

MIMICKING BIPOLAR SEXTUPOLE POWER SUPPLIES FOR LOW-ENERGY OPERATIONS AT RHIC*

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Abstract

RHIC operated at energies below the nominal ion injection energy of $E=9.8$ GeV/u in 2010. Earlier test runs and magnet measurements indicated that all defocusing sextupole unipolar power supplies should be reversed to provide the proper sign of chromaticity. However, vertical chromaticity at $E=3.85$ GeV/u with this power supply configuration was still not optimal. This uncertainty inspired a new machine configuration where only half of the defocusing sextupole power supplies were reversed, taking advantage of the flexibility of the RHIC nonlinear chromaticity correction system to mimic bipolar sextupoles. This configuration resulted in a 30 percent luminosity gain and eliminated the need for further polarity changes for later 2010 low energy physics operations. Here we describe the background to this problem, operational experience, and RHIC online model changes to implement this solution.

INTRODUCTION

The Relativistic Heavy Ion Collider (RHIC) consists of two superconducting storage rings capable of accelerating beams to rigidities of $B \cdot \rho = 830$ T · m, which for fully stripped gold ions corresponds to a beam energy of 100 GeV. The two rings intersect at six locations along their circumference. Each ring therefore consists of six arcs altogether, three inner arcs and three outer ones, as shown in Figure 1.

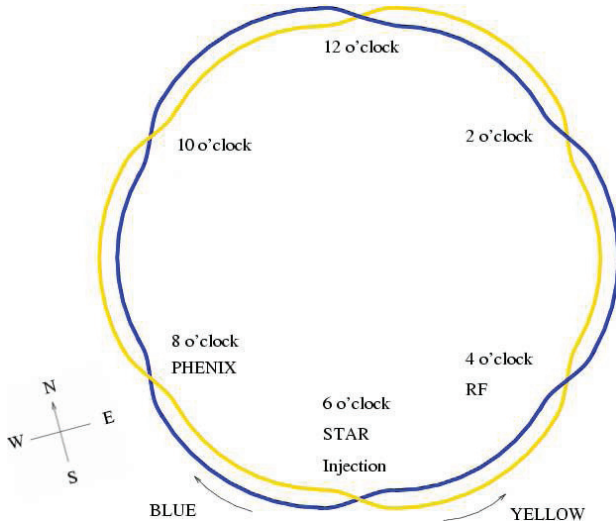


Figure 1: Schematic view of RHIC with its two intersecting superconducting storage rings.

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During part of the FY10 run, RHIC provided gold-gold collisions at several energies below its regular injection energy of 10.5 GeV. In preparation of this low-energy operations, the multipole errors of one spare dipole and one spare quadrupole were measured during a hysteresis cycle between the RHIC power supply “park” current of 50 A, and a maximum current of some 2000 A, which corresponds to 100 GeV proton operations.

As Figure 2 shows, the measured sextupole error in that spare dipole assumes a minimum of -22.1 units at 182.6 A, which corresponds to a beam energy of 3.85 GeV, or $\sqrt{s} = 7.7$ GeV.

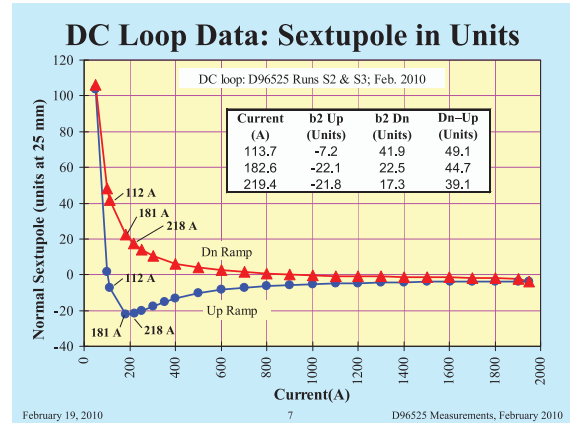


Figure 2: Measured sextupole component b_2 in a spare RHIC dipole. The tabulated currents correspond to $\sqrt{s} = 5$ GeV, 7.7 GeV, and 11.5 GeV, respectively.

Based on the measured sextupole component $b_2 = -22.1$ units in the dipole, it was predicted that a negative strength of the SD sextupole family would be required to correct the resulting natural chromaticity to $\xi_x = \xi_y = -2$, as shown in Figure 4. During operations above the regular injection energy, where $b_2 > -10$, these sextupoles have a positive strength. Since all sextupole power supplies at RHIC are unipolar, it was therefore decided to flip the polarity of all the SD power supplies for low energy operation at $\sqrt{s} = 7.7$ GeV.

When first reliable chromaticity measurements were performed and analyzed after a couple of days into the 7.7 GeV run, the vertical chromaticity was measured at $\xi_y = 10$, with the SD sextupoles at zero strength. Correcting the vertical chromaticity to the desired value of $\xi_y = -2$ would therefore have required a slightly positive strength in all the SD sextupoles, contrary to earlier predictions. However, instead of reverting the initial polarity flip, a novel sextupole scheme was developed that mimicked bipolar sextupole power supplies, thus increasing the flexibility of the chromaticity correction scheme.

