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High resolution fast neutron spectroscopy of the reaction $^9Be(p,n)^9B$ at 20 MeV*

R. J. Slobodrian, H. Bichsel†, J. S. C. McKee†† and W. F. Tivol

Abstract: High resolution fast neutron spectra (to about 1%) have been obtained by means of the proton radiator method, detecting the proton recoils with solid state detector telescopes and particle identifier circuits. Our spectra confirm a broad peak at 1.4 MeV and resolve another at 3.2-MeV excitation.

The reaction $^9Be(p,n)^9B$ was studied at 14.1-MeV laboratory energy by Saji[1] with a proton recoil neutron spectrometer capable of achieving 3% resolution, but operating typically at 5% resolution. We have measured neutron spectra produced in this reaction by 20-MeV protons. Figure 1 shows a schematic drawing of our neutron spectrometer. Basically it consists of a suitable collimation system, a radiator of protons (recoils from a thin film of polyethylene), and a solid state detector telescope consisting of two detectors (ΔE, E). The electronics includes low noise preamplifiers, amplifiers, particle identifier circuits[2] and multichannel analyzers.

In the recent past the direct application of solid state detectors to neutron spectroscopy has been studied and discussed[3,4]. The (n,α) reactions in silicon are so numerous that such direct use is at present impractical for

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spectroscopic purposes[4]. Birk et al.[3] considered the spectroscopy of 6-MeV neutrons detecting proton recoils from a proton radiator using a single silicon detector. Such a method becomes rapidly impractical at higher neutron energies because it would be very hard (if not impossible) to separate the recoil protons from the peaks due to the (n,α) reactions in silicon. Figure 2 shows a spectrum of the E detector of our telescope. Thus, at higher energies the proton recoil detection with silicon detectors depends vitally on the coincidence requirement between the ΔE and E detectors[1,5]. A further refinement is achieved by means of a particle identification system[2]. A more detailed description of our spectrometer and possible improvements will be published elsewhere[6].

Considerable effort has been vested recently in establishing the existence of a state in ^9B, analogue to the 1.70-MeV state in ^9Be. A state at about 1.4 MeV in ^9B was first reported by Marion et al.[7] and was also weakly seen at some angles by Saji[1] in his $^9Be(p,n)^9B$ experiment. More recent work on ^9B was carried out through reactions where an outgoing charged particle was detected, like $^{12}C(p,\alpha)^9B$,[8,9] $^{10}B(^3He,\alpha)^9B$,[10] and $^{10}B(d,t)^9B$.[11,12] Symons and Treacy[8] observed a broad peak in the α-particle spectrum of the reaction $^{12}C(p,\alpha)^9B$ at a channel energy of approximately 1.4 MeV. They calculated a fit to the observed peak using the procedure and notation of Barker and Treacy[13] with a channel radius of 4.35 fm and an energy of 1.7 MeV. Bauer et al.[9] reached states of ^9B through the reactions $^{12}C(p,\alpha)$, $^9Be(p,n)$ and $^6Li(\alpha,n)$, using α-particles between 12.7 and 18.3 MeV and protons at 6.3 and 7.4 MeV. They concluded that there was no state of ^9B at 1.7 MeV and argued against the possibility of its existence on the basis that the ^{9}Be "state" was probably ascribed to the neutron emission threshold, but that the "analogue" could not be attributed to a proton threshold inasmuch that ^{9}B is proton unstable. However, it should be noted that a broad peak with barycenter at about 1.4 MeV is prominently visible in the spectra of Bauer et al.[9] from ^{12}C(p,α)^{9}B at 12.7 MeV, as well as the other reactions they studied, in excellent agreement with the results of Symons and Treacy[8]. Therefore we conclude that the search of Bauer et al.[9] for a sharp state at 1.7-MeV excitation was the result of a misunderstanding of the work of Symons and Treacy[6].

Our experiment was performed at 20-MeV laboratory energy, using protons from the Berkeley 88" variable energy cyclotron. To reduce background the beam was accelerated as 40-MeV H_2^+. The typical current was 1 μA on the target. Our ^{9}Be(p,n)^{9}B spectra agree in general with the results of Saji[1], except that we have a significantly higher resolving power. Figure 3 contains some sample spectra, showing evidence for a peak at about 1.4 MeV in the neutron spectra. In addition the state assigned an energy of 3.07 MeV by Saji[1] and not well resolved from the 2.3-MeV state, is seen completely resolved in our spectra, and we assign to it an energy of 3.16±0.07 MeV. It is worth noting that the ^{9}Be(p,n)^{9}B time of flight spectra of Bauer et al.[9] at 7.4 MeV and 15° laboratory angle show a peak at about 3.1 MeV, and the same is true for the ^{6}Li(α,n) spectra at 14.4 MeV at several laboratory angles.

