FONT R&D status

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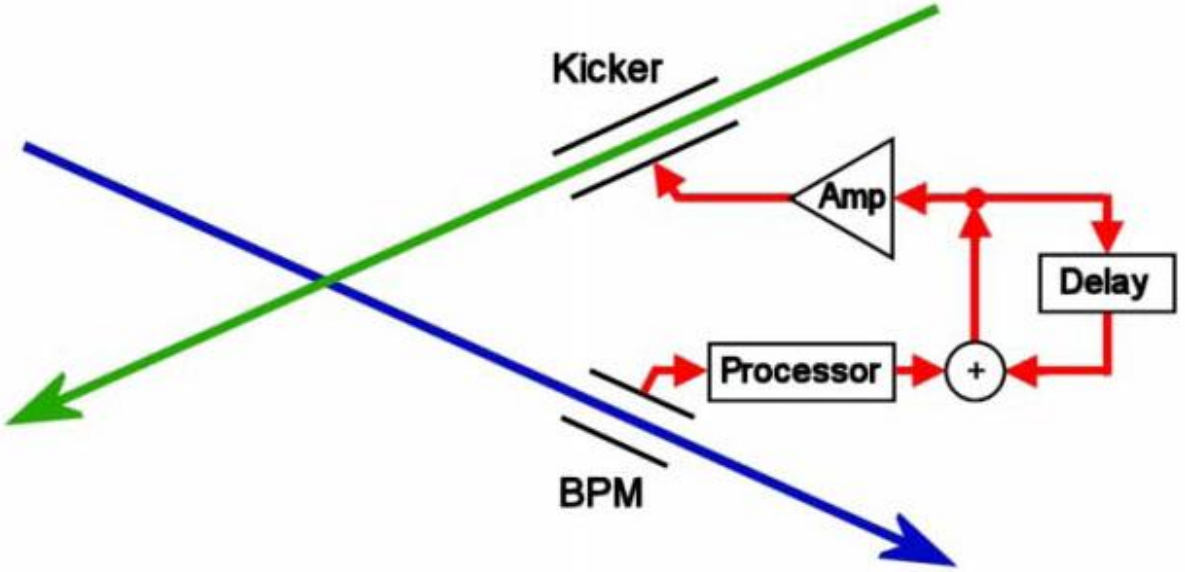
IP intra-train feedback system - concept

- Last line of defence against relative beam misalignment
- Measure vertical position of outgoing beam and hence beam-beam kick angle
- Use fast amplifier and kicker to correct vertical position of beam incoming to IR



FONT – Feedback On Nanosecond Timescales

(Oxford, RHUL, Valencia, CERN, DESY, KEK, SLAC)

FONT beam tests

	NLCTA	ATF(2005)	ATF(2008)	
Beam energy	0.065	1.3	1.3	GeV
Electrons/bunch	0.01	0.1-1	1	10**10
Bunches/train	2000	20	3	
Bunch spacing	0.087	2.8	140-154	ns
Train length	177	56	~300	ns
Train repetition rate	60	1.5	1.5	Hz

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CLIC-like

FONT prototype history: CLIC

CLIC-relevant: all-analogue systems

- NLCTA (SLAC): 65 MeV beam, 170ns train, 87ps bunch spacing

FONT1 (2001-2):

First demonstration of closed-loop FB: latency 67ns

10/1 beam position correction

FONT2 (2003-4):

Improved demonstration of FB: latency 54ns

real time charge normalisation with logarithmic amplifiers

beam flattener to straighten train profile

solid-state amplifier

- ATF (KEK): 1.3 GeV beam, 56ns train, 2.8ns bunch spacing

FONT3 (2004-5):

Ultra-fast demonstration of FB: latency 23 ns

3 stripline BPMs

high-power solid-state amplifier

FONT beam tests

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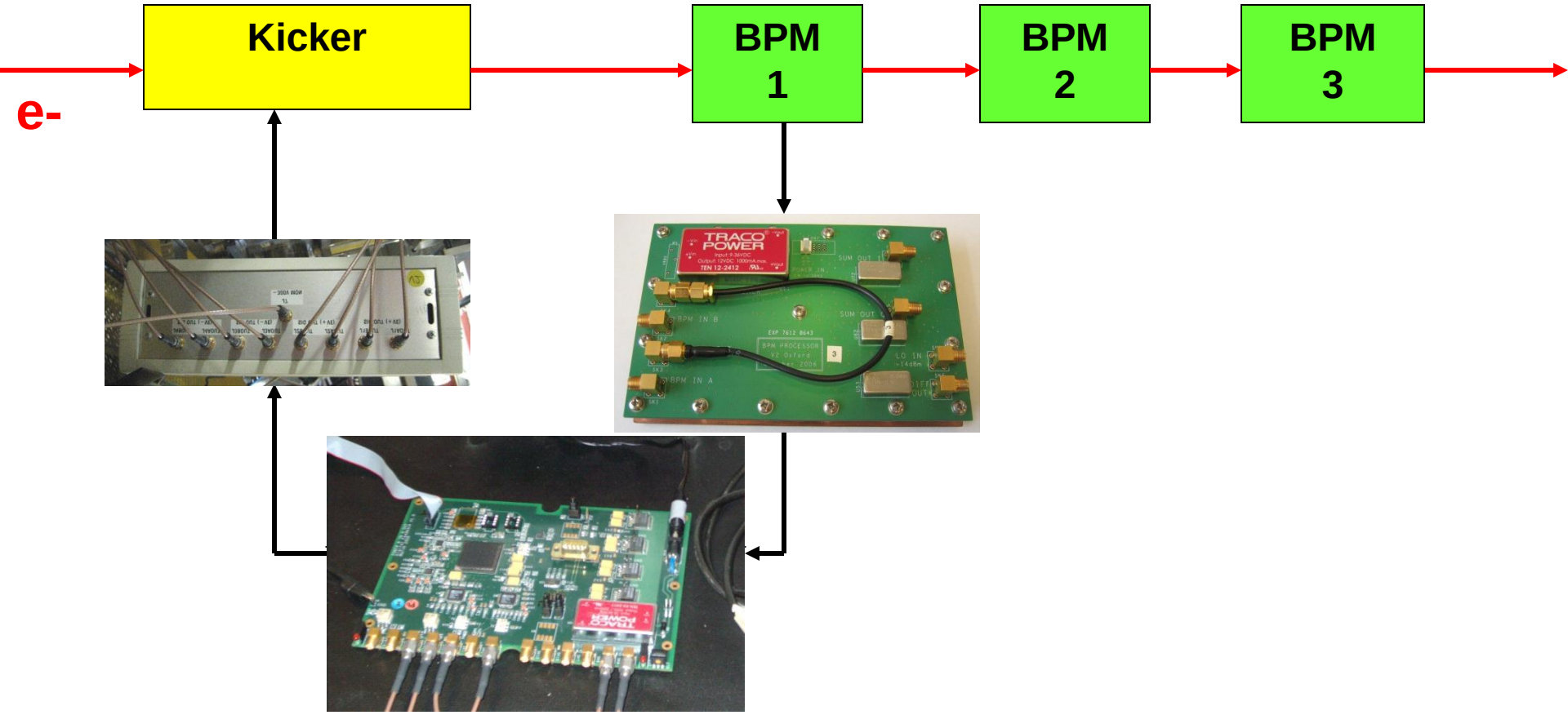
ILC-like

ILC prototype: FONT4 at ATF



FONT ILC prototype status

Bunch-by-bunch feedback for intra-train operation

Stripline BPM resolution in single-pass mode: goal ~ 1um

→ < 0.5 um achieved (world record?)

BPM processor resolution

- **3 BPM processors (5,7,10) on BPM P2**

8-hour shift:

0.55 0.56 0.60 μm

0.56 0.54 0.51 μm

0.53 0.40 0.35 μm

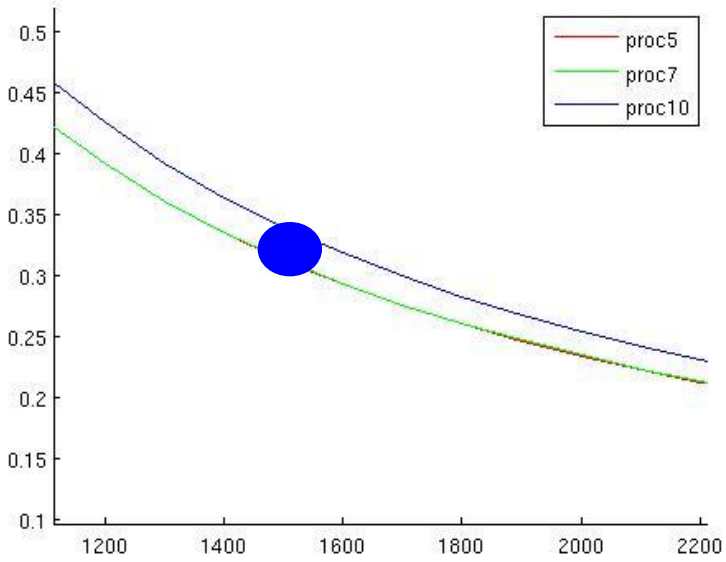
0.50 0.35 0.33 μm

0.45 0.44 0.35 μm

0.50 0.43 0.36 μm

Beam position jitter 3- 4 μm

expectation from ADC noise alone:



FONT ILC prototype status

Bunch-by-bunch feedback for intra-train operation

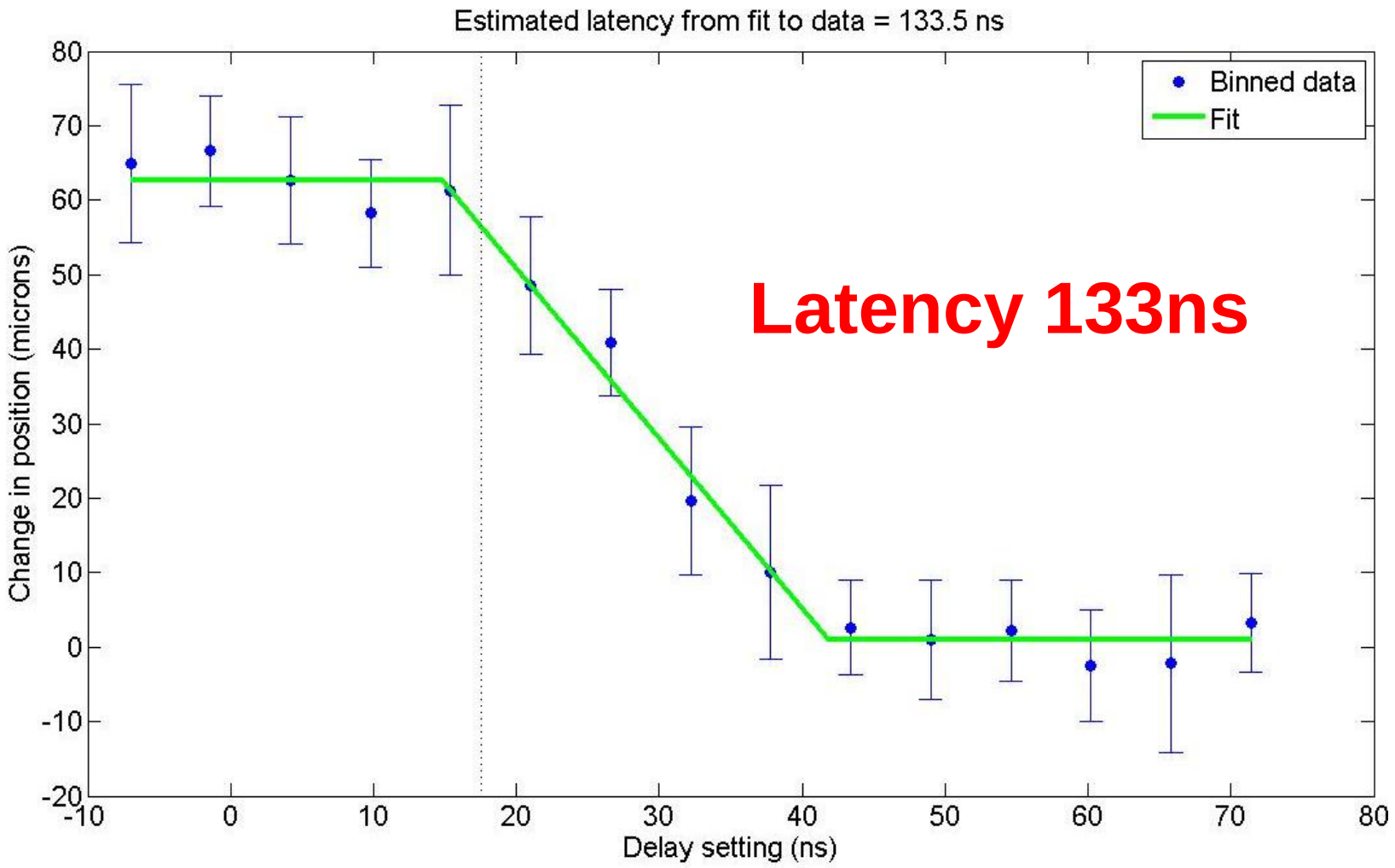
Stripline BPM resolution in single-pass mode: goal ~ 1um

→ < 0.5 um achieved (world record?)

Latency: goal ~ 150ns (shortest possible ILC bunch spacing)

→ 133ns achieved (including cables)

Latency


Estimated latency from fit to data = 133.5 ns
Binned data
Fit
Latency 133ns
Change in position (microns)
Delay setting (ns)
80
70
60
50
40
30
20
10
0
-10
-20
-10
0
10
20
30
40
50
60
70
80

Latency estimate

- Time of flight kicker – BPM: 12ns
- Signal return time BPM – kicker: 32ns

  Irreducible latency: 44ns

- BPM processor: 10ns
- ADC/DAC (4.5 357 MHz cycles) 14ns
- Signal processing (8 357 MHz cycles) 22ns
- FPGA i/o 3ns
- Amplifier 35ns
- Kicker fill time 3ns

  Electronics latency: 87ns

- Total latency budget: 131ns

FONT ILC prototype status

Bunch-by-bunch feedback for intra-train operation

Stripline BPM resolution in single-pass mode: goal ~ 1um

→ < 0.5 um achieved (world record?)

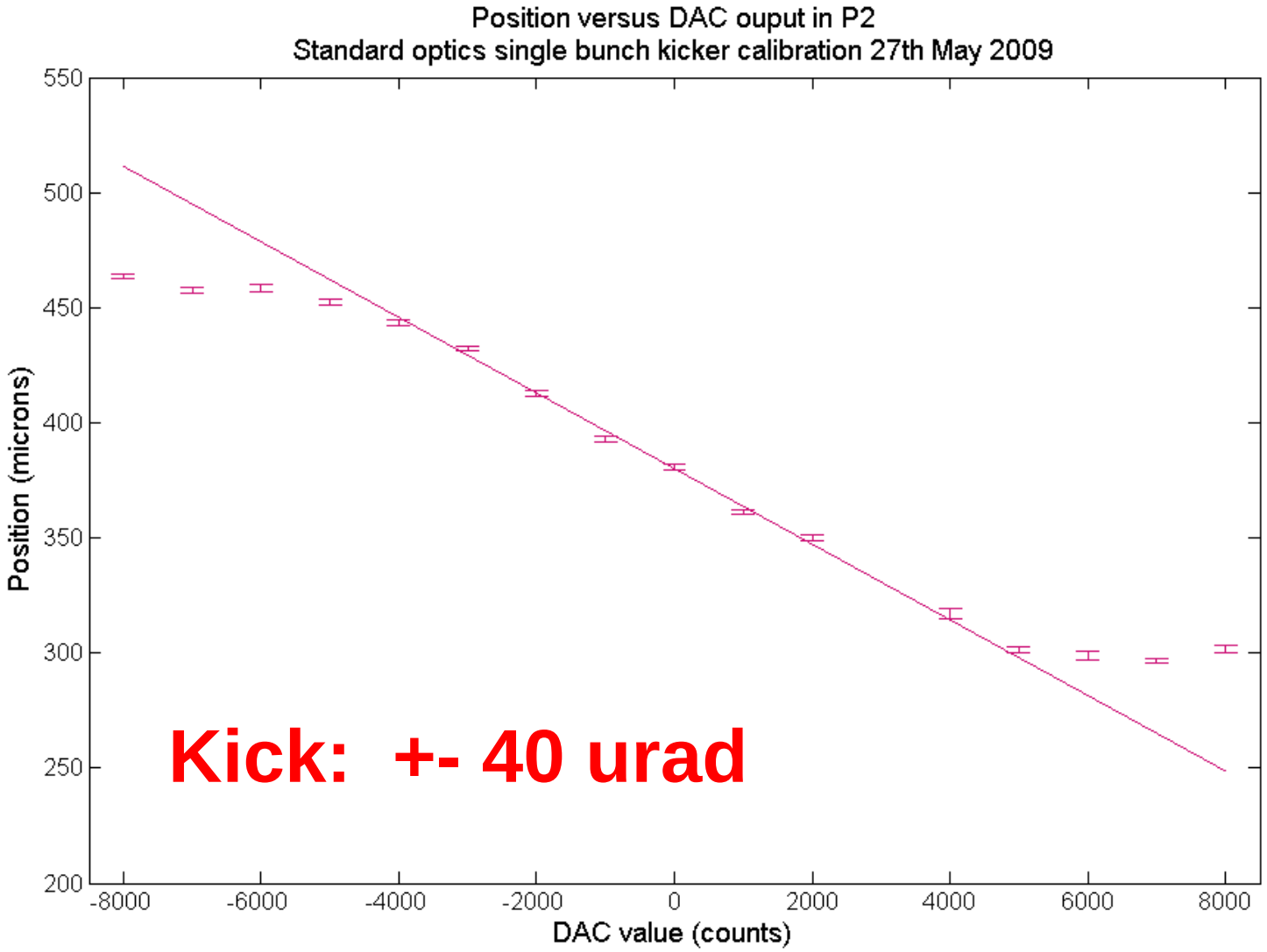
Latency: goal ~ 150ns (shortest possible ILC bunch spacing)

→ 130ns achieved (including cables)

Dynamic range: goal +- 250 nm (250 GeV ILC beam energy)

