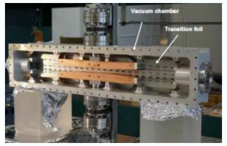
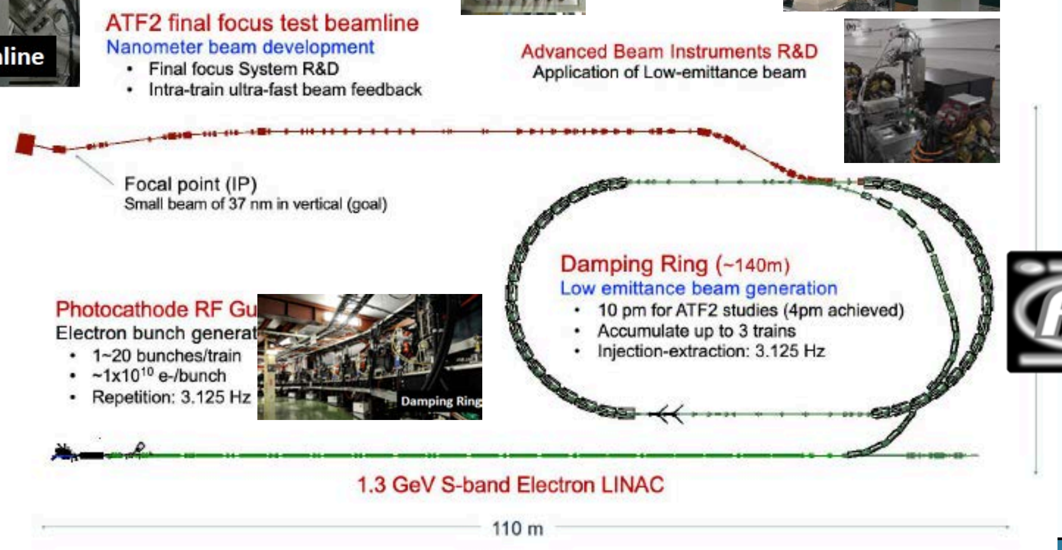
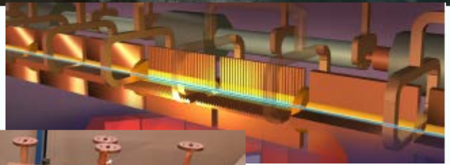






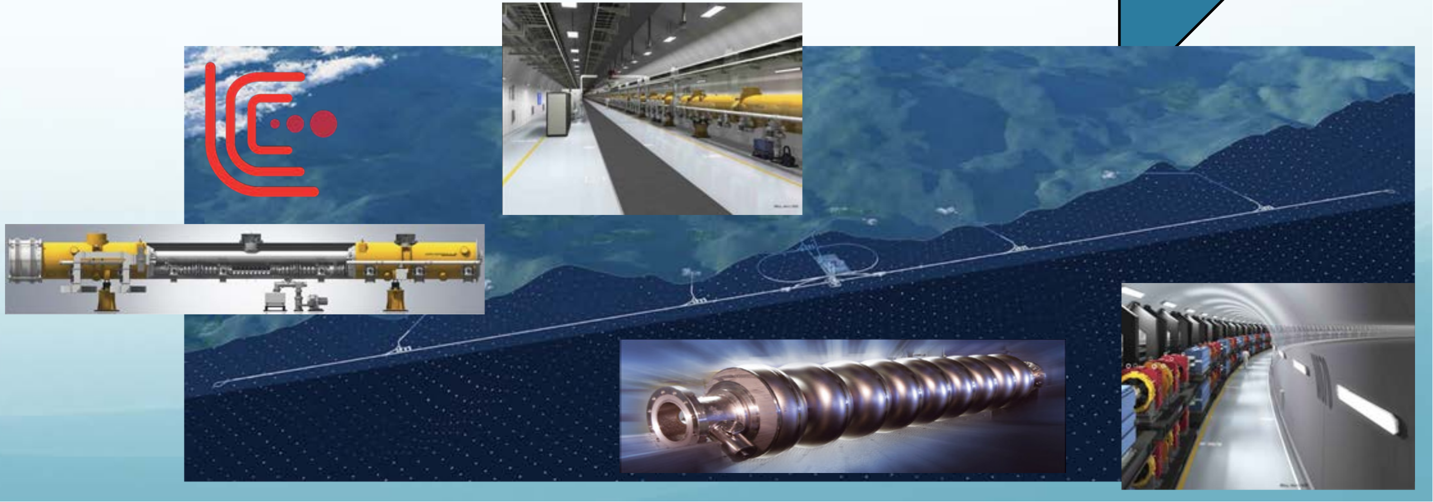
ATF 3

ATF3 and ILC-IDT WG2: ILC FFS

A. Faus-Golfe
on behalf of ATF collab.

IJCLab Irène Joliot-Curie
Laboratoire de Physique des 2 Infinis

CNRS IN2P3 Les deux infinis

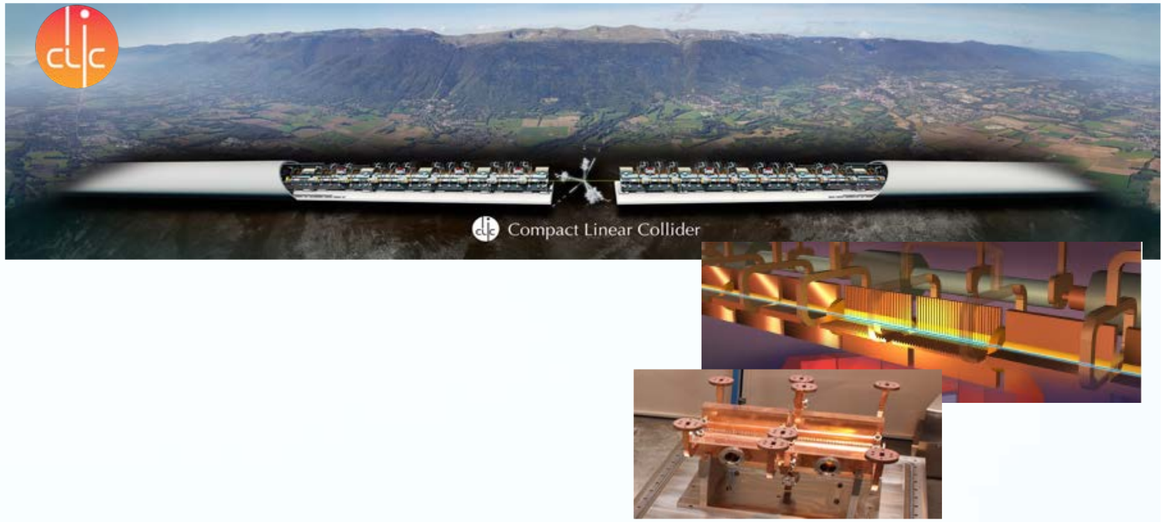


LCWS2021

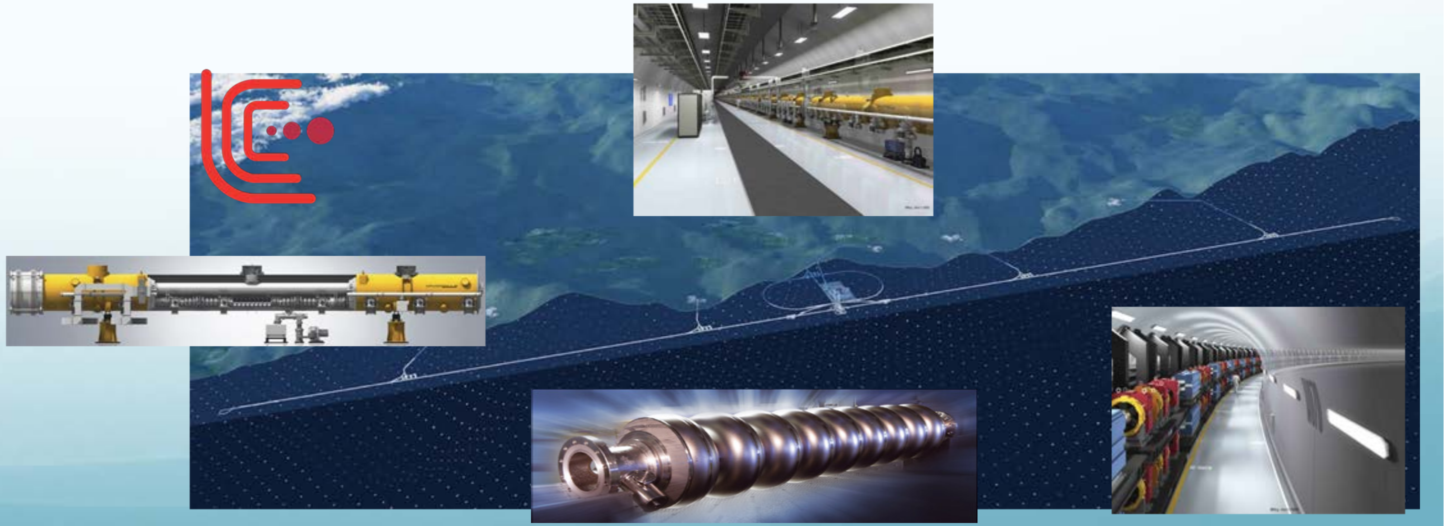
15-18 March 2021

Outline

- ATF3
  - Objectives and Collaboration
- ILC-IDT WG2: BDS – ILC FFS
  - Goals and Tasks



