Beam stabilisation at the IP using the upstream FONT system

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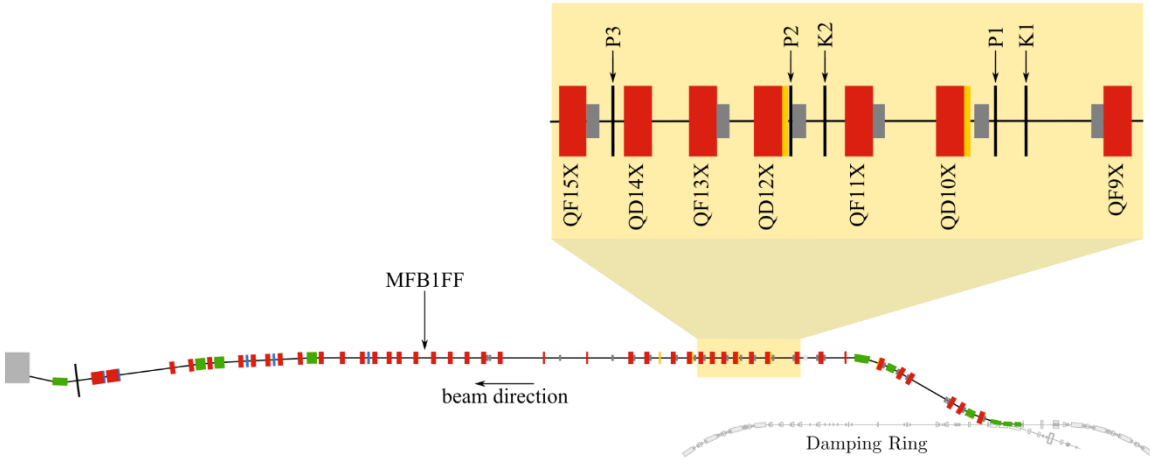
Contents

- Stripline BPM system's hardware upgrade
- K2-P3 single-loop feedback
- Coupled-loop upstream feedback

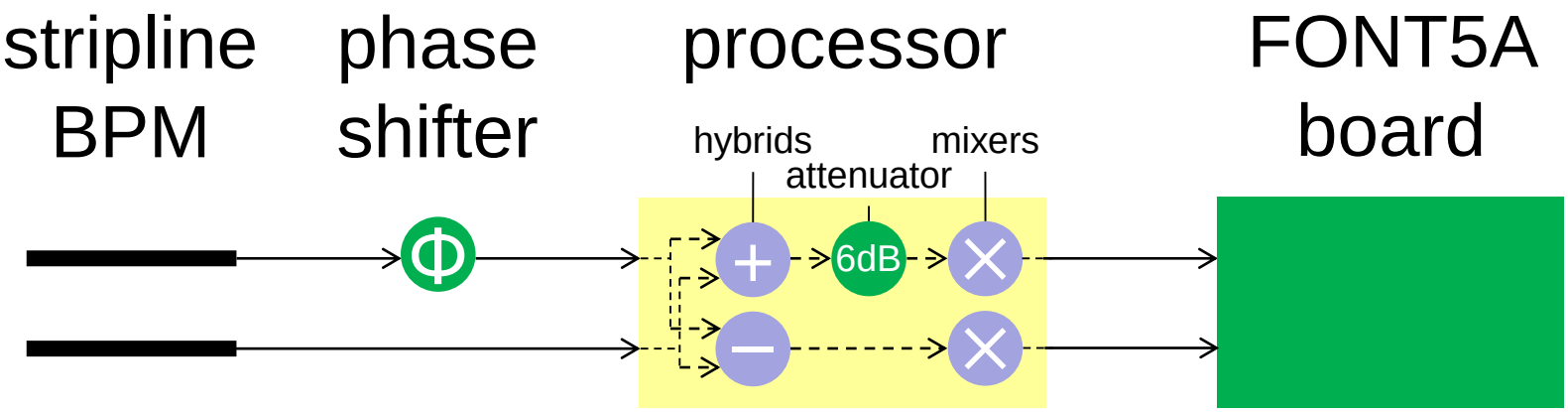
Stripline BPM system

- 3 stripline BPMs P1, P2 & P3 in EXT line
- Previous resolution 291 ± 10 nm at charge of 0.5 x 10^{10} (PRST-AB 18, 032803, 2015)

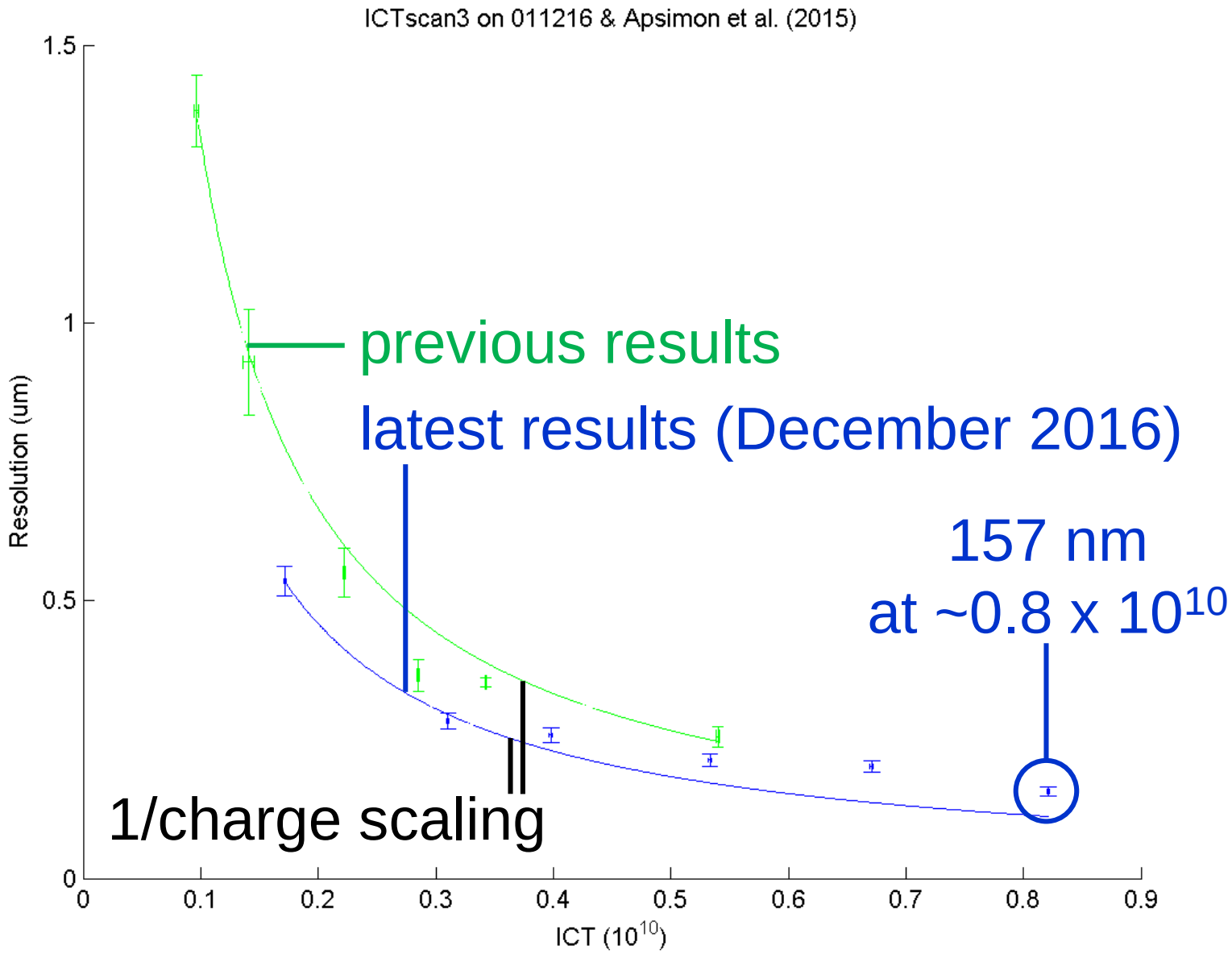


based on figure from G. White et al. (PRL, 2014)