→ +- 800 nm achieved

Kick strength



FONT ILC prototype status

Bunch-by-bunch feedback for intra-train operation

Stripline BPM resolution in single-pass mode: goal ~ 1um

→ < 0.5 um achieved (world record?) **CLIC** ✓

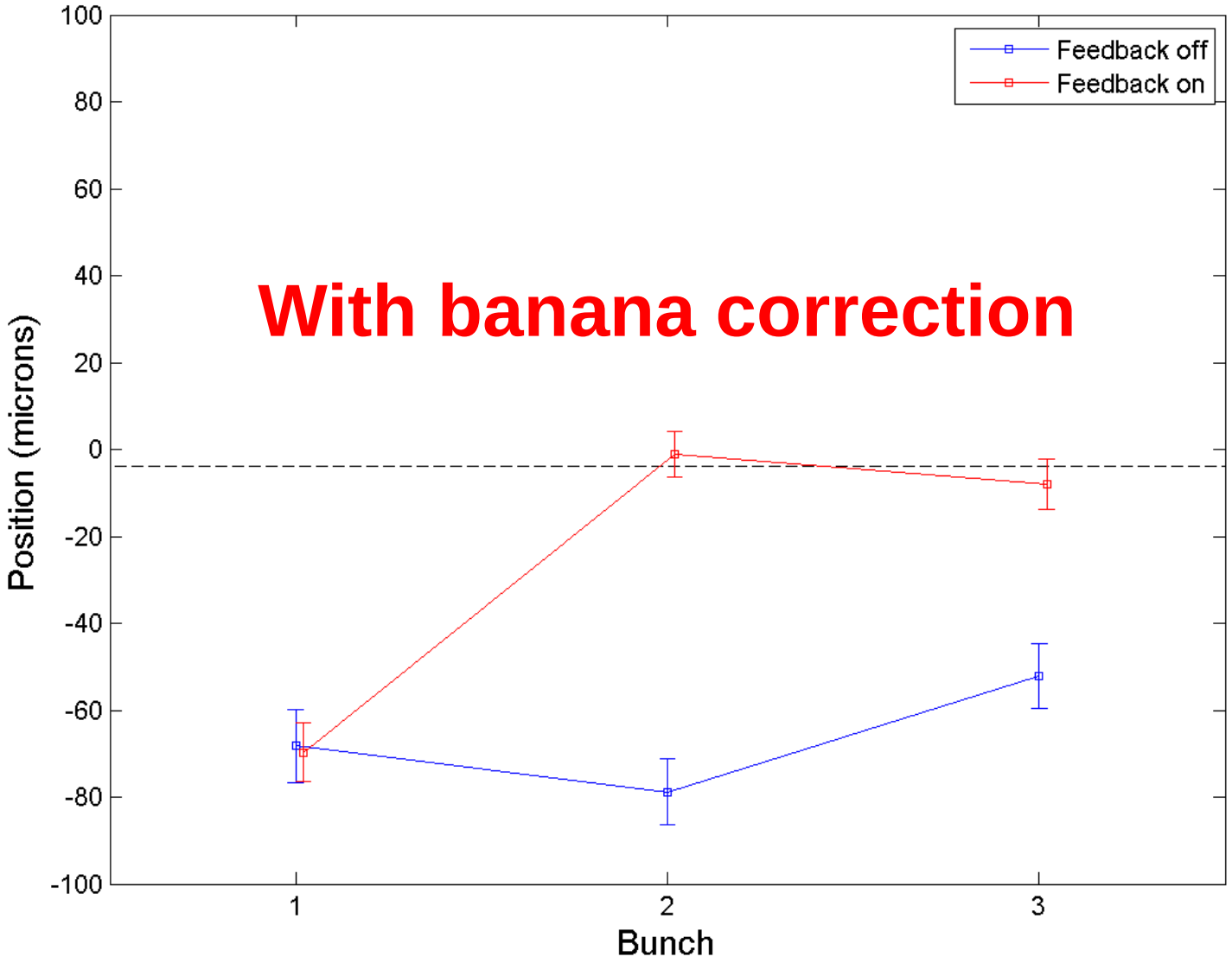
Latency: goal ~ 150ns (shortest possible ILC bunch spacing)

→ 130ns achieved (including cables)

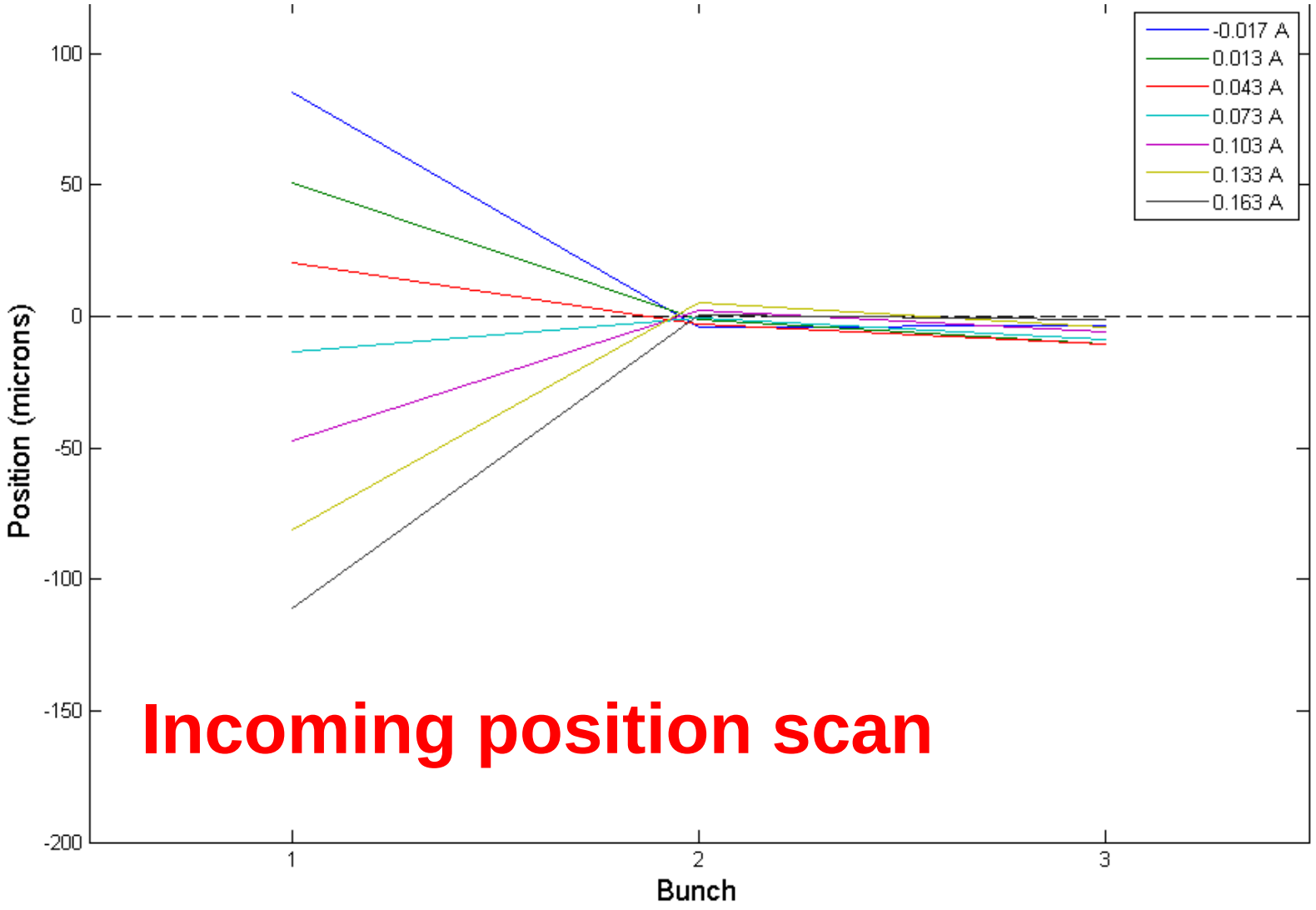
Dynamic range: goal +- 250 nm (250 GeV ILC beam energy)

→ +- 800 nm achieved **CLIC** ✓

FB performance

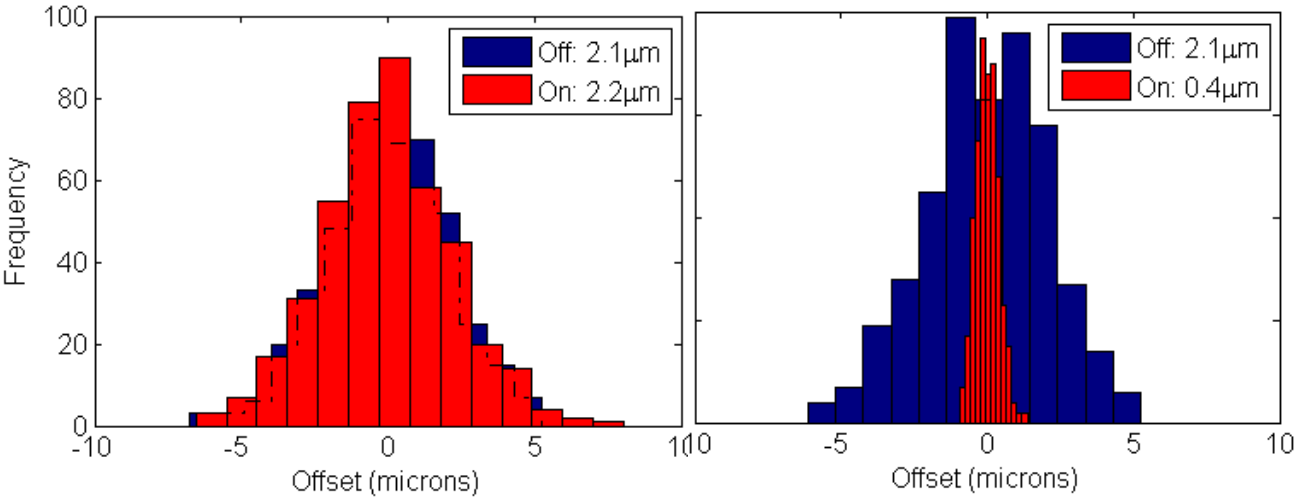


FB performance



FB jitter reduction (good beam)

