REPORT ON CE19: $^{16}O(p,n)^{16}F(0^-)$ IN THE IUCF COOLER

T.W. Bowyer, S.E. Vigdor, S.M. Bowyer, C.D. Goodman,
W.W. Jacobs, S.F. Pate, E. Pierce, S.W. Wissink, and G. Xu
Indiana University Cyclotron Facility, Bloomington, Indiana 47408

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

W. K. Pitts
University of Wisconsin, Madison, Wisconsin 53706

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$80 MeV, where reaction mechanism ambiguities severely complicate the interpretation of the measurements. CE19 proposes[1] to study this reaction at the more suitable energy of 300 MeV in the IUCF Cooler, by exploiting an ultra-thin gas target to detect the low-energy ($\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). In May 1991, the first feasibility study of this reaction was performed in the T-section of 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, so some alternative source of gaseous oxygen was needed. The only stable gas which contains oxygen without contaminants that might mock up the signature or create a background for the CE19 experiment is H_2O vapor. A water vapor jet was developed, tested and reported on earlier[3] for use in CE19; the details of the target performance during the test run are described elsewhere in a separate contribution to this report.[4]

In the test run, neutrons were detected over the angle range θ_n^{lab} $\approx$1°–9° in a 14-element scintillator hodoscope developed for the CE03 experiment.[5] 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 the ion's rest frame. The detector layout is shown in Fig. 1.

In order to monitor luminosity, we set up to acquire simultaneously p-p elastic scattering events from the hydrogen in the water vapor target. p-p coincidences involving a backward low-energy proton were monitored both by the neutron hodoscope-microstrips combination and by a second detector combination comprising forward plastic scintillators on the beam left side at laboratory angles $\approx$9.5° to 14° and a position sensitive silicon detector (PSD) for the recoil proton on beam right. The latter combination allowed software

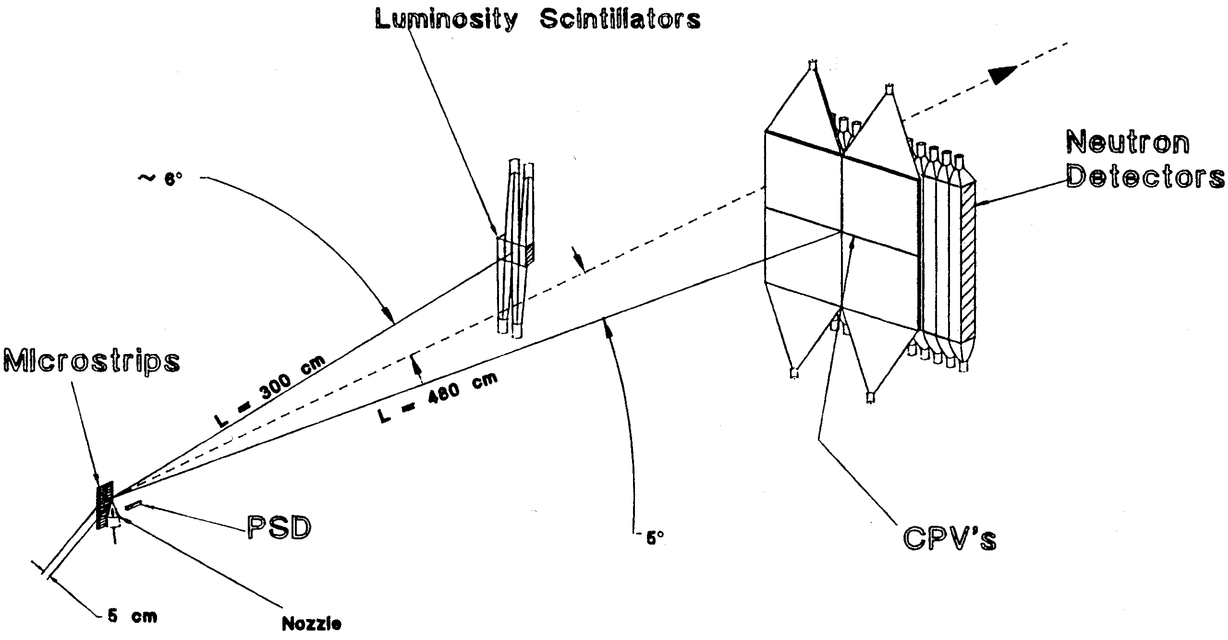

Figure 1. Experimental layout for the CE19 test run.

