ATF2 Software tasks:
- EXT Bunch-Bunch FB/FF
- IP Bunch-Bunch FB
- FB Integration
Status

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FONT meeting
1th August 2008

EXT Bunch-Bunch FB

Aim and goals:

- Position and angle jitter corrections to achieve goal 2: control of the beam position at level $\approx 5\ \%\ \sigma^{*}_{y}$ (ATF2 goal 2)
- Design of a fast intra-train FB to be located in the ATF2 EXT line (FONT project)
- Simulations to understand the dynamics of the system, assuring an optimal performance of the FB system
- Realistic simulations: understand and determine the several error sources
- Joint operation of the different FB systems: bunch-bunch, pulse-pulse (FB integration)

Simulation set up

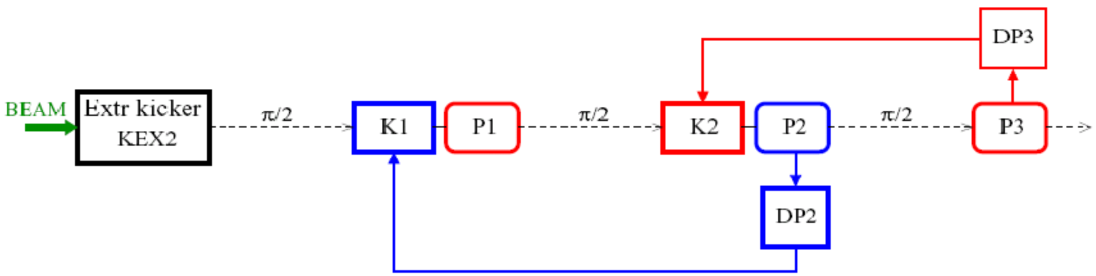
- Using the tracking code PLACET-Octave (developed at CERN)
- First only considering the y, y' correction (most critical). Straight extension to x, x' correction
- Added a total of 50 BPM along the ATF2 line in order to study the jitter propagation and the correction effect from the correction region to the IP
- EXT-bunch-bunch FB system:
  - Two kickers (K1 & K2) for vertical position (Y) and angle (Θ) correction
  - Three pickups (P1, P2, P3) for transfer matrix reconstruction and for FB loop
  - Assuming a BPM rms noise of 1 μm (input BPM resolution)
  - Assuming a kicker strength error (Here we assume < 0.5 %)
- Normal random distribution of 100 initial vertical jitter positions with a width of +/- 40 % σ_y (rms beam size at the entrance of the extraction line)
- Apply static misalignment using "standard errors" (list by GW) + alignment procedure (connection with other tasks: BBA methods and tuning knobs)
- Introducing ground motion (GM) misalignment (model K)
- IP-Bunch-bunch FB system:
  - IP-BPM (resolution ~ nm)
  - Kicker in between of the final doublet quadrupoles
  - More detailed study in progress

EXT Bunch-Bunch FB

Using a SVD algorithm:

- The SVD algorithms easy to implement and very robust. Commonly used in orbit steering correction (using several correctors and BPMs), it can also be used for fast FB
- In the case of a fast-FB important to select appropriate BPMs and correctors for the FB
- Measure the position and angle jitter of the first bunch in a train,
- Knowing the response matrix, apply the SVD method to correct the rest of the bunches of the train

