Feedback On Nanosecond Timescales

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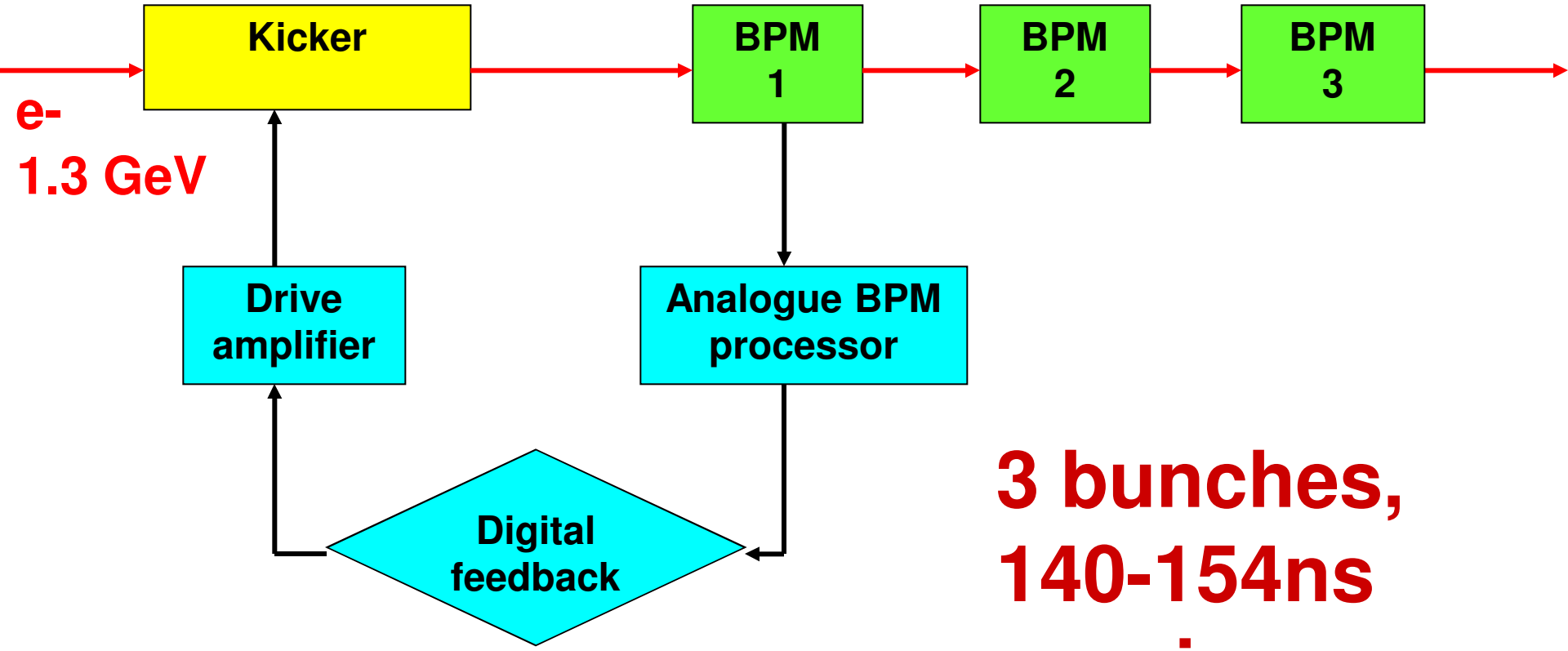
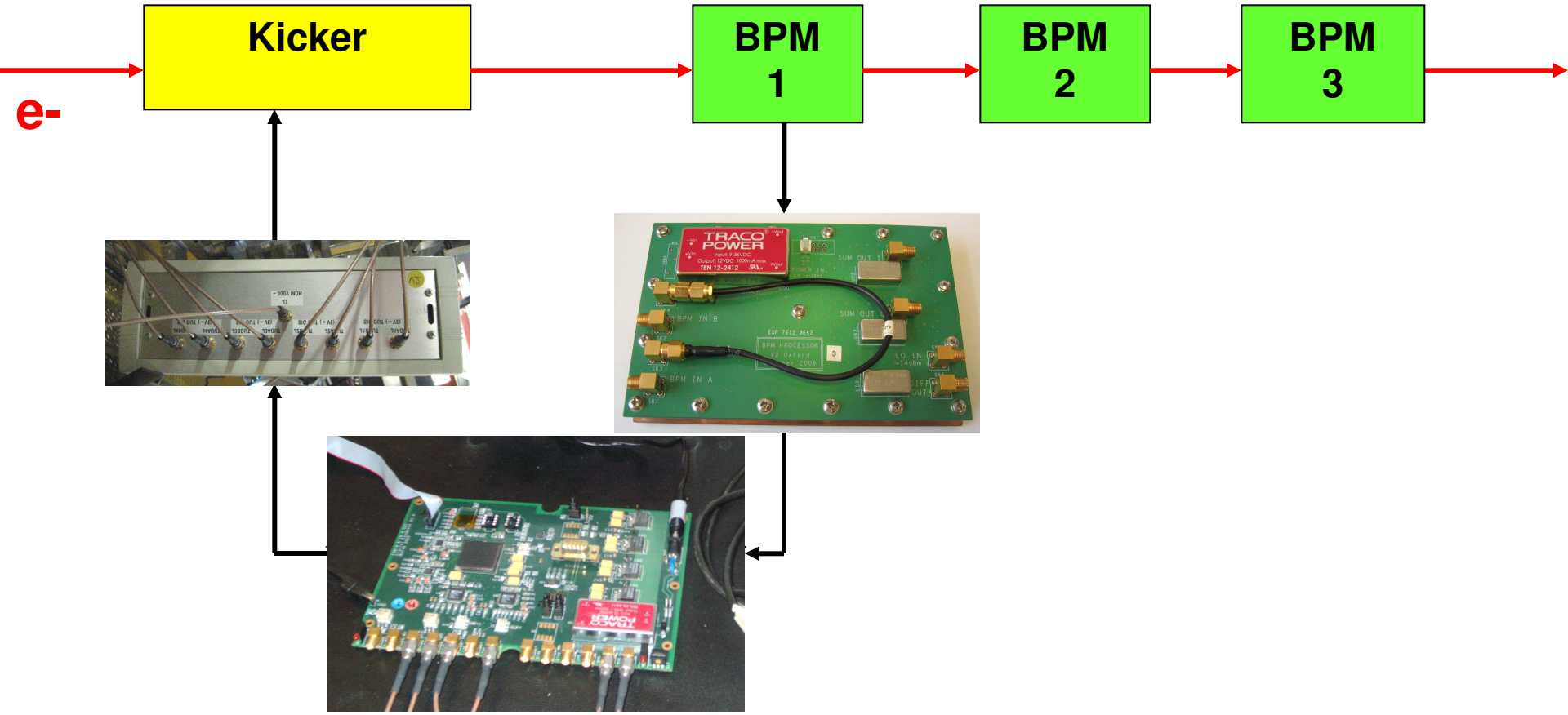
CERN, DESY, KEK, SLAC

FONT4/5 prototypes at KEK/ATF2

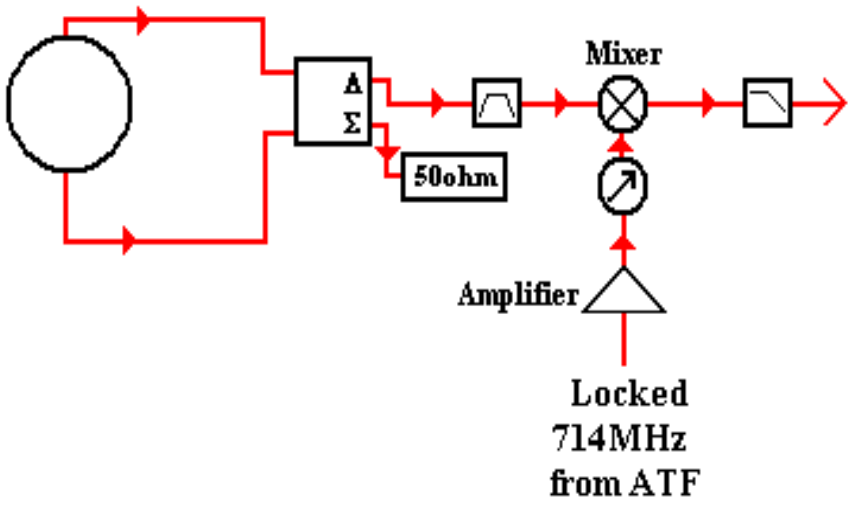


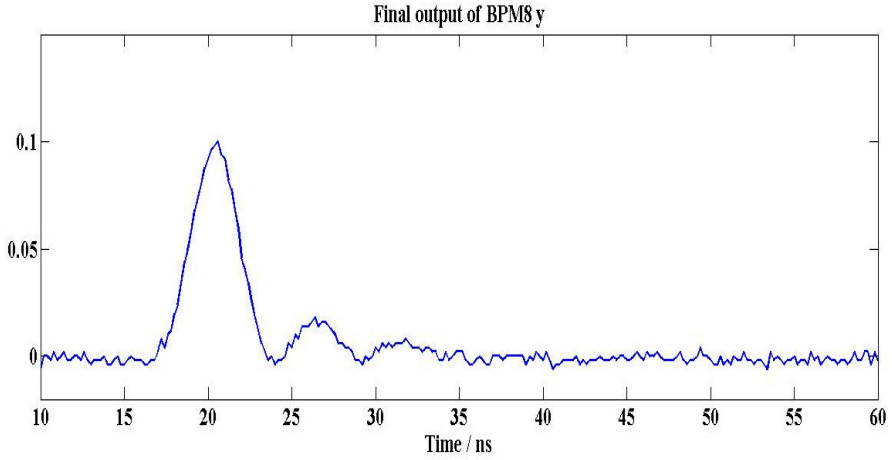
3 bunches, 140-154ns spacing

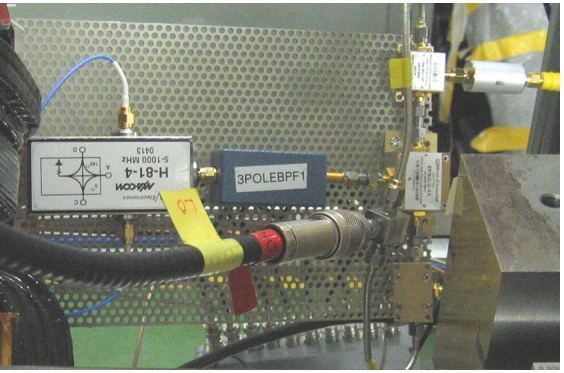
FONT4 prototype at KEK/ATF



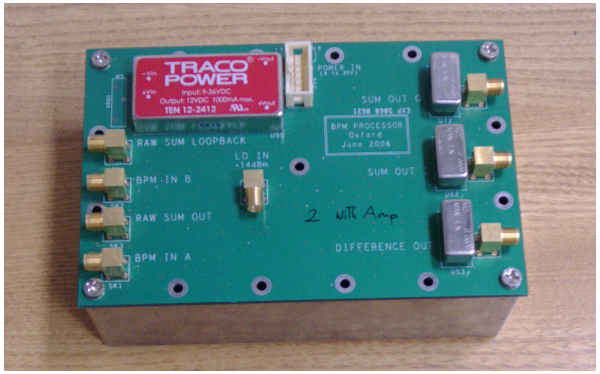
BPM processor



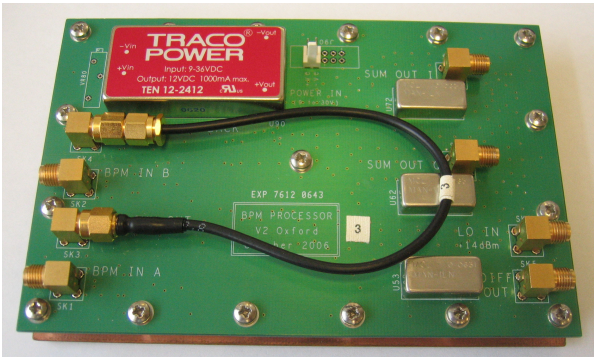




2005

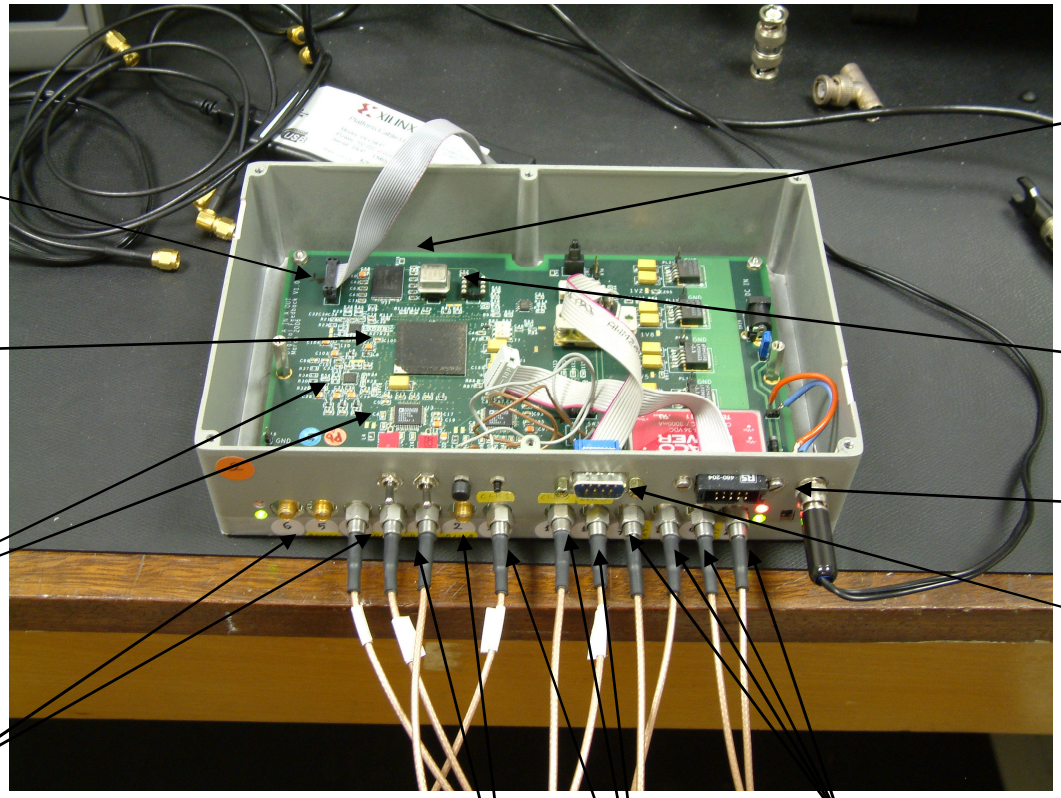


2006



2007

Digital Feedback Board



Kicker driver amplifier

Specifications:

- **+- 15A (kicker terminated with 50 Ohm)**
- **+- 30A (kicker shorted at far end)**
- **35ns risetime (to 90%)**
- **pulse length 10 us (specified for 20-60 bunches)**
- **repetition rate 10 Hz**

