Beam jitter localisation and identification at ATF2

Jürgen Pfingstner

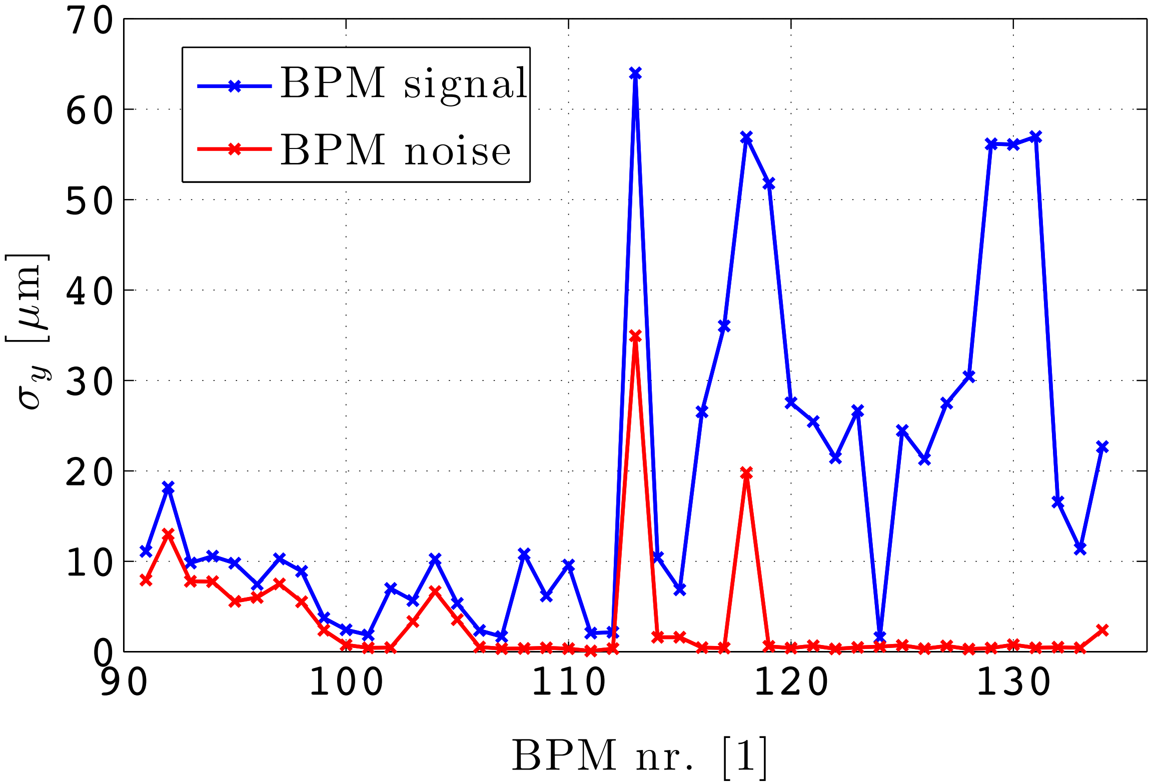
Beam jitter source localisation via correlation studies

Motivation of the studies

- For ATF2 goal two, it is necessary to limit the beam jitter at the IP below 5% of the beam size.
- Currently the beam jitter is between 10% and 40%.

- Measurements with all BPMs in the ATF2 beam line were performed to identify the origin(s) of the current beam jitter.
- The main analysis methods are correlation studies in combination with SVD (DoF plot).

Signal and noise levels



- BPM noise calculation from data as described in Kim et al. PRST Accel. and Beams 15, 42801
- Jitter level fits now much better than before
- BPM 102 is the first BPM with sufficient signal to noise ratio.
- Better BPMs would help

Method 1: Detection of jitter sources with Model Independent Analysis (MIA)

Methods described in paper by J. Irwin et al. PRL 82(8) about Model Independent Analysis (MIA)

