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Counting Efficiency of Nuclear Multiplate Camera

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A nuclear multiplate camera has been constructed to observe nuclear processes resulting from the bombardment of rectangular target of some extent with a neutron beam. Twelve Ilford K-Z plates are held in a rigid geometry which allows simultaneous measurements of nuclear reaction at the angles of 15°, 30°, 45°, 60°, . . . and 165°. In this paper the determination of counting efficiency of the nuclear plate is described. A scheme of a numerical calculation for the counting efficiency is programed and carried out. As a check measurements of efficiency are made by counting the number of n-particles on the nuclear plates from Po-210 source electro-plated on the target. The results are in good agreement with the calculated ones.

1. INTRODUCTION

A camera, as shown in Fig. 1, that utilizes nuclear emulsions[1),2),3)] as proton detectors for the measurement of the (n, p) reaction cross sections at neutron energy of 14 Mev has been constructed in our laboratory. The feature of the camera utilized in

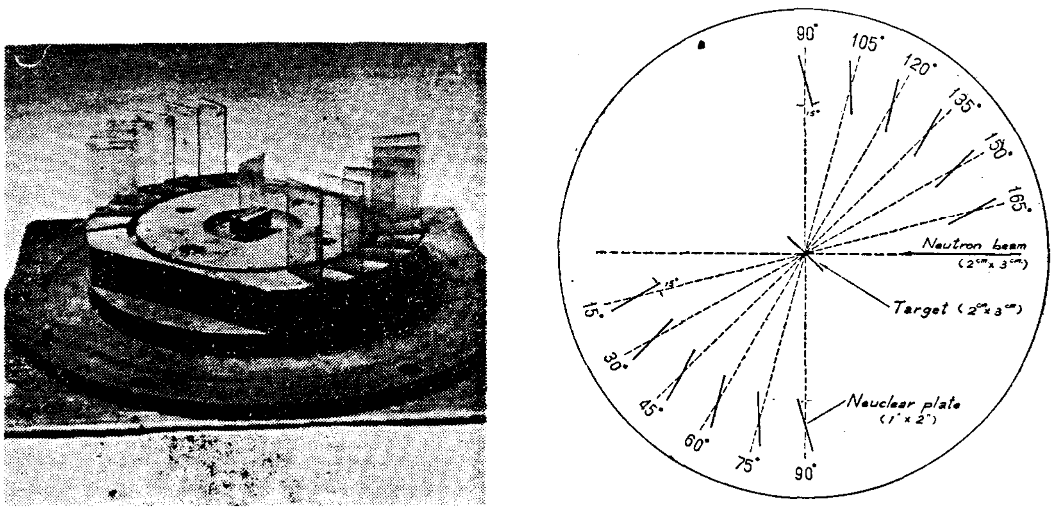

Fig. 1. Nuclear multiplate camera.

[1)] J. C. Allred, L. Rosen, F. K. Tallmadge, and J.H. Williams, Rev. Sci. Instr. 22, 191 (1951)
[2)] L. Rosen and J.C. Allred, Phys. Rev. **82,** 777 (1951)
[3)] I. Kumabe and R. W. Fink, Nuc. Phys. 15, 316 (1960)

the present work is that the target has a considerably large size of 2 cm. x 3 cm., in order to observe the protons from the (n, p) reaction the cross section of which is very small.

Unlike the case of circular- source and circular window of detector[4], no convenient formula for the counting efficiency of the rectangular plates with a rectangular target is available yet. Consequently, the angular counting efficiency, whose reciprocal must weight the raw yields to produce meaningful angular distributions, should be determined by numerical analysis or experiments.

2. EXPERIMENTAL PROCEDURE

An a-particle source was prepared by electroplating Po-210 on a silver plate of 2 cm. x 3 cm. area. In order to know the number of a-particles per unit time emitted from the source, we have used the counting system[4],[5] shown in Fig. 2. A circular

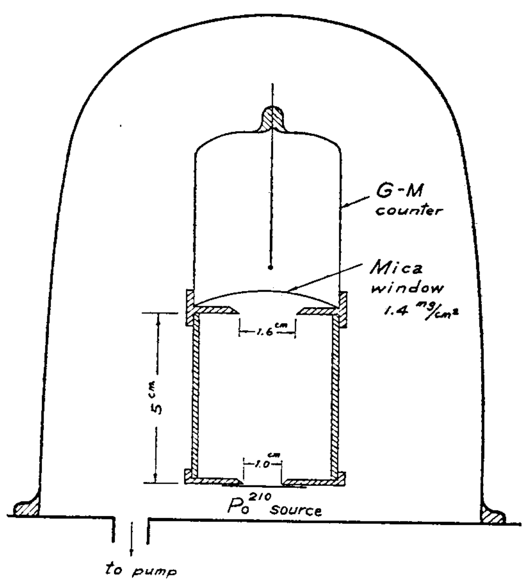

Fig. 2. G-M Counting system employing defined geometry.

definer having an aperture of 1.6 cm. diameter was placed on a brass pipe of 5 cm. height coaxial with the G-M counter. The source was adhered to the bottom of circular disk 6 cm. dia. with an aperture of 1 cm. diameter. The total assembly was covered with a bell jar, and was evacuated to a pressure of 20 cmHg in order to prevent a-particles from significant energy loss. The observed activities are given by

$$n = NG$$

Where N is the number of a-particles per unit time emitted from the source and G the geometric efficiency given by[4]

[4] Such as: B. P. Burtt, Nucleonics, 5, No. 8, 28, (1949).

