REPORT ON CE-19: $^{16}O(p,n)^{16}F(0^-)$ IN THE IUCF COOLER

T.W. Bowyer, S.E. Vigdor, S.M. Bowyer, W.W. Jacobs, Y. Kim,
B. von Przewoski, E. Pierce, T. Rinckel, F. Sperisen, and G. Xu
Indiana University Cyclotron Facility, Bloomington, Indiana 47408

W.K. Brooks
University of Pittsburgh, Pittsburgh, Pennsylvania 15269

The relatively weak $^{16}O(p,n)^{16}F(0^-)$ transition is of great interest because it carries the pion's quantum numbers and is thus sensitive to potential many-body effects of the pion field in a nucleus. Previous experimental studies relied on neutron time-of-flight in order to obtain adequate energy resolution to distinguish the (ground state) 0^- from the ($E_{ex}\approx$200 keV) 1^- state of ^{16}F. The required energy resolution limited these studies to bombarding energies $\lesssim$80 MeV, where reaction mechanism ambiguities severely complicated the interpretation of the measurements. The goal of CE-19 was to study this reaction at the more suitable energy of 300 MeV in the IUCF Cooler by exploiting an ultra-thin gas target to detect the low-energy ($\approx$0.5 MeV) decay protons from ^{16}F as a high-resolution tag in coincidence with prompt neutrons (detected over a relatively short flight path).[1] Two test runs were performed in the spring of 1991 to study the feasibility of this experiment in the IUCF Cooler.

Since ultra-thin internal targets must be used in the Cooler, a gaseous form of oxygen was desired for this experiment. Due to the corrosive and potentially damaging effects O_2 would have on the turbomolecular pumps[2] of the existing jet target, pure O_2 could not be used. The only stable gas which contains oxygen without contaminants that might mock up the signature or create a background for the CE-19 experiment is H_2O vapor. A water vapor jet for use in CE-19 was developed, tested and reported earlier.[3]

In the test runs, neutrons were detected over the angle range $\theta_n^{lab}\approx1°$–$9°$ in a 14-element scintillator hodoscope developed for the CE-03 experiment.[4] The hodoscope was positioned 4.8 m from the target and covered a laboratory solid angle of $\approx$34 msr. Low-energy protons were detected in coincidence with the neutrons in one of two cooled, 4 cm×6 cm, 500 μm thick silicon microstrip detectors. These detectors were placed $\approx$5 cm from the beam axis in order to maximize the solid angle for the ^{16}F decay protons, which for the 0^- state are emitted isotropically in the ion's rest frame. The detector layout is shown in Fig. 1.

