Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

Preliminary Considerations on a Fast IP Feedback Design

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XVII SuperB Workshop and Kick Off Meeting
La Biodola, Isola d'Elba,
May,28th – June,2nd

Still open issues in detector

Forward and Backward Regions.

1. The vertical size of bunches is O(40 nm) ➡ peak luminosity is strongly dependent on alignment and feedback a precise control of luminosity is needed in almost real time. **A luminosity monitor rad hard , fast and precise is needed.**

2. A precision determination of beam polarization is required for measuring asymmetries to extract SM parameters better than at LEP and SLD. ➡ **A detector giving the polarization with a precision better than 0.5% is needed.**

From Marcello Giorgi's talk in this General Meeting
It underlined the importance of the alignment and luminosity feedback

Basic points

- In the SuperB project, two trains of ~900 (maybe, in a second phase, up to 1800) electron and positron bunches will collide at the IP (Interaction Point) to achieve a foreseen extremely high luminosity (10**36 cm-2 s-1)
- The collision scheme is based on ultra low emittance, and the beam vertical dimension specifications are of the order of 36 nm at the IP
- Given these two points, of course *diagnostic systems* have fundamental importance to have a perfect beam-beam overlap and to achieve the very ambitious luminosity goal, and need to be carefully evaluated
- In addition, to maintain stable collisions along the bunch train, SuperB diagnostics must include powerful and multiple *feedback systems,* with different characteristics and features
- A short discussion is carried on in the following slides

SuperB parameter:

version Sep/28/10

(Bold: computed values)		V12		V13		V14	
Parameter	Units	HER (e+)	LER (e-)	HER (e+)	LER (e-)	HER (e+)	LER (e-)
LUMINOSITY	$cm^{-2}\ s^{-1}$	1.00E+36		1.10E+36		1.11E+36	
Energy	GeV	6.7	4.18	6.7	4.18	6.7	4.18
Circumference	m	1258.4		1263.5		1159.5	
X-Angle (full)	mrad	66		60		60	
β_x @ IP	cm	2.6	3.2	2.6	3.2	2.6	3.2
β_y @ IP	cm	0.0253	0.0205	0.0253	0.0205	0.0253	0.0205
Coupling (full current)	%	0.25	0.25	0.25	0.25	0.25	0.25
Emittance x (without IBS)	nm	1.97	1.82	2.09	1.93	1.90	1.82
Emittance x (with IBS)	nm	2.07	2.37	2.19	2.51	2.00	2.37
Emittance y	pm	**5.17**	**5.92**	**5.49**	**6.27**	**4.99**	**5.92**
Bunch length (zero current)	mm	4.69	4.29	4.8	4.4	4.53	4.29
Bunch length (full current)	mm	5	5	5	5	5	5
Beam current	mA	1892	2447	**1930**	2470	1892	2447
Buckets distance	#	2		2		2	
Buckets distance	ns	4.20		4.20		4.20	
Ion gap	%	2		2		2	
RF frequency	Hz	4.76E+08		4.76E+08		4.76E+08	
Revolution frequency	Hz	**2.38E+05**		**2.37E+05**		**2.59E+05**	
Harmonic number	#	**1998**		**2006**		**1841**	
Number of bunches	#	**978**		**982**		**901**	
N. Particle/bunch	#	**5.08E+10**	**6.56E+10**	**5.18E+10**	**6.63E+10**	**5.08E+10**	**6.57E+10**
σ_x @ IP	microns	**7.334**	**8.701**	**7.554**	**8.960**	**7.202**	**8.701**
σ_y @ IP	microns	**0.036**	**0.035**	**0.037**	**0.036**	**0.036**	**0.035**
$\sigma_{x'}$ @ IP	microrad	**282.1**	**271.9**	**290.5**	**280.0**	**277.0**	**271.9**
$\sigma_{y'}$ @ IP	microrad	**143.0**	**169.9**	**147.3**	**174.9**	**140.4**	**169.9**
Piwinski angle	rad	**22.50**	**18.96**	**19.86**	**16.74**	**20.83**	**17.24**
σ_x effective	microns	**165.22**	**165.29**	**150.24**	**150.31**	**150.22**	**150.30**
Σ_x	microns	**11.379**		**11.719**		**11.295**	
Σ_y	microns	**0.050**		**0.052**		**0.050**	
Σ_x effective	microns	**233.35**		**212.13**		**212.13**	
Hourglass reduction factor		0.950		0.950		0.950	
Tune shift x		**0.0021**	**0.0033**	**0.0026**	**0.0040**	**0.0026**	**0.0040**
Tune shift y		**0.0989**	**0.0955**	**0.1067**	**0.1041**	**0.1089**	**0.1070**
Longitudinal damping time	msec	13.4	20.3	13.6	20.6	11.6	20.3
Energy Loss/turn	MeV	2.11	0.865	2.08	0.88	2.24	0.865
Momentum compaction		4.36E-04	4.05E-04	4.69E-04	4.35E-04	4.60E-04	4.05E-04
Energy spread (zero current)	dE/E	6.31E-04	6.68E-04	6.30E-04	6.68E-04	6.52E-04	6.68E-04
Energy spread (full current)	dE/E	6.43E-04	7.34E-04	6.43E-04	7.34E-04	6.64E-04	7.34E-04
CM energy spread	dE/E	**5.00E-04**		**5.00E-04**		**5.11E-04**	
Energy acceptance	dE/E	0.01	0.01	0.01	0.01	0.01	0.01
SR power loss	MW	**3.99**	**2.12**	**4.01**	**2.17**	**4.24**	**2.12**
Touschek lifetime	min	33	16	33	16	33	16
Luminosity lifetime	min	**4.81**	**6.22**	**4.48**	**5.73**	**3.99**	**5.16**
Total lifetime	min	**4.20**	**4.48**	**3.94**	**4.22**	**3.56**	**3.90**
RF Wall Plug Power (SR only)	MW	**12.22**		**12.38**		**12.71**	
Total RF Wall Plug Power	MW	17.08					

