Fast feedback/feedforward systems

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Overview

LCABD: Daresbury, Oxford, (QMUL)

Collaborators: SLAC, KEK, Tokyo Met, DESY, CERN

Task: prototype beam-based (intra-train) feedback system

Completed: ultra-fast analogue feedback prototypes

FONT2 / NLCTA: 54ns latency

FONT3 / ATF: 23ns latency

Ongoing: ILC digital feedback prototypes

FONT4 / ATF: 1st digital FB processor

FONT@ESA: EM background impact on FB BPMs

FONT goals

Prototype components required for ILC intra-train beam feedback system(s):
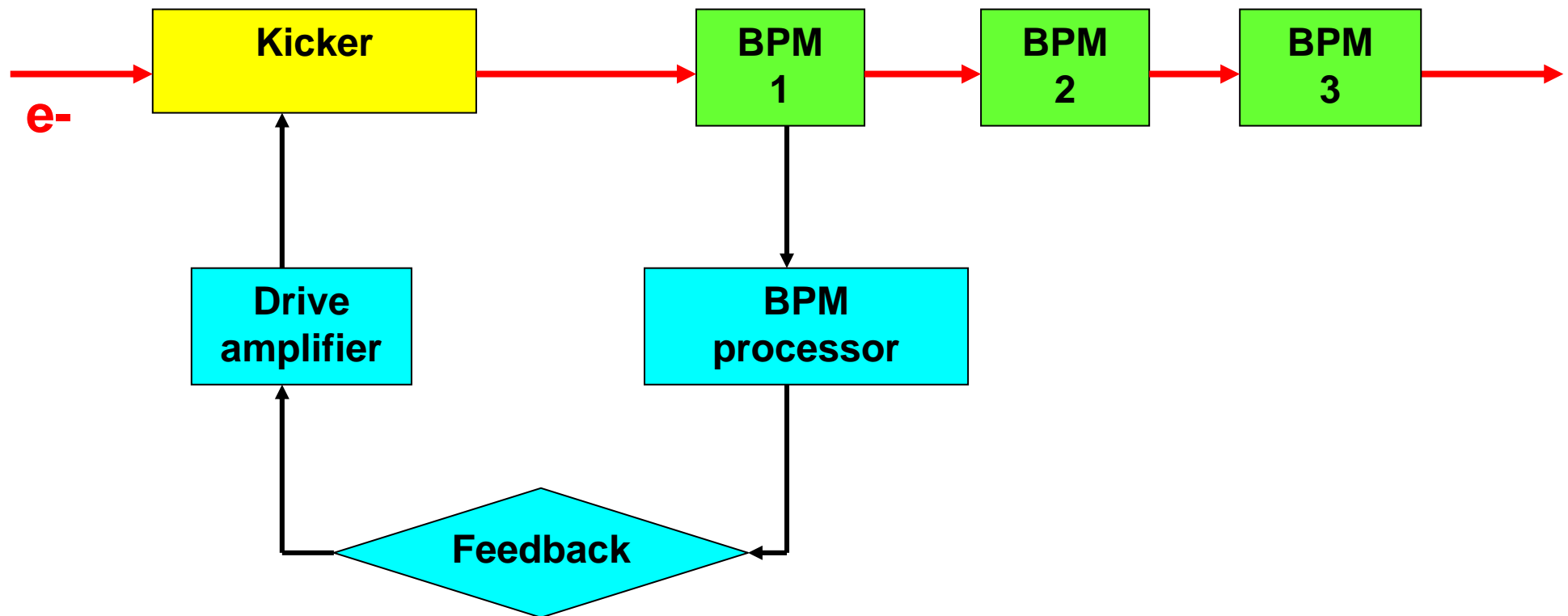
    BPMs, signal processor, feedback circuit, amplifier, kicker

and demonstrate system performance with real beam

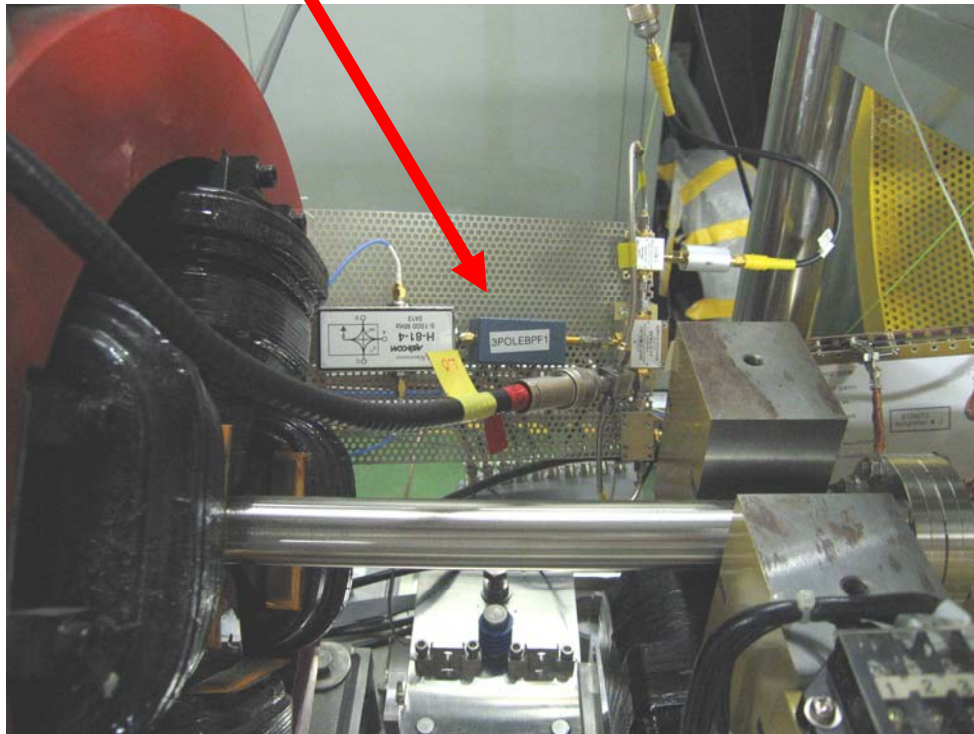**NB technology applicable more widely through ILC:**

    RTML feed-forward, linac orbit FB,

    linac train straightener, BDS orbit FB,
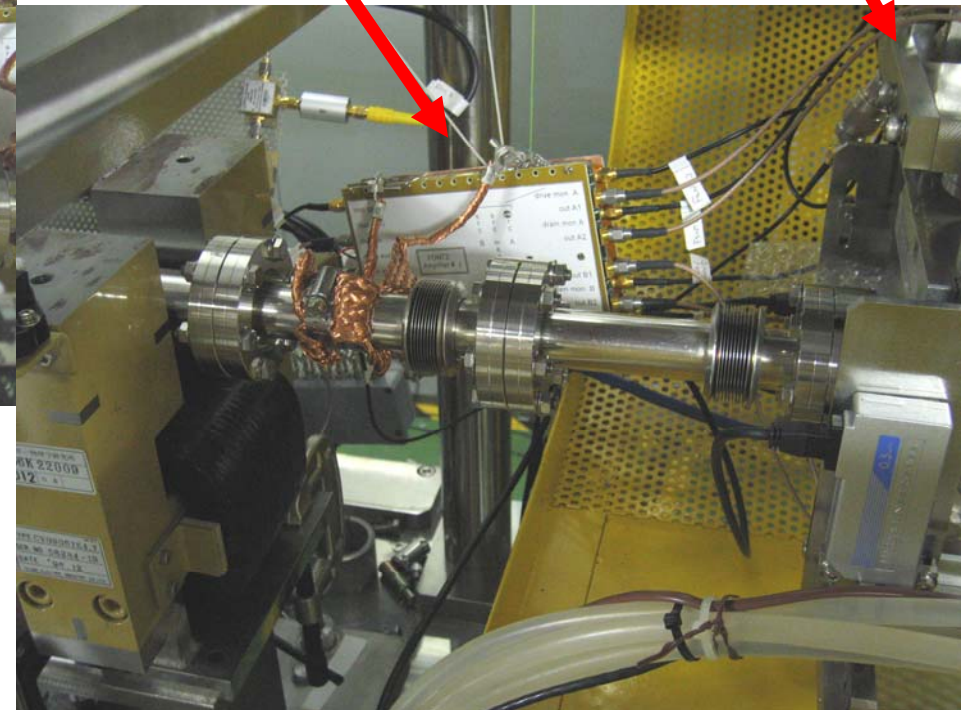
    IP pulse-pulse FB …

Feedback experiments

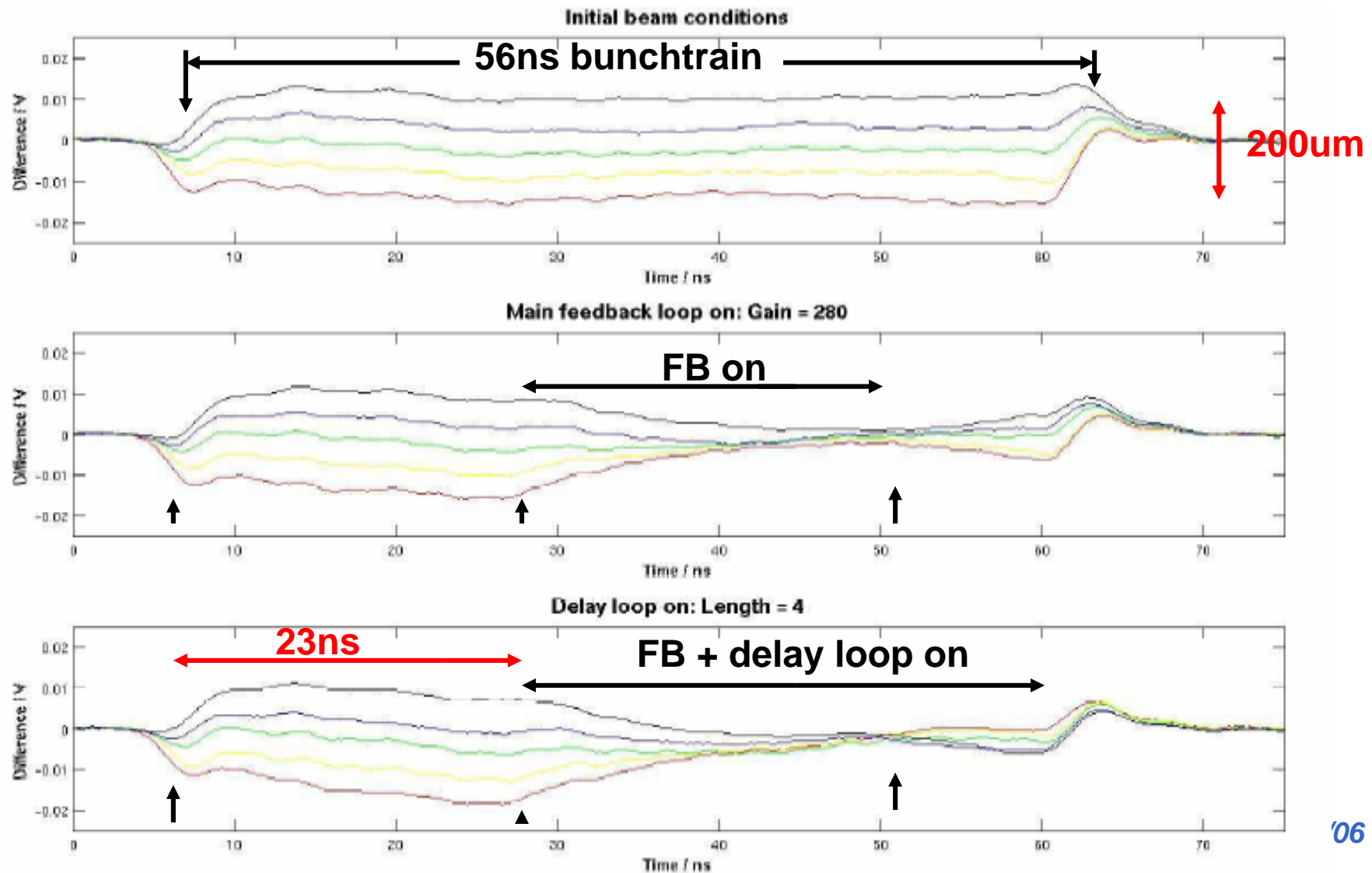# FONT3: beamline at KEK ATF (June 05)