ATF2 final focus test beamline



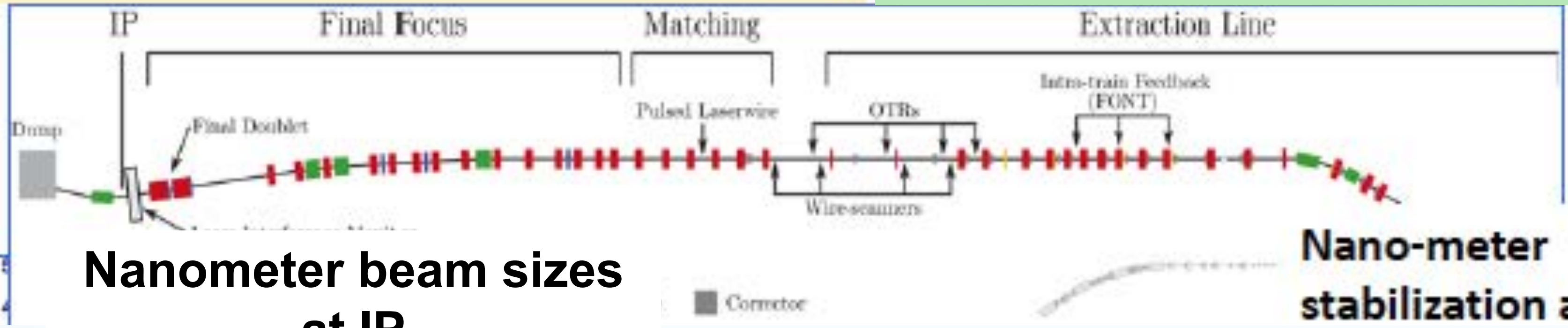
ATF2 goals and achievements

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)

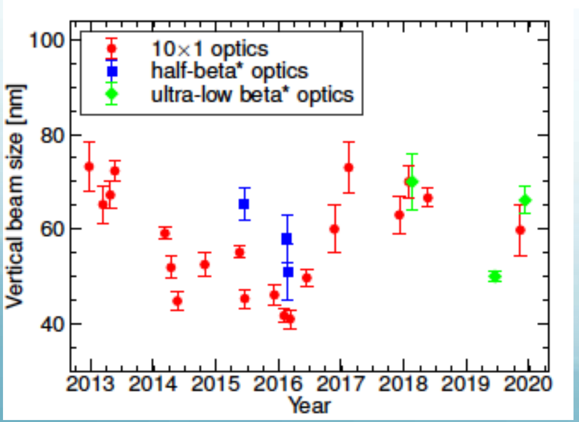
Goal 2: 2 nm beam stabilization at ATF2 IP, (much harder than nm stabilization in collision at ILC).

- **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.**

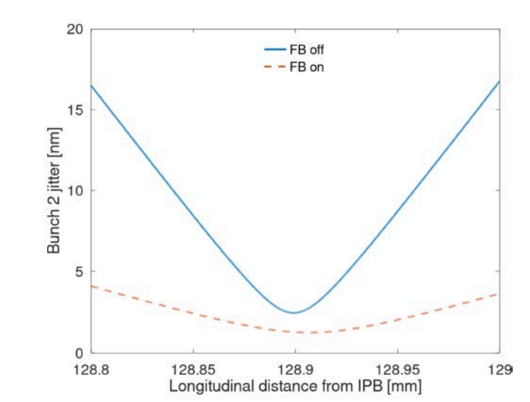


Nanometer beam sizes at IP

Nano-meter stabilization at IP

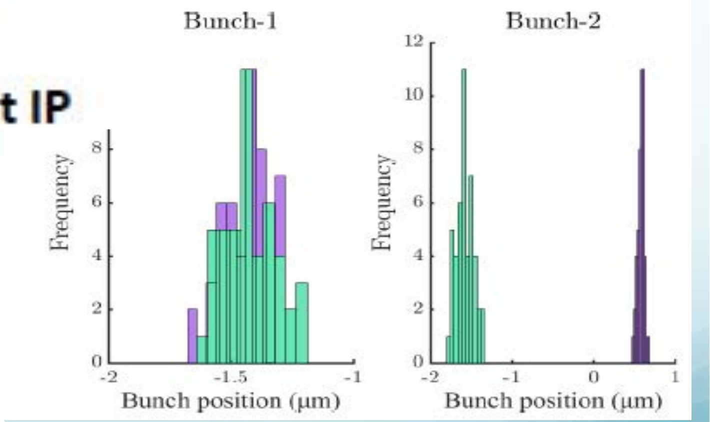


Small beam sizes were obtained with beam intensities of 0.5-1.5 10^9 e^- /bunch (10^{10} design value) and reduced aberration optics ($10\beta_x^* \times \beta_y^*$)



Predicted vertical position jitter with FB on-off

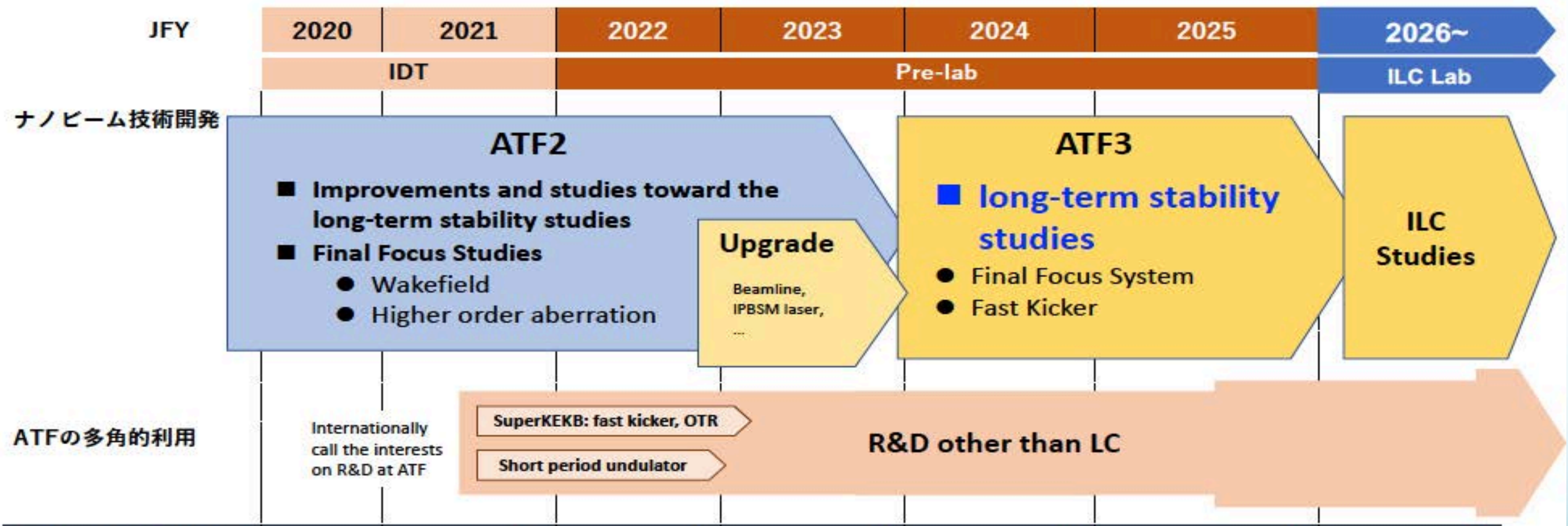
Distribution of bunch positions measured at IPB, with two-BPM FB off (green) and on (purple)