Diagnostics for SuperB [Alan Fisher,Annecy,10-03-17]

- Monitors:
  - Beam position
  - Beam profiles
  - Beam loss
  - Tunes
  - Total current
  - Bunch current
  - Luminosity
  - Polarization (LER)
- Measure/tweak in collision:
  - Coupling
  - Chromaticity
  - Phase advance
- Feedbacks:
  - 1 Orbit
  - 2 Luminosity *(=> Dither fb !)*
  - 3 Tune
  - 4 Transverse motion
  - 5 Longitudinal motion
  - 6 → Fast IP
- Too much for 25 minutes
- Some are in other talks.
- Others are similar to PEP-II.
- I will concentrate on a few difficult issues.

Multiple feedback systems to maintain stable collisions

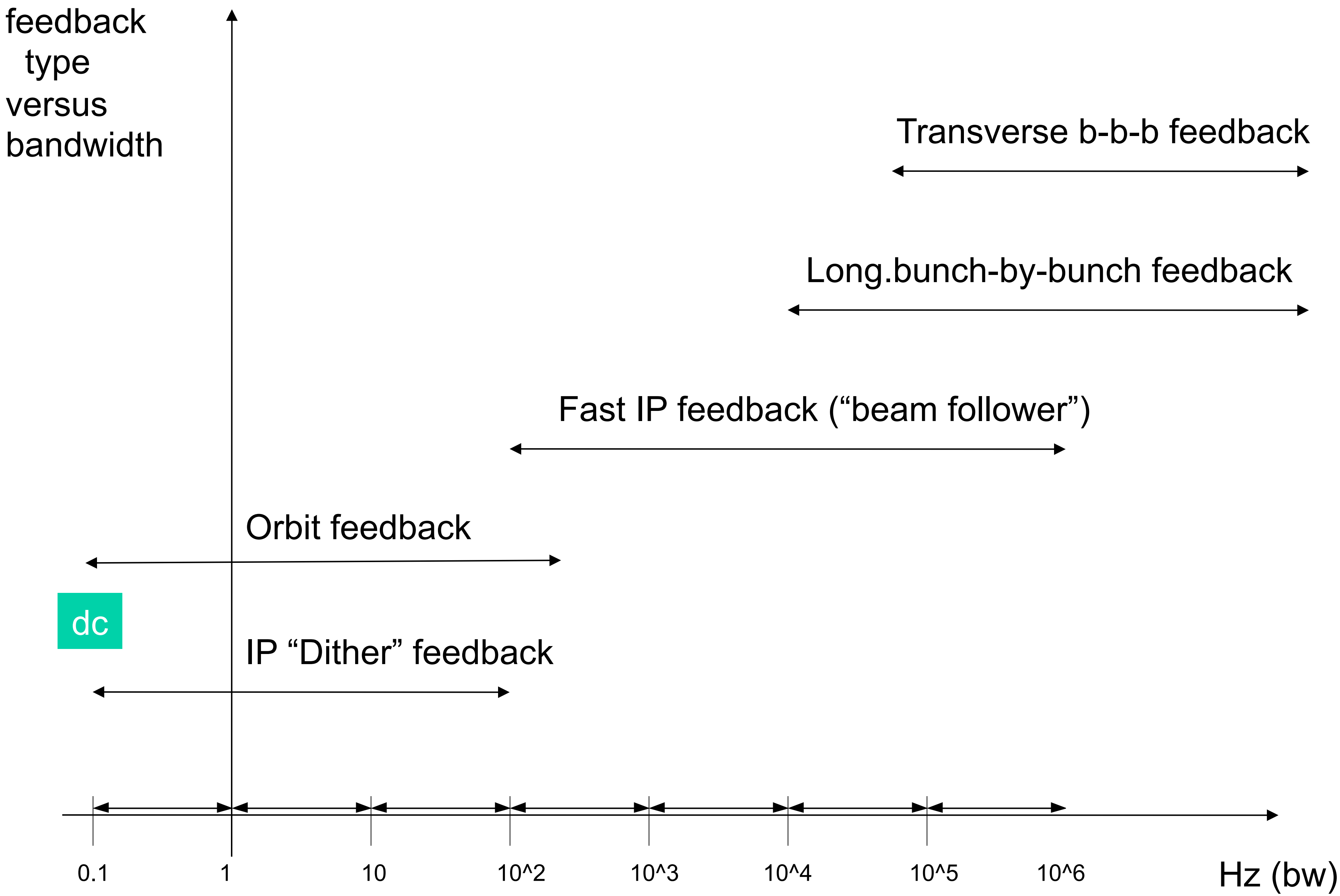
a) *Betatron and synchrotron bunch-by-bunch feedback systems*: these are used to maintain under control the transverse and longitudinal bunch-by-bunch motions (kicking each bunch every turn in V, H, and L planes)

