BNL-95190-2011-CP

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Presented at the 2nd International Particle Accelerator Conference (IPAC 2011)
San Sebastian, Spain
September 4-9, 2011

Collider-Accelerator Department

Brookhaven National Laboratory

U.S. Department of Energy
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RHIC PERFORMANCE FOR FY2011 Au+Au HEAVY ION RUN *

G.J. Marr[#], L. Ahrens, M. Bai, J. Beebe-Wang, I. Blackler, M. Blaskiewicz, J.M. Brennan, K.A. Brown , D. Bruno, J. Butler, C. Carlson, R. Connolly, T. D'Ottavio, K.A. Drees, A.V. Fedotov, W. Fischer, W. Fu, C.J. Gardner, D.M. Gassner, J.W. Glenn, X. Gu, M. Harvey, T. Hayes, L.T. Hoff, H. Huang, P.F. Ingrassia, J.P. Jamilkowski, N. Kling, M. Lafky, J.S. Laster, C. Liu, Y. Luo, M. Mapes, A. Marusic, K. Mernick, R.J. Michnoff, M.G. Minty, C. Montag, J. Morris, C. Naylor, S. Nemesure, S. Polizzo, V. Ptitsyn, G. Robert-Demolaize, T. Roser, P. Sampson, J. Sandberg, V. Schoefer, C. Schultheiss, F. Severino, T. Shrey, K. Smith, D. Steski, S. Tepikian, P. Thieberger, D. Trbojevic, N. Tsoupas, J.E. Tuozzolo, B. VanKuik, G. Wang, M. Wilinski, A. Zaltsman, K. Zeno, S.Y. Zhang, Collider-Accelerator Department, BNL, Upton, NY, 11973

Abstract

Following the Fiscal Year (FY) 2010 (Run-10) Relativistic Heavy Ion Collider (RHIC) Au+Au run [1], RHIC experiment upgrades sought to improve detector capabilities. In turn, accelerator improvements were made to improve the luminosity available to the experiments for this run (Run-11). These improvements included: a redesign of the stochastic cooling systems for improved reliability; a relocation of "common" RF cavities to alleviate intensity limits due to beam loading; and an improved usage of feedback systems to control orbit, tune and coupling during energy ramps as well as while colliding at top energy. We present an overview of changes to the Collider and review the performance of the collider with respect to instantaneous and integrated luminosity goals.

INTRODUCTION

At the conclusion of the FY 2011 polarized proton run [2], preparations for heavy ion run proceeded on April 18, with Au+Au collisions continuing through June 28. Our standard operations at 100 GeV/nucleon beam energy was bracketed by two shorter periods of collisions at lower energies (9.8 and 13.5 GeV/nucleon), continuing a previously established program of low and medium energy runs [3]. Table 1 summarizes our history of heavy ion operations at RHIC.

MACHINE CONFIGURATION

For the most part, the machine conditions as run previously were the basis for the start of this operating period; however, as is typical with the shutdown and maintenance period over the summer, repairs and upgrades were put in place prior to this fiscal year's restart. A few notable items are listed below.

Collider Lattice

In the interest of expedient start up, and without compelling evidence for lattice improvements, the initial lattice for Run-11, from injection to high energy, was essentially a copy of that used during Run-10 and featured β^* = 0.7 m at the collision points for the experiments PHENIX and STAR. The 9.8 GeV/nucleon run provided collisions at the nominal RHIC injection energy; the injection lattice was modified to reduce β^* at the intersection points (IP) from 10 m to 2.5 m (at STAR) and 3.0 m (at PHENIX). For collisions at 13.5 GeV/nucleon, β^* = 3.0 m was chosen for both experiments.

Stochastic Cooling

Given our experience with stochastic cooling in both transverse and longitudinal planes from previous runs, components were redesigned and repaired to improve reliability as well as allow for simultaneous operation of all planes in both rings [4]. A horizontal system was not in place for this run, but the vertical system accomplishes cooling in both transverse planes via coupling.

Feedback Systems

Feedback systems during the energy ramp to control betatron tune and coupling, as well as orbit, have been utilized during the initial setup period for previous runs, with excellent results [5, 6] – typical measured orbit rms at store is about 20 μm. This year the feedback systems were operating for all energy ramps over the course of the entire run; additionally, orbit feedback was periodically engaged while colliding at storage energy, in order to maintain a consistent orbit over many hours.

Relocation of RF Cavities

While the 28 MHz, harmonic h = 360 RF acceleration system employs two cavities in each collider ring (designated Blue and Yellow rings), the 197 MHz h = 2520 RF storage system, used with colliding beams, previously consisted of three cavities in each ring, with an additional four "common" cavities located at one IP of the Blue and Yellow rings. In previous runs these common cavities posed an intensity limitation due to beam loading from both rings. Prior to this run the common cavities were removed in favour of five storage cavities in each ring [7].