Stripline BPM system upgrades



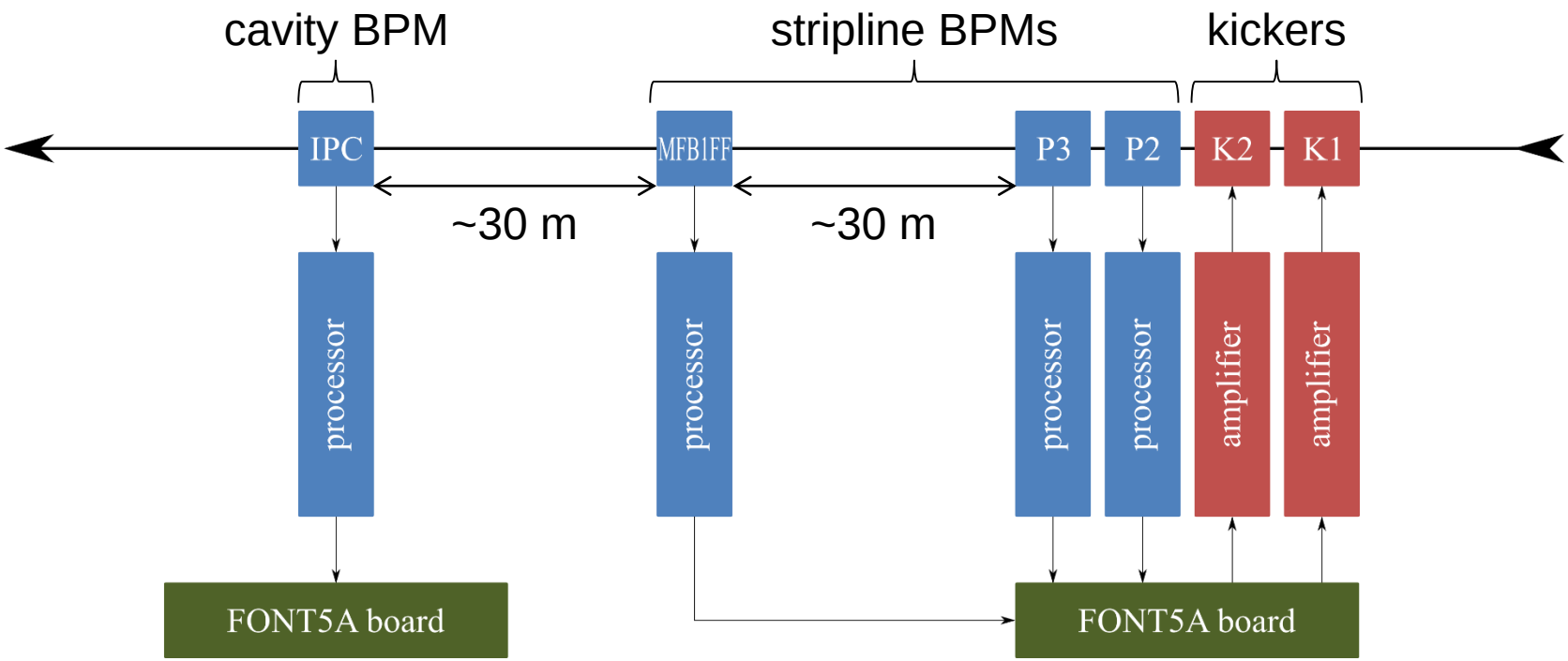
- Upgraded phase shifter (finer setting)
- Installed 6 dB attenuator in processor (double maximum operating charge: 10^{10})
- Introduced FONT5A board clock filtering


ICTscan3 on 011216 & Apsimon et al. (2015)
Resolution (um)
ICT (10^{10})
1.5
1
0.5
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
previous results
latest results (December 2016)
157 nm
at ~0.8 x 10^{10}
1/charge scaling

Intra-train feedback

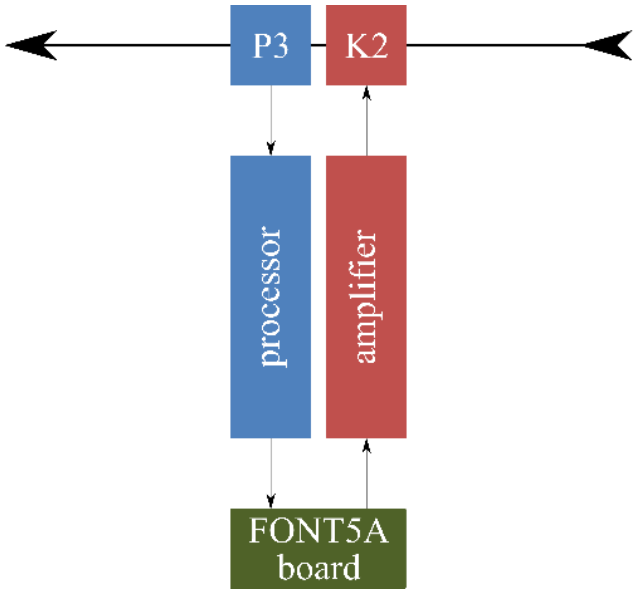
- The upstream FONT intra-train feedback system operates by:
  - Measuring the position of bunch 1 at P2 & P3
  - Processing the signals on an FPGA-based FONT5A board
  - Correcting the position of bunch 2 at K1 & K2
- Correction witnessed at MFB1FF & IPC (close to beam waist) with nominal optics

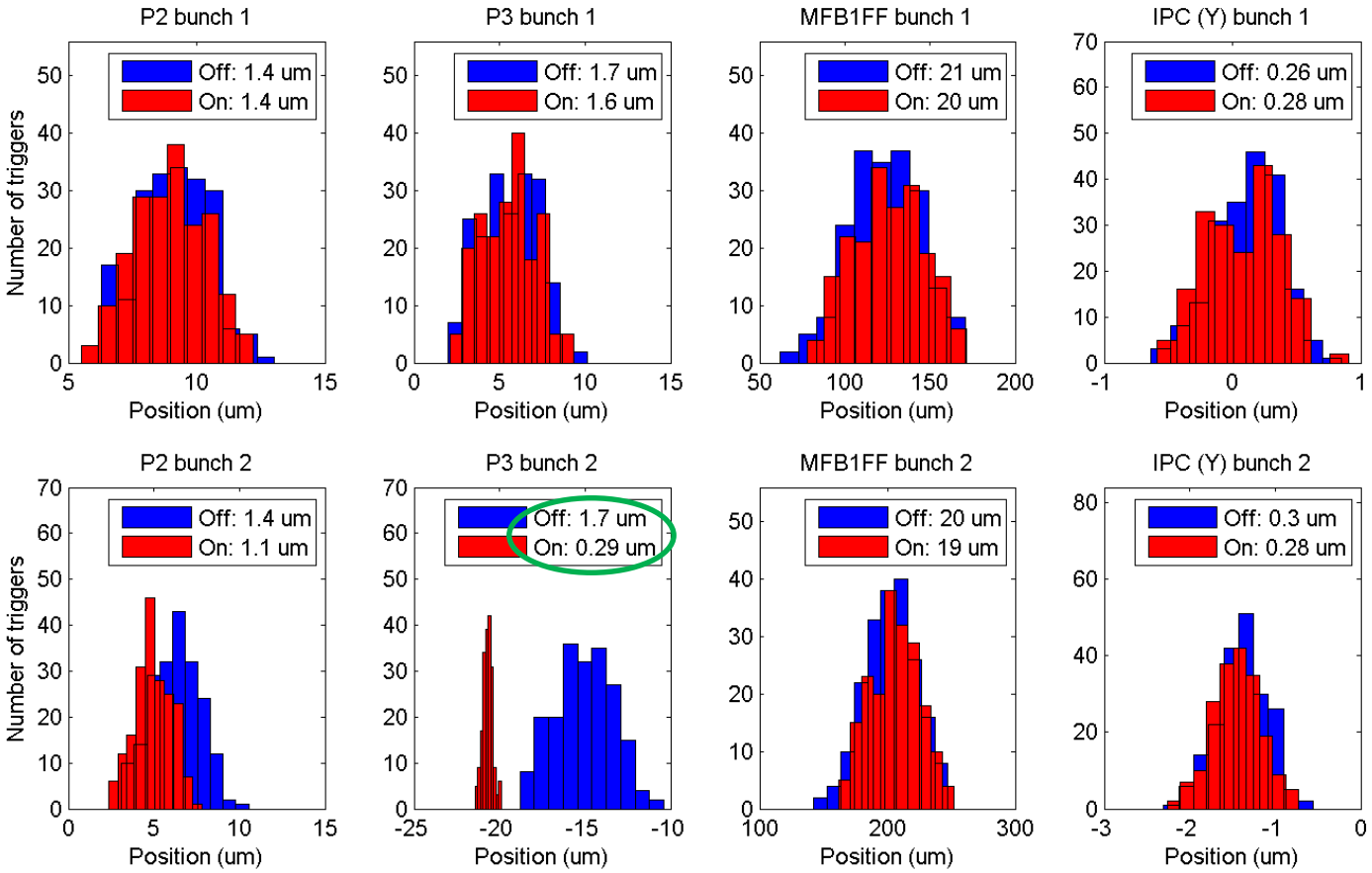
FONT system


cavity BPM
stripline BPMs
kickers
IPC
MFB1FF
P3
P2
K2
K1
~30 m
~30 m
processor
processor
processor
processor
amplifier
amplifier
FONT5A board
FONT5A board

