Title
ELECTRON-NEUTRINO ANGULAR CORRELATION IN THE BETA DECAY OF NEON-19

Authors
Good, Myron L.
Lauer, Eugene J.

Publication Date
1956-06-22

UCRL 3450

UNIVERSITY OF CALIFORNIA

Radiation Laboratory

BERKELEY, CALIFORNIA

UCRL-3450

UNIVERSITY OF CALIFORNIA

Radiation Laboratory
Berkeley, California

Contract No. W-7405-eng-48

ELECTRON-NEUTRINO ANGULAR CORRELATION IN THE BETA DECAY OF NEON-19

Myron L. Good and Eugene J. Lauer

June 22, 1956

Printed for the U. S. Atomic Energy Commission

ELECTRON-NEUTRINO ANGULAR CORRELATION IN THE BETA DECAY OF NEON-19*

Myron L. Good and Eugene J. Lauer

Radiation Laboratory
University of California
Berkeley, California

June 22, 1956

ABSTRACT

The distribution in kinetic energy of the recoil ions associated with beta rays of known energy in the beta decay of Ne^{19} has been measured. For the coefficient λ in the theoretical distribution in the cosine of the angle between the outgoing electron and neutrino, $(1 + \lambda (v/c) \cos \theta)$, we find a value of $\lambda = + 0.14 \pm 0.13$, suggesting that the Fermi component of the beta decay interaction is scalar.

INTRODUCTION

Measurements of the electron-neutrino angular correlation coefficient for the beta decay of He^6 have shown that the Gamow-Teller component of the beta-decay interaction is tensor.[1,2] In the experiment reported here, the angular correlation coefficient is measured for the decay of Ne^{19} (which can have a mixture of Gamow-Teller and Fermi-type interactions) in order to determine whether the Fermi component is scalar or vector. When an atom beta-decays, there are three quantities that can be measured (if the neutrino is not detected)--the energy of the beta particle, the energy of the recoil ion, and the angle ϕ between these two. In the experimental arrangement used for this experiment, the distribution in kinetic energy of the recoil ions associated with beta rays of known energy was measured. Because of the geometry of the experiment and the relatively high energy of the beta particles that were used, all possible angles ϕ were accepted. The beta-ray energy and recoil energy are sufficient to completely determine the decay, and thus to permit calculation of θ for each event. The beta-particle energy was measured with a scintillation counter and

* This work was done under the auspices of the U. S. Atomic Energy Commission.

[1] J. S. Allen and W. K. Jentschke, Phys. Rev. 89, 902 (A) (1953).

[2] B. M. Rustad and S. L. Ruby, Phys. Rev. 97, 991 (1955).

the associated recoil-ion kinetic energy was determined by measuring the time delay needed after the beta pulse for the recoil ion to traverse a known drift distance and hit the first dynode of an electron-multiplier tube.

Previous experiments[3,4] have indicated that the Fermi component of the beta decay interaction is scalar, and our results strengthen this conclusion.

PRODUCTION OF NEON-19

Ne^{19} was produced by the (p, n) reaction on F^{19}, by bombarding tightly packed 0.001-inch thick lathe turnings of teflon with about 10^{-8} ampere of 32-Mev protons from the UCRL 40-foot linear accelerator. The active gas diffused in an approximately 10^{-4} mm Hg vacuum from the bombardment target through a liquid nitrogen-cooled charcoal trap (which pumps air and all impurity activities except He and Ne) and through about 15 feet of 1-inch-diameter copper tubing to the recoil chamber and counting apparatus outside the shielding wall.

Decay curves taken with the beta counter and with the recoil ion counter both indicated a single activity, with a half life in agreement with the published value of 18.5 ± 0.5 seconds.[5] The purity of the activity, as judged from the decay curve, was better than 99%.