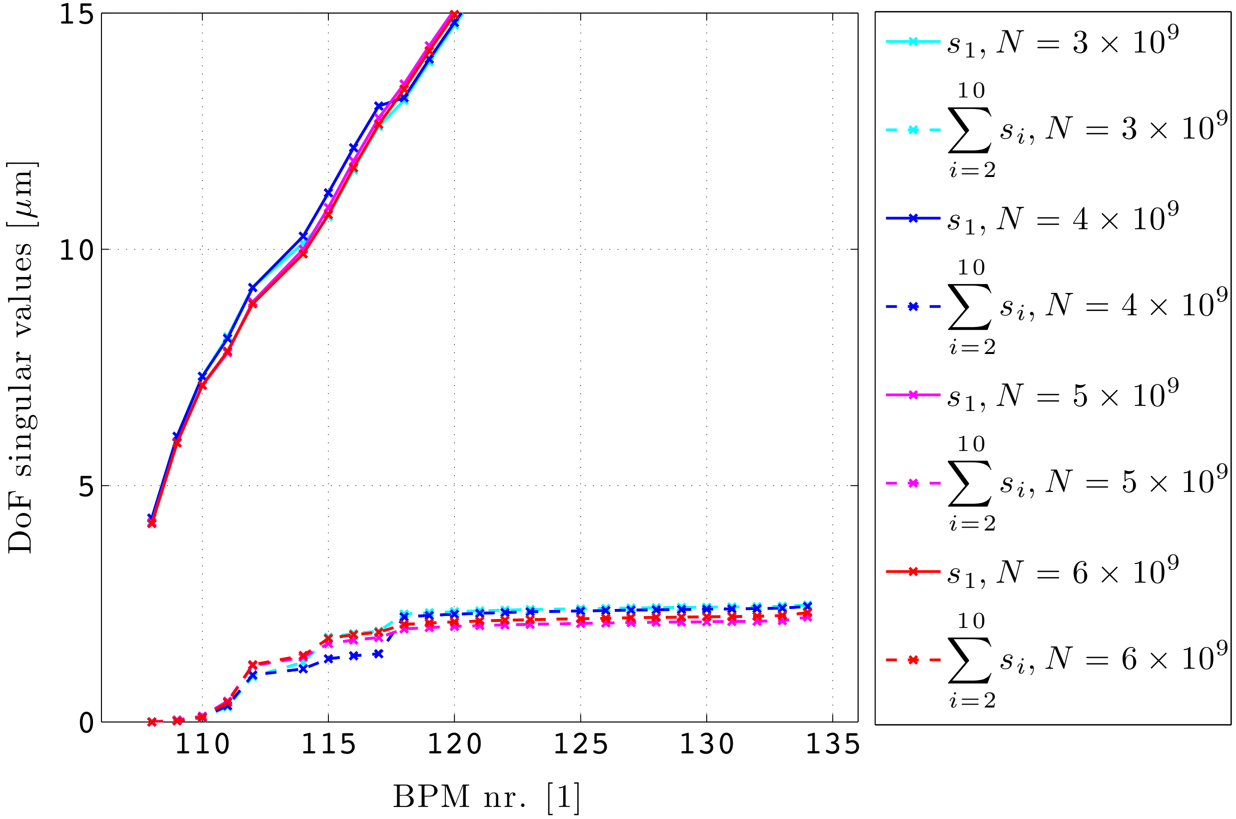
- Degree-of-Freedom plot (DoF-plot)
  - Connection of SVs for SVDs with increasing number of used BPMs.
  - Lines are the connections of largest, second largest, … SVs.
  - Change of slope indicates physical source.

Methods all just try to find location of sources, but are not capable of determining the form of the according oscillation:

> “Note that each of the eigenmodes in Eq. (4) does not correspond uniquely to the physical pattern in Eq. (2).”

- We use instead of the SVs of the full data, the SVs of the correlation matrix, because we believe that is more robust (no dependence on beta function).

DoF-plot of the jitter correlation matrix



- Change of slope indicates physical source.
- Only cavity BPM with good signal to noise ratio are used
- Change around BPM 111 (MQF21X) and 112 (MQM16FF)
- Observation of direction does not give good hinds of oscillation shape.
- No intensity dependence

Method 2: Extraction of beam jitter

- **Step 1:** Starting at the first BPM, and remove the correlation coefficients *r* of this BPM with all downstream BPMs. For details please refer to ATF report ATF-12-01.

$$r = \frac{\sigma_{ij}}{\sigma_i \sigma_j}$$

σ_i … standard deviation σ_{ij} … cross correlation

- **Step 2:** Apply this correlation removal to all BPMs before the detected source.

