Intra-train Beam-based Feedback Systems

Philip Burrows

Queen Mary, University of London

- System overview
- FONT @ NLCTA
- FONT/FEATHER plans at ATF
- Possible future directions

International Fast FB Collaboration

- **FONT:**

  Queen Mary: Philip Burrows, Glen White, Tony Hartin,

  Stephen Molloy, Shah Hussain, Christine Clarke + 2 new staff

  Daresbury Lab: Alexander Kalinine, Roy Barlow, Mike Dufau

  Oxford: Colin Perry, Gerald Myatt, Simon Jolly, Gavin Nesom

  SLAC: Joe Frisch, Tom Markiewicz, Marc Ross, Chris Adolphsen, Keith Jobe, Doug McCormick, Janice Nelson, Tonee Smith, Steve Smith, Mark Woodley

- **FEATHER:**

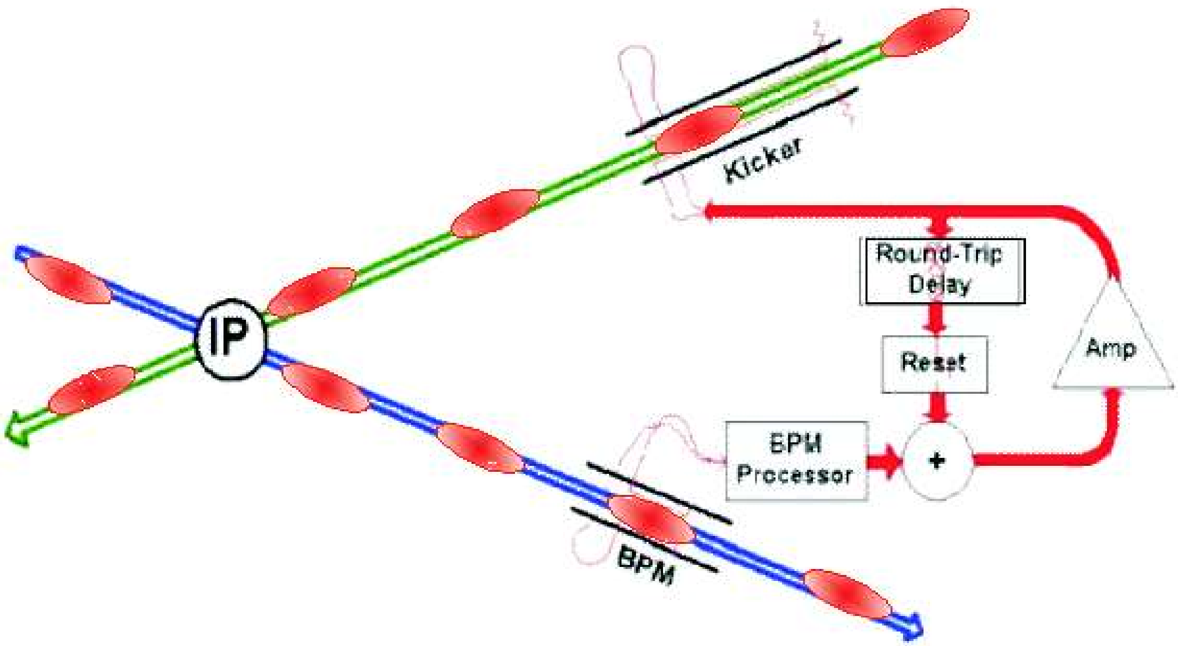
  KEK: Nicolas Delerue, Toshiaki Tauchi, Hitoshi Hayano

  Tokyo Met. University: Takayuki Sumiyoshi, Fujimoto

- **Simulations: Nick Walker (DESY), Daniel Schulte (CERN)**

Intra-train Beam-based Feedback

Intra-train beam feedback is last line of defence against ground motion



Key components:

Beam position monitor (BPM)

Signal processor

Fast driver amplifier

E.M. kicker

Fast FB circuit

Warm: augments active stabilisation

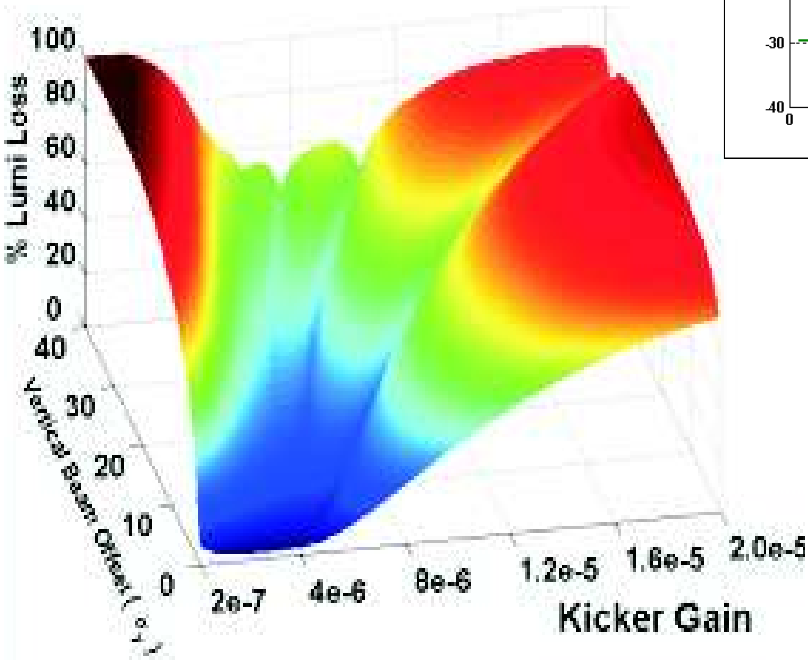
Cold: principal ground-motion correction

Beam Feedback Luminosity Recovery

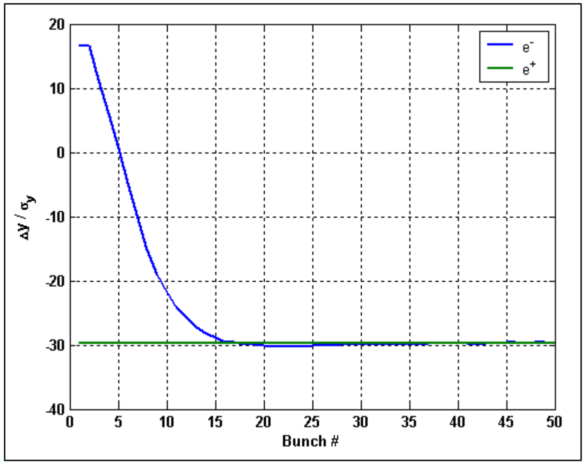
G/NLC:

recover > 80% of

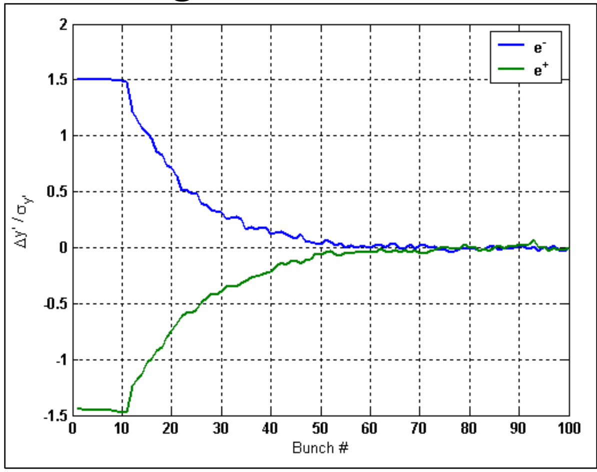
design luminosity



Position scan:



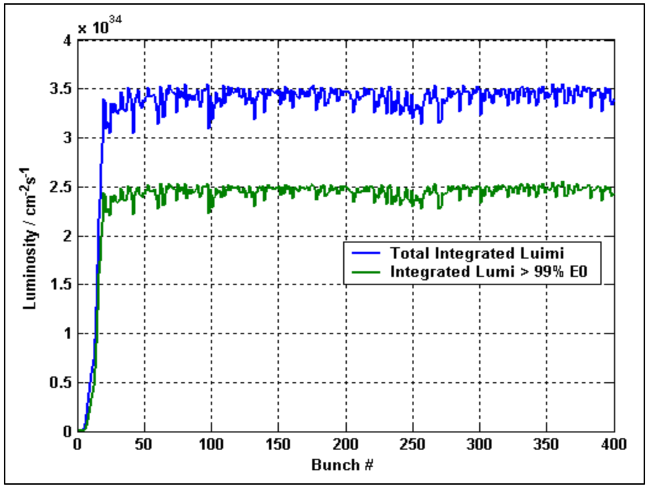
Angle scan:



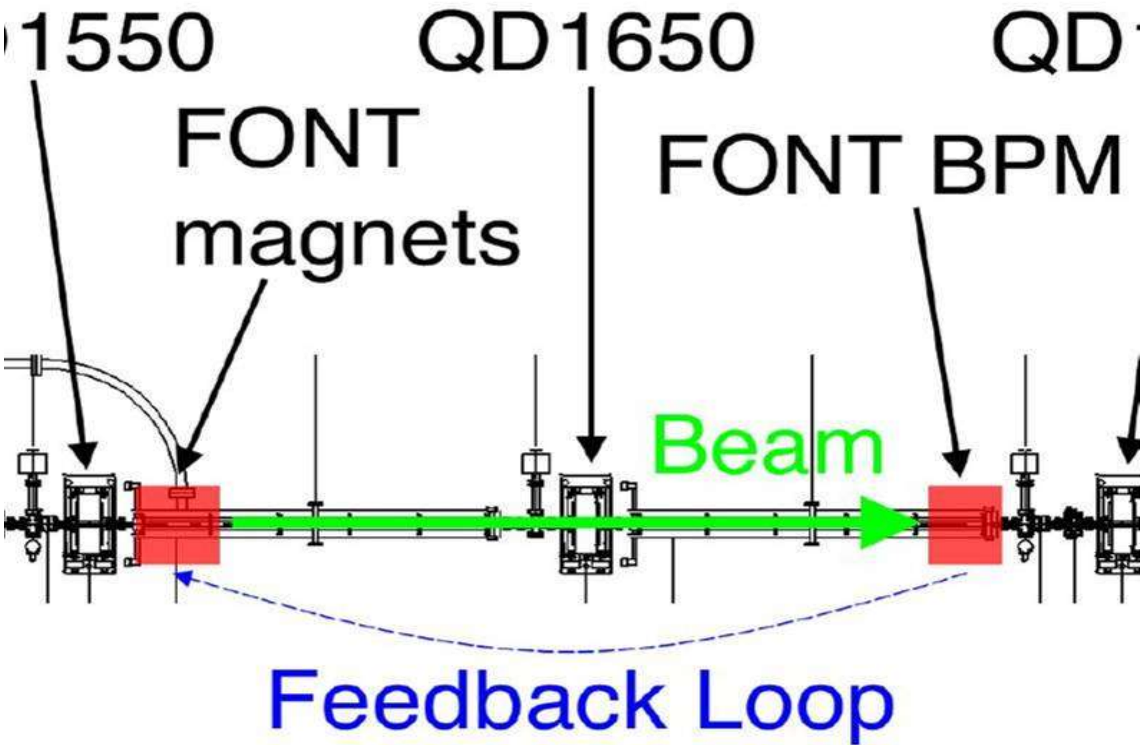
Cold:

> 95%

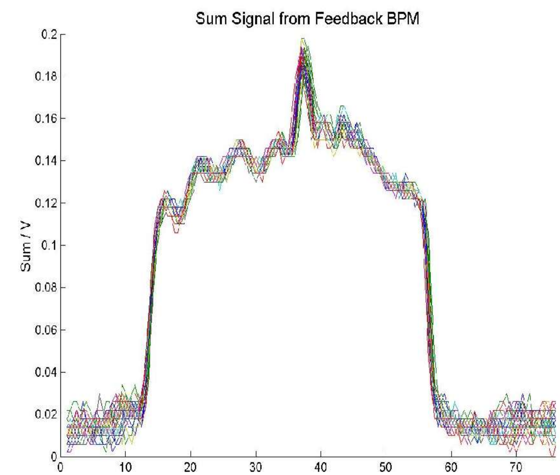
feasible



Feedback on Nanosecond Timescales (FONT) (SLAC/NLCTA)



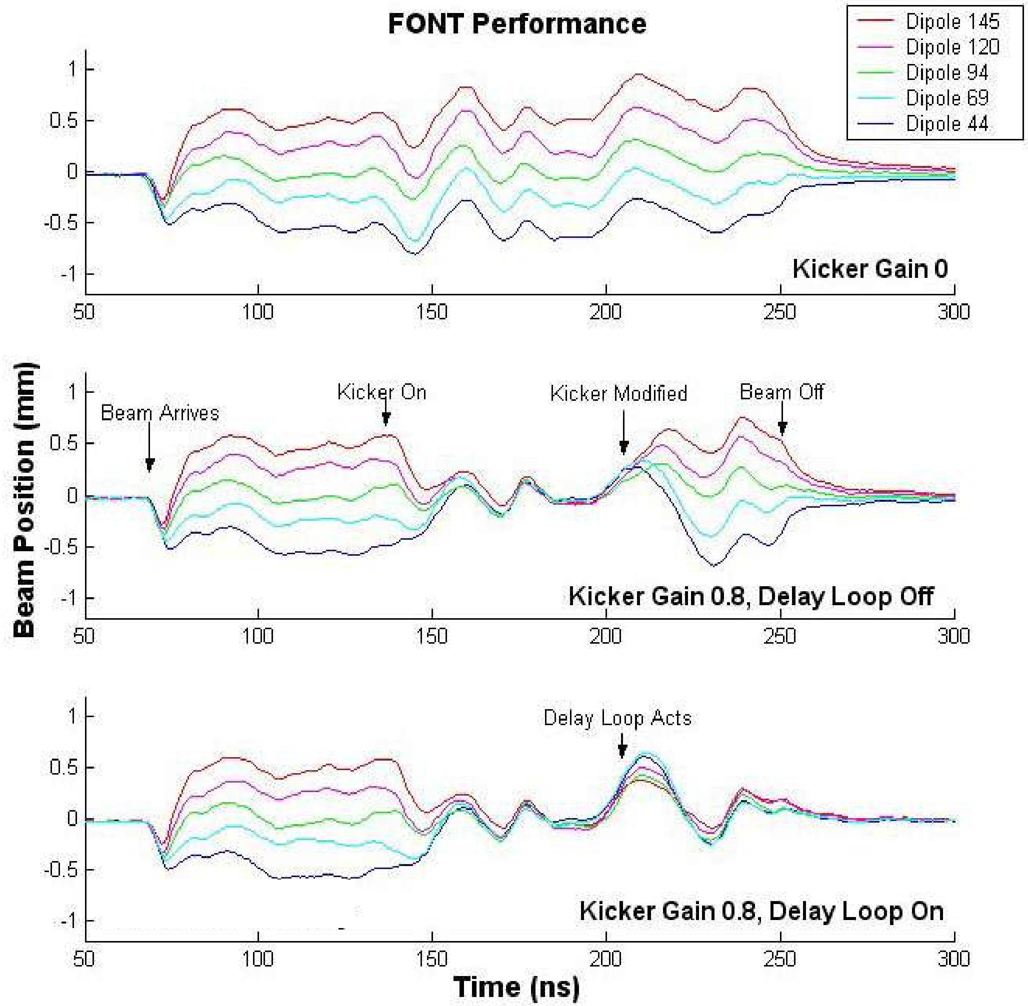
- **100 micron train-train jitter**
- **bunched at X-band (87ps)**
- **50% Q variation along train:**



- **170ns long train**
- **1mm size beam**
- **few 100 micron offsets**

FONT1: results (September 2002)

