Interaction Point Fast Feedback

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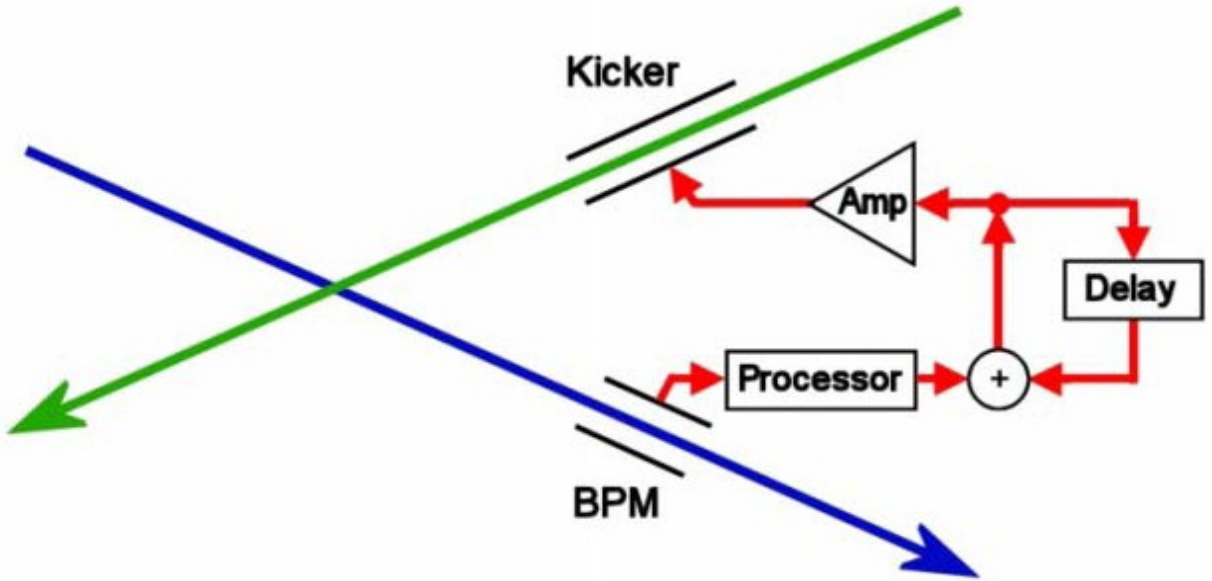
Outline

- Concept
- Brief history of FONT (Feedback on Nanosecond Timescales)
- Considerations for C^3

Concept

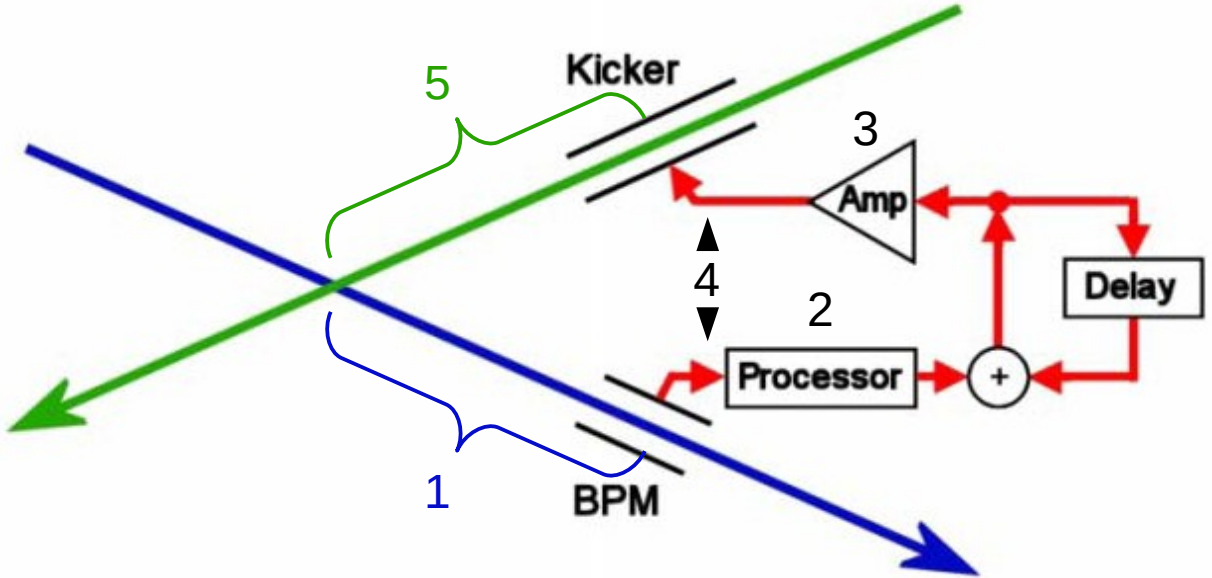
- Last line of defence against relative beam misalignment
- Measure vertical position of outgoing beam and hence beam-beam deflection
- Use fast amplifier and kicker to correct vertical position of other beam



