ORBIT RECONSTRUCTION, CORRECTION AND MONITORING IN THE ATF2 EXTRACTION LINE*

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Abstract

The orbit in the ATF2 extraction line has to be accurately controlled to allow orbit and optics corrections to work well downstream. The Final Focus section contains points with large beta function values which amplify incoming beam jitter, and few correctors since the steering is performed using quadrupole movers, and so good orbit stability is required.

First experience monitoring the orbit and measuring transfer matrices in the extraction line during the ATF2 commissioning is described, along with relative orbit reconstruction, allowing comparisons with simulations to identify sources of variations.

INTRODUCTION

Layout of ATF-ATF2

ATF is a facility composed of a 1.3 GeV linac and a damping ring producing small emittance beams (Ex=1.2 nm.rad, Ey=12 pm.rad). This beam is then injected in ATF2 which is an Extraction (EXT) followed by a Final Focus (FF) beamline (Figure 1) [1,2].

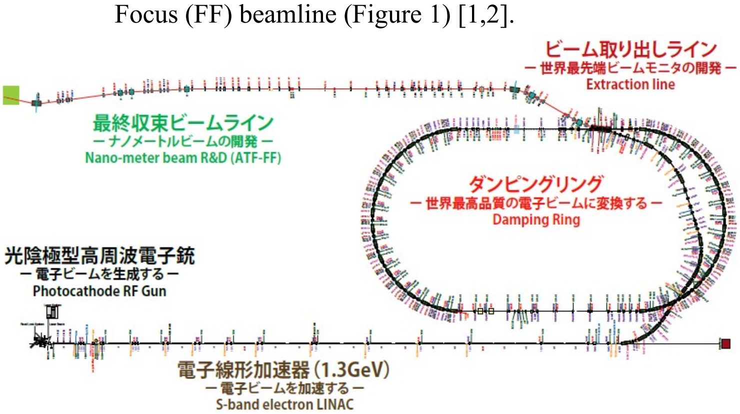

Figure 1: ATF and ATF2 layout.

Objectives

The first goals of ATF2 are to get reliably 37 nm vertical beam size at the interaction point (IP), with less than 10 nm position jitter. It will be the first experimental validation of the local chromaticity correction scheme, planned to be used in ILC and CLIC.

To reach these goals, a good orbit control is needed, especially in the FF sextupoles. Reconstruction of the orbit allows to monitor the parameters of the injected beam, which is the first step to implement feedback. As these studies were done at an early stage of the commissioning, it also helped to find and correct several hardware or software problems.

Principle of orbit reconstruction

Transfer matrices between the injection point and the BPMs give the influence of an input parameter's variation on the BPM readings. The reconstruction, solving equation 1, achieves the opposite : find the parameters of the beam at the injection point from the BPM readings.

$$\begin{pmatrix} R_{1,1}(1) & R_{1,2}(1) & R_{1,3}(1) & R_{1,4}(1) & R_{1,6}(1) \\ R_{1,1}(2) & R_{1,2}(2) & R_{1,3}(2) & R_{1,4}(2) & R_{1,6}(2) \\ & & \vdots & & \\ R_{3,1}(1) & R_{3,2}(1) & R_{3,3}(1) & R_{3,4}(1) & R_{3,6}(1) \\ & & \vdots & & \end{pmatrix} \times \begin{pmatrix} x(IEX) \\ x'(IEX) \\ y(IEX) \\ y'(IEX) \\ \frac{\Delta E}{E}(IEX) \end{pmatrix} = \begin{pmatrix} x(1) \\ x(2) \\ \vdots \\ y(1) \\ \vdots \end{pmatrix} \quad (1)$$

TRANSFER MATRIX MEASUREMENTS

As the reconstruction relies heavily on transfer matrices, the model of the beamline was first tested, allowing at the same time a check of BPMs and corrector polarities and scales, by measuring R_{12} and R_{34} matrix elements between correctors and BPMs.

The measurements were made changing a corrector strength and averaging 10 readings for each setting, to obtain the coefficient between the angle introduced by the corrector and the variation of the position measured at each BPM, in order to compare with the model value. The results for the first horizontal and vertical corrector are shown in Figure 2 and 3.

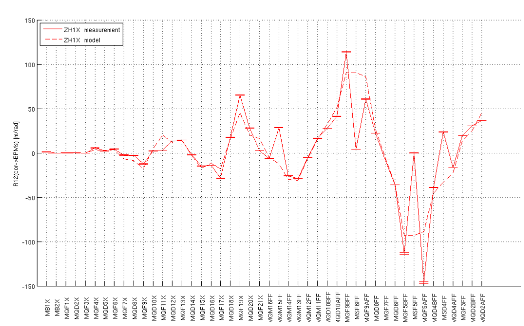

Figure 2: R_{12} measured (solid line) and modeled (dashed line) for all BPMs.

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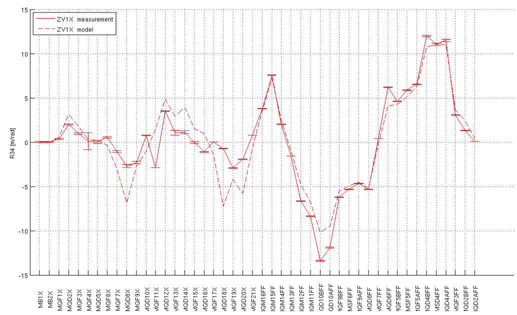

Figure 3: R_{34} measured (solid line) and modeled (dashed line) for all BPMs.