BPM processor board

FEATHER Kicker
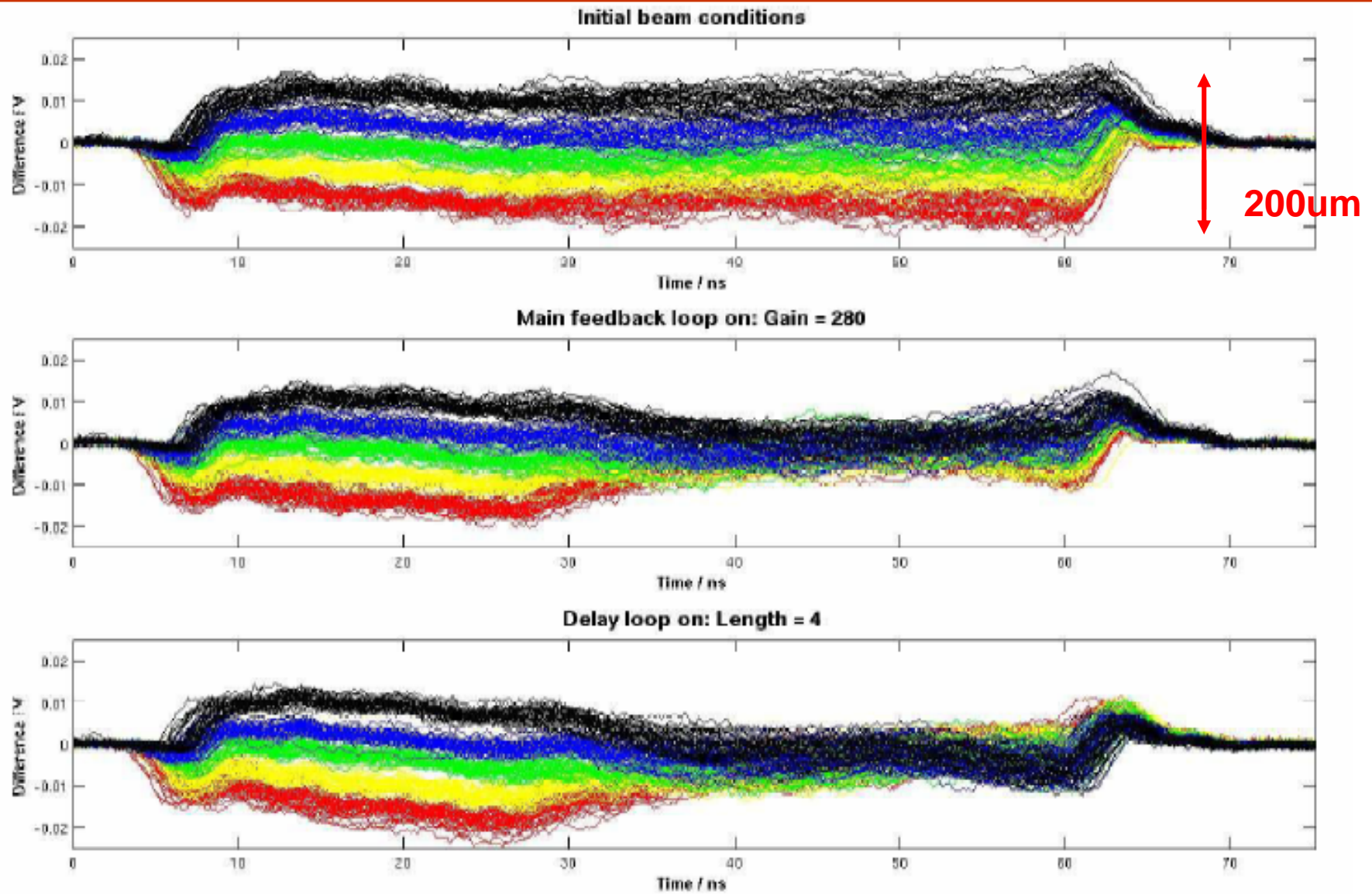
Amplifier/FB board

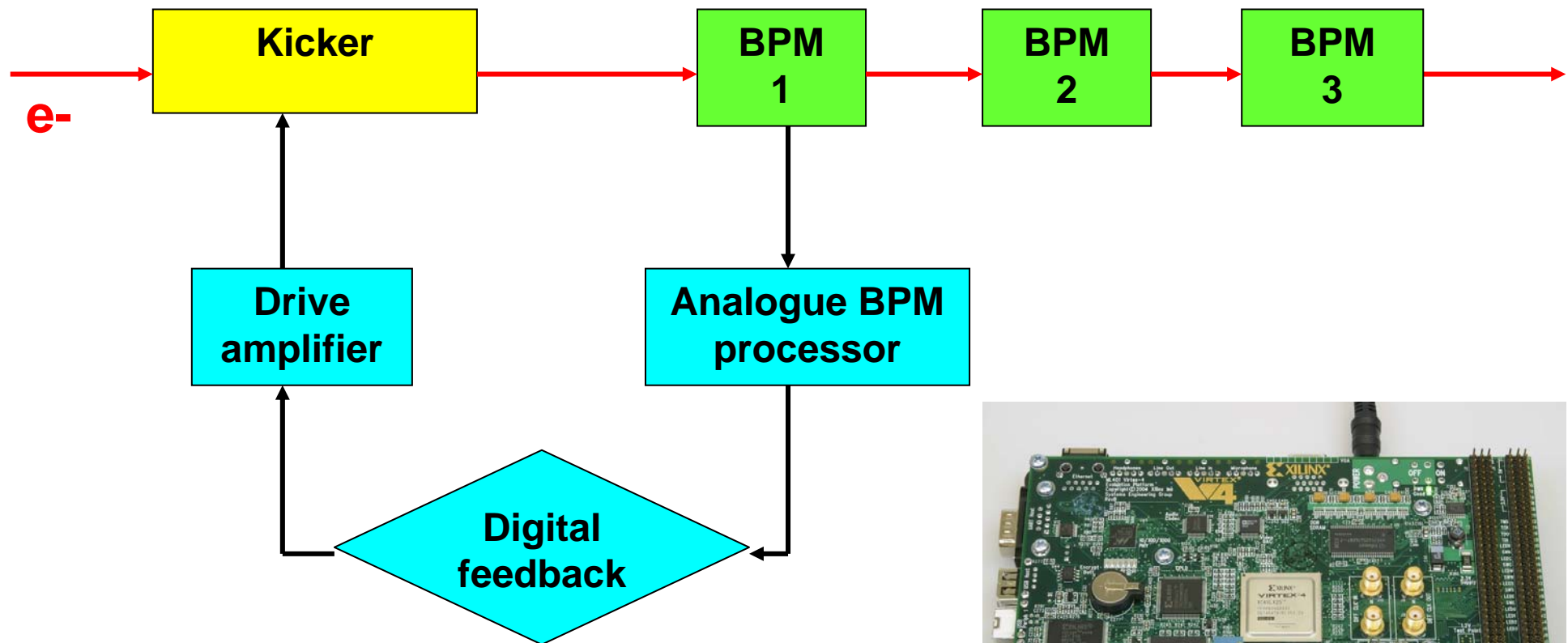*P.N. Burrows*

FONT3 position correction performance
(June 3 2005)

FONT3: raw data (June 3 2005)

ILC digital feedback prototype tests

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Digital system test plan

FONT4 (2005-6):
modified FONT3 BPM processor
digital FB processor
solid-state amplifier
adjustable-gap kicker

ATF: initial tests with
3 bunches with spacing c. 150ns

aiming for latency <120ns (electronics);
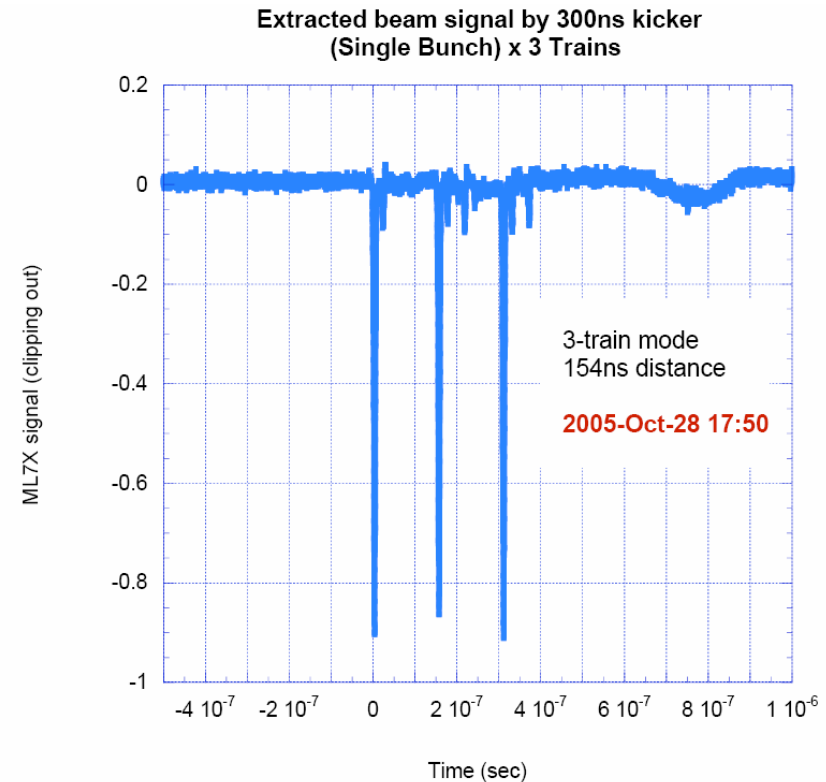**stabilisation of 3rd bunch at um level**

Digital board tests April, June 2006
Closed-loop tests Dec 2006

FONT5 (2008-9):
improved FB system + algorithm development; **+ feed-forward?**
tests with 20-60 bunch trains at ATF(2), or TTF2

Extracted beam signal by 300ns kicker
(Single Bunch) x 3 Trains

3-train mode
154ns distance

2005-Oct-28 17:50

ML7X signal (clipping out)

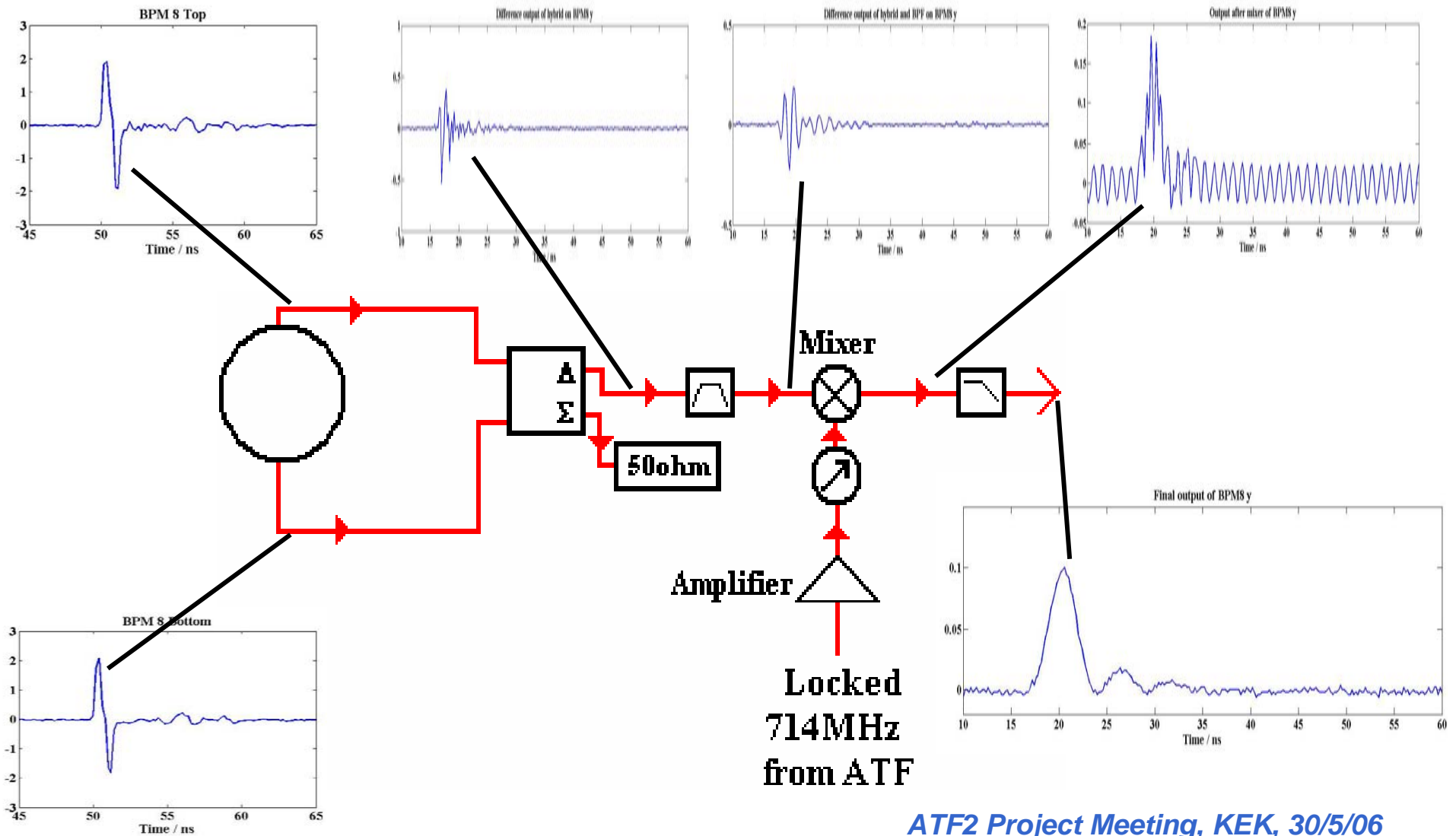Time (sec)

