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Polarized beams in AGS and RHIC in Run-2015

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Abstract

The upgraded high-intensity polarized source operation and improvements in the injector chain and at RHIC have allowed higher bunch intensities and lower emittance for colliding beams in RHIC. The successful commissioning of the electron lenses resulted in operation at a higher beam-beam parameter and therefore higher luminosity. For the first time polarized proton-Gold, proton-Aluminum collisions. Polarization in collisions 60-65% achieved at high luminosity operation at: $\sqrt{S}$ =200 GeV.

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1. Introduction

The goals of the first ten weeks of polarized proton on proton collisions at a beam energy of 100 GeV were studies of gluon contribution to the proton spin with longitudinally polarized beams and transversity (Sivers effect studies) with trnsversly polarized colliding beams. Due to higher bunch intensity integrated beam luminosity in Run-2015 exceeded the luminosity in all previous runs combined. For the first time polarized proton-Gold, proton-Aluminum collisions with high luminosity and polarization were achieved in RHIC for saturation physics studies and as a reference for heavy ion collisions.

The largest effort consisted commissioning of the electron lenses, one in each ring, which are designed to compensate one of the two beam-beam interactions experienced by the proton bunches. The e-lenses raise the per bunch intensity at which luminosity becomes beam-beam limited. In previous runs strong space-charge forces at injection to Booster caused the emittance growth and did not allow to take full benefits of high polarized source and linac pulse intensity. In Run 15, a different capture scheme was implemented, which defocuses the center of the bunch longitudinally and reduces the peak current. The resulting transverse emittances at AGS extraction and in RHIC were 20% smaller than in previous runs owing largely to this improvement. The higher brightness Booster and AGS beam allowed to take advantage of the increased by electron lens beam-beam limit on the maximum bunch intensity and resulted in significant increase of the integrated beam luminosity. As a result the total integrated luminosity in Run 2015 exceeded the integrated luminosity of all previous runs combined (see Fig.1) [1].

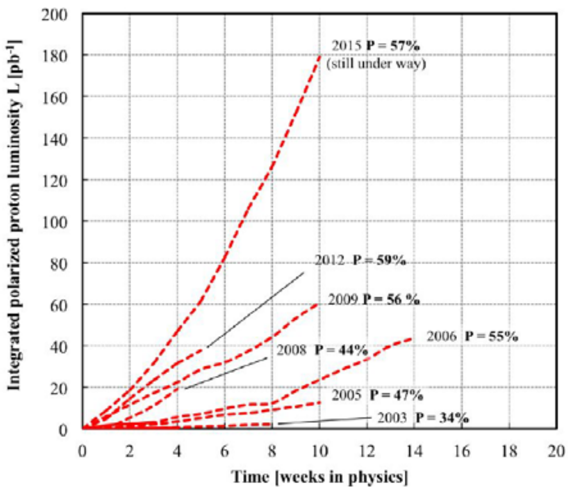

Fig.1. RHIC luminosity for pp collision in Runs-203-15.

2. Polarized source upgrade

A novel polarization technique had been successfully implemented for the RHIC polarized H^- ion source upgrade to higher intensity and polarization. In this technique a proton beam inside the high magnetic field solenoid is produced by ionization of the atomic hydrogen beam (from external source) in the He-gaseous ionizer cell. Further proton polarization is produced in the process of polarized electron capture from the optically-pumped Rb vapor. The use of high-brightness primary beam and large cross-sections of charge-exchange cross-sections resulted in production of high intensity H^- ion beam of 85% polarization [2]. The source very reliably delivered polarized beam in the RHIC Run-2013 and Run-2015. High beam current, brightness and polarization resulted in 70-74% polarization at 23 GeV.