Outline design done in Oxford

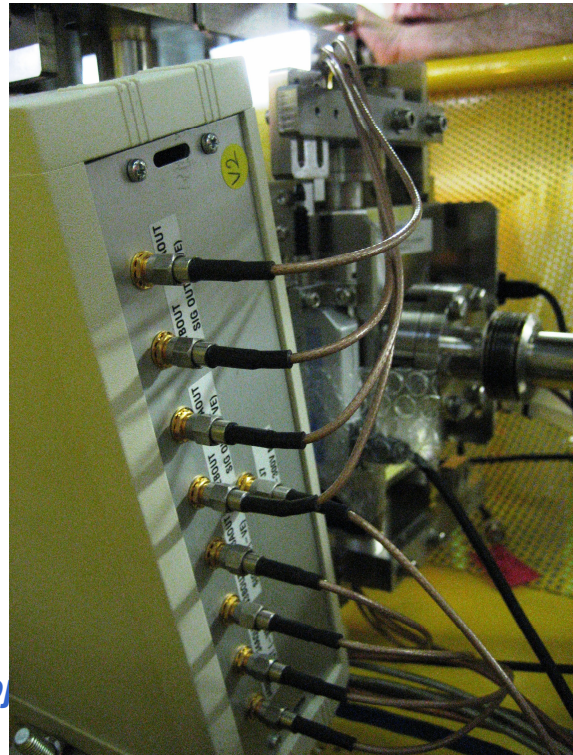
CASE studentship w TMD Technologies

Order placed with TMD Sept 06

Two prototype units delivered Dec 06

2 units in service at KEK since 2007

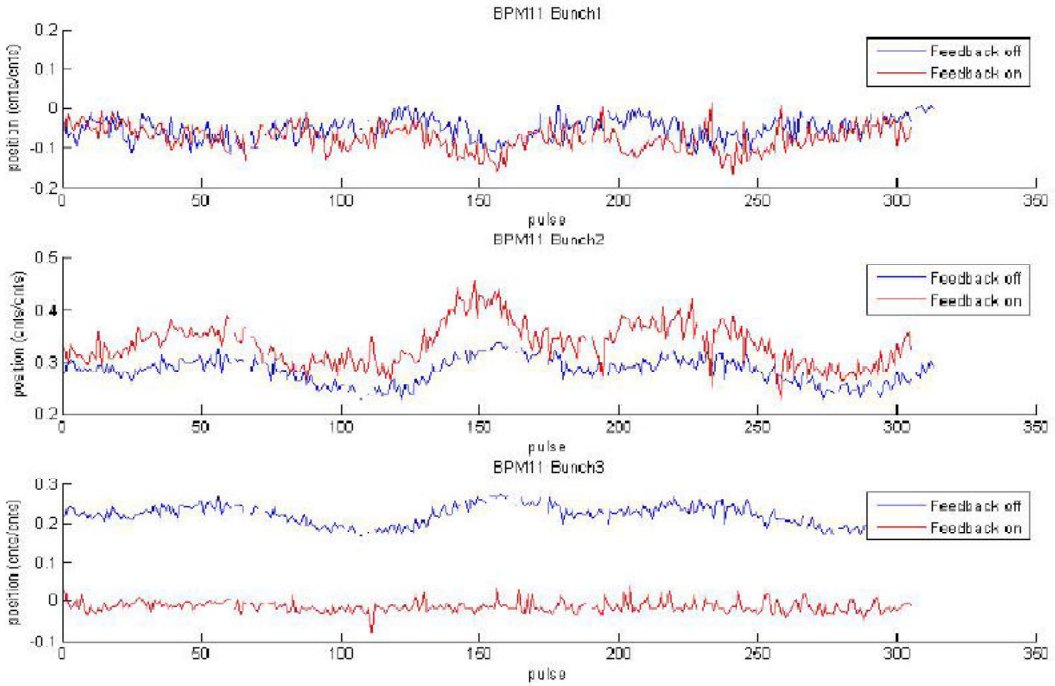
(2009: upgrades made + 1 unit)



FONT4 status

- **FONT4 basic operation demonstrated in 2008 running:**

  beam feedback along single axis (y) with few micron resolution



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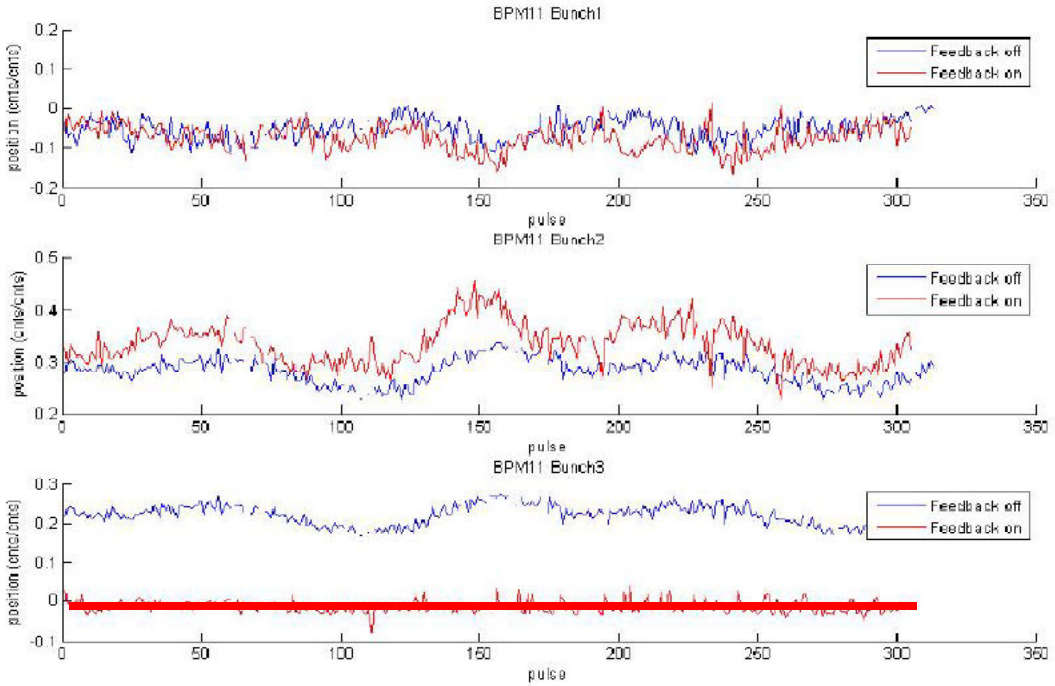
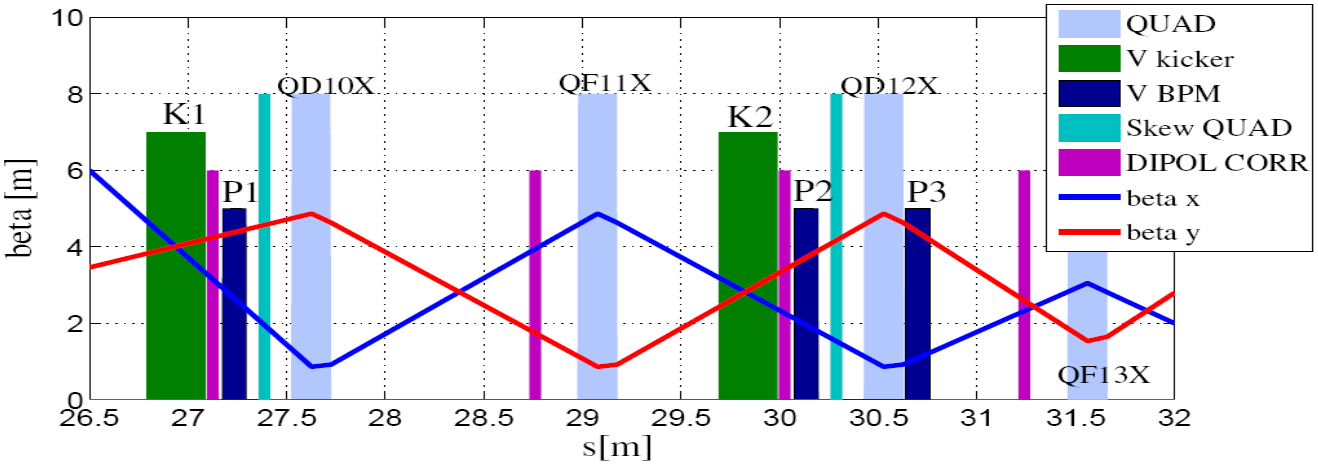


FONT operations in 2009

- **FONT4 installation was dismantled when ATF extraction line was reconfigured late 2008**

ATF2 FB system: FONT5

Dedicated system:



- **2 stripline kickers + fast drive amplifiers**
- **3 stripline BPMs + fast analogue front-end electronics**
- **9-channel digital FB processor**

ATF2 FB system: FONT5

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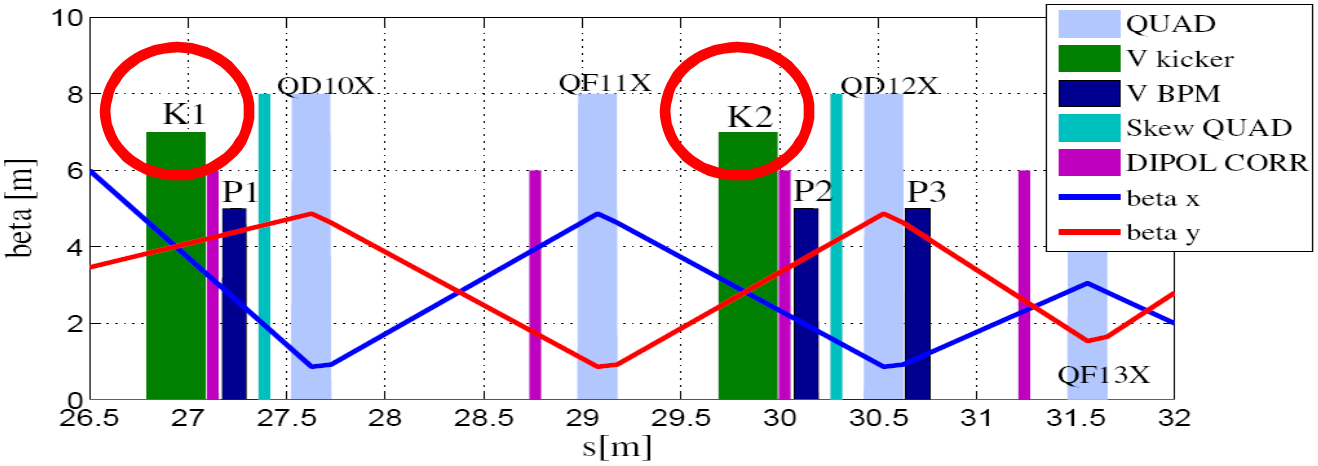

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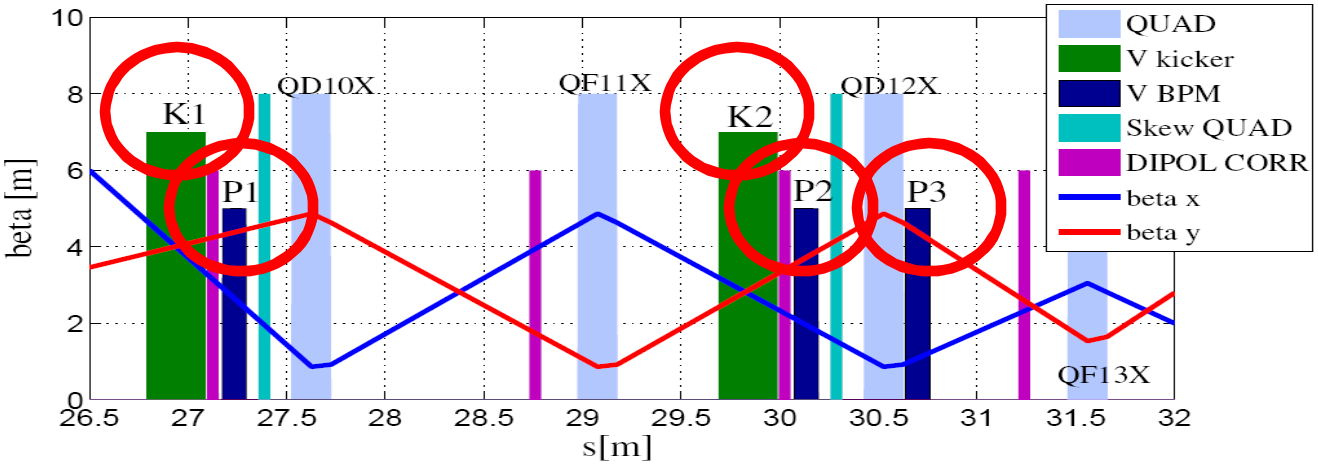
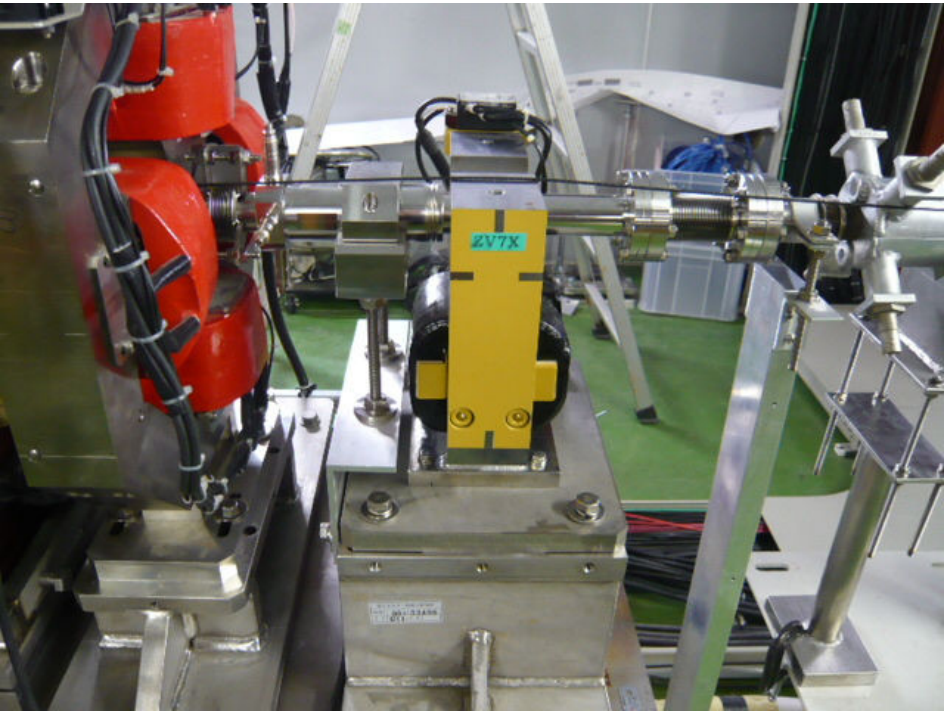


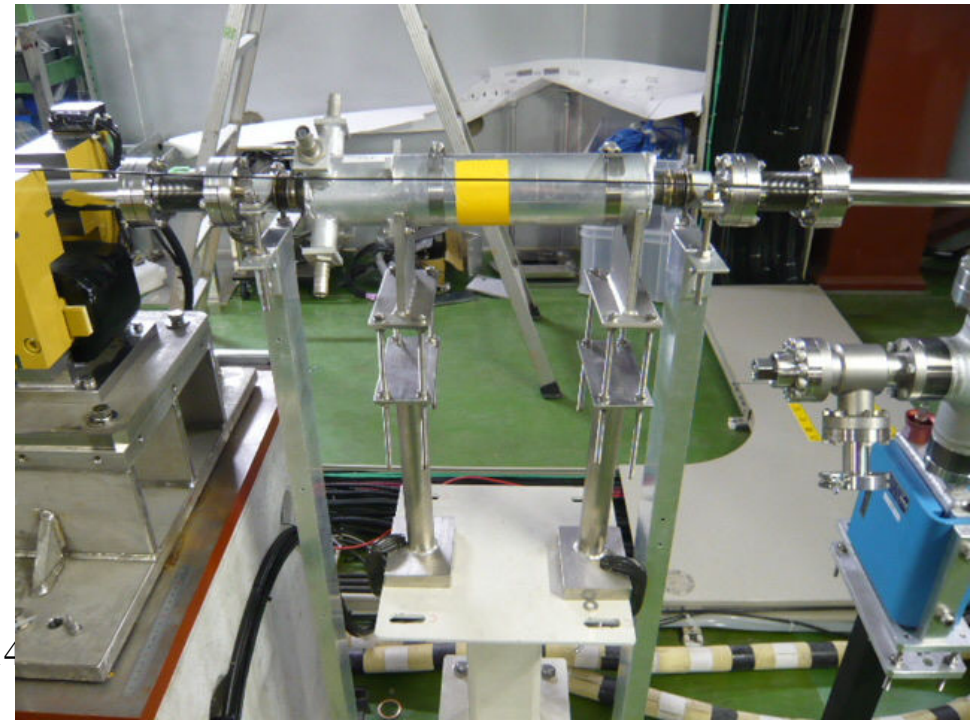
- **2 stripline kickers + fast drive amplifiers**
- **3 stripline BPMs + fast analogue front-end electronics**
- **9-channel digital FB processor**

