STATUS OF AN INVESTIGATION OF THE ³He WAVE FUNCTION BY QUASI-FREE SCATTERING

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This experiment (CE-25) will measure the asymmetries in quasifree knockout of protons and neutrons from polarized ³He using polarized proton beams of 200 to 400 MeV. The polarized target and detectors are located in the A-section of the Cooler. The motivation for the measurements is an investigation of the ground state spin structure of the ³He nucleus. This nucleus has the advantage that exact non-relativistic calculations using the Faddeev technique are available. These calculations indicate that in the ground state of ³He, which consists primarily of an S-state with the proton spins anti-aligned, the neutron accounts for $\sim 90\%$ of the polarization of the ³He nucleus. The remainder of the wave function is dominated by the D-state and the mixed-symmetry S'-state. Recent measurements of the asymmetries in quasifree knockout from polarized ³He at TRIUMF[1] with incident proton energies of 220 and 290 MeV indicate considerable disagreement with PWIA calculations. These results have been interpreted as evidence for final-state interaction effects. CE-25 will check the TRIUMF data, cover a broader kinematic range, and will extend the measurements to higher energies.

The experiment utilizes a polarized ³He internal gas target[2] developed at MIT and the stored polarized proton beam of the IUCF Cooler. In the target scheme shown in Fig. 1, a continuous flow of 1×10^{17} atoms of ³He per second is polarized by metastability exchange laser optical pumping in a glass cell outside the vacuum system. This flow is directed with a capillary tube into a open ended storage cell (1.4 cm × 1.6 cm × 40 cm) inside the vacuum chamber, resulting in a target thickness of 1×10^{14} cm^{-2} pure polarized ³He atoms. The target polarization can be reversed in 600 ms by flipping the magnetic
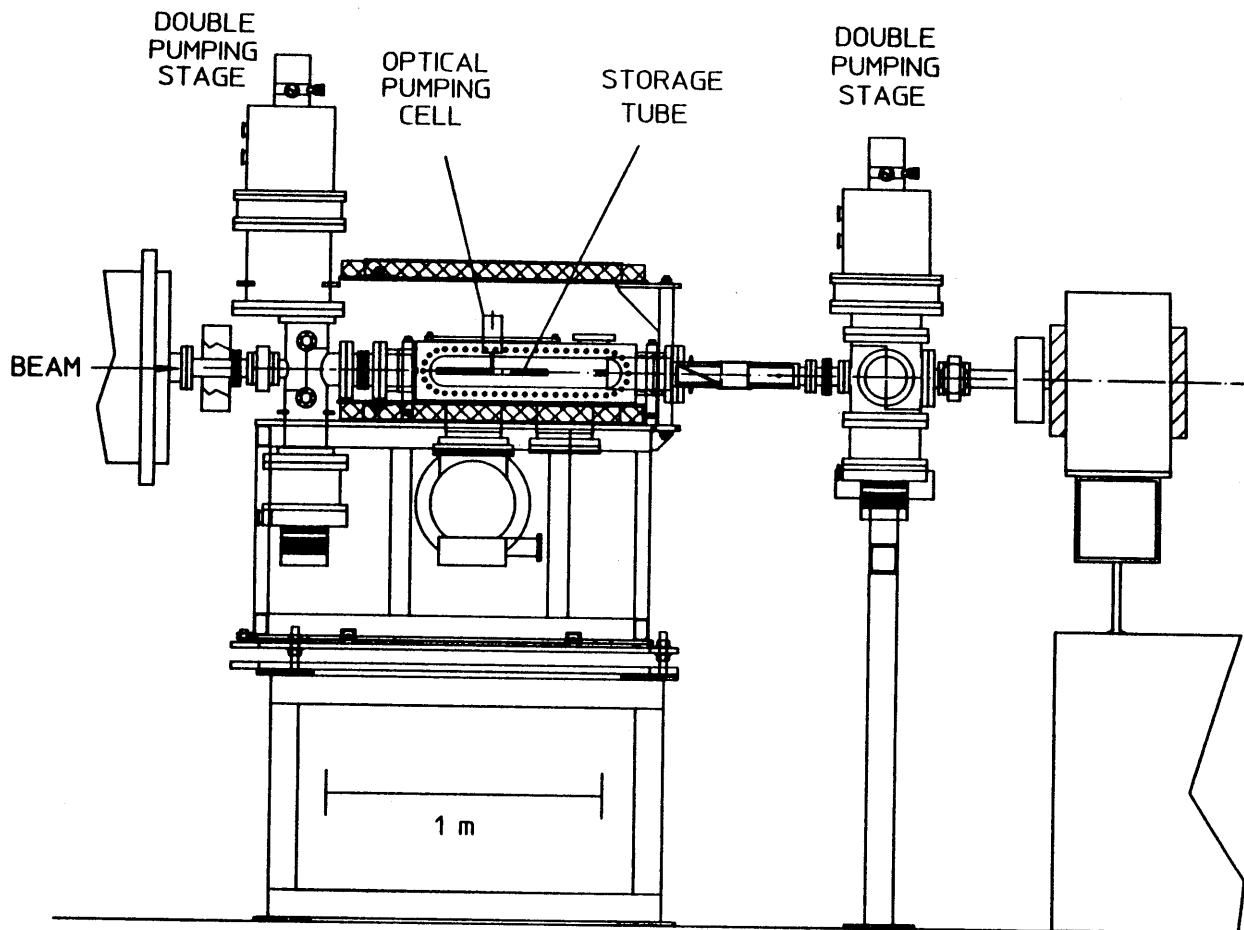
Figure 1. Side view of the polarized ^{3}He target. ^{3}He gas flows into a glass optical pumping cell, where it is polarized, and then to an open-ended storage tube in the vacuum chamber where the beam interacts with it. There are two pumping stages upstream and downstream of the target region in order to reach ambient Cooler vacuum. The beam enters from the left.