The old RHIC OPPIS based on ECR primary proton source was retired after successful operation in Runs 2000-12. The new source with atomic beam hydrogen injector and He-ionizer was developed in 2010-12 and commissioned for operation in Run-2013 [8,9]. It produces significantly higher brightness primary proton beam, which resulted in higher polarized beam intensity and polarization delivered for injection to Linac-Booster-AGS-RHIC accelerator chain. Practically all OPPIS systems were modified (in addition to the ECR-source): a new superconducting solenoid; new He-ionizer cell with a pulsed He-injection and new pulsed electro-dynamic gas valve; beam energy separation system developed for un-polarized residual beam suppression; new vacuum system with turbo-molecular pumps for He-pumping; laser control, diagnostics and transport systems. LEBT was modified to reduce losses of high-intensity beam and increase energy resolution for better suppression of residual un-polarized beam component. The performance of new source in Run 2015 is presented in Table 1 (Rb-cell thickness **NL**$\times 10^{13}$ atoms/cm^2. Linac pulse duration-300 μs. Booster input $\times 10^{11}$ ions/pulse):

Table 1.

Rb-cell thickness, **NL**	4.5	5.5	7.5	10.4
Linac current, **μA**	500	560	680	750
Booster input, $\times 10^{11}$	9.0	10.0	12.2	13.5
Polariz. at 200 **MeV**, %	84.0	83.0	80.5	78.5

Very reliable operation and reduced maintenance time was demonstrated. Already in the first year of operation in Run-2013 the new source performance exceeded the old ECR-based source parameters and performances were further improved in Runs 2014-15 (see Fig.2). High beam current, brightness and polarization resulted in 75% polarization at 23 GeV out of AGS (due to beam emittance reduction by strong beam scraping at extraction from Booster) and 60-65% beam polarization at 100-250 GeV colliding beams in RHIC.

3. Polarization

In the RHIC complex, there are two absolute proton polarimeters: the elastic proton-Carbon polarimeter at beam energy 200 MeV and the CNI proton-proton H-jet polarimeter at the RHIC store energies of 23-255 GeV [3]. The polarization of the 200 MeV beam is 80-84% and was measured with an accuracy of better than 0.5%. The H-jet polarimeter measures the average polarization over the whole beam intensity profile. The polarization transport simulations show that depolarization occurs at the edge of the beam and polarization of the beam core (center of the beam intensity profile) should be preserved during acceleration. Polarization distribution across the beam intensity profile (beam polarization profile) is measured by the scanning p-Carbon CNI polarimeters in AGS and RHIC [4]. These measurements produce complimentary information to the H-jet polarimeter on polarization losses along the accelerator chain. The knowledge of polarization profiles of both beams are also required for calculation of the polarization values for colliding beams, which are used for the normalization of experimental spin asymmetries [5].

The polarization profiles at 200 MeV after the Linac and after the Booster at injection to AGS are flat, which is consistent with no losses in Booster after the careful tuning of the orbit harmonics. In AGS the use of two partial helical snakes and Jump Quads greatly improved the polarization preservation, but still there are some losses depending on beam emittance. The non-flat polarization profiles at AGS flattop energy were measured by CNI polarimeters in AGS and at injection to RHIC. The AGS polarization vs. beam intensity is presented in Fig. 3. Polarization in excess of 70 % was achieved at beam bunch intensities up to 2.4*10^11. Extrapolation to zero bunch intensity gives polarization value about 80%, which is close the polarization value measured in 200 MeV polarimeter, as expected, from polarization loss model. Polarization profiles were also measured at different beam intensity and also are consistent with polarization loss model.

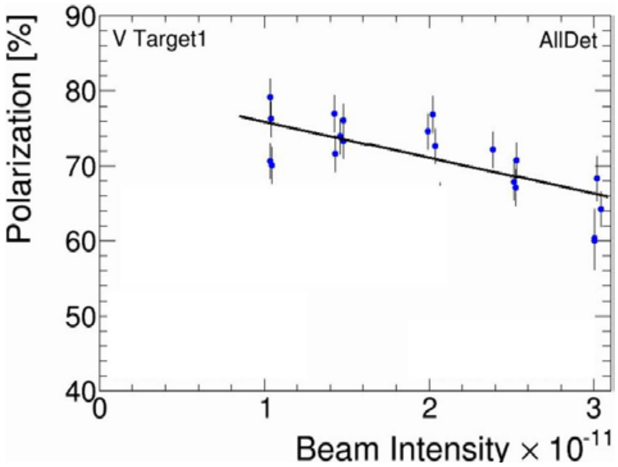

Fig.3. AGS polarizations dependence vs. bunch intensity.

