Polarized Atomic Hydrogen Beam Tests in the Michigan Ultra-Cold Jet Target [1]

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Abstract. Progress on the Michigan ultra-cold proton-spin-polarized atomic hydrogen Jet target is presented. We describe the present status of the Jet and some beam test results.

We are developing an ultra-cold high-density Jet target of proton-spin-polarized hydrogen atoms (Michigan Jet) to study spin effects in high energy collisions. The Jet uses a very high magnetic field and an ultra-cold separation cell coated with a superfluid ^{4}He-film to produce a slow monochromatic electron-spin-polarized atomic hydrogen beam. This beam is focused by a parabolic mirror coated with superfluid ^{4}He and a superconducting sextupole magnet. An rf transition unit will then convert this beam into a proton-spin-polarized beam [1].

The layout of the Michigan Jet is shown in Fig. 1. Atomic hydrogen is produced with a room-temperature rf dissociator and guided to the ultra-cold separation cell coated with superfluid ^{4}He to suppress the surface recombination of hydrogen atoms (see Fig. 2). The double walls of the cell form the mixing chamber of a dilution refrigerator. The cell's entrance and exit apertures are respectively located at about 95% and 50% of the superconducting solenoid's 12 Tesla magnetic field. After the hydrogen atoms are thermalized by collisions with the cell surface, the magnetic field gradient physically separates the atoms according to their electron-spin states. The "high-field-seeker" atoms in the two lowest hyperfine states ($|3\rangle$ and $|4\rangle$) are attracted up toward the high field region and escape from the cell. They quickly recombine on bare surfaces and are cryopumped. The "low-field-seeker" atoms in the two higher hyperfine states ($|1\rangle$ and $|2\rangle$) are pushed down toward the low field region and effuse from the exit aperture, forming a rather monochromatic electron-spin-polarized beam. To increase the Jet density, we use a gold-coated copper focusing mirror with a polished surface covered with a ^{4}He superfluid film similar to the prototype mirror [2]. After an rf transition unit, which changes state $|2\rangle$ atoms into state $|4\rangle$ atoms, the beam will pass through a supercon-

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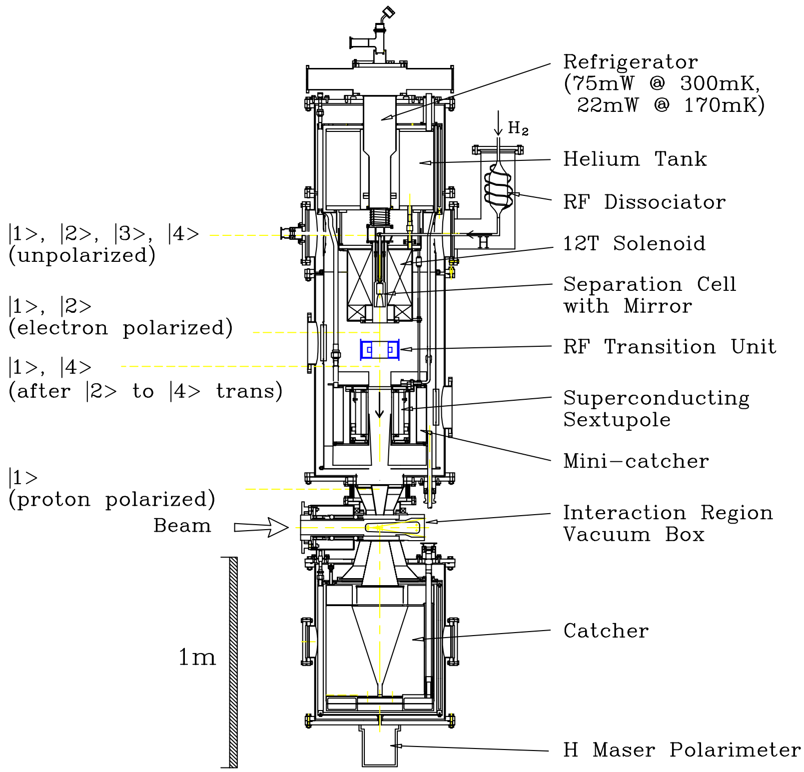

FIGURE 1. Layout of the Michigan ultra-cold Jet.

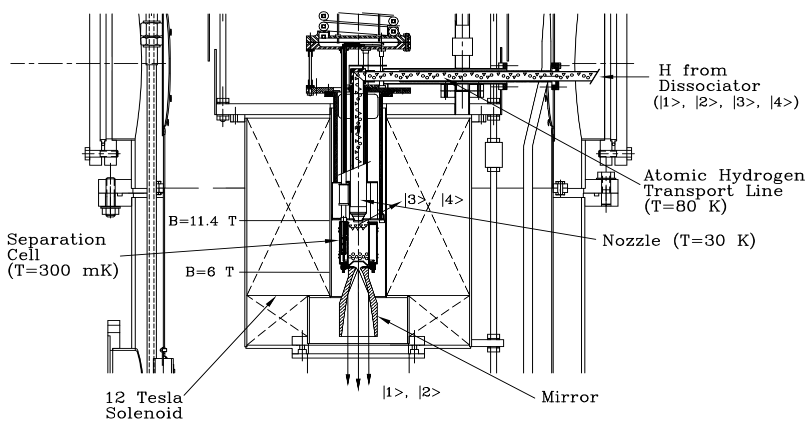

FIGURE 2. Details of the Michigan Jet's electron-spin separation region.

