INSTALLATION OF THE POLARIZED HYDROGEN TARGET AND DETECTOR SYSTEM IN THE COOLER A-REGION

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The thickness requirement for internal targets in the Cooler is such that it becomes feasible to use the output of a source of polarized atoms to generate a target. To overcome the severe limits in production rate of polarized H atoms (3.5×10^{16} atoms/s) by such sources, a buffer cell is used to increase the dwell time of target atoms near the beam. A buffer cell is simply a narrow tube through which the stored beam passes with another tube joined at the center through which the polarized atoms enter from the side. That such buffer cells are compatible with the operation of the IUCF Cooler has been demonstrated.[1,2]

In preparation for a series of Cooler experiments with a polarized proton target, an atomic beam source (ABS) for polarized atoms has been installed in the A-region of the Cooler. This source was developed at the University of Wisconsin. It was moved to IUCF in June 1993. Prior to the move, the performance of the source as a target was tested with an 8-MeV proton beam from the Wisconsin Tandem accelerator in Madison (see elsewhere in this report). During these tests a flux of about 3.5×10^{16} polarized atoms per second in one of the four spin states was measured.[3]

If the use of such a target in the Cooler can be successfully demonstrated, this will constitute a significant new capability of proton storage rings. However, before the polarized hydrogen target in the Cooler can be used for experiments, the following development objectives have to be accomplished: (i) determine the thickness of the polarized gas target (compared to predicted value of 3.6×10^{13} atoms/cm^2); (ii) measure the target polarization as a function of beam current and as a function of radiation exposure of cell walls; (iii) demonstrate target polarization in the X, Y, and Z directions; (iv) determine the variation of the target polarization along the cell; (v) measure the target polarization as a function of the strength of the applied guide field; (vi) establish methods to measure background and determine background rates; (vii) confirm the choice of cell aperture; (viii) test the alternative 3-micron thick cell wall material for depolarization and radiation damage.

The new target chamber in the A-region (see Fig. 1) was designed specifically for the first experiment (CE-35), but adaptability for future experiments was one of the design considerations. The chamber consists mainly of a 40-cm diameter tube along the beam axis. It has eight large ports to connect pumps (on top), to connect the ABS (on the side), and to mount the target cell and detector assembly (from below). The ABS beam is aimed at the interaction region at an angle of 30° towards the upstream direction in order to free