Alternative: using a classical PID control loop



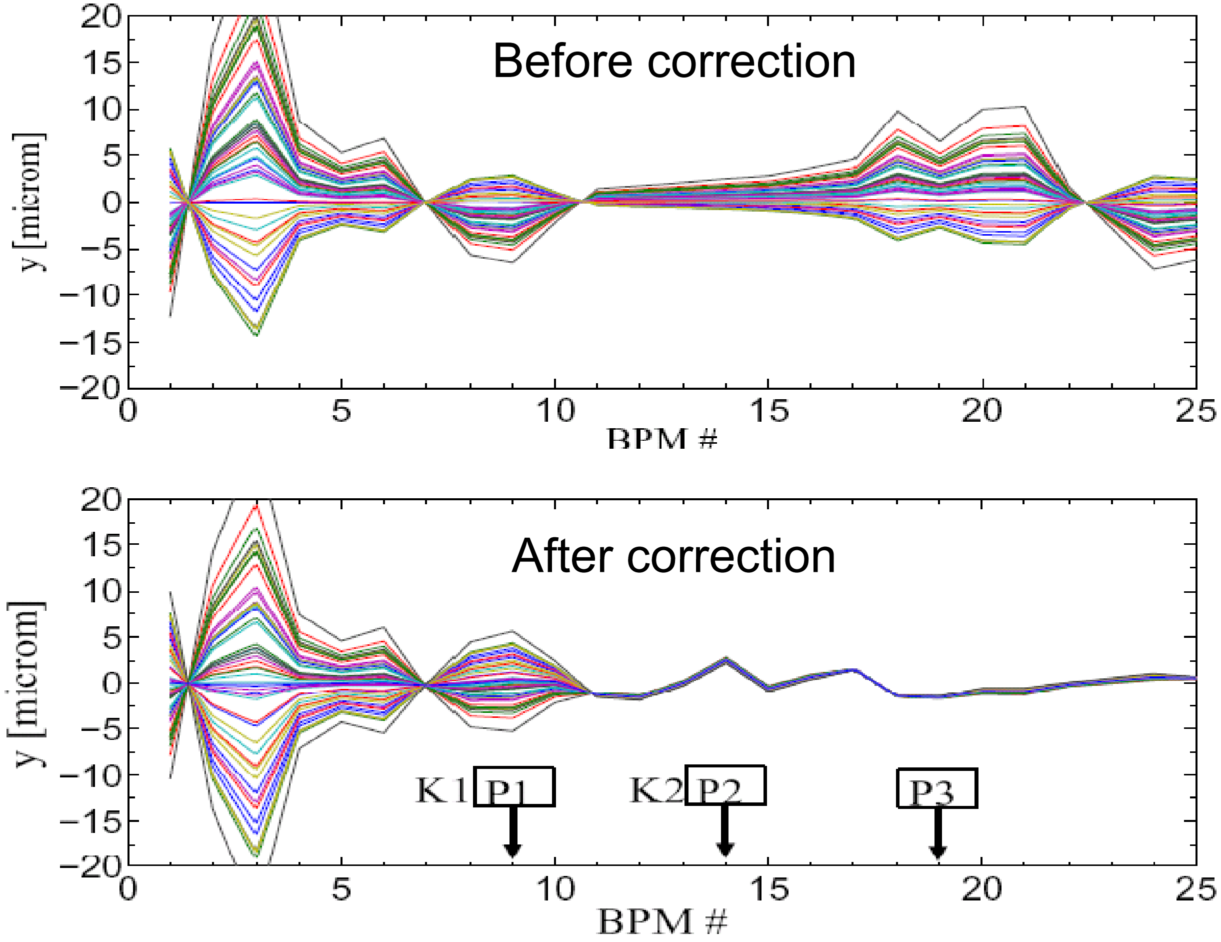
Time of flight P2-K1 = 10.65 ns
Time of flight P3-K2=10.53 ns

Example #1 of vertical position correction.

Residual jitter propagation

Optimistic case:

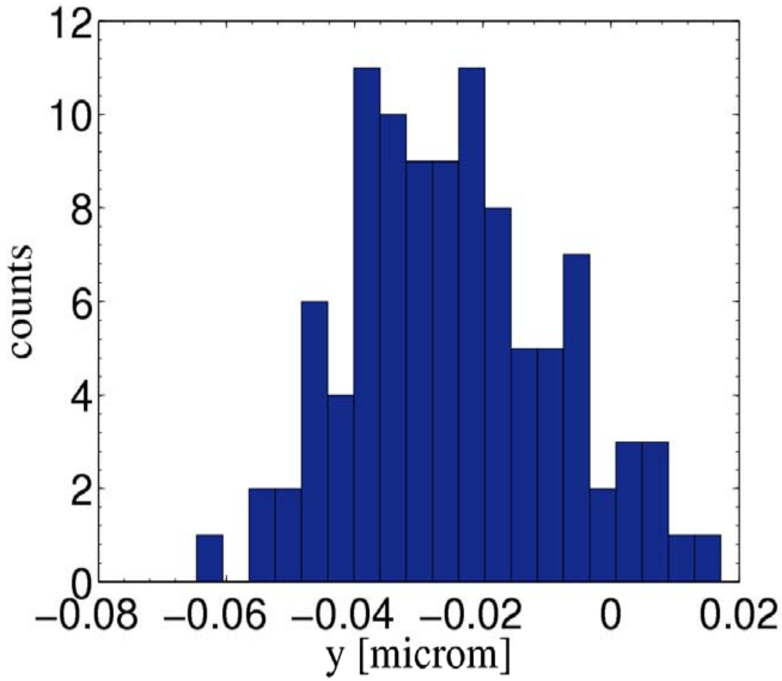
- Example for 100 shots with 40 % σ^*_y initial jitter
- Only applying GM model K (10 s)
- No static misalignment
- Input BPM resolution: 1 μm
- Kicker strength error: 0.5 %
- Applying then EXT shot-shot FB correction



