ATF2

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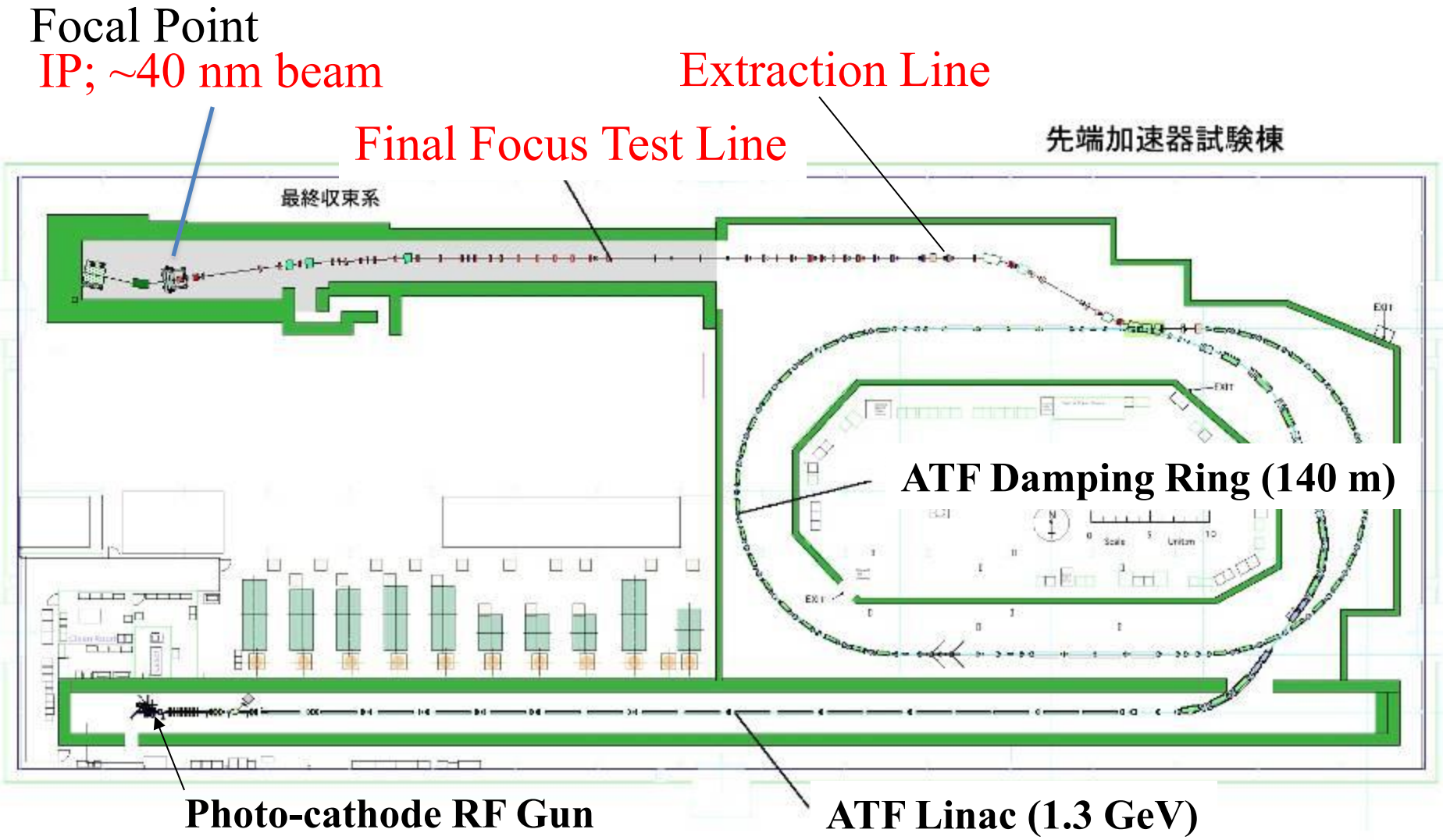
Accelerator Test Facility (ATF) at KEK

- ATF
  - Designed as a prototype of damping ring and injector of LC
  - Achieved low vertical emittance (ε_y ~4 pm, $\gamma\varepsilon_y$ ~10 nm)
  - R&D of various instrumentations.
- ATF2
  - Extended part of ATF designed for testing Final Focus of ILC (Local Chromatic Correction Scheme).
  - Goal 1: Small vertical beam size, ~ 40 nm
  - Goal 2: Stable beam position (with feedback), ~2 nm

Accelerator Test Facility (ATF) at KEK



Goals of ATF2 project

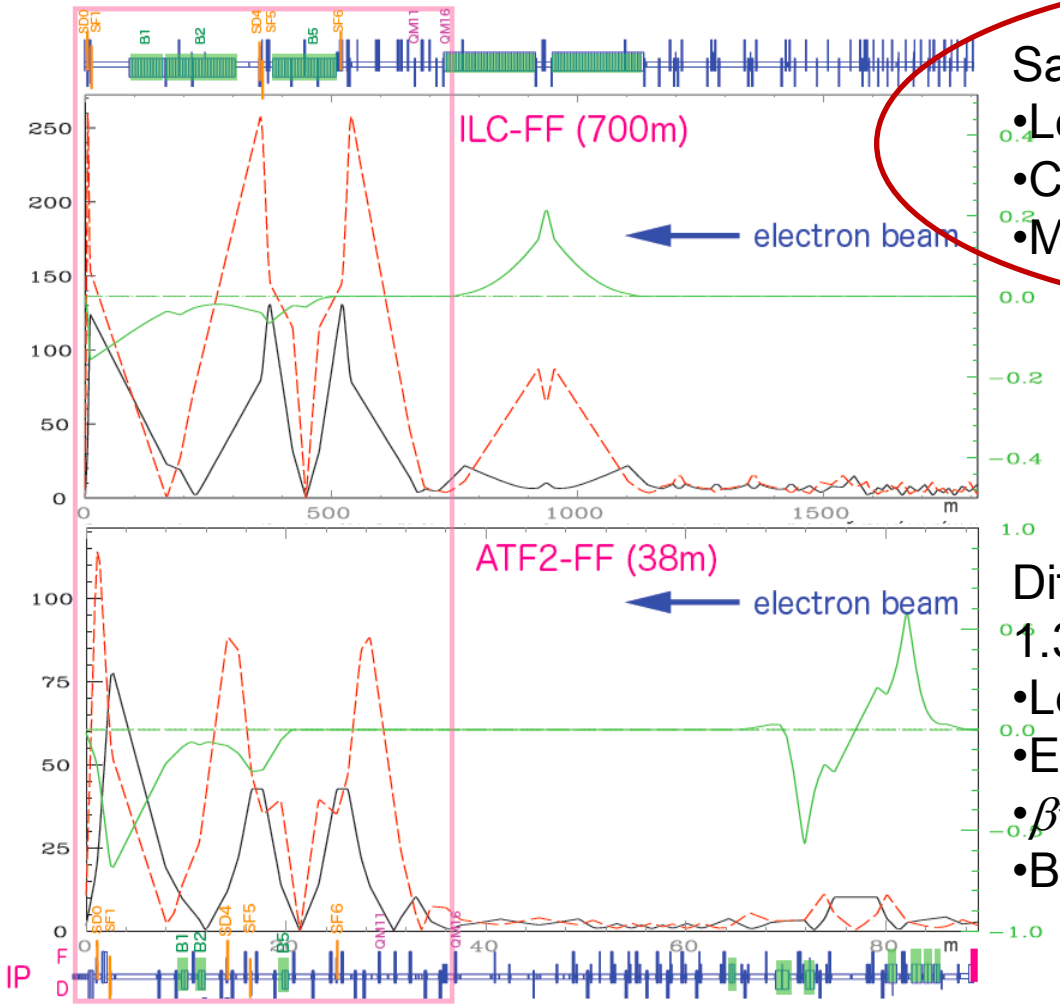
Goal1: Produce and Confirm Small Beam Size

