BEAM OPTICS MEASUREMENTS THROUGH TURN BY TURN BEAM POSITION DATA IN THE SLS

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ABSTRACT

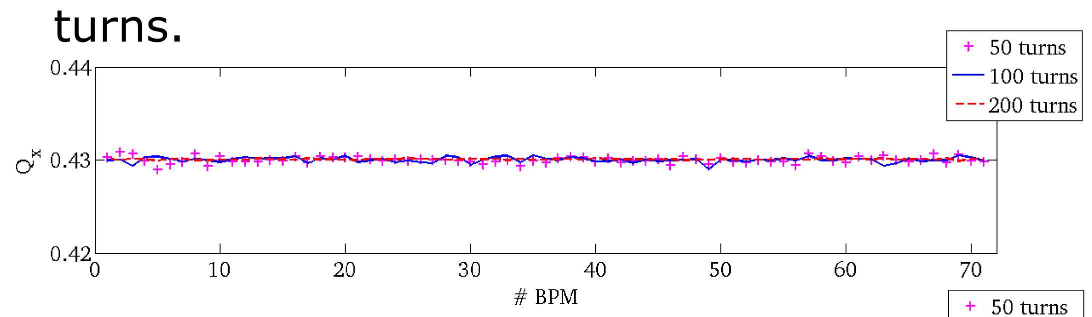
Refined Fourier analysis of turn-by-turn (TBT) transverse position data measurements can be used for determining several beam properties of a ring, such as transverse tunes, optics functions, phases, chromatic properties and coupling. In particular, the Numerical Analysis of Fundamental Frequencies (NAFF) algorithm is used to analyze TBT data from the Swiss Light Source (SLS) storage.

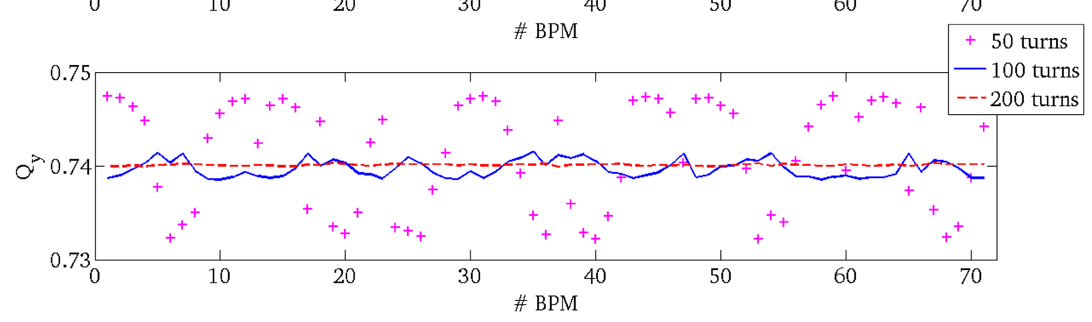
INTRODUCTION

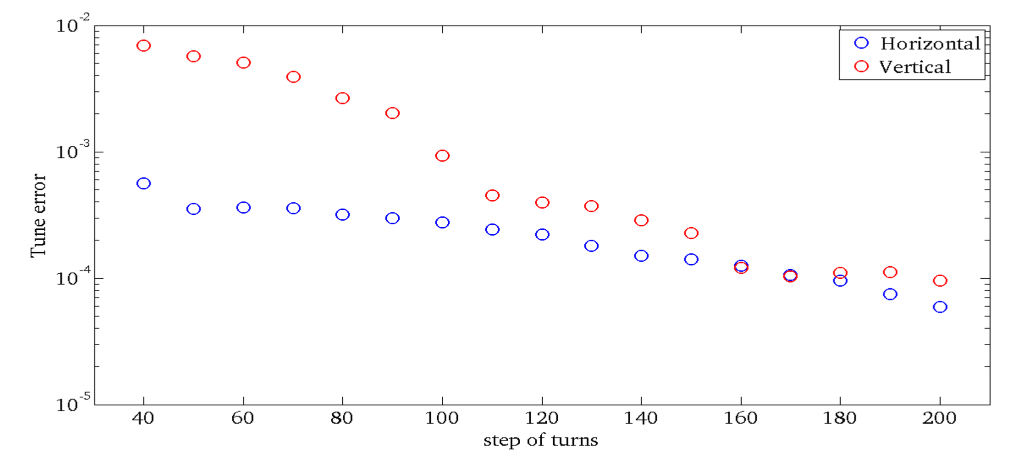
The SLS is a third generation light source which provides photon beams of high brilliance to 20 beam lines. The SLS a storage ring of 288 m with 2.4 GeV nominal energy and transverse tunes of (20.44,8.74), is equipped with 73 beam position monitor (BPM) electronics. In order to estimate the transverse tunes and other ring parameters, the bunches are kicked transversally by a kicker magnet to induce coherent betatron oscillations. In this paper, the **NAFF** method [1] is employed in order to analyse a sample of TBT horizontal and vertical position data from the 73 BPMs of the SLS ring**. Of particular interest is the comparison of tune evaluation with the traditional method of Fourier analysing single BPM data and for an alternate and ultra-fast method mixing all BPM signals for every turn**. Beta function estimations are also possible with two methods, using the Fourier amplitude of the main spectral line or by using the phase information between three consecutive BPMs [3] and its comparison with a perfect lattice model.

