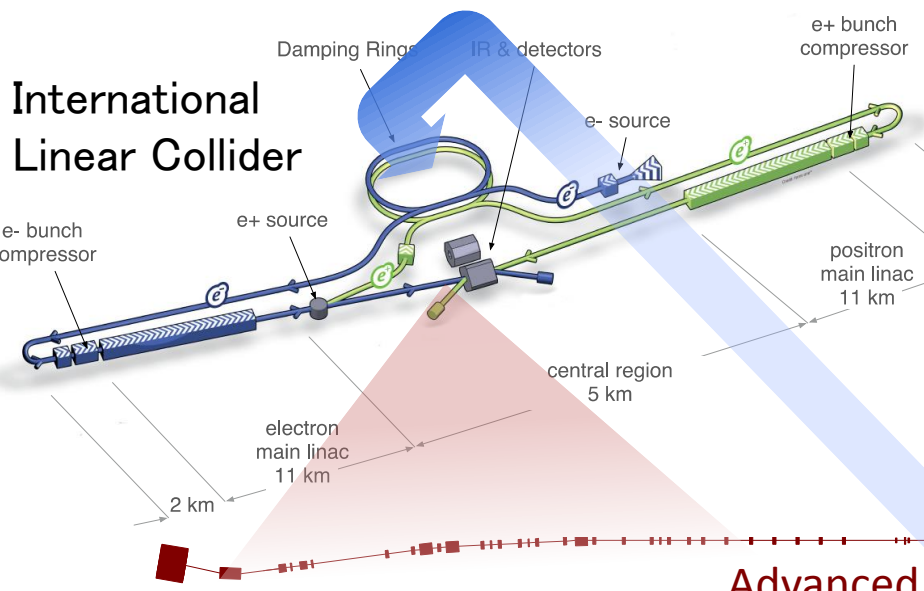


# Brief Introduction of ATF

2021.03.17

LCWS2021 Kiyoshi KUBO

# International Linear Collider



# ATF Accelerator Test Facility

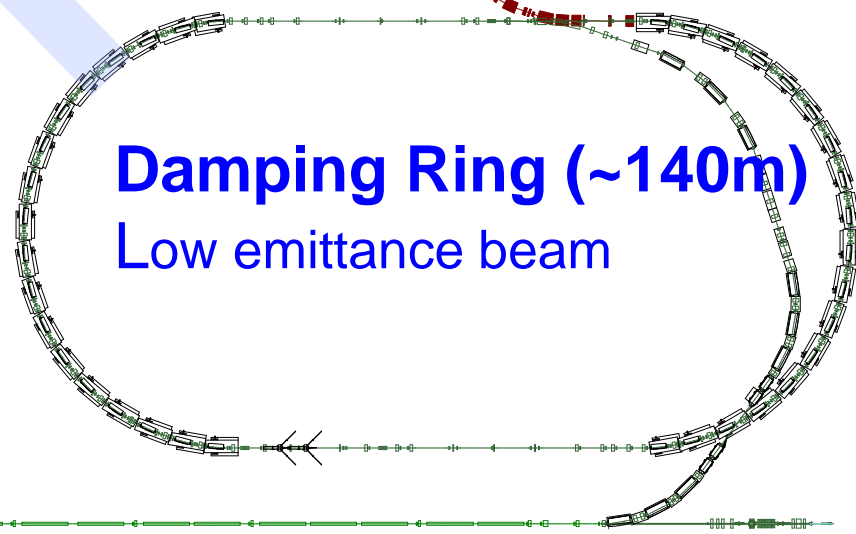
Designed, constructed, and operated as international collaboration