field. It can also be reversed by changing the handedness of the circularly polarized light in 30 s without changing the field. The target has been at IUCF since the beginning of 1992, and was installed in the ring in March. It has now operated in two runs, routinely producing ~50% polarization with a flow rate of 1×10^{17} atoms/s. More detail about the target is contained in the Cooler Target section of this report.[3]

The magnetic holding field used with the polarized target is low, 10-30 G. However, the beam sees a field integral, for 30 G central field, of about 3 kG-cm or close to the strength of steerers in the ring. Turning on the field without making a correction would cause significant closed orbit distortions and would make it very difficult to operate the ring. Two additional steerers were added to the A-region downstream of the experiment to make a local "combo." The three magnets bend the beam away from the closed orbit (magnet 1 - the target), bend the beam back toward the closed orbit (magnet 2 - a steerer) and finally bend it back onto the closed orbit (magnet 3 - a steerer). The time response of the two steerers is such that they are able to compensate for the target field even when it is flipping in 600 ms. This scheme has been used in two runs and has allowed us to move the beam by 16 mm in the A-region with less than 1 mm motion in the rest of the ring. Fast flipping of the target field has been observed to have no effect on stored beam. Cooling and injection are not affected by the state of the magnet.

The detector array consists of scintillators and wire chambers. The layout is shown in Fig. 2. The wire chambers were originally used in the IUCF charge symmetry breaking experiment. The large neutron detector arrays are the contribution of the (p,n) group. The detector configuration shown emphasizes free scattering kinematics and allows for a large range of scattering angles. The detectors can also be arranged symmetrically, both centered at 53° in the lab. This geometry emphasizes the high momentum parts of the wave function.

Additional detectors are placed inside the chamber for use as luminosity and polarization monitors. Six microstrip detectors, three on each side, are placed along the side of the target cell in order detect recoil ^{3}He nuclei. Scintillators are placed downstream at small angles to detect protons. The scintillators and microstrips will detect p-^{3}He elastic scattering for use as a luminosity monitor as well as beam polarization monitor. Coincidences between protons in the large external detector arms and ^{3}He in the microstrip detectors will allow us to measure p-^{3}He elastic scattering over the full angle range of the detectors. Alpha particles and pions from the ^{3}He(p,π)^{4}He reaction should also show up in the detectors. Because of the spin structure of this reaction the spin correlation, C_{NN}, is identically 1 at all energies and angles. This should allow us to check the product of beam and target polarization normalizations.