FONT5 operations in 2009

- **FONT4 installation was dismantled when ATF extraction line was reconfigured late 2008**
- **3 new BPMs and 2 new kickers installed in new ATF2 extraction line week of February 9**

New FONT5 ATF2 hardware

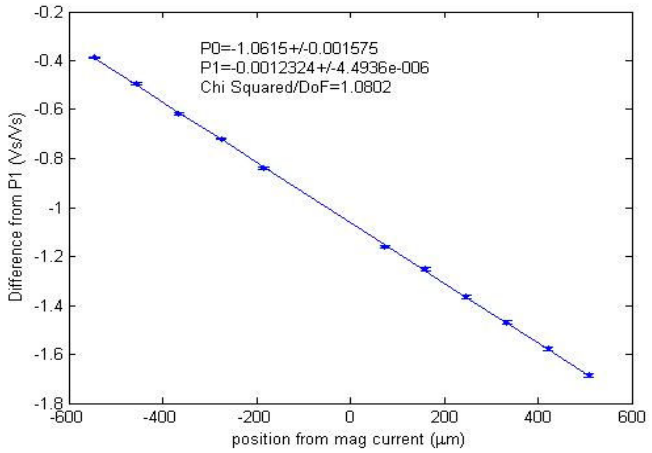


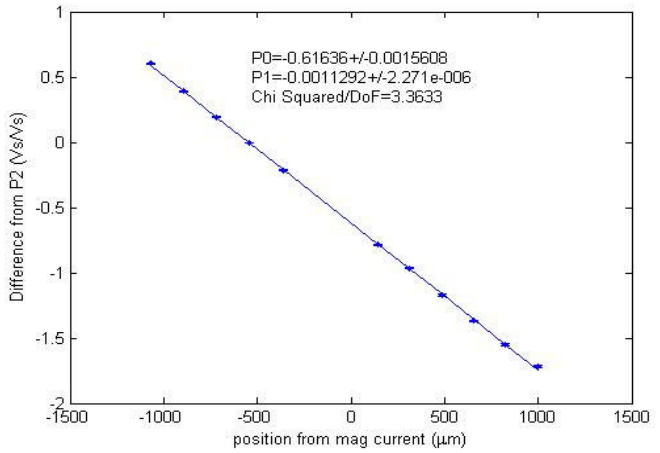


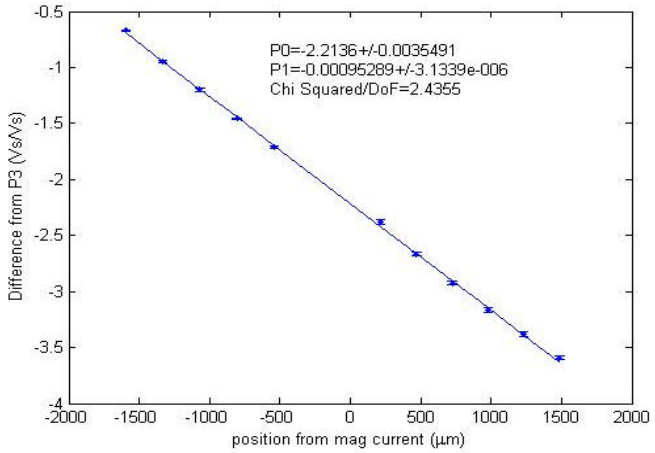
FONT5: Jan-May 2009

- FONT4 installation was dismantled when ATF extraction line was reconfigured late 2008
- 3 new BPMs and 2 new kickers installed in new ATF2 extraction line week of February 9
- Main aims:
  - 1) commission new BPMs and kickers (digital DAQ)
  - 2) work on improved resolution → 1 um level
  - 3) understand beam dynamics in FONT region
- Much commissioning work done parasitically - now have FONT 'standalone' hardware
- We typically took 1 shift per week March - May, a total of 6 shifts (!)

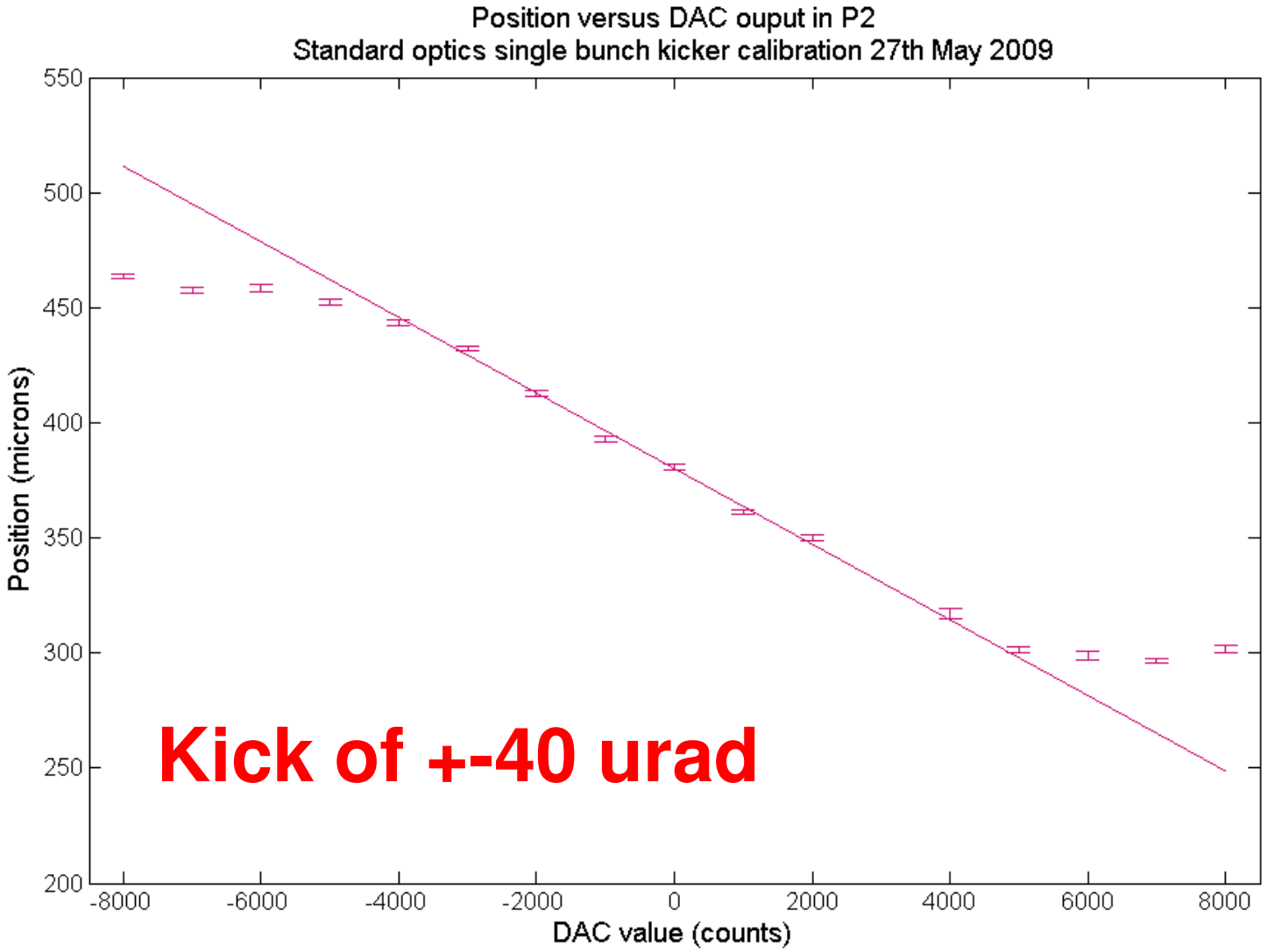
Example: BPM calibrations



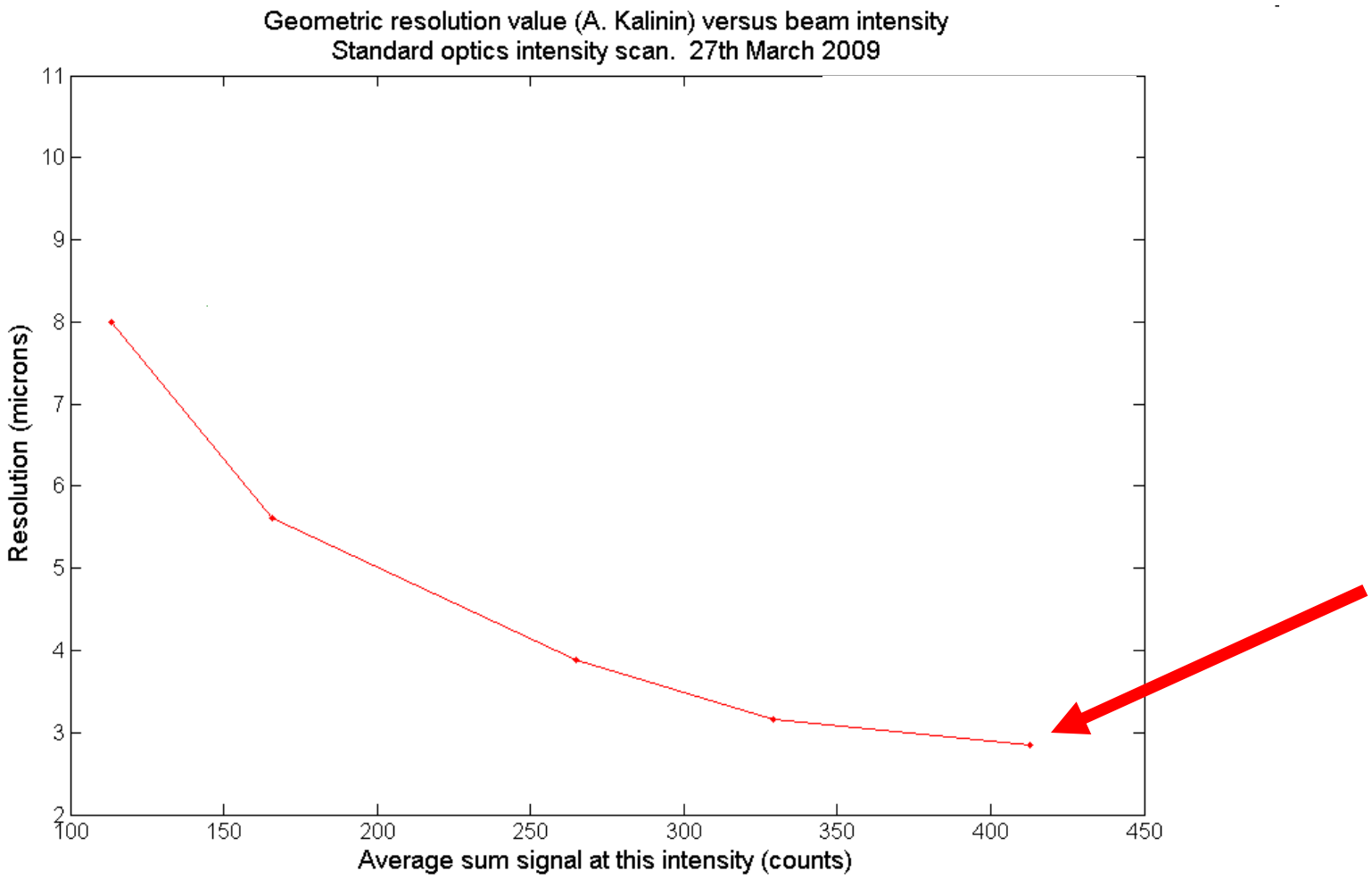




Example: kicker calibration



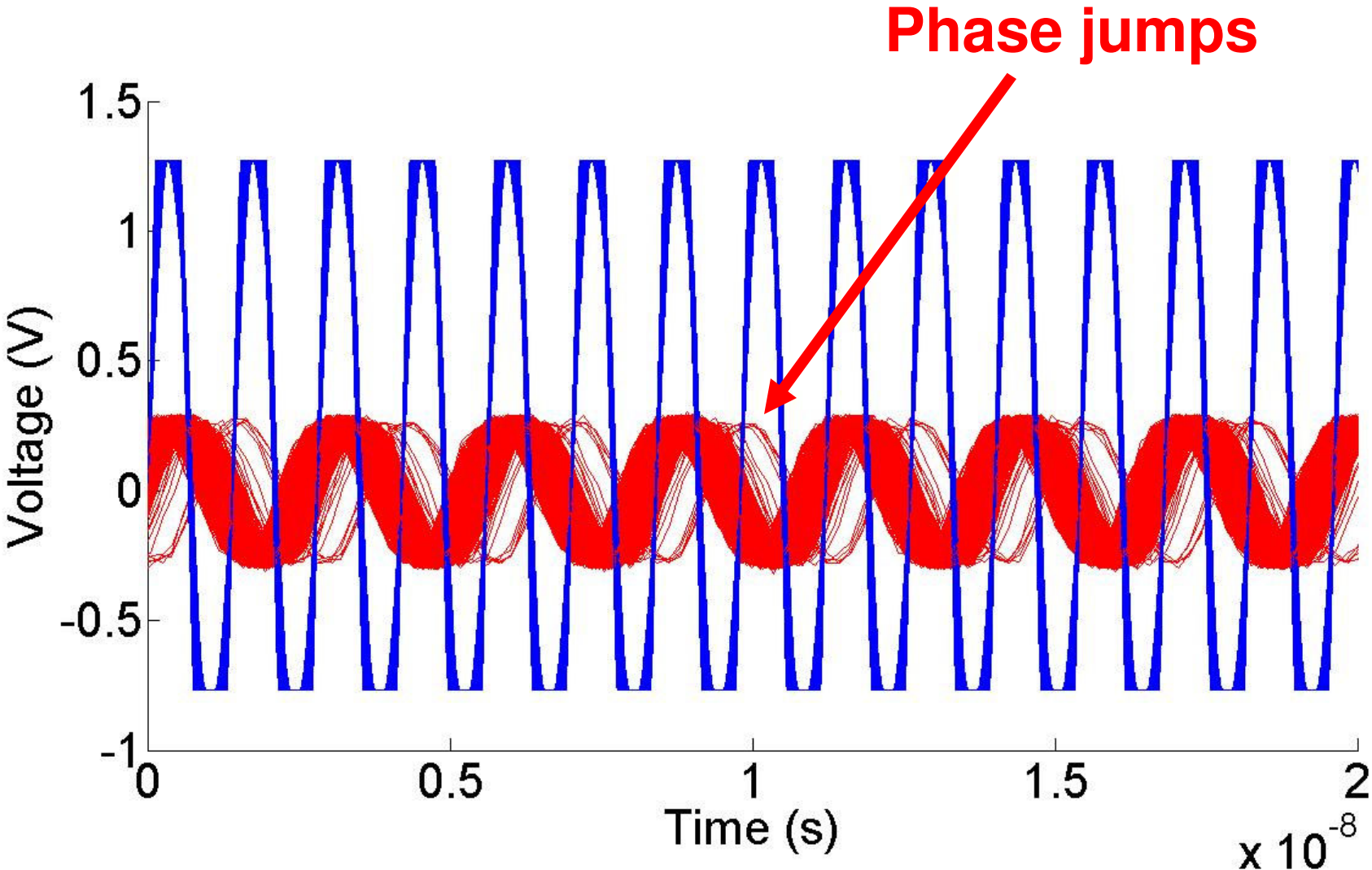
Example: resolution vs. bunch Q



Phase stability of 357 vs. 714 MHz

- We take 714 MHz signal from machine as LO signal for down-mixing of BPM signals
- Frequency divide 714 MHz to obtain 357 MHz for clocking the FONT digital FB board
- We observed phase jumps between 357 and 714 MHz signals