Single-loop feedback

- Measure at P3, correct at K2
- Charge: ~0.9 x 10^{10} in February 2017



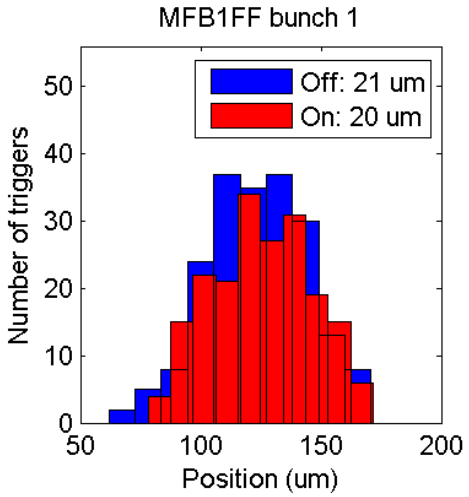


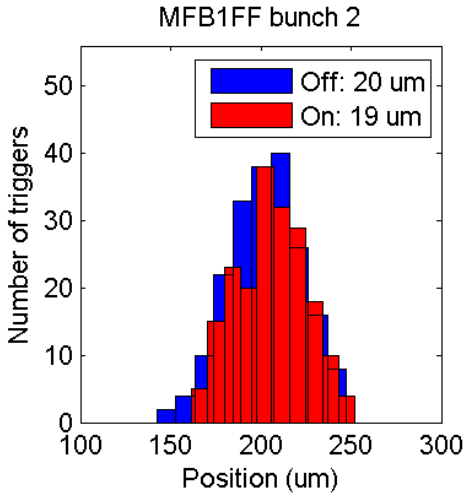
stabilisation to 290 nm

Jitter propagation

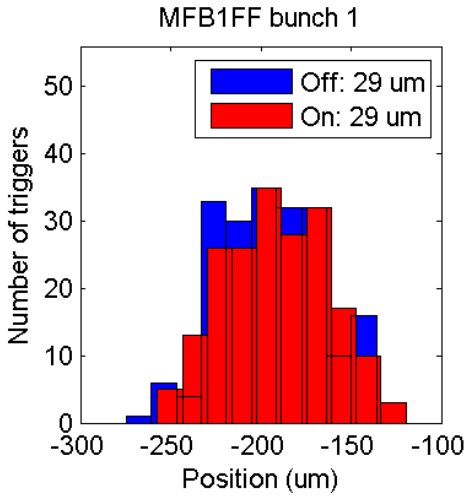
- Data at P2 & P3 can be propagated to MFB1FF & IPC using transfer matrices
- Shows that jitter reduction is not expected