reconstruction of the jet profile in a manner similar to previous Cooler experiments.[5,6] Both arms should also provide an absolute normalization via p-p scattering for $^{16}O(p,n)^{16}F(0^-)$ cross sections measured simultaneously. In order to avoid overwhelming n-p coincidence contamination by p-p scattering events, we placed four veto scintillators in front of the neutron detectors, and only allowed a small sample (1%) of p-p data to be written to tape.

Roughly half of the time during the test run was devoted to setup of all the electronics with p-p scattering events from an H_2 gas jet target (used instead of H_2O to avoid possible ^{16}O(p,2p) quasifree scattering events in the jet profile reconstruction). We then acquired ≈5 hours of data with this target and an additional ≈1.5 hours with a D_2 gas jet. D(p,pp)n double and triple coincidence events will eventually be used to measure neutron detector efficiencies. Finally, we acquired ≈17.5 hours of data with the H_2O target. The Cooler tune was poor during this run, and the luminosity achieved with the H_2O target was only $\approx 2\times10^{27}cm^{-2}s^{-1}$. This is too low to expect a significant number of events coming from the 0^- state in ^{16}F, but is sufficient for an initial exploration of background levels and for a measurable yield for the 2^- state in ^{16}F at $E_x \approx 400$ keV.

We observed many real n-p coincidence events with the water vapor target, as revealed by the time-difference spectrum shown in Fig. 2b. This spectrum was obtained in off-line analysis, after performing relative time alignment of the signals from all 14 neutron hodoscope elements and all the 14 microstrips. Fig. 2b includes all neutrons and protons giving pulse heights above the respective hardware thresholds, set typically at about 10 MeV electron-equivalent for the neutron detectors and at about 200 keV for the microstrips. The latter threshold corresponded to the noise level resulting from electronic pickup of turbopump signals. The low, flat background in Fig. 2b is dominated by the accidental coincidences with noise triggering the proton detector electronics; random coincidences with protons from the next Cooler beam burst (88 nsec removed) appear in the small bump near t_{np}=150 nsec. Clearly, the true prompt coincidence rate is much larger than these random rates. The t_{np} resolution, deduced from the sharp edge of the prompt peak in Fig. 2b, is ≈5.5 nsec FWHM, and this is dominated by the rather long rise times (≈50 nsec) and poor signal-to-noise ratios characteristic of the low-energy proton signals in the microstrips.

Coarse cuts can be placed on the neutron energy via its measured flight time with respect to the Cooler RF signal. The spectrum obtained with the H_2O target is shown in Fig. 2a. The t_{RF} resolution is only ≈5 nsec FWHM, dominated by the structure of the Cooler beam buckets. In contrast, the proton is detected with very good energy resolution in the silicon microstrips. We measured this resolution to be ≈70 keV FWHM in the Cooler environment using a ^{228}Th source α-source kept inside the Cooler vacuum during the run. This resolution is more than adequate to distinguish the 0^- from the 1^- state in ^{16}F.

Analysis of the test run data will be going on throughout June and part of July to optimize timing gates and implement kinematic correction software in order to extract the low-energy decay-proton spectrum with optimal resolution. In late July we will have a second test run in which we hope to increase the luminosity by two orders of magnitude. We should then be able to observe the 0^- state clearly and to search for triple coincidences among the prompt neutron, the decay proton, and the recoiling ^{15}O nucleus (also detected in the microstrips). This triple coincidence requirement should vastly improve the signal/background ratio at larger neutron scattering angle where the cross section is smaller than at more forward angles.

