Progress and future of ATF experimental program

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LCWS2012 at Arlington, Texas

Contents

KEK Accelerator Test Facility (1.3 GeV)

- *R&D for the advanced accelerator technologies using the Low emittance multi-bunch beam; for ILC,…*
- *Global collaboration*
- *Education of the young researches*

ATF2 beamline

Nano-meter beam studies;
Advanced beam instruments R&D

Damping Ring

Low emittance beam studies

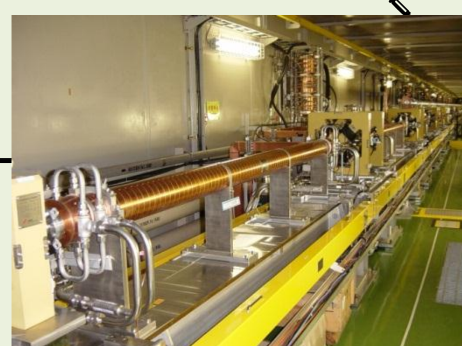


Photo-cathode RF gun

Multi-bunch electron source

S-band Linac

Multi-bunch beam acceleration, 1.3 GeV

Challenging goals for ATF/ATF2

An important technical challenge of ILC is the collision of extremely small beams of ***a few nanometers in vertical size.***

ATF/ATF2 will address the development of the techniques for following issues:

- ***achieve the small vertical emittance***
  ATF DR 4 pm(achieved)→ 2 pm or less
- ***achieve the design vertical beam size at the IP; 37 nm***
- ***stabilize the the beam position in a few nanometer level at the IP.***

The ATF international collaboration is strongly promoting these activities.

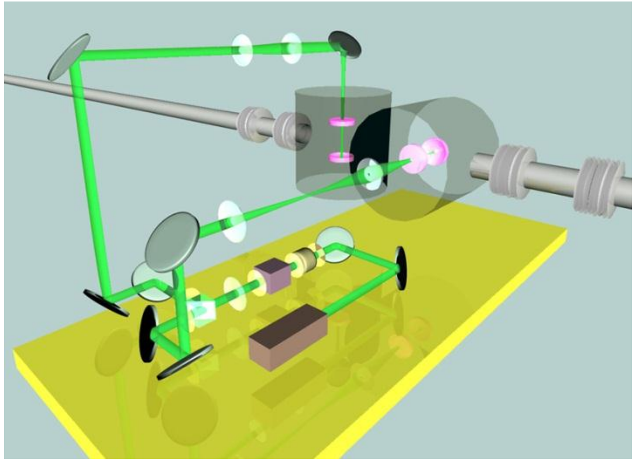
Development of the Beam Size Monitor for ILC

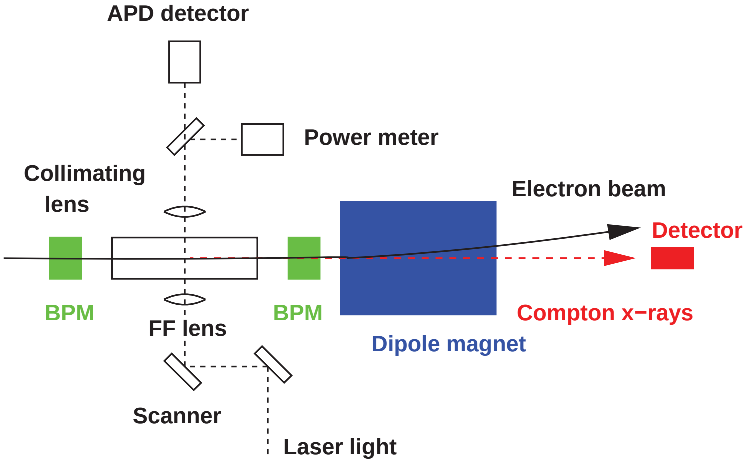
Non-destructive beam profile measurement
Survive against the high intensity multi-bunch beam

→ The Laser Wire Scanner

Two types of laser wires have been developed at ATF.

- *based on the Optical Cavity → in DR*
- *based on the Pulsed Laser → in EXT-line/ATF2-FF*





Development of the Pulsed Laser Wire - Beam Size Monitor for BDS -

ILC design requirement:

< 1 um laser wire scanner

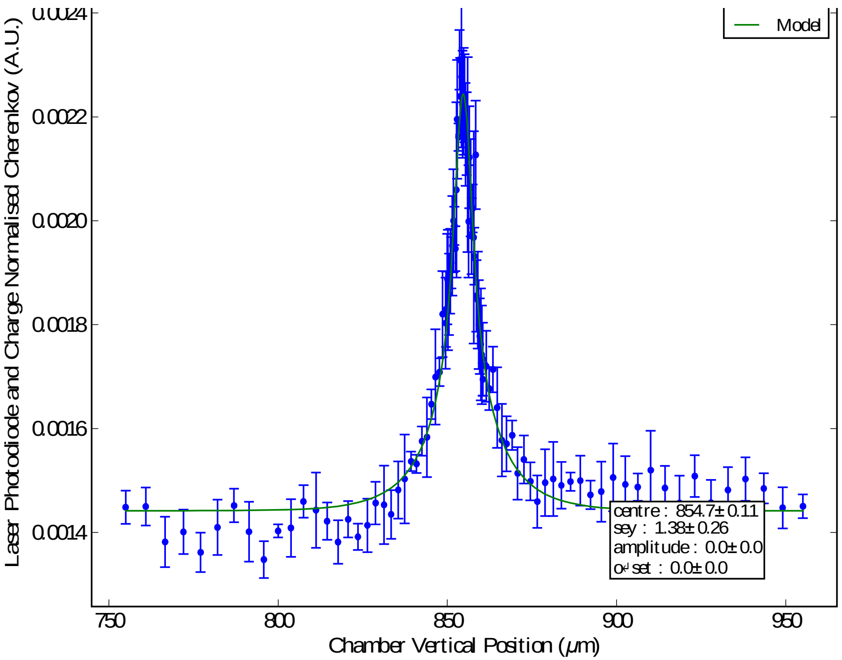
Results at ATF extraction line (2008)

$\sigma_{lw} = 2.2\ \mu m$

Results at ATF2 FF line (2012 June)

$\boldsymbol{\sigma_{lw} = 0.9 \sim 1.4\ \mu m}$

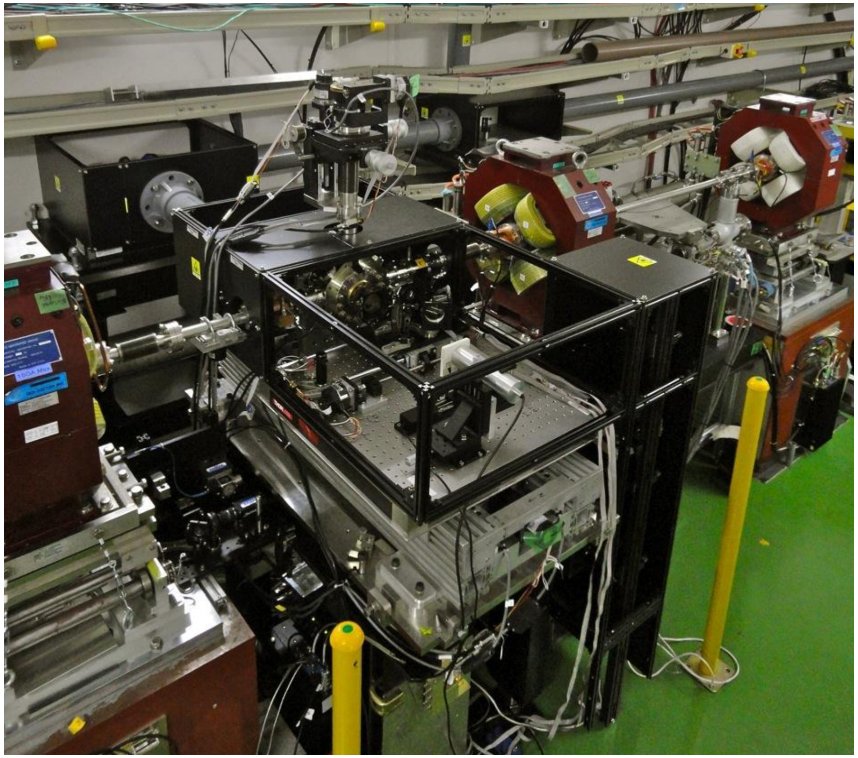
Almost achieved the goal.



Relocated in the matching section of ATF2 beam line.

Virtual IP of ATF2 IP

e- beam ~1.4um (by OTR meas.)