b) *Tune feedback* can use a pilot bunch out of collision or the internal bunch-by-bunch feedback diagnostics

c) *Orbit feedback* (Libera or Libera–like based): it takes as reference a “golden orbit” for each ring and applies corrections using the “regular” corrector magnets

d) *IP “dither” feedback (or luminosity feedback)*: it should use 4 (dual-axis) air-core coil correctors to generate orbit-bumps in 3 dimension (in just one of the two rings) being based on the Luminosity monitor real-time data

e) *Fast IP feedback* or feedforward (“beam-follower”): this system, freely inspired to FONT project, is under study.


feedback type versus bandwidth
Transverse b-b-b feedback
Long.bunch-by-bunch feedback
Fast IP feedback (“beam follower”)
Orbit feedback
dc
IP “Dither” feedback
0.1
1
10
10^2
10^3
10^4
10^5
10^6
Hz (bw)

A PROPOSED FAST LUMINOSITY FEEDBACK FOR THE SUPER-B ACCELERATOR*

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Abstract

We present a possible design for a fast luminosity feedback for the SuperB Interaction Point (IP). The design is an extension of the fast luminosity feedback installed on the PEP-II accelerator. During the last two runs of PEP-II and BaBar (2007-2008), we had an improved luminosity feedback system that was able to maintain peak luminosity with faster correction speed than the previous system. The new system utilized fast dither coils on the High-Energy Beam (HEB) to

For SuperB, we have the advantage of including a fast feedback system in the original design rather than trying to retrofit one later. We propose a similar system to PEP-II, but with dithering of the Low-Energy Beam (LEB) rather than the HEB and use of a higher frequency (1-3 kHz). Simultaneous excitation with lock-in amplifiers should allow corrections to about 300 Hz. We will also investigate sequential excitation, which may allow faster corrections of the more critical y position. The best feedback approach will be dependent on the noise environment, which will not be known until the machine is commissioned, so the system must be flexible.

DITHER COILS

Coil Locations

magnets (see Fig. 1).

SuperB

Fast Luminosity Feedback

Super-B
2-13-09

Kirk Bertsche

PEP-II poster presented
at EPAC'06 and PAC'07.
The upgraded version
at the VIII SuperB General
Meeting and at PAC'09
by **Kirk Bertsche**

IP “Dither” (Luminosity) feedback

I. The old IP “Dither” feedback system was designed in 2006 for PEP-II using dedicated corrector magnets and luminosity signal to optimize the overlap of colliding beams at the interaction point.

II. The luminosity signal comes from a real time luminosity detector (with very fast response).

III. One beam (HEB , high-energy beam) is steered through the IP to maximize the signal from the detector.

IV. The other beam (LEB), is driven with small dither motions 1 to 3 kHz to allow luminosity detection of best beam overlap.

V. The dither and applied corrections occur in three directions: horizontal, vertical, and vertical angle.

VI. The SuperB design allows for dither amplitudes of up to 25 microns horizontal, 2 microns vertical, and >0.5 mrad in vertical angle.

VII. Relative to the IP, the dither coils inSuperB are foreseen at ±3.5 meters and ±15 meters, with horizontal and vertical pairs at each location.

Luminosity Feedback

- PEP-II dithered LER position and angle against HER
  - Initially dithered x, y, and y' sequentially, in steps
  - Later simultaneously, with small sinusoidal drive at 3 frequencies
  - Rate limited to 1 Hz by software magnet controls
  - Often ran at 0.3 Hz to use smaller dithers
- Integrate luminosity feedback with orbit feedback

!!!

