RHIC POLARIZED PROTON OPERATION FOR 2017 *

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Abstract

The 2017 operation of the Relativistic Heavy Ion Collider (RHIC) involved the running of only a single experiment at STAR with PHENIX offline in the process of the upgrade to sPHENIX. For this run there were several notable changes to machine operations. These included, transverse polarization, luminosity leveling, a testing of a new approach to machine protection and the development of new store and ramped lattices. The new 255 GeV store lattice was designed to maximize dynamic aperture. The new lattices on the ramp were designed to maximize polarization transmission during the three strong intrinsic spin resonances crossings. Finally we are also commissioning new 9 MHz RF cavities during this run.

INTRODUCTION

During the current polarized proton 255 GeV run we have achieved integrated luminosity of 400 pb^{-1} to date. In Fig. 1 the progression of the integrated luminosity compared against the run goals are plotted. Average polarization values are shown in Table 1

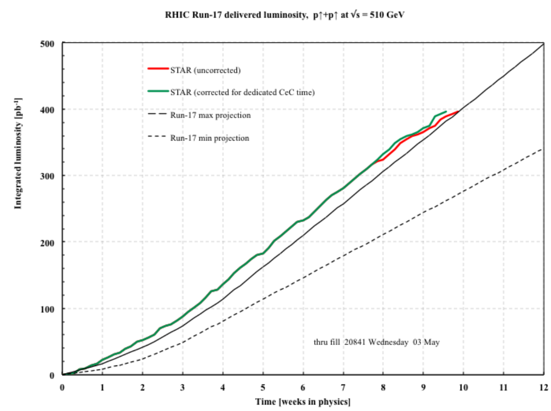

Figure 1: Integrated luminosity to date.

Table 1: Polarization Values for Run 17

Measurement	Blue Ring	Yellow Ring
Avg. Jet	54.4±0.3 %	54.8 ±0.3 %
Avg. CNI	58.35 ± 0.18 %	60.00±0.18 %
Avg. ramp eff.	92.93%	91.28%
Store lifetime	-0.19±0.03 % /hr	-0.29 ±0.03 %/hr

Several notable differences from previous runs include, restoring the DX magnets to a symmetric position, only one collision and experiment at STAR (PHENIX being converted to sPHENIX). The STAR experimental beam pipe was changed, from 4 cm ID Be NEG coated to 8 cm ID Be without coating with the adjacent Al pieces NEG coated. The PHENIX experimental beam pipe was also changed from 4 cm ID Be to 12.2 cm ID SS, both NEG coated. Additionally 1 of 3 new 9 MHz cavities were installed and commissioned in each ring (60 kV/cavity design, operated at 26 kV/cavity). The new ion optical sytem increased the OPPIS beam by 20% (03/01/2017). There was an e-lens cryo upgrade with both superconducting solenoids run stably at 6 T. To reduce space charge near injection a dual harmonic RF system was used in the AGS. A special Yellow Au ramp for CeC PoP (γ = 28.702) was commissioned and beam was extracted from LEReC DC gun. Finally to achieve transverse polarization, the rotators were not run this year (except for RHICf).

LUMINOSITY LEVELING

This 255 GeV polarized proton run was unique primarily due to the requirement for luminosity leveling and transverse polarization. Luminosity leveling was driven due to limitations of the STAR detector caused by signal pile up. This required the collision rates to be held within the optimal rate level throughout the store. To accomplish this we instituted a secondary beta squeeze. Stores were began at 1.5 m beta star and then when rates dropped below $1.15\times10^{32} cm^{-2}s^{-1}$ the lattice was squeezed to 1.2 m beta star to bring the rates back up to about $1.35\times10^{32} cm^{-2}s^{-1}$. An example of the luminosity response is shown in Fig. 2. This second squeeze

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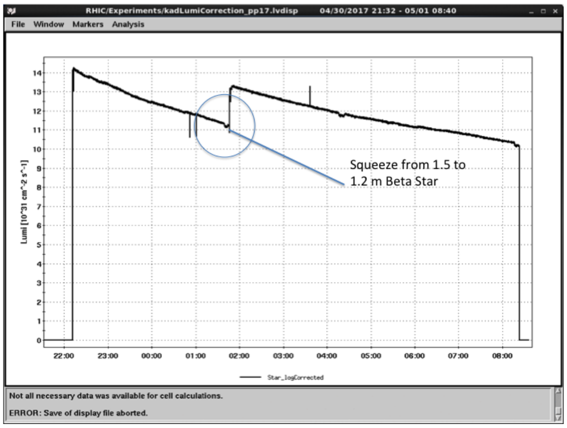

Figure 2: Luminosity Response to squeeze from 1.5 to 1.2 meter Beta Star.

was commissioned in 03/13/2017. Additionally store length was limited to 8 hours.

