Intra-train Beam-based Feedback Systems

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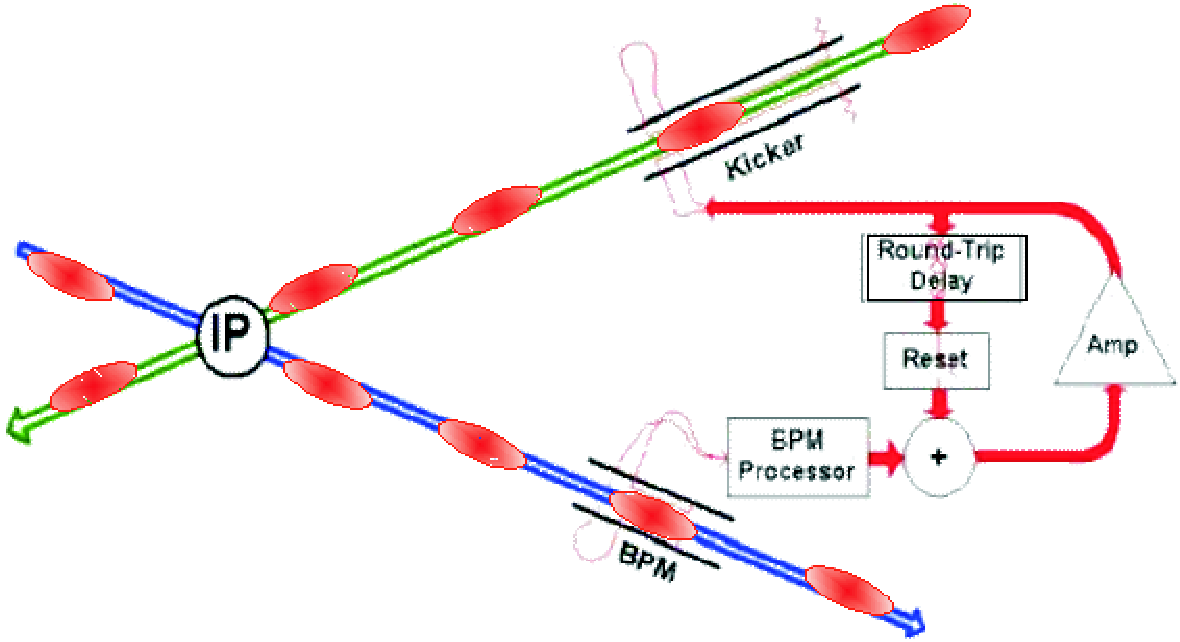
- System overview
- FONT/NLCTA
- FEATHER/ATF
- Future plans

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

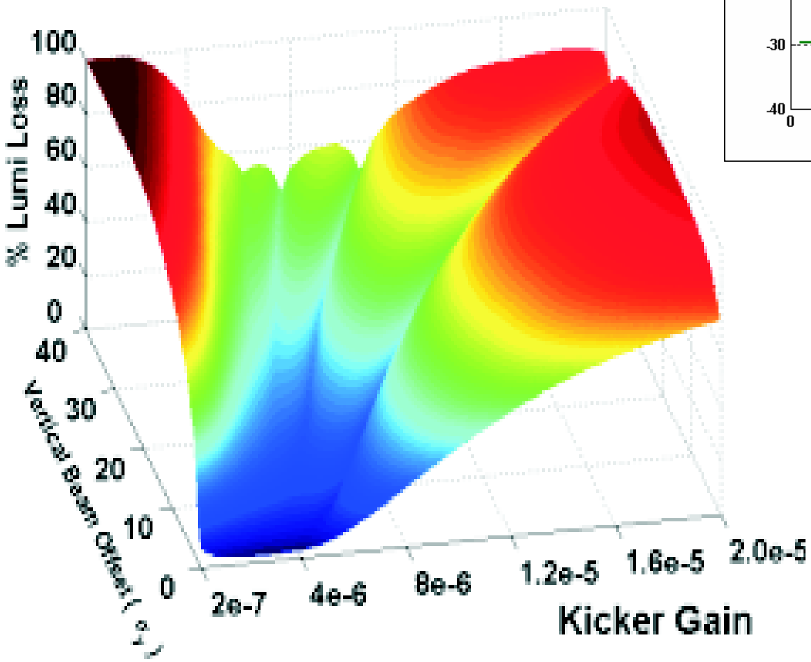
Warm: augments active stabilisation

Cold: principal ground-motion correction

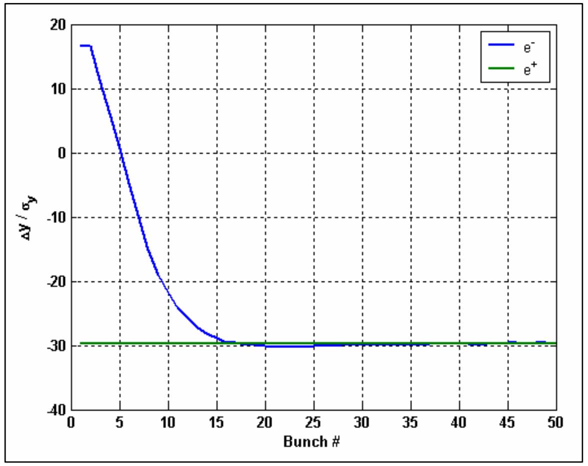
Beam Feedback Luminosity Recovery

G/NLC:

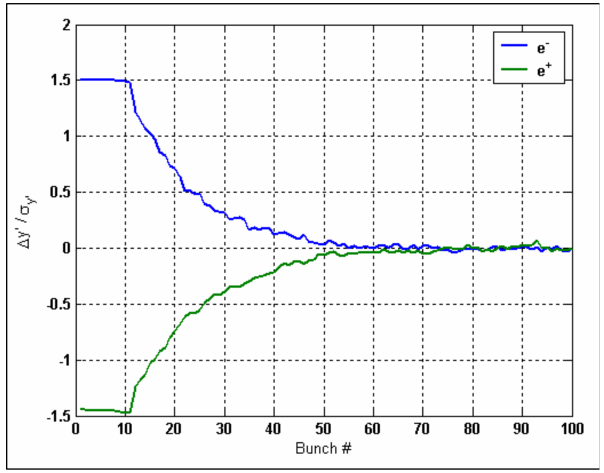
recover > 80% of design luminosity



Position scan:

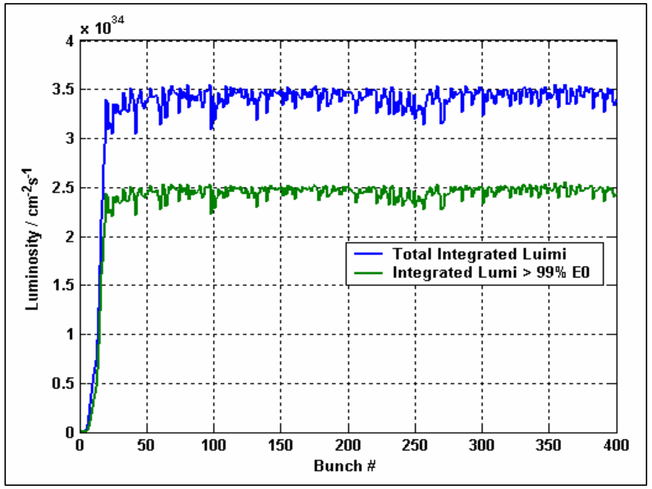


Angle scan:

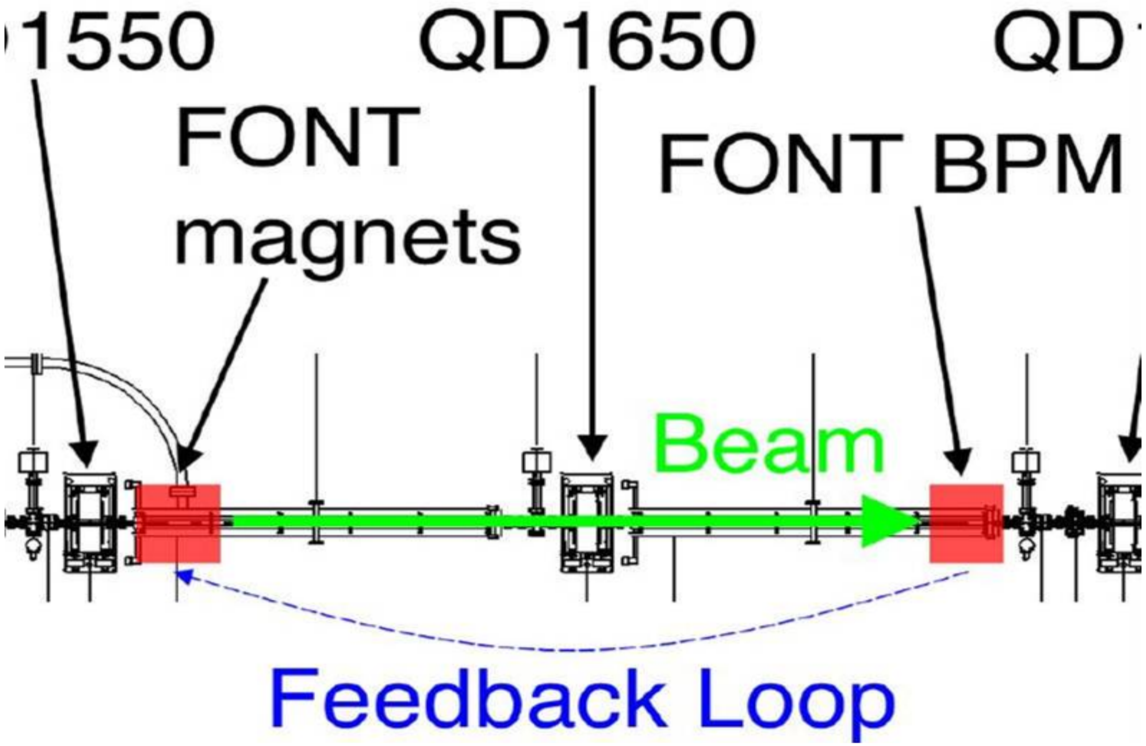


TESLA:

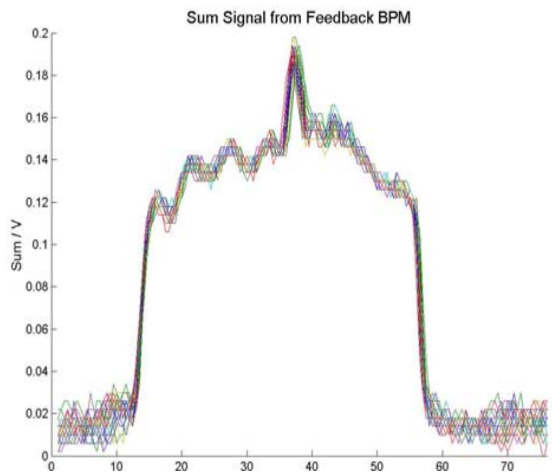
> 95% feasible



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



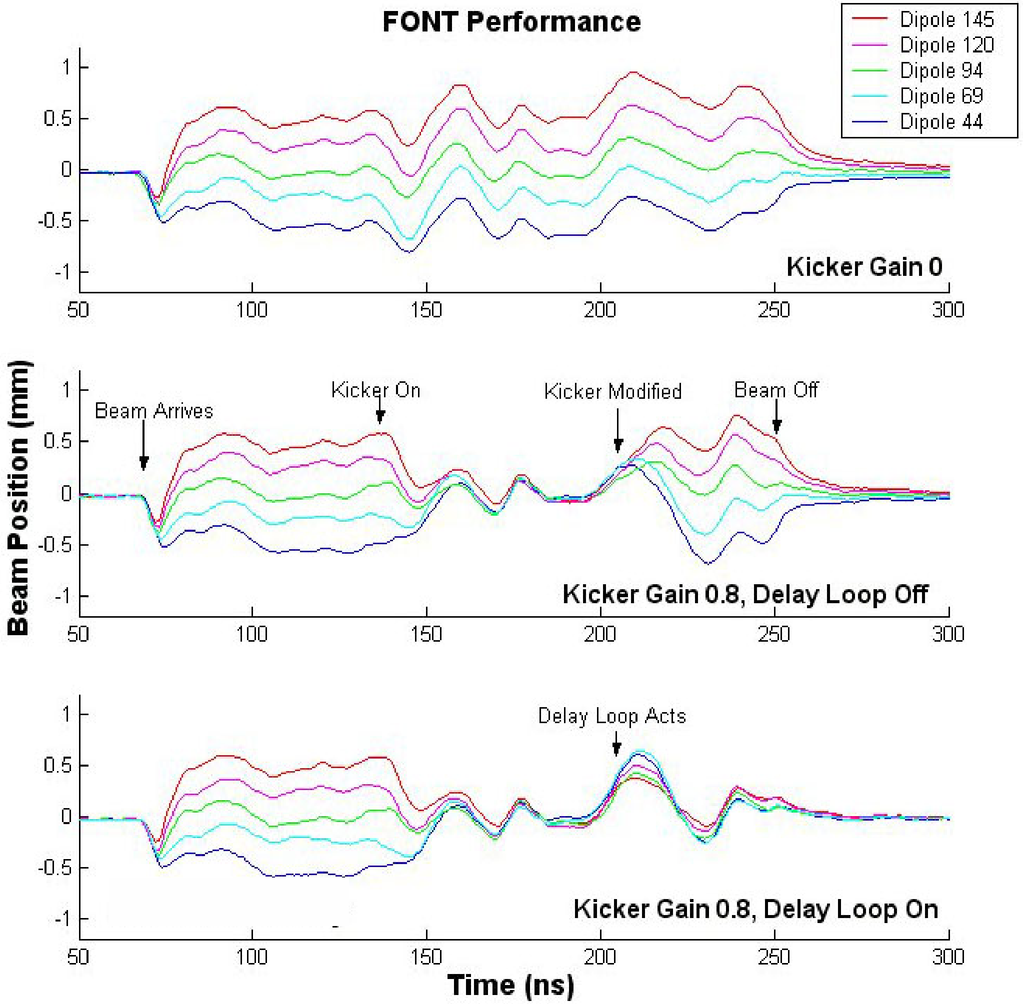
- **100 micron train-train jitter**
- **bunched at X-band (87ps)**
- **50% Q variation along train:**



- **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:**

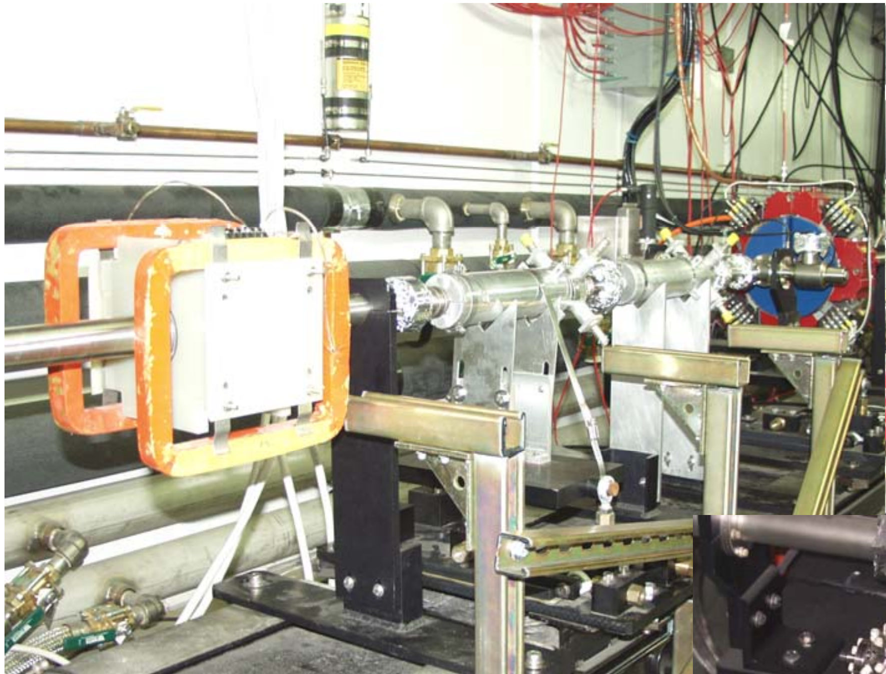
  allows 170/53 = 3.2 passes through system
- **Added 'beam flattener' to remove static beam profile**
- **Automated DAQ including digitisers and dipole control**

