Beam jitter studies at ATF and ATF2

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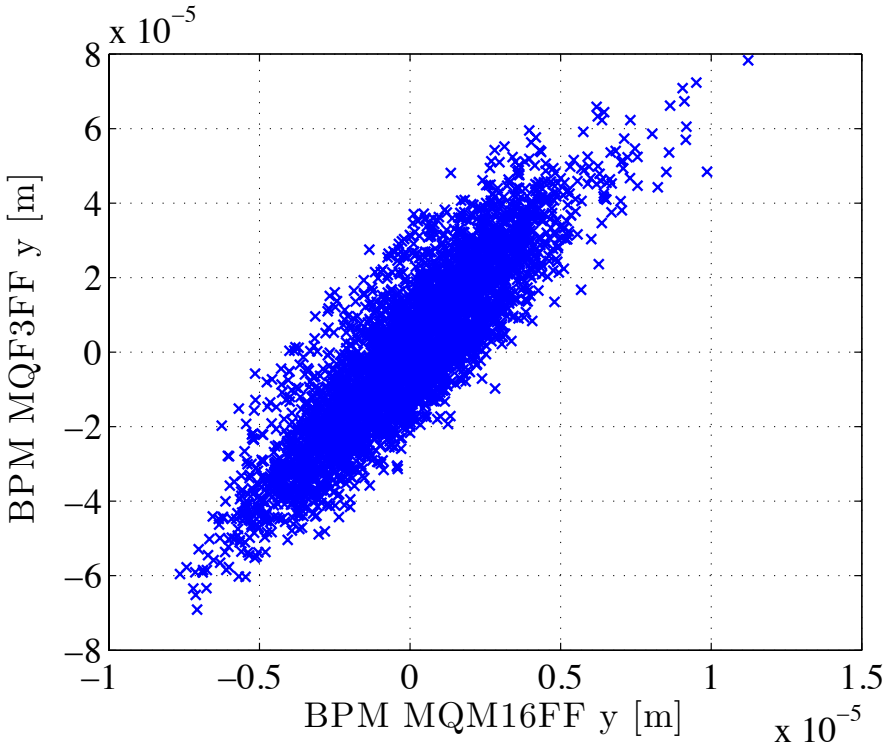

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Many thanks to Y. I. Kim, J. Snuverink, G. White and M. Woodley for supporting us with all necessary information at ATF and for the many very helpful discussions!

1. Measurement and analysis setup

Intention of the jitter studies

- Intention:
  1. Study beam motion in damping ring and ATF2 beam line
     -> Beam jitter has to be reduced from 10-20% to below 5%
  2. Locate beam motion sources, especially beam jitter sources
  3. Study the performance of already operating orbit feedback systems and try to make suggestions for possible improvements if necessary

- Setup:
  1. Some scripts to read BPM data in the damping ring and the ATF2 beam line have been written
  2. Several data set have been taken under different conditions between the 13th and 18th of December 2012

Used BPM systems and EPICS

- Used BPM systems
  1. 96 button-BPMs in the damping ring, resolution of 20μm, only 90 used since others did not work properly
  2. 12 strip-line BPMs at the beginning of the ATF12beam line, resolution 5μm
  3. 34 cavity BPMs in the end of the ATF2 beam line, resolution 0.1μm

- EPICS system
  1. The *Experimental Physics and Industrial Control System* (EPICS) is a collection of software tools to create distributed soft real-time applications for large scientific applications.
  2. EPICS data (PVs) of BPMs have been accessed via Matlab commands

Analysis tools

- Correlation coefficient:

$$r = \frac{\sigma_{ij}}{\sigma_i \sigma_j}$$ σ_i … standard deviation σ_{ij} … cross correlation

- Power spectral density (PSD) estimated as:

$$\hat{P}[\omega_n] = \frac{T_0}{N^2}\left|X[n]\right|^2$$ $X[n]$ … DFT of x_k T_0 … acquisition time of x_k, N … sample number in x_k

- Integrated root mean square (IRMS):

$$I[\omega_m] = \sqrt{\frac{2}{T_0}\sum_{\omega=\omega_m}^{\omega_{MAX}} \hat{P}[\omega]}$$

- Full and differential motion:

x_k … full beam motion data $\tilde{x}_k = x_k - x_{k-1}$ … differential beam motion data

Beam motion source search method (for beam lines)

Search method

- Correlate BPM with all others (correlation coefficient)
- If correlation starts at BPM, there is a jitter source close by
- Remove detected correlation (see talk of Hector) and search for next jitter source
- Especially good if correlation starts between BPMs with same phase advance. Otherwise one BPM does not sample full oscillation and several BPMs have to be used for one source

Source types

1. Dipole kicks

Location of the source is upstream of the BPM where correlation is detected -> kick needs a phase advance to become an offset.