FONT4: latency budget

- **Time of flight kicker – BPM:**   **7ns**
- **Signal return time BPM – kicker:**   **15ns**
  - **Irreducible latency:**   **22ns**

- **BPM processor:**   **7ns**
- **ADC/DAC (3.5 89 MHz cycles)**   **40ns**
- **Signal processing (8 357 MHz cycles)**   **25ns**
- **FPGA i/o**   **3ns**
- **Amplifier**   **40ns**
- **Kicker fill time**   **3ns**
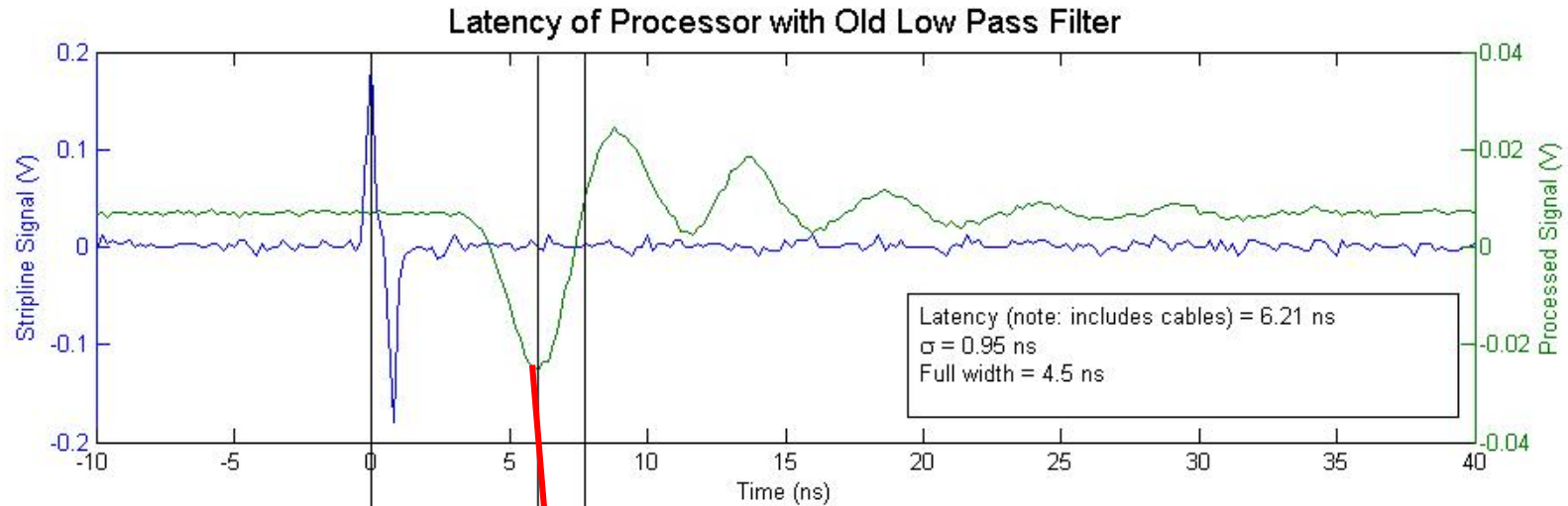 - **Electronics latency:**   **118ns**

- **Total latency budget:**   **140ns**

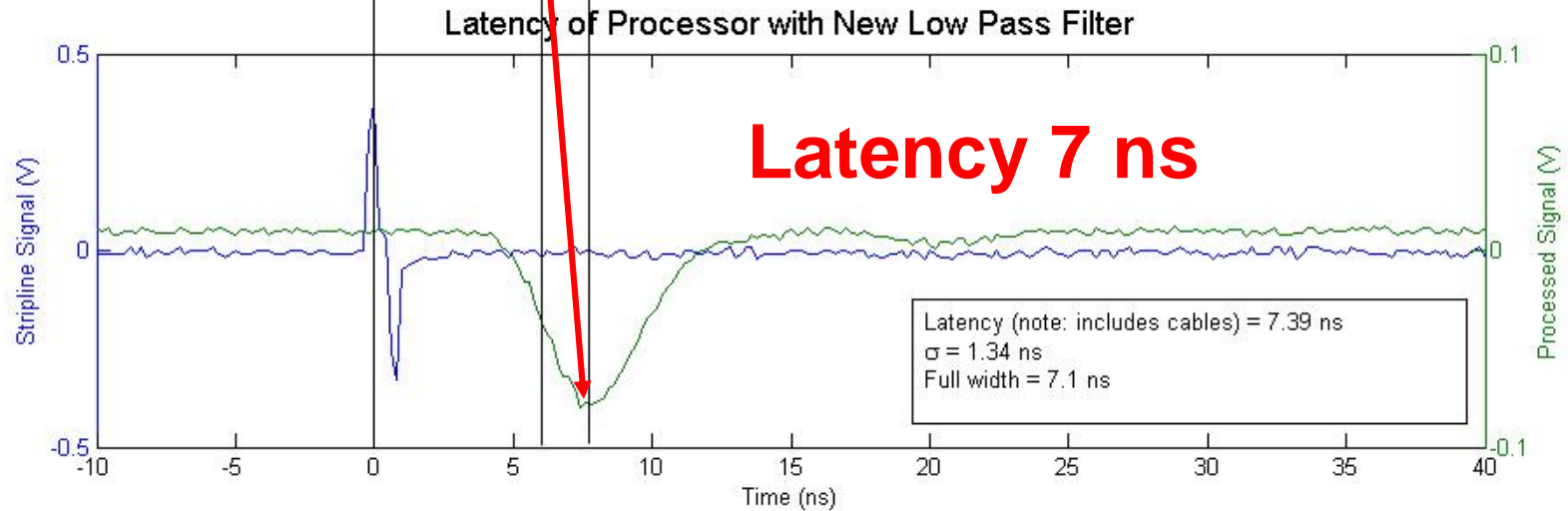# FONT4: BPM analogue signal processor

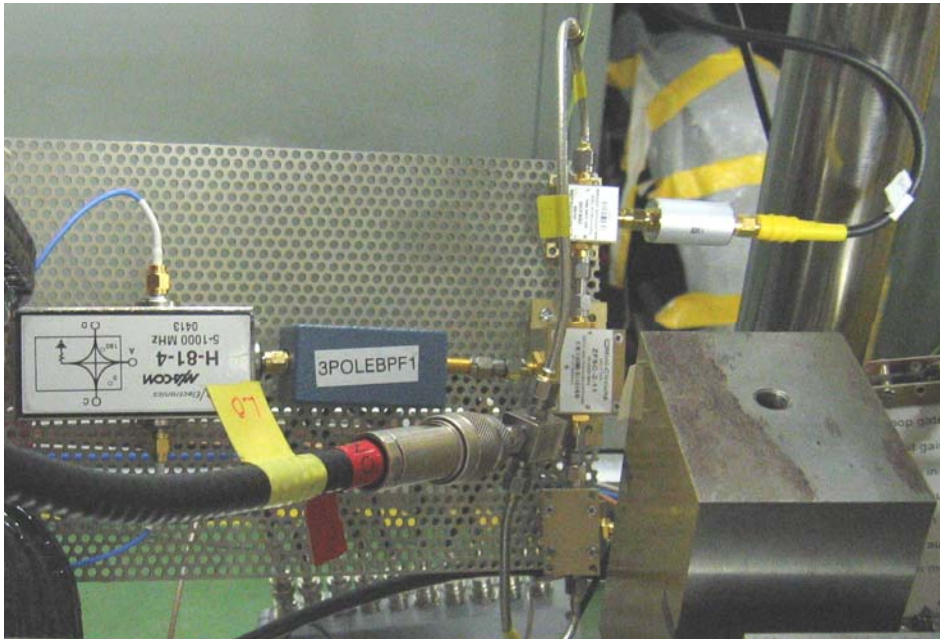# FONT4: BPM processor latency measurement
(December 2005)

FONT3

Latency of Processor with Old Low Pass Filter

Latency (note: includes cables) = 6.21 ns
σ = 0.95 ns
Full width = 4.5 ns

FONT4

Latency 7 ns

Latency of Processor with New Low Pass Filter

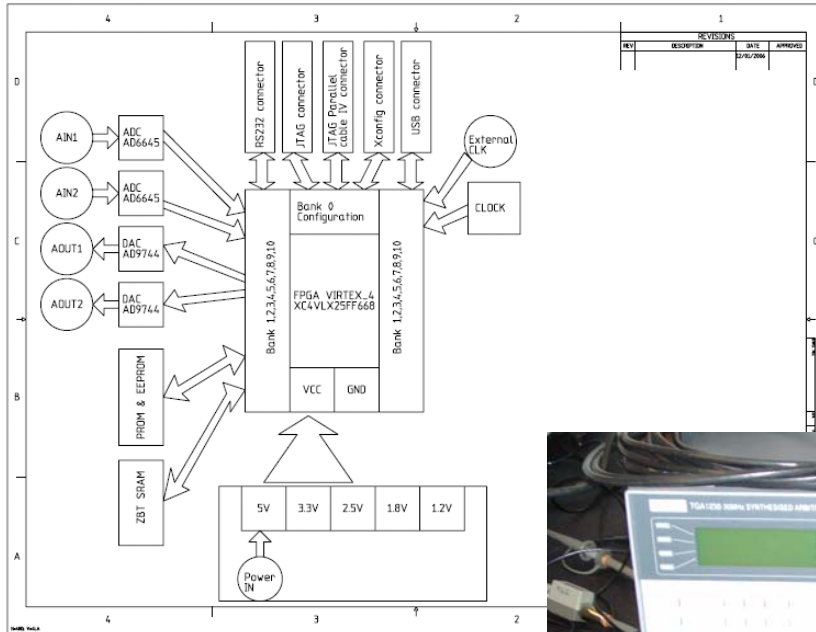Latency (note: includes cables) = 7.39 ns
σ = 1.34 ns
Full width = 7.1 ns

P.