- 37 nm (sigma) (Emittance 12 pm, beta* 0.1 mm)
- Single bunch

Goal2: Produce and Confirm Stable Beam

- 2 nm RMS position jitter at focal point (As required in ILC Interaction Point)
  - Tail bunch(es) in multi-bunch beam with fast feedback.

Optics of ATF2 and ILC-BDS



Same
- Local Chromatic Correction
- Chromaticity ~ L^*/β^* ~ 10000
- Momentum spread ~ 0.1%

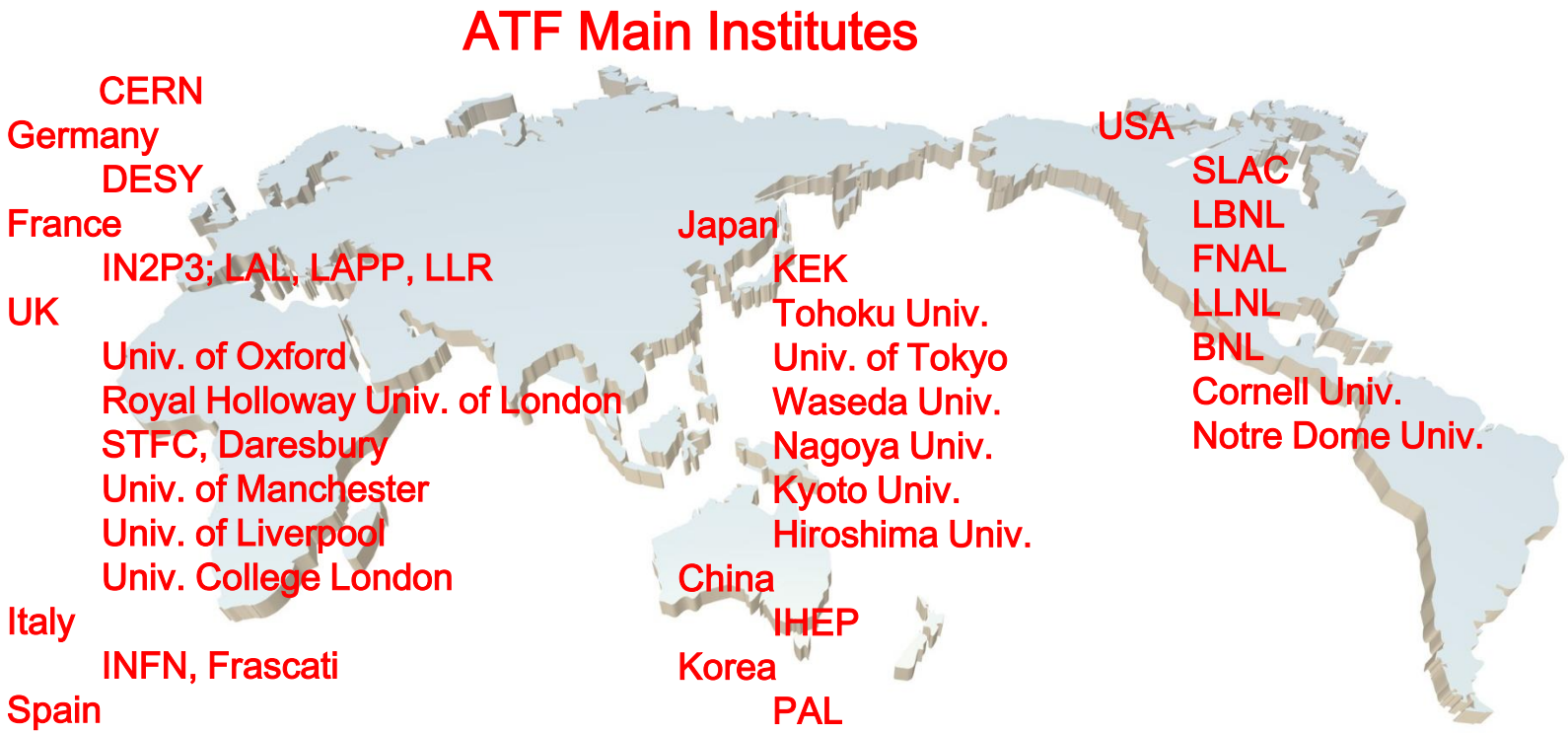
Same method
Similar difficulty

Different Beam energy
- 1.3GeV/250GeV
- Length 38m/700m
- Emittance 12pm/0.08pm
- β^* 0.1mm/0.5mm
- Beam size 40nm/6nm