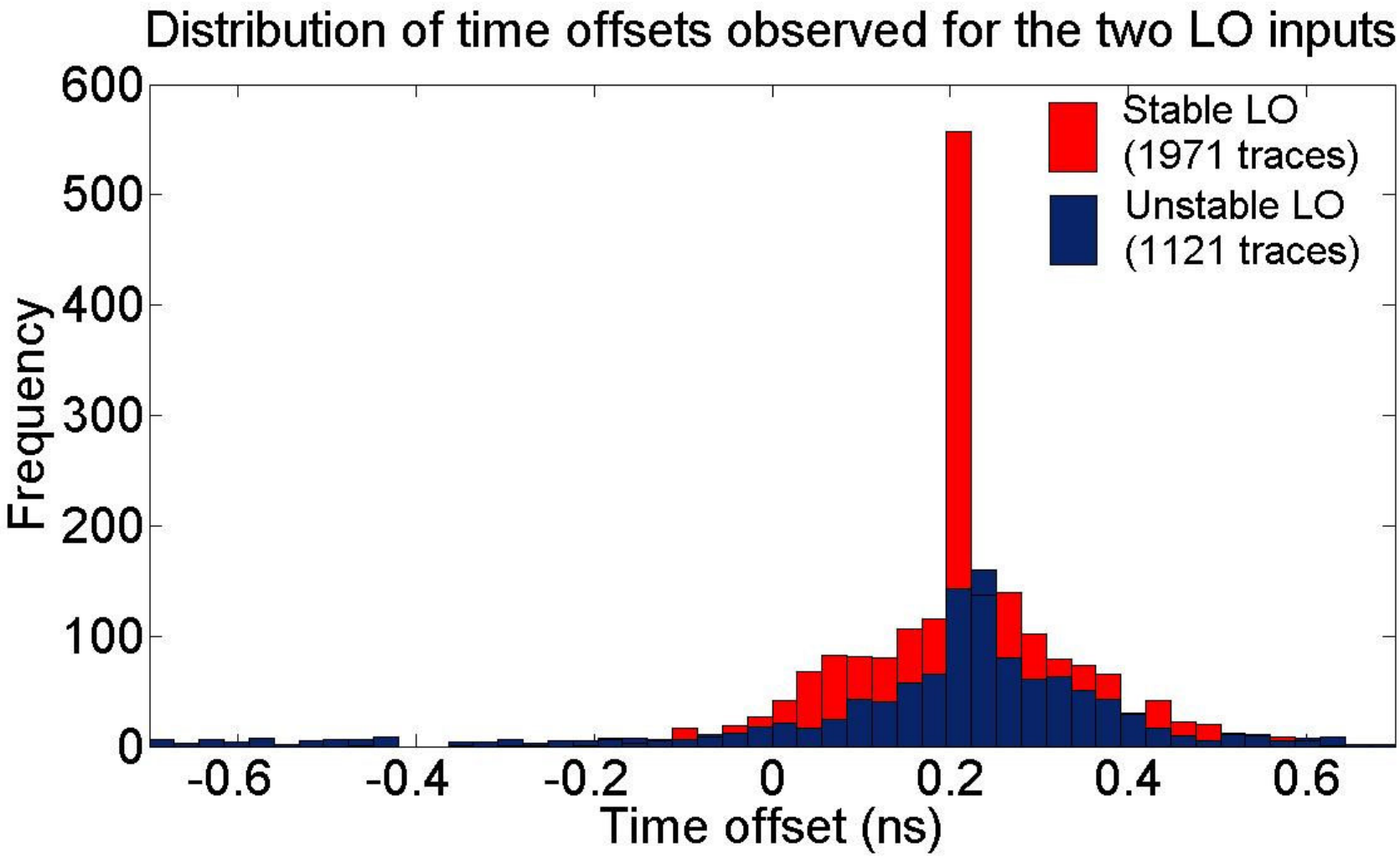
Phase difference of 714 and 357 MHz signals



Phase stability of 357 vs. 714 MHz

- We take 714 MHz signal from machine as LO signal for down-mixing of BPM signals
- Frequency divide 714 MHz to obtain 357 MHz for clocking the FONT digital FB board
- We observed phase jumps between 357 and 714 MHz signals
- A 180-degree shift of 357 MHz would cause ADC sample to miss beam by 2.8ns → reduce signal by up to 50%
- We tried 'stable' source of 714 MHz derived from frequency generator phase-locked to master oscillator

Comparison of ‘stable’ and ‘unstable’ 714 MHz

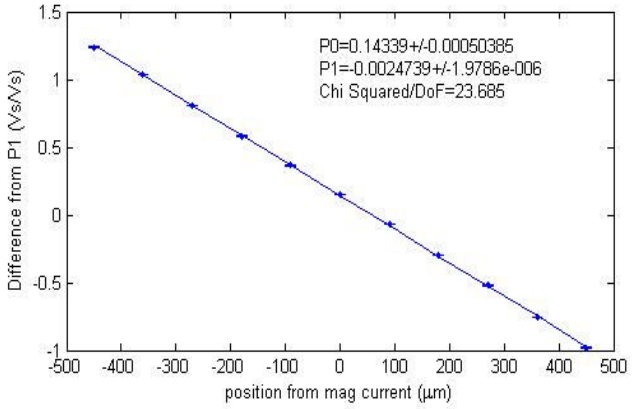


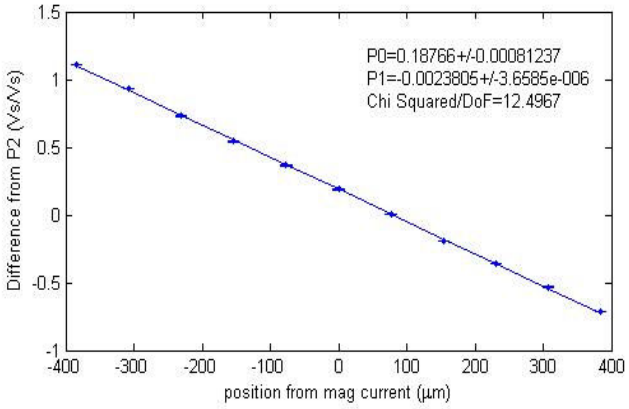
FONT5 since June 2009

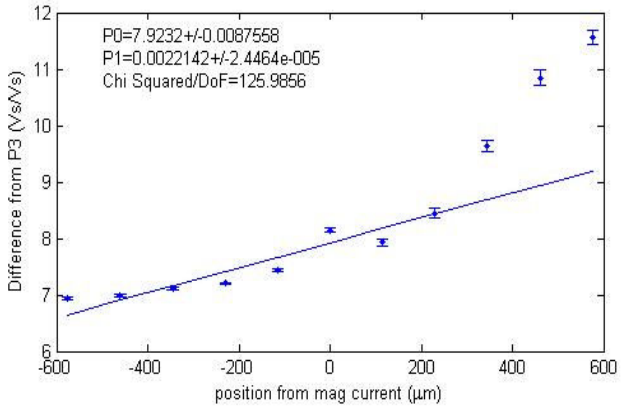
- New FONT5 9-channel FB/FF board (y, y') assembled (Sept. 2009)
- Bench tested in Oxford (October)
- Sent to KEK (November) for beam tests
- Shipped back and repaired (1 week turnaround)
- Now undergoing further beam tests