FONT4: new BPM analogue signal processor

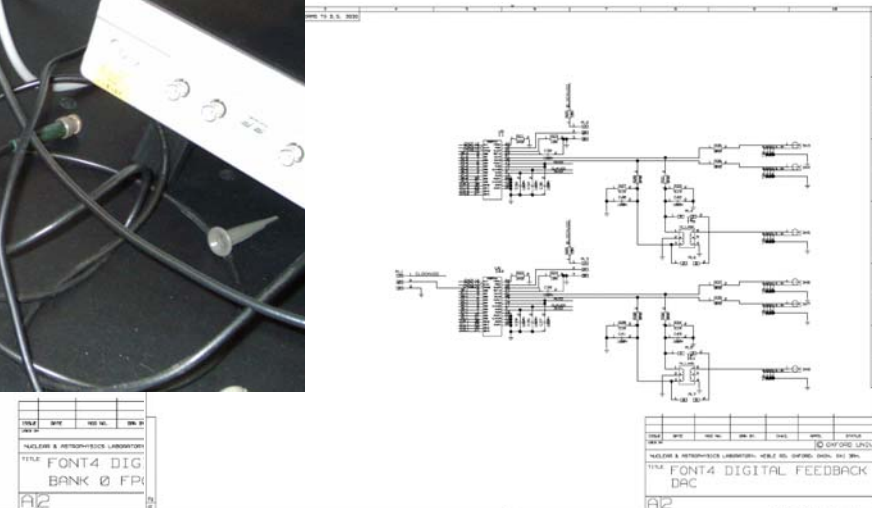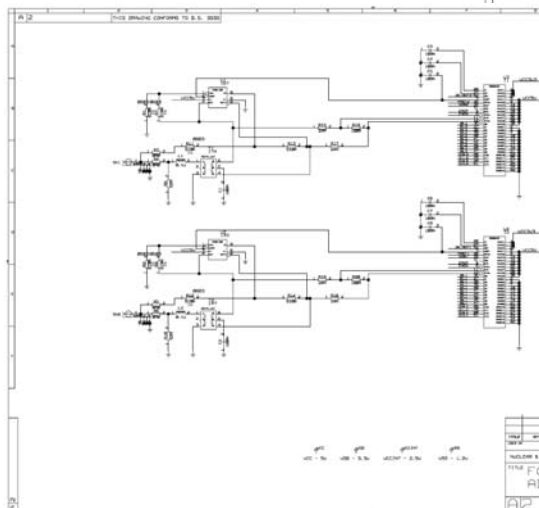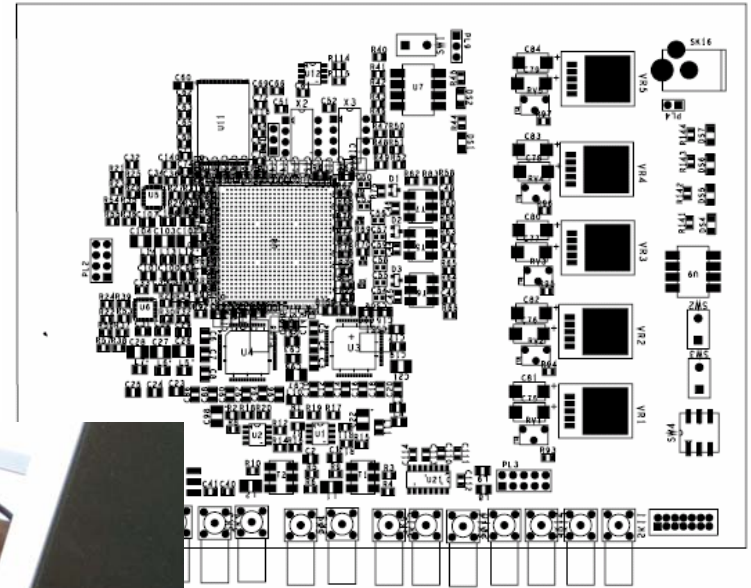We are replacing connectorised version with PCB:

- **Order placed 28/5/06**

- **Boards loaded 5/6/06**

- **Test at ATF 12/6/06**
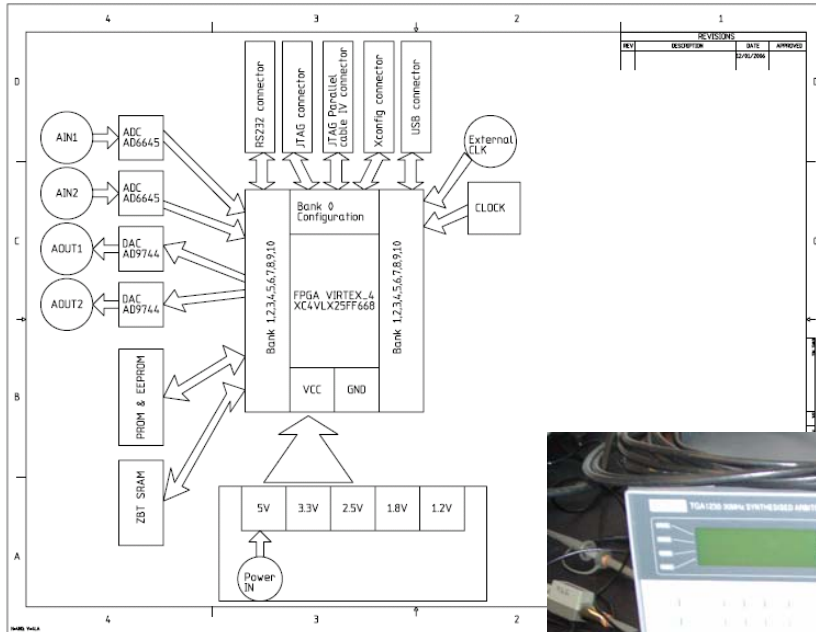
FONT4: digital feedback processor

**PCB loaded
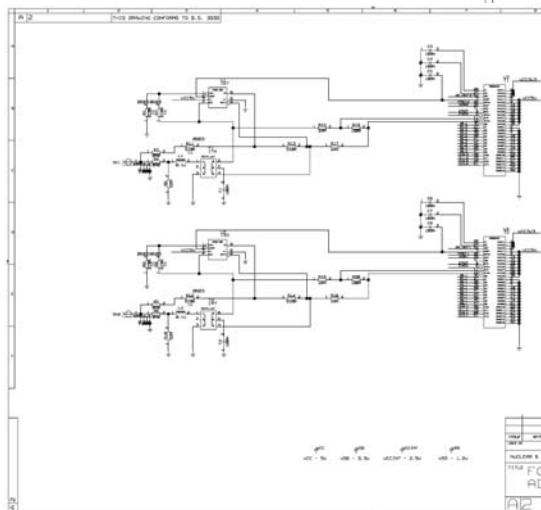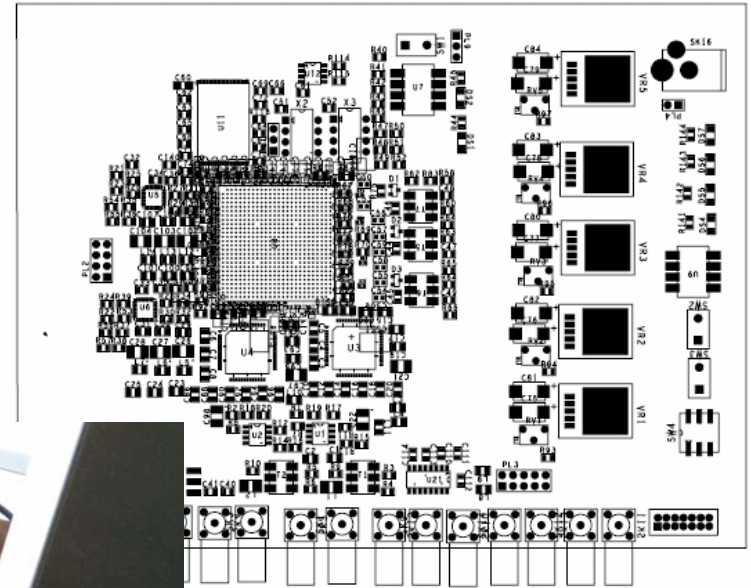April 4**

**Bench tests
April 5-14**
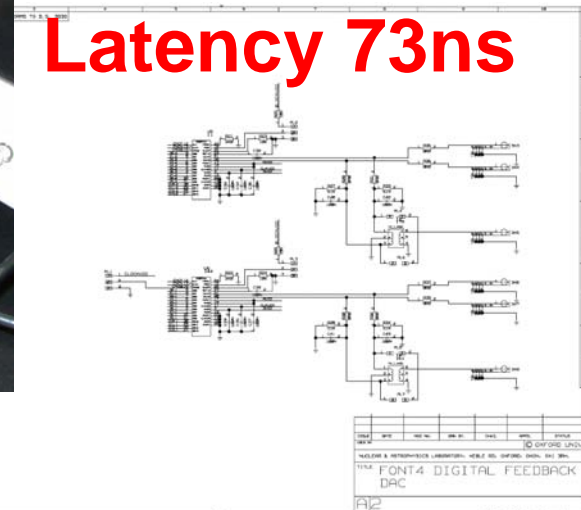
FONT4: digital feedback processor

PCB loaded
April 4

Bench tests
April 5-14

Latency 73ns

1st beam test results (20 April 2006)

