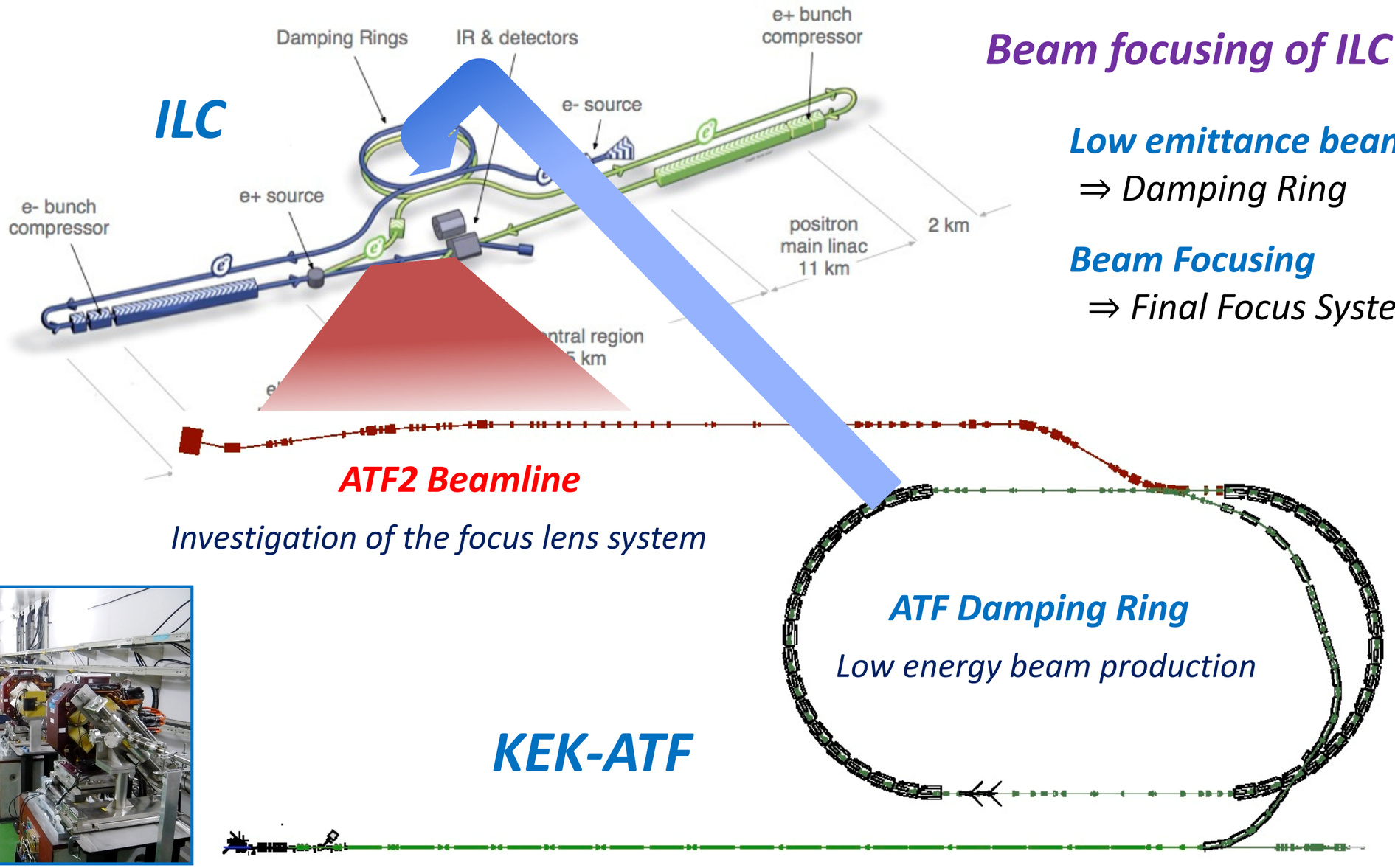
ATF2/3 planning and status

Overview of ATF2/ATF3 project
Recent researches at ATF
ATF Beam schedule of JFY2022

Toshiyuki OKUGI, KEK
2022/05/12
CLIC project meeting

Accelerator Test Facility (ATF)



