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BETA-DELAYED PROTON DECAY* OF ^{9}C

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ABSTRACT

The delayed-proton spectrum following the β-decay of ^{9}C [$\tau_{1/2}$ = 126.5±1.0 msec] was found to consist primarily of a continuum extending from 13 MeV to 1.5 MeV, the latter being the lowest energy observed. The energies and widths of discernable peaks were determined.

Our recent paper[1] concerning the delayed-proton precursors ^{17}Ne and ^{33}Ar mentioned the observation of ^{9}C, also a precursor, but contained no details of its proton spectrum. Previously, Hardy et al.[2] had observed the decay of ^{9}C to result in two high-energy proton peaks riding on a continuum. However, they could not have observed protons below about 3 MeV due to the thickness of the first counter of their telescope. In addition it was not clear whether the observed continuum was due solely to protons or in part to a high γ- and β-background.

Observation of peaks in the delayed-proton spectrum of ^{9}C would be of particular interest since they would correspond to levels in ^{9}B, many of which are still not well characterized.[3] These levels, in particular those of negative parity, could be compared to the predictions of intermediate coupling calculations,[4] which have proved quite successful elsewhere in the 1p shell. Fortunately, β-decay from ^{9}C should preferentially populate such levels, since ^{9}C should have $J^{\pi} = 3/2^{-}$, as does its mirror ^{9}Li.

The methods of target preparation, activity transport, particle identification, and data collection were described in detail previously.[1] Oxygen swept the ^{9}C (produced via the $^{10}B(p,2n)^{9}C$ reaction using an external 43-MeV proton beam from the Berkeley 88-in cyclotron) to a shielded counting chamber. Beta-delayed protons were detected by a counter telescope consisting of either a 14-μm or a 50-μm phosphorous-diffused silicon ΔE-counter and a 1.5 mm lithium-drifted silicon E-counter; identification was performed by a Goulding-Landis identifier.

Figure 1 shows the proton spectrum following the β-decay of ^{9}C. The peaks at 9.28 and 12.30 MeV are less intense than in data taken with a thicker

(50 μm) ΔE-detector; this is because higher energy protons deposited insufficient energy in the 14-μm detector during acquisition of the data in Fig. 1 to operate the electronics reliably. All peaks decayed with the same half-life, 126.5±1.0 msec, and therefore are believed to result from the decay of ^{9}C. This half-life agrees well with earlier work[2,5] and results in an average value of 126.5±0.9 msec. Any contribution to the spectrum from ^{13}O, produced from a possible nitrogen contaminant in the sweeping gas, is eliminated by its short half-life, 9 msec, since counting began about 100 msec after the gas was swept past the target.

The peak energies were determined by calibrating the three higher energy peaks against the known[1] spectrum of ^{17}Ne (produced via the $^{16}O(^{3}He,2n)^{17}Ne$ reaction) using data taken with the 50-μm ΔE-counter. These peaks were then used to calibrate the data taken with the thinner ΔE-counter. The line on Fig. 1 shows the continuum level assumed in the extraction of peak widths and energies. Since our previous delayed-proton experiments[1] with virtually identical apparatus had very low background, the continuum should be composed almost entirely of protons.

Table I lists the energies of all proton peaks observed, and tentatively correlates them with known[3] states in ^{9}B. The 4.97-MeV proton group has been assumed to result from decay of the positive parity state at 4.85 MeV. Beta-decay to this state is first forbidden and therefore would not be expected to be readily observable. However, the log ft values for allowed beta decays in the mirror nucleus, ^{9}Li, are known[6] to range from 5 to 6 while first forbidden transitions in ^{15}C and ^{11}Be have only slightly larger log ft values, ranging from 6 to 6.8. Furthermore, α-p coincidence experiments[7] in which ^{9}B was populated in the $^{10}B(He^{3}, \alpha)^{9}B$ reaction indicate that the 2.80-MeV state

($J^{\pi} = 3/2^{+}, 5/2^{+}$) in ^{9}B decays almost entirely via proton emission to the ground state of ^{8}Be, while the 2.33-MeV state ($J^{\pi} = 5/2^{-}, 1/2^{-}$) has less than a 0.5% branch via this channel. This selectivity in decay channel, if characteristic of all low-lying states, could make it possible to detect protons from a positive parity level even if its feeding from beta-decay were rather weak. Similarly, the unassigned 6.10-MeV proton group may follow the decay of an unknown positive parity state also formed via first forbidden β-decay.

The 3.45-MeV proton group could result from decay of a ^{9}B state at 3.2 MeV. In fact, intermediate coupling calculations[4] predict a hitherto unobserved $J^{\pi} = 3/2^{-}$ state at about 4.6 MeV but do not provide a precise estimate for the strength of the beta decay to this state. Predictions[4] of the ft-value range over two orders of magnitude, depending on the parameters used in determining the wave functions. Even though Clough et al.[3] have tentatively assigned $J^{\pi} = 3/2^{-}$ to a level at 3.2 MeV, the existence of a state at this energy has not been definitely established.[3,8] Though further work is clearly necessary, our data are consistent with a state at 3.2 MeV.

The strong proton continuum probably results from several sources. First, the levels of ^{9}B are quite broad, as is the first excited state of ^{8}Be (1.4 MeV), so the combination of many broad peaks tends to produce a featureless spectrum. Second, a level in ^{9}B may emit an α-particle resulting in an extremely broad distribution of proton energies. Finally, there may be some contribution to the continuum from direct three-body decay. The existence of a large continuum and the suggestion from the work of Wilkinson et al.[7] that those states fed most strongly in beta decay may prefer to decay via $^{5}Li + \alpha$ preclude the determination of ft values from the peak intensities in the delayed-proton spectrum.