Figure from G.White, ATF2 Technical Review, 201304

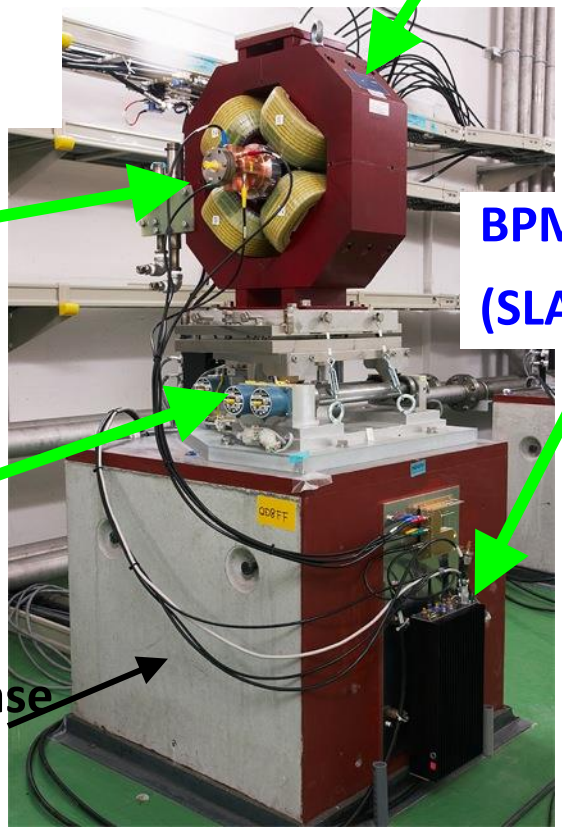
ATF2, International Collaboration

Design, Construction and Operation



International Contribution, Construction

Magnets (IHEP/SLAC/KEK)
Magnet Power Supply (SLAC/KEK)
Final Doublet Supports and Table (LAPP)
Cavity BPM System
(KNU / PAL / KEK / RHUL / SLAC)
Beam Size Monitor (TokyoU./KEK)



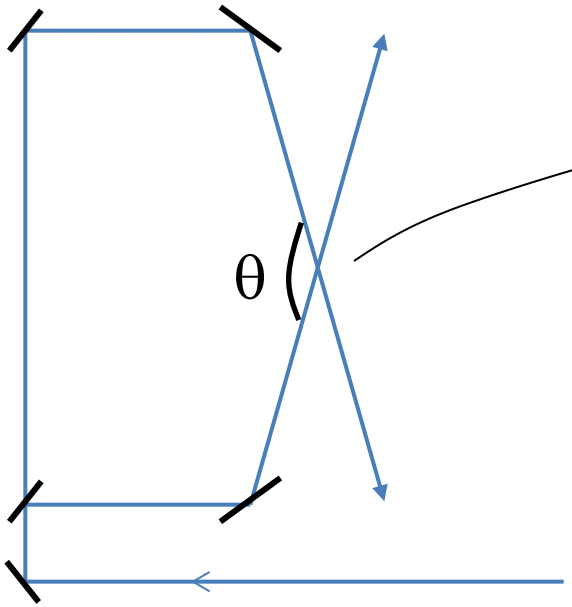
Daily Operation Meeting in ATF Control Room

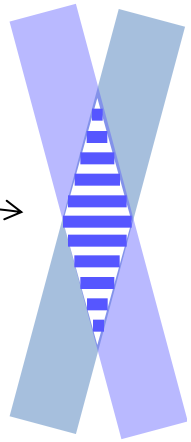
S. Araki

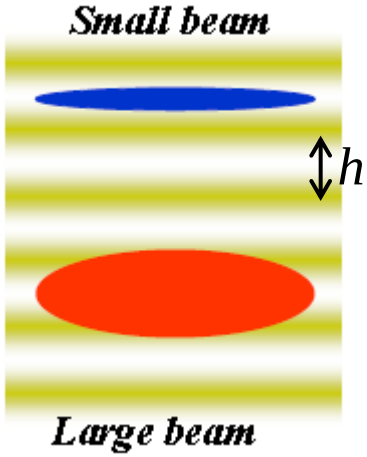
Measurement of Beam Size at Focal Point

(IPBSM)

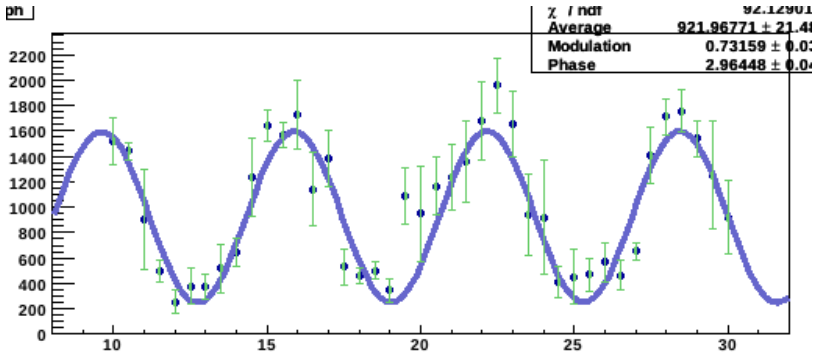
Shintake-monitor,
Interference of two laser beams







$$h = \frac{\lambda}{2\sin(\theta/2)}$$



$$\text{Modulation} = \frac{\text{peak} - \text{bottom}}{\text{peak} + \text{bottom}}$$

$$= |\cos\theta| \exp\left(-\frac{2\pi^2\sigma^2}{h^2}\right)$$

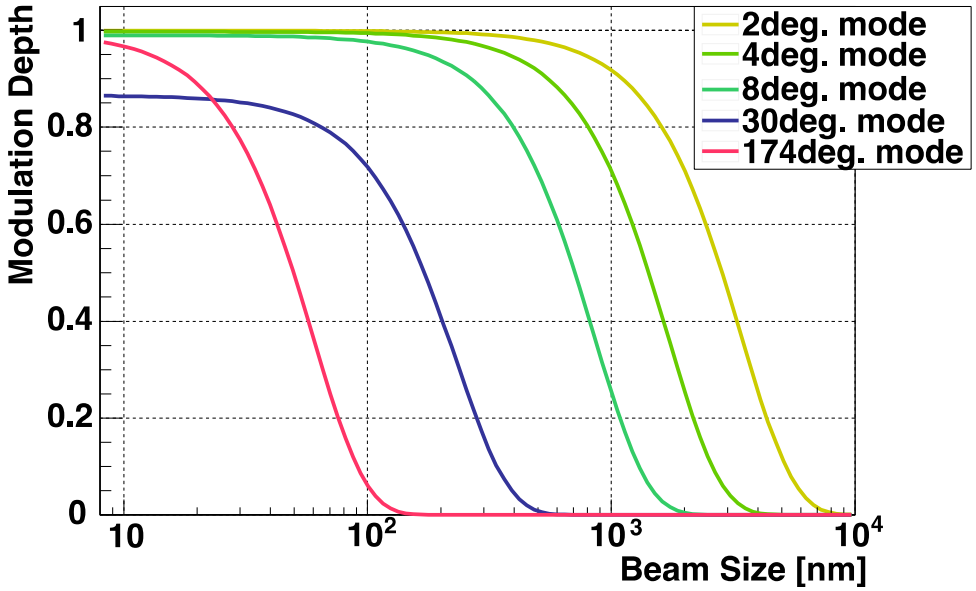
Scan interference fringe position.
Measure modulation.

Increase Laser Crossing Angle
As Electron Beam Size being Squeezed

Beam tuning with
2-8 deg.

