IP FB tests at ATF2

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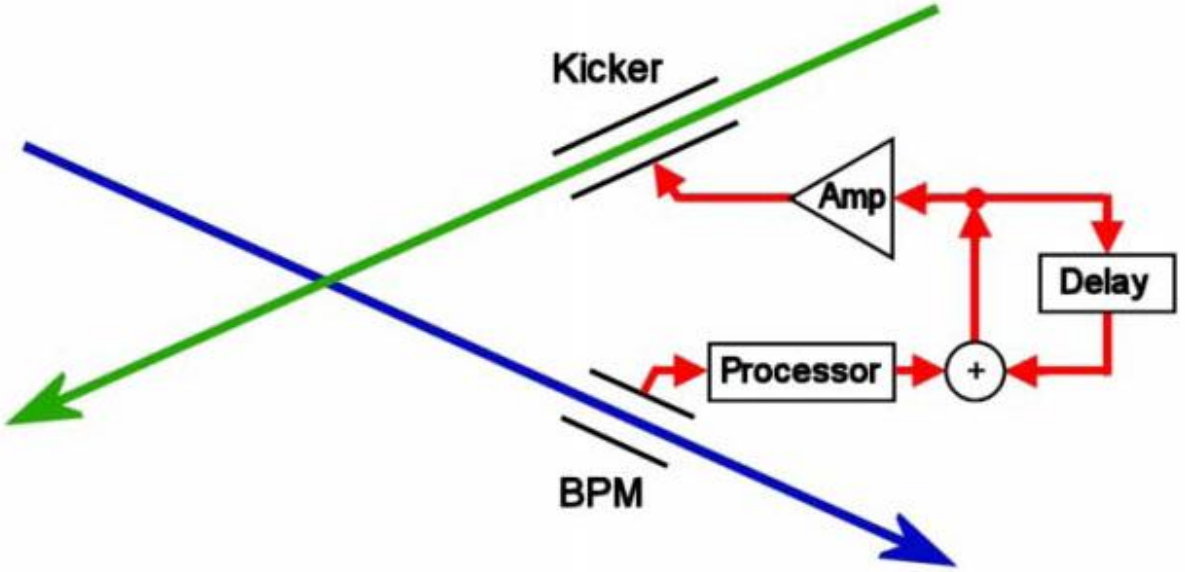
IP intra-train feedback system - concept

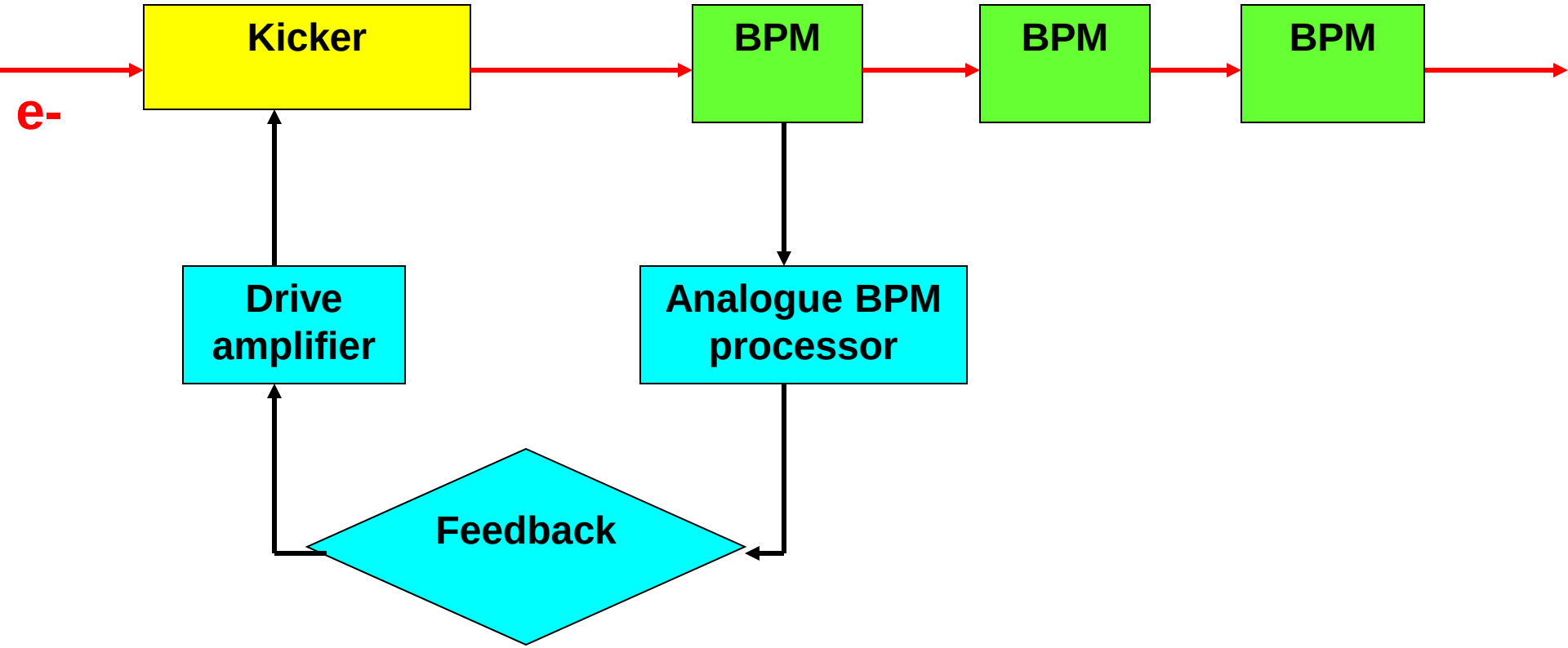
- Last line of defence against relative beam misalignment
- Measure vertical position of outgoing beam and hence beam-beam kick angle
- Use fast amplifier and kicker to correct vertical position of beam incoming to IR



FONT – Feedback On Nanosecond Timescales

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

Prototype schematic



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 CLIC-relevant prototypes

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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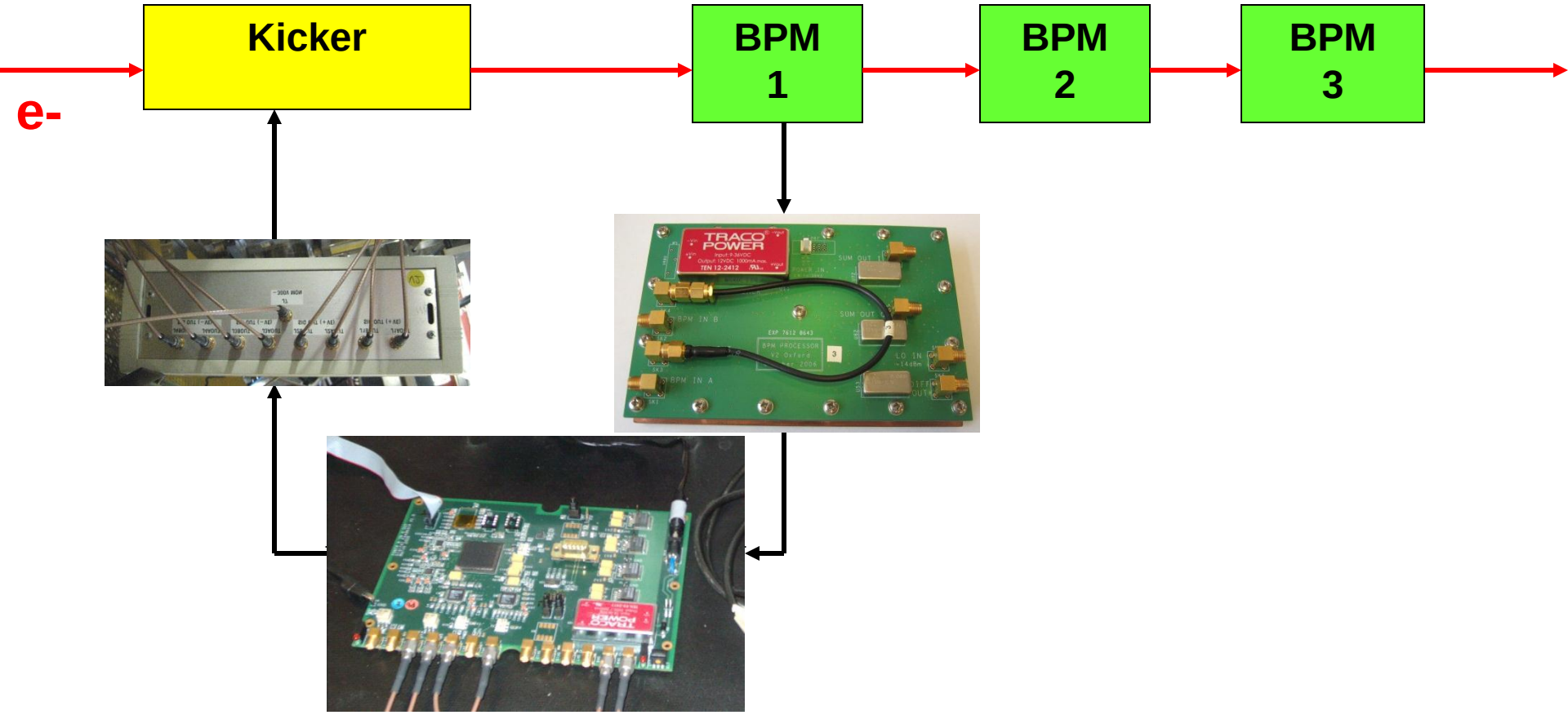
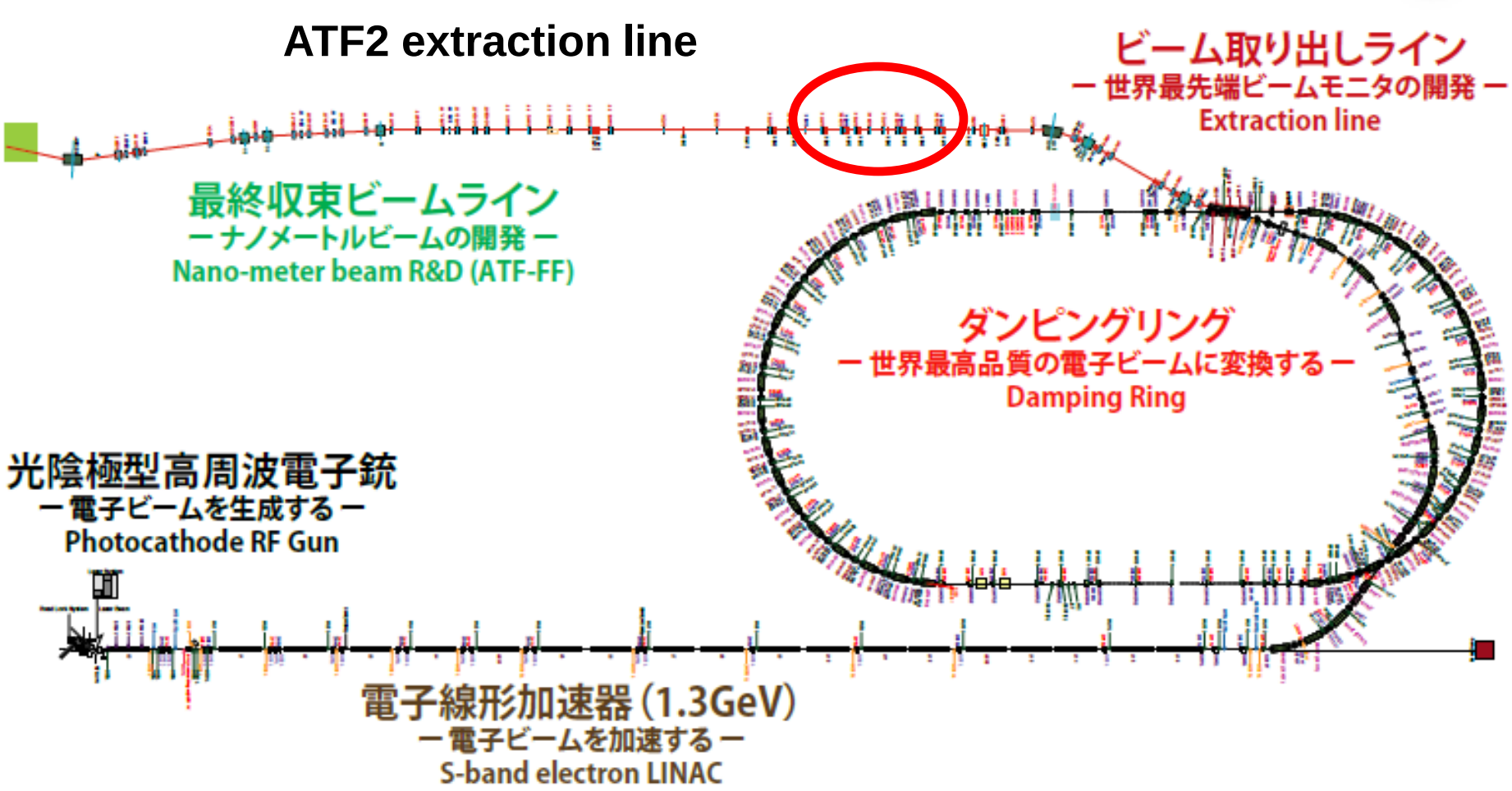
ILC-like