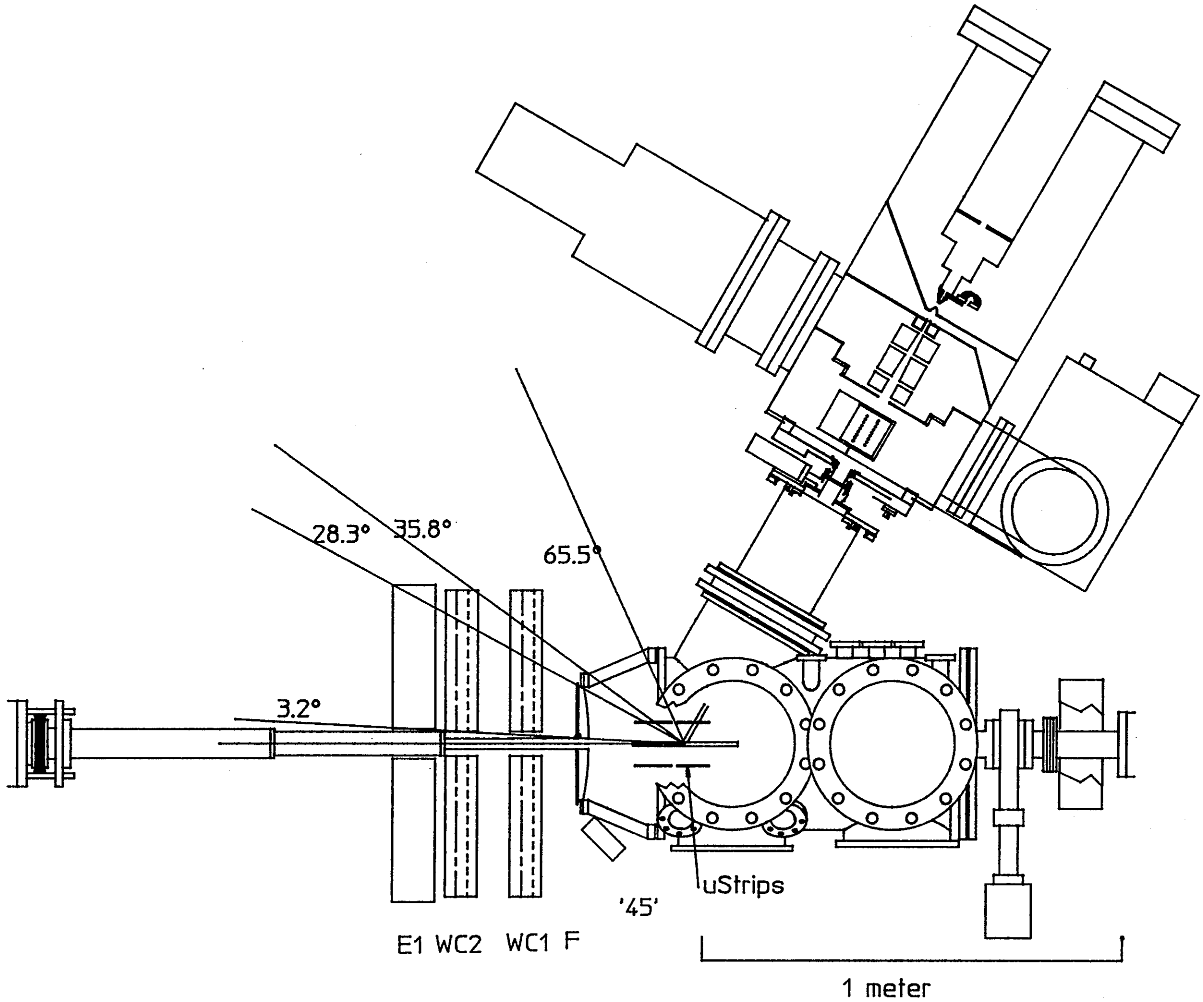

Figure 1. CE-35 setup in the A-region of the IUCF Cooler Ring, including the ABS from Wisconsin, forward CE-01 detector array, and target cell assembly including silicon microstrip detectors.

space in the forward hemisphere. The ABS is mounted on rails so as to allow easy removal from the chamber (and the Cooler vacuum) when it is not in use. This also makes off-line testing of the source possible.

The pumping of the target region is accomplished by large (5600 l/s) cryo-pumps, two on the target chamber and a third downstream of the detector assembly. A partition with a diaphragm that is tailored to the ring acceptance, located inside the chamber between the target region and the upstream portion, allows for differential pumping. To complete the hardware setup of the A-region, a jib-crane was installed to facilitate the moving of heavy equipment when working with these pumps or the ABS.

The downstream end of the target chamber consists of a thin-walled, conical stainless-steel can ('nose cone'). It allows particles from 3° to 28° to exit the vacuum through a 0.1-mm stainless-steel foil. Particles exiting at angles from 36° to 65° (i.e., near 45°) traverse a sheet of stainless steel 1-mm thick. The beam pipe which continues through the center of the detector assembly is brazed to the thin exit foil. Because the beta functions in the A-region are smaller than in the G-region, the exit pipe could be made narrower than for CE-01 (2.5-cm diameter) which allows detectors to be placed closer to the beam axis.

The direction of the target spin is controlled by the presence of a magnetic guide field which is uniform in direction (but not necessarily in magnitude). Three sets of Helmholtz coils are provided to generate this field, one for each direction (X (sideways), Y (vertical), and Z (longitudinal)). These coils are water-cooled and mounted outside the target chamber. The X and Y coils include a second set of compensating coils upstream to minimize spin-dependent shifts of the Cooler beam at the target location. During the installation process, the guide field in the target region has been carefully mapped. Figure 2 shows the guide field in the vertical direction together with the two unwanted sideways components which can be seen to be small (on the order of the earth's magnetic field).