The very good agreement (especially in the FF) for most of the BPMs gave us good confidence in the modeling of the beamline. The precision is not as good where there were too large amplitudes because of saturation in BPM readings.

RELATIVE ORBIT RECONSTRUCTION

Reconstruction of parameters at injection

The reconstruction was then tried on 500 BPM readings, changing the energy by varying the frequency of the ring cavity. The x, x', y, y', dE/E parameters at the injection point were fitted by least square minimisation solving Equation 1. Results for the horizontal plane are shown in Figure 4.

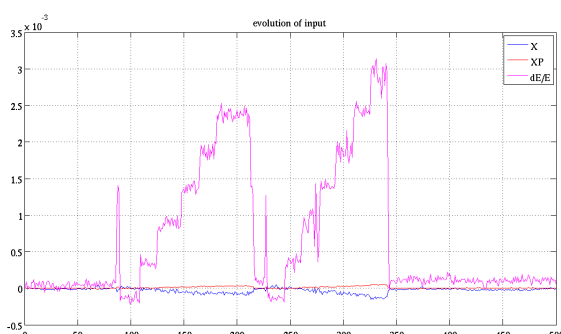

Figure 4: Evolution of x, x' and dE/E reconstructed at the injection point.

One can clearly see that the steps in energy are well reconstructed. Also a correlation between x and dE/E and between x' and dE/E is visible, indicating some anomalous dispersion at that point.

In the vertical plane, natural fluctuations of the beam being 10x lower than in horizontal, reconstruction was not successful.

Scale factor determinations

The reconstructed orbit deduced from these parameters is then compared to the measurements to obtain scale factors in BPM readings by a linear fit (see Figure 5).

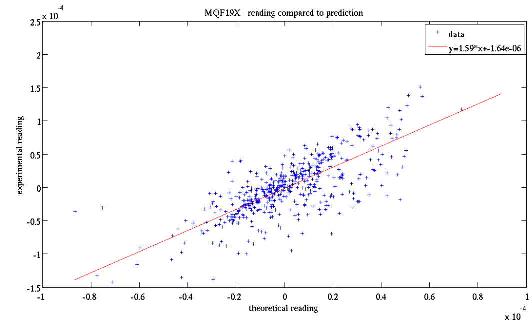

Figure 5: Example of scale factor fit. Horizontal and vertical axes show the reconstructed and experimental readings, respectively.

Horizontal scale factors of all BPMs obtained in this way are shown in Figure 6.

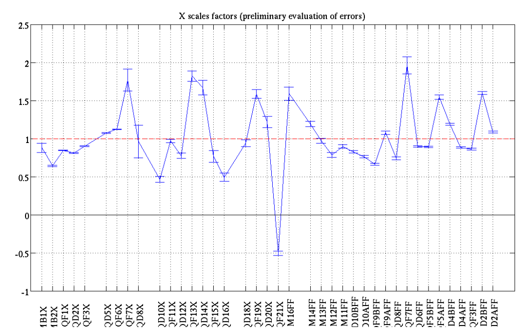

Figure 6: Horizontal scale factors of all BPMs, with estimated errors from the fit.

This estimation can be biased by an overall scale factor common to all BPMs, and should be calibrated, thanks to the energy fit or the transfer matrix measurements.

Most BPMs have scale factors between 0.75 and 1.5.

To evaluate the quality of the fit, the spread of residuals is computed for each BPM, with or without correcting for the scale factors, and compared to the initial spread of the BPM readings (see Figure7).

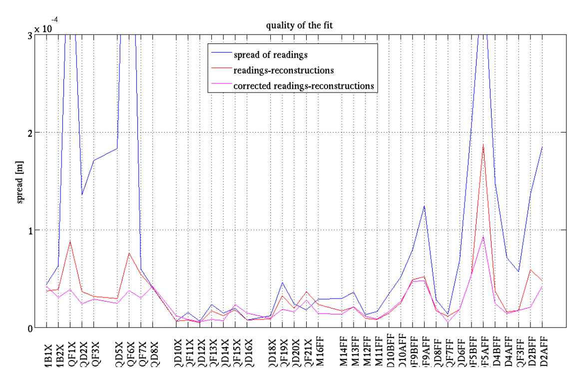

Figure 7: Spread of initial measurements and of the residuals to the reconstruction, with and without correction for scale factor.

For almost all BPMs, the spread of the residuals of the reconstruction is significantly smaller than the spread of the measurements.

It is especially true in the first part of the line where the dispersion function is large. That is a very good indication that the energy is well reconstructed.

One can also see a good reconstruction of x and x' at the end of the line where the the beta functions become very large, which is, this time, due to a good reconstruction of the positions at that location.

For the BPMs with non-unitary scale factors, the spread is further reduced when the reading is corrected by the found scale factor.

CONCLUSION AND PROSPECTS

It was shown that the modeling of ATF2 is reliable, allowing successful reconstruction of the horizontal positions, angles and of the energy at the injection point.

Thanks to this reconstruction, one can estimate parasitically, with just beam fluctuations, the scale factors of the BPMs.

Nevertheless, because the reconstruction suffers from the bad resolutions of the first BPMs, work is on-going on their electronics, trying to improve it. That, combined with a reconstruction optimized to exploit the sub-micron resolution of the last BPMs, should allow us to reconstruct as well the vertical plane.

REFERENCES

[1] ATF2 Proposal, Vol 1 & 2.ATF2 Collaboration, August 11 2005 and 13 February 2006, http://lcdev.kek.jp/ATF2/proposal

[2] Status repport of ILC Final Foccus test beamline at ATF, Bobuhiro Terunuma, contribution to this conference