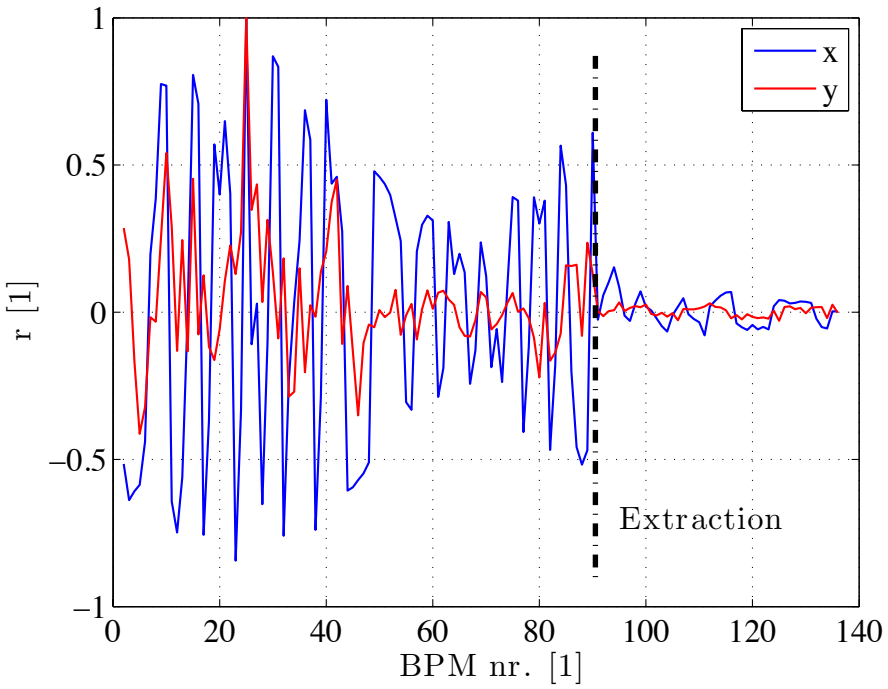
2. Wakefield kicks:

Location of the source is close to the BPM where correlation is detected -> kick is proportional to beam offset in source

We have to search up- and down-stream of the BPM and cannot predict exact location.

