BETA DELAYED NEUTRON EMISSION FROM ^{19,20}N

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A series of studies of β-delayed neutron emission have been conducted at the NSCL that have provided detailed spectroscopic information on a number of exotic nuclei. The experiments have concentrated on light elements with $A < 20$ [1,2 and references therein] as these nuclides are produced in high yields with excellent purity by the A1200 fragment separator. The nuclei extend out to the neutron drip line with large Q-values for beta decay that provide strong challenges for shell model predictions. In the most recent study we have investigated the decay of ^{19}N and ^{20}N with a combination of detectors to observe both sequential neutrons and gamma rays in order to more fully characterize the decay processes. The details of this work are contained in the dissertation by D. Anthony [3].

The nitrogen nuclei were produced by the fragmentation of a ^{22}Ne beam with E/A = 80 MeV/A in a beryllium target (564 mg/cm^2) in the A1200 fragment separator. Nearly pure beams of ^{16}C and ^{17,19,20}N were separated by a plastic wedge (241 mg/cm^2 aluminum-equivalent) in the usual energy-loss mode of the device. The two lighter nuclei were used to provide calibrations of the Time-of-Flight (ToF) and of the efficiency of the system. The radioactive nuclei were rapidly transported to the N3 vault where they were implanted in a plastic scintillator positioned at the center of a large array of neutron detectors. The implantation system and the neutron array have been described previously [1,2]. The ions transversed silicon detectors to provide on-line monitoring of the implantation rate and isotopic purity and stopped in a plastic scintillator. The plastic scintillator provided a common START signal for Time-of-Flight neutron spectroscopy from the subsequent β-decay.

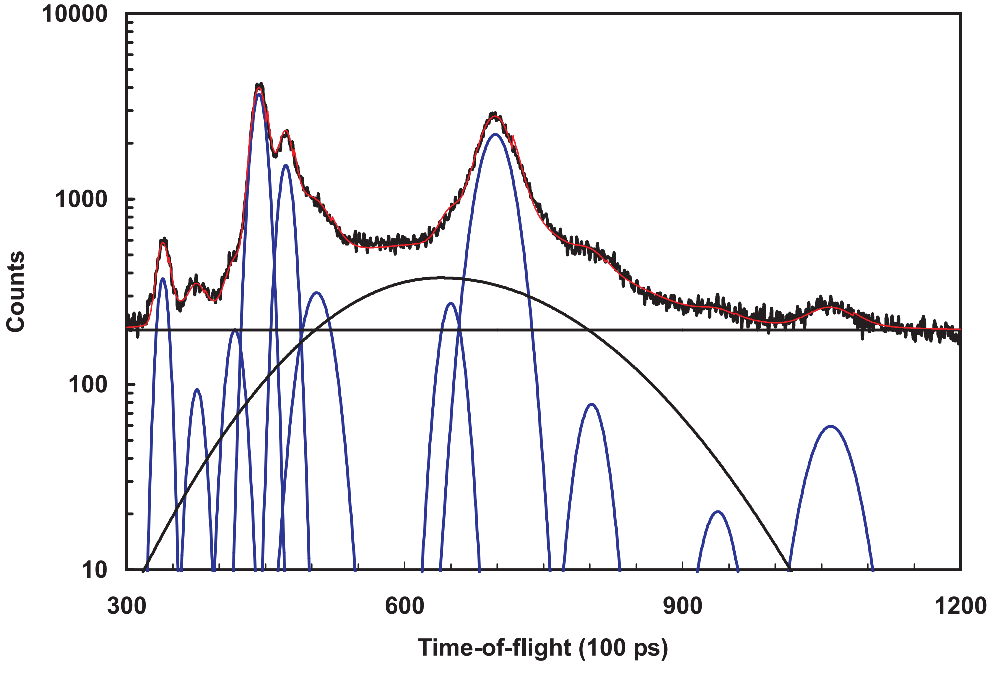

Figure 1: The summed time-of-flight spectra for ^{19}N is shown along with curves representing the results of peak-fitting. The broadest curve and the straightline correspond to backscattered neutrons and other background events, respectively.

The cyclotron beam and thus the secondary fragment beams were rapidly cycled ON and OFF under the control of the data acquisition system. The implantation scintillator recorded the decay of implanted isotopes during the beam-off periods. The scintillator signal was utilized to START the neutron ToF measurements and, in conjunction with a real-time clock, to measure their half-lifes. The results of a detailed analysis of the half-life data for ^{19}N and ^{20}N gave $T_{1/2} = 299 \pm 3 \pm 16$ ms and 121±5 ± 16 ms, respectively. These results resolved a discrepancy in the literature [4,5,6].