  - Avoids having orbit feedback "fix" the luminosity dither
    - Especially in x, which the BPMs will see

Important comment by Alan Fisher

Orbit feedback based on “*Libera*” or *Libera*-like system

a) Probably the choice will be for the same system (by Instrumentation Technology) used in DIAMOND and in other accelerators
b) Implemented in many circular light sources but, if I remember well, still not in a lepton collider (two rings with a common Interaction Region)
c) It should have ~2kHz bandwidth (acquisition at 10kHz)
d) How fast can corrector magnet be applied?
e) ~10 micron stability/sensitivity (maybe less)
f) Strategy: in each ring the feedback operates to move orbit toward the reference orbit applying command to the “regular” correctors
g) At the IP (that is a common part of the vacuum chamber) it is necessary to avoid unstable situations or conflicts between the two orbit feedback systems

PERFORMANCE AND FUTURE DEVELOPMENT OF THE DIAMOND FAST ORBIT FEEDBACK SYSTEM

M. G. Abbott, J. A. Dobbing, M. T. Heron, G. Rehm, J. Rowland, I. S. Uzun, Diamond Light Source, Oxfordshire, U.K. S. Duncan, University of Oxford, Oxfordshire, U.K

INTRODUCTION

The Fast Orbit Feedback (FOFB) system on the Diamond Light Source storage ring began routine operation in July 2007. It achieves integrated beam stability, up to 100 Hz, of X < 1.0 µm and Y < 0.4 µm, at primary eBPMs, which are well within the required 10% RMS beam dimensions. The FOFB implementation has been refined during this operational period to improve stability and to cope with anomalous behaviour in eBPMs and the communications network.

While the FOFB meets the current requirements it is recognised that the system needs to be further developed to meet increasing demands on beam stability arising from smaller vertical beam sizes, higher sensitivity beamlines and additional sources of beam motion.

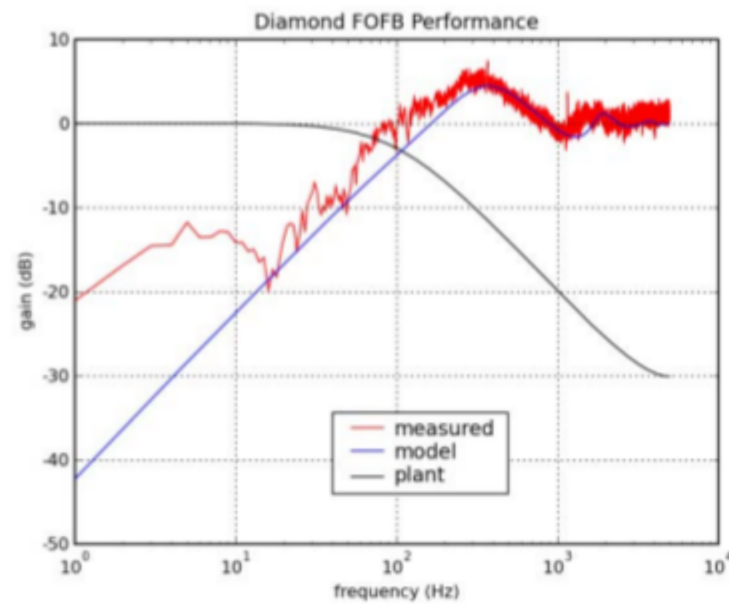
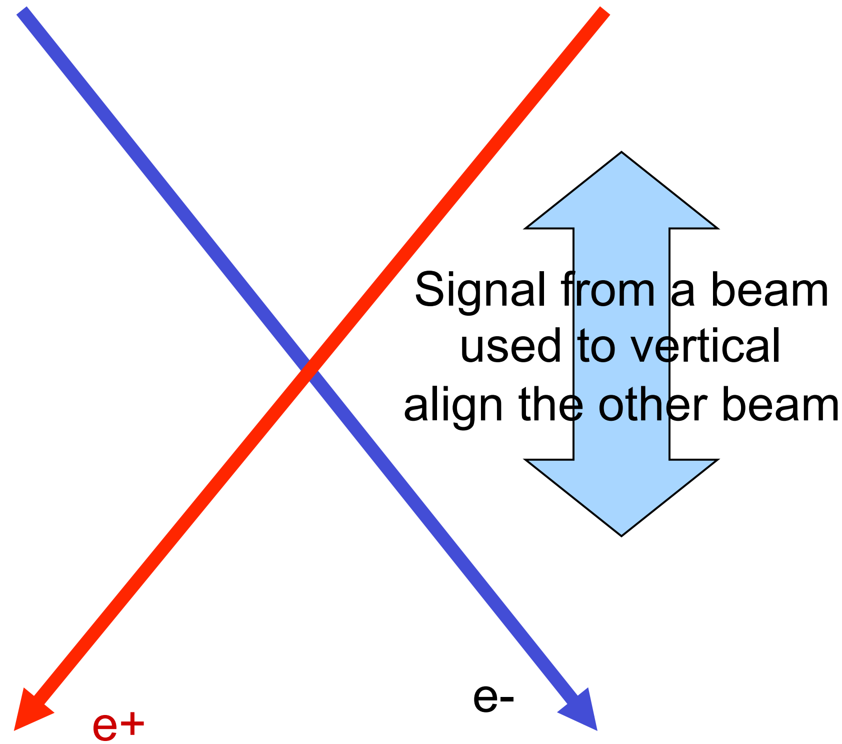