- **Step 3:** From the remaining motion remove the motion that is correlated to the BPMs at the source and store it.

- **Step 4:** The source motion is now removed an can be analysed.

Identified sources

Before there where 3 sources, but with the resolution of the problem there are only 2 sources left.

- Source 1: Main contribution (19%) of the beam jitter comes from upstream of the sensitive cavity BPMs. There the resolution is not fine enough to make further statements.

- Source 2: Only contributes to about 5% of the beam jitter, but is very well localised.

- Results do not depend on the beam charge. Therefore we assume it has to be a not a wake field and therefore produced by an active device. Passive devices in the region are some wire scanners and OTRs.

Beam jitter source identification:

Experiment 1
June 2013

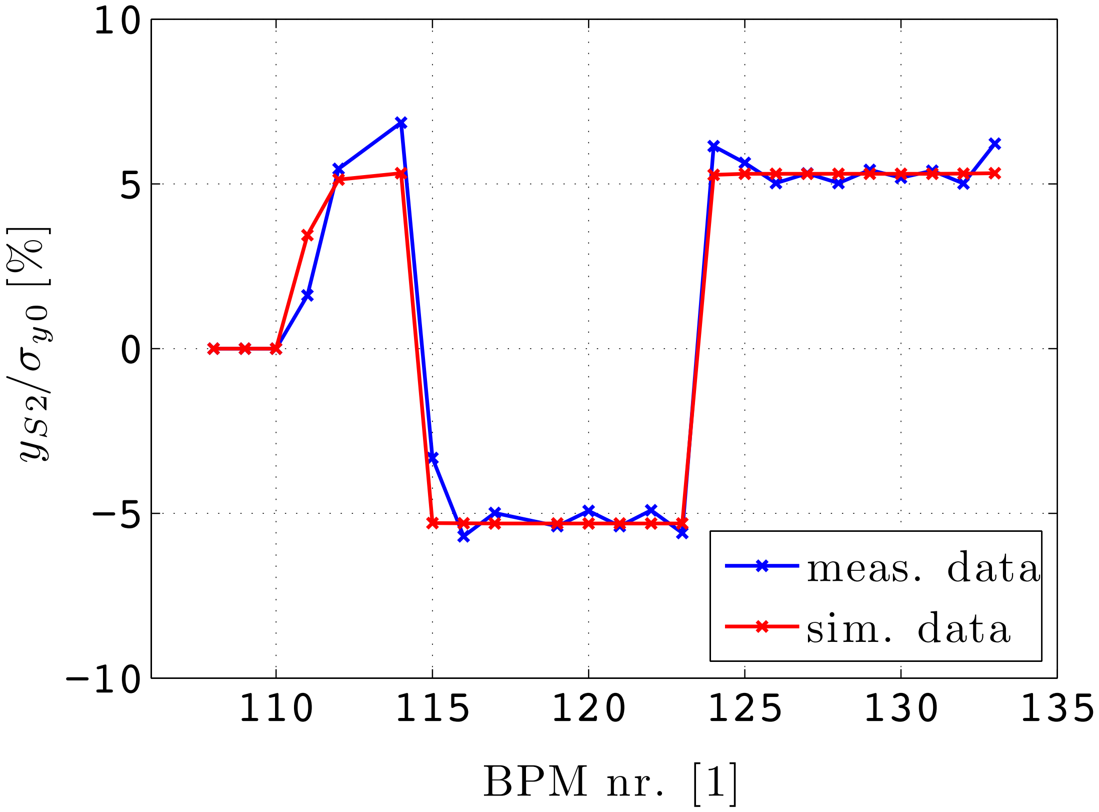
Reasoning about possible sources

- Elements in the area:
  - Active elements: Q20X Q21X, ZV11X, ZH10X
  - Passive elements: Wire scanners, OTRs, ICT,

- The following field would explain the observed kicks:
  - In Q20X: 3 microT, 1kV
  - In Q21X: 10 microT, 3kV

- Since there was not wake field dependence and electric field must be rather high, we concluded that the device responsible for the jitter should be active.

