POLARIMETRY AND LUMINOSITY ISSUES AT RHIC

GERRY BUNCE
Brookhaven National Laboratory and RIKEN BNL Research Center,
Upton, N.Y. 11973, U.S.A.
E-mail: bunce@bnl.gov

The plans for polarimetry at RHIC are presented, along with a discussion about luminosity measurement and determining the polarization for each experiment from the polarimeter data.

1 Polarimetry at RHIC

From the Polarimetry Workshop in August led by K. Imai and D. Fields (Proceedings with summaries and transparency copies are available from the RIKEN BNL Research Center, rikenbnl@bnl.gov.) we have developed the following plan for RHIC polarimetry:

- Commission polarized beam in 1 ring to 100 GeV (spring 2000), polarimetry: $p + C \rightarrow \pi^- + X$ and $p + C \rightarrow p + C\ CNI$
- First spin physics run, 100 GeV x 100 GeV (spring 2001), polarimetry: $p + C \rightarrow p + C\ CNI$, $p + p \rightarrow p + p\ CNI$, $p + C \rightarrow \pi^- + X$ $(1\ ring\ only)$
- Subsequent spin runs with full luminosity ($320\ pb^{-1}$ for $root(s) = 200\ GeV$ and $800\ pb^{-1}$ for $root(s) = 500\ GeV$, polarimetry: $p + C \rightarrow p + C\ CNI$ and $p + p \rightarrow p + p\ CNI$.

For the π^- inclusive polarimeter we are building a 1-arm device in 1 ring. We have a design for left and right arms (providing much better systematic error control), described by F. Mariam in Spin96, but we have limited funds. (Note that RIKEN is funding the apparatus for spin, and we have been hit by a large reduction in $/Yen.) I. Alekseev gave details of our plan for this polarimeter in the next talk. Also, Y. Makdisi presented a measurement made in November 1997 at the AGS, which indicated significant analyzing power(0.1 to 0.2) for RHIC injection of 22 GeV. The E704 data from Fermilab shows similar analyzing power with 200 GeV protons on a fixed target (hydrogen).[1]

The $p + C \rightarrow p + C$ polarimeter in the Coulomb Nuclear Interference region is a work in progress. The recoil carbon alone would be observed, and the analyzing power is expected to be 0.03 to 0.04. It is necessary for 200-300 KeV carbon ions to escape the target and be measured with time of flight, energy and position. The carbon ions arrive in between the prompt background from adjacent bunches at RHIC. At this time, tests have been performed at the Indiana University Cyclotron Facility and at Kyoto, with kinematics set to study carbon emitted at 200 KeV to 1 MeV. These tests have been very successful and feature ultrathin carbon targets[2] and silicon and microchannel plate detectors. We plan to measure the analyzing power of the reaction at the AGS in the spring of 1999.

The *pp CNI* polarimeter requires an unpolarized hydrogen jet, expected to be provided by Italian collaborators (A. Penzo). Both recoil and forward protons would be observed. The jet would be located at an intersection region to be used by both beams. Roman pots with silicon detectors of the pp2pp experiment would be used to observe the forward proton. Theoretical estimates predict the analyzing power to be 0.04 to $\pm 10\%$ (see the RIKEN BNL Research Center Workshop on Hadron Spin Flip at RHIC Energies, 1997, organized by E. Leader and T.L. Trueman, proceedings available at rikenbnl@bnl.gov).

With a polarized hydrogen jet the beam polarization can be directly related to the target polarization for pp elastic scattering. This is expected to give a few % absolute calibration of the other polarimeters. At the conference we discussed the possibility of also using the electron polarization of the target for a polarimeter based on proton electron scattering, where A_{SL} has a large analyzing power (see D. Toporkov's talk in this session). This approach was suggested by S. Nurushev and collaborators.

We would also like to verify longitudinal polarization at the Phenix and Star intersection regions (see T. Roser plenary talk). A relative polarimeter based on inclusive π^0 production has been suggested by S. Nurushev and the IHEP Group, which could measure both vertical and radial polarization and confirm their absence, vs. the spin rotator settings. An electromagnetic calorimeter would need to be placed after the dipole DX which splits the two RHIC beams.

2 Systematic Error Issues at RHIC

With bunched beam and with each bunch prepared and accelerated to RHIC injection independently, we have a powerful way to eliminate many typical systematic error problems, but we also introduce other problems. The bunch spacing for RHIC will be 100 nsec with a bunch width of about 2 nsec.

We will prepare the bunches to flip the spin every crossing, so that the relative acceptance of any apparatus at any time will be equal for (++) and (+-) spin combination collisions to high precision. However, we cannot assume that the luminosity for (++) and (+-) is the same. In addition, at full luminosity ($2\ x\ 10^{32}\ cm^{-2} sec^{-1}$) we will have 1 interaction per cross. Therefore there is a high probability of 2 or more interactions for a cross, and coincidence-type luminosity monitors will frequently be fooled. Due to the small statistical errors expected (10^{-3}) for some asymmetries (jets) we need 10^8 counts in a luminosity monitor for the data taking period. We have used 4 x 10^6 seconds as the period, and there will be 4 x 10^{13} crosses in this time. Therefore, we plan to use luminosity monitors with small geometrical acceptance (around 10^{-5}) to satisfy the needed counts and not saturate.

Another interesting issue at RHIC is that the experiments collide different combinations of bunches, some of each beam sees an empty bucket in the other beam at an intersection region due to abort gaps (which allow the beam to be extracted quickly if a machine problem occurs), and the average polarization seen by a fixed target polarimeter will not in general equal the average polarization seen at the experiments.

We propose to measure the polarization of each bunch with the polarimeter. The experiments then take the weighted average of the polarizations for the bunches used at the experiment, weighted by the crossing luminosity there:

$$P^+ = (sum\ L_i^+ P_i^+)/(sum\ L_i^+) \tag{1}$$

where the superscript $^+$ represents bunches with positive sign polarization, and L_i^+ is the crossing i luminosity. P_i^+ is measured at the polarimeter and L_i^+ at the experiment. Then the asymmetry becomes

$$A_L = (1/P_{avg})(N^+ - N^-)/[(N^+ + N^-) - (N^+ - N^-)(P_{dif}/P_{avg})] \tag{2}$$

where $P_{avg} = (P^+ + P^-)/2$ and $P_{dif} = (P^+ - P^-)/2$ and P^- is defined as P^+, but for the negative polarization sign bunches. For 2-spin asymmetries, a similar weighting would be done, using the beam-beam polarization combinations P^{++}, P^{+-}, P^{-+}, and P^{--}.

Since we will need to know the polarization of each bunch, left and right polarimeters will be needed to cancel luminosity differences, and the differences in acceptances for the left and right polarimeters will need to be measured, possibly with unpolarized beam.

RHIC will also have the capability to flip the spin of the bunches, with little expected polarization loss. The two beams can also be recogged so that different bunches collide at a given experiment.

References

1. D.L. Adams *et al*, *Phys. Lett.* B **264**, 462 (1991).
2. W.R. Lozowski and J.D. Hudson, *Nucl. Instrum. Methods* A **303**, 34 (1991).