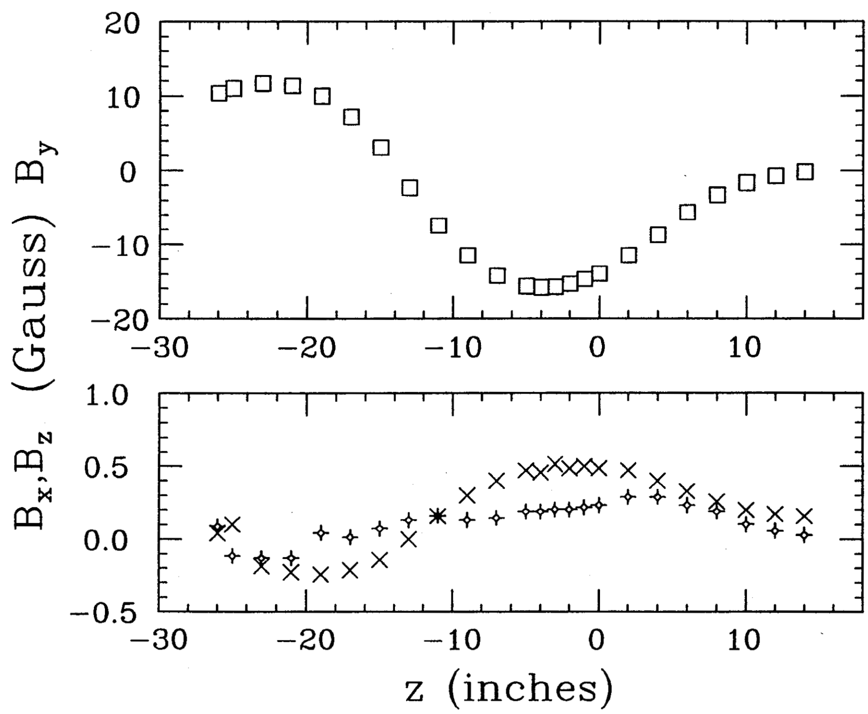

Figure 2. Guide field with the pair of Helmholtz coils that produce a field in the vertical (Y) direction. Shown is a) the component in the Y-direction and b) the (unwanted) components in the X-direction (+) and along the beam (X). The horizontal axis is the distance along the beam measured in inches from the center of the cell. The cell extends from Z = −5 to Z = +5 inches.