The most significant new results were the neutron spectra; the primary detection device to obtain delayed neutron spectra was the Neutron Bar Array (NBA). The NBA consists of sixteen plastic detectors cast to a constant radius of curvature and mounted such that the START detector, mentioned above, is exactly one metre from any point on the array. Neutron energies are directly determined from the ToF and this flight path. Calibrations are provided by observation of the beta particles and neutrons from the known decays of ^{16}C and ^{17}N.

The beta-delayed neutron ToF spectra are shown in Figures 1 and 2 as Counts versus elapsed time in 0.1 ns bins. The thin curves are the gaussian components of the peak fits while the thicker broad lines and curves correspond to random background and scattered-neutron background terms. The curve representing the sum of all contributions goes through the data.

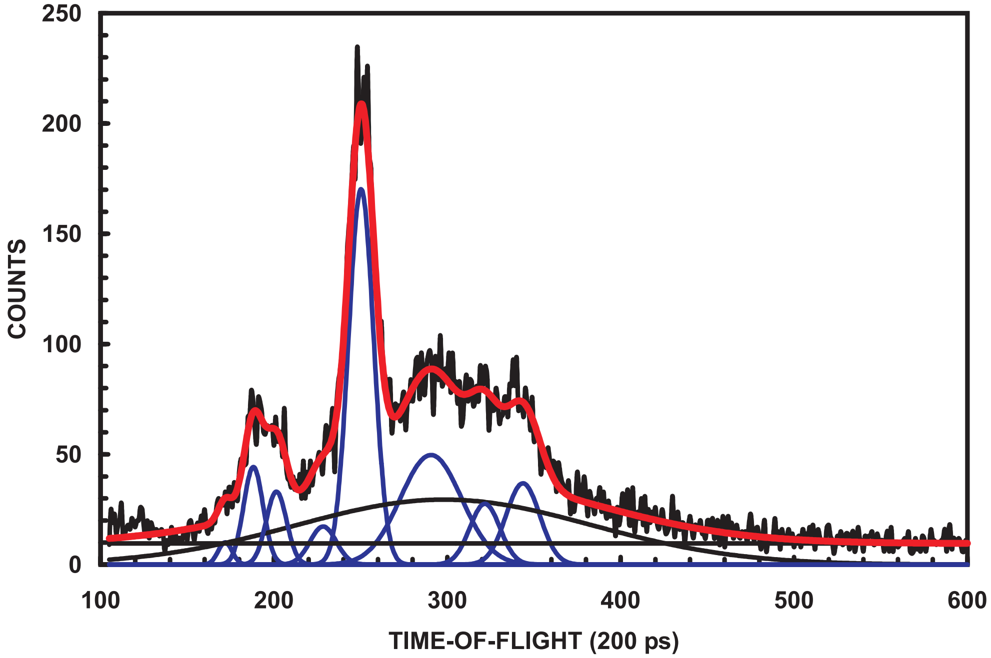

Figure 2: The summed time-of-flight spectra for ^{20}N is shown along with curves representing the results of peak-fitting, similar to figure 1.

Three small ^{6}Li-glass scintillators were added to the setup to facilitate the detection of lower energy neutrons from the decay of ^{19}N. These detectors were cylindrical pieces of lithiated glass (all 25 mm diameter; 25, 25 and 10 mm deep) mounted on PMTs that were positioned relatively close to the implantation detector (25, 25 and 10 cm, respectively). The ^{6}Li-glass detectors showed that there is an additional beta-delayed neutron at 280 keV – one that was below the threshold of the NBA.

In addition, two high purity Ge-detectors (120% and 80%) were positioned near the implantation detector (17 and 22 cm, respectively) to observe the beta delayed γ rays. The γ rays provided information on beta and neutron branching to the bound states in the oxygen daughters. For example, the γ ray spectra (in keV) following the decay of ^{19}N is shown in Figure 2. The blue arrows indicate transitions among states in ^{19}O below the neutron emission threshold while the red arrows indicate those in ^{18}O produced after neutron emission.

