Testing and Development of Feed-Forward System for ATF2

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Fifth ATF2 Project Meeting

KEK, December 19, 2007

The bunch-by-bunch Feed-Forward Correction (FF) done at ATF2 EXT is intended for transverse jitter originated in DR.

In DR, at start of the last turn, the bunch position and angle are measured with a pair of BPMs, and the correction is applied to the same bunch in EXT, using a pair of kickers. The propagation time (feed-forward time) is about 0.4μs.

correction residue << beam size

2007

1. **FF Layout. Places of pickups and kickers in EXT.**
2. **FF Layout. Places of pickups and kickers in DR.**
3. **FF Matrix and FF Gain measurement.**
4. **BPM prototype beam test result.**

1. FF elements in ATF2 EXT

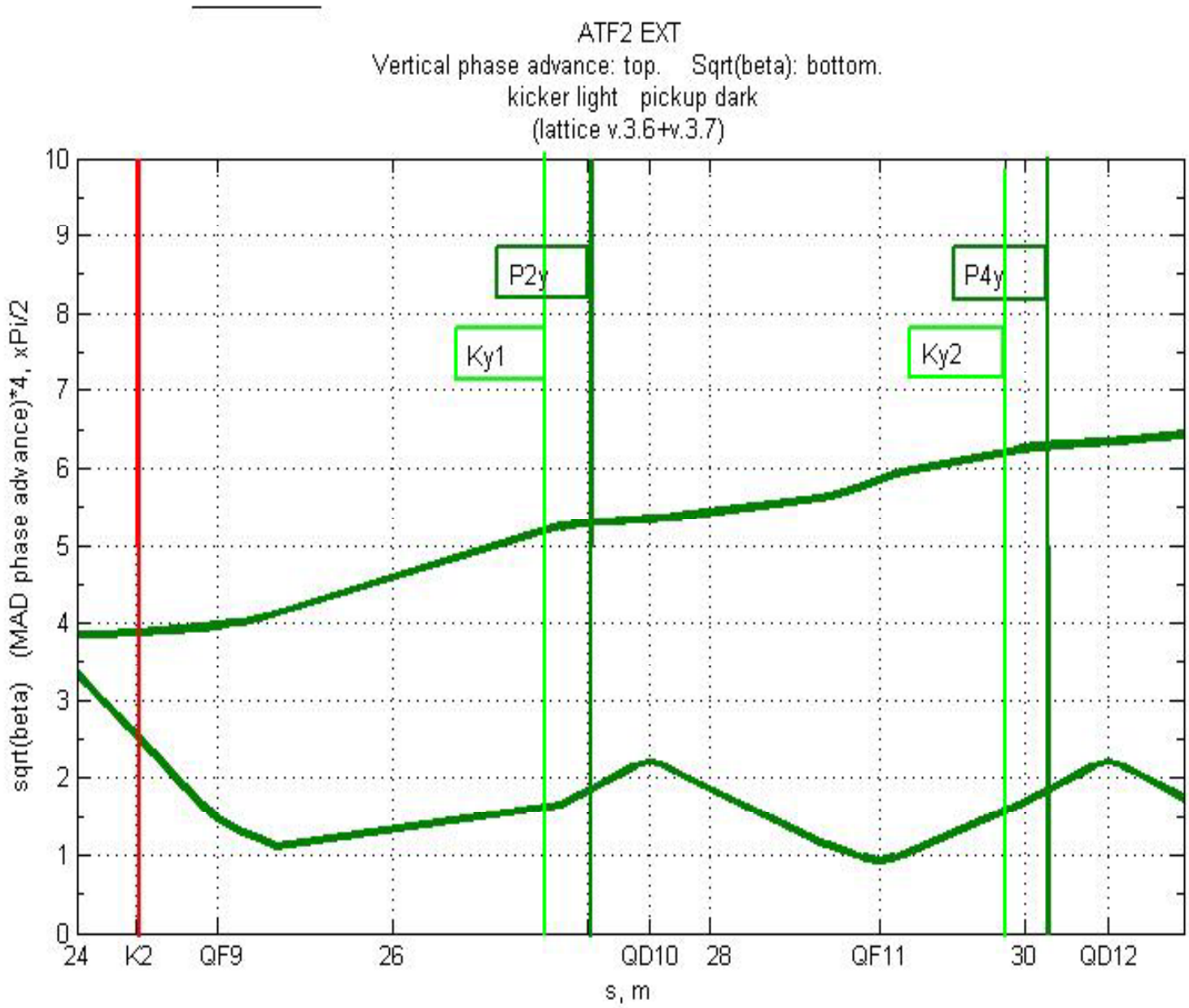
The following requirements and factors are taken into consideration:

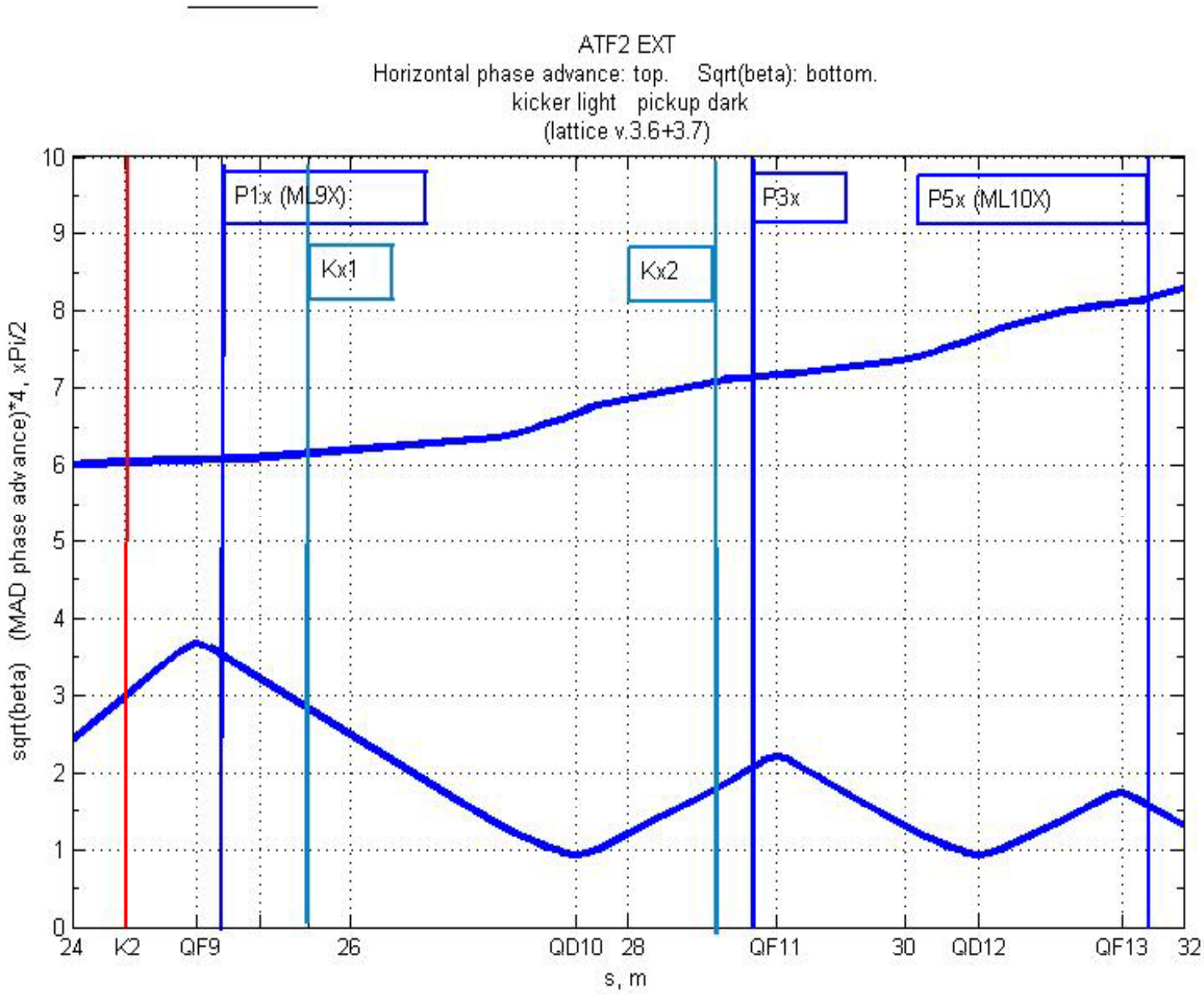
- FF correction should be accomplished upstream of the Diagnostic Section.
- FF correction is done for both (y, y') and (x, x'). The (y, y') is most required.
- Preferable places for BPMs and kickers are where the beta function comes to its maximums.
- The optimal phase advance in a pickup pair or a kicker pair is $\pi/2$.
- A preference grade of the places for a pickup pair or a kicker pair: a drift space, one quad in-between, two quads…