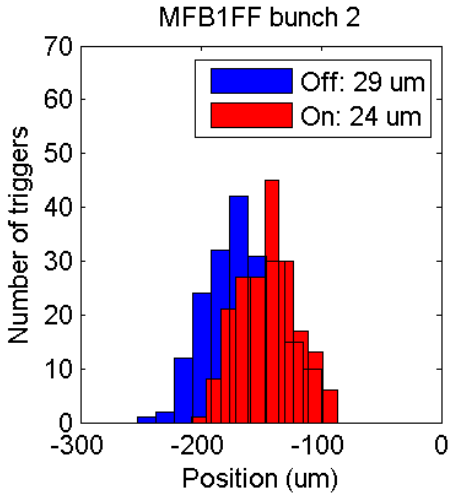
measured at MFB1FF



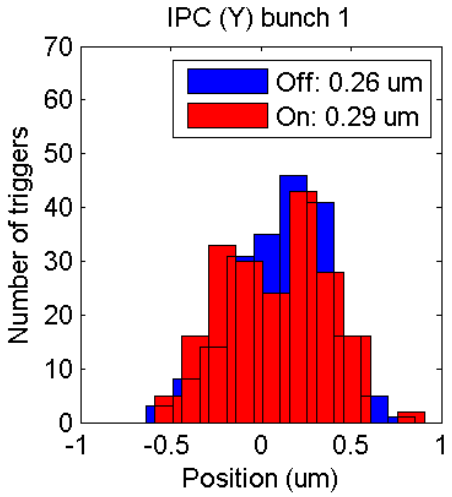


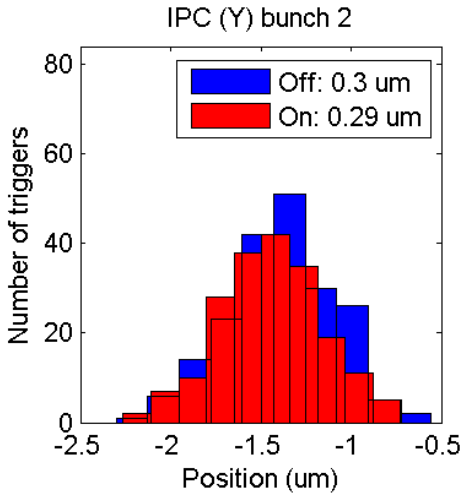
propagated to MFB1FF



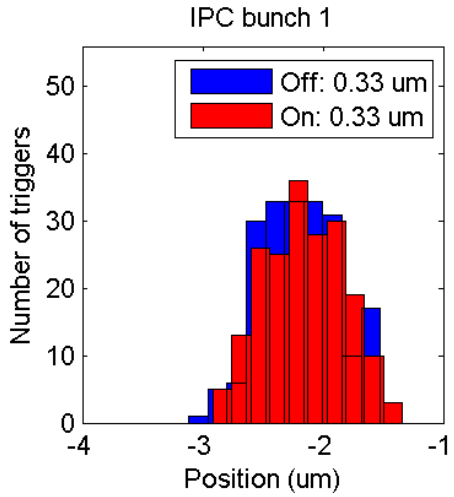


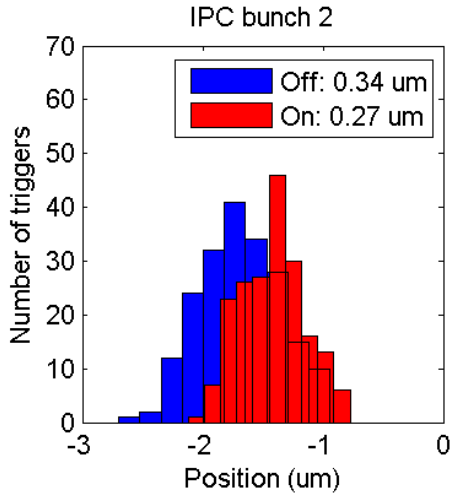
measured at IPC





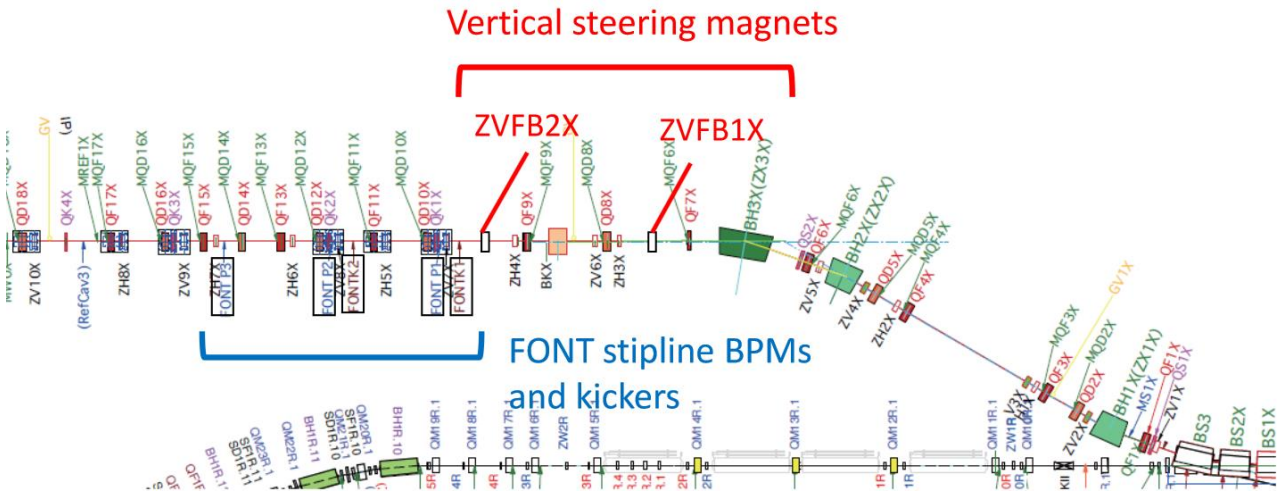
propagated to IPC





Random jitter scan

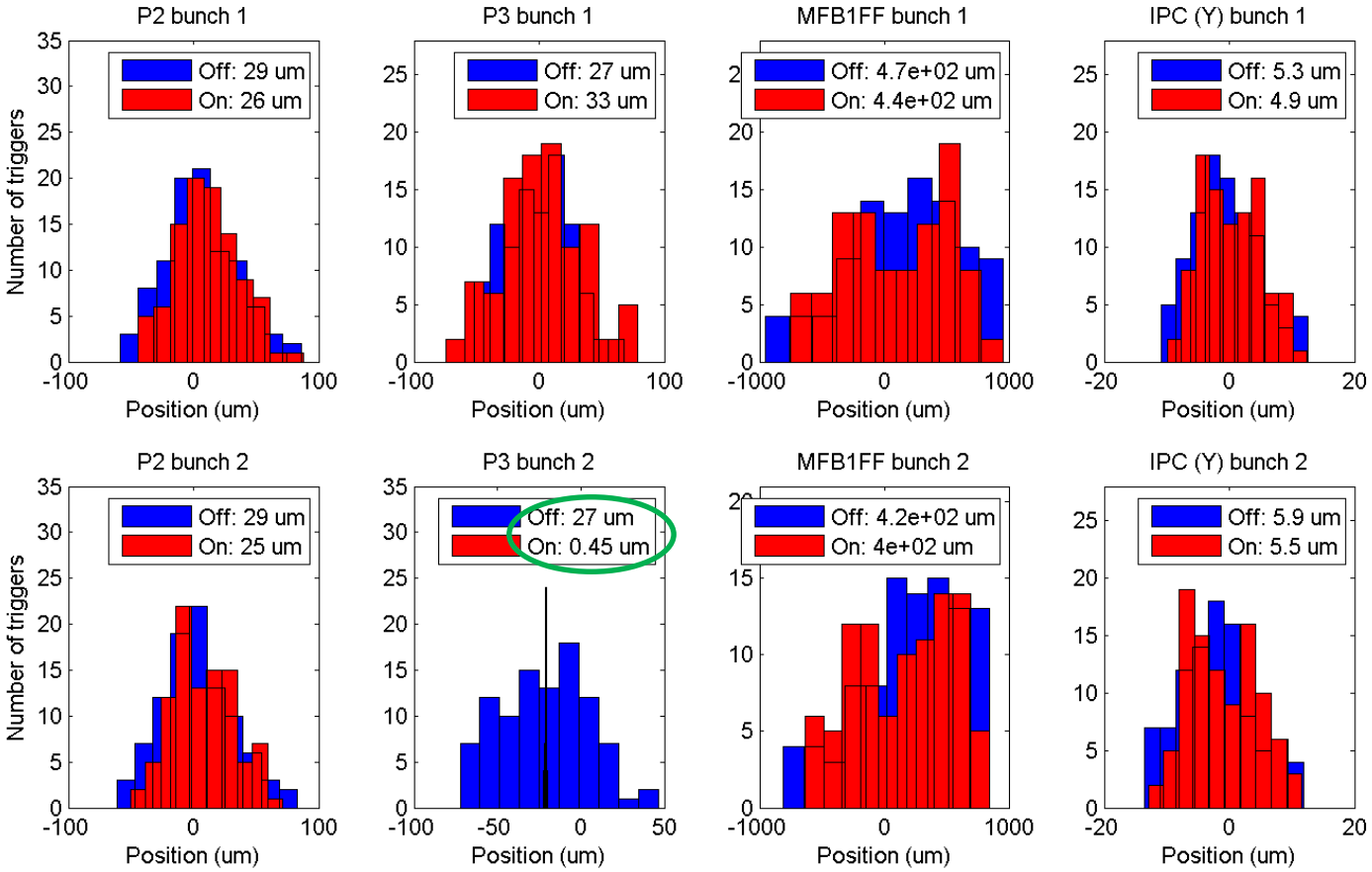
- Random jitter introduced pulse-to-pulse using ZVFB1X & ZVFB2X