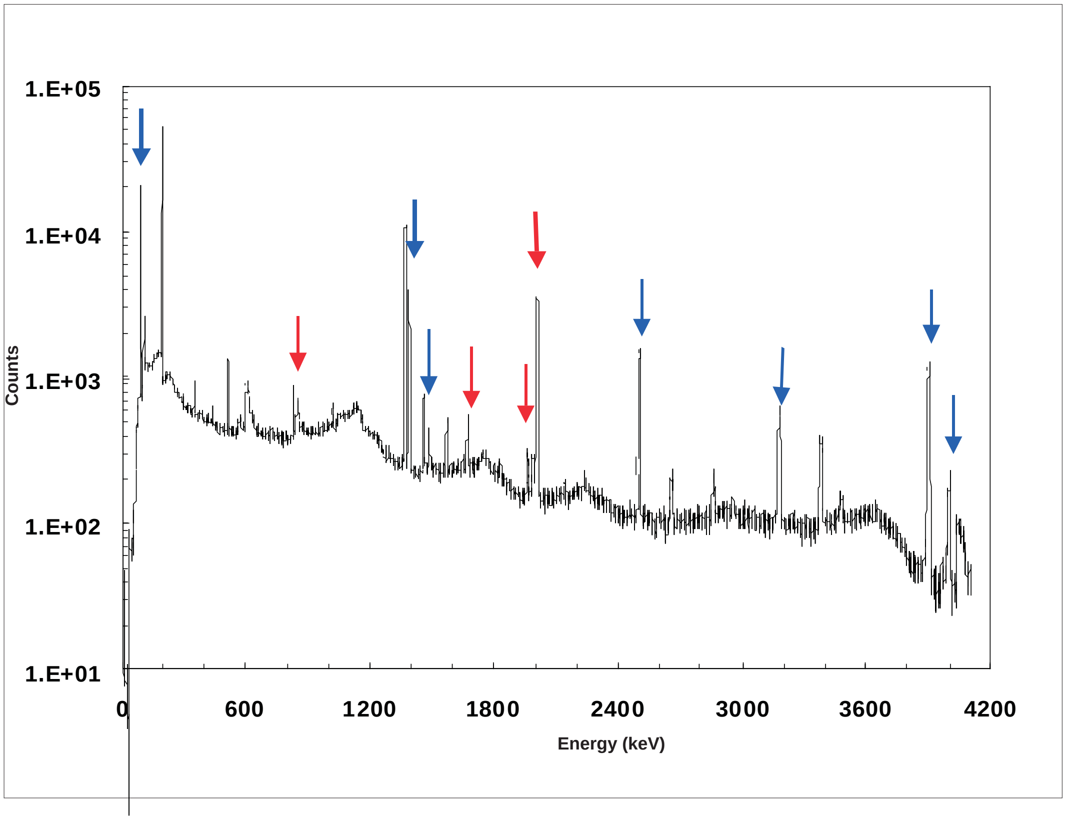

Figure 3: The γ ray spectrum for ^{19}N is shown along with arrows to identify the emitting nucleus, blue arrows for ^{19}O and red arrows for ^{18}O.

Seven gamma rays characteristic of ^{19}O were observed accounting for 39.4(38)% of the total decay strength. The gamma rays suggest direct beta feeding to three, possibly four, bound excited levels of ^{19}O. The levels populated are the 3945 (3/2-), 3232 (1/2-), 1472 (1/2+) and possibly the 96 (3/2+) level, with branching ratios of 34.2(37), 4.9(6), 0.27(12) and 4.3(UL), respectively. The results of the gamma ray spectra are not consistent with those published in [5] as the 709 keV gamma ray reported there was not observed in this experiment. Twelve delayed neutrons were observed by the neutron bar array and the ^{6}Li glass detectors. The neutrons ranged in energy from 300 keV up to nearly five MeV and in branching ratio from 0.37(4)% up to 16.2(17)% of the total decay strength. In addition, gamma rays from ^{18}O were determined to be from the ^{19}N source suggesting delayed neutron emission to bound excited states of ^{18}O rather than direct population of the ground state. The total delayed neutron emission probability for ^{19}N was found to be 50.9(62)% of the decay strength; which is in agreement with reference [4]. The branching ratio for delayed neutron emission to bound excited states of ^{18}O was found to be 16.5(21)% of the total.

Analysis of the gamma ray data showed that five transitions arise from ^{20}O indicating direct beta feeding to bound levels of the daughter. From the gamma ray energies and the inferred cascades the beta decay can be demonstrated to populate four, possibly five, bound excited levels of ^{20}O. The populated levels are the 5387 (0+), 4456 (0+), 4072 (2+), 1674 (2+) with branching ratios of 1.8(4), 1.2(4), 3.7(8) and 19.5(22) percent, respectively. The fifth possible level is at 3570 (4+) with a branching ratio of 0.8(8) percent (which is also consistent with zero percent). From these spin/parity values and the calculated log(ft) of the beta decay, the ground state of ^{20}N is most consistent with a (1-) spin and parity assignment. The neutron bar array permitted identification of eight delayed neutrons ranging in energy from 1.16 to 4.46 MeV and ranging in branching ratio from 0.5(1) to 12.1(13)% of the total decay strength. The probability for neutron emission is calculated to be 34.0(40)% of the total decay strength for neutrons above 1.1 MeV in energy. From the gamma ray data, two transitions characteristic of ^{19}O are observed and assigned as following directly from the decay of ^{20}N. These are the 96 keV and 1374 keV lines and their observation suggests delayed neutron emission from ^{20}N populating excited levels of ^{19}O rather than the ground state.

References

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