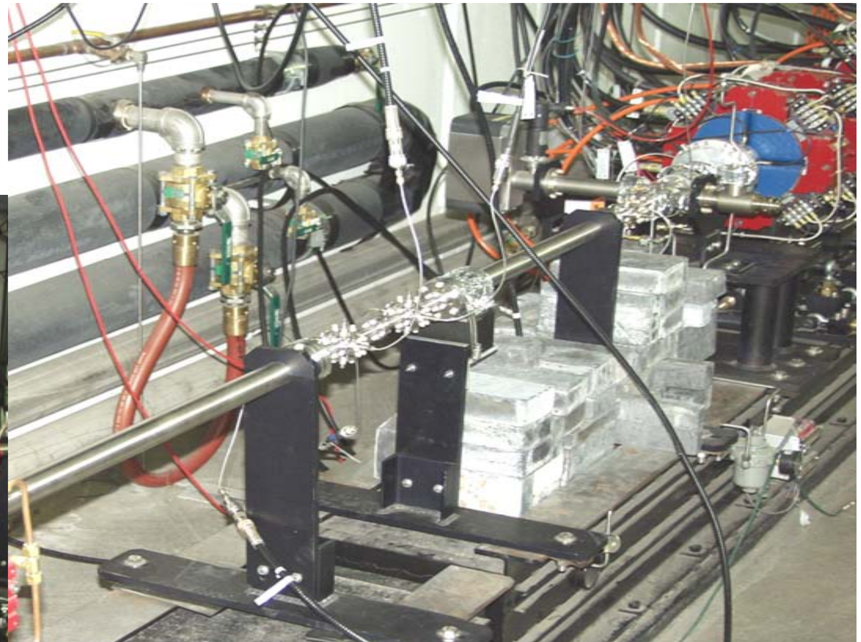
FONT2: expected latency

• 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

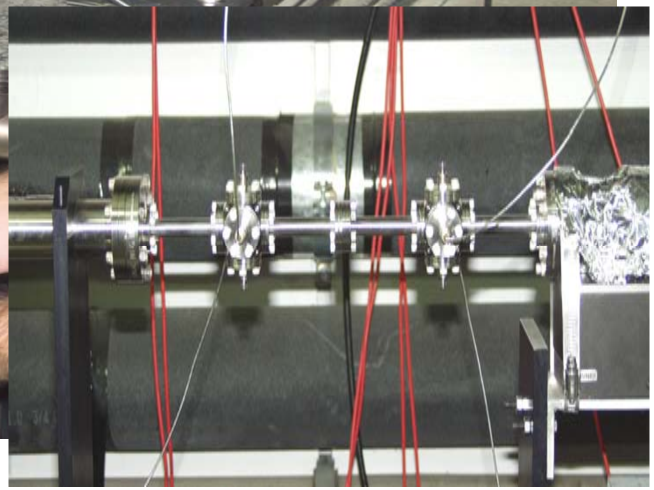
FONT2: beamline configuration

Dipole and kickers

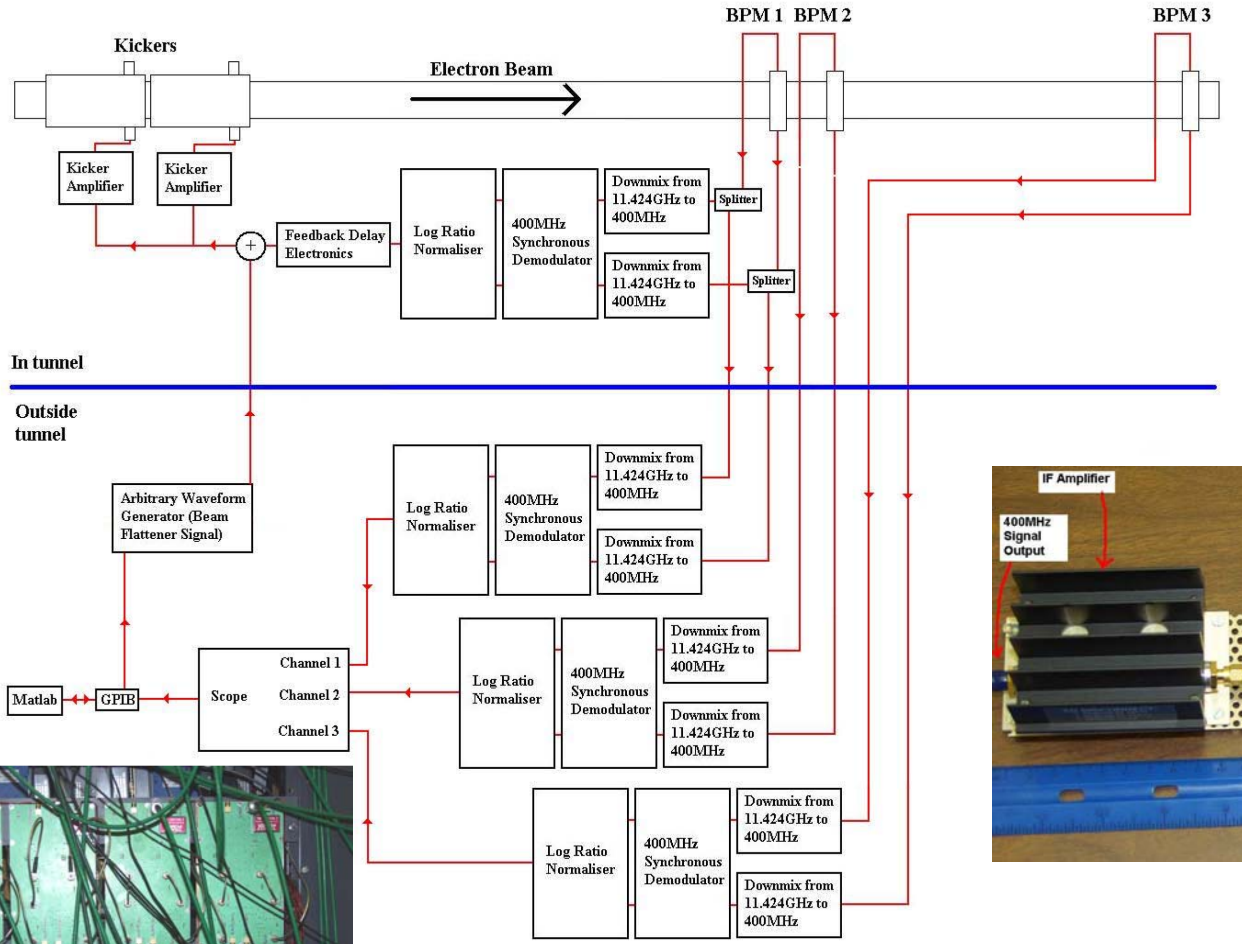


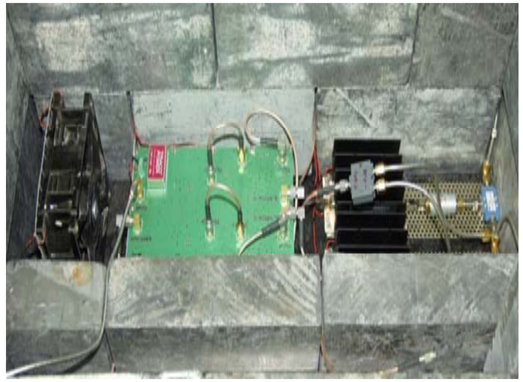


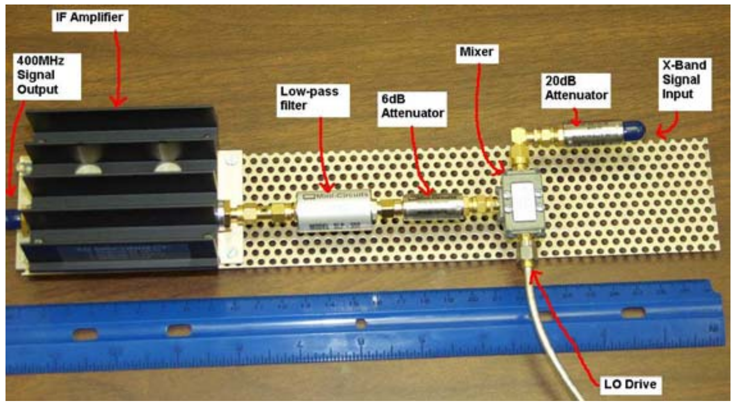
New BPMs

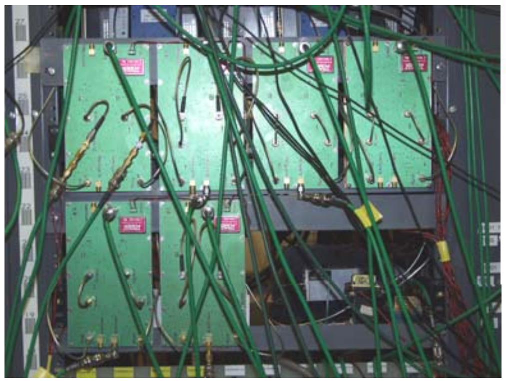


FONT2: BPM signal processing



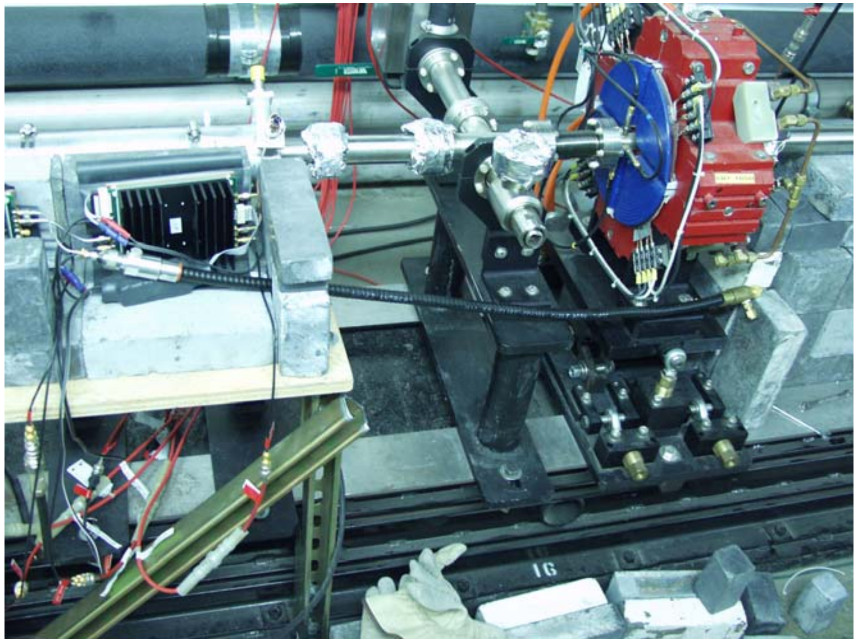




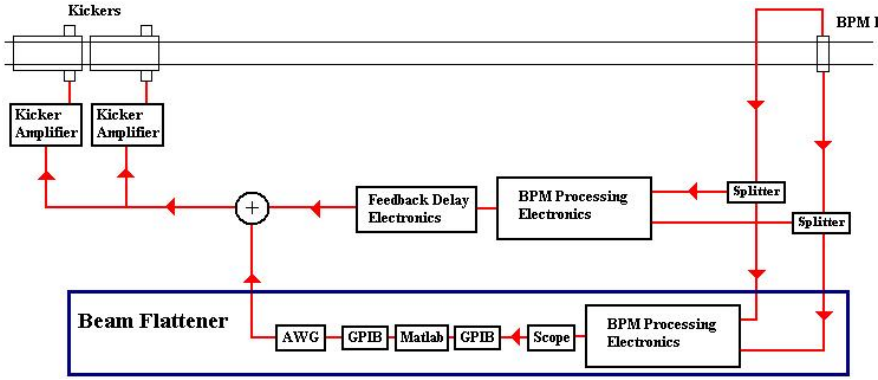


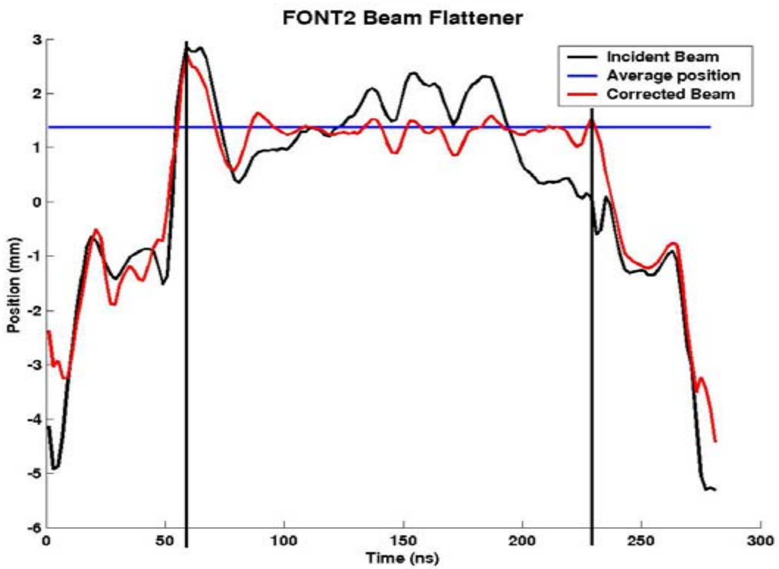
FONT2: amplifier + beam flattener

FB signal into amplifier:



Beam flattener:





Bandwidth

limited (30 MHz)

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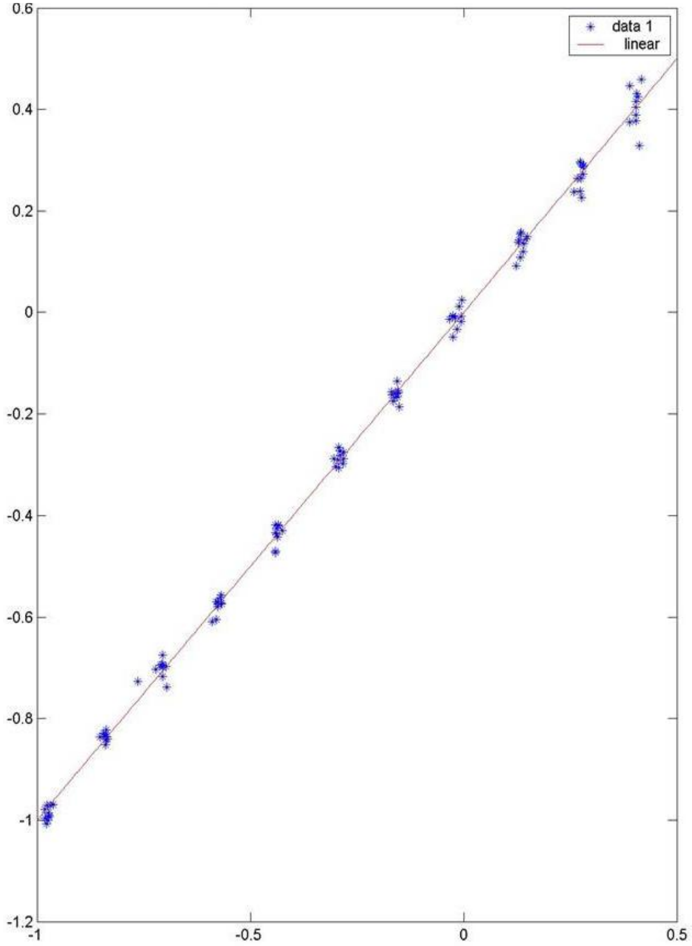
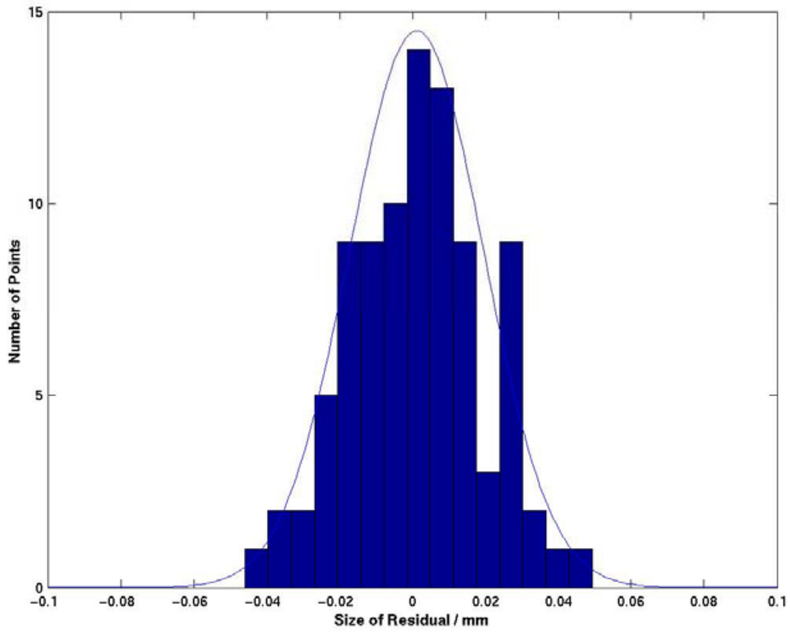
FONT2 BPM resolution



Actual position

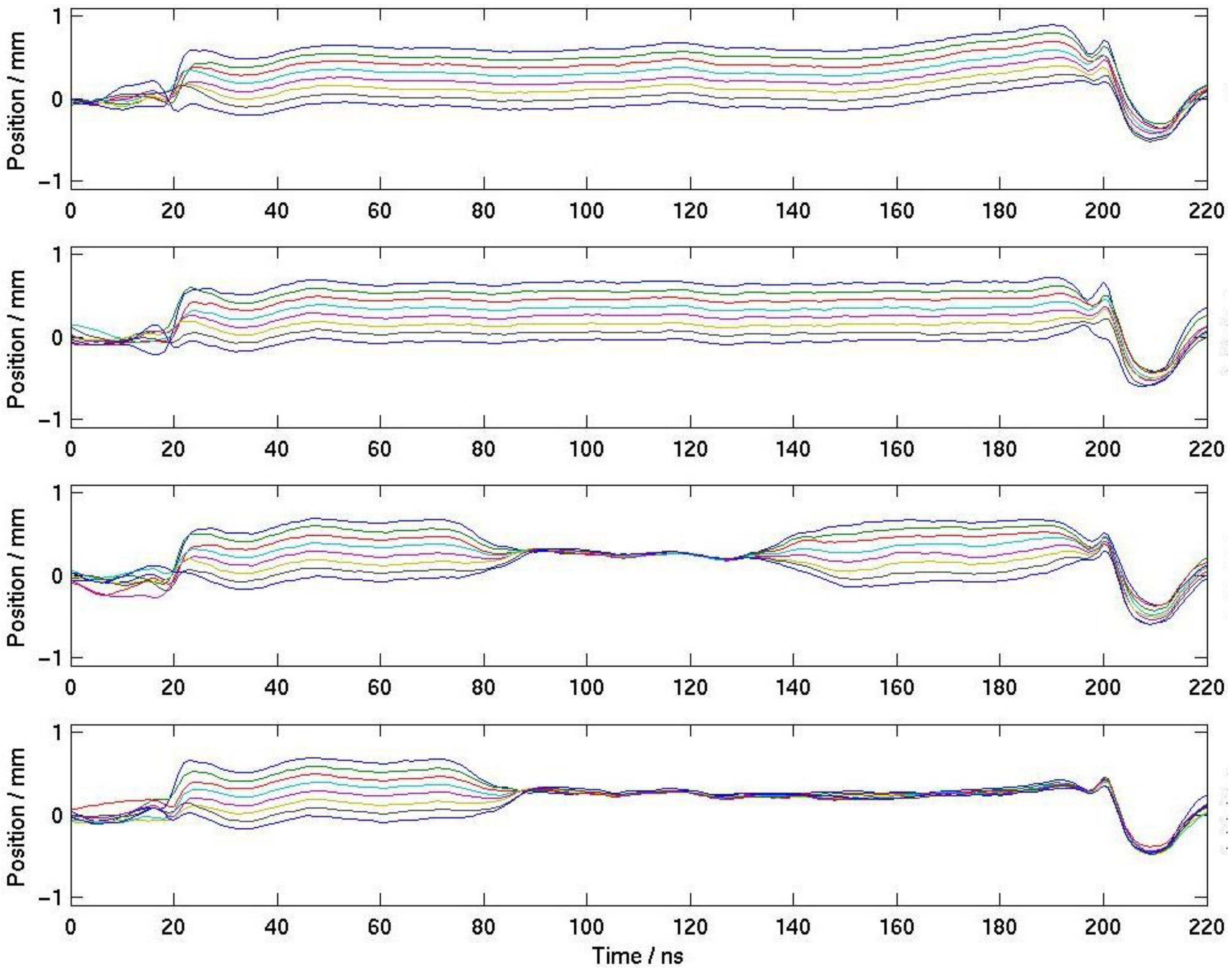
Predicted position

Residuals:



Resolution 14 microns

FONT2 results: feedback BPM



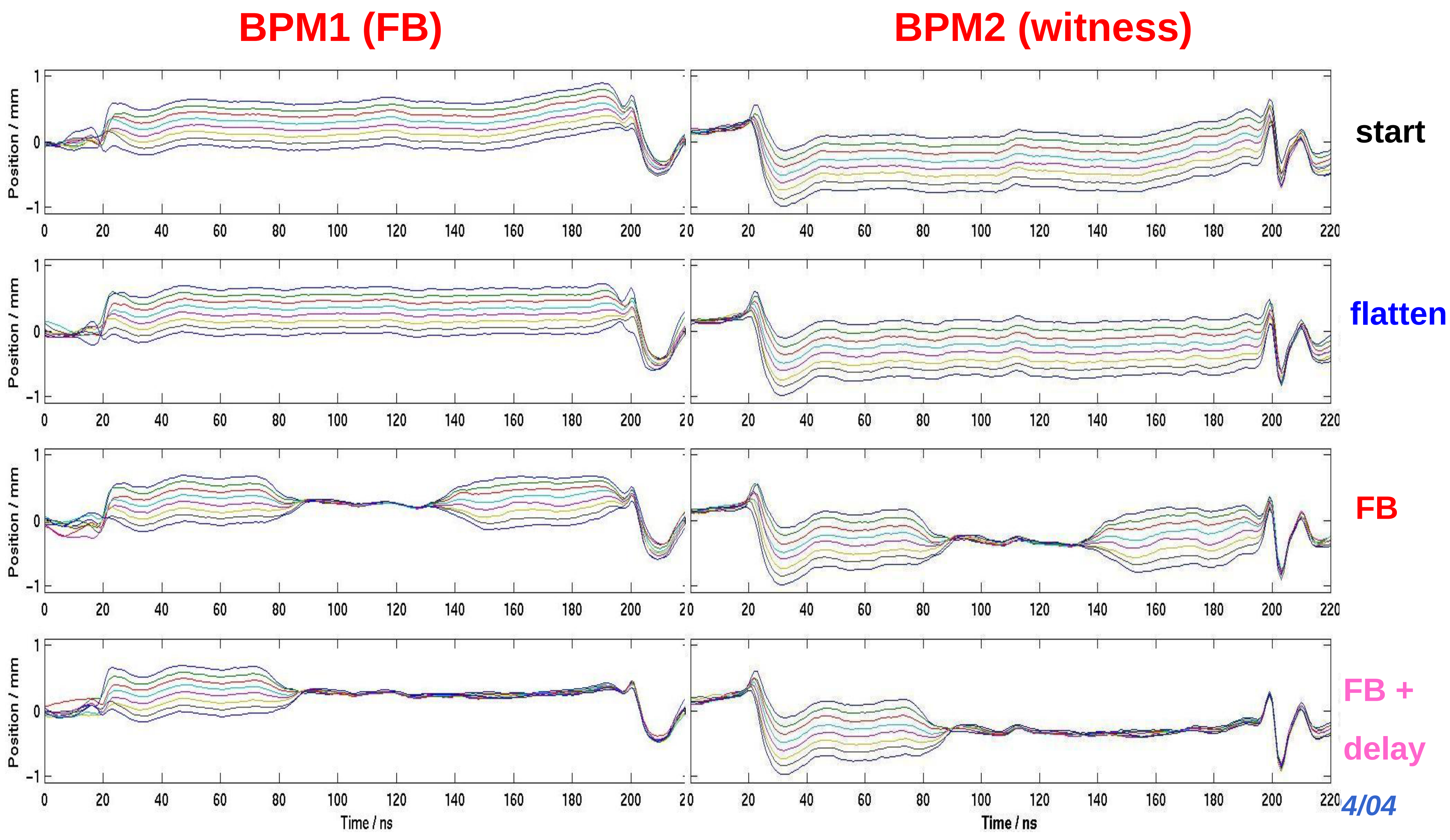
Beam starting positions

Beam flattener on

Feedback on

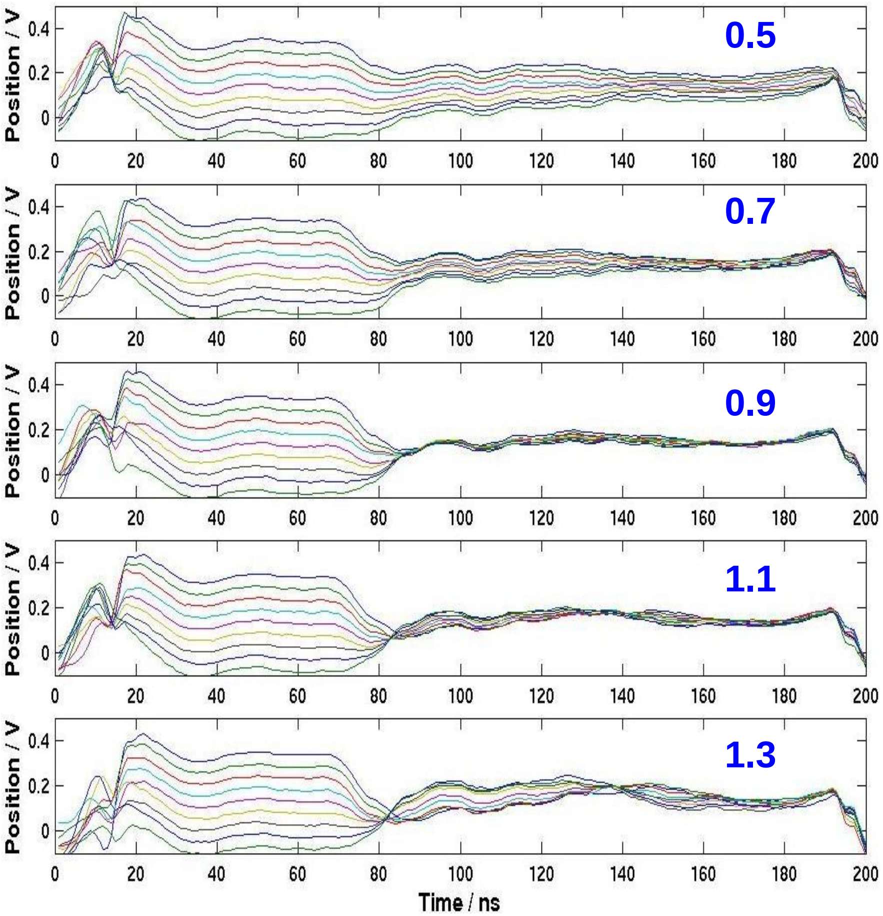
Delay loop on

FONT2 results: witness vs. FB BPMs

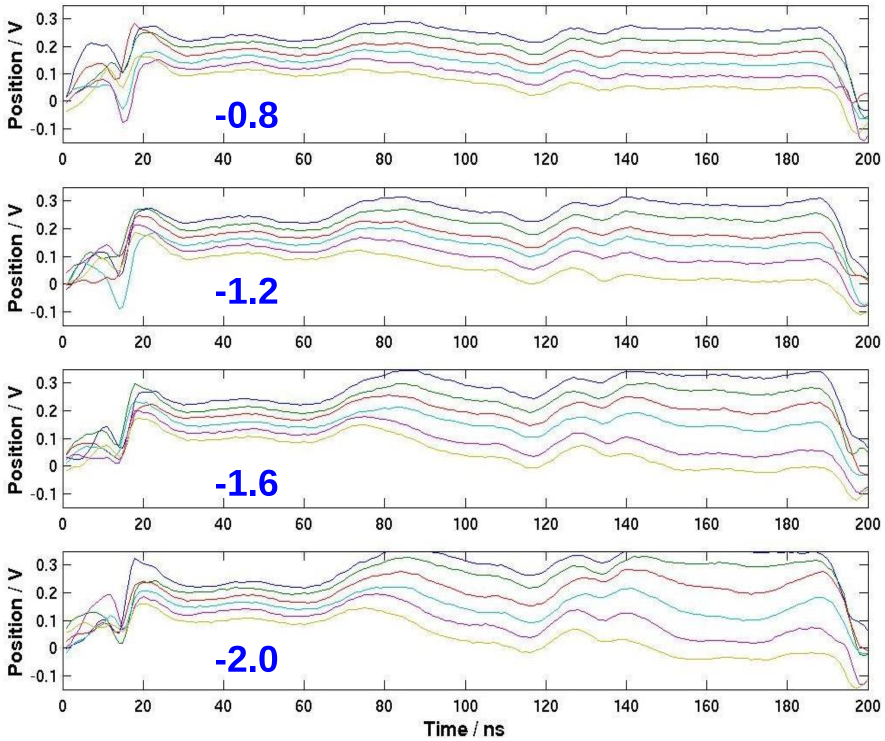


FONT2 results: gain studies

Vary main gain



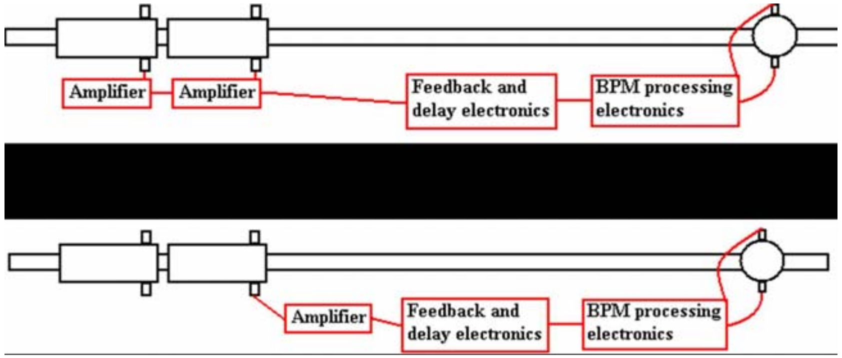
Main gain –ve (!)



Also: delay loop length + gain …

FONT2 final results (Jan 22 2004)

Super-fast modified configuration:

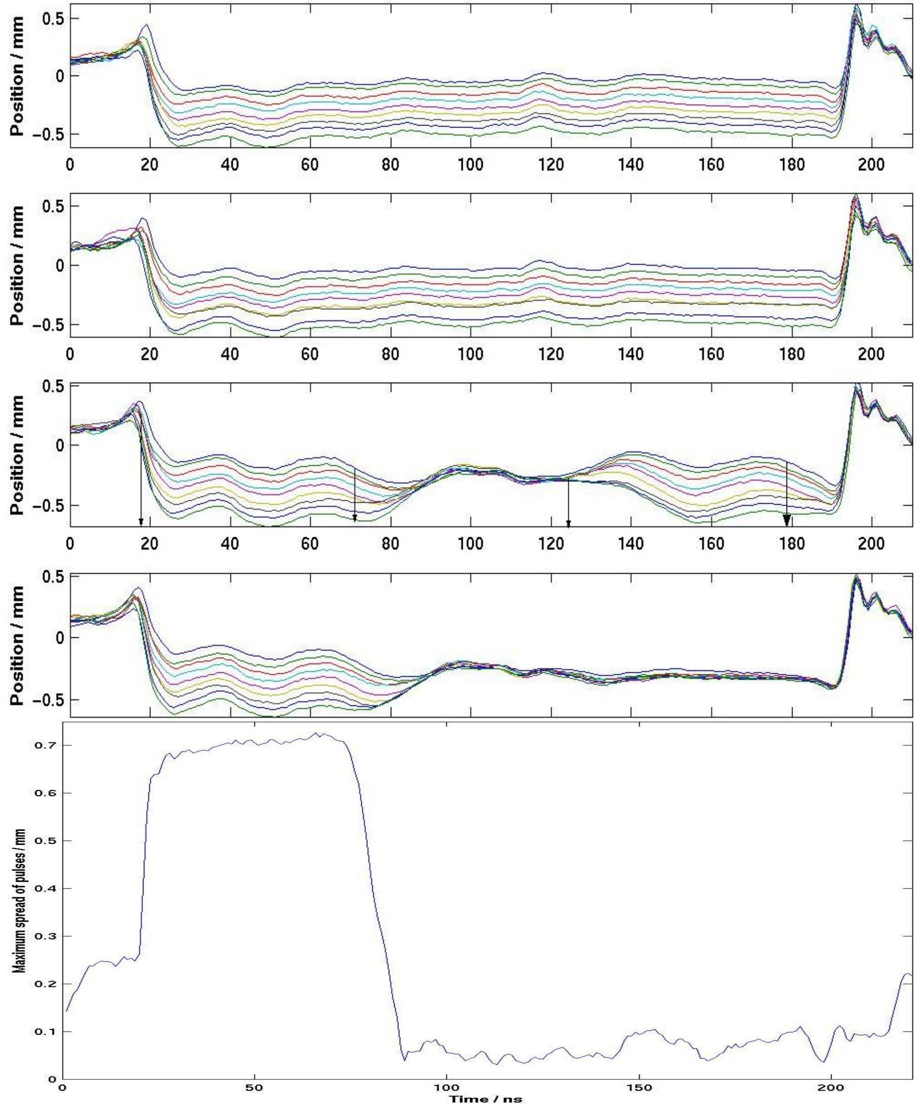


Latency 54ns

Correction 14:1

(limited by gain knob resolution)

dispersion



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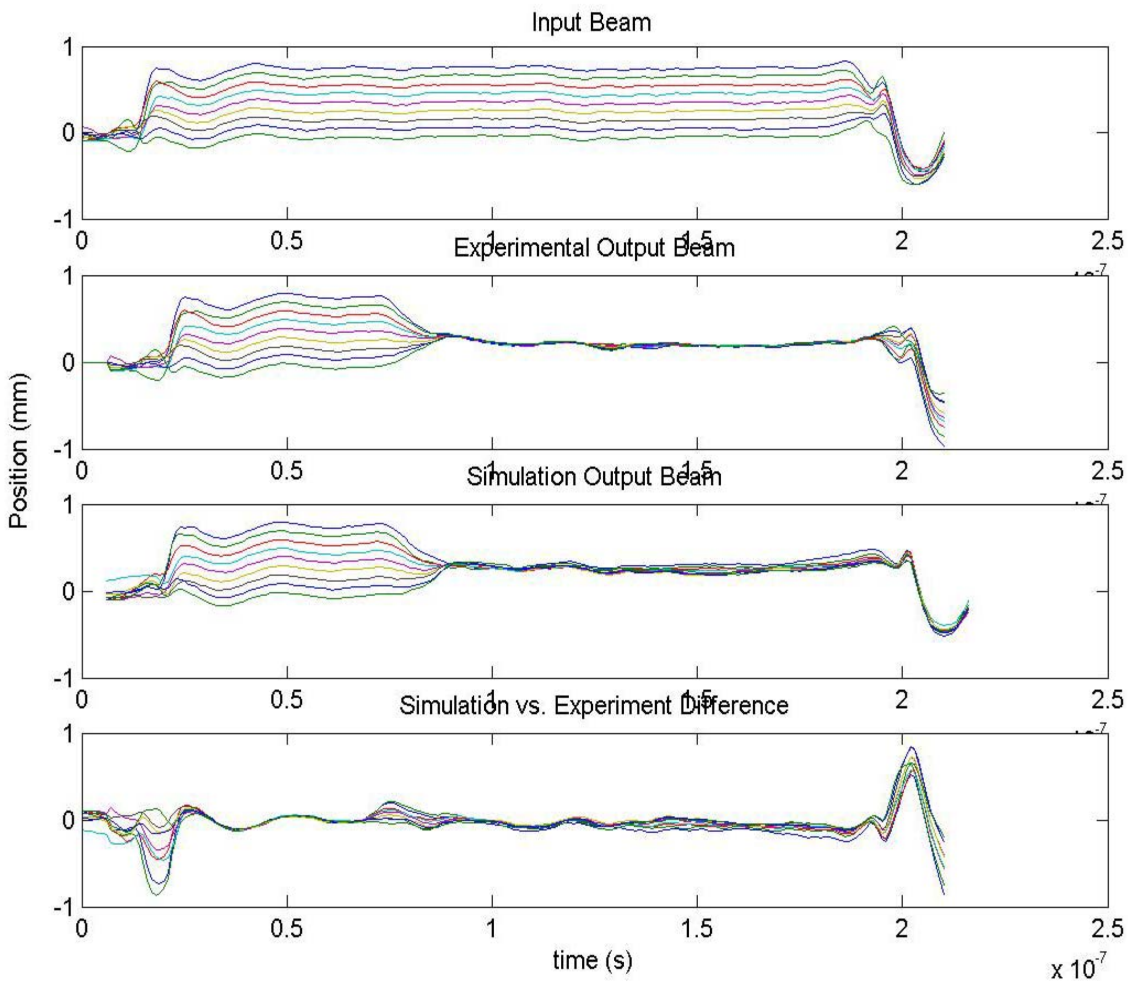
FONT2 Simulation

Simulation includes:

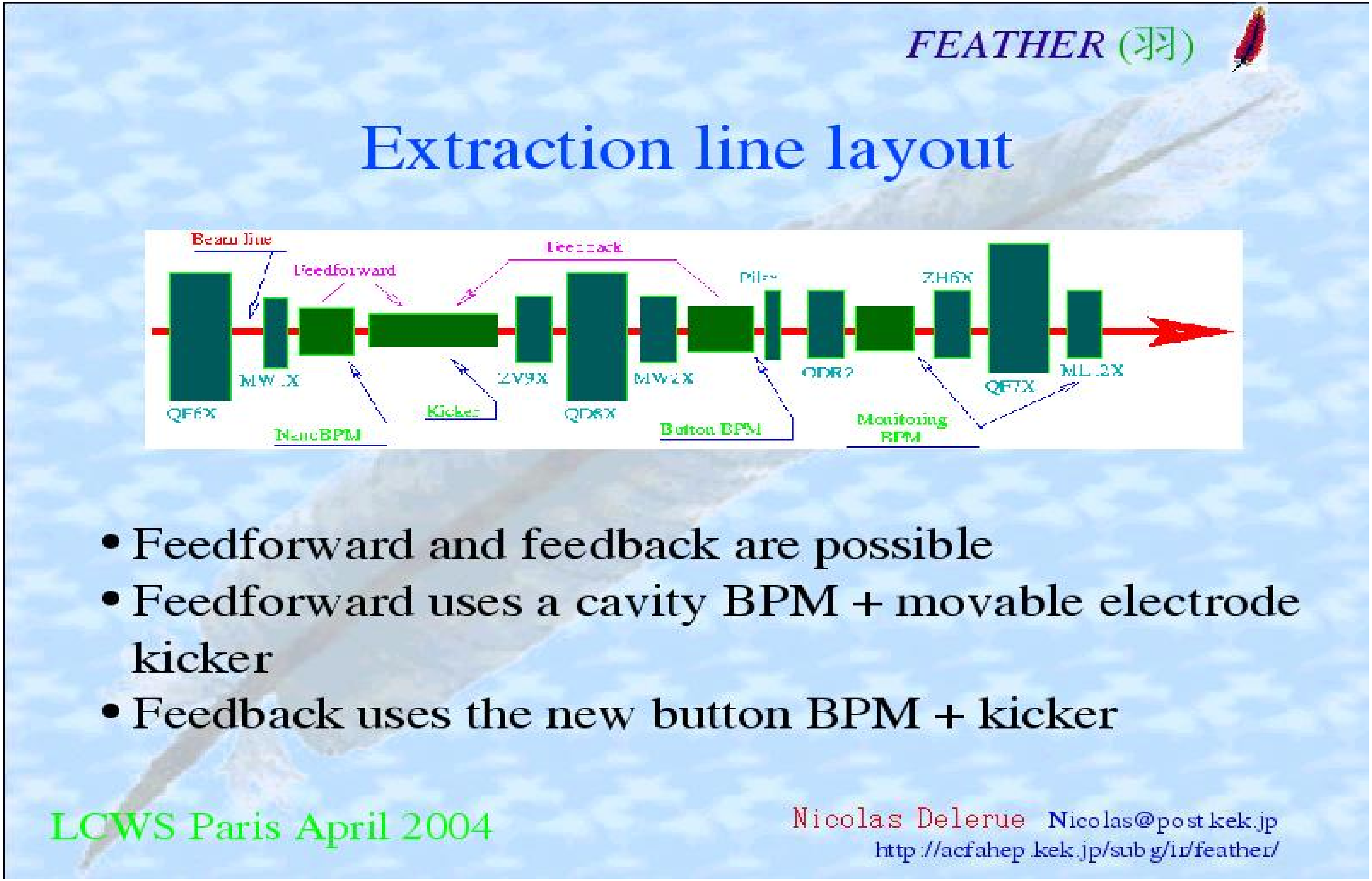
- **time of flight**
- **cable delays**
- **latencies**
- **bandwidths**
- **delay loop**