  looks very promising

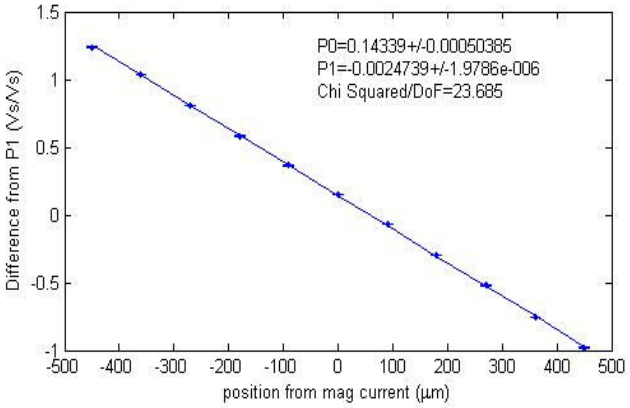
Single bunch calibration: November 19

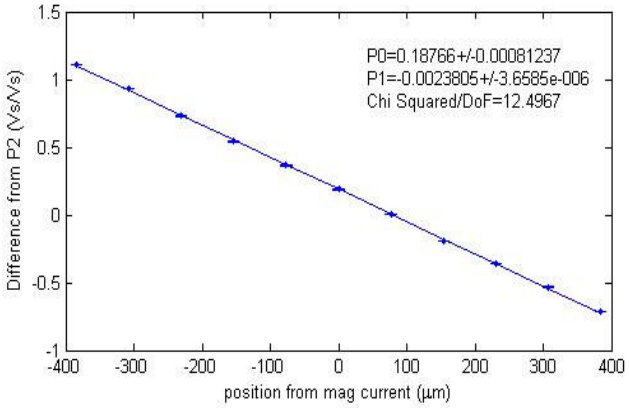


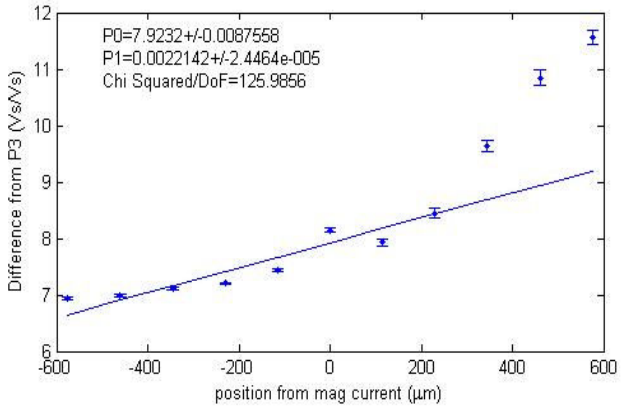




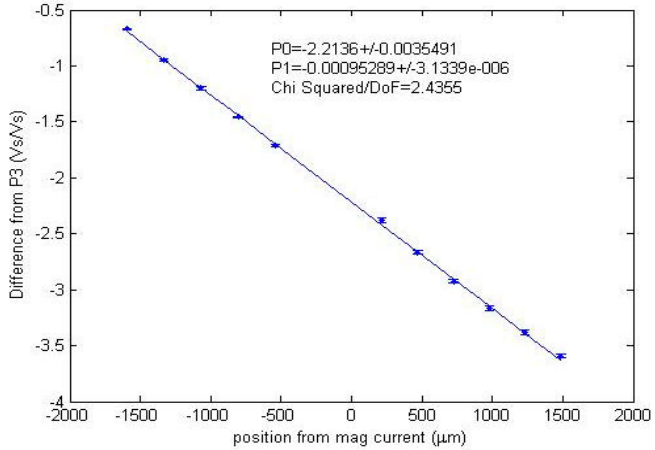
Single bunch calibration: P3 problem







November

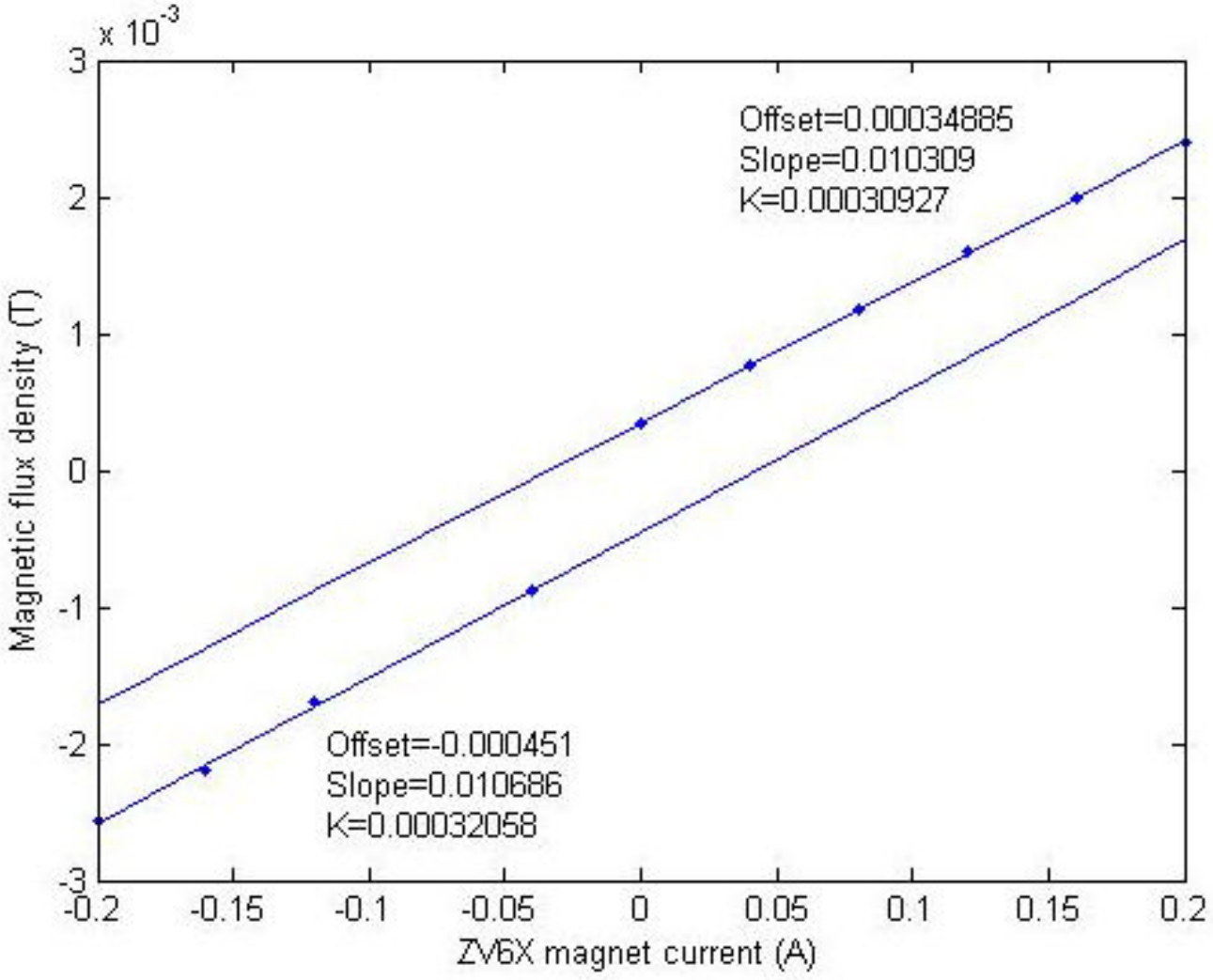


May

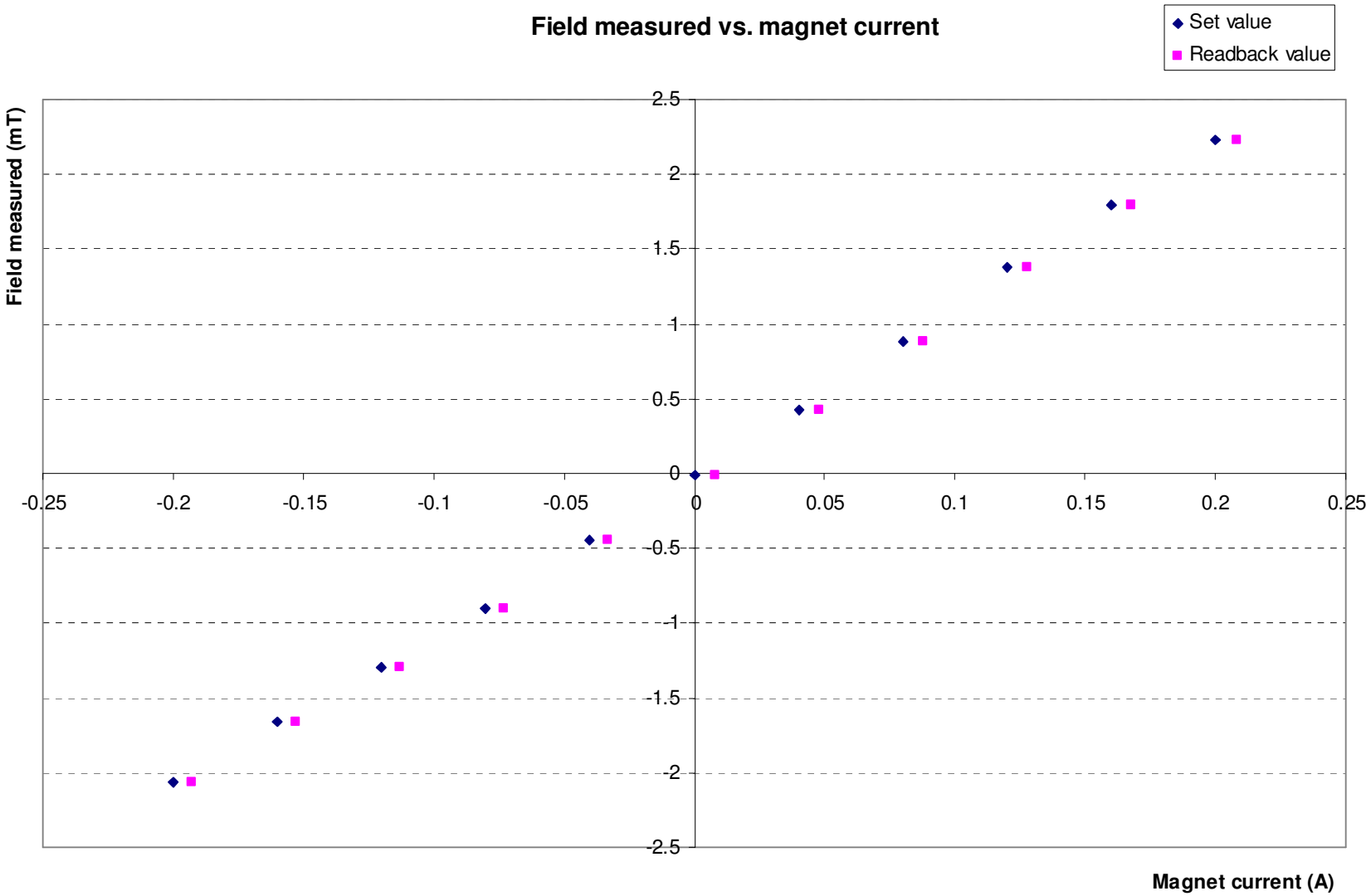
P3 problem

- Bottom stripline had 20 db lower response
- Pickup removed from beamline and examined during November down week
- Lot of dust found inside!
- Noticed that bottom electrode closer to BPM housing than other electrodes – fabrication error?
- BPM rotated by 90 degrees and reinstalled
- Will be replaced in December shutdown
- BPM had been removed in summer for welding of bellows: probably rotated by 90 degrees then