[5] José Goldemberg, Rev. Sci. Instr. 26, 41 (1955).

$$G=0.5\left[1-\frac{1}{(1+\beta)^{1/2}}-\frac{3}{8}\cdot\frac{\beta\gamma}{(1+\beta)^{5/2}}\cdots\right],$$

$$\text{where } \beta=\frac{b^2}{a^2}, \qquad \gamma=\frac{c^2}{a^2},$$

a= the distance between source and definer,

b= radius of definer,

and c-radius of source.

The uniformity of the intensity of the α-soruce was checked by changing the mounting position several times and the average intensity of the source was found to be 3265 ± 49 c. P. s.

In Fig. 3 a holder of 1 cm. height was installed in the center of the camera to ensure the accurate position and direction. The Po-210 source (2 cm. x 3 cm.) was mounted at 45° to AB. a-particles were recorded with Ilford K-2 emulsions (1″ x 2″, 400 micron thick) placed at the angles of 15°, 30°, 45°, 60°, 75°, and 90” to AB, and 7 cm. away from the center of the source. The emulsion surface was vertical and the glancing angle was 15° to the direction of a-particles incident from the center of the Po-210 source. The camera was covered by an evacuated cylinder of 21 cm. diameter and 18 cm. height, and the pressure of the chamber was usually kept at 0.1 mm of Hg. The irradiation time was 20 min. The emulsions were processed by the temperature method with the use of amidol developer[6]. The analysis of the nuclear plates were

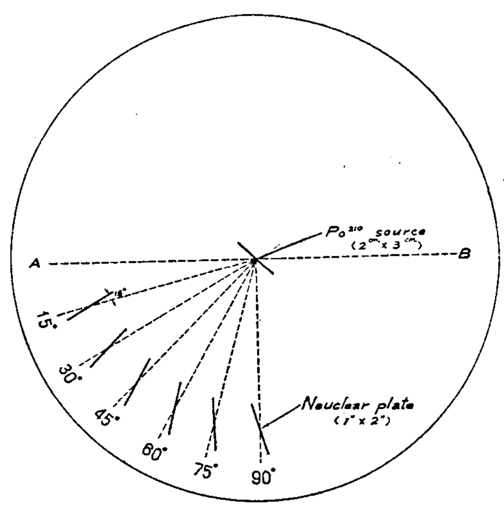

Fig. 3. Multiplate camera showing arrangement of nuclear plates.

made by using Tiyoda binocular microscope. Objectives of 40 x and eyepieces of 10 x were used. The scanning was carried out in 2 cm. x 3 cm. area at the central position on each plate and a sufficient number of trackes was counted on each plate up to approximately 10,000 tracks.

[6] B. Stiller, M. M. Shapiro and F. W. O ' Dell, Rev. Sci. Instr. 25, 340 (19.54).

3. CALCULATION OF G FOR NUCLEAR PLATE AND TARGET

A typical example for the position of a nuclear plate relative to the rectangular source is illustrated in Fig. 4, where the glancing angle θ is fixed to 15° and the

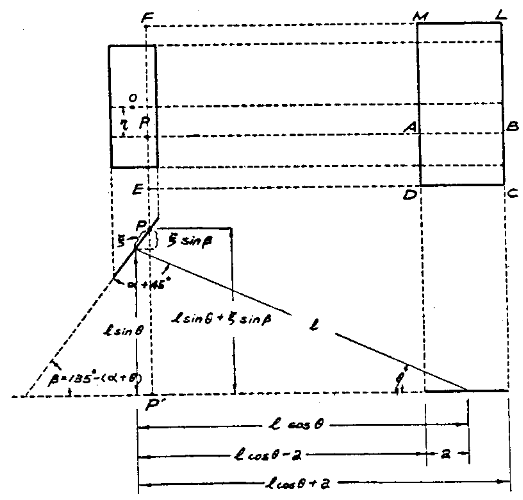

Fig. 4. The position of a nuclear plate MLCD relative to the rectargular source.

observation angles α take the values $15°, 30°, 45°, 60°, 75°$ and $90°$. The angle β between the source and plate is thus equal to $135° - (\alpha + \theta)$. The solid angle at the' apex of a pyramid (Fig. 5), one of whose edges is perpendicular to the plane of its