Bunch 1 **Bunch 2**

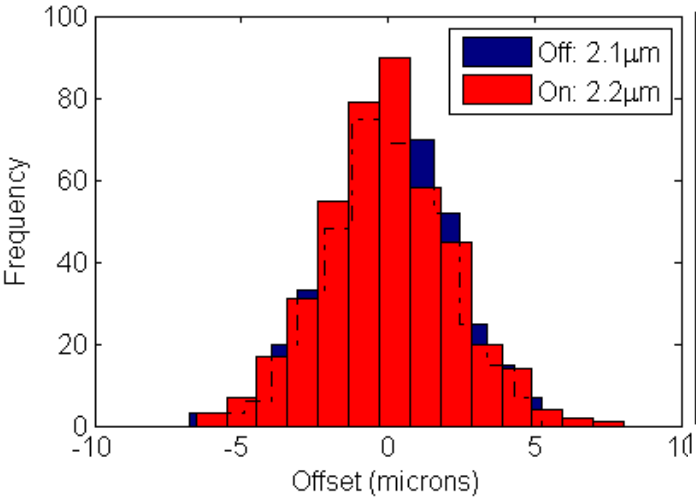


2.1 um → **0.4 um**

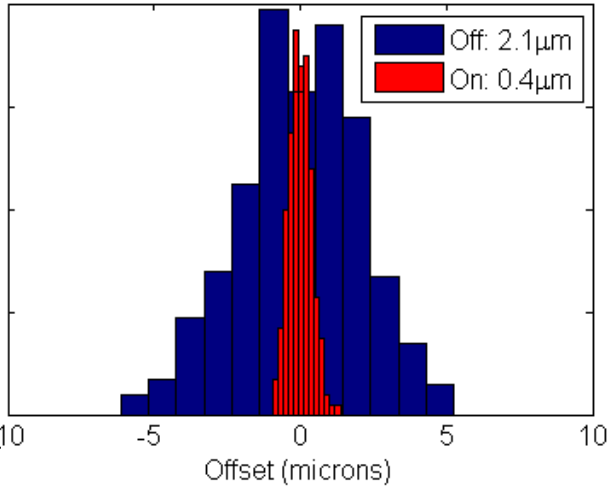
Factor of 5 jitter reduction

FB jitter reduction (good beam)

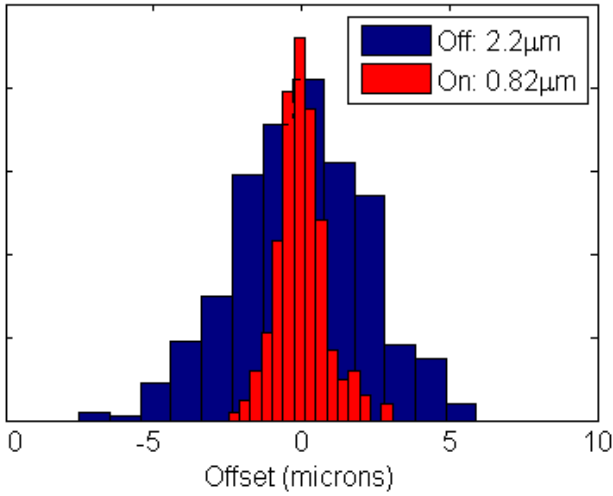
Bunch 1



Bunch 2



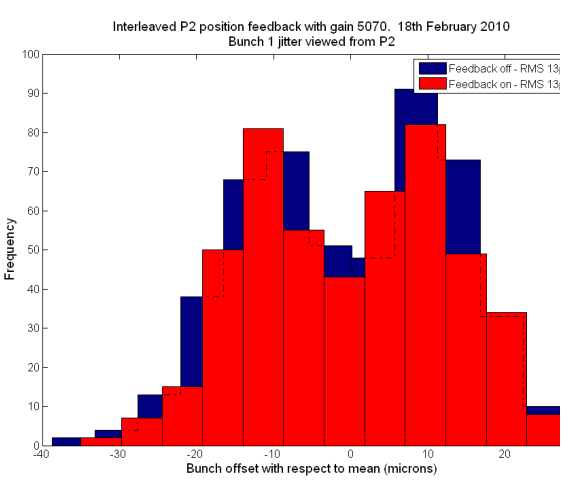
Bunch 3



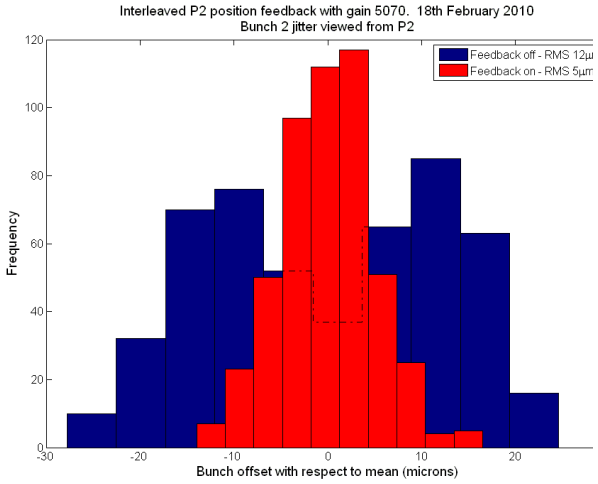
2.1 um → 0.4 um → 0.8 um

FB jitter reduction (bad beam)

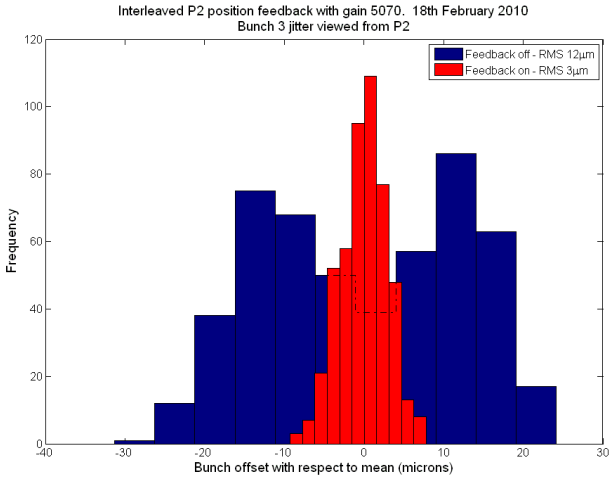
Bunch 1



Bunch 2



Bunch 3



13 um → 5 um → 3 um

FONT ILC prototype status

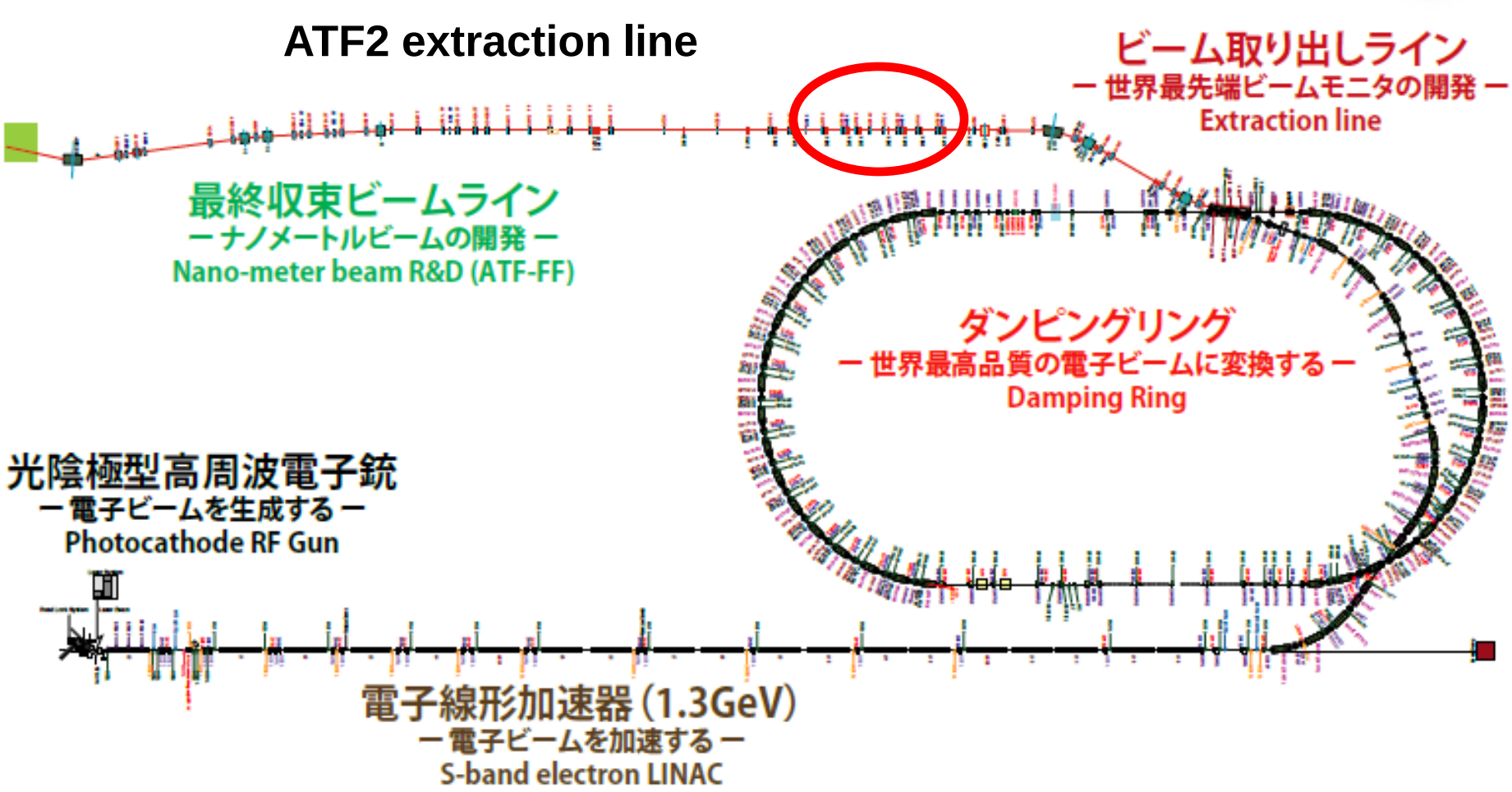
- **Prototype system designed to meet ILC specifications for IP intra-train FB**
- **Extensively tested with beam**
- **Performs well**

