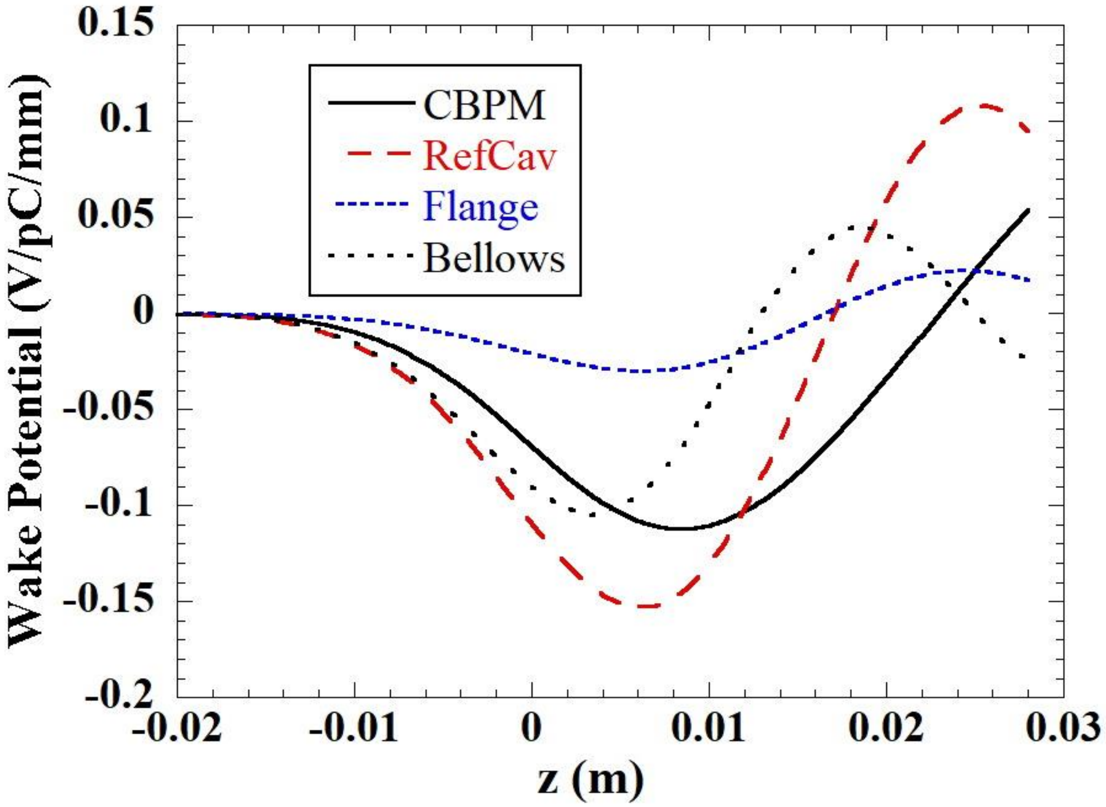
Effect of each wakefield source depends on misalignment, can be positive or negative.

We demonstrated reduction of this effect
by introducing movable wakefield source and searching optimum position.

But cannot completely cancel the effects if shape of wakefield of the movable structure is different from the others.

