Turn-by-turn measurement at the ATF damping ring

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Headlines

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Previous Status

Motivation

- Fast measurement of Twiss functions in DR.
- Correction of Beta beating in the DR.
- Reduce the emittance.

Procedure

- Measure β and tunes from the amplitude of the betatron oscillation at each BPM.
- Measure (or compute from model) their variation with quadrupoles strengths.
- Compute and apply the correction (least square minimization with weight and constraints).

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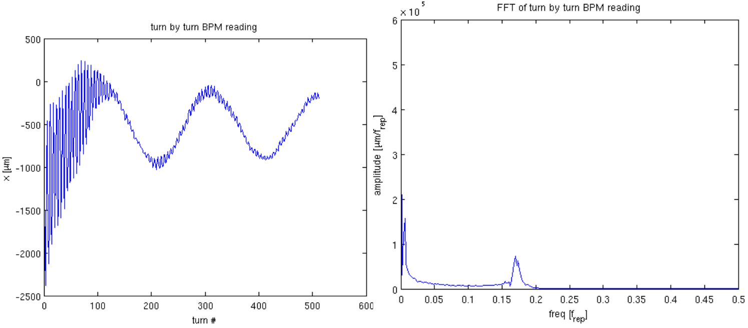
Principle

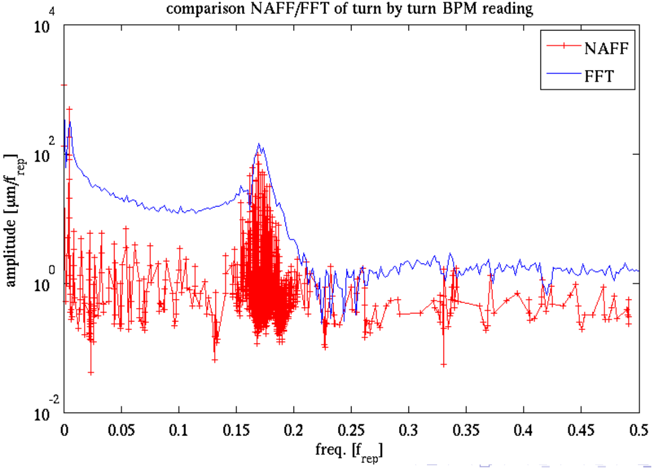


- Peak at 0 is offset read by BPM.
- Peak at 5×10^{-3} is synchrotron tune (amplitude prop. to $D \times \frac{\Delta E}{E}$).
- Other large peak is tune (amplitude prop. to $\sqrt{\beta}$ and offset of the beam at injection).

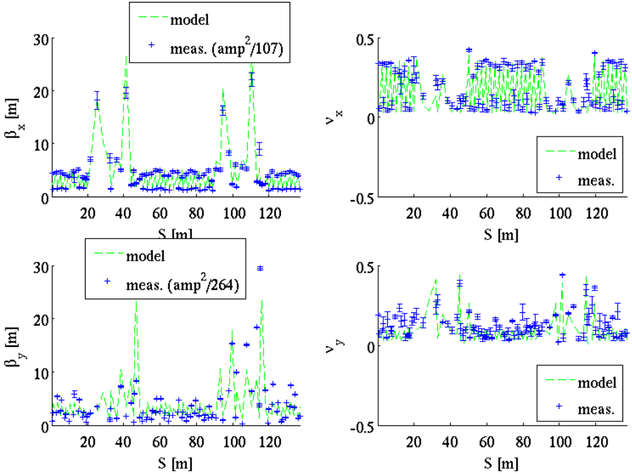
SUSSIX/NAFF

Comparison with FFT

SUSSIX/NAFF compute accurately the amplitude, phase and frequency of the largest peaks. They are much more precise than traditional FFT.



Initial Twiss



- measure amplitude and phase of the spectral line at the tunes frequency.
- β is prop. to the square of the amplitude.
- ν is the difference of the phase between each BPMs.

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Measurement the response matrices

Motivation

- Correction based on model failed.
- Fast measurement of beta functions available.
- Try to correct using measured response matrix.

Method

- for each of the 99 quadrupoles get $Q_x, Q_y, \beta_x, \beta_y, \phi_x, \phi_y$ function of I.
- linear fit from measurements at 3 intensities $I_0 + (-3A, 0A, +3A)$.
- for each intensity, 10 measurements are done.