→ 30 deg.

→ 174 deg.



	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

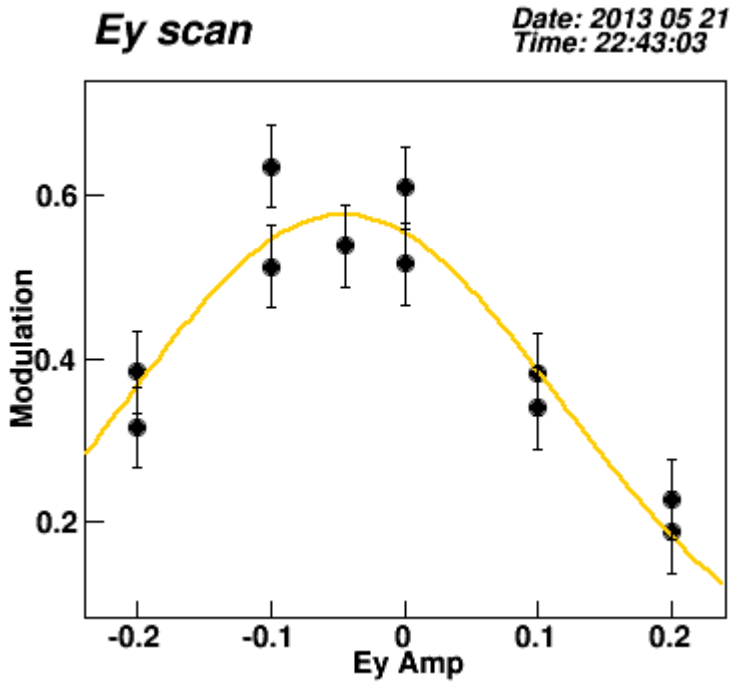
Sensitive beam size region
With each crossing angle.

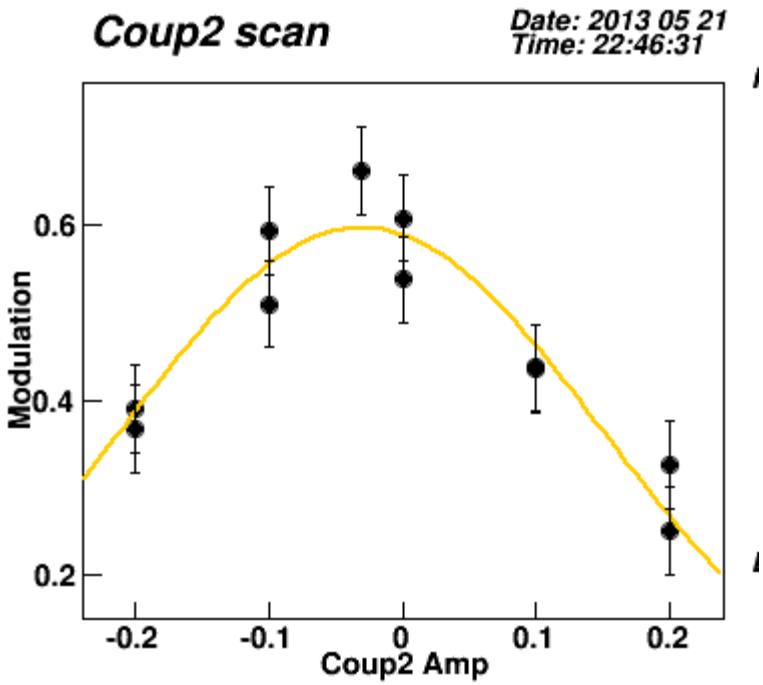
Tuning knobs

		Corrected coupling
Linear knob	Horizontal move of sextupole magnets	yy’
	vertical move of sextupole magnets	Ey
		x’y
Non-linear knob	Strength change of sextupole magnets	x’yy’
		Eyy’
	Strength change of skew sextupole magnets	xxy
		Exy
		EEy
		yy’y’

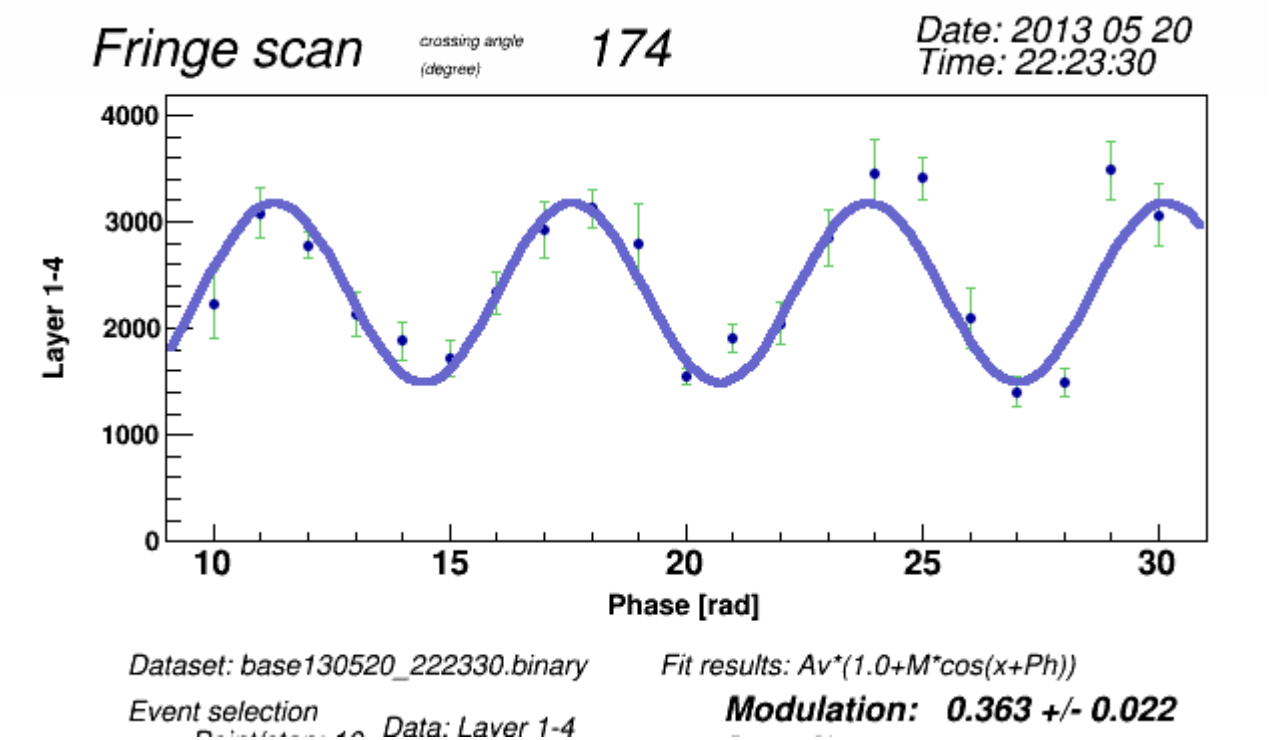
5 sextupole magnets (on movers) and
4 skew-sextupole magnets