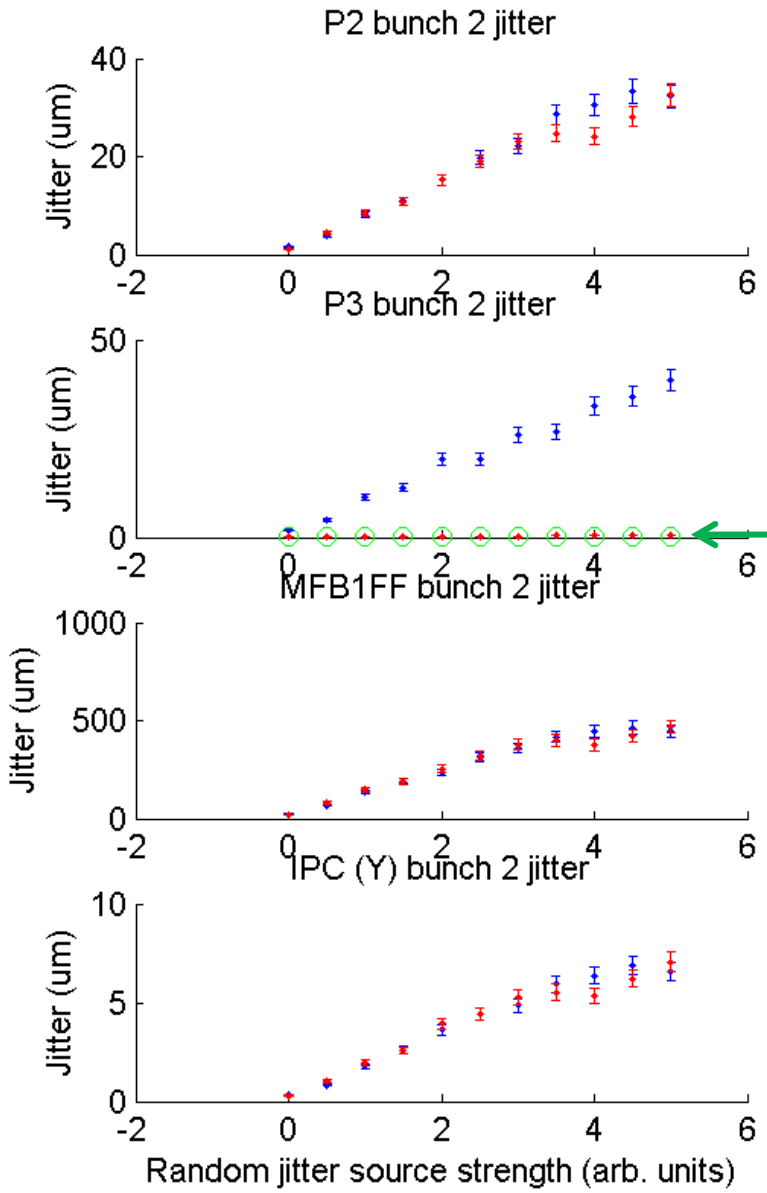
from Y. Kano

- Operate K2-P3 single-loop feedback

Random jitter source strength: 3.5 arb. units



factor 60 stabilisation



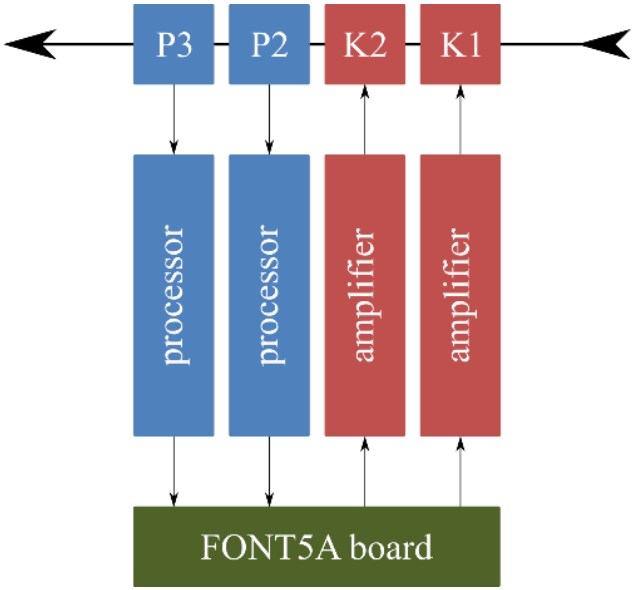
feedback off jitter (blue)

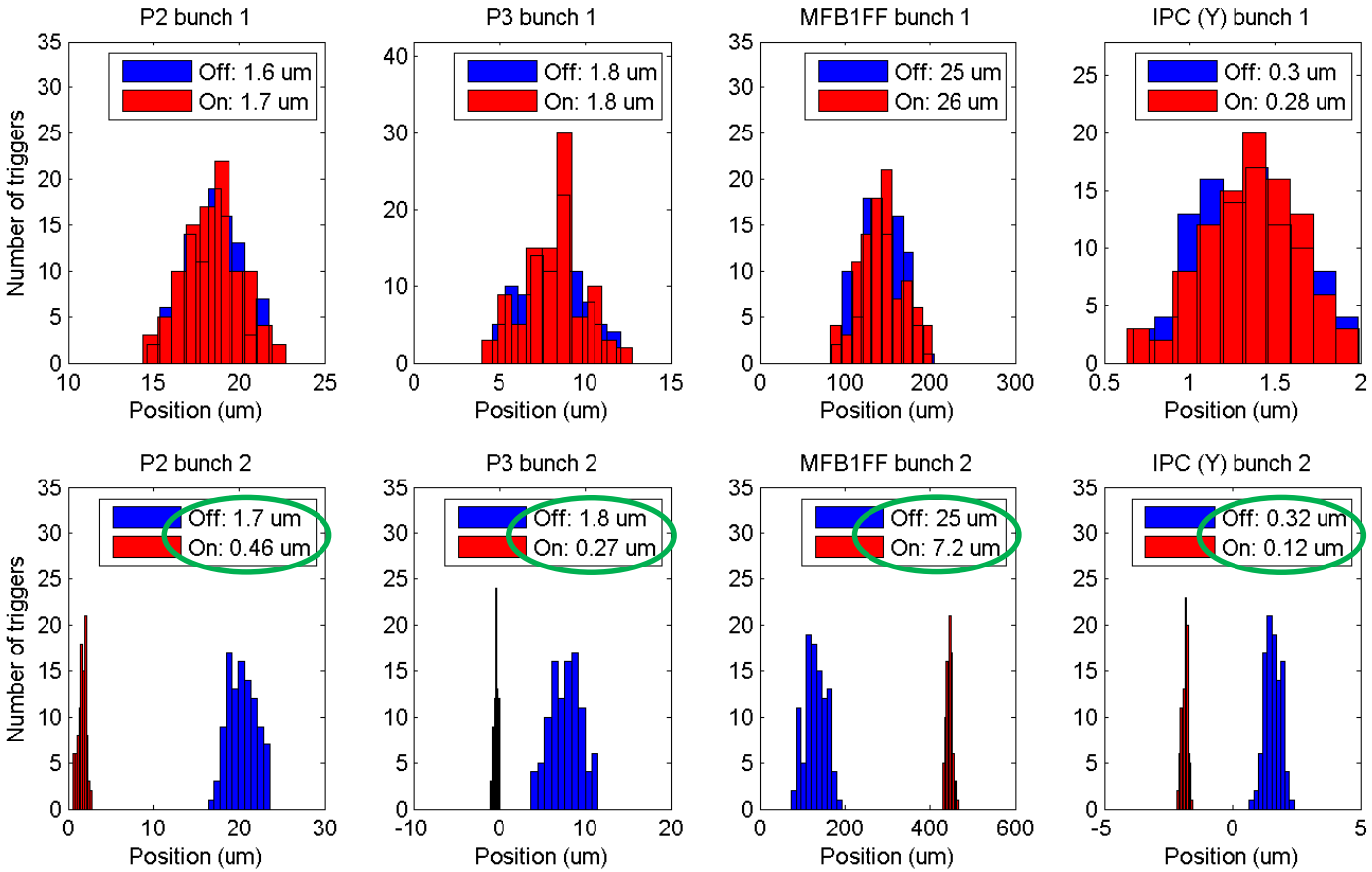
feedback on jitter (red)

predicted performance at P3 given incoming position jitter & bunch-to-bunch correlation (green circles)

Coupled-loop feedback

- Measure at P2 & P3, correct at K1 & K2
- Charge: ~0.85 x 10^{10} in February 2017