3kW tube amplifier:



10/1 position correction

latency of 67 ns

FONT1: expected latency

- **Time of flight kicker – BPM: 14ns**
- **Signal return time BPM – kicker: 18ns**

Irreducible latency: 32ns

- **BPM cables + processor: 5ns**
- **Preamplifier: 5ns**
- **Charge normalisation/FB circuit: 11ns**
- **Amplifier: 10ns**
- **Kicker fill time: 2ns**

Electronics latency: 33ns

- **Total latency expected: 65ns**

FONT2: outline

Goals of improved FONT2 setup:

- **Additional 2 BPMs:** **independent position monitoring**
- **Second kicker added:** **allows solid state amplifiers**
- **Shorter distance between kickers and FB BPM:**

  irreducible latency now c. 16 ns
- **Improved BPM processor:**

  real-time charge normalisation using log amps (slow)
- **Expect total latency c. 53 ns:**

  allows 170/53 = 3.2 passes through system
- **Added 'beam flattener' to remove static beam profile**
- **Automated DAQ including digitisers and dipole control**

FONT2: expected latency

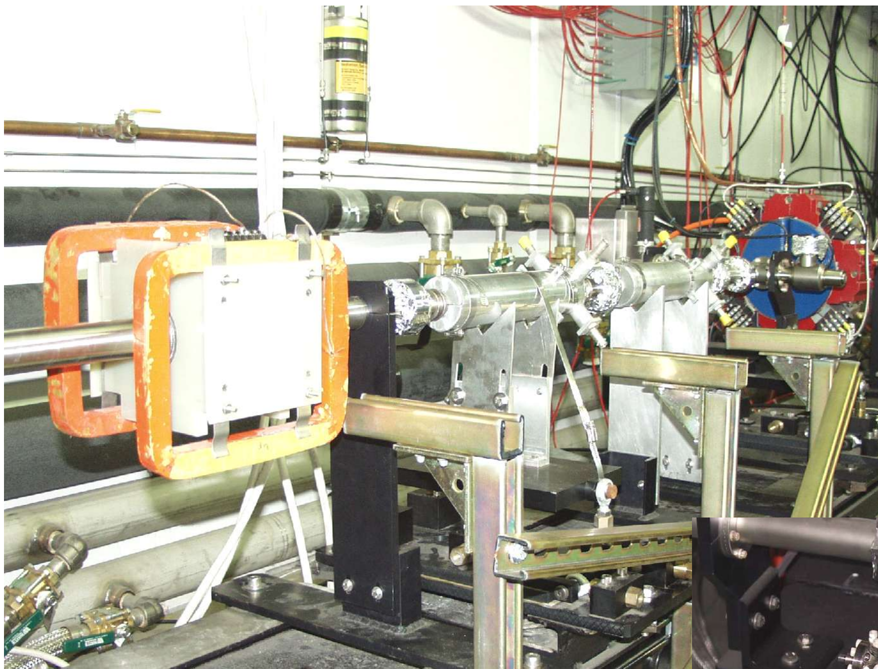
- Time of flight kicker – BPM: 6ns
- Signal return time BPM – kicker: 10ns

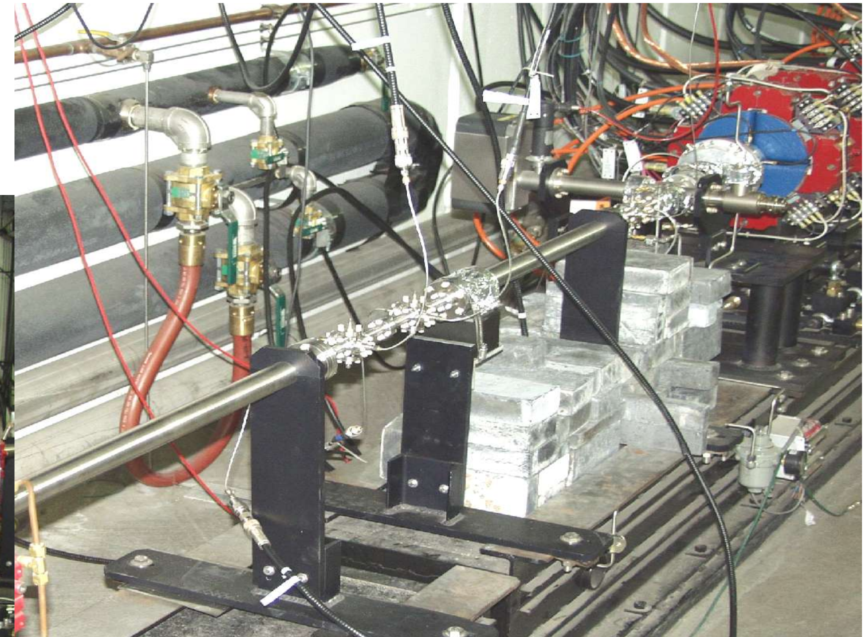
  Irreducible latency: 16ns
- BPM processor: 18ns
- FB circuit: 4ns
- Amplifier: 12ns
- Kicker fill time: 3ns

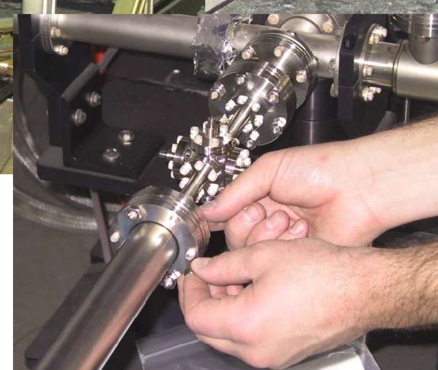
  Electronics latency: 37ns
- Total latency expected: 53ns

