ATF2: the perfect test-bed for intra-train feedback systems of future linear colliders

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Introduction

ATF2: Final focus test beam line facility at KEK

- Provides a prototype of final focus system (Raimondi-Seryi's scheme) for future linear colliders, such as ILC and CLIC

- Currently under commissioning

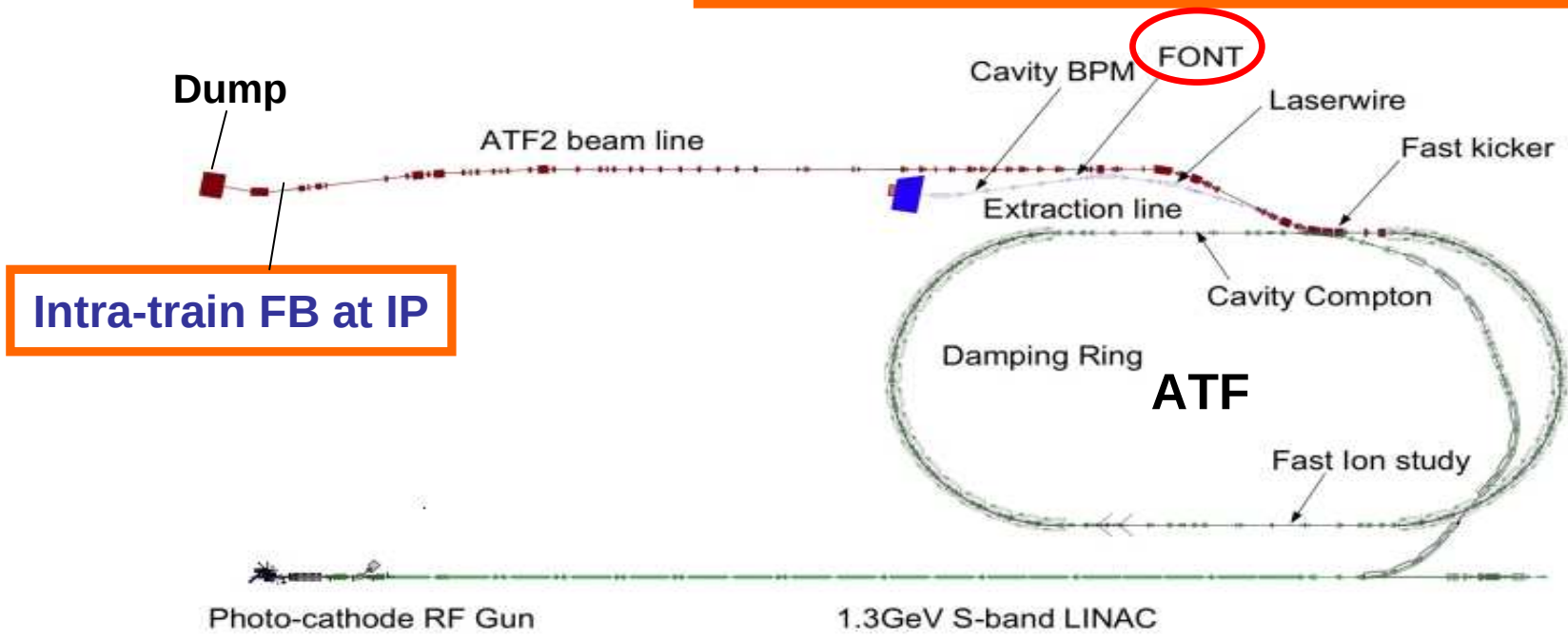
- Major goals:
    1) Achievement of 30-40 nm beam sizes
    2) Stabilization of the small beams at the nanometer level

- In multi-bunch mode operation beam-based intra-train feedback (FB) systems will be essential to achieve the required beam stability (goal 2)

Introduction:
Beam-based intra-train FB systems at ATF2

- ATF-ATF2 schematic layout

Intra-train FB at EXT line:
Feedback On Nano-second Timescales (FONT)



Intra-train FB at IP

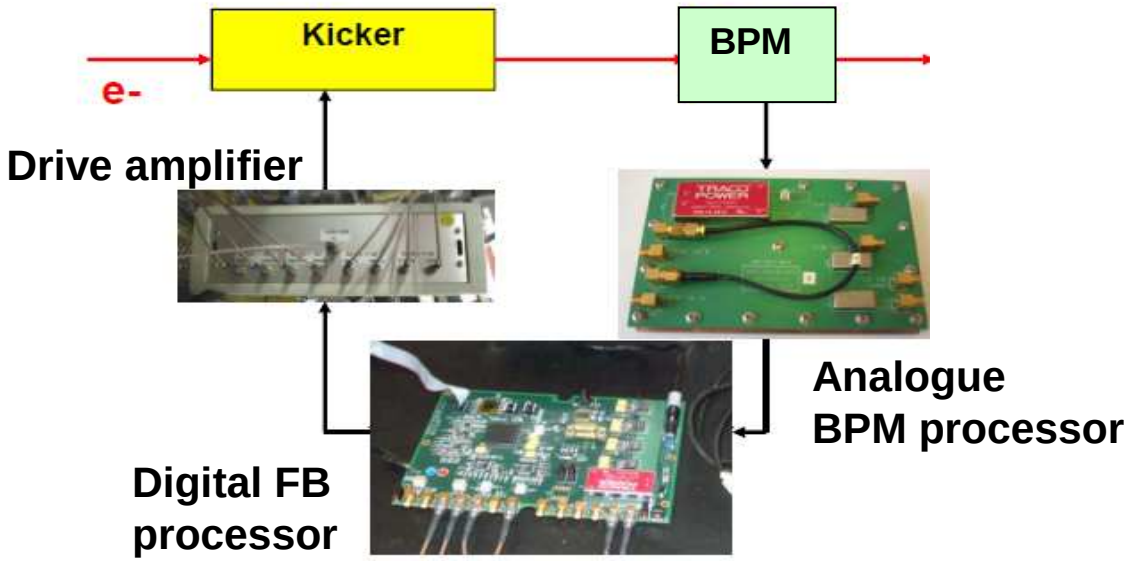
Intra-train FB system in the EXT line

- In the context of the Feedback On Nano-second Timescales **(**FONT**)** project, an intra-train feedback system has been designed and installed in the extraction line of ATF2. The main goals are:
  - The development and test of the necessary technology for the intra-train feedback systems of future linear colliders (Vital for high luminosity!).
  - Beam position stability control better than 1 μm rms at the ATF2 final focus entrance (for phase 2, end of 2010?).

