LUMINESCENCE BEAM PROFILE MONITOR FOR THE RHIC POLARIZED HYDROGEN JET POLARIMETER*

N. Luciano, A. Nass, Y. Makdisi, P. Thieberger, D. Trbojevic, and A. Zelenski,
Brookhaven National Laboratory, Upton, New York 11901

Abstract

A new polarized hydrogen jet target was used to provide improved beam polarization measurements during the second polarized proton run in the Relativistic Heavy Ion Collider (RHIC). The luminescence produced by beam-hydrogen excitations was also used to test the feasibility of a new beam profile monitor for RHIC based on the detection of the emitted light. Lenses, a view-port and a sensitive CCD camera were added to the system to record the optical signals from the interaction chamber. The first very promising results are reported here. The same system with an additional optical spectrometer or optical filter system may be used in the future to detect impurities in the jet, such as oxygen molecules, which affect the accuracy of the polarization measurements.

INTRODUCTION

The present polarized proton 'spin physics run' in RHIC produces collisions at 200 GeV between two beams. To improve the accuracy of spin measurements of the two RHIC beams ('blue' and 'yellow'), a special hydrogen jet system was built and installed at the "12 o'clock" interaction region (IR). This report is about an attempt to obtain the beam profile from the interactions between the two polarized proton beams with the hydrogen jet target. Luminescence beam profile monitors are already in use in high energy colliders [1]. Although the beam profile is a primary goal of this project, future measurements of the optical signals, not only from hydrogen but also from possible 'impurities' such as oxygen or water molecules, make this experiment unique. This would allow parasitic and continuous monitoring of the composition of the jet by observing the "impurities" optical signal strengths in real time and to make corrections as needed.

Organization of the report:

The next section describes the setup used during preliminary measurements, which were performed prior to the installation of the hydrogen jet in the RHIC tunnel. Properties of the hydrogen jet are described in the subsequent section, and the experimental layout is presented in the third section. Summary with conclusions follow the experimental results.

BENCH MEASUREMENTS

The polarized hydrogen jet system was set up in the laboratory and was in operation long before the start of the RHIC polarized proton run. This year a few additional units were added, some on to the proton beam ports, to better characterize the hydrogen jet properties and to prepare for the profile monitor test. One of the additional items was an optical lens and view-port installed at 45° with respect to the direction of the proton beams. The hydrogen jet was characterized by either a residual gas spectrometer (RGA) with the ionization chamber placed close to the jet, or by a mass spectrometer with an ion extraction system placed again close to the jet. An electron gun was built and used to create ions from the jet's neutral atoms and molecules. Four different set-ups were tried to detect the optical signals from the electron-jet de-excitations: a small spectrometer with a built-in CCD camera providing the entire visible spectrum at once, a standard monochromator with motorized grid rotation and photo-multiplier behind the slits, a standard CCD camera with a large acceptance lens, and a hydrogen spectra narrow band-pass filter with the lens connected directly to the photo-multiplier. Due to the large background present, we were not able to distinguish clearly the excitation signals. Although peaks of three hydrogen lines were detectable at $\mathbf{H}_\alpha$ = 656.2nm, $\mathbf{H}_\beta$=486.1 nm, and $\mathbf{H}_\gamma$= 434 nm, there was no difference in signal strength with the jet off and the jet on. After the jet was installed in the RHIC tunnel, a bench setup with a cooled CCD camera designed for astronomical measurements was used. The set-up was configured so that an optical camera lens at the correct distance would produce a clearly focused image of a standard resolution chart produced as presented in Fig. 1.

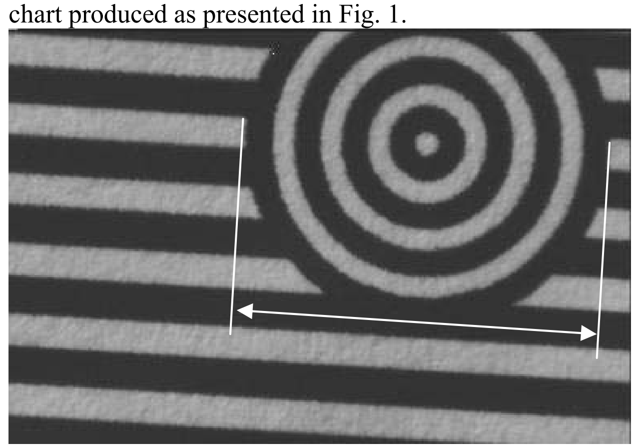

Figure 1: Calibration of the camera: the diameter of the largest circle is 10 mm. The entire picture is 384x256 pixels giving a calibration of 22 pixels/mm.