Some comments are in order concerning the 1.4-MeV peak in the spectra leading to the ^{9}B nucleus. It is certainly true that such a peak may not be related to a proton threshold effect as mentioned above. Instead it seems reasonable to relate it to the threshold of the channel $^5Li + \alpha$, located at 1.685 MeV[14] in the ^9B system. The relation between thresholds and states has been discussed repeatedly by Baz[15], Inglis[16] and others. The conclusions are not clear cut, but indicate that it is more probable to observe states near thresholds than elsewhere. It is beyond the scope of this note to investigate this point in detail. With reference to our peak at 3.16 MeV it is worth noting that it appears consistently in the spectra reaching ^9B through the emission of a neutron i.e. $X(x,n)^9B$, but is absent in charged particle spectra. It seems reasonable that the state at 2.8 MeV observed in the latter is different from the state at about 3.2 MeV observed in neutron spectra, and in fact figure 3b) seems to support this point.

We gratefully acknowledge the help of T. M. Chan with the design of the neutron spectrometer assembly, J. Meneghetti who supervised its construction, and R. Lothrop who made the Si detectors. The cooperation of the 88" cyclotron crew and supporting personnel is highly appreciated.

References

1) Y. Saji, J. Phys. Soc. Japan 15 (1960) 367

2) F. S. Goulding, D. A. Landis, J. Cerny and R. H. Pehl, Nucl. Instr. Meth. 31 (1964) 1

3) M. Birk, G. Goldring and P. Hillman, Nucl. Instr. Meth. 21 (1963) 197 and references therein

4) J. A. Shannon and J. B. Trice, Nucl. Instr. Meth. 41 (1966) 255 and references therein

5) A Si detector telescope with three detectors and a triple coincidence requirement may further improve the performance, particularly at higher energies

6) R. J. Slobodrian, J. S. C. McKee and H. Bichsel (to be published)

7) J. B. Marion, C. F. Cook and T. W. Bonner, Phys. Rev. 94 (1954) 807; J. B. Marion and J. S. Levin, Phys. Rev. 115 (1959) 144

8) G. D. Symons and P. B. Treacy, Phys. Letters 2 (1962) 175

9) R. W. Bauer, J. D. Anderson and C. Wong, Nucl. Phys. 56 (1964) 117

10) L. G. Earwaker, J. G. Jenkins and E. W. Titterton, Nucl. Phys. 46 (1963) 540; J. G. Patterson, J. M. Poate and E. W. Titterton, Proc. Phys. Soc. 85 (1965) 1085

11) G. D. Symons, Phys. Letters 18 (1965) 142

12) K. Bähr, W. Fitz, R. Jahr and R. Santo, Phys. Letters 21 (1966) 686

13) F. C. Barker and P. B. Treacy, Nucl. Phys. 38 (1962) 33

14) T. Lauritsen and F. Ajzenberg-Selove, Nucl. Phys. 78 (1966) 1 and references therein

15) A. J. Baz, Soviet Phys. JETP 6 (1958) 709

16) D. R. Inglis, Nucl. Phys. 30 (1962) 1

Figure captions

Fig. 1. Schematic of the collimator, radiator and detector telescope assembly of the neutron spectrometer.

Fig. 2. Spectrum of the E detector of the telescope. Most pulses are due to (n,α) reactions inside the silicon detector.

Fig. 3. Sample spectra obtained in the present experiment. The n-p cross section has not been unfolded as it does not alter the spectroscopic content appreciably. Solid lines have been drawn to help the eye.

a) Particle identifier spectrum. Discriminators were normally located at A and B to select the proton recoils, however, a display of the energy spectrum of pulses above B did not show any structure.

b) Spectrum at 9° Lab, using a ^{9}Be target of 18.8 mg cm^{-2} with E-ΔE coincidence requirement and no particle identification. The radiator thickness was approximately 0.08 mm.

c) Spectrum at 12° Lab, same target as 3b) with coincidence requirement and particle identification.

d) Spectrum at 17° Lab, obtained with a 4.70 mg cm^{-2} ^{9}Be target and detection conditions as in 3c). The resolution of our neutron spectrometer, unfolding the target thickness effect, was 200 keV near 18 MeV, i.e. 1.1%.