2. Results: damping ring

Differential beam motion in the damping ring

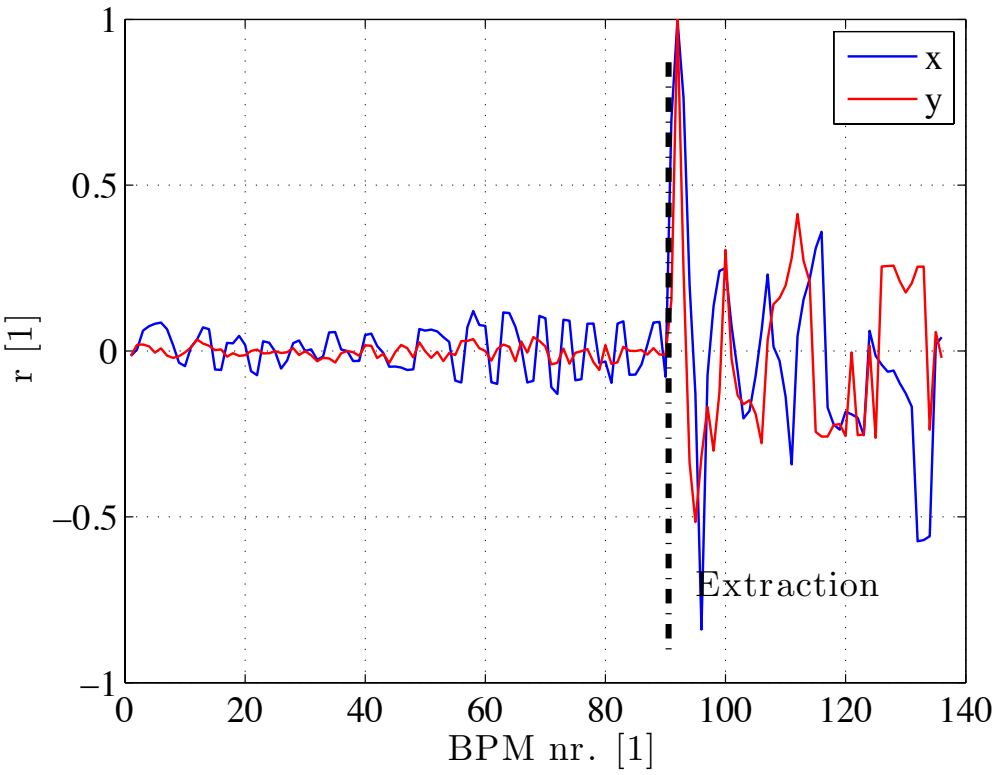


Correlation coefficient of BPM MB46R (number 25) with all other BPMs

- Differential beam motion is only slightly correlated in the damping ring (strong signal contribution of BPM noise).
- In the ATF2 beam line hardly any effect has been observed -> no orbit jitter from the damping ring (but only orbit data used)

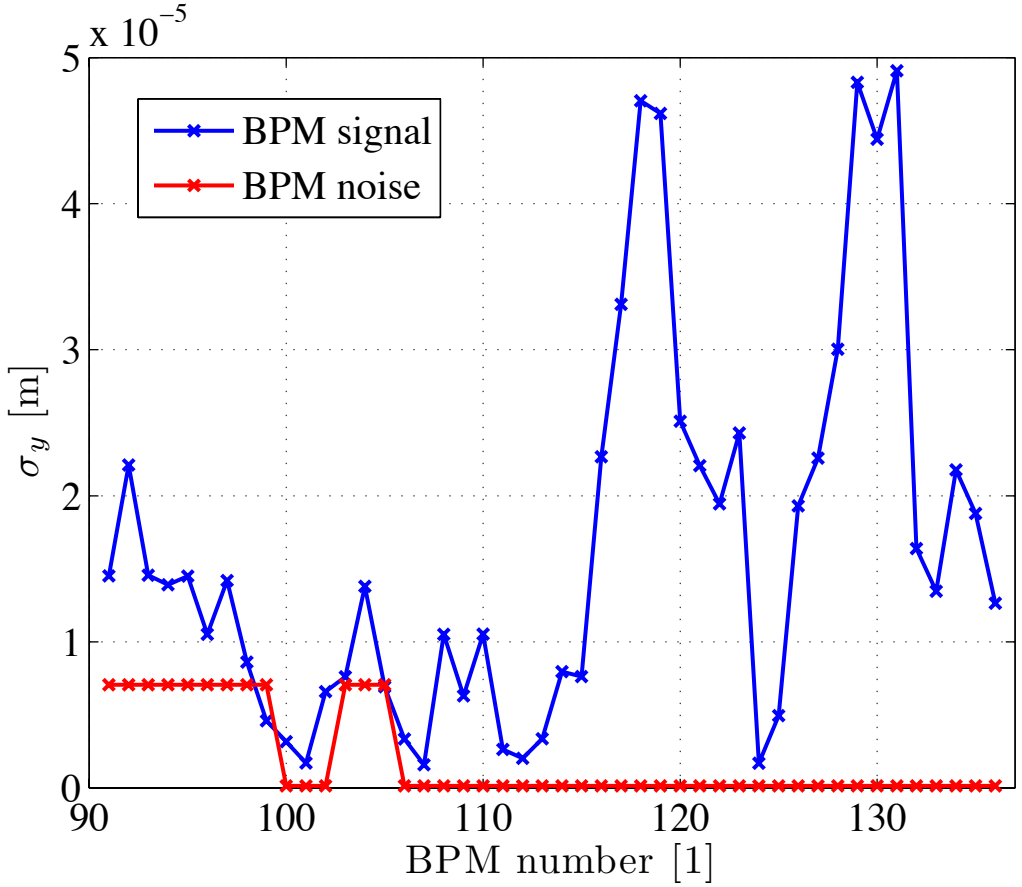
3. Results: ATF2 beam line

Small correlation from the start of the beam line (kicker?)