Intra-train FB system in the EXT line: FONT

Key components:

- Three stripline BPMs for registering the beam orbit: P1, P2, P3, with 1 μm resolution
- A pair of stripline kickers for y and y' corrections: K1, K2

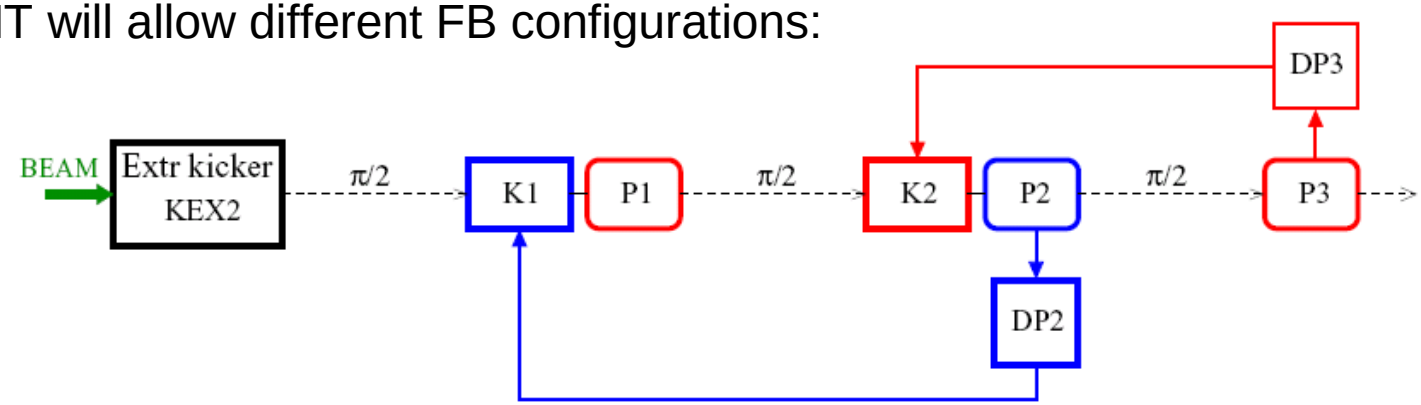


The FONT amplifier specified to allow FB tests using a long ILC-like train of 20-60 bunches !

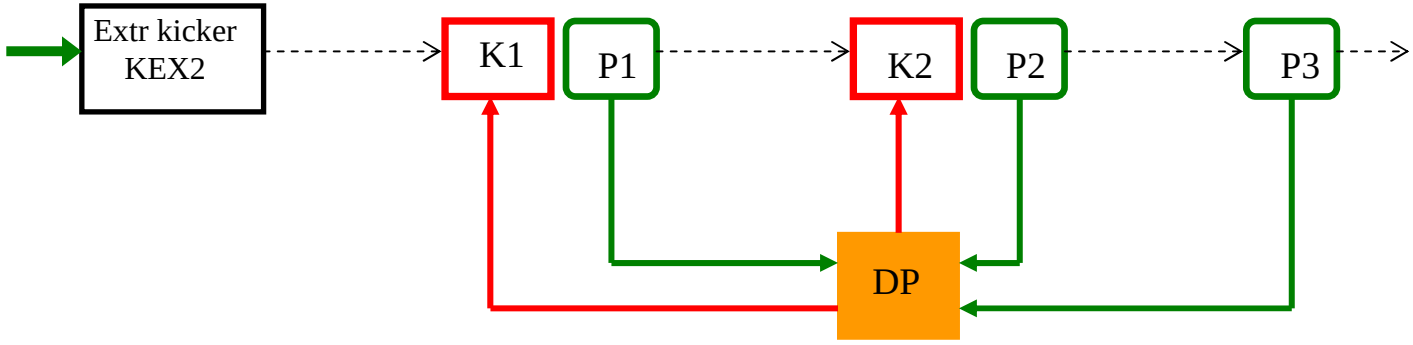
FB loops for vertical position and angle correction

Flexible operation

FONT will allow different FB configurations:

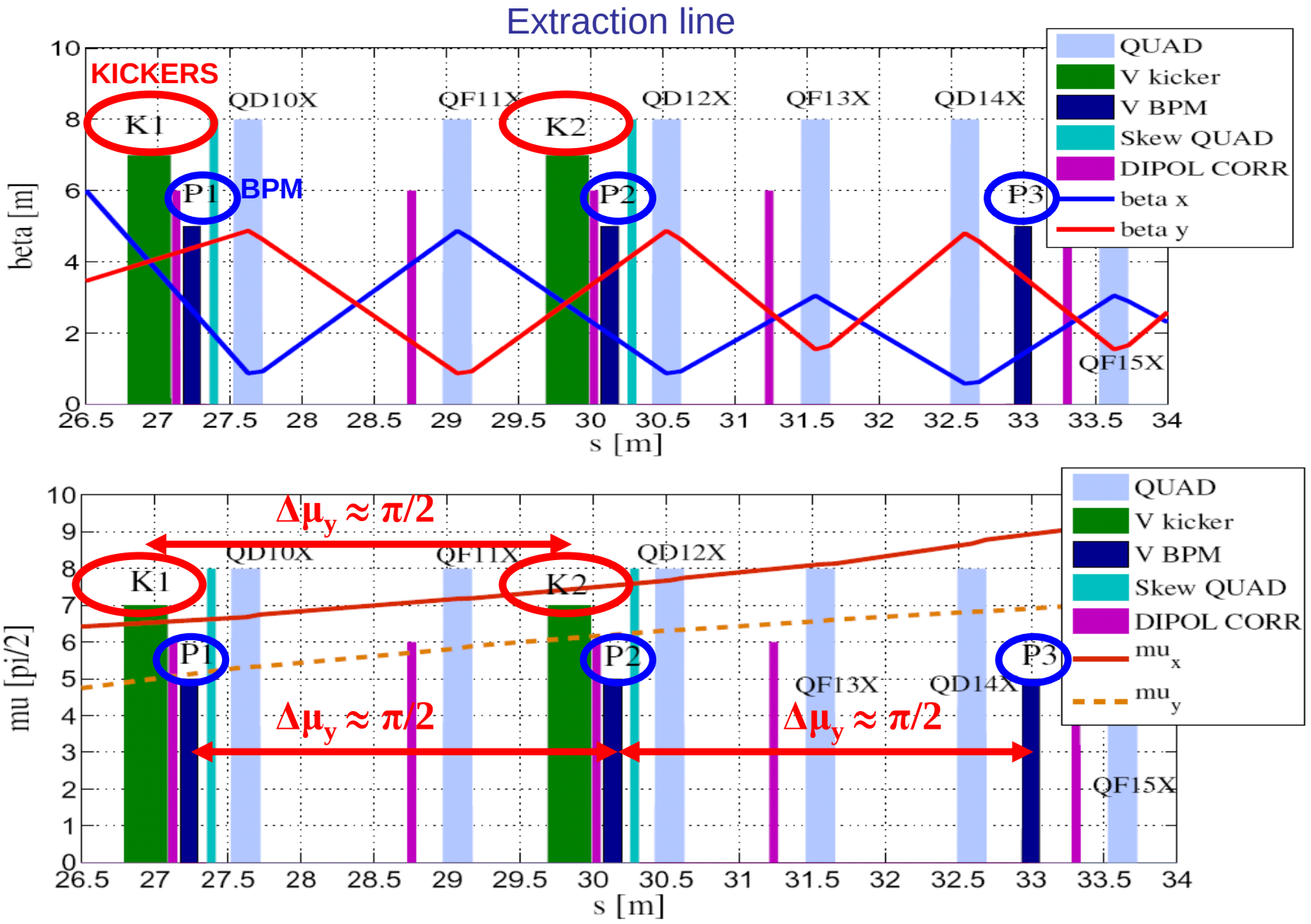


One single digital FB board (with FPGA) for **simultaneous y and y' correction**
9 ADC channel board: to be tested during next run period (October/November 09)