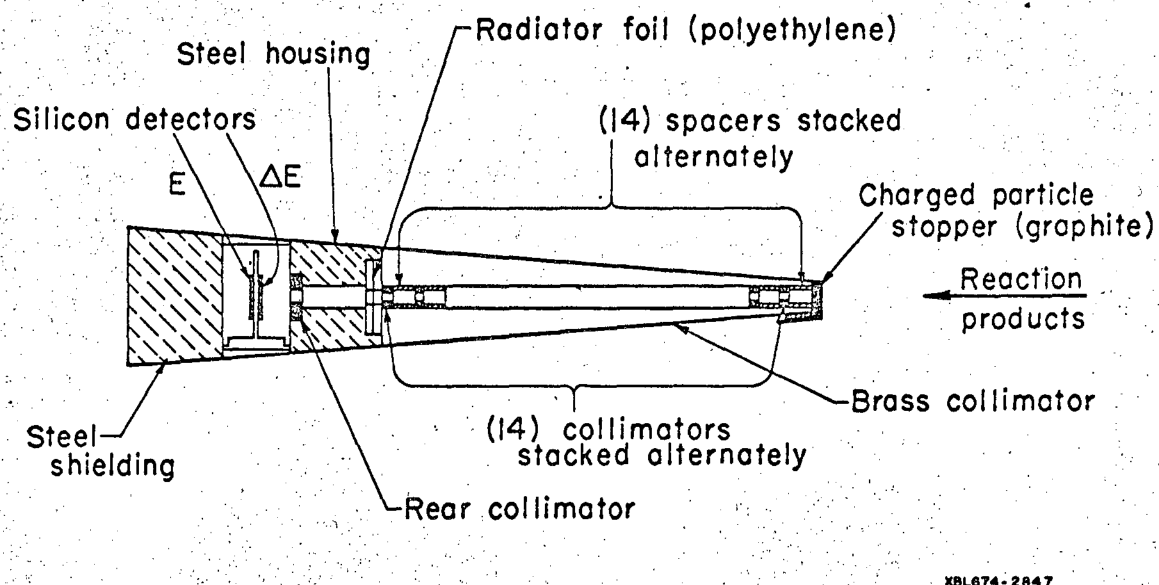

Radiator foil (polyethylene)
Steel housing
Silicon detectors
E
ΔE
(14) spacers stacked alternately
Charged particle stopper (graphite)
Reaction products
Brass collimator
Steel shielding
(14) collimators stacked alternately
Rear collimator
XBL674-2847

Fig. 1.