Beam focusing of ILC

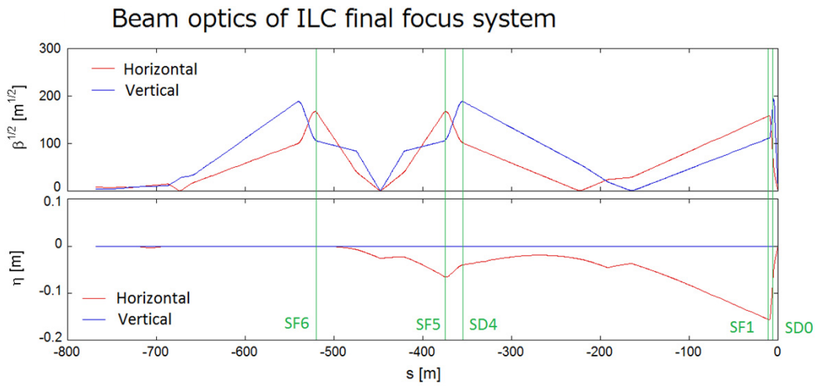
Low emittance beam

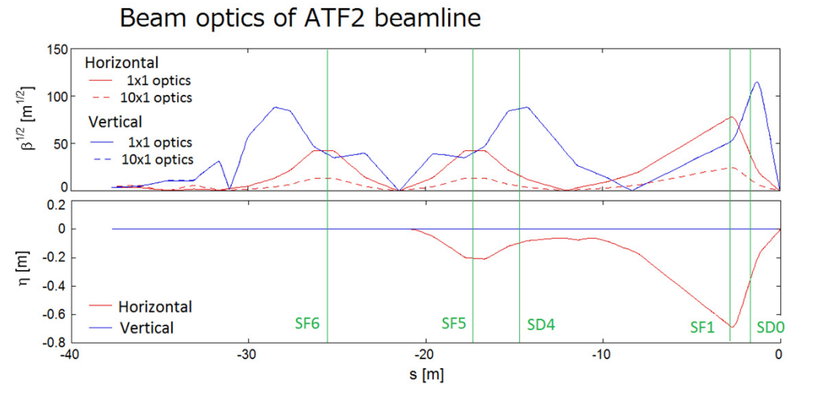
⇒ *Damping Ring*

Beam Focusing

⇒ *Final Focus System*

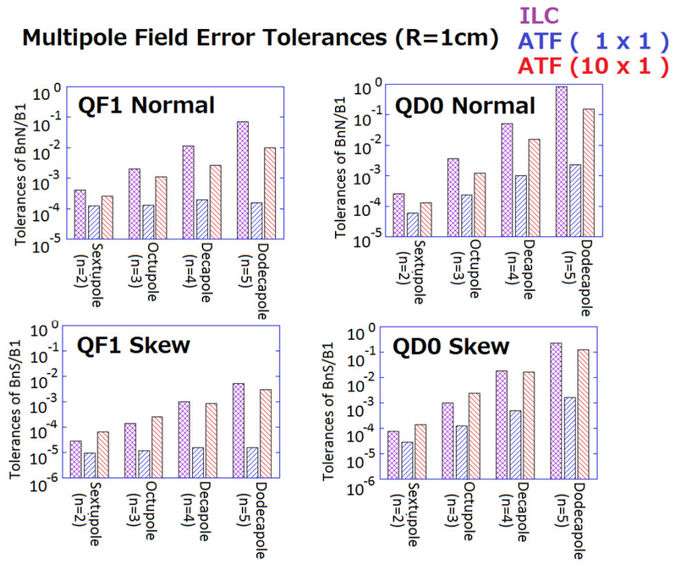
ATF2 Goal 1 *: Establish the beam tuning method for ILC final focus with same optics and compatible beam line tolerance*



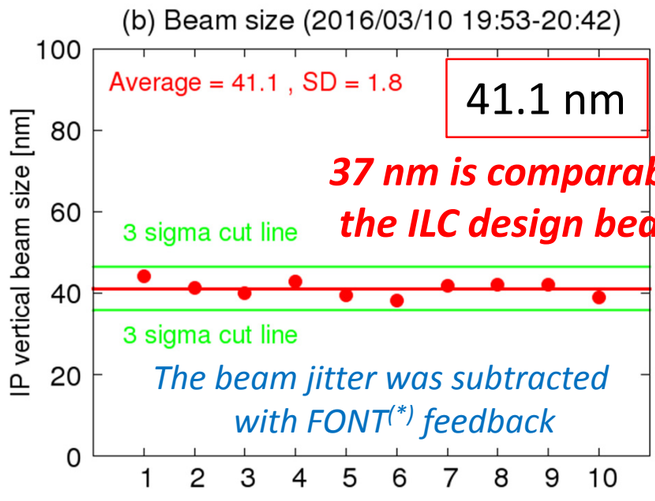


ATF2 Beam Optics

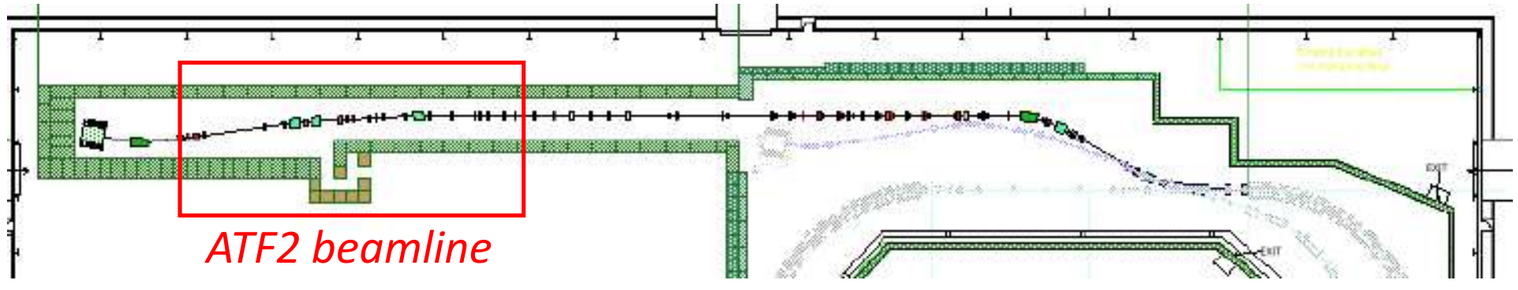
- ✓ *ILC final focus system and ATF2 beamline are both based on the Local Chromaticity Correction.*
- ✓ *Same magnet arrangement*



Minimum beam size (2016/03/10)



(*) Feedback On a Nanosecond Time scale, developing by Oxford Univ.

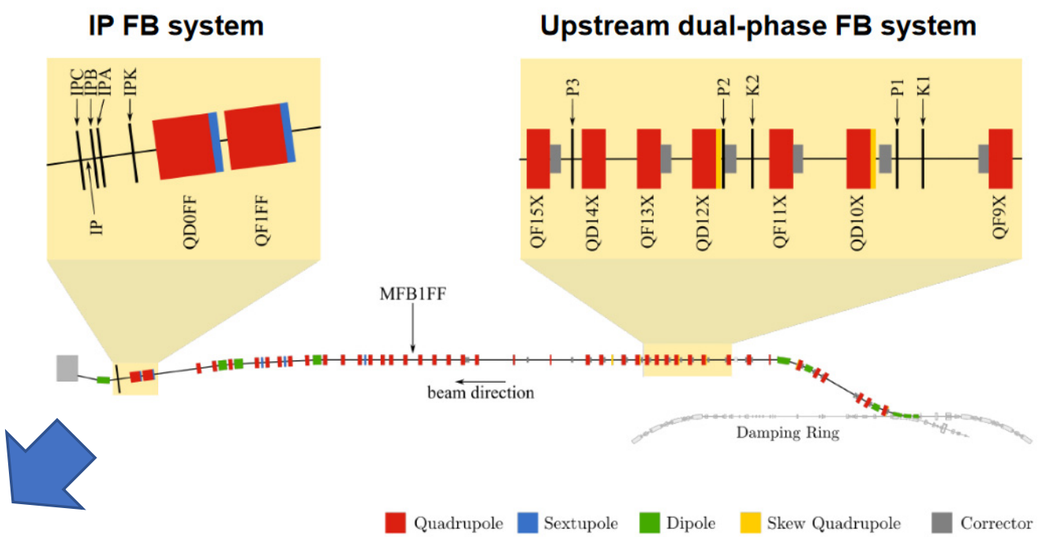


ATF2 Goal 2 *: Development a few nm position stabilization for the ILC beam interaction point*

The IP beam position is stabilized up to the BPM resolution for both Upstream and IP.

