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Study of the Levels of Light Nuclei by Angular Correlation Measurement in the (d, $p\gamma$) Reaction*

SHENG-LIANG HUANG (黃勝良), WU-SHIUNG HSU (徐武雄) and YUEN-CHUNG LIU (劉遠中)

Department of Physics, National Tsing Hua University
Hsinchu, Taiwan

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The scattering chamber arrangement and the electronics system for the particle-gamma-ray angular correlation measurements are set up and described. The total set up system is then used to study the first excited state of ^{10}Be by the reaction ^{9}Be$(d, p\gamma)^{10}$Be at incident energy E_d=1.5 MeV. The obtained spin and parity assignment for the level is 2^+.

THE scattering chamber and the electronics system for the particle-gamma ray angular correlation measurements following Method II developed by Litherland and Ferguson[1] are set up and used to study the first excited state of ^{10}Be by the ^{9}Be$(d, p\gamma)^{10}$Be reaction.

The 1.5 MeV deuteron beam, obtained from the 3 MeV Van de Graaff accelerator of Tsing Hua University, passed through a collimating system before entering the chamber (Fig. 1). The collimating system is composed of three apertures, with a lead cylinder of 5 mm thick between each one. Each apeture is a round shape Ta foil of thickness 0.05 mm with a hole of diam. 2 mm at its center. On the back of the annular detector, there is also a Ta aperture with a hole of diam. 1.5 mm at its center. Between the latter aperture and the detector, there is an annular Cu disc of thickness 0.5 mm and i. d. 2 mm, with an erecting cylinder of i. d. 2 mm and 5 mm long at its center to fit into the annular detector to protect it from the direct bombardment of the incident beam. The chamber is made of a stainless cylinder of wall thickness 1.5 mm and its inner diameter is about 10 cm. The target used in this experiment was self-supporting thin film of ^{9}Be.

The exit charged particles after the reaction were detected in an annular surface barrier silicon detector located at 180° relative to the deuteron beam. Its sensitive area was annular of i. d. 4 mm and o. d. 13 mm (-100 mm^2), It was mounted on a movable cylinder which might be used to adjust the distance between the detector and the target. In this experiment, the distance was about 7 cm. To stop the undesired background and the alpha particles from the competing rea^{9}Be$(d,\alpha)^{7}$Li, an aluminium film of thickness 0.015 mm was used as an absorber.

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(1) A. E. Litherland and A. D. Ferguson Canadian J. Phys. 39 788 (1961).