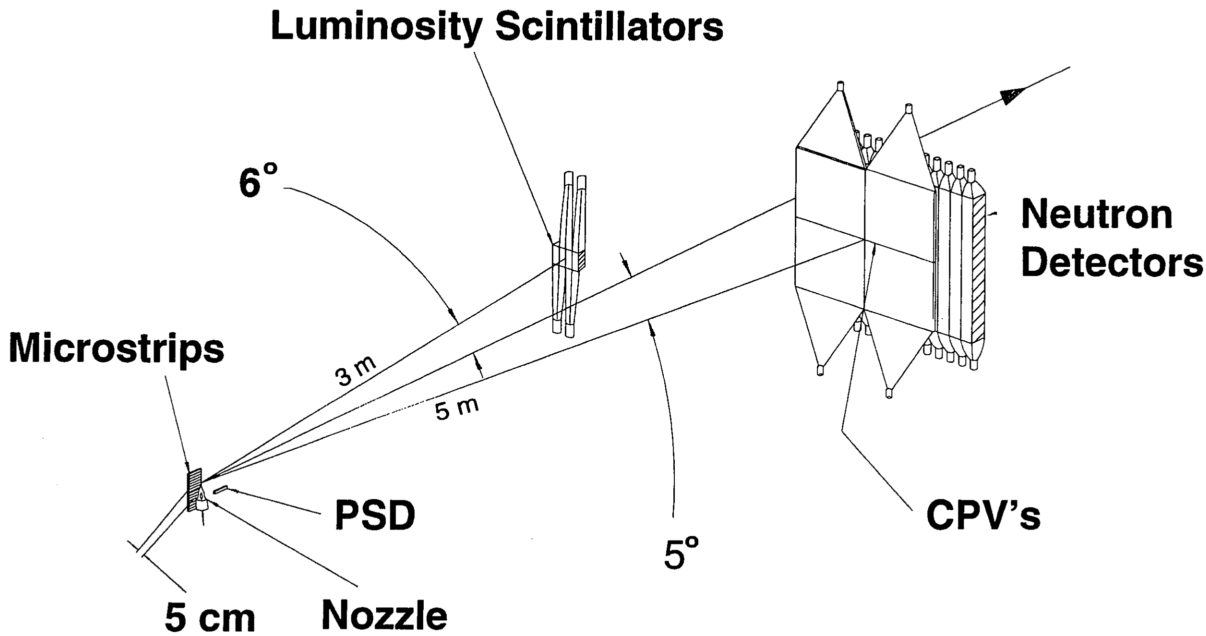

Figure 1. Experimental layout for the CE-19 test runs.

In order to monitor luminosity, we set up to acquire simultaneously p-p elastic scattering events from the hydrogen in the water vapor target. Those p-p coincidences involving a backward low-energy proton were monitored both by the neutron hodoscope-microstrip combination and by a second detector combination comprising forward plastic scintillators on the beam left side at laboratory angles ≈9.5° to 14°, and a position sensitive silicon detector (PSD) for the recoil proton on beam right. The latter combination allowed software reconstruction of the jet profile in a manner similar to previous Cooler experiments.[4,5] Both arms should also provide an absolute normalization via p-p scattering of the $^{16}O(p,n)^{16}F(0^-)$ cross sections measured simultaneously. In order to avoid overwhelming n-p coincidence contamination by p-p scattering events, we placed four charged-particle veto (CPV) scintillators in front of the neutron detectors, and only allowed a small sample (1%) of p-p data to be written to tape.

The first test run went smoothly though the low beam current (100-150 μA average) and low Cooler acceptance ($\sim 4\pi$ mm-mrad) limited our luminosity to only $\approx 2\times 10^{27}$ $cm^{-2}s^{-1}$ for p-p events. This was far too small to get a statistically significant number of 0^- (p,n) events above background. Nonetheless, the analysis of the first test run was encouraging, since the strongly populated 2^- state ($E_x \approx 400$ keV) in ^{16}F clearly showed above the background in the decay proton spectrum with excellent (≈90 keV) energy resolution. Fig. 2a shows the corrected pulse height spectrum from the silicon strip detectors: the 2^- state is seen roughly at channel 200, corresponding to approximately 900 keV proton energy. This spectrum was gated on neutron time-of-flight, RF time and neutron-proton time difference.

