Optics corrections in the ATF damping ring

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Introduction and method

Motivation

- Errors due to beta functions due the field errors result in beta beating.
- This deviation from the perfect beta function can lead to:
    - Problems at injection and extraction (matching and losses).
    - Blow up of the extracted emittance.

- The vertical emittance in a damping ring is mainly determined by the coupling between horizontal and vertical plane.
- Coupling correction is important to lower the vertical emittance.

> Therefore: Beta function and coupling correction can lower especially the vertical emittance!

- In this work we try to correct the beta function first.

Measurement of tune and beta functions with NAF
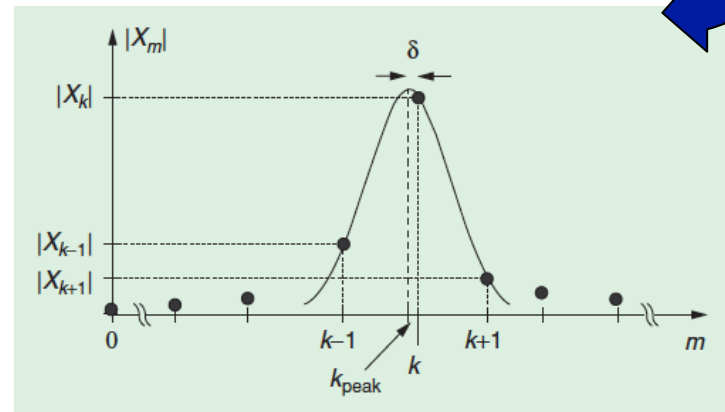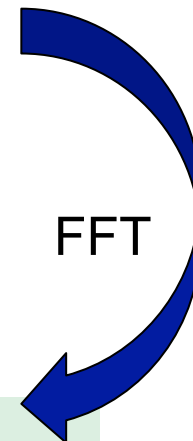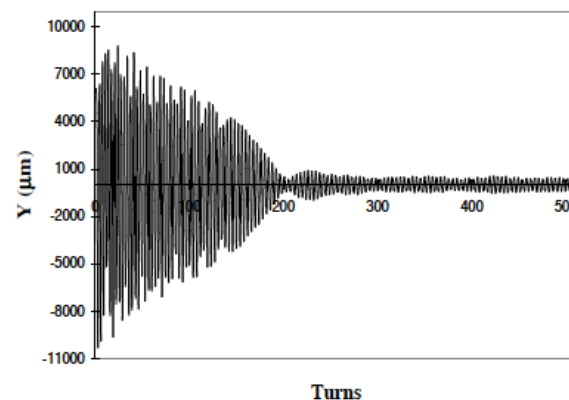
Turn-by-turn measurement

1. Tune measurement

   - FFT of injection oscillations

   - Optimised FFT used (SUSSIX/ NAF)

   - Info about form of spectrum (spikes) is included in estimation

2. Beta function

   - Relative beta functions can be inferred from relative amplitude of BPM data.

   - Absolute scale, by normalising size to model beta functions

Principle: Interpolated FFT


FFT

Beta function correction

1. Trim correctors on quadrupoles are used to change optics.

2. Change of beta and tune for unit chance is recorded (R measurement).

3. Calculate corrector changes Δc so that target beta function is created. Therefor solve:

$$
\begin{bmatrix}
Q_x - \overline{Q_x} \\
Q_y - \overline{Q_y} \\
\beta_x - \overline{\beta_x} \\
\beta_y - \overline{\beta_y} \\
0
\end{bmatrix}
=
\begin{bmatrix}
R_{Qx} \\
R_{Qy} \\
R_{\beta x} \\
R_{\beta y} \\
I
\end{bmatrix}
\Delta c
$$