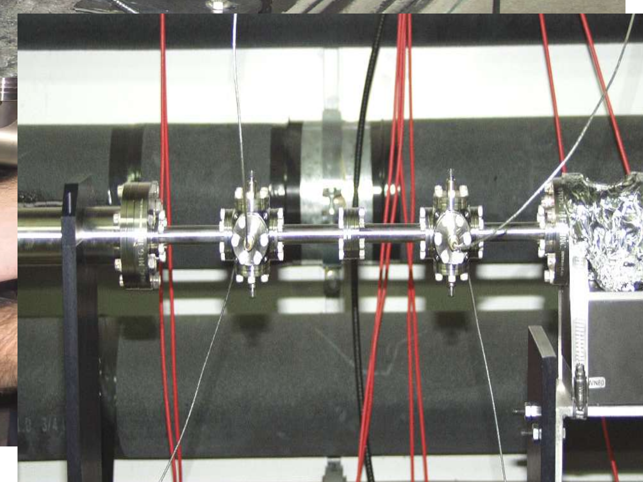
FONT2: beamline configuration

Dipole and kickers



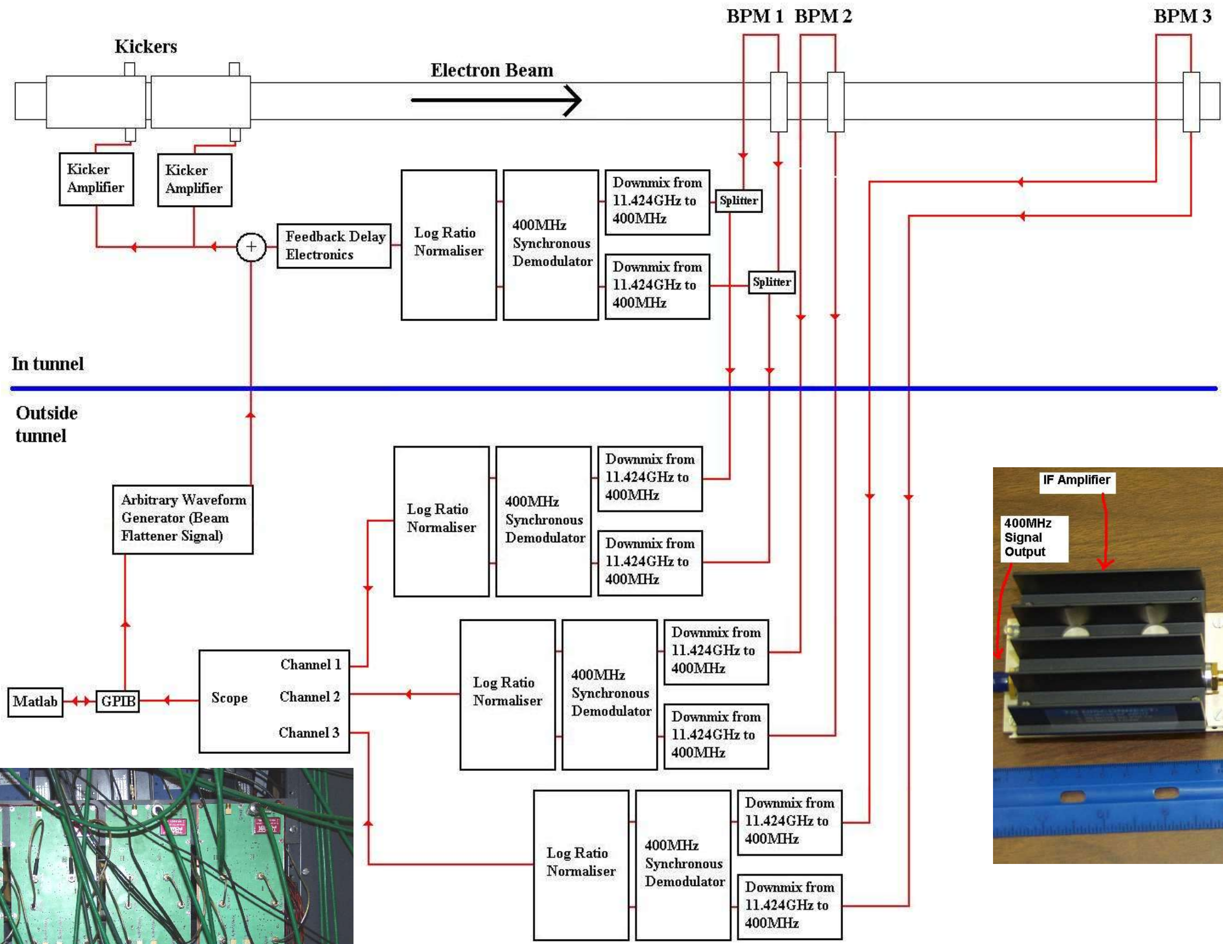


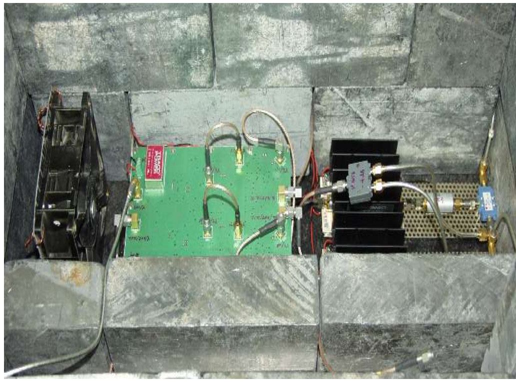


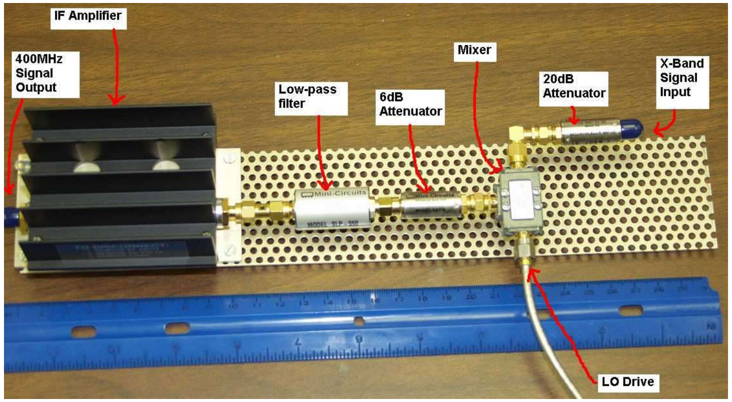


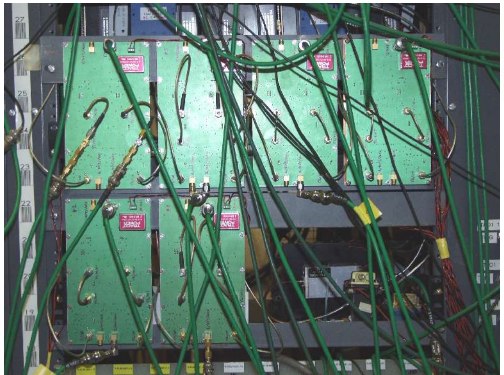
New BPMs

FONT2: BPM signal processing



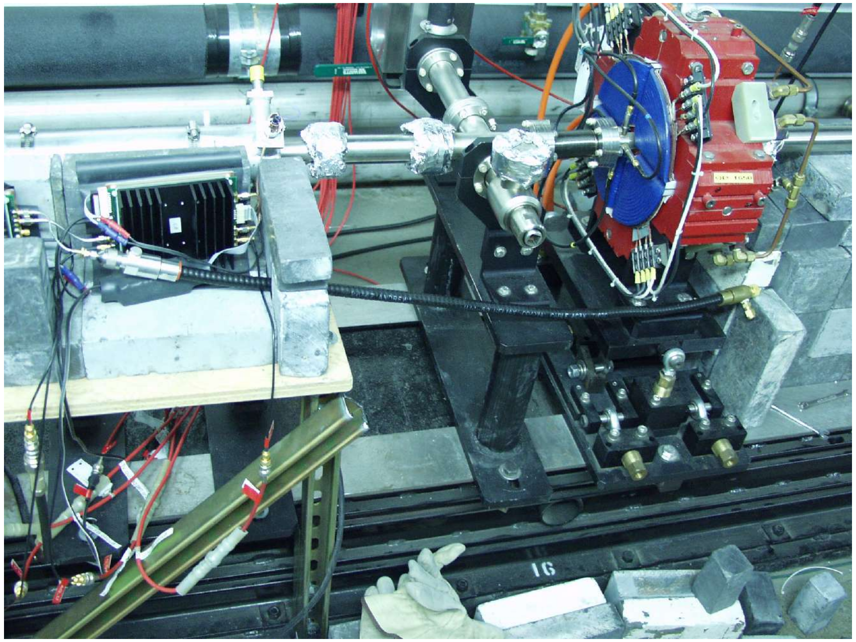




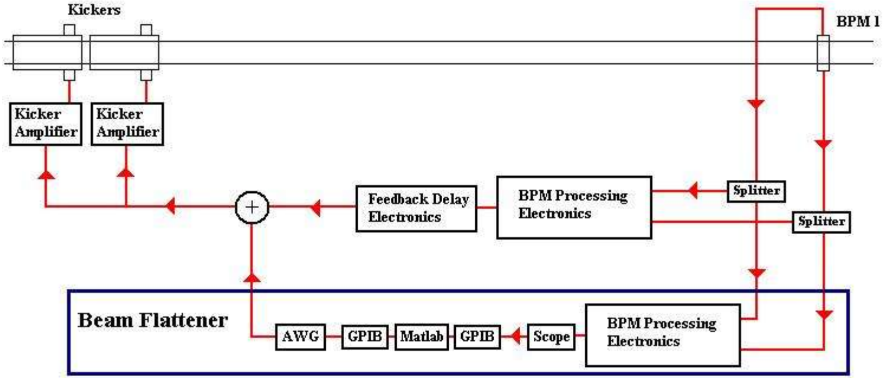