RECOIL CHAMBER AND COUNTERS

Figure 1 shows the recoil chamber, the beta scintillation counter, and the recoil-ion counter. A good event was a Ne^{19} beta decay which: (a) occurred inside the good source volume (between the foil on the scintillator and the movable foil), (b) sent the recoil ion through one of the holes of the "holey plate" in a direction to pass through the grid-covered hole in front of the recoil-ion counter, and (c) had a beta-particle energy ≥ 1.4 Mev. Betas of

---

3 W. P. Alford and D. R. Hamilton, Phys. Rev. 95, 1351 (L) (1954).

4 D. R. Maxson, J. S. Allen, and W. K. Jentschke, Phys. Rev. 97, 109 (1955).

5 G. Schrank and J. R. Richardson, Phys. Rev. 86, 248 (1952) (L).

this high energy have two or more times the momentum of the associated neutrino, and so go within 30° of the opposite direction from the recoil ion. Because of the geometry, such beta rays were certain to hit the scintillator, for all values of θ. The distribution in cos θ is then determined in a simple way from the beta-ray energy W and the recoil energy E. If p is the beta-ray momentum, q the neutrino momentum, and R the recoil momentum, then

$$R^2 = p^2 + q^2 + 2\,pq\,\cos\theta,$$

$$E = \frac{R^2}{2M} = \frac{p^2 + q^2}{2M} + \frac{pq}{M}\cos\theta = a + b\cos\theta \quad (M = \text{recoil-ion mass})$$

where a, b are constants for fixed beta-ray energy.

The recoil energy is thus a linear function of cos θ.

The "holey plate" was an aluminum plate 0.015 inch thick with 0.006-inch-diameter closely spaced holes drilled through in a circular region, centered on the axis of the counters. This plate offered impedance to the flow of Ne^{19} gas from the good source volume to the drift space, so that the diffusion pump, which pumped on the drift space and discharged into the good source volume, could maintain an active gas density about 1/100 as great in the drift space as in the good source volume. (This was determined by pressure measurements using stable Ne.)

The charcoal pump maintained the air pressure at about 3×10^{-6} mm Hg in the drift space and about 2×10^{-4} mm Hg in the good source volume.

The movable foil was used to subtract the background of delayed coincidences due to decays in the drift space. With the foil "open," decays in the good source volume and the drift space could cause delayed coincidences; with the foil "closed," delayed coincidences due to decays in the good source volume were prevented because the ions could not penetrate the 0.0005-inch-thich aluminum foil. However, decays in the drift space could cause delayed coincidences, since their beta rays could penetrate the foil. A gas conductance path, large compared with the gas conductance of the holey plate, was provided around the movable foil so that the density distribution of Ne^{19} atoms was nearly the same with foil open or closed. The small change in the density distribution was measured by using stable Ne at low presures, and the data were corrected for this.

The energy scale and energy resolution of the beta counter were measured by use of the pulses due to the 1.28-Mev γ rays from Na^{22}, and checked with the electrons from a magnetic beta-ray spectrograph. The full width at half maximum of the pulse-height distribution due to monoenergetic particles was about 20% of the mean energy.

The recoil-ion counter consisted of the electron-multiplier structure of a Dumont 6292 phototube, obtained by cutting off the photocathode end of the glass envelope. The cylindrical envelope was then waxed into a metal groove. After evacuation, the dynodes were reactivated by heating to a full red with an induction heating coil. A potential of 2.5 kilovolts was applied between the grounded grid (Fig. 1) and the first dynode.* A fluorothene plug and socket was used on the recoil counter to minimize leakage pulses. The recoil-ion counter was tested with positive ions or electrons that could be obtained by heating a thin tungsten filament in the drift space. The pulse-height discriminator was set at 1/3 the maximum height of the pulses due to a single electron leaving the first dynode (as determined by bombarding it with ions of very low energy). Typical recoil-ion pulse sizes were much larger than this. The sensitivity of the counter to recoil energy of the recoil ions was not measured, but should be small because the number of secondary electrons released by ions in this energy range is proportional to the ion energy, while the energy of the ions after acceleration varied only from 2.5 kilovolts for a recoil of zero initial kinetic energy, to 2.7 kv for a recoil of 200 ev initial kinetic energy.