POLARIZED HYDROGEN JET

A state of the art hydrogen-jet polarimeter has been built and used for the absolute polarization measurements

*This manuscript has been authored by Brookhaven Science Associates, LLC under contract No. DE-AC02-98CH1-886 with the U.S. Department of Energy.

 0-7803-8859-3/05/$20.00

in RHIC. It is based on elastic proton-proton scattering in the Coulomb-Nuclear Interference (CNI) region. Due to particle identity, polarization of the accelerated proton beam can be directly expressed in terms of proton target polarization. The measurements are used for calibration of the other carbon target polarimeters. The polarimeter target is a free atomic beam, which crosses the RHIC beam in the vertical direction. A polarized atomic beam source produces the H-jet target of 1.2 x 10^{12} atoms/cm^2 thickness. The profile of the atomic beam measured by a compression tube technique [2] is presented in Fig. 2.

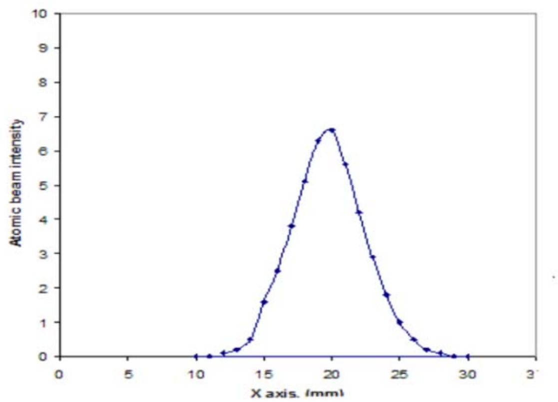

Figure 2: Measured atomic beam profile at the collision point. FWHM=5.5 mm

EXPERIMENTAL LAYOUT

The interaction of 100 GeV protons with the 'target' of atomic hydrogen produces hydrogen ions, or hydrogen atoms with excited electron states. The de-excitation is used to detect the optical signals at 45^{o} angle with respect to the path of both proton beams ('blue' and 'yellow') traveling in opposite directions.

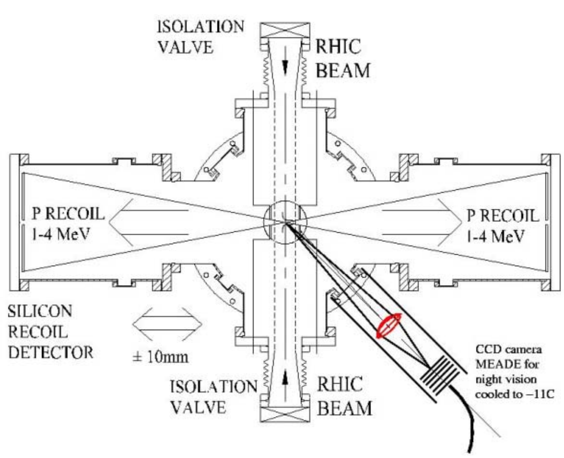

Figure 3: The layout of the optical set-up at the polarimeter.

The cross section of the layout is shown in Fig. 3. Inside the chamber there is a 60x60mm copper shield along the axis of the RHIC beam path. The left and right faces of this shielding are RF mesh wires with a diameter of 0.762 mm and a vertical spacing of 3.175 mm. These wires were used in the experiment to calibrate the measurement of the beam and jet profiles. The first attempt in the experiment with a standard CCD camera was not successful. Replacing the camera with a more sensitive one (Meade Pictor 416) resulted in very nice beam profiles, even with exposure times as low as one-second. This camera is equipped with a thermoelectric cooling system that uses the Peltier Effect. The temperature of the CCD chip was usually around –12^{o} C.

RESULTS

The first picture of both RHIC beams was observed during the RHIC acceleration.