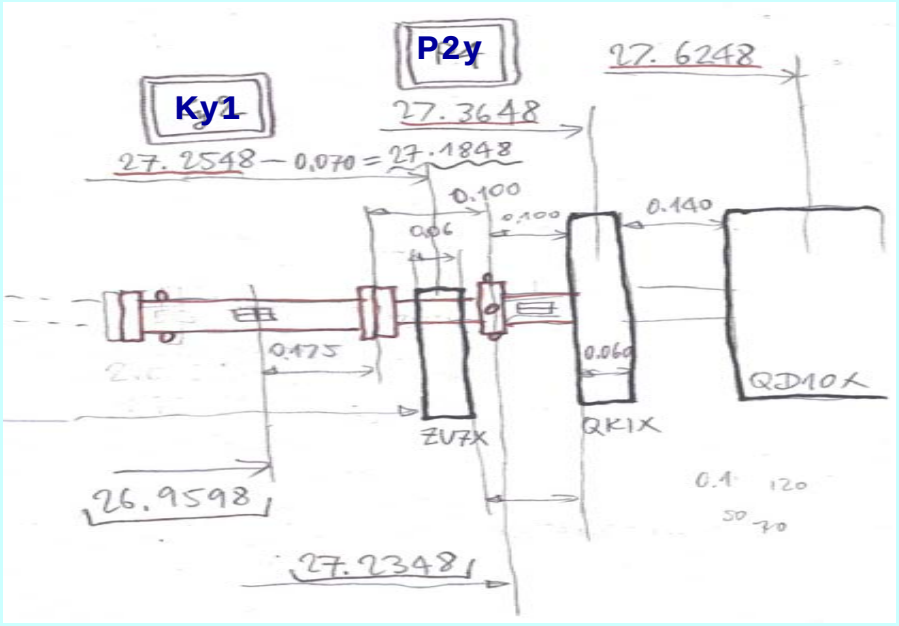
(continued)

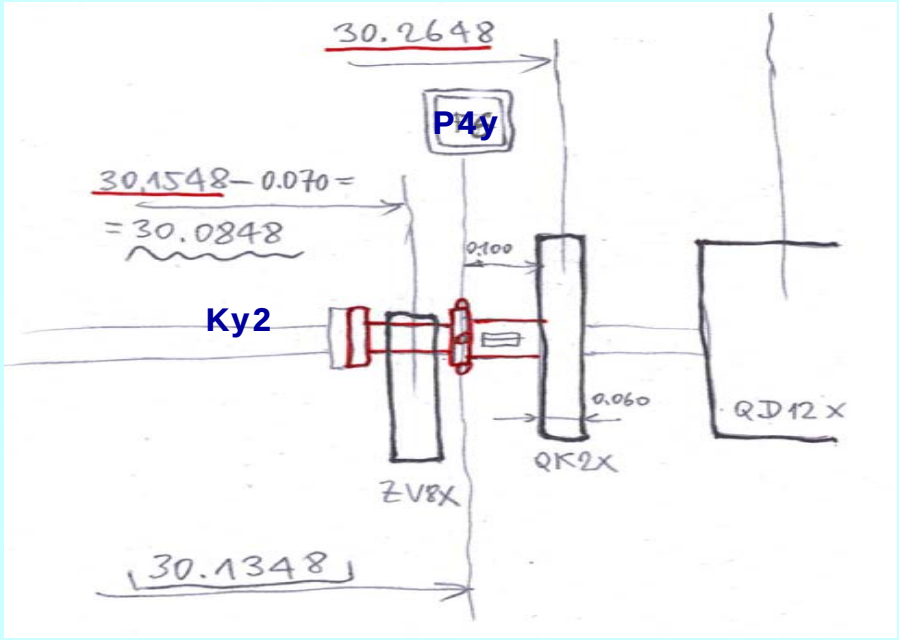
- A kicker in each pair has an adjacent pickup that is necessary for FF matrix measurements.
- For FF correction residue measurement, a FB downstream pickup pair can be used.
- A pickup is a standard EXT (x, y) 12cm strip line pickup. Some pickups in EXT are shared by FF and FB and some of them by the EXT Orbit system as well.

