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Operation experience of p-Carbon polarimeter in RHIC

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Abstract

The spin physics program in Relativistic Heavy Ion Collider (RHIC) requires fast polarimeter to monitor the polarization evolution on the ramp and during stores. Over past decade, the polarimeter has evolved greatly to improve its performance. These include dual chamber design, monitoring camera, Si detector selection (and orientation), target quality control, and target frame modification. The preamp boards have been modified to deal with the high rate problem, too. The ultra thin carbon target lifetime is a concern. Simulations have been carried out on the target interaction with beam. Modification has also been done on the frame design. Extra caution has been put on RF shielding to deal with the pickup noises from the nearby stochastic cooling kickers. This paper summarizes the recent operation performance of this delicate device.

INTRODUCTION

RHIC is the first and only polarized collider in the world. During the acceleration, there are possible polarization loss due to snake resonances. In addition, there are also gradual polarization loss during the typical 8 hours physics store. Therefore, fast polarization measurements are essential for the machine setup and physics programs [1]. The absolute polarization of RHIC beams are determined from polarized hydrogen jet [2]. However, the jet can only provide polarization with statistical error bars of 2-3% for a whole store. It is used to provide absolute beam polarization information for physics stores and to calibrate the p-Carbon polarimeter. The p-Carbon polarimeter provides the polarization decay during a store, the polarization profile information for experiments to use, and for possible polarization loss during acceleration.

The p-Carbon polarimeters in RHIC are based on elastic proton scattering with low momentum transfer and measurement of asymmetry in recoil carbon nuclei production [3]. This process has a large cross-section and sizable analyzing power of a few percents which has weak energy dependence in the 24-255 GeV energy range. A very thin (10 $\mu g/cm^2, 5-10\mu m$ wide) carbon ribbon target in the high intensity circulating beam produces high collision rate and a highly efficient DAQ system acquires up to 7×10^6 carbon events /sec. The details of the design and construction are described in Ref. [4]. A schematic of the chamber is shown in Fig. 1.

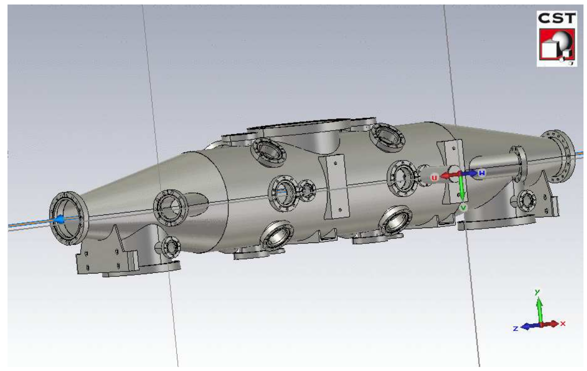

Figure 1: The 3D drawing of the polarimeter chamber. The taper structure (5:1) is to reduce the impedance impact on the overall RHIC ring impedance budget. The two view ports on both taper structure are used to monitor the target operation with remotely accessible cameras. The big view port on the top is for target installation and target motion monitor. Three cameras are mounted on these view ports to monitor the polarimeter target operation. There are two sets of six Si detectors ports surrounding the chamber on both sides of the big view port. There are six targets in both vertical and horizontal directions for each set.

TARGETS AND VACUUM CHAMBER

The use of thin target in polarimeter is essential to reduce multiple scattering for recoil carbon ions and also keep the event rate within the detectors and DAQ capabilities. Manufacturing of the ultra-thin carbon (amorphous graphite) targets requires high skill and is a time-consuming process [5]. To increase the yield of target production, the target thickness for last a few runs were at 10 $\mu g/cm^2$, instead of 5 $\mu g/cm^2$. The higher rate can be compensated by smaller Si detector strip size. As intensity increases over years, the target loss rate is higher. Cameras were installed before 2013 run. Camera videos show that the targets tails are glowing when crossing beam or even at park position, if it is near beam. About 2/3 of broken targets were broken at the tails instead of center where beam hits. This leads to hypothesis that the heat generated by the induced current on the target is the culprit [6]. The RF voltage is reduced during polarization measurement to prolong the target lifetime, as induced fields are weaker with longer bunch. Round shape fins are added this year based on the experiment test last year year. The preliminary results show that the target lifetime is prolonged, even though the glowing light is not completely eliminated.