## ATF2 beamline

## Nano-meter beam R&D

Testing Final Focus System of LC

Advanced Beam Instruments R&D



Damping Ring (~140m)  
Low emittance beam

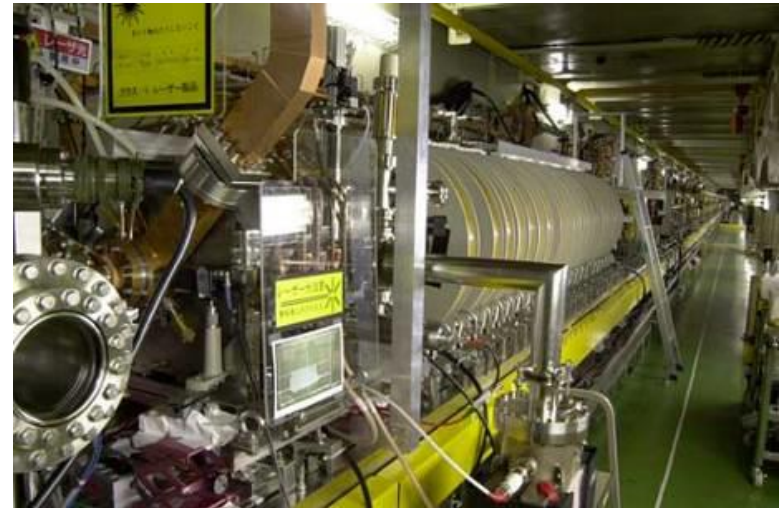
Cs<sub>2</sub>Te Photocathode RF Gun

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

# ATF Injector (to damping ring)

## Photo-Cathode RF Gun

- Photocathode: Cs<sub>2</sub>Te
- RF Gun: S-band (2.856 MHz), 3.6 cells



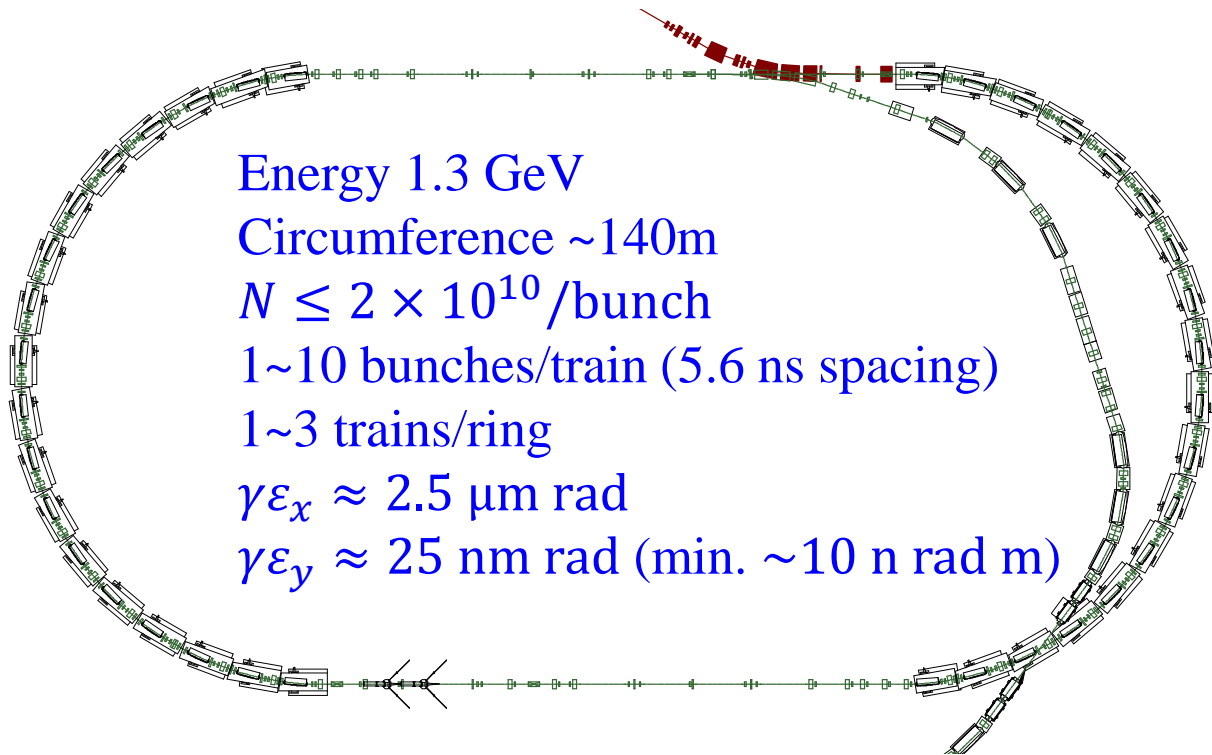
## Linac

- S-band (2.856 MHz)
- 3 m long/accelerating structure
- 19 structures + 2 for multi-bunch energy correction

## Beam parameters

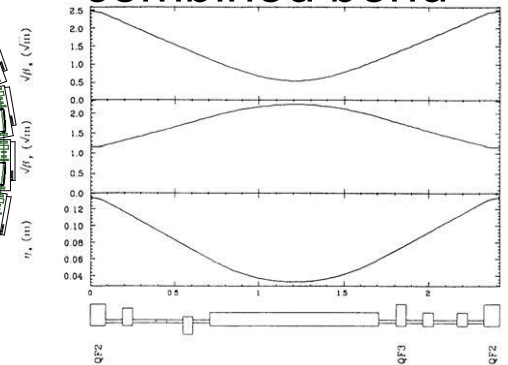
- Beam Energy 1.3 GeV
- Up to 4E10 e-/bunch (usually 1E10)
- Up to 10 bunches/pulse
- Rep. rate: 3.125 Hz

# ATF Damping Ring



Energy 1.3 GeV  
Circumference ~140m  
 $N \leq 2 \times 10^{10}$ /bunch  
1~10 bunches/train (5.6 ns spacing)  
1~3 trains/ring  
 $\gamma\epsilon_x \approx 2.5 \mu\text{m rad}$   
 $\gamma\epsilon_y \approx 25 \text{ nm rad (min. } \sim 10 \text{ n rad m)}$

Arc cell:  
FODO using  
combined bend



Producing low vertical emittance beam was main goal of ATF

$\gamma\varepsilon_y \sim 10$  nm rad achieved ( $\sim 2003$ )

$\leq 25$  nm routinely produced (required for Final Focus Study)

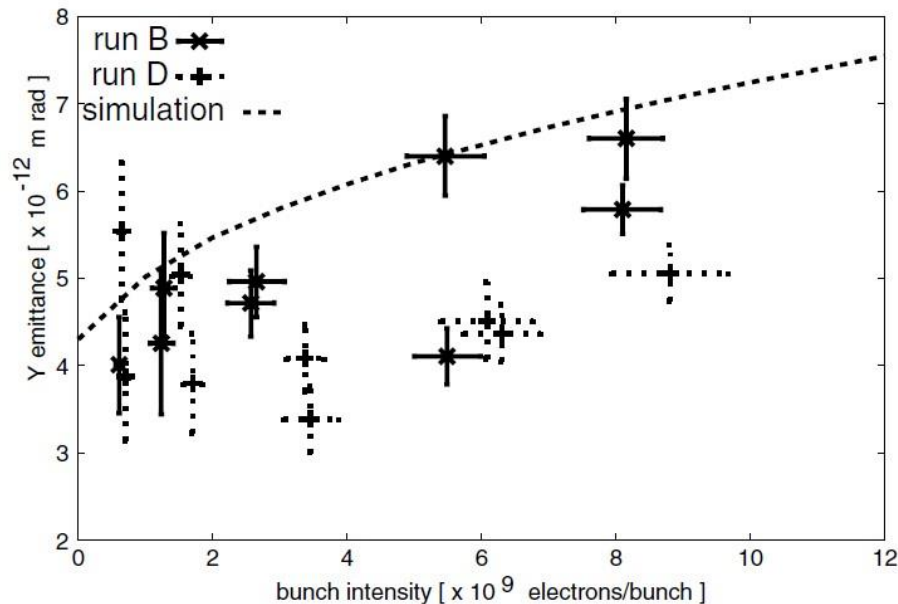


FIG. 2. Current dependence of the vertical emittance: Data for the smallest emittance cases (runs B and D) are shown. The result of a SAD simulation for 0.4% coupling is superimposed.

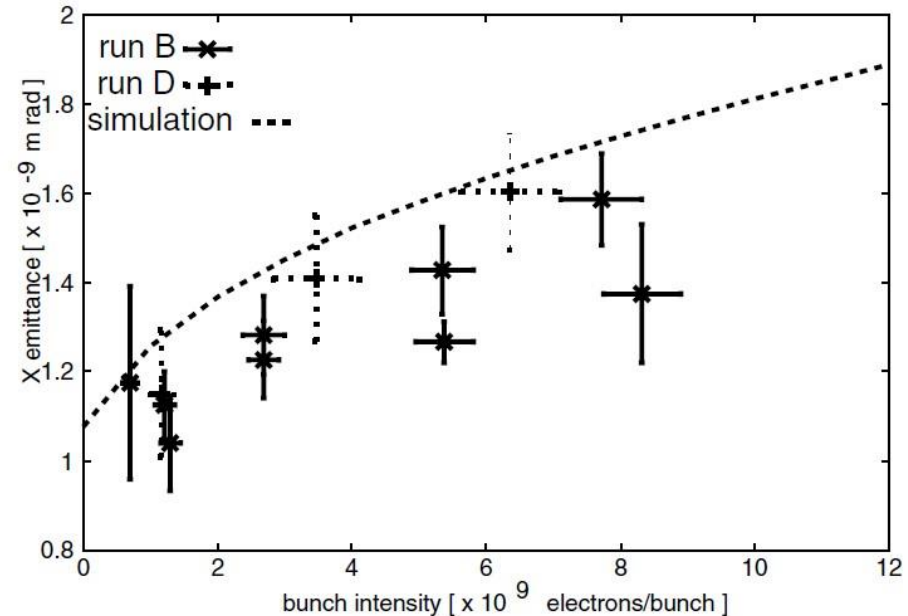
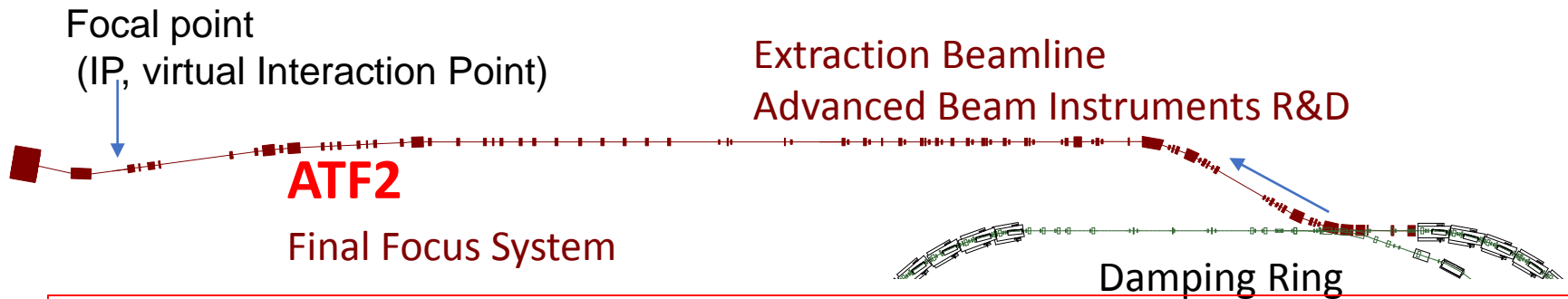


FIG. 3. Current dependence of the horizontal emittance: Data for the smallest emittance cases (runs B and D) are shown. The result of a SAD simulation for 0.4% coupling is superimposed.