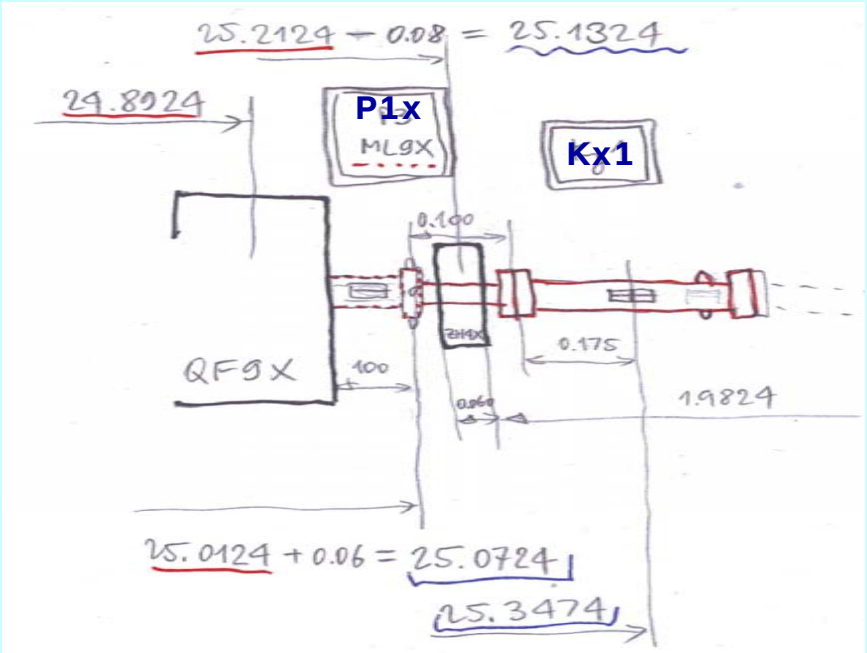
- The kickers are common for FF and FB. Combining the kick signals is done on the kicker amplifier input.
- A kicker is a single plane strip line kicker. The length is supposed to be about 30cm.