MACHINE PROTECTION

This year we tested a new machine protection system. On occasion the abort kicker's thyratron would pre-fire outside of the abort gap region and create large losses around the ring [1]. This year mechanical serial switches were added after the thyratron to prevent these pre-fires. To accomodate the slower response time of the serial switches new permit inputs were added to the machine protection system. These included, RF, orbit correctors, 10 Hz orbit feedback and fast BPM readings (coherence signal). Also the BLM thresholds wer lowered at store.

During a test of this new system, RHIC sustained severe quenches in the yellow ring when 4 of 5 new mechanical serial switches failed to close after a beam dump. As a result of this event, dipole magnet, yi7-d6 sustained damage to it's quench protection diode. This manifested itself as a small bypass current. In order to reduce the bypass current the ramp rate was reduced by a factor of 2.

NEW LATTICE DESIGNS

One of the major goals of the lattice design effort was to mitigate polarization losses during acceleration. Recent theoretical effort [2, 3] has provided a guide to help us accomplish this. This with a lot of tracking work has provided a theoretical framework to handle depolarization due to the overlap of spin resonances in the presences of snakes. One of the key discoveries has been the importance of interference from neighboring spin resonances during acceleration and the threshold at which they can significantly impact polarization losses. In Fig. 3 the changes to spin resonance structure are shown.

Here the nearby interfering spin resonances have been reduced for the strongest intrinsic resonance on the 255 GeV energy ramp ($G\gamma = 393 + Q_y \approx 422$). In Fig. 4 the benefit to the polarization transmission is shown via spin tracking.

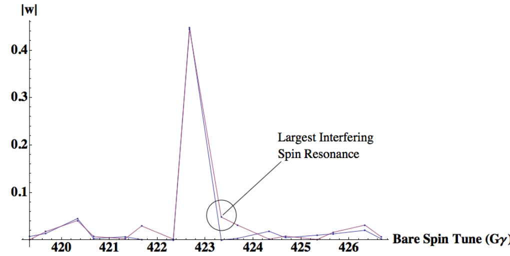

Figure 3: Calculation of intrinsic spin resonance strength at an emittance of 10 mm-mrad, near the strongest intrinsic spin resonance on the 255 GeV ramp ($G\gamma = 393 + Q_y$). The calculations are for two lattices: the standard (old) lattice and the new lattice. Note the reduction of the neighboring resonances in the new lattice (largest one is circled).

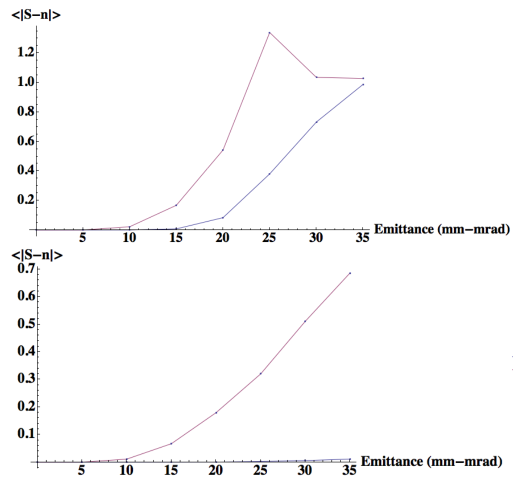

Figure 4: Polarization Transmission aperture for Blue (top) and Yellow (bottom) lattice. Each trace represents the amount of net difference between the stable spin direction and spin after crossing the $G\gamma = 393 + Q_y$ spin resonance. This amount is calculated for each emittance. This shows the improvement compared to the old standard lattice.

This can be seen in the expansion of the polarization transmission aperture for Blue and Yellow lattices.