FONT4 prototype at ATF



FONT5 location at ATF2



FONT 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?)**
- → **next talk by Glenn**

FONT prototype status

Bunch-by-bunch feedback for intra-train operation

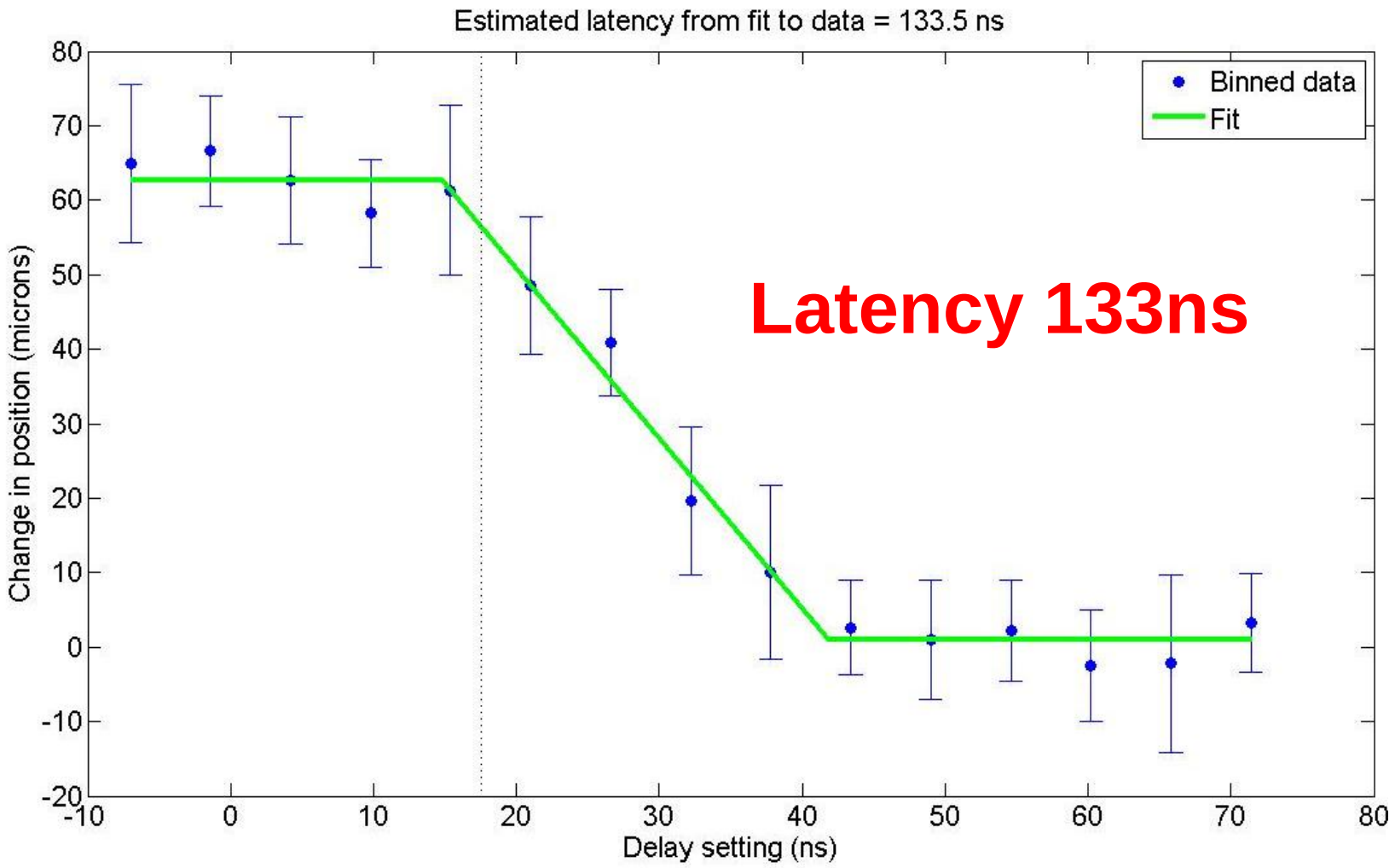
Stripline BPM resolution in single-pass mode: goal ~ 1um

→ < 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 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?)

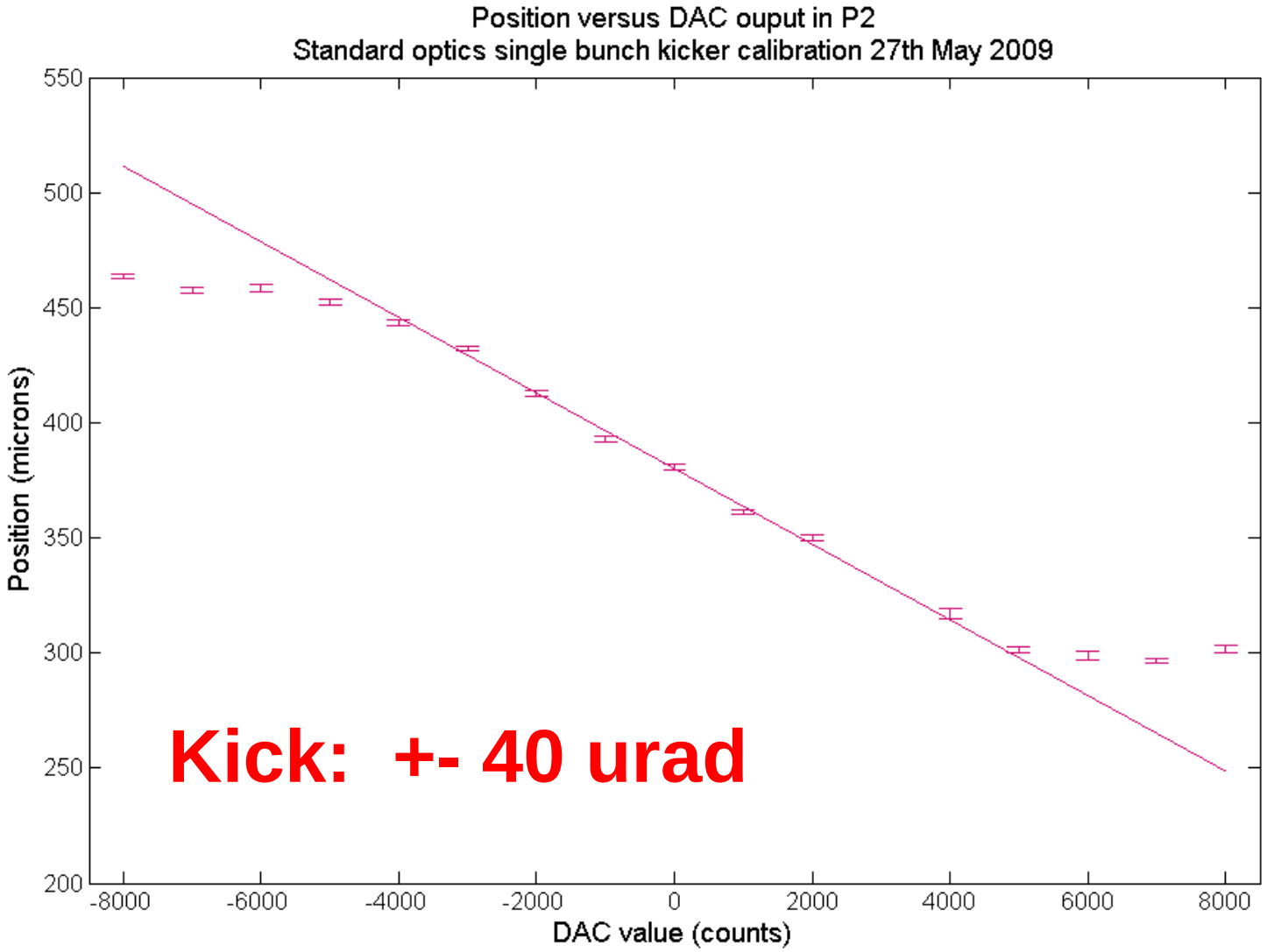
Latency: goal ~ 150ns (shortest possible ILC bunch spacing)

→ 133ns achieved (including cables)