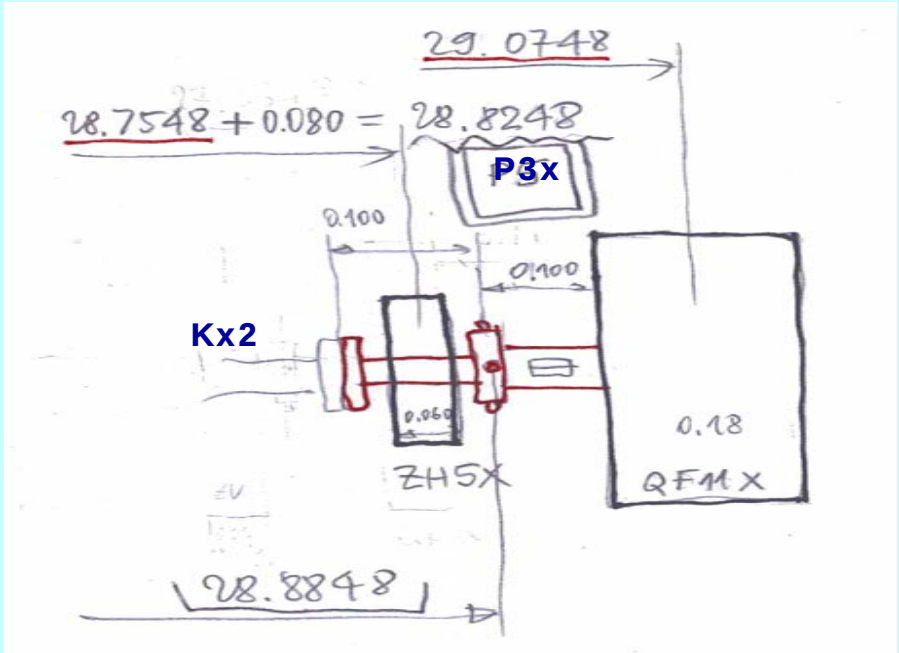

ATF2 EXT
Vertical phase advance: top. Sqrt(beta): bottom.
kicker light pickup dark
(lattice v.3.6+v.3.7)
sqrt(beta) (MAD phase advance)*4, xPi/2
s, m
P2y
P4y
Ky1
Ky2
0
1
2
3
4
5
6
7
8
9
10
24
K2
QF9
26
QD10
28
QF11
30
QD12


ATF2 EXT
Horizontal phase advance: top. Sqrt(beta): bottom.
kicker light pickup dark
(lattice v.3.6+3.7)
P1x (ML9X)
Kx1
Kx2
P3x
P5x (ML10X)
sqrt(beta) (MAD phase advance)*4, xPi/2
s, m
24
K2
QF9
26
QD10
28
QF11
30
QD12
QF13
32
0
1
2
3
4
5
6
7
8
9
10


P2y
Ky1
27.6248
27.3648
27.2548 – 0.070 = 27.1848
0.100
0.100
0.140
0.06
0.175
0.060
QD10X
ZV7X
QK1X
26.9598
27.2348
0.1
120
50
70


