SHORT COMMUNICATIONS

THE DESIGN OF A MULTIPLE–WIRE PROPORTIONAL COUNTER AND ITS USE IN THE STUDY OF THE α-PARTICLES FROM THE REACTION ^{7}Li$+p$†

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Introduction

This counter was designed originally for the study of a two stage break-up process such as

$$^{11}\mathrm{B}+p \rightarrow \alpha_1+{}^{8}\mathrm{Be},$$
$$^{8}\mathrm{Be} \rightarrow \alpha_2+\alpha_3,$$

where correlations are sought between α_1 and α_2 as discussed by Treacy (1955). In this case the α-particles α_2 and α_3 are emitted into a cone of semi-angle 10° and could readily be accepted by the counter. The design was not specific to this experiment but enables α-particles of energies up to 8 MeV, falling within a cone of semi-angle 60° to be detected with electron collection times of less than 1 μsec.

A proportional counter was chosen but, since the particle ranges must be contained wholly within the sensitive region of the counter, it is difficult to achieve fast electron collection in a single-wire counter with an E.H.T. supply of the order of 1 kV. This difficulty can be avoided by subdividing the sensitive region into a number of separate counters, each with its anode and cathode. In such a system the speed of collection can be increased considerably without changing anode wire diameter or E.H.T. voltage.

Construction

Figure 1 shows a schematic cross section of the counter. The sensitive region is within a cube of side 8 in. containing 16 independent anode-cathode systems. Each anode wire A is located at the centre of a square array of eight thicker wires C all earthed and which form the cathode. The dotted lines in Figure 1 indicate the cone of semi-angle 60° within which particles from a target T at the cone apex can be detected and which has no line of axial symmetry. Thus detection occurs with equal speed and efficiency for all directions within this cone.

The anode wires are of 0·0035 in. diameter beryllium-copper and are attached at their ends to two ebonite sheets mounted by screws on a brass frame F. This frame has large holes H drilled through it to expose the ebonite E

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around each anode wire and thus allow the necessary insulation. The common anode lead emerges through a spring-loaded contact to a " Kovar "-glass seal and is arranged so that the top flange of the vacuum box, with frame attached, can be lifted out of the cylinder. The cathode wires are of 0·010 in. diameter copper and are attached directly to the frame.

The outer vacuum box comprises a 12 in. diameter cylinder (rolled from 0·25 in. brass sheet) with rubber vacuum seals. It may be evacuated through a glass tube held by a semi-flexible O-ring seal. There is provision elsewhere for two similar glass seals, so that the counter gas may be circulated over sodium metal for purification. A thin mica window, supported on a brass grid, is shown in Figure 1 attached to the target box. The holes of the grid are countersunk at the back to allow wide angle penetration of the counter.

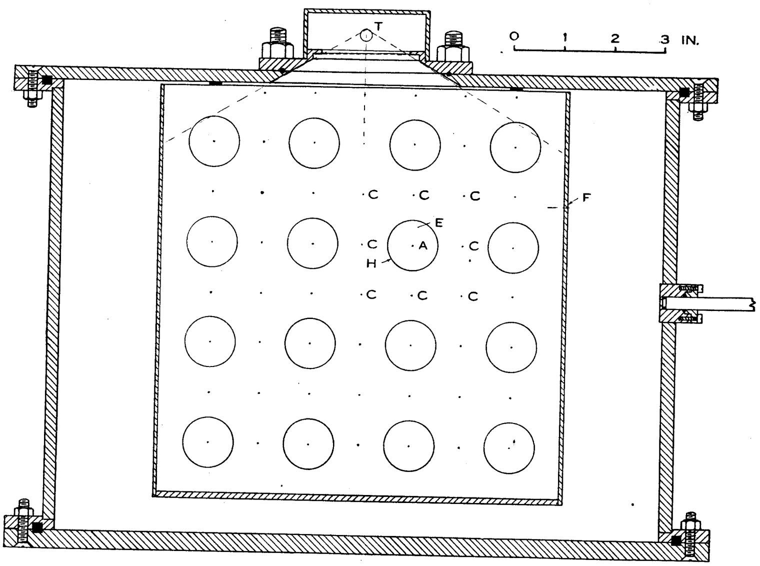

Fig. 1.—Schematic view of the counter in cross section.