Example of tuning knob scan

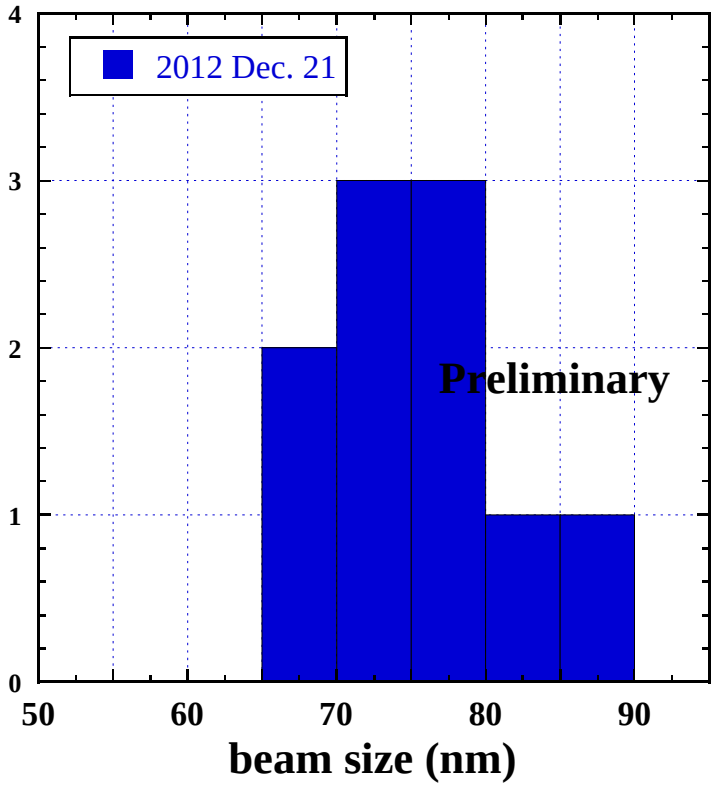


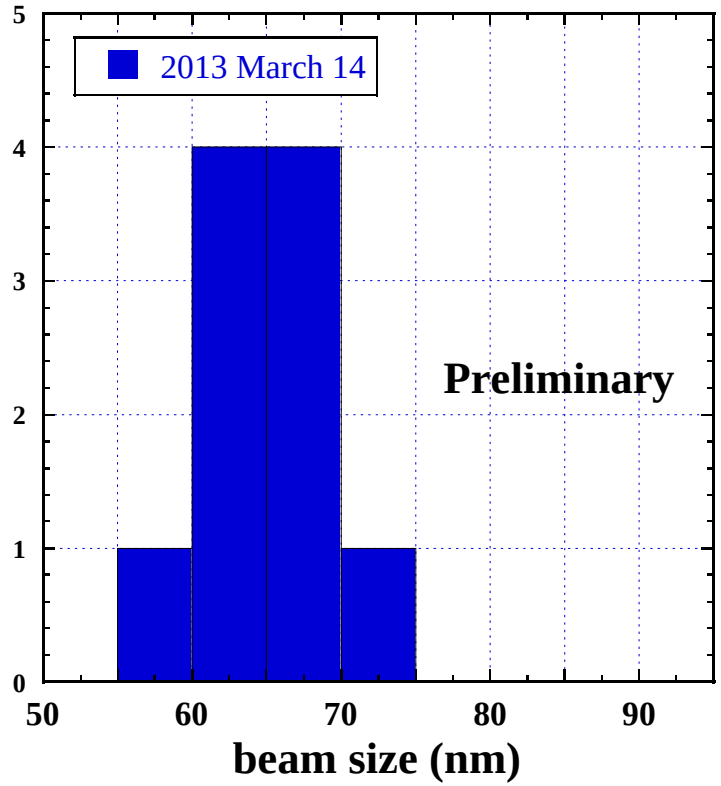


Example of fringe scan



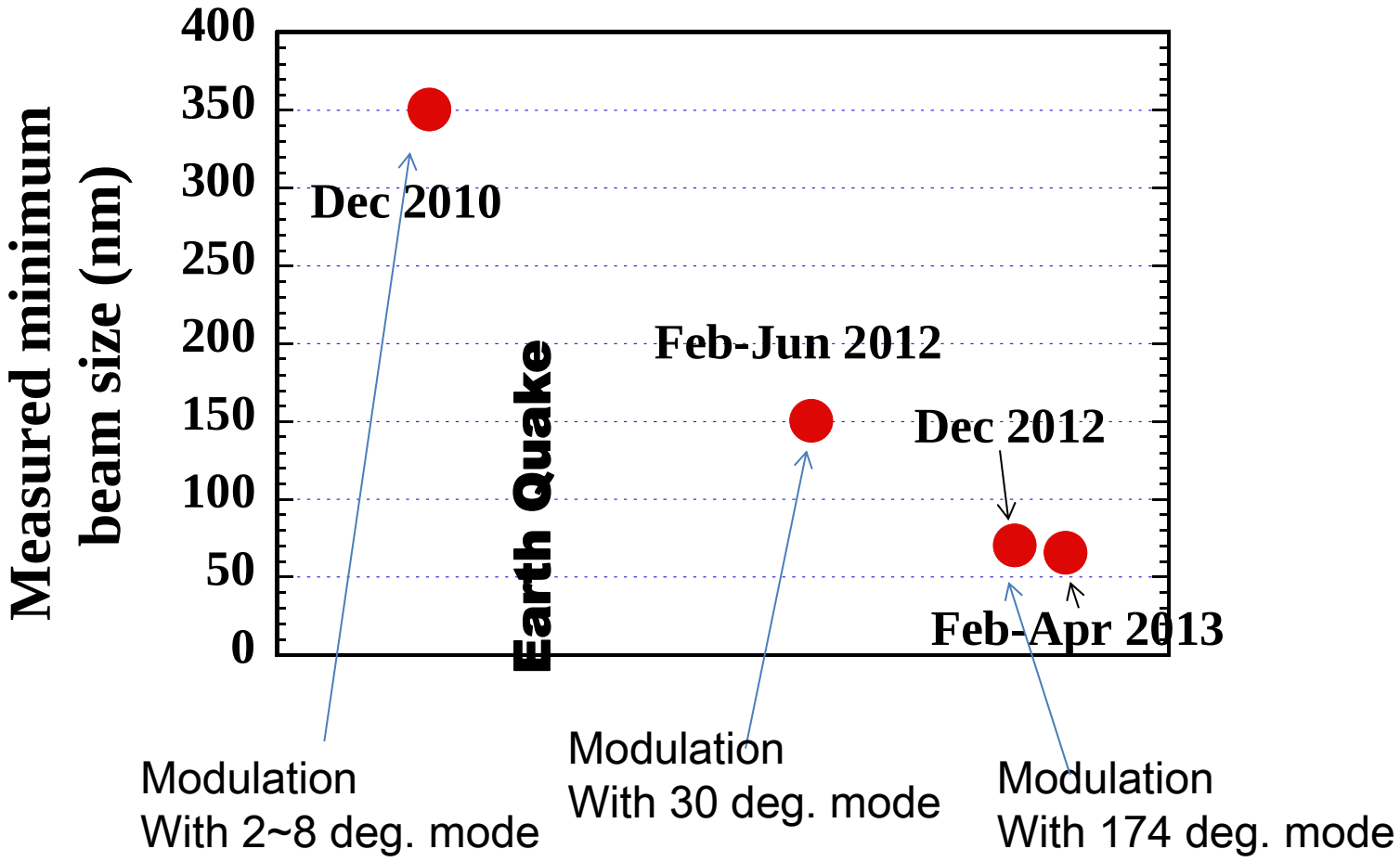
<70 nm beam size confirmed first in Dec. 2012, and continuously observed





