Absolute calibration of the RHIC beam polarization

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Absolute knowledge of the beam polarizations is critical to the entire RHIC spin program, and challenging since no polarization standards exist in this energy regime. To date, beam polarization measurements in the rings have been provided by polarimeters measuring p-C scattering (from ultra-thin targets provided by IUCF) in the Coulomb-nuclear interference (CNI) regime, by assuming the analyzing power for this process to be independent of energy above RHIC injection at 24 GeV. An absolute calibration experiment has now been commissioned by a collaboration comprising Brookhaven National Laboratory, University of Wisconsin and IU physicists. The experiment exploits the indistinguishability of the two protons in p-p scattering, permitting calibration of the beam polarization (hence, of the CNI RHIC polarimeters) against that of a fixed polarized hydrogen gas jet target. As the transverse spin asymmetries for pp CNI scattering are at the 1-2% level, and one must compare the beam and target asymmetries with a precision no larger than ~5% of this small value, the calibration experiment must be performed with careful control of systematic errors. The main IU contribution to date has been systematic error studies influencing the design of the polarized target, recoil proton detectors and data analysis techniques when both beam and target are simultaneously polarized.

Rapid progress on the fabrication and installation of the equipment for the calibration experiment has followed a DOE review held in December, 2002. During the 2004 RHIC run, the equipment was commissioned at the 12 o'clock intersection point of the rings, and used to provide a preliminary calibration during the polarized proton collision operation in April-May 2004. The equipment includes: an atomic beam polarized ion source (ABS), including carefully designed sextupole magnets and RF transition units, to provide the jet; a Breit-Rabi polarimeter (BRP) located opposite the source to measure the atomic beam polarization after it passes through the RHIC beam; a holding field magnet to define the polarization direction for the target and to avoid depolarization by the RF structure of the circulating RHIC beam; scattering chambers extending about 1 m on either side of the target position; silicon detectors to observe the CNI recoil protons; waveform digitizers to record the silicon detector data.

Tests of the ABS and BRP in Fall 2003 revealed excellent performance. The center of the beam was less than 0.7 mm from the original alignment axis of the source. The fringe field at the location of the RF transitions met the adiabatic conditions necessary for a large polarization. Initial polarization measurements with the BRP of 0.94 and 0.95 were recorded for holding field strengths of 1.0 and 1.2 kG, respectively. These values are within 1% of the theoretical maximum at those field strengths, which are only about a factor of two above the proton critical field. Measurements with all the apparatus installed in RHIC have been equally encouraging, revealing low background in the recoil proton spectra and stable asymmetries. The data are currently being analyzed to extract an initial calibration. More extensive measurements are planned for 2005, when it is hoped the goal of a 5-6% absolute calibration will be attained. Further diagnostic measurements on the atomic beam, to determine its molecular fraction, and on the RHIC beam, to assess the conditions under which the beam polarization exhibits a significant dependence on transverse position within the beam at the 12 o'clock location, will precede final calibration. Ed Stephenson will continue to be strongly involved in the upcoming testing and in the study of systematic effects in the extraction of the calibration information.