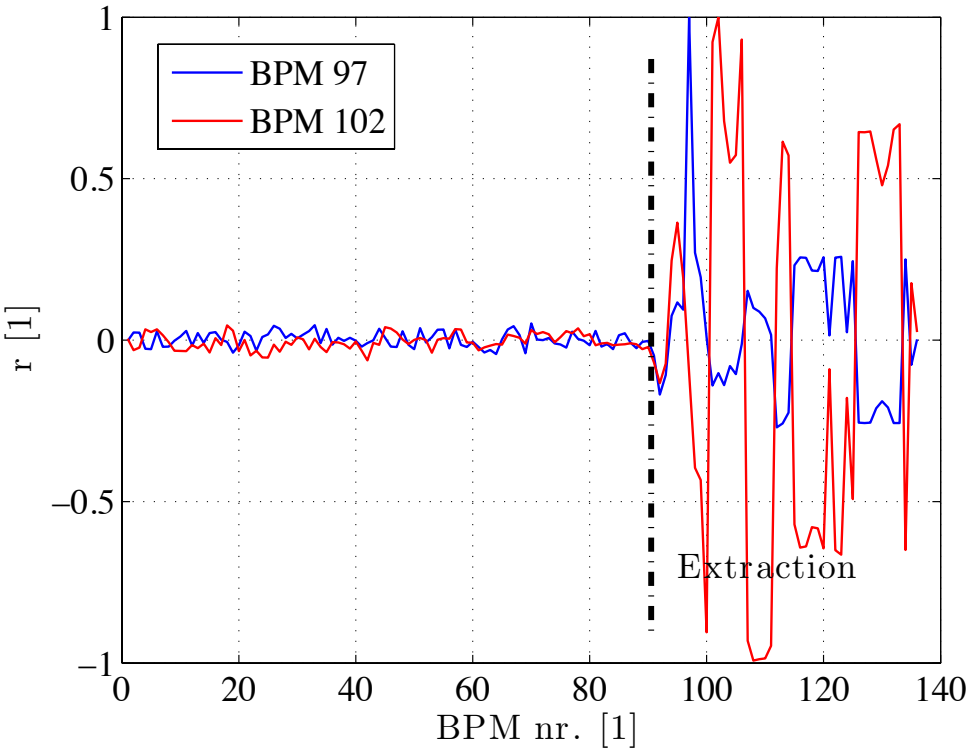
- Data of strip-line BPMs had to be shifted by one time step wrt. cavity BPMs.
- Correlation can be assigned to begin of beam line (maybe the kicker)
- Only small effect for the beam jitter at the end of the beam line
- But …

Signal and noise levels



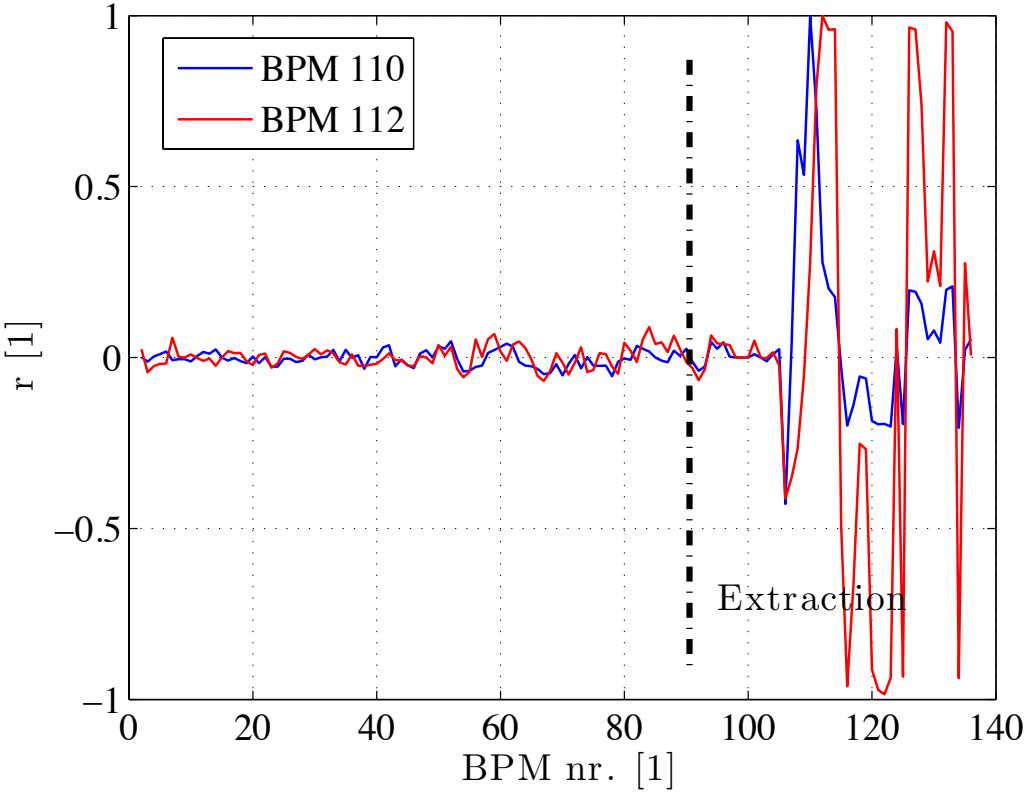
From this plot it is questionable if the data measured by the strip-line BPMs are dominated by noise.