After amplification, the pulses from the beta counter and from the recoil counter were sent to a mixing circuit, the output of which triggered the sweep of a Tektronix 517 oscilloscope if the recoil pulse was between -0.6 and +3.4 microseconds after the beta pulse. The amplified pulses were also delayed and applied to the two vertical plates of the oscilloscope. A 35-mm strip camera photographed the pairs of pulses. The pulses were displayed in a film viewer, and for each pair of pulses the height of the beta pulse was measured

* This grid was a double grid, especially designed to minimize leakage of the high accelerating field into the field-free drift space.

to give the energy of the beta particle and the time delay of the recoil pulse after the beta pulse was measured to give the energy of the recoil ion. The random coincidence background was measured by a separate scaler and mixer circuit which counted the recoil pulses that occurred between 40 and 80 microseconds after each beta pulse.

RESULTS

The experiment was run for approximately five 16-hour days, alternating between "foil open" and "foil closed" about every 25 minutes. After the film was read to give the beta energy and recoil ion time delay for each pair of pulses, the data were divided into eleven equal beta-energy windows between 1.4 and 1.9 Mev. Each of these sets of data was analyzed separately by calculating the recoil-ion delay times for the edges of cos θ windows, each 0.25 unit wide, for a decay in which the beta particle had the mean energy for that beta window, and counting the number of delay times that fell in each of these cos θ windows. Finally, the data for the eleven beta-energy windows were added, to form a distribution in cos θ including all the data. This procedure was carried out for all the "foil open" data and for all the "foil closed" data, the random count as deduced from the random scaler was subtracted from each, and then the "foil closed" data were subtracted from the "foil open" data. Figure 2 shows the measured distribution, and also shows the "foil closed" background and random background.

The theoretical distribution in cos θ, $(1 + \lambda v/c \cos\theta)$,[6] was averaged over the energy resolution of the beta counter and the distribution in drift distances from different regions of the good source volume to give a predicted distribution $A\left[S_1(\cos\theta) + \lambda S_2(\cos\theta)\right]$. The average value of $S_2(\cos\theta)$ is zero, therefore the constant A was determined by making the average value of $A\ S_1(\cos\theta)$ equal to the average of the experimental curve. The theoretical curves for four values of λ are plotted on Fig. 2. The deviation of the $\lambda = 0$ curve from a rectangle measures the resolution of the apparatus. The effect of counting some annihilation γ rays was small but was included in calculating these curves.

[6] S. R. de Grott and H. A. Tolhoek, Physica 16, 456 (1950).

A least-squares fit of the theoretical curve to the data of Fig. 2 gives $\lambda = +0.14 \pm 0.13$. For the tensor-vector interaction, $+1/3 \leq \lambda \leq +1$ and for the tensor-scalar combination, $-1 \leq \lambda \leq +1/3$, so that the result given suggests that the Fermi component of the beta-decay interaction is scalar, in agreement with previous determinations.[3,4] None of the three determinations of λ overlap, but a weighted average of our result with that of Allen et al.[4] agrees well with the expected value for tensor plus scalar of -0.05 ± 0.05, and neither is in serious disagreement with it. (Fig. 3.)

ACKNOWLEDGMENTS

The authors are pleased to acknowledge valuable discussions with Dr. Luis Alvarez, assistance during the early stages of the experiment by Dr. Arthur Schelberg, untiring service by the linear accelerator operating crew, and aid in calculating the theoretical distribution by Keith Johnston and Charles Stableford.

FIGURE CAPTIONS

Fig. 1. Vacuum chamber, recoil counter, and beta-ray scintillation counter.