JAI(RHUL,Oxford) / KEK

Nano-meter Beam Size Monitor

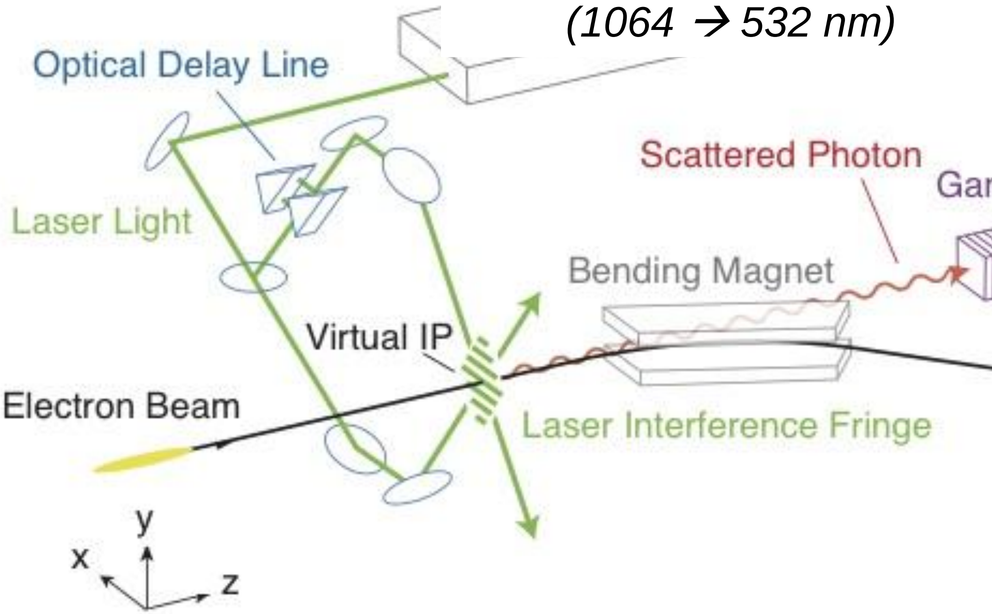
Univ. Tokyo / KEK

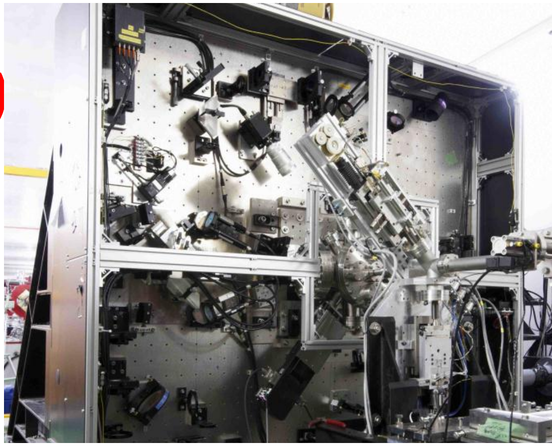
Beam Size Measurements at ATF2-IP

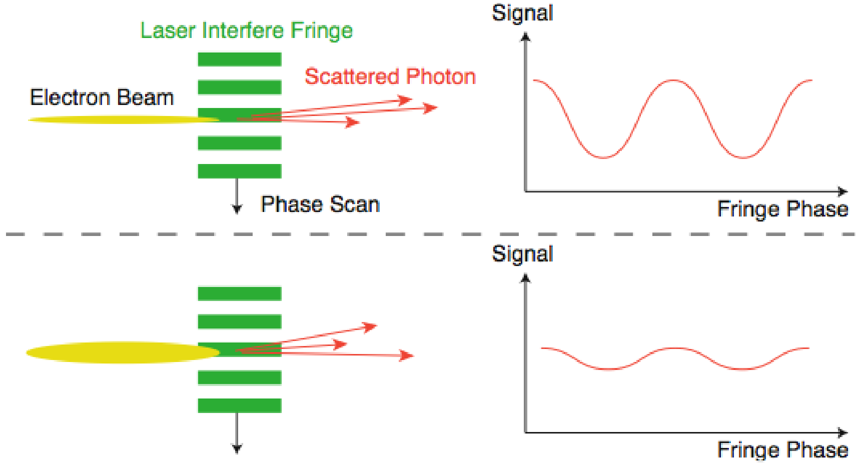
- Solid (W,C) wire Scanners (meas. for 2um or more)
- Laser interference fringe monitor (meas. for 20nm~6um)

FFTB ~70nm(measured) -> ATF2 37nm(goal)

Laser wavelength
(1064 → 532 nm)

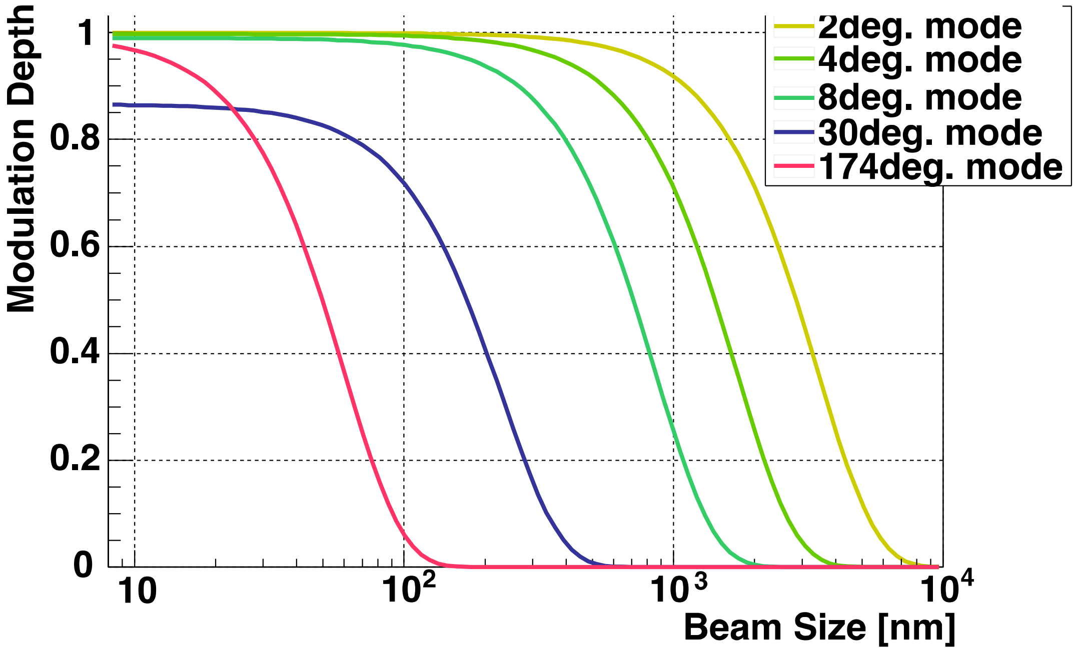


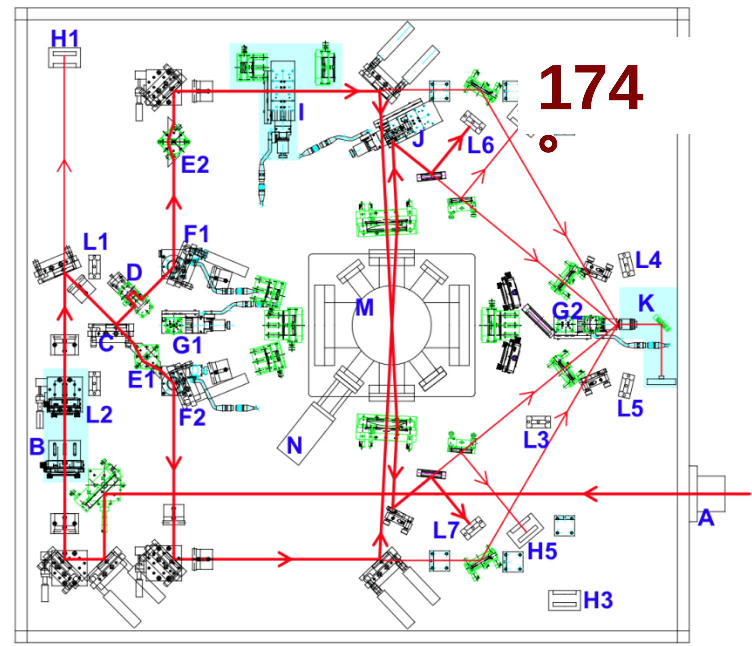




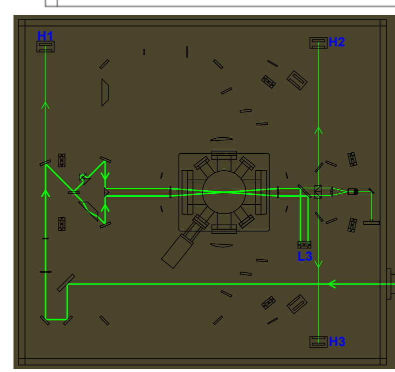
Laser Interference Fringe Monitor for ATF2

Measureable beam size

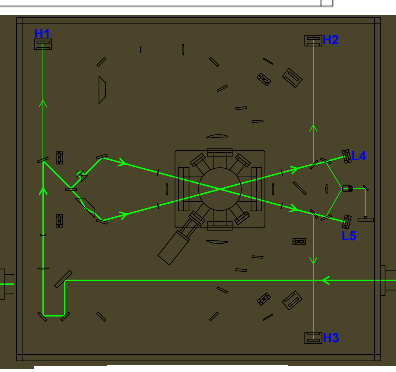




	174°	30°	8° ⟷	2°
Fringe pitch	266 nm	1.03µm	3.81µm	15.2µm
Minimum	**25 nm**	100 nm	360 nm	-
Maximum	**100 nm**	360 nm	-	6 µm



2~8°



30°

Laser Interference Fringe Monitor for ATF2

2-8° mode

Spend most beam time in 2010~2011.

- beam tuning down to 300 nm
- commissioning of the fringe monitor
- beam size ~ 300 nm

30° mode

First modulation was detected in February 2012.

- beam size ~165 nm

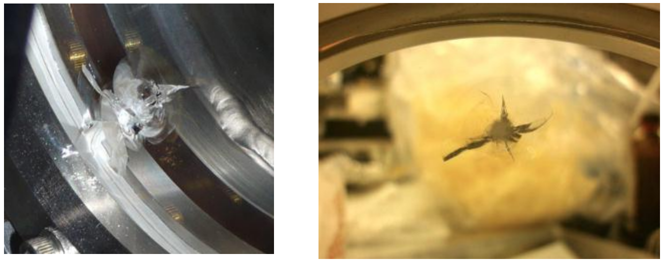
174° mode

Modulation is not yet detected.

- Need improvement on the split laser handling (crossing angle control) in summer. Almost done.