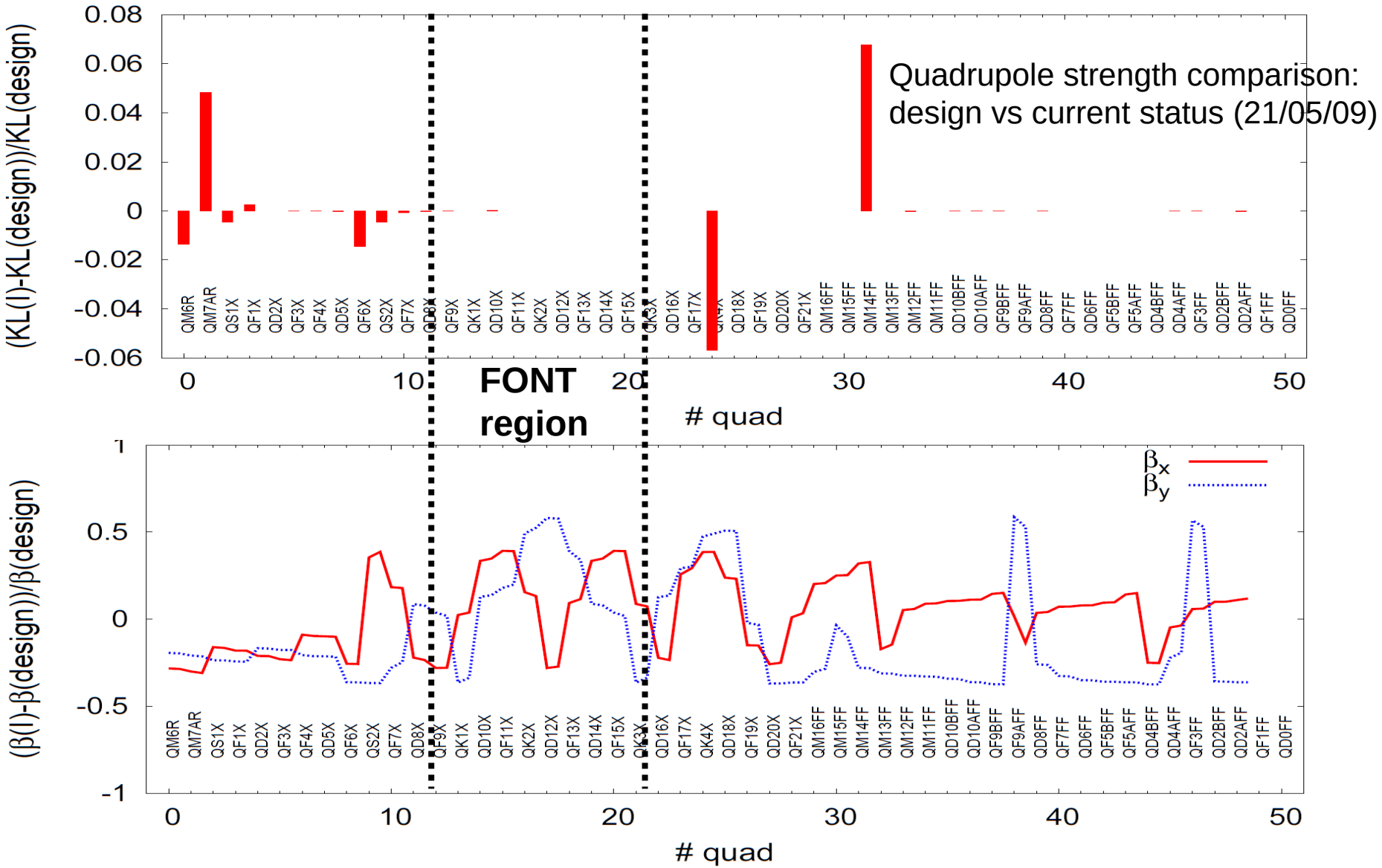


Additionally, this system can be carried over to feed-forward

Layout of FONT at ATF2

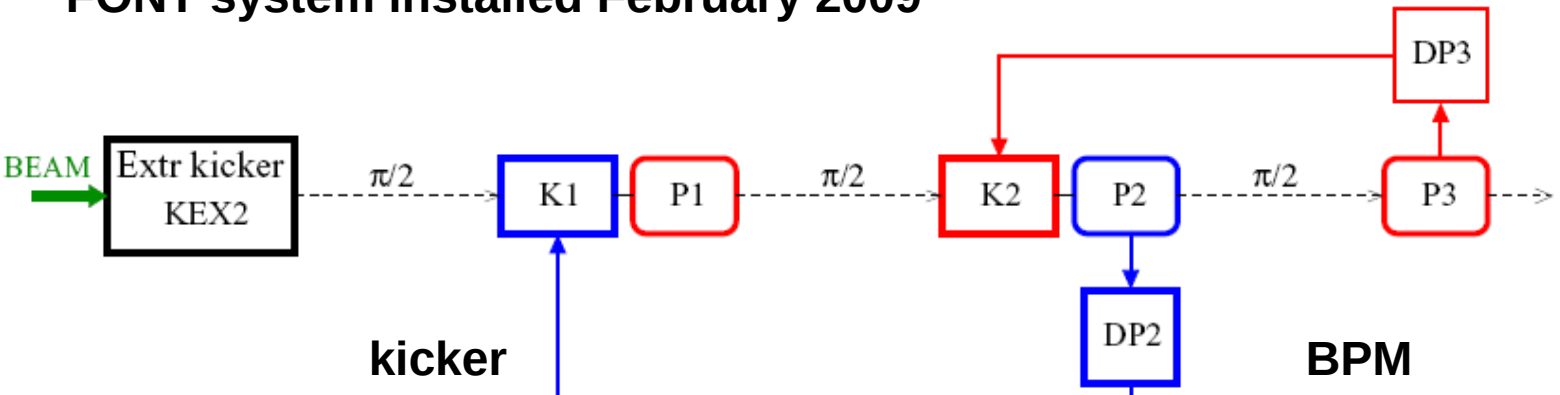


Optics characterisation of the FONT region

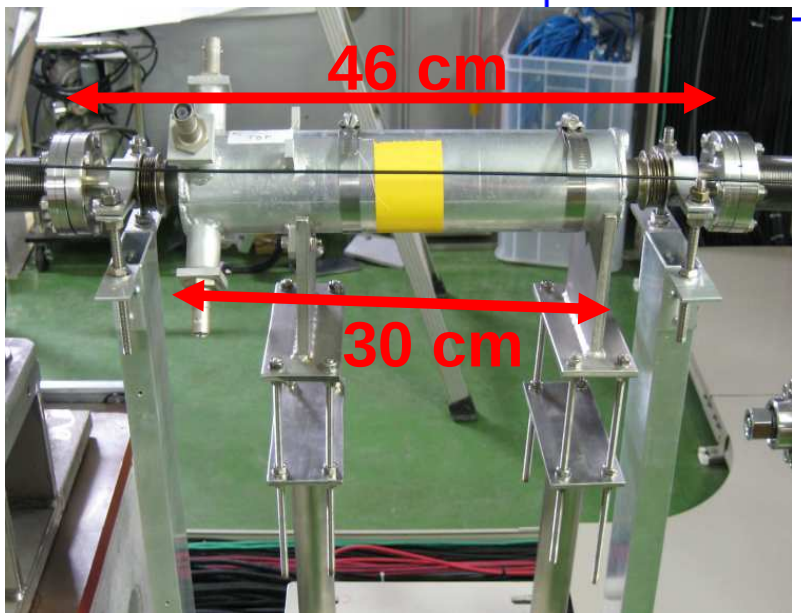


FONT Kicker and BPM

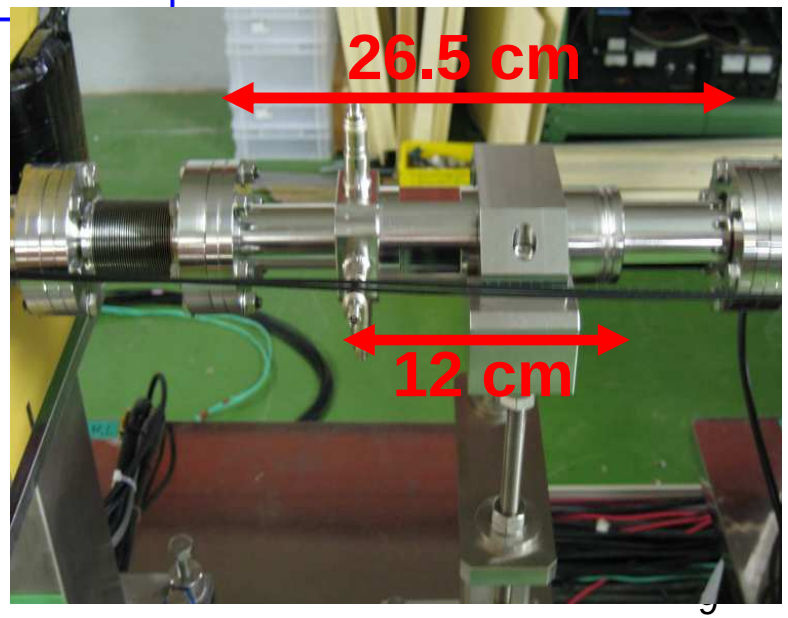
FONT system installed February 2009



kicker



BPM



Latency budget

• **Time of flight kicker – BPM:**	**11ns**
• **Signal return time BPM – kicker:**	**17ns**
• **Irreducible latency:**	**28ns**
• **BPM processor:**	**7ns**
• **ADC/DAC (3.5 89 MHz cycles)**	**40ns**
• **Signal processing (9 357 MHz cycles)**	**28ns**
• **FPGA i/o**	**3ns**
• **Amplifier**	**35ns**
• **Kicker fill time**	**3ns**
• **Electronics latency:**	**116ns**
• **Total latency budget:**	**144ns**

Simulations