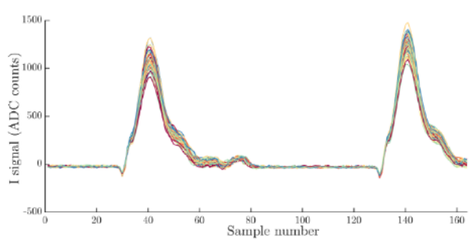
P. Burrows at ATF review (2020)

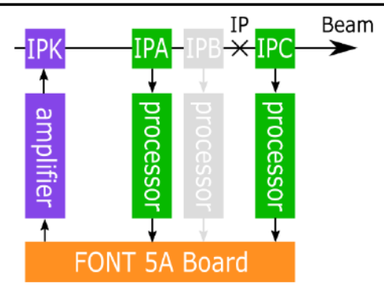
FONT5 installation at ATF2



ATF2 IP feedback

Digitization of IP BPM waveform

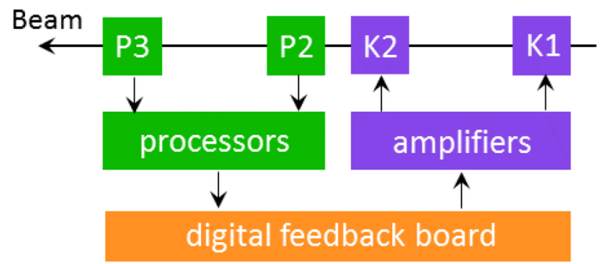




	Position jitter (nm)	
Bunch	Feedback off	Feedback on
1	106 ± 16	106 ± 16
2	96 ± 10	41 ± 4

Upstream dual-phase FB

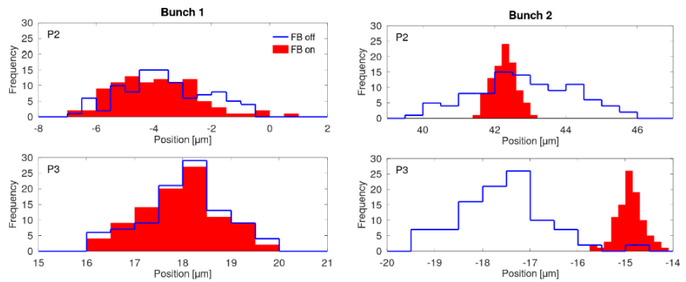
Upstream dual-phase FB system



Upstream dual-phase FB system

In-loop BPMs

Jitter reduced by factor ~4,
to BPM resolution (~200nm) limit



ATF Review 2020 (September 20th, 2020)

International review panel :

K. Oide (KEK-CRERN; chair), V. Shiltev (FNAL), Z. Zao (SARI), T. Pieloni (EPFL), M. Kato (Hiroshima U.)

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

Detailed info on: "ATF Report 2020", October 2020

KEK report 2020-4, CERN-ACC-2020-0029, IJClab 2020-001

ATF Review Report

ATF Report 2020

Alexander Aryshev[3], Philip Bambade[2], Douglas Bett[3], Laurent Brunetti[4], Philip Burrows[5], Vera Cilento[1], Angeles Faus-Golfe[2], Pavel Karataev[6], Pierre Korysko[5], Kiyoshi Kubo[3], Shigeru Kuroda[3], Andrea Latina[1], Alexey Lyapin[6], Takashi Naito[3], Toshiyuki Okugi[3], Andrii Pastushenko[1], Rebecca Ramjiawan[5], Nobuhiro Terunuma[3], Rogelio Tomas Garcia[1], and Renjun Yang[1]

On behalf of the ATF International Collaboration

[1]CERN, European Organization for Nuclear Research, Geneva, Switzerland
[2]IJCLab, Laboratoire de Physique des 2 infinis Irène Joliot-Curie, Orsay, France
[3]KEK, High Energy Accelerator Research Organization, Tsukuba, Japan
[4]LAPP, Laboratoire d'Annecy de Physique des Particules, Annecy, France
[5]John Adams Institute, University of Oxford, Oxford, UK
[6]John Adams Institute, Royal Holloway University of London, Egham, UK

Abstract

The KEK accelerator test facility (ATF) conducts R&D on a beam for the Linear Collider. The damping ring provides a low emittance electron beam and the final focus test beamline (ATF2) provides studies on small beam of nanometer level by utilizing a low emittance beam. These R&D are conducted under the ATF international collaboration with many contributions of graduate students around the world.

A review meeting to discuss the further studies at ATF will be held on September 29, 2020 as a short tele-conference. This report provides the information necessary for discussion.

We summarize the remaining studies that will be done in the coming years and ILC preparatory period for further improvements of nanometer beam technology, and the use of ATF facility as a test bench for ILC subsystem in the preparatory period and after. The possible utilizations of the ATF/ATF2 beams for R&D beyond Linear Colliders are also presented.

Report for the review

Report for ATF Review 2020

October 6, 2020

This is the review report for the ATF Review 2020 held on September 29, 2020 as a Zoom meeting. The program and materials are available at https://agenda.linearcollider.org/event/8626/ with charges given to the committee:

1. Evaluate the scientific results at ATF/ATF2
2. Evaluate future ATF operation for LC R&Ds
3. Evaluate future ATF operation (other than LC)

The committee appreciates the scientific progress made by the ATF/ATF2 team, as well as the presentations and documents given to us, under the unusual circumstances.

1. Overview

Below are the answers to the charges:

Scientific results at ATF/ATF2

The committee has been impressed on outstanding and unique results achieved in ATF/ATF2:

- The smallest spot size, 40 nm, in any accelerators.
- Intra-train bunch orbit feedback (FONT).
- Vertical emittance in the ring, 4 pm, smallest at the beginning of the century.

The committee also applauds pioneering developments on various accelerator components:

- Fast extraction kickers with rise/fall time less than 3 ns
- Laser wires measuring 1 μm beam size
- Cavity BPMs with 20 nm resolution
- Single- and multi- OTR/ODR beam profile monitors

Some of these devices have been spread to other accelerators including CERN PS and light sources.

Educating graduate students and young scientists under international collaboration was another achievement of ATF, which is the best project at KEK in this aspect.