Example #1. Jitter distribution at the IP

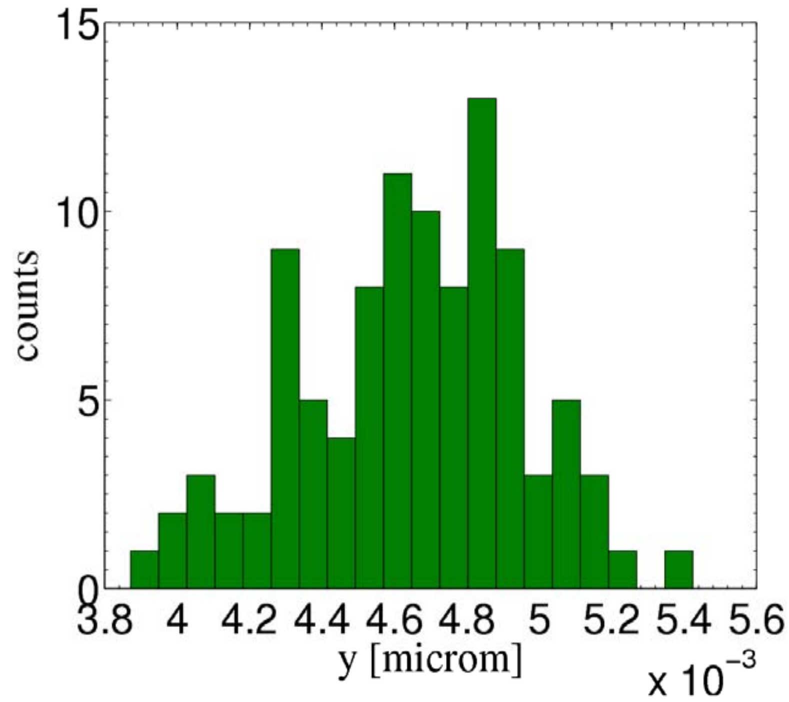
Assuming 1 μm BPM resolution and 0.5 % kicker strength error

