ATOMIC BEAM STUDIES IN THE RHIC H-JET POLARIMETER

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The results of atomic beam production studies are presented. Improved cooling of the atoms before jet formation in the dissociator cold nozzle apparently reduces the atomic beam velocity spread and improves beam focusing conditions. A carefully designed sextupole separating (and focusing) magnet system takes advantage of the high brightness source. As a result, a record beam intensity of a $12.4 \cdot 10^{16}$ atoms/s was obtained within 10 mm acceptance at the collision point. A 3% polarization dilution factor (by the hydrogen molecules at the collision point) was measured with a modified Quadrupole Mass Analyzer.

A polarized H-jet polarimeter is based on elastic proton-proton scattering in the Coulomb-Nuclear Interference (CNI) region. Due to particle identity, the polarization of the accelerated proton beam can be directly expressed in terms of proton target polarization, which can be precisely measured by a Breit-Rabi polarimeter. A detailed H-jet polarimeter description and results of the beam intensity and density measurements were presented at the PST 2003 in Novosibirsk [1]. Atomic polarization measurements and the H-jet project overview are presented at this conference (A. Nass et al. and T. Wise et al.). The focus of this paper is atomic beam production, dissociator long-term performance, and our first measurements of polarization dilution factor by molecular hydrogen.

Dissociator. In a conventional dissociator design, hydrogen atoms are produced in an RF-discharge with velocities equivalent to a few thousand degrees gas temperature. The atoms are cooled down in collisions with the pyrex or quartz walls of the dissociator discharge tube. The tube is usually cooled by a water jacket, and only the aluminium nozzle at the end of the tube is cooled to 30-100 K temperatures. As was described in [1], a new dissociator design has an extended 12 cm cold tube section upstream of the nozzle that is cooled by cryocooler to 70-140 K. This allows a reduction in wall surface recombination, improves hydrogen thermal equilibrium conditions, and possibly reduces the beam velocity spread.

A number of different dissociator "neck" and nozzle cooling system modification were tested over the last year. These cooling improvements resulted in beam intensity increases for the same nozzle temperature. They also allowed the dissociator operation at higher RF-power. The operational power was increased to 250 W. At a higher power of 280-300 W, the beam intensity is about 10% higher, but the nozzle cooling is insufficient. At this power the RF-discharge penetrates further into the cold "neck" where wall recombination is reduced at 80-140 K temperatures. Also an ice layer formation on the tube and nozzle surfaces reduced recombination. There is a significant heat transfer to the heat sink copper clamp (attached to the cryocooler) from plasma cooling and recombination. This heat transfer varies in time for the same input RF-power, and depends on the tube wall conditions and the quality of the thermal contact between the copper clamp and the quartz tube. Better contact actually reduces the heat load due to a decrease in the tube wall temperature, which reduces recombination. The copper clamp-quartz tube thermal conductance is limited in all of our tested designs. At present a thin ($\sim$0.2 mm) layer of "Apiezon" cryogenic vacuum grease (instead of finger springs [1]) is used to provide the heat conductance between copper and quartz. It worked quite reliably during the RHIC run, but the reproducibility of the grease application is still a problem and needs to be improved.

The production of silicon oxide in the discharge plasma reaction with the quartz tube sometimes causes nozzle plugging by a "snow-ball" of SiO_2. The oxide is accumulated in the region of the plasma boundary. The plasma penetrates about halfway into the cold dissociator "neck", where the wall temperature is about 130 K. During continuous operation the oxide is bounded, perhaps by ice, and stable dissociator operation for up to three weeks was recorded. But sometimes the "snow-ball" plugged the nozzle completely after only five days. The procedure of vacuum cleaning of the dissociator with a plastic tube attached to a vacuum pump was developed and was effectively used during the H-jet run in the RHIC. Less than 0.5-hour ring access was required for this procedure.

In the H-jet dissociator, the cold surface area of the "neck" and nozzle is much larger than in the conventional dissociator, where only the nozzle is cold. The water vapour, which is produced mostly in the discharge, condenses and freezes upstream of the nozzle, and there is no need to warm the dissociator up to clean ice from the nozzle. During three weeks of continuous operation there was a steady increase (about 10%) in the beam intensity. This effect can be explained by a reduction in recombination due to better wall coating by the ice.