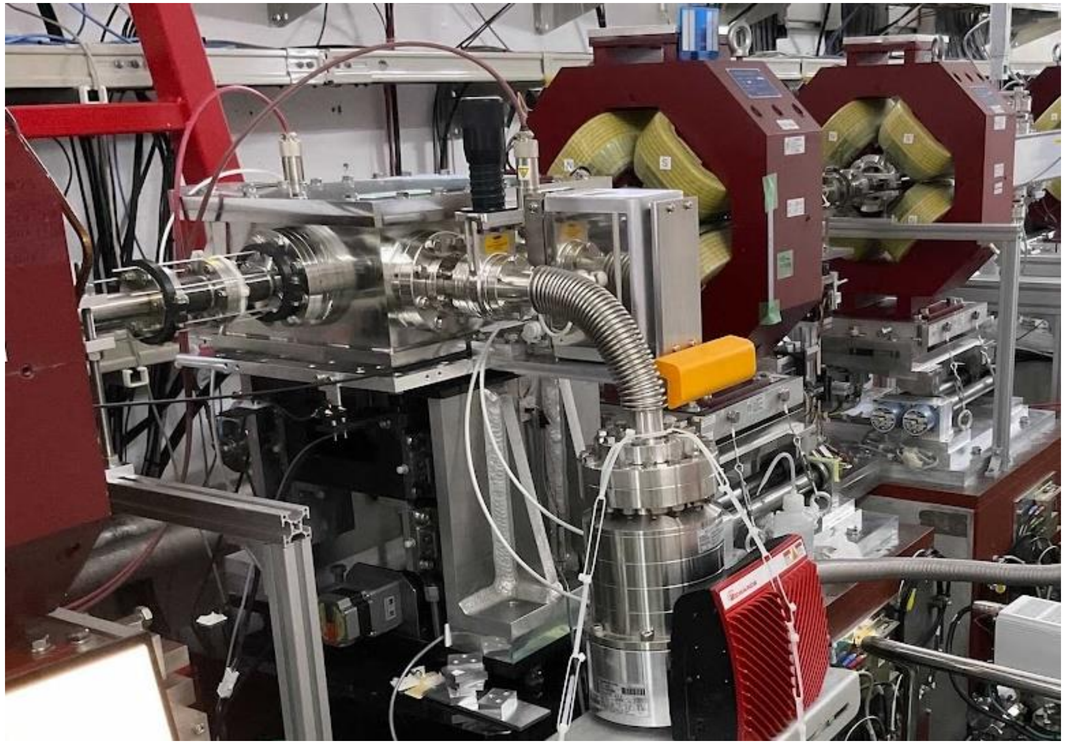
For complete cancellation of the wakefield, the movable structure should have the same wakefield shape as the wakefield shape of sum of the other wakefield sources.