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

→ +- 800 nm achieved

Kick strength



FONT 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** ✓

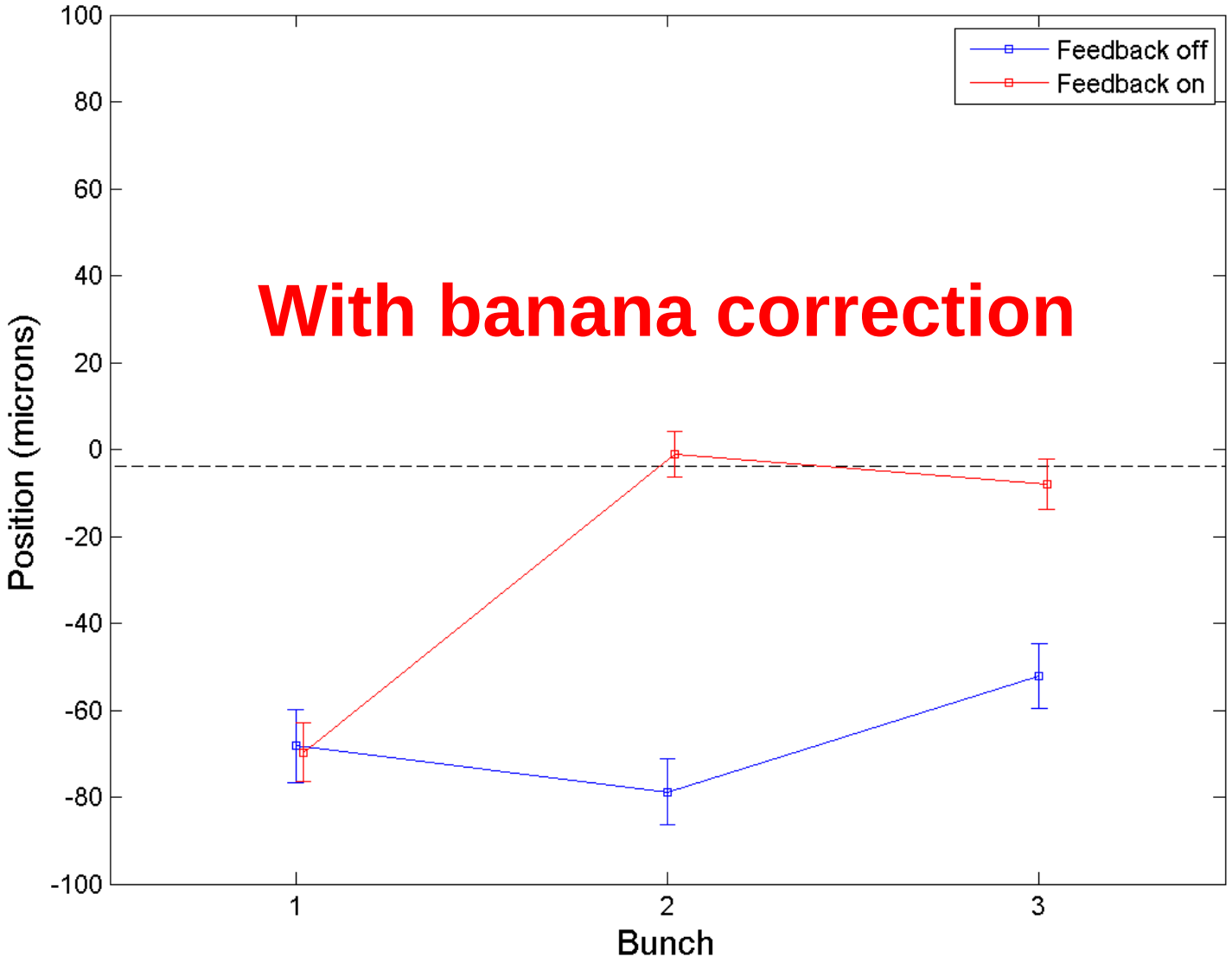
Latency: goal ~ 150ns (shortest possible ILC bunch spacing)

→ 133ns achieved (including cables)

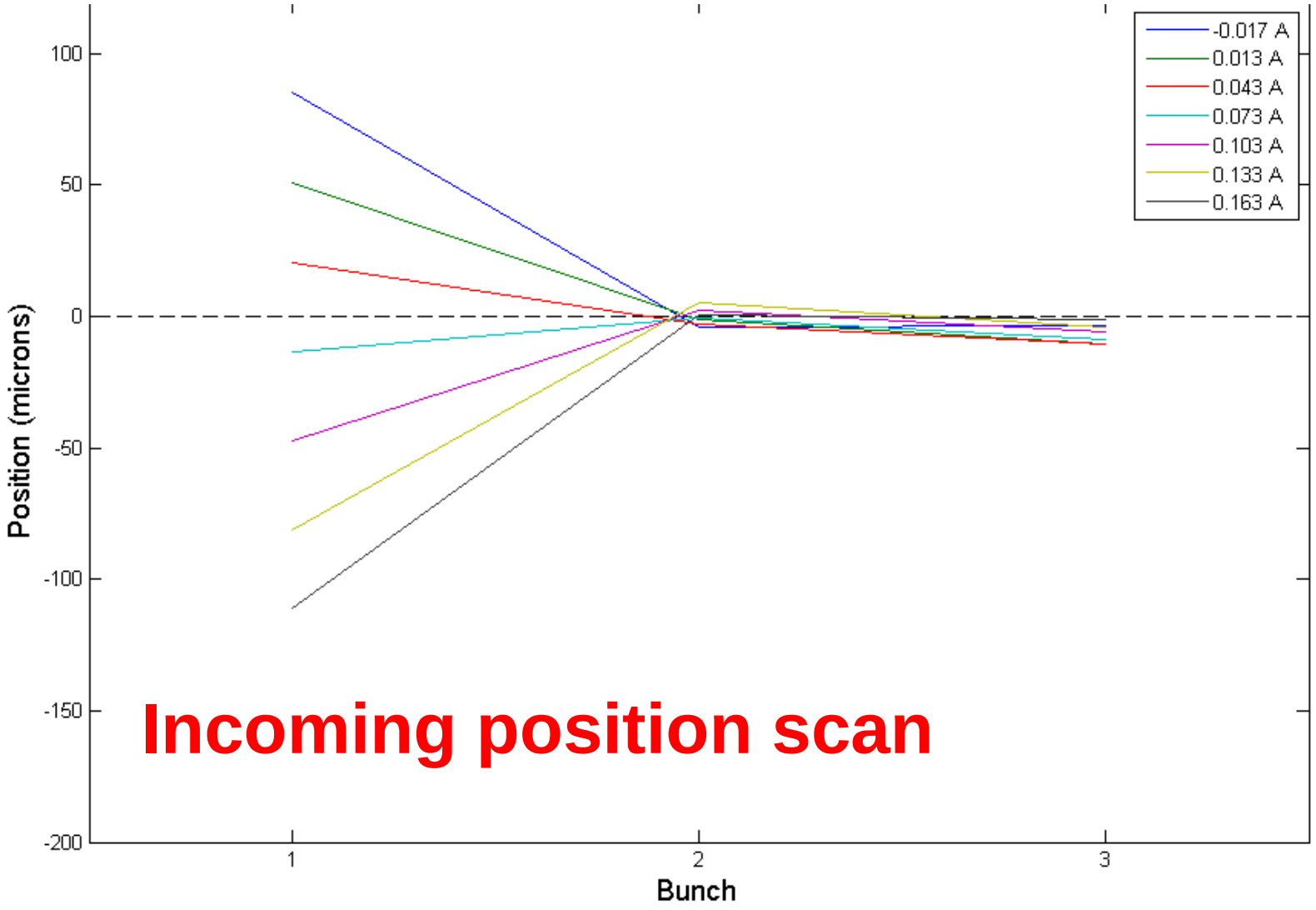
Dynamic range: goal +- 250 nm (250 GeV beam energy)

→ +- 800 nm achieved **CLIC** ✓

FB performance

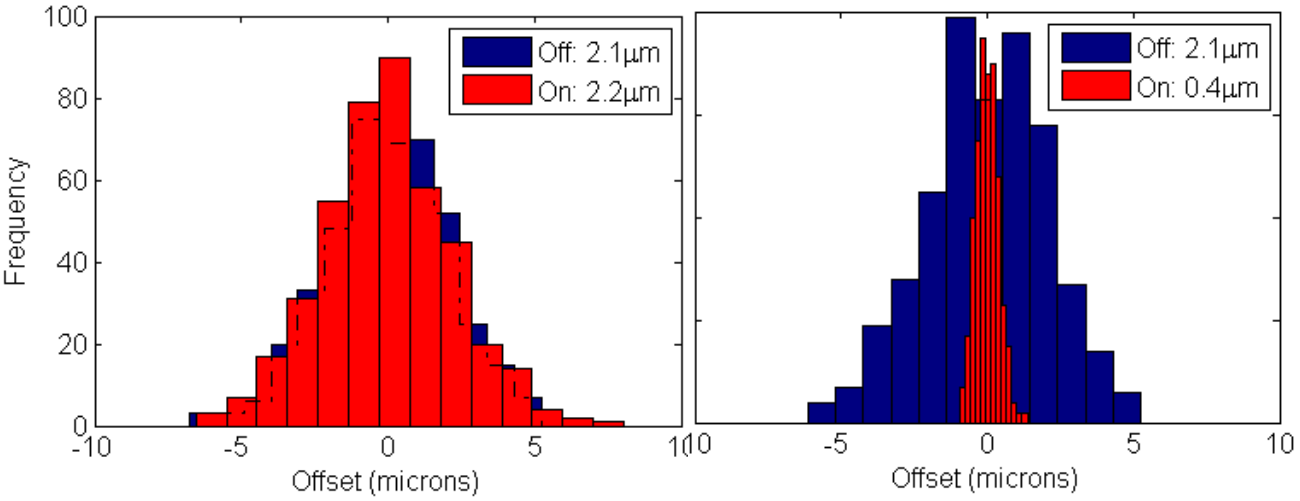


FB performance



FB jitter reduction (good beam)

Bunch 1 **Bunch 2**

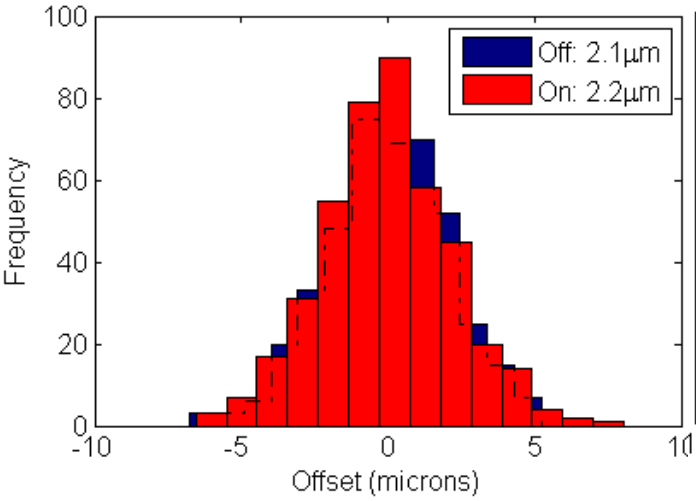


2.1 um → **0.4 um**

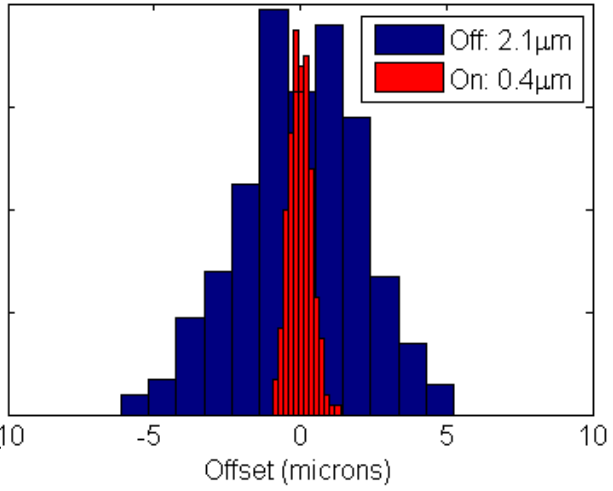
Factor of 5 jitter reduction

FB jitter reduction (good beam)