30.2648
P4y
30.1548 – 0.070 =
= 30.0848
0.100
Ky2
0.060
QD12X
QK2X
ZV8X
30.1348

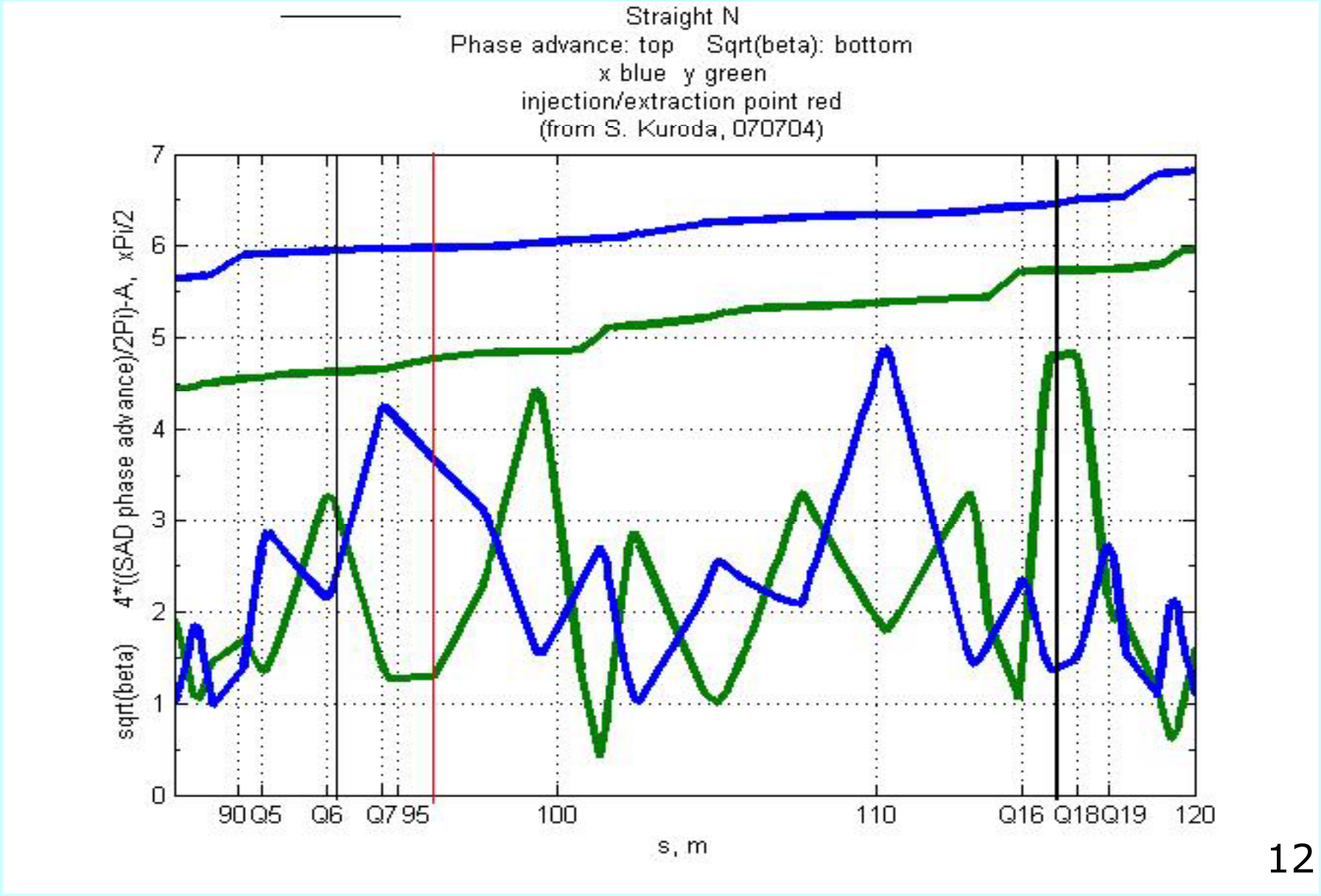

25.2124 – 0.08 = 25.1324
24.8924
P1x
ML9X
Kx1
0.100
0.175
QF9X
100
0.060
1.9824
25.0124 + 0.06 = 25.0724
25.3474


29.0748
28.7548 + 0.080 = 28.8248
P3x
0.100
0.100
Kx2
0.060
0.18
ZH5X
QF11X
28.8848

Some conclusions and observations

- The sqrt beta values at the pickups and kickers are typically somewhat lower than 2. This makes the requirement to the BPM resolution as tight as 1μm.
- The optimal position of a kicker or a pickup may fall in the place of other device. Combining is possible, as a steering magnet on a kicker/pickup, etc.
- A single plane strip line kicker can be similar to the KEK ILC prototype fitted to the EXT aperture. The length with flanges is taken as 35cm. The pickup length is taken as 15cm.
- It is supposed that we know how to split the pickup signals precisely.
- Attention should be taken to imbalance of the pair of pickup strip lines. Imbalance may deteriorate performance of the dif-sum BPM. In advance to installation, the pickups should be tested on a coaxial wire bench.

2. FF DR Pickups



- Pickup 1 is downstream of Q6 in LQ6C (93.05m), pickup 2 is downstream of Q17 in LZV43 (115.63m).

- Vertical phase advance in the pair is π/2, horizontal one is about π/4.

- These FF pickups are supposed to be special DR pickups which are identical to the present EXT 12cm strip line pickups.

3. TURNAROUND FEED-FORWARD CORRECTION AT THE ILC*

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MATRIX MEASUREMENT

The matrix R and the kicker matrices $K_{1,2}$ can be individually measured with the beam, using two pairs of BPMs.

To obtain a pair of row matrix components, two different trajectories are necessary. To exclude errors from BPM zero offsets, one can use one more reference trajectory. The BPM scale errors should be taken into

solutions of the R equation system for differences reads:

$$R_{h12}=\frac{1+\delta_{xK1}}{1+\delta_{xBPM1}}\left[\frac{(x_{BPM1a}-x_{BPM1})\cdot(x_{K1b}-x_{K1})-}{(x_{BPM1a}-x_{BPM1})\cdot(\theta_{BPM1b}-\theta_{BPM1})-}\right.$$
$$\left.\frac{-(x_{BPM1b}-x_{BPM1})\cdot(x_{K1a}-x_{K1})}{-(x_{BPM1b}-x_{BPM1})\cdot(\theta_{BPM1a}-\theta_{BPM1})}\right] \quad (18)$$

where the two trajectories are denoted by a and b. As triplets of trajectories, trajectories of three bunches can be used that are different just due to jitter. The matrix

The accuracy of the matrix measurement can be evaluated using the fundamental property det = 1.