Beam size evaluated assuming no systematic error of the beam size monitor.

History of measured beam size



Multi-pole field problem and cures

Magnets have multi-pole field errors and affect beam size at focal point. Especially final h-focus magnet.

- **Adopted optics of large beta-x at focal point** (small beam size in the magnets and reduce effect of multi-pole field).
- **Replaced final h-focus magnet** (small aperture, large multi-pole field error) by a magnet with large aperture and small multi-pole field
- **Add multi-pole field correctors** (skew sextupoles)

Intensity dependence

Small beam size was observed only at low intensity.

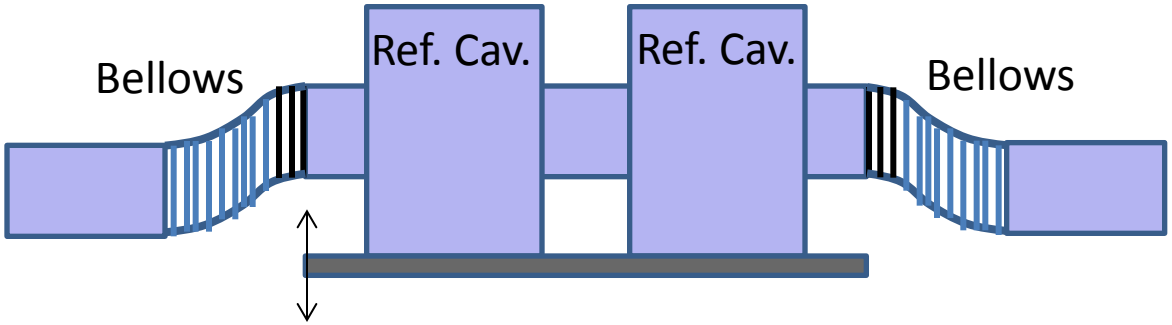
Strong intensity dependence.

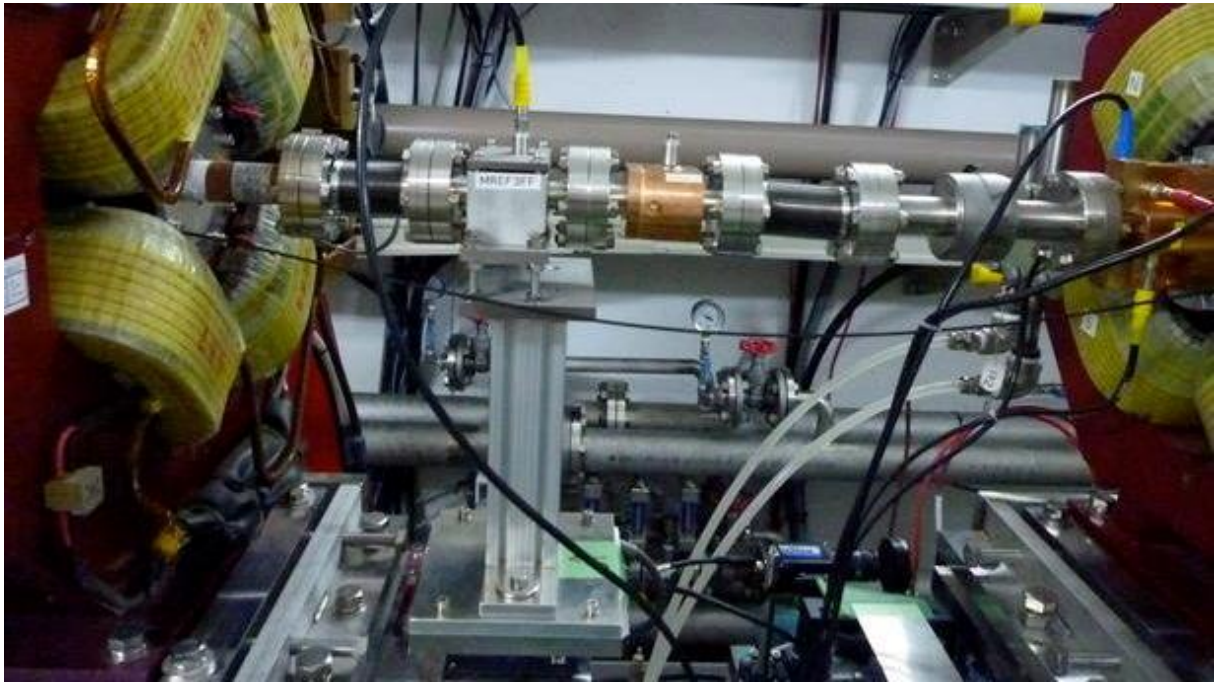
Wakefield in the final focus line is suspected.