IP position feedback latency

Bunch-by-bunch position correction latency

1. Beam flight time
   IP ► BPM
2. Signal processing,
   FB calculation
3. Amplifier & kicker
   response time
4. Cable delays
5. Beam flight time
   kicker ► IP



A brief history of FONT: FONT1

- FONT1: proof-of-concept at NLCTA

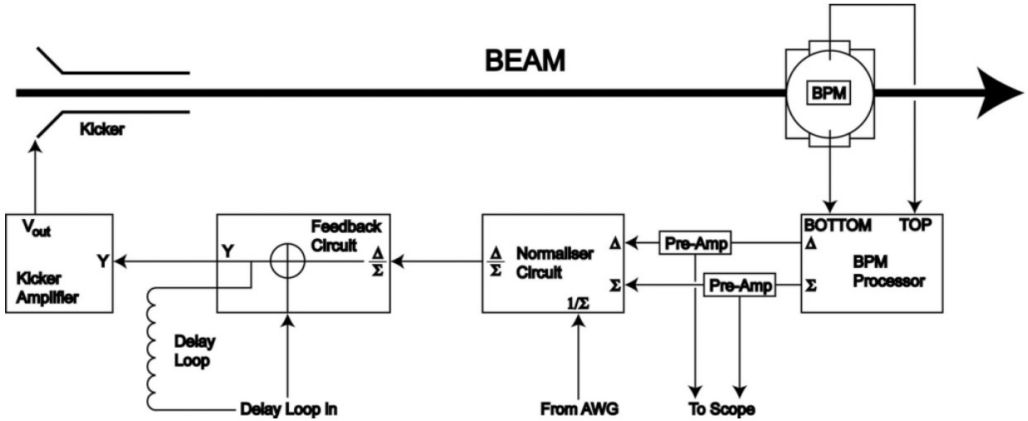
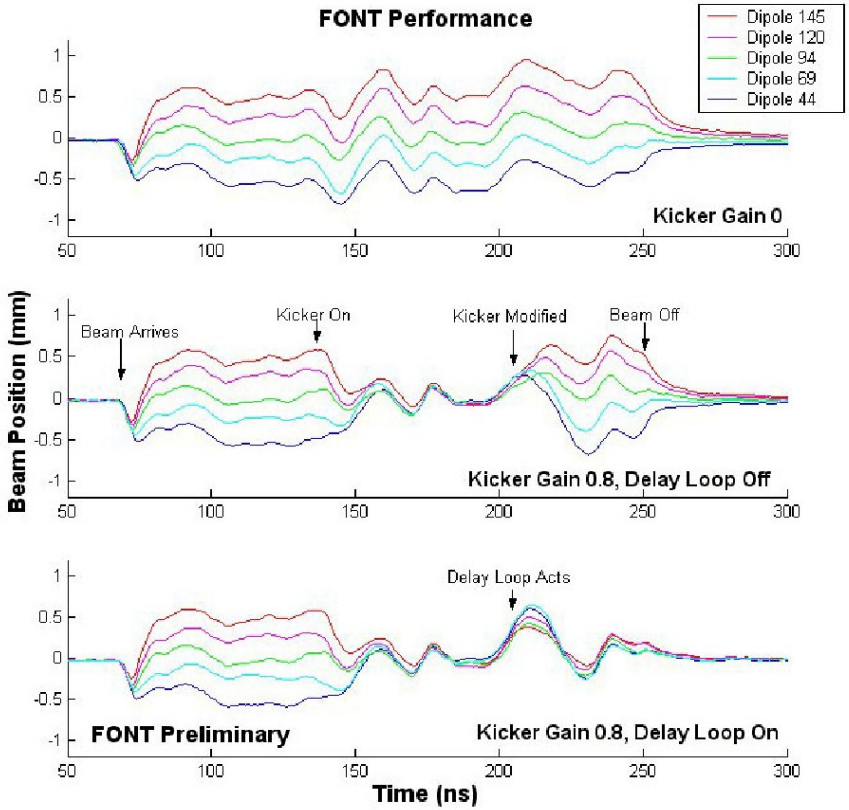