Tracking with LUCRETIA: QD20X



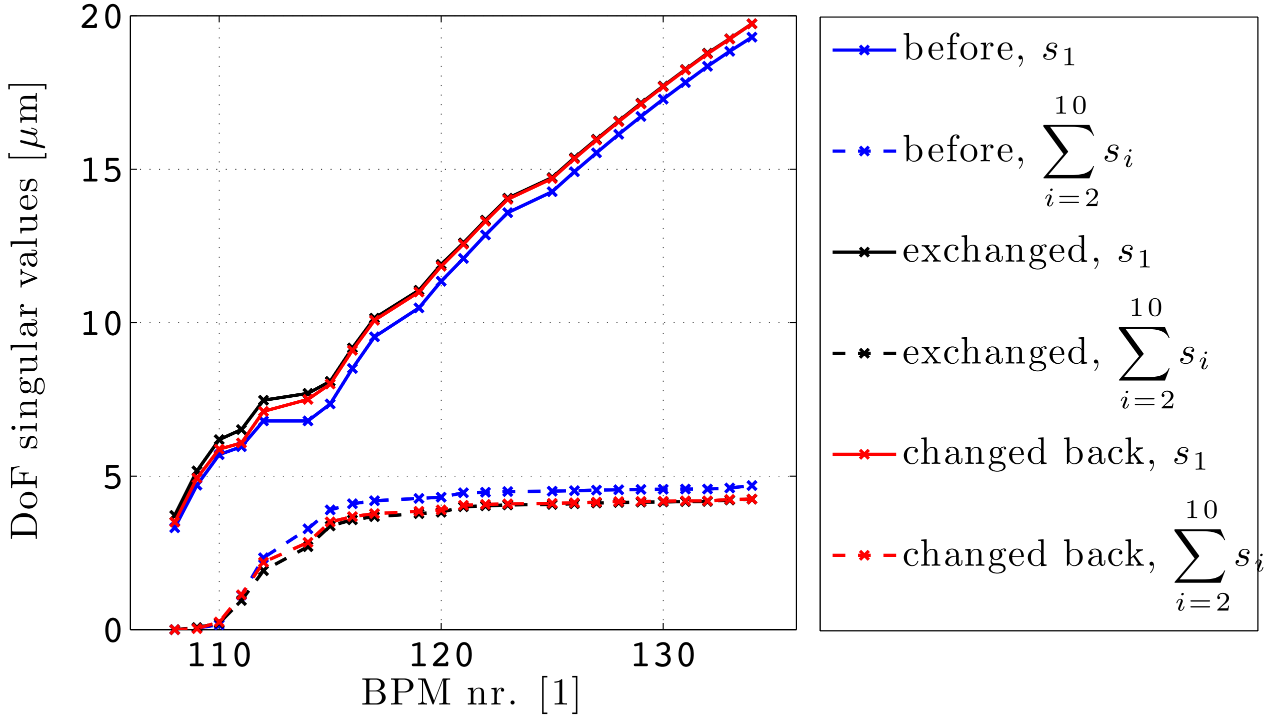
Fits quite well (offset of 0.2 micron)

Proposed experiment

1. Measure the beam jitter (M1)
2. Exchange the power converters of QD20X with another one
3. Measure the beam jitter (M2)
4. Revert the change of the power converter
5. Measure again (M3)

=> If the correlation starting around these quadrupole shows up in M1 and M3 and is gone in M2, the power converter is the reason for the beam jitter.