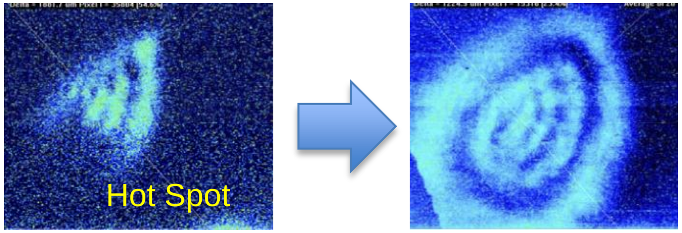
Improvements on the fringe monitor

Damage → laser spot size optimization vs Compton Signal

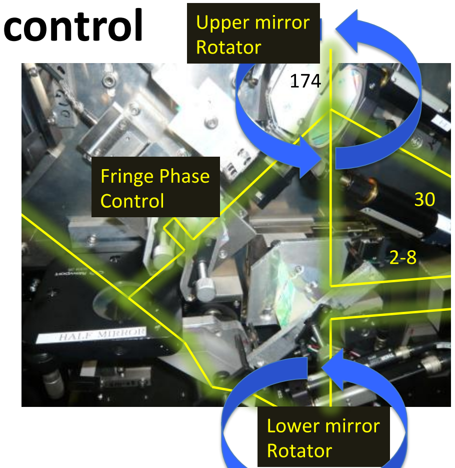


pointing stabilization → *Beam Lok* device

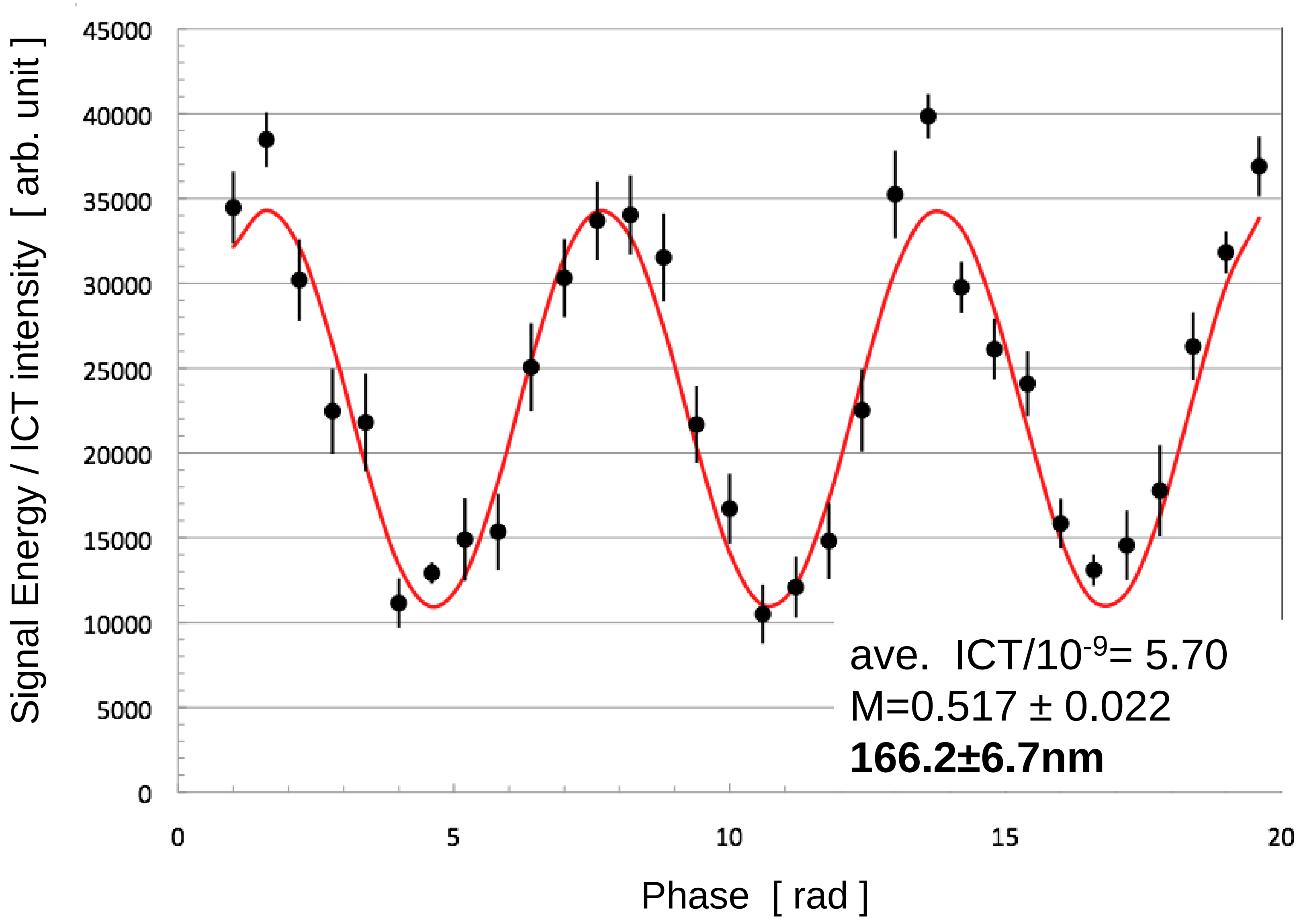
profile improvement → laser cavity exchange



Laser crossing angle control

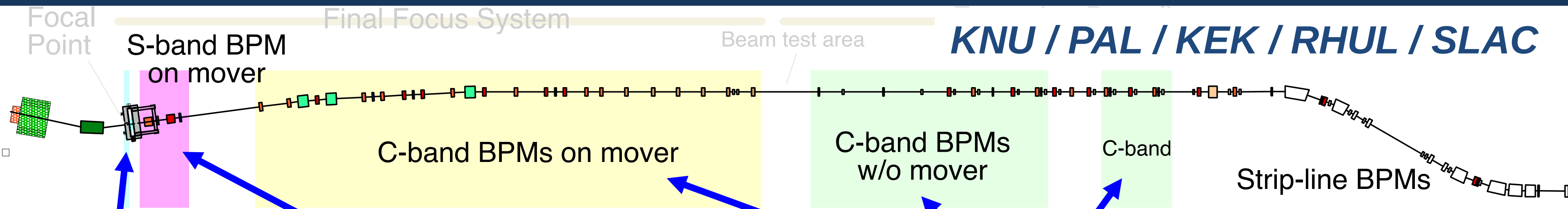


2012.2.23 data, 30 degree mode, 10points/phase

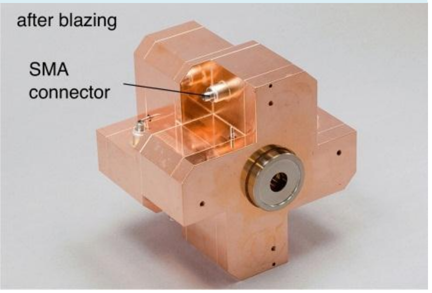


Nano-meter Beam Position Monitors

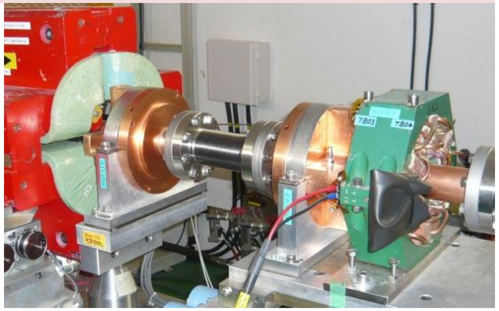
KNU / PAL / KEK / RHUL / SLAC



IP BPM system
(BPM + Ref) Cavity **1 unit**
Target : 2 nm
Aperture: 6 mm(V)



S-band BPM system
BPM cavity: **4 units**
Ref. cavity: **1 unit**
Target : 100 nm
Aperture: ϕ40 mm



C-band BPM system
BPM cavity: **34 units**
Reference cavity: **4 units**
Target resolution: 100 nm
Aperture: ϕ20 mm

Achieved resolution at ATF
8.72 +-0.28(stat) +-0.35(sys) nm
@ 0.7 × 10^{10} electrons/bunch,
@ 5 μm dynamic range
[Y. Inoue et al., Phys. Rev. ST-AB 11, 62801 (2008)]

Proto-type
Achieved resolution
15.6 nm
@dymamic range ±20μm

Operational status of the ATF2 Cavity BPMs

C-band BPM

It is in the steady operation for ATF2.

Achieved Resolutions:

- **200 nm for typical BPMs with 20 dB attenuator to realize the wider dynamic range (~10 mm) for ATF2 tuning.**
- **50 nm for BPMs w/o attenuator**
- 27 nm was confirmed when BPMs are carefully tuned and a beam is well centered.

The Cavity BPM on ATF2 demonstrates well the target resolution of ILC, 100 nm.

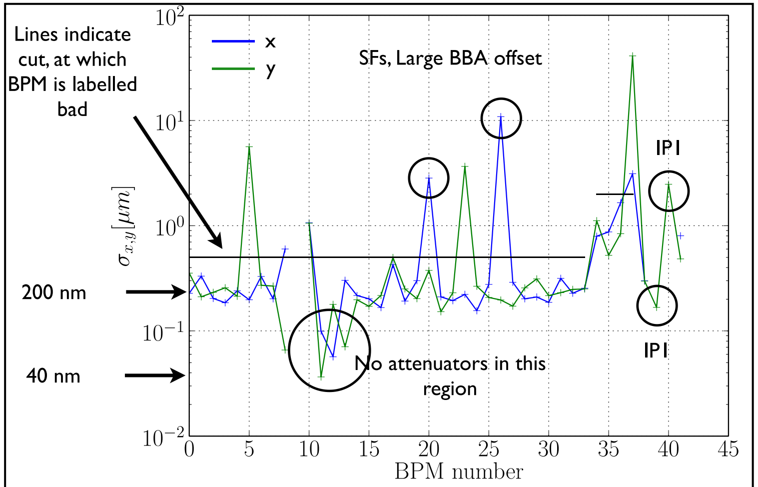
S-band BPM

It needed only for the ATF2 large aperture final doublet. Not for ILC.

