Intra-train Beam-based Feedback Systems

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- **System overview**
- **FONT/NLCTA**
- **FEATHER/ATF**
- **Future plans**

International Collaboration

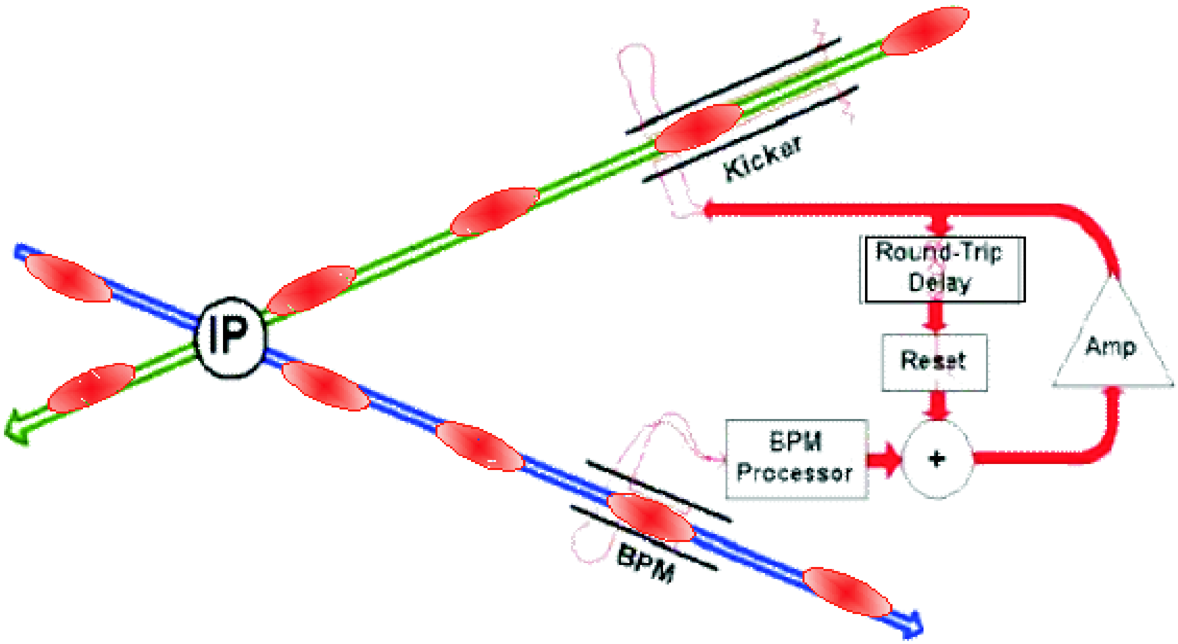
- **FONT:**
  - Queen Mary: Philip Burrows, Glen White, Tony Hartin, Stephen Molloy, Shah Hussain
  - Daresbury Lab: Alexander Kalinine, Roy Barlow, Mike Dufau
  - Oxford: Colin Perry, Gerald Myatt, Simon Jolly, Gavin Nesom
  - SLAC: Joe Frisch, Tom Markiewicz, Marc Ross, Chris Adolphsen, Keith Jobe, Doug McCormick, Janice Nelson, Tonee Smith, Steve Smith, Mark Woodley

- **FEATHER:**
  - KEK: Nicolas Delerue, Toshiaki Tauchi, Hitoshi Hayano
  - Tokyo Met. University: Takayuki Sumiyoshi

- **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

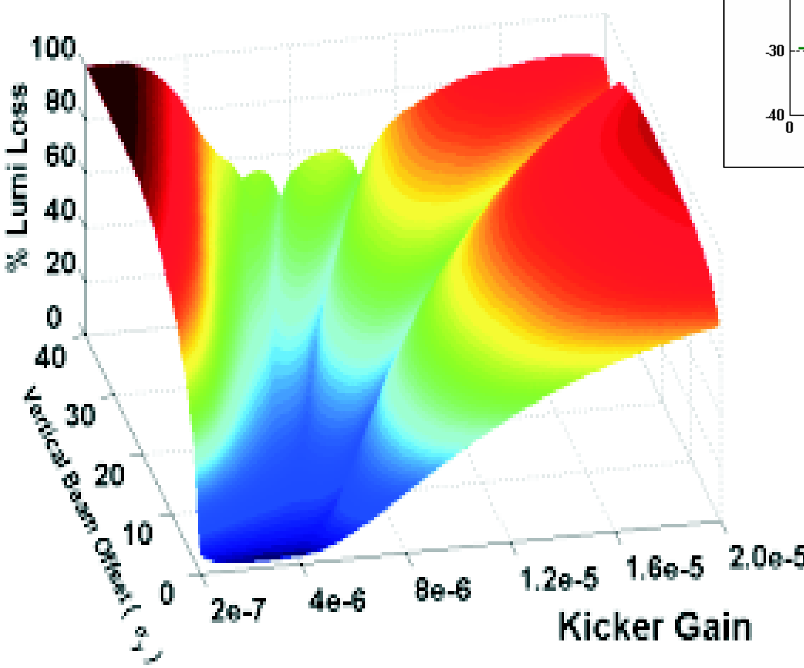
Warm: augments active stabilisation

Cold: principal ground-motion correction

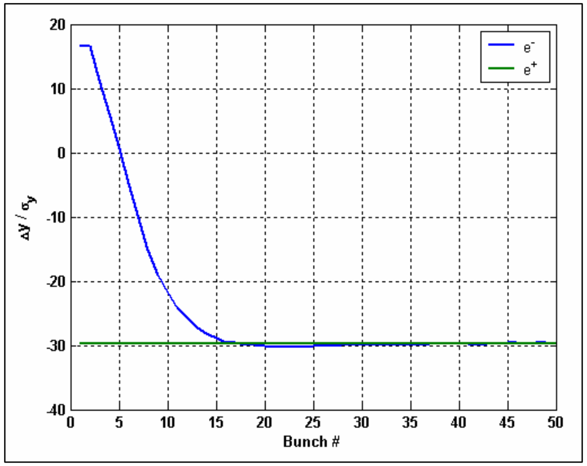
Beam Feedback Luminosity Recovery

G/NLC:

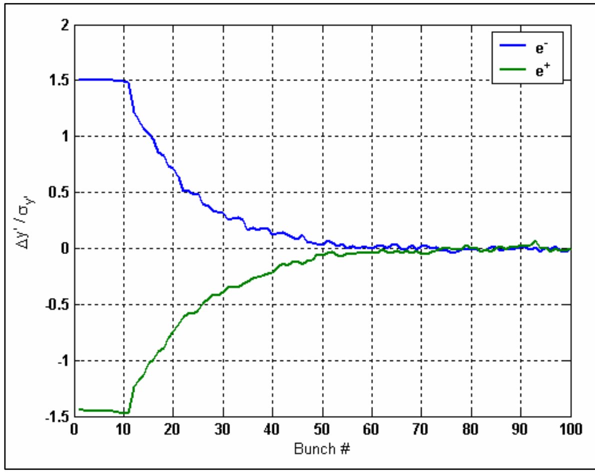
recover > 80% of design luminosity



Position scan:

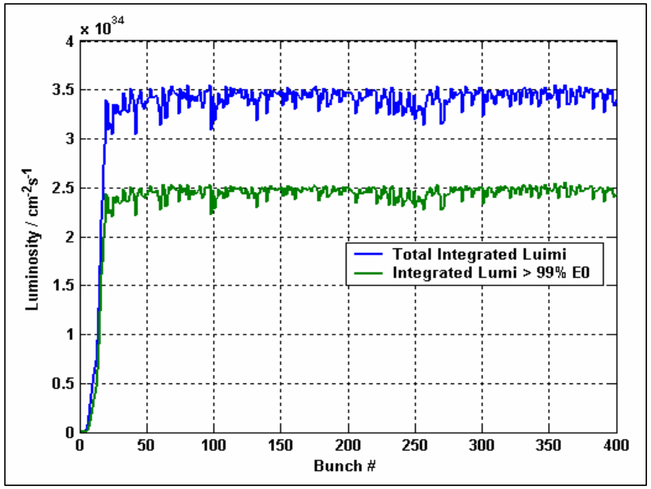


Angle scan:

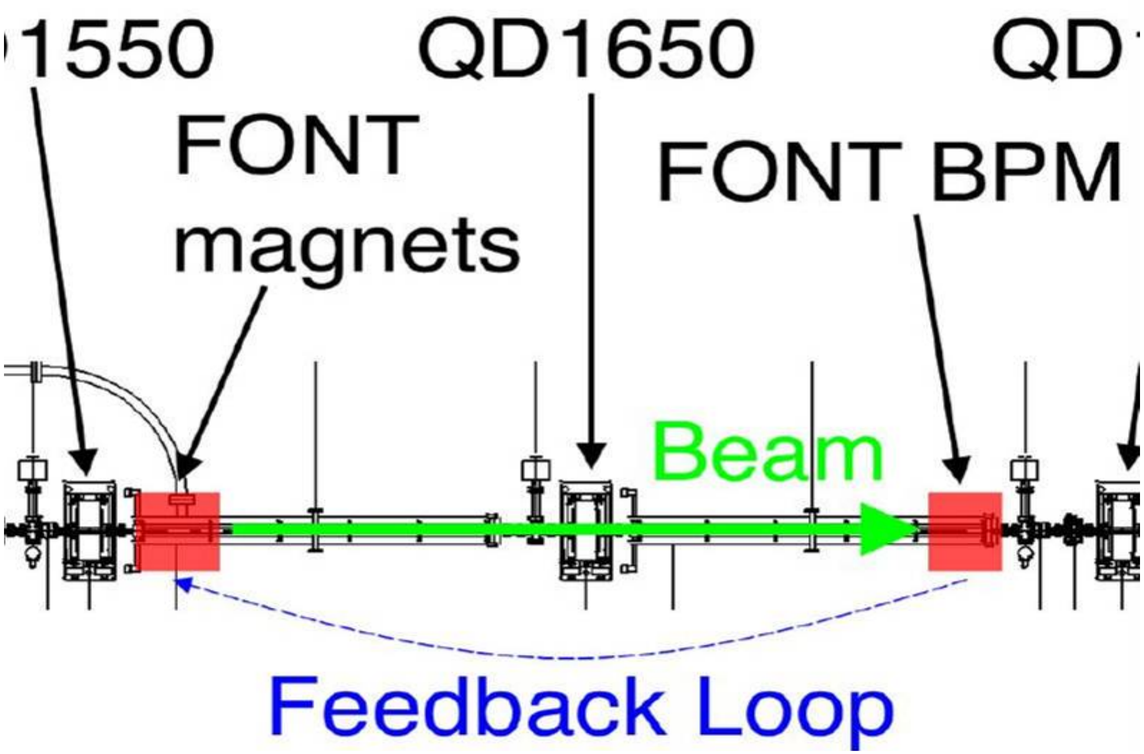


TESLA:

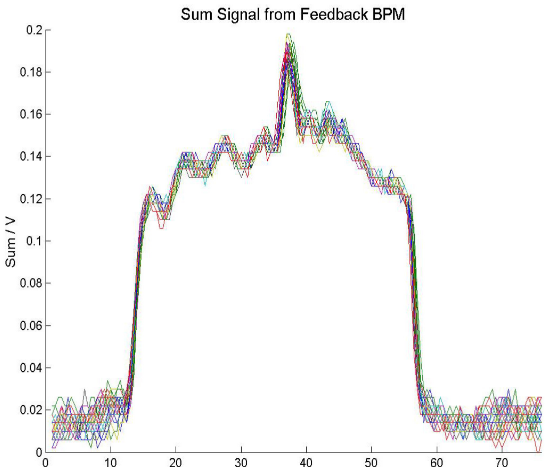
> 95% feasible



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



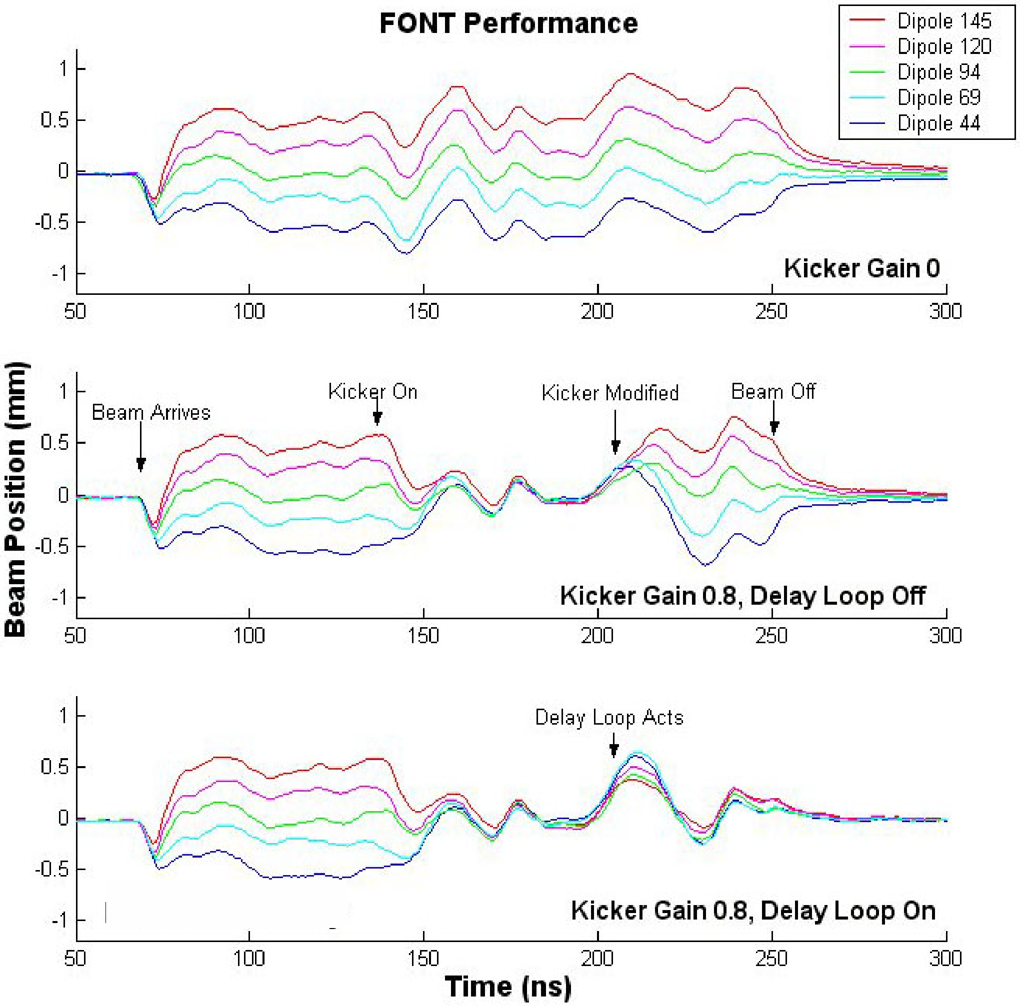
- **100 micron train-train jitter**
- **bunched at X-band (87ps)**
- **50% Q variation along train:**



- **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:

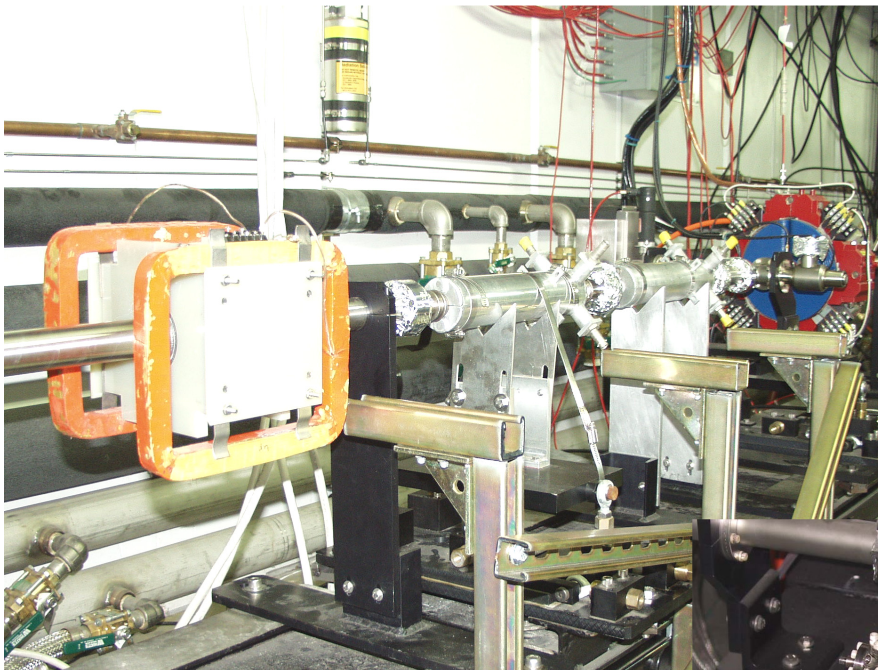
- **Additional 2 BPMs:** independent position monitoring
- **Second kicker added:** allows solid state amplifiers
- **Shorter distance between kickers and FB BPM:**
  irreducible latency now c. 16 ns
- **Improved BPM processor:**
  real-time charge normalisation using log amps (slow)
- **Expect total 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**

