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

C.E. Jones
Argonne National Laboratory, Argonne, Illinois 60439

A. Smith, G. Savopulos, B. von Przewoski, M. Leuschner, J. Sowinski, J. Doskow, F. Sperisen, C. Bloch, C.D. Goodman, W.W. Jacobs, H.O. Meyer, and T. Rinckel
Indiana University Cyclotron Facility, Bloomington, Indiana 47408

J-O. Hansen, K. Lee, R.G. Milner, W. Korsch, R. Ent, S.F. Pate, C. Tschalaer, D. DeSchepper, L.H. Kramer, N. Makins, and P. Welch
Massachusetts Institute of Technology, Cambridge, Massachusetts 02139

D. Marchlenski and E.R. Sugarbaker
The Ohio State University, Columbus, Ohio 43210

W.K. Pitts
University of Louisville, Louisville, Kentucky 40292

W. Lorenzon
TRIUMF, Vancouver, B.C., V6T 2A3 Canada

M. Miller, J. Neal, J.F.J. van den Brand, H.J. Bulten, Z-L. Zhou, and O. Unal
University of Wisconsin, Madison, Wisconsin 53706

P.V. Pancella
Western Michigan University, Kalamazoo, Michigan 49008

In the past year the CE-25 collaboration has assembled their experiment in the A-region of the Cooler and completed the measurement of analyzing powers and spin correlations in quasi-free knockout of protons and neutrons from polarized ^{3}He. In preliminary tests during the spring of 1992 we were the first to measure a spin correlation using an internal polarized target and a storage ring[1] thereby demonstrating the realization of this long sought technique. The motivation for the measurements is an investigation of the ground state spin structure of the ^{3}He nucleus. This nucleus has the advantage that exact non-relativistic calculations using the Faddeev technique are available. These calculations indicate that the ground state of ^{3}He consists primarily of an S-state with the proton spins anti-aligned such that the neutron accounts for ~90% of the polarization of the ^{3}He 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 quasi-free knockout from polarized ^{3}He at TRIUMF[2,3] with incident proton energies of 220 and 290 MeV indicate considerable disagreement with PWIA calculations. They interpret these results as evidence for final-state interaction and rescattering effects. CE-25 extends these measurements to higher energy and covers a much broader kinematic range while overlapping the TRIUMF kinematics. The higher incident energy and larger scattering angles should result in higher-momentum exiting particles and therefore tend to reduce the effects of FSI and rescattering, resulting in a more reliable PWIA.

In the experiment we utilize a polarized ^{3}He internal gas target[4] developed at MIT and the stored polarized proton beam of the IUCF Cooler. In this target a constant flow of ^{3}He atoms is polarized by metastability exchange laser optical pumping in a glass cell outside the target chamber. These atoms are directed with a capillary tube into an open ended storage cell (1.4 cm × 1.6 cm × 40 cm) inside the vacuum chamber. The low mass storage cell is made of thin aluminum and 1.7 μm aluminized mylar side foils, allowing the low energy recoil ^{3}He nuclei to exit and be detected by microstrip detectors mounted inside the scattering chamber. Polarizations of 45% to 50% were maintained