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.**

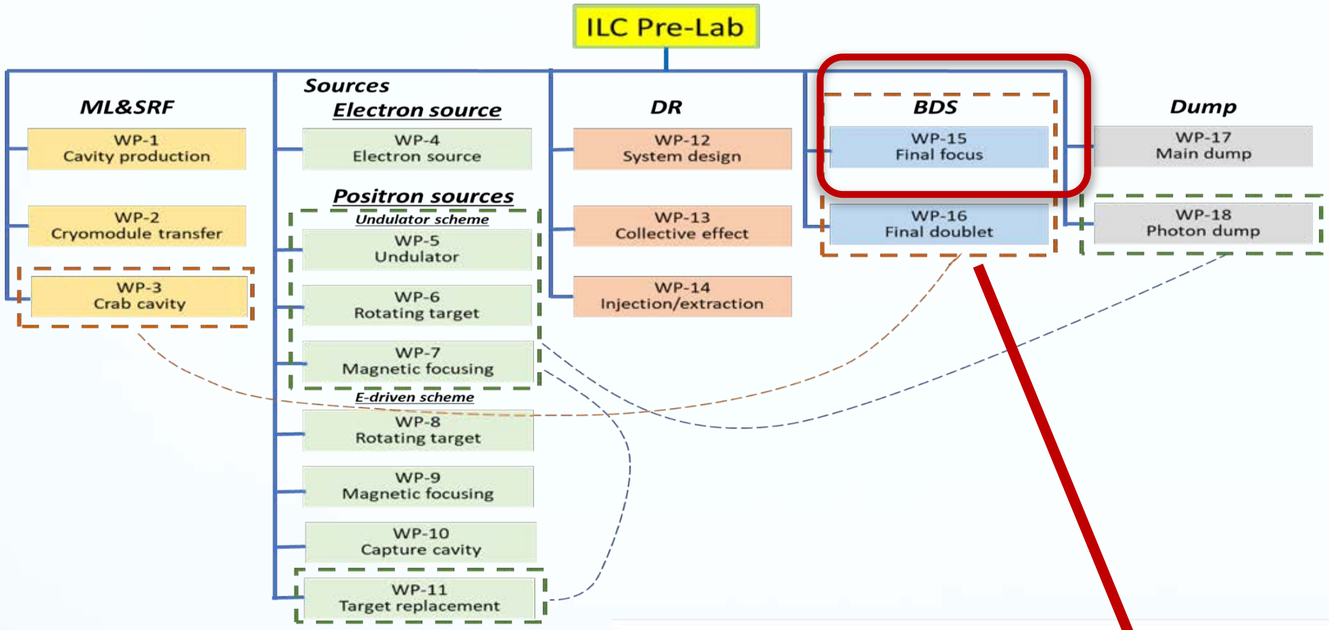
Tentative Plan of ATF (should be updated by international discussions) 2020/10/30

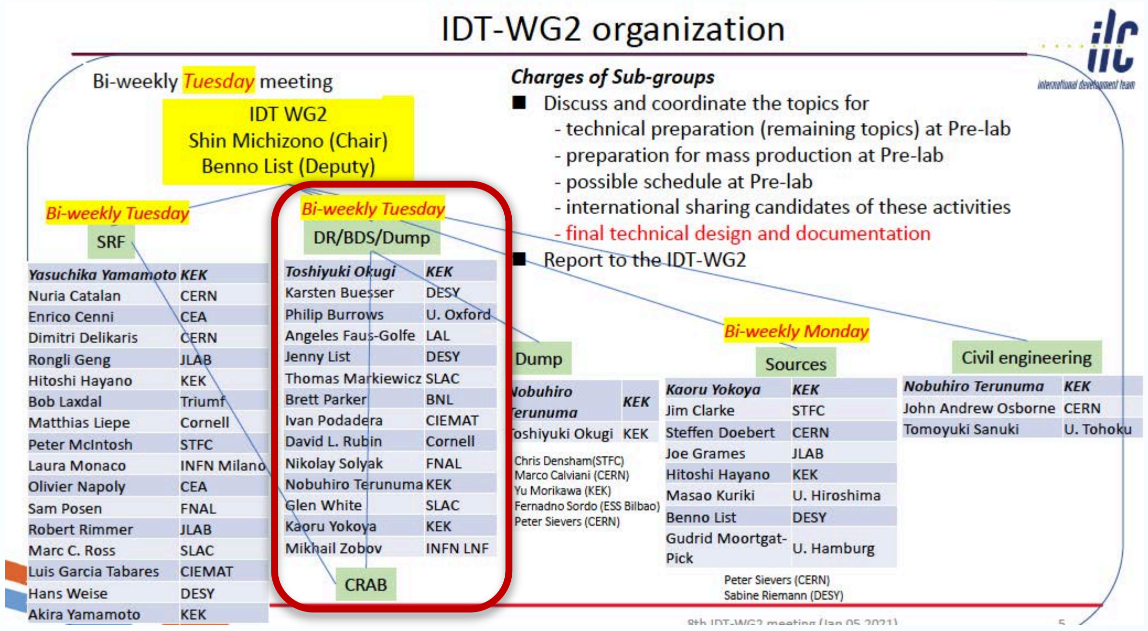


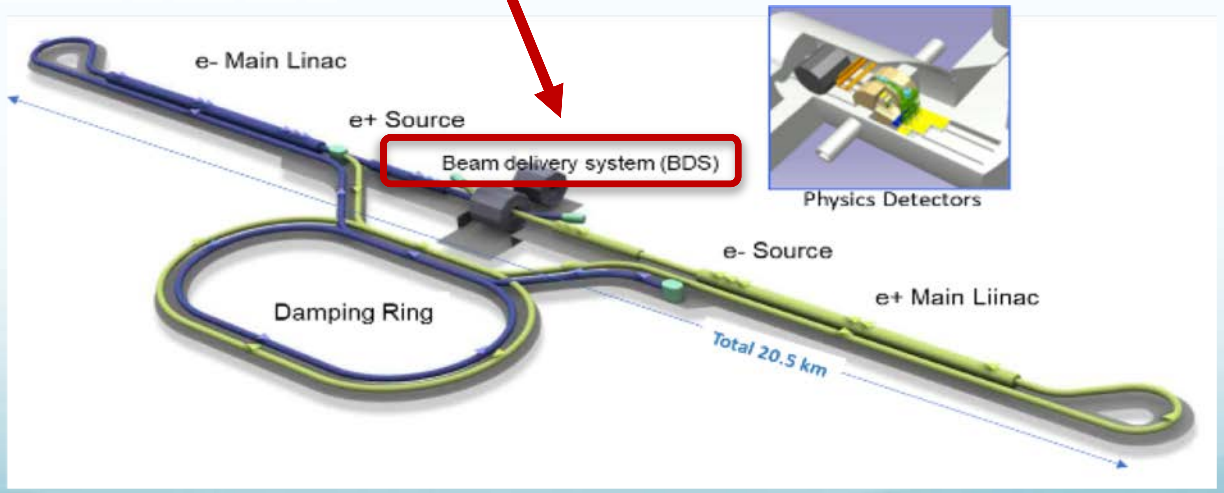
		2020	2021	2022	2023	2024	2025	2026~
Operation weeks		5	15	15	20	20	20	20
Electric power	MWh	3275	5525	5525	6650	6650	6650	6650
Estimated Budget	-	-	-	-	-	-	-	-

Translated in English for your reference. Detailed budget profile was omitted here but presented to DG. N.Terunuma

ILC-IDT WG2 Technical proposal: DR and BDS



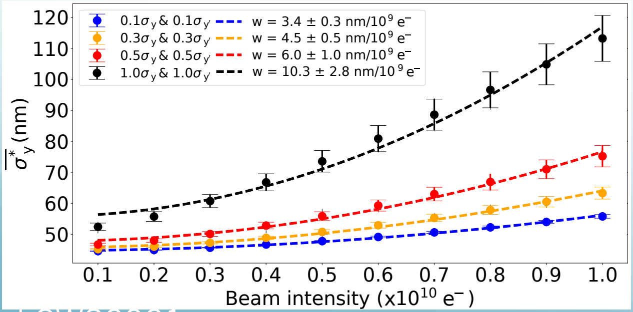




ILC FFS Technical Preparation Plan: Tasks

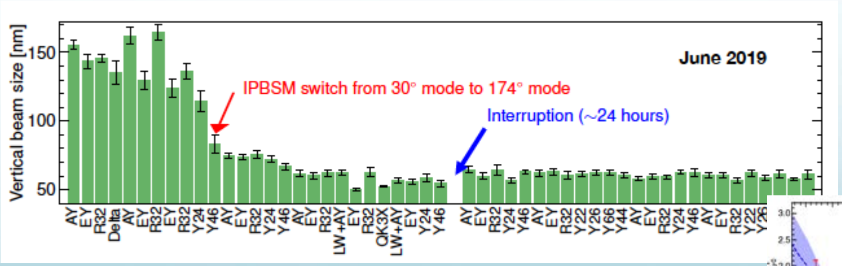
ILC-FFS Tasks : Maximize Luminosity potential of ILC	
T1: **ILC-FFS system design**	**T1.1**: Hardware optimization
	T1.2: Realistic beam line driven / IP design
T2: ILC-FFS beam tests	**T2.1**: Long-Term stability
	T2.2: High-order aberrations
	T2.3: R&D complementary studies