- Low energy compared with ILC
- Long bunch length
- High beta-function as same as ILC BDS

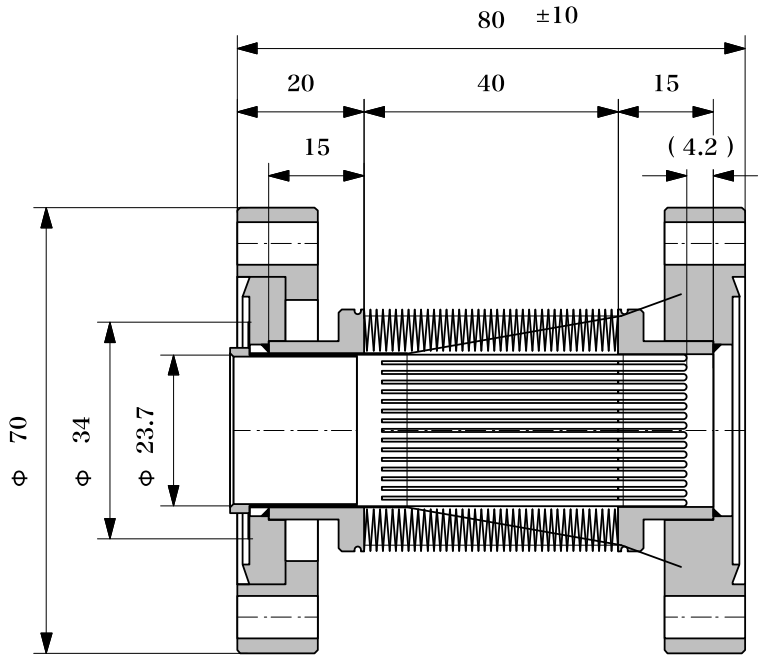
Cannot exclude other effects: E.G., Intra-beam scattering in the damping ring (increase horizontal emittance and momentum spread) + non-linear coupling in ATF2 beam line.

Wakefield source on mover for study and compensation





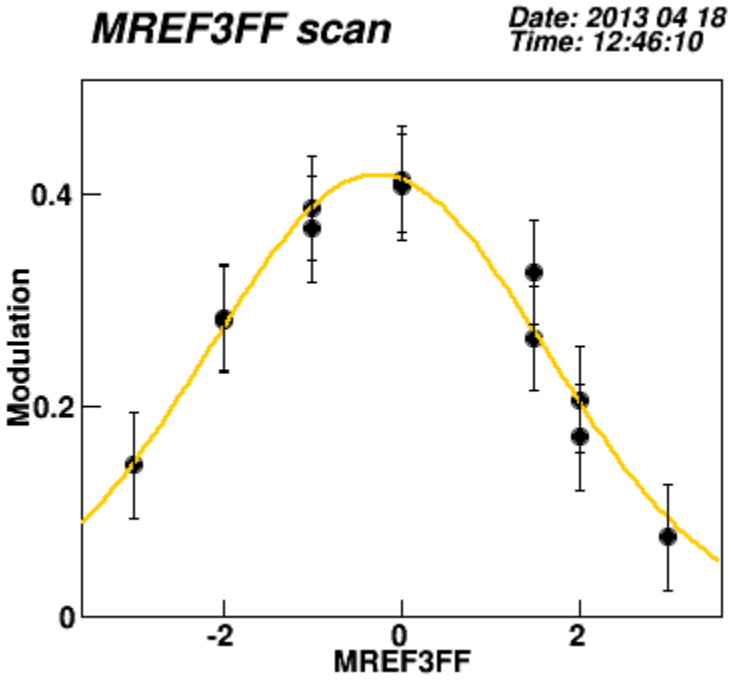
Shield of Bellows



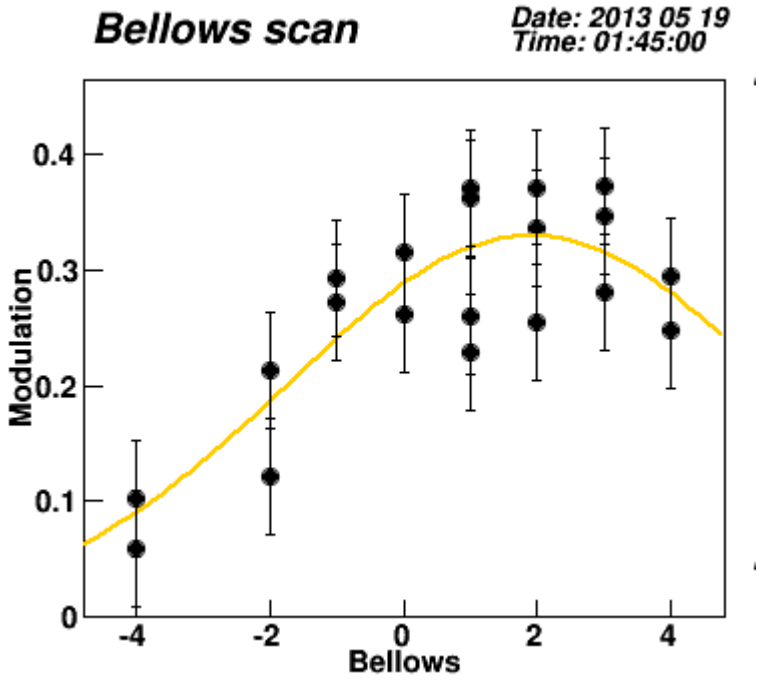
Shields were inserted
for most of bellows in high-beta region in May 2013.

Beam size (IPBSM modulation) vs. position of wakefield source on mover

Cavity BPM
Reference cavity



Bellows without shield



Effect of wakefield is still under investigation

Possible reason of larger size than design

- Non-linear field
  - Which cannot be corrected by our tuning knobs
    - Imperfection of tuning knob set ?
    - Higher order fields than 6-poles? (No corrector)
- Wake field
- Beam position jitter
- Systematic error of the beam size monitor

All can have significant effects.

Still under investigation.