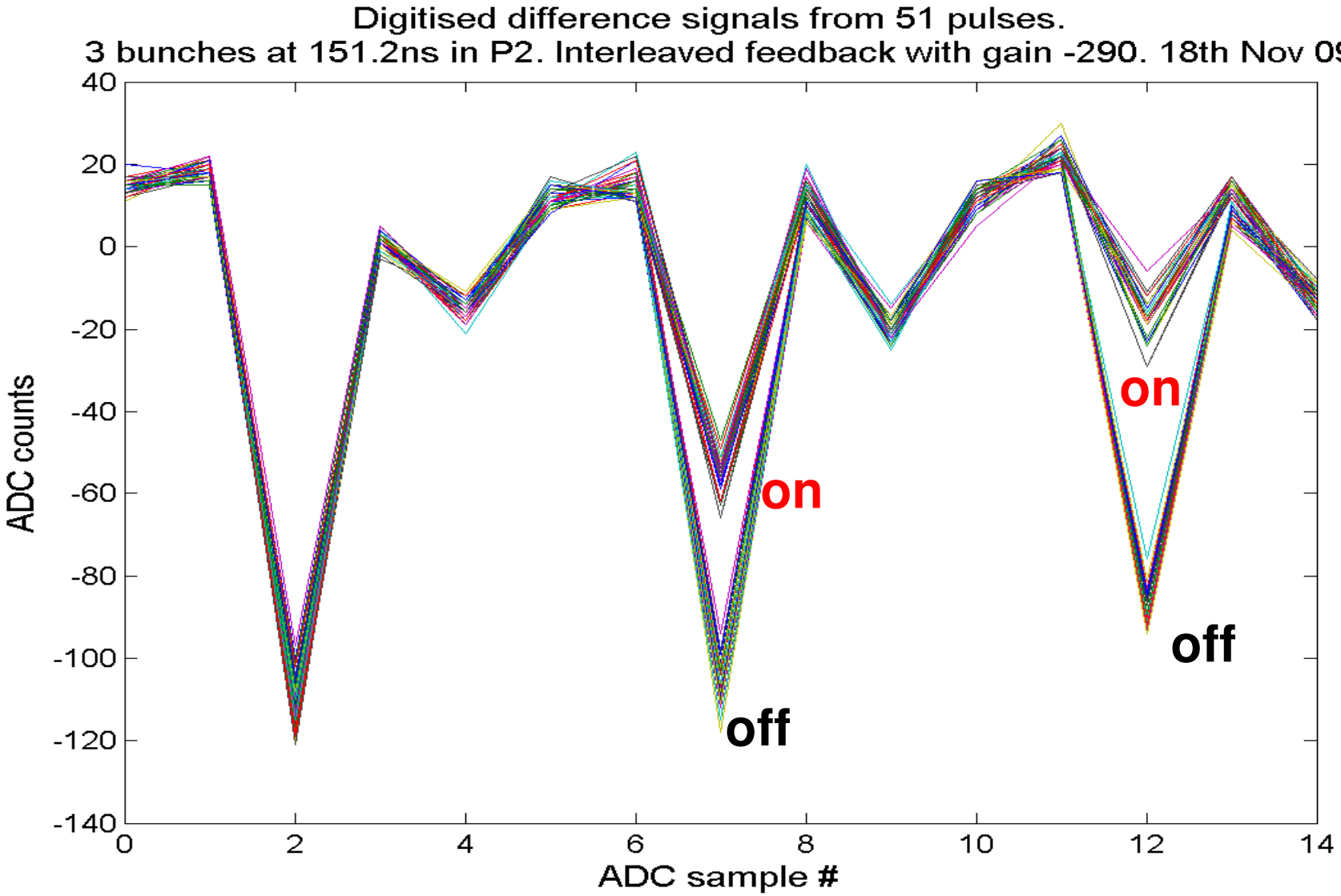
ZV6X corrector setting: May



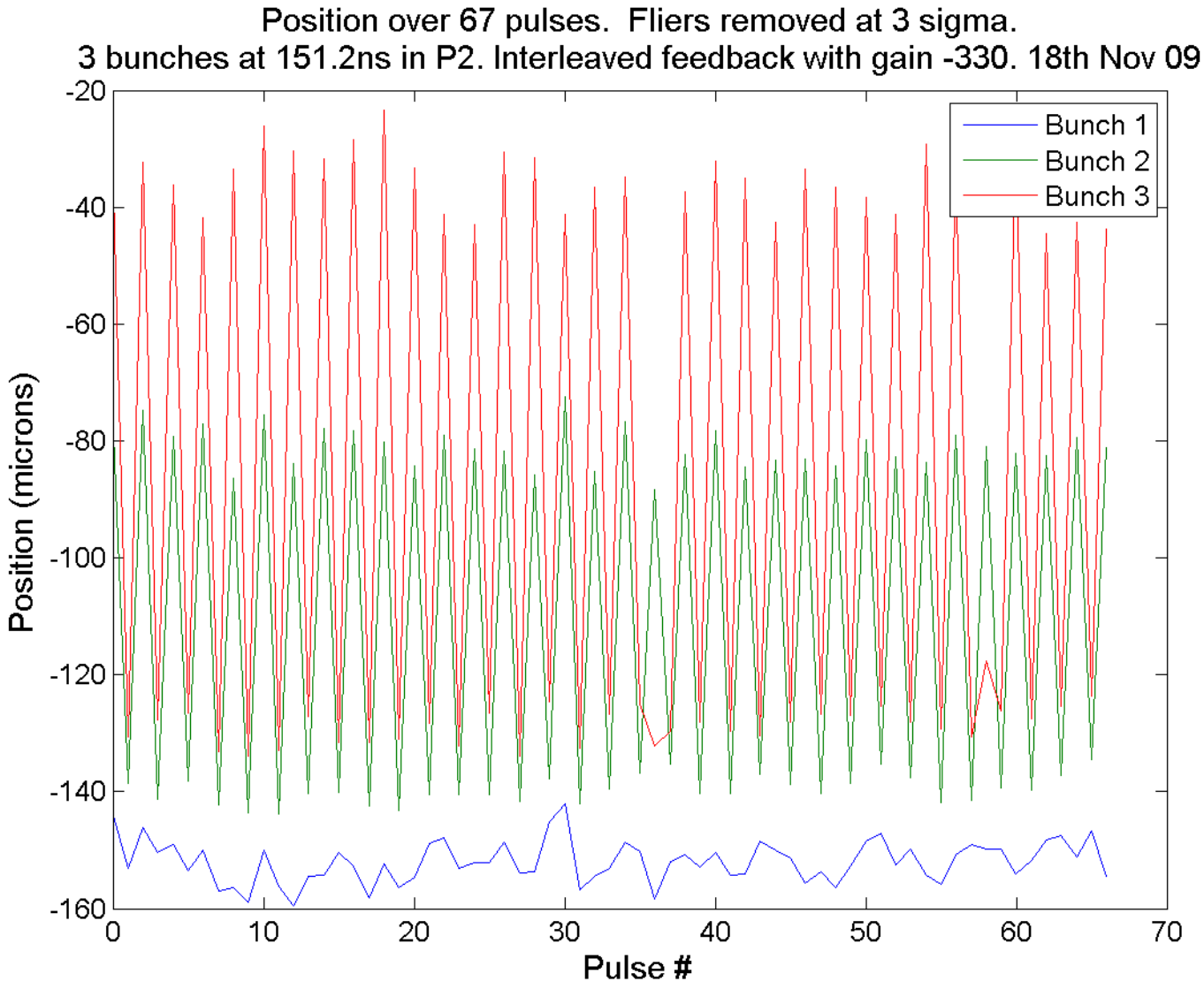
ZV6X corrector setting: November



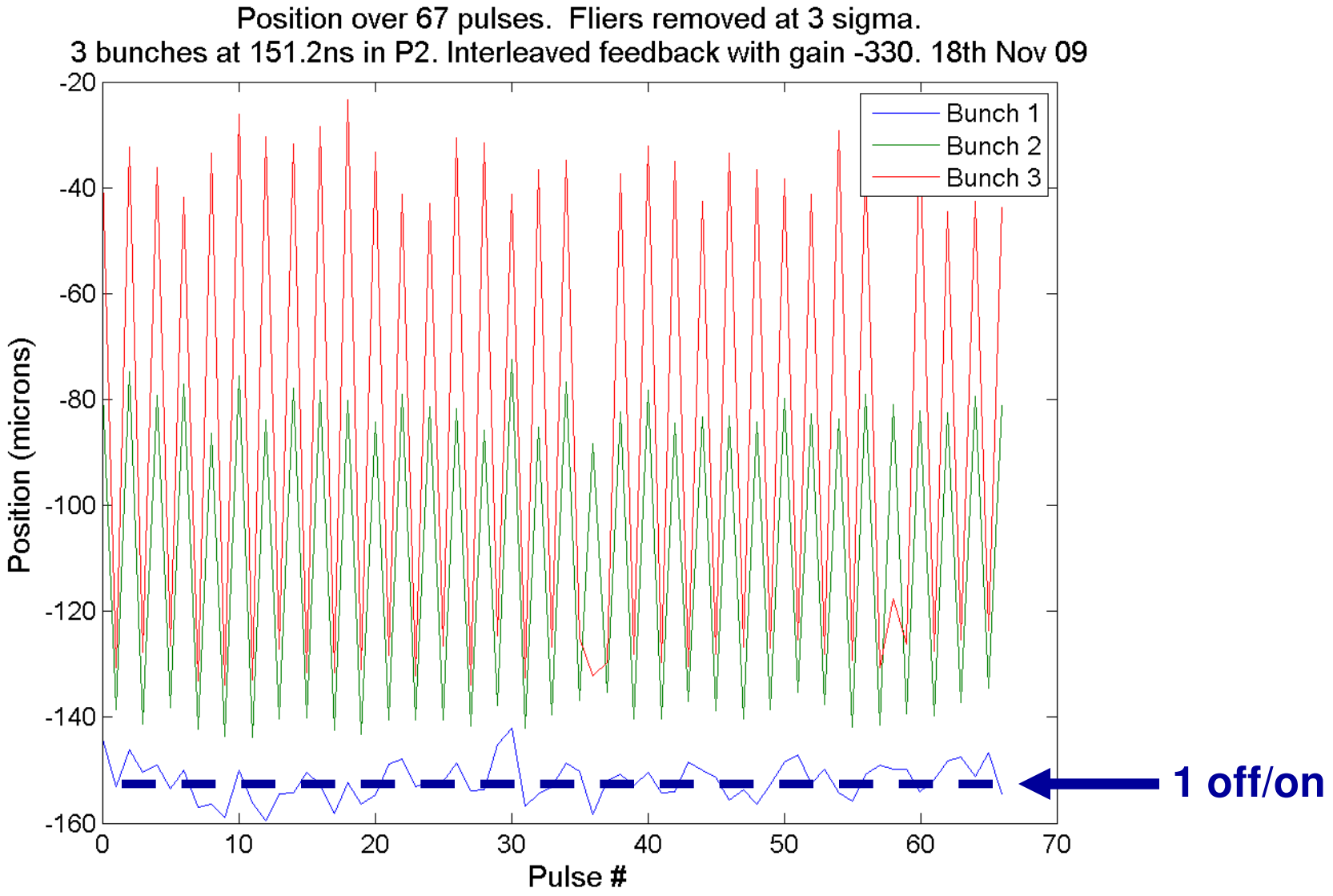
FB loop closed



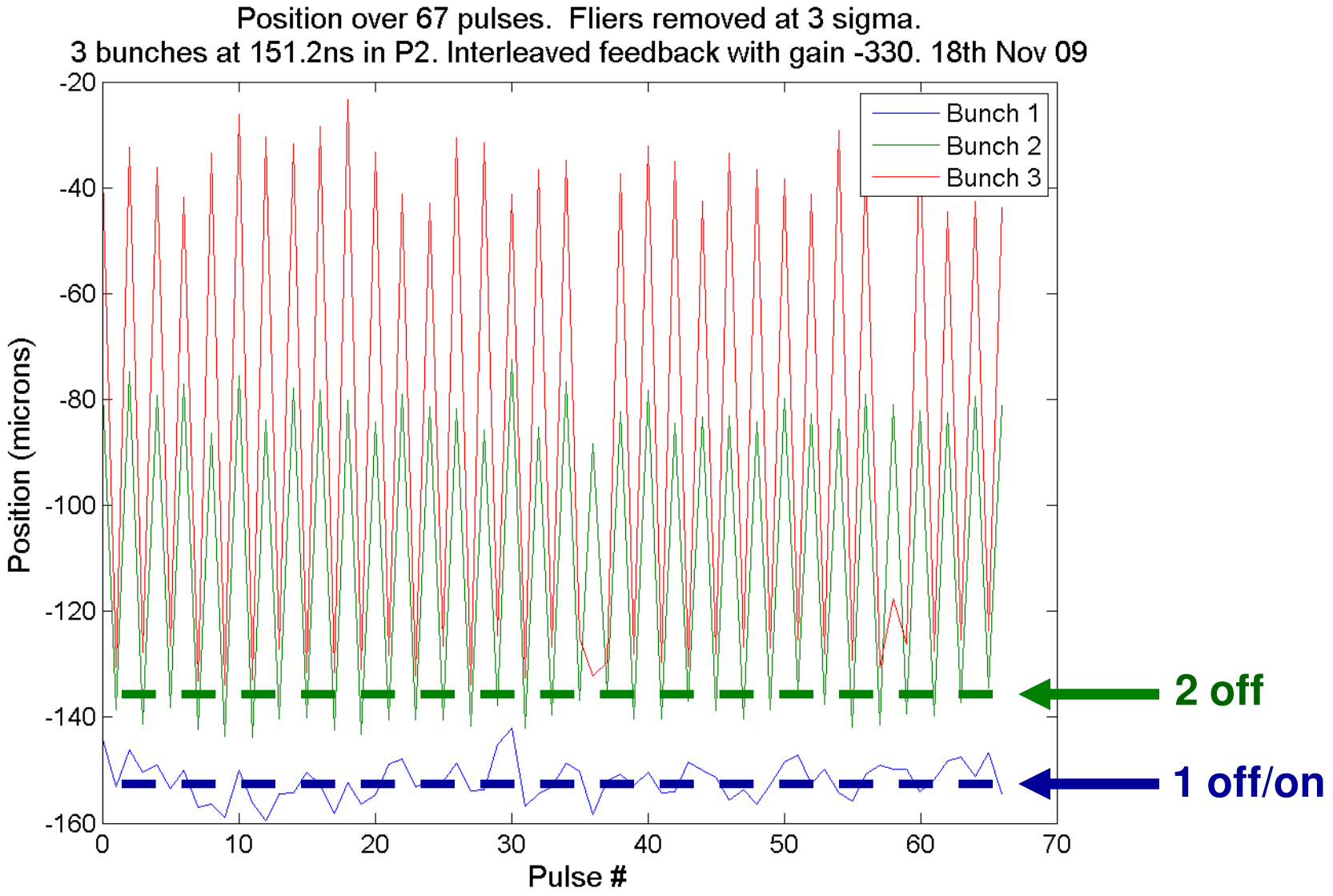
Interleaved FB on/off mode



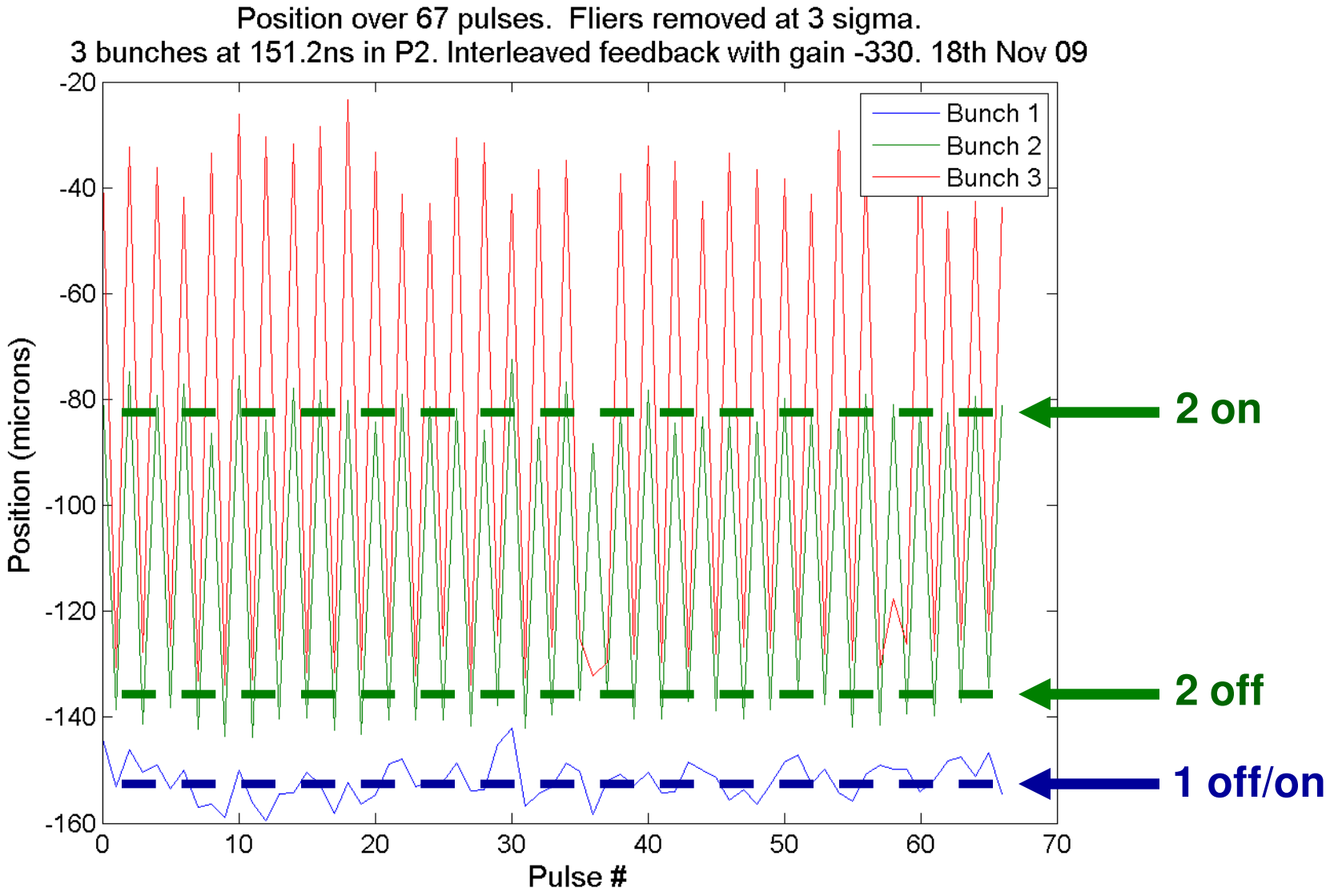
Interleaved FB on/off mode



Interleaved FB on/off mode



Interleaved FB on/off mode



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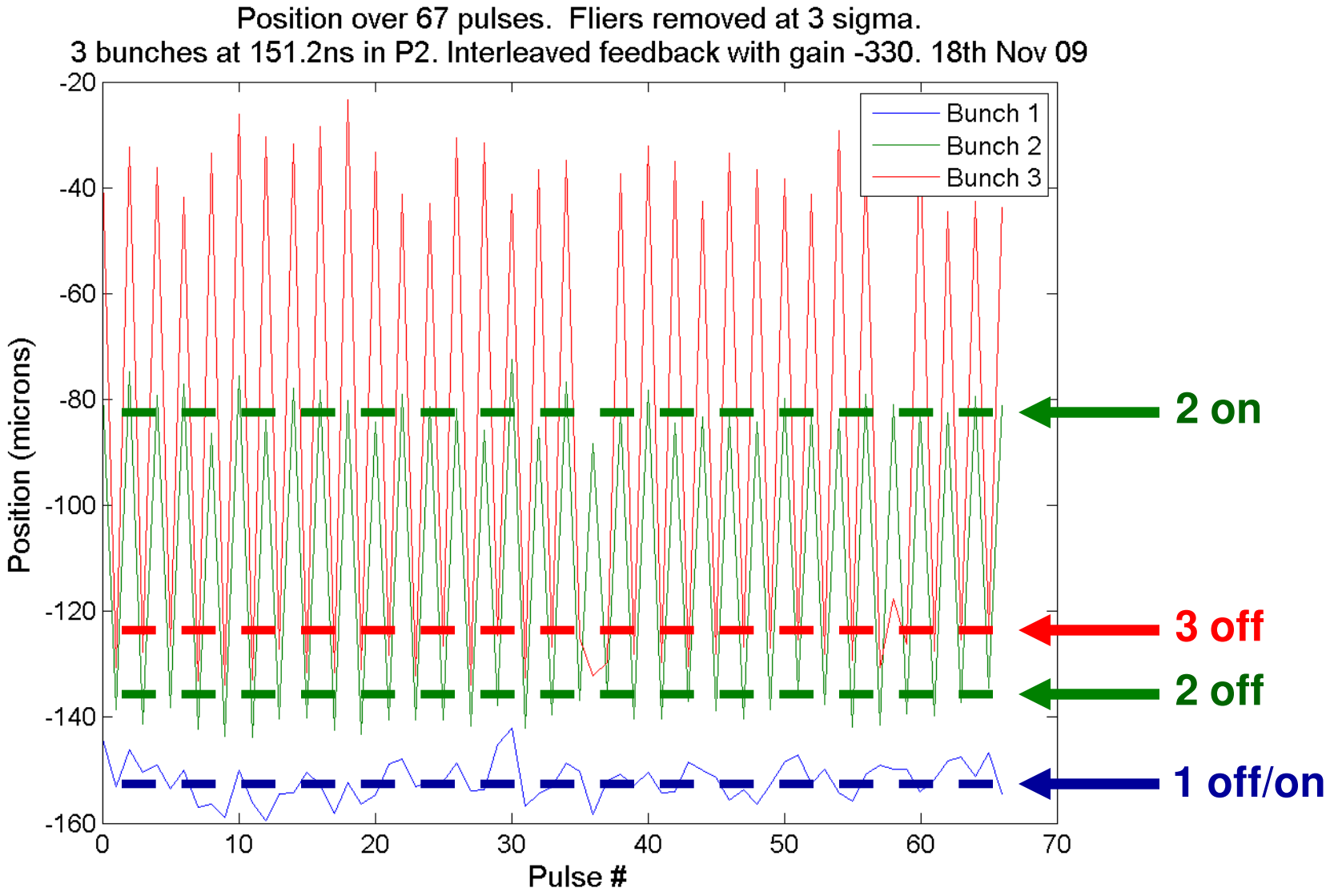

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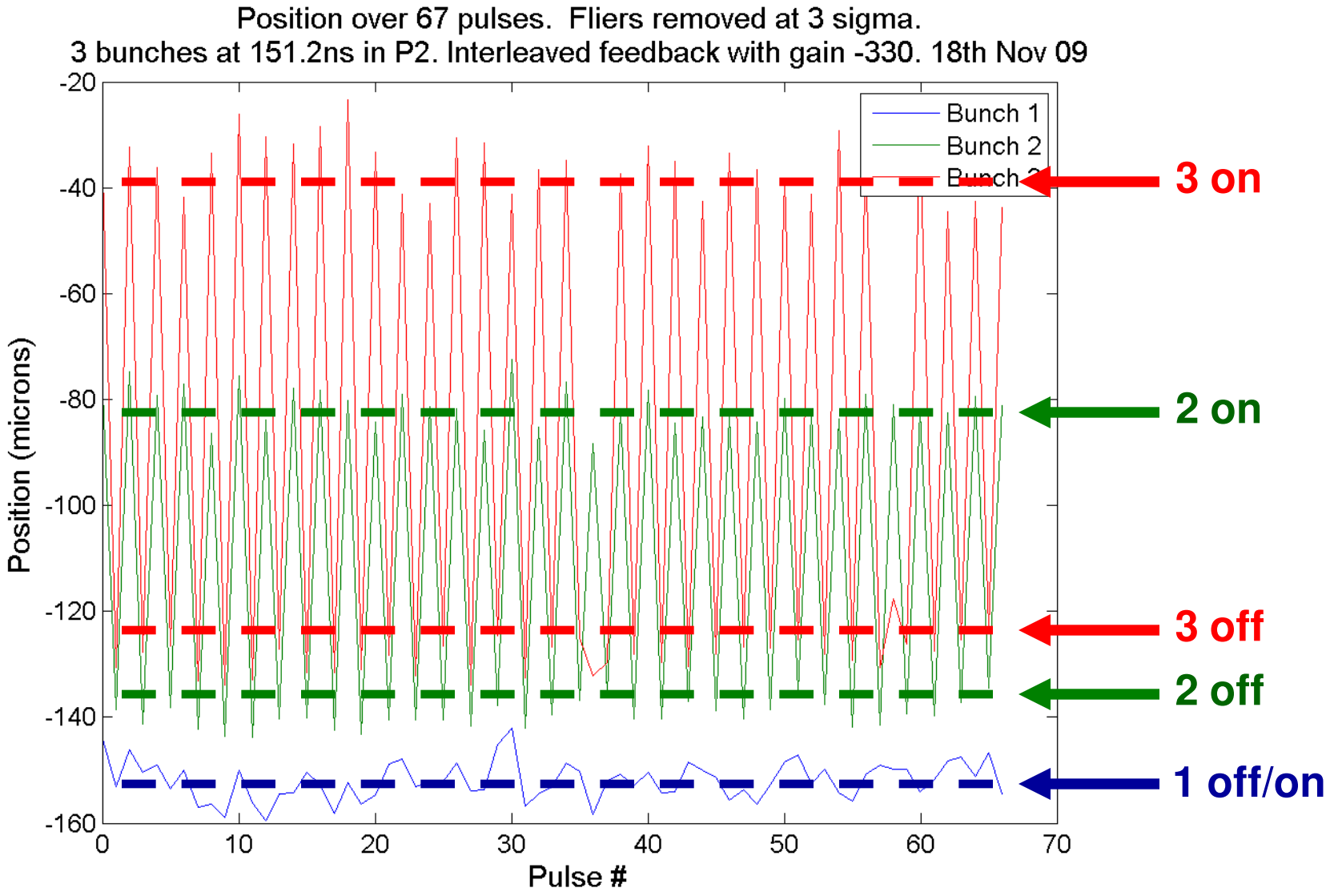
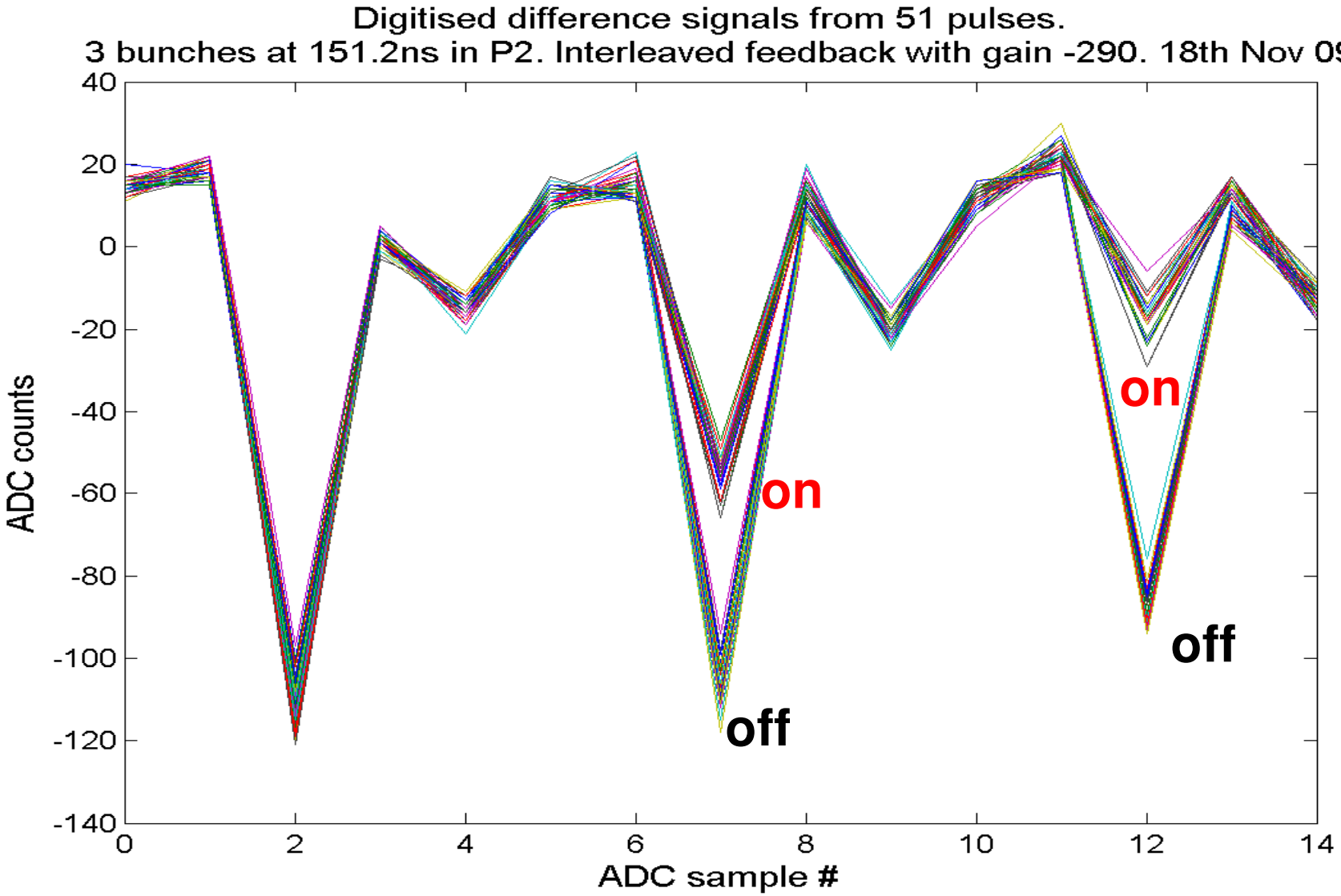