Before correction



Mean = -0.0267 μm
Sigma= 0.0169 μm

After correction

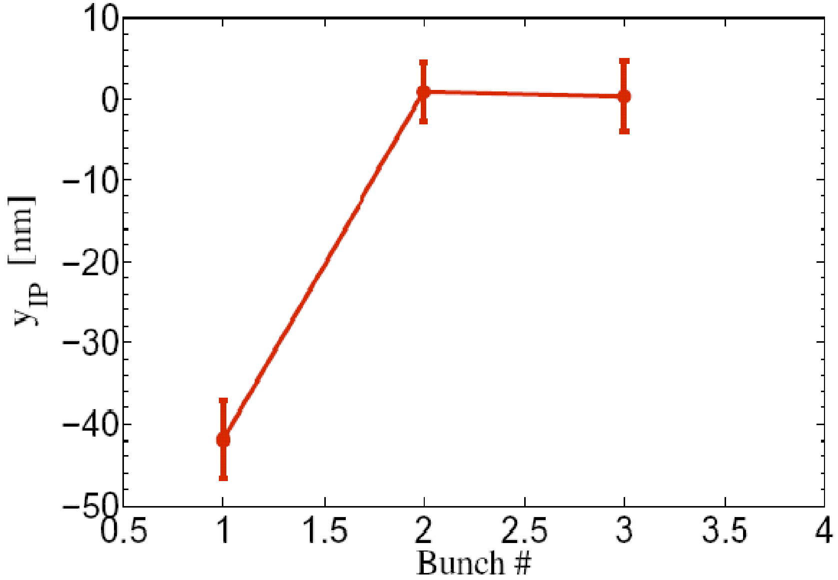


Mean = 0.00463 μm
Sigma= 0.000312 μm

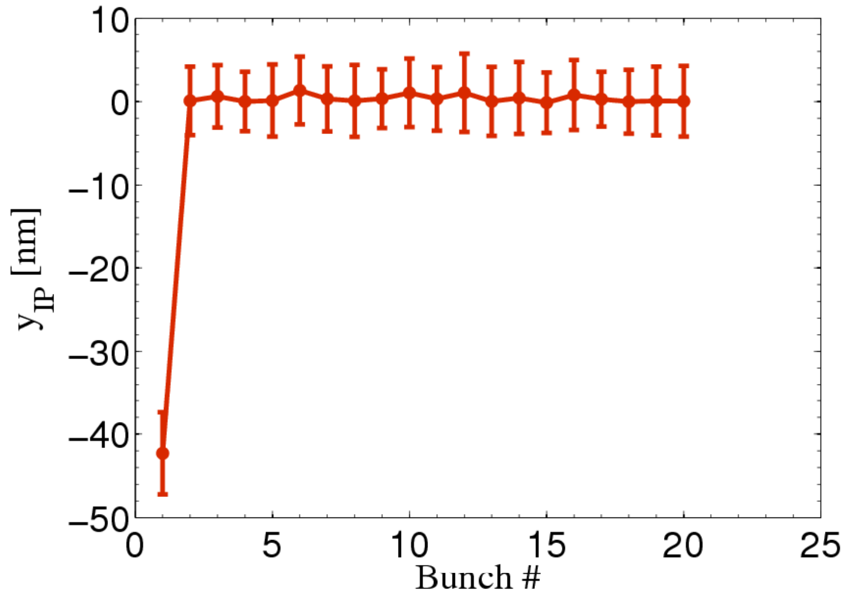
Example #1. Multibunch operation

Simulations performed for 100 pulses (10 % σ_y pulse-pulse position jitter)
Example for an initial position offset of 40 % σ_y (at the start of the EXT line)

3 bunches / train operation



20 bunches / train operation



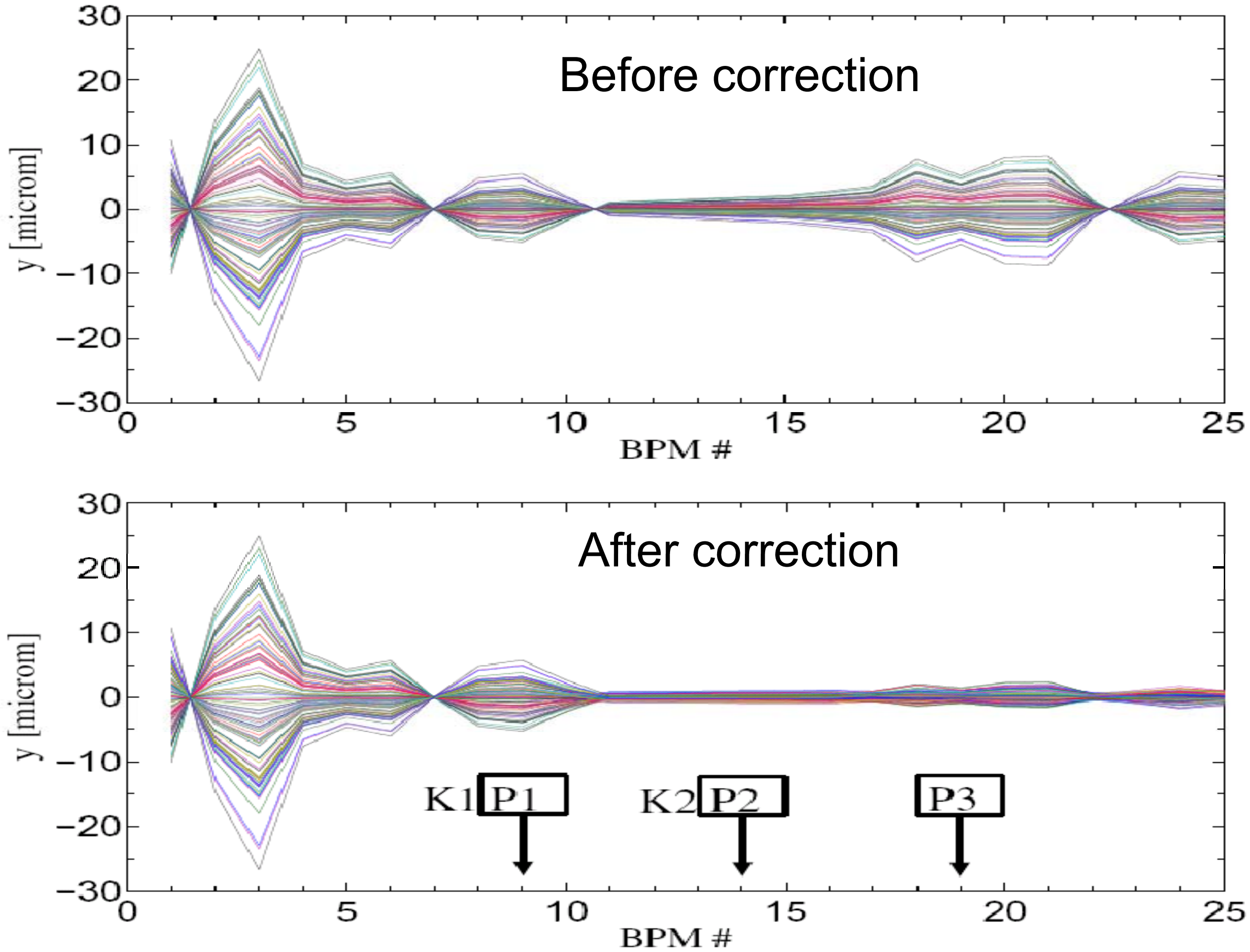
Too optimistic!
More realistic simulations, including other kind of errors and effects are in progress