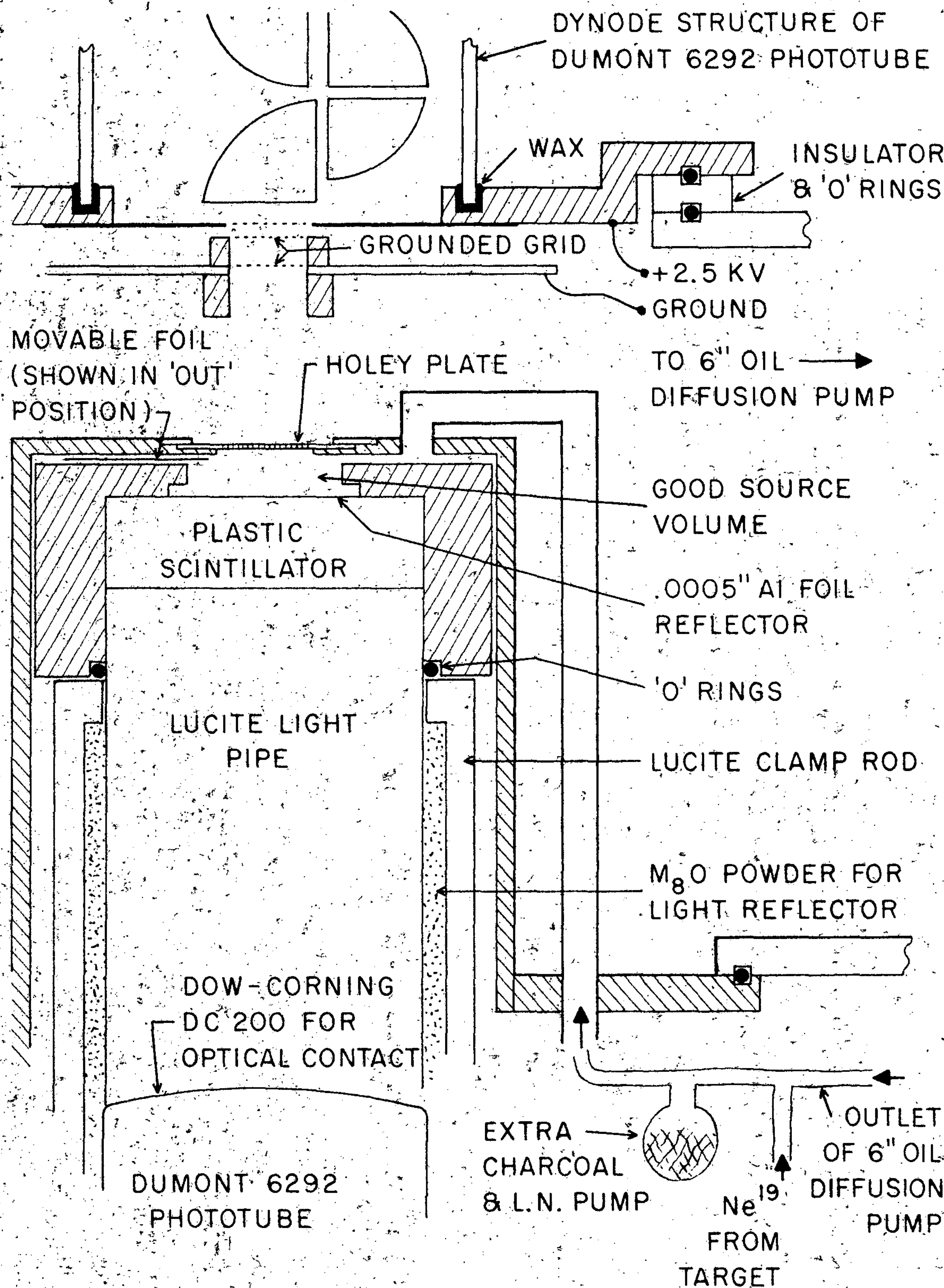
Fig. 2. Distribution in cos θ of Ne^{19} beta-decay events. Solid rectangles give the measured distribution in cos θ, with random background and foil-closed background subtracted. The dotted rectangles are the foil-closed background with foil-closed randoms subtracted, and the solid curve labeled R is the foil-open random background. Height of rectangles is two times the standard deviation.

Solid curves are theoretical, with instrumental resolution folded in, for various values of λ.