# Extraction- Final Focus Test Beamline



## ATF2: Final Focus Test

### Goals of ATF2

- **Small beam size (~37 nm), test of local chromaticity correction scheme**
- **Stabilize beam at focal point (nm level), test of fast orbit feedback**

# Final Focus System, ILC and ATF2

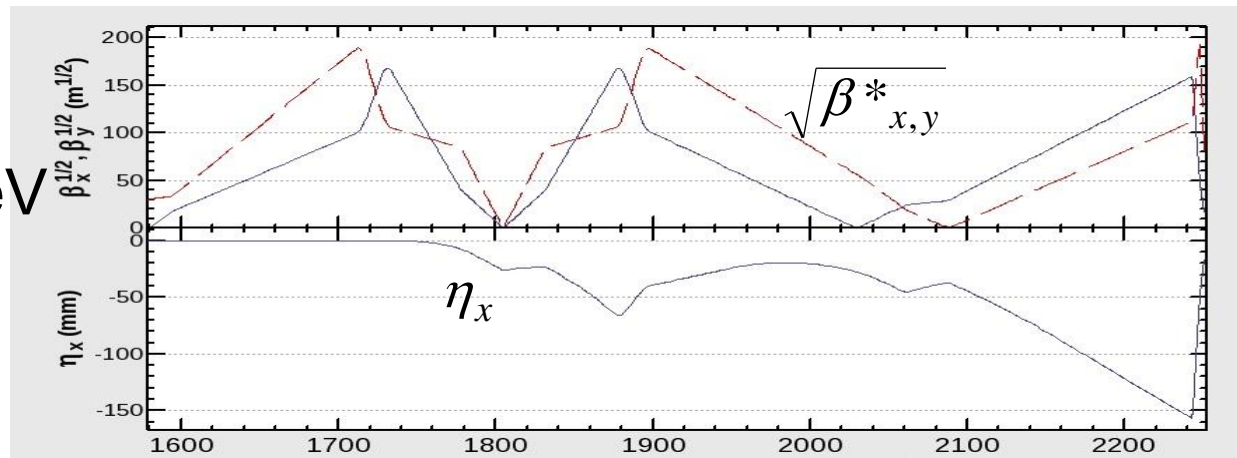
Same design as ILC (local chromaticity correction)

Same magnet configuration (same magnet names)

