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Studies and proposed changes to the RHIC p-Carbon polarimeters for the upcoming RUN-11

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Abstract. The RHIC polarized proton complex utilizes polarimeters in each of the Blue and Yellow beams that measure the beam polarization through the p-Carbon elastic scattering process in the Coulomb Nuclear Interference kinematic region. This along with a Polarized Hydrogen Jet Target that utilizes the proton-proton elastic scattering process to first measure the analyzing power of the reaction and using the reverse process to measure the beam polarization. The latter is used to calibrate the p-Carbon polarimeters at the desired beam energy. In Run 9 RHIC ran with beams at center-of-mass energies of 200 and 500 GeV respectively. The higher beam intensities as well as the fact that the 250 GeV beam size is much smaller than that at 100 GeV resulted in significantly higher rates seen by the polarimeters and led to observed instability. In this paper, we will discuss the problems encountered and the tests that were carried out using the AGS as a proxy in an attempt to solve the problems and the path forward we took towards the upcoming polarized proton Run11.

1. Introduction

The choice of pp and p-Carbon elastic scattering in the CNI region was based on the high cross section as well as an estimated analyzing power of the order of 4% and 3% respectively, Figure 1. While the electro-magnetic component is precisely calculable, the contribution from the hadronic single spin flip amplitude is not well known but was expected to play a less important role as the beam energy increases [1]. In order to get around this problem it was decided to utilize a polarized hydrogen jet target the polarization of which was measured using a Breit Rabi polarimeter [2], measure the analyzing power of the pp elastic scattering and use the identical particle condition namely:

$$\varepsilon_{beam} = A_N \cdot P_{beam}$$
$$\varepsilon_{target} = -A_N \cdot P_{target}$$

Where ε_{target} and ε_{beam} are the measured raw asymmetries when considering the target (jet) and beam polarization respectively and A_N is the analyzing power in pp elastic scattering. Thus

$$P_{beam} = -\frac{\varepsilon_{beam}}{\varepsilon_{target}} \cdot P_{target}$$

Which in turn provides the absolute beam polarization directly and in effect a calibration mechanism for the p-Carbon polarimeters, running simultaneously, at any energy.

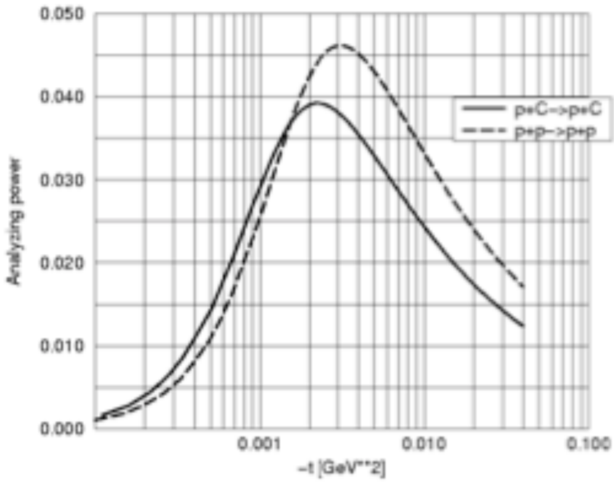

Figure 1. The Analyzing power in pp and p-Carbon elastic scattering.

The RHIC p-Carbon polarimeters [3] consist of a vacuum vessel in which several thin carbon targets are mounted on a special target drive operated by a motor to select horizontal or vertical targets for scanning across the beam to measure both the beam polarization and beam polarization profile. Carbon targets 5-10 um wide and 5 ug/cm2 thick are mounted on ladders and surrounded by three pairs of silicon detectors that are mounted at approximately 18 cm away with one pair at 90 degrees in the horizontal plane and the other two at + /- 45 degrees above and below, Figure 2. Each beam has a pair of polarimeters systems and allows redundancy and a venue to test detector upgrade concepts.

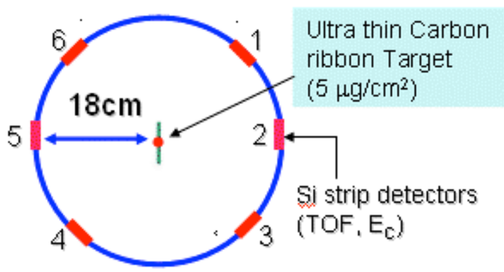

Figure 2. A beam view of the silicon detectors in the RHIC polarimeters.

