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STATUS OF THE POLARIZED H-JET POLARIMETER DEVELOPMENT FOR RHIC

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Abstract

The status of the H-jet polarimeter development is reviewed. The preliminary results of atomic beam intensity and density measurements are presented.

INTRODUCTION

A polarized H-jet polarimeter was proposed for the absolute polarization measurements in RHIC [1, 2, 3, 4]. 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, which can be precisely measured by the Breit-Rabi polarimeter [5]. These measurements will be used for calibration of a fast p-Carbon CNI polarimeter, which is proven to be a very effective instrument for depolarization studies and polarization time-evolution monitoring during acceleration and storage in RHIC [6].

The polarimeter target is a free atomic beam jet, which crosses the RHIC beam in the vertical direction. With a state-of-art atomic polarized source, the H-jet target thickness of about 10^{12} atoms/cm^2 was expected [3]. The measured H-jet thickness in the collision region (as seen by stored high-energy beam) is consistent with the calculations. This will provide the polarimeter counting rate of about 100 events/sec for the 2004 run and the proton beam polarization can be measured to $\sim$2% statistical accuracy in 20 hrs integration time. It is estimated that systematic errors will limit the total accuracy to about 10% (the goal for the first run) and eventually to 5% absolute polarization measurement accuracy [2]. The H-jet polarimeter will be installed at the RHIC beams intersection IP-12, which is presently not occupied. Due to small H-jet target thickness, the polarimeter can be operated continuously, without any effect on the RHIC polarized proton beams. The remote location excludes any background generation for the other experiments.

EXPERIMENTAL SETUP

<u>**Polarimeter vacuum system:**</u> The H-jet polarimeter includes three major parts: polarized Atomic Beam Source (ABS), scattering chamber, and Breit-Rabi polarimeter (BRP) (see Fig.1). The polarimeter atomic beam axis is vertical and the recoil protons are

detected in the horizontal plane. The common vacuum system is assembled from nine identical vacuum chambers, which provide nine stages of differential pumping. The system building block is a cylindrical vacuum chamber 50 cm in diameter and 32 cm long with the four 20 cm ID pumping ports. Each chamber is pumped by two turbomolecular pumps (TMP) with ceramic bearings. A third pump is installed at the first dissociator stage. The TMP features high $\sim 10^6$ compression ratio for H_2 pumping and about 1000 l/sec pumping speed.