Similar tolerances of multi-pole magnetic field errors

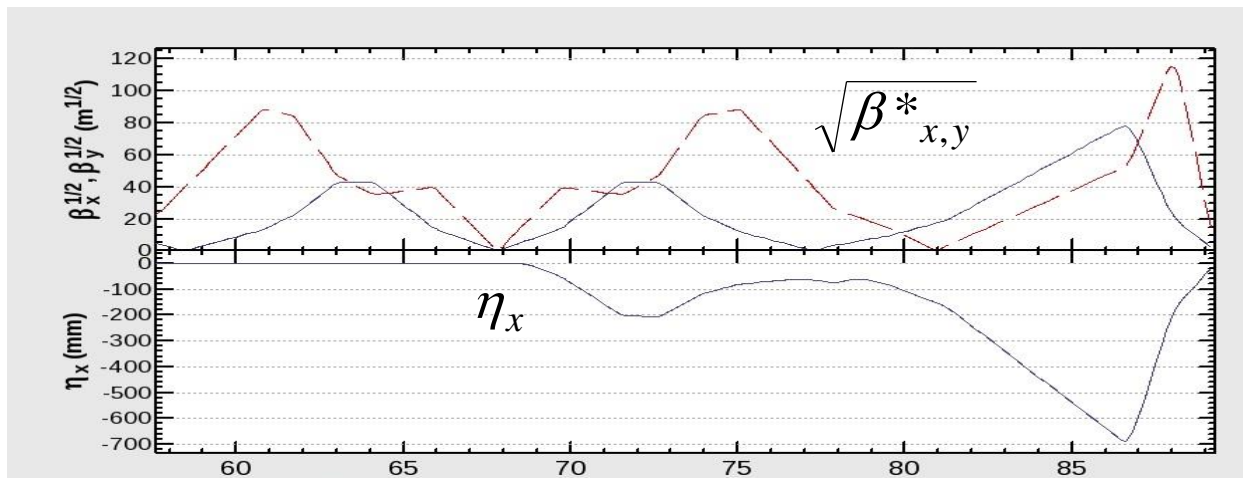
ILC

Up to 500 GeV  
~700 m

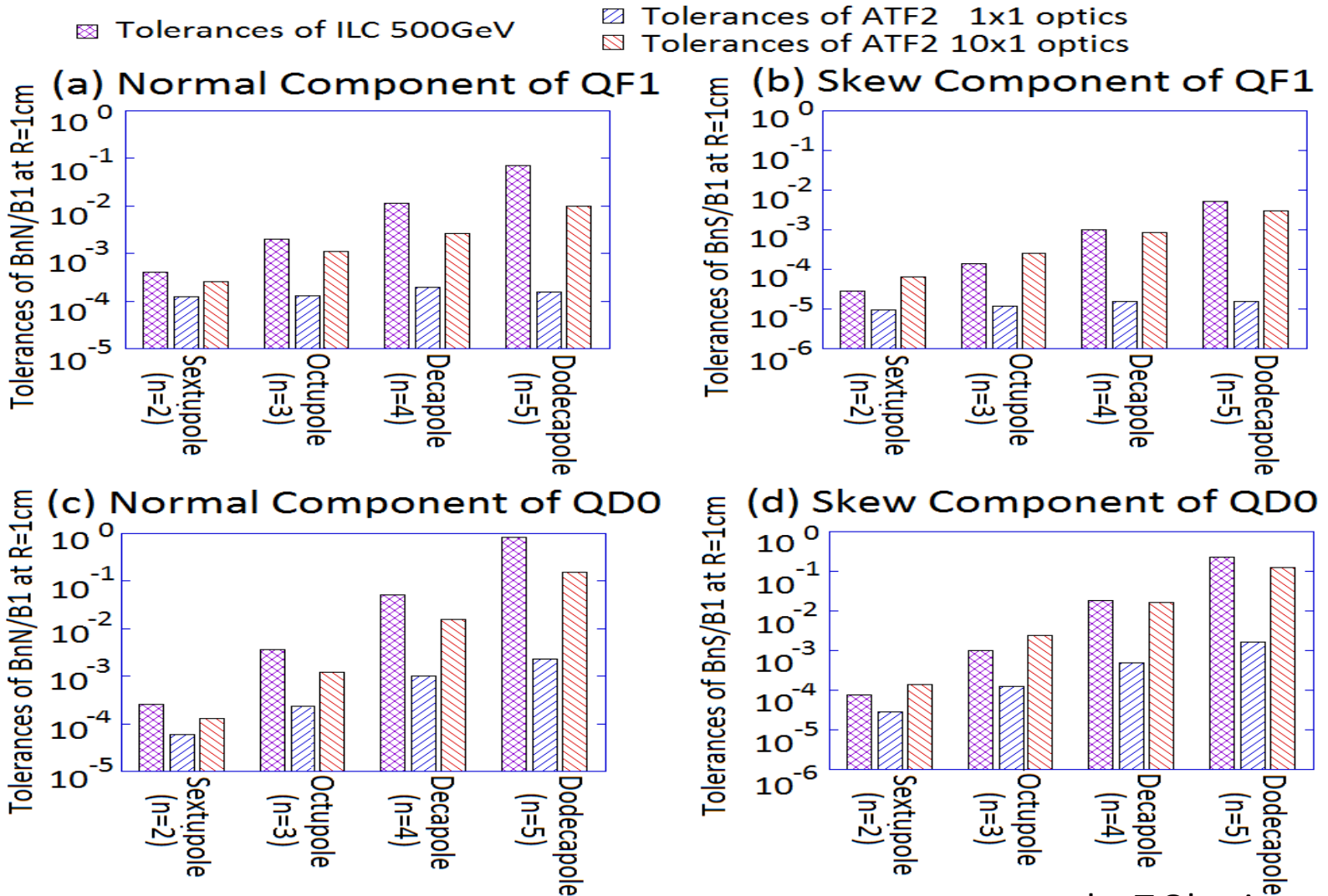


ATF2

1.3 GeV  
~30 m

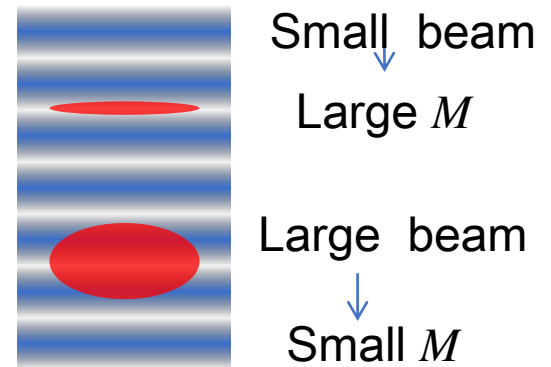
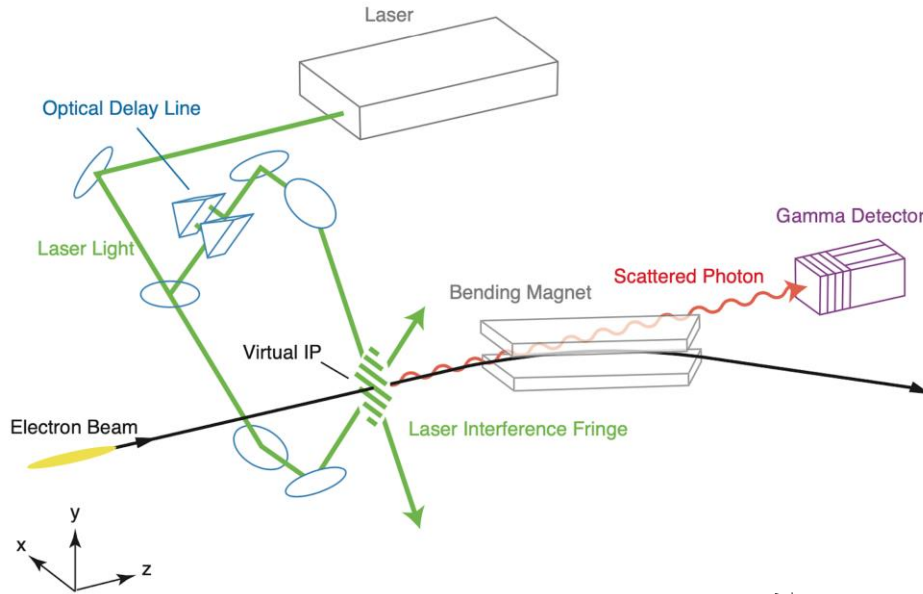


# Tolerances of multi-pole field error of Final doublet magnets



by T.Okugi

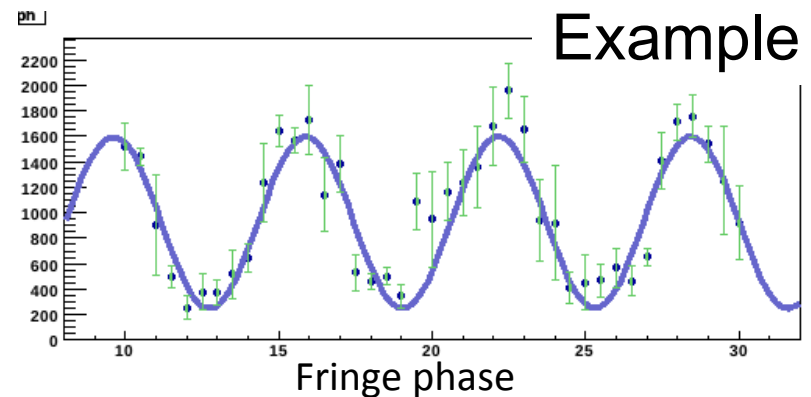
# Beam Size Monitor at IP (IPBSM)



Scan interference fringe phase.  
Fit modulation  $M$ :