Performance

The counter is used in conjunction with a linear amplifier having rise and clipping times of 0·16 and 1·6 μsec respectively. With the counter filled to 38 cm Hg pressure with argon (99·8 per cent. pure) and operated at an E.H.T. voltage of 720 V, a 5·3 MeV α-particle, after traversing the 7 mm mica window, produces a pulse equivalent to $7 \cdot 65 \times 10^5$ ion pairs. This represents a gas amplification factor of about 4·7 times with a noise equivalent at the input of $2 \cdot 7 \times 10^4$ ion pairs. The noise in the absence of the counter capacity, 56 μμF, is effectively $7 \cdot 8 \times 10^3$ ion pairs, the reduction being ascribed to shot effect.

In practice the gas gain can be increased up to the Geiger region ; moreover, the performance of the counter is quite conventional. As is shown below, in discussing Figure 2, the counter is proportional, having a pulse spread for 9·0 MeV α-particles of approximately ±6 per cent. at half height : this spread is attributed to the grid-like construction and " square " geometry of each cathode, which results in variation of electric field in different directions out from the anode wire, and also to small non-uniformities of wire diameter.

Under the conditions quoted above, the pulse rise time due to positive ion motion was measured as $2 \cdot 4$ μsec, using the method given by Gillespie (1953). This represents a constant delay in pulse rise which is limited by the size of the anode wire and could be reduced if desired. The electron collection time, which is subject to fluctuations, is estimated to be less than 1 μsec. Good linearity was obtained in the experiment referred to in the introduction, with a coincidence resolving time of $1 \cdot 2$ μsec.

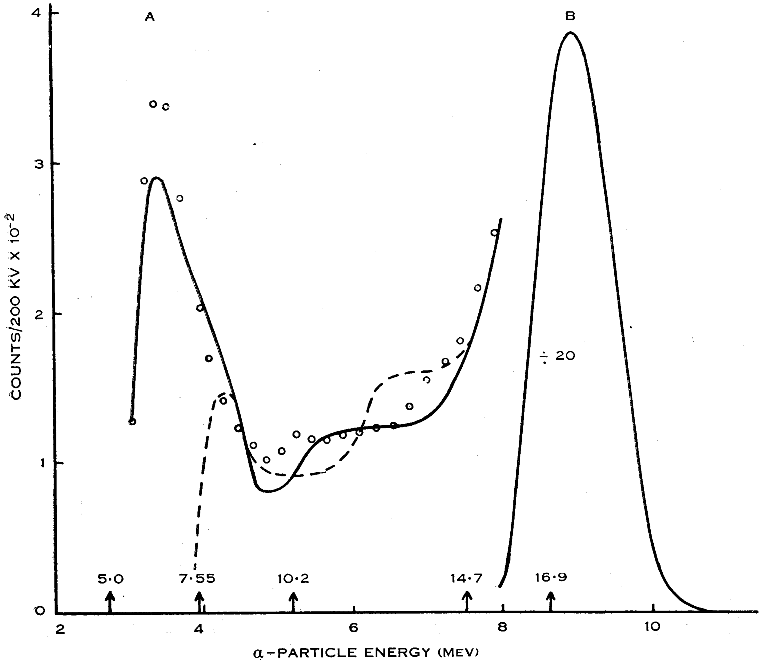

Fig. 2.—α-Particle spectra from $^{7}Li+p$. Full curve, spectrum taken at proton energy of $0 \cdot 47$ MeV ; circles, mean of spectra at proton energies of $0 \cdot 40$ and $0 \cdot 54$ MeV ; broken curve, spectrum of ^{210}Po α-particles. All curves are normalized to 5×10^4 counts in the main group *B*.