Present resolution ~ 1 μm

IP-BPMs

Trial installation: ~several 100 nm



Nano-meter Beam Position Stabilization

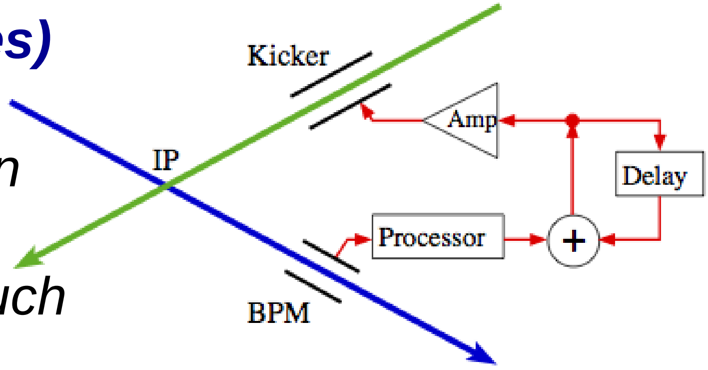
Oxford / KNU / RHUL / KEK

One of the challenging goals for ATF2

1. *achieving of the 37 nm vertical beam size*
2. ***Stabilize a beam in a few nanometer level at the IP.***

FONT (Feedback On Nano-Second Timescales) has been developed

- *as a prototype of a beam-based intra-train feedback system for IP of LCs.*
- *Correct the impact of fast jitter sources such as the vibration of magnets.*



FONT1~FONT3

Analogue feedback system for very short bunch-train LCs.

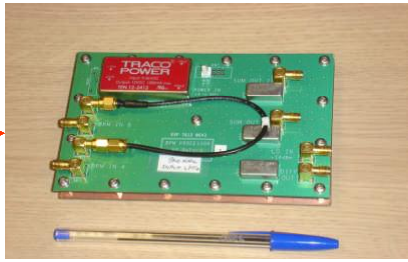
Latency FONT3(ATF) 23 ns.

FONT4 & FONT5 (ATF2)

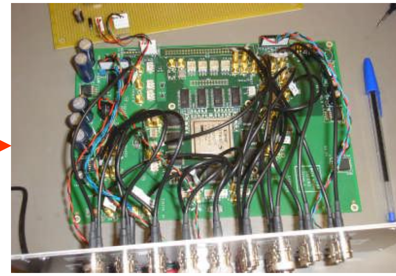
Digital feedback system for long bunch-train ILC.

allow the implementation of more sophisticated algorithms

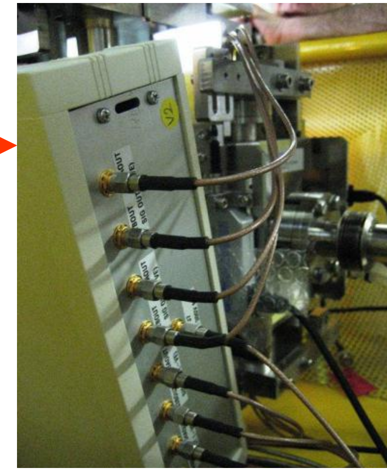
FONT-5 Digital feedback system at ATF



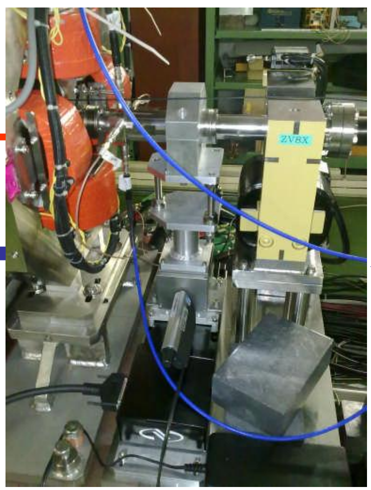
Analog Front-end BPM processor



FPGA based digital processor



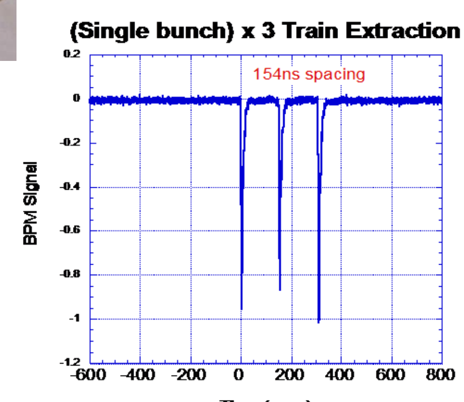
Kicker drive Amplifier



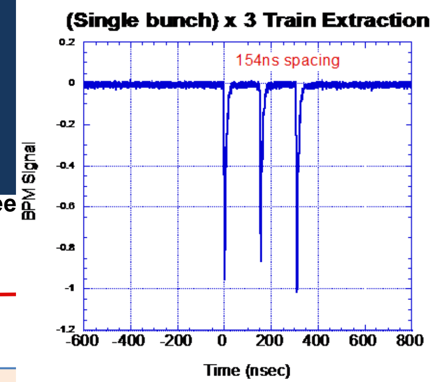
Beam Position detection

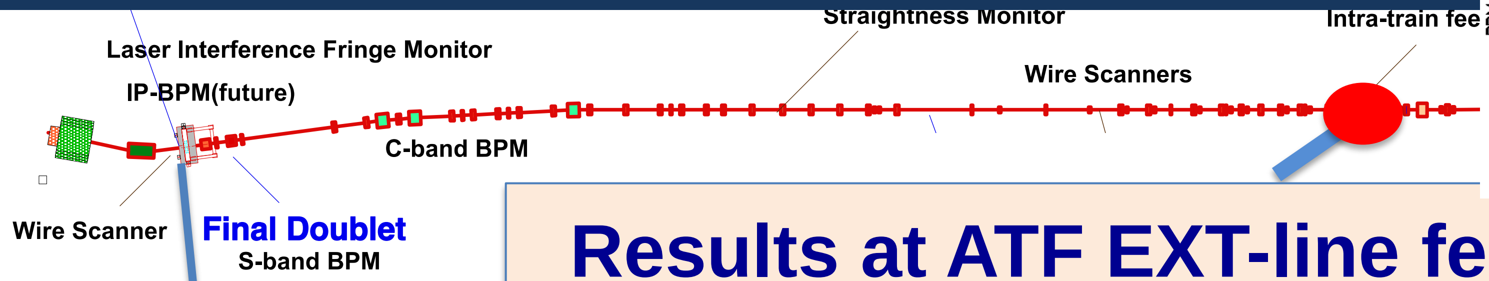
Strip-line kicker

Multi-bunch beam

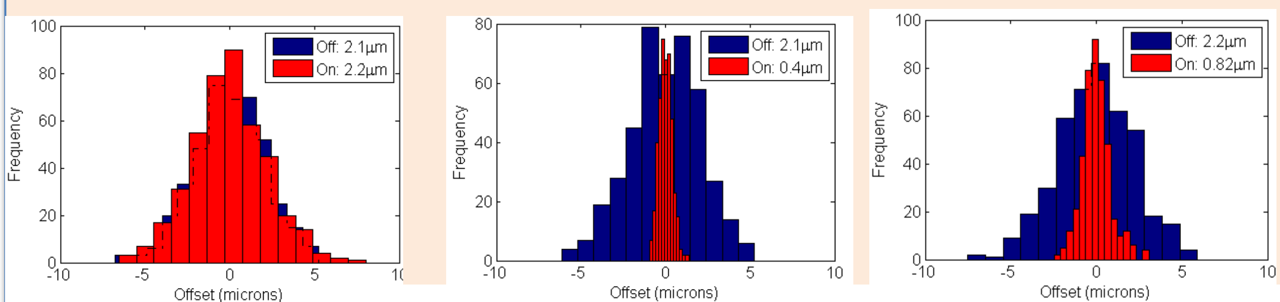


Results of the fast feedback



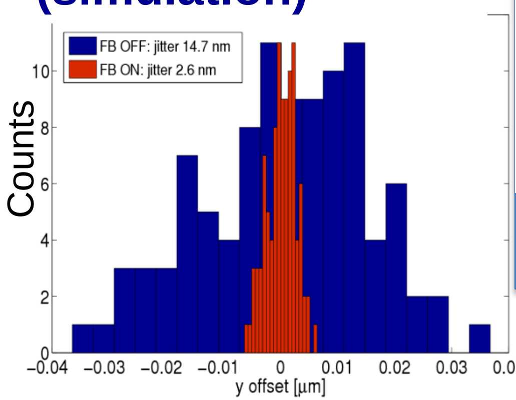


Results at ATF EXT-line feedback



2.1 um → 0.4 um → 0.8 um

Jitter comparison at ATF2-IP (simulation)



Assuming perfect lattice, no further imperfections (!)

Simulation

FB OFF: jitter 14.7 nm

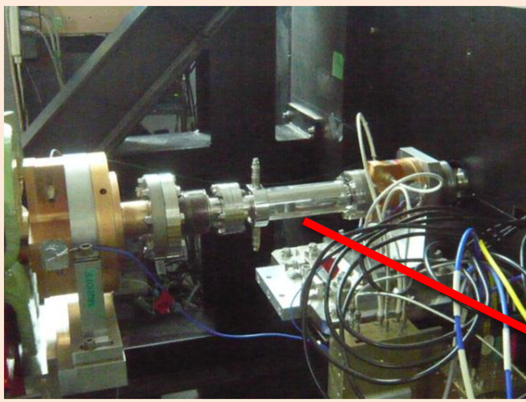
FB ON: jitter 2.6 nm

FONT + IP-BPM "for ATF2 Goal 2"

Preparation for the nm-beam position stabilization IPBPM+FONT

FONT-kicker

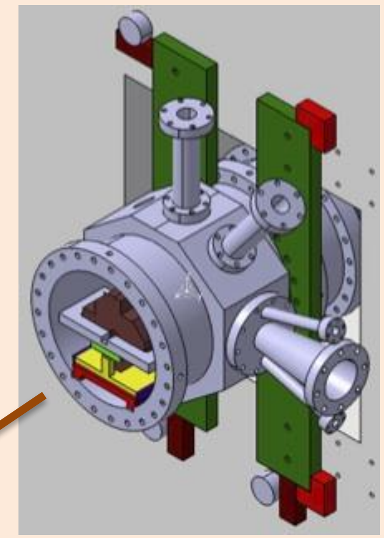
Installed near the ATF2-IP.
Tested in June 2012.