$$G(\phi) = G_0(1 + M \cos(\phi + \phi_0))$$

Gamma-ray signal  $G$



# Tuning knobs for Vertical Beam Size at IP (Final stage of beam tuning)

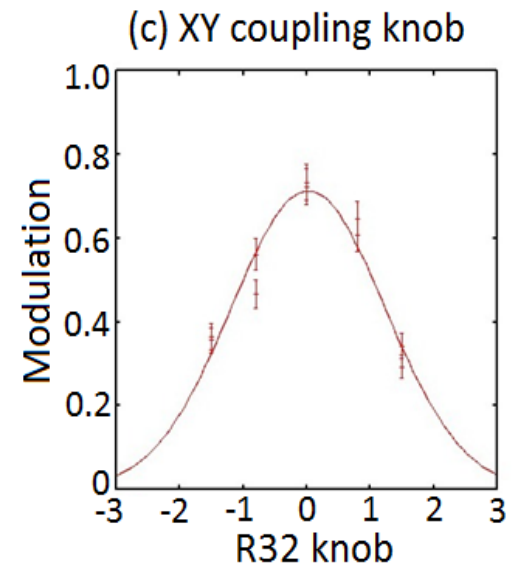
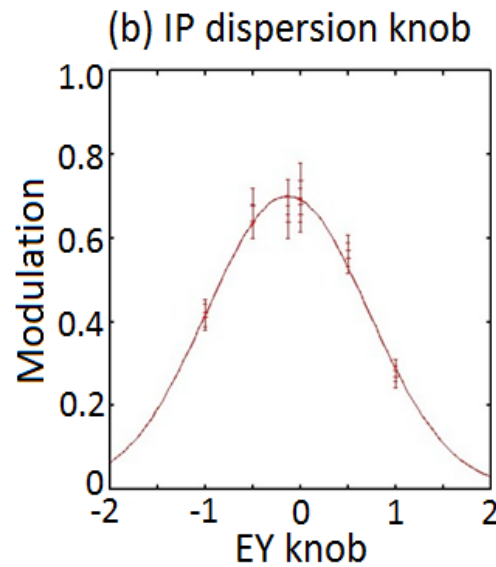
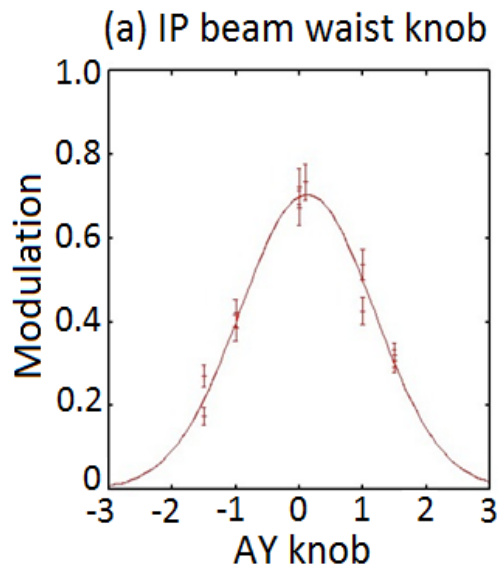
	Changing parameters	Corrected coupling
<b>Linear knobs</b> (Linear Optics adjustment)	6-poles horizontal moves	$yy'$ (Focal Position) (AY)
	6-poles vertical moves	$yE$ (Dispersion) (EY)
		$x'y$ (x-y coupling) (R32)
<b>Non-linear knobs</b> (2 <sup>nd</sup> order optics adjustment)	6-poles strength	$x'yy'$
		$yy'E$ (chromaticity)
	Skew 6-poles strength	$xxxy$
		$xyE$
		$yEE$ (2 <sup>nd</sup> order dispersion)
		$yy'y'$

Each knob changes one coupling (correlation) term.

# Tuning with Linear Optics Knobs

## Procedure of linear optics correction established

Examples of tuning with linear knobs



(ATF Review Report)

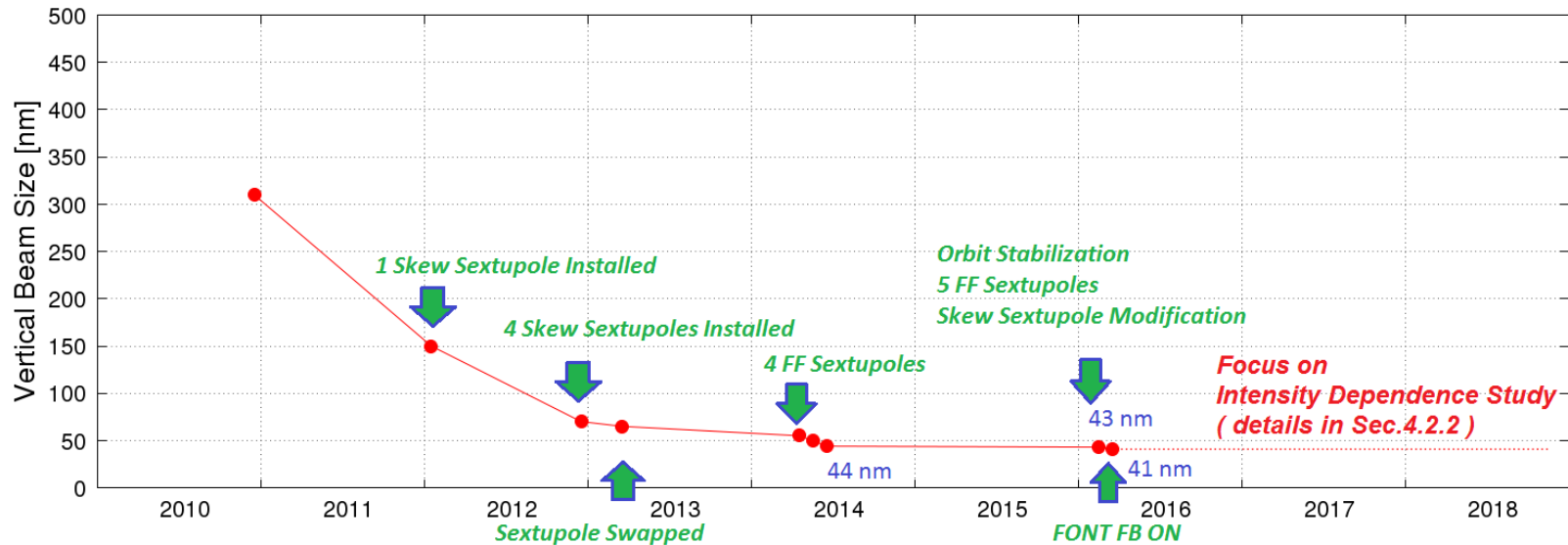
After each knob scan, the knob is set at the peak of the Modulation.

# Tuning with 2<sup>nd</sup> order Optics Knobs

- Successfully integrated into tuning procedure
- Effects are expected to be visible only at very small beam
- **Systematic study and correction of non-linear aberrations have not been fully demonstrated yet.**

Studies with ultra-low beta\* optics (stronger higher order aberration effects) will be reported by next speaker (?)

# Goal 1: History of minimum achieved beam size



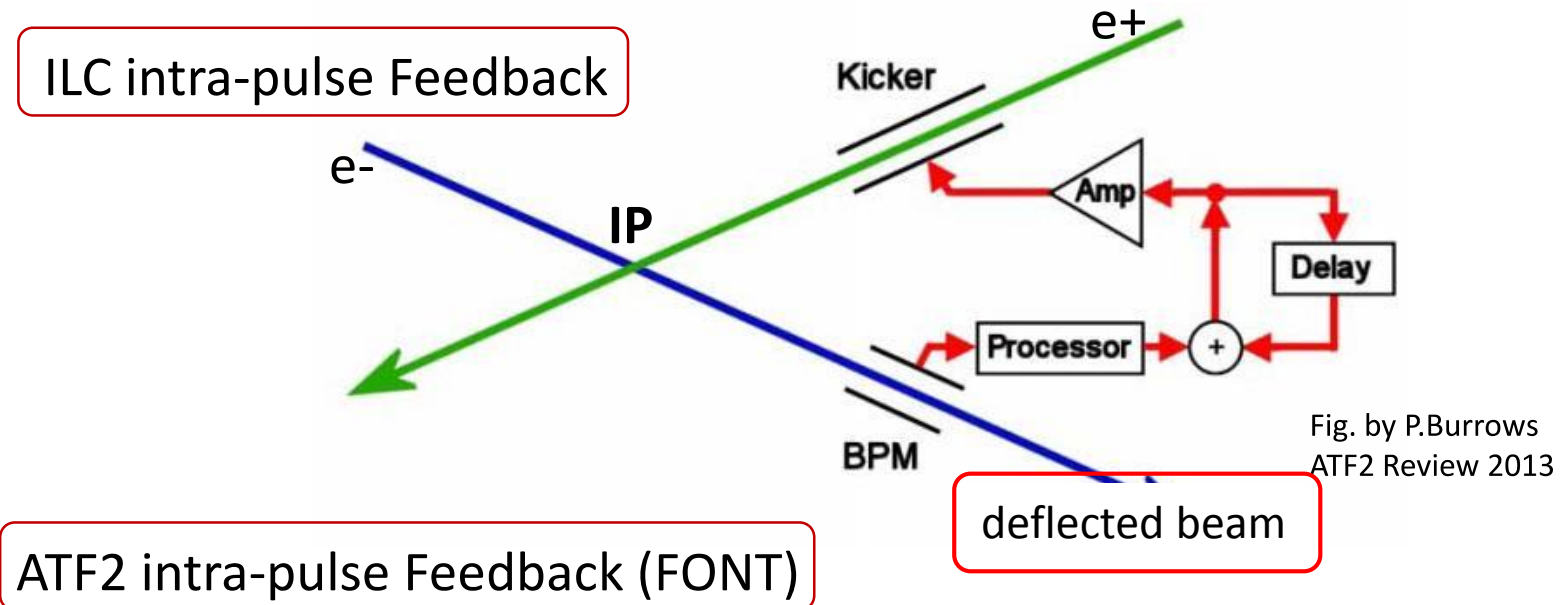
Local chromaticity correction scheme validated