First beam jitter source



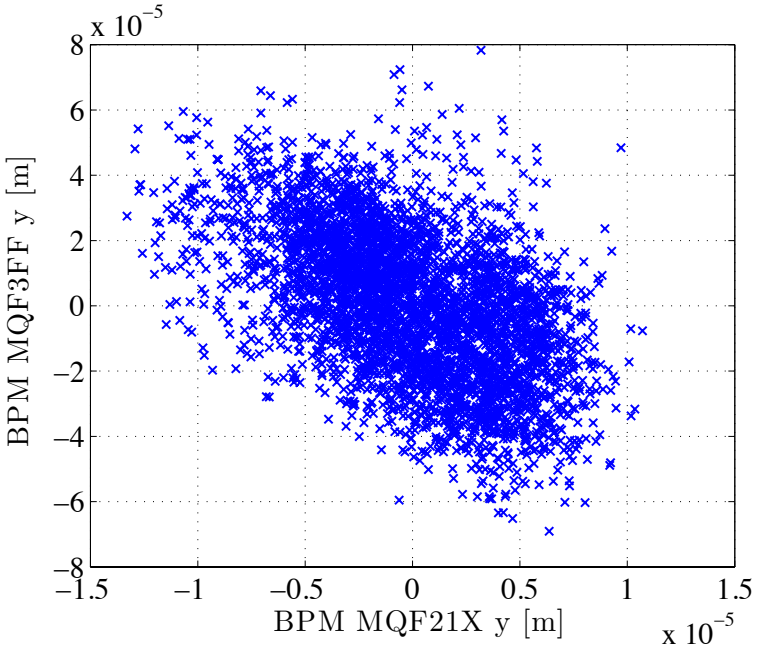
- Located between BPMs 97 and 102 (MQF7X and MQD12X).
- Probably several sources but strongest signal from BPM 102
- Candidates:
  - FONT equipment
  - Correctors: ZH5X, ZH6X, ZV8X
  - QPs: QF11X, QD12X, QD13X, QD14X, QK2X
- But it could also be a noise level artifact.
- Cavity BPMs instead of strip-line BPMs would help