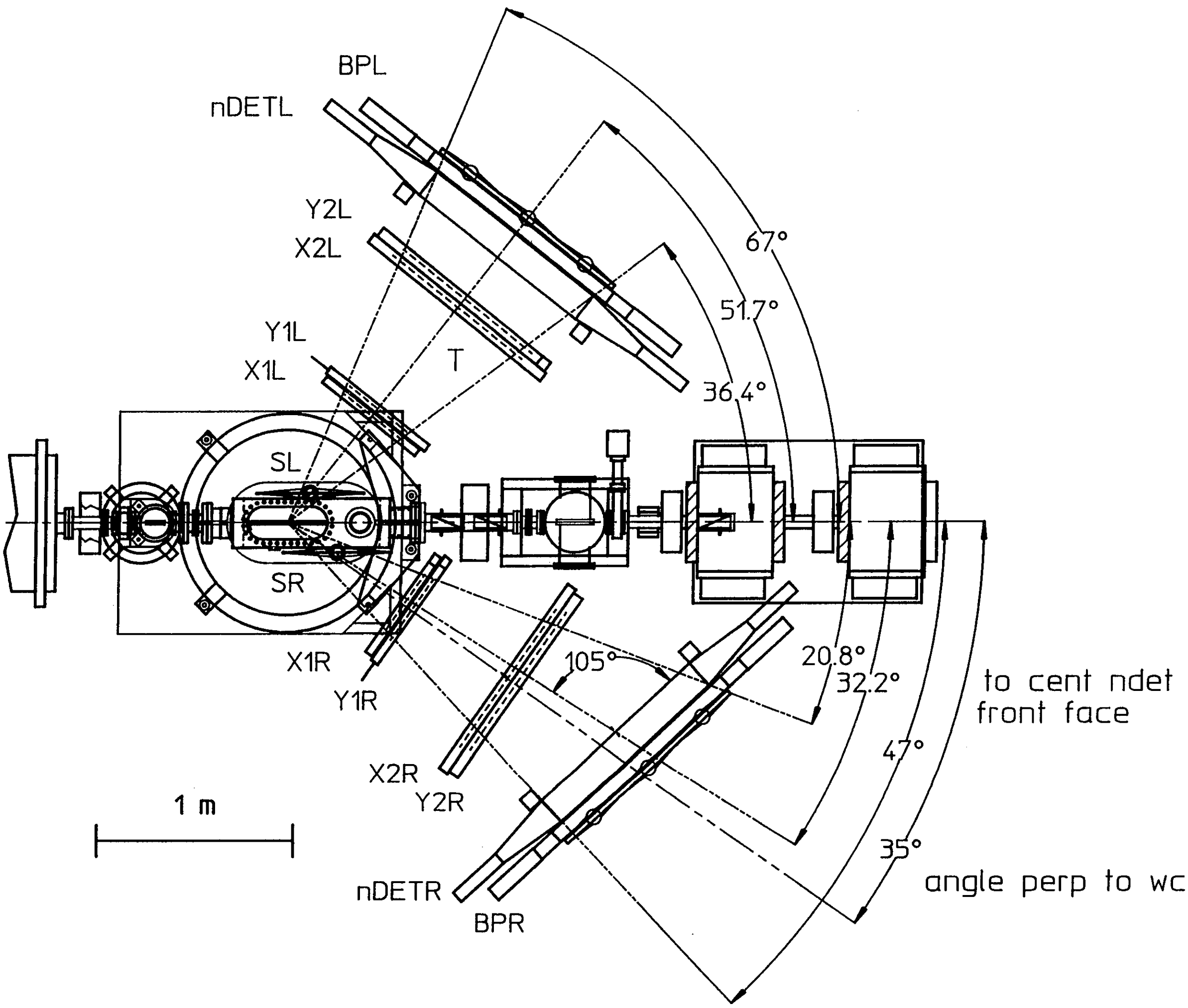

Figure 1. Schematic top view of the experimental setup. Protons are detected by a start scintillator (S#), two pair of x-y wire chambers (X#,Y#), a plastic scintillator array (nDET#) and additional backing plastics (BP#). Neutrons are detected only in the plastic scintillator array.

throughout the measurements with a flow rate of 1.2×10^{17} atoms per second and a resulting target thickness of 1.5×10^{14} cm^{-2}. The target was very reliable and very little overhead was required for its operation. There is no evidence in the scattering measurements for depolarization of the ^{3}He atoms in the storage cell.

The development of ramped polarized beam was concurrent with the CE-25 runs over the last year. Although maintaining full polarization during the ramp proved more difficult than originally expected due to an unforeseen coupling resonance, the problems were solved[5] and high beam currents and full polarization were achieved for the production runs. In fact, data acquisition rates limited the beam current to 100 μA, which could be injected into the ring in less than 2 minutes during our final run. With the long flat top times of 10-15 minutes allowed by the thin target, quite good duty factors were achieved. The time averaged luminosity during a typical run was 5×10^{28} s^{-1}cm^{-2}, meeting our design goals.

The detector array consisted of scintillators and wire chambers. The layout is shown in Fig. 1. 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. In order to calibrate the detectors, H_2 was placed in the target, allowing us to use the kinematic correlations in p-p scattering for determining absolute angles and energies of the scattered particles. Results from raytracing are shown in Fig. 2, which displays the measured x, y and z distributions of the reconstructed vertex.