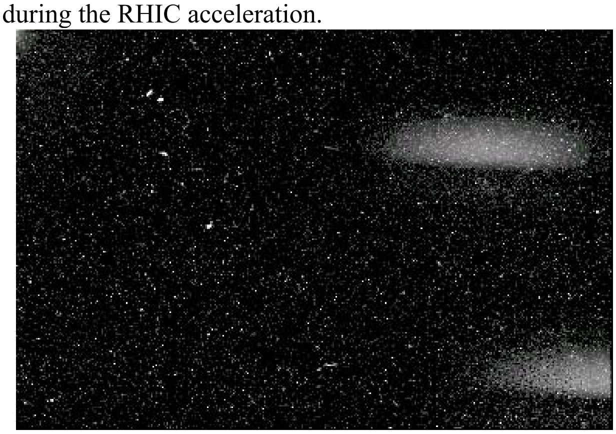

Figure 4: Acceleration of the polarized proton beams to 100 GeV. The camera observed both beams.

A special vacuum valve controls the flow of the hydrogen jet. When the valve is closed it blocks passage of the atomic beam from above. There was no light observed above background as soon as the jet was removed. The measured profile of the jet, as presented in Fig. 2 shows that it is considerably larger than the beam size.

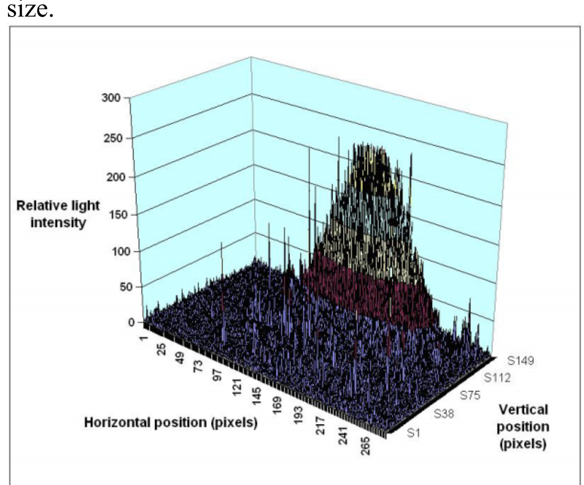

Figure 5: Relative light intensity vs. pixel location.

The polarized proton vertical and horizontal emittances, measured by the ionization profile monitor (IPM) at 100 GeV, were the order of 20 and 30 π mm mmrad, respectively. The vertical and horizontal beam sizes at the jet position are expected to be σ_v=0.56 mm and σ_h=0.68 mm. During the vertical scan we did not expect the observed beam size to be different from the IPM results. This was confirmed in the vertical scan.

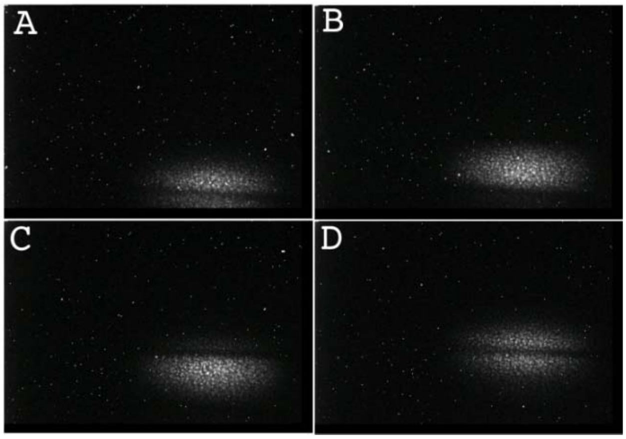

Figure 6: The result of a vertical scan in 1 mm increments shows the beam spot moving accordingly. The wires separated by 3.175mm provided a scale of 23 pixels/mm.

The scans were performed in both planes by using a four-bump through the interaction region. Positions were monitored by the BPM's (Beam Position Monitors). Additional confirmations of our results with the BPMs measurements were obtained by observing the wire mesh positions. They were used as a reference when moving the beam vertically and provided the scale to the image. An additional agreement comes from the bench calibration of the camera using the target placed at the focal length as presented in Fig. 1.