Found strong intensity dependence

Due to wakefield.

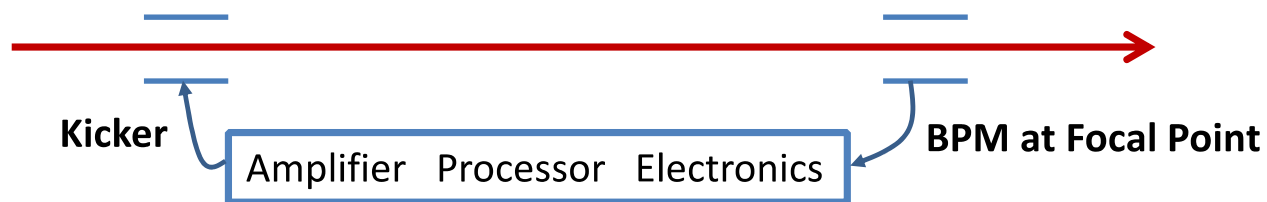
Another important study issue. (→ later slides)

# Goal2: Nano Beam Stabilization by intra-pulse orbit feedback

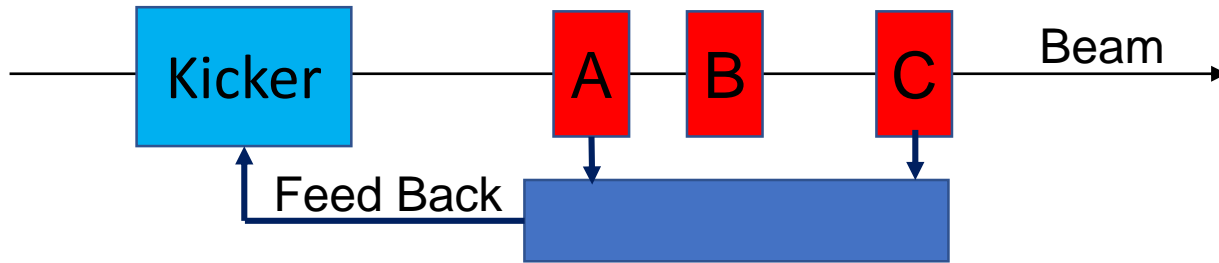


## ATF2 intra-pulse Feedback (FONT)

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



# Feedback system satisfying ILC requirement



Example:

Measure Bunch 1 position at A and C,  
and Feedback to correct Bunch 2 at B:

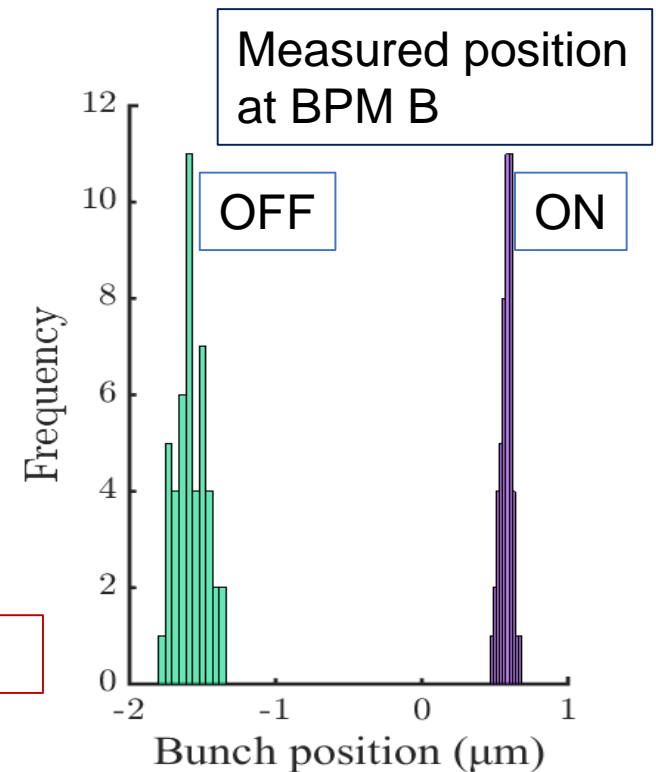
**Feedback OFF: jitter ~ 96nm**

**Feedback ON: jitter ~ 41nm**

**Bunch Spacing 280 ns**

**Latency 235ns**

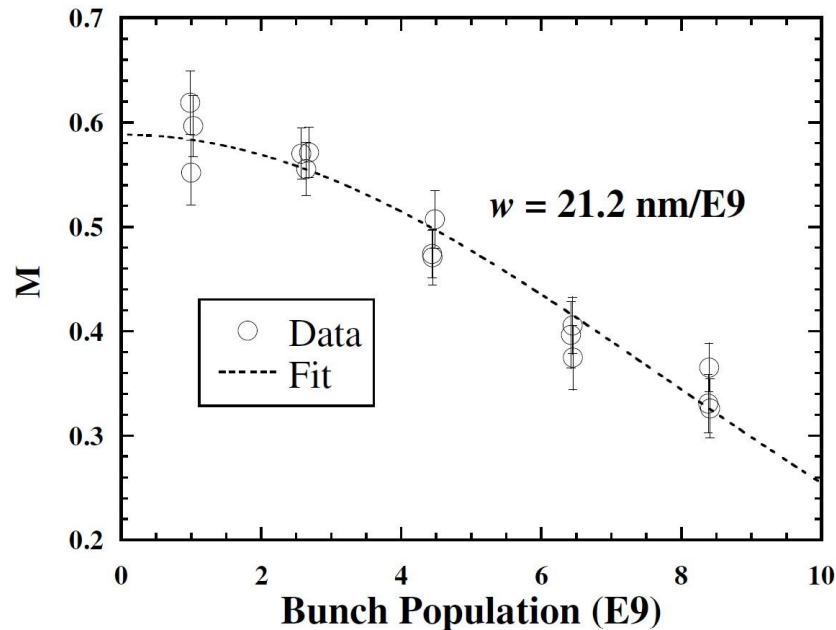
Residual jitter was from BPM resolution.



