Beam jitter studies at ATF and ATF2

Jürgen Pfingstner, Hector Garcia Morales

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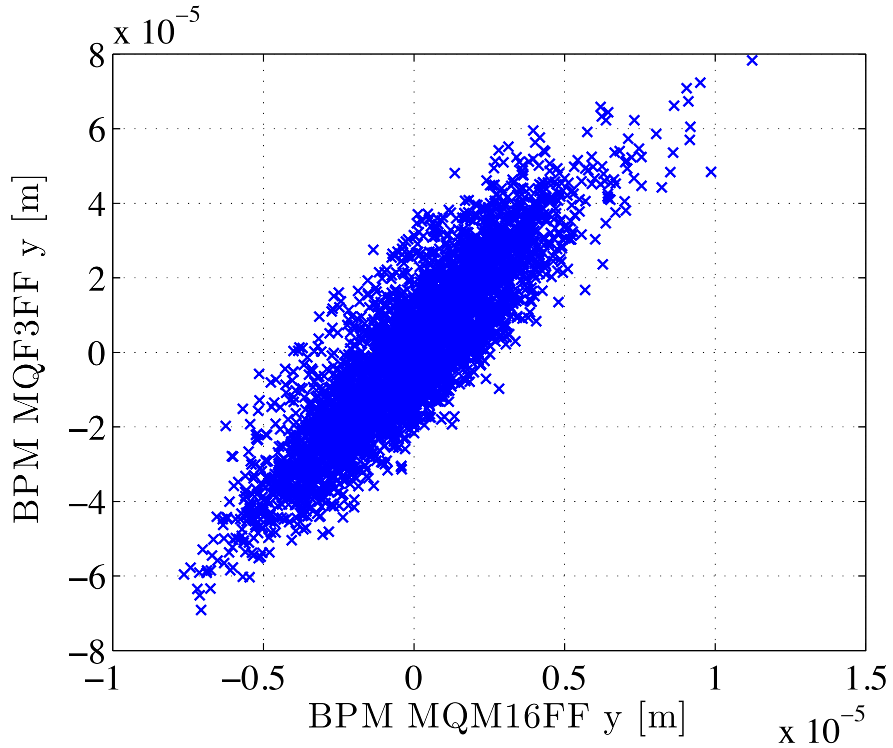

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Many thanks to Y. I. Kim, J. Snuverink, G. White and M. Woodley for supporting us with all necessary information at ATF and for the many very helpful discussions!

1. Search for beam jitter sources

Motivation of the measurement

- 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 20%.

- 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 as shown on the next slides.

Method of finding beam jitter sources

- **Step 1:** Starting at BPM *N*, try to find correlation pattern by calculating the correlation coefficient *r* for all BPMs.

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

σ_i … standard deviation σ_{ij} … cross correlation

- **Step 2a:** If there is no significant correlation -> $N=N+1$.

- **Step 2b:** If there is significant correlation -> source has to be expected close to BPM *N.*

- **Step 3:** Remove motion that corresponds to found jitter source (see next slide).

- **Step 4:** Go to step 1 with $N=N+1$, or stop if $N=N_{max}$.

Removal of correlated beam motion

- To not disturb the search for jitter sources by sources already identified, the according beam jitter is removed.
- **Idea:** De-correlate all other BPMs *j* from the BPM *i* corresponding to the source, by finding a new motion