FEED-FORWARD GAIN ADJUSTMENT

Assume for simplicity that the matrix R is errorless. The correction residue is:

$$\begin{pmatrix}x_d\\ \theta_d\end{pmatrix}=\left[\begin{pmatrix}1 & L_K\\ 0 & 1\end{pmatrix}-G\right]\cdot R\cdot\begin{pmatrix}x_{BPM1}\\ \theta_{BPM1}\end{pmatrix}\equiv Z\cdot\begin{pmatrix}x_{BPM1}\\ \theta_{BPM1}\end{pmatrix} \quad (19)$$

where G in the feed-forward gain matrix.

In either plane, the gain can be adjusted and monitored using just the beam jitter being corrected. The correction residue is measured by the BPM pair downstream of the kickers. To exclude the BPM zero offset, one can use in (19) the differences $Tx_n=x_n-x_{n+1}$, $T\theta_n=\theta_n-\theta_{n+1}$ where n and $n+1$ are the bunch numbers. One can calculate products (index BPM is omitted in (20)):

$$\begin{cases}Tx_{1n}\cdot Tx_{dn}=Z_{11}\cdot(Tx_{1n})^2+Z_{12}\cdot Tx_{1n}\cdot T\theta_{1n}\\ T\theta_{1n}\cdot Tx_{dn}=Z_{11}\cdot Tx_{1n}\cdot T\theta_{1n}+Z_{12}\cdot(T\theta_{1n})^2\end{cases} \quad (20)$$

and a similar pair $Tx_{1n}\cdot T\theta_{dn}$ and $T\theta_{1n}\cdot T\theta_{dn}$ for Z_{21} and Z_{22}. If for N increasing, each from four correlation series

$$\left(\sum_{n=1}^{N}T_{1n}\cdot T_{dn}\right)/\left(\sum_{n=1}^{N}T_{1n}{}^2\right) \quad (21)$$

converges to zero or at least to $|\varepsilon|\le 1/D_h$, the gains are correct. Otherwise change G_y by small increments/decrements until convergence occurs.

4. Feed-Forward BPM Resolution Test

ATF Weekly Meeting, 17 December 2007

- Objective: For a single-bunch strip-line BPM break through to 1um resolution (a 14bit BPM).

- Two types of single bunch BPMs were tested with beam:
  a FF dif-sum BPM and a BPM with multiplexing two pickup signals into a single channel.

  A set of newly designed circuits common for both the types: Square Wave Cascaded Couplers, Low Noise Input Amplifiers, Synchronous Detectors (SD), a Beam-Based SD Clock, Low Noise ADC Driver.