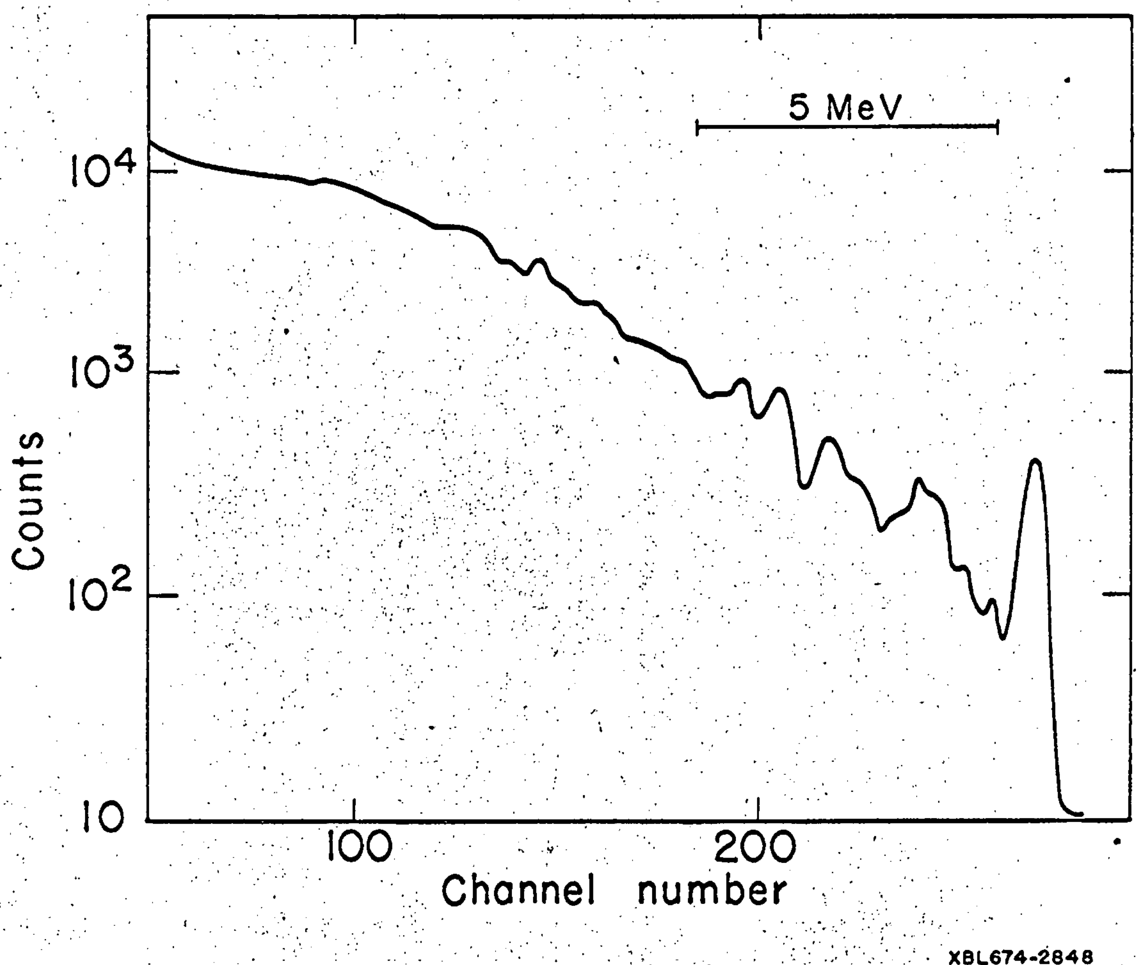
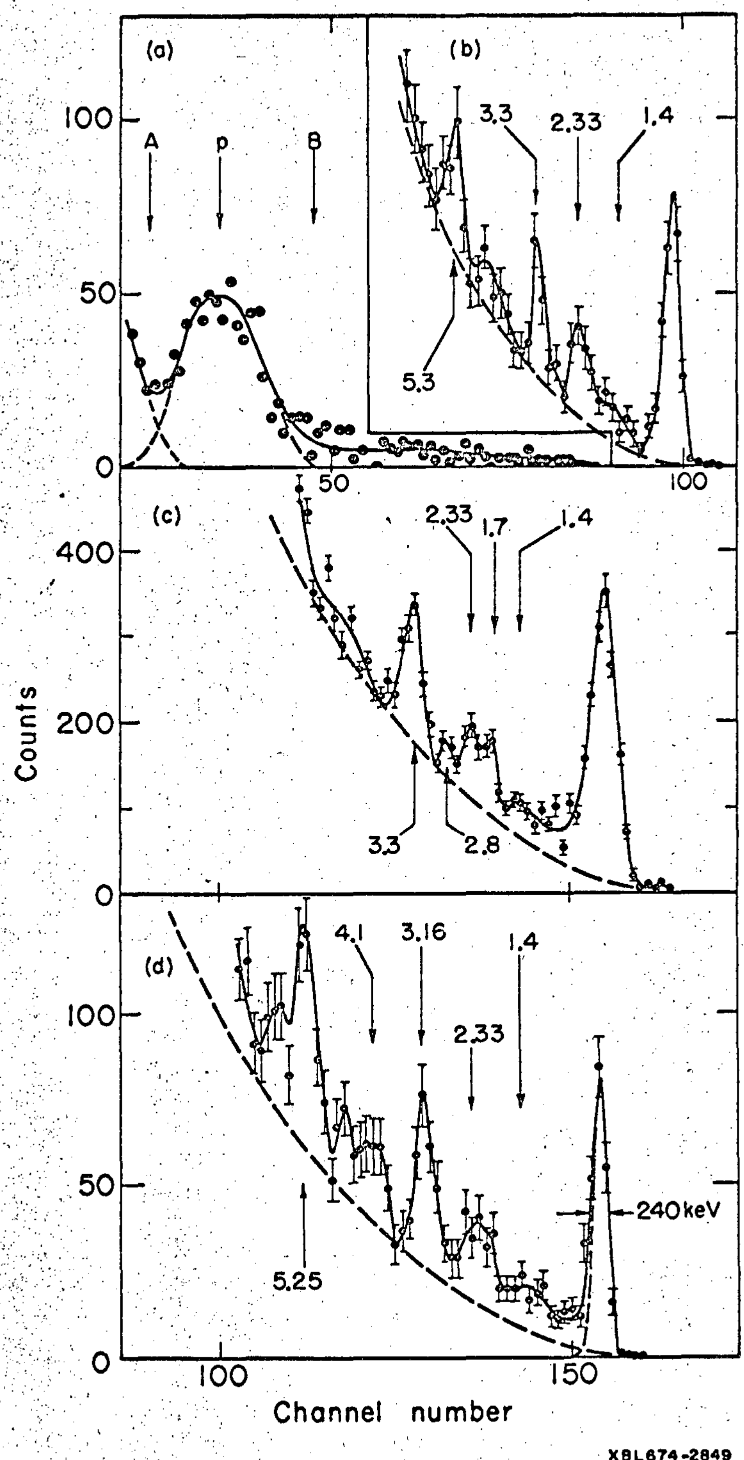

5 MeV
10^4
10^3
10^2
10
Counts
100
200
Channel number
XBL674-2848

Fig. 2



(a)
(b)
(c)
(d)
A
p
B
3.3
2.33
1.4
5.3
1.7
2.8
4.1
3.16
5.25
240 keV
Counts
Channel number
XBL674-2849

Fig. 3