Figure 3: Theoretical and measured suppression in the vertical plane. Below 10 Hz is noise dominated in the measured data.

Fast IP feedback or feedforward ("beam-follower")

- This design is freely inspired to the FONT project (by P. Burrows)
- Design and specification are in very preliminary stage
- STRATEGY: The feedback should take the vertical position of the first and second beam moving vertically the second beam for a better very fast overlap in the Interaction Point



Fast IP feedback or feedforward ("beam-follower")

- Why another feedback ?
- Many reasons:
  - The betatron and synchrotron bunch-by-bunch feedback work as band pass filter and cannot do almost anything about slow motions
  - Luminosity and orbit feedbacks will realistically work between 100Hz and 1kHz
  - There are mid-frequency motion range to be considered (1kHz-1MHz)
  - Each corrector magnet transitions can produce losses of luminosity if not perfectly synchronized (for bad overlapping)
  - The Fast IP feedback must make a beam able to overlap the other beam as a vertical follower for the necessary short period of time
  - What about horizontal and angle ? Also these options in principle could be considered

Fast IP feedback or feedforward ("beam-follower")

Tentative specifications and algorithm

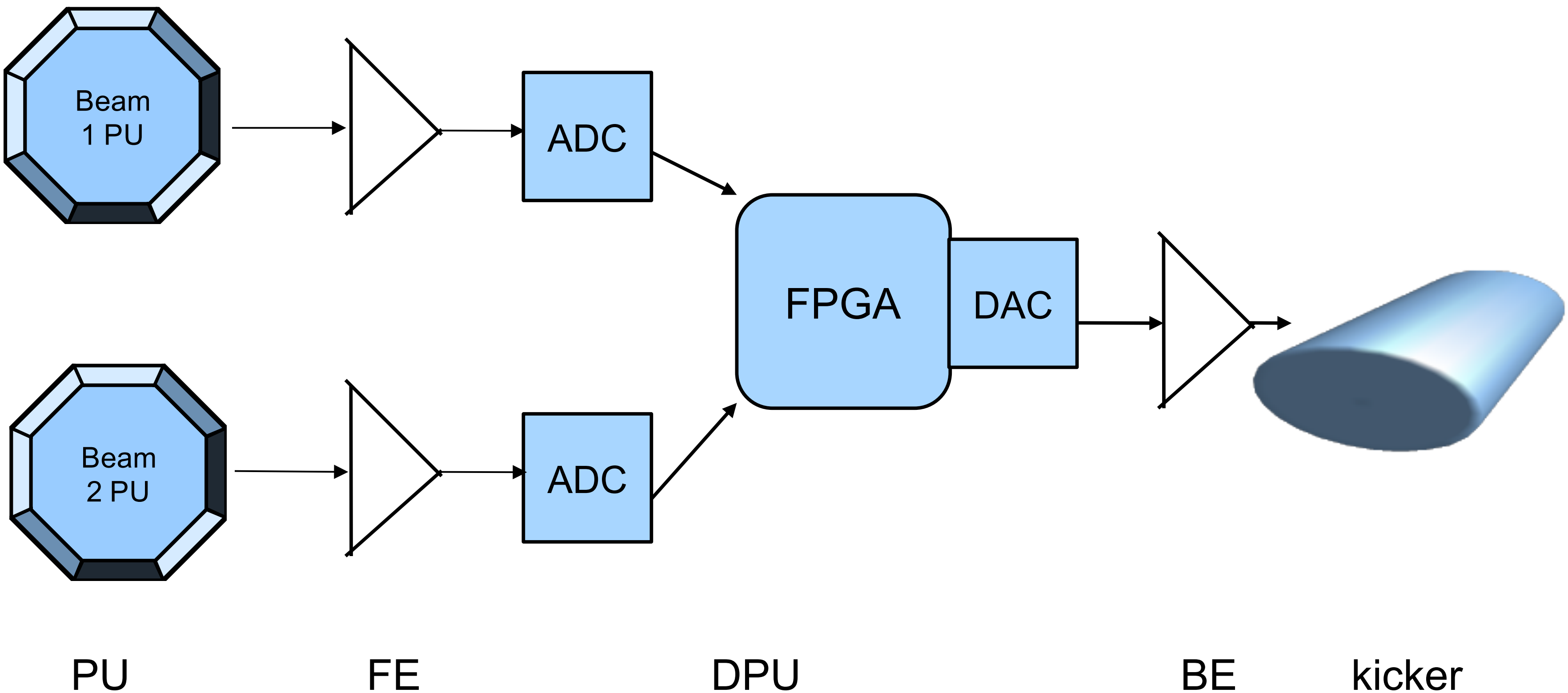
- Propagation delay: ~150ns
- It should be able to acquire position signals with a precision better than 36 nm from the first and the second beam
- It should be compute average values from 30-40 bunch trains for e+ and e- beams
- It should compare the two signals (avoiding noise problems) and generate a correction signal to be applied to the second beam that have to be perfectly overlapped to the first beam
- Bandwidth: at least up to revolution frequency, better if up to 1MHz
- Great noise immunity is fundamental
- Dynamic range: the feedback should work at least between 10 nm and ± 10 μm, so the minimum is 60dB, better if >70dB
- It should be based on FPGA to be extremely flexible and to give possibility to try different feedback transfer functions & algorithms
- Powerful software to monitor and change parameters in real time