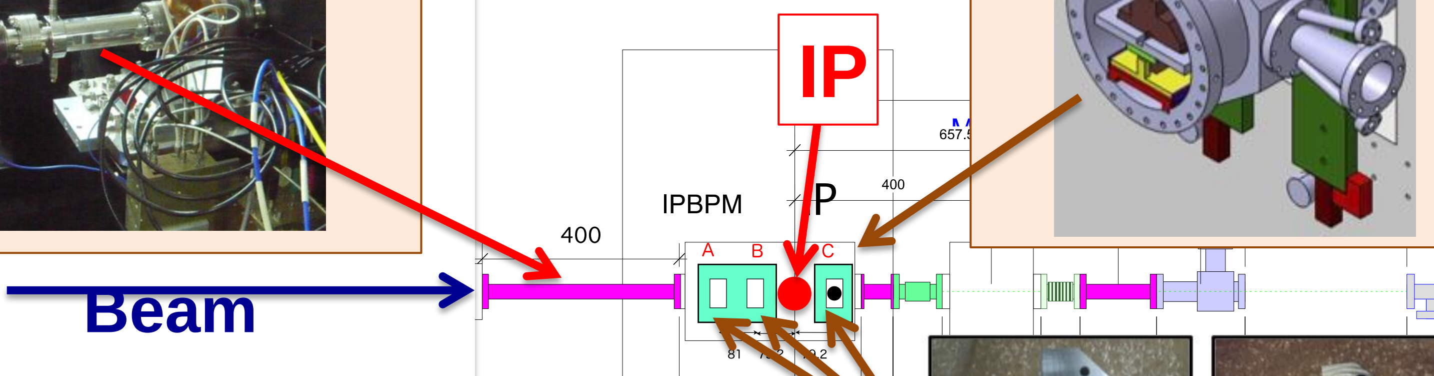


Full setup will be assembled at IP in early 2013.

New vacuum chamber

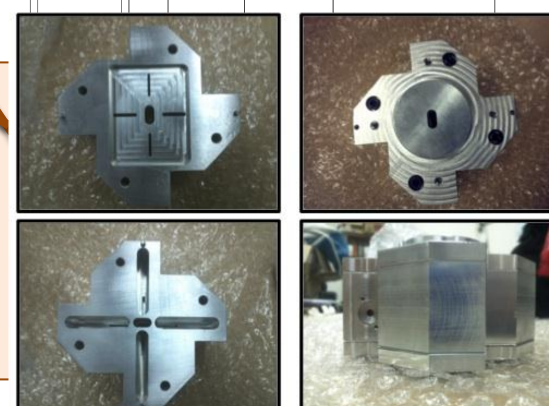
Store the triplet of IPBPM.
Under fabrication at LAL.



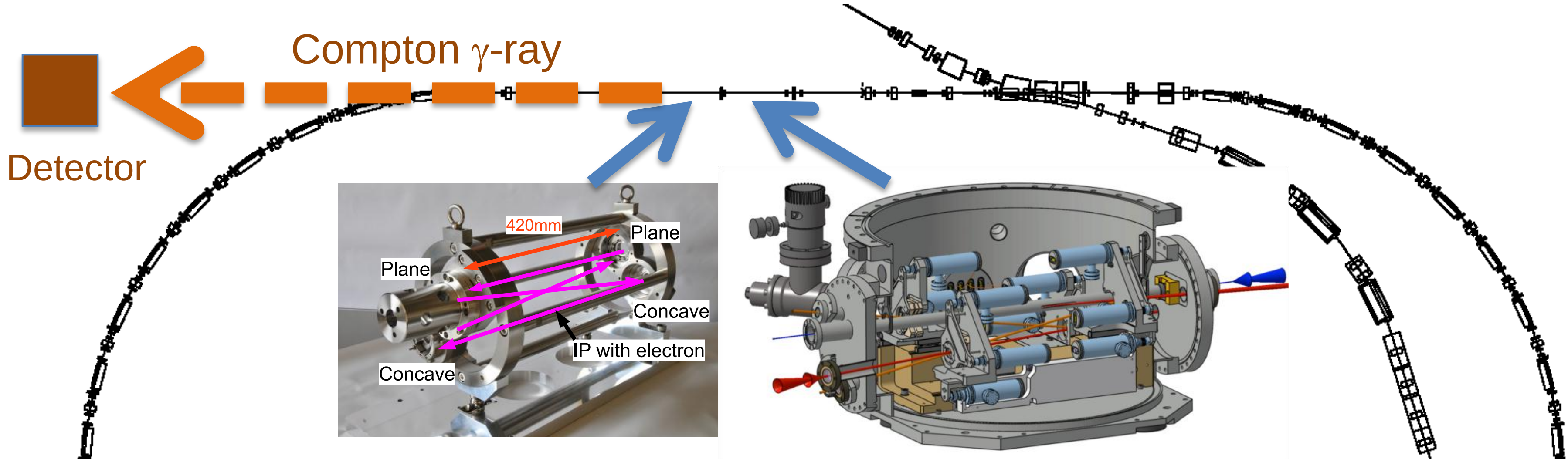


IPBPM

Triplet of the Low-Q cavity BPM. Fabricated by KNU. Sensitivity was tested at ATF LINAC.
Readout electronics has been tested at ATF2.



Polarized Positron Source R&D



Hiroshima/KEK
2-mirror cavity
→ **4-mirror cavity system**
Installed in 2011 Nov.

LAL
4-mirror cavity system
Installed in 2010 Aug.

High-intense laser by Optical cavity
2-mirror system → **4-mirror system**

- Higher tolerance
- **Higher number of Compton γ-ray**

→ **Polarized positron source**
→ Future **γ-γ collider technique**

4-mirror Optical Cavities

Hiroshima/KEK System

Improvement by 2→4-mirror

σ~30um → 15um

finesse 2000 → 5000

~100 photons/train was observed.
Stored power 2.6kW

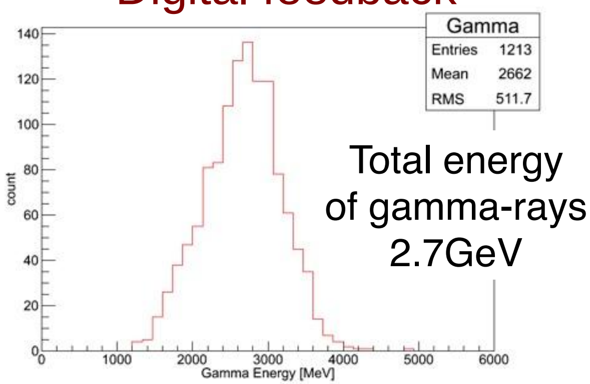
More improvements in JFY2013

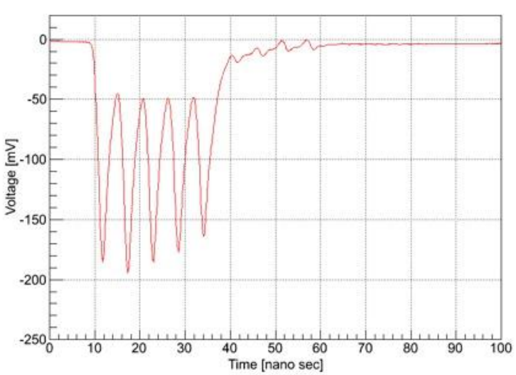
- finesse 5000 → 28000 or more (R>99.996%)
- Digital feedback

LAL System

Detect the first Compton signal on October 2010.

Laser trouble was happened.
Checkout of the Improved system with new laser is carried out at LAL.
It is planning to install in ATF again in early 2013.

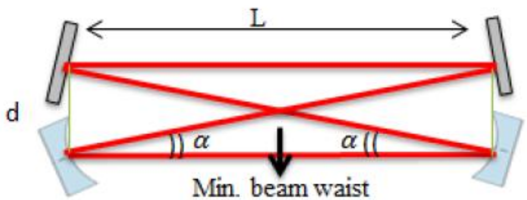


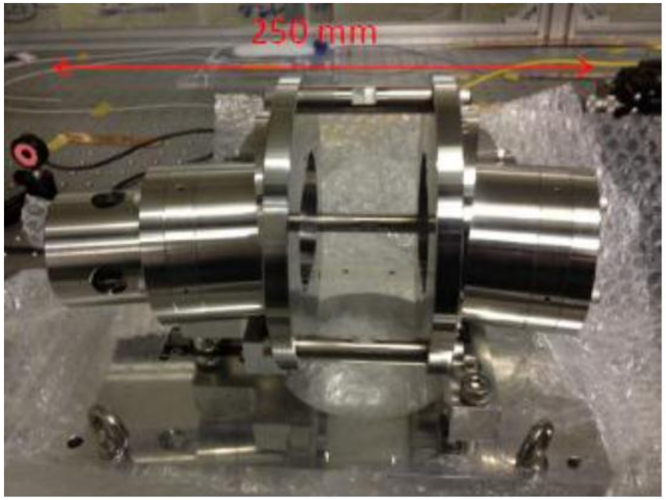


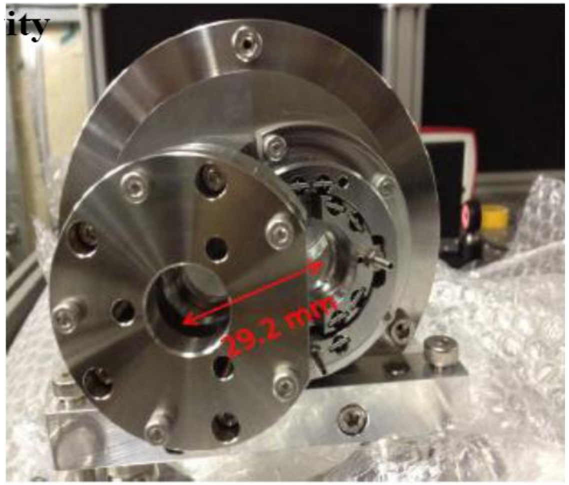
~100 photons/train observed !