Example #2 of vertical position correction.

Residual jitter propagation

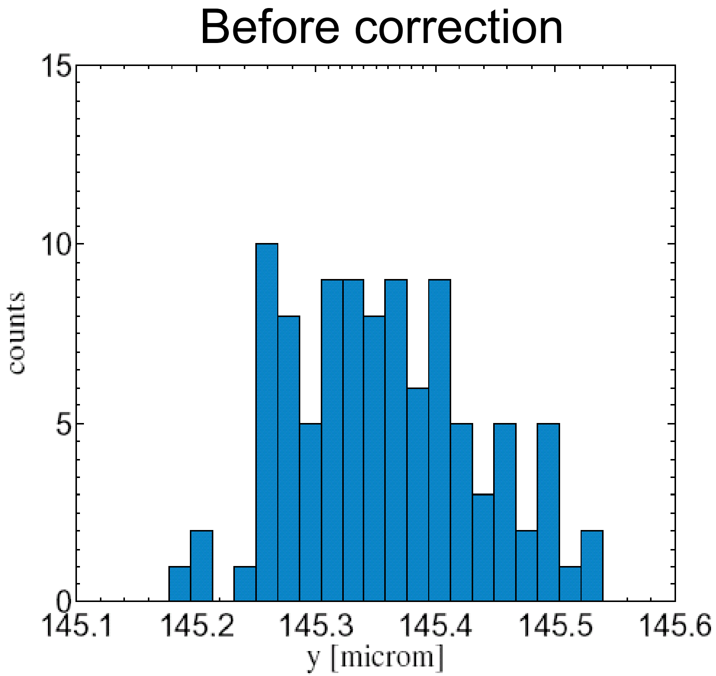
A little more realistic:

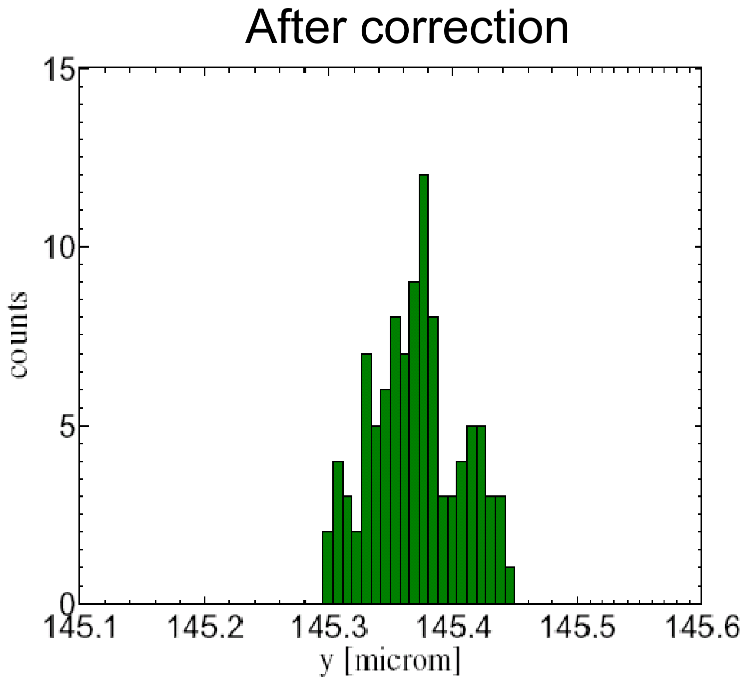
- Example for 100 shots with $40\ \%\ \sigma^*_y$ initial jitter
- Including standard static misalignment errors + BBA technique
- Applying GM model K (10 s)
- Input BPM resolution: 1 μm
- Kicker strength error: 0.5 %
- Applying then EXT shot-shot FB correction



