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POLARIZED HYDROGEN GAS TARGET IN THE COOLER

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In the previous Annual Report we described the installation of the Wisconsin polarized hydrogen gas target in the Cooler. The installation was nearly completed at that time, but no tests with beam through the target had yet been made. In the meantime, considerable experience has been gained in the use of this target. Preliminary results on pp spin correlation measurements are described in another contribution to this report.[1]

Briefly, the target consists of a 25-cm long cell into which polarized hydrogen atoms from an atomic-beam source are injected. The open aperture of the cell, through which the proton beam of the Cooler passes, is an 8 mm $\times$ 8 mm square. The purpose of the cell is to increase the target thickness by a factor of several hundred compared to using the atomic beam as a jet target. Protons scattered into forward angles ($\theta_{lab} = 3°$ to $18°$) by hydrogen nuclei in the cell are detected by a set of wire chambers and scintillators.[1] Recoil protons are detected in coincidence by eight silicon-strip detectors which surround the target cell. The detectors are 4 cm $\times$ 6 cm each and are placed 5 cm from the beam axis. The cell walls are made of Teflon film of 5 μm thickness. Separate tests carried out earlier at Wisconsin had shown that hydrogen atoms can tolerate at least 400 wall collisions with Teflon walls without significant loss in polarization.

In the following, we summarize the most important findings that were obtained since the commissioning of the polarized target setup at IUCF began a year ago. More details, in particular on the results of some of the measurements described here, can be found elsewhere in this report.[1]

1) In spite of the small cell aperture, beam can be stack-injected and stored in the Cooler in the presence of the target. To protect the detectors during injection, a beam blocker was added in the T-region.

2) The measured ring acceptance with the cell in place typically has been $2\pi\ 10^{-6}$ m. This is about five times less than what one expects based on cell geometry and ring optics, and also than what was measured during previous test with slits and test cells in the A-region.[2] However, it is now believed that the cell is misaligned with respect to the preferred beam position of the ring by about 3 mm in the vertical direction. The cell will be raised for the next run, which should increase the ring acceptance. The beam life time in the presence of the target has not been very reproducible, but has been as long as 3000 s.

3) In view of the fact that the walls of the target cell are about 10^9 more massive than the hydrogen target, possible background events from interaction of beam halo with the cell wall or other material were of concern. The extensive experience now available shows that the detector system allows clean identification of pp events (see Ref. 1). Additional studies are planned for the next run to place tight quantitative limits on background events.

4) Measurements of the target polarization were made using a stored beam of 200 MeV protons. Both vertically polarized and unpolarized beams were used. When the beam was polarized, spin up and spin down orientations were alternated for subsequent cycles. The target polarization was pointed in succession horizontally ($\pm x$), vertically ($\pm y$), and along the beam directions ($\pm z$). The direction of polarization was changed every 2 s. The polarization rise time after switching was less than 50 ms. The target polarization can be measured in the x and y-directions and was found to be about 70%. Whatever changes have been seen in target polarization are associated with the RF transitions of the polarized atomic-beam source. So far no evidence has been found for deterioration of the target polarization from radiation damage to the cell walls.

5) The target thickness can be determined from the known pp cross section, beam current and detector solid angle. The measured target thickness is 3.6×10^{13}, in excellent agreement with the value predicted[3] from the measured atomic-beam intensity and the gas conductance of the cell. With a stored beam current of 200 μA, good pp events with scattering angles between 6° and 18° are acquired at a rate of 10 Hz.

6) An algorithm has been developed to determine which of the 28 strips of a given recoil detector fired. Each strip is 2 mm wide. Thus, each event can unambiguously be assigned a vertex position along the beam direction with an uncertainty of ± 1 mm. From this, it was deduced that the density along the cell axis has the expected triangular shape with a maximum in the center.

Among the remaining operational problems that are presently being resolved are various aspects of the guide fields. In order to minimize the effect of the guide field on the equilibrium orbit of the stored beam, an additional horizontal field coil has been introduced downstream of the experiment, and in order to compensate for the small variation of the medium field in the transition region of the source with varying B_x guide field, a correction coil has been wound on the yoke of the medium-field magnet. Both these coils are operated in series with the B_x coils in the target region. To make sure that a guide field of sufficient magnitude is present where required, the field along the axis of the atomic beam has been carefully mapped. A similar map in the target region yielded detailed information on direction and magnitude of the ambient field at the target. To first order, this small field (about 0.5 Gauss) will be compensated by a constant offset current in all the guide field coils.

The experience that has been accumulated so far is sufficient to establish that a target cell ("storage cell", Ref. 4) for polarized H is compatible with operation of the Cooler, and that it meets the design values of target thickness and target polarization on which the proposals for experiments CE-35, CE-42, CE-44 and CE-45 were based. At the present state of development of this new technique, only CE-35 is ready to run. The other experiments still depend on additional important developments, in particular down-ramping of the energy of the stored beam in the presence of the target cell, and production of longitudinally polarized protons. The first of these requires significant machine development studies, the other requires capital investments in solenoids and calculations on the effect of strong solenoids on the machine properties.

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