  → 2 nm beam stabilisation @ 250 GeV

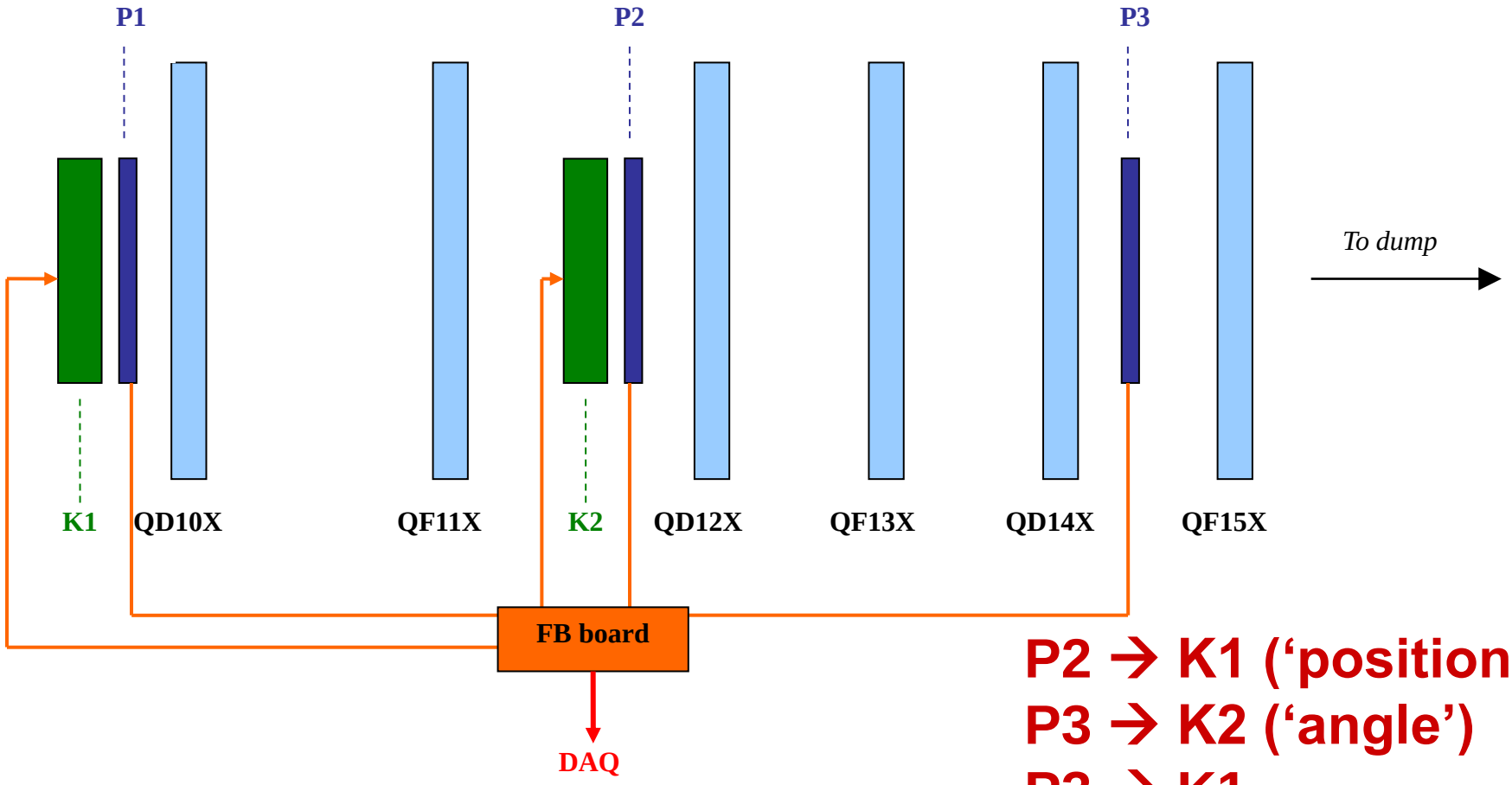
FONT5 system

- When ATF beamline was reconfigured for ATF2 we installed 2 kickers and 3 stripline BPMs in upstream section
- Dedicated position + angle FB system
- Emphasis is on quality of beam correction, with y, y' system, in terms of reduction of train jitter
- Typically use 2-bunch train so as to maximise bunch 1 – bunch 2 correlation

FONT5 location at ATF2

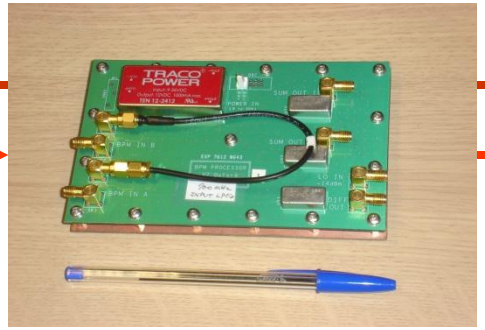


FONT5 setup



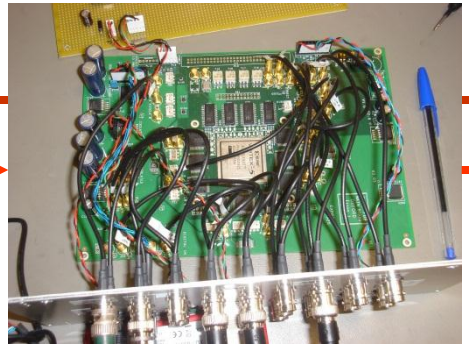
P2 → K1 ('position')
P3 → K2 ('angle')
P3 → K1
P2 → K2