Long Term stability

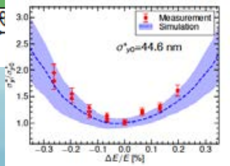


Intensity dependence studies

High-order aberrations

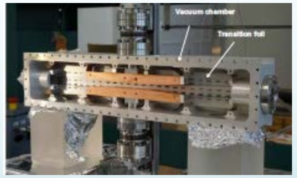


Ultra-low β* studies

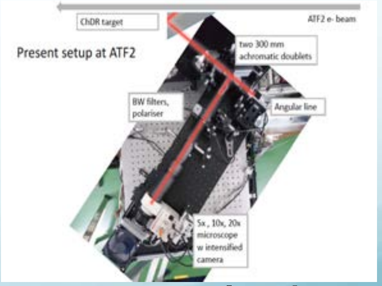


Energy bandwidth

Instrumentation R&D



Collimator



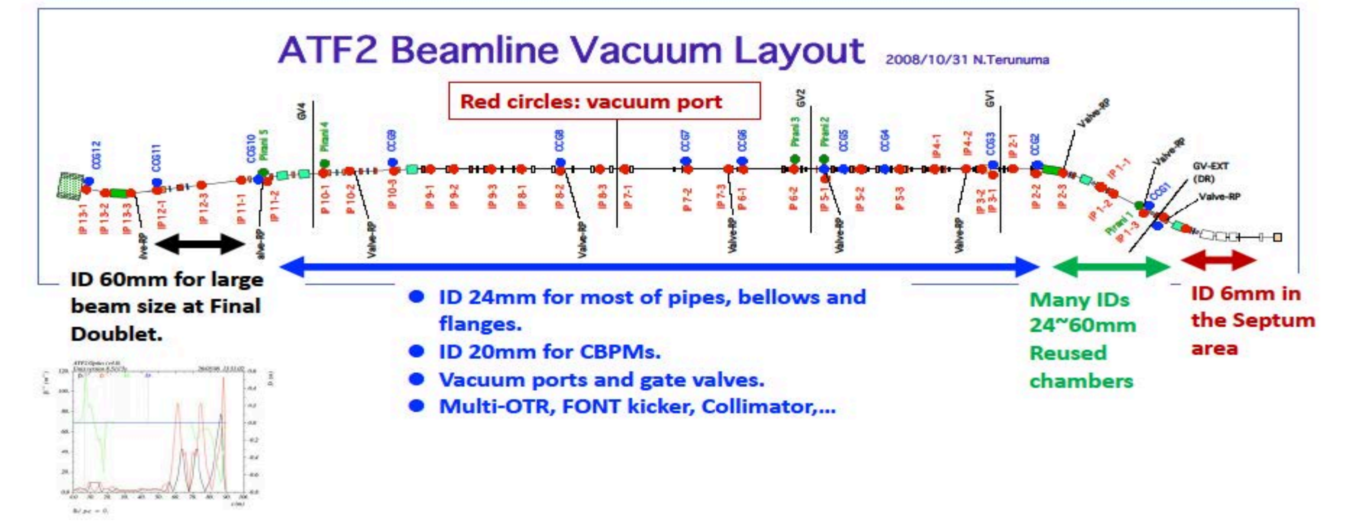
Incoherent Diffraction Cherenkov Radiation Monitor

Waveguide BPM

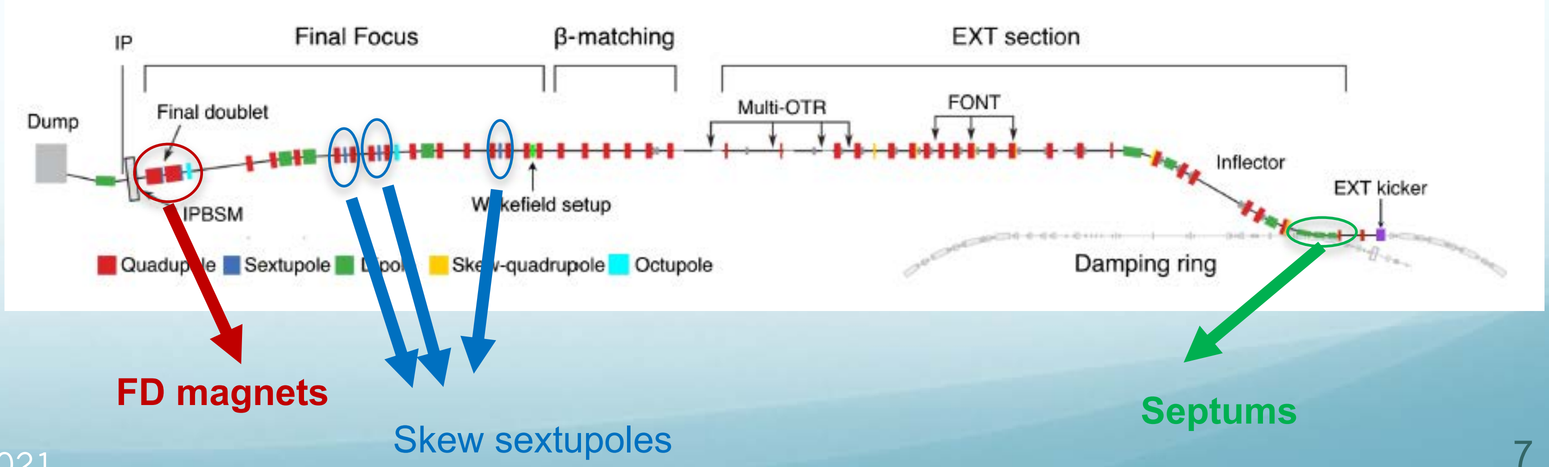
T1.1 ILC FFS system design: Hardware optimization

Why this is needed?

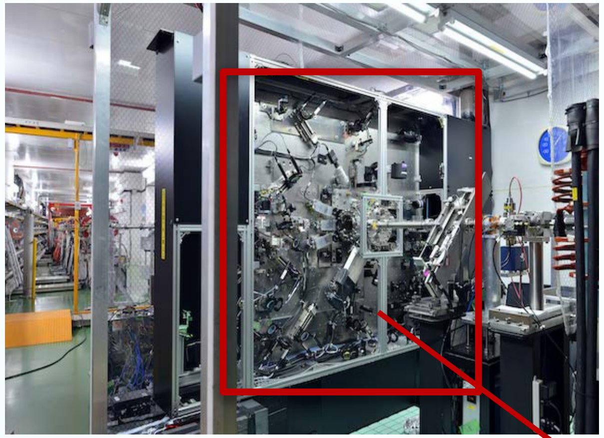
- **Vacuum Chambers**
  - Most of the present EXT-FF vacuum chambers are reused /duplicated
  - The standard ID beam pipe is 24 mm, but due to additional features, the special sections use different cross sections.
  - Wakefields on the EXT line was not taken seriously as the beam passed once, while that on the DR was considered because of the multi-turn of 2 Hz



- **Magnets**
  - Final Doublet recup from SLAC
  - Skew sextupoles poor assembling
  - Septums not optimized



Why this is needed?

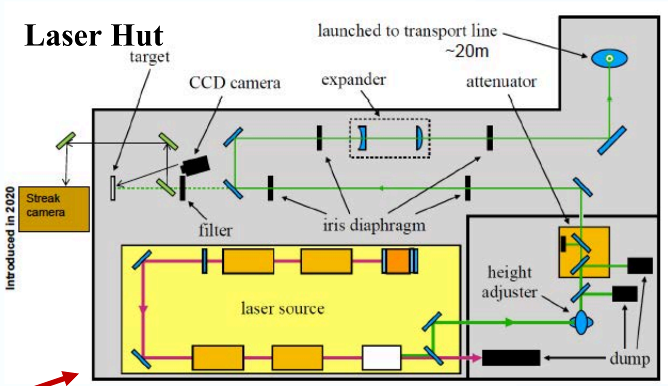


IPBSM (nanometer beam size monitor)

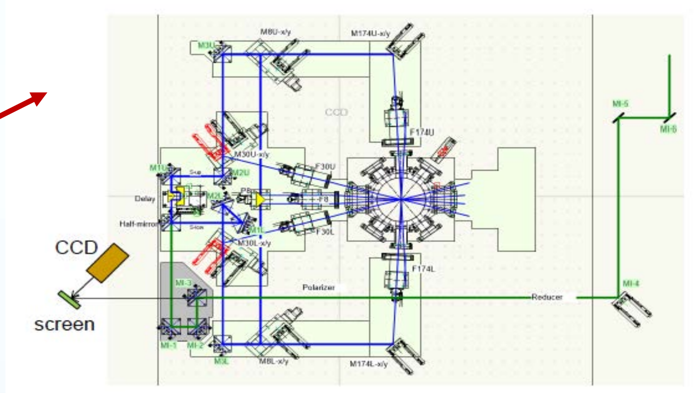
IP-BSM is not just a laser

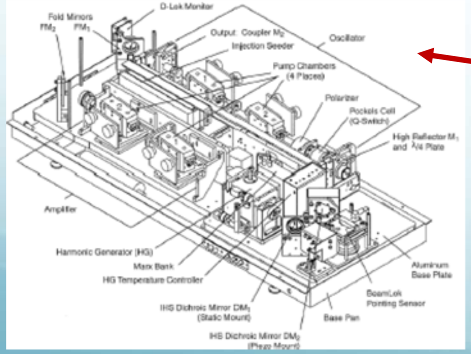
➢ IP-BSM Laser current problems:

- Stability (Energy, Modes = fringe pattern)
- Laser beam parameters reproducibility and resolution
- Nd:YAG Laser aging (tuning, dust, etc)
- Laser Transport Line (LTL) and laser FF-IP tuning and optimization