The α-Particles from the Reaction ^{7}Li+p

The behaviour of the counter can be illustrated by results obtained on the spectrum of α-particles produced by bombarding lithium with protons of energies in the neighbourhood of the 440 keV resonance. This experiment, although of interest in the study of ^{8}Be, has not previously been carried out in any detail (Ajzenberg and Lauritsen 1955). α-Particles can be produced by the following processes :

$$\left.\begin{array}{l} {}^{7}Li+p \rightarrow {}^{8}Be+\gamma, \\ \qquad {}^{8}Be \rightarrow {}^{4}He+{}^{4}He, \end{array}\right\} \quad \ldots\ldots\ldots\ldots \quad (1)$$

$${}^{7}Li+p \rightarrow {}^{4}He+{}^{4}He. \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

In reaction (**1**) the various ^{8}Be levels give rise to α-particles of different energies. Burcham and Freeman (1950) have analysed the α-particles of energy up to $2 \cdot 4$ MeV from reaction (**1**) and found that the ground and first excited states of ^{8}Be are formed as intermediate stages. In reaction (**2**) a direct process occurs giving a single group of α-particles of energy $8 \cdot 98$ MeV (Strait *et al.* 1951). α-Particles of energies between these limits would be expected corresponding to other ^{8}Be levels. These levels would be formed by γ-ray emission from the $17 \cdot 63$ MeV state formed at the 440 keV resonance (Inall 1954) unless such photon emission is of high multipolarity resulting in a relatively low intensity.

To examine these possibilities an experiment was carried out as follows. The counter was set at 90° to the proton beam of the Canberra $1 \cdot 2$ MeV accelerator, the beam being collimated by a $\frac{3}{16}$ in. diameter aperture and allowed to strike a 50 keV thick, solid-backed target of lithium aluminium hydride. α-Particles passed through an aperture subtending $\pm 10°$ at the target and entered the counter through a mica window of 7 mm air equivalent. Each pulse from the counter was displayed on an oscillograph and recorded photographically. The α-particle spectra detected at $0 \cdot 40$, $0 \cdot 47$, and $0 \cdot 54$ MeV proton energies are represented in Figure 2. The run at $0 \cdot 47$ MeV proton energy is drawn as a full curve and, for comparison, only the points of the mean of the upper- and lower-energy runs are plotted. It is evident that no resonant effects are present. The positions of known ^{8}Be levels are indicated by arrows labelled with the appropriate excitation energies. The resolved peaks A and B are due to $^{18}O(p\alpha)^{15}N$ and reaction (**2**) respectively. All results are normalized to 5×10^{4} counts in the main group B.

Apart from these a background is present which is due to the counter. This can be seen from the dotted curve in Figure 2 which is the spectrum obtained for a ^{210}Po α-particle source where the counter gas pressure has been reduced to 16 cm Hg. At this pressure the range of ^{210}Po α-particles in the counter is equal to that of the α-particles from reaction (**2**) under the previous conditions. A range-energy relation for argon was derived from data given for air by Bethe (1950), the non-linearity of which accounts for the difference in shape between the dotted and full curves.

From the known target thickness, data on total α-particle and γ-ray yields (Boyle and Inall, personal communication 1954) and by using the yield curve from Heydenburg *et al.* (1948) it can be shown from the results that, if ^{8}Be levels between 7 and 15 MeV are excited, their intensity must be less than 3 per cent. of the intensity of the transitions to the ground state. As the transition to the ^{8}Be level at $7 \cdot 5$ MeV is only of relative intensity 1 per cent. (Inall 1954), this would not have been detected above the background in the present experiment. Transitions by reaction (**1**) to levels higher than 15 MeV (Wilkins and Goward 1953) would here be masked by the α-particles produced by reaction (**2**).

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References

Ajzenberg, F., and Lauritsen, T. (1955).—*Rev. Mod. Phys.* **27**: 77.

Bethe, H. A. (1950).—*Rev. Mod. Phys.* **22**: 213.

Burcham, W. E., and Freeman, J. M. (1950).—*Phil. Mag.* **41**: 921.

Gillespie, A. B. (1953).—"Signal, Noise and Resolution in Nuclear Counter Amplifiers." (Pergamon Press Ltd.: London.)

Heydenburg, N. P., Hudson, C. M., Inglis, D. R., and Whitehead, W. D. (1948).—*Phys. Rev.* **74**: 405.

Inall, E. K. (1954).—*Phil. Mag.* **45**: 768.

Strait, E. N., Van Patter, D. M., Sperduto, A., and Buechner, W. W. (1951).—*Phys. Rev.* **81**: 747.

Treacy, P. B. (1955).—*Proc. Phys. Soc. Lond.* A **68**: 204.

Wilkins, J. J., and Goward, F. K. (1953).—*Proc. Phys. Soc. Lond.* A **66**: 661.