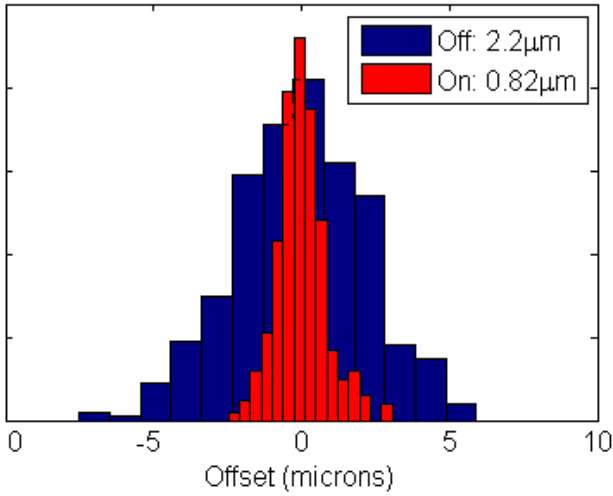
Bunch 1



Bunch 2



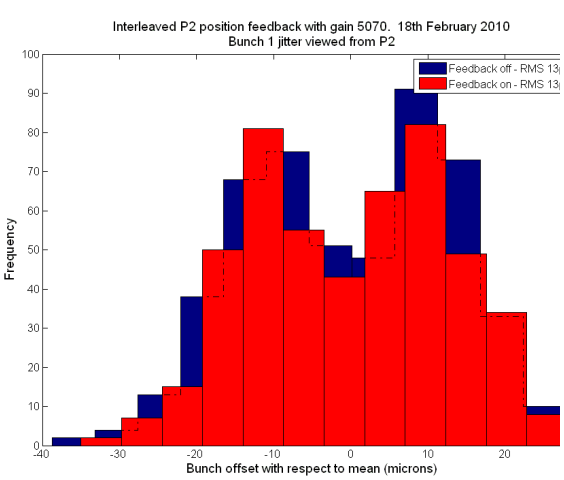
Bunch 3



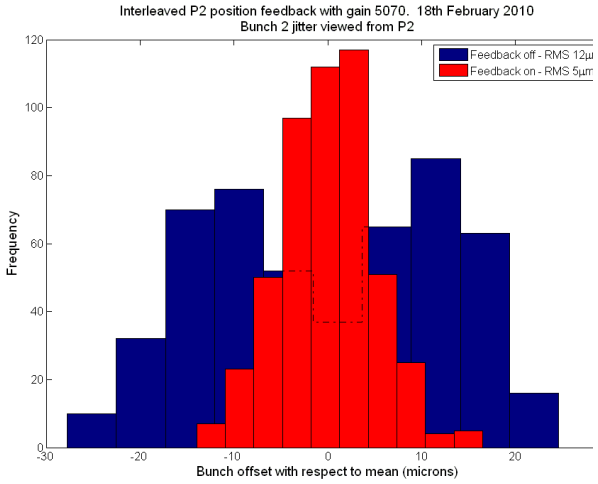
2.1 um → 0.4 um → 0.8 um

FB jitter reduction (bad beam)

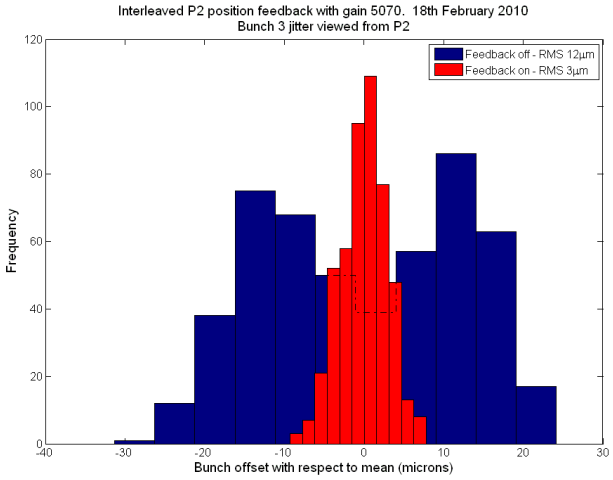
Bunch 1



Bunch 2



Bunch 3



13 um → 5 um → 3 um

FONT prototype status

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

  → correction with resolution

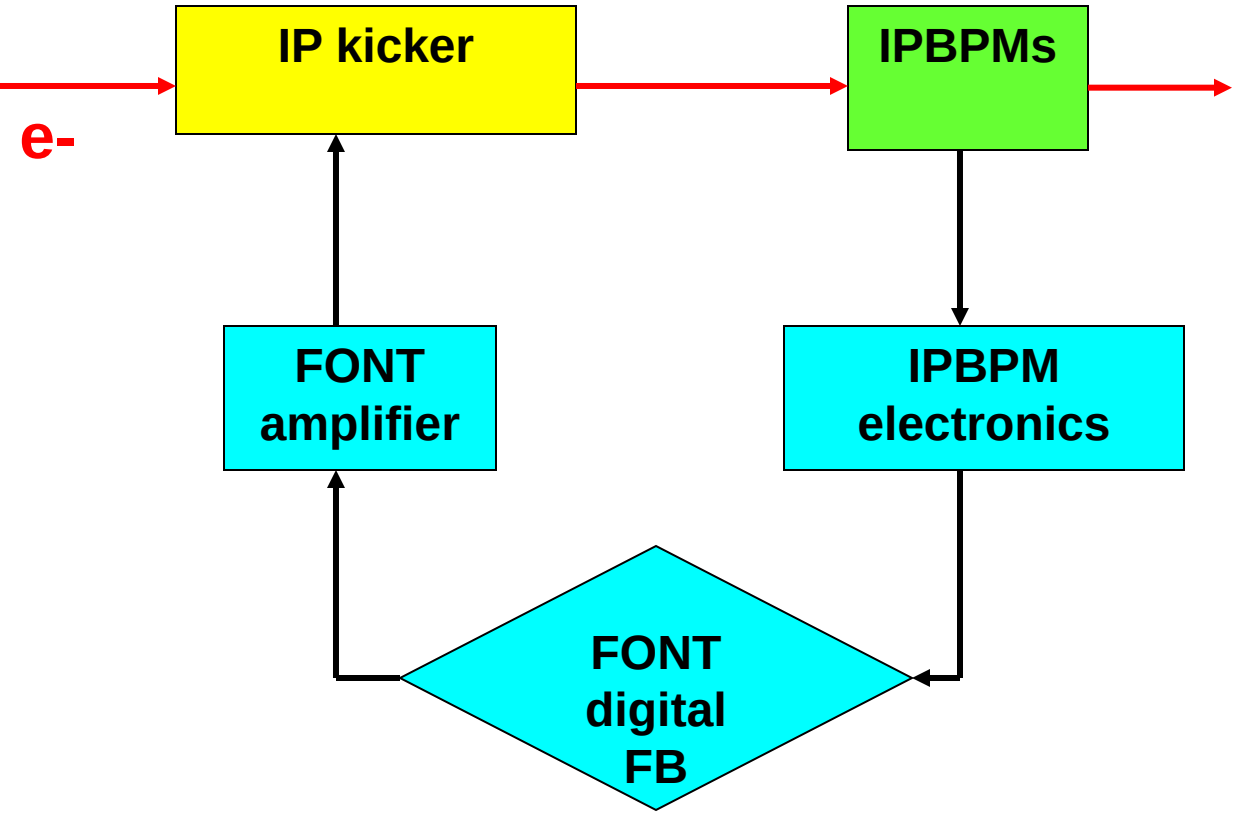
  equivalent to 2 nm @ 250 GeV

ATF2 goals

After small beam (37nm) has been obtained (goal 1), stabilisation of ATF2 beam at the nanometre level (goal 2) will need to be addressed

