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Abstract. During Run-8, the Relativistic Heavy Ion Collider (RHIC) provided collisions of spin-polarized proton beams at two interaction regions. Physics data were taken with vertical orientation of the beam polarization, which in the "Yellow" RHIC ring was significantly lower than in previous years. We present recent developments and improvements as well as the luminosity and polarization performance achieved during Run-8, and we discuss possible causes of the not as high as previously achieved polarization performance of the "Yellow" ring.

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INTRODUCTION

The RHIC polarized proton run in fiscal year 2008 (Run-8) lasted for six weeks, from January 28 to March 10, following a long deuteron-gold run [1]. This period includes the necessary start-up of the machine as well as the actual physics run. The main goal of this short run was to provide proton-proton collisions for comparison purposes with deuteron-gold data, and to develop higher luminosity for future runs.

MACHINE CONFIGURATION

During Run-6 luminosity performance with polarized protons was limited by beam-beam effects [2]. To overcome this limitation, a new near-integer working point was proposed and extensively studied in both simulations and experiments; however, the latter had been limited to studies at injection energy [3]. Simulations indicated that the dynamic aperture at the near-integer working point was significantly larger than at the Run-6 fractional tunes of (.685/.695). Therefore the initial set-up of RHIC was performed with the "Blue" ring at store fractional tunes of (.96/.95), while the working point of the "Yellow" ring remained at (.695/.685).

TABLE 1. RHIC parameters during the polarized protons physics run.

Beam energy [GeV]	100
No. of bunches/beam	109
No. of protons/bunch [10^{11}]	1.5
95% norm. emittance [μm]	20 – 25
L_{peak} [$10^{30}\,\text{cm}^{-2}\text{sec}^{-1}$]	35
$L_{\text{store avg.}}$ [$10^{30}\,\text{cm}^{-2}\text{sec}^{-1}$]	23
β^* [m]	1.0
No. of collision points	2
Spin orientation at PHENIX	vertical
Spin orientation at STAR	vertical

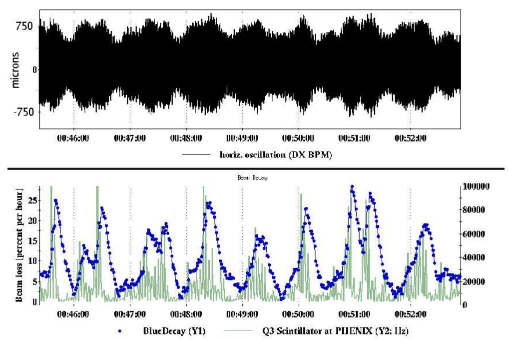

FIGURE 1. Horizontal oscillation of the "Blue" beam (black, top graph), together with the hourly beam loss rate (blue curve in lower graph, in percent) and the beam-induced background at PHENIX (green bars).

When first collisions were provided in this configuration [4], detector backgrounds from the "Blue" beam were found to be unacceptably high, and in near-perfect correlation to the fluctuating amplitude of the 10 Hz orbit oscillations [5], which had been increased by a factor five due to the near-integer working point as shown in Figure 1. The near-integer working point therefore had to be abandoned, and RHIC was set up in the same configuration as during Run-6. Table 1 lists the machine configuration and parameters used during the physics run.

PERFORMANCE

During the Run-8 physics run, working points of both beams were placed below the diagonal, around (.695/.685). The necessary tune separation to avoid coherent beam-beam effects was provided by separating the tunes along the $Q_x = Q_y$ diagonal, rather than by mirroring them across this diagonal. In this configuration, no obvious beam-beam limit was observed, in contrast to the Run-6 experience with working points mirrored across the diagonal. Bunch intensities of $1.6 \cdot 10^{11}$ protons/bunch were routinely injected and accelerated; the maximum bunch intensity reached $1.8 \cdot 10^{11}$ protons/bunch. Typical peak luminosities at the beginning of stores were approximately $30 \cdot 10^{30}\,\text{cm}^{-2}\text{sec}^{-1}$,