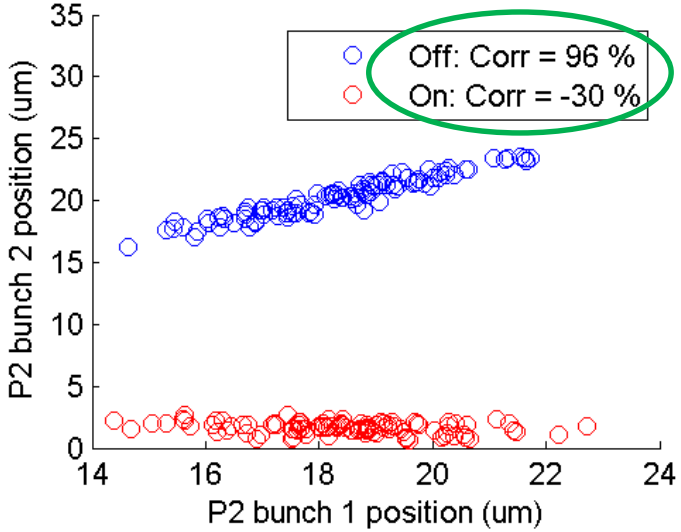


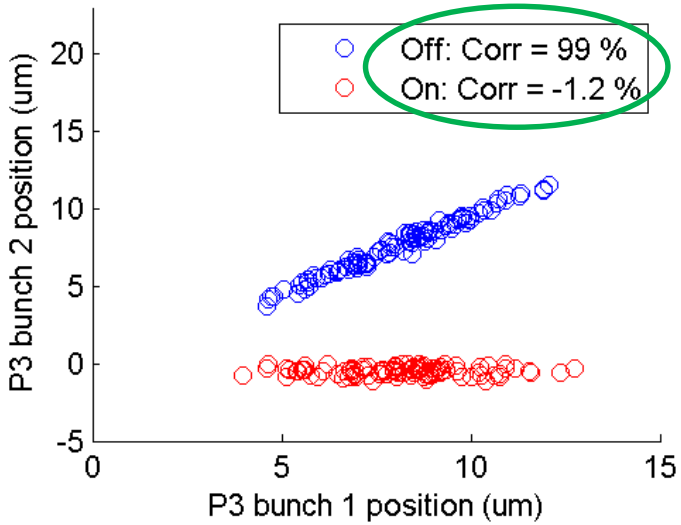


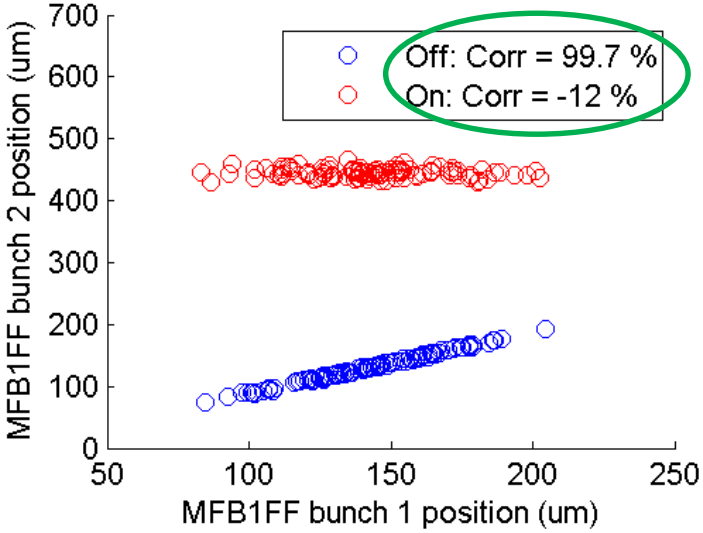
stabilisation to <500 nm upstream

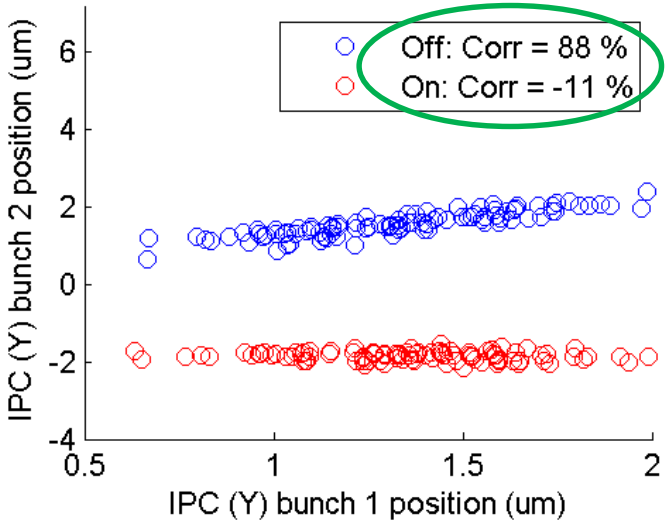
factor 3 stabilisation downstream

correlation removed at all BPMs

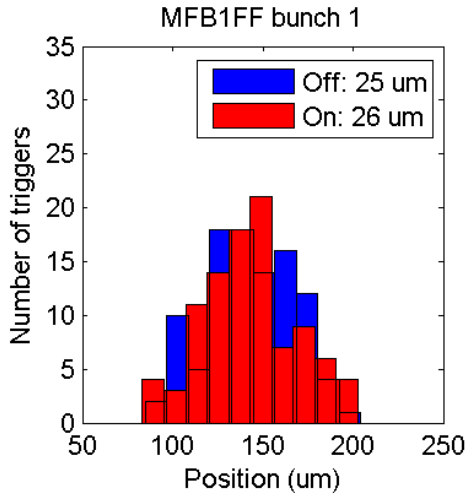


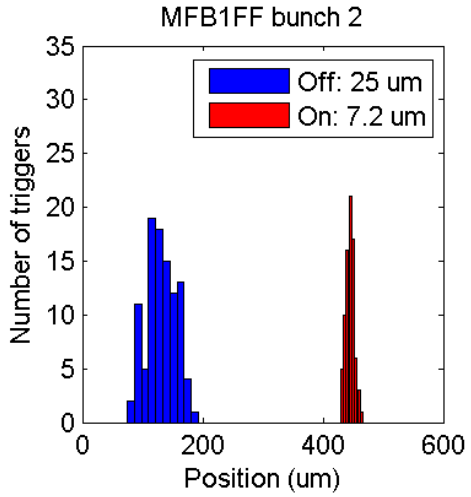




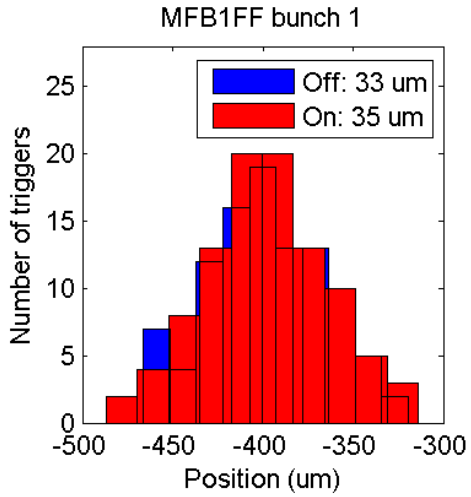


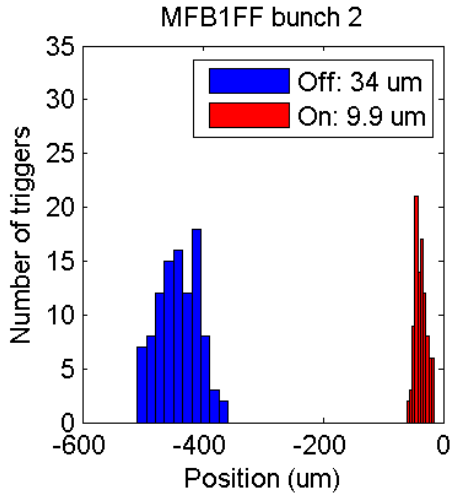
measured at MFB1FF





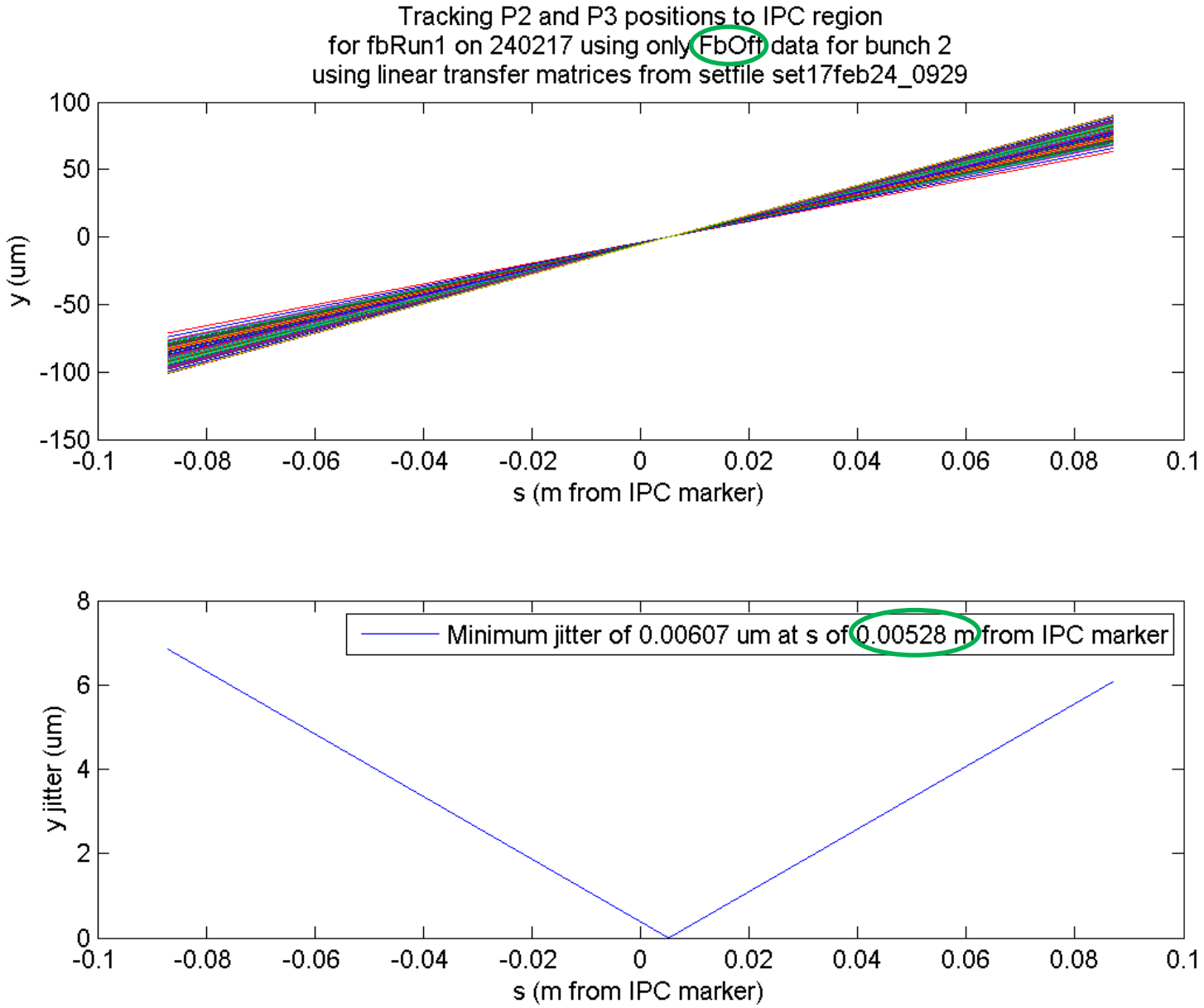
propagated to MFB1FF