About 3000 Twiss function measurements ! (3h)

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Correction principle

with:

- R the transfer matrix
- ΔI a vector containing the variation of intensity supplied at the quadrupole
- C a vector containing the variation of $Q_x, Q_y, \beta_x, \beta_y, \nu_x, \nu_y$.

we have:

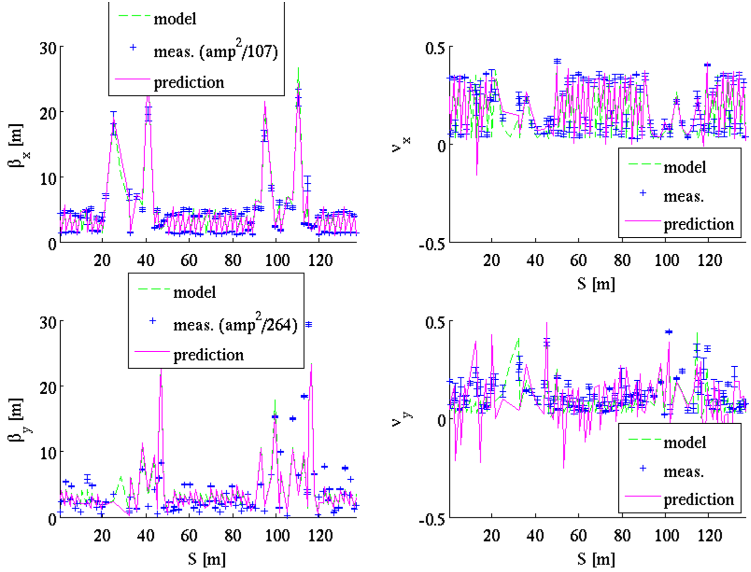
$$C = R \times \Delta I$$

correction is computed as :

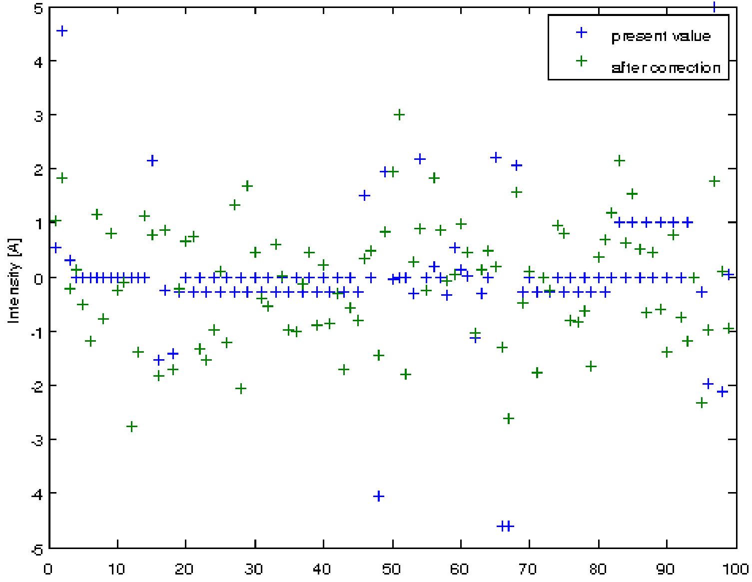
$$\Delta I_{corr} = -\begin{pmatrix} \mathrm{R} \\ \mathrm{Id} \end{pmatrix}^{-1} \times \begin{pmatrix} \mathrm{C} \\ I_0 \end{pmatrix}$$

Weights can be used to give more importance to Q, β, ν or constraint the intensities of the quadrupoles.