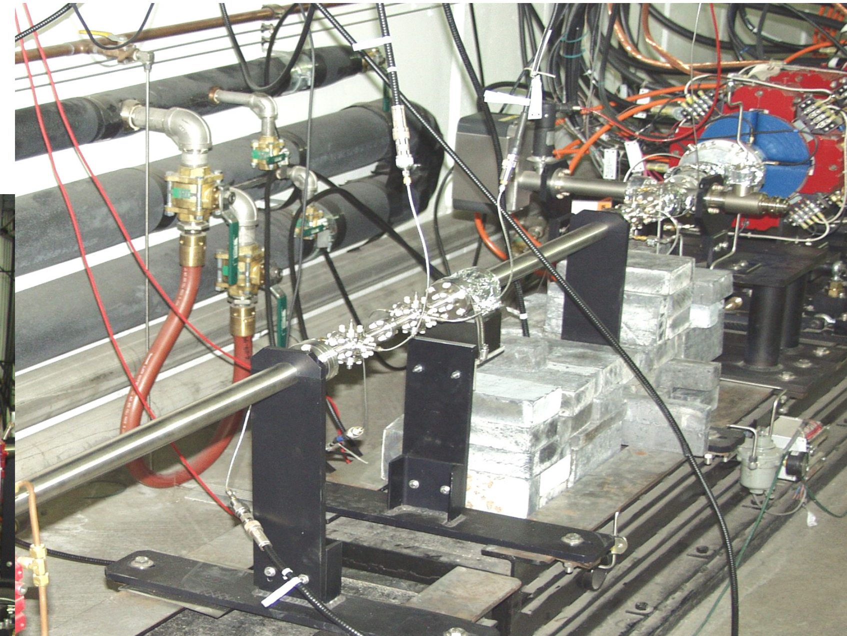
FONT2: expected latency

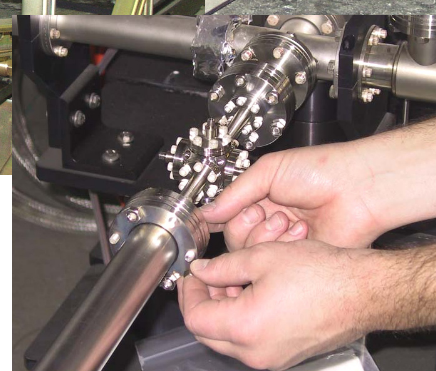
• Time of flight kicker – BPM:	6ns
• Signal return time BPM – kicker:	10ns
Irreducible latency:	16ns
• BPM processor:	18ns
• FB circuit:	4ns
• Amplifier:	12ns
• Kicker fill time:	3ns
Electronics latency:	37ns
• Total latency expected:	53ns

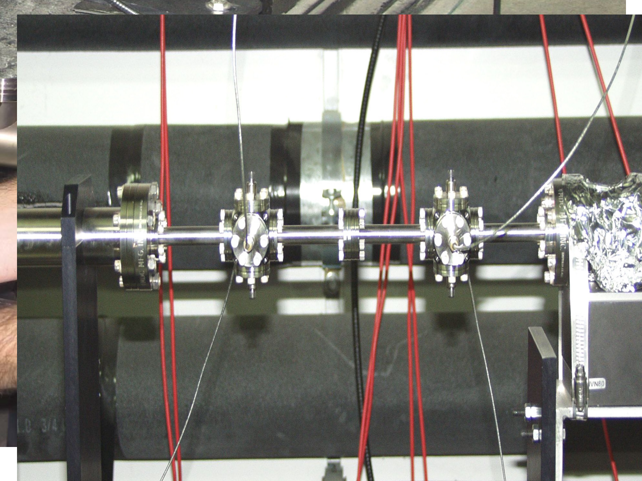
FONT2: beamline configuration

Dipole and kickers









New BPMs

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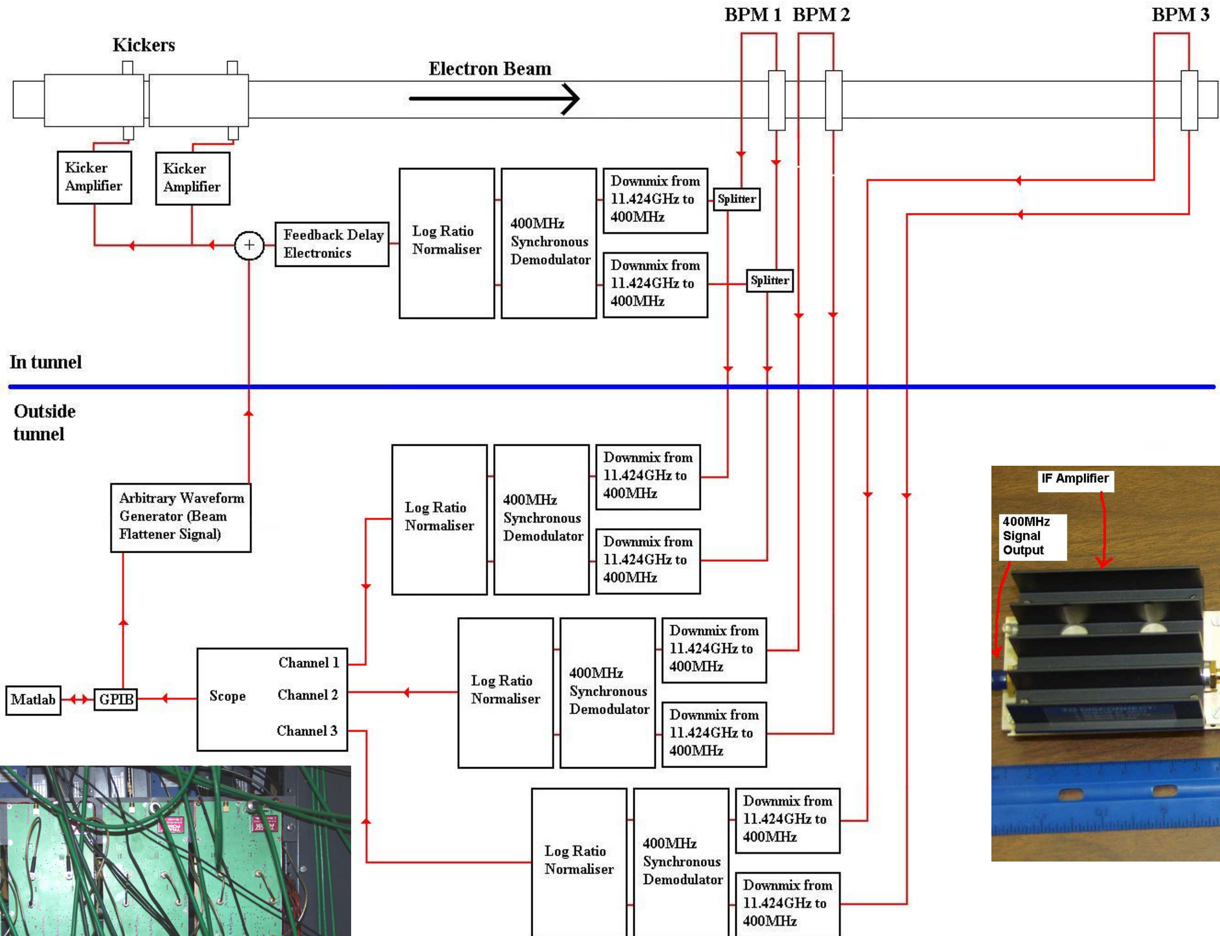
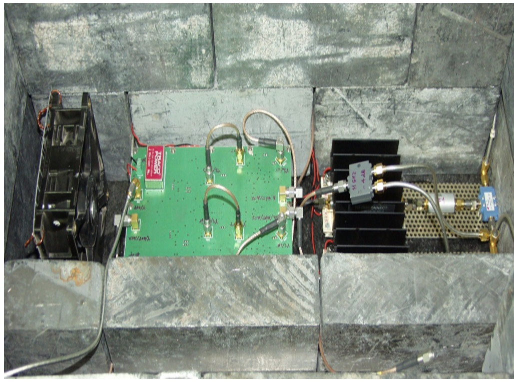
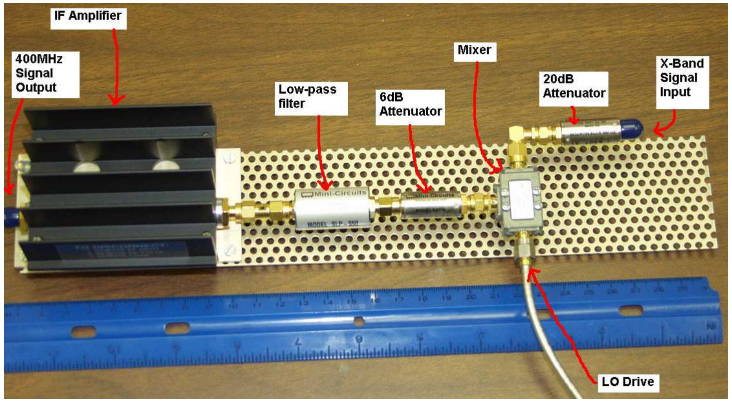
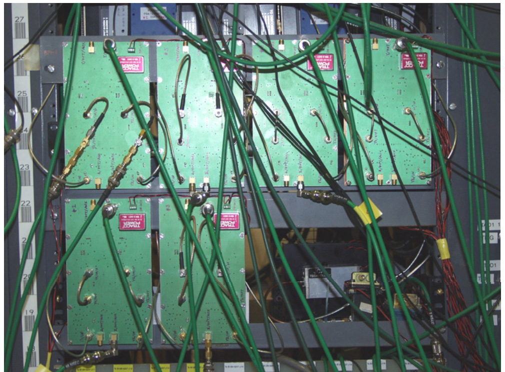
FONT2: BPM signal processing



