THE RHIC ORBIT CONTROL

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Abstract

The paper describes the methods used at RHIC collider for both global orbit correction over the whole ring and local orbit control in particular regions. Most routinely used tools of the local orbit control include the beam separation, to avoid beam-beam effects at the acceleration, and the beam steering for collisions. The correction on the ramp uses feed-forward approach. The tools for rms and mean orbit control up the ramp are described.

1 INTRODUCTION

The RHIC orbit control system is responsible for the closed orbit correction of the whole RHIC rings as well as of local intervals of the rings. The special task is the orbit correction on the ramp. The orbit control system also includes specific orbit manipulations, like the local orbit control in different regions using dedicated orbit bumps, the $B\rho$ correction of the systematic error of the main dipole field, the radius correction during the acceleration using a selected dipole corrector. As the part of the RHIC control system the orbit control system interacts closely with BPM system, Ramp system and online model. The control room codes RhicOrbitDisplay and orbStat provide the neccesary interface for the orbit display and orbit control.

2 CLOSED ORBIT CORRECTION

The orbit correction system consists of the orbit measuring devices (Beam Position Monitors), dipole correctors and the correcting algortihms which calculates the required corrector strength based on the beam position measurements. From the BPM system there is input of measured closed orbit data, with 162 orbit values for each plane and for each ring [1]. Two seconds acquisition rate provides sufficient amount of measurements during acceleration. The dipole correctors placed at focusing, for the given plane, quadrupoles, are powered by 50A power supplies and provide 0.31 mrad dipole kick at top RHIC energy.

The Sliding Bumps algorithm had been choosen and used as the main algorithm for the orbit correction. The method is based on the local orbit bumps which are formed using three adjacent dipole correctors. Thus the orbit correction of the whole ring is made by making one-by-one consecutive local orbit corrections using the bumps. The method performed very well during the run. The known drawback is the local correction of places with faulted BPMs. In this case the orbit bump optimization was done using the corrector strength minimization.

2.1 Correction on the ramp

The feed-forward correction approach is used for the orbit correction on the RHIC ramps. The orbit data are logged on a disk with 2 sec interval during the beam acceleration. This process is controlled through the updated RhicOrbitManager program. After the ramp is finished, the orbit correction calculation is done and the calculated corrector settings are applied to the next ramp. The RHIC ramp control system, which utilizes so-called stepping stones, allows to install the orbit corrector settings at any energy during acceleration, whenever the correction is required. At the gold ion acceleration, the ring optics is hanging due to the β^* squeeze done continously on the ramp. The online model provides the optics calculations neccesary for the orbit correction system at the given stepping stones on the ramp. The orbit correction made at 6-7 stepping stones proved to be sufficient to keep orbit rms about 1mm and less along the most of the ramp. Most difficulties were met at the correction at energies around the transition energy. The betatron tune space is limited at that energy range because of using special γ_t quadrupoles as well as the more strict requirements come for the centering beam orbit in these quadrupoles.

2.2 Orbit for polarized protons

The good quality of the closed orbit is crucial for preserving the proton beam polarization during the acceleration. In the last run polarized protons were succesfully accelerated up to 100 Gev energy [2]. One of the tricks, which was used to accomplish this, was the special vertical orbit in the both RHIC rings. To minimize the depolarizing effect of spin resonances the orbit should be as flat as possible. Using the measured data for quadrupole vertical misalignments the effect of the misalignments had been taken into account and as result the golden orbit had been constructed which does not go through the quadrupole centers but is really flat. The ideal vertical orbit based on the misalignment data for Blue ring is shown in Figure 1. It includes also the separation bumps in RHIC interaction regions.

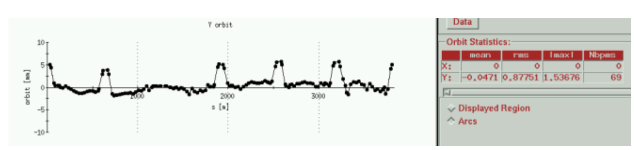

Figure 1: The ideal orbit for polarized protons as seen on BPMs.

Keeping the orbit rms below 1mm on the ramp was enough to provide the polarization preservation at the acceleration up to 100Gev. Figure 2 demonstrates the orbit rms and mean values based on the beam position monitor data in the arcs of RHIC rings.

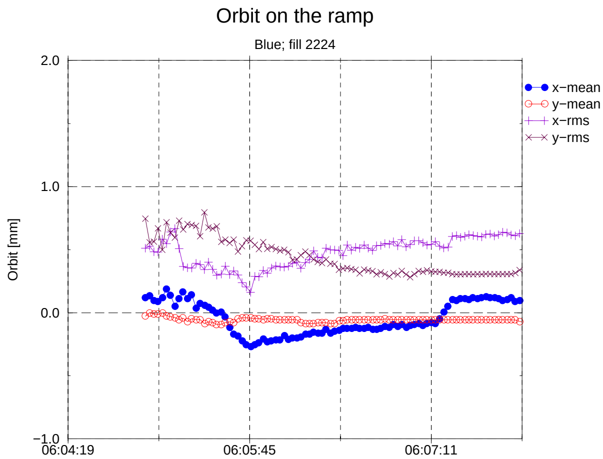

Figure 2: The typical rms and mean orbit on the ramp.