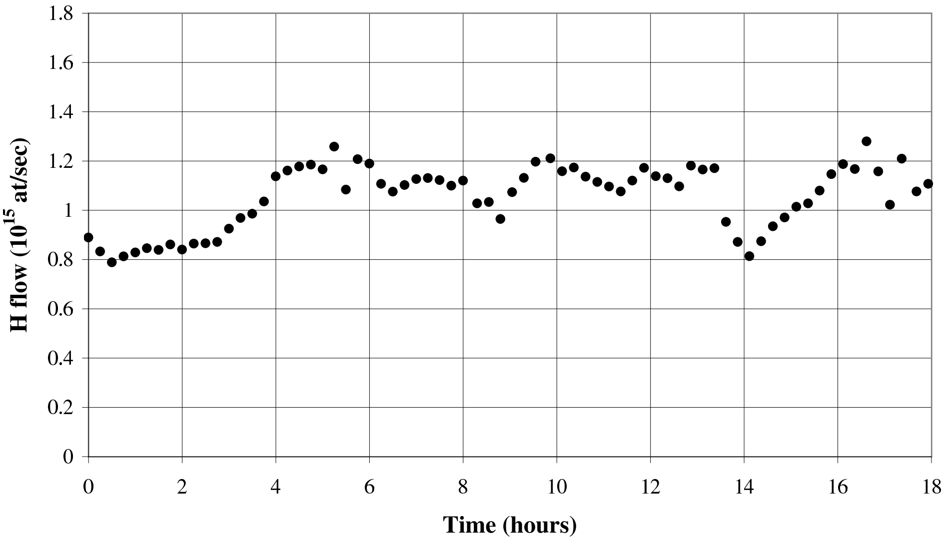

FIGURE 3. The observed hydrogen Jet intensity in an 18-hour run.

ducting sextupole magnet. The sextupole selects atoms in electron spin state +1/2, by focusing atoms in state $|1\rangle$ into the interaction region and defocusing atoms in state $|4\rangle$, which are then cryopumped away. The proton-spin-polarized beam then passes through the interaction region where it can collide with a proton beam in a high energy storage ring. The Jet beam is then captured below by a huge cryopumping catcher [3] to keep the interaction region and storage ring vacuum uncontaminated. A maser polarimeter below the catcher monitors the beam proton polarization.

Most of the Michigan Jet parts have been fabricated and successfully tested. This hardware includes a 12 Tesla superconducting solenoid with a very sharp gradient at the downstream end, a dilution refrigerator with a cooling power of about 22 mW at 170 mK, a 20 cm long superconducting sextupole magnet with a 0.31 T field at its iron poles and a 10.5 cm diameter bore, a cryocondensation catcher pump with a measured pumping speed of about 1.2×10^7 liters s^{-1} (4.2×10^{26} atoms torr^{-1} sec^{-1}) [3], and a hydrogen maser polarimeter capable of monitoring the polarization with a precision of about $\pm2\%$ in a few minutes.

We studied a polarized beam of hydrogen atoms focused by the superconducting sextupole into a compression tube detector which measured the polarized atoms' intensity. By building a thick ^{4}He superfluid film, we were able to produce a high intensity spin-polarized hydrogen beam, which operated with good stability during an 18-hour run, until our liquid ^{4}He supply was depleted, as shown in Fig. 3. The average measured hydrogen intensity, into the 11 mm by 1.4 mm compression tube slot, was about 1.1×10^{15} H s^{-1}. This intensity corresponds to a hydrogen Jet thickness of 6×10^{11} H cm^{-2}. The maximum beam intensity fluctuation was about $\pm20\%$. It was not needed during this 18-hour run, but when necessary, we can heat the separation cell to about 40 K to remove the residual frozen H_2 molecules; this usually takes about 2 hours.

The Jet's highest measured spin-polarized atomic hydrogen Jet intensity was about 2.2×10^{15} H s^{-1}; this corresponds to a Jet thickness of about 1.1×10^{12} H cm^{-2}. The fully electron-spin polarized beam has a proton polarization of about 50%. We plan to convert the electron polarization into the proton polarization by an adiabatic passage of the beam through an rf transition unit, which has a novel dielectric-ring-resonator that accepts the 6 cm diameter beam. A room temperature prototype rf transition unit was built and successfully tested; its maximum measured transition efficiency was 97% at 235 mW rf power. A preliminary design and some tests of the cryogenic rf unit were also made [4]. The observed Q value of the cryogenic rf unit at 5 K was about 17,000, which is 2.5 times higher than that of the room temperature prototype rf unit; hence, less power should be needed for the cryogenic rf transition unit. We plan to soon fabricate and install this cryogenic rf transition unit, which should increase the proton polarization to over 90%.

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REFERENCES

1. B.B. Blinov *et al.*, *"Michigan Ultra-Cold Polarized Atomic Hydrogen Jet"*, in *Proc. of 14th Internatioanl Spin Physics Symposium*, Osaka 2000, edited by K. Hatanaka *et al.*, American Institute of Physics, New York, 2001, AIP Conference Proceedings **570**, pp. 856-860
2. V.G. Luppov *et al.*, Phys. Rev. Lett. **71**, 2405 (1993)
3. J.D. Arnold *et al.*, Nucl. Instr. Meth. A**391**, 398 (1997)
4. R.S. Raymond, *"Development of a Large-bore Cryogenic 2-4 Transition Unit"*, in *Proc. of International Workshop on Polarized Source and Targets*, edited by A. Gute *et al.*, Erlangen, Germany (1999)