Initial Twiss

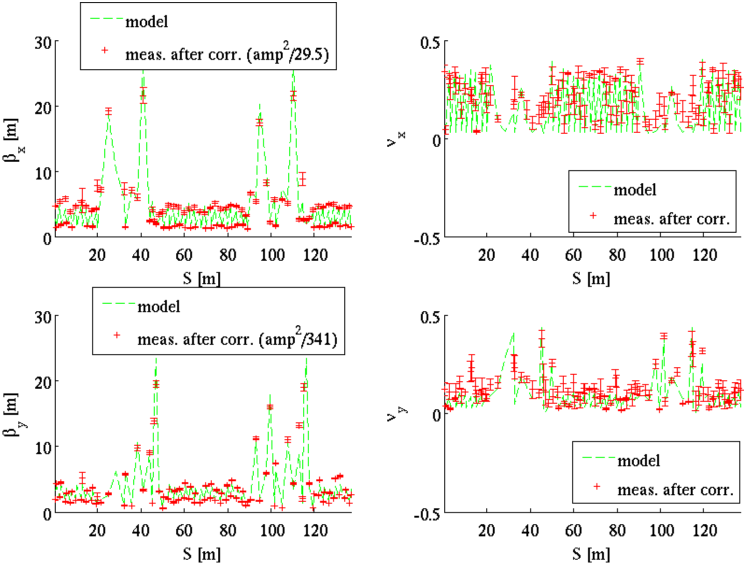


Correction



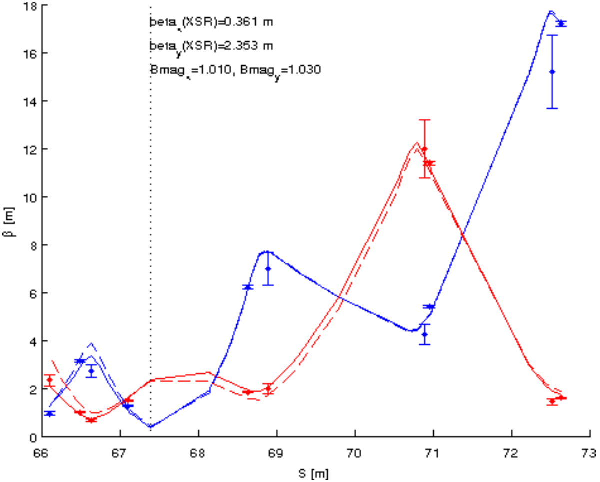
present value
after correction
Intensity [A]
5
4
3
2
1
0
-1
-2
-3
-4
-5
0
10
20
30
40
50
60
70
80
90
100

After Correction



- β_y beating decreased a lot, β_x looks still good.

Fit of Beta at XSR



	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

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Conclusion

Conclusion

- Successful correction of the beta beating ($< 20\%$ after correction).
- Measurement of the response matrices was the key.
- No big intensity loss found.
- Reasonable trim intensity values found (all $< 3A$).
- Emittance decreased significantly (down to $< 6.5pm$ after only 2 iterations).
- Available on Flight Simulator computer.

Prospects

Prospects

- Improve response matrices measurement:
  - better phase measurement.
  - adaptive scan range.
  - dispersion measurement.
  - coupling measurement.
  - sextupoles induced resonances.
- custom weights for correction (betas, phases, tunes, amplitude minimization).

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Useful functions

- Get turn-by-turn data:

```
[xread,yread,tmit]=acquire_TBT(start_turn,nturn,nshot);
```

- Get Twiss functions from TBT data:

```
[Q,beta,phase,factor_beta,goodbpm,dQ,dbeta,dphase,...
  dfactor_beta]=analyse_TBT(data,freqmin,beta_model);
```

- Beta function propagation to a point:

```
[twissx0,dtwissx0,twissy0,dtwissy0]=
  fitbeta(betax_meas,dbetax_meas,betay_meas,...
  dbetay_meas,index_meas,index_fit);
```

- Measure response matrices:

```
meas=measure_resp_matrix_DR(dI_scan)
```

- Plot response matrices:

```
plot_resp_matrix_DR(meas,knobs)
```

- Correct beta beating in DR:

```
correct_DR(meas)
```

Tutorial: Correct DR

- Measure response matrices (3h):

  ```
  meas=measure_resp_matrix_DR(dI_scan);
  ```

  or load previous measurement:

  ```
  load('userData/resp_matrix_DR.mat');
  ```

- (optional) check response matrices:

  ```
  for i=1:99; plot_resp_matrix_DR(meas,i); pause(2);end
  ```

- Compute and apply correction:

  ```
  correct_DR(meas);
  ```

- (optional) measure beta at XSR to get emittance:

  ```
  [betax_XSR,dbetax_XSR,betay_XSR,dbetay_XSR]=fitbeta_XSR();
  ```

  no PV for XSR measurement exist, if one is made, "direct" emittance measurement possible.