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Two identical polarimeter vacuum chambers are located in the warm RHIC sections which are separated for the two circulating beams and have the separate vacuum systems. Due to the complexity of the chamber and the electronics, it is not practical to bake the chamber. To meet the RHIC vacuum requirement all polarimeter components were carefully measured for out-gassing rates. The high out-gassing rate ceramic material is replaced with low out-gassing rate material. A NEG (Non-Evaporable Getter) cartridge pump is added to each chamber to provide additional continuous pumping. As a result, the pump down speed is greatly improved. Due to limited lifetime of the thin targets, it is inevitable to replace targets during a normal 20 weeks physics run. A high intensity physics store can be resumed within 24 hours (vacuum down to 10^{-8} Torr). RF shielding meshes are added on the Si detector ports to make the chamber surface smooth. All front-end electronics are hosted by metal boxes to shield the RF noises generated from nearby stochastic cooling pickup devices.

DETECTORS AND ELECTRONICS

The time-of-flight and recoil carbon energy measurements are required for elastic scattering identification. The silicon-strip detectors are used in the polarimeters since they allow measurements of energy and arrival time of Carbons in the RHIC ring vacuum environment. The late arrival time of the recoiled carbons is advantageous since the detection can be done in almost noise-free environment after all beam-induced disturbances are gone. Three pairs of detectors sitting at 90° and 45° allow measurement of both transverse polarization components (vertical and radial).

In Run9, significant rate problem was encountered when the polarimeter was first used for 250GeV operation. The problem was traced down to preamplifiers. the charge sensitive preamps were replaced with current sensitive ones. To cur event rate per Si strip, the smaller strip size (1mm) was tested. Currently, two sizes of Si detectors are used, 1mm and 2mm ones. Due to better resolution of 1mm detectors, one pair of 1mm detectors are mounted with strips perpendicular to the beam moving direction for each polarimeter to monitor the target looseness and to provide systematic effects on the asymmetry due to energy loss in the targets. The downside of 1mm detector is the gain jumps.

POLARIZATION MEASUREMENTS

Typical RHIC physics store is 8 hours. Polarization is measured in both rings at the beginning of the store and every 2-3 hours. Past experience shows that there are some gradual polarization losses over the store. The losses are driven by some high order depolarizing resonances, which are very weak but do show effect in the long time scale. Since every polarization measurement causes some beam loss ($<$0.5%) and physics run has to stop, we compromise to measure polarization every 2-3 hours.

Larger amplitude particles experience stronger depolarizing resonance effect and have lower polarization. Polarization profiles, i.e., variation of polarization value versus betatron amplitudes, develop during beam acceleration and storage. These profiles affect the observed polarization and polarization weighted luminosity.

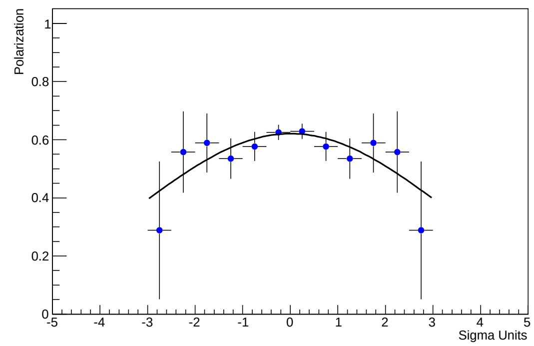

Figure 2: The polarization profile from a single measurement at store. The horizontal axis is in unit of beam size sigma.

The fast polarimeter can measure the polarization profile which is important to determine the actual polarization seen by physics experiments [7]. The carbon target width is much smaller than the beam size therefore intensity and polarization profile can also be measured. The polarization measurement usually is done by a profile measurement with target scanning through the beam. Polarization profiles were measured in RHIC beams. Part of these profiles is produced in AGS (which was measured directly in AGS). There are also some possible polarization profile generation in RHIC on the ramp and during the store. The effect depends on accelerator parameters and can be different for two rings. One example of polarization profile measurement is given in Fig.2 for blue ring.

The RHIC collision experiments are sensitive to the convolution of the two beam polarization and polarization profiles. Therefore, all polarization measurements for the physics stores were done in the scanning mode and polarization profiles were measured and correction to the polarization values as seen by the experiments were implemented [8]. During Run 2012, an increased target loss rate was observed. To investigate this problem video cameras were installed to watch the target motion during the scan. Strong target deformations were observed (see Fig.3). This picture clearly shows that due to the target-beam interaction the excess length of loose targets is attracted into the beam. This changes the amount of target material interacting with the beam. Larger numbers of events are coming from the beam core (with the higher polarization) due to target deformation. These effects corrupt the polarization profile measurements.