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 Scientific and Technical Report, May 1990-April 1991, p. 166.
4. F. Sperisen, *et al.*, IUCF Scientific and Technical Report, May 1991-April 1992.
5. W. Daehnick, *et al.*, IUCF Scientific and Technical Report, May 1990-April 1991, p. 52.
6. H.O. Meyer, *et al.*, Phys. Rev. Lett. **65**, 2846 (1990).

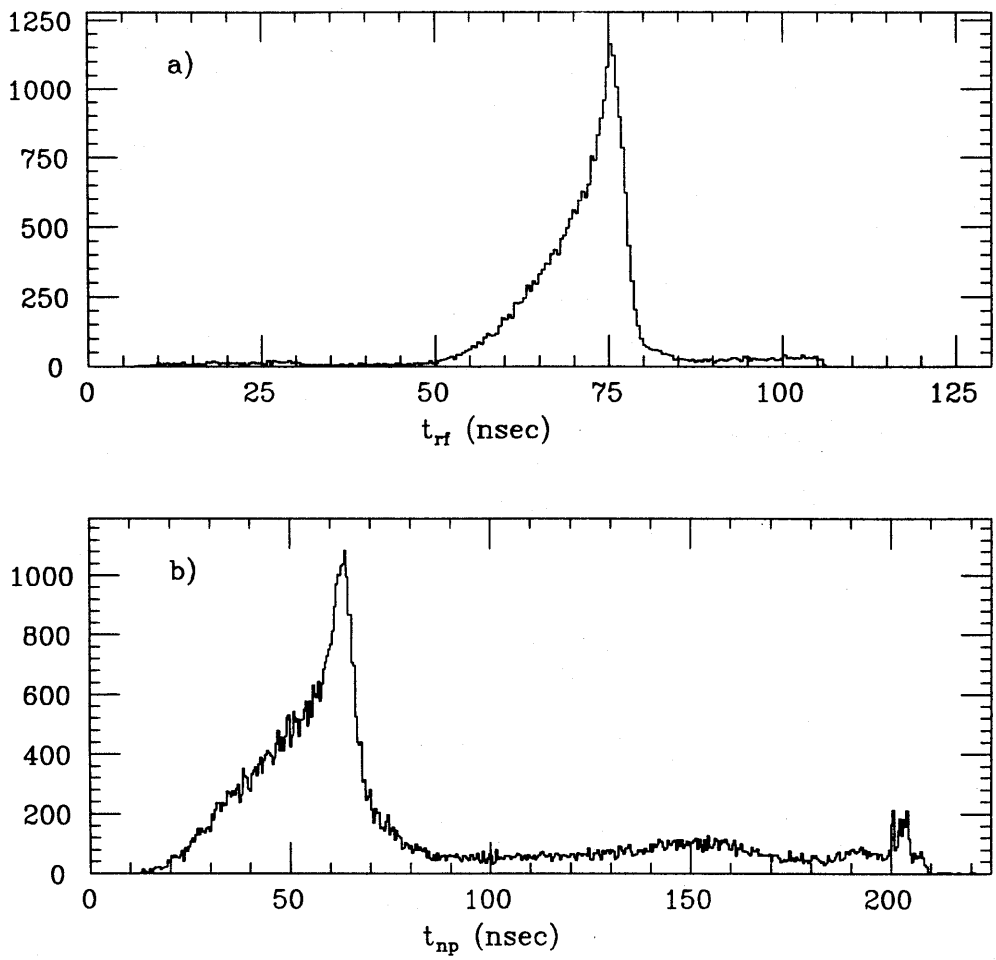

Figure 2. Spectra of neutron time-of-flight with respect to the Cooler RF (a) and time difference between detected neutron and proton (b), obtained with 300 MeV protons on H_2O vapor jet target.