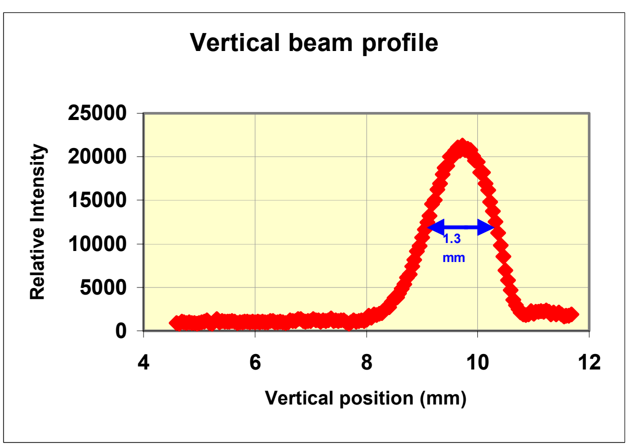

Figure 7: Vertical profile of the polarized-proton beam.

A horizontal scan, as presented in Fig. 8 and Fig. 9 was performed by centering the beam on the jet using the BPMs and sweeping across the jet in each direction. As expected, the image became dimmer for a constant exposure time as the beam was moved away from the center of the jet, becoming very dim at ±4mm. This scan is in a good agreement with the jet profile as measured by the compression tube technique.

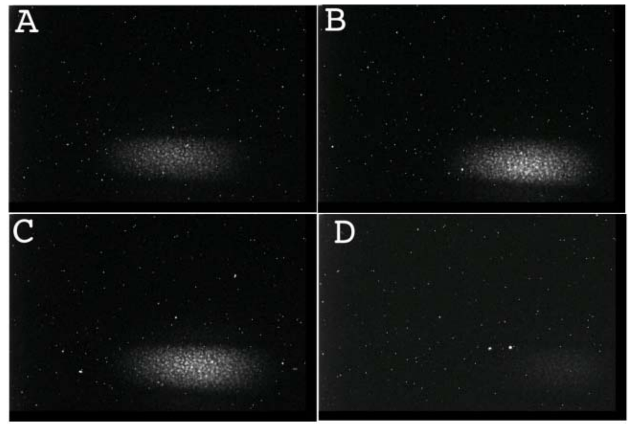

Figure 8: The horizontal beam scan where the beam position measured by the BPM's was: A=-4 mm, B=0 mm, C=+2 mm, D=+4mm.

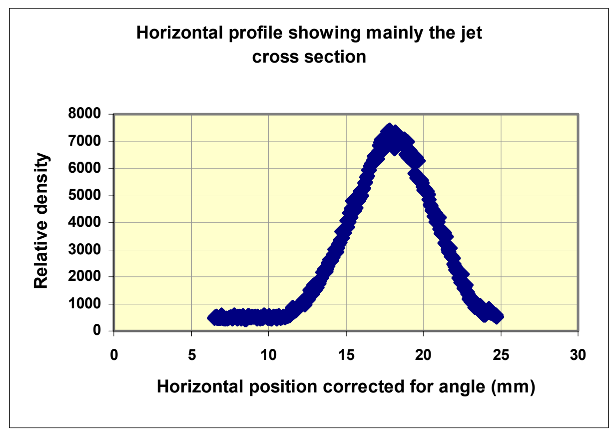

Figure 9: Horizontal profile of the hydrogen jet beam.

SUMMARY AND CONCLUSIONS

The first attempt to obtain the beam profile measurements in RHIC from the proton-hydrogen gas jet interaction was very successful. These very encouraging results show that all additional goals we had previously set like monitoring the jet impurity content and measurement of the optical de-excitation cross section from proton-hydrogen collisions could be achieved. We will also develop a new beam profile monitor in RHIC to monitor beam emittances by building a new small gas jet and optical detection system.

Special thanks to J. Carlson, T. Curcio, D. Gassner, and S. Bellavia for their knowledge and expertise.

REFERENCES

[1] G. Burtin, J. Camas, G. Ferioli, R. Jung, J. Koopman, R. Perret, A. Variola, J. M Vouillot, "The Luminescence Profile Monitor of the CERN SPS", Proceedings, EPAC 2000, Vienna, Austria, pp. 255-258.

[2] A. Zelenski, A. Bravar, D. Graham, W. Haeberli, S. Kokhanovski, Y. Makdisi, G. Mahler, A. Nass, J. Ritter, T. Wise, and V. Zubets, Nucl. Instr. Methods A, 536 (2005) pp. 248-254