Example #2. Jitter distribution at the IP

The EXT fast intra-train FB help to improve the shot-to-shot deviation at the EXT line. However, downstream … big impact from the misalignment of the quadrupoles and sextupoles in the FFS. The main impact coming from the final doblet alignment errors



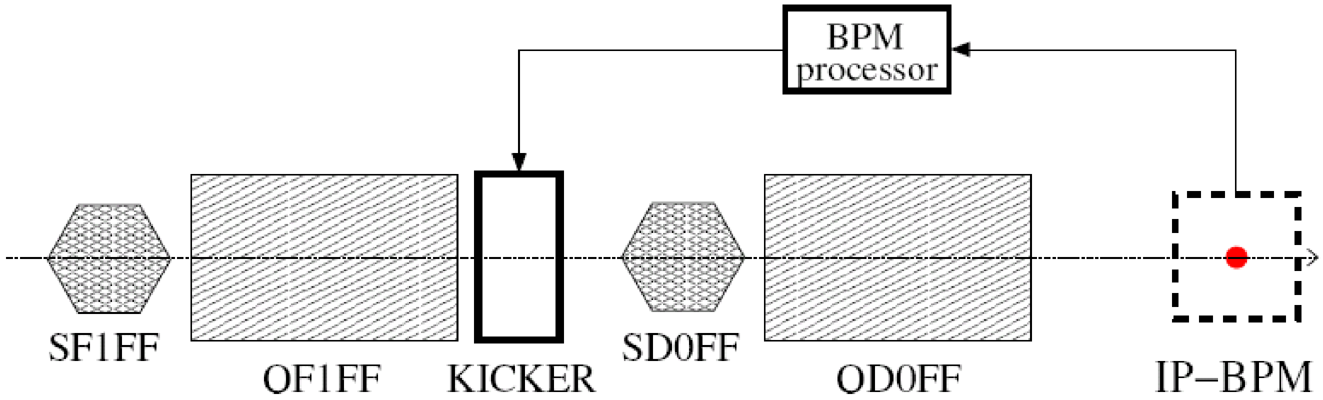


Necessary the combination of several BBA methods, orbit steering techniques, feedback systems (at EXT and IP), …

IP Bunch-Bunch FB

Using Honda IP-BPM with nm resolution level
(Y. Honda et al., Phys. Rev. ST-AB 11, 62801 (2008))

Necessary:
Specify kicker position
Detailed design and optimisation of a robust FB algorithm:
PID control loop, adaptive system (neural net), …?
Performance simulation and study of the limitations



Simulations of the IP Bunch-Bunch FB

- Using a PI control loop (discrete implementation):

$$u_k = u_{k-1} + K_p(e_k - e_{k-1}) + K_i e_{k-1}$$
$$k = 1, 2, \ldots, N_b$$

N_b: number of bunches
$e_k = r_k - y_k$: error to be corrected
r_k:set-point (in our case $r_k=0$)
y_k: process value
u_k: output value
K_p: proportional gain
K_i: integral gain

Gain coefficient Tuning, different methods:
- Manual tuning (trial and error!)
- Ziegler-Nichols (some trial and error, very aggressive!), …

Plan: try some automatic tuning algorithm (?).

To obtain the necessary kicker strength: interpolation in a curve IP offset vs kicker strength (previous scan)