Wake-potential of major components

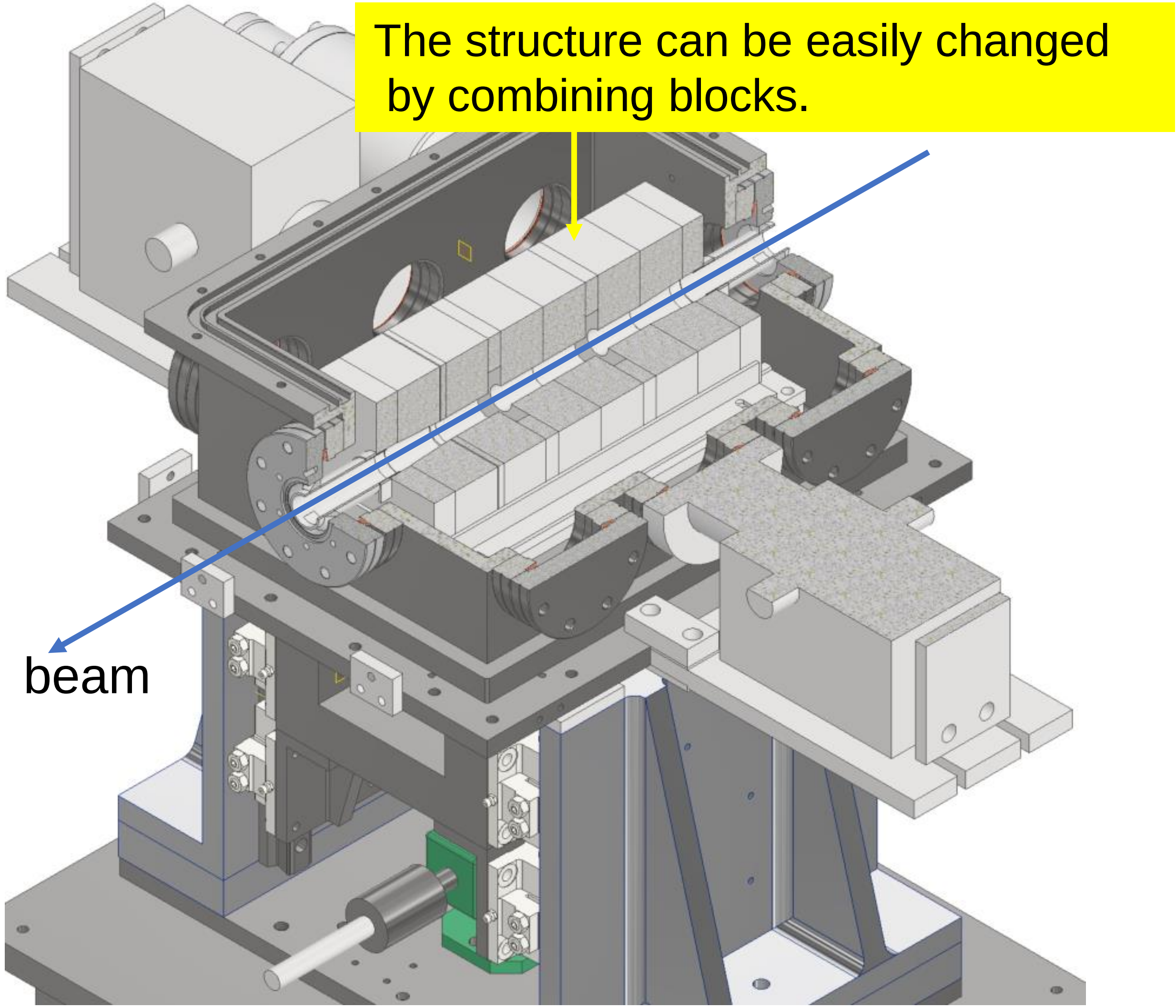


→ Try many different wakefield sources on mover.

Newly installed chamber
for wakefield study

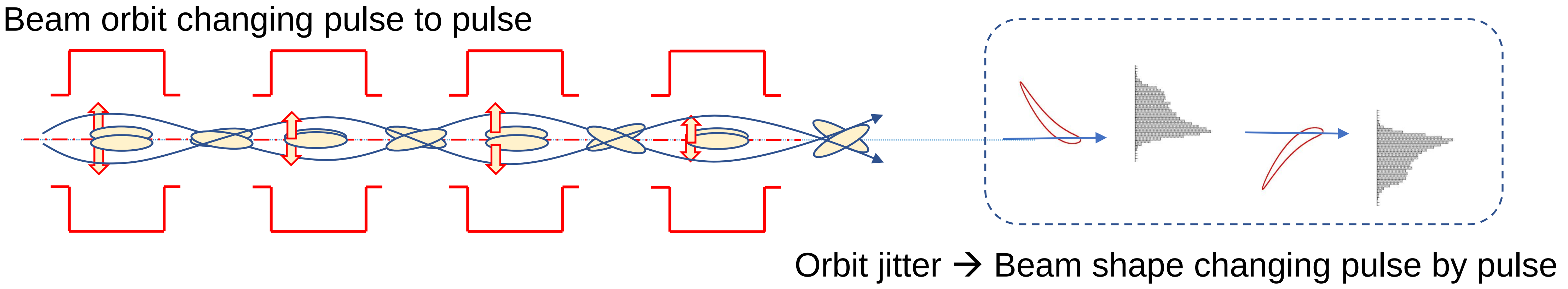


Wakefield sources can be set in the vacuum.



Figures by Y. Abe

Dynamic wakefield effect



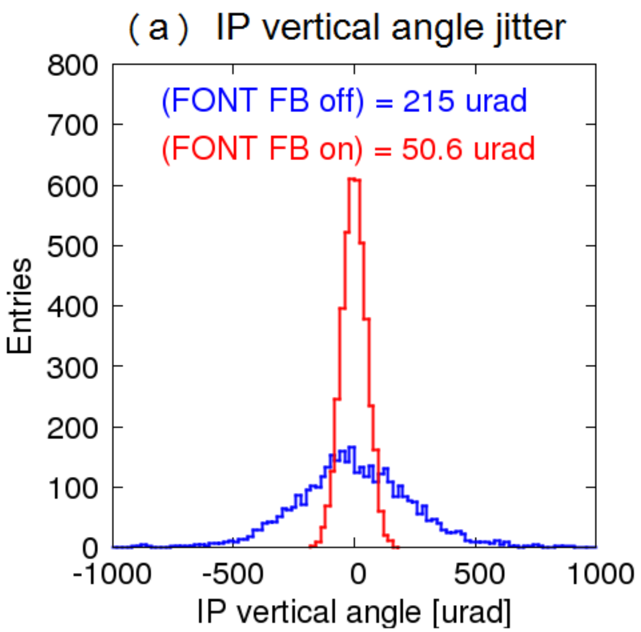
Our monitor measures beam size of projection of many pulses.
→ large beam size