Position calibration

Board 1 calibration (bs=140ns)
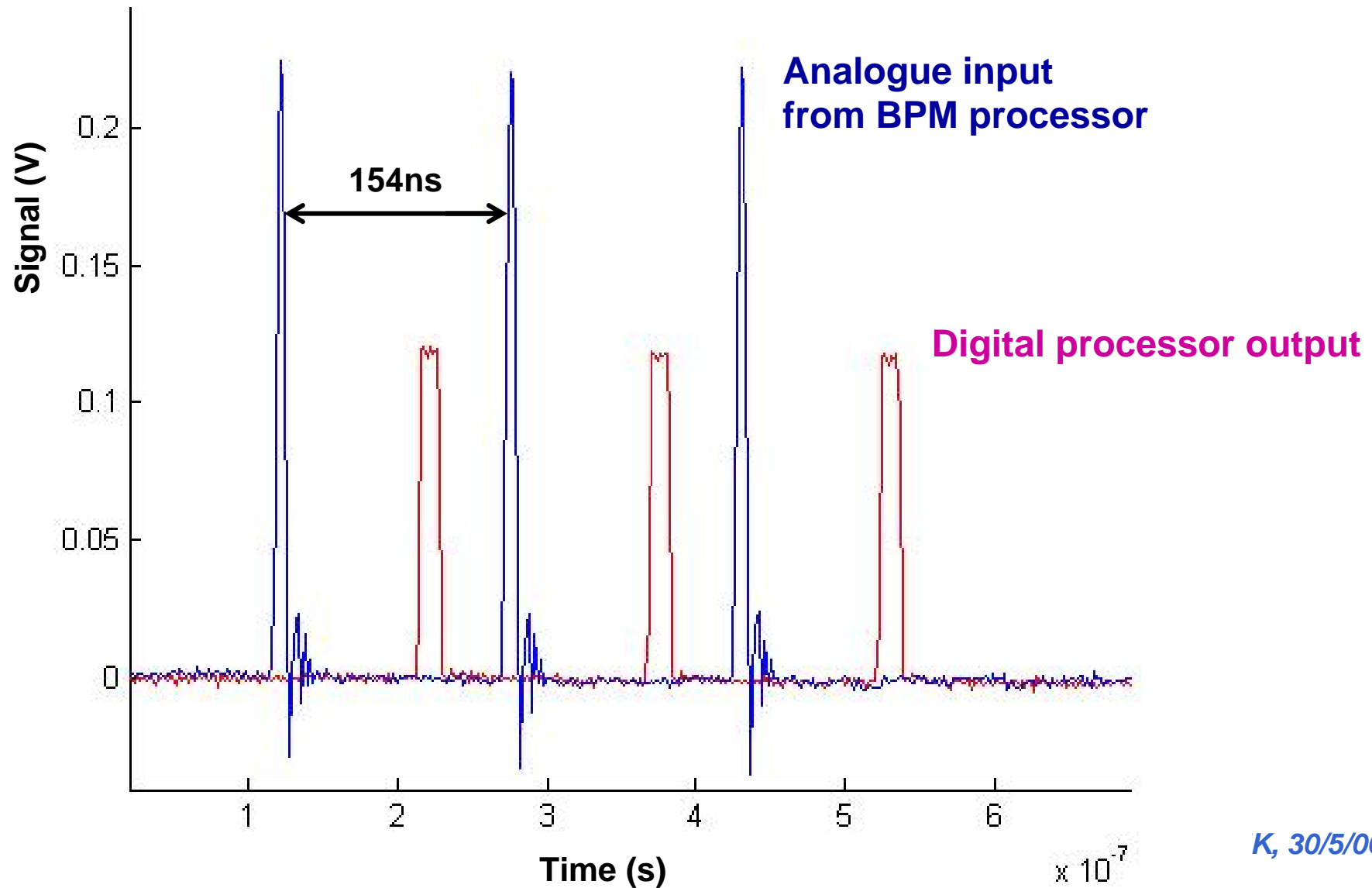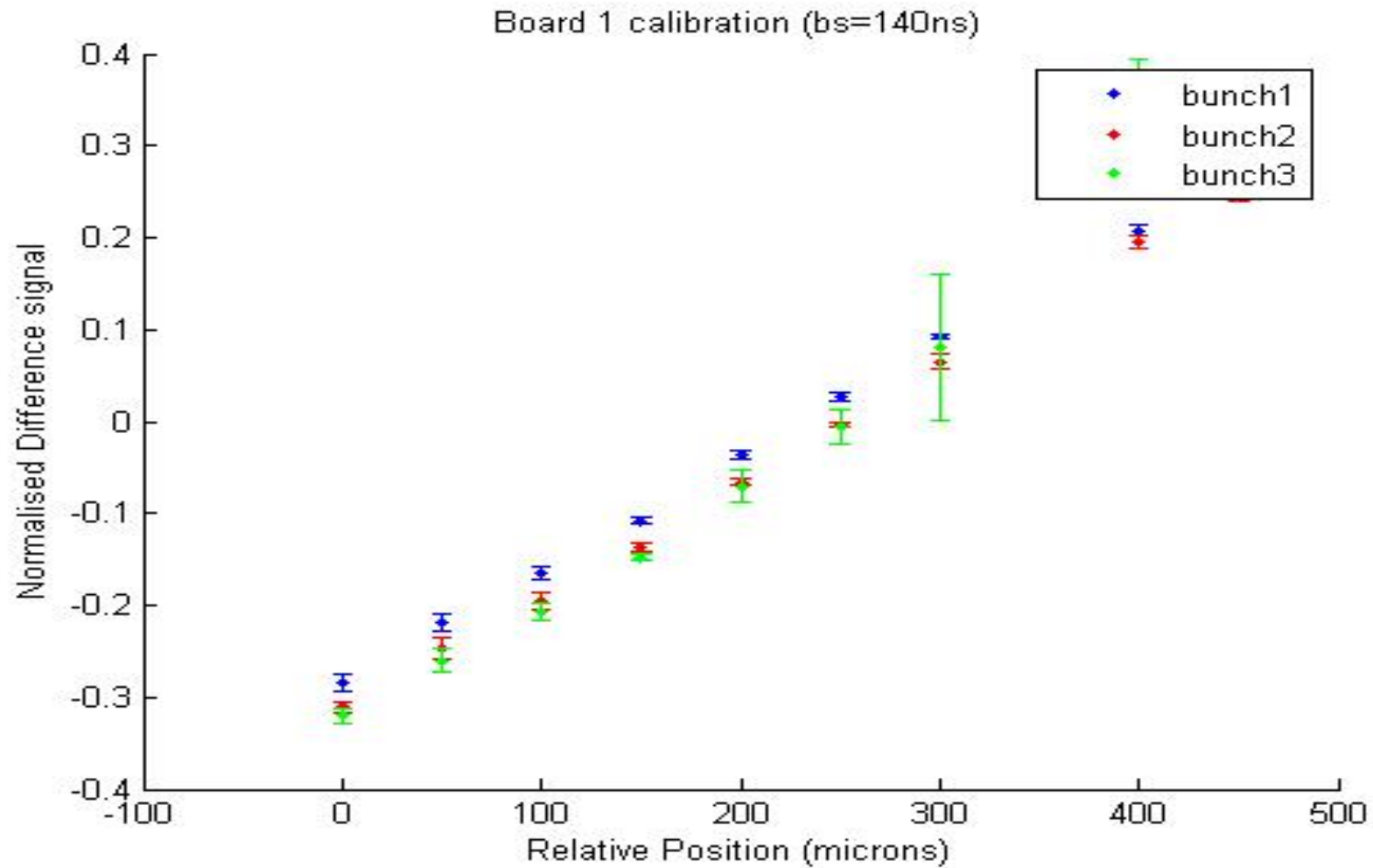
Lyrtech Signalmaster Board + Xilinx FPGA

714 MHz

/ 10

Trigger

ML12X Analogue Processor
Diff --->
SUM --->

Lyrtech SignalMaster (FPGA)

Q normalised Position Out

FB Out

- Clocked at 71.4 MHz
- 11 clock cycles per bunch crossing
- Latency ~196ns (14 cycles)
- 14-bit accuracy with 2-channel ADC/DACs
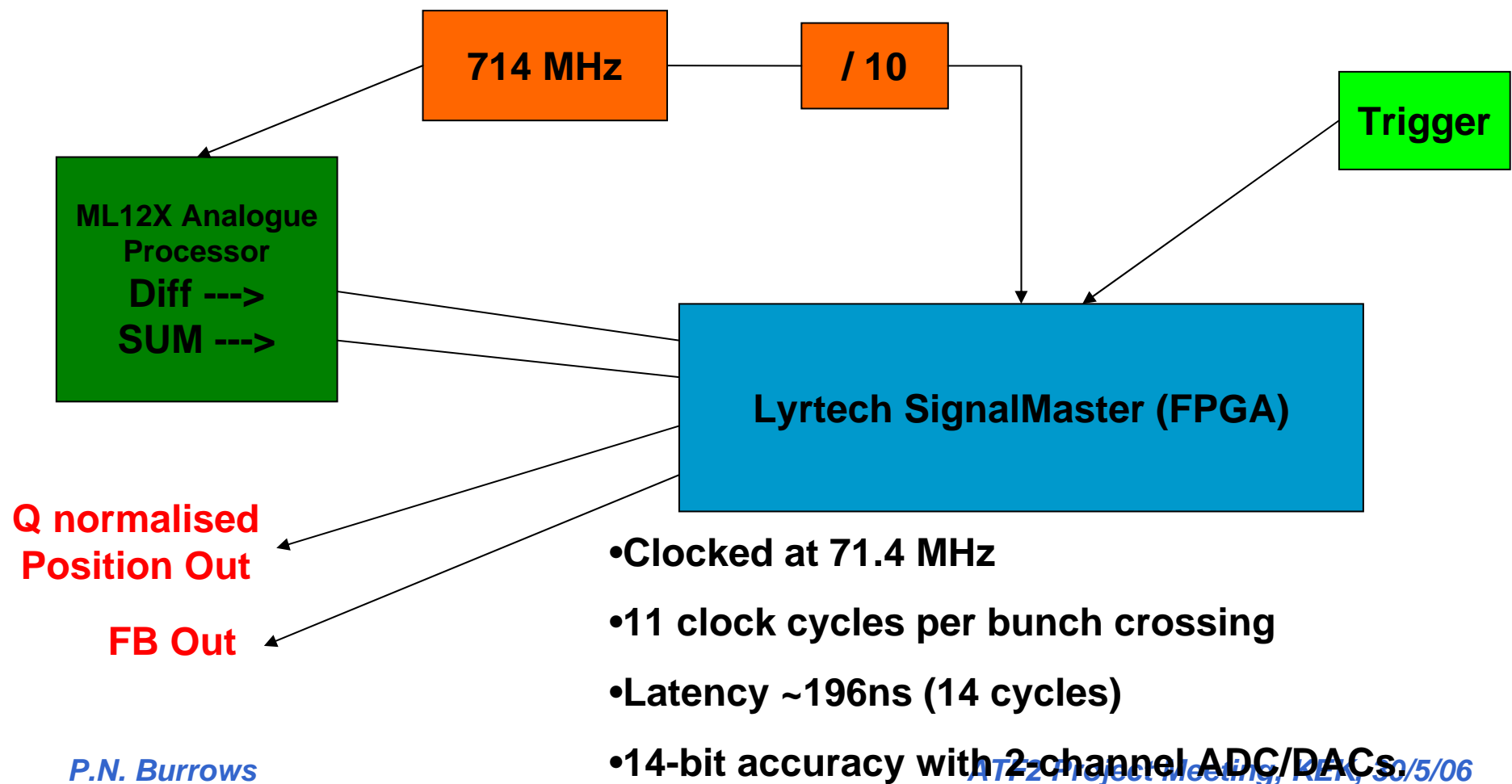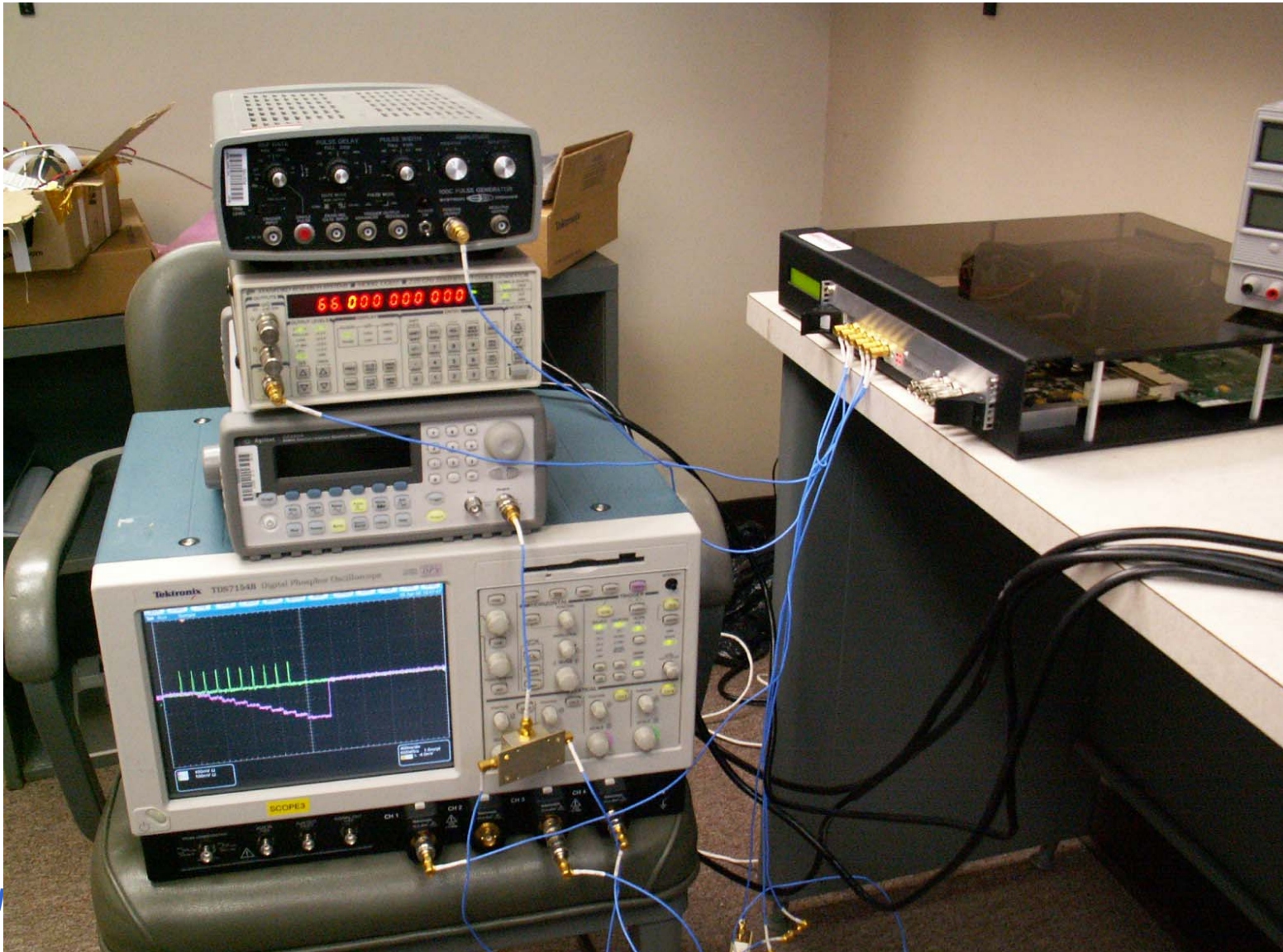
Lyrtech bench test