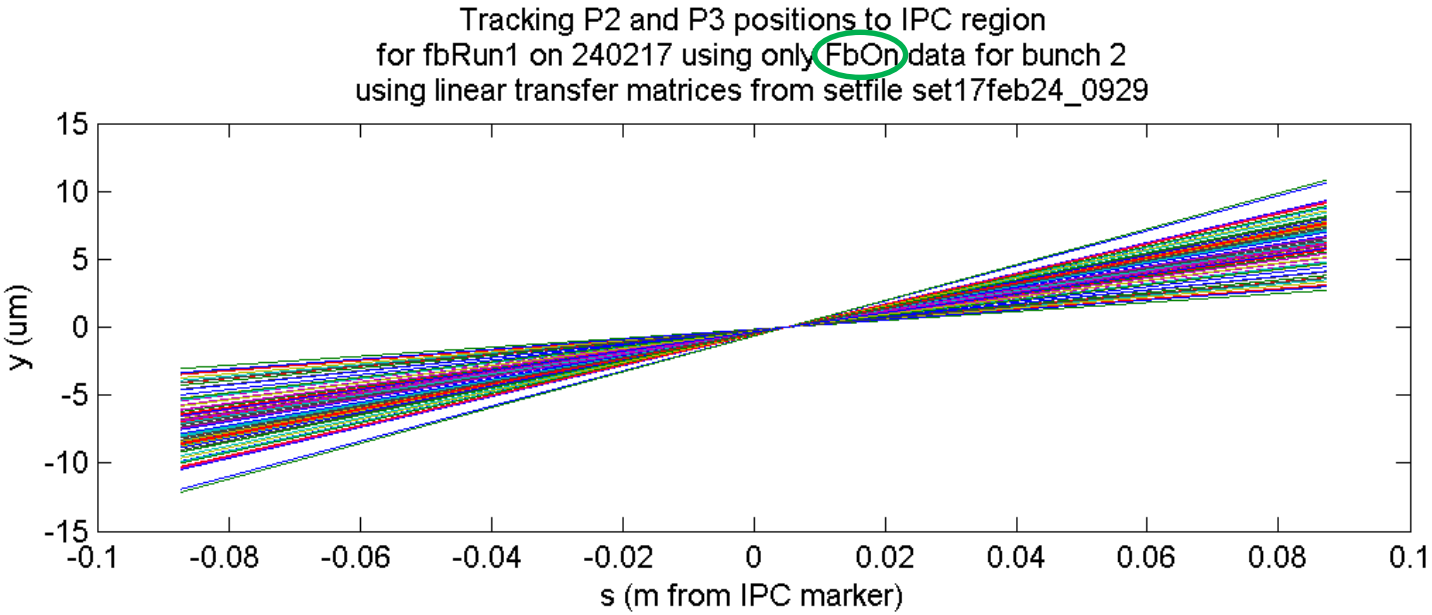




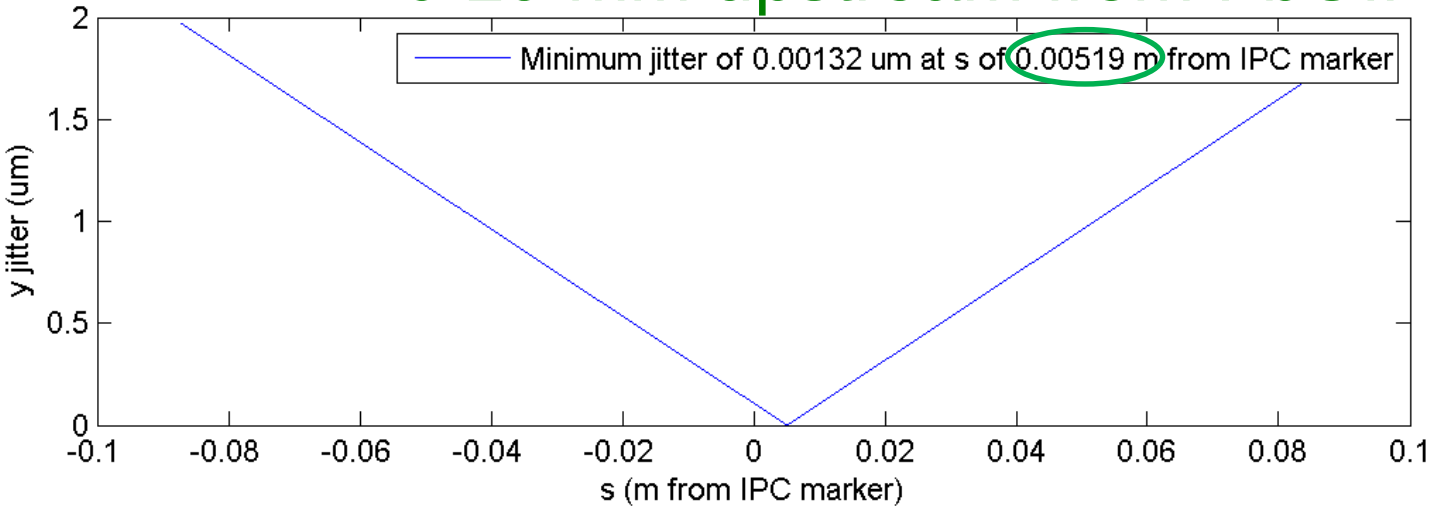
Jitter propagation to IP area

- Data at P2 & P3 propagated to IP area
- Bunch trajectory reconstruction in IP area allows beam waist to be located

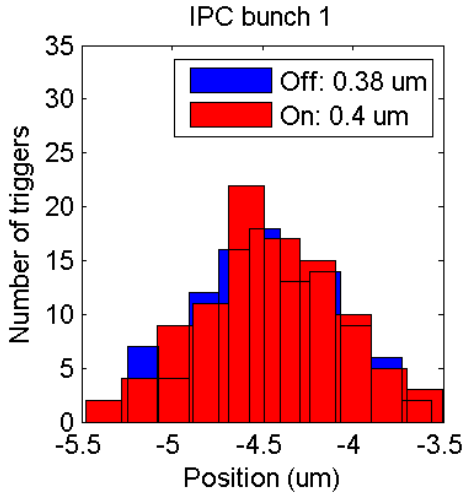

Tracking P2 and P3 positions to IPC region
for fbRun1 on 240217 using only FbOff data for bunch 2
using linear transfer matrices from setfile set17feb24_0929
y (um)
s (m from IPC marker)
Minimum jitter of 0.00607 um at s of 0.00528 m from IPC marker
y jitter (um)
s (m from IPC marker)

