GLOBAL LINEAR OPTICS CORRECTION FOR LOW ENERGY RHIC RUN*

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Abstract

There has been increasing interest in low energy runs in RHIC, in order to probe the phase diagram at the low energy end. The optics is one of the critical pieces for a successful low energy run since it affects the beam lifetime and thus the achievable luminosity. While acquiring optics measurement data remains difficult, progress has been made in recent years in the analysis of such data and in correcting global optics errors. The analysis technique and the results of optics correction for low energy runs are presented in this report.

INTRODUCTION

Collisions in the low energy range are motivated by one of the key questions of quantum chromodynamics (QCD) about the existence and location of a critical point on the QCD phase diagram [1]. The beam energy range for low energy runs is between 2.5 and 20 GeV/nucleon. Within this range an energy scan will be conducted over 7 different energies. The luminosity of low energy collisions is expected to improve substantially with the help of low energy electron cooling of the colliding beams [2].

The dynamic aperture of the low energy beam has been improved over the years by fixing the machine nonlinearity [3]. On the other hand, it was not possible to systematically measure the optical functions due to the low beam intensity and its short lifetime. During the 2013 and 2014 runs, we managed to measure the linear optics using injection oscillations recorded by turn-by-turn beam position monitors (BPMs), which avoided exciting coherent betatron oscillation. Furthermore, optics corrections were implemented which reduced the global relative errors of beta functions (beta-beat) and corrected the beta functions at the collision points. The analysis technique applied to the turn-by-turn BPM data is presented in the following together with the measured and successfully corrected linear optics during the low energy runs.

OPTICS MEASUREMENTS DURING LOW ENERGY TEST IN 2013

RHIC was operated for a dedicated test with proton beams at ∼ 6 GeV in 2013. One horizontal injection oscillation BPM data is shown in Fig. 1. Two irregularities can be seen in this data set. One is the beam positions reported around turn 200, which looks like pure noise and is present in data recorded by all BPMs. The other one is the sudden increase of the coherent oscillation amplitude around turn 800. Both remain not understood due to time limitations during the test.

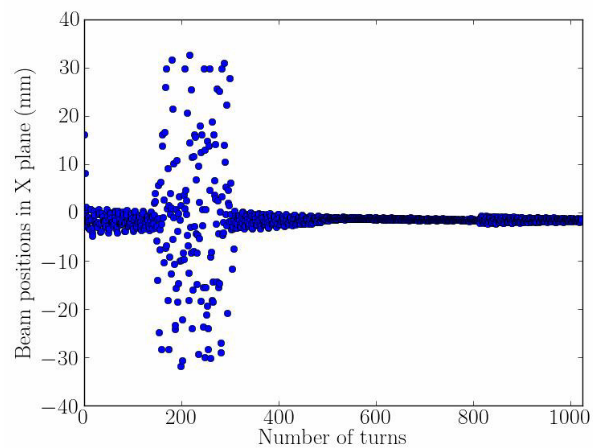

Figure 1: The horizontal injection oscillation BPM data in the Yellow ring during the low energy test in 2013.

The acquired injection oscillation data imposed difficulties on the analysis, which is based on a frequency domain Fourier transform. The Fast Fourier Transform (FFT) produced a spectrum shown in Fig. 2, which is dominated by noise. Therefore, one can neither extract useful tune information nor any other optical functions.

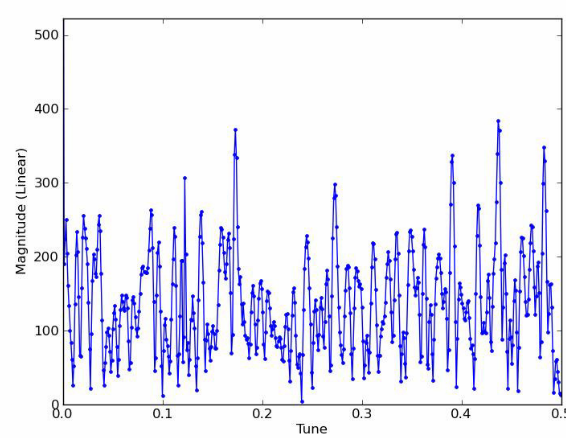

Figure 2: The raw spectrum of the injection oscillation obtained using the FFT technique.

The noise problem was solved later by applying a window (or filter in frequency domain) on the turn-by-turn

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BPM data [4]. Two clearly visible peaks, corresponding to the horizontal and vertical tune, are dominating the spectrum. It is obvious that strong coupling was present in the machine during the test. We had to tweak the tune setting and check the response of the peaks to determine which one corresponded to the horizontal or vertical tune.