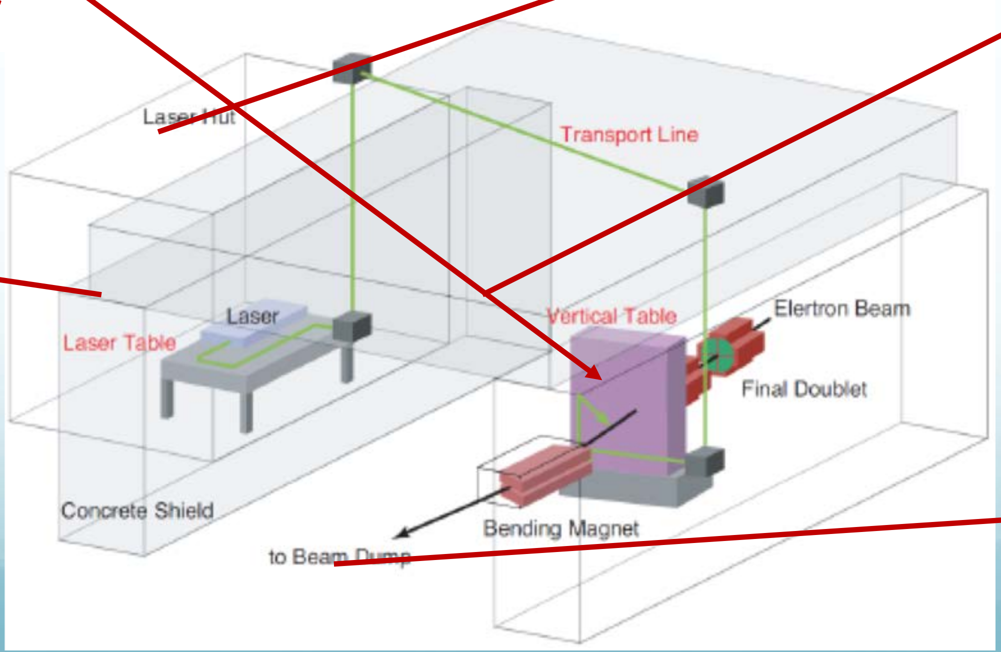


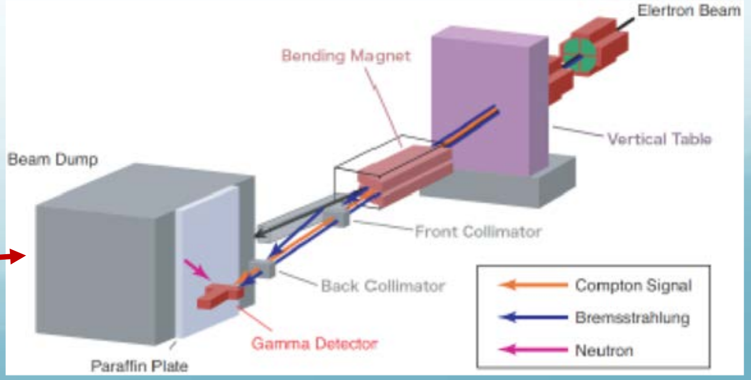
Vertical Table





Spectra-Physics Quanta-Ray PRO 350





T1.1 ILC FFS System design: Hardware optimization

- **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)

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

- **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.

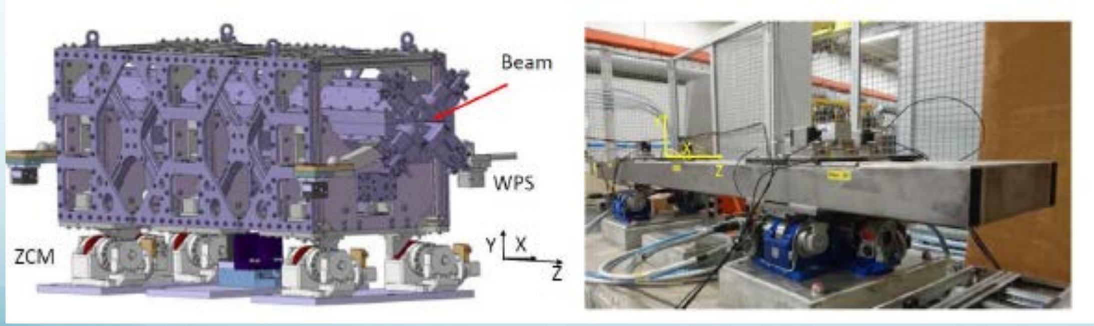
T1.1 ILC FFS System design: Hardware optimization

➢ 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

➢ FD vibration girder

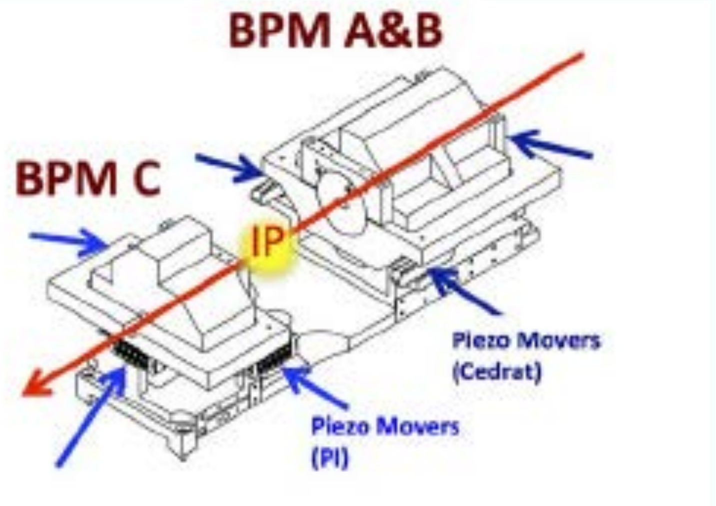
- Girder for all the final elements coupled with a global positioning system



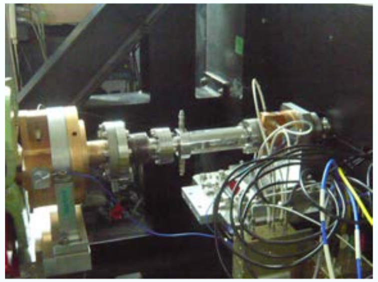
CLIC : Type 4 MBQ and stabilization system mounted on cam movers (left) and test setup including ZCMs, follower girder and local coordinate system (right).

➢ IP-BPMs

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



Layout of the three Cavity BPMs at ATF2-IP



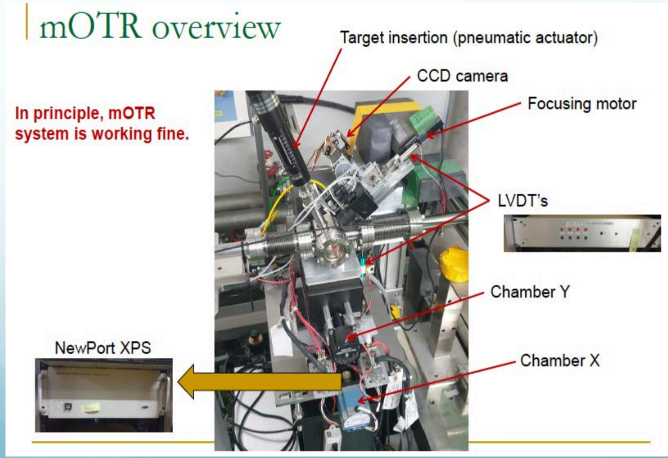
Compact IP kicker

➢ FONT IP feedback

- Font kicker to improve wakefields

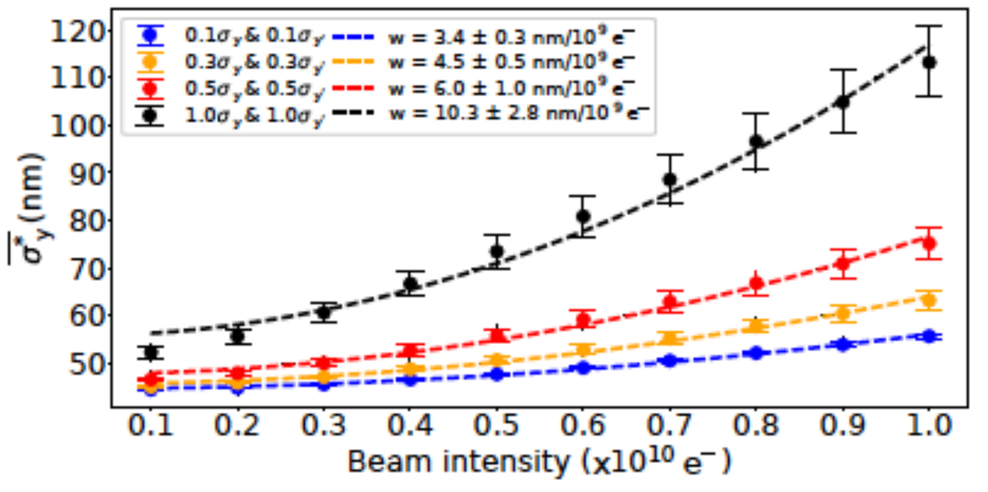
➢ Multi-OTR system

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



T1.2 ILC FFS system design: Realistic beam line driven / IP design

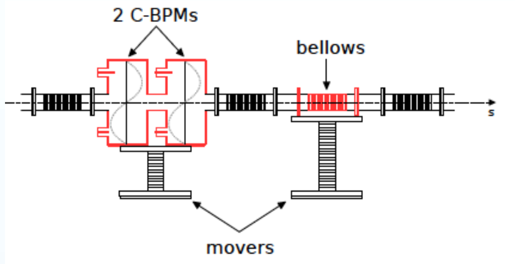
- ➢ **Driven realistic beam dynamics specifications**
  - o Realistic simulations should drive the design choices and the goals
    - Jitter assessment/measurement
    - Magnet errors
    - Wakefields sources (hardware change)
  - o Establish the scaling for ILC in terms of intensity