Atomic Beam Intensity Measurements. 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 [1]. The maximum atomic beam intensity of $(12.4 \pm 0.2) \cdot 10^{16}$ atoms/sec was measured at $\sim$75 sccm flow, the dissociator RF-power was 280 W, and the nozzle temperature 75 K (see Fig.1a). The maximum intensity is significantly higher than in other ABS. Remarkably the HERMES ABS intensity of a $6.4 \cdot 10^{16}$ atoms/s was obtained at just 30 sccm H_2 flow i.e. three times less gas supply

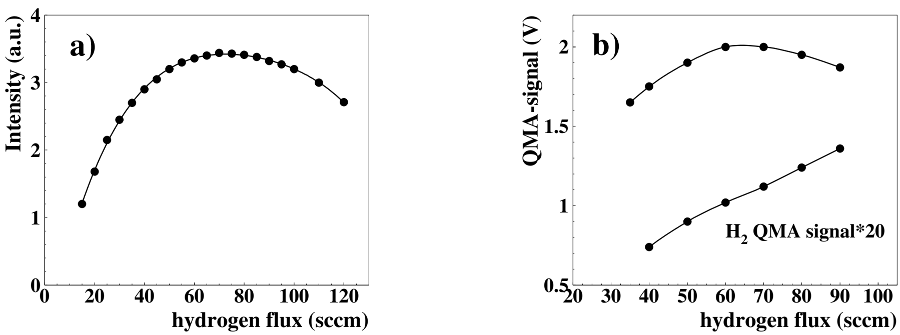

Fig. 1. Atomic beam intensity vs. H_2 flow in dissociator (a). Atomic and molecular hydrogen density vs. H_2 flow as measured by the QMA (b).

in the dissociator than HERMES ABS [2] utilized to obtain that intensity. This intensity dependence was measured after the dissociator cooling upgrade. The intensity decrease rate is not as fast as before [1], and the maximum is shifted to the higher flow. Apparently precooling the atoms before the nozzle improves beam formation out of the nozzle, and insufficient cooling limits the intensity increase. At higher H_2 flow the heat load to the dissociator "neck" is increased, and the plasma penetrates further into the "neck". This may change the equilibrium velocity distribution and affect the beam quality. The dissociation ratio might also decrease. The operational temperature of the cooling bracket in the top part of the "neck" is about 140 K, which is close to minimum for recombination reduction at the quartz. But the inside wall temperature can be significantly higher. Further cooling system improvements are still required.

The target polarization dilution by molecular hydrogen. Atomic beam polarization close to 96% was measured in the Breit-Rabi polarimeter (A. Nass et al. at this conference). The target polarization dilution by the molecular hydrogen (at the collision point) was measured by a modified quadrupole mass analyzer. The original RIBEN QMA sensitive area was expanded from 5mm to 10 mm to accommodate the full 9mm beam width and significantly reduce atomic beam recombination at the QMA electrodes, which was observed in the first measurements. The QMA signal amplitude dependence on hydrogen flow in the dissociator is presented in Fig.1b. The maximum of the QMA atomic beam signal is shifted to a lower flow from the compression tube maximum. The difference from a compression tube is because the QMA measures the beam density, not intensity. The density is the figure of merit for the H-jet target. Therefore the maximum of the QMA signal (at 60 sccm flow) is the best operational point. The absolute atomic beam density of about $1.0 \cdot 10^{12}$ atoms/cm^3 at the collision point can be calculated from the atomic beam intensity, the beam profile, and the velocity. The QMA sensitivity factor to the molecular hydrogen was calibrated at different hydrogen pressures (hydrogen gas was supplied to the collision chamber through a needle valve) measured by a hot filament ion gauge closely positioned to the QMA sensor. The molecular hydrogen density of about 1.5% of the atomic beam density was determined from these measurements, which provide a preliminary measurement of the polarization dilution factor of about 3% at 60 sccm H_2 flow in dissociator. This gives an effective H-jet target polarization of a $93^{+1}_{-2}\%$. To meet the project goal of a 1% absolute accuracy for H-jet target polarization, new diagnostics devices are under development. A device for off-line measurements is based on electron beam ionizer and magnetic analysis of the ion components. For on-line polarization dilution monitoring, an optical technique development is in progress. It is based on detection of a luminescence light from atoms and molecules excited by the RHIC proton beam.

References

1. A. Zelenski et al., Proc. PST 2003, NIM A 26367 (2004).
2. A. Nass et al., Nucl. Inst. and Meth. A505 (2003), 633.