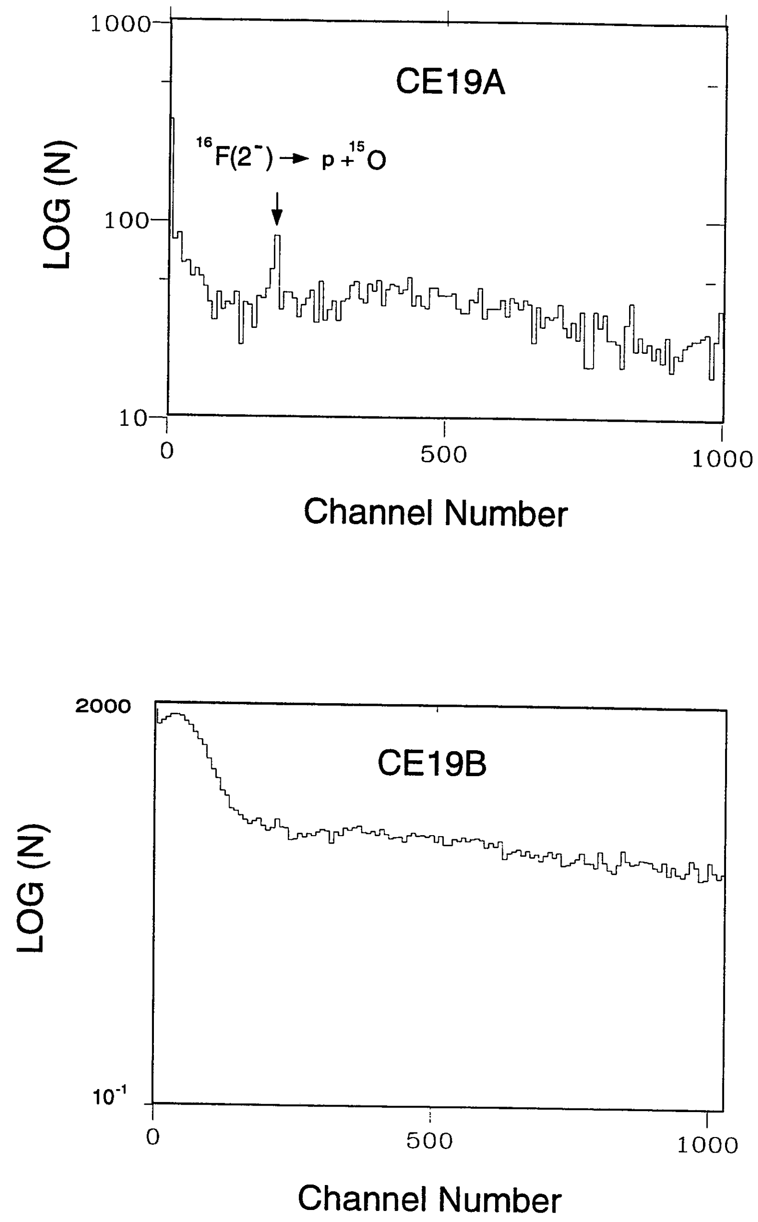

Figure 2. Spectra of silicon microstrip pulse height gated on neutron time-of-flight, RF time and n-p time difference. (a) First test run (CE-19A). (b) Second test run (CE-19B), obtained with 300 MeV protons on H_2O vapor jet target.

The goal of the second test run was to run with an improved luminosity in order to gain enough statistics to see the 0^- state above background. The average beam current was increased in the second test run to about 500-600 μA, increasing the luminosity to $\approx 2\times 10^{28}$ $cm^{-2}s^{-1}$ for p-p events. Unfortunately, the singles counting rates in the silicon microstrips increased by much more than an order of magnitude. This increase came from *real particles* correlated with the detected neutrals, all below 1 MeV energy deposition in the microstrips. We found that the singles rate *without a target* depended strongly on the amount of current injected into the Cooler and seemed to decrease with a half-life of $\approx$4 s after beam cooling. There was also a long-lived component of the singles rates which had a half-life of $\approx$15 minutes. We surmise that the increased rate of low energy deposition particles may have come from activation of the copper nozzle from the vapor jet target and/or pumping apertures in the target box. We tried without significant success to adjust the beam tuning to eliminate the apparent activation problem.

The analysis of the data from the second test run showed that the 2^- state was completely swamped by the low energy tail in the microstrips. Fig. 2b shows the microstrips' energy spectrum from the second test run with the same gating conditions as Fig. 2a. Obviously, there was no chance to see the relatively weak 0^- ground state in this case. The results from the test runs suggest that the technique we employed for measuring observables in the $^{16}O(p,n)^{16}F(0^-)$ reaction works in principle; however, coincidences between neutral particles and very low-energy charged particles offer no opportunity to ray-trace to a reconstructed event vertex, and hence make the technique very susceptible to background from non-target sources. One thus needs far better control and reproducibility of beam tuning than presently exists for the T-section of the Cooler. The experiment will be deferred until appropriate advances in beam tuning have been made.

1. T.W. Bowyer and S.E. Vigdor, spokespersons, "Study of the $^{16}O(p,n)^{16}F(0^-)$ Reaction at $T_p = 300$ MeV in the IUCF Cooler," IUCF Proposal No. 90-07, June 1990.
2. R. Hellmer, Balzer's High Vacuum Prod., private communication.
3. T. W. Bowyer, *et al.*, IUCF Sci. and Tech. Rep., May 1990-April 1991, p. 166.
4. W. Daehnick, *et al.*, IUCF Sci. and Tech. Rep., May 1990-April 1991, p. 52.
5. H.O. Meyer, *et al.*, Phys. Rev. Lett. **65**, 2846 (1990).