Beam dump upgrade

The RHIC dump system kicks the beam into a block next to the circulating beam pipe. At high proton and

* Work performed under Contract Number DE-AC02-98CH10886 with the auspices of the US Department of Energy.
[#]gmarr@bnl.gov

Table 1: Historical Run Parameters for 100 GeV Au+Au Runs

	Design	Run-2	Run-4	Enhanced Design	Run-7	Run-10	Run-11
No. of bunches	55	55	45	111	103	111	111
Ions/bunch [10^9]	1.0	0.6	1.1	1.0	1.1	1.1	1.3
β* at IP [m]	2.0	1.0	1.0	1.0	0.8	0.75	0.75
Peak luminosity [$10^{26}cm^{-2}s^{-1}$]	9	4	15	30	30	40	50
Avg. store luminosity [$10^{26}cm^{-2}s^{-1}$]	2	1.5	5	8	12	20	30
Luminosity per week [μb^{-1}/week]	50	24	160	300	380	650	1000
Run length [weeks of physics]	--	15.9	12	--	12.8	10.9	6.4
Time in store [% of calendar time]	--	26	53	--	49	53	59

heavy ion intensities, secondary particles leaked back into the beam pipe and travelled to the superconducting magnet downstream, and could induce a quench. Prior to this year's runs, inserts were installed to shield against the secondaries. No quadrupole quenches were observed in Run-11.

PERFORMANCE

Owing in part to the fact that the heavy ion run was immediately preceded by polarized proton operations, beam development progressed rapidly. For each of the three energies, we were able to establish the necessary conditions to begin the physics program without significant delay.

9.8 GeV/nucleon Operations

Original plans defined the beam energy to be 9 GeV/nucleon. However, RF cavity work during the last shutdown period affected the frequency range of the acceleration cavities. In the course of resolving the issue, the energy was changed to our nominal injection energy, which was of little consequence to the experiments and better meshed with the subsequent 100 GeV/nucleon setup and operation.

Despite this setback, the collider was in physics production in three days. Figure 1 shows the integrated luminosity for STAR and PHENIX. Nearly all experimental goals were met in 10 days of running. With typical store lengths around 30 minutes, efficient turnaround of stores by operations staff was an integral part of the achieved 71% of calendar time in store. Collimation was used continuously and allowed experimental detector systems to remain on during the refilling process.

100 GeV/nucleon Operations

Since the low energy run had already established injection and circulating beam, the 100 GeV/nucleon setup was rapid and completed in 4 days. Beams in both rings were accelerated to full energy on the second ramp attempt, due in large part to the tune, coupling and orbit feedback systems. Since no ramp intensity limitations were observed, high instantaneous luminosities were achieved quickly. The initial luminosities at store often exceeded last year's best values. This run also reached a new peak instantaneous luminosity of $52.6x10^{26}$ $cm^{-2}s^{-1}$, a new record for any heavy ion collider. Figure 2 shows the integrated luminosity for STAR and PHENIX. Included are the conservative (L_{min}) and optimistic (L_{max}) predictions for the run. The achieved luminosity for PHENIX in Run-10 is also displayed for comparison.

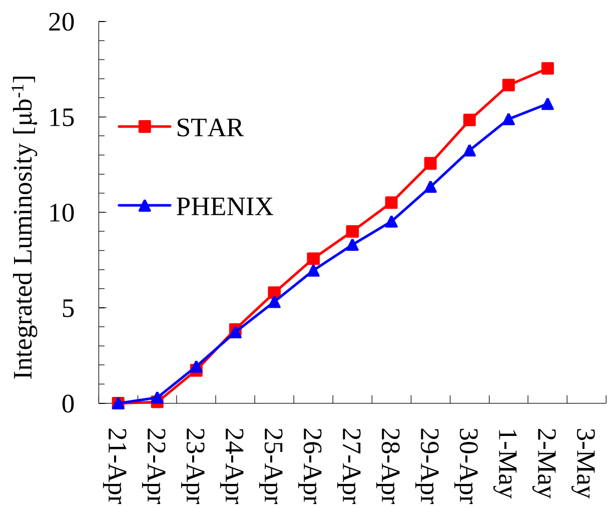

Figure 1: Integrated luminosity at 9.8 GeV/nucleon.