Observed orbit jitter is about 0.1-0.3σ.
"angle at IP" phase jitter causes significant beam size growth due to wakefield.
Direct effect of "position at IP" phase orbit jitter is very small.
(0.3σ orbit jitter induces beam size growth of only 0.044σ, $\sigma \rightarrow \sqrt{1+0.3^2}\sigma$)

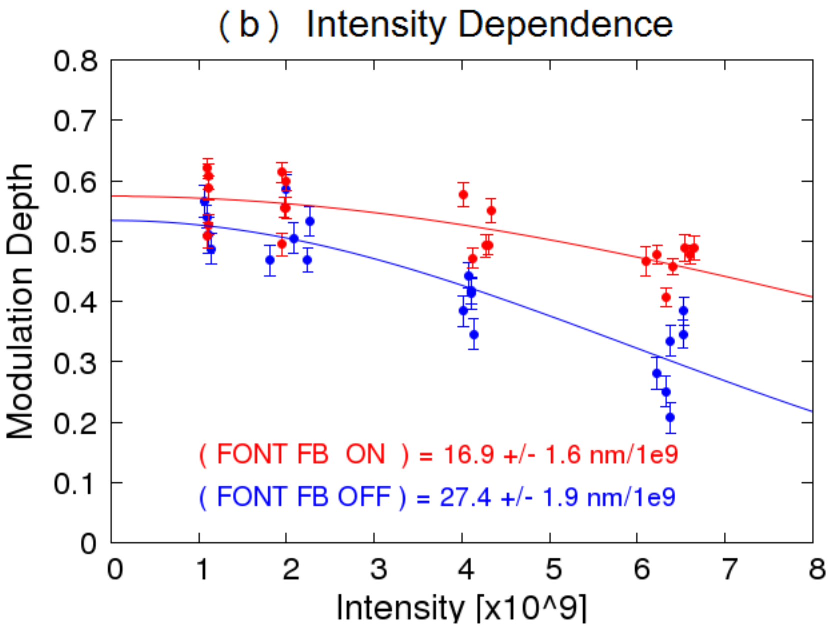
Mitigation of “Dynamic” wakefield effect to beam size by orbit jitter reduction

Beam size measured with and without orbit feedback (FONT).
2-bunch operation. Beam size of 2^{nd} bunch.