Results of the experiment

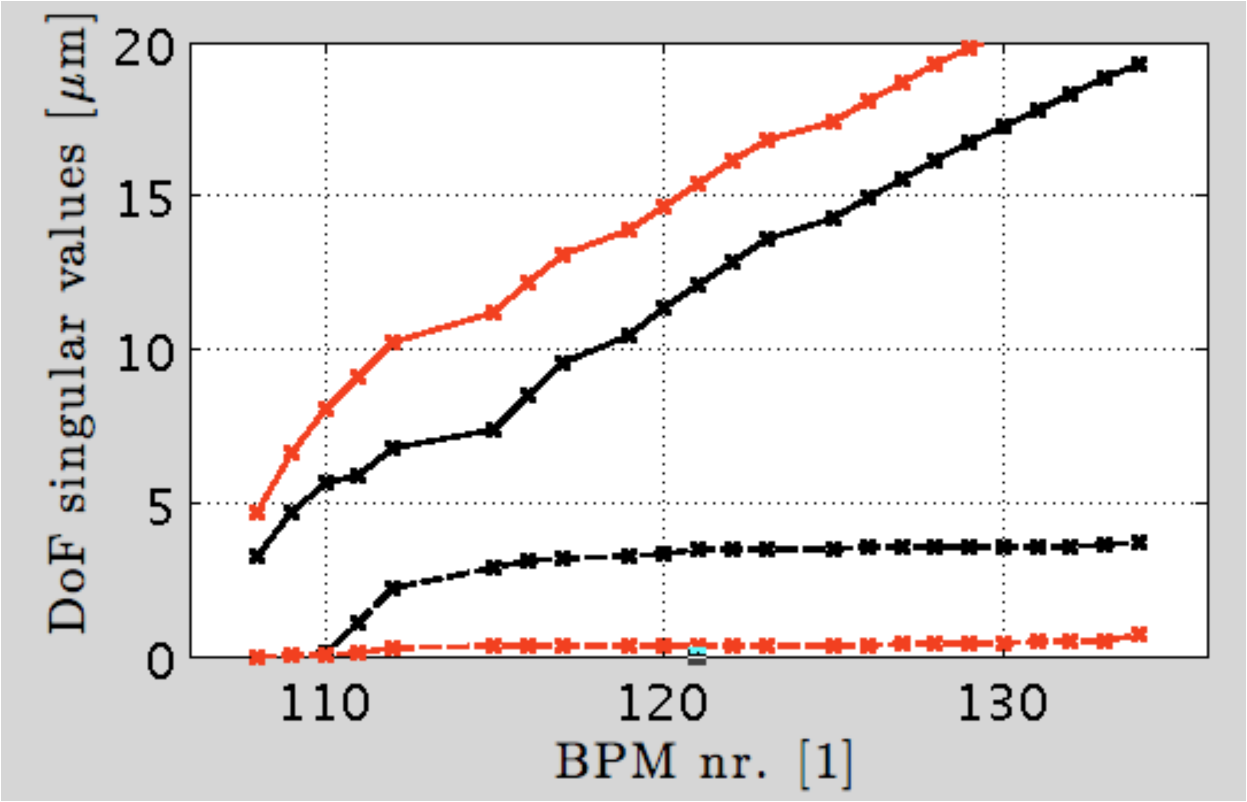


- No change in the amplitude of the jitter has been observed
- Also the shape of the jitter stayed approximately the same.

Beam jitter source identification:

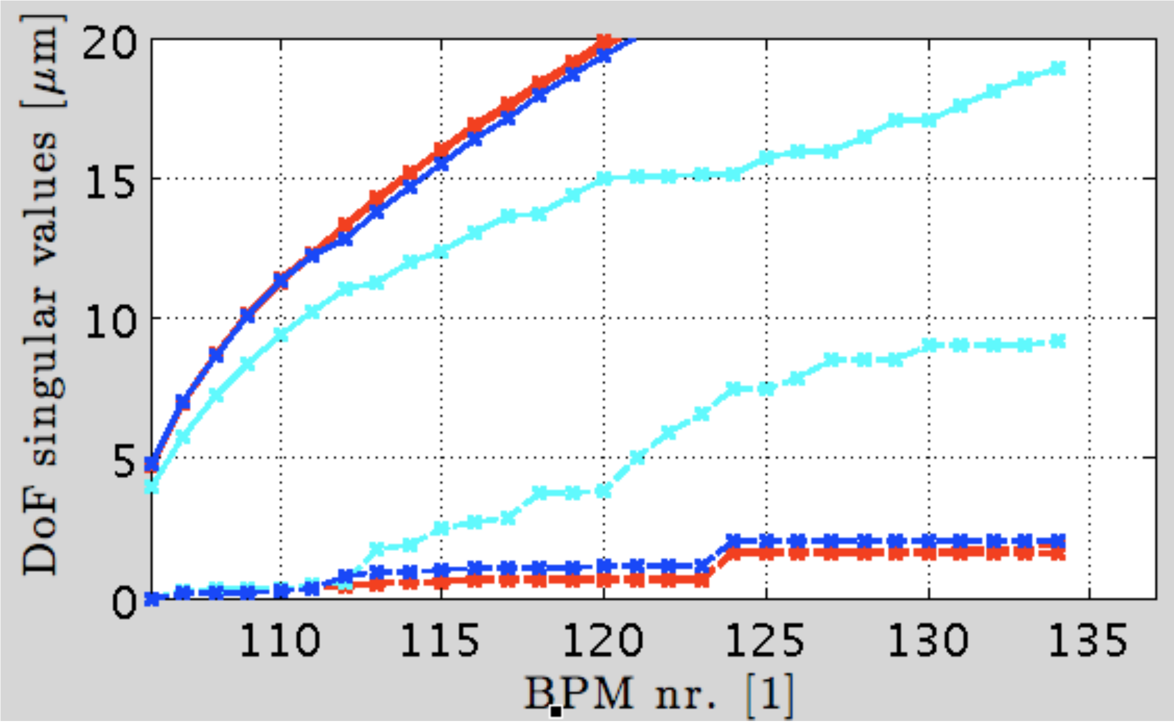
Experiment 2
November 2013

Nominal operation (red)



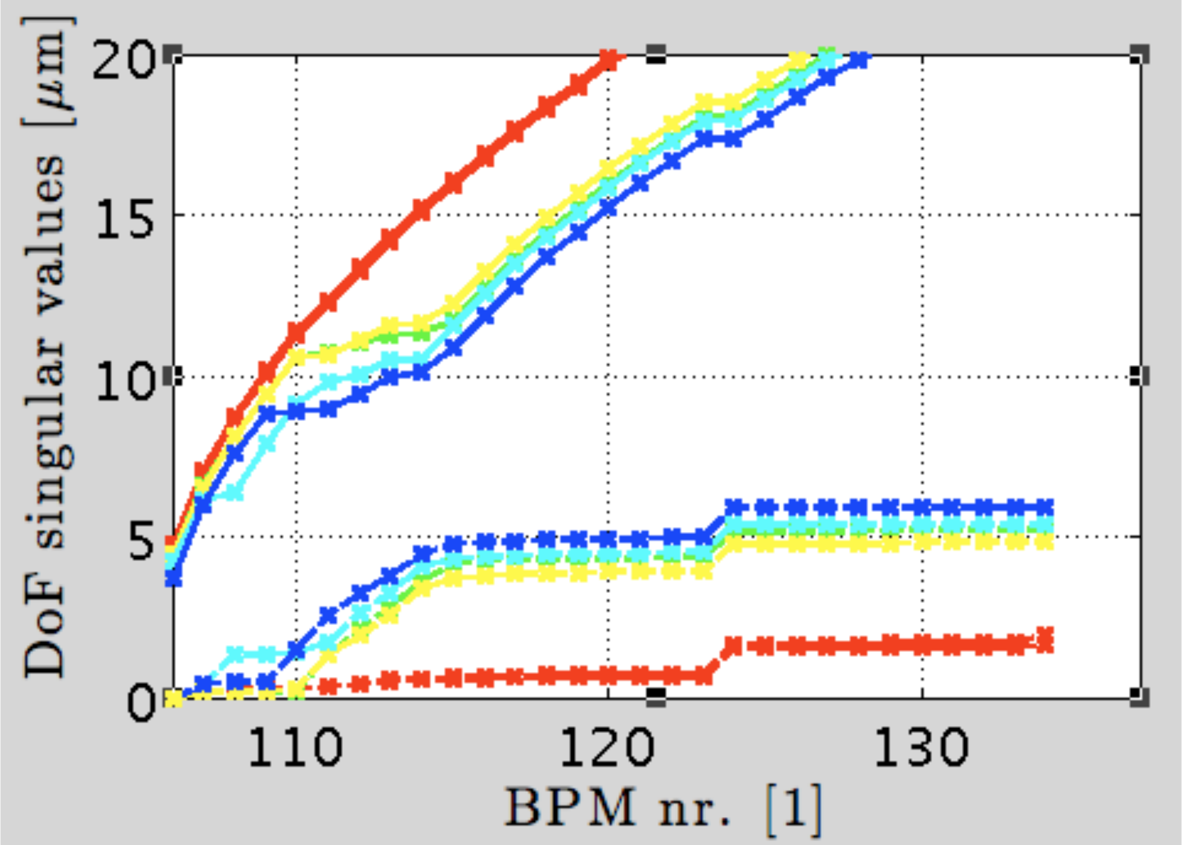
- General jitter level was about 40%(strongly increased)
- Jitter source 2 was gone!