BETATRON TUNES EVALUATION

- The horizontal and vertical betatron frequencies are plotted versus the BPM number for 50 (purple), 100 (blue) and 200 (red) turns. The fluctuation of the tune estimate for all the BPMs is large for **50** turns and reduced to minimum for **200** turns.

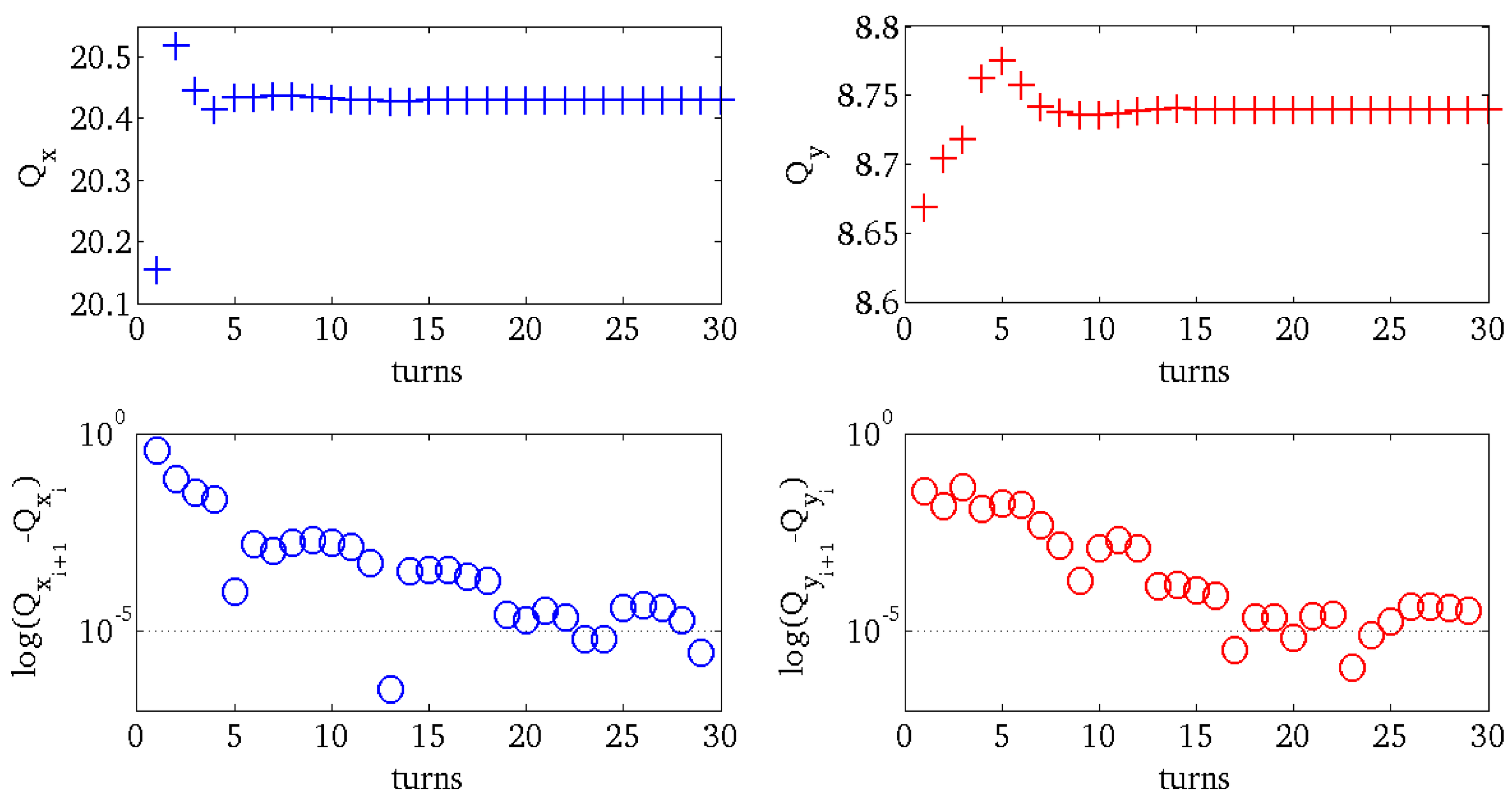






- Standard deviation for the horizontal plane is less than **10^{-3}** for only **40** turns. Drops even below for **200** turns
- For the vertical plane **at least 100 turns** are needed for **10^{-3}** standard deviation

TUNES MEASUREMENT FROM BPM DATA MIXING



- Another method is to **combine the data** from all the BPMs analyse them and ignore the fact that the monitors are **not symmetrical** neither in longitudinal position nor with respect to the machine optics