Reduction of angle jitter



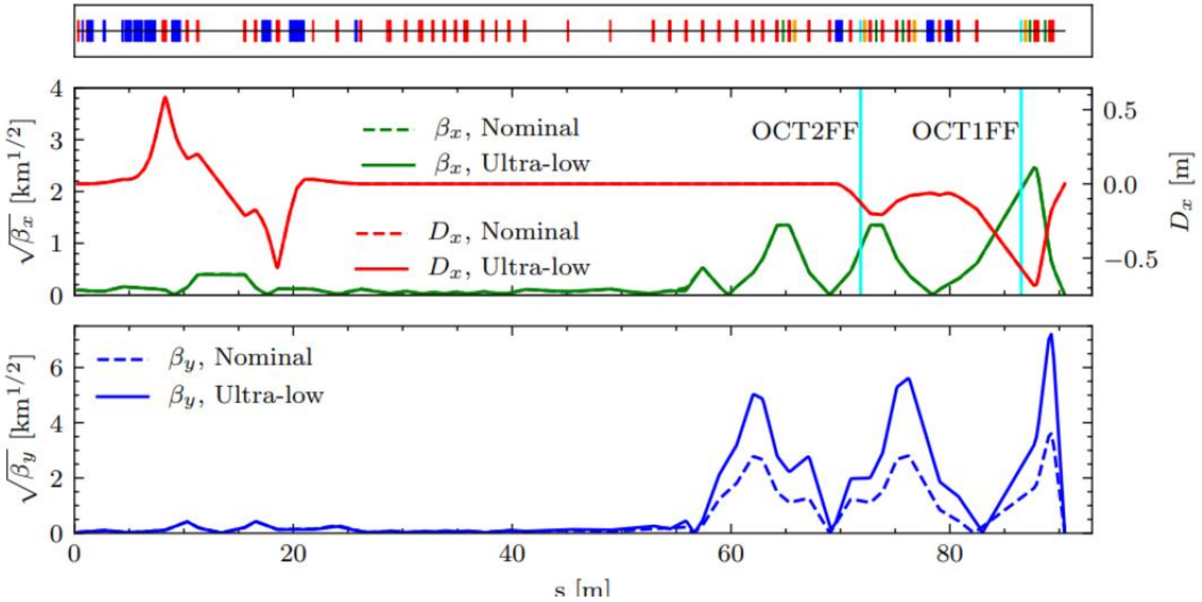
Reduction of beam size intensity dependence



ATF Review Report, 2020, Figure 27

We demonstrated reduction of this effect
by intra-bema feedback, in two bunch operation for the 2nd bunch.
But only partially reduced. Still some effects remained.

ATF2 Ultra-low β optics



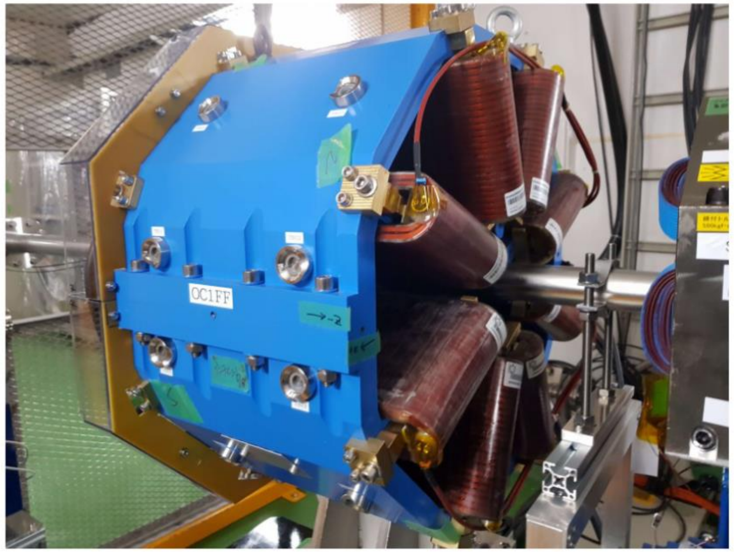
	ATF2 optics Nominal $10\beta_x^* \times \beta_y^*$	ATF2 optics Ultra-low $\beta_x^* \times 0.25\beta_y^*$	ILC	CLIC	CLIC
Beam energy [GeV]	1.3		250	380	3000
Vertical emittance [pm]	12		0.035	0.008	0.003
Horizontal emittance [nm]	1.2		5.0	2.55	0.2
Energy spread [%]	0.008		0.2	0.3	0.3
Beta-function β_x^*/β_y^* [mm]	40/0.1	4/0.025	13/0.4	8/0.07	4/0.12
Vertical chromaticity $\frac{L^*}{\beta_y^*}$	10000	40000	10000	86000	50000
Vertical beam size [nm]	37	27 (20[a])	7.7	2.4	1.0

[a]with octupoles.