Lyrtech bench test results
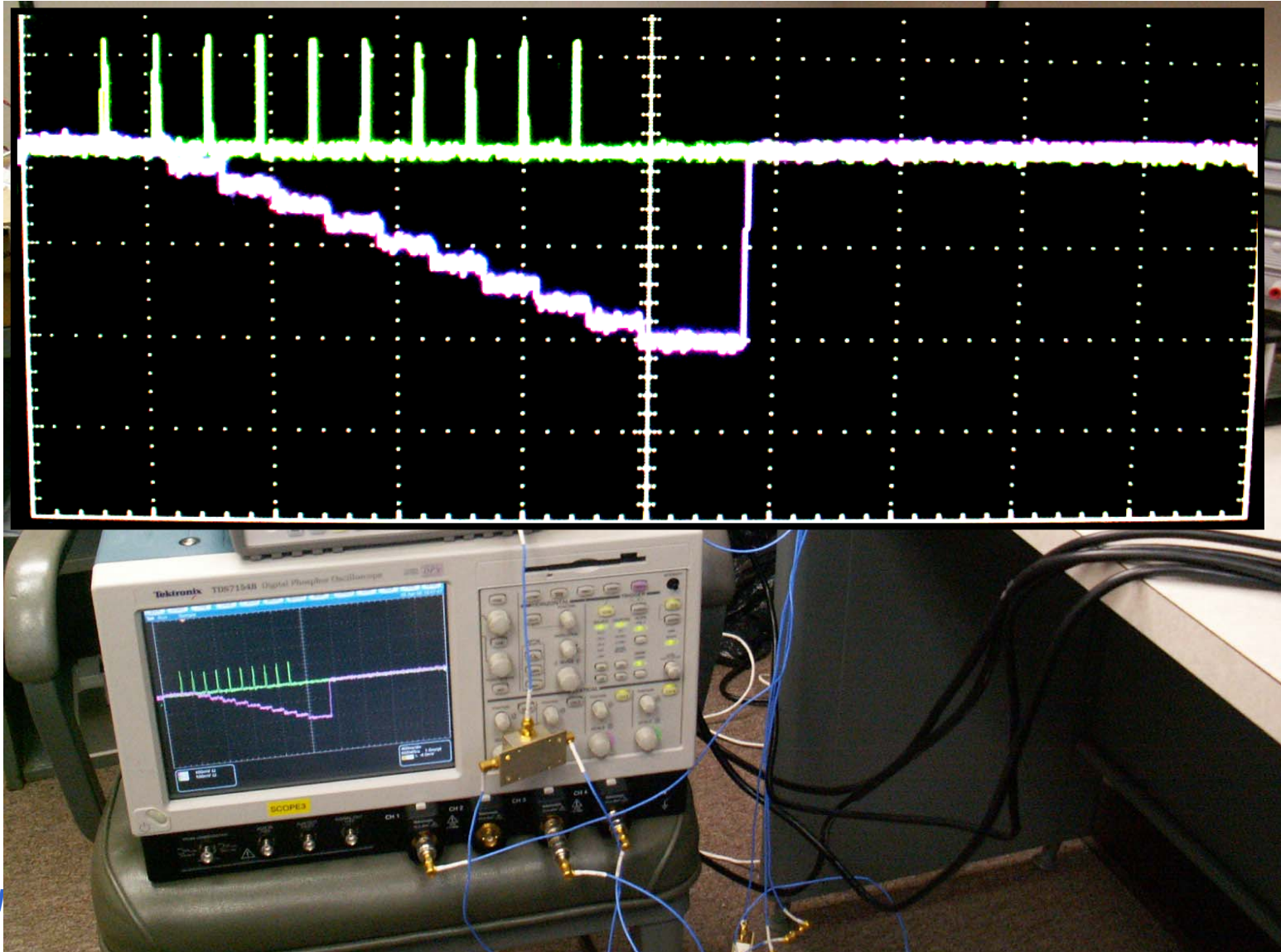
Lyrtech beam test results (14/4/06)
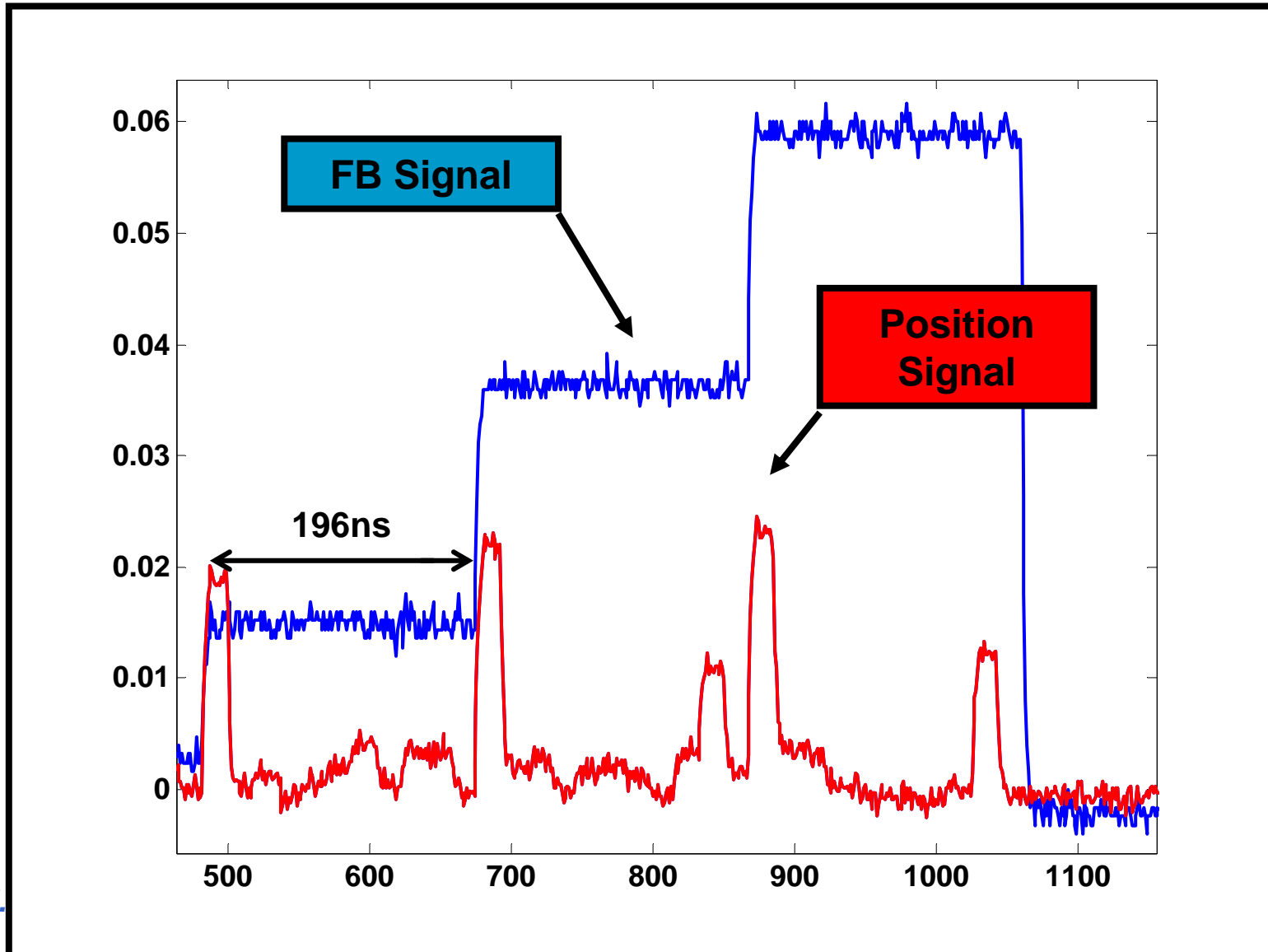
FONT4 test plan

June 2006:

    1st test of PCB version of analogue BPM processor

    2nd tests of digital FB: timing, synchronisation, triggering,

        gain adjustment in FPGA

        (ADC clocking @ 714/10 = 71 MHz)

December 2006:

    1st test of FONT4 amplifier

    3rd tests of digital FB: ADC clocking @ 357/4 = 90 MHz

    2nd tests of PCB BPM processor

    Closed-loop FB

March/April 2007:

    Closed-loop FB

FONT5 test plan

The next major development would be FB tests using a long ILC-like train of 20-60 bunches

Depends on success of fast-extraction kicker tests

2008/9?

I will discuss ATF2-specific needs in next talk …

FONT bench test system

Dedicated bench test lab being set up in Oxford:

    fast impulse generator for simulation of beam signals

    signal generator for machine-phased clocks (714MHz)

    analogue front-end + digital board

    fast scope for DAQ

-> bench test complete FB system

Develop and test robust feedback algorithms:

    include noise effects, long-range bunch correlations,

    'adaptive' gain, feed-forward …

Feed-forward system (1)

A feed-forward system has been discussed in vague terms for some time!

A ring -> extraction line system is conceivable based on FONT/FEATHER-type technology

In multi-bunch mode a feed-forward system JUST in extraction line is also conceivable (operationally like a feedback)

Is feed-forward necessary?

    1) ATF / ATF2 operations?

    2) ILC prototype (eg. RTML system)?

Feed-forward system (2)

- **What do we want to stabilise?**

  Energy? (Kalinin idea)

  Vertical position/angle?
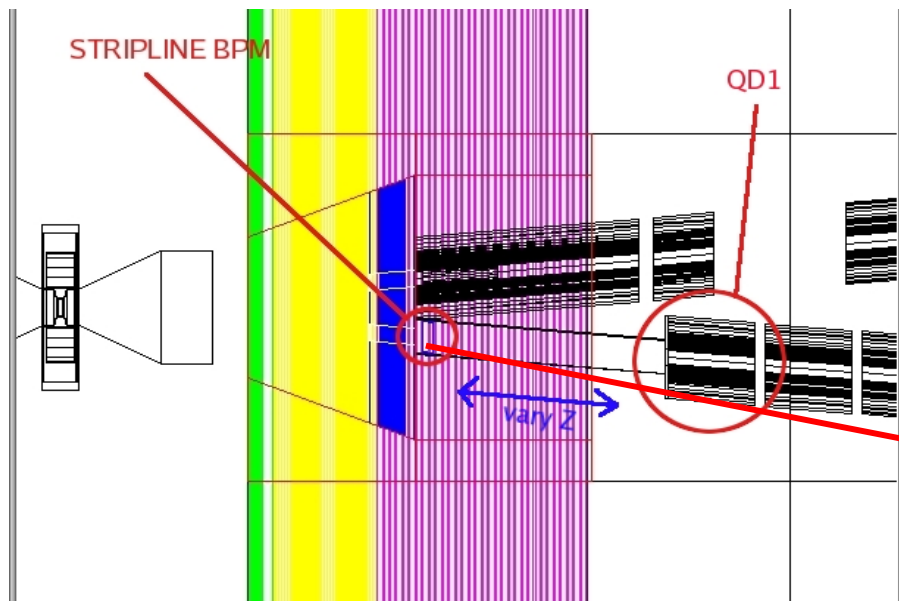
  Horizontal position/angle?