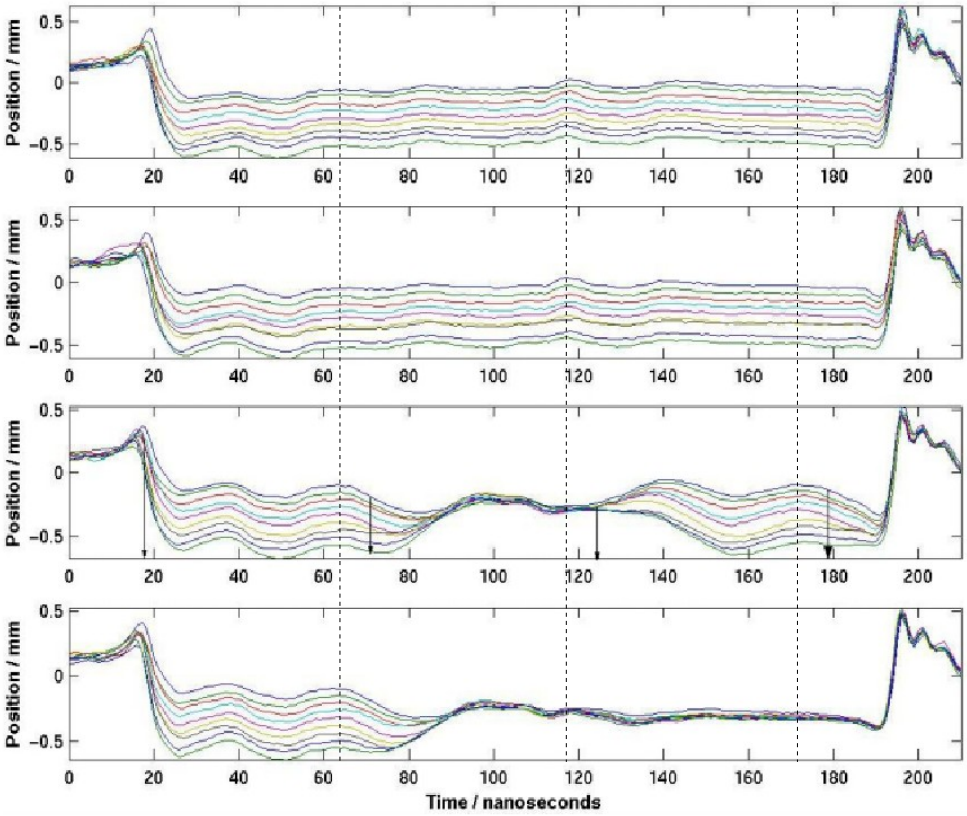
Figure 2: Schematic of FONT1 system in the NLCTA beamline.

PAC'03: Achieved latency: 66 ns



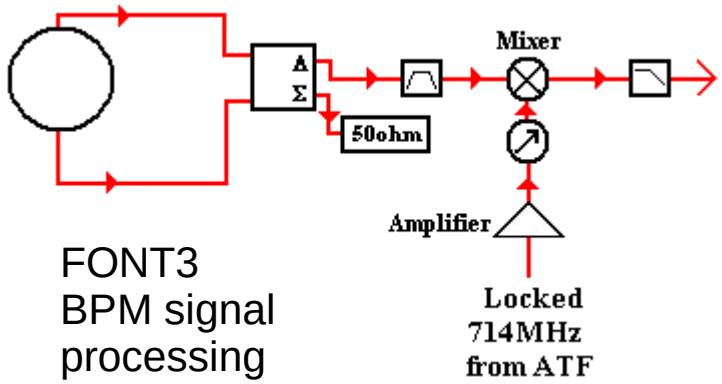
A brief history of FONT: FONT2

- FONT2: second-gen prototype
- Two witness BPMs added to monitor performance
- Second kicker to reduce amplifier drive power
- Reduced distance between BPM and kicker(s)
- Added “beam flattener”
- EPAC'04: Achieved latency = 53 ns