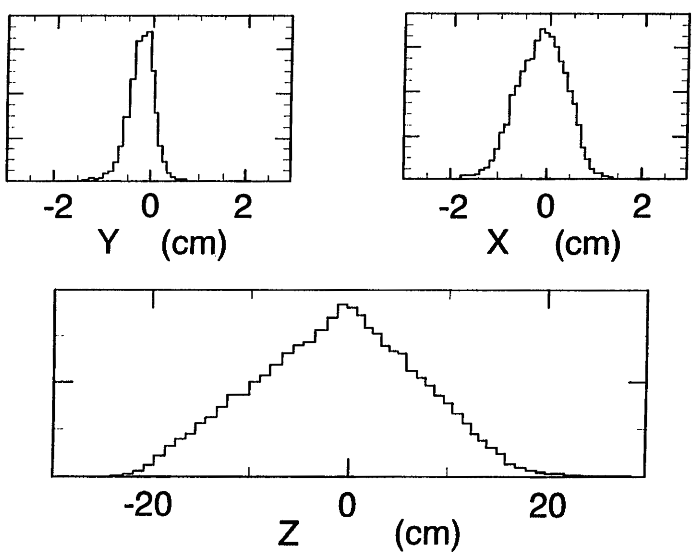

Figure 2. Reconstruction of the vertex position from wire chamber raytracing of two protons. The coordinate y is vertical and z is along the beam axis.

The vertical (y) resolution is about 8 mm FWHM, which means we can resolve the beam path from the massive parts at the top and bottom of the cell. The distribution along the beam axis (z) shows the triangular shape expected from the gas dynamics of the cell.

We have also used p-p elastic scattering to investigate possible backgrounds from the cell. This provided two charged particles for vertex reconstruction with the angle between the two particles essentially constant. A plot of this opening angle between the two protons is shown in Fig. 3. One sees a peak of about 2° FWHM associated with free scattering on top of a broad distribution that may arise from various background processes. In this spectrum with no cuts the background under the peak is already less than 1% of the peak counts. If we cut to select the regions outside the peak in Fig. 3, we see no preference for these events to be coming from the massive regions of the cell. They are uniformly distributed over a region twice the size of the cell. This would seem to indicate that a large fraction of these events are, in fact, free scattering from the target where the tracks have been poorly reconstructed due, for example, to large angle scattering of a proton in one of the detectors. In any case it is clear that essentially background free experiments

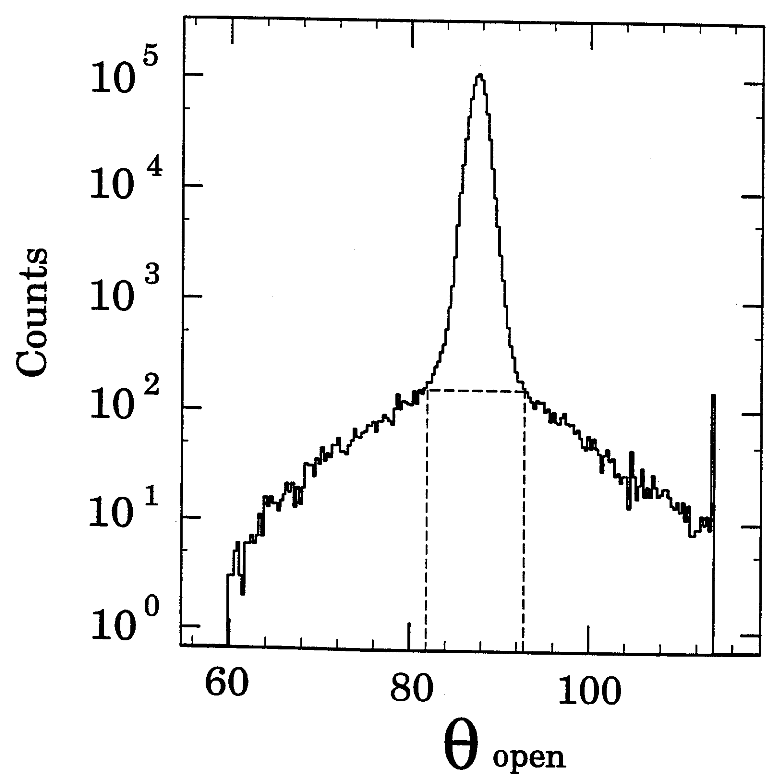

Figure 3. Angle between protons in p-p elastic scattering at 300 MeV.

can be performed with storage cells in a ring. It should be noted that, in achieving these small backgrounds, care was taken to make the cell very low in mass and the dimensions were chosen to have an acceptance almost twice that of the typical machine acceptance to avoid backgrounds from beam halo and steering misalignments.