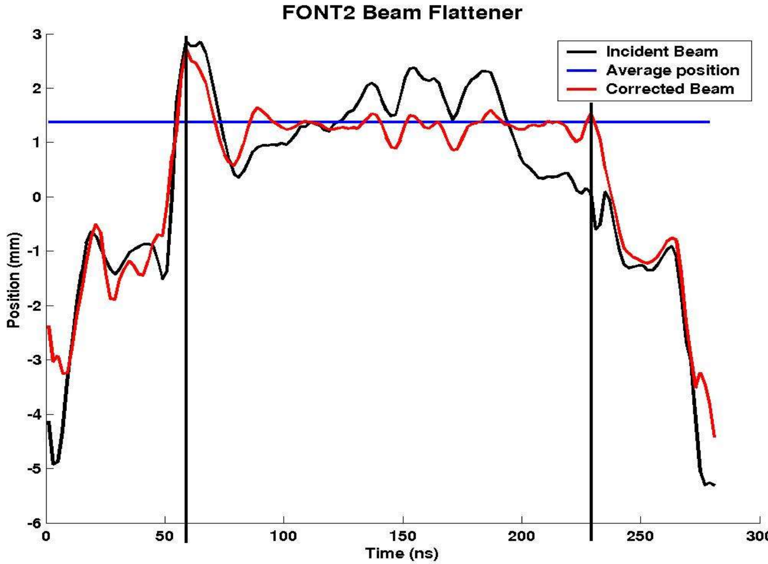
FONT2: amplifier + beam flattener

FB signal into amplifier:



Beam flattener:



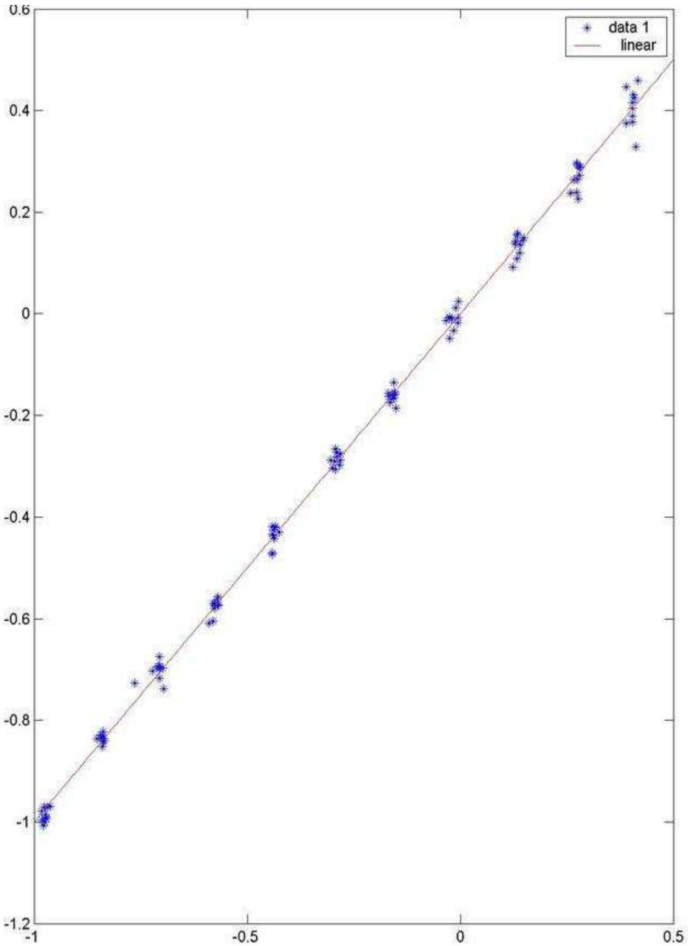


Bandwidth limited (30 MHz)

Philip Burrows

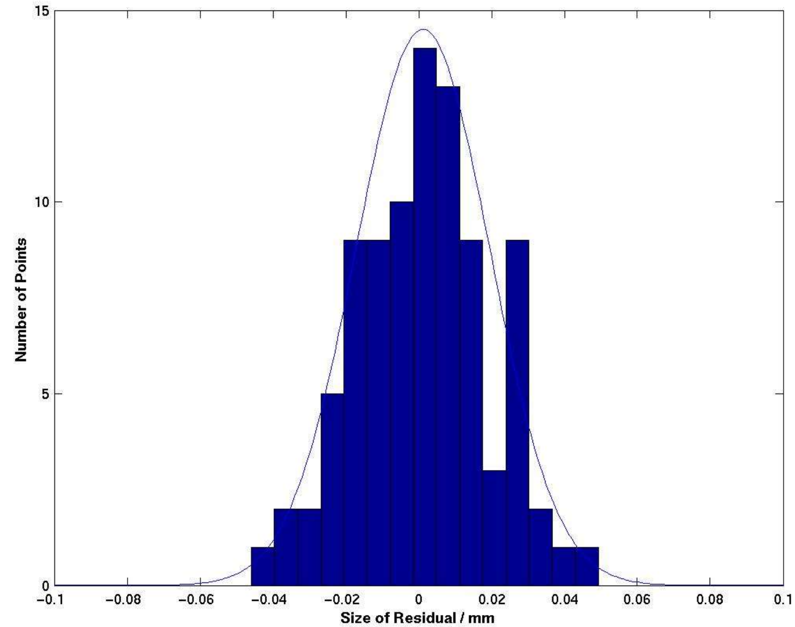
FONT2 BPM resolution

Actual position



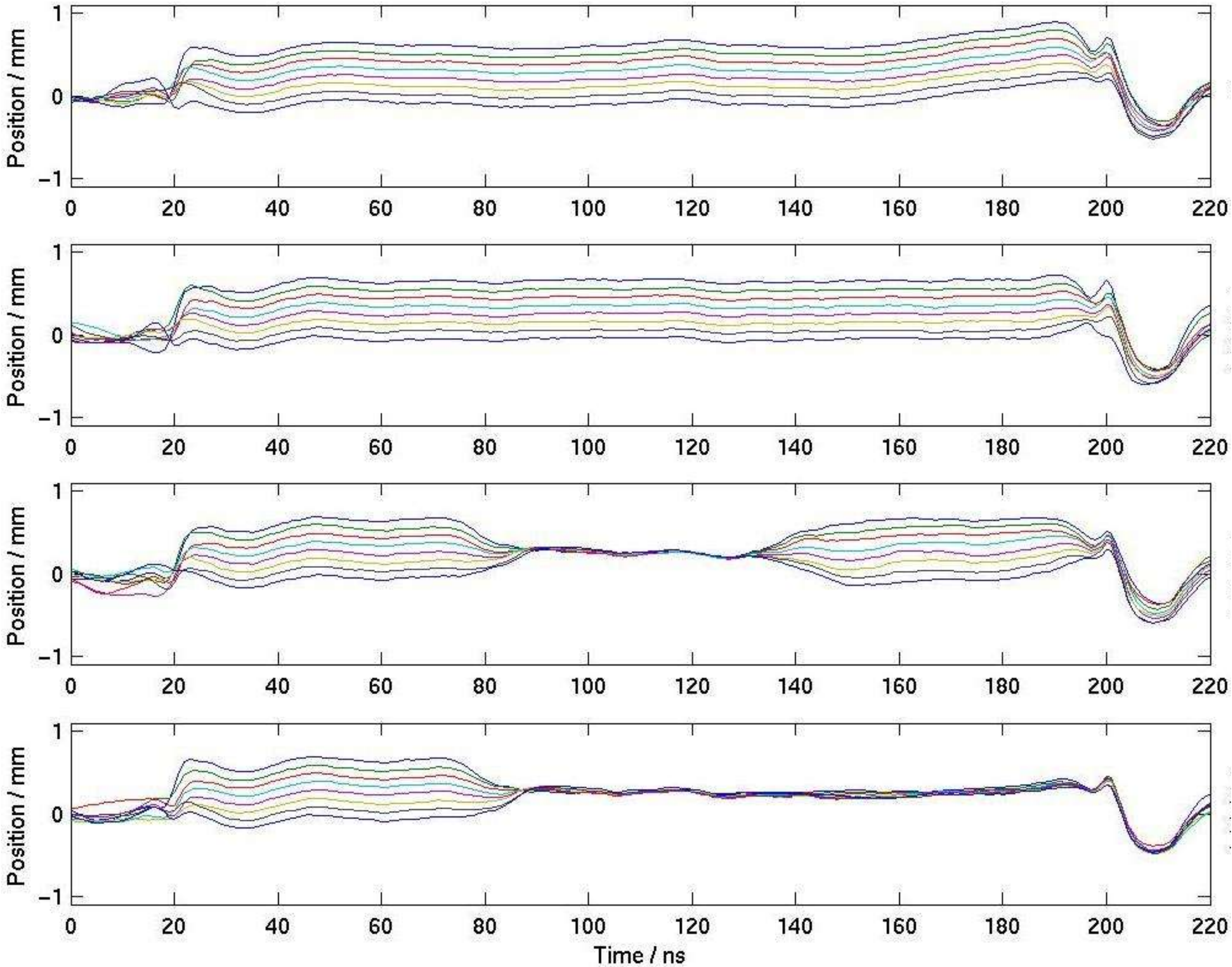
Predicted position

Residuals:



Resolution 14 microns

FONT2 results: feedback BPM



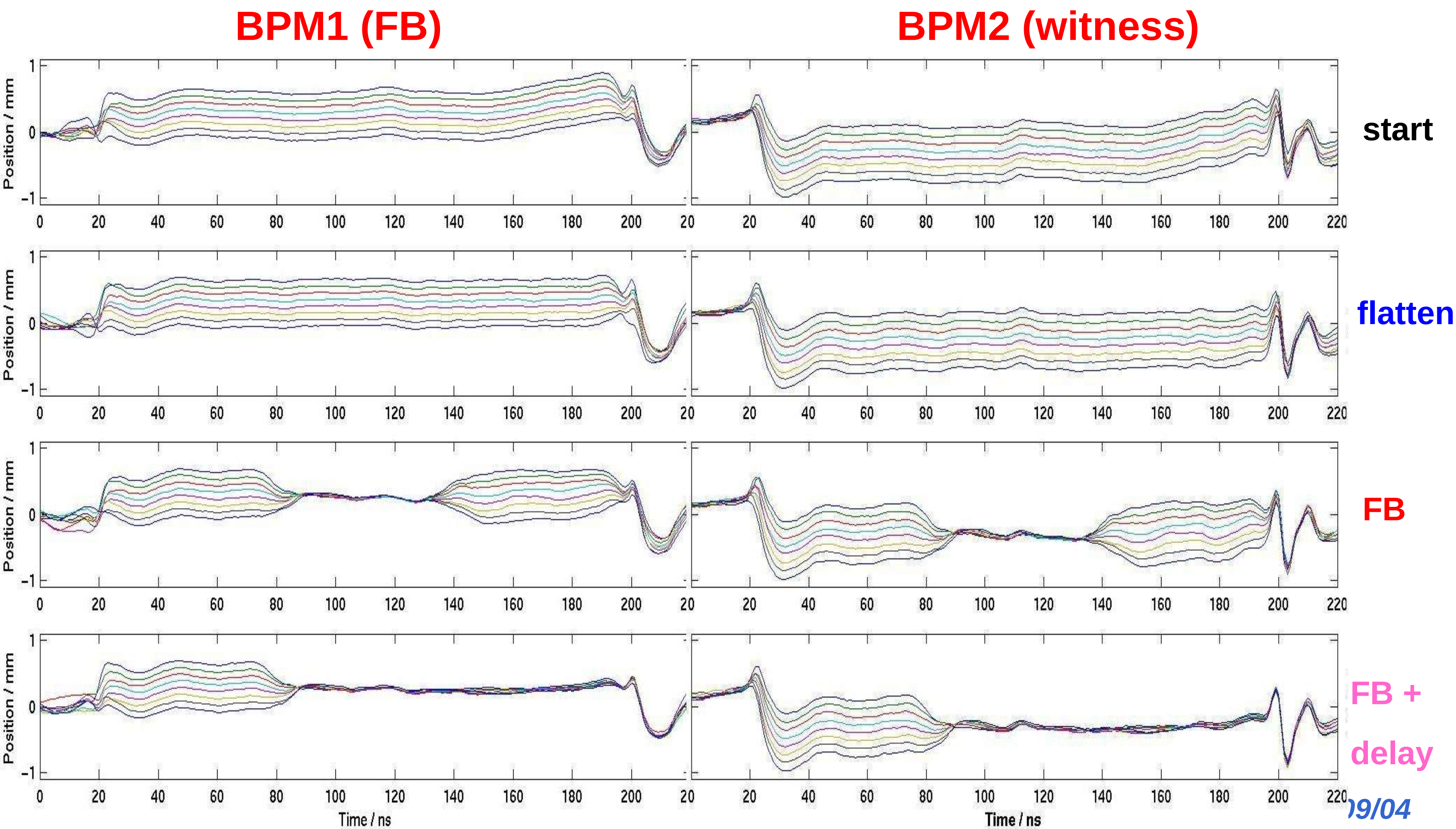
Beam starting positions

Beam flattener on

Feedback on

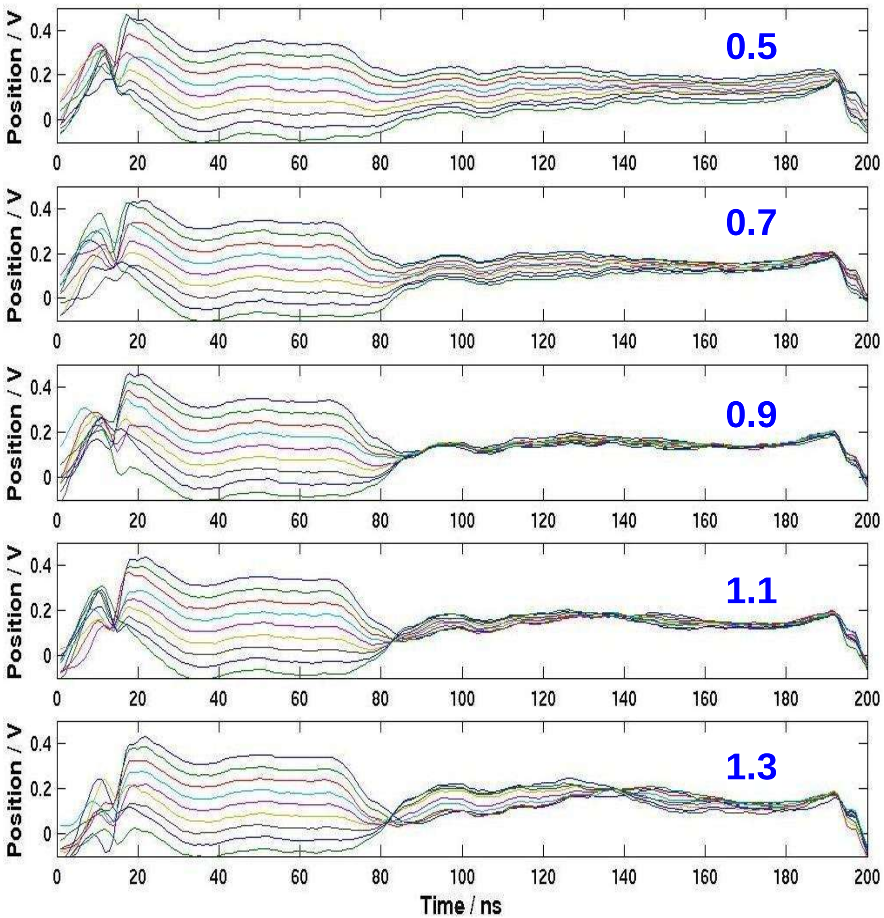
Delay loop on

FONT2 results: witness vs. FB BPMs

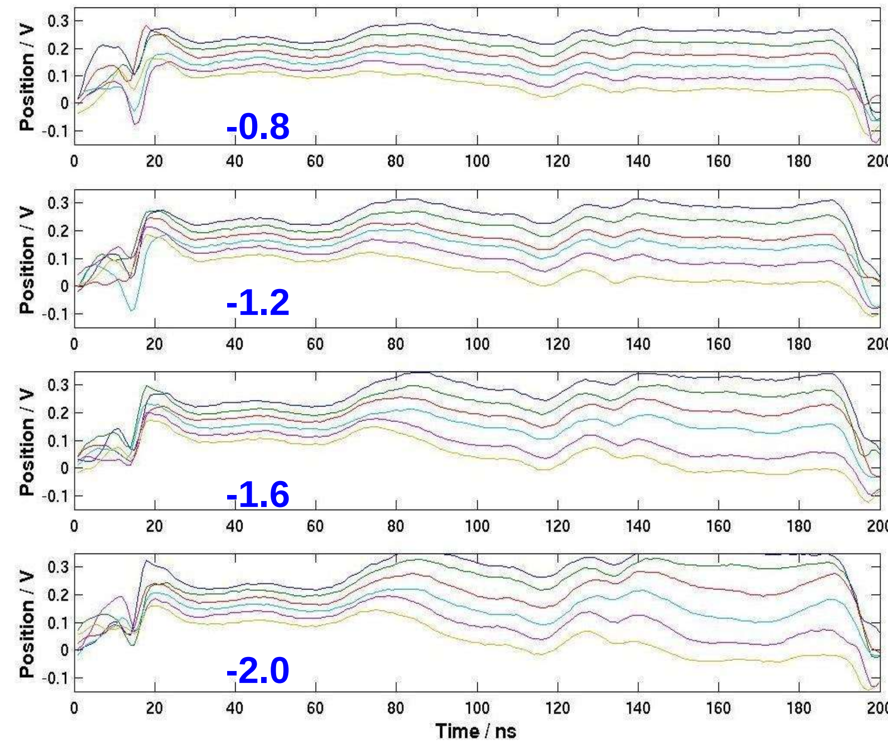