Key to addressing this challenge is beam position correction near the ATF2 IP

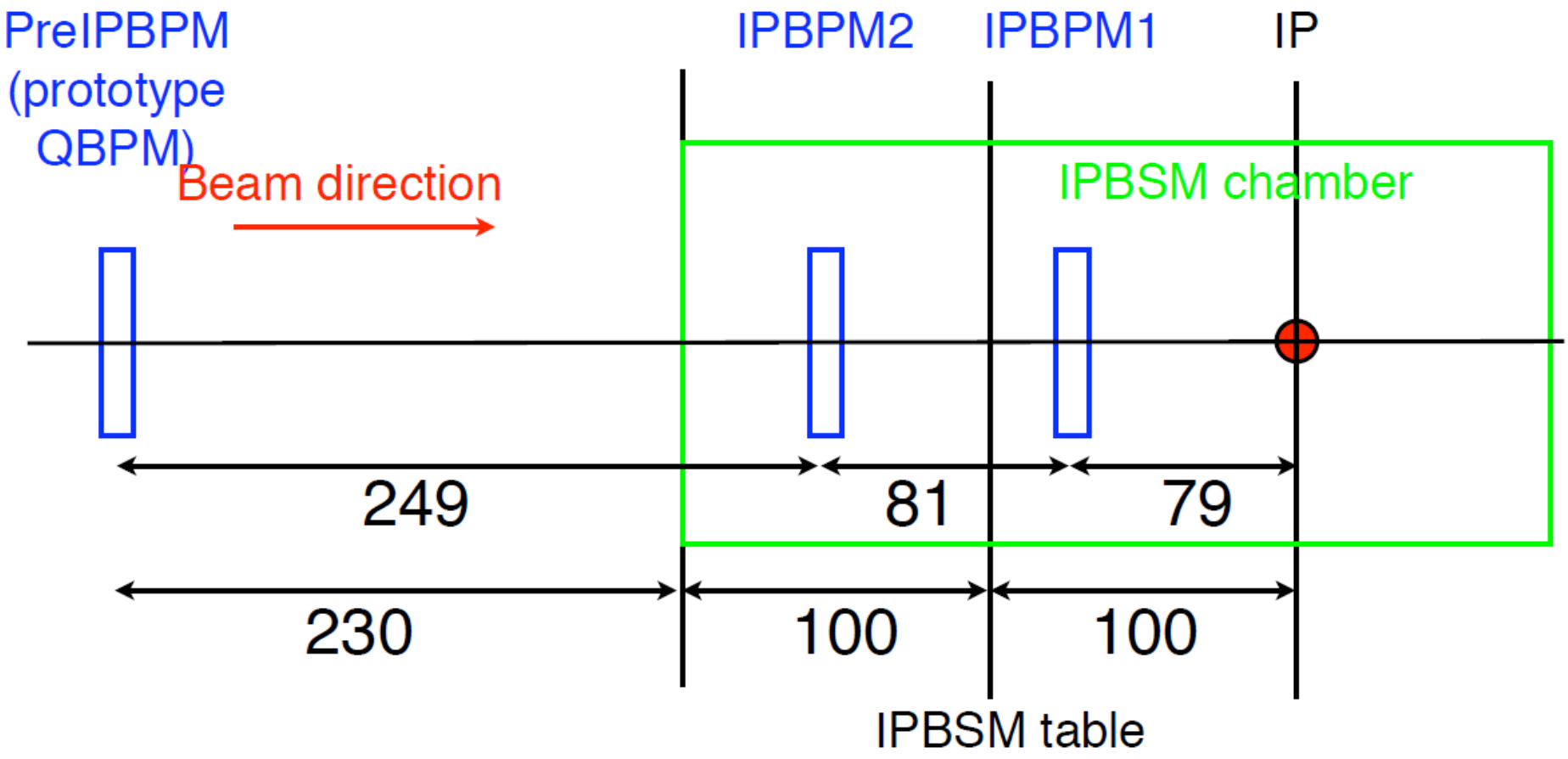
ATF2 IP FB loop scheme



Existing IP-BPM geometry

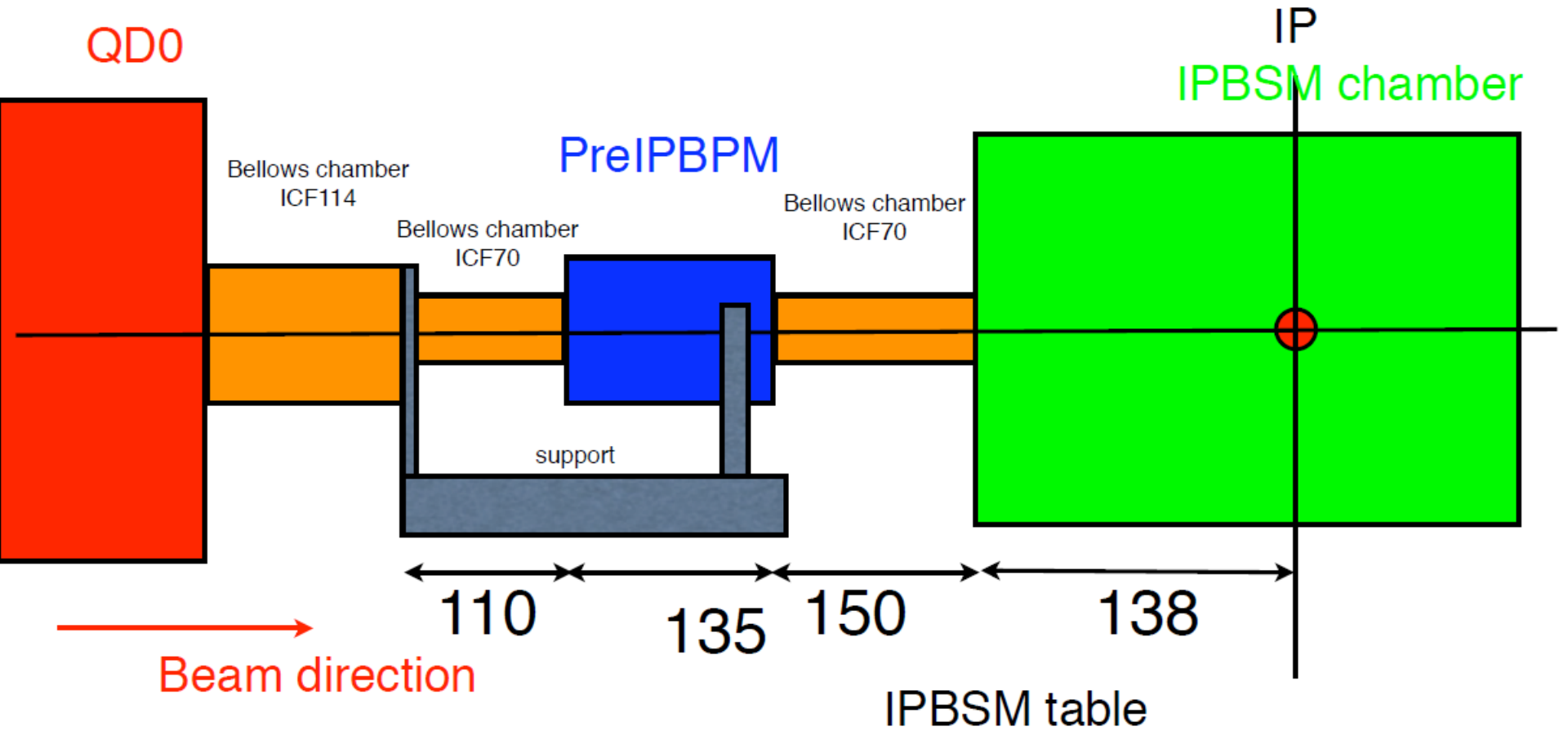
2011.6.29 Y.Honda

- Relative location of IP and two IPBPMs in BSM chamber and PreIPBPM.
- Accuracy of the number should be a few mm.

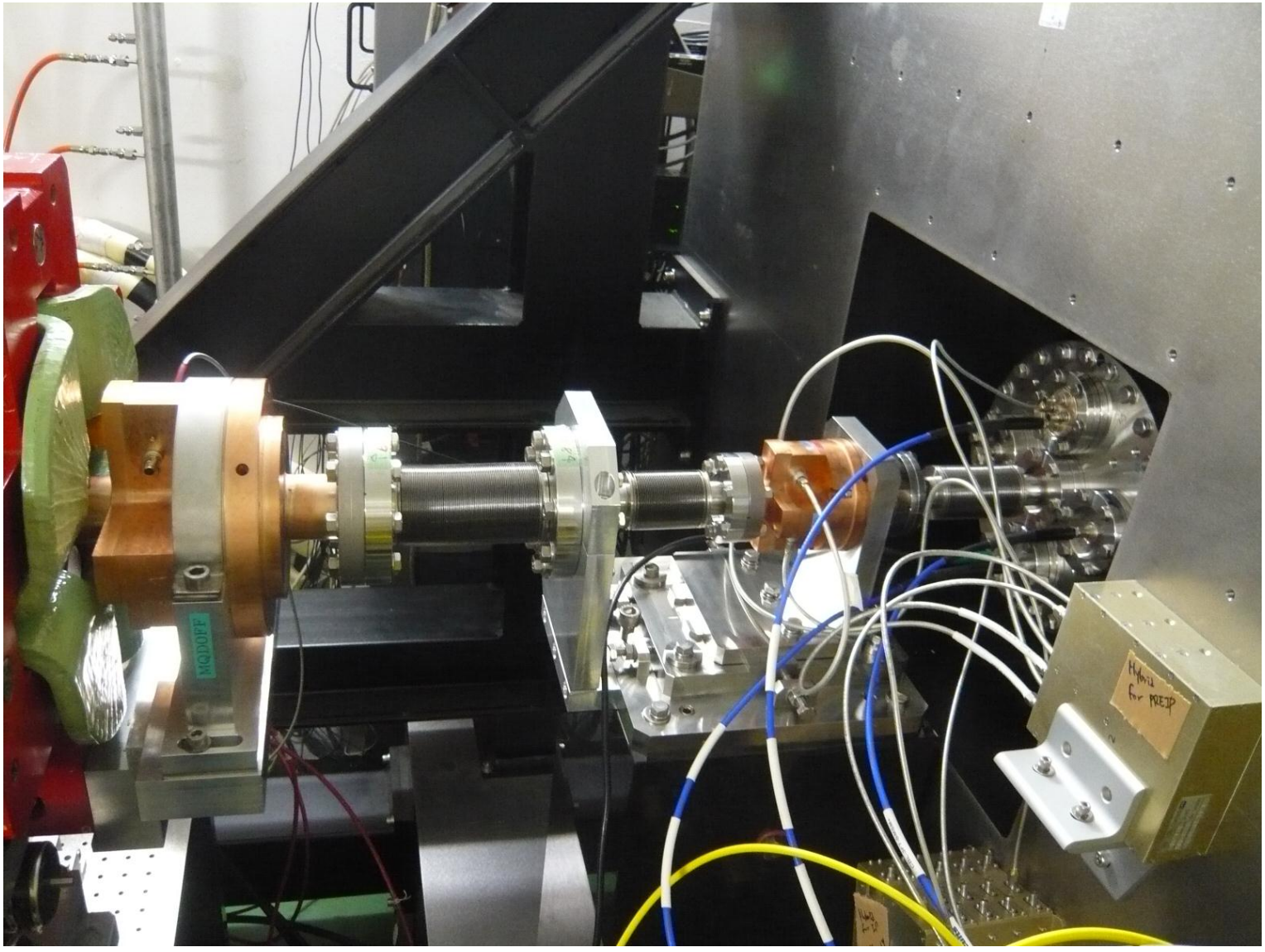


Chamber geometry

- PreIPBPM is connected with ICF70 bellows at both ends for position adjustment.
- QD0 is with ICF114 bellows for its position adjustment. (Since it needs to balance vacuum force for both ends, this should be ICF114 size.)
- ICF70-114 bellows joint is supported from PreIPBPM table.