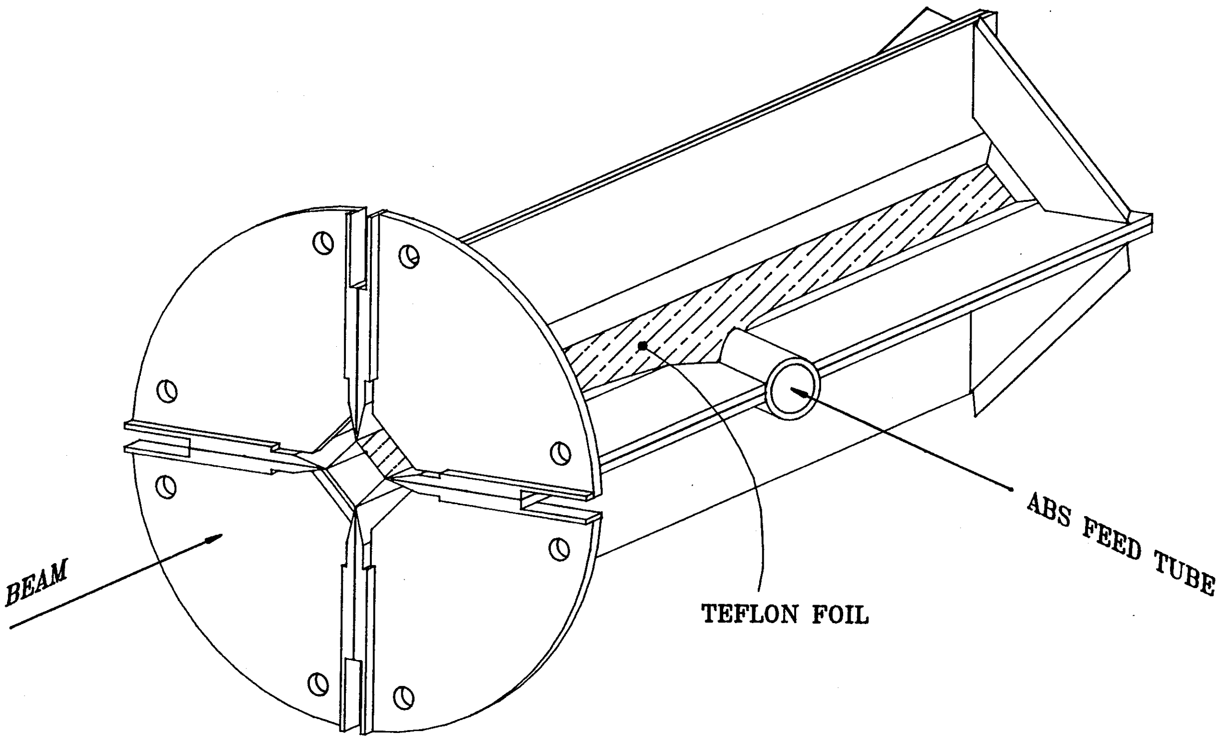

Figure 3. Target cell showing thin Teflon foils, aluminum-foil holding fins and ABS feed tube.

The target cell is constructed to satisfy the requirements of CE-35. The design minimizes the amount of material between target and detectors in two reaction planes. In CE-35 these reaction planes are rotated with respect to the the horizontal plane by 45°. In these planes exiting particles in the forward direction traverse at most 0.2-mm of aluminum. Since CE-35 also calls for the detection of low-energy recoil protons near 90°, the cell walls in the entire length of the cell are made from 5-micron thick Teflon. This material was chosen in order to minimize the depolarization by wall collisions of the atoms in the cell. The Teflon foils are mounted on aluminum frames that are either glued (with high-vacuum epoxy) or bolted together. When assembled, they form a tube of 8×8-mm cross section and 25-cm length with an entry hole at the center of the cell to which a feed tube is attached (see Fig. 3). The feed tube can be adjusted in direction to the ABS axis. The ABS axis is in the horizontal plane and thus between the reaction planes. All parts of the target cell are made from aluminum; where they are in contact with the atomic beam they are coated with Teflon (DuPont TE3170). With this cell we anticipate being able to provide a hydrogen target of 3.6×10^{13} H/cm^2 thickness with a polarization of about $P = 0.7$.

Integrated in the target assembly are four pairs of silicon microstrip detectors, each 4-cm wide and 6-cm long. These serve to detect the recoiling protons in pp elastic scattering. The silicon detectors are 1-mm thick with 28 individual strips, each 2.1-mm wide. The division of the detectors into strips makes it possible to reconstruct the position of the vertex of an individual event along the cell axis. The entire assembly consisting of target cell and microstrip detectors is mounted on a holder that allows alignment of the cell which sits on a flange that is attached to the target chamber from below (see Fig. 4). The same flange contains the feedthroughs for the signals from the microstrip detectors. The flange can be installed and removed easily and with reproducible alignment. A special elevator system has been constructed to facilitate this process.

A readout system has been built that provides the position along each detector along with energy and timing information. For each detector a signal that indicates the strip number and an energy and timing signal from the back plane are read out. Preamplifier–discriminator cards for the position readout and preamplifier–shaper cards for the energy and timing signals have been bought from the electronics laboratory of the Technische Universität München.[4] The energy signal has a shaping time of 4 μs and an amplitude of 400 mV/MeV. The fast timing signal has a rise time of 20 ns and an amplitude of -70 mV/MeV. The position signals are DC levels whose magnitude is proportional to the strip number. The DC level is fed directly into a QDC and integrated over 900 ns.

Active electronic components are all outside the vacuum to make them accessible in case of failure. UHV compatible materials were used for all parts inside the target chamber. The mounting boards for the silicon detectors were made from laminated Teflon glass. Teflon coated single-stranded cables were used to bring signals from individual strips out of the vacuum. The position readout electronics features 32 pin UHV feedthroughs.[5] Individual position readout boxes ($5 \times 5 \times 6.5$ cm) for each detector plug directly onto the feedthroughs in order to minimize the cable capacitance between detector and preamplifier.

The readout system was built to be capable of detecting particles down to 500 keV. The detectors and all components of the electronics which are in the close vicinity of the accelerating cavity of the Cooler (1-6 MHz), H_2 dissociator (18 MHz) and medium field transition (62.5 MHz) of the source were carefully shielded against RF noise. The RF noise could be minimized to 20 mV peak-to-peak at the timing output of the preamplifier–shaper. We tested the electronics with an ^{241}Am source when the medium field transition, accelerating RF and dissociator were running. During that test the threshold of the discriminator for the timing signal was set to 33 mV (=470 keV) and the threshold of the position readout was set to 400 keV. The position and energy spectra that were obtained during that test are shown in Fig. 5. Evidently, the noise on the position readout can be seen only on a log scale.