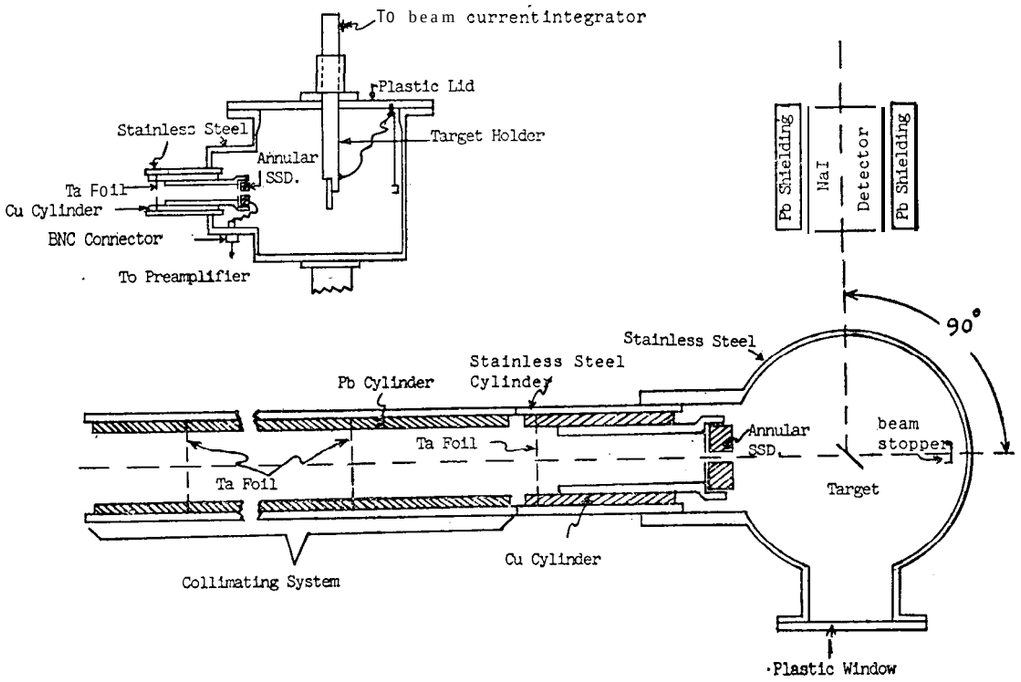

Fig. 1. Schematic diagram of the scattering chamber arrangement

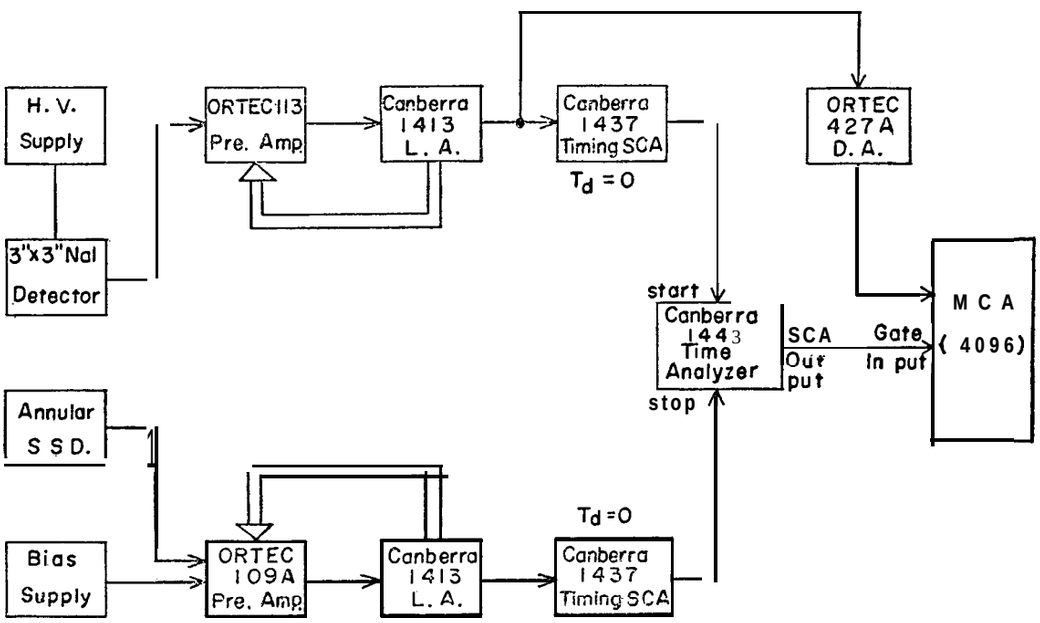

Fig. 2. Block diagram of the electronics system of coincidence

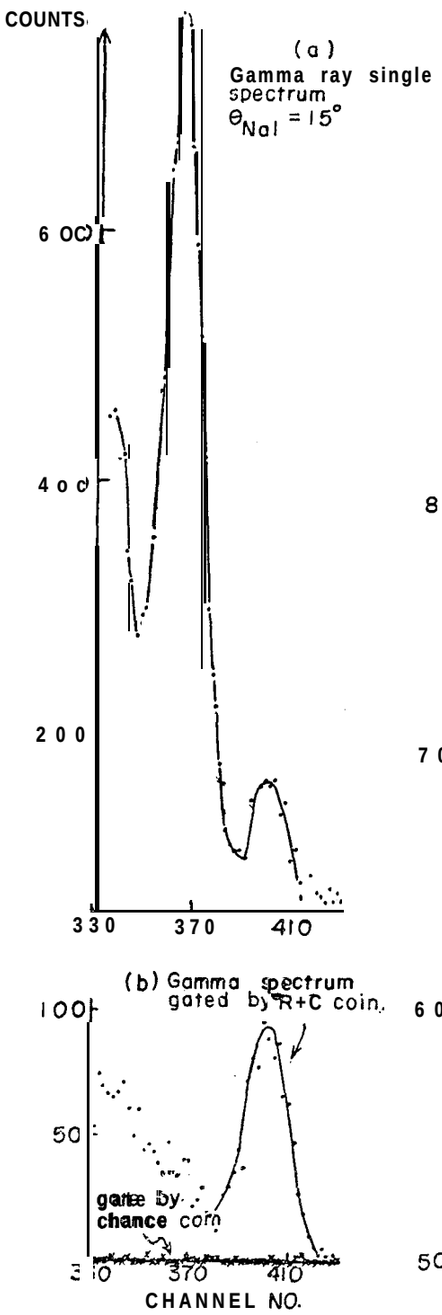

Fig. 3. The gamma ray spectra gated by coincidence with $\theta_{NaI}=15°$

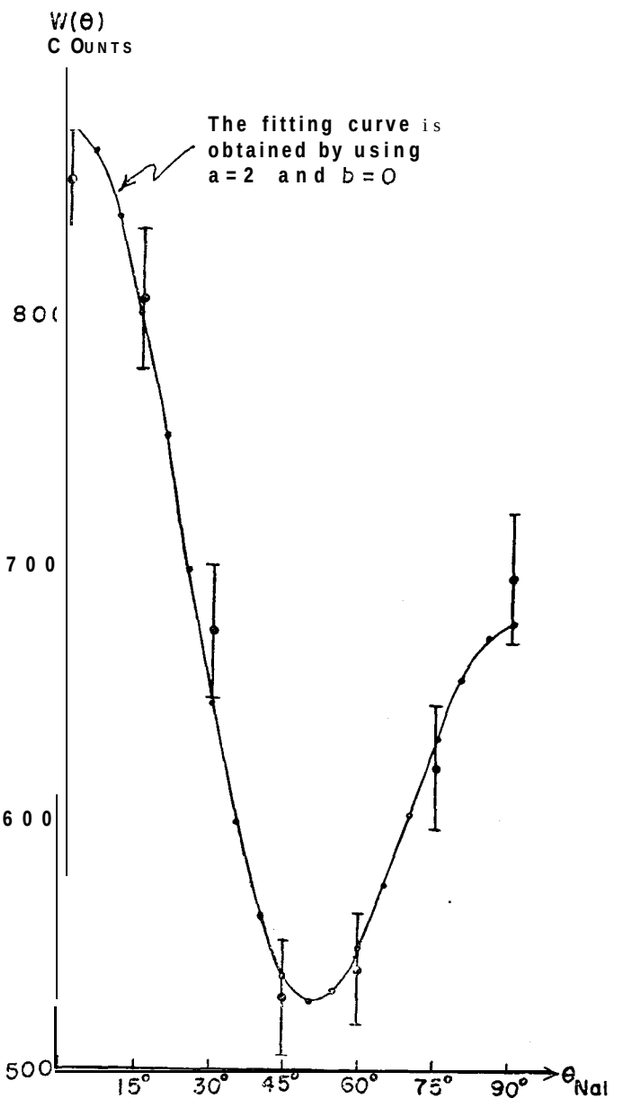

Fig. 4. The angular correlation **W(e)** curve measured at $E_d=1.5$ MeV

The gamma-ray detector was a $3'' \times 3''$ NaI (Tl) scintillation counter. Its front face was at a distance of 7.5 cm from the target. To minimize the gamma rays background due to the activation of the neutron capture in Na and I_2, the front face of NaI crystal was shielded by a 10 mm thick $^6Li_2CO_3$ package, a 0.5 mm thick Cd sheet and a 1.5 mm thick lead sheet, the latter is used to minimize the low energy Compton gamma ray[2]. The NaI(T1) crystal was also surrounded by a 5 cm thick lead cylinder shielding to reduce the background. The gamma ray detector assembly was mounted on a trolley which could be rotated about the vertical axis of the correlation table from 0 ° to 90 ° relative to the beam direction. The intrinsic isotropy of the chamber system was checked