$$(\sigma_y^*)^2 = (\sigma_{y0}^*)^2 + w^2 q^2$$

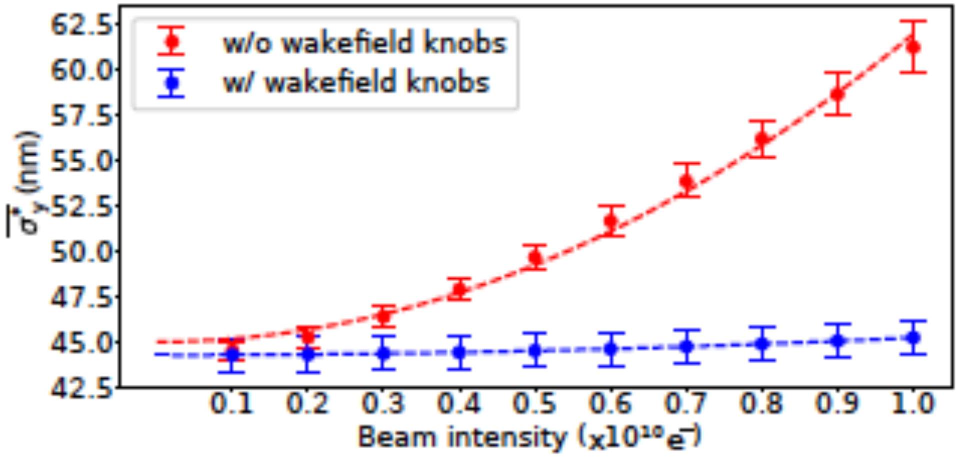
w: intensity dependence parameter

- ➢ **Vibration mitigation for new FD**



ATF2 wakefield knobs system between QD10BFF and QD10AFF

- ➢ **Instrumentation assessment**
  - o CBPMs calibration and resolution
  - o Multi-OTR, screens,...



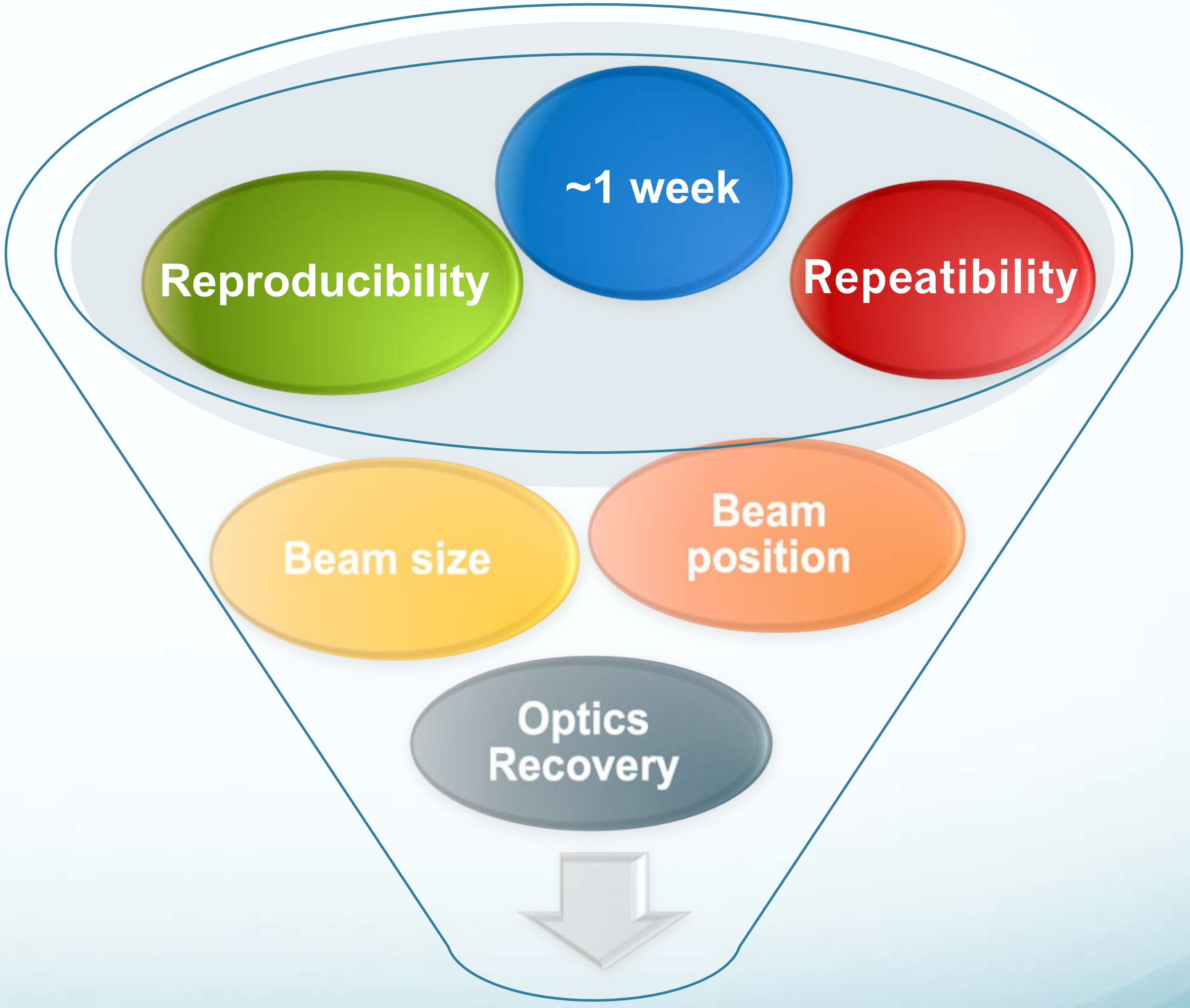
- ➢ **IP Instrumentation assessment**
  - o IP-BSM
  - o IP-BPMs

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

Long-term stability is not simply the length of continuous operation, but a combination of:

- Beam performance stability (size and position)
- Repeatability and Reproducibility of performances (in separate periods including recovery of the optics)

in about one week period.