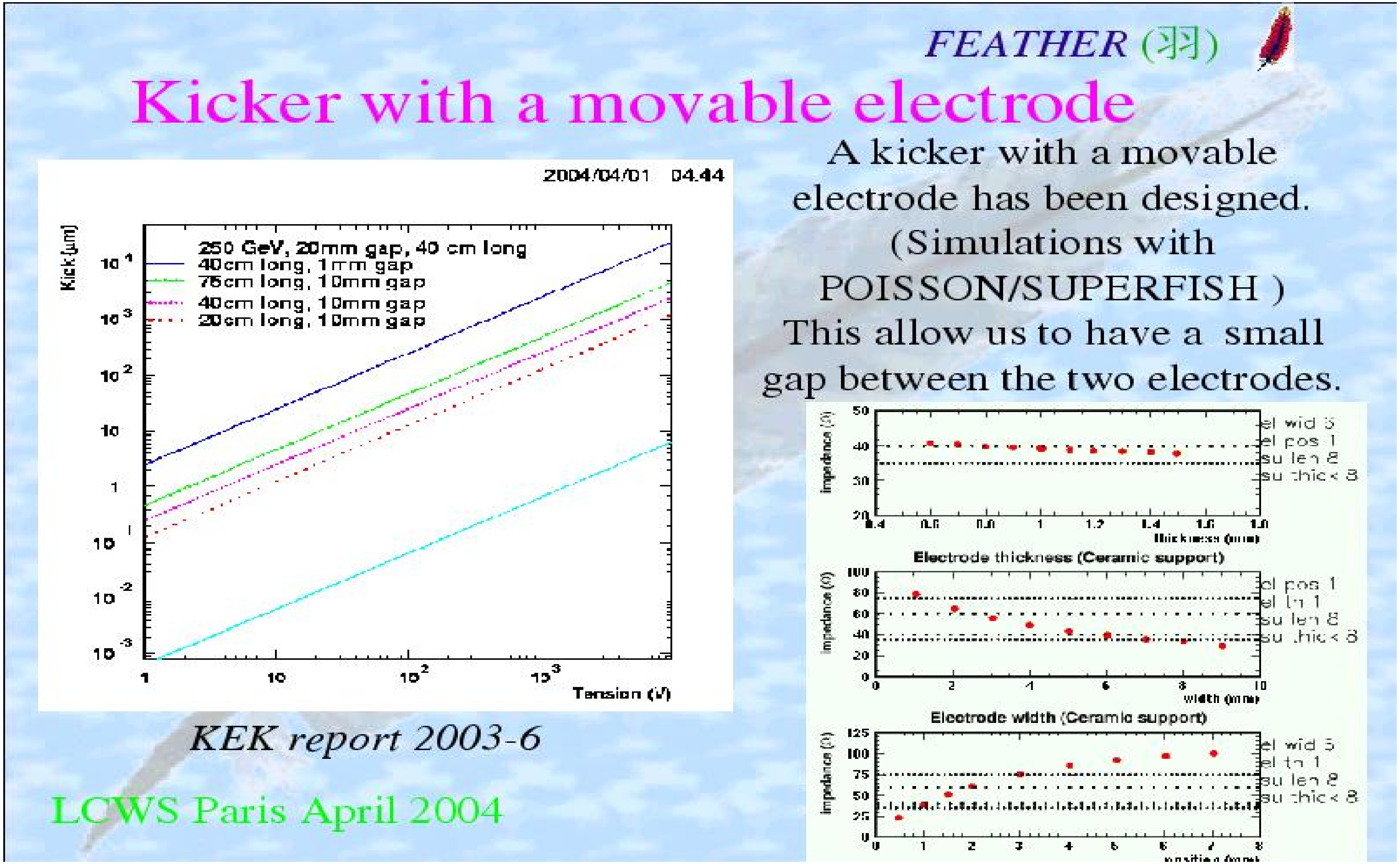
Useful tool for LC

FB simulations

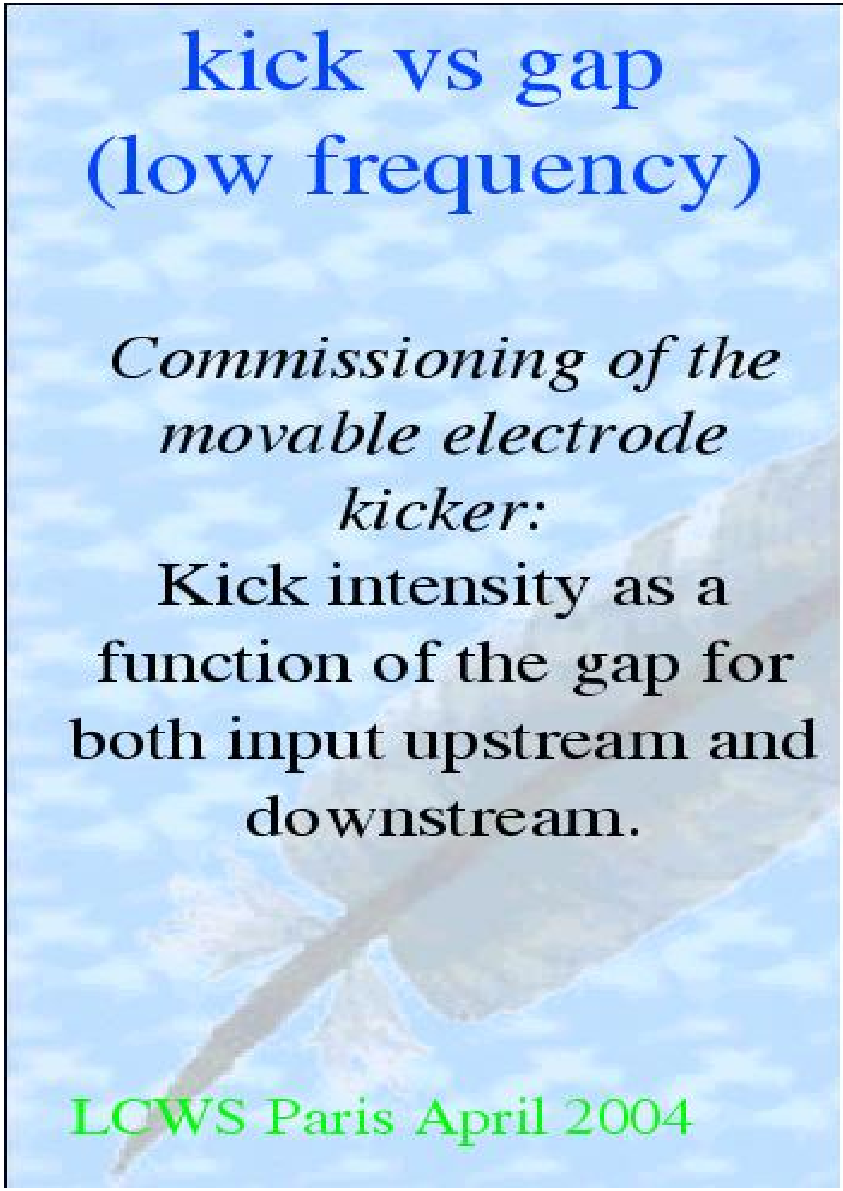
Feedback At High Energy Requirements (FEATHER) (KEK/ATF)

