POLARIZED HYDROGEN JET TARGET FOR MEASUREMENT OF RHIC PROTON BEAM POLARIZATION

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The performance and unique features of the RHIC polarized jet target, and our solutions to the important design constraints imposed on the jet by the RHIC environment are described. The target polarization and thickness were measured to be $0.924 \pm 2\%$ and $1.3 \pm 0.2 \times 10^{12}$ atoms/cm^2 respectively.

Introduction

The jet target was installed in the RHIC beam line for the polarized proton run in spring 2004. During this time the source produced a highly polarized gas target with record thickness for a polarized jet. We required vertical target polarization with a strong (0.12 T) and uniform ($\Delta B/B < 5 \times 10^{-3}$) vertical guide-field. The field uniformity is necessary to avoid depolarizing bunch field induced resonances from the circulating RHIC beam. The source, see Fig. 1, is mounted vertically to allow freedom in the midplane for recoil particle detection near 90°. Nass et al., this conference, describe the conventional design of the source and the measurement of the jet density and polarization. Here we point out some of the unique features we believe are responsible for the record intensity of 12.4×10^{16} atoms/s, significantly higher than the prediction of modeling codes [1,2]. We employed improved RF coupling in the dissociator and pre-cooling of the dissociated gas before final thermal

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accommodation in the usual 2 mm diameter expansion nozzle cooled to 75 K. More details are given in A. Zelenski et al., this conference. Large bore permanent 6-pole focusing magnets allow the beam to expand to 32 mm diameter over an unusually long 650 mm drift length before refocusing to a 5.8 mm FWHM target spot of $1.3 \pm 0.2 \times 10^{12}$ atoms/cm^2 thickness. The larger bore of the six-pole magnets implies both an increased gas conductance inside the magnets and a reduced beam density over much of the beam trajectory compared to other designs. These two factors may be responsible for a portion of the increased beam intensity.

Magnetic field configuration

The magnetic fields experienced by the atomic H beam are crucial for preservation of its nuclear polarization. To avoid non-adiabatic field changes we required that, in the atomic beam rest frame, the applied magnetic field direction may rotate no faster than $10^{-3}\ \omega_L$, the Larmor precession rate (γ_pB). Unfortunately, the target guide field configuration we employed to minimize the deflection of low energy (< 10 MeV) recoil protons resulted in two distinct locations where the field seen by the atomic beam reverses direction and strongly violates the adiabatic condition. Use of massive iron shielding allowed us to move the violation regions. In one case it was moved into the middle of a six-pole magnet, and in the other into the field of a 2-4 RF transition. The transverse fields in these regions restored the adiabatic condition. Nass et al., this conference, show that the residual depolarization is below 0.4%.

Vacuum

The source is divided into 9 pumping stages, 6 for the beam formation and target region and 3 for the BRP (Breit-Rabi Polarimeter). We utilized two Varian 1000 liter/s turbo pumps (2×10^6 compression ratio for hydrogen) in each stage except for the first stage which has 3 pumps. Application of a fourth pump would achieve an intensity increase of 3.5%. We achieved an operating pressure in the target region of 1.4×10^{-8} Torr and a base (jet OFF) of 4×10^{-9} Torr.

Breit-Rabi polarimeter

The layout of the BRP is shown in Fig. 1. In the usual BRP polarization measurement, all possible combinations of RF transitions are used to solve for the fractional hyperfine occupation numbers. In our case it is sufficient to determine the efficiency of the two RF transitions located upstream of the interaction region.

Furthermore it is possible to operate the two upstream transitions simultaneously. If those transitions have 100% efficiency, no chopped beam should reach the BRP detector. The ideal situation is nearly realized for our setup. We observed a rate of 52 Hz in the detector with both upstream transitions on, and a rate of about 20,900 Hz with the transitions off, leading to a lower limit to the average of the RF transition efficiencies of 99.7%.

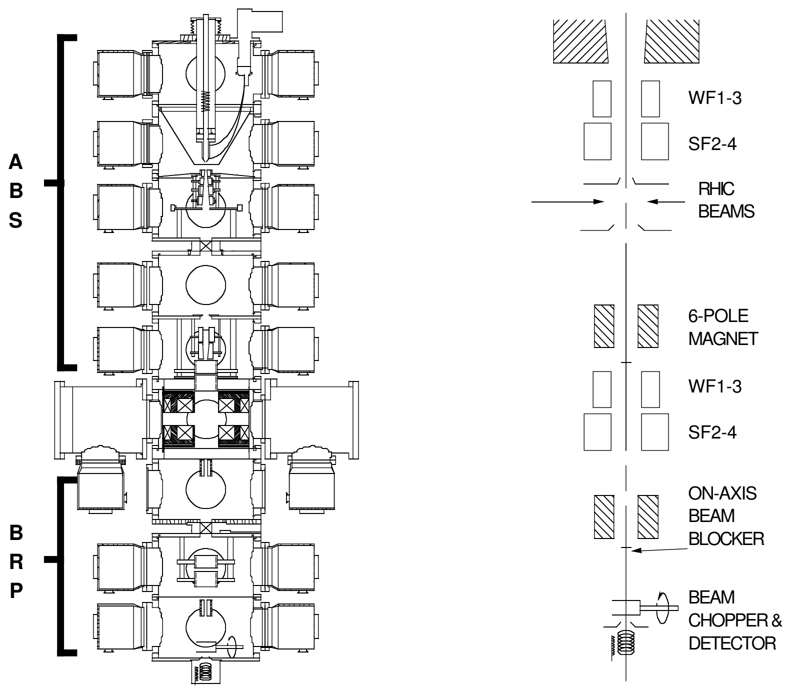

Fig. 1. Left, the overall layout of the jet to scale. The third turbopump on the first stage and the massive iron shielding are not shown. The large centrally located chambers house silicon recoil detectors for calibration of the RHIC beam polarization. Right, the configuration of the lower portion of the jet assembly showing the arrangement of RF transitions, beam blockers, six-pole magnets and beam chopper. The BRP detector is a commercial ion gauge biased with low ripple power supplies.

Jet polarization

Even with perfect RF transition efficiency the jet polarization will deviate from 100% because of several factors. At 0.12 T guide field, state 2 and 4 atoms have polarization $|P| = 0.921$, whereas state 1 and 3 atoms have $|P| = 1$, giving a two-state (1+4 or 2+3) theoretical $|P_{max}| = 0.961$. In addition, the jet beam includes a dilution of approximately 3% nucleons of unpolarized H_2 gas measured with a QMA located at the RHIC beam interaction point. Although there was a possible depolarization from bunch field interaction with the circulating RHIC beam, none was observed. Combining the above factors yields a jet polarization of $P_+ = 0.923 \pm 2\%$ and $P_- = -0.925 \pm 2\%$. The difference between P_+ and P_- is due to a small but consistent difference in the efficiency of the 1-3 and 2-4 RF transitions. The quoted errors are entirely dominated by the uncertainty in the molecular dilution. Construction and calibration of hardware for a more precise measurement of the molecular content of the jet is in progress.

References

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2. A. Zelenski et al., Absolute Polarized H-Jet Polarimeter Development for RHIC, *Proc. PST 2003, NIM A* **26367** (2004).