$$\hat{y}^{(j)} = y^{(j)} + k_j y^{(i)}$$

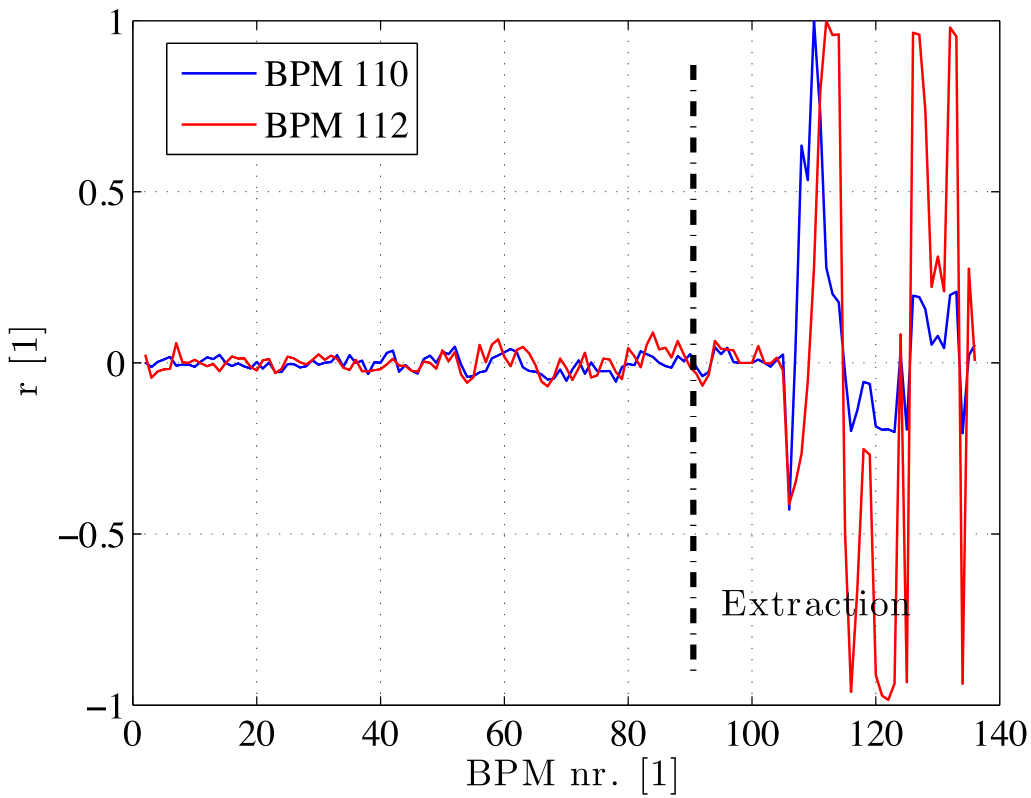
such that the covariance

$$\sigma\left(\hat{y}^{(j)}, y^{(i)}\right) = 0$$

- Using the definition of the covariance and solving the last equation for k_j gives

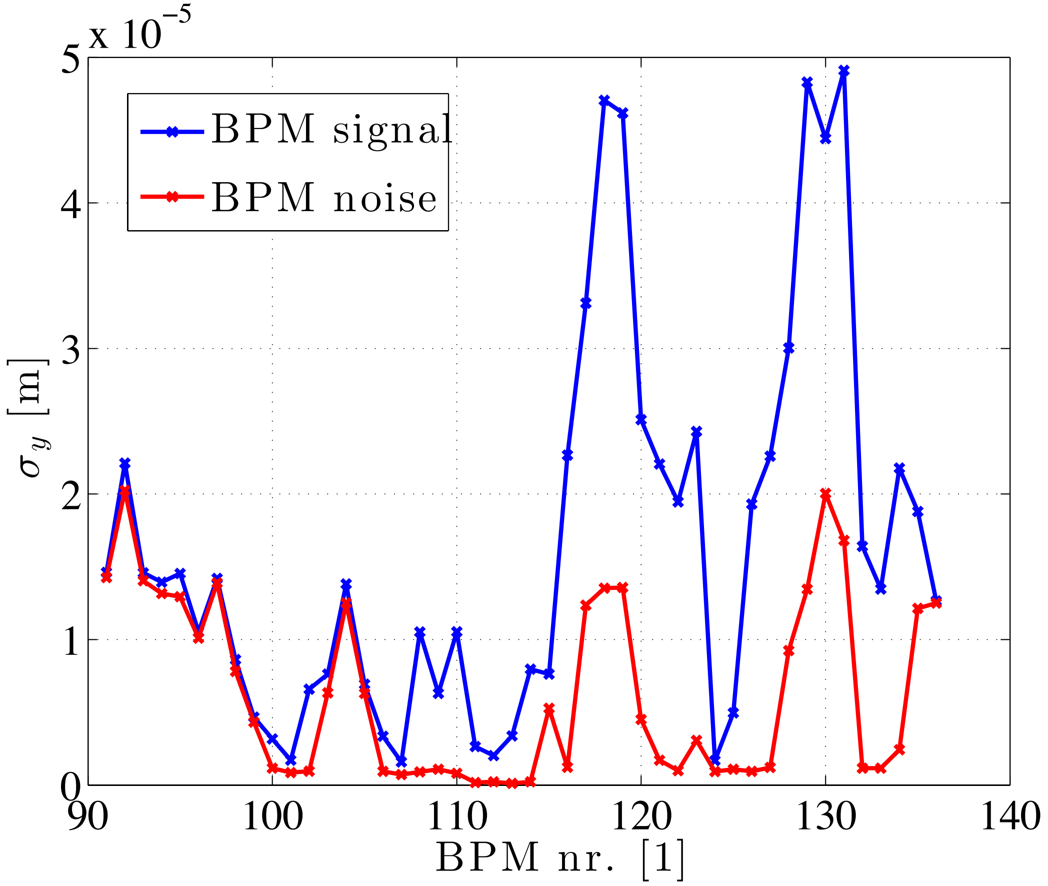
$$k_j = -r_{ij}\frac{\sigma_i}{\sigma_j}$$