FOOTNOTES AND REFERENCES

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Table I. Delayed protons following the beta-decay of $^{9}C(J^{\pi} = 3/2^{-})$.

Proton energy[a] (MeV)	Γ[b] (keV)[a]	Corresponding state in ^{9}B (MeV) If decaying to ^{8}Be(g.s.)	If decaying to ^{8}Be(2.9 MeV)	Known State (MeV)	J^{π}
3.45±0.25	200±100	3.26±0.25	c	(3.2)	$(3/2^{-})$
4.23±0.25	1000±200	4.04±0.25	6.94±0.25	4.05	$(5/2^{-})$
4.97±0.15	400±150	4.78±0.15	c	4.85	$(3/2,5/2)^{+}$
6.10±0.10	400±100	5.91±0.10	c		
9.28±0.24[d]	1800±200	9.09±0.24	11.99±0.24	12.06	$(1/2,3/2)^{-}$
12.30±0.10[d]	450±100	12.11±0.10	c	12.06	$(1/2,3/2)^{-}$

[a]Energies and widths are given in the center-of-mass system.

[b]The width given is the full-width at half-maximum.

[c]The relatively narrow width indicates that this proton group does not lead to the first excited state of $^{8}Be(\Gamma = 1.4$ MeV).

[d]The ratio of the intensities of the 9.28- and 12.30-MeV groups is 1.0±0.2.

FIGURE CAPTION

Fig. 1. Spectrum of delayed protons following the beta-decay of ^{9}C. A counter telescope employing a 14-μm ΔE-detector was used.

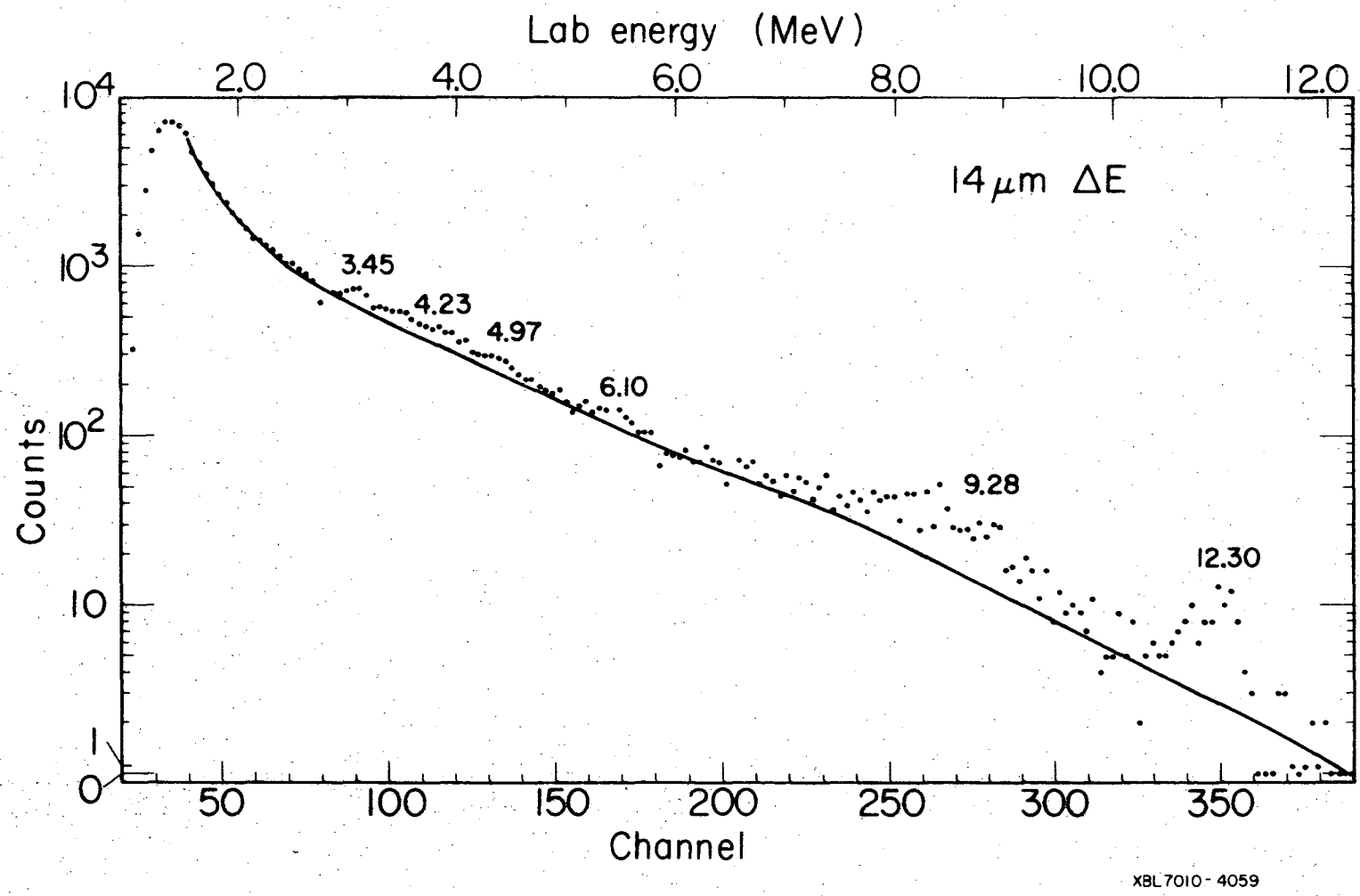
Lab energy (MeV)
2.0
4.0
6.0
8.0
10.0
12.0
14 μm ΔE
3.45
4.23
4.97
6.10
9.28
12.30
Counts
10^4
10^3
10^2
10
1
0
50
100
150
200
250
300
350
Channel
XBL7010-4059

Fig. 1

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