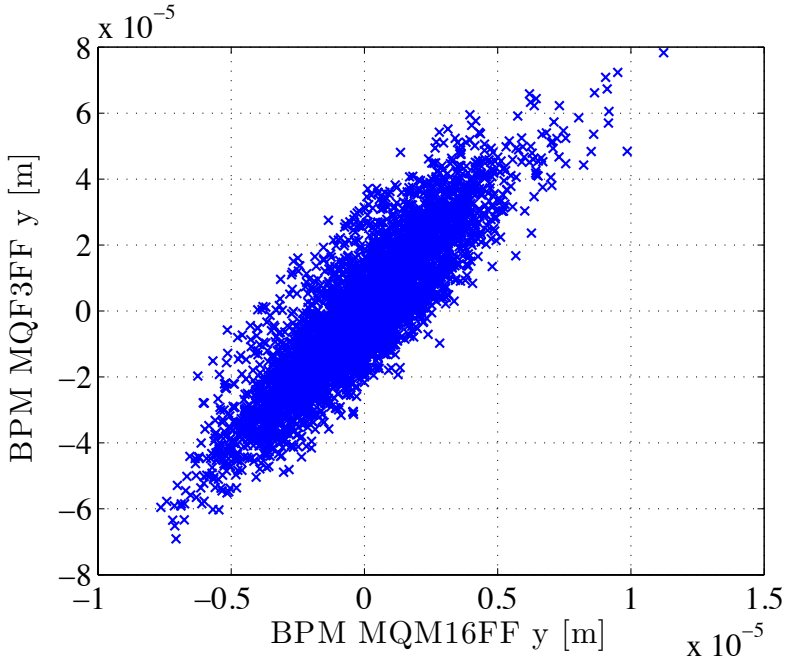
Second beam jitter source 1/2



- Located at BPM 112 (MQM16FF)
- Very strong source
- Candidates:
  - Wire scanner: MW3X, MW4X
  - Profile monitor: OTR3X
  - Correctors: ZH1FF, ZV1FF
  - QP: QM16FF

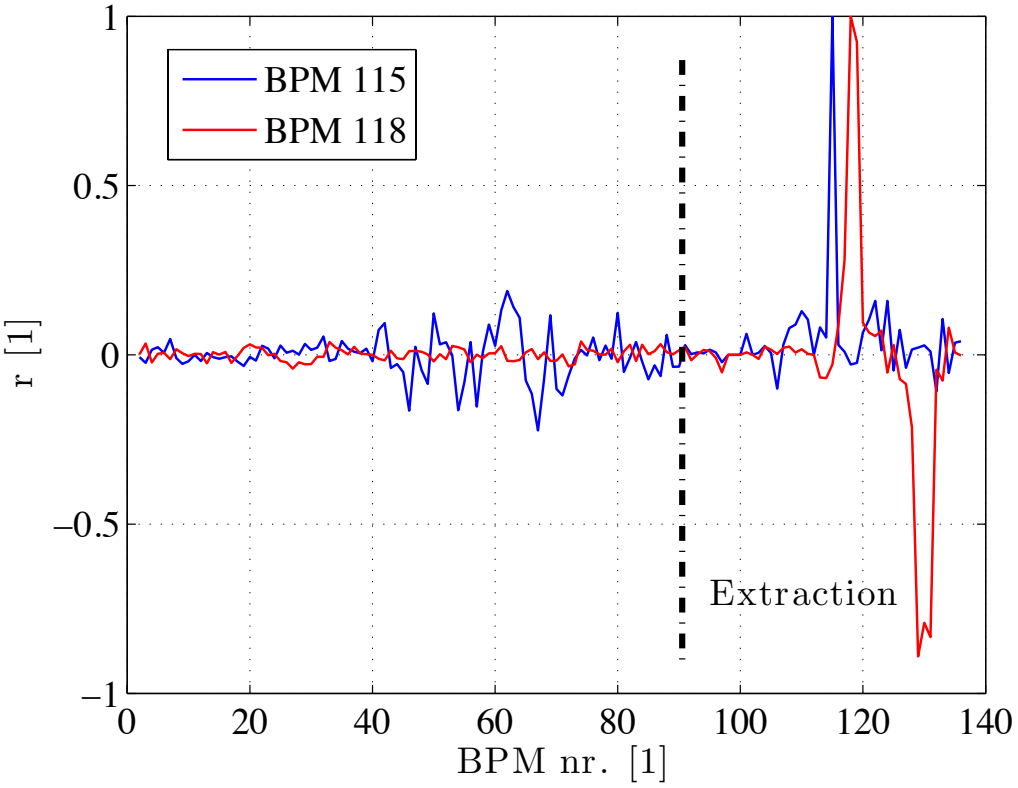
Second beam jitter source 2/2





Measured vertical beam position data of the BPMs 111 (left) and 112 (right) versus BPM 134. A strong change in correlation can be seen.

Third beam jitter source



- Located at BPMs 118 and 119 (MQD10BFF and MQD10AFF)
- Candidates:
  - Ref. cavity: MF3FF
  - Monitor MFB1FF
  - QPs: QD10B, QD10AFF, QM11FF
- Wakefield effect observed?