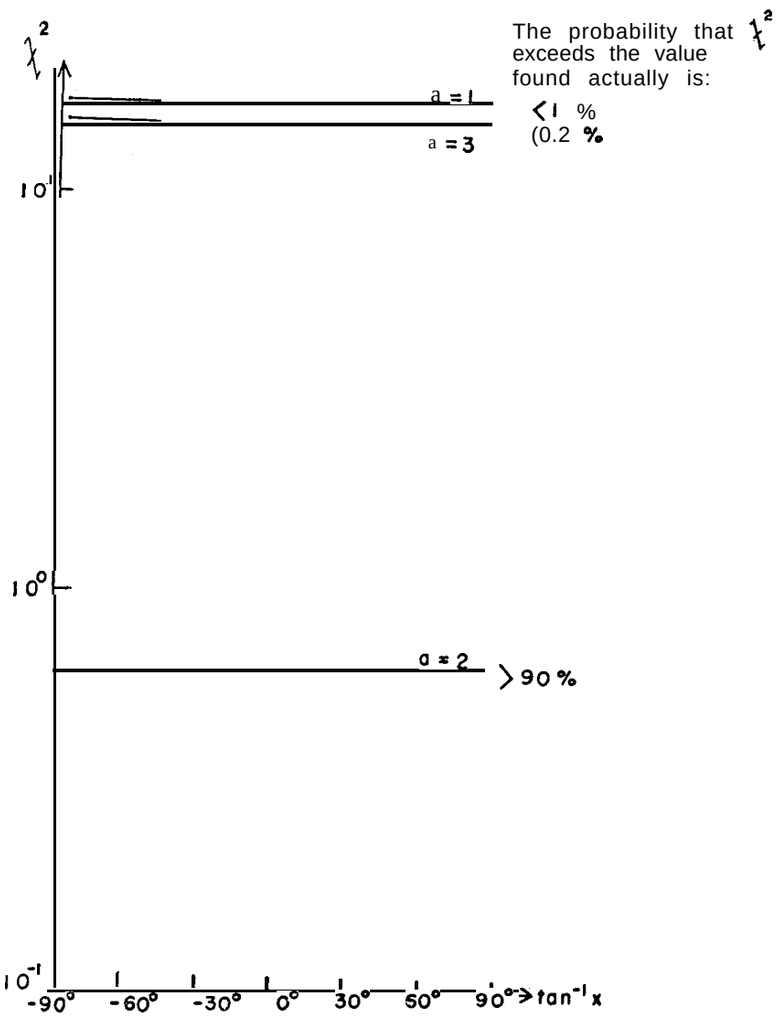

Fig. 5. The χ^2 vs $\tan^{-1}x$ curve

(2) S. J. Skorka, T. W. Retez-Schnudt, H. Schmidt, J. Norgenstern and D. Evers: Nucl. Phys. 68 177 (1965).

by placing a ^{60}Co source in the target position and counting at each angle for a fixed time, for angles from 0° to 90° in steps of 15°.

The block diagram of electronics system is shown in Fig. 2. The coincidence resolving time was better than 40 ns. The gamma rays spectra, gated by real plus chance coincidence, were recorded for a fixed integrated counts of incident beam current with the NaI(Tl) detector at angles from 0° to 90° *in* steps of 15°. The gamma ray spectra gated by chance coincidence were also taken in the same way. The results with the NaI(Tl) detector at 15° relative to the beam direction are shown in Fig. 3, in which the corresponding gamma ray single spectrum is also given for the comparism.

The angular correlation curve $W(\theta)$ vs θ is shown in Fig. 4. The data were fitted with the formula given by Polatti and Warburton[3]. The χ^2 values, obtained from the least square fitting in terms of the population and the multipole mixing amplitude ratio are shown in Fig. 5. The probability that χ^2 exceeds the value found actually is -Cl% for $a=1$; those are $>90\%$ for a=2 and <0.2 % for a= 3 respectively[4],[5] (b is kept to be zero in this analysis). It is evident that the spin of the first excited state of ^{10}Be is 2. In this case, the fitted substate populations are:

$$P(0) = 0.1349,\ P(1) = 0.5939,\ P(2) = 0.2712$$

The previous work in this laboratory[6], fitting the p_1 angular distribution by DWBA theory, shows that l_n, the angular momentum of the stripped neutron, is one. Hence, the spin and parity assignment for this level is 2^+. This agrees with the results of Green and Middleton[7], Inglis[8] and those given by Lauritzen et *al.*[9]. Further studies on this measurement and its application to other interested reactions will be expected.

(3) A. R. Polatti and E. K. Warburton Phys. Rev. **137** B595 (1965).
(4) Donald B. Owen, *Handbook of Statistical Tables,* p. 49. (Addison Wesley Publishing Co. Inc. Reading Mass., 1962).
(5) A. H. Wapstra, G. J. Nijgh and R. Van Lieshout: Nuclear *Spectroscopy Tables* p. 16 (North-Holland Publishing Co., Amsterdam 1959).
(6) K. S. Cheng, *Dissertation for master degree,* directed by Dr. Y. C. Liu, 1970.
(7) T. S. Green and R. Middleton Proc.Phys.Soc. A69 28 (1956).
(8) Inglis: Revs. Modern Phys. **25** 290 (1953).
(9) T. Lauritzen, F. Ajzenberg-Selove Nucl. Phys. **78** 1 (1966).