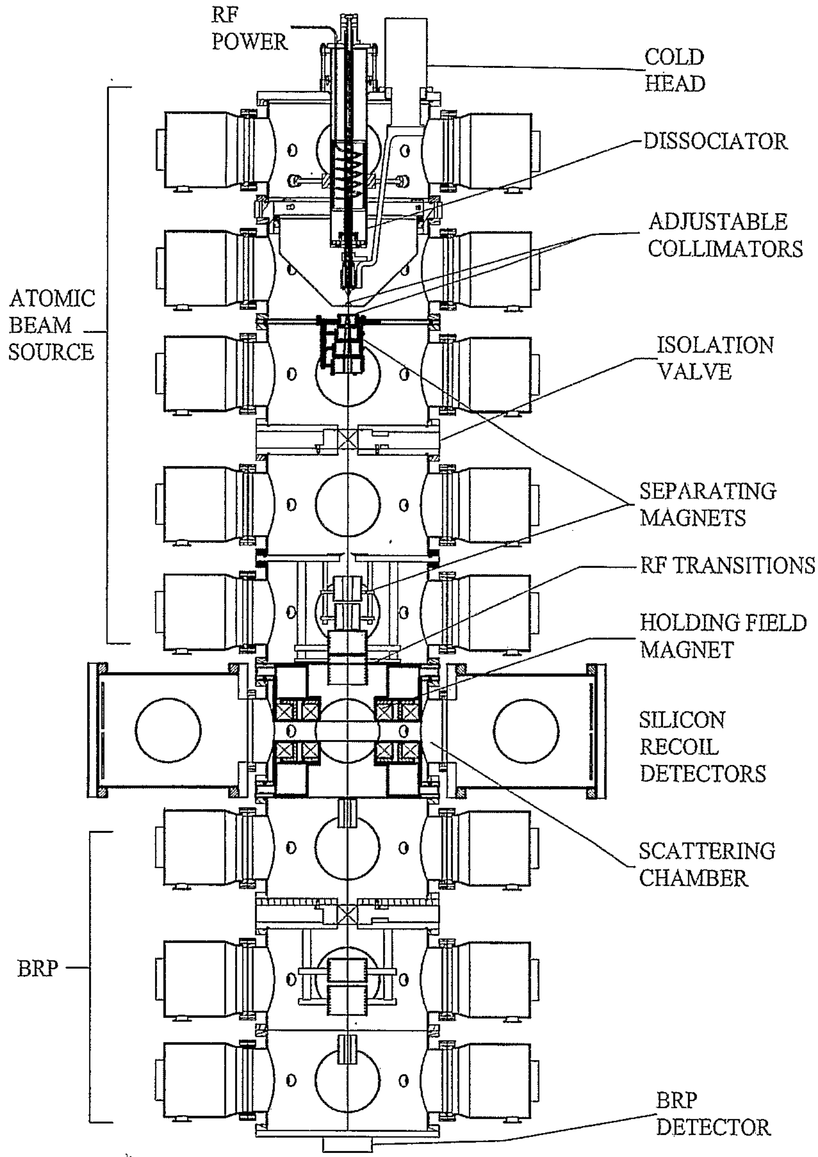


Figure 1: H-jet polarimeter general layout.

Polarized atomic beam source: The ABS section includes five vacuum chambers and five differential vacuum stages (see Fig.1). The sextupole separating permanent magnet system is designed to maximize the atomic beam density in the collision region [3]. The dissociator nozzle is cooled by a Leybold 140 cryocooler, which produces about 30W cooling power at 40 K operating temperature. This power is sufficient for cooling a 12 cm long dissociator neck (see Fig.1) well below the temperatures available in conventional dissociator designs with a water-cooled neck. A tunable master oscillator and broadband amplifier (0.2- 35 MHz range) are used to power the dissociator RF-cavity, which is similar to the BLAST ABS design [7]. The RF matching for minimal reflected power is produced by frequency tuning, typically a reflected power doesnt exceed 2%. The dissociator and the first skimmer positions can be adjusted without breaking vacuum. This allows tuning of the nozzle-skimmer and skimmer-sextupole magnet gaps, which are critical for the optimal ABS performance. The dissociator transverse alignment is produced by four movable rods (see Fig.1). The rods also hold the long dissociator body in place and reduce vibrations caused by the cooling head.

Scattering chamber: The CNI elastic p-p collision asymmetry peaks at a momentum transfer of about t$\sim$0.001-0.01 GeV^2, which corresponds to the recoil proton scattering angles of 85-89° for RHIC beam energies of 25-250 GeV [2]. The silicon strip recoil detectors are situated at a distance of 80 cm from the jet-target in the recoil-arm cylindrical chambers, which are attached to the standard central chamber (see Fig.1). The scattering angle is defined by the collision point (within $\sim$8 mm wide H-jet) and the position sensitive silicon detector. The recoil proton energy is defined from a silicon detector pulse height and the time-of-flight, which is used to suppress the background. The scattering angle can be further constrained by remotely adjustable collimators located at a distance of 4.0 cm from the target. At the intersection point bunches from the 2 beams arrive at the same time and cannot be resolved by TOF. Therefore, the two beams will be separated spatially in the horizontal plane by about 10 mm, and the entire polarimeter apparatus can be scanned across the two beams in horizontal direction. By this method, the scattering for one beam at a time can be selected in the polarimeter target, since the H-jet size is less than 10 mm and the RHIC beam size is less than 1.0 mm.