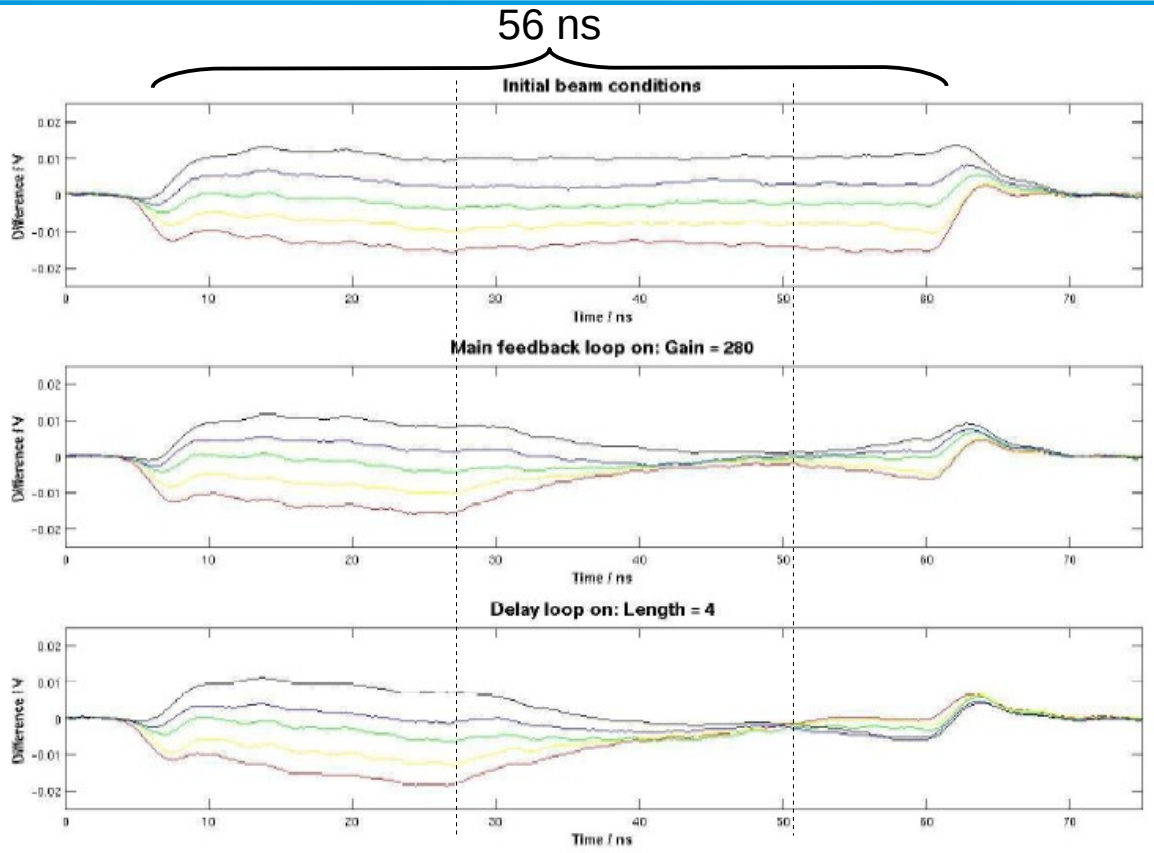


A brief history of FONT: FONT3

- FONT3: KEK ATF
- New low-latency BPM processor and kicker drive amplifier
- EPAC'06: Achieved latency = 23 ns

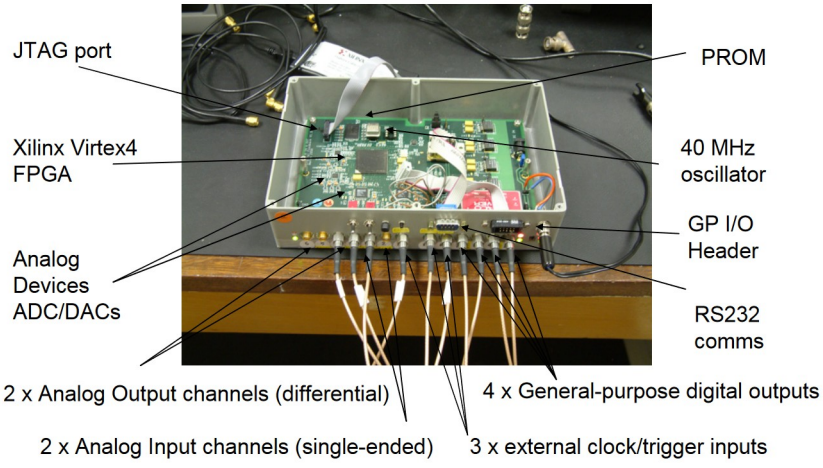


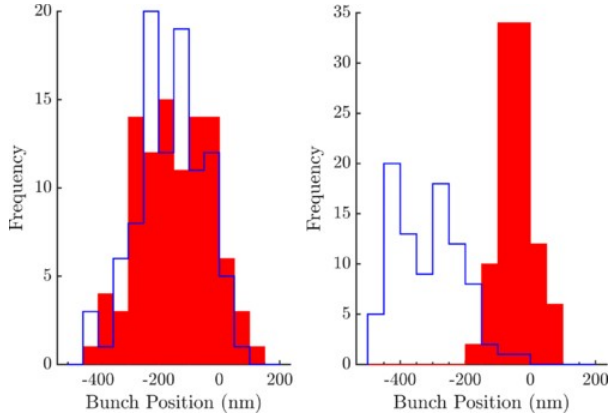
FONT3
BPM signal
processing



A brief history of FONT: FONT4/FONT5

- FONT4: Digital prototype
- 150 ns bunch spacing at ATF allows for more sophisticated feedback algorithms to be implemented
- Virtex-4 FPGA, ADCs 89 MSPS