- In order to study the accuracy of the orbit correction using the FONT elements, we have used the **SVD algorithm** implemented in the tracking code **Placet-octave** (https://savannah.cern.ch/projects/placet) for the correction of y and y' beam offsets.

- For the simulations we have considered 40% σ_y beam position jitter at the entrance of the EXT line, and the following errors for the FONT instruments: 1 μm BPM resolution and 0.5% kicker field imperfection.

- We have also added 30 μm position jitter for all the ATF2 quadrupoles

- In a second step, **BBA** has been applied with 11 steering magnets and 50 BPMs along the lattice (EXT line + FFS) to minimise $\sqrt{(\sigma^*_x \sigma^*_y)}$ at the IP applying the Simplex algorithm

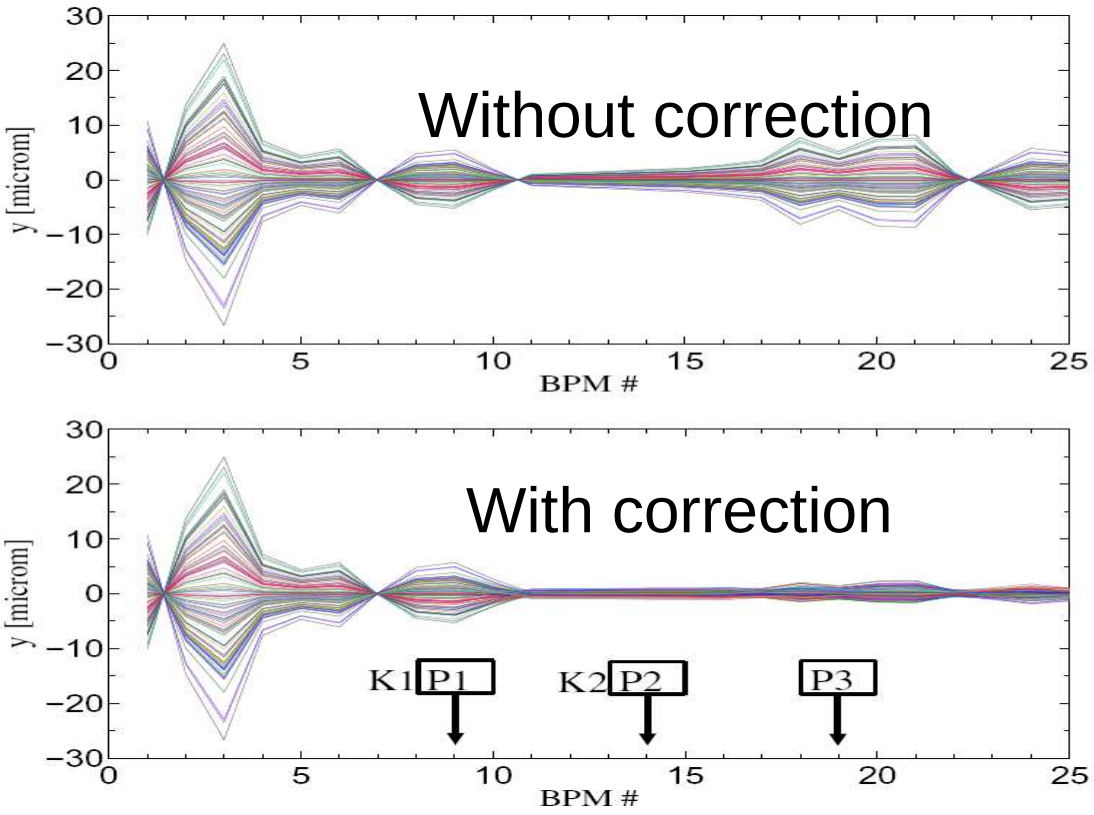
- After BBA, dynamic imperfections have been included: **model K (A. Seryi's models) of ground motion**