The detector assembly in the A-region also makes use of the former CE-01 detector system for detecting forward-going particles. This system was moved from the G-region to the A-region. As described elsewhere[6] this system has a thin 'F' detector, four wire chamber planes (U, V, X, and Y), a 10-cm thick 'E' detector and a veto detector. The detectors are segmented to resolve multi-pronged events. The data acquisition electronics were also moved to read out these detectors.

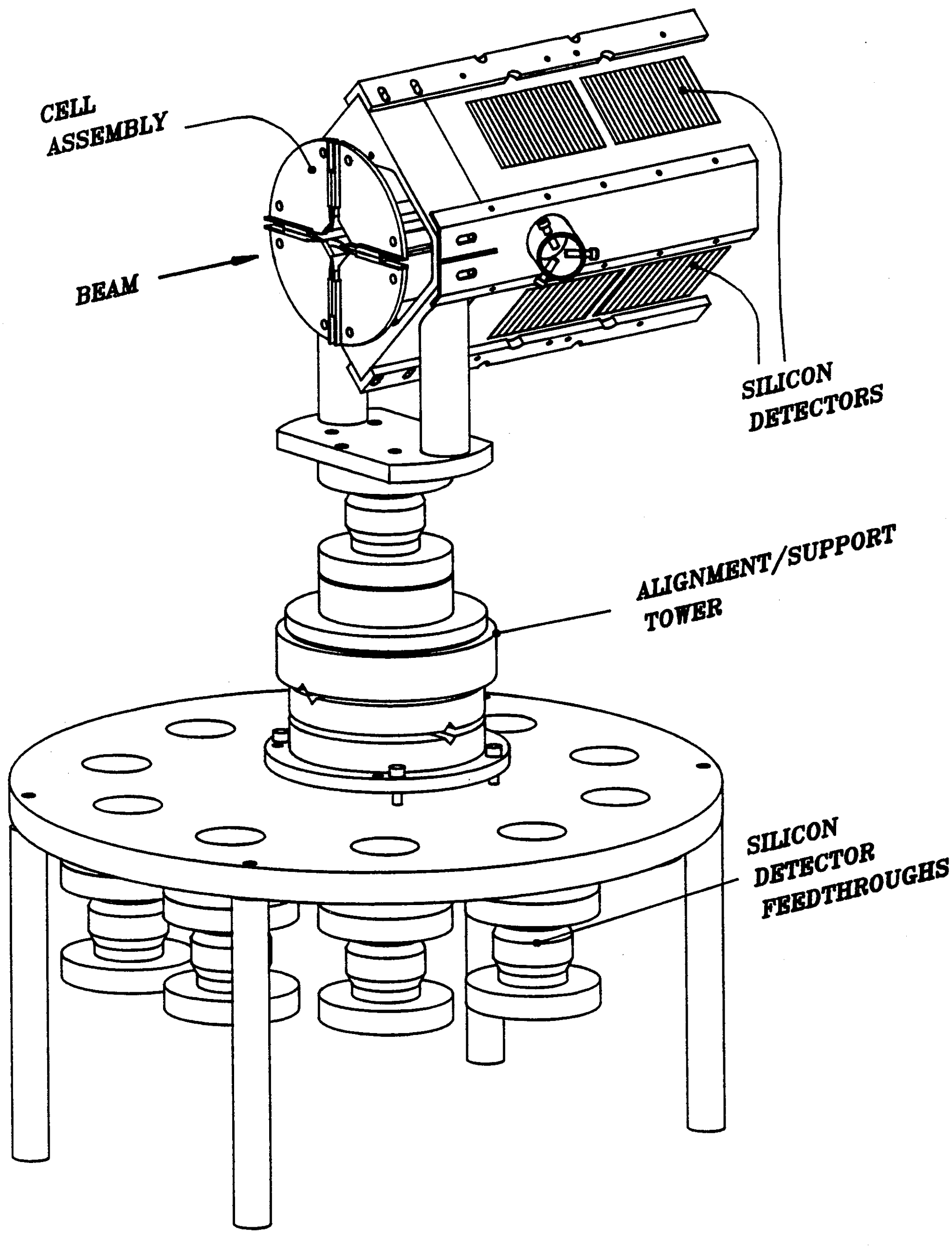

Figure 4. Target cell assembly including silicon microstrip detectors, support tower and mounting flange.