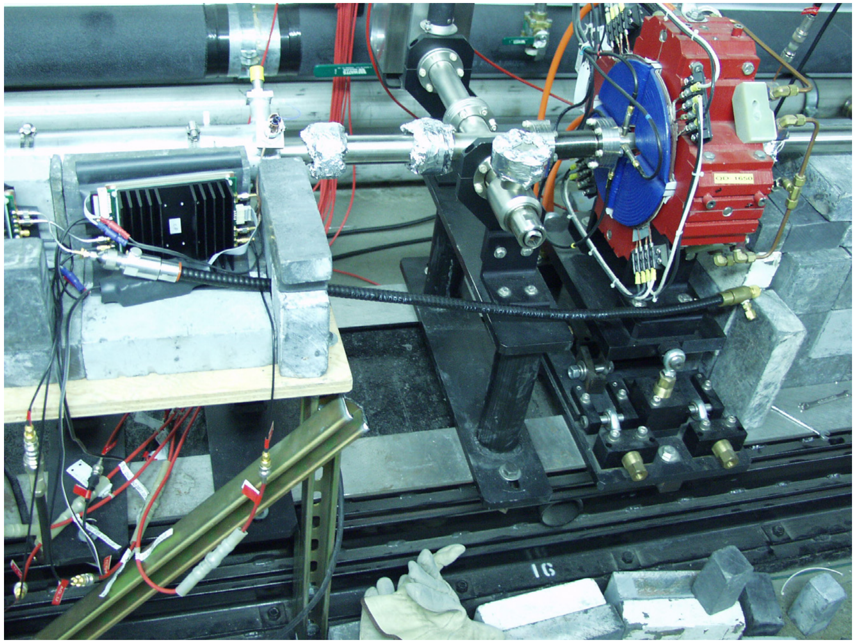




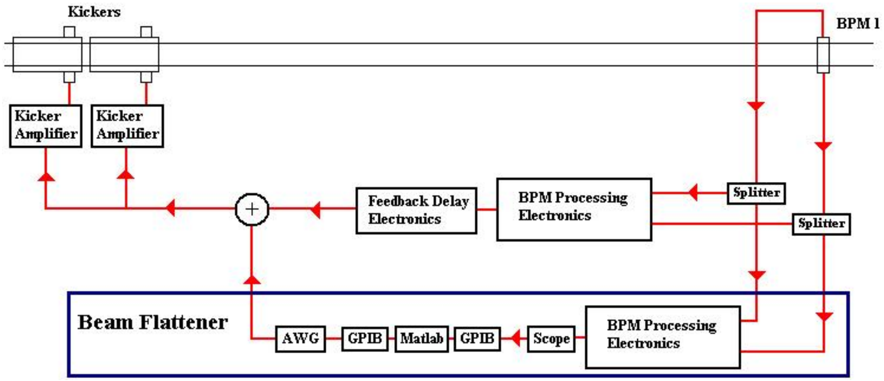


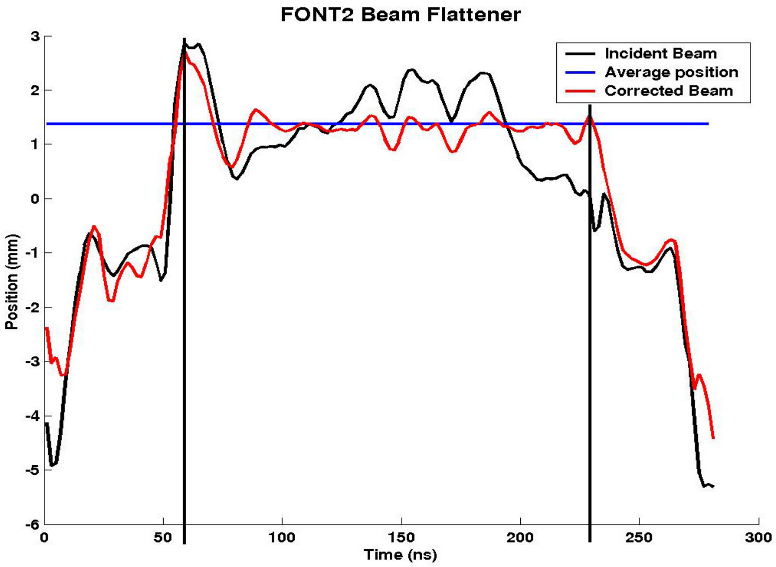
FONT2: amplifier + beam flattener

FB signal into amplifier:



Beam flattener:





Bandwidth

limited (30 MHz)

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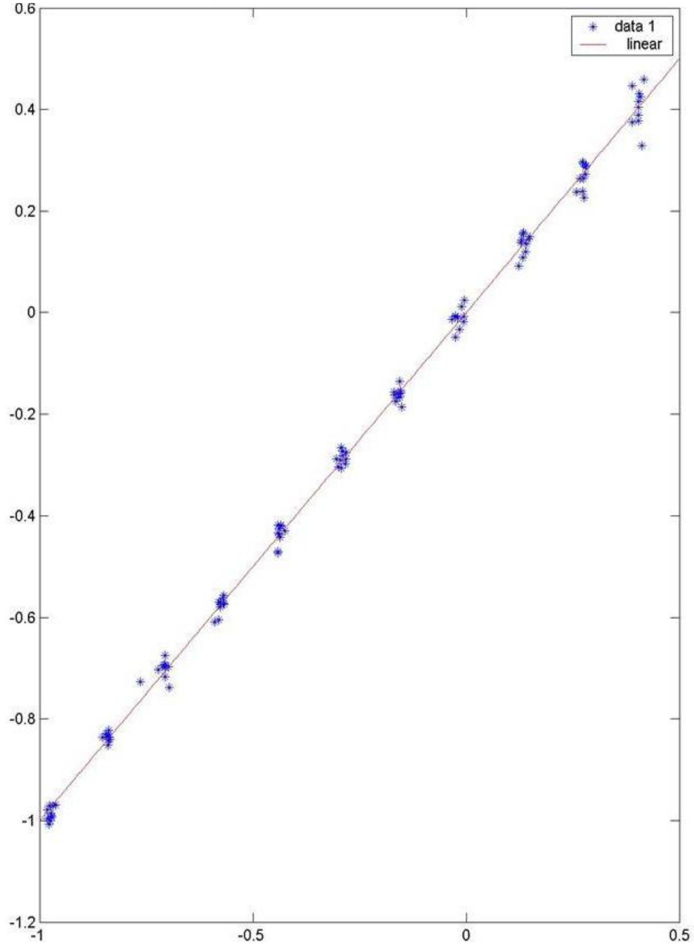
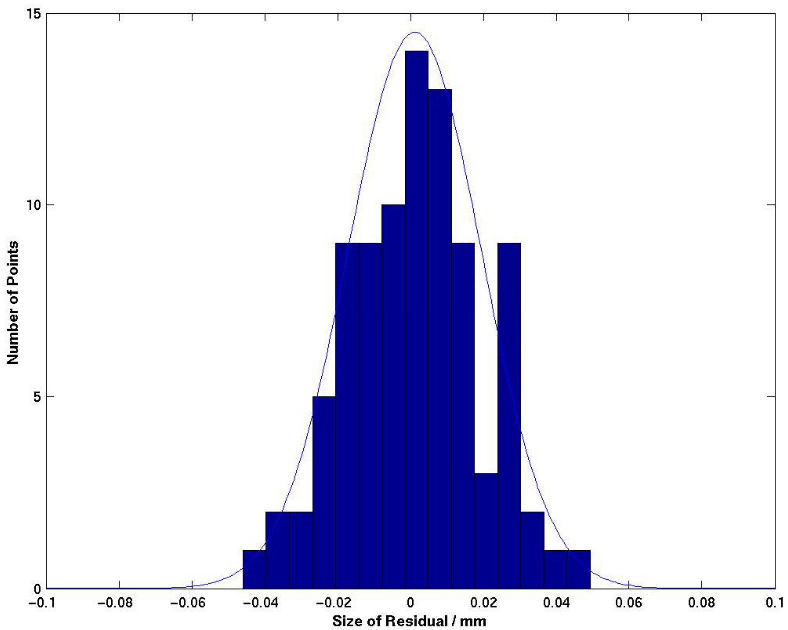
FONT2 BPM resolution