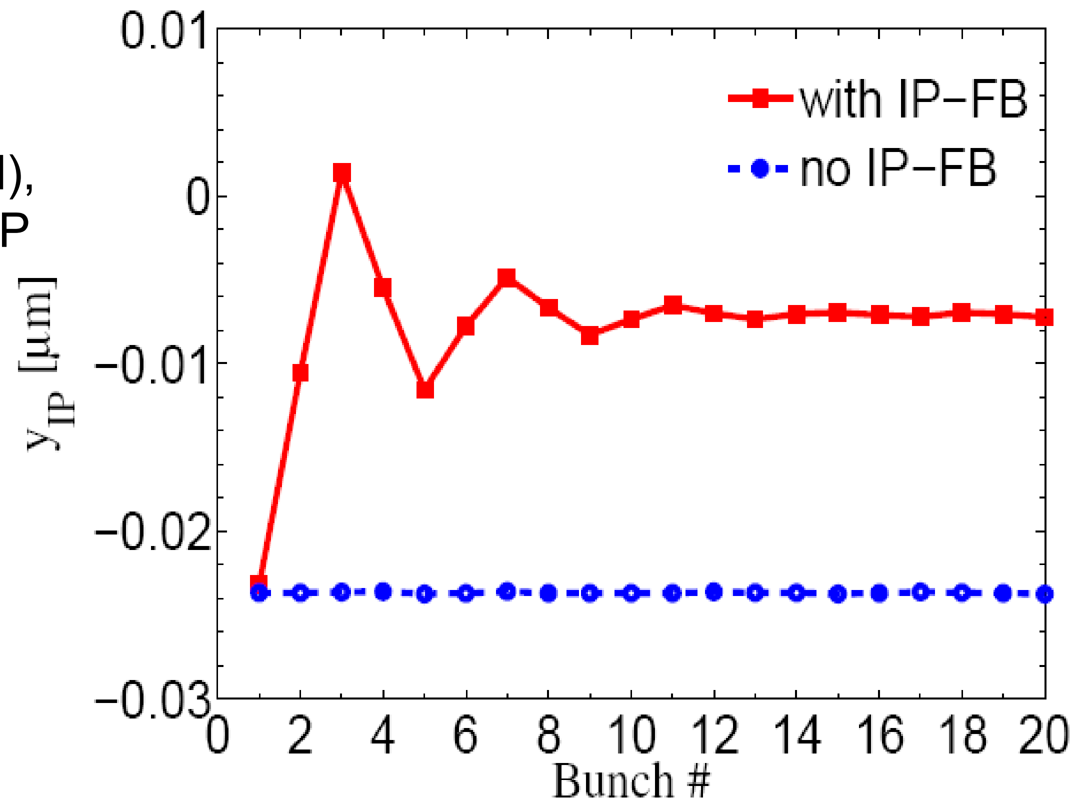
Simulations of the IP Bunch-Bunch FB

Simple model:

10 seconds of GM model K (1 seed), no other vibrations ✸ mean beam IP offset 🕓 -0.024 μm (0.6 σ^*_y)

Gain tuning: Kp=0.98, Ki=0.45

Plan: gain optimisation

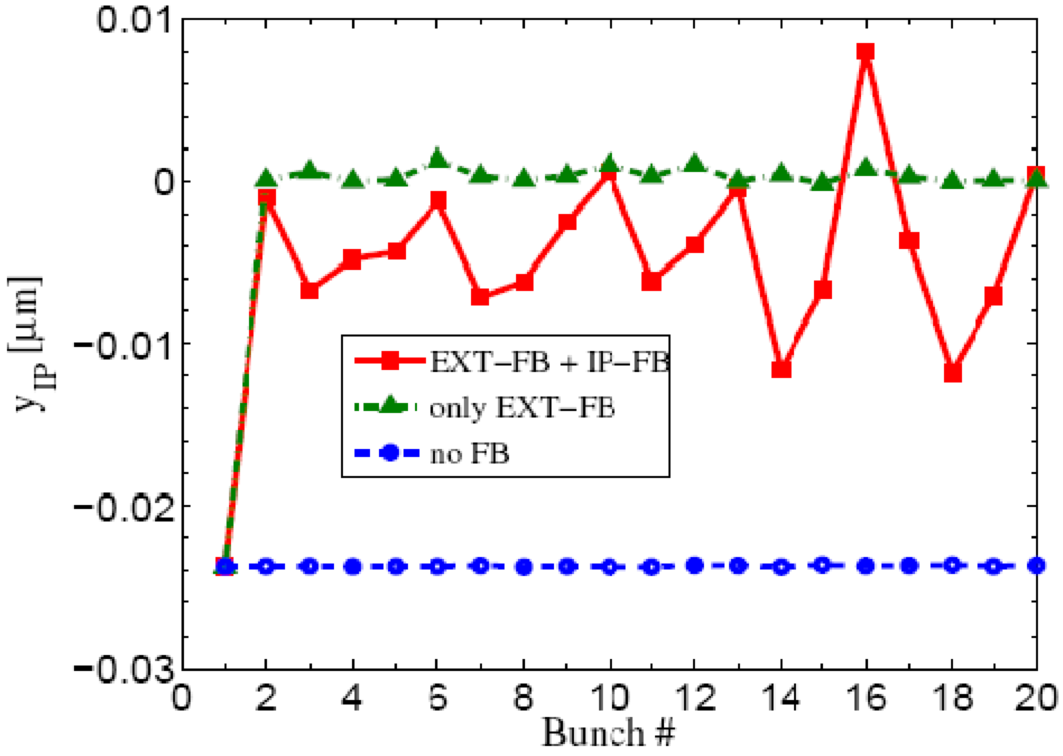


FB Integration (preliminary)

Applying GM model K (10s)
(1 seed)

EXT-FB (using SVD)