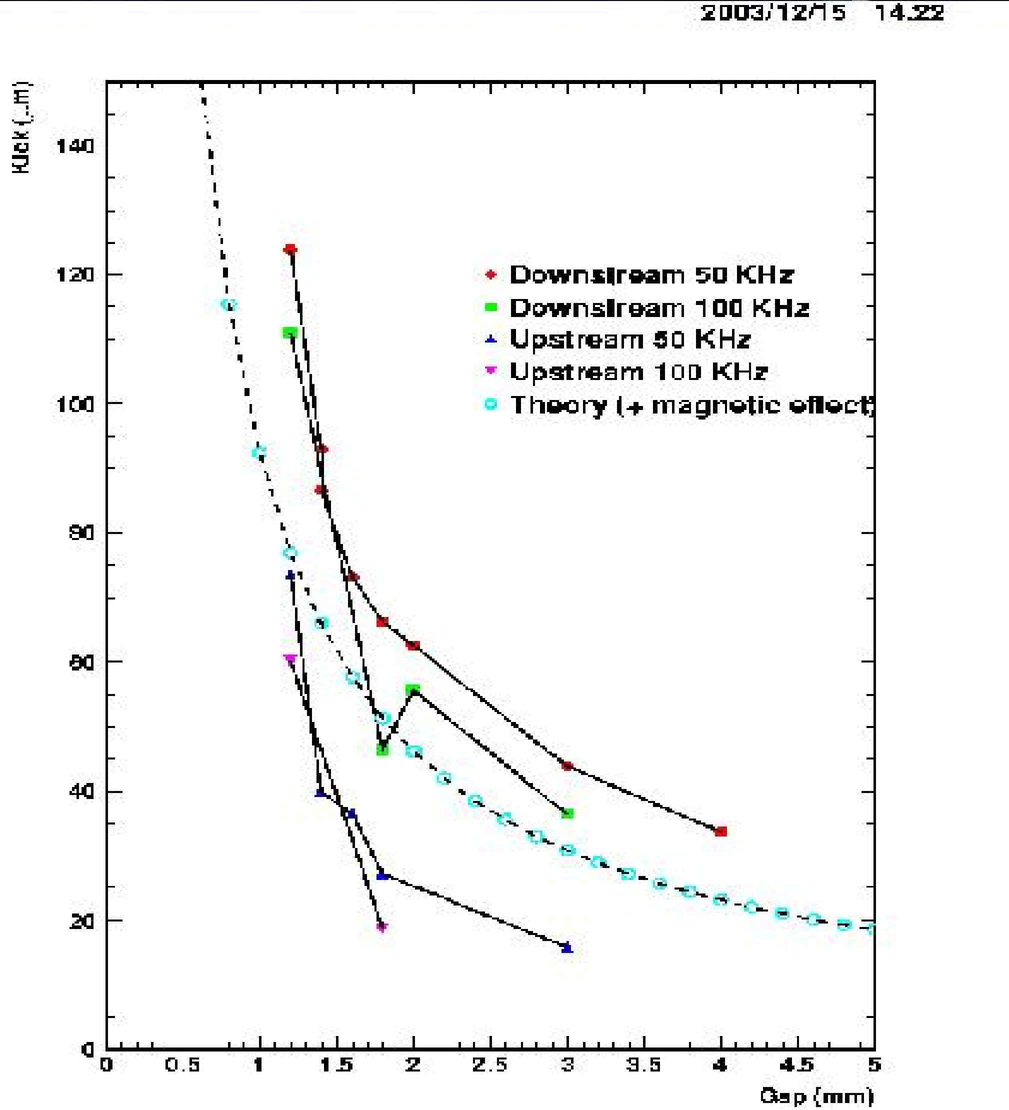


FEATHER: kicker simulations



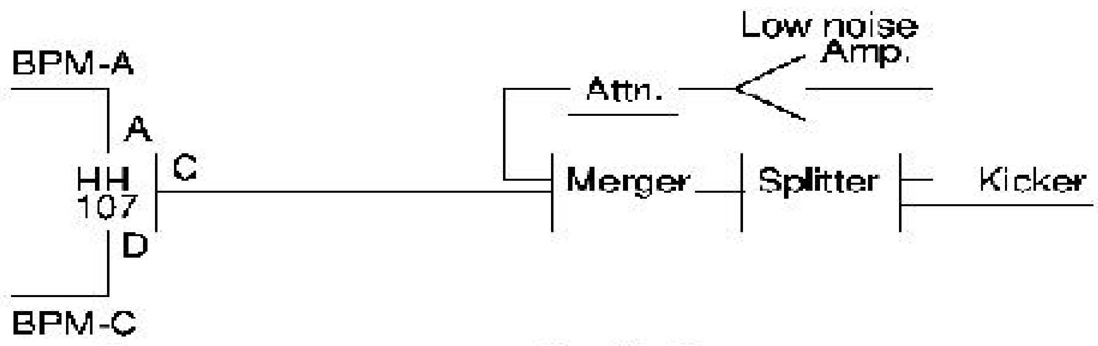
FEATHER: kicker perfomance





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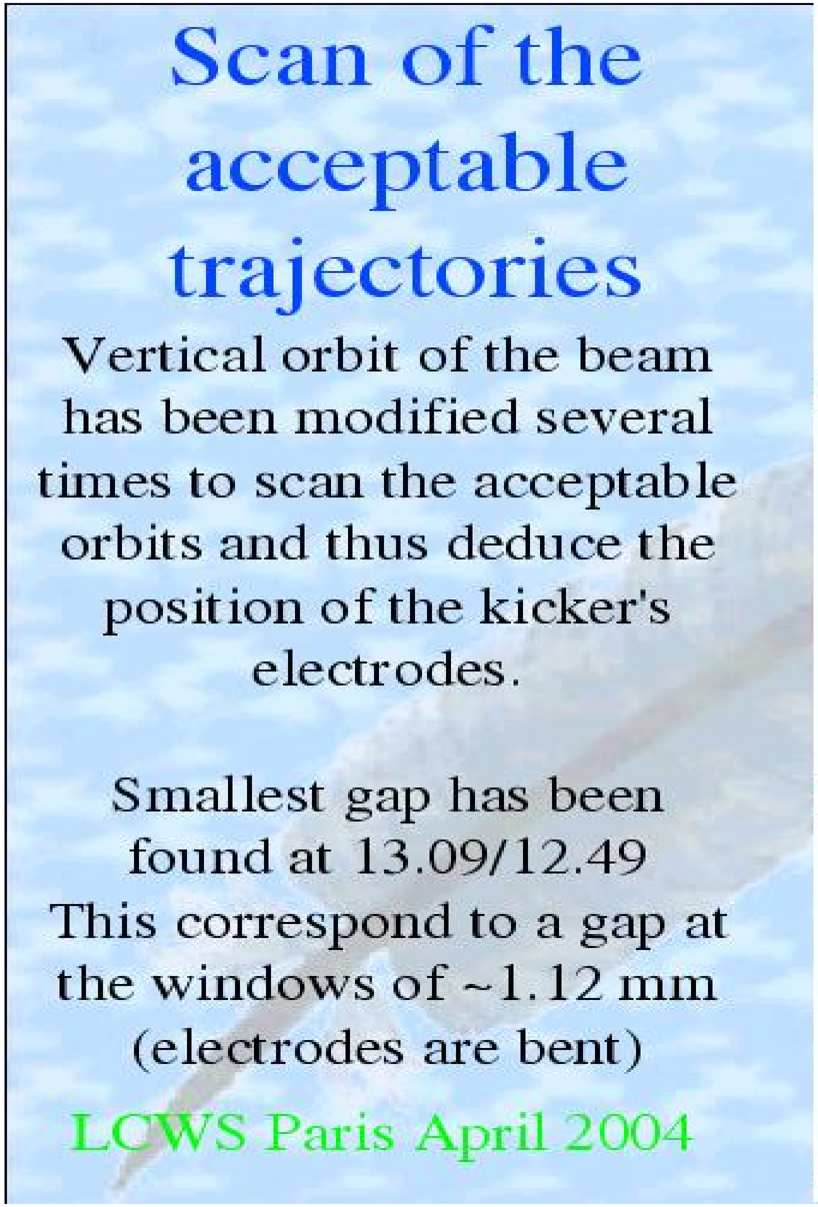
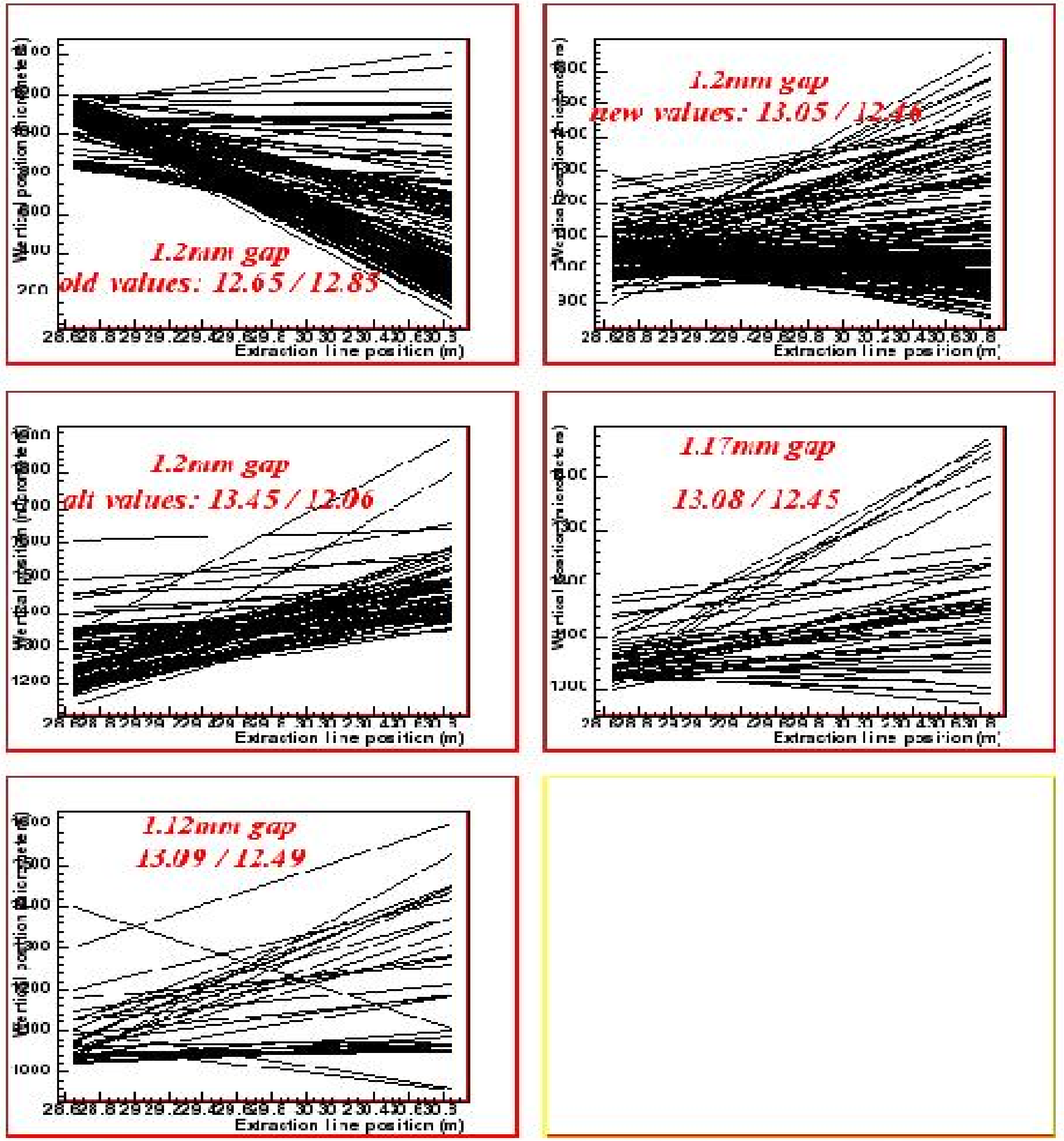
http://acfahep.kek.jp/subg/ir/feather/

FEATHER: beam scan across kicker gap





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:

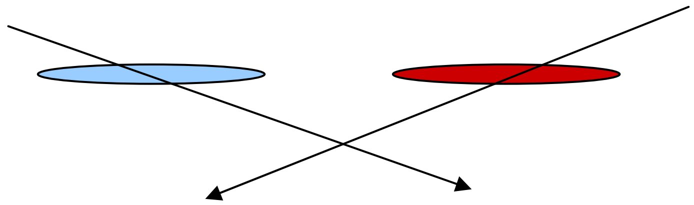
Train charge, length, bunch spacing … parameters can be made relevant for warm or cold machine (Woods)

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