Actual position



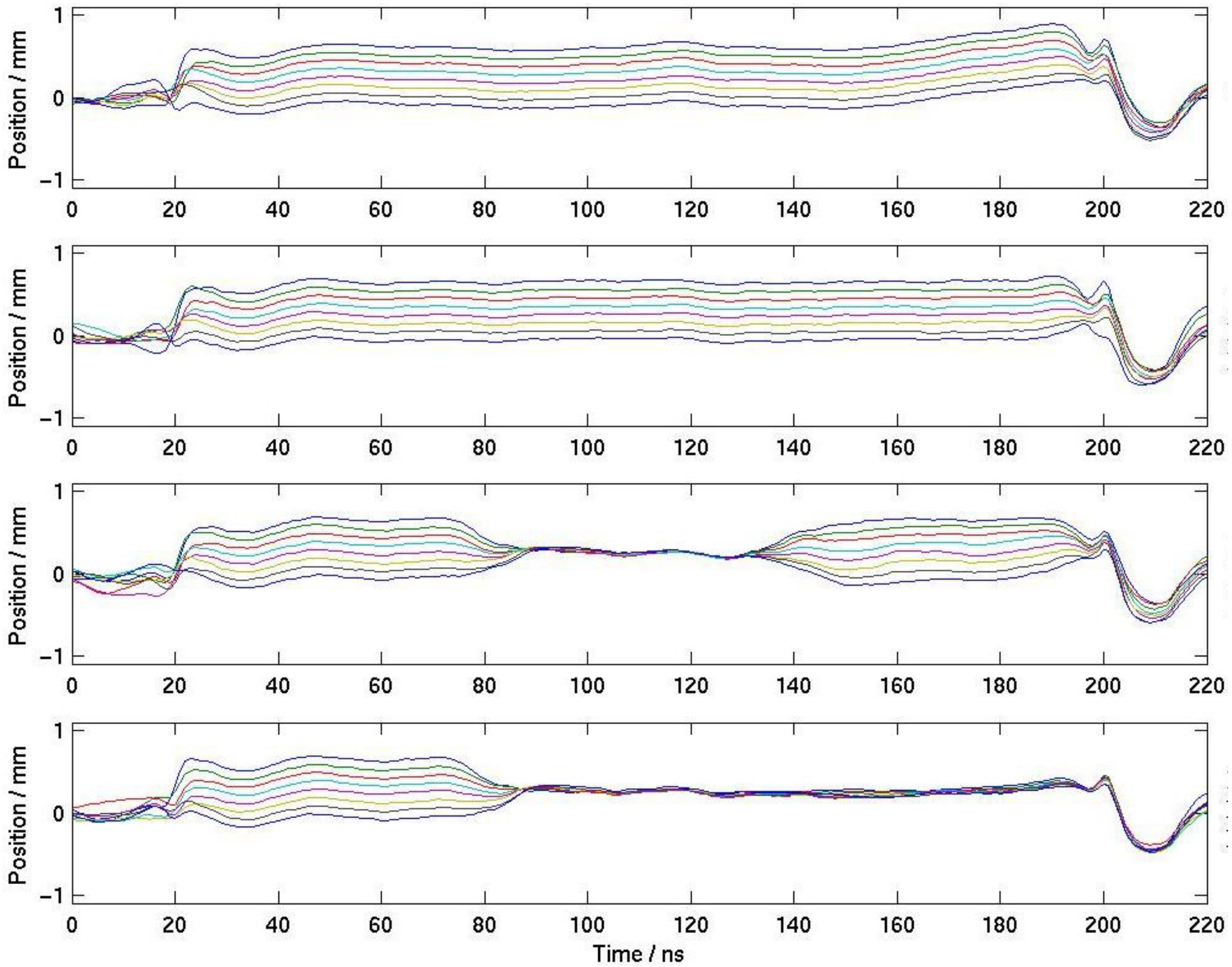
Predicted position

Residuals:



Resolution 14 microns

FONT2 results: feedback BPM



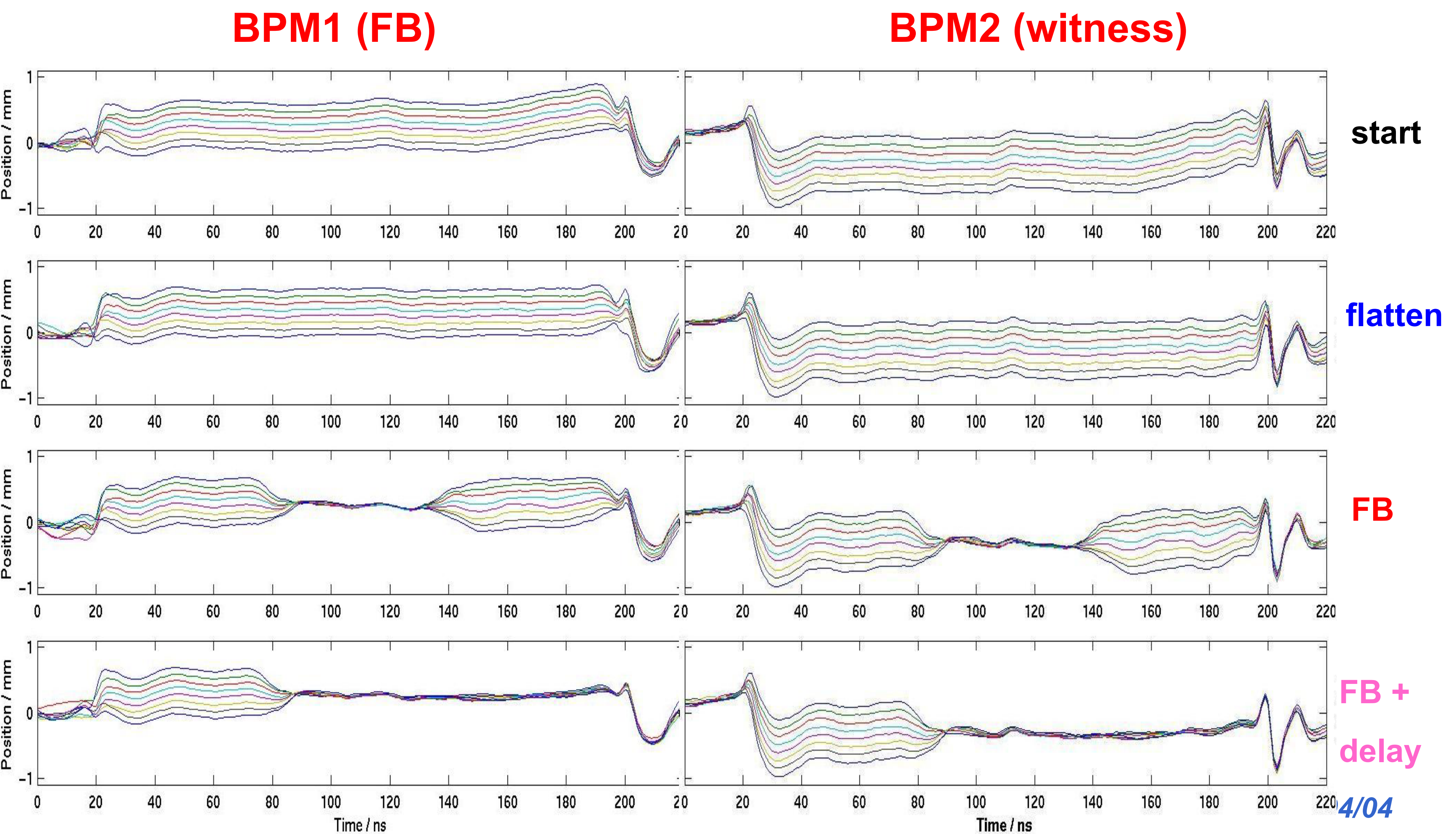
Beam starting positions

Beam flattener on

Feedback on

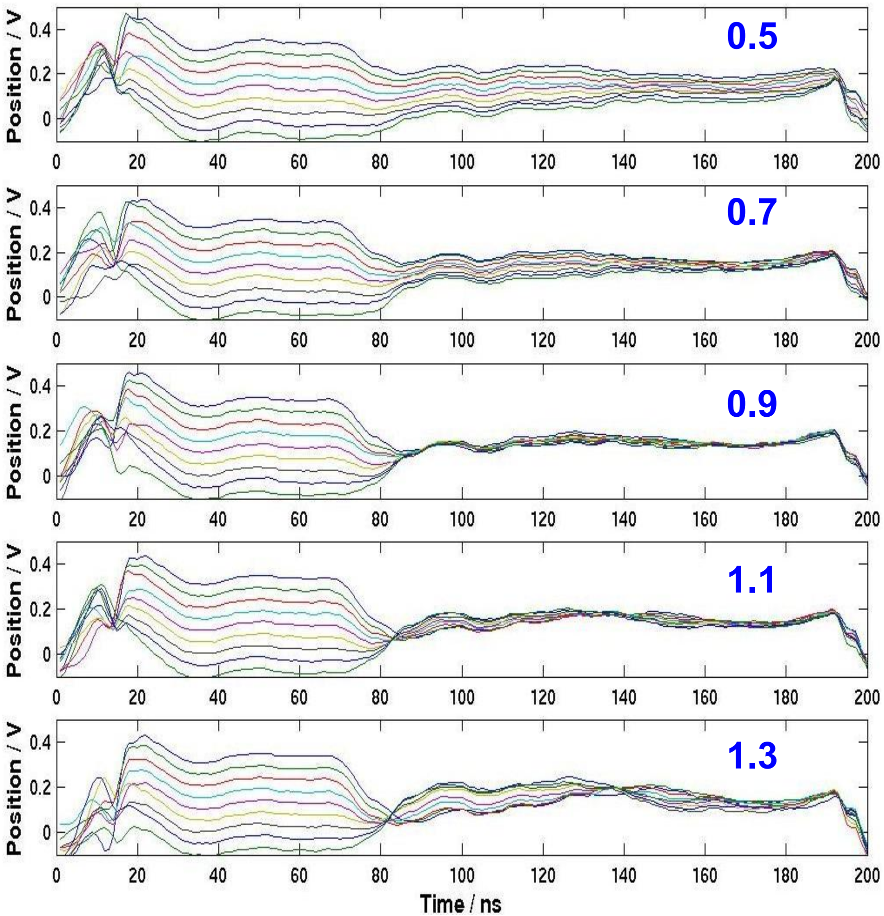
Delay loop on

FONT2 results: witness vs. FB BPMs

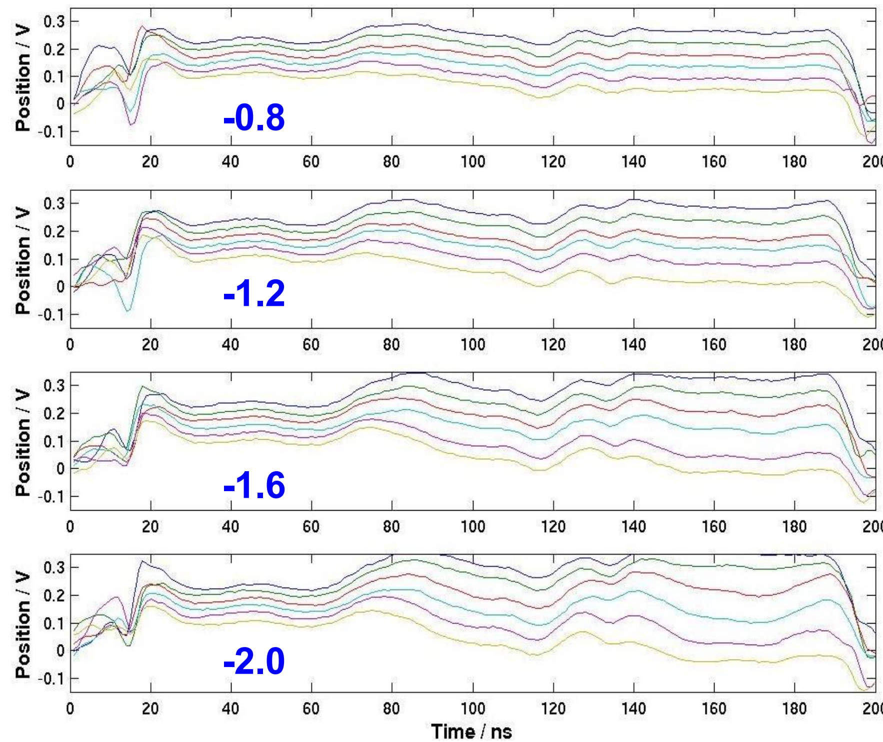


FONT2 results: gain studies

Vary main gain



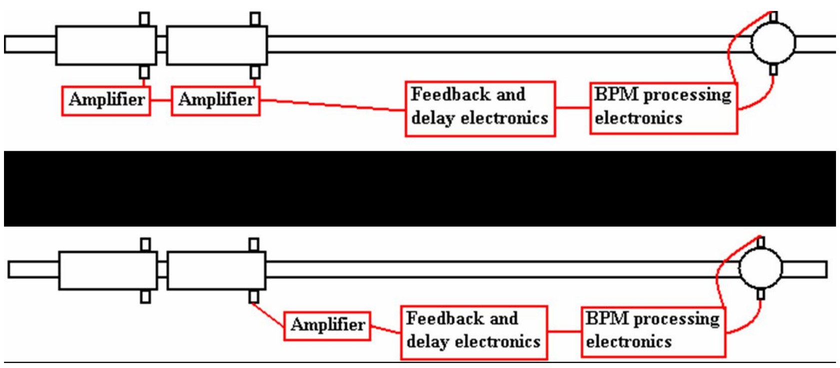
Main gain –ve (!)



Also: delay loop length + gain …

FONT2 final results (Jan 22 2004)

Super-fast modified configuration:

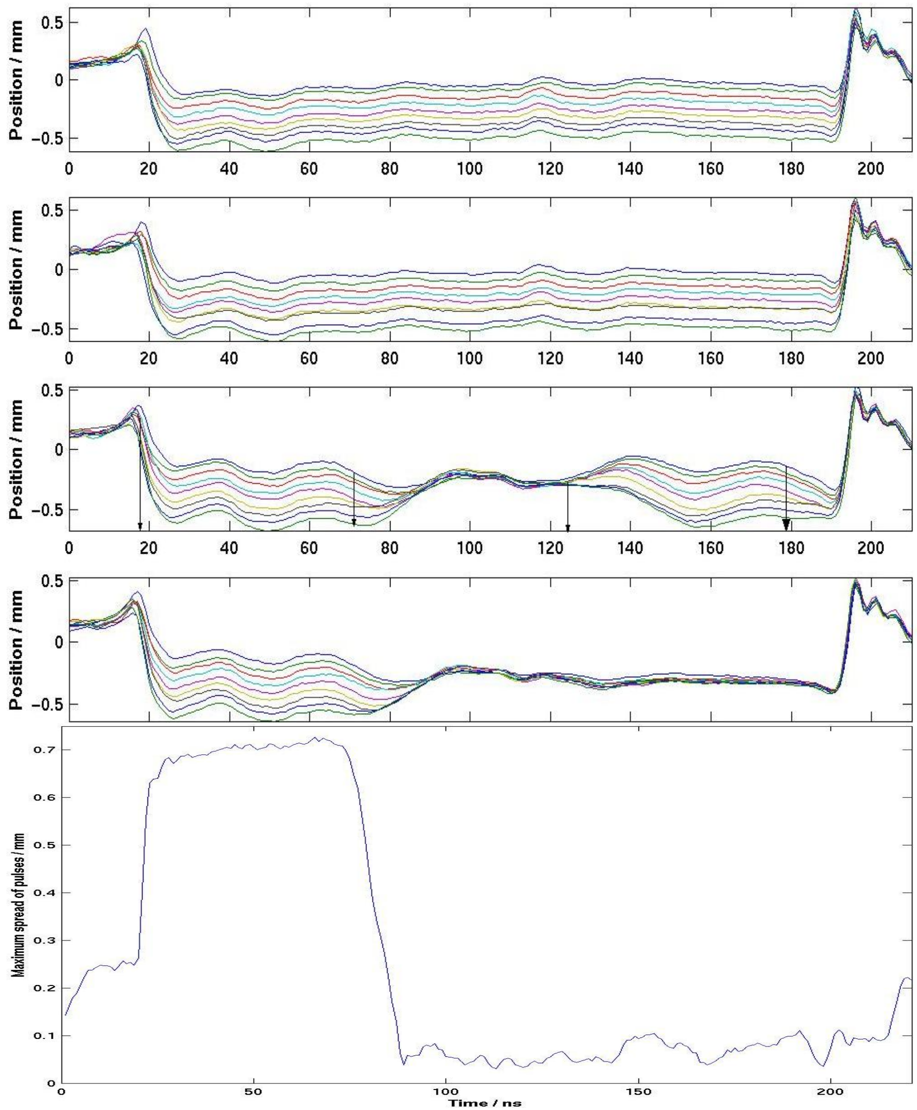


Latency 54ns

Correction 14:1

(limited by gain knob resolution)

dispersion



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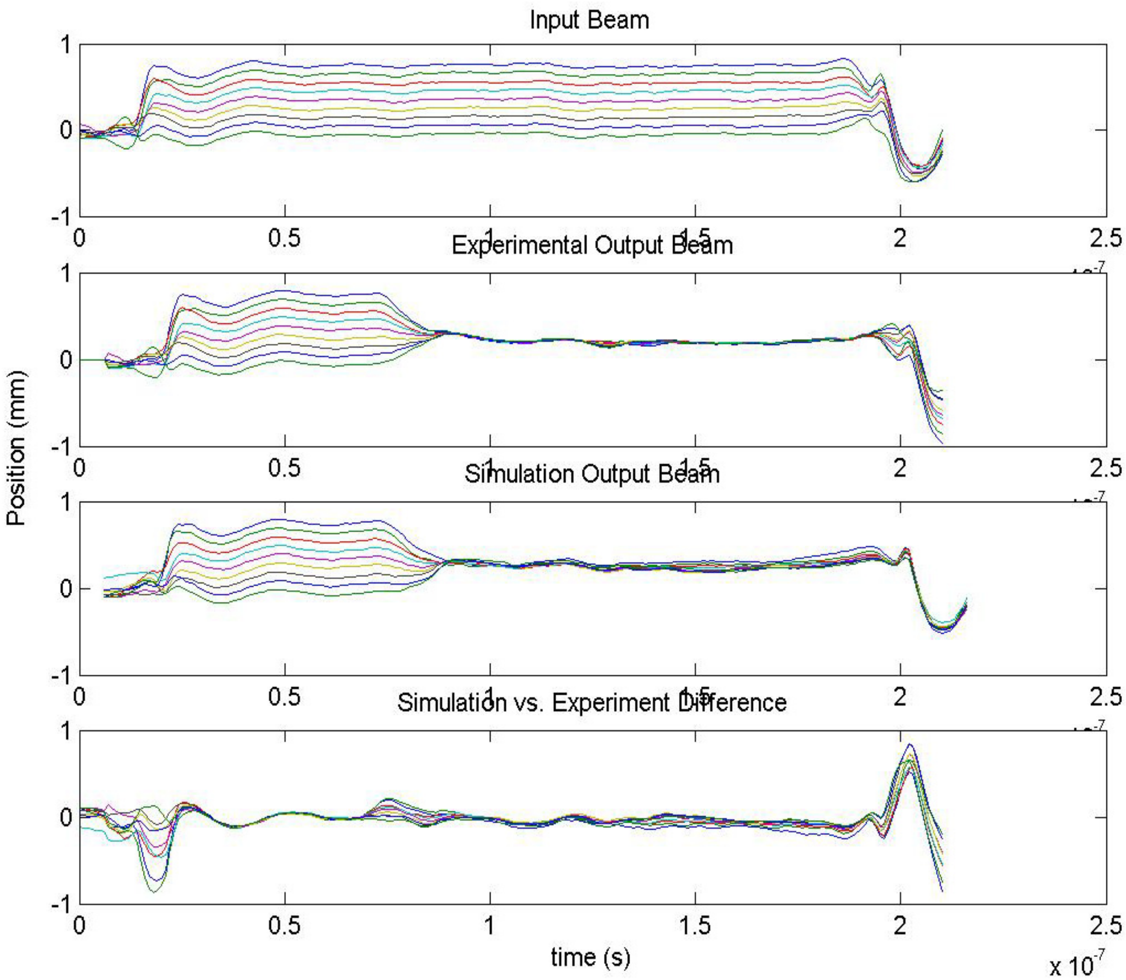
FONT2 Simulation