- **Need to know dominant jitter source(s):**
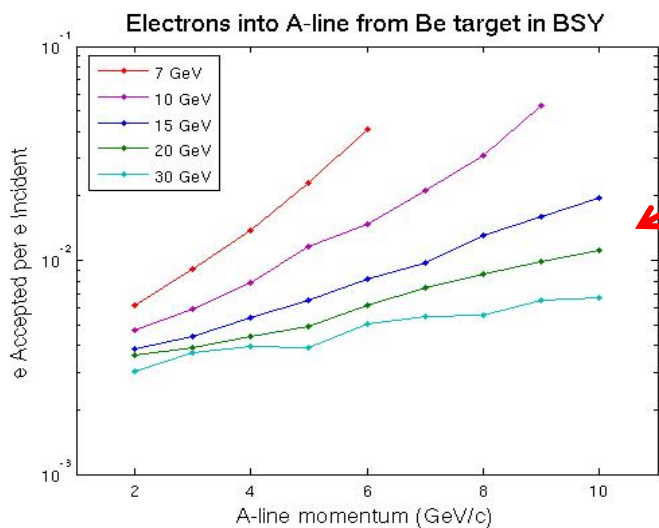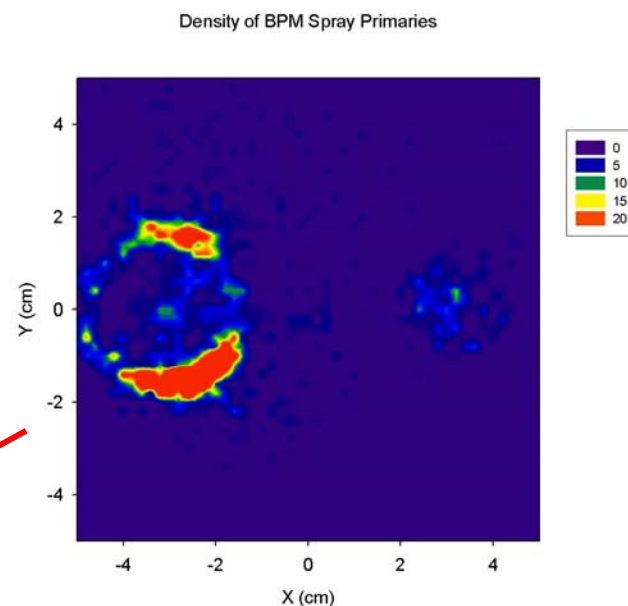
  Eg. if extraction kicker,

  ring -> extraction line no use!

  upstream -> downstream in extr. line (multi-bunch mode) OK
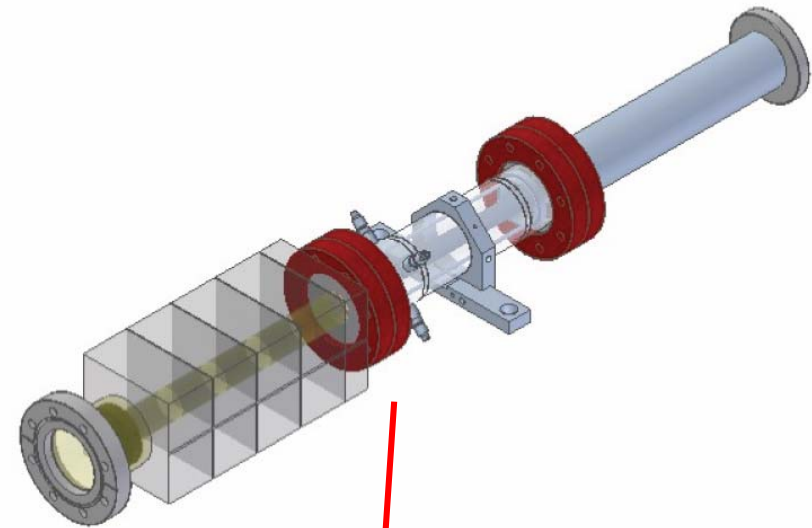
EM Background Environment for FB BPM

STRIPLINE BPM
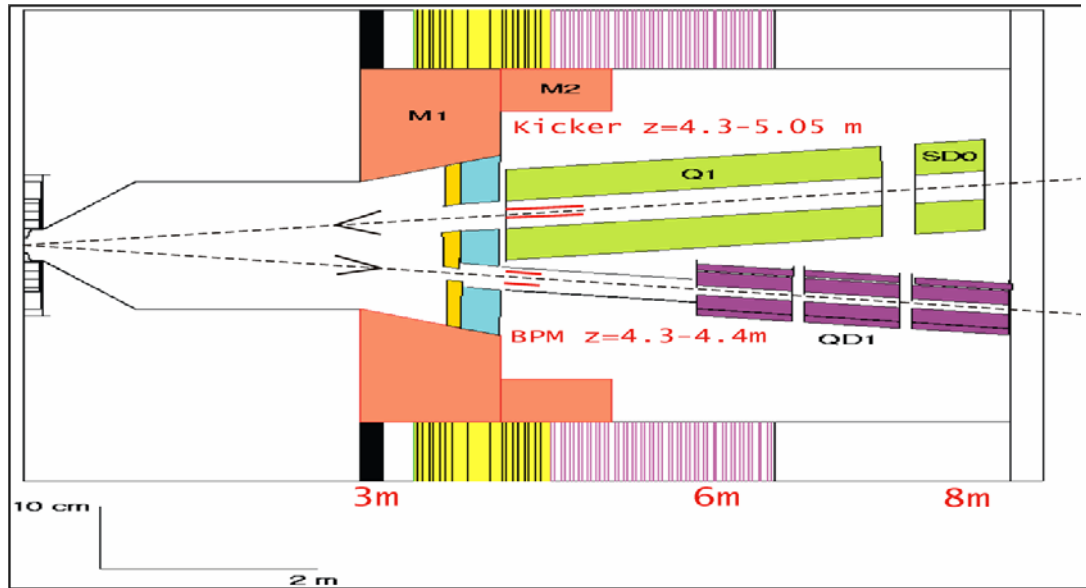
QD1

vary Z

Energy deposition on mask:

Density of BPM Spray Primaries

| 0 |
| 5 |
| 10 |
| 15 |
| 20 |

Y (cm)

X (cm)

Electrons into A-line from Be target in BSY

7 GeV
10 GeV
15 GeV
20 GeV
30 GeV

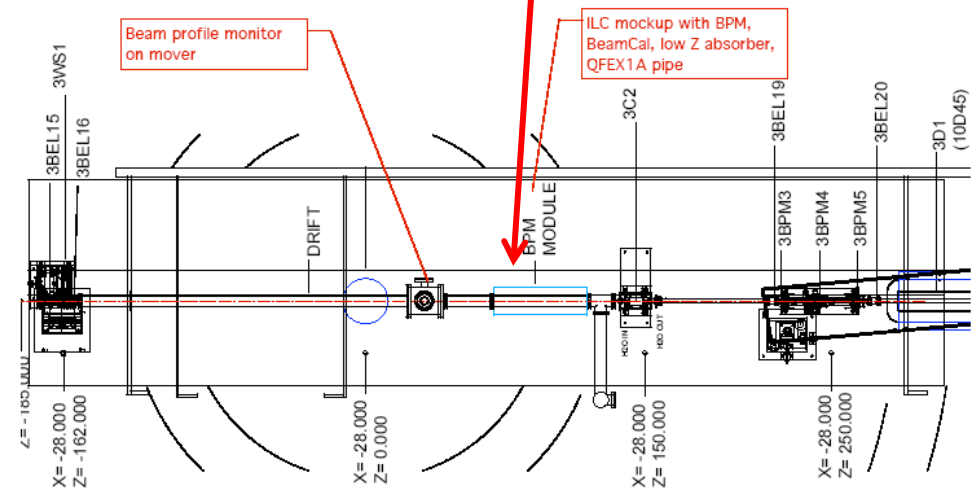e Accepted per e Incident

A-line momentum (GeV/c)

Create using ESA 'spray beam' for experimental test

FONT Test Module for ESA

FONT Spray Beam Test Layout in SLAC ESA

First beam tests
July 7 – 21 2006

*P.N. Burrows*

Strategic ILC FB outlook

- **Continuing intra-train IP FB hardware prototyping deemed 'critical' in BCD – FONT programme ongoing at ATF, ESA, ATF2**

- **Optimisation of BPM design(s) for feedback/feed-forward systems**

- **Need to design bunch-by-bunch luminosity signal into IP FB**

- **Intra-train FB technology required for BDS, linac, RTML FF …**

- **Hardware directly applicable to 5Hz feedbacks throughout machine**

- **Development of robust algorithms critical – test setup in Oxford**

- **Integrated design of whole alignment + feedback strategy critical**
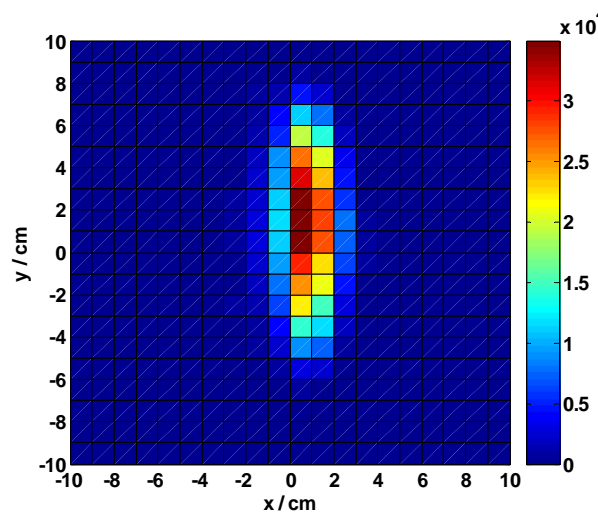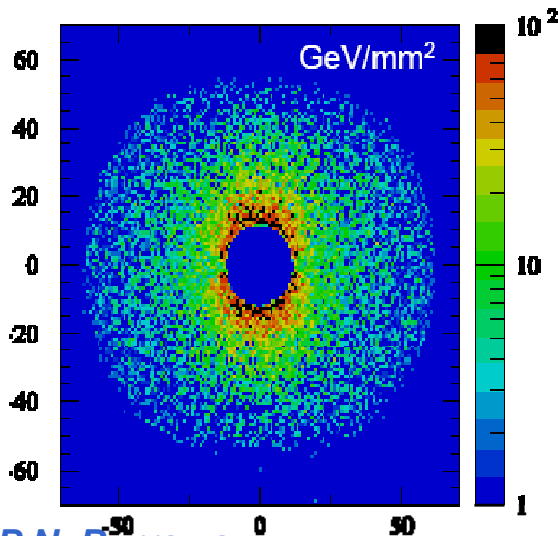
BeamStrahlung (White)

ILC IR
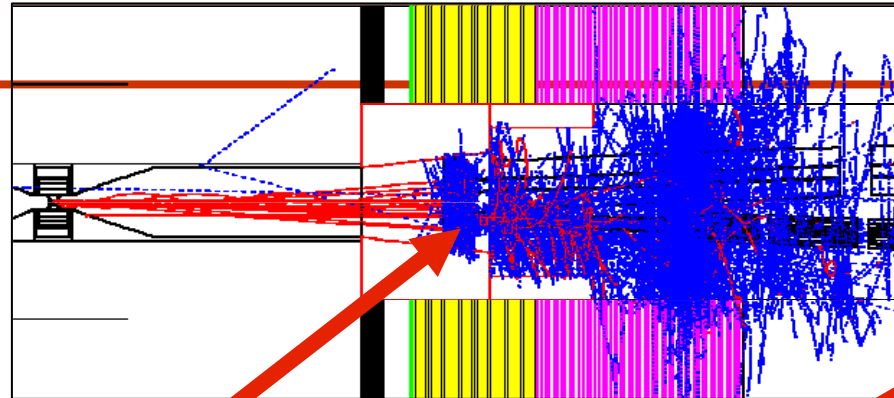
200m

Diagnostics of bunches at IP.