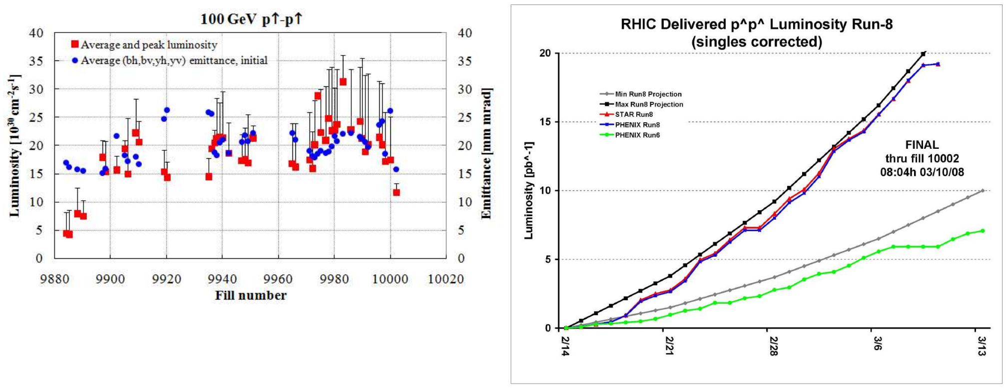

FIGURE 2. Left: Peak (vertical bars) and average (red squares) store luminosity vs. store number during the polarized proton Run-8. The average emittance, as calculated from measured luminosity and beam intensities for round beams, is indicated by blue dots. Right: Integrated delivered luminosity for PHENIX (blue) and STAR (red) during Run-8. For comparison, the integrated delivered luminosity during Run-6 is included (green line). The two smooth lines indicate the minimum and maximum projections for Run-8.

with an average store luminosity of $23 \cdot 10^{30}\,\mathrm{cm}^{-2}\mathrm{sec}^{-1}$ (Figure 2). This resulted in a delivered integrated luminosity of approximately $18\,\mathrm{pb}^{-1}$, close to the maximum projected for the run.

Polarization in both rings was significantly lower than during Run-6, with roughly 50 percent in the "Blue" and 40 percent in the "Yellow" ring, compared to approximately 60 percent in both rings during Run-6. This low polarization can be attributed to several reasons. First, the beam polarization at the source reached only 80 percent, vs. 85 percent in Run-6. Furthermore, the AGS was set up in a new mode with injection "on-the-fly" [6]. While this was expected to provide a higher polarization due to a faster ramp rate across the lowest-energy depolarizing resonance, it resulted in a stronger intensity-dependence of the polarization at extraction, effectively lowering the polarization at intensities required for RHIC. For the final week of the physics run, the Run-6 set-up for the AGS was therefore re-loaded.

During the entire run the polarization transmission in the "Yellow" ring was significantly lower than in the "Blue" ring. This was most likely caused by the non-parallel "Yellow" beam orbits through the two Siberian snakes, which are located on opposite sides of the ring. This resulted in a deviation of the spin tune from its ideal value of $\nu_s = 1/2$, causing the depolarizing resonances to split into pairs. This splitting effectively reduced the available resonance-free tune space between depolarizing resonances.

Due to a broken beam position monitor in the snake area of the "Yellow" ring, orbit information were not readily available to confirm this theory. However, survey data taken during the shutdown after Run-8 (Figure 3) show that in the "Yellow" ring the two snakes are aligned with a net angle error of $-0.11\,\mathrm{mrad}$, while the corresponding angle in the "Blue" ring is only $-0.03\,\mathrm{mrad}$. These angles translate into spin tune errors that appear to be consistent with direct measurements of the spin tune at injection. In preparation for future runs, the alignment in the snake region has now been corrected, and the BPM has been repaired.

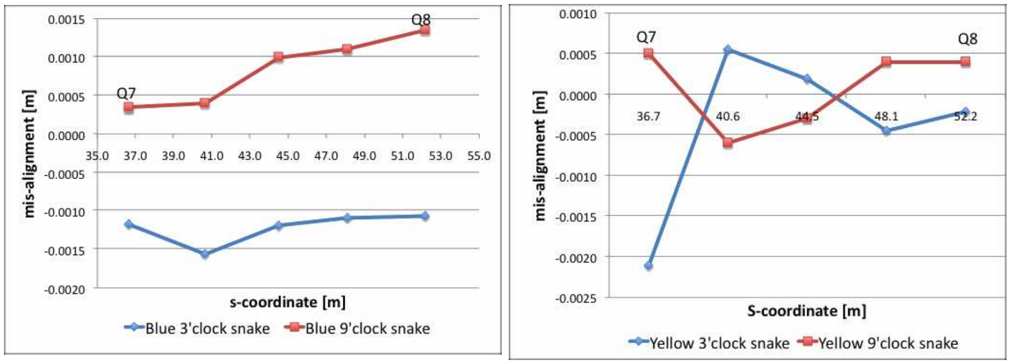

FIGURE 3. Measured horizontal magnet positions in the snake regions of the "Blue" (left) and "Yellow" (right) RHIC rings.

MACHINE DEVELOPMENT

To develop the machine towards higher luminosities in future runs, the β-functions at the two experiments were reduced from the operational $\beta^* = 1.0\,\mathrm{m}$ to $0.68\,\mathrm{m}$ during several dedicated development periods. Up to 56 bunches in both rings were accelerated and brought into collision. The luminosity scaled well with the reduced β^*, and after collimation detector background rates were at similar levels as in the regular configuration. Beam lifetimes at store were acceptable after correcting the nonlinear chromaticity.

SUMMARY

The polarized proton operations during Run-8 was successful, with weekly integrated luminosities reaching levels similar to those in Run-6. However, polarization levels in both rings were lower than in Run-6 for several reasons. The reduced β^*, which was developed but not used operationally during Run-8, is expected to significantly boost the luminosity in future runs.

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