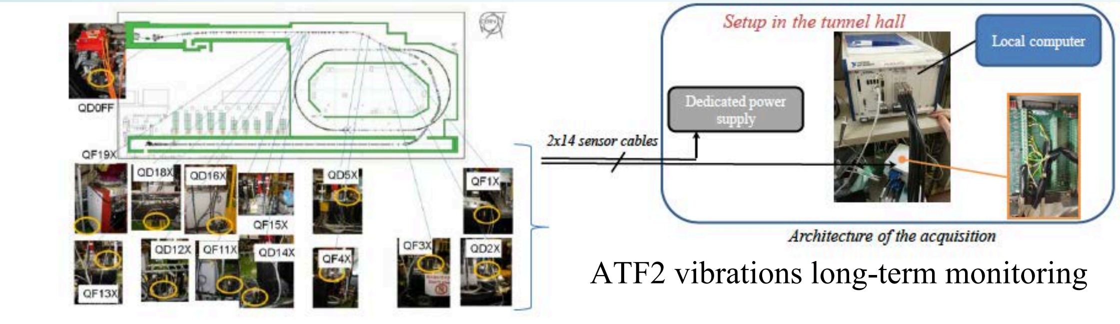
Long-term stability

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**

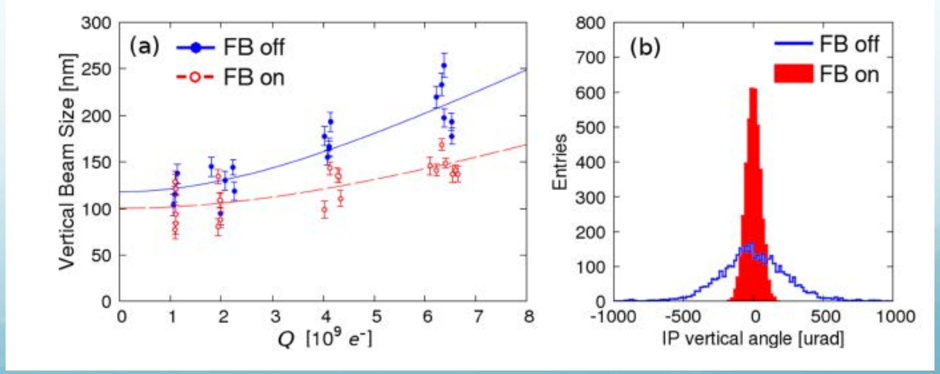


ATF2 vibrations long-term monitoring

- **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

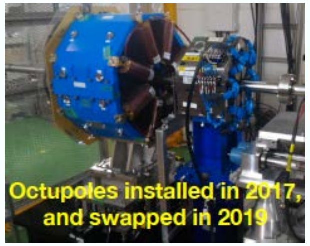


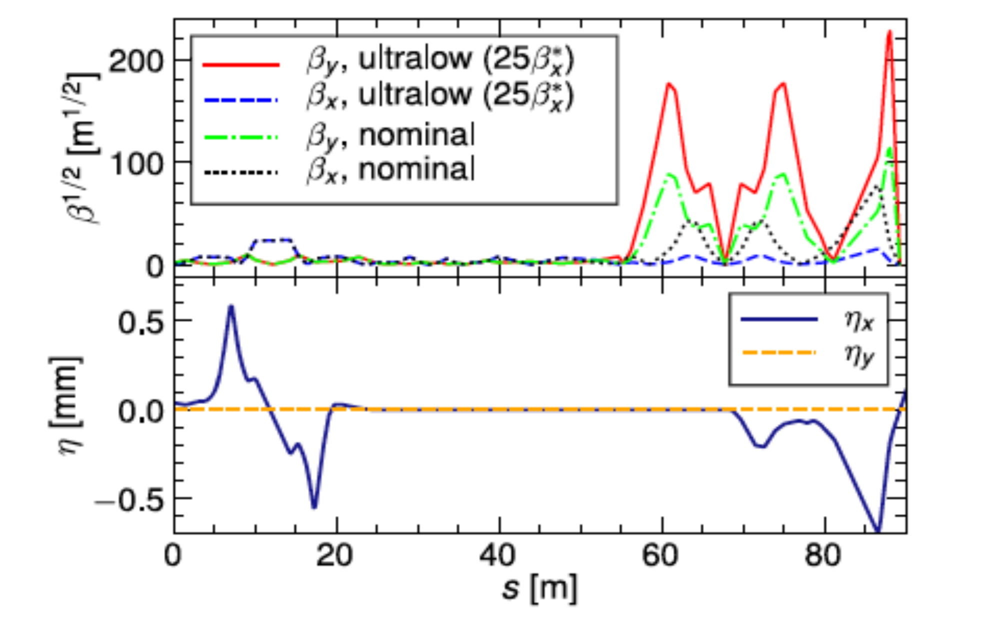
Two bunch operation

T2.2 ILC FFS beam tests: High-order aberrations

➢ **Design (β_x^* x β_y^*) optics**

- Automated steering procedures and basic tuning algorithms (like envisaged for ILC)
- 2nd order correction knobs assessment (sextupoles and skew, octupoles)
- Energy bandwidth measurements

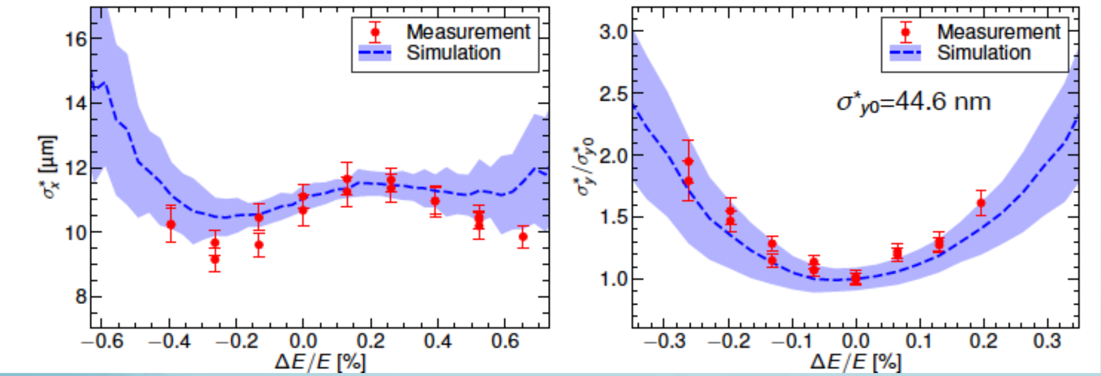




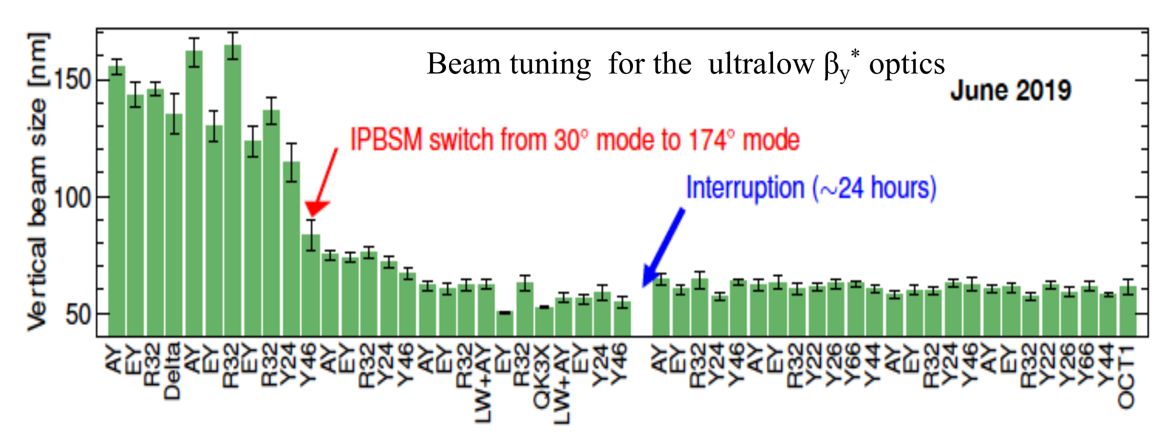
➢ **Ultra-low β_y^***

- Octupoles need and alignement
- Longer L* (move FD to the right /IP towards the dump)

Defined as a 10% increase of σ_{xy}^* for mono-energetic beam



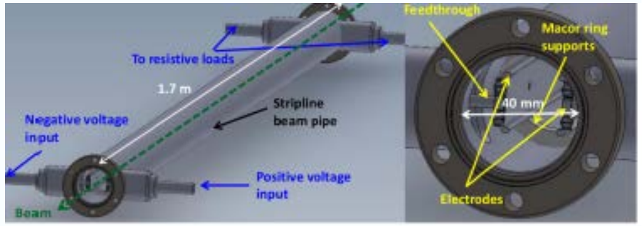
H/V Momentum bandwidth measurement



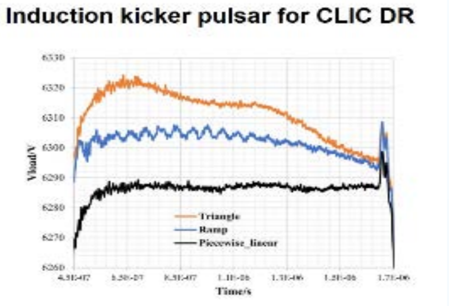
T2.3 ILC FFS beam tests: R&D complementary studies

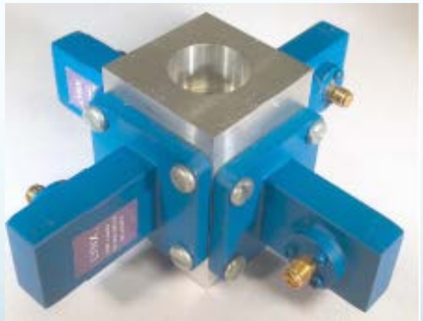
- **ILC DR injection/extraction kickers long term stability**
  - Fast kicker
  - E-driven kicker

- **New CBPMs ideas:**
  - ILC type cavities with Integrated electronics from Instrumentation Technologies
  - Off-the-shelf (FMB-Oxford-Instrument Technologies) triplet of CBPMs
  - Low-wakefield wavegide BPMs, aperture/resolution issues to be estimated (sensitivity degrades as 1/a)

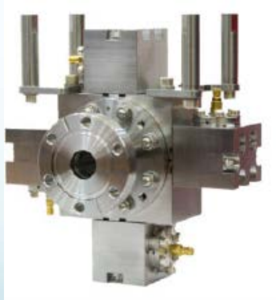


CLIC DR induction kicker





Waveguide BPMs



Complete off-the-shelf CBPM system (FMB-Oxford - Instrumentation Technologies)

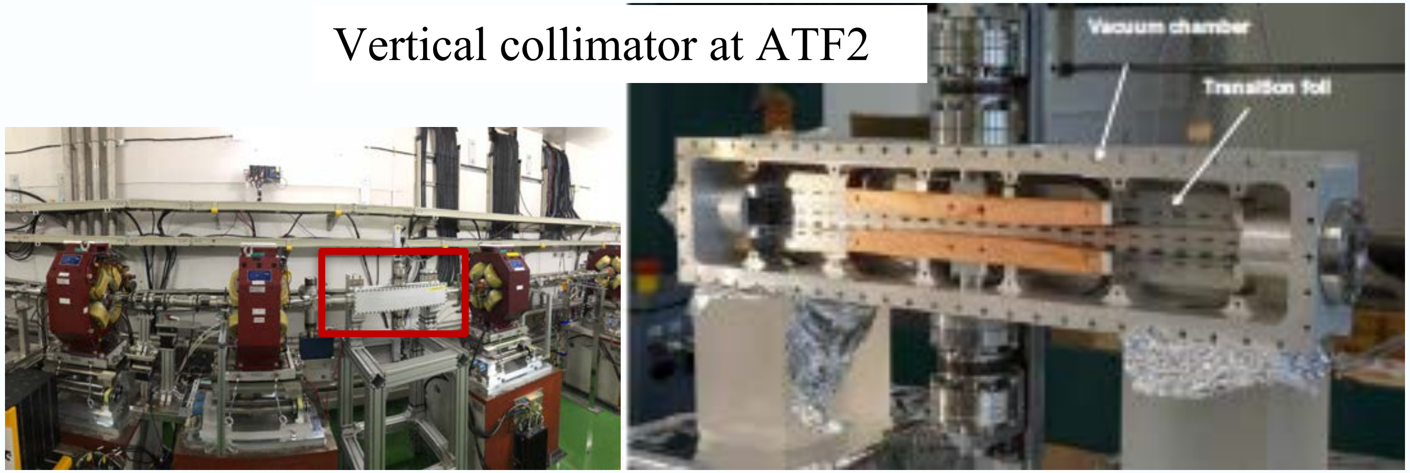
T2.3 ILC FFS beam tests: R&D complementary studies

