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Neutrons from the Proton Bombardment of Be^9†

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Be^9 has been bombarded with 6.59-Mev protons. The resultant neutrons, studied by means of nuclear emulsions, indicate an excited state of B^9 at 2.37±0.04 Mev. A continuum of neutrons has also been observed.

I. INTRODUCTION

THE level structure of Be^9 has been investigated by the study of a number of nuclear reactions.[1] In particular, a level at 2.429 Mev has been observed in the inelastic scattering of protons, deuterons, and alpha particles from Be^9 and in the $B^{11}(d, \alpha)Be^9$ reaction.[2] A level at approximately 1.5 Mev in Be^9 postulated by Mullin and Guth[3] has not been confirmed by other observers.[2]

It is of some interest to study the corresponding region in the mirror nucleus B^9 to determine whether a state analogous to the 2.429-Mev level can be found. If such a state were to exist, it would be another link in the overwhelming chain of evidence for the charge symmetry of nuclear forces.

A previous attempt[4] [by means of the $Be^9(p, n)B^9$ reaction] to observe an excited state of B^9 has indicated that there are no narrow levels in the excitation region studied ($E_x<1.4$ Mev). We decided to repeat this experiment and to study B^9 for $0<E_x<3.8$ Mev, using higher-energy protons than were available to the previous experimenters.

II. EXPERIMENTAL PROCEDURE AND RESULTS

The experimental setup is indicated in Fig. 1. A thin foil of beryllium[5] mounted on a 0.03-in. tantalum backing was bombarded by 6.59-Mev protons from the MIT-ONR Van de Graaff generator. The resultant neutron spectrum was observed by means of 200-μ Ilford C-2 nuclear emulsions mounted 10 cm from the target and at a number of angles to the direction of the beam. In addition background plates were exposed at the same angles to protons hitting bare tantalum in the target position. The criteria for the measurements of the recoil proton tracks have been discussed previously.[6] The range-energy relation used

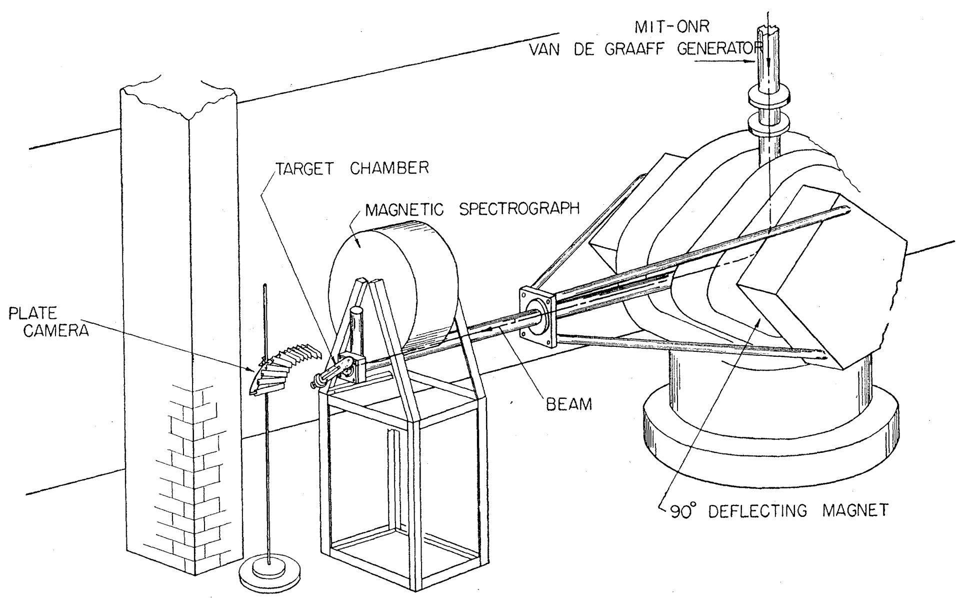

FIG. 1. Experimental setup.

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[1] F. Ajzenberg and T. Lauritsen, Revs. Modern Phys. **24**, 321 (1952).
[2] E. H. Rhoderick, Proc. Roy. Soc. (London) **201**, 348 (1950); R. Britten, Phys. Rev. **88**, 283 (1952); Arthur, Allen, Bender, Hausman, and McDole, Phys. Rev. **88**, 1291 (1952); Cowie, Heydenburg, and Phillips, Phys. Rev. **87**, 304 (1952); Browne, Williamson, Craig, and Donahue, Phys. Rev. **83**, 179 (1951); K. Boyer, Massachusetts Institute of Technology Laboratory for Nuclear Science Progress Report (July 1950); McMinn, Sampson, and Rasmussen, Phys Rev. **84**, 963 (1951); Van Patter, Sperduto, Huang, Strait, and Buechner, Phys. Rev. **81**, 233 (1951).
[3] C. J. Mullin and E. Guth, Phys. Rev. **76**, 682 (1949).
[4] Johnson, Ajzenberg, and Laubenstein, Phys. Rev. **79**, 187 (1950).
[5] We are indebted to Dr. H. Bradner for this foil.
[6] Johnson, Laubenstein, and Richards, Phys. Rev. **77**, 413 (1950).