Fast IP feedback or feedforward ("beam-follower")

Parts under study that could be used for implementation:

- ML605 by Xilinx with the last Virtex-6 FPGA
- ADS 5474 (Analog-to-digital converter) by Texas Instruments:
  * 400-MSPS Sample Rate
  * 14-Bit Resolution, 11.2-Bits ENOB
  * 1.4-GHz Input Bandwidth
  * SFDR = 80 dBc at 230 MHz and 400 MSPS
  * SNR = 69.8 dBFS at 230 MHz and 400 MSPS
  * 2.2-Vpp Differential Input Voltage
  * LVDS-Compatible Outputs
- MAX 5891 by Maxim: 16-Bit, 600Msps, High-Dynamic-Performance DAC with LVDS Inputs

Fast IP feedback
R&D activity: schematic plot



Simulations are necessary to find an algorithm with good noise immunity

Fast Feedback development at ATF, and relevance to SuperB

Glenn Christian, Phil Burrows, Colin Perry
John Adams Institute, University of Oxford

SuperB mini-workshop, Oxford,
18 May 2011

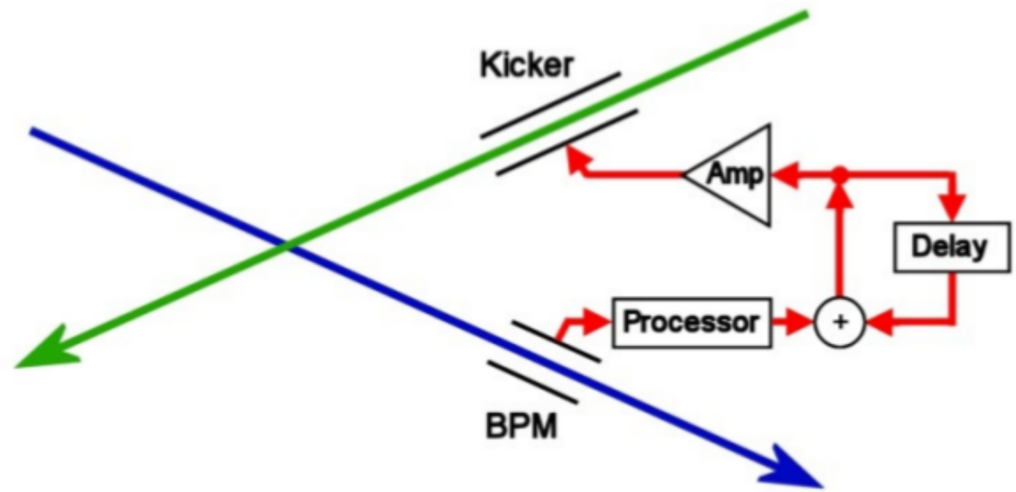
SuperB FB requirements

(from discussion with Marica Biagini and Alessandro Drago)

- Spot size at IP: 36 nm (y) by 7-9 um (x)
- Stability: 10 nm @ IP
- As well as orbit correction feedback, requirement for IP feedback to correct for ground motion, vibrations – cause beam jitter and lumi loss