- **Collimation issues for ILC**
  - Wakefiled impact
  - Design options

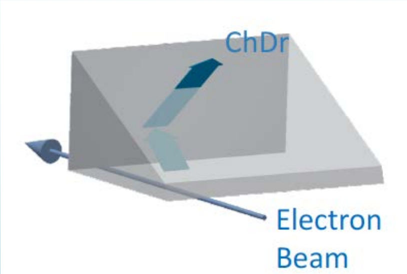
- **New wakefields setups**
  - Passive corrugated structures

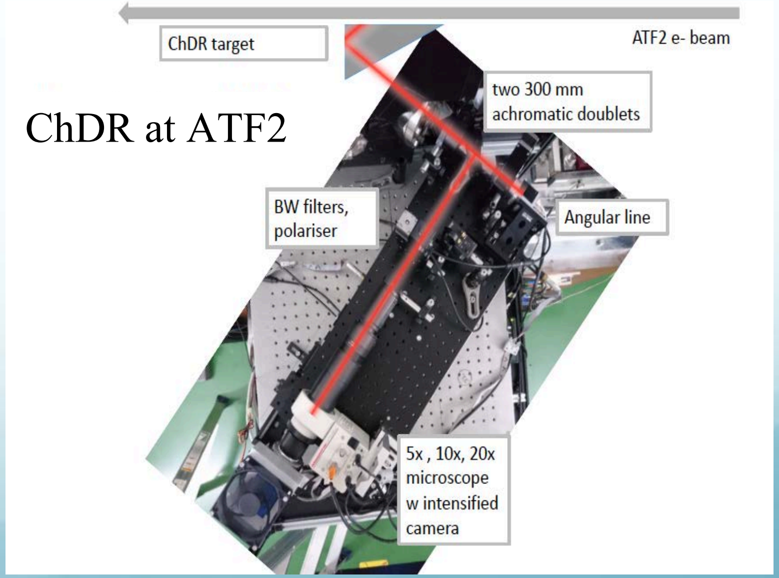
- **OTR, ODR and ChDR beam size monitors**
  - OTR at shorter UV wavelength (sub-micron resolution)

- **ML technique** applied to speed up operational issues



Vertical collimator at ATF2





ChDR at ATF2

Summary

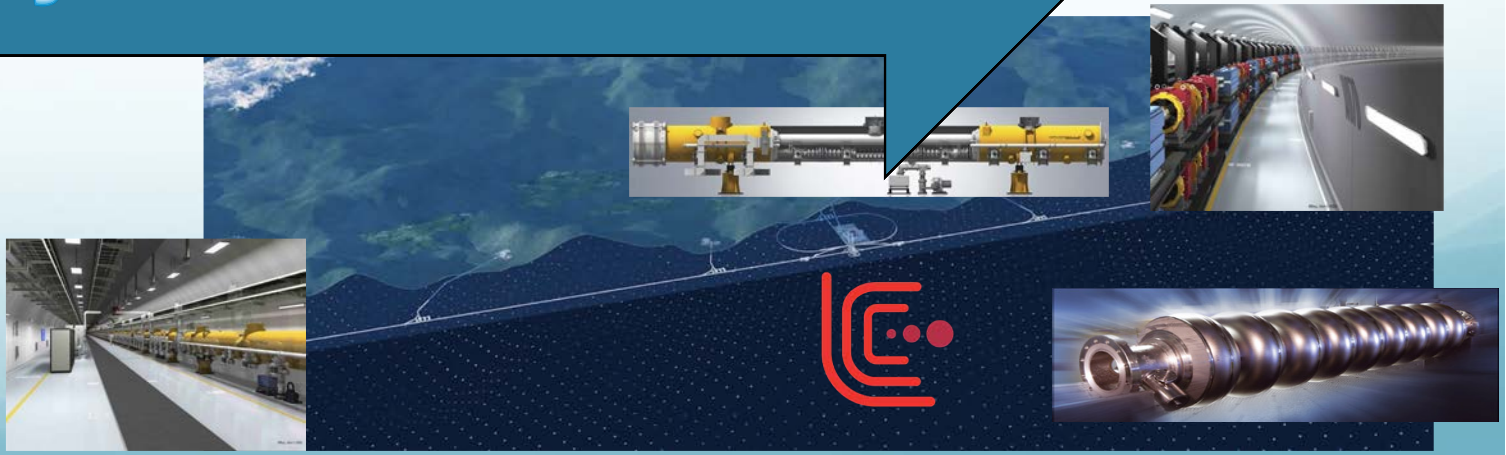
➢**ATF3** plan is to pursue the necessary **R&D** to **maximize** the **luminosity potential** of **ILC**. In particular the assessment of the **ILC FFS system** design from the point of view of the **beam dynamics aspects** and the technological/hardware choices and the **long-term stability** operation issues

➢A detailed **R&D Plan** in the framework of the **ILC-IDT Technical Preparation Plan** has been made for the **DRs** and **BDS** during the **ILC pre-lab**.

ILC-FFS Tasks: Maximize Luminosity potential of ILC		**Timeline**				**During construction period**
		Y1	**Y2**	**Y3**	**Y4**	
T1: ILC-FFS system design	**T1.1**: Hardware optimization	■	■	■		NO
	T1.2: Realistic beam line driven / IP design	■	■	■		NO
T2: ILC-FFS beam tests	**T2.1**: Long-Term stability			■	■	YES
	T2.2: High-order aberrations			■	■	YES
	T2.3: R&D complementary studies			■	■	YES

➢This ILC pre-lab period will be of paramount importance for the **training of young acceleration physicist generation** that will play a **key role** in the early stages of **ILC** commissioning and operation.

Thanks for your attention



	Imperfections / issues	Detrimental effect	Potential cures (by design or hardware improvement)	Potential cures (during operation)
Static	Dipole / quadrupole misalignment	• Introduces unwanted dispersion (emittance growth) • Deflects the beam • Introduces coupling	• Careful pre-alignment • Add a dipole corrector, or • Put quads on movers • Add skew quads to correct coupling	• BBA techniques • If movers are available, align the quads
Static	Bpm misalignment	• Causes wakefields effects • Falses beam-based alignment algorithms	• Reduce wakefields • Careful pre-alignment • Put bpms on movers	• DFS, WFS • If movers are available, align the bpms
Static	Poor bpm resolution	• Fools beam-based alignment algorithms	• Better resolution	• Statistical averaging (but suffers from jitter)
Static	Sextupole misalignment	• Introduces coupling, beta-beating	• Careful sextupole pre-alignment • Put sextupole on movers	• If movers are available, align the sextupoles
Design	Presence of sextupoles (and octupoles)	• Introduces nonlineartities • reduce the momentum acceptance, etc.	• Revisit the optics to reduce strength • Add skew quadrupoles to correct coupling	• Tuning knobs • Beam-based coupling correction techniques
Design	Lack of diagnostics	• Forces blind operation	• Careful design of diagnostic sections	• Use the diagnostics
Design	Long bunches	• Amplifies wakefield effects	• Bunch compressor [likely not possible]	
Dynamic	Beam jitter	• All of the above	• Reduce jitter at the source	• Feedback systems
Dynamic	Ground motion / vibrations	• All of the above	• Stabilization	• Stabilization

Long term stability goals "quantification" / Criteria for success

In this context, **"long-term stability test"** means, keeping the beam **stable, with repeatability, reproducibility over separate periods, including recovery of the optics,** during **1 week**. To achieve this objective a period of at **least 2-3 years** will be necessary.

- **Long-term stability** of beam size and position in ATF2 have **not yet** been **evaluated** systematically.

- A **monitoring** is needed to evaluate and quantify properly the **long-term stability**, including the **beam intensity** dependence and **higher-order aberrations** effects between others.

A **"comprehensive test"** of the long term stability is **needed** to realize **ILC**, including quantitative evaluation of beam intensity dependence, correction of higher-order aberration effects, and development and implementation of stable monitor systems.

Furthermore this period will be of paramount importance for the **training of young acceleration physicist generati**on that will play a **key role** in the early stages of **ILC** commissioning and operation.

Perspectives: ATF3

A. Aryshev

➢ 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 (green) / Intermediate (blue) / Difficult (red)