FONT5 Hardware



Analogue Front-end

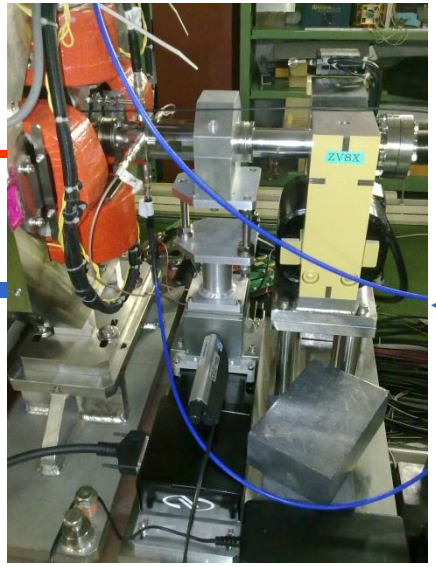
BPM processor



FPGA-based digital processor

Kicker drive amplifier

Strip-line kicker



Strip-line BPM with mover system

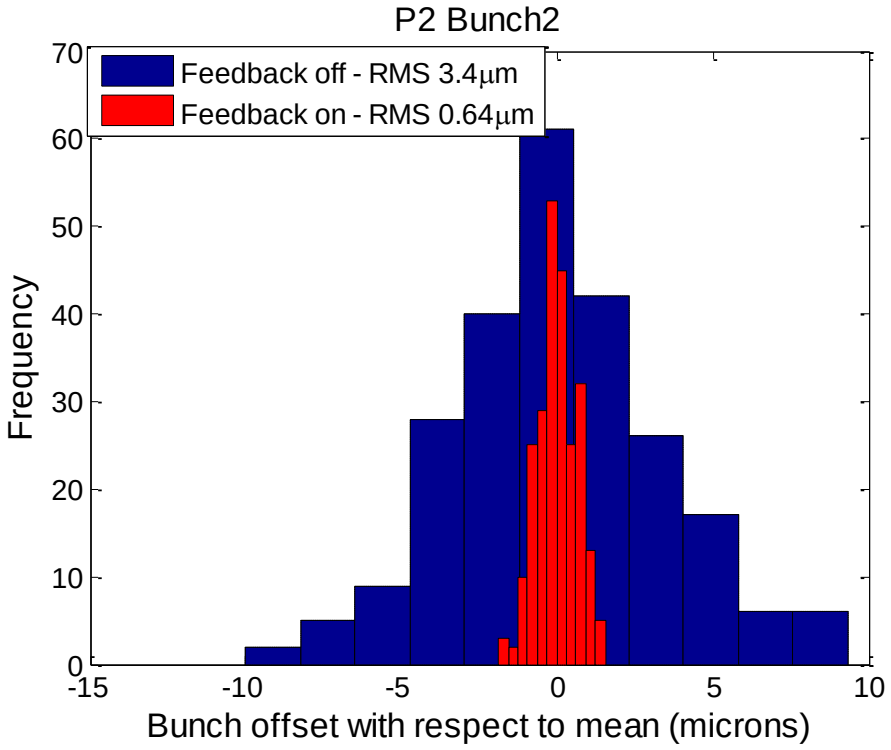
Gain matrix

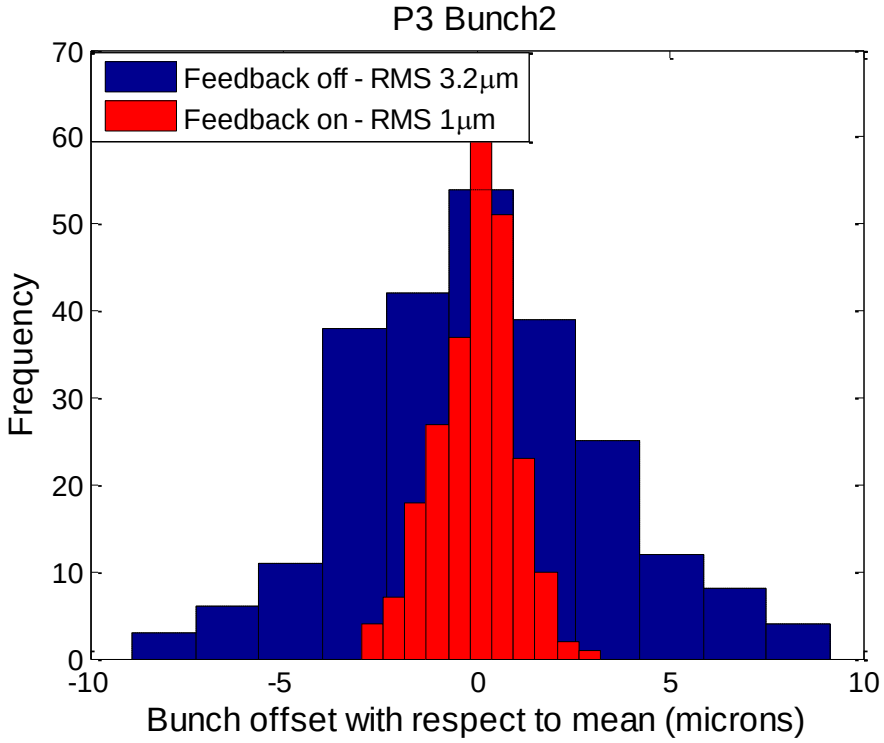
G (K1 - P2) **G (K1 - P3)**

G (K2 - P2) **G (K2 - P3)**

Feedback Performance

(example)





Feedback Performance

(example)

bunch	1	2
	FB off	FB off
Jitter P2	3.42	3.42
P3	3.24	3.21

Feedback Performance

(example)

bunch	1		2	
	FB off	on	FB off	on
Jitter P2	3.42	3.39	3.42	0.64
P3	3.24	3.16	3.21	1.04

Feedback Performance

(example)

bunch	1		2		
	FB off	on	FB off	on	Pred.
Jitter P2	3.42	3.39	3.42	0.64	
1-2 correl 98%					0.67
P3	3.24	3.16	3.21	1.04	
1-2 correl 97%					0.83

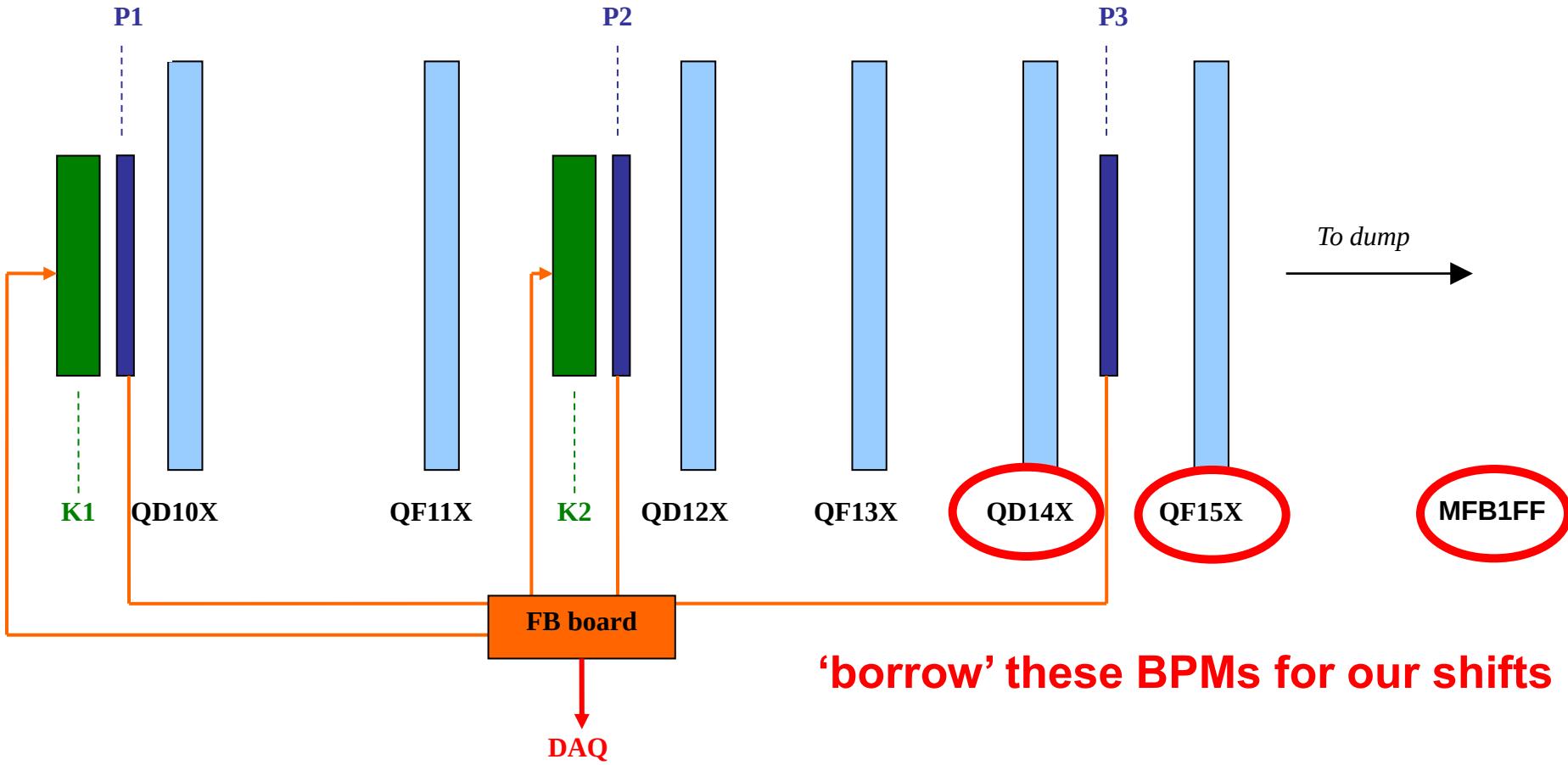
$$\sigma_2'^2 = \sigma_1^2 + \sigma_2^2 - 2\sigma_1\sigma_2\rho_{12} \geq 2\sigma_r^2$$

Tests (Dec 2011 – April 2012)

Instrumentation of downstream stripline BPMs as witnesses

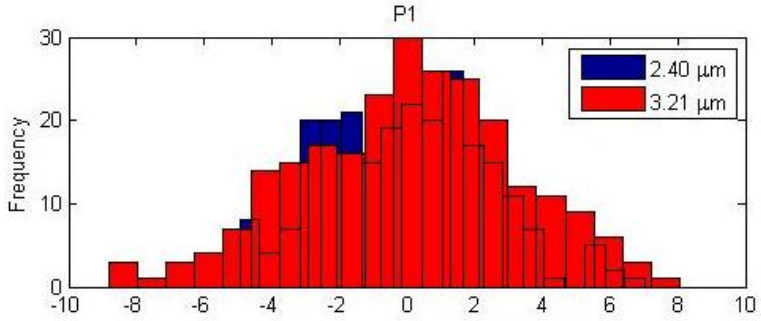
Brief study of variation of ATF2 optics (1 shift)