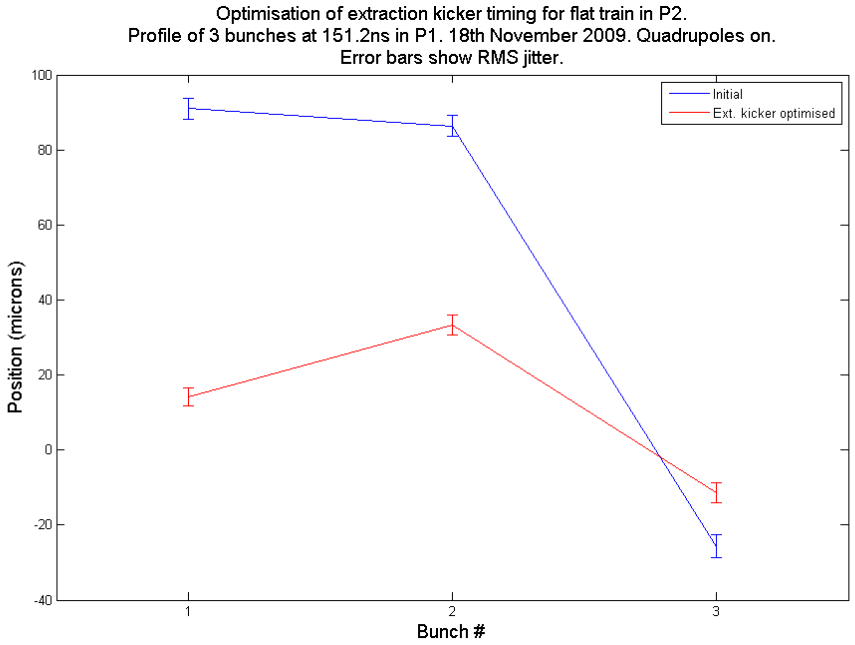
FB loop closed

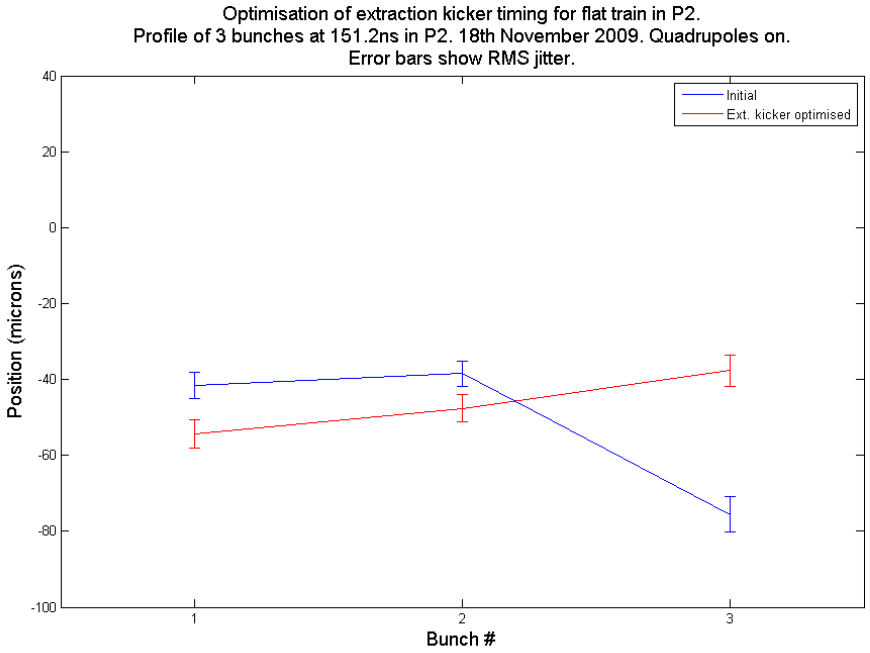


Beam issues

- **Banana-shaped train**
  - **studies to see if train can be extracted flat**
  - **‘flattening’ signal implemented in firmware**
- **Significant bunch-bunch jitter within train**
- **Bunches 1 and 3 typically poorly correlated**
  - **studies to understand origin of decorrelations**

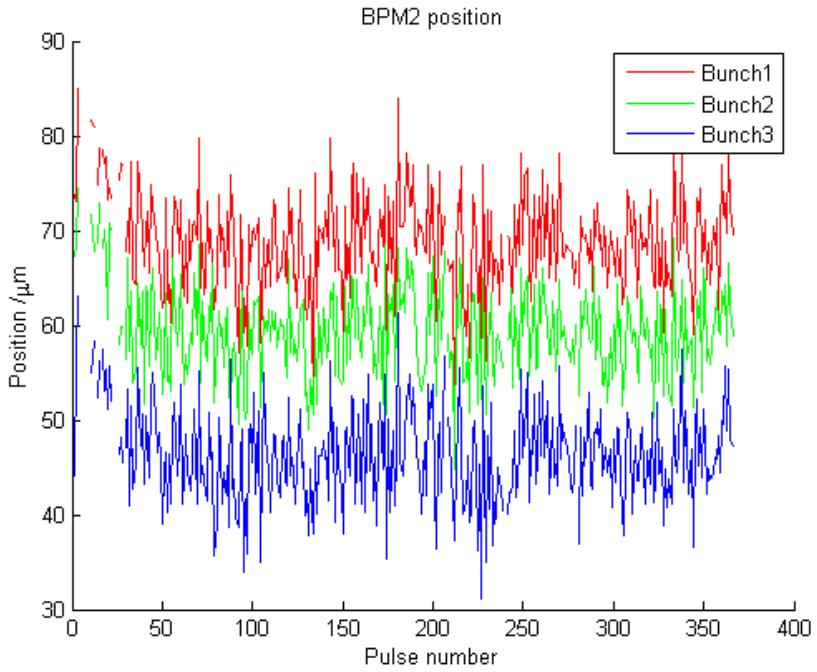
Extraction kicker timing studies





Beam jitter/correlation studies

18 November 2009, Std Optics, 3 train, 151.2 ns BS (with FONT4 electronics, P1 & P2 only)



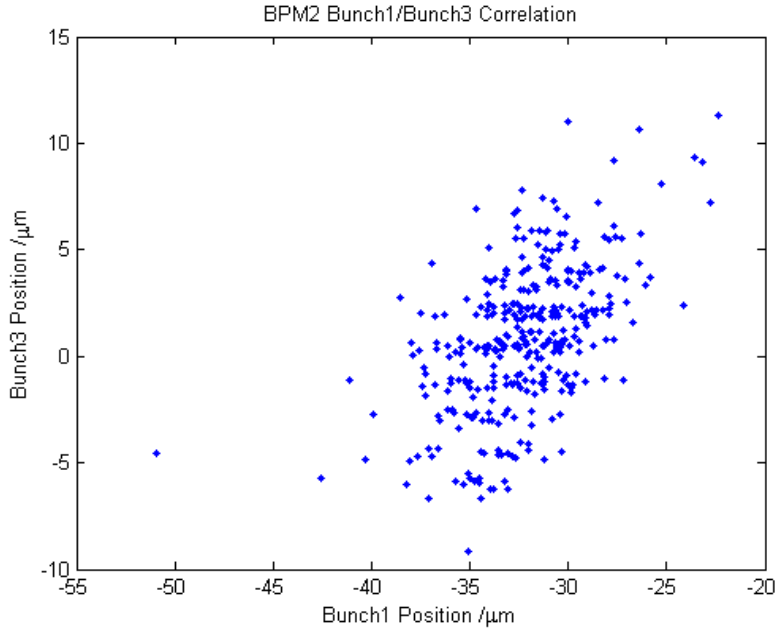
Mean position and RMS jitter at P2:

Bunch1: 68.9 +/- 5.1 um

Bunch2: 59.4 +/- 4.7 um

Bunch3: 46.3 +/ 5.0 um

RMS sagitta wrt train mean: 11.3 um



Bunch-to-bunch correlations at P2:

B1/B2: 0.76

B2/B3: 0.77

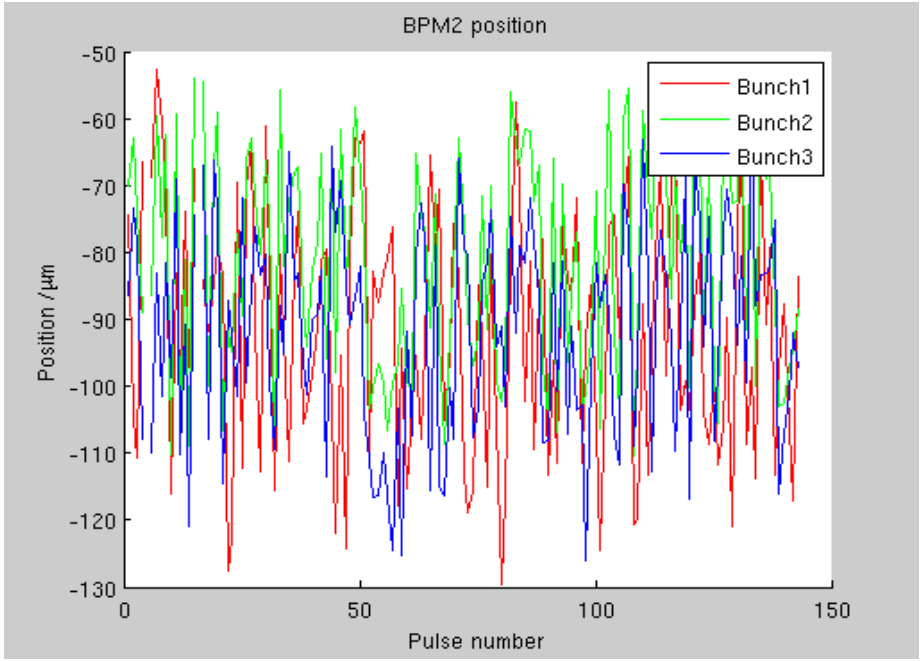
B1/B3: 0.78

resolution < 2.3 um, based on jitter and correlation observed.

P.N. Burrows

Beam jitter/correlation studies

11 December 2009, Std Optics, 3 train, 151.2 ns BS (with FONT5 electronics - P1, P2, & P3)



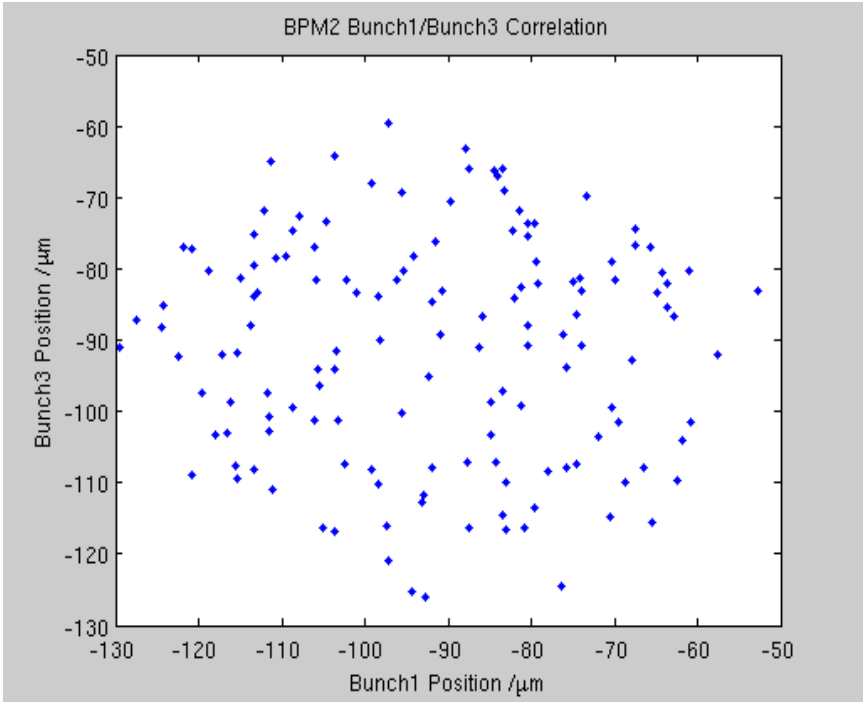
Mean position and RMS jitter at P2:

Bunch1: -91.7 +/- 18.4 um

Bunch2: -80.9 +/- 16.7 um

Bunch3: -91.3 +/ 15.7 um

RMS sagitta wrt train mean: 6.1 um



Bunch-to-bunch correlations at P2:

B1/B2: 0.48

B2/B3: 0.75

B1/B3: -0.02 (non sign.)