The knowledge of absolute polarization measurements at different beam energies is very important for understanding of the polarization losses during acceleration and transport in the RHIC accelerator chain: Source-Linac-Booster-AGS-RHIC. The combination of polarization transport simulation in AGS and RHIC and absolute polarization measurements tools at 200 MeV and RHIC store energies provide complimentary information on polarization losses along the RHIC accelerator chain.

A number of major upgrades were completed for Run-2015 to improve H-jet performances and reliability: a new high-purity hydrogen gas generator (palladium based), a new set of RF transition power supplies. As a result H-jet operation at high beam intensity increased to two weeks between the maintenances.

Limitations of p-Carbon polarimeters operation at high beam intensity increased the value of H-jet polarimeter measurements. A new Si-strip detectors were developed for Run-2015 to statistical errors by about 1.5-2.0 times due to larger solid angle and extended kinematic range. Extended kinematic range also provide better handle on systematic errors contributions.

Data acquisition upgrade with new WFD took advantagec of the higher energy resolution and also improved the background discrimination.

Figure 4 shows the H-jet measured polarization for all RHIC fills in Run 15. The Yellow ring polarization was 2-3% higher as expected from polarization direction mismatch in between AGS and RHIC rings. In addition stronger polarization decay was observed in Blue ring, in particular at the end of the Run. Also intermittent polarization losses were observed in AGS at high beam intensity, perhaps due to instabilities of jump-quad timing.

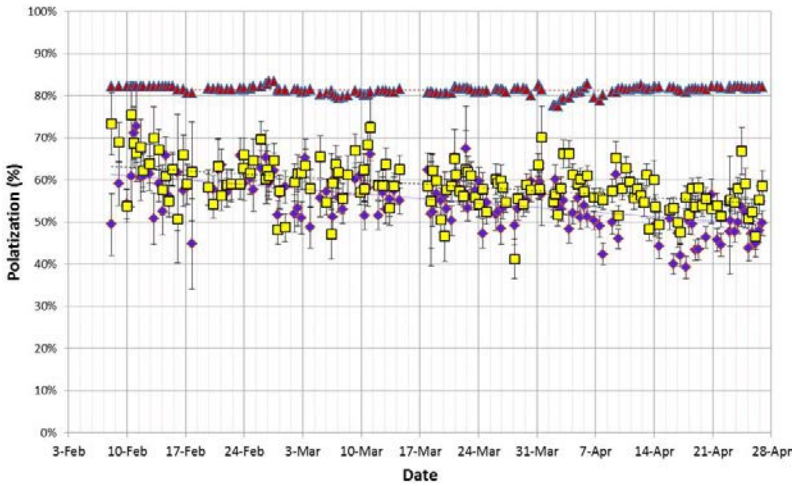

Fig.4. H-jet polarization measurements for pp-collisions in Run-2015.

4. Summary

The high-intensity polarized source and improvements in the injector chain and RHIC have allowed operation at higher bunch intensities and lower emittance. The successful commissioning of the electron lenses resulted in operation at a higher beam-beam parameter and correspond higher luminosity. For the first time polarized proton-Gold, proton-Aluminum collisions. Still there are polarization losses in AGS ~ 10 -15 % (intensity dependence, instabilities) and RHIC ~ 5 -10% (polarization decay, larger with spin-rotators). Polarization in collisions 60-65% achieved at high luminosity operation at: √S =200 GeV.

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