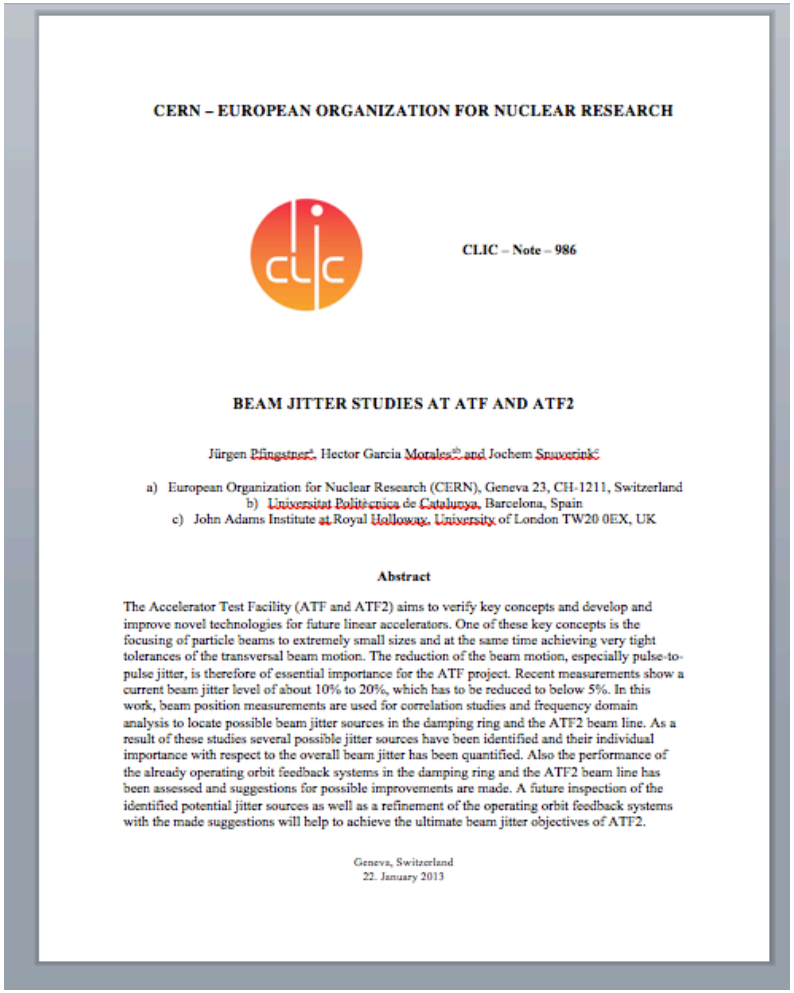
4. Conclusions

- **Beam motion/jitter**
  1. No significant effect of beam motion in the damping ring on the beam motion in the ATF2 beam line has been observed. However, only orbit data have been used instead of single turn data.
  2. Three locations in the ATF2 beam line have been identified in which most likely beam motion/jitter is created
  3. No dispersive patterns have been observed. Therefore, the influence of the beam energy seems to be negligible.
  4. No indications have been found that the extraction kicker creates a significant amount of beam jitter, but this could be due to limited resolution if the strip-line BPMs.
- **Feedback performance**
  1. The damping ring feedback system could act slightly stronger and the actuation itself could be smoother.
  2. The ATF2 beam line feedback works very well, but an adaptive controller with e.g. PSD estimation could improve mode-like changes.

More Details

- Hector's talk
- CLIC note 986

  will also be very soon on-line available
- There will be also an ATF note



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CLIC – Note – 986

BEAM JITTER STUDIES AT ATF AND ATF2

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Abstract

The Accelerator Test Facility (ATF and ATF2) aims to verify key concepts and develop and improve novel technologies for future linear accelerators. One of these key concepts is the focusing of particle beams to extremely small sizes and at the same time achieving very tight tolerances of the transversal beam motion. The reduction of the beam motion, especially pulse-to-pulse jitter, is therefore of essential importance for the ATF project. Recent measurements show a current beam jitter level of about 10% to 20%, which has to be reduced to below 5%. In this work, beam position measurements are used for correlation studies and frequency domain analysis to locate possible beam jitter sources in the damping ring and the ATF2 beam line. As a result of these studies several possible jitter sources have been identified and their individual importance with respect to the overall beam jitter has been quantified. Also the performance of the already operating orbit feedback systems in the damping ring and the ATF2 beam line has been assessed and suggestions for possible improvements are made. A future inspection of the identified potential jitter sources as well as a refinement of the operating orbit feedback systems with the made suggestions will help to achieve the ultimate beam jitter objectives of ATF2.

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Thank you for your attention!