Application of 4-mirror cavity
- Upgrade of the DR Laser Wire -

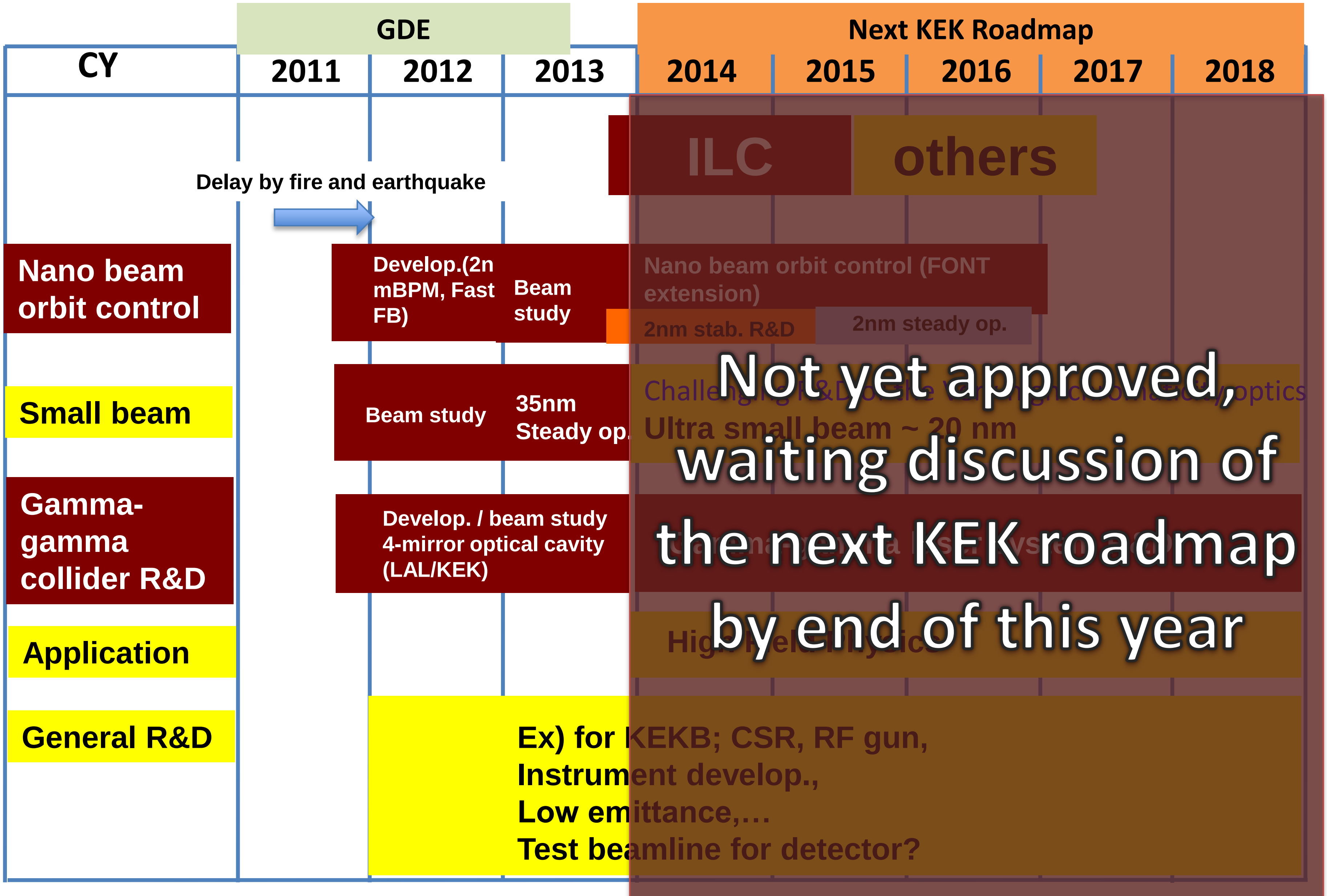
- **Emittance measurement by direct collision of a laser and an electron beam.**
- 2-mirror LW system → 4-mirror system
  - **expect 100 times increase of the Compton signal**
  - reliable and faster measurement
  - **for vertical, horizontal and longitudinal beam size measurement.**
- manufacturing has been started.
- the system will be installed in DR by the end of this year.







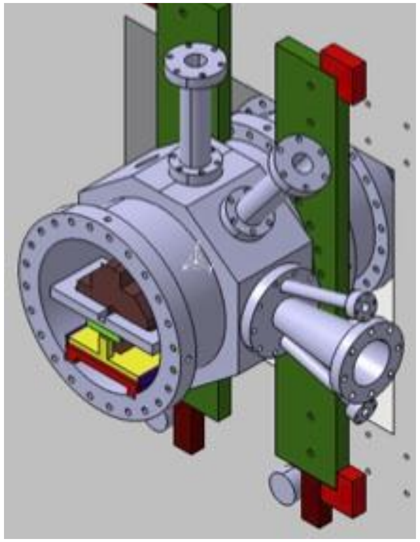
ATF Future Plan



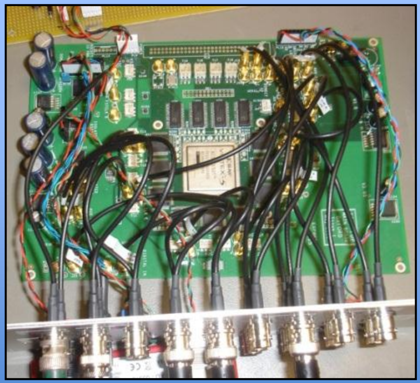
Proposal : nm beam orbit control

The nm-level beam stabilization is one of the key for ILC and Goal-2 on the ATF2 project. It is so challenging then will not be completed at the end of FY2013. Extension of this program will be necessary.

Full setup at IP will be assembled in early 2013.



Upgrade of 2 nm readout



Upgrade of FONT feedback system

nm Stability R&D

Proposal : nm small beam

- Explore the small beam after the 37 nm at ATF2
- Collaborated R&D for CLIC
- Demonstration of the final focus with **the Very high chromaticity optics** and establish the beam tuning method → **20 nm beam**

Critical Developments

- Beam Size Monitor (Highly stable Laser Interference Fringe Monitor at ATF2); Modulation 0.8 (37nm) → 0.9 (20nm)
- Beam Stabilization (IP-BPM + FONT)
- Renew the Final Doublet Quadrupole (QF1) at ATF2; **CERN proposed In-kind Contribution**

CLIC R&D proposals for ATF/2/3

- CLIC challenges are pushing technology in different areas of linear colliders
- Beam tests are a major aspect of the feasibility demonstration
- ATF facility (being half a collider!) represents a unique opportunity for the following topics:
  - **Ground motion orbit feed forward**
  - **Ultra-low beta***
  - **CLIC DR extraction kickers**

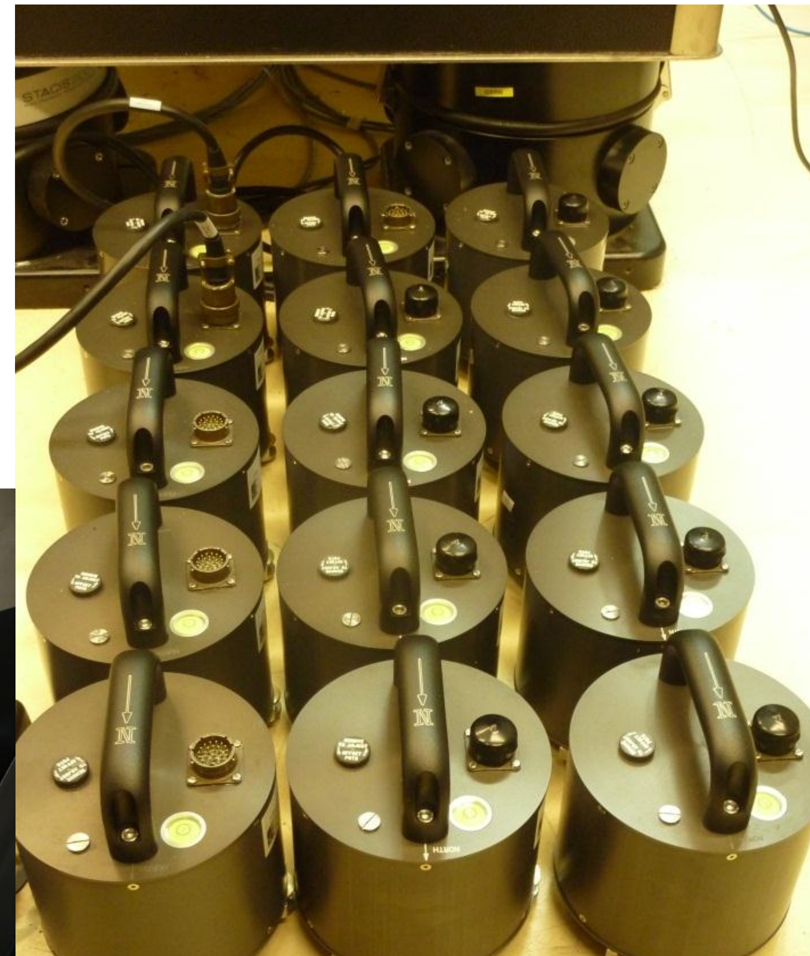
Ground Motion feed forward

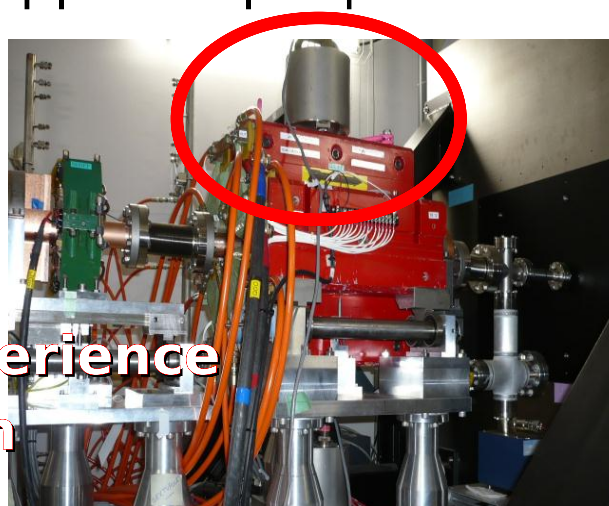
- CLIC train repetition frequency is 50 Hz
- So no beam information during 0.02 s
- Daniel's idea: “Install GM sensors along the beamline to correct beam orbit based on GM”
- Labs involved: CERN, KEK, LAL and LAPP

Grand Motion Sensors prepared by LAPP

52000€ investment +
approx 3 people from LAPP
(A. Jeremie et al)

CERN is providing low noise cables + approx 5 people.