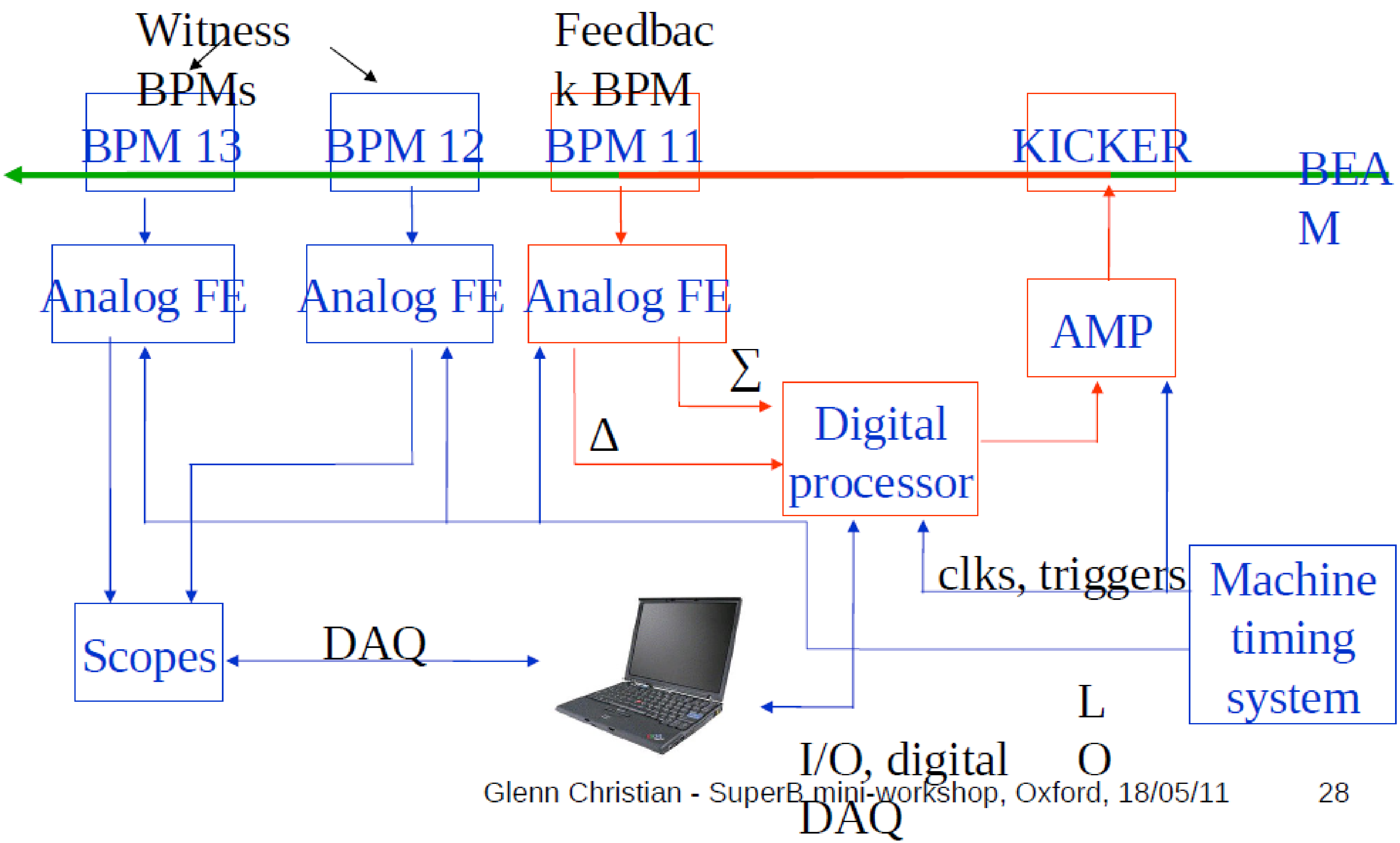
ILC IP Feedback system - concept

- Several slower beam-based feedbacks/feedforwards required for orbit correction
- Fast intra-train feedback system essential for the ILC interaction point to compensate for relative beam misalignment.
- Measure vertical position of outgoing beam and hence beam-beam kick angle
- Use fast amplifier and kicker to correct vertical position of beam incoming to IR
- Delay loop necessary to maintain the correction for subsequent bunches in the train