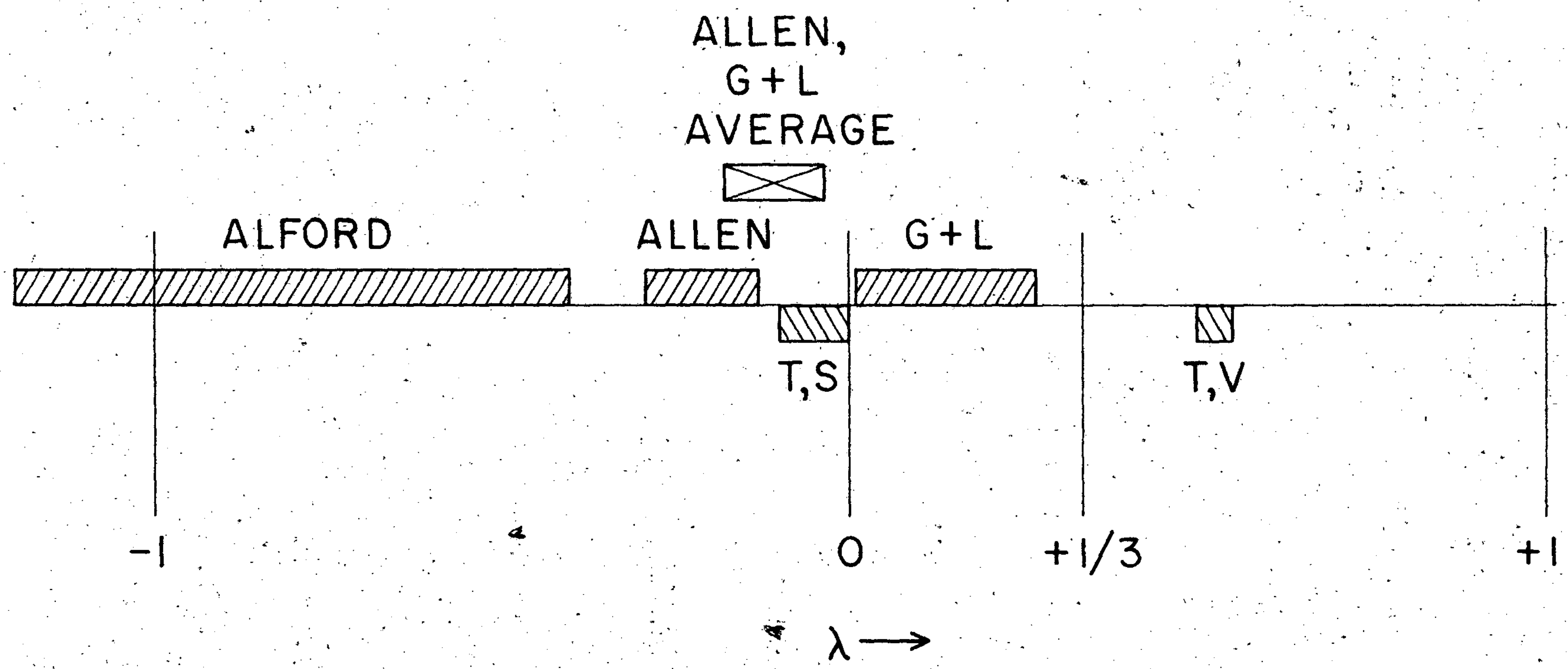
Fig. 3. Determinations of λ' for Ne^{19}. The expected values for T, S, and T, V are arrived at by using the Ne^{19} and O^{14} ft. values.[3,7]