Past experience
B. Bolzon

Ultra-low β*

- Pushing the σ^*_y below the 37 nm is of interest for both CLIC and ILC
- Multipolar errors in FD already force an increase of β^*_x for the Nominal lattice
- Replacing FD quads with high accuracy magnets would allow nominal β^*_x for the Nominal lattice and reaching σ^*_y of 25 nm for the Ultra-low β* lattice.
- Goal-1 has to be reached before Ultra-low β*!

Ultra-low beta-function

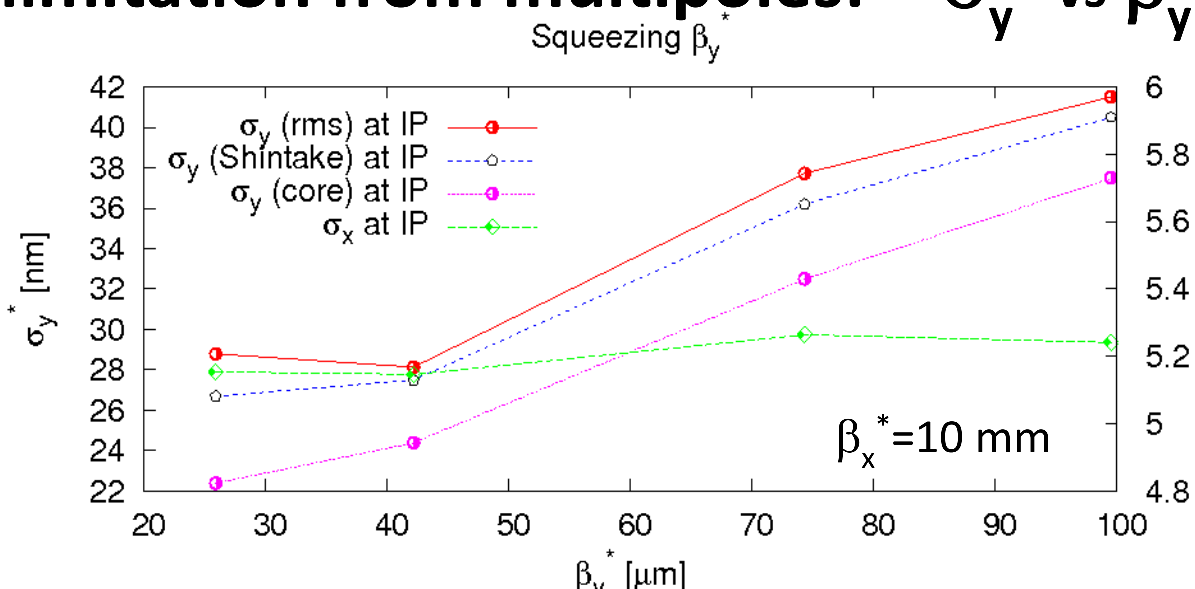
R. Tomas

motivation

project	L^*[m]	β_y^* [μm]	ξ_y
ATF2 nominal	1.0	100	~19000
ILC design	3.5	400	~15000
ATF2 ultra-low	1	25	~76000
CLIC 3 TeV	3.5	90	~63000

To prove CLIC chromaticity levels in ATF2 requires a factor 4 lower IP beta function. The main obstacle is the field quality (already issue for ATF2 nominal)

limitation from multipoles: σ_y^* vs β_y^*

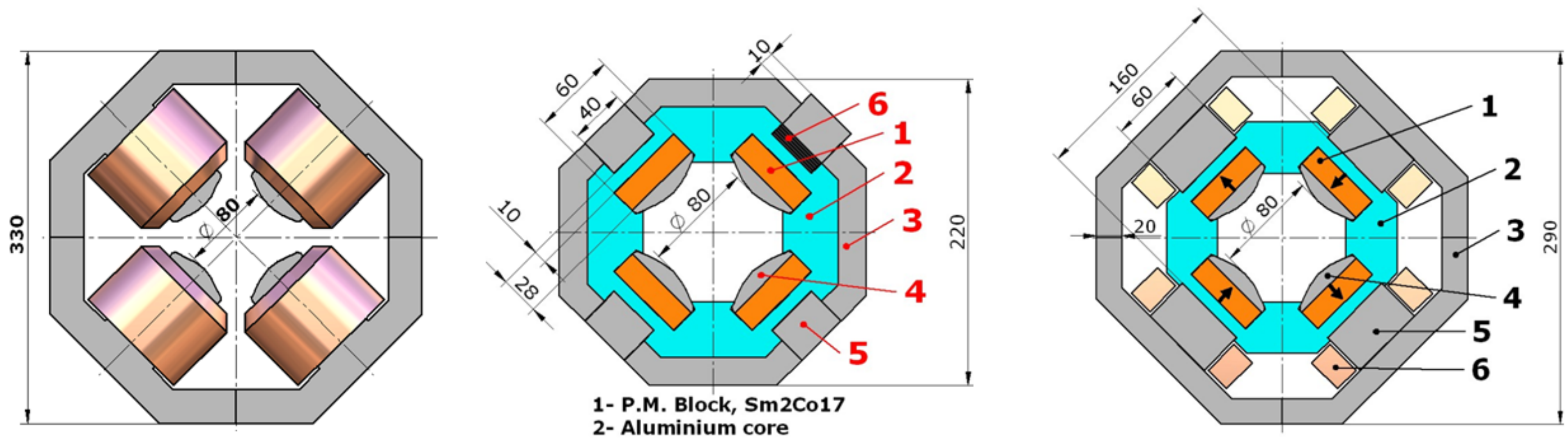


with measured magnetic multipoles; optimization with MAPCLASS; no further reduction when decreasing β_y^* below 40 μm

…from FJPPL-FKPPL WS on ATDF2 in March 2012:

Magnet design

1) EM quadrupole: 2) PMQ 3) Hybrid(based on PMQ)

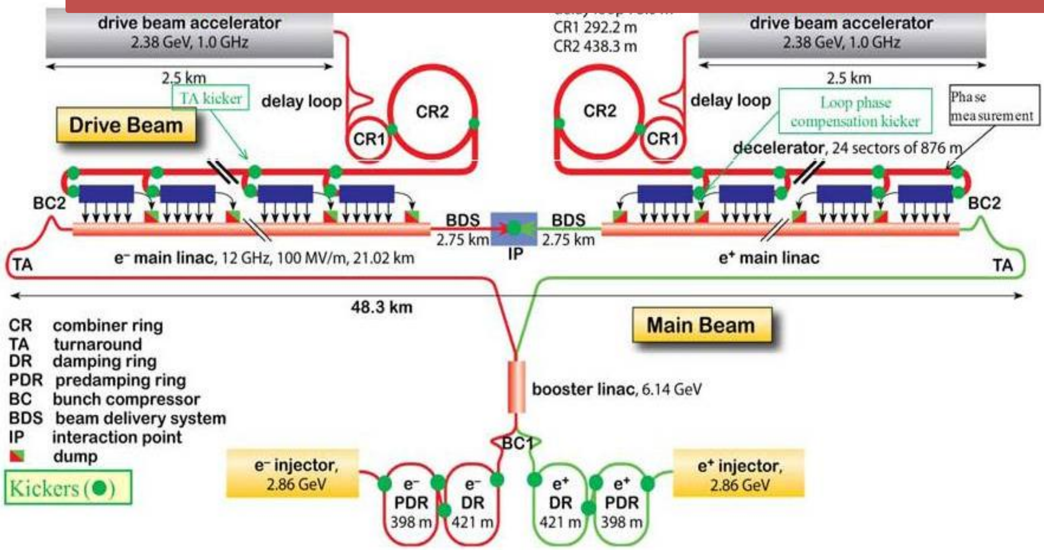


1- P.M. Block, Sm2Co17
2- Aluminium core
3- Return Yoke, AISI 1010
4- Pole Tip, AISI 1010
5- Tuning block, AISI 1010
6- Spacers, Stainless steel

<u>The PMQ solution looks more preferable over than the EMQ and the hybrid magnet due to the following reasons:</u>

- Compactness of the PMQ structure
- No vibration of the magnet induced by an active water cooling system which is required for EMQ option.
- No failures in the power supplies, which increases the reliability of the magnet.
- Maintenance of coils, cables and power supplies is not required.
- Set to zero operational costs related to electrical energy and cooling systems.
- PMQ can be assembled from one or two pieces, while for the EMQ option only four pieces yoke structure is possible.
- The proposed PMQ design has an ability to suppress the possible higher order multipole errors performed by the tuning blocks, while for the EMQ and the hybrid cases an additional trim coils and four independent power supplies are needed.