4. Additionally weights are used for different compoents (degrees of freedom)

Results in June

Beta function measurement at XSR location
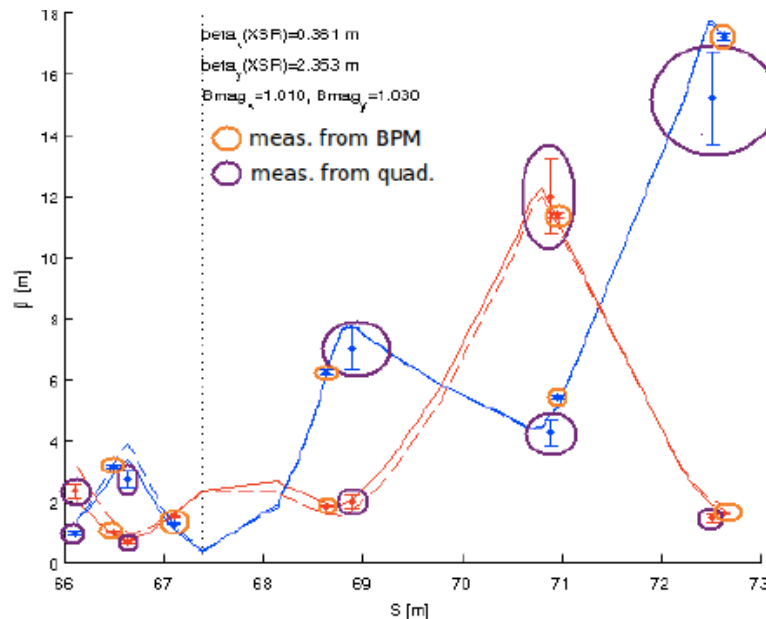
- Calculate the emittance in the ring from beta function and beam size measurement at XSR monitor location

- Extracted emittance has not been measured

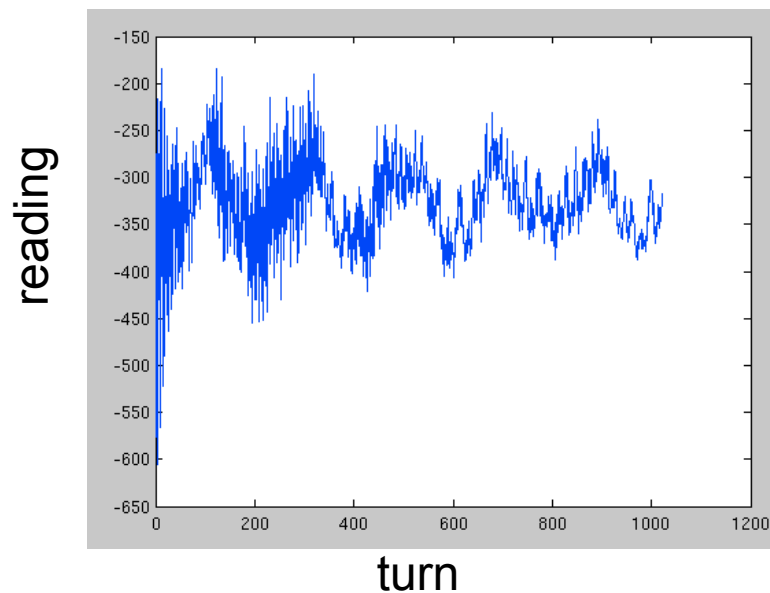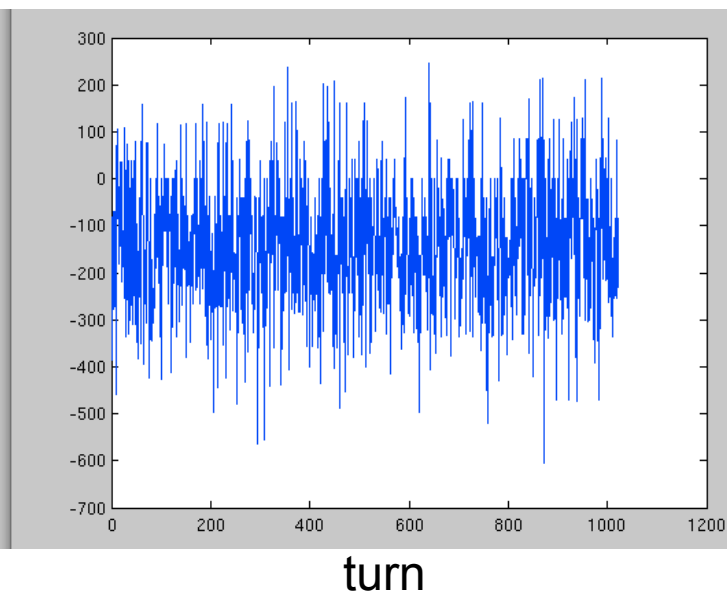|	before corr	after corr 1	after corr 2
σ_y(XSR) [μm]	10	5.3	3.9
β_y(XSR) [m]	2.73	1.85	2.34
ϵ_y [pm]	37	15	6.5
$charge 10^9$ [e^-]	6	6	6