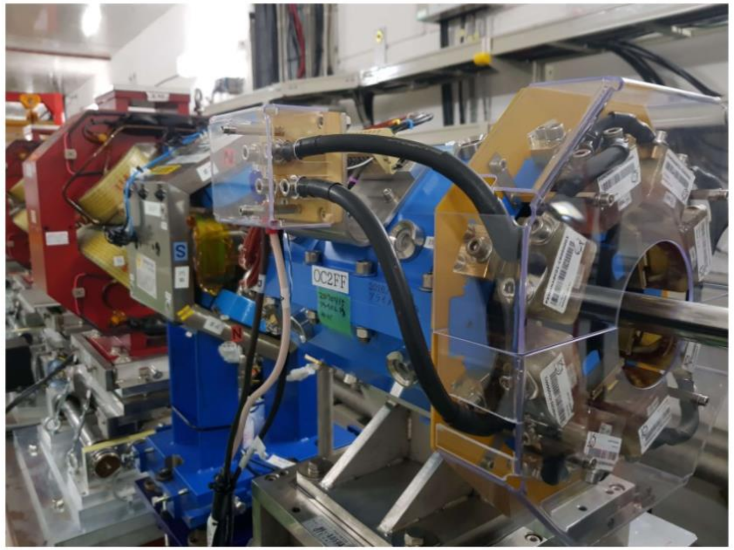
- Ultra-low β^* ($0.25\beta_y^*$) optics aims to test the FFS tunability at **higher chromaticity level**, approaching CLIC ones.
- To reduce the **impact of the multipolar errors**, the optics runs with larger ($25\beta_x^*$) horizontal beta-function.
- To tackle the **3rd order aberrations** pair of octupoles had been installed.

A. Pastushenko, 2023.03.09, in ATF3 kickoff meeting

Octupoles



OCT1FF



OCT2FF

- Installed in 2017.
- Repositioned in 2019.

The octupoles impact starts to be visible once we reach the beam size ~ 40 nm.

- Octupoles BBA was performed multiple times in the past.
  - → Using dipole component (with IPBPMs). ~ 2017/2018
  - → Using quadrupole component (with IPBSM). ~ 2019/2020
- No beam size reduction observed with octupoles yet.

A. Pastushenko, 2023.03.09, in ATF3 kickoff meeting

Project collaboration meeting

ATF3 Kick-Off meeting

8 Mar 2023, 09:00 → 9 Mar 2023, 20:45 Europe/Paris

18/3-008 - CLIC Meeting room (CERN)

Angeles Faus-Golfe (IJClab IN2P3 CNRS-Universite Paris-Saclay (FR)), Steinar Stapnes (CERN)

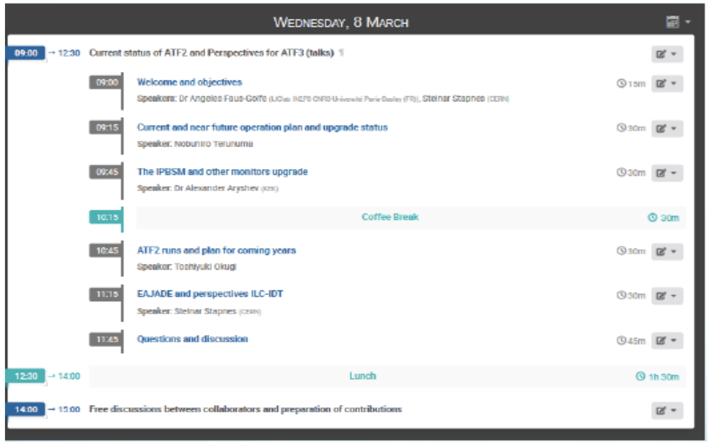
Description

After two years without having abroad collaborators participation in ATF2, it is again possible for abroad collaborators to contribute to the ATF2 experimental program. During these two years there have been changes and improvements in the ATF2 beamline and more maybe possible with the recent planning of the "International Technology Network - R&D for future accelerators" prior to the ILC pre-lab (detailed info in the docs attached) and the recent approval of the EAJADE (Europe America Japan Accelerator Development Exchange Programme) EU project starting in March 2023.