BeamCal

Photon Detector

3 potential sources of information:

1. **Energy-distribution of Pairs.**

2. **Number-distribution of Pairs.**

3. **Energy-distribution of Photons.**

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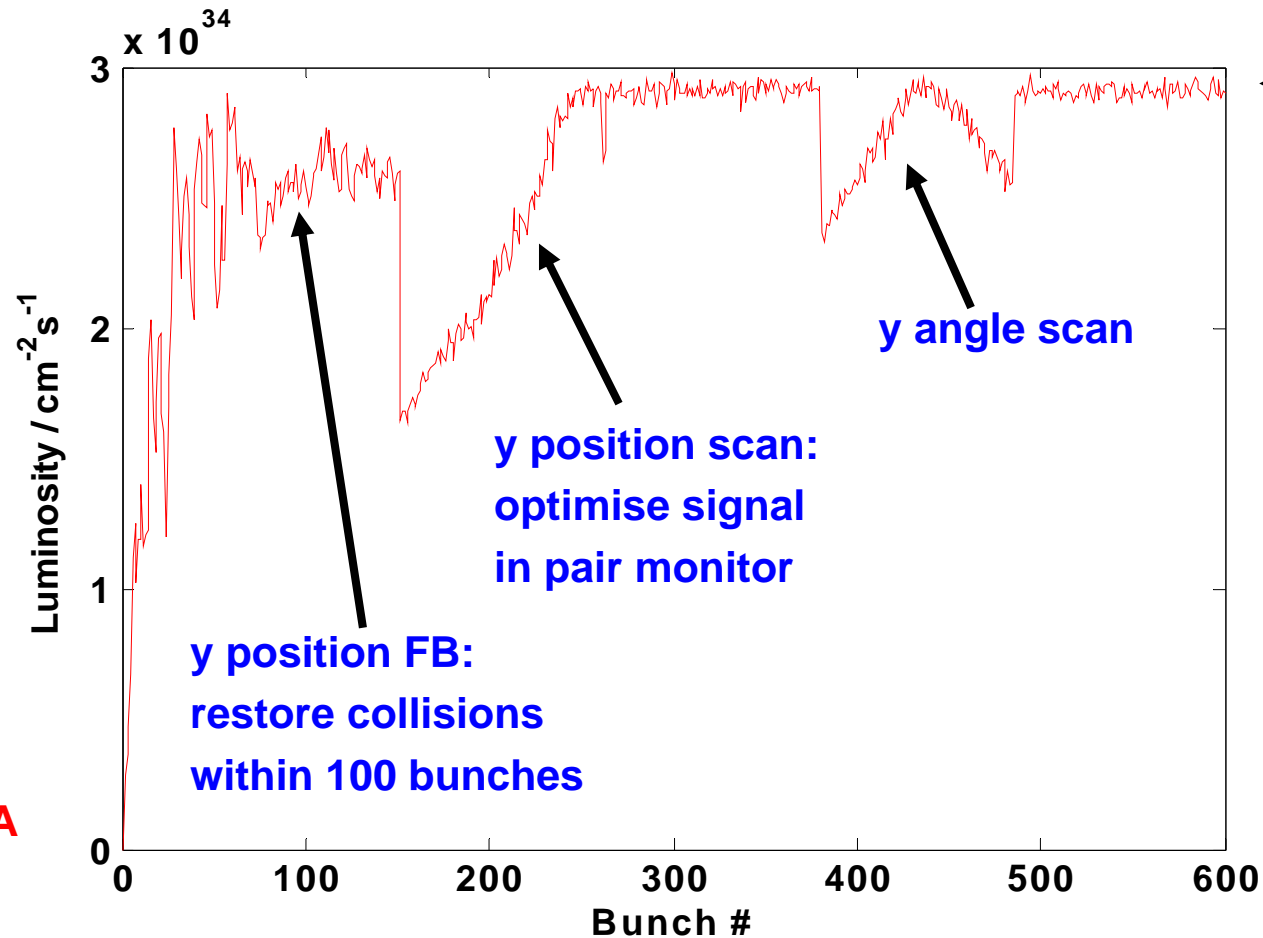*ATF2 Project Meeting, KEK, 30/5/06*

Possible additional developments

Add (beam related?) 'luminosity' signal input to FB
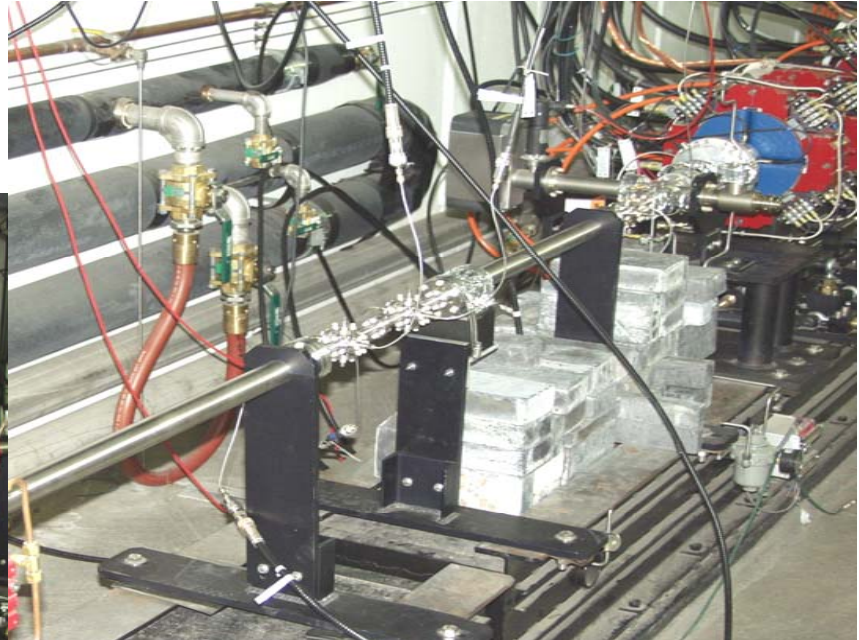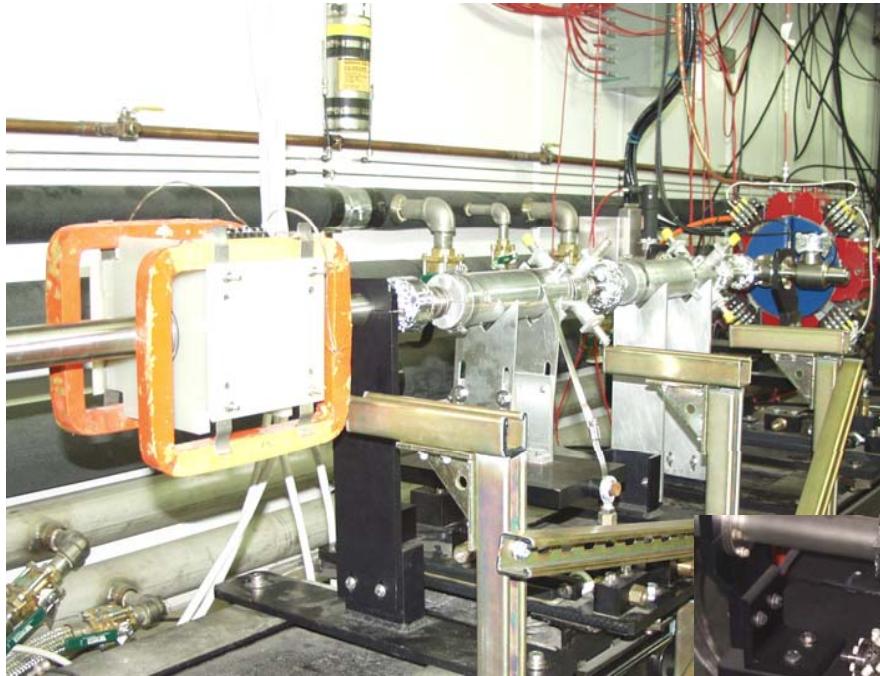   system at ATF(2)

Add angle FB

Extra material
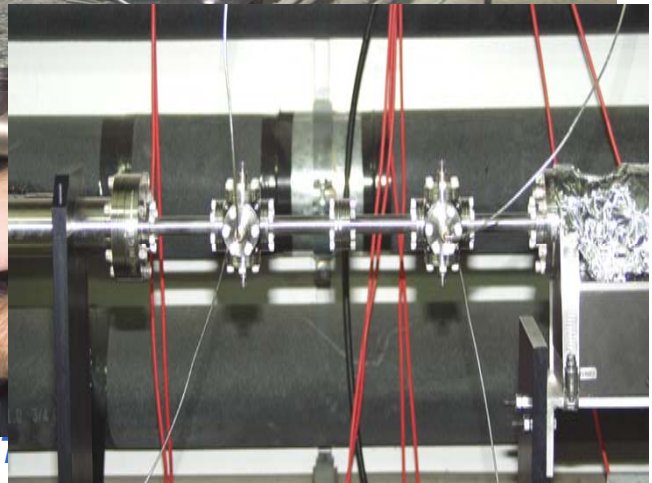
Intra-train feedback simulations

OPTIMAL LUMINOSITY

y angle scan

y position scan:
optimise signal
in pair monitor

y position FB:
restore collisions
within 100 bunches

1 seed:

post-BBA

+ GM

+ wakes

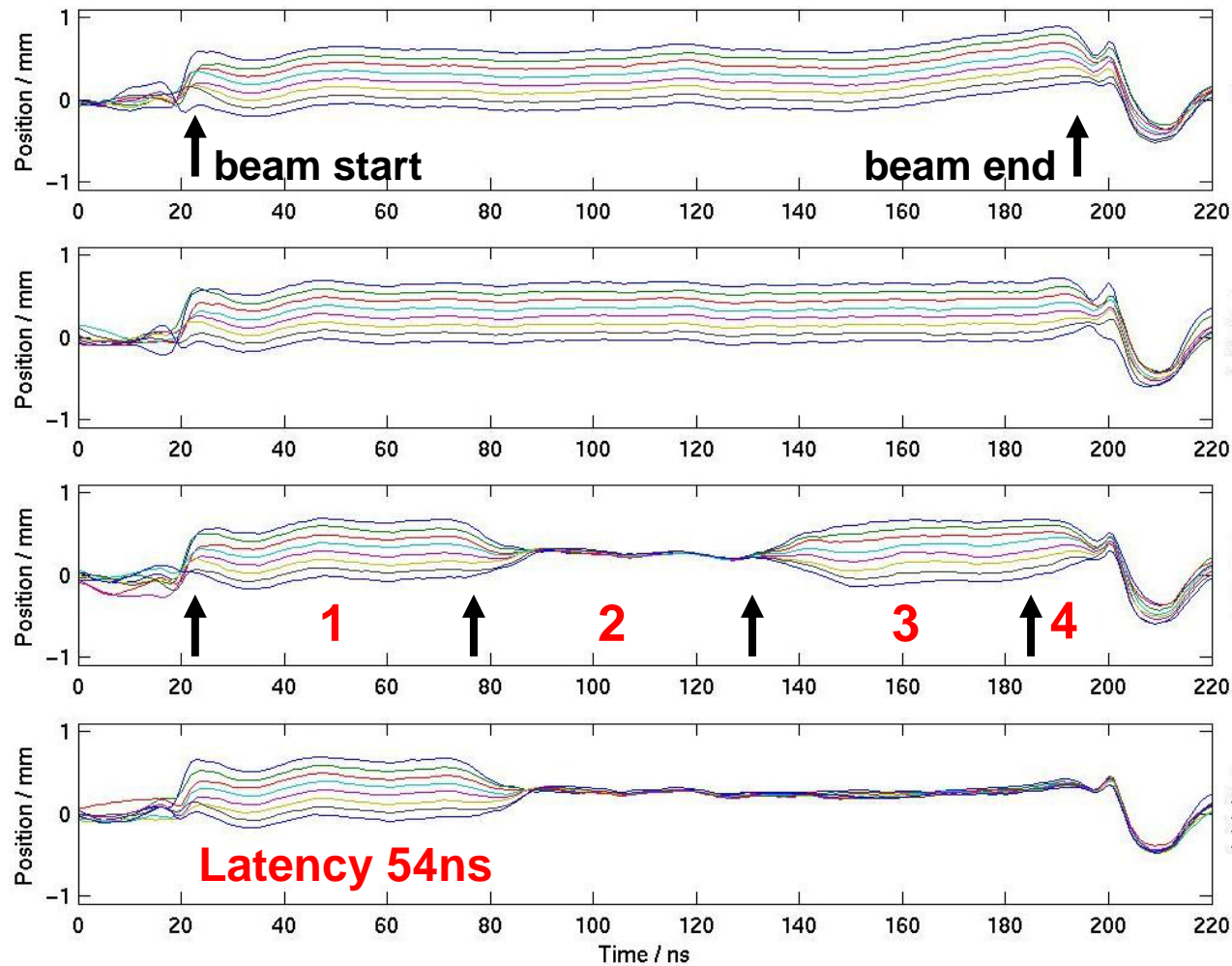*P.N. Burrows*

FONT2 beamline at SLAC NLCTA

Dipole and kickers

BPMs

FONT2 position correction performance

Beam starting positions

Beam flattener on

Feedback on

Delay loop on

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