- Finally, **FB correction** is carried out

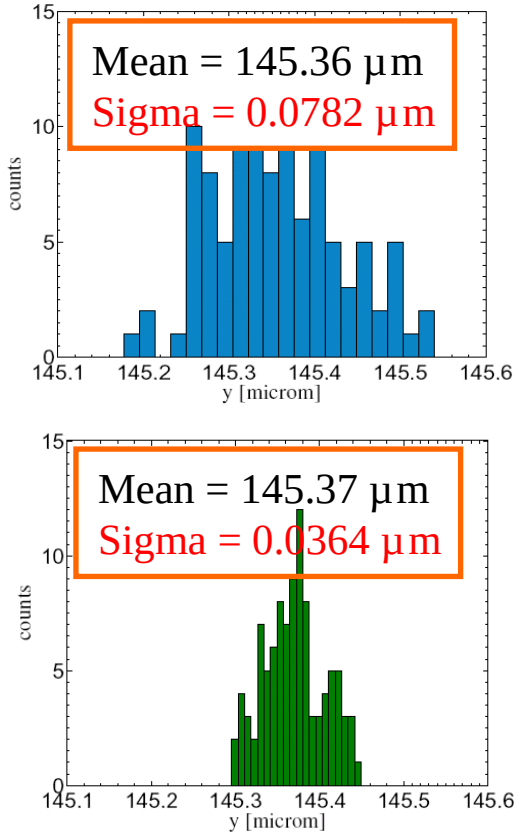
Simulation result example

Vertical position jitter propagation along the ATF2 EXT line and residual jitter distribution at the IP without and with correction by the FB system

EXT line



IP



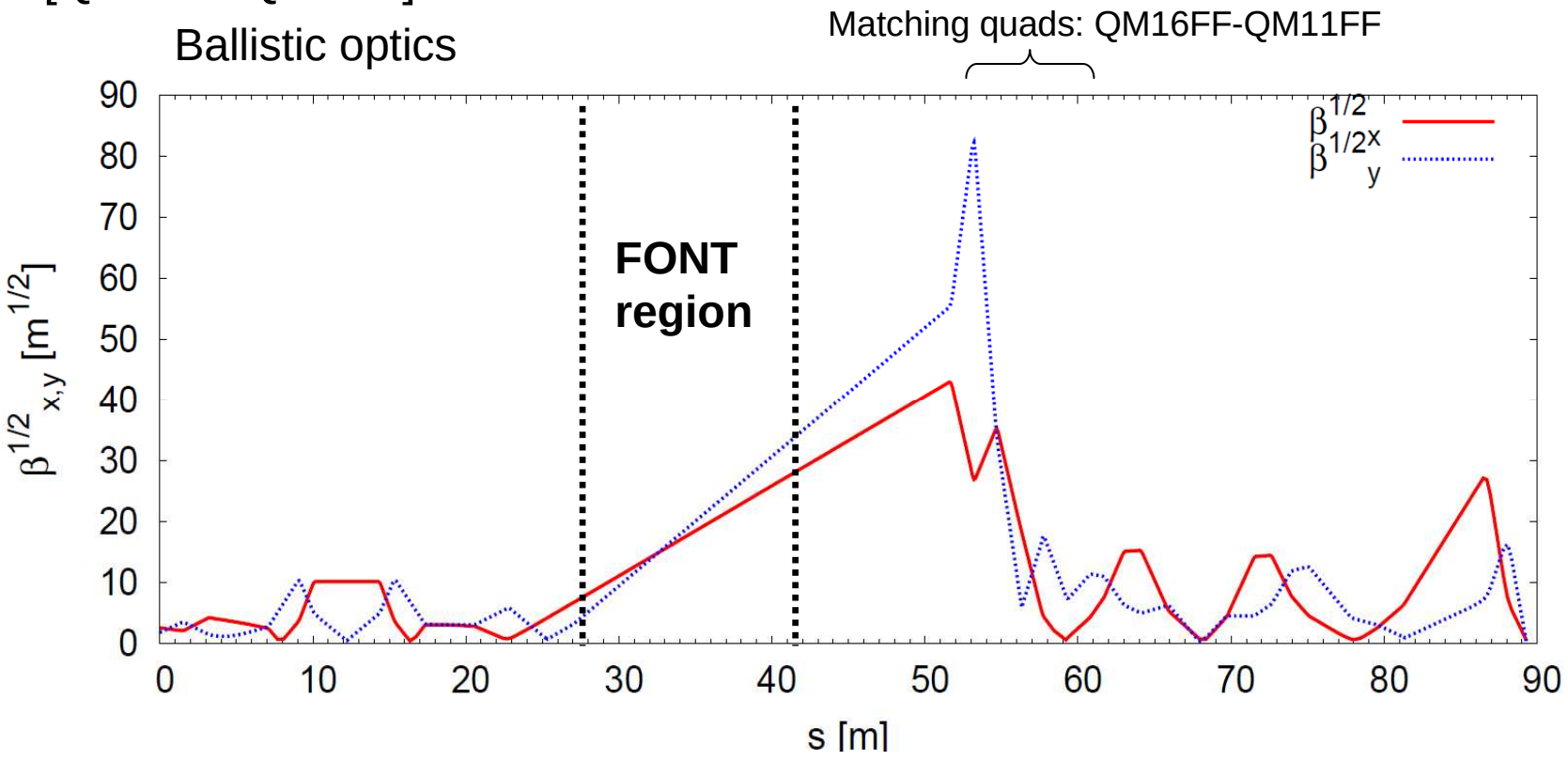
Jitter reduction by a factor 2

FONT commissioning schedule

- February 09: FONT system was installed
- March-May 09: checking the FONT instruments in the beam line; FONT BPMs calibration; kicker tests (linear response range); new DAQ tested; several problems fixed
- Summer 09 shutdown:
  - FONT BPM movers installation (mechanical movers provided by IFIC-Valencia)
- October/November/December 09:
  - Test of new 9-channel digital board (improved BPM processors)
  - BPM calibration with movers
  - FB tests in multi-bunch mode: starting with 3 bunches
- Aim: System commissioned end 2009/beginning 2010