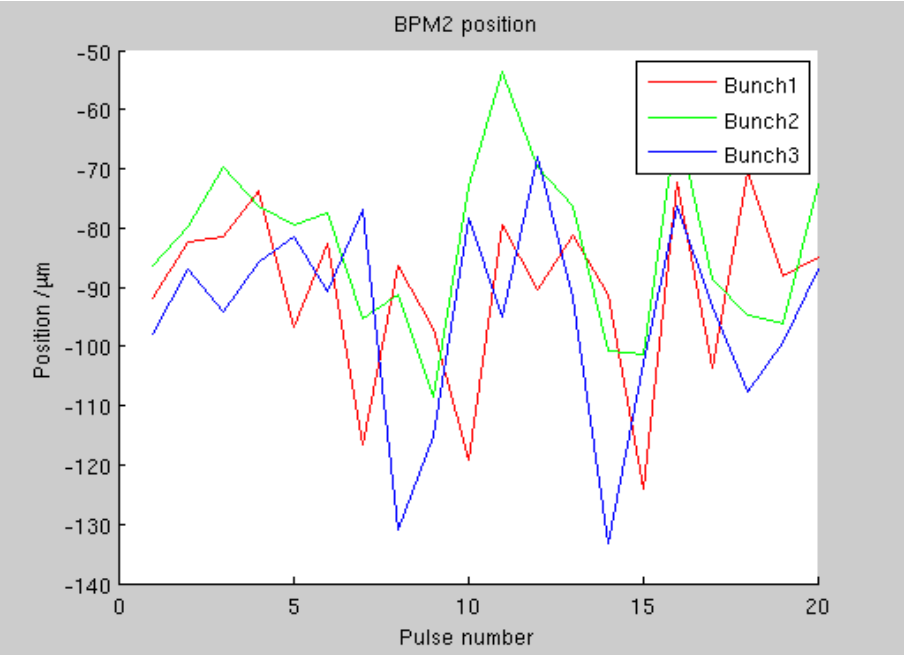
3-BPM resolution estimates:

P.N. Burrows

B1: 3.9 um, B2: 3.3 um, B3 3.4 um

Beam jitter/correlation studies

11 December 2009, Std Optics, 3 train, 151.2 ns BS, AFTER DR CHROMATICITY CORRECTION



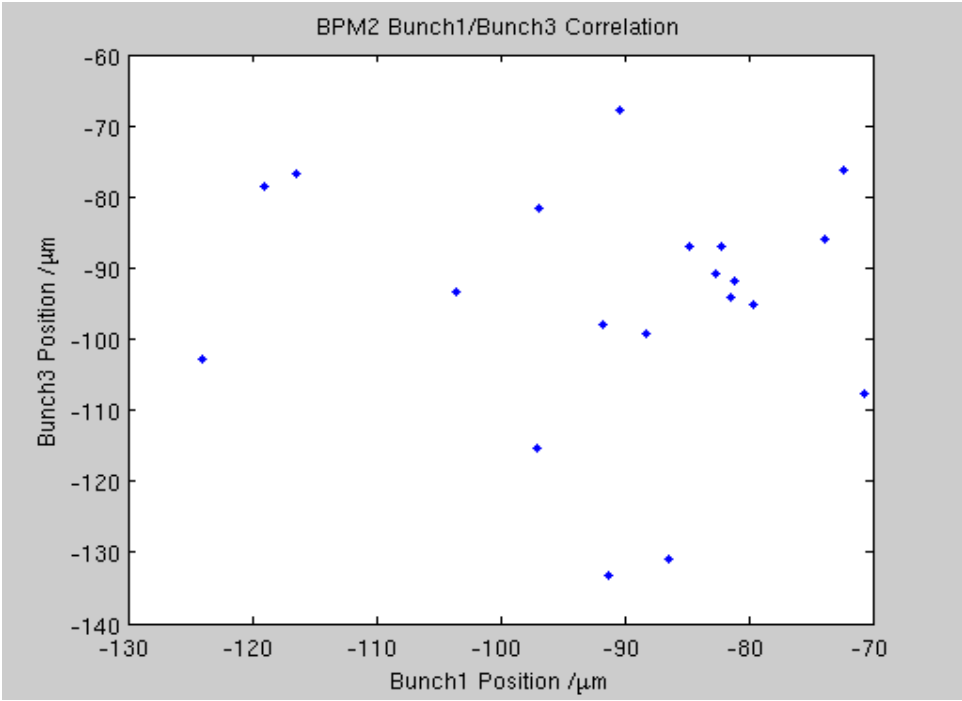
Mean position and RMS jitter at P2:

Bunch1: -90.7 +/- 15.1 um

Bunch2: -82.6 +/- 14.3 um

Bunch3: -94.6 +/ 17.0 um

RMS sagitta wrt train mean: 6.1 um



Bunch-to-bunch correlations at P2:

B1/B2: 0.42 (non sign.)

B2/B3: 0.60

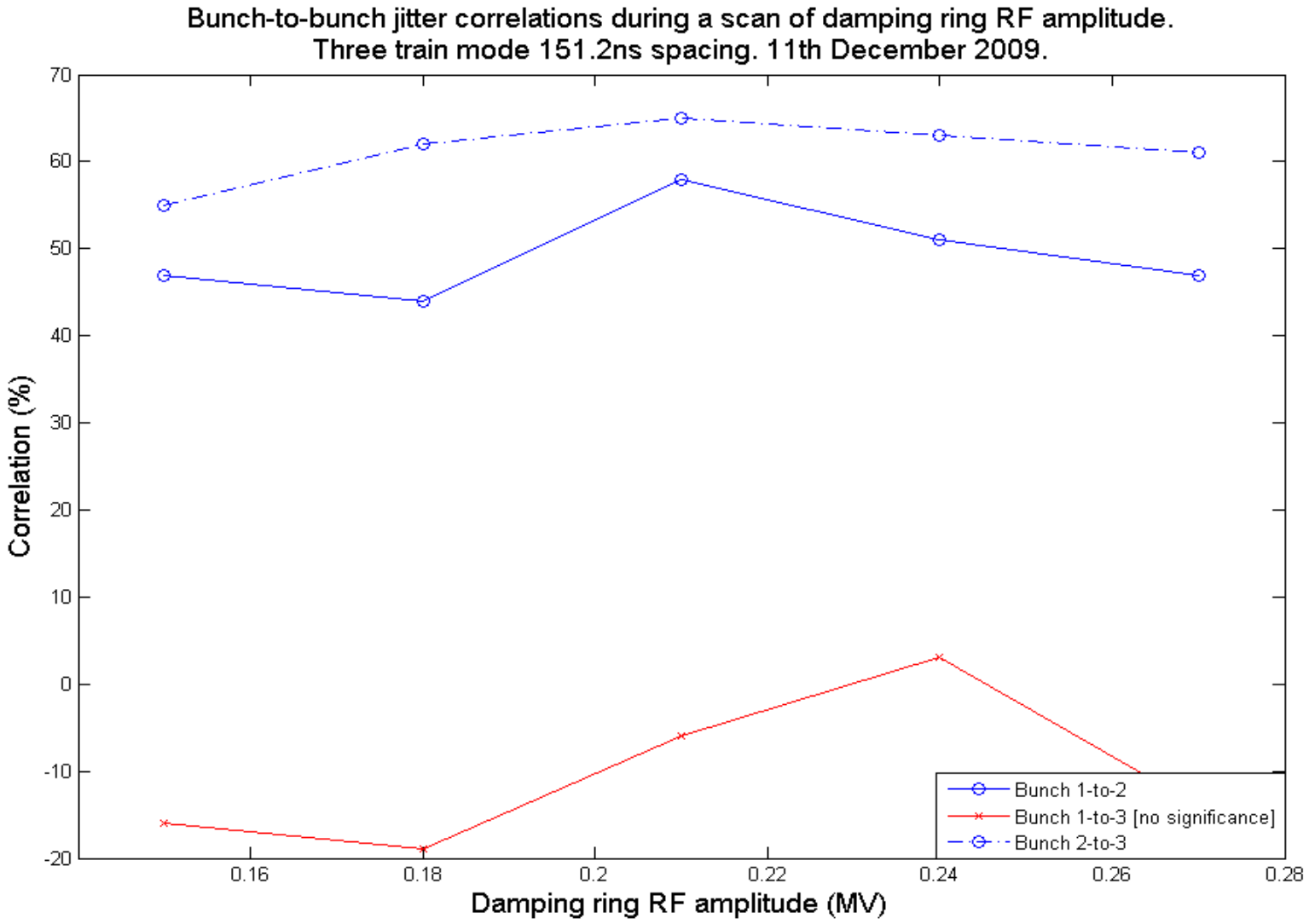
B1/B3: -0.07 (non sign.)

3-BPM resolution estimates (low stats):

B1: 3.6um, B2: 2.9 um, B3: 2.8 um

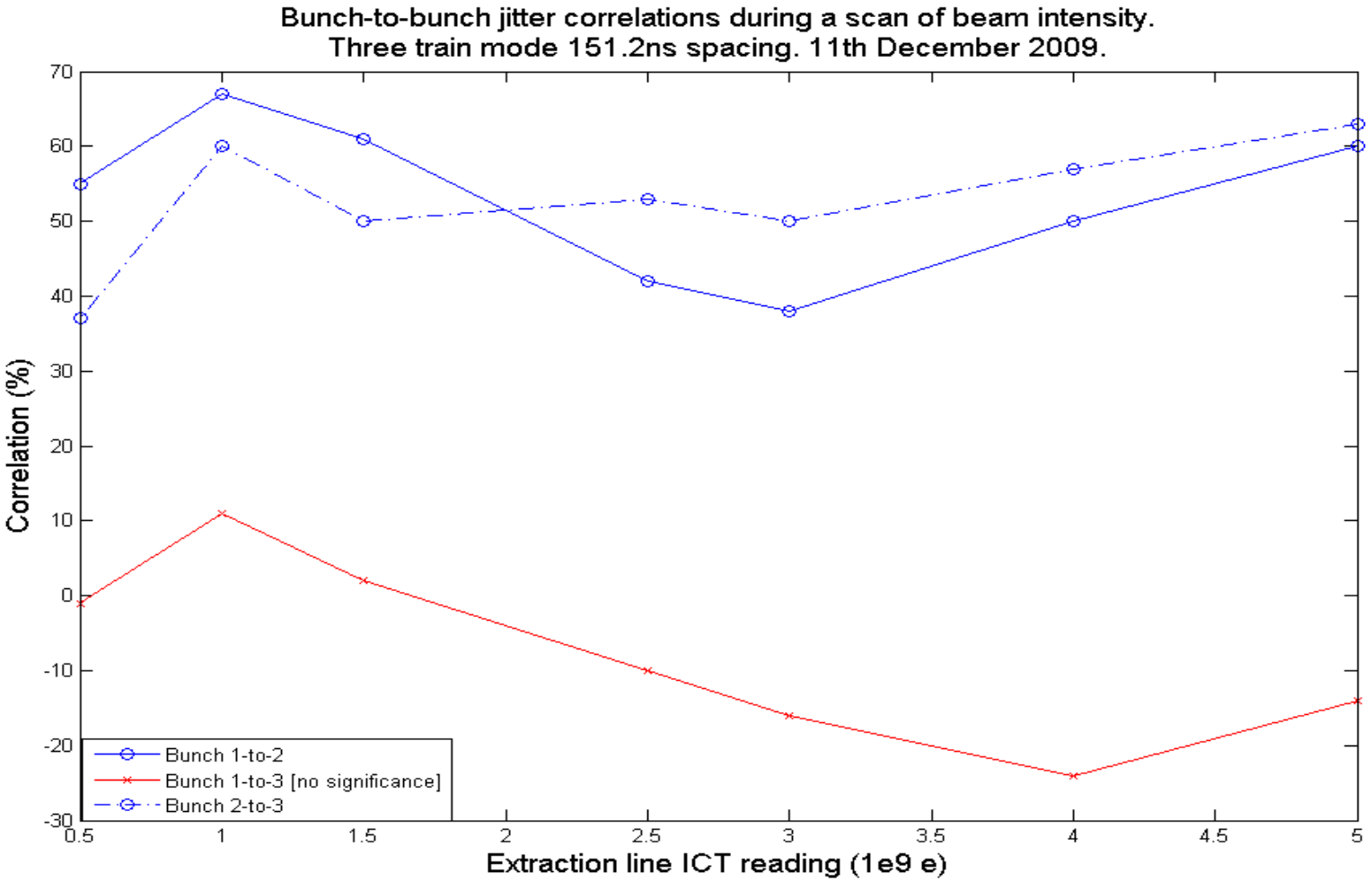
Bunch correlations vs. DR RF scan

11 December 2009, Std Optics, 3 train, 151.2 ns BS, ~50 pulses/setting



Bunch correlations vs. beam charge

11 December 2009, Std Optics, 3 train, 151.2 ns BS, ~100 pulses/setting



FONT5 summary 2009

- New BPMs and kickers installed + working
- FONT5 FB board fabricated and commissioned
- FB loop closed
- Beam quality is a serious issue:

  banana-train can be tuned away (or corrected)

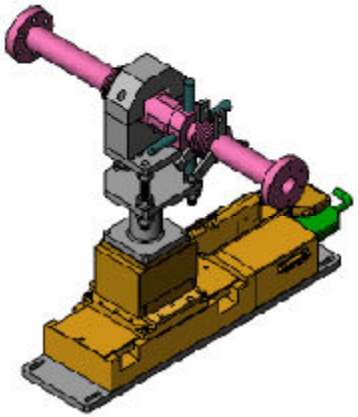
  large jitter and

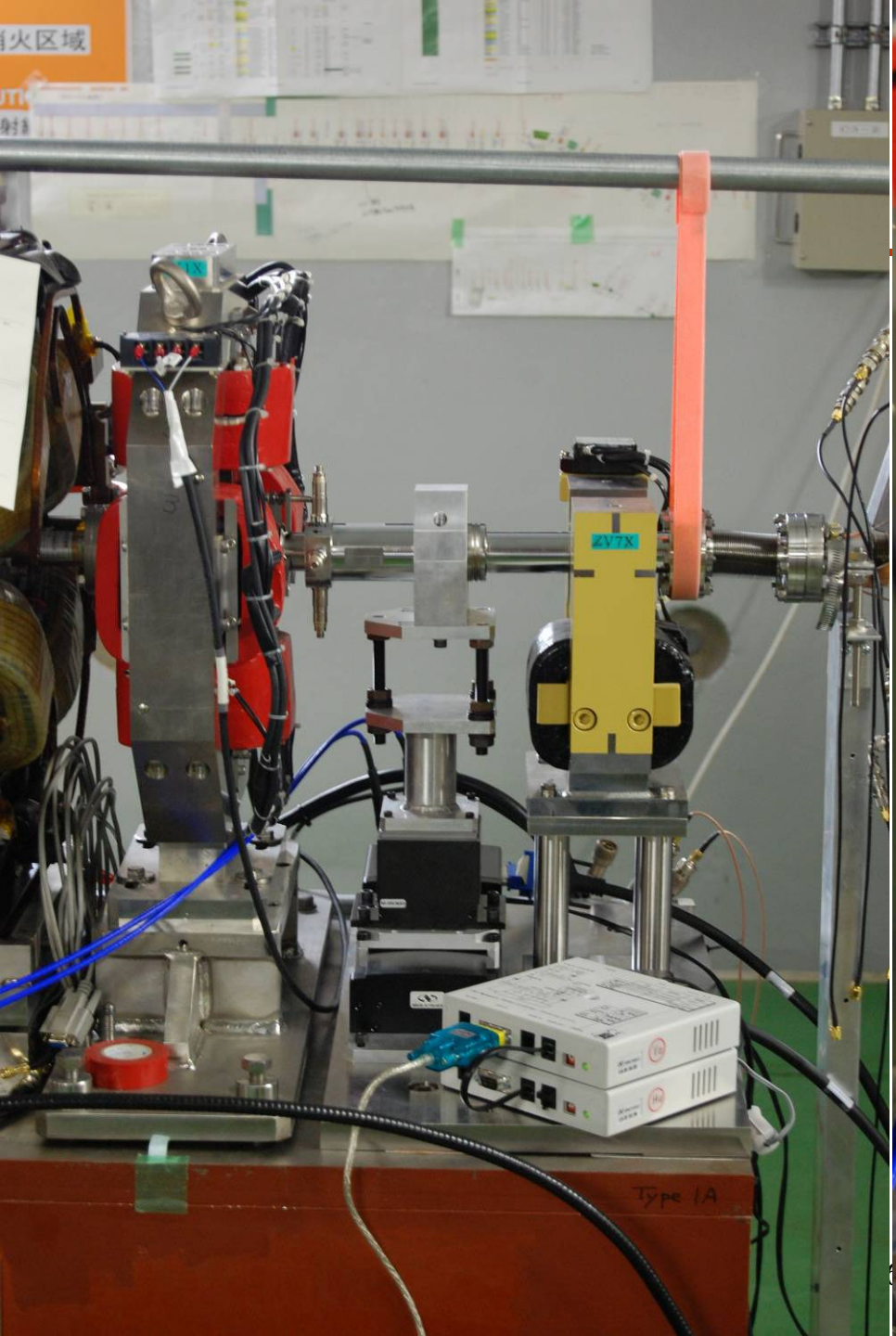
  lack of correlation between bunches are major problems

  (sometimes jitter is small and well correlated!)

THIS WILL NOT BE BETTER WITH 30 BUNCHES!

Valencia Movers




ZV7X
Type 1A


+- 2.5 mm horizontal
+- 2mm vertical

FONT plans: 2010

- **Install Valencia movers (January)**
- **Provide ‘turn-key’ bunch-by-bunch FB system for achievement of ATF2 goals**
- **Plan to replace LO-based BPM processor scheme**