We propose to install a first prototype stripline kicker, together with the inductive adders for the pulsed power supplies, for testing in a straight section of the extraction line of ATF2. This kicker system is being designed to extract horizontally the beam from the CLIC Damping Rings. The main objective of these tests is the validation of the proposed design from the field stability, field homogeneity and impedance points of view



- Several challenging kicker systems are required to inject the beam into and extract the beam from the PDRs and DRs
- In order to achieve both low beam coupling impedance and broadband impedance matching to the electrical circuit, striplines have been chosen for the kicker elements

A set of protoype striplines will be built by the Spanish company Trinos Vacuum Projects under the Centro de Desarrollo Tecnológico e Industrial (CDTI) program in collaboration with the IFIC and the CIEMAT Accelerators groups

Specifications for the CLIC DR, CLIC PDR and ATF2

Parameter	CLIC PDR		CLIC DR		ATF2		
	1 GHz	2 GHz	1 GHz	2 GHz	1-bunch	3-bunch	20-bunch
Beam energy (GeV)	2.86		2.86		1.30		
Total kick deflection angle (mrad)	2.0		1.5		1.5		
Aperture (mm)	40		20		20		
Effective length (m)	3.4		1.7		1.7		
Field rise time (ns)	428	1000	560	1000	560/1000		
Field fall time (ns)	428	1000	560	1000	560/1000		
Pulse flat top duration (ns)	900	160	900	160	900/160		
Extraction field inhomogeneity (%)	±0.1 (3.5 mm)		±0.01 (1mm)		±0.01 (1mm)		
Repetition rate (Hz)	50		50		1.56		
Vacuum (mbar)	10^{-10}		10^{-10}		10^{-10}		
Pulse voltage per stripline (kV)	± 17.0		± 12.5		± 5.5		
Stripline pulse current (A)	± 335		± 250		± 115		
Longitudinal coupling impedance (Ω)	< 0.05		< 0.05		< 0.05		
Transverse coupling impedance (kΩ/m)	< 200		< 200		< 200		
Peak beam current (A)	70	50	110	120	60	30	20
Bunch length (ps)	10	14	6	5.3	16.7		

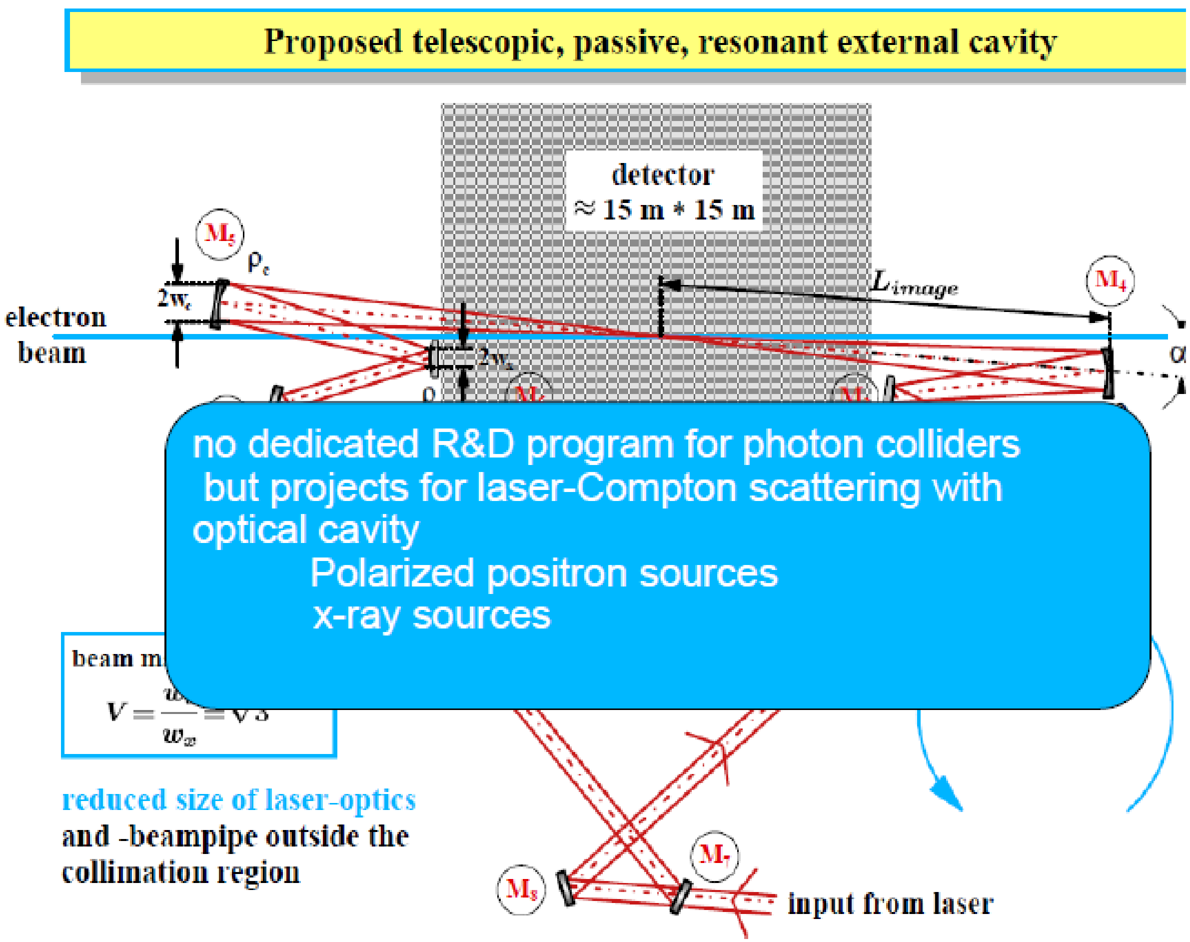
Proposed Schedule and Commissioning

We have essentially finalized the cross section design of the striplines. Once the beam coupling impedance study is finished, the striplines will be manufactured by December 2012. The tests planned by 2013 are the following:

- **Laboratory test at CERN:** verification of the stripline dimensions, field homogeneity, longitudinal and transverse beam coupling impedance, vacuum performance and high voltage performance.
- **Tests and measurements at ALBA:** using d.c. power supplies instead of a pulse generator, to determine transverse beam coupling impedance and, if possible, longitudinal beam coupling impedance. Field homogeneity measurements will be carried out with the d.c. power supplies and a closed bump.
- It is planned that two inductive adders will be built and tested by 2014: hence **our goal is that the kicker striplines and the two inductive adders are installed in ATF2 during 2014**.
- We anticipate being able to commission the kicker system immediately after the kicker has been installed

Proposal : Gamma-gamma R&D

Apply the Grant for Scientific Researches, In-kind contribution (LAL)



no dedicated R&D program for photon colliders
but projects for laser-Compton scattering with optical cavity
Polarized positron sources
x-ray sources

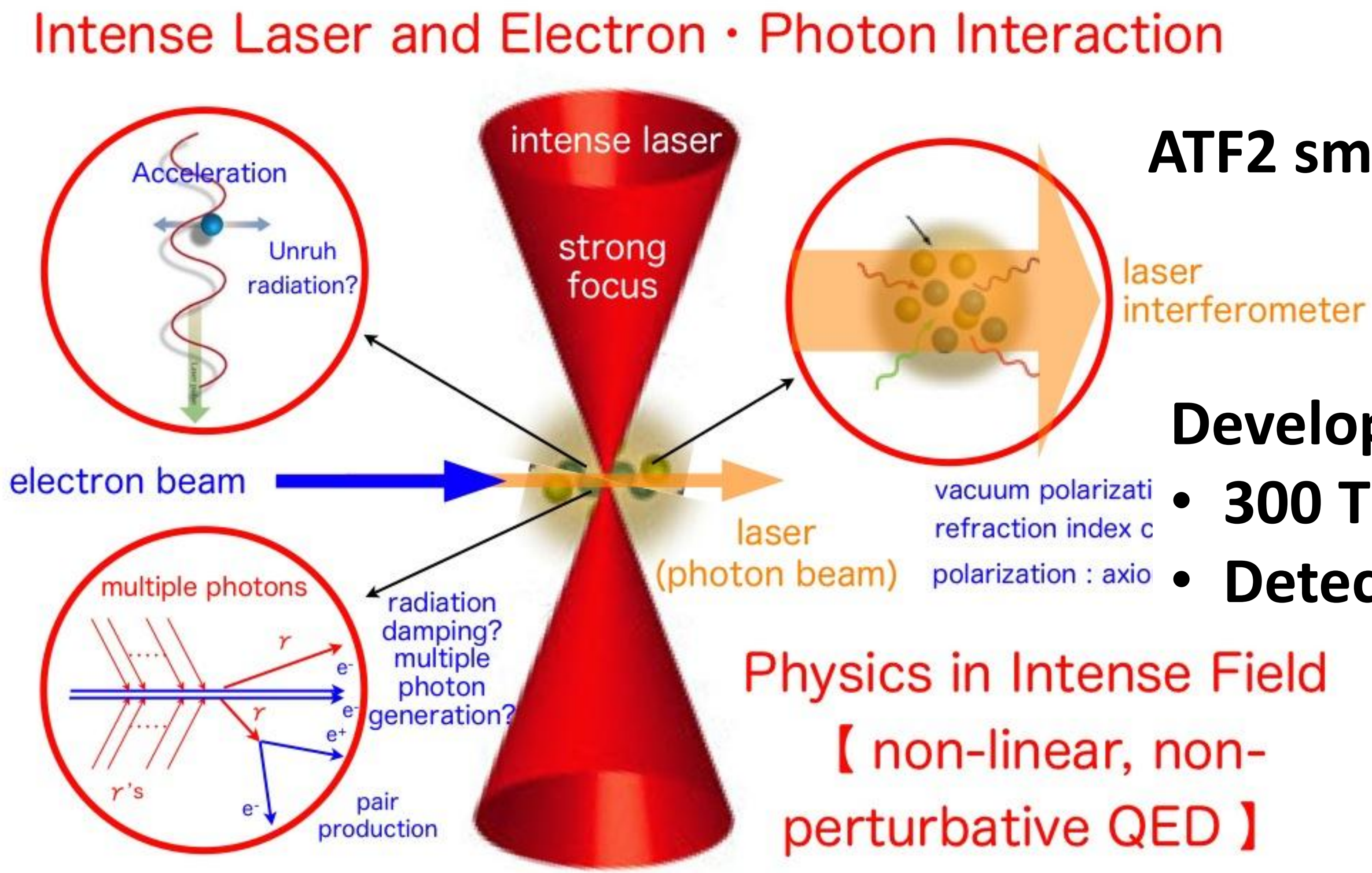
Establish the fundamental technology for Photon LC

- several 10 m scale high power Optical Cavity
- (100 m for PLC)

- Laser cavity system at ATF-EXT line
- Realize several micron laser

Proposal : High Field Physics

Apply the Grant for Scientific Researches



ATF2 small beam

Development

- **300 TW laser**
- **Detector**