Simulation includes:

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



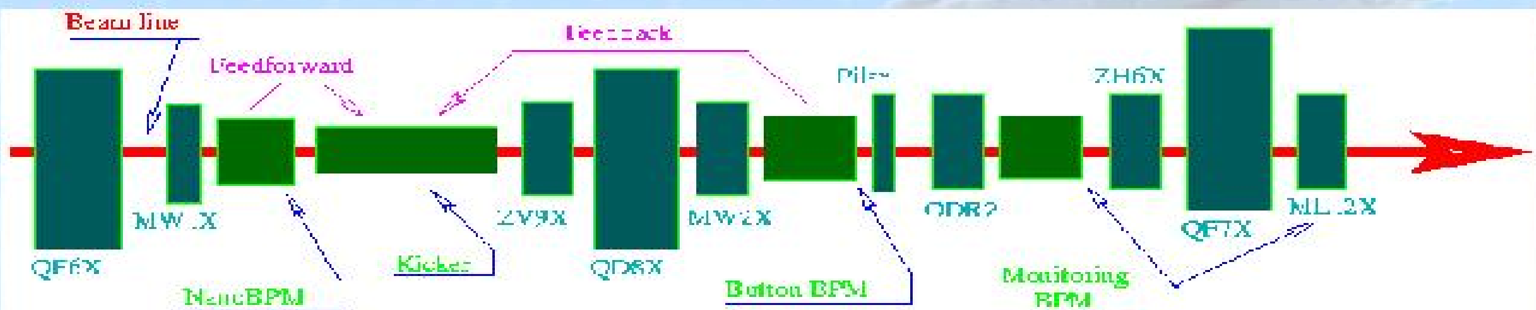
Useful tool for LC

FB simulations

Feedback At High Energy Requirements (FEATHER) (KEK/ATF)

FEATHER (羽)

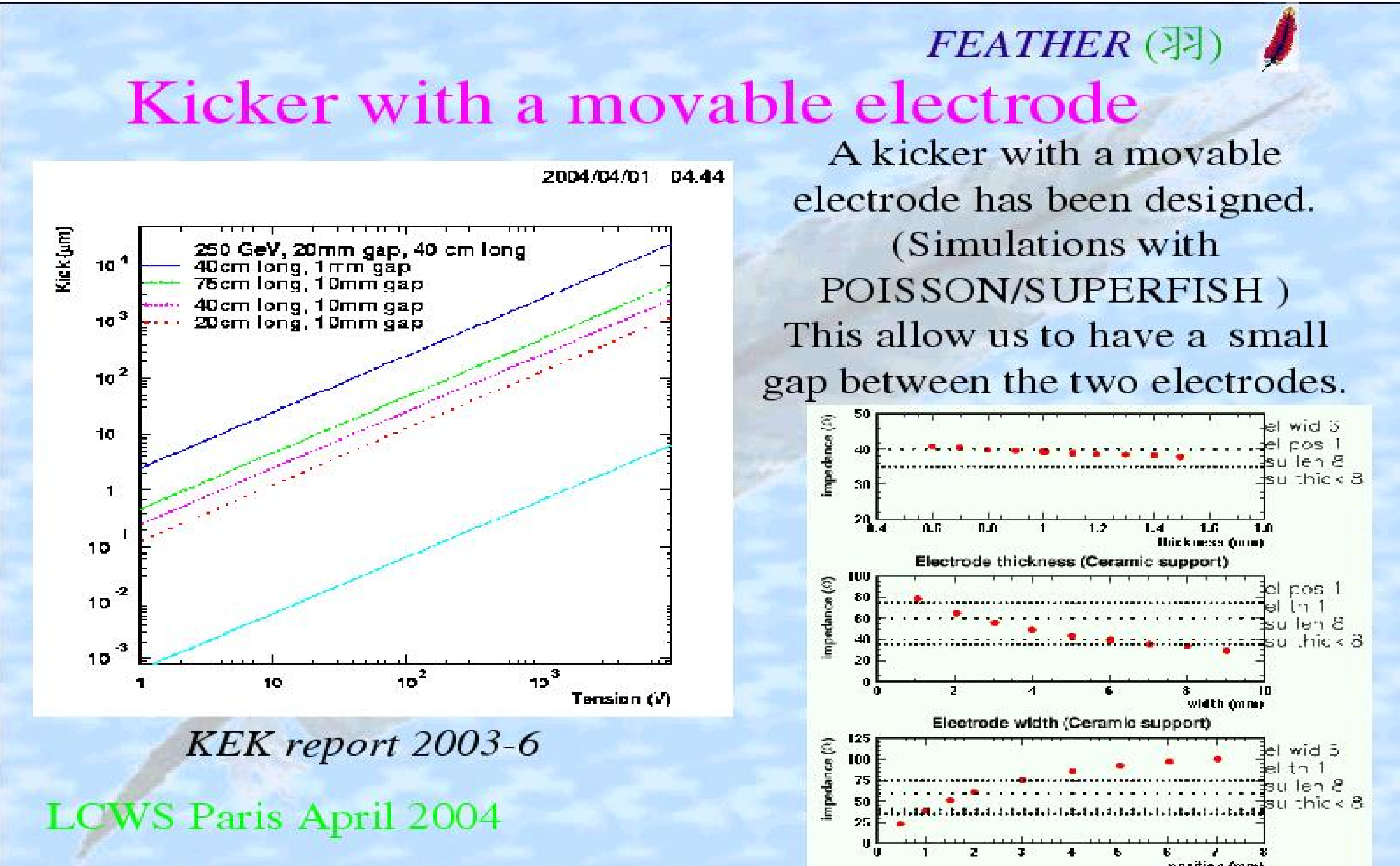
Extraction line layout



- Feedforward and feedback are possible
- Feedforward uses a cavity BPM + movable electrode kicker
- Feedback uses the new button BPM + kicker

Nicolas Delerue Nicolas@post.kek.jp
http://acfahep.kek.jp/subg/ir/feather/

FEATHER: kicker simulations



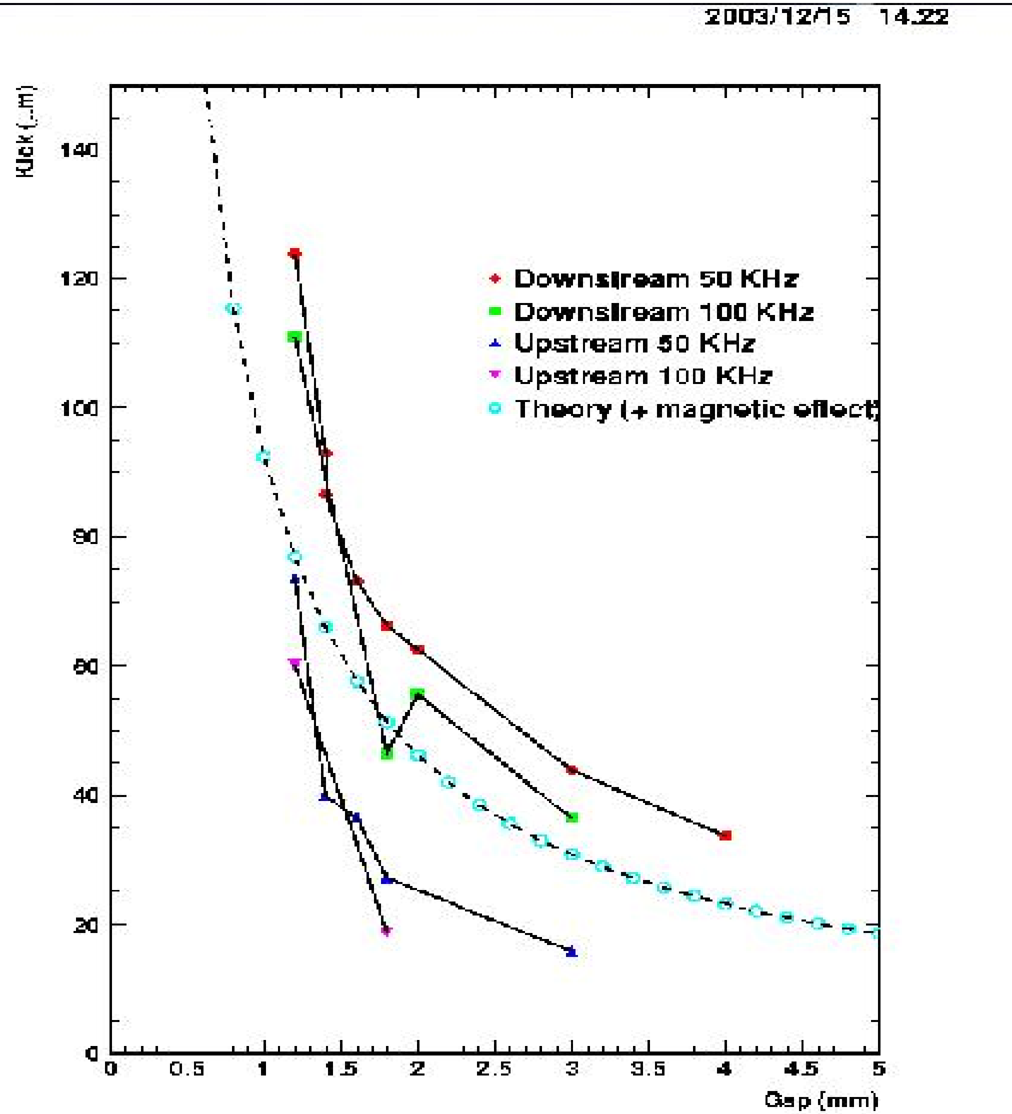
FEATHER: kicker perfomance

kick vs gap (low frequency)