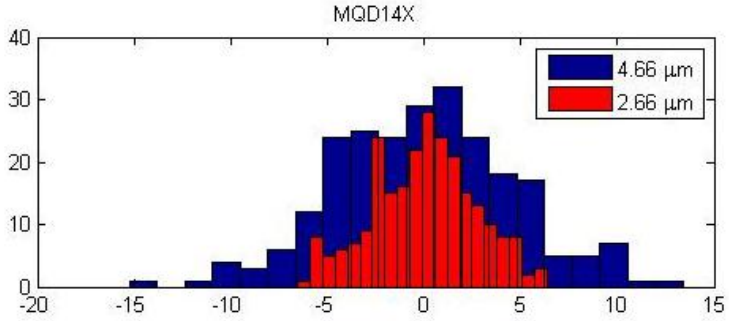
Additional witness BPMs

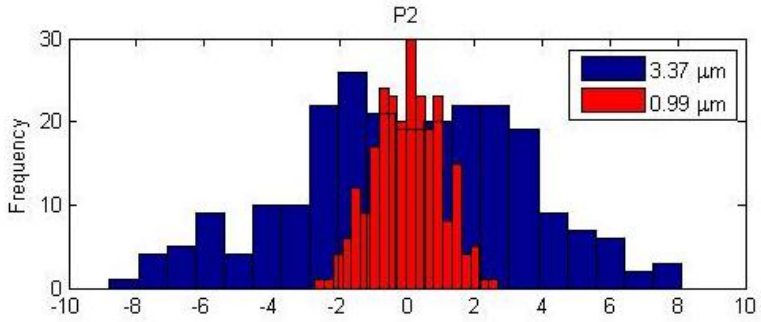


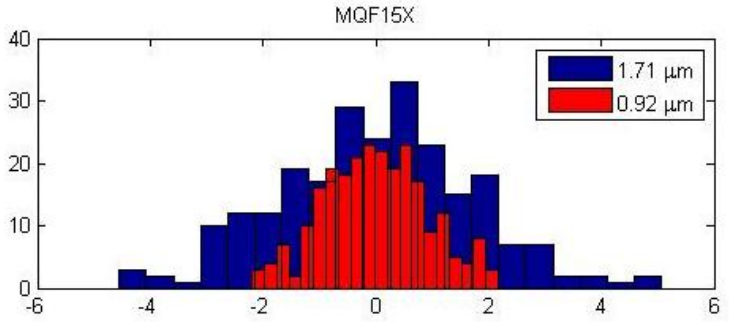
'borrow' these BPMs for our shifts

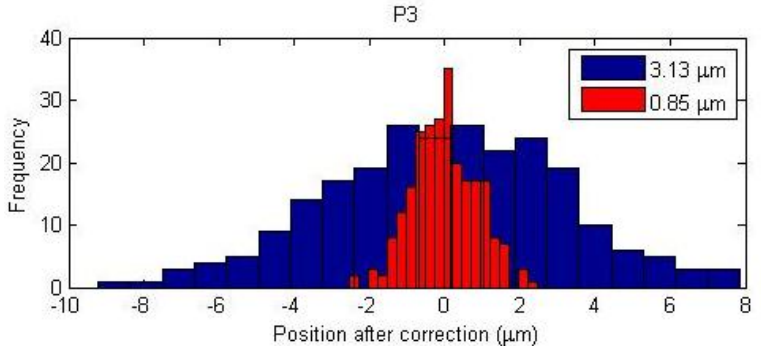
07/12 FB Run 23 (nom. optics)

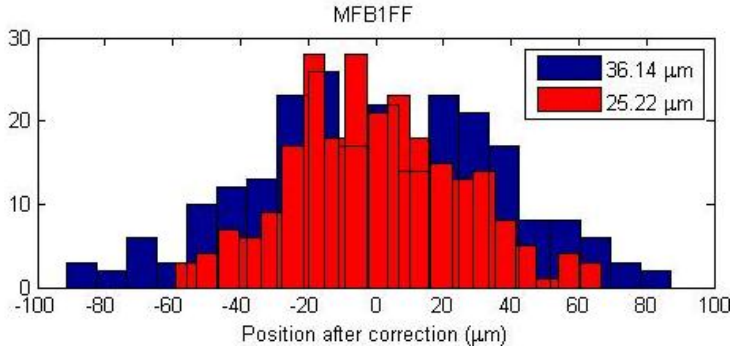




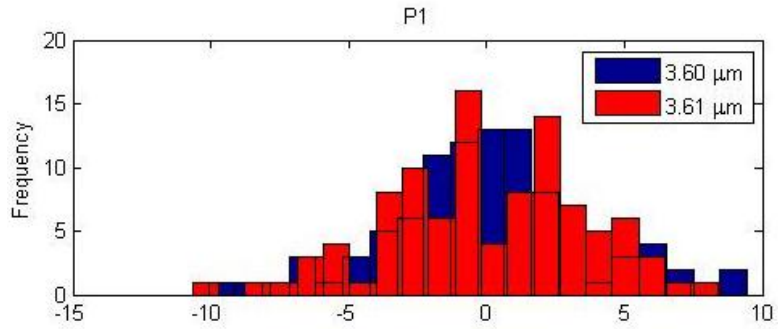


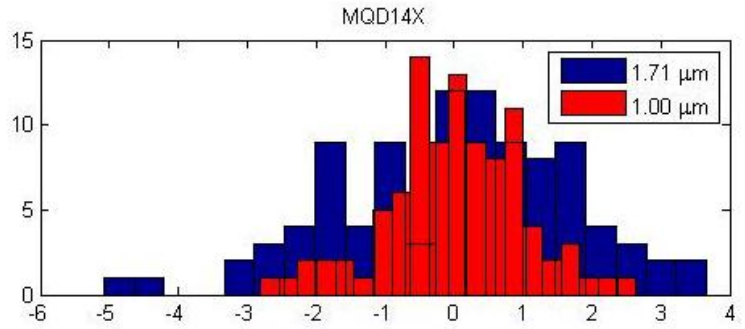


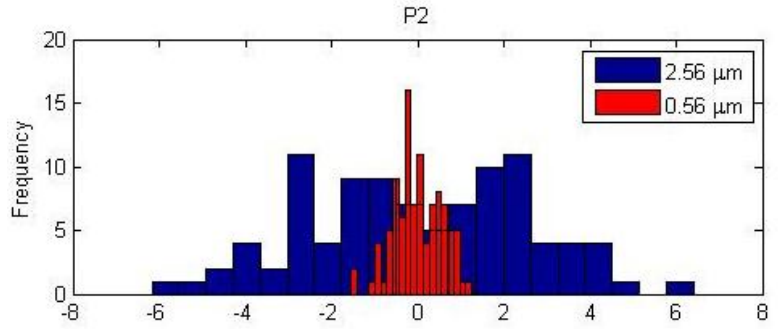


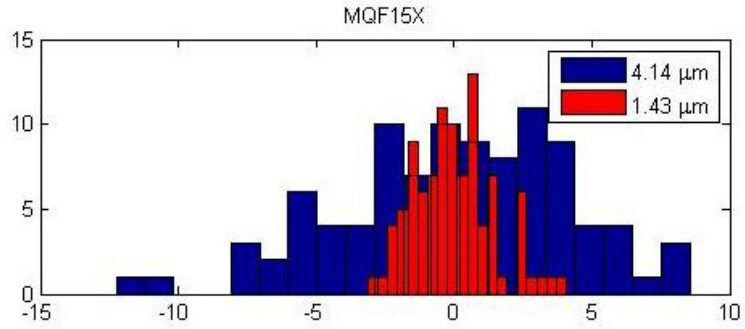


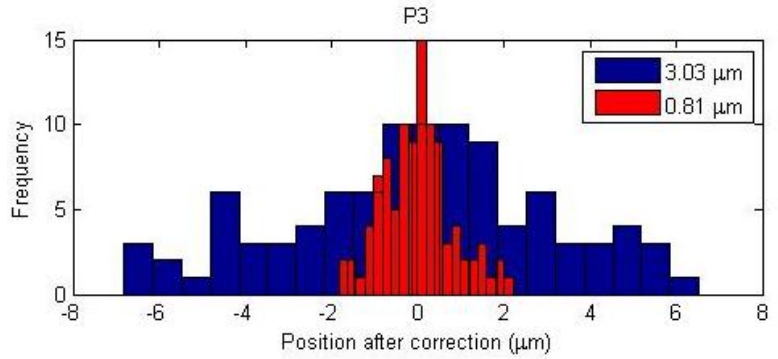
13/12 FB Run 3 (nom. optics)