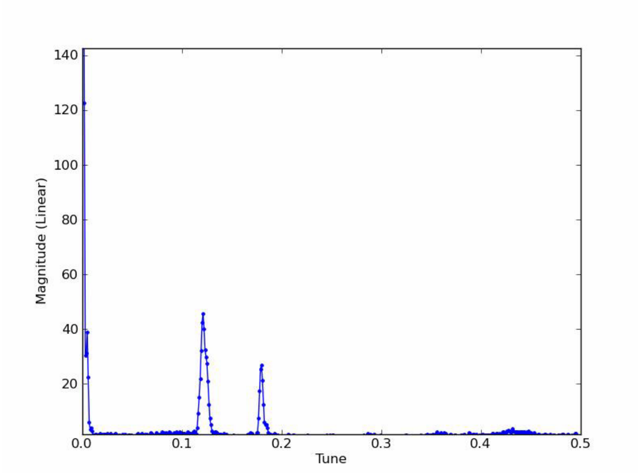

Figure 3: The spectrum of the injection oscillation obtained by applying window and then using FFT technique. The peaks correspond to the horizontal and vertical tune respectively.

By going through the spectrum of all available BPMs, one could obtain the measured tunes from all the functioning BPMs. The histogram of the horizontal tune retrieved from one data set (contains turn-by-turn data from ∼ 160 BPMs) is plotted in Fig. 4.

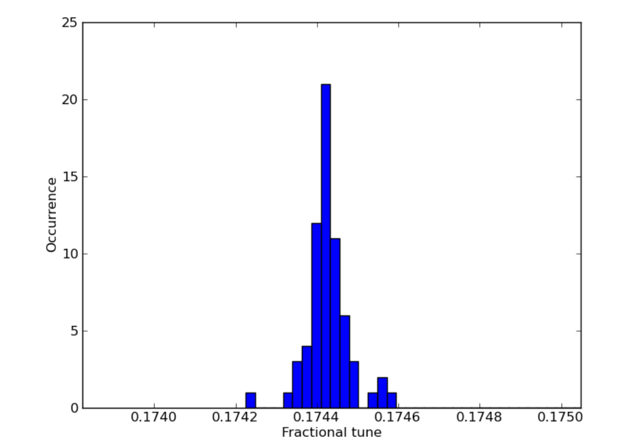

Figure 4: The histogram of the horizontal tunes, measured by all BPMs.

Based on the amplitude of the tune peaks, the relative error of the beta functions at all available BPMs was calculated and is shown in Fig. 5. We did not attempt optics corrections at that time since the analysis was offline and took some time.

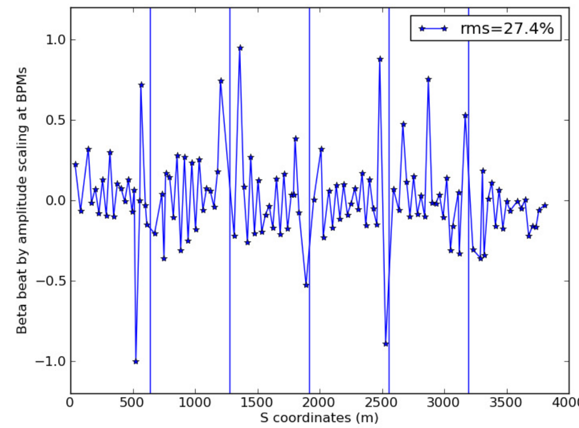

Figure 5: The global beta-beat in the horizontal plane measured during a low energy proton test in 2013.

OPTICS MEASUREMENTS AND CORRECTIONS DURING LOW ENERGY RUN IN 2014

In 2014 Au-Au collisions at 7.3 GeV/nucleon beam energy was provided to the experiments for a period of ∼ 3 weeks. Noise was no longer dominating the injection oscillation BPM data (Fig. 6).

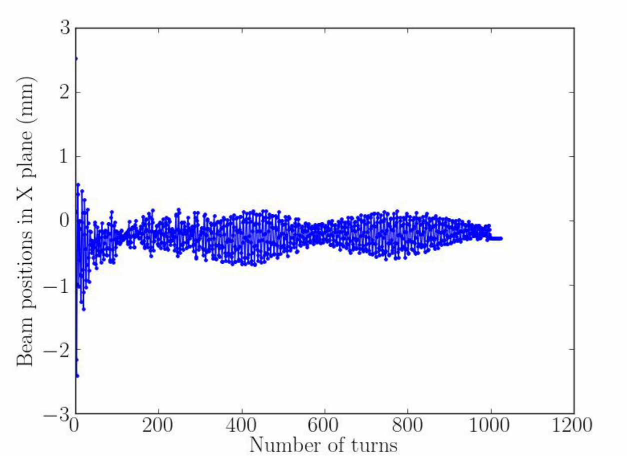

Figure 6: Horizontal injection oscillations recorded by a BPM in the Yellow ring during the low energy run in 2014.

To improve the measurement precision, a Gaussian window was applied to the turn-by-turn BPM data. The beta functions, and thus the beta-beat, were retrieved using the same technique as described in Ref. 4. The correction strengths for the 72 trim quadrupole power supplies were calculated using the SVD algorithm [5]. The corrections were implemented in the machine and the resulting optics

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were remeasured. The global beta-beat before and after correction are plotted in Figs. 7-10 for both planes in both rings. Significant improvement of the global optics were observed in all cases.