Layout (before May 2012)

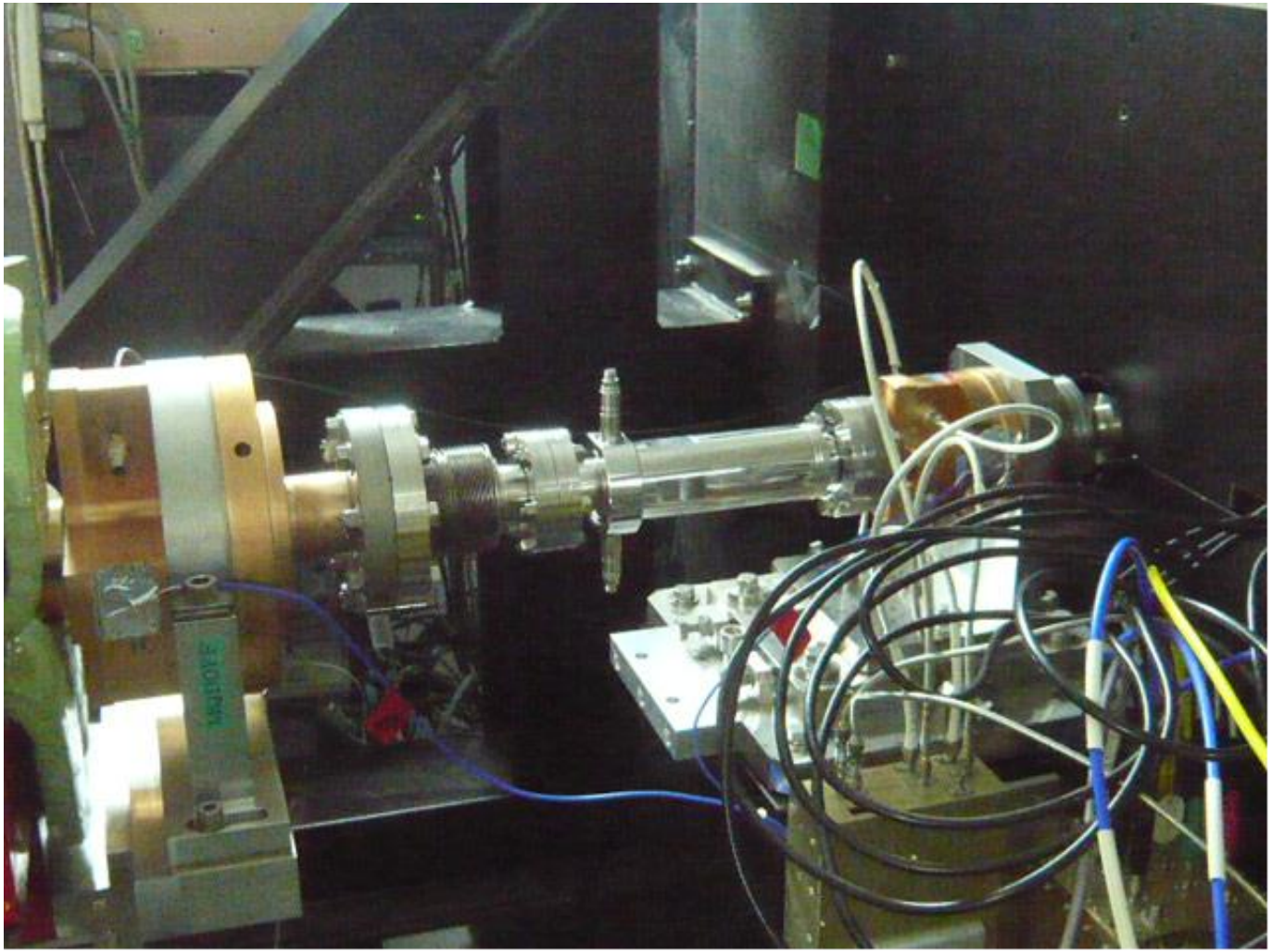


New IP kicker

Designed by Oxford

Fabrication arranged by KEK

Installed May 2012

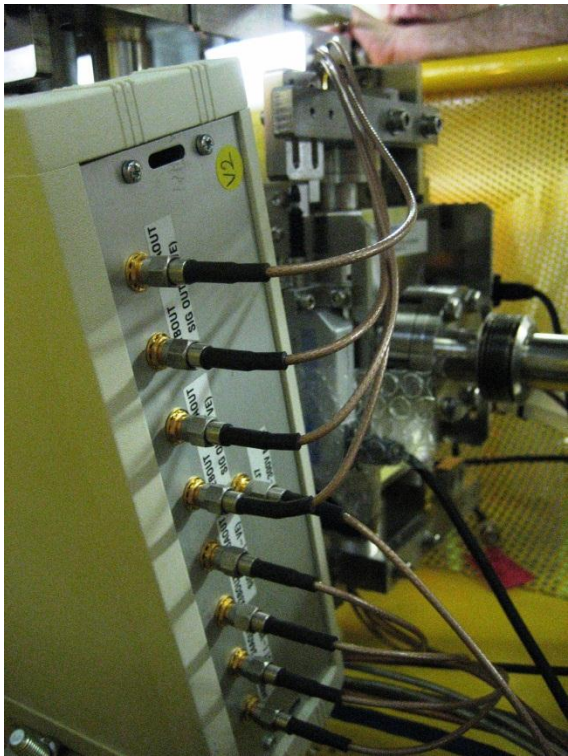


FONT drive amplifier

FONT5 amplifier, built by TMD Technologies

Specifications:

- **+- 15A (kicker terminated with 50 Ohm)**
- **+- 30A (kicker shorted at far end)**
- **35ns risetime (to 90%)**
- **pulse length 10 us**
- **repetition rate 10 Hz**



First preparations (June 2012)

- **Test new IP kicker with FONT amplifier:**

  ensure functionality

  measure dynamic range of kick

- **Instrument existing IPBPMs w. Honda electronics, for 2-bunch readout:**

  digitise signals with FONT5 board

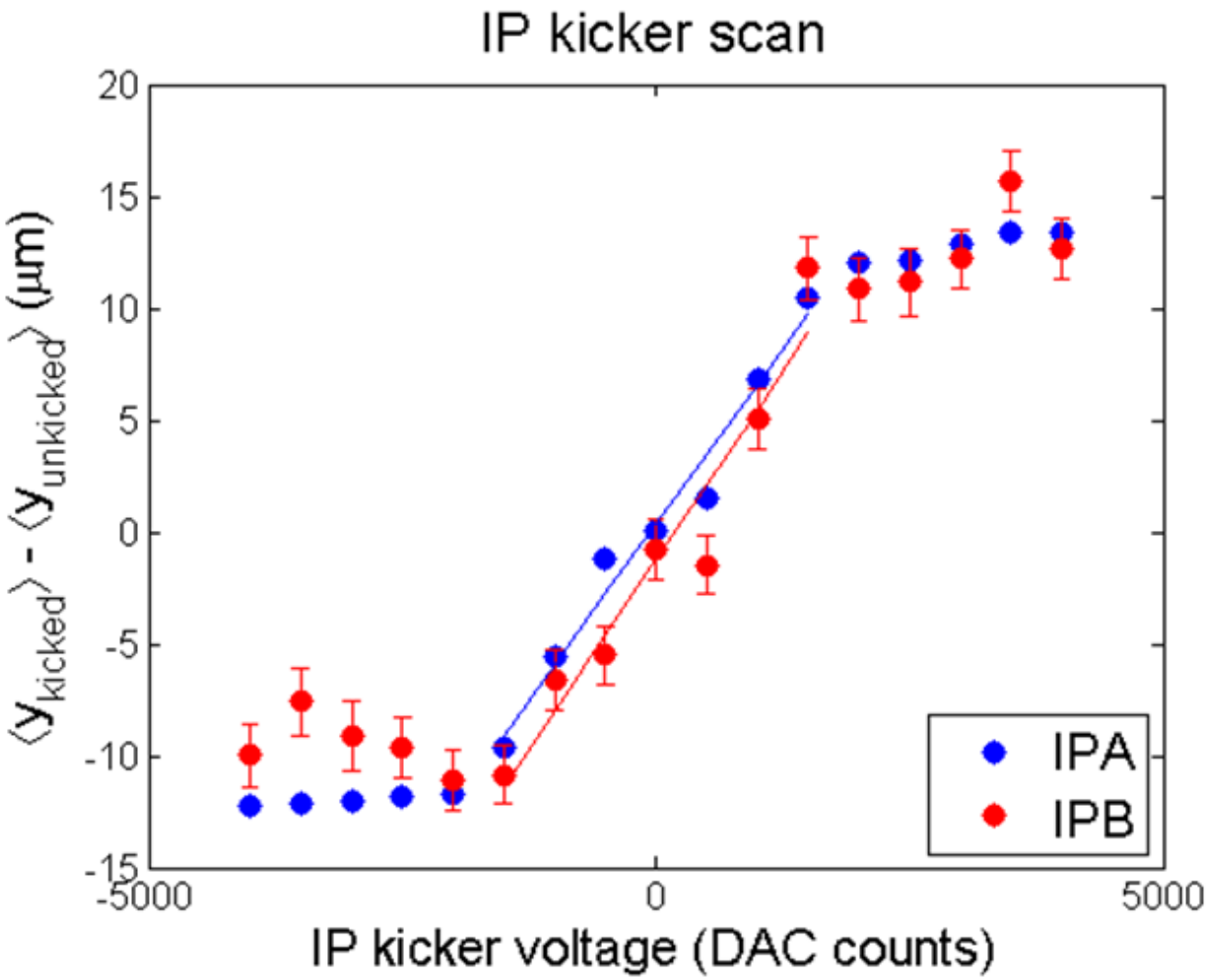
  cross check with EPICS in 1-bunch mode

  understand cavity BPM signals w. 2 bunches

  exercise system in preparation for IPFB

IP kicker drive scan

EPICS readout of IPBPMs



IP kicker conclusions

- **Kicker is working well**
- **FONT amplifier is able to drive kicker**
- **Dynamic kick range almost +- 15 um at IPBPMs**
- **Linear kick range > +- 10 um**

→ plenty of drive for beam stabilisation @ IP

IPBPM tests (single bunch)

- **IPBPM A+B signals split:**

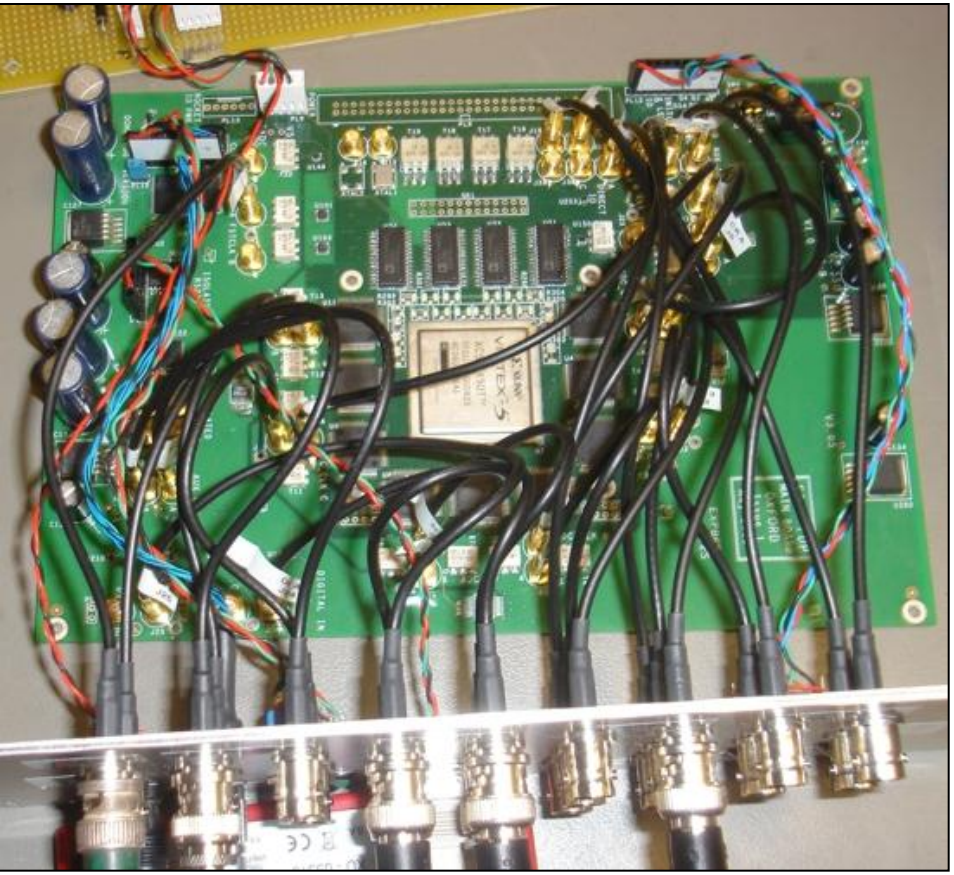
  1) SLAC electronics → ATF EPICS controls