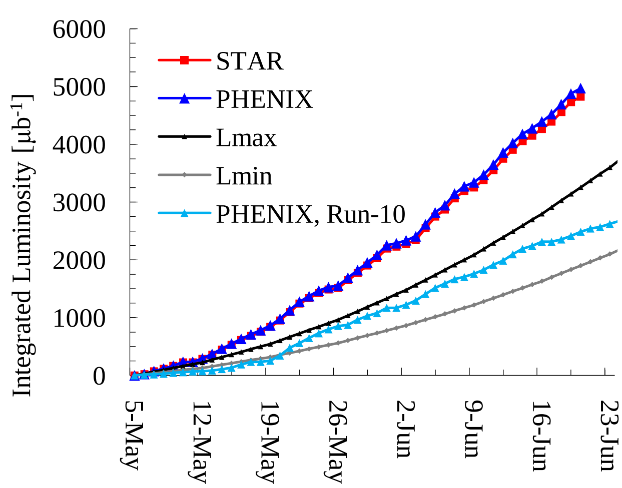

Figure 2: Integrated luminosity at 100 GeV.

Similar to the low energy run configuration, collimators were inserted during injection, with position adjustments throughout the ramp and store. By maintaining the limiting aperture at the collimators, losses in superconducting magnets around the rings were reduced, thus minimizing failure time due to beam-induced quenches. Employing orbit feedback on every ramp maintained the consistent beam positions necessary to set collimator positions during acceleration.

Integrated luminosity was helped in large part by the stochastic cooling systems. Running longitudinal and transverse cooling simultaneously in both rings had a significant effect on luminosity lifetime over the course of a store, as shown in Figure 3. Development was also initiated to dynamically squeeze β* at one experiment IP over the course of the store, to maintain high collision rates and take advantage of reduced beam emittances offered by stochastic cooling. This is intended to be implemented operationally for future runs.

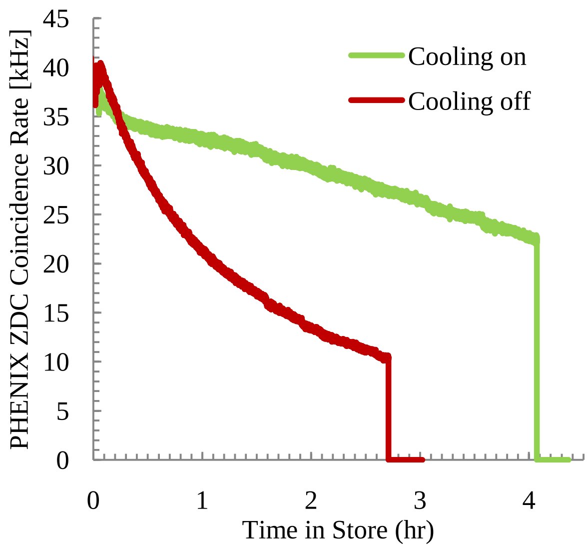

Figure 3: Luminosity lifetime for two similar stores, with and without stochastic cooling.

Combined with high machine availability, the improvements in luminosity and lifetime allowed us to deliver similar integrated luminosity totals compared to last run, but in approximately 60% of the calendar time.

Additionally, collisions were established at a third IP in order to perform ZDC calibrations and other initial tests for the proposed A_NDY experiment [8].

13.5 GeV/nucleon Operations

Given that 100 GeV/nucleon luminosity goals were attained ahead of schedule, there was an opportunity to include a medium energy run which was in future run plans. With beam development previously established for injection, acceleration, and storage at high energy, commissioning of the medium energy was rapid. Beam was accelerated to store in the first attempt, and physics conditions were established in one day. Integrated luminosity, shown in Figure 4, exceeded the experimenters' goals.

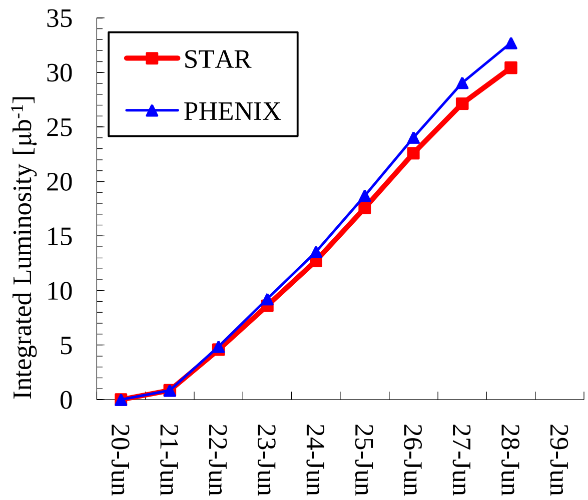

Figure 4: Integrated luminosity at 13.5 GeV/nucleon.

SUMMARY

The heavy ion portion of RHIC Run-11 was a great success. Improved design and operation of longitudinal and transverse stochastic cooling systems, along with high machine availability, allowed for more integrated luminosity per week than in previous runs. Enhanced tune, coupling and orbit feedback systems, combined with relocation of the RF storage cavities and a beam dump upgrade, resulted in higher beam intensities available at collision energy, and thus higher instantaneous and peak luminosities. As a result, this run met or exceeded nearly all goals set forth by the experiments, and set a new record for peak instantaneous luminosity in a heavy ion collider.

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