The fast polarization measurements were also used on the acceleration ramps in RHIC. The RHIC energy ramp is about 300 seconds for 250 GeV. The sufficient statistical

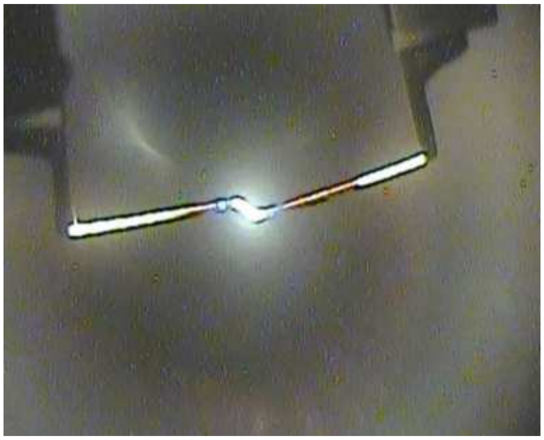

Figure 3: Polarimeter target deformation at store due to electrostatic interaction with proton beam. The electric fields are stronger due to smaller beam size and higher beam current. The whole chamber is lighted.

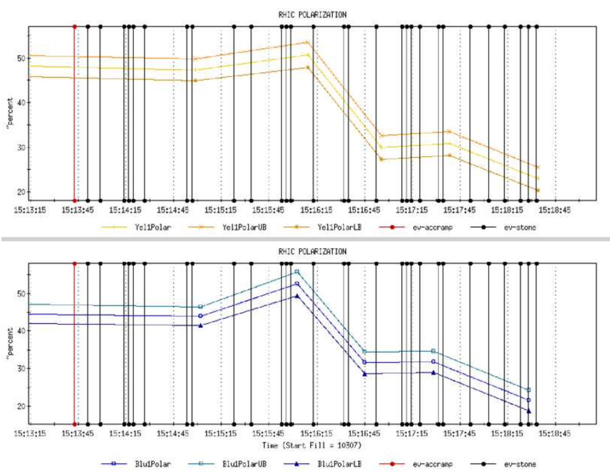

Figure 4: Polarization measurements on ramp. The vertical lines are step stones on the ramp to define energy, optical parameters. The dense lines usually indicate strong depolarizing resonance locations.

accuracy can be obtained in a single ramp. These measurements were especially useful in the development of the 250 GeV energy ramps, where the polarization loss at strong intrinsic resonances at several energy ranges was observed in the ramp measurements. One example during 250GeV acceleration setup is shown in Fig. 4. Several measurements done on the ramp clearly pinpointed the locations and amount of polarization losses, which is vary helpful for accelerator setup [9].

BEAM PROFILE MEASUREMENTS

In a scanning mode of polarimeter operation the counting rate dependence on the target position can be used for the beam intensity profile measurements in addition to polarization measurements. Every elastic event has a time stamp attached and each event is sorted by the bunch crossing. With the high event rate, a large statistics can be accumulated in a short time (of a few hundred milliseconds for the target scan through the beam), which were used for bunch-by-bunch beam profile (emittance) measurements. Due to target deformation in the beam, good beam profile is not a given. For fewer bunches or very straight targets, polarization measurements can give beam profiles, even bunch-by-bunch. One example is shown in Fig. 5 for 2.4×10^{13} total intensity. Overall fit to a Gaussian is in the bottom left plot. The top right plot shows the sigmas of each of 111 bunches. The sigmas of the first 15-20 bunches are larger due to the residual kicks from the injection kicker magnet.

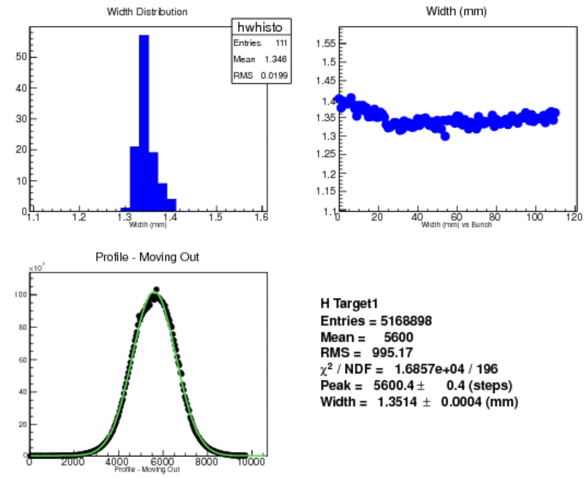

Figure 5: Emittance measurement in Blue ring. The profile at left bottom is for all 111 bunches, the beam width on the right top is for all individual bunches.

SUMMARY

The pC CNI polarimeters at RHIC provide fast, polarization and polarization profile measurements. It can also measure beam profile, but the quality of beam profile depends on the target stiffness. The analyzing power of this polarimeter has been calibrated by the simultaneous polarization measurements in the absolute H-jet polarimeter.

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