The silicon detectors, manufactured by the BNL instrumentation division, comprise 12 strips each and independently measure the scattered recoil carbon energy and time of arrival. The silicon detectors energy response is calibrated using americium sources that emit alphas with energy of 5.5 MeV. The large elastic cross section provides a fast measurement of the left right asymmetry and thus the degree of beam polarization with 2% statistical accuracy in less than one minute. The polarized jet target is located within 100 meters from the polarimeters and using Hamamatsu silicon detectors calibrated using americium as well as gadolinium (3.2 MeV) alpha sources, alternately measures the absolute beam polarization to better than 5% in an 8-hour store at a beam energy of 250 GeV. Thus it takes a few stores to calibrate each polarimeter. The jet measurement, on the other hand is limited by the unpolarized molecular hydrogen background that, at this stage, is estimated at 3% and contributes a systematic accuracy of the order of 2% [4].

2. The experience in Run 9

RHIC Run 9 comprised running at two beam energies, the traditional 100 GeV and for the first time at 250 GeV, the goal of the latter being the first measurement of the longitudinal asymmetry in $W^{+/-}$ production.

The increased bunch intensity coupled with the fact that the beam size is significantly smaller at the higher energy, the p-Carbon polarimeters witnessed some instabilities and rate effects. These were seen as a shift in the measured Carbon mass as well as possibly baseline shifts. Several studies were carried out to discern the causes which we suspect is due to the fact that the preamplifier and shaper that was employed to readout the silicon detectors utilized a charge sensitive amplifier with a 7 usec decay time, that along with the shaper allowed for a dynamic range of about 2 MeV/usec and did not allow sufficient recovery time at high rates within the 106 nsec time window between bunches.

Having realised this as the potential problem, two approaches were then pursued in an effort to ameliorate the situation. One comprised the development of a current sensitive amplifier (it should be noted that this option was passed over in the early stages of designing the polarimeter readout for fear of noise issues). This was a fast amplifier with full pulse duration of about 30 nsec. The second approach was to use a commercial MSI-8 charge sensitive preamplifier with a decay time of about 1 usec but with a factor of 10 higher dynamic range compared to the preamplifier discussed above. Unfortunately, there was no polarized proton running scheduled for RHIC Run 10, thus we reverted to testing the two new approaches using the AGS.

3. The AGS as a test bed

The AGS polarimeter was reconfigured as a test set up of the new approaches, Figure 3. The 90 degree arms had the conventional old style RHIC polarimeter readout system, while each of the 45 degree arms were then equipped with a) the current sensitive preamplifier approach read through the original WFD system, and b) the new commercial MSI-8 charge sensitive preamplifier/ shaper approach read through a separate ADC / TDC system.

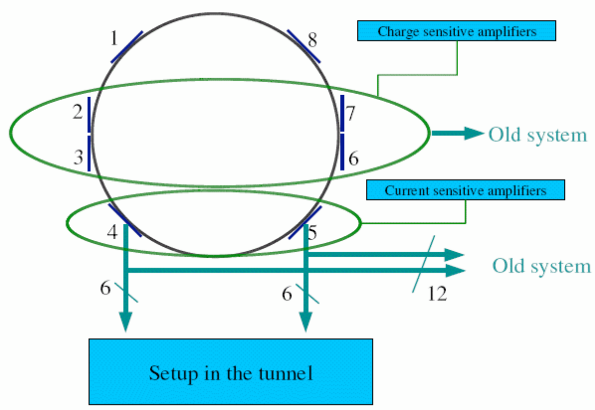

Figure 3. A beam view of the arrangement of the test set up in the AGS polarimeter. Locations 1and 8 had new Hamamatsu photodiode detectors connected to the new charge sensitive MSI-8 preamplifier and ADC/TDC system.

As an injector for RHIC, the AGS circulates one bunch at a time with a maximum intensity of $2x10^{11}$ protons. In order to emulate as closely as possible to the RHIC conditions, the AGS RF system was reconfigured to circulate as many as 12 bunches with a maximum intensity of 1.5×10^{11} per bunch each. The time between bunches was 240 nsec compared to the 106 nsec in RHIC. However and in an effort to stress the system rate wise, we utilized significantly thicker carbon targets.