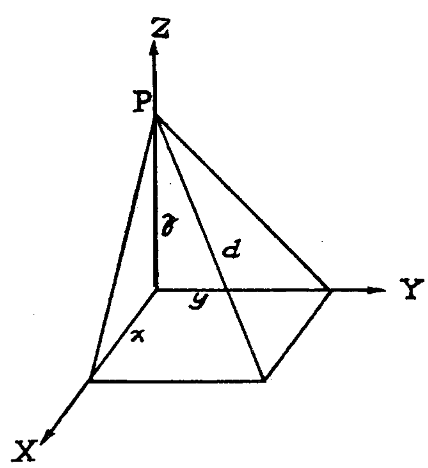

Fig. 5. Solid angle subtended at P by a rectangle.

rectangular base may be evaluated by the formula[7].

$$\omega = \tan^{-1}\left(\frac{xy}{zd}\right)$$

The solid angle subtended at a piont *P* on the plane of the source by the plate MLCD may be expressed by a combined application of the above formula as

[7] For example, see, J. Goldenberg, Rev. Sci. Instr. 26, 41 (1955).

$$\Omega = \tan^{-1}\left(\frac{P'B \cdot P'E}{PP' \cdot PC}\right) - \tan^{-1}\left(\frac{P'A \cdot P'E}{PP' \cdot PD}\right)$$

$$+ \tan^{-1}\left(\frac{P'B \cdot P'F}{PP' \cdot PL}\right) - \tan^{-1}\left(\frac{P'A \cdot P'F}{PP' \cdot PM}\right),$$

where P' is the projection of P on the extension of the plate.

Introducing a rectangular coordinates (ξ, η) on the plane of source, with the center as the origin, the quantities involved in the above equation may be written in

$$P'A = l \cos\theta - a - \xi \cos\beta,$$

$$P'B = l \cos\theta + a - \xi \cos\beta,$$

$$P'E = b - \eta, \quad P'F = b + \eta,$$

$$PP' = l \sin\theta + \xi \sin\beta,$$

$$PC = \left(\overline{P'B}^2 + \overline{P'E}^2\right)^{1/2} \text{ and } PD = \left(\overline{P'A}^2 + \overline{P'E}^2\right)^{1/2}.$$

Thus we obtain

$$\Omega(\xi, \eta) = \tan^{-1}\frac{(l\cos\theta + a - \xi\cos\beta)(b-\eta)}{(l\sin\theta + \xi\sin\beta)\left[(l\cos\theta + a - \xi\cos\beta)^2 + (l\sin\theta + \xi\sin\beta)^2 + (b-\eta)^2\right]^{1/2}}$$

$+$ (other three terms).

The counting efficiency is then given by an integration over the area of source,

$$G = \frac{1}{4\pi}\iint \Omega(\xi, \eta)\, d\xi\, d\eta,$$

where the intensity of the source is assumed to be uniform everywhere. The double integral is evaluated by a numerical integration using the Gaussian 7-points and 5-points schemes on a half part of the source. The result is then twiced because of symmetry. Because of the high accuracy of the Gaussian scheme we assure that the tabulated results in Table 1. and Fig. 6. are accurate enough.

Table 1.

Angle	15°	30°	45°	60°	75°	90°
Calculated efficiency	0.0024132	0.0024330	0.0024754	0.0025273	0.0025744	0.0026084
Experimental efficiency	0.002411 ±0.000031	0.002425 ±0.000031	0.002585 ±0.000032	0.002553 ±0.000032	0.002578 ±0.000032	0.002608 ±0.000033

4. RESULTS

A comparison between calculated values and the experimental ones for the counting efficiency of nuclear multiplate camera is presented in Table 1 and Fig. 6, in which the solid curve represents the calculated efficiency.

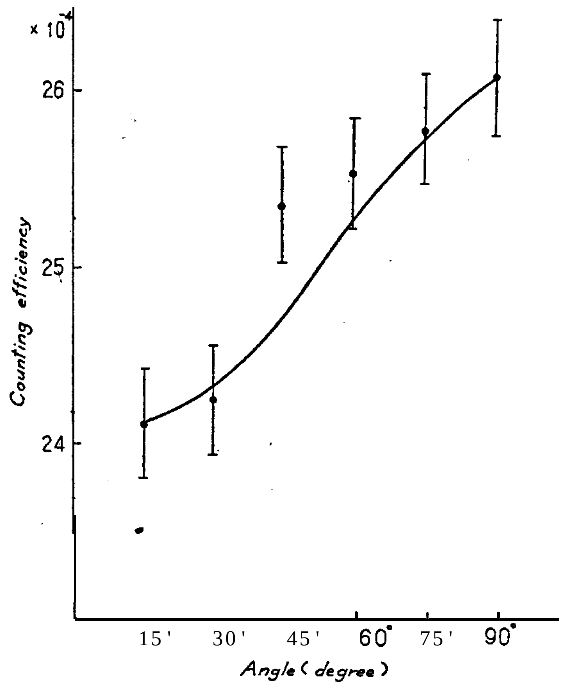

Fig. 6. Calculated efficiency and experimental efficiency.

5. ACKNOWLEDGMENTS

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