- FONT5: Second-gen digital
- Dual-BPM, dual-kicker system for correcting position and angle to achieve ATF2 beam stability goal
- Operated with high-resolution stripline or cavity BPMs
- Virtex-5 FPGA, ADCs 357 MSPS

C^3 Parameter Table

Parameter	Symbol[unit]	NLC [3]	CLIC [21]	ILC-250 [22]	ILC-500 [22]	C^3-250 [6]	C^3-550 [6]
CM Energy	$\sqrt{s}$[GeV]	500	380	250	500	250	550
RMS bunch length	σ_z^*[μm]	150	70	300	300	100	100
Horizontal beta function at IP	β_x^* [mm]	10	8.2	13	22	12	12
Vertical beta function at IP	β_y^* [mm]	0.2	0.1	0.41	0.49	0.12	0.12
Normalized horizontal emittance at IP	ϵ_x^* [nm]	4000	950	5000	5000	900	900
Normalized vertical emittance at IP	ϵ_y^* [nm]	110	30	35	35	20	13
RMS horizontal beam size at IP	σ_x^* [nm]	286	149	516	474	210	142
RMS vertical beam size at IP	σ_y^* [nm]	6.7	2.9	7.7	5.9	3.1	1.7
Num. Bunches per Train	n_b	90	352	1312	1312	133	75
Train Rep. Rate	f_r [Hz]	180	50	5	5	120	120
Bunch Spacing	[ns]	1.4	0.5	554	554	5.26	3.5
Bunch Charge	Q[nC]	1.36	0.83	3.2	3.2	1	1
Bunch Population	N_e[10^9 particles]	8.49	5.18	20.0	20.0	6.24	6.24
Beam Power	P_{beam} [MW]	5.5	2.8	2.63	5.25	2	2.45
Final RMS energy spread	%	0.38	0.35	~ 0.1	~ 0.1	~ 0.1	~ 0.1
Crossing Angle	θ[rad]	0.020	0.0165	0.014	0.014	0.014	0.014
Crab Angle	θ[rad]	0.020/2	0.0165/2	0.014/2	0.014/2	0.014/2	0.014/2
Gradient	[MeV/m]	37	72	31.5	31.5	70	120
Effective Gradient	[MeV/m]	29	57	21	21	63	108
Shunt Impedance	[MΩ/m]	98	95			300	300
Effective Shunt Impedance	[MΩ/m]	50	39			300	300
Site Power	[MW]	121	168	125	173	~ 150	~ 175
Length	[km]	23.8	11.4	20.5	31	8	8
L*	[m]	2	6	4.1	4.1	4.3	4.3

Considerations for C^3

- C^3 more NLC-like than ILC-like, so the low latency of an analogue system like FONT3 probably more suitable

	FONT4	FONT3	
Time of flight kicker – BPM:	4ns	4ns	} depends on how close to the IP you can get your components
Signal return time BPM – kicker:	10ns	5ns	
Irreducible latency:	14ns	9ns	
BPM processor:	10ns	5ns	
ADC/DAC (3.5 89 MHz cycles)	40ns		} based on obsolete digital components
Signal processing (9 357 MHz cycles)	27ns		
FPGA i/o	3ns		
Amplifier	35ns	5ns	
Kicker fill time	3ns		
Electronics latency:	118ns	10 ns	
Total latency budget:	132ns	20ns	

Summary

- The FONT group developed multiple feedback systems:
  - FONT3 - for NLC, all analogue, latency 23 ns
  - FONT5 - for ILC, flexible mixed digital/analogue system, latency 150 ns
- FONT3 probably more suitable due to C^3 parameters

Credit for this work belongs to the FONT team over the years:

Robert Apsimon, Neven Blaskevic Kraljevic, Ryan Bodenstein, Talitha Bromwich, Philip Burrows, Glenn Christian, Christine Clarke, Ben Constance, Michael Davis, Tony Hartin, Young Im Kim, Simon Jolly, Steve Molloy, Gavin Neson, Colin Perry, Rebecca Ramjiawan, Javier Resta Lopez, Jack Roberts, Christina Swinson