  2) Honda-san electronics → FONT5 board

  allowed cross-check of standard electronics and FONT digitised readout

- **Temporary cabling and setup used for tests**

FONT5 digital FB board



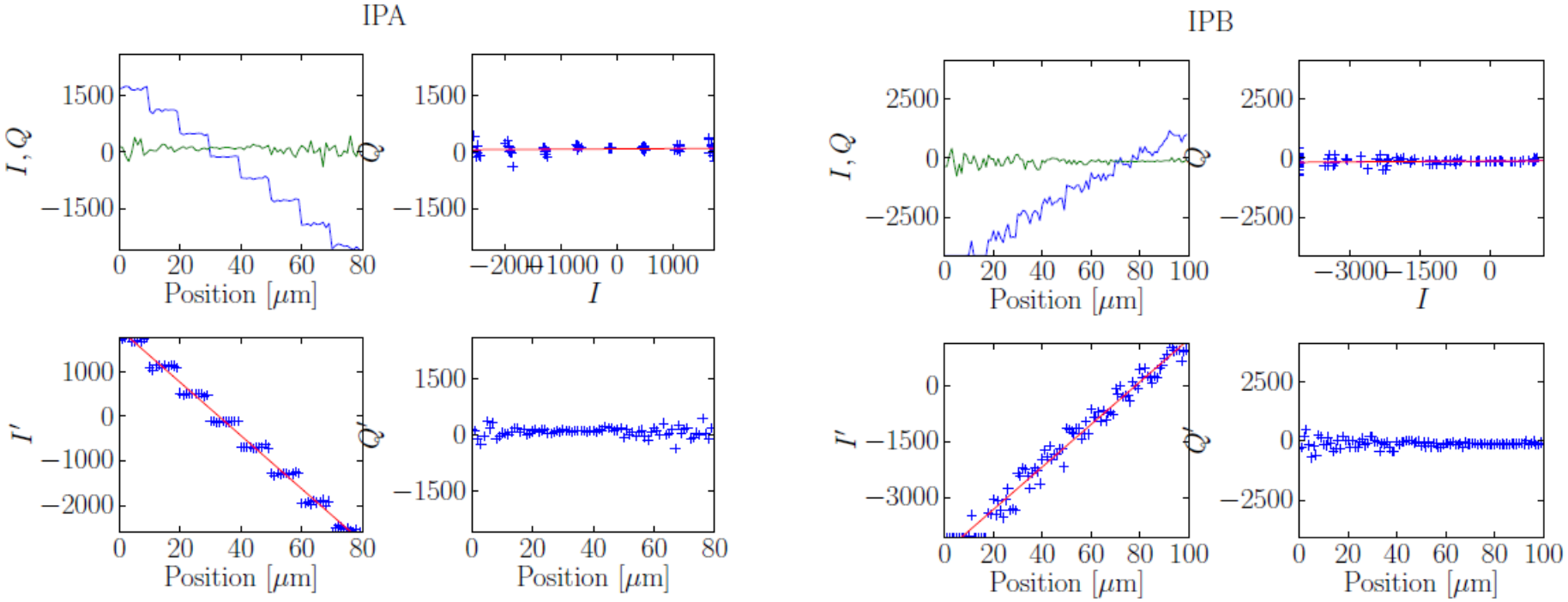
Xilinx Virtex5 FPGA

9 ADC input channels (TI ADS5474)

4 DAC output channels (AD9744)

Clocked at 357 MHz phase-locked to beam

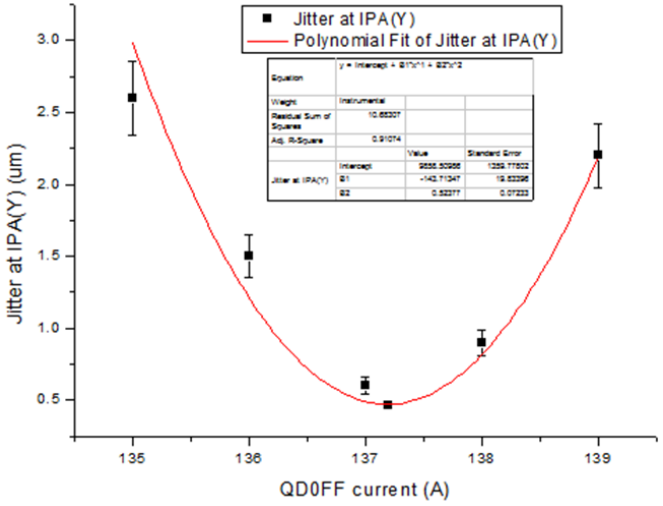
FONT digitisation of IPBPMs



Digitisation and calibration successful, with single-bunch beam

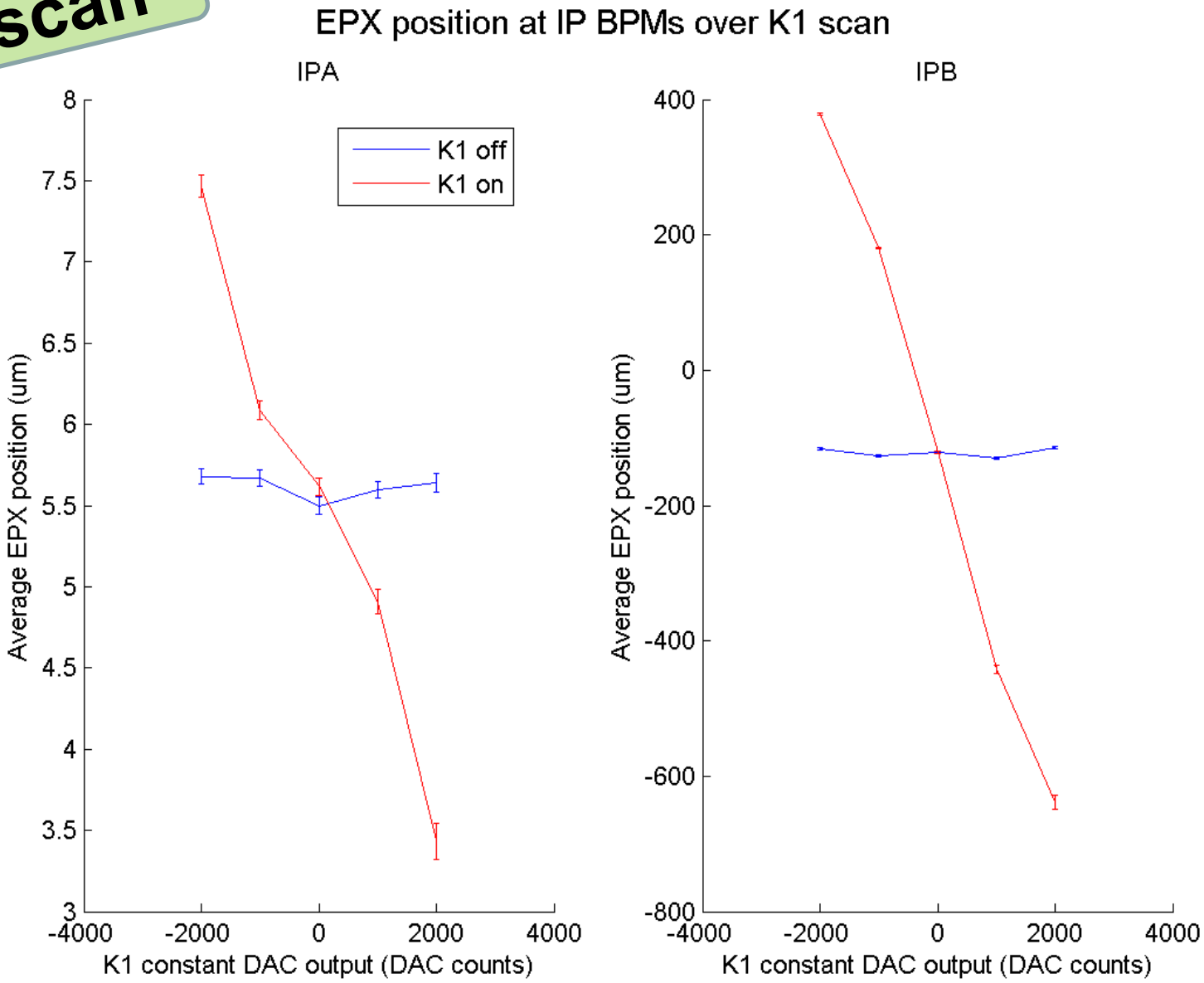
Upstream FONT kicker tests

- **Beam waist set to IPBPM A**
- **Jitter minimised**



- **Upstream FONT kickers K1, K2 scanned**
- **Beam position recorded in IPBPMs**

K1 scan


EPX position at IP BPMs over K1 scan
IPA
IPB
K1 off
K1 on
Average EPX position (um)
K1 constant DAC output (DAC counts)
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
400
200
0
-200
-400
-600
-800
-4000
-2000
0
2000
4000

Upstream FONT kicker tests

- **Position change at IPBPMs clearly observed**

  → upstream FONT FB can stabilise beam @ IP

Test Programme

Preparations for beam stability in IP region with 2-bunch beam:

1. Readout of IPBPMs with 2-bunch beam

2. Upstream FONT FB: record beam in IPBPMs

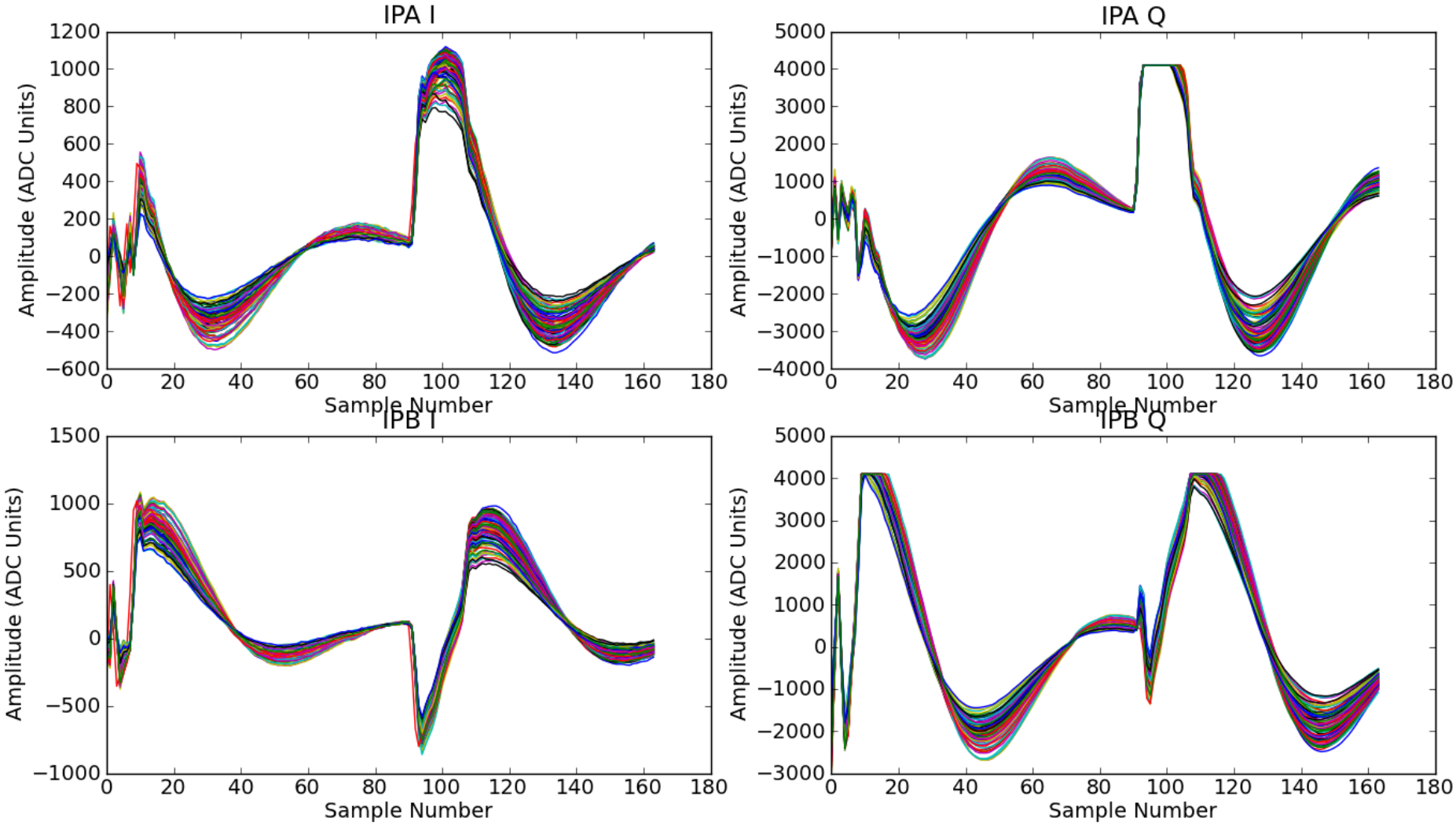
3. Feed-forward from upstream FONT BPMs → IP kicker: record beam in IPBPMs

4. IP FB using IPBPM signal and IP kicker

Issues (October 2012 – 4 shifts)

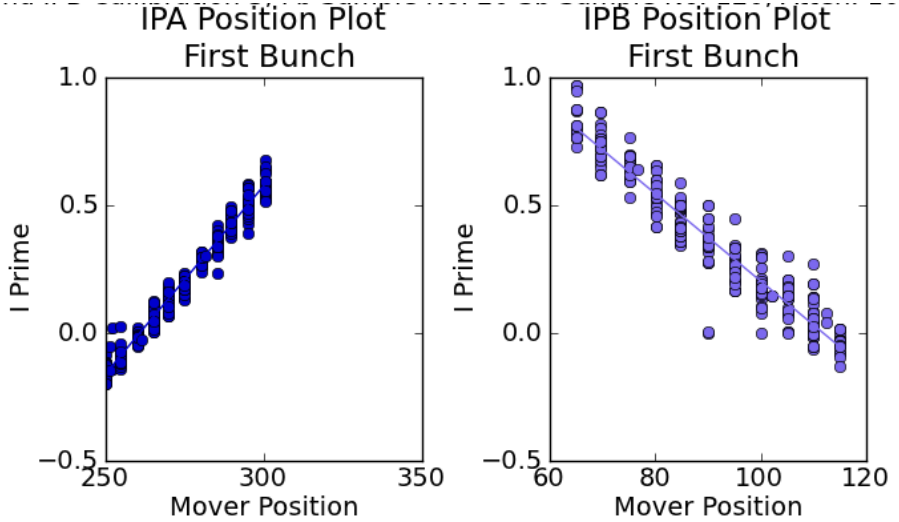
- First experience with Honda electronics connected locally to IPBPMs (previously tested upstream, with low-Q BPMs)
- Required extensive recabling/setup of electronics near IP
- Signal levels + attenuation need careful attention:
  - saturation of IPBPM electronics: 1st stage mixer
  - signal variation with bunch charge and position
  - bunches 1 and 2 not necessarily on same orbit
- Arrival time of reference cavity signal is ‘late’ by 30ns due to cabling

Digitised waveform examples

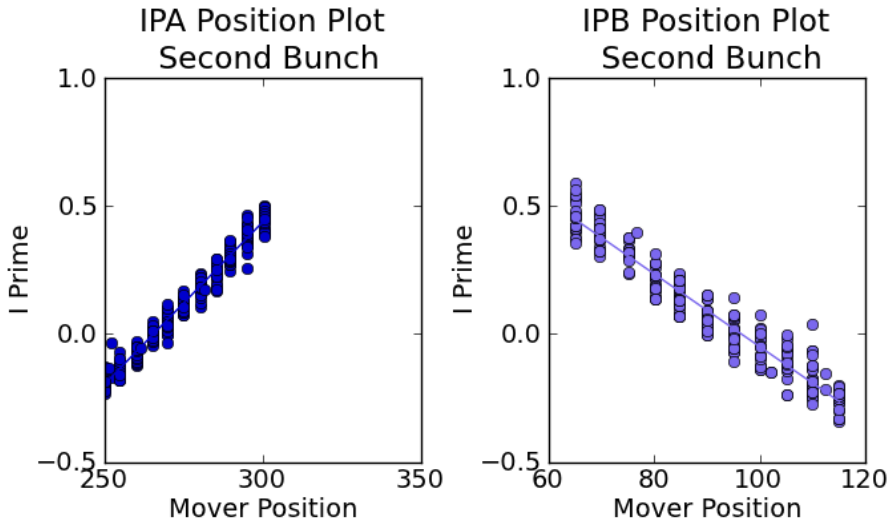


Calibrations

Bunch 1



Bunch 2



2-bunch beam

- **Sampling and digitisation working well**
- **Single-sample calibration procedure works**

Test programme

Preparations for beam stability in IP region with 2-bunch beam:

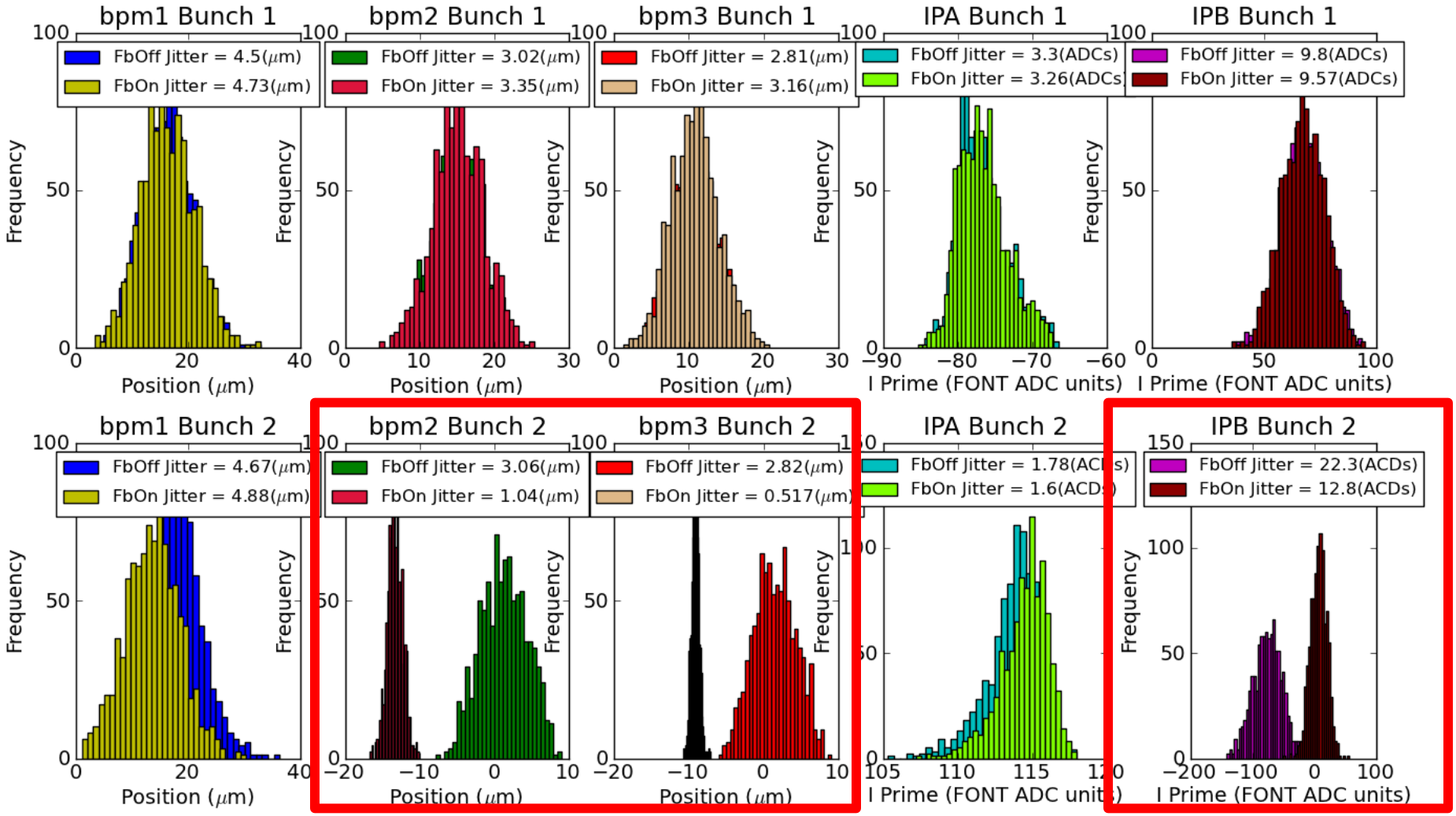
1. Readout of IPBPMs with 2-bunch beam ✓

2. Upstream FONT FB: record beam in IPBPMs

3. Feed-forward from upstream FONT BPMs → IP kicker: record beam in IPBPMs

4. IP FB using IPBPM signal and IP kicker

Beam waist at IPB: FB off/on



Test programme

Preparations for beam stability in IP region with 2-bunch beam:

1. **Readout of IPBPMs with 2-bunch beam** ✓
2. **Upstream FONT FB: record beam in IPBPMs** ✓
3. **Feed-forward from upstream FONT BPMs → IP kicker: record beam in IPBPMs**
4. **IP FB using IPBPM signal and IP kicker**

IP FB loop scheme