Example for source localisation (source 2)



- Only a weak correlation pattern can be observe for BPM 110
- Strong correlation pattern observed for BPM 112

Signal and noise levels



- BPM noise calculation from data as described in Kim et al. PRST Accel. and Beams 15, 42801
- BPM 102 is the first BPM with sufficient signal to noise ratio.
- Location of the first source can only be determined before BPM 102.
- Better BPMs would help

Three identified sources

- Source 1:
  - Located between BPMs 97 and 102 (MQF7X and MQD12X)
  - Position can only be determined before BPM 102, since signal to noise ration is too bad before.
  - Cavity BPMs instead of strip-line BPMs would help
- Source 2:
  - Located at BPM 112 (MQM16FF)
  - Very strong source
  - Candidates: Wire scanner: MW3X, MW4X, Profile monitor: OTR3X, Correctors: ZH1FF, ZV1FF, QP: QM16FF
- Source 3:
  - Located at BPMs 118 and 119 (MQD10BFF and MQD10AFF)
  - Candidates: Ref. cavity: MF3FF, Monitor MFB1FF QPs: QD10B, QD10AFF, QM11FF

2. Additional data analysis with MIA

Model Independent Analysis (MIA)

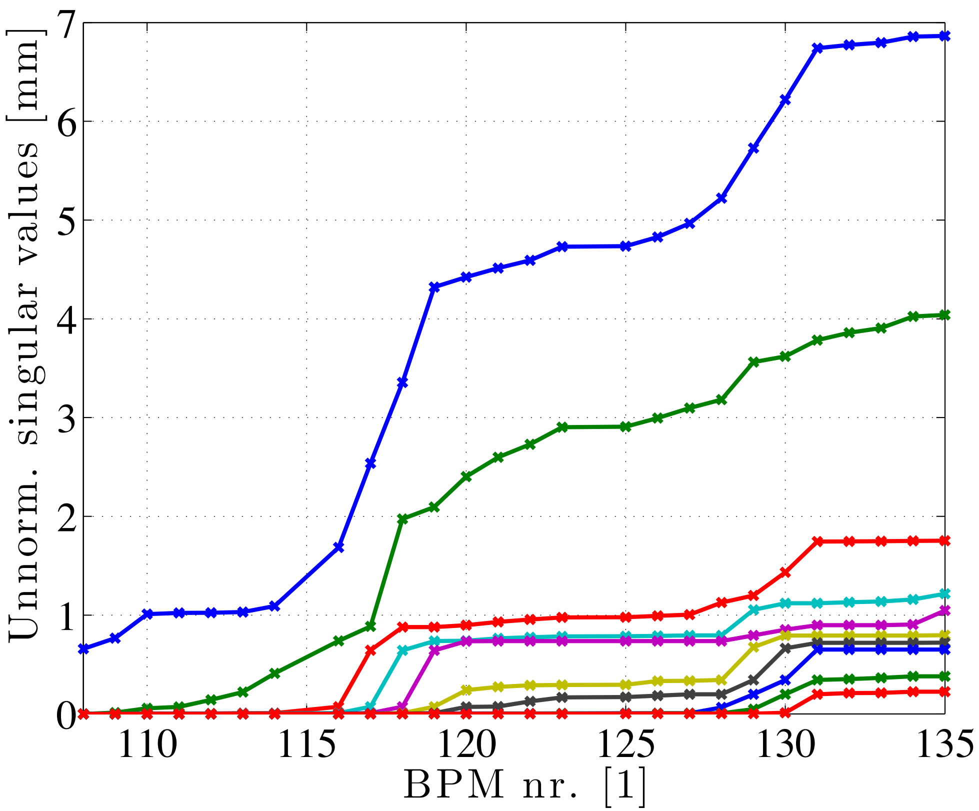
Try to use methods described in paper by J. Irwin et al. PRL 82(8) about Model Independent Analysis (MIA) (thanks Young-Im)

1. Data cleaning via SVD decomposition:
   - Remove noisy BPMs
   - Remove BPM noise floor
2. 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:

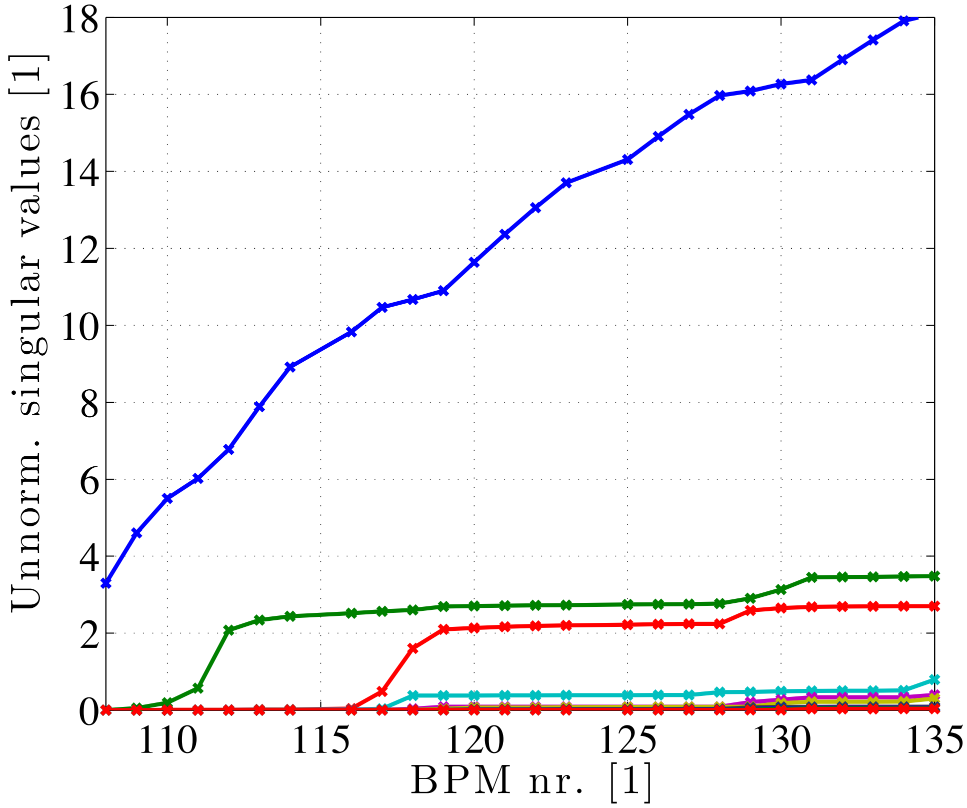
> “Note that each of the eigenmodes in Eq. (4) does not correspond uniquely to the physical pattern in Eq. (2).”