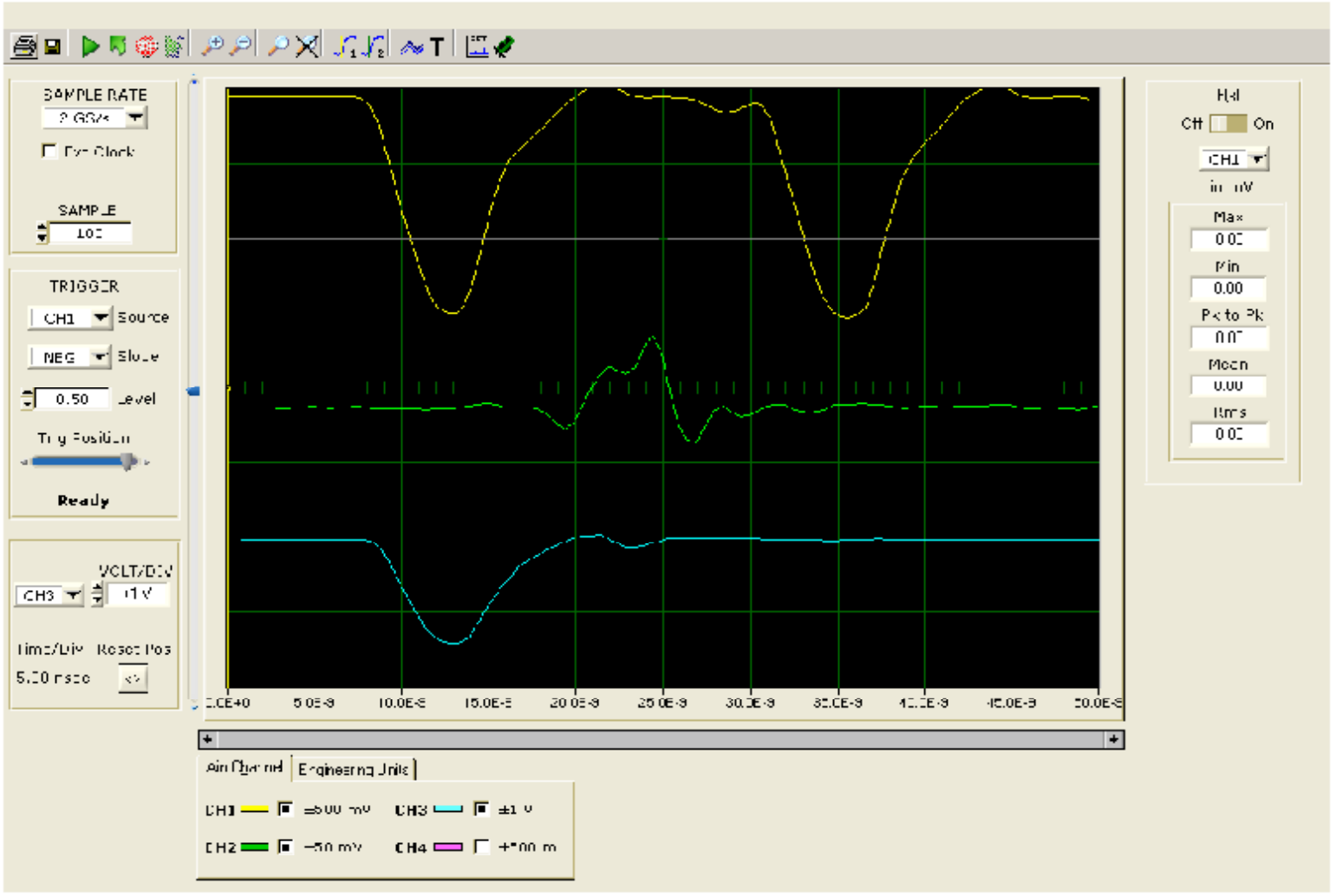
A simplest resolution measurement method was used:

- One pickup strip line – cable – Coupler – Splitter – two inputs of Dif-Sum BPM.
- Another pickup strip line - cable – Coupler – Splitter – two inputs of Multiplex BPM.

With two or more BPMs available, a more advanced method can be used: the BPMs are connected in parallel to same pickup. STD of difference of the readings.

- With two BPM in parallel, they should be identical. With three or more BPMs in parallel, the resolution of each BPM can be calculated individually.

The BPM signals at a 2GHz 14bit ADC (GFT)



Preliminary processing was done for the FF Dif-Sum BPM, and the resolution has been calculated.

- Picking up the values from the data arrays, a table can be filled, and then standard deviation of the ‘position’ can be calculated.

- Two arrays from the recorded data were analysed.
- First 30 samples were used.
- No fliers were removed. It was two-three big positive and two-three big negative fluctuations. Not knowing the distribution, these fluctuations were retained.

$\sigma = 1.6 \mu m$

Really the resolution is expected somewhat better as the value 1.6um includes a contribution of amplitude jitter due to asynchronous sampling. A BPM ADC will catch a sample at the same moment of each shot pulse. GFT catches at moments varying within 0.5ns. Interpolation and then Max.

Plans of further BPM development:

- Optimise BPM circuits and settings.
- Continue and complete Synchronous Detector investigation.
- Build in the BPM an ADC with a Memory and a port of some DAQ.
- Conduct exhausting table tests.