Future ATF operation for LC R&Ds

The committee recognizes that the achievements at ATF/ATF2 have already verified the minimum technical feasibility on the beam focusing and control for the ILC. However there will be a number of possibilities for further extensions to investigate:

- intensity dependent effects on the spot size
- optical aberrations, esp. with smaller horizontal β*
- beam halo and collimation
- even smaller spot sizes with higher chromaticities

Close-out of the review (October 6th, 2020)

Outstanding and unique results achieved in ATF/ATF2:

- ✓ *The smallest spot size, 40 nm, in any accelerators.*
- ✓ *Intra-train bunch orbit feedback (FONT).*
- ✓ *Vertical emittance in the ring, 4 pm, smallest at the beginning of the century.*

Highly appreciated

Future ATF operation for LC R&Ds :

- ✓ *Intensity dependent effects on the spot size*
- ✓ *Optical aberrations <<< βx**
- ✓ *Beam halo and collimation*
- ✓ *Smaller spot sizes with higher chromaticities*

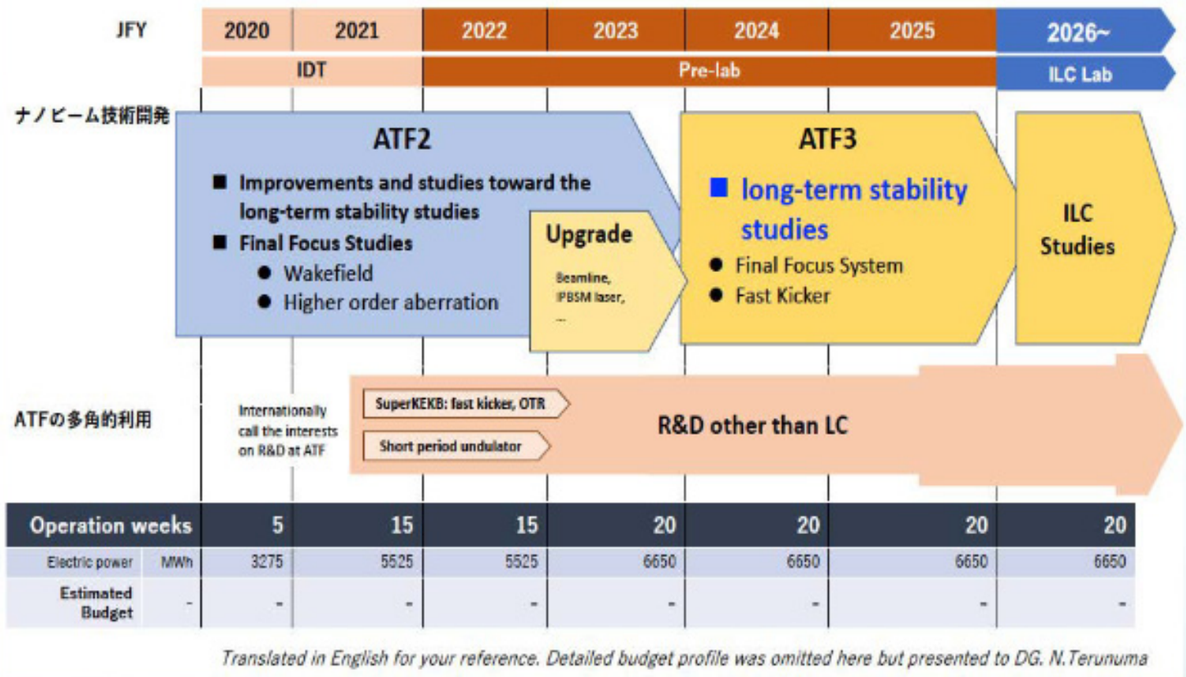
Understood the importance of ATF2 for LCs.

ATF3 collaboration was proposed as a developmental project of the ATF2 project.

ATF3 objective and collaboration:

Implementation Plan

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



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

Extended Technical Board

N. Terunuma - KEK
A. Faus-Golfe - IJClab
T. Okugi – KEK
P. Burrows – JAI
A. Aryshev – KEK
M. Fukuda – KEK
S. Kuroda - KEK
L. Brunetti – LAPP
P. Bambade – IJClab
P. Karataev – RHUL
S. Stapnes – CERN
R. Tomas Garcia – CERN
A. Latina – CERN
R. Corsini - CERN
G. White – SLAC
K. Kubo – KEK
T. Naito – KEK
A. Lyapin - RHUL

presented by A. Faus-Golfe at IDT group meeting

Technical Preparation for ILC Construction (2021 May)

- *Under the IDT (International Development Team), the Technical Preparation items required for the ILC Pre-Lab period were listed up and positioned as 18 work packages.*
- *The development research in ATF2/ATF3 is positioned as WP-15 in this package.*

IDT−WG2

IDT EB

IDT WG2

Shin Michizono (Chair)
Benno List (Deputy)

ML&SRF group

Yasuchika Yamamoto	***KEK***
Sergey Belomestnykh	FNAL
Nuria Catalan	CERN
Enrico Cenni	CEA
Dimitri Delikaris	CERN
Luis Garcia Tabares	CIEMAT
Rongli Geng	ORNL
Hitoshi Hayano	KEK
Bob Laxdal	Triumf
Matthias Liepe	Cornell
Peter McIntosh	STFC
Laura Monaco	INFN Milano
Olivier Napoly	CEA
Sam Posen	FNAL
Robert Rimmer	JLAB
Marc C. Ross	SLAC
Roger Ruber	JLAB
Kensei Umemori	KEK
Hans Weise	DESY
Akira Yamamoto	KEK

DR/BDS/Dump group

Toshiyuki Okugi	***KEK***
Karsten Buesser	DESY
Philip Burrows	U. Oxford
Angeles Faus-Golfe	LAL
Andrea Latina	CERN
Kiyoshi Kubo	KEK
Jenny List	DESY
Thomas Markiewicz	SLAC
Brett Parker	BNL
Ivan Podadera	CIEMAT
David L. Rubin	Cornell
Nikolay Solyak	FNAL
Nobuhiro Terunuma	KEK
Glen White	SLAC
Kaoru Yokoya	KEK
Mikhail Zobov	INFN LNF

Dump sub-group

Nobuhiro Terunuma	***KEK***
Toshiyuki Okugi	KEK

Crab sub-group

Peter McIntosh	***STFC***
Yasuchika Yamamoto	KEK

Sources group

Kaoru Yokoya	***KEK***
Jim Clarke	STFC
Steffen Doebert	CERN
Joe Grames	JLAB
Hitoshi Hayano	KEK
Masao Kuriki	U. Hiroshima
Benno List	DESY
Jenny List	DESY
Gudrid Moortgat-Pick	U. Hamburg
Tsunehiko Omori	KEK
Sabine Riemann	DESY
Peter Sievers	CERN -retired
Tohru Takahashi	U. Hiroshima

Civil engineering group

Nobuhiro Terunuma	***KEK***
John Andrew Osborne	CERN
Tomoyuki Sanuki	U. Tohoku

Technical preparation document

WP-15 : System design of ILC final focus beamline

Technical Preparation Plan:

The beam size at the ATF2 focal point is designed to be 37 nm, which is technically equivalent to a 7.7 nm beam size for ILC250. A vertical electron beam size of 41 nm, which essentially satisfies the ATF2 design goal, has been produced at ATF2, with a bunch population of approximately 10% of the nominal value of 10^{10} electrons and with a reduced aberration optics. Recent studies indicate that the vertical beam size growth with the beam intensity owing the effects of wakefields. Furthermore, SCJ expressed technical concerns about the technology of the control and feedback systems and the long-term stability of the beam focus and position for the ATF2 beam experiment.