This experiment was completed in March and the equipment used in CE-47 this past May. It has now all been removed from the ring. We are currently busy with data analysis. As an example of the sort of statistics we were able to achieve, Fig. 4 shows preliminary

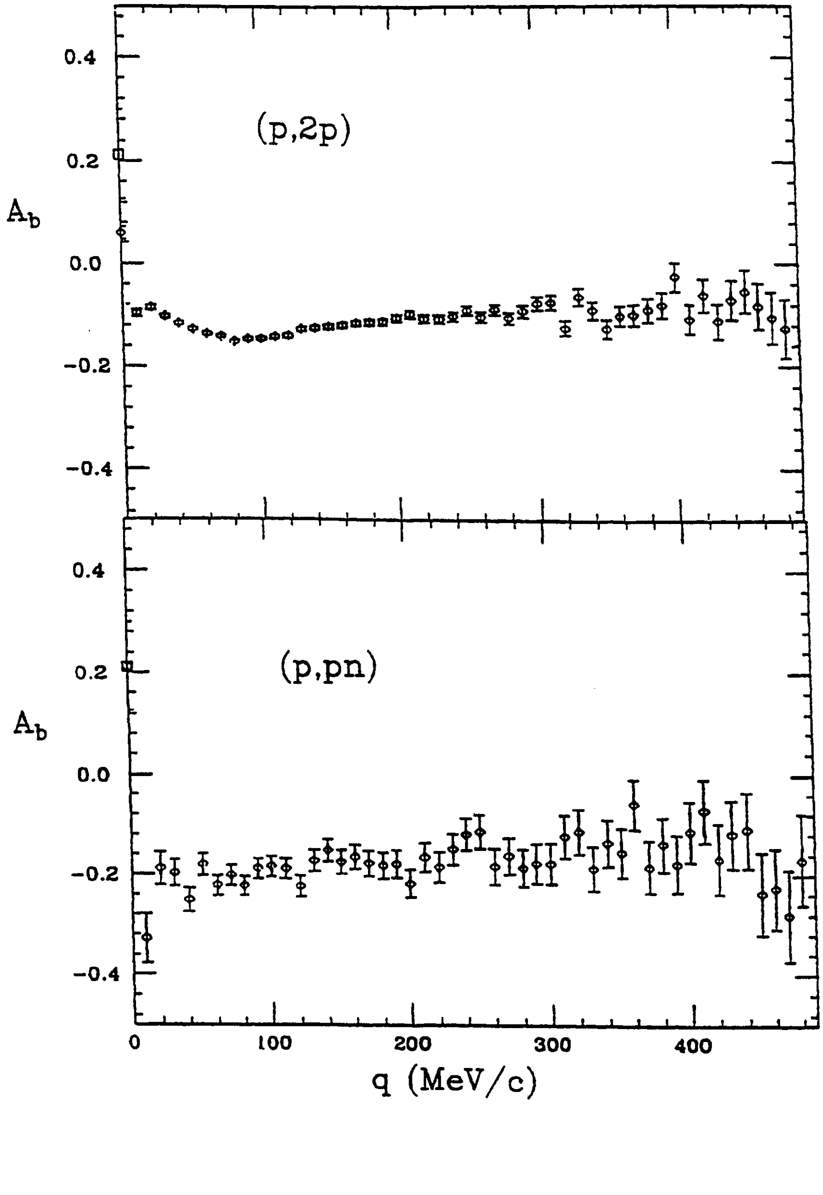

Figure 4. Above are shown preliminary results of the beam analyzing powers for $^3\overrightarrow{\mathrm{He}}(\vec{\mathrm{p}},2\mathrm{p})$ and (p,np) at 415 MeV. The data are summed over the full acceptance of the detectors with a proton going to the back detector (centered at 52°) in both cases and a proton or neutron going into the forward detector (centered at 32°). Similar quality data were taken for the neutron going to the back angle detector.

results for the beam analyzing powers for ^{3}He(p,2p) and (p,pn) plotted versus the missing momentum at 415 MeV. Similar data are available for the target analyzing power and spin correlation as well as at 200 MeV and 300 MeV. The experiment has been quite successful and we expect to have preliminary results soon.

1. K. Lee, *et al.*, Phys. Rev. Lett. **70**, 738 (1993).
2. E.J. Brash, *et al.*, Phys. Rev. C **47**, 2064 (1993).
3. A. Rahav, *et al.*, Phys. Lett. **B275**, 259 (1992); Phys. Rev. C **46**, 1167 (1992).
4. K. Lee, *et al.*, submitted to Nucl. Instrum. Methods.
5. See description of accelerator development, D. Friesel and G. East, this report.