In order to discuss and plan these contributions we will have an ATF2 collaboration meeting 8-9 March 2023 at CERN in hybrid format (in person participation is highly recommended). We encourage your contribution.

re-start participation of oversea collaborators to ATF after covit-19

Outline



WEDNESDAY, 8 MARCH

09:00 → 12:30 Current status of ATF2 and Perspectives for ATF3 (talks)

09:00 Welcome and objectives — 15m
Speakers: Dr Angeles Faus-Golfe, Steinar Stapnes (CERN)

09:15 Current and near future operation plan and upgrade status — 30m
Speaker: Nobuhiro Terunuma

09:45 The IPBSM and other monitors upgrade — 30m
Speaker: Dr Alexander Aryshev (KEK)

10:15 Coffee Break — 30m

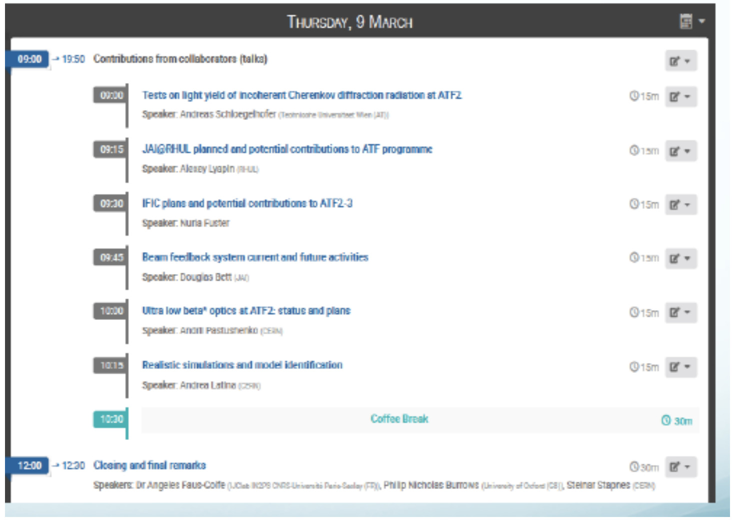
10:45 ATF2 runs and plan for coming years — 30m
Speaker: Toshiyuki Okugi

11:15 EAJADE and perspectives ILC-IDT — 30m
Speaker: Steinar Stapnes (CERN)

11:45 Questions and discussion — 45m

12:30 → 14:00 Lunch — 1h 30m

14:00 → 15:00 Free discussions between collaborators and preparation of contributions



THURSDAY, 9 MARCH

09:00 → 19:50 Contributions from collaborators (talks)

09:00 Tests on light yield of incoherent Cherenkov diffraction radiation at ATF2 — 15m
Speaker: Andreas Schloegelhofer

09:15 JAI@RHUL planned and potential contributions to ATF programme — 15m
Speaker: Alexey Lyapin (RHUL)

09:30 IFIC plans and potential contributions to ATF2-3 — 15m
Speaker: Nuria Fuster

09:45 Beam feedback system current and future activities — 15m
Speaker: Douglas Bett (JAI)

10:00 Ultra low beta* optics at ATF2: status and plans — 15m
Speaker: Andrii Pastushenko (CERN)

10:15 Realistic simulations and model identification — 15m
Speaker: Andrea Latina (CERN)

10:30 Coffee Break — 30m

12:00 → 12:30 Closing and final remarks — 30m
Speakers: Dr Angeles Faus-Golfe, Philip Nicholas Burrows, Steinar Stapnes (CERN)

Articles, conference talks & posters related to the TYL project

- An important milestone has been the **LCWSs on March 2021 and October 2021** both in virtual, and the next LCWS2023 in person at SLAC 15-19 May 2023.
- A report summarizing the experimental program carried out during this period at ATF2 has been made and presented in the **ATF review last September** https://agenda.linearcollider.org/event/8626/. In particular for the ultra-low β^*_y sizes a CERN report CERN-ACC-NOTE-2020-0006 and a referred paper PRAB 23, 071003 (2020) have been published.
- A **technical report** document has also being prepared in the framework of the **ILC-IDT WG2** https://agenda.linearcollider.org/event/9047/ The report has been reviewed on February 23 - March 18, 2021 by an International committee (Deepa Angal-Kalinin,Camille Ginsburg, Mike Harrison, Erk Jensen, Heung-Sik Kang, Eugene Levichev, Tor Raubenheimer, Naruhiko Sakamoto, Nick Walker).