To overcome these apprehensions, the main objective of this plan is to pursue the necessary R&D to maximize the luminosity potential of ILC. In particular, the ILC final focus system (FFS) design must be assessed from the point of view of beam dynamics, choice of technology and hardware, and long-term stability operation issues. To implement this program based on the outstanding and unique results achieved by the ATF/ATF2 collaboration, an **ATF3 collaboration** is underway with the ATF2 partners and with new possible partners worldwide. The results are expected to provide important information necessary for the system design of the ILC final focus beamline. Through these studies, we will optimize the FFS design, which is optimized for the current ILC design of 250 GeV and has energy updatability to higher energies.

Tasks
ILC-FFS system design: Hardware optimization
ILC-FFS system design: Realistic beam line driven / IP design
ILC-FFS beam tests: Long-Term stability
ILC-FFS beam tests: High-order aberrations
ILC-FFS beam tests: R&D complementary studies

Time-critical work packages (2022 March)

- *The MEXT advisory panel's report stated that the ILC Pre-Lab is premature.*
- *However, positive reactions were received regarding the promotion of technical preparation through international cooperation.*
- *Then, high priority topics from the work package will be selected as time-critical work packages.*

Prioritizing the essential and time-consuming work packages

- ✓ *Establish IDT-WG2 steering panel*
- ✓ *Steering panel members will be assigned with the discussion to IDT-EB.*
- ✓ *Each group's steering panel will discuss about the prioritization.*

IDT-WG2 with steering members

Shin Michizono (Chair)
Benno List (Deputy)

Steering panel

ML&SRF steering panel

Yasuchika Yamamoto	***KEK***
Sergey Belomestnykh	FNAL
Enrico Cenni	CEA
Peter McIntosh	STFC
Laura Monaco	INFN Milano
Akira Yamamoto	KEK

Sources steering panel

Kaoru Yokoya	***KEK***
Joe Grames	JLAB
Masao Kuriki	U. Hiroshima
Gudrid Moortgat-Pick	U. Hamburg

DR/BDS/Dump steering panel

Toshiyuki Okugi	***KEK***
Philip Burrows	U. Oxford
Angeles Faus-Golfe	LAL
David Rubin	Cornell
Glen White	SLAC
Nobuhiro Terunuma	KEK

- *Establish IDT-WG2 steering panel*

(group leader (SRF, Sources, DR/BDS/Dump)+ steering panel members will manage each group.)

Time-critical WPs relevant to ATF

WP-prime 15:

Program and schedule:

The purpose of WP-15 is the system design of the ILC BDS and the advancing of the beam technology required for it. For this purpose, we propose various beam tests at the ATF2 beamline from the original WP-15. The technical research of the final focus system for the ILC at ATF2 beamline has proceeded with international cooperation under the ATF international collaboration. WP-15 must also be based on the ATF international collaboration, or an international collaboration extension of the ATF international collaboration. The time-critical WP should also continue to be based on the ATF international collaboration, or its extension .

ATF2 beamline is the only existing test accelerator in the world to test the final focus beamline of linear colliders and is important for the ILC. However, since some of the items listed in the WP-15 can be performed after the ILC Pre-Lab start, it is appropriate for the time-critical WP to select only the higher priority research topics. The research topics described in WP-15 of the TPD are intricately tied to each other. Thus the time-critical WPs cannot be easily selected. Thus new items have been defined for the time-critical WPS. We have selected the following 3 research topics as new topics as the time-critical WPs along with their existing budgets. Furthermore, since items are deeply related to each other, it would be difficult to set a priority for each item, so all were grouped together as priority A.

1. wakefield mitigation
2. mitigation and correction of higher-order aberration
3. training for ILC beam tuning (machine-learning etc.)

These three items should be started before the ILC Pre-Lab starts and should be continued into the Pre-Lab period along with the other research topics in TPD WP-15.

	P1	P2	P3	P4	
Pre-lab proposal	Pre-lab ~4 years				Construction ~10 year
	Y1	Y2	Y3/P1?	Y4/P2?	
Time-critical WPs	~4 years				
			Pre-lab 3~4 years		Construction ~10 year

Recent researches at ATF

1. ***Beam tuning with machine learning technologies (M. Kurata ; KEK researcher)***

2. ***Wakefield study (Y. Abe ; Ph.D student of SOKENDAI)***

Brief introduction will be done in this presentation.

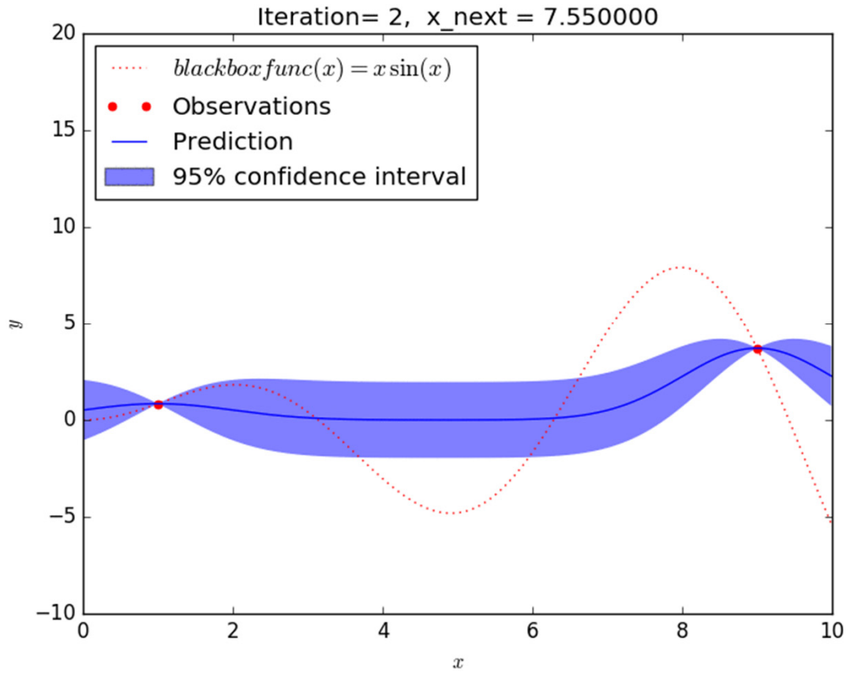
3. ***IP-BSM improvement (A. Aryshev)***

to be presented in next presentation by A. Aryshev.