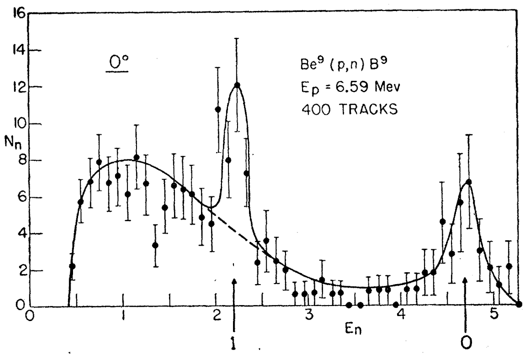

FIG. 2. 0° data. N_n is the relative number of neutrons/100-kev interval.

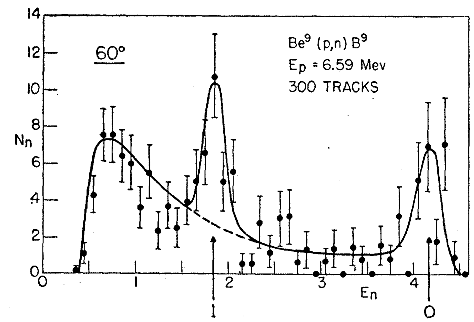

FIG. 3. 60° data. N_n is the relative number of neutrons/100-kev interval.

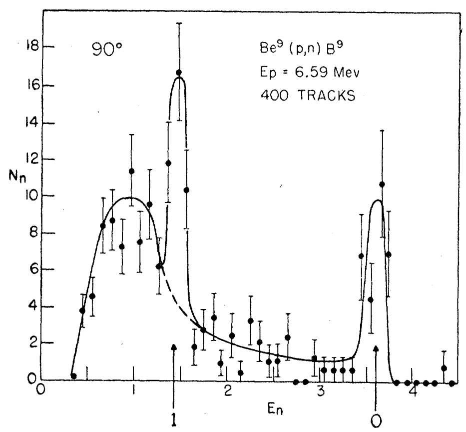

FIG. 4. 90° data. N_n is the relative number of neutrons/100-kev interval.

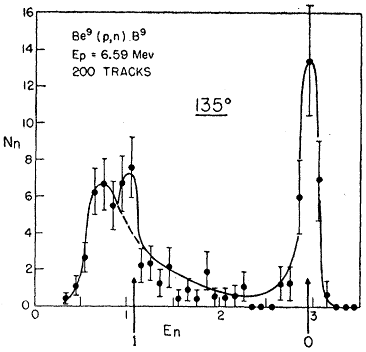

FIG. 5. 135° data. N_n is the relative number of neutrons/100-kev interval.

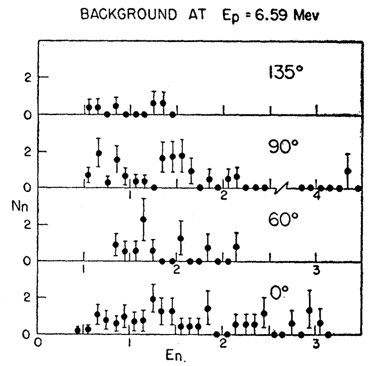

FIG. 6. Background data at 0°, 60°, 90°, and 135°. N_n is the relative number of neutrons/100-kev interval.

was that derived by Rotblat.[7] The data shown on Figs. 2–6 have been corrected for geometry[8] and for variation of the n-p scattering cross section.[9]

Only plates exposed at 0, 60, 90, and 135 degrees to the beam have been scanned, since it is felt that sufficiently convincing evidence for the existence of an excited state in B^9 has been derived from the results at these angles. The ground state of B^9 is indicated as 0 on Figs. 2–4 and the excited state as 1. The most convincing evidence for the excited state of B^9 stems from the 0, 60, and 90 degree data, although the corresponding neutron group appears fairly meaningfully at 135 degrees. Computing the Q of the first level of B^9 on the basis of the 0, 60, and 90 degree results, we obtain -4.22 ± 0.04 Mev, which yields an excitation energy of 2.37 ± 0.04 Mev above the ground state of B^9. The neutron energies, at which the peaks corresponding to the excited state and to the ground state should occur at each angle, were calculated on the basis of $Q=-4.22$ Mev and $Q=-1.851$ Mev,[1] respectively, and the arrows indicate these expected positions.

The background plate at a given angle has been scanned over the same relative area as the $Be^9(p, n)B^9$ plate at that angle, and the corresponding data have been plotted on the same scale.

The continuous distribution of neutrons, on which the peaks corresponding to the ground state and to the excited state are superimposed, has also been observed in Johnson, Ajzenberg, and Laubenstein's earlier experiment.[4] This continuum is perhaps due to the (p, pn) reaction.

Note added in proof: No particular effort was made to measure tracks caused by recoil protons of $E_p<0.5$ Mev. Thus the sudden cutoff at approximately 0.5 Mev at the various angles is "instrumental."

The 2.37-Mev level is probably the mirror level to the 2.429-Mev state in Be^9. There does not appear to be a state in B^9 with $E_x<2.3$ Mev which would be analogous to the state postulated by Mullin and Guth[3] at $E_x\sim1.5$ Mev in Be^9.

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[7] J. Rotblat, Nature **167**, 550 (1951).
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