IP-FB (using PI), gain optimisation
on progress



FB Integration (preliminary)

• Misalignment with survey errors

+

• BBA procedure: 100 correctors (ZH & ZV) and 50 BPMs along the lattice to minimise $\sqrt{(\sigma^*_x \sigma^*_y)}$

+

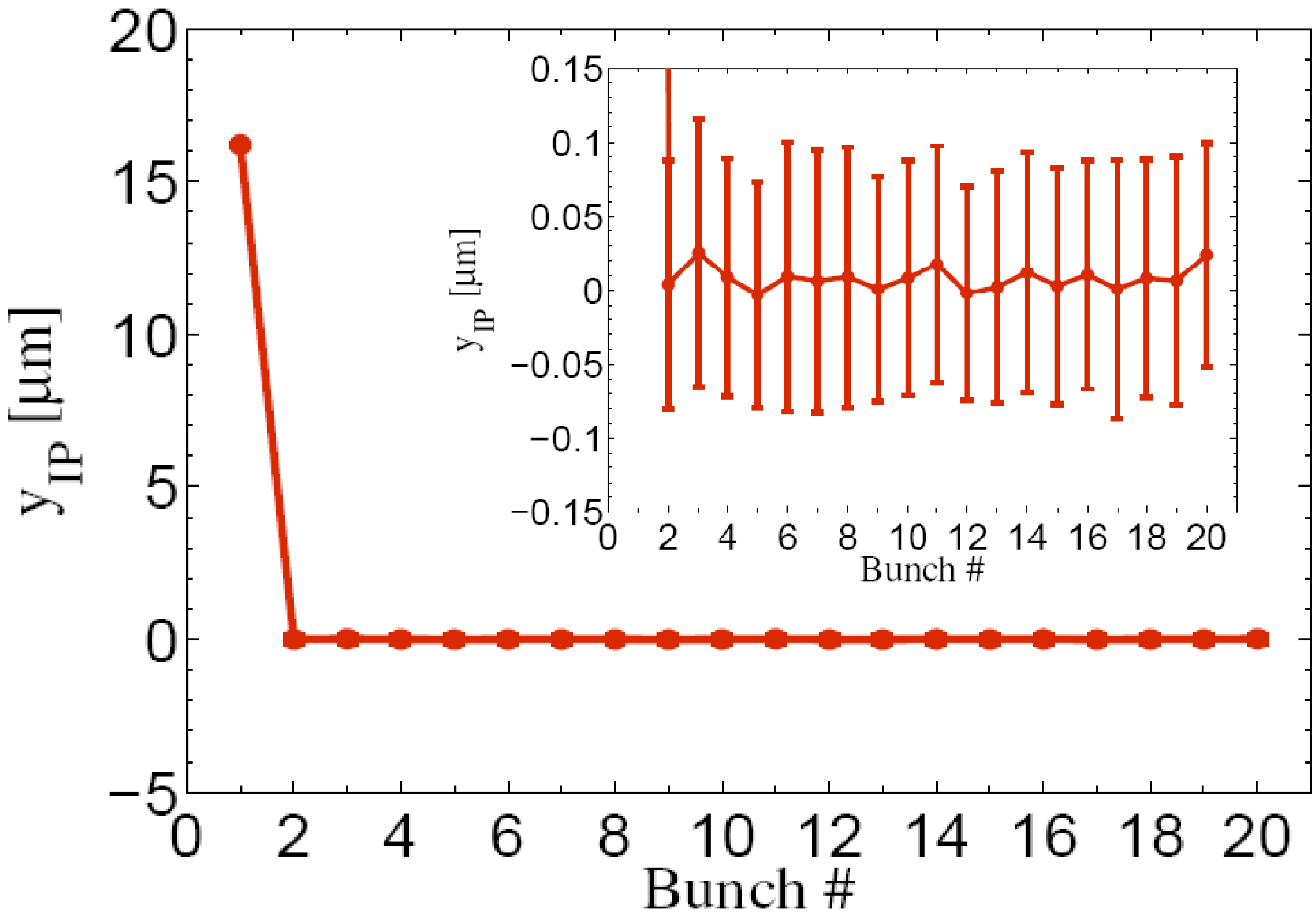
• EXT-FB & IP-FB (possibility to join both using a common response matrix and SVD method? In reality may be challenging!)

• Simulated 100 events (pulses), with 20 bunches per event

• 40 % σ_y (rms beam size at the beginning of the EXT line) offset

• 10 % σ_y position jitter between events

FB Integration (preliminary)



WORK ON PROGRESS!