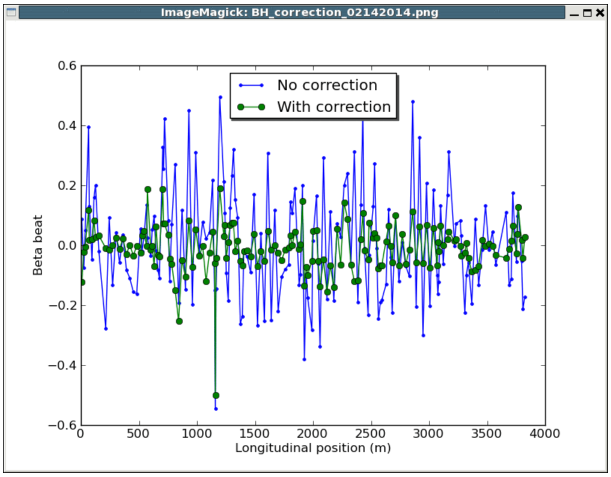

Figure 7: The global beta-beat before and after correction in the Blue horizontal plane. Only one iteration of correction was implemented in the 72 trim quadrupole power supplies.

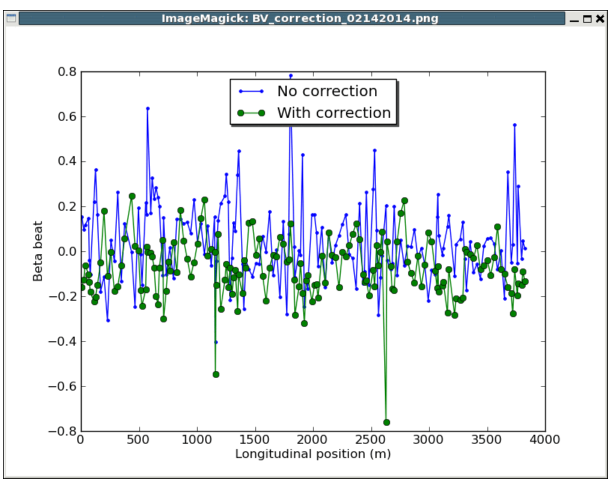

Figure 8: The global beta-beat before and after correction in the Blue vertical plane.

SUMMARY

For low energy runs in RHIC, injection oscillation BPM data sets were used for the analysis of optical functions. In 2013, even though the BPM data was dominated by noise, we managed to extract reasonable optical functions by applying a window to the raw data before performing an FFT. In 2014, the global optical functions were analyzed without much difficulty. The optics corrections were calculated and implemented in operation for the first time in a low energy run. Substantial improvement of the global optics were observed by the subsequent measurements.

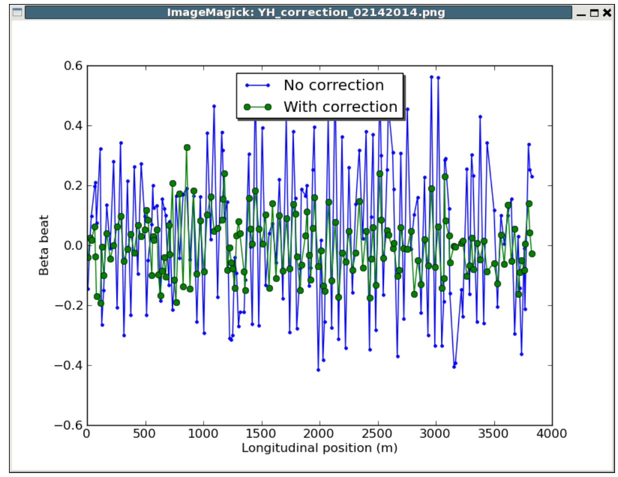

Figure 9: The global beta-beat before and after correction in the Yellow horizontal plane.

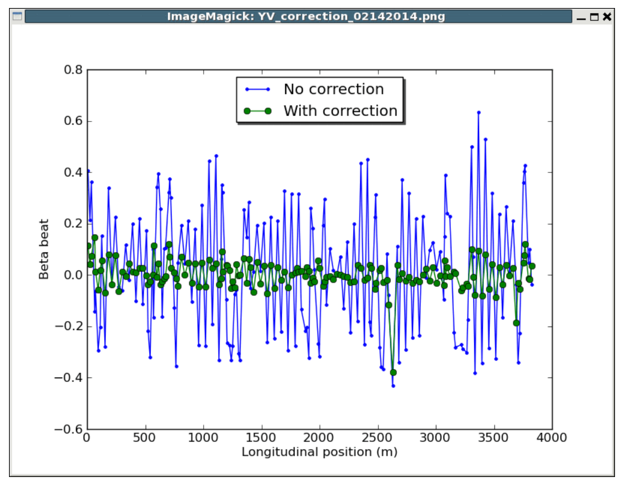

Figure 10: The global beta-beat before and after correction in the Yellow vertical plane.

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