For CE-35, four detectors have been mounted to detect protons elastically scattered from hydrogen near 45° on both sides of the beam in coincidence. These detectors consist of $5 \times 5 \times 7.5$ cm blocks of plastic scintillator located close to the nose-cone surface and in the two reaction planes which have been discussed earlier. In order to minimize gain shifts induced by the guide field, the photomultipliers are removed from the field region by 30-cm

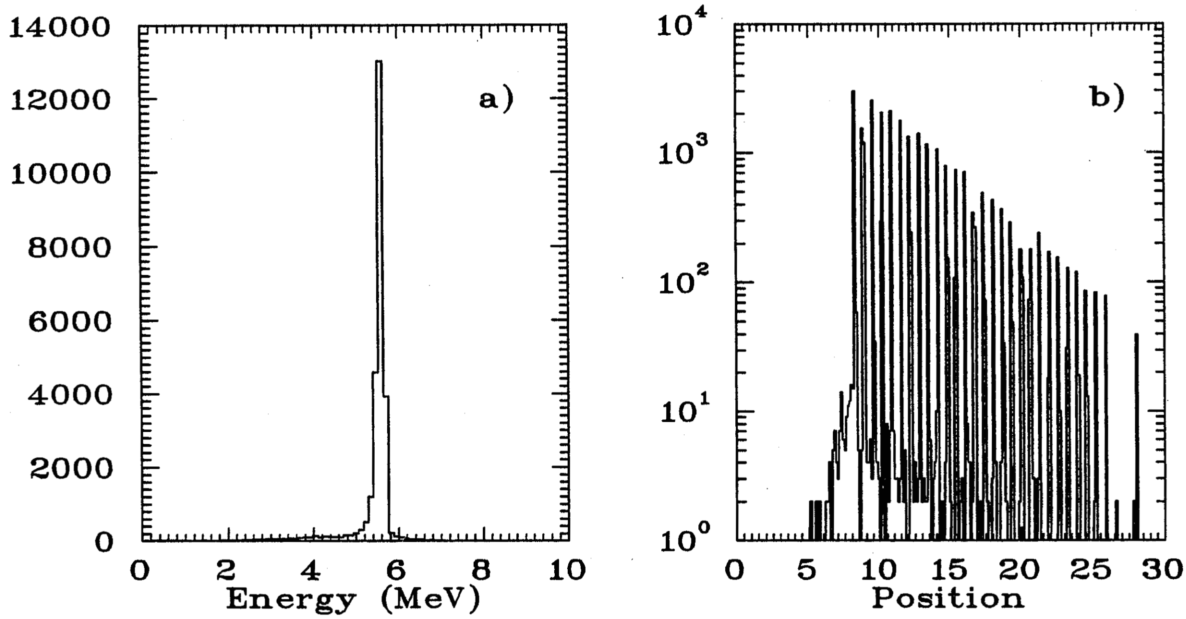

Figure 5. Energy (a) and position (b) obtained with an ^{241}Am source. The spikes in the position spectrum correspond to individual strips. The decrease in amplitude of the spikes is due to the fact that the source was mounted in front of the downstream part of the detector.

long light guides. These detectors are a preliminary version of the detector arrangement that will be required for CE-42. Additional use will be made of these detectors as monitors of luminosity and beam and target polarization in future experiments with the A-region setup. Some information on the tracks of particles going to the 45° detectors is also obtained from the microstrip detectors.

The installation of a polarized atomic beam source in the A-region marks the beginning of a new research program at IUCF. So far, four experiments have been accepted by the PAC. Two more have been proposed, but have been deferred for specific reasons. The four accepted experiments have been designed as a sequence to provide the step-by-step commissioning and testing of new experimental capabilities, while at the same time generating publishable nuclear physics results. The sequence culminates in a measurement of pion production in $p + p \rightarrow p + p + \pi^0$ with polarized beam and polarized target.

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