FONT commissioning issues

- FONT BPMs calibration with ballistic optics:
- [QF9X – QF21X] OFF

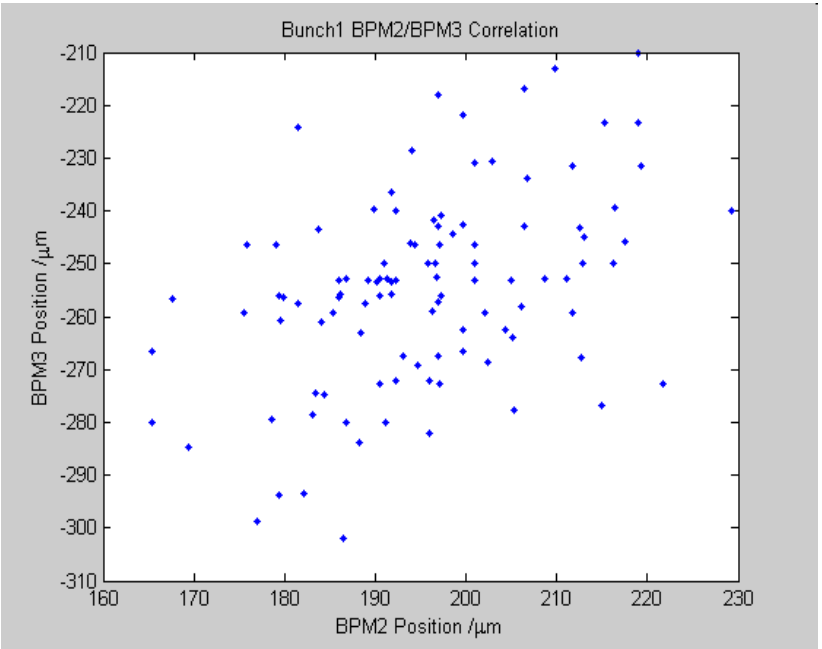


- Scans of the ZV6X corrector are giving consistent calibrations across the 3 BPMs

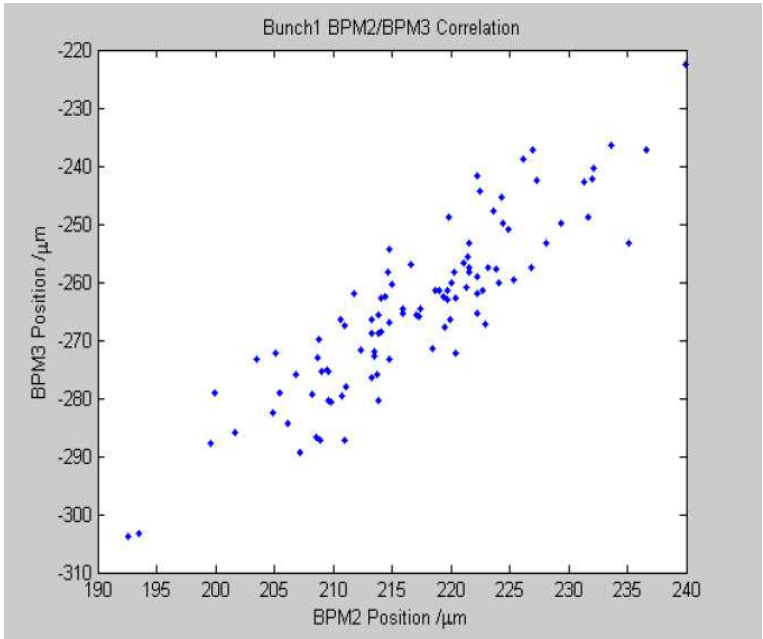
FONT commissioning issues

- Pulse-to-pulse beam jitter and correlation between BPMs
- As intensity was increased, correlations appear in data

~ 0.1 x 10^{10} electrons/bunch



~ 0.3 x 10^{10} electrons/bunch

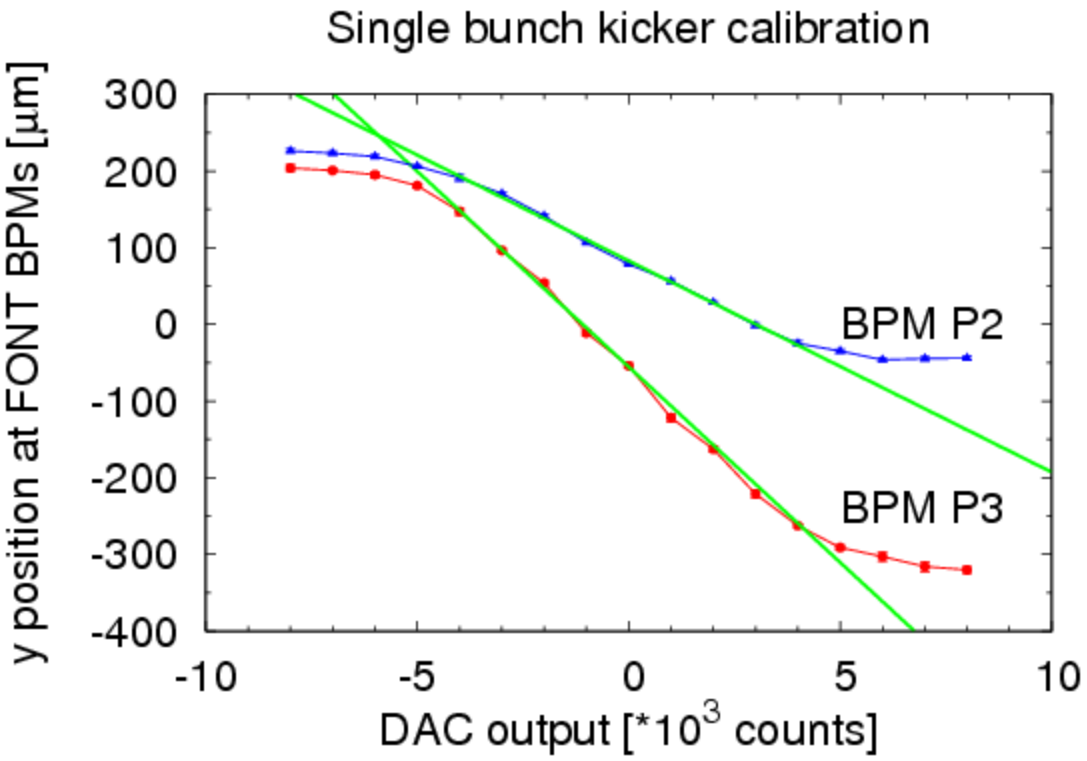


Resolution estimate ~ 4 microms (to be improved during next run period)