Dispersion Prime Matching at the Snakes

In addition, effort was made to design lattices with equal dispersion prime at the snakes to reduce the spin tune spread. Lattices were prepared and implemented in the Blue ring, at injection, on the ramp and at store. A reduction in the spin tune spread has several benefits. Firstly it will help increase the coherent response of the spin to the operation of the spin flipper/tune meter. As a result of this effort the spin tune spread at injection was reduced by a factor of 10 which helped achieve a 95% spin flip for the first time. This also increased the signal to noise in the measurement of spin tune via turn-by-turn analysis. The signal to noise problem was a significant barrier for accurate non-destructive spin tune measurements [4]. Secondly on the ramp the reduction of the spin tune spread should provide some benefit for polarization

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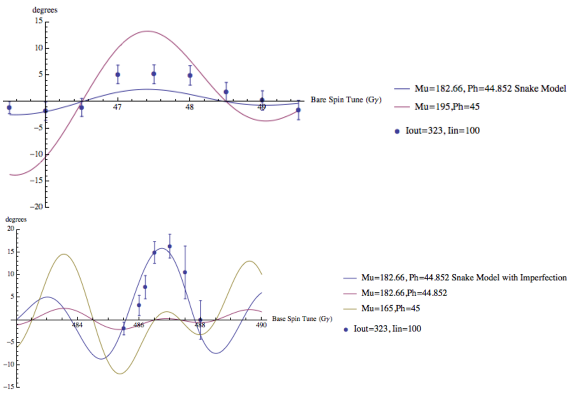

Figure 5: Energy scans of the projection of average spin tilt into horizontal plane at Injection (top) and at store (bottom) in Blue ring. We compared response to simple model with snakes at settings based on model value for Iin=100 and Iout=323 amps and with detuning of snakes and a strong imperfection source at $G\gamma = 487$ (0.25).

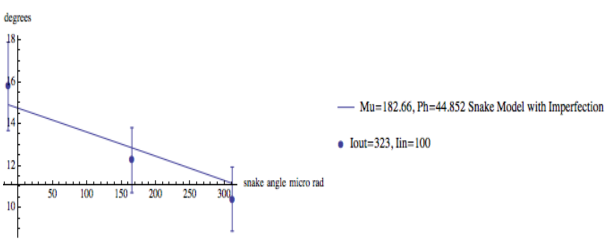

Figure 6: Response of average spin tilt at store in Blue ring to changes in the orbital angle between snakes. We compared response to simple model with snakes at settings based on model value for Iin=100 and Iout=323 amps with a strong imperfection source at $G\gamma = 487$ (0.25).

transmission since this reduces the number of resonance crossings driven by the synchrotron oscillations.

DIAGNOSIS OF SPIN TILT ANOMALY

Since the 255 GeV polarized proton run of 2012, the carbon polarimeter has measured a spin tilt at Store of about 15 degrees. This spin tilt was not observed at injection, at 100 GeV or at 250 GeV. 2012 was the first year we went from 250 to 255 GeV as well as the first year we modified the snake current settings at store by 5 amps in an attempt to optimize the snakes at higher energy. During the current run we restored the snake settings from 321 to 323 amps for the inner helical magnet (Iin), and 95 to 100 amps for the outer helical magnet (Iout). However the spin tilt remained.

We conducted several studies in an attempt to diagnosis the causes of this tilt. We performed energy scans at Injection and store energy to observe the angle response for various snake settings (see Fig. 5). We also scanned the orbital angle between the snakes to observe the response of the spin tilt angle (see Fig. 6). In the most recent study we collapsed the separation bumps one by one at store to observe the spin tilt response.

At this point we are investigating the possibility that the tilt is driven by strong imperfection resonances. This is because a defect in the snake response would mainfest itself as a larger spin tilt and deviations in the measured spin tune beyond what has been observed at injection (see also [5]). Additionally collapsing of the separation bumps revealed a swing of the spin tilt by as much as 5-6 degrees, both facts point to an orbitally driven imperfection spin resonance in the ring at store.

PROSPECTS

While modifications to minimize the neighboring intrinsic spin resonances at $G\gamma = 393 + Q_y$, $411 - Q_y$ and $231 + Q_y$ were applied, further analysis is required to determine the benefit if any these changes had to polarization transmission efficiency. This is because the data needs still to be normalized against beam emittance and injected polarization. While we have efficiency calculations using measurements made at injection and flattop by the carbon polarimeter, there exists some doubt that the measurements at injection are valid since they consistently differ from those made in the AGS. We are currently investigating to what extent the desired optics was achieved. Kicked turn-by-turn measurements were made on the ramp, but these still need to be analyzed to extract estimates of the actual lattice spin resonance strength. Furthermore analysis of the spin tilt indicates that there are significant imperfection resonance sources present in the ring. These are beyond what is suggested by a naive reckoning of the orbit based on the bpm data. If these imperfection resonances are above 0.01 level they can adversely impact the polarization transmission through each of the strong intrinsic resonances.

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