In addition, and to test the effect of the signal degradation (reduced pulse height and spread) due to the long cables from the tunnel to the counting house (~300 ft) we also set up a parallel readout in an alcove inside the AGS tunnel with cable lengths of some 40 ft. The tests provided:

- A comparison to assure the measured polarization with all three systems yield identical results
- A stress test and comparison between various systems
- For the current sensitive preamplifier system, a comparison between short and long cables and at the same time whether one needs pulse integration or pulse height only
- An effort to establish a T0 (start time or time for an infinite particle traversal) by having a pair of silicon detectors at two distances from the carbon target (32.3 and 104.9 cm respectively)
- Test the effect of dead time on the triggered ADC/ TDC readout system

Unfortunately, the ADC/TDC polarimeter set up suffered some significant RF noise problems primarily due to an insufficient grounding scheme on the ceramic board used to anchor the Hamamatsu detectors and rendering a few channels usable with full analog pulse investigation. The rest of the tests with this system utilized a high discrimination threshold and a scalar readout scheme.

An open readout configuration without any cuts shows the relative rates seen by the detectors are shown in Figure 4.

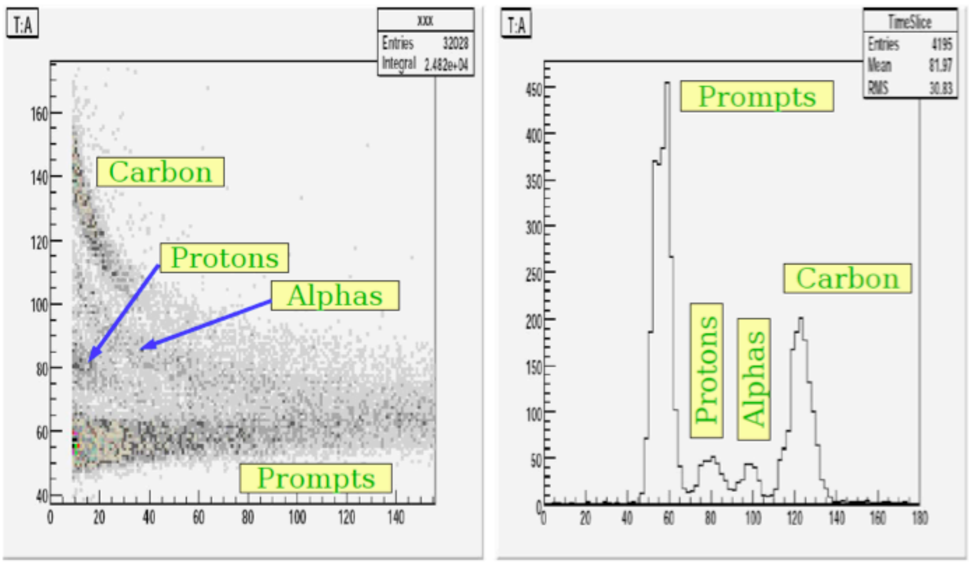

Figure 4. The time and energy spectrum and the relative rates of various particles detected by the silicon detectors with the proton beam impinging on the carbon target. It should be noted that for beam polarization measurements, the species of interest are the elastically scattered recoil carbons

A comparison of the pulse shapes between the old charge current preamplifiers and the new current sensitive design is shown in Figure 5.

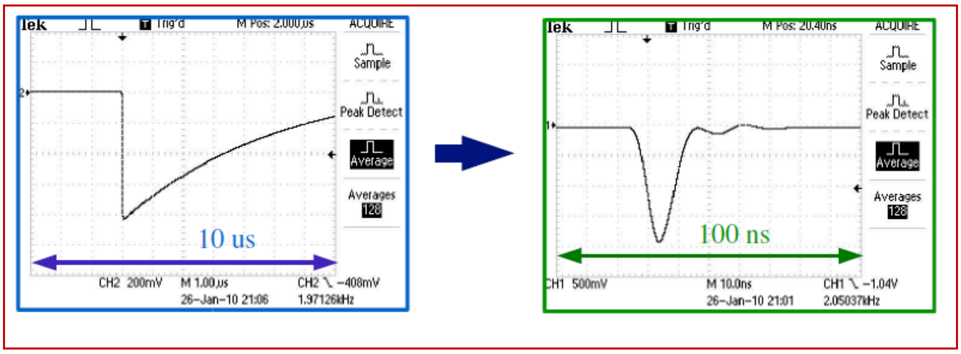

Figure 5. A comparison between the old and new preamplifier systems. The faster amplifiers should allow batter baseline recovery and thus rate capability.