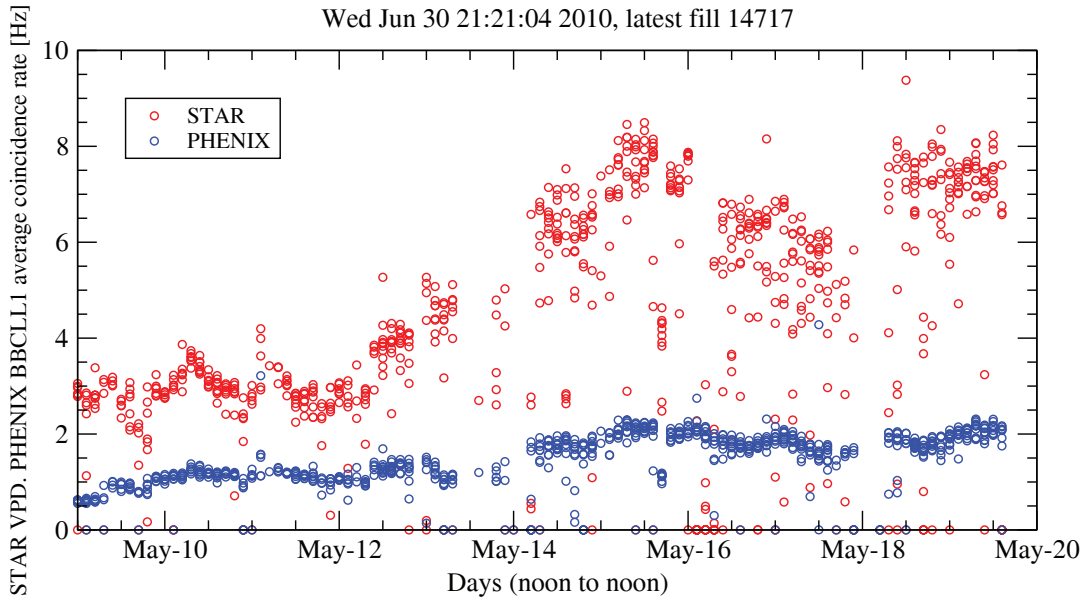


Figure 3: Fill-by-fill average experiment coincidence rates during part of the FY10 low energy run. The SD sextupoles were reconfigured on May 13. Note that typical high energy RHIC collision coincidence rates are 10+ kHz. STAR and PHENIX coincidence rates are different because both experiments operated with different β^* . STAR has a larger acceptance for low energy collisions and so could tolerate larger backgrounds produced by lower β^* .

THE “BIPOLAR” SEXTUPOLE SCHEME

After having operated with only two sextupole families per arc for a several years, the RHIC sextupole scheme was upgraded in 2005 in an effort to correct higher-order chromatic effects as well [1]. The SD and SF families were each split up into two sub-sets, resulting in four sextupole families per arc, as schematically shown in Figure 5.

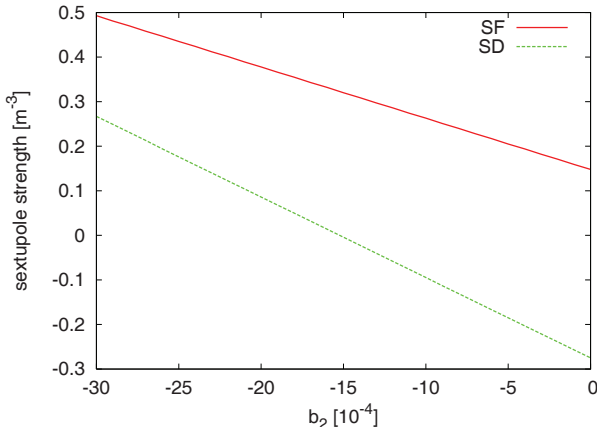


Figure 4: Required sextupole strength for correction of the machine chromaticity vs. dipole error b_2 .

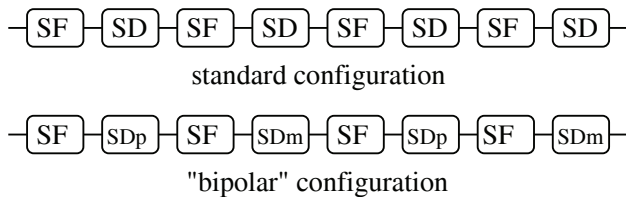


Figure 5: Sextupole families in the standard and the “bipolar” configuration.

Taking advantage of this sextupole scheme, the polarity of only half the SD sextupoles, namely the SDp family, was reversed. Together with the appropriate modification of the RHIC online model and the controls software, this resulted in dedicated families for positive (SDp) and negative (SDm) adjustments of the natural machine chromaticity ξ_y , thus mimicking bipolar sextupole power supplies. Since the required strength in these sextupoles was very small, no negative effects on dynamic aperture was to be expected. This modification was implemented in the RHIC online model such that it was completely transparent to the operator.

OPERATIONAL EXPERIENCE

With the new “bipolar” sextupole scheme, the chromaticity was corrected to the desired value of $\xi_x = \xi_y = -2$. This resulted in an increase of the fill-by-fill average luminosity by some 30 percent, as shown in Figure 3. Obviously, the same results could have been achieved by reverting all SD sextupoles to their original polarity. However, the “bipolar” scheme provides additional operational flexibility to correct chromaticities in different machine configurations, for instance different values of β^* , which change the natural machine chromaticity. This sextupole configuration remained unchanged for the remainder of the run, when the energy was increased to $\sqrt{s} = 11.5$ GeV after several weeks of operation at $\sqrt{s} = 7.7$ GeV.

REFERENCE

[1] Y. Luo et al., “Sorting chromatic sextupoles for easily and effectively correcting second order chromaticity in the Relativistic Heavy Ion Collider”, C-A/AP/348