- Horizontal (top left figure) and vertical (top right figure) tunes are plotted against the number of turns after the simultaneous combination of the BPM data

- The tunes converge to a value within **10 to 20** turns revealing the **speed** of the method

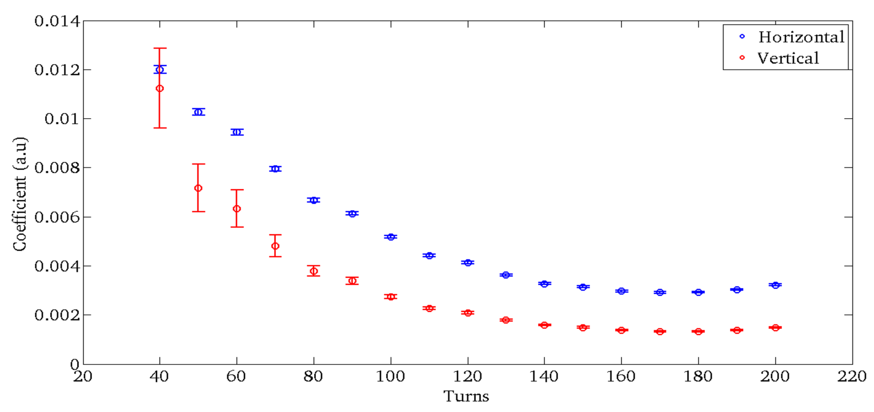
- In the bottom plots the difference between consecutive tune values with respect to the number of turns for both planes is shown testifying the **accuracy** of the method

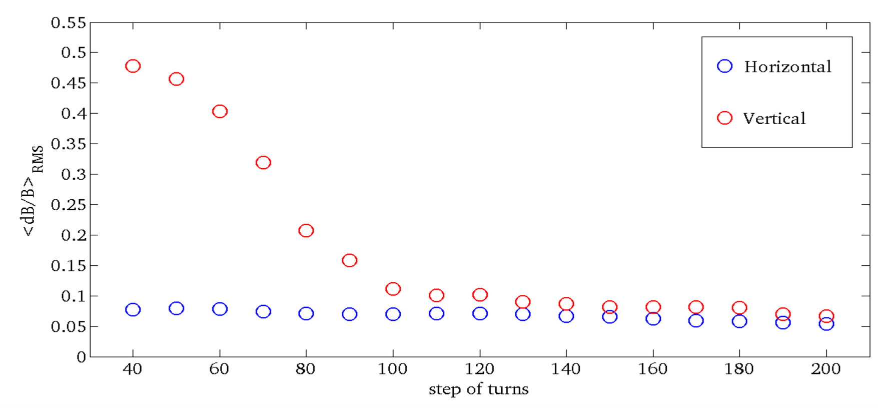
BETATRON FUNCTION ESTIMATION

- For the Fourier component amplitude A^i_z for any plane z at each BPM location i holds:

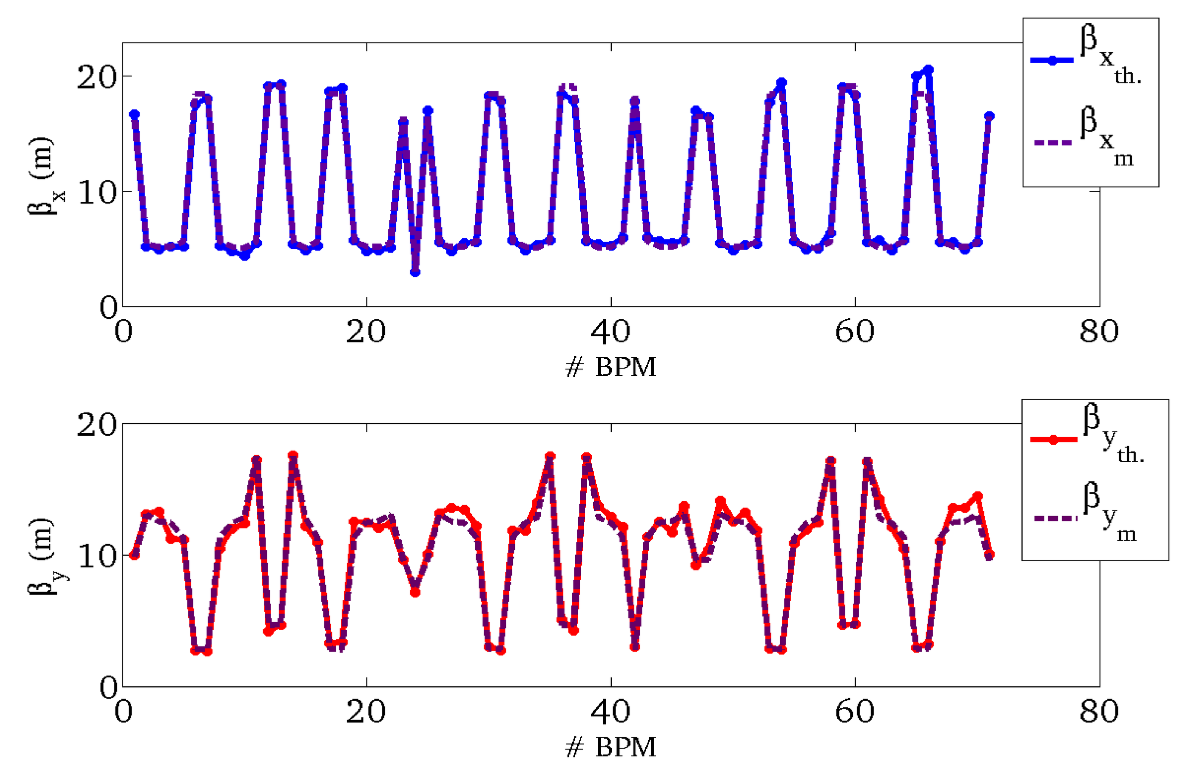
$$A^i_z = c_z \cdot S_i \sqrt{\beta^i_z}$$

- By linear fit the pseudo invariant c_z can be estimated for the horizontal plane (blue curve on top plot below) and the vertical (red curve on top plot below)





- After an analysis of **200** turns, the beta functions are estimated for the horizontal (blue curve), vertical (red curve) and the ideal machine values (purple dashed line for both planes)



- The RMS value of the relative beta difference is plotted revealing great **accuracy** for the horizontal plane (blue curve on the left bottom plot) but also the need of at least 120 turns for the vertical (red curve on the left bottom plot) plane to reach a value of **10^{-1}**