The high rate stress tests yielded some definitive answers in that they reproduced the problems experienced at RHIC with the old charge sensitive preamplifier readout while the current sensitive system scheme did not suffer comparable rate problems, Figure 6.

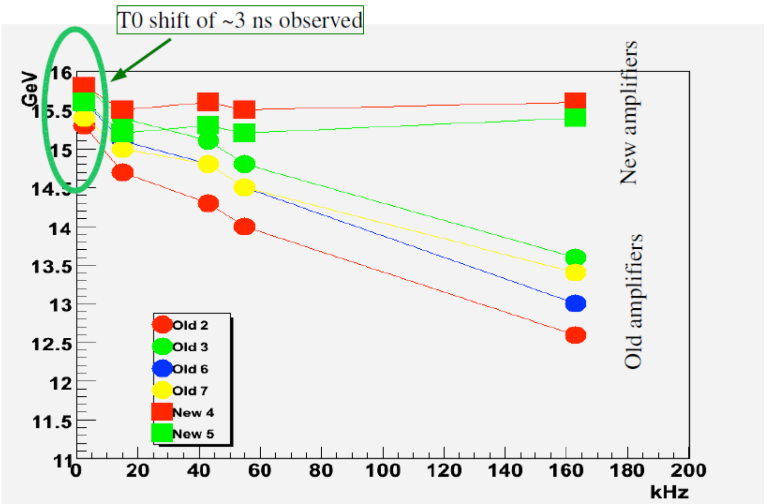

Figure 6. The recoil Carbon mass as determined from the ToF and energy measurement vs. the observed rate per silicon detector strip. The current sensitive preamplifiers "new" seem to have survived twice as high a rate as that seen at RHIC. The charge sensitive preamplifier "old" did not as the measured energy was affected by rate.

The commercial charge sensitive MSI-8 preamplifier / discriminator system seems to also have survived the high rate problem in scalar mode only. Studies on this system will continue in the AGS next year with a new design of the ceramic board grounding scheme.

In a test setup using carbon beams from the BNL Tandem Van de Graph the Hamamatsu detectors seem to attain better energy resolution that the BNL made detectors. Figure 7 shows a representative carbon banana (time vs energy) plot that shows a clean signal to lower energies. That being the case, one hopes of reaching lower t and thus higher analyzing power. More work is needed to complete this effort.

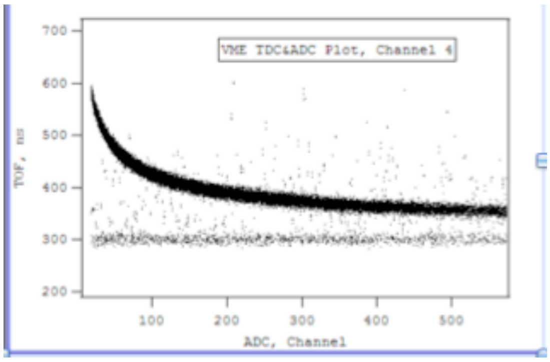

Figure 7. The time of flight vs energy distribution from the Hamamatsu photodiode detectors indicating little background under the elastic scattering Carbon signal.

4. The polarized hydrogen jet target

RHIC Run 9 represented the first time when the polarized hydrogen jet target ran with two beams incident of the target simultaneously. Aside from the increased efficiency, this was fortuitous as the instabilities experienced by the p-Carbon polarimeters made the jet the polarimeter of last resort to provide a decent statistical beam polarization assessment on a fill-by-fill basis. At 250 GeV this provided a 5% statistical accuracy in an 8 hr fill while at 100 GeV the accuracy was 7% in a 6 hr fill.