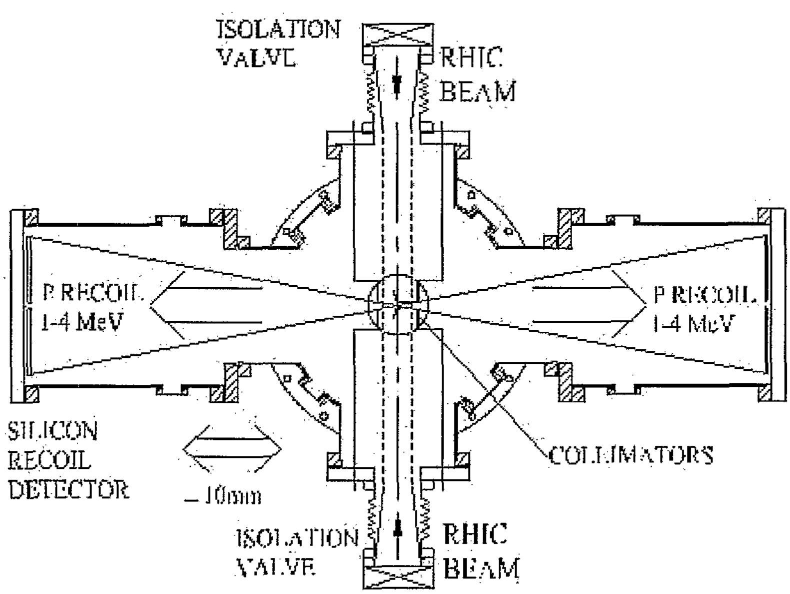


Figure 2: Plan view of the scattering chamber.

Holding field magnet: The direction of the H-jet proton polarization in the collision region is vertical as determined by the holding field magnet. The coils and magnetic steel plates of the magnet are enclosed in stainless steel casings, which are sealed in between standard vacuum chambers, so that high-current vacuum feedthroughs are not required. The deflection of the recoil protons by the holding field is minimized by use of the compensation coils, whose fields are adjusted to keep the total vertical field integral along the recoil proton path near zero. The maximum field in the collision region is 1.4 kG, which gives a maximum proton polarization ~97%. A magnetic field homogeneity better than 10^{-3} within ~4.0 cm center region was measured, which should allow to tune the holding field magnitude in-between the depolarizing resonances and avoid depolarization by the bunch field induced transitions in the atomic beam. The RF-transition cavities, which produce the proton polarization in the atomic beam, are shielded from holding field by additional magnetic screens. The RF-transitions were tuned with the BRP polarimeter. RF-transition efficiencies of 99.9±0.1% were measured for both weak- and strong-field transitions with the BRP polarimeter.

ATOMIC BEAM INTENSITY AND PROFILE MEASUREMENTS

The atomic beam profile was measured by a movable compression tube with an opening aperture 2 mm in diameter. At the center of the collision chamber the FWHM of the beam is 5.5 mm (see Fig.3). The total beam intensity in the collision chamber was measured with a compression tube 10 mm in diameter and 100 mm in length. The compression tube was calibrated by the conventional technique (pressure drop in the calibrated, hydrogen filled volume) and by using MKS mass-flow controller (1 sccm total range). The maximum atomic beam intensity of $(12.4\pm0.2)\cdot10^{16}$ atoms/sec was measured at ~70 sccm H_2 flow

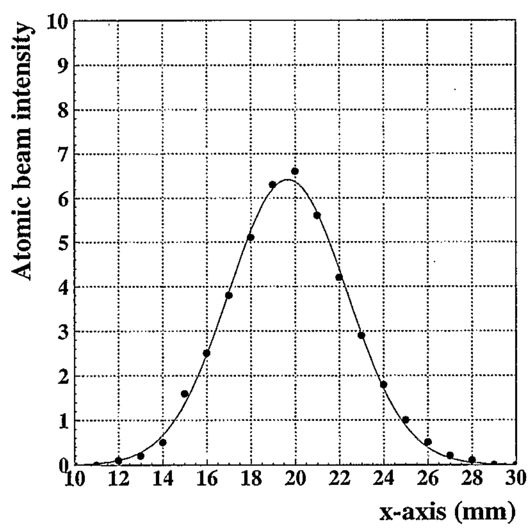
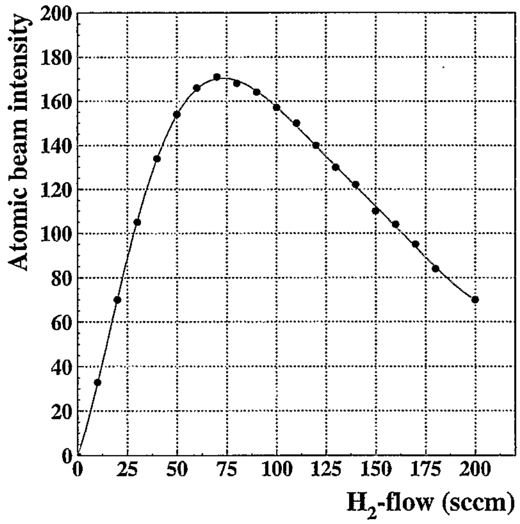


Figure 3: The measured atomic beam profile at the collision point. The FWHM, corrected for the finite size of the compression tube aperture, is 5.5 mm).