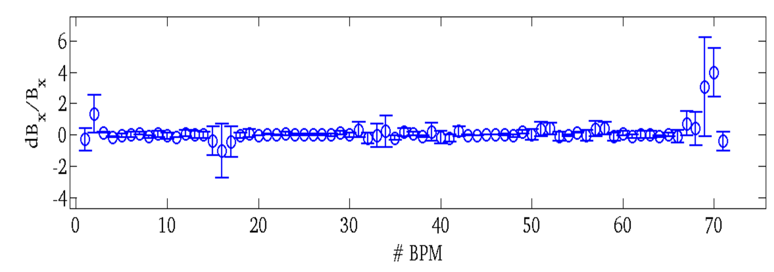
A DIFFERENT METHOD FOR BETA FUNCTION ESTIMATION

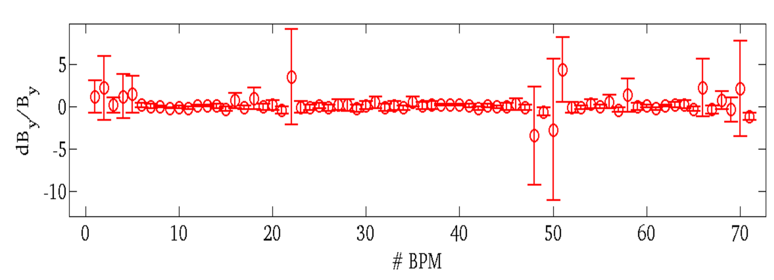
$$\beta'_1 = \beta_1 \frac{\cot\phi'_{12} - \cot\phi'_{13}}{\cot\phi_{12} - \cot\phi_{13}}$$

$$\beta'_2 = \beta_2 \frac{\cot\phi'_{12} - \cot\phi'_{23}}{\cot\phi_{12} - \cot\phi_{23}}$$

$$\beta'_3 = \beta_3 \frac{\cot\phi'_{23} - \cot\phi'_{13}}{\cot\phi_{23} - \cot\phi_{13}}$$

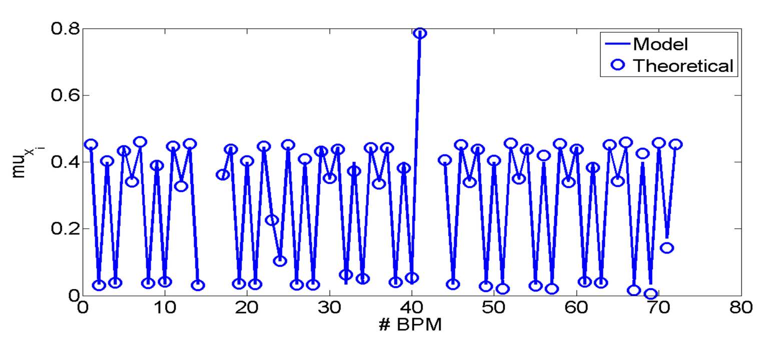
- The measured phase advances ϕ' between **3 consecutive BPMs** can be used in order to estimate the beta function on every BPM

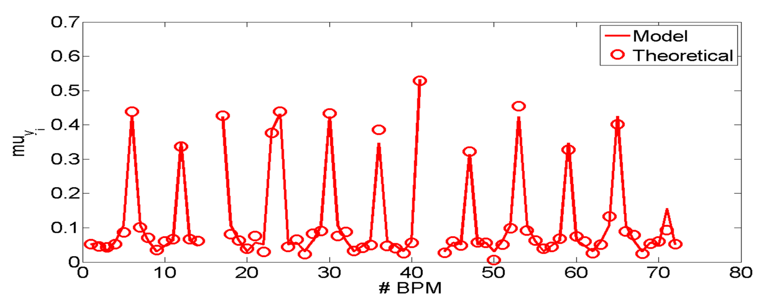




- Relative beta difference for horizontal plane (blue curve) and vertical (red curve) is shown

- The agreement is quite good although some discrepancies exist especially in the vertical plane





- Comparison of the measured ϕ' for horizontal (top figure) and vertical (bottom figure) Further analysis is needed to explain the discrepancies of this method

SUMMARY

The NAFF algorithm was applied on beam position TBT data of the SLS storage ring. The measured fractional tune was measured quite accurately in around 100 turns with the traditional method of analysing single BPMs. Mixing BPM data in every turn and analysing them as a block, was once again demonstrated, enabling the measurement on the tune in around 10 turns. The amplitude and the phase of the principle spectral line for each BPM were finally used in order to measure the beta functions around the ring, which were found quite close to the ideal machine model

REFERENCES.

[1] J. Laskar, "Frequency analysis for multi-dimensional systems. global dynamics and diffusion", Physica D 67, 1993, p. 257-281

[2] Y. Papaphilippou et al., "Experimental Frequency Maps for the ESRF storage ring", EPAC04, Lucerne, 2004

[3] P.Castro-Garcia, Doctoral Thesis, Luminosity and beta function measurement at the electron-positron collider ring LEP, CERN SL/96-70, p. 51-57