FONT commissioning issues

- FONT kicker calibration:

Constant currents were fed to the K1 kicker using the P2 FB board DAC



Positions averaged over ~ 30 pulses

Linear response in expected region

+/- 40 μrad maximum deflection

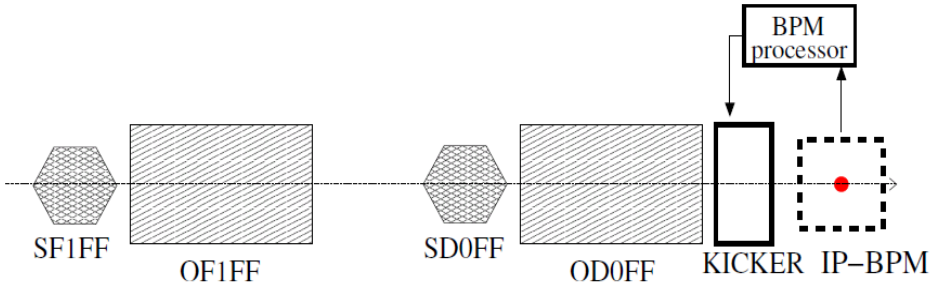
Possible intra-train FB system at IP

- To combat residual jitter at the IP
- Crucial for phase 2 goal (~nm beam stability level)

Key components:

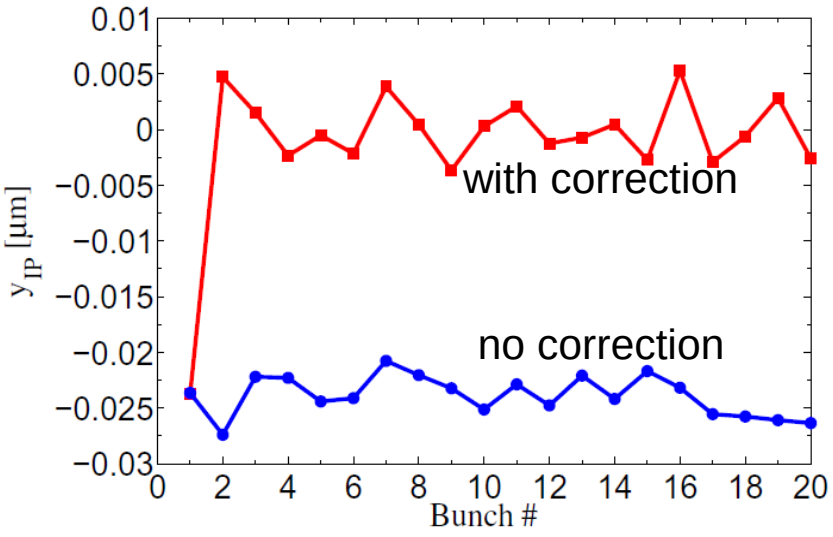
Cavity IP-BPM **(Y. Honda et al.)** with nanometer level resolution: up-to-date resolution measurements ≈ 8.7 nm. Further improvement is necessary

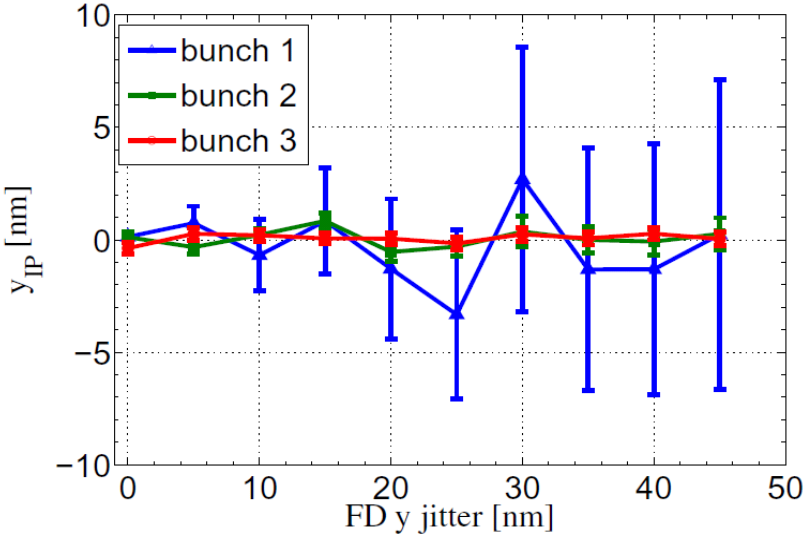
Stripline kicker located upstream of the IP-BPM



Simulation procedure and results

- For the simulations we have used a **PI algorithm** implemented in the tracking code Placet-octave to correct beam position
- **2 nm IP-BPM resolution** and introducing 0.5% kicker field imperfection
- Study of the FB system performance in terms of correcting beam position offset caused by ground motion (model K) and by vertical position jitter of the FD quadrupoles.





Summary

- Intra-train FB systems will be essential to achieve goal 2 of ATF2
- FONT R&D and commissioning in progress
- FONT instruments have been tested and calibrated during the March-May 09 campaign
- Next campaign: electronics upgrade, planning for 9-ADC channel FB board; mechanical upgrade with BPM movers; Tests of FB system in multi-bunch mode
- A combination of the FONT system in the EXT line and a possible IP FB system could be very effective to achieve beam stability at the nanometer level at the IP (simulations in progress)