The analyzing power in pp elastic scattering has been measured using the jet at various energies: 24, 31, 100, and 250 GeV respectively [5], [6]. While the underlying physics processes, namely the hadronic single spin flip amplitude, may change, the overall analyzing power seems to be rather constant over this range, Figure 8.

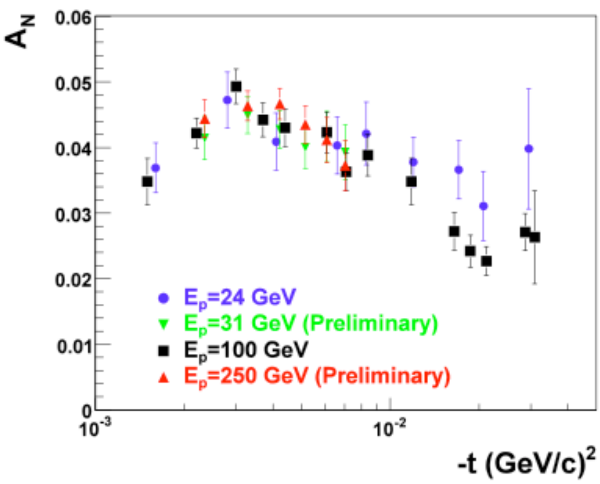

Figure 8. The measured analyzing power in pp elastic scattering vs. t (4-momentum transfer) at various incident beam momenta. The data from 24 and 100 GeV were collected in 2006 [5], [6] using a different silicon detector configuration positioned to one side to access the larger t region.

With RHIC running at 100 GeV per beam in several runs, the respective Jet measurements indicate some inconsistency beyond the statistical errors to the extent that we believe the systematic errors are closer to 5%. We are examining these issues (See Bazilevsky in these proceedings) and plan to carry out targeted studies in Run 11 to assess the sources of such variations. This will be needed if 1-2 % accuracies are desired as called for eRHIC physics for example [7] (E. Aschenauer these proceedings).

5. The path forward towards RHIC Run 11

RHIC Run 11 is scheduled for a 10 week run with 250 GeV polarized proton beams. Towards that end we have opted for the following polarimeter configuration:

- Each ring will be equipped with two polarimeters. One of the polarimeter utilizes (on all 6 stations) a set of BNL-fabricated silicon detectors readout with the new current sensitive preamplifiers. The other polarimeter will use the same BNL silicon detectors at the 45 degree positions while the 90 degree positions will be reserved for yet another set of Hamamatsu photodiode detectors albeit with a smaller area.
- Using a multiplexer system allows one polarimeter in each ring to be readout through the conventional system along 300 ft long signal cables to connect to the shaper boards and then to the CAMAC WFD channels.
- The other polarimeters will be readout using a DAQ set completely inside the RHIC tunnel. This uses short 40 ft long signal cables to the specially prepared shaper used as amplifiers / attenuators (for alpha calibration) and then fed to a similar WFD system. A diskless PC is also used to readout the CAMAC WFD channels in the tunnel. This system is equipped with an APC remote power turn on/ off switching should the need arise to reset the system without entry into the tunnel. This arrangement is meant to test the system susceptibility to radiation.
- This configuration allows us to revert all poalrimeters to either system (inside or outside) should the need arise.
- In Run 9 we had quality control problems with carbon target thicknesses, using new production masks and selecting the desired targets widths has ameliorated this. We also installed a number of carbon targets produced through the laser ablation process at TRIUMF using a 10-watt laser power that seems to result in better quality control. The hope is to compare the two target production schemes. A BNL R&D effort is underway to see if such targets can be produced using a 1-watt laser.
- In an effort further study timing and preamplifier baseline stability, test pulses have been introduced and readout within the same time and energy window through the WFD system concurrently with the regular channels.
- Ramp measurements software has been upgraded to better monitor the system during and after data taking.
- In addition, scintillation detector sandwiches are employed to look at prompt particle production in an effort to monitor the stability of the start timing signal T0 when the bunch arrives.

The writing of this paper coincides with the RHIC polarimeter installation process for Run 11, which is nearing completion. A fair part of the apparatus has been installed and the software and multiplexer systems have been subjected to dry-run tests. We are confident that we have put in place a system that offers better stability than what we have experienced in the past. Of course, the true tests will commence when we have beam in RHIC

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