Two test runs were carried out this spring. In the first run we used 45 MeV unpolarized protons to test the target operation in the ring. We used the internal microstrip detectors to detect ^{3}He recoils in coincidence with protons in external scintillators placed to cover the exit windows of the chamber. Both the protons and ^{3}He recoils stopped in the detectors allowing us to identify elastic scattering from the total energy. The angles were determined from kinematics by the energy deposited in the microstrip detectors. The absolute energy of signals in the microstrips was calibrated with alpha sources.
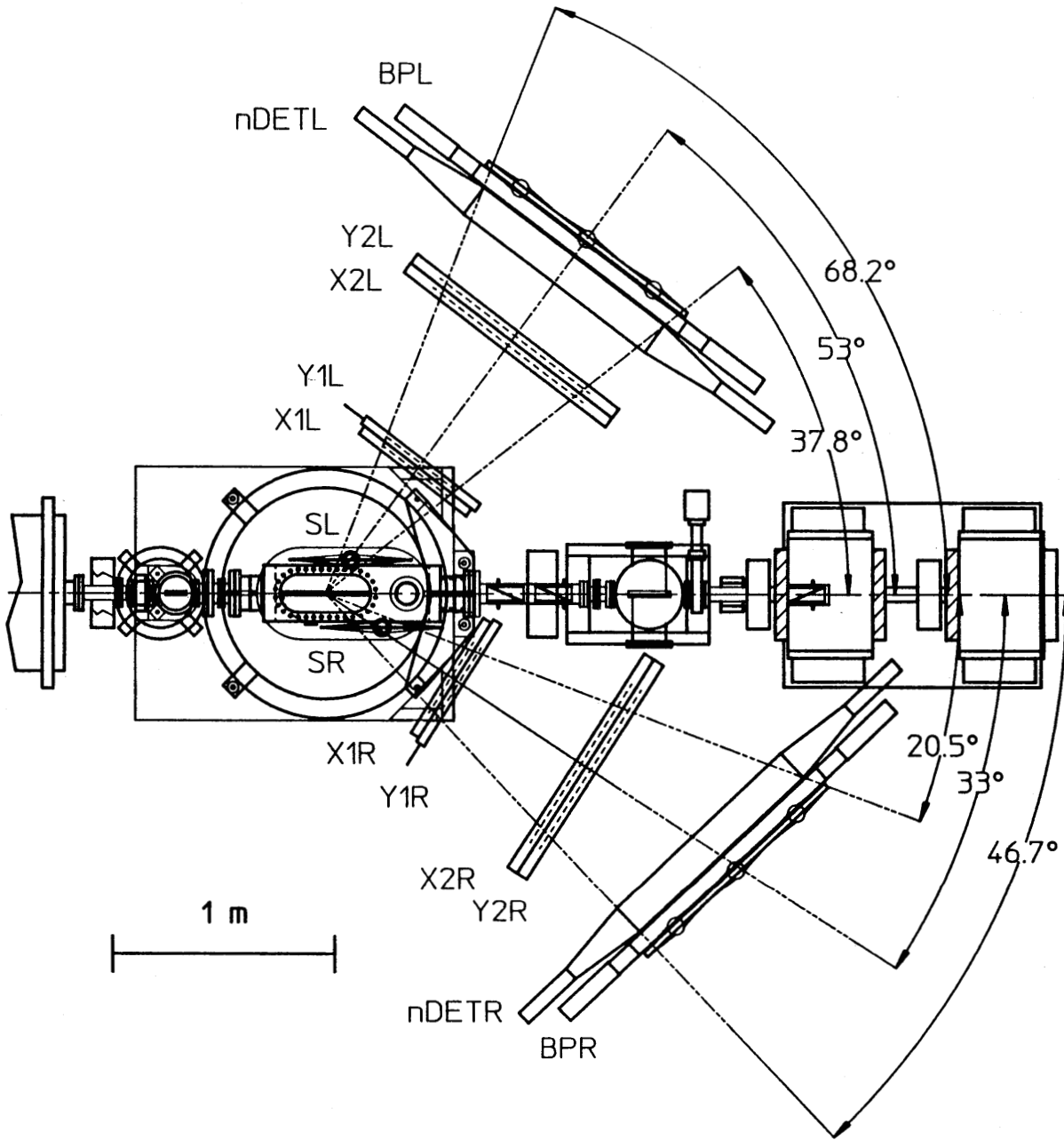
Figure 2. Schematic top view of the experimental setup. Protons are detected by a start scintillator (S#), two pair of x-y wire chambers (X#,Y#), a plastic scintillator array (nDET#) and additional backing plastics (BP#). Neutrons are detected only in the plastic scintillator array.

The measured p-^{3}He elastic scattering target analyzing power at 45 MeV is shown in Fig. 3. The target polarization is determined by measuring the polarization of the $3^1D \rightarrow 2^1P$ transition in the ^{3}He discharge. The data are compared to previous data[4] at nearby energies and agree quite well. These data are the first asymmetries measured with an internal polarized target in a storage ring with electron cooling.