# Beam Size Intensity Dependence

**Small beam size can be observed only at low bunch intensity.**

Example of  
Measured  
IPBSM Modulation  
vs. bunch population



Fitting:

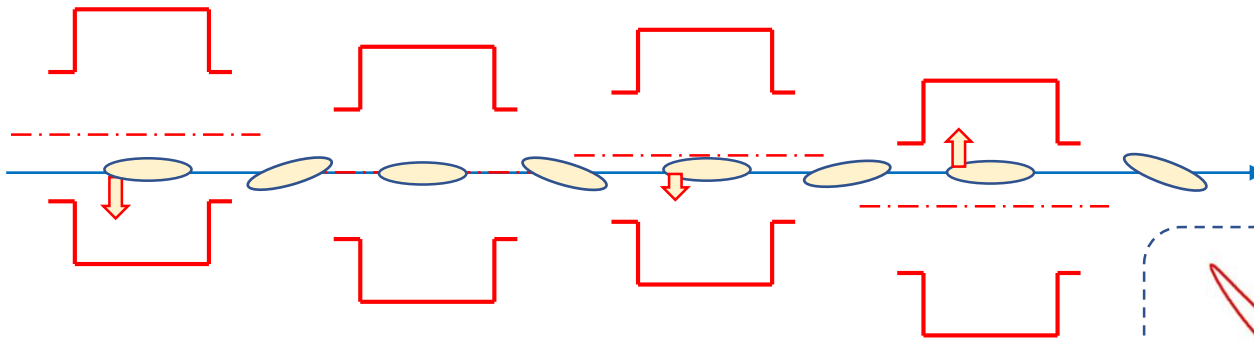
$$\sigma^2 = \sigma_0^2 + w^2 N^2$$

Beam size growth  
 $\sim 21 \text{ nm} / 1 \times 10^{10} \text{ e}$

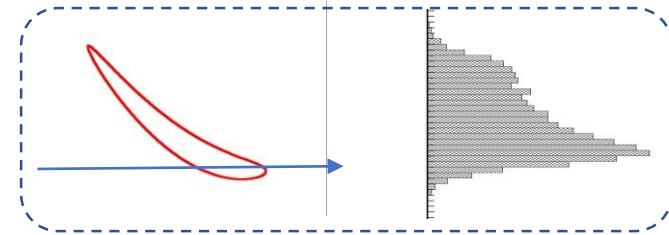
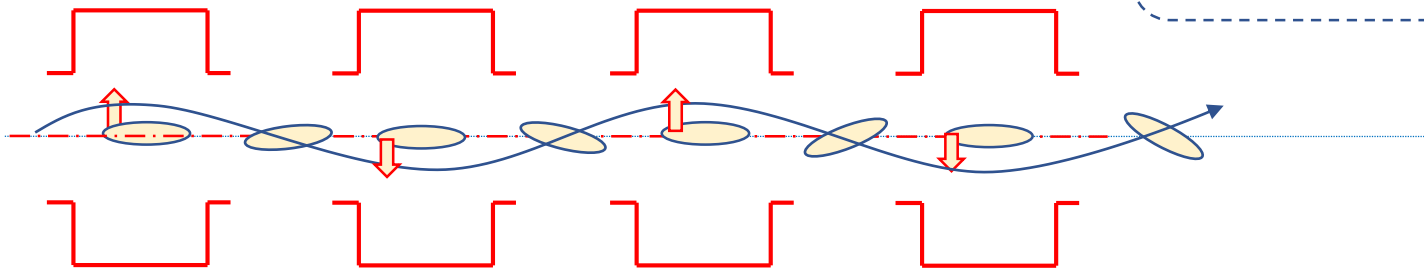
**Transverse wakefield is dominant cause of the dependence.**

# Effects of transverse wakefield to beam size

Misalignment of beam line components



Beam orbit

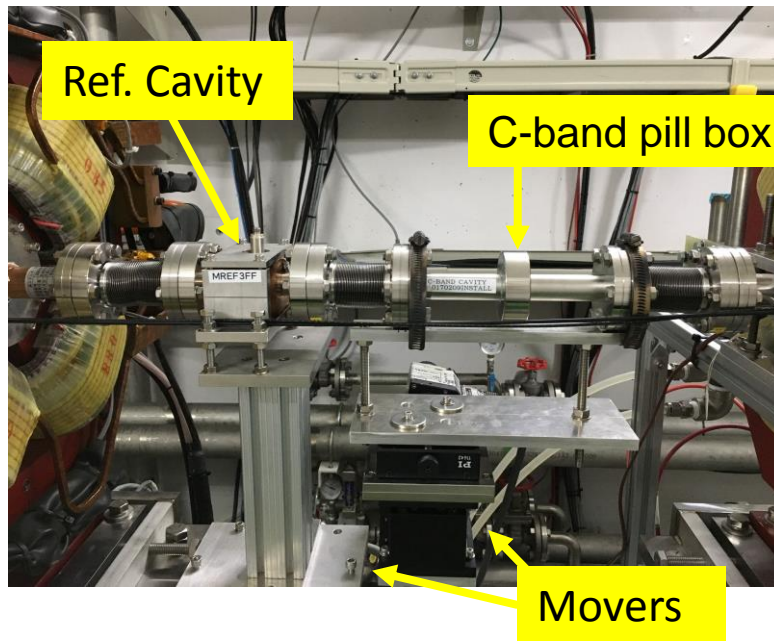


**Effects can be divided into static and dynamic:**  
**Static: misalignments and fixed beam orbit**  
**Dynamic: orbit jitter**

# Wakefield source on mover

Wakefield sources (Cavities or Bellows) on movers are installed in beam line.

Present setup



Experiments

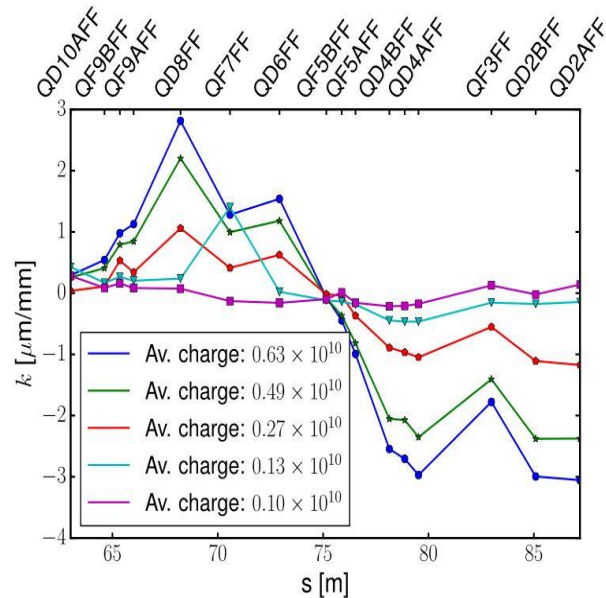
- Downstream orbit change as function of mover position.
  - Good agreement with calculations
- Beam size at IP
  - Cancellation of wakefield in beam line
  - Estimation of wakefield strength in beam line

# Orbit change by wake source on mover

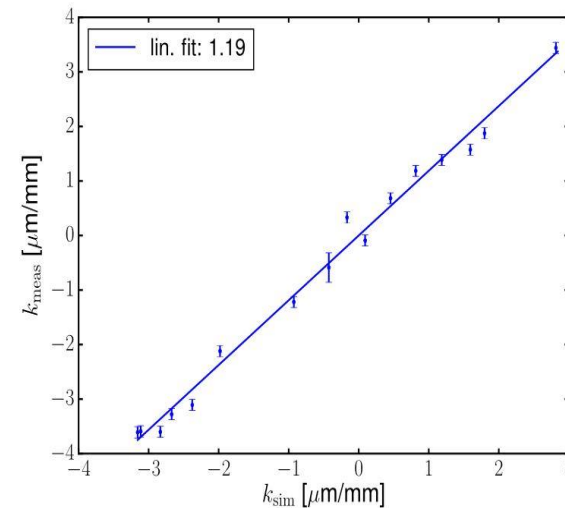
## Consistent with simulations

Orbit change dependence on mover position was measured.