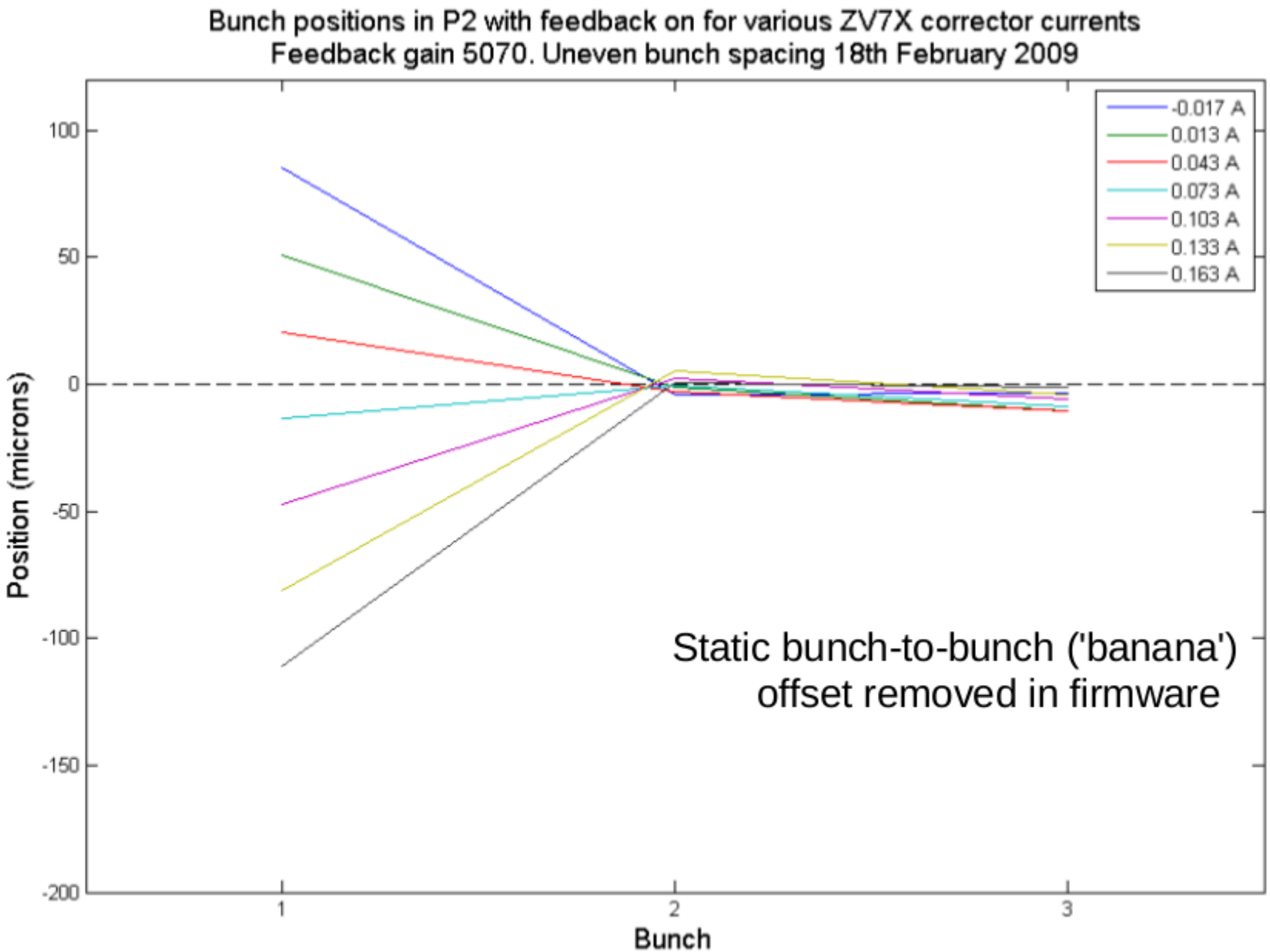


Last line of defence against relative beam misalignment

FONT4 system overview



Feedback Performance (1) – Offset correction/gain optimisation (averaged over ~50 pulses per point)



FB Considerations

- BPM processor
  - Main question is measurement location and hence required BPM resolution
  - Bunch-by-bunch measurement (i.e. do we need to resolve individual bunches) or integrating continuous beam ?
    - Current processor output has width of ~10 ns, can be tweaked by changing the filtering(possibly at the cost of resolution)
    - If mixing with 714 MHz, then integrating will not work at 2.1 ns bunch spacing.
  - Processor type: mixer or baseband (better resolution, better suited to bunch-by-bunch measurement)
  - If new processors required, what is the availability of test beams?
- Feedback
  - Averaging (slower) or minimum latency (fastest, but may introduce extra noise) – needs detailed optimisation
- Amplifier
  - Would require continuous rated amplifier rather than pulsed – less kick for the same power
  - Power: tradeoff of dynamic range and resolution ?
  - Multiple kickers, if larger dynamic range needed?
- Next step:
  - Study the lattice and define optimal location for BPM and kicker
  - Determine required resolution, dynamic range, and required amplifier power

Conclusions

To achieve the Superb luminosity specifications a perfect real-time overlap of the two beams is necessary.

- Some of the diagnostic systems are crucial to achieve the luminosity goal
- Many different feedback systems are under study
- In particular all the systems that we are considering <u>should cooperate</u> to achieve the challenging luminosity goals giving a perfect beam-beam overlap
- Orbit feedback and luminosity feedback should be implemented taking in mind the previous design experiences
- The Fast IP feedback is in a preliminary specification phase
- Nevertheless we should go carefully in depth to understand possible unstable behaviors made by real-time conflicts between the different systems
- For the Fast IP Feedback a strong collaboration with John Adams Institute is possible and can be very productive