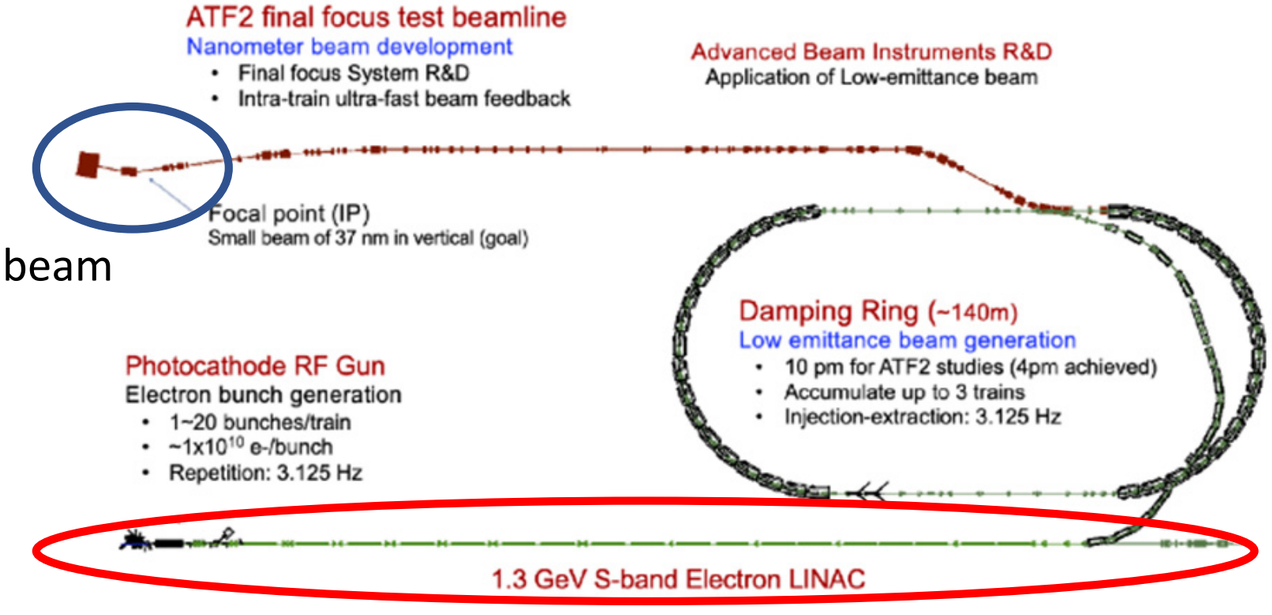
Beam tuning with machine learning technologies (M. Kurata)

- Beam optimization, but…
  - Effective accelerator parameter search for optimal beam
  - Simultaneous search of several parameters for the beam
  - Optimization without prerequisite knowledge or prejudice, bias
- Beam optimization: looks like “black box optimization”

  - Doing Design of experiment automatically using “**Bayesian Optimization**”



- **Knob scan**:
  to obtain small beam



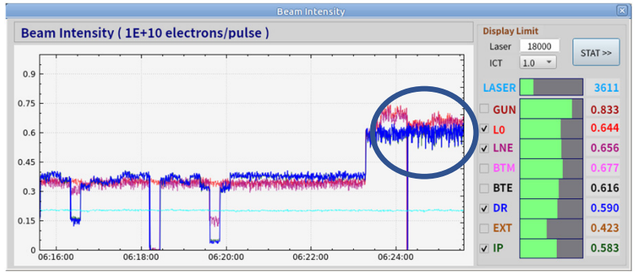
- **Linac tuning**:
  to make beam intensity at DR as high as possible

Example of the Bayesian Optimization at ATF

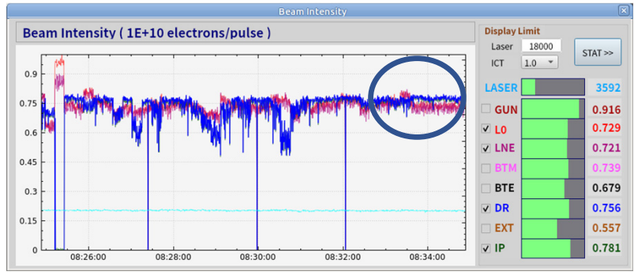
DR injection tuning

Injection tuning was performed just after the beam current was switched to be higher.

Before



After

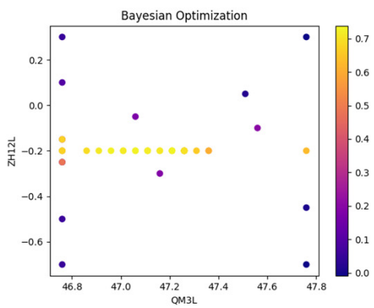


- ✓ After optimization: good intensity for high current case
- ✓ ～1.5h optimization, 6 cases of parameter search are performed

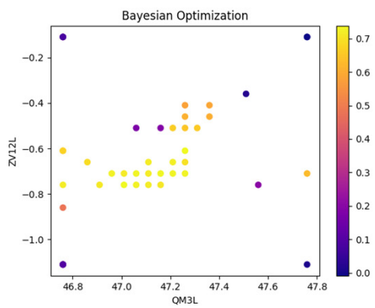
Parameter search example: 3D search with steer & Q

- ✓ Looks effective search can be realized (QM3L, ZV11L, ZH12L)

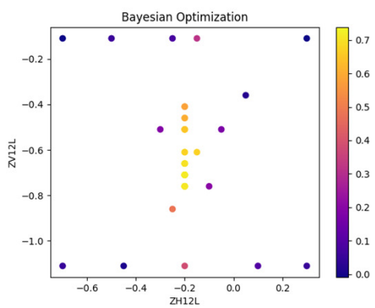
QM3L - ZH12L



QM3L - ZV11L



ZH12L - ZV11L

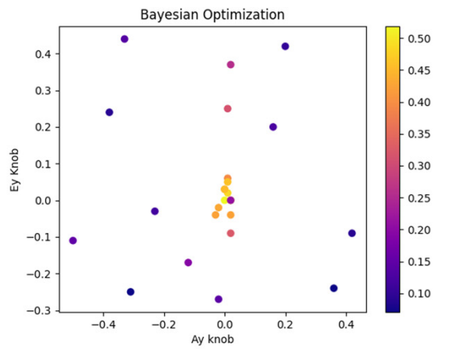


IP-BSM linear knob scan

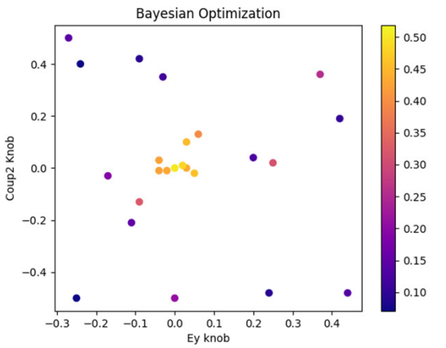
Looking for the optimum linear knob setting just after the linear knob optimization was done.