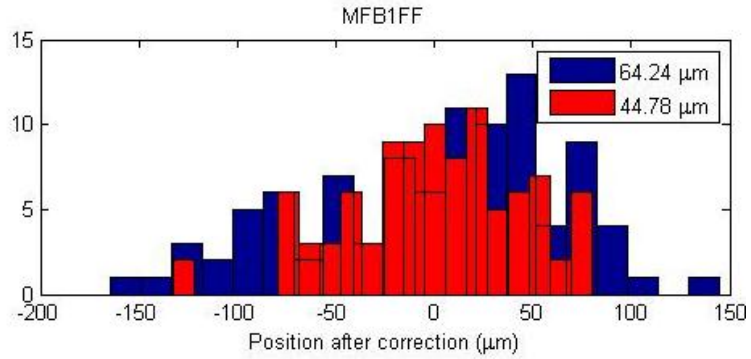




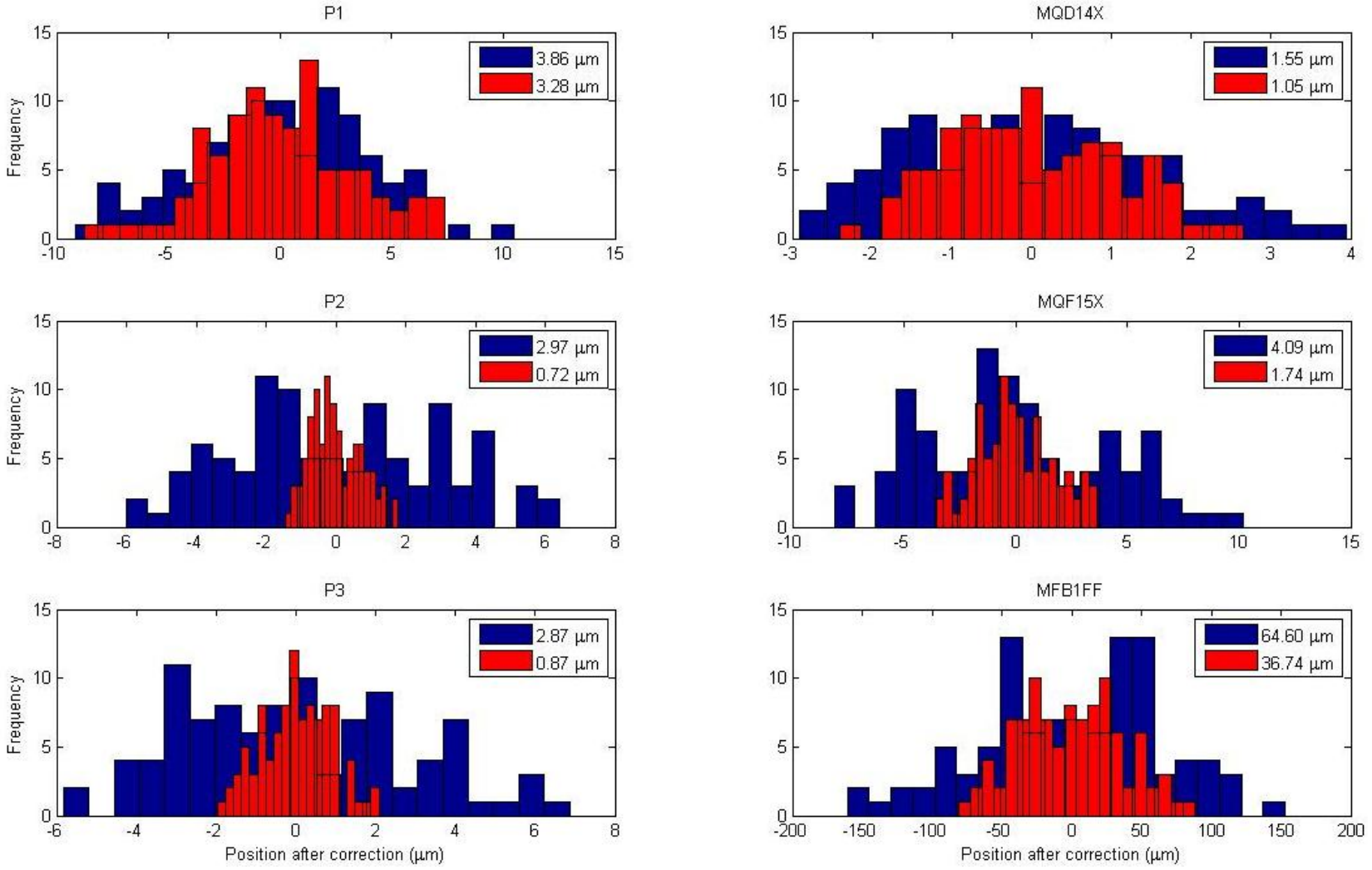




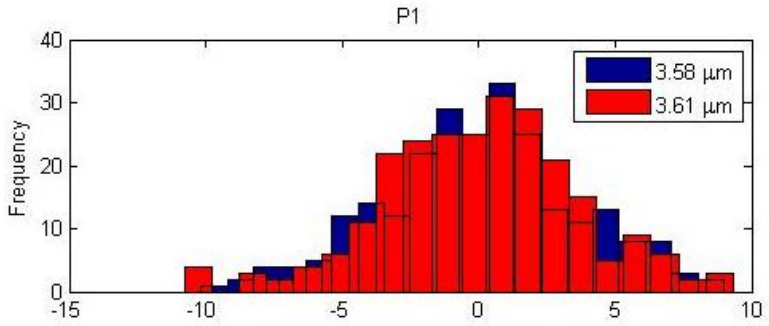


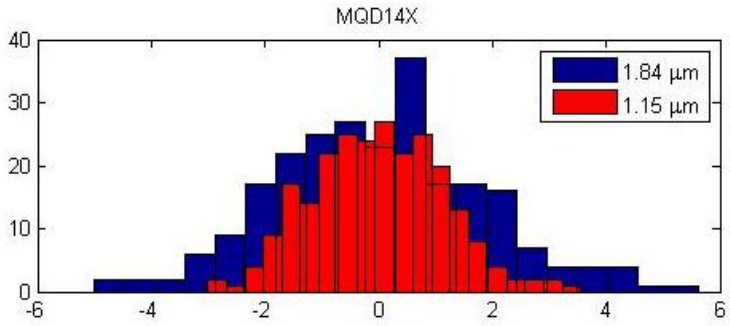


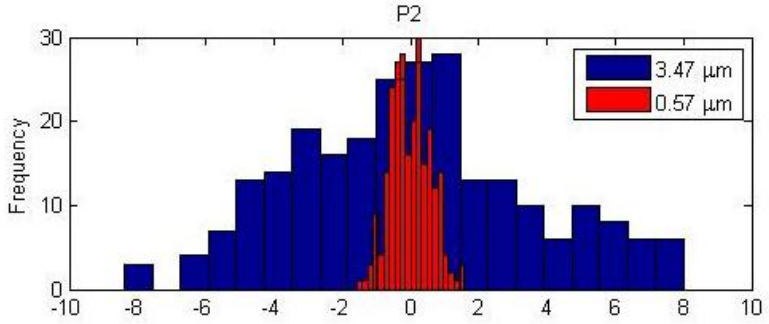
13/12 FB Run7 (QS,QK off)

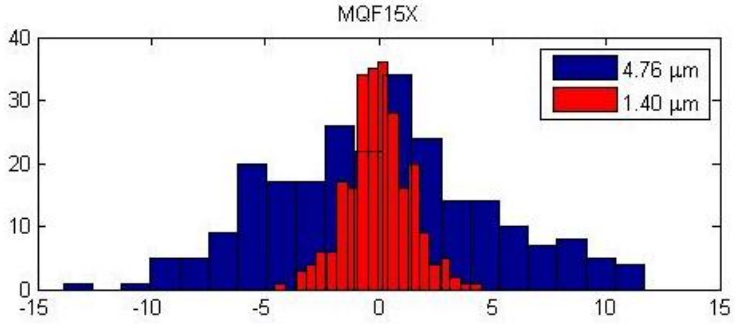


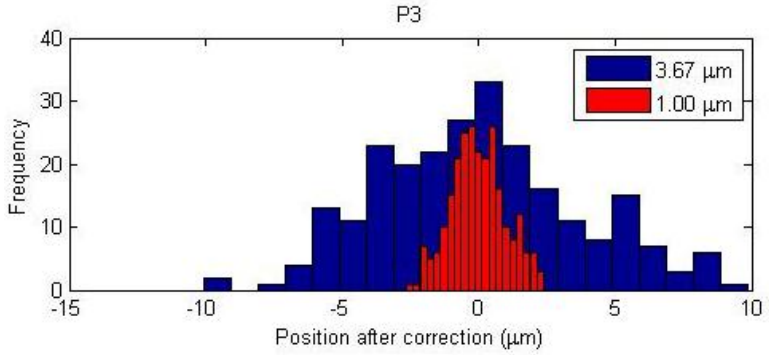
14/12 FB Run 6 (QK off)

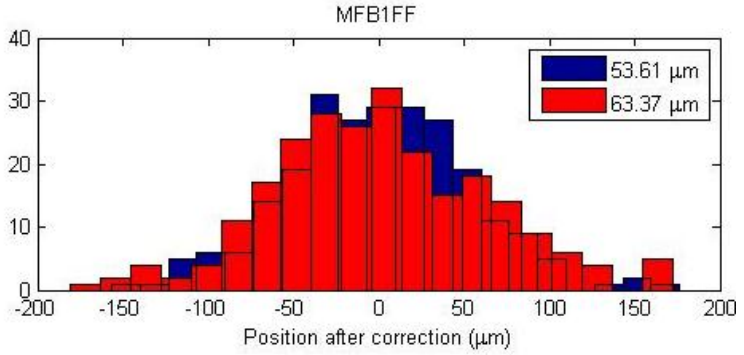












Tests (Dec 2011 – April 2012)

Instrumentation of downstream stripline BPMs as witnesses

Brief study of variation of ATF2 optics (1 shift)

Study of LO phase jitter on FB performance (2 shifts)

Tests of new firmware including LO phase compensation (2 shifts) – study ongoing

Tests (June – Oct 2012)

Preparations for beam stability in IP region with

2-bunch beam:

1. **Readout of IPBPMs with 2-bunch beam + test of IP kicker (4 shifts)**
2. **Upstream FONT FB: record beam in IPBPMs (4 shifts)**

   → report in Friday session on ATF2 goal 2
3. **Feed-forward from upstream FONT BPMs → IP kicker: record beam in IPBPMs**
4. **IP FB using IPBPM signal and IP kicker**