Results in November

Problem with certain BPMs

- Due to the varying measurement results in certain BPMs, the raw data were plotted

- There was a problem in BPMs 13, 22, 41, 42, 47, 77, 87, 88

BPM 5   BPM 77

Improvements of Software robustness

Problems with response matrix measurement:

- Try to measure the response matrix of the beta function and tune due to change of trim coils of all 99 quadrupoles
- Beam was lost several times, which caused warnings/errors in measurement program
- After 2 1/2 hours (of 3 hours) measurement program crashed
- Correction could not be applied

Improvements in Software (error handling):

- In case too many BPMs are noisy in one run (e.g. beam loss): user is asked if measurement should be repeated
- If the specified current values for the trim coils are out of bound they are automatically limited.
- After each corrector, results are stored so that the measurement can be resumed at any time.
- Still want to implement that if too much current is lost in the DR during the measurement the step size is automatically reduced.

Correction of the beta functions

- With improvements R measurement worked.

- Now all correctors and BPMs that have been detected to have problems at one measurement are not used for the correction

- Correction:
  – During the first correction attempt, the beam was lost.
  – The main cause was that the tune was strongly changed by the corrector changes
  – After putting a higher weight on the tune, the beam current in the DR stayed mainly the same and beta functions were corrected (see next slide)
  – Emittance was not reduced and stayed around 13pm
  – The correction was not very stable and dependent on the actual BPM measurement

Beta function before correction
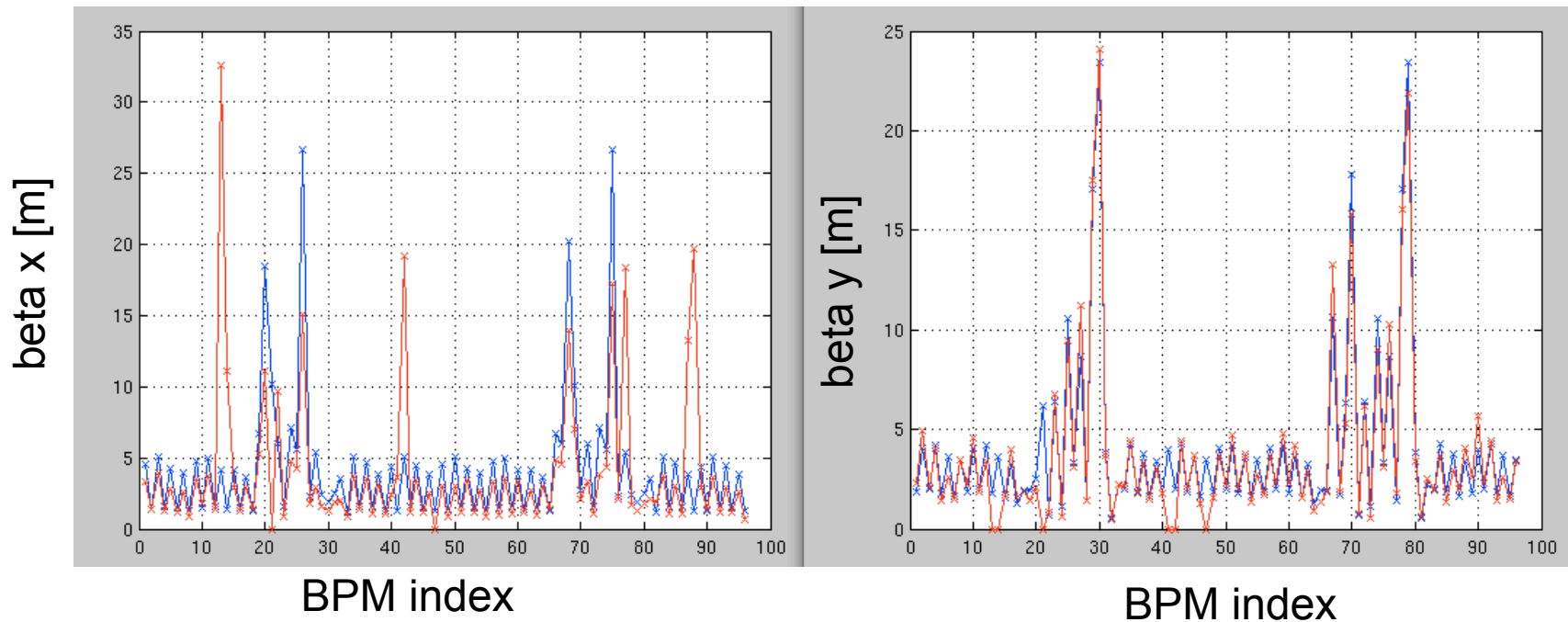
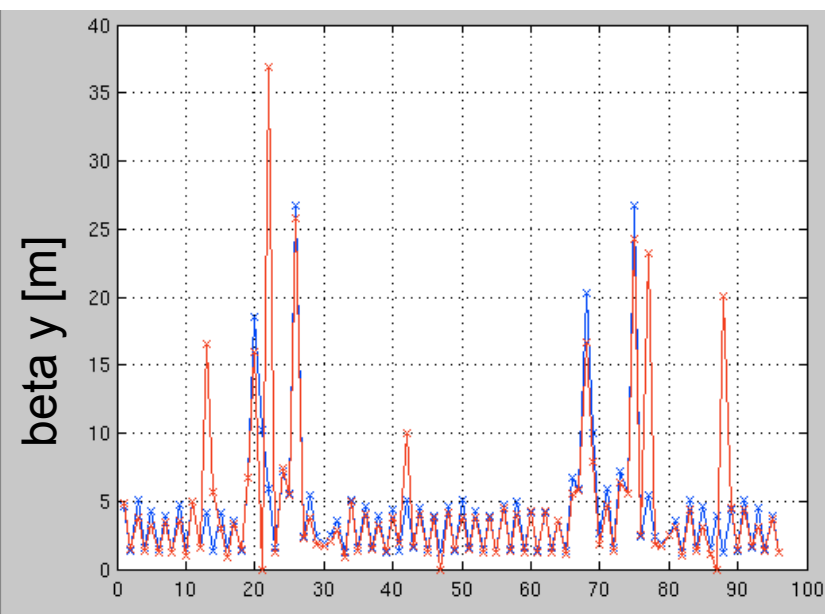- Measured optics functions (red) fitted quite well with the model (blue)
- Emittance was 13.3 pm