(orbit change at BPM)/(mover position change)  
for different bunch intensities



Orbit response factor at BPMs  
Measurement vs. calculation



Phys. Rev. Accel. Beams 19, 091002 (2016)

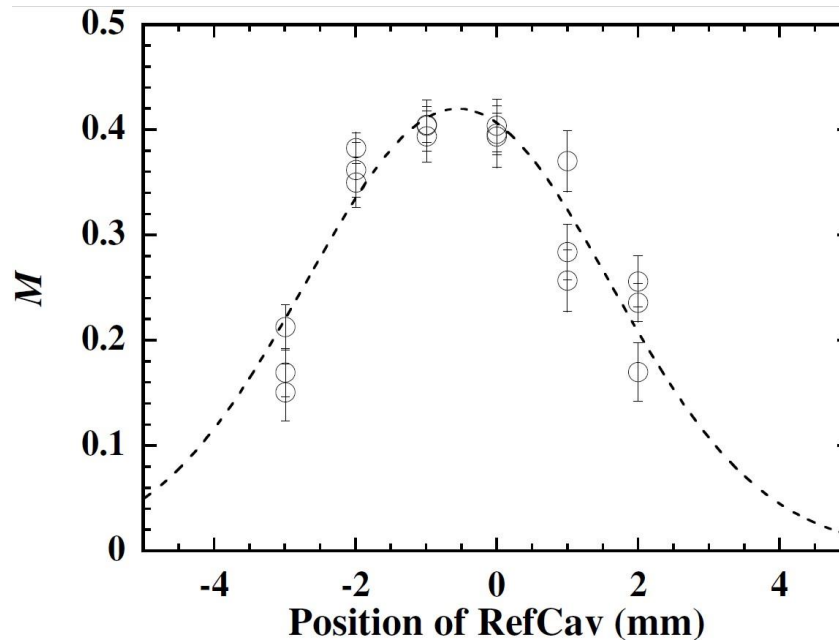
**Wakefield calculation of moving part agreed with measurement.  
(Difference is about 20%)**

# Wakefield cancellation by wakefield source on mover

**“Static” wakefield is cancelled by adjusting the mover position, for wakefield sources with similar shape of wake-potential.**

Example of cancellation

IPBSM modulation vs. mover position of RefCav

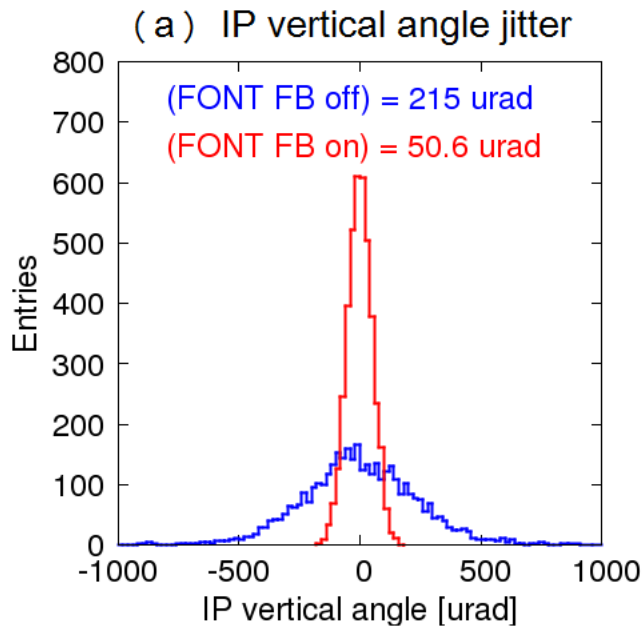


(ATF Review Report)

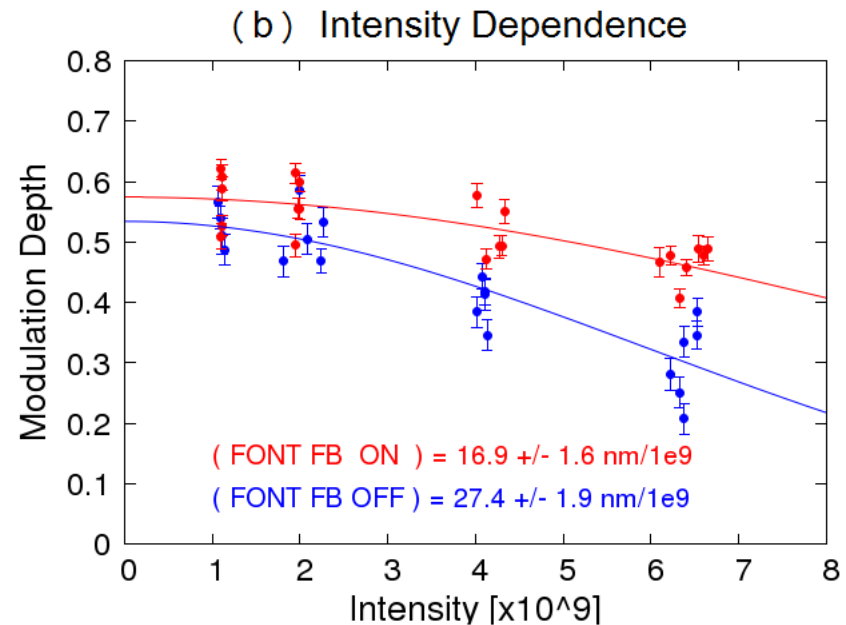
# Mitigation of “Dynamic” wakefield effect to beam size by orbit jitter reduction

Beam size measured with and without fast orbit feedback (FONT).  
2-bunch operation. Beam size of 2<sup>nd</sup> bunch.

Reduction of angle jitter



Reduction of beam size intensity dependence



(ATF Review Report)

# Status of Intensity Dependence (Wakefield) studies

- Intensity dependence was reduced by removing some structure
- “Static” wakefield cancellation by “structure on mover” was confirmed.
- Significant “Dynamic” wakefield effect was confirmed and partly reduced by orbit feedback.
  
- **Observations and calculations/simulations are qualitatively well matched, but quantitative agreements are not perfect.**
- **Effect at ILC Final Focus will not be significant (high beam energy, short bunch). But still to be studied for understanding.**

(some details will be reported by later speakers?)

# Various other studies at ATF

- Beam halo
- Ground motion - orbit feedback
- Fast kicker
- Cavity BPMs
- Collimator
- Laser wire
- Optical (transition diffraction) radiation monitor
- ,,,