

## LONGITUDINAL PROTON POLARIZATION IN THE COOLER

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Three approved Cooler experiments, all of them utilizing the polarized internal hydrogen target in the A-region, require longitudinal proton beam polarization at that location in the ring. These are experiments to measure the spin correlation coefficient  $A_{zz}$  in pp elastic scattering at 198 MeV (CE45), and to study the spin-dependent total cross-sections at energies between 300 and 375 MeV in  $pp \rightarrow pp\pi^0$  (CE44), as well as in  $pp \rightarrow pn\pi^+$  (CE67). After much progress over the past year in the development of such a beam at 198 MeV, the new capability was used for the first of the above experiments (CE45), which has since completed data acquisition. In the following, we summarize the technical aspects of our effort to produce a proton beam that is longitudinally polarized at a given point in the ring (here, the A-region).

Normally, the stable spin direction in a storage ring is vertical. To get longitudinal beam polarization in the A-region, spin-precessing solenoids are inserted elsewhere in the Cooler. As explained in last year's annual report,<sup>1</sup> we have decided on a scheme which makes use of the solenoids of the electron-cooling system in the C region and of a superconducting solenoid in the T region. A preliminary test with the C solenoids alone showed that it has a relatively small effect on Cooler performance.<sup>1</sup> At the maximum strength of 0.81 Tm, stack injection still worked and the stored beam was accelerated from 198 to 320 MeV. Furthermore, the ratio of the vertical-to-sideways polarization components, measured in the A-region, agreed well with the spin-closed orbit calculated from the known solenoid fields.

Early in 1996 a superconducting solenoid was installed in the T-region, just upstream of the target chamber and 6° magnet. Inserting the solenoid after the 6° bend would have been preferable, because somewhat higher longitudinal polarization could have been achieved in the A-region. However, it would then have interfered with other experiments using this region. A later move downstream of the 6° bend may be considered if justified by the expected benefit for CE44/CE67.

Prior to its move to the Cooler T-region, the superconducting solenoid, which was purchased from Cryomagnetics Inc., was used in a high-energy beam line (BL4) to prepare non-vertical polarization. The solenoid has a coil with 17,491 turns, producing a maximum

field integral of 2.0 T·m at 90 A. Its cryostat boils liquid helium at a rate of about 1 l/hr when cold, requiring refills at maximum intervals of 26 hours. The effective length of the magnet is about 35 cm, causing relatively strong focussing of the beam. This has to be compensated by adjustments to the currents of existing ring quadrupole magnets. Other effects, related to the coupling of the transverse phase-space coordinates introduced by the solenoidal field, cannot be compensated, as there is no space for special compensating quads in the T-region.

To get some guidance on quad adjustments necessary to run the Cooler with the T and C solenoids, we studied their effects on the beam using the CERN MAD program. A fitting routine was written which calculates quad DAC control changes needed to constrain the beta functions at certain points around the ring (e.g., at the narrow PINTEX storage-cell target in the A-region) while keeping the tunes away from depolarizing resonances. We found that while the C solenoids effects are relatively small (consistent with our experience during the earlier test run), running the T solenoid at about 1 T·m (needed for CE45) would require significant changes to a relatively large number of quad controls.

The T solenoid was commissioned in two short development runs preceding CE45. After careful physical alignment to minimize steering effects, the field integral was gradually increased up to 1.4 T·m (at 198 MeV this produces a 58% snake). The predicted quad changes were qualitatively borne out. The transverse ring acceptance appeared to be little affected, while a slight decrease in the accumulation rate was observed. In preparation for CE44 we succeeded in ramping the beam energy to 400 MeV, but have not measured the polarization yet at this energy. For CE45 (at 198 MeV), the T solenoid was run at 1.10 T·m and the C solenoids at 0.88 T·m. At these values the stable polarization is predicted to be nearly vertical in the injection region, and 96% longitudinal, 25% sideways, and 12% vertical (relative to its magnitude) in the A-region. The measured values are consistent with these predictions. At 375 MeV, the highest energy requested by the pion production experiments, the longitudinal polarization will be 82% if we can run the C and T solenoids at their maximum strengths of 0.9 and 2 T·m, respectively.

1. H.O. Meyer *et al.*, IUCF Sci. and Tech. Rep. May 1994 - April 1995, p. 142.

## COOLER TARGET LAB

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The two major Cooler gas target facilities, the Wisconsin/IUCF polarized hydrogen target<sup>1</sup> of the PINTEX collaboration and the unpolarized jet target,<sup>2</sup> remained operational through the reporting period in the A- and T-regions, respectively. The former was used