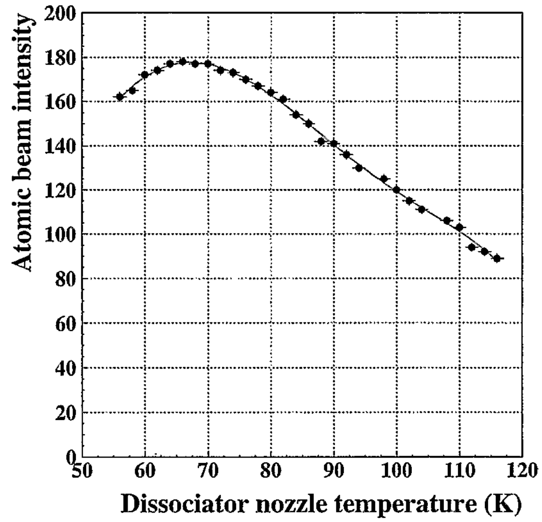


Figure 4: Atomic beam intensity vs. H_2 flow in dissociator (left) and vs. dissociator nozzle temperature (right). The maximum $12.4 \cdot 10^{16}$ atoms/s intensity was obtained at 70 sccm H_2 flow.

(see Fig.4) and nozzle temperature of 65-70 K (see Fig.4). A polarized H-jet thickness of about $1.2 \cdot 10^{12}$ atoms/cm^2 (as seen by the 1mm diameter RHIC beam) was estimated from the above atomic beam profile and intensity measurements. An atomic beam velocity of $2 \cdot 10^5$ cm/s was taken from simulations [3]. It is planned to measure the velocity directly to improve the accuracy of the density value. The total beam intensity through the 18 mm collimator was also measured in the vacuum chamber #7 (below the collision chamber, with the BRP isolation valve closed). The pressure increase produced by the beam was compared with the increase from calibrated flow, similar to compression tube measurement. This measurement helps to exclude the possible systematic errors caused by the different gauge sensitivities to atomic and molecular hydrogen.

In the compression tube and large vacuum chamber, the recombination and equilibrium conditions are quite different; also a hot cathode gauge is used in the compression tube measurements and cold cathode gauge in chamber #7. Nevertheless, the measurements agreed to within 5%. As an independent cross-check, the beam intensity was also estimated from the known TMP pumping speed (a 1000 l/sec pumping speed for hydrogen is specified by the manufacturer and measured in separate tests). The intensity of a $(13 \pm 1) \cdot 10^{16}$ atoms/sec was calculated using this assumption, which agrees well with the other measurements.

H-JET POLARIZATION MEASUREMENTS

The proton polarization of the beam can be measured to $\sim$0.2% accuracy by taking a set of atomic beam intensity measurements in BRP at different RF-transition settings. To derive the effective target proton polarization, as seen by the RHIC beams, from BRP measurements a number of systematic error contributions have to be determined with high accuracy.

Beam induced depolarization: The effect of bunched-beam induced resonance depolarization can be directly measured in the BRP. To avoid this problem, the plan is to suppress the depolarization resonances by tuning the strength of the holding field in-between the adjacent resonances. The resonance position as a function of the holding field value will be measured using the BRP.

The target polarization dilution by molecular hydrogen and water vapor: The molecular hydrogen contamination of the atomic beam can be at the 5-10% level. The target polarization dilution by molecular hydrogen (or water vapor) is the main systematic error contribution to the polarization measurement. Detailed studies of polarization dilution will be required to reduce the contamination to the lowest possible level. It is planned to develop techniques for precision correction measurements to meet the polarimeter accuracy design goal. Beam diagnostics based on TOF measurements of the ion beams produced by an electron beam ionizer will be used for this purpose.

The polarimeter construction and tests were carried out at the test facility in the linac injector complex. The polarimeter will be moved to the RHIC tunnel for a dry run in October 2003 after which it will be returned to the lab for further development. The polarimeter is designed to be movable, i.e. it can be taken apart and reinstalled in either place in 3 days. The first H-jet polarimeter operation in RHIC is planned for the polarized proton run in April 2004. The goals for the first run will be to attain reliable operation at the designed intensity and high (over 95%) atomic beam polarization and the RHIC accelerated beam polarization measurement to about 10% absolute accuracy.

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