DoF-plot for beam jitter data



- Change of slope indicates physical source.
- Only cavity BPM with good signal to noise ratio are used
- Change around BPM 118 (MQD10BFF), but also around 130 (MSD4FF)
- No clear localisation possible
- Observation of direction does not give good hinds of oscillation shape.

DoF-plot of the jitter correlation matrix



- Much clearer localisation of sources is possible: BPM 112 (MQM16FF) and BPM 118 (MQD10BFF)
- Also a small change in slope around BPM 130 (MSD4FF)
- Result is the same as for manual method
- Tool for faster source localisation in the future!

3. Tracking studies

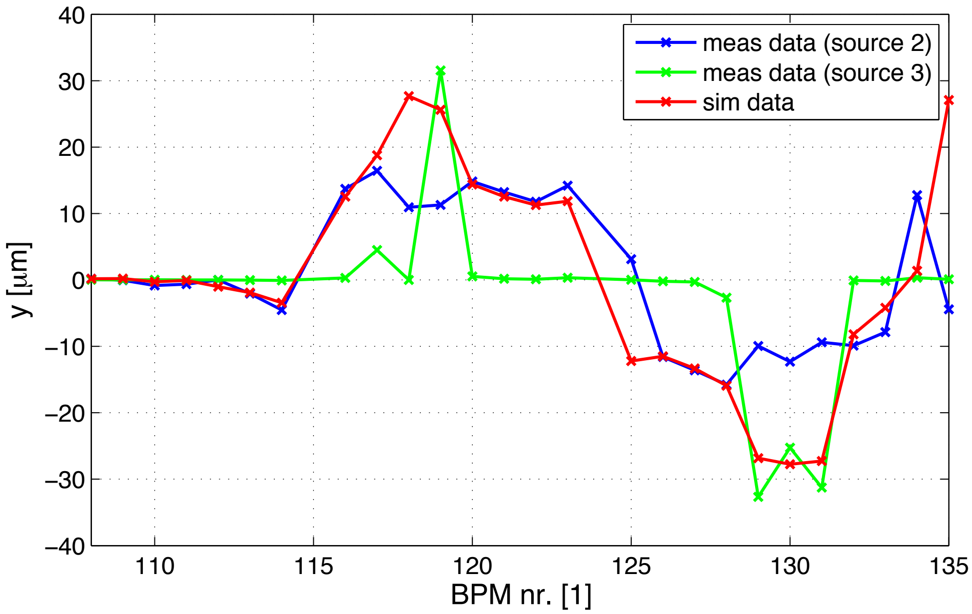
Kick tracking with Lucretia

•Best "guess" for shape of beam jitter along the beam line is the motion removed to de-correlate from a certain source.

•Try to localise sources better, by introducing dipole kicks along the beam line and compare shape of oscillations with removed correlated jitter motion.