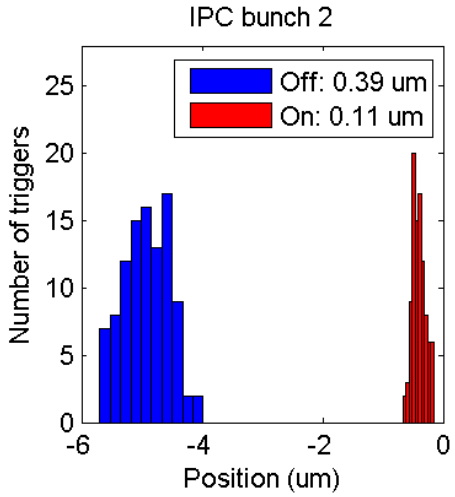


0.19 mm upstream from FbOff waist

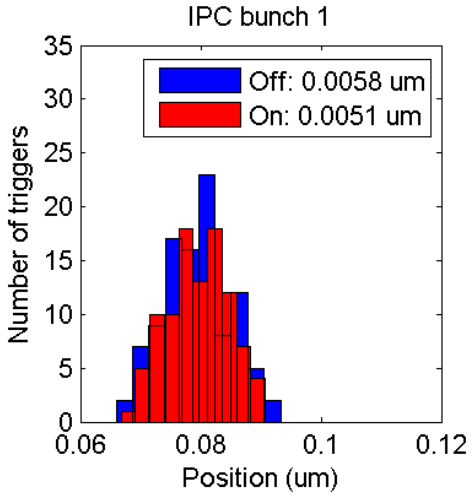


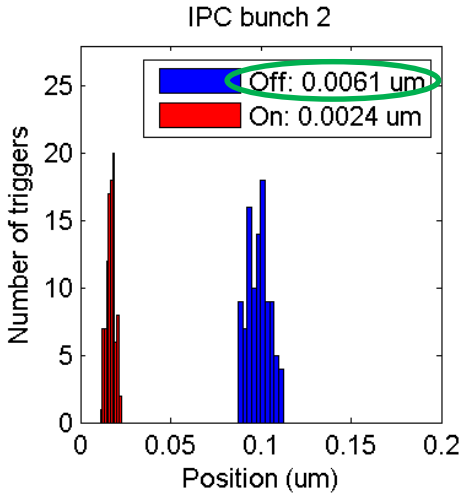
propagated to IPC



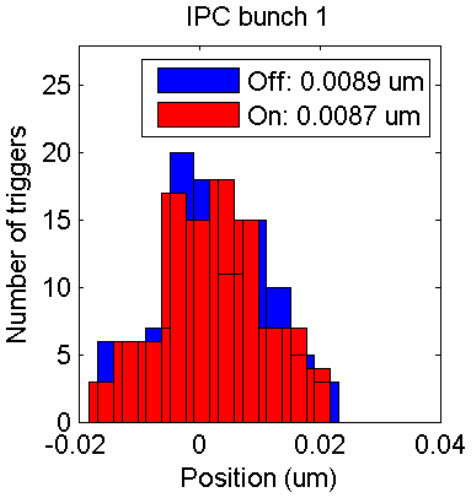


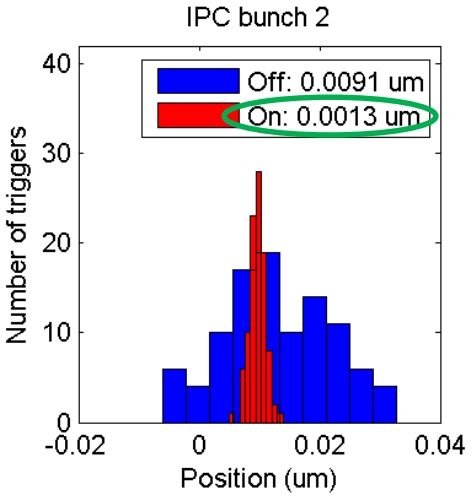
propagated to FbOff waist





propagated to FbOn waist



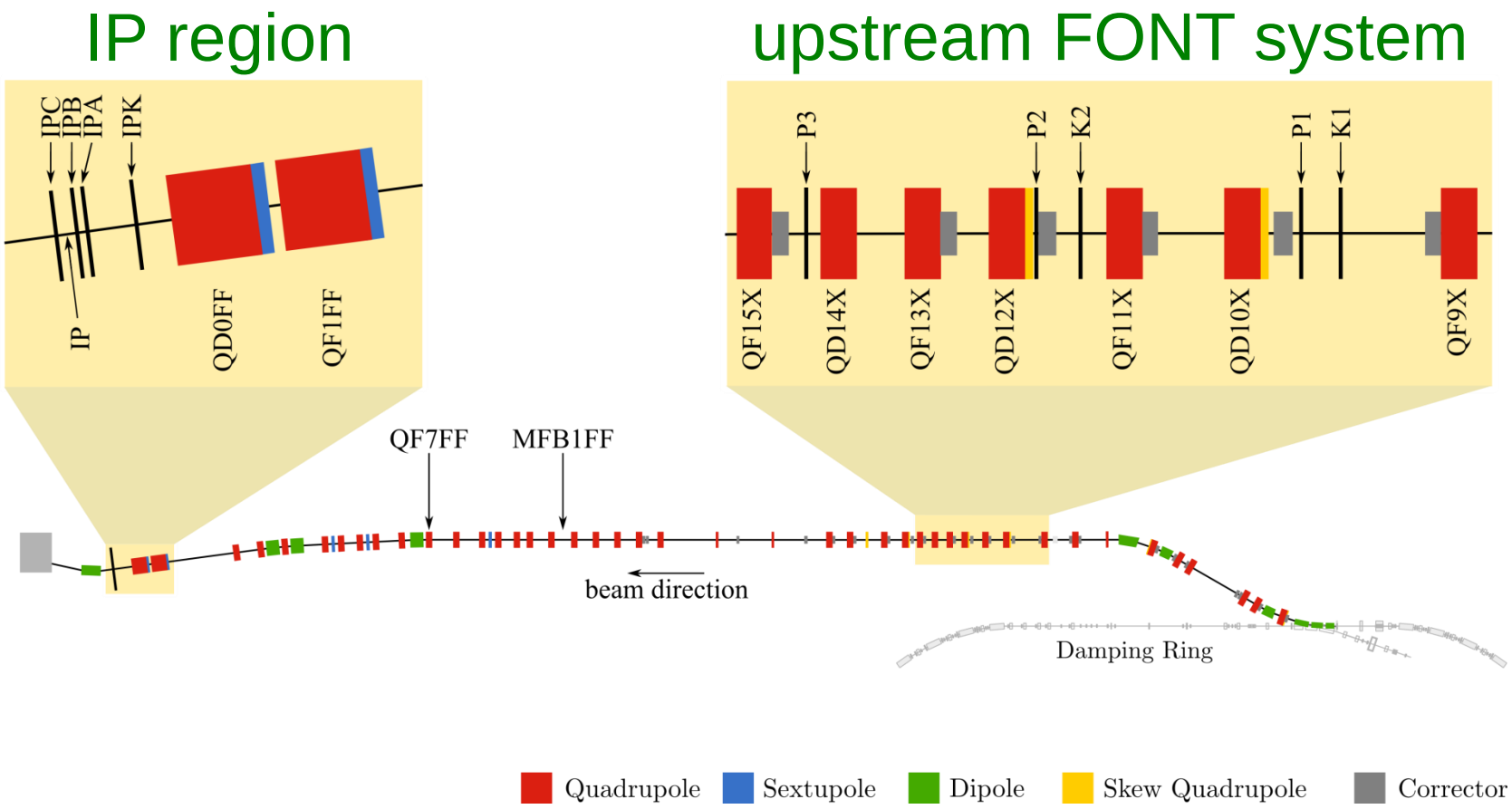


Conclusions

- Stripline BPM system hardware upgraded for improved resolution: ~150 nm
- K2-P3 single-loop feedback
  - Beam jitter stabilised to < 300 nm at P3
  - With extra jitter: factor 60 jitter reduction
- Coupled-loop upstream feedback
  - Beam stabilised: 460 nm at P2, 270 nm at P3
  - Factor 3 reduction in jitter at MFB1FF and IPC
  - Propagating data to IP waist: nm-level stability

Thank you for your attention!

Extraction and final focus lines



based on figure from G. White et al. (PRL, 2014)

Resolution

- P2, P3 & MFB1FF geometric resolution (with 6 dB attenuation on MFB1FF strips):
  - K2-P3 single loop feedback: 443 nm
  - Coupled loop feedback: 479 nm

Feedback jitter prediction

- Bunch 2 feedback on jitter prediction σ_{Y_2} at feedback BPMs:

  $$(\sigma_{Y_2})^2 = (\sigma_{y_1})^2 + (\sigma_{y_2})^2 - 2\sigma_{y_1}\sigma_{y_2}\rho_{12}$$

  where
  - σ_{y_1} is the bunch 1 feedback off jitter
  - σ_{y_2} is the bunch 2 feedback off jitter
  - ρ_{12} is the bunch 1 to 2 feedback off correlation