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

ILC intra-pulse Feedback

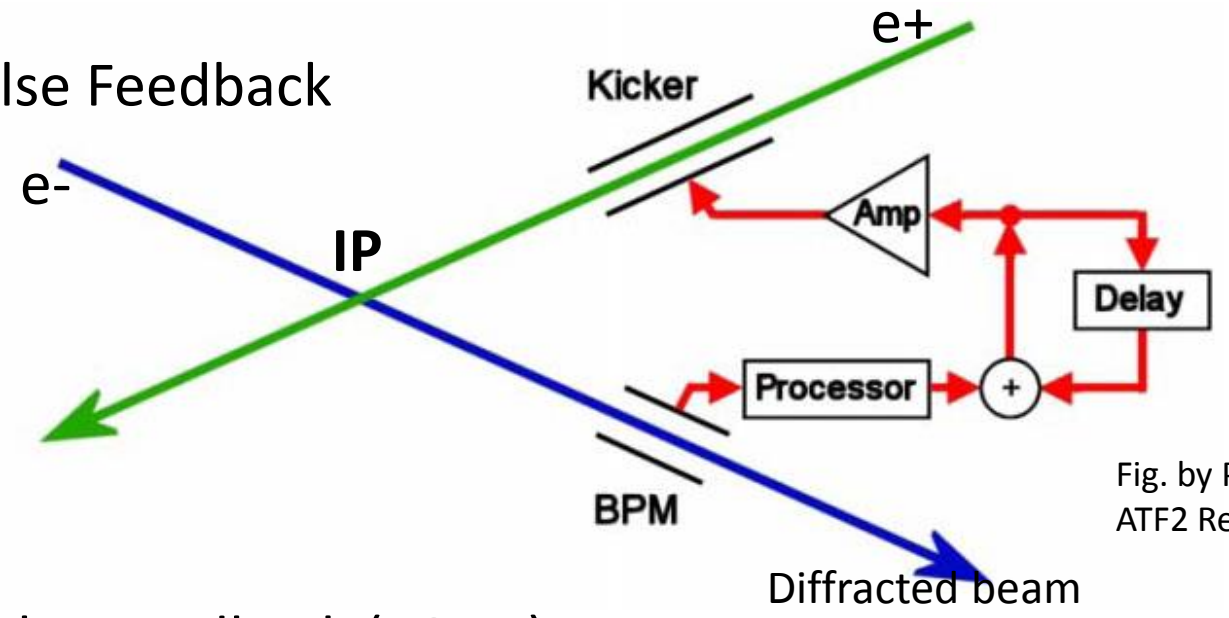
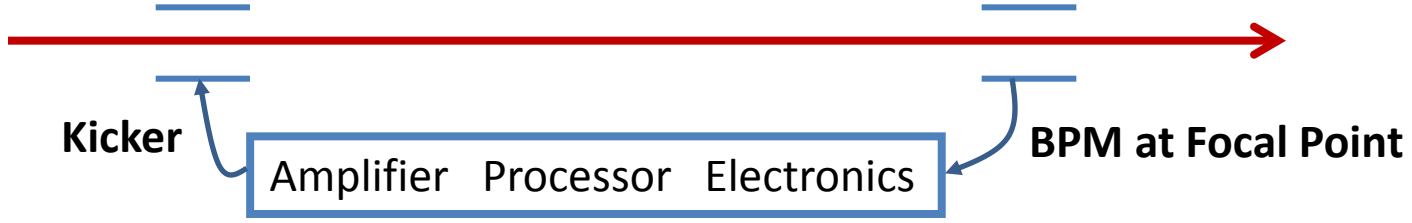


Fig. by P.Burrows
ATF2 Review 2013

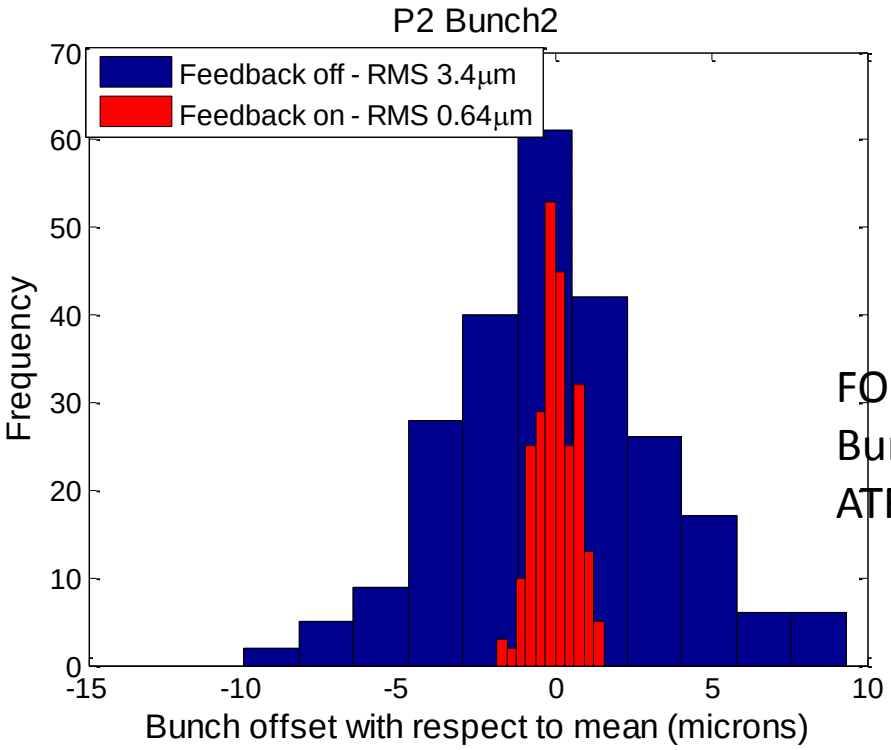
ATF2 intra-pulse Feedback (FONT)

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).

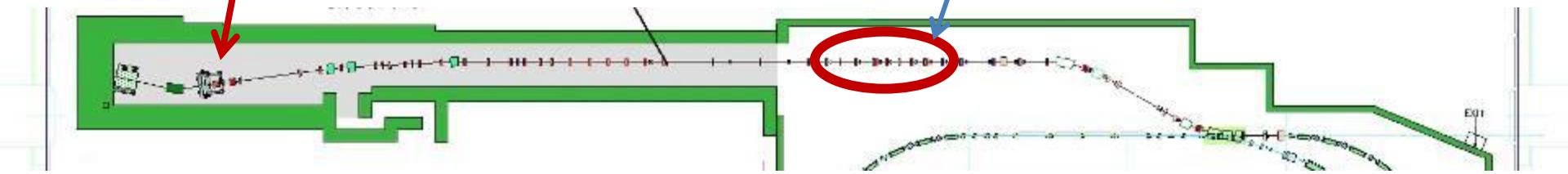
ATF2 Intra-pulse orbit feedback



FONT, Burrows 2013 ATF2 Review

Feedback at Focal Point is being prepared (BPM resolution ~ nm)

Feedback Tested and Demonstrated (BPM resolution ~ micron)



Damping ring

Summary

- ATF2 Goal 1 (small beam size)
  - Achieved and continuously observed < 70 nm vertical size beam at low intensity.
  - For smaller size, and understanding intensity dependence, we are studying
    - Effect of higher order multi-pole field
    - Effect of wakefiled
    - Beam position jitter
    - Systematic error of beam size monitor
- ATF2 Goal 2 (stable beam)
  - Intra-pulse feedback demonstrated in middle of beam line.
  - Test of stabilization at focal point is being prepared and starting in this autumn.

ATF/ATF2 Plan

- Continued studies for making small beam size (Goal 1)
  - Program for even smaller beam size proposed (~CLIC)
- Studies for stable beam as main program of ATF (Goal 2)
- R&D on critical instrumentation and accelerator physics for e+e- colliders.

- Other proposals
  - R&D for gamma-gamma collider
  - High field physics
  - , , ,

ATF Control Room