- ➢ 30degree mode
- ➢ Iteration: 24
- ➢ Domain: [-0.5, 0.5]

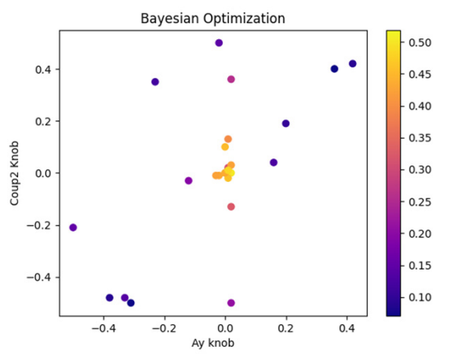
Ay - Ey



Ey – Coup2



Ay – Coup2

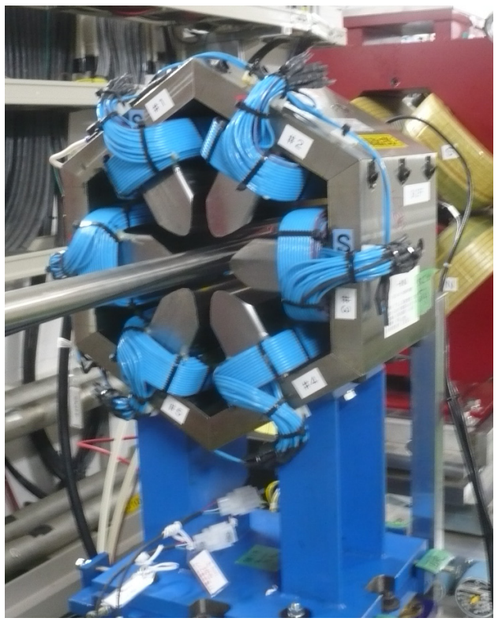


B.O. (Ay, Ey, Coup2)=(0., 0., -0.)

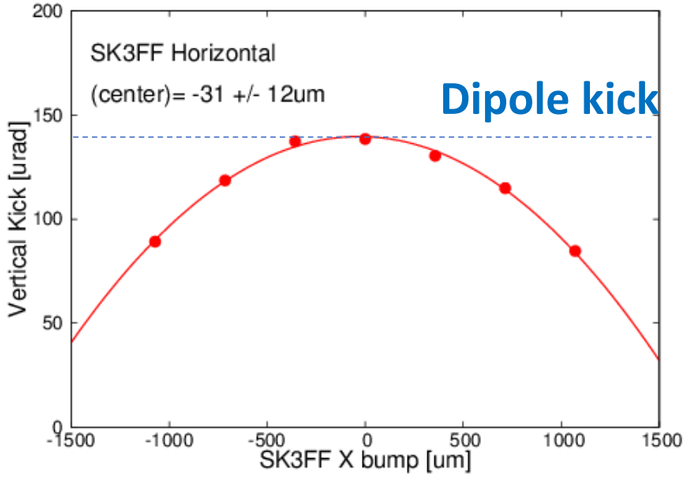
- ✓ B.O. can focus on around (0,0,0) search
- ✓ Probabilistically, look for other parameter sets

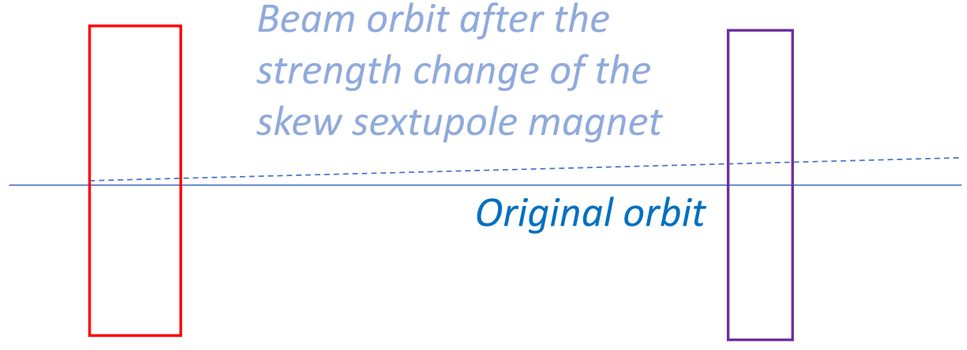
Application of ML to multipole field mitigation

- ✓ The Skew sextupole magnet used in ATF2 does not have good pole alignment accuracy, and when the position is set to minimize the quadrupole component, the dipole component remains.
- ✓ When scanning the non-linear knob, the optimal value of the liner knob is shifted.
- ✓ We are considering using the ML procedure to optimize the non-linear knob at the same time as the linear knob (i.e. ***Ay, Ey, Coup2*** and ***Y22***).