In the second run a subset of the detectors and electronics were set up to measure 200 MeV p-^{3}He elastic scattering. The ^{3}He recoils were again stopped in the microstrip detectors. The neutron detector bars were stacked so that scattered protons entered at an angle to the face and thereby were stopped. Coincidences between left and right bars were also recorded to look at (p,2p) and (p,pn) triggers and event rates. Wire chambers were not installed, so good angle information is only available for the p-^{3}He elastic events where, again, the scattering angle is reconstructed from deposited energies in the detectors.
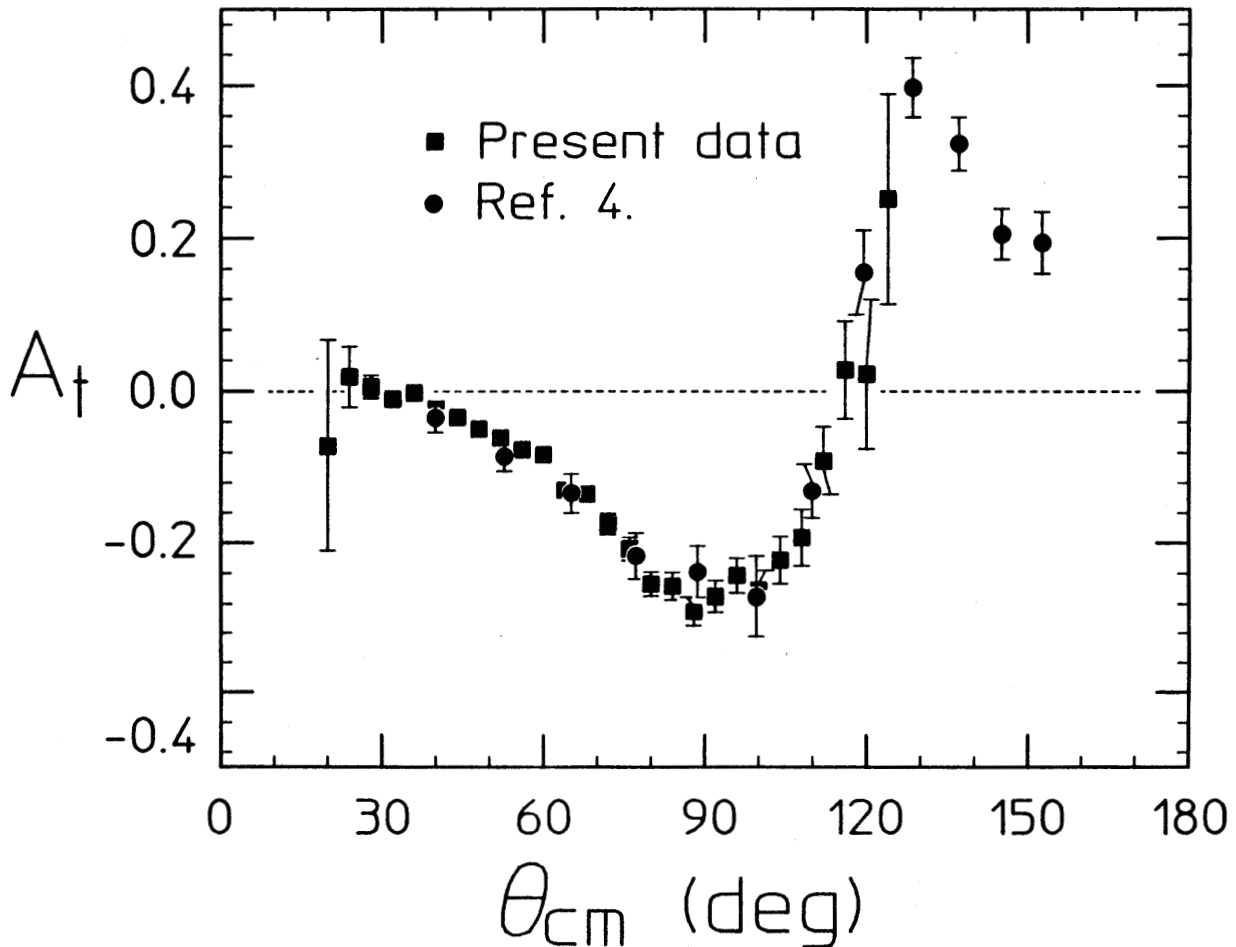

Figure 3. Target analyzing power for p-^{3}He elastic scattering at 45 MeV. Previous data[4] at nearby energies are shown for comparison.

This run, completed after the deadline for this report, was also quite successful. We were able to get data on the p-^{3}He elastic scattering spin correlation, as well as beam and target analyzing powers at 200 MeV. This is the first time that a spin correlation has been measured with an internal polarized target. In addition the electronics setup was checked out and valuable information about expected rates was obtained. During the summer the detectors will be placed in their final configuration. Two more runs are scheduled late this summer and production running should be finished near the end of the year.

1. A. Rahav *et al.*, Phys. Lett. **B275**, 259 (1992).
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3. K. Lee, *et al.*, this report.
4. R.H. McCamis, *et al.*, Phys. Rev. C **1651**, 1651 (1985).