---

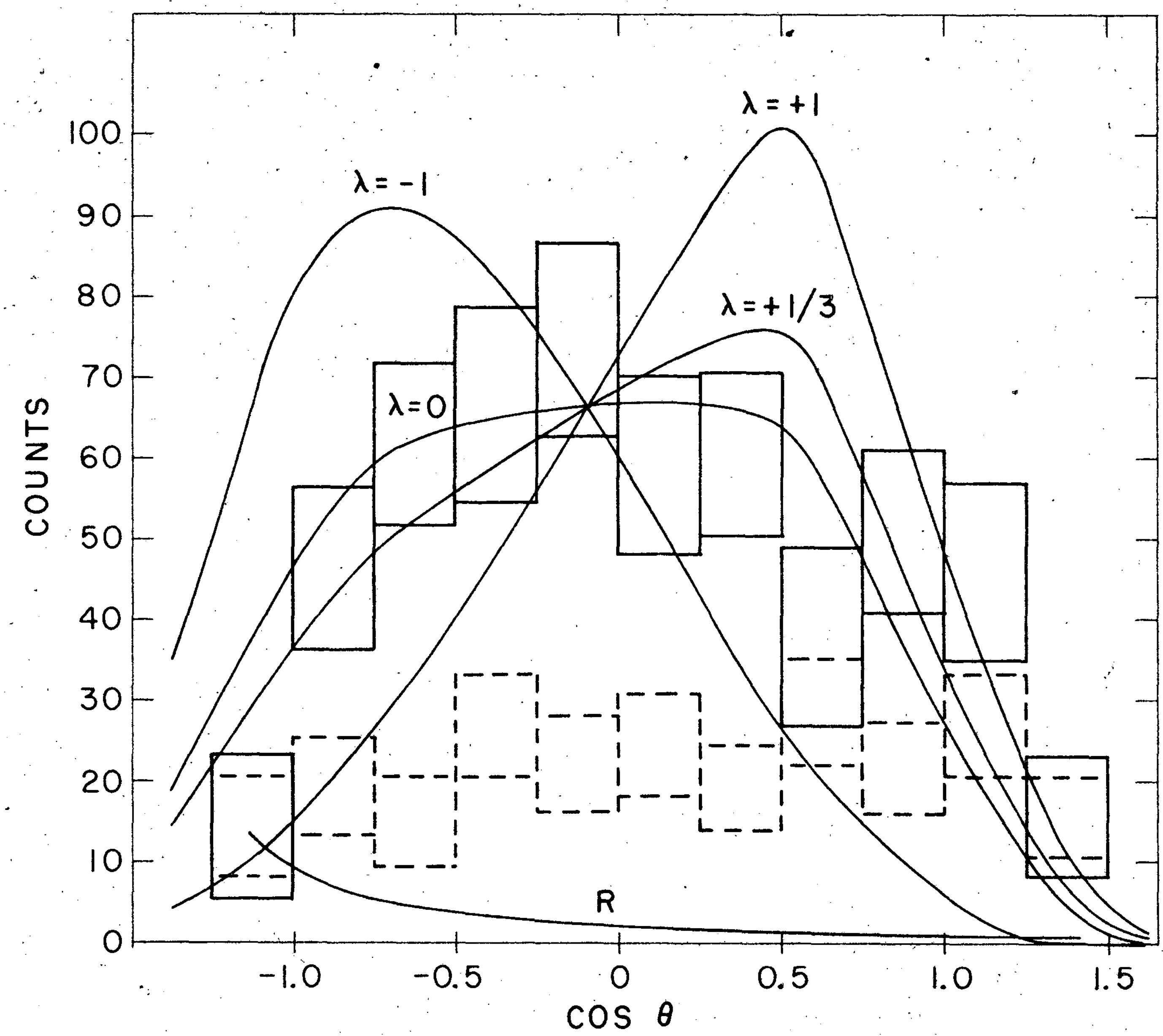
7 J. B. Gerhart, Phys. Rev. **95**, 288 (1954).


DYNODE STRUCTURE OF
DUMONT 6292 PHOTOTUBE
WAX
INSULATOR
& 'O' RINGS
GROUNDED GRID
+2.5 KV
GROUND
MOVABLE FOIL
(SHOWN IN 'OUT'
POSITION)
HOLEY PLATE
TO 6" OIL
DIFFUSION PUMP
GOOD SOURCE
VOLUME
PLASTIC
SCINTILLATOR
.0005" Al FOIL
REFLECTOR
'O' RINGS
LUCITE LIGHT
PIPE
LUCITE CLAMP ROD
M8O POWDER FOR
LIGHT REFLECTOR
DOW-CORNING
DC 200 FOR
OPTICAL CONTACT
EXTRA
CHARCOAL
& L.N. PUMP
OUTLET
OF 6" OIL
DIFFUSION
PUMP
Ne19
FROM
TARGET
DUMONT 6292
PHOTOTUBE

25301-1



25300-1


λ = -1
λ = +1
λ = +1/3
λ = 0
R
COUNTS
COS θ
0
10
20
30
40
50
60
70
80
90
100
-1.0
-0.5
0
0.5
1.0
1.5

25_99-1