Commissioning of the movable electrode kicker:

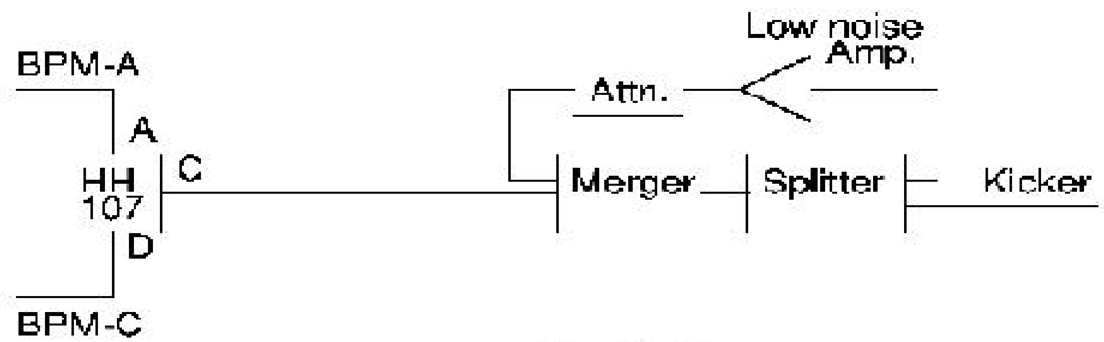
Kick intensity as a function of the gap for both input upstream and downstream.

LCWS Paris April 2004



FEATHER: latency

Time budget



- The response time of our new amplifier has been measured: 5.6 ns
- There is ~1 meter between our kicker and our BPM
  => Beam flight ~ 4 ns
  => Cable delay ~ 7 ns
- Various electronics delay should be less than 5ns
- Response should come ~20ns after first bunch
- Delay loop needs ~11ns more (Total ~35 ns)
- 20 bunches at 2.8 ns make a 56ns train
  => Should be possible to test our delayed model

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http://acfahep.kek.jp/subg/ir/feather/

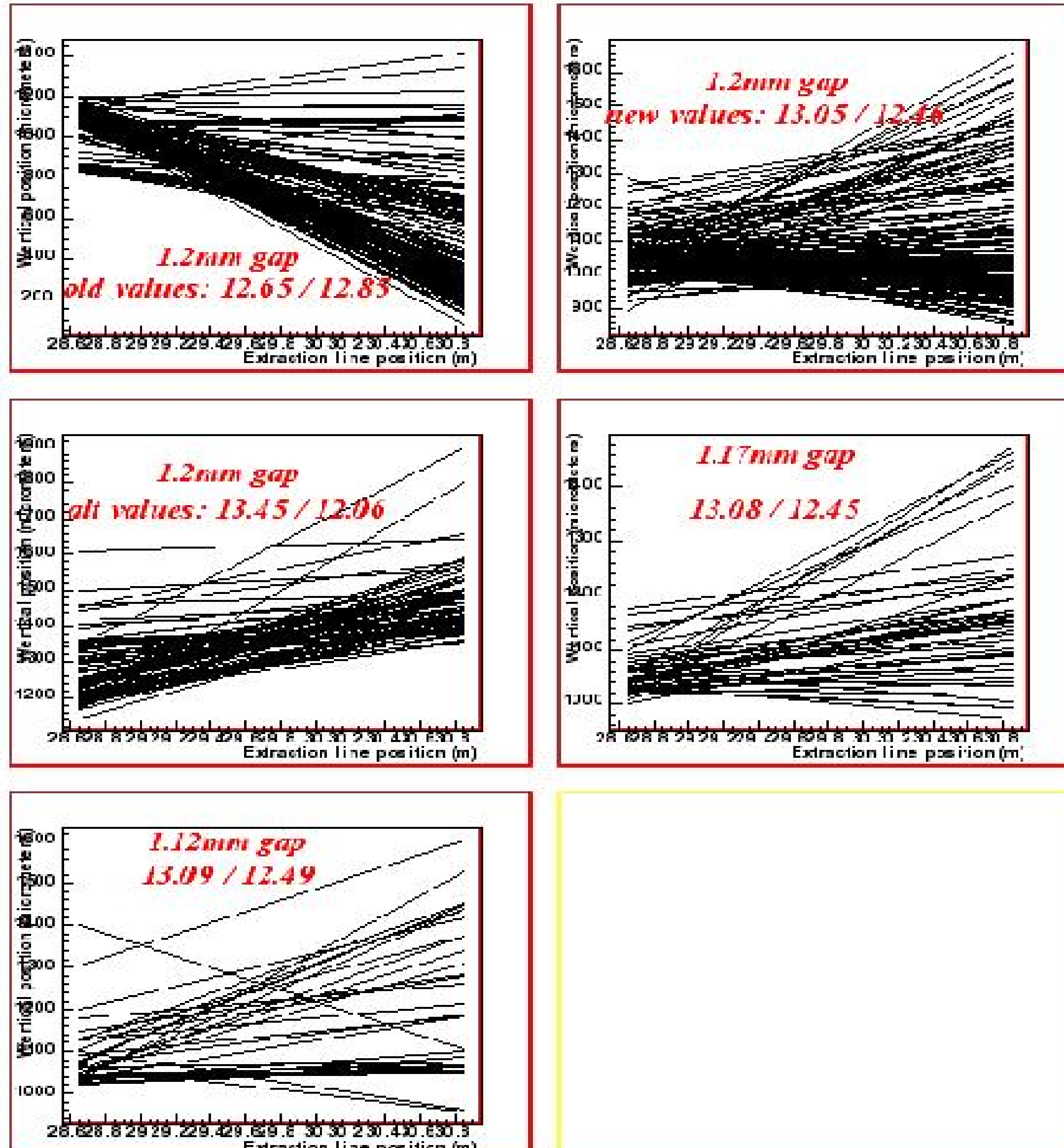
FEATHER: beam scan across kicker gap

Scan of the acceptable trajectories

Vertical orbit of the beam has been modified several times to scan the acceptable orbits and thus deduce the position of the kicker's electrodes.

Smallest gap has been found at 13.09/12.49
This correspond to a gap at the windows of ~1.12 mm (electrodes are bent)

LCWS Paris April 2004



Comparison of NLCTA with ATF

	NLCTA	ATF
Train length	170 ns	300 ns
Bunch spacing	0.08 ns	2.8 ns
Beam size (y)	500 mu	5 mu
Jitter (y)	100 mu	few mu
Beam energy	65 MeV	1.3 GeV

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

For the warm machine:

ATF has ‘right’ bunch spacing and train length, and the beam is smaller and more stable than at NLCTA

-> much better place for fast feedback prototypes

Future Experimental Programme at ATF

FONT and FEATHER are joining forces!

1. Stabilisation of extracted bunchtrain at 1 micron level:
   - low-power (< 100W), high stability amplifier
   - stripline or button BPM w. ~ 1 micron resolution

   these are exactly what are needed for the LC!

2. Stabilisation of extracted bunchtrain at 100 nm level:
   - requires special (cavity) BPM and signal processing

   useful as part of nanoBPM project

3. Test of intra-train beam-beam scanning system:
   - high-stability ramped kicker drive amplifier

   very useful for LC

Future Experimental Programme at SLAC

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

Train charge, length, bunch spacing … parameters can be made relevant for warm or cold machine (Woods)

Well instrumented laboratory for BPM tests

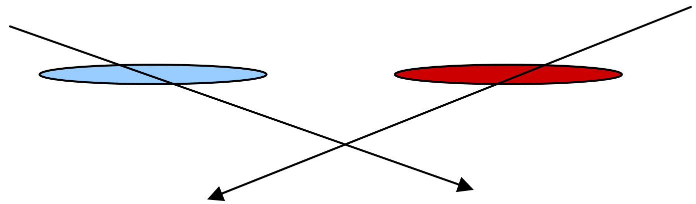
High-flux e+e- pairs mimic LC IR environment:

study impact of pair background on BPM resolution;

radiation damage issues for feedback components

Other issues for intra-train feedbacks

- **Beam angle-jitter:**



warm machine: correction best done near IP with RF crab cavity (needed anyway):

design + prototyping starting in UK

- **Ideally, feedback on luminosity:**

bunch-by-bunch luminosity measurement would allow intra-train luminosity feedback