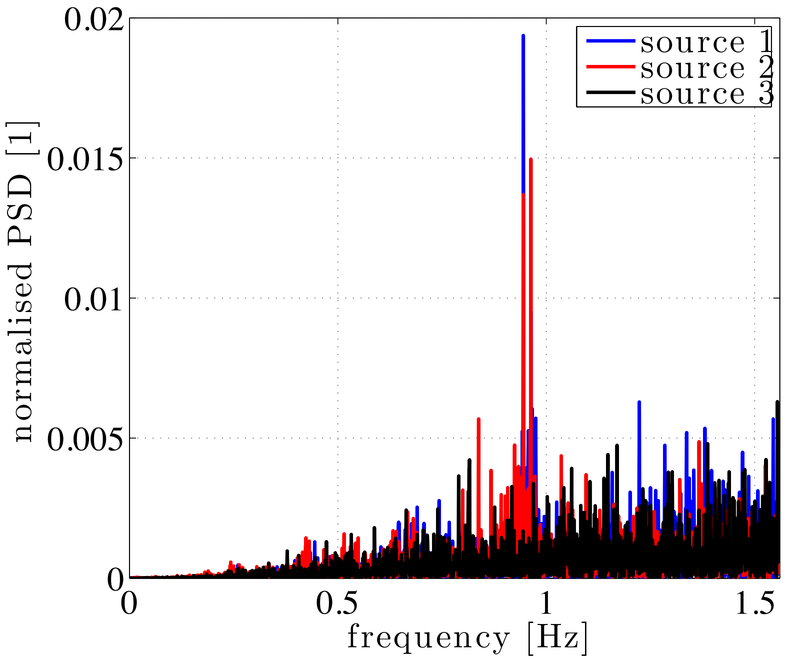
- Using lattice version 5.1: 10x1 optics with non-linearities and new QF1 matching
- Track beam with perfect beam line to a certain position
- Apply dipole kick by adding const. $\Delta y'$ to beam.
- Use same beam to track to the end of the beam line.
- Compare BPM readings in the region of the cavity BPMs with good signal to noise ratio.

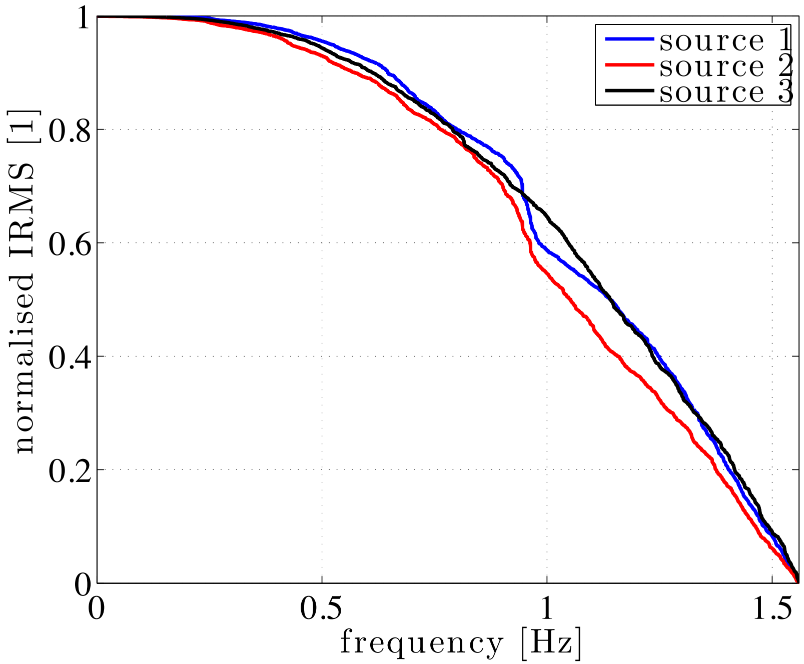
Matching tracking results with removed correlated beam jitter motion



- Different kicks between BPM 111 and 112 fit the combination of both source 2 and source 3 reasonable well.
- $\Delta y'$ = -4e-7 (Lucretia units)
- Devices in this area: MW3X, OTR3X, TILTM, IPBPM, ATIPBPM, MW4X
- Separately sources were not fitted well

PSD and IRMS of removed correlated beam jitter motion





- Source 1 and source 2 have obvious components at 0.945Hz and 0.963Hz
- These components do not contribute significantly to the overall jitter.
- Source 3 has no such components.

4. Conclusions

1. Three beam jitter sources have been identified with correlation studies.
2. Source 1 can be not clearly localised due to limitations of the BPM system.
3. Complementary studies with MIA have been performed and results fit for correlation data.
4. Tracking simulations with Lucretia have been performed
   - The removed jitter motion of the individual sources could not be fitted.
   - But the combination of both motions can be fitted reasonable well.
   - Some beam diagnostics devices are located in this region.
   - No clear signature has been found however.
5. The removed jitter motion of source 1 and 2 show significant frequency peaks in PSD (0.945Hz and 0.963Hz).

Thank you for your attention!