FONT2 results: gain studies

Vary main gain



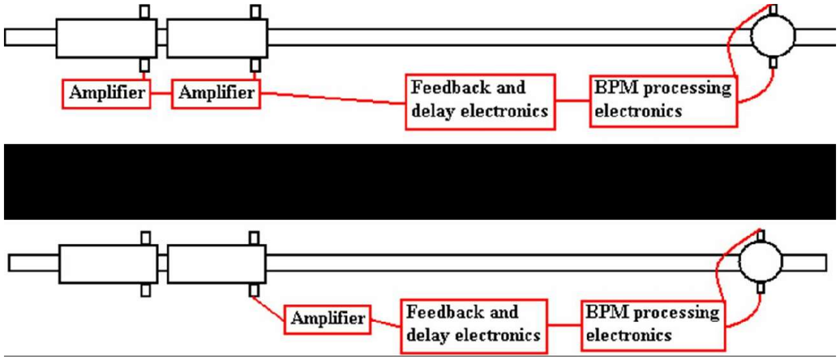
Main gain –ve (!)

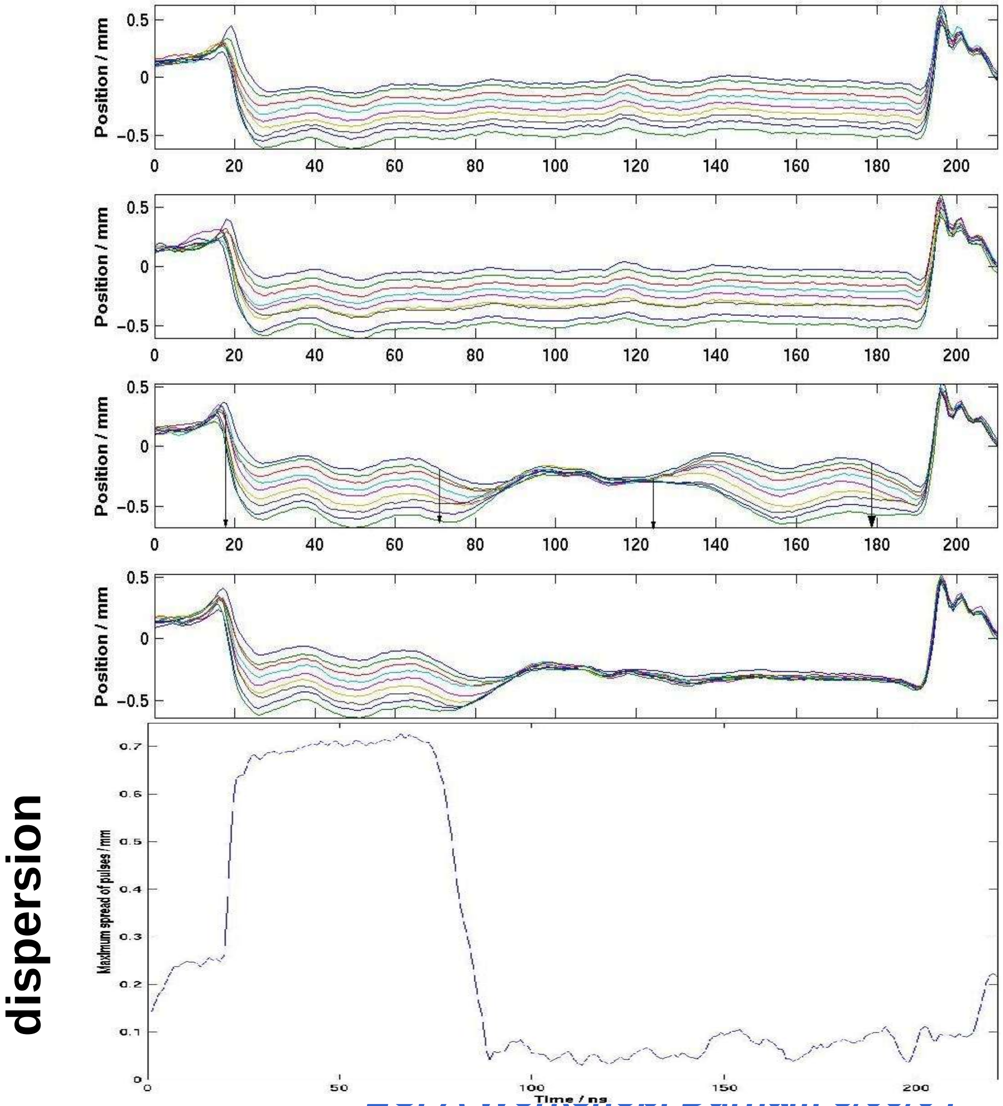


Also: delay loop length + gain …

FONT2 final results (Jan 22 2004)

Super-fast modified configuration:





Latency 54ns

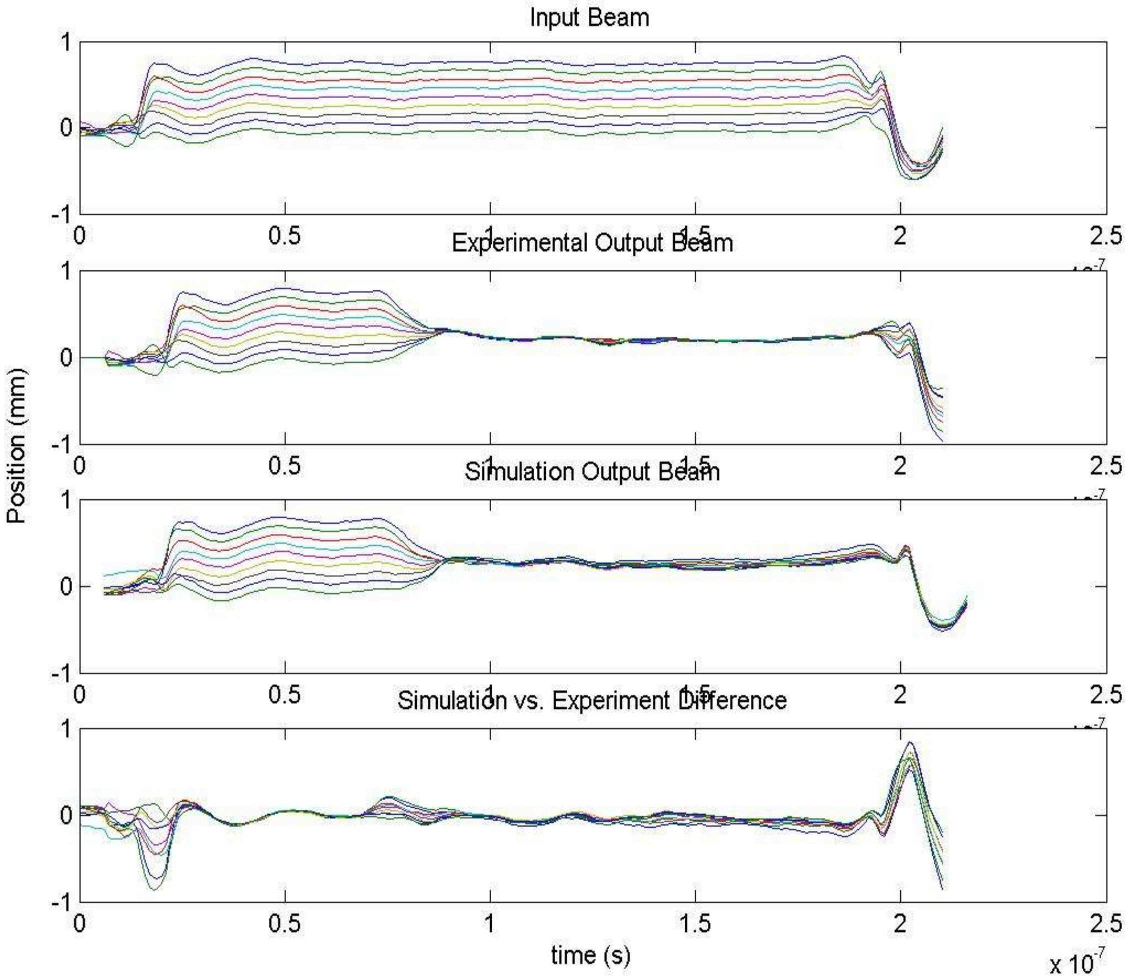
Correction 14:1

(limited by gain knob resolution)

FONT2 Simulation

Simulation includes:

- **time of flight**
- **cable delays**
- **latencies**
- **bandwidths**
- **delay loop**



Useful tool for LC

FB simulations

Summary

- We have prototyped and tested with beam the essential components of fast beam-based feedback systems:

  BPMs, signal processors, FB, amplifiers, kickers

- The achieved latency satisfies requirements for cold Linear Collider

Future Directions (1)

- **To be coordinated with Eurotev, regional partners, GDI:**

  Stabilising 1000 GeV @ 1 nm ⇘ 1 GeV beam @ 1 mu

  requires: low-power (< 100W), high stability amplifier

  + BPMs with micron resolution

  -> exactly what are needed for LC FB systems

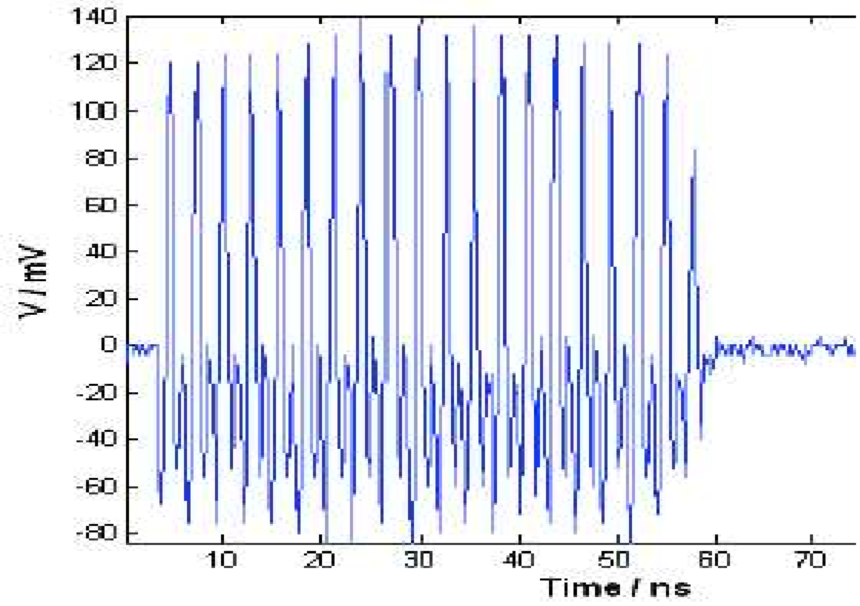
- **Planning FONT3 at ATF extraction line: stabilise 1.3 GeV beam at micron level (56ns train, bunched at 2.8ns)**

  test: BPM processor (December 04)

  amplifier (March 05)

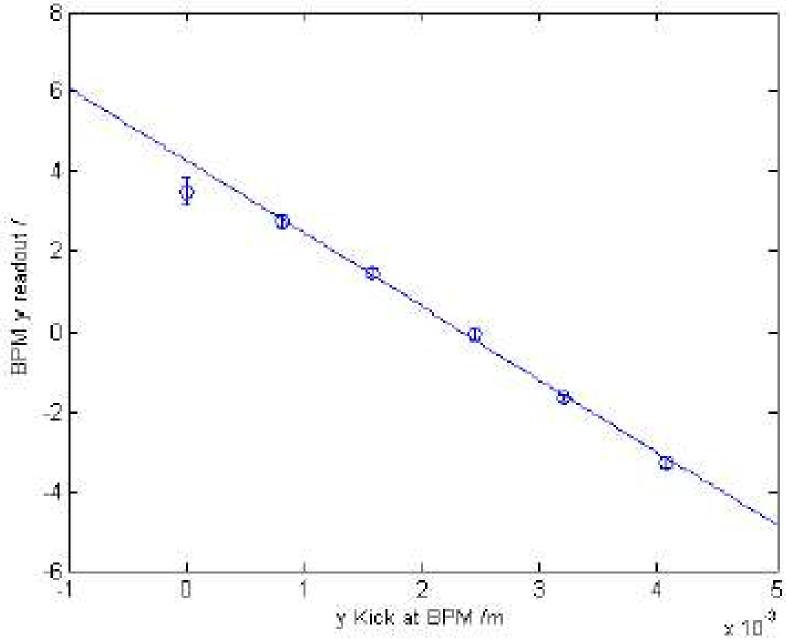
  closed loop FB (June 05)

Beam tests at ATF extraction line (June 04)



20-bunch train measured with BPM processor

beam position scan



Future Directions (2)

- **For cold LC the signal processing can be digital:**

  more sophisticated algorithms,

  higher robustness,

  larger dynamic range

- **System tests at TTF2/XFEL are in principle possible**

Future Directions (3)

The SLAC A-line is potentially extremely useful for IP FB system tests:

High-energy bunches w. ILC charge can be delivered to well instrumented laboratory (BPMs, magnets):

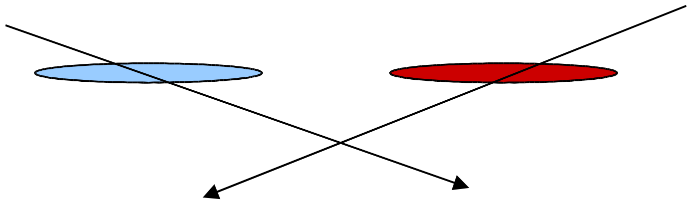
RF pickup studies

High-flux e+e- pairs mimic LC IR environment:

study impact of pair background on BPM resolution

Other issues for intra-train feedbacks

- **Beam angle-jitter:**



correction best done near IP with RF crab cavity (needed anyway for 2nd IR):

design + prototyping starting in UK

- **Ideally, feedback on luminosity:**
  bunch-by-bunch luminosity measurement would allow intra-train luminosity feedback – much easier for cold LC!