Beta function after correction
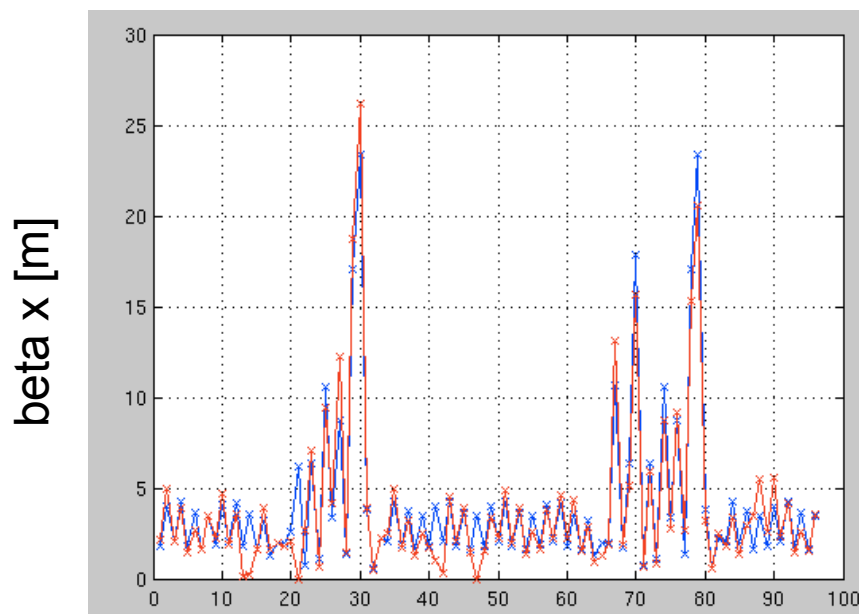
BPM index   BPM index

- Good correction in x, but not much change in y
- Emittance was 12.8 pm

Conclusions

- Got started with the use of the software

- Some changes to make the scripts more robust have been implemented

- The response matrix was measured

- The corrections corrected the beta function, but could not lower the emittance below 13pm

Future work

- Still some open degrees of freedom in the scaling (x vs. y)

- Some ideas how the correction could be made more robust (matrix conditioning)

- Include coupling correction

- Graphical interface

- Beta function measurement function is already regularly used by operators

Thank you for your attention!