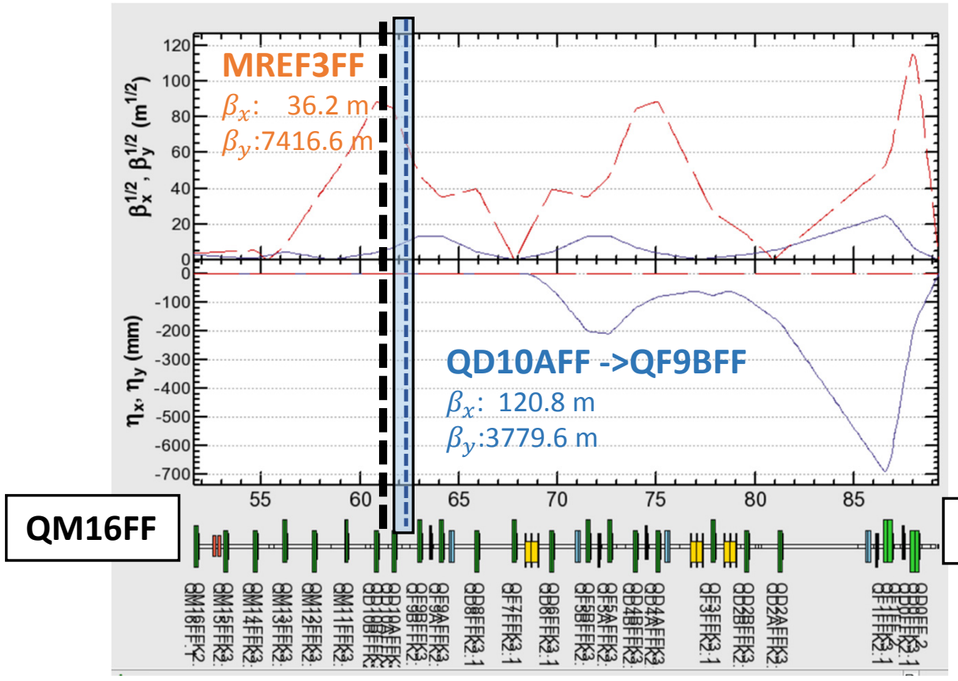


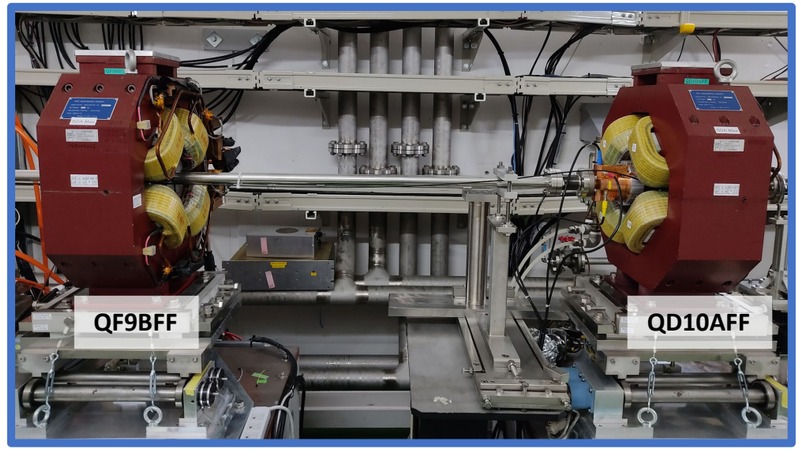
BBA for ATF skew sextupole





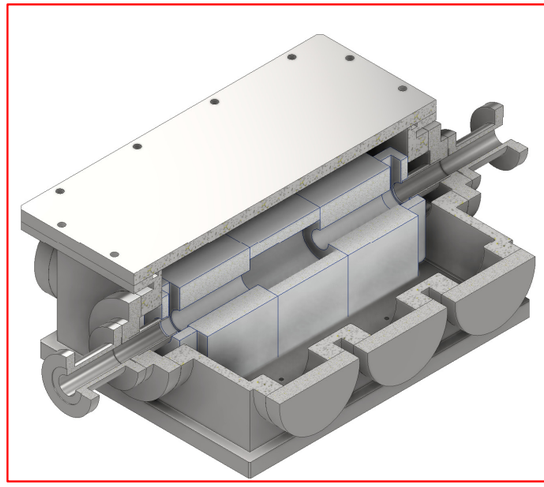
Wakefield study (Y. Abe)





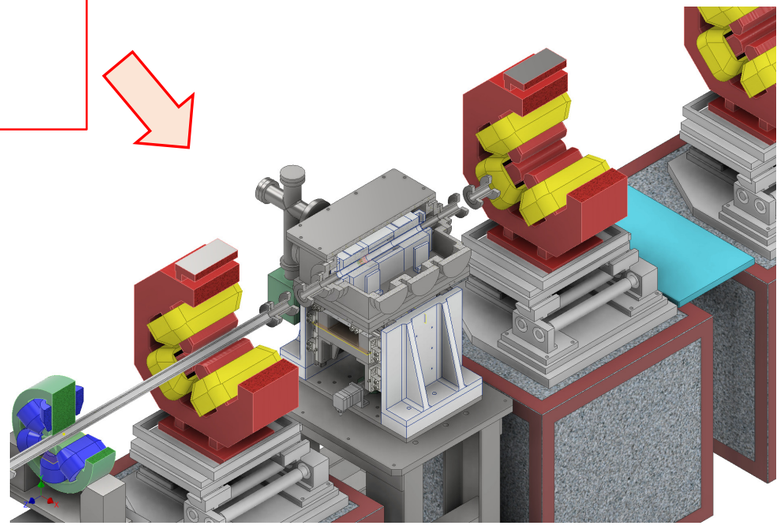
Subject of the study

- ✓ Minimization of wakefield effects on ATF2 beamlines
- ✓ Development of vacuum components to reduce wakefield effects



Preparing a wakefield test station

The vacuum chamber will be installed in ATF2 beamline in this autumn.



ATF Beam schedule of JFY2022

JFY2022 ATF Operation Plan

Ver. 2022.05.06

Beam　Reserved　→ Moved

2022 **4** April

Sun	Mon	Tue	Wed	Thr	Fri	Sat
					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

2022 **5** May

Sun	Mon	Tue	Wed	Thr	Fri	Sat
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				

2022 **6** June

Sun	Mon	Tue	Wed	Thr	Fri	Sat
			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		

2022 **7** July

Sun	Mon	Tue	Wed	Thr	Fri	Sat
					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						

2022 **8** August

Sun	Mon	Tue	Wed	Thr	Fri	Sat
	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			

2022 **9** September

Sun	Mon	Tue	Wed	Thr	Fri	Sat
				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	

2022 **10** October

Sun	Mon	Tue	Wed	Thr	Fri	Sat
						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					

2022 **11** November

Sun	Mon	Tue	Wed	Thr	Fri	Sat
		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			

2022 **12** December

Sun	Mon	Tue	Wed	Thr	Fri	Sat
				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

2023 **1** January

Sun	Mon	Tue	Wed	Thr	Fri	Sat
(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				

2023 **2** February

Sun	Mon	Tue	Wed	Thr	Fri	Sat
			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				

2023 **3** March

Sun	Mon	Tue	Wed	Thr	Fri	Sat
			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	

- ✓ Operation in February and March will depend on the extent of the electricity cost increase.
- ✓ Fall (October to December) is preferable for participation this year.