The next step for polarized protons, the acceleration to 200Gev and higher, would require much tighter orbit control, with rms 0.4 mm or less. There are two things that should be done to accomplish this. The first one is the improving quality of the orbit correction. This quality presently is limited by the gradient errors in the interaction regions. These errors seem to be account for the most of difference between the model calculations, which are used for the orbit correction, and the real machine. The different analysis methods have been used to reveal the value of the optics errors and their sources [3],[4],[5].

The second thing, neccesary to improve the closed orbit quality, is the revision of a data for vertical misalignment of the RHIC quadrupoles. Besides the resurvey of RHIC magnets, which is underway, it is planned to extract some knowledge of misalignments from the analysis of dipole corrector strength from the last RHIC run.

Using the harmonic correction might be useful if there would be need to fight of the effect of an individual strong spin resonance.

3 SPECIAL TOOLS

The local closed orbit bumps have been used for the different purposes. The main local bump application was for the beam position and angle control at interaction points on the level of tens or hundreds microns, in order to optimize the beam collisions or do Vernier scans. These IR bumps are formed using 4 dipole correctors.

The same IR bumps, but with amplitude 5mm, have been used to separate beams of the two RHIC rings transversely during acceleration. The separation was done in the vertical plane to prevent beam-beam collisions and beam losses induced by them. Compared with the previous run the quality of the bump closure was improved considerably after the interaction region skew correctors had been utilized to compensate for rolls of IR triplet quadrupoles [6]. Remaining bump imperfections might be traced to the gradient errors, mentioned in the previous section.

The special local bump based on 3 dipole correctors were used in the region with limited or nonsymmetric aperture as well as for aperture scans. The typical examples of such a bumps are the bumps at the injection regions and and the beam abort locations.

The crossing angle up to 1.8 mrad has been tried successfully at IP2 by adjusting separation magnets (D0 and DX dipoles). This crossing angle was used through the whole RHIC energy range for gold ion beams. No noticable effect on the beams was observed as a result of it except for some luminosity degradation.

The $B\rho$ correction was succesfully done several times to eliminate the difference in beam revolution frequencies between the two RHIC rings. The correction utillized horizontal dipole correctors and was essentially a usual closed orbit correction with a goal orbit constructed, using the dispersion function, as the off-momentum particle orbit.

The beam average position (or beam radius) during acceleration is controlled by RF system through the radial loops. The raidal loop control works very well. Nevertheless the delicate radius adjustment has been added to the orbit correction system. This adjustment uses a horizontal dipole corrector located between beam position monitors used for the radial loop control. Powering this corrector affects the radial loop work and produces the required radial shift of horizontal closed orbit.

4 SOFTWARE TOOLS

Several software tools have been written to provide a control room interface for described orbit control tasks. The main orbit control application is RhicOrbitDisplay. It includes orbit acquisition, including turn-by-turn mode, and orbit display. It also provides some tools for acquired orbit data manipulation and statistic. The correction part of the RhicOrbitDisplay provides connections with the online model and with RHIC ramp system and calculates the required corrector settings. The separate part of the code is dedicated to the local orbit bump control. The example of main RhicOrbitDisplay window is shown in Figure 3.

A separate application, orbStat, does the statistical analysys of the orbit data on the ramp. The example of the data produced by this code is demonstrated in Figure 2.

5 REFERENCES

[1] T. Satogata, et al., *RHIC BPM System Performance, Upgrades and Tools*, these proceedings.

[2] W. MacKay, et al., *Accelerating and Colliding Polarized Protons in RHIC with Siberian Snakes* these proceedings.

[3] F. Pilat, P. Cameron, J.-P. Koutchouk, V. Ptitsyn, *Linear and Nonlinear Correction in the RHIC Interaction Regions*, these proceedings.

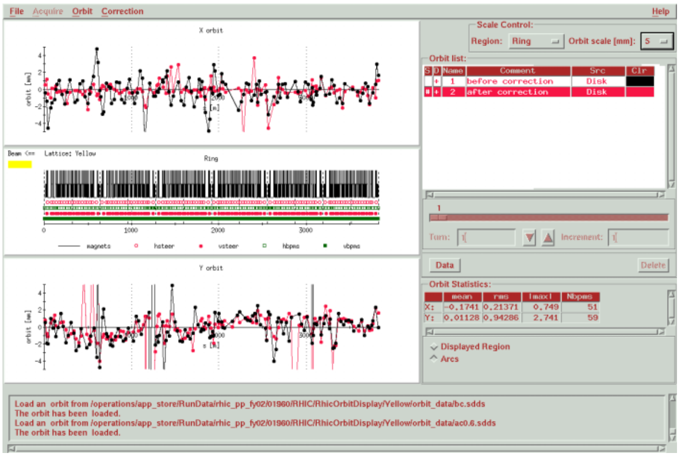

Figure 3: The RhicOrbitDisplay application main window.

[4] J. Cardona, et al., *Determination of Linear and Non Linear Components in RHIC Interaction Regions from Difference Orbit Measurements*, these proceedings.

[5] T. Satogata, et al., *Linear Optics During The RHIC 2001-2 Runs*, these proceedings.

[6] F. Pilat, et al., *Correction of Coupling Effects at RHIC*, these proceedings.