Change position of QM16FF and QM15FF with movers



- Nominal
- Cyan: QM15FF 0.5mm
- Blue QM16FF: 1mm
- Dependence of jitter on the beam orbit far downstream of the creation (offset was very large). No kicker changed

Change of strength of different steering magnets and limiting offset in FF with ZV1FF



- Nominal
- Green: ZV11X
- Yellow: ZV10X
- Cyan: ZV09X
- Blue ZV08X:
- Actuations created similarly large offsets in the area of Q20X Q21X, Q16FF, Q15FF

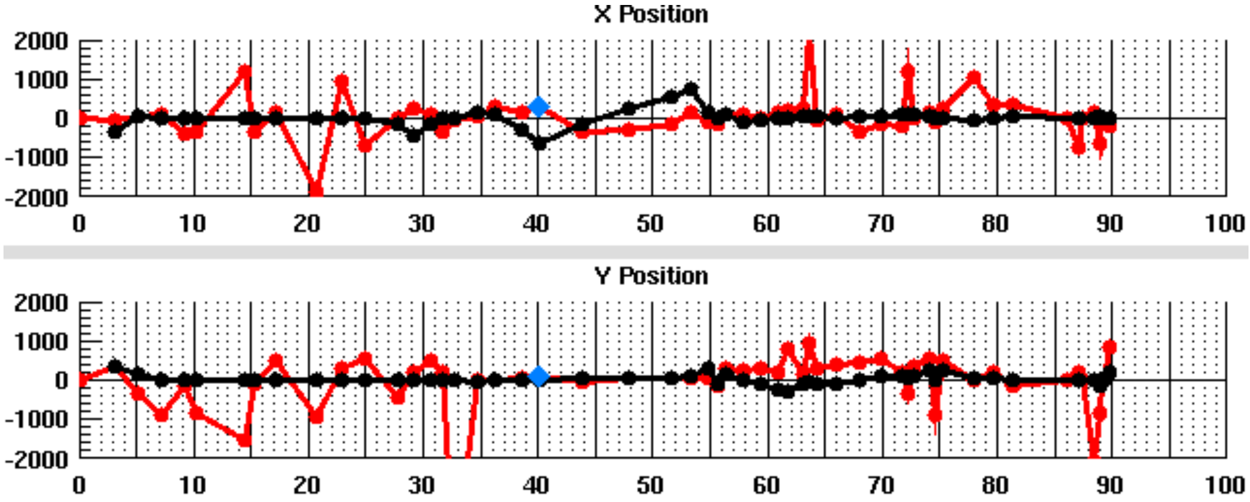
Conclusion for search upstream

- Jitter seems to be dependent on offset in quadrupole magnets more then on steering magnets
- The effect seems to be distributed and not explainable with one single quadrupole
- The earlier observed jitter could be explained with 1mm offset in QD20X and a field jitter of $2x10^{-4}$

Upstream

•The magnets further upstream are more sensitive. For 1mm offset and $2x10^{-4}$ field jitter, each QP would individually create

	QF1X	QD2X	QF3X	QF4X	QD5X	QF6F	QF7X	QD8X	QF9X
QD20X	16%	51%	19%	18%	50%	21%	8%	22%	7%
QF21X	21%	68%	25%	24%	66%	28%	10%	29%	10%



Beam orbit 27th Nov. 2013

Further work

- Reason for jitter cannot be for sure determined, but there are indications that it is connected with the orbit in the QPs.
- From simplified estimates, offsets upstream would have to potential of explaining the observed beam jitter of currently 40%.
- We plan to study the beam jitter dependence to orbit bumps further upstream in the beam line.
- We also plan to collaborate with the FONT team which could improve the resolution of some of the strip-line BPMs to about 300nm and for the first few BPMs to about 1um.
- This resolution should be sufficient to determine if jitter comes from upstream the first BPM (kicker, damping ring)

Thank you for your attention!